Status of SPS 2011 W-AHCAL data analysis

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Introduction

2011 data taking

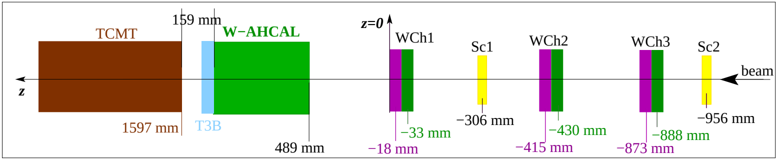
- W-AHCAL: 38 layers, absorber: tungsten, active media: scintillator tiles read out by SiPMs (+ Tail Catcher and Muon Tracker, TCMT)
- CERN SPS: June, July and September 2011
- Beam: mix of pions, protons, kaons, muons and electrons
- Energies: from 10 to 300 GeV
- More details about data taking conditions and beam-line instrumentation: LCD-Note-2012-002

Status of the analysis

- This talk: analysis of data with $p_{beam} \leq 100$ GeV
  (for higher energies need to consider the TCMT, see talk by Eva Sicking)

Introduction

- Identification of electrons, pions, protons and kaons done with two **Cherenkov counters**
- Muons tagged using W-AHCAL high granularity and rejected
- Simulation: Mokka model `TBCern2011WAHCAL`

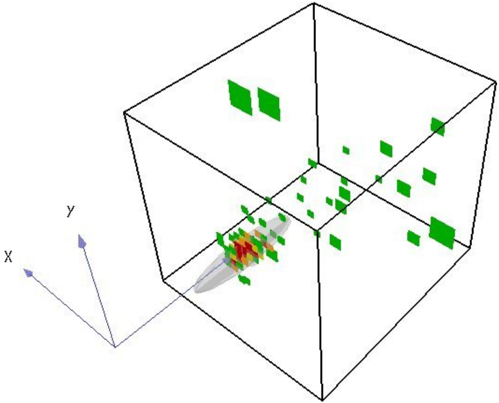


- GEANT4 physics lists: combined with the data driven Neutron **High Precision (HP)** models and cross-section
  - important for tungsten, which is a neutron-rich material

Analysis of e^+/e^- data

Selection of e^+/e^- events

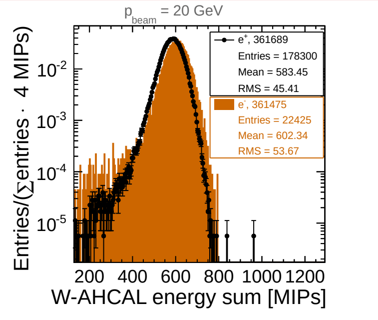
- Tungsten: dense material (about 3 X_0 per layer) $\rightarrow$ electromagnetic shower will form a cluster in the first calorimeter layers
- Selection:
  - one identified cluster
  - there should be no tracks



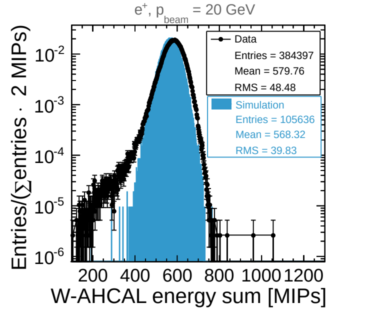
Analysis of e^+/e^- data

- Example: energy sum distributions for 20 GeV e^+/e^- (similar behaviour for all energies)

- e^- energy about 3% higher than for e^+ (not understood, negative runs taken in July, positive ones in September 2011)

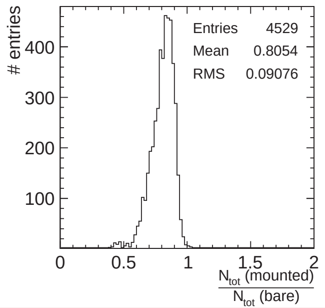


- Low energy tail (due to material in the beam-line?)
- Tail not present in the Monte Carlo

