Analysis of pion showers in the ECAL from CERN Oct 2007 Data

David Ward

- We study the properties of pion showers in the ECAL
- Compare with GEANT models, including new physics lists in the β-release version Geant4.9.3.β01
- Main focus on energies ~8-20 GeV – important for ILC jets and also the main problem region for modelling.
- CAN/Paper is in its editorial board (aim for LCWS10).
- But, Geant4.9.3 was released just before Christmas; some significant changes.

Summary of data and MC simulations

- Reconstructed data

2007 data from CERN

with v0406 reconstruction

and calibrations

Run330641 – 8GeV π^-

Run330332 – 10GeV π^-

Run330645 – 12GeV π^-

Run330328 – 15GeV π^-

Run330326 – 20GeV π^-

Run331298 – 30GeV π^+

Run331286 – 50GeV π^+

Run331324 – 80GeV π^+

- GEANT4 simulations

Mokka version 6.8.p01.calice

GEANT 4.9.3.b01

with physics lists...

LHEP

QGSP_BERT

QGSC_BERT

QGS_BIC

FTFP_BERT

FTF_BIC

(as recommended by G4 authors)

and new in GEANT4.9.3.b01

QGSC_QGSC

QGSC_CHIPS

QGSC_FTFP_BERT

FTFP_BERT_TRV

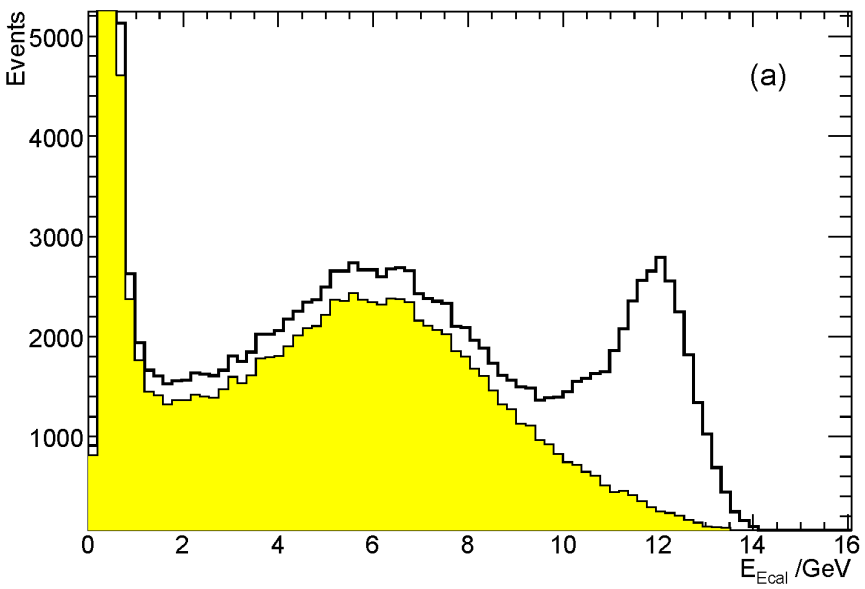
Models used in Physics Lists (for $\pi^{\pm}$)

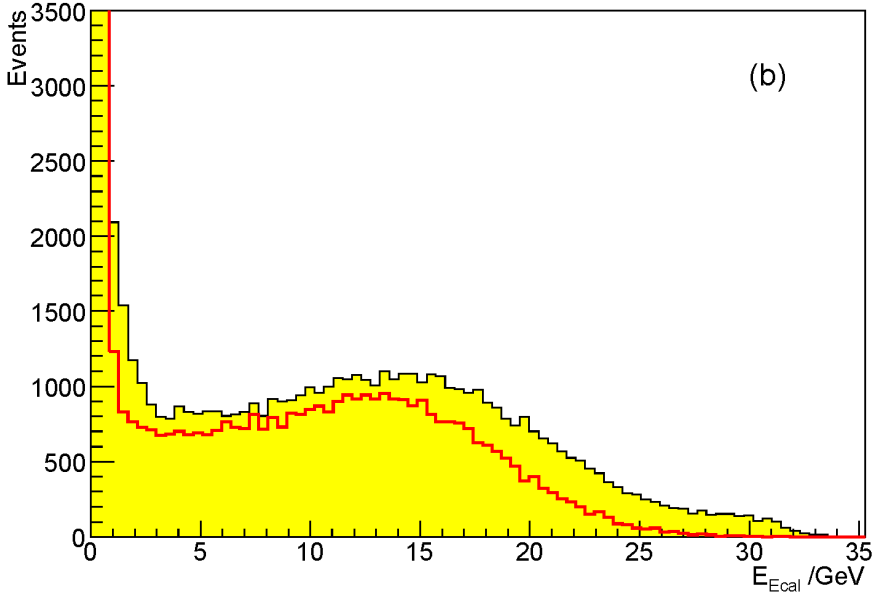
- LHEP — LEP (<55); HEP (>25)
- QGSP_BERT — BERT (<9.9); LEP (9.5-25); QGSP (>12)
- *QGSP_FTFP_BERT* — BERT (<8); FTFP (6-25); QGSP (>12)
- QGS_BIC — BIC (<1.3); LEP (1.2-25); QGSB (>12)
- QGSC_BERT — BERT (<9); QGSC (>6)
- *QGSC_CHIPS* — QGSC_CHIPS ($\forall$ energies) "energyflow i/f to CHIPS"
- *QGSC_QGSC* — QGSC ($\forall$ energies) "multisoft i/f to CHIPS"
- FTFP_BERT — BERT (<5); FTFP (>4)
- *FTFP_BERT_TRV* — BERT (<8); FTFP (>6)
- FTF_BIC — BIC (<5); FTFB (>4)

- n.b. Ranges overlap to provide smooth transitions between models. Energies in GeV
- Prerelease lists in *italics.*

Event Selection I

- Electron/proton events reduced using signal from the Cerenkov.
- (Still Kaon contribution? And ~1% e^+ at 30 GeV)



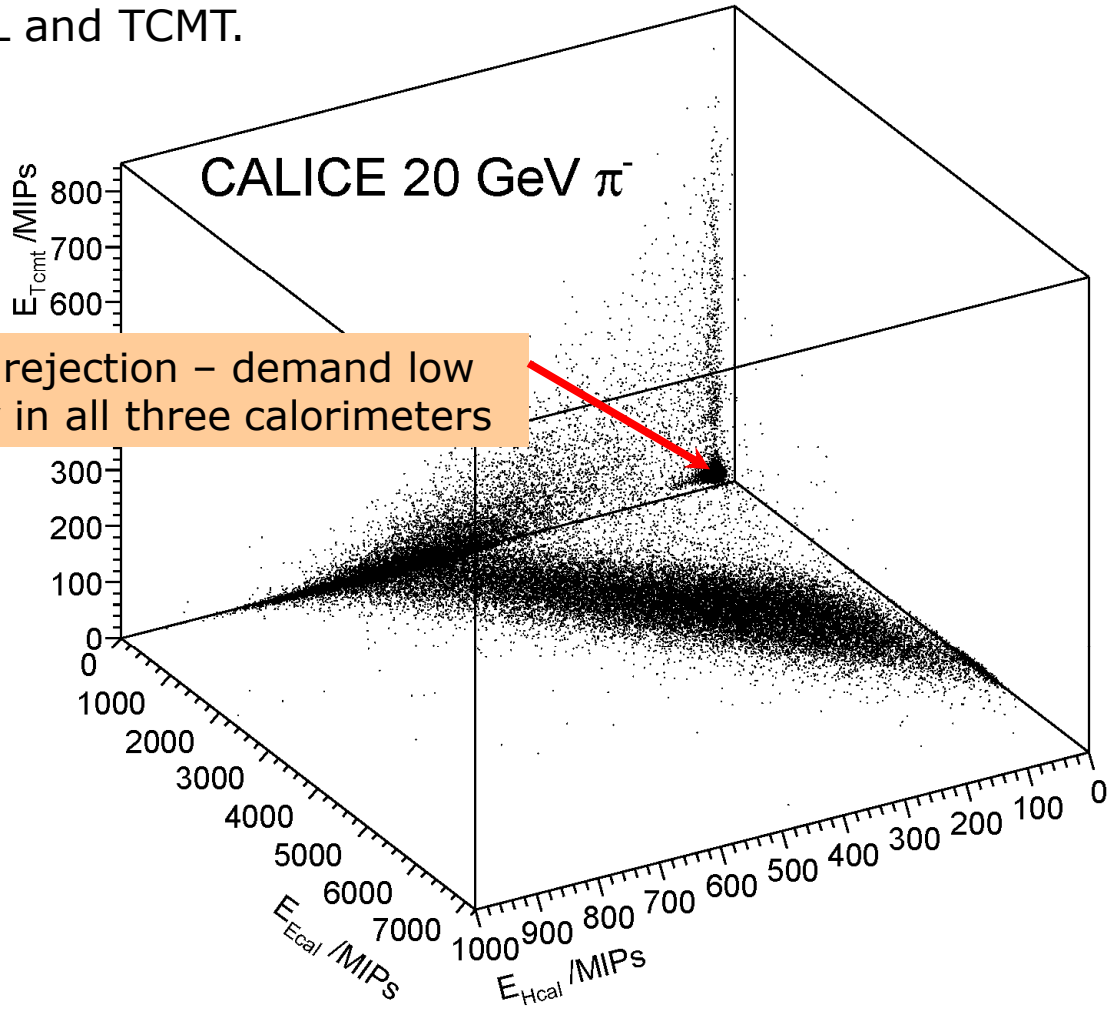


π^- runs : demand Cerenkov **off (yellow)** to remove e^- (8,10,12,15,and 20GeV)

π^+ runs : demand Cerenkov **on (yellow)** to remove p (30, 50, 80GeV)

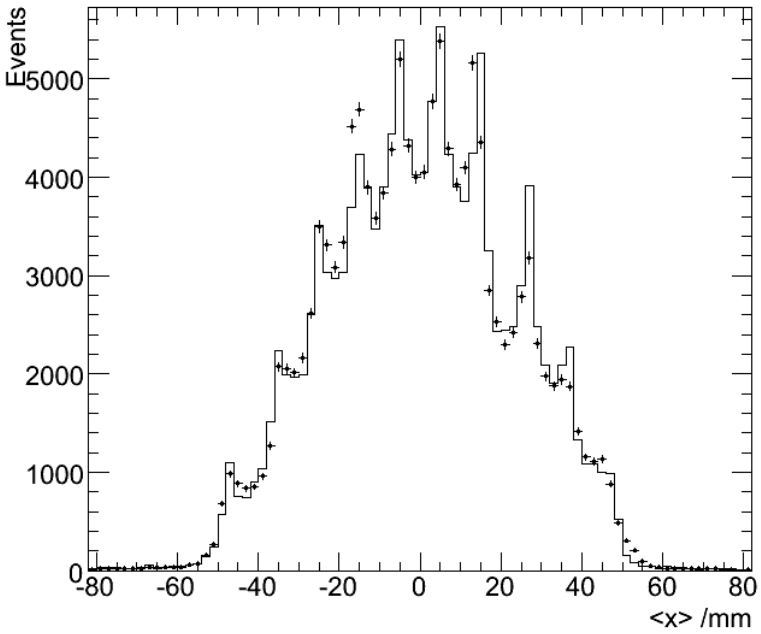
Event Selection II

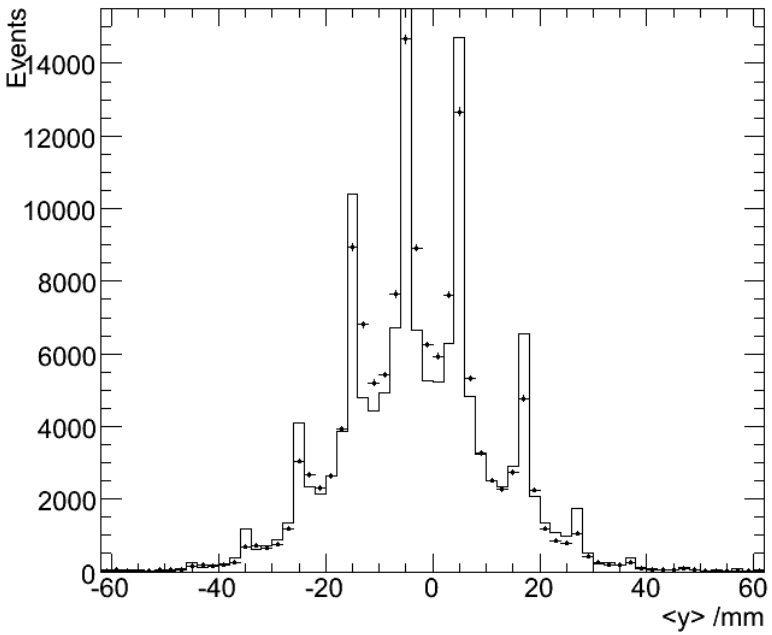
- Muon events are distinguished from the rest by comparing the data and pure muon MC simulation, looking at distribution of energy deposited in ECAL, HCAL and TCMT.



