Tungsten HCAL simulation studies

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CLIC 09

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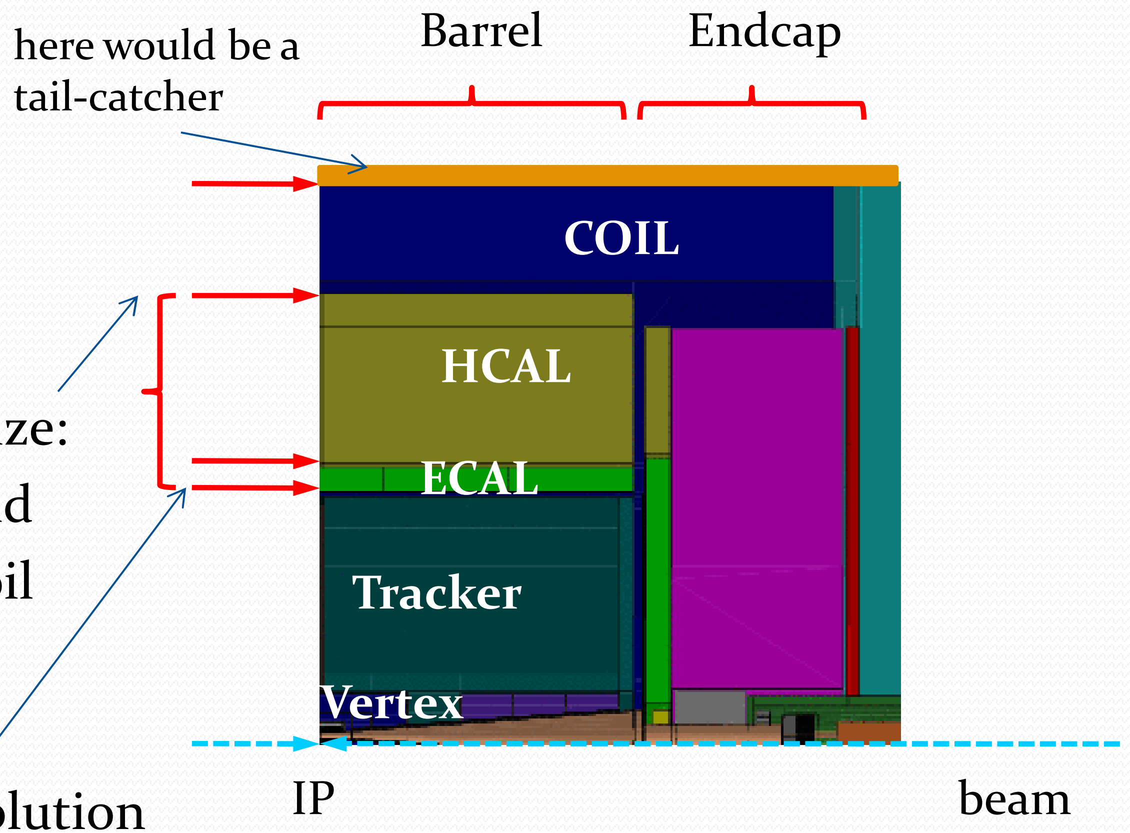
considerations for HCAL depth and material

shower leakage worsens energy resolution

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



HCAL absorber material

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

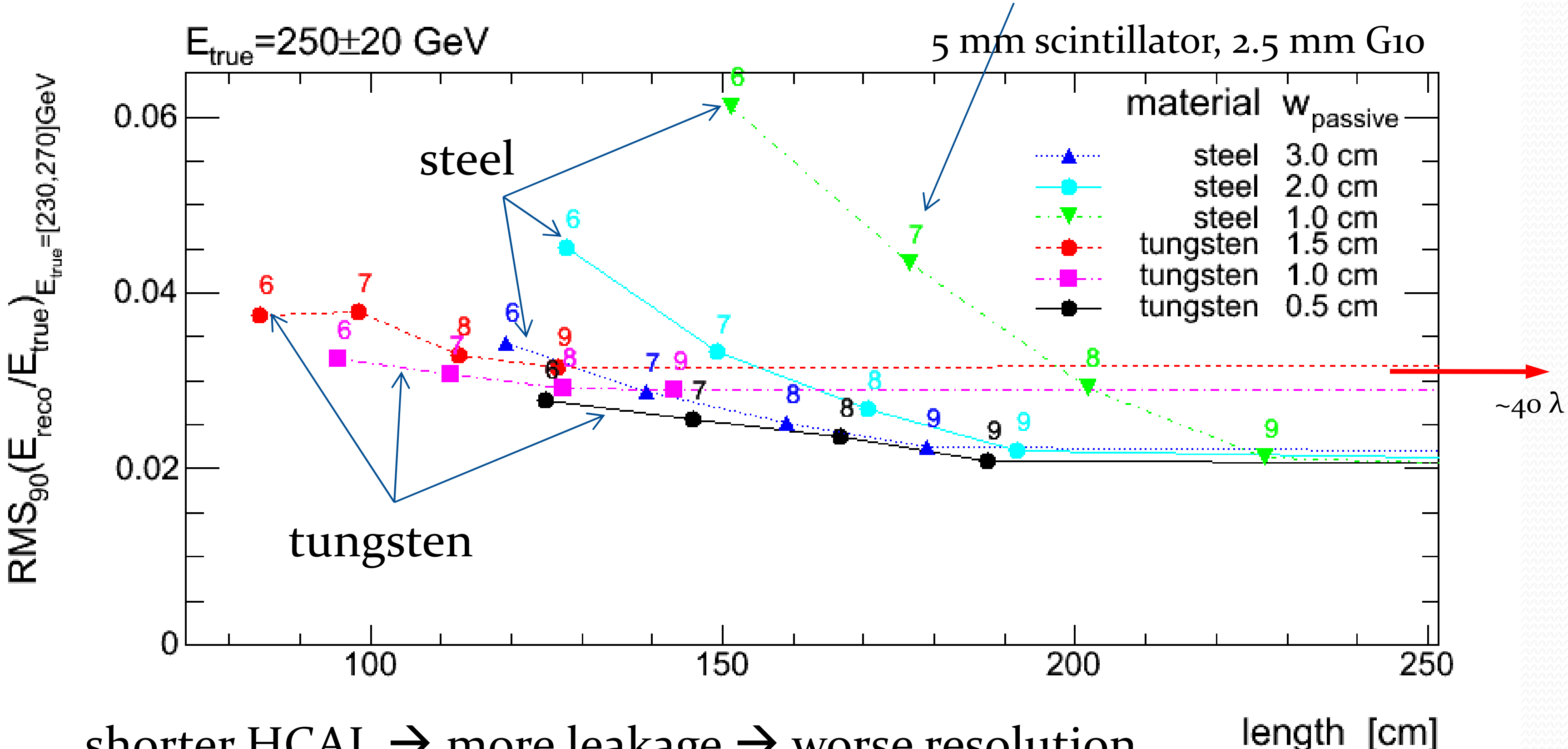
- Tungsten
  - expensive!
  - more contained showers (compared to Fe) with the same HCAL geometrical depth → less leakage
  - smaller shower diameter → better separation of showers (probably good for particle flow)

