Comparison of Steel and Tungsten AHCAL data and Shower Decomposition

- Introduction
- Validation of the simulation
- Comparisons
    - Tungsten data to iron data
    - Data to simulation

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Introduction

- HCAL with tungsten absorber discussed in the context of CLIC

  → need to understand what are the differences compared to iron absorber in terms of energy deposition, shower shape, timing, ...

- look into 2 – 10 GeV pion data taken with AHCAL physics prototype active layers
  - 2008/2009 with at FNAL with iron
  - 2010 at CERN with tungsten

- **38 iron layers:**

thickness per layer	~ 1,7	cm
total calorimeter depth	~ 5.1	λ_{int}
interaction length λ_{int}	17	cm
radiation length 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 X_0	0.35	cm

Main changes compared to previous presentation

- data
  - better identification of channels where calibration was not working, improved treatment of default values (also affects simulation)
- simulation
  - calibration factor (“MIP2GeV”):

    data are calibrated to have Most Probable Value of muons at 1.0

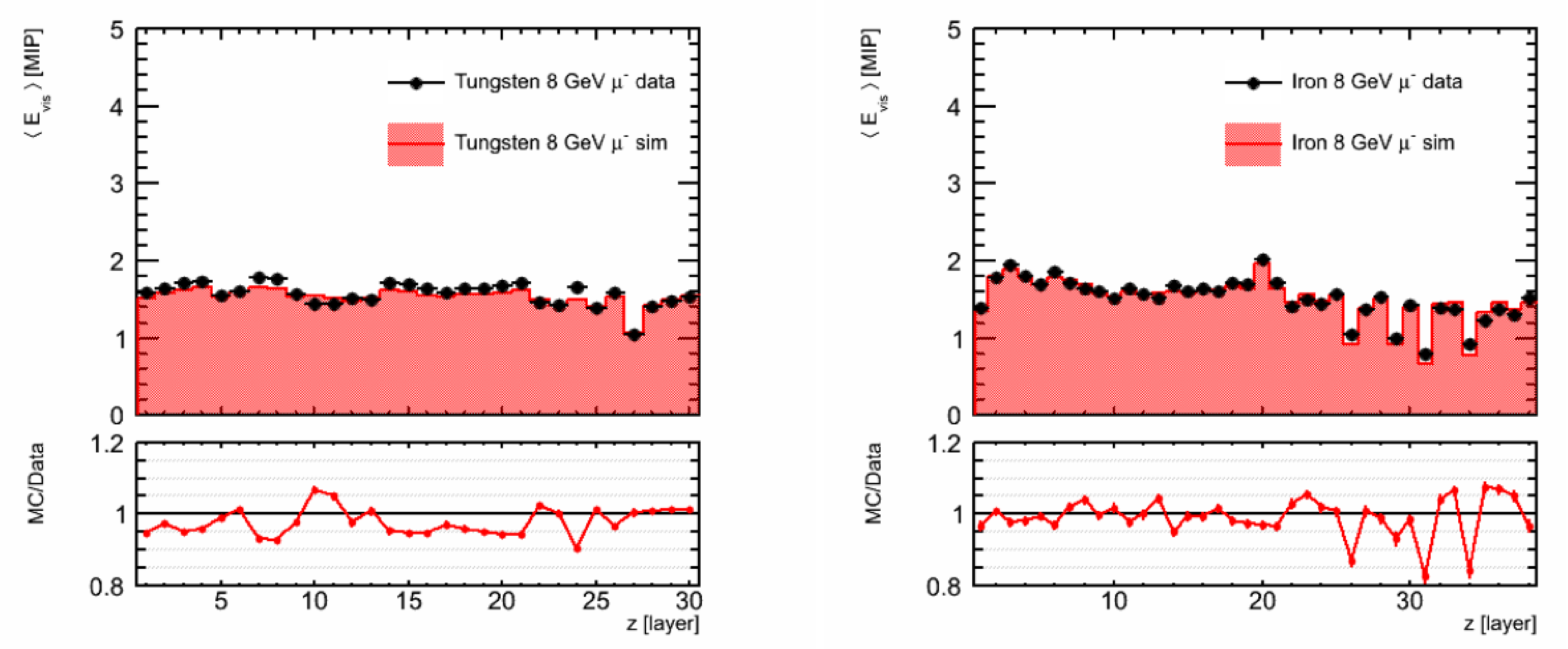
    simulation before: take calibration factor from MPV of GEANT energy deposition in scintillator

    simulation now: adjust calibration factor such that reconstructed muons (with all detector effects) have MPV at 1.0
  - Optical cross talk between tiles:

    have single tile measurements, and measurements with full layers with horizontal and vertical layers, ranging from 2.5% per tile edge (10% in total) to 4.5% per tile edge (18% in total)

