W HCAL simulations and test-beam plans

Peter Speckmayer, LCWS2010, Beijing

Outline

- Calorimetry (HCAL) for higher collision energies

- Test-beam
  - requirements
  - constraints

- Test-beam
  - status
  - outlook

Calorimetry

for a high energy future linear collider detector

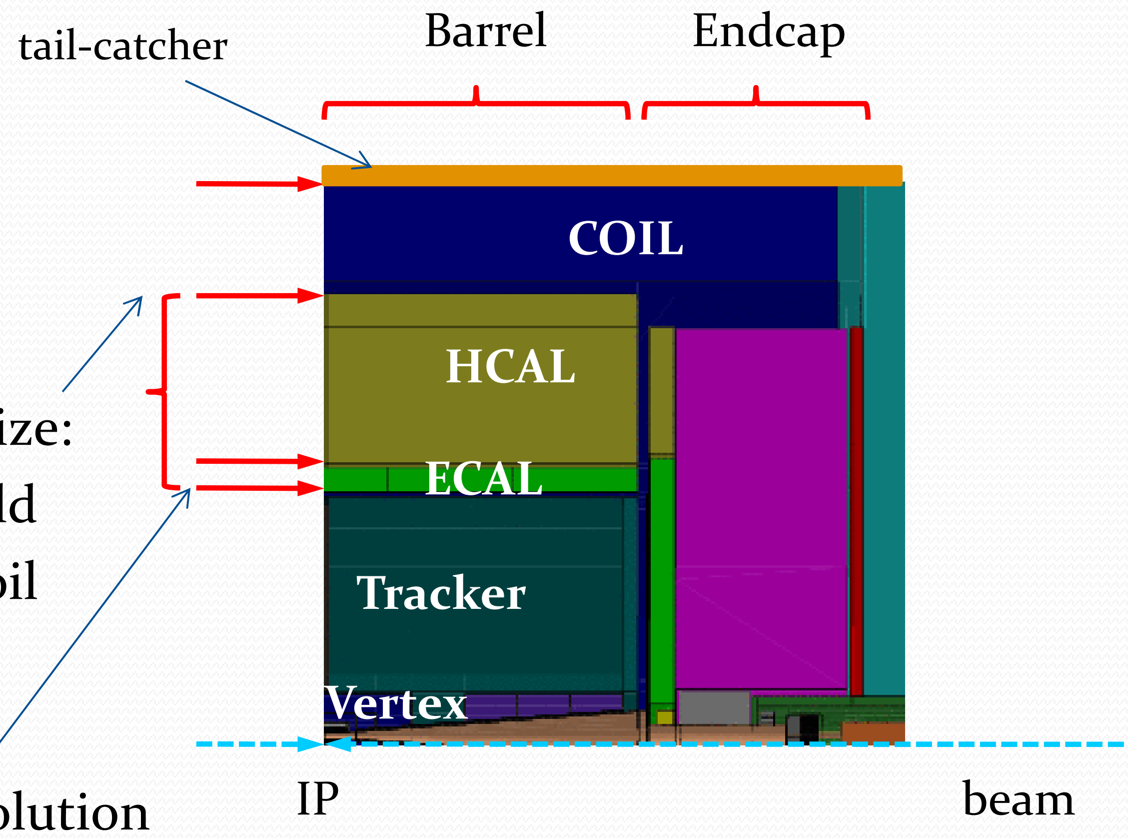
Considerations for HCAL depth and material

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, … ?

	λ (cm)	X_o (cm)	R_M (cm)
Fe	16.77	1.757	1.719
W	9.946	0.3504	0.9327
Fe/W	1.686	5.014	1.843

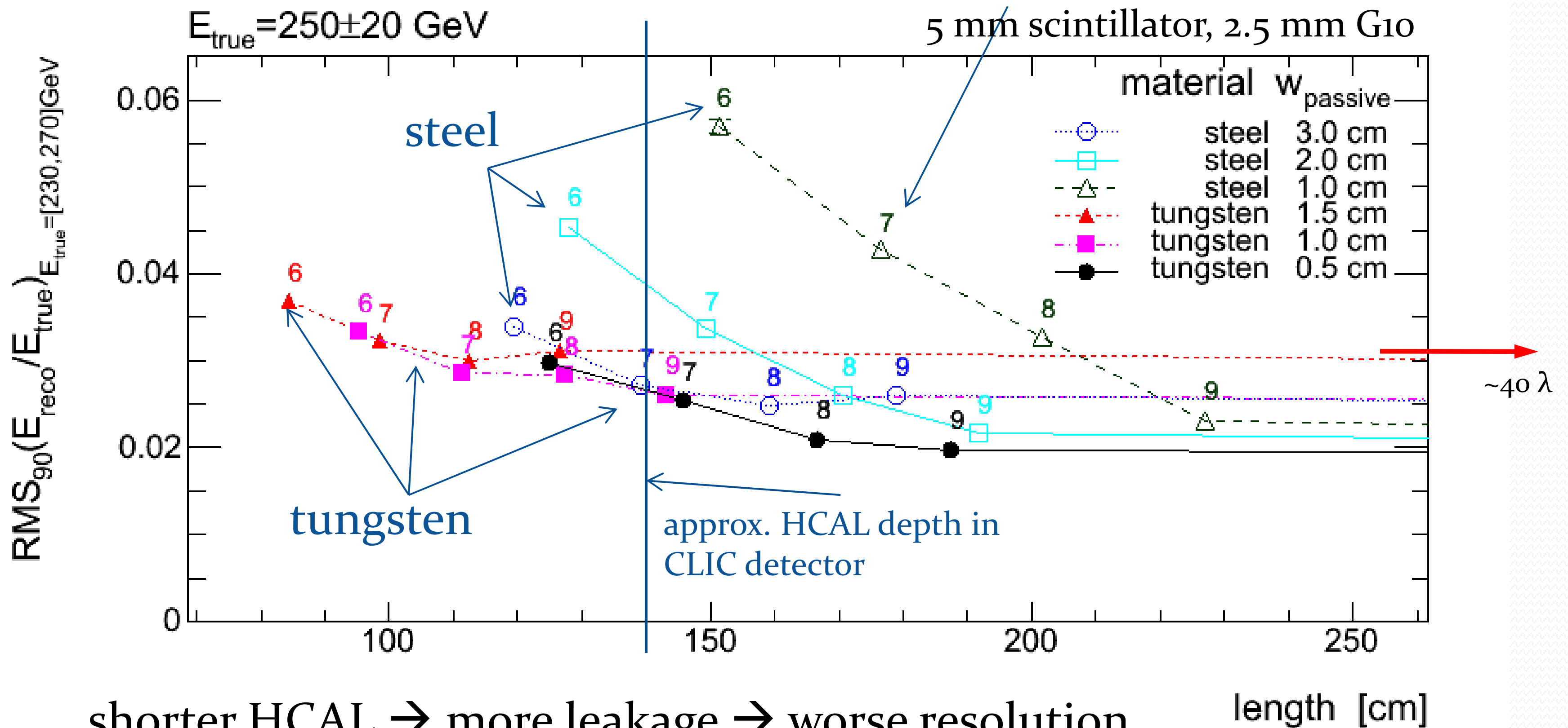
- Tungsten
  - expensive
  - more contained showers (compared to Fe) with the same HCAL geometrical depth → less leakage
  - smaller shower diameter → better separation of showers (probably good for particle flow)
  - different ratios (Fe/W) of X_o and λ → electromagnetic parts of showers get more "compressed" than hadronic parts compared to Fe

- final goal → good energy resolution with whole detector (PFA)

