Shower Profile and Leakage Studies

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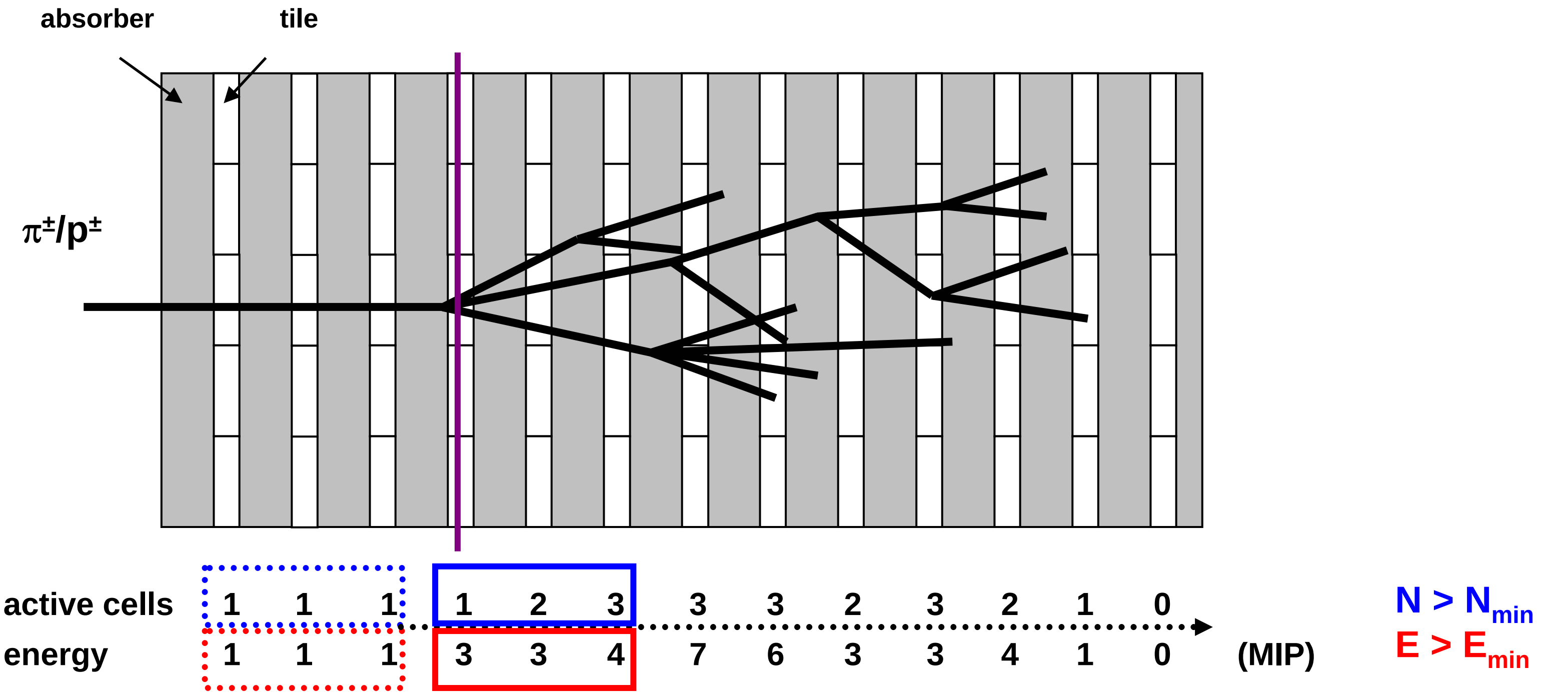
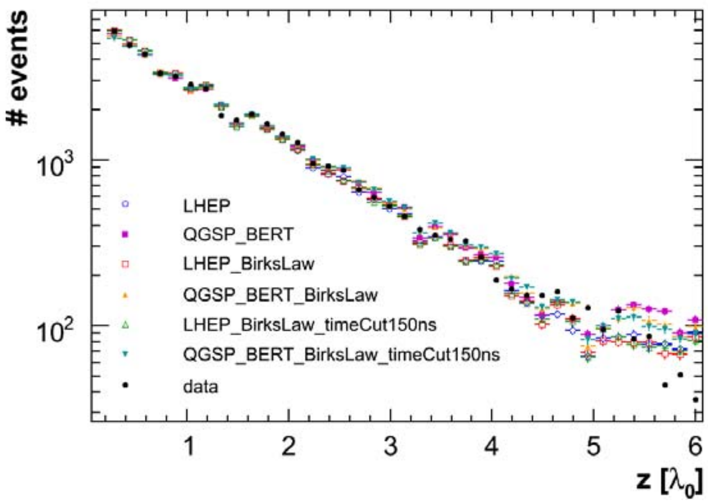
Method to Find Shower Start



