



Hadronic Showers in Geant4 **11.2.ref05**

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Main Hadronic Changes in G4 11.2.ref05 vs. ref04 (1/2)

- *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/abla/*
 - Added the dissipation parameter for heavy hypernuclei
- *hadronic/models/coherent_elastic/ , lend/*
 - Technical fixes to avoid compilation warnings
- *hadronic/models/de_excitation/*
 - Several improvements, both technical and physics-related
 - *G4NuclearLevelData, G4PairingCorrection, G4CameronGilbertPairingCorrections, G4CameronGilbertShellCorrections* : simplified computation of corrections
 - *G4EvaporationChannel, G4EvaporationProbability* : fixed usage of pairing corrections; agreement with test data is improved.
 - *G4EvaporationChannel* : fixed computation of minimal kinetic energy of fragments
 - *G4DeexPrecoParameters* : added default width of nuclear level, needed for the selection of final excitation in a decay of an excited state. This new width parameter is used in *G4VEmissionProbability*

Main Hadronic Changes in G4 11.2.ref05 vs. ref04 (2/2)

- *hadronic/models/nudex/*
 - New alternative and more sophisticated nuclear de-excitation model (**NuDEX**)
 - This model de-excites nuclei by emitting gammas and internal conversion electrons, based on the data library **G4NUDEXLIB.1.0**, which is pointed by the environmental variable **G4NUDEXLIBDATA**.
When NuDEX is not applicable - e.g. because the corresponding nucleus is not present in the data library - the **G4PhotonEvaporation** class is utilised instead.
Currently NuDEX is used only for the **neutron capture** process, when ParticleHP is utilised; in the future it can be used more generally as one of the possible "evaporation" models.
In the current reference tag, NuDEX cannot be switched on; from the next tag (11.3.beta.cand00), NuDEX will be available only in the physics list **QGSP_BERT_HP** (later on, it will be extended to any HP-based physics list).
- **New hadronic data libraries**
 - **G4NDL4.7.1**
 - Removed all files for Argon-36 and Argon-38 as significantly different from those of ENDF/B-VIII.0
 - Reprocessed thermal scattering files after fixing a problem in NJOY. Addressing problem report #2552
 - **G4NUDEXLIB1.0**
 - Data set required when the NuDEX hadronic model is enabled.
Including: data file with general parameters, and data from BrICC, RIPL-3, ENSDF and IAEA Photon Strength

Crashes & Warnings

- No crashes
- No infinite loops
- No new or more frequent warnings

Reproducibility

- OK in all cases

Pion- showers: FTFP_BERT

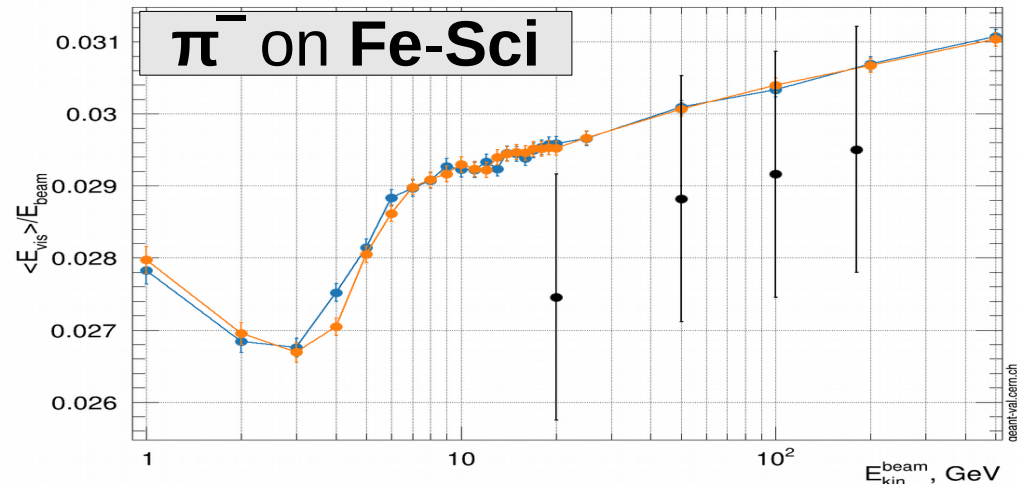
G4 11.2.ref04

G4 11.2.ref05

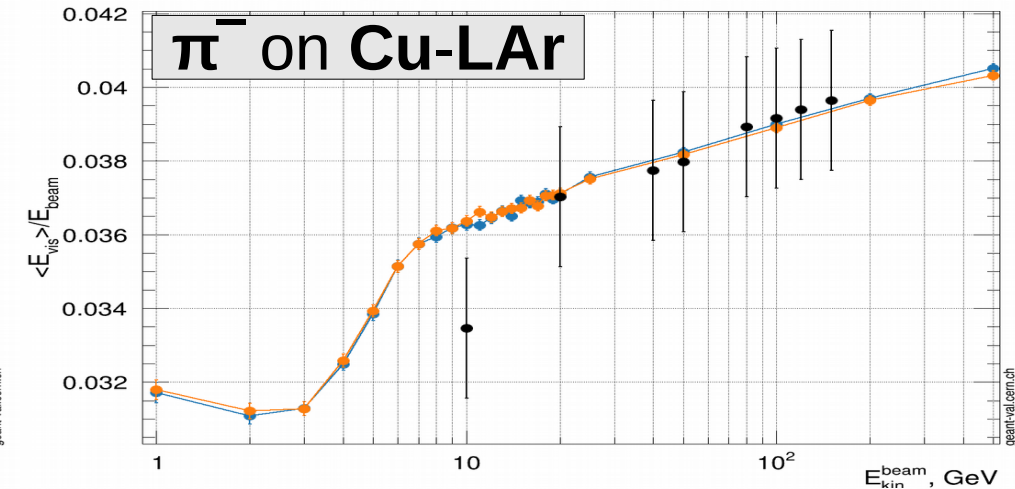
*Note : conventional Birks treatment
(easier and no experimental h/e to fit !)*

Energy Response

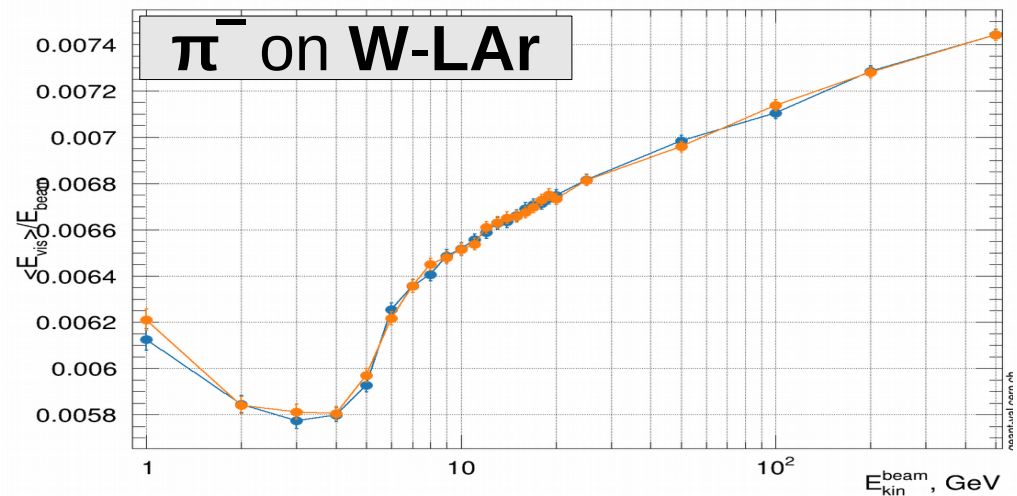
Energy response | Beam: pi- | Target: TileCal