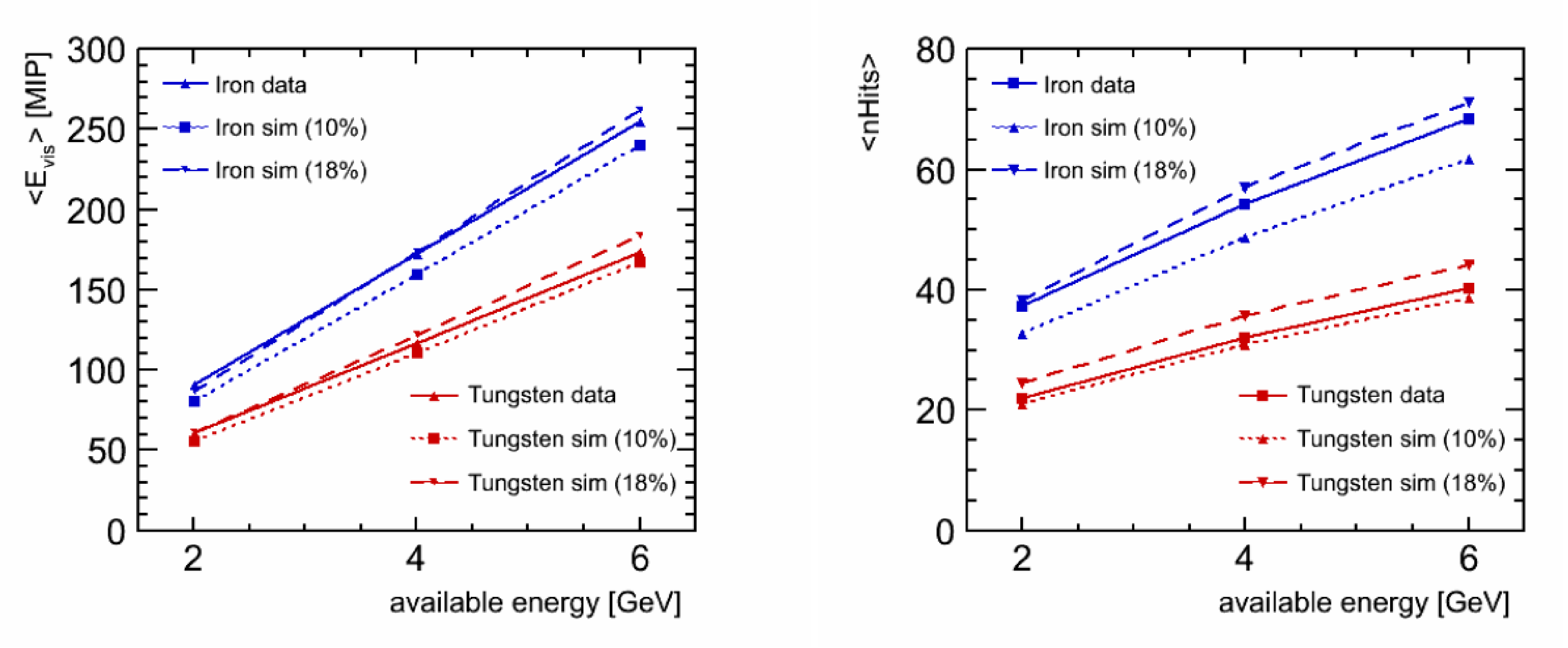
Validation of Simulation: Muons

- layer by layer variations of detector response reasonably well described



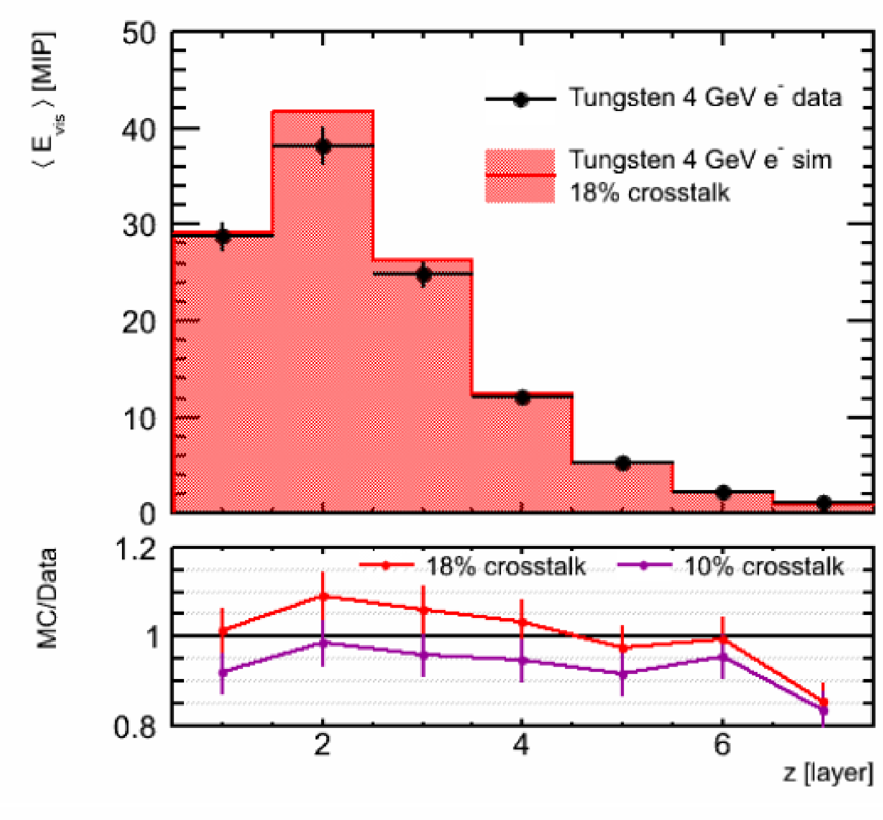
Validation of Simulation: Electrons

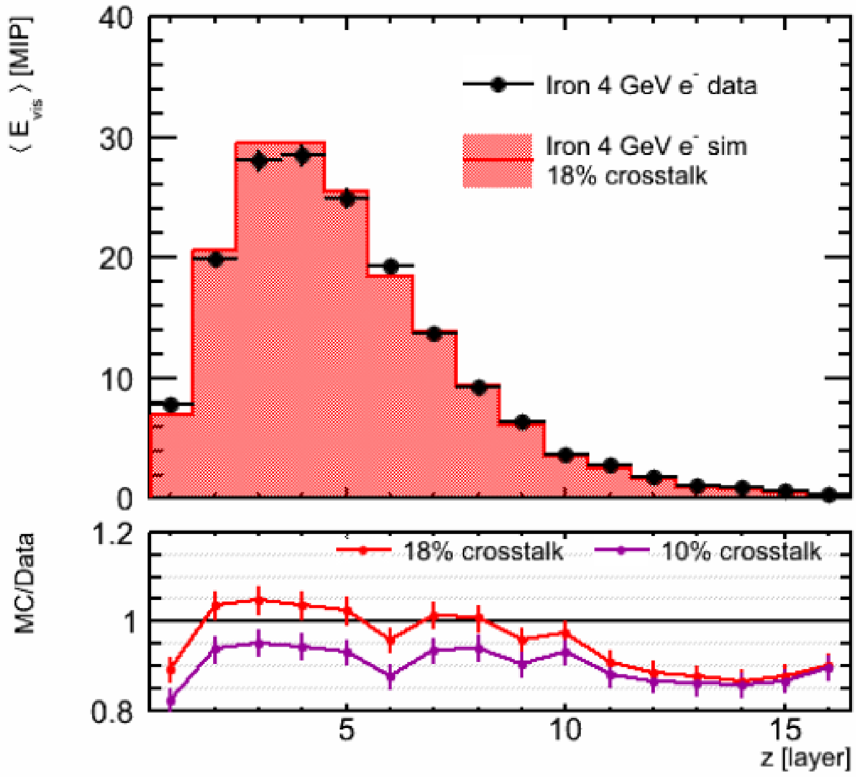
- simultaneous description of visible energy and number of