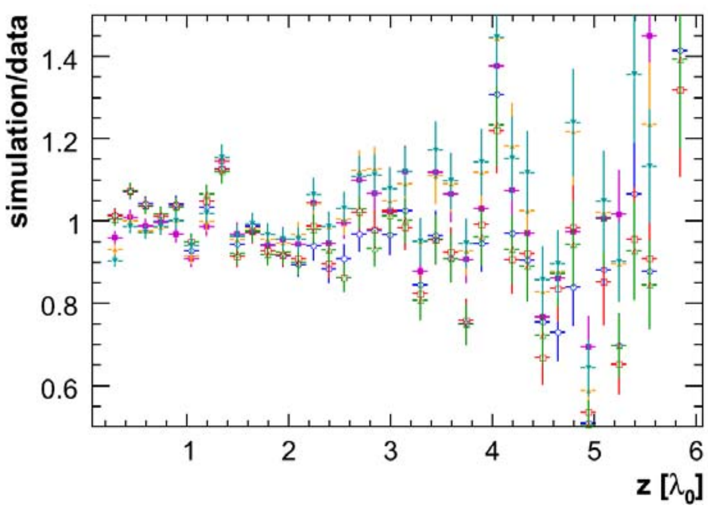
- sum energy and hits within an active layer
- scan from the front
- if three neighboring layer show signal significantly larger than MIP assume shower start
- simple but robust

Verification of Shower Start



general:

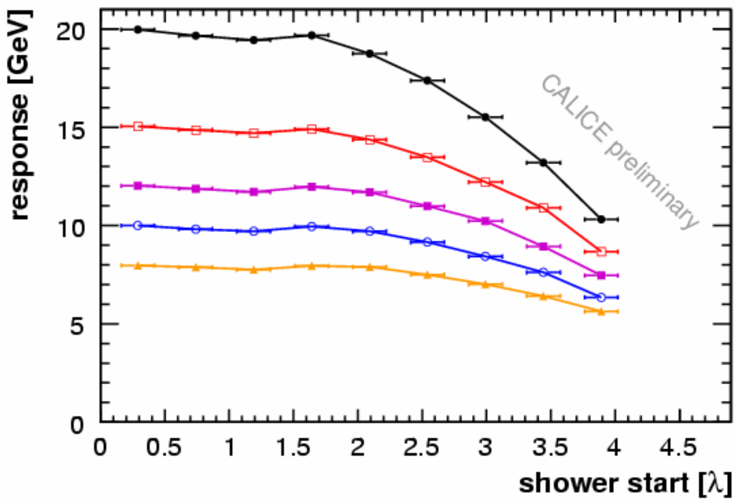
- exponential drop
- slope agrees with PDG values for $\pi^{\pm}$ (within material uncertainties)

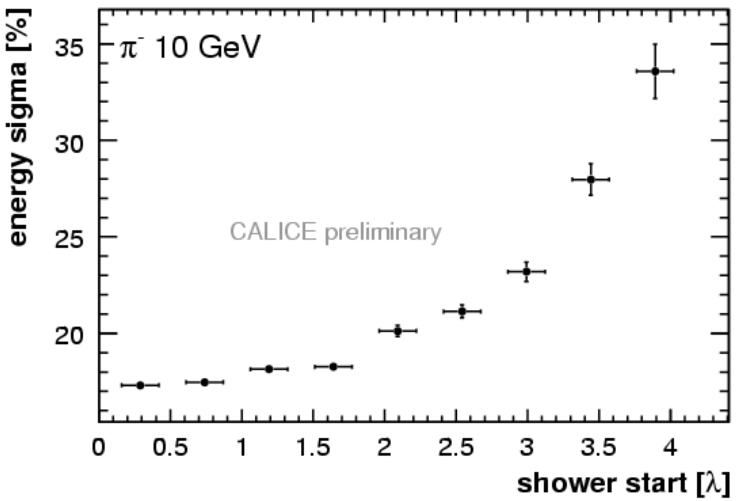


comparison to simulation:

