

Hadronic Showers in Geant4 **10.6**

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CERN EP/SFT

Status of G4 10.6.ref00

- Changes in hadronic showers *w.r.t.* G4 10.5 are mainly due to the change in transition region, which is now **[3, 6] GeV**
 - Motivated by thin target (HARP) data
 - @5 GeV, BERT and FTFP similar; @8 & 12 GeV FTFP better
- Seen a few crashes due to FTF
 - Fix ready, will go to the first patch
- Significant CPU slowdown in HP-based physics lists not fully understood
 - Slow down seen in G4 10.5.ref10, when we moved to G4NDL4.6 (based on JEFF) and activated radioactive decay in all HP-based physics lists (this was already the case for half of them)...

Pion- showers: FTFP_BERT

G4 10.6

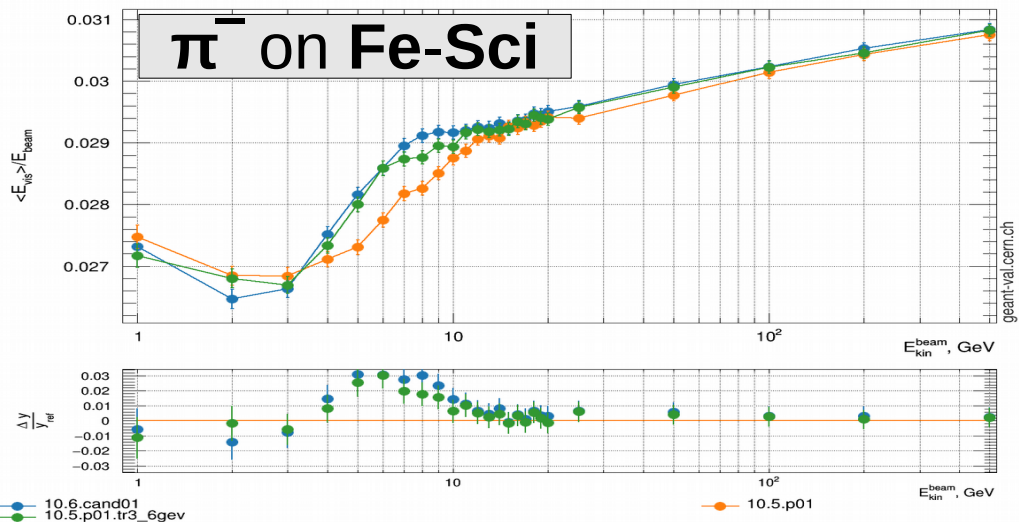
G4 10.5.p01.tr3_6gev ([3, 6] GeV)

G4 10.5.p01

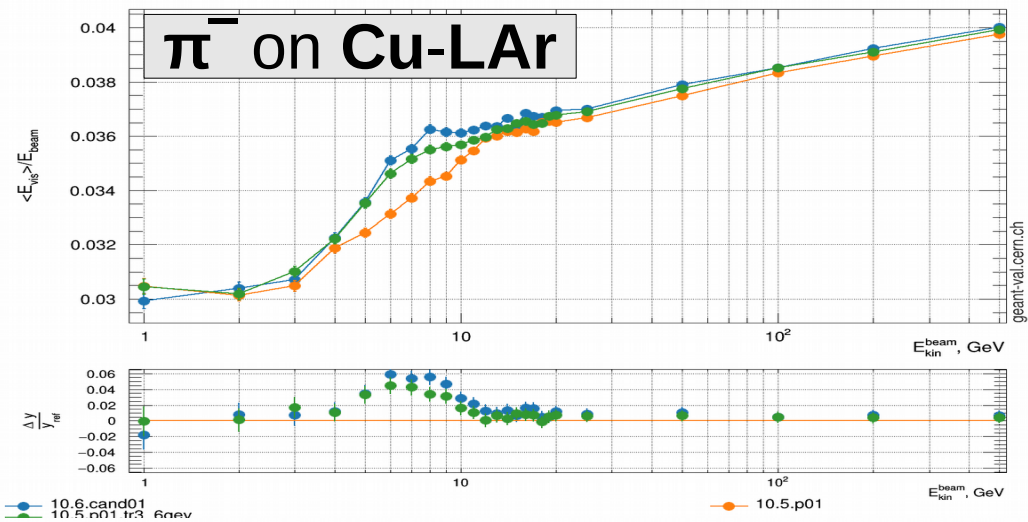
*Note : conventional Birks treatment
(easier and no experimental h/e to fit !)*

FTFP_BERT : Energy Response

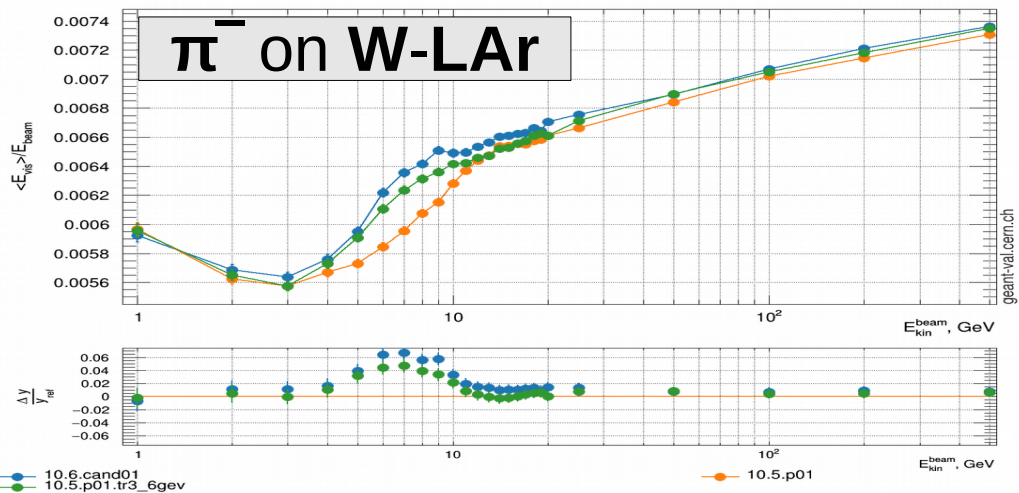
Energy response | Beam: pi- | Target: TileCal | FTFP_BERT



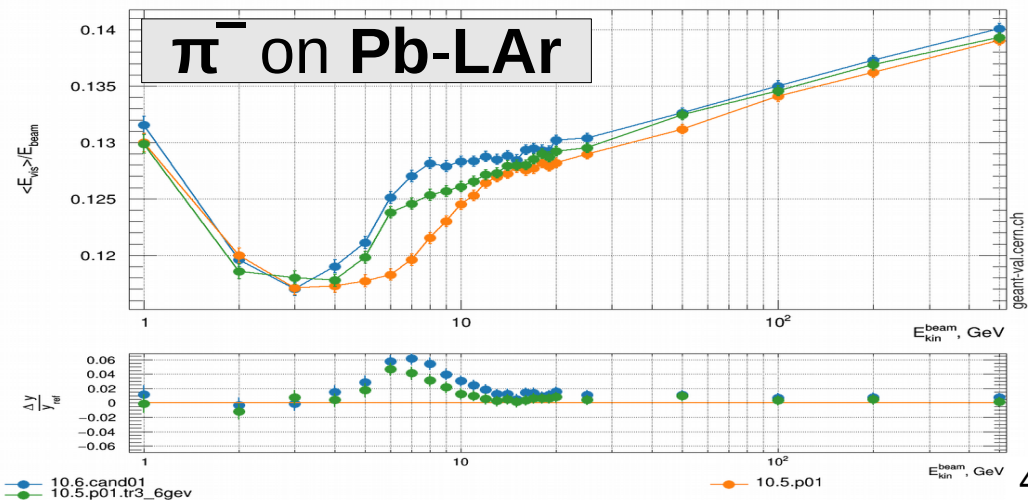
Energy response | Beam: pi- | Target: AtlasHEC | FTFP_BERT



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



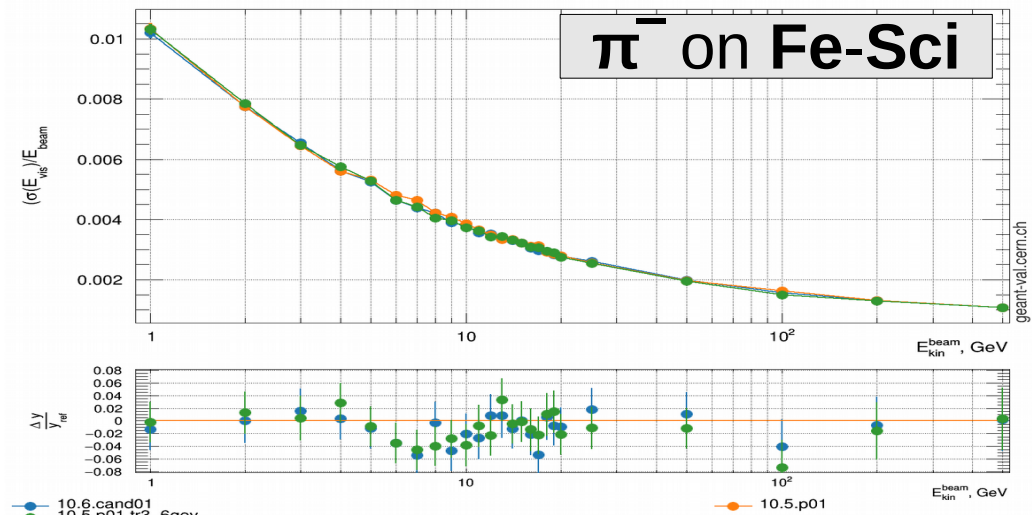
Energy response | Beam: pi- | Target: AtlasECAL | FTFP_BERT



FTFP_BERT : Energy Width

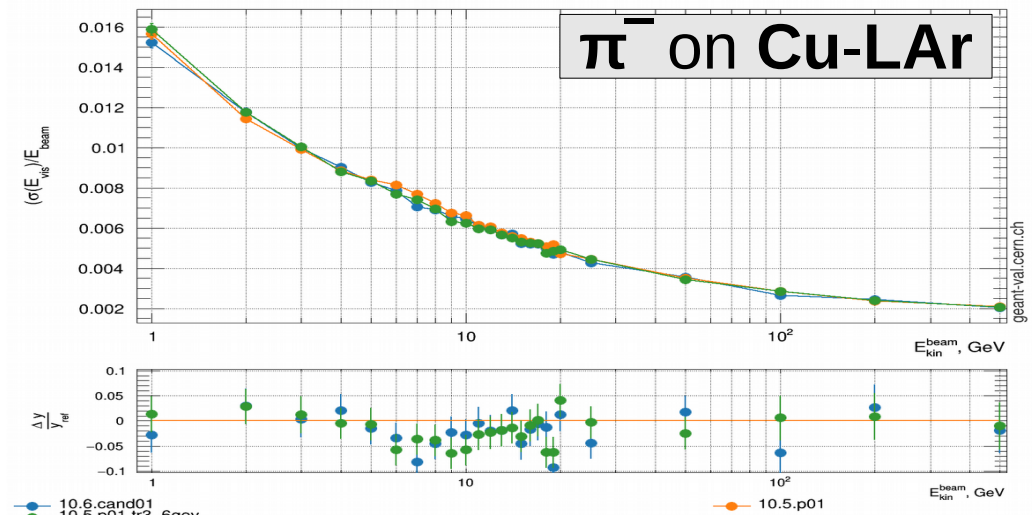
Normalized width | Beam: pi- | Target: TileCal | FTFP_BERT

π^- on Fe-Sci



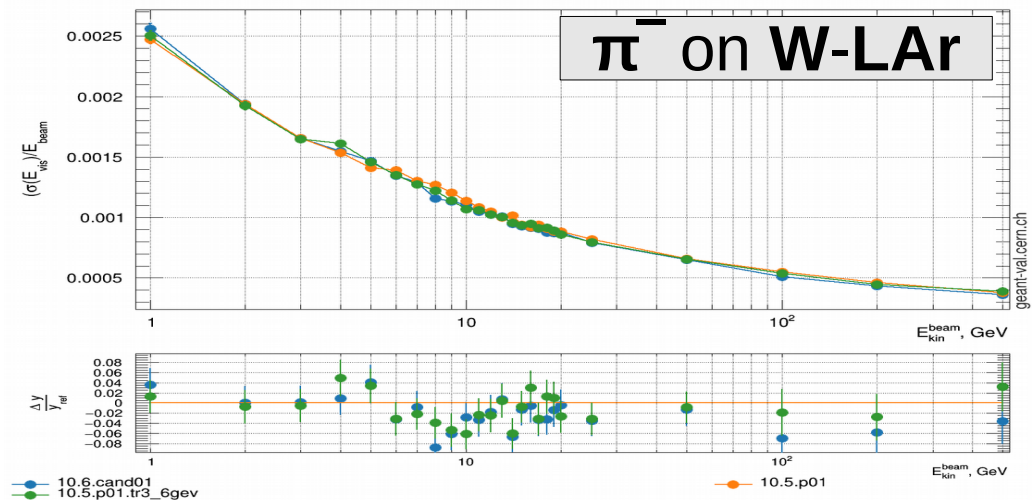
Normalized width | Beam: pi- | Target: AtlasHEC | FTFP_BERT

π^- on Cu-LAr



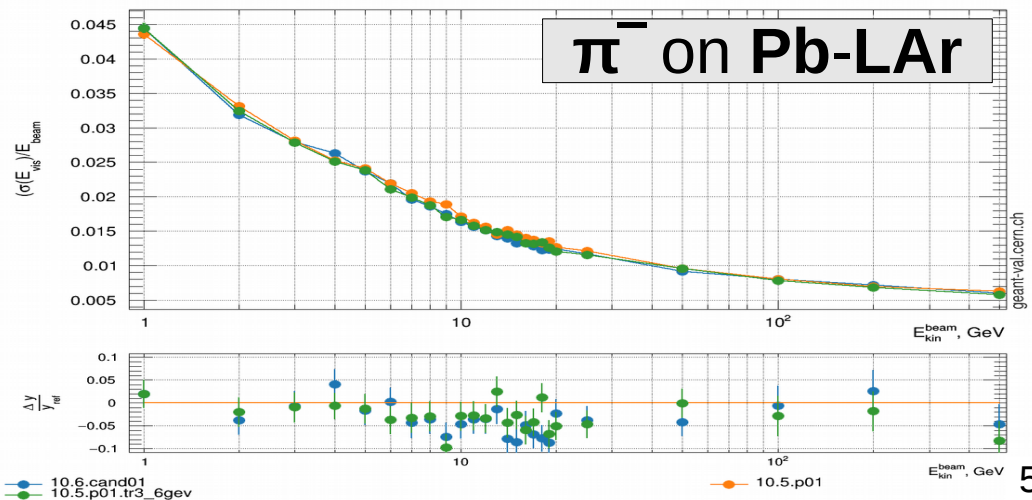
Normalized width | Beam: pi- | Target: AtlasFCAL | FTFP_BERT

π^- on W-LAr



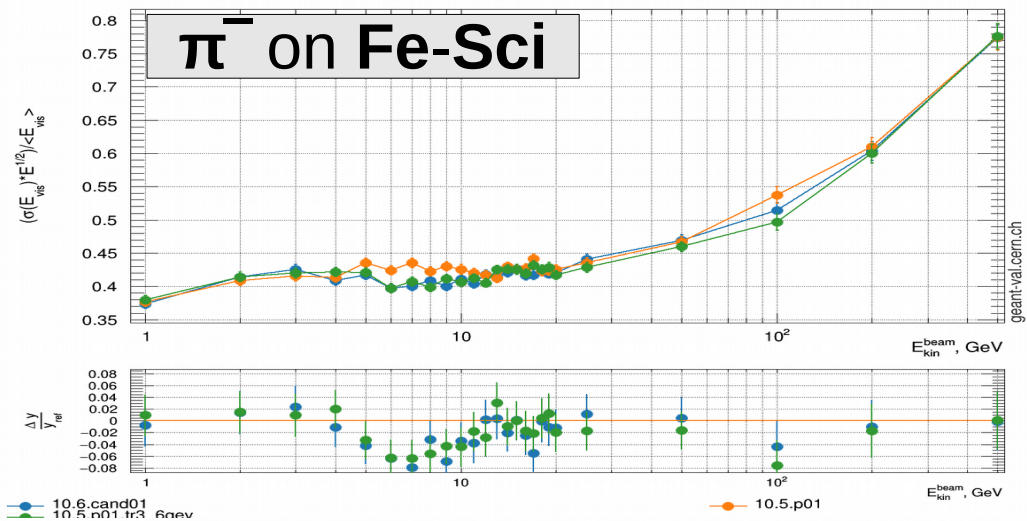
Normalized width | Beam: pi- | Target: AtlasECAL | FTFP_BERT