Energy resolution: W/Fe

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

numbers denote HCAL length in units of interaction lengths



shorter HCAL → more leakage → worse resolution

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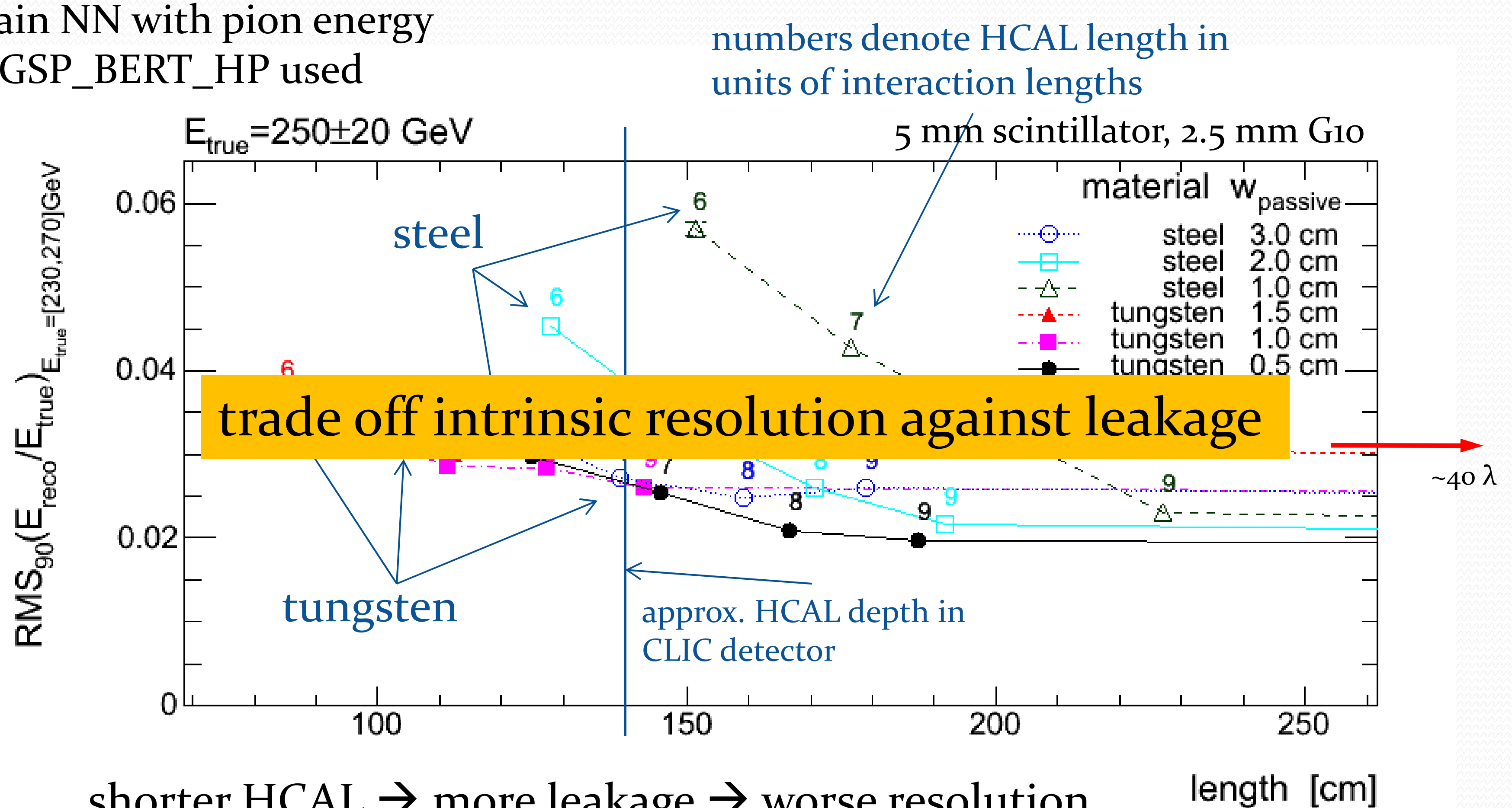
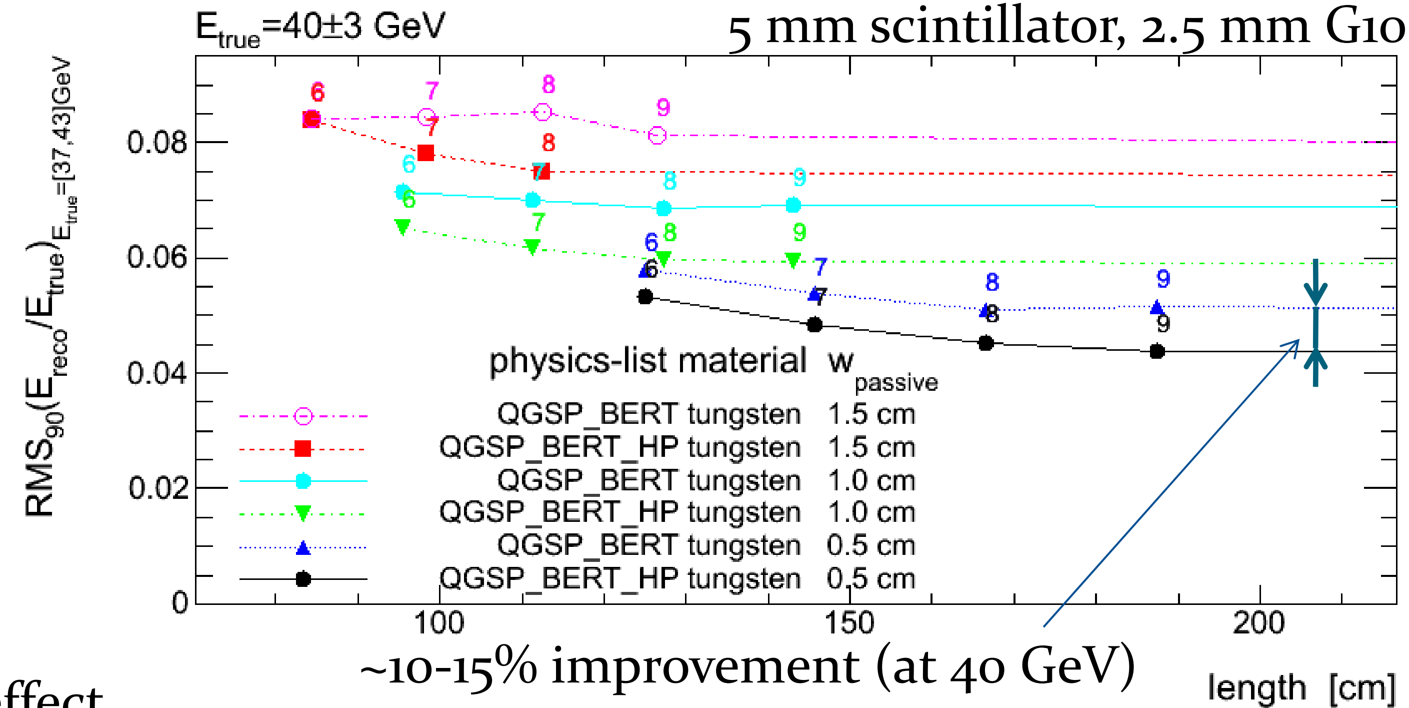


shorter HCAL → more leakage → worse resolution

Effect of physics list on predicted resolution

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

5 mm scintillator, 2.5 mm G10



~10-15% improvement (at 40 GeV)

→considerable effect

→but: perfect readout assumed, no cut-off in time

→why: n are captured farther away from shower core (→2γ)

→ "halo" produced which reduces reconstruction performance.

→removing halo (with HP n tracking)

Experimental validation of simulations with a test-beam

- Validate detailed picture of showers in W
  - in space ...
  - ... and time
  - validated simulations
    - trust more in detector simulations → trust more in detector optimizations
    - trust more in PFA

- Time structure of signal broadened by n-content
  - time stamping (important in CLIC environment)
    - 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

- validate physics lists (QGSP_BERT, QGSP_BERT_HP, etc.)

W HCAL testbeam

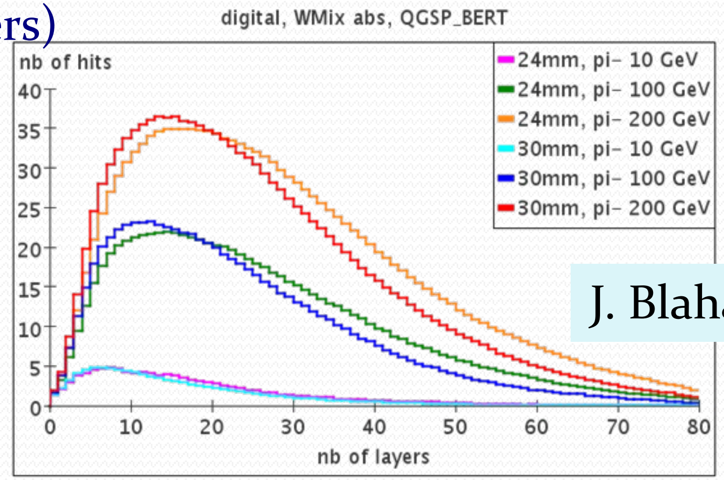
Design

Simulations of test-beam

- Several set-ups simulated
  - (by C.Grefe, J.Blaha, A.Lucaci-Timoce)
  - energies: 3 to 200 GeV
    - test-beam initially with E smaller than ~10 GeV
    - ... but preserve option to go to higher energies later on
  - absorber materials: W, W alloy, Fe (for comparison)
  - active materials: Scintillator and gas

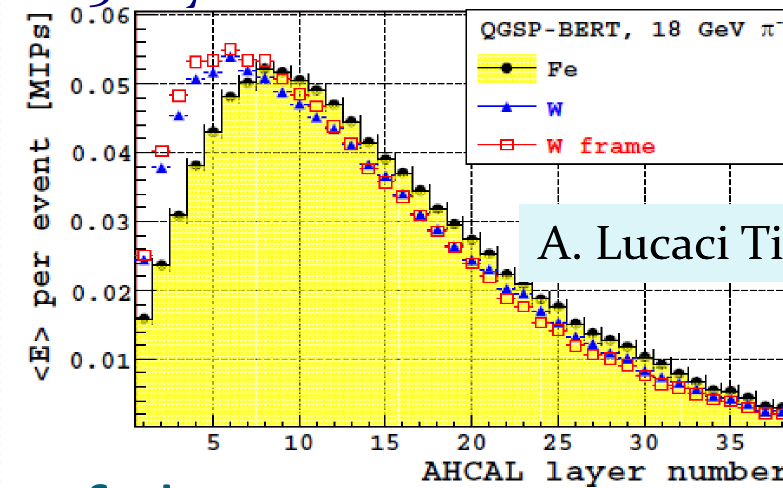
Longitudinal shower profiles

10 mm WMix + µMegas (two 2 mm Fe covers)



