Comparison of the performance of tungsten and steel hadronic calorimeters

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IWLC 2010

HCAL depth and material

Calorimetric resolution driven by intrinsic resolution and by leakage

to reduce leakage:

→deeper calorimeter

→denser calorimeter

(more interaction lengths)

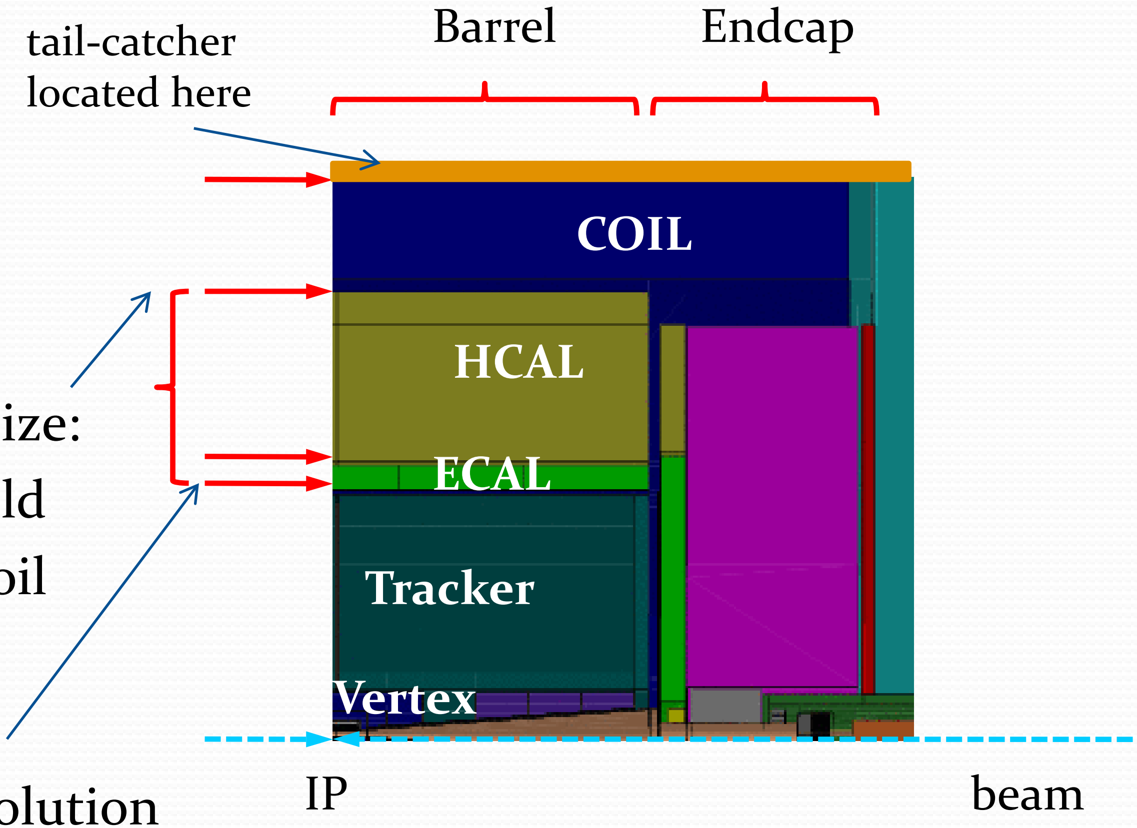
depth limited by feasible coil size:

→larger coil with smaller B-field

→larger B-field with smaller coil

depth limited by tracker size:

→larger tracker →better p-resolution



(talk is an update to the talk given at the CLIC 2009 Workshop at CERN)

HCAL absorber material

- which material for the absorber?
  - steel, tungsten, … ?

- Tungsten
  - expensive!
  - more contained showers (compared to Fe) with the same HCAL geometrical depth → less leakage
  - smaller shower diameter → better separation of showers (probably good for particle flow)

- final goal → good energy resolution with Particle Flow (Tracking+Calorimeters+Muon system)

Energy reconstruction with neural network

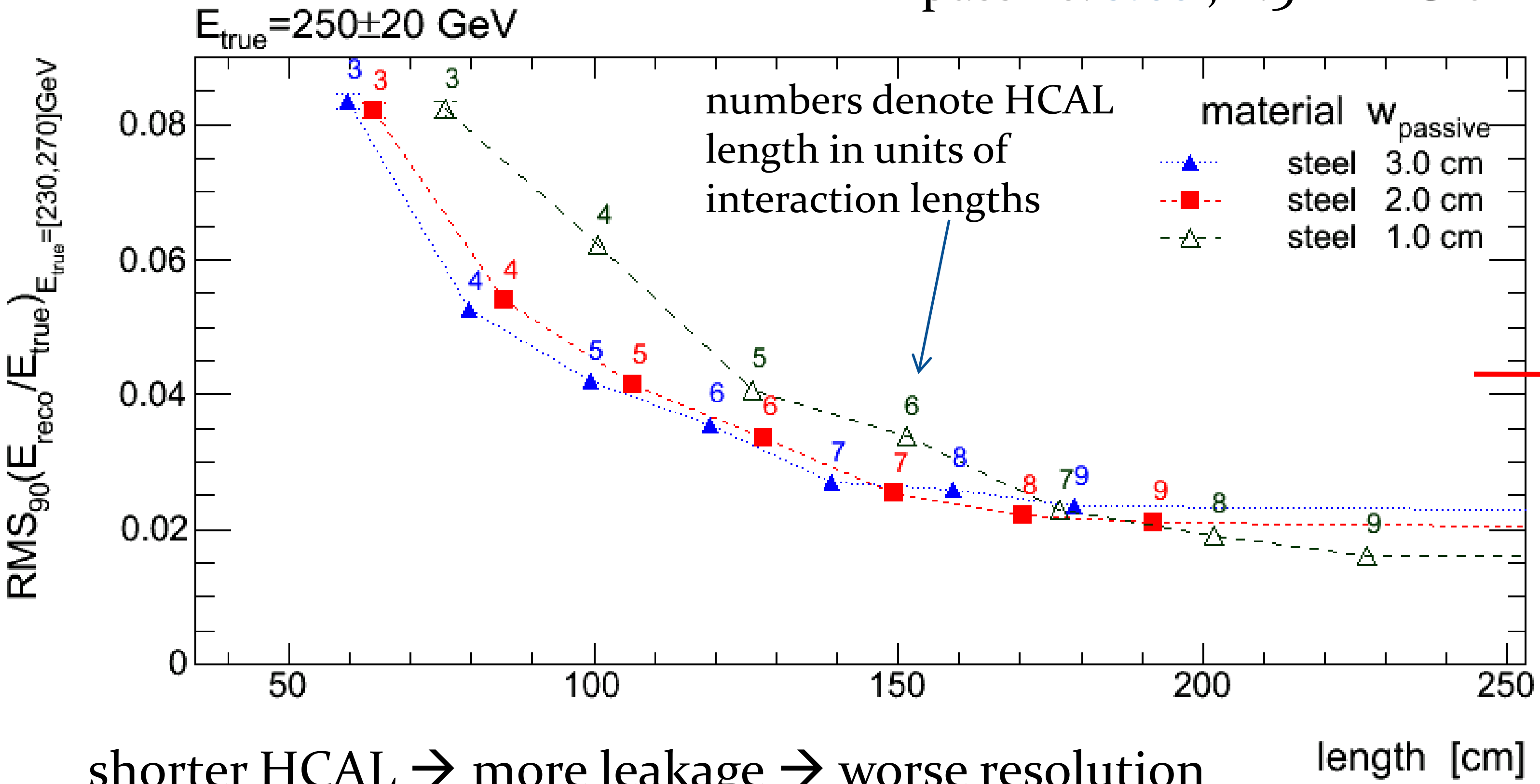
(information from fine granularity of calorimeter not used → traditional approach)