π^- on Pb-LAr

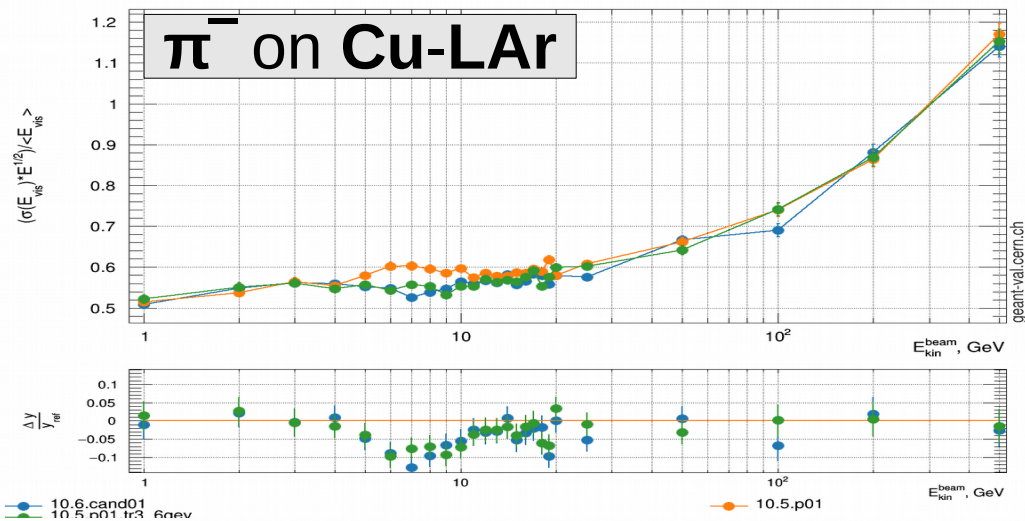


FTFP_BERT : Energy Resolution

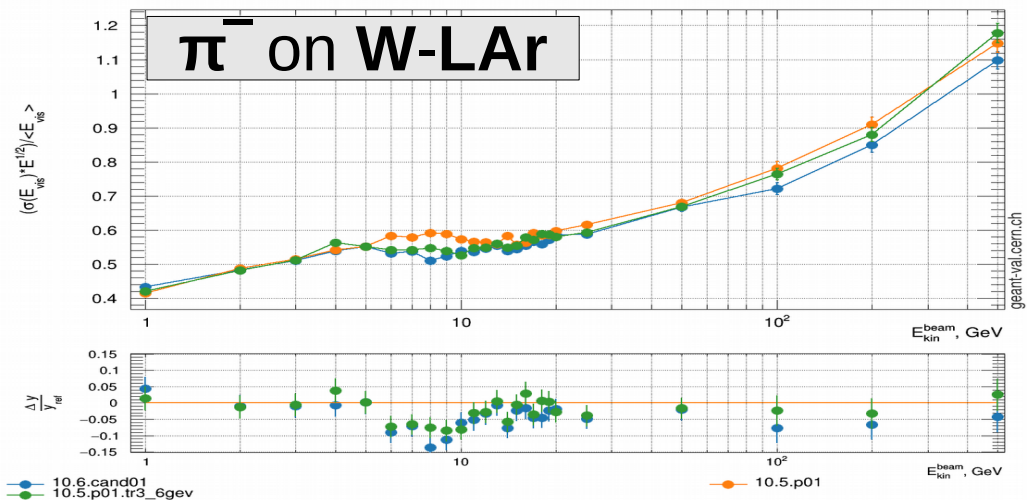
Energy resolution | Beam: pi- | Target: TileCal | FTFP_BERT



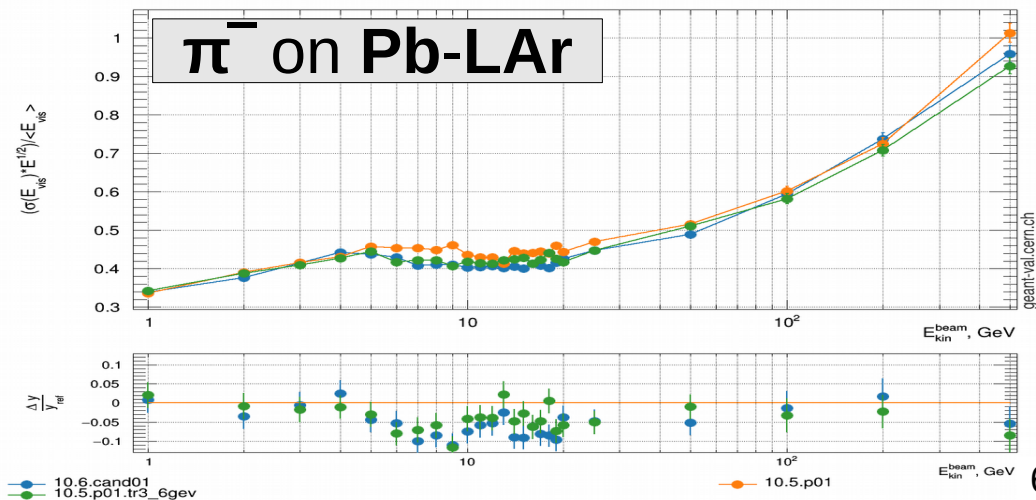
Energy resolution | Beam: pi- | Target: AtlasHEC | FTFP_BERT



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

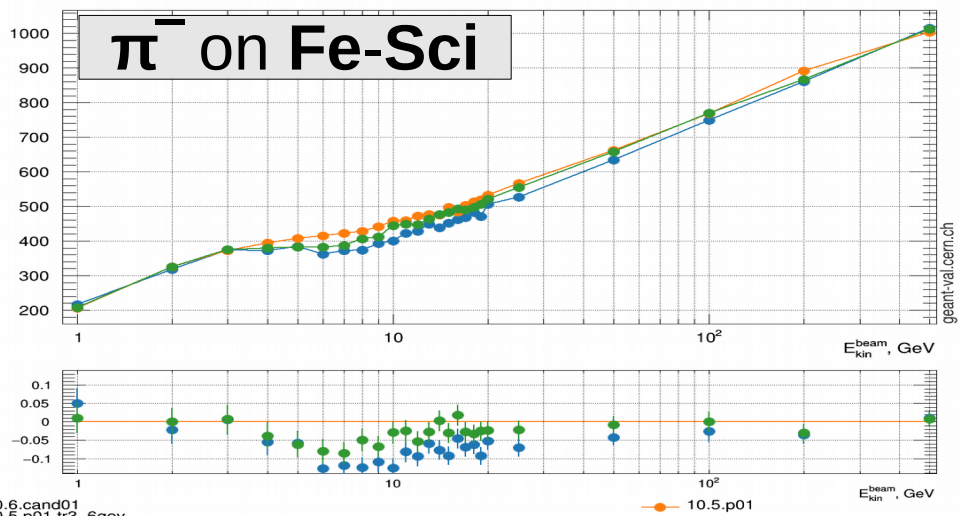


Energy resolution | Beam: pi- | Target: AtlasECAL | FTFP_BERT

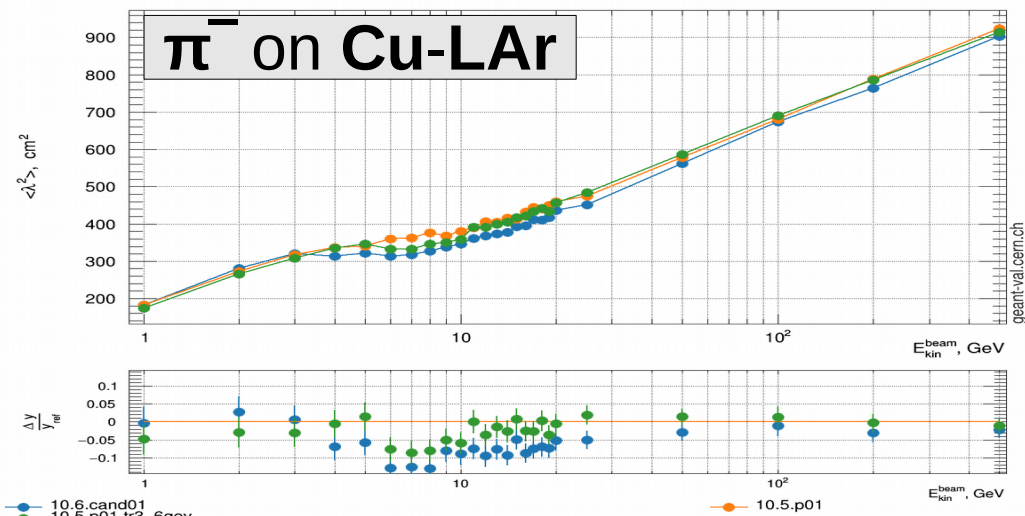


FTFP_BERT : Longitudinal Shape

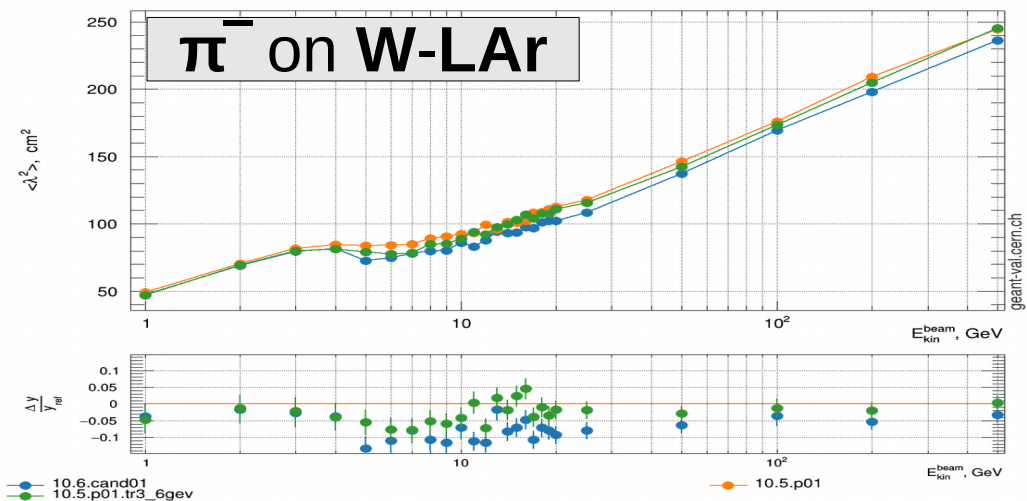
Longitudinal shower shape | Beam: pi- | Target: TileCal | FTFP_BERT



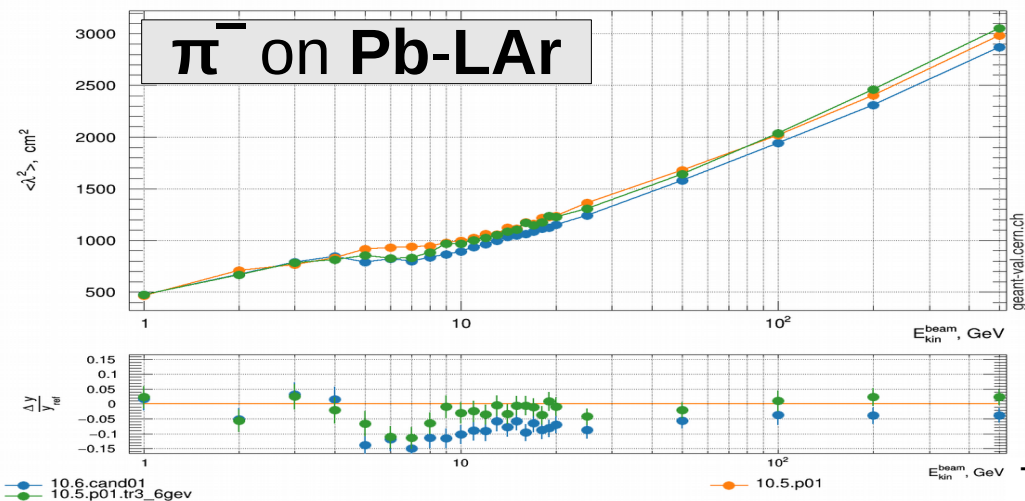
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | FTFP_BERT



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

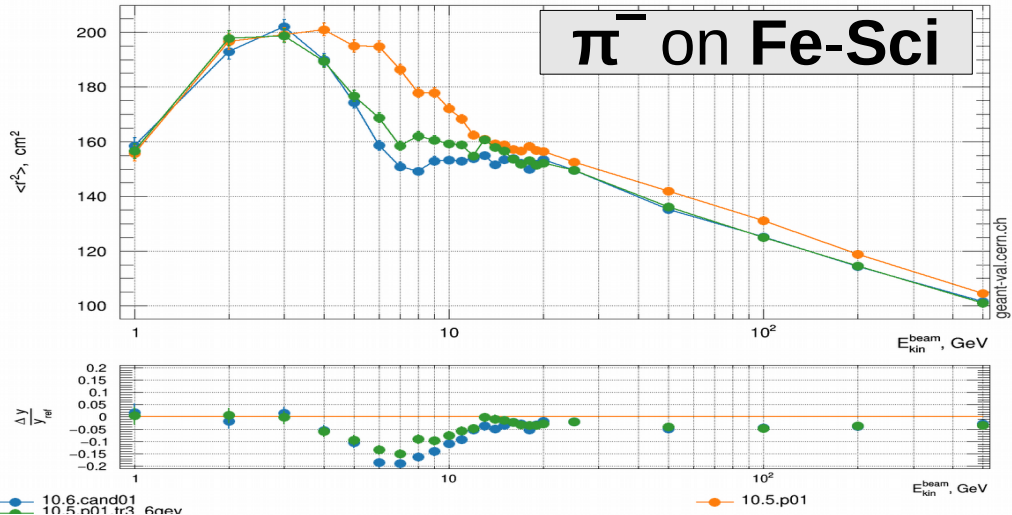


Longitudinal shower shape | Beam: pi- | Target: AtlasECAL | FTFP_BERT

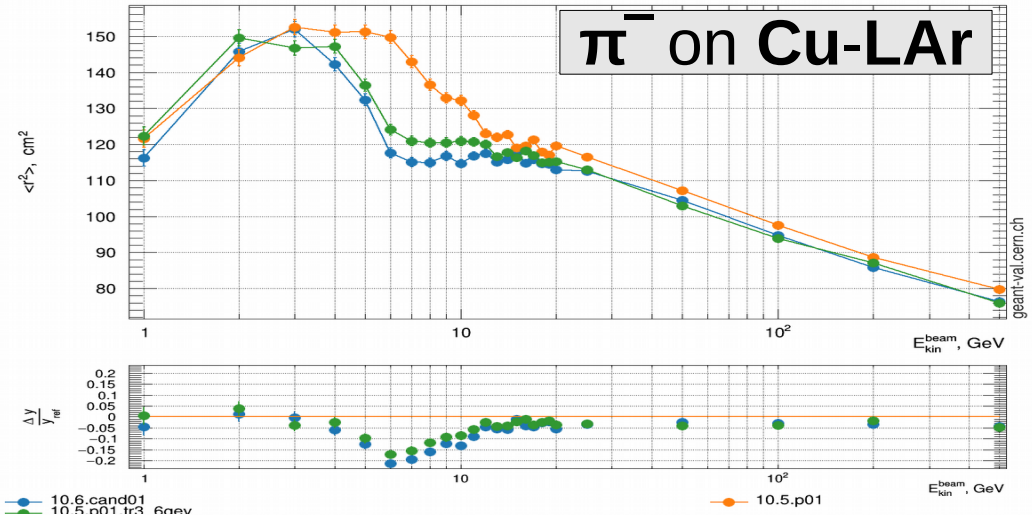


FTFP_BERT : Lateral Shape

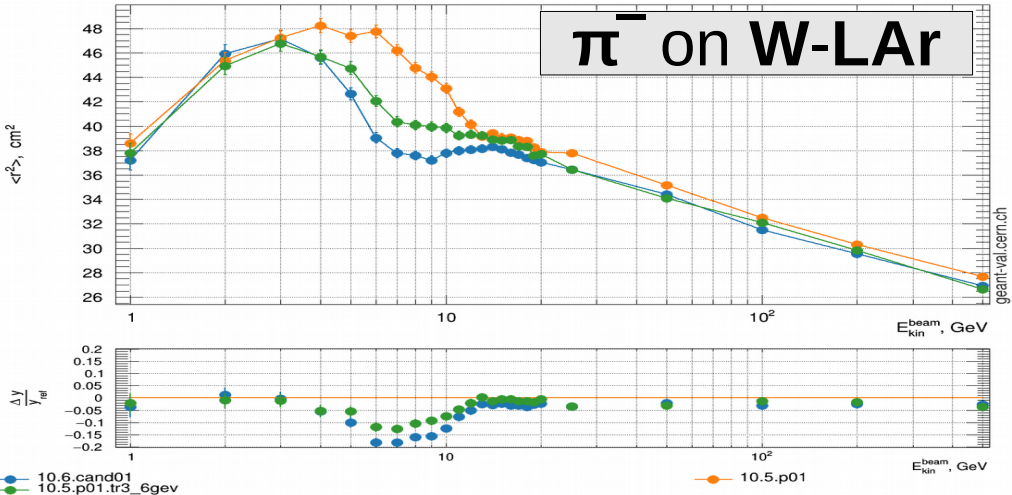
Lateral shower shape | Beam: pi- | Target: TileCal | FTFP_BERT



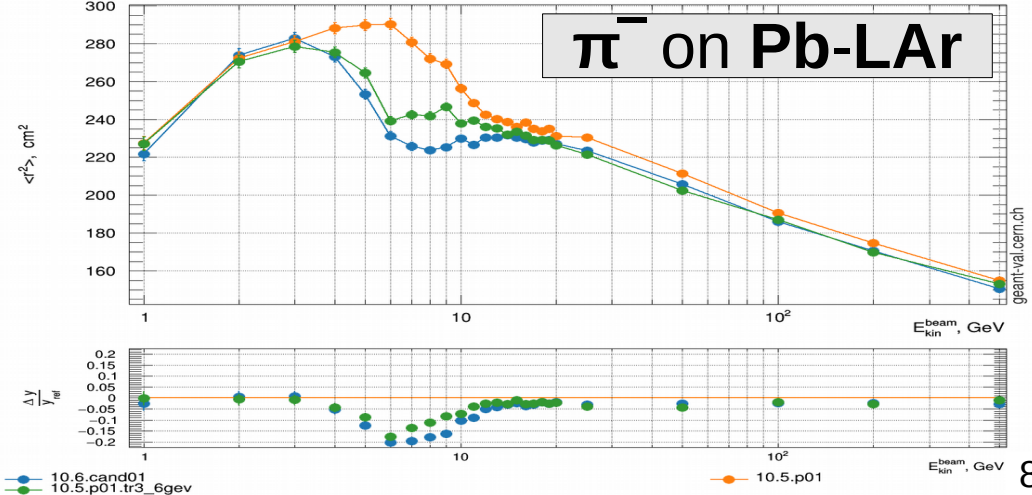
Lateral shower shape | Beam: pi- | Target: AtlasHEC | FTFP_BERT



