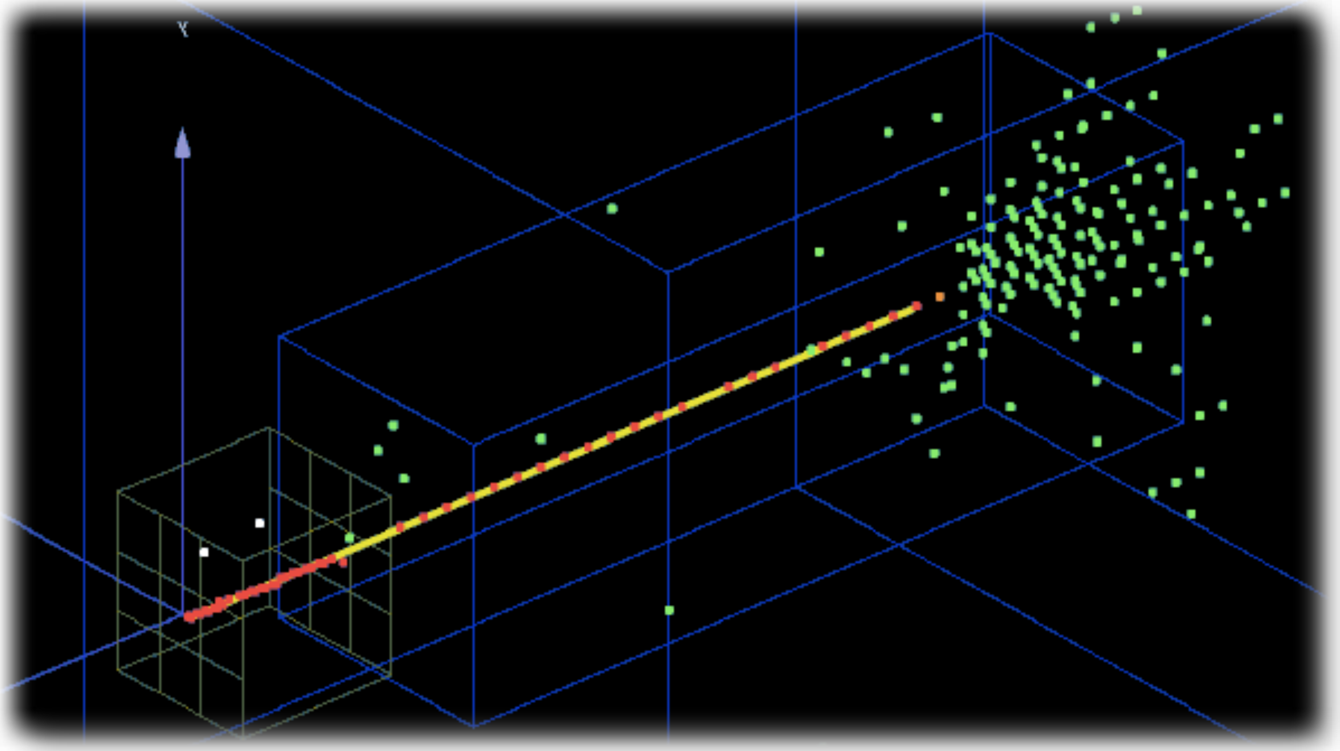
Hadron Shower Analysis

Alexander Kaplan, Universität Heidelberg

Overview

- Primary Track Finder
- Measurement of λ_{int}
- Event Selection
- EM Content of Hadron Showers
  - Hit Classification
  - Deep Analysis
- Summary & Conclusion

Primary Track Finder (PTF)



- Finds track of incoming particle up to shower starting point
- Developed by M. Chadeeva
- Accumulated average

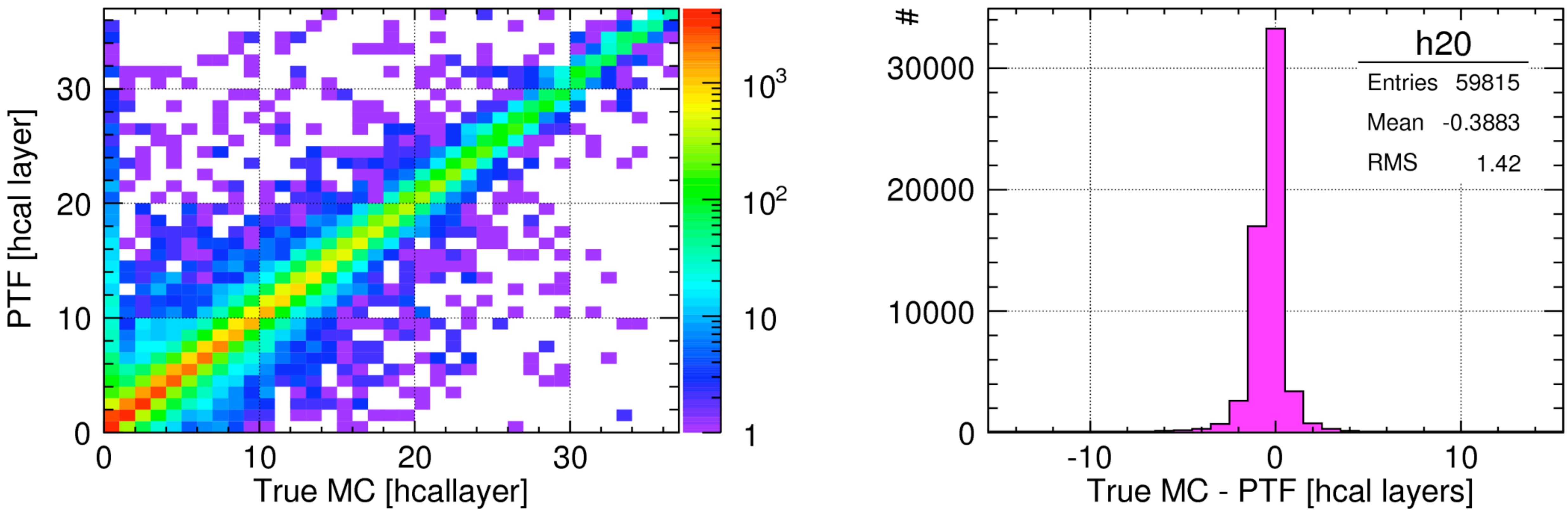
$$A_i = \sum_{k=0}^{i} E_k/(i+1)$$

- Definition: shower starting in layer i, if:

  - $((A_i + A_{i+1}) > 6.5\mathrm{MIP} \quad \mathrm{AND} \; (nHits_i + nHits_{i+1}) > 8 \; \mathrm{MIP})$
  - $\mathrm{OR} \; (E_{i+1} > mipTreshold)$

- Slightly modified original PTF to use energy dependent MIP threshold - using energy sum in calorimeter