-variables describe shower shape and size and energy

-train neural network with pion energy

-interpret length in λ as ECAL+HCAL

active: 5 mm scintillator
passive: steel, 2.5 mm G10



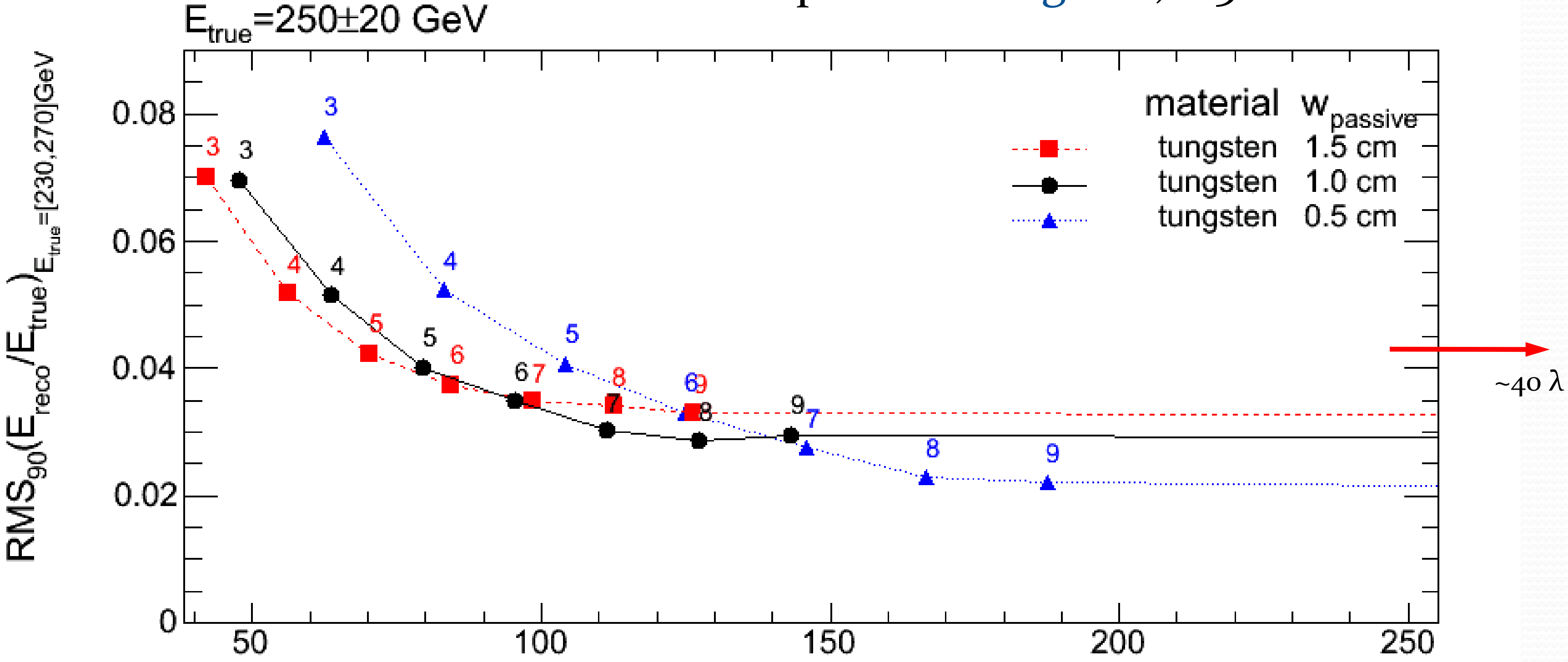
numbers denote HCAL length in units of interaction lengths