- ratio 1 (+ digitization inaccuracies)
- no MC-model dependence

Detector Response versus Shower Start



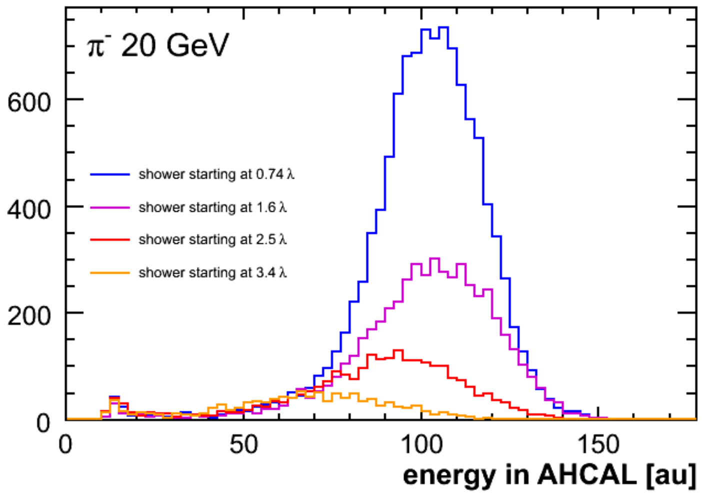


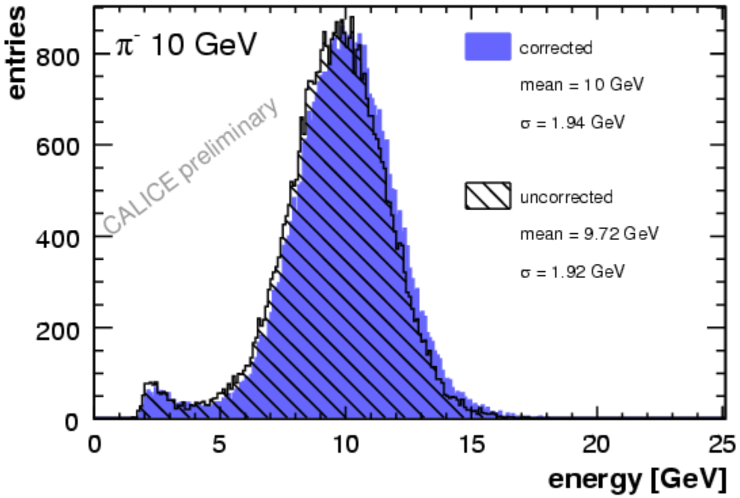
depth of first interaction influences for each event:

- visible energy
- energy resolution

due to leakage at the back of the calorimeter

Leakage Correction



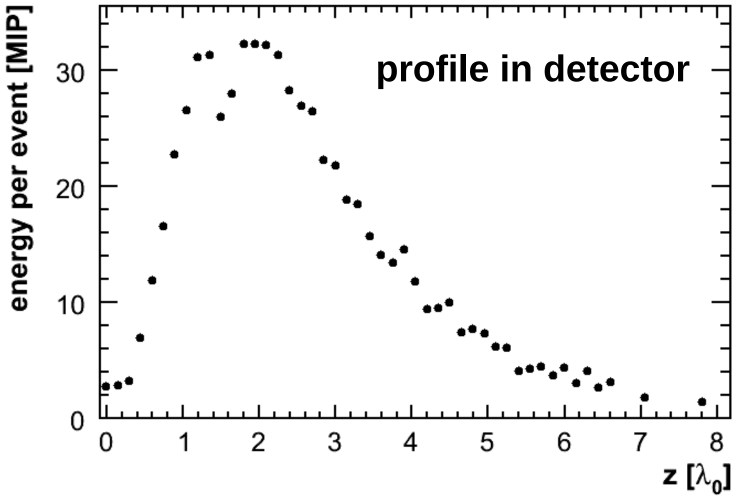


- cannot shrink relative width of showers with certain start point
- but can scale shower energy to the right mean energy

