First Steps of W-AHCAL+TCMT Analysis

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CLIC Workshop, CERN
Physics & Detectors: Calorimetry (HCAL)

30-01-2013

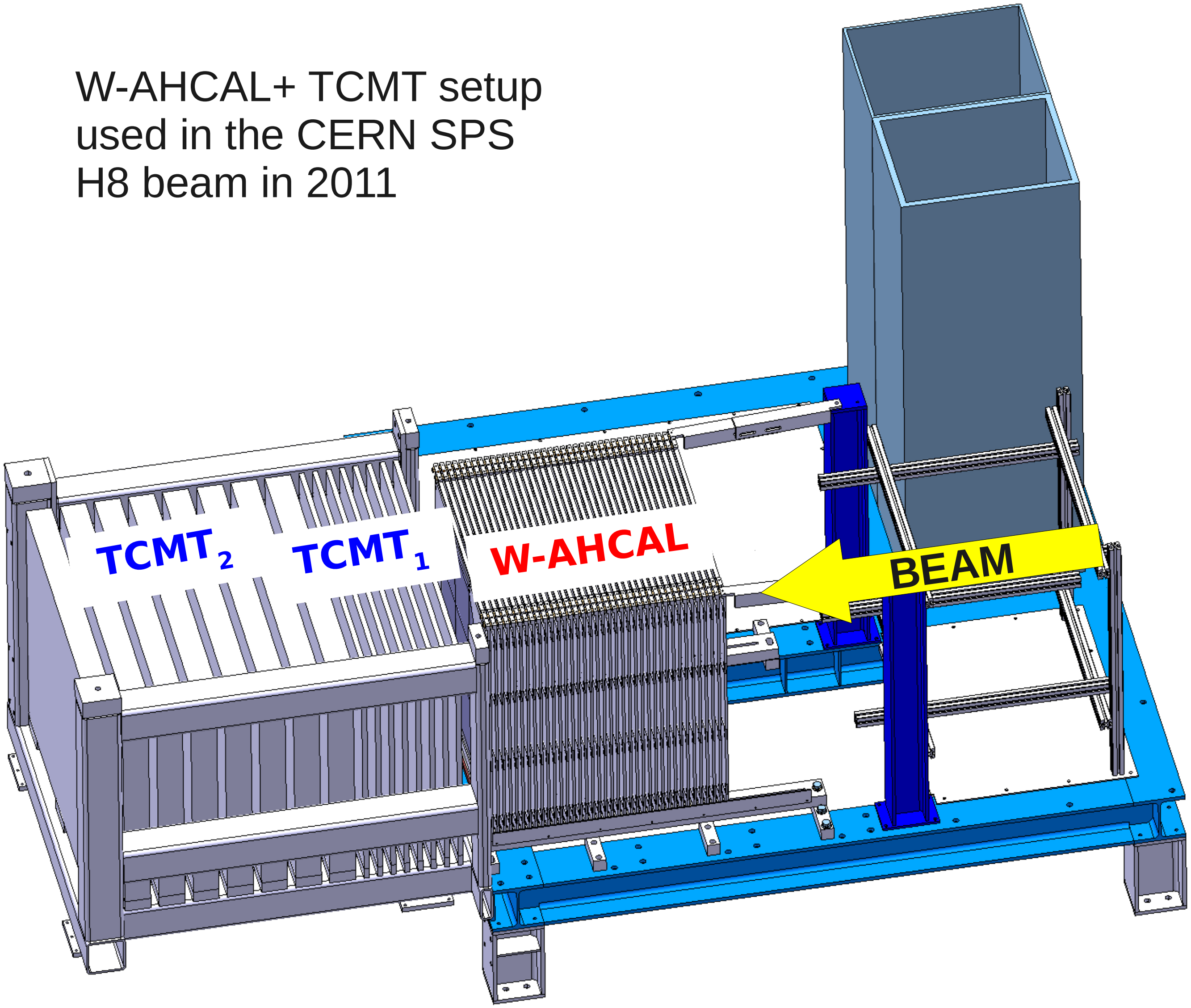
Introduction

- Test beam study of CALICE W-AHCAL and Tail Catcher Muon Tracker (TCMT) at CERN SPS in 2011

- Purpose of TCMT:
  - At SPS energies, hadronic shower can leak out of W-AHCAL of 4λ
  - TCMT can catch the tail of these showers
  - Expect that combination of W-AHCAL and TCMT will give improvement of energy resolution for high energy data

W-AHCAL + TCMT

W-AHCAL+ TCMT setup used in the CERN SPS H8 beam in 2011



LCD Note 2012-002
https://edms.cern.ch/file/1211436/1/LCDnote_WAHCAL_testbeam.pdf

