# CERN-Japan fellowship report (2006-2009)

Takanori Kono (PH/ADT-TR)
6th December, 2009

I started my fellowship in April 2006 as a member of the ATLAS trigger group. During the period between April 2006 and March 2009, I worked on various areas of the ATLAS trigger to prepare for the experiment startup. In parallel, I worked within the B-physics group to develop the method to measure the di-muon trigger efficiency using $J/\Psi \rightarrow \mu\mu$ events. In the following, I describe the main achievements in three topics where I worked the most; a) the level-2 algorithm development for selecting cosmic-ray muons, b) the development of the trigger menu and c) the study on the di-muon trigger efficiency measurement.

The first topic that I worked on was to develop a level-2 trigger algorithm to select cosmic-ray muons. In addition to the algorithm development, an important goal was to integrate the level-2 algorithm with the level-1 trigger and detector systems. I wrote a new algorithm using data from the muon chambers (RPC, TGC and MDT) which had a larger acceptance against cosmic-ray muons than the existing algorithm. Then I worked together with colleagues from the level-1, RPC and MDT groups to test the interfaces between different sub-systems. Various problems were identified, e.g. actual data format from the level-1 hardware, decoders and cabling information of the detectors. After all the work to fix these problems, I succeeded to run a level-2 algorithm online in situ for the very first time in early 2007. The procedure of checking the input from the level-1 and data format/decoder based on real data, has been followed later by other algorithms in order to integrate them online.

After this integration work, I became interested in testing the trigger/DAQ system under a realistic condition, namely to run a realistic trigger consisting of many different algorithms and with the full detector system. Therefore, I focused more on preparing the trigger that we can use for the first data-taking, which includes various triggers for selecting physics and/or calibration events, commissioning purpose and triggers for monitoring and measuring efficiency of the primary selections. In ATLAS, the selection implemented in the trigger system as a whole, is called the trigger menu. This work was done by working closely with various physics groups and trigger developers, and I have been responsible for the implementation and validation of the menu

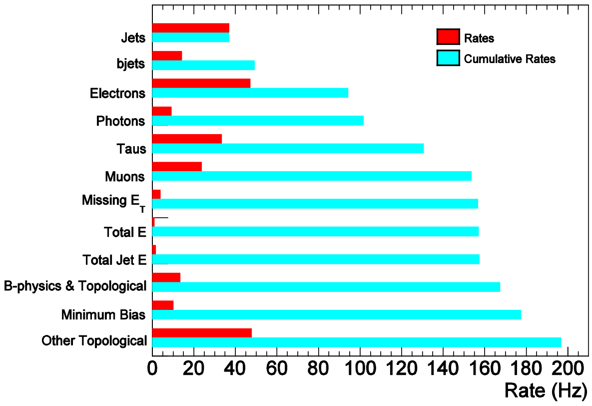

Figure 1: Output rates after the EF for different groups of triggers for the trigger menu at the luminosity of $10^{31}$ cm$^{-2}$s$^{-1}$.

used by the whole collaboration. We identified the physics requirements and optimized the menu within the constraints of the online system, in particular the bandwidth and processing power requirements. While working on the menu, I also developed software to configure the trigger system. This is essential for the work, as the configuration of the entire trigger, especially for the High Level Trigger (HLT), is quite large and complicated. Since we prepared the first version of a realistic trigger menu, which included ~130 triggers at level-1 and ~180 at the HLT, it was used in various activities in the ATLAS collaboration, such as in simulation studies and tests of the real trigger and DAQ systems [2]. By running such large trigger menus with the real online system, we could measure the actual execution time and data flow rates at the HLT farms, and confirm that the menu is operational with the real system. Figure 1 shows the expected output rates of different types of triggers after the final stage of the selection, Event Filter (EF).

On 10th September, the LHC delivered the first circulating beam. Our main goal was to trigger on activity related to the beam and to commission the level-1 trigger. In order to achieve this, we used the signal from a beam pick-up system (BPTX) to trigger the event when the beam arrives at ATLAS. The Minimum Bias Trigger Scintillator (MBTS) was also very useful to trigger on activities in the detector. During three days with beam, we collected useful data to investigate the relative timing of the input signals to the level-1 Central Trigger Processor (CTP). After the beam operation stopped, we prepared quickly the trigger for taking cosmic runs with the full ATLAS detector. The goal here was to collect as many track as possible traversing the inner detector volume. We collected around 7 million events triggered by the inner detector tracking algorithm which have been very important for commissioning the detector, and the calibration and alignment studies. I have been working as the trigger menu on-call expert during the data-taking.

