Pion Showers in the AHCAL Prototype

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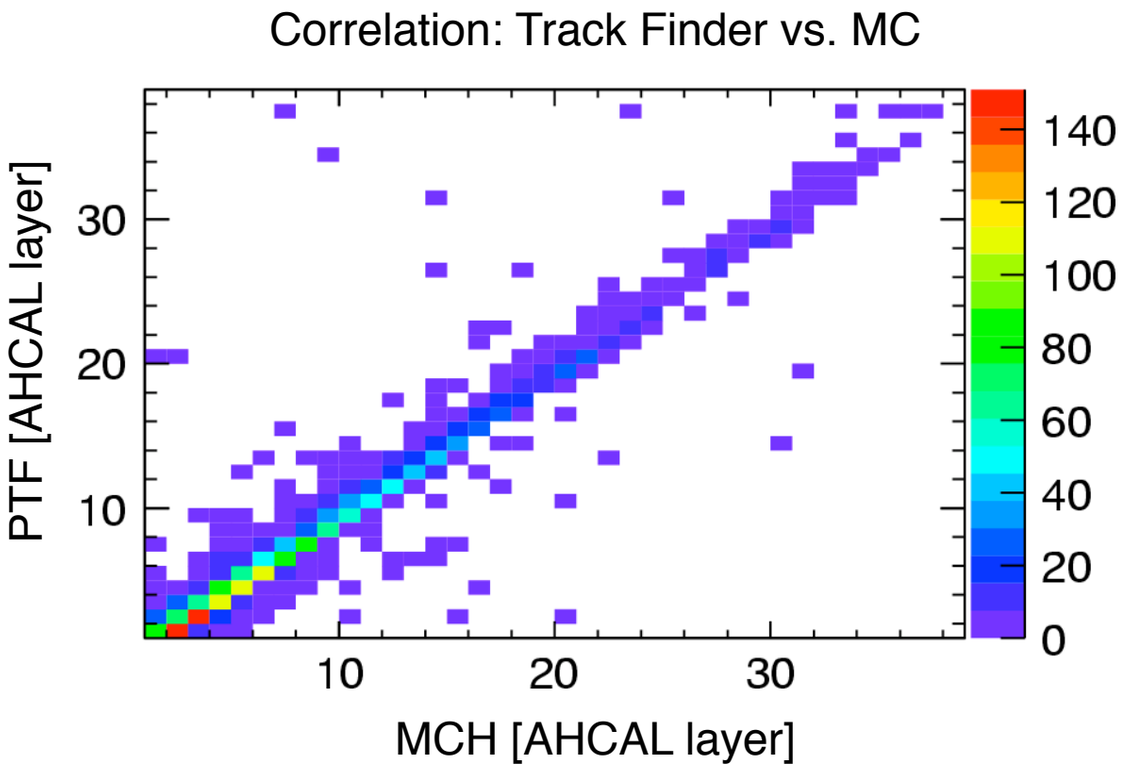
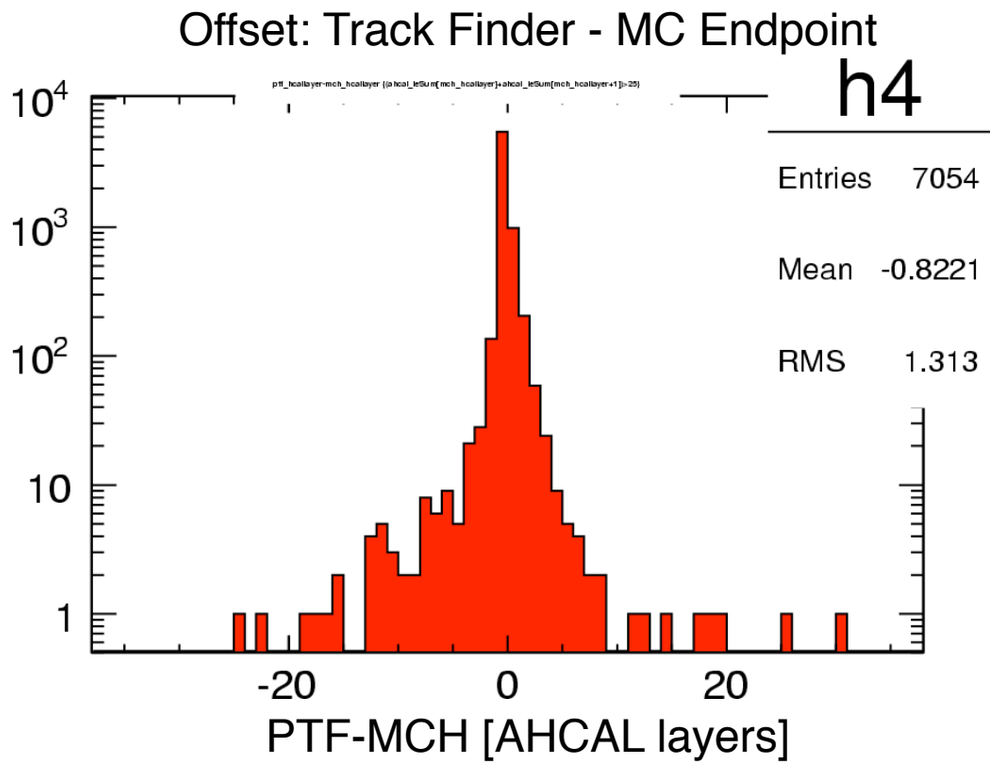
Introduction

- Find first interaction point: Primary Track Finder
- Distribution of the Shower Start
- Event Selection
- Monte Carlo Simulations / GEANT4 physics lists
- Composition of Energy deposited in MC
- Longitudinal Profiles

Shower Start Finder

- Using “Primary Track Finder” v3 (PTF) by M.Chadeeva
- Compare to endpoint of incoming particle MC (MCH)
- For 95% of the events the difference in the layer found as shower start is below ±1, for 98 % it is below ±2
- There is an systematic offset of roughly -1



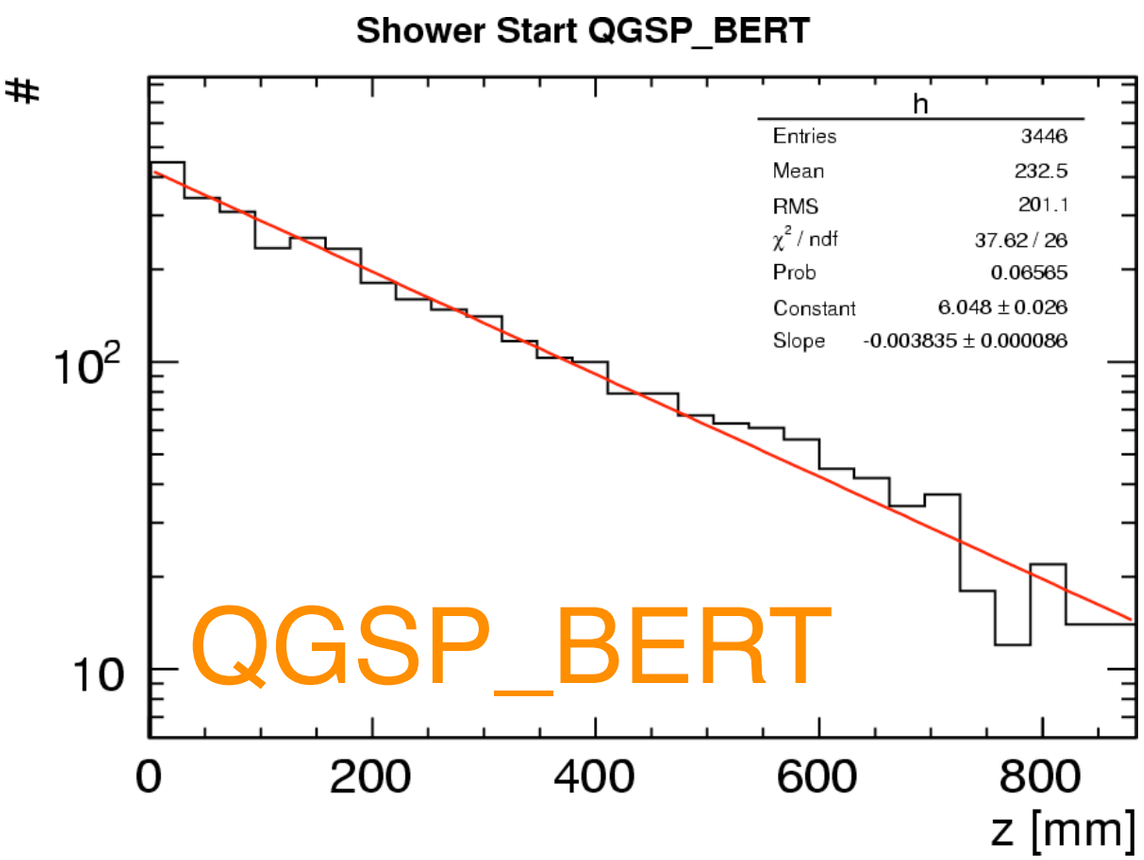


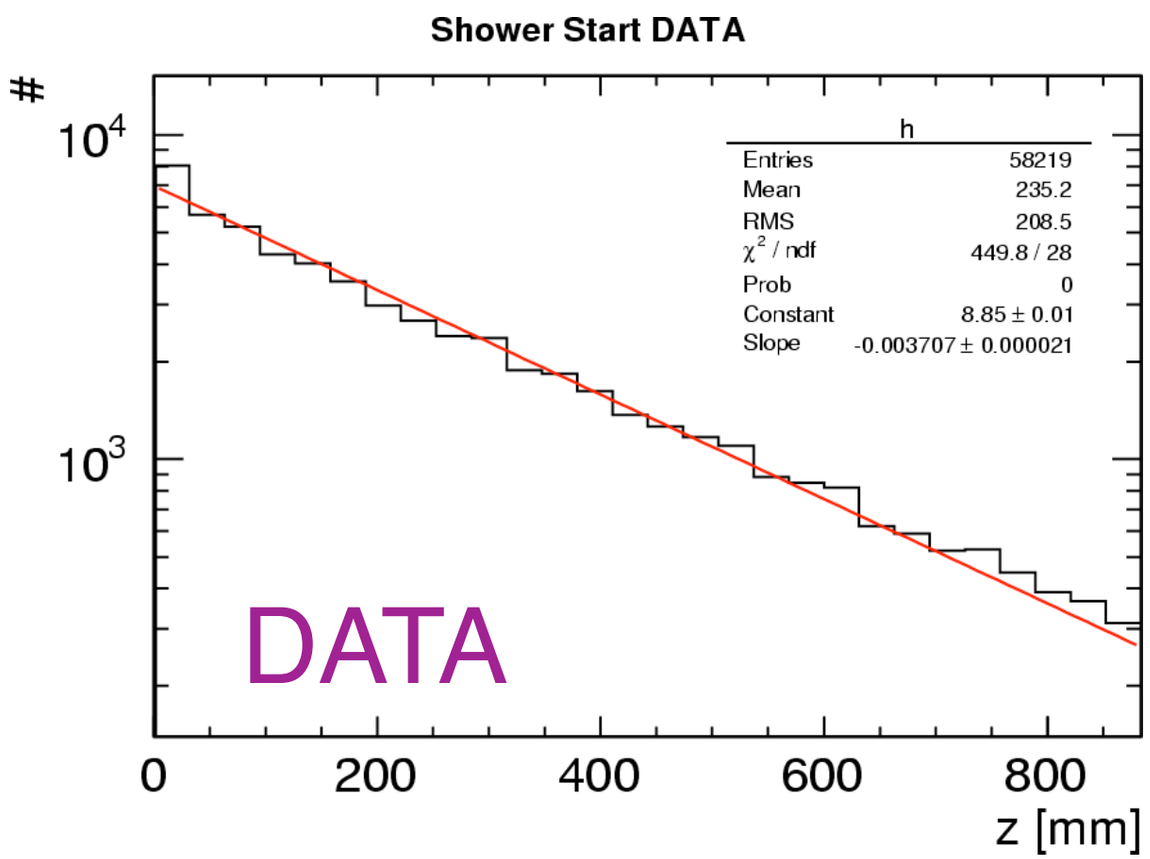
Longitudinal Distribution of Shower Start

- From this plot one can directly get pion interaction length in the AHCAL → fit to exponential: $A\exp(kz)$
- QGSP_BERT: $\lambda = (261 \pm 6)\mathrm{mm}$
- DATA: $\lambda = (270 \pm 2)\mathrm{mm}$

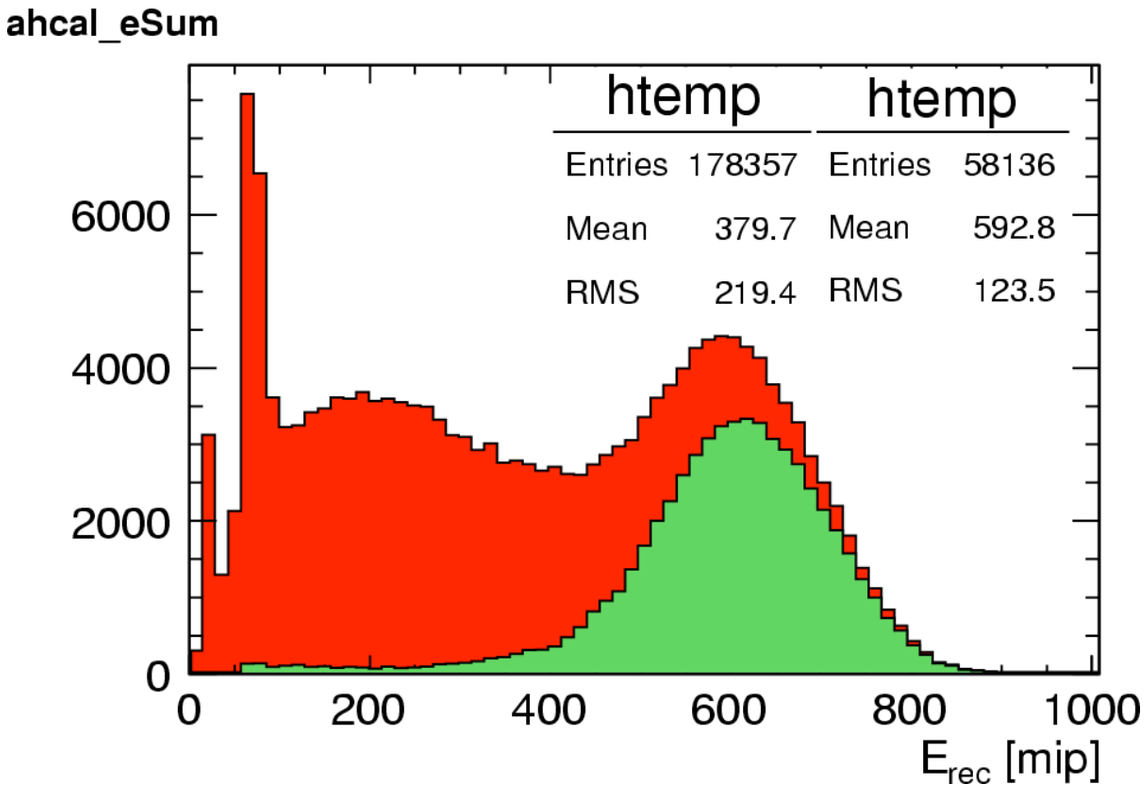
(only statistical errors)

- Calculation for AHCAL: $\lambda_n \approx 230$ mm





Event Selection



- To investigate shower shape and to minimize effects due to leakage, only events interacting in the first 10 layers of the AHCAL are accepted

- In most of the events the shower already starts in the ECAL
- Statistics go down with decreasing beam energy

Run	Energy	Tot. Events	Ev. after Cut	Efficiency
330962	80 GeV	179750	39526	23.0 %
330961	45 GeV	174574	38945	22.3 %
330960	35 GeV	182884	35532	19.4 %
330325	25 GeV	177607	40852	23.0 %
330326	20 GeV	180265	41822	23.2 %
330327	18 GeV	178357	41225	23.1 %
330328	15 GeV	179117	40275	22.5 %
330330	12 GeV	261586	50469	19.3 %
330332	10 GeV	178494	29736	16.7 %
330334	8 GeV	176501	27186	15.4 %
330908	6 GeV	122382	4744	3.9 %