- final goal → good energy resolution with whole detector

Energy reconstruction with neuronal network

(information from fine granularity of calorimeter not used → traditional approach)
-variables describe shower shape and size and energy
-train NN with pion energy

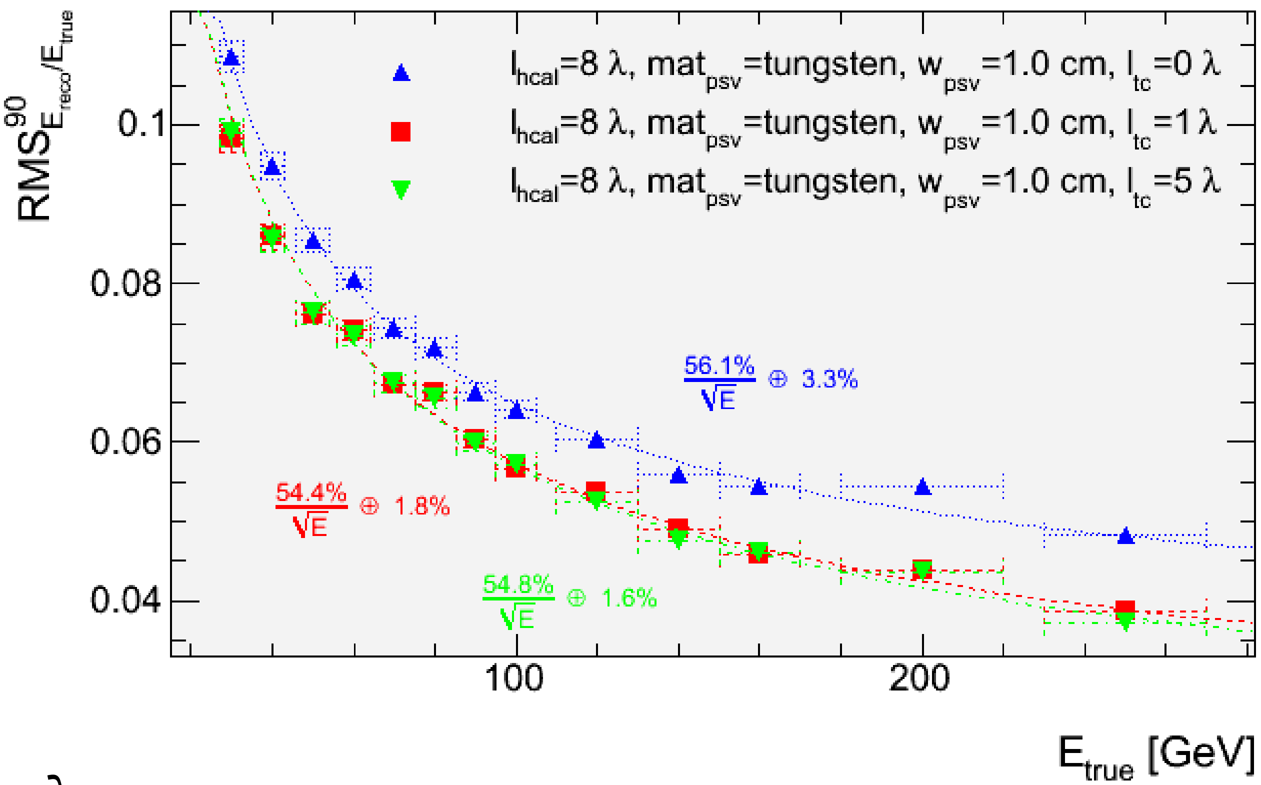
numbers denote HCAL length in units of interaction lengths