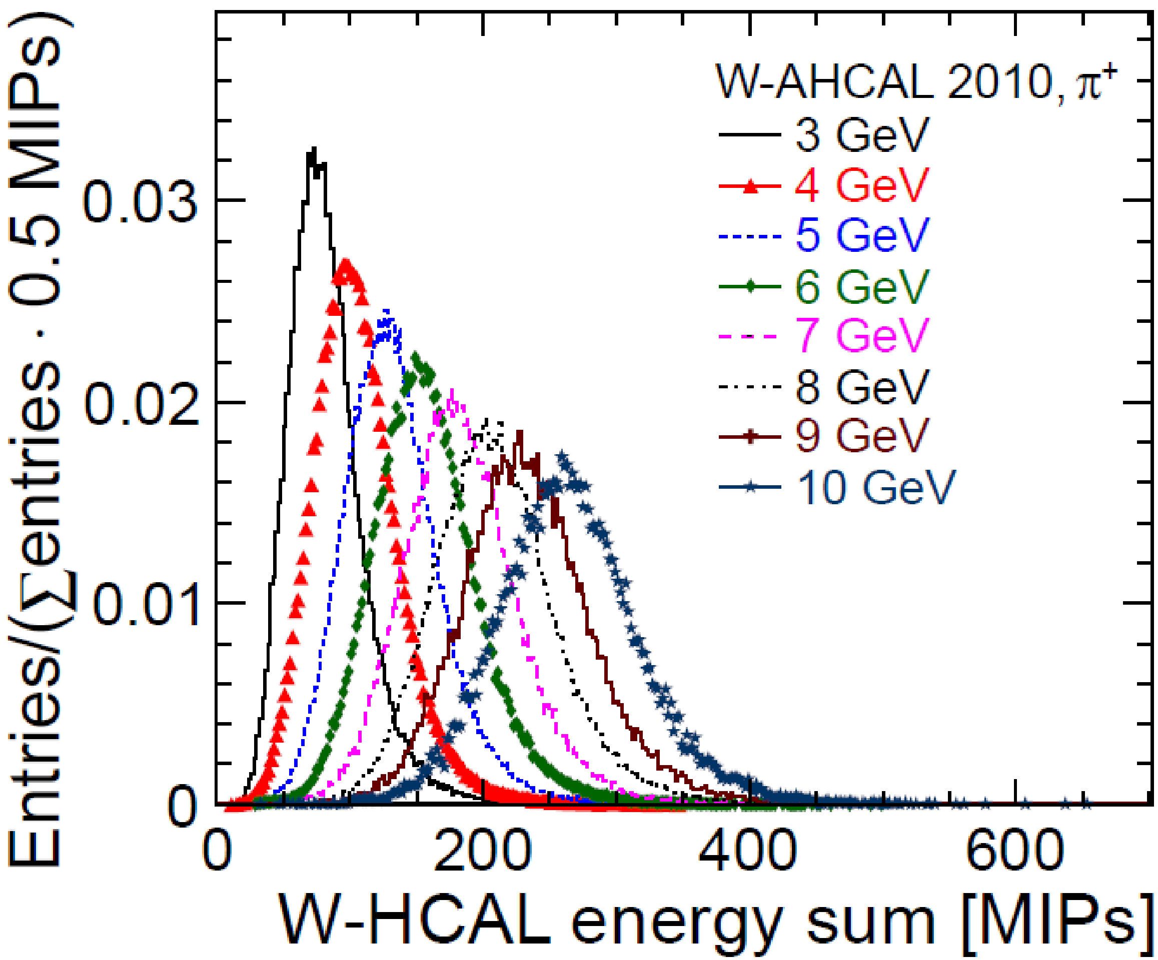
- W-AHCAL:
  38 tungsten layers, each 1cm thick, corresponding to ~4λ_I
- $TCMT_1$: 8 Fe layers, each 2cm thick
- $TCMT_2$: 8 Fe layers, each 10cm thick
- Distance between layers 32mm leaving space for sensor layers
- TCMT read-out: scintillator strips and SiPM

Data & Events Selection

- **Pion Data**
  - Reconstructed CERN 2011 test beam data of W-AHCAL+TCMT
  - Data at beam energies from 10 GeV to 300 GeV for positive and negative particles
- **Pion Simulations**
  - Geant4 Simulation
  - Physics List: QGSP_BERT_HP
  - Calibration as in real data

- Pion events selection for data and MC
  - Check if energy-sum is within reasonable limits
  - Muon & electron rejection
  - Rejection of empty events,
  - Rejection of events with pre-shower
  - Shower must start **either**
    a) in one of the first 4 W-AHCAL layers (as in W-AHCAL analysis) **or**
    b) in any layer

