

Hadronic Highlights of G4 10.1

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Particles

- Updated particle properties to [PDG-2014](#)
- [Mass width](#) is taken into account in decays of short-lived hadrons: daughter hadrons have dynamical mass according to Breit-Wigner distribution
- [Ions and isomers are instantiated on-the-fly](#), i.e. during the event loop as they become necessary
 - In 10.0, all ions and isomers were instantiated before the event loop

Fritiof (FTF) model

- The model has been significantly improved, resulting in **closer agreement with thin-target data** (See backup plots)
 - Revisions in string fragmentation affect the meson production, and in particular the π^0 fraction of hadronic showers
 - This is largely counteracted by other improvements of FTF and an imposed reduction of ω^0 production
 - The overall effect on hadronic showers is found to be small in our simplified calorimeters
 - See backup plots

Quark-Gluon-String (QGS) model

- Improvements in the **fragmentation part** of QGS
 - This implies that the hadronic showers produced with QGS-based physics lists (e.g. QGSP_FTFP_BERT) become wider and longer, and with a lower energy response, in closer agreement with the ones produced by FTF
 - See backup plots

Bertini-like (BERT) model

- New **pi-nucleon 2-body angular distributions**
 - Below 2.6 GeV, distributions taken from SAID phase shift calculations with Coulomb phase removed.
Above 2.6 GeV, taken from data.

Liege Intranuclear Cascade (INCLXX) model

- The INCLXX model has been extended up to **15-20 GeV** incident energy
 - The physics lists FTFP_INCLXX(_HP) and QGSP_INCLXX(_HP) use INCLXX for pions, protons, and neutrons below 20 GeV, and the string model (FTF or QGS) above 15 GeV
 - For kaons and hyperons BERT is used

Precompound / de-excitation

- Mostly technical improvements to reduce the memory footprint and churn
- Enabled **isomer production**
 - Mechanism was in place already in G4 10.0, but not used
 - **Non-reproducibility is sometimes caused by the isomers, under study**

Photon Evaporation and Radioactive Decay

- New data-sets:
 - **G4PhotonEvaporation-3.1**
 - **RadioactiveDecay.4.2**
- **Disclaimer**
radioactive decay in G4 10.1 is OK except when isomeric transitions are invoked
 - *α , β^+ , β^- and electron capture should be OK*
 - *Isomeric transitions got worse because they are based on G4PhotonEvaporation*
 - *A fix is available, but is still being tested*

NeutronHP & ParticleHP

- Improvements of NeutronHP for **multi-threading**.
Requires new data set **G4NDL-4.5**
- **ParticleHP** is a new module for treatment of low-energy charged particles (p, d, t, α , etc.), based on neutron_hp. This is still under testing, but it is aimed to replace neutron_hp in the future

Physics Lists

- Switched on **muon-nuclear** by default in all physics lists
- In all physics lists using neutron-HP, the production threshold range of proton is set to zero
 - to simulate all recoils from elastic scattering
- New hadron elastic scattering in FTFP_BERT_TRV
- New experimental physics lists **ShieldingM** and **NuBeam**
 - ShieldingM is based on Shielding with BERT – FTFP transition at 9.5 – 9.9 GeV (instead of 4.0 – 5.0 GeV)
 - NuBeam is based on FTFP_BERT with BERT – FTFP transition at 3.0 – 3.5 GeV for protons, pions and kaons, and for protons above 100 GeV uses QGSP+G4LundStringFragmentation
- The physics lists based on INCLXX use this model for pions, protons and neutrons up to 20 GeV

Hadronic showers *(see plots in backup slides)*

- Hadronic showers in G4 **10.1** are similar to those in G4 10.0
- **FTFP_BERT** our recommended HEP physics list
 - To consider also the variant **FTFP_BERT_TRV** and **QBBC**
 - Smoother (because of the wider transition region **3 – 12 GeV**)
 - For FTFP_BERT_TRV, new elastic scattering
 - For QBBC, also use of Binary Cascade (BIC) for protons and neutrons below 1.5 GeV

Changing Hadronic Parameters by Users

Requests from users to change hadronic parameters. This was discussed in the Hadronic Group and the following proposal was accepted by the Geant4 Steering Board

In selected cases, to be evaluated by the Geant4 hadronic group, Geant4 supports changes of hadronic model parameters with partners.

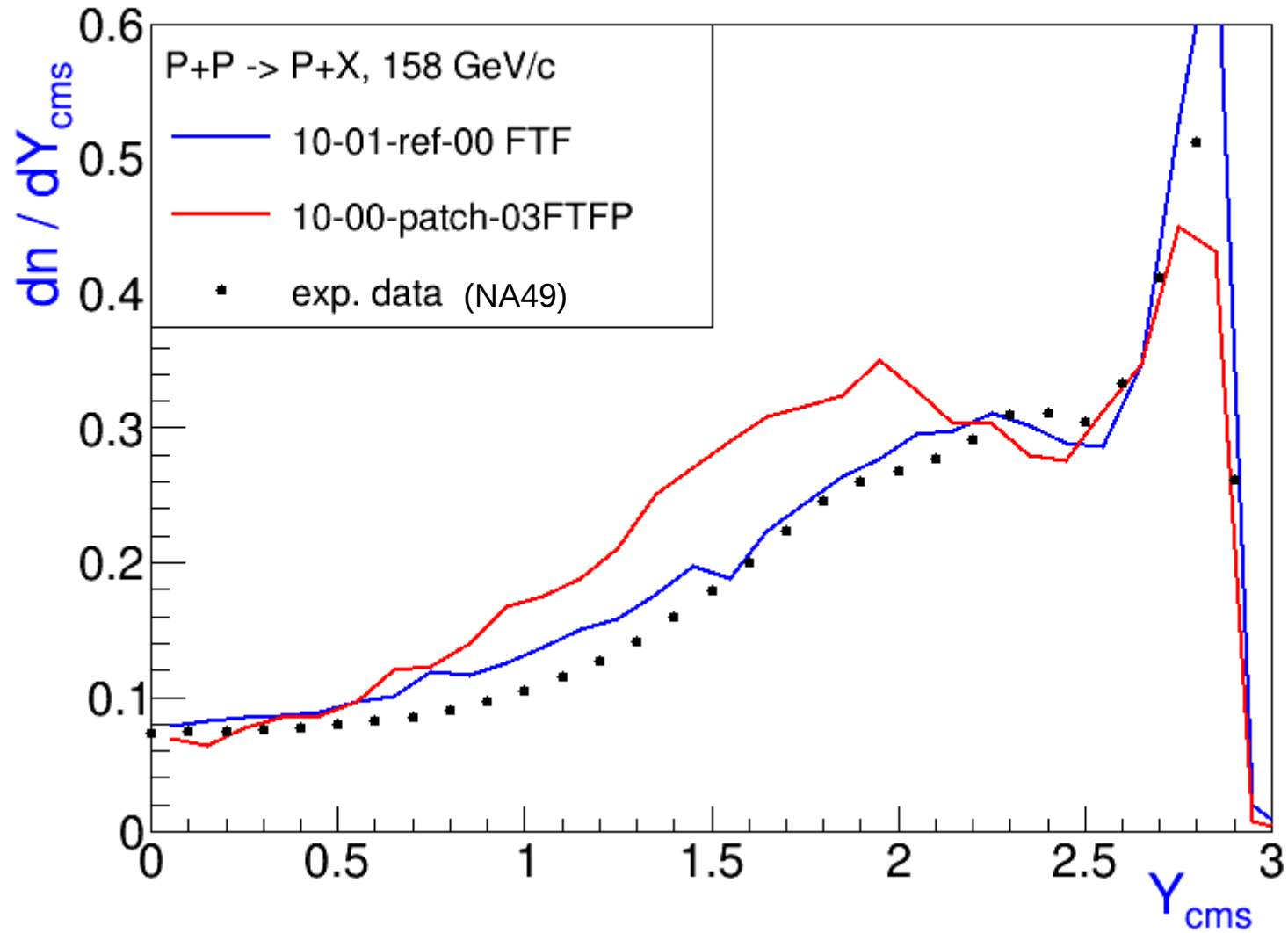
- *For "support" we mean documenting which parameters can be varied and within what range, debugging in the case of problems, and performing some physics validation.*
- *For "partners" we mean Geant4 users willing to help the developers in this effort, to provide feedback and complete information, and to perform physics validation requested by Geant4.*
- *In those cases in which Geant4 does not support changes of hadronic model parameters, users are anyhow allowed to try do it themselves given that code is open, or even seek the help of individual Geant4 collaborators, but no support by the Geant4 collaboration should be expected.*
- *For any use of modified models, each public presentation and publication of the results must clearly state that a modified version of Geant4 has been used, and document the parameters changed and their values.*
- *The Geant4 Steering Board will be informed of all the decisions taken by the* 12 *Hadronic Working Group on this regard.*

Bug in Neutron Elastic Cross Section

- We have found, last week, a “bug” in neutron elastic cross section, affecting the following versions of Geant4:
 9.6 (up to **p03**), **10.0** (up to **p03**) and **10.1**
- What happens is that instead of using **Chips** neutron elastic cross section – as claimed – **Gheisha** neutron elastic cross section is *silently* used
- In practice, the effect is expected to be small, and affecting mainly scintillator-based calorimeters (where **H** is present)
 - The differences between the two neutron cross sections (Chips and Gheisha) are small
 - Comparing with the precise neutron-HP elastic cross section, it seems that in most cases Gheisha is closer to it than Chips
 - So it is not even obvious whether it should be fixed or not (the fix would be trivial)

Backup slides

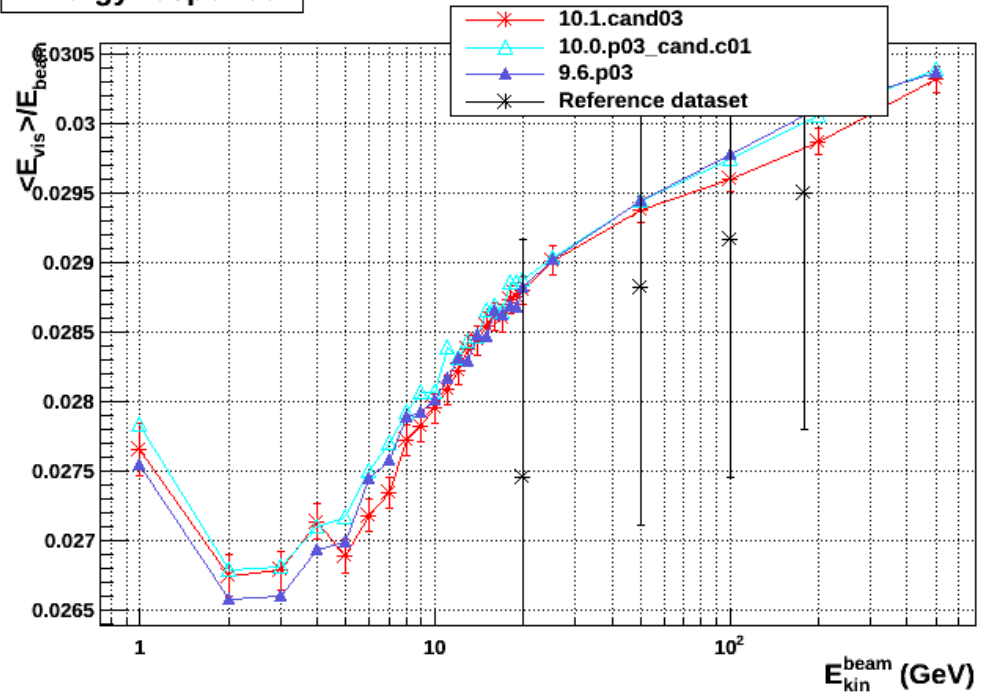
Example of thin-target improvement of FTF



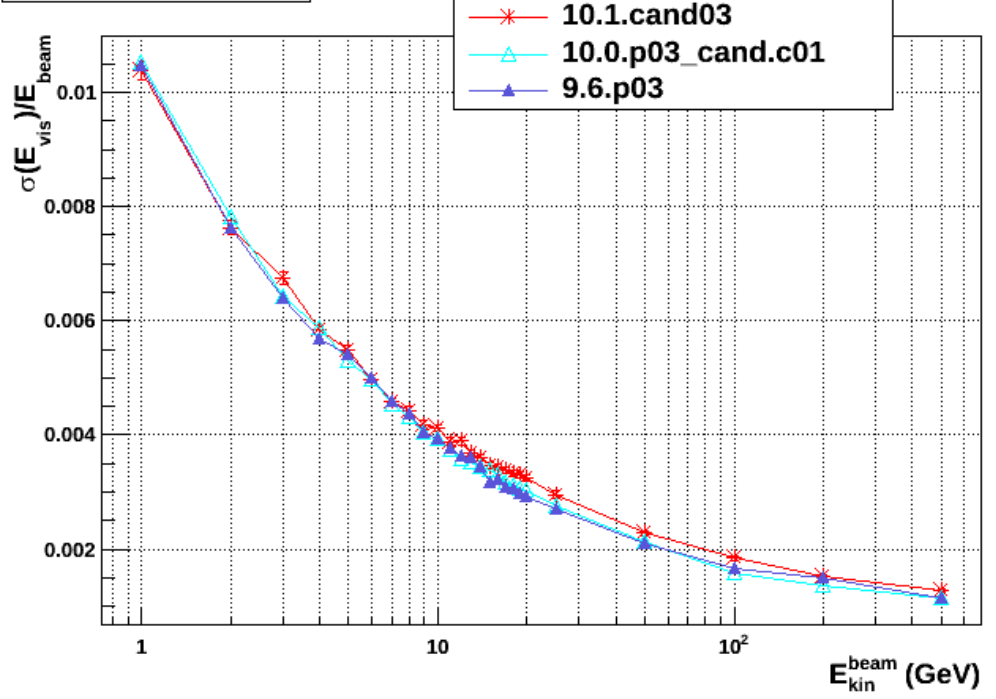
Comparing G4 versions:

10.1 , 10.0.p03 , 9.6.p03

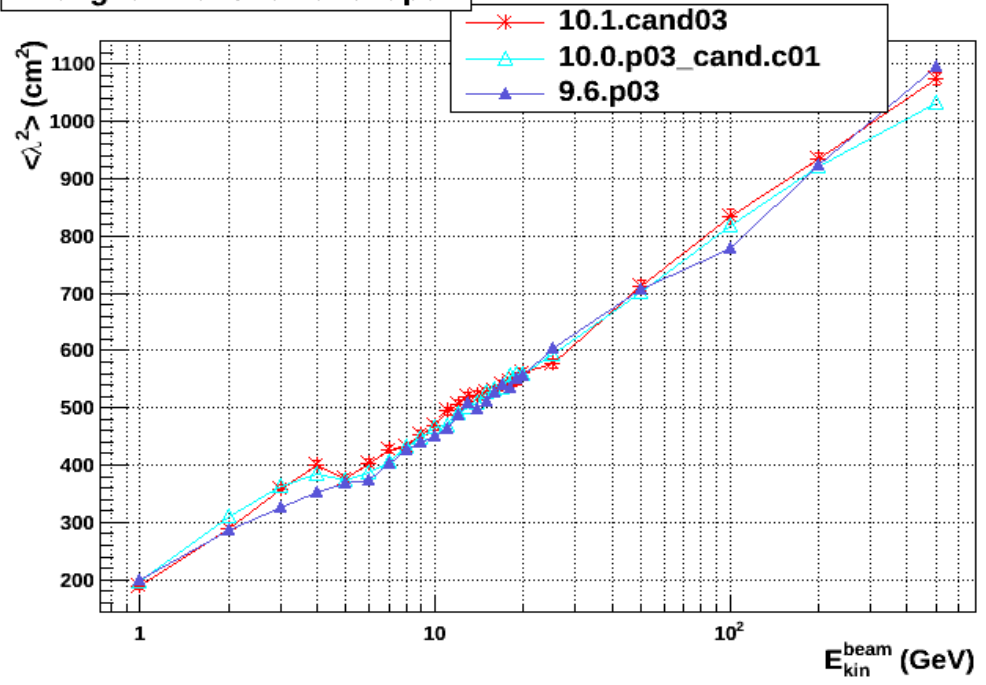
Energy response



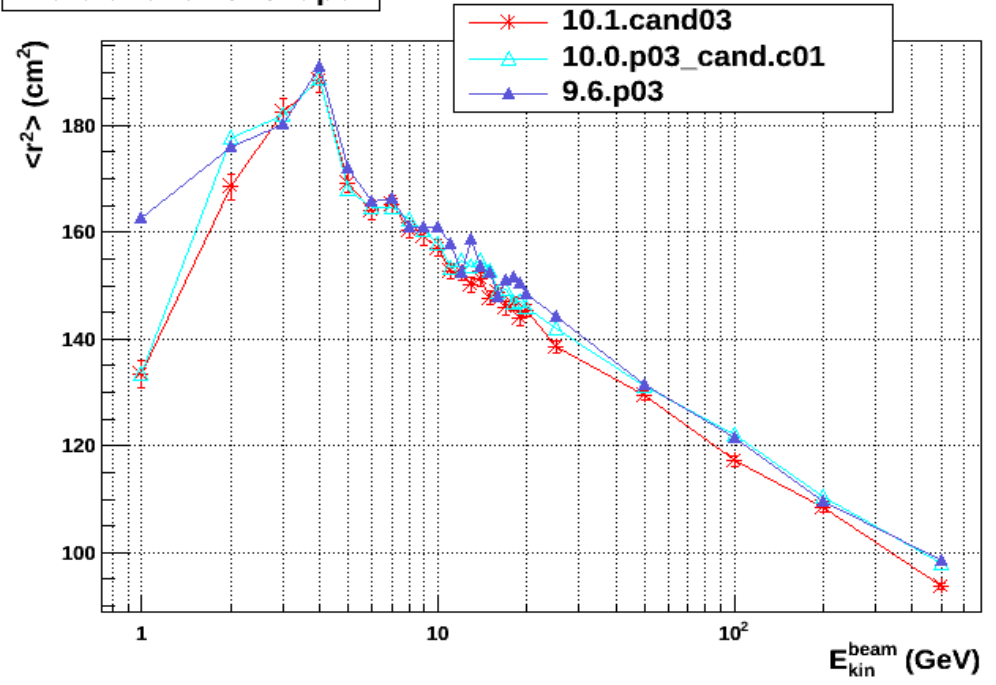
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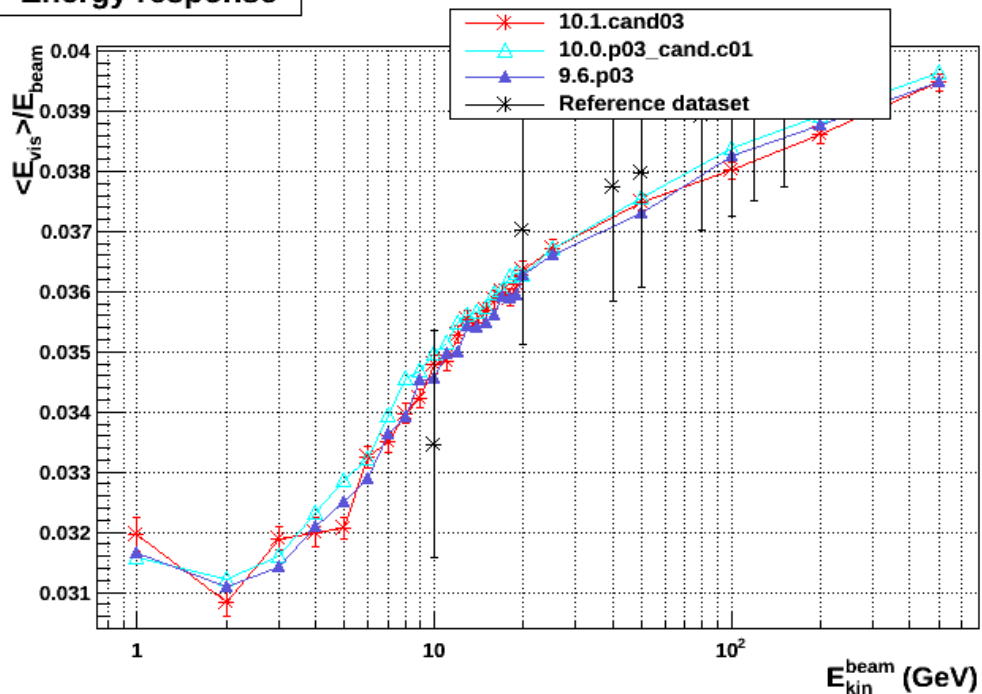
Longitudinal shower shape



