Hadronic Highlights of G4 10.3

Alberto Ribon
CERN PH/SFT

Hadronic Data Sets

- Achieved consistent set of data in terms of energy levels and lifetimes of excited nuclides, and physics models that use these data (photon evaporation, de-excitation, radioactive decay)
  - G4ENSDFSTATE**2.1**
  - PhotonEvaporation**4.3**
  - RadioactiveDecay**5.1**

- Optional: G4TENDL**1.3**
  - Needed by ParticleHP when used for p, d, t, He3, α

Fritiof (FTF) model

- The latest improvements – driven by thin-target data – and fixes of FTF model are not producing better hadronic showers (i.e. higher energy response and narrower shapes)
- Therefore, as a temporary solution to provide to the experiments reasonable hadronic showers (e.g. for the jet-energy scale), we have decided to release a version of FTF which is expected to produce showers similar to those in G4 10.1
  - Starting from G4 10.2.p02, but with the treatment of the excited nuclear remnants more similar to the one in G4 10.1
    - The treatment of the excited nuclear remnants introduced in G4 10.2 was the main responsible of the worsening (i.e. higher energy response) of hadronic showers with respect to G4 10.1

Quark-Gluon-String (QGS) model

- Minor changes in G4 10.3 with respect to G4 10.2 (and 10.1)

Note: the new version of QGS, with a first re-tuning of the parameters, is available in our latest development (G4 10.2.ref10); for this G4 10.3 release we decided to keep the stable (older) version

Intra-nuclear Cascade models

- Bertini-like (BERT)
  - Improved the **evaporation spectrum**. This reduces the overproduction of low-energy neutrons and protons
  - Added 8- and 9-body final states to kaon-induced reactions
- Liege (INCLXX)
  - Extended to include **η** and **ω** meson production
- Binary (BIC)
  - No significant developments

Precompound / de-excitation models

- Major improvement of the code structure in order to use the same data as the Radioactive Decay model
  - Previous internal hard-coded data are no longer used
- Introduced the possibility, not yet activated, to simulate the correlated emissions of gammas
- New data-set: PhotonEvaporation**4.3**

Radioactive Decay model

- Consistent use of the same data sets as the Precompound/de-excitation models
- Several improvements and fixes, including in biasing
- New data-set: RadioactiveDecay**5.1**

ParticleHP model

- Reminder: NeutronHP plus **p** , **d** , **t** , **He3** , **α** below **200 MeV**
- Several fixes
- Testing still on-going for charged particles
  - As in the previous release, the mode "PHP_AS_HP" is the default; users can change this behaviour by setting the environment variable of "DO_NOT_SET_PHP_AS_HP" before compilation: this is recommended for physics studies
- New data set G4TENDL**1.3** to be downloaded from the Geant4 site
  - Introduced a new environmental variable **G4PARTICLEHPDATA** as default base name for data modules

Physics Lists

- In FTFP_BERT and FTFP_BERT_HP changed the transition region between FTFP and BERT : **[3, 12] GeV**
  - Instead of [4, 5] GeV
    - For pions, kaons, proton and neutron
    - For hyperons, left unchanged: [2, 6] GeV
    - For anti-nucleons, FTFP is used at all energies
  - To smooth out unphysical kinks and to leverage more on BERT
    - BERT produces hadronic showers with lower energy response and wider with respect to FTFP
      - This was also the motivation to introduce, last year, the new physics list FTFP_BERT_ATL, in order to improve the jet energy scale of ATLAS

Hadronic showers *(see plots in backup slides)*

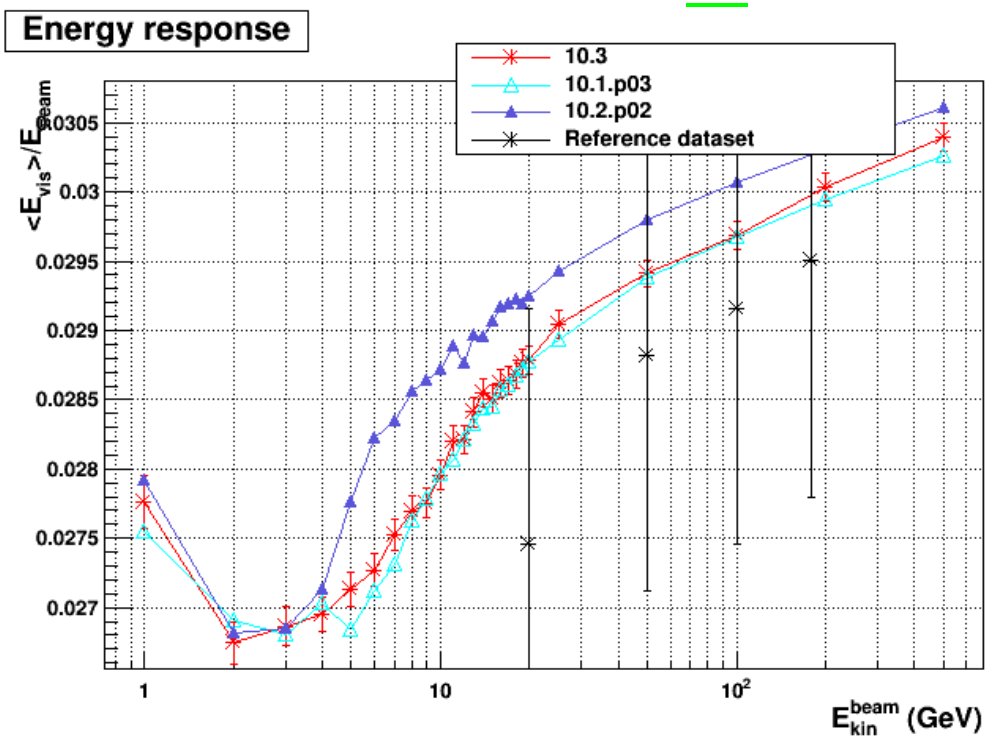
- FTFP_BERT hadronic showers in G4 10.3 are expected to be as good as, is not slightly better than, those of G4 10.1
  - Some differences – in particular smoother behaviour and wider hadronic showers as a function of the projectile energy, especially between 4 and 12 GeV – are due to the change of transition region between FTFP and BERT
  - Energy response in Fe & Cu is similar to G4 10.1, i.e. a few % lower than in version 10.2
  - Energy response in heavier absorbers (W & Pb) is a few % lower than both versions 10.1 and 10.2

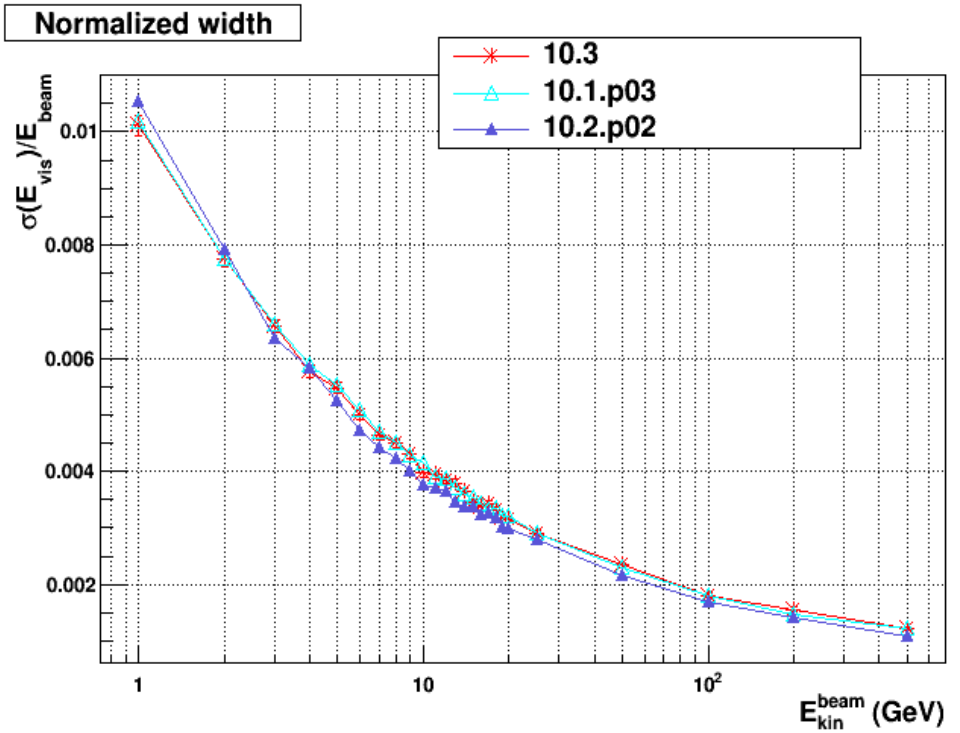
Backup slides

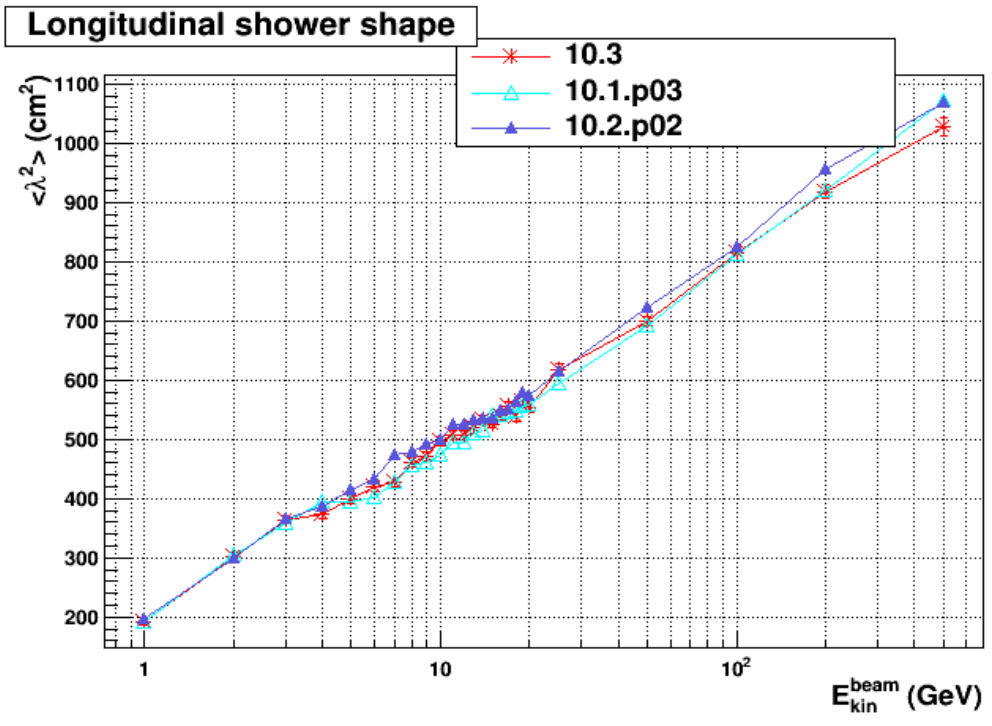
Pion showers
in Simplified Calorimeters
FTFP_BERT
Comparing G4 versions:
10.3 , 10.2.p02 , 10.1.p03

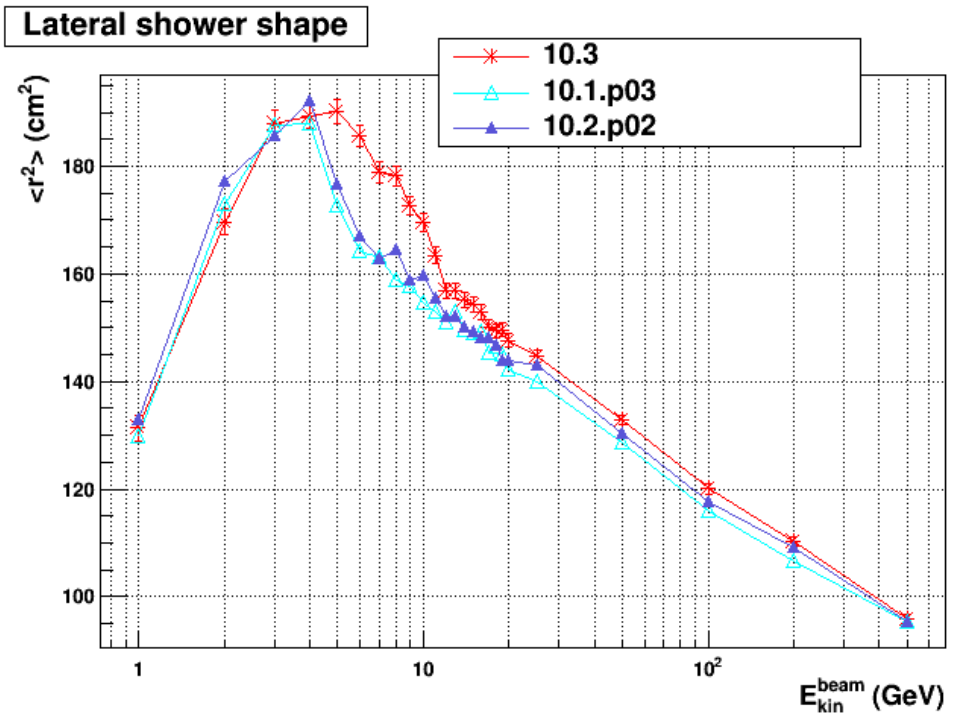
FTFP_BERT

π^- on Fe-Sci





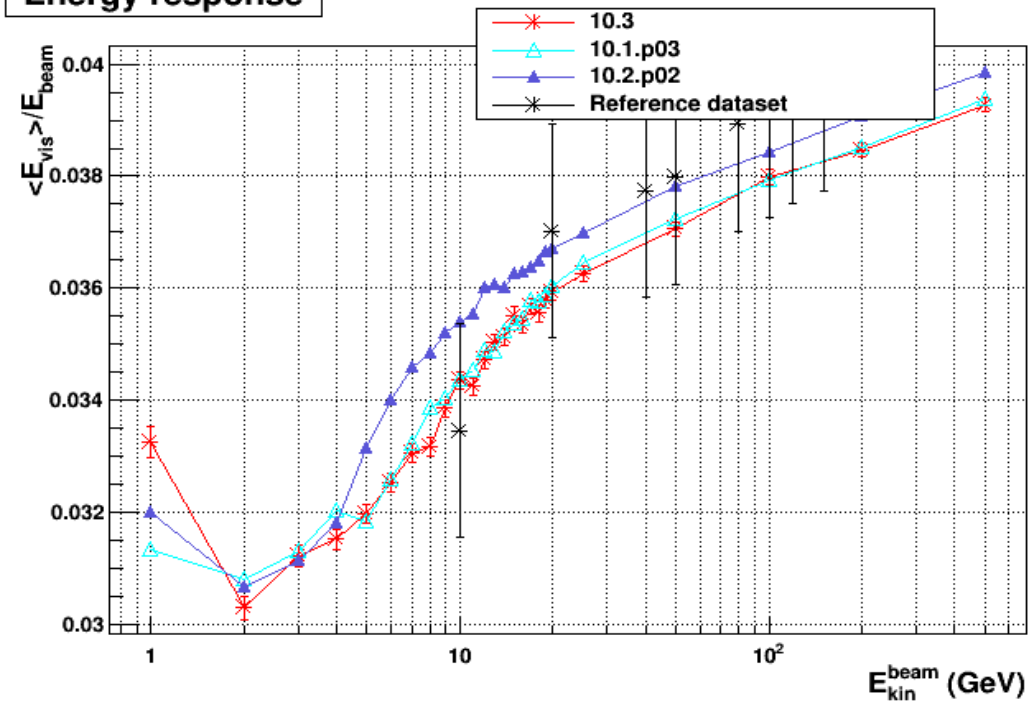




FTFP_BERT

π^- on Cu-LAr

Energy response



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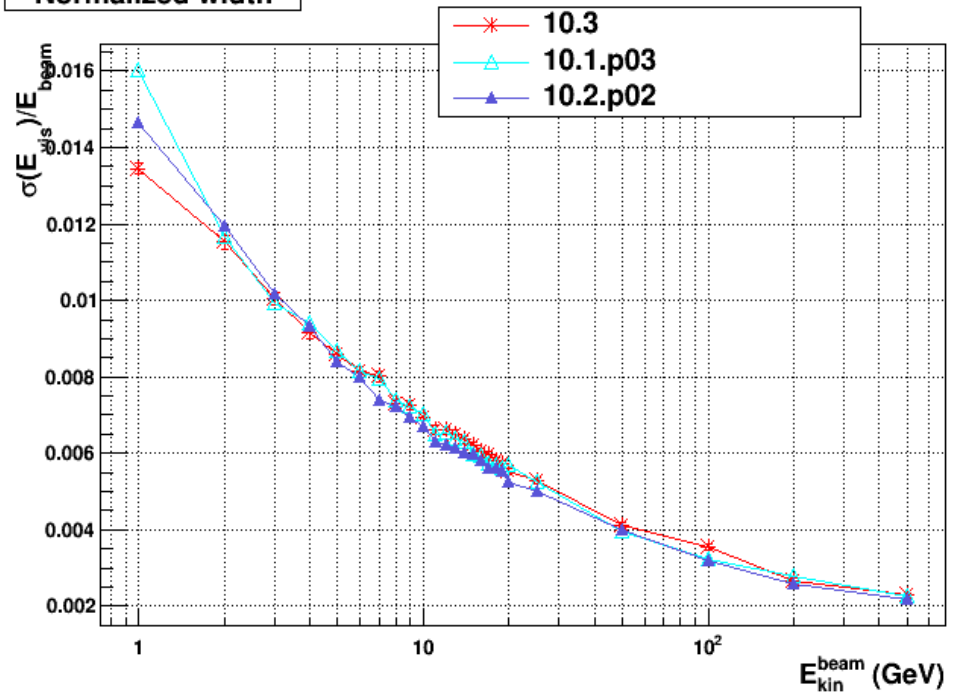
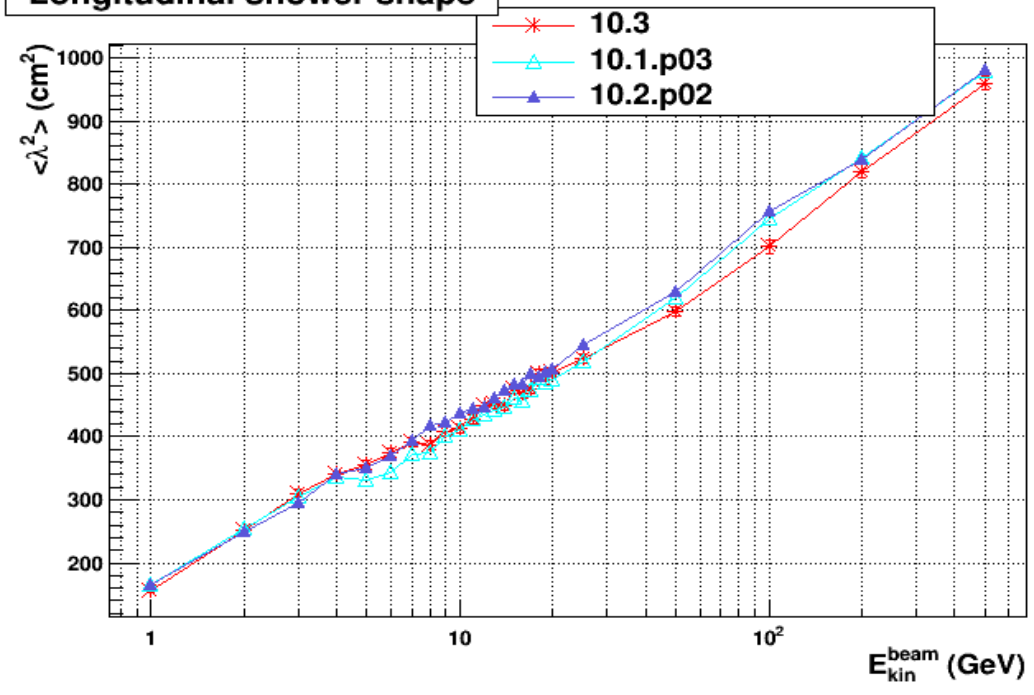


Longitudinal shower shape



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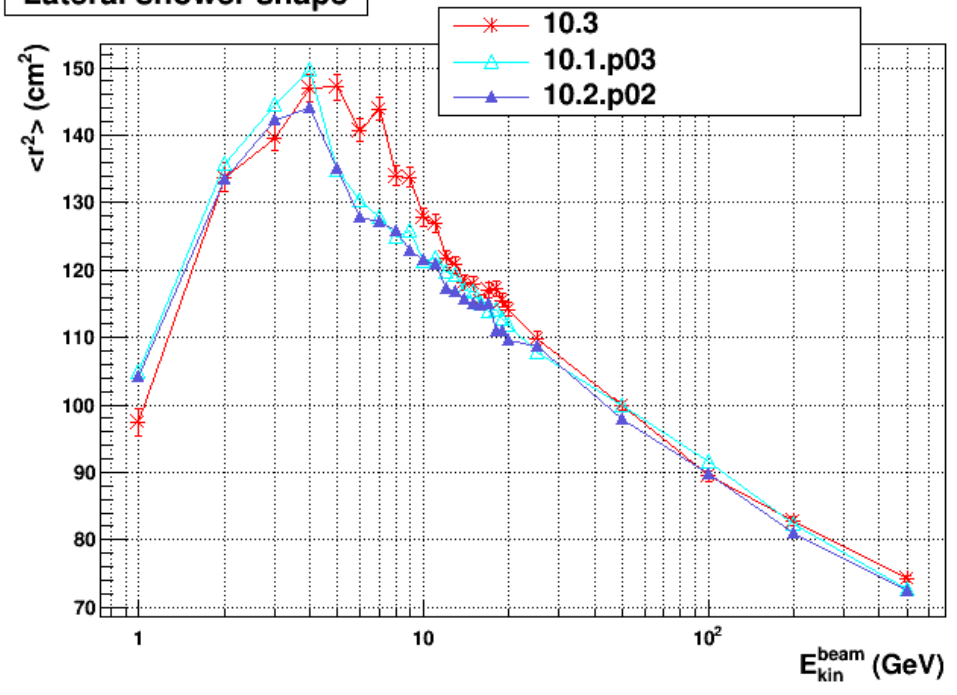
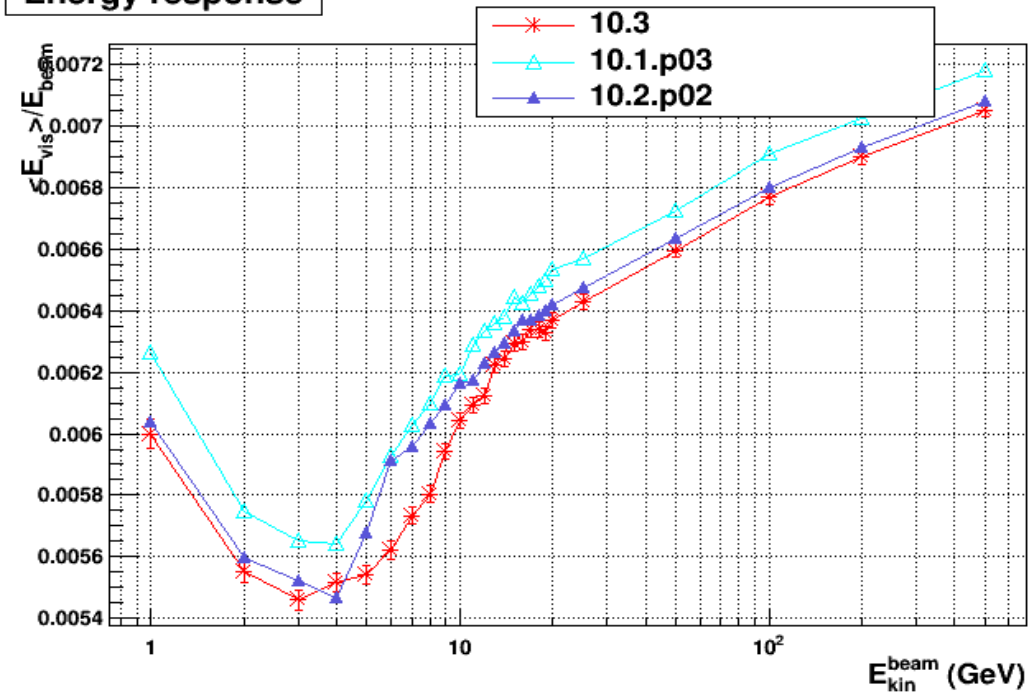


