Hadronic Highlights of G4 10.2

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Hadronic Data Sets

- G4ENSDFSTATE**1.2**
  - It is now mandatory to define the environmental variable **G4ENSDFSTATE**
    - Needed to build the **G4NuclideTable**, which is used in the **G4IonTable**, which, in turn, is used in both EM and HAD physics
- PhotonEvaporation**3.2**
- RadioactiveDecay**4.3**

- Optional: G4TENDL**1.0**
  - Needed by ParticleHP when used for p, n, d, t, He3, α

Fast Math and Checking *While*-loops

- Used, wherever possible, the fast math functions
  - Replaced the slow mathematical functions:
    std::exp , *std::log* , *std::pow*
    with the corresponding faster VDT versions:
    G4Exp , *G4Log* , G4Pow

- Checked all *while*-loops
  - When not guaranteed to end, a counter is introduced so to exit the loop when a specified threshold in the number of loops is reached

Fritiof (FTF) model

- Improved the preparation of the excited nuclear remnant by the FTF model to hand over to Precompound/de-excitation
  - Affecting the production of low-energy nucleons
  - Resulting in closer agreement with thin-target data (See backup plots)
  - Few % increase in the energy response of hadronic showers in Fe and Cu absorbers (See backup plots)

Quark-Gluon-String (QGS) model

- Minor changes in G4 10.2 with respect to 10.1

Note: a major development in the final-state model (included in the June beta release) has been postponed to next year (G4 10.3): the algorithm changes require re-tuning of the parameters, and with the current parameter values some thin-target comparisons would get worse.

Intra-nuclear Cascade models

- Bertini (BERT)
  - Extended K+n and K+p up to 32 GeV and 9-body "final" states
  - Introduced (optional) improved nucleon evaporation from giant dipole resonance excitation
- Liege (INCLXX)
  - No significant developments
- Binary (BIC)
  - No significant developments

Precompound / de-excitation

- Revised the computation of evaporation cross sections, unifying between Precompound and de-excitation
  - They share the same cross sections (although used in different kinematical ranges) which are now factorized in one place
- New structure of gamma levels
  - Consistent between PhotonEvaporation and RadioactiveDecay
  - To be extended (next year) to FermiBreakUp, GEM and MultiFragmentation
- New gamma de-excitation model
- New data-set: PhotonEvaporation**3.2**

Radioactive Decay

- Now using *G4UAtomicDeexcitation* to handle fluorescence and Auger electrons
- Improved energy conservation for IT and EC modes
  - ~30 eV by using approximate shell energy method of A. Zoglauer
- Adapted to changes in particle category by providing a mass defect check between parent and daughter nuclei
- Removed dependence on local isotope table in favor of that in *G4NuclideTable*
- New data-set: RadioactiveDecay**4.3**

ParticleHP

- Merged **NeutronHP** into **ParticleHP**
  - No changes in user code required !

- **ParticleHP** for ***p*** , ***d*** , ***t*** , ***He3*** , ***α*** below **200 MeV**
  - Validation still on-going
  - Physics List **QGSP_BIC_AllHP** shows how to use it
  - New data set **G4TENDL1.0** to be downloaded from the Geant4 site
    - Derived mostly from **TENDL-2014**, with a few isotopes taken from **ENDF/B-VII.1**

Hadronic Cross Sections

- Bug-fix in *G4NeutronInelasticXS* and *G4NeutronCaptureXS*
  - Affect elements with natural isotopes of comparable fractions
    - e.g. W , Pb , Cu; little effect on Fe
  - Good effect on lateral shower shapes:
    brings FTFP_BERT closer to FTFP_BERT_HP
    - Although FTFP_BERT showers got ~5% narrower
- In physics lists, used now *G4NeutronElasticXS* and *G4ComponentGGHadronNucleusXsc*
  - See next slide

Physics Lists

- Neutron elastic cross *G4NeutronElasticXS* used in all non-HP physics lists
  - Instead of Chips neutron elastic cross section
- Glauber-Gribov kaon inelastic cross sections used in all physics lists
  - instead of either Chips or Gheisha kaon inelastic cross sections
- In QBBC, transition between FTFP and BERT : [3, 4] GeV
  - Instead of [3, 12] GeV
- In FTFP_BERT_TRV, use new GS msc model; and transition between FTFP and BERT : [2, 4] GeV
  - Instead of [3, 12] GeV
- QGSP_BIC_AllHP uses ParticleHP for p , d , t , He3 , α below 200 MeV

Hadronic showers *(see plots in backup slides)*

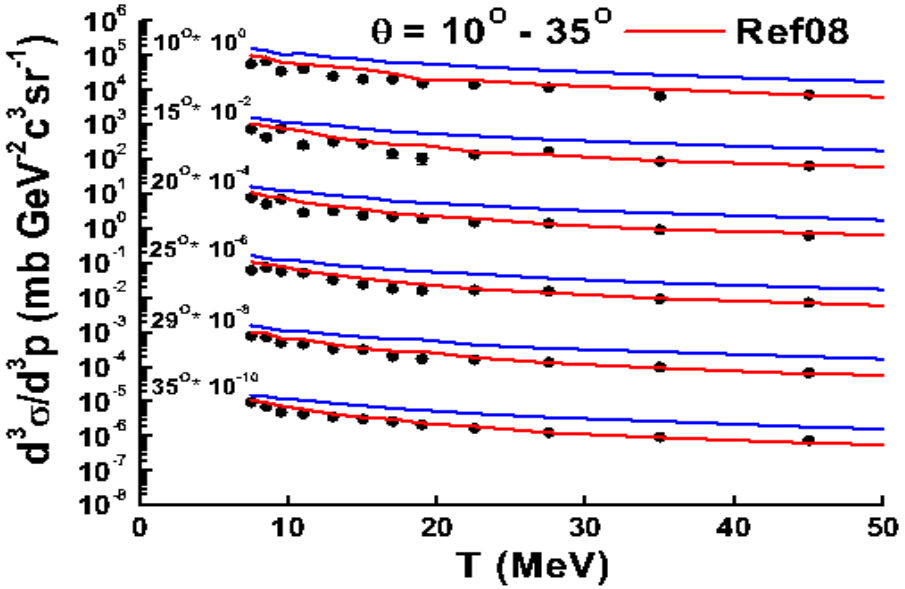
- FTFP_BERT hadronic showers in G4 10.2 have changed with respect to those in G4 10.1 as follows:
  - Higher energy response in non-heavy absorbers (Fe, Cu)
    - Few %
    - Mostly due to the changes in FTF
  - Narrower lateral shapes (W, Pb, Cu)
    - ~5% for Pb and Cu; ~10% for W
    - Due to bug-fix in NeutronXS (inelastic and capture) cross sections, and, for W, to the new de-excitation model

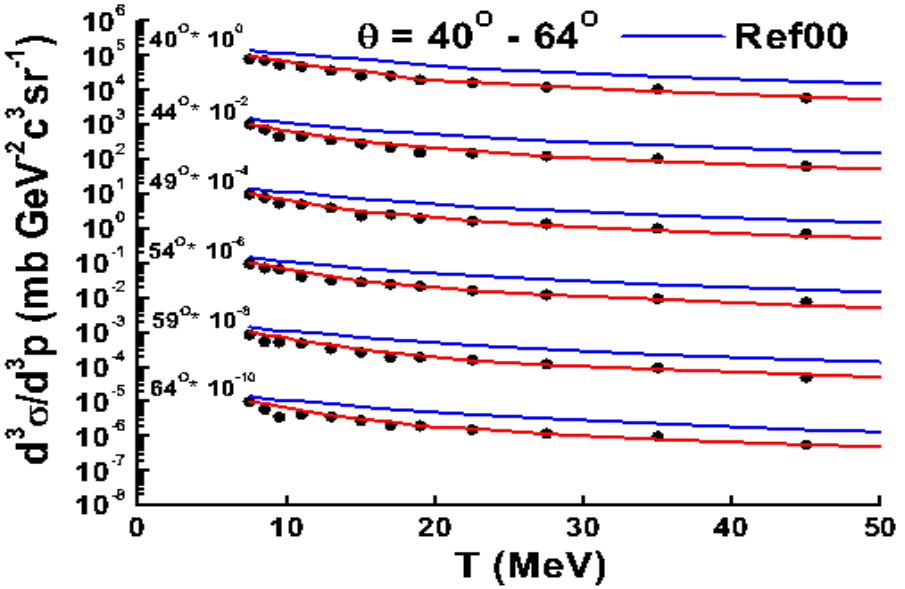
Backup slides

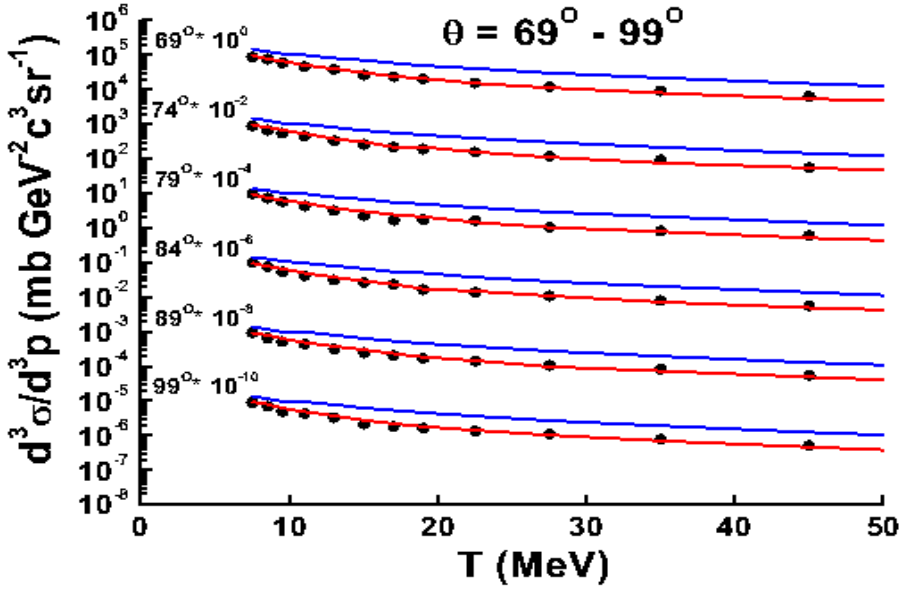
Example of thin-target improvement of **FTF**

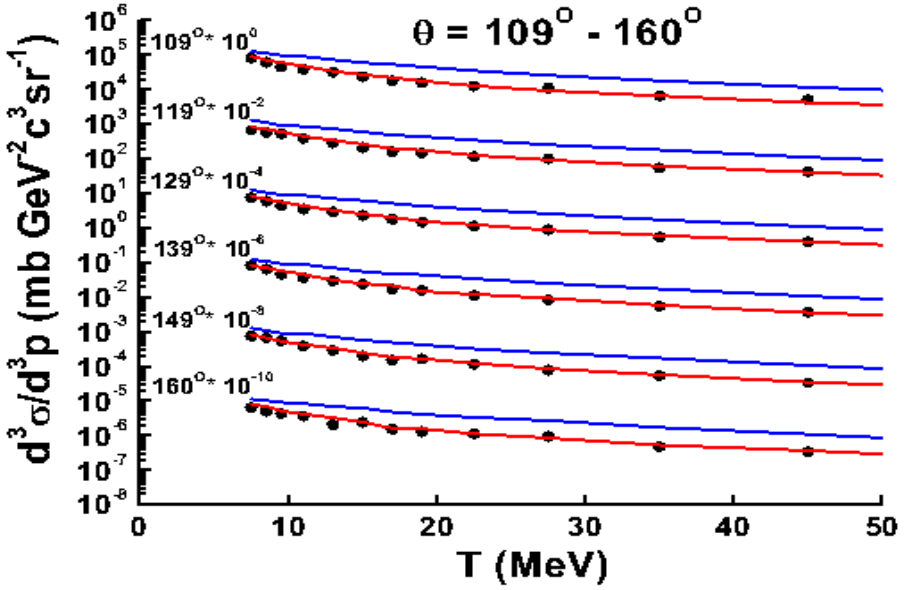
ITEP Data : 7.5 GeV/c p Cu

G4 10.1.**ref08** vs 10.1.**ref00**









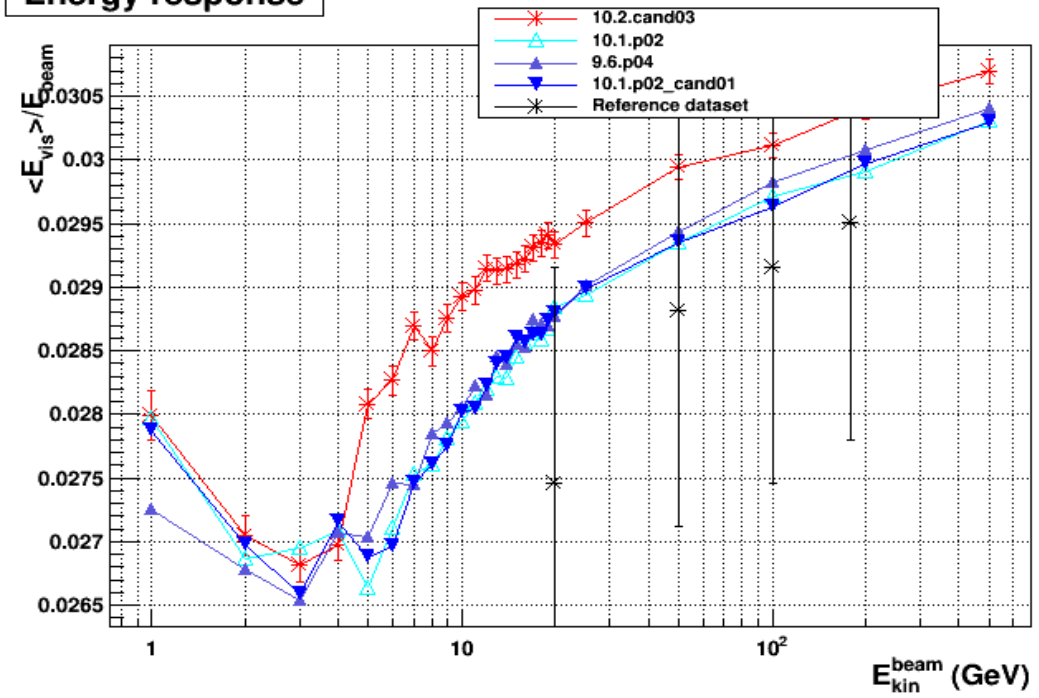
Pion showers
in Simplified Calorimeters

Comparing G4 versions:
10.2 , 10.1.p02 , 10.0.p04 , 9.6.p04

FTFP_BERT

π^- on Fe-Sci

Energy response



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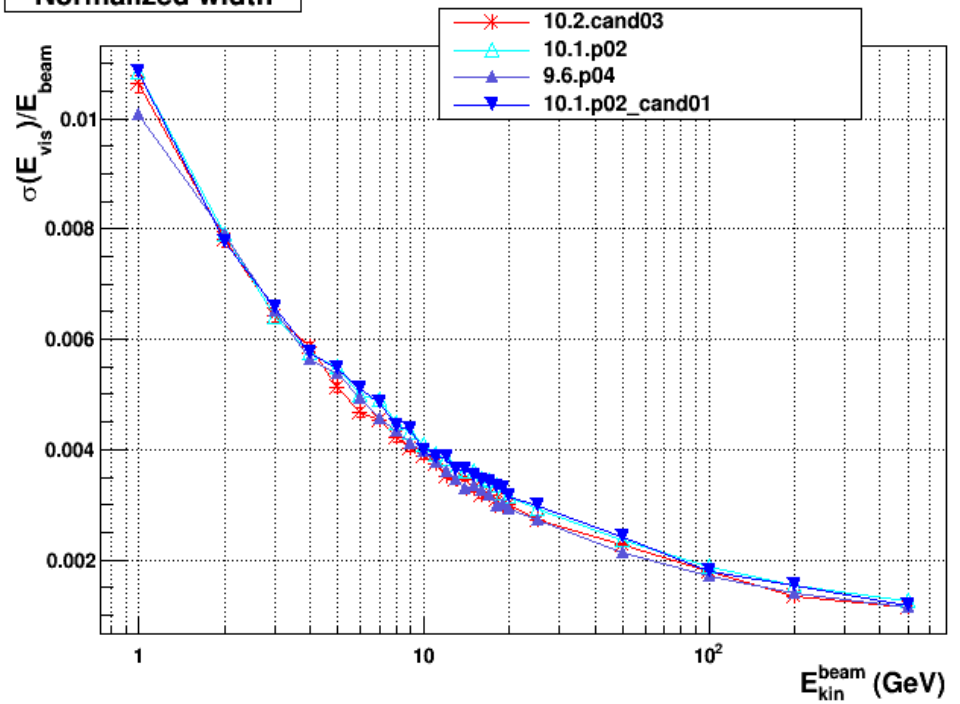
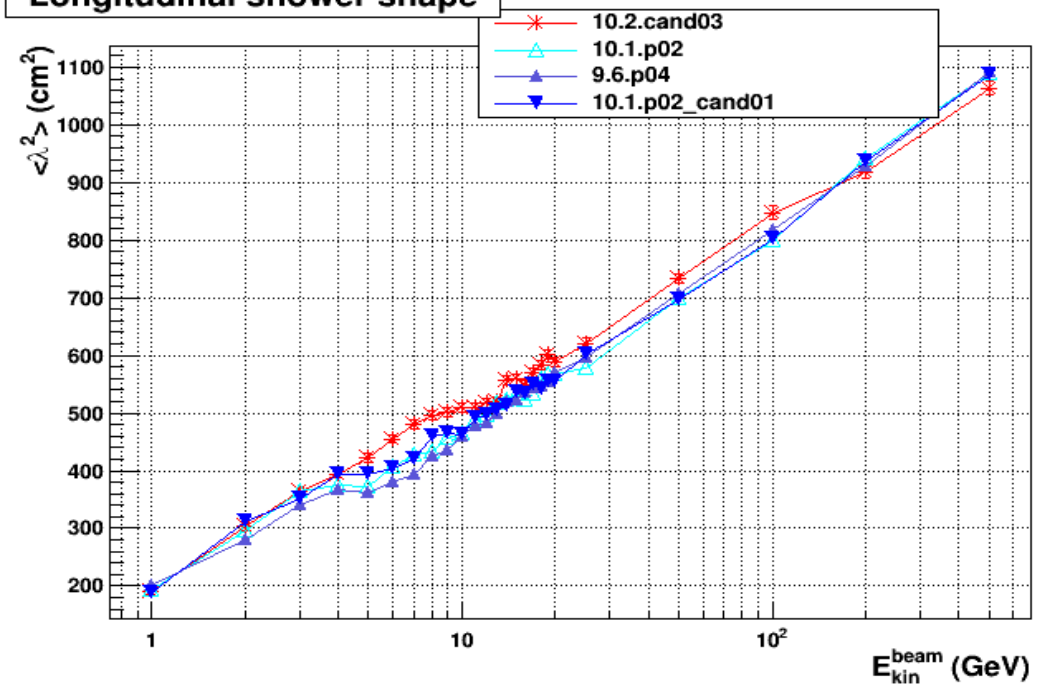
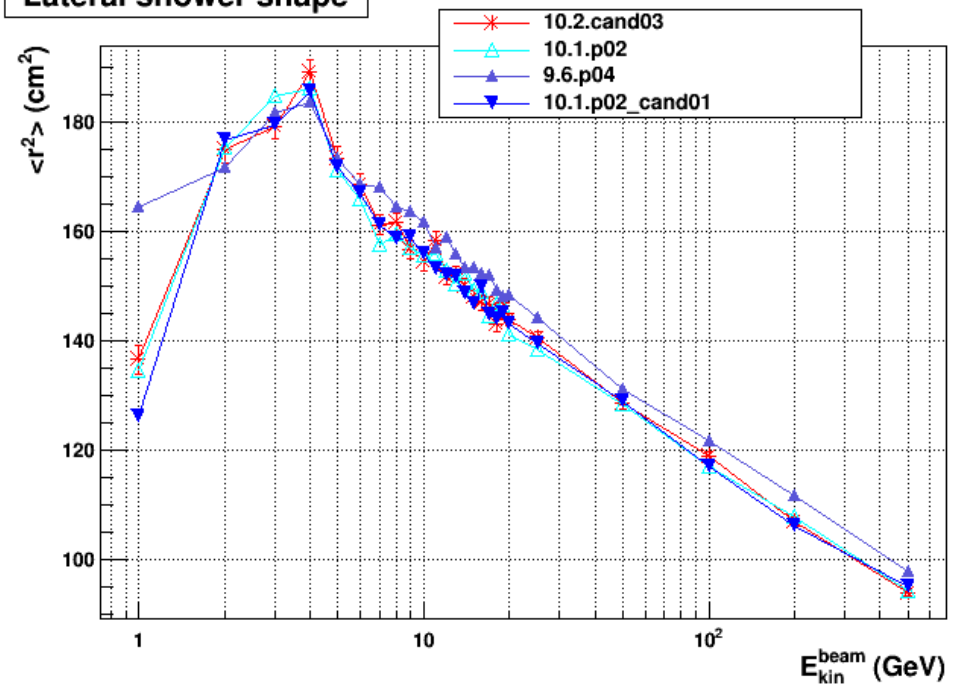


