Comparison between Fe and Tungsten HCAL

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Overview

Introduction

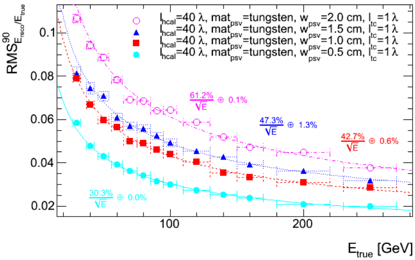
- **CLIC at 3 TeV**: high energetic jets, which need to be (longitudinally and laterally) contained
- Strong constraints imposed by the coil, due to costs and feasibility
- HCAL with **tungsten** absorber may be a solution

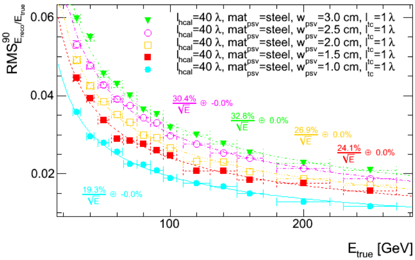
Material	Fe	W
λ_I [cm]	16.77	9.95
X_0 [cm]	1.76	0.35
dE/dx [MeV/cm]	11.4	22.1
$R_M[cm]$	1.72	0.93

- Studies done by the **Linear Collider Detector project at CERN** (Lucie Linssen, Christian Grefe, Peter Speckmayer et al.) and DESY HCAL group
- Questions:
  - How many interactions lengths are needed?
  - Which is the optimal sampling frequency?
  - Does Particle Flow work for a tungsten HCAL?
  - What do GEANT4 models say?

HCAL Stack Simulations

- **Linear Collider Detector project at CERN group**: simulation of an HCAL stack with different geometries (Fe, W, and combination of both); active part: 5 mm scintillator
- Large dimensions to guarantee shower containment: 5×5 m^2 and 25 λ_I
- Simulated 100000 π^+ events between 1 GeV and 300 GeV for each geometry (should cover the energy range of events with more than 3 jets at 3 TeV)





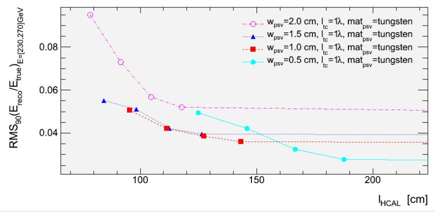
⇒ Finer passive layers are better

⇒ Fe better than W

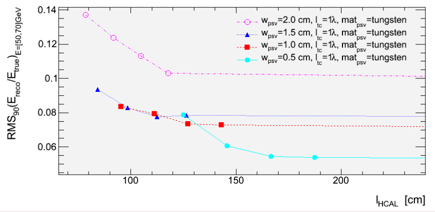
HCAL Stack Simulations: HCAL Depth

- **The CERN group**: one point of each graph for 6, 7, 8 and 9 λ_I

$E_{MC} \sim 250$ GeV



$E_{MC} \sim 60$ GeV

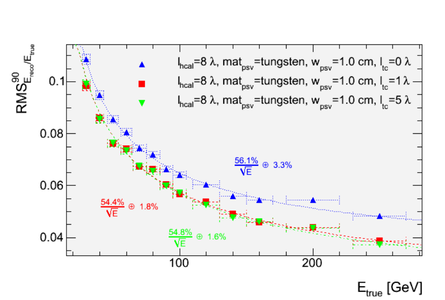


$\Rightarrow$ For an HCAL depth of around 140 cm, W thickness of 1 cm seems optimal

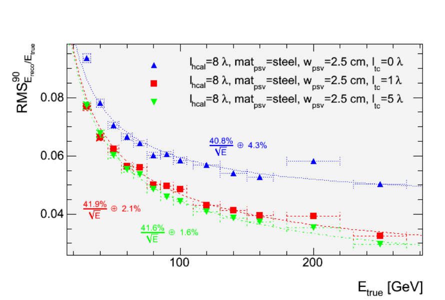
$\Rightarrow$ this corresponds to 8 λ_I's. Taking into account 1 λ_I for ECAL, a 7 λ_I's HCAL seems sufficient for CLIC energies