→ improves linearity

→ improves jet energy resolution

Shower Profile from Shower Start



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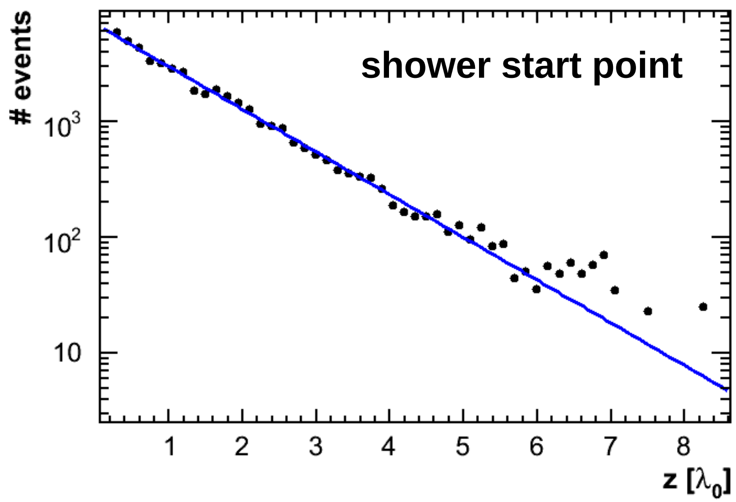
measure independently
- position of first interaction
- spatial shower development

→ gives new possibilities to test simulation predictions

=



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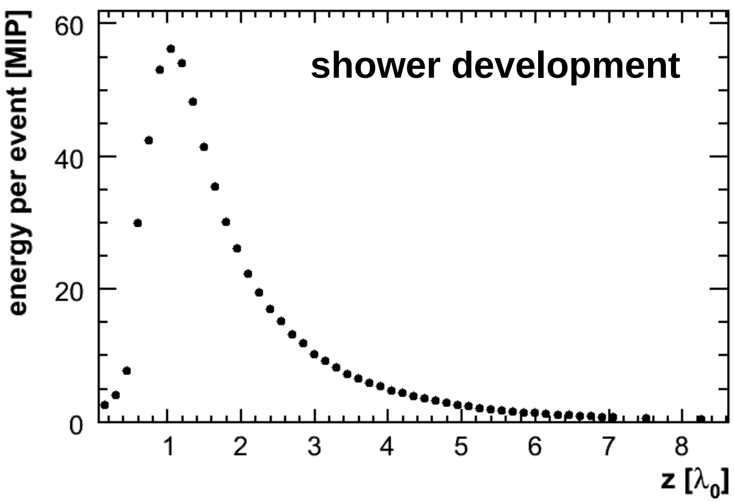


Monte Carlo and Digitization

- Mokka (Geant4)
  - simulates the physics using
    - model of haronic physics (physics lists)
    - detector geometry
  - gives energy deposit for each 1x1cm^2 cell
    - as sum (default)
    - as list of hits

- digitization
  - translates energy to electronic units
  - has to model
    - energy to photo conversion
    - photo to electrical signal conversion
    - response of electronics

The Summing Problem

- saturation in the scintillator (Birks' Law)
  - nonlinear relation between deposited energy and scintillation light
  - once cell can have several deposits with different intensities

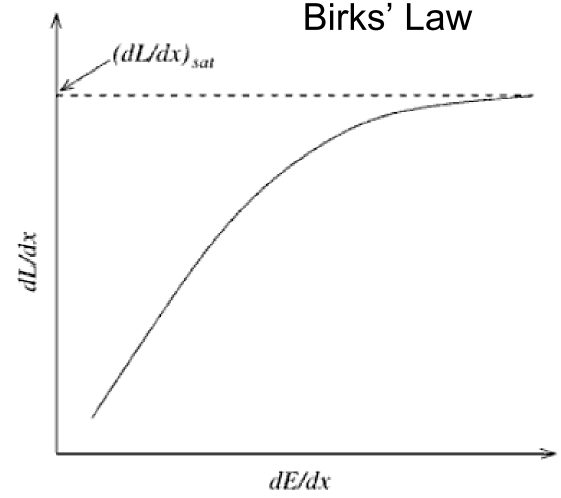
- timing of electronics
  - time window is defined by primary particle (trigger)
  - energy deposits in the shower will be distributed over some time
  - one cell can have several hits at different times

☝ rather detector effects than physics but digitization (currently) has no access to individual energy deposits