hits for Iron and Tungsten data within range between two values for optical cross talk



Validation of Simulation: Electrons

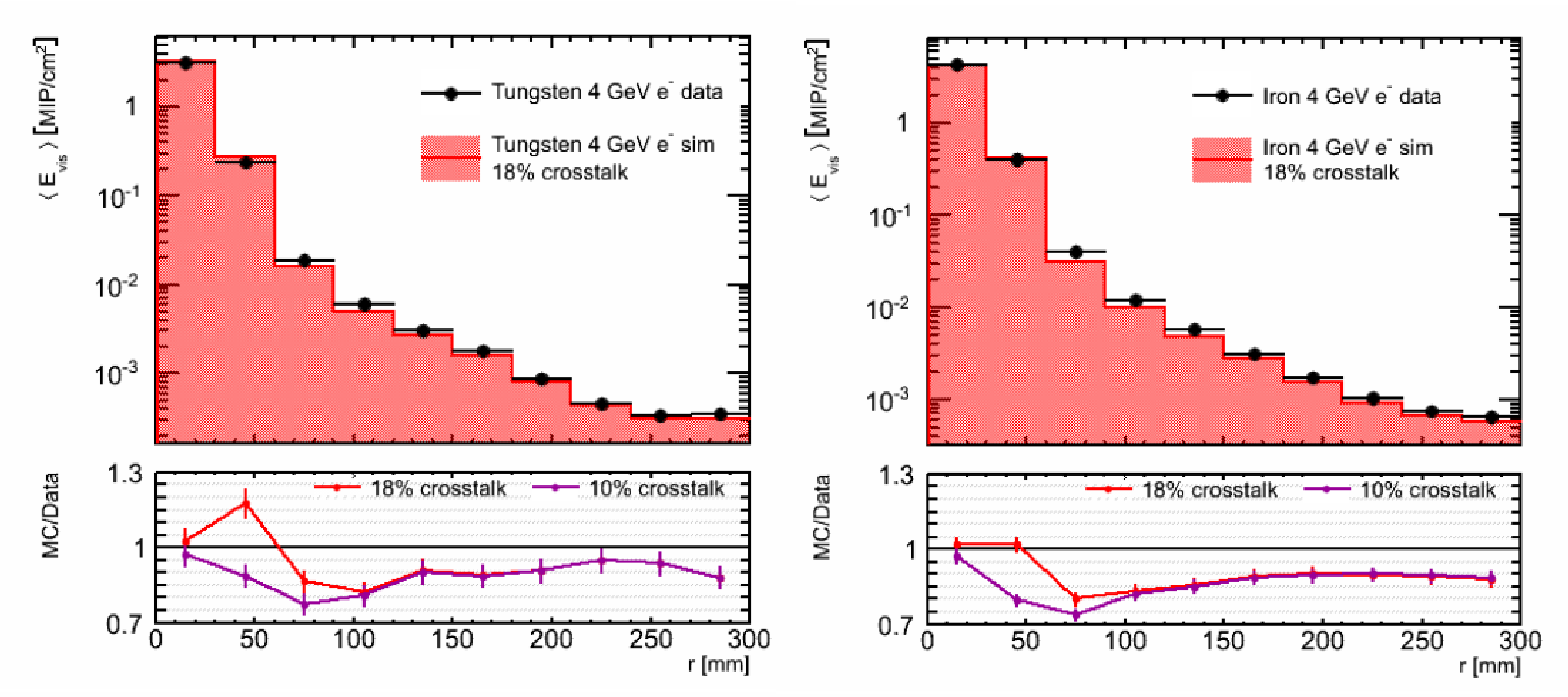
- Longitudinal shower profile described within ~5% in first part, within ~15% in tail
  - First part sensitive to optical cross talk
  - Tail sensitive to noise