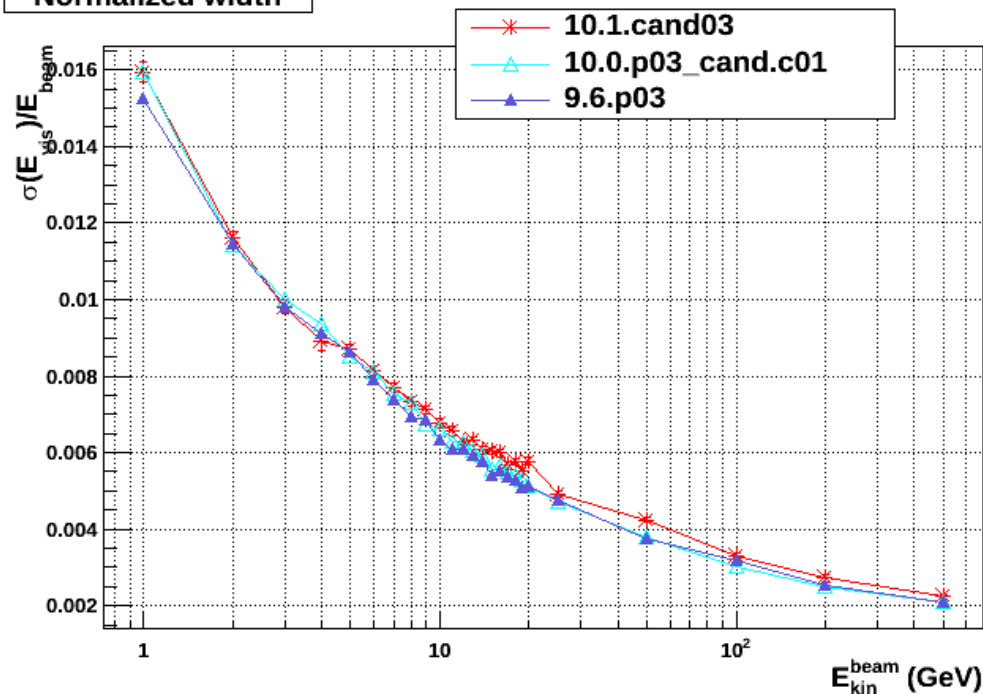
Lateral shower shape



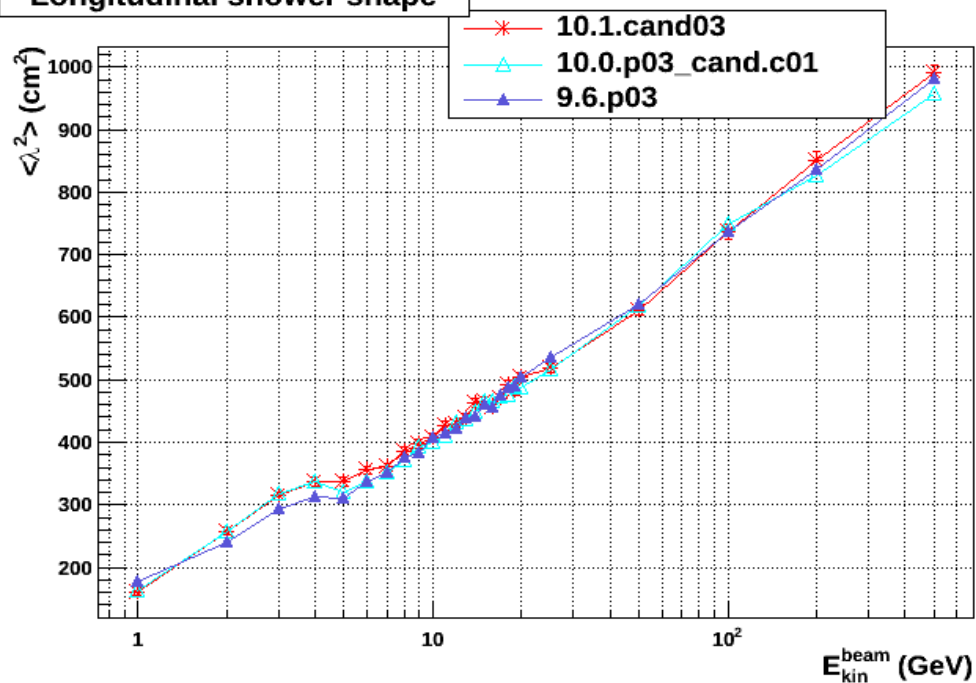
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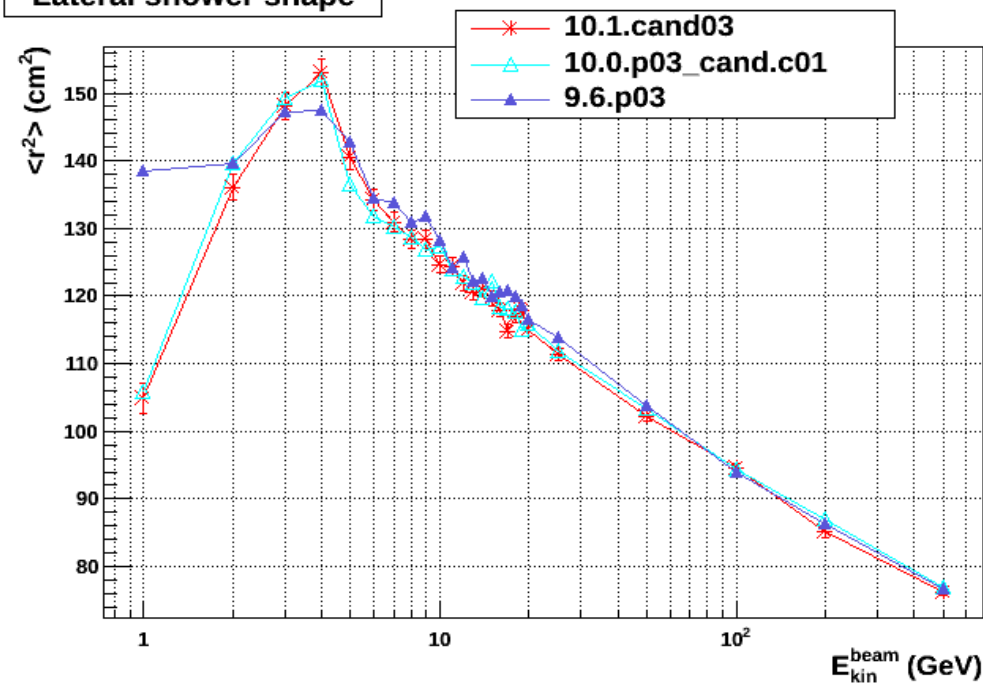
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Longitudinal shower shape



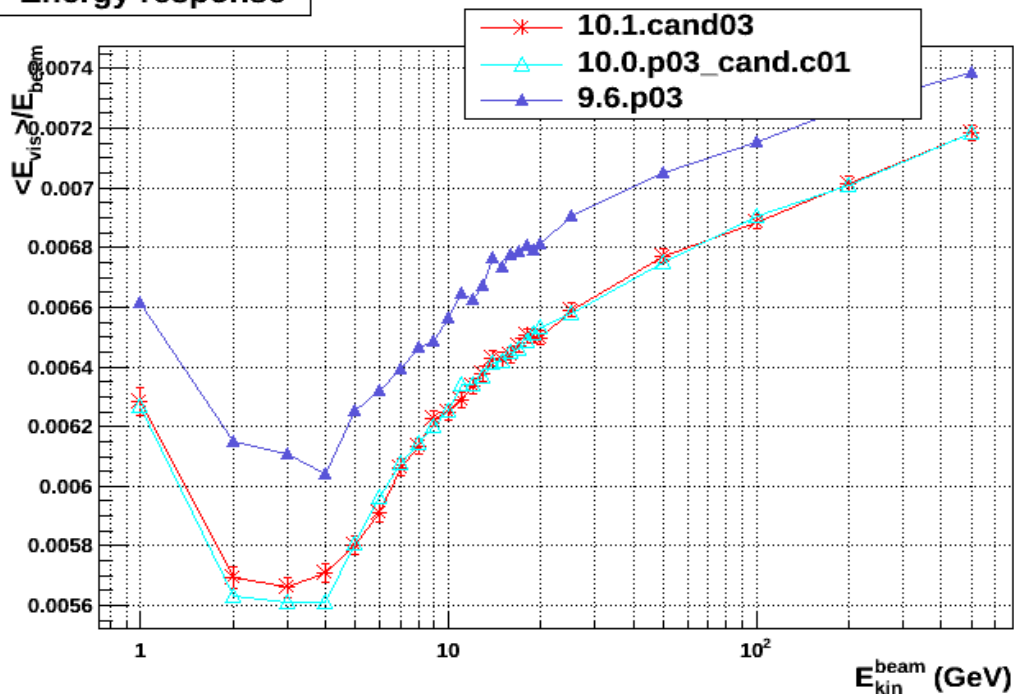
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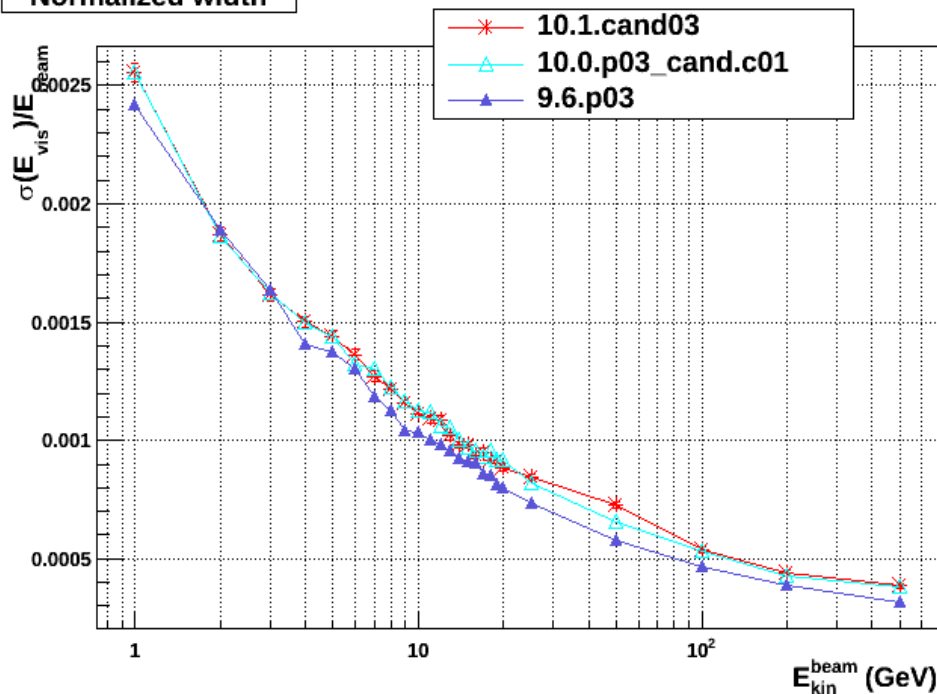
FTFP_BERT

π^- on W-LAr

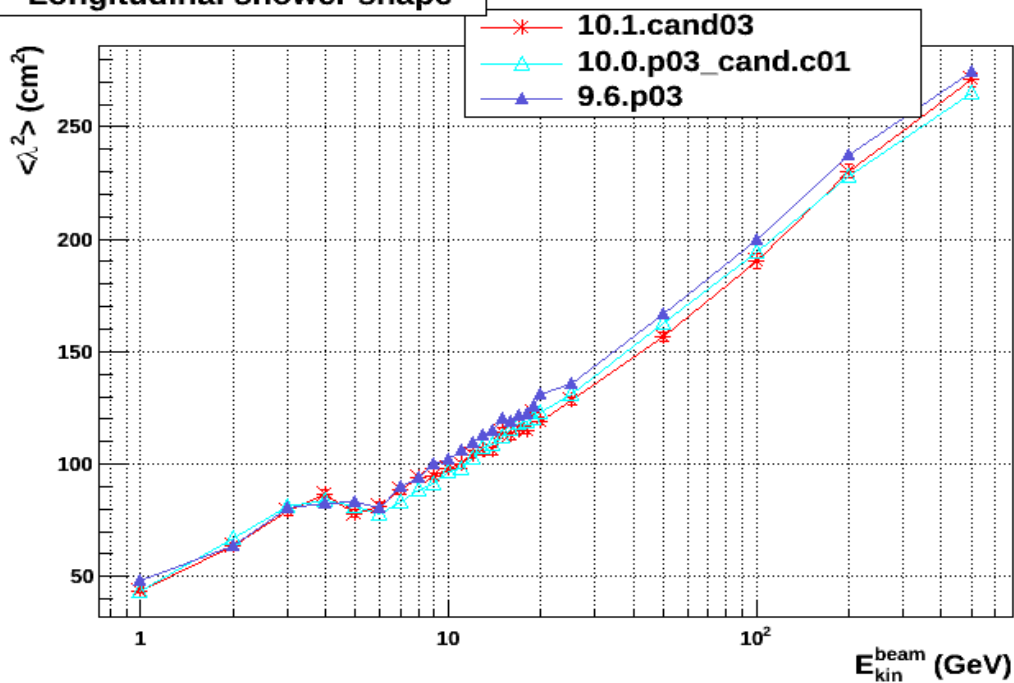
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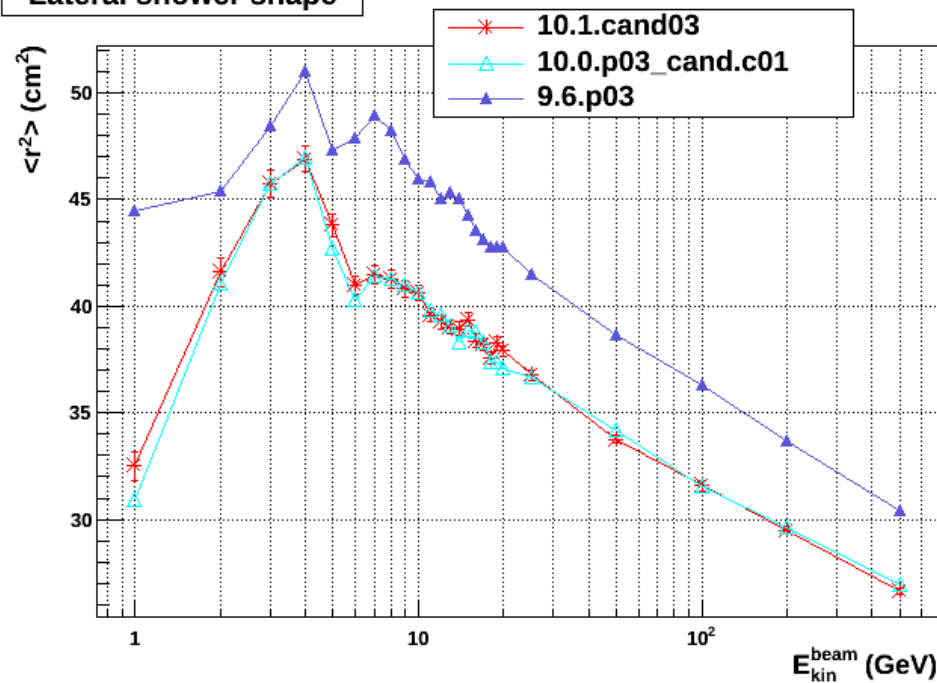
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Longitudinal shower shape



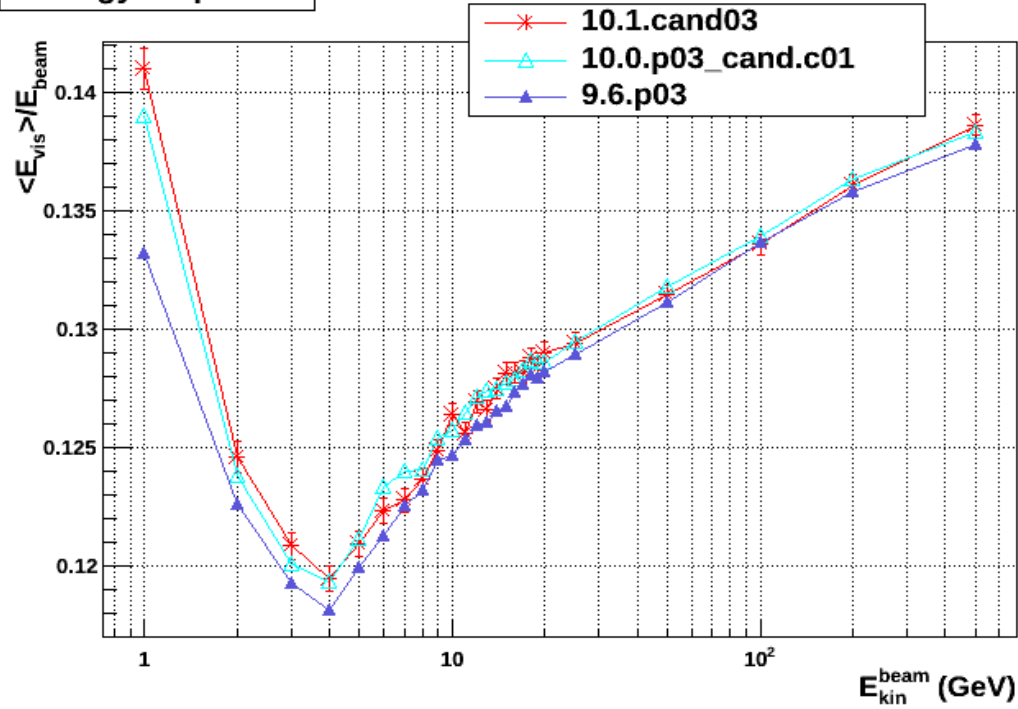
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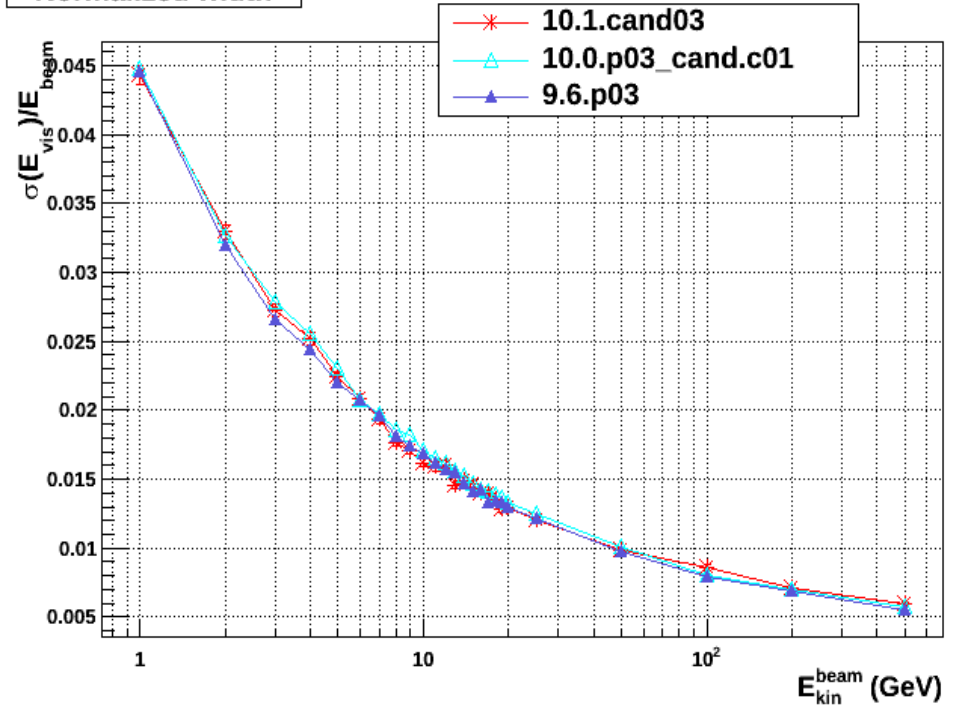
FTFP_BERT