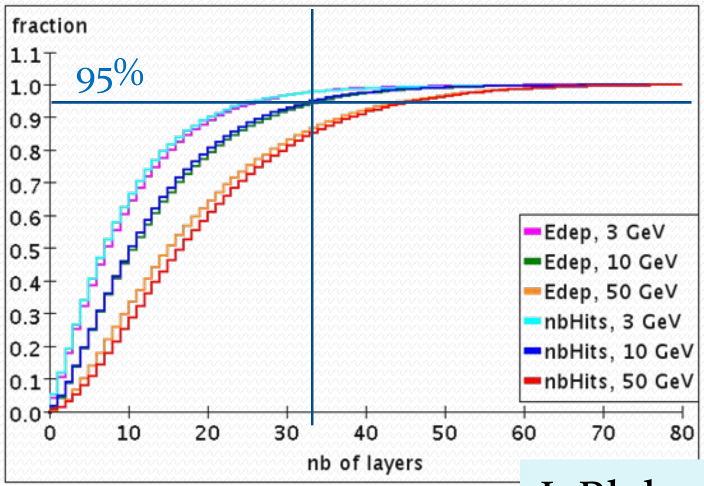
J. Blaha

10 mm W + 2 mm air + 5 mm scint, 38 layers AHCAL



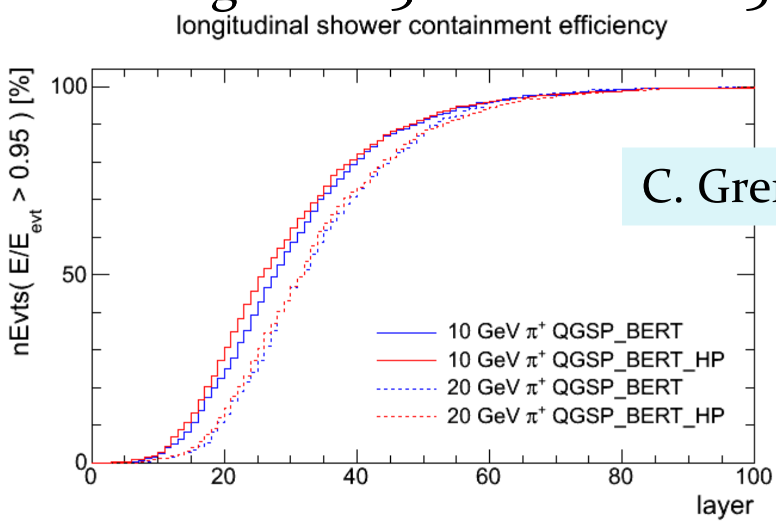
A. Lucaci Timoce

Longitudinal containment of showers



J. Blaha

12 mm tungsten + 5 mm Scint + 2.5 G10



C. Grefe

Longitudinal shower profiles

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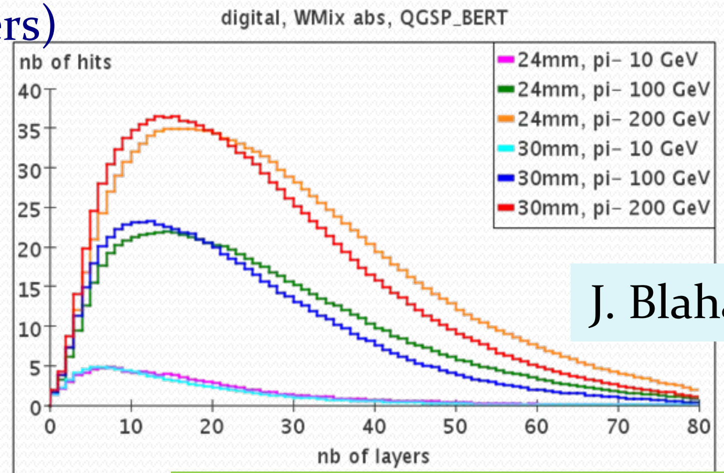

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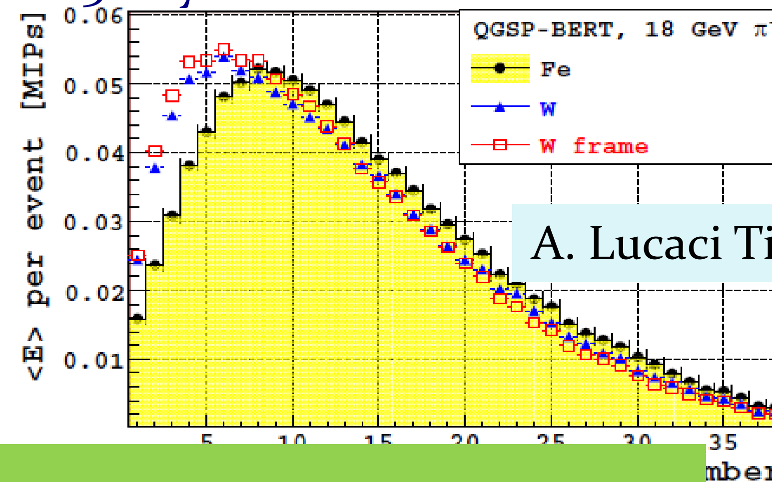
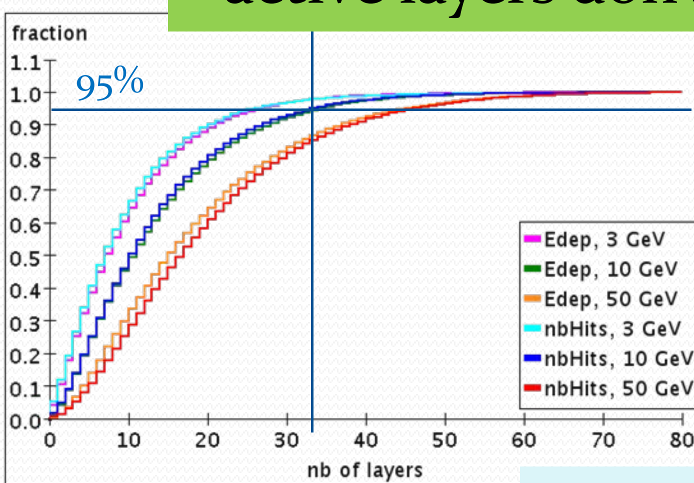


A. Lucaci Timoce

- different simulations agree
- active layers don't change the general picture



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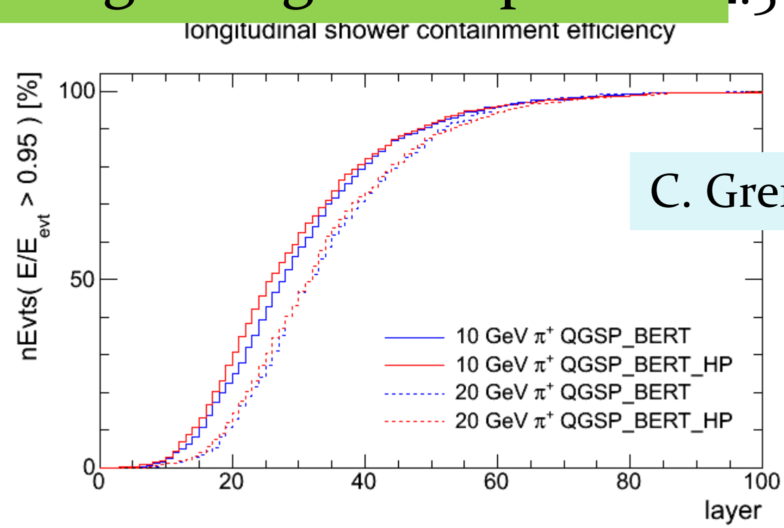

C. Grefe

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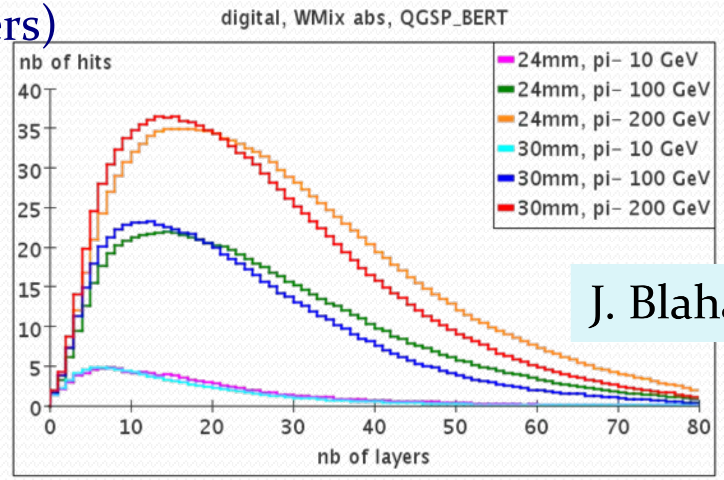