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



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



Pion- showers: QGSP_BERT

G4 10.6

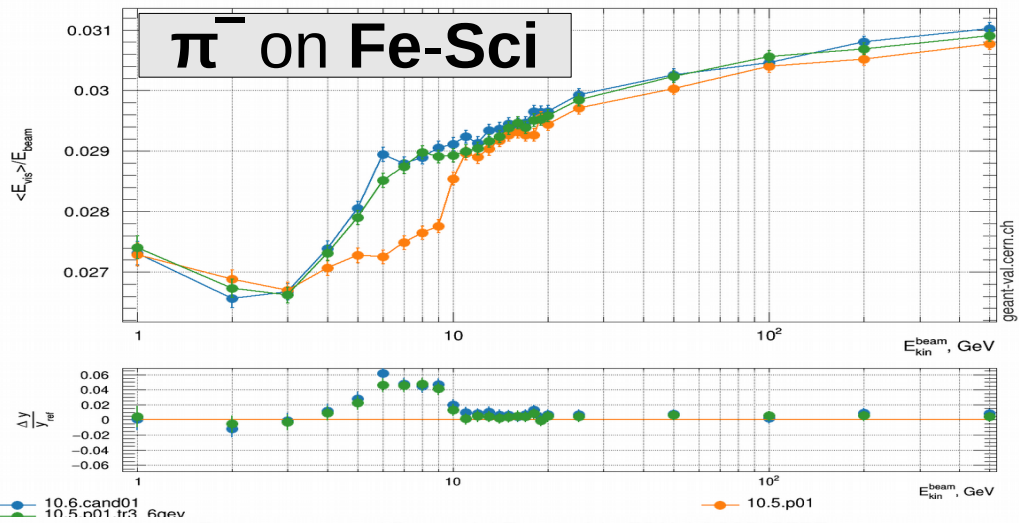
G4 10.5.p01.tr3_6gev ([3, 6] GeV)

G4 10.5.p01

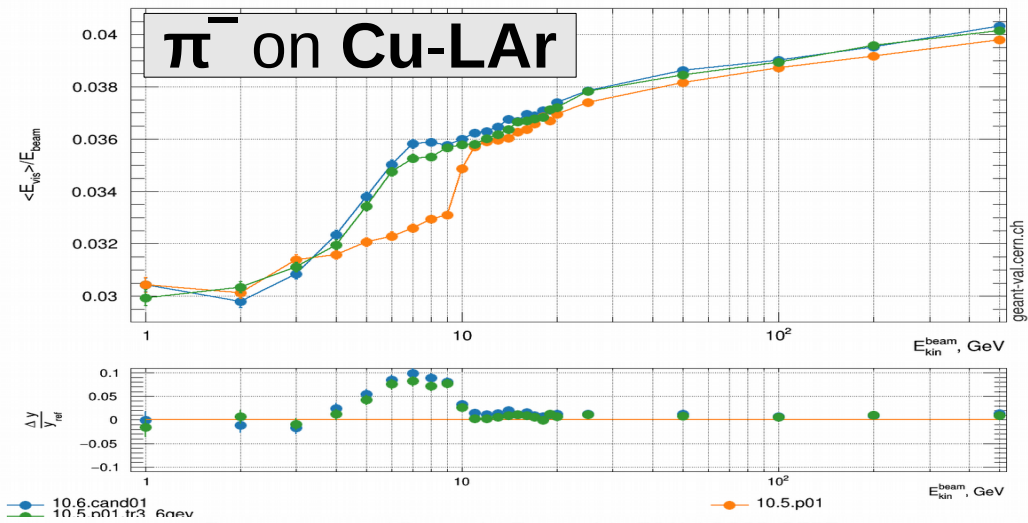
*Note : conventional Birks treatment
(easier and no experimental h/e to fit !)*

QGSP_BERT : Energy Response

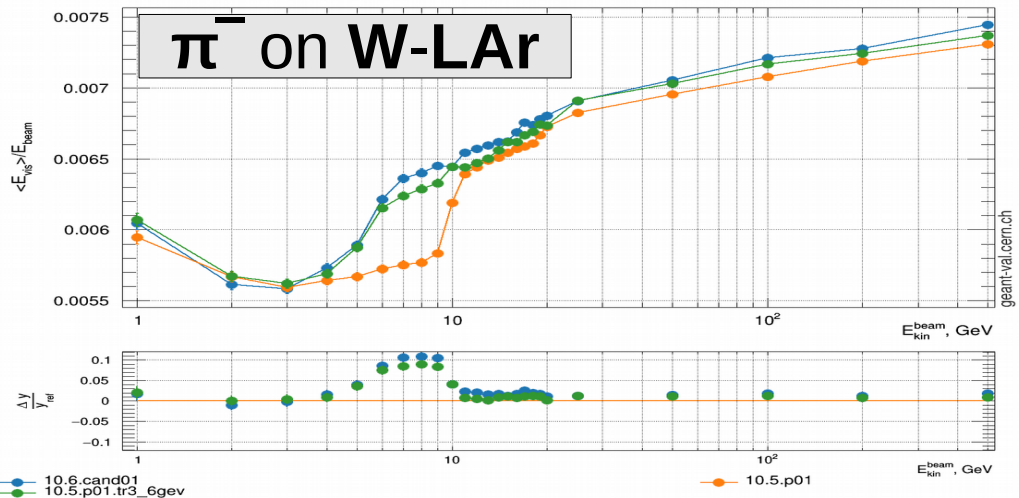
Energy response | Beam: pi- | Target: TileCal | QGSP_BERT



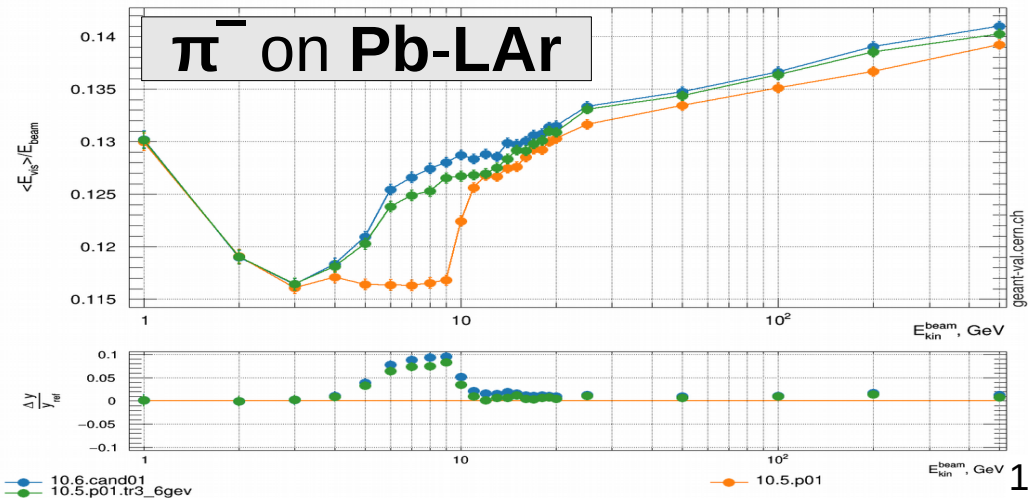
Energy response | Beam: pi- | Target: AtlasHEC | QGSP_BERT



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



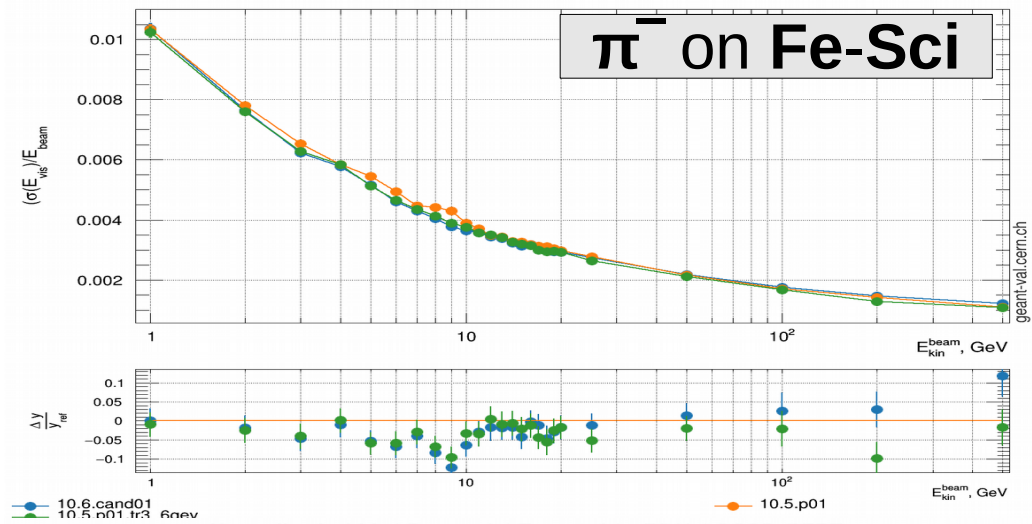
Energy response | Beam: pi- | Target: AtlasECAL | QGSP_BERT



QGSP_BERT : Energy Width

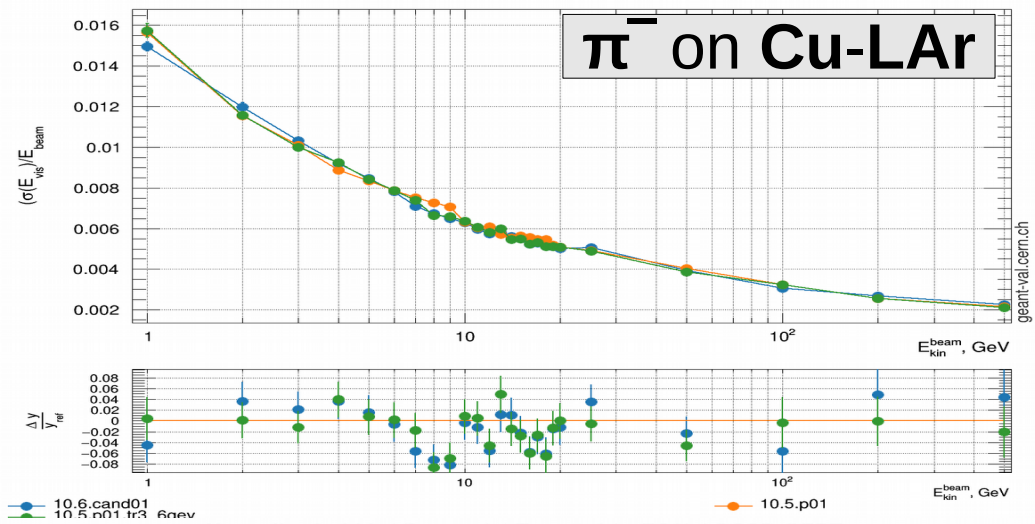
Normalized width | Beam: pi- | Target: TileCal | QGSP_BERT

π^- on Fe-Sci



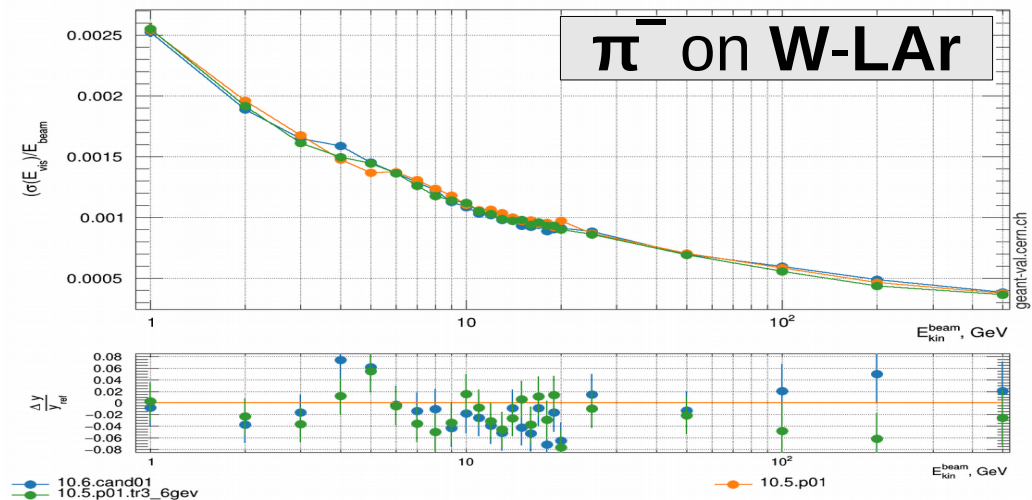
Normalized width | Beam: pi- | Target: AtlasHEC | QGSP_BERT

π^- on Cu-LAr



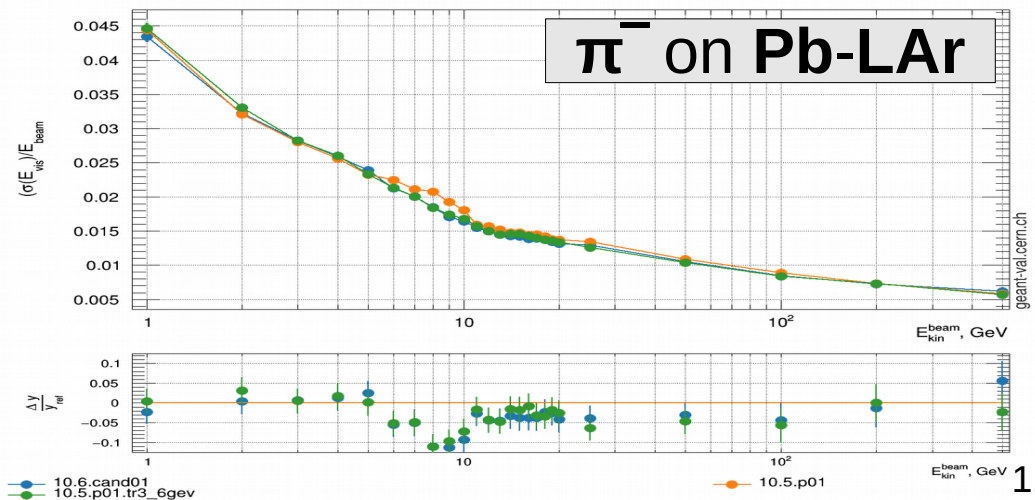
Normalized width | Beam: pi- | Target: AtlasFCAL | QGSP_BERT

π^- on W-LAr



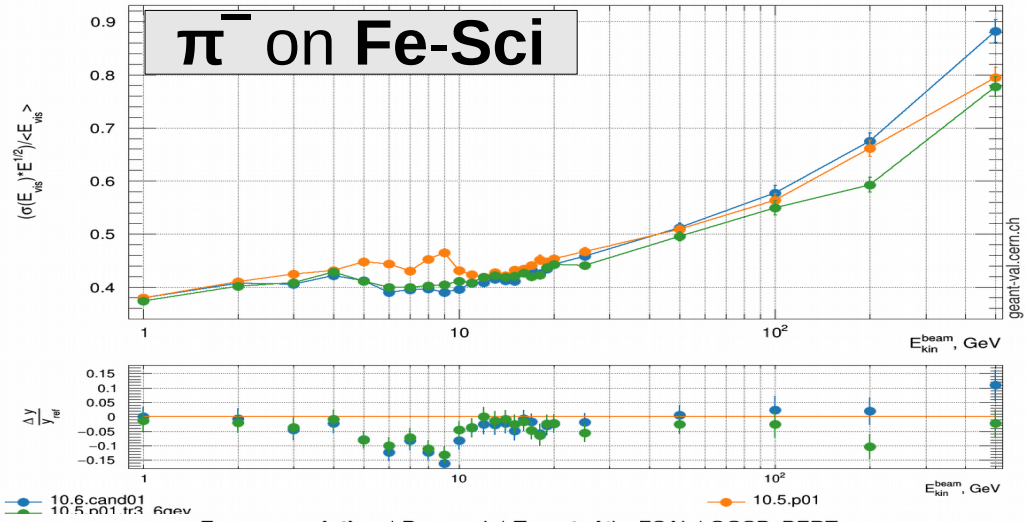
Normalized width | Beam: pi- | Target: AtlasECAL | QGSP_BERT

π^- on Pb-LAr

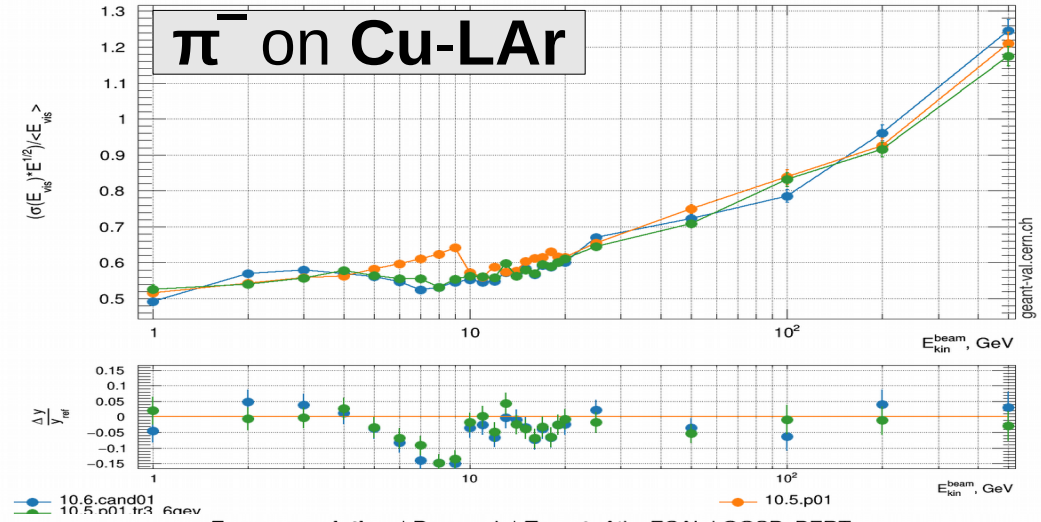


QGSP_BERT : Energy Resolution

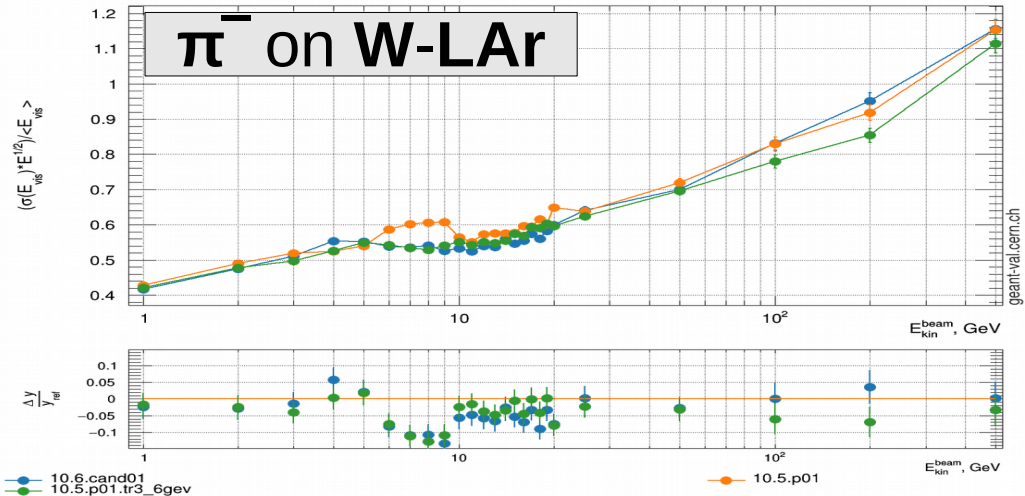
Energy resolution | Beam: pi- | Target: TileCal | QGSP_BERT