Monte Carlo Simulation

Simulations were done using Mokka 7.02 / GEANT4 9.3

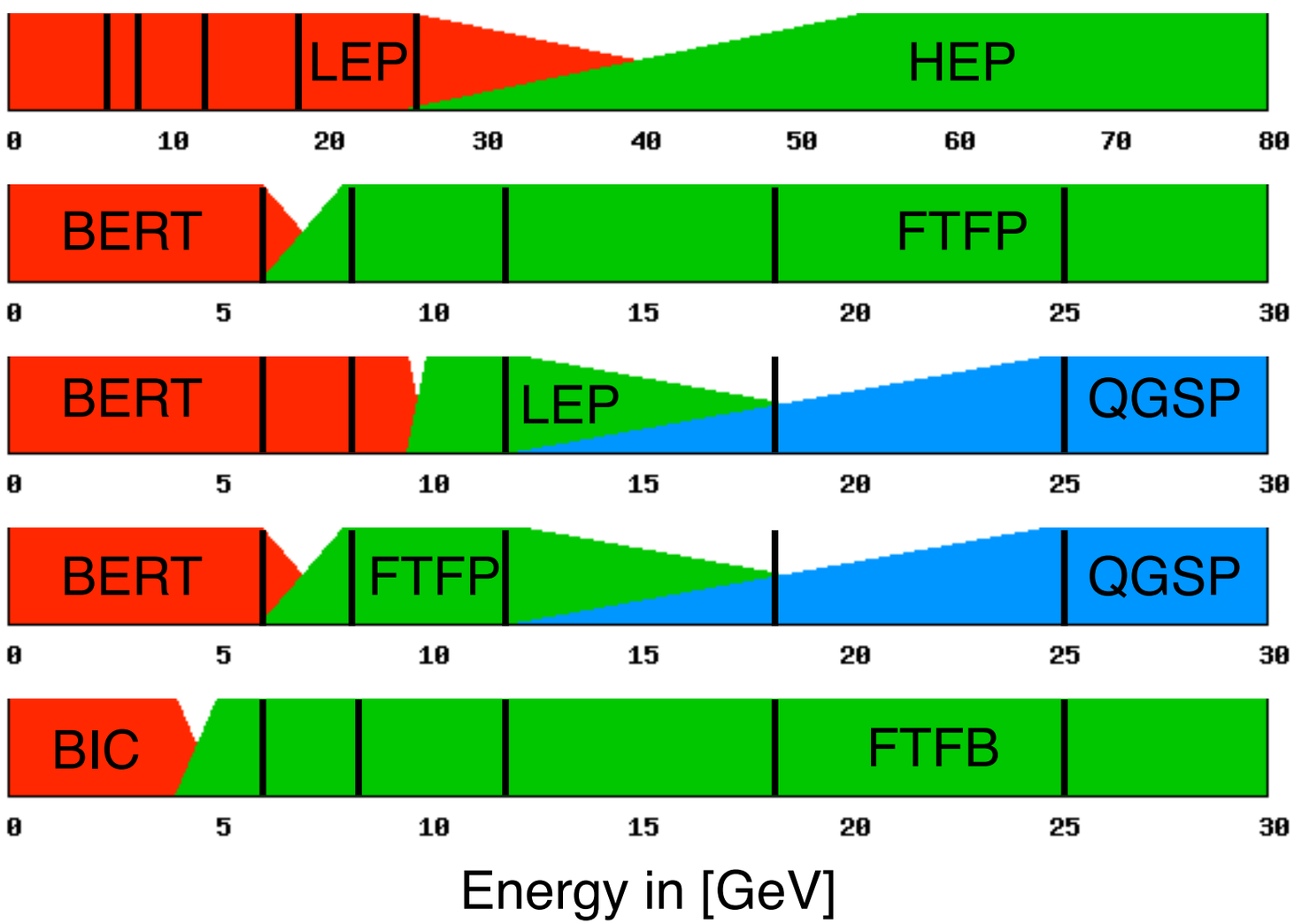
LHEP (diff. energy scale)→

FTFP_BERT_TRV

QGSP_BERT

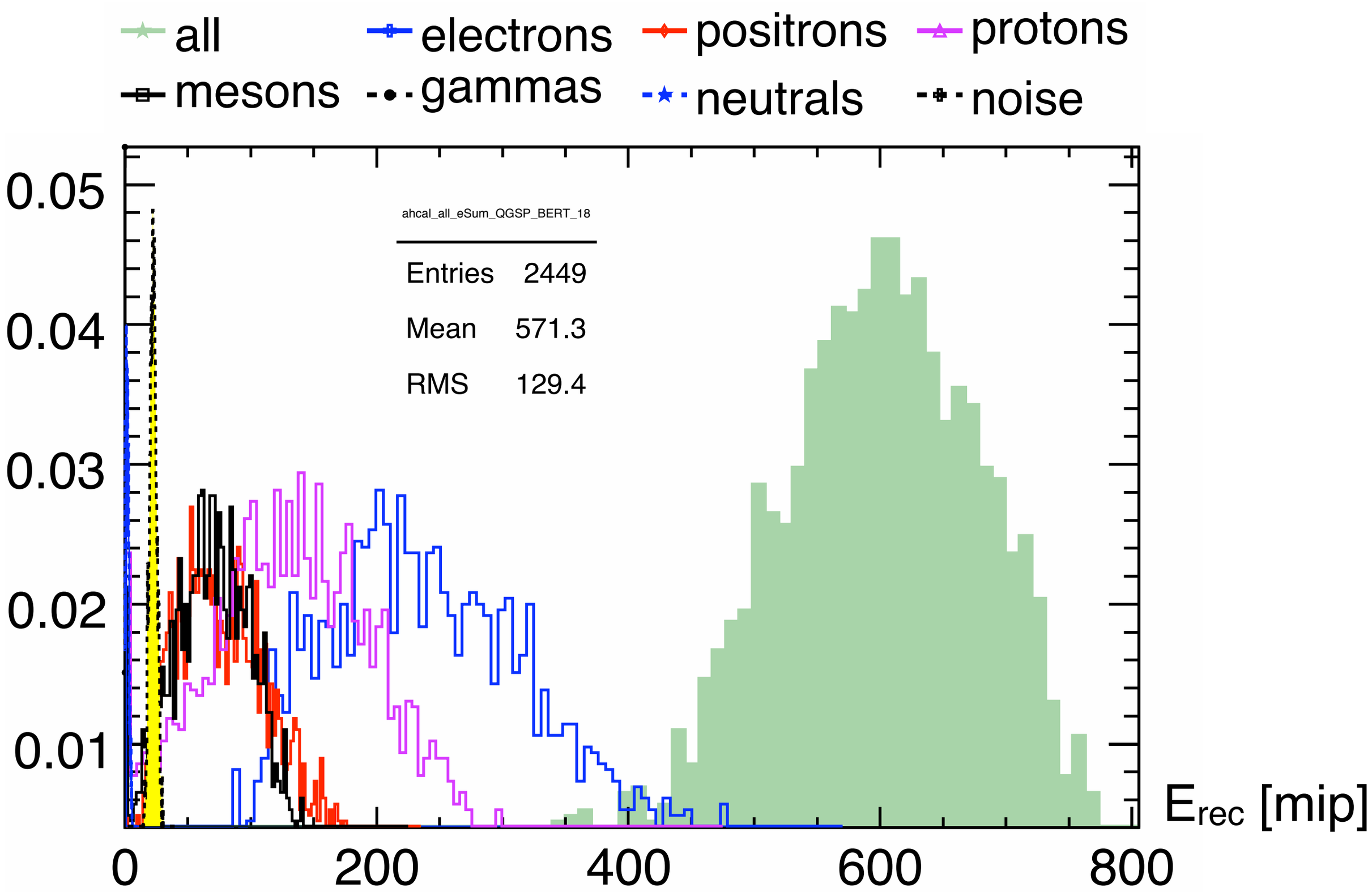
QGSP_FTFP_BERT

FTF_BIC

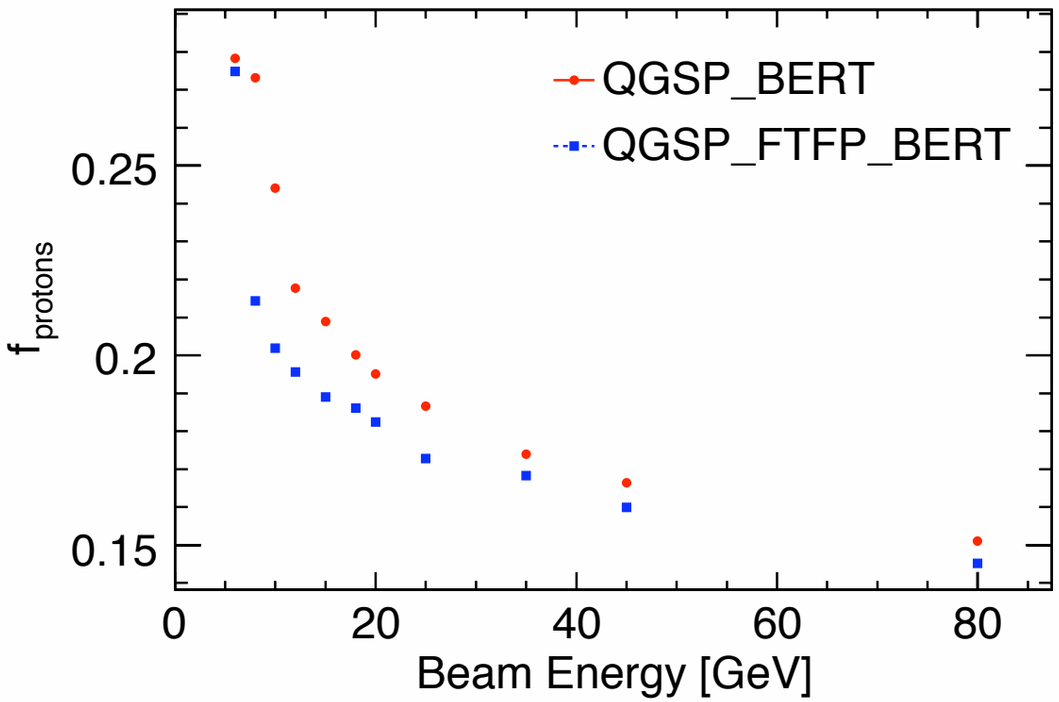


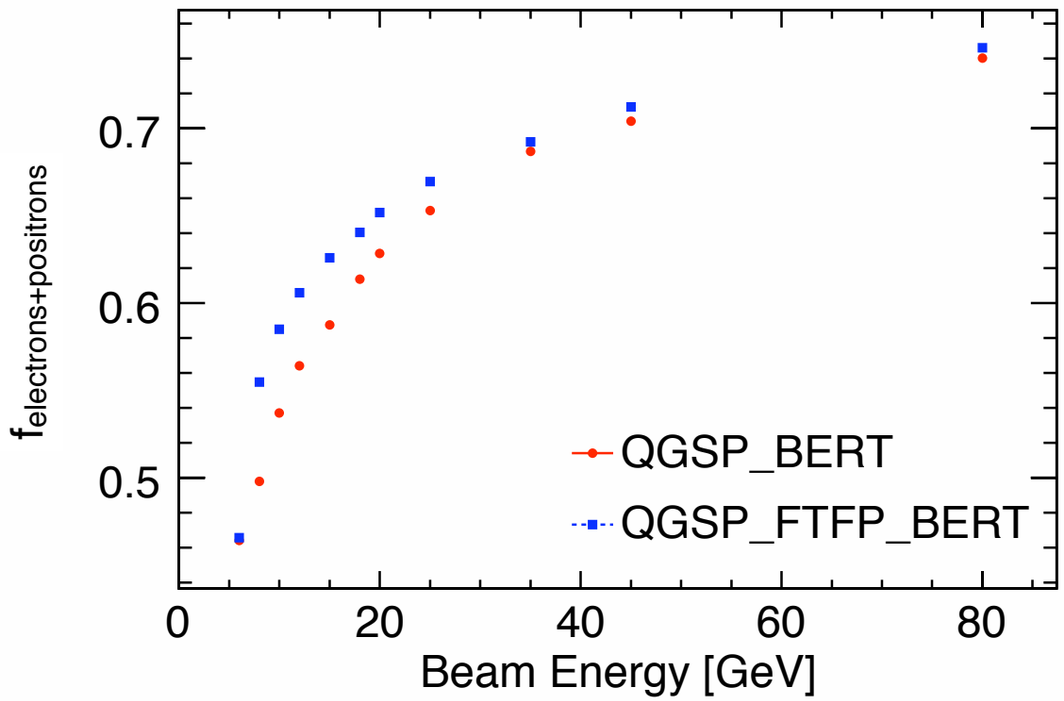
Interesting energy points: 6, 8, 12, 18, 25 GeV

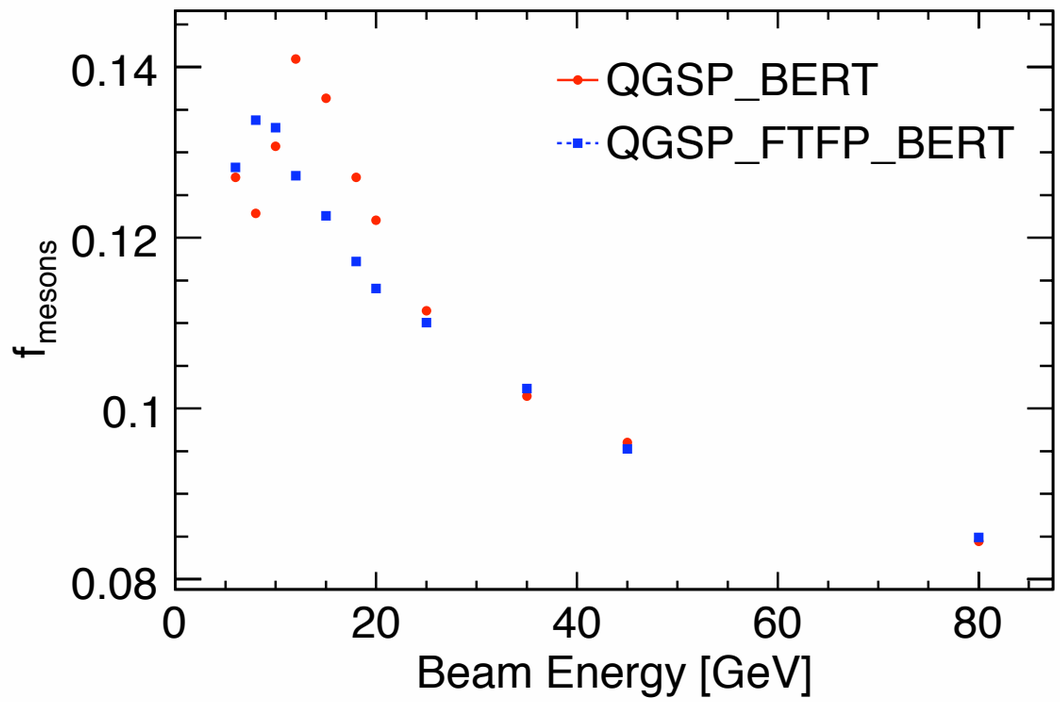
Composition of Energy deposited in MC



Energy Fractions vs. Beam Energy

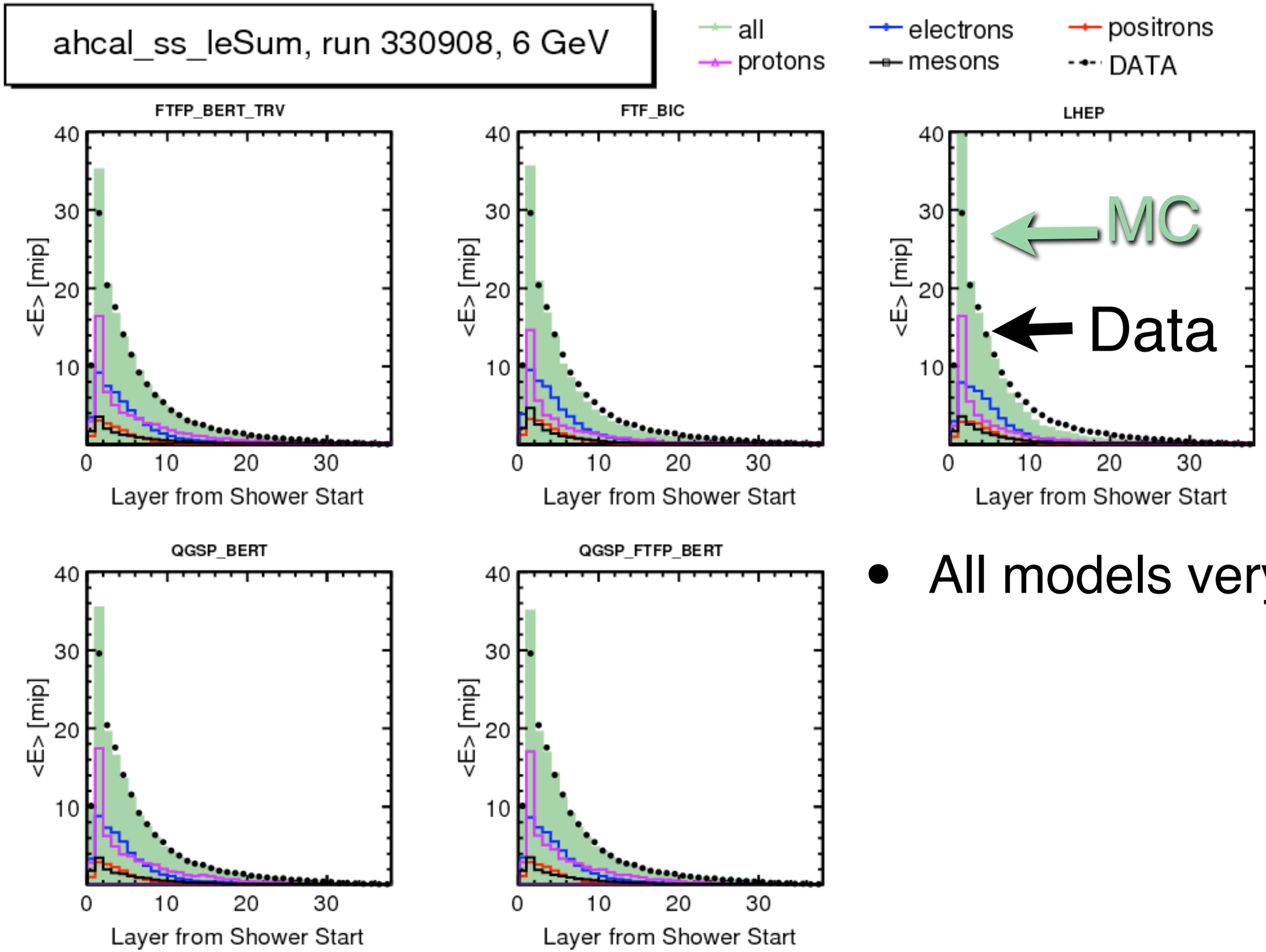






- $f_{electrons}$ grows with energy, $f_{protons}$ and f_{mesons} fall
- QGSP_BERT (LEP) produces less electrons and more protons & mesons than the FTFP list
- QGSP_BERT proton fraction at 6 GeV looks strange
- In Both QGSP_BERT and QGSP_FTFP_BERT there is a strange kink in the meson energy.

