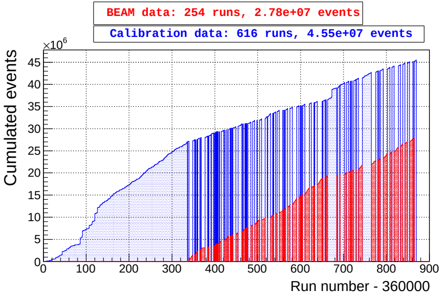
W-AHCAL analysis status

Angela Lucaci-Timoce

Introduction

- Data taken with W-AHCAL at CERN PS in September and November 2010
- Mixed beams with energy between 1 and 10 GeV



People working on W-AHCAL data

- From DESY Hamburg:

People	Task
Andrea Vargas Trevino	μ and π separation, longitudinal profiles
Clemens Günter	noise, LED temperature, correction, tile cross-talk

- From the CERN LCD group:

People	Task
Erik van der Kraaij	gain
Martin Killenberg	dead and noisy channels
Christian Grefe	MIPs
Astrid Münnich	tracking, Mokka
Dominik Dannheim, Wolgang Klempt, Bruno Lenzi	particle ID, analysis
Angela	reconstruction, analysis
Jacopo Nardulli	Mokka
Peter Speckmayer, Angela	CALICE Pandora

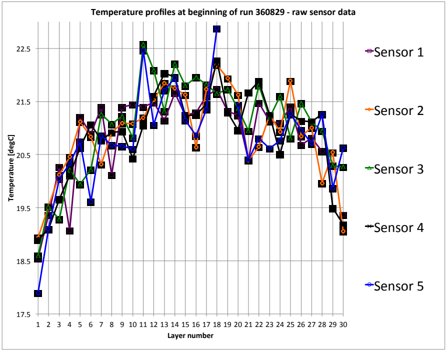
Analysis strategy

- Calibrations: MIP, gain, inter-calibration, temperature correction
- Noise study
- Beam composition
- Muons: basic check of calibration
- Electrons: check of geometry and material in GEANT4
- Hadrons: the physics we want to look at

- For initial understanding, concentrate on large statistics runs (typically 150000 events), see https://twiki.cern.ch/twiki/bin/view/CALICE/ListOfCERN2010BEAMRunsWhichCanBeUsedForAnalysis

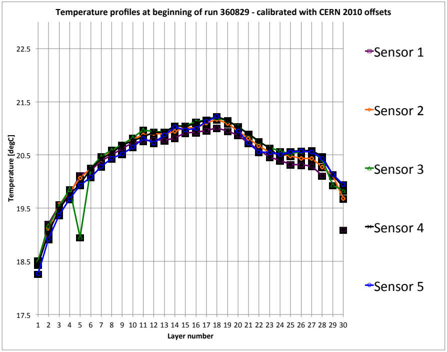
Measurements of temperature sensors offsets

- AHCAL temperature measured with 5 sensors per layer
- Example temperature profile using raw sensor data:



Measurements of temperature sensors offsets

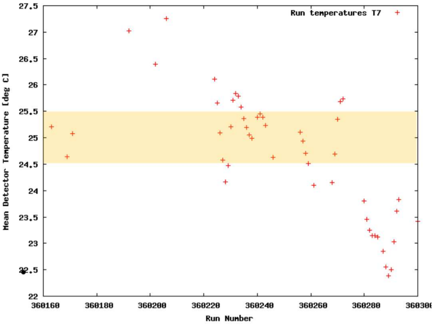
- Temperature measurements involve hardware offsets which need to be determined
- After applying the offsets, the temperature profile is smoother



- Developed software to take care of sensors which are 'mis-behaving'
- Procedure and tools documented in CALICE SVN (`calice_calib` package)

MIP calibration

- Dedicated muon runs taken in September in T7
- Mean detector temperature vs. run number:

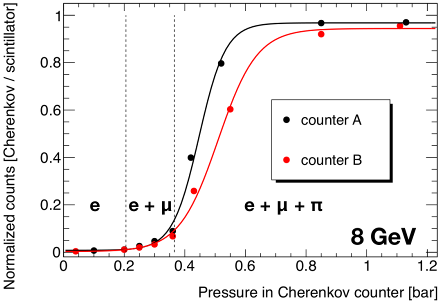


- Need stable temperature to measure MIP slopes ⇒ selected $T = 24.5 \pm 0.5^\circ$ C because of higher statistics
- Not possible to calibrate all channels (10×10 trigger only)
- Idea: for missing channels (25% of all channels), use 2007 calibration values and scale them if necessary (same voltages)
- New MIP values available

Particle identification

- Particle identification based on 2 Cherenkov triggers

- Cherenkov yield vs pressure for 8 GeV beam energy:

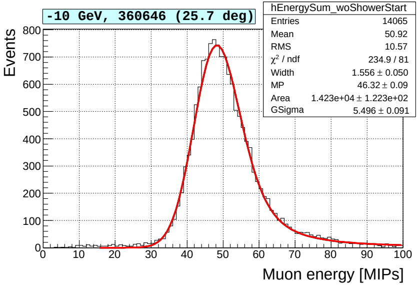


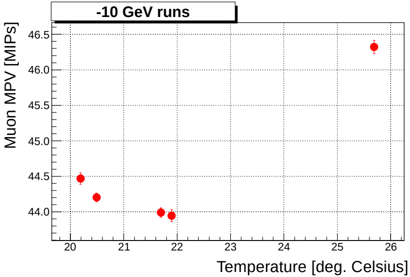
- Dashed lines: calculated thresholds for μ, π
- Arbitray fit function

- Run conditions (beam energy, Cherenkov pressure) written to the data base
- Cherenkov thresholds tabulated in a Marlin processor (`HCalPIDProcessor`)
  $\Rightarrow$ User can easily select particle type (but can have large contamination from other particles, depending on energy, Cherenkov pressure)

Precision of MIP temperature correction

- Muon candidates selected using events with no shower start
- Example fit for run 360646 (Landau convoluted with Gaussian)





- Within runs of the same energy, variation of the muon MPV of around 5%
- Not clear in the moment if this is the precision of our temperature correction, or if there are some hidden effects (artefact of fit?)
- Not yet checked for other energies

Temperature dependence in Monte Carlo

From generated to reconstructed AHCAL hits: several steps

1. Events generated with GEANT4 (Mokka);
2. Digitisation (i.e. from GeV to ADC counts)
3. Reconstruction (i.e. from ADC counts to MIPs)

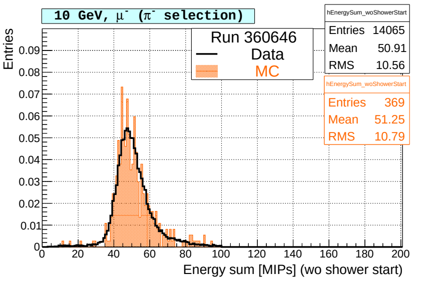
- Idea: Since in GEANT4 there is no temperature dependence of AHCAL response, **DO NOT apply temperature correction** of MIP and GAIN values in digitisation and reconstruction
- But: the devil is in the detail
- At the end of digitisation, the AHCAL noise is added
- This noise (electronic + SiPM noise) depends on temperature

In addition,
analysis usually done for hits with $E > 0.5$ MIPs, in order to suppress noise.

Temperature dependence in Monte Carlo

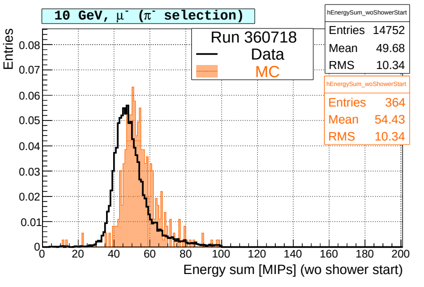
- **Muon energy spectra WITHOUT MIP/gain temperature correction applied in Monte Carlo:**