shorter HCAL → more leakage → worse resolution

Tail-catcher

tungsten



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

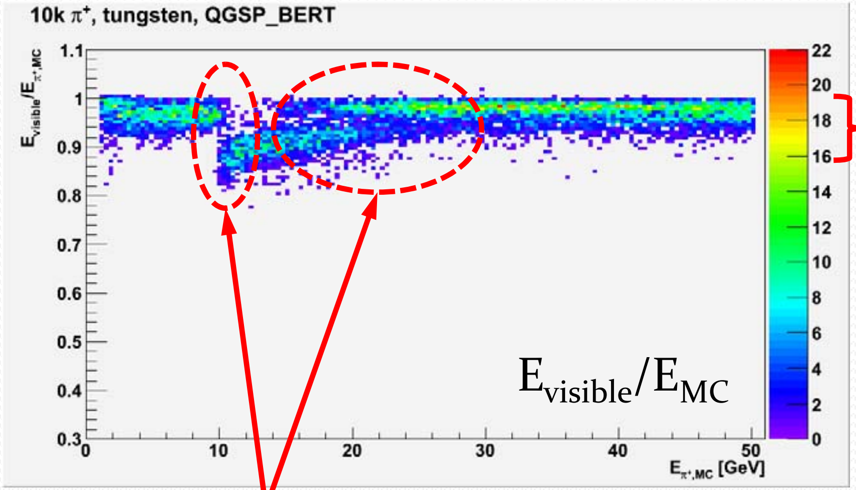
Tungsten HCAL

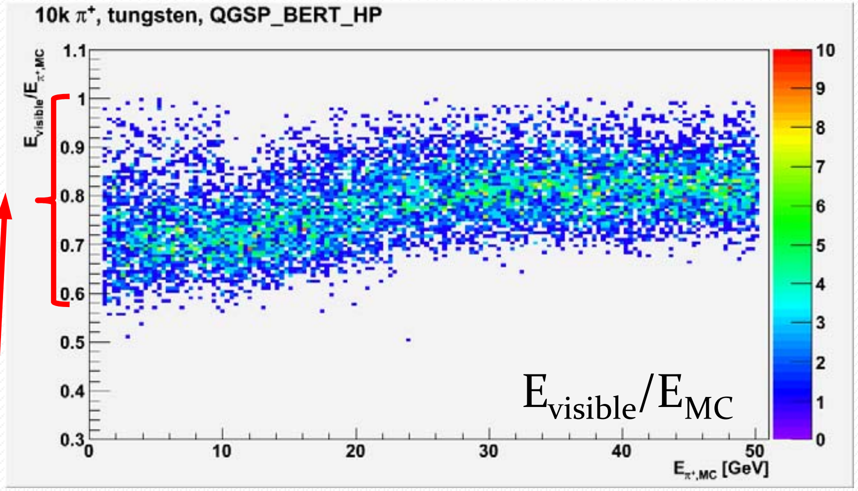
- Tungsten used in ECALs
  - typically ~1λ deep
- No experience with tungsten HCALs
  - ~4 – 9 λ deep
- simulation of tungsten not validated
  - no MC/data comparisons
  - no validation for high granularity
- If tungsten is used → have to be sure, that energy resolution of whole detector is better (PFA)

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

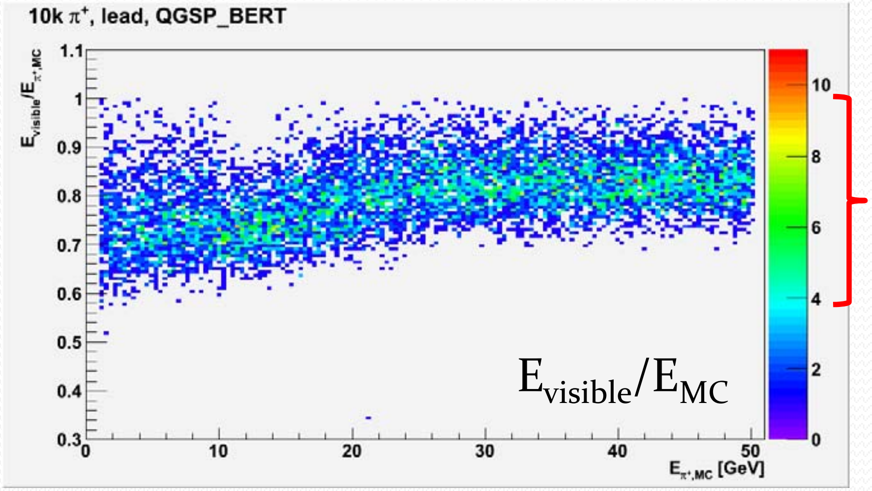
which one can we trust more?