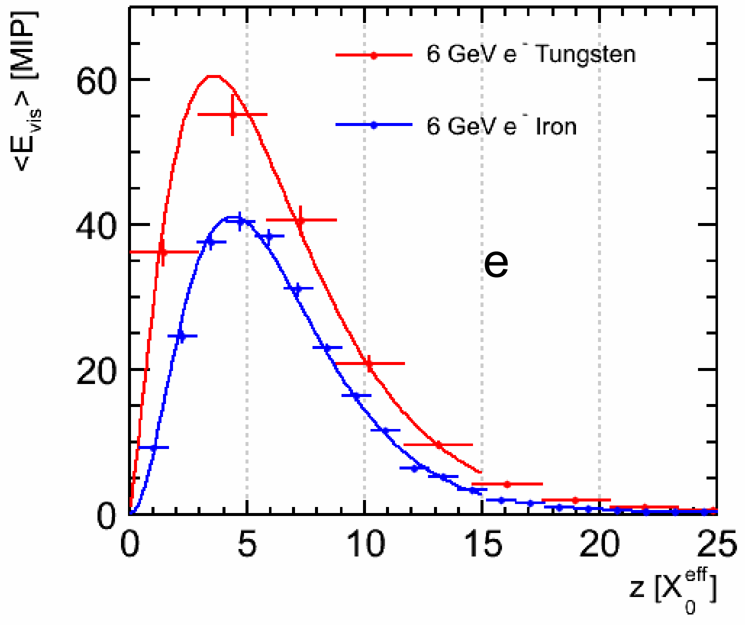
Validation of Simulation: Electrons

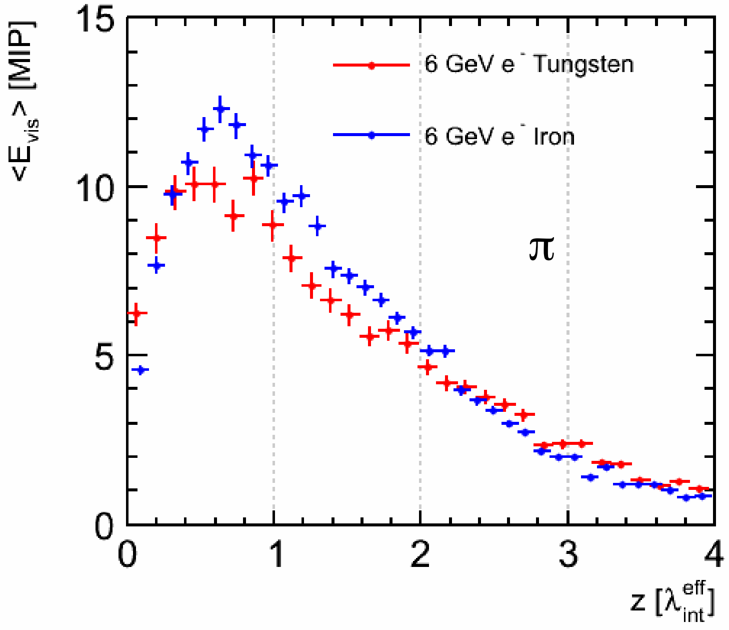
- radial shower profile described within ~25%
  - central part very sensitive to optical cross talk
  - tail sensitive to noise



