Answers from ScECAL group to questions on sub-detector calibration and alignment

ScECAL group*

October 29, 2016

1. **Outline the strategy for alignment and calibration of your sub-detector**

   - Alignment:
     - Tolerance in detector assembly
       - Cell position tolerance $< 30\,\mu$m in an EBU(it was measured when we constructed a technological prototype layer.)
       - EBU position tolerance $100\,\mu$m
     - Tools for alignment
       - ECAL track
         - Cell-wise, layer-wise
         - Module-wise from matching between tracker-track and ECAL track
       - Laser
         - Module-wise
   - Calibration:
     - Equalization of cell response
       - MIPs: During construction and in-situ:
         - During construction: 1–2 days cosmic run allows cell-by-cell calibration. See detailed discussion in question 8
         - In-situ: beam halo muon as discussed in question 9 and one day Giga Z provide sufficient calibration for each cell
       - SiPM gain: During construction and in-situ: LED runs between physics runs will give sufficient information.
       - Not yet clear how frequently LED run should be done
     - Electromagnetic and hadronic scales, weight factors: Start from test beam information and will be improved in situ by invariant mass reconstruction,
     - Monitoring
       - SiPM gain with LED system

*Discussed mainly by Katsushige Kotera, Wataru Ootani and Tohru Takeshita.

    - Temperature. Five temperature sensors are currently installed on each EBU ($180 \times 180\,\mathrm{mm}^2$),
    - We are discussing a possibility to monitor SiPM gain from single photoelectron charge in the physics data. (high/low gain data can show some high gain p.e. peaks in physics runs).

2. **What calibration and alignment parameters need to be measured with particles (either from collisions or cosmic) for your sub-detector?**

   - Alignment with muons and charged pions in jets.
   - Calibration: parameters to be measured are;
     - MIP constant as a function of temperature,
     - Gain constant as a function of temperature,
     - Inter calibration constant (ratio of gain between high gain and low gain, determined with LED runs),
     - Scale factor between electromagnetic and hadron.
     - Those are determined with muons and charged pions in jets as MIP.

3. **What precision is needed on the calibration and alignment parameters for your sub-detector? What is the basis for this assessment?**

   - Alignment: A few hundred microns can be achieved by 50 cell hits by calorimeter tracks. This is sufficient.
   - Calibration:
     - Random cell-by-cell fluctuation of $\sim 15\%$ is acceptable from the same consideration as in CAN-18 for AHCAL, assuming 20 hits/GeV (10 hits/GeV for AHCAL) and 15% of the stochastic term of the energy resolution (see Table 1).

Table 1: Impact of cell by cell fluctuation on the energy resolution.

assumption	
assuming stochastic term $\times\sqrt{E(\mathrm{GeV})}$	0.15
assuming cell by cell: σ	0.15
assuming [number of hits/E(GeV)] = n	20
Result	
$(\sigma/\sqrt{N}) \cdot \sqrt{E(\mathrm{GeV})}$	0.044
(stochastic term $\oplus$ due to this)$\cdot\sqrt{E(\mathrm{GeV})}$	0.154
impact on the resolution	0.025
$N = n \cdot E(\mathrm{GeV})$	

     - Detailed simulation studies for jet energy resolution are ongoing.
     - Layer-wise and global precision and global energy scales: studies are ongoing for physics cases.

4. **How many usable particles per sub-detector element are needed to establish the calibration and alignment constants at the above level of precision?**

Table 2: Number of days to get 50 hits on a cell.

$\sqrt{s}$ (GeV)	luminosity ($\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	required days
91 GeV	4×10^{33}	1
200 GeV	2×10^{34}	200
500 GeV	2×10^{34}	1200

- Alignment: A few hundred microns can be achieved by 50 cell hits by calorimeter tracks shown in Table 2 for Giga Z option. This is also achieved by cosmic muons.
- Calibration:
  - Based on a previous study by a student of Shinshu University (a master thesis in Japanese).
  - Need 50 MIPs per cell for the cell-wise precision of 15%. (see Fig. 1.)

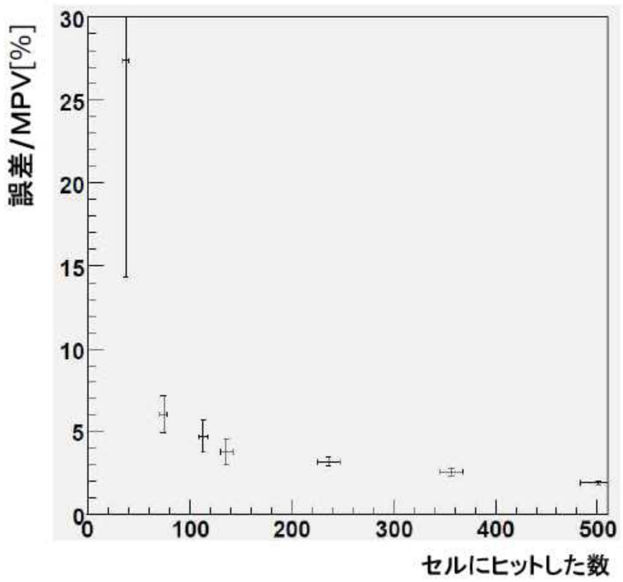

Figure 1: Uncertainty of MIP constant as a function of the number of hits on a cell.

  - Table 2 lists necessary days to get 15% of calibration precision for each channel with $z \to q\bar{q}$ events at $\sqrt{s}$ =Z pole, 200 GeV, and 500 GeV.

5. **What particles and kinematic criteria are needed?**

   - Cosmic muons and hadron in jets as MIPs

6. **What is the smallest solid-angle subtended by an individual sub-detector element?**

   - Cell at z = 0: $0.045 \times 0.005 / 2.03^2 = 0.05$ milli-steradian.
   - Cell on the endcap: $0.045 \times 0.005 / 2.4^2 = 0.04$ milli-steradian.
   - Cell at the end of barrel: 0.016 milli-steradian.

7. **Do your sub-detector plan to use power-pulsing?**

- Yes.

8. **Are cosmic useful for the alignment/calibration of your sub-detector?**
   - Alignment
     We can do cell by cell alignment using cosmic.
   - Calibration
     - 2000 MIPs/cell/day without power pulsing at surface.
     - Need dedicated cooling system coupled to absorber structure.

9. **Are the beam halo muons useful for the alignment/calibration of your sub-detector?**
   - Alignment: we can do cell by cell alignment using halo muons.
   - Calibration:
     - Very useful without the beam spoiler.
     - Thick scintillator allows calibration in barrel either.

10. **If power pulsing is used, what is the effective live-time percentage?**
    - 0.5 - 1%.

11. **Is data with the magnetic field off needed for your sub-detector?**
    - Not crucial but straight tracks may help alignment procedure.

12. **On which time-scales do you anticipate that the alignment/calibration of your detector will be stable? In particular would it be reasonable to assume that data collected over multiple running period in multiple years can be used collectively to refine the overall calibration or alignment?**
    - No aging effects of scintillators or SiPMs have been observed.
    - We can combine multiple data in long periods by using each calibration taken in the period.

13. **Do you foresee particular challenges in the alignment and calibration of your sub-detector?**
    - Good S/N for readout electronics is necessary to cope with the lower gain of 10 μm pitch SiPM.