Comparison of Iron and Tungsten Testbeam data

Status Report

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CALICE Collaboration meeting, 16.9.12

Motivation and overview

Motivation:

- Compare pion showers for iron (FNAL 2008 & 2009) and tungsten (CERN 2010) data for energies from 2-10 GeV (overlap of both testbeams)
- Investigate and understand the differences between iron and tungsten absorber (tungsten absorber proposed for CLIC)

Overview:

- Testbeam setups
- Event selection
- Results for this event selection
- Shower decomposition in simulations

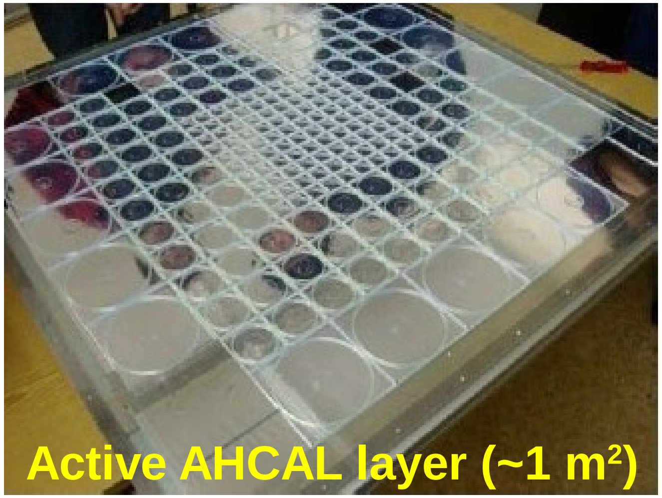
Reminder: AHCAL technology

- Sandwich hadron calorimeter
- Active layers: scintillator with SiPM readout
- Two different absorber stacks available
  - **38 iron layers:**

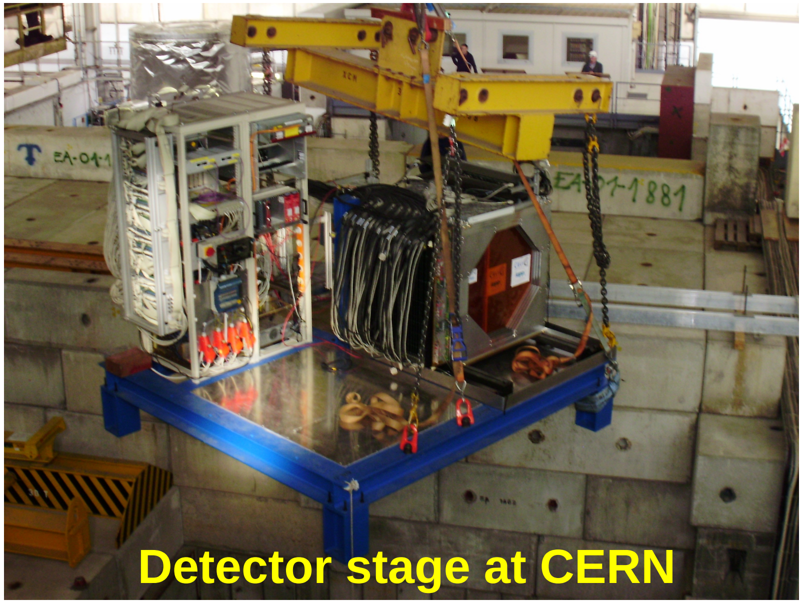
thickness per layer	~ 1,7	cm
total calorimeter depth	~ 5.1	λ_{int}
interaction length λ_{int}	17	cm
radiation length $\mathbf{X}_0$	1.8	cm

  - **30 Tungsten layers:**

thickness per layer	~ 1,0	cm
total calorimeter depth	~ 3.9	λ_{int}
interaction length λ_{int}	10	cm
radiation length $\mathbf{X}_0$	0.35	cm

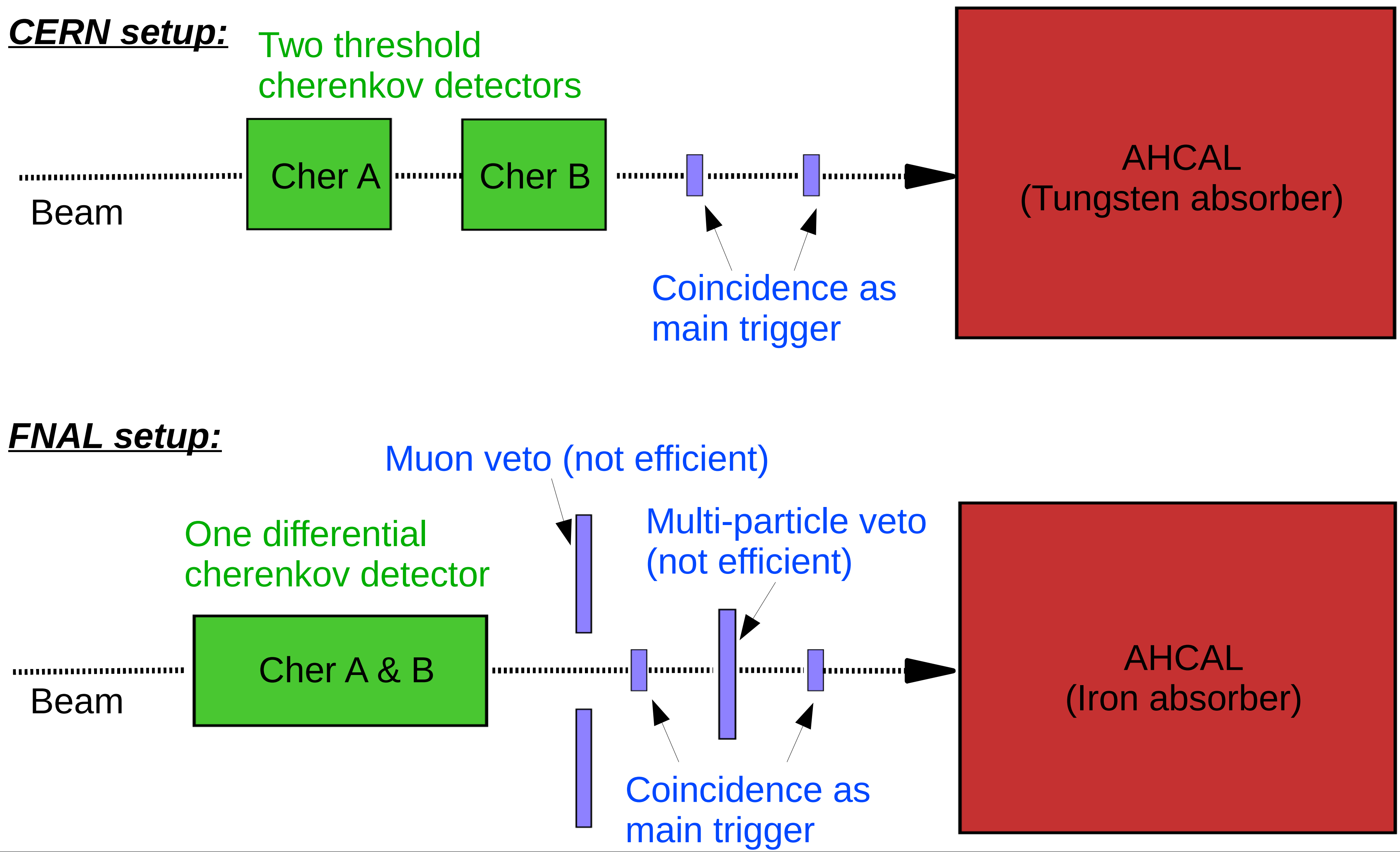


Active AHCAL layer (~1 m^2)



