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CMS Submission to the 2009 PPGP Review

Report on Activities and Planned Future Programme

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1. Part A: January 2007-December 2008

1.1 The UK contribution to CMS

CMS was completed (except for PreShowers) in 2008 and successfully took data in the first LHC run in September 2008, which unfortunately ended prematurely. The experiment as a whole appears to be in excellent shape and will be fully ready for the LHC restart in 2009.

The UK has now delivered important major subsystems: the Electromagnetic Calorimeter endcaps, Tracker readout electronics and the Global Calorimeter Trigger. We have a major role in software for reconstruction and analysis and in development of GRID-based computing, as well as significant physics analysis activities.

In addition the UK has played notable roles in CMS scientific management. This report focuses mainly on construction progress and preparations for CMS physics but we note that the CMS Spokesperson since January 2007 (and Deputy for many preceding years) is T Virdee (Imperial College) whose term runs to December 2009. In addition to this important responsibility, the UK has consistently taken leading positions in the overall scientific management of CMS. Most are noted in the reports below but some are not. The post of CMS Electronics Coordinator was occupied by J Nash (Imperial) who now serves as Upgrade Project Manager, and P Sharp was Tracker Project Manager until December 2008. While based in CERN he was supported by UK resources and associated with Imperial. R Brown continues to serve on several CMS management bodies following formal retirement in 2007.

1.2 Tracker Status

The UK role in the CMS silicon microstrip tracker was to deliver major components of the electronic readout system, mainly ~150,000 APV25 front end chips, 500 9U Front End Driver (FED) boards and several APVe emulators, with firmware and software, with a value of 2.7MCHF. It was very successful, pioneering 0.25μm CMOS technology and achieving 99.8% yield for FED production. The Tracker electronics was managed by Hall, who also served as Deputy Tracker Project Manager.

The APV25 was a joint RAL TD-Imperial development, with analogue design by Raymond and digital sections and layout by RAL. It provides unsparsified analogue data, transmitted optically to FEDs in peak and deconvolution modes, devised at Imperial, and has demonstrated excellent performance. It was the first major chip produced in 0.25μm CMOS and shows exceptional radiation hardness, beyond 100Mrad. All evaluation and acceptance testing was done by Imperial, and many studies of SEU and radiation effects (Bainbridge, Barrillon, Fulcher, Hall, Raymond, students). It has proved highly robust, very flexible and with important diagnostic capabilities; all vital to CMS. Significant numbers of APV25s are now, or will be, in use by COMPASS, Belle, STAR and several smaller projects.

The FED was also a joint project, to specifications provided by the RAL PPD-TD and Imperial team (with notable contributions from Bell, Coughlan, Foudas, Hall, Tomalin, and others). It converts analogue optical signals to electrical, with digital processing, including cluster finding and zero suppression. Design was by RAL TD, installation by Zorba, Fulcher (Imperial) and Church (RAL-TD) and commissioning by Fulcher, Zorba, Bainbridge, Cole and students. Firmware was also shared between Imperial and RAL. Manufacture was supervised by RAL TD (Coughlan et al.) using equipment and software developed by Imperial installed in RAL and the UK company. Operational experience has been excellent, with high reliability over 2-3 years.

The APVe, designed and built by Imperial (Iles, Jones, Noy), plays a vital role emulating each (identical, synchronous) APV25 to prevent buffer overflow and protect against out-of-synch conditions, eg from SEU. It throttles the trigger in case of DAQ problems and vetoes conditions which generate crosstalk noise, as observed in certain infrequent trigger sequences. APVe software was provided by Imperial (Iles, Noy, students).

We also contributed substantially to offline simulation and reconstruction software, with Tomalin having led the CMS Tracker Software group and numerous sub-groups.

By early 2007, the Tracker sub-systems (Inner and Outer Barrels, and two Endcaps) were delivered to CERN, and integrated into a single unit. Cosmic triggers provided about 5M events over several months in the CERN Integration Facility, with about 15% of the Tracker under power. This was essential by developing the DAQ and debugging data, power, control and safety systems prior to installation. Effects such as trigger related noise, performance and other issues could be investigated. It allowed calibration and alignment studies and resulted in several CMS notes, to be published.

Installation took place in December 2007. Connection required three months, with a pause to solve cooling plant problems. In June 2008 the Tracker successfully participated in a Global CMS cosmic run after only three weeks commissioning. Pixels were installed in late July, completing the Tracker. Intensive studies followed, with and without magnet field. Over 99.3% of the Tracker was operational, with signal to noise similar to that achieved in the TIF.

During November, CMS took cosmic data at 4T to run all sub-systems continuously for four weeks. The Tracker was operational 96% of the time, with down-time attributable to cooling plant, using 98% of the SST and 97% of pixels. The Tracker collected 290M triggers, which should provide 8.5M tracks in the strip tracker and 100k in the pixels. From these data the alignment precision of the barrel was already improved to 30μm (strips) and 50μm (pixels, which did not profit from TIF operation).

Online software was developed by a small expert team, including UK staff on CERN LTA (Fulcher, Bainbridge, Cole, students). It uses standard CMS software frameworks: XDAQ for online developments, and CMSSW offline. A challenge comes from the huge size of the Tracker (9.3M channels) and that minor issues (<1%) emerge only when the entire system is operating. It is an immense effort to fully verify software tools and provide all features needed for data analysis and monitoring. UK procedures to configure, calibrate and synchronize the system were used extensively to validate and optimize performance.

Imperial and PPD provide software libraries for FED functions, and tools for DAQ and debugging; they were developed by a team consisting of Fulcher, Cole *et al*. Software to store and retrieve parameters in the online database was also developed. During commissioning and start-up, each FED is configured with constants to sparsify each tracker channel requiring ~120kB of data. A full history is stored, so each time pedestals, noise or cluster finding thresholds change a new data set is created. Careful management is essential. Any errors recorded are passed to the central error logging/handling system.

Offline DAQ software was developed at Imperial (Bainbridge, students) for calibration of readout chain components, i.e. APV25, FED and analogue optical links, and to measure constants, including channel gain and noise, timing delays and signal-to-noise ratios. Algorithms identify faulty components, tune hardware and offline reconstruction software. They were used during TIF assembly in 2007 and to commission the Tracker at P5.

UK work on event reconstruction includes algorithms to provide calibrated detector signals for pattern recognition and unpack data efficiently (Bainbridge, Cole, students). Two schemes were developed for prompt, full reconstruction at Tier0 and Tier1 centres and a novel, regional approach to track reconstruction optimised for the High Level Trigger (HLT). It was essential during 2007 to meet HLT speed targets and was used, for example, in development of an HLT algorithm based on b-tagged jets. Other work tuned Tracker hit resolution parametrization (Tomalin, Gay). Tomalin made substantial code improvements, allowing for the first time reconstruction of tracks not originating near the primary vertex, useful for exotic physics studies, V0 reconstruction and particle flow algorithms.

Stoye is an alignment expert, having written a thesis on the Millipede algorithm used during the CSA08 alignment challenge, and in early data analysis. Alignment constants obtained with Millipede outperformed other algorithms in precision as well as computing resources required and are reported in plenary conference talks and publications.

Bainbridge convened the microstrip monitoring group, validating data quality. Tools were developed (Bainbridge, students) to monitor payloads within the online event data stream, focusing on APV25 chips, FEDs and DAQ. A Brunel student contributed software and a new statistical test for Data Quality Management (DQM) publishing, with Reid, Lopes and Hobson, two papers on the Kolmogorov-Smirnov test to compare two-dimensional data, and a CMS Note introducing the "Energy Test" to compare DQM histograms.

During 2007, Tomalin coordinated CMS b-tag & vertexing prioritizing methods to measure b-tag performance with real data. Highlights included notes on measuring b-tag efficiency (using top-quark events and independent lifetime and lepton b tags), measuring mis-tag rates (using –ve impact parameter tracks), and on effects of Tracker misalignment. Tomalin also demonstrated that primary vertex information could dramatically improve jet rapidity measurements.

1.3 ECAL Endcap Status

The UK was responsible for design, construction, installation and commissioning of the ECAL Endcaps (EE) comprising 14,648 tapered lead tungstate crystals instrumented with Vacuum Photo-Triodes (VPTs) specially developed by RAL and Brunel. Deliverables are VPT procurement and testing, VPT HV system, support structures, electronics integration, assembly of Supercrystals (SCs) and the half-endcap subsystems (Dees), test beam calibration, installation and commissioning. All this was achieved by August 2008, in time for the CMS closure and first beams. Key roles were undertaken at RAL by Cockerill (EE Project Manager) and Bell (Coordinator for ECAL Installation and Commissioning). The EE design was led by RAL PPD and RAL TD (J.Hill, EE Project Engineer, Lodge).

Production of 16,100 VPTs was completed in 2006 and reception tests to 1.8T at RAL completed by summer 2007 (Bell, Camanzi, Kennedy, Sproston, Williams), with ~2000 VPTs tested to the full 4T field at Brunel (Hobson, Selby). The overall pass rate was over 90%. A significant fraction of failed devices showed anomalous, noisy behaviour at specific angles to the magnetic field. To ensure sufficient VPTs a further 500 were delivered and tested.

The on-detector VPT high voltage system comprises ~3000 filter cards designed at RAL (Lodge), located inside the SCs, now inaccessible. Stringent acceptance tests were carried out using dedicated test stands developed by Bristol (Cussans, H.Heath, S.Nash). HV is supplied by power supplies in the service cavern to eight distribution crates designed at RAL (Bell, Brown, Camanzi, Cockerill, Torbet). Prototype crates were made before production. The first production crate has been installed and the remainder will follow in early 2009. High voltage was so far provided by fan-out crates without full functionality (S.Nash).

During 2007, the UK (Cockerill, Ryan, Lodge), led assembly of a Dee subsection comprising 20 SCs (500 channels of 3662 in total- a SC comprises a 5x5 array of crystals and VPTs) to test system performance (cooling, noise, cross-talk, optical data fibre routing). This gave vital input for final design of service structures inside Dees and, most importantly, for final configuration and layout of the welded electronic cooling units. The Dee was calibrated in an electron test beam in autumn 2007, including systematic scans to study energy resolution, and used to normalise lab measurements of crystal light yield and VPT response to the correct energy scale to provide pre-calibrations for all 14,648 EE channels.

Mass production of 624 Supercrystals at CERN ran from April 2007 to May 2008. By end 2007, 16 SCs per week were being assembled and tested using VPTs shipped from the UK in batches, which were re-tested at CERN before being glued to crystals. All were subjected to HV and LED signal tests prior to being mounted on the Dees (V.Smith, Cussans).

Dee assembly was undertaken at a specially equipped CERN lab. It involved 4 major tasks: mounting and HV testing of SCs using a special loader arm (Williams), routing of HV and LV cabling and installation of the neutron moderator, routing and trigger mapping of SC signal lines to front end motherboards, and mounting and testing of electronics on cooling systems. The first Dee was started in autumn 2007. By July 2008, all Dees were completed and fully tested with LEDs and test pulses before shipment and installation in CMS.

Key responsibilities were undertaken by Bristol and Imperial (H.Heath, Ryan) for the complex trigger mapping and trigger fibre readout, requiring over 2900 fibres to be mapped to corresponding ribbons. RAL (Williams) managed SC mounting, and installation of a fibre optic laser system to monitor and correct for changes in crystal transparency. A light pulser system for the EE, to reduce VPT rate-dependent effects during LHC operation, was built and installed, under supervision from RAL and Brunel (Brown, Cockerill, Flower, Hobson, Leslie). VPT studies at 4T are ongoing at Brunel to characterise VPT behaviour at the high rates expected at LHC and to develop optimal running procedures with the pulser system.

Bell led installation and commissioning of both barrel and, with J.Hill, the endcap. All 36 barrel supermodules were ready by autumn 2007 with EE commissioning in August 2008. The EE took part in laser and global runs before successfully recording ‘splash’ events from the first LHC beam. Endcap Preshower detectors will be added by Easter 2009. EE performance in CMS matches our target and lab measurements; pedestal noise in 3.8T field corresponds to transverse energy noise of ~50 MeV per channel.

A complete validation of new CMS reconstruction software, requiring detailed comparisons with results obtained for the Physics TDR, was completed in March 2007. The new software was used to analyse test beam data from 2006 when nine barrel supermodules were precision calibrated in an electron beam. Detailed validation of the Monte Carlo model was studied with both electrons, and low energy pions. UK physicists (Seez, Zabi) were involved with data taking and subsequent data analysis, particularly of signal amplitude reconstruction from digitized time-samples, and measurement of basic performance, for which a UK physicist (Zabi) was the working group convener. Results were presented in March 2007.

UK physicists (Seez, Futyan) have contributed significantly to developing calibration methods and both software and the workflow and dataflow plans to realize the ECAL inter-calibration and correction of crystal transparency changes under irradiation. These are crucial ongoing tasks. Particular progress has been made with inter-calibration with neutral pions, and a realistic test of the dataflow with four different inter-calibration techniques was part of the 2007 and 2008 computing challenges. Much progress has been made in laser transparency correction software and dataflow preparation, both online and offline.

ECAL clustering and corrections are important inputs to ECAL calibration and achieving ultimate performance. The corrections are constants applied to clustered energy sums made with perfectly calibrated channels. Some of these are obtained from test beam data, or from Monte Carlo validated by test beam data, but some must be obtained from data taken in situ. Large scale simulations have been undertaken to calculate some detector structure corrections (Tourneur). The UK (Seez, Futyan) has led the clear separation, both conceptually and in the software and database organization of these two categories of corrections, and implementation of refinements to clustering and superclustering algorithms to minimize the corrections. The aim is to build a robust scheme ready for LHC startup which is minimally sensitive to fine tuning of Monte Carlo with data. UK physicists (Shepherd-T, Seez, Harper, student) are leading refinement and development of clustering algorithms.

