



**GEANT4**  
A SIMULATION TOOLKIT

# Hadronic Showers in Geant4 **11.3.ref01**

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# Main Changes in Hadronics vs. G4 11.3.ref00 (1/2)

- *hadronic/model/de-excitation*
  - *G4ExcitationHandler, G4GammaTransition, G4PhotonEvaporation* : removed production of unphysical states. Addressing problem report #2584
  - *G4NucLevel, G4PhotonEvaporation* : minor, technical fixes
  - *G4DeexPrecoParameters* : added extra enumerator to choose variants of the pre-compound model
- *hadronic/model/pre\_equilibrium*
  - *G4PreCompoundInterface, G4PreCompoundTransitionsInt, G4PreCompoundEmissionInt* : new classes (introduced by Vladimir Ivanchenko) for an alternative pre-compound model with respect to the default one (which remains unchanged)
  - *G4PreCompoundModel, G4PreCompoundTransition, G4PreCompoundEmission* : introduced the option to use alternative pre-compound models

# Main Changes in Hadronics vs. G4 11.3.ref00 (2/2)

- *hadronic/util*
  - *G4Fragment* : added protection against precision loss in the computation of Lorentz boost vector (for a fragment nearly at rest)
- *hadronic/model/particle\_hp*
  - *G4ParticleHPThermalScatteringData* : several technical improvements, in particular for initialisation, multi-threading and in throwing exceptions
- *hadronic/model/radioactive\_decay*
  - *G4RadioactiveDecay* : fix to enable biasing in radioactive decay. Addressing problem report #2592
- *hadronic/model/lend*
  - *G4LENDCombinedModel* : fix in photo-fission
  - Collected all inelastic models (neutron- and gamma-induced) into a new inelastic physics list constructor, *G4HadronicPhysicsLEND*, and then update accordingly the physics list constructors *G4EmExtraPhysics* and *G4HadronPhysicsShielding*, as well as the physics list *Shielding*

# Crashes & Warnings

- No crashes
- No infinite loops
- No new warnings

# Reproducibility

- OK in all cases

# Pion- showers: FTFP\_BERT

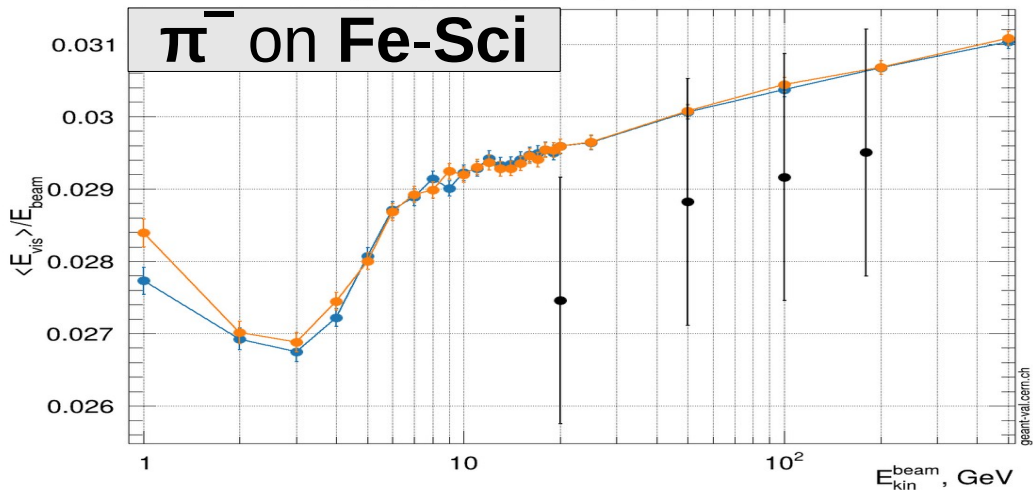
G4 [11.3.ref00](#)

G4 [11.3.ref01](#)

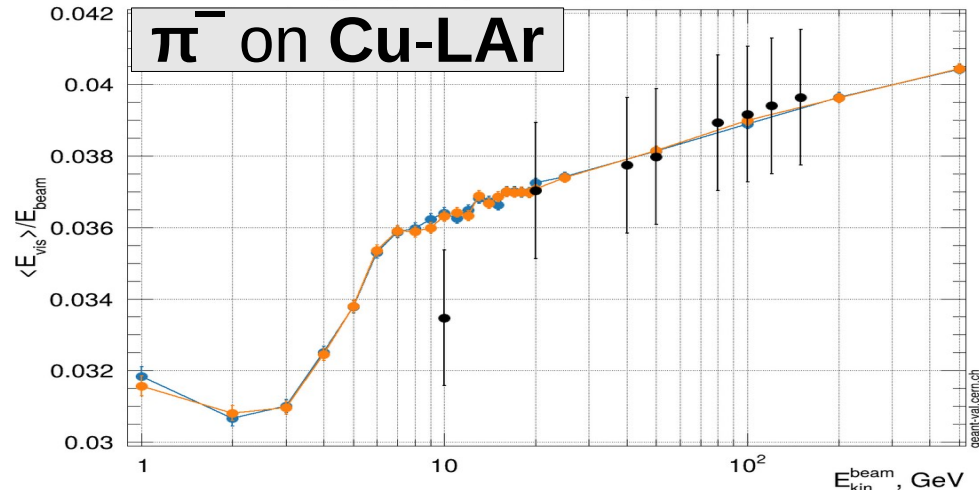
*Note : conventional Birks treatment  
(easier and no experimental h/e to fit !)*

# FTFP\_BERT : Energy Response

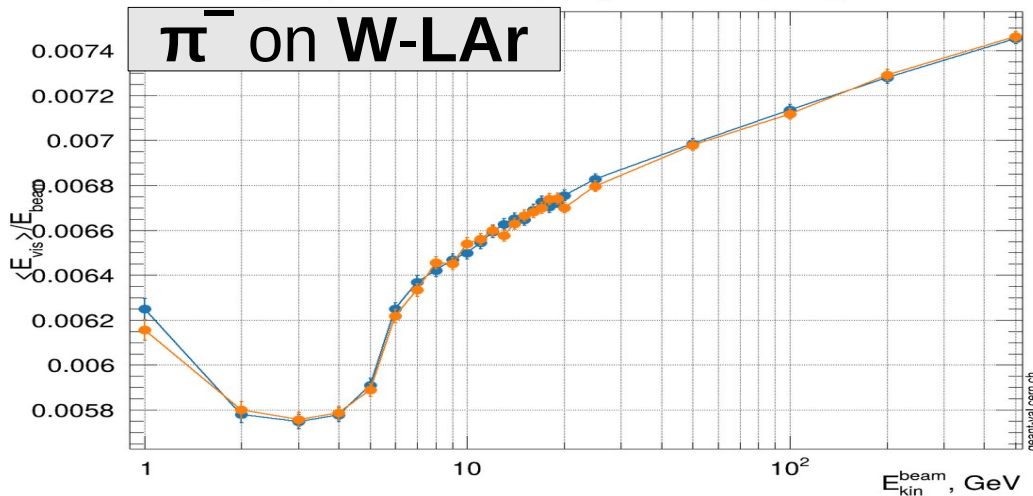
Energy response | Beam: pi- | Target: TileCal



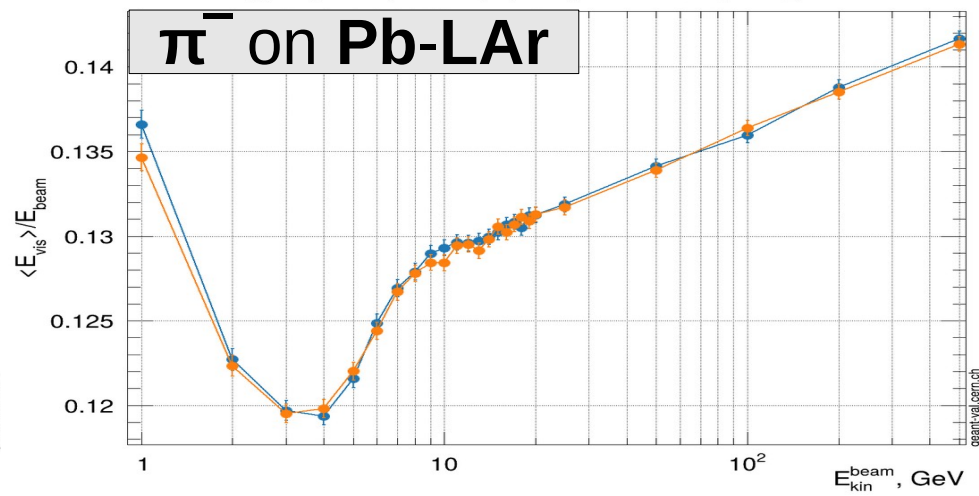
Energy response | Beam: pi- | Target: AtlasHEC