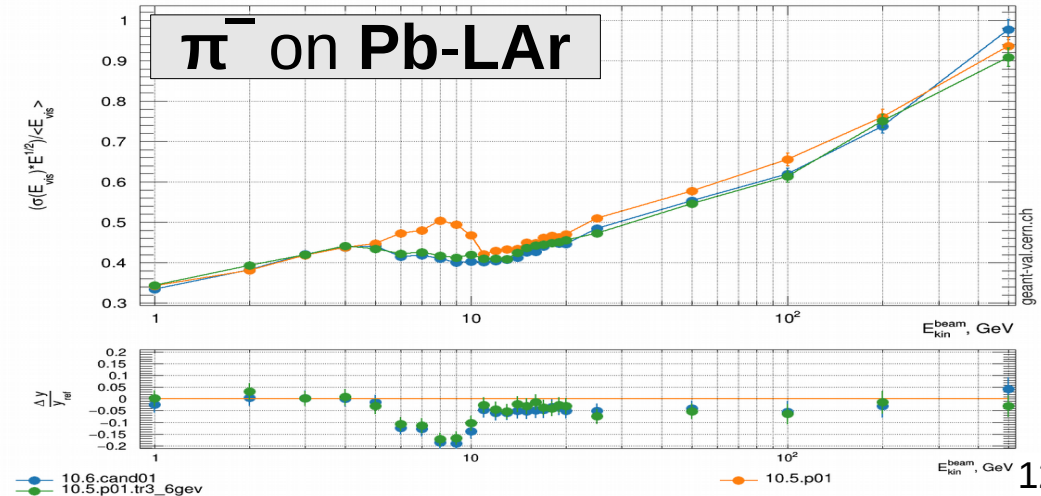
Energy resolution | Beam: pi- | Target: AtlasHEC | QGSP_BERT



Energy resolution | Beam: pi- | Target: AtlasFCAL | QGSP_BERT

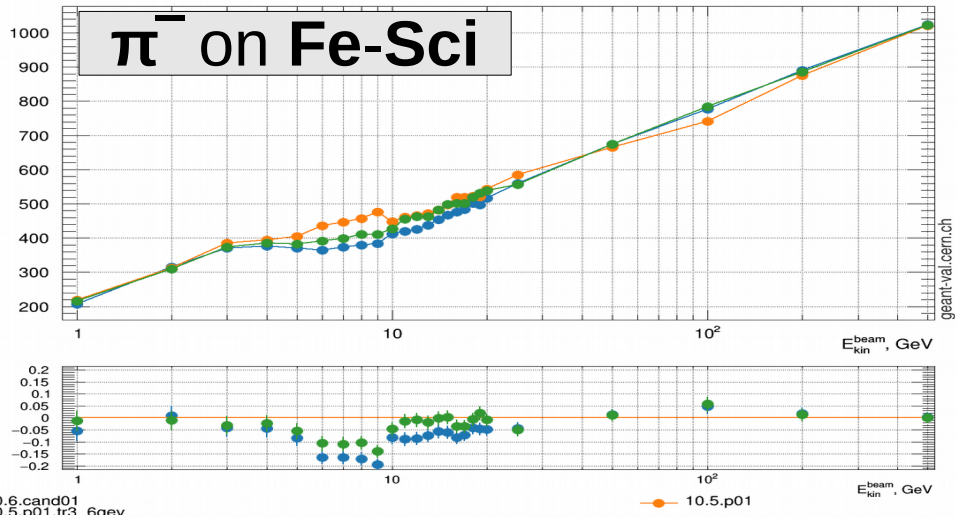


Energy resolution | Beam: pi- | Target: AtlasECAL | QGSP_BERT

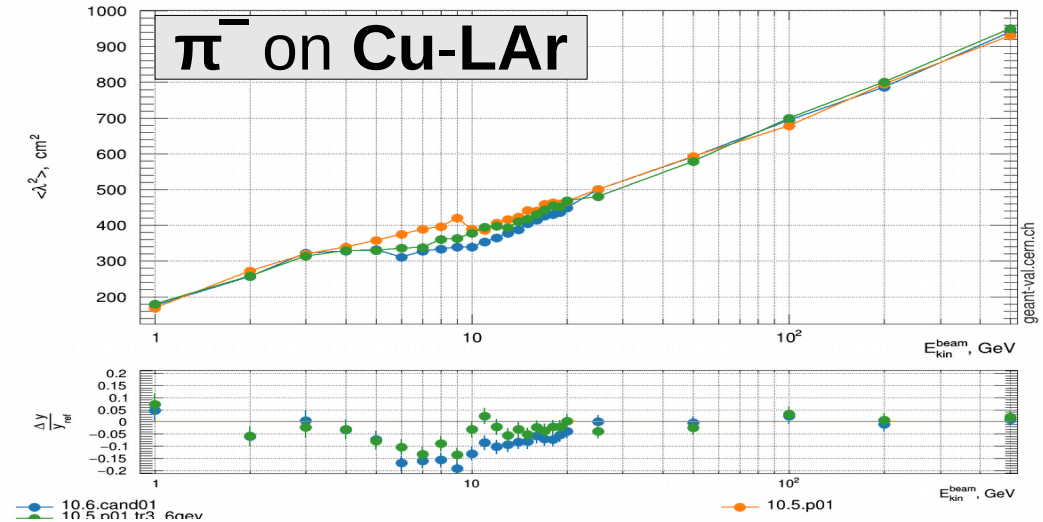


QGSP_BERT : Longitudinal Shape

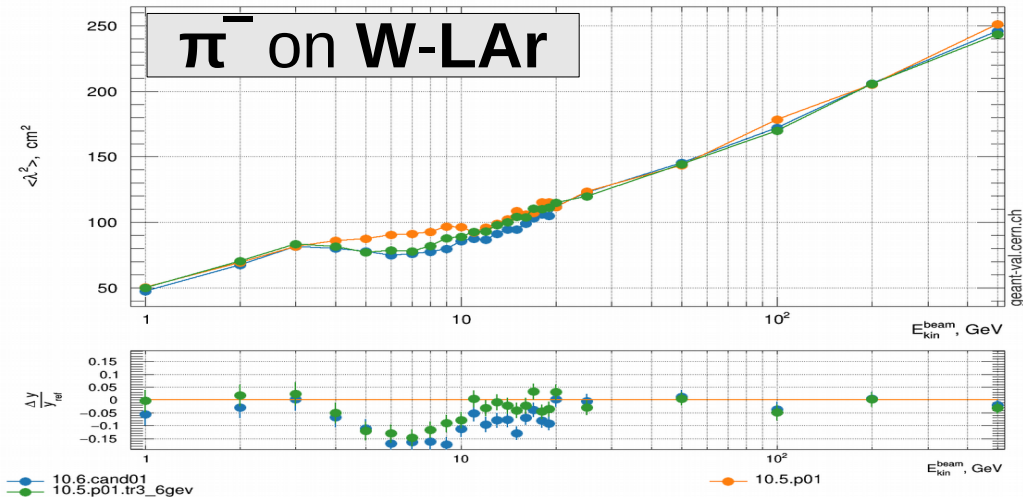
Longitudinal shower shape | Beam: pi- | Target: TileCal | QGSP_BERT



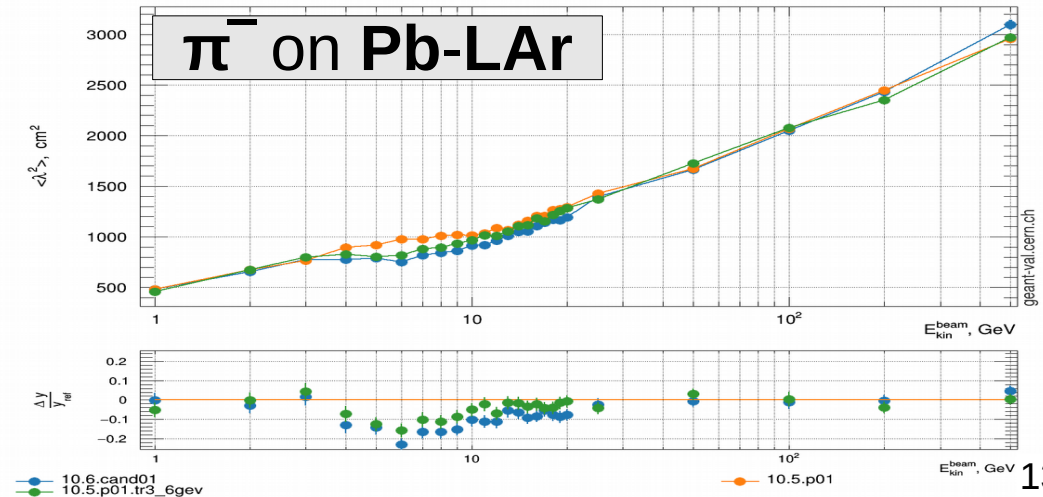
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | QGSP_BERT



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



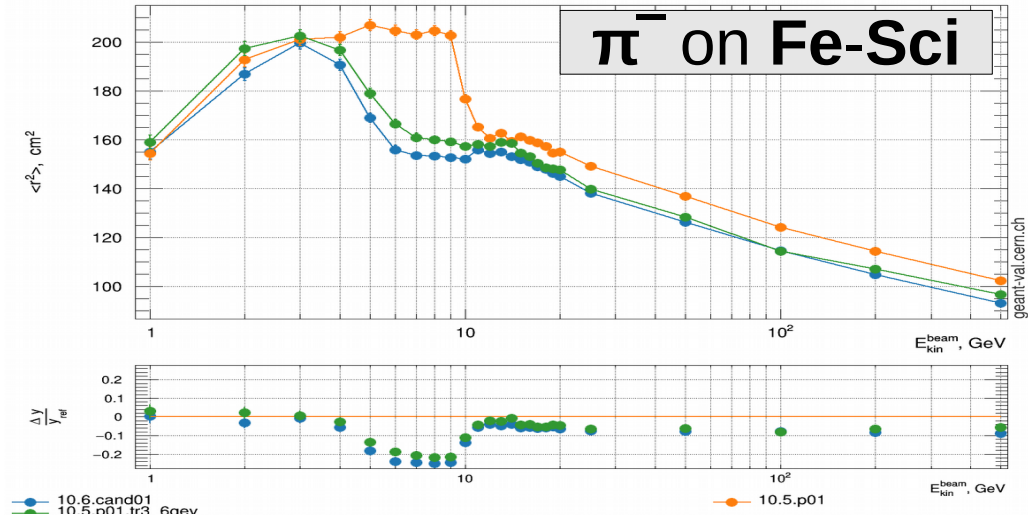
Longitudinal shower shape | Beam: pi- | Target: AtlasECAL | QGSP_BERT



QGSP_BERT : Lateral Shape

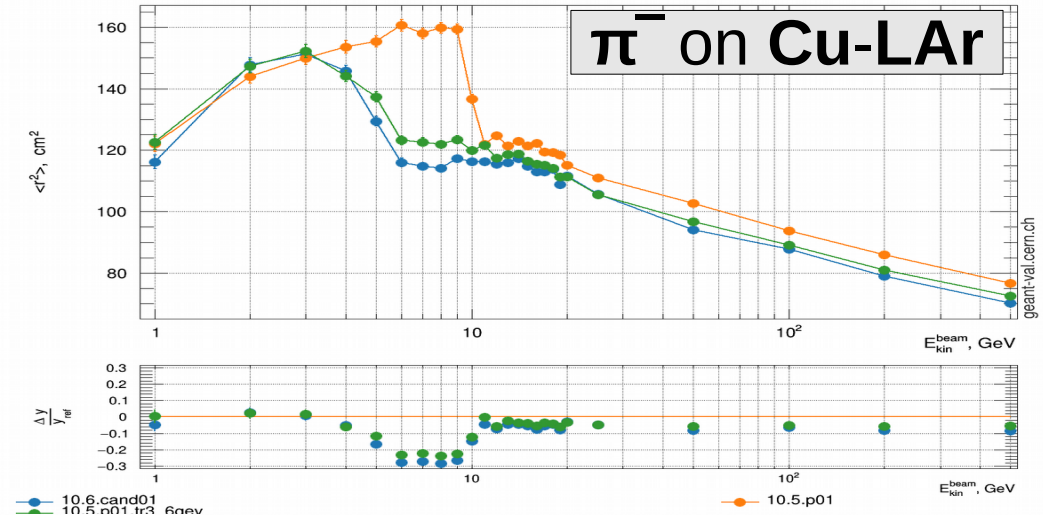
Lateral shower shape | Beam: pi- | Target: TileCal | QGSP_BERT

π^- on Fe-Sci



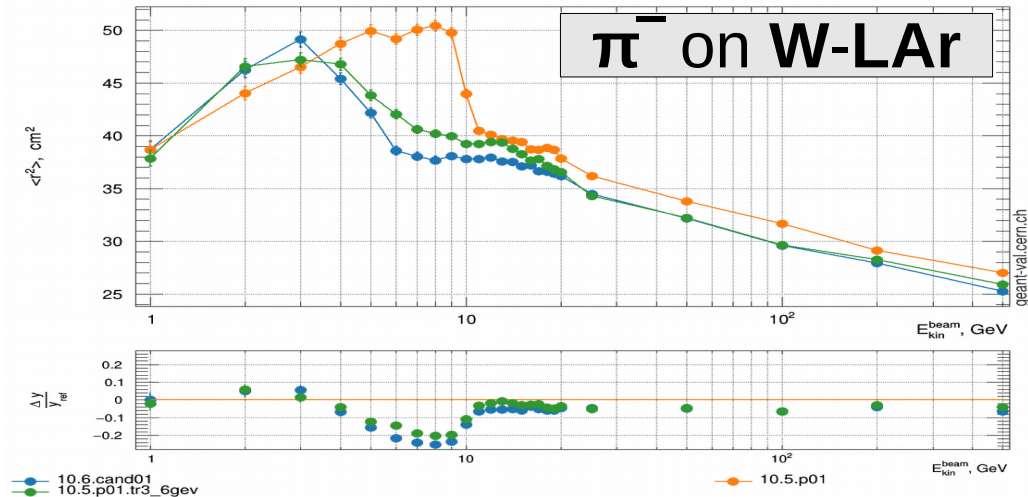
Lateral shower shape | Beam: pi- | Target: AtlasHEC | QGSP_BERT

π^- on Cu-LAr



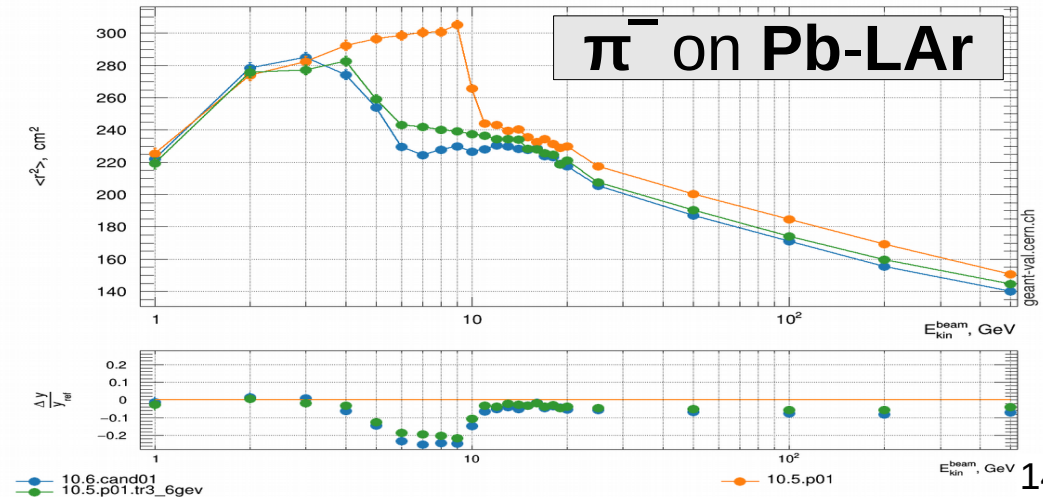
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | QGSP_BERT