FTFP_BERT

π^- on W-LAr

Energy response



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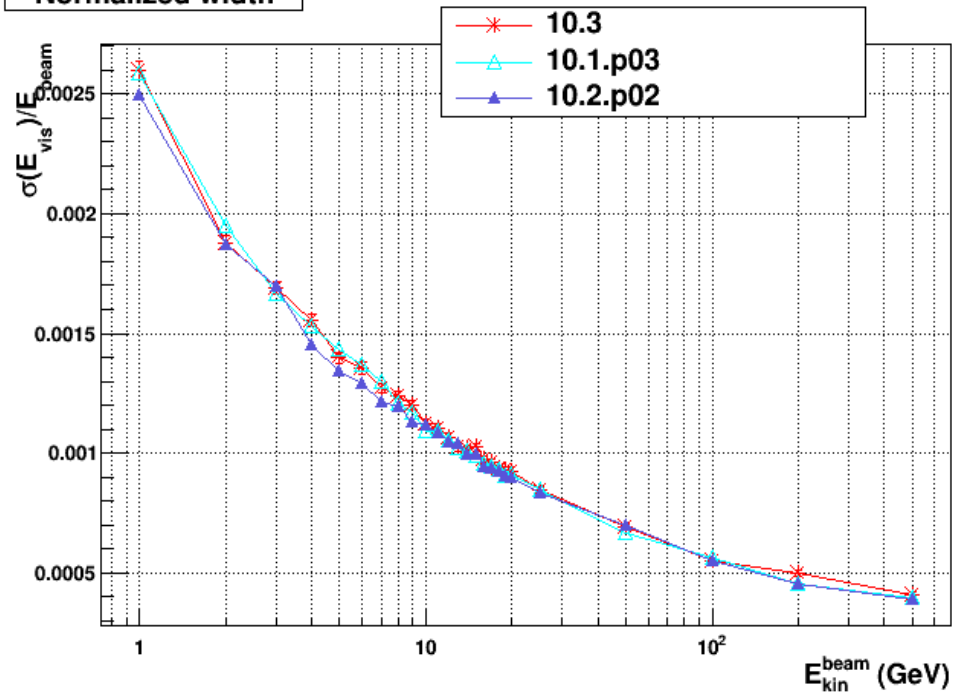

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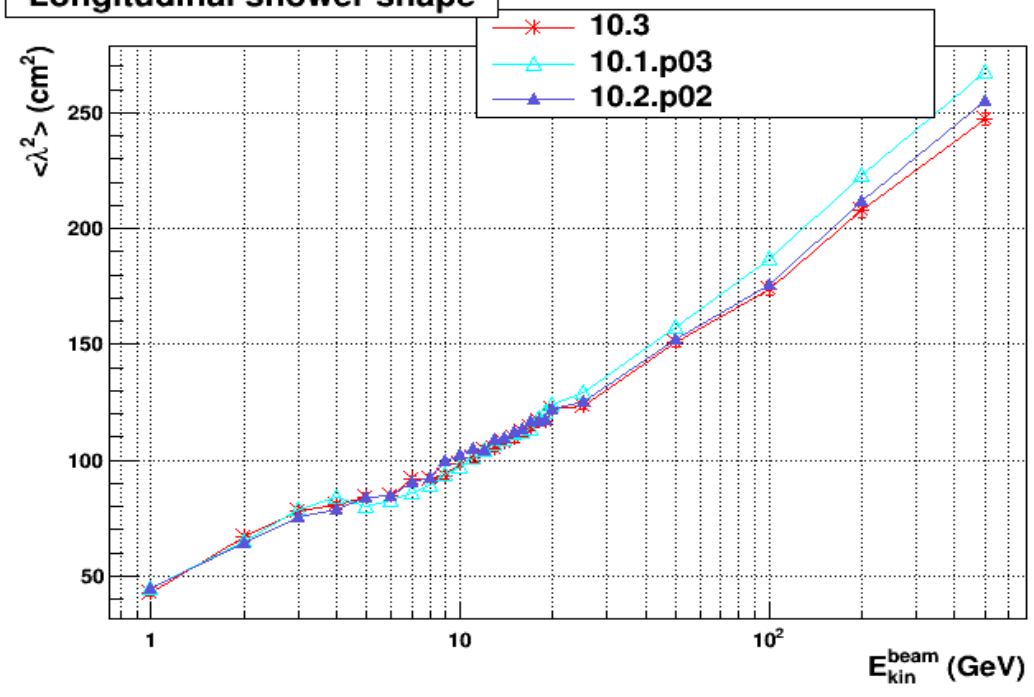
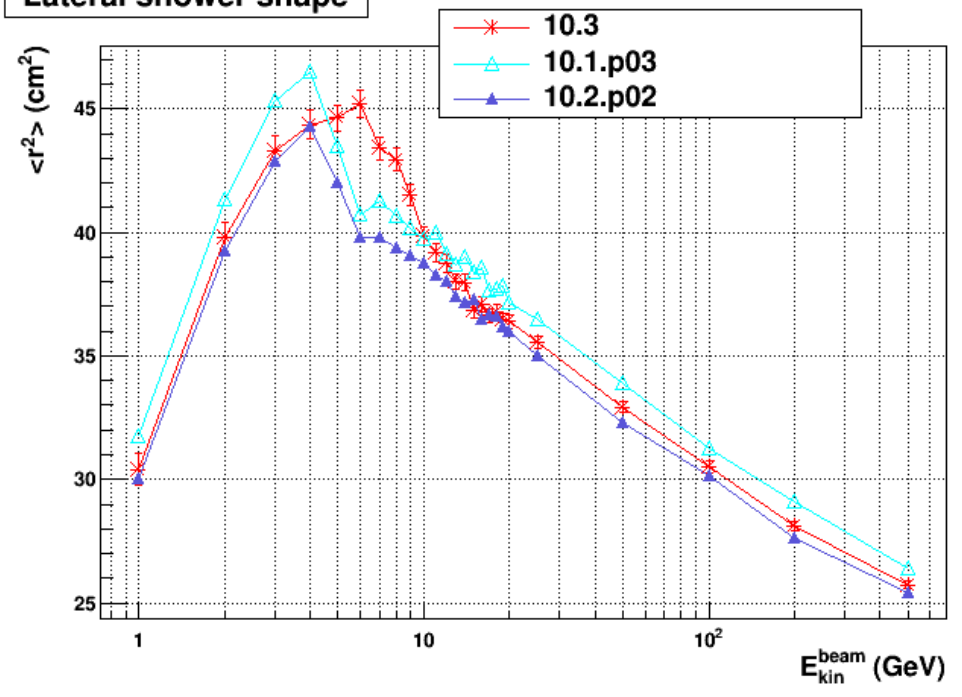
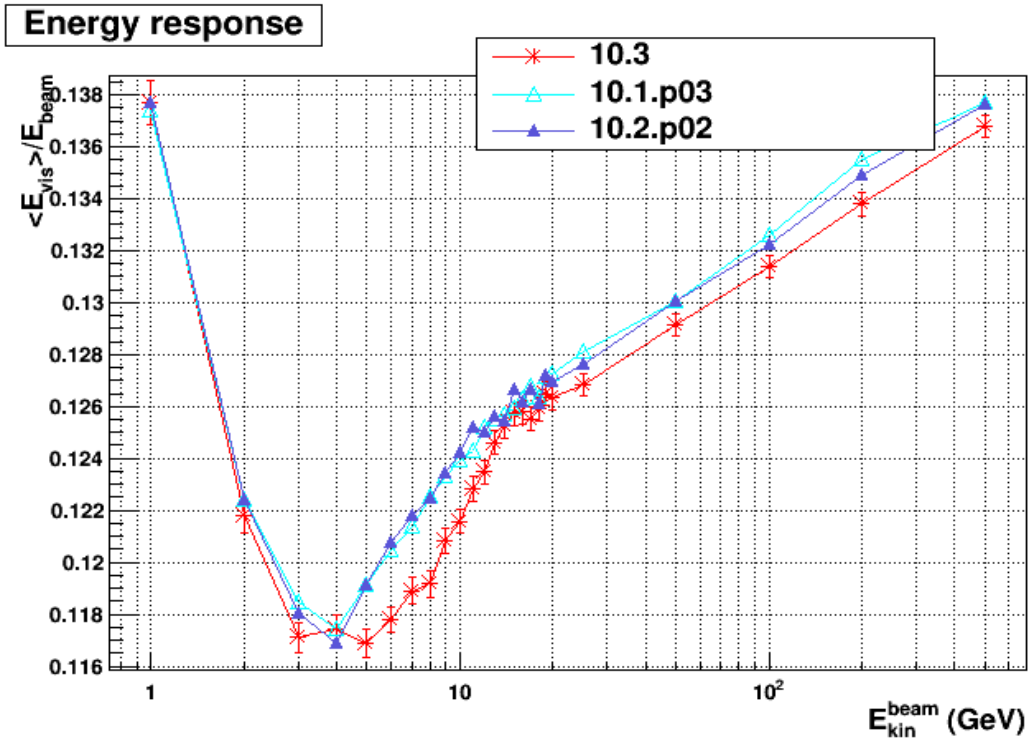