Longitudinal shower shape

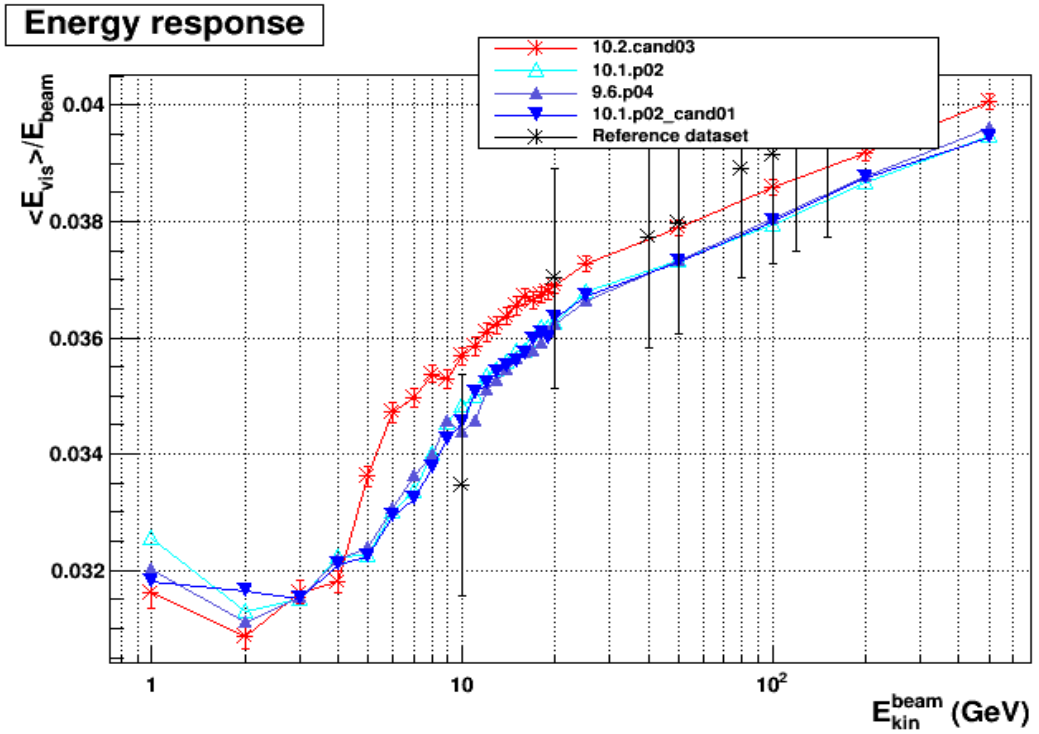


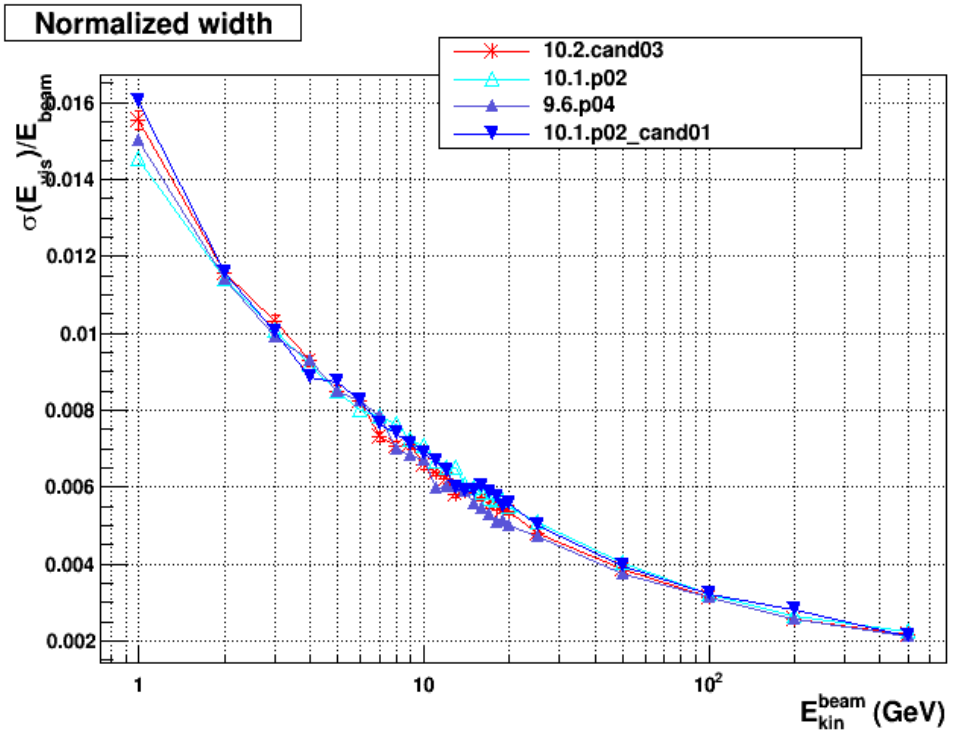
Lateral shower shape

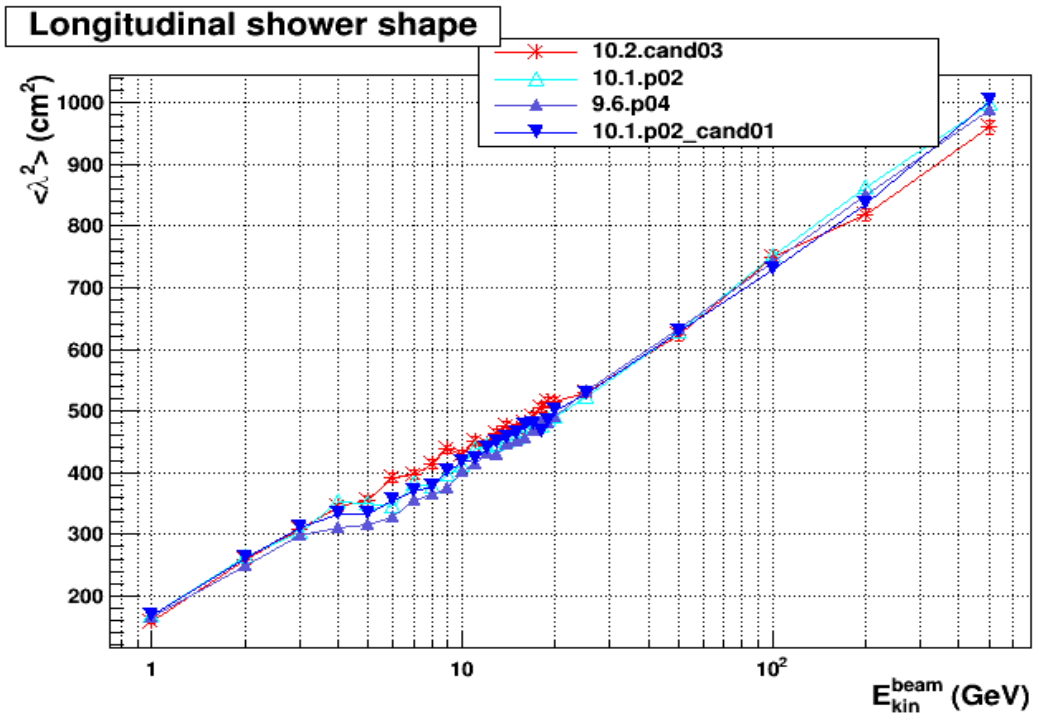


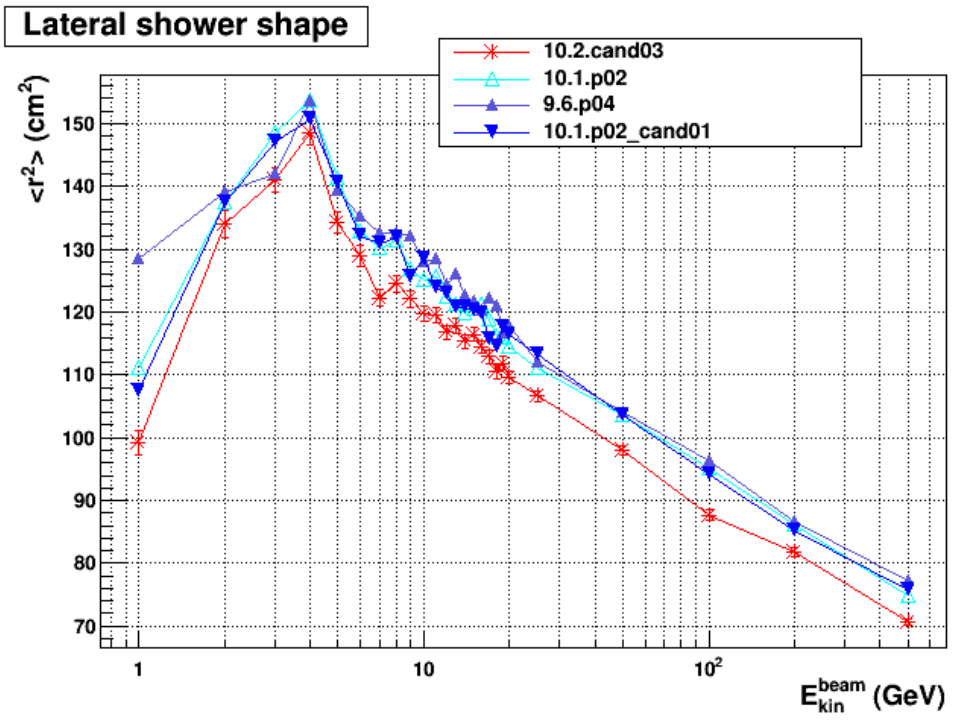
FTFP_BERT

π^- on Cu-LAr





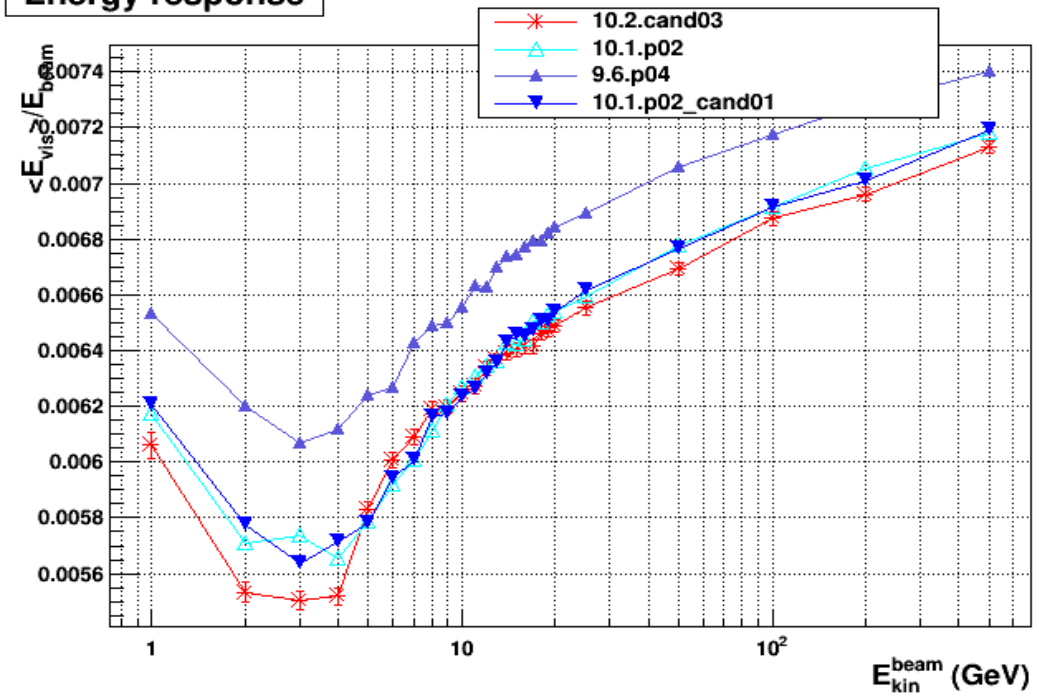




FTFP_BERT

π^- on W-LAr

Energy response



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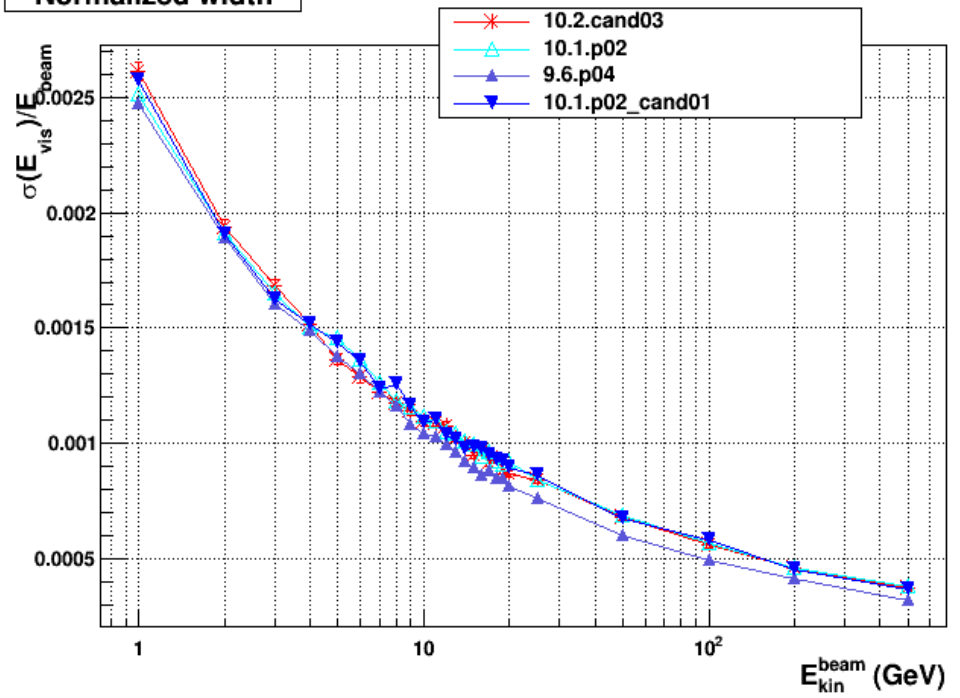
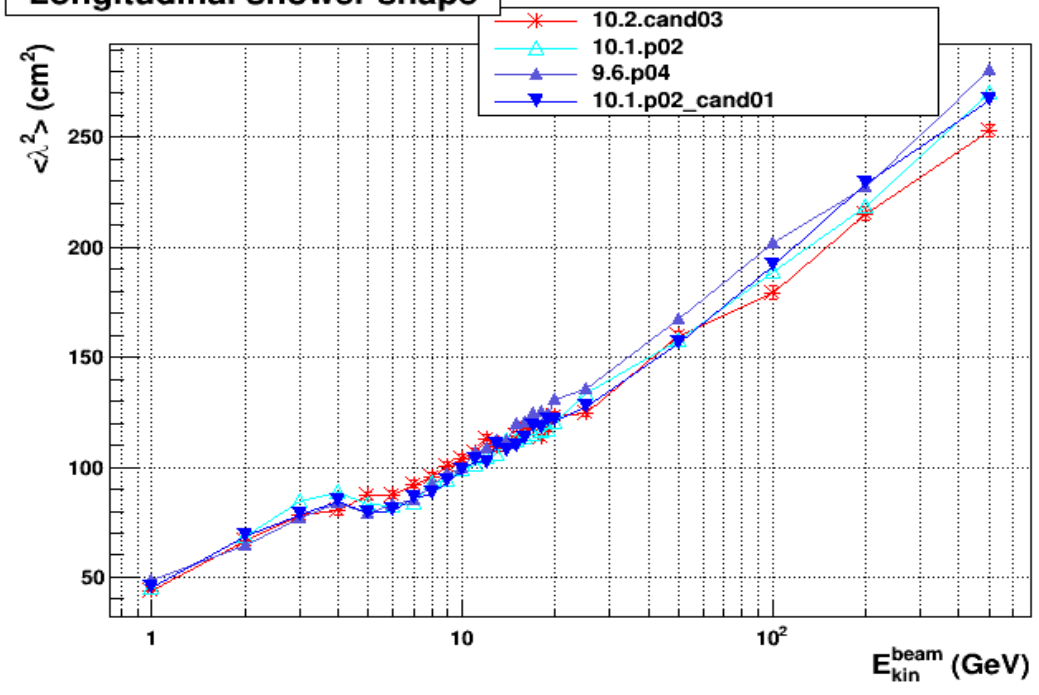
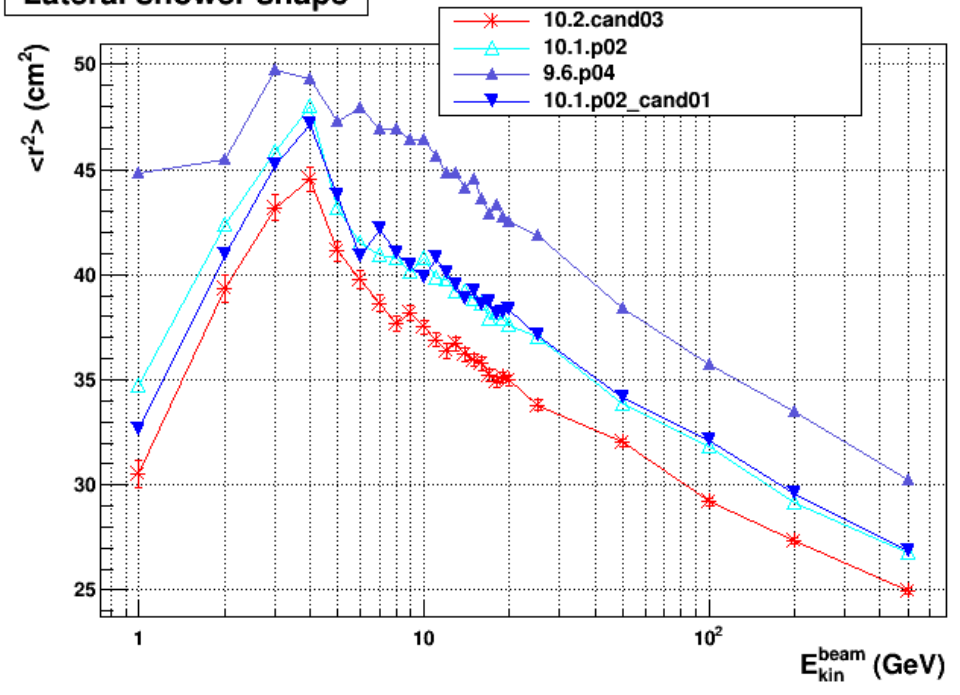