π^- on W-LAr



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

π^- on Pb-LAr



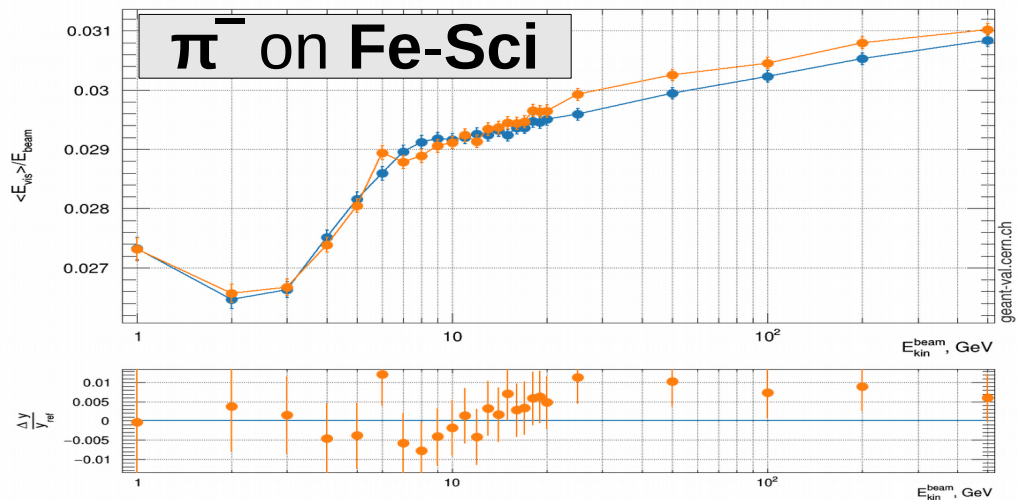
Pion- showers: G4 10.6

FTFP_BERT vs. QGSP_BERT

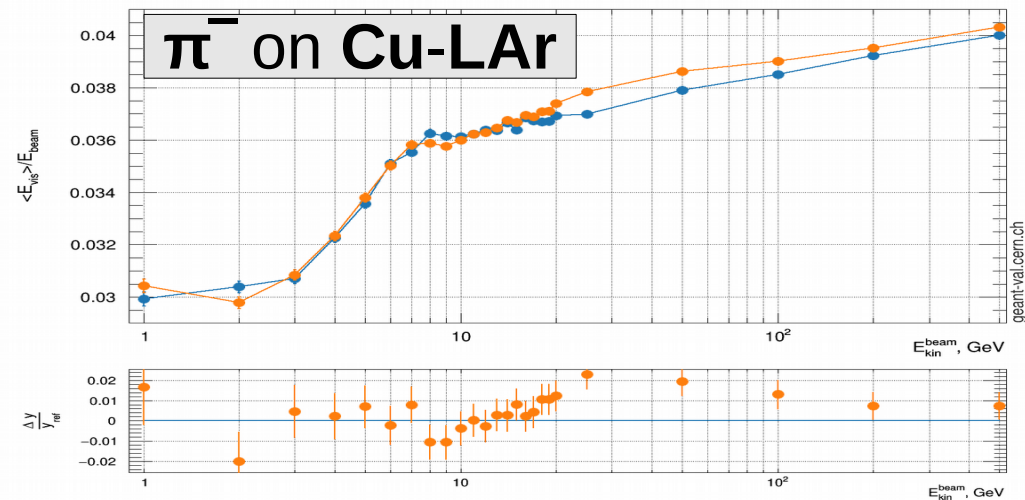
*Note : conventional Birks treatment
(easier and no experimental h/e to fit !)*

Energy Response

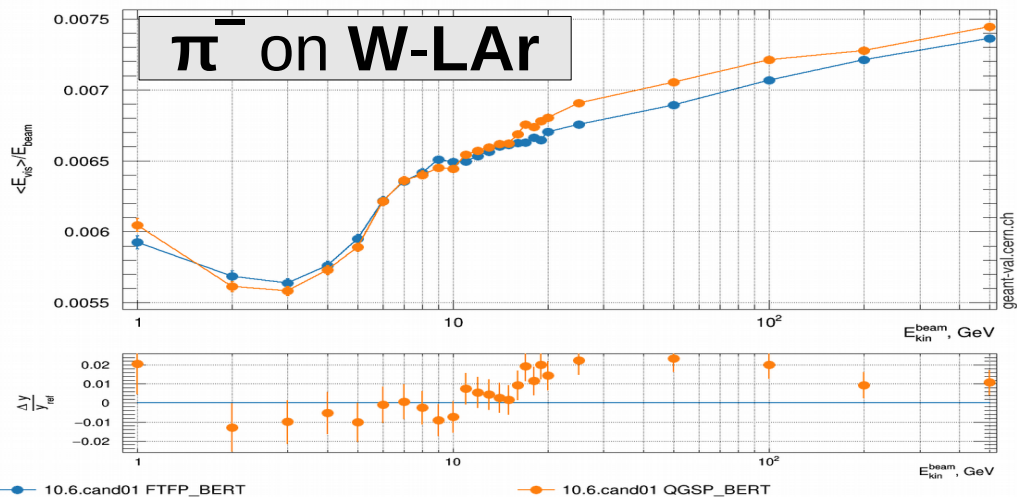
Energy response | Beam: pi- | Target: TileCal | $\chi^2/n.d.f. = 1.1395$



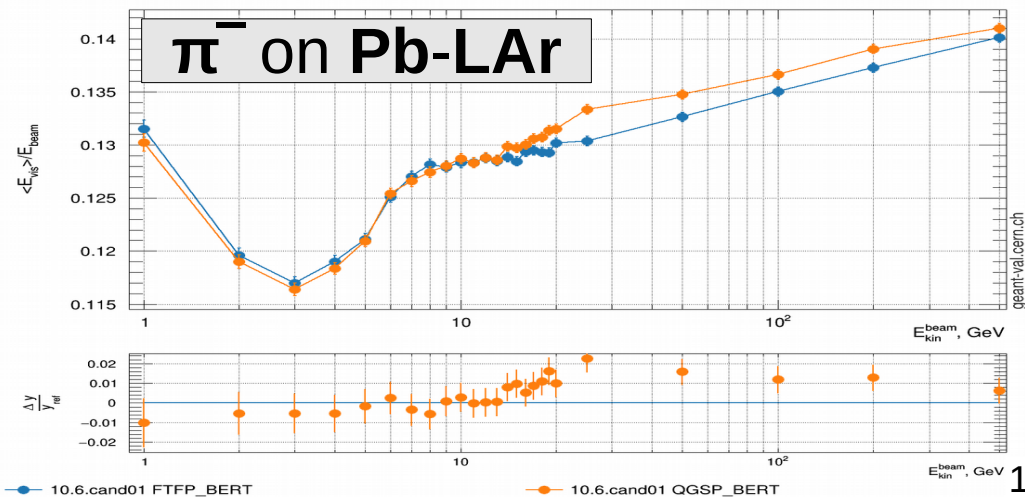
Energy response | Beam: pi- | Target: AtlasHEC | $\chi^2/n.d.f. = 2.27489$



Energy response | Beam: pi- | Target: AtlasFCAL | $\chi^2/n.d.f. = 3.3894$



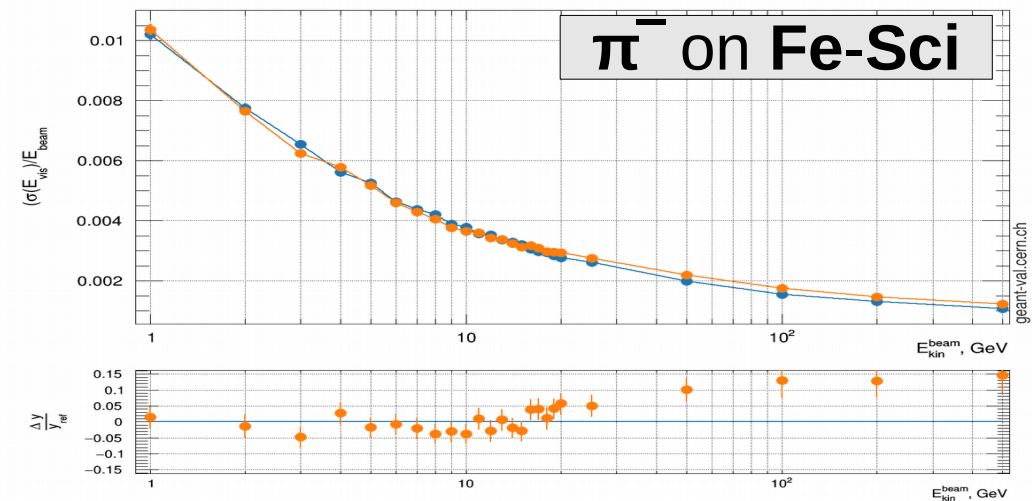
Energy response | Beam: pi- | Target: AtlasECAL | $\chi^2/n.d.f. = 2.28367$



Energy Width

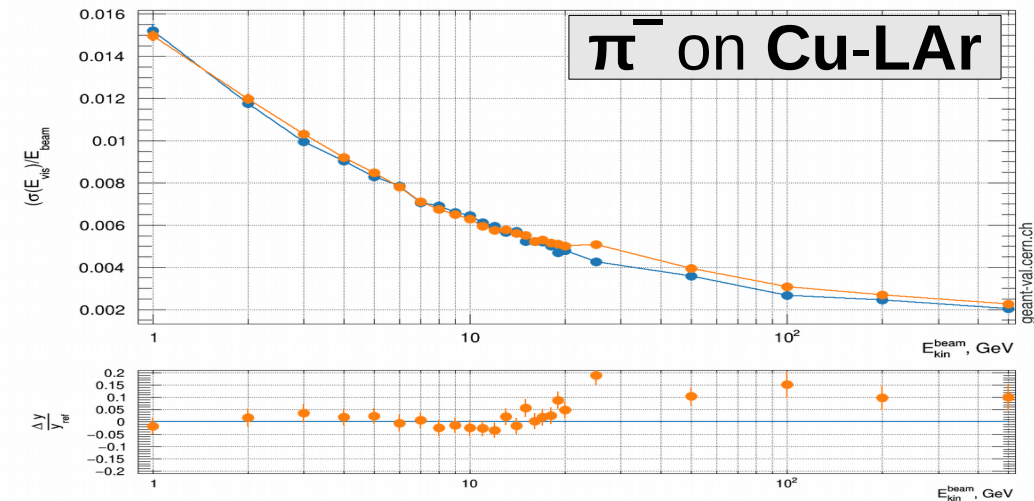
Normalized width | Beam: pi- | Target: TileCal | $\chi^2/n.d.f. = 4.01667$

π^- on Fe-Sci



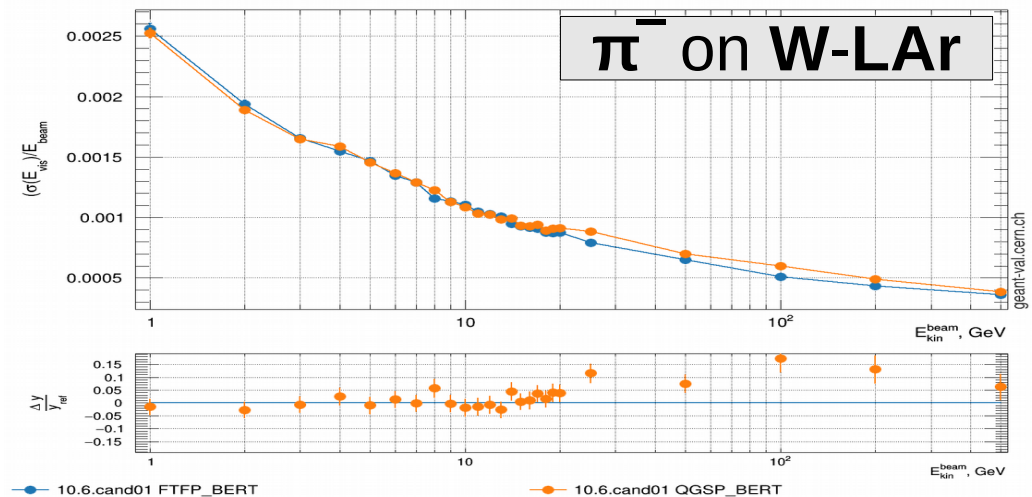
Normalized width | Beam: pi- | Target: AtlasHEC | $\chi^2/n.d.f. = 5.17613$

π^- on Cu-LAr



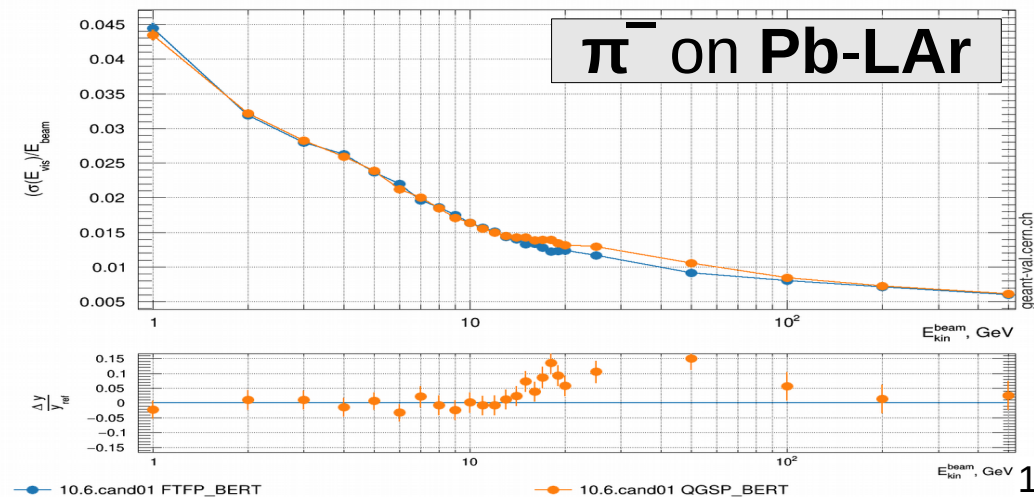
Normalized width | Beam: pi- | Target: AtlasFCAL | $\chi^2/n.d.f. = 3.2431$

π^- on W-LAr



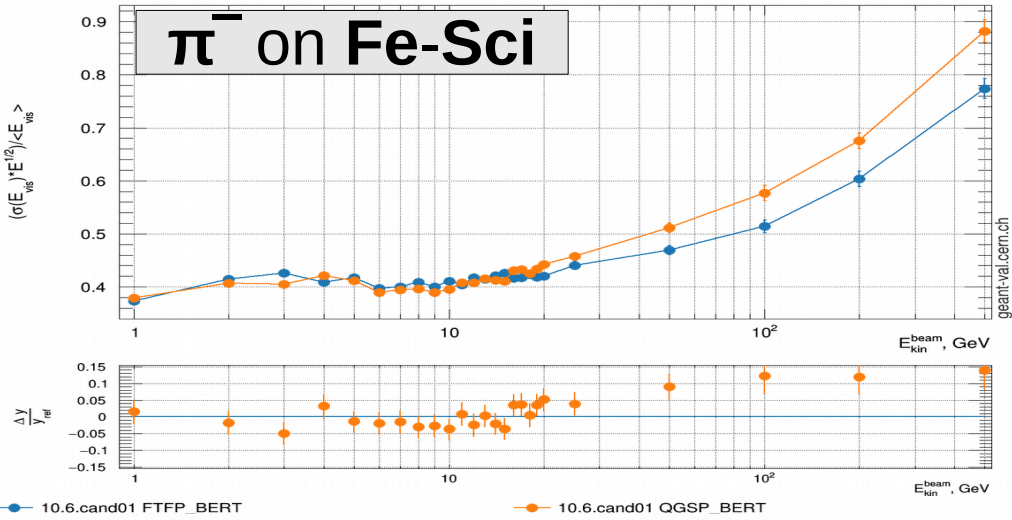
Normalized width | Beam: pi- | Target: AtlasECAL | $\chi^2/n.d.f. = 4.51083$

π^- on Pb-LAr

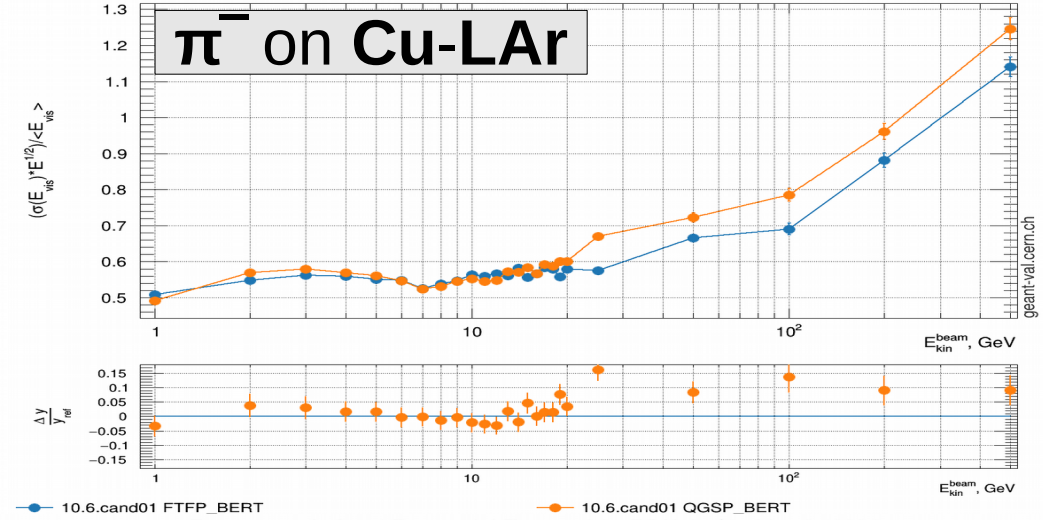


Energy Resolution

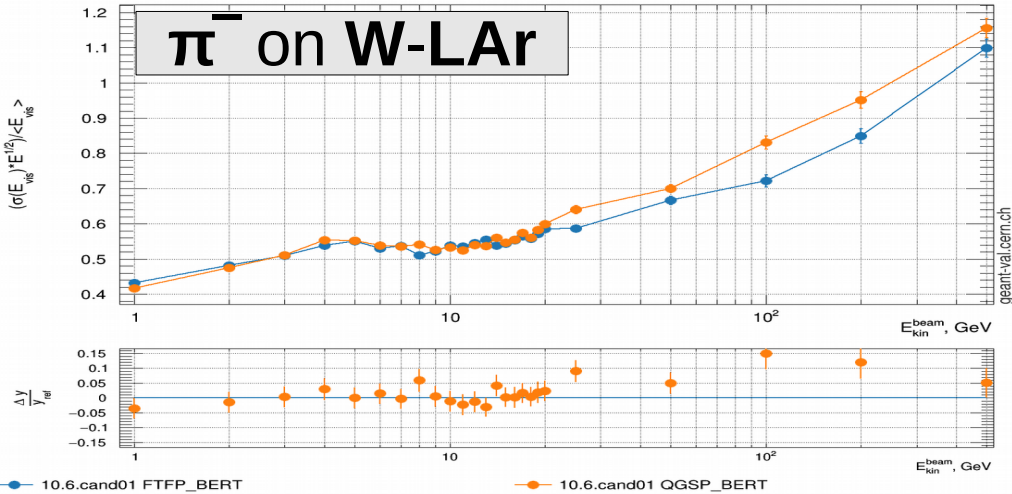
Energy resolution | Beam: pi- | Target: TileCal | $\chi^2/n.d.f. = 3.65869$



