Status of W-AHCAL data analysis

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on behalf of the CERN CALICE group

Introduction

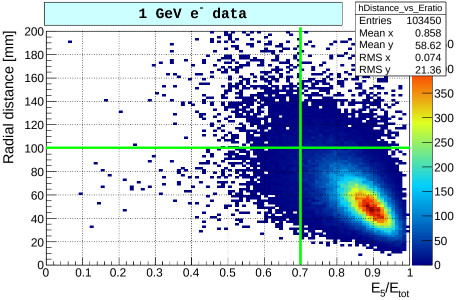
- Data taken with W-AHCAL at CERN PS/SPS: **September-October 2010 and June-July 2011**

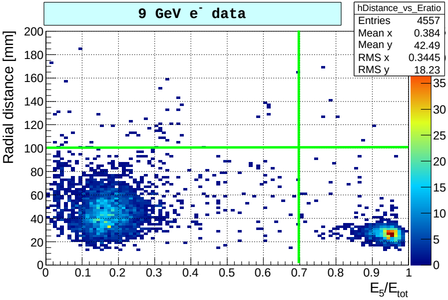
E_{beam} GeV	*Beam content*	*Comment*
Sept-Oct 2010		
1-10	e, π, (p) μ	Used for MIPs, but no temperature dependence extracted
June 2011		
10-50	π	
July 2011		
10-300	e, π, (K) μ	TCMT included To be used for MIPs

- For more details about the test beam itself, see talk by Erik van der Kraaij

Electrons 2010: Data selection

- First level of selection: based on Cherenkov counters (but not 100% efficient)
- At low energies: clean electron sample
- At high energies: some contamination from muons (and maybe pions)

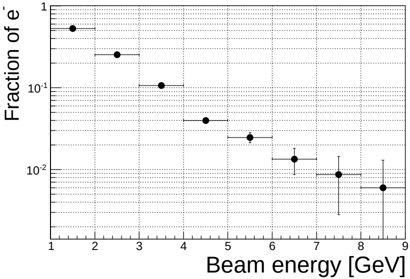




- Apply a box cut: $E_5/E_{tot} > 0.7$ and $d < 100$ mm
  where E_5/E_{tot} = energy in first 5 layers/total energy
  and $d = \frac{\sum_i E_i \cdot \sqrt{(x_i - x_{track})^2 + (y_i - y_{track})^2}}{\sum E_i}$,
  i.e. energy weighted distance of hits from shower axis

Electrons 2010: Data selection

- Fraction of electrons in 2010: lowers with increasing energy

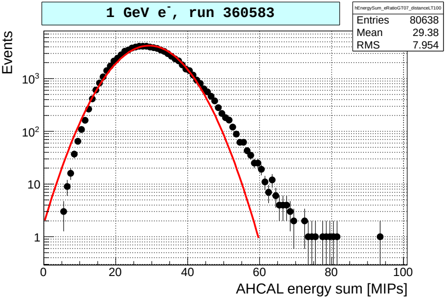


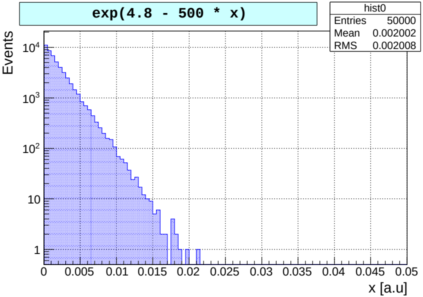
- Very small statistics at high energies (approximately hundreds of events) $\Rightarrow$ include only runs up to 8 GeV

Electrons 2010: Fit of energy sum distribution

- Problem: Energy sum distribution non-Gaussian for low energies ($E < 5$ GeV), although the data is apparently clean

- Idea: maybe this is a statistical effect (number of active cells is small at low energies)
- For each cell, the signal spectrum is exponential (for hits above noise threshold)



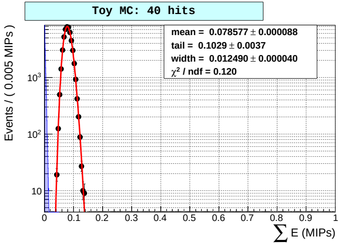


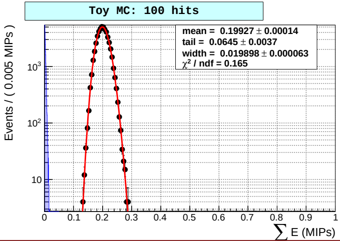
- Decided to use Novosibirsk function: Gaussian with asymmetric tails

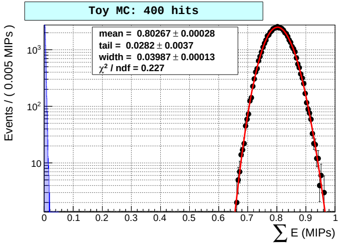
Electrons 2010: Fit of energy sum distribution

Central limit theorem

The distribution of an average tends to be Gaussian, even when the distribution from which the average is computed is decidedly non-Gaussian.