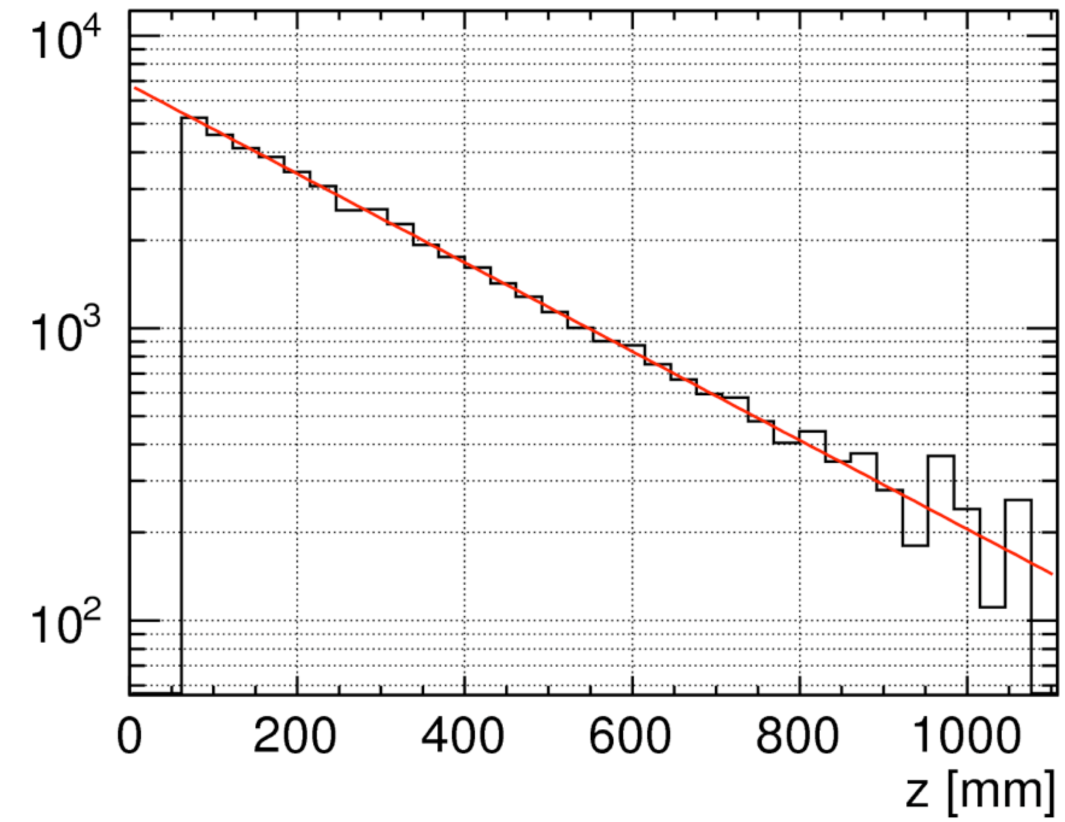
Performance of Primary Track Finder



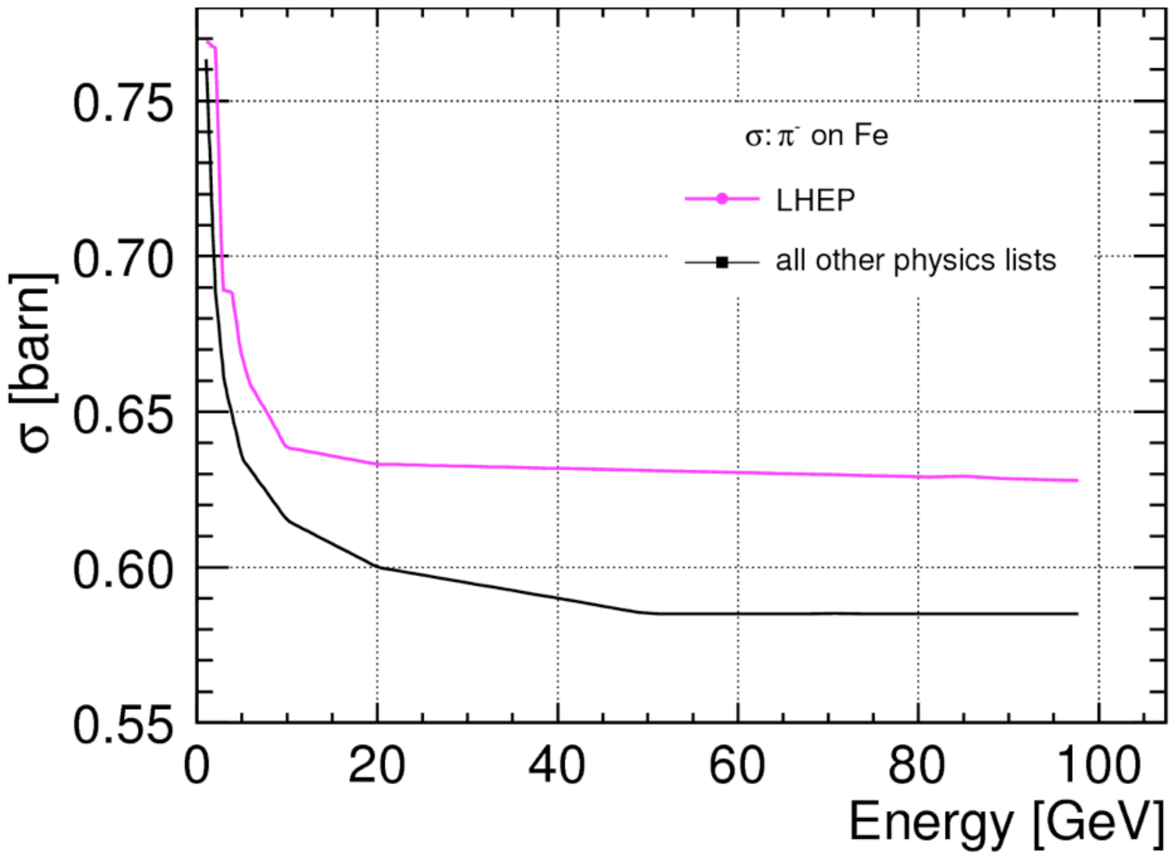
- Performance depends on energy and physics list
- On average correlation is 91.7%
- For all physics lists and all energies:
  - at least 69% of events are within ±1 layer and at least 79% are within ±2 layers compared with true MC