The E/gammma HLT offline DQM has been designed and implemented by Harper with input from Shepherd-T, Newbold and Jackson. During data taking this will ensure that we are trigging on good electron and photon objects and will monitor efficiency of the relevant suite of triggers as well as the performance of the relevant variables. This work includes defining and refining the strategy for higher luminosity triggers.

Such work connects directly with physics aims: measurement of W and Z cross-sections in electron decay channels, searches for new heavy objects decaying to electrons (Z′, W′ etc), and preparation for discovery physics where W and Z bosons are significant backgrounds.

Seez coordinated the ECAL Detector Performance Group (DPG) to Dec 2007, including the beam test of the 500 crystal endcap prototype in the CERN H4 beam line, and development of a new, fully parameterized, endcap geometrical description (Kennedy) used both for reconstruction and GEANT simulation. Cockerill leads the EE performance and stability subgroup of the ECAL DPG.

1.4 Global Calorimeter Trigger Status

The UK GCT group is responsible for delivering validated electron and jet triggers, including control, monitoring and emulator packages used for physics analysis. The design started in February 2006 with a mandate to deliver within 18 months. The main tasks are:

- **The Isolated Electron Trigger:** GCT selects the 4 highest transverse energy, E_t, isolated and non-isolated electron/photon candidates.
- **The Jet Triggers:** GCT searches the calorimeter for jets and transmits to the Global Trigger (GT) the 4 highest E_t central-, tau- and forward-jet candidates.
- **The E_t, H_t and Missing E_t triggers:** E_t, H_t and Missing E_t are the total transverse energy, the total jet transverse energy and total missing energy computed for every event.
- **The Q- and M-bit system:** GCT transmits to the Global Muon Trigger 252 bits to indicate that a given energy deposition is consistent with no activity (Q-bit) or with a minimum ionizing particle (M-bit).
- **The Calorimeter Trigger Readout system:** GCT is responsible for transmitting all calorimeter trigger data to the CMS DAQ system.

We have been able to develop, design and commission the new system in a very short period. The Electron Trigger was commissioned in Summer 2007. Both electron and jet triggers were ready for the September 2008 LHC run. The core GCT project has been completed and the status and activities still ongoing are briefly summarised.

The Electron Trigger was the first trigger to be installed and participated in data taking runs from early Summer 2007 (Tapper, Foudas, Iles, Brooke, Frazier plus students). By September 2007 it had been validated using cosmic ray data and by injecting entire Monte Carlo events and comparing the output with predictions of the GCT emulator. Results were presented in TWEPP 2007 by Foudas. Until Summer 2008 the Electron Trigger was the main calorimeter trigger and sufficient for CMS commissioning.

We maintained the electron trigger hardware in constant readiness to provide triggers for all other CMS sub-detectors. Triggering was provided for runs aimed at timing the CMS trigger, collecting ECAL and HCAL data to map noisy towers, as well as tests of data transmission integrity from the calorimeter to GCT. Through these tests we gained running experience resulting in improvements of online and error diagnostic software.

GCT has provided reliable readout of the entire calorimeter trigger for almost two years since installation in 2007. The GCT readout has proven an essential diagnostic tool and is used by all calorimeter trigger groups to monitor activity and performance.

Jet Trigger hardware was installed in Spring 2008 and by mid-summer jet triggers were part of the trigger menu. They were validated in August 2008 using cosmic ray events (Foudas, Tapper, Iles, student). Data were processed by the emulator and results compared event-by-event with GCT outputs. Algorithms and results were presented at LECC06 (Iles), TWEPP08 (Iles, Frazier) and IEEE08 (Tapper). Commissioning of the E_t, H_t and Missing E_t triggers was planned for Autumn 2008 and relevant software and firmware already installed. However, the electron and jet triggers cover all current CMS needs so commissioning of Et, Ht and MET triggers was postponed to 2009.

During GCT commissioning software development has closely followed the hardware. GCT operation and integration into the CMS DAQ and offline system requires three categories of software:

Online Control and Monitoring software operates and monitors the GCT during data taking. Experience from 2008 was used to develop automated software to reduce significantly the service effort which consumed a significant part of personnel resources over the past year (Frazier, Rose). The current package services all GCT hardware and Electron and Jet Triggers.

Offline Software for handling GCT data sent to the DAQ and the Higher Level Triggers (HLT). Fairly complex low level software unpacks and makes available GCT data to HLT algorithms and offline monitoring (Tapper). A large emulator package contains a C++ bit-to-bit hardware emulator to process both Monte Carlo data for computing trigger efficiencies as well as input data to monitor GCT performance on an event-by-event basis (Brooke, G.Heath, student). Both packages are complete for the triggers currently available.

Data Base software: GCT configurations are stored in a data base accessed by online software during running and also accessed offline so that offline reconstruction for a given run or Monte Carlo generation is always in synch with the experimental trigger conditions. A large part is written (Frazier), with the rest to be completed well before the next LHC run.

Level-1 software coordination: the UK provided one of two coordinators of this activity (Brooke) during 2007-08. Bit-level emulators for all L1 subsystems have been merged into a coherent framework, with tools for validating the code against each new release of the software. The database machinery described above, for synchronising between the emulator and the experimental conditions, has been developed and implemented.

After the LHC incident the CMS priority was to collect large cosmic ray samples for alignment and calibration. Throughout these runs, the GCT provided robust service with all Electron and Jet Triggers; CMS collected 360 million events. The GCT group has had three extremely productive years and achieved its objectives.

1.5 Computing Status

In the CMS computing model events selected by the High Level Trigger are transferred to the CERN Tier-0 (T0) to be reconstructed and separated into primary data sets sorted by trigger type. A custodial copy of all raw data is stored in CERN tape vaults and primary datasets are shipped to the seven Tier-1 (T1) centres around the world; at one of them a second custodial copy is saved for security. At each T1 data are skimmed to produce analysis samples. Data re-processing also occurs at T1s (and T0 when data are not being collected). Skimmed datasets are distributed to Tier-2 (T2) centres where all physics analyses are performed, except for a few high priority studies performed on the CERN Central Analysis Facility (CAF). All Monte Carlo production is also undertaken at T2s.

The UK provides a T1 centre at RAL, and two T2s: LondonGrid and SouthGrid. These T2s maintain five analysis groups: LondonGrid supports SUSY, Trigger Studies, Electroweak and EGamma, and SouthGrid supports Exotica. The UK receives 5.3FTE of MoA credit for running these centres. However, in reality this work is actually performed by 2.5FTE (0.5FTE Brew, 0.5FTE Wakefield, 0.5FTE Vazquez Acosta, 0.5FTE Jackson (student) and 0.5FTE Colling). This is only possible because this is a close-knit team, but it is a fragile situation. The ratio of delivered to expected effort is the lowest of any comparable country.

The UK is also active in offline development and made significant contributions to software for moving data between sites (PhEDEx), job submission and workflow tools (BOSS and ProdAgent), and Web Tools activity. Currently the UK co-convenes the Data Management and Workflow Management (DMWM) group (Metson) and within that group leads development of the ProdAgent package (0.5 FTE Wakefield) used to run all the workflows within the CMS computing system. We also provide effort for development of the Web Tools (0.5 FTE Ball- student).

1.5.1 Track record

Since 2004 CMS has run tests to assess its ability to meet data taking challenges. As a result we are confident that, while the computing system will require future improvements, CMS is capable of taking the initial data taking load. An example of improved performance is shown in Fig. 1 which displays how capability to move data volumes increased with time, as tools and our understanding of configuring network links improved.

During 2008 CMS stressed computing infrastructure as much as possible during three distinct periods. The first two were during the wLCG Combined Computing Resource Challenges (CCRC) in February and May. The second CCRC phase was combined with the initial phase of the CMS specific Computing, Software and Analysis (CSA08) challenge.

During these challenges the entire computing system was tested with Monte Carlo data shipped from CMS to the T0 for reconstruction and data then transferred to appropriate T1 centres. At T1s data were skimmed and then re-reconstructed (as shown in Fig. 2). Skimmed data were then distributed to the T2 centres for analysis, using both regimented Job Robots and ~450 normal users operating chaotically. High profile analyses were also carried out on the CERN CAF. Activities performed at T2s and the CAF covered the full range expected during early data taking, from calibration and alignment to complete physics analyses. [CMS IN-2008/044 *The 2008 CMS Computing, Software and Analysis Challenge*]

The aim in CSA08 was to reach levels then expected during 2008 running. Failing to reach 75% of nominal values was viewed as failure, between 75% and 100% as a qualified success, and 100% or greater of nominal values as complete success. Complete success was achieved in the vast majority of challenges, with at least partial success in all areas. However, success was not instantaneous and many lessons were learnt and problems overcome. The UK played a full part in all these challenges and both the RAL T1 and the two UK T2s achieved "complete success" on all metrics.

The UK has a long history of involvement and leadership in the DMWM area. Metson coordinated development of the CMS data moving tool, PhEDEx, until 2008 and produced the design actually implemented. He relinquished this role only after promotion to coordinating the whole DMWM group. The UK (Wakefield) coordinates development of the ProdAgent workflow software that runs all workflows within the CMS computing system. ProdAgent proved capable of producing a million Monte Carlo events per month, as well as managing all data processing workflows within T0 and T1s. Both pieces of software are core to CMS computing. The UK played a leading role in Web Tools development since 2006.

UK collaborators (Khan and student) also worked with the CMS Dashboard team to give users the ability to view execution status of their analysis jobs, as well as read application and Grid messages from them. As user analysis over the Grid continues to increase this will prove an invaluable tool.

The UK chaired the Computing Resource Board (Geddes) in 2008 and its predecessor, the Computing Coordination Committee (Newbold) on which the other UK representative was Shepherd-T, and has jointly led User Support activity in 2008 (Khan). Colling leads the UK CMS Computing and Offline Project. With Geddes, he represents the UK on the CMS CRB and UK CMS on GridPP Project Management and Collaboration Boards.

2. Part B: April 2009 – March 2013

UK deliverables require significant support for which we must be responsible. Notable are the Tracker electronics (~500 complex modules), the Global Calorimeter Trigger and EE HV system. FEDs and the GCT make extensive use of FPGAs, requiring firmware maintenance and development, and on-line software. Details of M&O are in appendices.

The UK is responsible for several major programming activities, providing Tracker software, ECAL physics tools and Trigger tools, all of which require long term commitments. All UK groups contributed and are expected to support them at a level commensurate with initial implementation effort. Shift duties for experiment operation and data quality monitoring should be shared proportionately to group size, but on-call experts supporting mission-critical items provided by the UK are vital.

CMS has evaluated in detail effort required to operate and maintain the experiment. It concluded that an average commitment of 0.25FTE is required from each CMS member. This does not include management duties, except for few special cases such as Spokesperson, and neither does it include upgrade work. Duties cover the full range from shifts to software and hardware maintenance but does <u>not</u> include physics analysis work. Certain UK individuals have specific key responsibilities; everyone has obligations to other shared work.

2.1 Physics programme

We report past activities and future programme together since they are tightly linked and there is no natural breakpoint, unlike construction. We have been very active in a broad range of physics. A focus has been placed on first data analyses and work using simulations has particularly emphasised methods to be used with genuine data, so called data driven methods. Stress has also been placed on aligning work reconstructing physics objects with analysis needs and requirements on sub-detector performance. CMS Physics Coordination increasingly emphasises readiness for data taking and UK efforts have fitted well into this perspective.

The UK has long-standing expertise in fundamental areas such as ECAL behaviour, tracking and triggering. Expertise in electron and tau identification, as well as b-tagging and jet reconstruction, has been exploited in numerous analyses leading to prominent UK contributions to many major CMS results. UK interests encompass most areas of LHC physics including Higgs physics, SUSY, "exotic" models leading to heavy resonances and long lived particles, as well as Standard Model topics of W and Z bosons and top quarks. Strong links with theorists have also been established.

2.1.1 Standard Model Physics

An Imperial group (Seez [CMS e-gamma Physics Object convener], Hays, Tourneur, Ryan plus students) is preparing first measurements of W and Z cross-sections in electron channels, likely to be among the first CMS publications. Work has focused on defining electron selection and developing, using data driven techniques, tuning methods central to the $W \rightarrow e+\nu$ cross-section measurement. Charge mis-measurement resulting from electron showering, and modelling the missing E_T spectrum in W events have also been studied. Wardrope (student) coordinated the electron exercise in the Computing Software and Analysis 2008 (CSA08) challenge, aimed at exercising data and work flows intended for the first 10 pb^{-1} of data.

Groups at Bristol (C.Hill, Cheng plus student) and Brunel (Khan, Barrett plus student) are leading work on di-top production where a single electron is produced in the final state. Currently this focuses on determination of backgrounds from QCD and W+jets where data-driven methods have been implemented. This will result in a cross section measurement, which will be an early CMS result. Future work will include a top mass measurement using this channel. In addition, C.Hill is convenor of the W/Z+jets working group whose objective is to span and bring together requirements of the Standard Model and BSM groups.

2.1.2 Z' Search

Groups at RAL (Shepherd-T, Harper plus student) and Bristol (C.Hill, Newbold plus student) play leading roles in searches for heavy resonances decaying to electrons. Shepherd-T was instrumental in creating, and now leads, the High Energy Electromagnetic Pairs (HEEP) group which has performed the definitive CMS preparatory analysis. UK physicists performed all elements of the analysis including triggering, electron identification, efficiency and background determination. The methods have been designed to use data only almost exclusively. Consequences of NLO corrections and pdf uncertainties have been studied in collaboration with theorists. This analysis will be one of the first CMS publications and the UK is poised to be the lead player. A CMS reviewed paper was published in July 2008.