$T = 25.7^\circ$ C



- MIP calibration taken at $T = 24.5 \pm 0.5^\circ$ C
- For close temperatures, the correction is very little, so the impact cannot be seen

$T = 20.2^\circ$ C

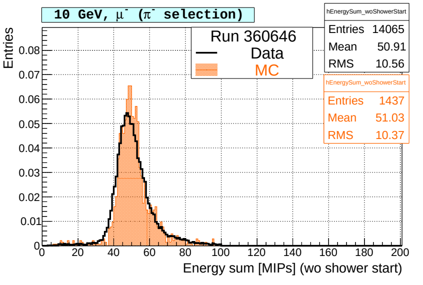


- For lower temperatures, clear impact of temperature difference seen
- Note: same Monte Carlo file, only difference is the noise file

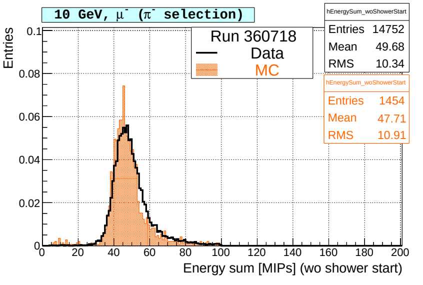
Temperature dependence in Monte Carlo

- **Muon energy spectra WITH MIP/gain temperature correction applied in Monte Carlo:**

$T = 25.7^\circ$ C



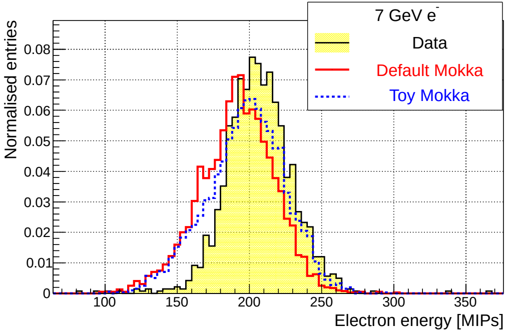
$T = 20.2^\circ$ C



- $\Rightarrow$ The temperature affects the level of noise added in Monte Carlo
- Need to apply temperature correction also in Monte Carlo

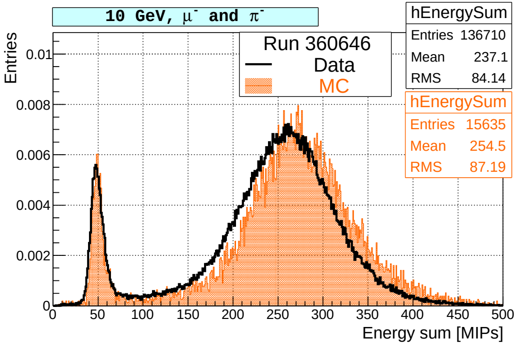
Electron energy spectra in Monte Carlo

- Once muons ok, started to compare electrons with Monte Carlo
- Energy in Monte Carlo lower than in data ⇒ looks like we have too much material in Monte Carlo
- But: W thickness can be smaller than 10 mm (cf. specifications)
- **Toy Monte Carlo**: W thickness $10 - 0.2$ mm + 90% W (default: 93%)



- Mean in toy MC closer to data (within 2.5%)
- But shape different
- MC: Tail at low energies (not present at generator level)
- Not clear why ⇒ to be studied

Pions

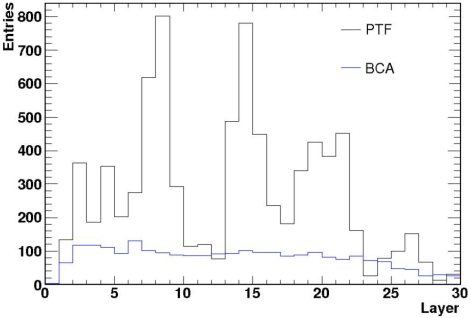


- Pions systematically higher in Monte Carlo than in data
- We'll get back to this once the electrons are understood