Measurement of λ_{int}

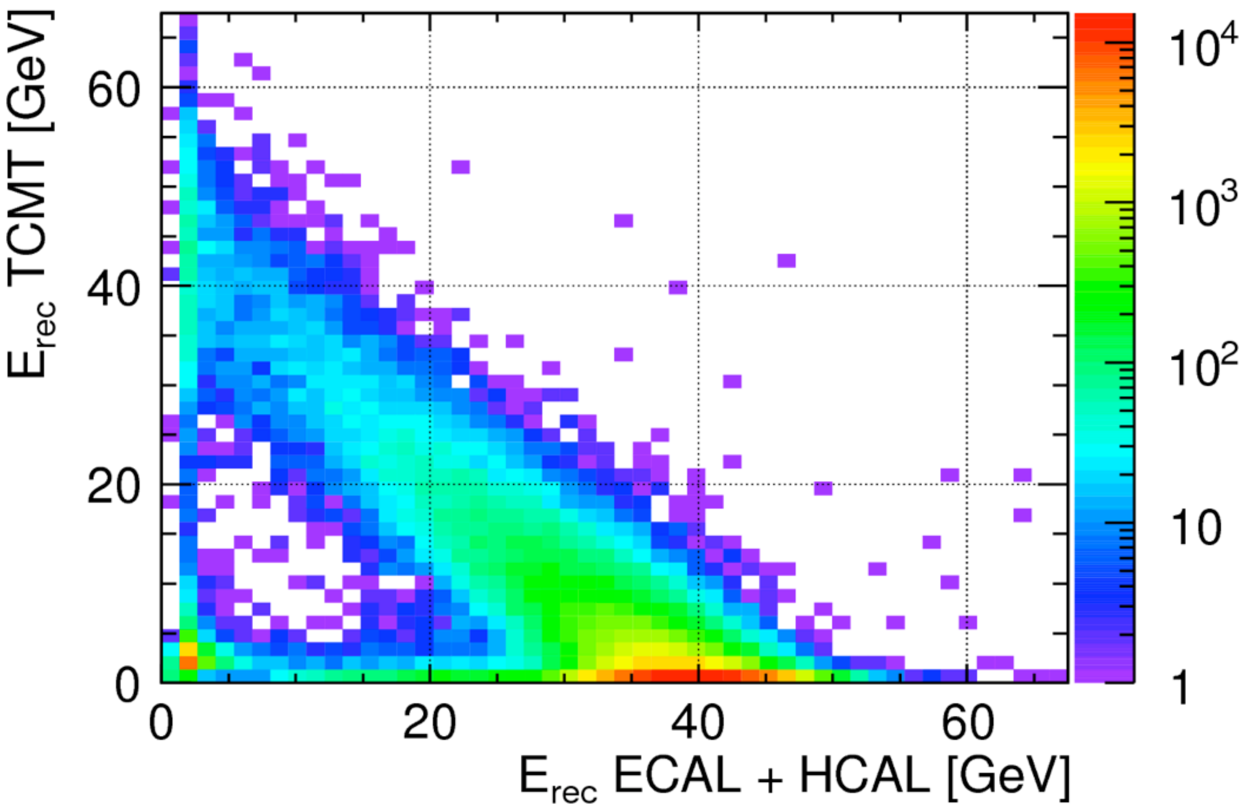
	λ^{π}_{int} [mm]	Δ_{stat}	Δ_{sys}
DATA	282	2	2
FTF_BIC	286	2	2
FTFP_BERT_TRV	284	2	2
QGS_BIC	288	2	2
QGSP_BERT	286	2	2
QGSP_BIC	283	2	2
QGSP_FTFP_BERT	286	2	2
LHEP	247	2	2

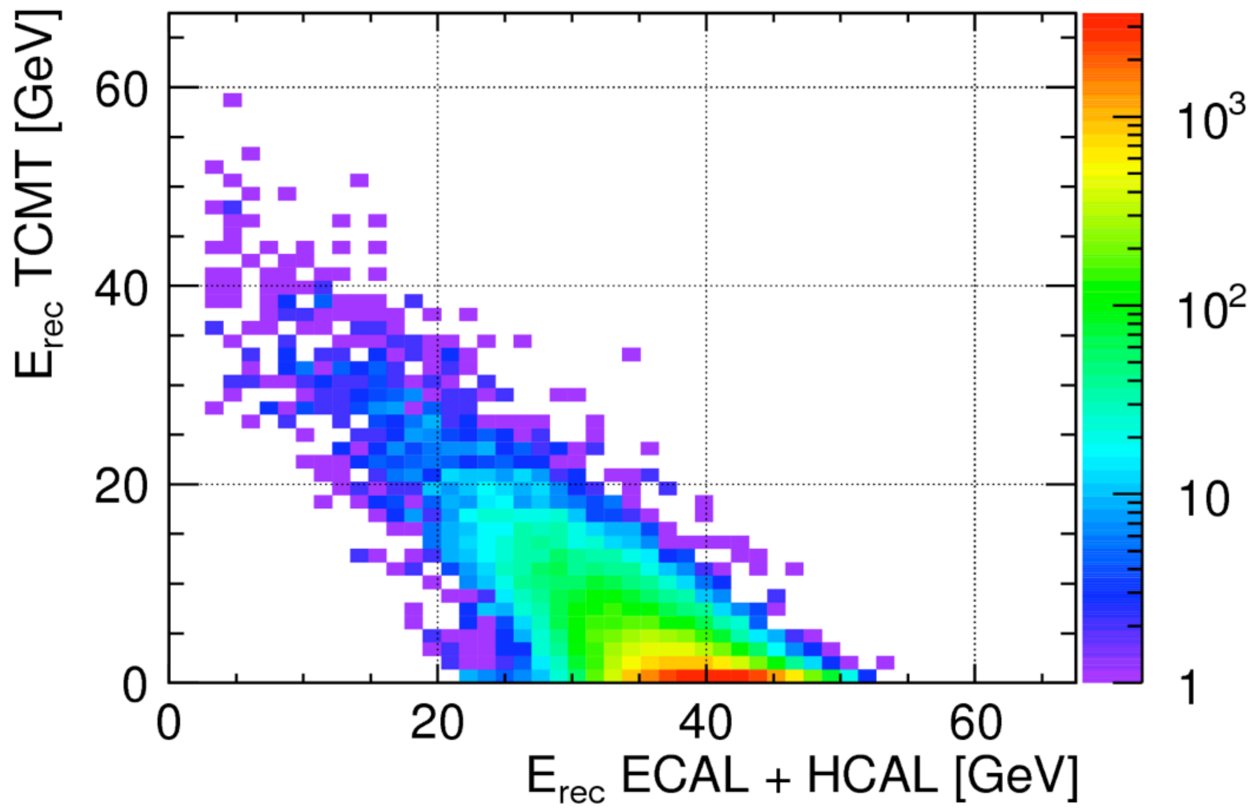


- λ_{int} can be extracted directly from fit to distribution of shower starting layer
- Good agreement within uncertainty for all physics lists but LHEP (has different σ)