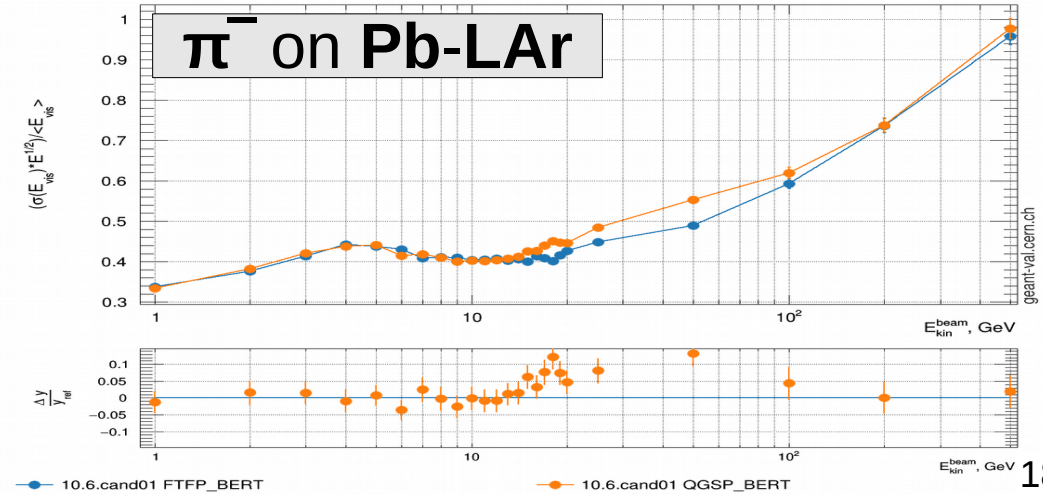
Energy resolution | Beam: pi- | Target: AtlasHEC | $\chi^2/n.d.f. = 3.99789$



Energy resolution | Beam: pi- | Target: AtlasFCAL | $\chi^2/n.d.f. = 2.53039$

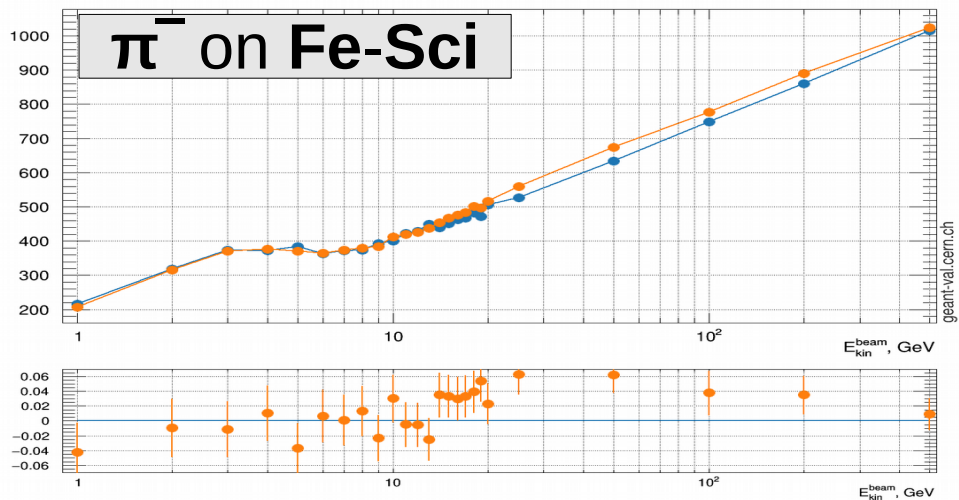


Energy resolution | Beam: pi- | Target: AtlasECAL | $\chi^2/n.d.f. = 3.10804$

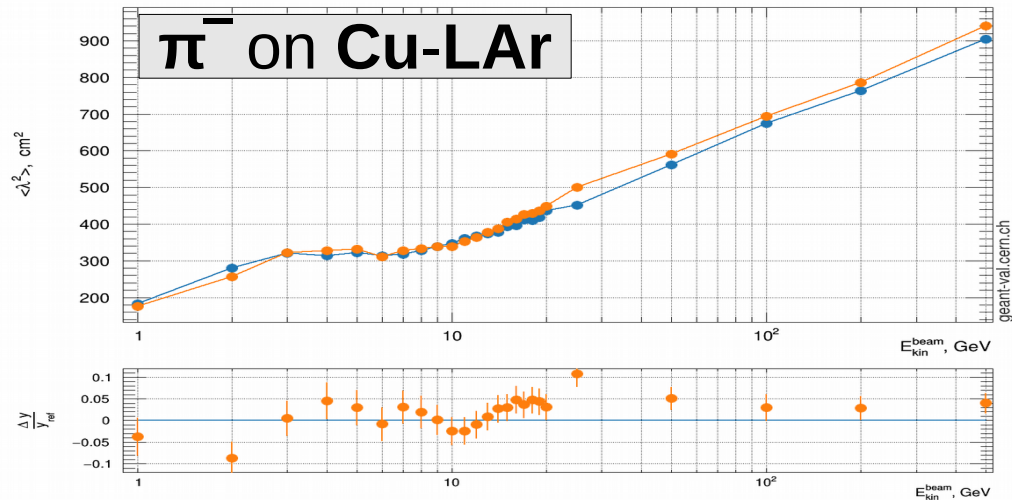


Longitudinal Shape

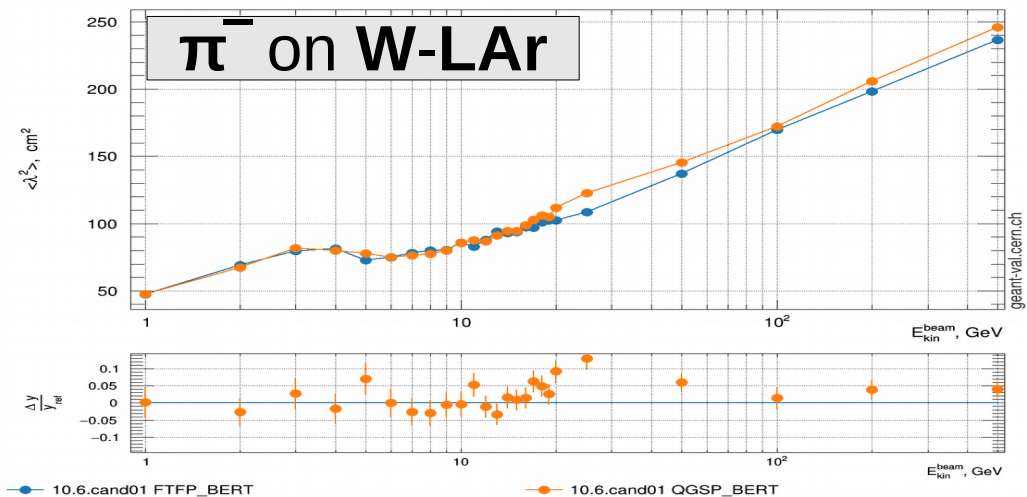
Longitudinal shower shape | Beam: pi- | Target: TileCal | $\chi^2/n.d.f. = 1.8361$



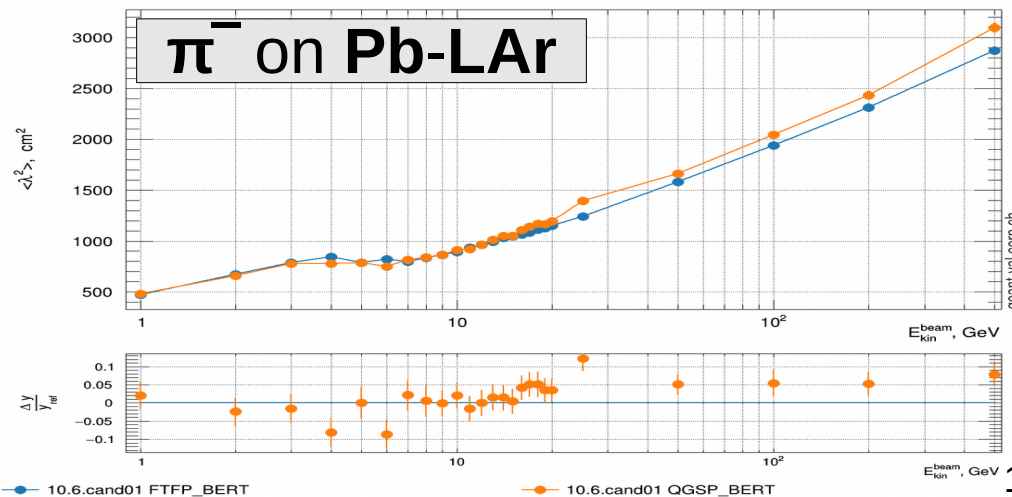
Longitudinal shower shape | Beam: pi- | Target: AtlasHEC | $\chi^2/n.d.f. = 2.43759$



Longitudinal shower shape | Beam: pi- | Target: AtlasFCAL | $\chi^2/n.d.f. = 3.05824$



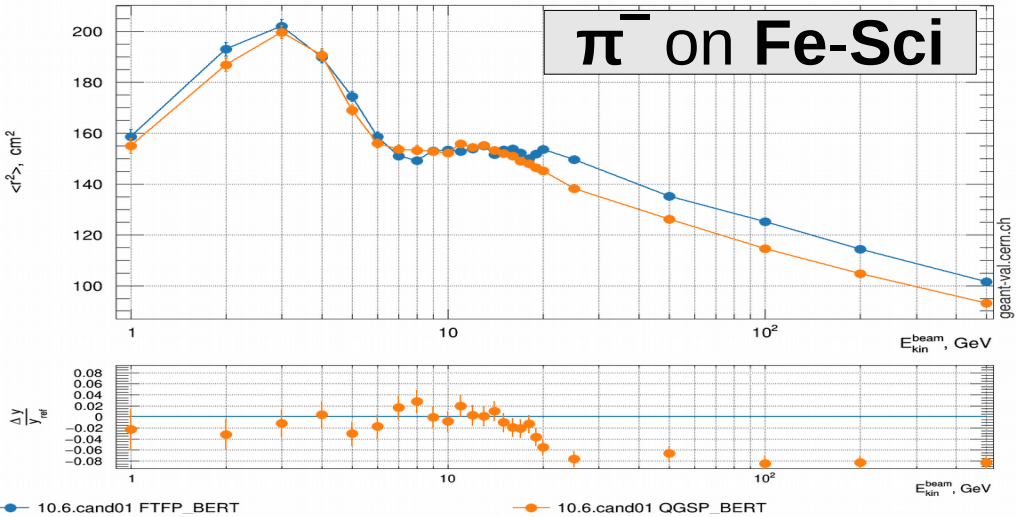
Longitudinal shower shape | Beam: pi- | Target: AtlasECAL | $\chi^2/n.d.f. = 2.98042$



Lateral Shape

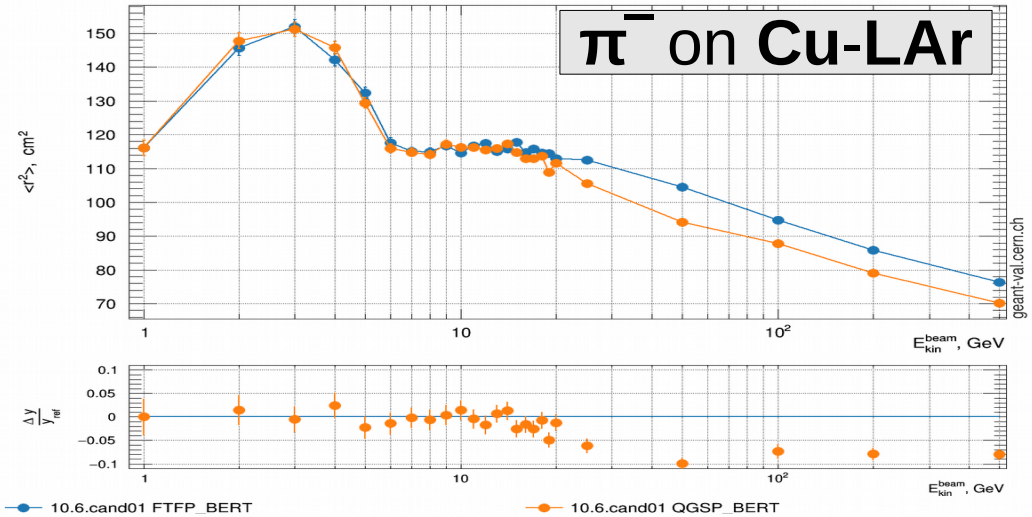
Lateral shower shape | Beam: pi- | Target: TileCal | $\chi^2/n.d.f. = 10.3471$

π^- on Fe-Sci



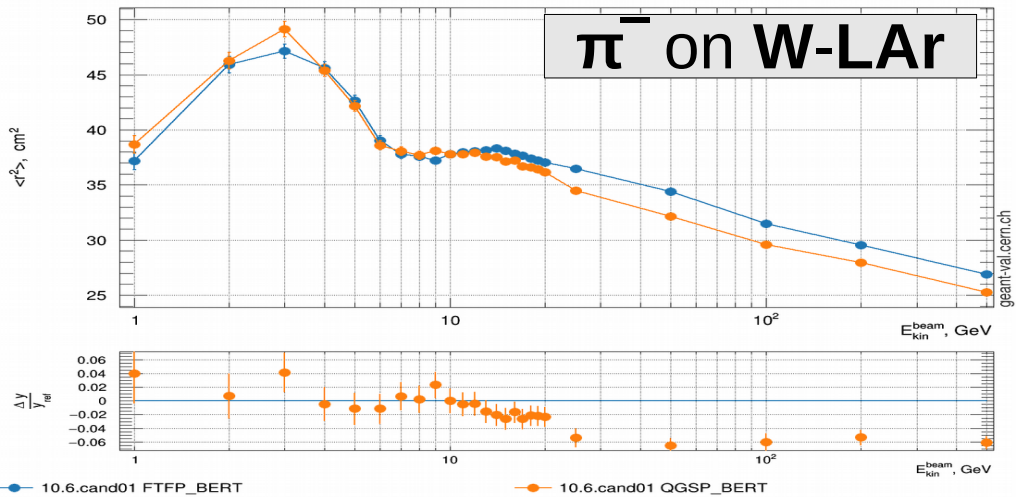
Lateral shower shape | Beam: pi- | Target: AtlasHEC | $\chi^2/n.d.f. = 10.5265$

π^- on Cu-LAr



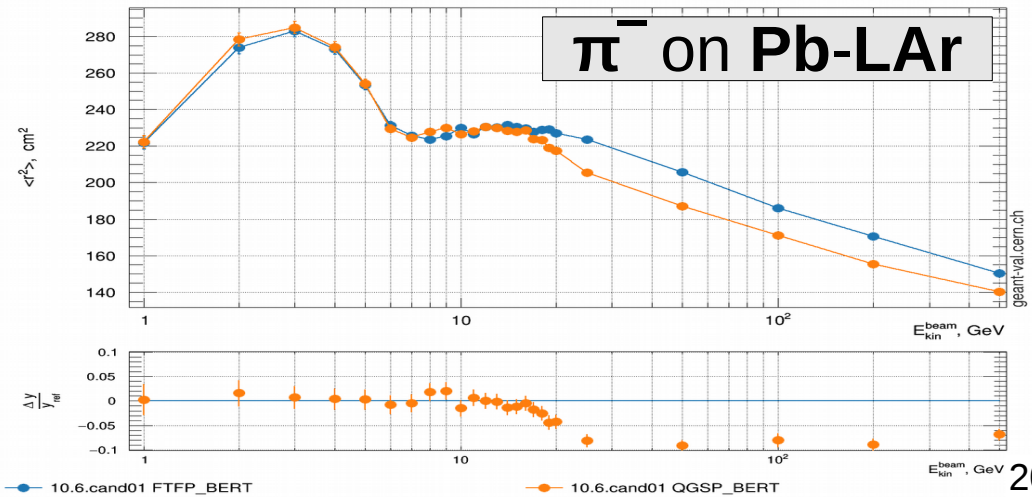
Lateral shower shape | Beam: pi- | Target: AtlasFCAL | $\chi^2/n.d.f. = 8.23811$