Muon/pion separation

- Ongoing studies by Andrea Vargas (DESY)
- Goal: find the best method to separate muon and pions
- Comparison of 2 different shower start finders
- `PTF=PrimaryTrackFinder` (Marina Chadeeva)
- `BCA=Beni's Cluster Algorithm` (Benjamin Lutz)
- Both are not tuned for energies $E < 6$ GeV, and have comparable efficiencies for higher energies

- Distribution of the shower starting layer for pure MC muons:

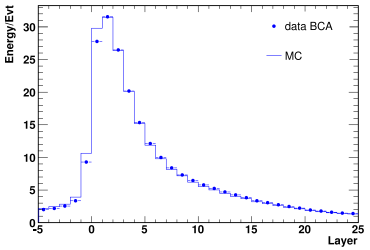


- In about 10% of the cases, muons are fakely identified as pions, and a shower start is found
- `PTF`: sensitive to noise
- `BCA`: flat distribution

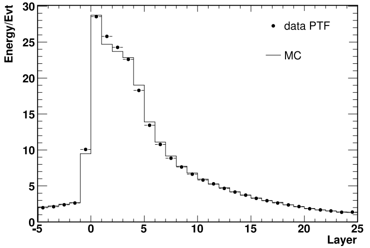
Pion longitudinal profile

- Longitudinal shower profiles (from shower start) for 9 GeV pion look different for the 2 finders

Beni's cluster algorithm



Marina's track finder



- Next: further studies using the shower starting point from true Monte Carlo

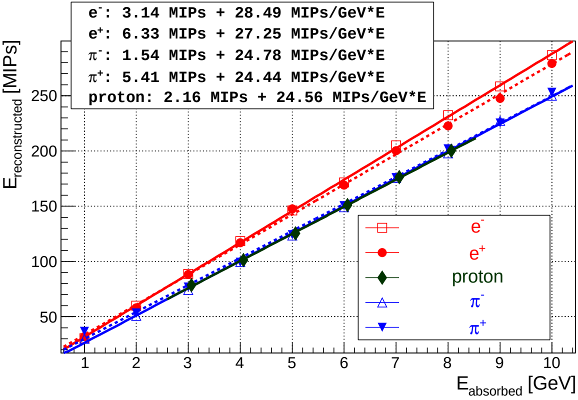
Reconstructed energy

- Let's go back to data

- We have data taken at all energies, but some points not included here because not yet fully understood

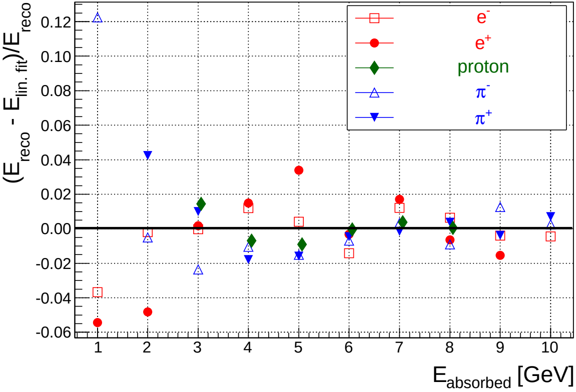
- Proton energy corrected for kinetic energy

- *All quoted numbers to be taken with a grain of salt*



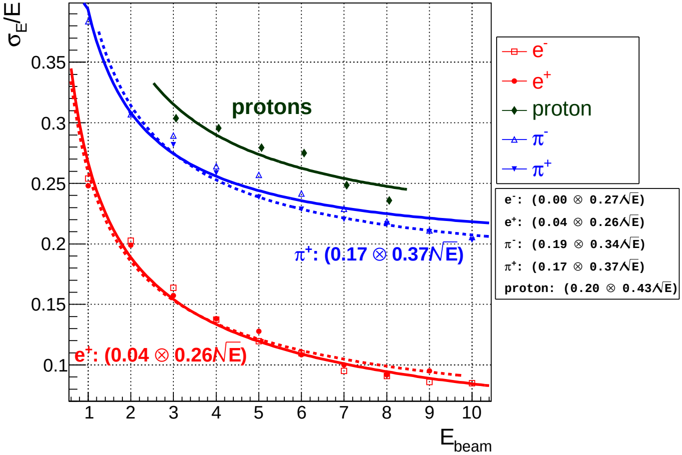
Deviation from linearity

- Clear need of improvement at low energies (difficult to distinguish between different particle types)



