



**GEANT4**  
A SIMULATION TOOLKIT

# Hadronic Showers in Geant4 **11.3.beta.cand00** and **11.2.2**

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G4 11.3.beta.cand00

# Main Changes in Hadronics vs. G4 11.2.ref05 (1/3)

- New optional hadronic data set : ***G4URRPT1.0***
  - Pointed by the new environmental variable ***G4URRPTDATA***
  - Used by the new treatment of the unresolved resonance region which can be utilised when the neutron-HP model is present
- *hadronic/models/particle\_hp/*
  - Introduced for neutron in ParticleHP the treatment of the Unresolved Resonance Region (URR) via ProbabilityTable (PT).  
This is a major physics development made by Marek Zmeska and Loic Thulliez (CEA Saclay), relevant for more precise simulations of nuclear reactor criticality and shielding applications. The last missing physics modeling feature of Geant4 with respect to specialized code for neutronics (MCNP, Tripoli)
    - The following existing classes have been modified: *G4ParticleHPChannel, G4ParticleHPChannelList, G4ParticleHPElementData, G4ParticleHPManager, G4ParticleHPMessenger, G4ParticleHPVector*
    - The following new classes have been introduced: *G4ParticleHPCaptureDataPT, G4ParticleHPCaptureURR, G4ParticleHPElasticDataPT, G4ParticleHPElasticURR, G4ParticleHPFissionDataPT, G4ParticleHPFissionURR, G4ParticleHPInelasticDataPT, G4ParticleHPInelasticURR, G4ParticleHPProbabilityTablesStore, G4ParticleHPIsoProbabilityTable, G4ParticleHPIsoProbabilityTable\_CALENDF, G4ParticleHPIsoProbabilityTable\_NJOY*

# Main Changes in Hadronics vs. G4 11.2.ref05 (2/3)

- *hadronic/util/*

- *G4HadronicParameters* : introduced flag to switch on the NUDEX gamma de-excitation module
  - By default it is switched off; to enable it, use the following C++ interface:  
*G4HadronicParameters::Instance() → SetEnableNUDEX( true );*

- *hadronic/models/nudex/*

- Few corrections

- *hadronic/models/de\_excitation/*

- *G4ExcitationHandle*, *G4NeutronRadCapture* : correct model ID for IC electrons
- *G4VCoulombBarrier*, *G4CoulombBarrier*, *G4GEMCoulombBarrier*, *G4FermiBreakUpUtil* : clean-up Coulomb barrier classes, removed unused headers and variables
- *G4GEMChannelVI*, *G4GEMProbabilityVI* : updated interfaces and simplified algorithm of computation of probability

- *hadronic/models/radioactive\_decay/*

- Renamed *G4RadioactiveDecay* -> *G4VRadioactiveDecay*, *G4Radioactivation* -> *G4RadioactiveDecay*
  - Kept the header *G4Radioactivation.hh* for backward compatibility

# Main Changes in Hadronics vs. G4 11.2.ref05 (3/3)

- *physics\_lists/lists/*
  - *G4PhysicsListFactory* : added 3 new variants of the *Shielding* physics list, using *G4LightIonQMDReaction* : ***ShieldingLIQMD*** , *ShieldingLIQMD\_HP* , ***ShieldingLIQMD\_HPT***
    - Addressing problem report #2615 (by the GATE Collaboration)
    - Note that *ShieldingLIQMD* and *ShieldingLIQMD\_HP* refer to the same configuration, the latter is introduced only for consistency
- *physics\_lists/constructors/hadron\_inelastic/*
  - *G4HadronPhysicsQGSP\_BERT\_HP* : used alternative NUDEX model of gamma de-excitation
    - Before (*i.e.* 11.2.ref05), NUDEX was not used anywhere
    - Note: for the time being, NUDEX is used only for neutron capture in QGSP\_BERT\_HP

# Crashes & Warnings

- No crashes
- No infinite loops
- No new warnings

# Reproducibility

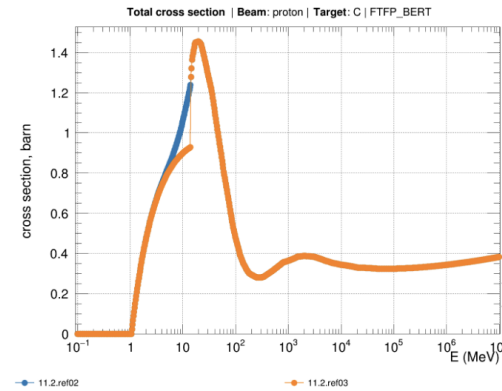
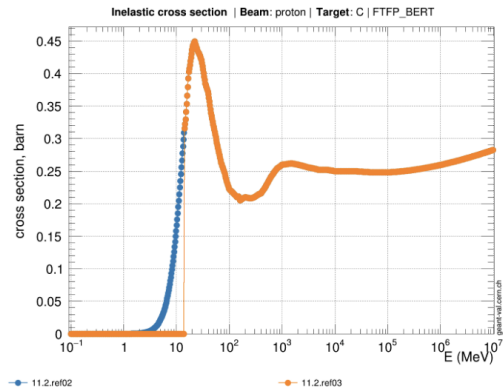
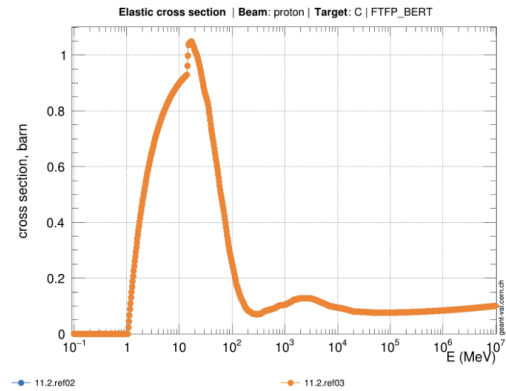
- OK in all cases

# Hadronic inelastic cross sections

proton + C

11.2.ref02

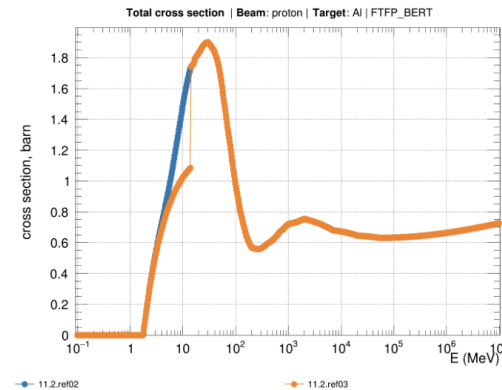
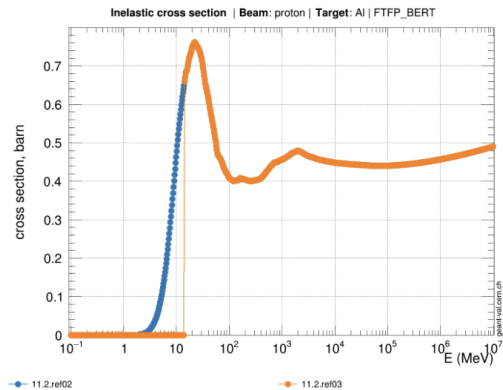
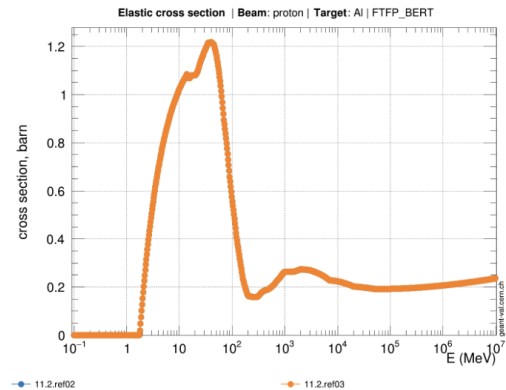
11.2.ref03



Differences appeared in G4 11.2.ref03, when G4PARTICLEXS-4.1 was introduced, together with several changes in the cross section classes.

proton + Al

Fixed by MR !4498, in class *G4BGGNucleonInelasticXS*



# Pion- showers: FTFP\_BERT

G4 11.2.ref05

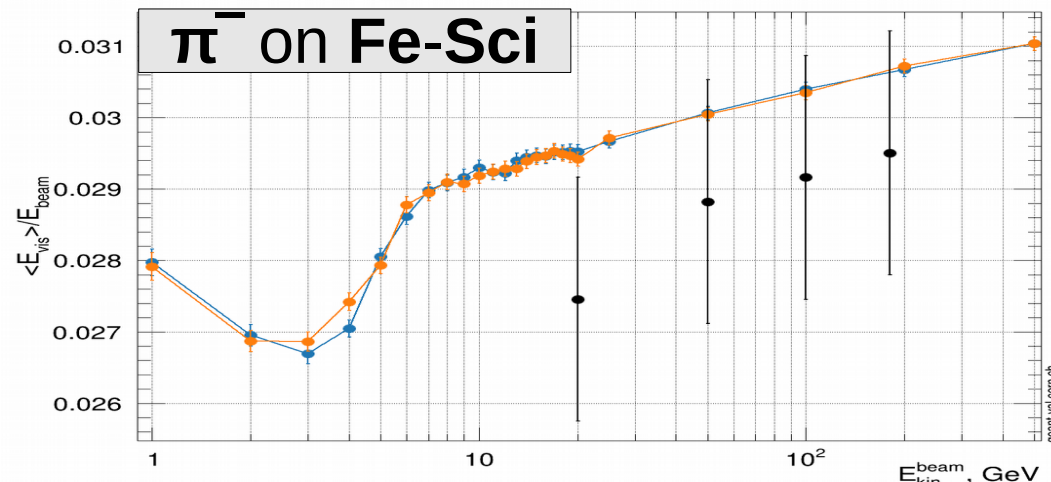
G4 11.3.beta.cand00

*Note : conventional Birks treatment  
(easier and no experimental h/e to fit !)*