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



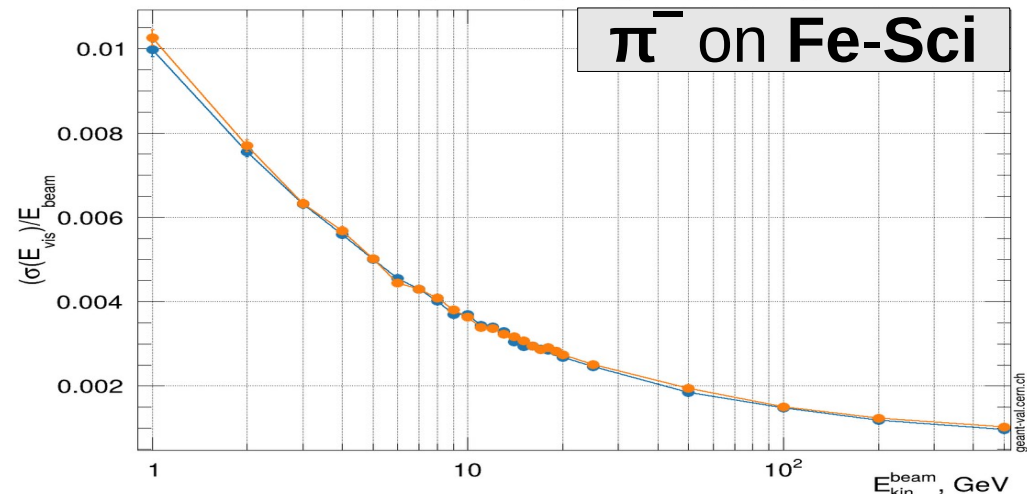
Energy response | Beam: pi- | Target: AtlasECAL | FTFP\_BERT



# FTFP\_BERT : Energy Width

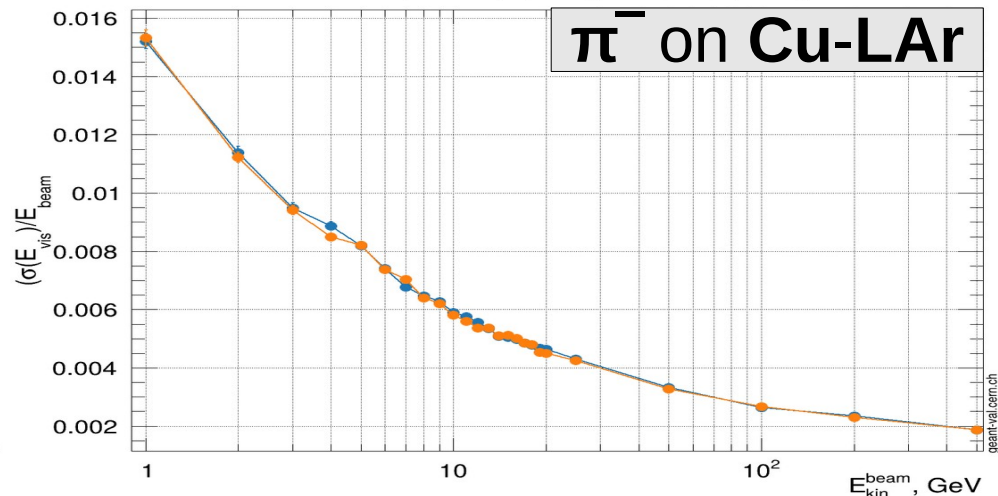
Normalized width | Beam: pi- | Target: TileCal | FTFP\_BERT

$\pi^-$  on Fe-Sci



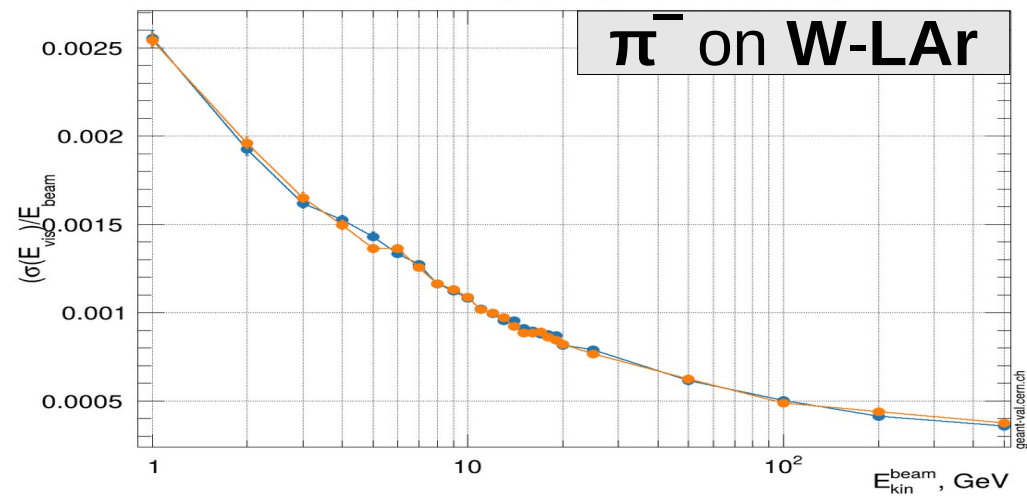
Normalized width | Beam: pi- | Target: AtlasHEC | FTFP\_BERT

$\pi^-$  on Cu-LAr



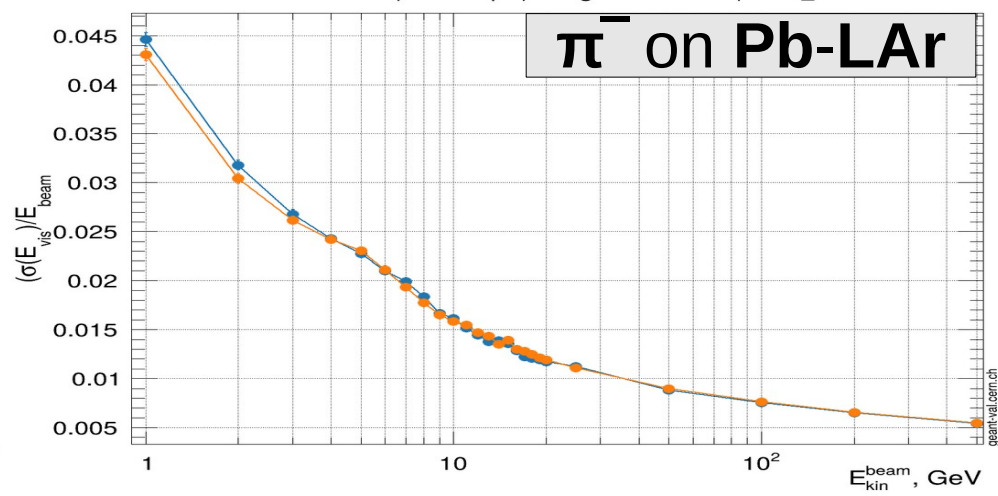
Normalized width | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