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

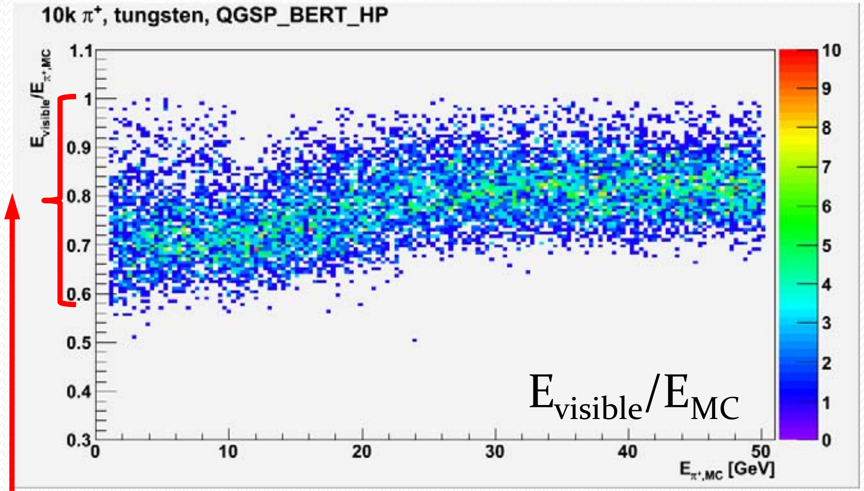
physics-list differences (Geant4)

simulations of pion showers in block of lead/tungsten

lead, QGSP_BERT



tungsten, QGSP_BERT_HP



lead simulations for hadrons are better validated

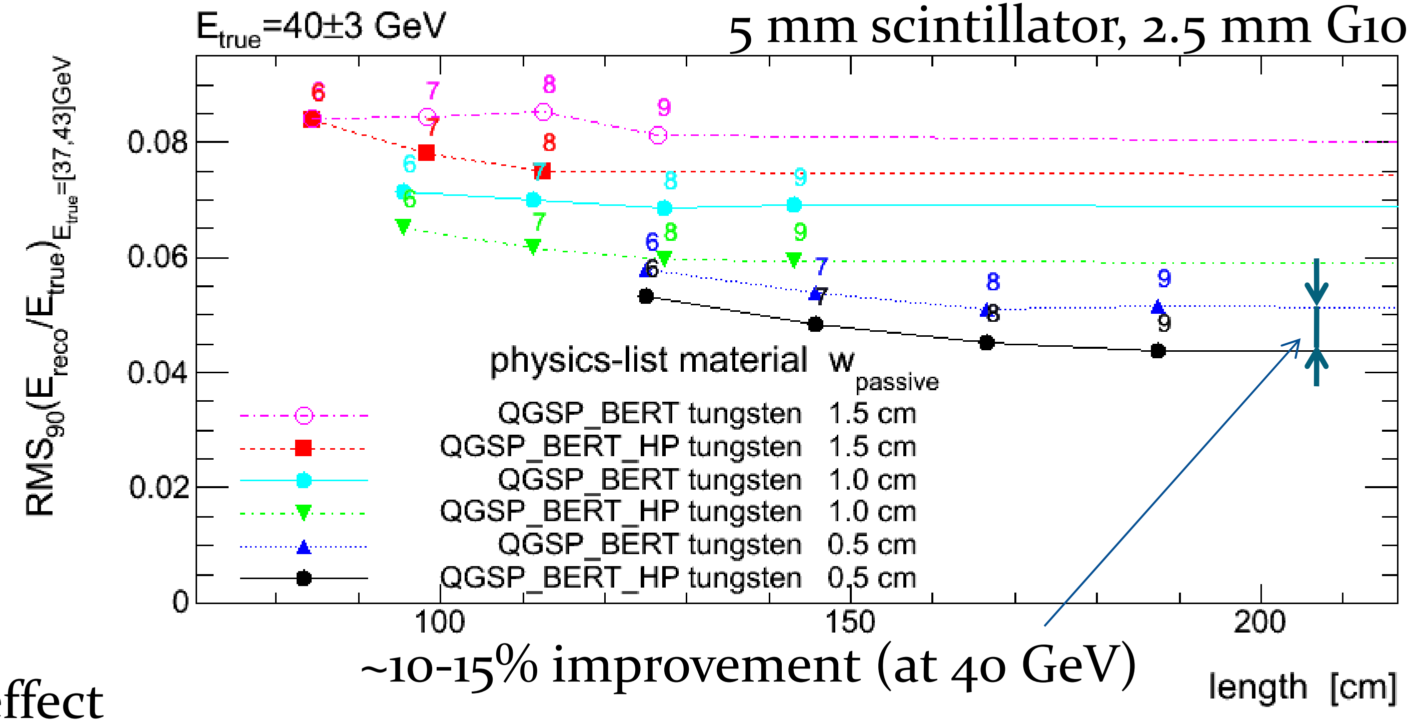
similar widths of lead and tungsten, when HP is used

→ "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)