The team who performed the original analysis has been augmented by Olaiya and Harder (RAL) and Goldstein (Bristol) plus a joint student. Observation of a Z' peak will lead to a programme of measuring its properties and identifying New Physics models that could give rise to the observation, in collaboration with theorists within the NExT Institute. Non-observation of a peak will lead to a search for discrepancies in the continuum.

Work is also being done to apply expertise in high energy electron identification to searches for signatures of other possible new physics models (Belyaev, Goldstein, Newbold, Shepherd-T plus student). For example, Z bosons with a large boost can be produced in various new physics models and a number of these are currently being implemented in CalcHEP by Belyaev, who is also the Exotics group liaison with the CMS Generator group.

2.1.3 TGC

Hobson (Brunel) plus a Bristol student provided the definitive CMS $W+\gamma$ anomalous gauge coupling result. The selection for both muon and electron channels was defined and optimized. The analysis requires a good understanding of the differential cross section distribution as a function of the photon p_T and work with a theorist who made his definitive Monte Carlo simulation available to CMS.

2.1.4 Supersymmetry

An Imperial group (Buchmueller [CMS SUSY Physics Analysis Group convener], Tapper [CMS SUSY hadronic working group convener], Foudas, Stoye, Pioppi, Karapostoli, Bainbridge plus students) is working on model-independent searches for production of dark matter candidates.

It has focused on devising analyses for all hadronic final states, the relevant high cross sections providing opportunities for early discovery. The group has led a novel analysis effort making use of the exclusive di-jet topology. The efficient and robust search designed for use with early data was recently published in a CMS reviewed note. It was a precursor to development of a comprehensive strategy for searches in the all-hadronic channel using early data. Buchmueller worked with several theorists to constrain masses of SUSY particles using indirect experimental and cosmological information, resulting in a published paper.

Work is being extended to searches with final state leptons with particular emphasis by Imperial (Pioppi, Karapostoli and students) on the same sign di-lepton final state. At RAL Shepherd-T, Harper and Olaiya will also work on such final states bringing expertise in electrons, from Z' searches.

Beyond the initial phase work will depend upon observations. Evidence of New Physics will lead to measurements of masses and a programme to determine the nature of the particular flavour of SUSY or other new physics.

2.1.5 Higgs Physics

Groups at Imperial and RAL are involved in Higgs physics. The Imperial group (Nikitenko [former CMS Higgs Physics Analysis Group convener], Colling, Vazquez-Acosta, Magnan, Wakefield plus students) aims to validate tau reconstruction and selection with first data, using the $Z \rightarrow \tau\tau$ channel, in preparation for Higgs searches in tau channels, addressing elements vital for full analysis. A method for determining the significant probability of an electron to fake a tau is being developed using the tag and probe approach. Jet energy and missing transverse energy resolution is improved using tracks in addition to calorimeter data. The single hadron calorimeter response is being studied using both test beam data and simulation. Criteria for selection of isolated charged particles and methods to measure track finding efficiency using data are being studied. Prior work has involved joint papers with theorists at Durham on MSSM Higgs studies, and NMSSM Higgs with Southampton/NExT and Shepherd-T.

A RAL group (Cole, Shepherd-T, Tomalin) investigated the CPX Higgs scenario where, in the presence of CP violation, a low mass Higgs can evade LEP limits. The feasibility of reconstructing the charged and neutral Higgs which arise in the decay chain studied was investigated and reported in 2007 Les Houches proceedings. A recent paper on Higgs production in association with stops, with Moretti, has also been published.

With the accumulation of several fb^{-1} of integrated luminosity, searches for Higgses decaying to taus will become possible. A comprehensive programme of Higgs physics analyses will be performed which will be dictated by the experimental observations.

2.1.6 Long lived particles

Various models predict particles with lifetimes ranging from picoseconds to days or even months. UK groups lead analyses encompassing two scenarios: RAL (Tomalin and Gay) searching for exotics decaying before the subsequent LHC bunch crossing, whereas Bristol (C.Hill, Brooke plus student) are searching for longer lived exotics.

In the first scenario, one expects displaced decay vertices inside CMS; tracking code has been modified to reconstruct them inside the Tracker. Initial work focused on decays to jets and current work includes decays to electrons. Trigger modifications have been proposed to ensure that such decays are not missed. Harder will join this effort with a student to work on the electron channel. Tomalin leads a collaboration with non-UK institutes to search for decays in CMS calorimeters or muon chambers.

In the second scenario, a search for particles with very long lifetimes that stop and remain embedded within CMS has been devised. It requires detection of decays while beam is off and hence development of a triggering system to be run during down-time. A complete analysis chain has been developed and present limits will be rapidly improved, leading to one of the earliest CMS publications.

A comprehensive programme in both these areas is proposed, with sensitivity increasing with accumulated luminosity. Any observations will lead to studies of particle properties plus collaboration with theorists to devise means to determine the new physics model.

2.1.7 Particle flow studies

Particle flow (PF) reconstruction consists in identifying and reconstructing each particle, such as photons, electrons, muons, V0's, charged and neutral hadrons, in an event or jet by combining measurements from all sub-detectors (e.g. Tracker and calorimeters) in an optimized fashion. It could have a significant impact on physics studies where missing energy is a signature, such as SUSY, and is well matched to Imperial expertise in CMS sub-detectors. A group led by Della Negra (former CMS Spokesperson) has made important PF contributions on single hadron calibration to wider CMS studies. Work is now being extended to include PF jet, tau and electron reconstruction (Pioppi and students) as well as their application to CMS physics analyses such as early SUSY searches. Alternative methods using Jets plus Tracks, which is a similar but simpler approach, have been proposed by Nikitenko and are under study (Nikitenko, Bainbridge, students). Both methods will be deployed as it is likely the full power of the PF approach will need longer to mature since it requires detailed calibration and precise understanding of the CMS detector.

2.1.8 Collaboration with theorists

Exploitation of LHC data will require close collaboration with theorists. Despite no in-house phenomenology groups, CMSUK has fostered connections through personal contacts and the NExT Institute, Shepherd-T being a founder. This provides valuable input to analyses, and puts CMSUK in an optimal position to interpret data. Several papers have recently been produced in collaboration with theorists including consequences of NMSSM for Higgs physics, a B-L extension of the SM, production of Higgs in association with stop quarks, constraints on SUSY masses as well as a contribution to Les Houches proceedings on NLO corrections to the Drell-Yan spectrum.

Contacts will be invaluable once results emerge. If New Physics (NP) evidence is found a programme of deciding "where to look next" will be followed. Already, low-energy data from flavour physics experiments, high precision electroweak observables and astrophysical data impose strong constraints on many NP scenarios. A collaboration of theorists (among them Ellis and Weiglein) and experimentalists has been formed to develop a consistent framework for interpretation of LHC discoveries including indirect collider data and cosmology constraints in the MSSM [e.g. Buchmueller et al, JHEP0809: 117,2008]. A similar project on a "Dictionary of LHC signatures" [arXiv:0806.2838] is being pursued by Shepherd-T with Belyaev et al. to identify ways of distinguishing NP models.

2.1.9 New Techniques

Work is being pursued at Brunel, led by Teodorescu, in analysis techniques such as using the Gene Expression Programming algorithm to identify analysis variables automatically, develop functional models for signal and background separation, and to identify physics objects. The RAL group (Shepherd-T in collaboration with Watts (Manchester) and Sastri (RAL e-science) plus student) is developing alternative methods to visualize data, such as parallel coordinates, and data mining techniques with similar objectives.

2.1.10 Physics effort

An estimate of the current level of FTE effort is tabulated below, based on the year 2008-09.

	Academic	**RG**	**Other**	**Student**
Bristol	1.0	1.3	0.0	4.2
Brunel	1.3	1.0	0.0	1.0
Imperial	1.6	5.7	2.0	7.3
RAL	1.7	1.5	0.2	0.1
Total	**5.6**	**9.5**	**2.2**	**12.6**

2.1.11 Conclusion

The UK has a strong programme to exploit early data and sub-detector expertise. The analyses described will dominate activities for the first two to three years. Observation or otherwise of evidence for New Physics will define a future programme and some possible routes have been outlined. The broad spectrum of activities plus extensive collaboration with theorists places us in a strong position to react to whatever is observed.

2.2 Tracker: Future activities

The UK must maintain FEDs, APVes, crates and controllers and associated firmware and software and provide expertise in many aspects of the electronics. This includes APV25s, despite their inaccessibility, since they are crucial to performance. Tracker system problems do occur, although often traced elsewhere than the APV25, FED or APVe.

The hardware/firmware load will be undertaken by Imperial College (Raymond, Hall, Fulcher, Zorba, Noy, Iles) and RAL TD staff (to date Coughlan, Tagavi, Church). Zorba has returned from CERN LTA but will continue to be on call and visit CERN regularly for FED operational support. He must also maintain APVe's and supervise crates and controllers.

Most FED hardware maintenance relies on engineering effort in RAL for which 1SY/year is estimated, dependent on FED reliability. This is required for (Back end) firmware maintenance and upgrades, and hardware diagnosis and repair.

Modifications are expected to the FED front-end FPGA firmware (Imperial) as CMS operations continue, to improve common-mode subtraction. Even if performance is excellent as it appears, evolutionary changes are expected, including the essential requirement to operate under (very different) heavy ion conditions.

There is a significant software maintenance task undertaken by Imperial and RAL-PPD (Bainbridge, Cole, Fulcher, and students). New features of the FED will be implemented, such as the synchronous spy channel to sample incoming data via VME, which is otherwise impossible at high rate. This is vital for offline analysis to evaluate common mode noise and cluster finding algorithms during data taking (Fulcher plus students). Other firmware improvements include a means to carry out (challenging) mid-run resynchronisation. Furthermore, the Tracker commissioning and calibration procedures must be maintained, and via studies with real data, optimised and improved (Bainbridge, Cole).

The UK will continue to make major contributions to Tracker offline software (Bainbridge, Cole, Harder, Reid, Stoye, Tomalin). Tracker performance with real data must be monitored and studied. Depending on results, refinements will be needed to DQM, and track reconstruction, which the UK is well placed to make. The difficult task of aligning the Tracker is particularly important (Reid, Stoye).

2.3 ECAL: Future activities

The UK is the primary group responsible for EE operation and maintenance (Bell, Cockerill, J.Hill, RAL-PHYS) and will play a key role in understanding and calibration of the detector under LHC operating conditions (Bell, Cockerill, Futyan, H.Heath, Hobson, Kennedy, Leslie, RAL-PHYS, Seez) which will evolve progressively over the period up to March 2013. The UK is already a major contributor to physics analyses that rely strongly on ECAL performance (Z' search, Standard Model Z, as outlined in the physics section). Ensuring a detailed level of detector understanding during data taking will be critical to maintaining a lead in analyses such as these. This work will be led by Cockerill who chairs the EE performance and stability working group and who is likely to be the deputy ECAL project manager responsible for EE performance from 2010 onwards.

Barrett, RAL-PHYS and Ryan will play key roles to ensure excellent performance, particularly on the ECAL DAQ, to develop real time Data Quality Management (DQM) tools for the ECAL, for use during data taking, and to provide input, with Shepherd-T, to the ECAL Prompt Feedback Group (PFG). Kennedy, with Cockerill and RAL-PHYS, will continue his work on detailed detector simulation and clustering algorithms.

The UK will make an important contribution to global operation of the ECAL. For example Bell is already undertaking the role of ECAL Field Technical coordinator. EE mission-critical items provided by the UK include the VPT HV system, general EE detector maintenance, both during shutdowns and while running, and possible dismounting (EE project engineer, J.Hill, Bell). These activities will require a sustained level of technical support that will be provided by Cussans, S.Nash, RAL-PHYS (HV) and a PPD technician. RAL-PHYS will need to be in residence at CERN to provide on call, round the clock service for the VPT HV system, with backup from Bell, Cockerill, Shepherd-T and Leslie. A serious system wide HV failure would require input from Torbet (RAL ID) and S.Nash.

Hobson, Kyberd, Selby and Leslie will continue to exploit the Brunel 4T VPT test facility. This system is unique and will be crucially important for optimising the LED VPT stability pulser operating parameters as LHC running conditions evolve.

During early exploitation of LHC data there will be continued development and optimisation of electron and photon correction and calibration algorithms involving experience and understanding of the ECAL. Electron and photon identification will be studied from data and developed. The efficiency and rejection power of selections will be measured from data, and continue to evolve in close association with physics channels under study. Seez, Hays, Futyan and Ryan together with students intend to continue their leading contribution to this work and connect it firmly to their physics interests. The work on electron identification by Harper and Shepherd-T together with a student will be continued as data are collected. This work will form a central element of the Z' search physics analysis where Harper and Shepherd-T are playing leading roles. Harper, with Shepherd-T, will play a major role in the trigger offline DQM. This will be used to monitor the performance of all the electron and photon triggers, and to develop the triggering strategy for higher luminosities.

Radiation, particularly in the inner regions of the EE, will lead to changes in VPT and crystal performance which raise issues of possible photo-detector and scintillator replacement and upgrade. In order to prepare for such challenges RAL (Bell, Cockerill, Shepherd-T, Kennedy), with PPD technical support, and Brunel (Hobson, Kyberd, Leslie, Selby) will lead studies on long term VPT and scintillator performance.

2.4 Global Calorimeter Trigger: Future Activities

The GCT is a relatively small but highly complex system, whose components are listed in Appendix ii. It plays a central role in CMS data taking and physics analysis by facilitating first level selection of all discovery channels searching for electrons, photons, jets and missing E_t. Hence, it is vital to provide uninterrupted service and well understood triggers. Equally important is flexibility and rapid response to requests for new triggers which inevitably arise. The design has considerable contingency and flexibility. It uses large FPGAs capable of accommodating far more sophisticated algorithms than those envisaged by the Trigger TDR (2000) and its logic can run at four times the current speed of 40 MHz. It is capable of executing essentially any calorimeter based trigger algorithm. We have provided a state of the art system and a powerful tool to meet trigger challenges of the LHC era.