~40 λ

shorter HCAL → more leakage → worse resolution

Energy resolution in W calorimeters: 250 GeV pions

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10

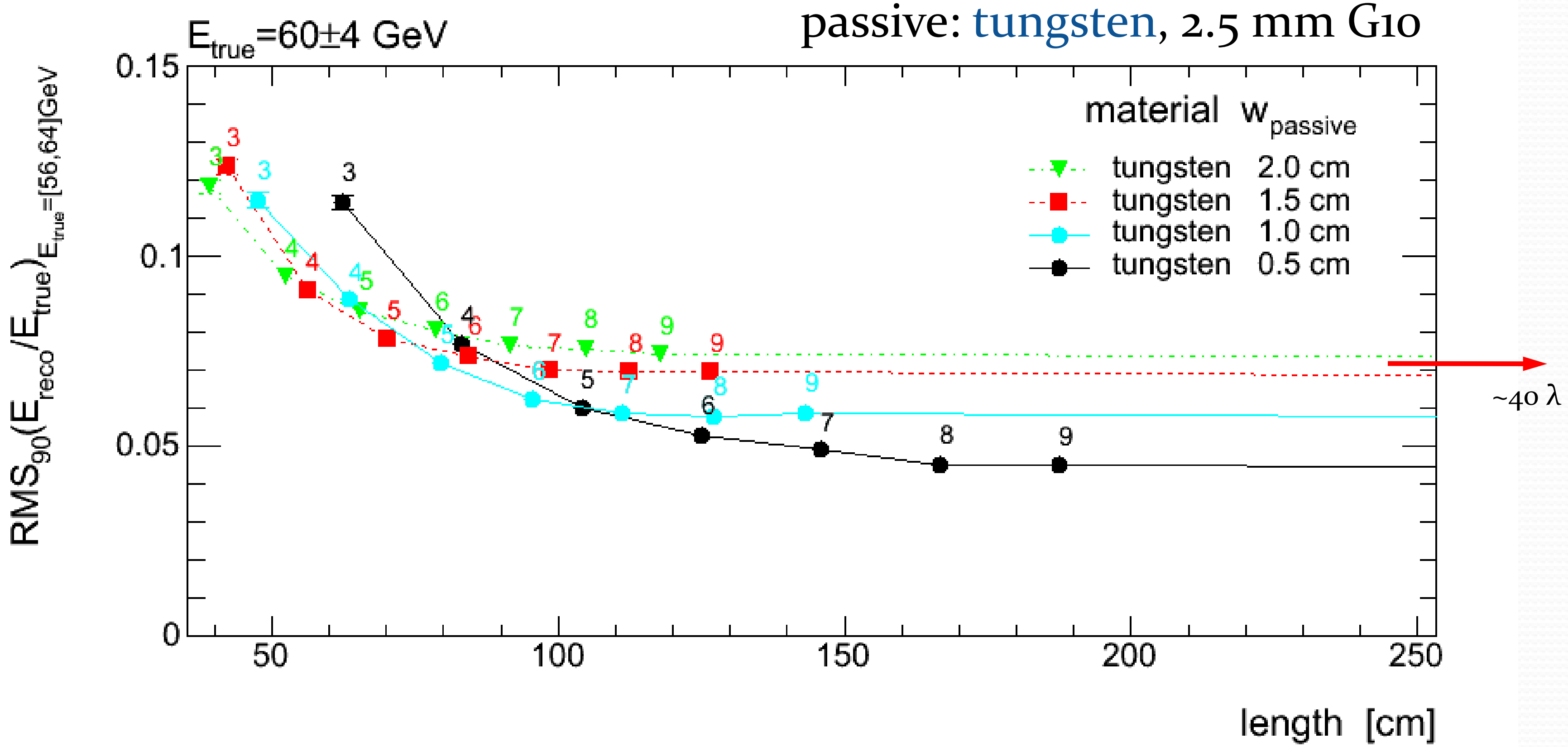


flat region reached earlier (shorter HCAL) than with steel

Energy resolution in W calorimeters: 60 GeV pions

lower energy → flat region reached earlier
(less interaction length needed to contain clusters)