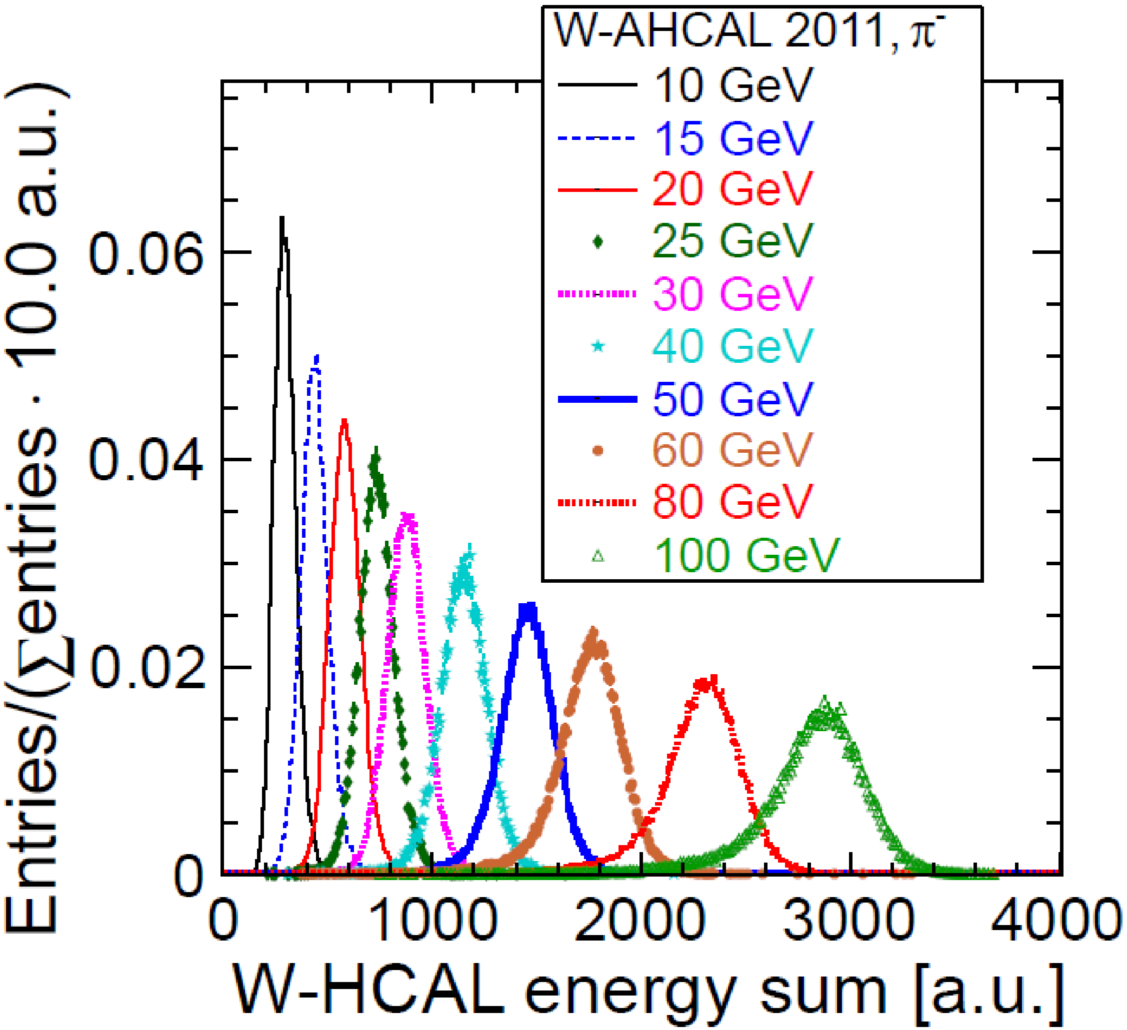
CALICE W-AHCAL Test Beam 2010



CALICE Analysis Note 036
https://edms.cern.ch/file/1224616/1/can_note_14June2012.pdf

- Test beam with W-AHCAL at CERN PS at energies from 1 to 10 GeV
- W-AHCAL of 30 layers
- Clear pion peak at all energies in HCAL-only
- By selection, shower fully contained in W-AHCAL
  - Select events with shower start in very first W-AHCAL layers (0-3)

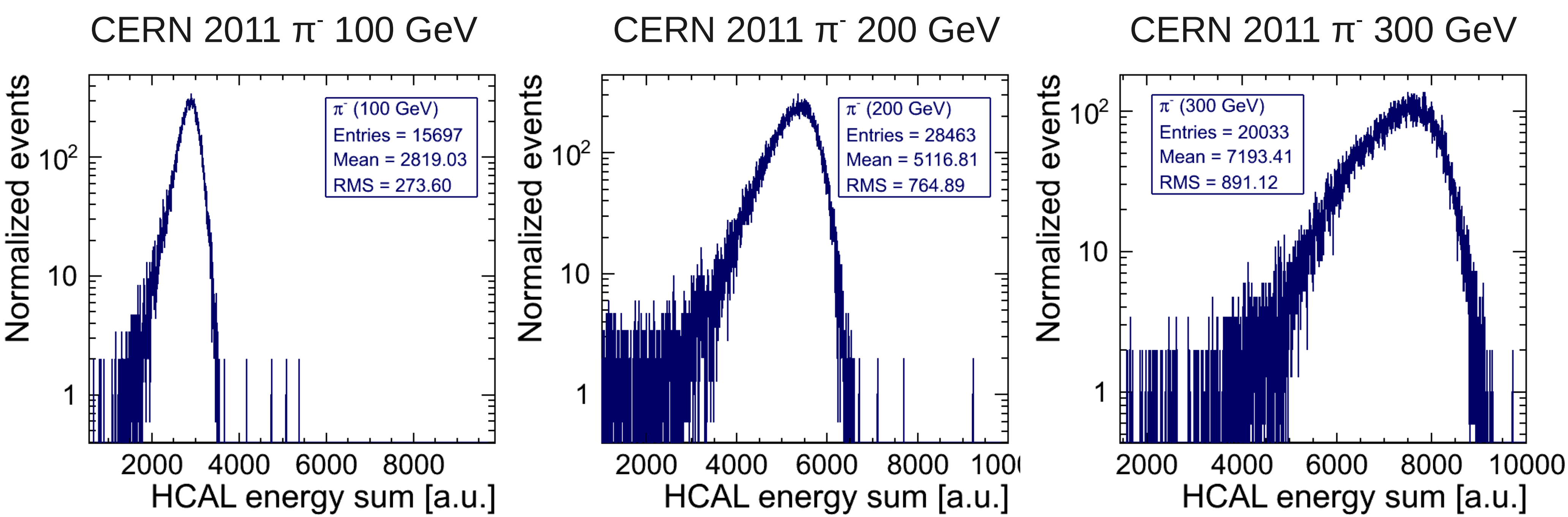
CALICE W-AHCAL Test Beam 2011



- Test beam with W-AHCAL at CERN SPS at energies from 10 to 300 GeV
- W-AHCAL of 38 layers
- No “significant” leakage effects are visible in HCAL-only up to highest presented energies (here: E_{beam} = 100 GeV)
  - Select only those events in which the shower starts in the very first layers (0-3) of the W-AHCAL
- Leakage effects for very high energies E > 100 GeV or for events with late shower start