Further reason for validation

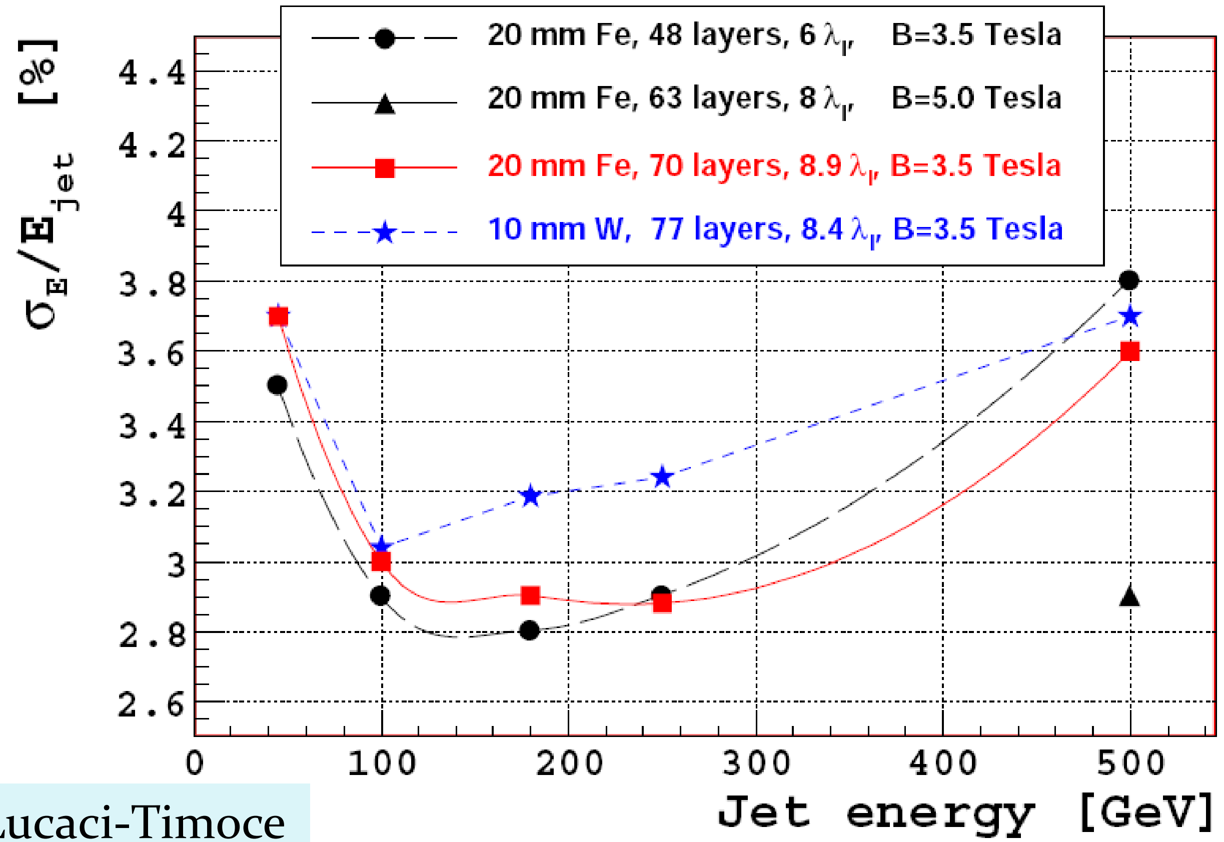
- Time structure of signal broadened by n-content
  - time stamping
    - used to separate signal/background on a time basis
    - (slow) n-content smears out energy deposits in calorimeters
    - know time-structure of n-content to set requirements for time stamping
  - dependent on active material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

Particle flow results so far

Comparison of around 8 ½ interaction lengths of HCAL with Fe and W

→W delivers comparable resolution to Fe

→no optimization of the PFA for W done



Angela Lucaci-Timoce

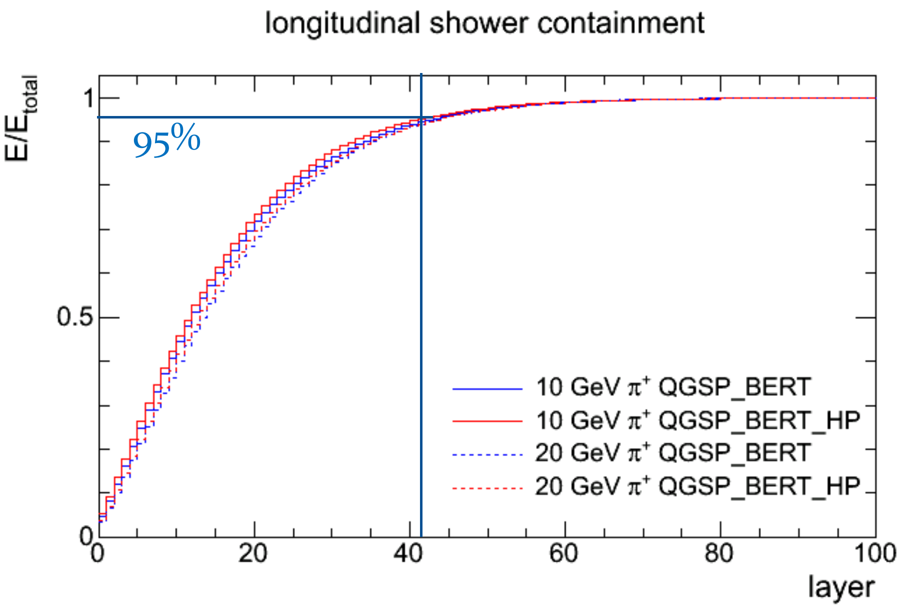
Tungsten HCAL Prototype What can we learn?