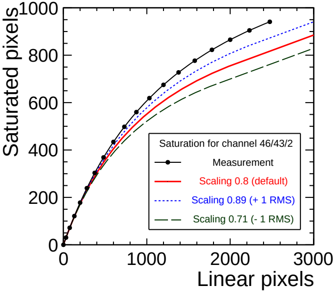


Scaling factor of the SiPM response curves

- SiPM response curves measured before mounting on the tiles
- Due to geometrical effects, maximum number of fired pixels in case of mounted SiPMs is about 80% of that for bare SiPM, with a large spread (from Fe-AHCAL em paper, arXiv:1012.4343)



- Example of saturation curves with different scaling factors, for a given cell

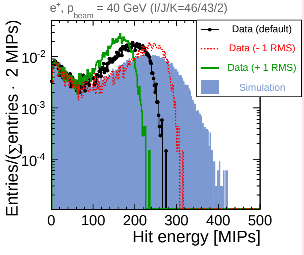


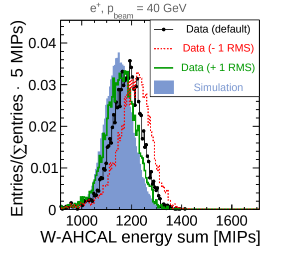
Scaling factor of the SiPM response curves

- Electromagnetic showers in W-AHCAL more compact that in Fe-AHCAL
  $\Rightarrow$ scaling factor expected to have a significant impact
- To estimate systematics due to scaling factor s: find the highest energetic cell and re-run the reconstruction with modified scaling factor for that cell: $s \pm 1$ RMS

Example: 40 GeV $\mathbf{e}^+$

- The highest energy cell contains more than 60% of the total energy in layer 2

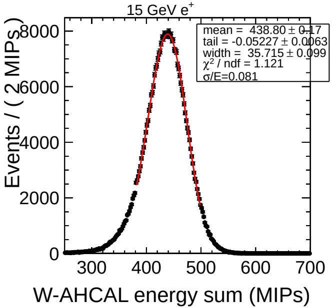


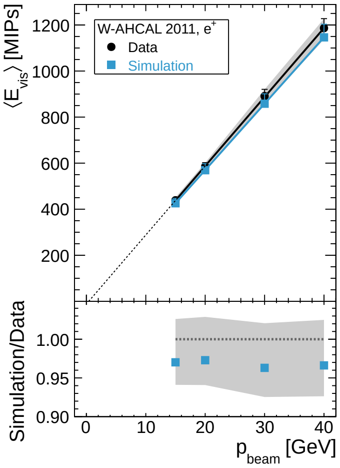


- Impact of scaling factor on the average energy at 40 GeV:
  $\langle E \rangle = 1186^{+3\%}_{-2\%}$ MIPs

Analysis of e^+ data: MC comparison

- Novosibirsk fit (Gaussian with tail) in a region defined by $mean \pm 1.5\ \sigma$



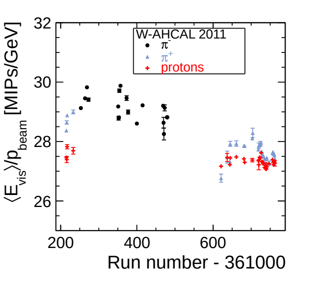


- Simulation predicts about 3% lower response than observed
- Implementation of detector material in Mokka was checked
- But: significant systematics from the scaling factor of the SiPM response curves

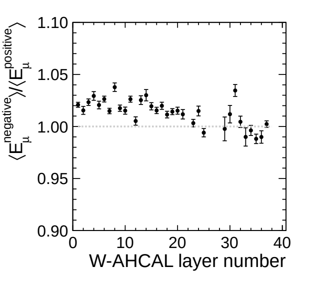
Analysis of hadron data

Hadron analysis: variation of detector response with time

- Calorimeter response to protons is stable with time, but variations observed for π^+ and π^-
- For the analysed energies: π^- higher response than π^+