Longitudinal Profiles: 6 GeV



- All models very similar

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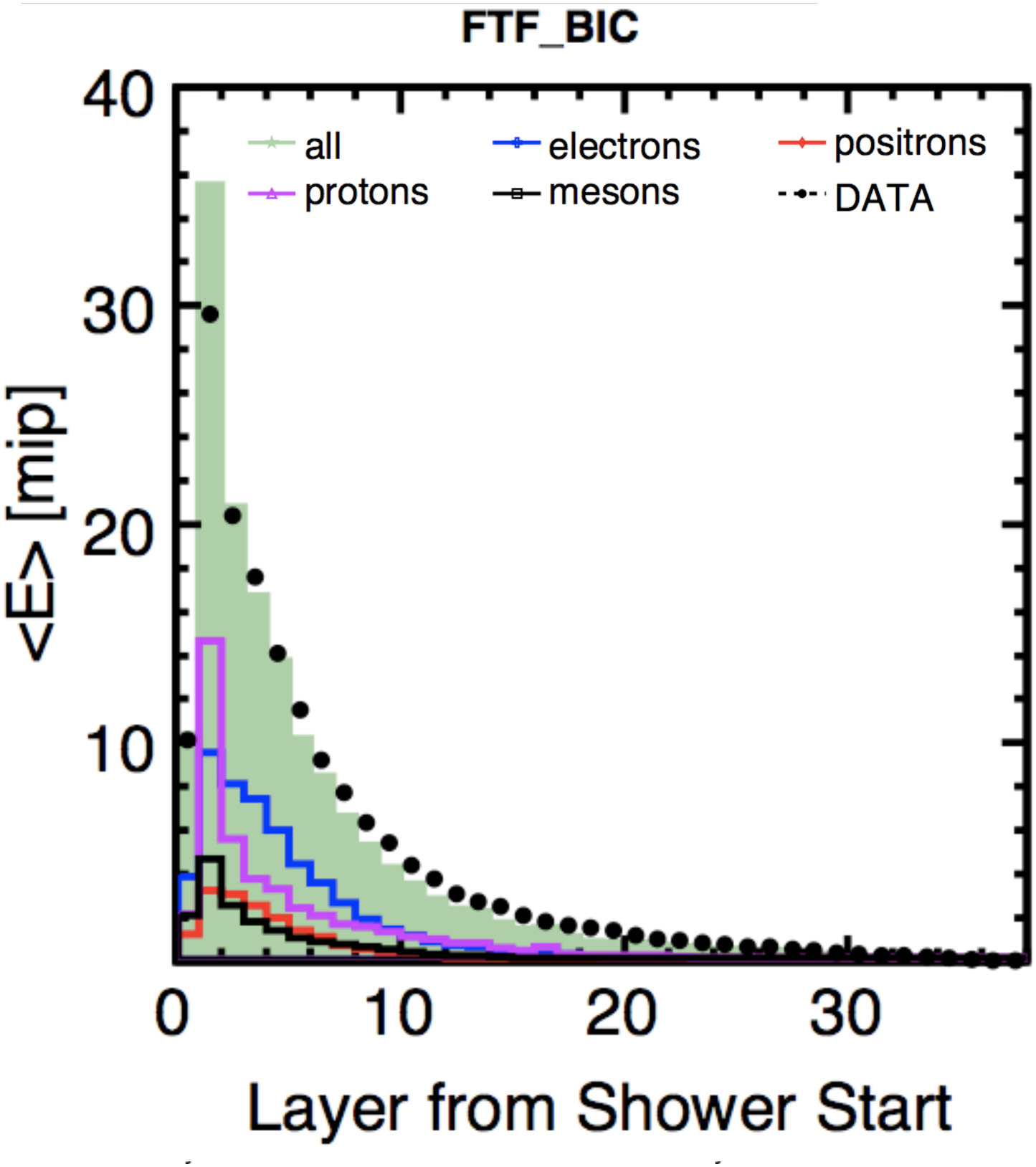

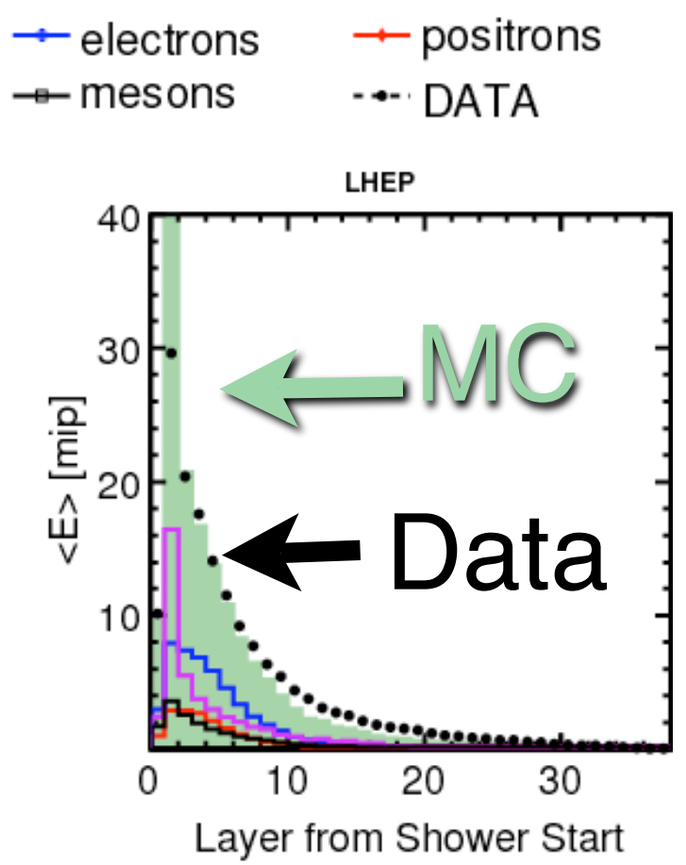

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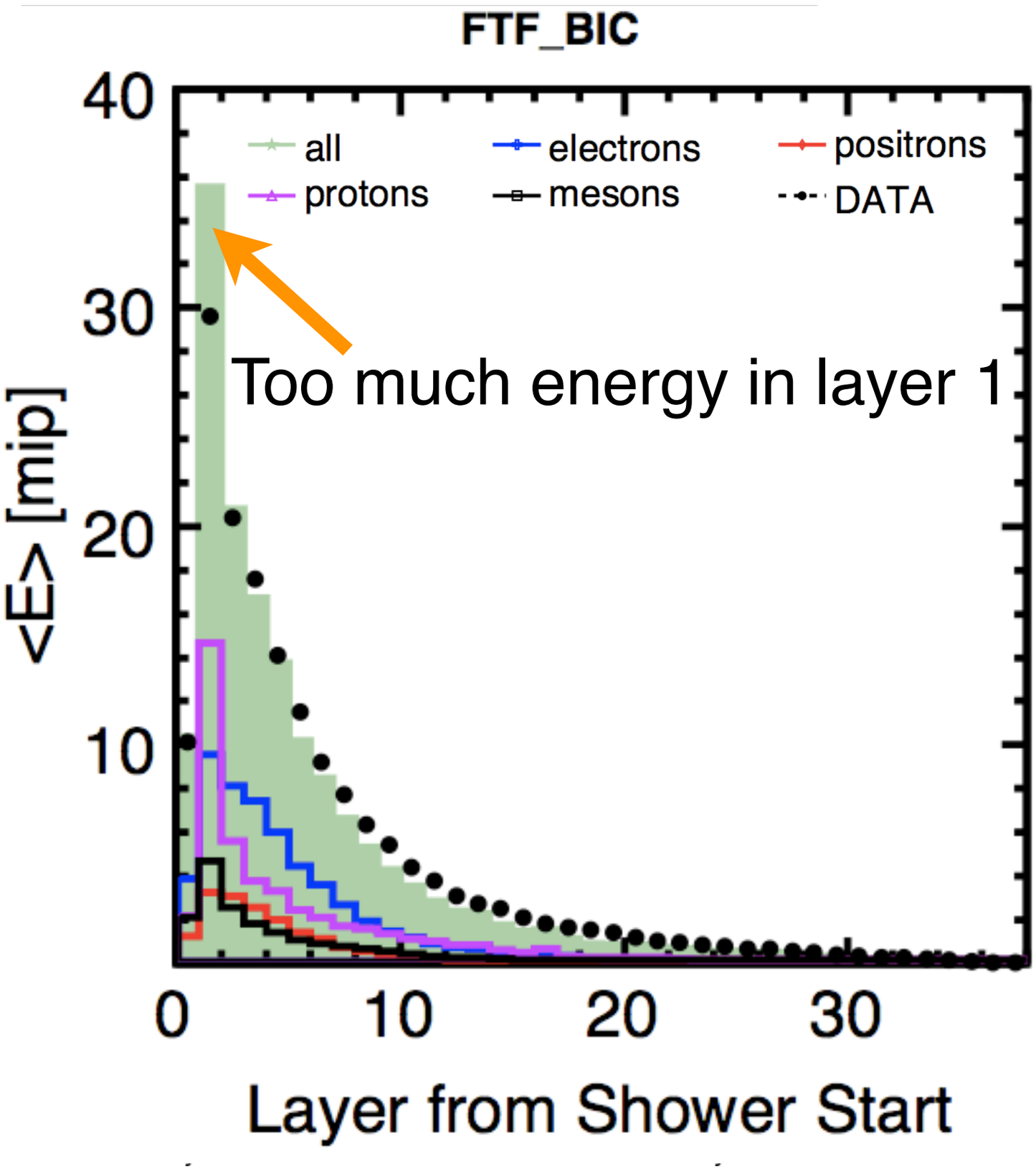

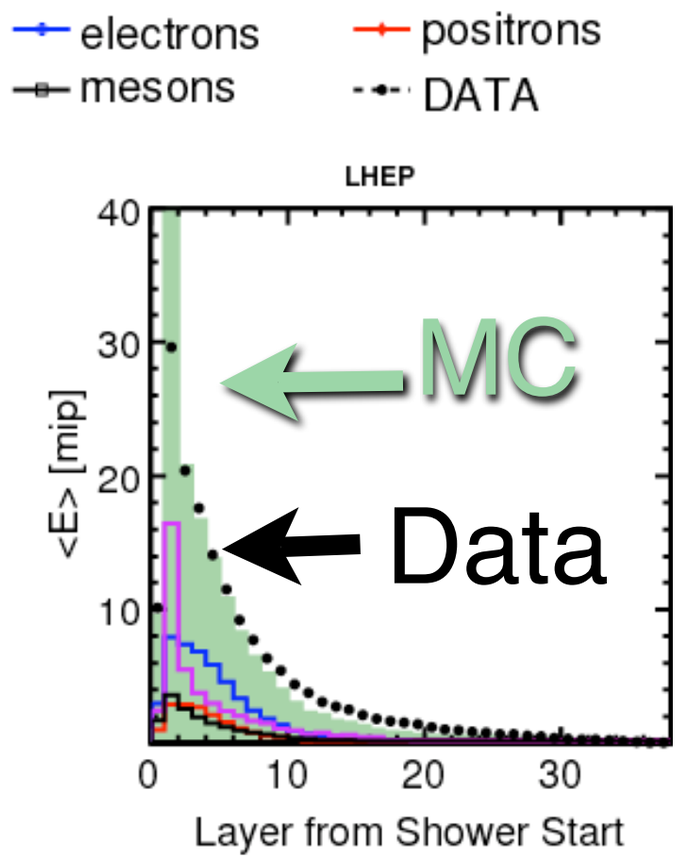

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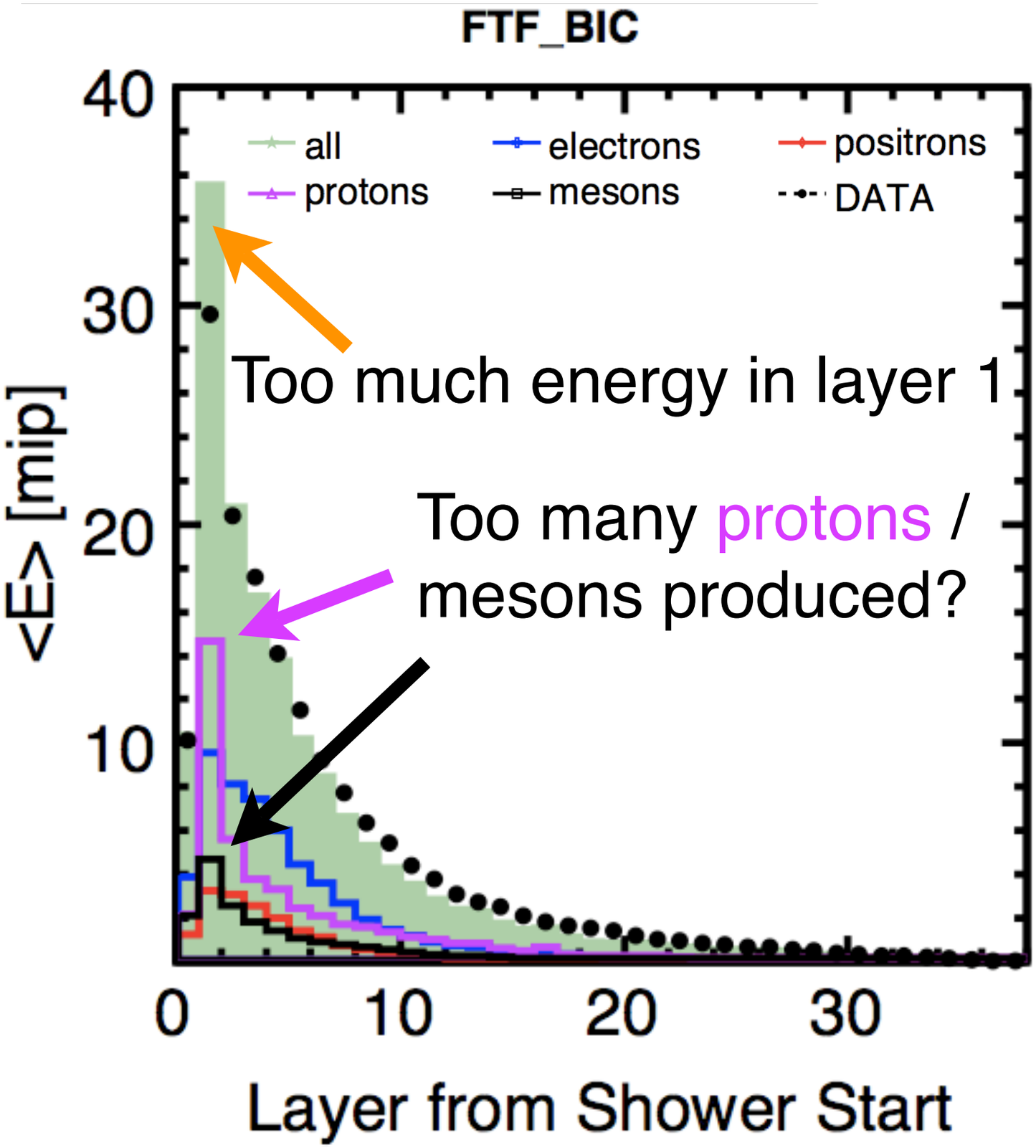
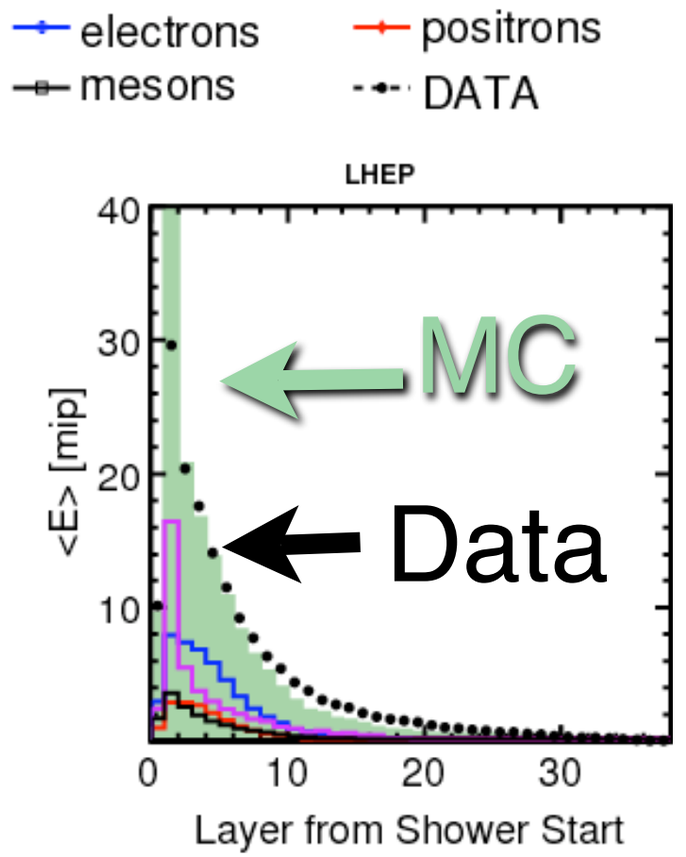