$\pi^-$  on W-LAr



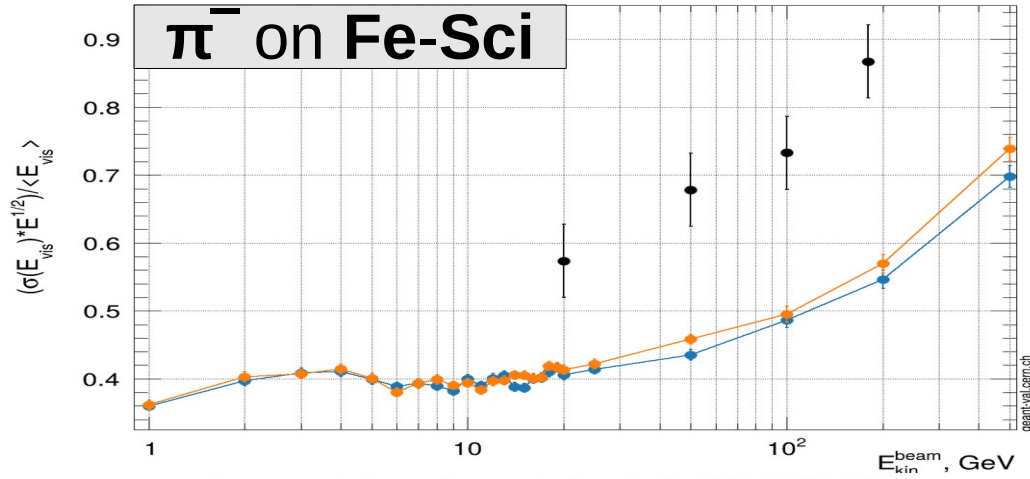
Normalized width | Beam: pi- | Target: AtlasECAL | FTFP\_BERT

$\pi^-$  on Pb-LAr

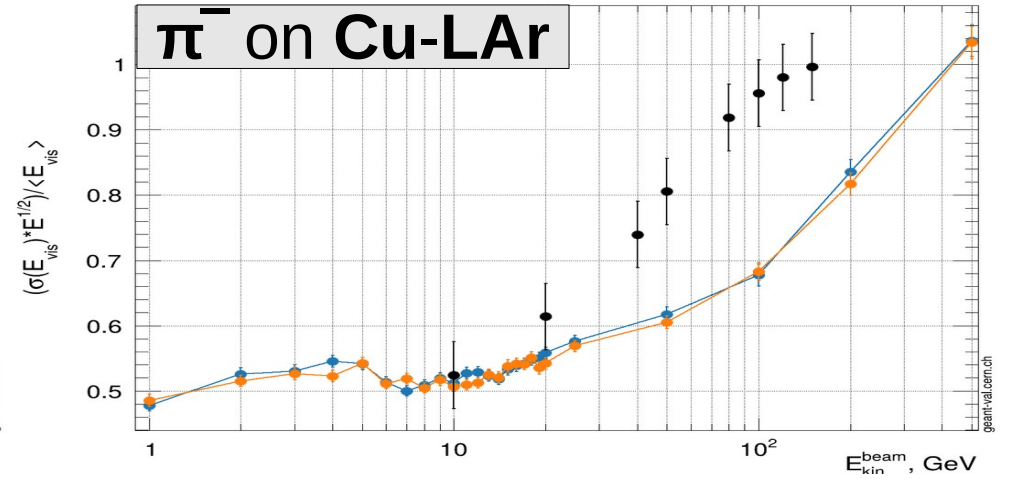


# FTFP\_BERT : Energy Resolution

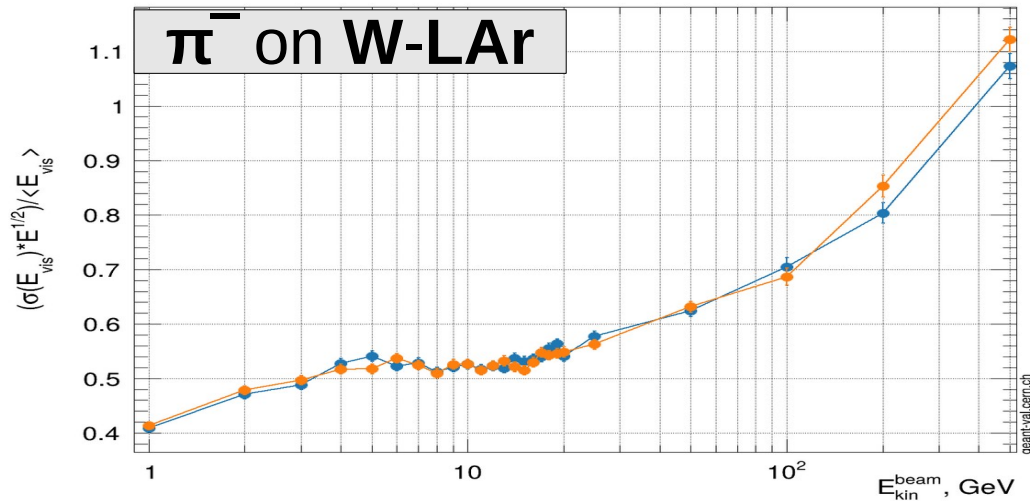
Energy resolution | Beam: pi- | Target: TileCal



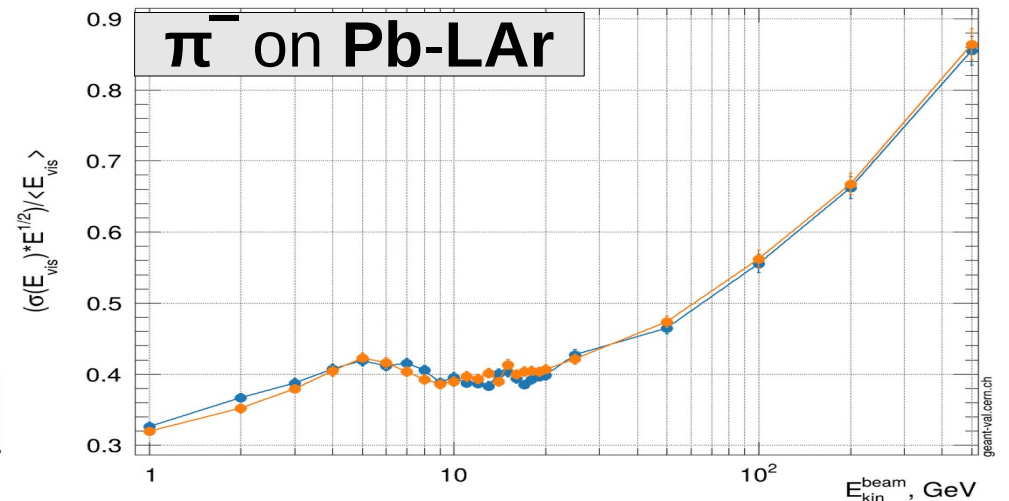
Energy resolution | Beam: pi- | Target: AtlasHEC