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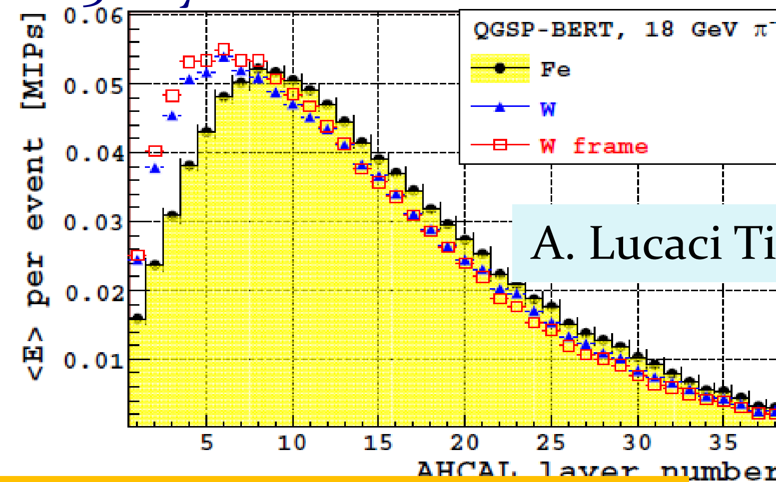
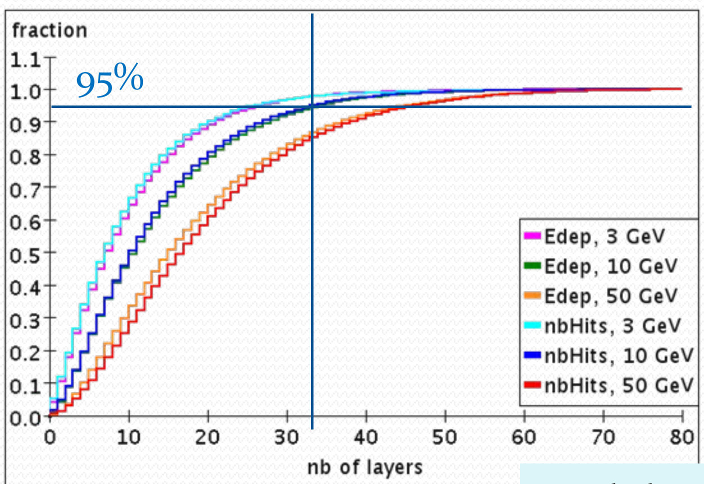


A. Lucaci Timoce

Longitu

95% of shower energy deposited in ~40 layers

12 mm tungsten + 5 mm Scint + 2.5 G10



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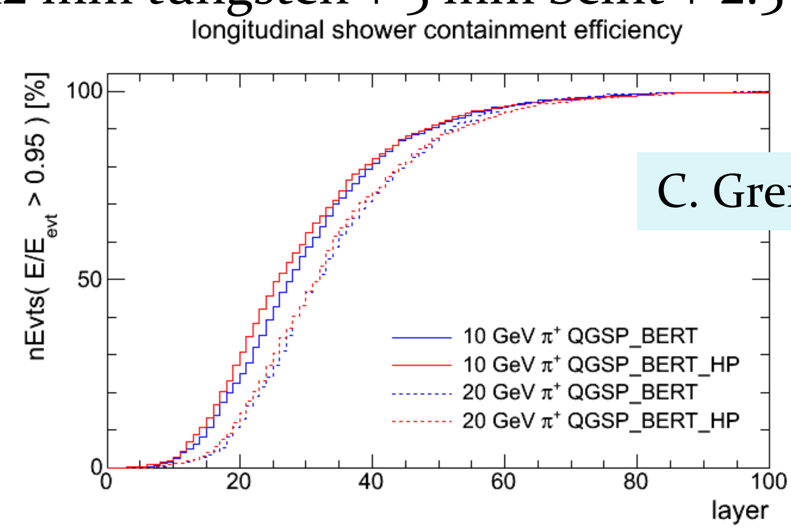
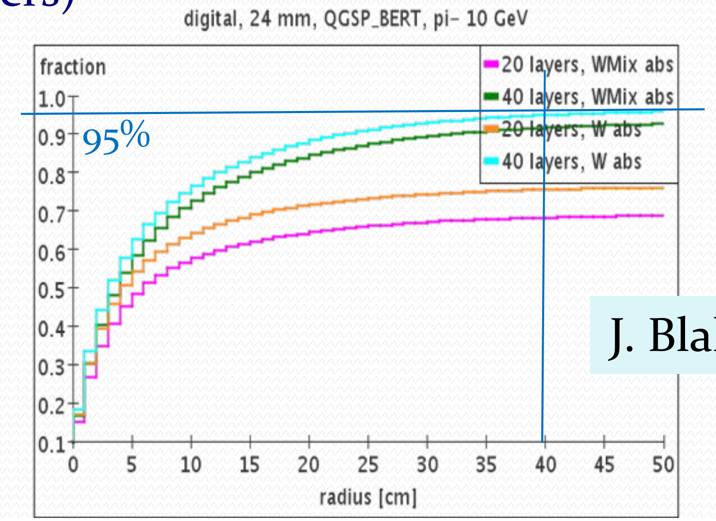


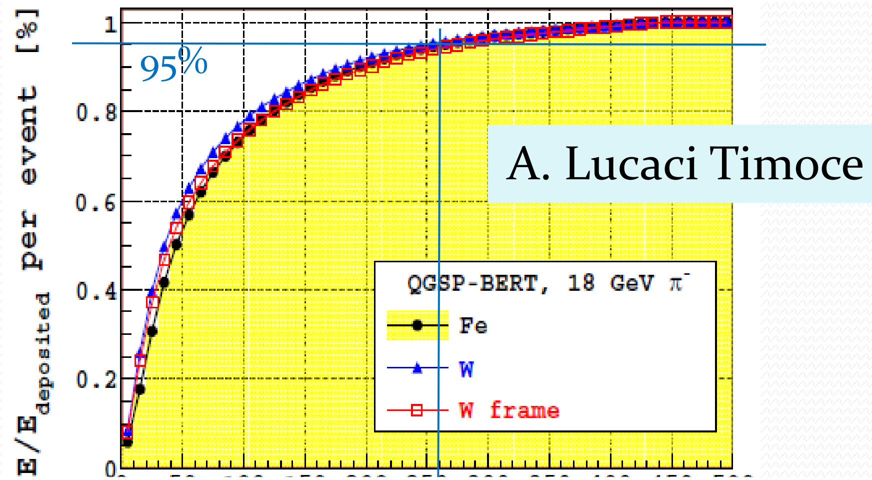
C. Grefe

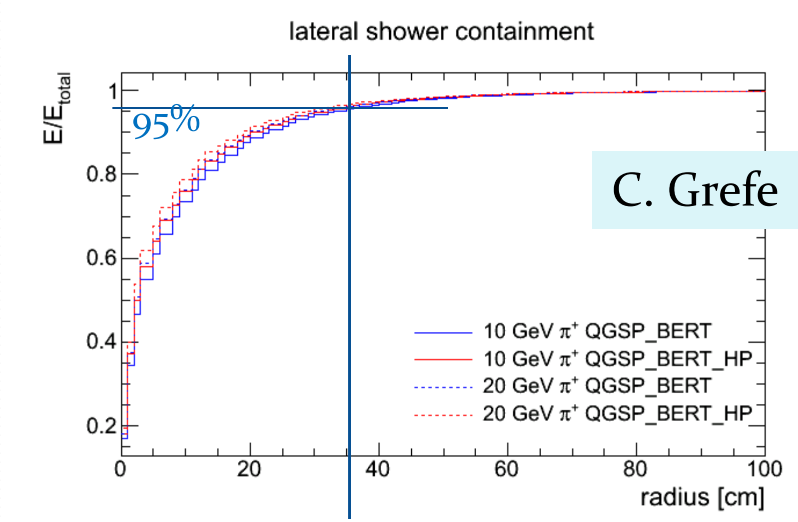
Lateral shower size

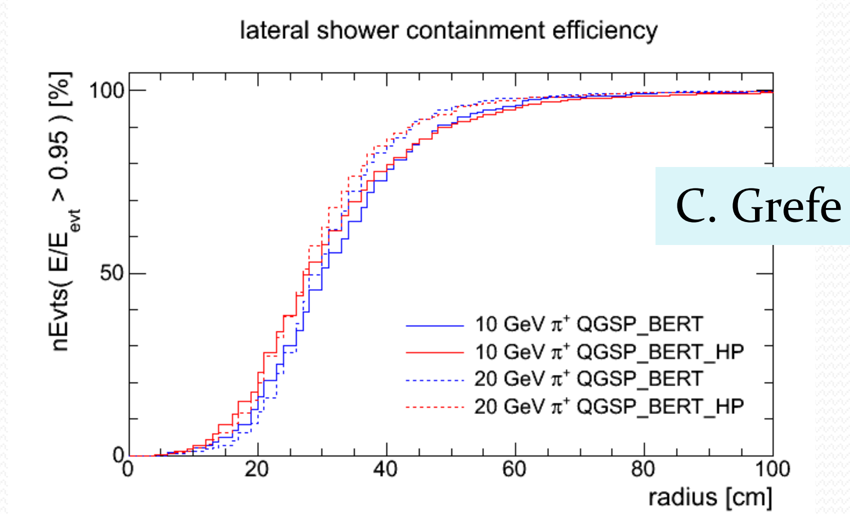
10 mm WMix + μMegas (two 2 mm Fe covers)