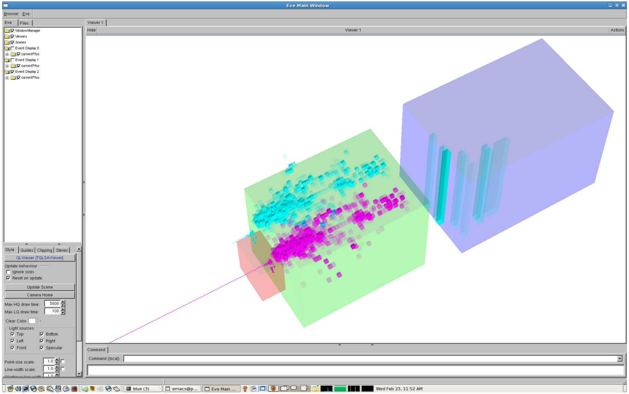
Resolution

- Electron energy resolution better for electrons than for hadrons
- Protons: not yet understood behaviour (should be similar to pions)
- *All quoted numbers to be taken with a grain of salt*



CalicePandora

- Development of `CalicePandora` package by Peter Speckmayer
- Available in CALICE SVN (includes example steering file)
- To be done: superimposing of tracks, documentation note (in preparation)
- Example of overlaid events from CERN 2007 (ECAL + HCAL + TCMT):



Conclusions

- Muons:
  - good agreement between data and Monte Carlo at all energies
  - still to understand: the run to run variations for -10 GeV
- Electrons:
  - on the way
  - need to cross-check material in Monte Carlo and energy spectra in digitisation
- Pions, protons:
  - once electrons are understood, to be compared with Monte Carlo (study hadron shower development in W for different physics lists)

- In parallel, prepare for next test beam (see Erik's talk on Saturday)

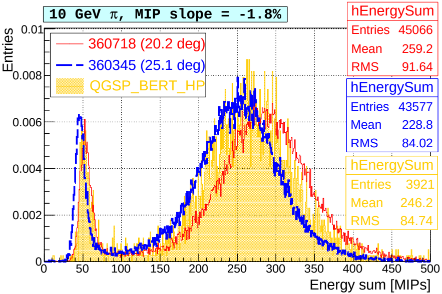
Special thanks

Wolfgang Klempt, Dieter Schlatter, Dominik Dannheim for daily support; and Benjamin Lutz for very useful discussions

Back-up slides

MIP calibration or how things can go wrong

- Initially, we've used CERN 2007 calibrations (i.e. a MIP temperature slope of −3.7%), but when compared to Monte Carlo, this resulted in a mismatch of the muon peak



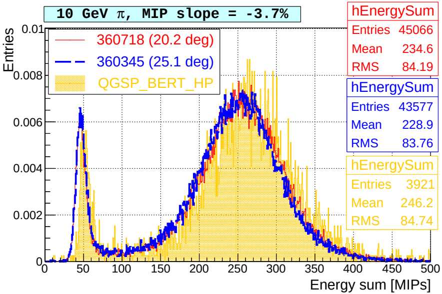
- By using half of the MIP slope (i.e. −1.8%), we got a match ⇒ we believed that is the right slope

- *Le comble*: Christian obtained the same reduced slope using 2010 muon runs

- Turned out that the agreement between data and Monte Carlo was only due to the fact that all the selected runs (about 10, at different energies) were taken around 20° C

MIP calibration or how things can go wrong

- After taking runs at other temperatures also, realised that -3.7% is the good value (because it gives the same mean for a given energy, regardless of temperature)



Lesson learned:

Always look at as many runs as possible, i.e. at different energies and at different temperatures