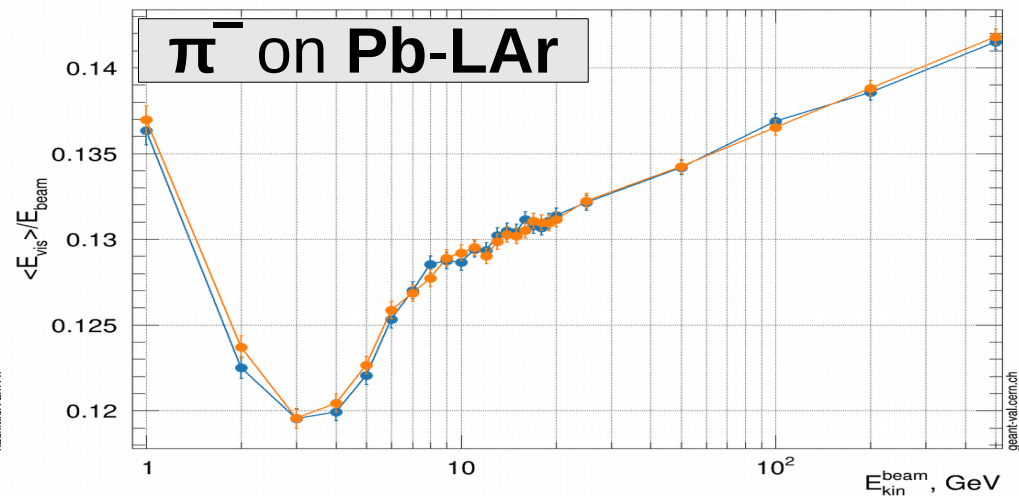
Energy response | Beam: pi- | Target: AtlasHEC



Energy response | Beam: pi- | Target: AtlasFCAL | FTFP_BERT

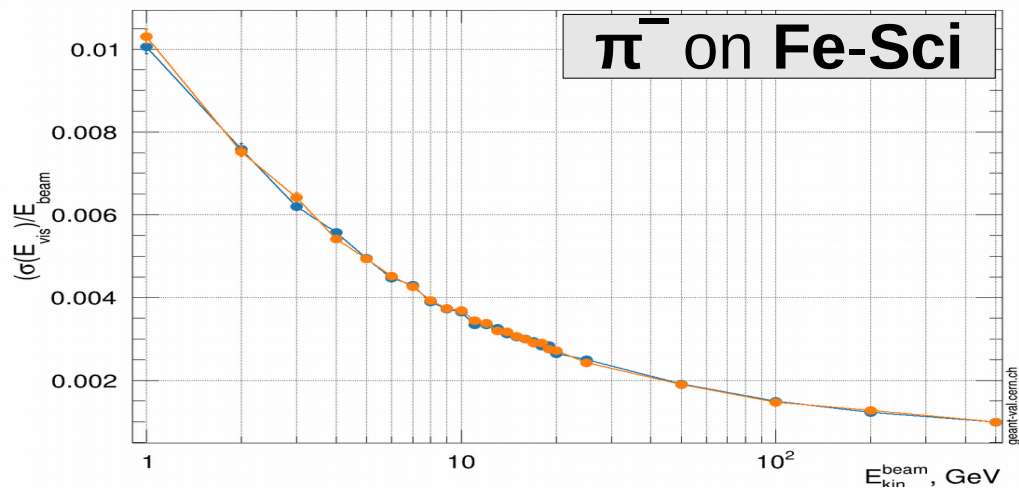


Energy response | Beam: pi- | Target: AtlasECAL | FTFP_BERT

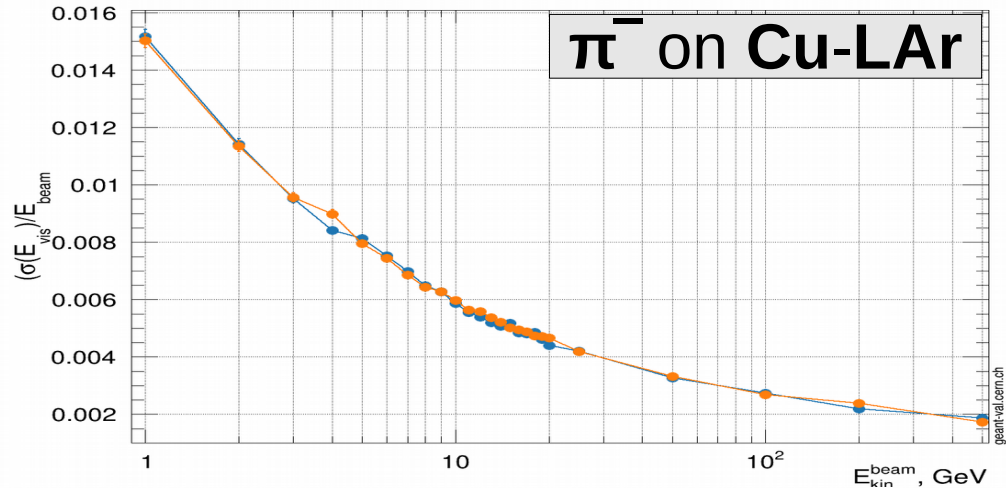


Energy Width

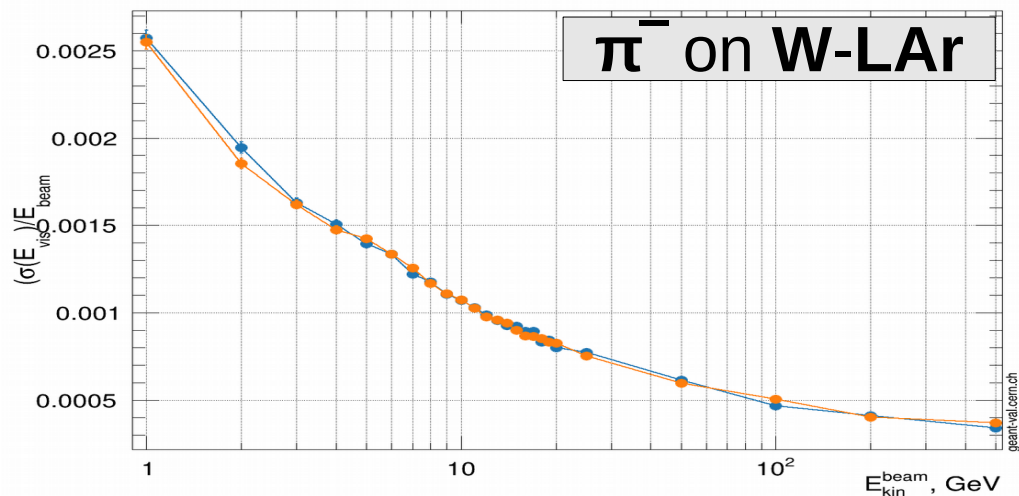
Normalized width | Beam: pi- | Target: TileCal | FTFP_BERT



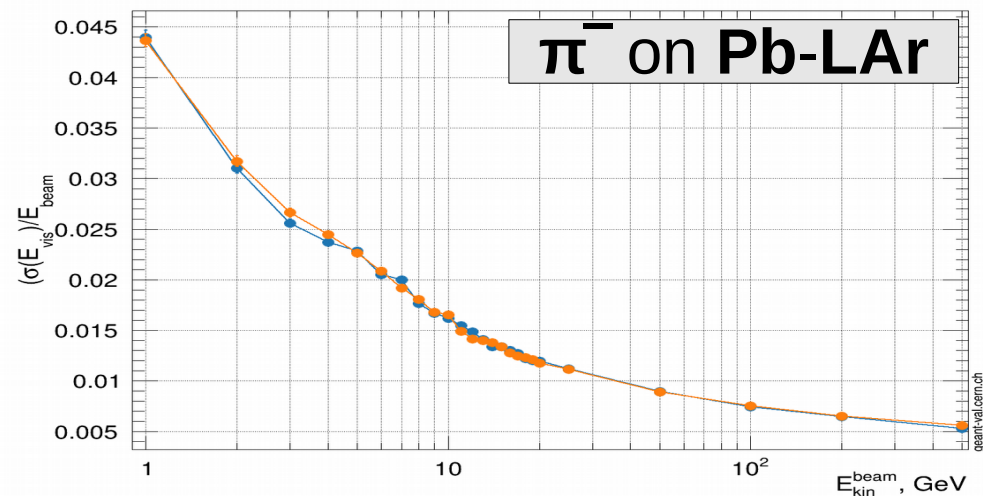
Normalized width | Beam: pi- | Target: AtlasHEC | FTFP_BERT