10 mm W + 2 mm air + 5 mm scint, 38 layers AHCAL









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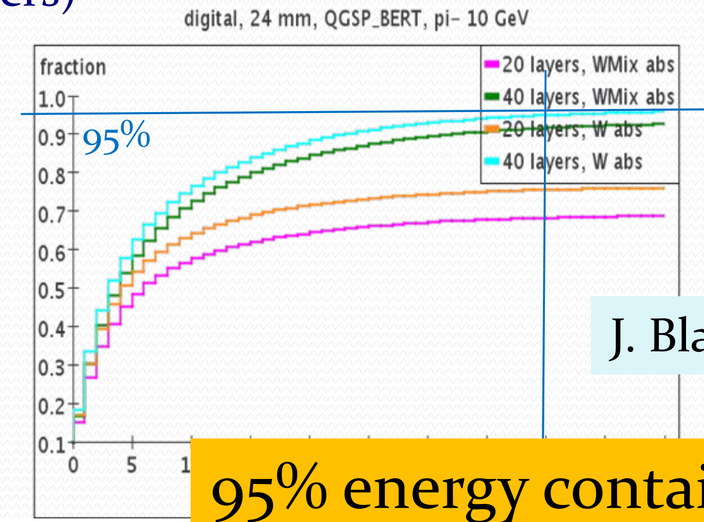

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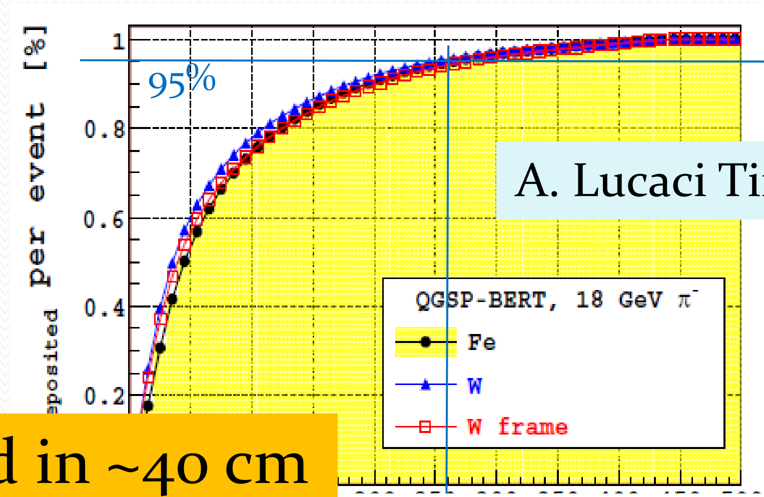
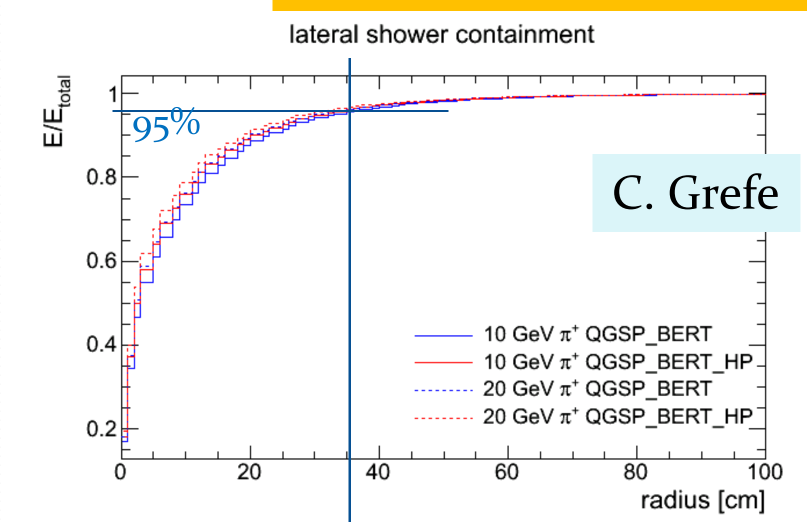
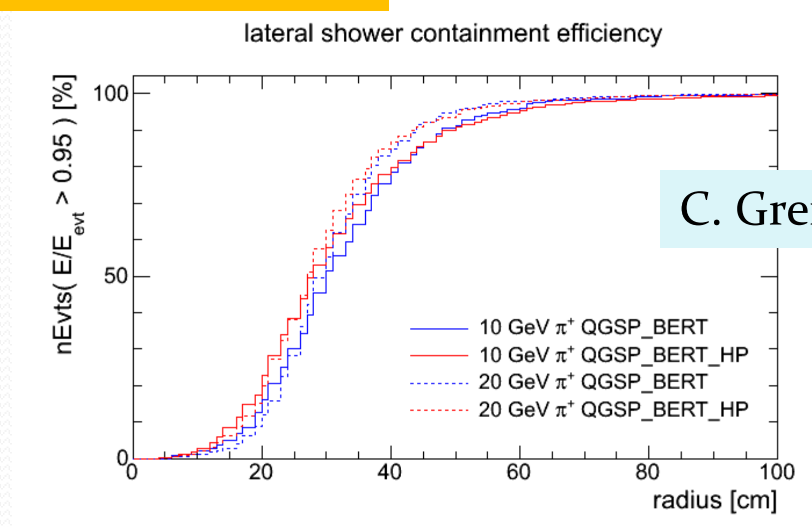


95% energy contained in ~40 cm





Conclusions of study results

- #layers: ~40
  - ~4.8 λ
  - cost constraints → initial configuration with 20 layers

- Radius:
  - take into account:
    - limited length
    - absorber material
    - energy containment, fraction of fully contained events (>95%)
    - existing active modules

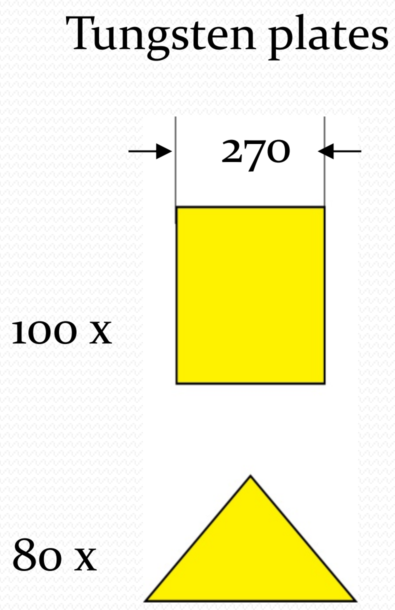
  - safe choice →~40 cm

W HCAL testbeam

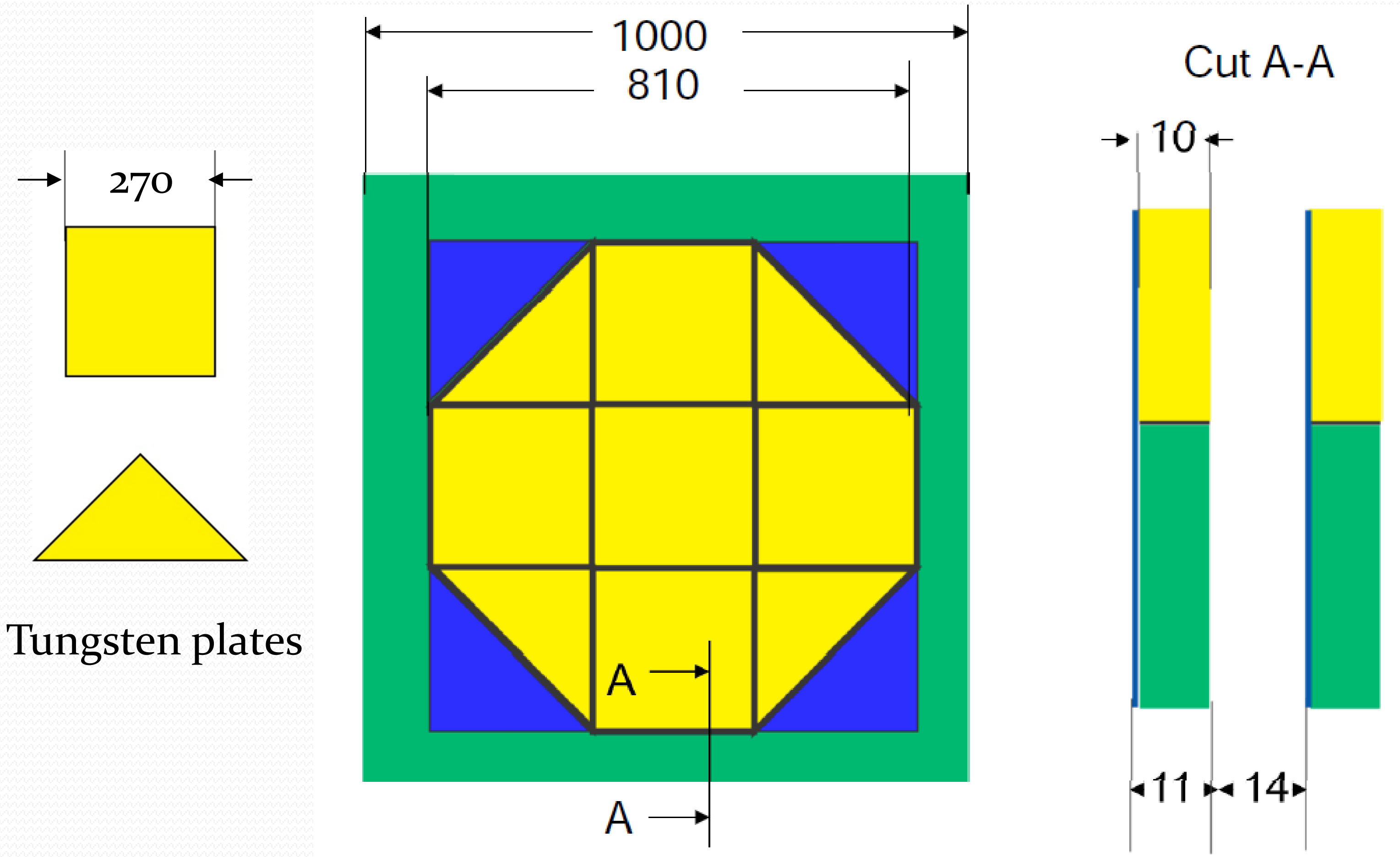
Preparation

Tungsten plates

- Start with 20 layers
- Market servey on tungsten supply
  - 3 positive answers received
- Invitation to tender (closes 12.04.2010)
- Place order by 30.04.2010
- Receive 4 batches of 25 squares and 20 triangles in June & July
- Start to equip absorber plates from 15 June onwards