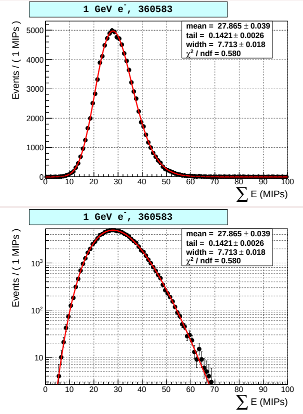




- At 1 GeV: 40 active cells on average
- With increasing beam energy, more hits → more Gaussian like distribution (tail tends to 0)

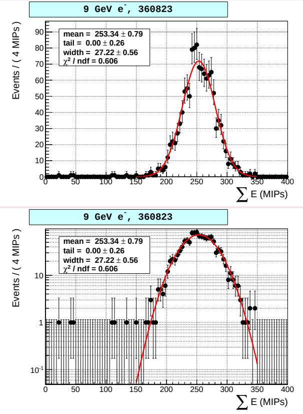
Electrons 2010: Fits

Low energies: $(E < 5\text{ GeV})$



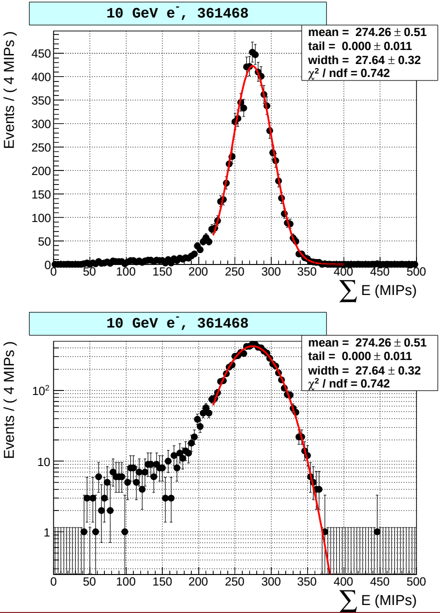
- Clean sample
- No problem with the fit

High energies $(E \geq 5\text{ GeV})$:



- Fit ok, but some tails at low energies
- Tails not present in Monte Carlo

Electrons 2011: Fits

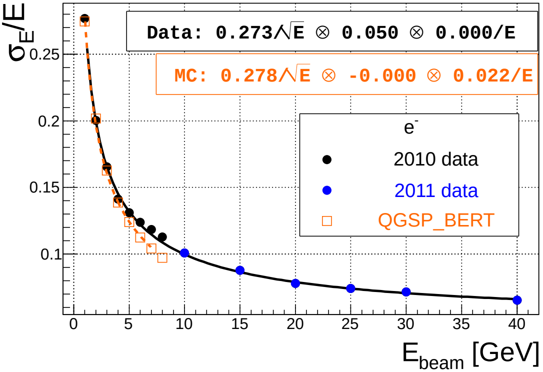


2011 electron data:

- Long tails at low energies
- Looked at those events in detail (event display, etc), no obvious problem observed
- Maybe these are low energy electrons (electrons loosing their energy already before reaching the calorimeter, by interacting with material in the beam upstream of W-AHCAL)
- For the moment, fit only the peak

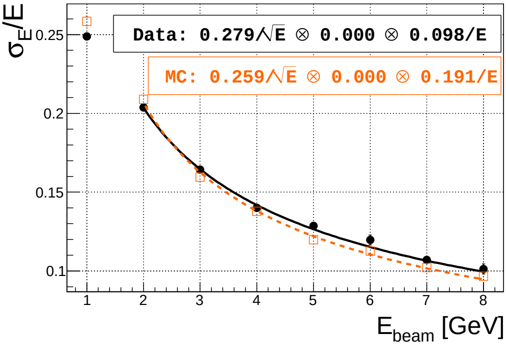
2010: e^- Resolution

- **Caveat**: Quote the resolution as σ_E/E, with σ and mean from Novosibirsk fit function (Novosibirsk becomes Gaussian at $E \geq 5$ GeV)