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



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



11.3.cand01

11.3.ref01

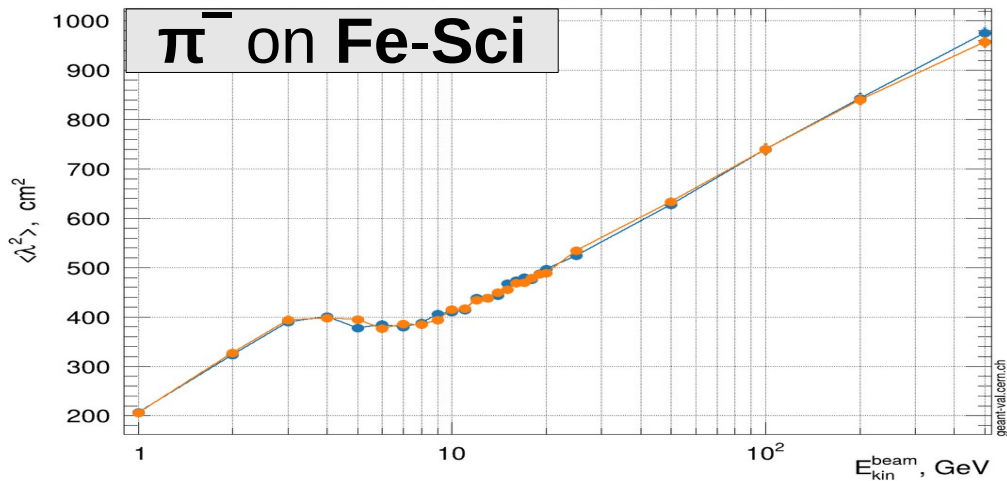
11.3.cand01

11.3.ref01

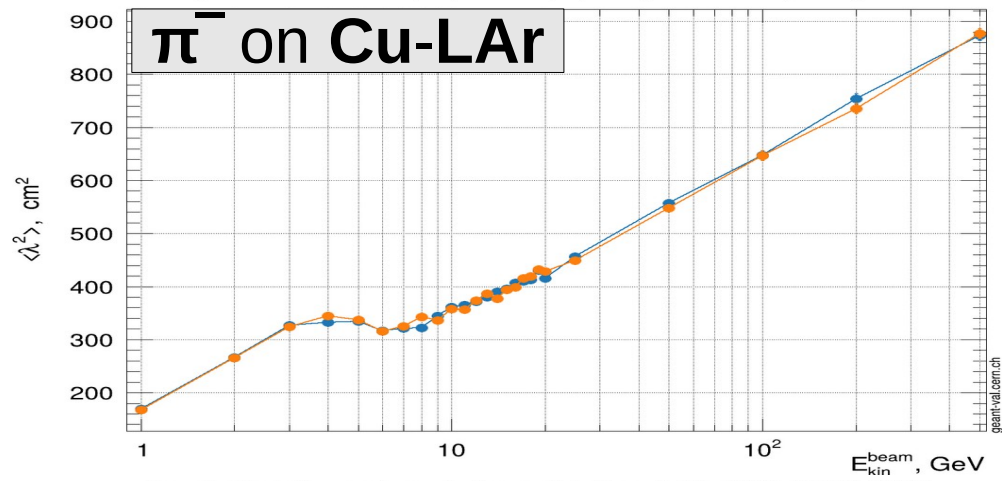


# FTFP\_BERT : Longitudinal Shape

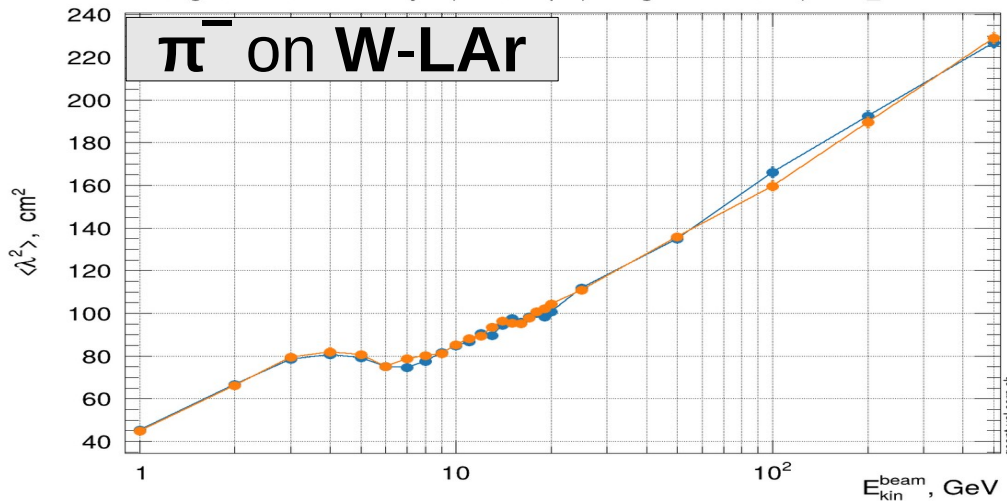
Longitudinal shower shape | Beam: pi- | Target: TileCal | FTFP\_BERT



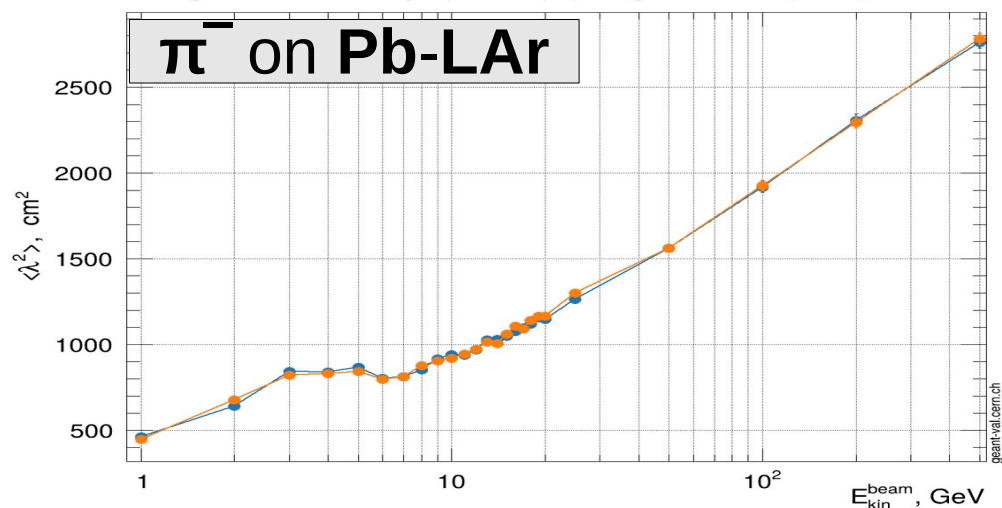
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | FTFP\_BERT



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



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



11.3.cand01

11.3.ref01

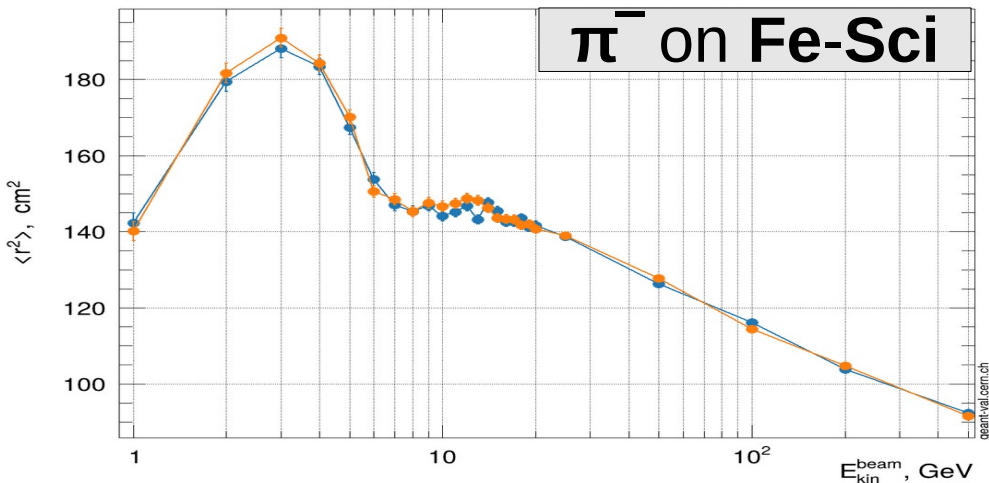
11.3.cand01

11.3.ref01

# FTFP\_BERT : Lateral Shape

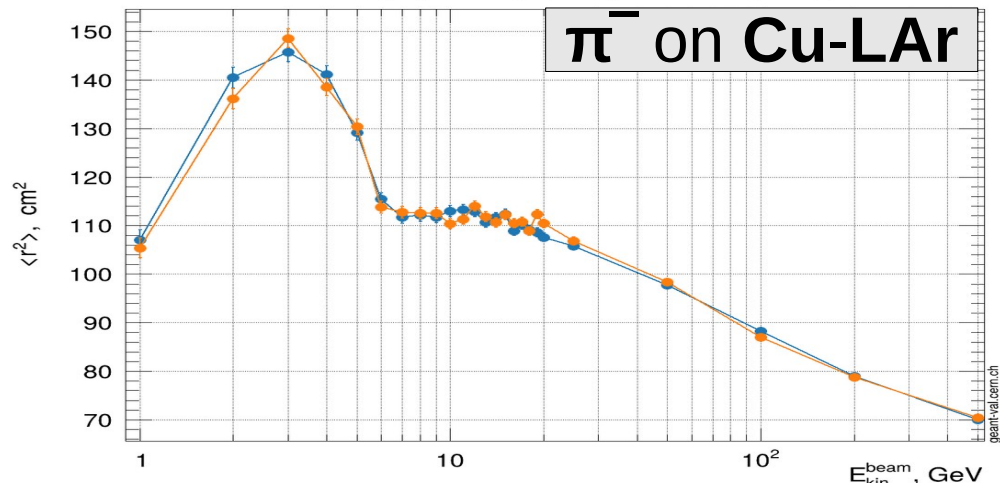
Lateral shower shape | Beam: pi- | Target: TileCal | FTFP\_BERT