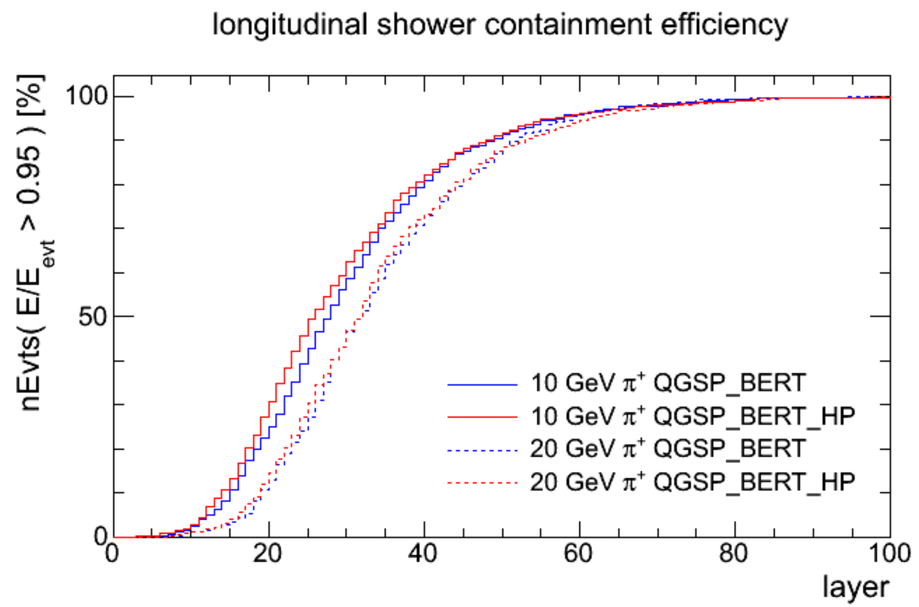
- Physics performance
  - Verify simulations (resolution, shower shapes, ...)
  - Include realistic noise levels (read-out, neutrons, ...)

- Tungsten plate production process
  - Test production of large thin plates
  - Feasibility of needed flatness
  - Machining of tungsten plates
  - Bolting, cutouts