Longitudinal shower shape

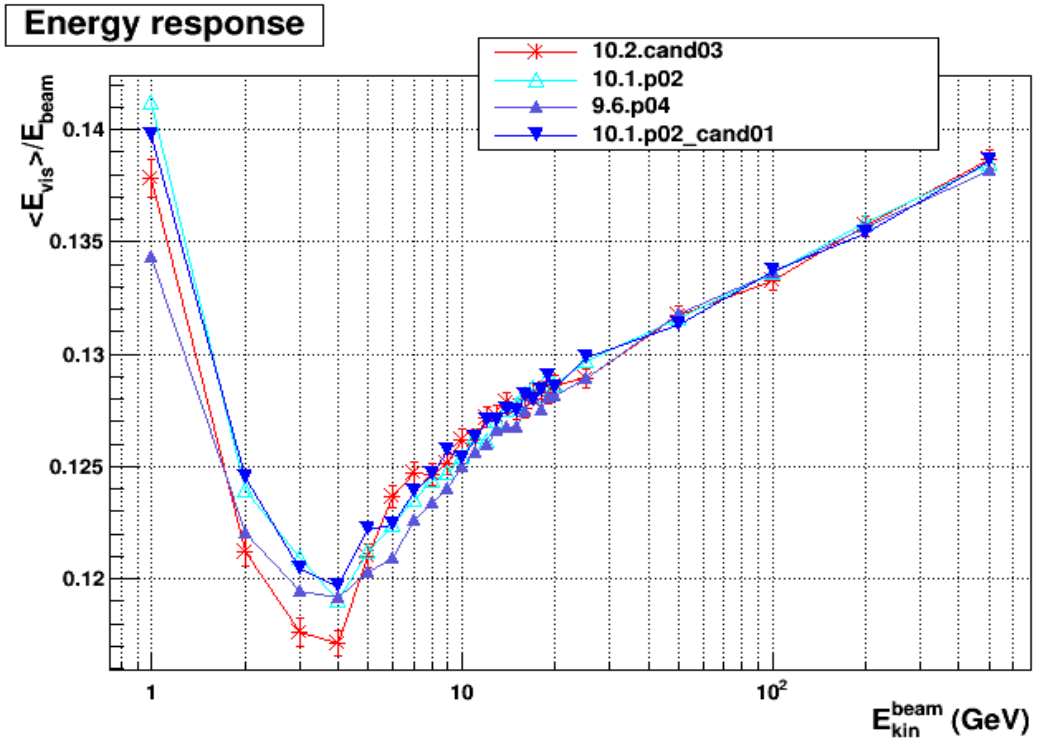


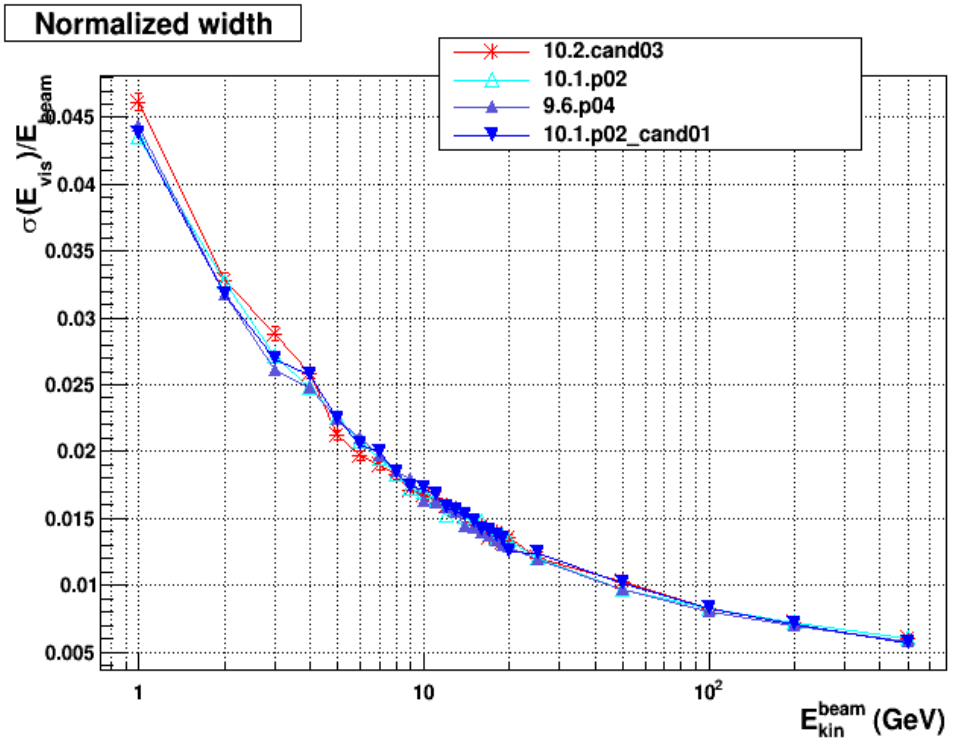
Lateral shower shape

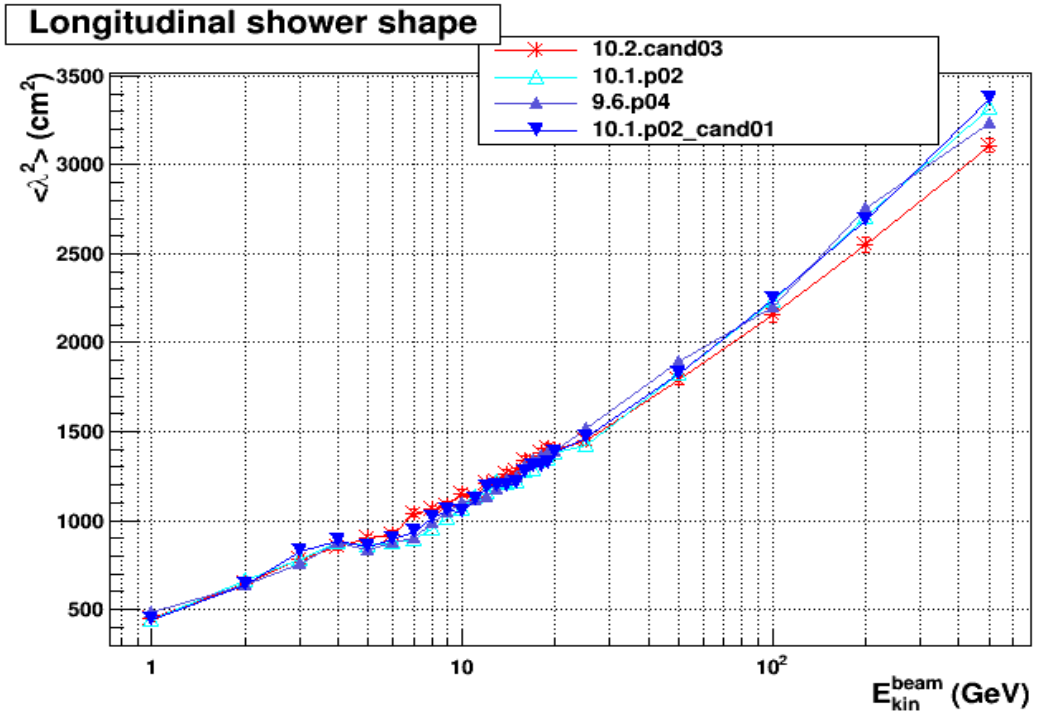


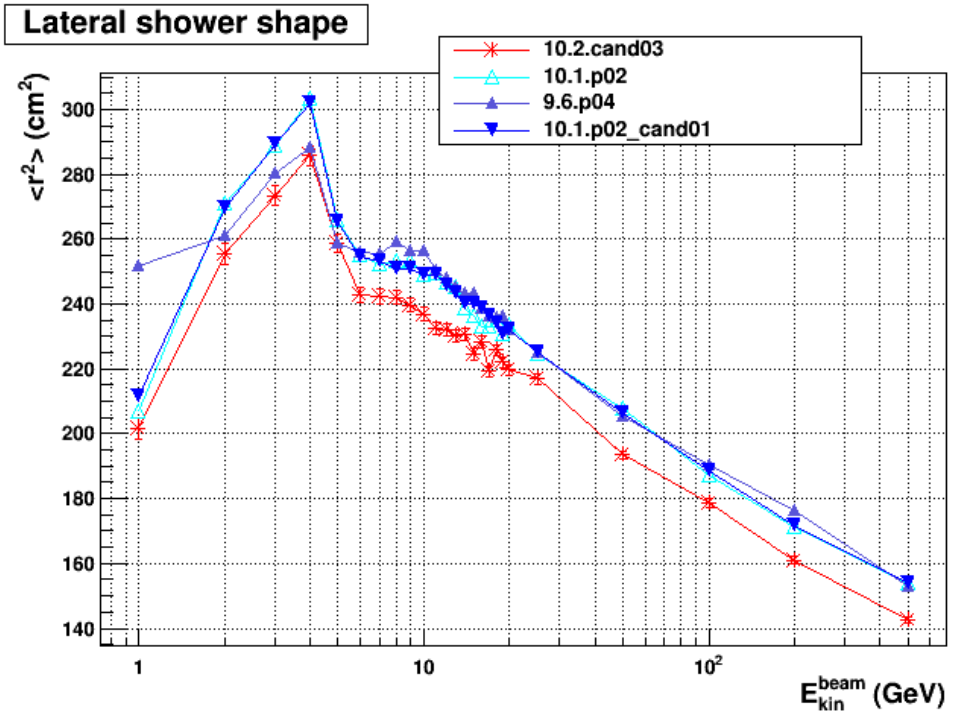
FTFP_BERT

π^- on Pb-LAr

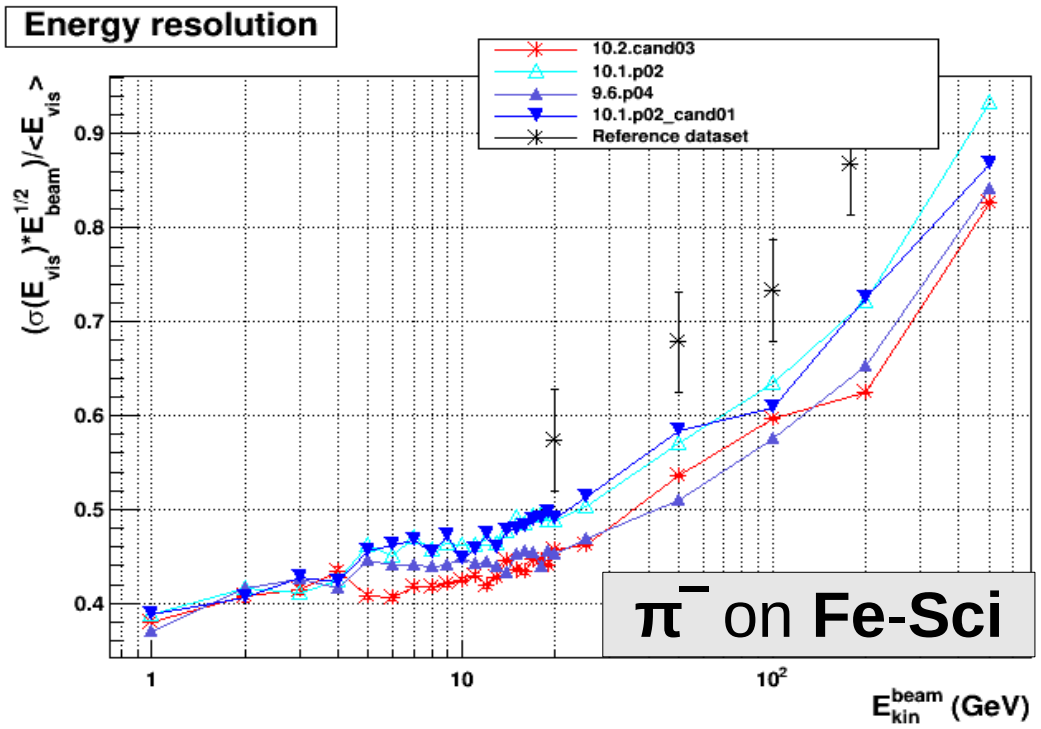


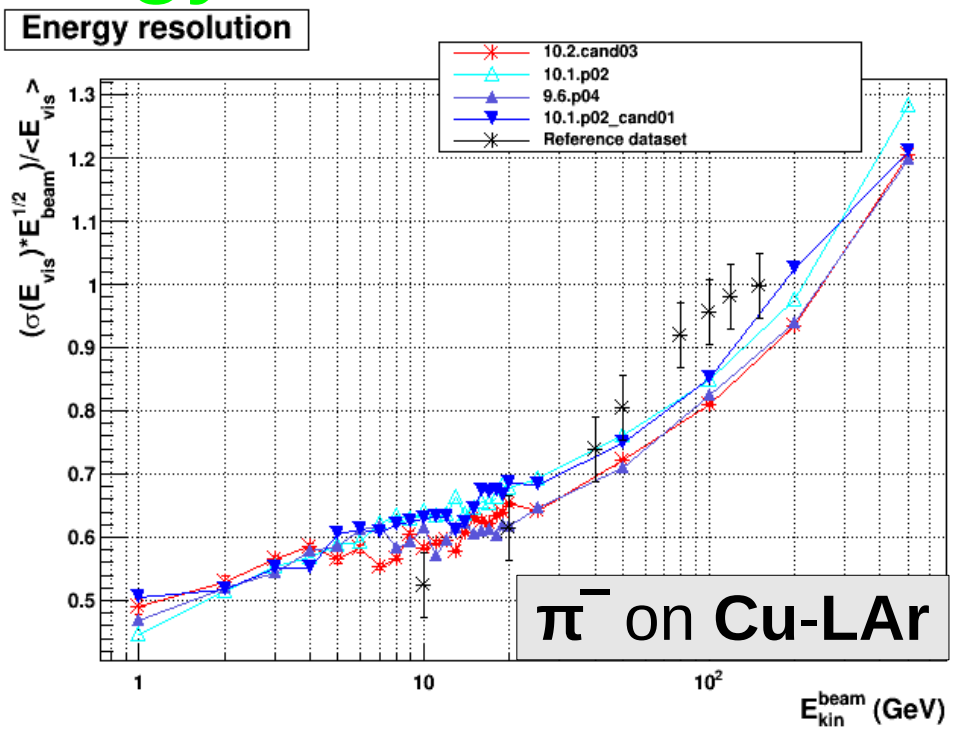


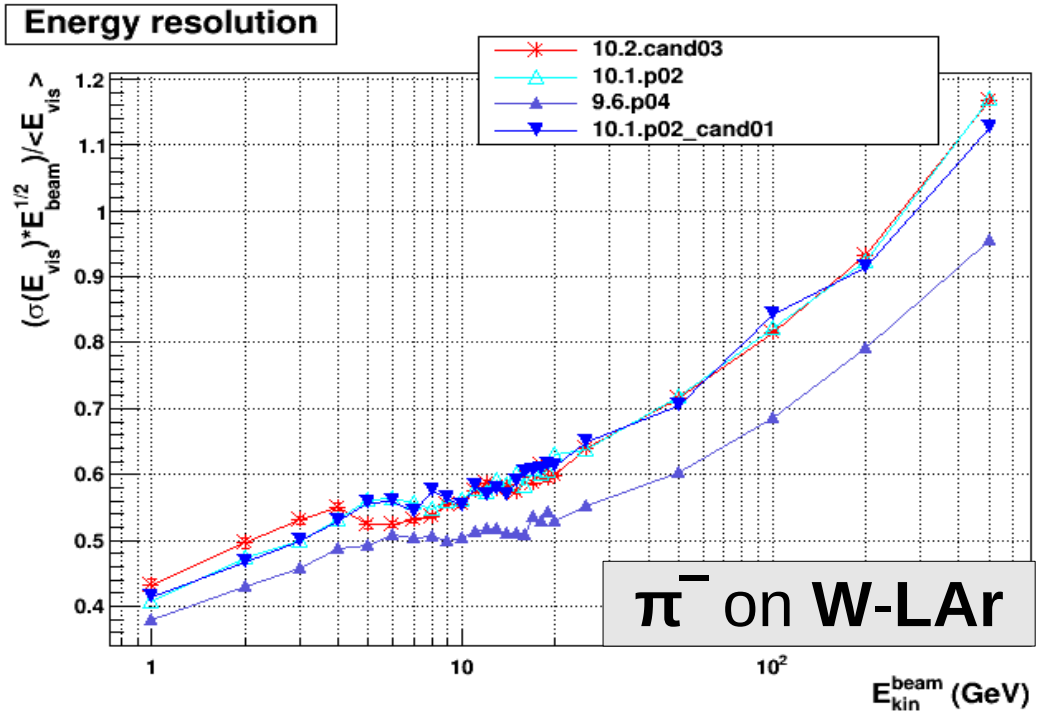


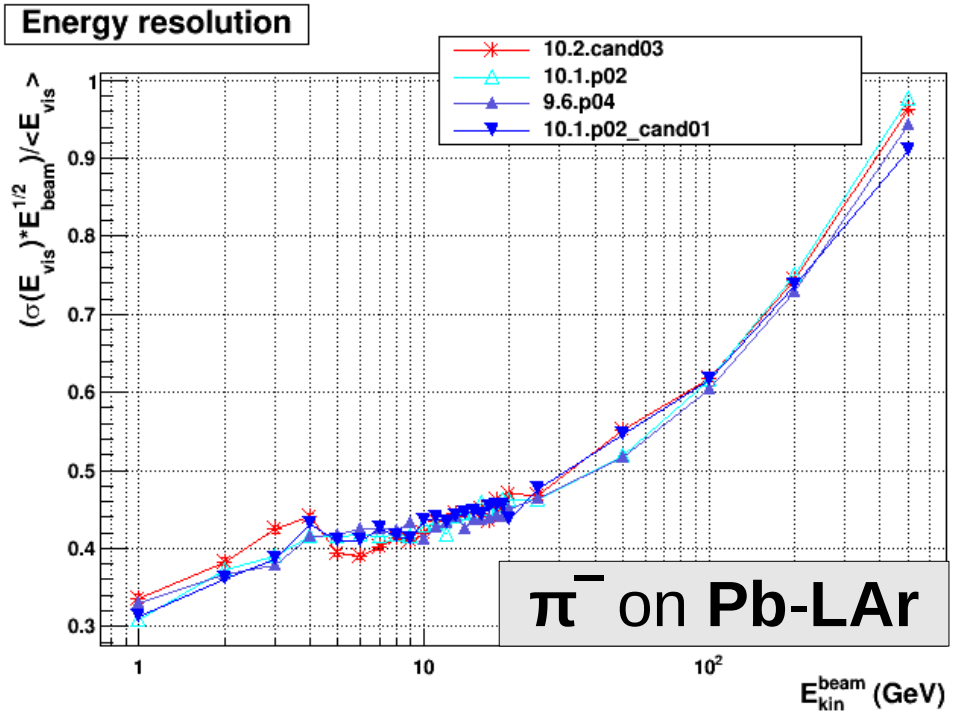


FTFP_BERT : Energy Resolution





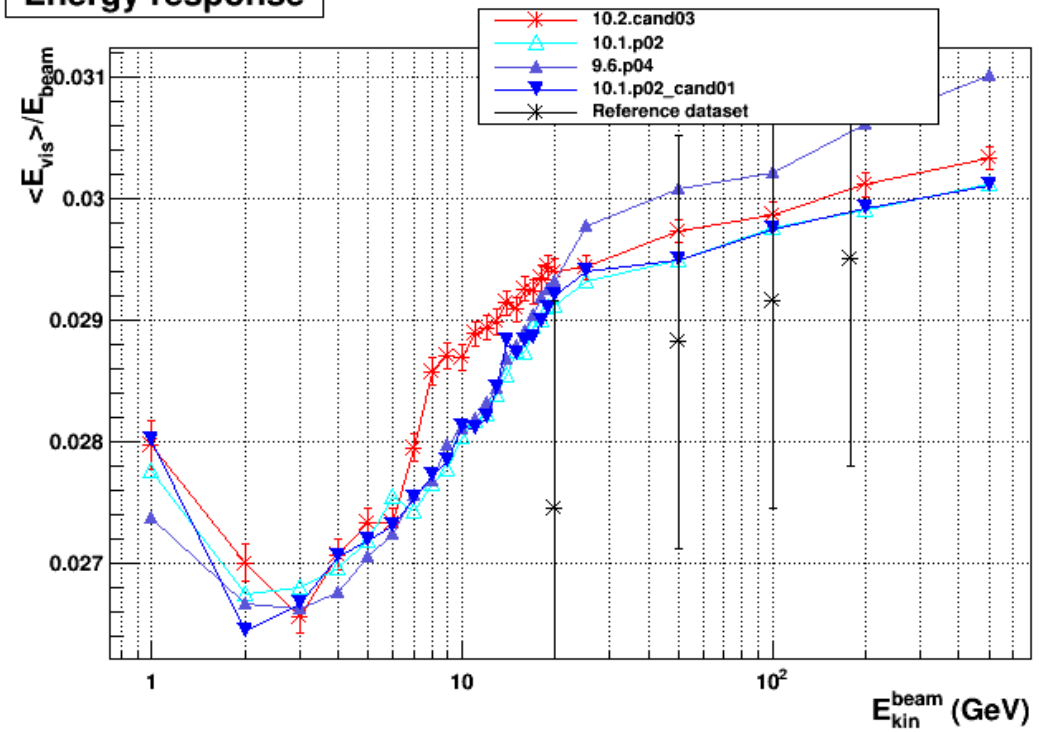




QGSP_FTFP_BERT

π^- on Fe-Sci

Energy response



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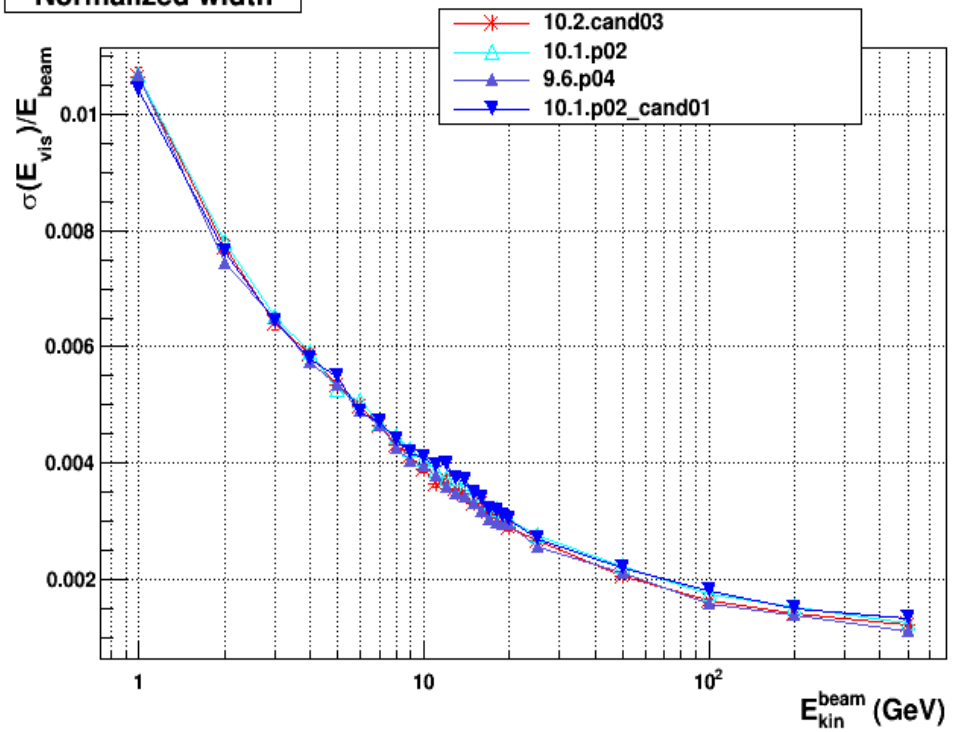
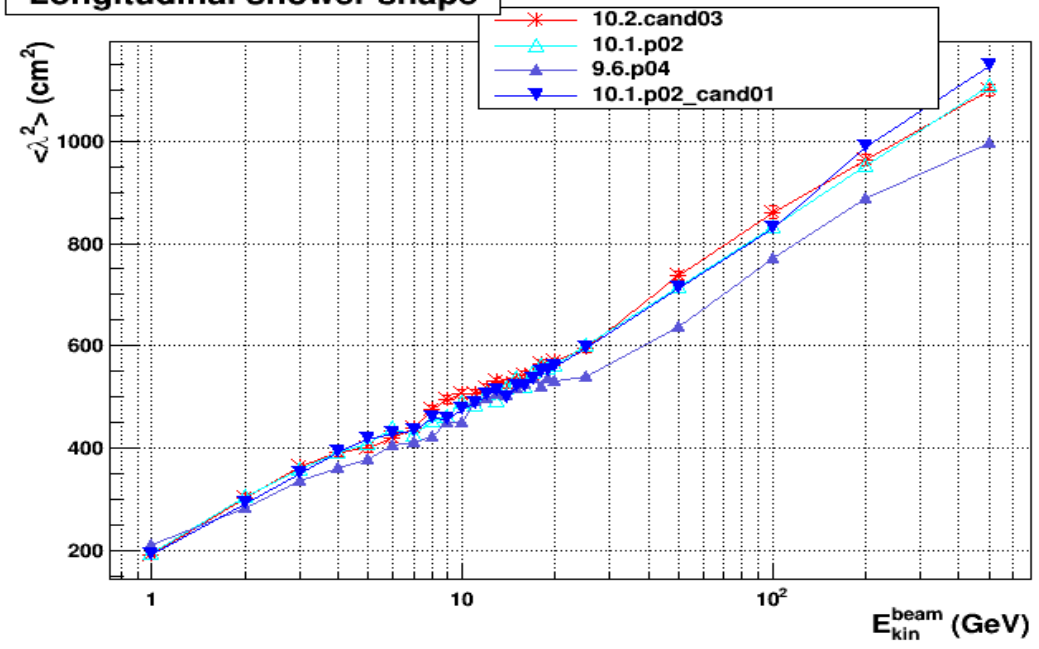
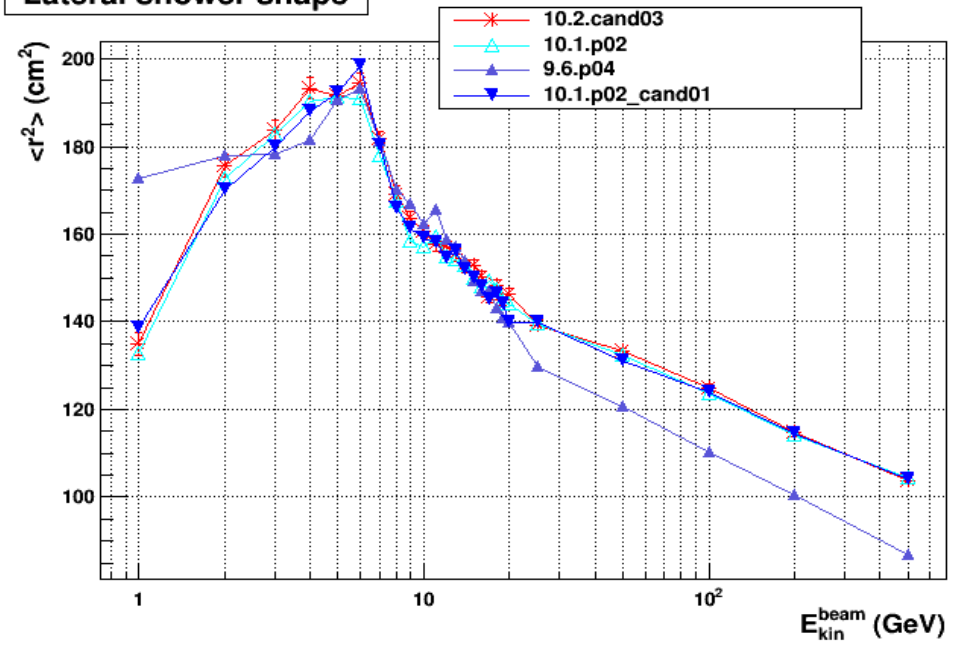