The GCT has met all requests from CMS physics groups. A recent example was a new **Minimum Bias Trigger** for events with large energy deposits in calorimeter towers around the beam pipe implemented for the September 2008 LHC run (Iles, Foudas, G.Heath, student). Two more triggers will be commissioned during 2009, which are:

New Tau Trigger: analysis of cosmic ray data and Monte Carlo studies have shown that the purity of the tau-trigger is improved by an algorithm providing better isolation for tau-jets.

Missing Ht Trigger: It has been shown that missing transverse energy computed from all jets in an event is more robust and less sensitive to noise and underlying event effects than the current estimate using all event information.

We will commission and validate these triggers, and provide a hardware emulator before the next LHC run. Other requests are expected in future, particularly after first data taking.

The GCT group is also committed to deliver the Q/M-Bit uTCA system. A first prototype Matrix Card is ready and a backplane-motherboard will be produced in 2009. This new system imposes further effort for commissioning, software and firmware development. Future activities fall into distinct categories: Hardware, Online Software, Offline Software and Operations:

Engineering Effort: The focus of the firmware effort before the 2009 run will be developing and commissioning new triggers and optimizing processing time (latency). Further firmware effort will be needed after experience with LHC data. Calibration corrections for jet triggers must be implemented online which will generate new firmware requests. In addition the Matrix Card of the uTCA system requires urgent firmware development. After the LHC run a test and integration setup for the uTCA backplane-motherboard is essential. Commissioning of this system will take place during 2010 to be ready for the second LHC data run.

During GCT construction, engineering effort was at the level of 3.5 FTE (Iles, Stettler, Sidiropoulos, Hansen, Jones). For exploitation only Iles (Imperial) remains available as the on-site expert uniquely capable of maintaining firmware and hardware.

Online Software Support: The GCT online software as well as data base access software was written by Frazier (Bristol) with an Imperial student and Brooke (Bristol). Only Frazier now remains available to develop and maintain it.

Online software tasks in 2009 will be to integrate E_t, H_t, Missing-E_t, tau and Missing-H_t triggers into the online control and monitoring software and then in the Trigger database. After the LHC data run focus will shift to integrating the new Q/M-bit uTCA system into the Trigger and DAQ chain, which must be finished before data taking in 2010.

A major future task is to develop a comprehensive package for diagnostics and testing the GCT. This should inject digital patterns at the inputs, under program control, and compare the

GCT output with emulator results. This is currently done by running several software packages which is slow and very laborious so must be automated and consolidated in a single package. This will increase system robustness and reduce trouble-shooting time.

The online expert is responsible for tasks which consume considerable time and are vital for triggering: (1) each time a trigger algorithm changes (CMS has 128 sub-triggers) a new configuration is made and entered in a data base, (2) when a detector or electronics related problem occurs monitoring software must be updated to prevent recurrences, (3) updating GCT PCs, underlying control software, higher level software, data base interfaces and other GCT software following operating system updates. This activity required 0.5 FTE so far and is not expected to diminish. In conclusion, an online software expert is critical and his loss would threaten GCT operation, so Frazier or replacement (Bristol M&O), is essential.

Offline Software Support: The main task here is to maintain the emulator and unpacker packages which are responsibilities of Bristol [G.Heath: emulator] and Imperial [Tapper: unpacker]. Both require updates each time a new trigger is introduced or new data for diagnostics and monitoring are required to be sent via the DAQ path.

Level-1 trigger performance: the UK will lead efforts to validate and monitor trigger performance using data (Brooke, Tapper); this work is already under way using cosmic rays. Other studies will focus on the trigger performance for electrons (Foudas, Newbold, Tapper)

Operations Support: During data taking an expert must be on-call 24-hourly to (1) ensure the trigger configuration is appropriate, (2) diagnose problems which inhibit data-taking (often not GCT-related but we service the entire calorimeter trigger chain), (3) be responsible for developing, validating and commissioning new triggers, (4) participate in frequent Trigger Coordination and Trigger Studies group meetings, (5) organize all maintenance and repair. This has been carried out by Tapper and Foudas (Imperial). Support for operations is critical and we require the Tapper post for this.

2.5 Computing: Future activities

The UK has two primary Computing and Offline objectives. The first is to provide a fully functioning T1 and two T2s for CMS. The GridPP project should provide sufficient hardware resources to do this and some staff, mainly to operate equipment. However CMS specific tasks require intervention from dedicated CMS staff. It is vital to maintain the highly effective team we currently have and we request continuation of the following posts, in addition to funding for Colling for management and coordination.

Brew (0.5FTE) for T1 liaison; this post is crucial for provision of the CMS T1 at RAL. His efficient performance resulted in him becoming one of two T1 representatives within the CMS Facilities and Operations group. He also runs CMS services at the SouthGrid T2 sites.

Wakefield (0.5FTE) and (the recently deployed) Olaiya (0.5FTE) to support CMS activity in LondonGrid and SouthGrid respectively. These people will keep all the services needed by CMS running at different sites around the distributed T2s. Without them there will be no CMS analysis running in the UK.

Vazquez Acosta (0.5FTE) as UK Data Manager, responsible for data transfers to UK sites, monitoring available space and deleting unused data sets to keep the system running efficiently, without which data transfers become chaotic. This post is vital for smooth running of CMS UK operations.

GridPP have funded a further 1.5FTE for CMS computing activities. This has been divided into 0.5FTE at the T1, matched by another 0.5FTE within RAL PPD to make a whole post to help coordinate CMS activity at the T1 and work alongside Brew. The remaining 0.5FTE is also based at RAL PPD but will act in a wider UK support role. While these funds have been available since the start of GridPP3 (April '08) delays within STFC have meant that only now have we been able to recruit the first of these posts (T1 liaison) and the second post will start in October 2009. At that time one of the current team (Jackson) will complete his thesis and depart.

The posts will continue to the end of GridPP3 (March 2011). To reduce the effect of the possible loss of these posts we are also applying for an additional 0.5FTE of new effort, Bristol (M&O), to strengthen this fragile team. This person will start in October 2010 and will work to support the activity at the T1 and the SouthGrid T2. They will also take a direct role in user support within the UK, which is an area often overlooked and yet extremely important.

The second objective is to continue to take both a leadership and software engineering role in the DMWM area. While tools that CMS has produced will function sufficiently well during initial data taking, this period is bound to identify undesirable features and require improvements essential for software usability. Existing expertise of UK collaborators will be of great benefit to CMS during this period. So CMS requests continuation of Metson (initially 1FTE, decreasing with time as involvement in other projects increases, but with CMS Computing and Offline remaining the greatest area of his activity during this rolling grant) as co-leader of the DMWM project and Wakefield (0.5FTE) as leader of the ProdAgent workflow package.

2.6 A comment on students

Most students have made contributions to construction, commissioning and operations and, since only partly mentioned above, we acknowledge these important efforts. All have made contributions to physics preparations as well. During the last period, they are:

- Tracker: Cripps, Pesaresi, Whyntie, Wingham
- GCT: Jones, Marrouche, Rose
- ECAL: Evans, Grant, Rompotis, Timlin, Wardrope, Yaselli
- Computing: Ball, Jackson, Metson, Wakefield
- Software: Goitom, Munro
- Physics: Ballin, Bostock, Croft, Hansen, Huckvale, Lynch, Nirunpong, Papageorgiou, Petridis, as well as those above.

2.7 Project support

A few comments supplement accompanying tables. We assume that CMS-UK remains at approximately its current size. M&O budgets scale with number of authors, as do travel requests. A large concern at present is the exchange rate which has fallen significantly recently. CMS has no Common Fund, other than M&O A costs paid directly by STFC.

2.7.1 Travel

It is difficult to make precise predictions much beyond the first couple of years of the grant period. A large fraction of the budget is dedicated to Long Term Attachments in CERN. While construction has ended, many staff (or replacements) closely associated with those activities must remain there to undertake expert support, such as to Tracker FED DAQ, GCT hardware and firmware, ECAL operation and performance. CMS is a huge and complex system and it has not yet been operated long term. It has estimated that all members will require to commit 0.25FTE effort on average to keep the experiment operating, maintain it and provide the first level of data reduction. This includes important tasks in data quality monitoring, which must be done promptly in real time to avoid detector inefficiencies, and calibration and alignment, to ensure data analysis can proceed rapidly, but it does not include management tasks. The hardware reliability is not yet established, nor the need for modifications where this is possible, such as firmware and online software.

We estimate that there may be a small decline in the total number of LTAs over the grant period, but with a consequent increase in short term travel.

2.7.2 UK M&O

The budget covers commitments to maintain sub-detector systems (M&O B) and support CMS-UK operations (e.g. van hire, office materials, telephones, computer repairs or replacement at CERN, stores costs, instrument repairs and replacement). Institutes should maintain their systems but M&O B costs are defined by fraction of eligible CMS members.

Our M&O B estimates are based on figures presented to the RRB in October 2008. In addition we estimate a requirement of approximately £12.5k/year/group for the expenses in support of UK operations, both in the UK and at CERN. Larger groups are expected to use proportionately more than smaller groups.

2.7.3 STFC Technology Department Effort

The requirements are summarised in Appendix ii and the Excel workbook.

2.7.4 Likely requests to the PPRP in the next 3 years

A proposal for CMS upgrade activities was submitted to the PPRP in 2007 and approved during 2008, with a start date of January 2009. It is a 3-year programme focused on our core activities of Tracker, Trigger and simulation work. Towards the end we foresee a definition of possible UK contributions to a CMS upgrade project, which will be specified by a TDR. This therefore looks likely to be submitted only about three years from now.

3. Figures

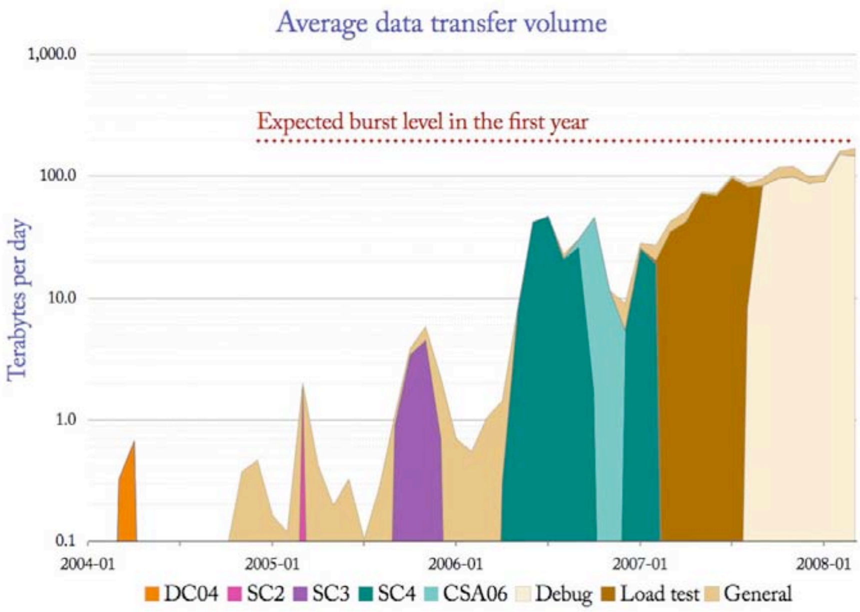

Figure 1 The growth of CMS data transfers since 2004. Taken from D. Bonacorsi June CMS week presentation. The different colours depict different challenges.

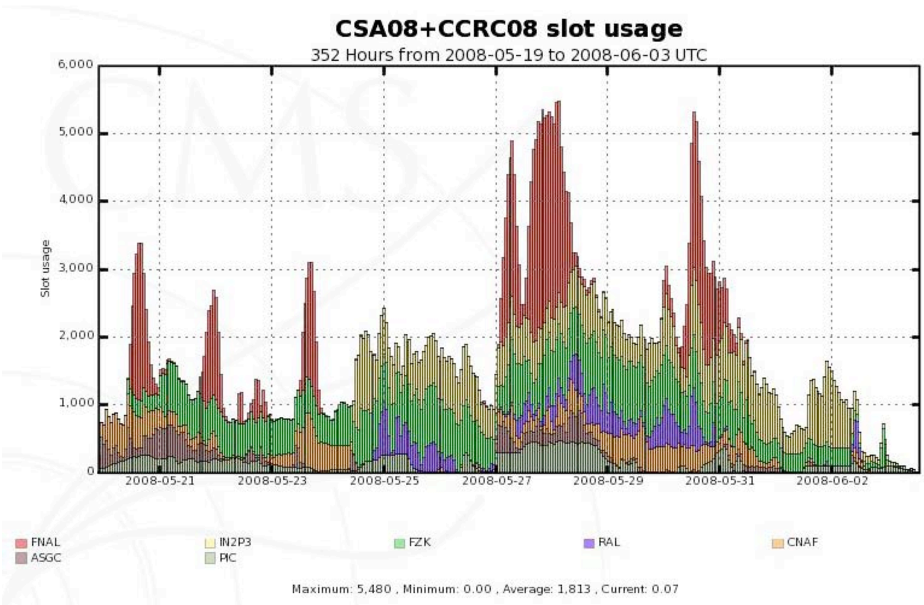

Figure 2 Re-reconstruction during the first phase of CSA08.

