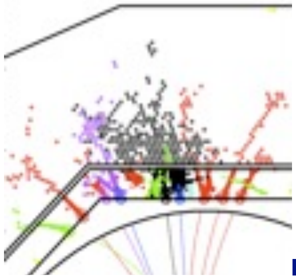
AHCAL answers to ILD questions on Calibration

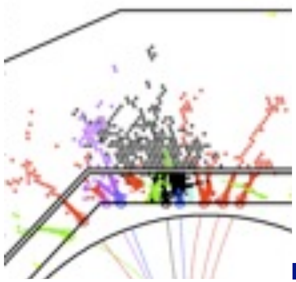
September 2016



Outline

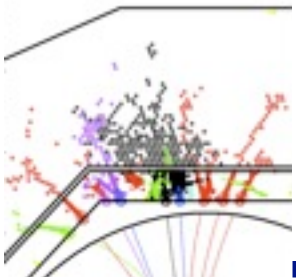
QUESTIONS

1. Outline the strategy for alignment and calibration of your subdetector.
2. What calibration and alignment parameters need to be measured with particles (either from collisions or cosmics) for your subdetector?
3. What precision is needed on the calibration and alignment parameters for your subdetector? What is the basis for this assessment?
4. How many usable particles per sub-detector element are needed to establish the calibration and alignment constants at the above level of precision?
5. What particles and kinematic criteria are needed?
6. What is the smallest solid-angle subtended by an individual sub-detector element?
7. Does your subdetector plan to use power-pulsing?
8. Are cosmics useful for the alignment/calibration of your sub-detector?
9. Are beam halo muons useful for the alignment/calibration of your sub-detector?
10. If power-pulsing is used, what is the effective live-time percentage?
11. Is data with the magnetic field off needed for your sub-detector?
12. On which time-scales do you anticipate that the alignment and/or calibration of your sub-detector will be stable? In particular would it be reasonable to assume that data collected over multiple running periods in multiple years can be used collectively to refine the overall calibration or alignment?
13. Do you foresee particular challenges in the alignment and calibration of your subdetector?



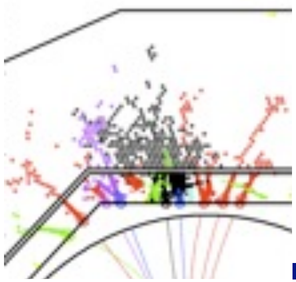
1. Calibration & alignment strategy

- Alignment:
  - stable within required precision
  - layer-wise (transverse) parameters sufficient
  - few tracks
- Equalisation of cell responses:
  - MIPs: cosmic or muon beams (many layers simultaneously)
  - SiPM corrections: test bench parameters and LED system
- Electromagnetic and hadronic scales, weight factors:
  - beam test of sample structures
  - should include boundary regions for dead material corrections
- Monitoring (= follow variations with time)
  - LED system to check SiPM stability
  - track segments add redundancy and cross-check
  - very insensitive to cell-wise variations
  - layer- and module-wise require smaller track statistics



2. Parameters to be determined with particles

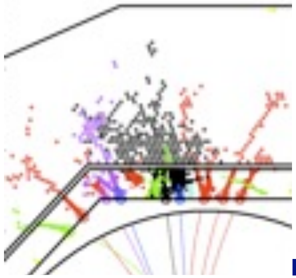
- MIP response sufficient
  - was used in all test beams so far
  - averaged over areas of order m^2, possibly few layers
    - was also tried with test beam data



3. Required precision

- Studied in response to IDAG questions to LOI and documented in addendum and CAN-018 (2009)

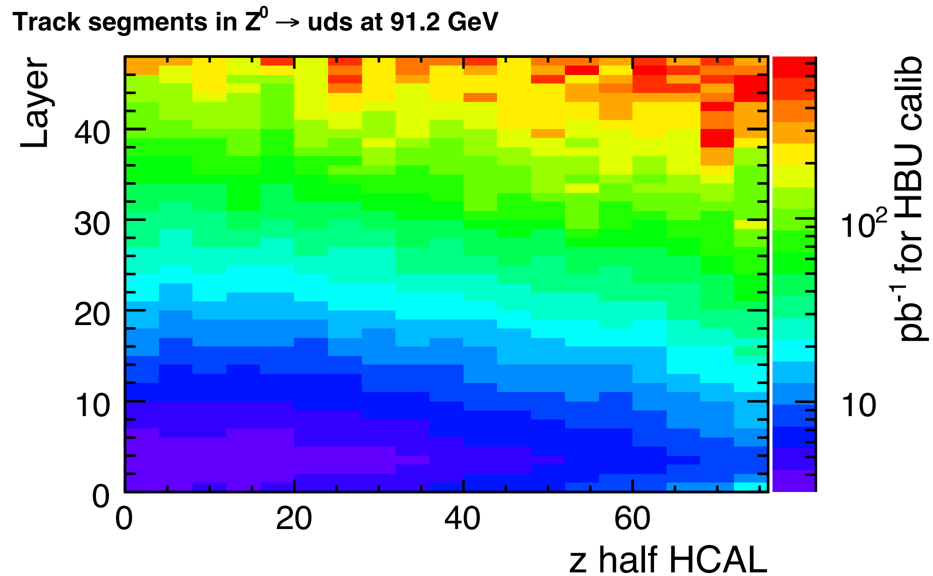
- Simulations of single hadrons and jets with different mis-calibration scenarios
- Cell-wise
  - 50% (limited by track finding for calibration check)
- Layer-wise
  - 15%
- Global:
  - 5% RMS gives 2% for jets at 100 GeV, 6% at 500 GeV
  - fast variation: never observed, small constant term in TB
  - slow variation: temperature compensation and LED cross-check
  - easy to detect with small statistics
- Global scale precision at jet level, beyond HCAL alone