- Similar variations observed in the muon response:

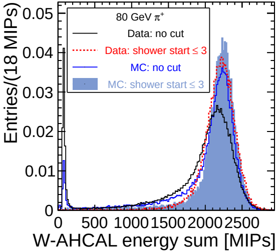


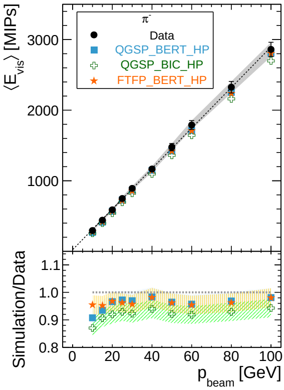
- $\Rightarrow$ Part of variations seem to be related to the calorimeter itself (not clear if due to charge, or just time dependence)

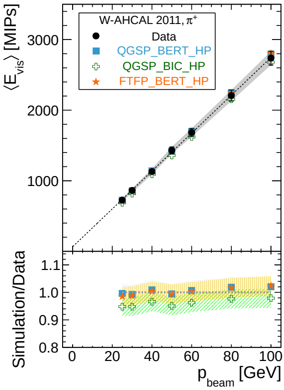
- Systematic uncertainties due to variation of detector response with time: $\pi^{\pm}$: $\pm 2.9\%$, protons: $\pm 0.7\%$

Analysis of π^-/π^+ data: $\langle E_{vis} \rangle$ vs p_{beam}

- Events with shower start in layer ≤ 3



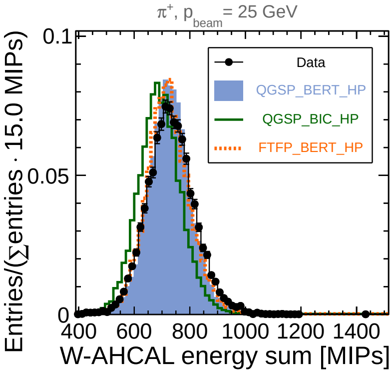


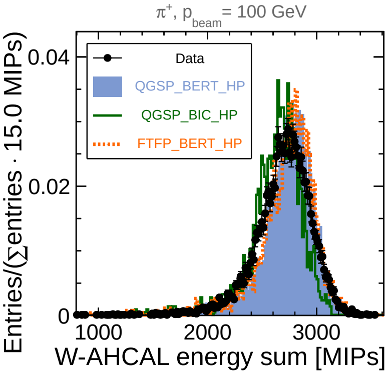


- Energy for π^- higher than for π^+ (variations of detector response in time of about 2.9%)
- Agreement between data and QGSP_BERT_HP/FTFP_BERT_HP for π^+

Analysis of π^+ data: energy sum

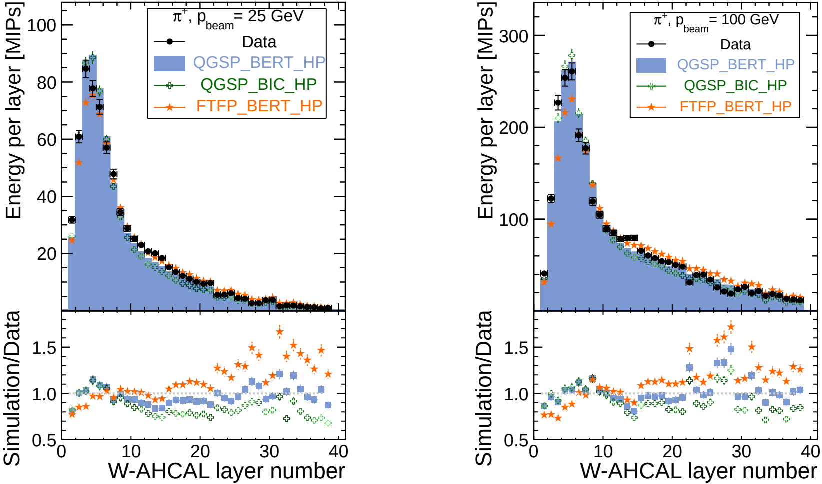
- π^+: good agreement between data and QGSP_BERT_HP/FTFP_BERT_HP for all analysed energies