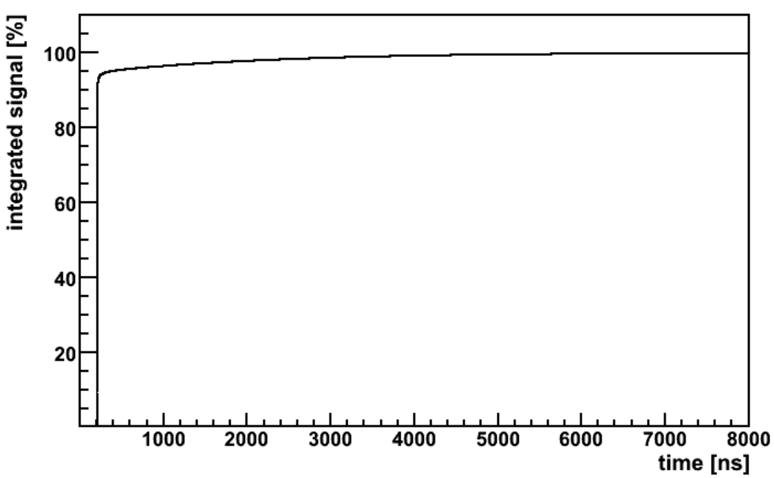
→ use Birks' implementation in Geant4

→ use time-cut already in simulation

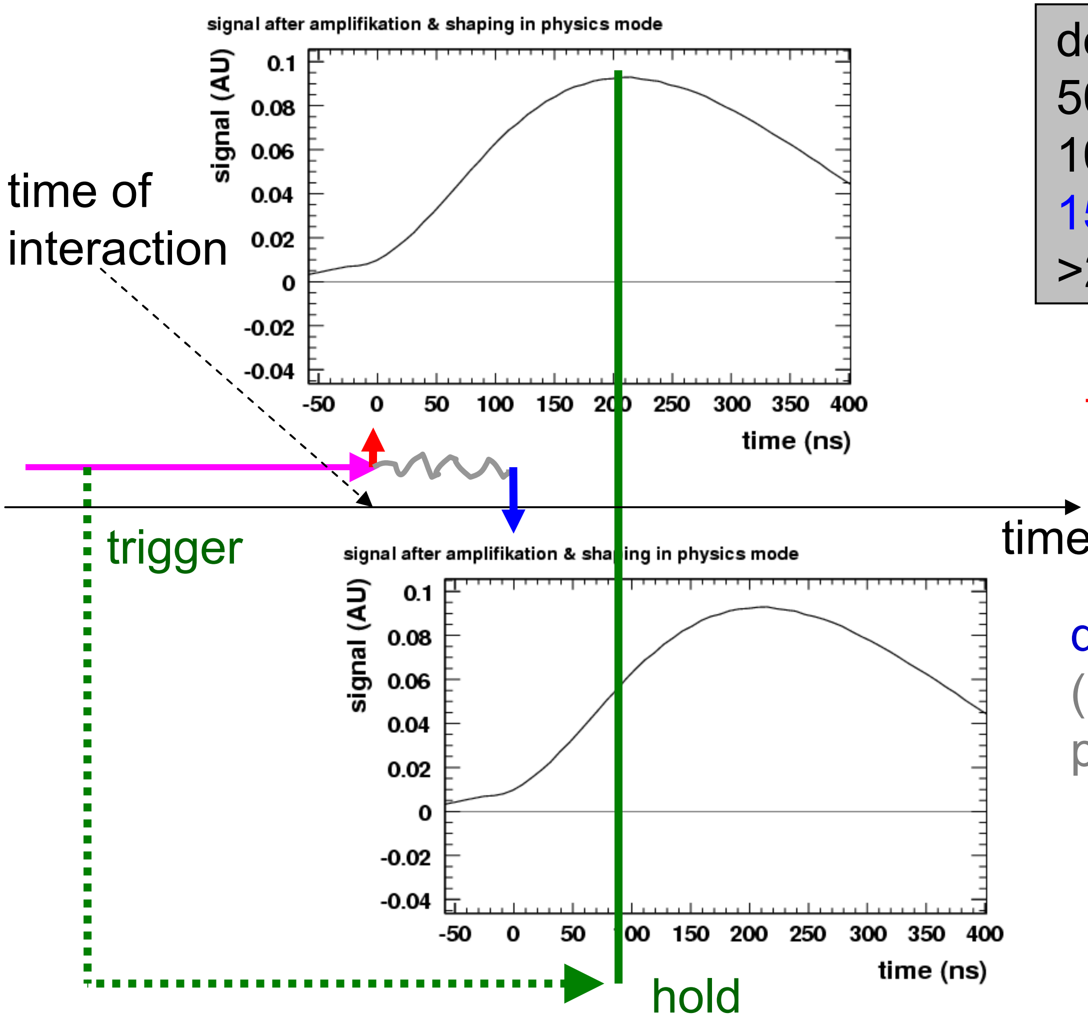
Birks' Law



integrated signal versus time