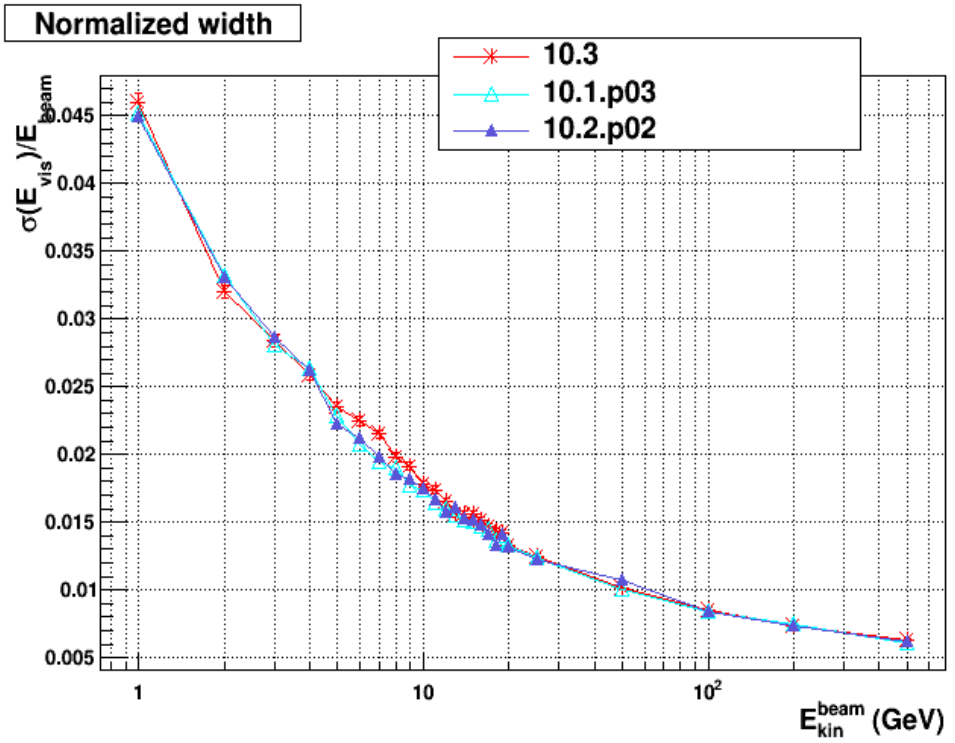
Lateral shower shape

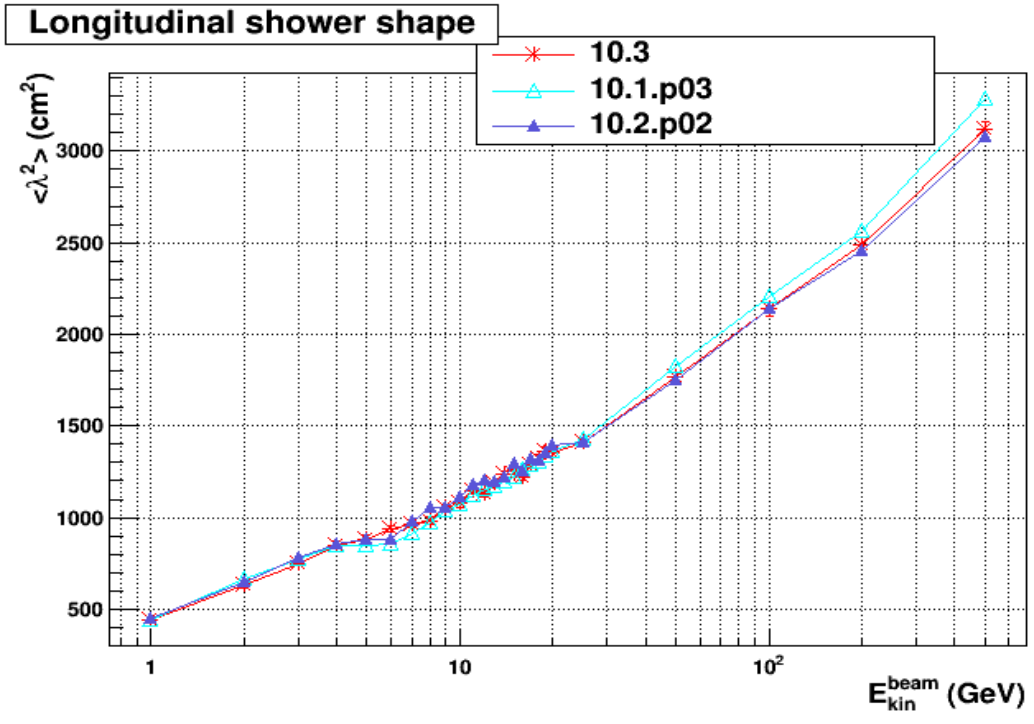


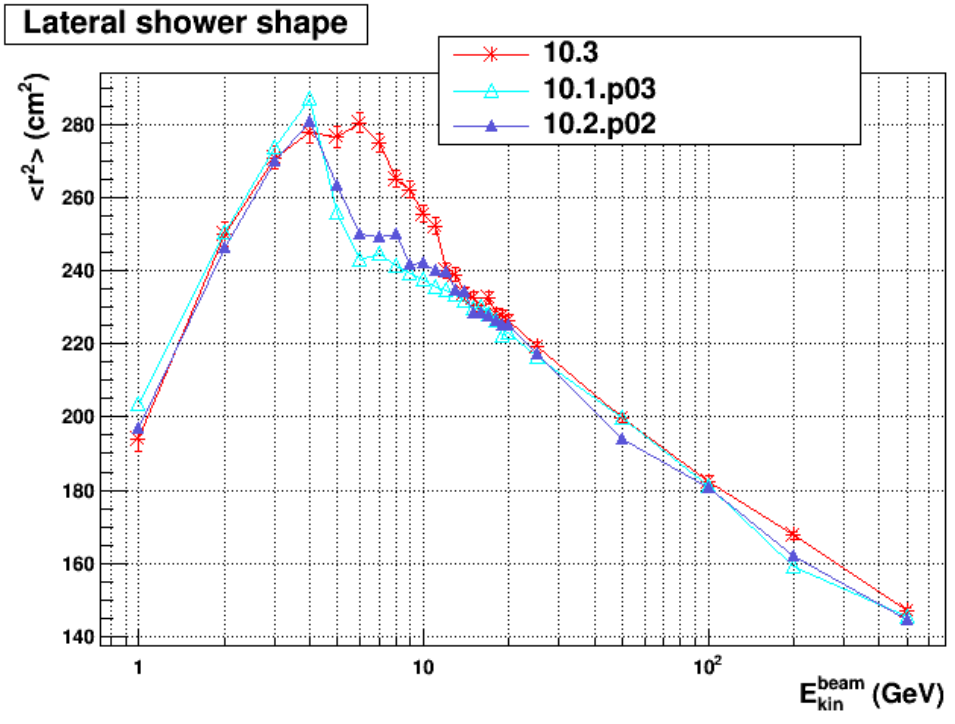
FTFP_BERT

π^- on Pb-LAr

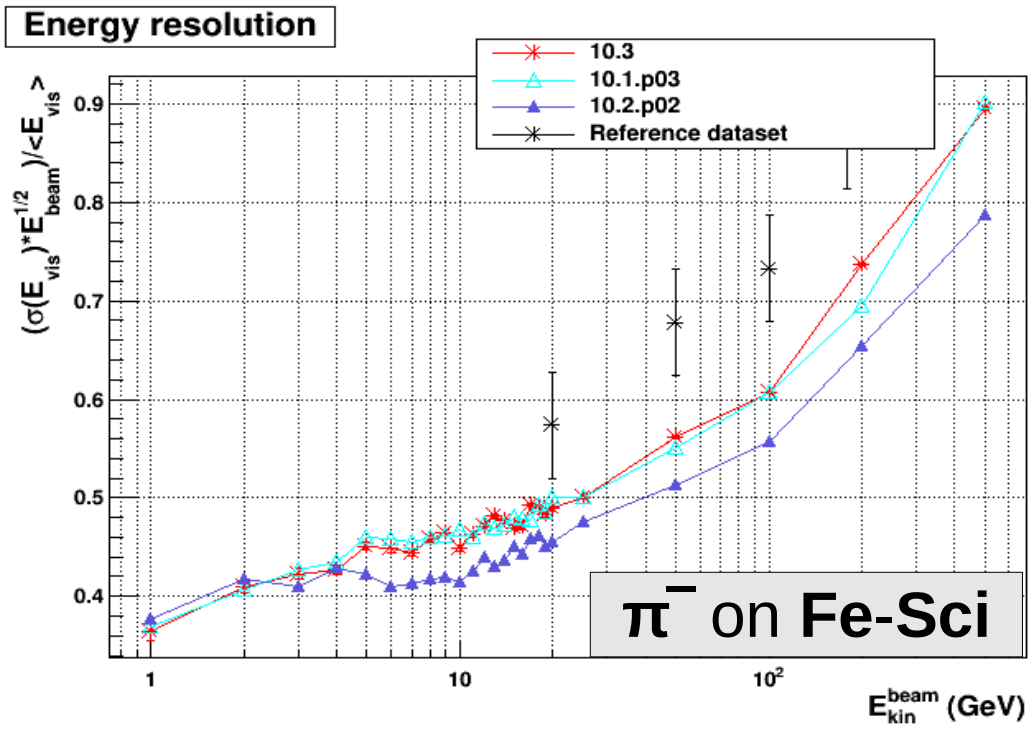


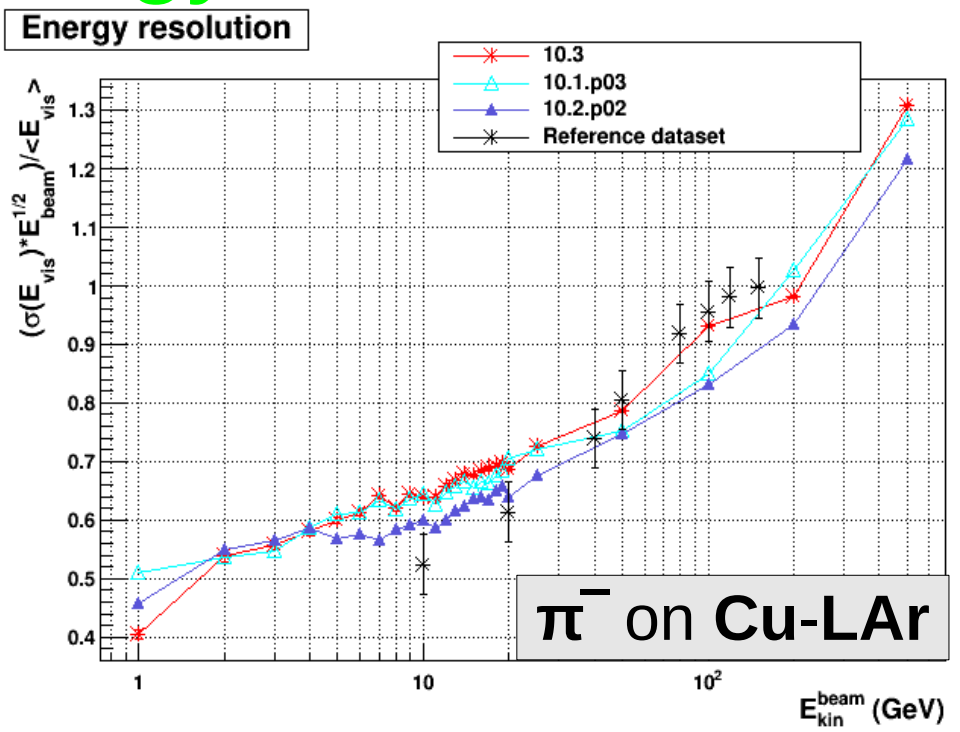


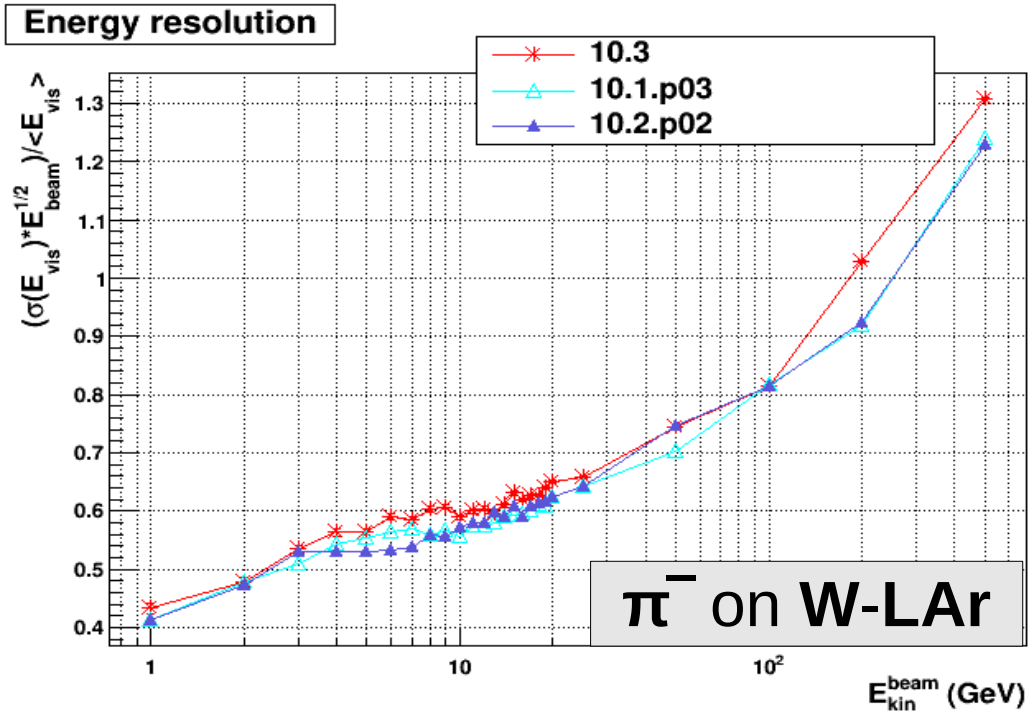


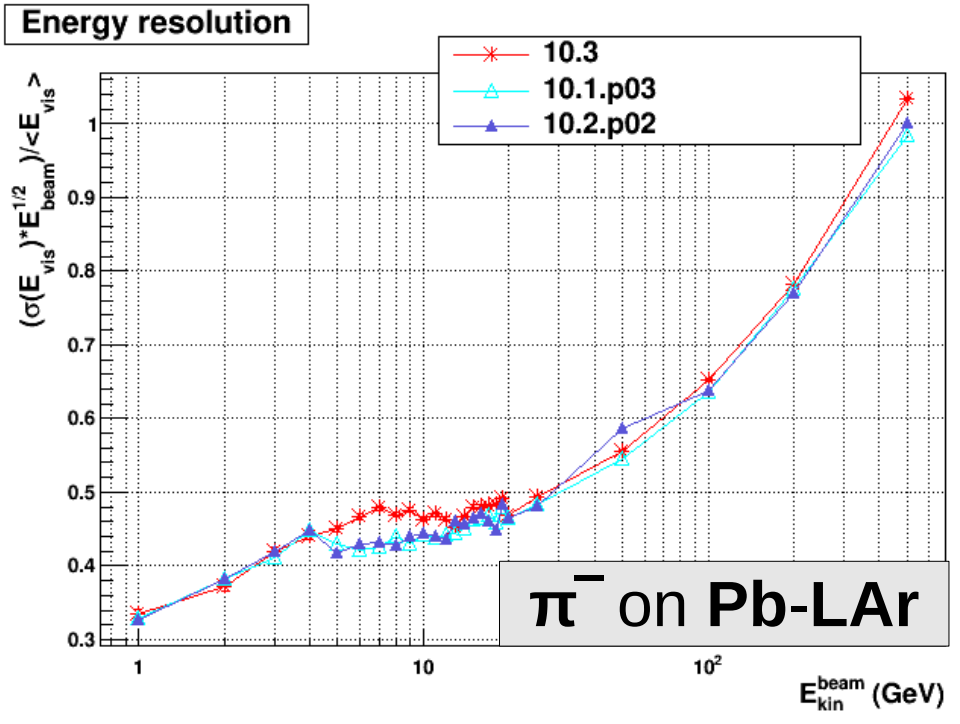


FTFP_BERT : Energy Resolution







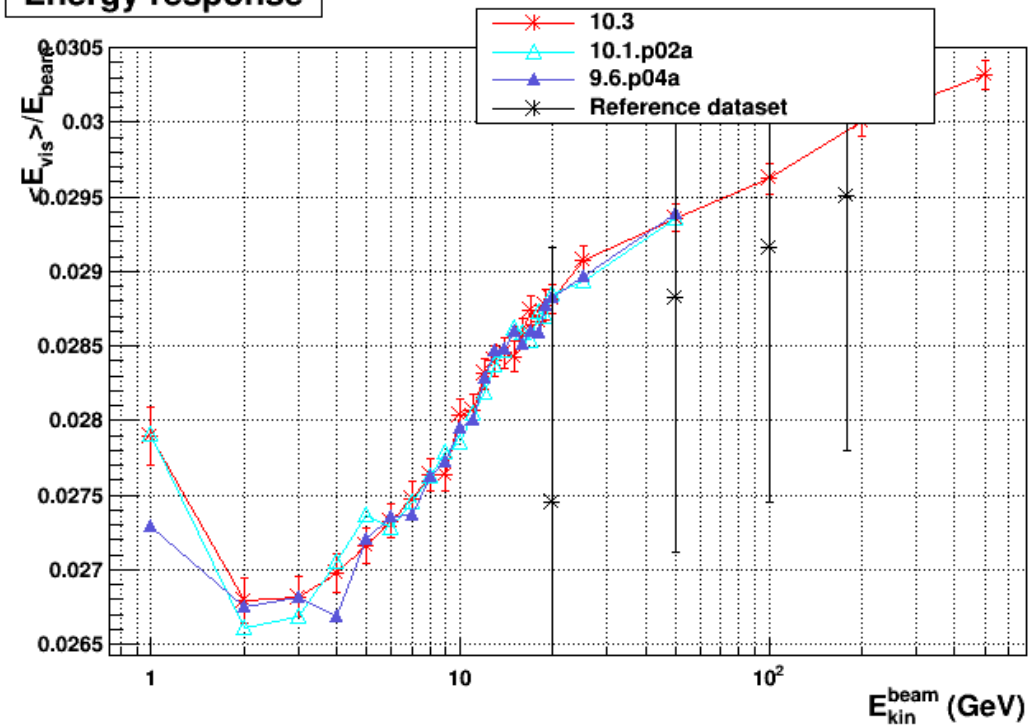


Pion showers
in Simplified Calorimeters
FTFP_BERT_ATL
Comparing G4 versions:
10.3 , 10.1.p02 , 9.6.p04

FTFP_BERT_ATL

π^- on Fe-Sci

Energy response



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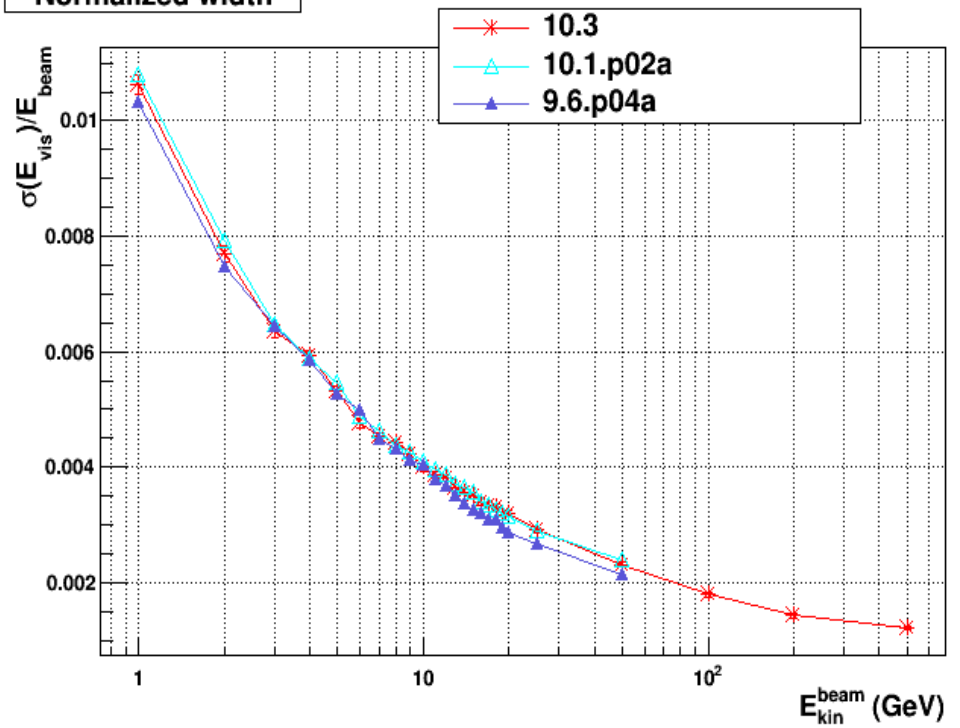
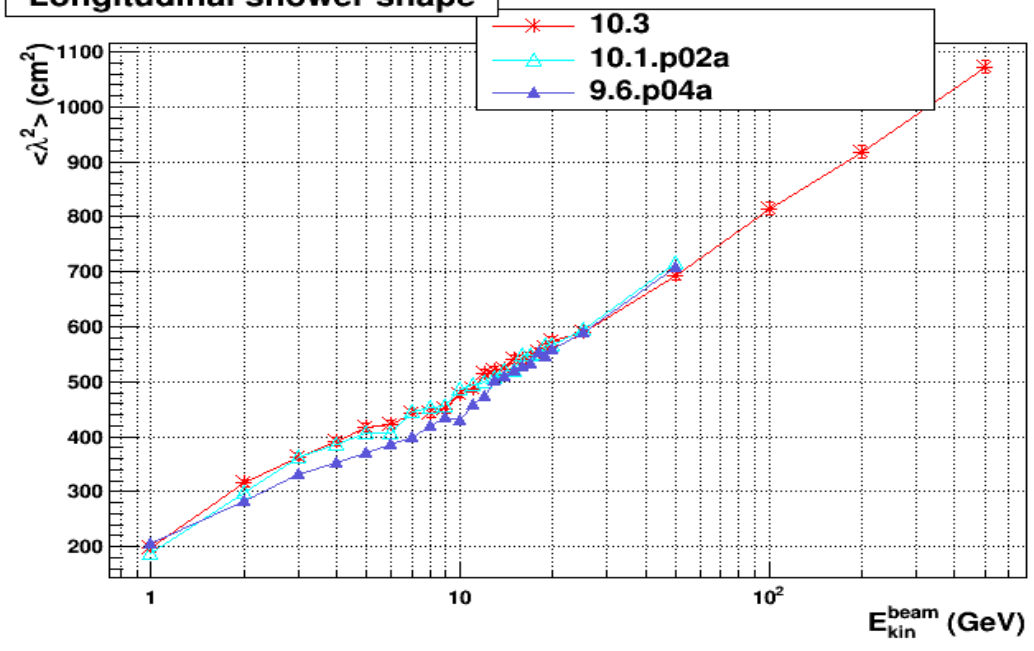
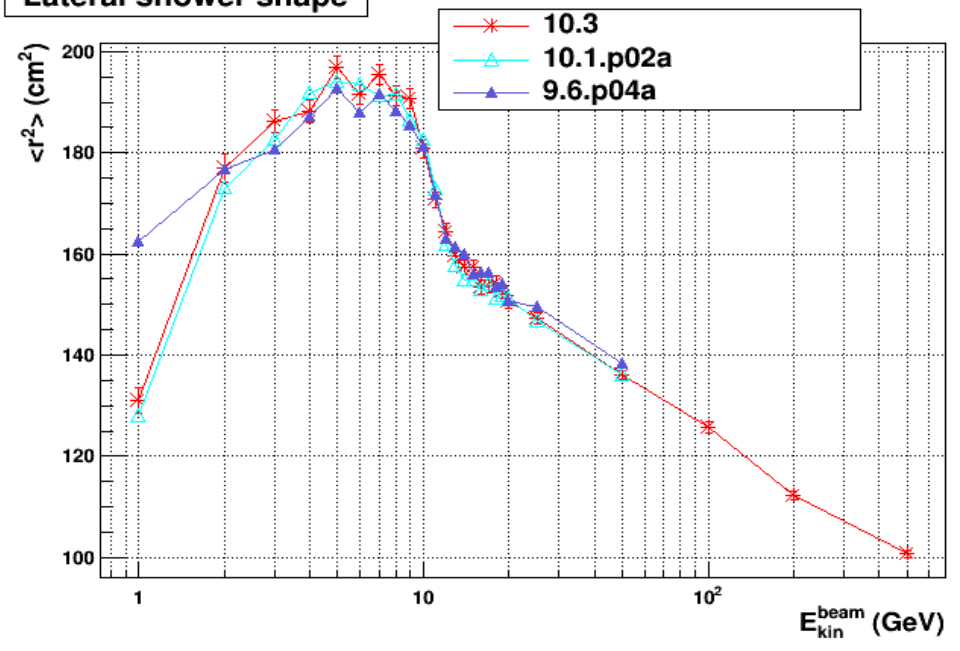