π^- on Pb-LAr

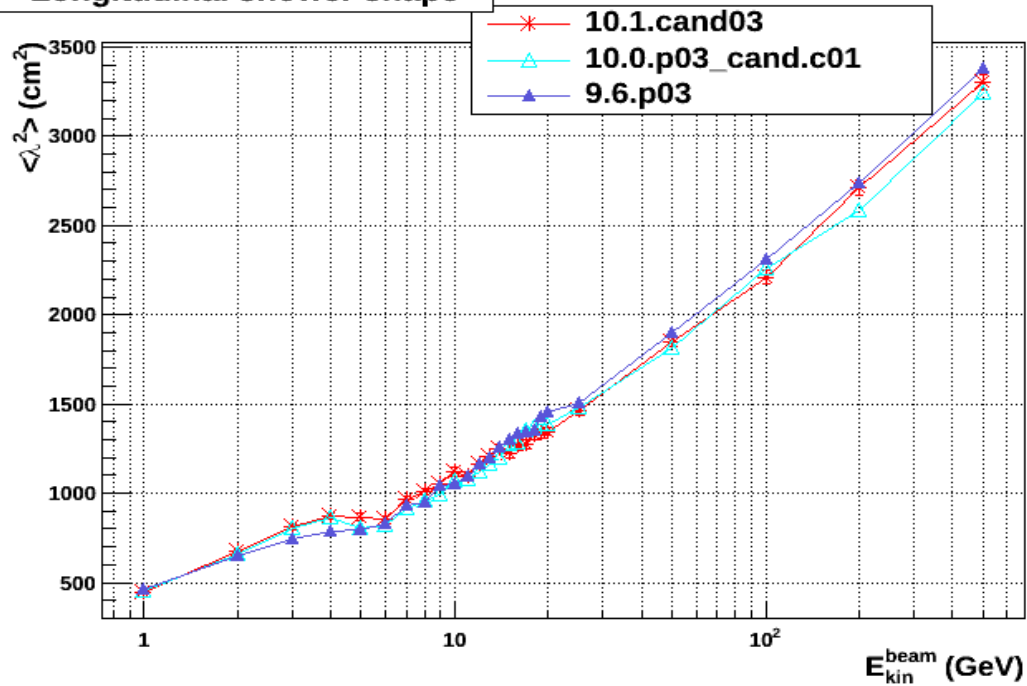
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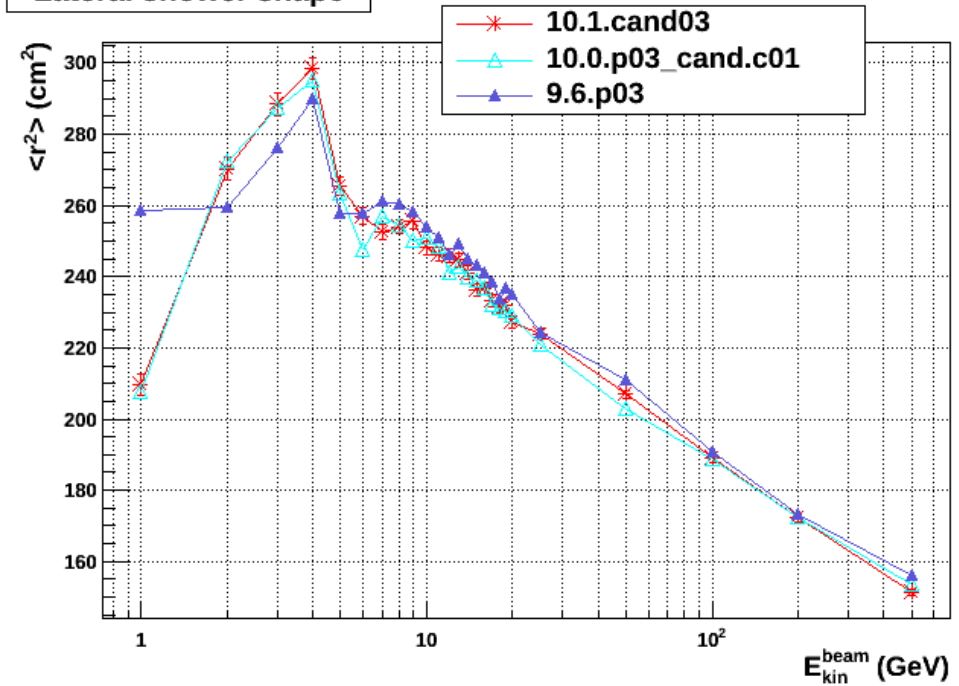
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Longitudinal shower shape

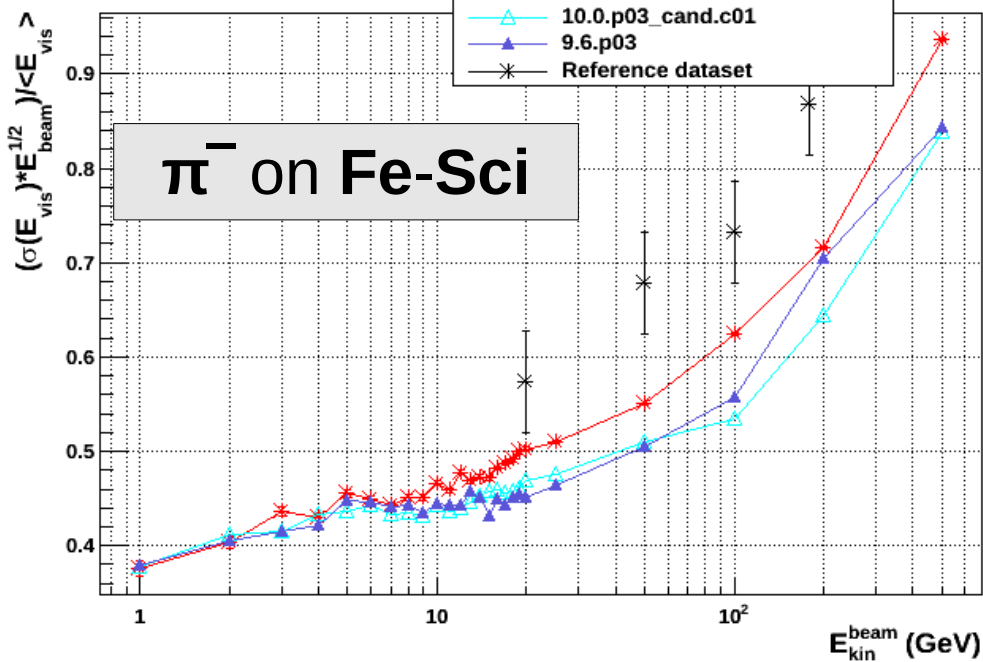


Lateral shower shape

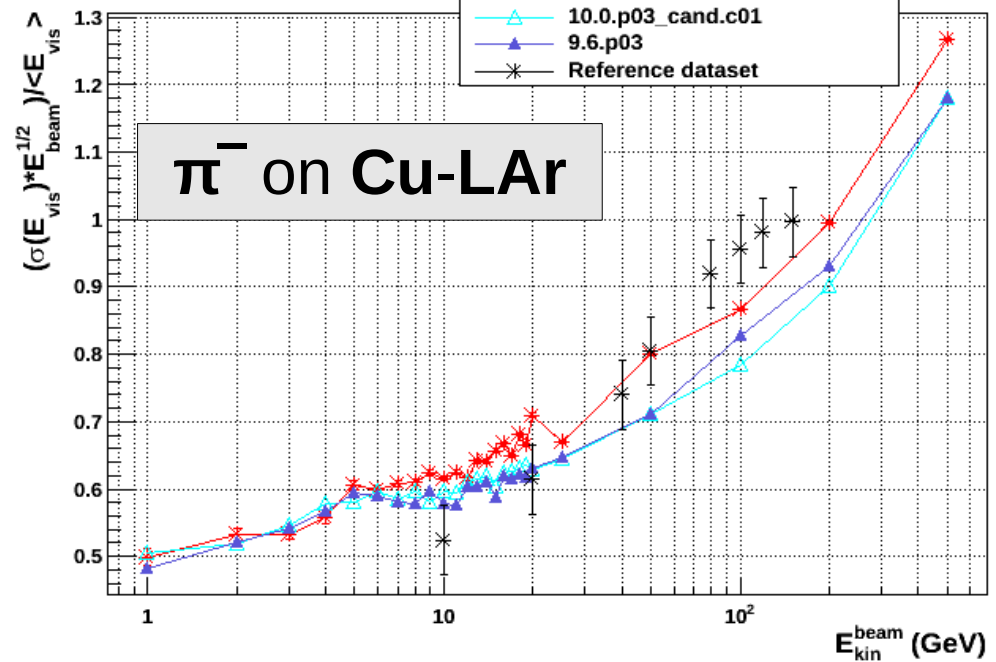


FTFP_BERT : Energy Resolution

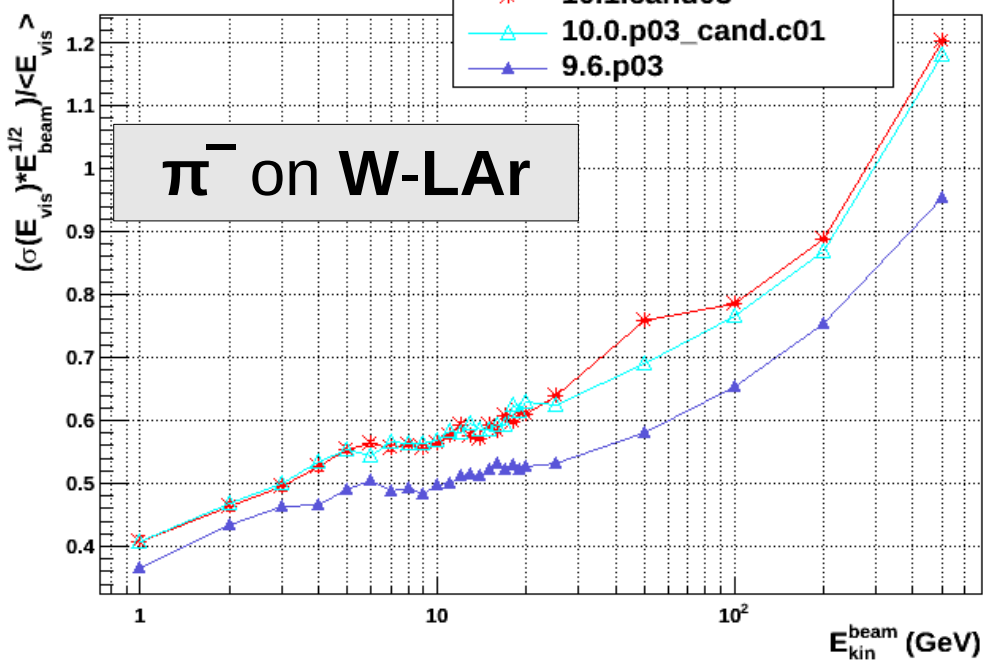
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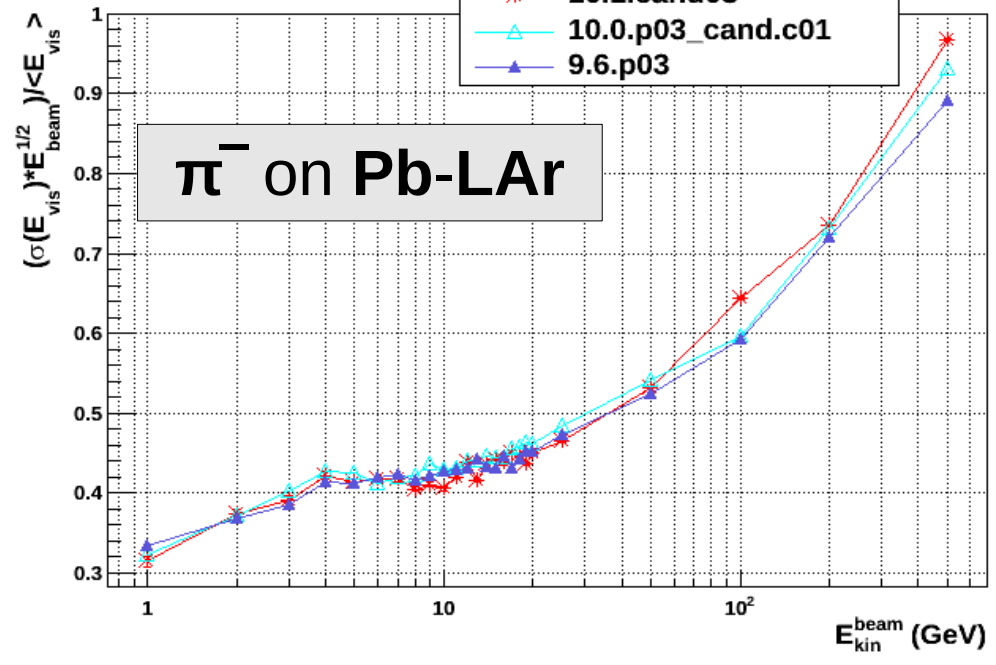
Energy resolution