Direct comparison of Iron and Tungsten data

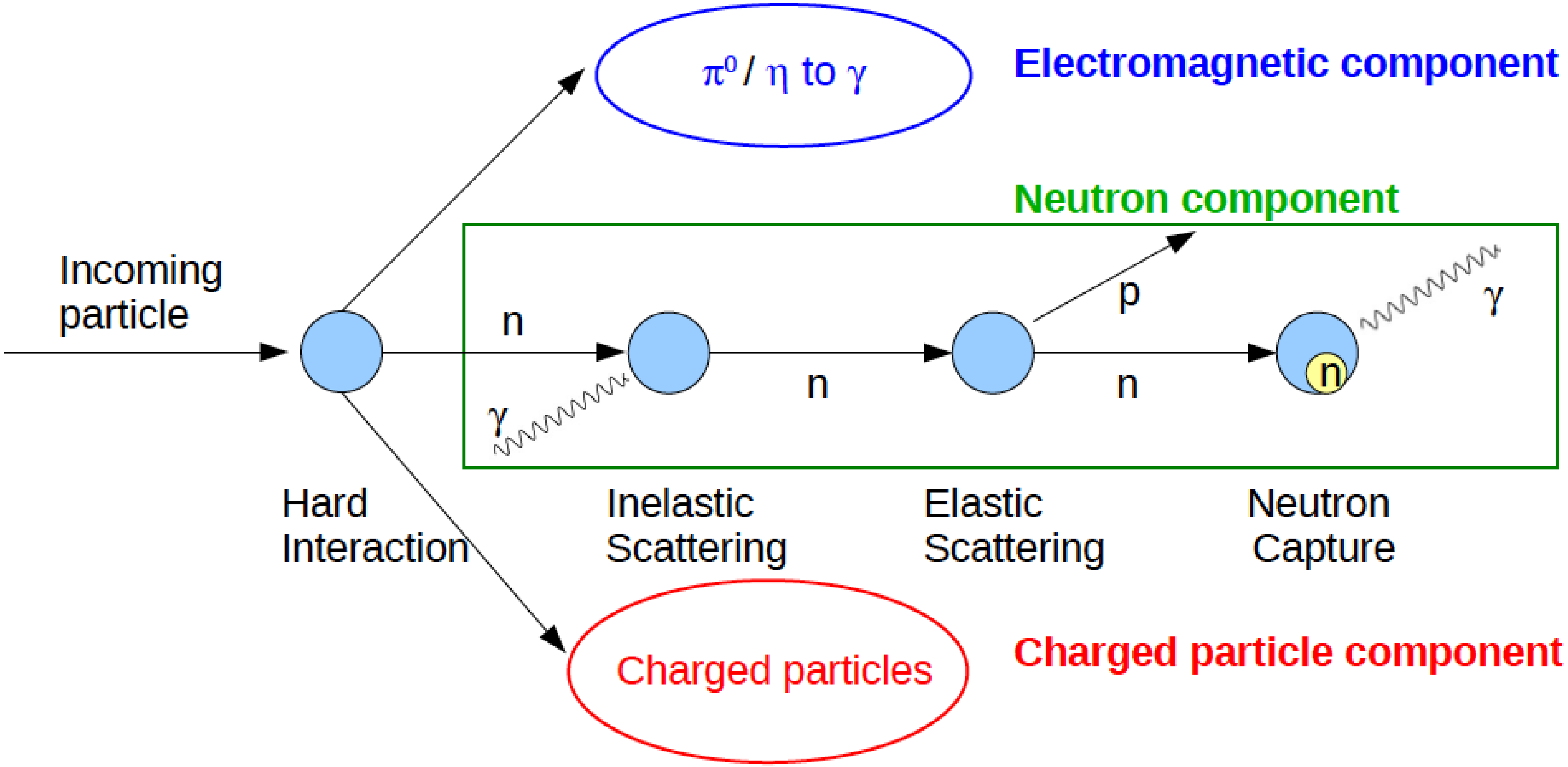
- EM showers
  - Large effect from rather different absorber thicknesses in X_0
  - Shapes very similar (maybe shower max. earlier in tungsten)
- HAD showers
  - Absorber has nearly the same thickness in λ_{int}
  - Total energy deposition in iron a bit larger than in tungsten
  - Relative contribution of first ~15 layers smaller in tungsten than in iron





Shower decomposition

Divide the shower into following components:



π^0 / η to γ

Electromagnetic component

Neutron component

Incoming
particle

n

p

γ

γ

n

n

n

Hard
Interaction

Inelastic
Scattering

Elastic
Scattering

Neutron
Capture

Charged particles

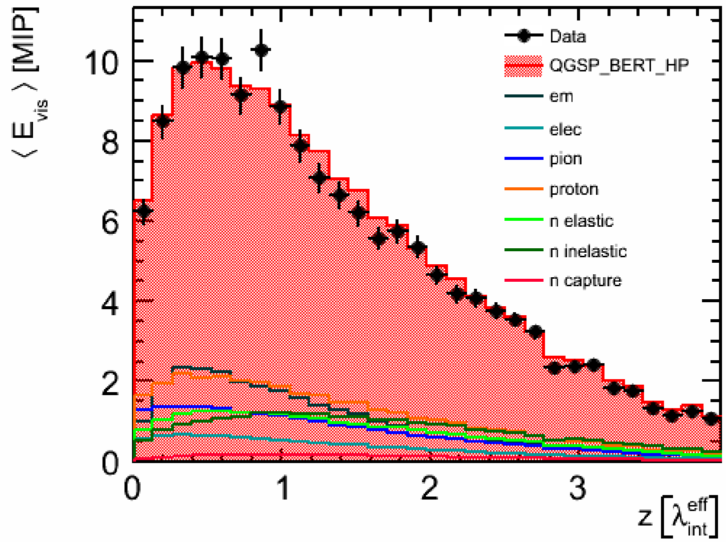
Charged particle component

Comparison of Pion data to simulation

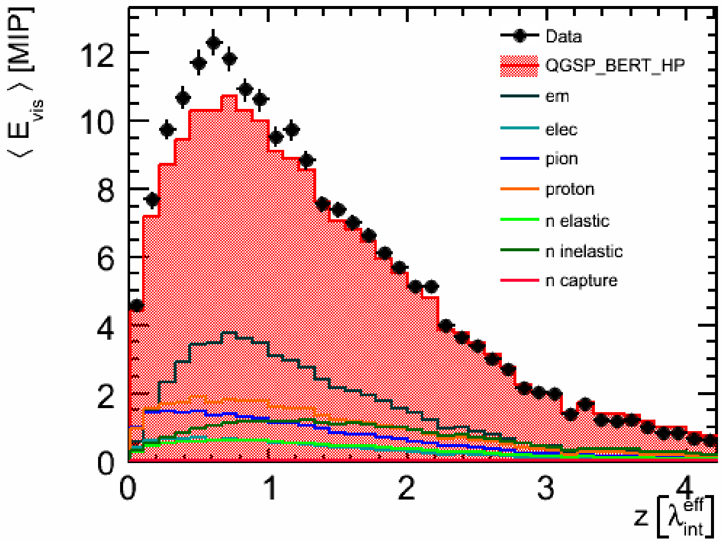
Comparison to GEANT4 9.5 (timing corrected)