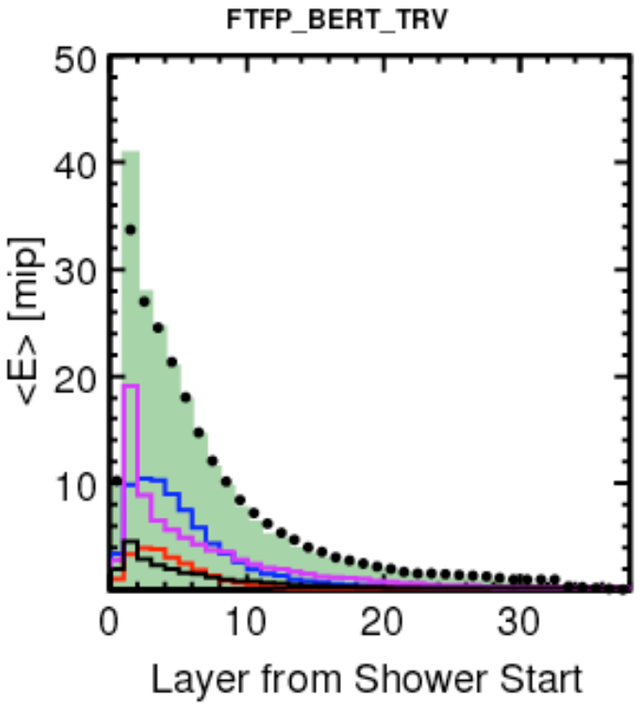


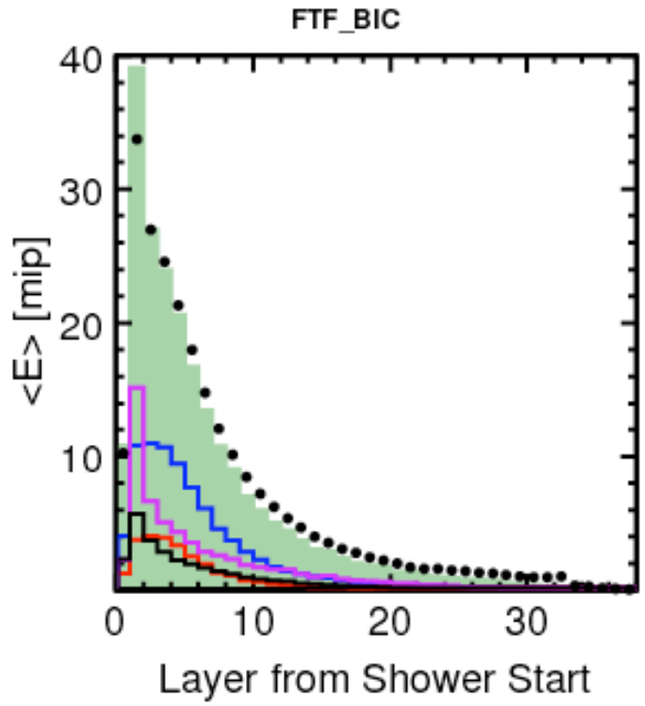
- All models very similar

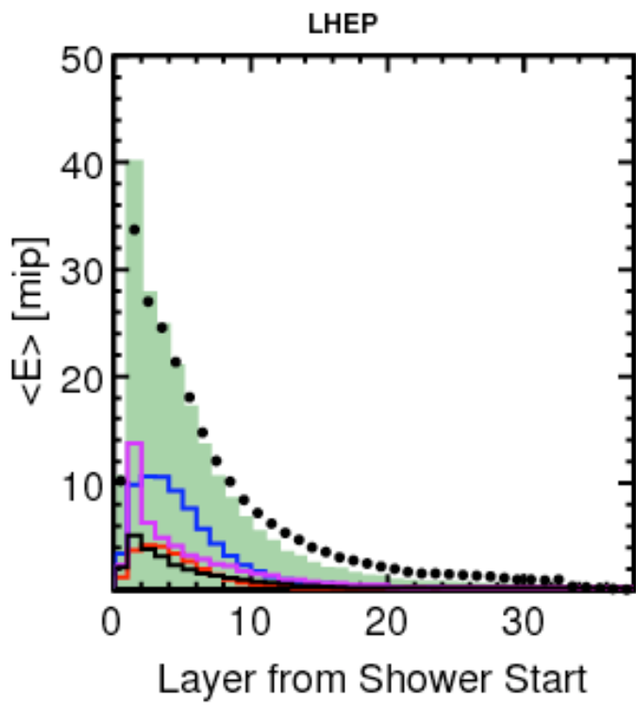
Longitudinal Profiles: 8 GeV

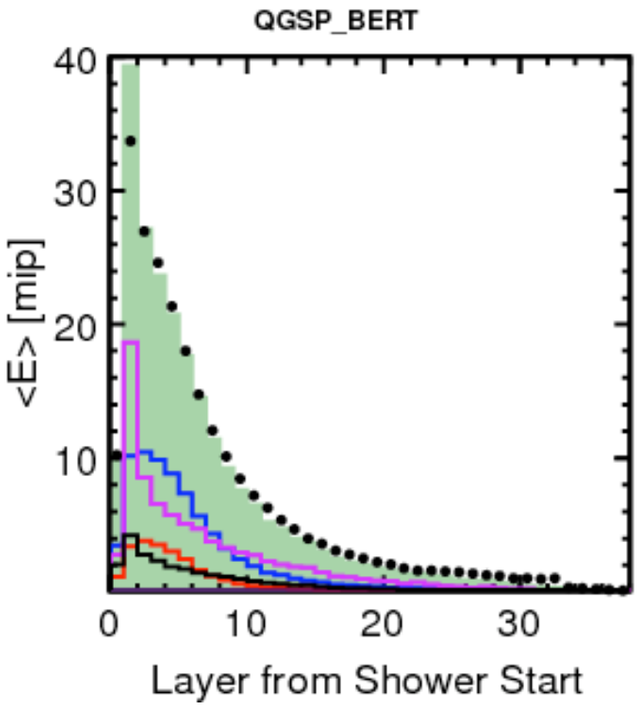
ahcal_ss_leSum, run 330334, 8 GeV

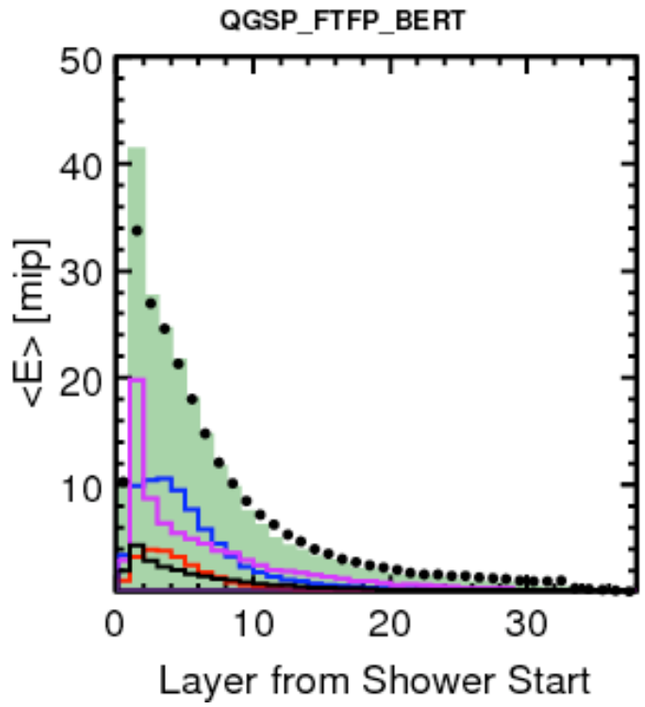
all, protons, electrons, mesons, positrons, DATA