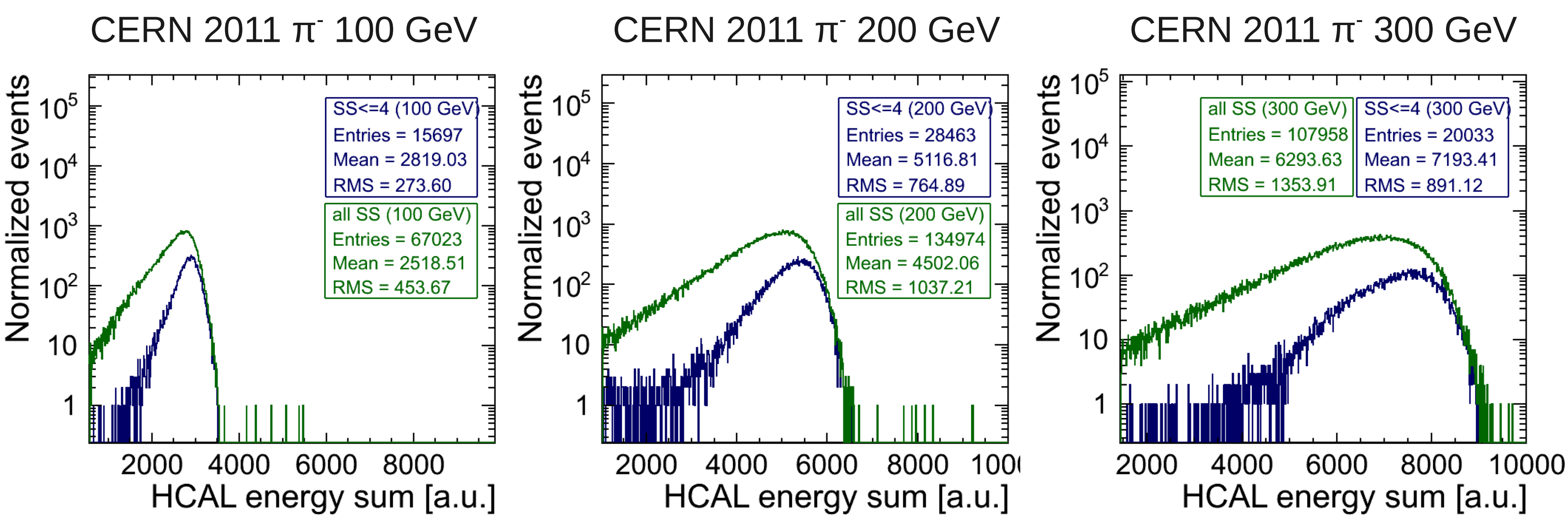
W-AHCAL at High Energies

- With increasing beam energy, a larger fraction of the shower leaks out of the W-AHCAL
- Increasing tail at low E_{sum} with E_{beam}
- Examples (here: shower start <= 3)



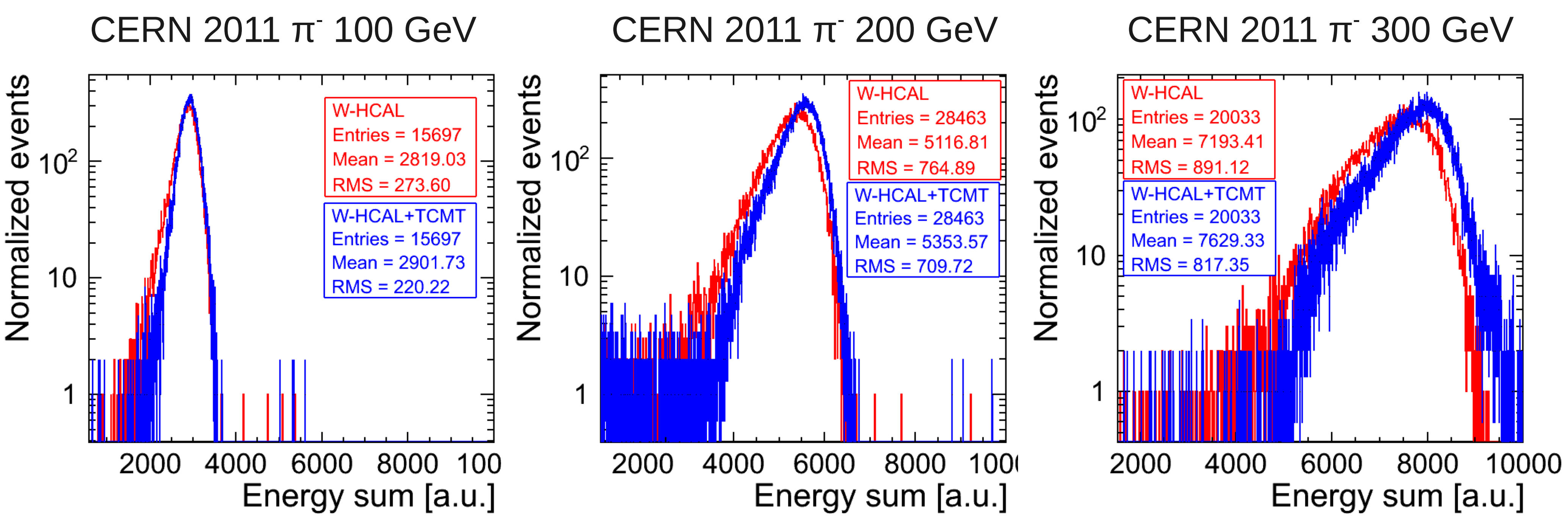
W-AHCAL with Later Shower Start

- Leakage effects grow when accepting all showers no matter in which layer the shower starts
  - W-AHCAL: Shower start <= 3 (HCAL analysis selection)
  - W-AHCAL: All shower start layers