Muon rejection – demand low energy in all three calorimeters

Tuning of beam profiles

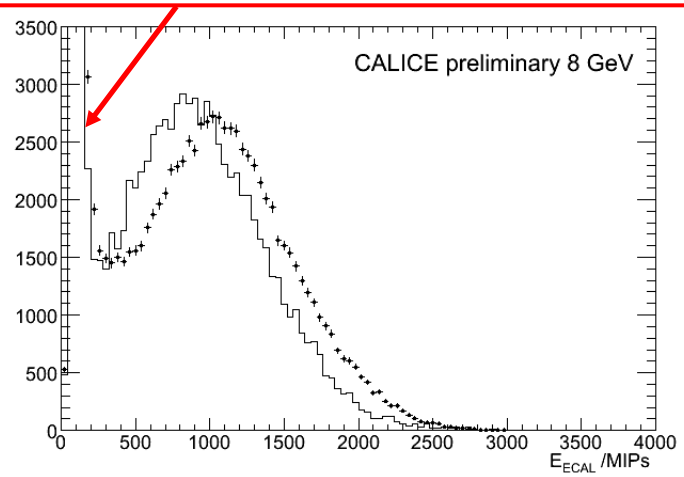


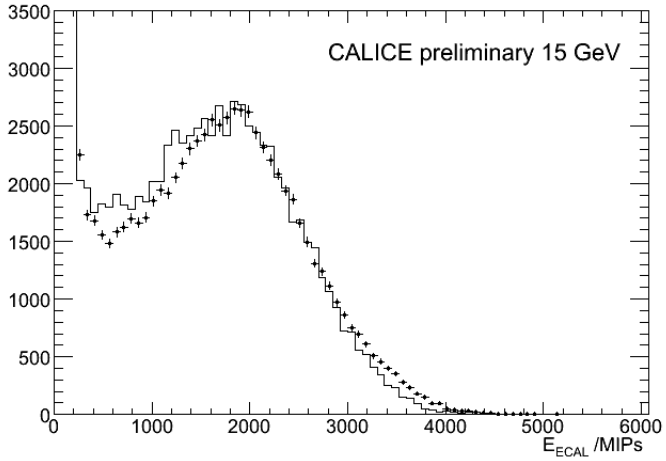


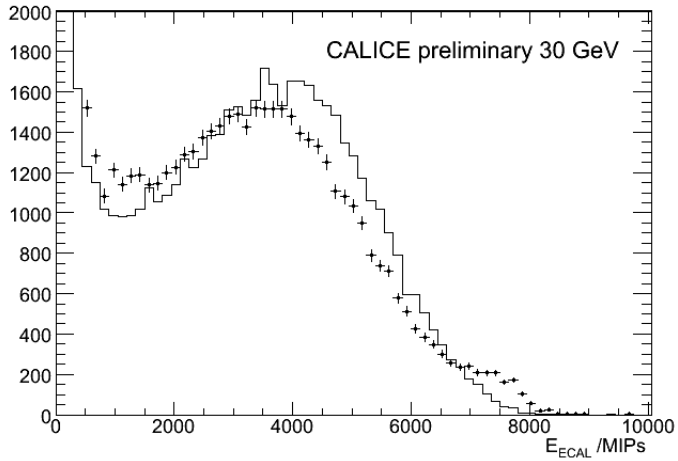
Gaussian profile 60m upstream
Not perfect, but good enough?

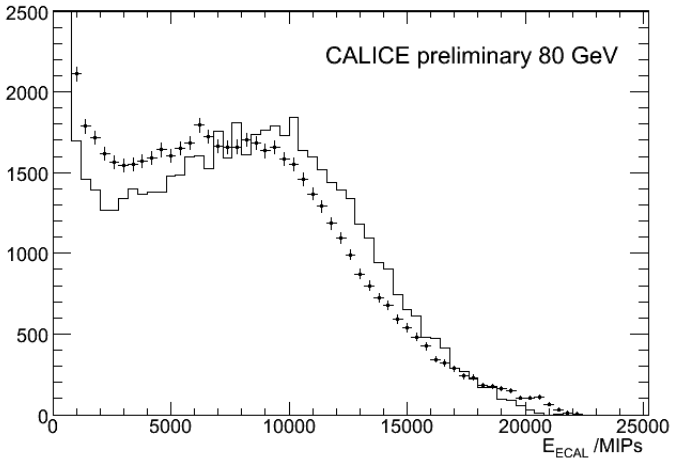
Data c.f. MC using QGSP_BERT

Non-interacting peak is well modelled ∀ energies and physics lists - suppressed



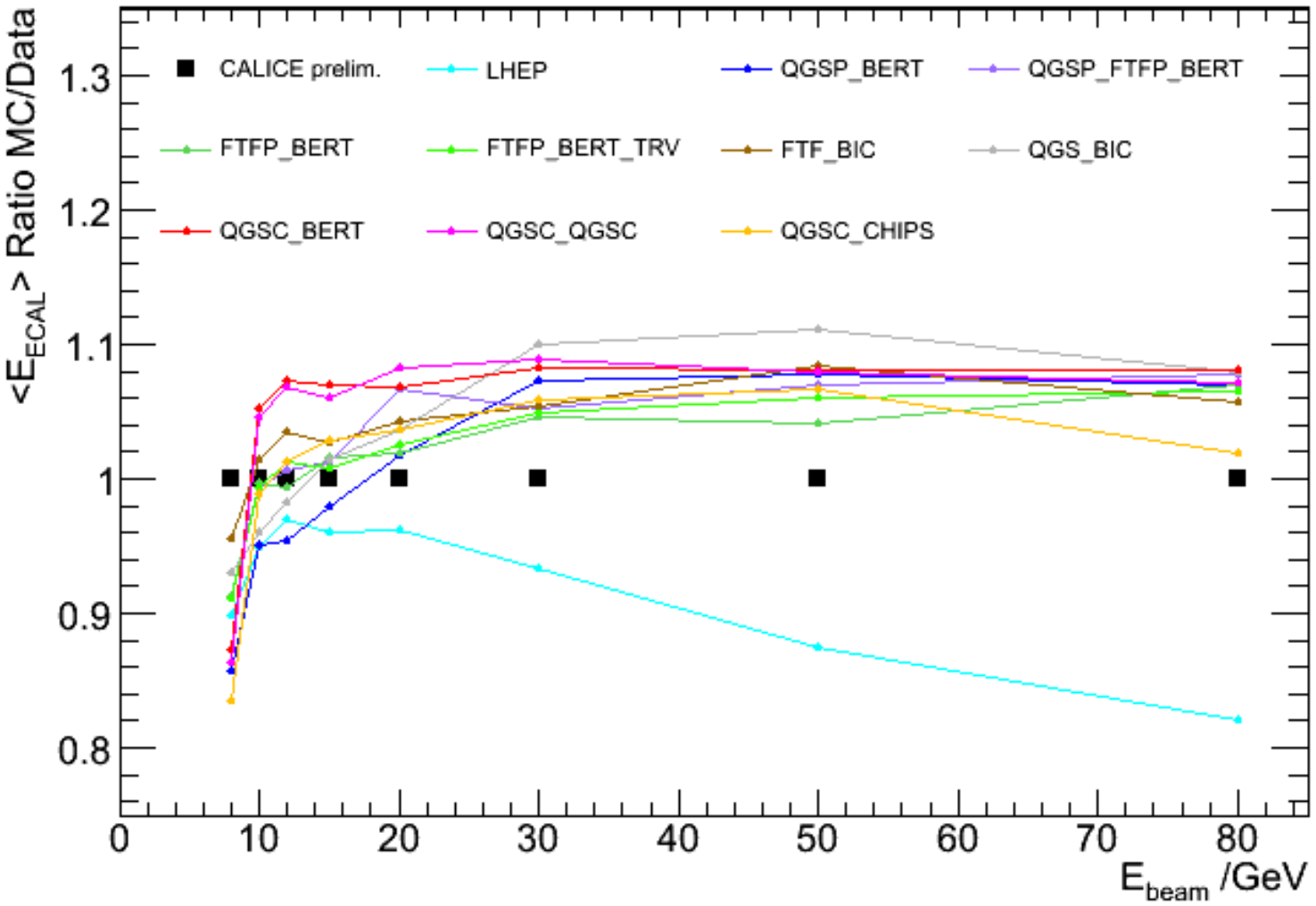




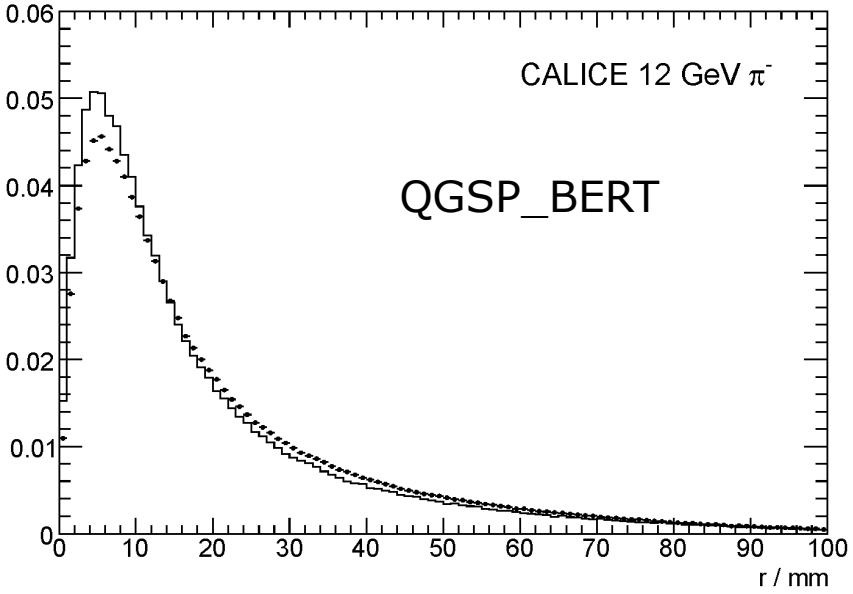


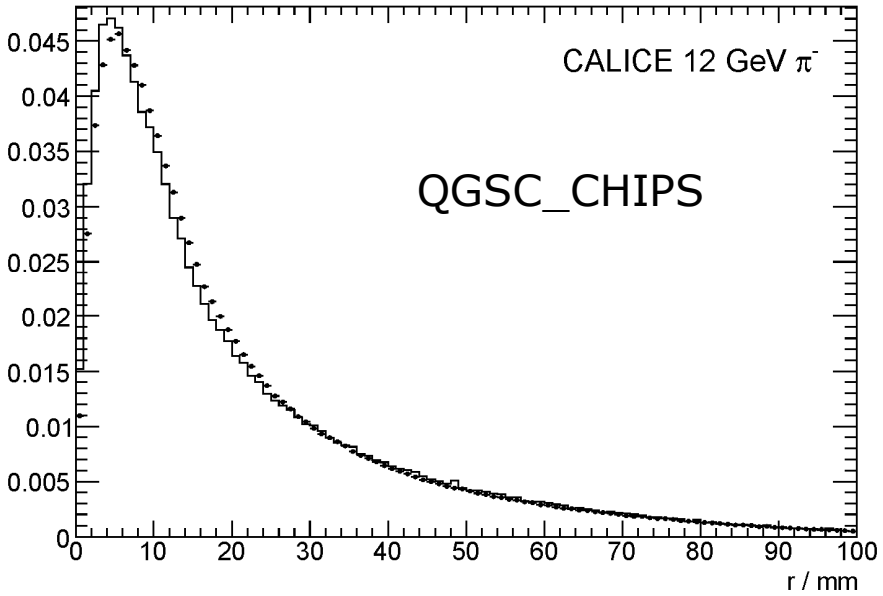
MC underestimates ECAL energy at low E_{beam}; overestimates it at high E_{beam}

$\langle E_{ECAL} \rangle$ vs E_{beam} – all energies and models



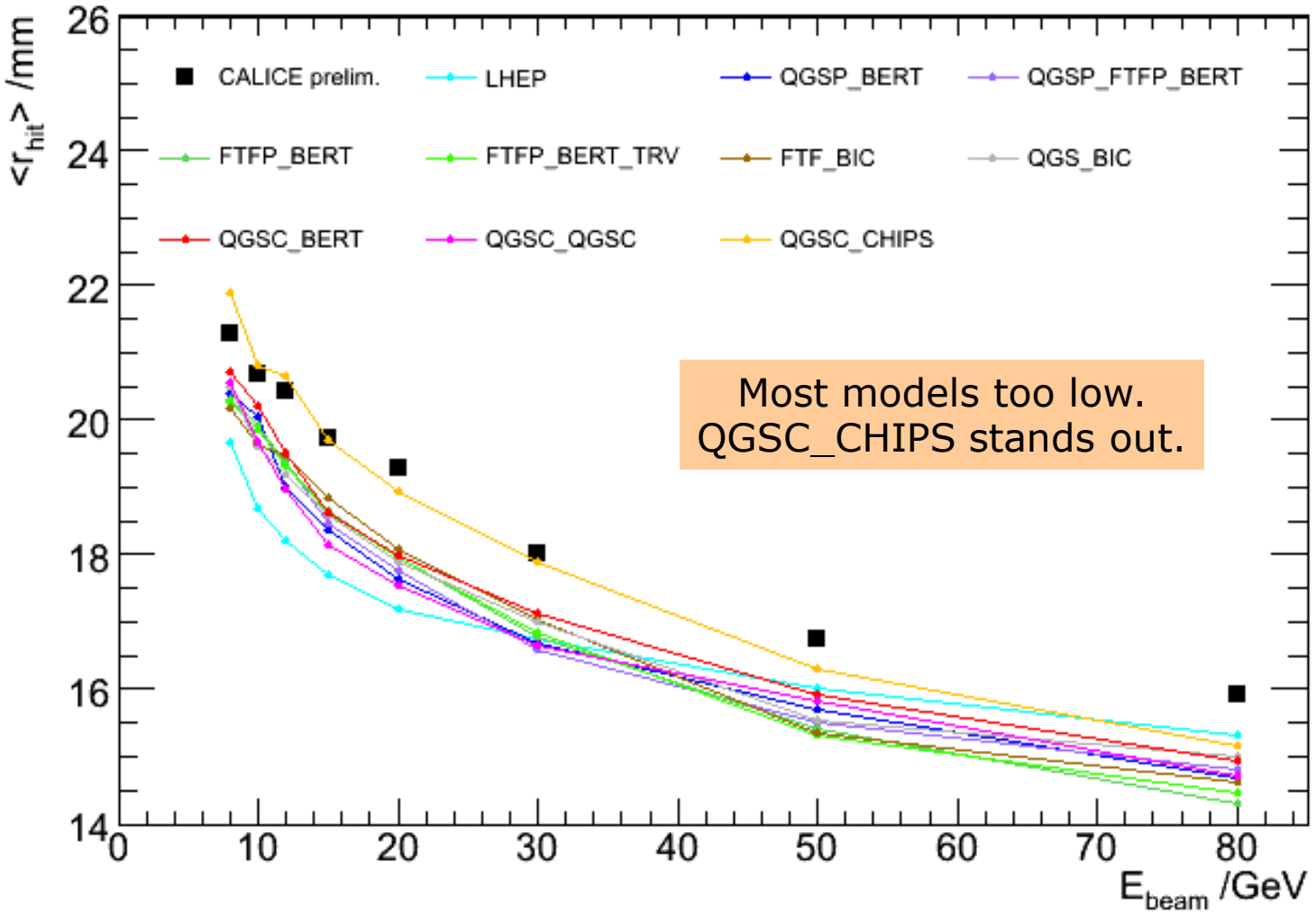
Energy-weighted transverse shower profile