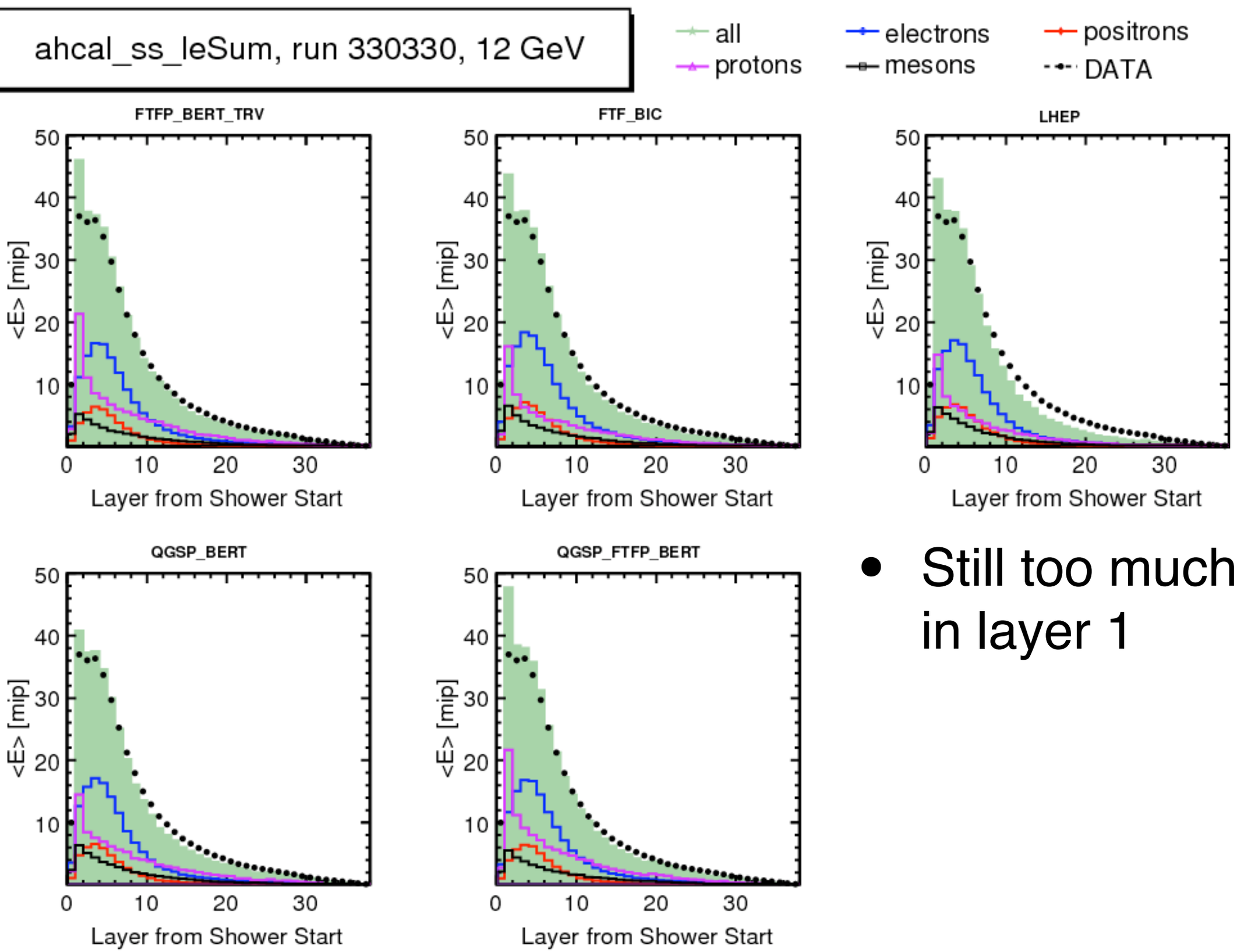




- At 8 GeV still all models are very similar
- Too much energy in layer 1

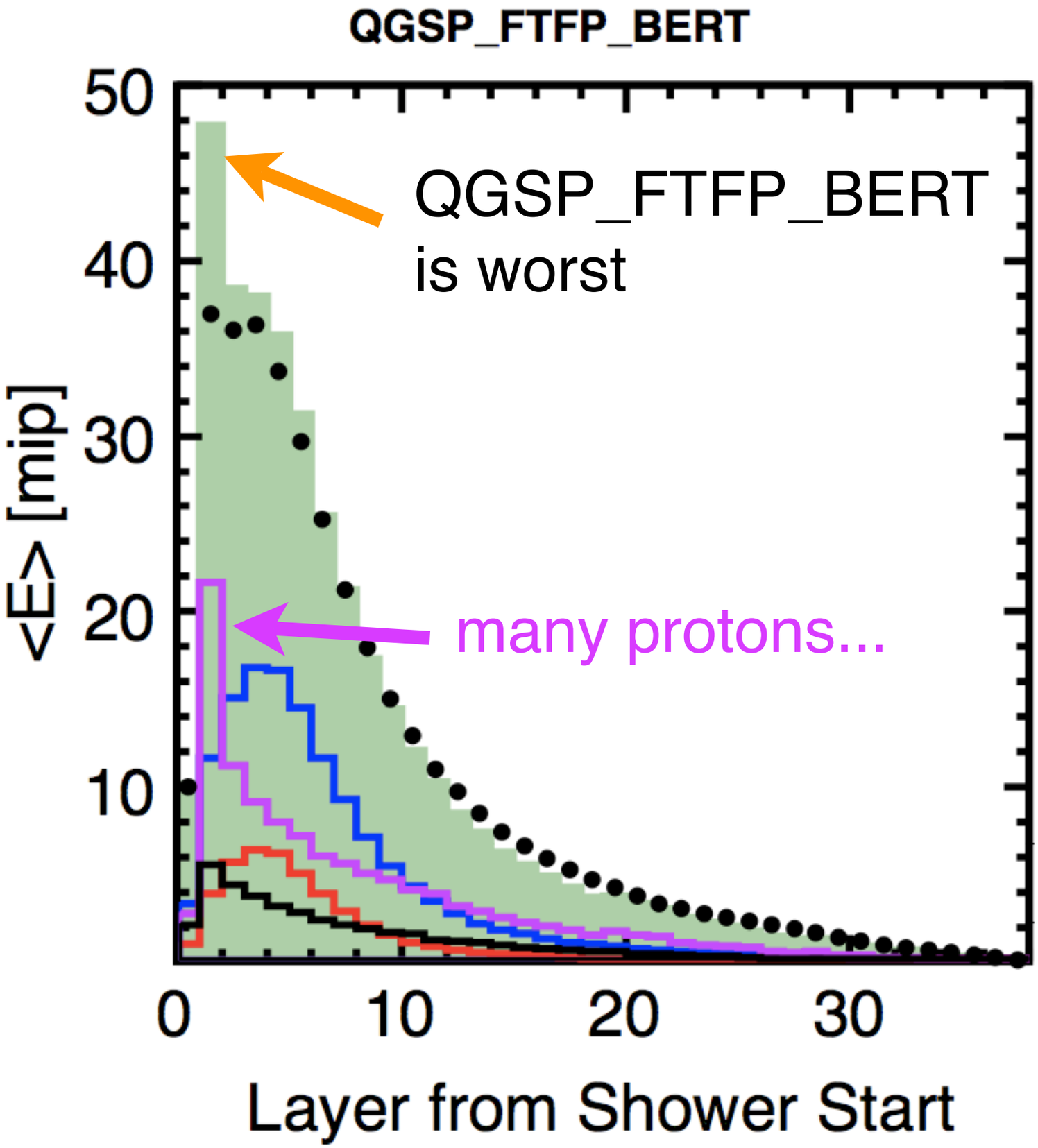
Longitudinal Profiles: 12 GeV

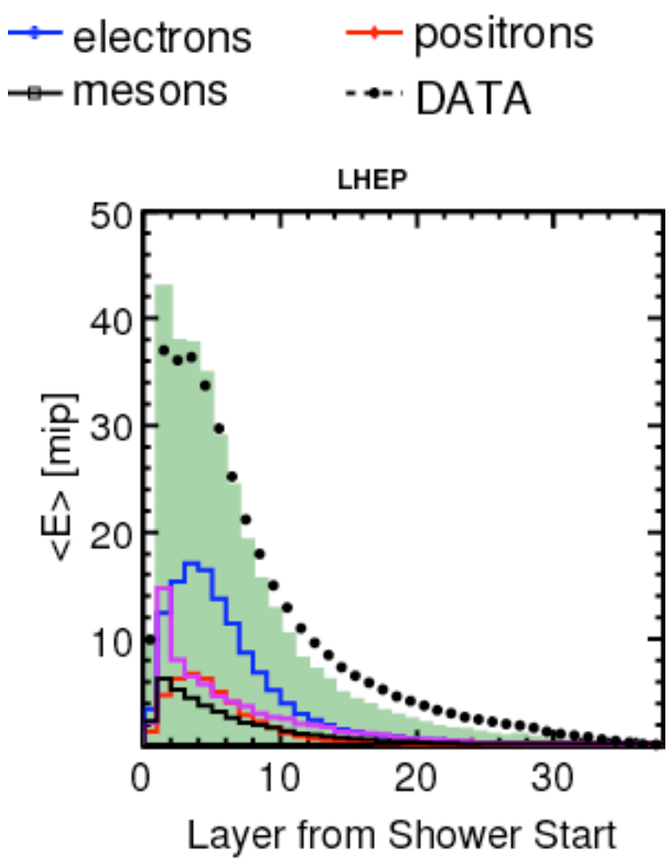
ahcal_ss_leSum, run 330330, 12 GeV



- Still too much energy in layer 1

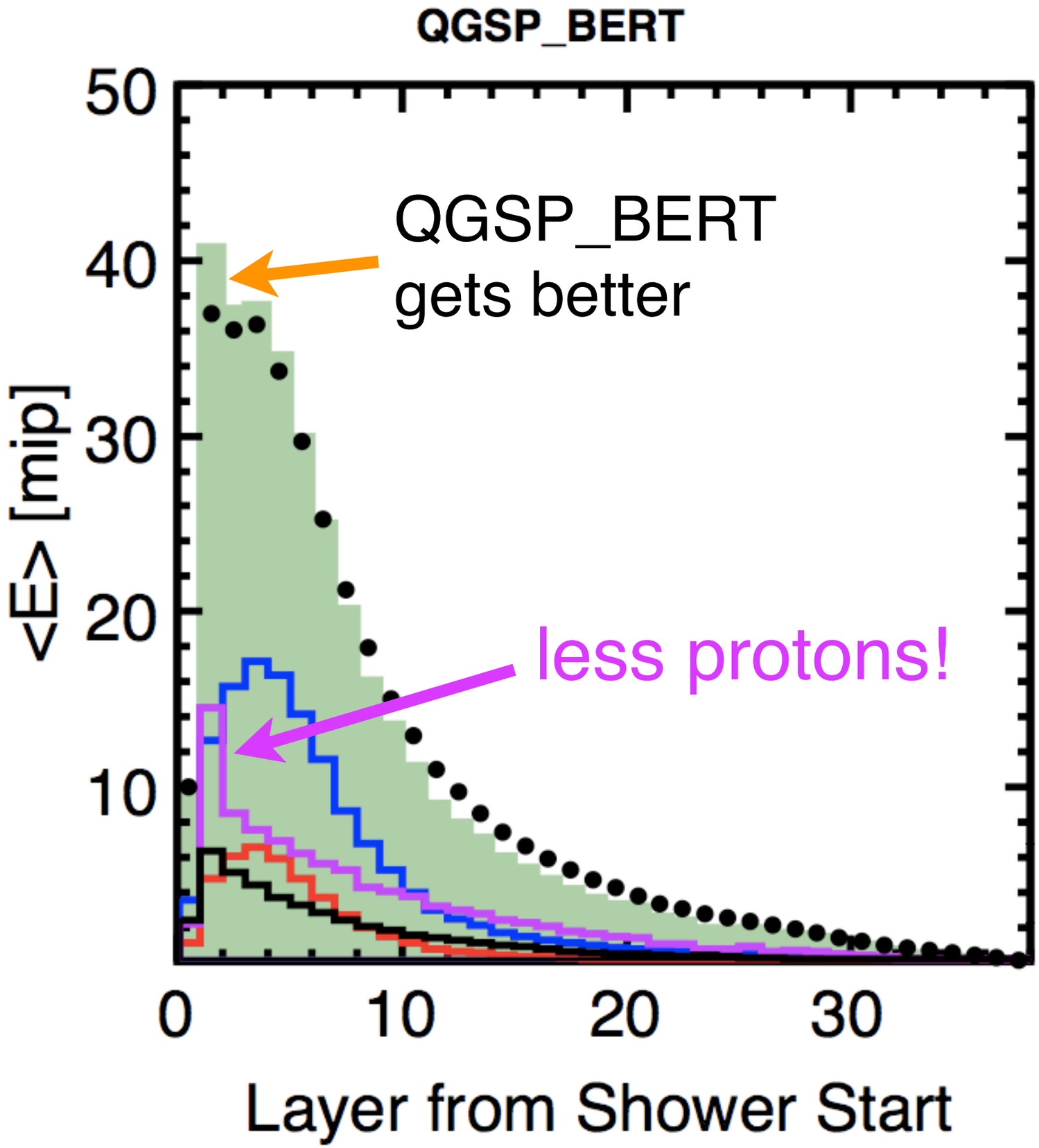
Longitudinal Profiles: 12 GeV

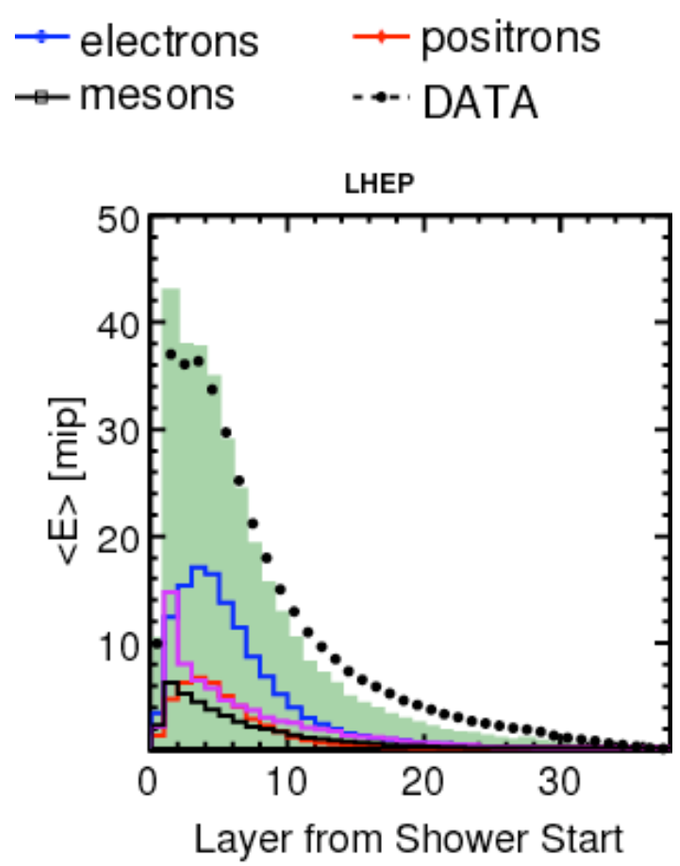




- Still too much energy in layer 1

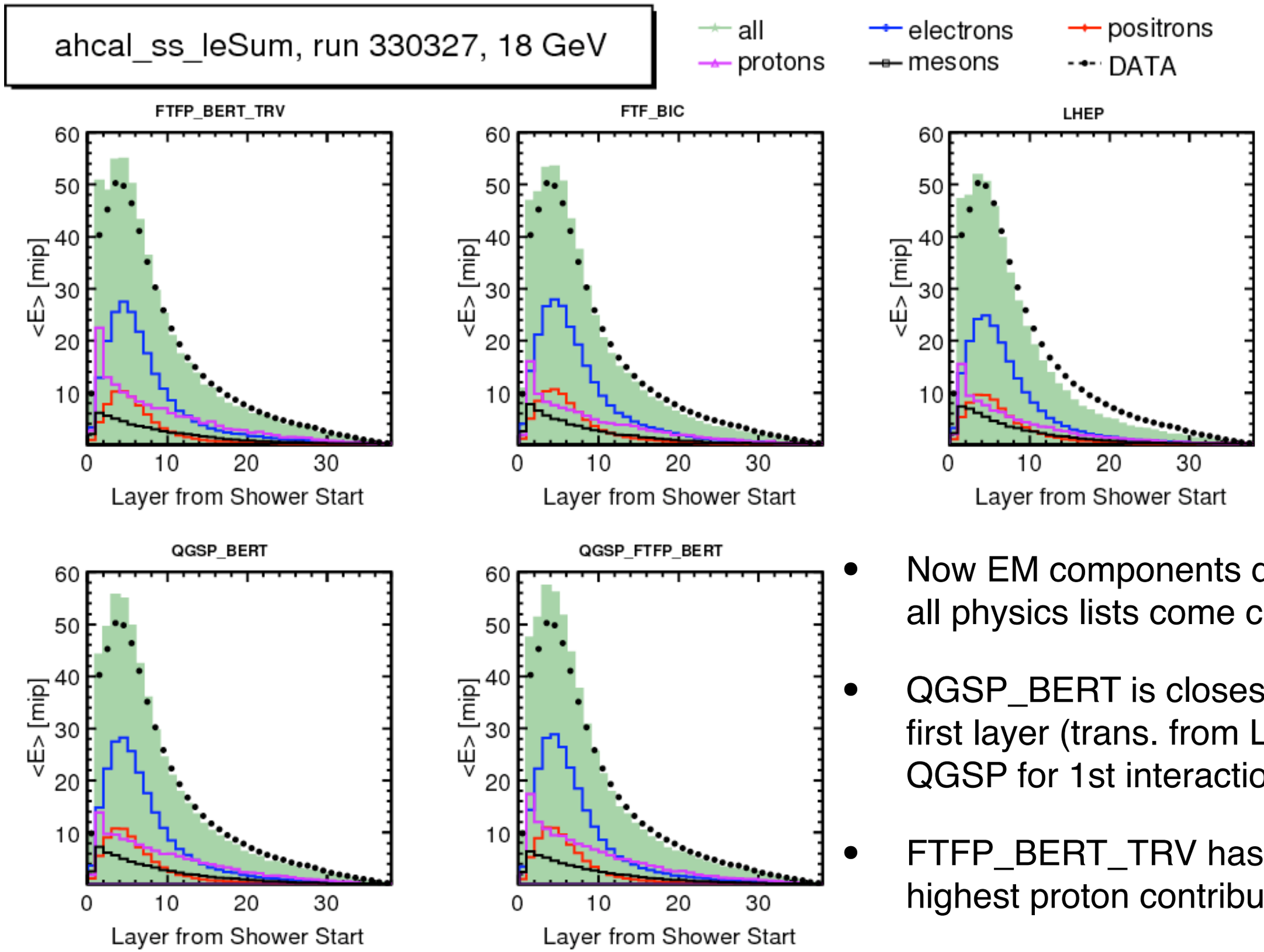
Longitudinal Profiles: 12 GeV





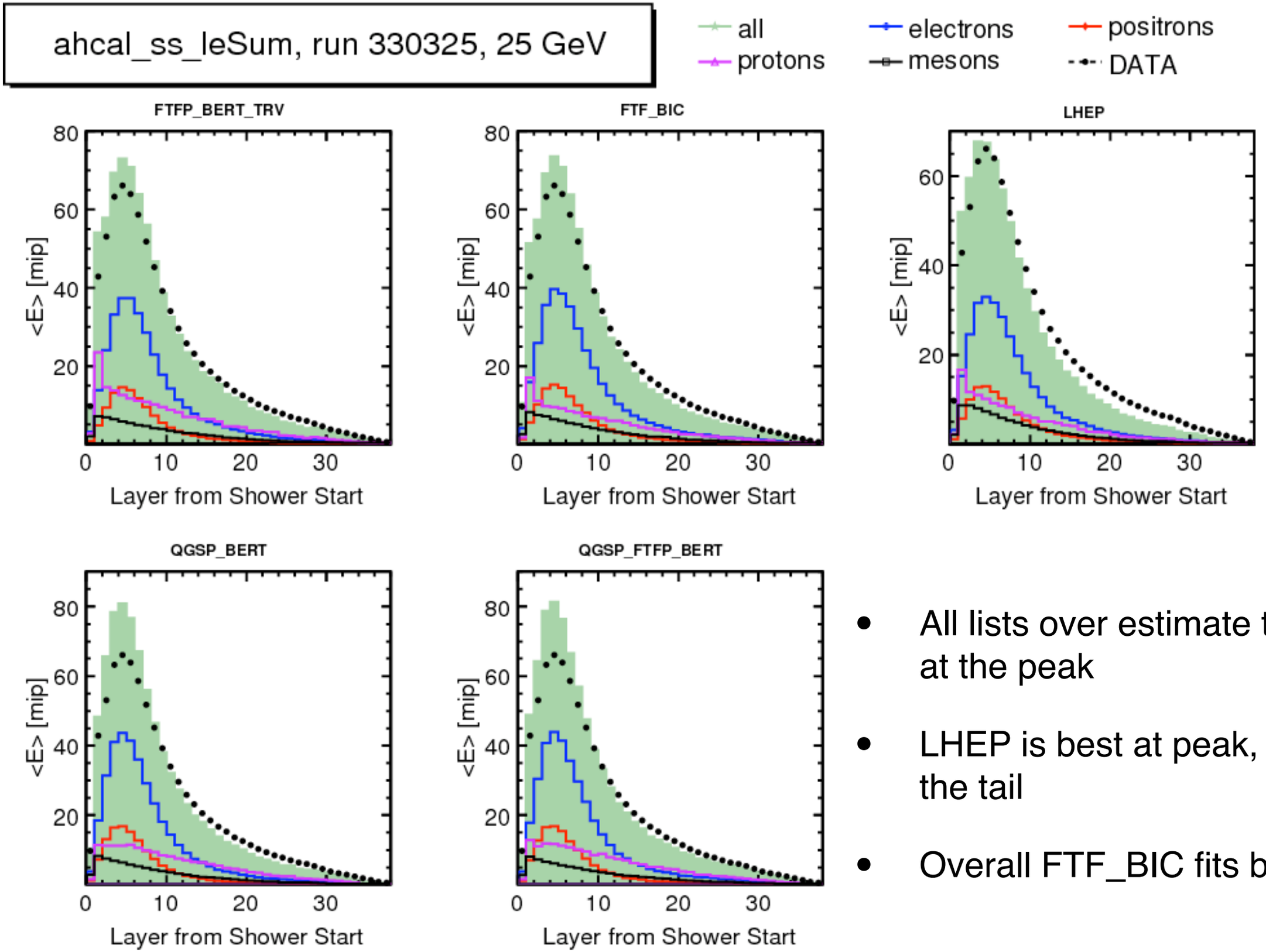
- Still too much energy in layer 1

Longitudinal Profiles



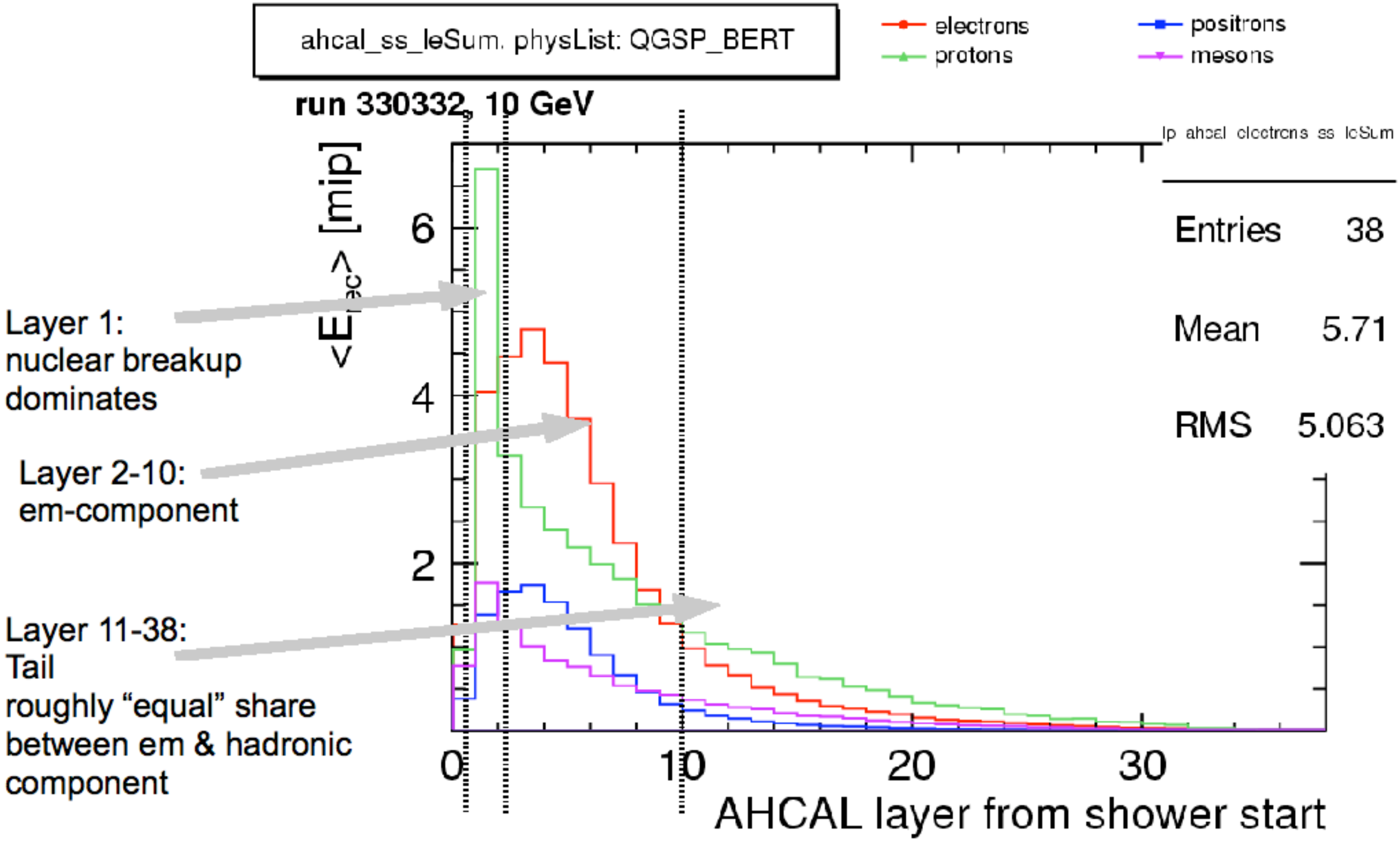
- Now EM components dominate and all physics lists come closer to data
- QGSP_BERT is closest to data in first layer (trans. from LEP to QGSP for 1st interaction)
- FTFP_BERT_TRV has by far the highest proton contribution