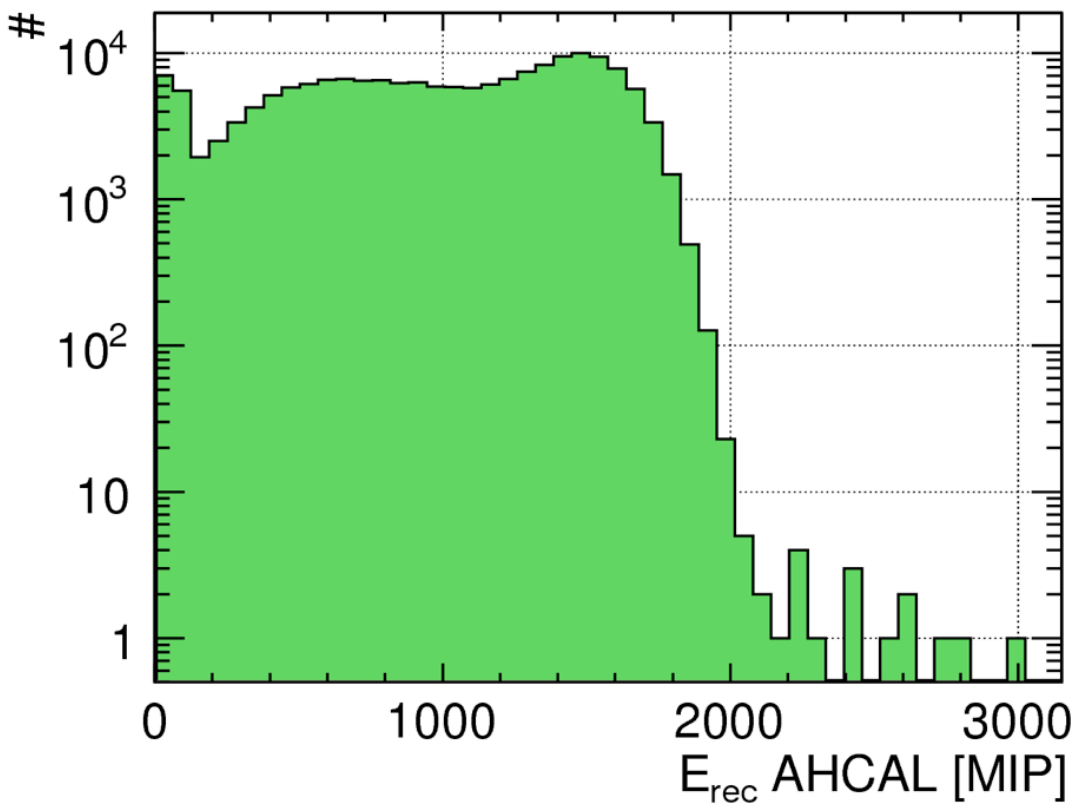
Event Selection

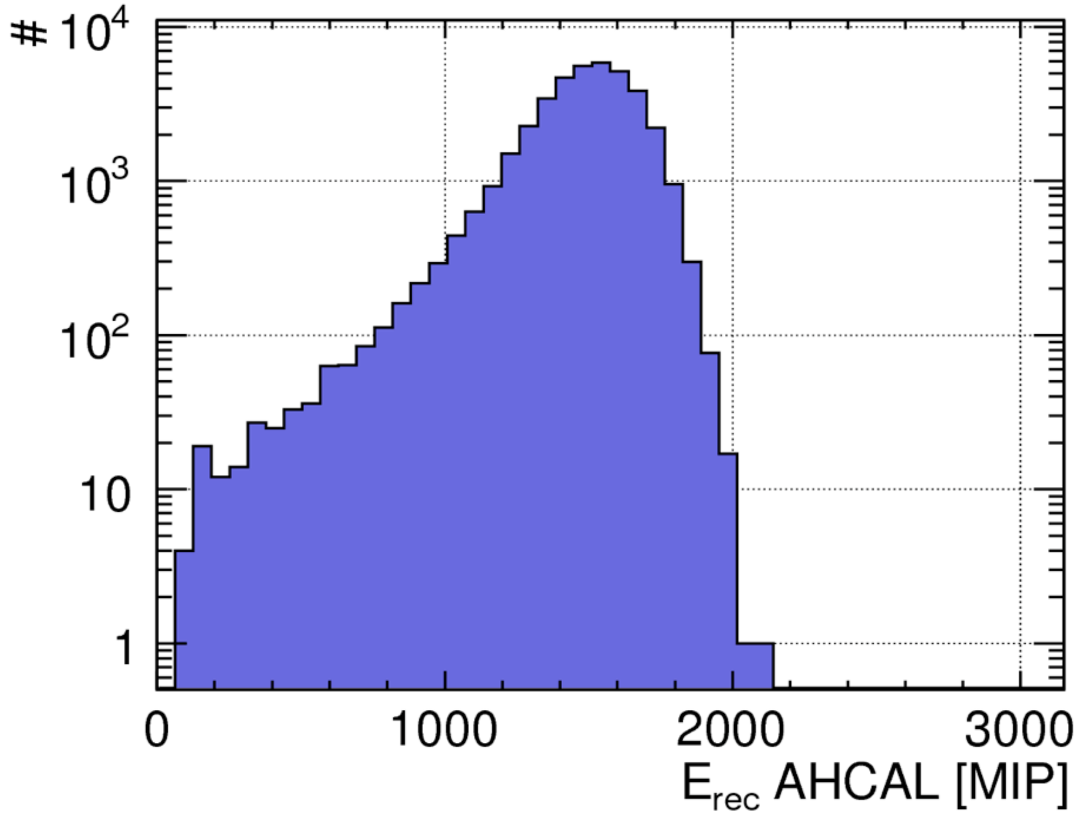




- Requirement: Shower start in 10 layers after the first HCAL layer
- Require Track in the ECAL
- Muons and double particles are rejected