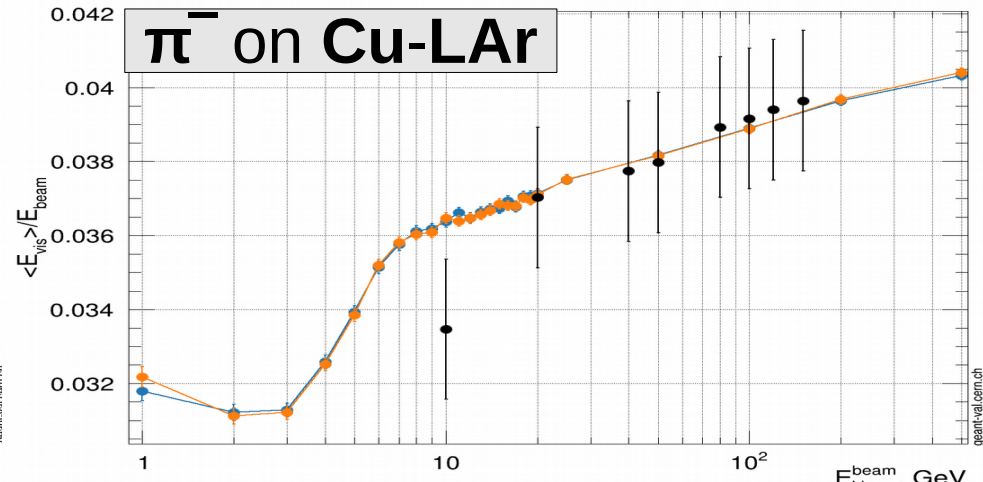


# FTFP\_BERT : Energy Response

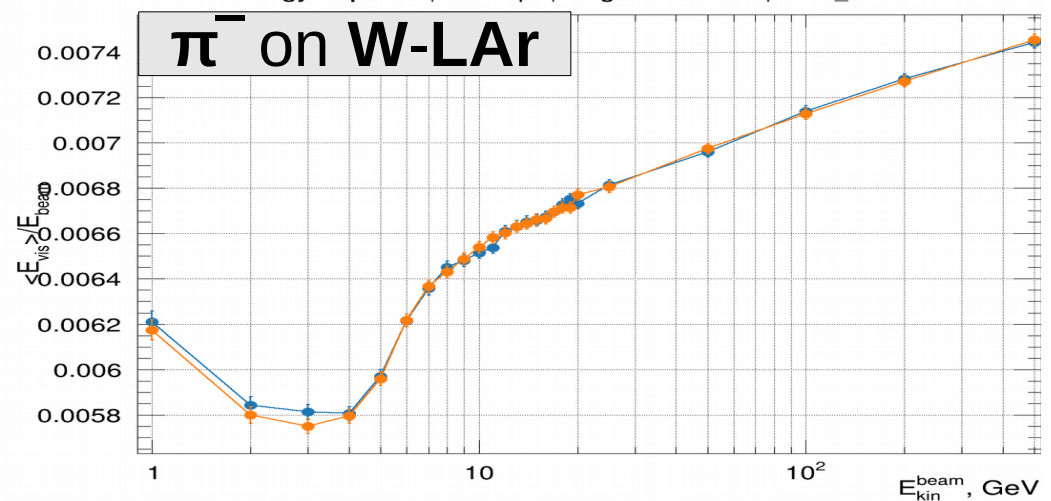
Energy response | Beam: pi- | Target: TileCal



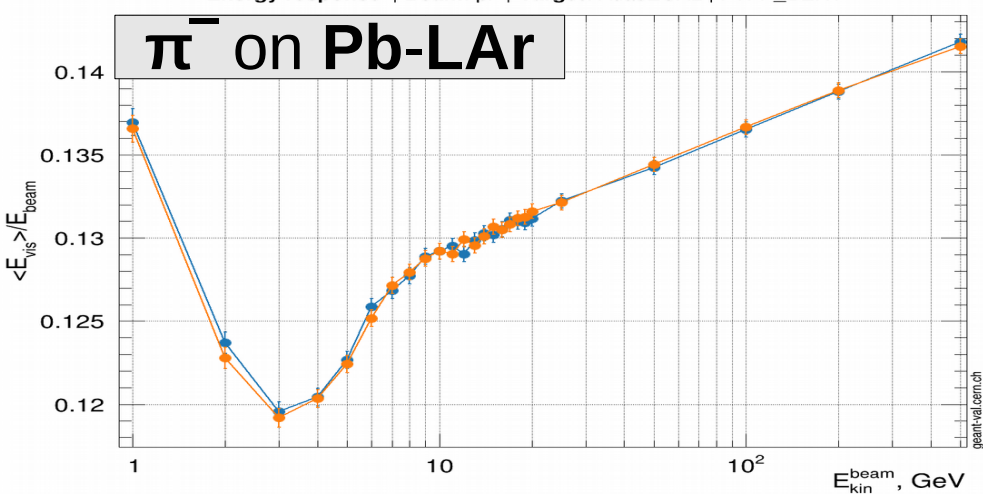
Energy response | Beam: pi- | Target: AtlasHEC



Energy response | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

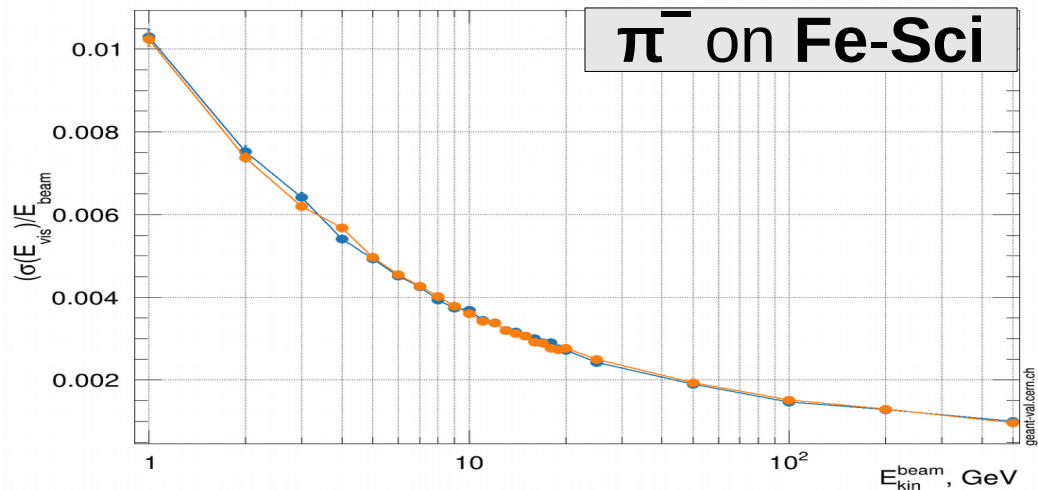


Energy response | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

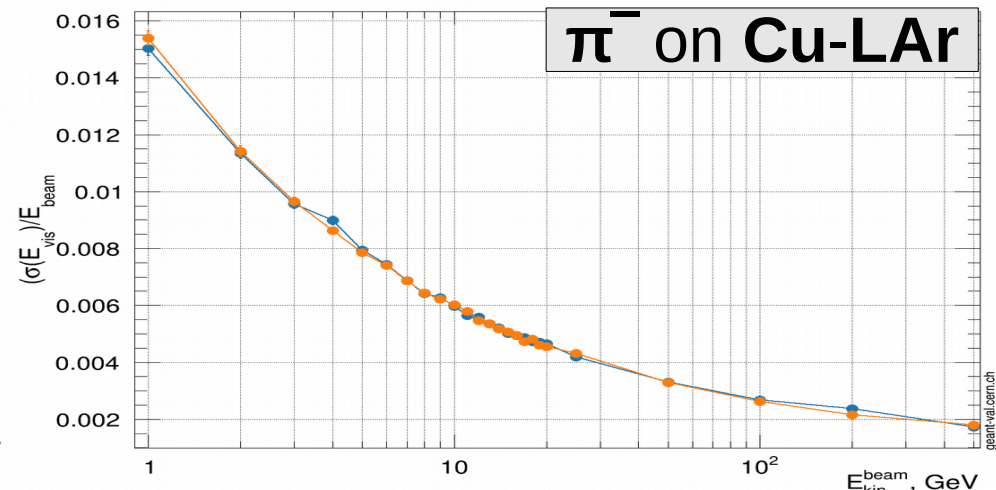


# FTFP\_BERT : Energy Width

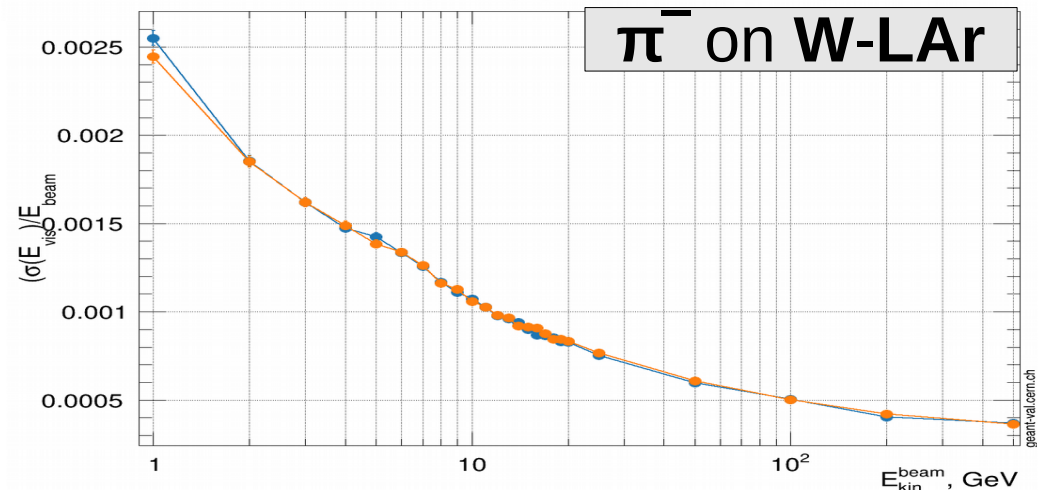
Normalized width | Beam: pi- | Target: TileCal | FTFP\_BERT