Longitudinal Profiles

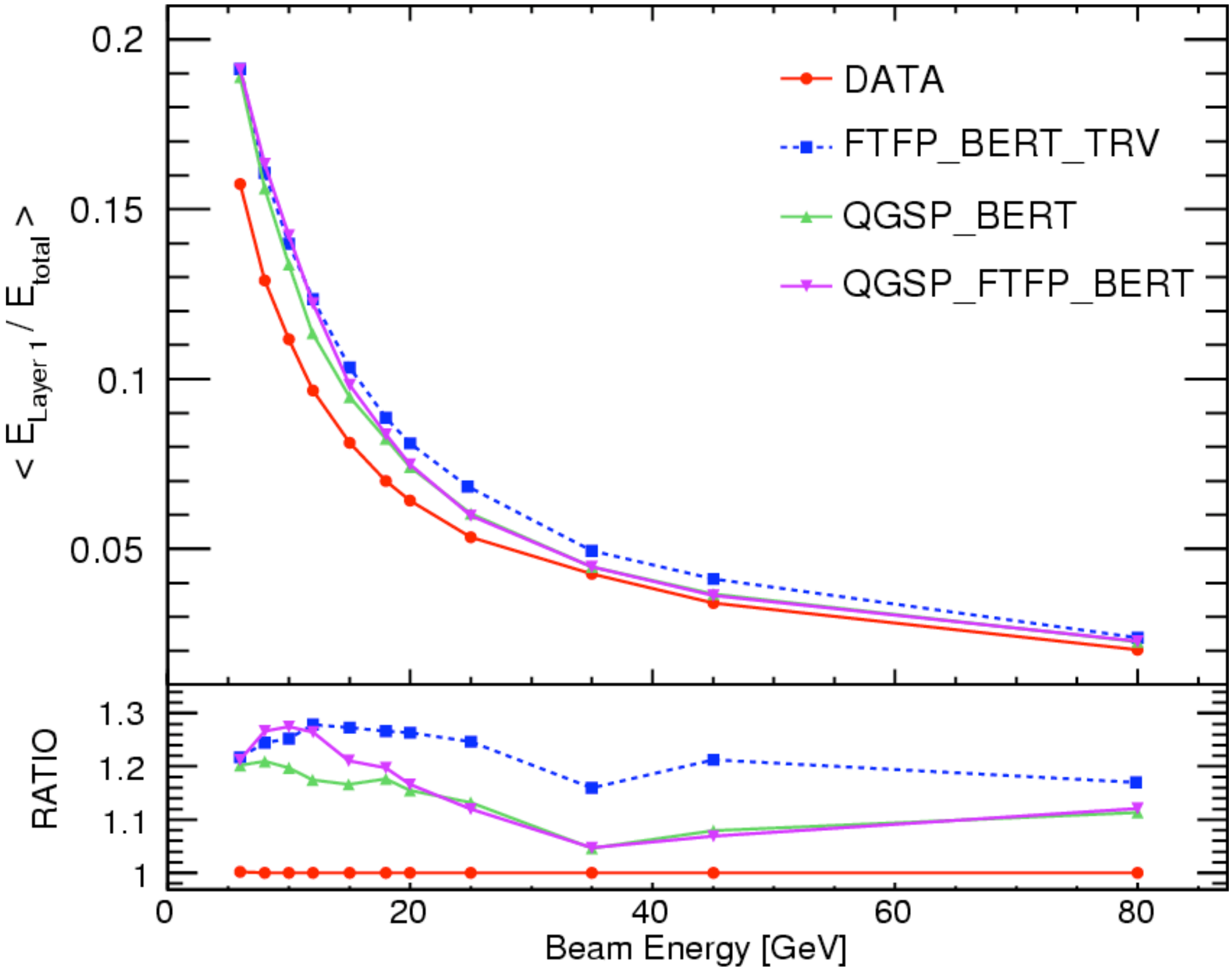


- All lists over estimate the energy in at the peak
- LHEP is best at peak, but worst in the tail
- Overall FTF_BIC fits best to data

Longitudinal Profile: Regions of Interest

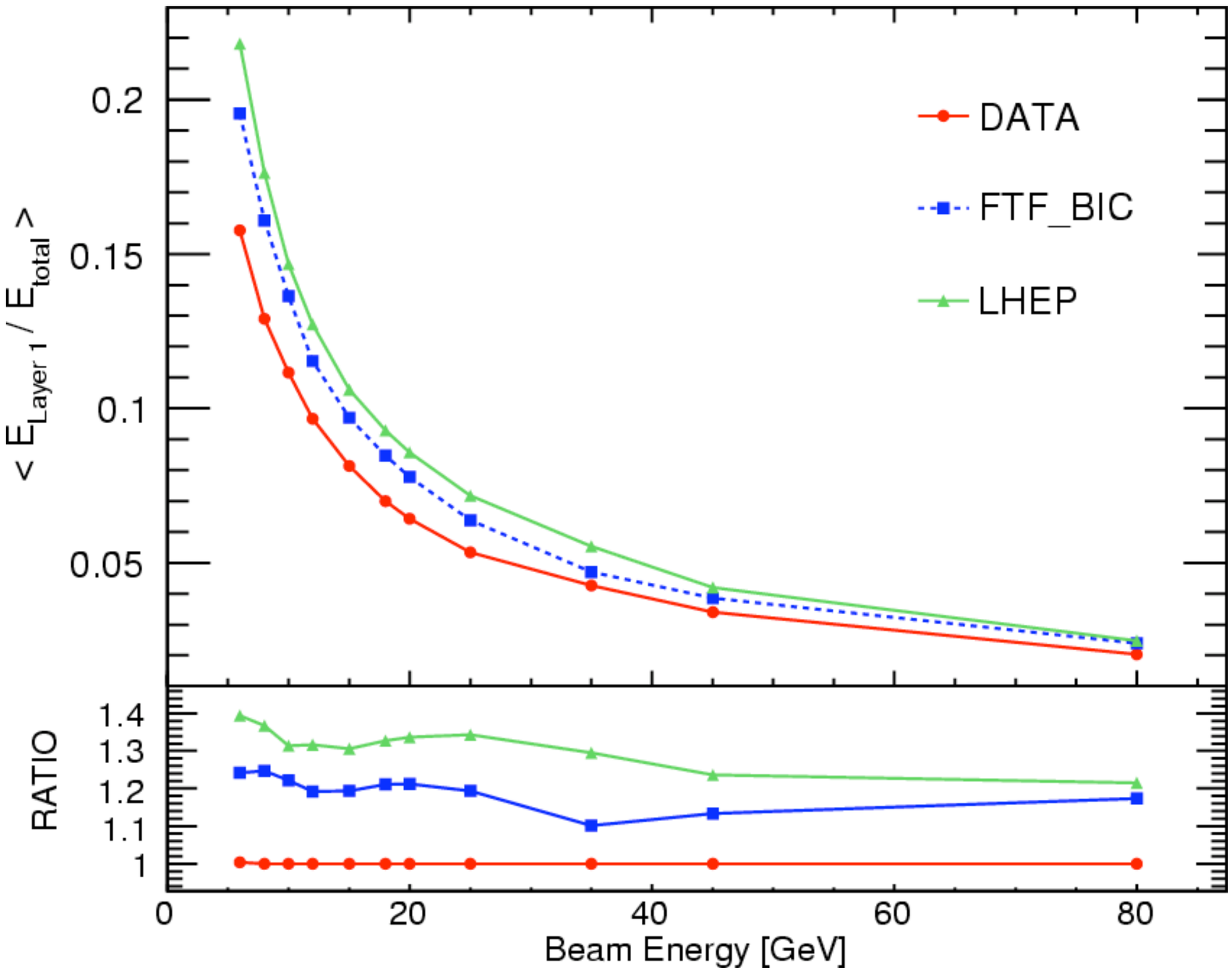


Mean Energy in Layer 1 vs Beam Energy



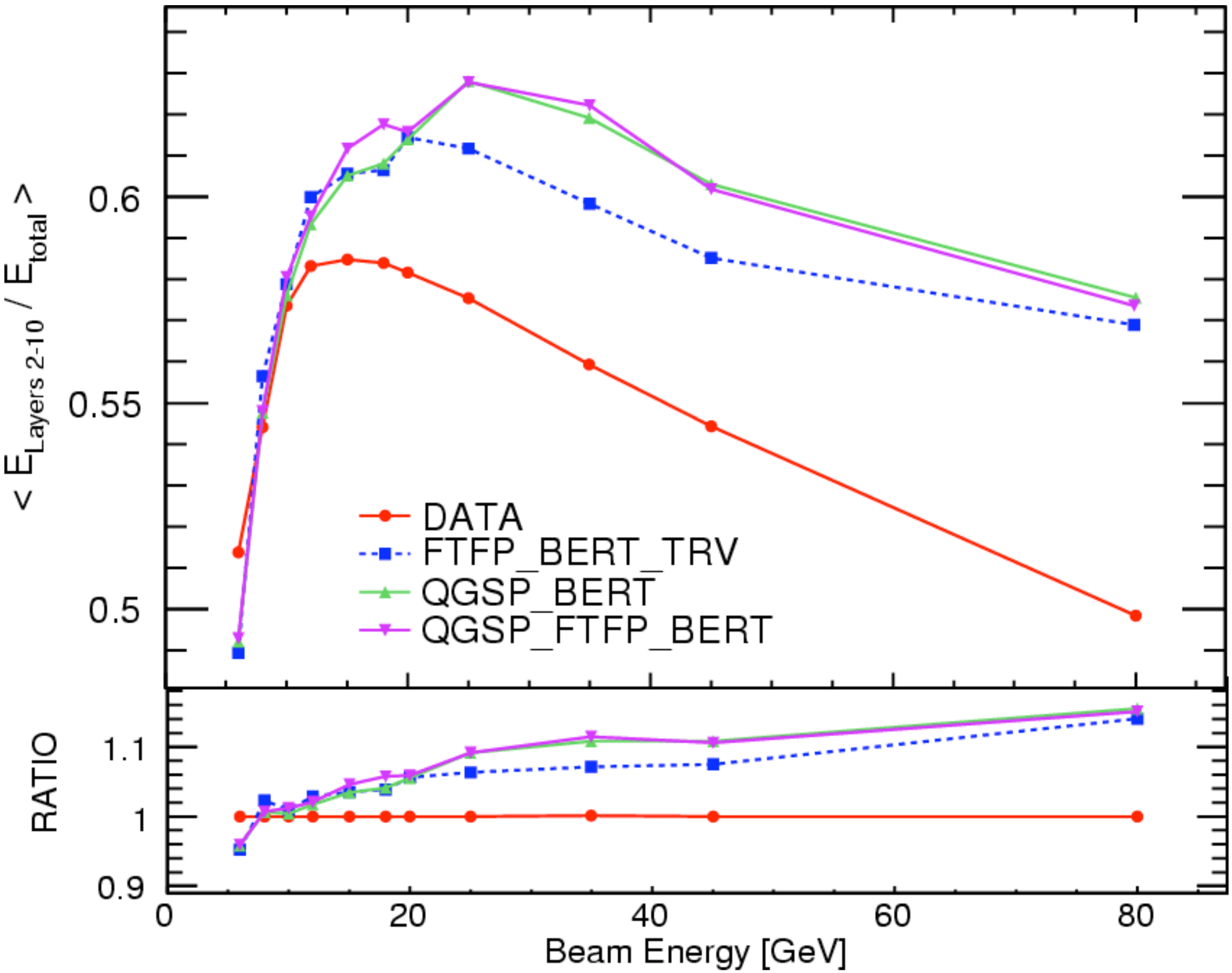
- All BERT physics lists over estimate energy deposition at all energies
- QGSP_BERT agrees best with DATA (better than 20% at all energies)
- For energies above 20 GeV
- QGSP_BERT is equal to QGSP_FTFP_BERT (both use QGSP model for 1st interaction)

Mean Energy in Layer 1 vs Beam Energy



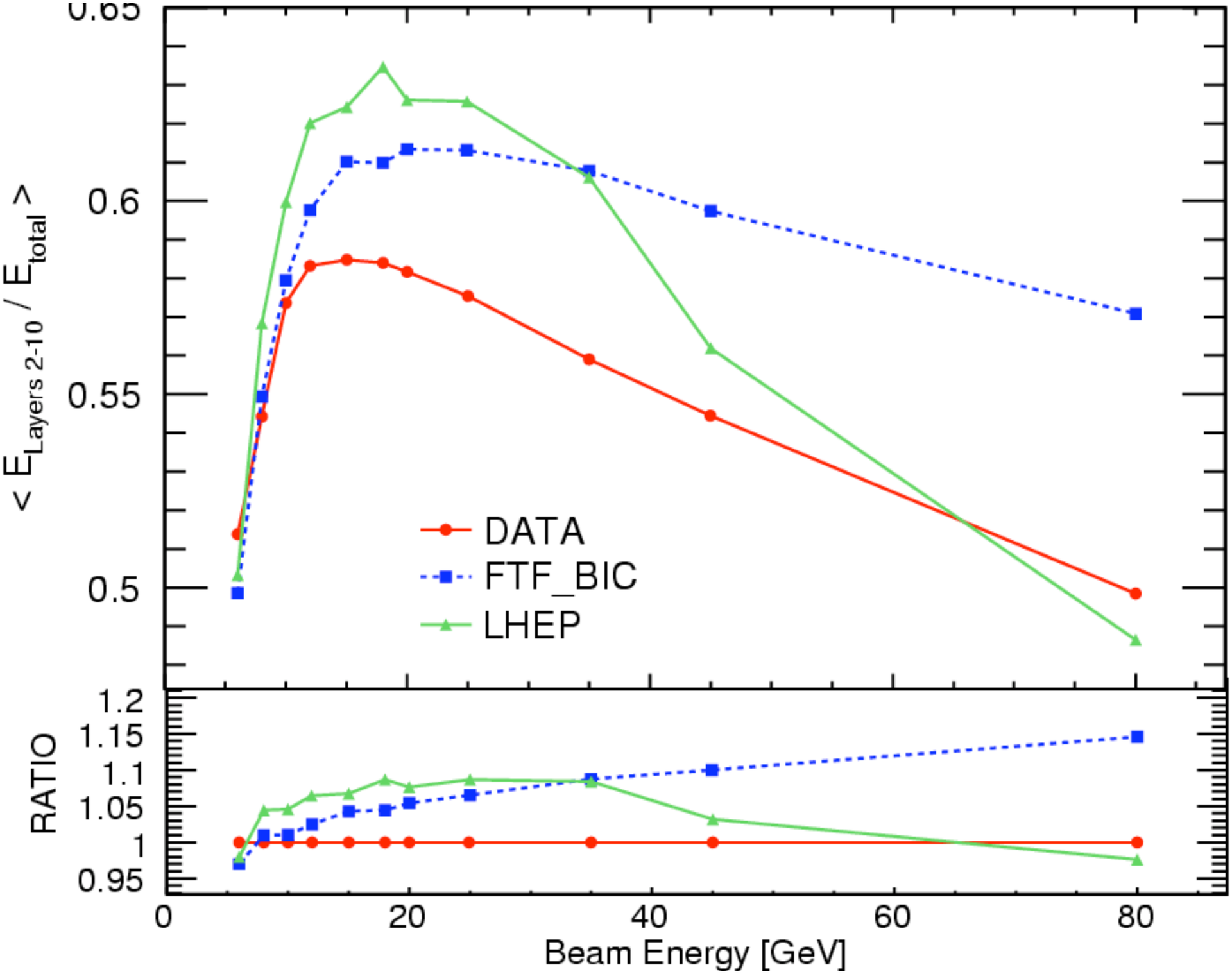
- Also LHEP and FTF_BIC physics lists over estimate energy deposition
- FTF_BIC agrees better with DATA (better than 25% at all energies)

Mean Energy in layer 2-10 vs. Beam Energy



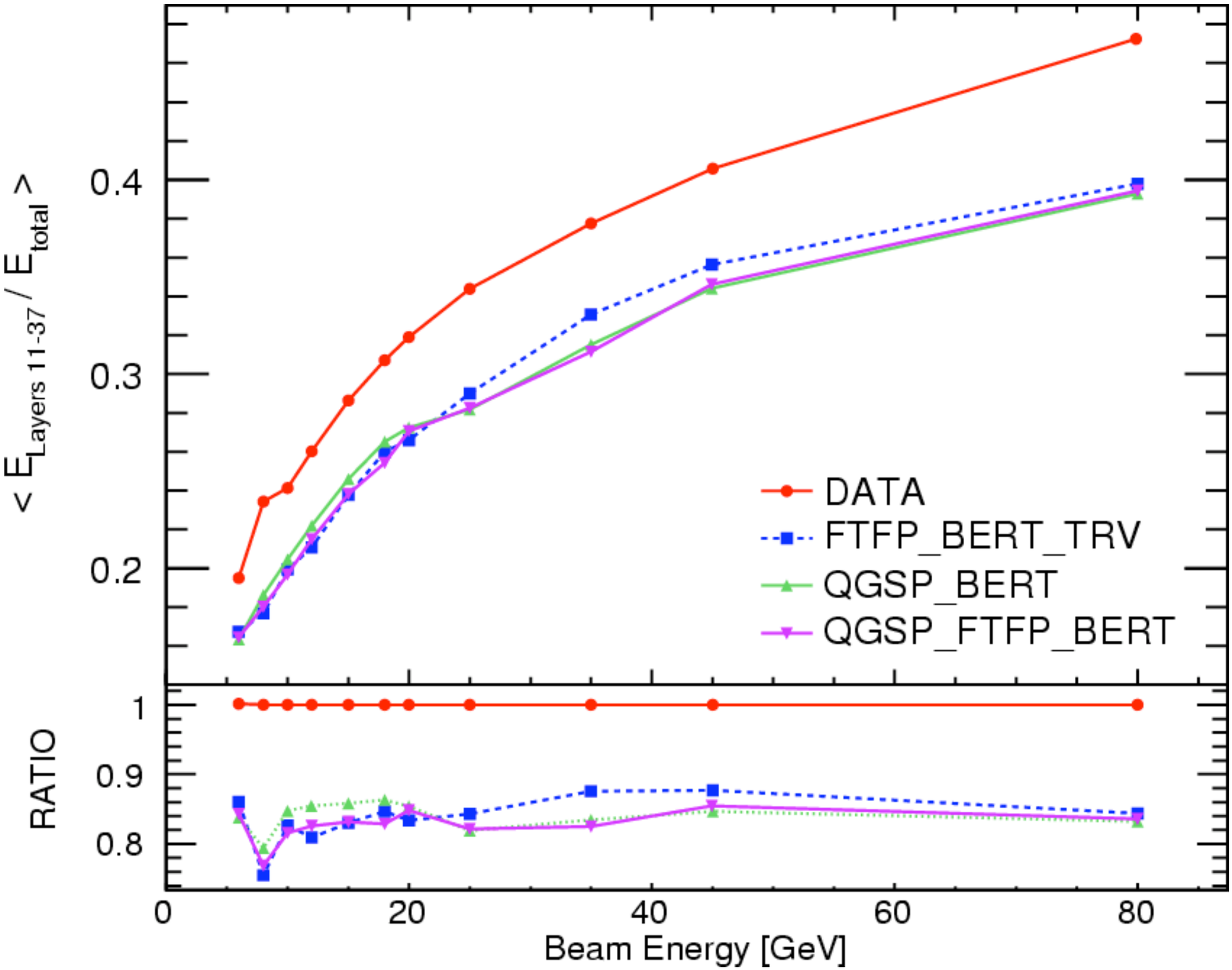
- All models underestimate energy deposition at 6 GeV and over shoot above 8 GeV
- FTFP_BERT_TRV agrees best with DATA (better than 8% up to 45 GeV)
- QGSP_BERT & QGSP_FTFP_BERT are almos the same again.