In addition to the development and operation of the trigger system, I studied the muon trigger efficiency measurement using the $J/\Psi \rightarrow \mu\mu$ sample. Due to the large cross section of $J/\Psi$ production, this sample can be used at the early days of the experiment. We used $J/\Psi \rightarrow \mu\mu$ events where two decay muons are reconstructed offline and require that at least one of the reconstructed muons was triggered. By investigating whether the second muon was also triggered or not, we can obtain the trigger efficiency directly from data. We have shown that with a few months of data-taking, we expect to measure the trigger efficiency with better than a few % precision. Also, we proposed a calibration trigger to collect the sample for such a study, namely to use a single-muon trigger at level-1 and apply a $J/\Psi$ selection with loose requirement on the second muon in the level-2 trigger. This new trigger significantly increases the $J/\Psi$ fraction in the triggered sample while keeping the bias low for the second muon. Figure 2 shows the level-1 trigger efficiency as a function of the pseudo-rapidity ($\eta$) of the

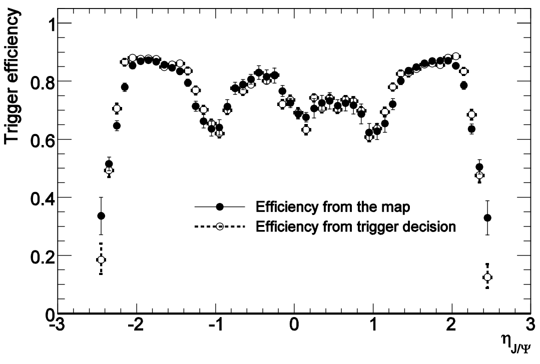

Figure 2: The level-1 efficiency to trigger on $J/\Psi \rightarrow \mu\mu$ events as a function of $\eta$.

J/Ψ. As can be seen, there is good agreement between the efficiency measured from the simulated data and that calculated with reference to the Monte Carlo “truth”. This study was conducted with two students where I coordinated the entire work of the group and wrote a note describing the work [4].

There has been a lot to do in the last three years to get the ATLAS experiment ready for data-taking. And it’s been a wonderful experience to work as a central expert in the trigger where I had the opportunity to work with many people to shape the trigger menu. It was a pity that we were not able to start the data-taking in 2008. Nevertheless, having three years to work at CERN was a very nice opportunity, especially to work efficiently in a big collaboration like ATLAS. Since April 2009, I have moved to the University of Hamburg while still working in the ATLAS Collaboration. Now I am based in Hamburg, but the expertise in the ATLAS trigger and software as well as the contact with people at CERN which I gained during the last three years are still valid and made me well prepared to analyze collision data at the LHC.

## Conferences and publication

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2. T. Kono for the ATLAS Collaboration, The ATLAS trigger menu for early data-taking, 19th Hadron Collider Physics Symposium 2008, 27-31 May, 2008, Galena, Illinois, USA
3. The ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, (2008) JINST **3** S08003
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December 2009

Masamitsu Aiba
CERN-Japan fellow
BE/ABP/LCU

CERN-KEK committee

# Summary report

## 1. Introduction

This report summarizes my research activities at CERN as CERN-Japan fellow from October 2006 to July 2009, which fall into two broad categories, one for the Proton Accelerator in the Future (PAF) and the other for the LHC, described in the following, respectively. Publication list during the fellowship is attached to this report.

## 2. Summary of research activities

### 2-1. Study for the PAF

Proton driver accumulator and compressor

A proton driver based on the CERN Superconducting Proton Linac (SPL) for the future neutrino factory has been proposed. This is not directly related to the LHC but interesting future plan. An accumulator and a compressor are necessary to provide very short high intensity bunch onto a production target. The design of two rings, however, was totally open. A detailed lattice design study has showed a feasibility of two rings [10, 12].

Proton Synchrotron Booster (PSB)

Study of space charge effect in the PSB is rather important since its performance is limited by direct space charge at low energy. A compensation scheme by introducing electron lens has been studied. The idea is that the space charge force in a proton beam could be neutralized by the negative charge of electrons. However, simulation study showed that it is difficult to save the emittance blow-up whereas the tune spread is successfully compensated [5,6].

One of approaches to mitigate space charge effect is to raise the injection energy. To push up the performance of the injector chain, Linac4, which will accelerates H- beam up to 160 MeV, has been designed and is under construction. The design of $H^-$ injection into the PSB is then an urgent task. A lot of studies on stripper foil feasibility, lattice issues and so on has been done [14, 16, 17, 18].

A practical fruit through these studies is to activate the usage of ORBIT at CERN [14], which is a modern tracking code for space charge and $H^-$ injection. It was imported from SNS but not used for a while.

PS2

The PS2 will be the successor of PS and provide 50 GeV proton beam into SPS. The main option of the beam injection into PS2 is the so-called charge exchange injection using a stripper foil. It is of importance to estimate the lifetime of stripper foil for the operation and maintenance aspects. However, the existing method is not applicable to the PS2 injection energy of 4 GeV. New method to estimate the foil lifetime with high-energy H- beam based on inelastic radiation damage is proposed and a paper is submitted to a journal [25]. This study is also useful for the proton driver accumulator.

## 2-2. Study for the LHC

### Optics measurement and correction

Due to the enormous stored beam energy and the tight aperture constraints of the LHC, it is essential to measure and correct its optics properly. Even for the early stage of commissioning, the beat-beating must be corrected down to ~20%. A software package has been prepared for the optics measurement and correction available in the accelerator control room through many discussions and some tests in the SPS and the RHIC.

Beam position data from ~500 beam position monitors over 90 turns was acquired on 12th September 2008. The first optics measurement was successfully performed with the data. A detailed analysis has been carried out and is published in a journal paper [20]. I have partly participated the commissioning 2009 as well.