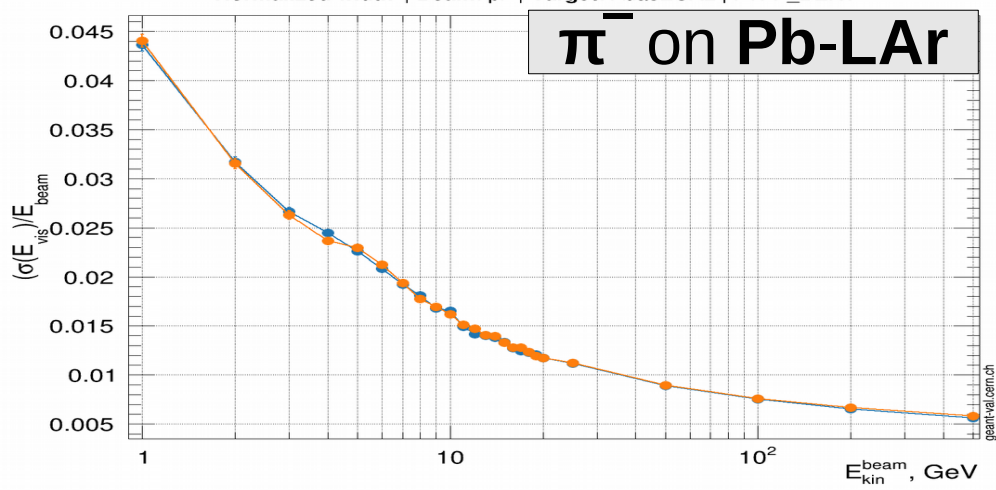
Normalized width | Beam: pi- | Target: AtlasHEC | FTFP\_BERT



Normalized width | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

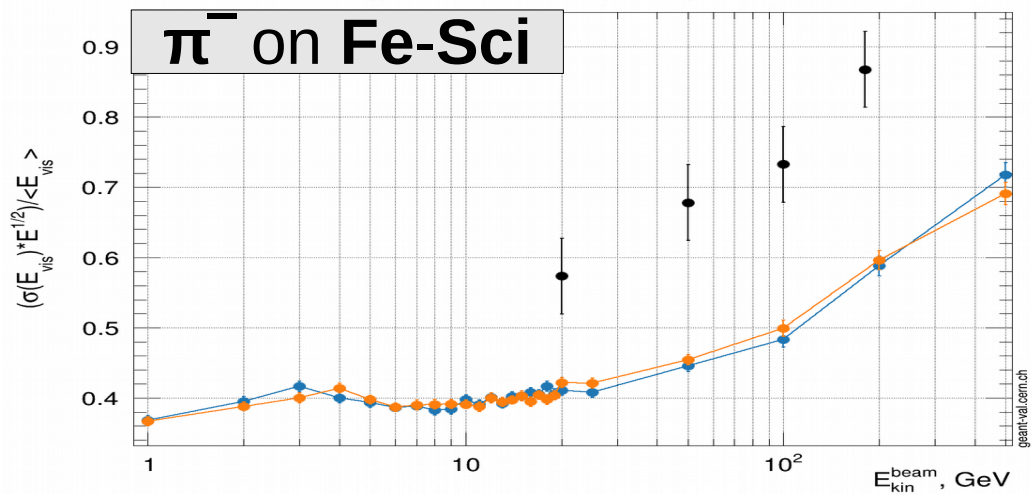


Normalized width | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

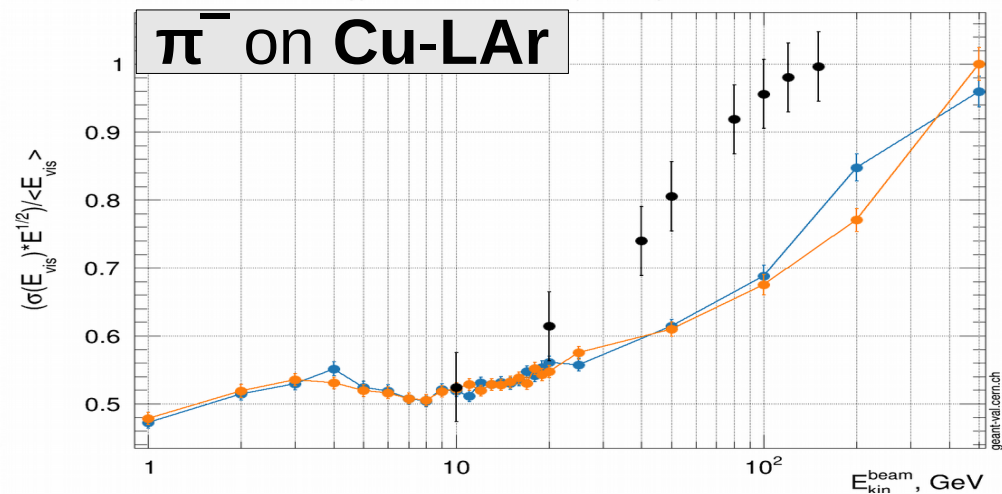


# FTFP\_BERT : Energy Resolution

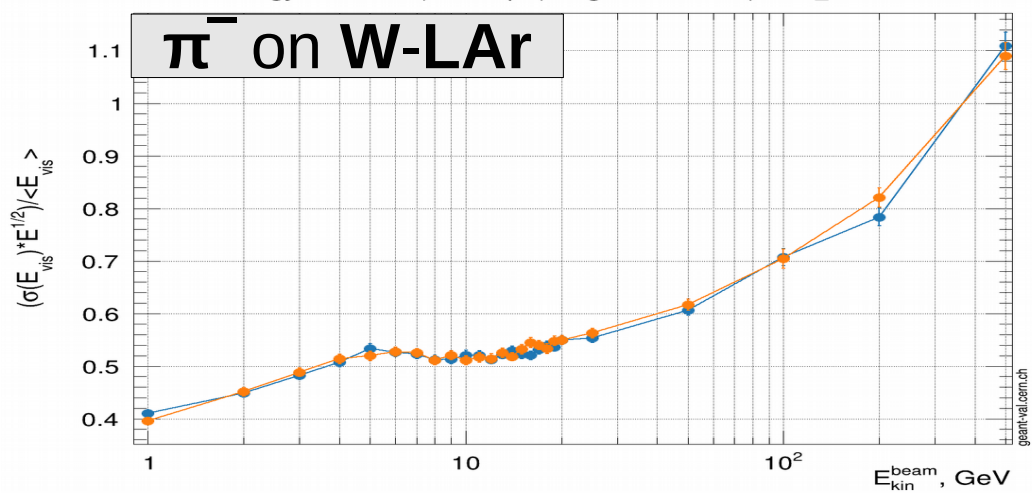
Energy resolution | Beam: pi- | Target: TileCal



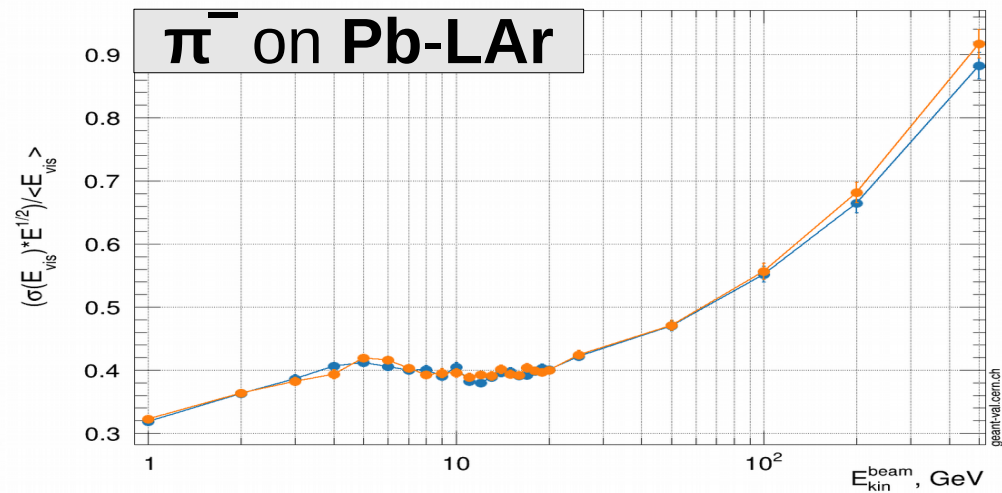
Energy resolution | Beam: pi- | Target: AtlasHEC