Event Selection





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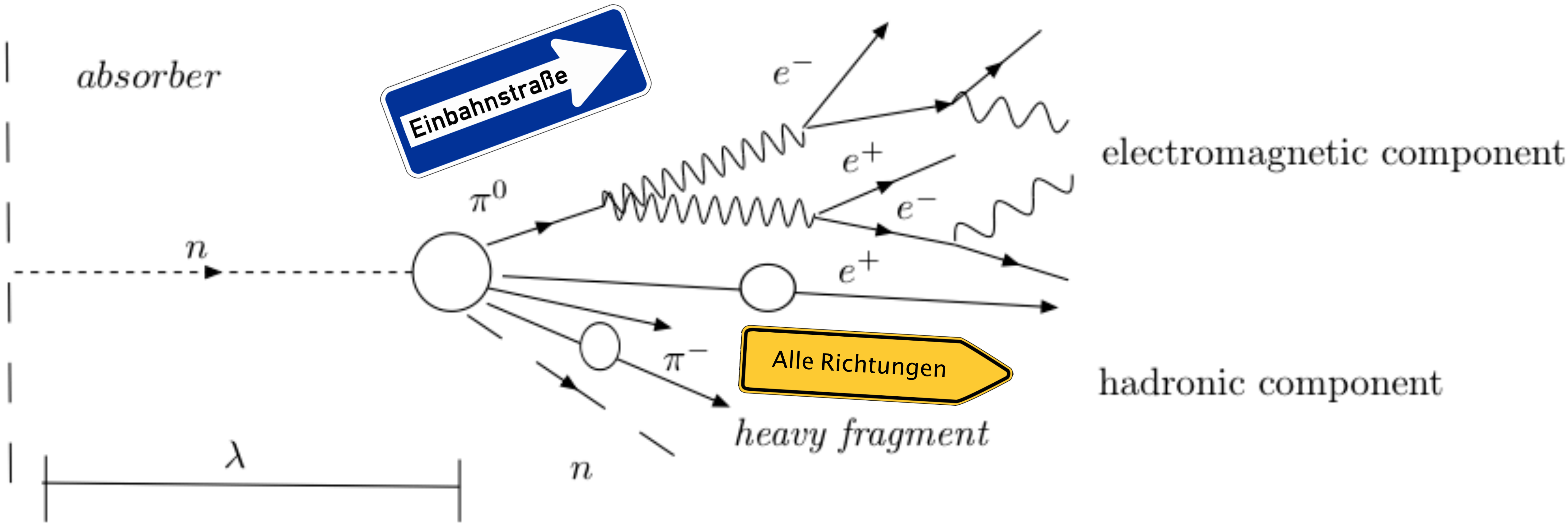
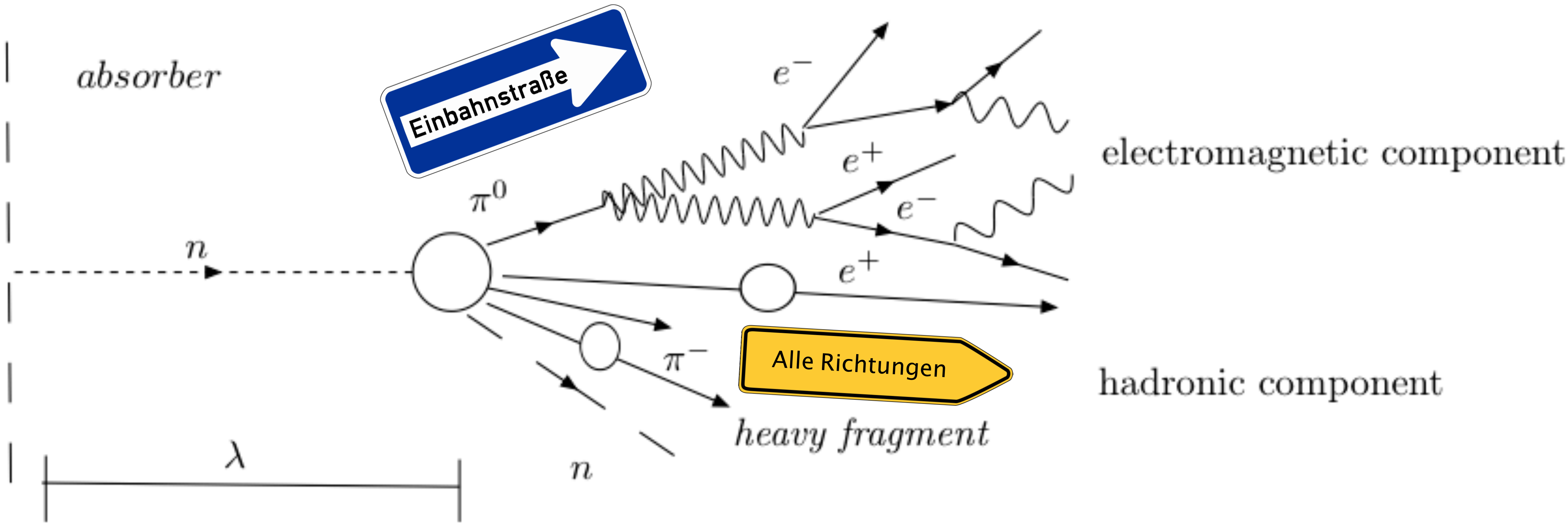
The EM Component in Hadron Showers



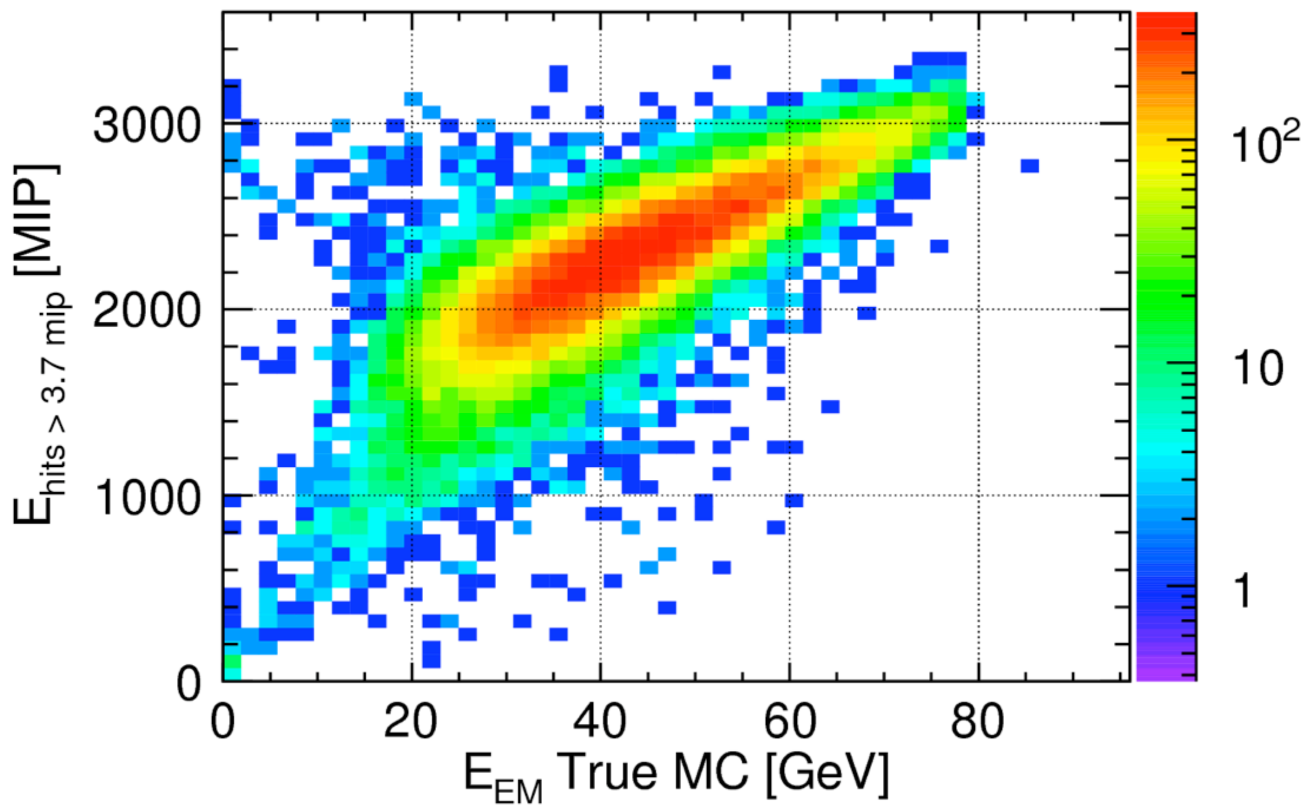
- where does EM Component come from?
- $\pi^0 \rightarrow \gamma\gamma$ (98.8%) and $\pi^0 \rightarrow e^+ e^- \gamma$ (1.2%)
- $\eta \rightarrow \gamma\gamma$ (39.3%), $\eta \rightarrow 3\,\pi^0$ (32.6%), $\eta \rightarrow \pi^+ \pi^- \pi^0$ (22.7%) and $\eta \rightarrow \pi^+ \pi^- \gamma$ (4.6%)