### Lattice studies

A study on the LHC lattice has been performed for various purposes, high-beta optics, upgrade optics and nominal optics as well.

The high-beta optics run is scheduled to measure absolute luminosity in ATLAS and CMS (TOTEM) with Roman pot technique. The beta* will be ~2600 m in ATLAS and at maximum ~1300 m in CMS, resulting in a loss of betatron tune about one unit. It has been showed that the betatron tunes could be kept constant with changing the optics in two or three IRs (2, 4 and 8) [8].

The phase I upgrade requires new optics, which promises a smaller beta* and a feasible collimation scheme for higher beam intensity. Several possible solutions were found partly with my contributions for the optics of IR4 and IR8.

New optics based on the latest nominal optics has been developed [21] aiming at improvement of the collimation efficiency by adjusting the betatron phase advance to be $\pi/2$ between IP1 and IP5 in order to suppress the off-momentum beta-beating at the betatron collimation section. The new optics will be verified with simulations and/or beam study. Also a new beam separation scheme is proposed in the study to improve the aperture at the triplet magnets, and it has been implemented to the control system.

## 3. Acknowledgements

I would like to thank the CERN-Japan fellowship committee and the CERN-KEK committee for administrations and encouraging me, especially to Profs. Takahiko Kondo, Katsunobu Oide and Akira Yamamoto. I am grateful to Drs. Oliver Brüning, Roland Garoby and Massimo Giovanozzi for their kind supervision. I am thankful to many colleagues in BE department, and it was always my pleasure to work and to have discussions with them. Last but not least, I thank to Dr. Patrick Fassnacht for helping me at the beginning of my stay at CERN.

# Publication list

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2. M. Aiba, “Accumulator lattice design for SPL beam”, CERN-NEUTRINO-FACTORY-NOTE-151; AB-Note-2007-016 (2007)
3. M. Aiba, “Compressor lattice design for SPL beam”, CERN-NEUTRINO-FACTORY-NOTE-151; CERN-AB-Note-2007-034 (2007)
4. F. Gerigk et al., “SIMULATION OF THE CERN PS BOOSTER PERFORMANCE WITH 160MeV $H^-$ INJECTION FROM LINAC4”, Proc. of PAC’07, pp.3390-3392 (2007)
5. F. Zimmermann et al, “SPACE-CHARGE COMPENSATION OPTIONS FOR THE LHC INJECTOR COMPLEX”, Proc. of PAC’07, pp.1595-1597 / CERN-LHC-PROJECT-Report-1020 (2007)
6. M. Aiba, “BENCHMARK OF ACCSIM-ORBIT CODES FOR SPACE CHARGE AND ELECTRON-LENS COMPENSATION”, Proc. of BEAM’07, CERN-2008-005, p104 (2008)
7. M. Aiba, “Accumulator and Compressor for the CERN SPL Proton Beam”, Proc. of NuFact’07, AIP Conf. Proc. 981, pp. 281-283 (2008)
8. M. Aiba et al,, “OPTICS FLEXIBILITY IN THE LHC AT TOP ENERGY”, Proc. of EPAC’08, pp.2524-2526; CERN-LHC-PROJECT-Report-1106 (2008)
9. R. Tomás et al., “OPTICS CORRECTION IN THE LHC”, Proc. of EPAC’08 pp.2572-2574; CERN-LHC-PROJECT-Report-1108 (2008)
10. M. Aiba, “SPL accumulator and compressor scenarios for neutrino factory”, Proc. of NuFact’08, http://pos.sissa.it//archive/conferences/074/114/Nufact08_114.pdf (2008)
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11. M. Lamont et. al, “The LHC Injection Tests”, CERN-LHC-Performance-Note-001 (2008)
12. M. Aiba, “A first analysis of 3-bunches and 1-bunch scenario for the SPL based Proton Driver”, CERN-AB-Note-2008-048-BI (2008)
13. R. Tomás et al., “First beta-beating measurement in the LHC”, Proc. of PAC’09 / CERN-ATS-2009-056 (2009)
14. M. Aiba, “Summary of ACCSIM and ORBIT benchmarking simulations”, CERN-BE-Note-2009-011 (2009)
15. R. Tomás et al., “Beam Based Measurement”, Proc. LHC Performance Workshop (Chamonix), pp.205-211 (2009)
16. W. Weterings et al., “Operational considerations for the PSB $H^-$ Injection System”, Proc. of PAC’09 / sLHC-PROJECT-Report-0006
17. B. Goddard et al., “Layout considerations for the PSB $H^-$ injection system”, sLHC-Project-Note-0004 (2009)
18. C. Carli et al., “Lattice Issues of the CERN PSB with H- Charge exchange injection hardware”, Proc. of PAC / CERN-ATS-2009-036 (2009)
19. G. Vanbavinckhove et al., “Beta-Beating Corrections in the SPS as a Testbed for the LHC”, CERN-ATS-2009-055 / Proc. of PAC’09 (2009)
20. R. Tomás et al., “First $\beta$-beating measurement and optics analysis for the CERN Large Hadron Collider”, Phys. Rev. ST Accel. Beams 12, 081002 (2009)
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24. R. Garoby et al., “Linac-Based Proton Driver for a Neutrino Factory”, CERN-NUFACT-Note-157 (2009)
25. M. Aiba et al., “Model to evaluate the lifetime of stripping foils with high energy $H^-$ beams”, submitted to Phys. Rev. ST Accel. Beams (2009)