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10

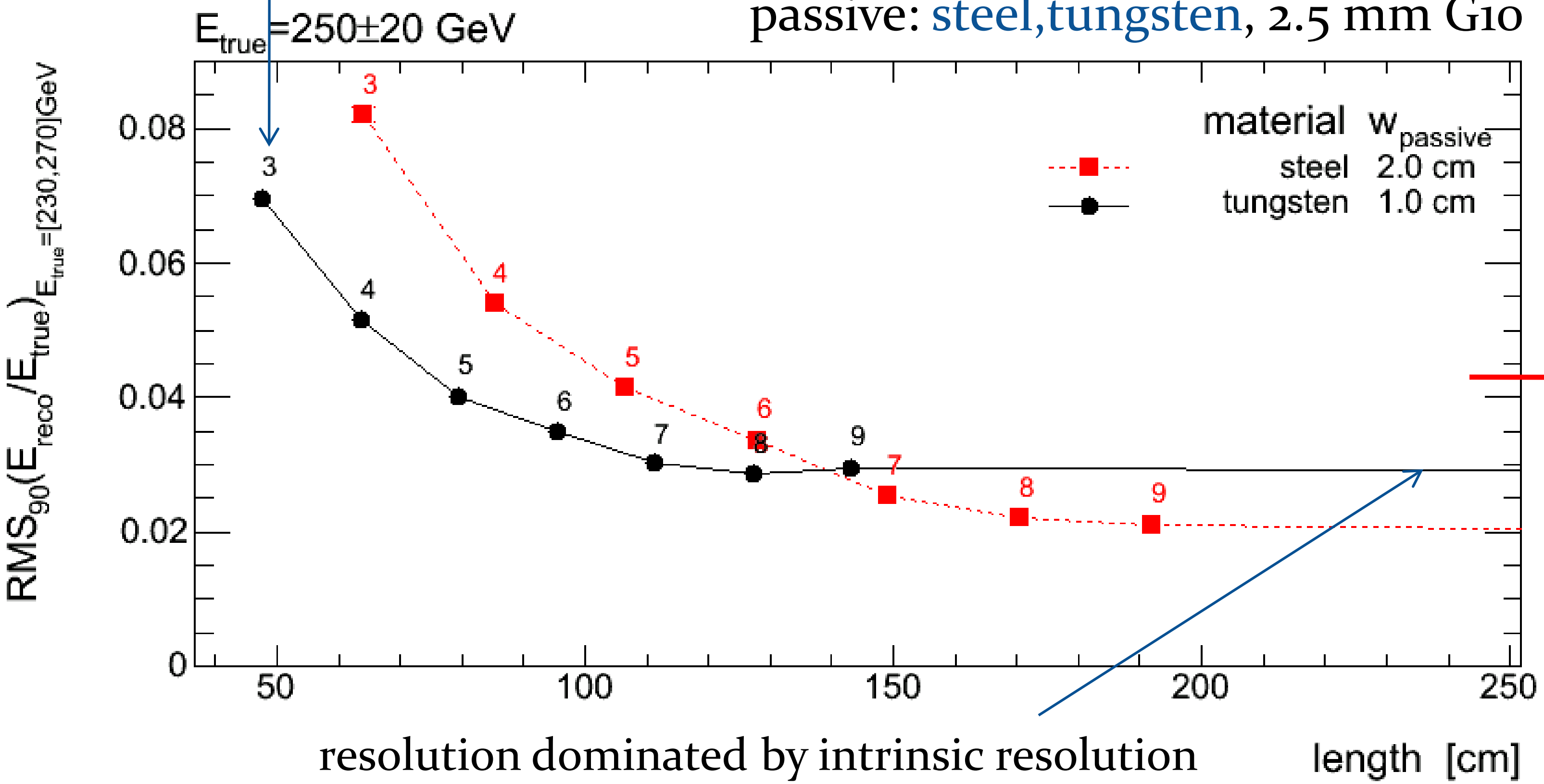


~40 λ

Energy reconstruction with neural network

resolution dominated by leakage

active: 5 mm scintillator
passive: steel,tungsten, 2.5 mm G10

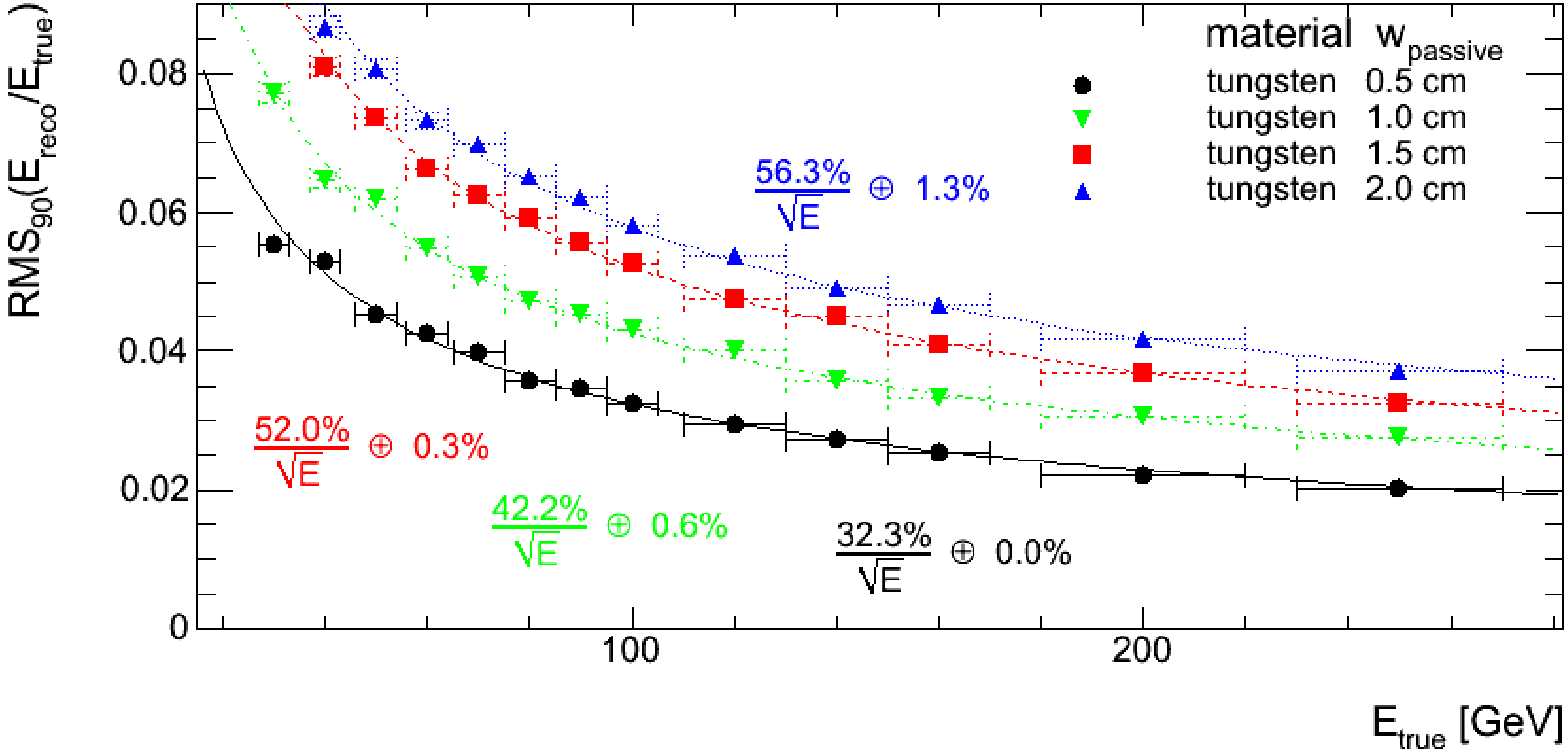


~40 λ

resolution dominated by intrinsic resolution

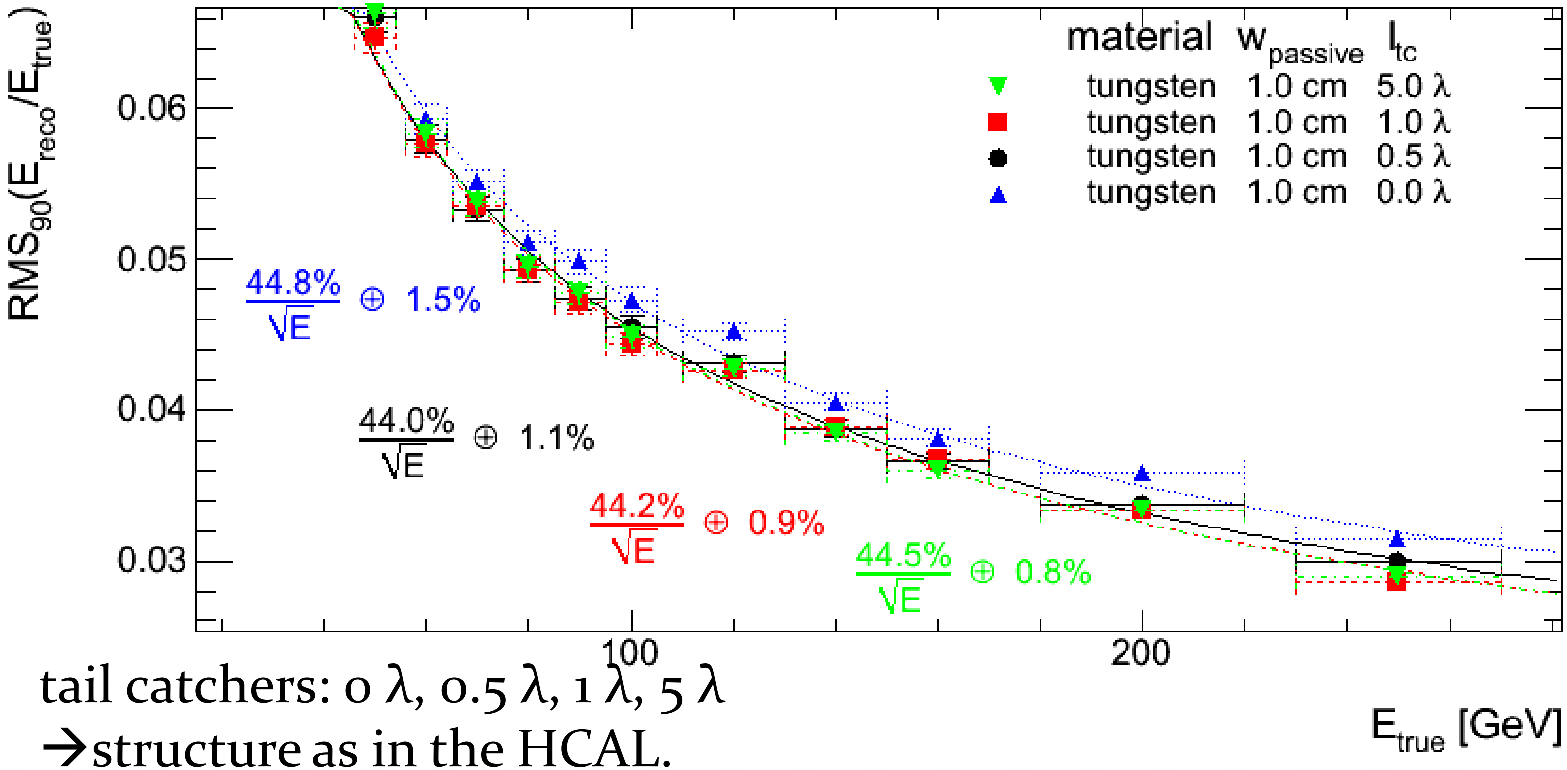
Energy resolution in a long W-calorimeter (>20 λ)

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10



Tail-catcher

active: 5 mm scintillator
passive: tungsten, 2.5 mm G10



tail catchers: 0 λ, 0.5 λ, 1 λ, 5 λ

→structure as in the HCAL.