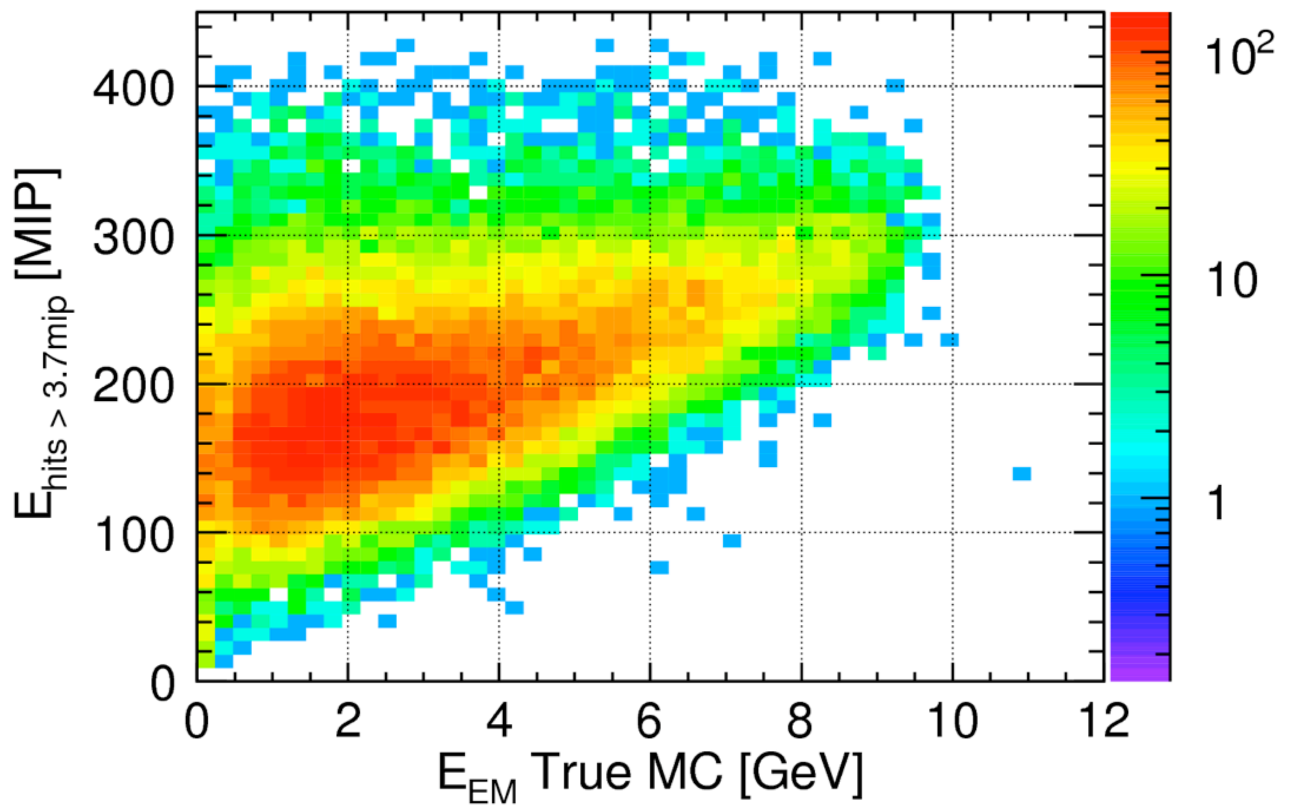
The EM Component in Hadron Showers



- ways to determine:
  - MC: save energy of all π^0 and all γ from η decay
  - From energy density in calorimeter cells
  - Clustering Algorithm: Deep Analysis by V. Morgunov