Mayuko Kataoka (9/2006~8/2009)

## Photon Conversion study in ATLAS Combined Test Beam

In ATLAS detector, we have a large amount of materials in front of the electromagnetic (EM) calorimeter. About 35% of photons will convert to electron pairs, and then a half of the signal events ($\mathrm{H} \to \gamma\gamma$) will be lost. With the CTB data and simulation, it is very important to understand the photon conversions before the start of LHC data taking. When I started studying photon conversions, track reconstruction for secondary particle was being developed. As a first step for the photon study, I confirmed carefully by eyes that the reconstruction software worked properly, e.g. dumping the information of track hits and looking at the tracks using event display. I validated the software of the track reconstruction and the vertex algorithm by confronting real data in the CTB. At the same time, I could improve MC simulation in terms of the beam conditions using converted photons and of beam energy using unconverted photons.

As the photon beam was created far by 30m from the Inner detector, the background was larger and complicated than our expectation in fact. I made an effort to remove the background. I found that 80% of converted photons in the pixel layers was able to be reconstructed and obtained a clear distribution of reconstructed vertex positions. And I performed determination of the material of the inner detector using the estimated conversion rate of photons in the detector. The results are currently at the paper reading stage in the group for the publication.

- **Photon purity measurement in early ATLAS data & Improvement of the reconstruction algorithm for photon conversions in ATLAS. (CERN fellow)**

An excellent understanding of photon identification and measurement are essential for the discovery of a low-mass Higgs. At an early stage of the data taking, direct photon processes (the Compton process $qg \to \gamma q$, the annihilation process $q\bar{q} \to \gamma g$) can be used for this understanding. I have been studying photon purity measurement using direct photon events. There are conversions from real and fake photons mixing in real data. So we can express $F_{conv}^{Data}$, which is the fraction of reconstructed conversions for photons determined by real data, as below,

$$F_{conv}^{data} = \frac{a F_{conv}^{signal} + b F_{conv}^{BG}}{a+b} \quad , a+b=1$$

where $F_{conv}^{signal}$ and $F_{conv}^{BG}$ are fractions of the reconstructed conversions estimated from simulation studies for real photons and fake photons, respectively. Parameters $a$ and $b$ denote the photon purity and the fake rate which we would like to study. As a first trial, instead of real data I analyzed at the FDR (Full Dress Rehearsal) sample which consisted of various kinds of SM physics events. The FDR sample included fake photons which mostly originate from isolated $\pi^0$ in QCD jets. I could show that the purity measurement using photon conversions was feasible. At the same time, I found the following problems, which is low vertex reconstruction efficiency because of increasing track multiplicity in multi-conversions in $\pi^0$. Currently, I am studying photon conversions to improve the problems and to be established as a tool for measurement of the photon purity.

# Status report for the CERN-KEK Committee 2009

**Hiroshi Yokoya (Physics Department, Theory Unit)**

## Overview

As a second year of my CERN-Japan Fellowship program, I have worked on the phenomenological studies on the high-energy particle physics at the CERN LHC.

In this year, I mainly worked on the bound-state effect on gluino-pair production, and also on the (all-order) Coulomb corrections to the fully-differential distribution in $bW^+\bar{b}W^-$ production at hadron colliders. These follow my previous work on the bound-state effect on top-quark pair production, which was reported last year.

## Bound-state effect on gluino pair production

In collaboration with Prof. K. Hagiwara in KEK, I studied the bound-state corrections in the gluino-pair production at hadron colliders. We performed the all-order summation of the Coulomb corrections using the Green's function formalism, and find sizable corrections in the gluino-pair invariant-mass distribution as well as in the total cross-section.

The consequence of the bound-state correction crucially depends on the decay width of the gluino. When $m_{\tilde{g}} > m_{\tilde{q}}$, the gluino decay-width is typically between a few and a few hundred GeV; see Fig. 1. In this case, the invariant-mass distribution below and near the mass threshold region receive a large enhancement, due to the formation of the gluinonium bound-states. We show that the gluino-pair production cross section below the threshold ($M < 2m_{\tilde{g}}$) grows about 5% of the total cross section due to the bound-states formation. For the large $\Gamma_{\tilde{g}}$ case, although the resonance peaks are smeared-out, the ratio is increased to around 10%, due to the smearing effect. When $\Gamma_{\tilde{g}}$ is significantly smaller than the binding energy of the gluinoniums, which grows from 10 GeV for $m_{\tilde{g}} = 200$ GeV to 40 GeV for $m_{\tilde{g}} = 2$ TeV (see Fig. 1), one or two resonance peaks arise in the invariant-mass distribution.