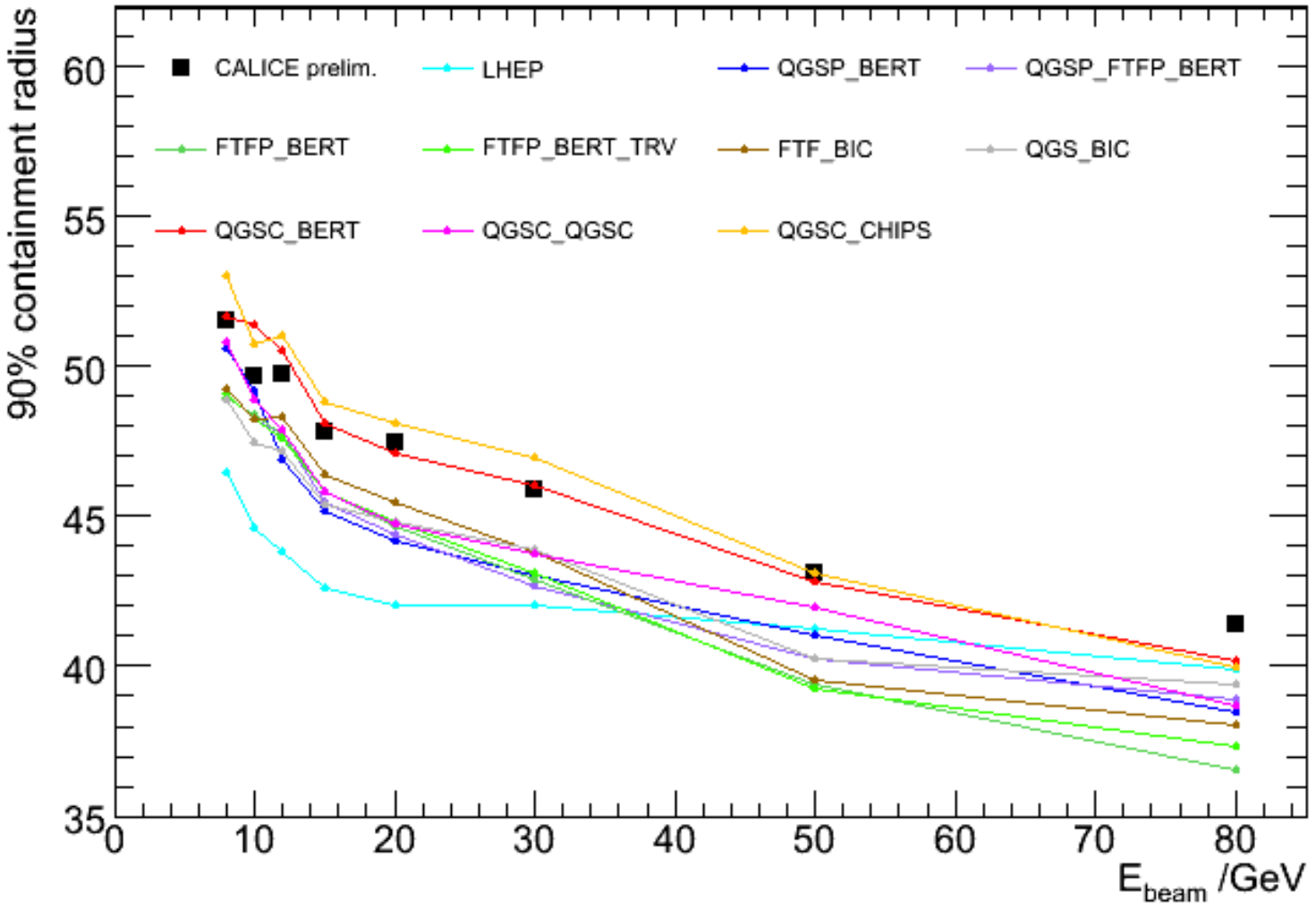


In order to compare many energies and physics lists, we characterise these distributions in terms of moments, or percentiles