→zero λ tail-catcher implies no active material after the coil

coil thickness: 2 λ

→having some tail-catcher (0.5 λ) improves resolution slightly

→effect of bigger tail-catcher is negligible

Tungsten HCAL

- Tungsten used in ECALs
  - typically ~1λ deep
- No experience with tungsten HCALs
  - ~4 - 9 λ deep

- simulation of tungsten not validated
  - no MC/data comparisons
  - no validation for high granularity

- Tungsten HCAL useful→ if significant performance improvement (jet energy resolution, improved particle ID) compared to steel HCAL

Further reason for validation

- Time structure of signal broadened by n-content
  - time stamping
    - (slow) n-content smears out energy deposits in calorimeters
    - know time-structure of n-content to set requirements for time stamping
    - used to separate physics signal from beam-induced background on a time basis
  - dependent on active material (e.g. scintillator, gas)
  - measurements necessary

Tungsten HCAL Prototype
What we have learned, what we will learn?

- Tungsten plate production process
  - Machining of tungsten plates
  - Test production of large thin plates (gluing)
  - Feasibility of needed flatness

- Physics performance
  - Verify simulations (resolution, shower shapes, …)
  - Include realistic noise levels (read-out, neutrons, …)

more about prototype

- see talk from E. van der Kraiij

CLIC W-HCAL depth studies with Pandora PFA

- see talk by Angela Lucaci-Timoce

Conclusions & Outlook

- From tungsten simulations:
  - 8-9 λ 's ECAL+HCAL seems sufficient up to 300 GeV (pions)
  - ~10-15 mm W absorber optimal
  - tail catcher useful, but no dramatic improvement
  - Particle Flow algorithm
    - →studies in progress (A.Lucaci-Timoce)

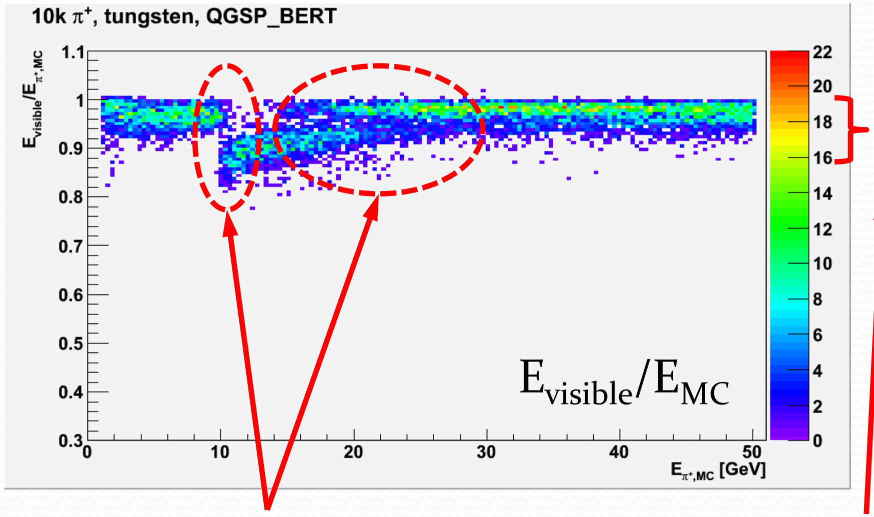
- From prototype results:
  - feed back MC/data comparions on prototype to Geant4-team

backup

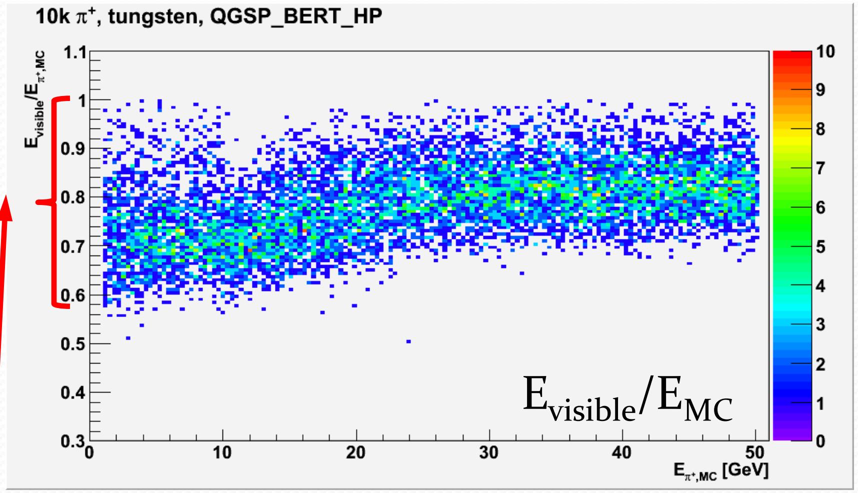
physics-list differences (Geant4)

simulations of pion showers in block of tungsten

tungsten, QGSP_BERT



tungsten, QGSP_BERT_HP



transition regions of models

with HP (high precision neutron tracking) enabled → much less energy deposit by ionization

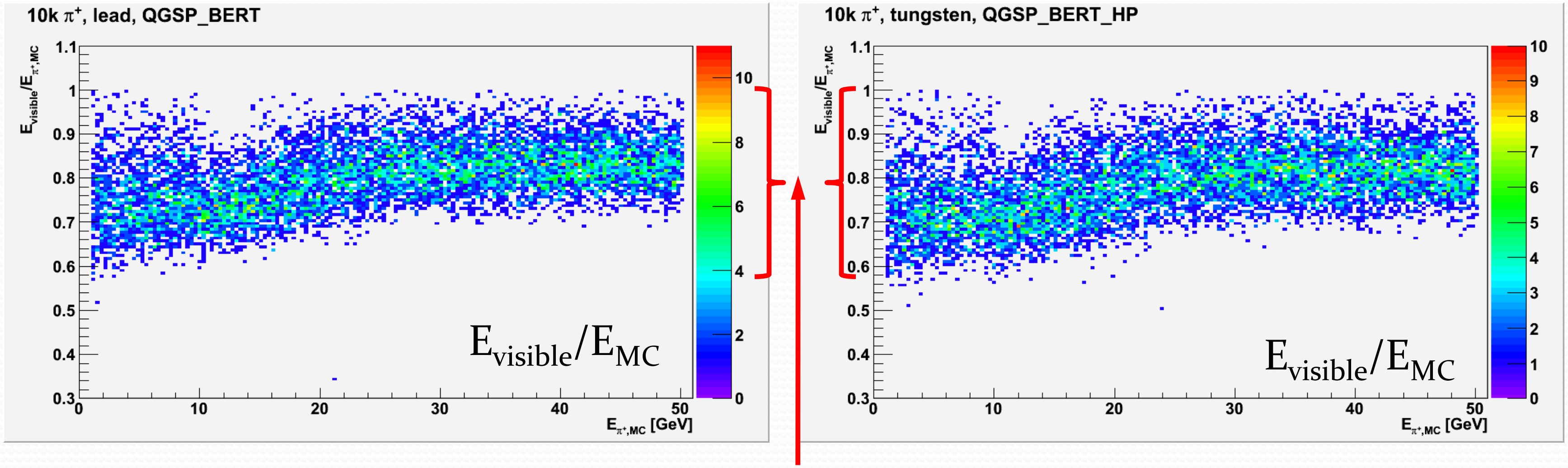
which one can we trust more?