Exact Shape of the Detector Acceptance in Time

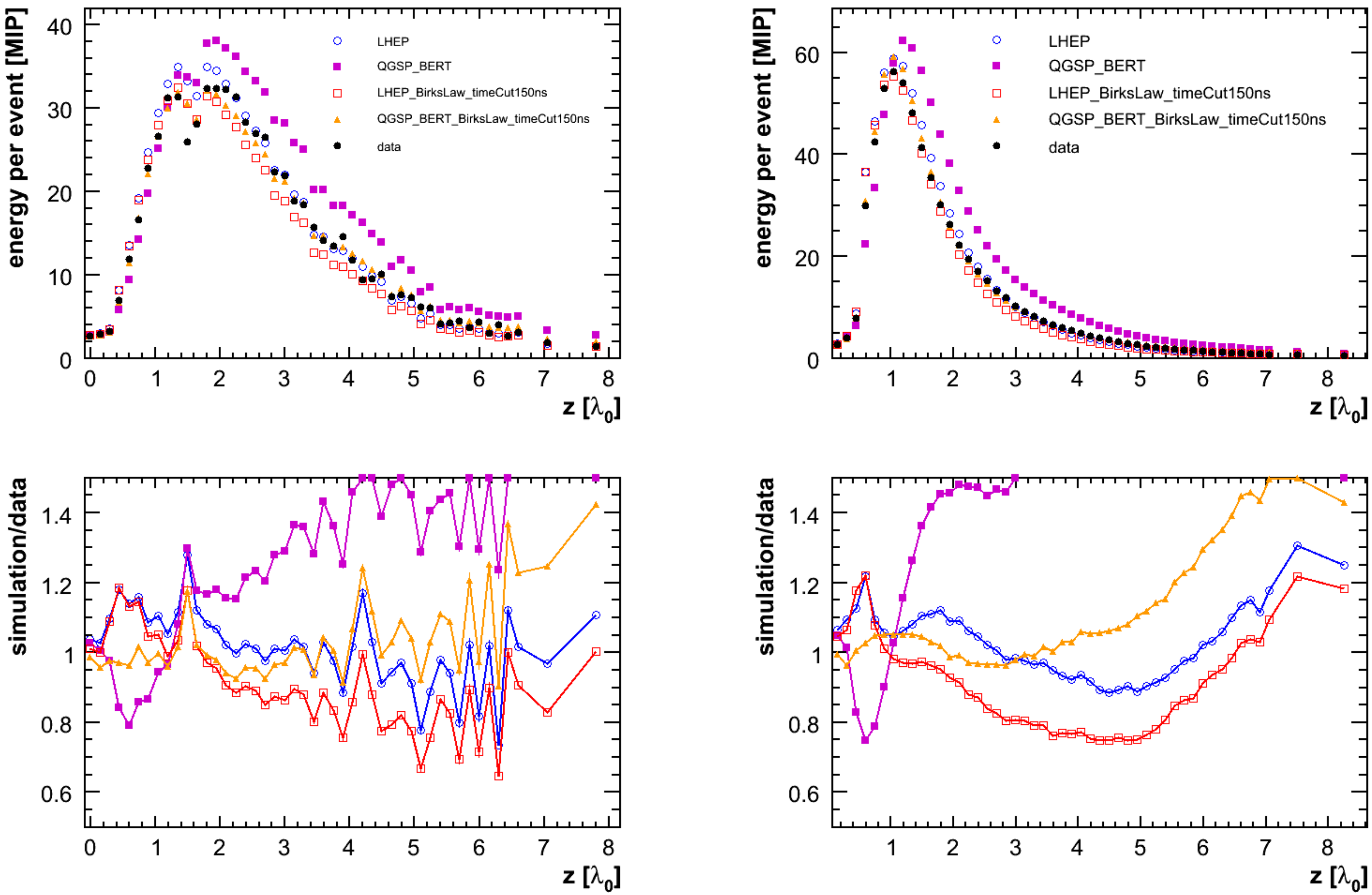


delay	visible signal	
50ns	90%	
100ns	65%	
150ns	30%	(time cut)
>200ns	0%	

fast signal

delayed signal
(after de-excitement process)