Mean Energy in layer 2-10 vs. Beam Energy



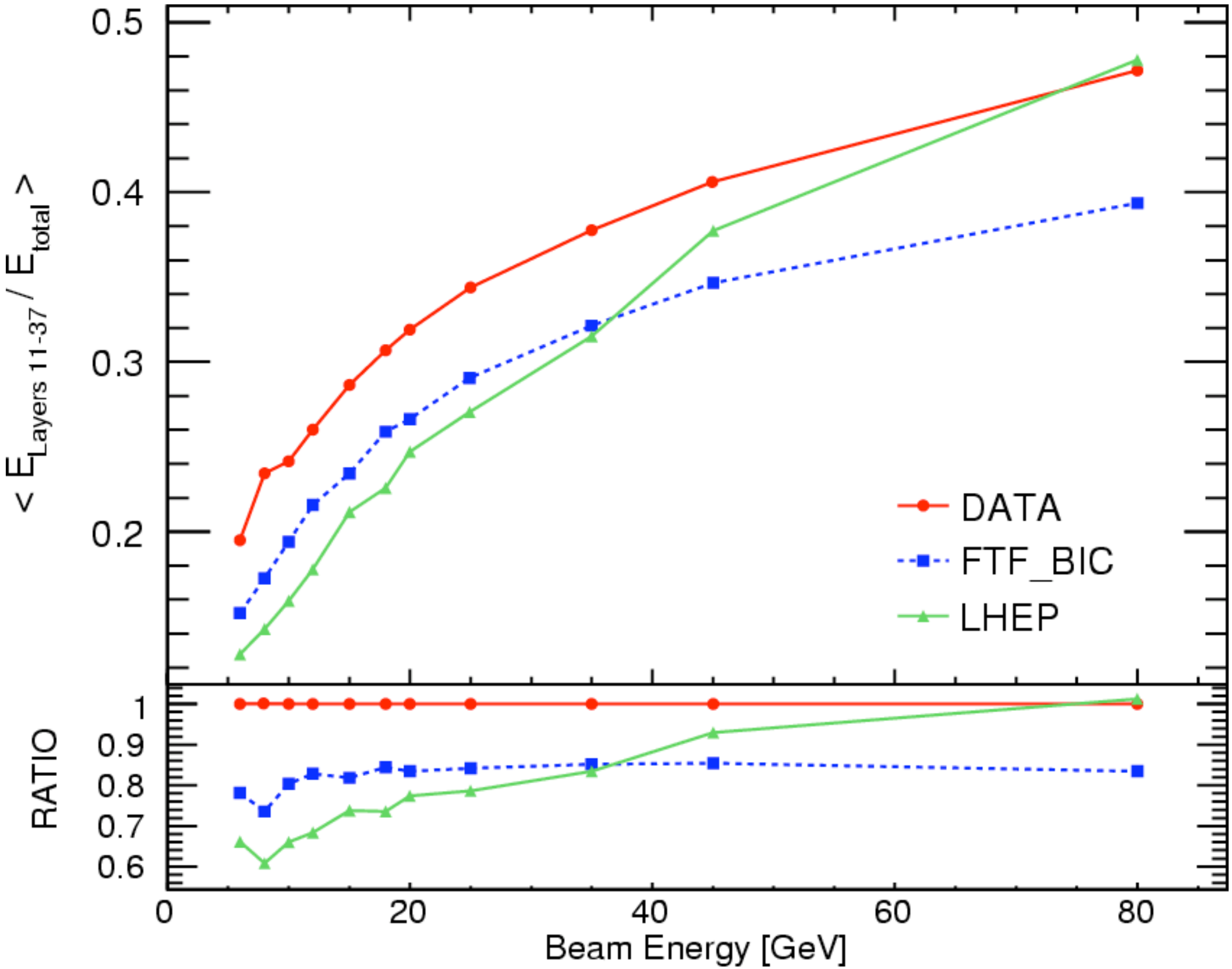
- Again,all models underestimate energy deposition at 6 GeV and over shoot above 8 GeV
- FTF_BIC agrees with DATA (better than 15% at all energies)
- For 45 an 80 GeV LHEP fits quite good to data - better than 3% (HEP parametrization is used)

Mean Energy in Shower Tail vs. Beam Energy



- All models underestimate energy deposition in the shower tail by approx. 15%
- QGSP_BERT is better at energies below 20 GeV
- FTFP_BERT_TRV is better at higher energies

Mean Energy in Shower Tail vs. Beam Energy



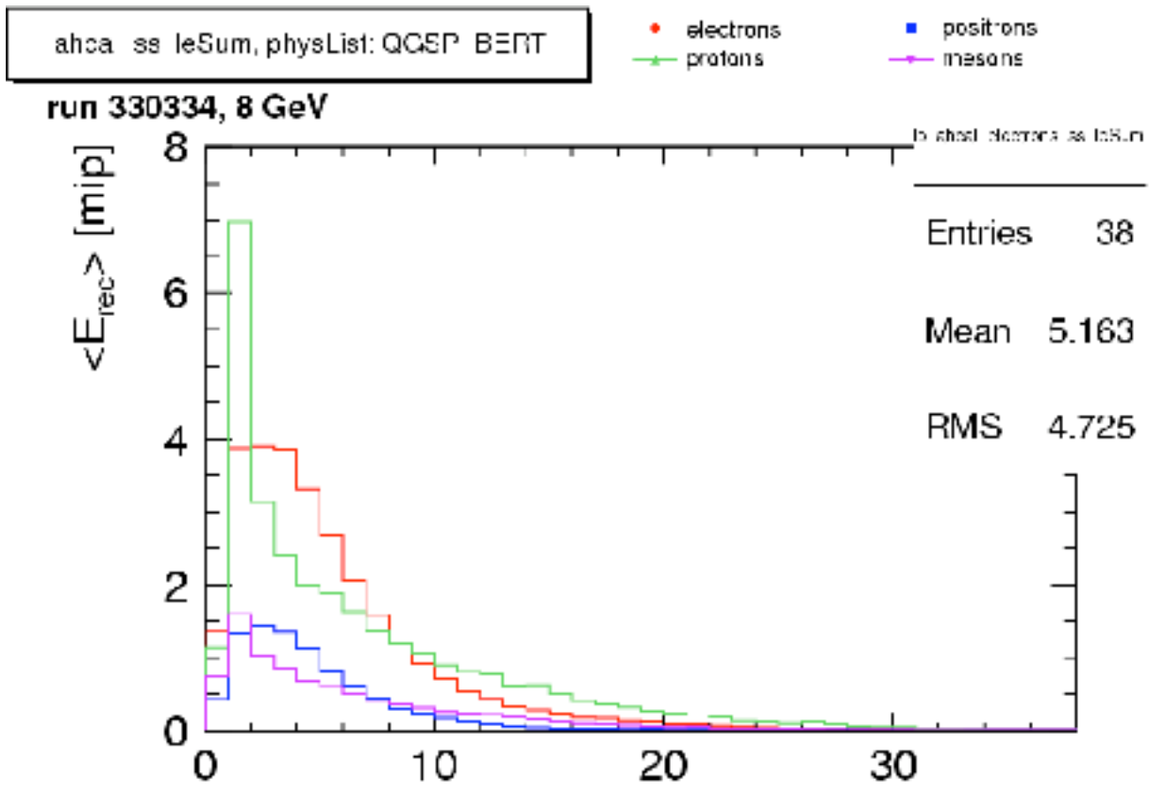
- FTF_BIC underestimates the energy deposited by approx. 20%
- LHEP is worse at energies below 35 GeV, but improves and almost perfectly agrees with data at 80 GeV (again HEP parametrization is used)

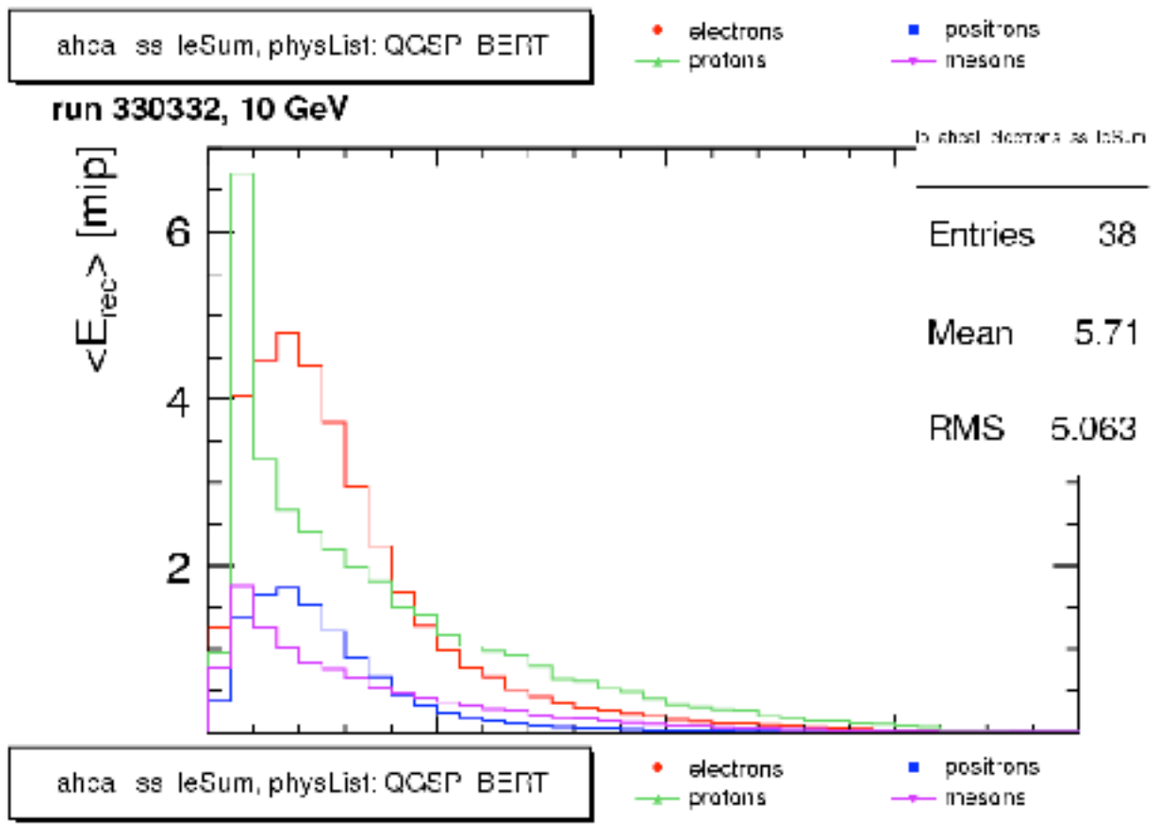
Summary / Conclusions

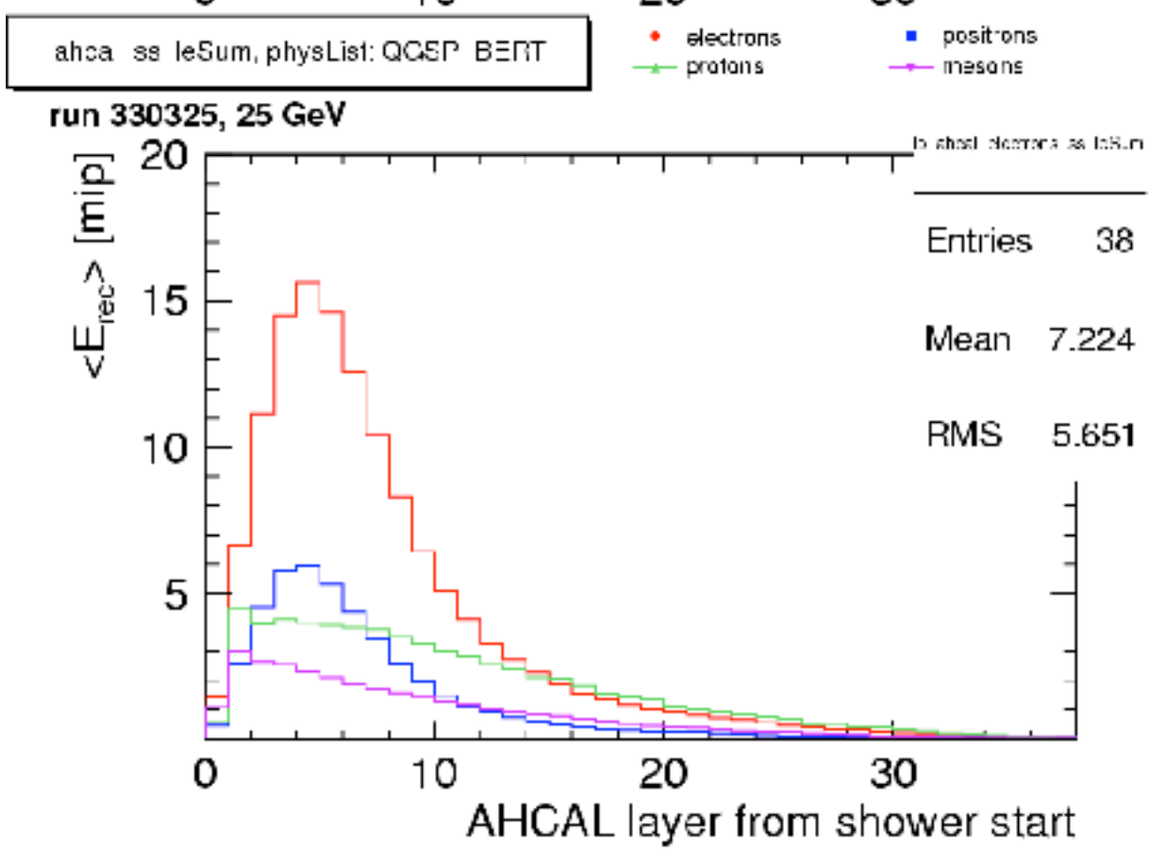
- Analysis: CERN 2007 data
- Shower Start Finder, measured λ
- Developed solution to look at the several contributions to energy deposited in the AHCAL
- Comparison of GEANT4 physics lists:
  - QGSP_BERT compares best to data in the first layer of the HCAL at all energies
  - For the center part FTFP_BERT_TRV is the best
  - The tail is described equally (bad) by all models