Energy resolution | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT



Energy resolution | Beam: pi- | Target: AtlasECAL | FTFP\_BERT



11.2.ref05

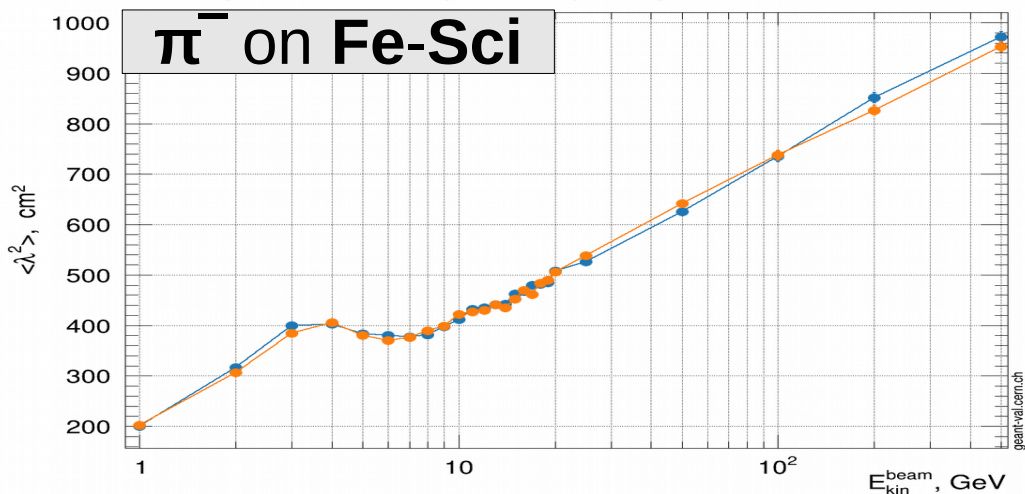
11.3.beta\_cand00

11.2.ref05

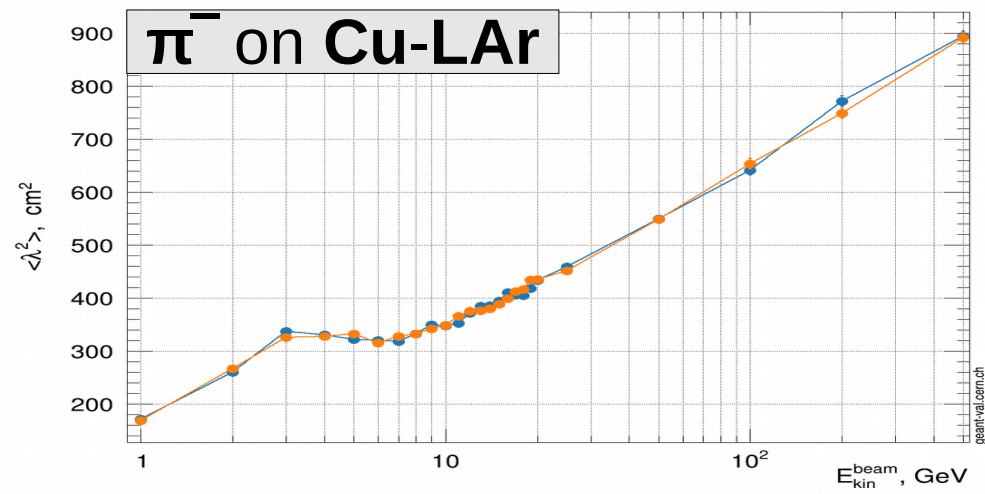
11.3.beta\_cand00

# FTFP\_BERT : Longitudinal Shape

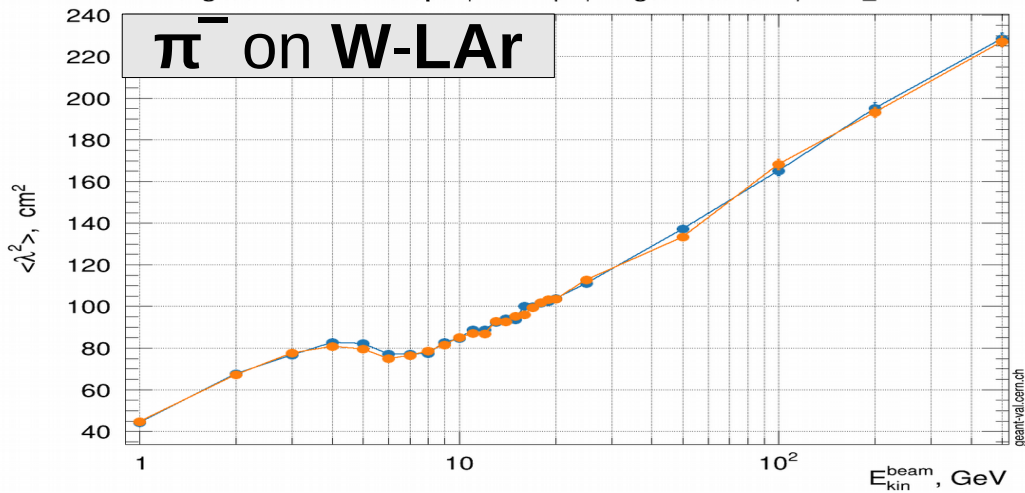
Longitudinal shower shape | Beam: pi- | Target: TileCal | FTFP\_BERT



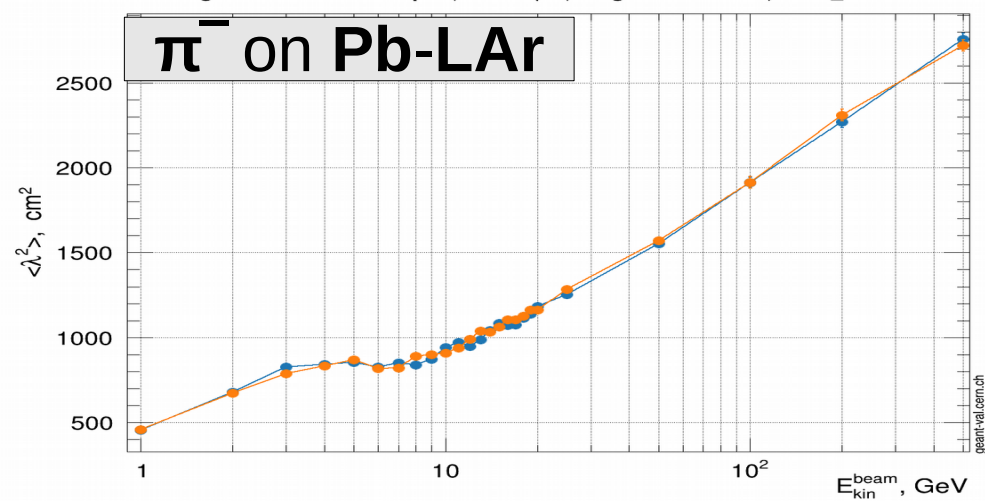
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | FTFP\_BERT



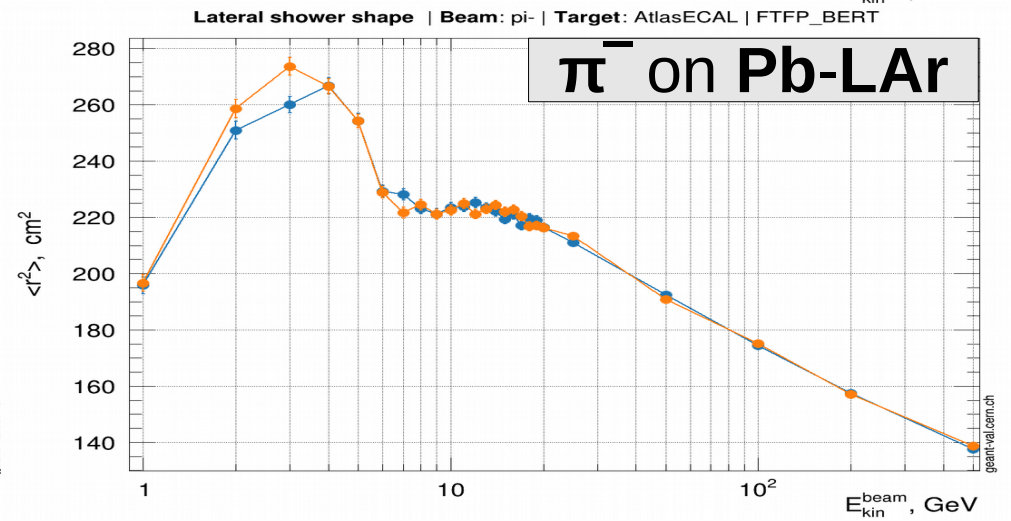
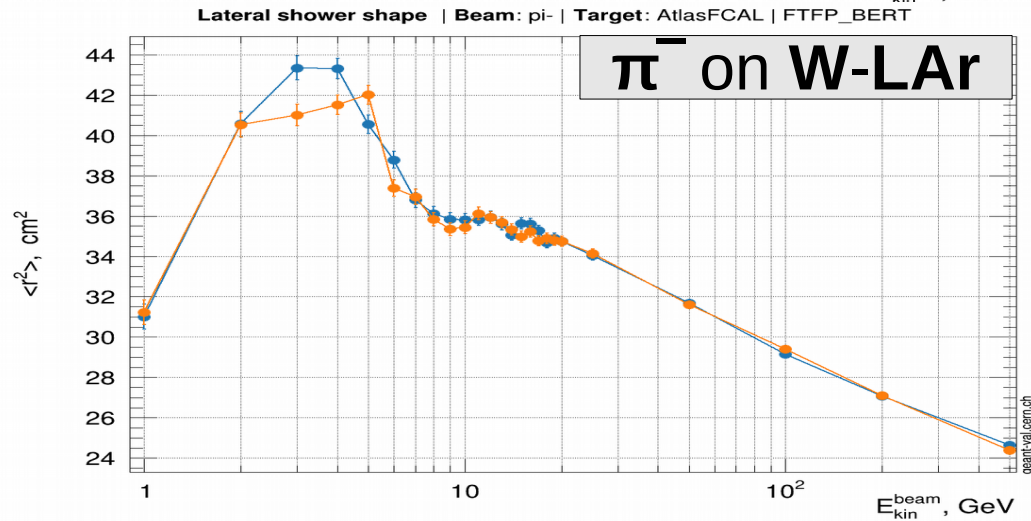
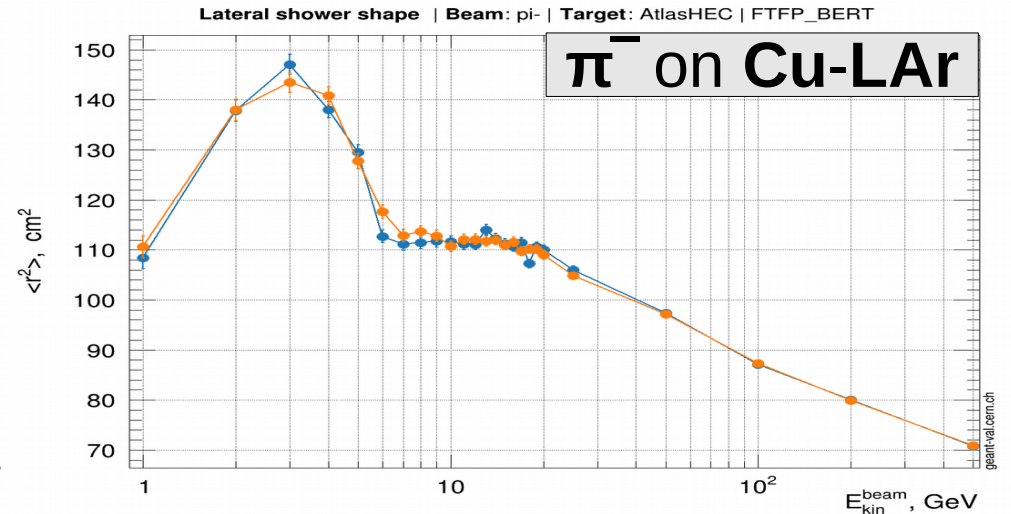
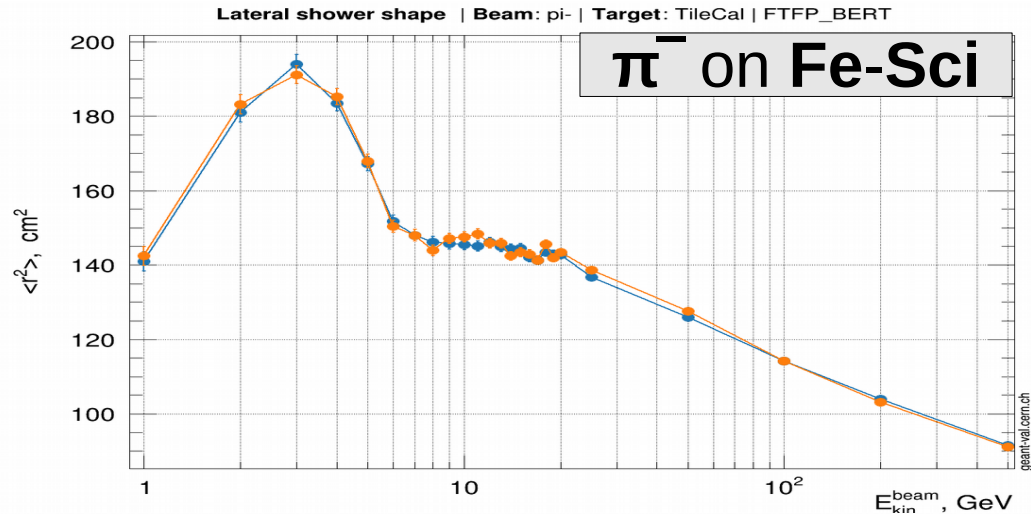
Longitudinal shower shape | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT



Longitudinal shower shape | Beam: pi- | Target: AtlasECAL | FTFP\_BERT



# FTFP\_BERT : Lateral Shape



# Conclusions

- **G4 11.3.beta.cand00**
  - No crashes, no infinite loops, no new warnings
  - Reproducibility fine in all cases
  - Hadron showers
    - For all physics lists, hadronic showers are similar as those of G4 11.2.ref05

G4 11.2.2

# Main Changes in Hadronics vs. G4 11.2.1 (1/2)

- Data set *G4NDL4.7.1*
  - Removed all files for Argon-36 and Argon-38
    - Natural isotopes with abundance < 1%, whose cross sections are significantly different from ENDF/B-VIII.0
  - Reprocessed thermal scattering files after fixing a problem in NJOY (problem report #2552)
- *hadronic/models/binary\_cascade/*
  - Removed throwing of exception if momentum cannot be corrected - in rare cases for D + H around 1600 MeV (reported by ATLAS in January) : the initial state is now kept unchanged instead
- *hadronic/models/radioactive\_decay/*
  - *G4BetaMinusDecay*, *G4BetaPlusDecay* : added protection to avoid neutrino with negative energy
    - Due to the inconsistency between Geant4 masses and Q-values from the data set RadioactiveDecay5.6 . It does not affect the kinetic energy of the electron/positron
- *hadronic/models/inclxx/*
  - *G4INCLInteractionAvatar* : not use local energy for all antibaryons



# Main Changes in Hadronics vs. G4 11.2.1 (2/2)

- *hadronic/models/particle\_hp/*
  - *G4CrossSectionHP* : taken into account temperature effect;  
fixed elastic and capture cross sections in Argon;  
fixed cross sections for rare target atoms (Promethium, Astatine, Radon, and Francium)
    - For the time being, this class, introduced in 2023, is used only in QGSP\_BERT\_HP physics list
- *physics\_lists/lists/*
  - *G4PhysicsListFactory* : added 3 new variants of the *Shielding* physics list, using  
*G4LightIonQMDReaction* : ***ShieldingLIQMD*** , ***ShieldingLIQMD\_HP*** , ***ShieldingLIQMD\_HPT***
    - Addressing problem report #2615 (by the GATE Collaboration)
    - Note that *ShieldingLIQMD* and *ShieldingLIQMD\_HP* refer to the same configuration, the latter is introduced only for consistency

# Crashes & Warnings

- No crashes
- No infinite loops
- No new warnings

# Reproducibility

- OK in all cases

# Pion- showers: FTFP\_BERT

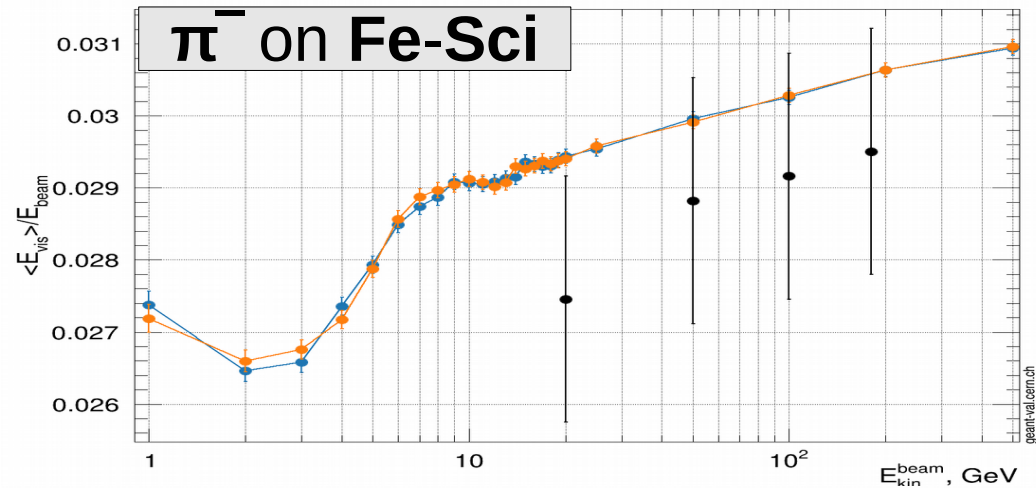
G4 11.2.1

G4 11.2.2

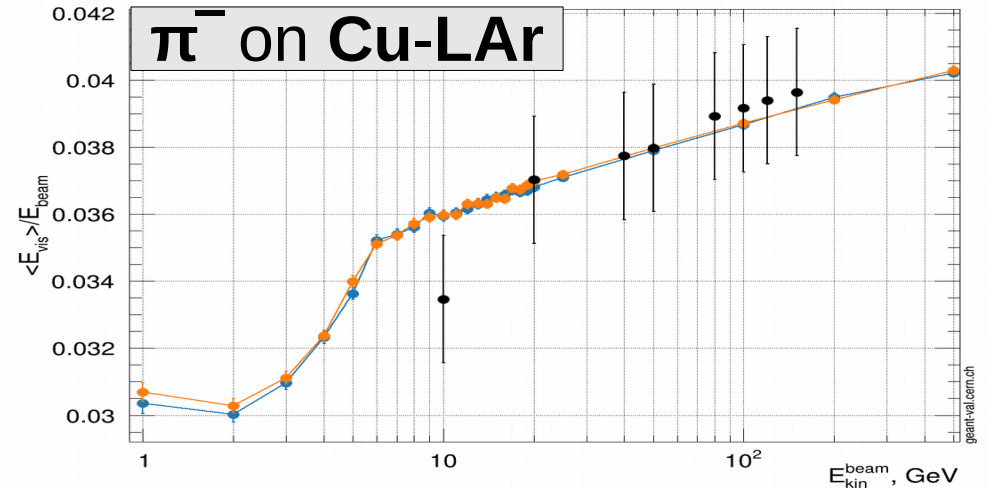
*Note : conventional Birks treatment  
(easier and no experimental h/e to fit !)*

# FTFP\_BERT : Energy Response

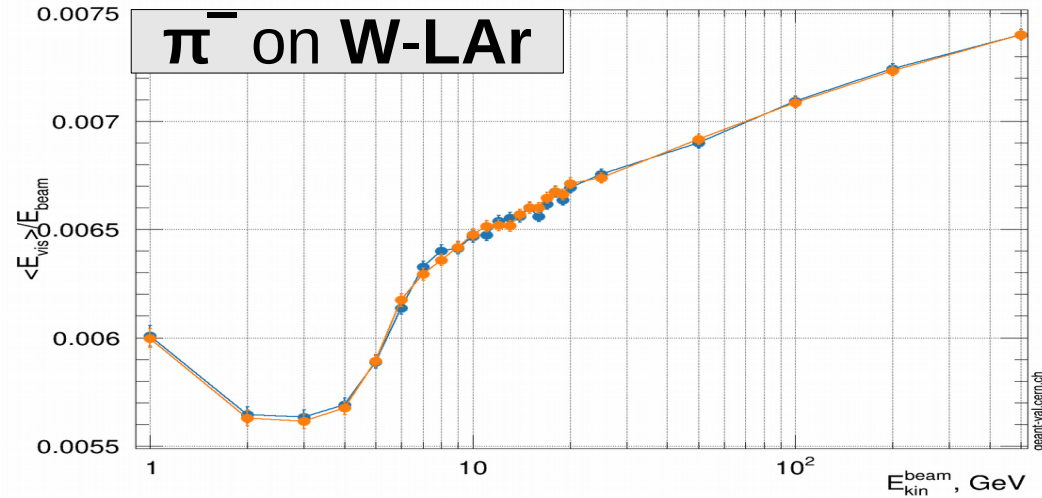
Energy response | Beam: pi- | Target: TileCal