Energy resolution



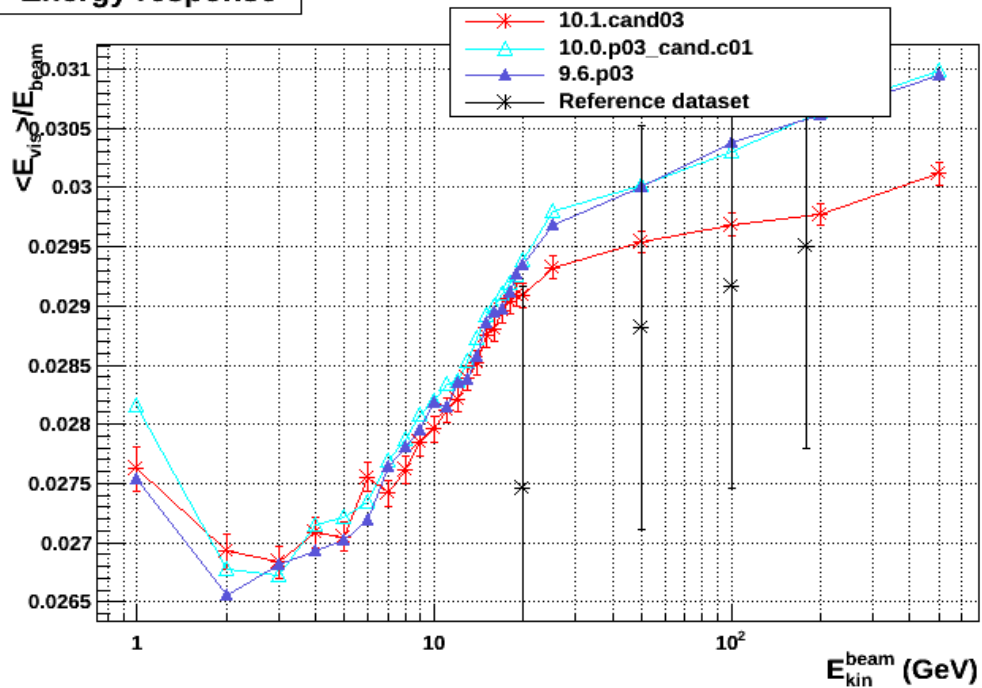
Energy resolution



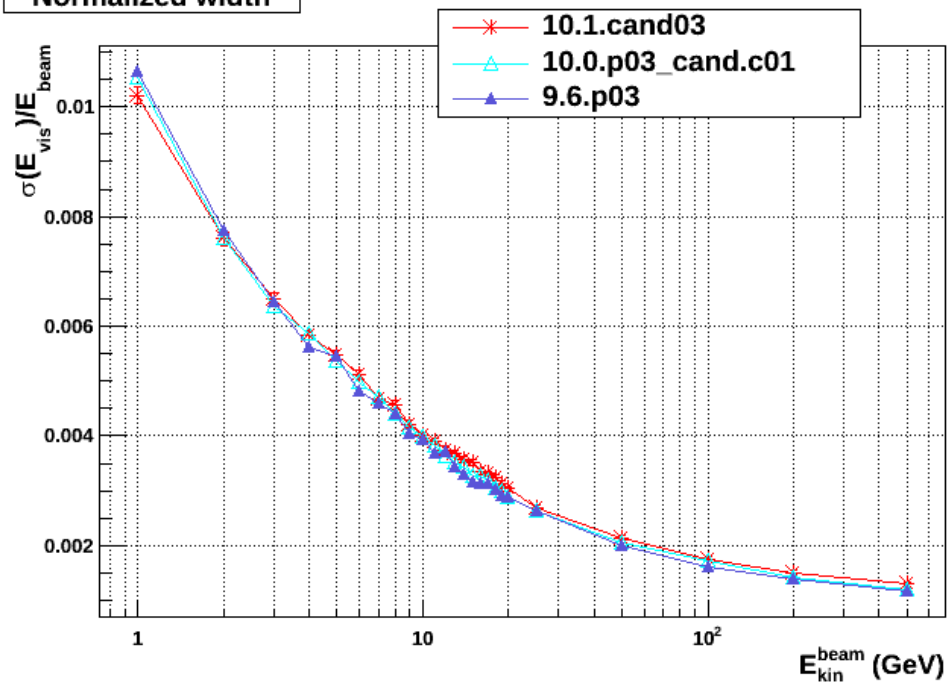
QGSP_FTFP_BERT

π^- on Fe-Sci

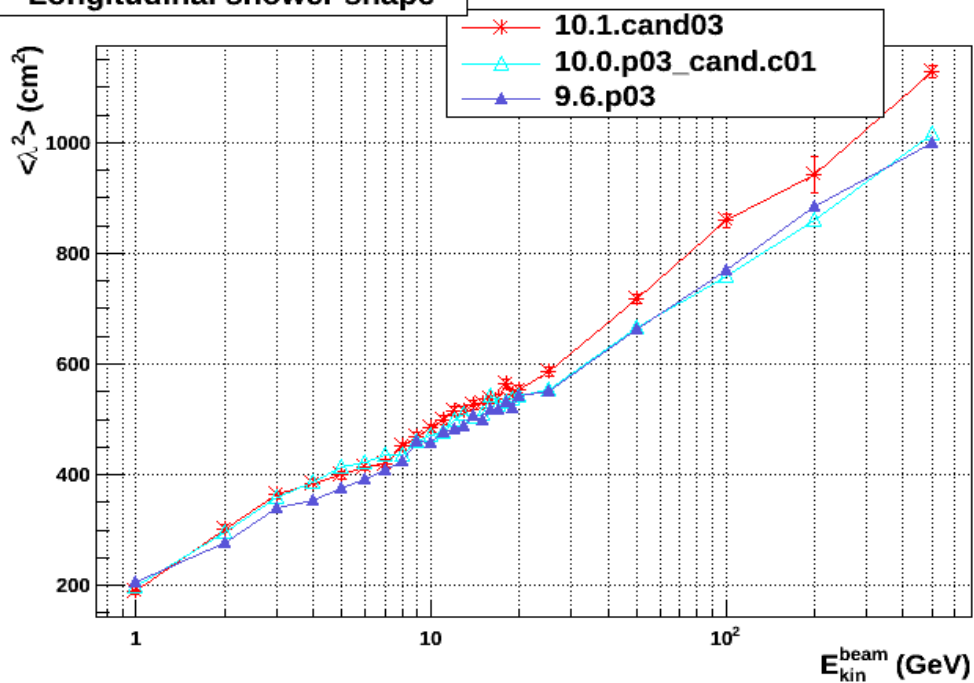
Energy response



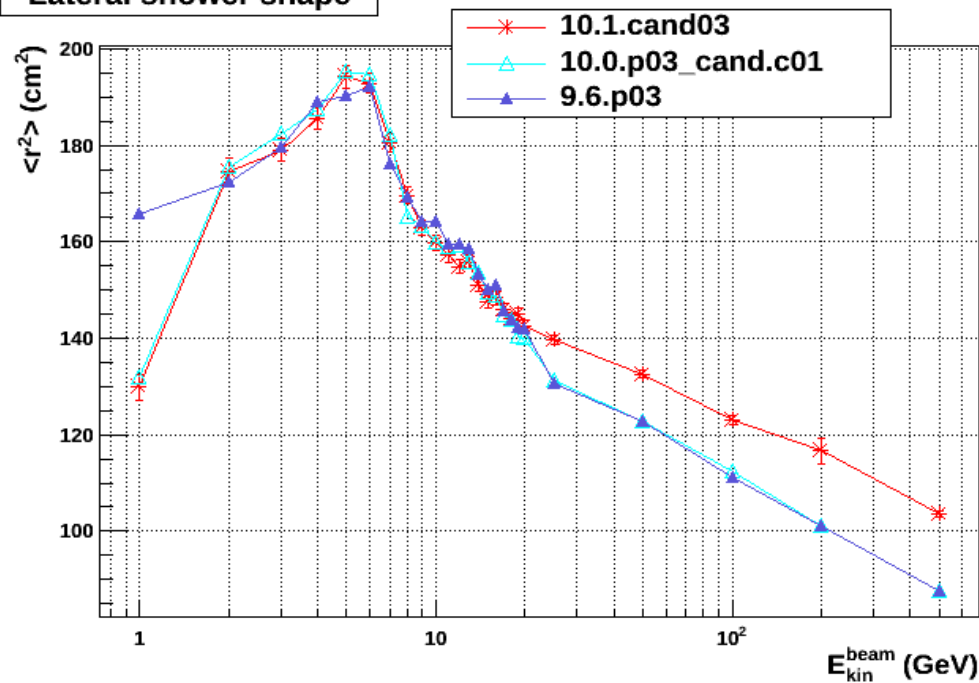
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Longitudinal shower shape



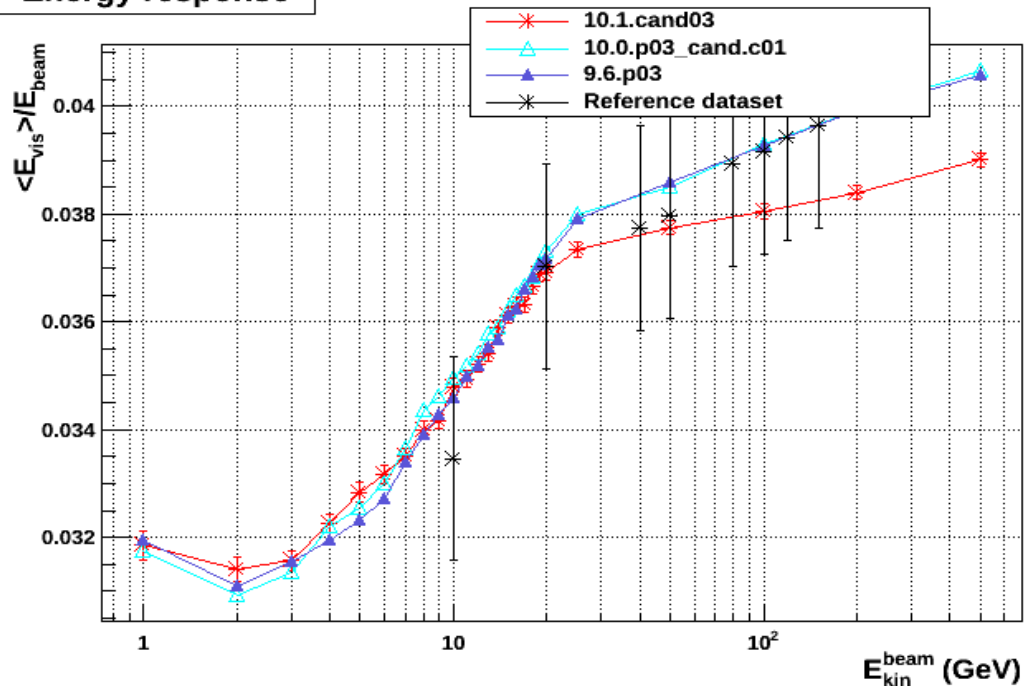
Lateral shower shape



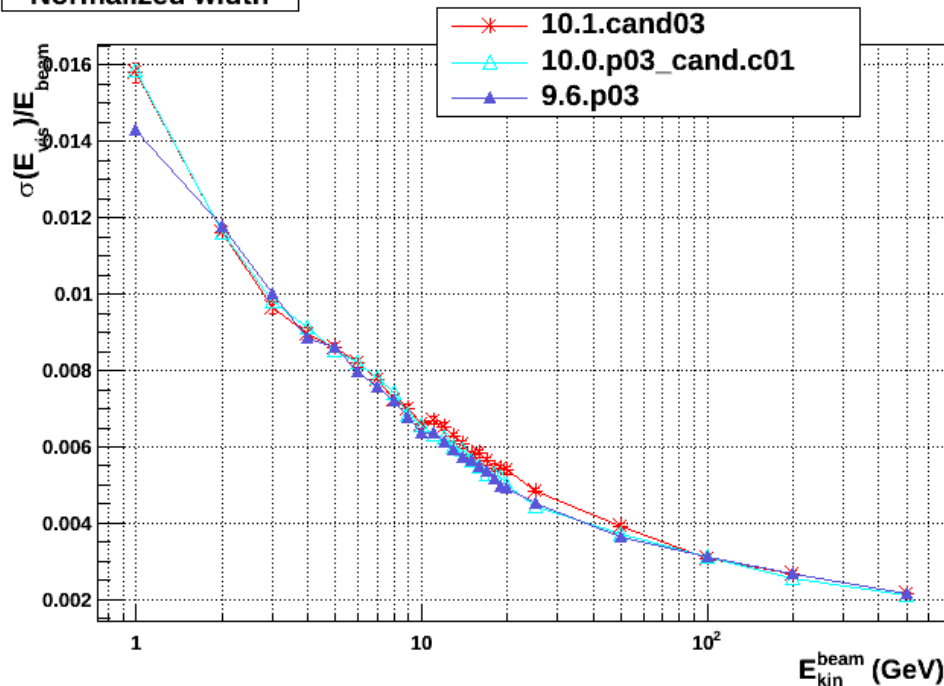
QGSP_FTFP_BERT

π^- on Cu-LAr

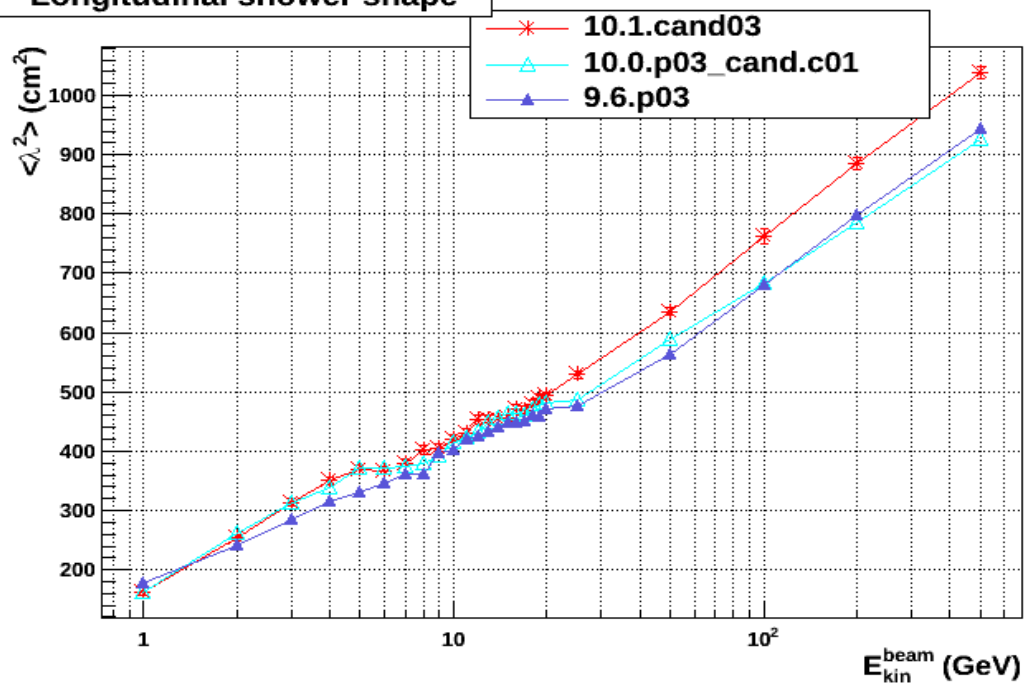
Energy response



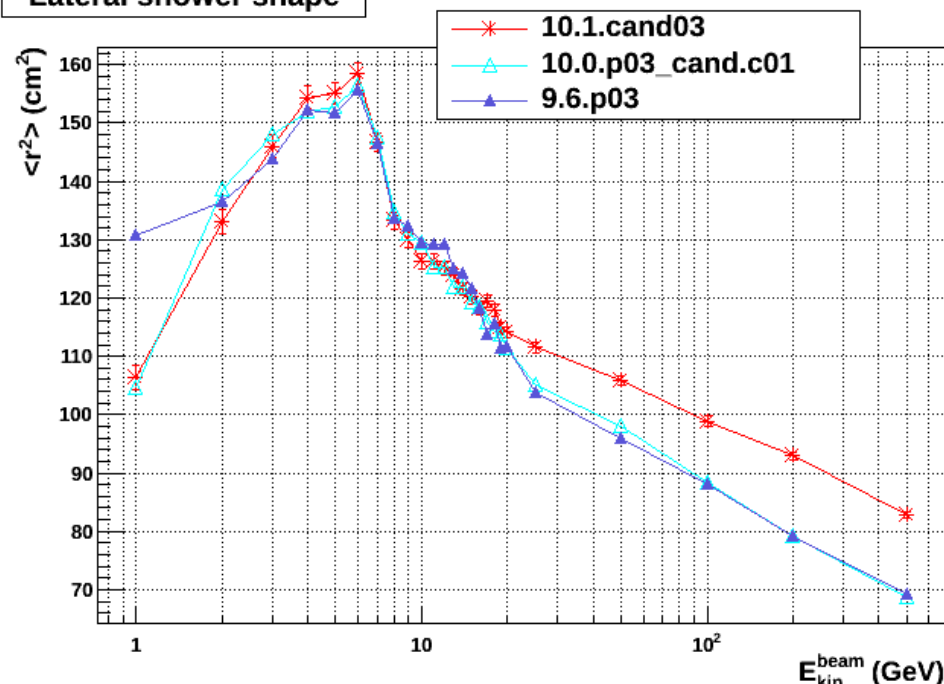
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Longitudinal shower shape



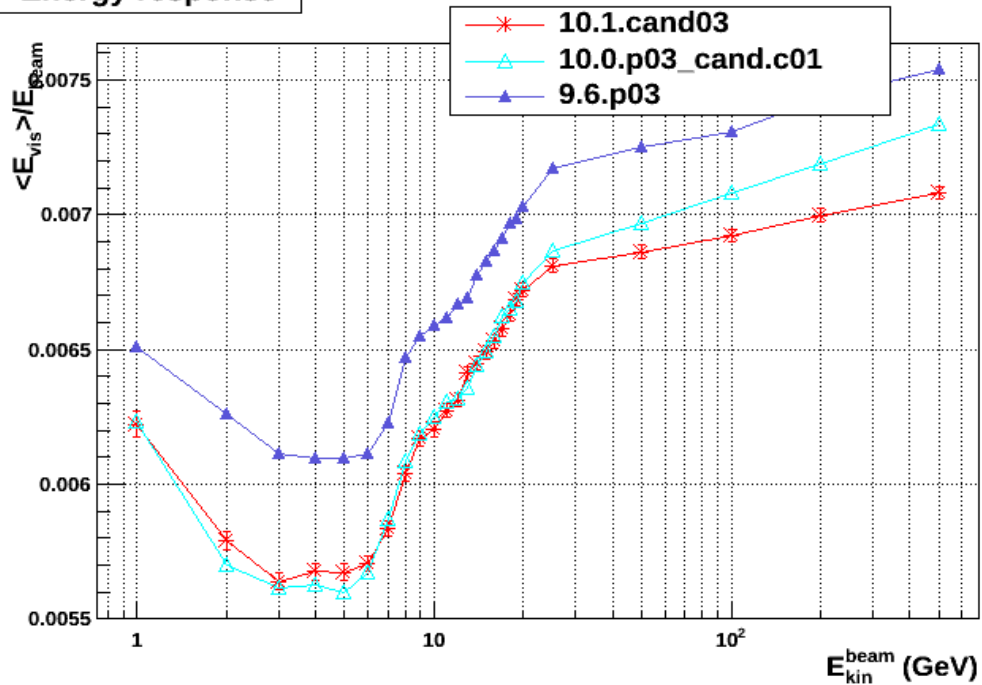
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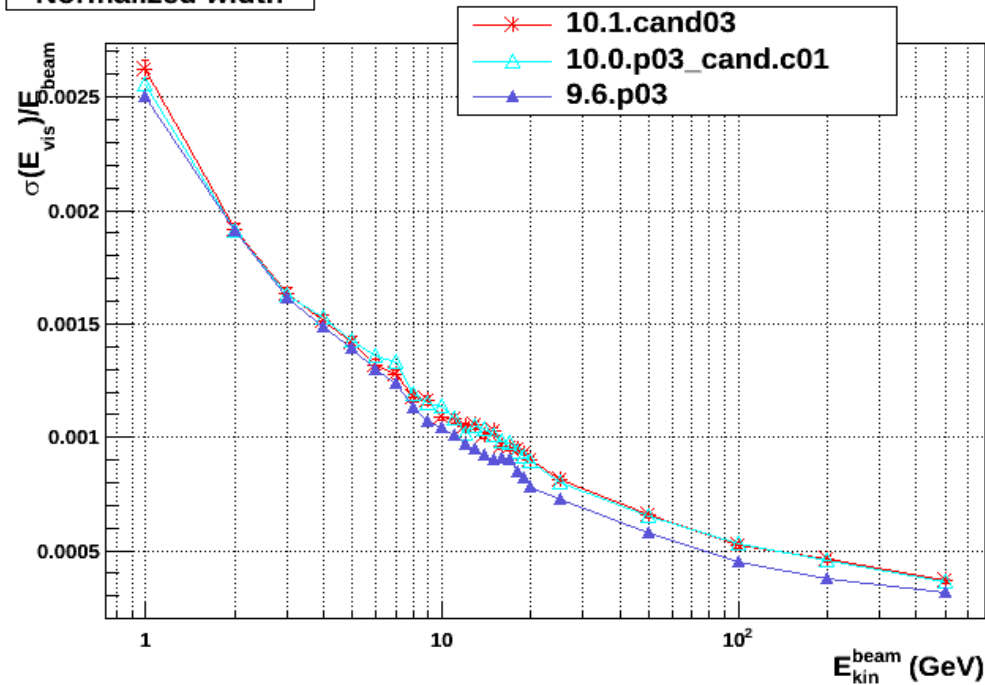
QGSP_FTFP_BERT

π^- on W-LAr

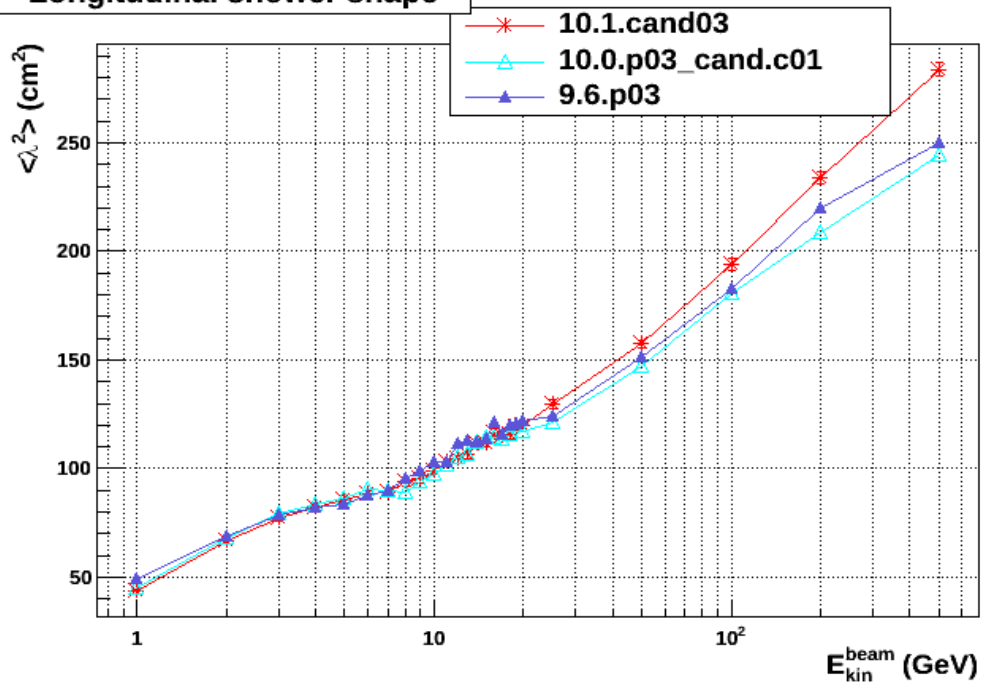
Energy response



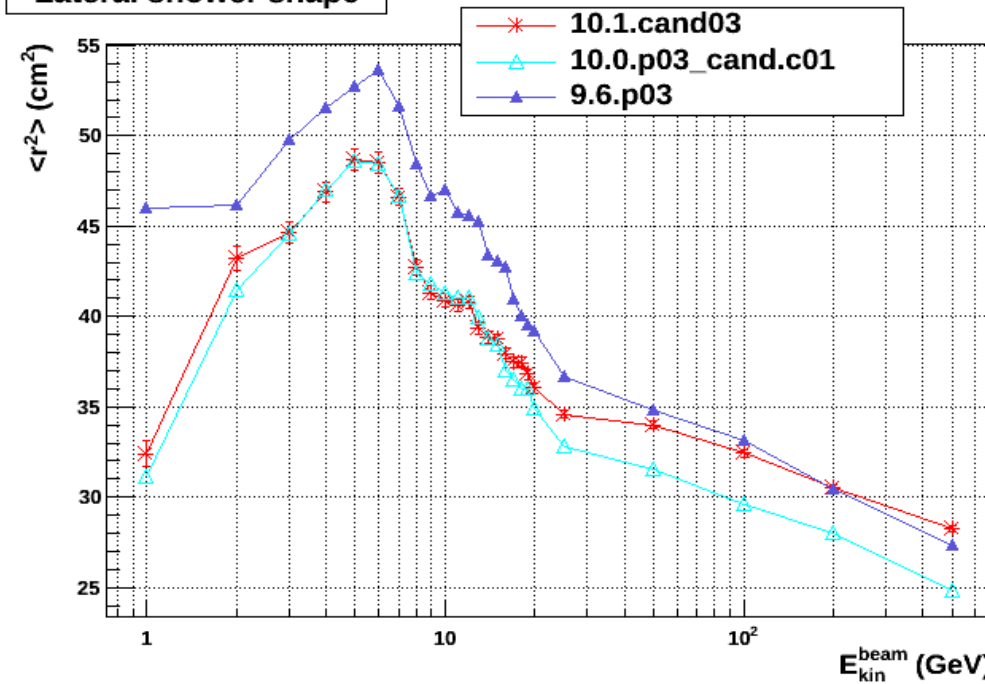
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Longitudinal shower shape