HCAL Stack Simulations: Impact of a Tail Catcher

Tungsten



Steel

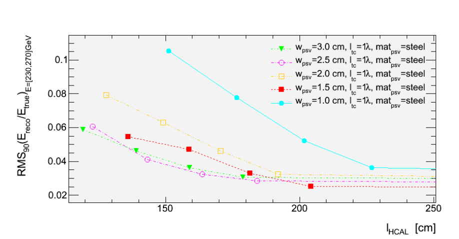


⇒ 0 λ_I implies no active material after coil

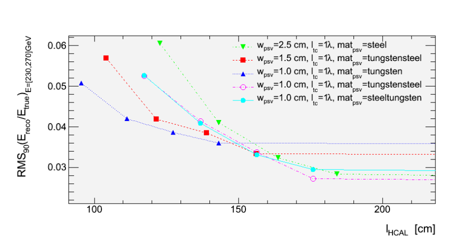
⇒ The resolution is improved by adding a tail catcher of approx. 1 λ_I, but the effect of an even bigger tail catcher is negligible

HCAL Stack Simulations: HCAL Depth

Steel



Steel, tungsten, steel and tungsten

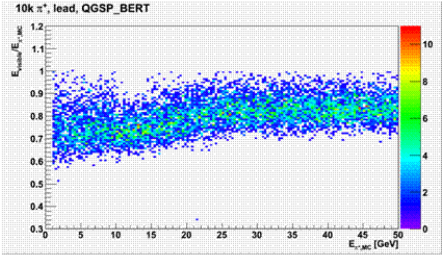


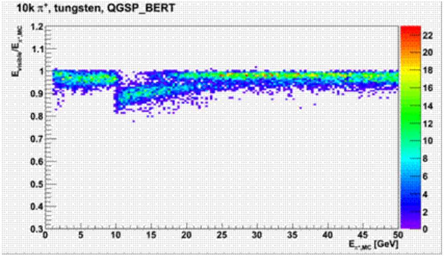
⇒ Fe: better performance than W, but only for a significantly deeper HCAL

⇒ For a Fe+W structure (50% each), the W-Fe-scint case performs slightly better than the Fe-W-scint case (more of the electromagnetic signal reaches the active layers)

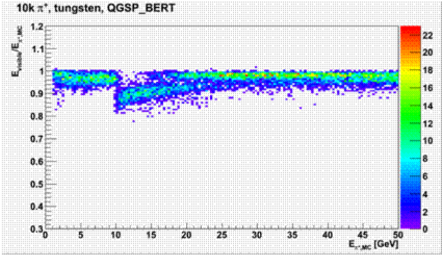
GEANT4 Issues

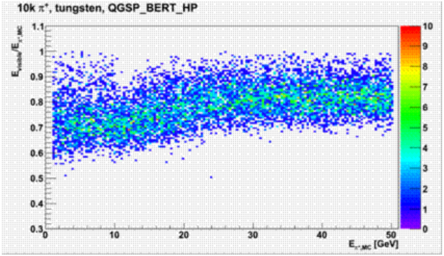
- GEANT4 issues discovered by the CERN group
- **Visible energy** in an infinite block of material for Pb and W: similar for LHEP, but very different for QGSP_BERT (edges due to model change)





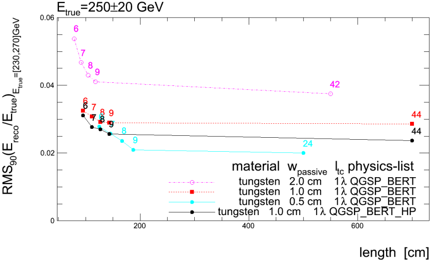
- After discussion with GEANT4 people: high threshold for treating low energy neutrons (to save computing time) ⇒ better use QGSP_BERT_HP (adds high precision neutron tracking)