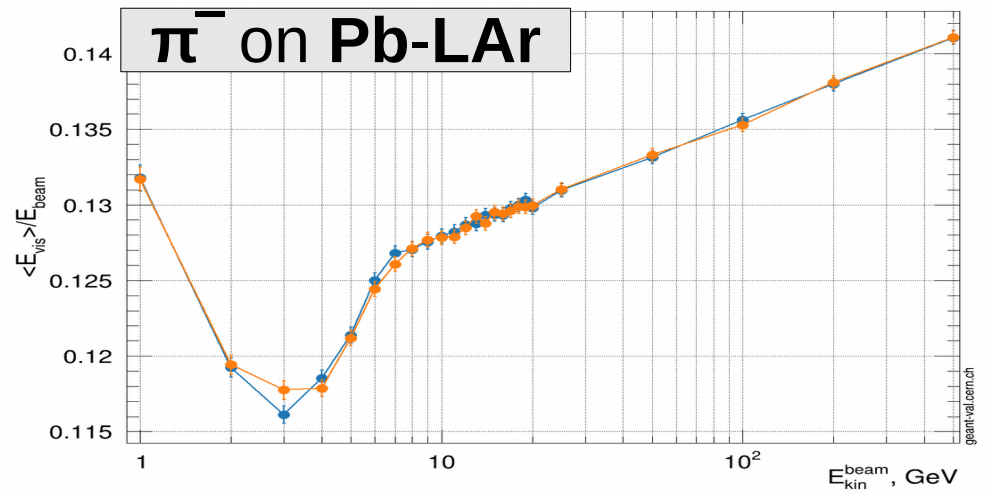
Energy response | Beam: pi- | Target: AtlasHEC



Energy response | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

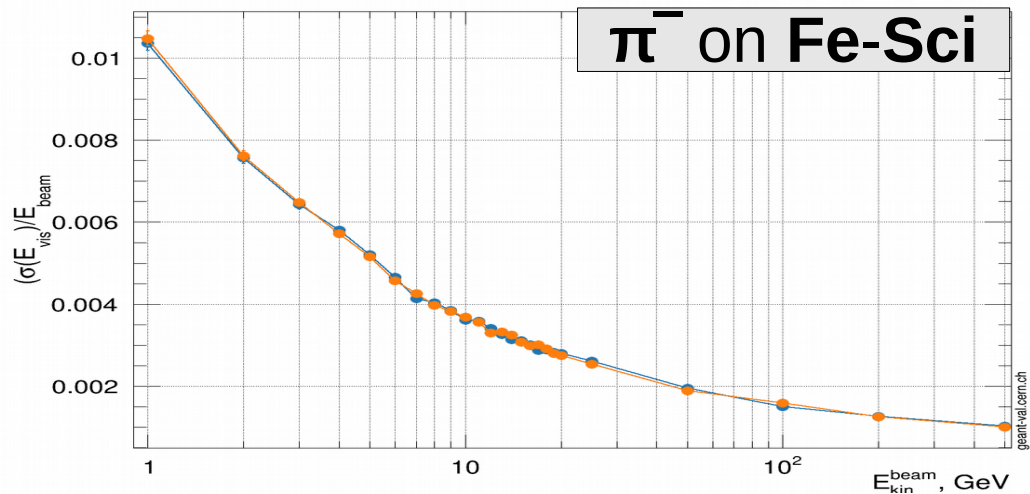


Energy response | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

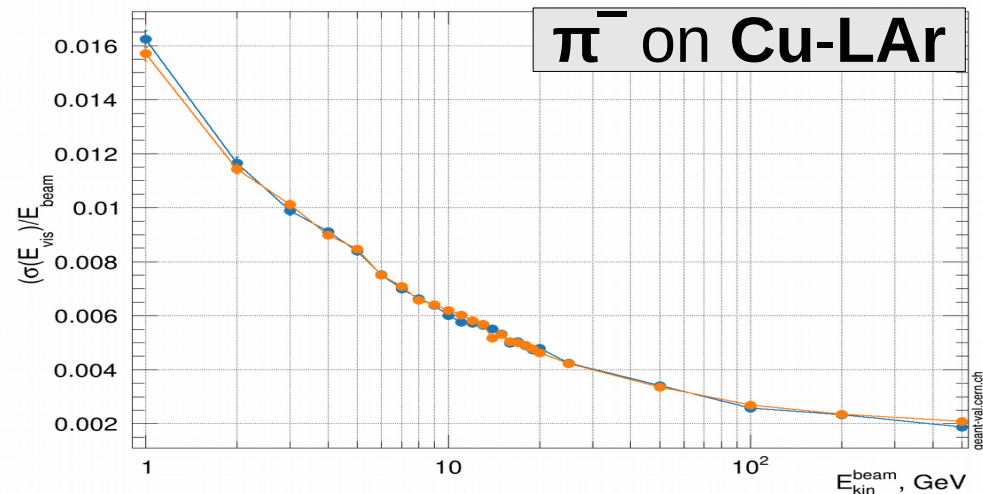


# FTFP\_BERT : Energy Width

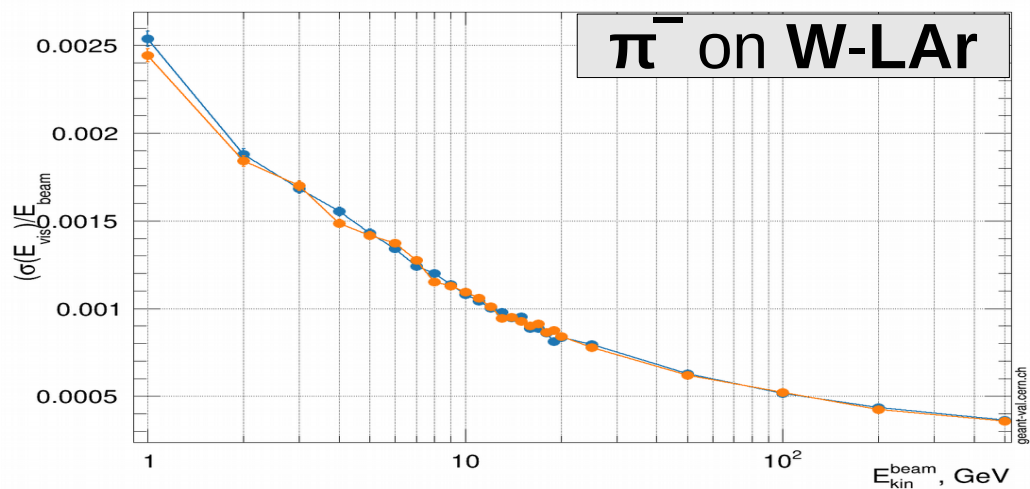
Normalized width | Beam: pi- | Target: TileCal | FTFP\_BERT



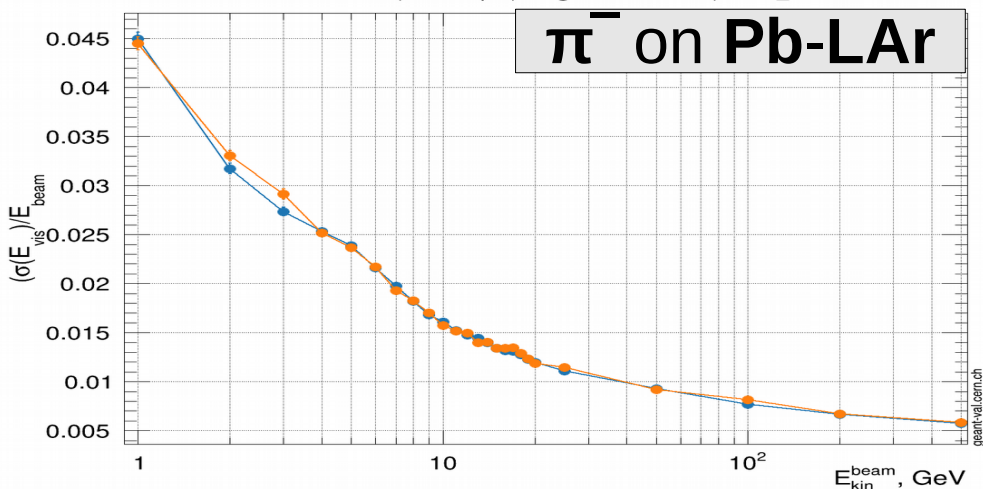
Normalized width | Beam: pi- | Target: AtlasHEC | FTFP\_BERT