4. Appendices

4.1 Appendix i: UK personnel in coordinating roles

a) Experiment-wide responsibilities

Brunel		
A Khan	CMS Offline and Computing: user support group coordinator	
Bristol		
J Brooke	CMS Offline and Computing: L-1 trigger software coordinator	to Dec 2008
	CMS Level-1 Trigger: Trigger Detector Performance Group convener	from Jan 2009
G Heath	Member CMS thesis prize committee	
C Hill	Joint Top and EWK Physics Analysis Groups: W+jets working group coordinator	from Sep 2008
S Metson	CMS Offline and Computing: Data & Workflow Management coordinator	
D Newbold	CMS Computing Resource Board chair	to Dec 2007
	LCG resource management liaison	to Dec 2007
	Upgrade Project: trigger simulation coordinator	from Apr 2008
Imperial College		
R Bainbridge	Tracker Data Quality Monitoring group coordinator: microstrips	
	Member Tracker Editorial Board	
O Buchmueller	CMS Physics: SUSY Physics Analysis Group convener	
D Colling	UK representative on Computing Resource Board	from Jan 2008
	Member WLCG Collaboration Board	
C Foudas	Trigger Project: Global Calorimeter Trigger Project Manager	
	Upgrade Project: trigger coordinator	
J Fulcher	Tracker Project: online DAQ group coordinator	
D Futyan	CMS Offline and Computing: calibration and alignment convener	from Jan 2008
	CMS Physics: egamma Physics Object Group convener	to Dec 2007
G Hall	CMS Tracker deputy Project Manager	
	Member CMS Management & Finance Board	
J Nash	CMS Electronics Coordinator	to Dec 2008
	CMS Upgrades Project Manager	from Dec 2008
	Member CMS Management & Finance Board	
A Nikitenko	CMS Physics: Higgs Physics Analysis Group convener	to Dec 2007
	Higgs Physics Analysis Group: Higgs-> tau + tau sub-group coordinator	from Jan 2009
C Seez	CMS Commissioning and Run Coordination: ECAL Detector Performance Group convener	to Dec 2007
	CMS Physics: egamma Physics Object Group convener	from Jan 2008
	Member ECAL Steering Committee	to Dec 2007
	Member ECAL Editorial Board	to Dec 2008
	Member of ECAL Conference Committee	to Dec 2008

P Sharp	CMS Tracker Project Manager	to Dec 2008
	Member CMS Management & Finance Board	
A Tapper	SUSY Physics Analysis Group: all-hadronic channel sub-group coordinator	
M Vazquez Acosta	Trigger Studies Group: Trigger Performance Group sub-group coordinator	to April 2009
T Virdee	CMS spokesperson	from Jan 2007
RAL PPD		
KW Bell	ECAL Project: installation and commissioning coordinator	
	ECAL Project: field technical coordinator	
	Member ECAL Steering Committee	
C Brew	Computing Facilities/Infrastructure Operations: Tier-1 coordinator	
RM Brown	ECAL Institution Board, chair	
	Member ECAL Steering Committee	
	Member ECAL Conference Committee	
	Member ECAL Editorial Board	
D.J.A. Cockerill	ECAL endcap Project: project manager	
	Member ECAL Steering Committee	
	Member ECAL Conference Committee	
	ECAL Project: endcap performance and stability working group chair	
J.Cole	Deputy-Chair of Tracker Editorial Board	
N Geddes (STFC)	CMS Computing Resource Board chair	to Dec 2008
J Hill (RAL ED)	ECAL Project: endcap project engineer	
D Newbold	- See Bristol (joint RAL-Bristol appointment)	
C Shepherd-Themistocleous	Exotica Physics Analysis Group: Z'->ee sub-group coordinator	
I Tomalin	CMS Physics: b-tag and vertexing Physics Object Group convener	to Dec 2007
J Womersley	Review of readiness for Physics, Trigger and Offline (2007), chair	

b) UK responsibilities

Brunel		
P Hobson	Member UK Steering Committee	
Bristol		
G Heath	Member UK Steering Committee	
D Newbold	UK Computing Project coordinator	to Dec 2007
	Member Offline and Computing Finance Board	to Dec 2007
	Member UK Steering Committee	
Imperial College		
D Colling	UK Computing Project coordinator	from Jan 2008
	CMS representative on GridPP Collaboration Board	from Jan 2008
	CMS Representative on GridPP Project Management Board	from Jan 2008
	Chair and CMS representative of LondonGrid T2	

	Management Board.	
	UK Member Computing Resource Board	
	Member UK Steering Committee	
	LondonGrid Tier-2 manager	
C Foudas	UK Trigger Project coordinator	
	Member UK Steering Committee	
G Hall	UK spokesperson	from Jan 2008
	UK Tracker Project coordinator	
C Seez	Member ECAL Joint Institution and Finance Board	
	UK Physics co-coordinator	
	Member UK Steering Committee	
M Vazquez Acosta	UK Data Manager	
S Wakefield	UK coordinator of offline production and processing	
	LondonGrid Tier-2 CMS technical and support coordinator	
RAL PPD		
C Brew	CMS Tier-1 liason	
	SouthGrid Tier-2 CMS technical coordinator	
RM Brown	UK spokesperson	to Dec 2007
	Member of ECAL Joint Institution and Finance Board	
D J A Cockerill	UK ECAL project coordinator	
	Member UK Steering Committee	
N Geddes (STFC)	UK Member Computing Resource Board	
D Newbold	- See Bristol (joint RAL-Bristol appointment)	
E Olaiya	SouthGrid Tier-2 CMS support coordinator	
C Shepherd-T Themistocleous	Member ECAL Joint Institution and Finance Board	
	NExT Institute co-director	
	Member UK Steering Committee	
	UK Physics coordinator	
I Tomalin	Member Tracker Institution Board	
	UK Budget Holder	
	Member UK Steering Committee	

4.2 Appendix ii: UK commitments to M&O and Computing Infrastructure

4.2.1 Tracker

The Tracker items for which the UK is responsible consists of a series of major electronics boards, supervision of their crates, power supplies and cooling along with the firmware and software to operate, test and monitor the system. The boards contain large (and small) FPGAs and must be updated and maintained constantly to ensure CMS operation is not compromised. The UK must also contribute to the maintenance and development of the online and offline software of the Tracker as a whole. Tracker operating shifts are a shared duty.

500 9U VME Front-End Driver (FED) boards. The system requires 440 FEDs for operation with the remainder as spares. However, it should be noted that it will be practically impossible to produce identical new boards in case of loss or damage, due to component obsolescence. In particular, the (expensive) optical receivers used on the FEDs can no longer be procured as the manufacturer has discontinued activities. Repairs and error diagnostics on the FEDs requires RAL ID staff.

500 Slink transition cards interfacing to the DAQ Frontend Readout Links, maintained by RAL ID.

Firmware maintenance and development for FED boards. The system FPGAs (VME interface and data transmission) are carried out by RAL ID staff. The Front End FPGA, carrying out data processing firmware, has been maintained by Imperial (Noy, Zorba) and will in future require Zorba and Fulcher.

FED rack, crate and power supply supervision and monitoring. Zorba (Imperial)

Online software maintenance & development for FED. Cole, Fulcher, Bainbridge (Imperial, RAL-PPD)

Maintenance of test systems for FED repair. RAL ID and Zorba (Imperial)

Maintenance of 8 6U APVe emulator boards, developed at Imperial College. **Firmware maintenance and development** by Fulcher and Zorba (Imperial) **Online software maintenance & development** by Fulcher, Bainbridge (Imperial)

The **APV25** chip cannot be replaced or modified, since the Tracker is completely inaccessible. However the expertise in its use must be maintained, and has already proven to be essential in understanding subtle features of operation. For this we require: **Maintenance of a local test system**, with detector modules, for diagnostics. **Technical support for APV25 operation**, eg, especially since full scale low temperature operation has not yet been undertaken. This work requires Raymond (Imperial) with assistance from Zorba (Imperial).

DAQ software & DAQ operation (including optimisation of calibration/commissioning procedures). Bainbridge, Cole, Fulcher. (RAL-PPD & Imperial).

Offline software development (including Tracker performance monitoring & alignment). Bainbridge, Cole, Harder, Reid, Stoye, Tomalin. (Brunel, RAL-PPD & Imperial).

Our estimate of **RAL ID staff** is based on experience to date and is expected to be approximately 1 FTE/year, with the balance of engineering (firmware, diagnosis) and technician effort evolving over the coming years.

For **RAL-PPD staff** we estimate 0.5 FTE Cole, 0.1 FTE Harder, 0.25 FTE Tomalin

For **Imperial staff** we estimate 0.2FTE Raymond, 0.5FTE Zorba, 0.75FTE Fulcher and 0.3FTE Bainbridge, 0.4 FTE Stoye. All supervision will continue to be provided by Hall.

For **Brunel** we estimate 0.5 FTE Reid.

4.2.2 ECAL

The CMS ECAL Memorandum of Agreement (MoA) task force defined and quantified service functions required to be carried out by collaborating institutes. The UK has discussed these functions and is contributing to those that match our obligations and future interests as closely as possible. The net average contribution is expected to be 0.25 FTE per person (including students) across the CMS ECAL community. Certain vital on-call roles, such as EE HV and Field Technical Coordinator, carry a higher credit weighting than, for example, the elapsed time spent on shift. Roles at the level of 25% FTE commitment or higher have been explicitly indicated.

The EE HV system The system consists of 2 CAEN HV supplies and 8 HV distribution crates with active controls for overvoltage and over current protection. Within the crates are a total of 8 HV control cards, 8 HV input cards and 52 output cards. The distribution crates are served by 2 low voltage supply crates. Spares will be available for all items.

EE HV on call RAL-PHYS (25%), Bell, Cockerill, Cussans, Leslie, Shepherd-T.

EE HV maintenance S.Nash, Torbet (35%).

VPT operation and data quality Cockerill (25%), RAL-PHYS, Barrett

EE maintenance and repair PPD technical support (25%), Bell, J.Hill (35%)

ECAL Field Technical Coordinator Bell (50%)

ECAL run coordination Bell

ECAL online data coordinator Responsible for the parameters and testing of the ECAL online system to ensure correct ECAL operation, Ryan (25%)

ECAL expert on-call responsibilities

- **Trigger** Responsible for the system producing the ECAL local trigger, Ryan
- **DAQ** Responsible for the online software modules associated with the acquisition of ECAL data, RAL-PHYS
- **Front End Parameters** Responsible to ensure correct pedestals, limits and thresholds for the front-end readout cards, RAL-PHYS
- **Laser/LED calibration** Responsible for the fast analysis of data to ensure laser/LED pulses are within range, Barrett (25%)

ECAL Offline Software Operator In charge of the developments and updates of the offline software for ECAL, Barrett (25%), H.Heath

ECAL Offline Calibration Operator In charge of the data processing to obtain the calibration coefficients for ECAL, Futyan (25%), H.Heath, Seez

CMS and ECAL Trigger DQM Responsible for offline trigger and data quality monitoring tools and electron ID Harper (35%) Shepherd-T.

ECAL clustering software Responsible for development and writing software. Kennedy, with Shepherd-T, Harper, Seez.

ECAL detector description Description for CMS detector and test beam layouts. Kennedy.

ECAL shifts involve principally **Brunel** (Barrett, Hobson, Khan, Kyberd, Leslie), **Bristol** (Cheng, Cussans, Heath) **Imperial** (Futyan, Hays, Nikitenko, Ryan, Seez, Tourneur), **RAL** (RAL-PHYS, Cockerill, Harper, Kennedy, Shepherd).

VPT 4T test stand at Brunel Hobson, Kyberd, Leslie, Selby

The ECAL Crystal Endcaps are already fully commissioned. However RAL ED support (J.Hill) will be required for CMS technical reviews, using the experience gained from installation, in order to prepare for possible dismounting scenarios where particular issues, such as significant activation of the Endcaps, will require additional engineering input. The EE handling equipment will also require occasional safety reviews and dry assembly exercises to maintain a satisfactory level of technical readiness at CERN. We therefore request 0.4 SY of ED in 2009/10 and 2010/11 to support these activities, and 0.3 SY in 2011/12 and 2012/13.

The HV distribution system will be fully operational from April 2009 onwards. However, unexpected problems may arise, for example noise entering the system, or higher than expected leakage currents during LHC operation, and these may require future system optimisation. In the long term these issues should have been addressed and the ECAL should need progressively less TD input (Torbet). We request 0.4SY from TD to support this area in 2009/10 and 2010/11, the first collision years of LHC operation, and 0.3 SY in 2011/12 and 2012/13.

4.2.3 Global Calorimeter Trigger

The GCT consists of 22 large algorithm and 63 data transmitting FPGAs distributed over 5 different type of cards:

63 Source Cards (6U VME) which convert the calorimeter data to optical format**,**

8 Leaf Cards which run the main electron and jet algorithms**,**

2 Wheel Cards (9U VME) and

1 Concentrator Card (9U VME) which form the GCT output data record and

1 Opto-GTI Card which transmits the data to GT in 3 GBps optical format.

In addition the Q/M-Bit system consists of:

6 Matrix Cards and

1 uTCA Backplane mother board.

These devices utilize optical links in the range of 2-3 GBps to receive and transmit data. All required GCT hardware except the Q- and M-bit system have been commissioned in the CMS underground cavern (USC-55).

This system must be kept constantly in working condition and response should be rapid in the event of even minor problems otherwise delays will result in significant data loss.

Hardware and firmware: only Iles (Imperial) is capable of repairing and maintaining GCT firmware and hardware. His expertise may be required, below 0.1FTE, for support of Tracker APVe and firmware. We require 0.8 FTE total of his time for the duration of the grant.

RAL engineering. With the removal of project-funded engineering effort, the reliance on a single individual is a dangerous situation for such a crucial component of CMS. We therefore request 0.5FTE/year engineering effort for GCT firmware and hardware maintenance.

Offline and Online Software Support: The emulator software is the responsibility of G.Heath (Bristol) required 0.2FTE. The unpacker software is the responsibility of Tapper (Imperial) who is required at 0.1FTE. Frazier (Bristol) is essential to develop and maintain the GCT online software, at 0.5FTE.