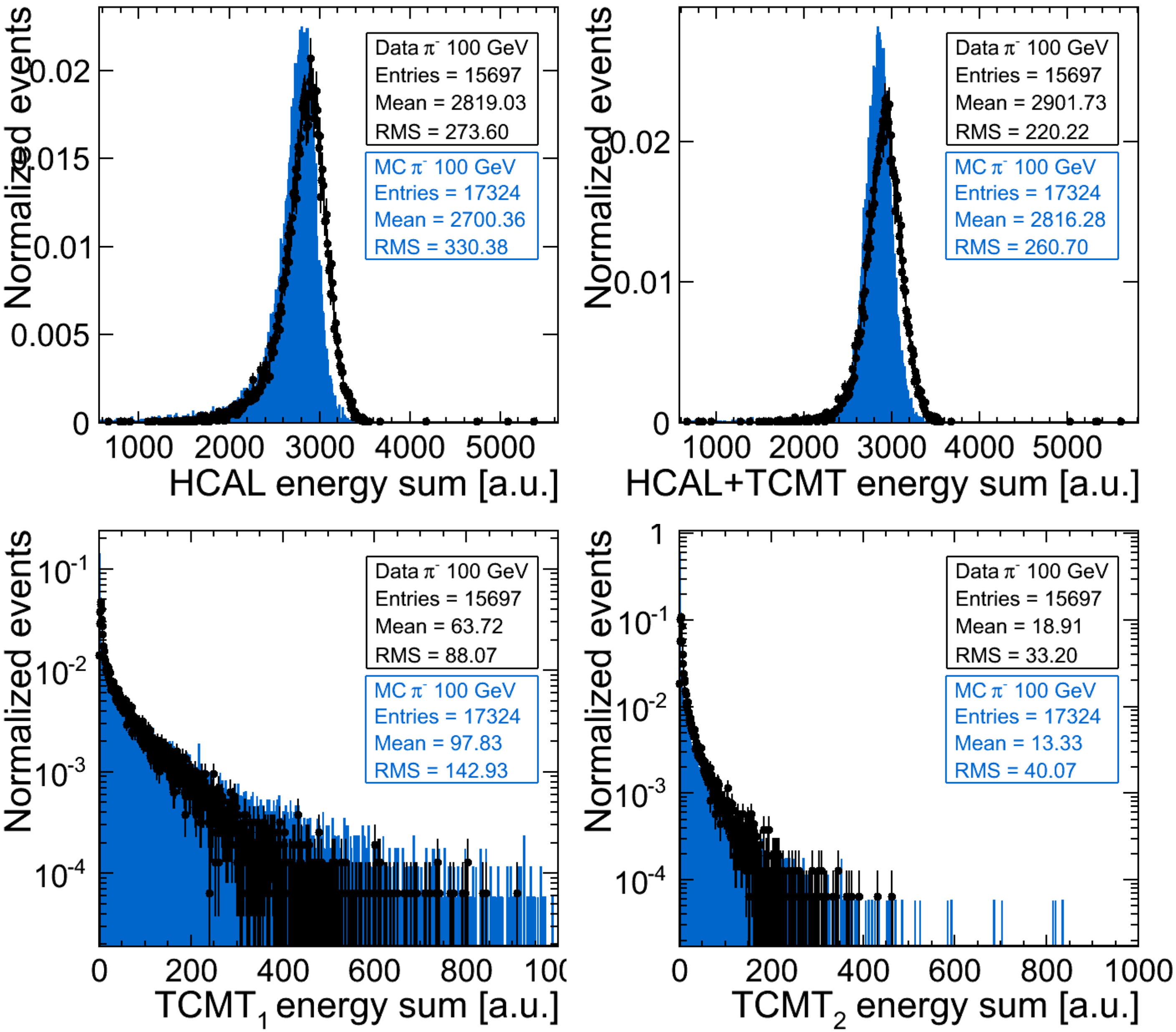


Reduced Leakage-Effect with Tail Catcher

- Indication of smaller tails towards low E_{sum} when combining W-AHCAL+TCMT in comparison to W-AHCAL-only
  - Here, the E_{sum} of W-AHCAL, $TCMT_1$, and $TCMT_2$ are combined in MIP units using a weight of 1 for each contribution