- Physics list QGSP_BERT_HP (gives best description of data)
- Tungsten data very well described, first ~12 layers in iron underestimated
- Neutron elastic component more relevant for tungsten, EM component more relevant for iron

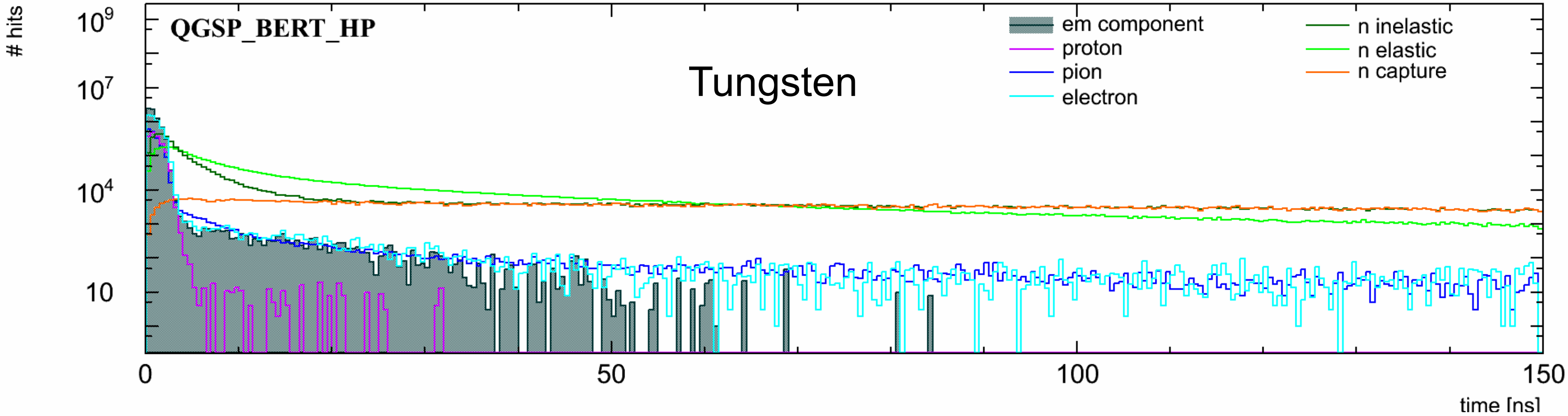
6 GeV Tungsten

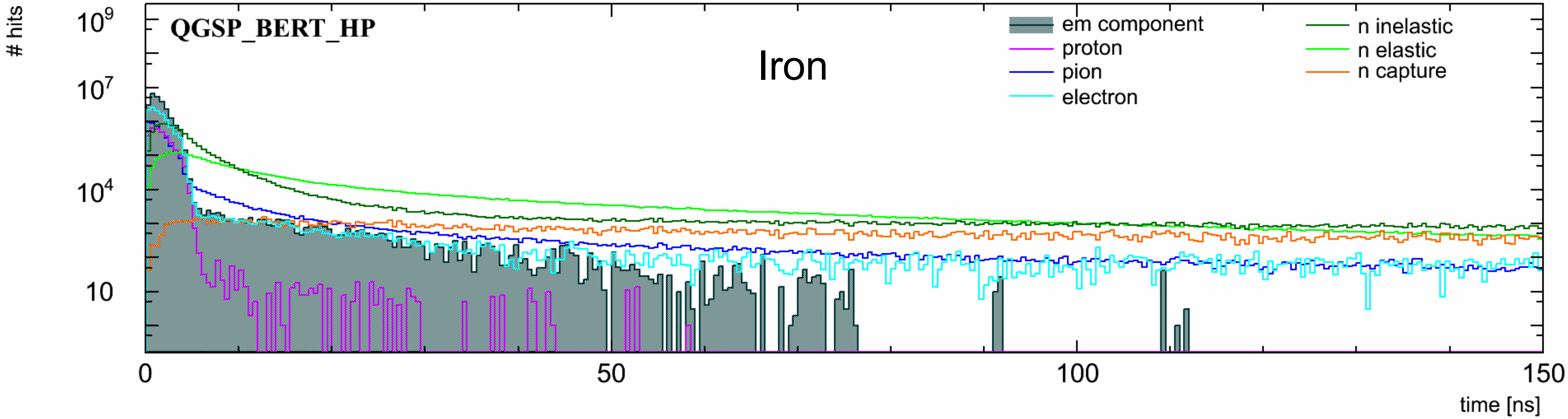


6 GeV Iron



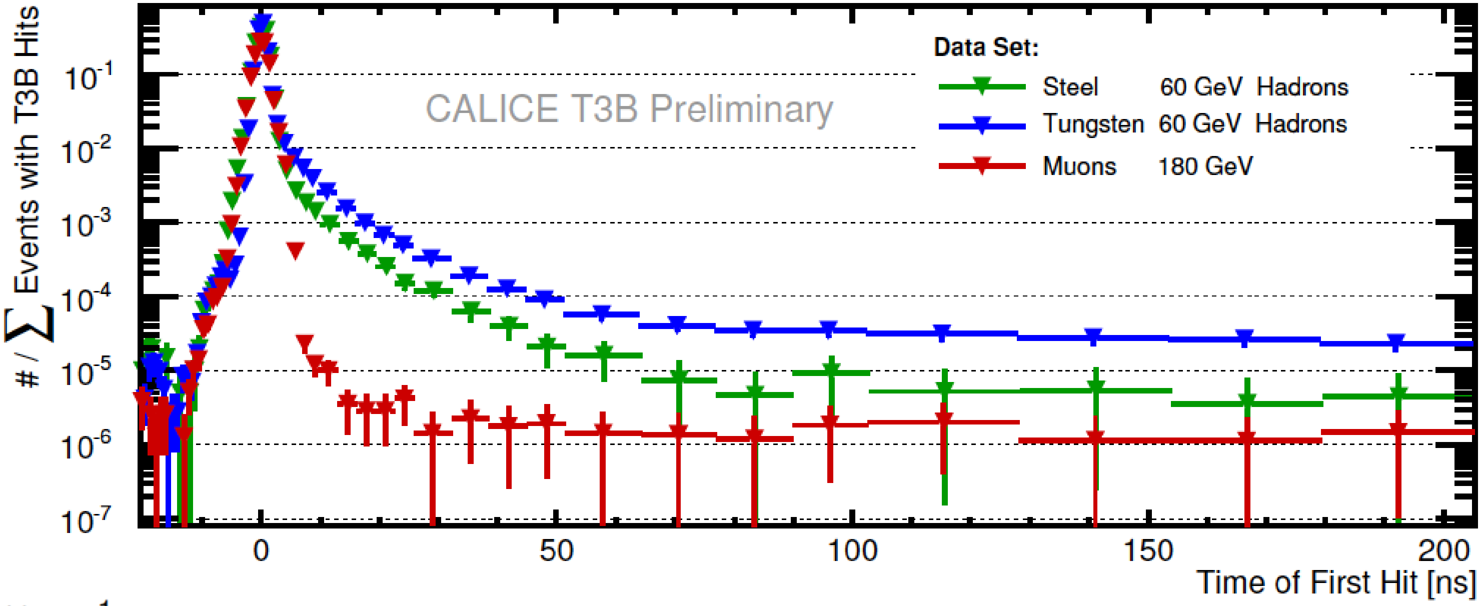