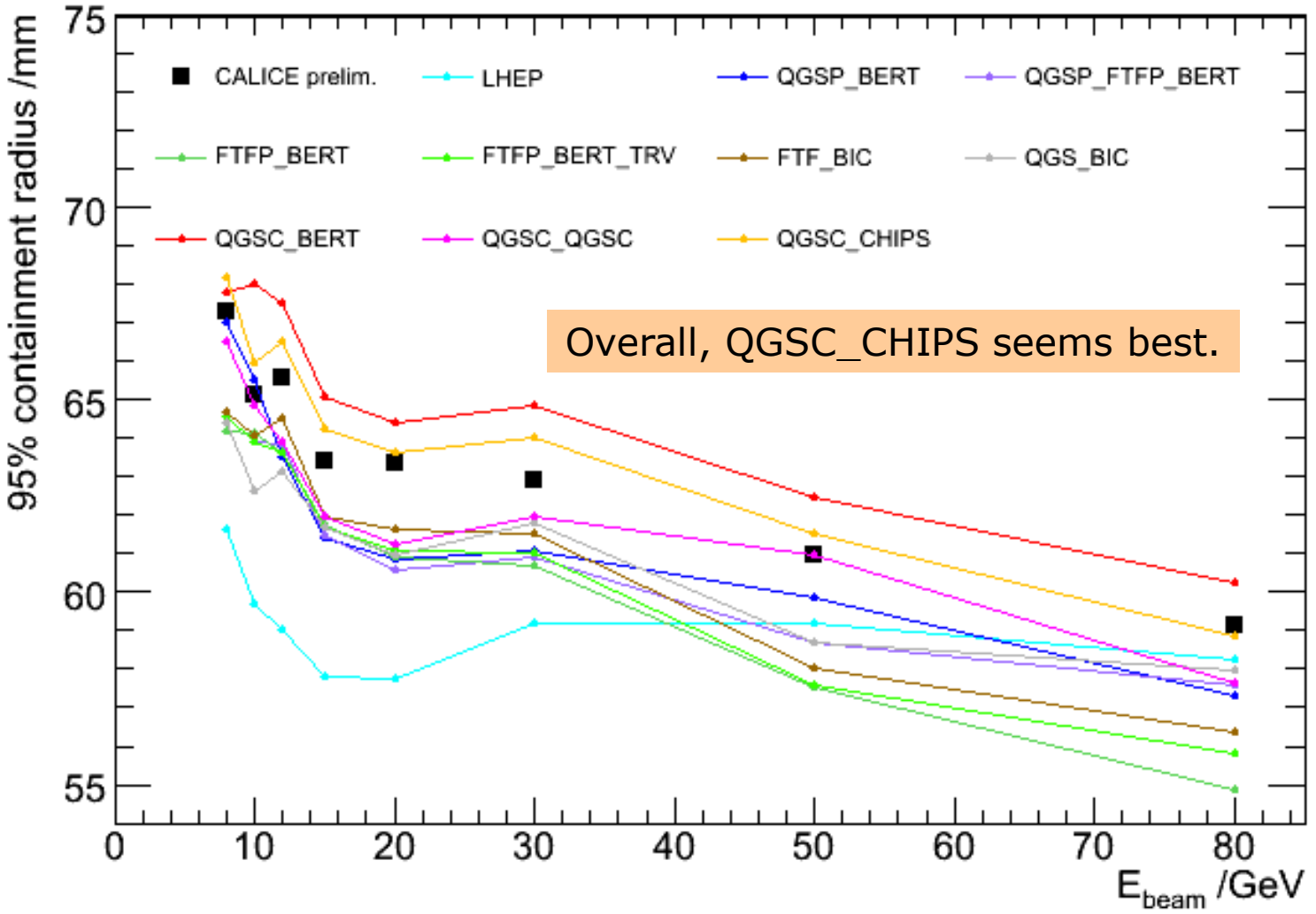
Mean shower radius



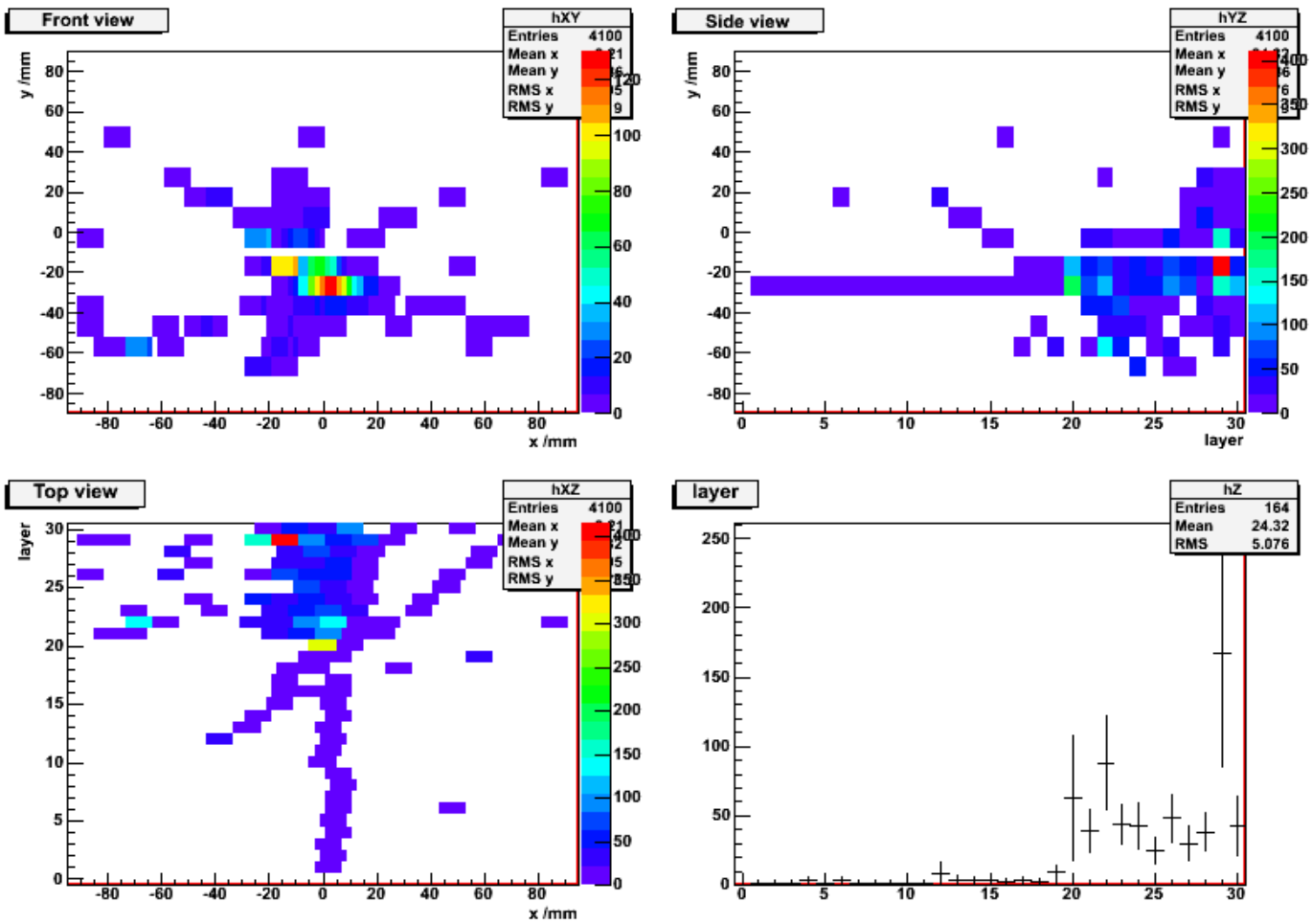
Radius for 90% shower containment



Radius for 95% shower containment



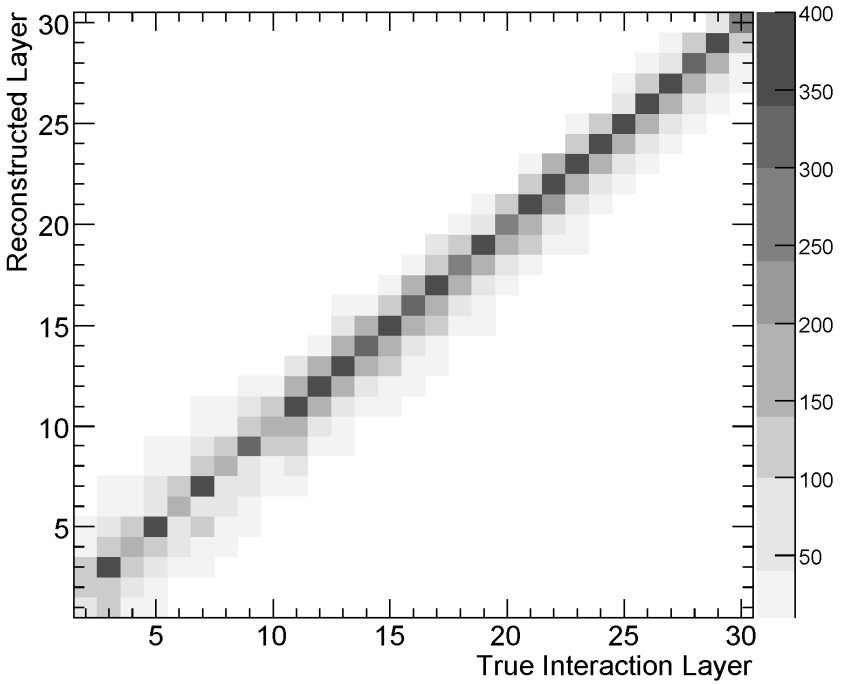
Identify first interaction layer

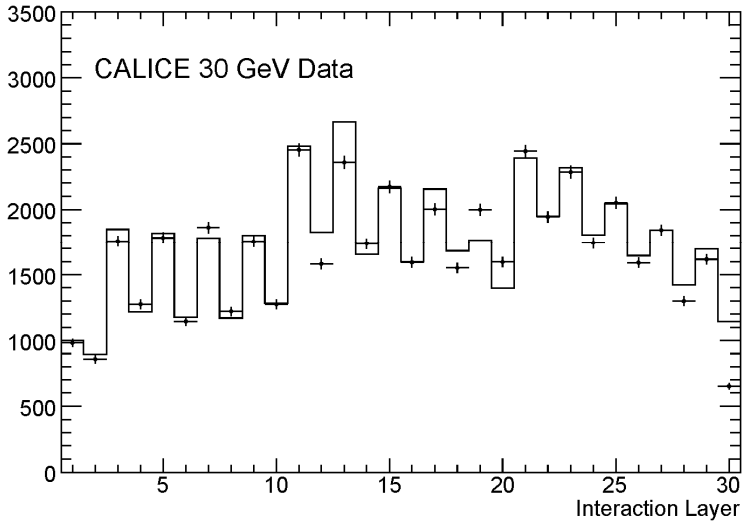


Identify the first layer at which 3 out of 4 consecutive layers >10MIPs

Very simple, but after extensive scanning, seems to work as well as any more sophisticated procedure.

Checks of interaction layer algorithm



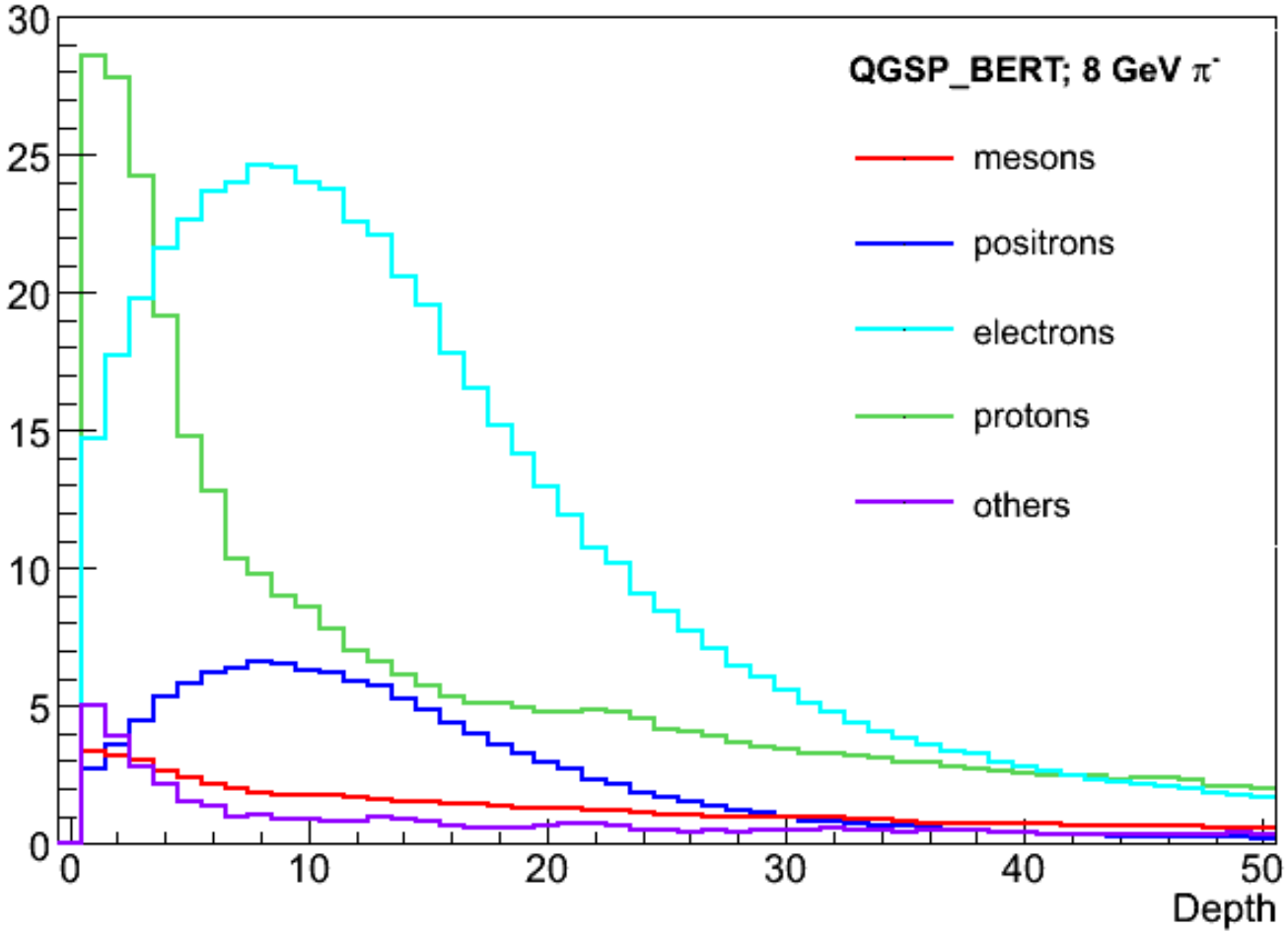


~70% OK within ± 1 layer
~90% OK within ± 2 layers
Differences between
physics lists < ± 1 layer

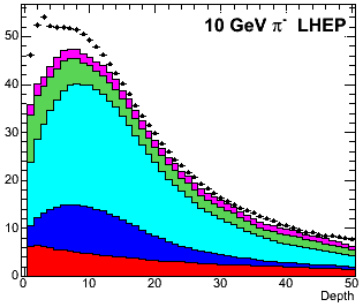
Features of data quite well modelled
∀ energies and ∀ physics lists

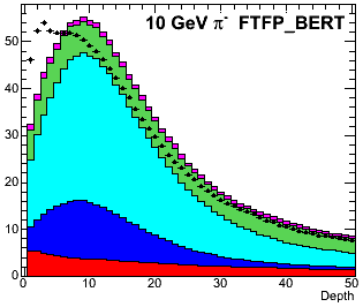
Use MC truth to separate longitudinal profile into components.

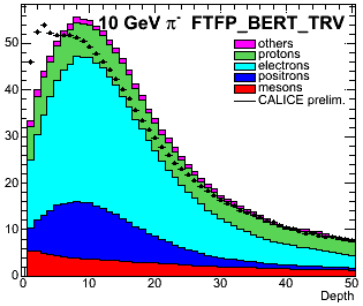
Shower depth in 1.4mm equivalent layers starting at the interaction point.