- Data look reasonable
- Disagreement with Monte Carlo for $E \geq 5$ GeV (too good sigma in Monte Carlo, not yet understood)

2010: e^+ Resolution

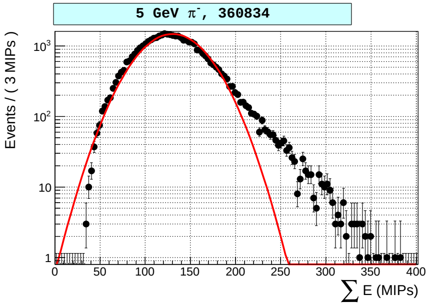


- Data at 1 GeV not included in the fit (see back-up slides)
- W-AHCAL positron energy resolution: worse than for Fe-AHCAL (arXiv:1003.2662): $\frac{\sigma_E}{E} = \frac{(21.9 \pm 1.4)\%}{\sqrt{E}} \otimes (1.0 \pm 1.0)\% \otimes \frac{58.0\ \mathrm{MeV}}{E}$

  $\rightarrow$ lower sampling ratio relative to X_0 (see back-up slide)

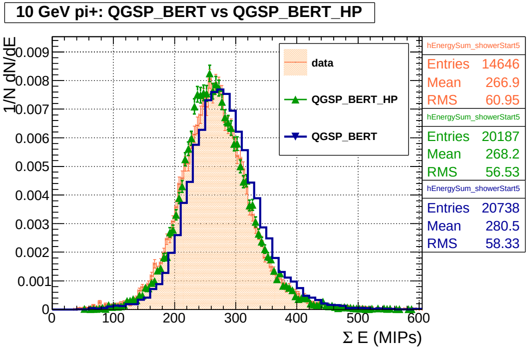
2010 Pions

- Energy distribution shows tail at high energies, reason unclear
- Example for 5 GeV: red line is Gaussian fit



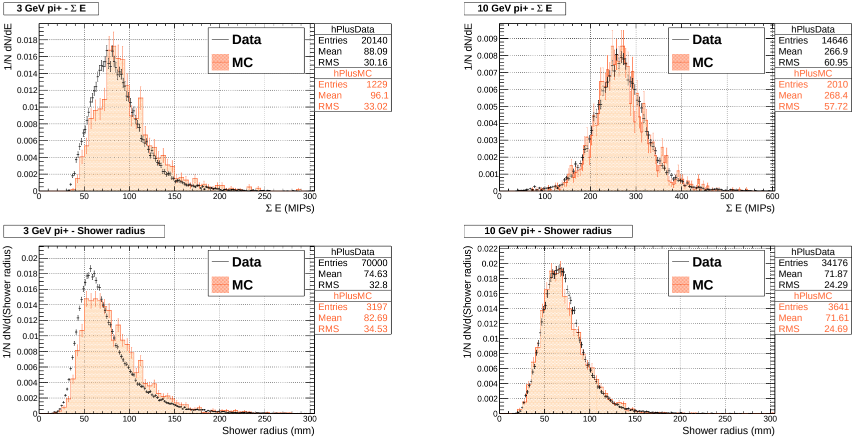
- Studies based on shower shapes (using TMVA) and comparison with Monte Carlo indicate no electron contamination
- Note: energy distributions shown for events with shower start in layer ≤ 5 (using Marina's track finder)

2010 Pions: Data compared to QGSP_BERT with/without HP



- Difference between QGSP_BERT and QGSP_BERT_HP, as expected
- Better agreement with data for the latter
  ⇒ use QGSP_BERT_HP from now on

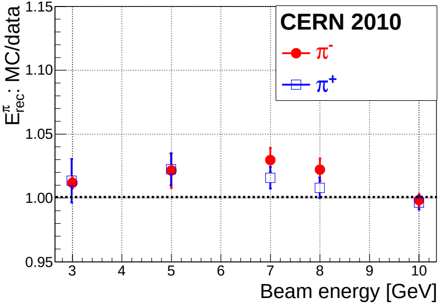
2010 Pions: Data compared to Monte Carlo



- For $E = 10$ GeV, nice agreement
- For lower energies, not so good anymore
  $\Rightarrow$ expect input from our data to GEANT4 to improve the situation