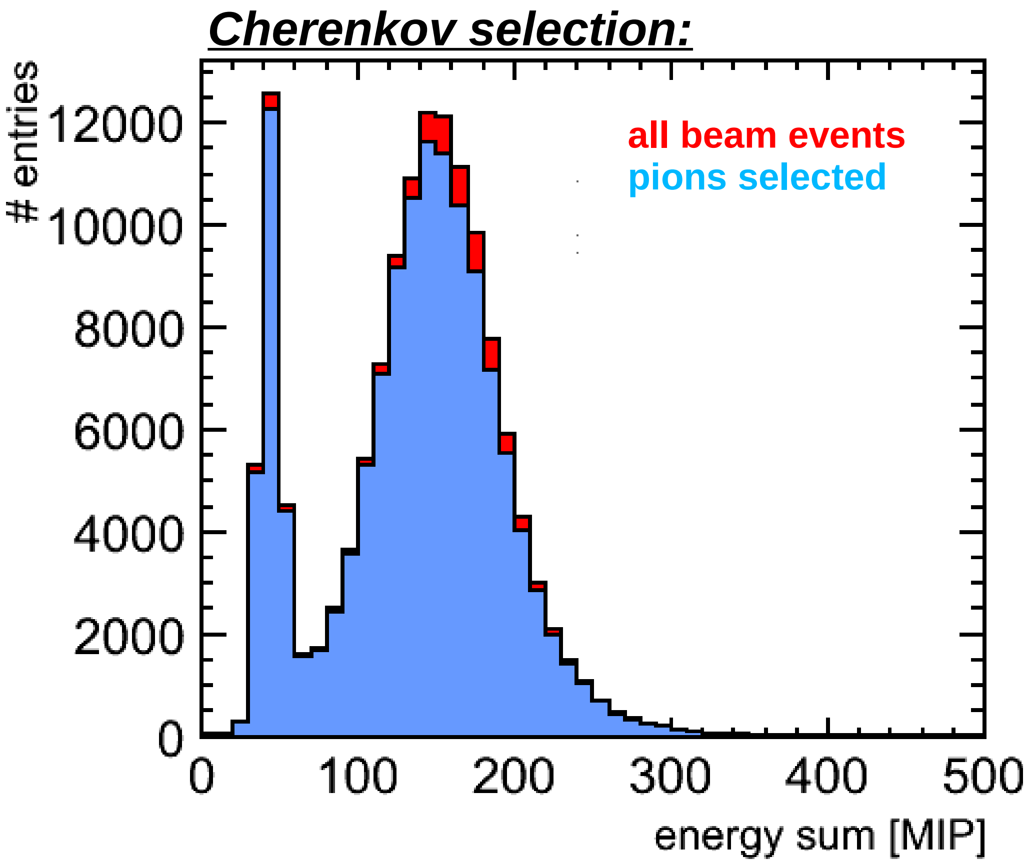
Detector stage at CERN

Schematic testbeam setups



Event selection

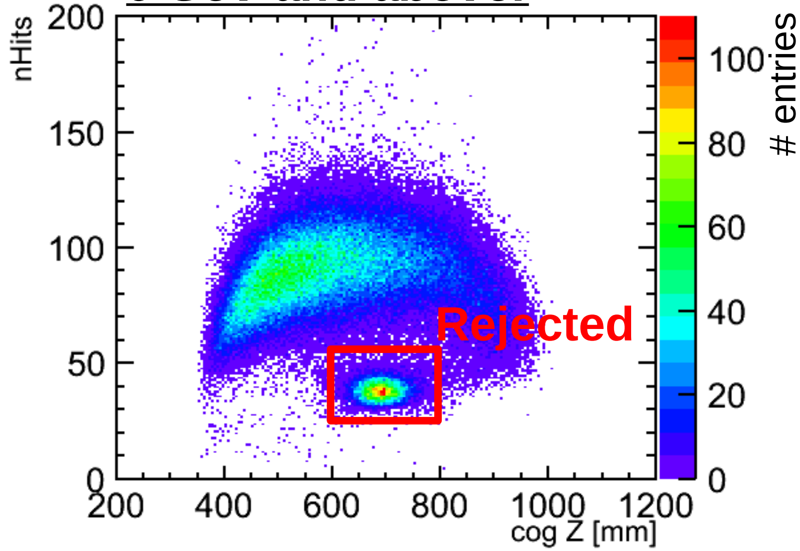
- Particle selection based on cherenkov information



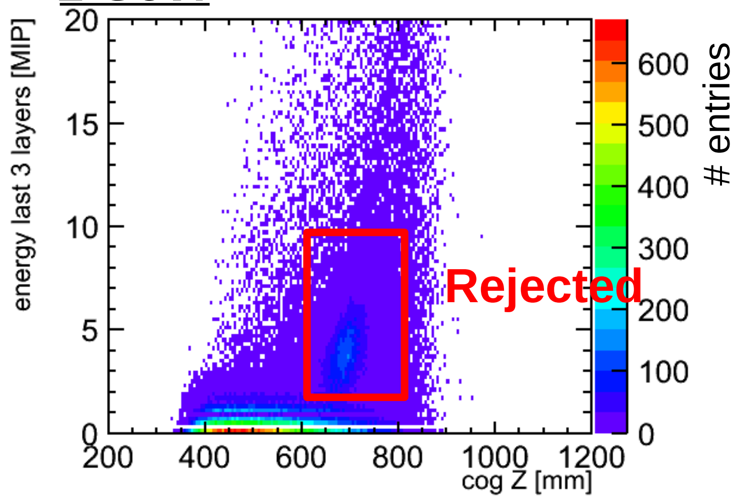
Event selection

- Particle selection based on cherenkov information
- Additional cuts needed to improve sample purity
- For pions, muon contamination needs to be rejected:
  - Down to 6 GeV => number of hits and center of gravity
  - 4 GeV => shower start found in calorimet
  - 2 GeV => combination of number of hits, center of gravity and energy deposit in last 3 layers

6 GeV and above:



2 GeV:



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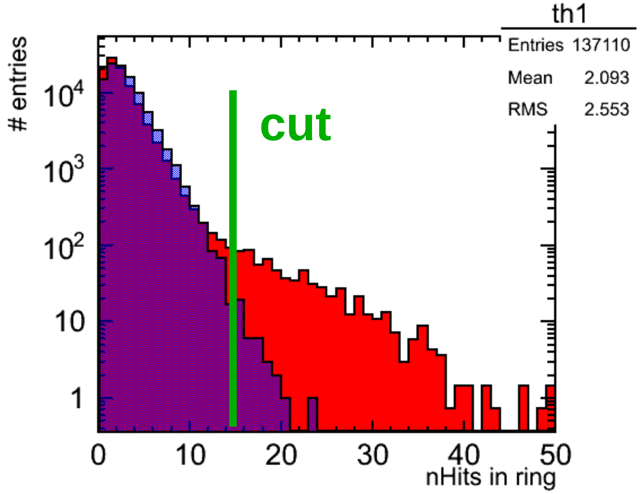
- Pre-shower event rejection based on studies with dedicated simulation with particle gun directly before calorimeter