Longitudinal shower shape



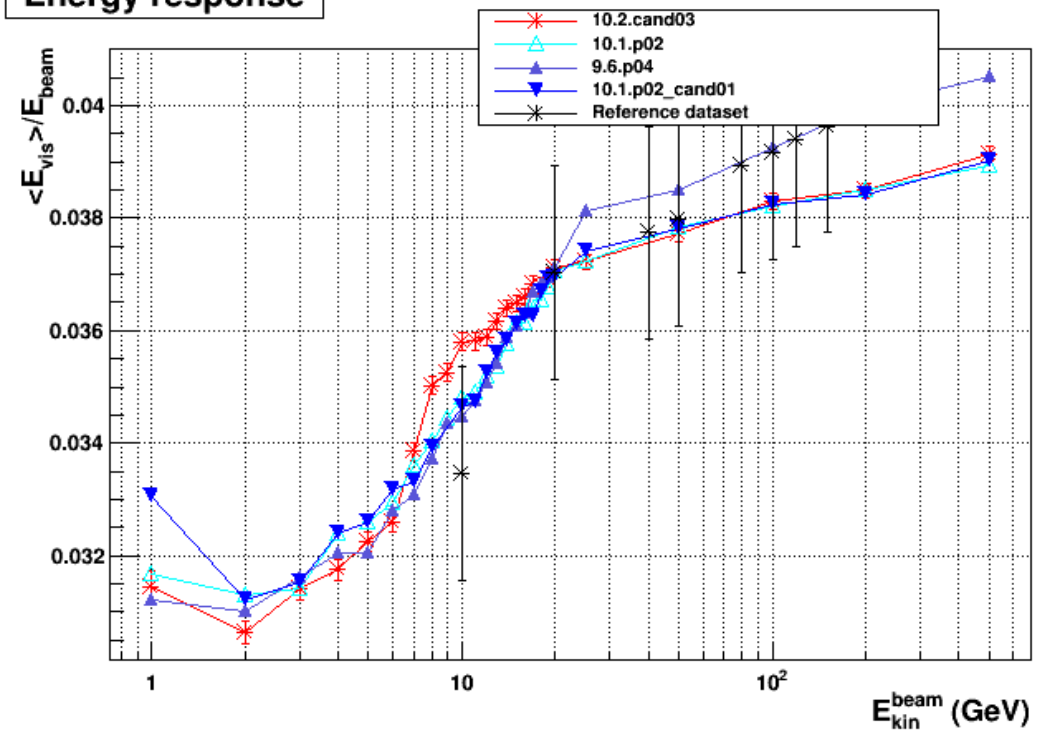
Lateral shower shape



QGSP_FTFP_BERT

π^- on Cu-LAr

Energy response



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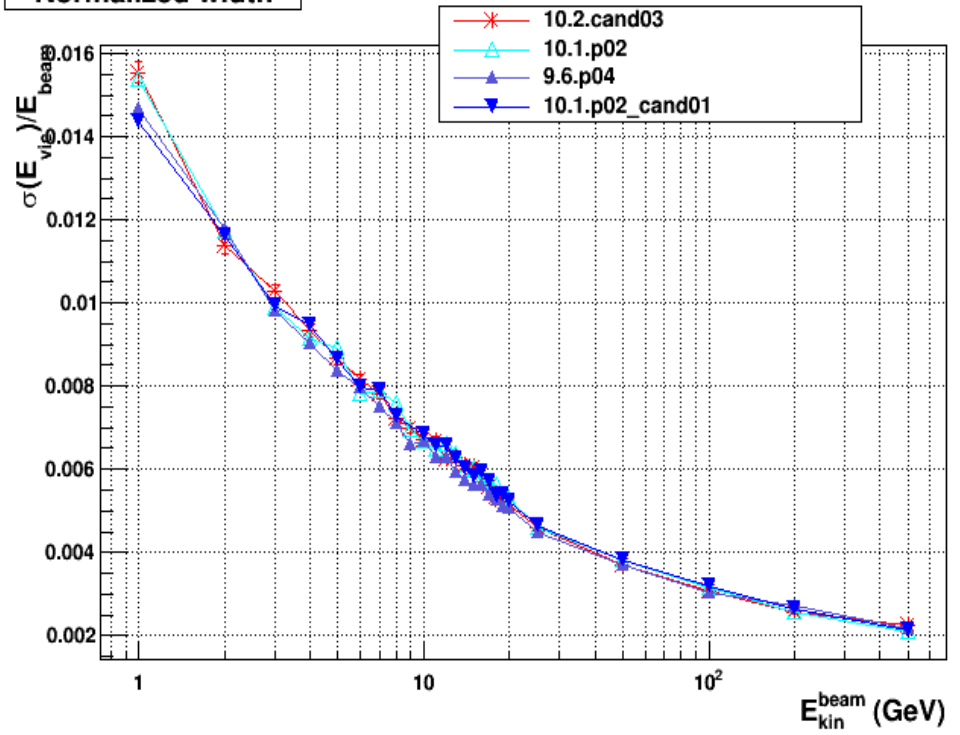
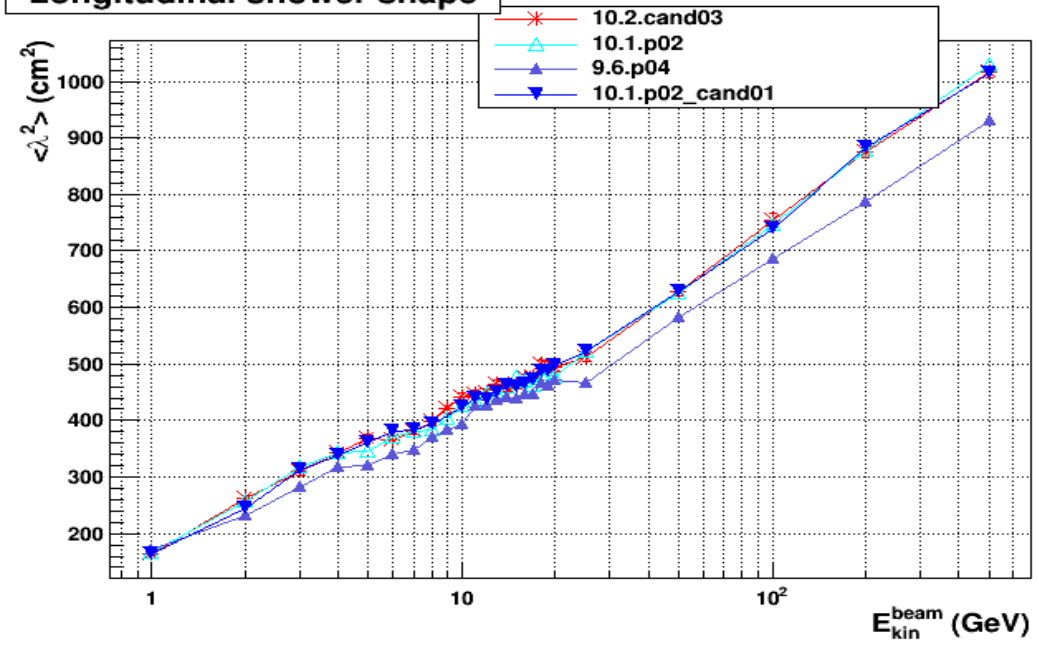
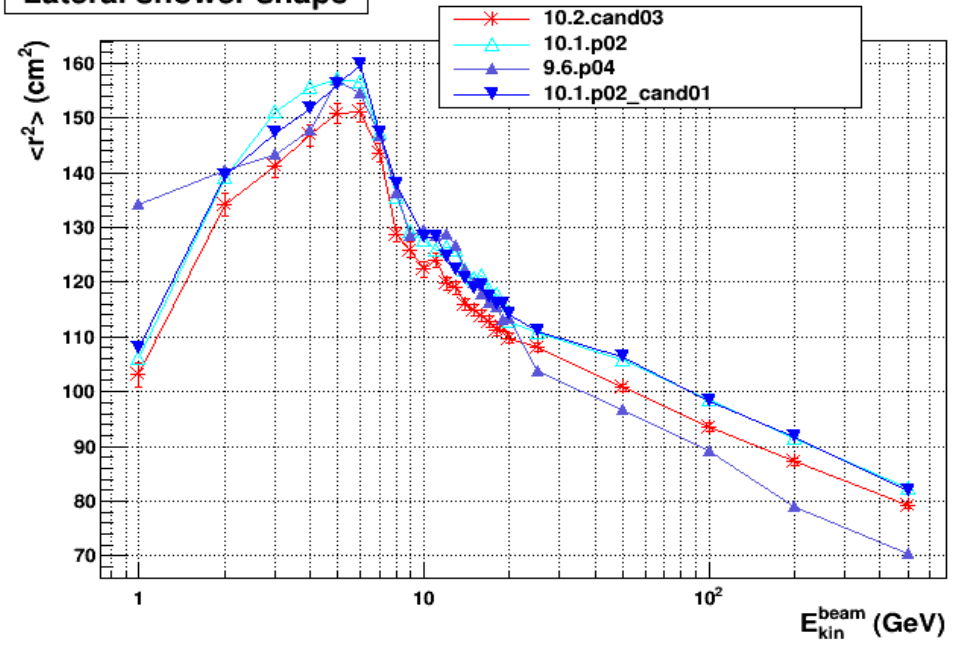


Longitudinal shower shape



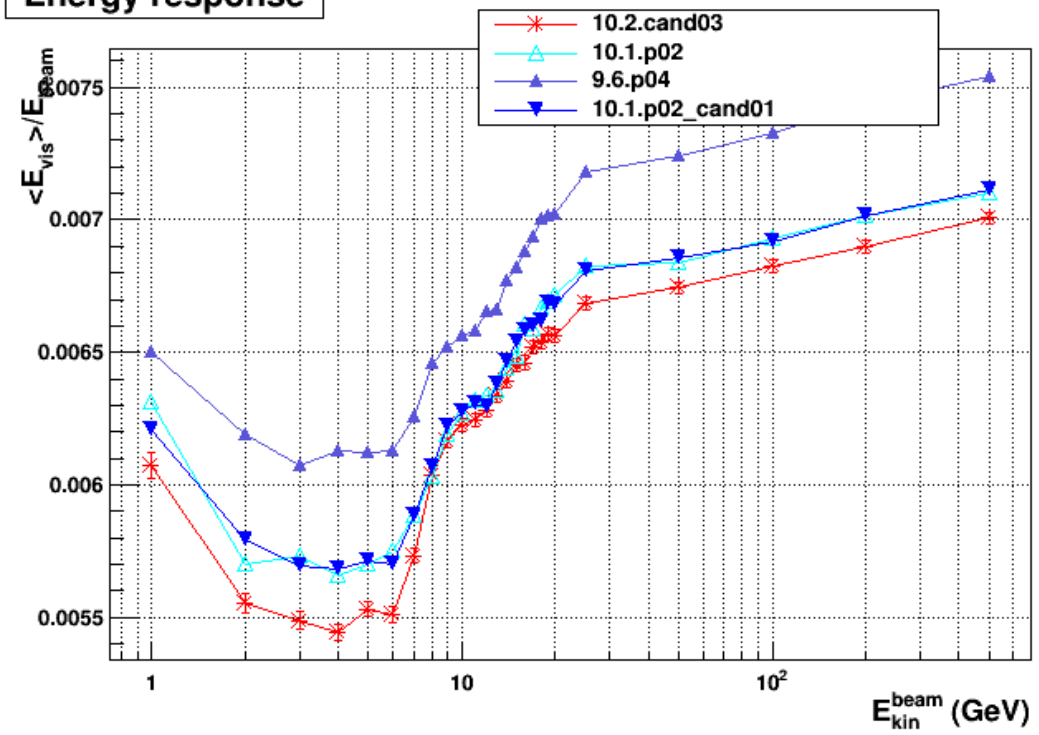
Lateral shower shape



QGSP_FTFP_BERT

π^- on W-LAr

Energy response



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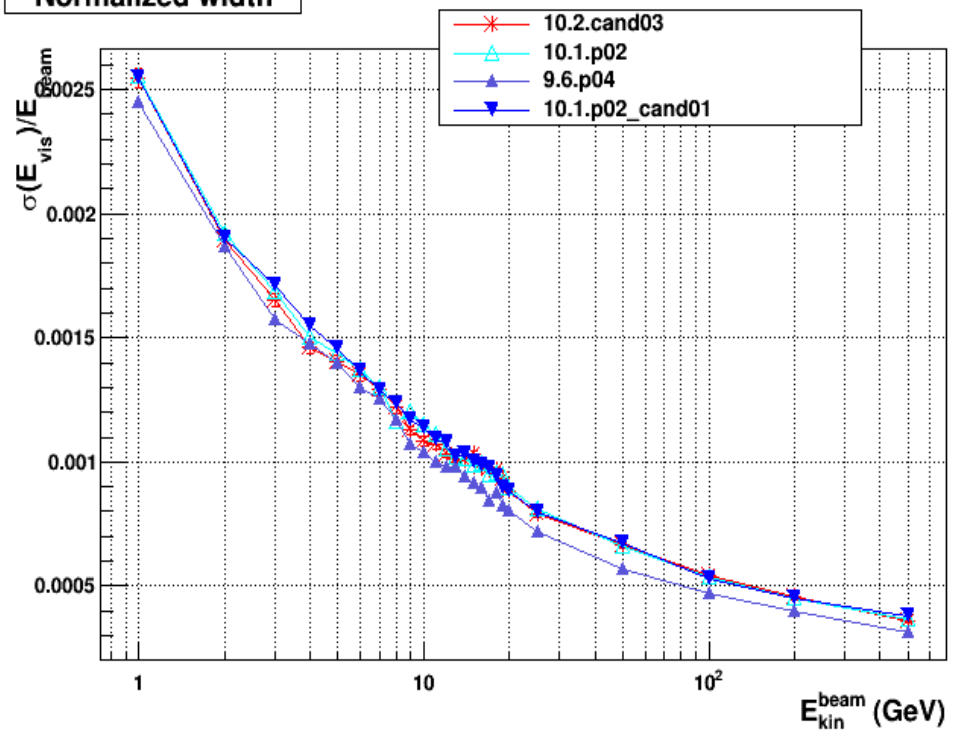
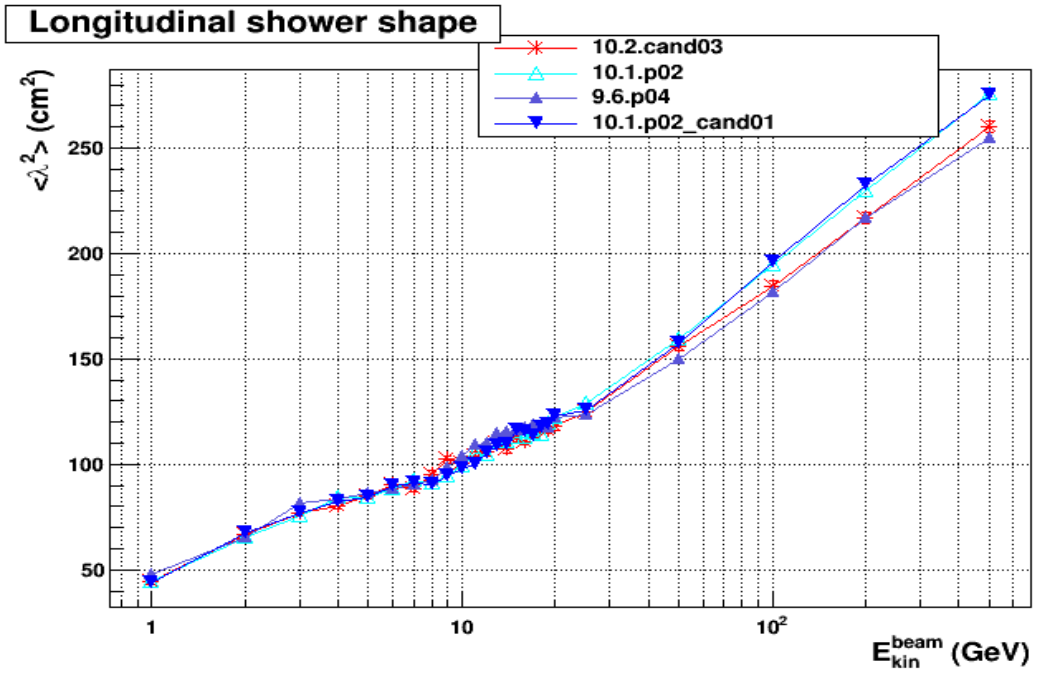
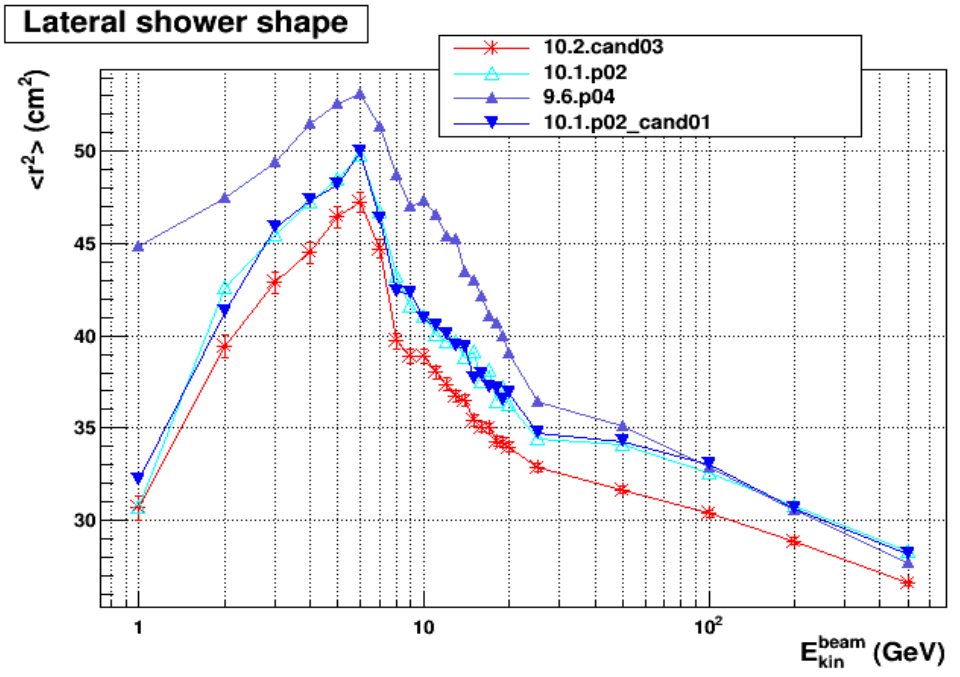


Longitudinal shower shape



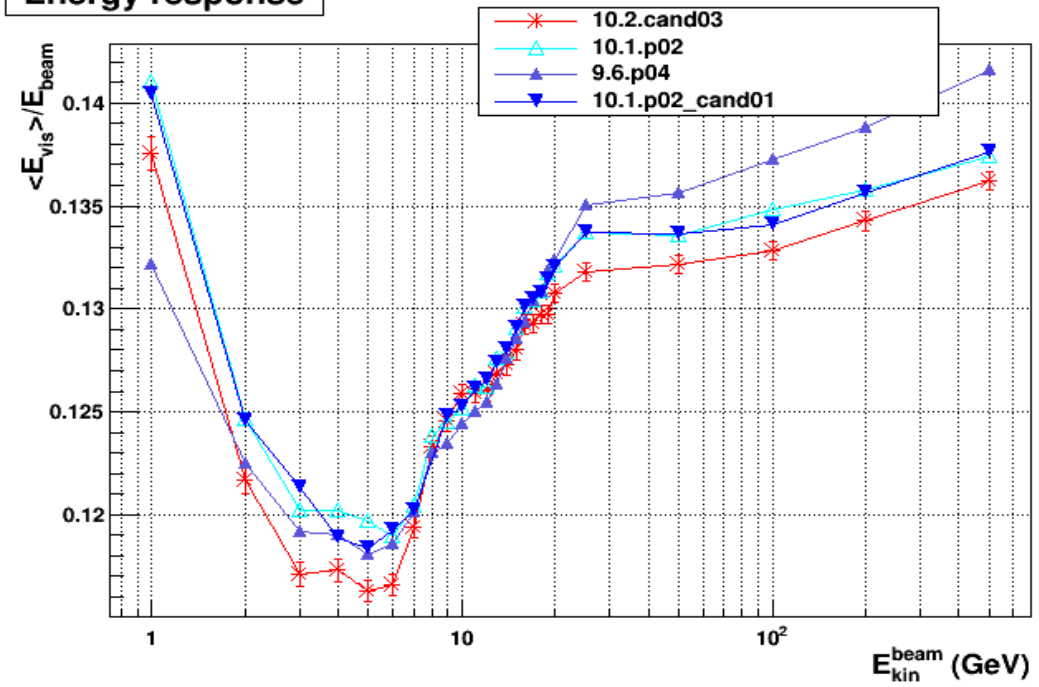
Lateral shower shape



QGSP_FTFP_BERT

π^- on Pb-LAr

Energy response



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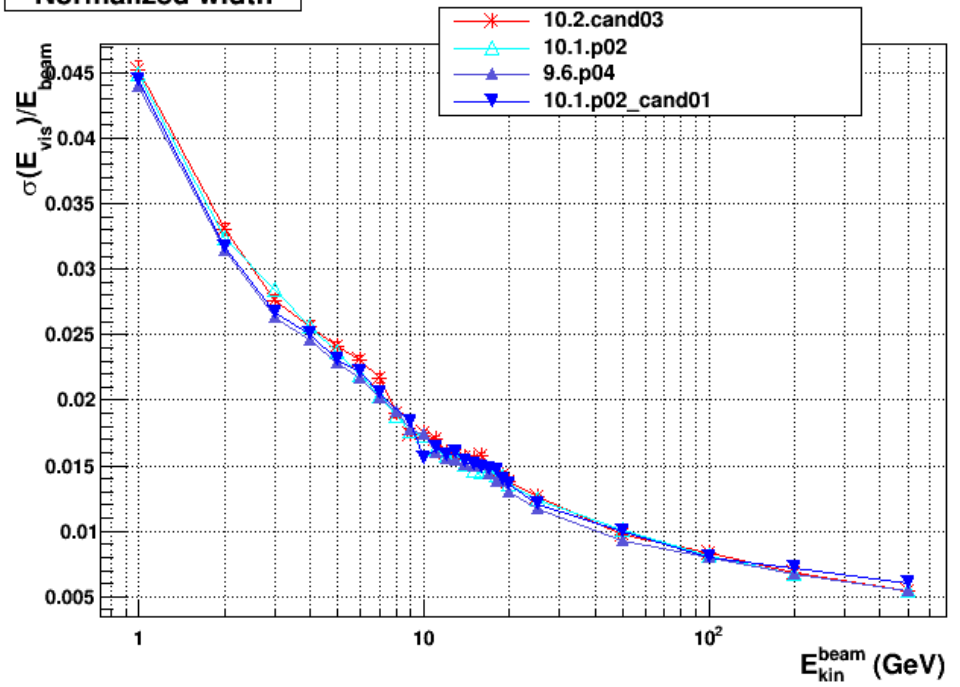
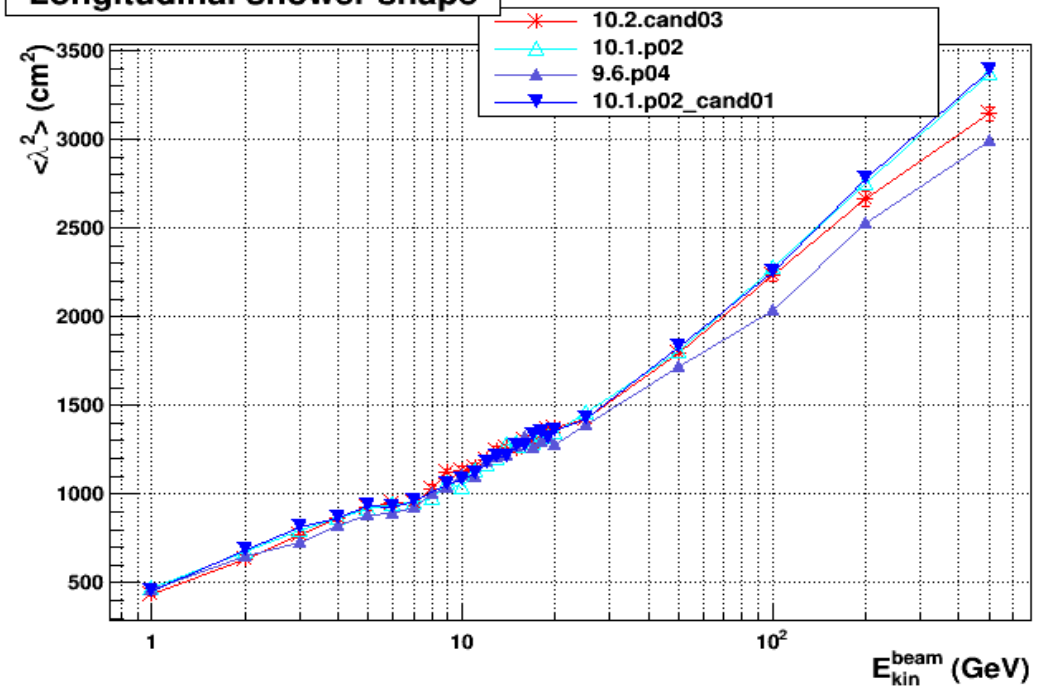
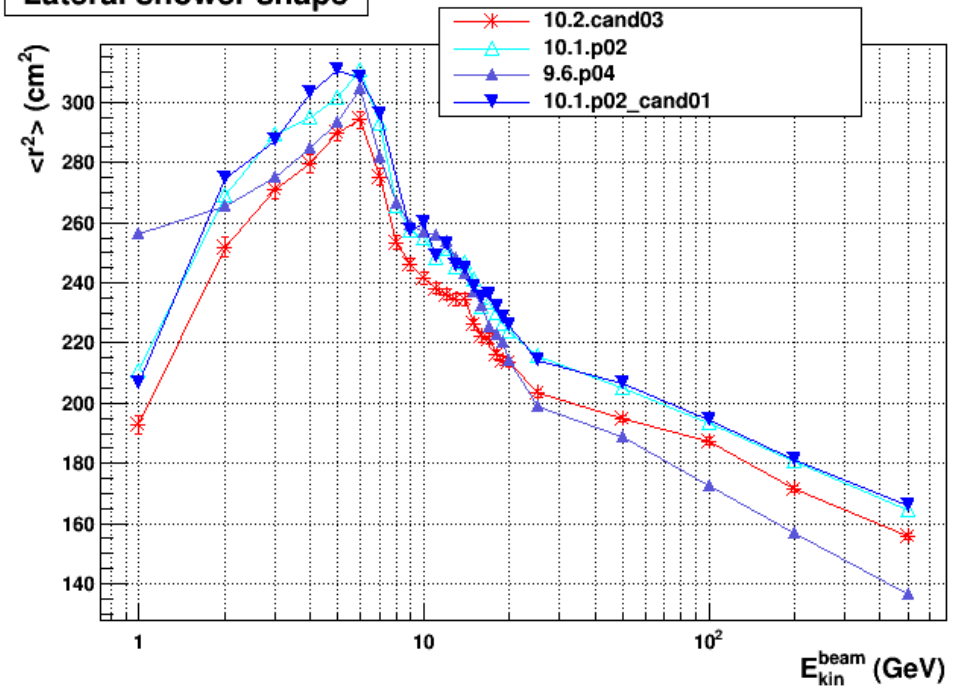