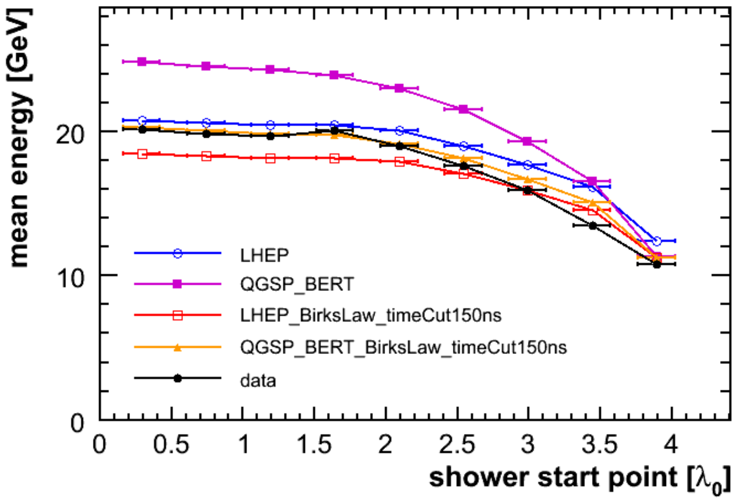
Profiles in Data and Simulation

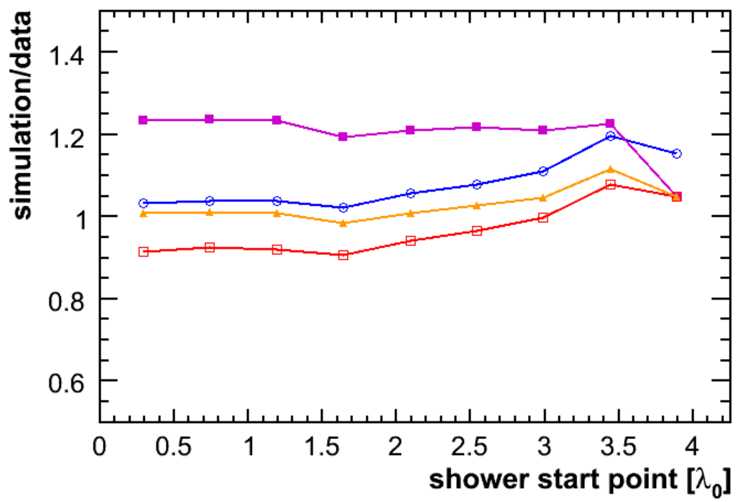


Profiles – Observations

- QGSP BERT
  - without modification far off
  - with Birks' and time cut matches data best
- LHEP
  - without modification reasonable result
  - Birks'
    - reduces energy
    - no improvement to shape
  - time-cut almost no influence
- degrading agreement around 5 λ
  - TCMT reconstruction?
  - TCMT digitization?