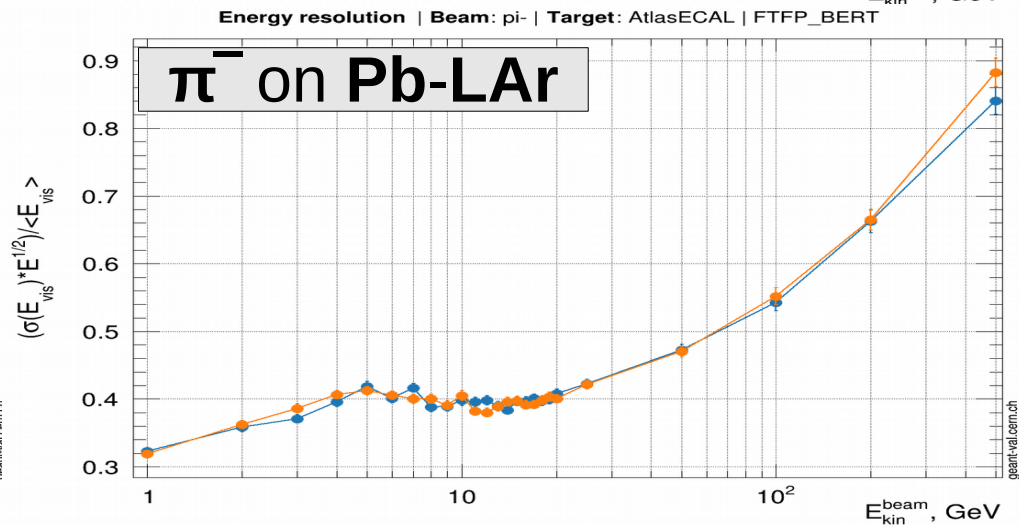
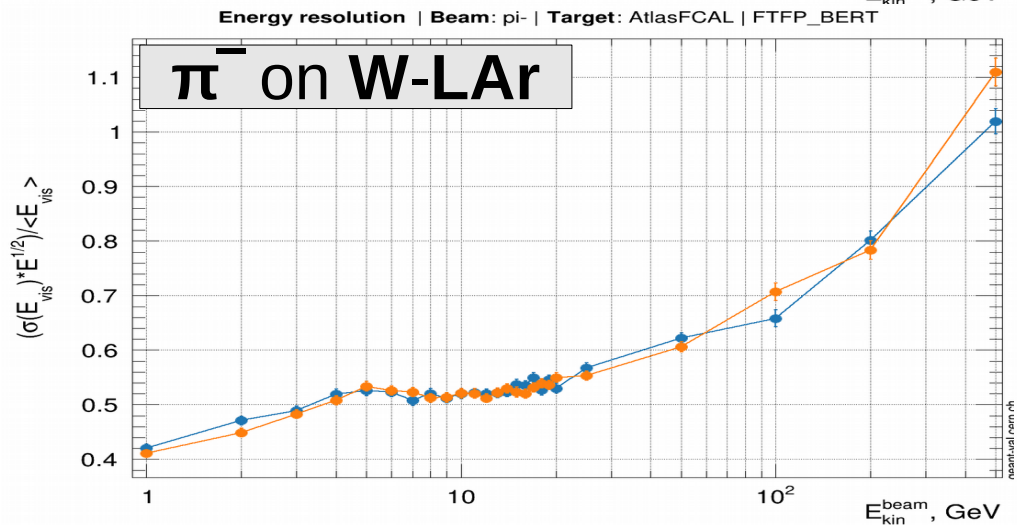
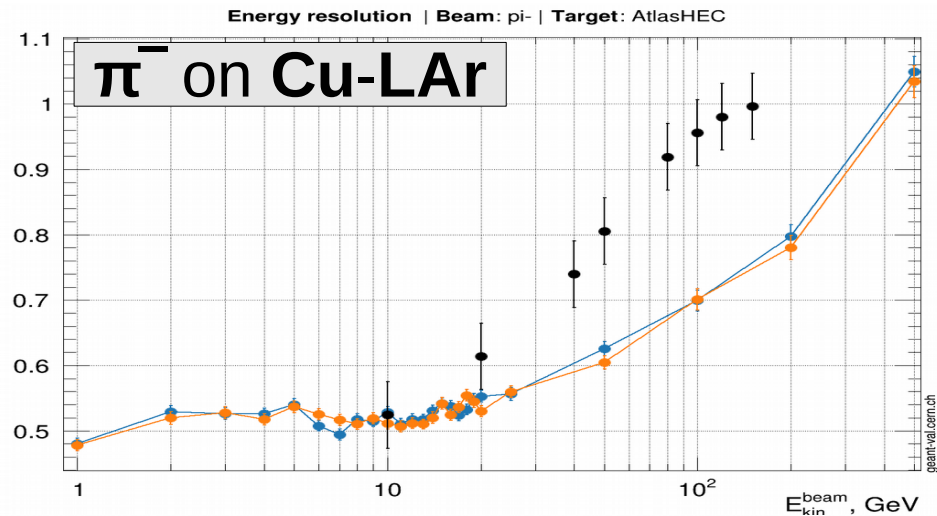
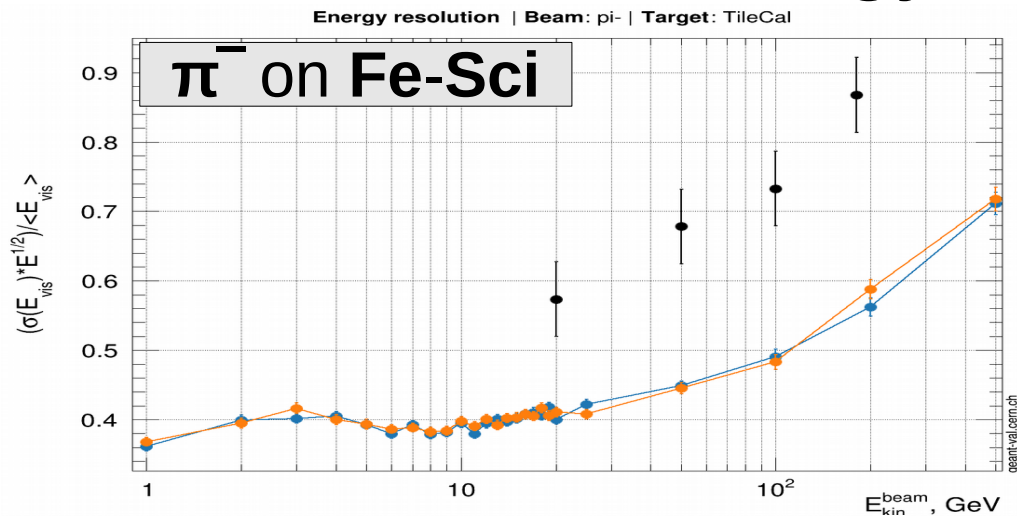
Normalized width | Beam: pi- | Target: AtlasFCAL | FTFP_BERT