Design of Frames



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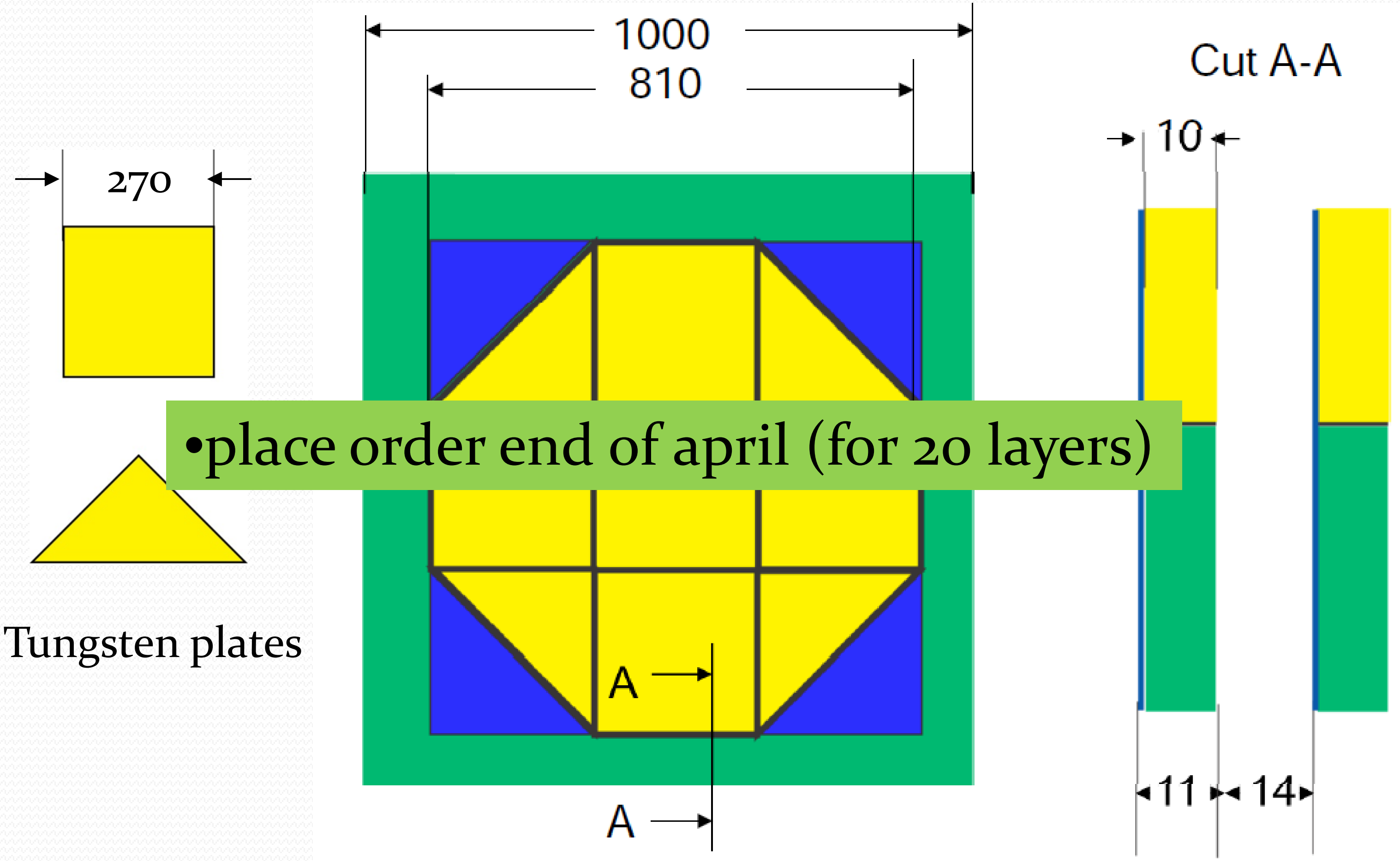
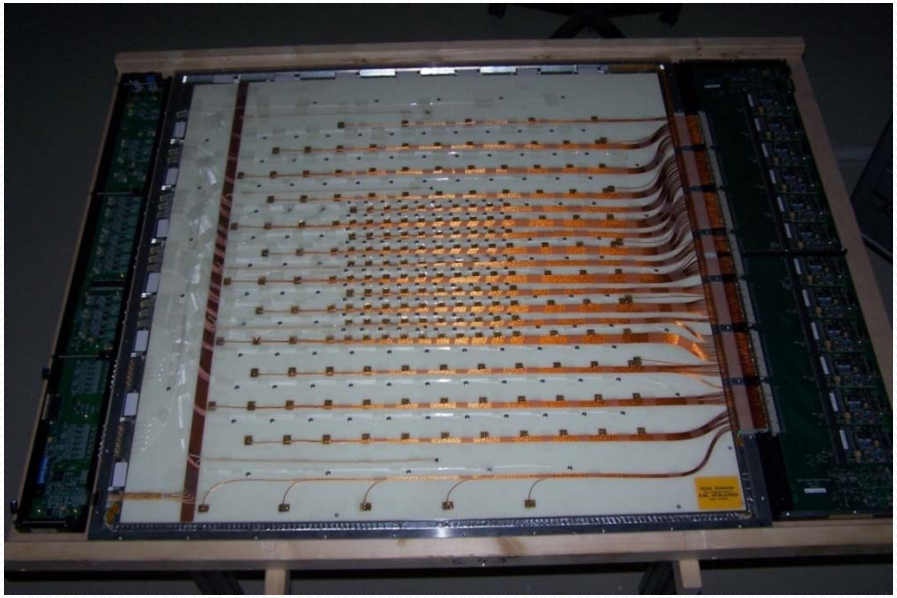
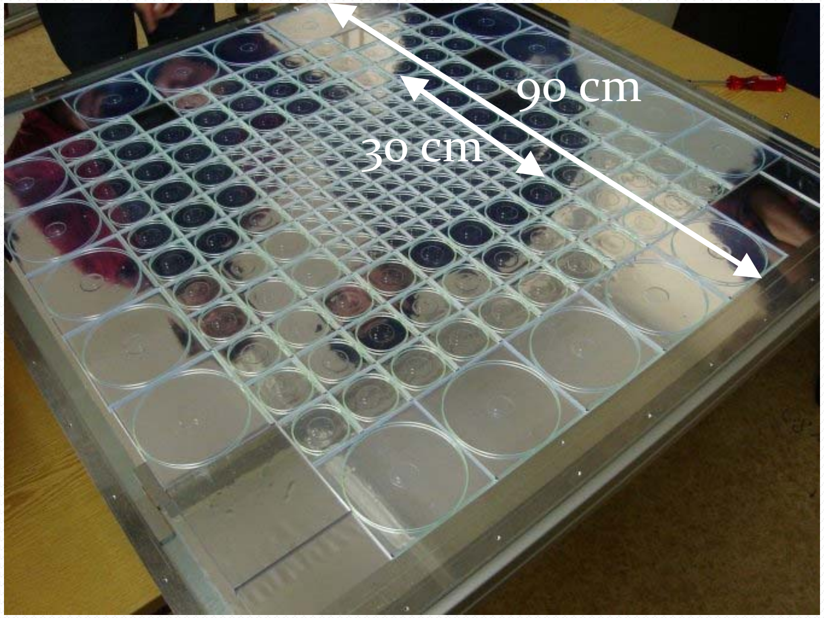


- place order end of april (for 20 layers)