Ring

- **first 5 layers**
- **6x6 and 12x12 cm² cells**



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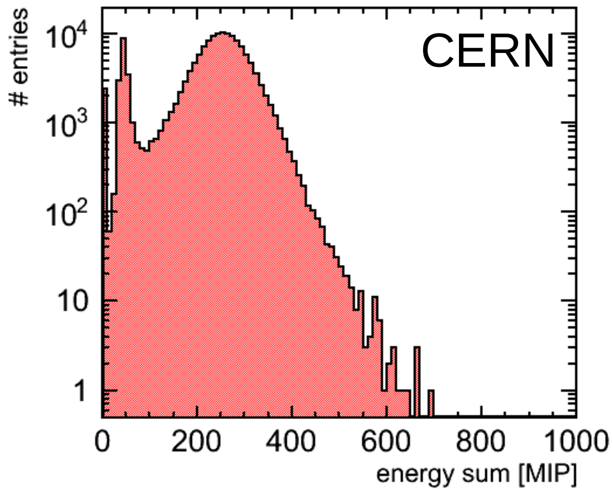
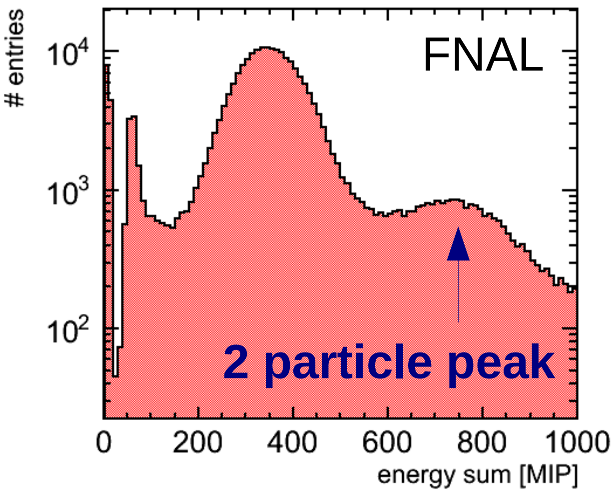
- Pre-shower event rejection based on studies with dedicated simulation with particle gun directly before calorimeter
- Multi-particle rejection is crucial for FNAL data as visible from energy sum

10 GeV, no selection:

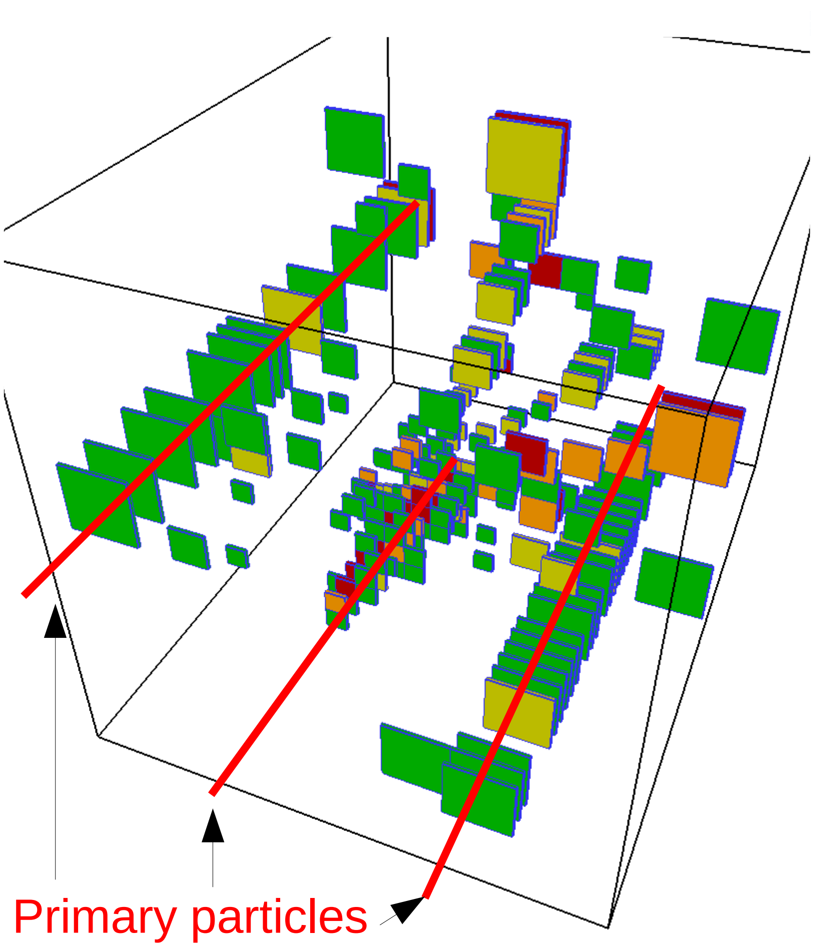




- Recently discovered possible proton contamination up to 6 GeV (no solution yet)

Multi-particle rejection

Two types of multi-particle events:



Event display 10 GeV multi-particle

- With additional muons
  (due to inefficiency of muon veto)

  => use tracking algorithms to reject in outer part
  (6x6 and 12x12 cm^2 cells)

  => small difficulties to to split tracks

- Two hadrons (no evidence for electron contamination!)
  (due to inefficiency of multi-particle counter)

  => almost never two incoming tracks in
  calorimeter middle visible

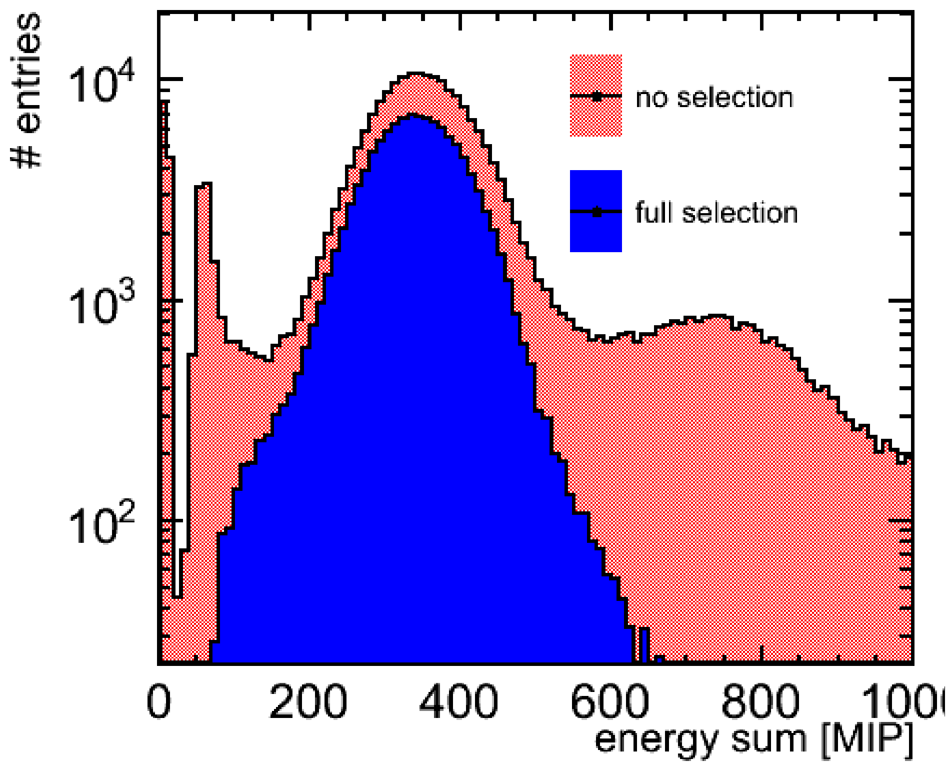
  => use clustering algorithms
  (number of clusters, number of hits in clusters)

  => difficult due to to overlap of distributions
  (large fluctuations in hadron showers!)