Normalized width | Beam: pi- | Target: AtlasECAL | FTFP_BERT

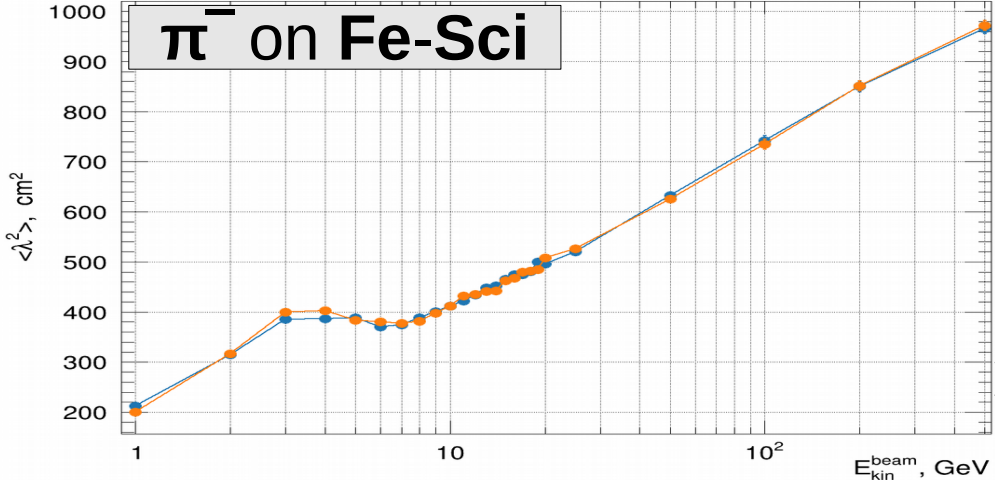


Energy Resolution

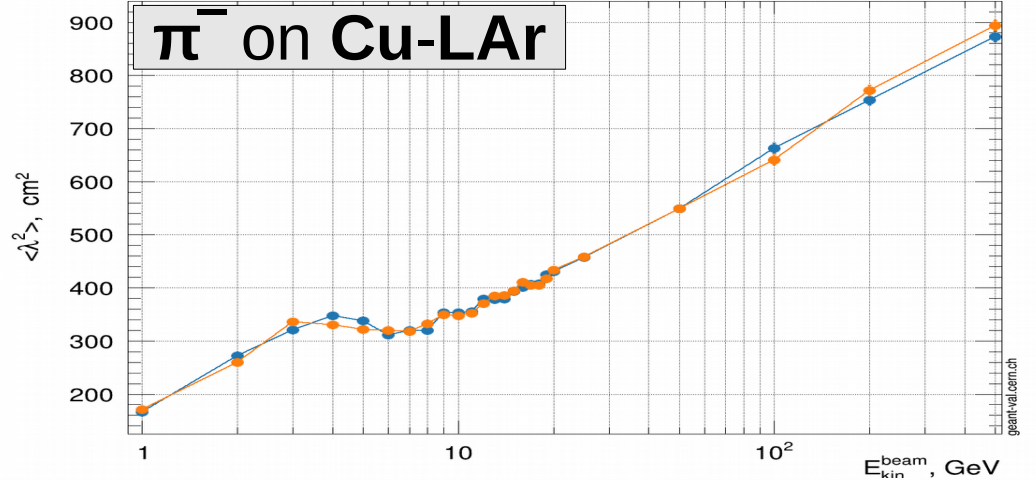


Longitudinal Shape

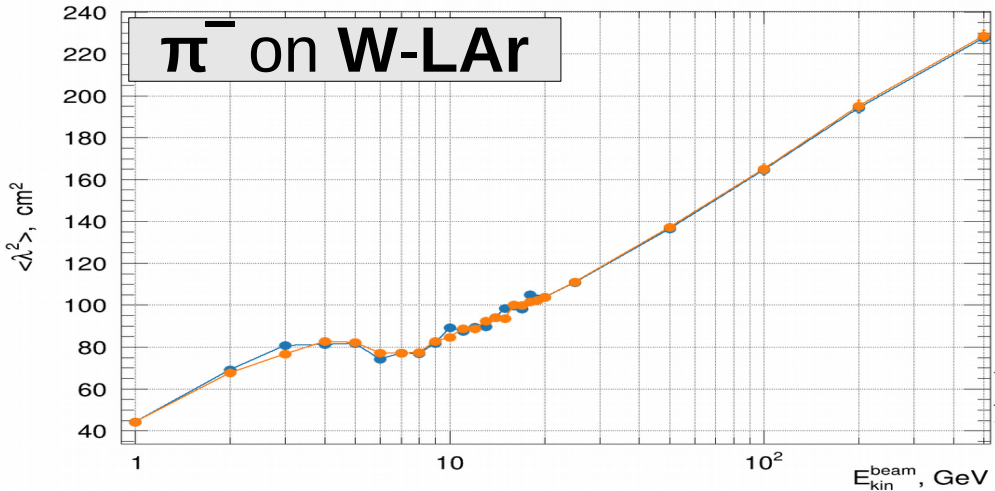
Longitudinal shower shape | Beam: pi- | Target: TileCal | FTFP_BERT



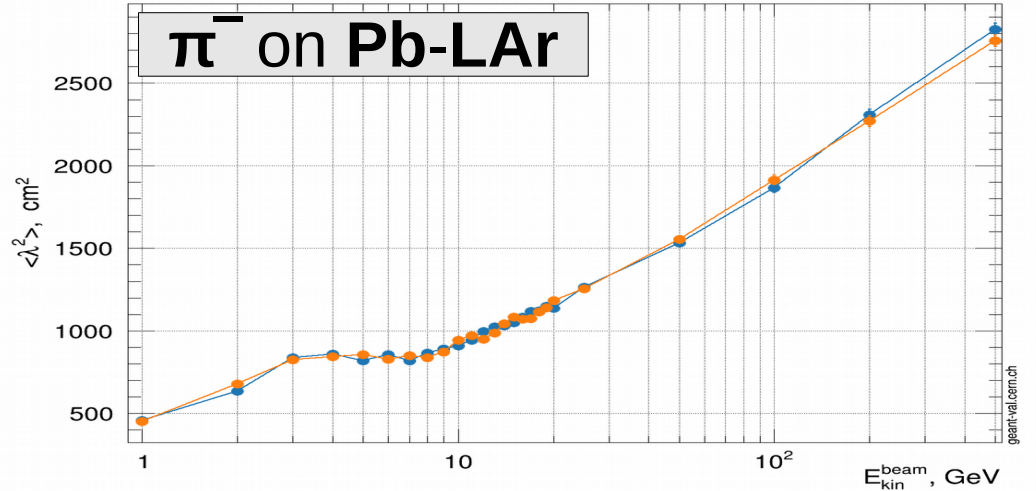
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | FTFP_BERT



Longitudinal shower shape | Beam: pi- | Target: AtlasFCAL | FTFP_BERT



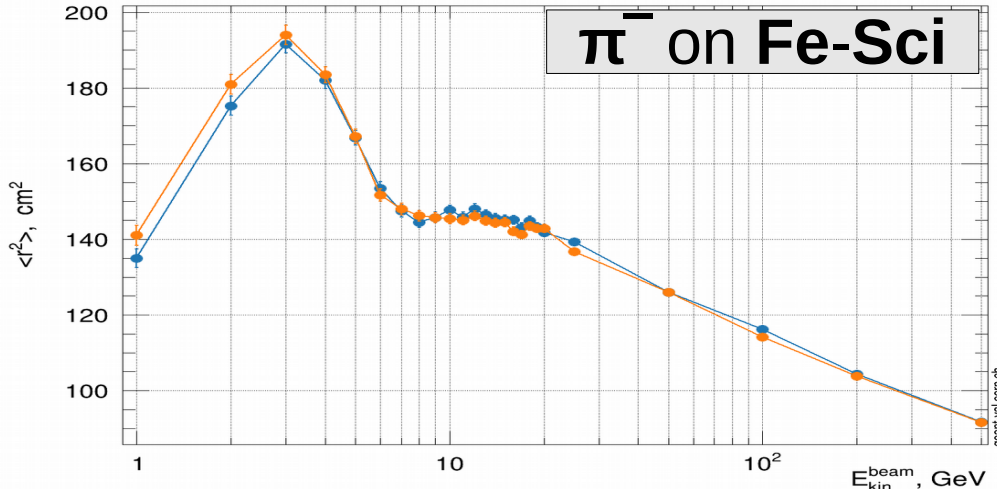
Longitudinal shower shape | Beam: pi- | Target: AtlasECAL | FTFP_BERT



Lateral Shape

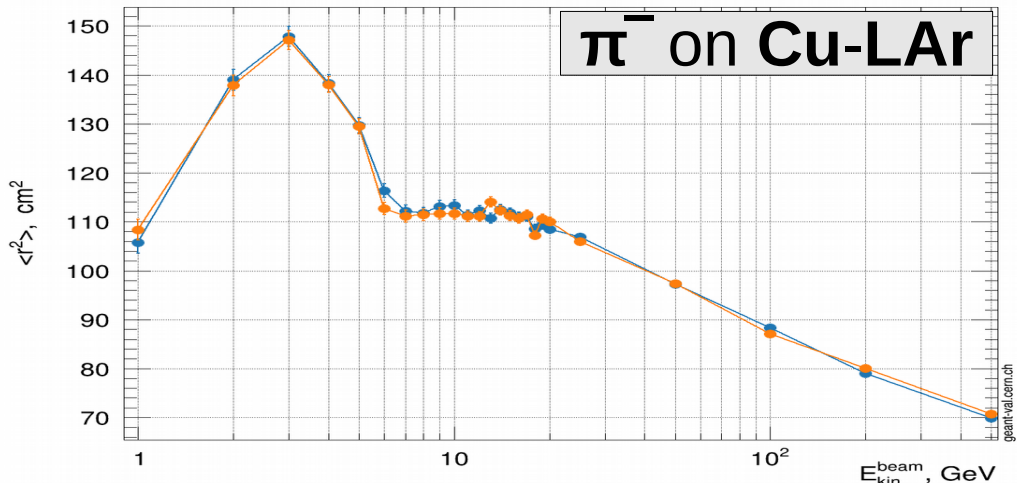
Lateral shower shape | Beam: pi- | Target: TileCal | FTFP_BERT