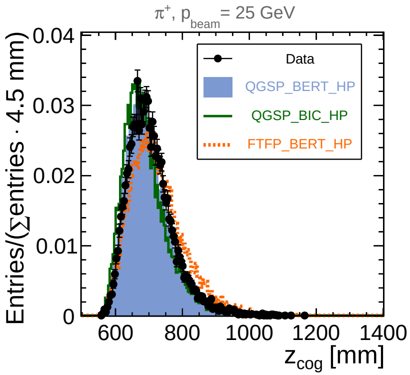
Analysis of π^+ data: longitudinal profile

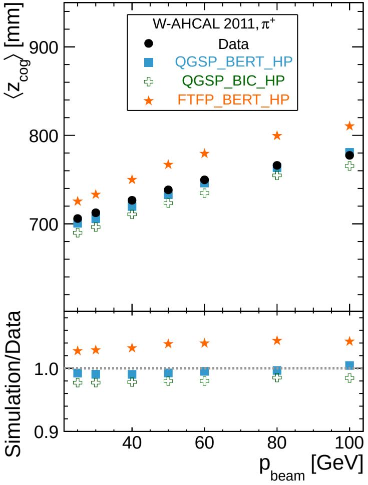
- Large variations (depending on the layer number)



Analysis of π^+ data: z_{cog}

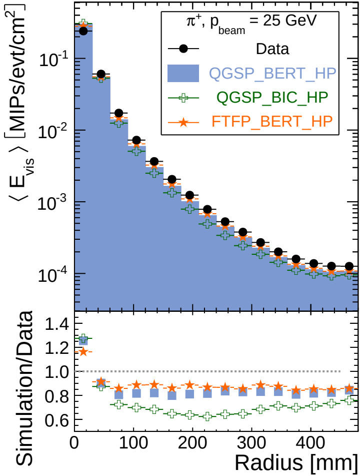
- z_{cog}: energy weighted centre-of-gravity
- Good agreement between data and QGSP_BERT_HP

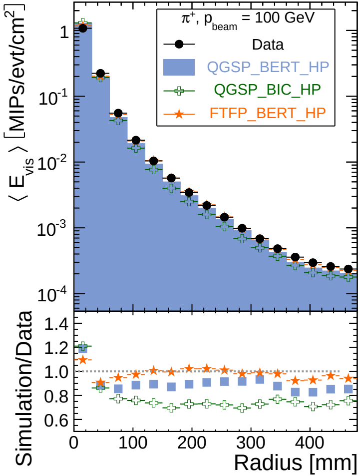




Analysis of π^+ data: radial profiles

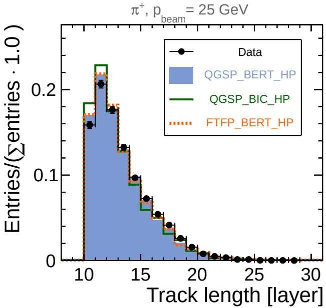
- Monte Carlo predicts a higher energy density in the core of the shower than observed

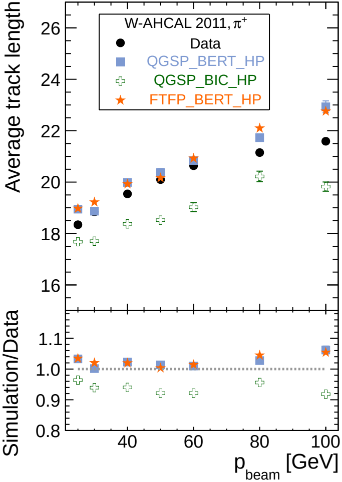




Analysis of π^+ data: track length

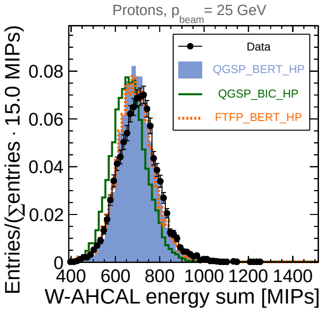
- Track selected with `HCalTrackingNNProcessor`, algorithm described in CAN-022
- Selection not optimised for track analysis (tracks passing at least 10 layers were selected for MIP calibration studies)