$\pi^-$  on Fe-Sci



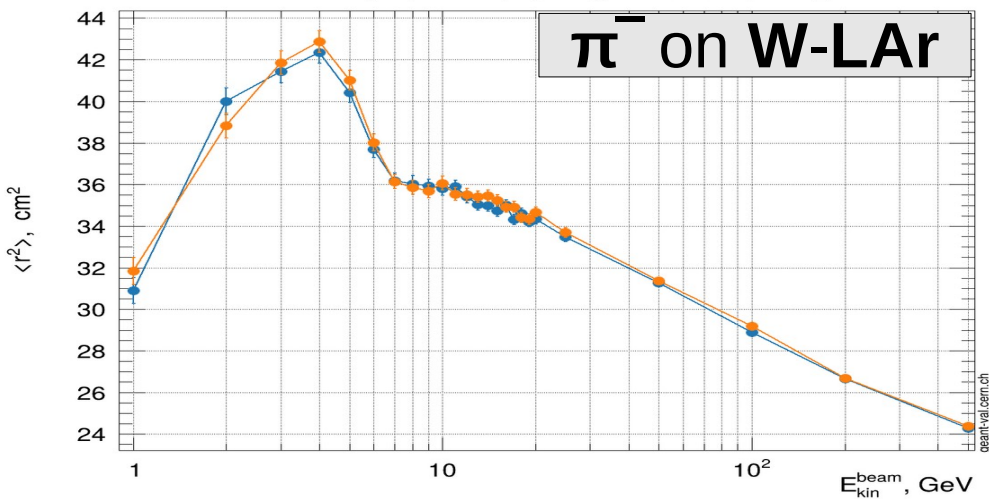
Lateral shower shape | Beam: pi- | Target: AtlasHEC | FTFP\_BERT

$\pi^-$  on Cu-LAr



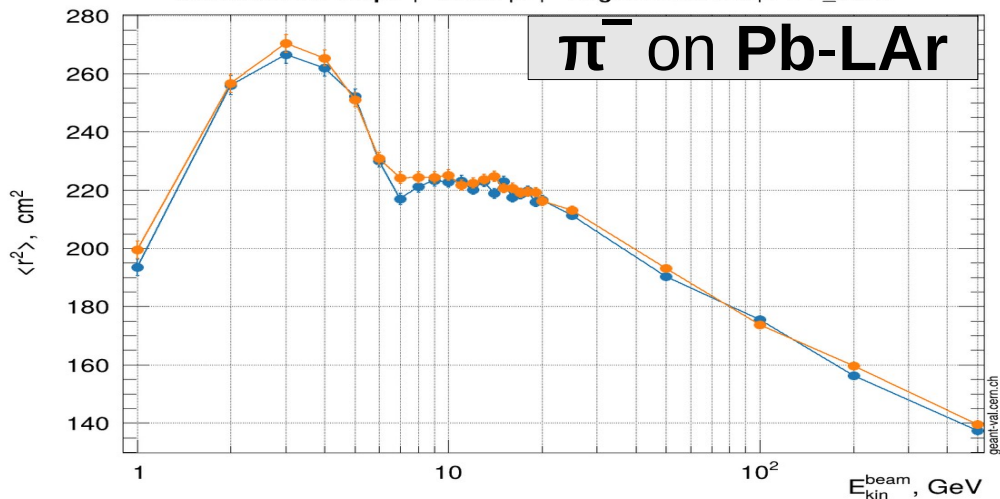
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | FTFP\_BERT

$\pi^-$  on W-LAr



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

$\pi^-$  on Pb-LAr



# Pion- showers: QGSP\_BIC

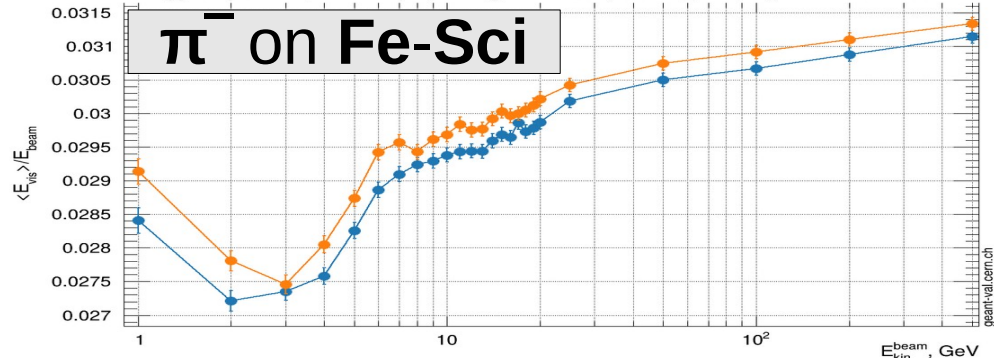
G4 [11.3.ref00](#)

G4 [11.3.ref01](#)

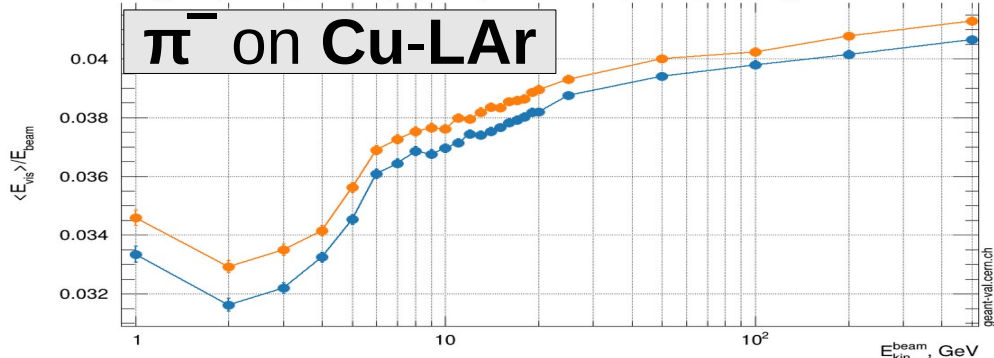
*Note : conventional Birks treatment  
(easier and no experimental h/e to fit !)*

# Energy Response

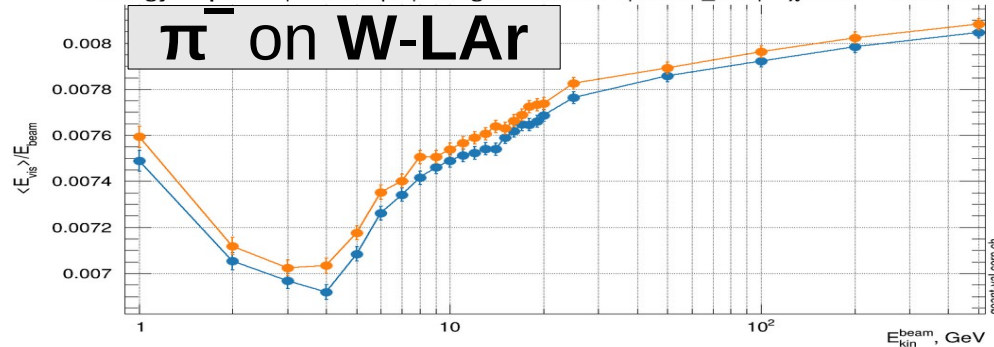
Energy response | Beam: pi- | Target: TileCal | QGSP\_BIC |  $\chi^2/n.d.f. = 0.708011$