Longitudinal shower size

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



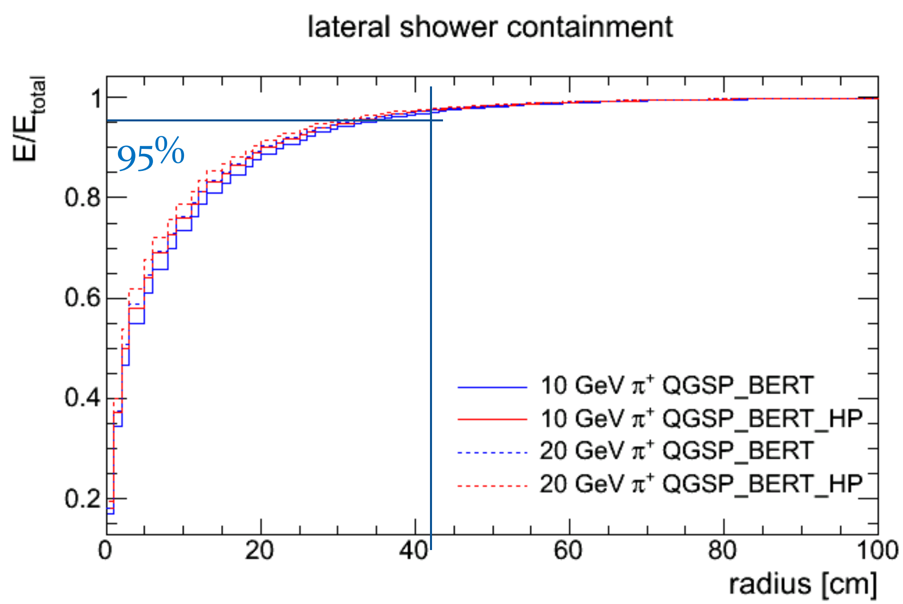


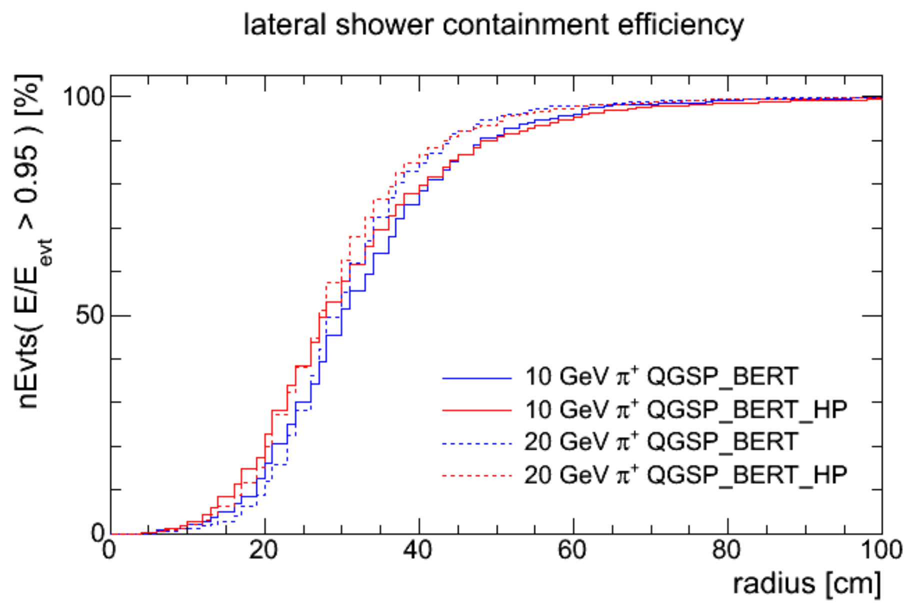
C. Grefe

12 mm tungsten + 5 mm Scint + 2.5 G10

Lateral shower size

95% contained energy → ~40 cm radius





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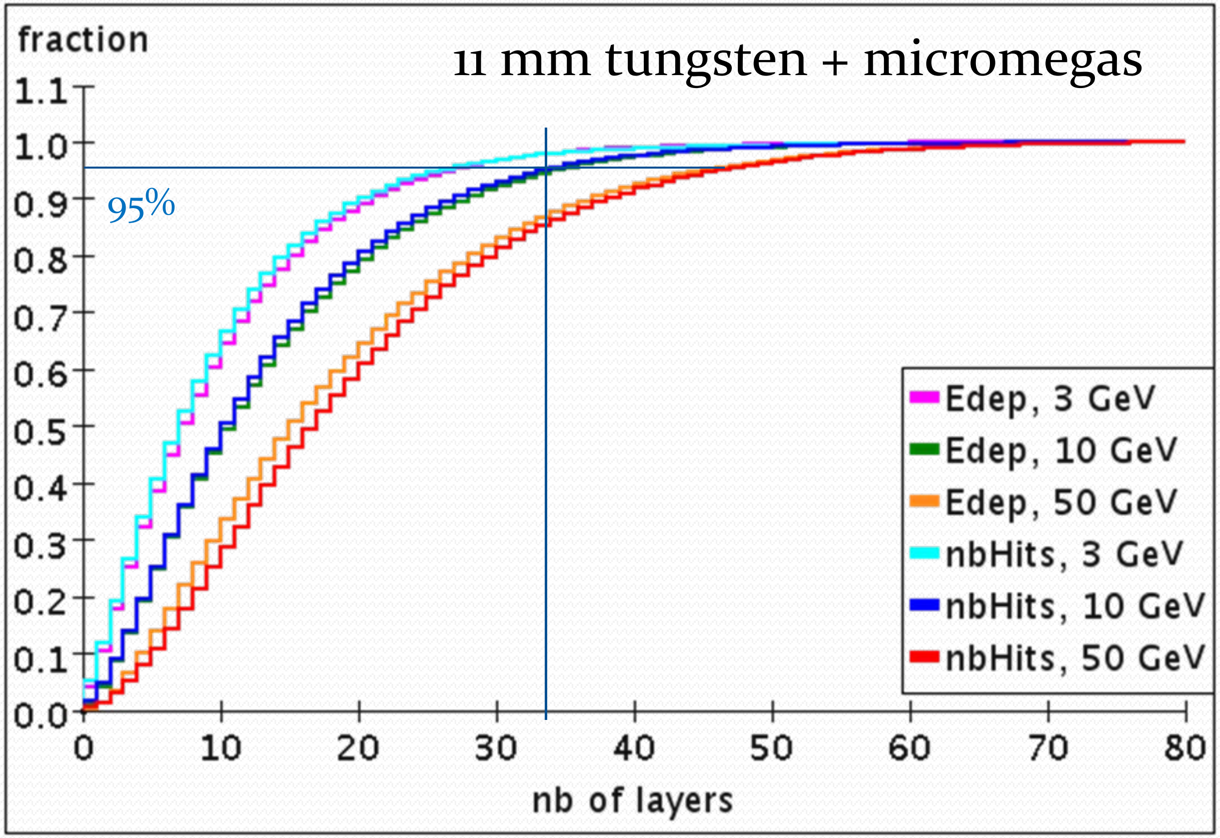
Longitudinal shower sizes: tungsten + micromegas