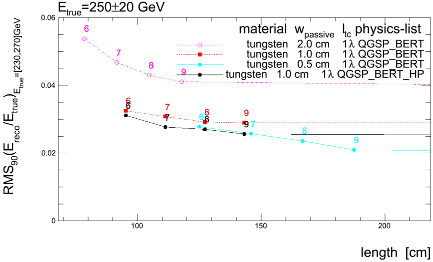




- Spectrum ok now, similar to the Pb case, i.e. more realistic, but much slower simulation
- Simulations with W stack redone, to check effect on resolution

GEANT4 Issues - continued





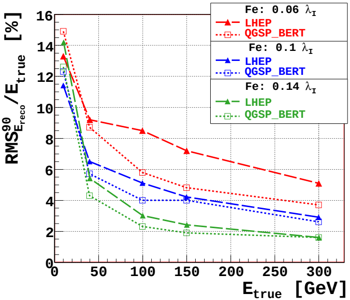
- Improved resolution!
- Explanation: slow neutrons can travel longer, and deposit energy in larger shower, with large fluctuations. Getting rid of them helps reconstruction.

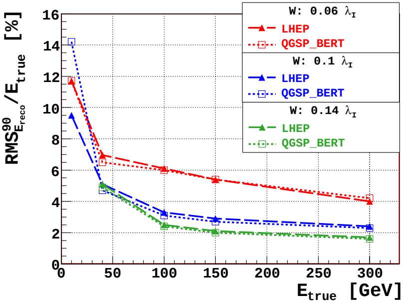
Simulations with CALICE HCAL

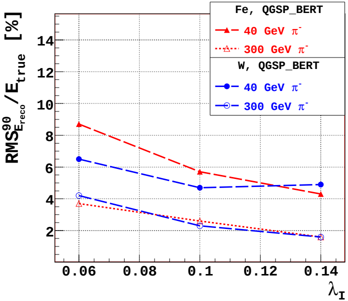
- Mokka simulations of π^- with 10, 40, 00, 150 and 300 GeV
- CALICE HCAL: **38 layers**, active part is **5 mm scintillator**

Fe thickness	W thickness	No. of λ_I's
10 mm	6 mm	0.06
16 mm	10 mm	0.1
23.5 mm	14 mm	0.14

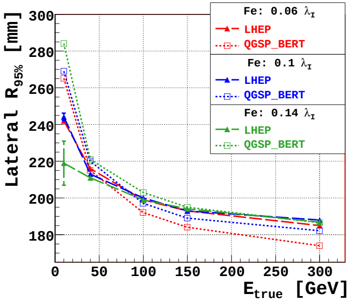
Simulations with CALICE HCAL: Energy Resolution