π^- on W-LAr



Lateral shower shape | Beam: pi- | Target: AtlasECAL | $\chi^2/n.d.f. = 13.2297$

π^- on Pb-LAr



Kaon0L showers: FTFP_BERT

G4 10.6

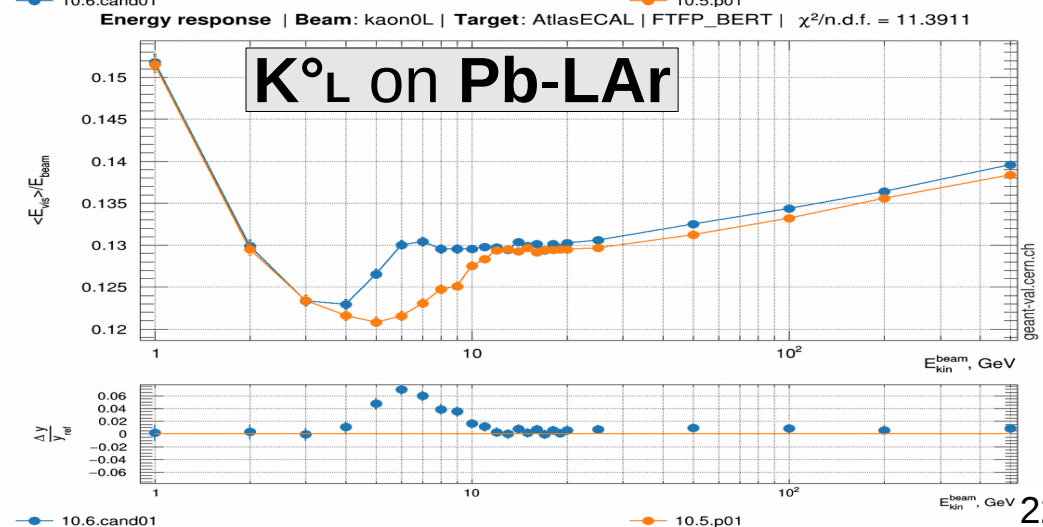
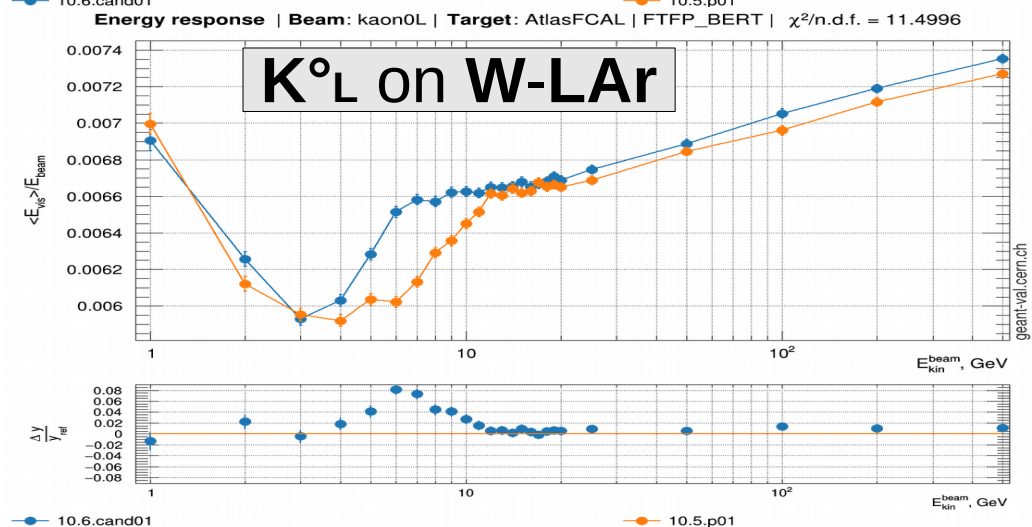
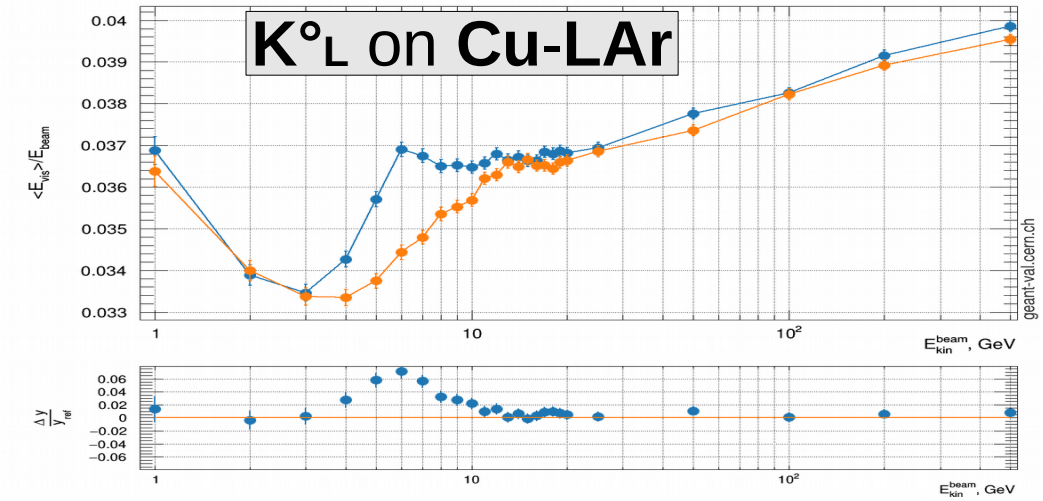
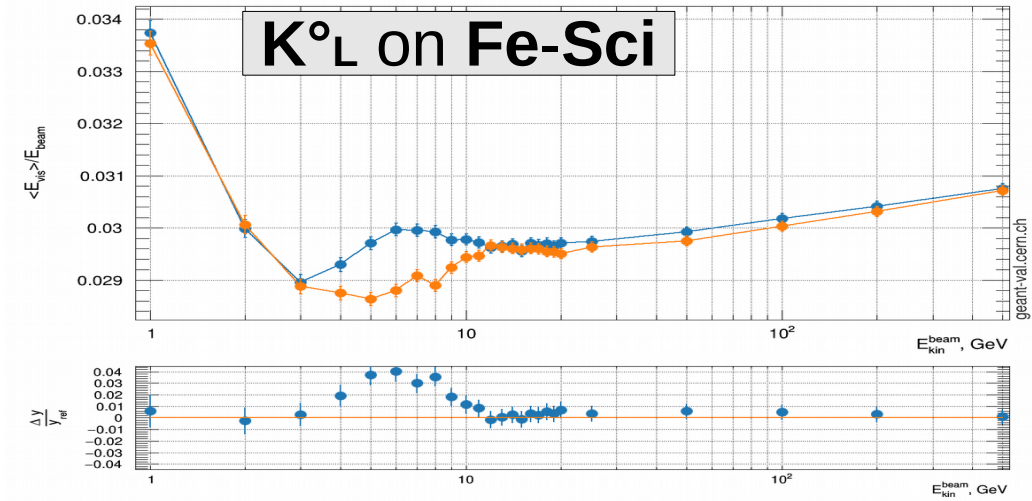
G4 10.5.p01

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

FTFP_BERT : Energy Response

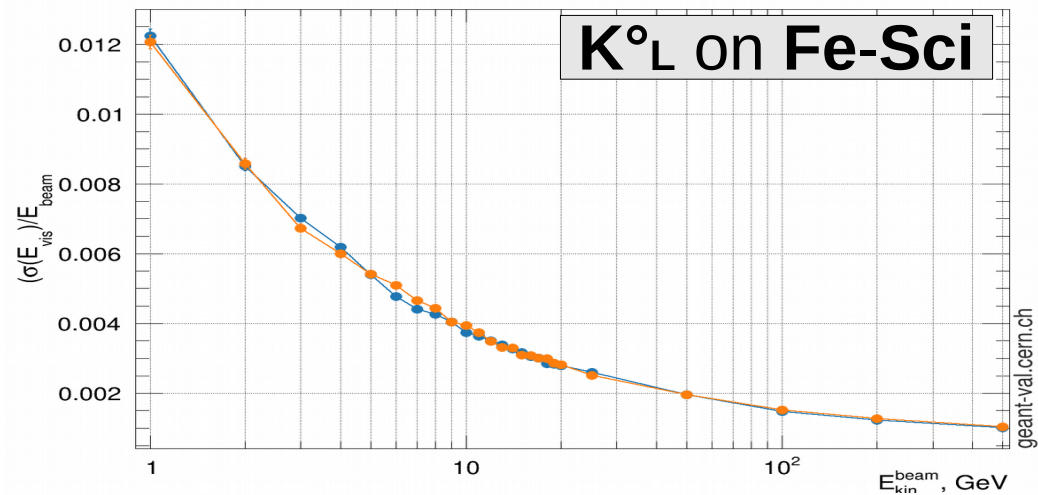
Energy response | Beam: kaon0L | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 4.95713$

Energy response | Beam: kaon0L | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 8.53353$

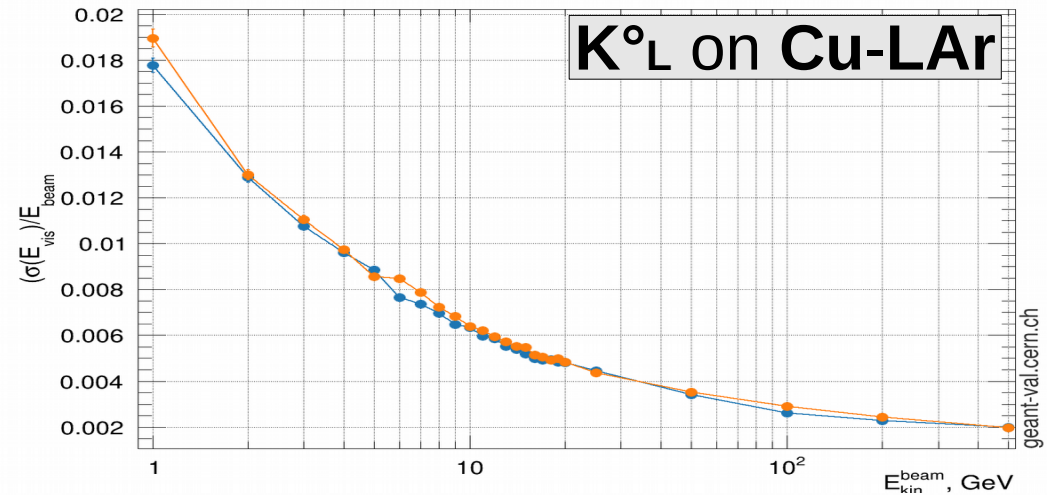


FTFP_BERT : Energy Width

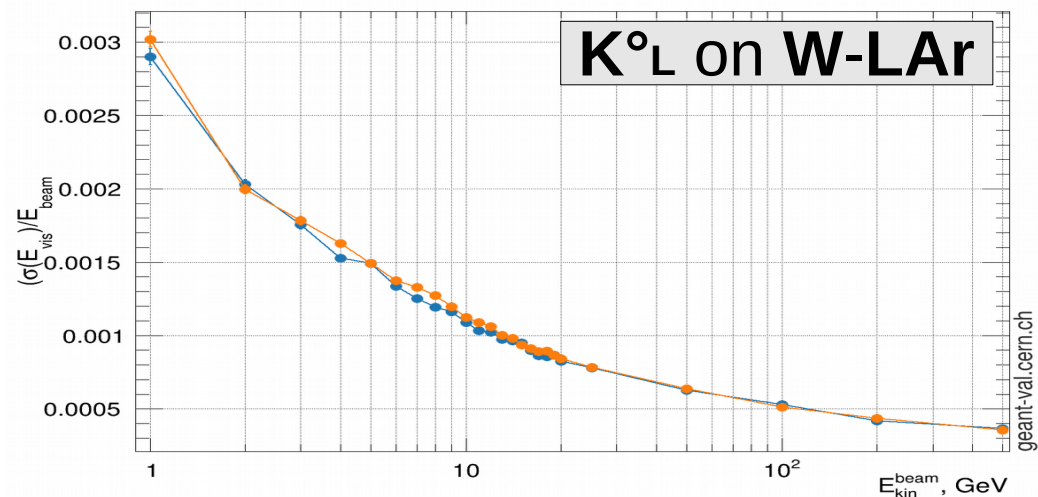
Normalized width | Beam: kaon0L | Target: TileCal | FTFP_BERT



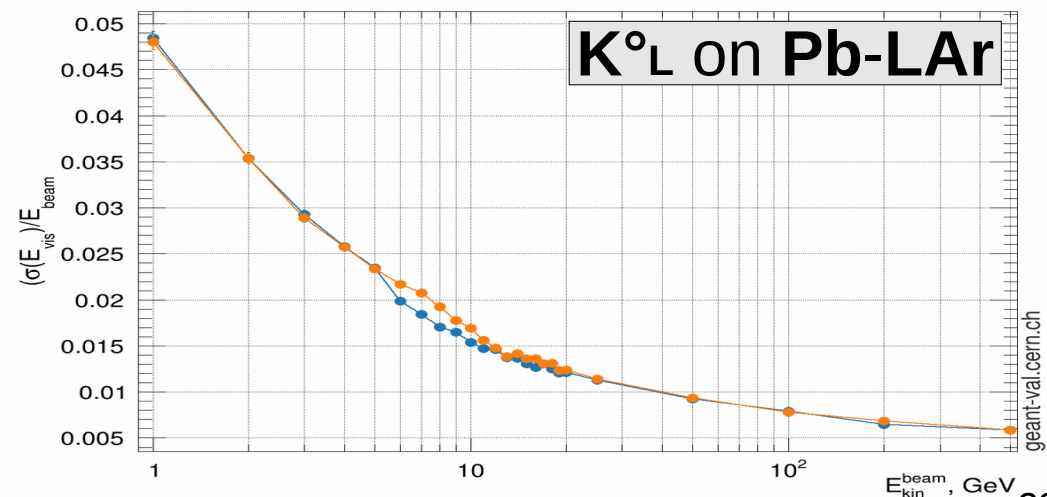
Normalized width | Beam: kaon0L | Target: AtlasHEC | FTFP_BERT



Normalized width | Beam: kaon0L | Target: AtlasFCAL | FTFP_BERT

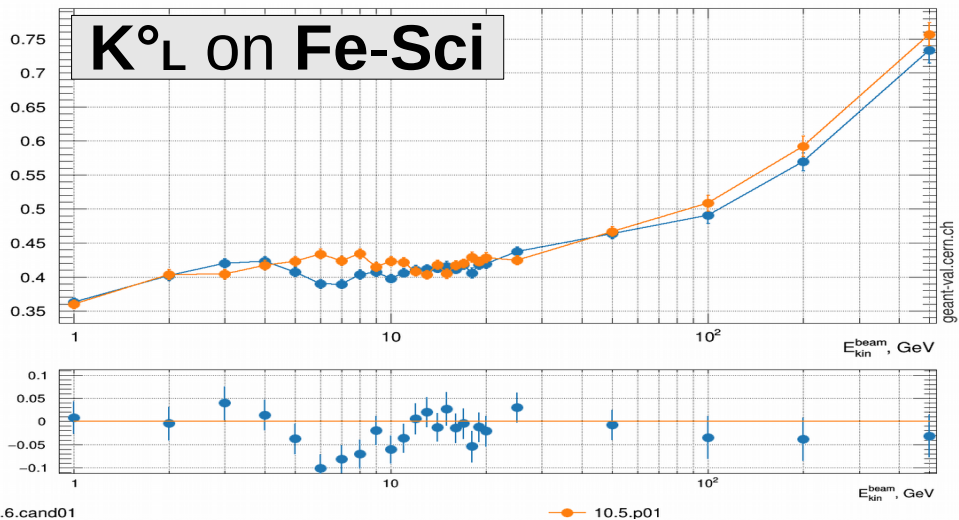


Normalized width | Beam: kaon0L | Target: AtlasECAL | FTFP_BERT

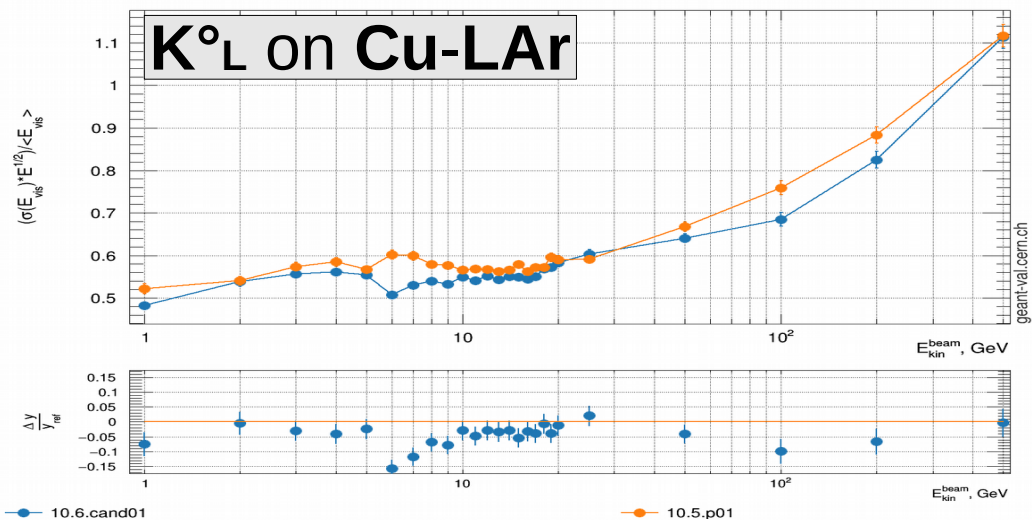


FTFP_BERT : Energy Resolution

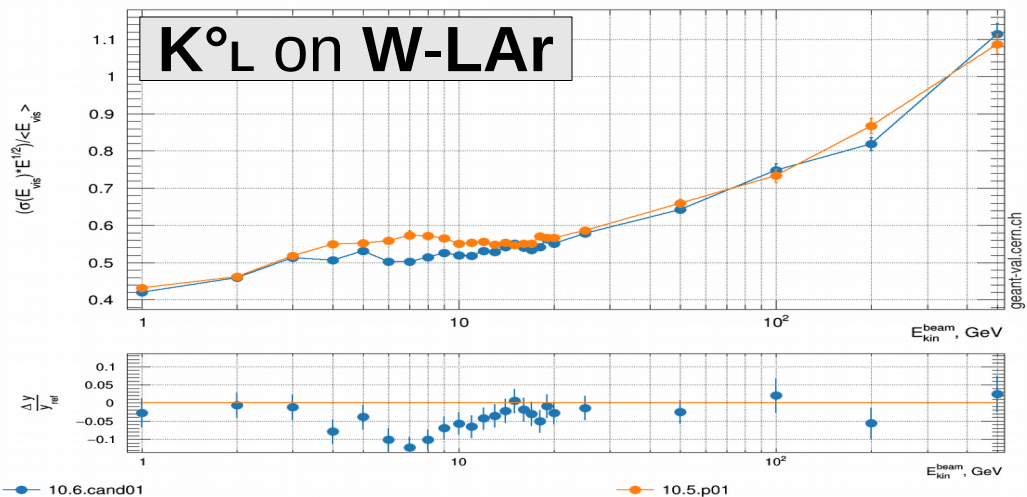
Energy resolution | Beam: kaon0L | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 2.4342$



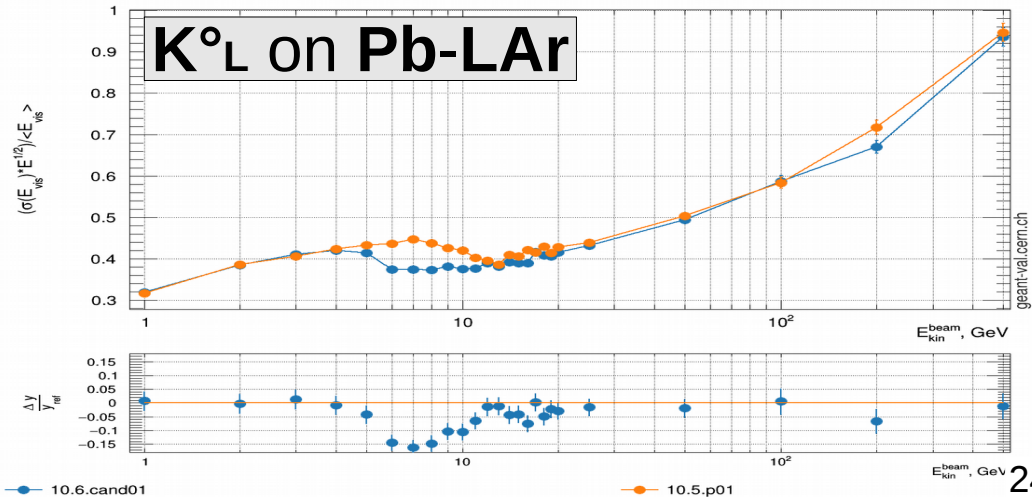
Energy resolution | Beam: kaon0L | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 2.74567$