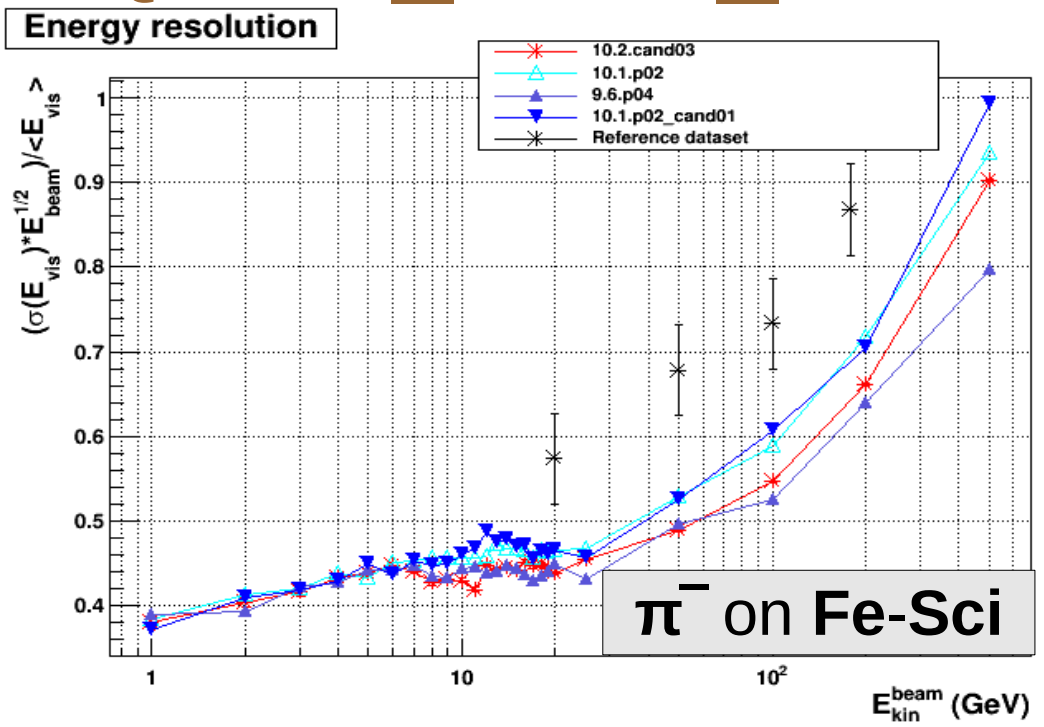
Longitudinal shower shape

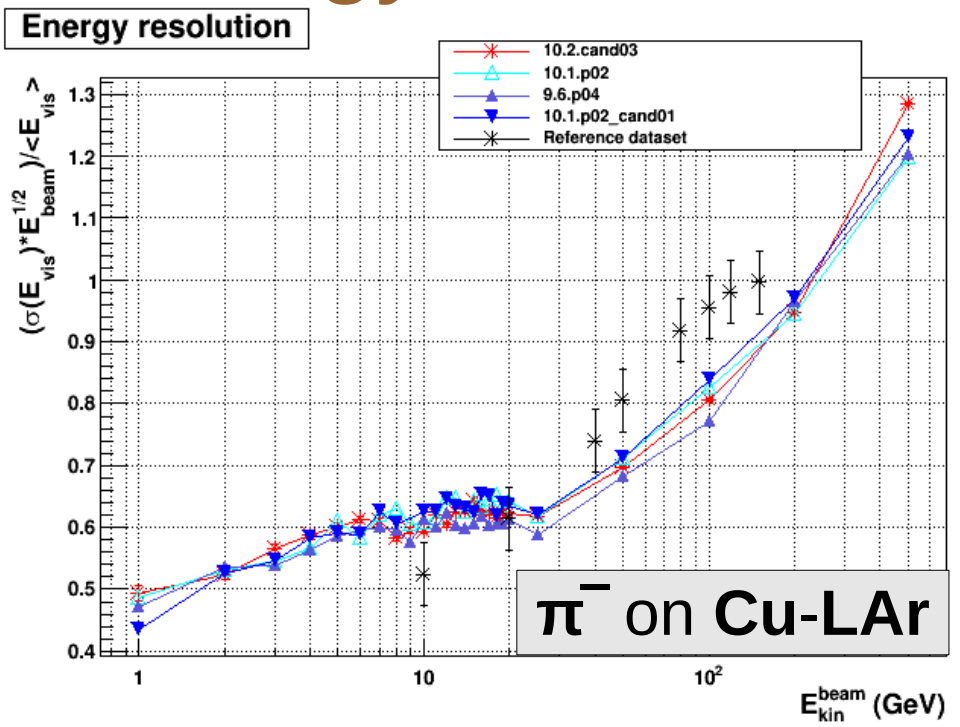


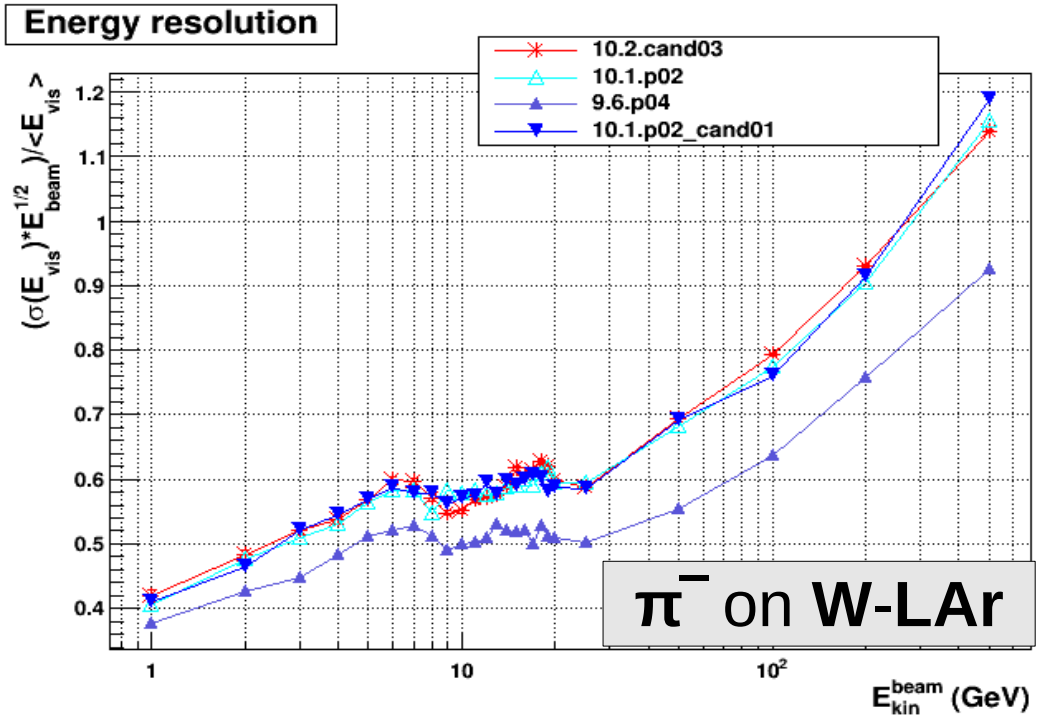
Lateral shower shape

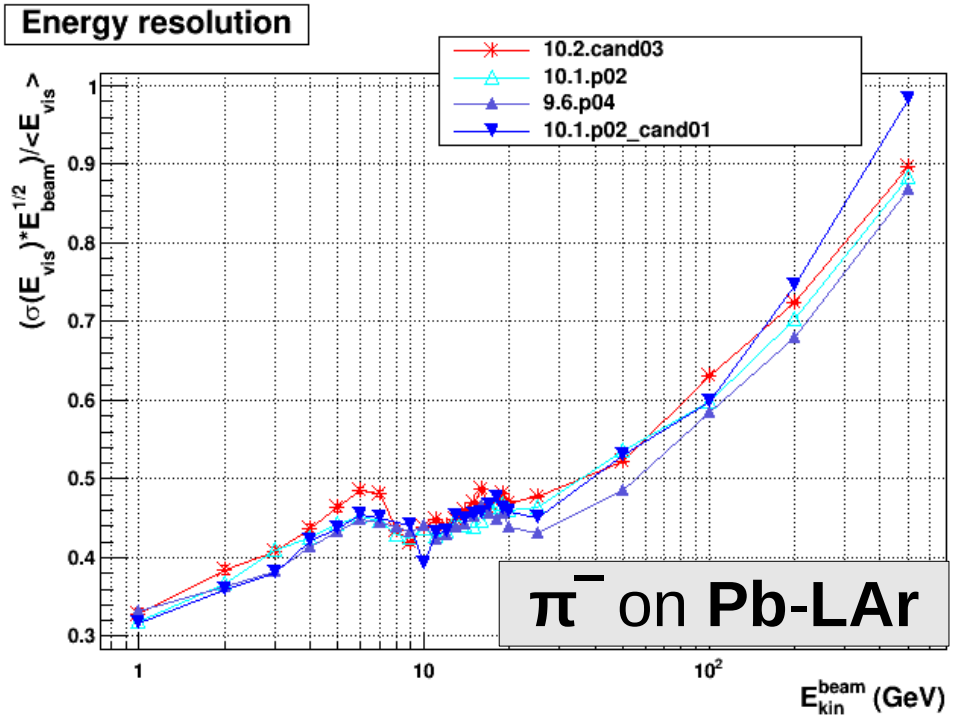


QGSP_FTFP_BERT : Energy Resolution









Pion showers
in Simplified Calorimeters

Comparing Physics Lists in G4 10.2 :

FTFP_BERT

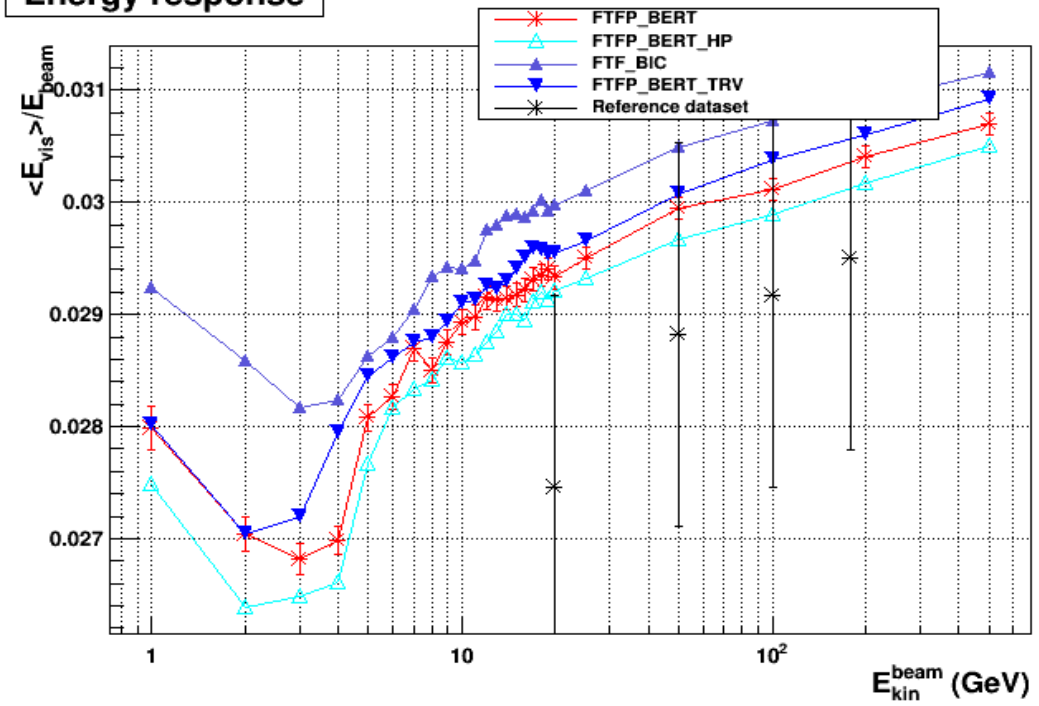
FTFP_BERT_HP

FTFP_BERT_TRV

FTF_BIC

π^- on Fe-Sci

Energy response



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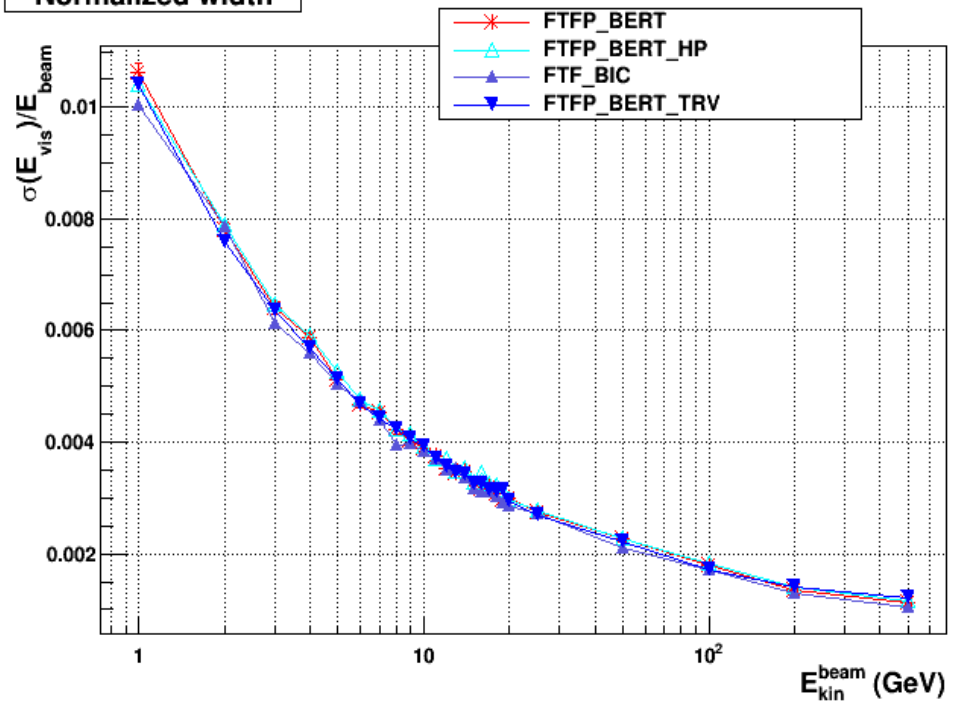
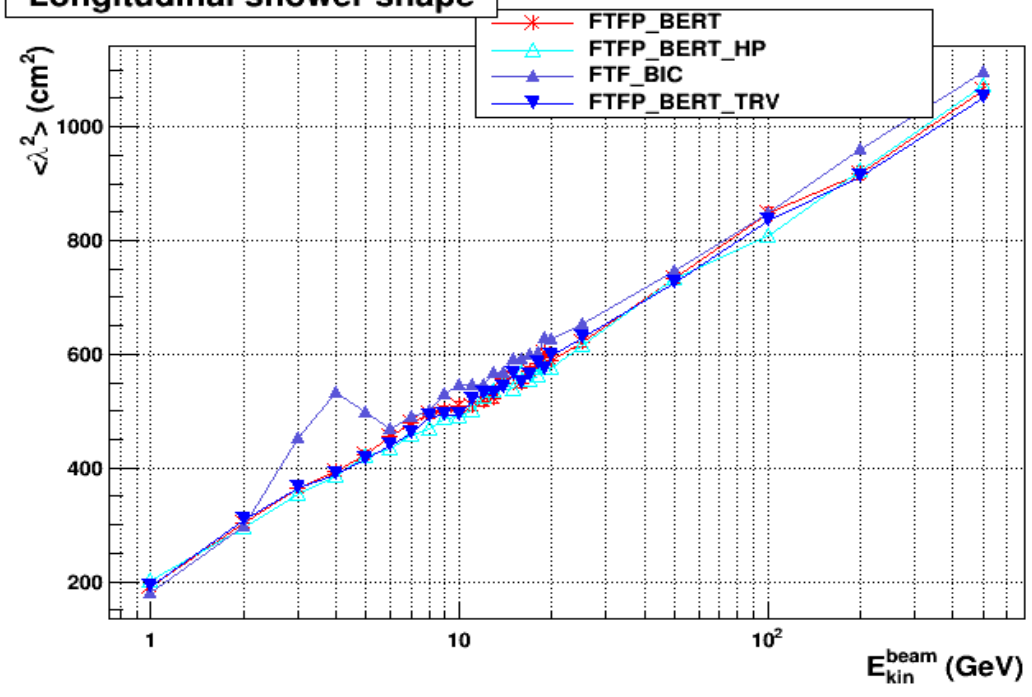
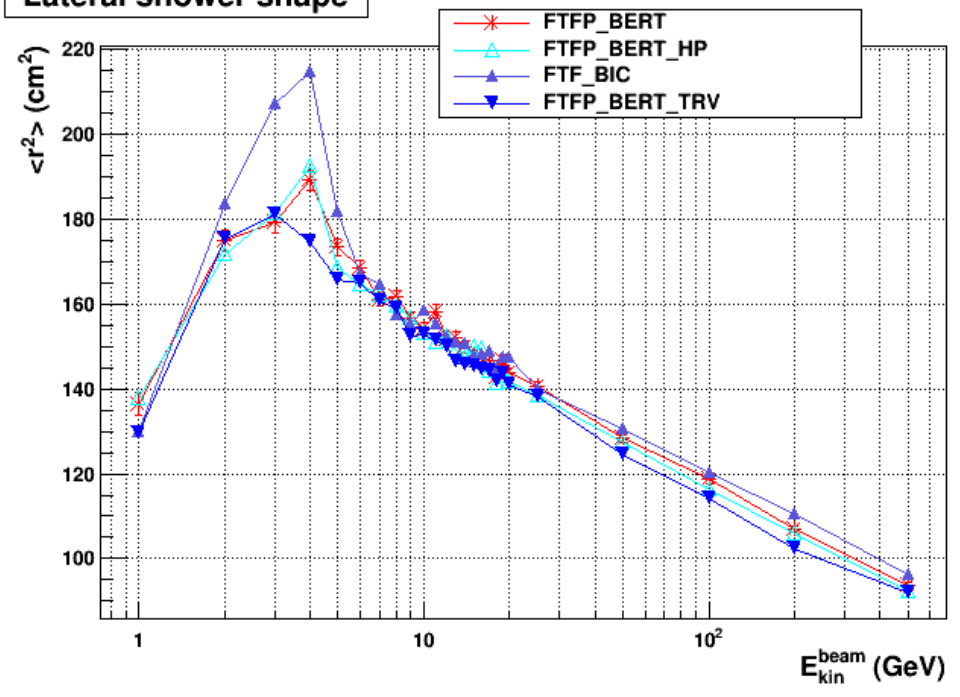