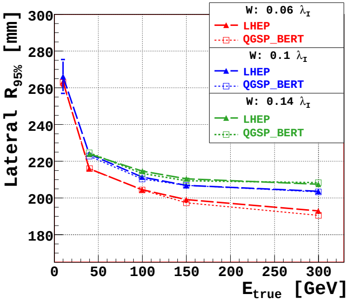


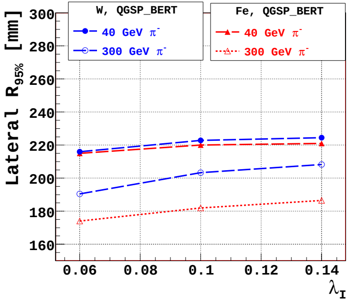




- 40 GeV pions: with finer sampling, W is better
- 300 Gev: Fe and W comparable

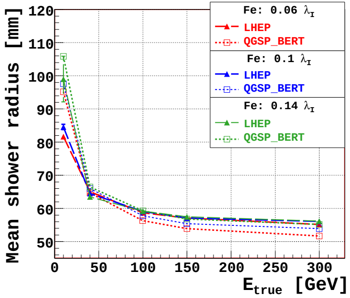


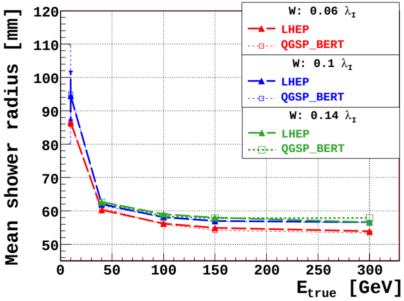


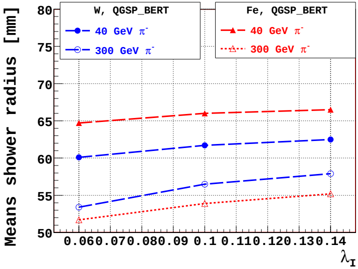


- 40 GeV: $R_{95\%} \approx 22$ cm for both W and Fe
- 300 GeV: 95% containment at smaller radius for Fe

Simulations with CALICE HCAL: Mean Shower Radius







- 40 GeV: smaller radius for W
- 300 GeV: smaller radius for Fe

Particle Flow Results

- The Linear Collider Detector project at CERN uses **10 mm W** and the inner coil radius of the CMS $\rightarrow$ this allows:

  (10 mm W + 5 mm scintillator) $\times$ **77 layers** $\approx 8.4\ \lambda_I$

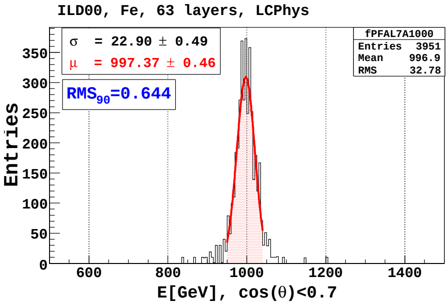
  and for comparison:

  (20 mm Fe + 5 mm scintillator) $\times$ **70 layers** $\approx 8.9\ \lambda_I$

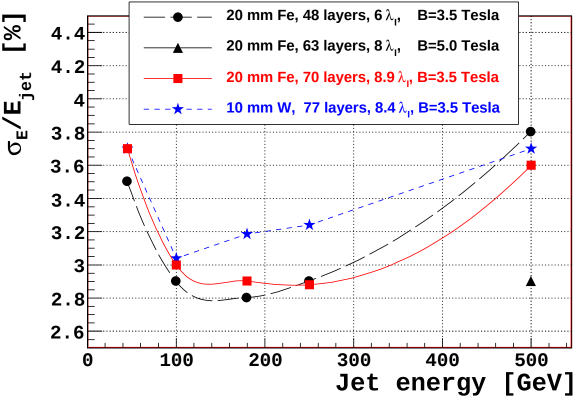
- Use these configurations and run Particle Flow Algorithm (Mark Thomson)
- No tuning of the algorithm for high energy
- Example for 8 λ_I HCAL, Fe absorber, $B = 5.0$ Tesla:

  $\sigma_E/E \approx 64\%/\sqrt{E/GeV}$

- Results consistent with the ones from Mark



Particle Flow Results - continued



- Jet energy resolution for W comparable with the one for Fe (at least for low energies), but
- No tuning of Particle Flow used

Conclusions

- Joined efforts of the Linear Collider Detector project at CERN group and CALICE AHCAL group in view of CLIC calorimetry
- From tungsten simulations:
  - 8-9 λ_I's ECAL+HCAL sufficient up to 300 GeV
  - 10 mm W absorber optimal
  - 1 λ_I tail catcher useful
  - Used GEANT4 model important (different results for W simulations)
  - Particle Flow algorithm gives results comparable to Fe
- For future of joined effort, see talk of Christian Grefe