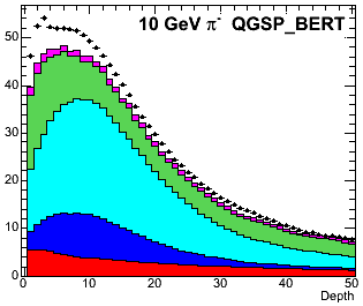


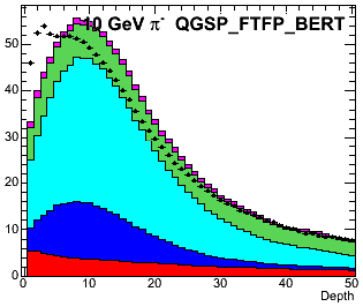
Longitudinal profile @ 10 GeV

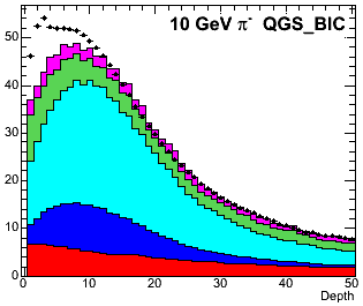


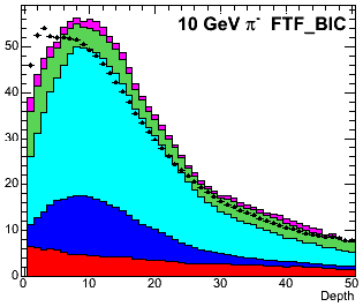


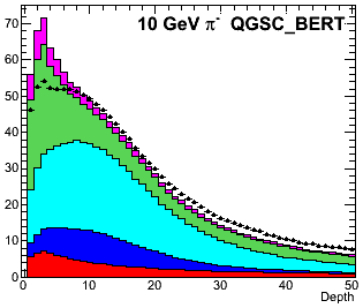


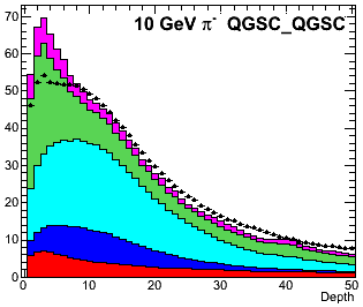


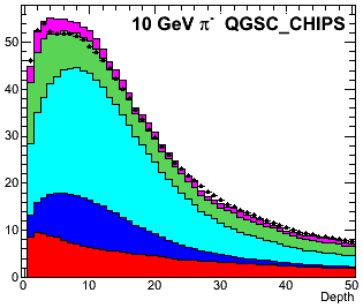




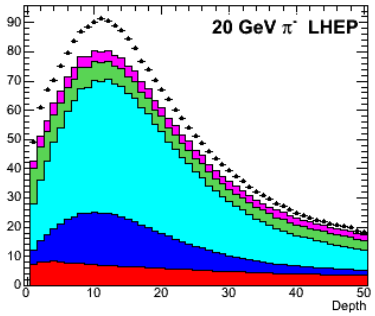


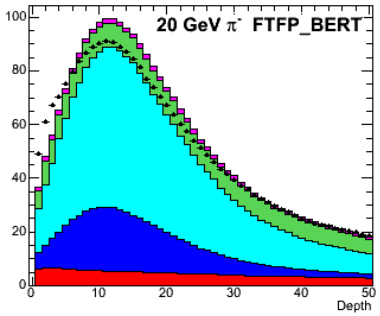


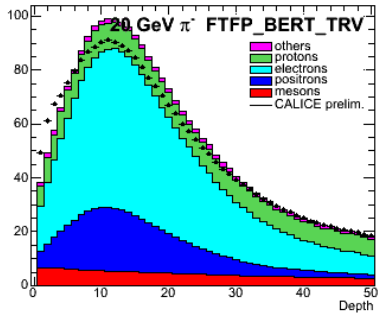


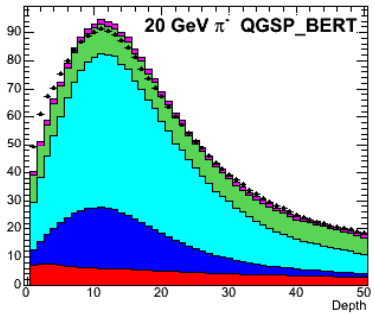


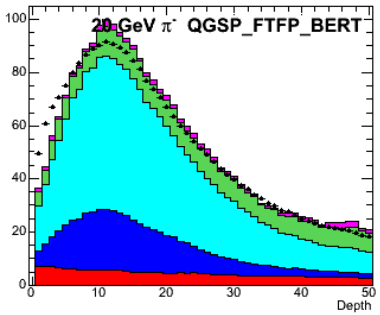
Longitudinal profile @ 20 GeV

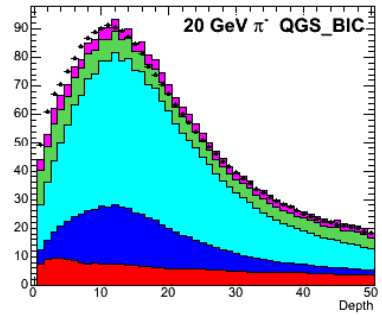


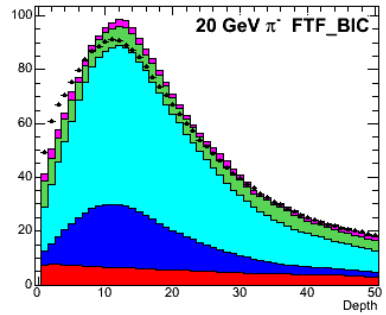


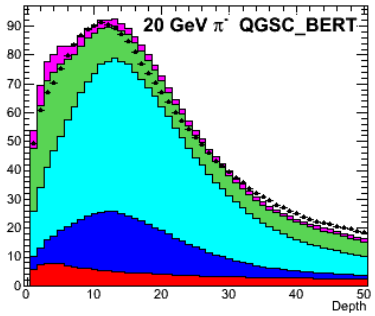


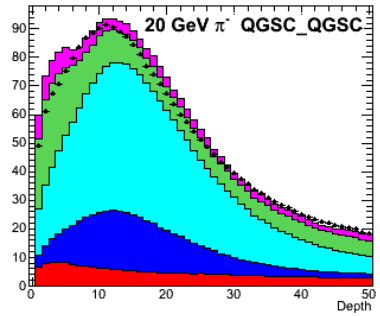


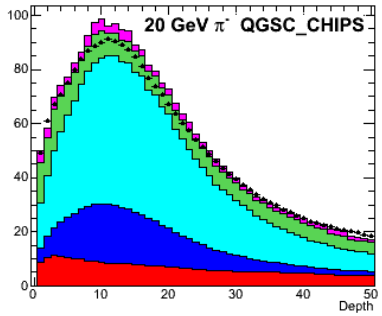




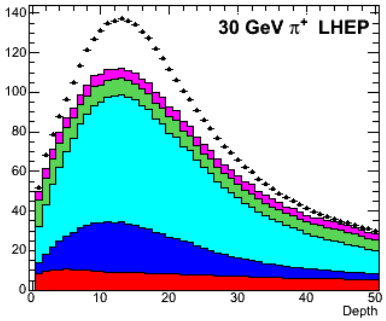


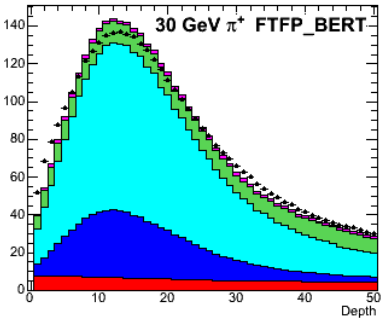


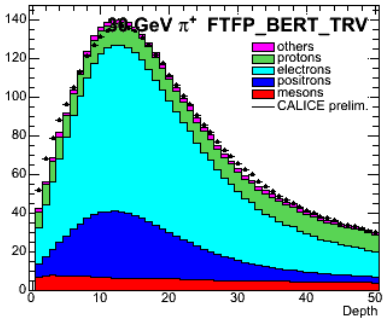


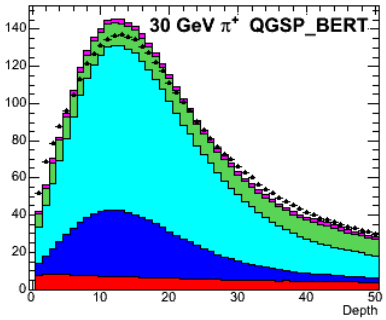


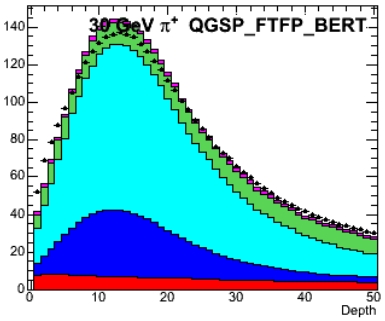
Longitudinal profile @ 30 GeV

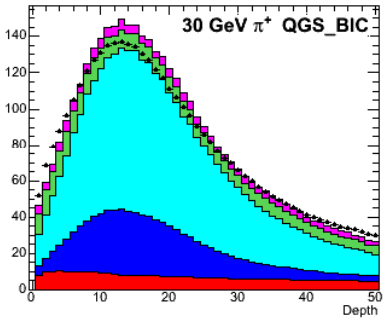


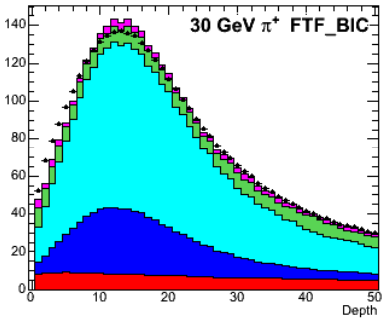


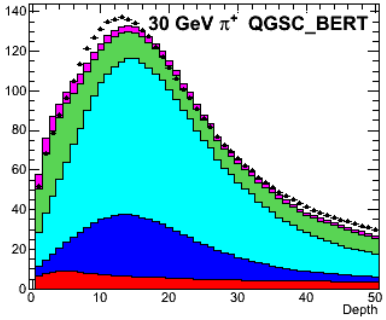


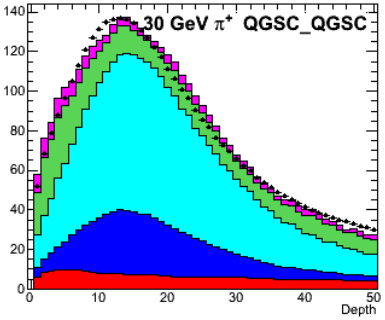


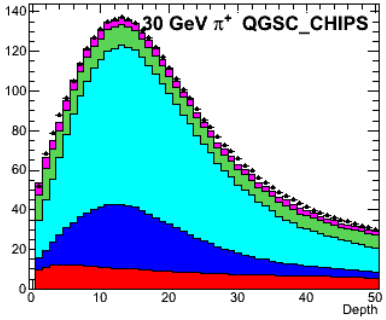