Longitudinal shower shape

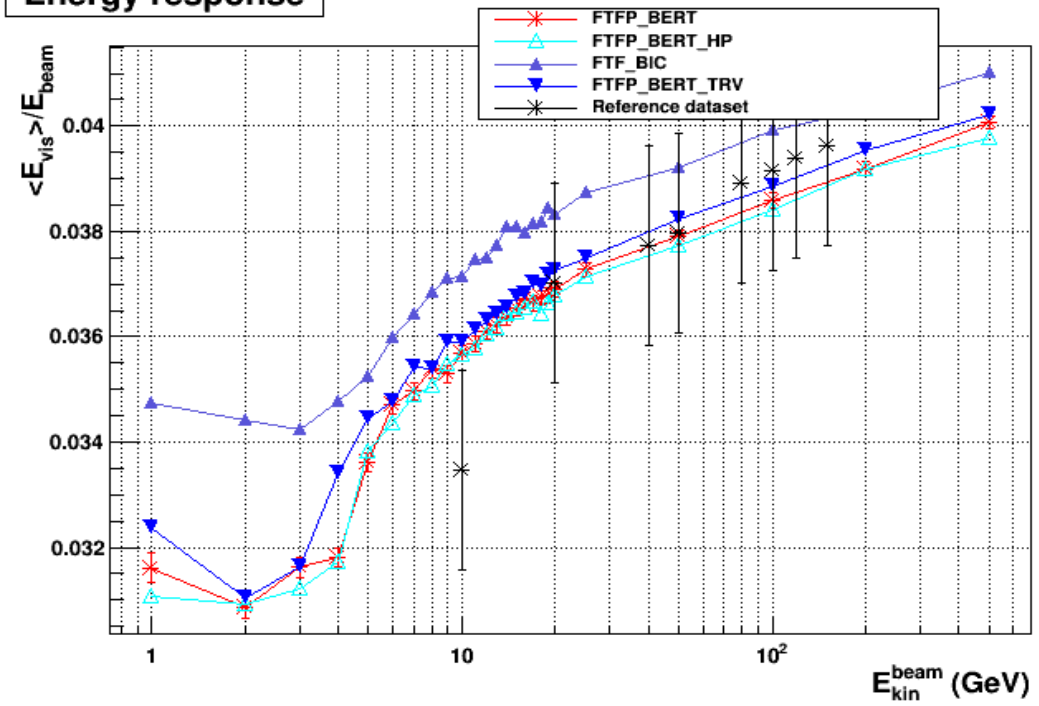


Lateral shower shape

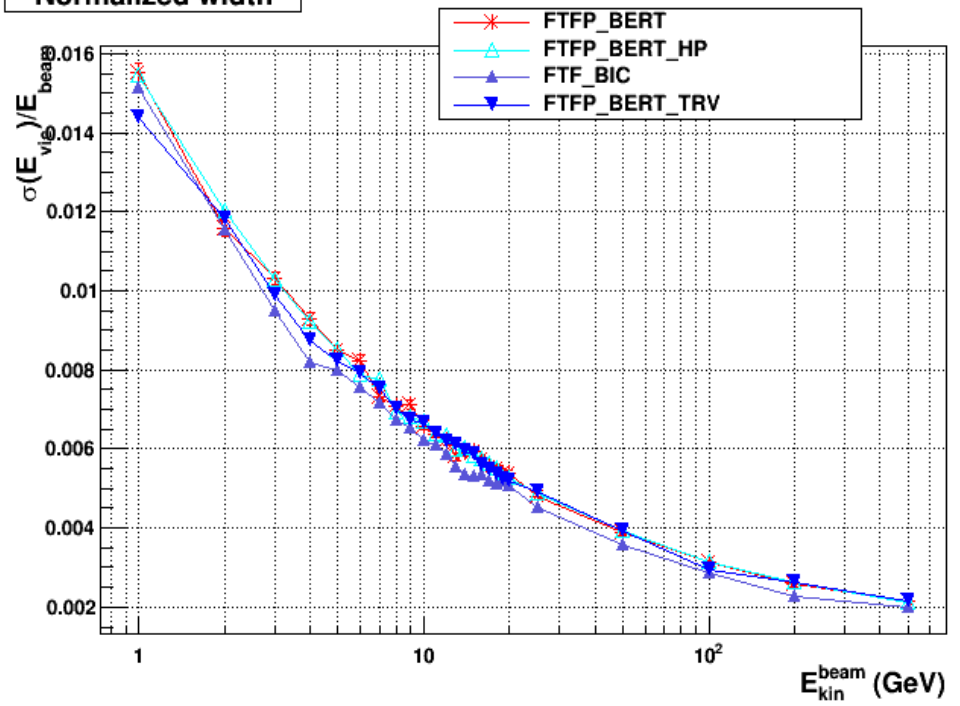


π^- on Cu-LAr

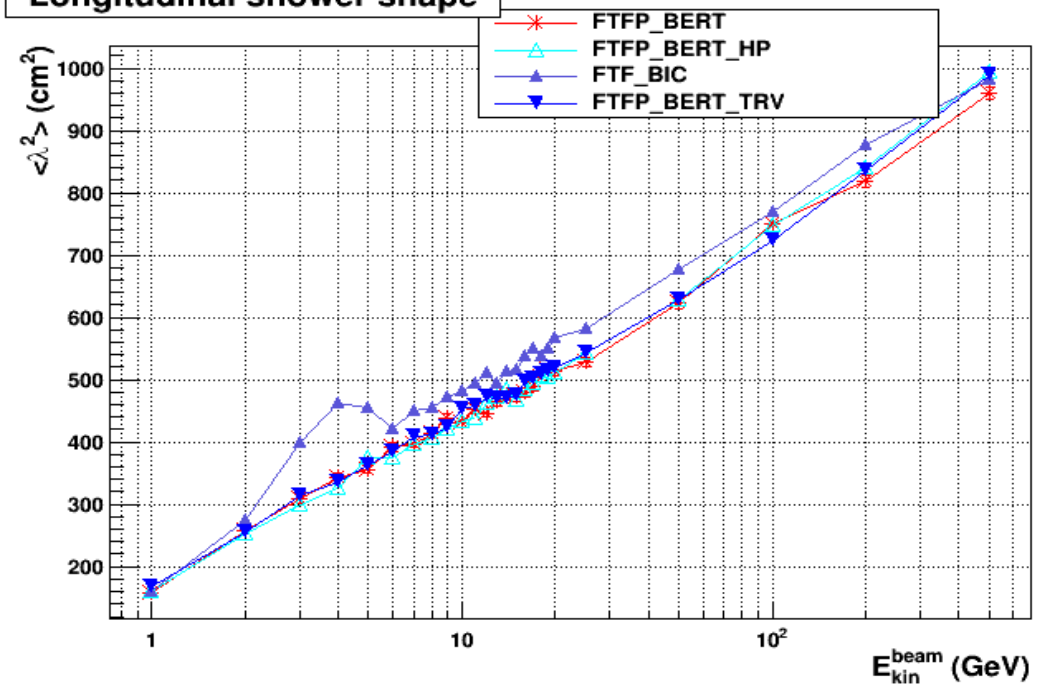
Energy response



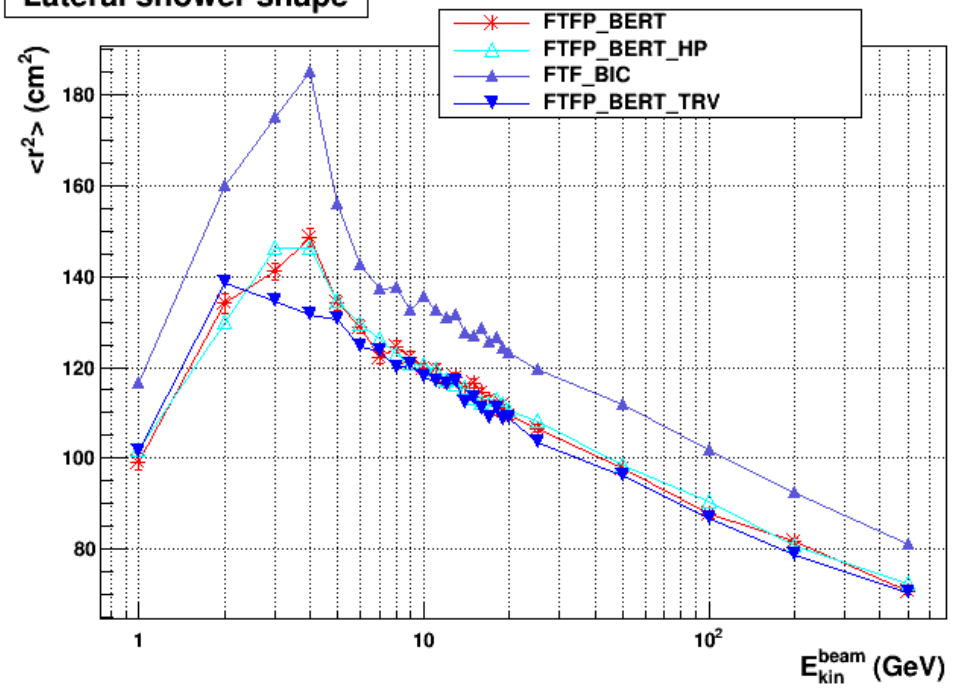
Normalized width



Longitudinal shower shape

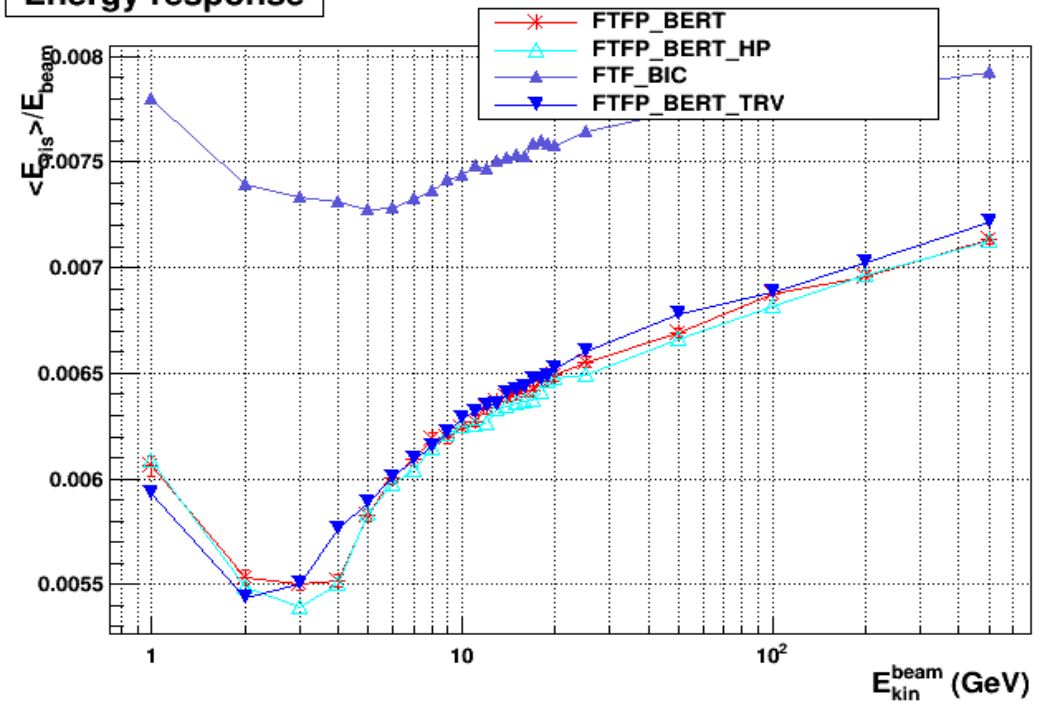


Lateral shower shape

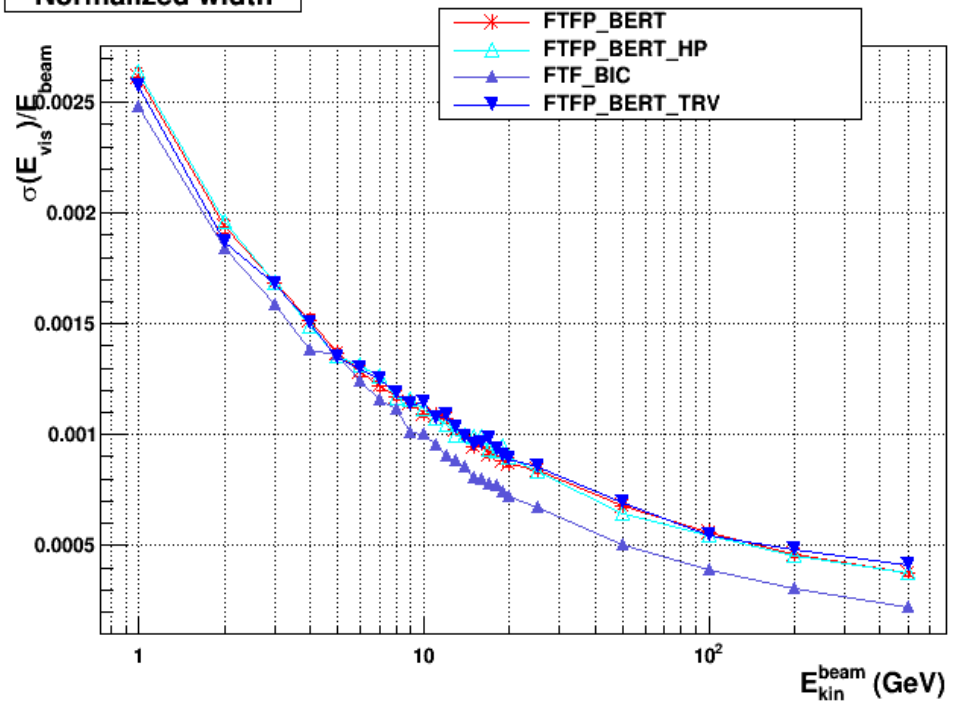


π^- on W-LAr

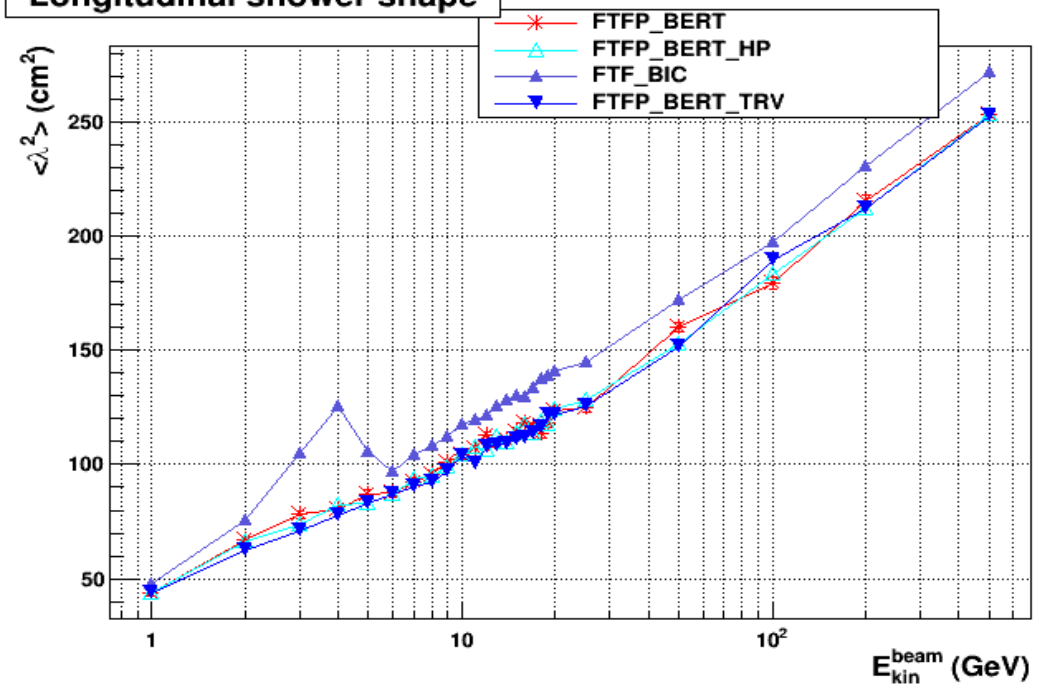
Energy response



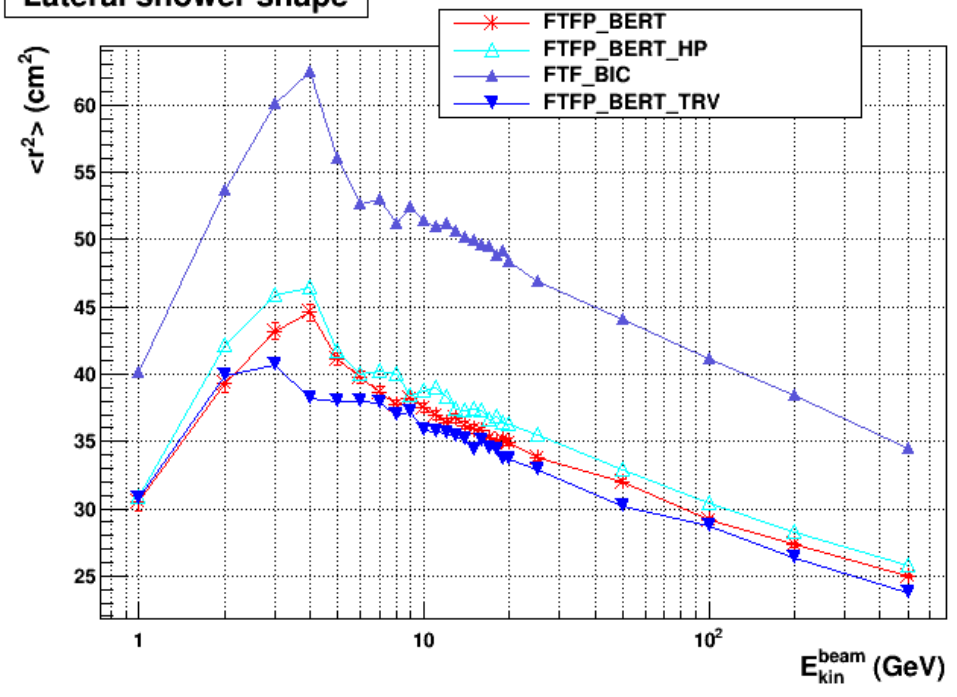
Normalized width



Longitudinal shower shape

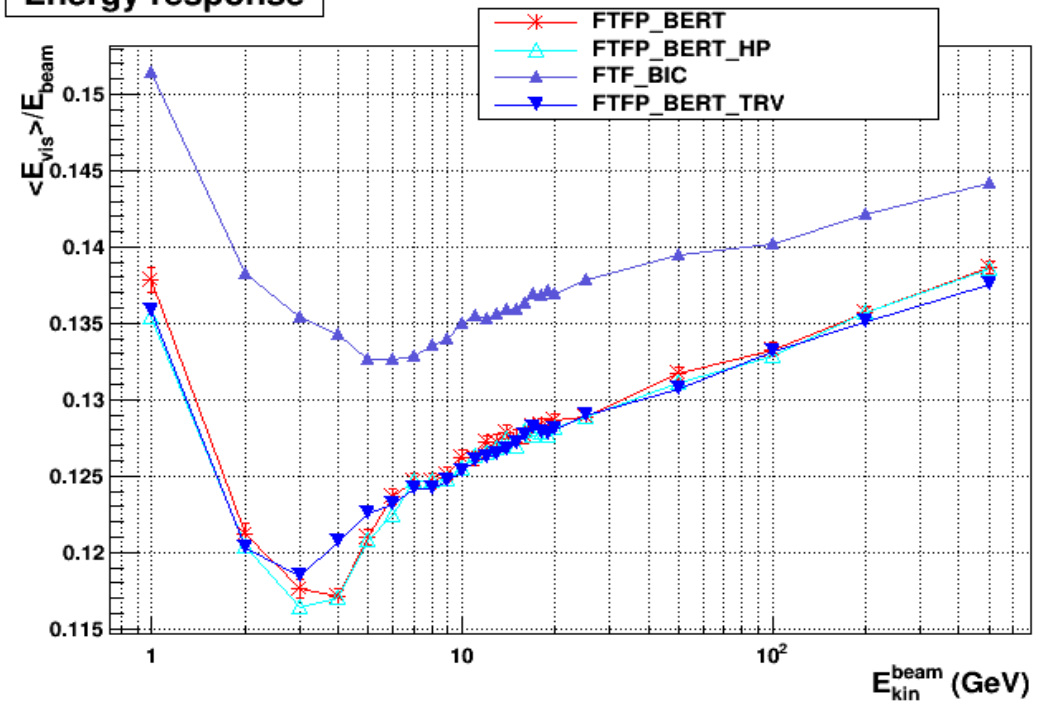


Lateral shower shape



π^- on Pb-LAr

Energy response



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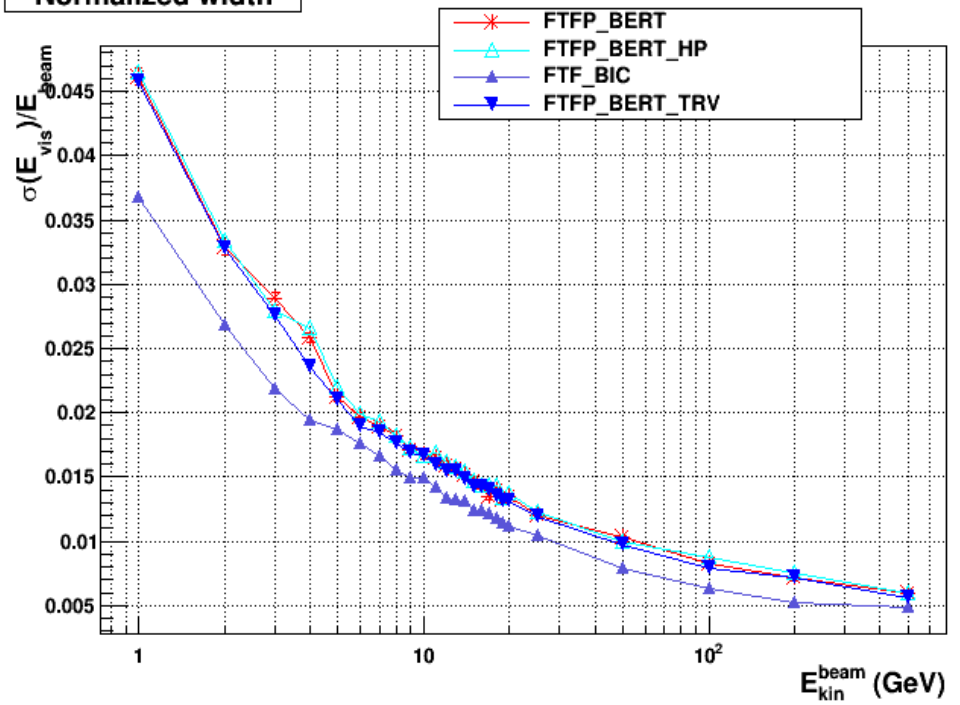
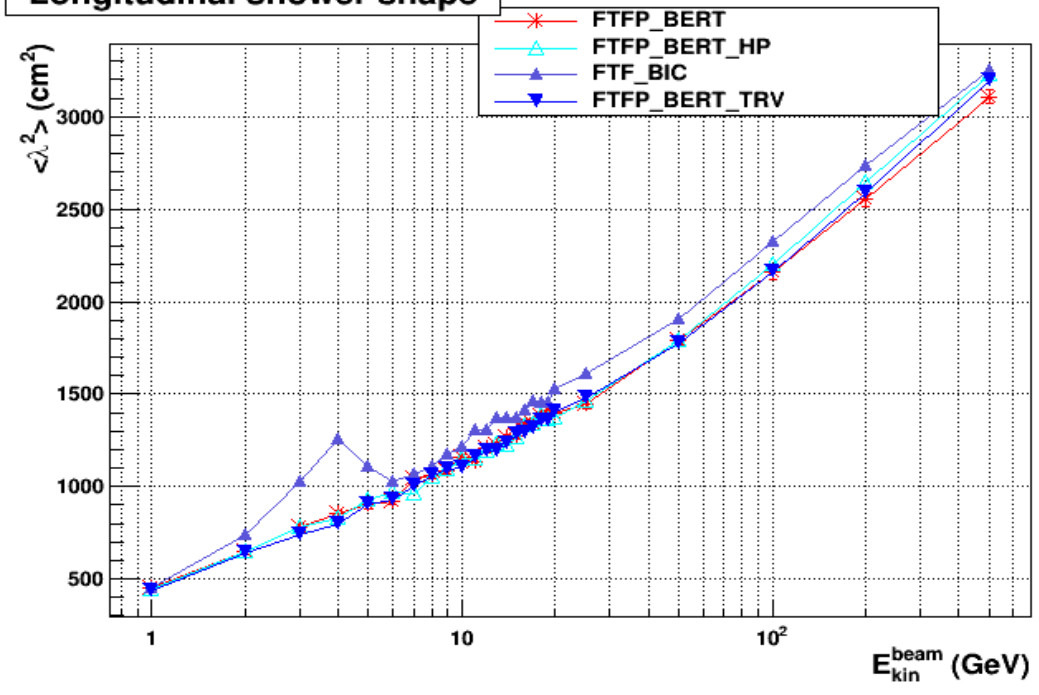
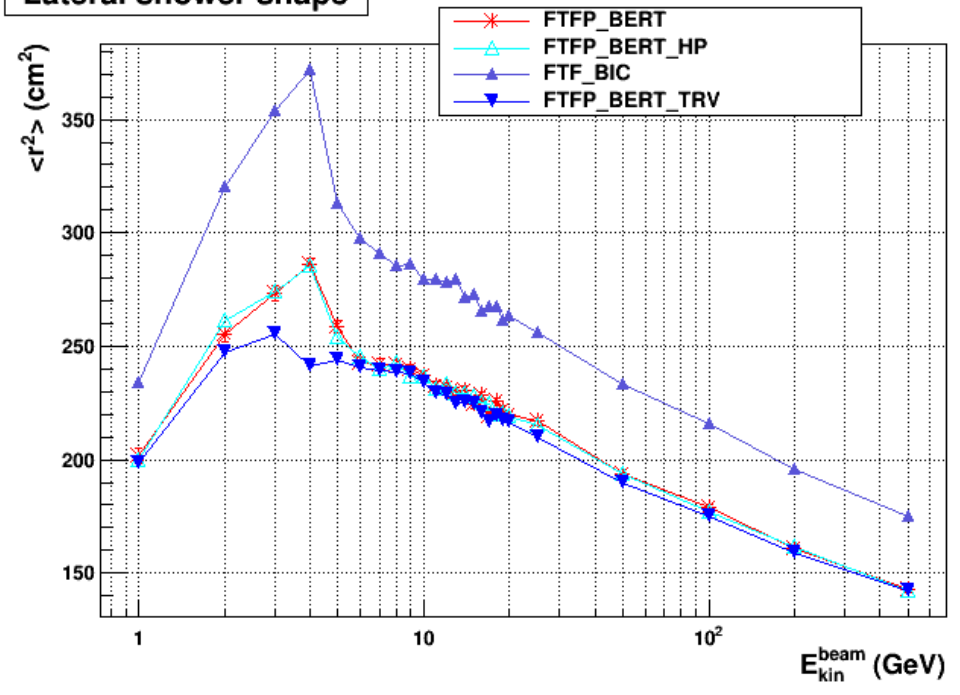