On the other hand, when $m_{\tilde{g}} < m_{\tilde{q}}$, the gluino decay-width is quite tiny; see Fig. 1. In this case, the gluinonium spectra are very sharp and more than two resonance peaks are expected (see Fig. 2). However, the produced gluinonium resonances would decay mainly

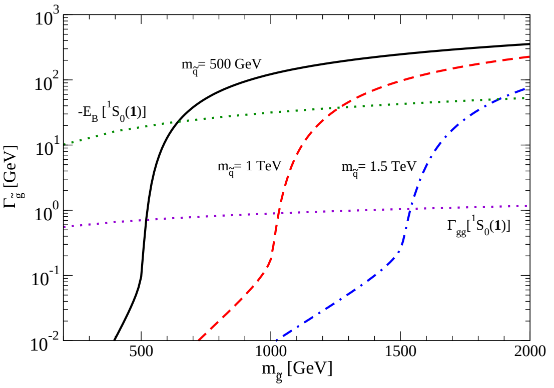

Figure 1: Estimate of the gluino decay-width with respect to the gluino mass.

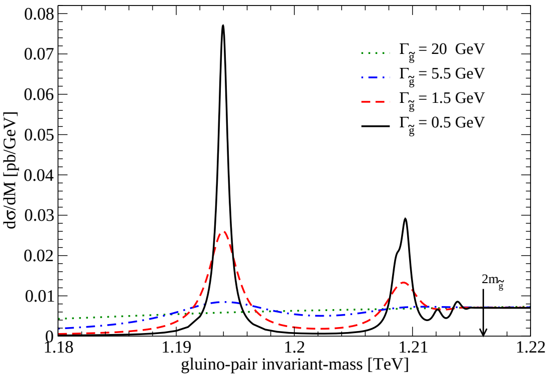

Figure 2: Gluino-pair invariant-mass distribution at the very threshold region.

into gluon jets and they may escape detections at hadron collider experiments.

## Coulomb corrections in fully-differential $bW^+\bar{b}W^-$ production

In addition, in collaboration with Dr. Y. Sumino in Tohoku university, I have worked on the all-order Coulomb corrections to the fully-differential distributions of the $bW^+\bar{b}W^-$ production, which is mostly via the $t\bar{t}$ intermediate-state.

We developed a formula using the momentum-space Green's function, following the formula in the $e^+e^-$ collider case. This enable us to calculate the Coulomb correction effects in the energy and momentum distributions of top-quarks, and also to implement the effects of the all-order Coulomb correction as well as the bound-state formation into the Monte-Carlo event generations. We plan to report this work soon [2].

## Ongoing subjects

In addition, following subjects are still in progress;

- A realistic reconstruction study for the threshold top-quark events using the Monte-Carlo event generation which properly includes binding correction and fast detector simulations (in collaboration with Dr. J. Kanzaki in KEK).
- Threshold resummation effect in top-quark pair-production at the high $t\bar{t}$ invariant-mass region, where a large correction is expected due to the increase of the soft-gluon emission probability and where a signal of the physics beyond the standard model may be inspected (in collaboration with Prof. M. Mangano in CERN).

# References

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"Bound-state effects on gluino-pair production at hadron colliders"
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[2] Yukinari Sumino and H. Yokoya,
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in preparation.

**Talks**

[3] "Bound-state effects on top-quark production at hadron colliders"
KEKPH2009, KEK, 3/3–6 (2009)

[4] "Threshold production of top-quarks and gluinos at the LHC"
Focus week "Determination of Masses and Spins of New Particles at the LHC", IPMU, 3/16–20 (2009)

[5] "Bound-state effects on top-quark/gluino production at the LHC"
CERN Theory Group Retreat, Les Houches Center de Physique, 11/4–6 (2009)

[6] "Bound-state effects on gluino-pair production"
Focus week "QCD in connection with BSM study at LHC", IPMU, 11/10–13 (2009)

# Commissioning of the ATLAS Tile calorimeter for LHC collisions

**November, 2009**
**PH-ADE-CA**
**Toshi SUMIDA**

In the last fiscal year, I joined the Tile Calorimeter (TileCal) group in the ATLAS experiment, and I have been working on the commissioning of the TileCal and the software for the analysis of collision data. TileCal is a large hadronic sampling calorimeter using scintillators as active material and steel as absorber. TileCal is crucial for the ATLAS experiment because TileCal measures the energy of the jets and eventually the missing transverse energy (MET). The aim of my work is to establish the electromagnetic (EM) scale in TileCal using muons produced in cosmic rays because the uncertainty on the EM scale in TileCal would directly go into the uncertainty of jets and MET.

TileCal has several stages for the energy calibration. At first the electronics is calibrated using the injected charge. Secondly, the response of the PMT is tested by injecting a laser pulse. Then, the light yield by the energy deposition in one "cell" of TileCal is calibrated in a method using a Cs radioactive source. In order to check our calibration and validate the detector for the measurement in the collision event, we used the cosmic ray data and the Monte Carlo simulation (MC) for the cosmic rays.