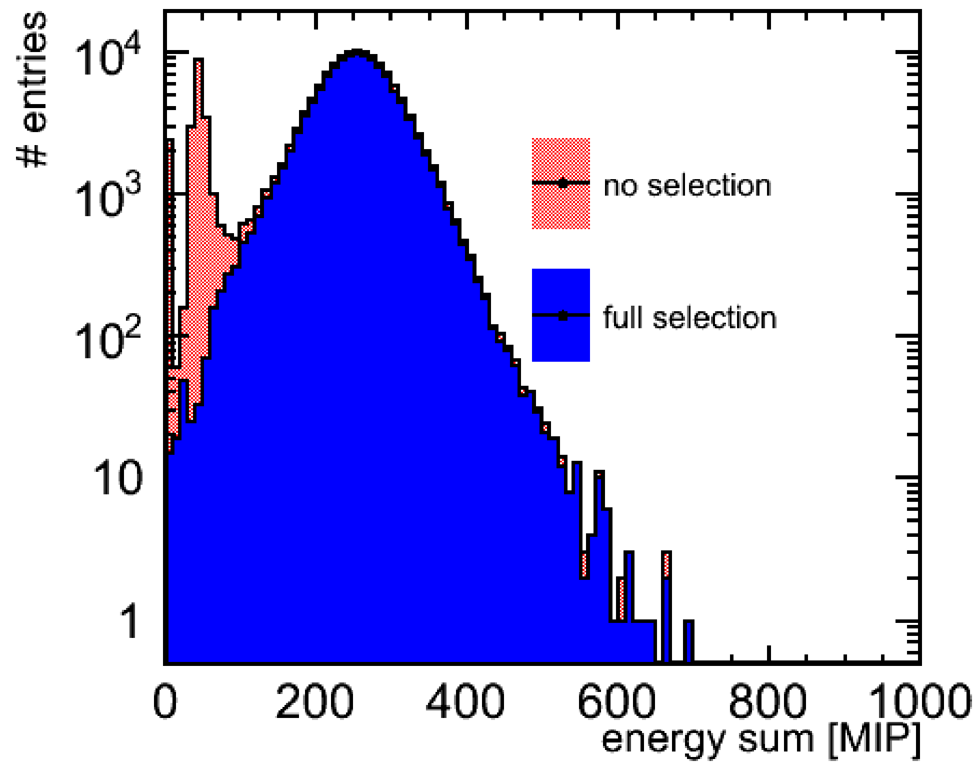
- Combination of both :-(=> still ongoing

Results for event selection

10 GeV pion selection for FNAL:

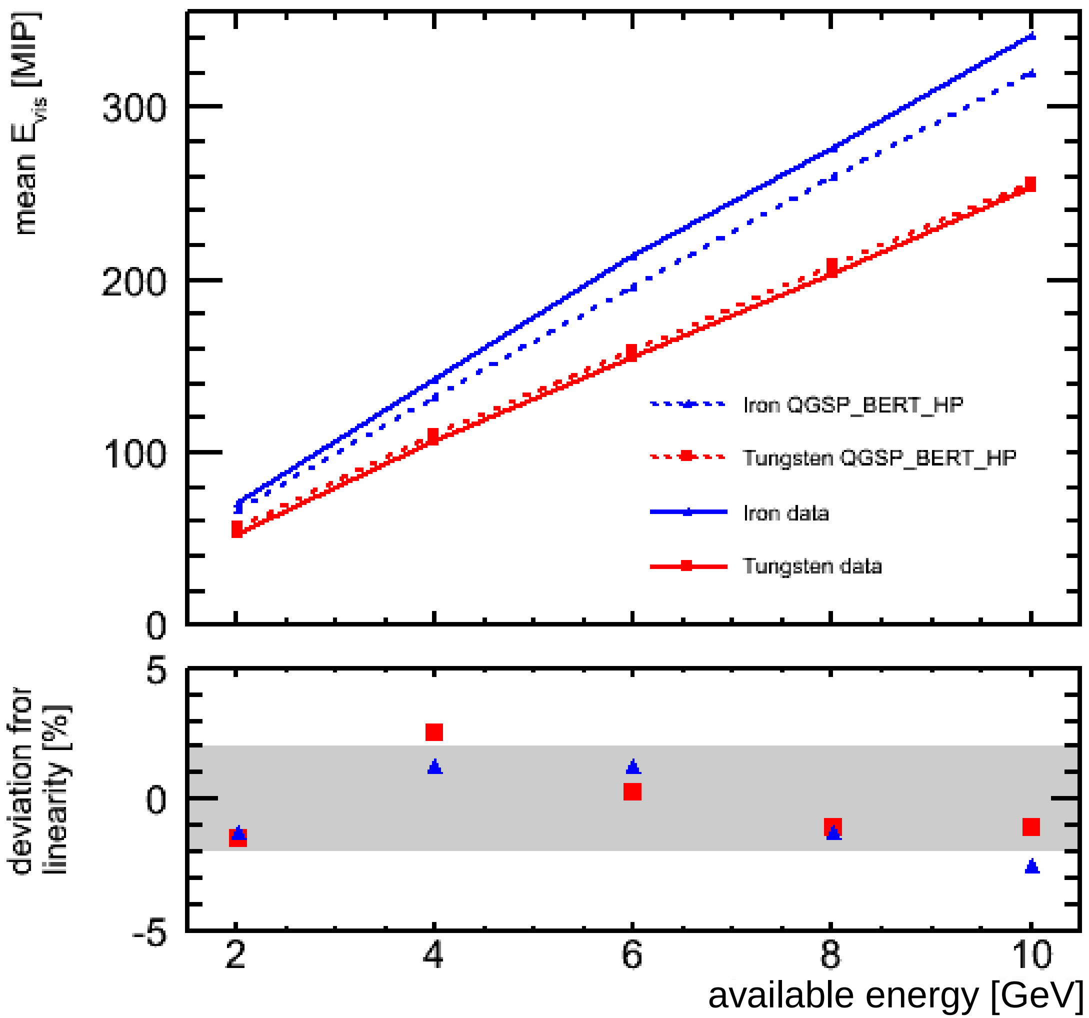


10 GeV pion selection for CERN:



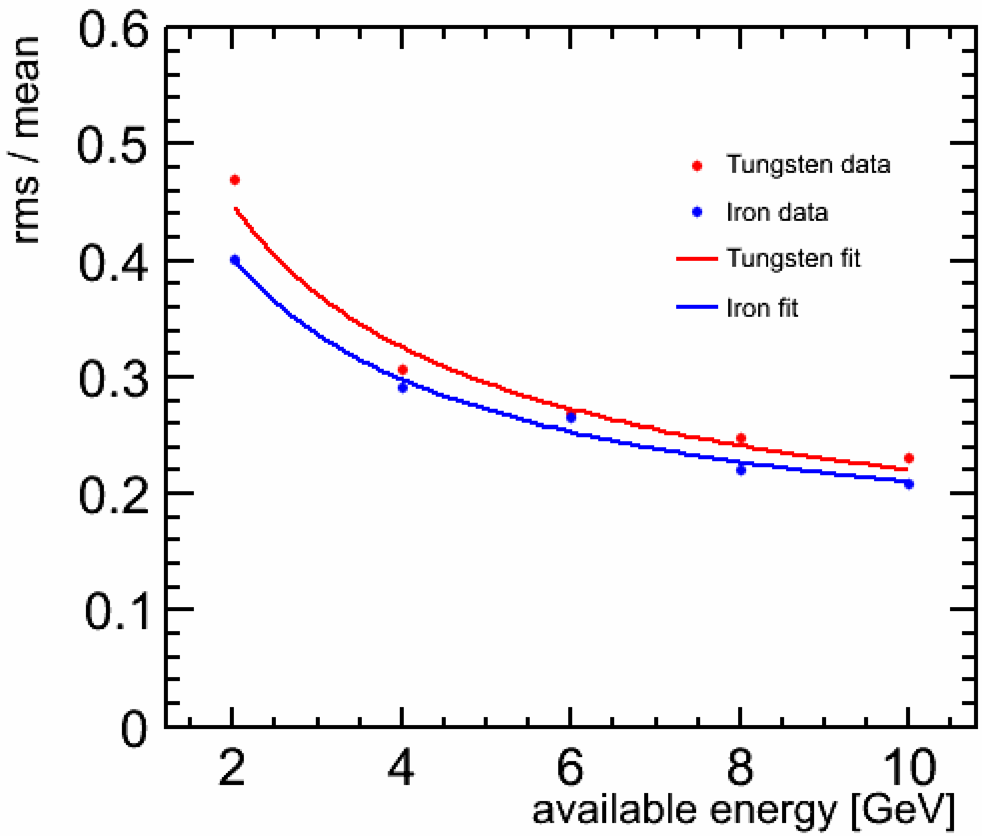
- Muon removed from sample by event selection
- Multi-particle contamination significantly removed by event selection (especially for FNAL)
- Leakage at 10 GeV visible (also present in simulation)