J. Blaha

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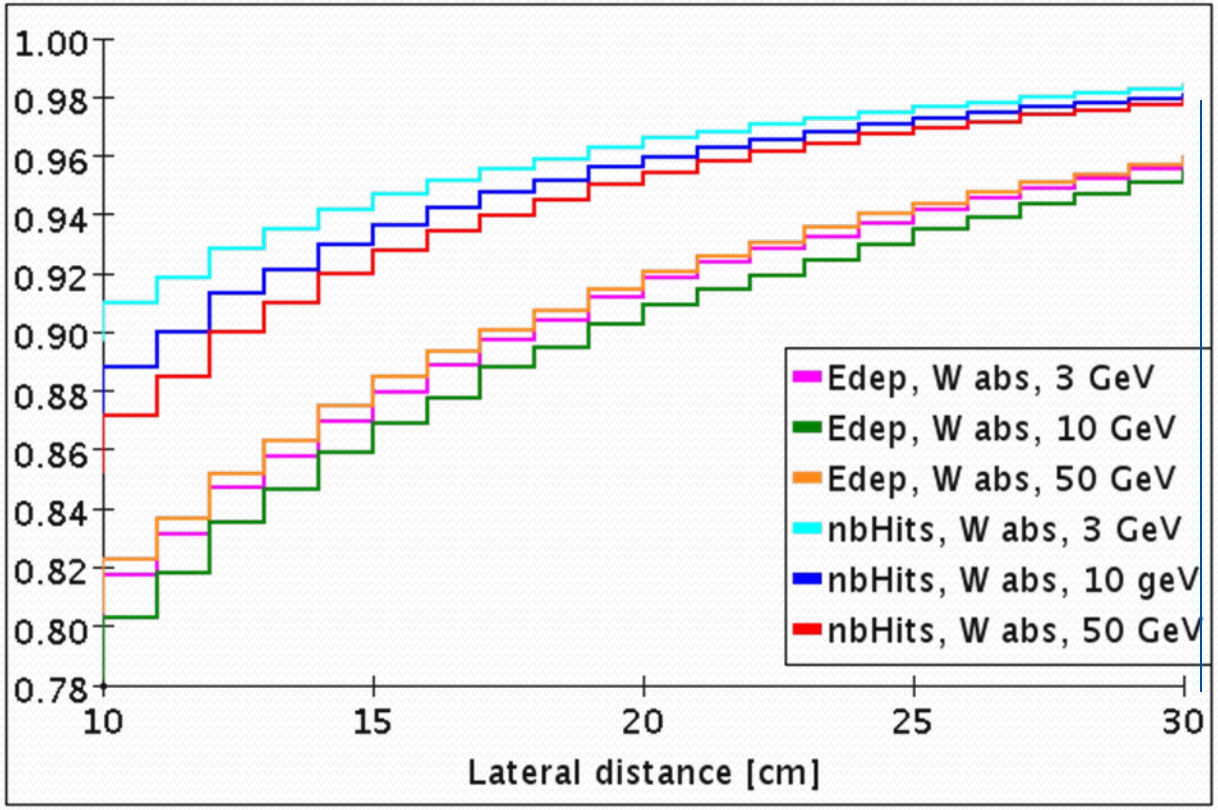


J. Blaha

more about prototype

- see following talk by W.Klempt

Conclusions & Outlook

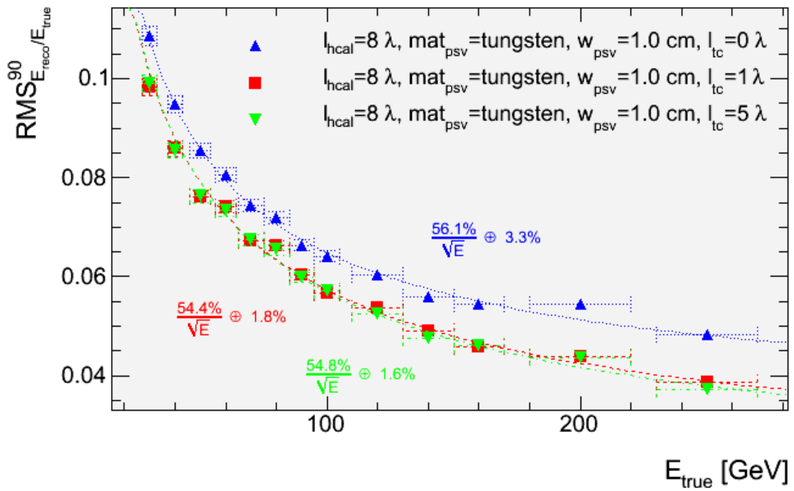
- From tungsten simulations:
  - 8-9 λ 's ECAL+HCAL seems sufficient up to 300 GeV (pions)
  - ~10-15 mm W absorber optimal
  - tail catcher useful
  - choice of GEANT4 physics list important (different results for W simulations)
  - Particle Flow algorithm → W and Fe first results are comparable → will be extended

- From future prototype results:
  - feed back prototype to G4-team

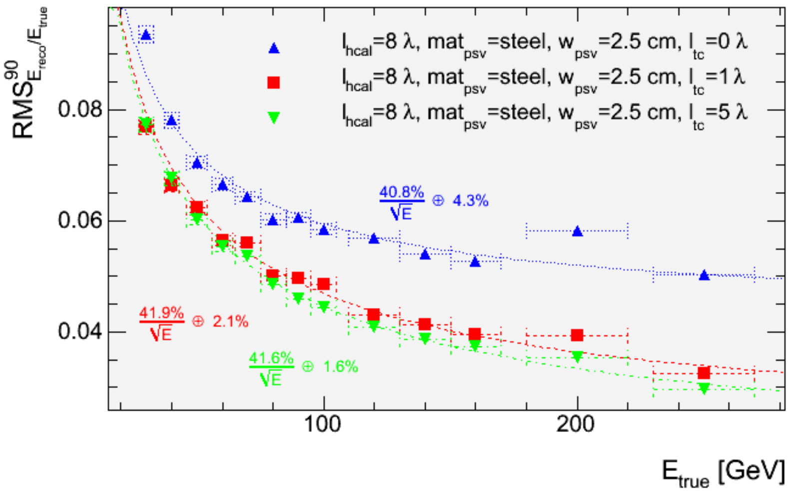
backup

Tail-catcher

tungsten



steel



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