π^- on Fe-Sci



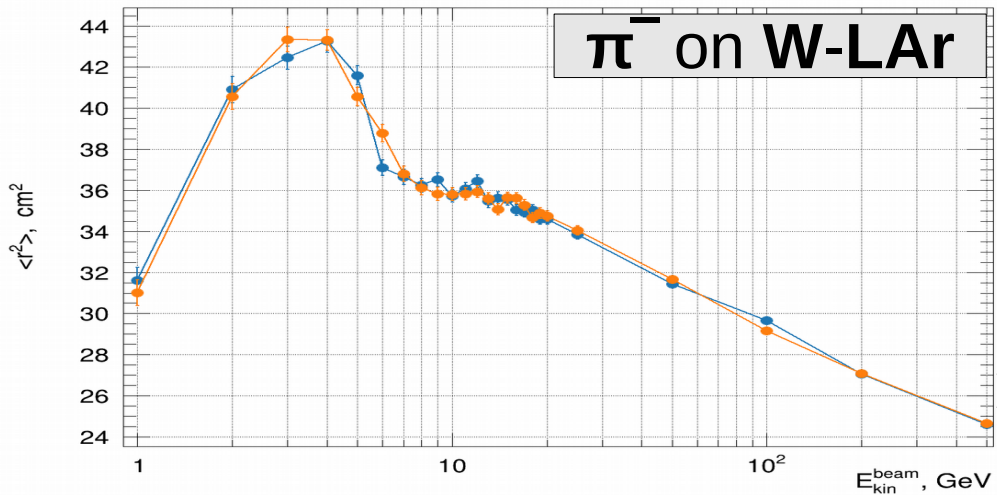
Lateral shower shape | Beam: pi- | Target: AtlasHEC | FTFP_BERT

π^- on Cu-LAr



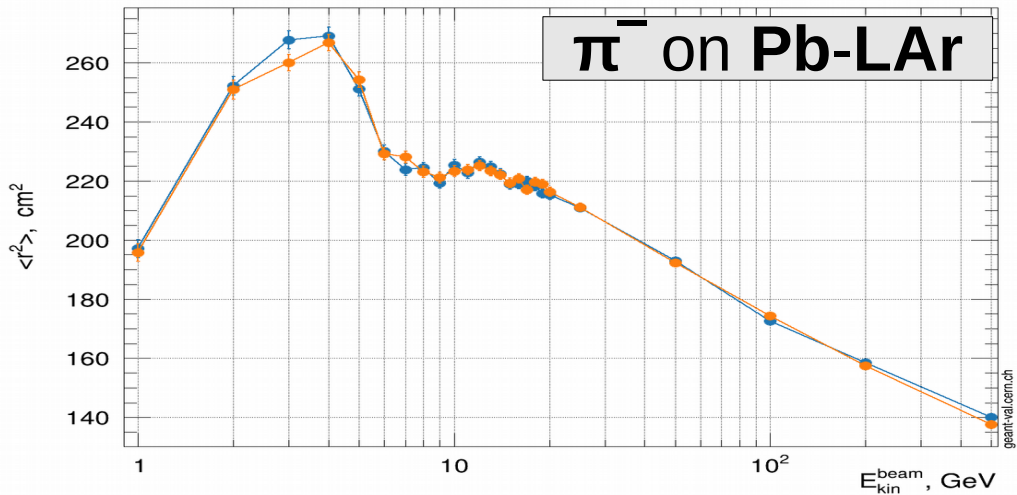
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | FTFP_BERT

π^- on W-LAr



Lateral shower shape | Beam: pi- | Target: AtlasECAL | FTFP_BERT

π^- on Pb-LAr



Pion- showers: QGSP_BIC

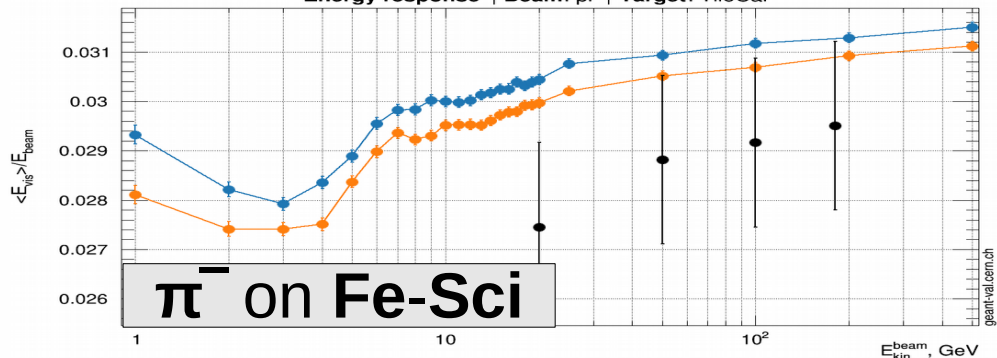
G4 11.2.ref04

G4 11.2.ref05

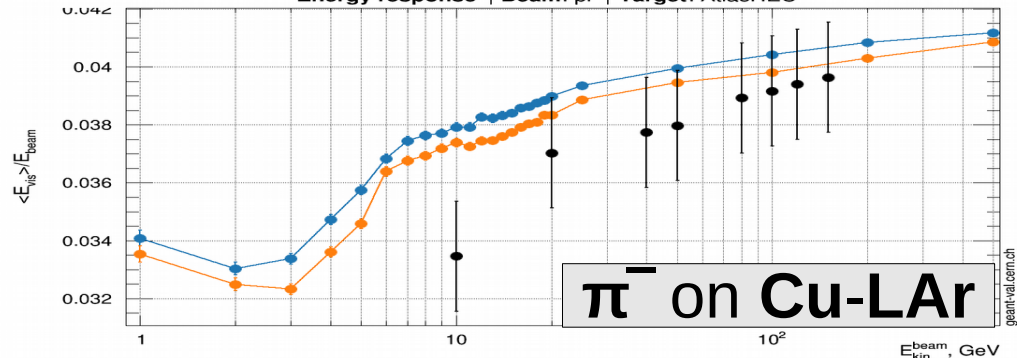
*Note : conventional Birks treatment
(easier and no experimental h/e to fit !)*

Energy Response

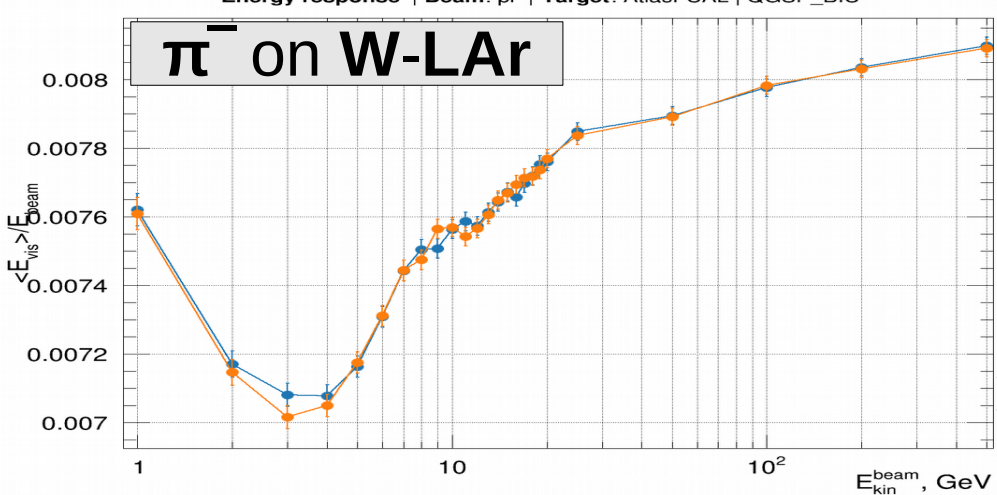
Energy response | Beam: pi- | Target: TileCal