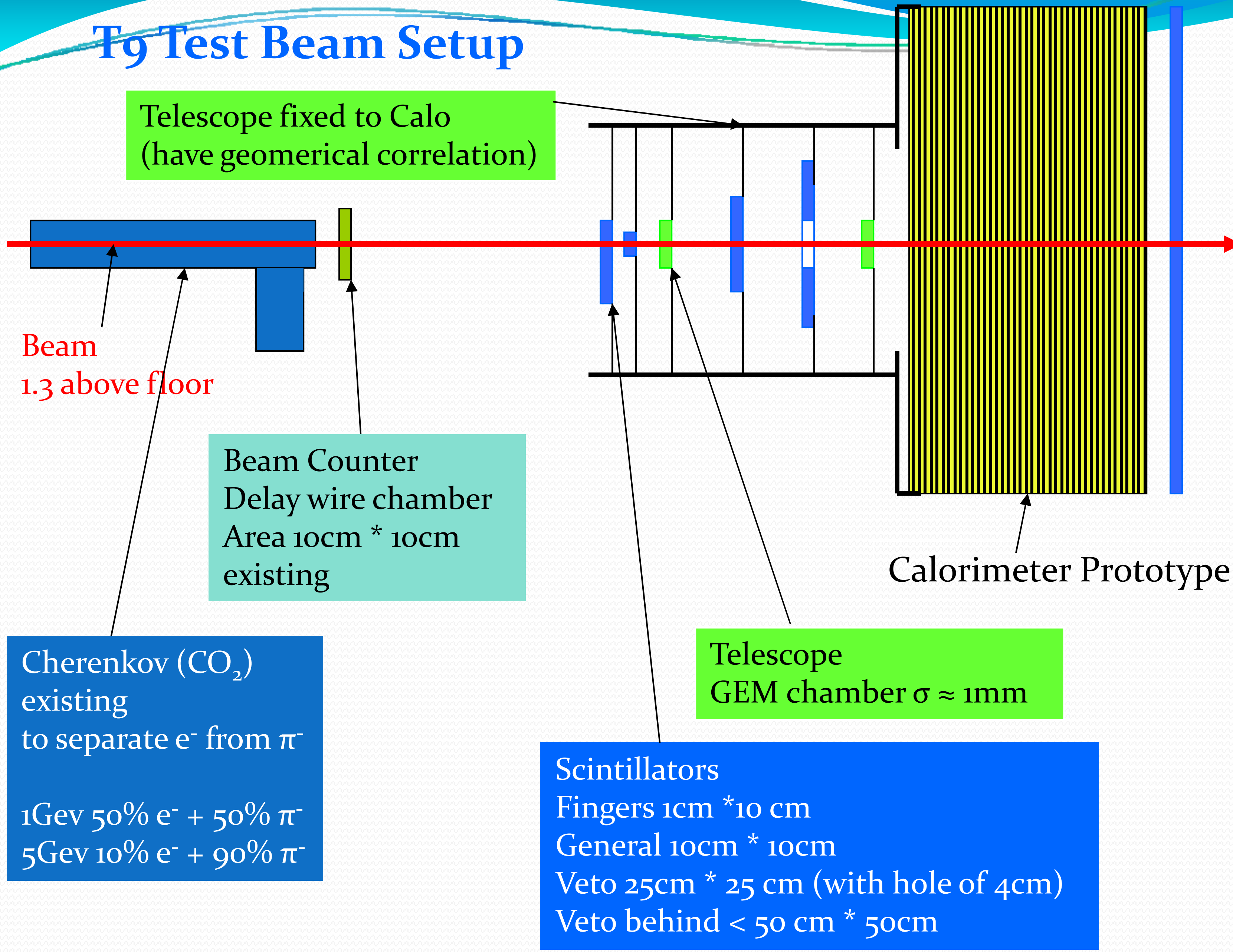
Active layers: CALICE AHCAL modules

active material: Scintillator
read out: Silicon photo multipliers





T9 Test Beam Setup



Test-beam

- @CERN
  - PS
  - November 2010

- 20 absorber layers to begin with
  - 40 layers planned for a second stage

- active layers: µMegas, Scintillators, RPC, GEM

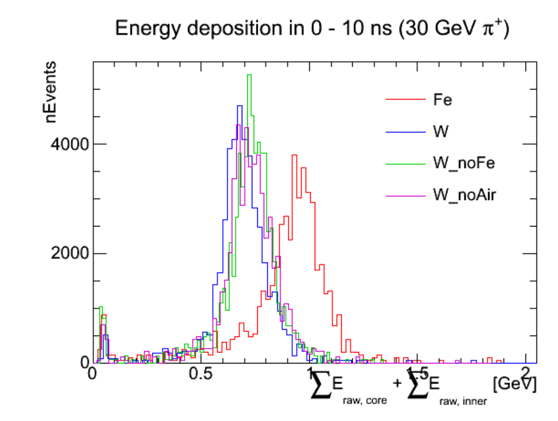
Conclusions

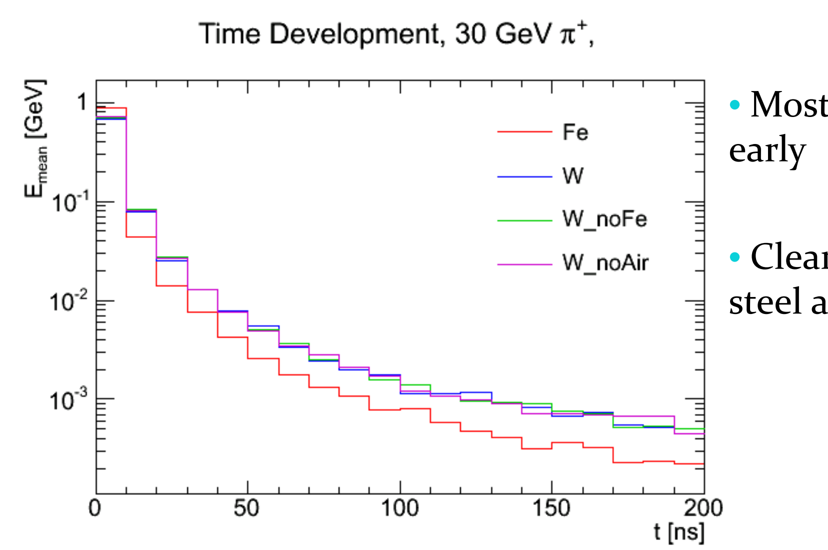
- Tungsten is viable option for HCAL at CLIC energies
- Validation of simulations is necessary
- W HCAL test-beam preparations are proceeding
- W HCAL test-beam:
  - muons from september onwards
  - 2 weeks in November 2010 beam-time

Thank you!

Backup

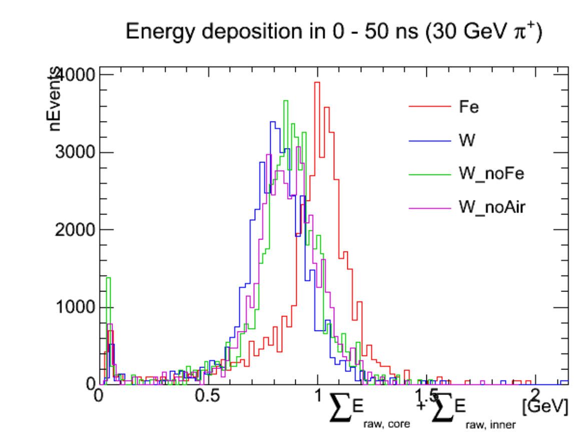
Time Development

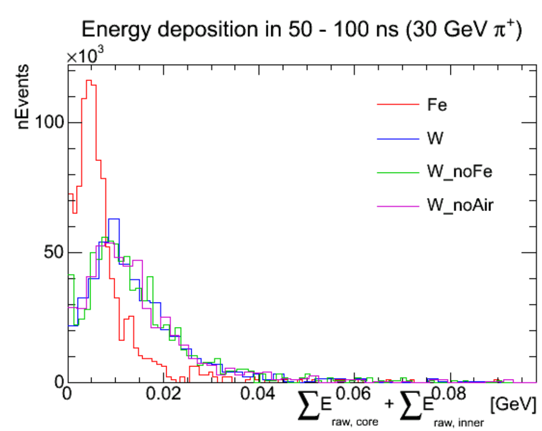


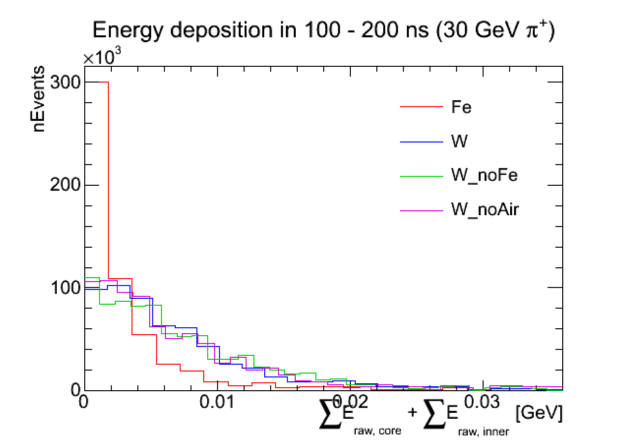


- Most of energy deposited early
- Clear difference between steel and tungsten setups