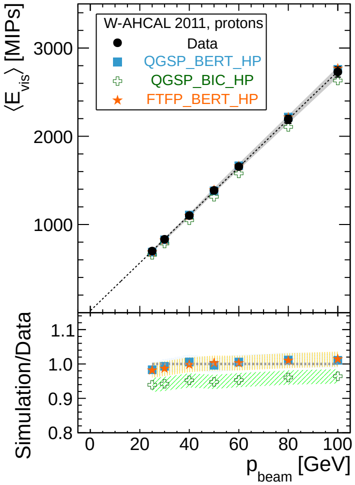




Analysis of proton data

- Good agreement between data and QGSP_BERT_HP/FTFP_BERT_HP



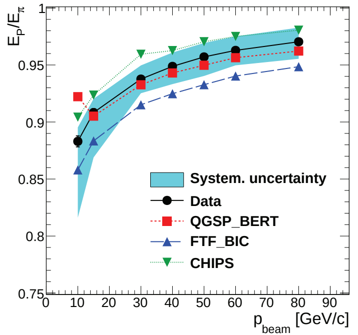


proton/π^+ ratio

- For a non-compensating calorimeter ($e/h > 1$), expect $E_{protons} < E_{\pi^+}$ (because $\pi^0 \rightarrow \gamma$ production is, on average, smaller in proton-induced showers)

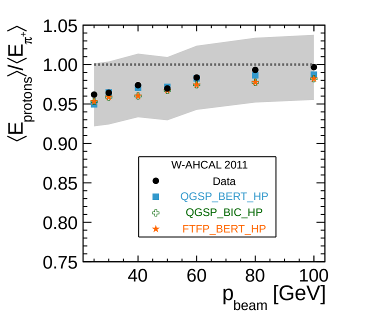
Fe-AHCAL

- M. Chadeeva, talk in the CALICE analysis meeting, 14th May, 2012



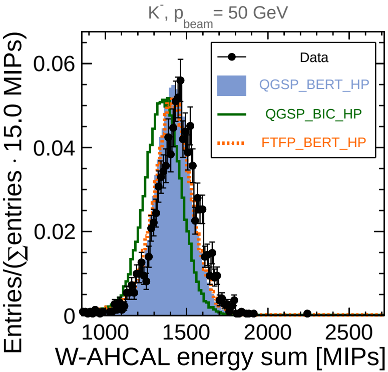
W-AHCAL

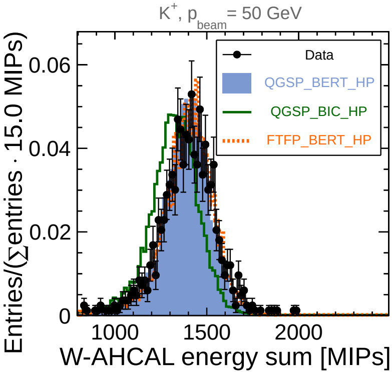
- W-AHCAL is closer to 'compensation'



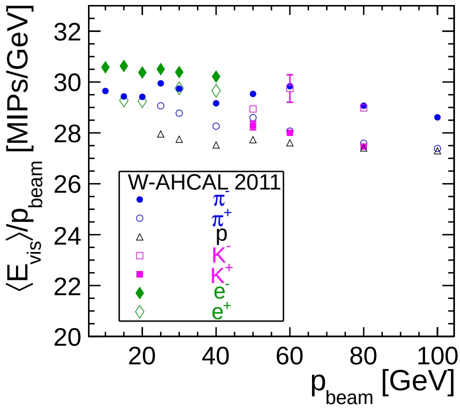
Analysis of K^-/K^+ data

- K^+: good agreement between data and QGSP_BERT_HP/FTFP_BERT_HP
- QGSP_BIC_HP predicts too low energy