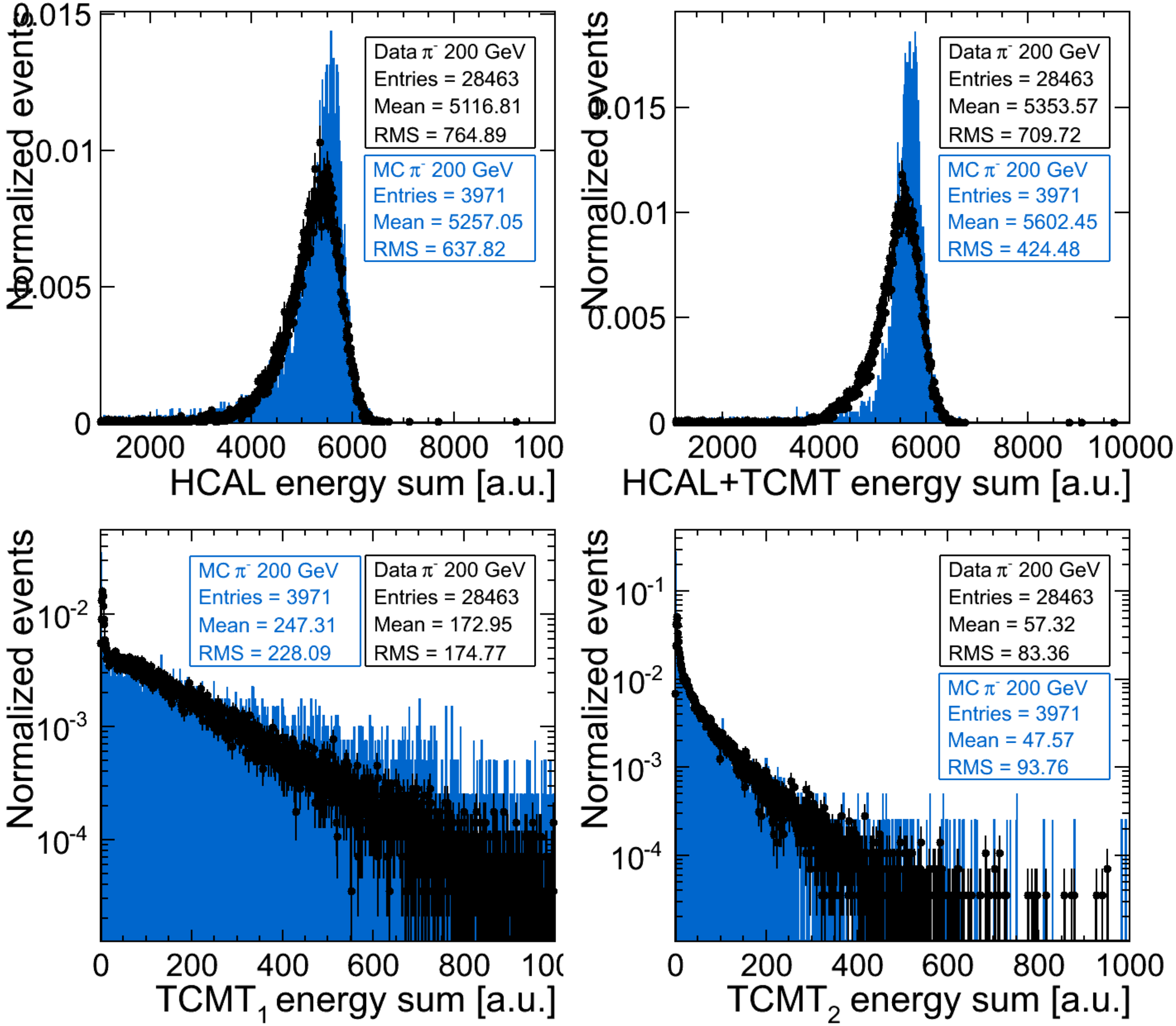


Example: Data - MC at 100 GeV



- First comparison of data and simulation

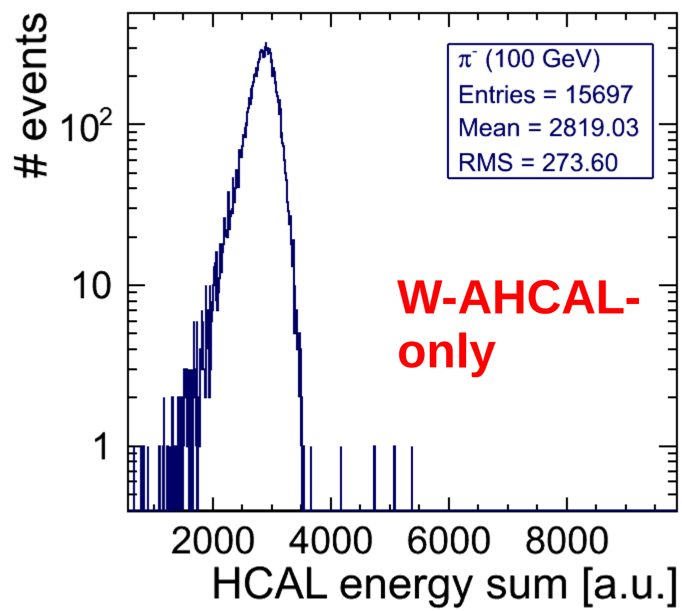
Example: Data - MC at 200 GeV

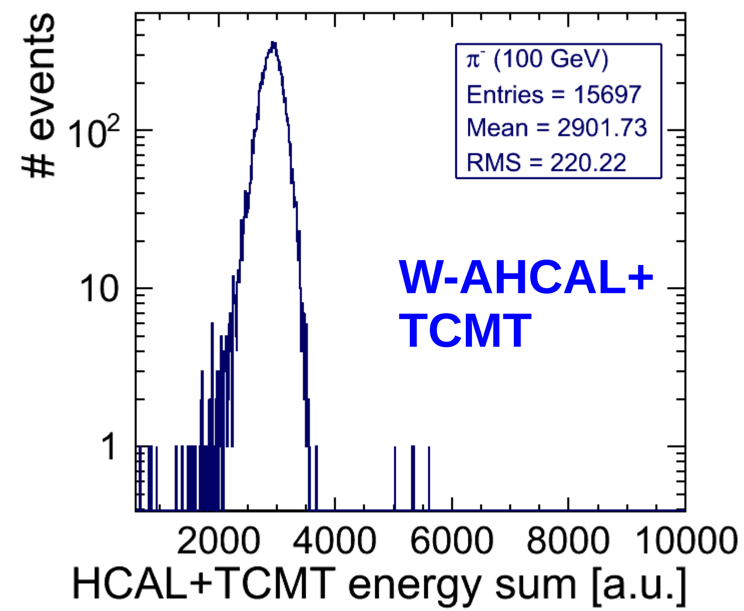


- First comparison of data and simulation

Optimization of Energy Resolution

- **First step**: Usage of W-AHCAL+TCMT instead of W-AHCAL-only
  - $E_{sum,W\text{-}AHCAL}$
  - $E_{sum,W\text{-}AHCAL,TCMT} = 1 * E_{sum,W\text{-}AHCAL} + 1 * E_{sum,TCMT1} + 1 * E_{sum,TCMT2}$
    - Drawbacks:
      - Weights are not correct
      - Possible domination by fluctuations in TCMT