C. Grefe



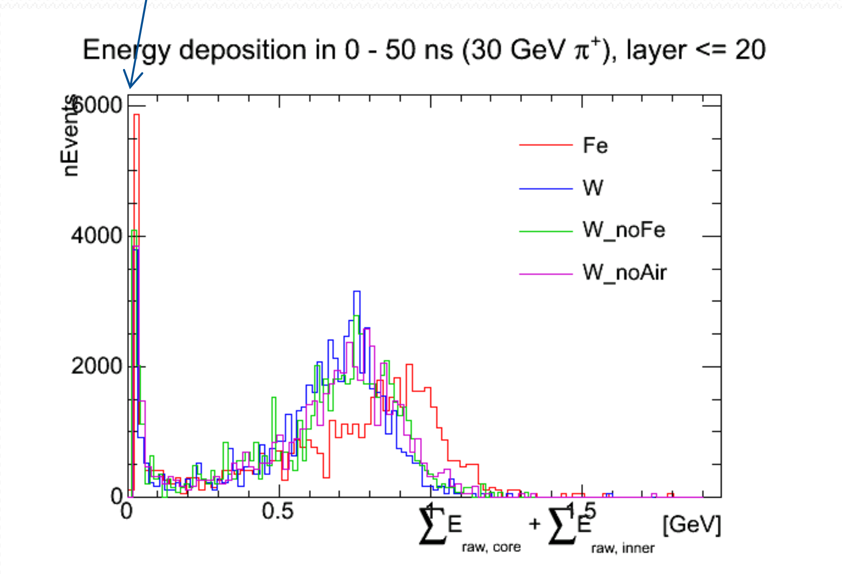


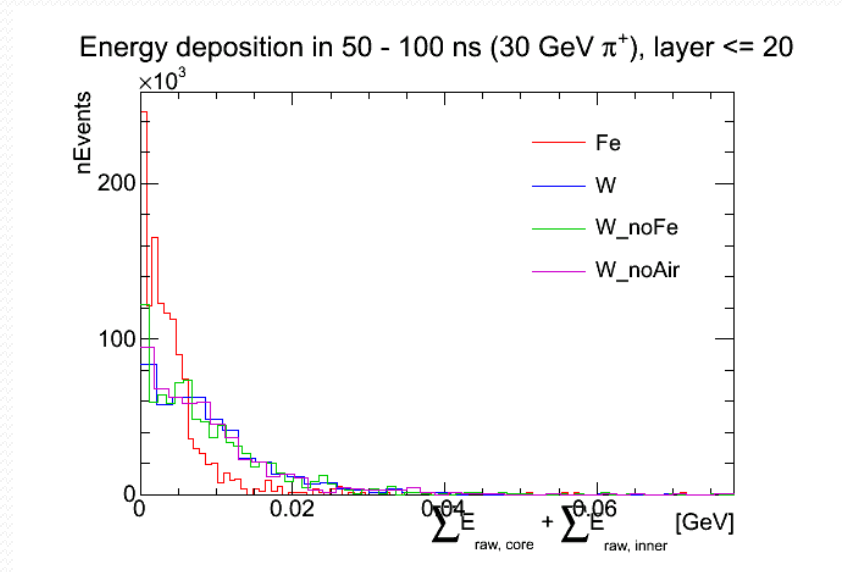


Energy deposit in first 20 layers

mip-like events

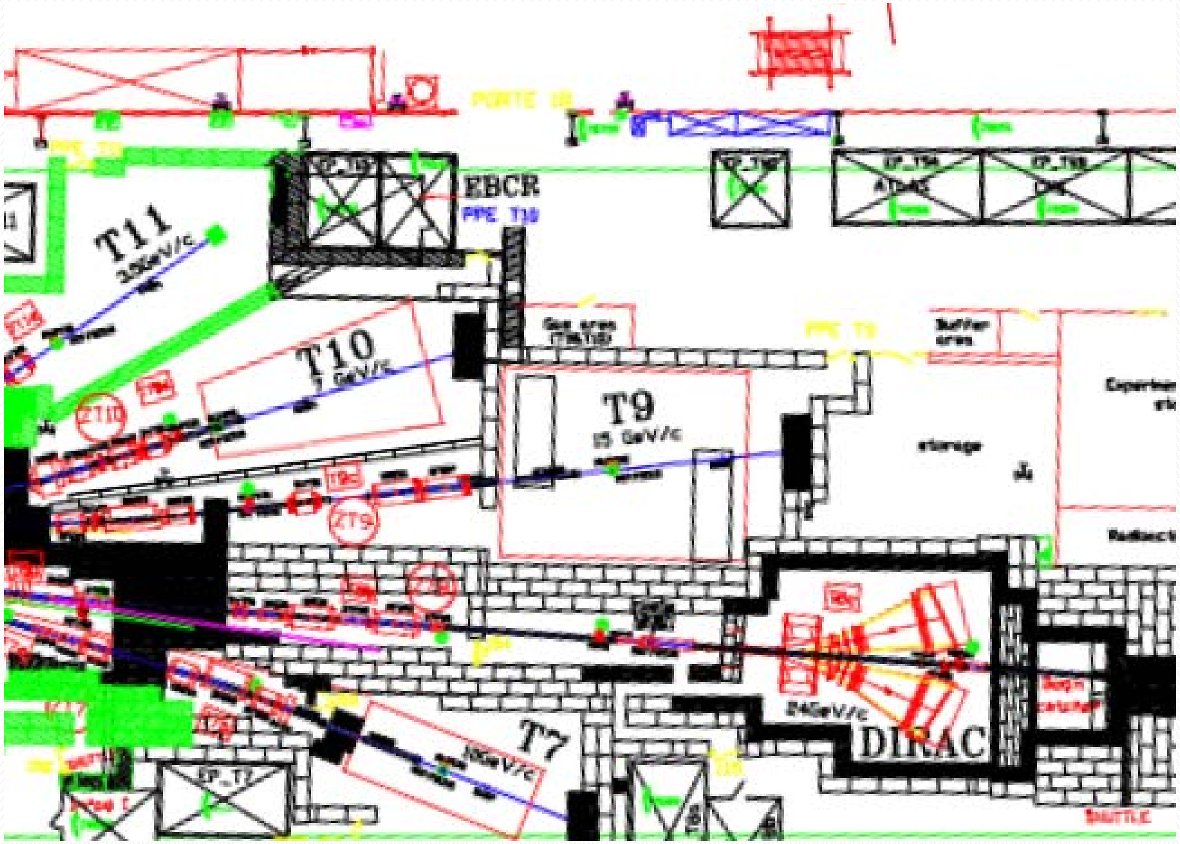
difference in time development between W and Fe can still be seen





C. Grefe

Proton synchrotron (PS) East-Hall/ T9 Layout

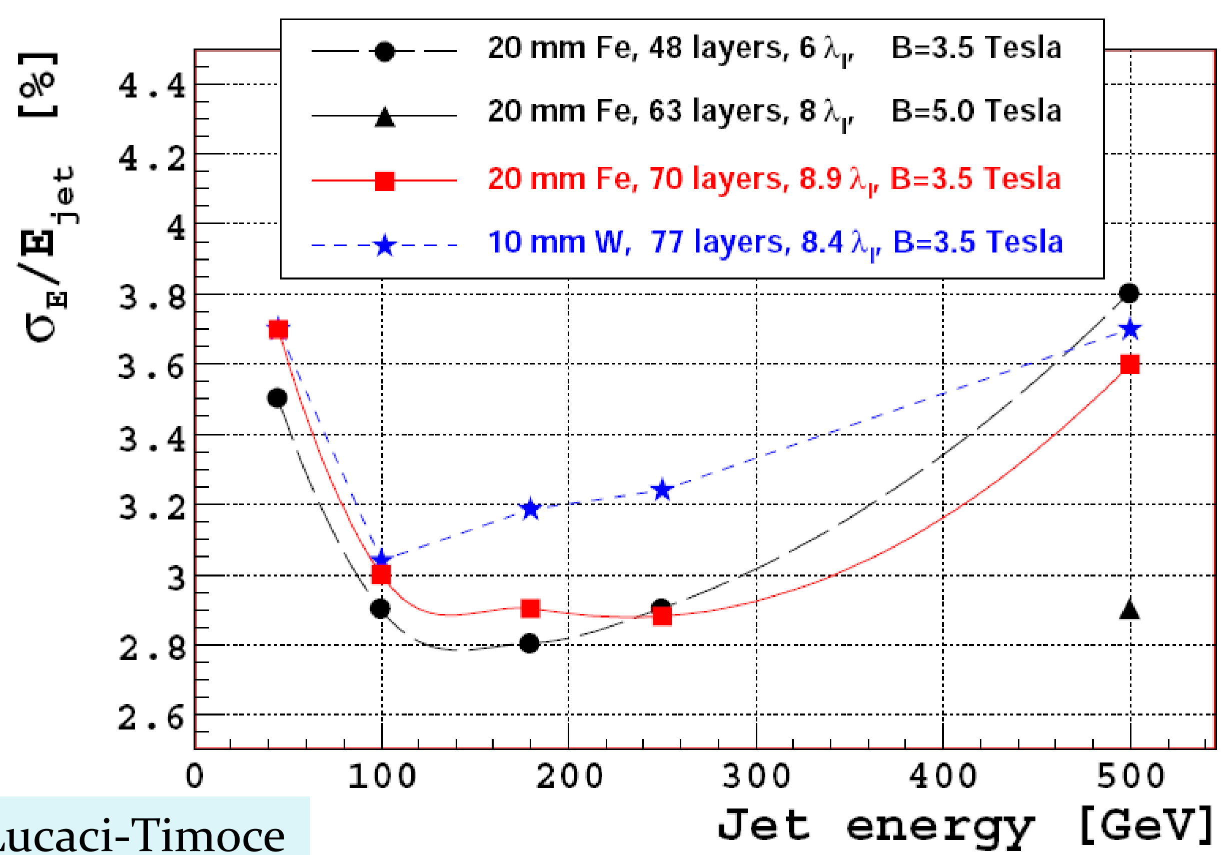


Particle flow results so far

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