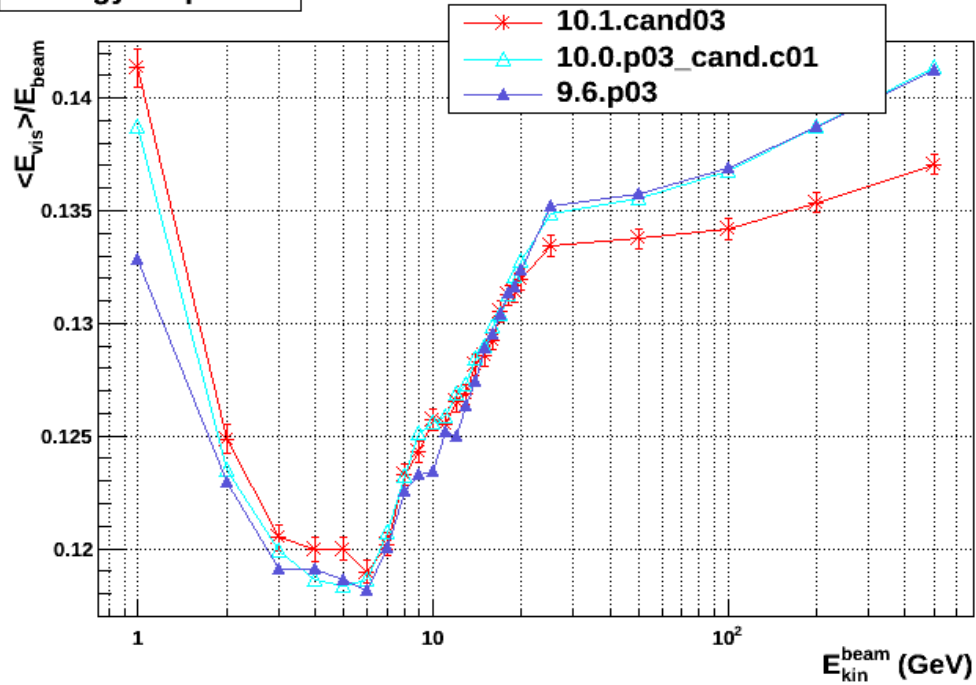
Lateral shower shape



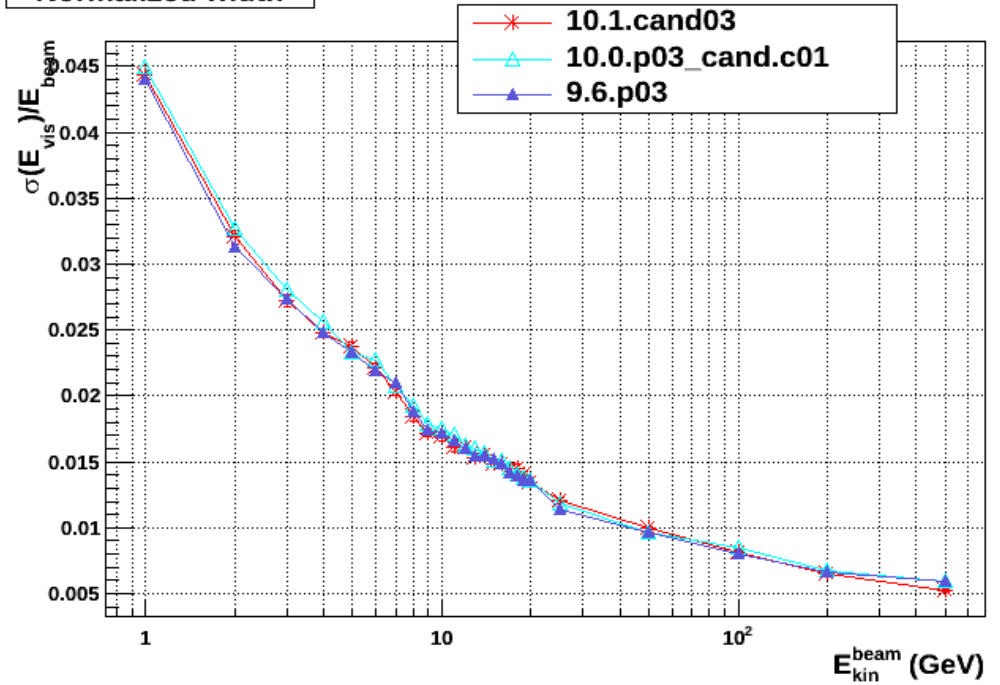
QGSP_FTFP_BERT

π^- on Pb-LAr

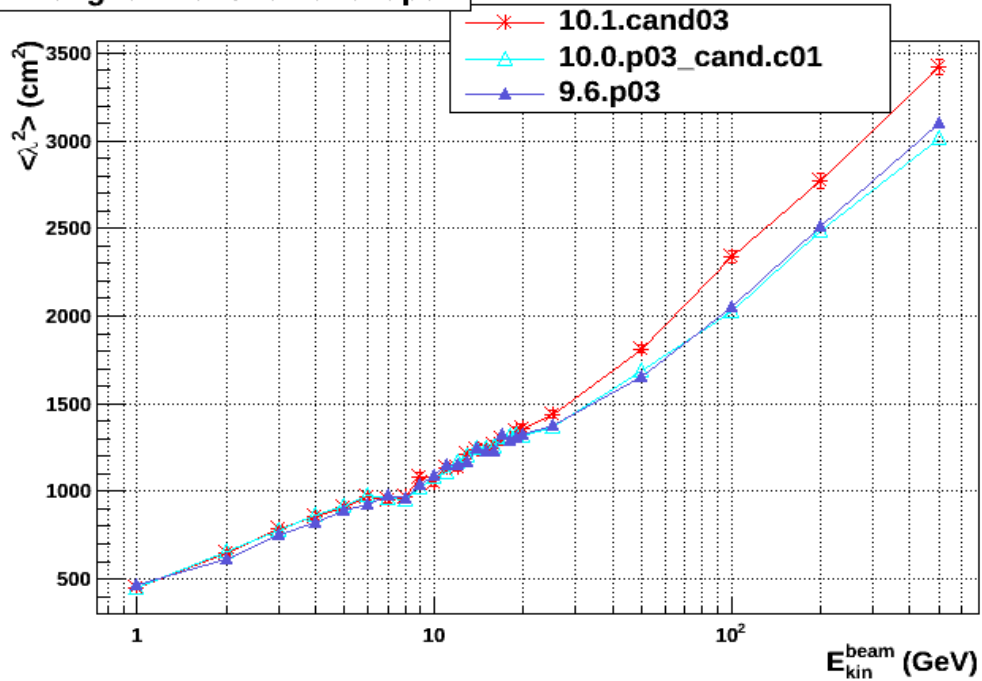
Energy response



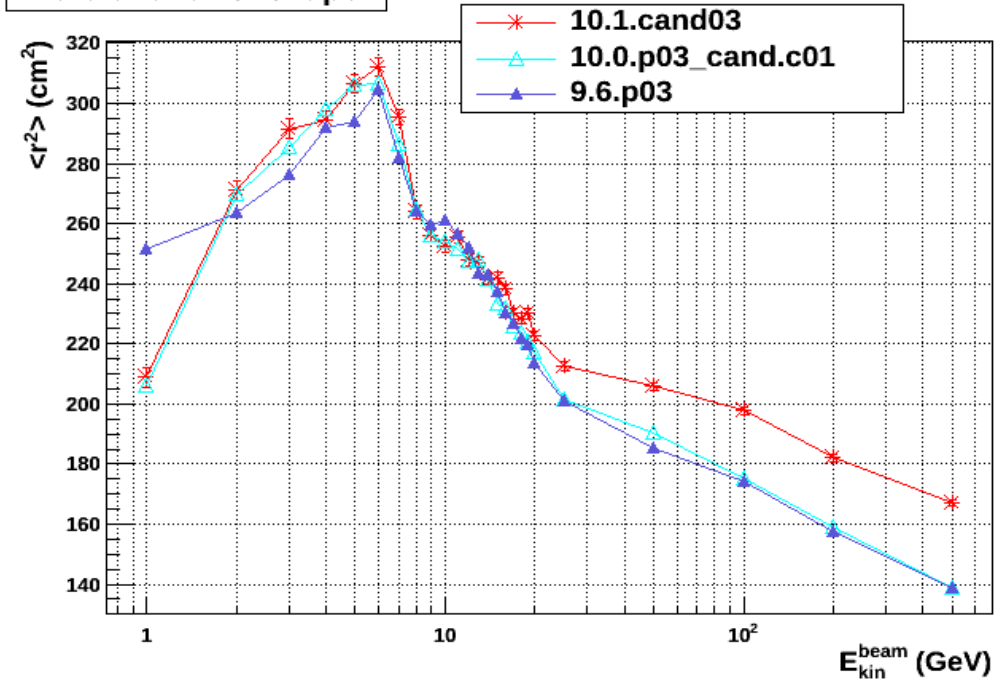
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Longitudinal shower shape



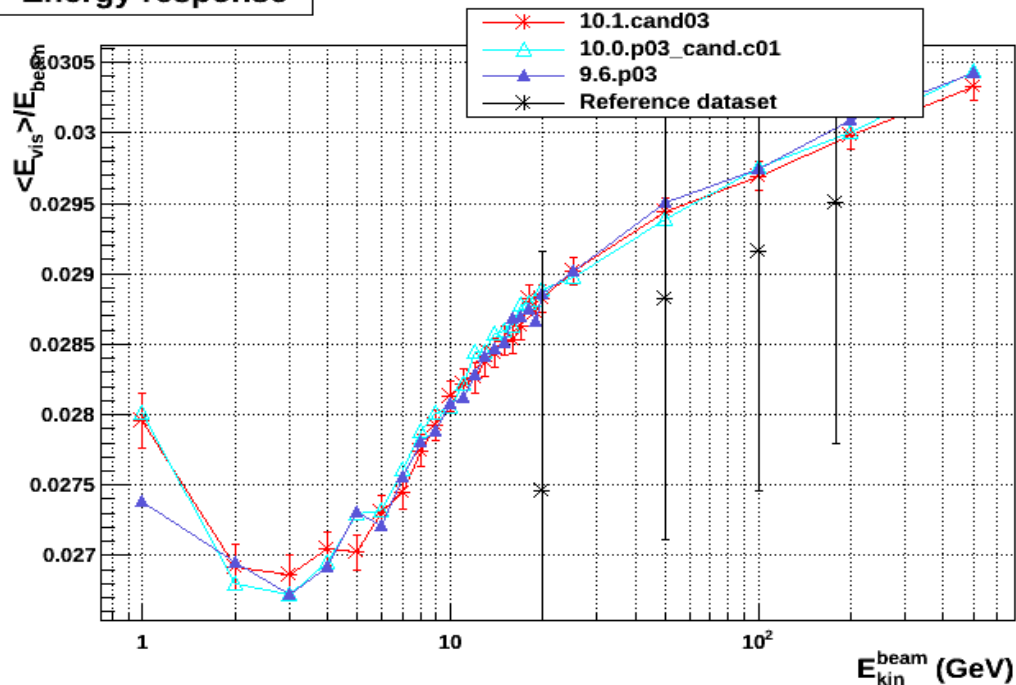
Lateral shower shape



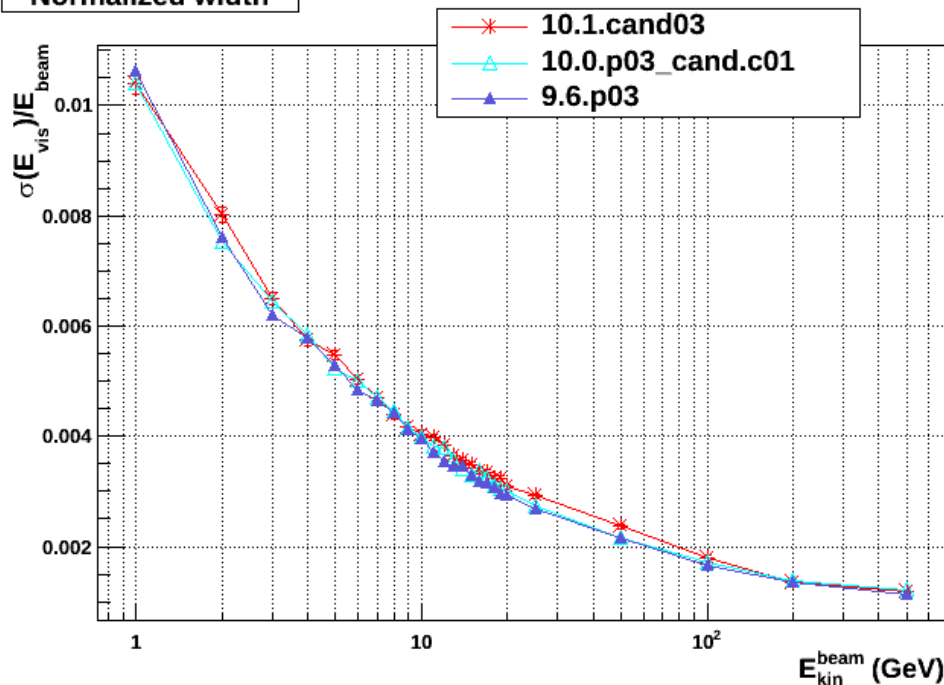
FTFP_BERT_TRV

π^- on Fe-Sci

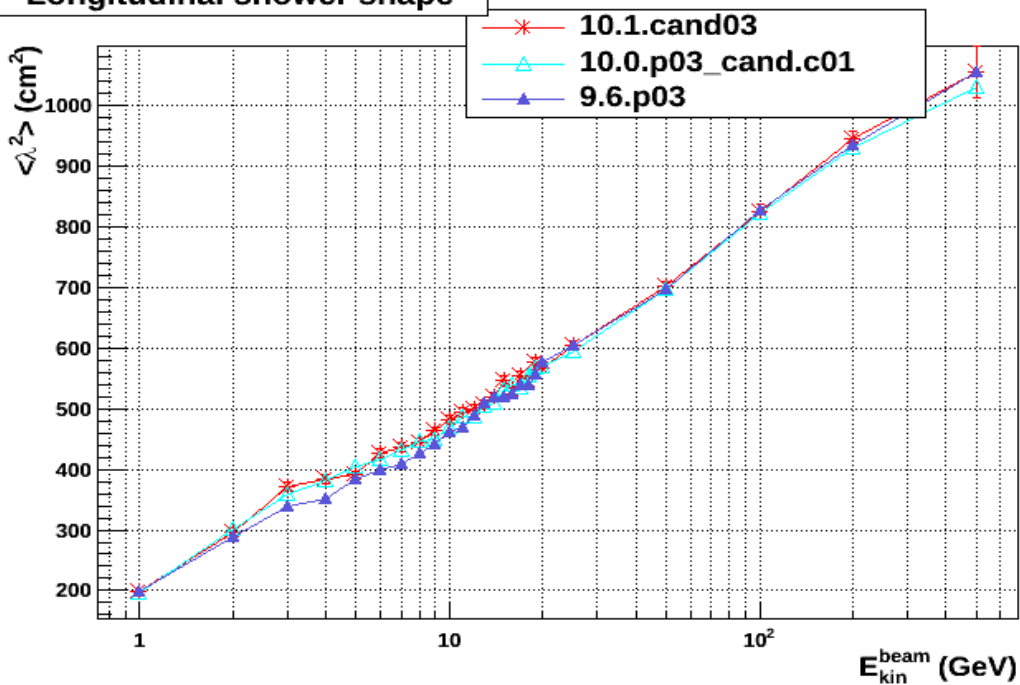
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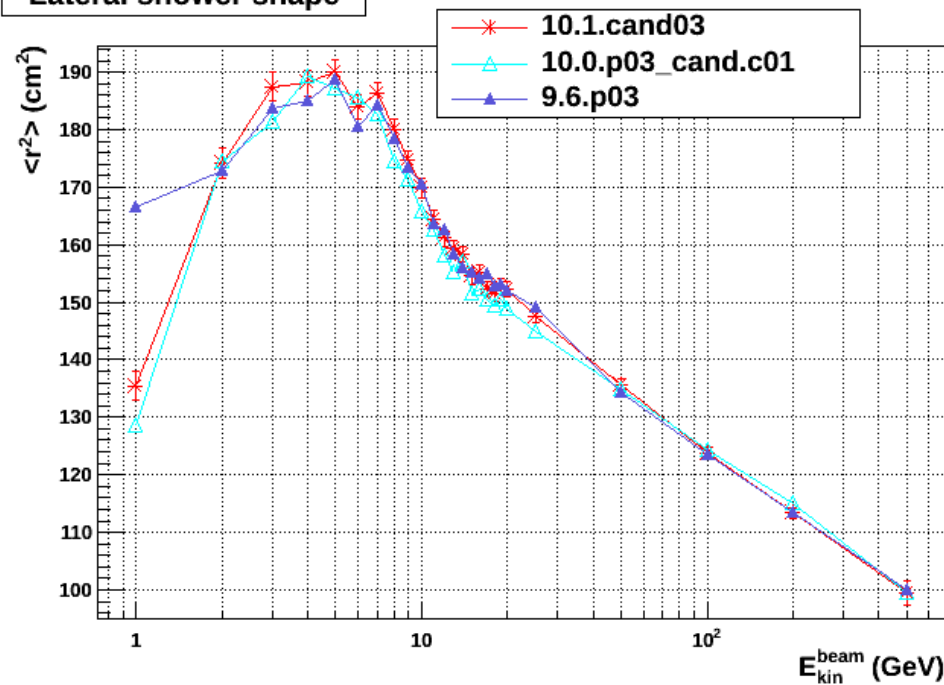
Normalized width