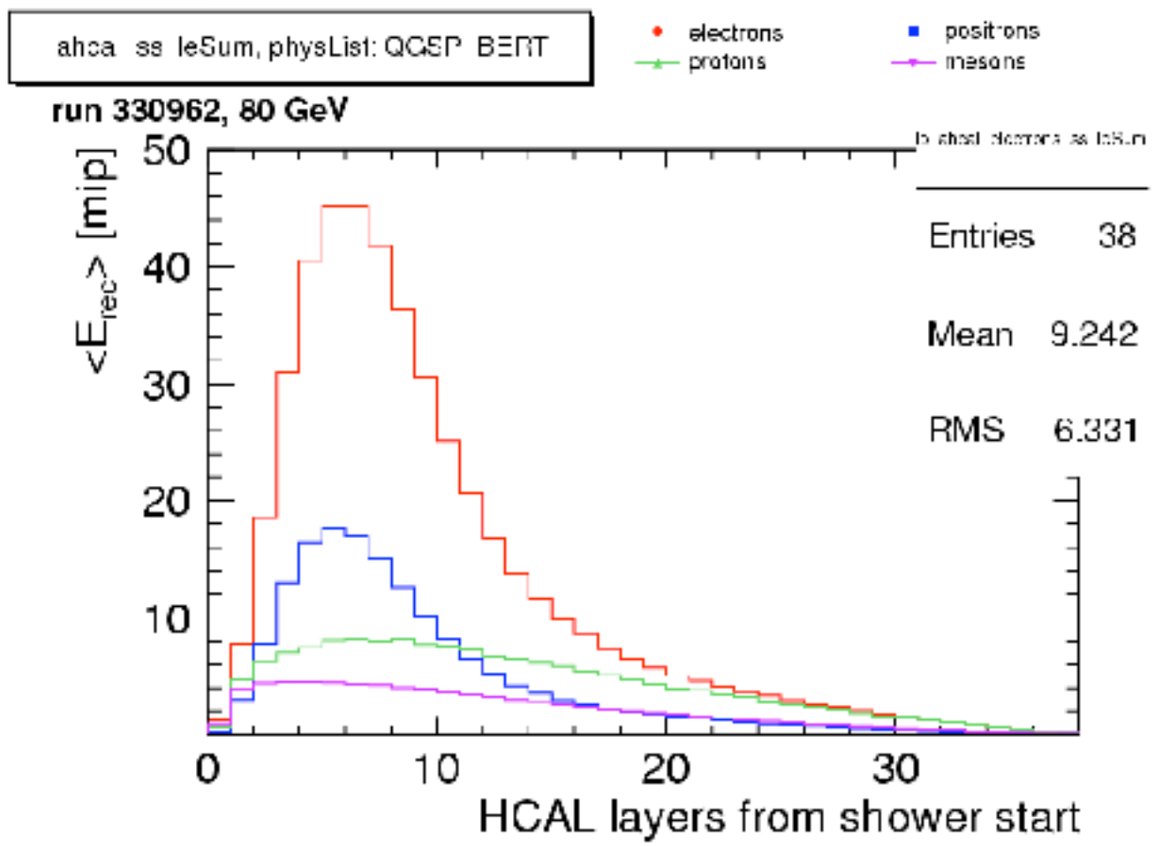
BACKUP SLIDES

Long. Prof. for QGSP_BERT @ typ. Energies

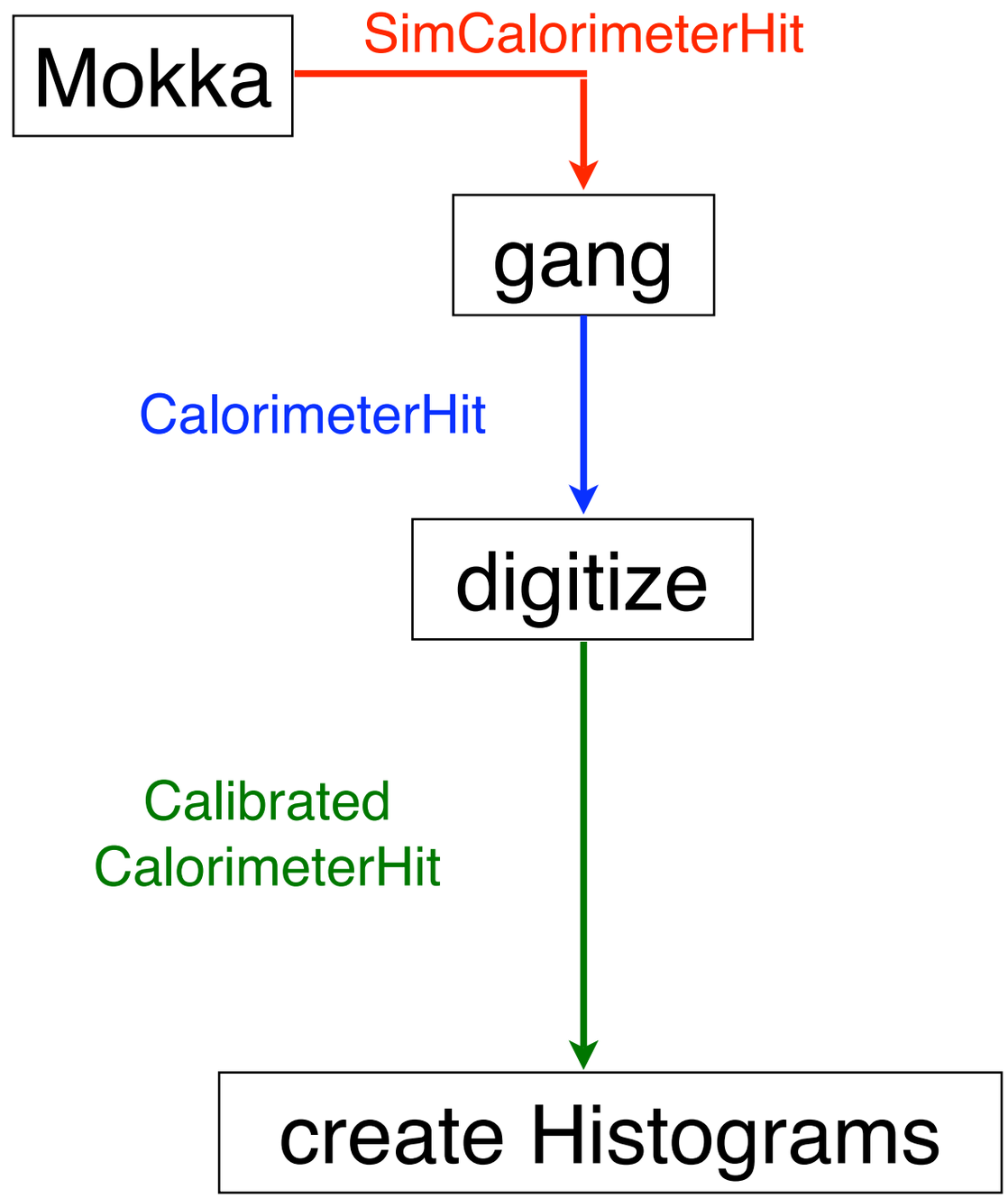








Decomposition Technique



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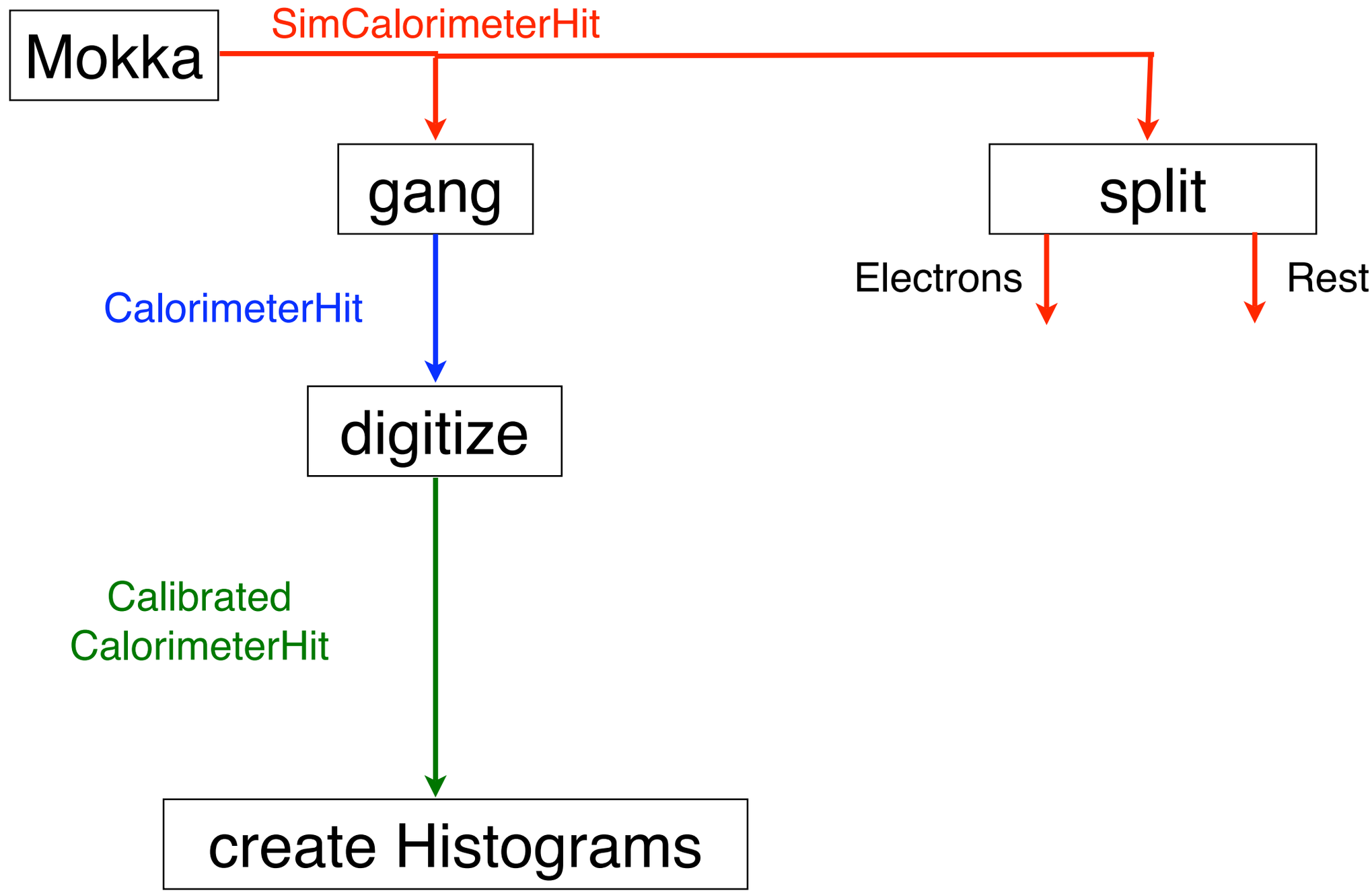

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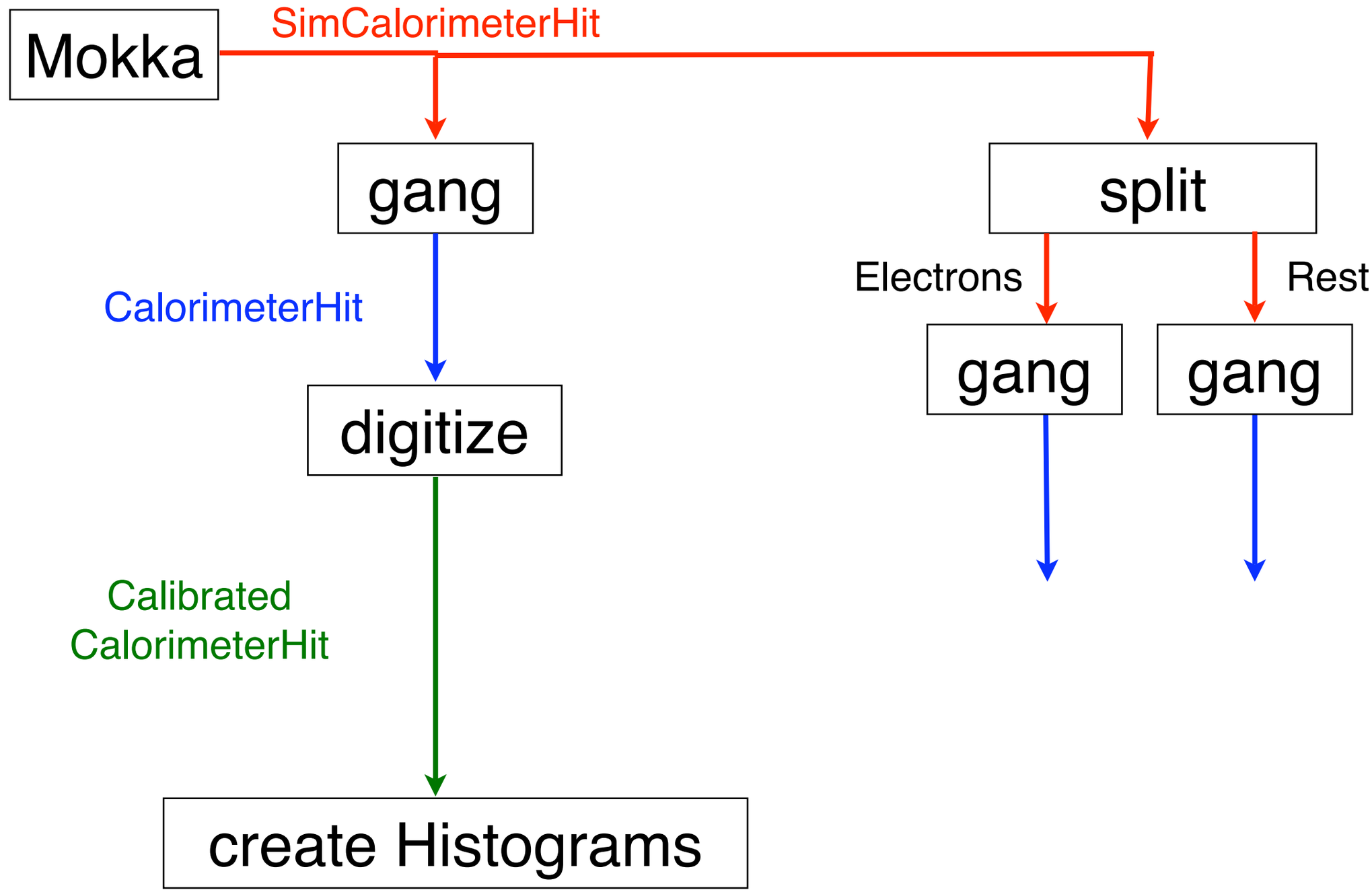

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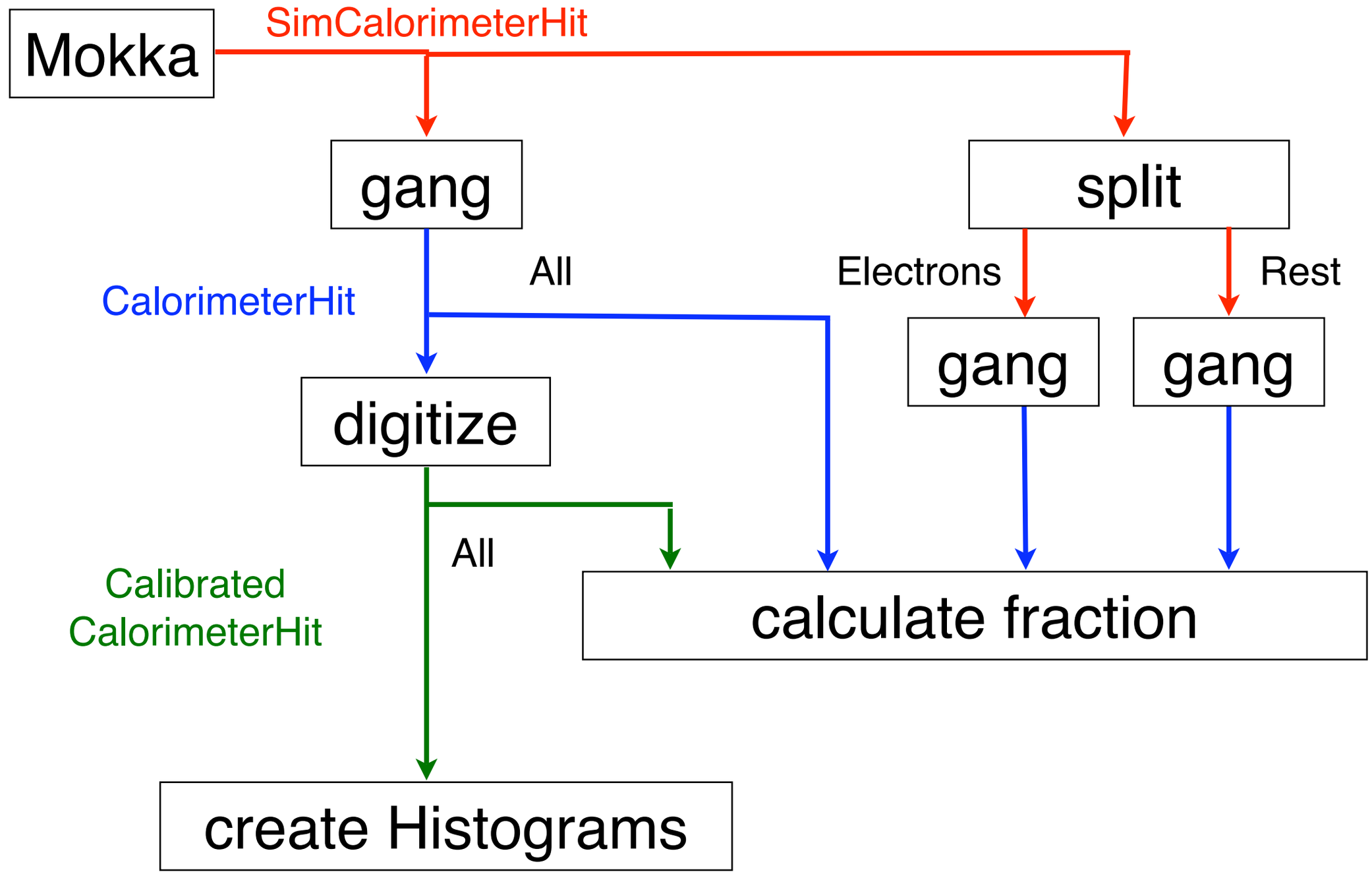

Decomposition Technique