Longitudinal shower shape

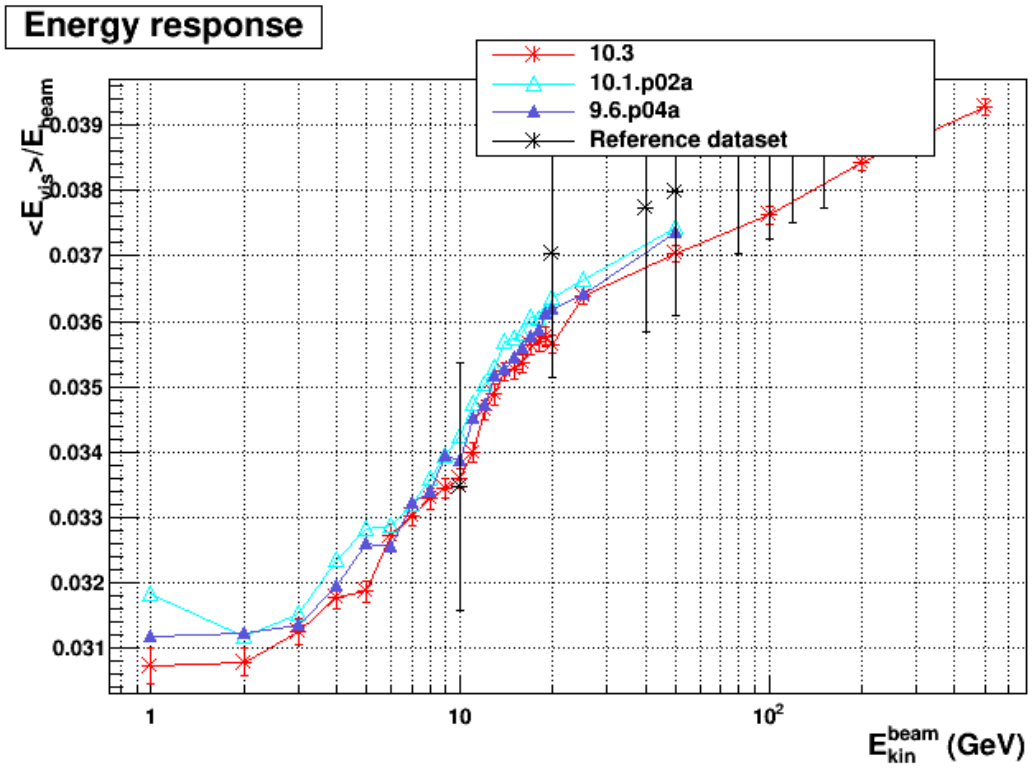


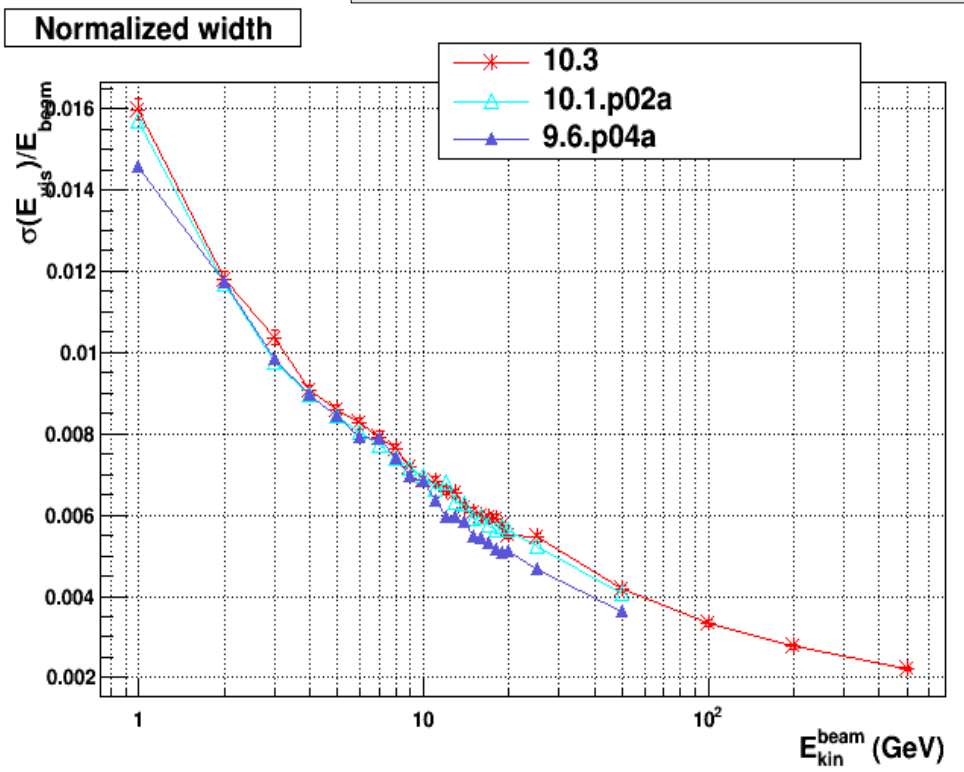
Lateral shower shape

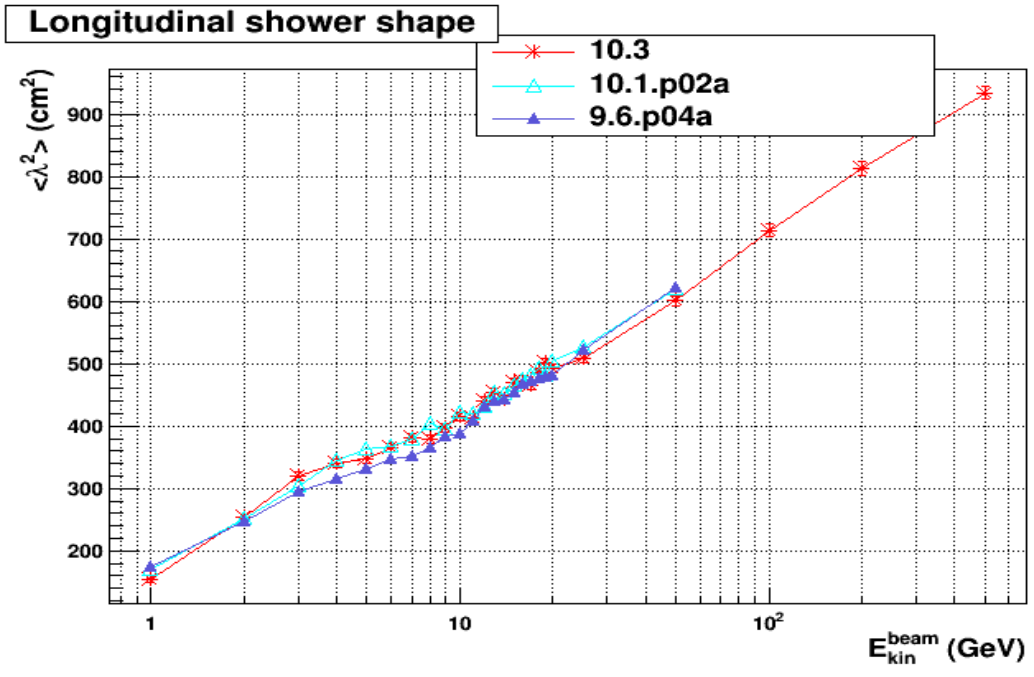


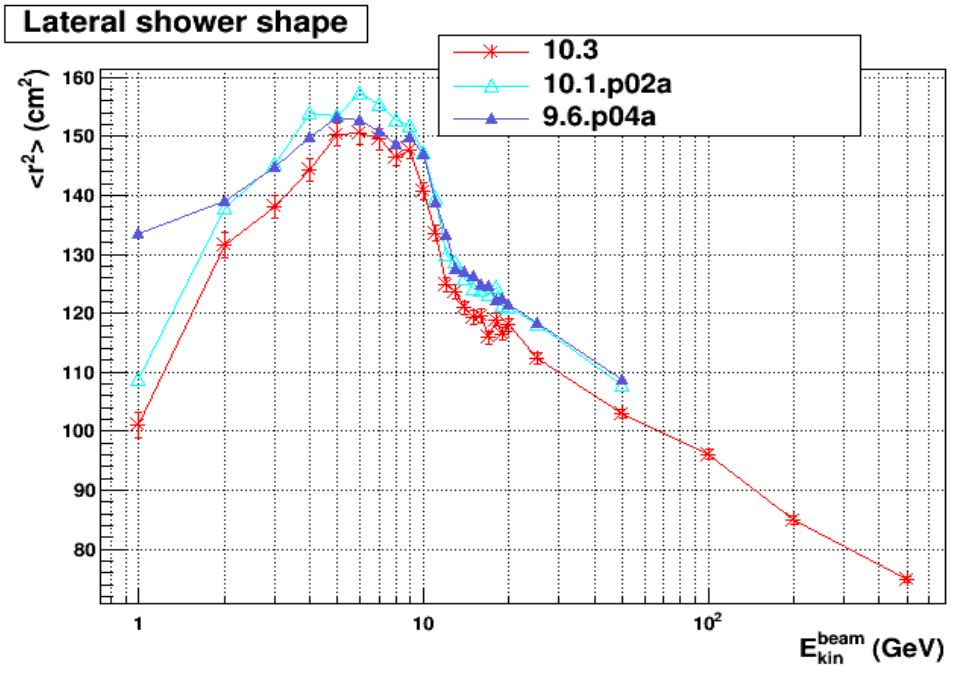
FTFP_BERT_ATL

π^- on Cu-LAr





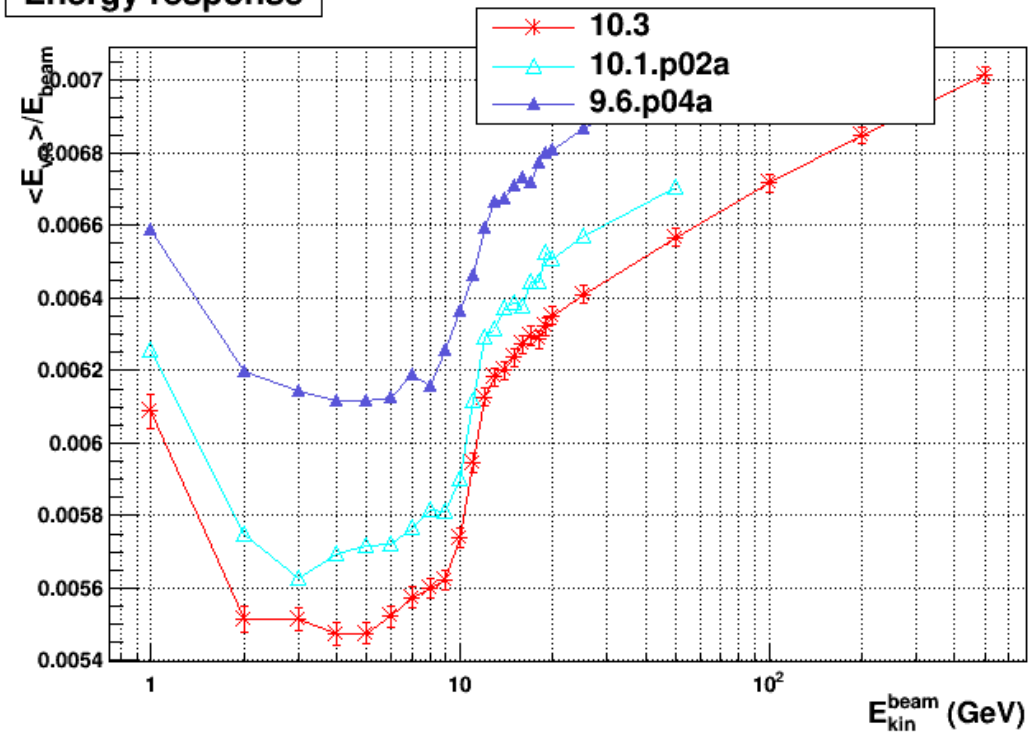




FTFP_BERT_ATL

π^- on W-LAr

Energy response



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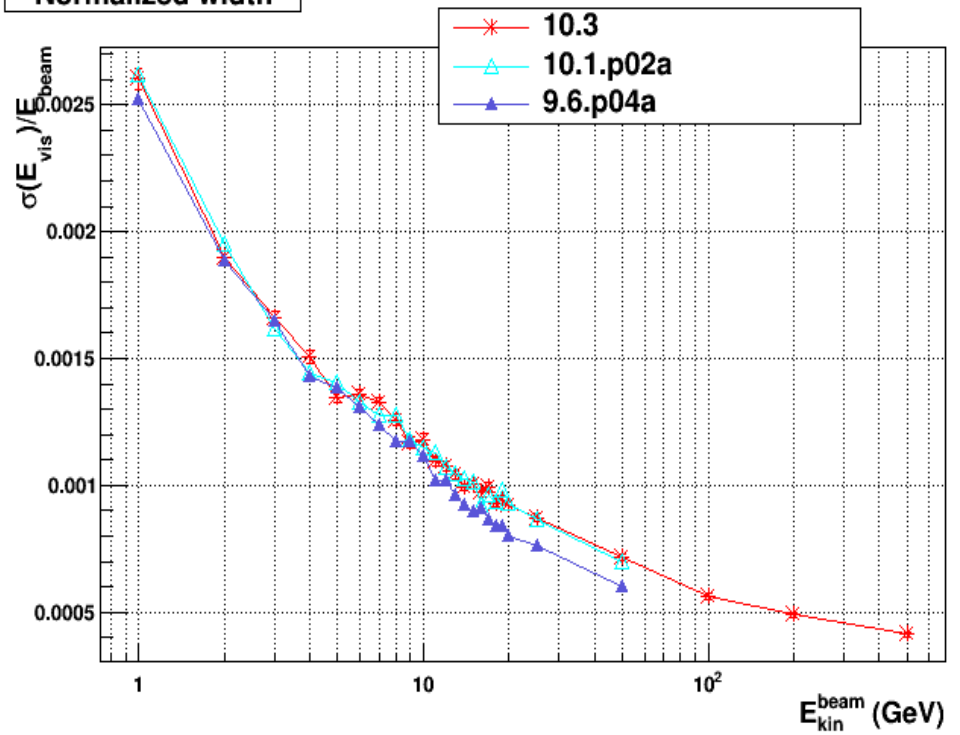
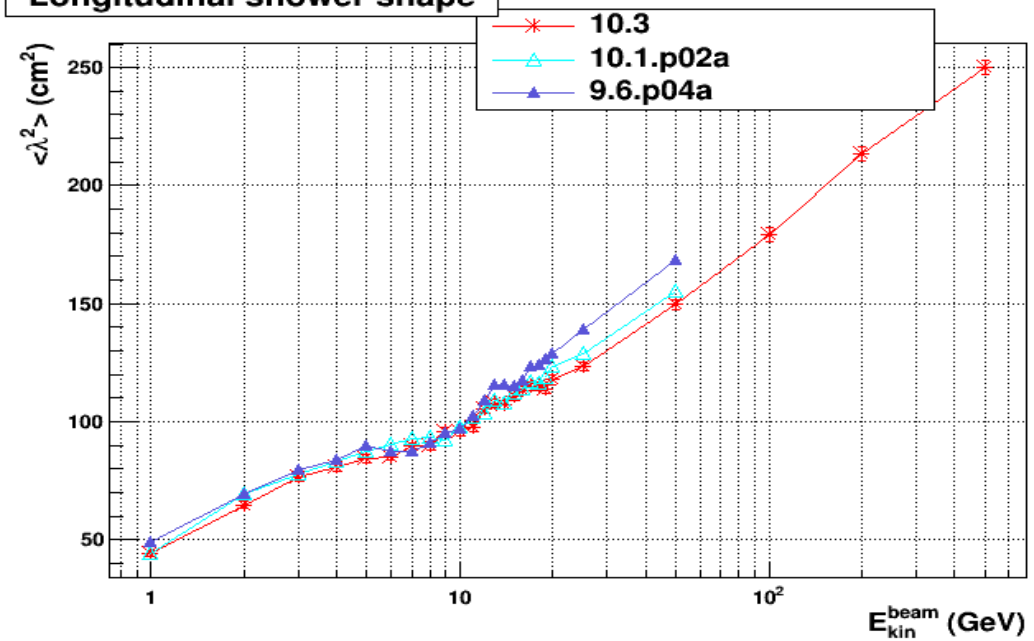


Longitudinal shower shape



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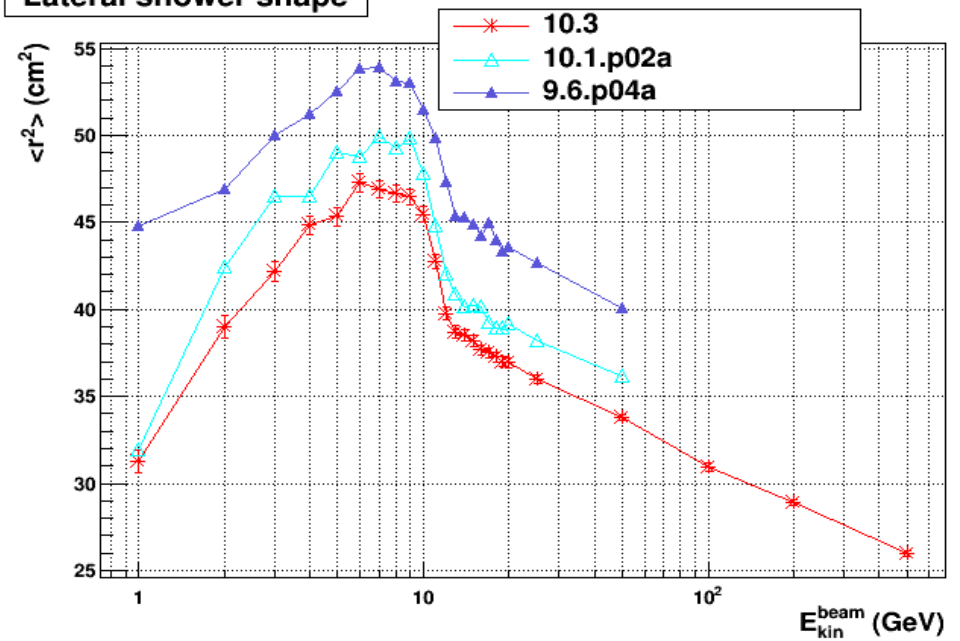
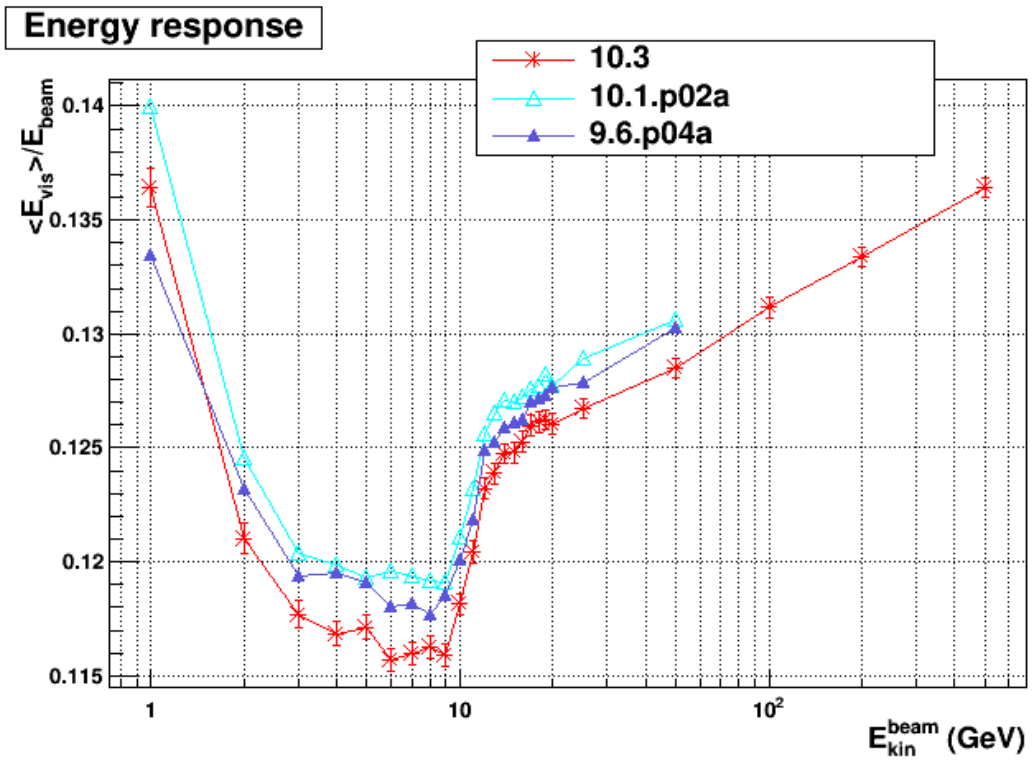
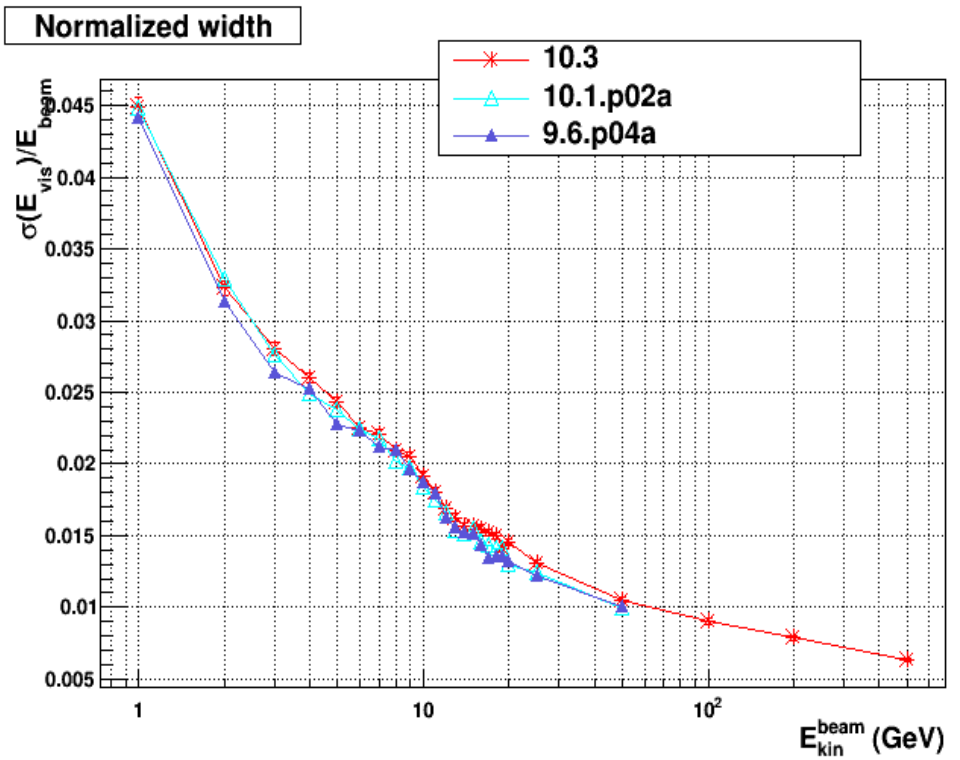
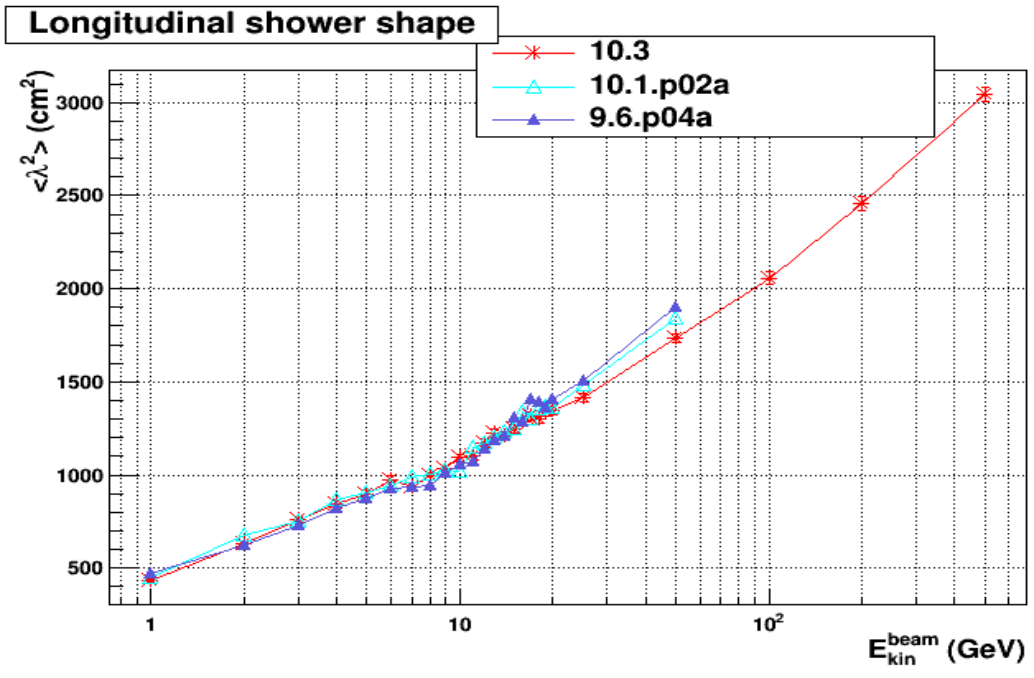