Time Evolution of 6 GeV Pion Showers

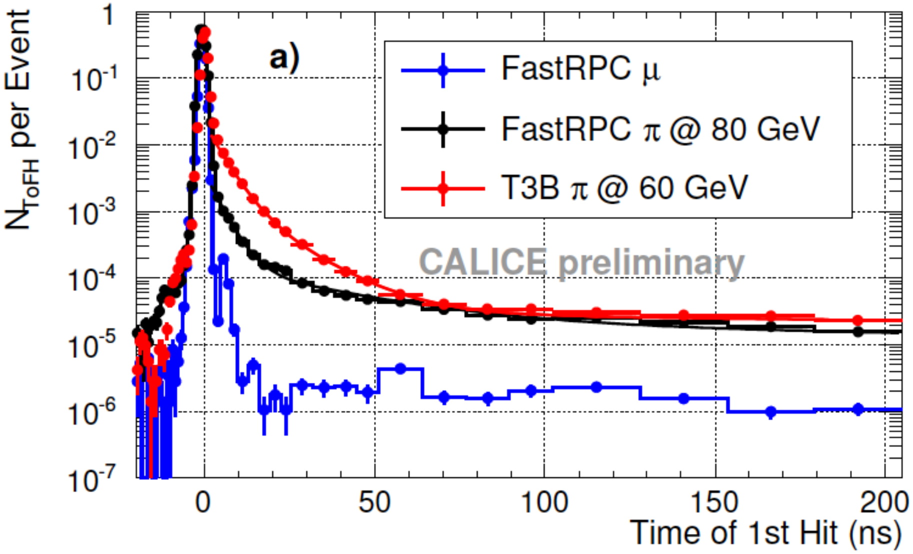




Neutron component much more relevant for tungsten, much slower

T3B results





- Differences in time evolution for Iron and Tungsten absorber observed with T3B
- For tungsten absorber, active material (T3B: scintillator, FastRPC: RPCs) also has significant influence