in QGSP_BERT → more n produced, more n captured
→ ~8MeV of photons each → accounts for difference

physics-list differences (Geant4)

simulations of pion showers in block of lead/tungsten

lead, QGSP_BERT   **tungsten**, QGSP_BERT_HP



lead simulations for hadrons are better validated

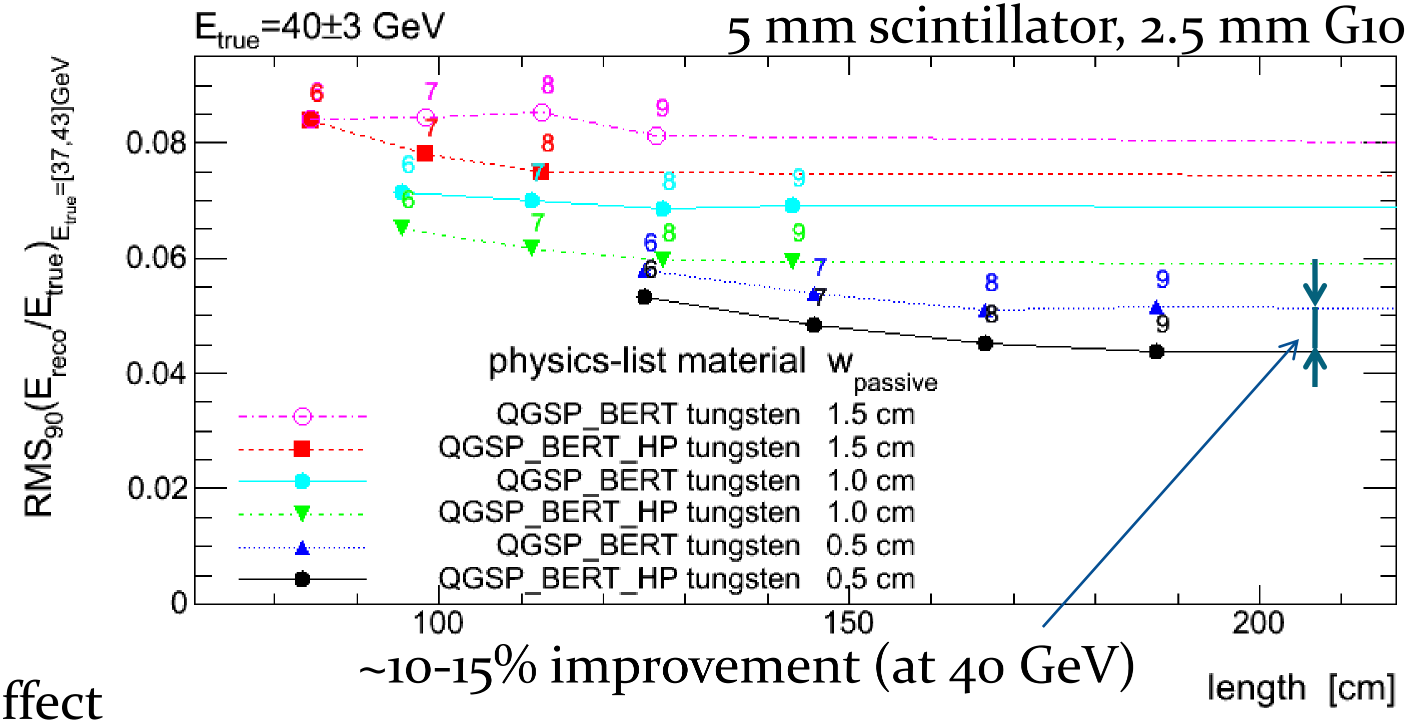
similar widths of lead and tungsten, when HP is used

→ "feeling" says: this is more trustworthy

Effect of physics list on predicted resolution

less energy deposited by ionization, but … →Improved resolution!

5 mm scintillator, 2.5 mm G10



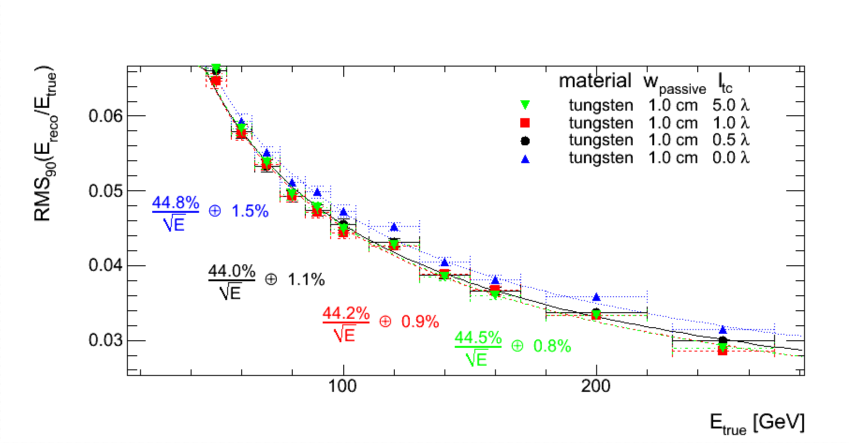
~10-15% improvement (at 40 GeV)

→considerable effect
→but: perfect readout assumed

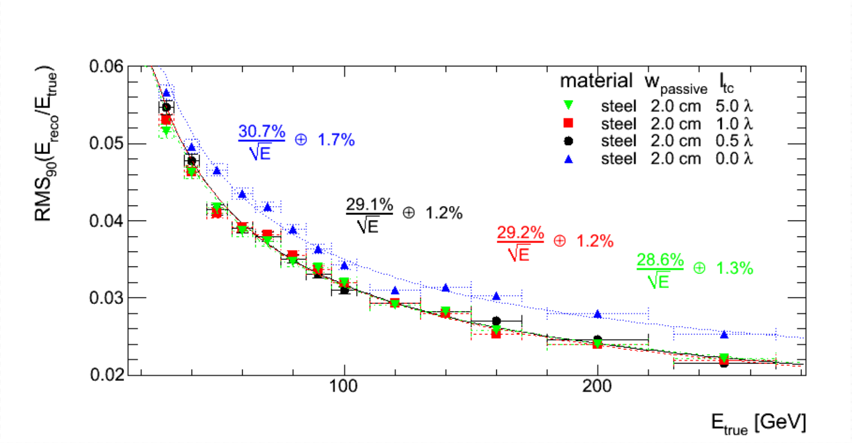
→why: n are captured farther away from shower core
→ “halo” produced which reduces reconstruction performance.
→removing halo (with HP n tracking)