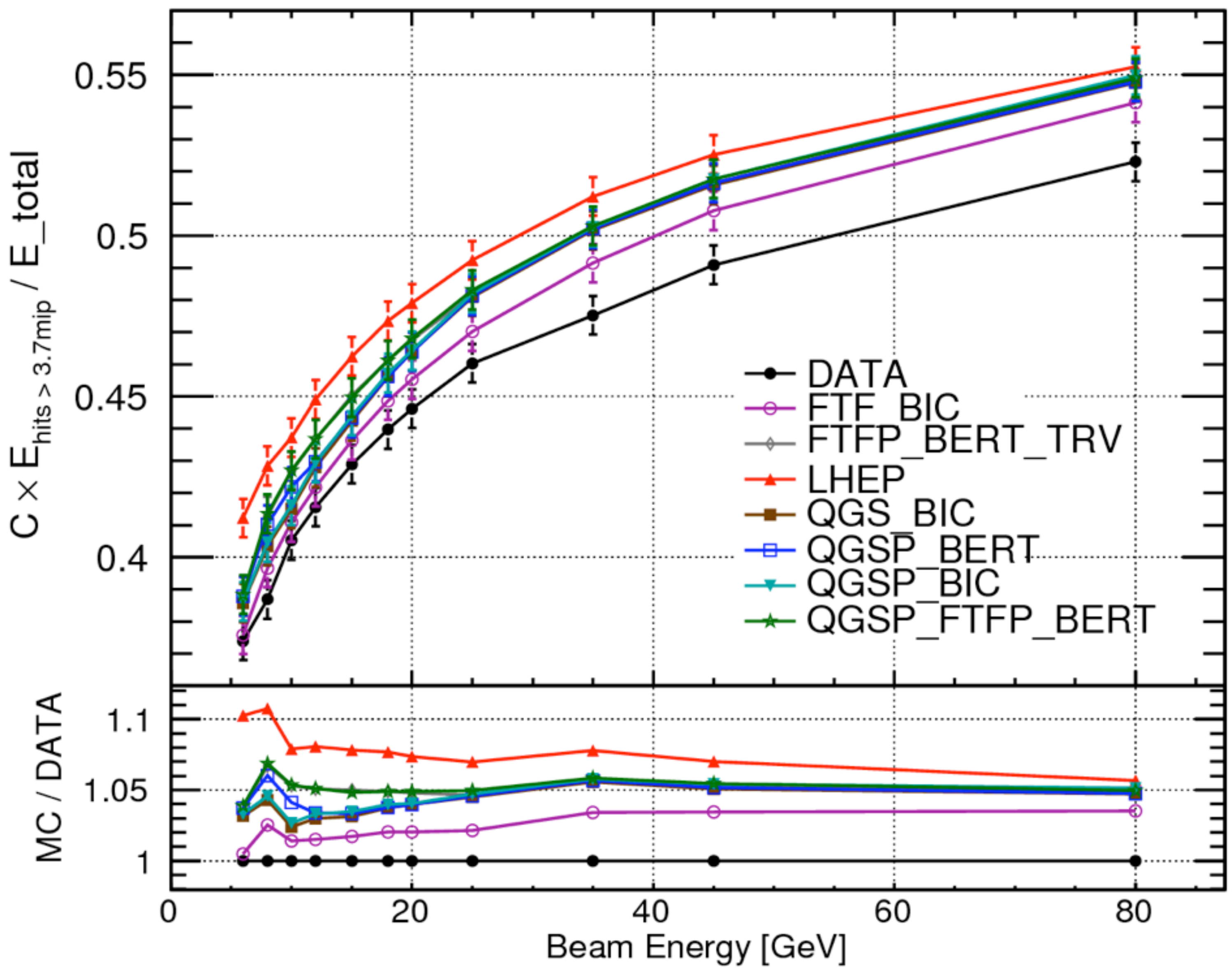
Hit Classification





- EM component of hadron shower has characteristically higher energy density
- Count hits above 3.7 mip to be EM-like
- Observable $E_{hits > 3.7\text{mip}} / E_{total}$ related to EM fraction
- Relatively high correlation at high energies, very low correlation at low energies

Hit Classification



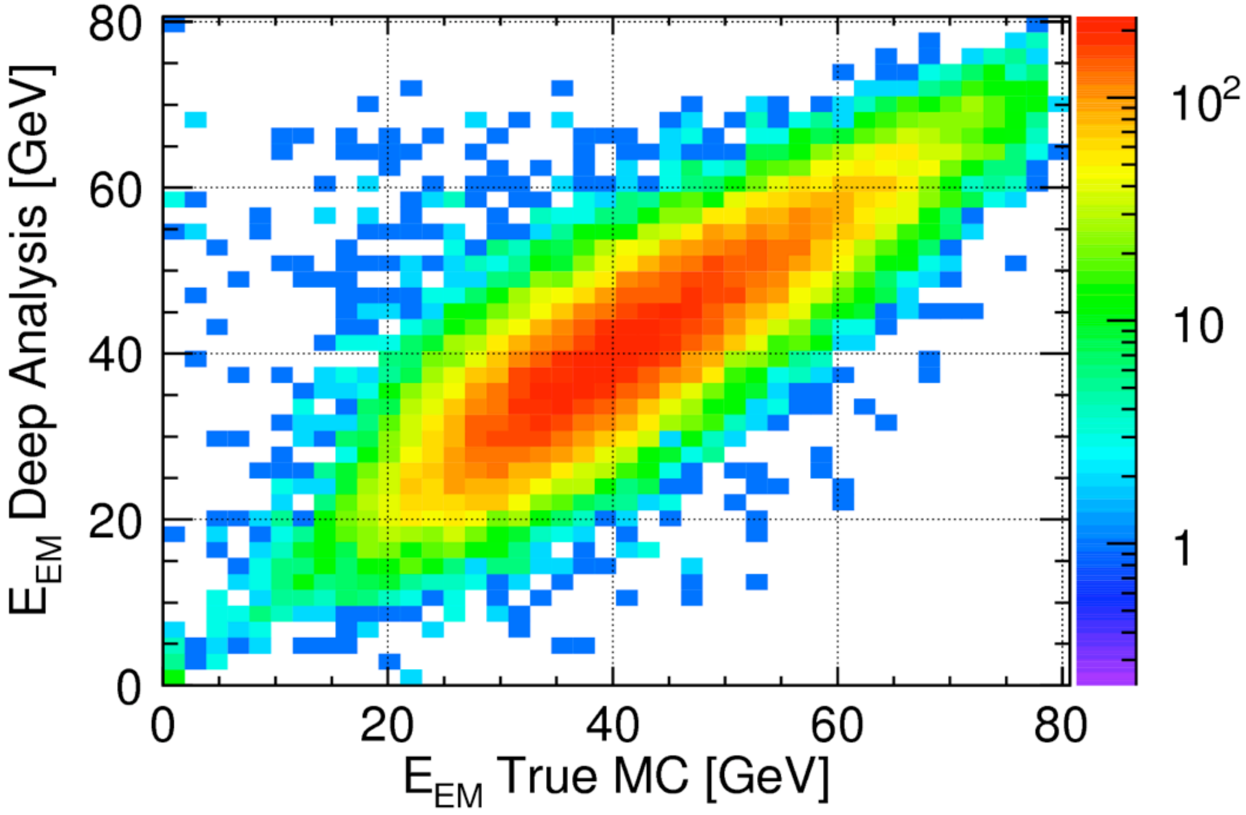
- Error bars estimated from calibration uncertainty of ~3%
- All physics list predict a too high $E_{hit>3.7}$ / E_{total}
- Overall FTF_BIC is closest to DATA (within 3.5%)