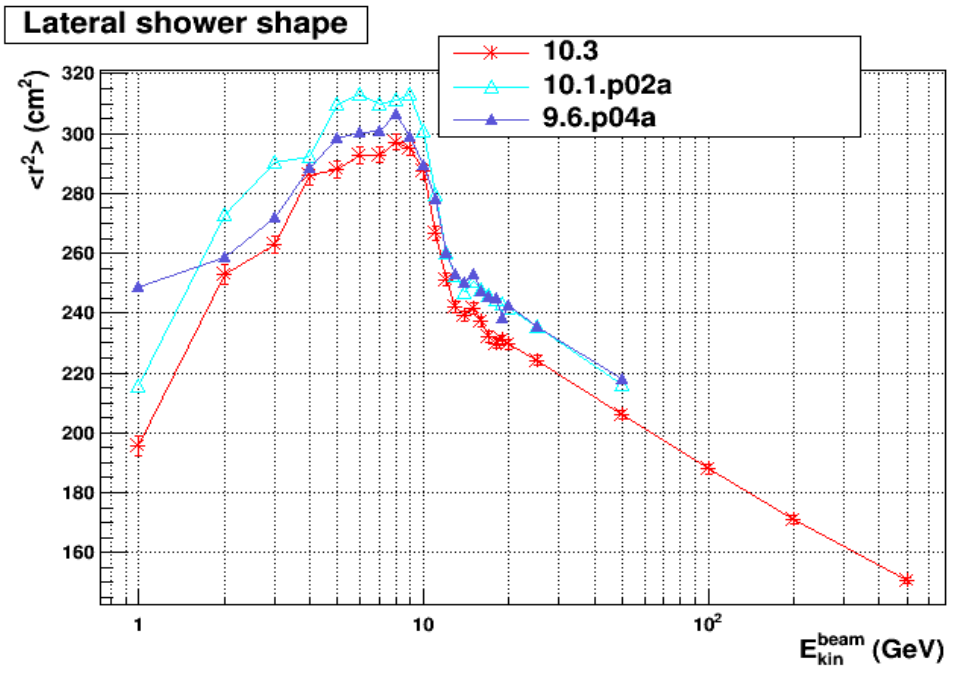
FTFP_BERT_ATL

π^- on Pb-LAr

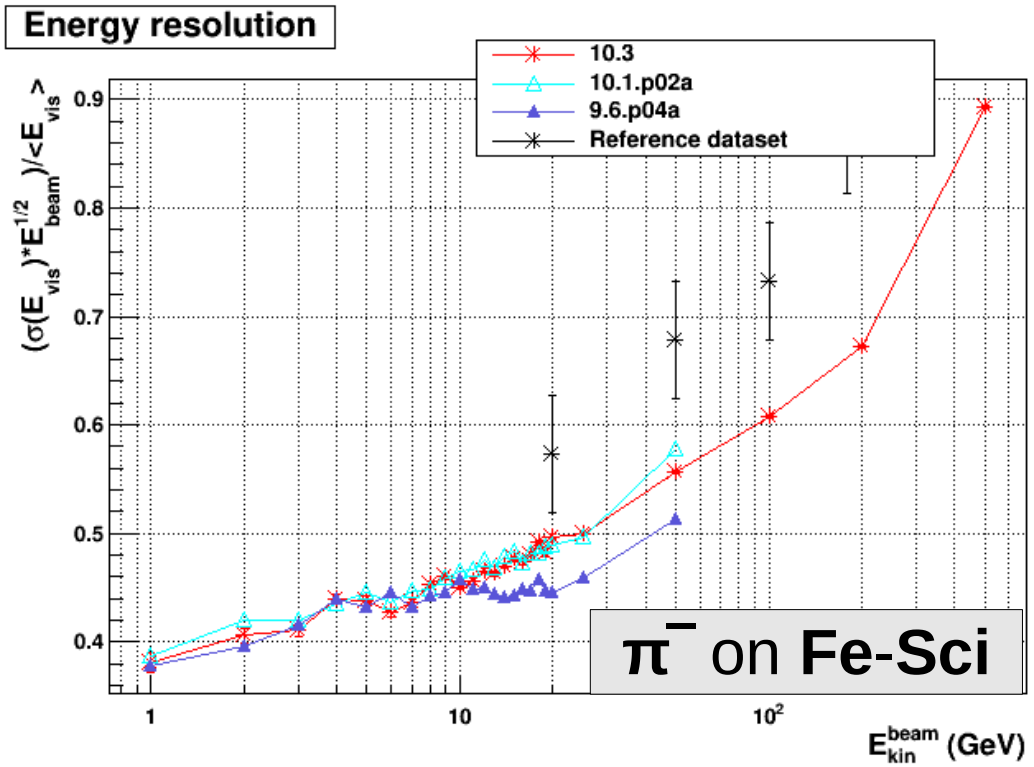


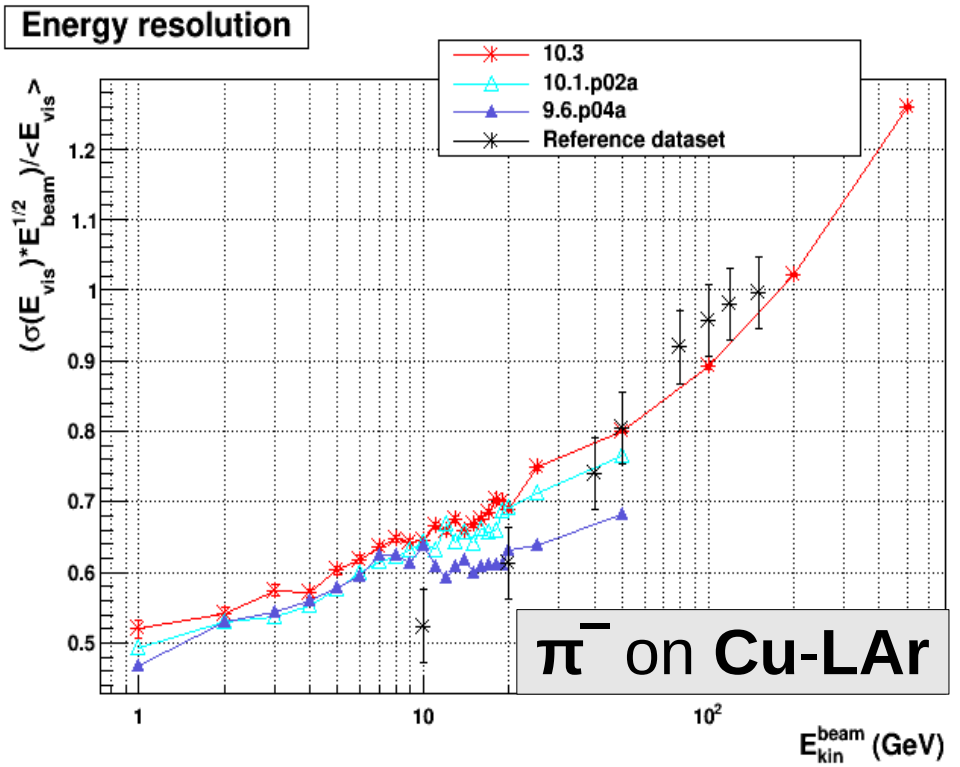


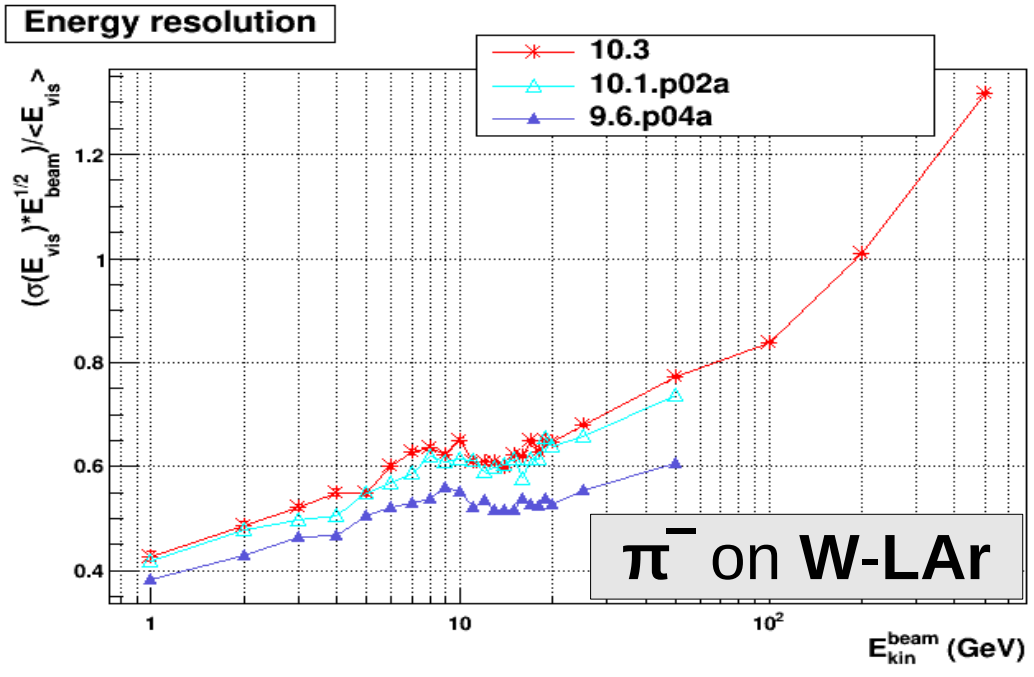


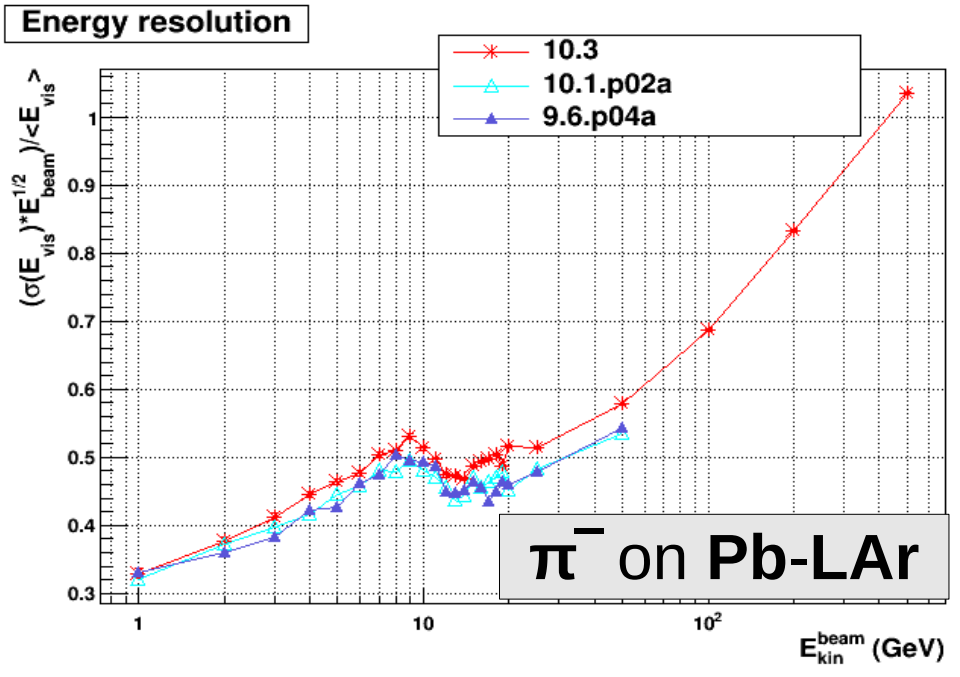


FTFP_BERT_ATL : Energy Resolution





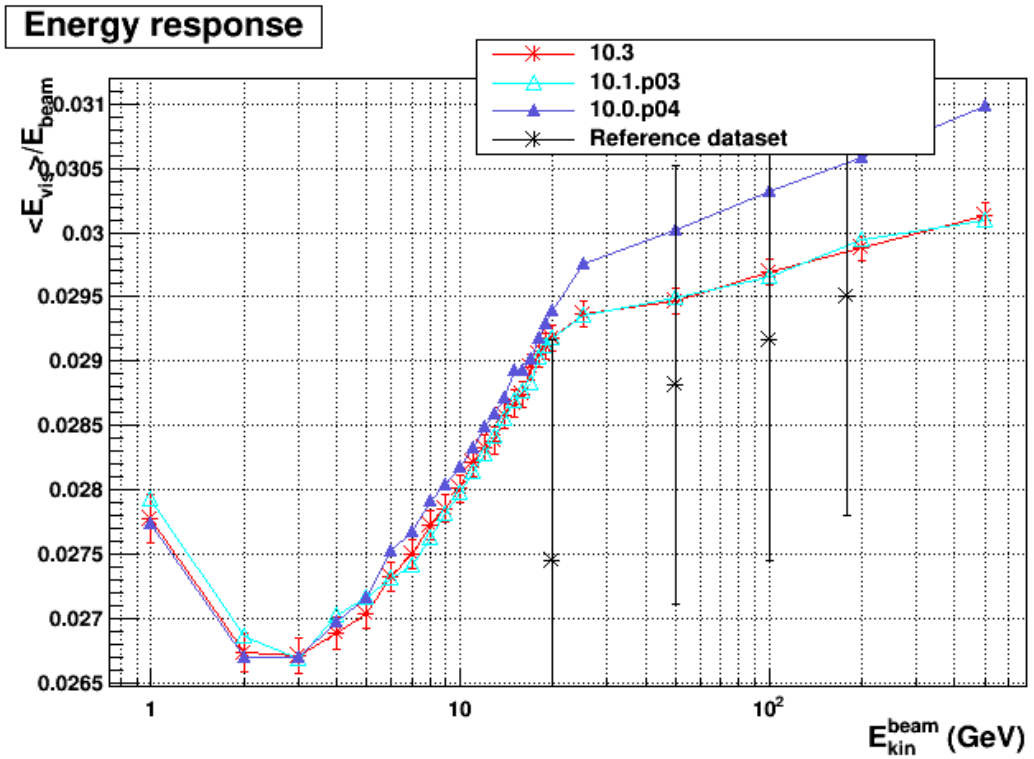


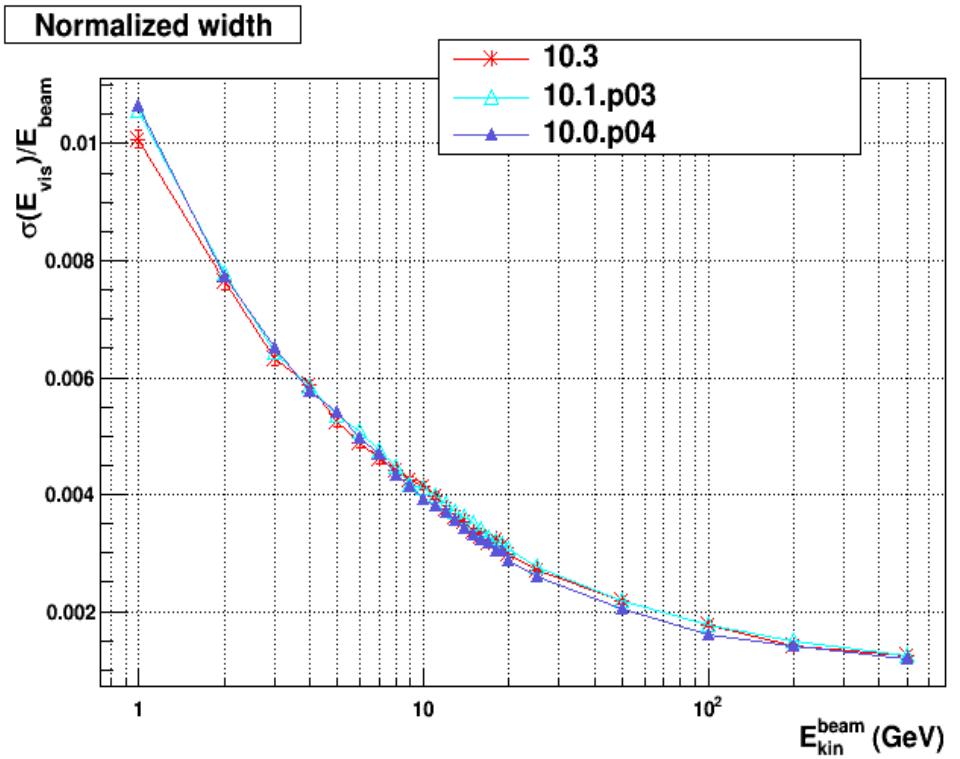


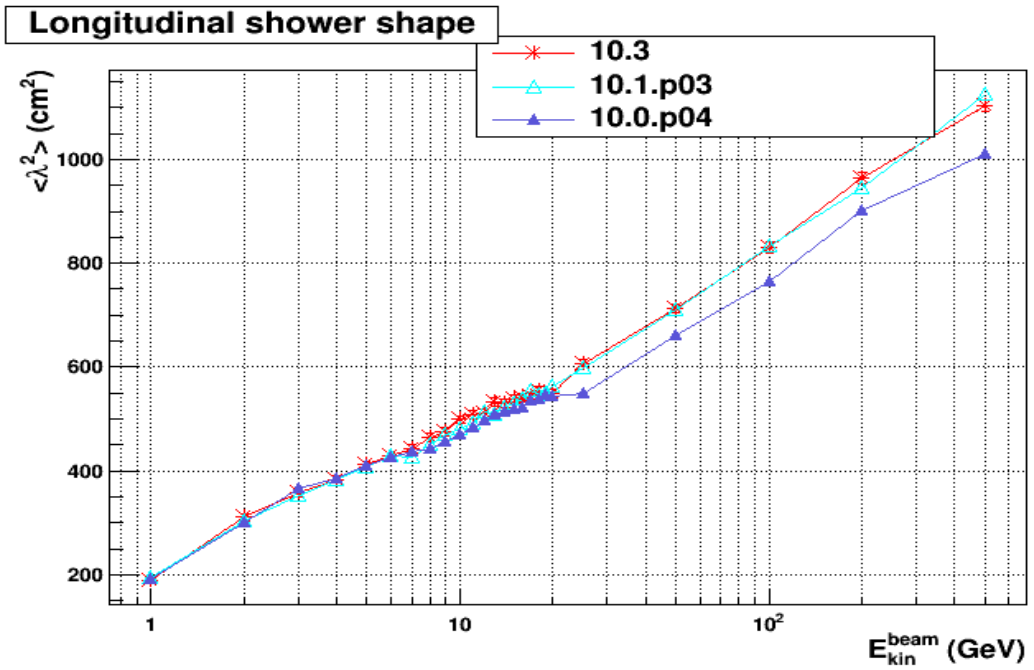
Pion showers
in Simplified Calorimeters
QGSP_FTFP_BERT
Comparing G4 versions:
10.3 , 10.1.p03 , 10.0.p04