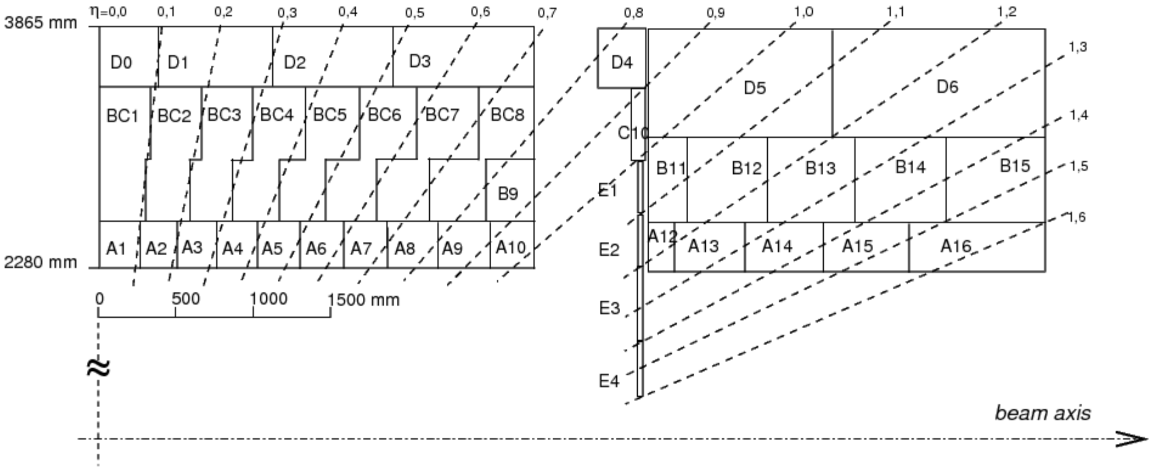

**Figure 1:** Segmentation in depth and pseudo-rapidity of a TileCal module in the central (left) and extended (right) barrels. The bottom of the picture corresponds to the inner radius of TileCal. TileCal is symmetric about the interaction point at the origin

Figure 1 shows the geometry of TileCal. Because of the segmentation in pseudo-rapidity($\eta$) and depth (radial direction), and the segmentation in azimuthal direction($\phi$), one muon from the cosmic rays hits several cells. A track fitting program called TileMuonFitter (TMF) is used to reconstruct the cosmic ray tracks with those hits of the cells. In the course of this work, TMF was improved several times. Examples are the path length calculation and the collection of the energetic cells.

For the calibration, we added a significant change from 2008 to 2009 data because of a problem found in the Cs calibration: we found 18% over-calibration in TileCal in 2008 using the Cs method. The over-calibration was corrected by applying the correction factor in the reconstruction. For the 2009 data, the high-voltage values for the PMTs in TileCal was changed to correct the 18% over-calibration.

In order to check all these effects(TMF updates, software and hardware re-scaling of the calibration), I prepared the samples with the same version of TMF because the releases of the Athena (a framework of

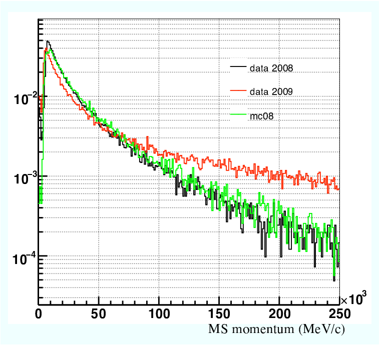

**Figure 2:** The momentum distribution measured by the Muon Spectrometer(MS).

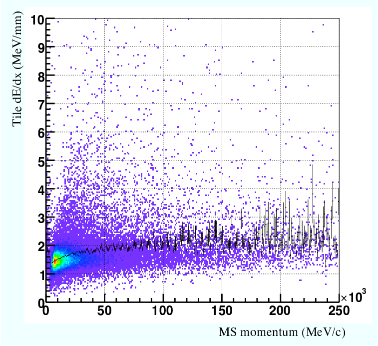

**Figure 3:** Correlation between the energy density the muon momentum by MS.

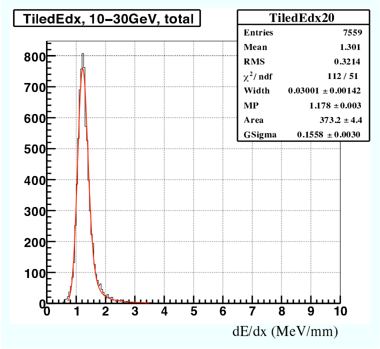

**Figure 4:** The distribution of the energy density calculated by the total energy in TileCal.

analysis in ATLAS) are different for the data taken in 2008 and 2009. I have also done re-reconstruction for the cosmic MC sample. Then I compared the energy density (dE/dx) calculated with the energy deposition and the path length in TMF for the 2008, the 2009 data, and the MC samples.

I used the muon momentum values measured by the Muon Spectrometer(MS) In order to select the muons in a certain region of the momentum. Figure 2 shows the momentum distribution measured by MS. As we can see in the figure, we have a different distribution in the 2009 data due to the change of configuration. Thus, we are now preparing a new MC sample for the 2009 data for precise comparison. As shown in Figure 3, dE/dx and the muon momentum has a correlation and we selected the region from 10 to 30 GeV/c with the momentum in this analysis. Figure 4 shows an example of the distribution of dE/dx calculated with the total energy deposit by the cosmic ray track in TileCal and the path length. Both of them are measured using TMF.

It's also important to understand the longitudinal (in radial direction) uniformity. The measured non-uniformities can eventually be implemented into MC simulations for studying the response to other particles or to jets.