Normalized width | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

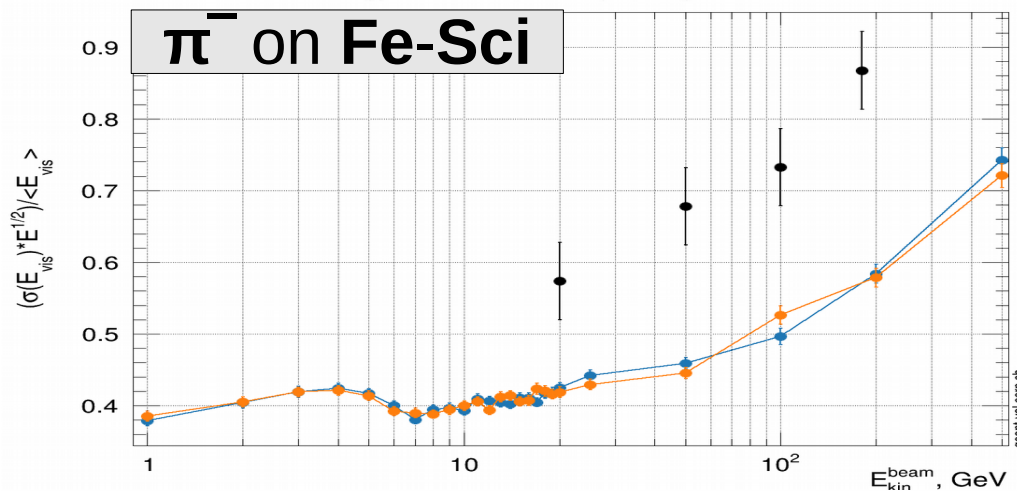


Normalized width | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

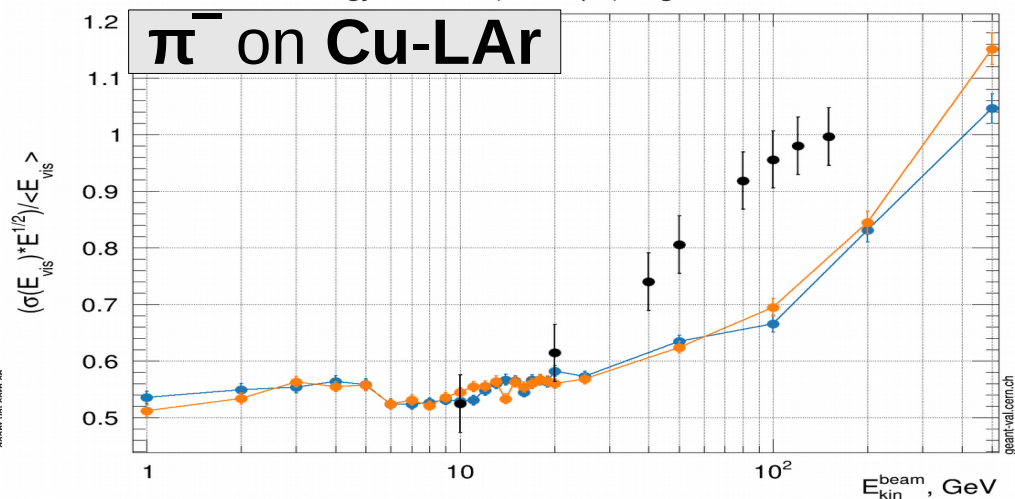


# FTFP\_BERT : Energy Resolution

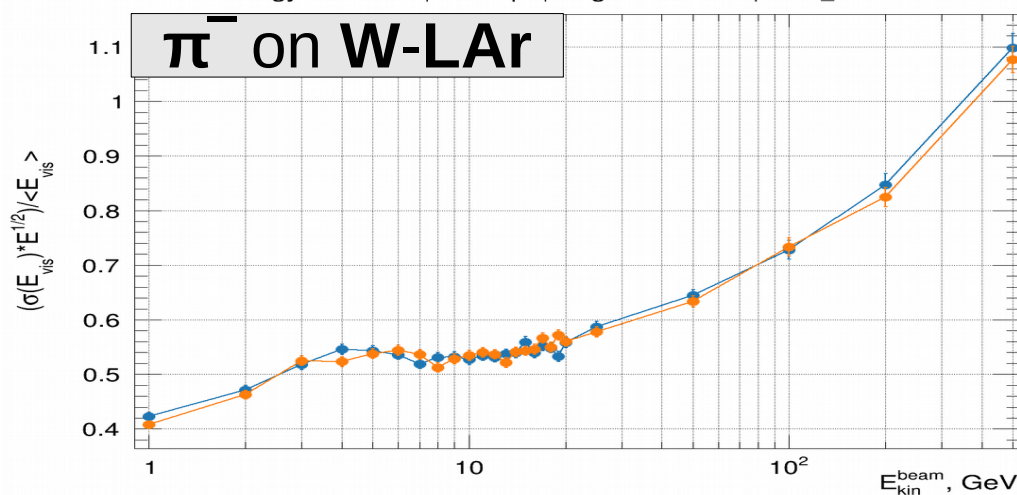
Energy resolution | Beam: pi- | Target: TileCal



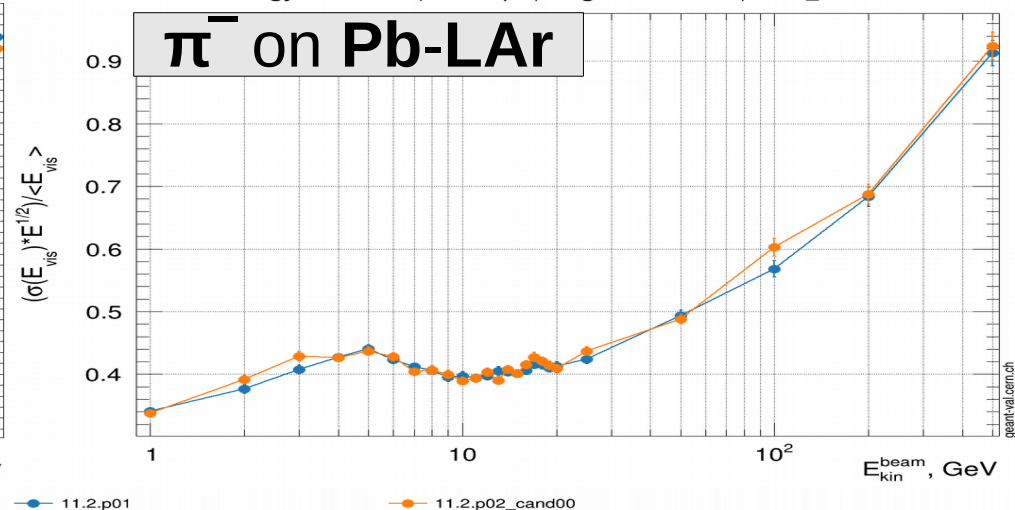
Energy resolution | Beam: pi- | Target: AtlasHEC



Energy resolution | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

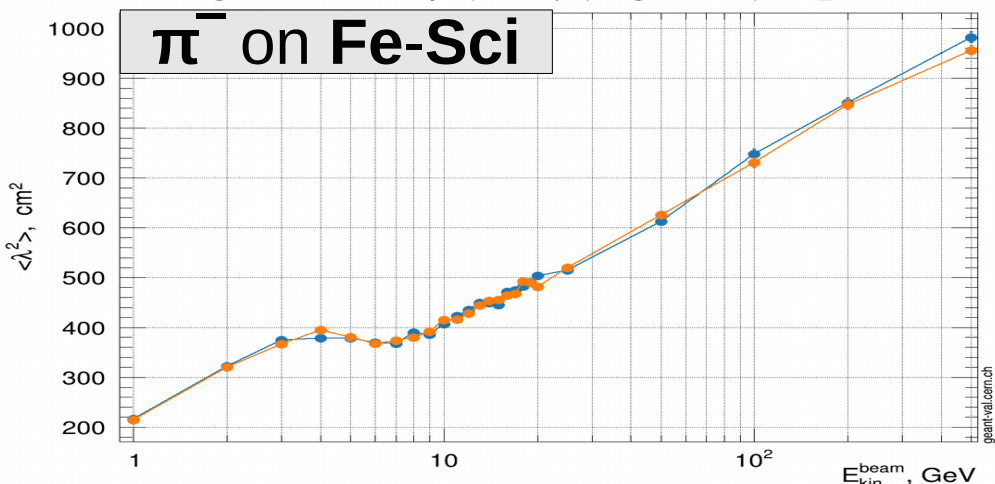


Energy resolution | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

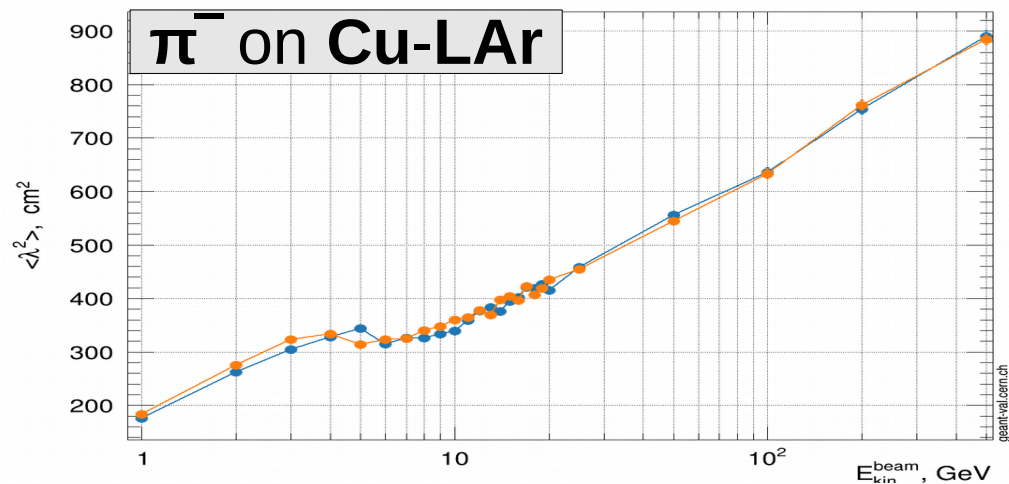


# FTFP\_BERT : Longitudinal Shape

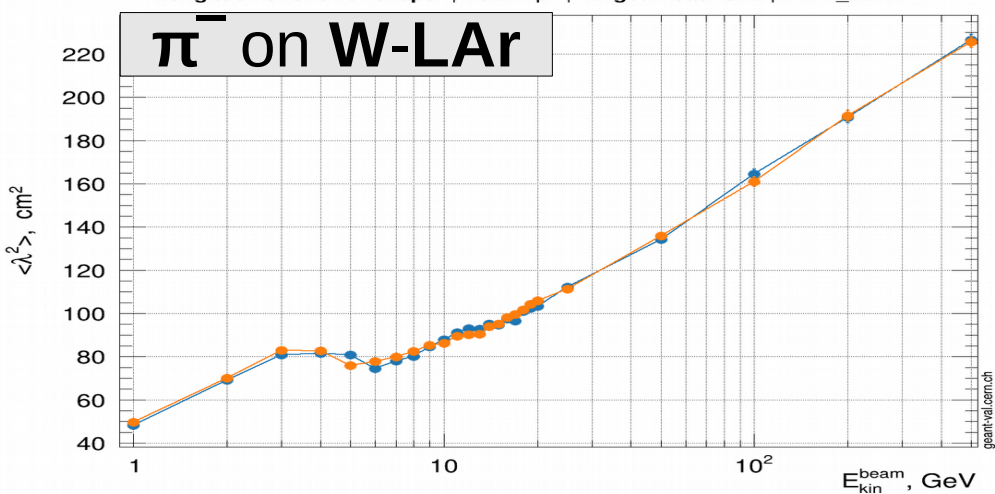
Longitudinal shower shape | Beam: pi- | Target: TileCal | FTFP\_BERT