Longitudinal shower shape



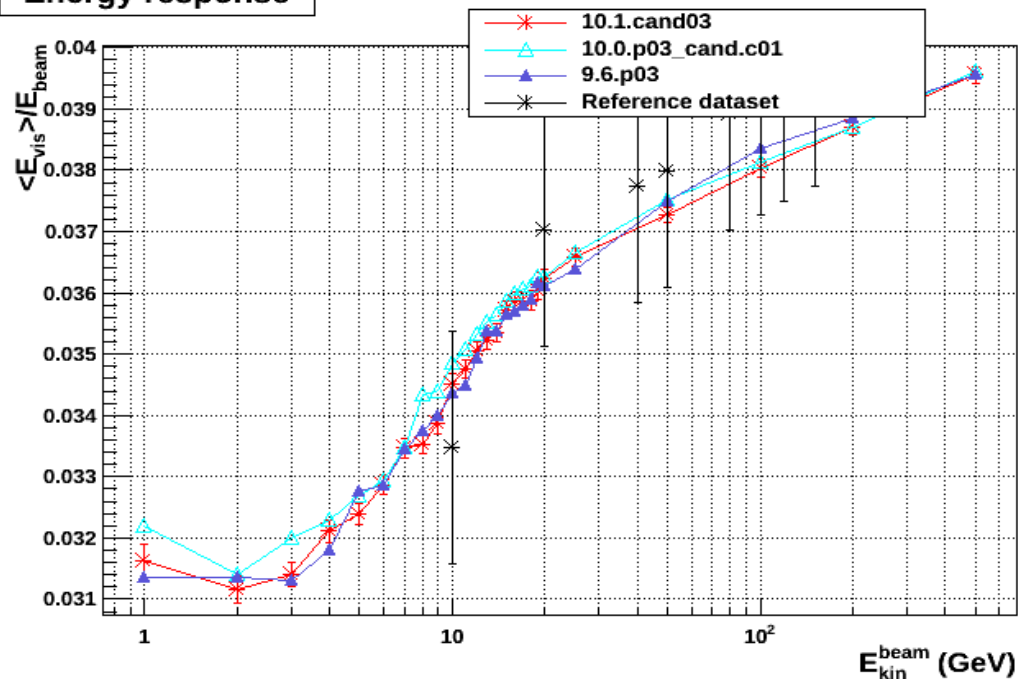
Lateral shower shape



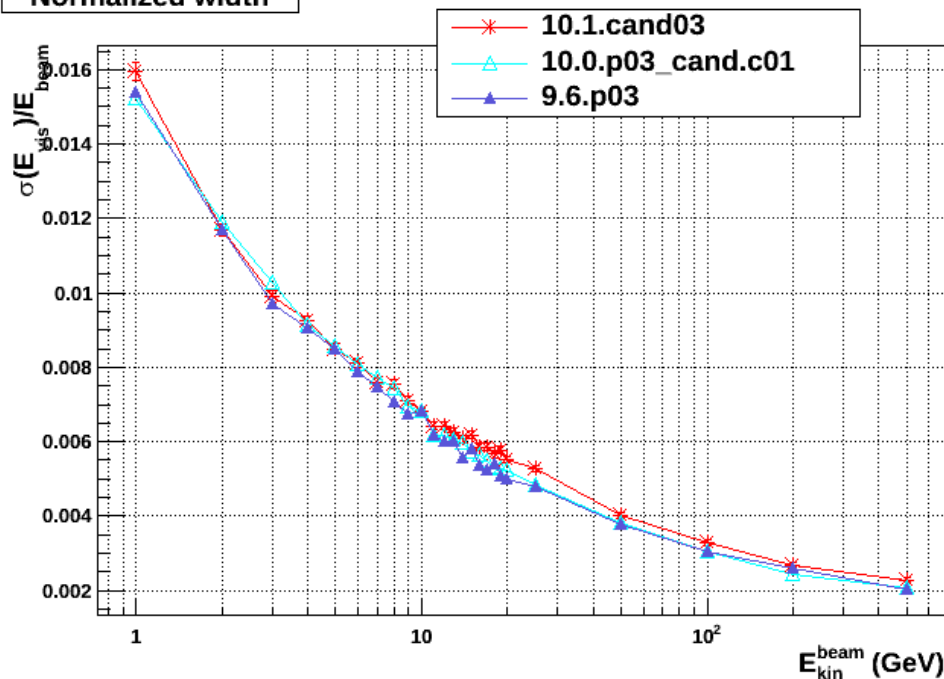
FTFP_BERT_TRV

π^- on Cu-LAr

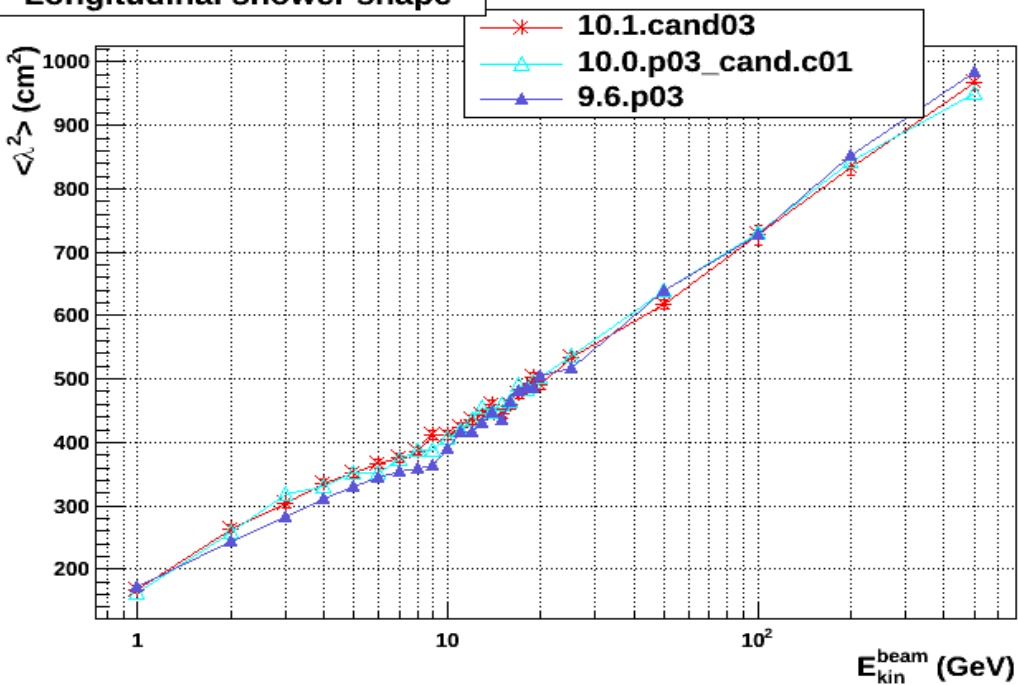
Energy response



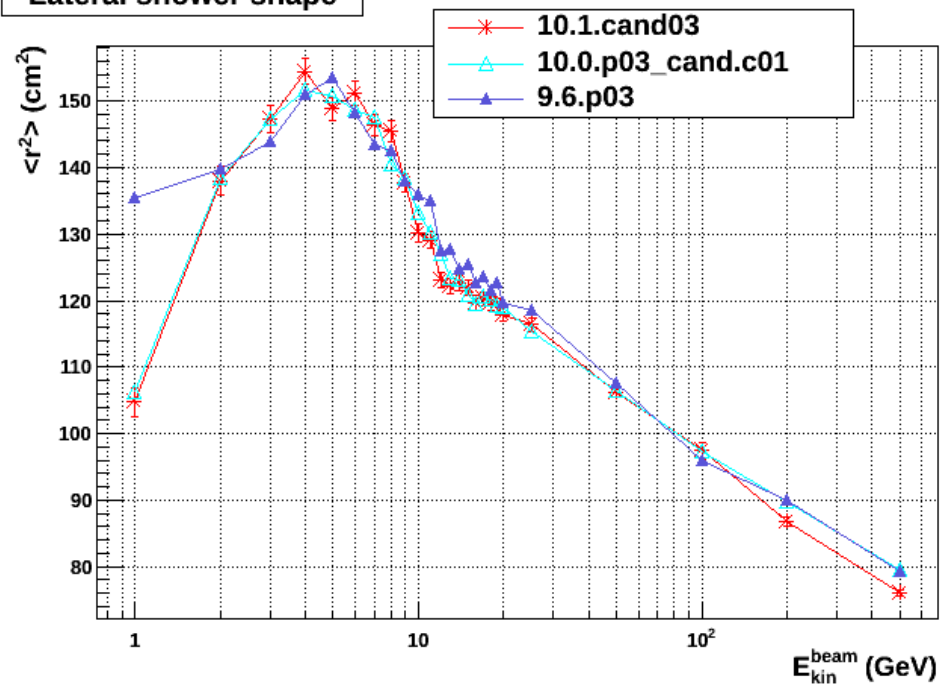
Normalized width



Longitudinal shower shape



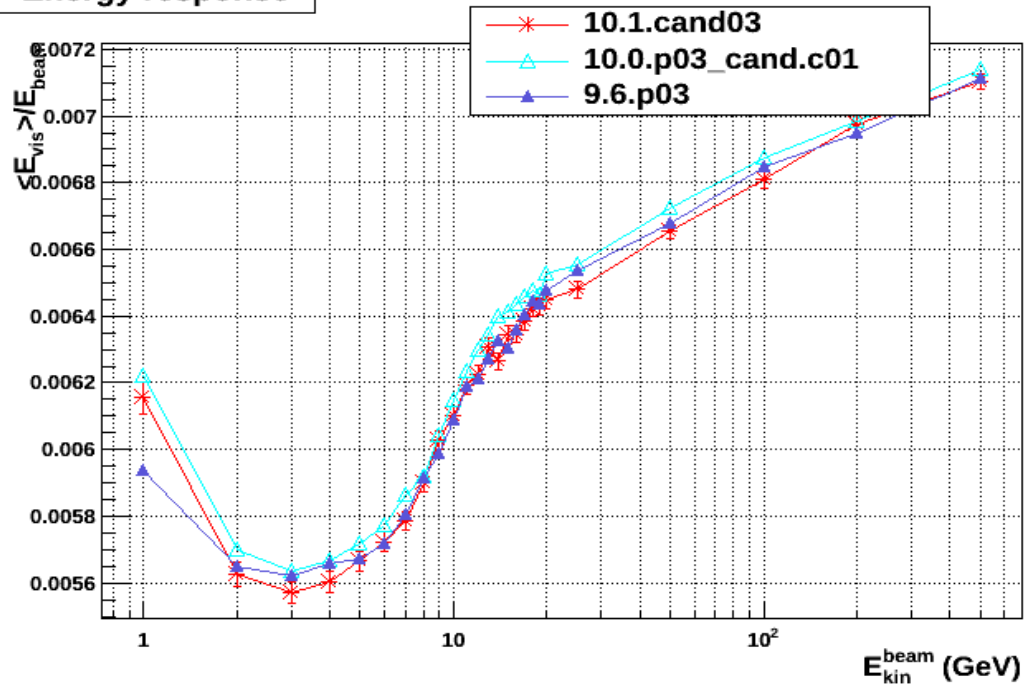
Lateral shower shape



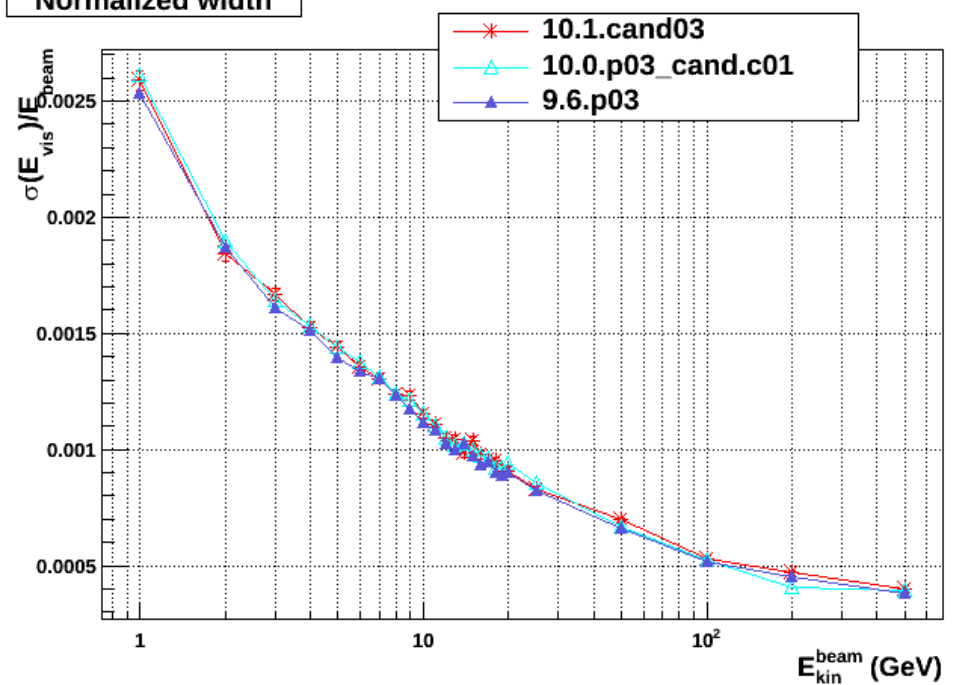
FTFP_BERT_TRV

π^- on W-LAr

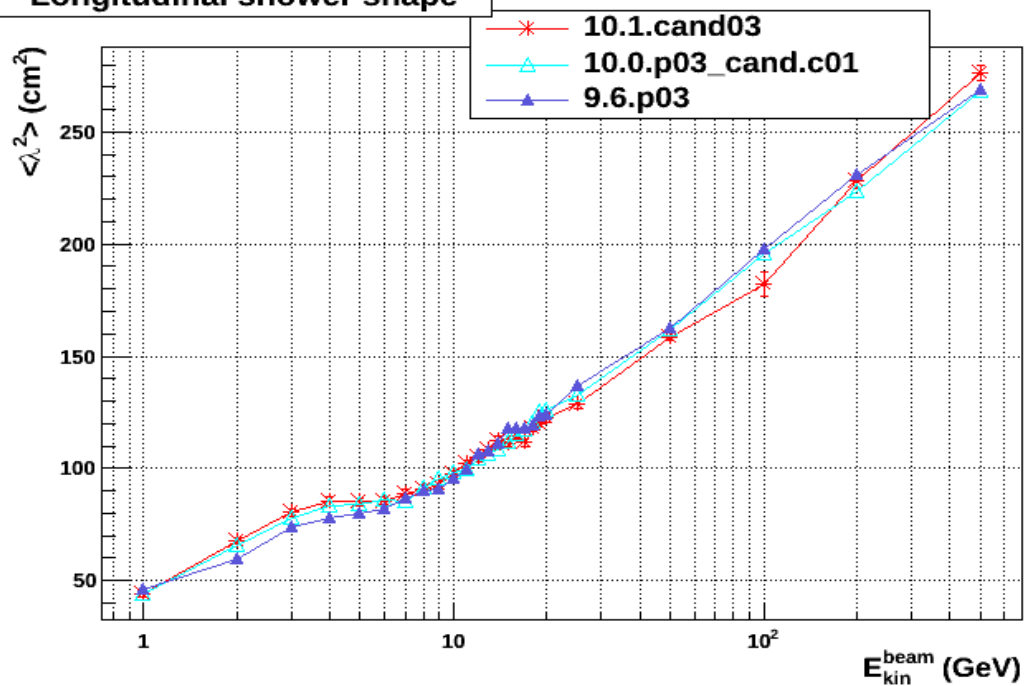
Energy response



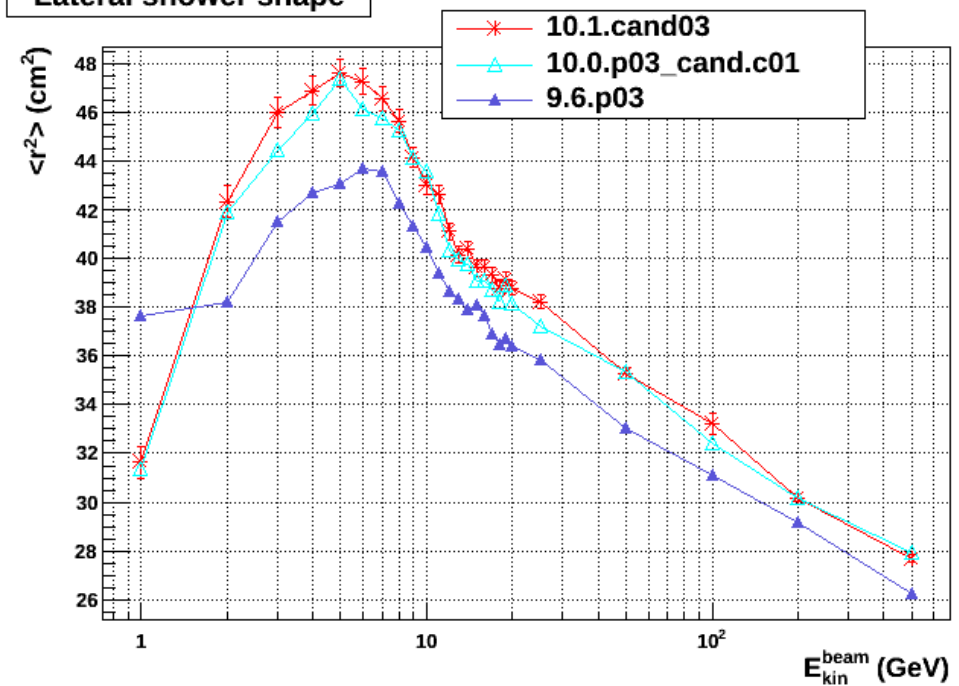
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Longitudinal shower shape