**Table 1:** Summary of the calibration in TileCal for comparison between data in 2008, 2009, and MC sample. They are based on the measurement in TMF and the values for dE/dx are the mean of the distribution. The values in the columns with "ratio" are with no unit. There are columns to check the longitudinal uniformity: dE/dx in BC-cells divided by one in A-cells and D-cells/A-cells.

| dE/dx(MeV/mm) | data'08 | data'09 | mc'08 | ratio data'09 / data'08 | data'08 / mc'08 |
|---|---|---|---|---|---|
| A-cell | 1.349 | 1.373 | 1.324 | 1.018 | 1.019 |
| BC-cell | 1.384 | 1.384 | 1.332 | 1.000 | 1.039 |
| D-Cell | 1.494 | 1.523 | 1.380 | 1.020 | 1.083 |
| Total | 1.411 | 1.421 | 1.344 | 1.007 | 1.050 |

| ratio | data'08 | data'09 | mc'08 | data'09 / data'08 | data'08 / mc'08 |
|---|---|---|---|---|---|
| BC/A | 1.036 | 1.009 | 1.007 | 0.983 | 1.020 |
| D/A | 1.108 | 1.110 | 1.042 | 1.002 | 1.063 |

Finally, I summarized the result of the comparison among the data 2008, 2009, and MC, and for the check of the longitudinal uniformity in Table 1. The data 2008 and 2009 show good agreement within 2% even when they are re-scaled in different ways. The data 2008 and MC have 5% difference in the total energy, and a little bigger difference (8%) in D-cells. Some part of them (∼4%) are now understood as a mis-calibration in the Cs method that will be corrected soon. For the longitudinal uniformity, we found 4% difference in the ratio between D-cells and A-cells even with the MC samples( as in the third column in the last raw of the table). Thus, this effect should be considered as an intrinsic effect of the detector. Taking this mis-calibration into account, in the Cs method and the MC study, we reached quite good understanding for the EM scale in TileCal, and the agreement between the data and MC can be within 2%.

From now on, I'd like to extend my research for the Jet calibration and the MET continuing the improvement of the calibration in TileCal.

# Progress report (Nov./2009)

**Shima Shimizu**

I have been working in the ATLAS Tile Calorimeter group. The ATLAS Tile Calorimeter is the hadronic calorimeter n the barrel ATLAS detector. It consists of a scintillator/iron sampling calorimeter. It is divided into three sections of one barrel and two extended barrels. In the region between the barrel and the extended barrel calorimeters, it has additional detectors. I have studied the calibration of the detectors in these crack regions using commissioning data taken with cosmic rays in 2008.

The crack regions are filled with inactive materials for services to the ATLAS sub-detectors which are located closer to the interaction point than the Tile Calorimeter. The detectors in the crack region were installed to be able to correct for the energy loss in the crack region. The schematic view of the detectors is shown in Fig. 1 together with a part of the extended barrel calorimeter. The figure is shown for the section in $z > 0$ (EBA), where the extended barrel sections in $z > 0$ and $z < 0$ are called EBA and EBC, respectively. The readout cells constitute radial layers in the calorimeter. The extended barrel has three layers, namely A, B and D layers as seen in the figure. In the crack region, from outer radii to inner, the intermediate Tile calorimeter (ITC) cells (D4 and C10) and two gap scintillator cells (E1 and E2) are situated in front of the extended barrel. The crack scintillator cells (E3 and E4) are situated in front of the LAr cryostats. The $\eta$ coverage from D4 to E4 is $\sim 0.8 - 1.6$. In the $r - \phi$ plane, 64 cells constitute $2\pi$. These detectors in the crack region are not included in the standard Tile Calorimeter calibration procedure or just poorly calibrated after the installation to the ATLAS detector. In addition, arbitrary calibration factors are applied for the gap and crack scintillators in the moment.

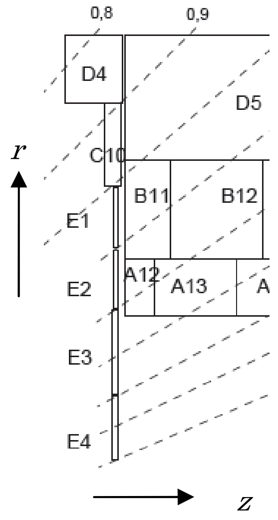

Figure 1: Schematic view of the detectors in the crack region and a part of the extended barrel.

In this analysis, the calibration of the detectors will be done in two steps. The first step is the phi inter-calibration among the same type of cells. The calibration factors are determined for each cell. The next step is the absolute calibration, where a scale factor will be determined for each detector type. The scale factor is determined by the comparison with MC, since the absolute energy scale in the scintillators is not known and this calibration uses the simulation as a reference. Since electromagnetic processes can be well simulated, this procedure can determine the energy deposited by a muon in the scintillators.