Tail-catcher

tungsten



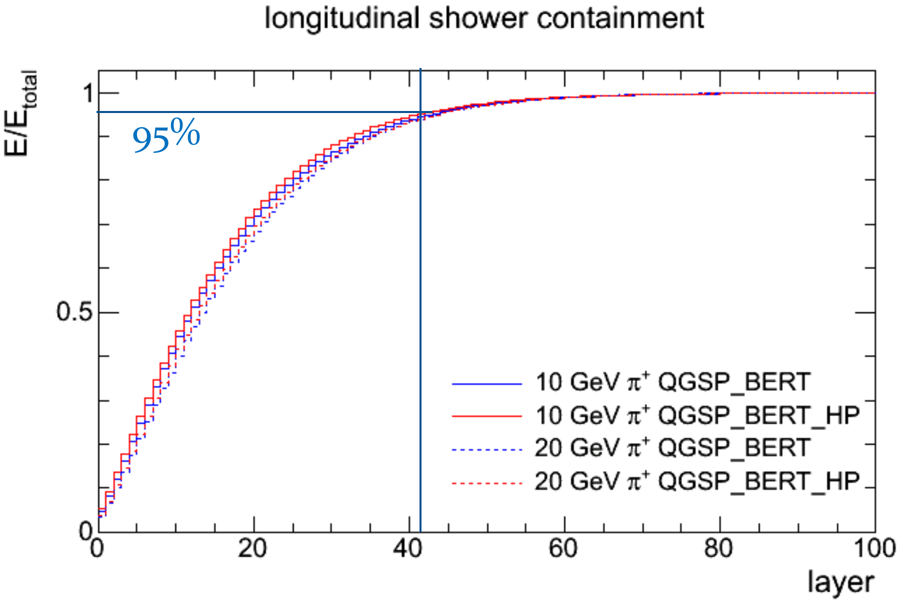
steel

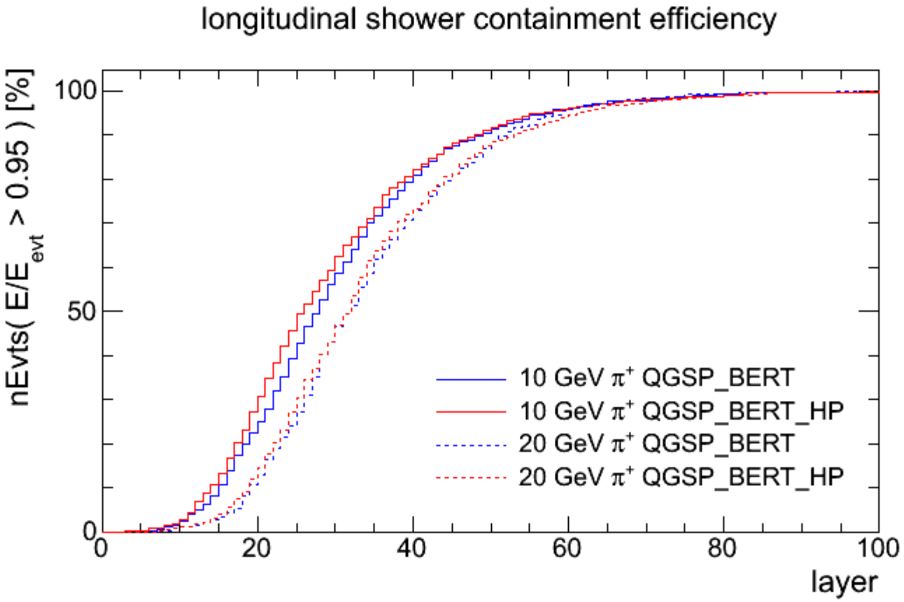


coil thickness: 2 λ
zero λ tail-catcher implies no active material after the coil
→having some tail-catcher (1 λ) improves resolution
→effect of bigger tail-catcher is small

Longitudinal shower size

95% contained energy → ~40 layers (~4.8 λ)