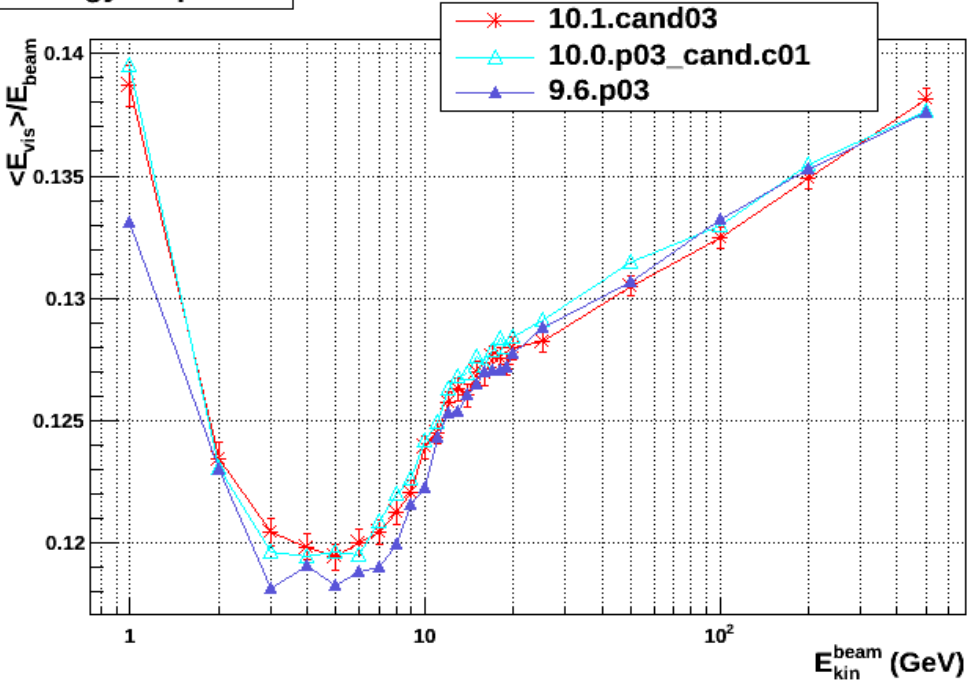
Lateral shower shape



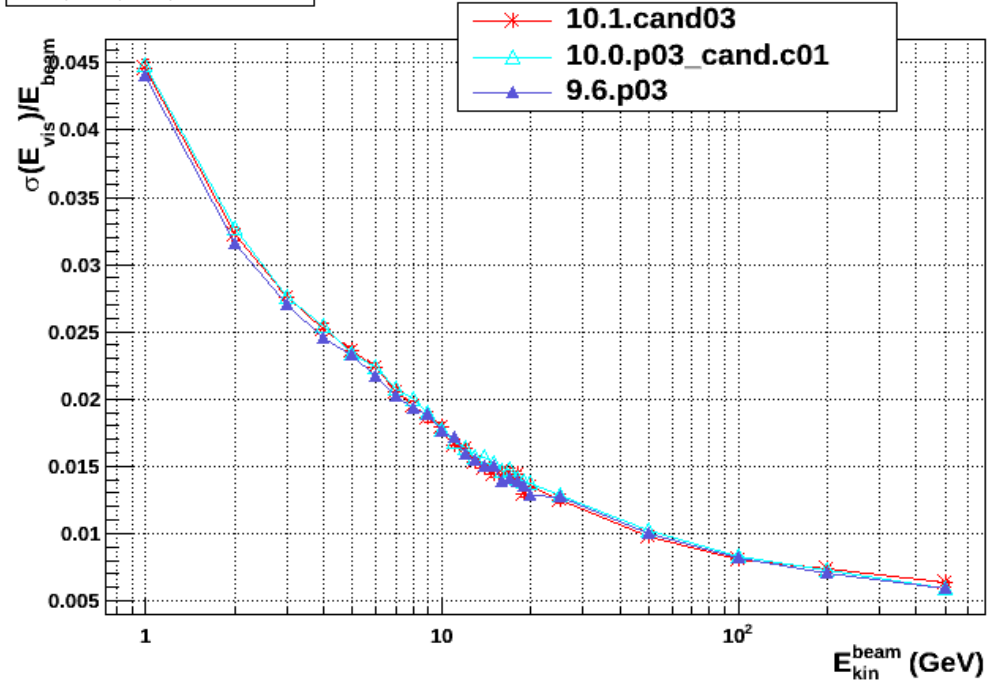
FTFP_BERT_TRV

π^- on Pb-LAr

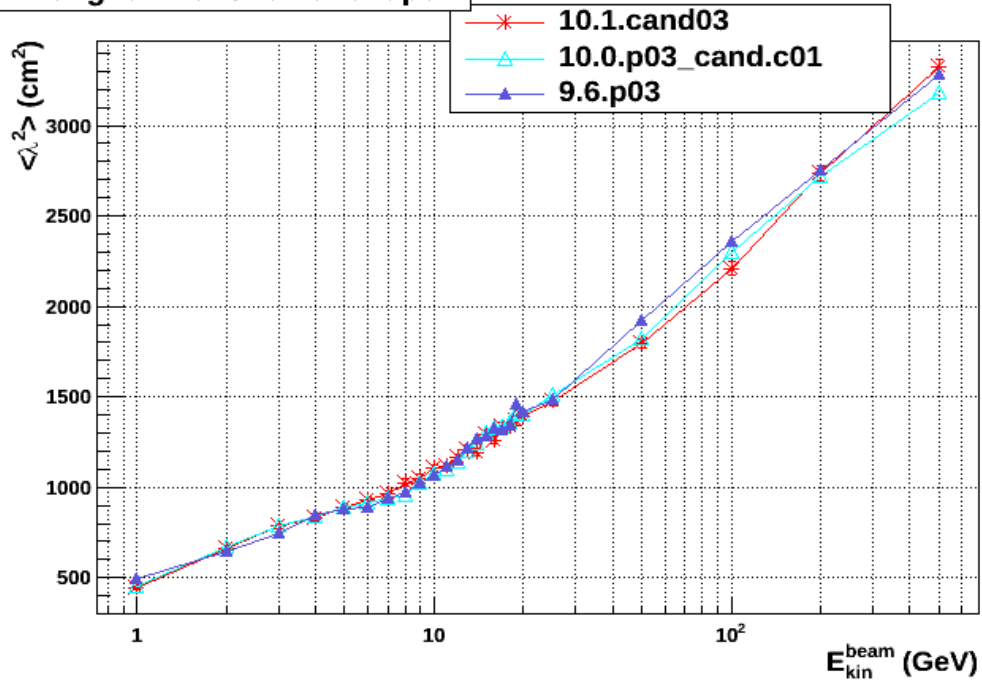
Energy response



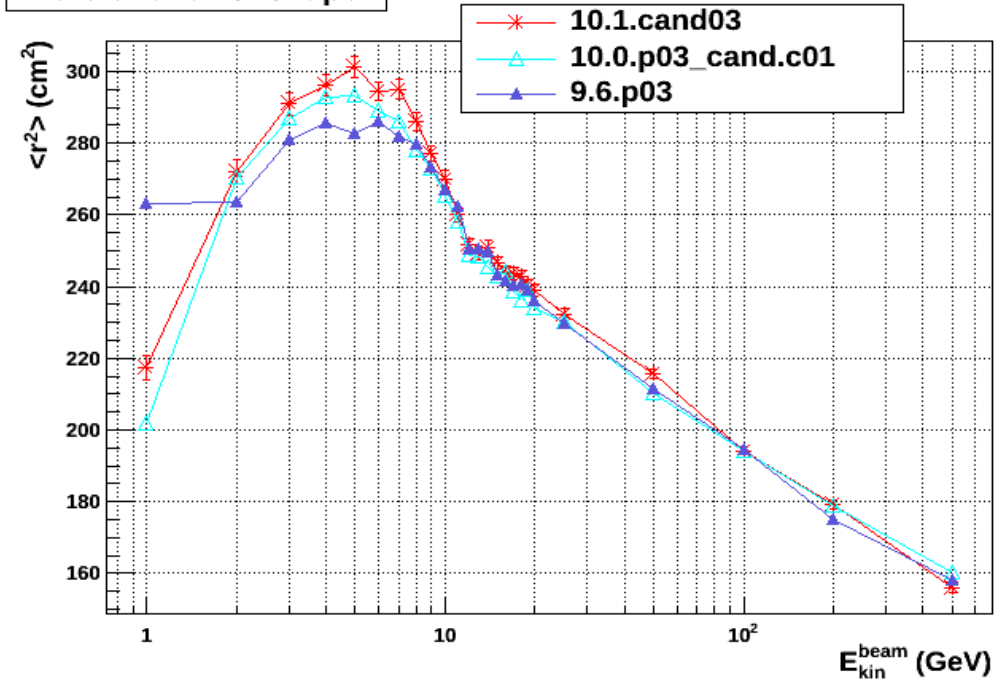
Normalized width



Longitudinal shower shape



Lateral shower shape



Comparing Physics Lists in G4 10.1

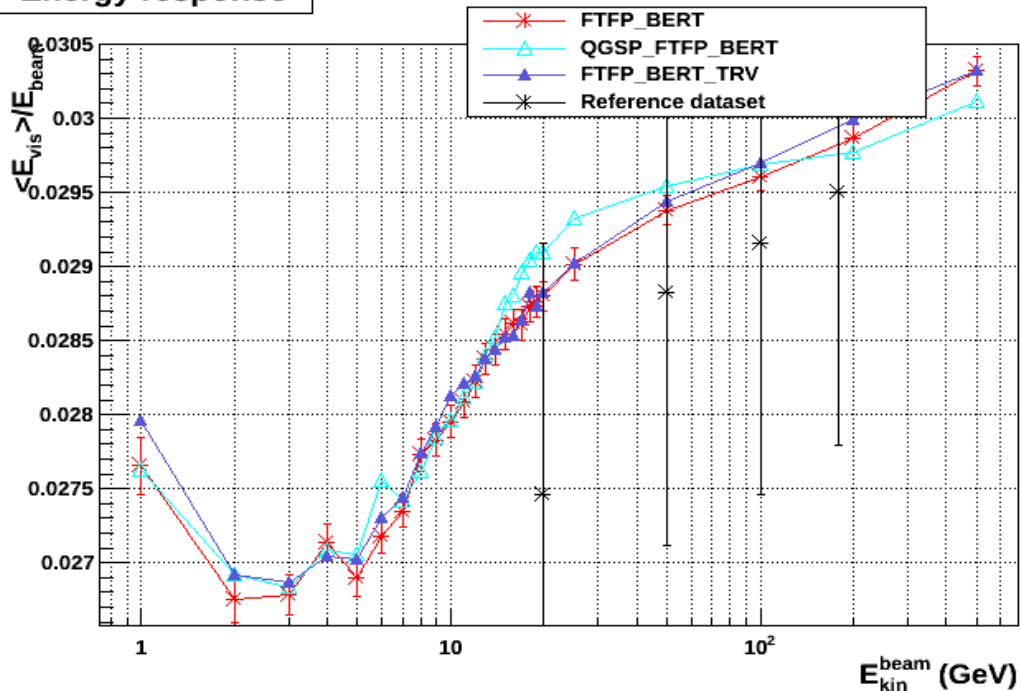
FTFP_BERT

QGSP_FTFP_BERT

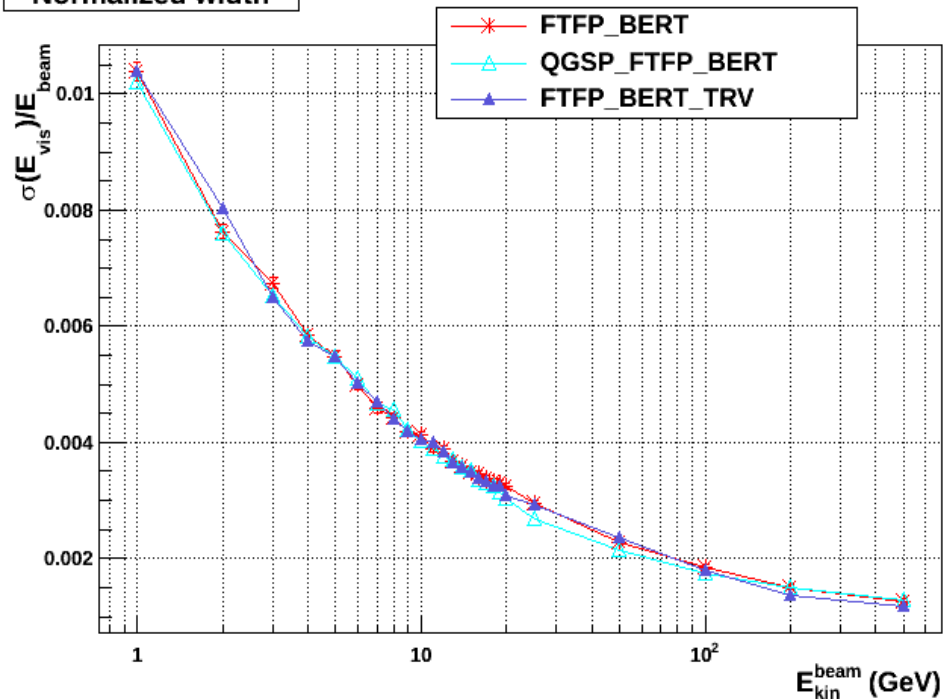
FTFP_BERT_TRV

π^- on Fe-Sci

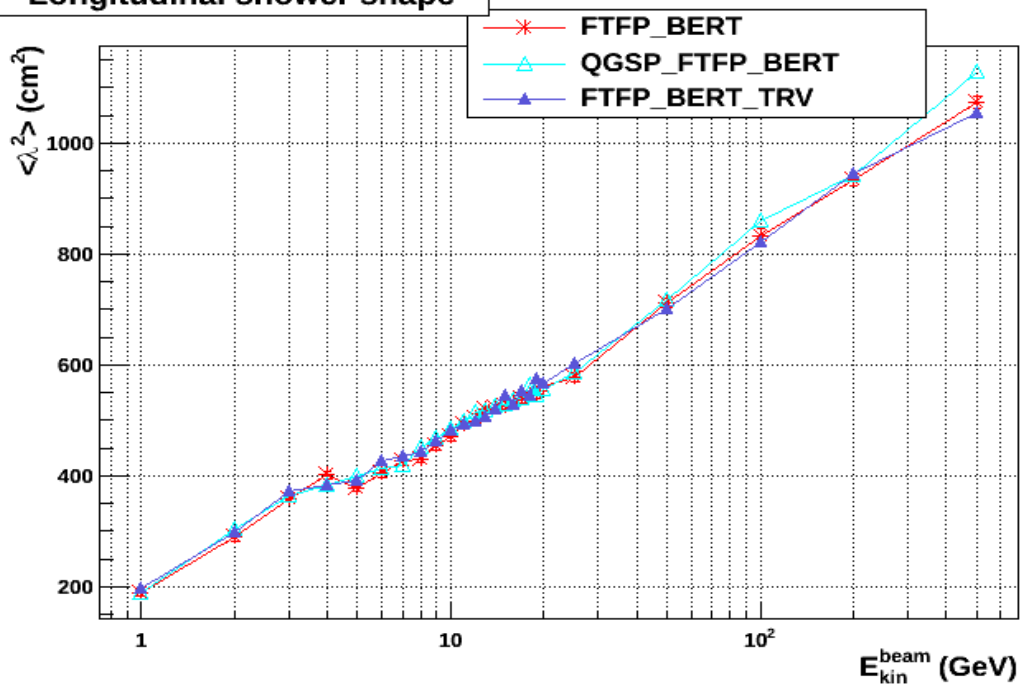
Energy response



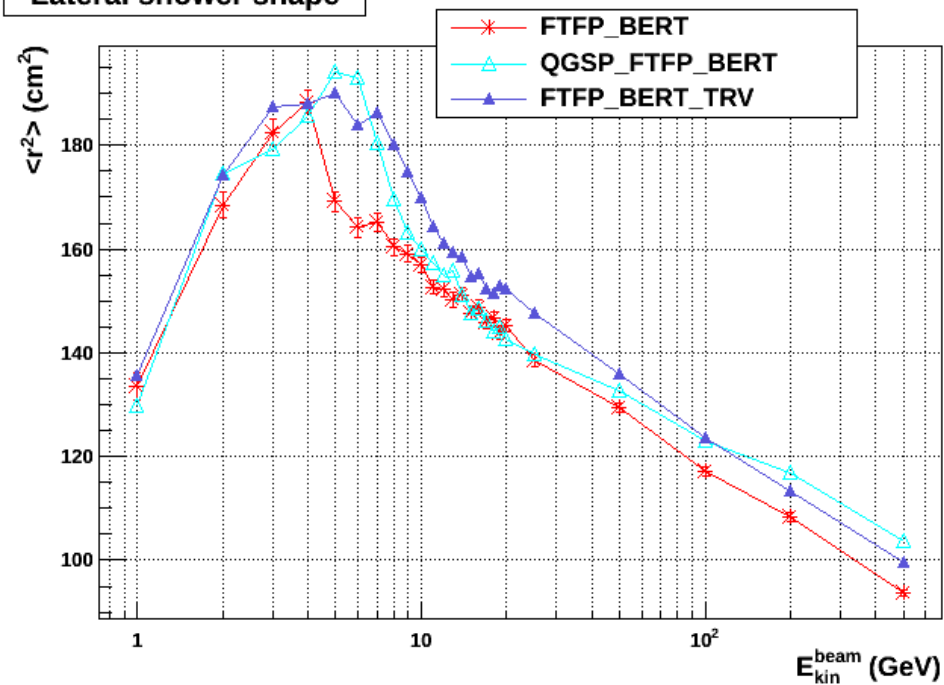
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Longitudinal shower shape