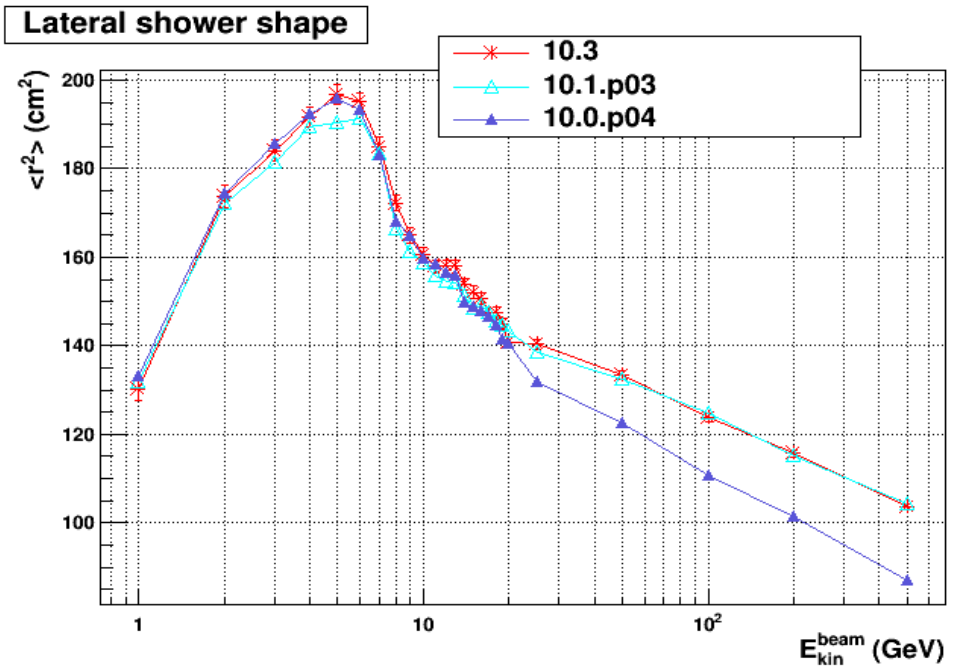
QGSP_FTFP_BERT

π^- on Fe-Sci



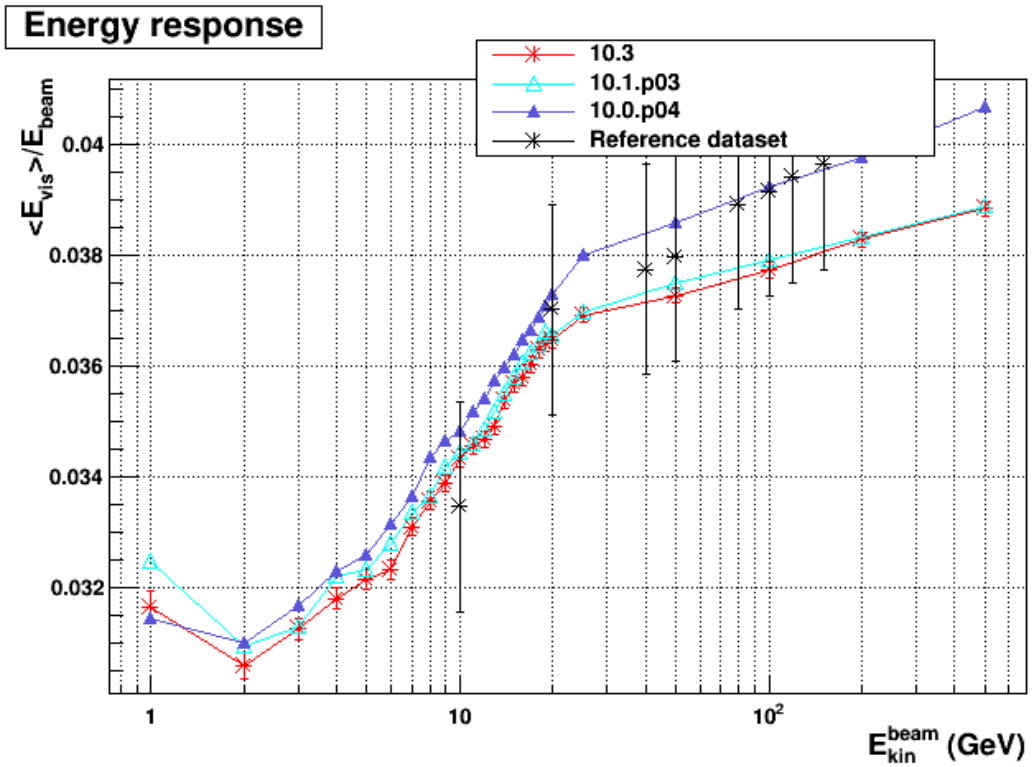


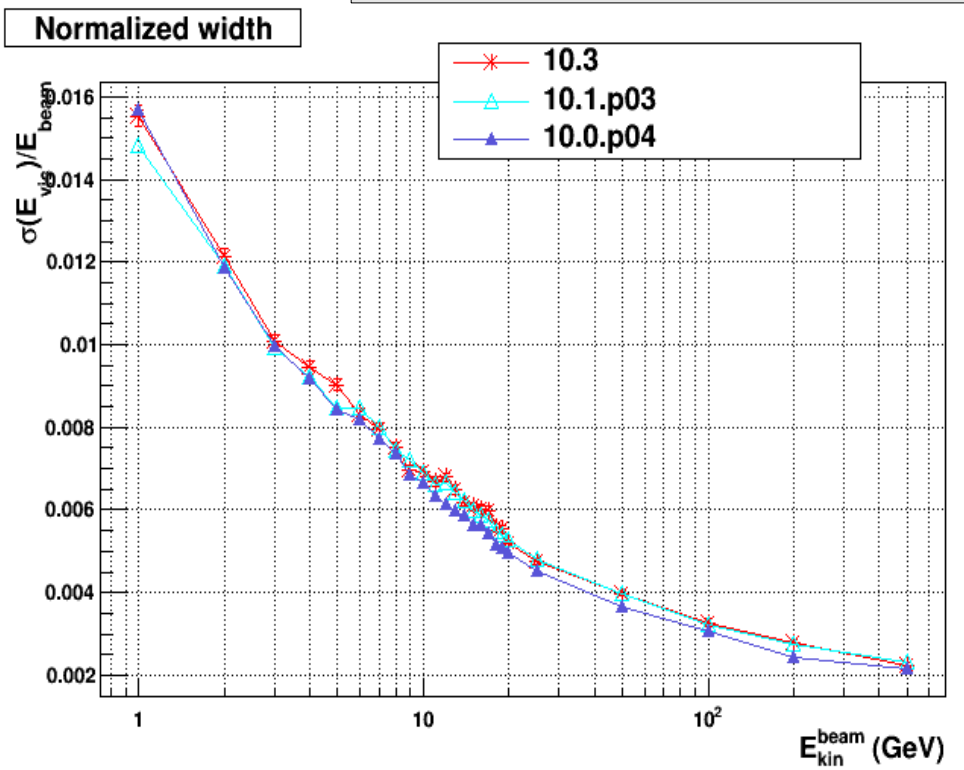


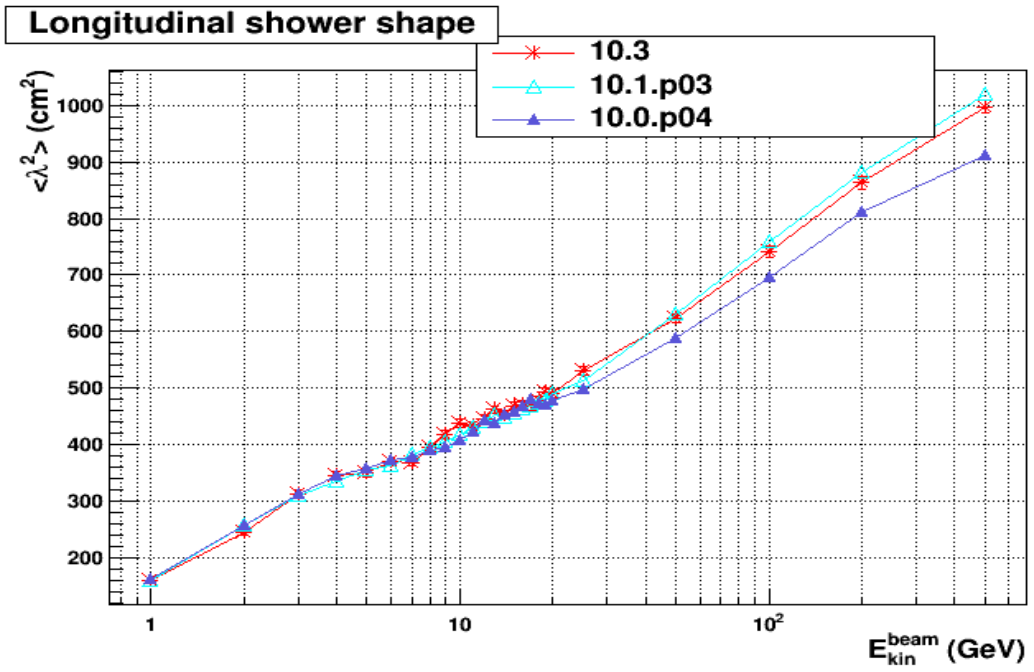


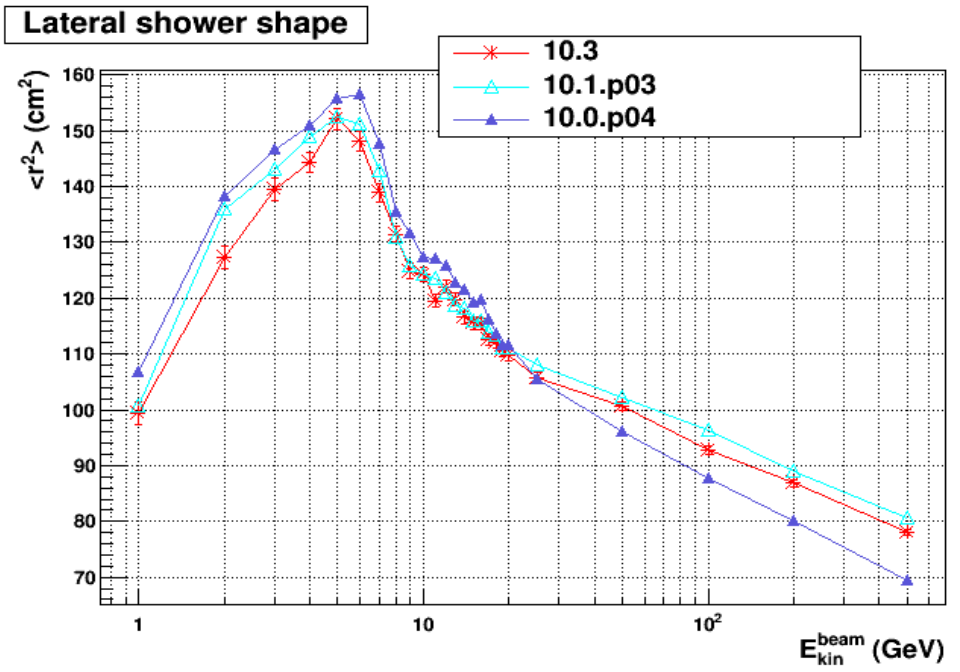
QGSP_FTFP_BERT

π^- on Cu-LAr





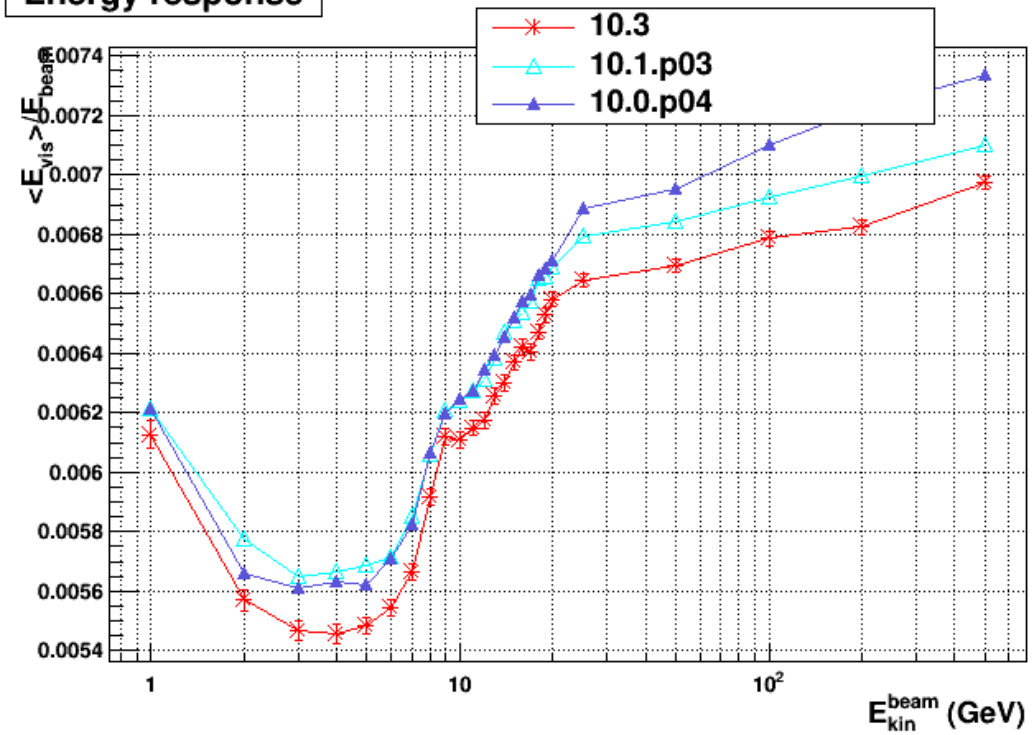




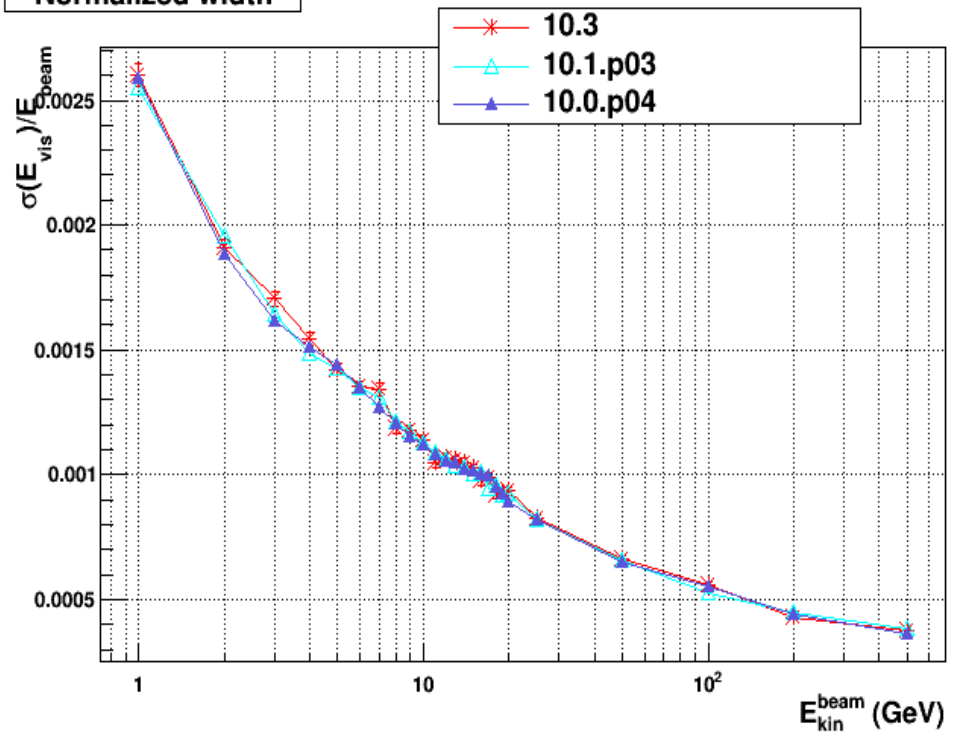
QGSP_FTFP_BERT

π^- on W-LAr

Energy response



Normalized width



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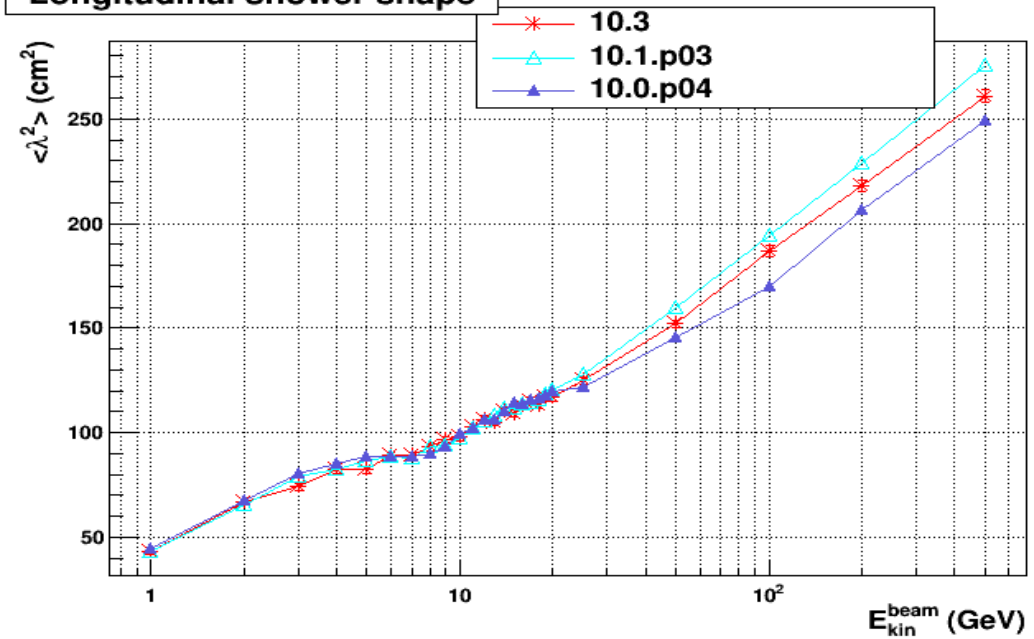

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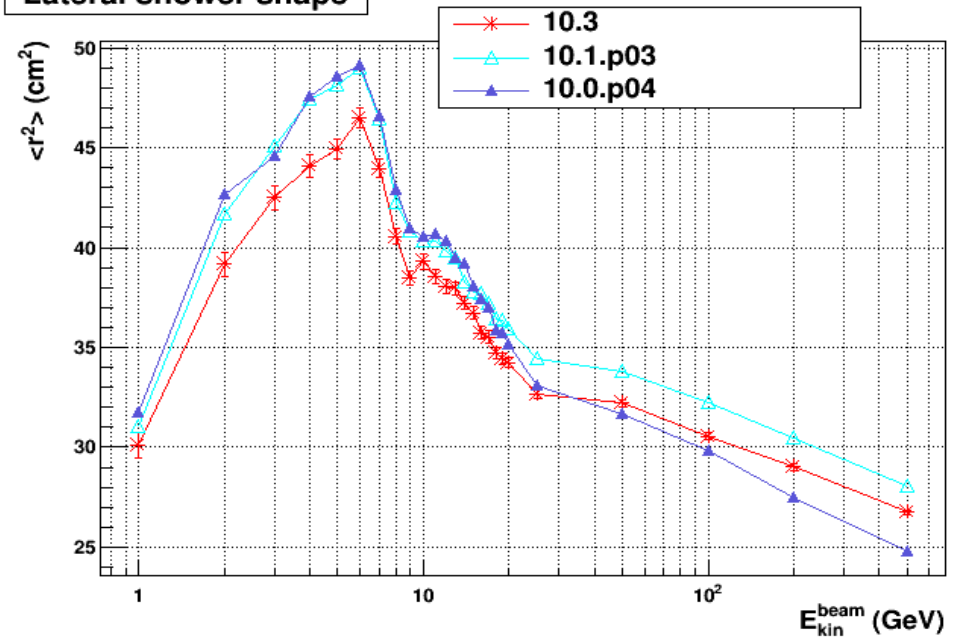
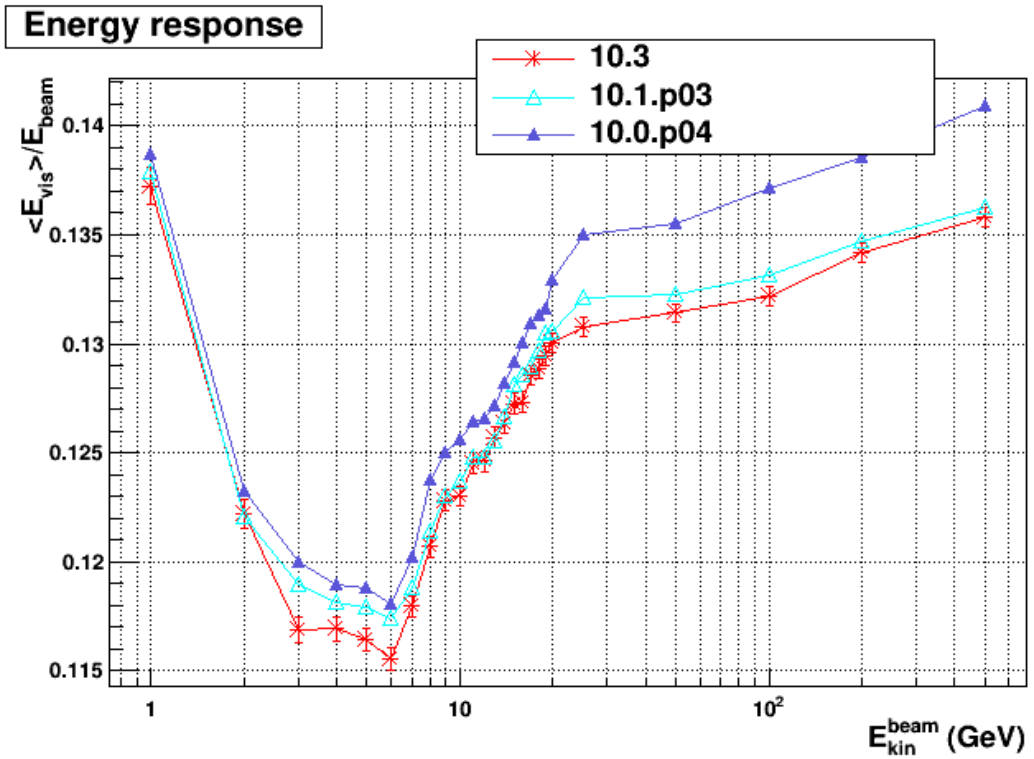
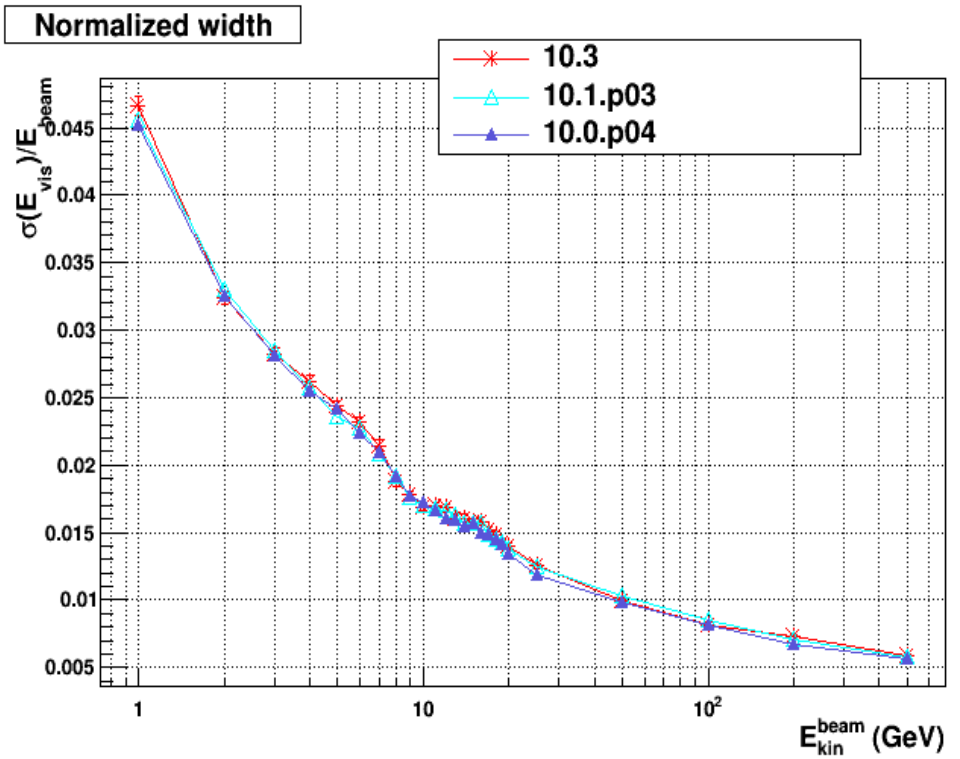
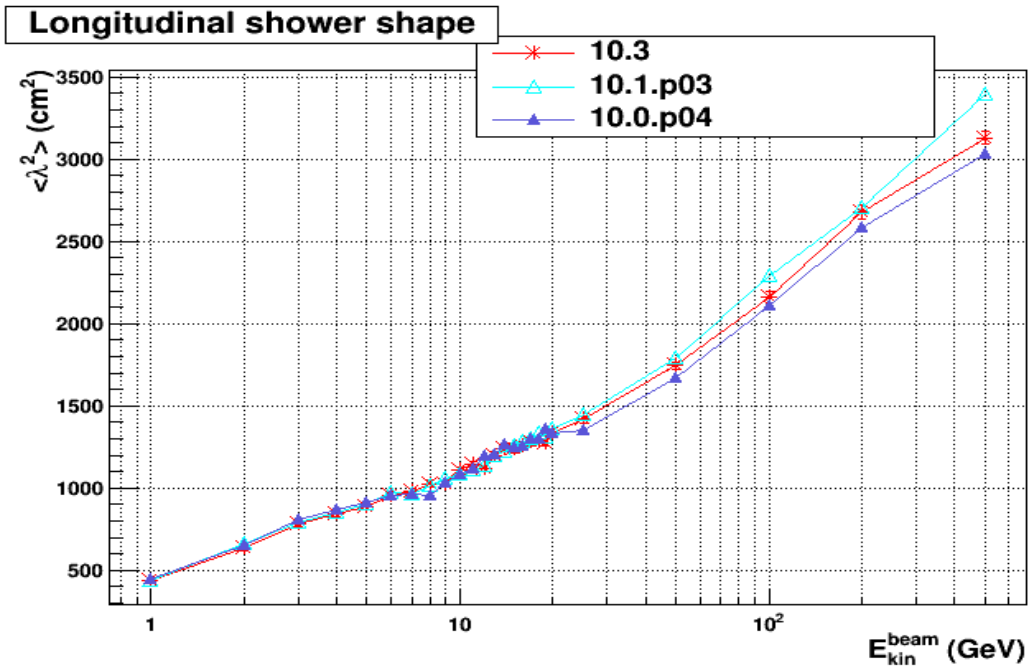