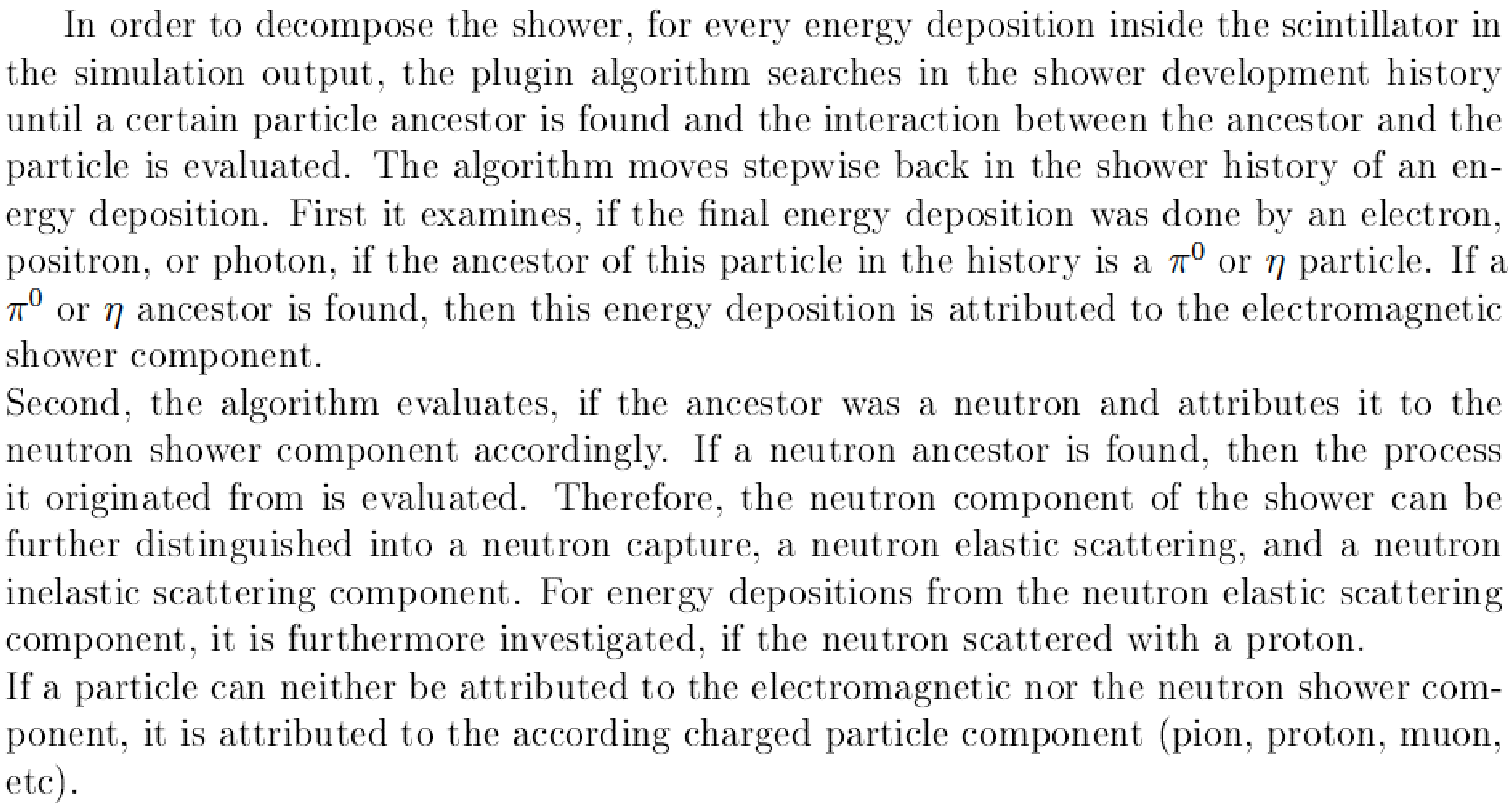
Conclusions and Outlook

- Detailed simulation of detector setup and imperfections allows reasonable description of muons, electrons and hadrons with iron and tungsten absorber
- Direct comparison of iron and tungsten:
  - EM showers different mainly because of different sampling fractions
  - Hadronic showers: relative contributions of first layers more important for Iron
- Comparison between data and simulation
  - Considerable differences in neutron component between iron and tungsten, leading to differences in time evolution of showers
  - **Definition of shower components in GEANT would be very helpful**

Backup

Shower Decomposition: Algorithm

from C. Guenter, PhD thesis in preparation



In order to decompose the shower, for every energy deposition inside the scintillator in the simulation output, the plugin algorithm searches in the shower development history until a certain particle ancestor is found and the interaction between the ancestor and the particle is evaluated. The algorithm moves stepwise back in the shower history of an energy deposition. First it examines, if the final energy deposition was done by an electron, positron, or photon, if the ancestor of this particle in the history is a π^0 or η particle. If a π^0 or η ancestor is found, then this energy deposition is attributed to the electromagnetic shower component.

Second, the algorithm evaluates, if the ancestor was a neutron and attributes it to the neutron shower component accordingly. If a neutron ancestor is found, then the process it originated from is evaluated. Therefore, the neutron component of the shower can be further distinguished into a neutron capture, a neutron elastic scattering, and a neutron inelastic scattering component. For energy depositions from the neutron elastic scattering component, it is furthermore investigated, if the neutron scattered with a proton.

If a particle can neither be attributed to the electromagnetic nor the neutron shower component, it is attributed to the according charged particle component (pion, proton, muon, etc).

Shower Decomposition: Algorithm

Determine particle type that does energy deposition in scintillator and step backwards through its ancestors

- if energy deposition by e or γ: if π^0 or η in ancestors: EM component
- if neutron in ancestors: neutron component
  - further distinction by process name(!): capture, elastic, inelastic
- everything else: charged component
  - further distinction by depositing charged particle: proton, pion, electron, ...