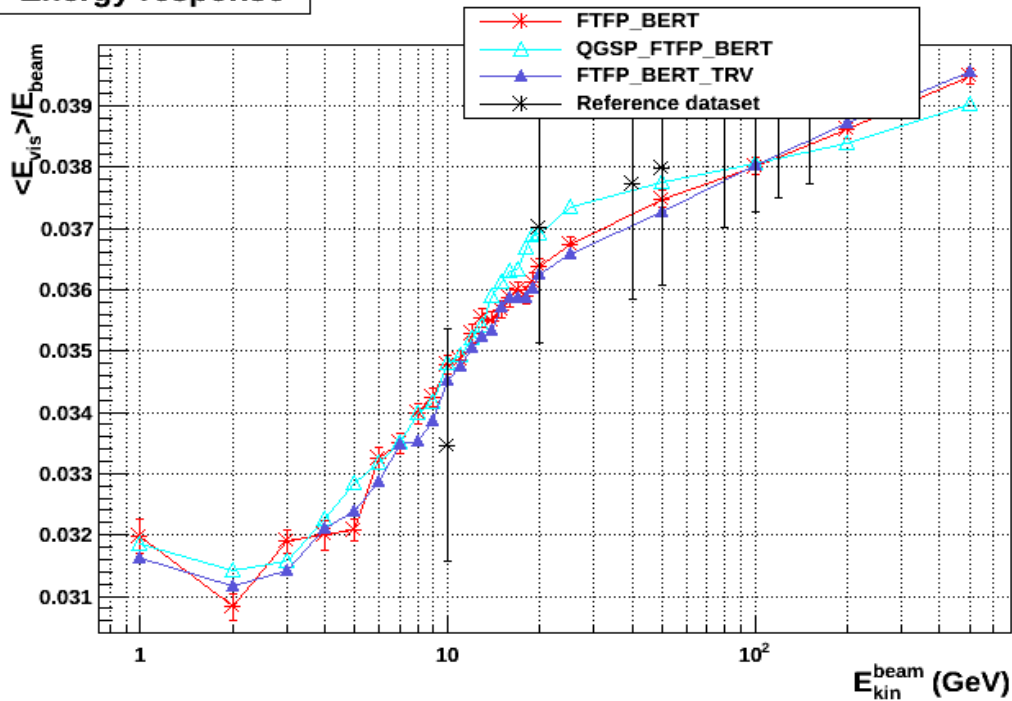


Lateral shower shape

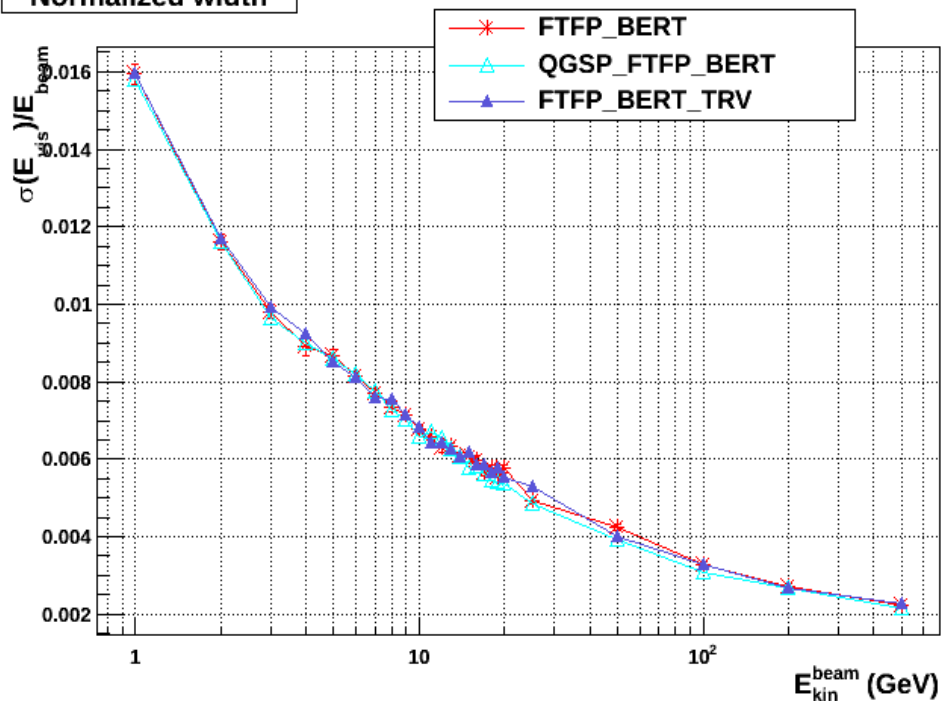


π^- on Cu-LAr

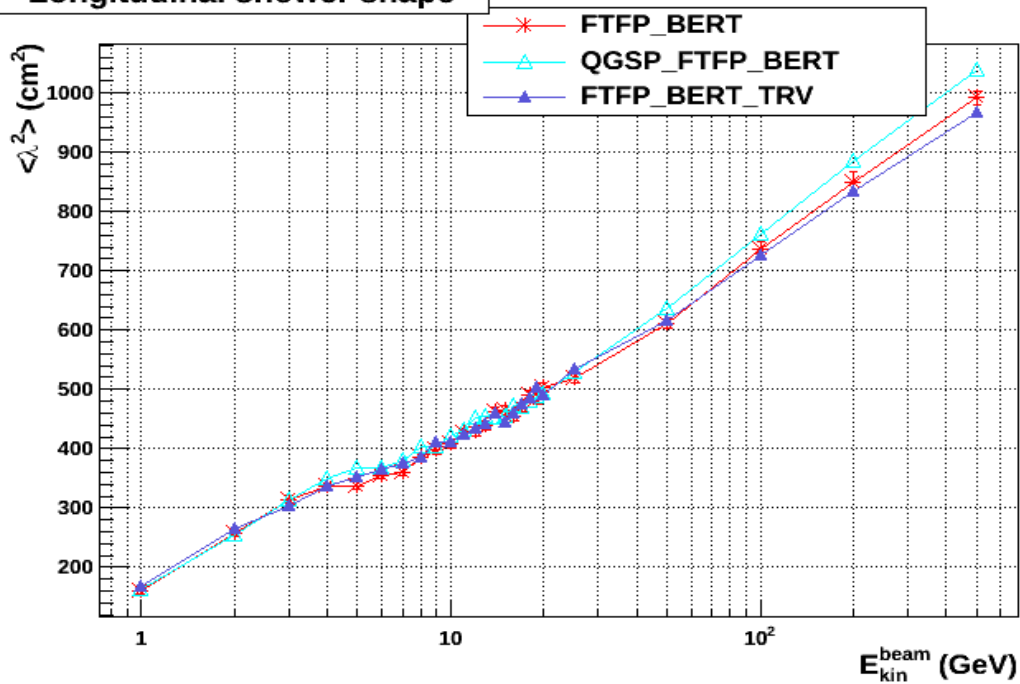
Energy response



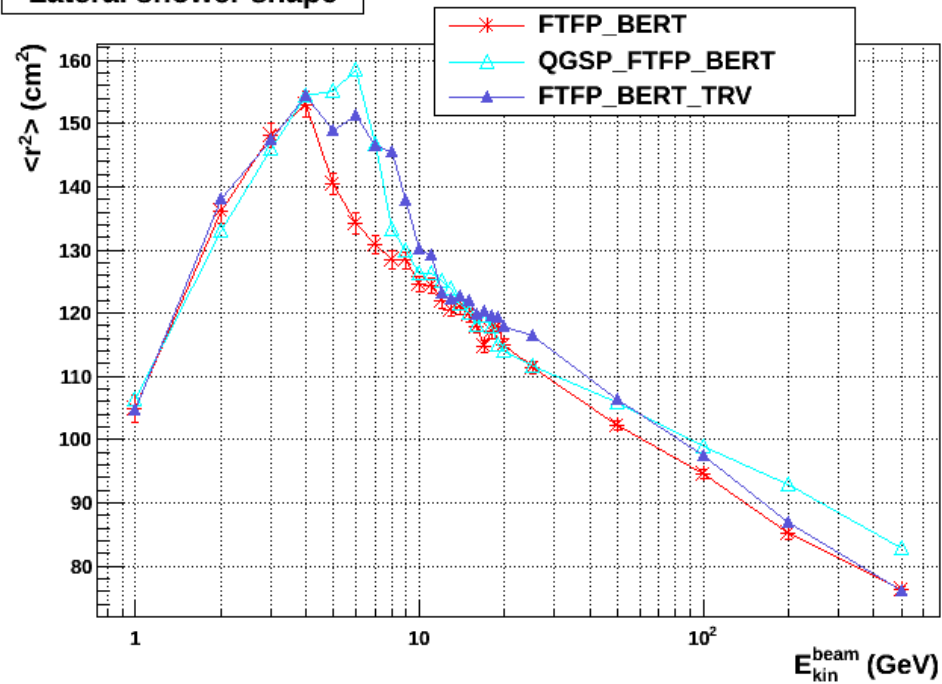
Normalized width



Longitudinal shower shape

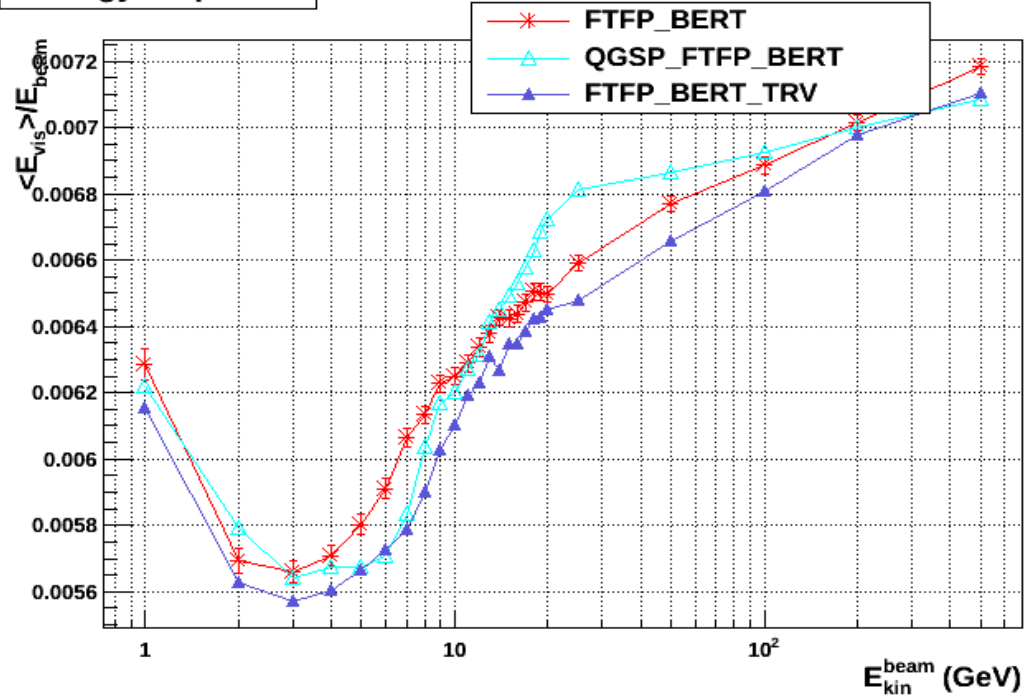


Lateral shower shape

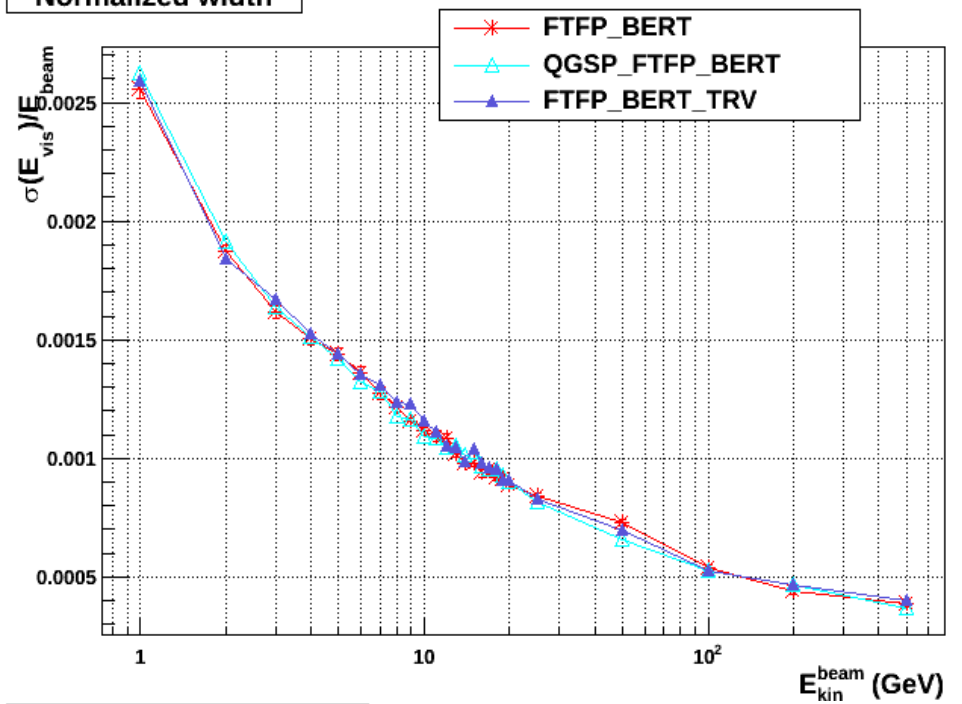


π^- on W-LAr

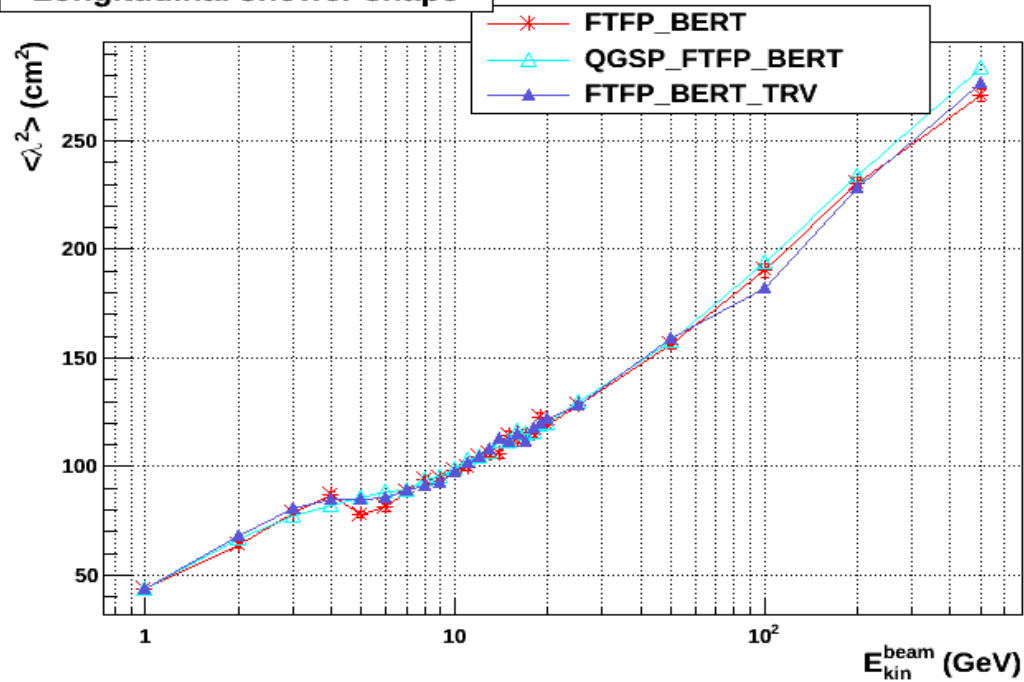
Energy response



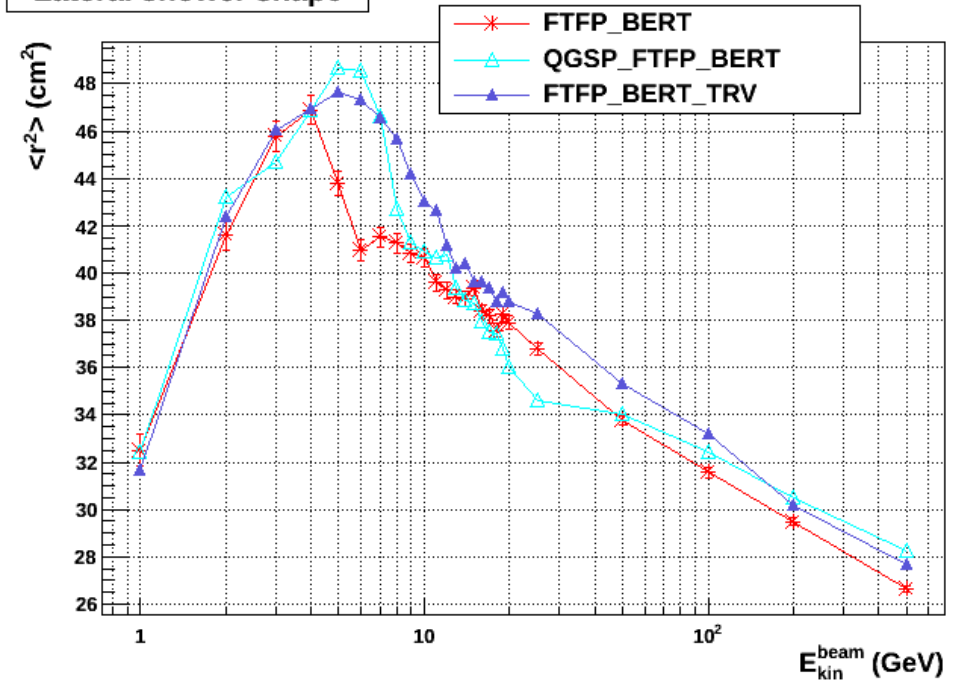
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Longitudinal shower shape

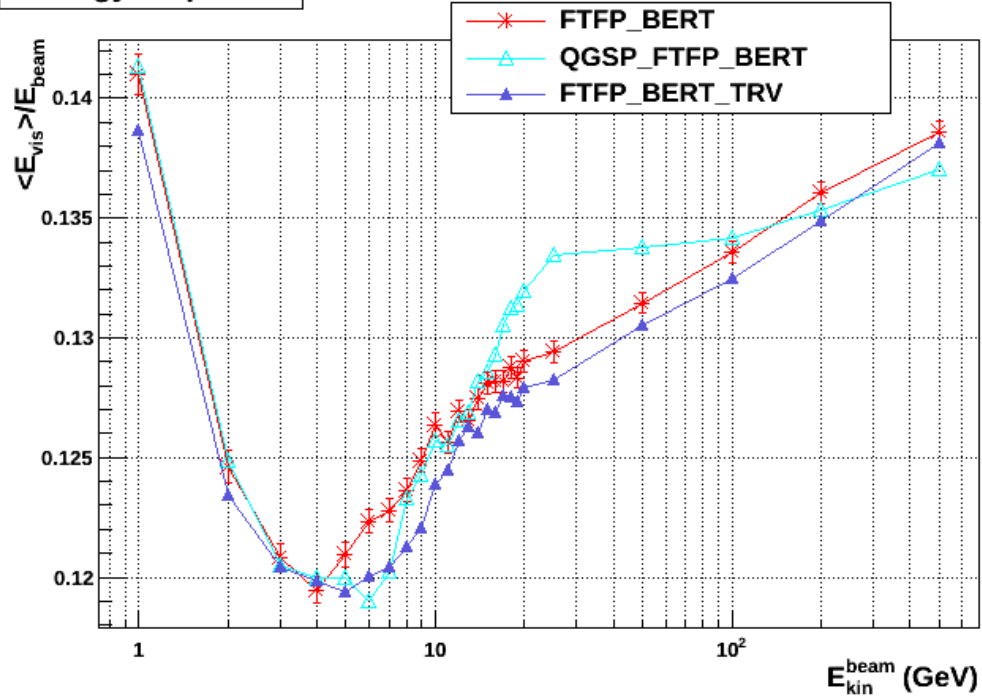


Lateral shower shape

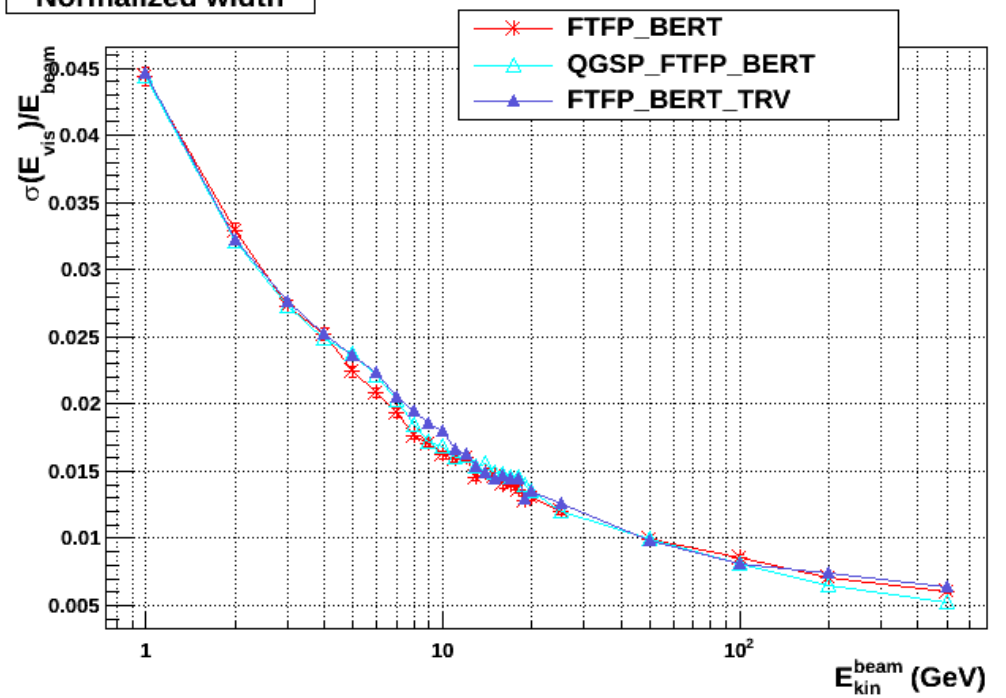


π^- on Pb-LAr

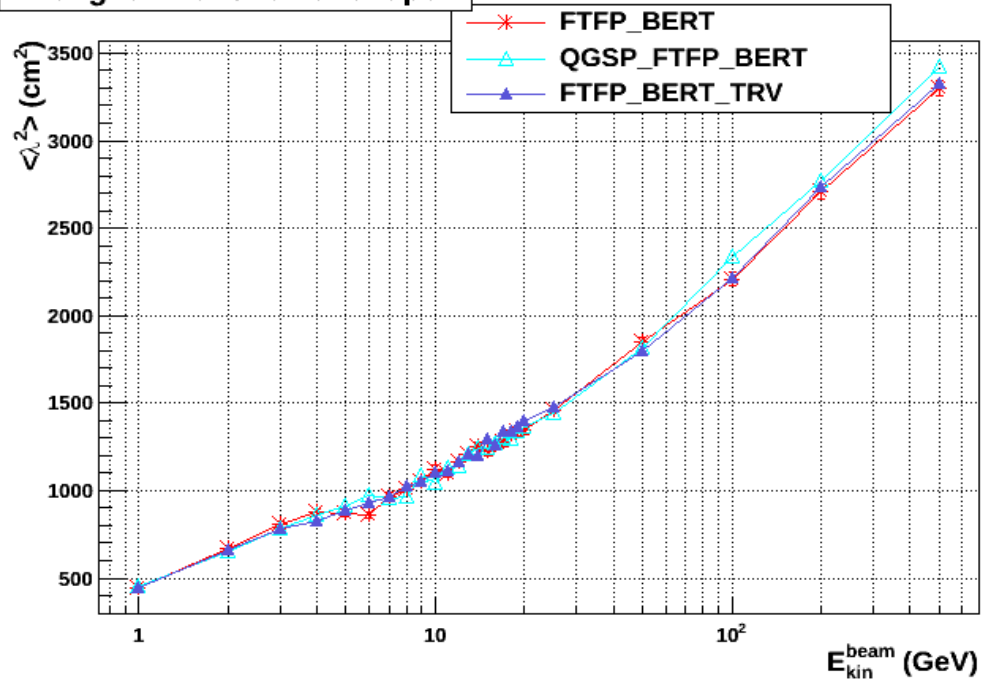
Energy response



Normalized width



Longitudinal shower shape



Lateral shower shape