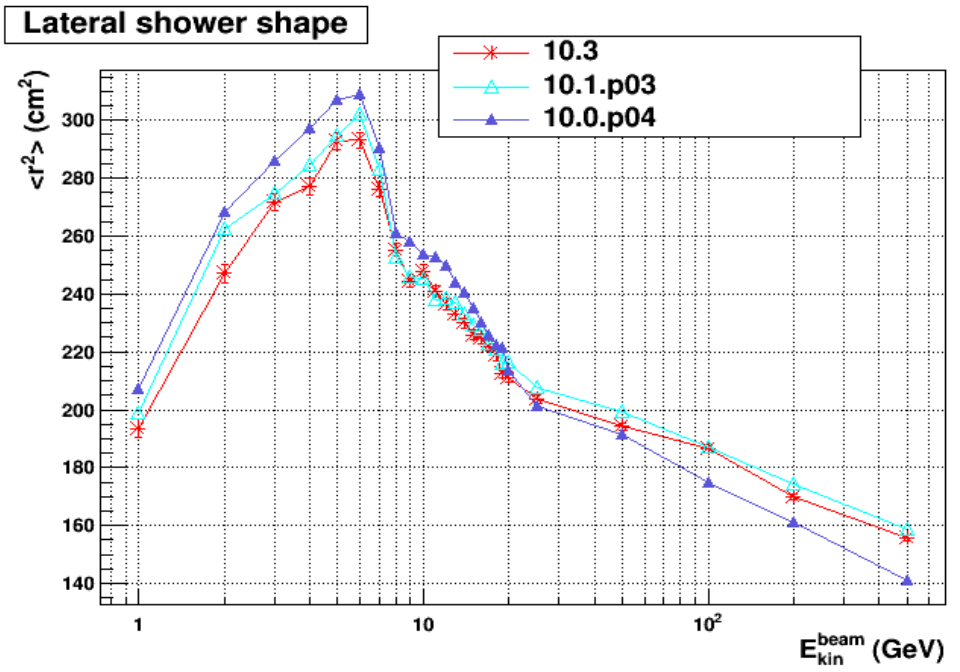
QGSP_FTFP_BERT

π^- on Pb-LAr

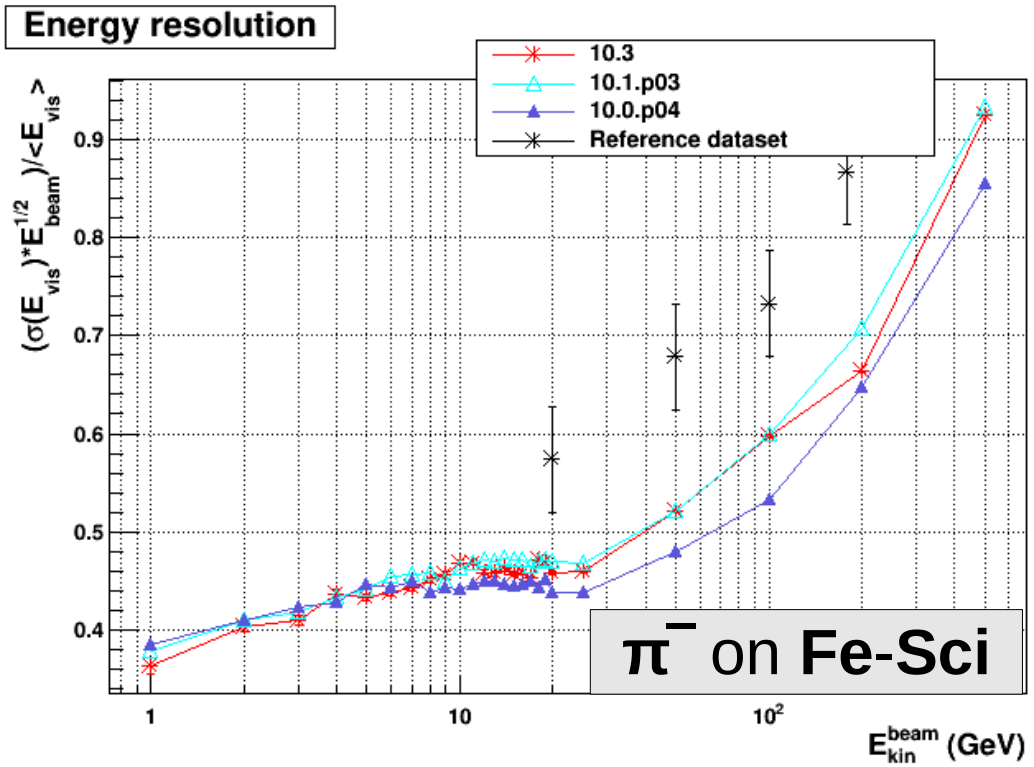


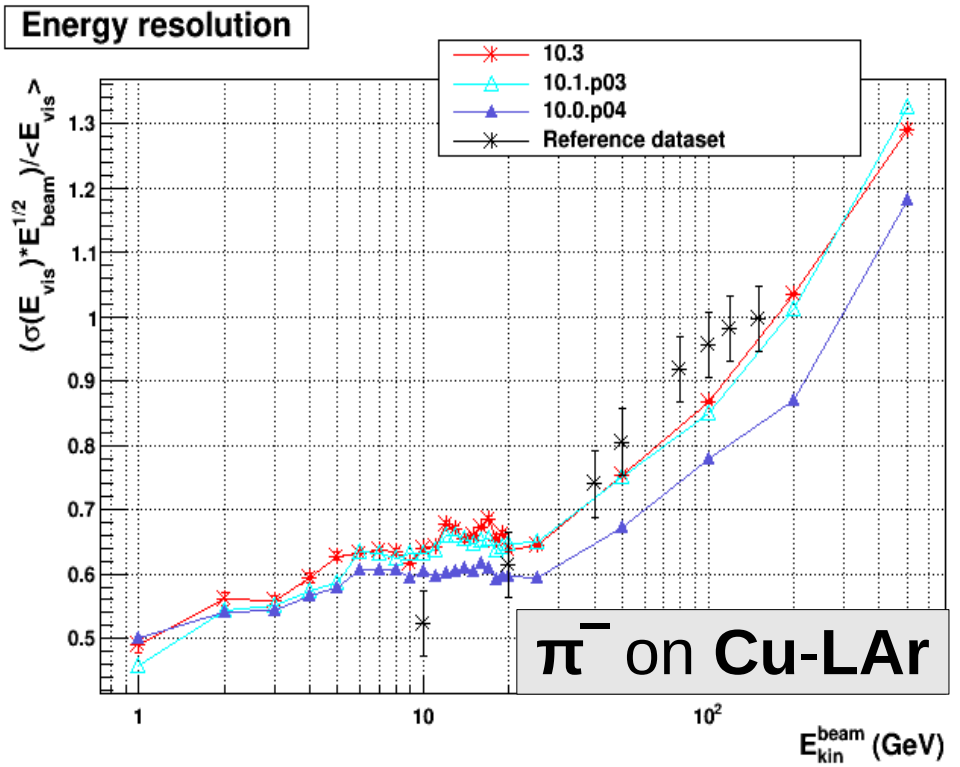


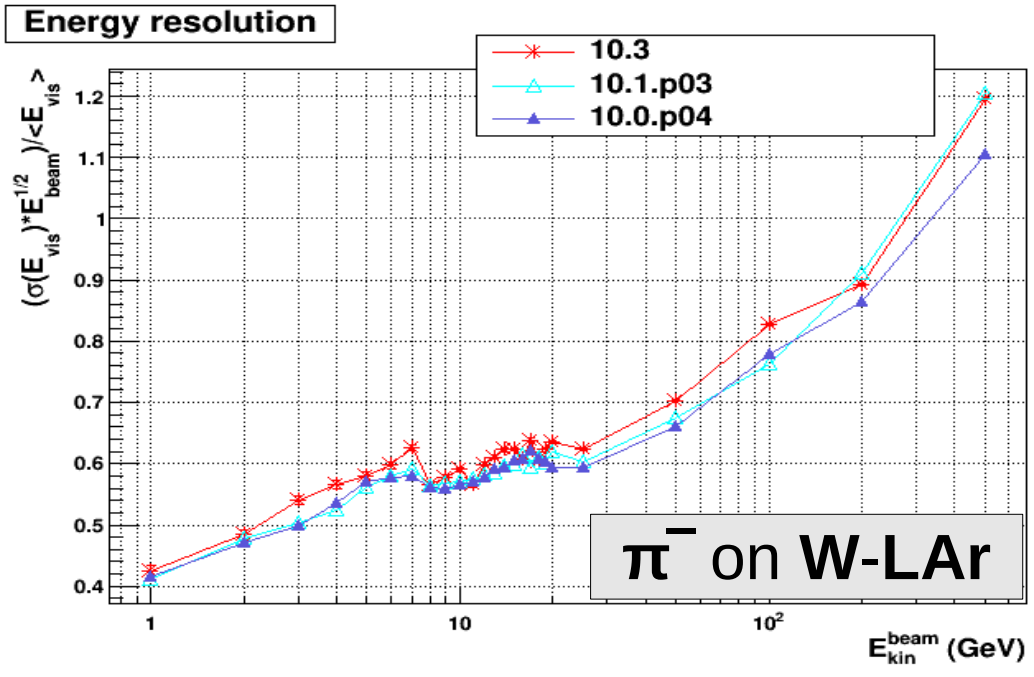


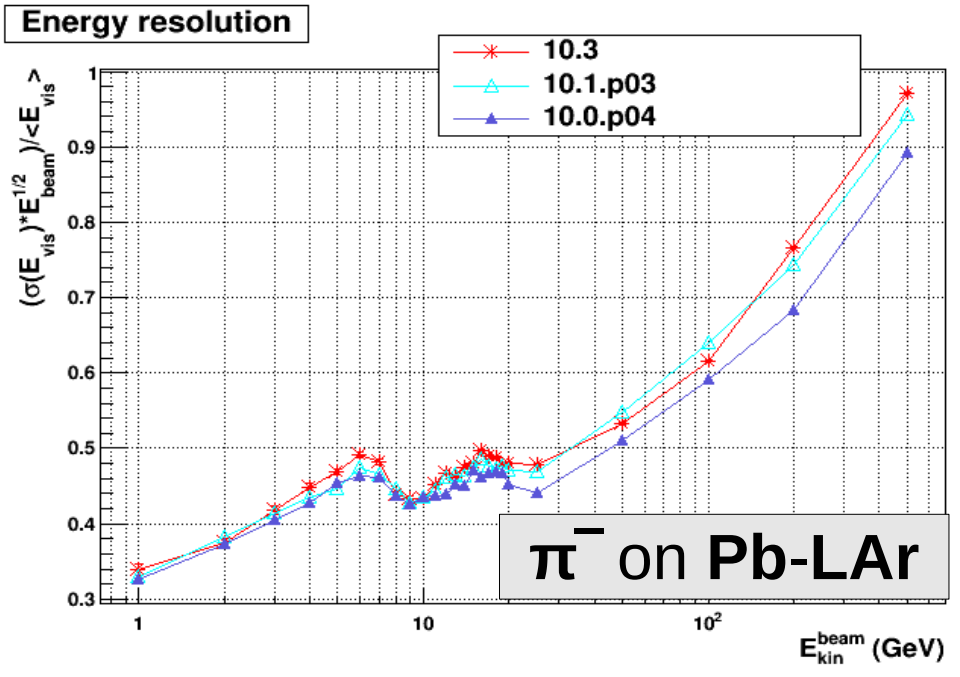


QGSP_FTFP_BERT : Energy Resolution









Pion showers
in Simplified Calorimeters
Comparing Physics Lists in G4 **10.3** :