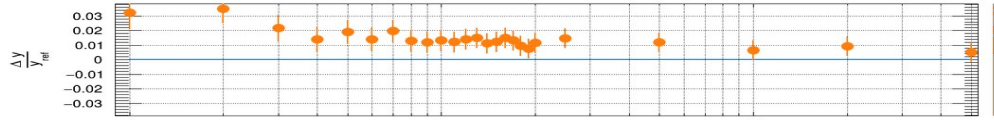
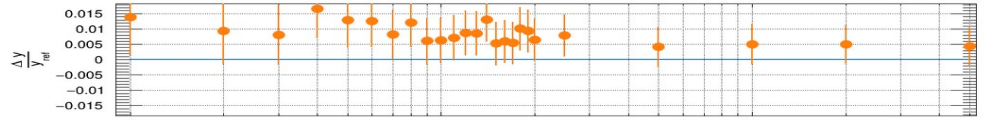
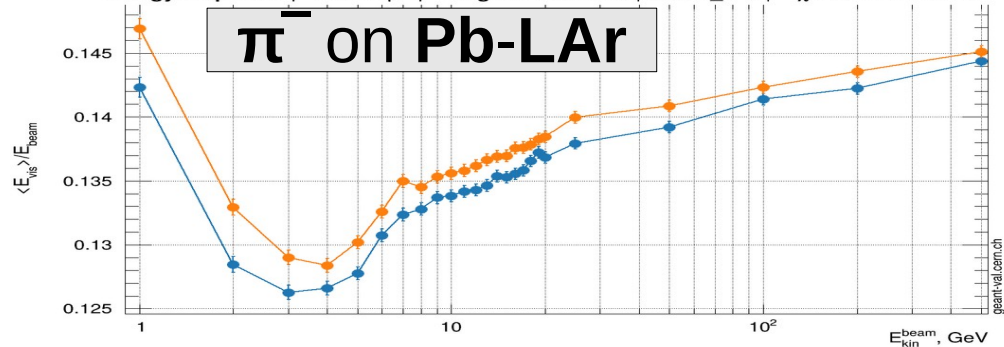
Energy response | Beam: pi- | Target: AtlasHEC | QGSP\_BIC |  $\chi^2/n.d.f. = 1.27067$



Energy response | Beam: pi- | Target: AtlasFCAL | QGSP\_BIC |  $\chi^2/n.d.f. = 0.366983$



Energy response | Beam: pi- | Target: AtlasECAL | QGSP\_BIC |  $\chi^2/n.d.f. = 1.28746$



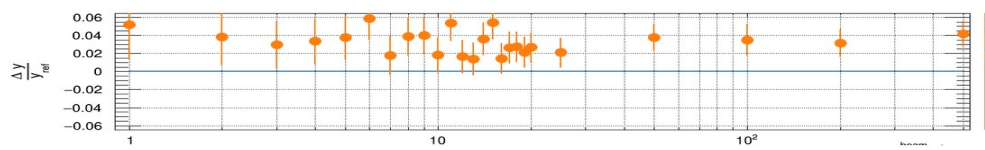
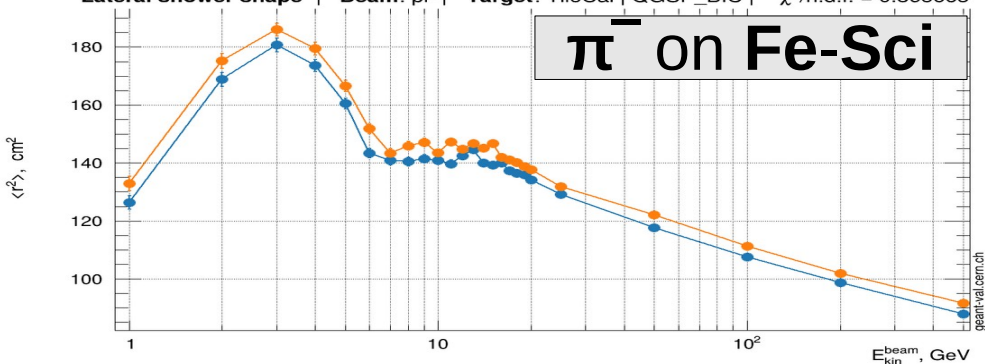
11.3.cand01 11.3.ref01

11.3.cand01 11.3.ref01

# Lateral Shape

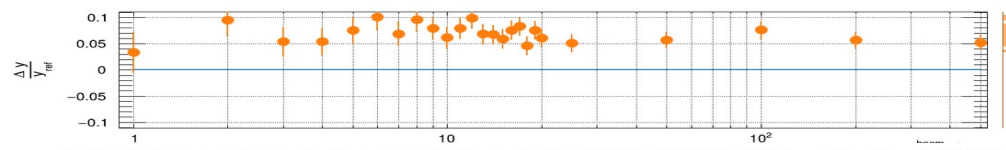
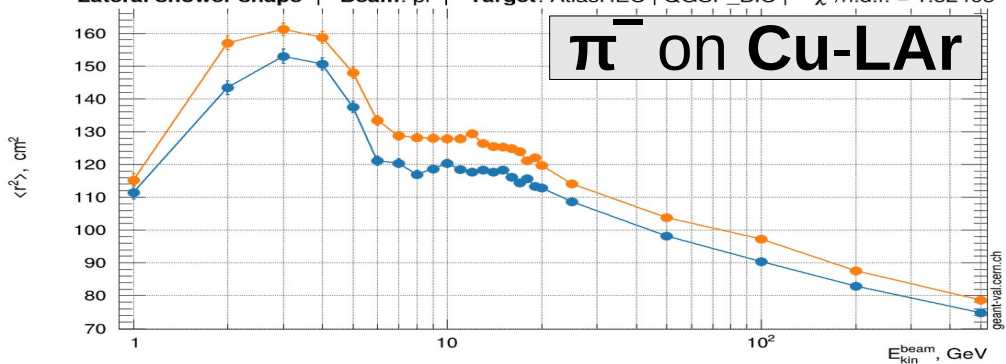
Lateral shower shape | Beam: pi- | Target: TileCal | QGSP\_BIC |  $\chi^2/n.d.f. = 0.865663$

$\pi^-$  on Fe-Sci



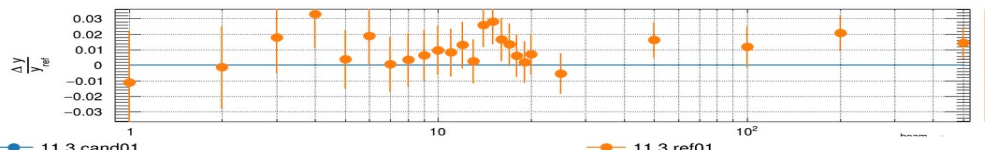
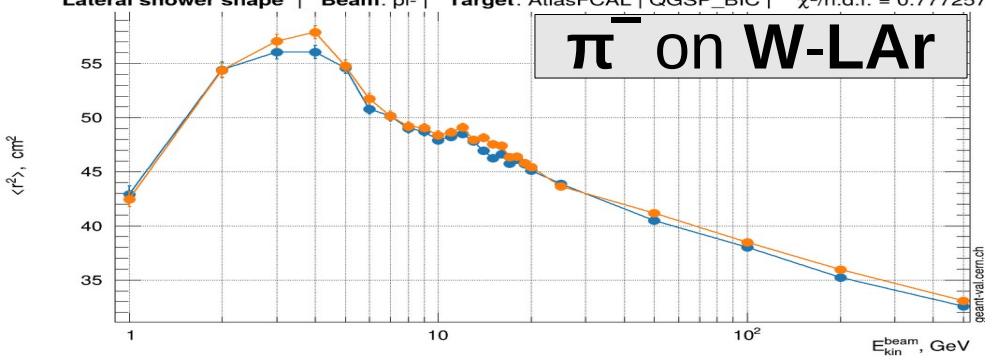
Lateral shower shape | Beam: pi- | Target: AtlasHEC | QGSP\_BIC |  $\chi^2/n.d.f. = 1.32403$

$\pi^-$  on Cu-LAr



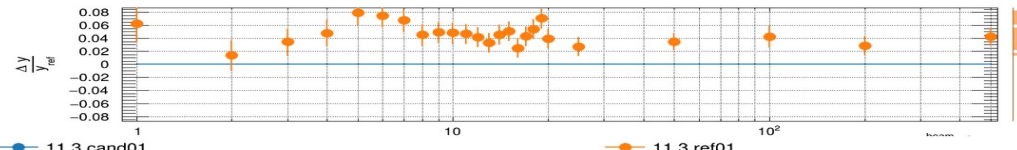
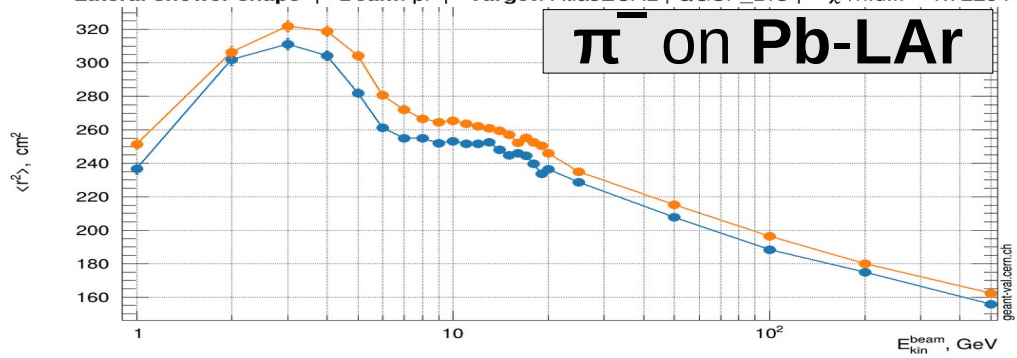
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | QGSP\_BIC |  $\chi^2/n.d.f. = 0.777257$