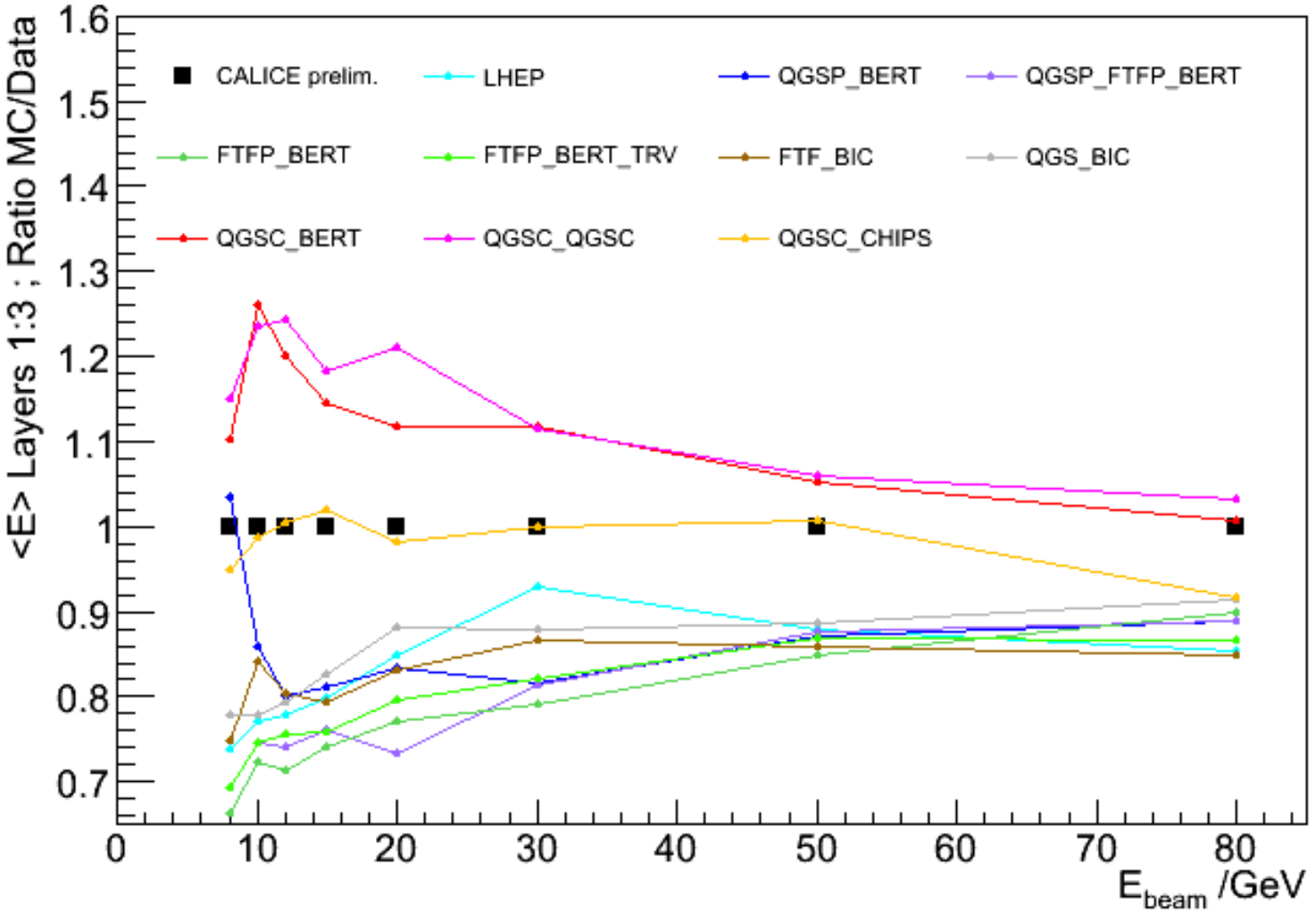




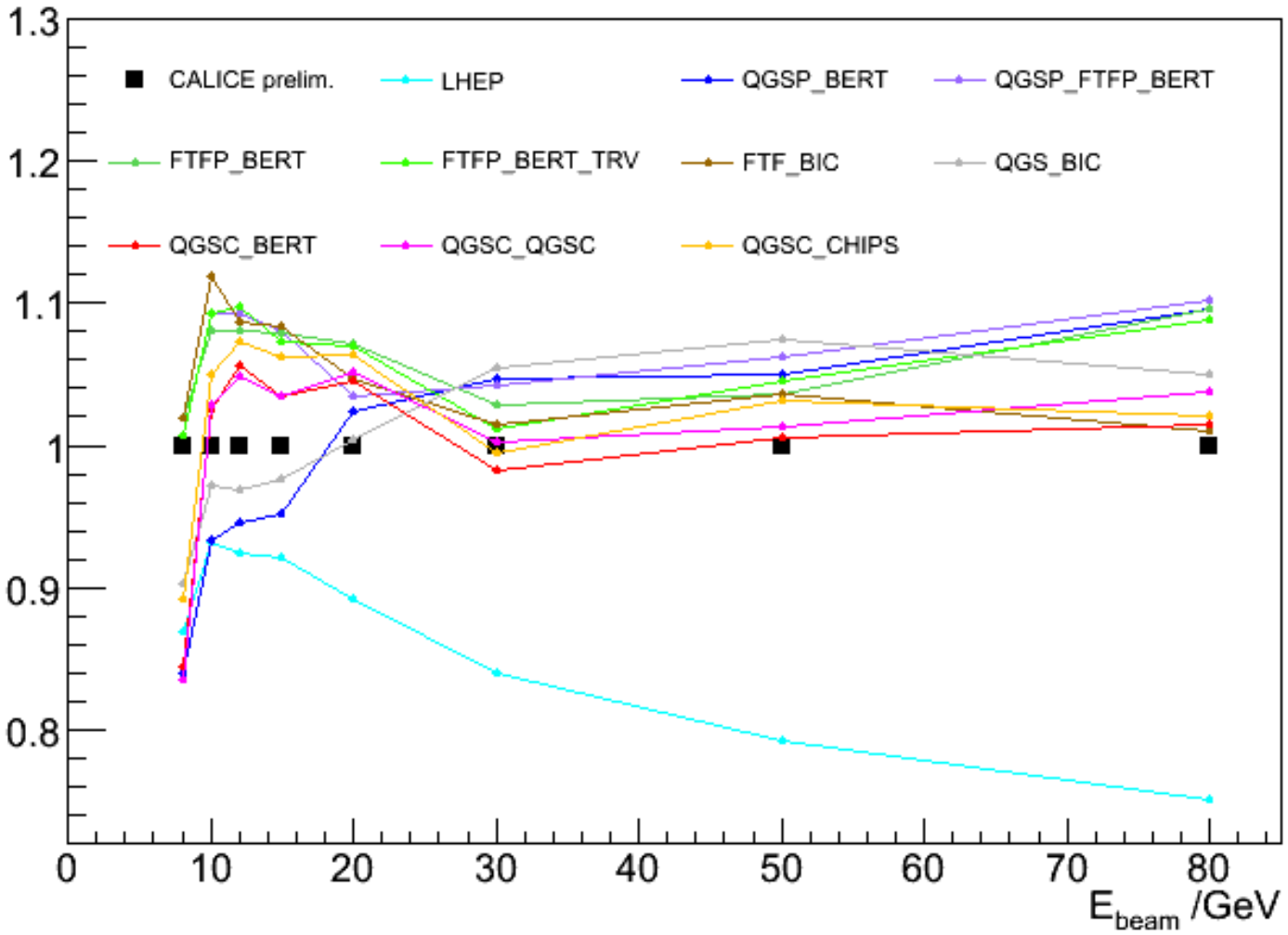




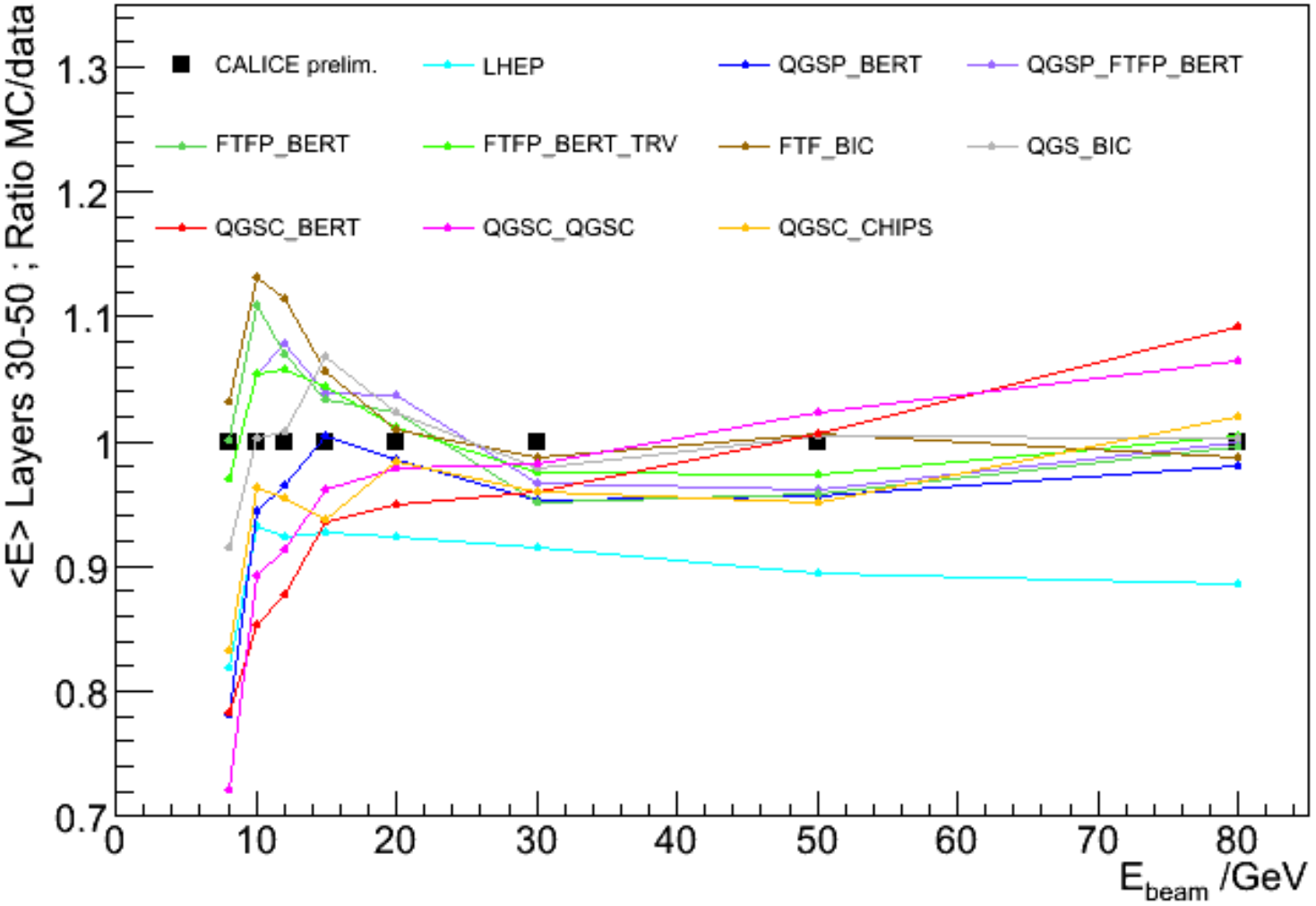
Energy in layers 1-3 (nuclear fragments)



Energy in layers 5-20 ($e^{\pm}$ dominated)



Energy in layers 30-50 (mainly hadronic)

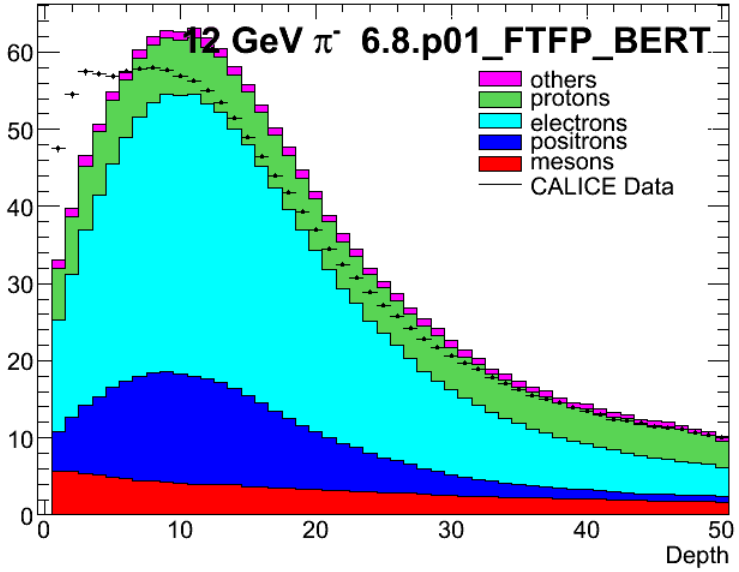


GEANT 4.9.3

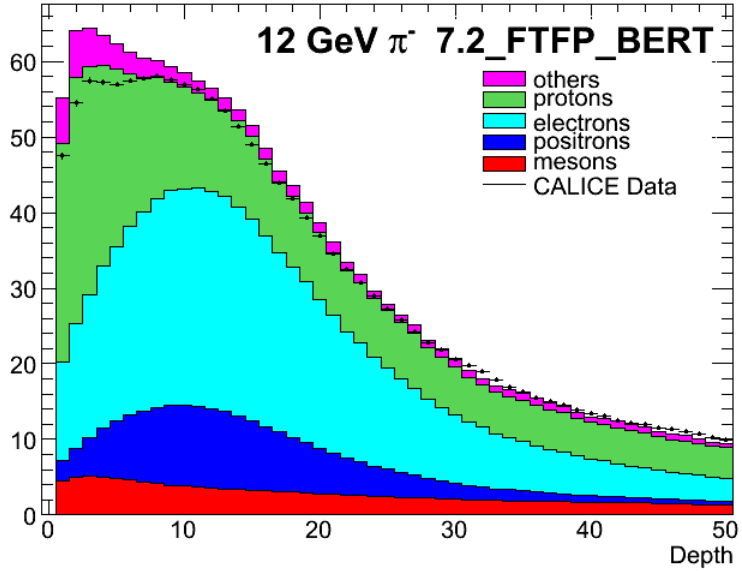
- Main changes:
  - Significant changes in the implementation of the Fritiof model; affects all FTF-based models
  - Significant development of CHIPS model into a full treatment of all energies
- New Physics Lists of potential interest
  - CHIPS (i.e. single model doing everything)
  - QGSP_BERT_TRV – modified transition energies, to reduce reliance on LHEP (Gheisha).
  - QGSP_BIC
- Physics lists QGSC_QGSC and QGSC_CHIPS are still available, but regarded as largely obsolete, replaced by CHIPS.
- Have made a few first tests, using Mokka 7.2 (hacked)
- Should we change to using the released version???

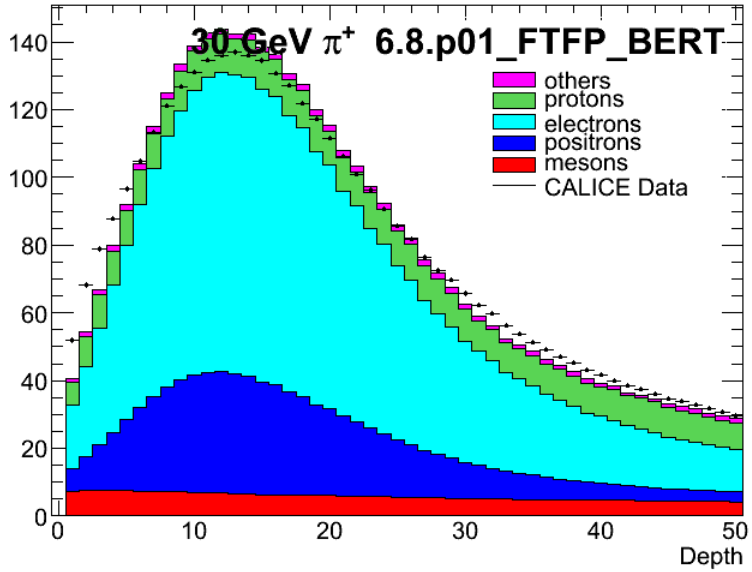
FTF models (improved ?)

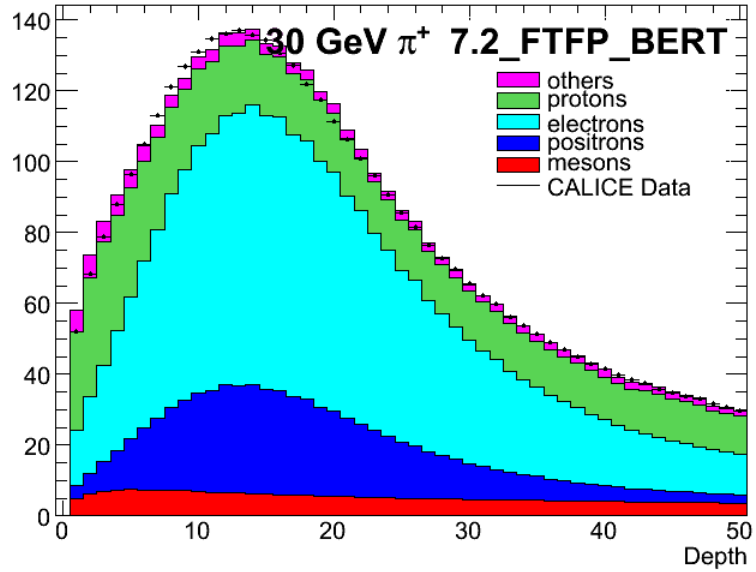
G4.9.3.b01 β version



Released G4.9.3 version

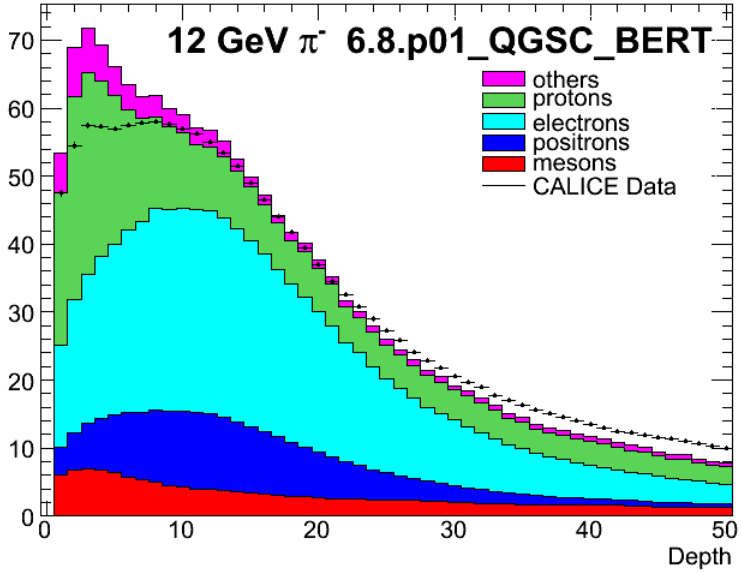




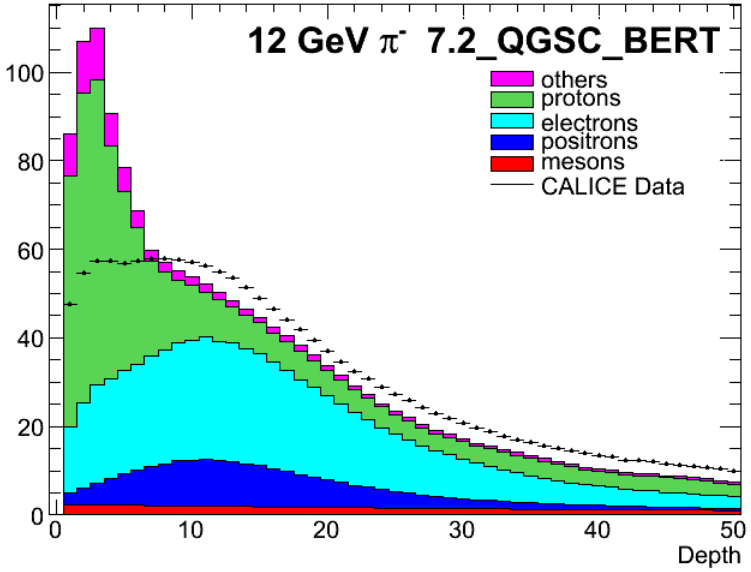


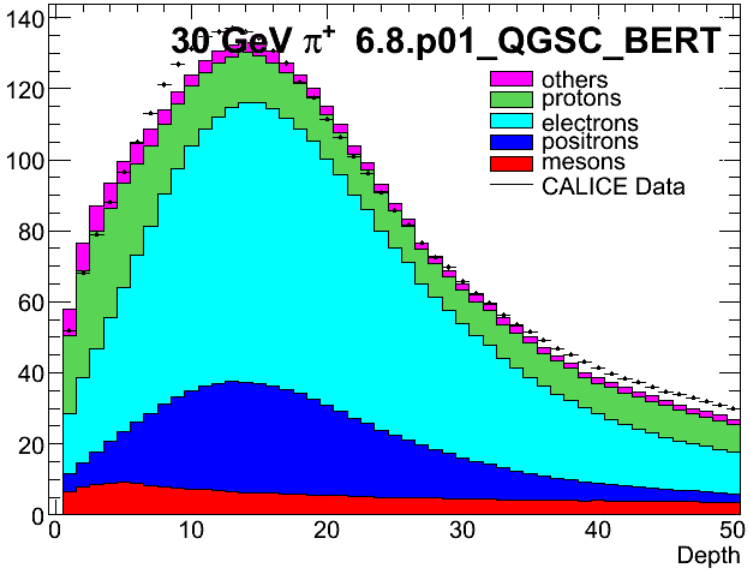
CHIPS models (much worse)