Linearity and comparison to simulation



- Mean energy deposit for tungsten well described by simulation
- Less agreement between data and simulation for iron
- Higher energy deposit in data points to remaining contamination of sample
- Deviation from linearity for all data points less than 3 %

Resolution comparison



Quoted papers:
CALICE EM-paper (arXiv:1012.4343)
CALICE Analysis Note CAN-036

- Resolution fit function:

$$\frac{rms}{mean} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

- Just statistical error taken into account
- Resolution comparable to previous CALICE results
- Resolution worse for tungsten data
- But worse sampling in tungsten
- Also shorter in terms of interaction length

Fit parameter	a [% * sqrt(E)]
Tungsten (CERN)	61.8
Iron (FNAL)	54.4

A scale to compare

- Detector setups very different for both absorber types (sampling, number of layers, etc.)

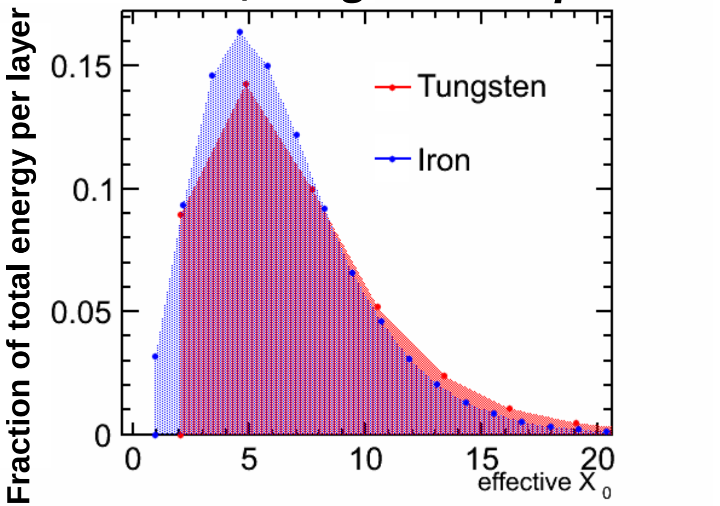
  => need scale to compare them => effective radiation (interaction) length

Effective radiation length $X_{0,eff}$:

$$\frac{1}{X_{0,eff}} = \sum \frac{V_i}{X_{0,i}}$$

V_i : fraction of total thickness for *i*-th material
$X_{o,i}$: radiation length for *i*-th material
(same for interaction length)

Validation with 6 GeV electrons, longitudinal profile:



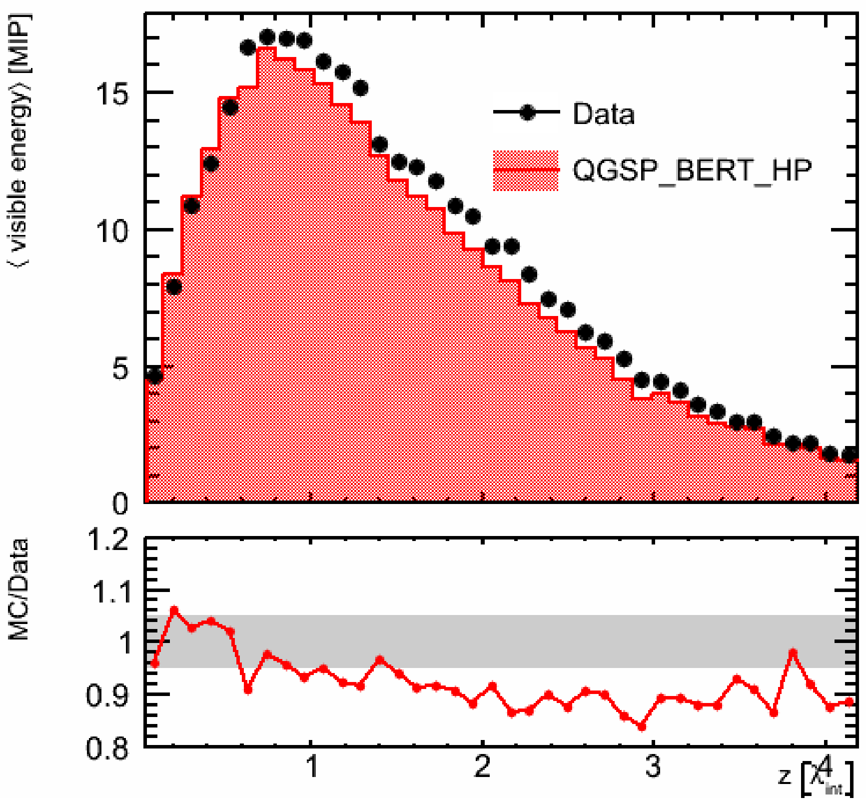
Calculated values:

(thickness, X_o, λ_i from Mokka descriptions of detector)

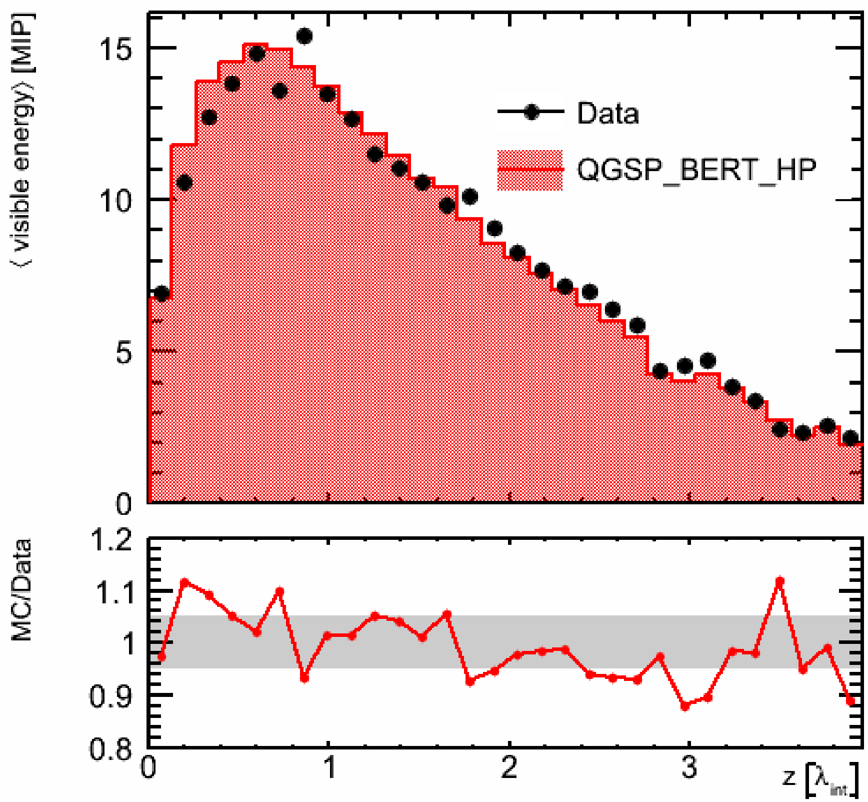
- Iron: $X_{0,eff}$ / mm of calorimeter = 0.0390
  $\lambda_{i,eff}$ / mm of calorimeter = 0.0043
- Tungsten: $X_{0,eff}$ / mm of calorimeter = 0.1152
  $\lambda_{i,eff}$ / mm of calorimeter = 0.0052