Operations Support: These functions have been carried out so far by Tapper and Foudas (Imperial). We request A. Tapper 0.9FTE for the duration of the grant.

4.2.4 Computing Infrastructure

For these resources, GridPP provides hardware and minimal effort to run generic services. No other hardware request is foreseen. CMS must provide CMS specific effort which has been explained in the section on Future Computing activities.

4.3 Appendix iii: Long term attachments

The first year of CMS operation is particularly important and we have a strong team in place. Our success and high profile in the experiment relies heavily on the availability of full time UK staff (and students) in CERN. CMS is fully stretched to cover all activities and the machine schedule for the coming year remains unclear, although it looks likely that the LHC once started may continue operation throughout the winter, except for a Christmas break. This makes it even more important that we are able to maintain the UK presence in CERN during this critical period.

We also note the important roles being played by those on LTA in early physics analysis. To capitalise on the large investment made by the UK in CMS, our front-line participation in the commissioning of first data taking is essential, during which time access to all relevant CMS data at the CAF at CERN may be important. Therefore, effective participation in this offline commissioning task makes presence at CERN highly desirable.

4.3.1 R. Bainbridge

Bainbridge is responsible for software to configure, synchronize and calibrate the CMS Tracker readout system, working closely with the tracker DAQ team. A major part of his activity has been Data Quality Monitoring. Presently, he convenes the tracker DQM group. He provides software support for commissioning, calibration, reconstruction and monitoring.

The tracker system is large, and probably the most complex in CMS. The procedures automatically tune the configuration of the tracker control and readout systems in a way that is optimal for physics data-taking and are also used to assess the long-term functionality and performance of these systems. They also provide calibration constants required by the offline event reconstruction and filtering processes.

It is essential to be located in CERN as part of the DAQ team, in close proximity to the hardware. The goal is synchronizing the tracker to LHC collisions and monitoring data, and optimising the overall performance. Fast response is crucial.

He is contributing to studies of jet reconstruction focussing on the tracker and how it can be used to improve efficiencies, energy scale and resolution. He works with the SUSY group on searches for evidence of super-symmetric particles and also to supervising Imperial students based in CERN.

4.3.2 M. Barrett

Barrett will be working on the ECAL, he will work with the ECAL DAQ group on data acquisition and monitoring systems, a critical task evolving as the needs of the CMS ECAL systems move into a running state following the start of colliding beam runs at the LHC. The system will need to be stable during running conditions, and able to adapt to changing beam conditions. Barrett will join the existing team, and will take over the development and maintenance of part of the system. This will require presence at CERN to fulfil.

Barrett is an active member of the CMS top quark physics analysis group, studying semileptonic top pair decays. At CERN he will work with the Brunel student based at CERN, and provide a link between physics activities at CERN and the Brunel group.

4.3.3 K.W. Bell

Bell has been a key person in the CMS ECAL project since the outset, and brings a wealth of electromagnetic calorimetry experience with him, particularly from OPAL, where he was responsible for the construction and running of the EE detector (read out with first generation VPTs) at LEP. Bell was ECAL Commissioning and Installation Coordinator responsible for the successful installation and commissioning of both the EB and EE in 2007/8. He is now the ECAL Field Technical Coordinator, responsible for all interventions on the ECAL. This is a particularly challenging role, carried out round the clock, requiring rapid response should any ECAL issues arise. Bell is responsible for all installation and maintenance activities during shutdowns and for their resolution before closure. He reports directly to the ECAL Project Manager and the CMS Technical Coordinator.

Bell is a crucial member of the EE team and will bring particular attention to EE operation and maintenance issues for which the UK is primarily responsible, such as the VPT HV system. He is scheduled to take on increasing responsibilities, for example as ECAL deputy run coordinator, as the ECAL reaches full operational status.

4.3.4 J.J. Brooke

Brooke has been resident at CERN on LTA since April 2005. He has overseen the development of both online and offline software for the Global Calorimeter Trigger project. His work leading this became an example throughout the CMS trigger group and he was asked to coordinate all CMS Level-1 Trigger software during 2007-08. Recently he was appointed to coordinate the Level-1 Trigger Detector Performance Group (TDPG) which must understand the efficiency, purity and rates of all Level-1 triggers at CMS. It is a vital activity over the early period of LHC running, which is currently under-resourced. His presence at CERN is essential for the CMS trigger and for him to fulfill these duties. He will continue to manage the maintenance and development of the GCT software; this will include adding trigger functionality, streamlining the online environment and improving the monitoring of performance and data integrity.

Jim will also spend fractions of his time developing the simulation package within CMSSW for use with upgrade studies; and contributing to the UK physics analysis programme. He will continue to be the senior Bristol physicist resident at CERN. This means he will provide a vital link between physics activities at CERN and the work of academics and others resident in Bristol. He will also have responsibility for local supervision of Bristol Ph.D. students during their time in CERN working on CMS.

4.3.5 O. Buchmueller

Buchmueller has worked intensively as an member of the Imperial College group since January 2008, joining full-time in January 2009 when his CERN staff post ended. His teaching commitments begin in October 2009. He became coordinator of the CMS SUSY group in 2008 and rejuvenated an activity which had run into some difficulties.

Within less than a year a strong SUSY activity has been established and today Imperial provides one of the strongest efforts in CMS SUSY activities. In the past six months the group has mainly focused on analyses in the all-hadronic channel. In particular the Imperial group led a novel analysis effort using the exclusive di-jet topology to search for dark matter candidates in the early days of LHC operation. This analysis was recently approved by CMS and it is considered a prime example of a very robust, yet still efficient SUSY search, optimized explicitly for the difficult start up environment. It has paved the way for the development of a comprehensive discovery strategy in the all-hadronic channel that is tailored for early searches in 2009/2010.

Both to drive the CMS SUSY activities and manage the Imperial team in this area, we propose to based him in CERN until his teaching duties commence in the first year, and similarly for part of the following year, as teaching duties permit

4.3.6 D.J.A. Cockerill

Cockerill has been the CMS EE Project Manager since its inception, and was responsible for overseeing all details of detector design and construction through to its installation and commissioning in August 2008. He is now chair of the EE Performance and stability group which brings together EE analysis and hardware teams to evaluate detailed detector response issues on a near daily basis. The group provides input to the ECAL Prompt Feedback Group (PFG) and the ECAL Detector Performance Group (DPG) to ensure the optimal running and performance of the detector. The group also appraises the possible hardware interventions that might be required to maintain EE in maximum working order. These activities require a full time presence at CERN. Cockerill is likely to become ECAL deputy project manager, responsible for the EE, from 2010 onwards.

Cockerill will apply his detailed knowledge of the ECAL to study physics channels, such as boosted Z' decays, and certain dark matter decay models, where electrons are close to one another, which offer particular challenges for particle identification and measurement.

4.3.7 J. Fulcher

Fulcher is responsible for software for the 440 Tracker FEDs, , plus spares, and online software. He is a key contributor to the CMS Tracker DAQ, which has been developed by a team of 4-5 people, some of whom have recently left CERN. He must also maintain and upgrade firmware and we expect him to take greater responsibility for this in future. He oversees the hardware and its operation in CMS.

The Tracker DAQ is now essentially complete but must operate flawlessly. Small issues with hardware, software and firmware upgrades do arise and need immediate attention. The online software necessary for this enormous system will undoubtedly require significant maintenance in close proximity to the hardware and other team members. This is the front line interface to the supervision of the UK-provided hardware, and its maintenance. It is vital to be located in CERN where CMS is operating, and to maintain the DAQ during CMS operations. His online effort is expected to be ~0.75FTE, rising to 1FTE during operational periods.

He also contributes to supervising Imperial students based in CERN.

4.3.8 D. Futyan

Futyan is an STFC Advanced Fellow, expecting to play a decisive leading role in discovery of new physics, focusing on ECAL and electron and photon channels.

He is co-convener of the e-gamma physics object group, responsible for triggering, reconstruction and identification of electrons and photons and played a leading role in defining objects for physics analysis, and of the framework for electron and photon identification. It also involved planning commissioning activities, including coordinating development of techniques for measuring electron efficiency with first data. He is co-responsible for coordination and integration into CMSSW of new e-gamma software releases.

Since 2008, he is co-convener of the Calibration and Alignment group, responsible for the design and implementation of the software and computing infrastructure align and calibrate of CMS. This will continue until 2010, and includes coordination of these crucial activities during first collision data taking.

The role also involves responsibility for the design and implementation of dedicated data streams required for calibration and alignment, both from Point 5 to the Tier0, and from Tier0 and Tier1 centres to the CAF, in collaboration with the Data Operations team. A key responsibility is definition of the set of information to be taken from the conditions database in any data taking or Monte Carlo production.

Location in CERN is essential for these tasks. From early 2010 he will move from commissioning to physics analysis, on new physics searches, in particular supersymmetry.

4.3.9 S. Harper

Harper has been at CERN for nearly one year. He has performed major work on electron identification particularly for high energy electrons. This work has been used in the Z' to electron analysis where Harper has played a central role. Harper has also defined and written the offline DQM for the electron and photon triggers. With the arrival of data Harper will have two major roles that will require his presence at CERN. He will be studying the performance of the elements of the electron ID which will feed directly into the detector performance as well as establishing a functioning CMS electron ID. He will be using the DQM system he wrote to both study the performance of the electron and photon triggers providing rapid feedback again to the detector and HLT systems and study the performance of variables that enter the electron identification procedure. To perform these roles effectively it is important that Harper be resident at CERN.

Harper has played a major role in preparations for the Z' to electron analysis and will put this work into practice with the arrival of data working towards one of the very earliest CMS publications. This work has included the electron work as well as a study of the QCD background both suppressing and measuring it. His work has resulted in major improvements in electron identification and background suppression in the CMS endcaps in particular. From this perspective he will work with the EE performance group to ensure optimal performance from this subdetector.

4.3.10 G. Iles

Iles is now the key, and only, remaining engineer on the Global Calorimeter Trigger project, uniquely responsible for hardware and firmware operation, which must be kept permanently operative during data taking. He has been with GCT since the beginning of the project in 2006 and has played a major role in commissioning, producing and testing hardware, developing firmware and writing Python software for subsequent implementation in C++. He is the designer of two of three GCT Cards (Concentrator, GTI and Opto-GTI). His immediate tasks include an upgrade of the high speed serial links that connect the GCT to the Global Trigger using 3.2Gb/s optical links and testing and commissioning of the Muon-Quiet Bit system.

The responsibility for implementing new GCT algorithms in firmware and maintaining and modifying existing algorithms when requested by CMS rests uniquely with him, so he is therefore an irreplaceable figure in GCT operation at CERN. His future work will focus on implementing new triggers, as requested during running and challenges posed to the calorimeter trigger by increased luminosity as it occurs. The new CMS tau and missing Ht triggers which will be implemented on GCT are the first examples of this. His expertise with high bandwidth devices for the telecom industry coupled with programmable modern electronics are valued CMS-wide and aim to allow common hardware platforms, thus simplifying the design and reducing cost.

His presence in CERN is crucial to the success of the GCT project and CMS.

4.3.11 G. Karapostoli

Karapostoli is a recent appointment, from December 2008. She has extensive experience in Grid job submission and participated in development of the CMS interface tool CRAB (CMS Remote Analysis Builder) and will provide user support for CMS computing as part of her service contributions to CMS. Her experience testing and debugging the CMS Data management system for functionality and performance for physics data analysis usage ensures that she is well suited to support our computing activities. It is valuable to locate her in CERN for the present, since most students and many staff are based there and the UK support can be provided remotely.

She is needed to support the GCT, for which CERN location is mandatory. Trigger shifts at P5 are required and she will provide expert operational support during running, including to be on-call solving GCT problems. This includes prompt DQM, in order to declare data good for GCT.

Presently work is under way to analyse CRAFT trigger data with jet and electron triggers based on the GCT and determining efficiencies as a precursor to full data analysis. This is valuable for GCT validation but required also for the whole L1 CALO trigger chain and was a missing element of the CMS data evaluation, as well as essential for deploying the trigger data directly in analysis.

The major remaining part of her work will be in physics analysis, especially in the SUSY area where she is also experienced and her CERN presence strengthens this early physics effort.

4.3.12 A. Nikitenko

Nikitenko led the CMS Higgs physics analysis group for several years and is a physics driver in CMS. He is leading analyses of bbZ, Z->ll cross-section in early CMS data and searches for the Standard Model Higgs produced in Vector Boson Fusion and decaying into tau pairs. He is preparing for such extraction of early physics results as LHC comes into operation. He convenes the H-tau sub-group in the Higgs PAG which is very active, often with daily meetings. These groups are large and occupied intensively with data analysis and he is engaged in a wide range of physics activities, including jet energy corrections, Jet plus tracking (as a robust alternative to particle flow techniques)

He directs work of several Imperial students who are based in CERN as well as in the UK.

The Higgs activity will remain a key one, probably growing in intensity, and Nikitenko's role is important for the Imperial profile and contributions to CMS physics. It is essential for him to be in CERN to take this leading position.

4.3.13 M. Pioppi

Pioppi is another recent appointment, starting November 2008. His principal activity will be physics data analysis. He has extensive experience of the Tracker, being widely considered one of the most talented experts during his preceding CERN Fellowship. He made notable contributions to track reconstruction of cosmic events with standard and custom software, increased significantly the tracking efficiency in multi-track events with an iterative procedure which maintained a negligible fake rate, and improved electron reconstruction for particles that lose significant energy by bremsstrahlung. In addition, he is one of the main developers of the particle flow algorithm where he personally contributed to the electron reconstruction, identification and energy and directional resolution improvement. All of these are highly complementary to our CMS interests. He is pioneering the application of particle flow to SUSY searches and also working on a high profile analysis with significant discovery potential (same sign di-lepton signature, which is basically background free).