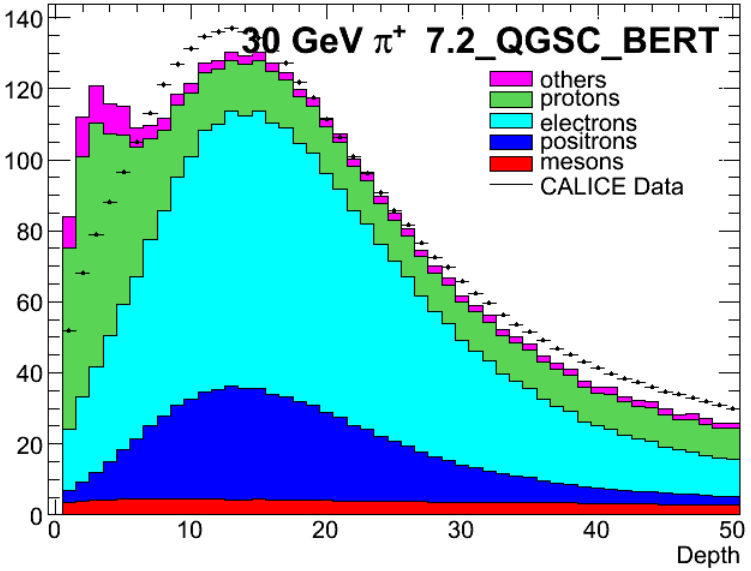
G4.9.3.b01 β version



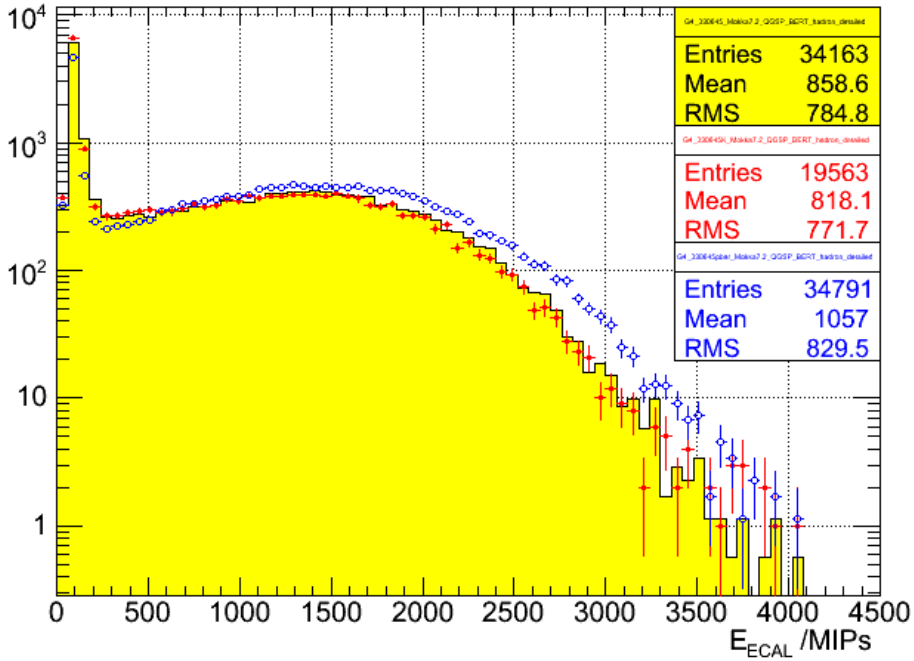
Released G4.9.3 version



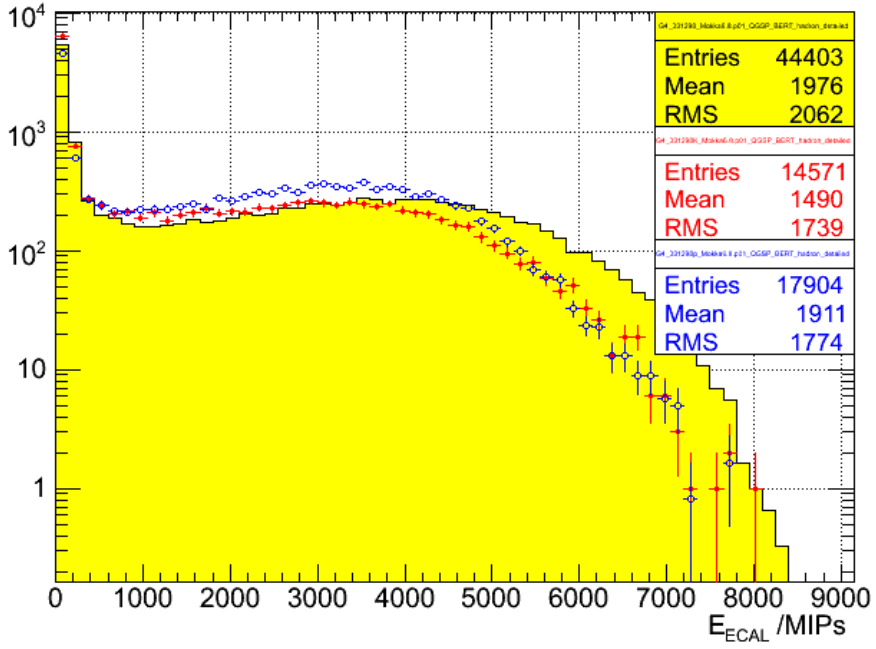




Outstanding worry -- non-pion background



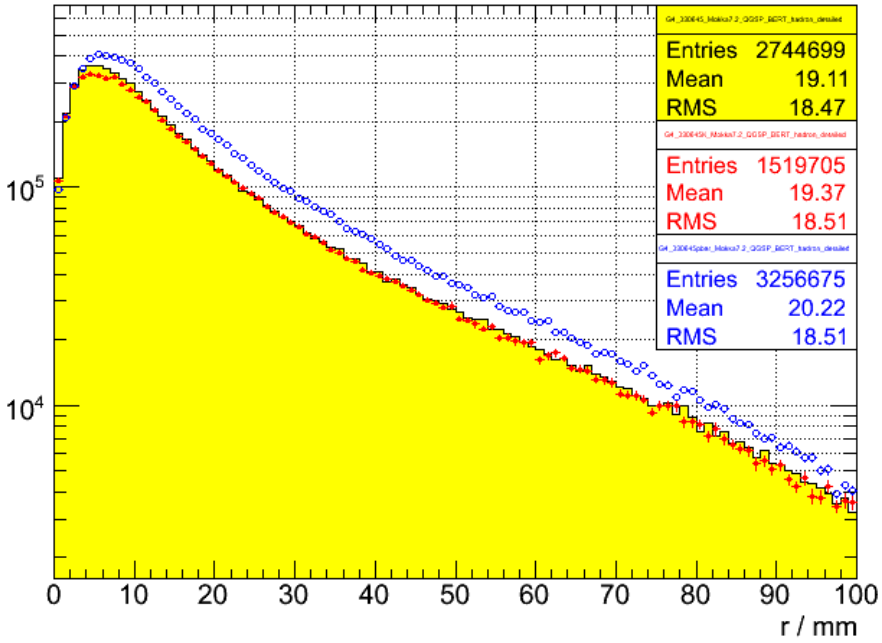
12 GeV QGSP_BERT
π, K, pbar



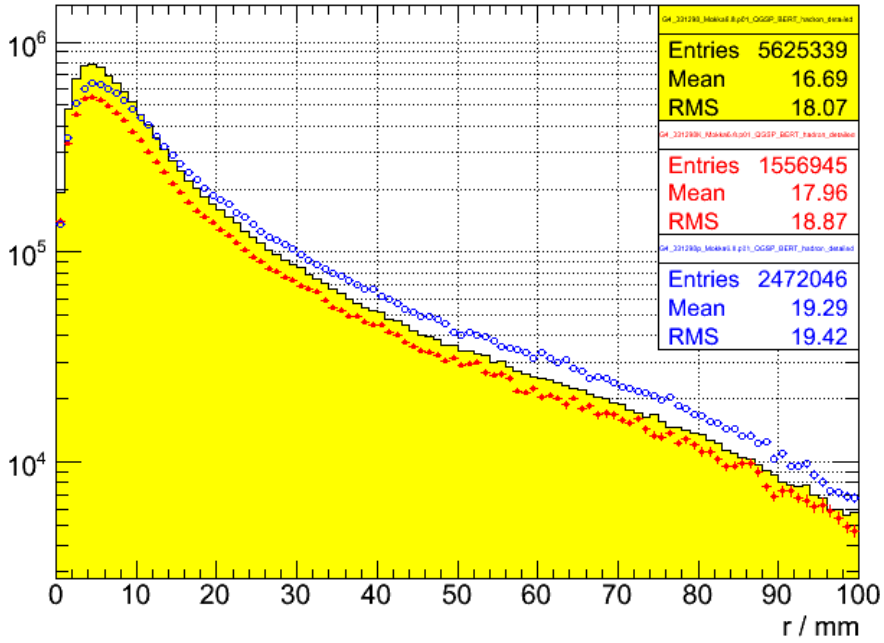
30 GeV QGSP_BERT
π, K, p

MC probably untrustworthy, but differences in probability of interaction, and in the energy deposited. Don't really know much about the beam composition.

Background contd.



12 GeV QGSP_BERT
π, K, pbar



30 GeV QGSP_BERT
π, K, p

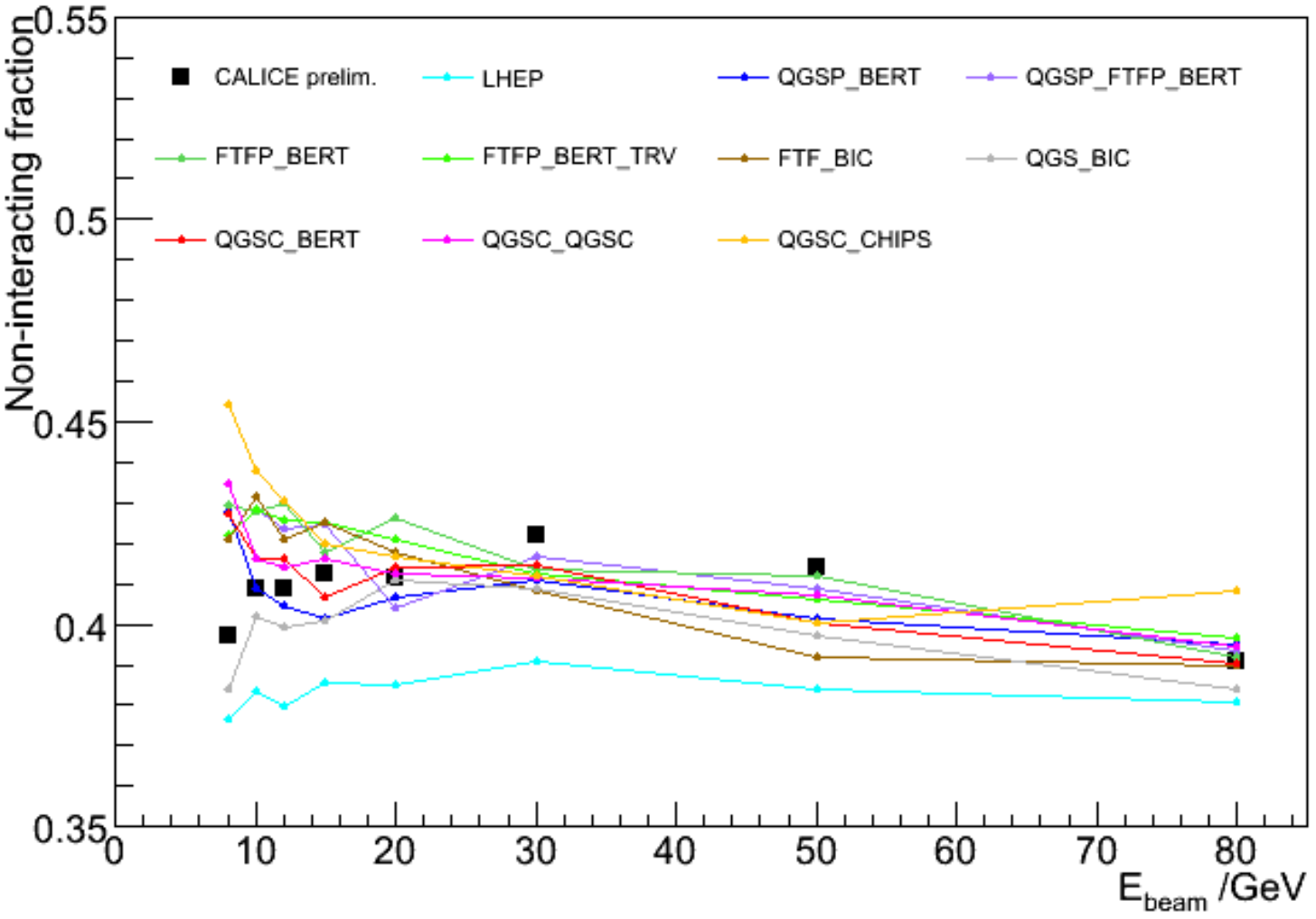
K, and especially p/pbar, may have broader showers.

Summary

- First draft of a paper/CAN based on G4.9.3.β01 – comments received from reviewers. Main outstanding issues are of presentation (too much information) rather than substance.
- We do have significant discrimination between physics lists in the ECAL. QGSC_CHIPS looks rather promising.
- Outstanding uncertainty about beam contamination from non-pions – hard to quantify.
- But have been overtaken by a new release of GEANT, with some significant differences.
  - FTF-based physics lists look quite a bit better ☺
  - CHIPS-based lists all much worse ☹ Not just the CHIPS standalone. QGSC_CHIPS also spoilt ☹
- Taking advice from G4 authors, and deciding what to do.