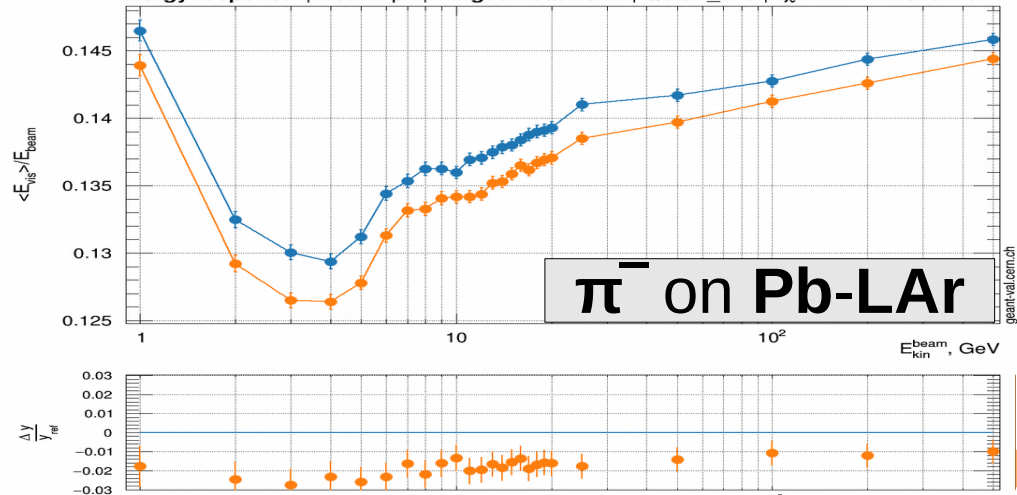
Energy response | Beam: pi- | Target: AtlasHEC



Energy response | Beam: pi- | Target: AtlasFCAL | QGSP_BIC



Energy response | Beam: pi- | Target: AtlasECAL | QGSP_BIC | $\chi^2/n.d.f. = 0.820416$



11.2.ref04

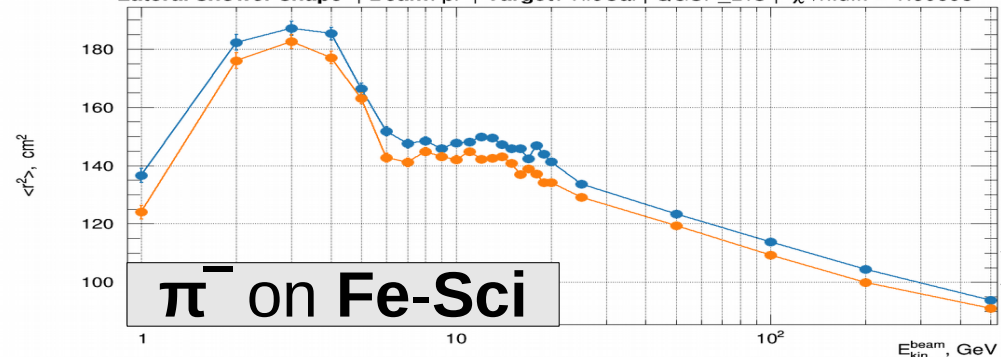
11.2.ref05

11.2.ref04

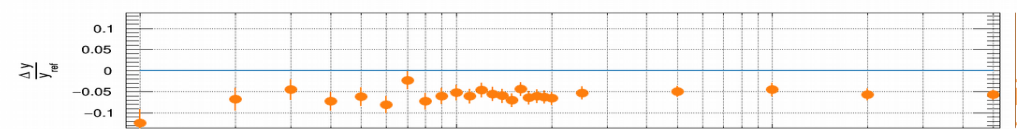
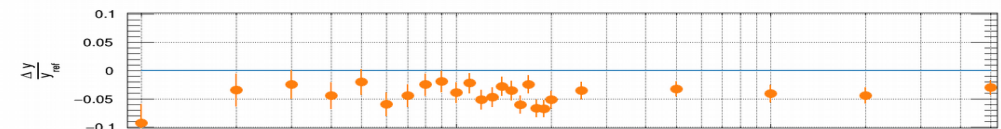
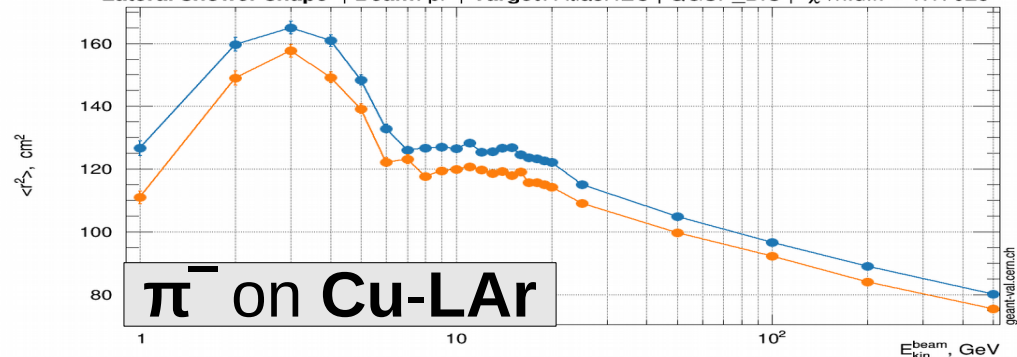
11.2.ref05

Lateral Shape

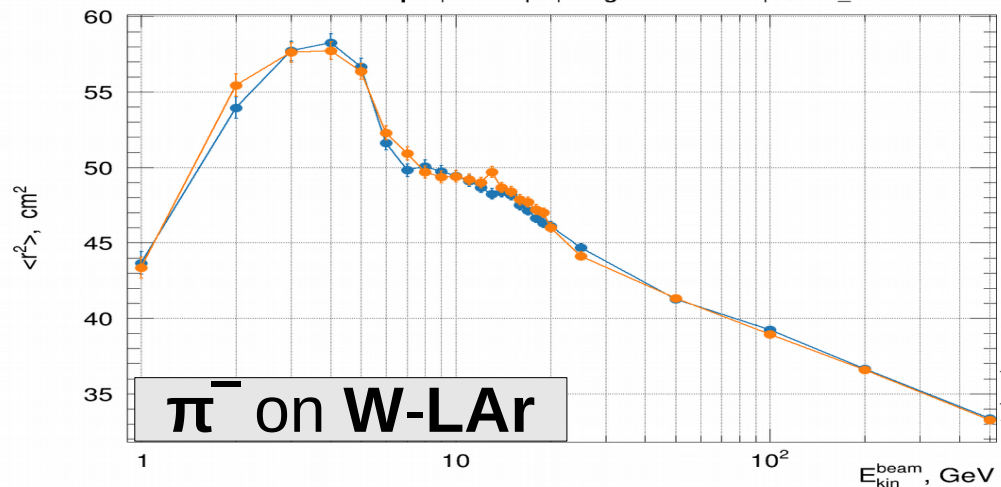
Lateral shower shape | Beam: pi- | Target: TileCal | QGSP_BIC | $\chi^2/n.d.f. = 1.60698$



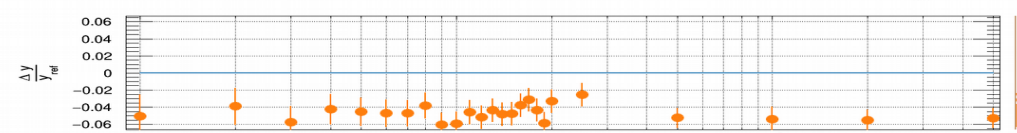
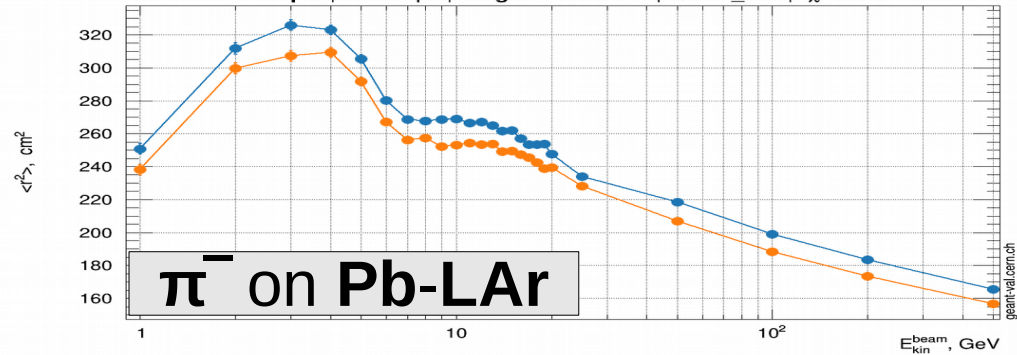
Lateral shower shape | Beam: pi- | Target: AtlasHEC | QGSP_BIC | $\chi^2/n.d.f. = 1.17025$