His service activities will be in the software areas, but his expected contributions to early data analysis motivate his location in CERN.

4.3.14 I. Reid

Following LHC start-up, Reid's experience in track reconstruction and measuring the misalignment of the silicon modules will be essential to the rapid exploitation of early physics from CMS.

Specifically Reid will develop and support code for track reconstruction, including the improvement of algorithms to deal with non-linear ADC baseline shifts and the effects of Heavily Ionising Particles on cluster charge location. The improvement of the current Kalman filter technique and the development of new analysis techniques to determine tracks and deal with the real-world complexities of a large tracker system will also be one of his tasks. Contributing effectively to this will require him being present at CERN during 08/09 and 09/10. He will also be engaged to a moderate extent from 2008 in supporting physics analysis (jet charge), as support duties allow.

4.3.15 M. Ryan

Ryan was posted to CERN to contribute to Endcap ECAL commissioning activities, where he was involved in several areas crucial to successful completion of the project, including electronics noise investigation, testing super-crystal performance and trigger mapping, which is extremely complicated in endcaps. He developed software testing procedures to check fibre mapping and conducted mapping tests for all endcaps both in the lab and during installation and commissioning. He will be contributing to ECAL data acquisition work, taking responsibility for the parameters and testing of the online system to ensure correct ECAL operation, and wih ECAL shift operation duties, with expert on-call responsibilities, and his presence in CERN will remain essential.

He is also beginning to investigate kinematics of electroweak boson production in a variety of MC generators including full detector effects to improve Monte-Carlo modelling. This will require development of software infrastructure and facilitate rapid analysis of first collision data for measurement of the W and Z production cross sections as well as providing infrastructure useful across the full range of analyses at CMS.

4.3.16 C. Seez

Seez is deeply involved on a daily basis in many aspects of the ECAL, playing major roles in design and performance studies, previously leading test beam activities and more recently driving data analysis and achievement of the ECAL resolution targets.

He led the CMS ECAL detector performance group and is currently e-gamma physics object convener. He is a member of several management bodies within CMS. This is foreseen to continue into the operation of CMS.

The responsibilities for software management and electron and photon physics concern many in the collaboration and he will continue to steer a large number of people, organizing meetings and setting goals. He is the Imperial deputy team leader. He supervises Imperial RAs and students. To do all this, it is essential he is based in CERN.

He will be in the front-line in 2009-2010, particularly in ECAL data analysis, and his expertise and experience will be essential there during CMS data taking.

4.3.17 M. Stoye

Stoye has two major activities: alignment and SUSY studies. Rapid and accurate alignment of the Tracker will be crucial to successful physics data analysis. So far improvements have been made to survey information using cosmic data but complete analysis will only be possible when collision data are available. Stoye is an expert on Millipede, which has proved to be the fastest and most successful method devised. The alignment constants obtained with Milipede outperformed other algorithms in precision as well as in computing resources used to calculate the constants. His involvement at a significant level is vital for future successful alignment and extensive testing and developing will continue to occupy him. This requires a substantial presence in CERN, hence the LTA.

His other work is setting up an analysis for fully hadronic SUSY searches, in close collaboration with other Imperial staff. This appears to be a very promising strategy and is attracting increasing interest. Being based in CERN, around a substantial group, has been very important to its rapid progress.

4.3.18 A. Tapper

Tapper has worked on the GCT for three years and is the person who made commissioning a success. He plays a crucial role in coordinating commissioning and is responsible for all aspects of underground operation and integration into the trigger chain. His individual contributions are in software, algorithm development and commissioning. He is a principal author of software to emulate the system, which is key to trigger logic design and evaluation of efficiencies for physics as well as to debug hardware during commissioning and validate the online decisions in routine running. He has also developed software to monitor trigger performance during operation. This provides tools to aid in commissioning, for example, to verify that sub-components have been correctly cabled.

He was personally responsible for validating the electron trigger in 2007 and for validating and commissioning the jet trigger with an Imperial student. In future he will play a major role in understanding the physics potential of the trigger using the first LHC data.

His presence in CERN is needed throughout CMS operation. During LHC runs he is essential to maintain the GCT system in working order, to be the local software expert to react and reconfigure the trigger according to physics needs, and to analyse data and perform studies to compute trigger efficiency. Rapid response is essential. A large effort will be dedicated to understanding GCT system performance, thereby contributing directly to physics analyses.

Tapper provides essential day-to-day connection of the GCT group to the CMS physics groups representing GCT in meetings and leading development studies for new triggers.

His work on the trigger matches well his strong interest in SUSY and over the past year he has been active in preparations for Supersymmetry searches. He coordinates the all-hadronic search SUSY sub-group.

4.3.19 S. Tourneur

Tourneur joined in November 2007 and has been devoted to physics performance of the electromagnetic calorimeter. The lead tungstate crystals were chosen by the need to have excellent energy resolution for searches for Higgs decaying to two photons. His work consisted of determining best possible corrections to be applied to the unconverted photon energy in order to provide a uniform energy response of the electromagnetic calorimeter all over its surface. Using a complete simulation of photons through the calorimeter and the CMS 4T magnetic field, he provided correction functions shown to improve the unconverted photon energy resolution from 0.98% down to 0.85%. His presence in CERN has been essential for the rapid evolution of these studies and will continue to be so.

He is active in the CMS electroweak physics group, joining efforts aimed at preparing for the early CMS measurement of the Standard Model W boson cross section in the electron decay channel. The electromagnetic calorimeter is central to this analysis. He will continue work to improve methods used to estimate QCD background, which is expected to contribute the biggest part of the systematic uncertainty in the W cross section measurement. This has consequences not only for Standard Model signals, the first goal of CMS, but also for searches for new physics involving missing energy in the detector.

4.3.20 M. Vazquez Acosta

Since joining Imperial in March 2008, Vazquez Acosta has coordinated the Trigger Performance subgroup (TPG) of the Trigger Studies Group studying performance of individual trigger algorithms: CPU, memory, background rejection and physics efficiency of signal events. It has been a major and recognized contribution and required constant interaction with the trigger groups, necessitating her full time presence in CERN. She will reduce her efforts on this shortly to concentrate on physics analysis using the first LHC data. However, she will continue to carry responsibilities in the Trigger project which will need her presence in CERN.

The focus of her activity of the next three years will be in measuring the cross-section for $Z \rightarrow \tau\tau$ using the first LHC data. This activity starts with understanding the trigger and tau-identification efficiency and goes all the way to the first publication, which should demonstrate that CMS can detect a Z boson decaying into two τ-leptons. In doing this she will be providing a vital link between the developments at CERN and the London based Imperial group involved in the same analysis. Her long term objective is to use this experience for detecting the Higgs produced via vector boson fusion and decaying into two τ-leptons which is one of the most promising channels for detecting a low mass Higgs. She will continue to contribute in supervising Imperial students based in CERN.

She is also Data Manager of all UK CMS computing sites including the RAL T1 centre and two Tier 2 sites in South Grid and London. She oversees all CMS data movements in the UK, monitoring available disk and tape space at each site as well as commitments of the sites to meet the physics analysis needs of local (UK) users.

4.3.21 Senior RAL PPD Physicist

We anticipate requiring LTA for a least one senior physicist from RAL PPD within the grant period. Both Shepherd-T and Tomalin are currently prominent in major physics analysis in CMS. Shepherd-T leads the CMS Z' to electrons search and Tomalin the CMS search for particles with long lifetimes. Tomalin has previously held several CMS coordination posts, namely CMS Tracker Software coordinator, CMS b tagging coordinator and CMS Tracker data-handling coordinator. Shepherd-T is the CMSUK physics co-coordinator. Amongst many other activities Tomalin is currently working on extending CMS tracking capability and has developed the b HLT algorithms. He has the expertise required to study tracker performance with data and provide advice on modifications to tracker software/calibration packages and has supervised such work. Shepherd-T is closely involved in the electron ID, electron triggering and ECAL clustering.

Given these activities it is very likely that one or both of the above people will be required to be on LTA to fulfil a senior physics coordination role. We therefore request that allowance be made for two years LTA within the grant period to cover this eventuality.

4.3.22 RAL-PHYS (PPD)

The PPD ECAL physicist will be responsible, on-call, round the clock, for the VPT HV system, one of the principal, mission critical UK hardware responsibilities for the CMS ECAL Endcap calorimeter. This person will need to be in residence at CERN to undertake these duties effectively and will play a key role to ensure excellent ECAL performance, particularly concerning the ECAL DAQ, for real time Data Quality Management (DQM) tools for use during data taking and to provide feedback to the ECAL Prompt Feedback Group (PFG). He will assist the ECAL Field Technical coordinator for any interventions required on the EE. He will contribute to the understanding of ECAL detector performance and the calibration of the detector, with particular emphasis on VPT operation and stability using the laser/led monitoring systems.

This person will contribute to the existing and developing PPD physics programme in particular capitalising on the ECAL expertise and understanding they will acquire in the role described above. The analysis work will initially focus on searches involving high energy electrons in searches for Z' and signals including boosted Z bosons. Contributions will also be made to the programme beginning on SUSY searches where the signature includes at least one electron. Ultimately observations will direct the field of work.

4.3.23 RAL Tracker RA (PPD)

The previous PPD Tracker RA on LTA was J. Cole. RAL PPD has contributed to major components of the Tracker readout system and has an important responsibility for the FED VME readout board, having developed specifications for it and written a significant fraction of the associated online software. Cole's duties included being responsible for the installation and validation of new releases of the Tracker software in the CMS control room, training shift crews and tracker commissioning runs. Following LHC start-up, there will be a need for continued maintenance of the FED and other Tracker DAQ software. This will include debugging of problems, software modifications arising from unexpected data taking conditions/signals, and improving error handling and automation in the light of increased experience. Tracker management has also requested that PPD provide effort to ensure the maintenance and possible additional functionality of the software used to commission and calibrate the Tracker. This work would include studies of Tracker performance with a view to refining calibration and commissioning procedures. PPD has considerable experience in this area, as I. Tomalin was former coordinator of the CMS Tracker Data-Handling Group and A. Gay performed detailed studies of Tracker hit resolution.

To cover these duties this RA will need to be resident at CERN on LTA. This person will also work on physics analysis with Tomalin. This will initially be on the search for particles with long lifetimes that he is leading.

4.3.24 RA Bristol

CMS is supporting the request for a new post at Bristol to maintain and develop the GCT online software currently provided by Frazier, and to strengthen the physics analysis activity. In order to contribute effectively to the GCT maintenance activities during the early years of CMS operation, it is essential that this post should be based at CERN to provide 24-hour cover.

This individual will also make important contributions to the Physics analysis; being based at CERN will increase not only their impact but the impact of the work of Bristol based academics and students, by ensuring that they are kept in touch with all developments.

4.4 Excel workbook

Provided separately.

5. CMS Notes and Publications

5.1 REFEREED PUBLICATIONS

Adzic, P. et al, (with **Heath HF, Lynch C, Mackay CK, Metson S, Newbold DM, Smith VJ, Tapper RJ, Bell KW, Brown RM, Cockerill DJA, Flower PS, Greenhalgh J., Hill J, Kennedy BW, Lintern L, Lodge AB, Shepherd-T C, Smith B, Sproston M, Williams JH, Beuselinck R, Britton D, Dewhirst G, Nikitenko A, Raymond DM, Ryan MJ, Seez C, Takahashi M, Timlin C, Zabi A, Zhang Y, Hobson PR, Sharif O, Yaselli Y,** "Intercalibration of the barrel electromagnetic calorimeter of the CMS experiment at start-up", *J. Inst.* **3** (2008)

W. Adam et al (with **R. Bainbridge**, **N. Cripps**, **J. Fulcher**, **G. Hall**, **M. Noy**, **M. Pesaresi**, **V. Radicci**, **D. M. Raymond**, **A. Rose**, **P. Sharp**, **M. Stoye**, **M. Wingham**, **O. Zorba**), "The CMS Tracker Operation and Performance at the Magnet Test and Cosmic Challenge" *J. Inst.***3** (2008)

CMS Collaboration (Adolphi, R. et al), "The CMS Experiment at the CERN LHC", *J. Inst.***3** (2008)

CMS Collaboration (Bayatian, G. L. et al), "CMS Physics Technical Design Report, volume II: Physics performance", *J. Phys. G* **34** (2007)

Brigljevic, V. et al, (with **Huckvale BJ, Mackay CK, Hobson PR**) "Study of di-boson production with the CMS detector at LHC", *J. Phys. G* **34** (2007)

Adzic, P. et al, (with **Heath HF, Lynch C, Mackay CK, Metson S, Newbold DM, Smith VJ, Tapper RJ, Bell KW, Brown RM, Cockerill DJA, Flower PS, Greenhalgh J., Hill J, Kennedy BW, Lintern L, Lodge AB, Shepherd-T C, Smith B, Sproston M, Williams JH, Beuselinck R, Britton D, Dewhirst G, Nikitenko A, Raymond DM, Ryan MJ, Seez C, Takahashi M, Timlin C, Zabi A, Zhang Y, Hobson PR, Sharif O, Yaselli Y "**Energy resolution of the barrel of the CMS Electromagnetic Calorimeter", *J. Inst.***2** (2007)

J.J. Brooke, D.G. Cussans, R.J.E. Frazier, G.P. Heath, B.J. Huckvale, D.M. Newbold, S.B. Galagedera, A.A. Shah "The design of a flexible global calorimeter trigger system for the compact muon solenoid experiment" *J. Inst.* **2** (2007)

Gennai, S. et al, (with **Nikitenko A**) "Search for heavy neutral MSSM Higgs bosons with CMS: reach and Higgs mass precision" *Eur. Phys. J. C* **52** (2007) 383-395