The analysis was done using single cosmic muon events collected in 2008. A muon track reconstructed by the inner tracking system is extrapolated to the calorimeter layers and the geometrical muon path length, $\Delta L$, is calculated by connecting the track positions on the layers with a straight line. The response of the cells, $E/\Delta L$, where $E$ is energy deposit in the cell, was checked for each cell. Its distribution was fitted with Landau function convoluted with Gaussian function. Figure 2 is an example of the $E/\Delta L$ distribution shown together with a fit for a E1 cell. The peak positions from the fits are compared as shown in Fig. 3. Shown are the peak values from each

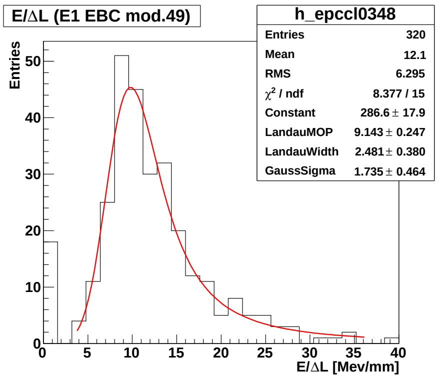

Figure 2: $E/\Delta L$ distribution in a E1 cell. The line indicates the result of a fit of a Landau distribution convoluted with a Gaussian.

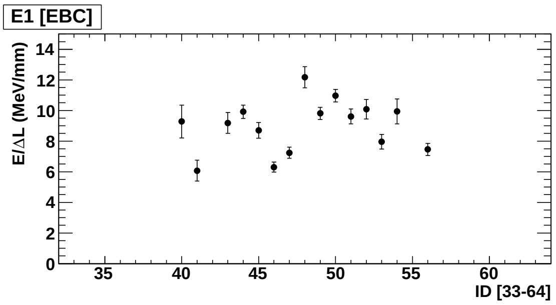

Figure 3: Peak values from the fits on $E/\Delta L$ distributions for each E1 cell in EBC bottom part.

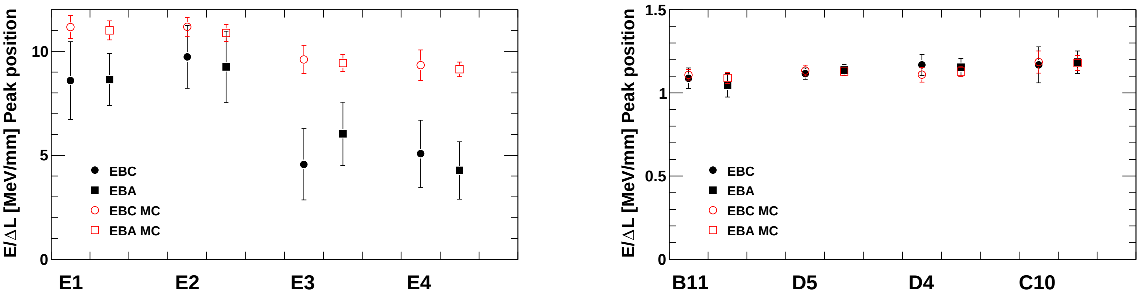

Figure 4: Responses of gap and crack scintillators and ITCs to cosmic muons. Shown are the average values of the peaks of $E/\Delta L$ distributions. The error bars indicate the RMS values.

fit for E1 cells in the EBC bottom ($y < 0$) part. The $x$-axis in the figure corresponds to the cell IDs and cells with insufficient statistics or with poor fits are excluded.

The average and the RMS of the peak values in each detector type are summarized in Fig. 4. Also shown is a comparison with the same analysis done for a simulation of single muons produced in cosmic rays. In the figures, the average values are plotted and the error bars show the RMS. They are shown for EBC and EBA for each detector type. The RMS values in data are $15\% - 20\%$ for gap scintillators (E1, E2), $\sim 10\%$ for C10 and $\sim 5\%$ for D4. The signals in the crack scintillators (E3, E4) are found to be too small for good separation from noise distributions as shown in Fig. 5. Their HVs should be increased for future running and the analysis will be redone to update the calibration. In figure 4, results for cells in the extended barrel (D5 and B11) are also shown for

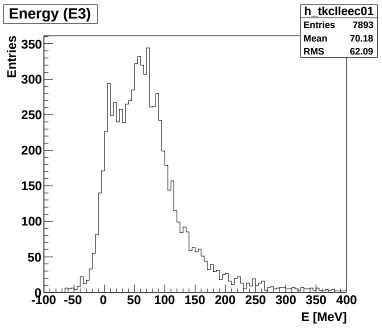

Figure 5: Energy distribution in all E3 cells.

comparison with ITC cells. The responses of ITC cells (D4 and C10) are consistent with the cells in the extended barrel, which are well calibrated with the standard Tile Calorimeter calibration procedure, and they are also consistent with MC within $\sim 5\%$. In the gap scintillators (E1, E2), there are discrepancies between data and MC roughly by 20%.

Based on this analysis, the HV values for the crack scintillators have been increased to have a good separation of signal and noise. Phi inter-calibration is implemented for the gap scintillators by offline correction factors. Scale factors for the gap scintillators will be also prepared after further checks with comparison with MC. The ITC cells are not touched, since it was seen that they are in reasonable condition.

**Plans:**

The current analysis on the detectors in the crack region with cosmic muons has limited $\phi$ coverage. The analysis will be continued not only with cosmic data but also with coming data with proton beams to have better understanding of the detectors. The detector will be calibrated and their energy in jet reconstruction and calibration will be studied.

I have joined the analysis group of the CERN-ATLAS team working on early jet measurements. I will work on comparison of jet distributions between data and MC towards cross section measurements for the early 2010 collision data. I have started to look into the jet distributions in several sets of MC.