2010 Pions: Data compared to Monte Carlo

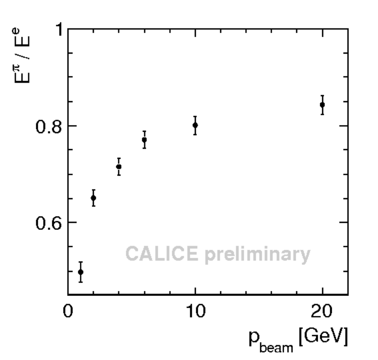
- MC: QGSP_BERT_HP
- Results by fitting only the peak with a Gaussian (fit range optimised to get good χ^2/ndf)
- MC/data agreement at 3% level



AHCAL: π/e ratio

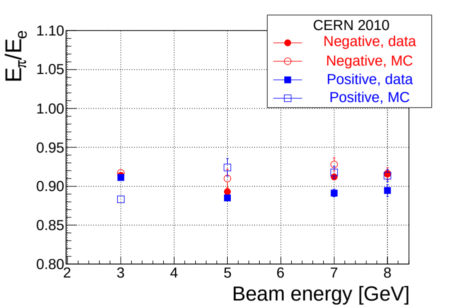
Fe-AHCAL

- Results from CAN-034 (N. Feege), using Fermilab data



W-AHCAL

- Only 2010 data for the moment
- π/e approximately 0.9



Summary

- **Electrons 2010**:
  - Novosibirsk fit function, valid for all our runs
  - $\sigma_E/E \backsimeq 27\%$
  - MC for $E \geq 5$ GeV shows too good sigma
- **Electrons 2011**: Long tail at low energies (under investigation)
- **Pions 2010**:
  - Tail at high energies, reason unclear (present also in MC)
  - Obvious differences between QGSP_BERT and QGSP_BERT_HP
  - Surprisingly good agreement between data and MC
- **Pions 2011** (not shown): Dominated by leakage, need TCMT information

Next steps

- Determination of MIP constants for both HCAL and TCMT with 2011 data
- Checks of temperature dependence of MIPs and gains
- Try to understand tails in distributions
- ...
- Publish note

Back-up slides

Electrons 2010: Novosibirsk fit function

- Gaussian with asymmetric tails:

$$f(x) = A \cdot \exp\left(-0.5 \cdot \frac{\ln^2[1 + \Lambda \cdot tail(x - mean)}{tail^2} + tail^2\right)$$

with $\Lambda = \dfrac{\sinh(tail \cdot \sqrt{\ln 4})}{\sigma \cdot tail \cdot \sqrt{\ln 4}}$

- May look complicated, but it has only 3 parameters: mean, tail and sigma

Fe and W properties

Material	λ_I [cm]	X_o [cm]	λ_I/X_0
Fe	16.77	1.76	9.5
W	9.95	0.35	28.4

- Fe-AHCAL: 1.6 cm Fe per layer $\Rightarrow \sim 1\ X_0$
- W-AHCAL: 1.0 cm W per layer $\Rightarrow \sim 3\ X_0$

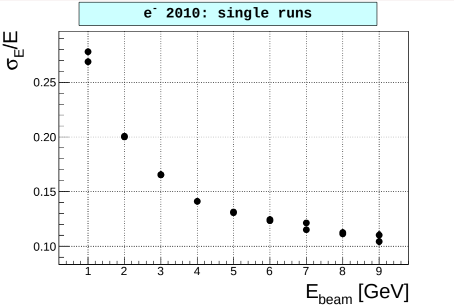
List of runs: 2010

Energy	Run number	
	Negative	Positive
1	360583 360584	360628, 360629 360629
2	360782 360785	360550, 360551 360552, 360573 360810, 360811
3	360835 360836	360598, 360599 360615, 360616
4	360774	360536, 360543 360570, 360571 360801, 360802
5	360834 360827	360591, 360597 360613, 360614
6	360707 360771 360772	360533, 360534 360617, 360618 360563, 360564 360799, 360800
7	360825 360826	360589, 360590 360611, 360612 360644, 360645
8	360767 360770	360532, 360561 360626, 360627 360633, 360796 360797
9	360823 360824	360619, 360642 360643, 360837 360838

2010: e^- and e^+

Electrons

- Temperature: $20 - 21^\circ$ C, i.e. similar temperatures for all runs



Positrons

- Temperature: $20 - 26^\circ$ C, i.e. large variations from run to run
  $\Rightarrow$ variations in the energy resolution from run to run, probably due to imperfect temperature calibration (temperature slope to be measured)