Longitudinal profiles

10 GeV pion iron:

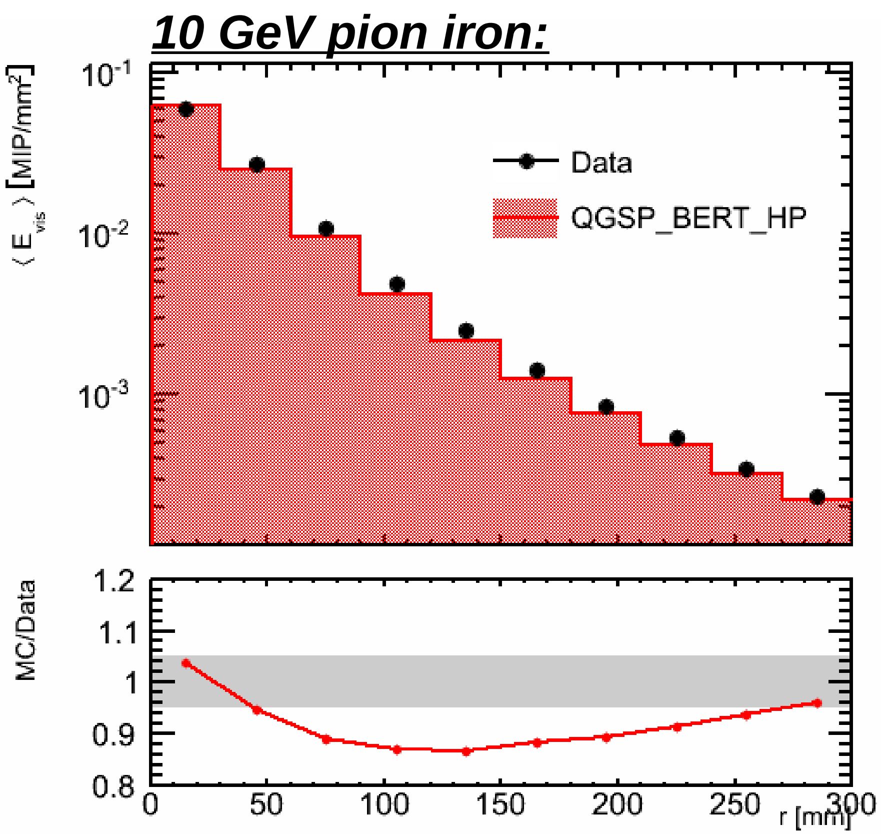


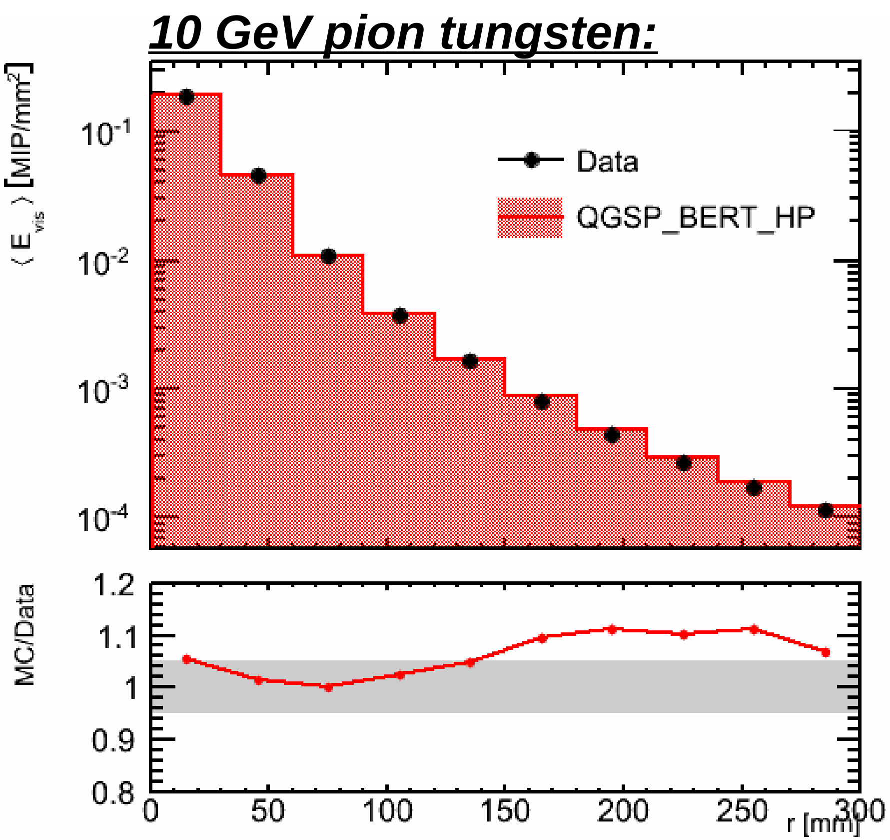
10 GeV pion tungsten:



- Longitudinal profiles well described by simulation for tungsten
- Less agreement for iron most likely due to sample contamination