Lateral shower shape | Beam: pi- | Target: AtlasFCAL | QGSP_BIC



Lateral shower shape | Beam: pi- | Target: AtlasECAL | QGSP_BIC | $\chi^2/n.d.f. = 0.864446$



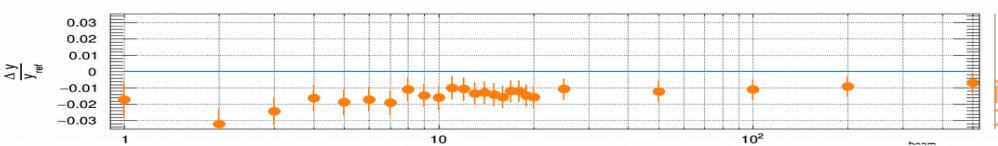
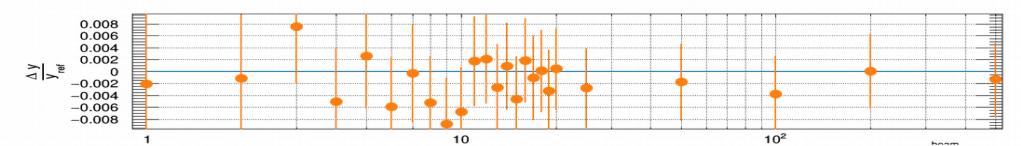
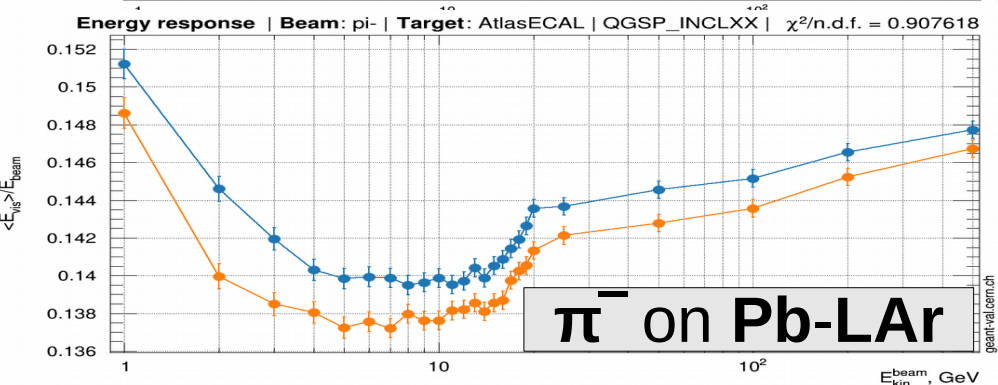
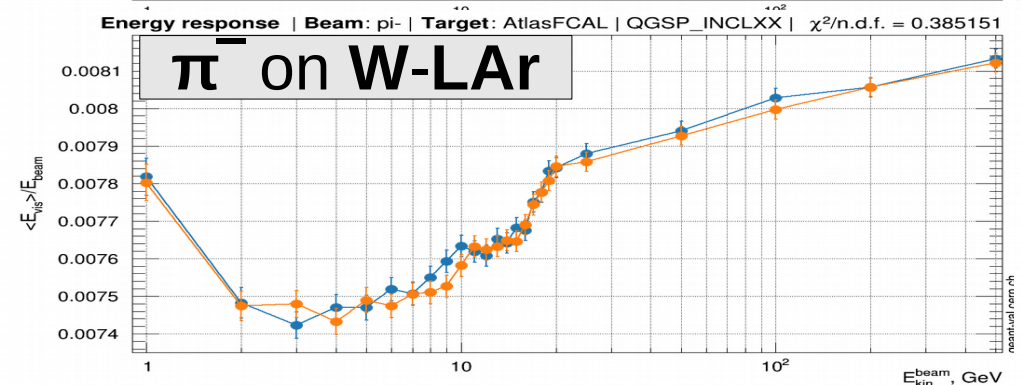
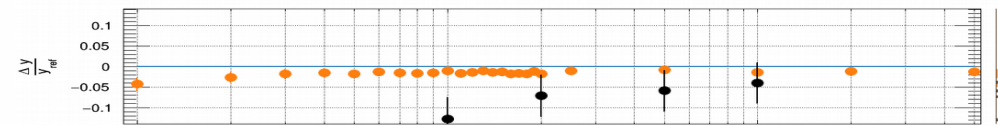
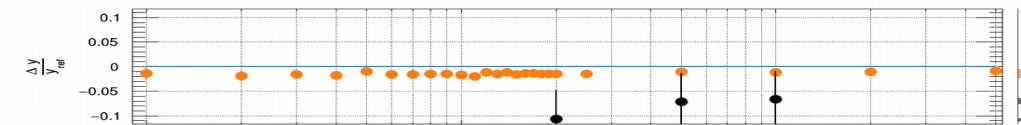
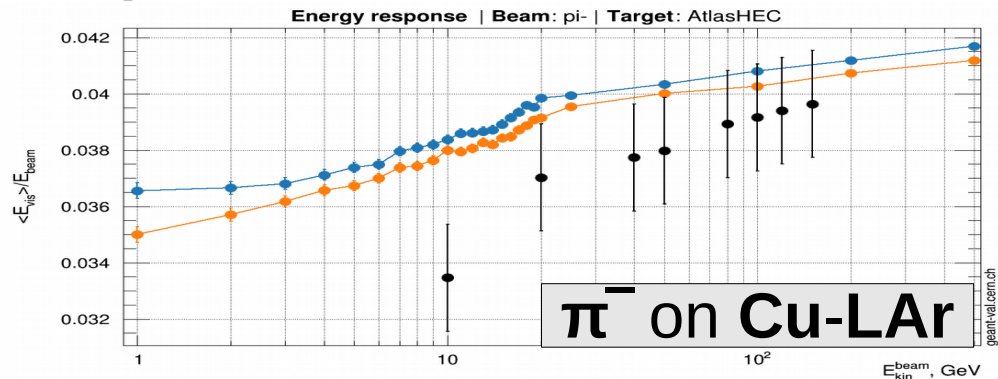
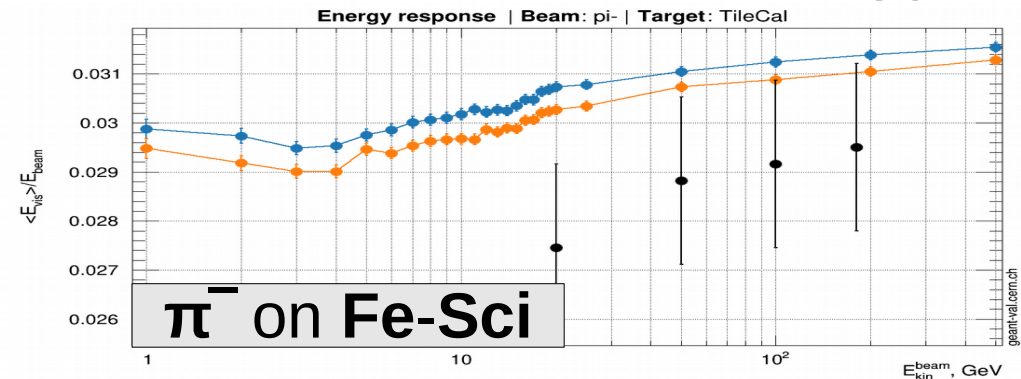
Pion- showers: QGSP_INCLXX