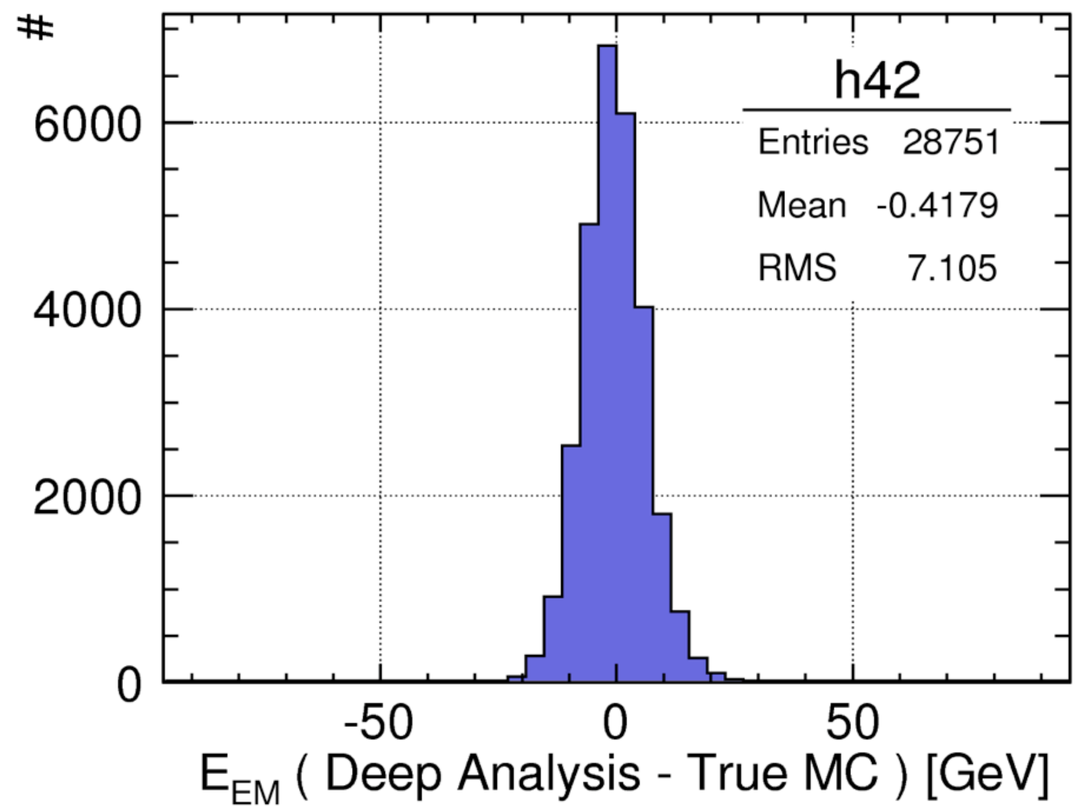
- above 35 GeV all other physics lists are equal
- below 20 GeV differences between the BIC models and the BERT model become visible

The Deep Analysis Algorithm

- Developed by V. Morgunov in 2004, later ported to Marlin C++ framework
- Ad-hoc clustering algorithm based on analog energy information
- Allows to study composition of hadronic showers in highly granular calorimeters
- Two Steps:
  - separation of EM-, hadronic- and track-like hits based on hit energy
  - clustering, joining of clusters in 3D

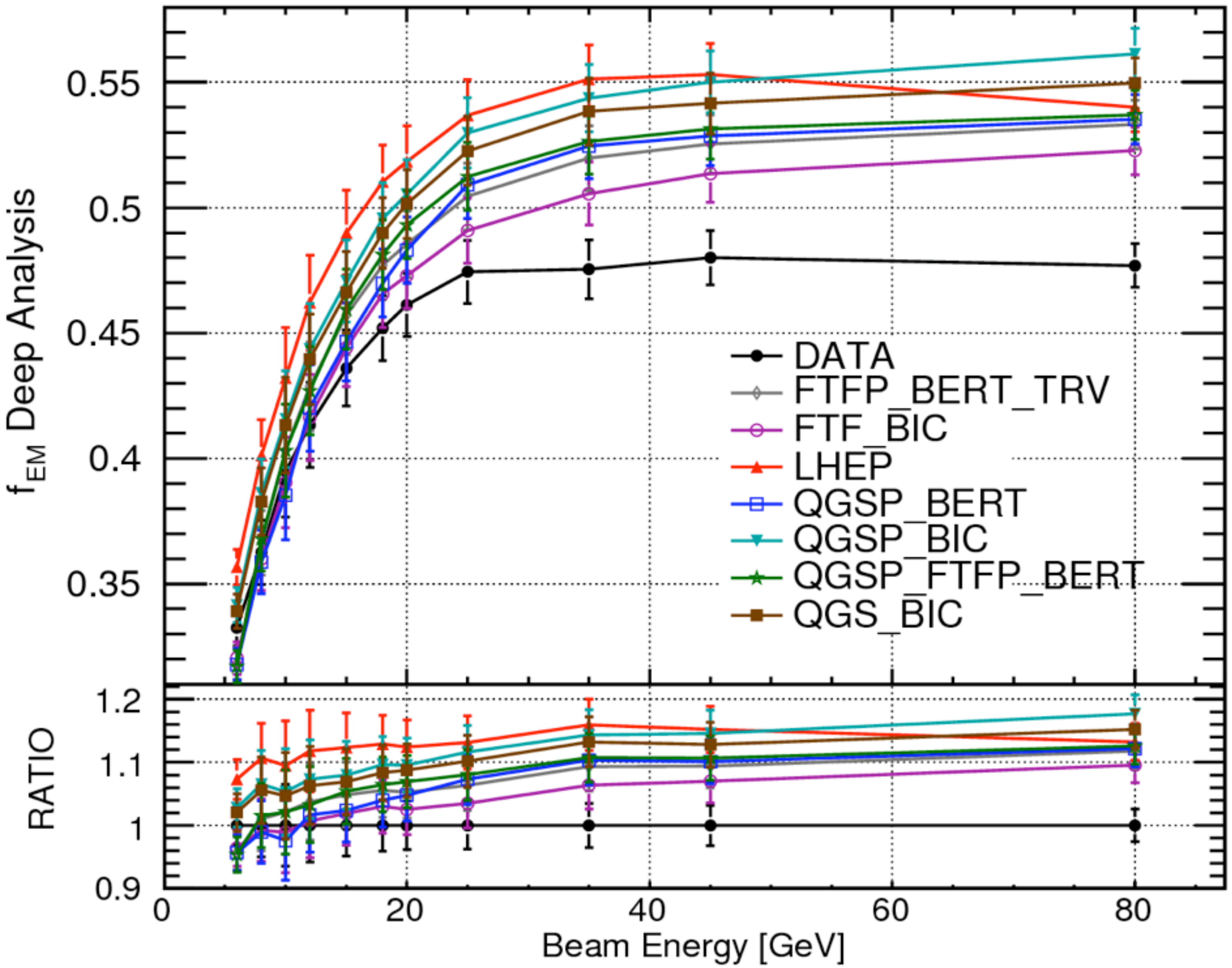
Deep Analysis Performance





- At 80 GeV: Correlation ~ 83%, uncertainty per event: ~17%
- For all energies: uncertainty on the mean value of EM energy smaller than 4.6%

EM fraction from Deep Analysis



- All physics list predict a too high f_{EM}
- Above 25 GeV f_{EM} for DATA seems to be constant (can be effect of clustering)
- Overall FTF_BIC is closest to DATA (within 10%)

- Differences between BIC and BERT models visible. BERT are all equal above 35 GeV, BIC are equal for lower enegies and start to differ at higher energies.

Summary & Conclusion

- Checked λ_{int} for π^- on Fe: good agreement between all physics lists using same σ - LHEP differs
- Mokka Plugin developed to extract true MC EM fraction
- Two variables related to the EM fraction:
  all MC models predict to high EM component
  →either EM component is more dense in MC models or EM fraction is really higher
- Overall FTF_BIC performs best in comparison with data