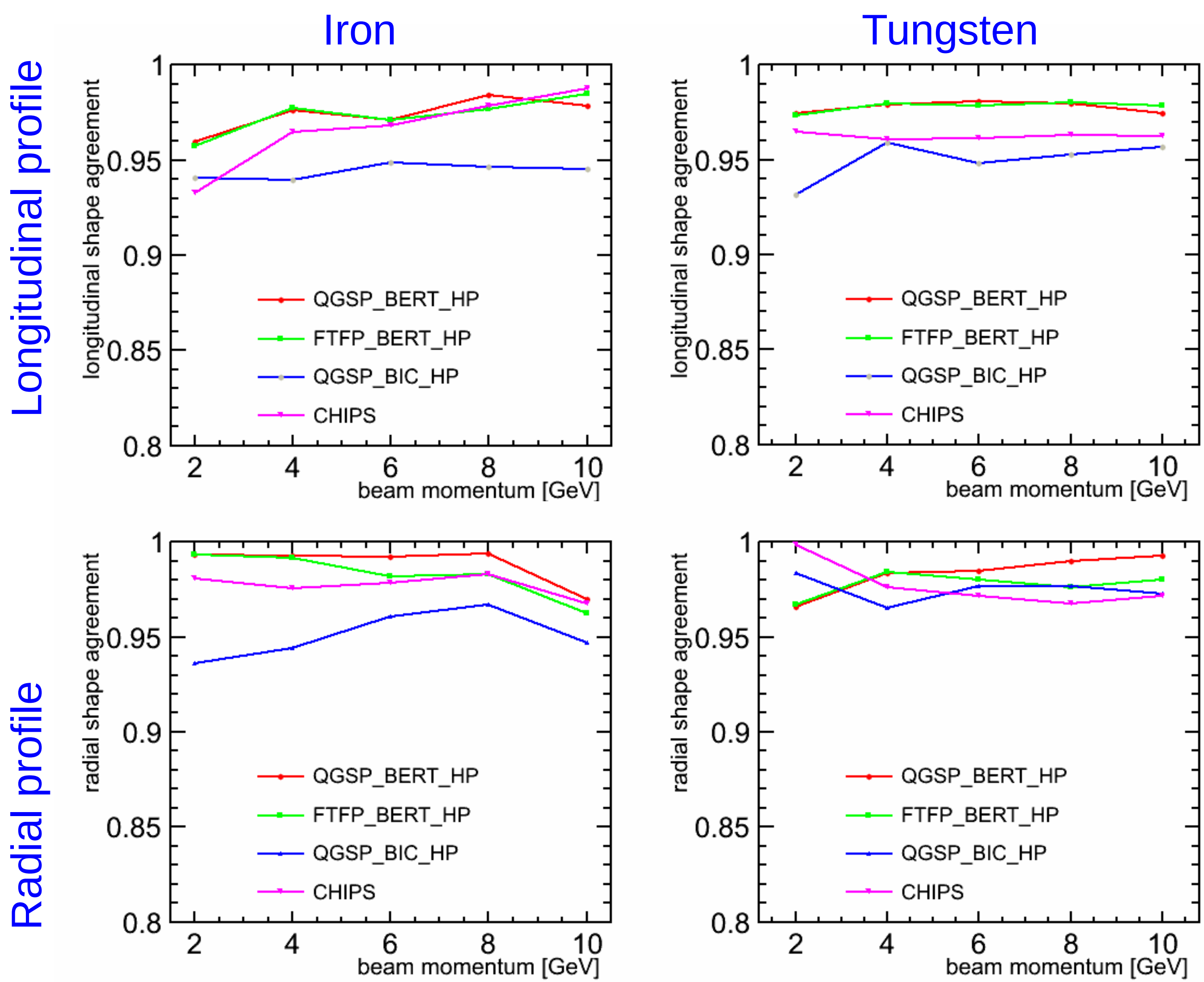
Radial profiles





- Radial profiles very similar in data and simulation (mostly within ±10%)

Profile shape agreement



- Shape agreement ξ:
  (describes overlap)

$$\xi = \sum_i min\left(\frac{E_i^{MC}}{E^{MC}}, \frac{E_i^{data}}{E^{data}}\right)$$

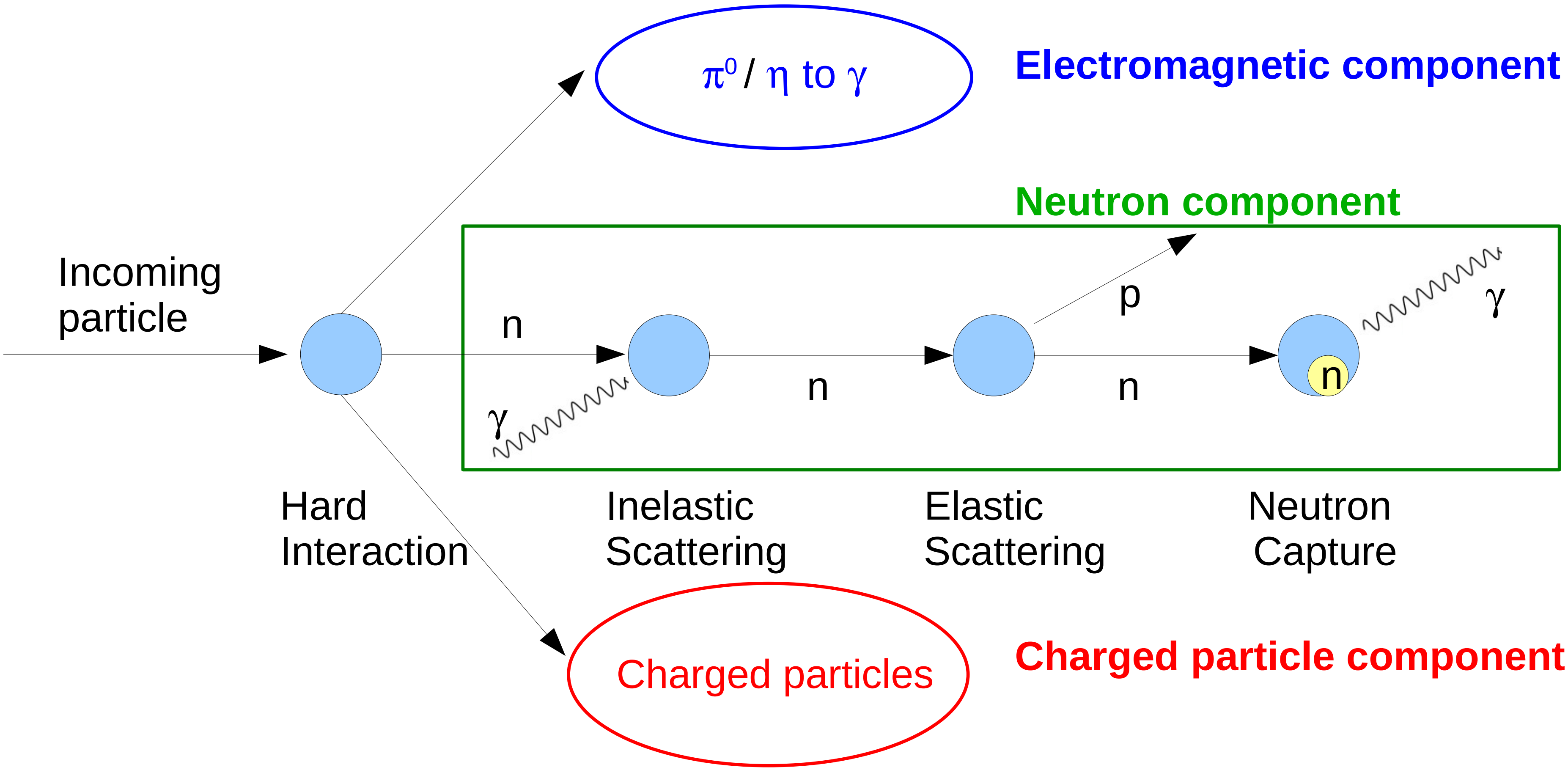
E_i : energy deposit in i-th layer

E : total energy deposit

- On average QGSP_BERT_HP gives best description of shower profiles

Shower decomposition

Divide the shower into following components:

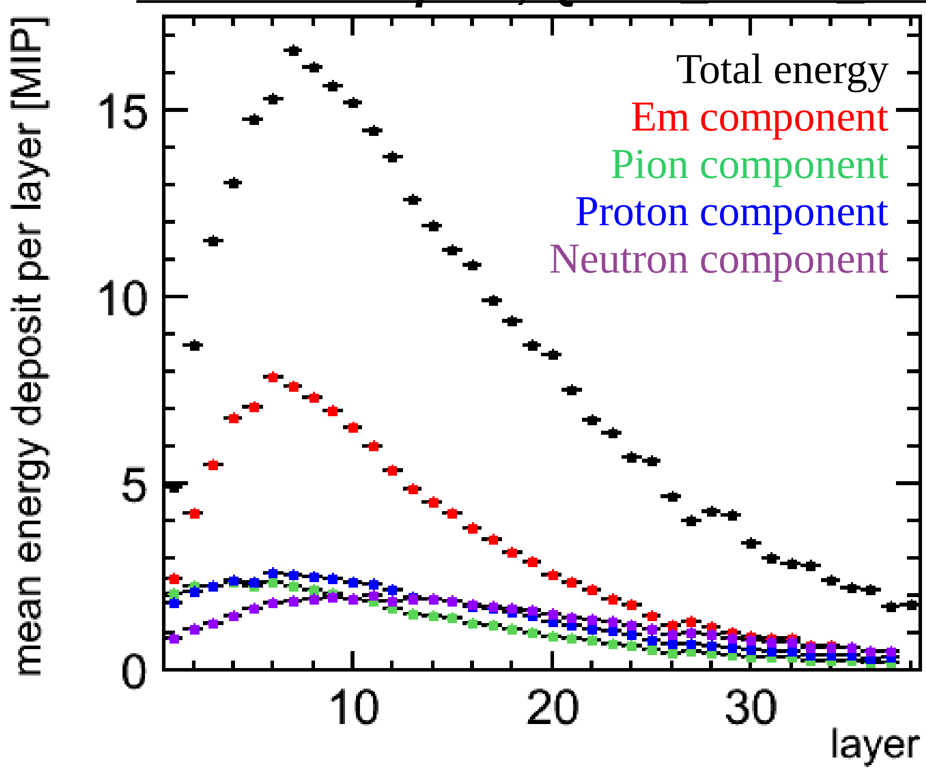


Shower profiles with shower components

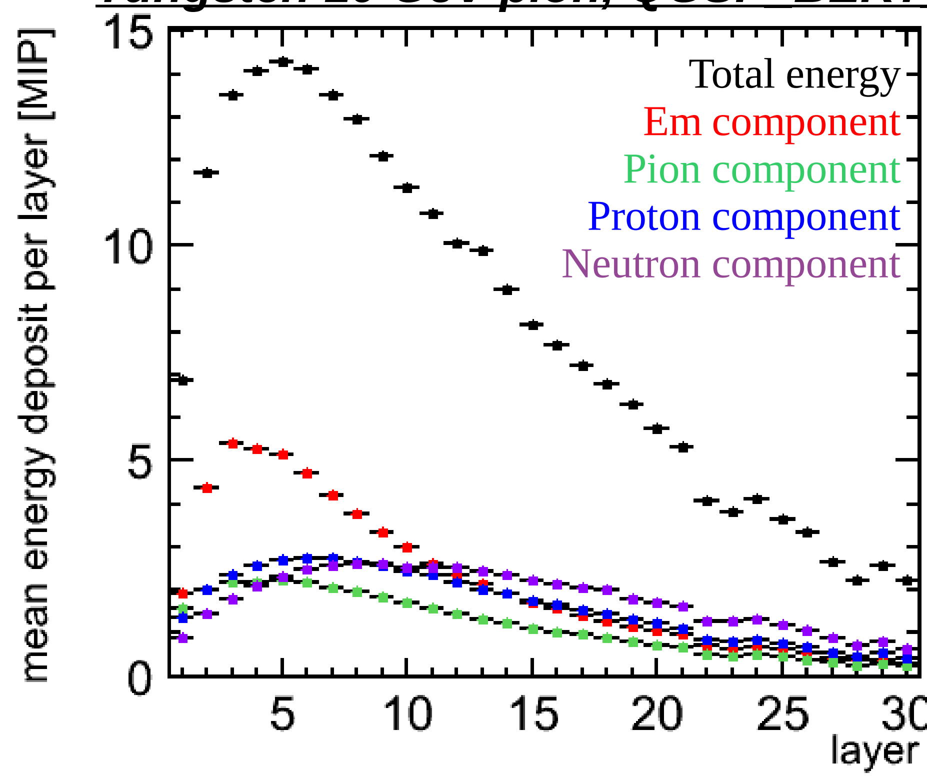
- Decomposed longitudinal profiles allow preciser statements about quality of simulations
- In tungsten, the em component peaks in the very first layers and dominates the energy deposit there

=> can distinguish quality of modeling

Iron 10 GeV pion, QGSP_BERT_HP:

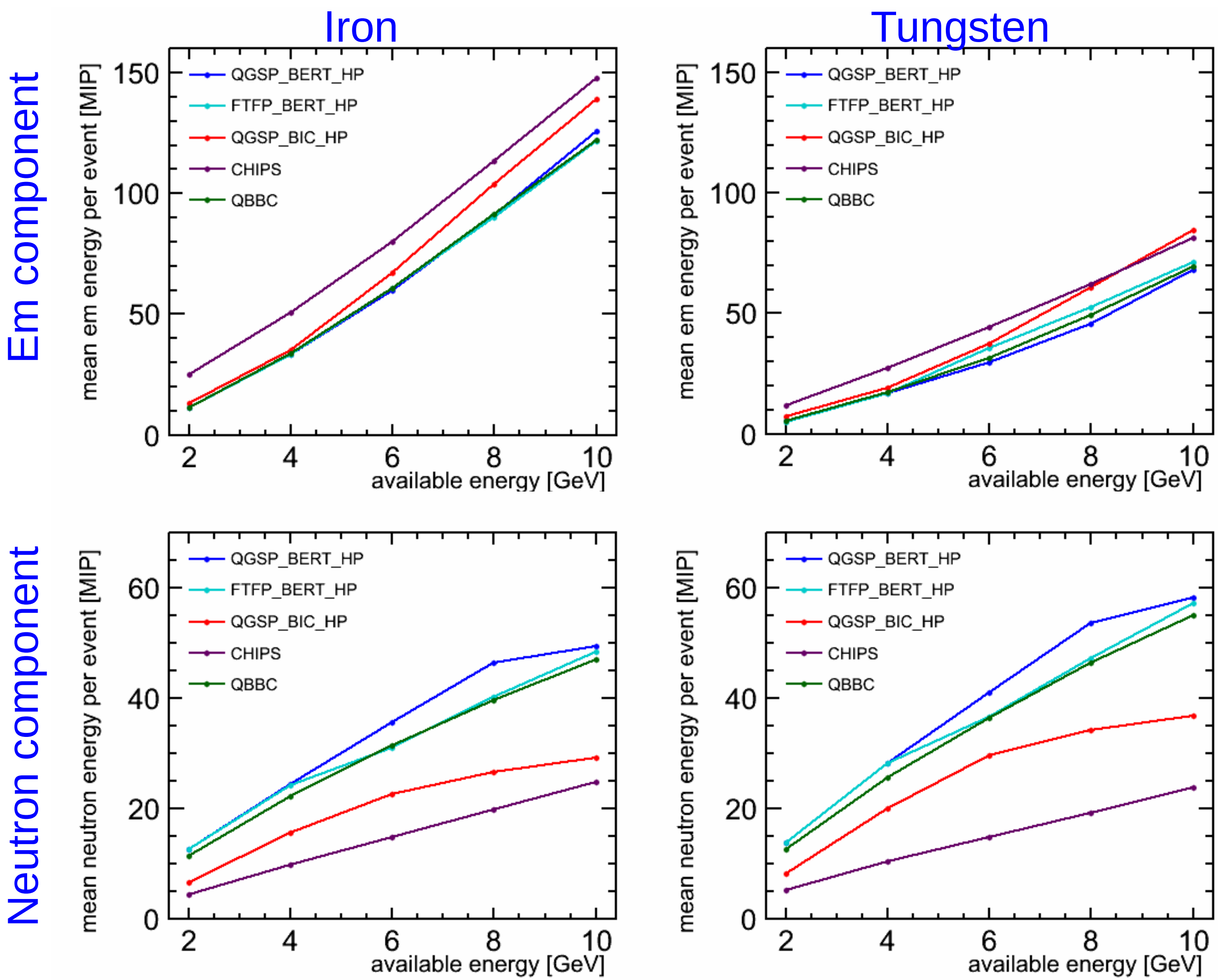


Tungsten 10 GeV pion, QGSP_BERT_HP:



Results for shower decomposition

Only two components of the shower show a major difference between iron and tungsten



- Predictions by simulation vary strongly between physics lists
- Visible em compnent smaller in tungsten (partially absorbed in non-active material)
- Neutron component only slightly higher than in iron (also suppressed because of absorption in non-active layers)

Summary

- Event selection for iron and tungsten low energy testbeams shown (Ongoing)
- Linearity of pion data better than 3 % for both testbeams
- Resolution similar to earlier measurements: Tungsten ~ 61 %
  Iron ~ 54 %
- Shower profiles for tungsten data agree well with simulation
- Shower profiles for iron data show less agreement due to sample contamination
- QGSP_BERT_HP gives on average the best description of the shower profiles
- Decomposed shower profiles enable to make precise descriptions on the quality of the modeling of individual shower components
- Shower decomposition shown and the differences between both absorber types (em and neutron component) investigated which is due to the difference in the X_o / λ_{int} ratio between both absorbers