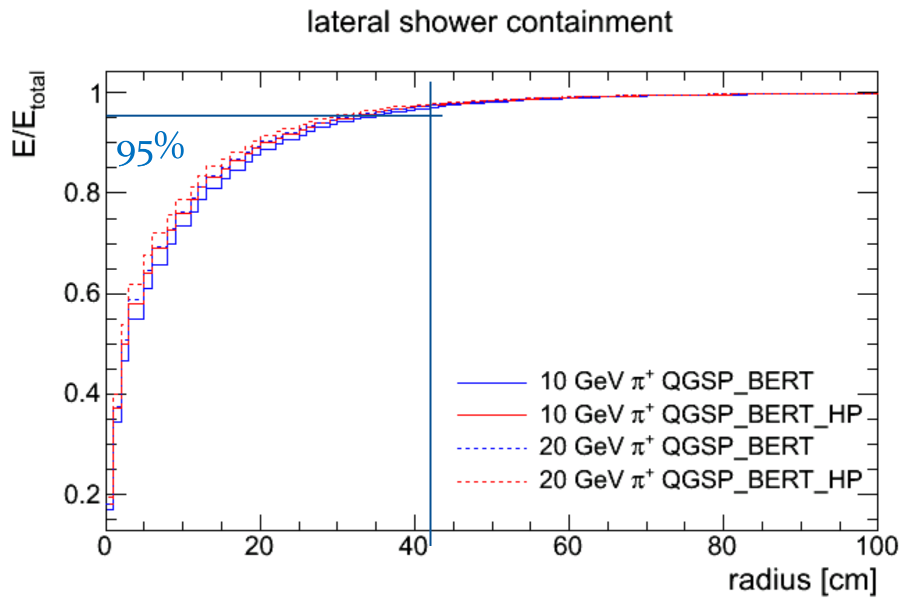


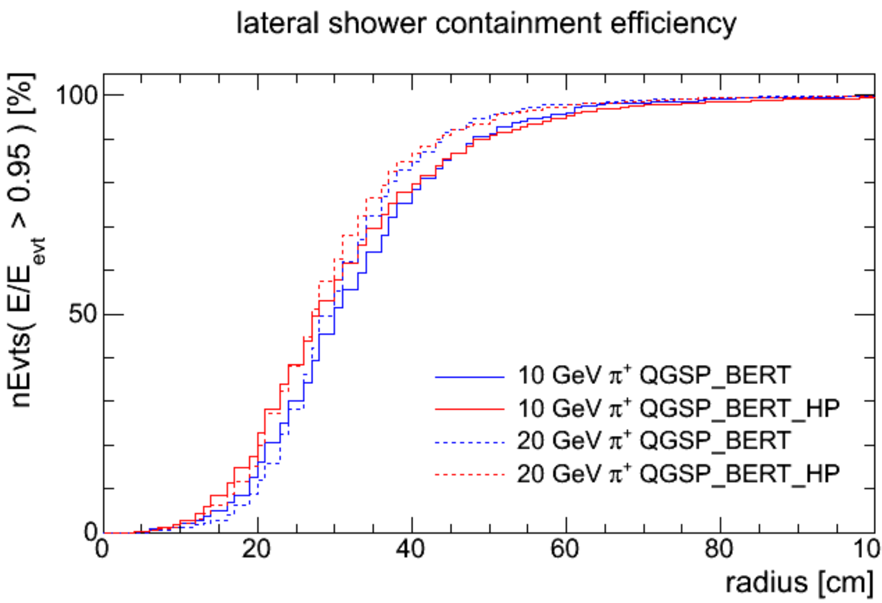
C. Grefe

12 mm tungsten + 5 mm Scint + 2.5 G10

Lateral shower size

95% contained energy → ~40 cm radius





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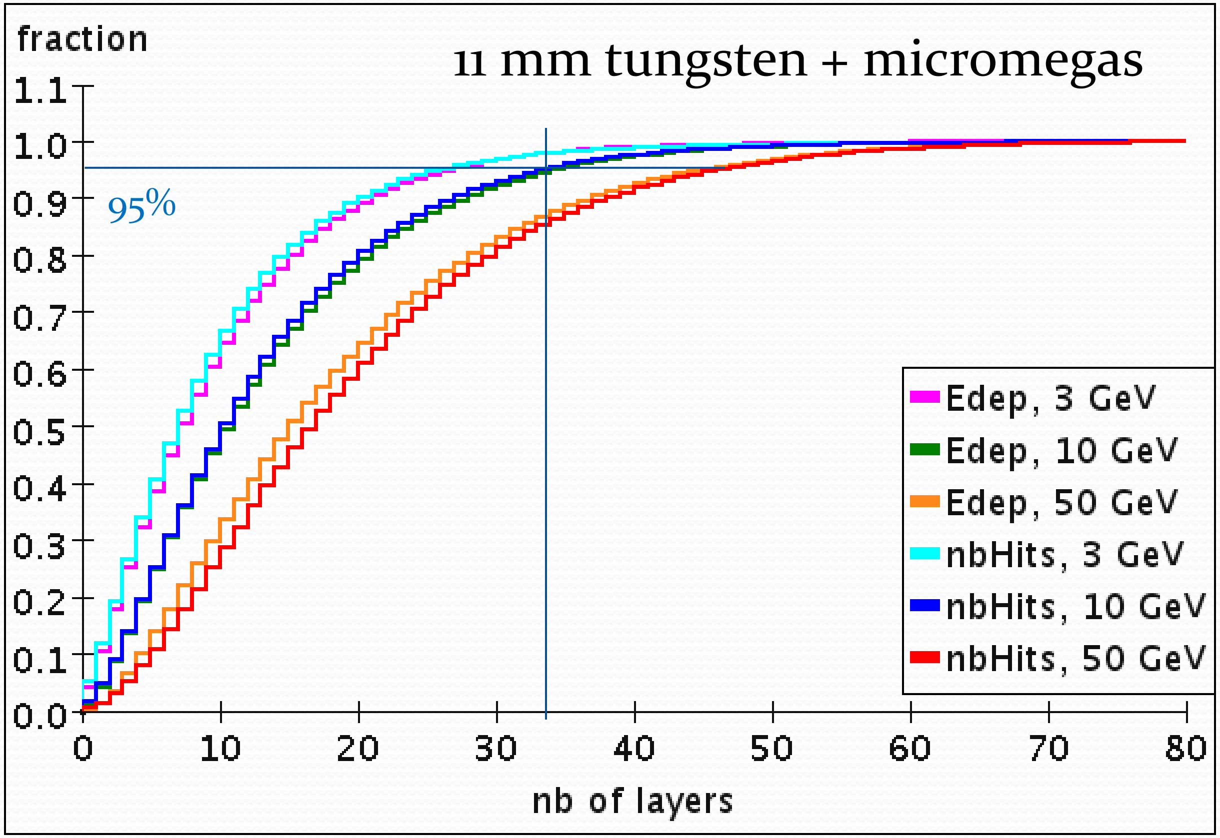
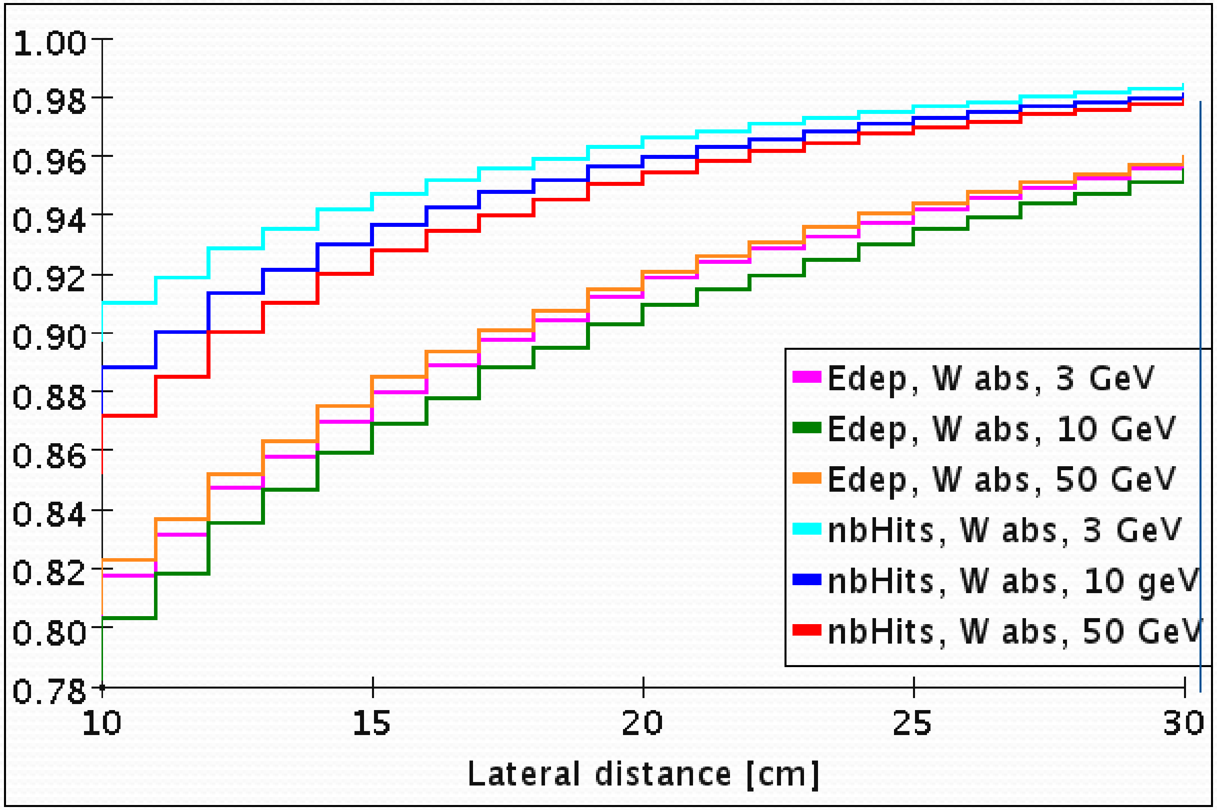
12 mm tungsten + 5 mm Scint + 2.5 G10

Longitudinal shower sizes: tungsten + micromegas



J. Blaha

Lateral shower sizes: tungsten + micromegas



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