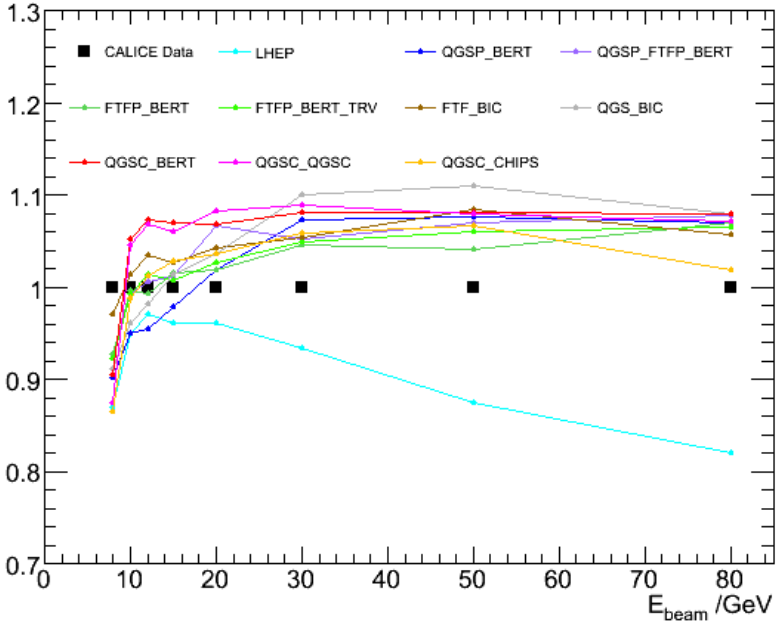
Spares

Fraction <100 MIPs in ECAL

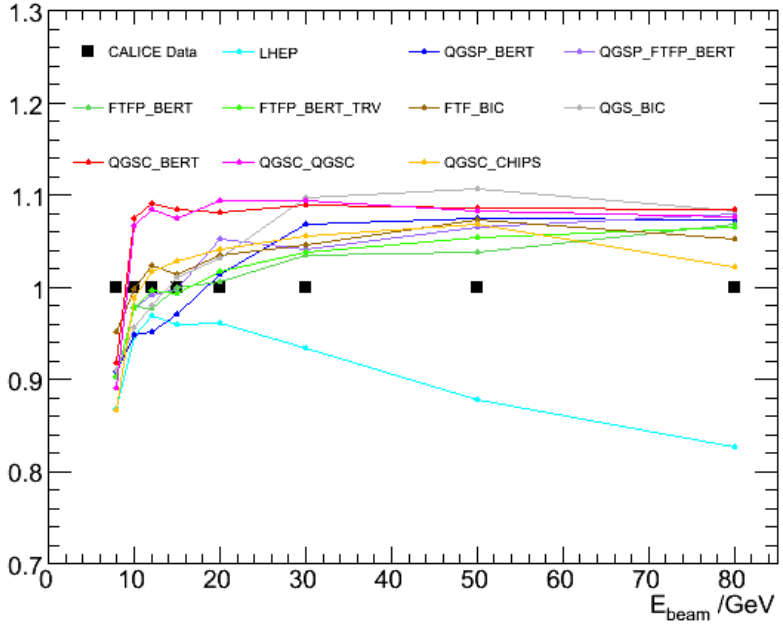


Change sampling weights

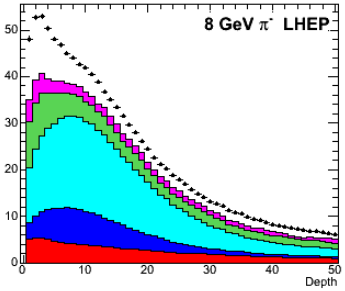
Weights 1:2:3

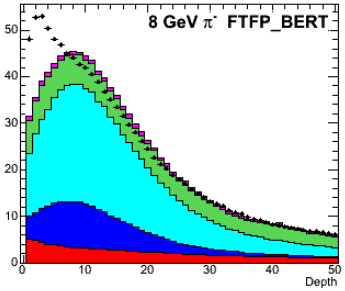


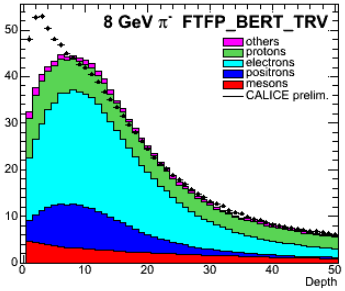
Weights 1:1:1

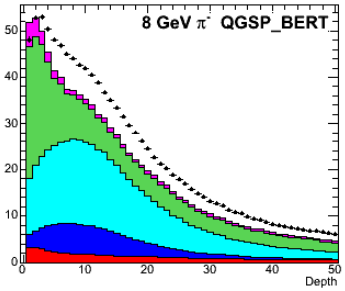


8 GeV


8 GeV π⁻ LHEP
Depth


8 GeV π⁻ FTFP_BERT
Depth


8 GeV π⁻ FTFP_BERT_TRV
others
protons
electrons
positrons
mesons
CALICE prelim.
Depth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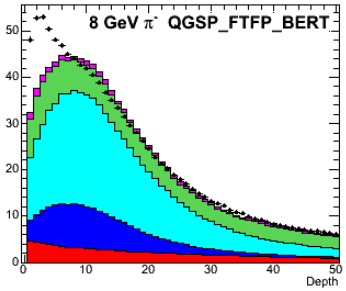
8 GeV π⁻ QGSP_FTFP_BERT
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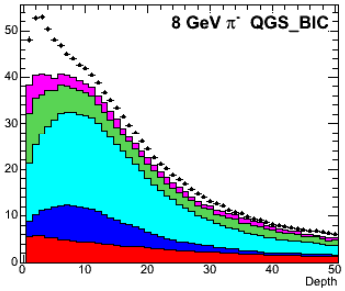
8 GeV π⁻ QGS_BIC
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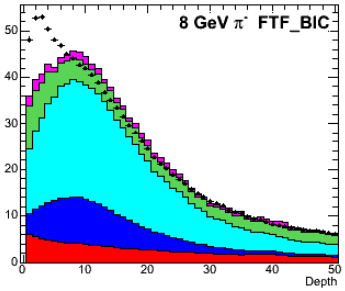
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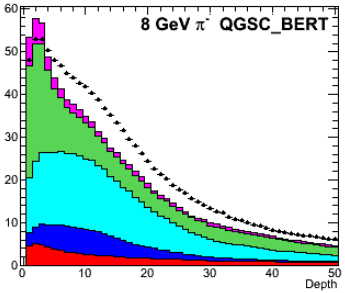
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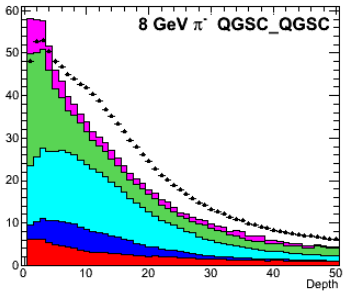
8 GeV π⁻ QGSC_QGSC
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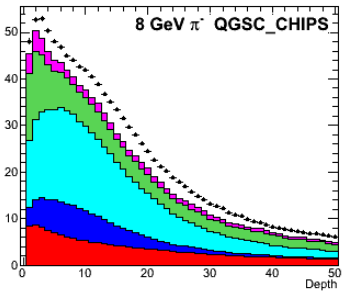
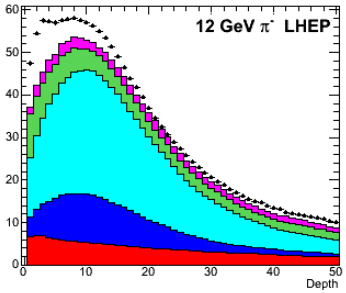

8 GeV π⁻ QGSC_CHIPS
Depth

12 GeV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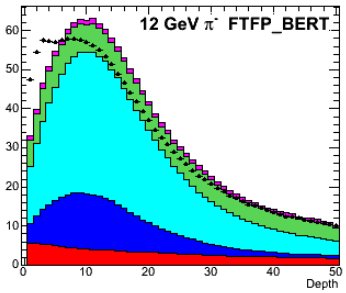
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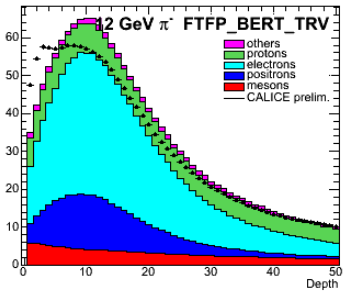
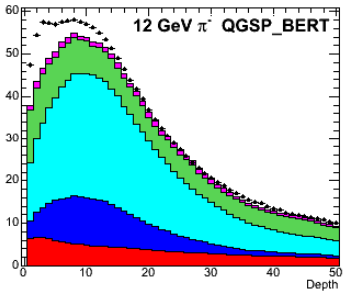
Depth


12 GeV π⁻ FTFP_BERT_TRV
others
protons
electrons
positrons
mesons
CALICE prelim.
Depth


12 GeV π⁻ QGSP_BERT
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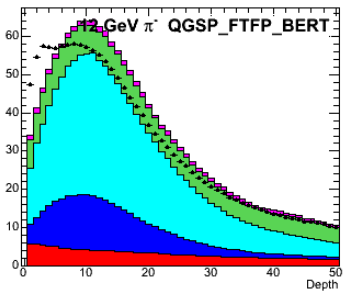
12 GeV π⁻ QGSP_FTFP_BERT
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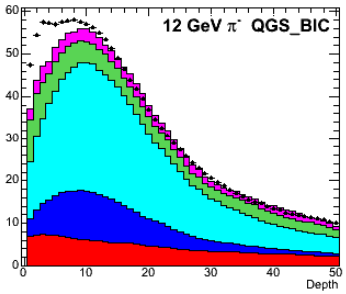
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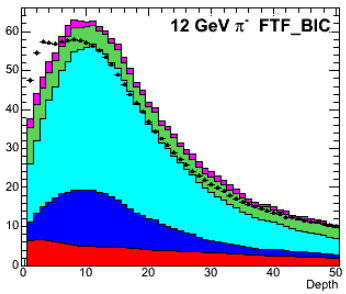
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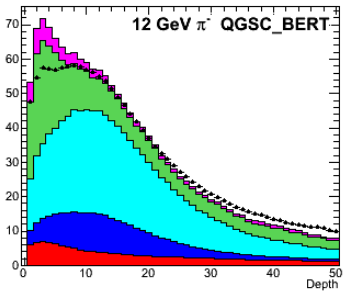
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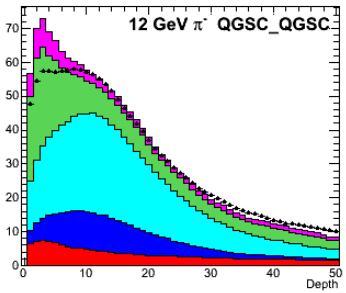
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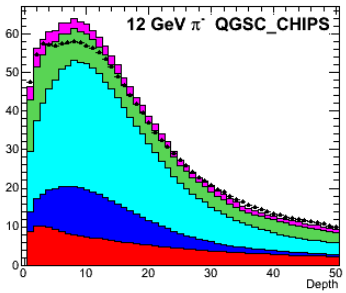
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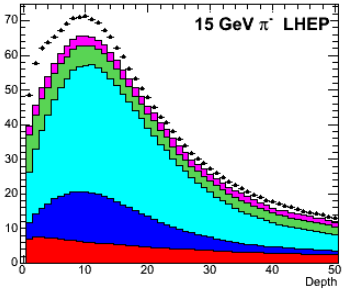
Depth

15 GeV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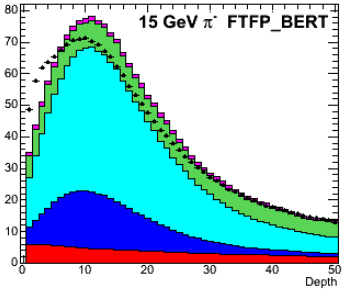
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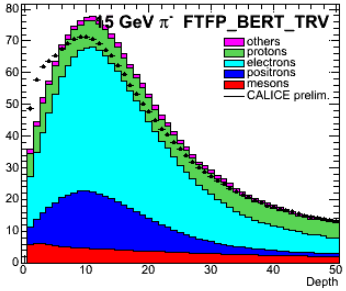
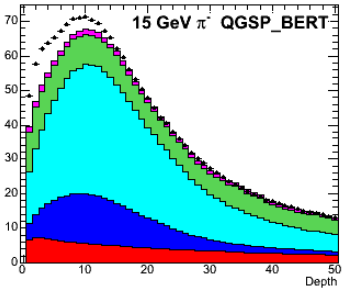
Depth


15 GeV π⁻ FTFP_BERT_TRV
others
protons
electrons
positrons
mesons
CALICE prelim.
Depth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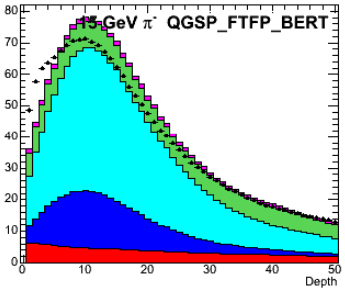
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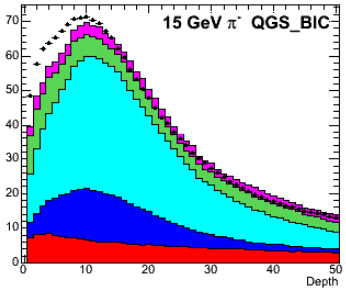
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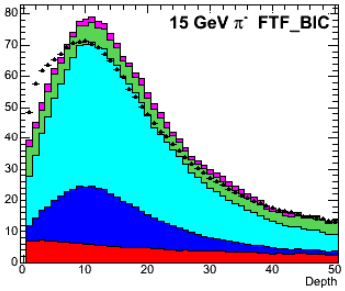
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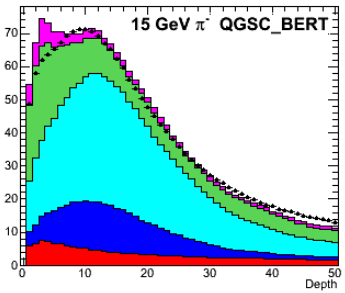
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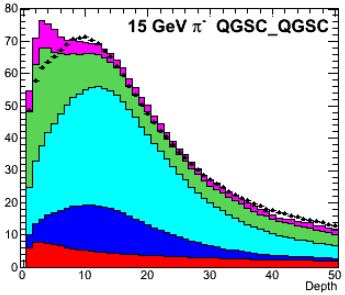
Depth


15 GeV π⁻ QGSC_QGSC
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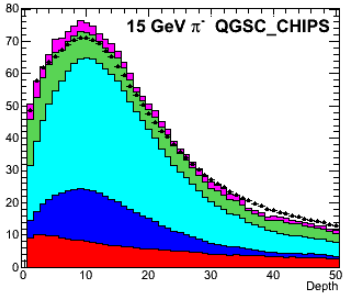
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Depth