$\pi^-$  on W-LAr



Lateral shower shape | Beam: pi- | Target: AtlasECAL | QGSP\_BIC |  $\chi^2/n.d.f. = 1.72234$

$\pi^-$  on Pb-LAr



# Pion- showers: QGSP\_INCLXX

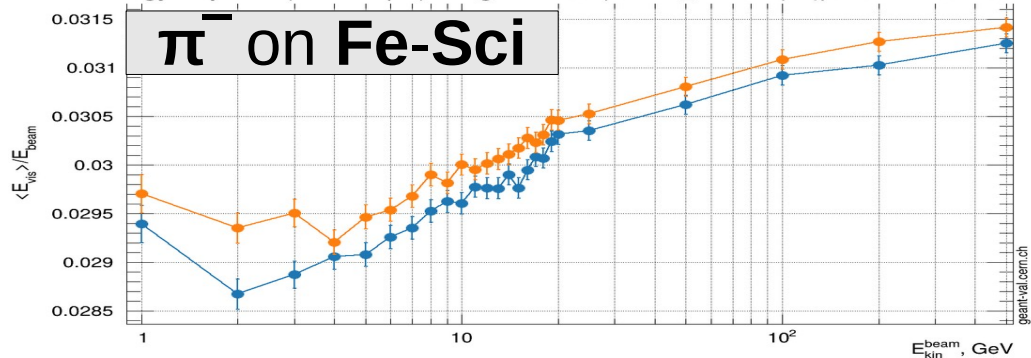
G4 [11.3.ref00](#)

G4 [11.3.ref01](#)

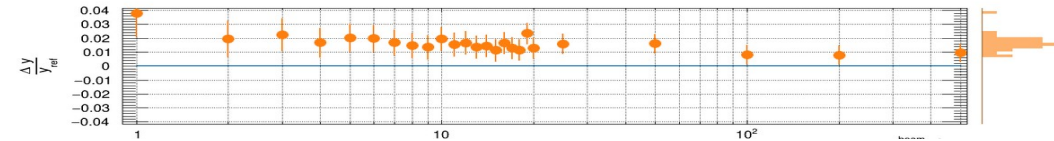
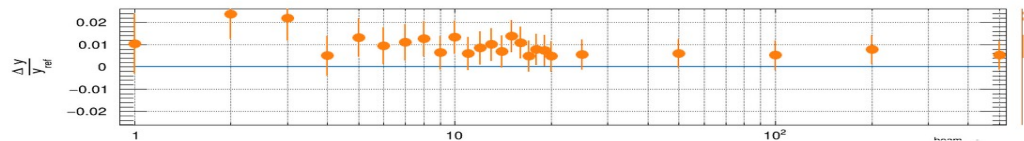
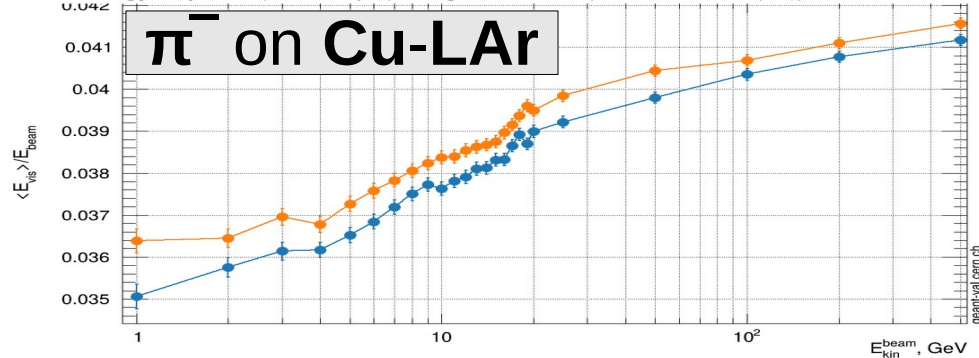
*Note : conventional Birks treatment  
(easier and no experimental h/e to fit !)*

# Energy Response

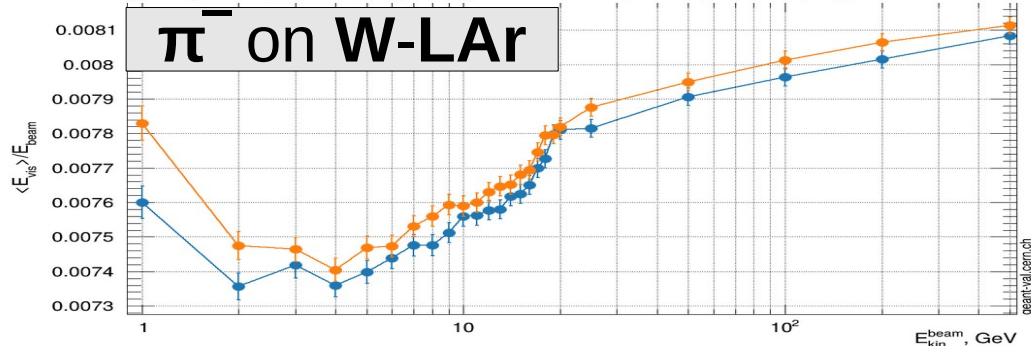
Energy response | Beam: pi- | Target: TileCal | QGSP\_INCLXX |  $\chi^2/n.d.f. = 0.651263$



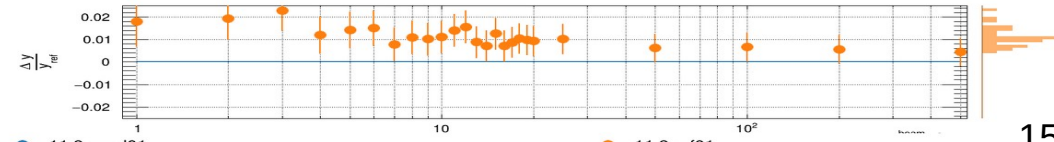
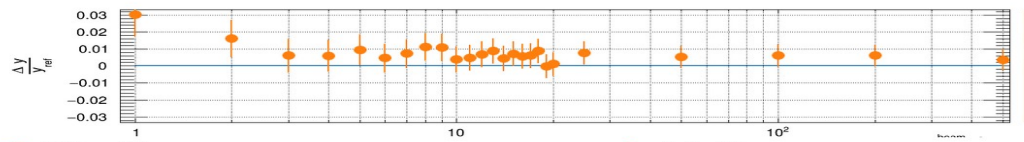
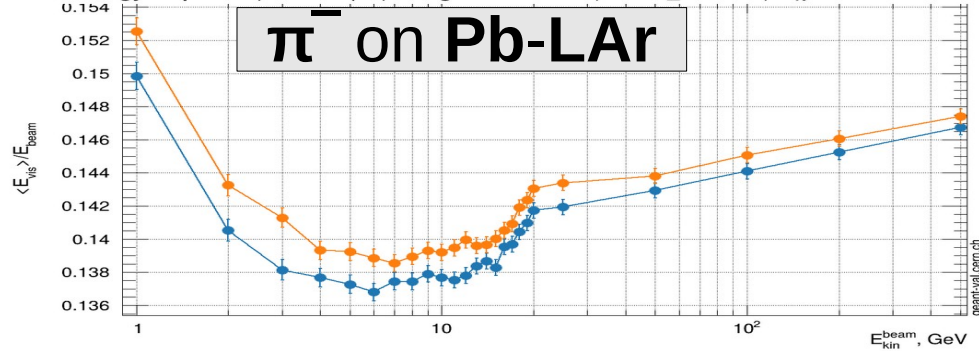
Energy response | Beam: pi- | Target: AtlasHEC | QGSP\_INCLXX |  $\chi^2/n.d.f. = 0.740177$