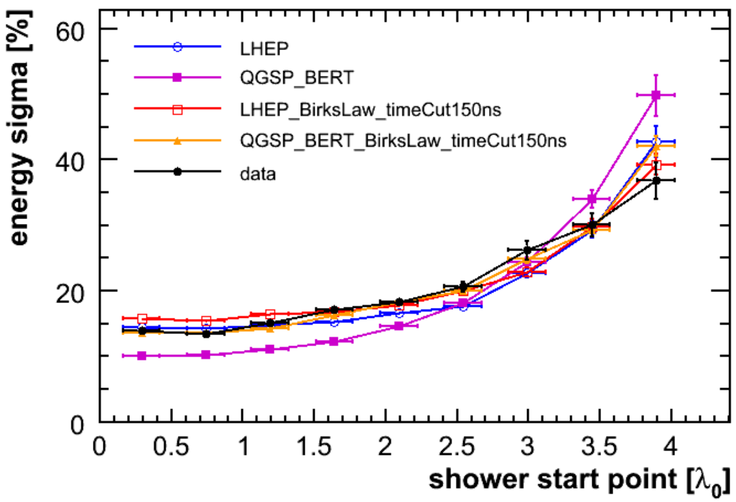
Response

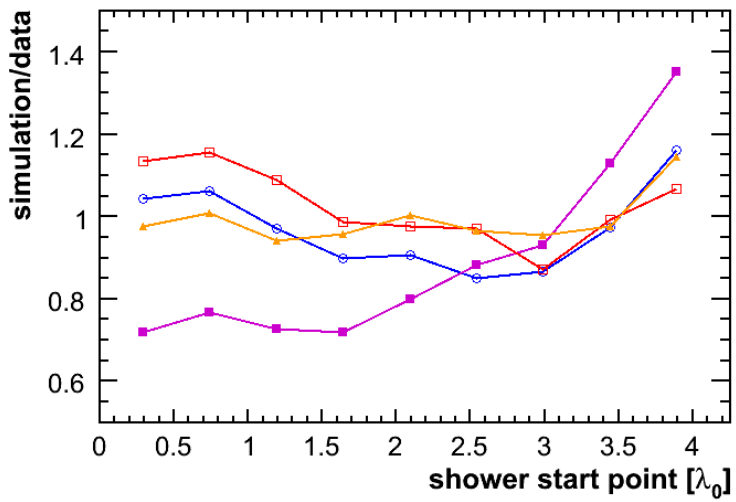




- QGSP BERT
  - too high without modification
  - good matching with Birks' and time-cut
  - ratio between data and simulation is flat
- LHEP
  - reasonable matching without modifications for early shower
  - to low response with Birks'
  - suggests higher values for late showers

Resolution





- QGSP BERT
  - big disagreement without modifications
  - good agreement with Birks' and time-cut
- LHEP
  - without modification
    - agreement within 10%
    - simulation/data ratio is not flat
  - with Birks'
    - agreement worsens
    - shape stays

Summary – Conclusion

Achievements:
- method to find shower start
- measurement of un-convoluted shower profile
- proof of principle for event by event leakage correction
- progress in the simulation/digitization

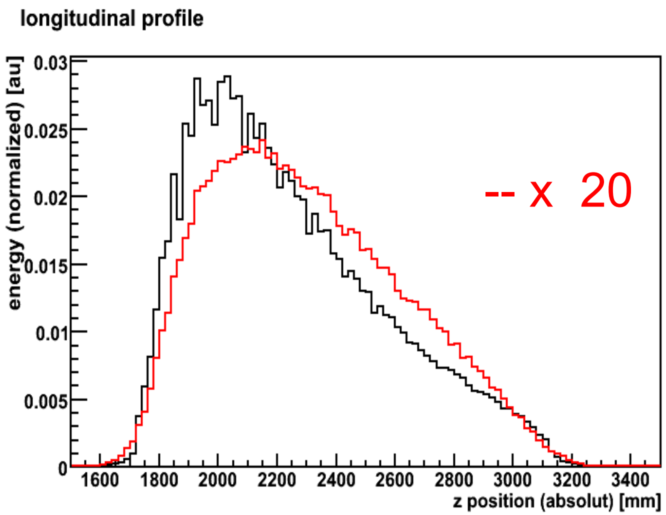
What did we learn?
- proper digitization is essential for comparing different MC models
  - ☝ If you simulate physics your detector cannot see, you might be comparing apples with oranges!
  - ☝ A simple model might describe a detector with limited response better than the "real physics".

Outlook

- extension of the energy range up to 80 GeV
- temperature effects
  - in reconstruction
  - in simulation
- tracking based shower start finding
- test to measure leakage by shape

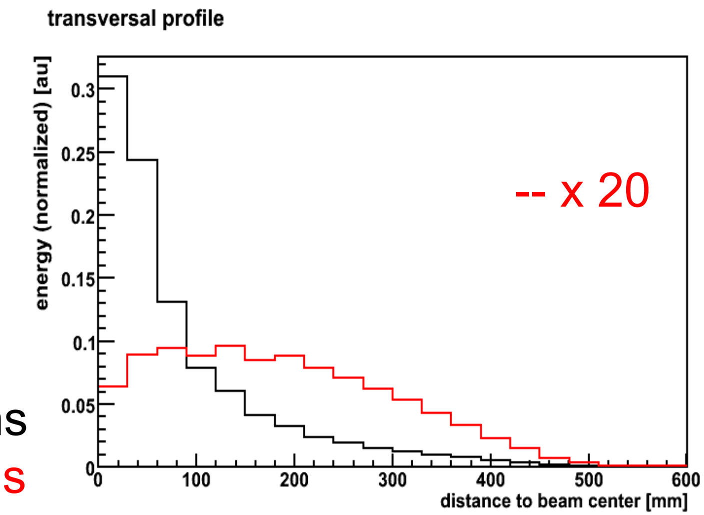
Backup

Time-Cut Influence on the Profiles



< 150 ns

≥ 150 ns



pictures: QGSP_BERT 20 GeV p- 30deg

QGSP_BERT:
- different spatial distribution of visible and invisible part
- invisible only 5% of total but might influence tails

LHEP:
- almost no difference between visible and invisible part
- invisible is 1%, no difference observable