G4 11.2.ref04

G4 11.2.ref05

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

Energy Response

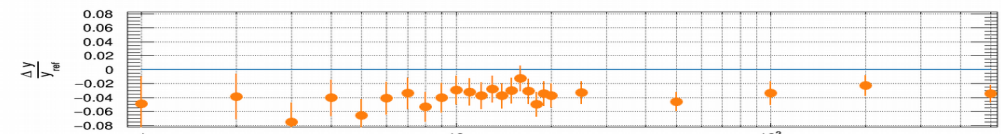
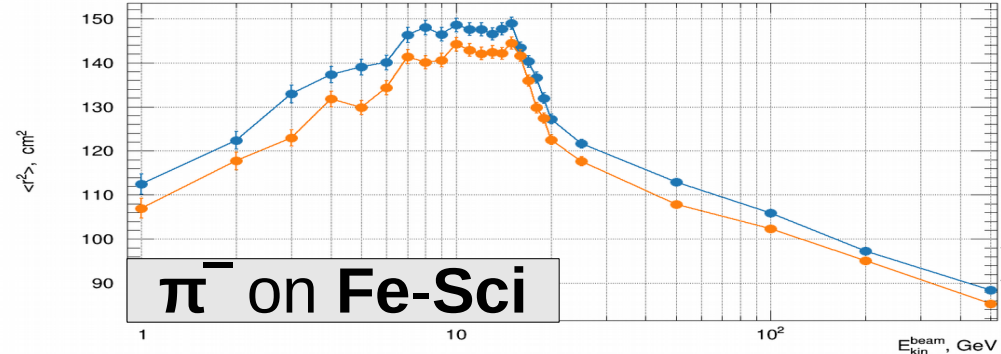


● 11.2.ref04 ● 11.2.ref05

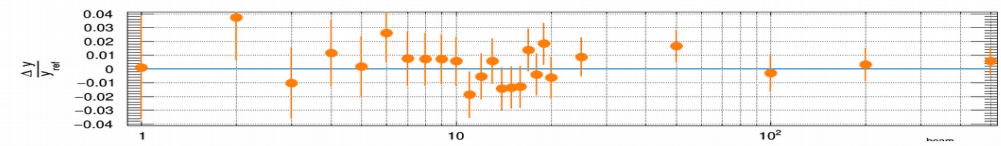
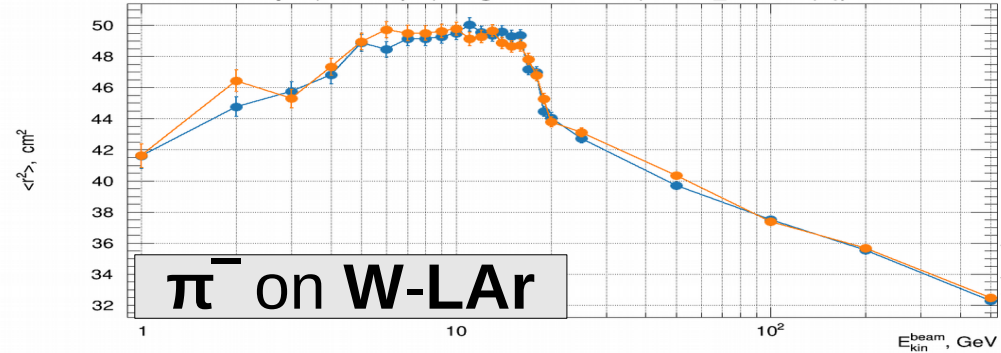
● 11.2.ref04 ● 11.2.ref05

Lateral Shape

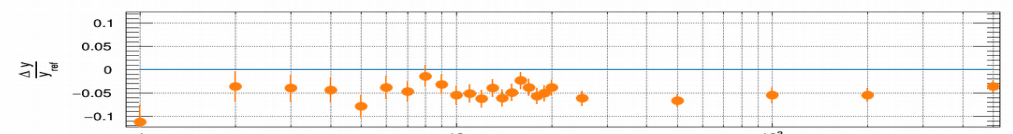
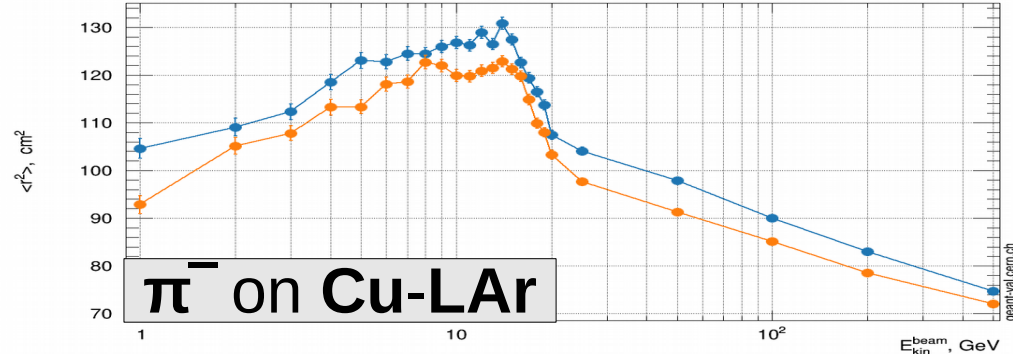
Lateral shower shape | Beam: pi- | Target: TileCal | QGSP_INCLXX | $\chi^2/n.d.f. = 0.759569$



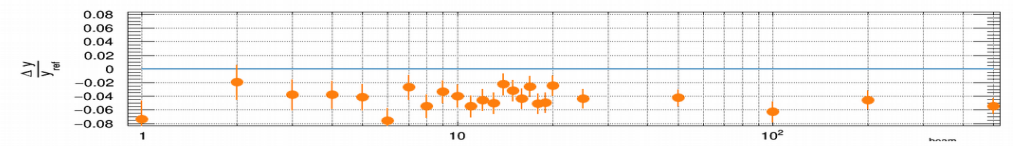
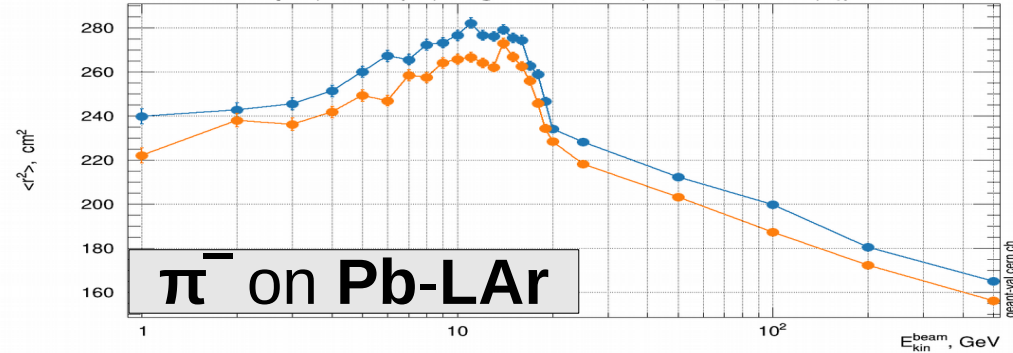
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | QGSP_INCLXX | $\chi^2/n.d.f. = 1.0359$



Lateral shower shape | Beam: pi- | Target: AtlasHEC | QGSP_INCLXX | $\chi^2/n.d.f. = 1.36901$



Lateral shower shape | Beam: pi- | Target: AtlasECAL | QGSP_INCLXX | $\chi^2/n.d.f. = 1.36598$



11.2.ref04

11.2.ref05

11.2.ref04

11.2.ref05

Conclusions

- **G4 11.2.ref05**
 - No crashes, no new or more-frequent warnings, and no infinite loops
 - Reproducibility fine in all cases
 - Pion showers similar to those of G4 11.2.ref04 for most physics lists, with only two exceptions, **QGSP_BIC** and **QGSP_INCLXX**, for which:
 - 1-3 % decrease in energy response (except in Tungsten)
 - ~5% narrower lateral shower shapes (except in Tungsten)

Notes:

- The pion showers of these physics lists become closer to the other physics lists (*e.g.* FTFP_BERT, QGSP_BERT, *etc.*)
- The development in nuclear de-excitation is the likely cause of the observed changes
 - Because BERT – used in most of reference physics lists, except QGSP_BIC and QGSP_INCLXX – has its own nuclear de-excitation, which is stable