Kodolova, O., Vardanyan, I., **Nikitenko, A**., Oulianov, A., "The performance of the jet identification and reconstruction in heavy ions collisions with CMS detector" *Eur. Phys. J. C* **50** (2007) 117-123

Munro C., Andreeva J., **Khan A**., "ASAP distributed analysis" *IEEE Trans. Nucl. Sci.* **54** (2007) 1753-1757

CMS Collaboration (David G. d'Enterria, (Ed.) *et al*.). "CMS physics technical design report: Addendum on high density QCD with heavy ions". *J. Phys. G* **34** (2007) 2307-2455

5.2 CONFERENCE / WORKSHOP PUBLICATIONS

Leslie D.E. "Timing performance of a Vacuum Phototriode", Proc. 10th ICATPP, Como Italy 2007, World Scientific (2008)

R.H.C. Lopes, **P.R. Hobson**, **I.D. Reid** "Computationally efficient algorithms for the two-dimensional Kolmogorov-Smirnov test", *J. Phys. Conf. Ser.* **120** (2008)

R Bainbridge et al (with **N. Cripps**, **J. Fulcher**, **V. Radicci**, **M. Wingham**), "Data Acquisition Software for the CMS Strip Tracker" *J. Phys. Conf. Ser.* **119** (2008)

S. Mersi et al (with **R. Bainbridge**, **N. Cripps**, **J. Fulcher**, **M. Wingham**), "Monitoring the CMS Strip Tracker Readout System" *J. Phys. Conf. Ser.* **119** (2008)

N. De Filippis et al (with **R. Bainbridge**), "Real-time Dataflow and Workflow with the CMS Tracker Data" *J. Phys. Conf. Ser.* **119** (2008)

Brown, R.M., “Avalanche photodiodes and vacuum phototriodes for the CMS electromagnetic calorimeter”, *Nucl. Instr. Meth. A* **572** (2007)

Brown, R.M., “The CMS electromagnetic calorimeter”, *Nucl. Instr. Meth. A* **572** (2007)

D. Newbold, **J. Brooke**, **R. Frazier**, “A First-Level Track Trigger Architecture for Super-CMS”, ”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-07, CERN–2007–007

C. Foudas et al (with **G. Iles**, **J. Jones**, **A. Rose**, **M. Stettler**, **G. Sidiropoulos**, **A. Tapper**, **J. Brooke**, **R. Frazier**, **G. Heath**, **M. Hansen**), “First Results on the Performance of the CMS Global Calorimeter Trigger”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-07, CERN–2007–007

M. Stettler et al (with **K. Fountas**, **M. Hansen**, **G. Iles**, **J. Jones**) “Modular Trigger Processing, The GCT Muon and Quiet Bit System”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-07, CERN–2007–007

G. Iles et al (with **J. Brooke**, **C. Foudas**, **R. Frazier**, **G. Heath**, **M. Hansen**, **J. Jones**, **J. Marrouche**, **A. Rose**, **G. Sidiropoulos**, **M. Stettler**, **A. Tapper**), “Performance and lessons of the CMS Global Calorimeter Trigger”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-08, CERN–2008–008

M. Raymond, **G. Hall**, “CMS Microstrip Tracker Readout at the SLHC”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-08, CERN–2008–008

P. Sharp, “Some Lessons from the LHC Projects”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-08, CERN–2008–008

M. Stettler et al (with **K. Fountas**, **M. Hansen**, **G. Iles**, **J. Jones**), “The GCT Muon and Quiet Bit System, Design and Production Status”, Proceedings of the Topical Workshop on Electronics for Particle Physics TWEPP-08, CERN–2008–008

C. Buttar et al (with **J. Jackson**, **D. Newbold**, **C. Shepherd-T)**, “Standard Model Handles and Candles Working Group: Tools and Jets Summary Report”, Proceedings of the Workshop on Physics at TeV Colliders, Les Houches, 2007.

S Metson et al (with **D Newbold**, **S Wakefield**) “CMS Offline Web Tools”, J. Phys.: Conf. Ser. 119 (2008)

A. Delgado Peris et al (with **S. Metson**) “Data location, transfer and bookkeeping in CMS”, HCP 2007, Nucl.Phys.Proc.Suppl.177-178 (2008).

L Tuura et al (with **S. Metson**) “Scaling CMS data transfer system for LHC start-up”, *J. Phys. Conf. Ser*. 119 (2008)

C.H.Shepherd-T, “Prospects for new physics searches at CMS”, Eds A Astbury et al. Proceedings of the 22nd Lake Louise Winter Institute 2007, World Scientific 2008,

5.3 PUBLIC CMS NOTES AND CONFERENCE NOTES

CMS NOTE-2008-023 "Comparison of Two-Dimensional Binned Data Distributions Using the Energy Test", **I.D. Reid**, **R.H.C. Lopes** and **P.R. Hobson**

CMS NOTE-2008-032 "Silicon Strip Tracker Detector Performance with Cosmic Ray Data at the Tracker Integration Facility", W. Adam et al (with **R. Bainbridge**, **N. Cripps**, **J. Fulcher**, **G. Hall**, **M. Noy**, **M. Pesaresi**, **V. Radicci**, **D. M. Raymond**, **P. Sharp**, **M. Stoye**, **M. Wingham**, **O. Zorba**)

CMS NOTE-2008-008 "A Study of Full Scale CMS Tracker Alignment using High Momentum Muons and Cosmics", G. Flucke et al (with **M. Stoye**)

CMS NOTE-2008-007 “Procedure for the fine delay adjustment of the CMS tracker”, C. Delaere et al (with **R. Bainbridge**, **N. Cripps**, **J. Fulcher**, **M. Wingham**)

CMS CR-2008-083 “Avalanche Photodiodes and Vacuum Phototriodes for the Electromagnetic Calorimeter of the CMS experiment at the Large Hadron Collider”, **P. R. Hobson**

CMS CR-2008-082 “The CMS Electromagnetic Calorimeter at the LHC”, **D. J. A. Cockerill**

CMS CR-2008-012 “W and Z Measurements with the Initial CMS Data”, **D. Wardrope**

CMS DN-2007/020 “CMS Electromagnetic Calorimeter: Amplitude Reconstruction Using Optimised Weights”, **C. Seez**, **D. Wardrope** and **A. Zabi**

CMS AN-2007-026 “Towards a Measurement of the Inclusive W-->ev and Z-->ee Cross Section in pp Collisions at sqrt(s) = 14 TeV”, N. Adam, et al (with **D.Evans, D.Futyan C.S.Hill, J.Jackson, C.Seez, C.Timlin, D.Wardrope**)

CMS-NOTE-2007-029 "Tracker Operation and Performance at the Magnet Test and Cosmic Challenge", D. Abbaneo et al (with **R. Bainbridge, J. Fulcher, O. Zorba**),

CMS AN-2007-019 “Measuring Electron Efficiencies at CMS with Early Data”, G. Daskalakis, **D. Evans, C.S. Hill, J. Jackson**, P. Vanlaer, J. Berryhill, J. Haupt**, D. Futyan, C. Seez, C. Timlin**, **D. Wardrope**

CMS AN-2007-055 “Plans for Jet Energy Corrections at CMS”, S. Esen, et al (with **A. Nikitenko**)

CMS AN-2007-037 “Search for the Higgs boson in the WW$^{(*)}$ decay channel with the CMS experiment”, C. Charlot, et al (with **A. Nikitenko**)

CMS AN-2007-035 “Search for the Standard Model Higgs boson produced in Vector Boson Fusion and decaying into $\tau \tau$ pair in CMS with 1 fb^{-1}”, **M. Vazquez-Acosta**, et al (with **R. Bainbridge, D. Colling, S. Greder, A. Nikitenko, M.Takahashi**)

CMS AN-2007-028 “Tau production from Z decays in ${\mathrm pp}$ collisions at $\sqrt{s} = 14~TeV$”, G. Bagliesi, et al (with **S.Greder**)

CMS AN-2007-018 “Misalignment Effects on Tau Jet Impact Parameter and Vertex Reconstruction”, L. Wendland, **A. Nikitenko**

CMS AN-2008-048 “Search for high mass resonance production decaying into an electron pair in the CMS experiment” **D.Evans** at al (with **C. Hill, J. Jackson, D. Newbold, S.Harper, C. Shepherd-T)**

CMS AN-2008-071 “SUSY search with dijet events” H. Flaecher et al, with **M. Stoy**e

CMS AN-2008-114 “Extending the early SUSY search with all-hadronic dijet events to n-jet topologies” **T. Whyntie** et al. with **O. Buchmueller, M. Stoye, A. Tapper**

CMS AN-2008-111 “Performance study of Jet Plus Track Algorithm using the H2 test beam 2007 data” A. Nayak et al, with **A. Nikitenk**o

CMS AN-2008-083 “Search for Invisible Higgs in CMS” S.Bansal et al, with **A.Nikitenk**o

CMS AN-2008-050 “Search strategy for the Higgs boson in the ZZ$^{(*)}$ decay channel with the CMS experiment” S.Baffioni et al, with **A.Nikitenko**

CMS AN-2008-037 “Search for the heavy charged MSSM Higgs bosons with the H+ -> tau+nu decay in fully hadronic final state in CMS” M. Guchait et al with **A. Nikitenko**

CMS AN-2008-025 “Search for the $t \to bH^{+}$, $H^{+} \to H_{1}W$, $H_{1}\to b\bar{b}$ channel in CPX MSSM scenario in CMS” A. Nayak, T. Aziz, **A. Nikitenk**o

CMS AN-2008-022 “Energy Correction from Combined Tracker and Calorimeter Measurements for Energetic One-prong tau Jets” R. Kinnunen, S. Lehti, **A. Nikitenk**o

CMS AN-2008-020 “Measurement of $Zb\bar{b}$, Z \to \ell \ell$ cross section with 100 pb^{-1} of early LHC data using CMS detector” A. Nayak, T. Aziz, **A. Nikitenko**

CMS AN-2008-009 “Measurement of $Z \rightarrow \tau\tau$ mass shape \break from the $Z \rightarrow \mu \mu$ data” N.Ilina, **A. Nikitenko**

CMS NOTE-2007-014 “Evaluation of the b-jet Energy Corrections Using bbZ, Z to ll Process”, A. K. Nayak, **A. Nikitenko**, T. Aziz

CMS DN-2007-005 “Pseudorapidity dependence of the energy containment at the 2006 ECAL testbeam”, F.Cossutti, G.Della Ricca, P.Govoni, P.Meridiani, C.Rovelli, R.Salerno, V.Tancini, **C.Timlin, A.Zabi**

CMS DN-2007-008 “Amplitude reconstruction and basic performance of the CMS electromagnetic calorimeter”, C.Baty, J.Fay, S.Gascon-Shotkin, J. Blaha, A.Ghezzi**, A.Zabi** and **D.Wardrope**

CMS AN-2007-045 “Search for massive resonance production decaying into an electron or a photon pair”, **J. Brooke**, et al (with **D. Evans, C. Hill, J. Jackson, D. Newbold, J. Cole, S. Harper, B. Kennedy, C. Shepherd-T, R. Walton, S. Worm**)

CMS NOTE-2007-018 “The design of a flexible Global Calorimeter Trigger system for the Compact Muon Solenoid experiment”, **J.J. Brooke, D.G. Cussans, R.J.E. Frazier, G.P. Heath, B.J. Huckvale, S.J. Nash, D.M. Newbold, S.B. Galagedera, A.A. Shah**

CMS CR-2007-041 “b Tagging in CMS”, **I. Tomalin**

CMS CR-2007-045 “Contact Interactions at the LHC”, **M. Vazquez Acosta**

CMS CR-2007-029 “Couplings and Beyond the Standard Model Higgs Production at LHC”, **J. Cole**

CMS CR-2008/092 "Experience in commissioning the CMS Silicon Tracker and readiness for LHC beams" **J. Cole**

CERN/LHCC-2007-021 (also CMS AN 2007/009) "CMS High Level Trigger", **CMS Collaboration** (**T. Virdee** et al) (with **R. Bainbridge, J. Brooke, D. Futyan, S. Greder, M.F. Hansen, G. Heath, A. Nikitenko, K. Petridis, A. Tapper, I.R. Tomalin, M. Vazquez Acosta, M.Wingham**)

CERN/LHCC-2007-014 "CMS Expression of Interest in the SLHC", **CMS Collaboration** (**J. Nash** (Ed.) *et al*.).

5.4 CMS Theses 2007-2009

Munro C., "Distributed data analysis using the grid for the Compact Muon Solenoid experiment", 2007

Jones J., "Development of Trigger and Control Systems for CMS", 2007

Wakefield S., "Distributed data analysis over the grid and a study of the decay MSSM A/H -> tau tau -> two jets at CMS", 2007

Croft R., "Diffraction trigger studies for the CMS experiment", 2007

Lynch C., "A study of Higgs production in association with squark pairs for the CMS experiment", 2007

Metson S., "An analysis of invisible decay of the Higgs boson at the CMS detector", 2007

Yaselli I., "Studying the Time Response of a Vacuum Phototriode and Measurement of Gamma Radiation Damage to High Voltage Capacitors and Resistors", 2008

Wingham M., " Commissioning of the CMS tracker and preparing for early physics at the LHC", 2008

Timlin C., "Commissioning of the CMS tracker and preparing for early physics at the LHC", 2008

Grant N., "Searching For Supersymmetry With Same-Sign Dimuons", 2008

Huckvale B., "Scripting control of the CMS Global Calorimeter Trigger and Anomalous Couplings of the WWγ vertex", 2008

Evans D., "Studies Of Electrons In The CMS Detector And A Proposed Search For High Invariant Mass e+e- Pairs", 2008

Goitom I., "Track Quality Monitoring for the Compact Muon Solenoid Silicon Strip Tracker", 2008

Hansen M., "Higgs boson study in a multi-jet environment at the CMS experiment", 2008