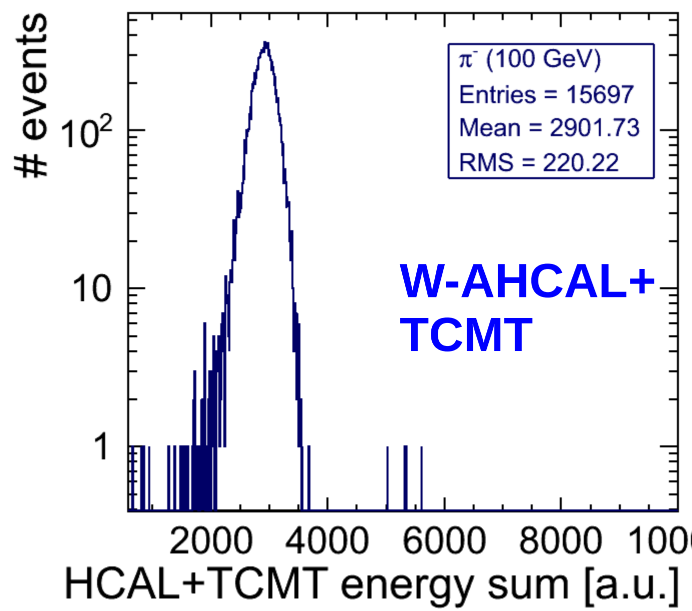


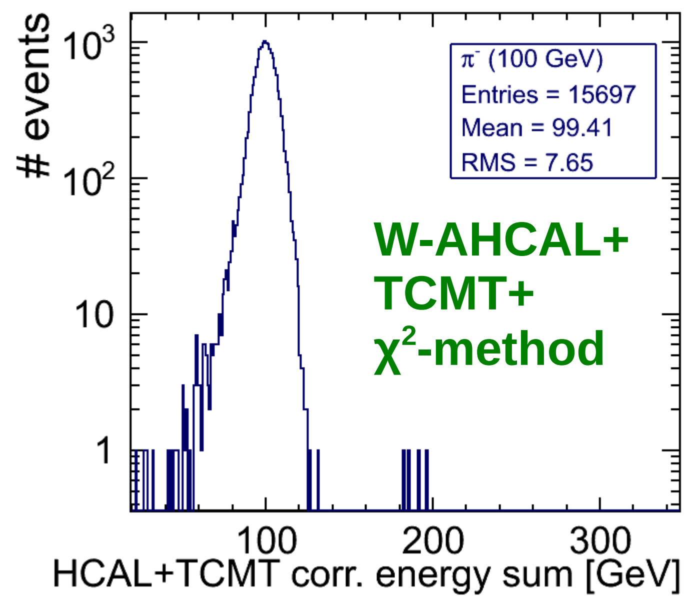
Optimization of Energy Resolution

- **Second step**: Determination of sampling fraction
  - **"χ^2-Method":** simultaneous minimization of several weights
    - χ^2 minimization of difference in E_{input}(=E_{beam}) and $E_{reco,corrected}$

$$E_{input} = \mathbf{w_H} * E_{W\text{-}AHCAL} + \mathbf{w_{T1}} * E_{TCMT1} + \mathbf{w_{T2}} * E_{TCMT2}$$

  - Drawbacks
    - Possible domination by fluctuations in TCMT
    - Weights might converge at physically incorrect values



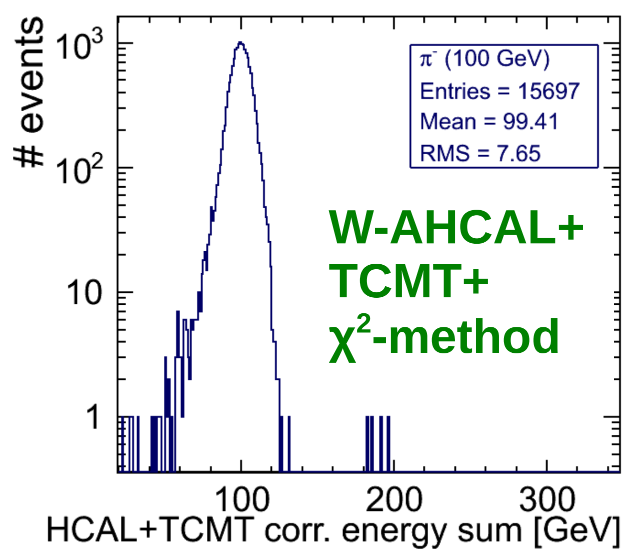


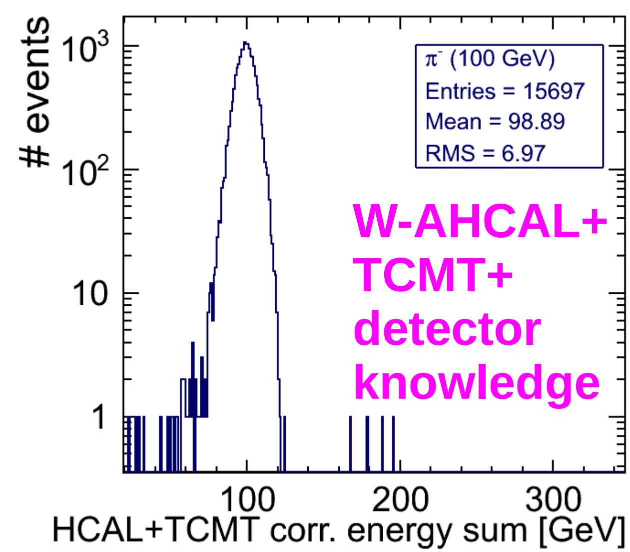
Here:
$\mathbf{w_H} \approx 0.03$
$\mathbf{w_{T1}} \approx 0.06$
$\mathbf{w_{T2}} \approx 0$