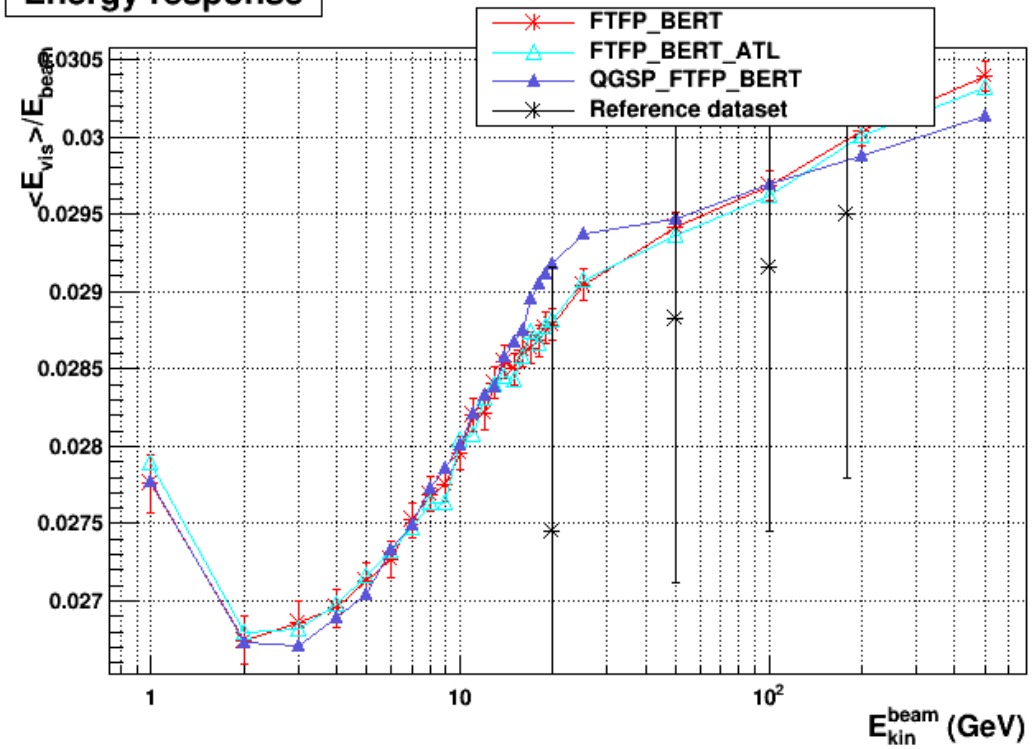
FTFP_BERT

FTFP_BERT_ATL

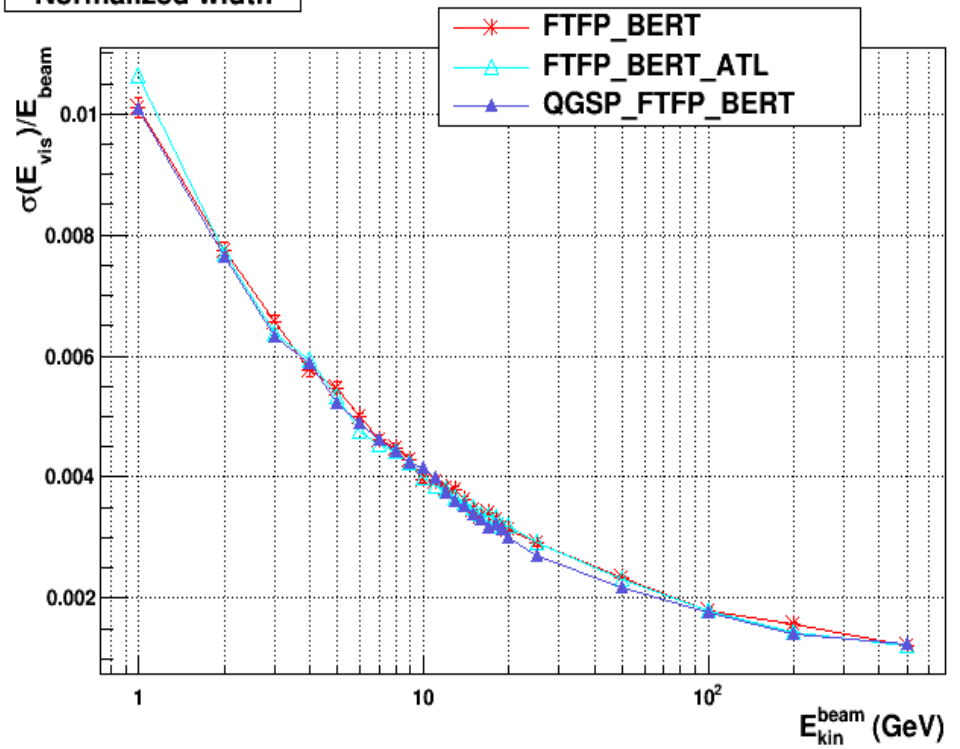
QGSP_FTFP_BERT

π^- on Fe-Sci

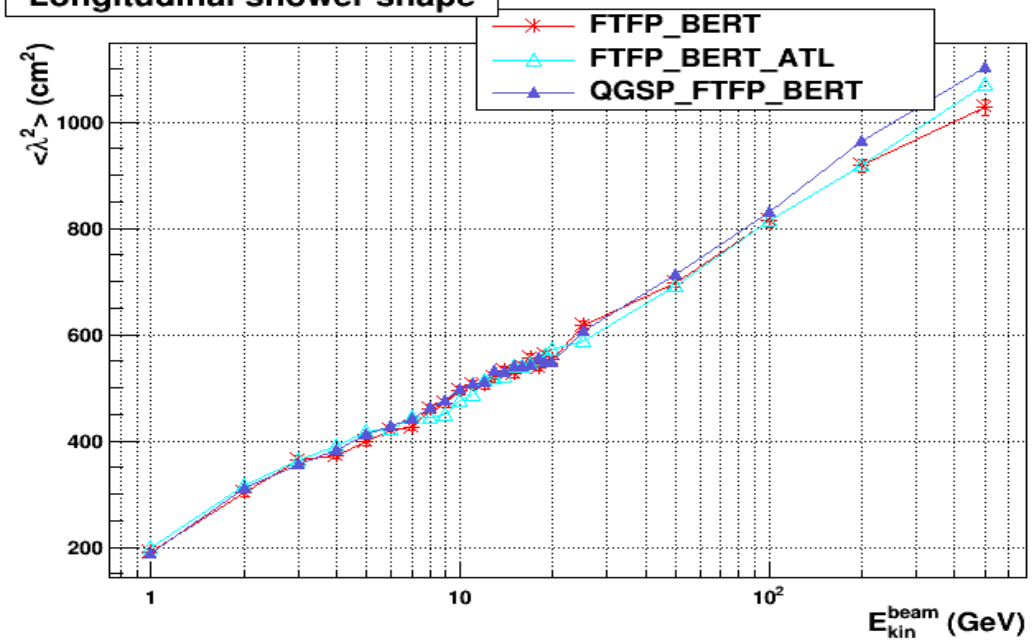
Energy response



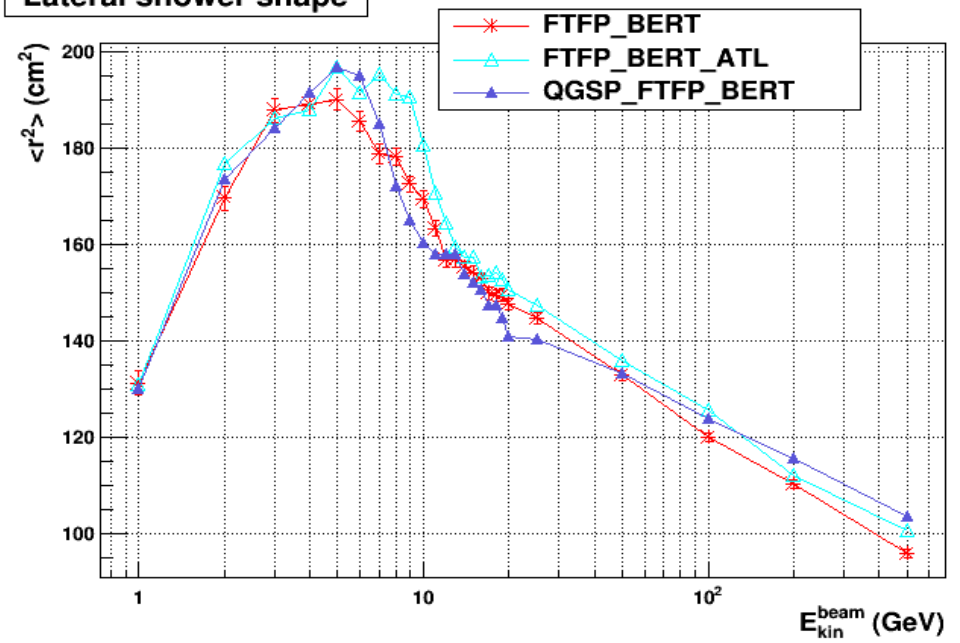
Normalized width



Longitudinal shower shape

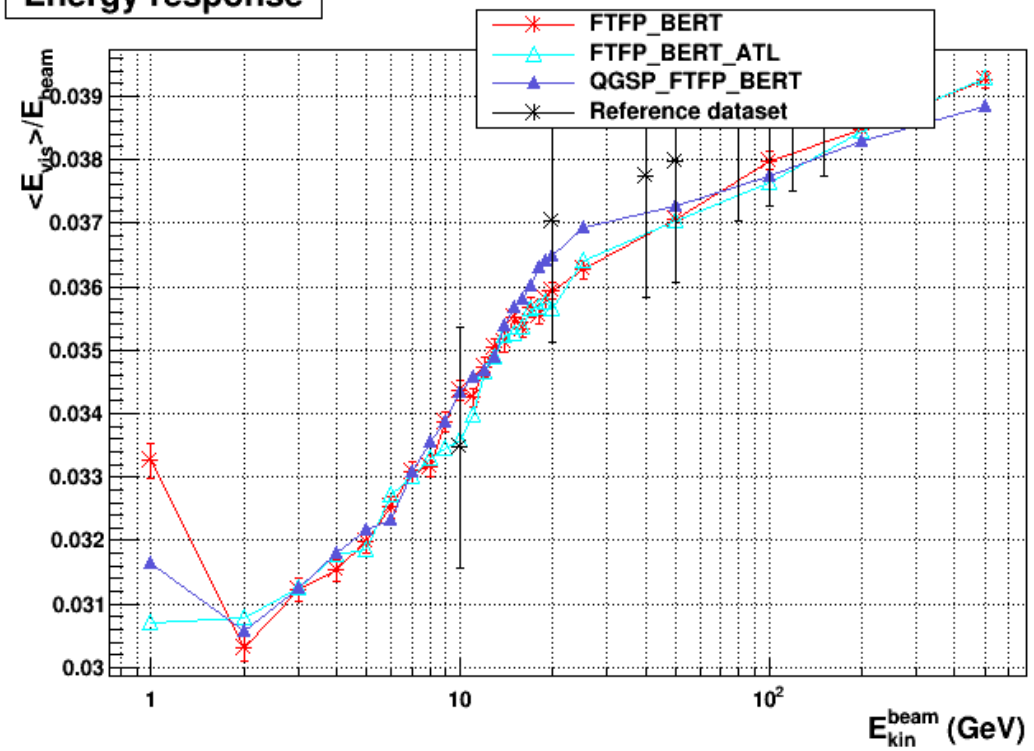


Lateral shower shape

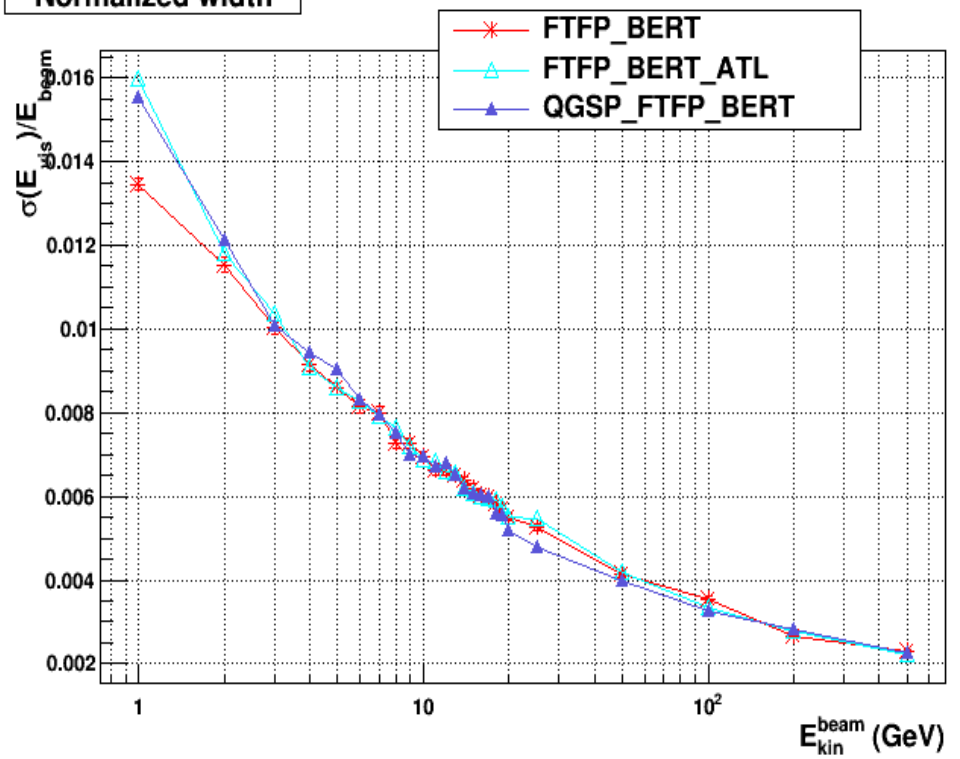


π^- on Cu-LAr

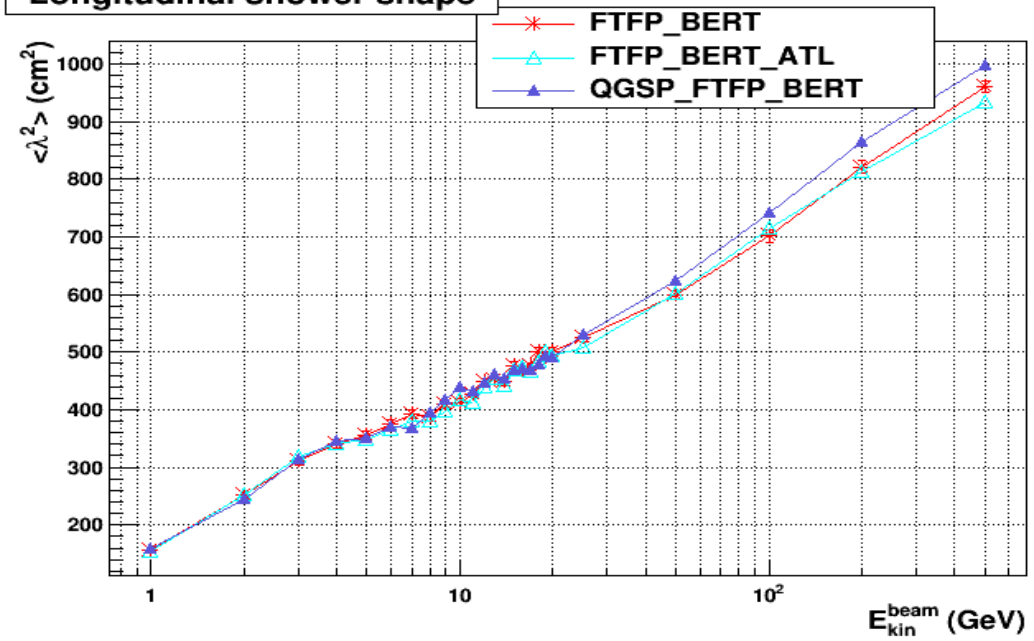
Energy response



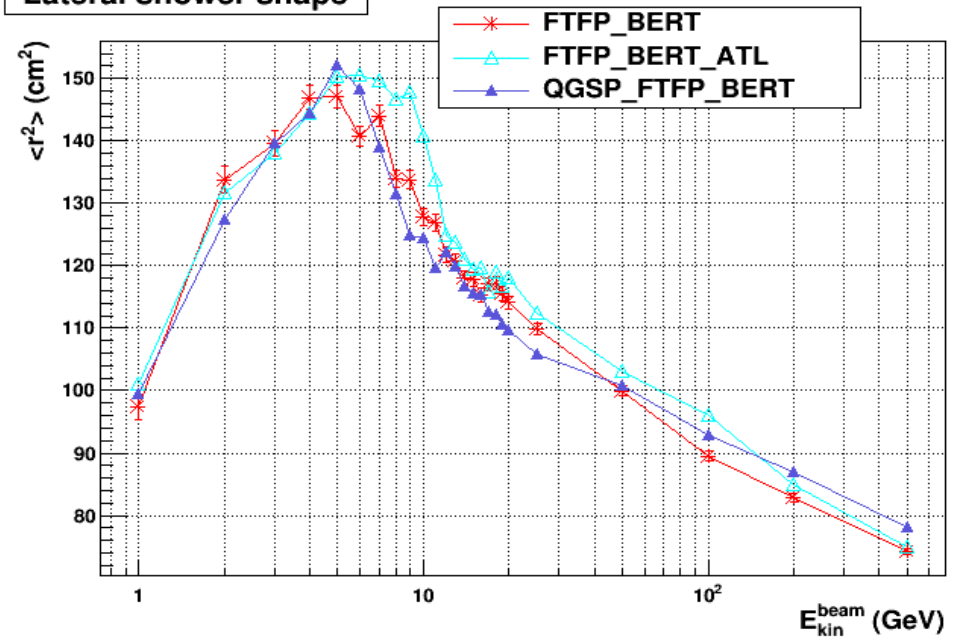
Normalized width



Longitudinal shower shape

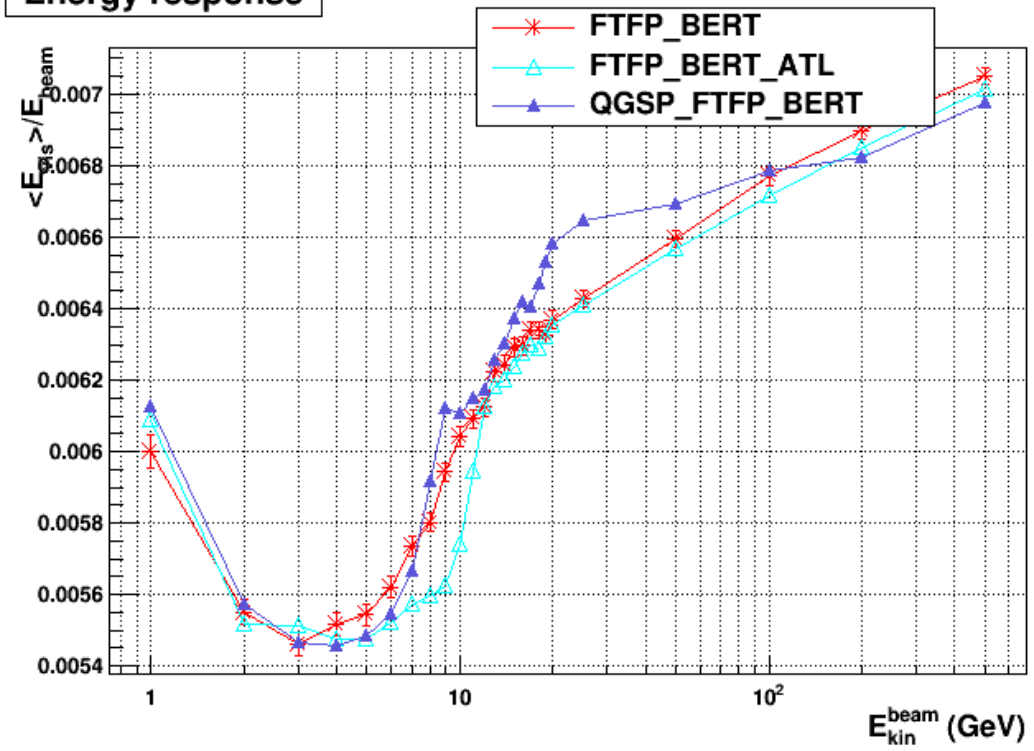


Lateral shower shape

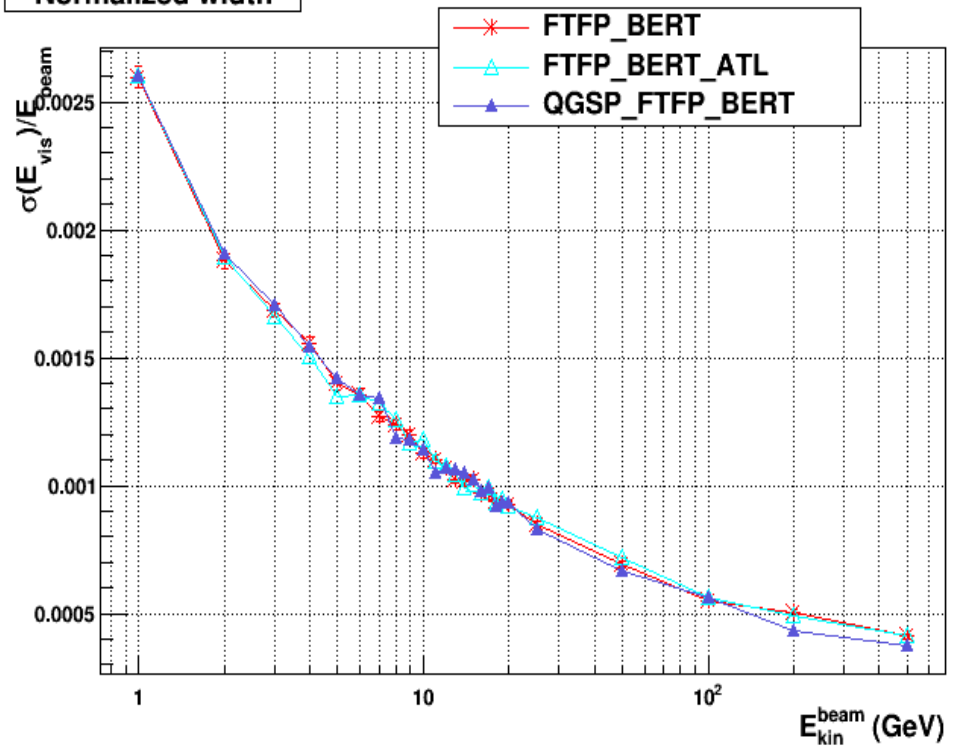


π^- on W-LAr

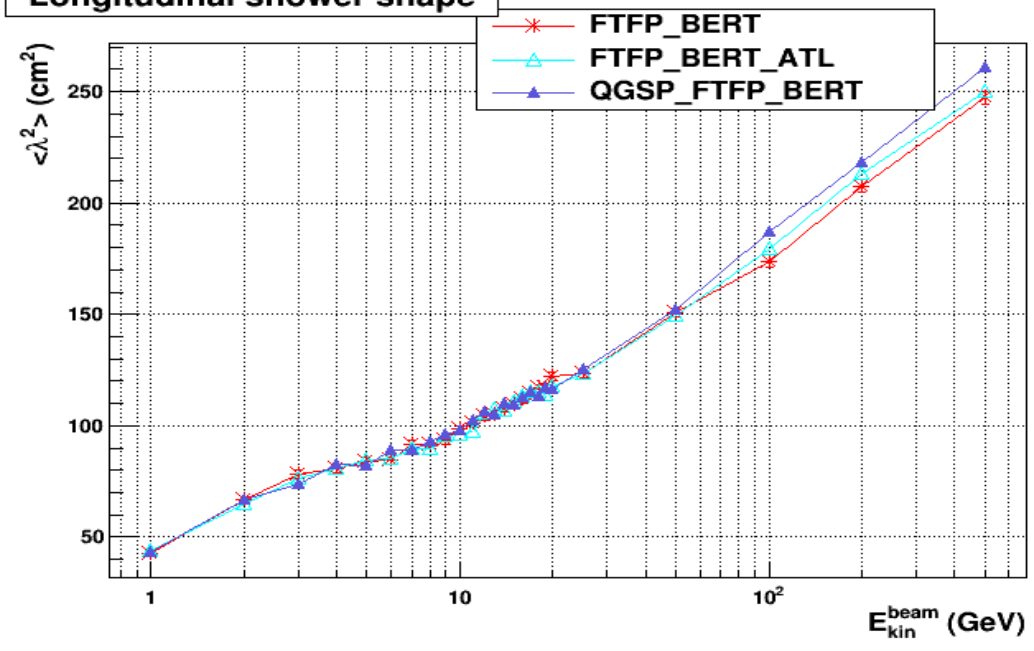
Energy response



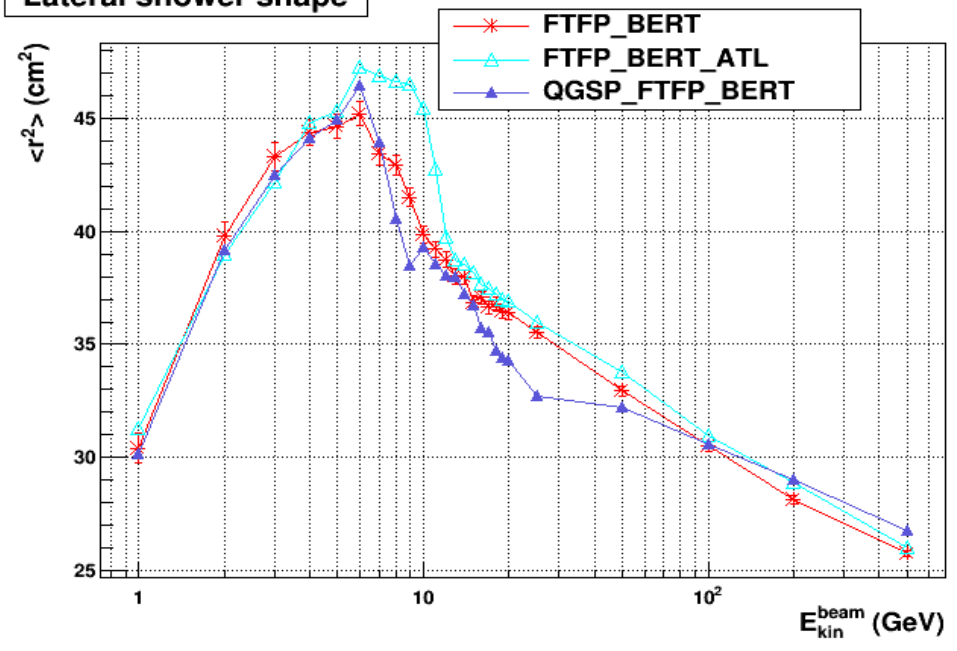
Normalized width



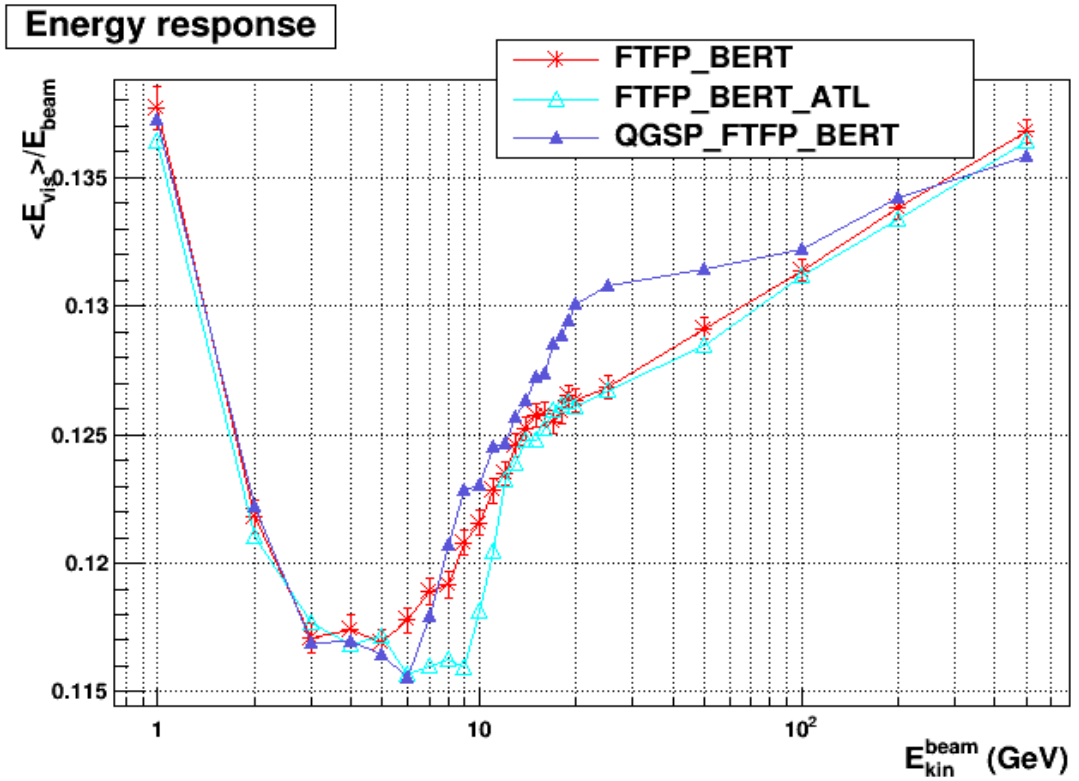
Longitudinal shower shape

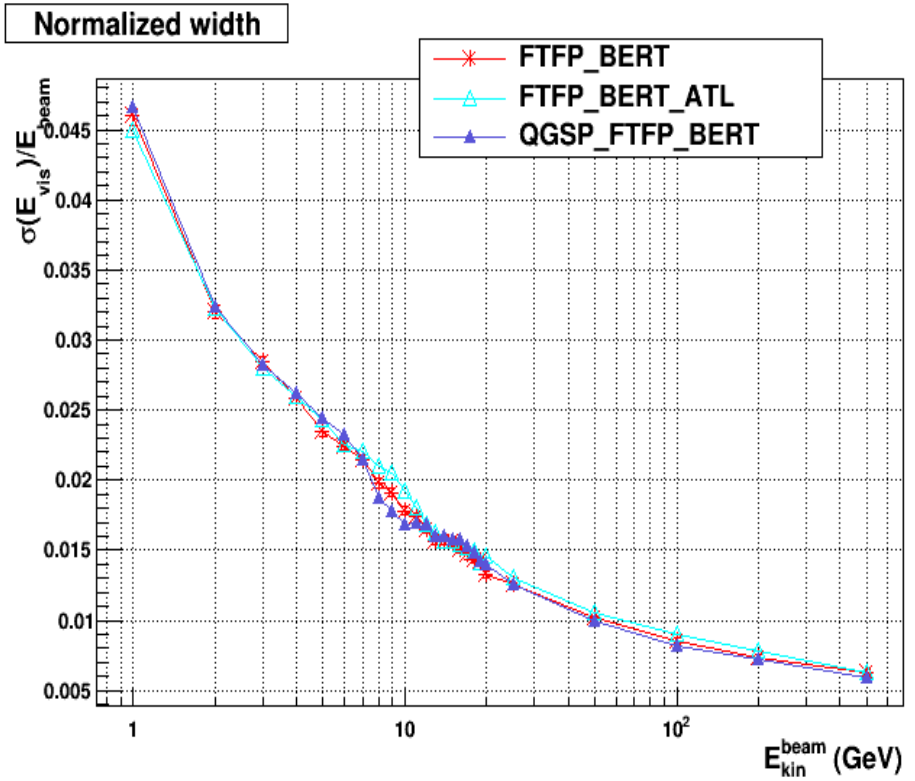


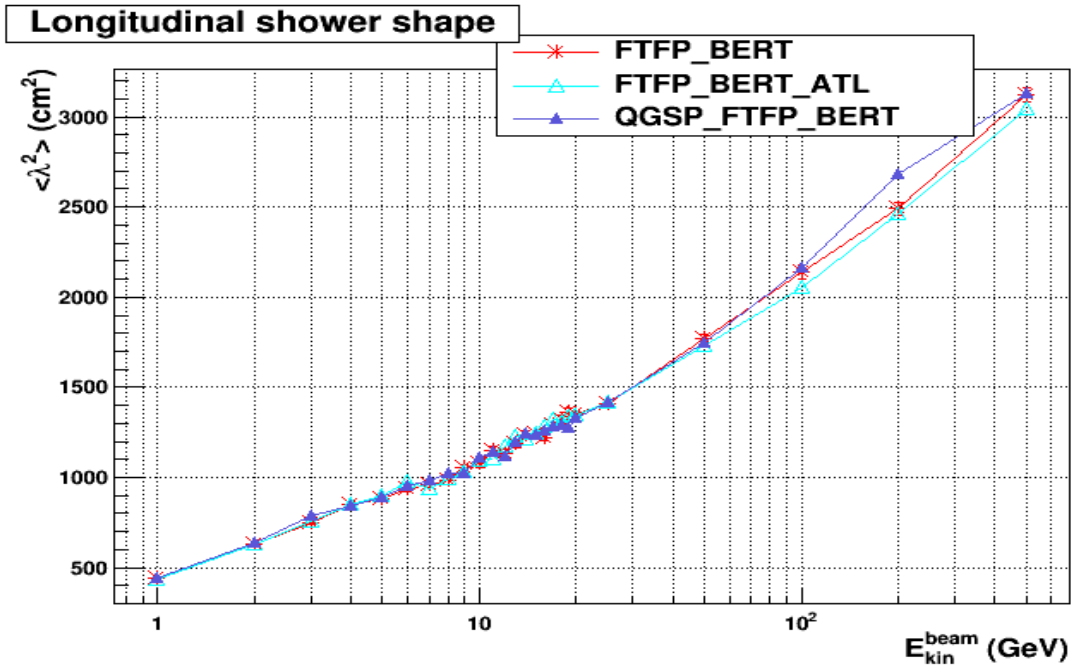
Lateral shower shape

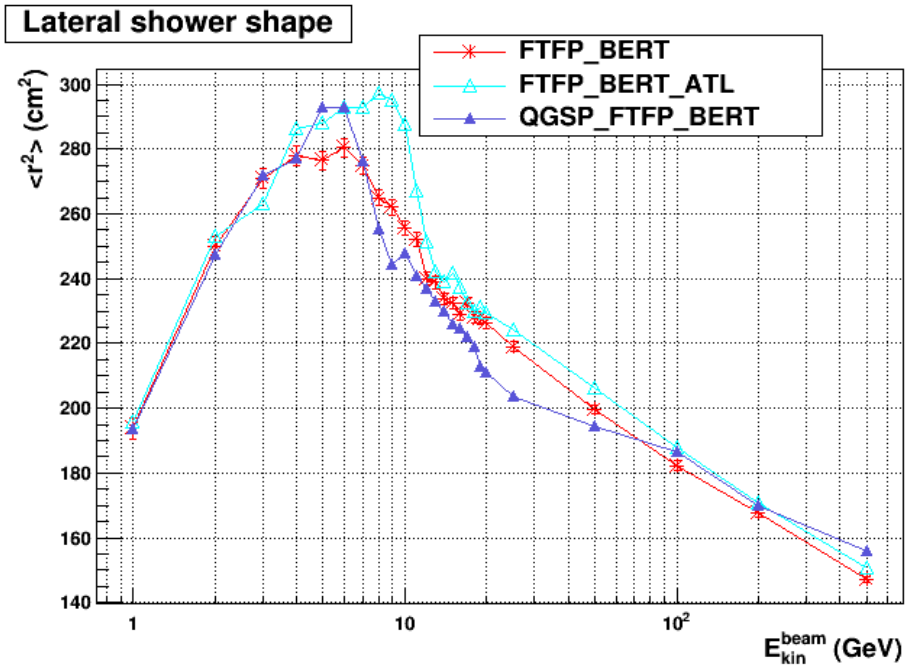


π^- on Pb-LAr


Energy response
FTFP_BERT
FTFP_BERT_ATL
QGSP_FTFP_BERT
<E_vis>/E_beam
0.135
0.13
0.125
0.12
0.115
1
10
10^2
E_kin^beam (GeV)


Normalized width
FTFP_BERT
FTFP_BERT_ATL
QGSP_FTFP_BERT
σ(E_vis)/E_beam
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
1
10
10^2
E_kin^beam (GeV)


Longitudinal shower shape
FTFP_BERT
FTFP_BERT_ATL
QGSP_FTFP_BERT
<λ^2> (cm^2)
3000
2500
2000
1500
1000
500
1
10
10^2
E_kin^beam (GeV)


Lateral shower shape
FTFP_BERT
FTFP_BERT_ATL
QGSP_FTFP_BERT
<r^2> (cm^2)
300
280
260
240
220
200
180
160
140
1
10
10^2
E_kin^beam (GeV)

Energy Resolution