Summary and conclusions

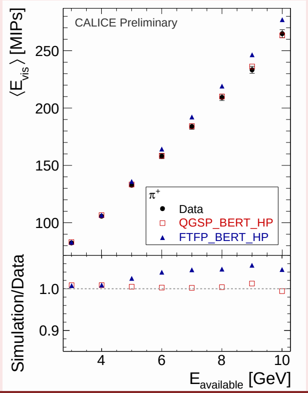


- Negative polarity runs have higher response than positive polarity runs (variations of detectore response with time of about 3%)
- e^+: disagreement between data and simulation (partially explained by imperfect scaling factors of the SiPM response curves)
- π^+, protons and K^+: good agreement between data and QGSP_BERT_HP

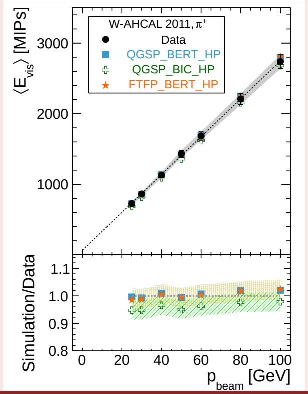
2011 and 2010 data

- We have one common energy point between the 2 data taking periods: 10 GeV π^-
- Unfortunately 2011 negative polarity runs have higher response than positive ones $\Rightarrow$ difficult to compare data of the 2 periods in order to judge on the compatibility, but can use Monte Carlo

2010



2011



- The agreement between data and QGSP_BERT_HP for positively charged particles indicates that the hadronic energy scales for 2011 and 2010 data taking agree

Outlook

Hinterher ist man immer schlauer...

Lessons learned...

- An optimised system could be realised considering:
  - **Temperature stabilisation**:
    - Usage of SiPMs with reduced temperature sensitivity, and/or of an improved temperature measurement system
    - Usage of temperature stabilisation system as for the CALICE digital HCAL test beam in 2012 at the CERN SPS
  - **Calibration data**: Taking high statistics of muon calibration runs at stable temperatures, and with large trigger counters, covering as much as possible the whole detector, such that all channels can be calibrated
  - **Improved test-bench characterization of SiPMs**: need better knowledge of saturation response curves
  - **Analysis procedure**: Development of a procedure to allow the analysis of the calibrated and temperature corrected data in a short time scale ($\sim$ a few hours), to allow for quick feedback

- Many more details about the analysis: LCD-Note-2013-002

BACK-UP

Systematic uncertainties

- **Data**:

Particles	Measurement	Assumed shifts	Total uncertainty
40 GeV e^+	Energy sum	$\pm 2.0\%$ (MIP scaling factor) $\pm 2.0\%$ (stability of detector response) $+3\%, -2.0\%$ (saturation scaling)	$+3.5\%$ -4.1%
	Longitudinal profile	$\pm 2.0\%$ (MIP scaling factor) $\pm 2.0\%$ (stability of detector response) $+9\%, -10\%$ (saturation scaling)	$+9.4\%$ -10.4%
$\pi^\pm$	Energy sum	$\pm 2.0\%$ (MIP scaling factor) $\pm 2.9\%$ (stability of detector response) -0.5% (saturation scaling)	$+3.5\%$ -3.6%
Protons	Energy sum	$\pm 2.0\%$ (MIP scaling factor) $\pm 0.7\%$ (stability of detector response) -0.5% (saturation scaling)	$+2.1\%$ -2.2%

- **Simulation**: $+5\%$ in the energy scale due to imprecise knowledge of the cross-talk factor