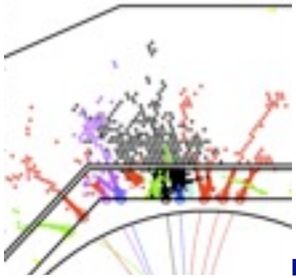
4. Required statistics

- MIP calibration: 1000 entries for 3-4% precision
- Test beam: typically 2 tracks per shower, 20 cells hit

- MIP calibration: 1000 entries for 3-4% precision
- Test beam: typically 2 tracks per shower, 20 cells hit

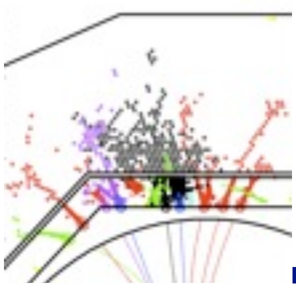


- Z pole:
  - 1 pb^{-1} 1000 tracks per layer in each module (3000 cells) up to layer 20
  - 20 pb^{-1} for layer 48, 10 pb^{-1} if $Z \to \mu\mu$ added, less if layers combined
- 500 GeV:
  - 2 fb^{-1} 1000 tracks per layer in each module (3000 cells) up to layer 20
  - 20 fb^{-1} for layer 48, less if outer layers combined



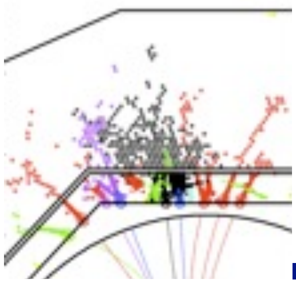
5. Particle types, kinematics

- Any MIP will do
- Any jet will do



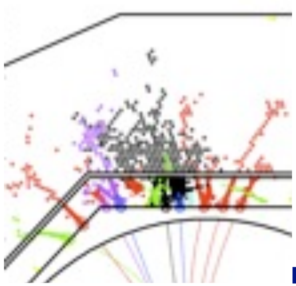
6. Smallest solid angle

- Cell at z=0
  - $0.03^2/2.2^2 = 0.2$ milli-steradian



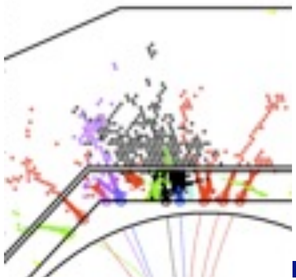
7. power pulsing

- yes



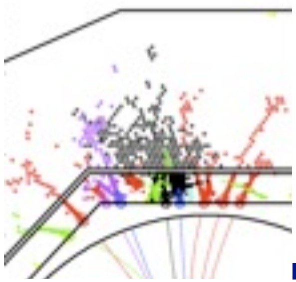
8. cosmics

- would be useful at surface
  - even with power pulsing
  - 70 min per layer, 1 day per HBU
- but not underground



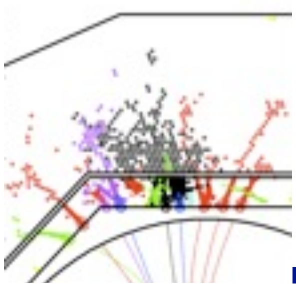
9. beam halo muons

- useful
- also with power-pulsing
- even cell-wise calibration conceivable in end-cap



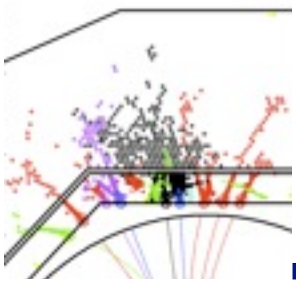
10. power pulsing duty cycle

- 0.5-1%
- some increase conceivable, re-assess when cooling system first design exits



11. data with B=0

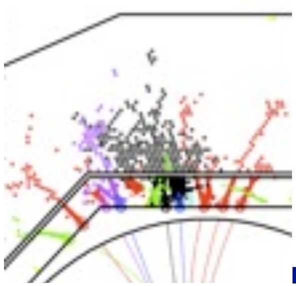
- not needed



12. stability time scale

- No ageing effects of scintillators or SiMs have been observed
- Data from different run periods can be combined to accumulate precision, e.g, on absolute energy scale

- Has been done with test beam data
  - possibly adjusting for global shift due to changes of supplies



13. challenges

- confidence built up during test beam
- no particular challenges

- some optimisations still to be done
  - active temperature compensation procedures
  - averaging of LED data
  - precision requirements for saturation correction