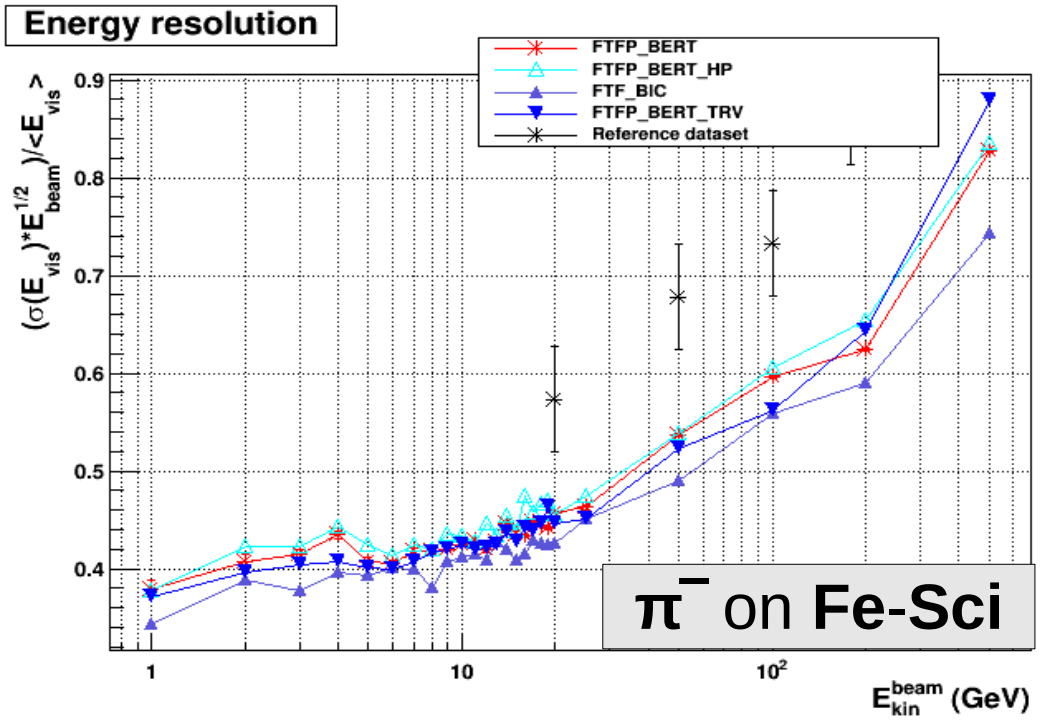
Longitudinal shower shape

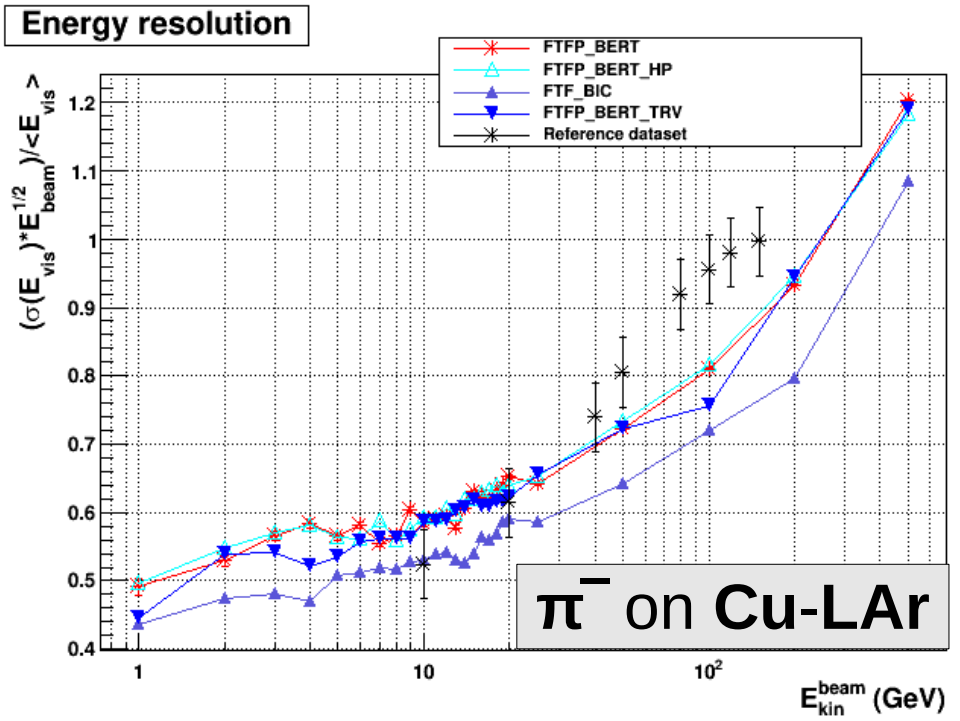


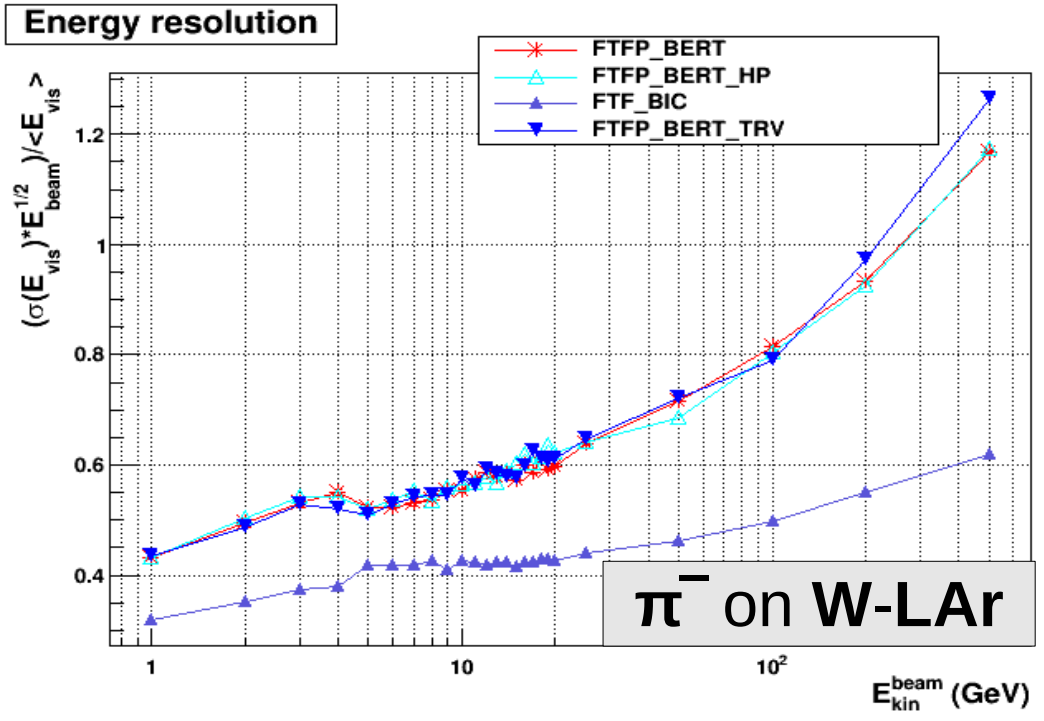
Lateral shower shape

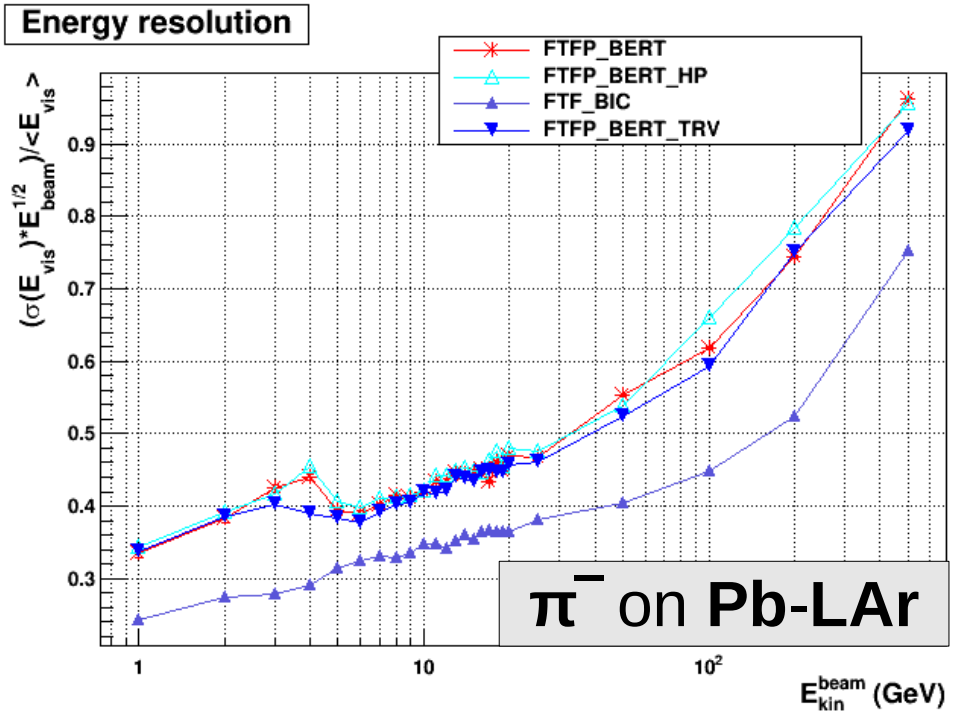


Energy Resolution









Pion showers
in Simplified Calorimeters

Comparing Physics Lists in G4 10.2 :