Energy response | Beam: pi- | Target: AtlasFCAL | QGSP\_INCLXX |  $\chi^2/n.d.f. = 0.652358$

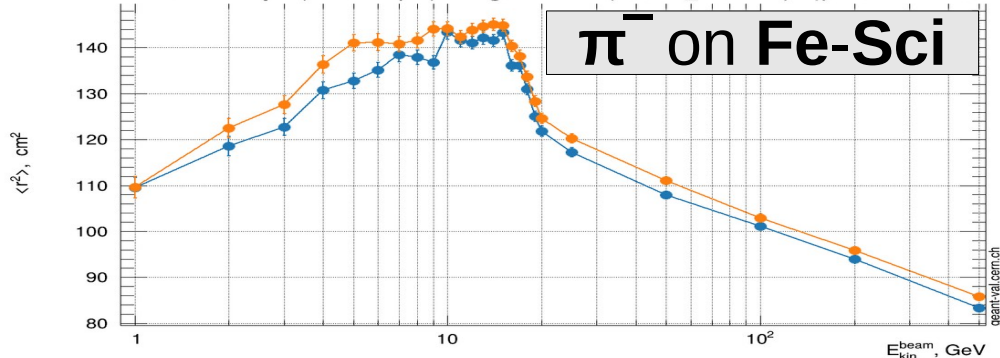


Energy response | Beam: pi- | Target: AtlasECAL | QGSP\_INCLXX |  $\chi^2/n.d.f. = 0.681227$

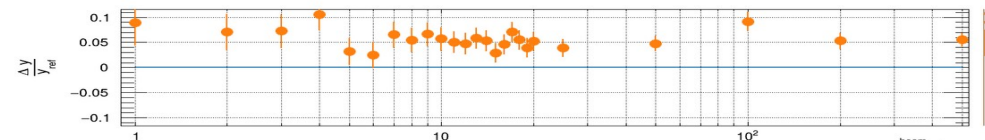
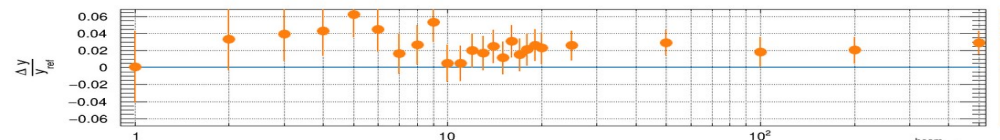
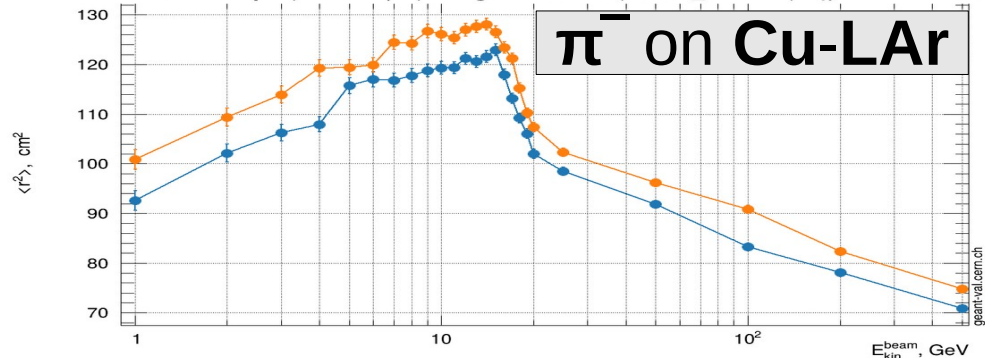


# Lateral Shape

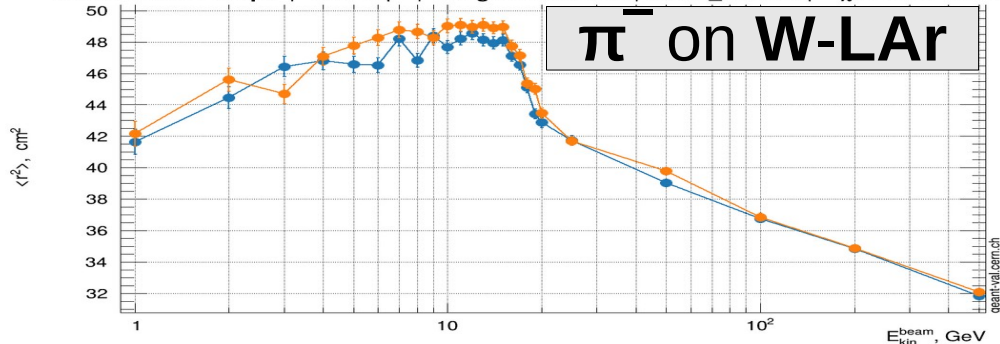
Lateral shower shape | Beam: pi- | Target: TileCal | QGSP\_INCLXX |  $\chi^2/n.d.f. = 0.728357$



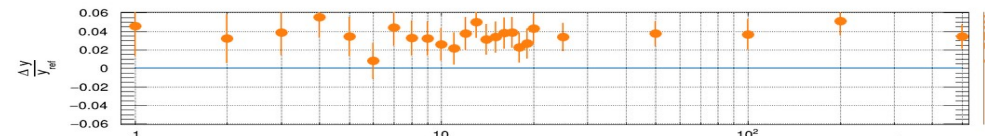
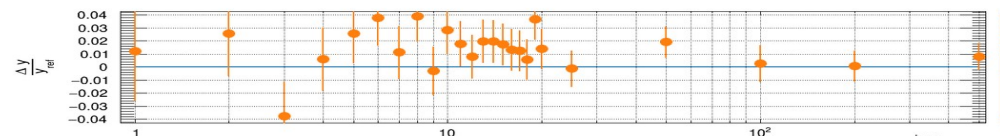
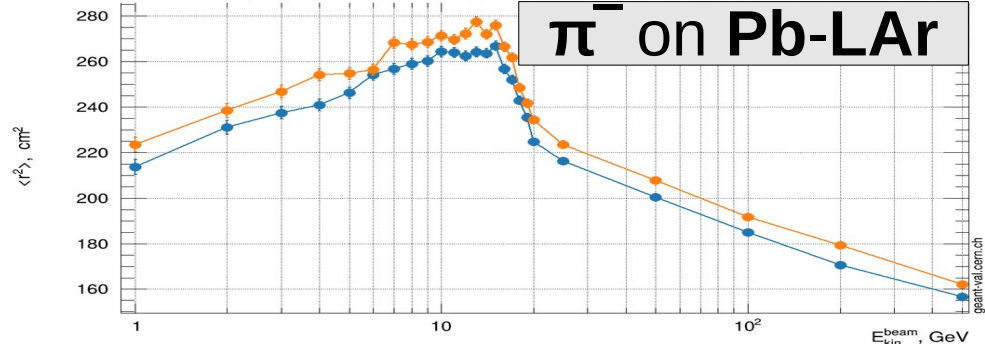
Lateral shower shape | Beam: pi- | Target: AtlasHEC | QGSP\_INCLXX |  $\chi^2/n.d.f. = 1.27007$



Lateral shower shape | Beam: pi- | Target: AtlasFCAL | QGSP\_INCLXX |  $\chi^2/n.d.f. = 1.27058$



Lateral shower shape | Beam: pi- | Target: AtlasECAL | QGSP\_INCLXX |  $\chi^2/n.d.f. = 0.60739$



11.3.cand01

11.3.ref01

11.3.cand01

11.3.ref01



# Conclusions

- **G4 11.3.ref01**
  - No crashes, no infinite loops, no new warnings
  - Reproducibility is fine in all cases
  - Hadron showers:
    - For nearly all reference physics lists, the hadronic showers of Ref01 are similar to those of Ref00
    - There are only 2 exceptions: **QGSP\_BIC** and **QGSP\_INCLXX**, for which
      - \* the **energy response increases by few %**
      - \* the **lateral shower shapes get wider by few %**in Ref01 with respect to Ref00
      - It is very likely due to the changes in **nuclear de-excitation** (because only these two reference physics list utilise the Geant4 nuclear de-excitation, whereas the others use the internal Bertini's nuclear de-excitation, which is stable)