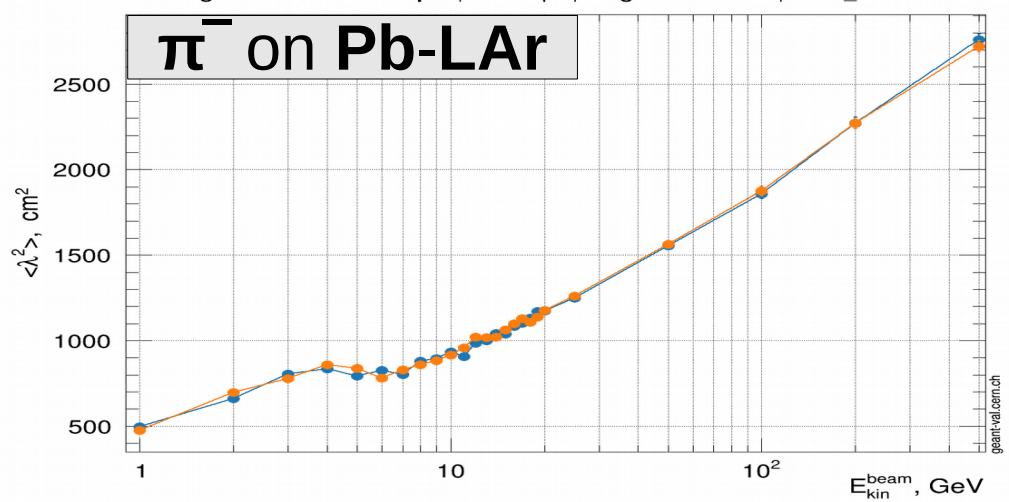
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | FTFP\_BERT



Longitudinal shower shape | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT



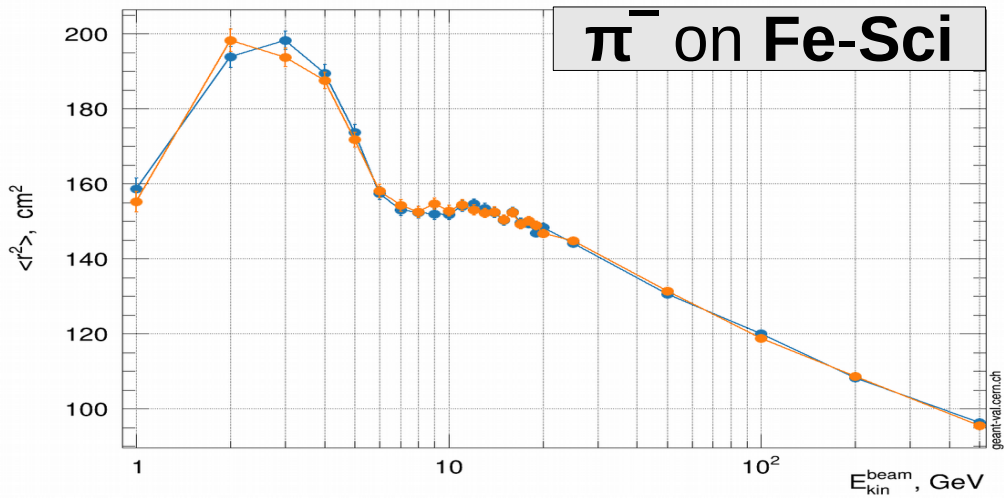
Longitudinal shower shape | Beam: pi- | Target: AtlasECAL | FTFP\_BERT



# FTFP\_BERT : Lateral Shape

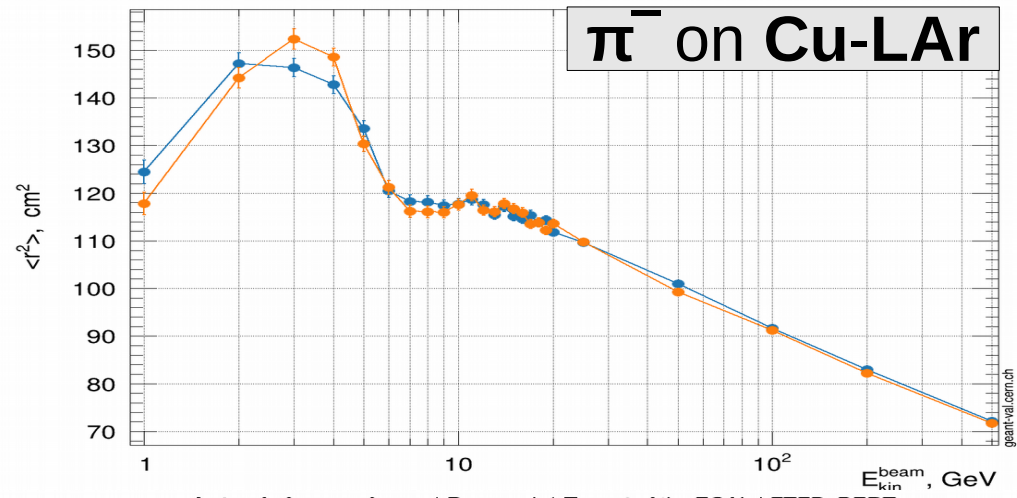
Lateral shower shape | Beam: pi- | Target: TileCal | FTFP\_BERT

$\pi^-$  on Fe-Sci



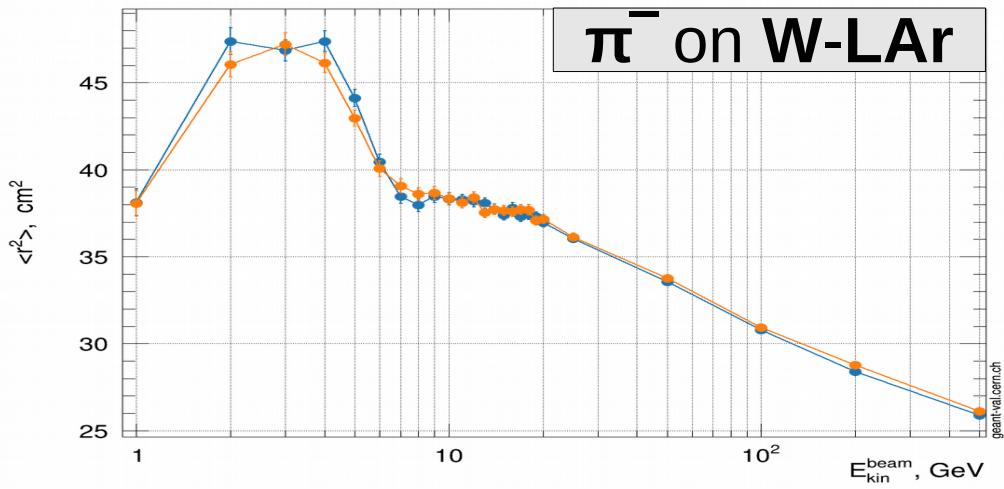
Lateral shower shape | Beam: pi- | Target: AtlasHEC | FTFP\_BERT

$\pi^-$  on Cu-LAr



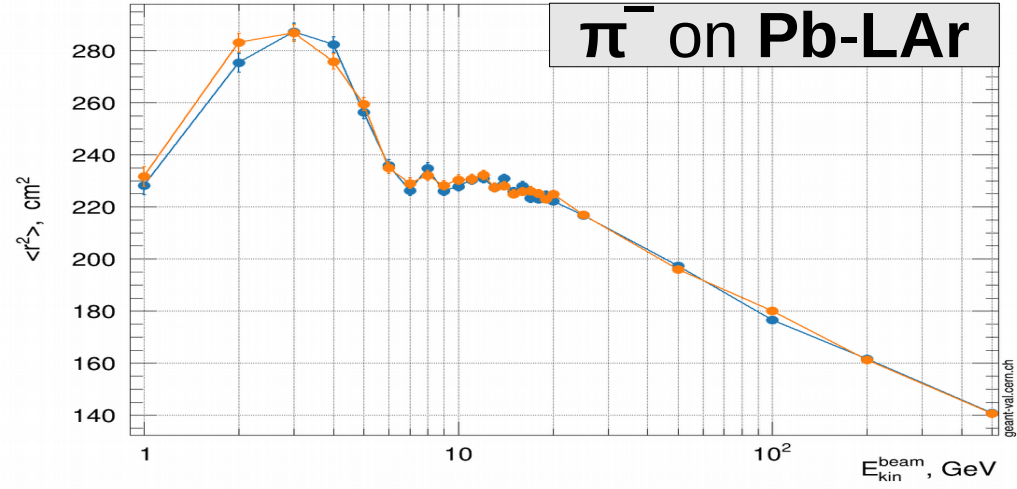
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

$\pi^-$  on W-LAr



Lateral shower shape | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

$\pi^-$  on Pb-LAr





# Conclusions

- **G4 11.2.2**
  - No crashes, no infinite loops, no new warnings
  - Reproducibility fine in all cases
  - Hadron showers
    - For all physics lists, hadronic showers are similar as those of G4 11.2.1