FTFP_BERT

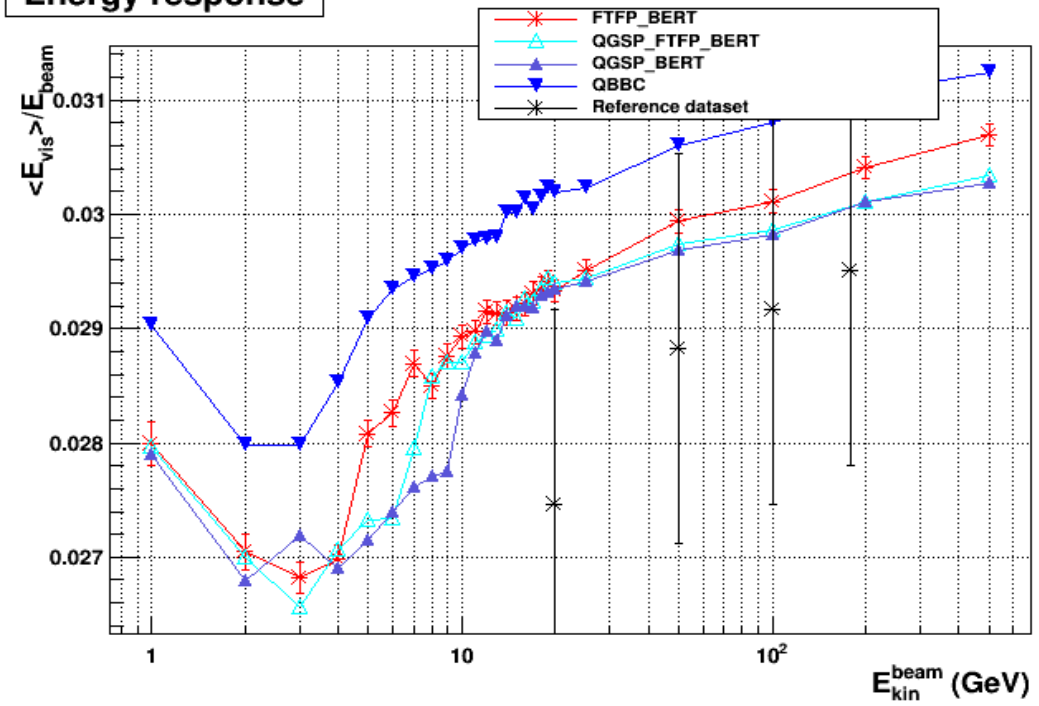
QGSP_FTFP_BERT

QBBC

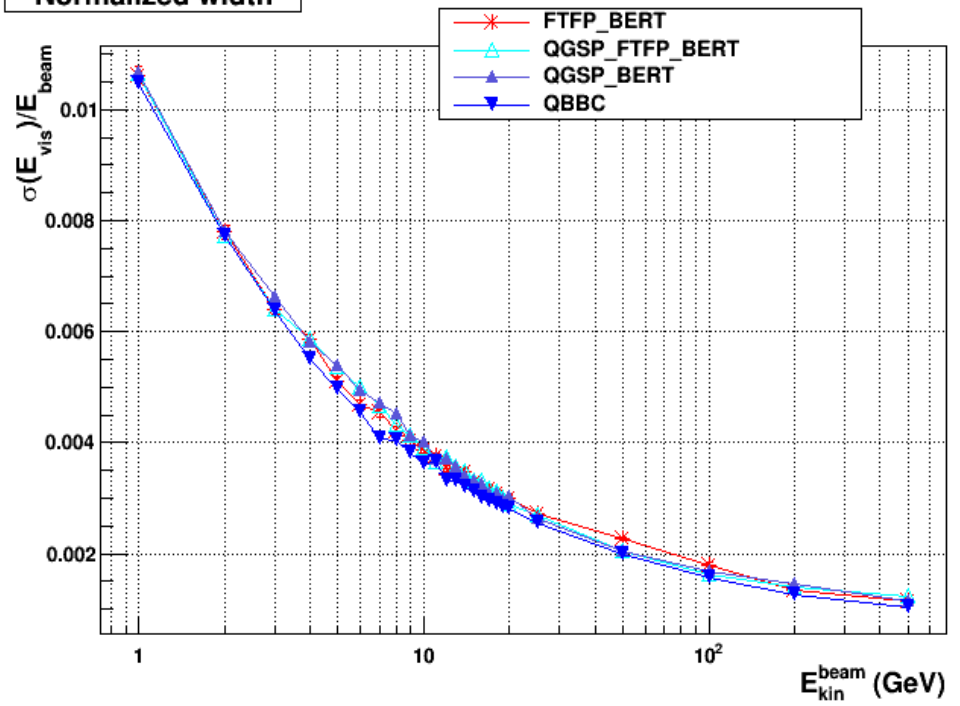
QGSP_BERT

π^- on Fe-Sci

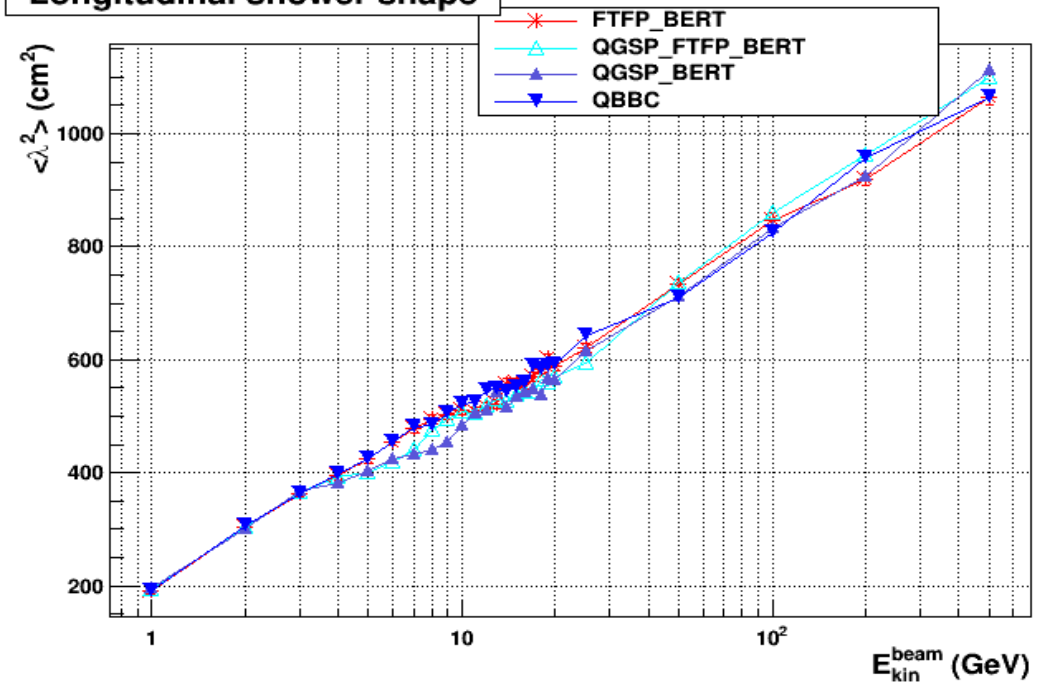
Energy response



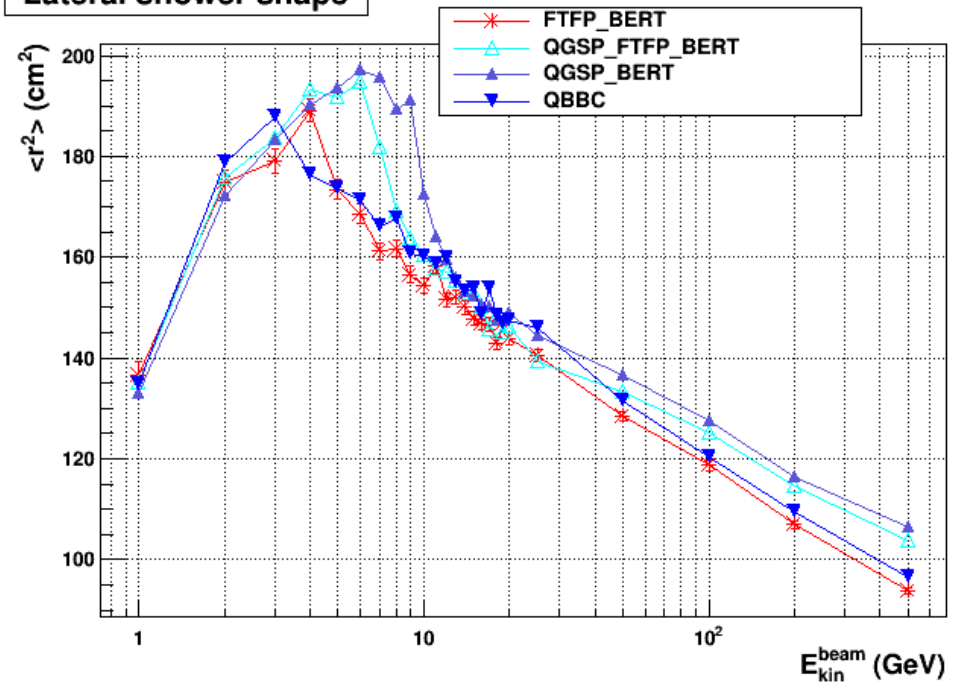
Normalized width



Longitudinal shower shape

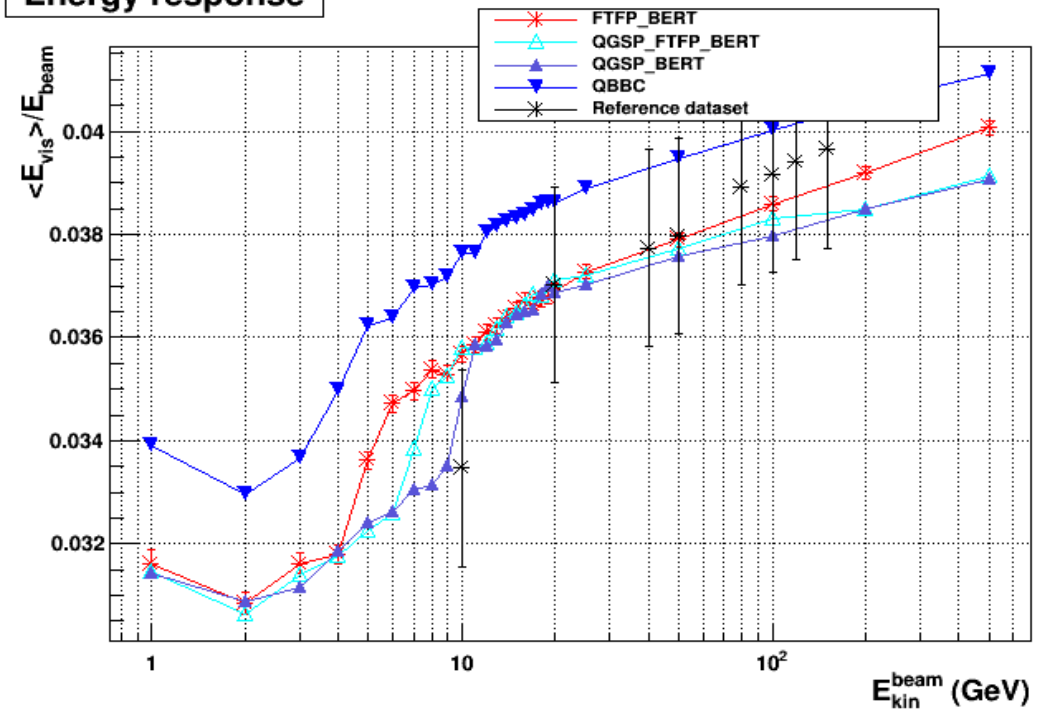


Lateral shower shape



π^- on Cu-LAr

Energy response



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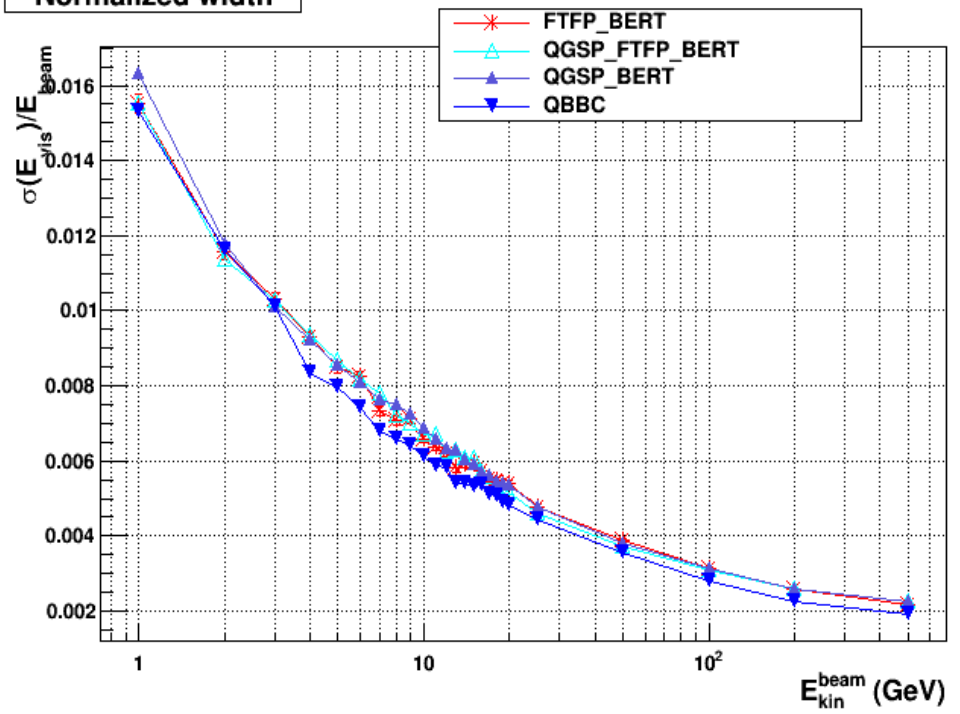
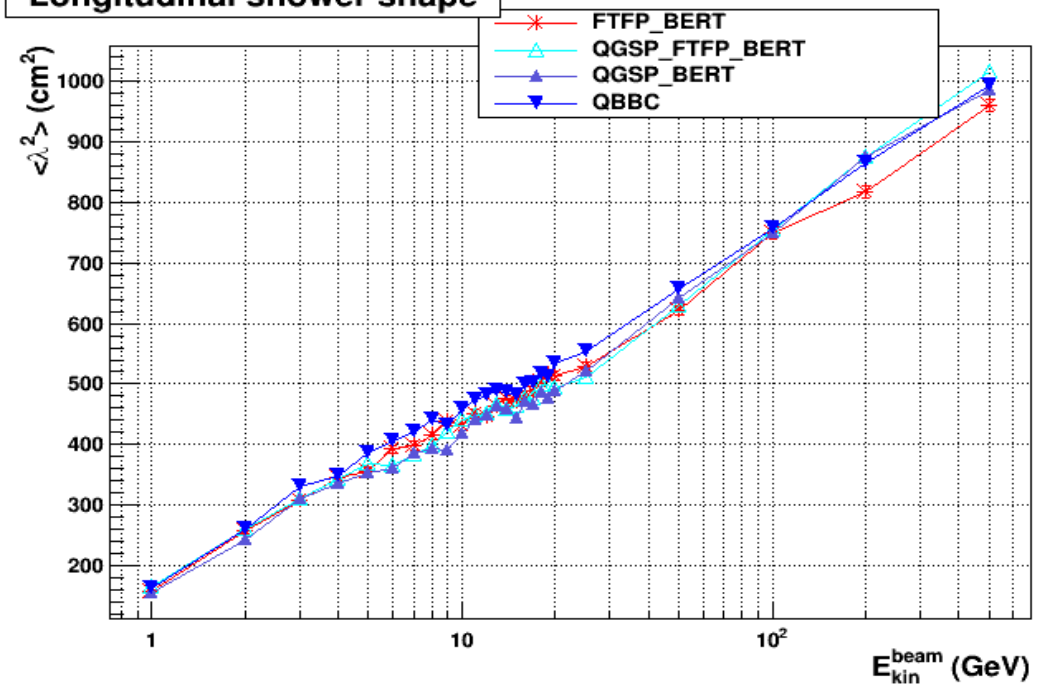
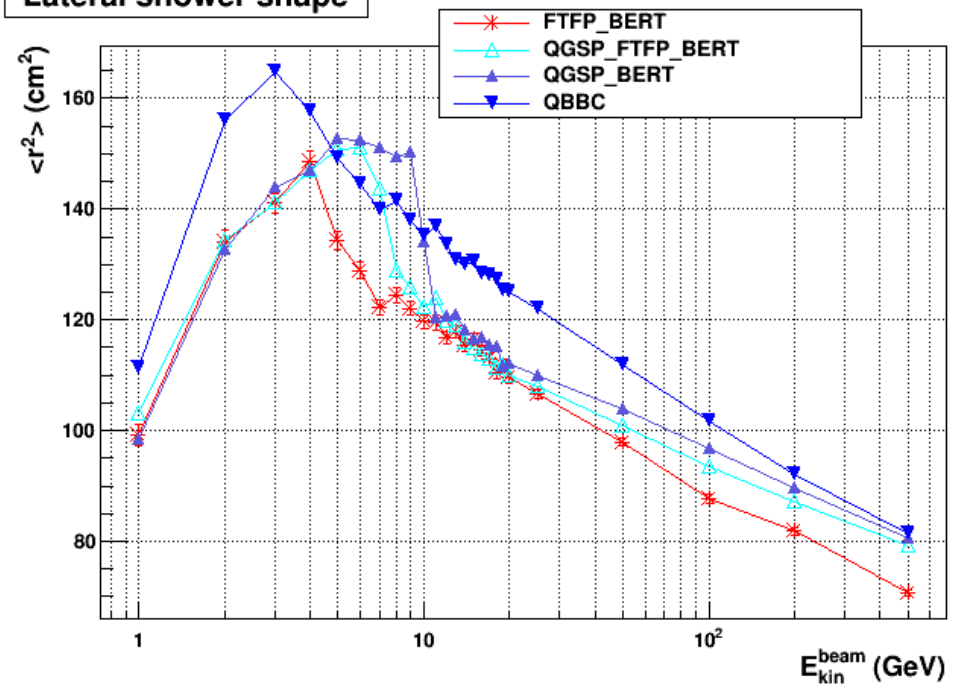


Longitudinal shower shape

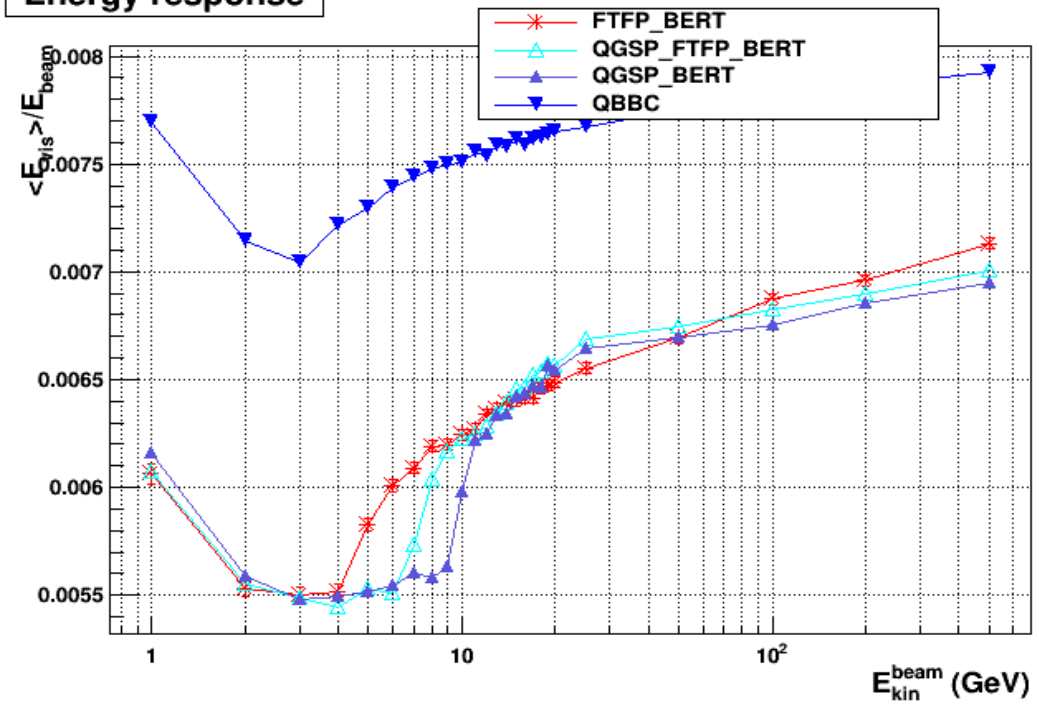


Lateral shower shape



π^- on W-LAr

Energy response



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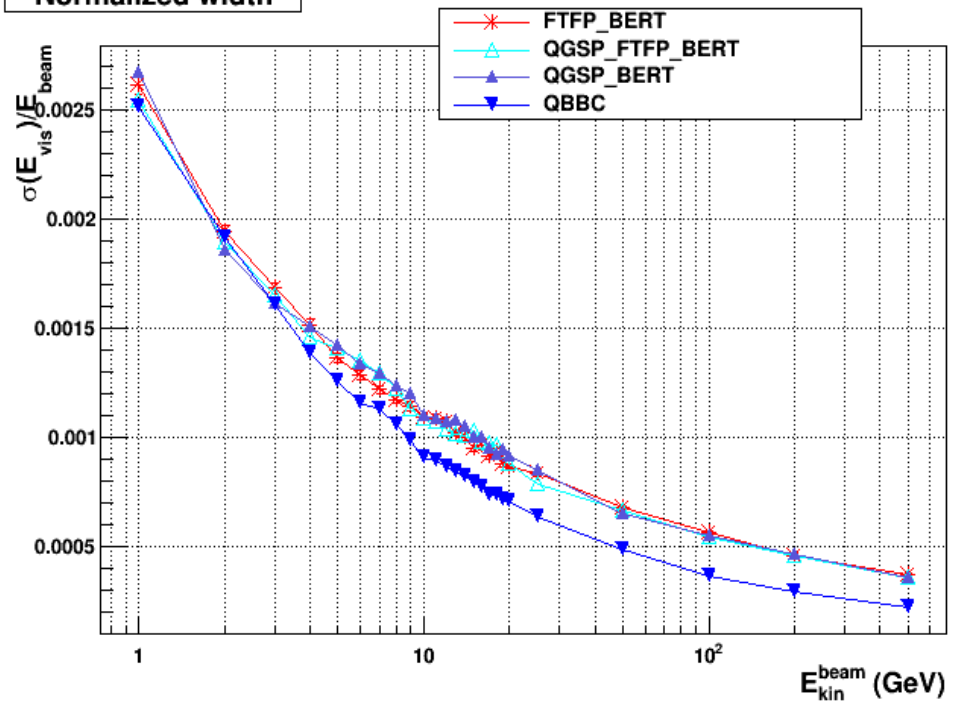
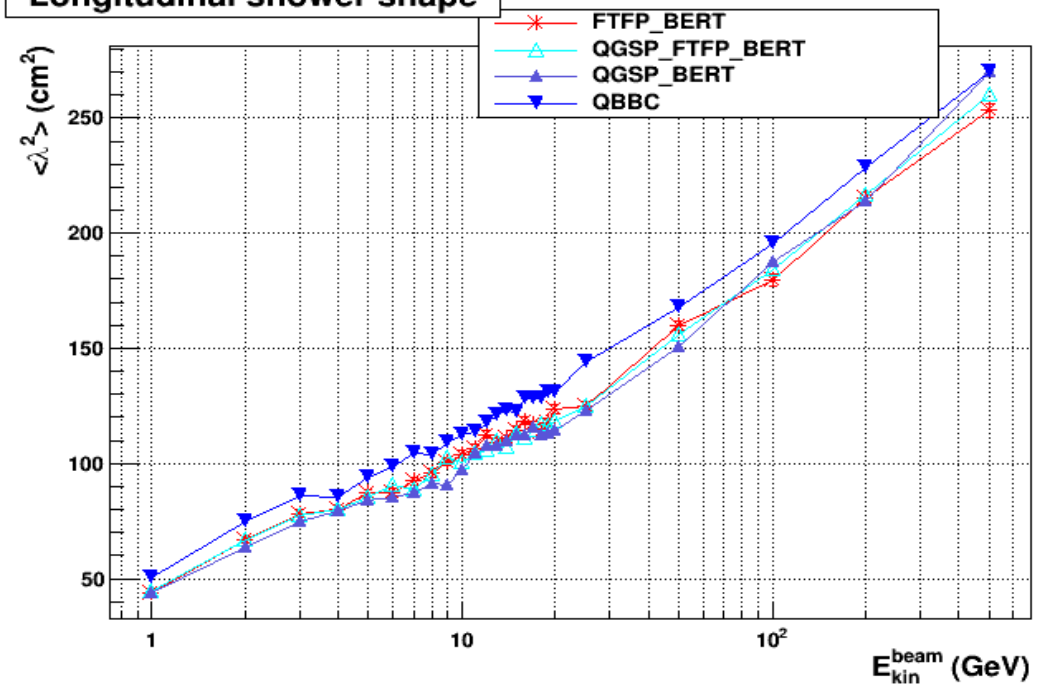
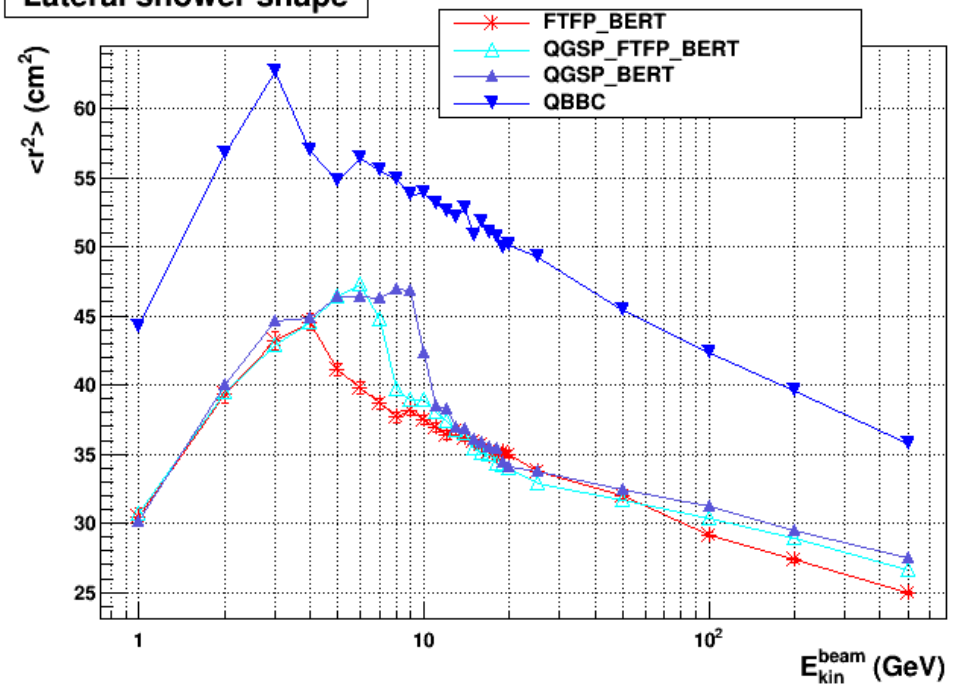


Longitudinal shower shape

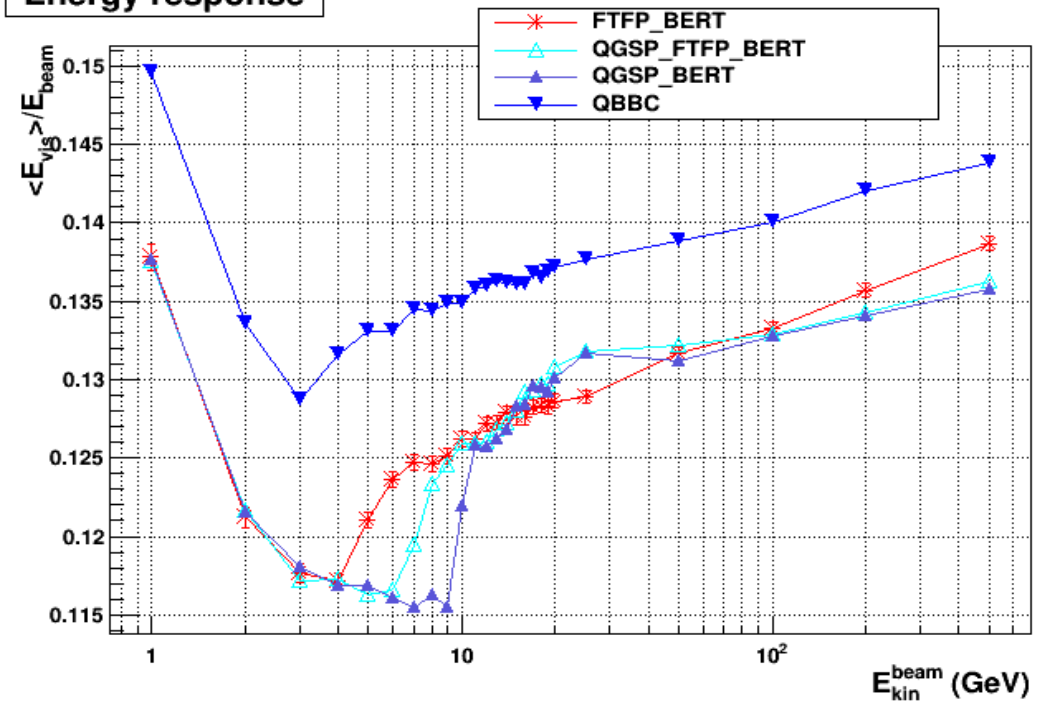


Lateral shower shape

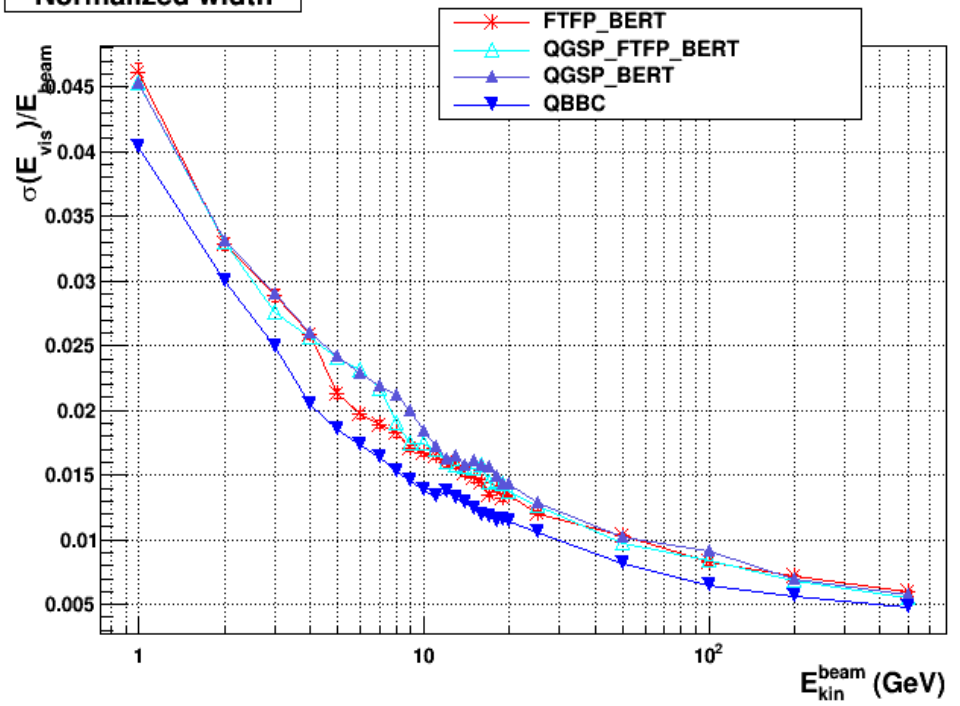


π^- on Pb-LAr

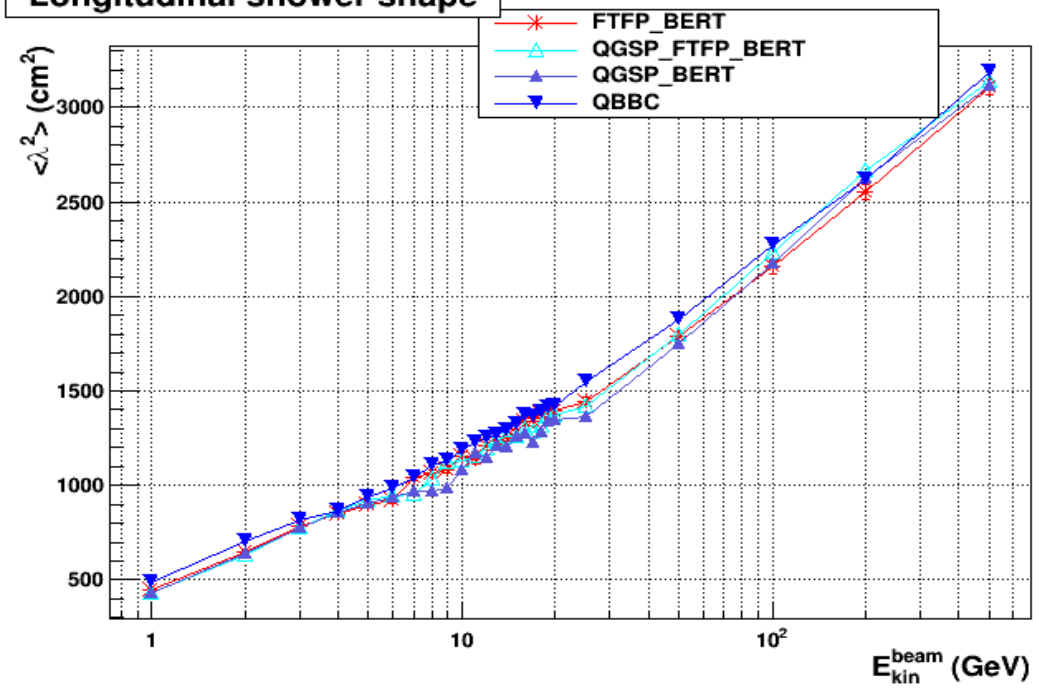
Energy response



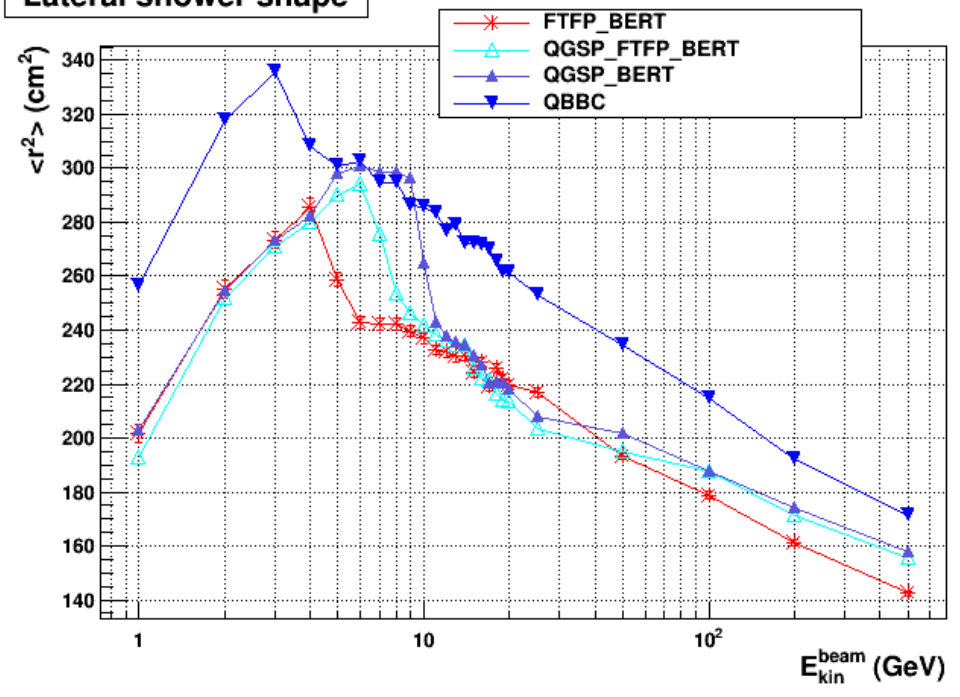
Normalized width



Longitudinal shower shape



Lateral shower shape



Energy Resolution