Optimization of Energy Resolution

- **Third step**: use known properties of W and Fe calorimeters (detector response) and 1 scaling factor
    - $(e/\pi)_W = 1.0$, $(e/\pi)_{Fe} = 1.19$,
    - $(MIP/GeV)_W$ = 27.0 MIP/GeV, $(MIP/GeV)_{Fe}$ = 42.3 MIP/GeV
  - **"Detector knowledge":**

$$E_{input} = \mathbf{w_{global}} * (e/\pi)_W * (MIP/GeV)^{-1}_W * E_{W\text{-}AHCAL} + \mathbf{w_{global}} * (e/\pi)_{Fe} * (MIP/GeV)^{-1}_{Fe} * E_{TCMT1} + \mathbf{w_{global}} * (e/\pi)_{Fe} * (MIP/GeV)^{-1}_{Fe} * \mathbf{5} * E_{TCMT2}$$

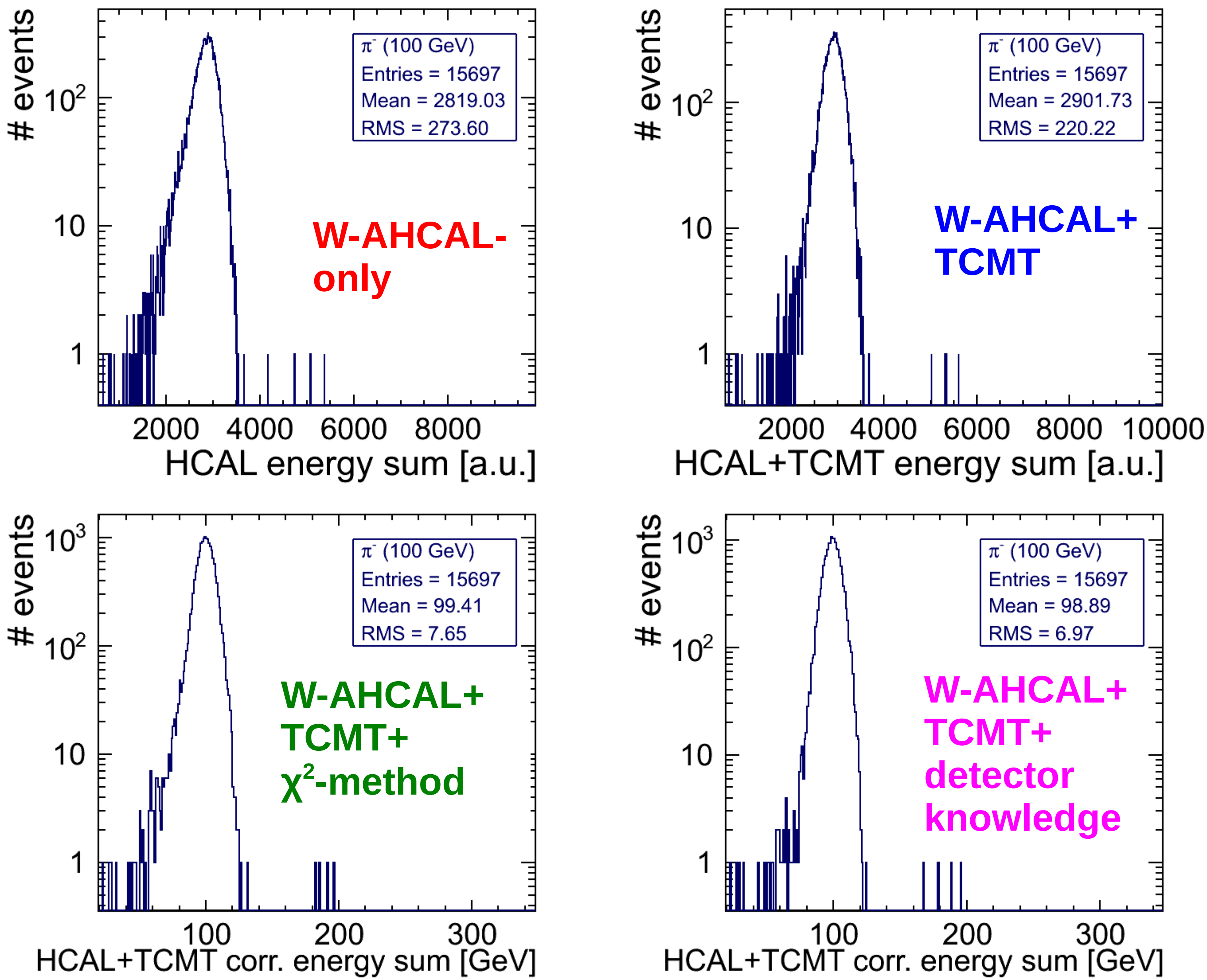




Here $\mathbf{w_{global}} \approx 0.91$

From CALICE notes
2012 JINST 7 P04015
2012 JINST 7 P09017, 2011 JINST 6 P04003, 2012 JINST 7 P04015

Comparison of Resolution: Example



Summary & Outlook

- Start of analysis of W-AHCAL and TCMT test beam data of 2011 at CERN SPS at energies from 10 to 300 GeV
- First look at data/MC
- First study of optimization of energy resolution for W-AHCAL+TCMT
  - χ^2-minimization
  - Use knowledge of detector response: (e/π) factors, (MIP/GeV) factors

- Next steps
  - Study event selection for TCMT coverage
    - Comparison of different shower start limits
  - Study energy dependence of sampling
  - Optimization of energy resolution
  - Determine best energy resolution of combined W-AHCAL+TCMT while preserving good linearity

Backup

Shower Start