Energy resolution | Beam: kaon0L | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 2.4146$

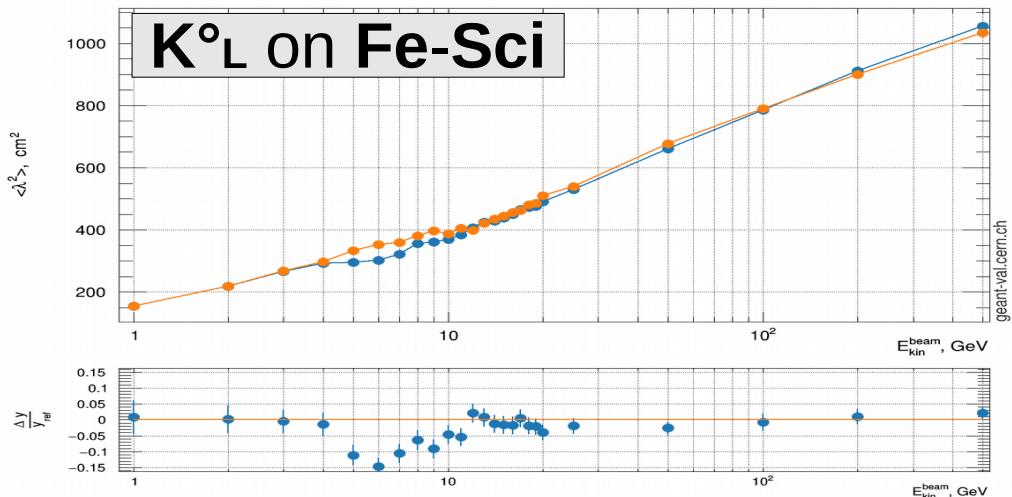


Energy resolution | Beam: kaon0L | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 5.23966$

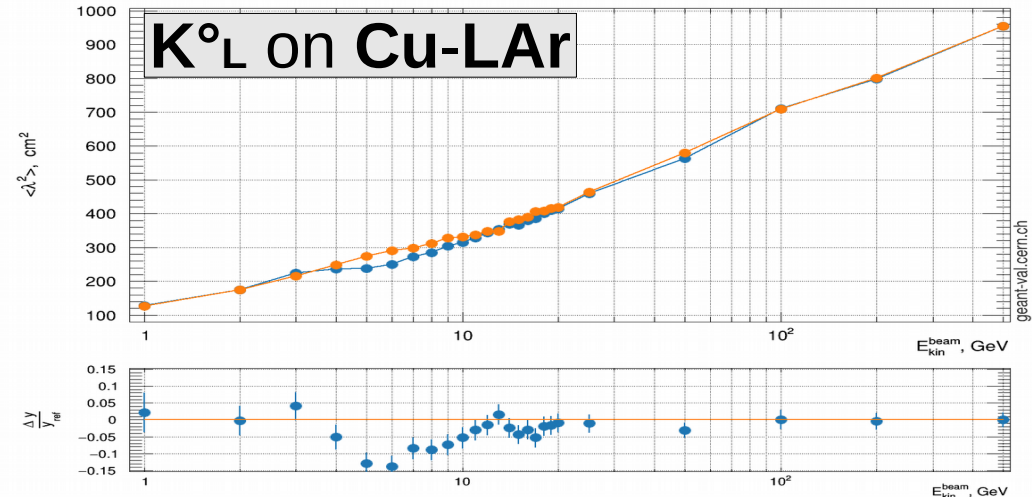


FTFP_BERT : Longitudinal Shape

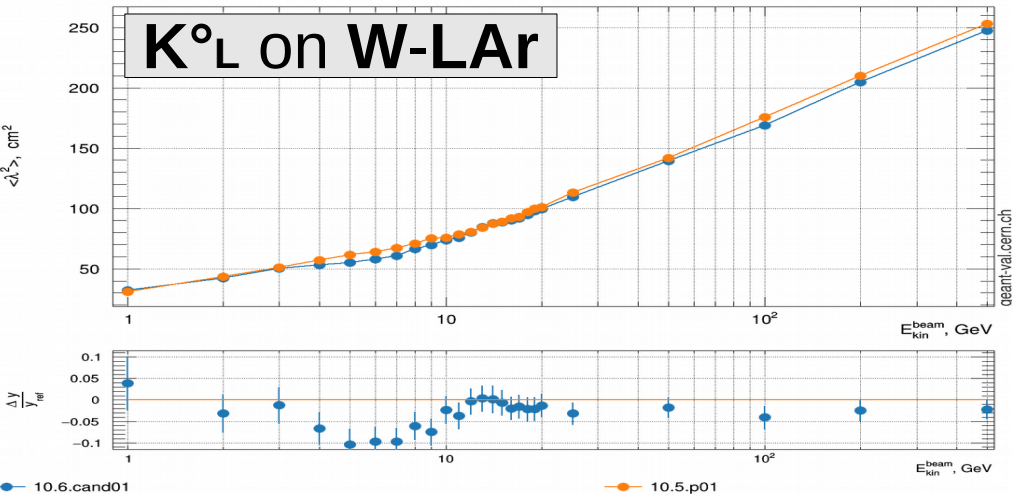
Longitudinal shower shape | Beam: kaon0L | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 4.548$



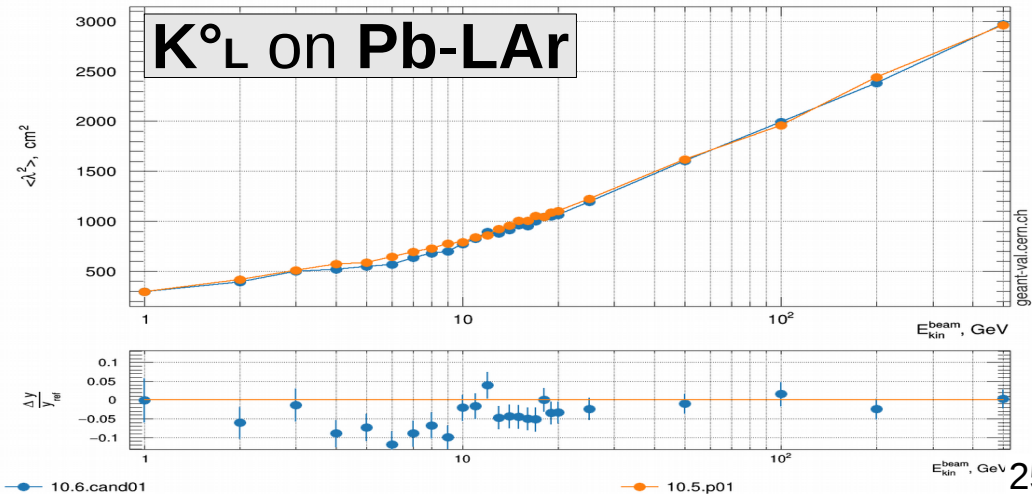
Longitudinal shower shape | Beam: kaon0L | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 3.50344$



Longitudinal shower shape | Beam: kaon0L | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 1.8719$

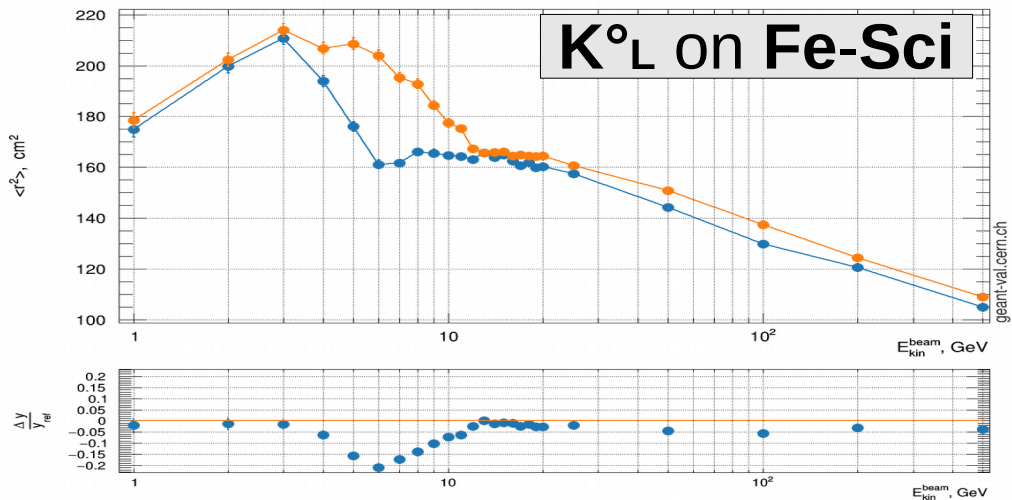


Longitudinal shower shape | Beam: kaon0L | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 2.56369$

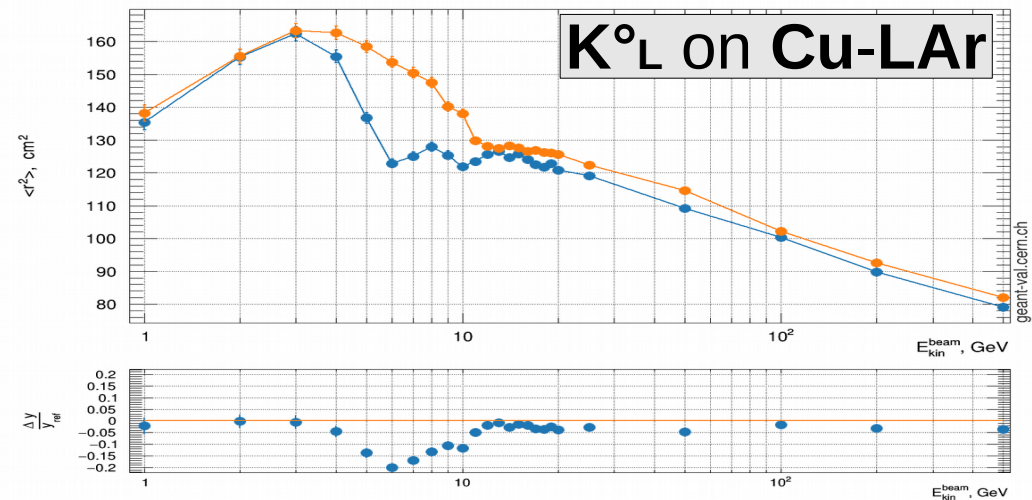


FTFP_BERT : Lateral Shape

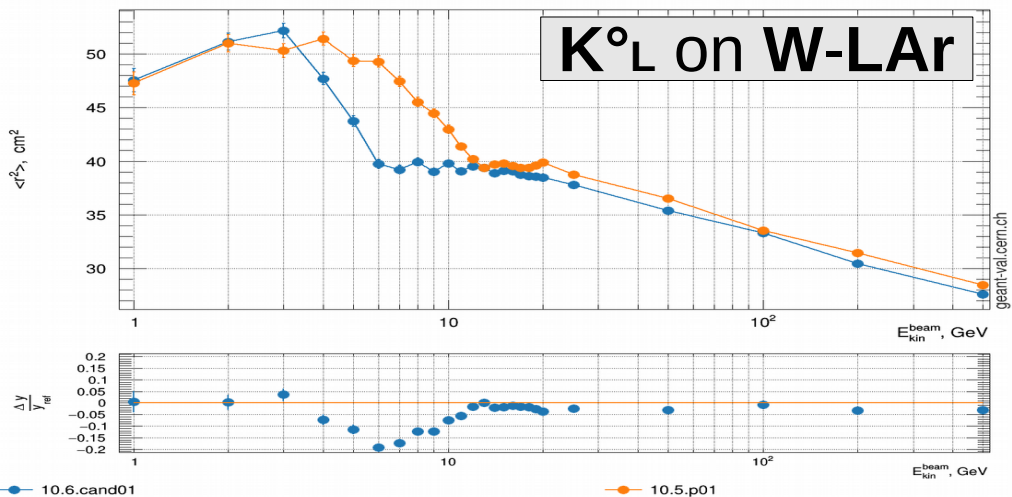
Lateral shower shape | Beam: kaon0L | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 22.0188$



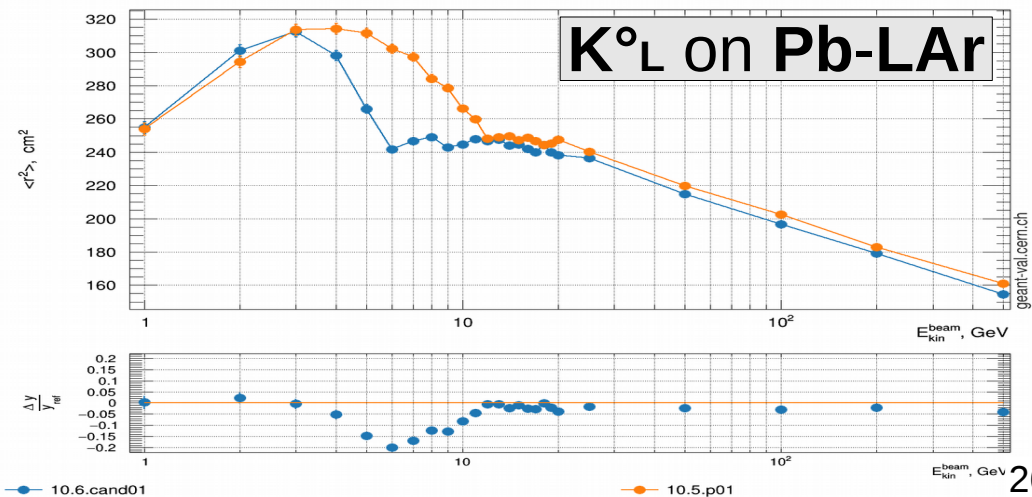
Lateral shower shape | Beam: kaon0L | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 17.5368$



Lateral shower shape | Beam: kaon0L | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 20.5652$



Lateral shower shape | Beam: kaon0L | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 27.4736$



Proton showers: FTFP_BERT

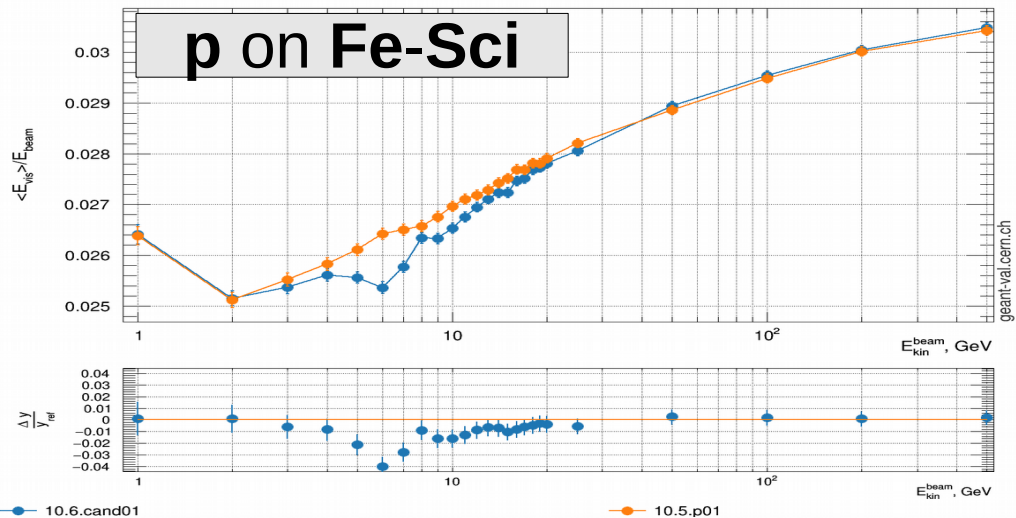
G4 10.6

G4 10.5.p01

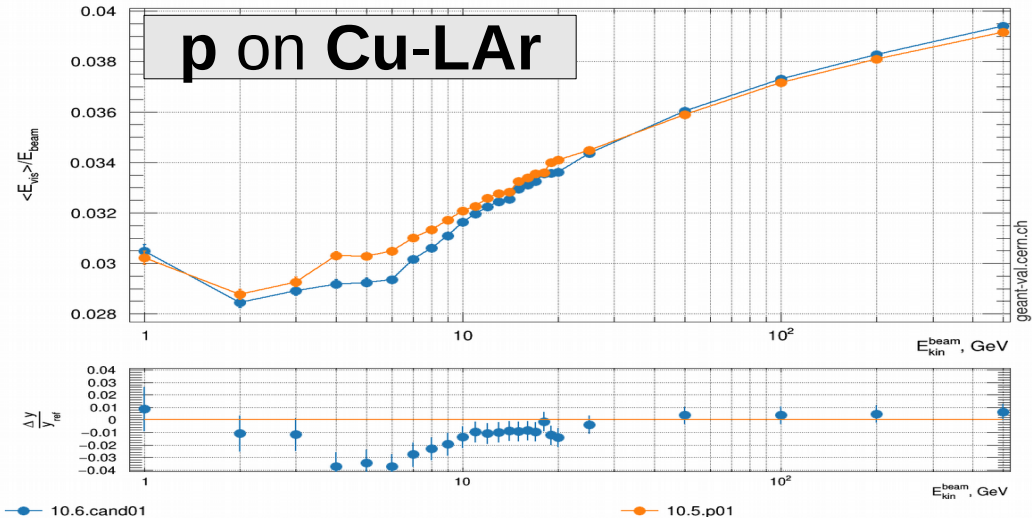
*Note : conventional Birks treatment
(easier and no experimental h/e to fit !)*

FTFP_BERT : Energy Response

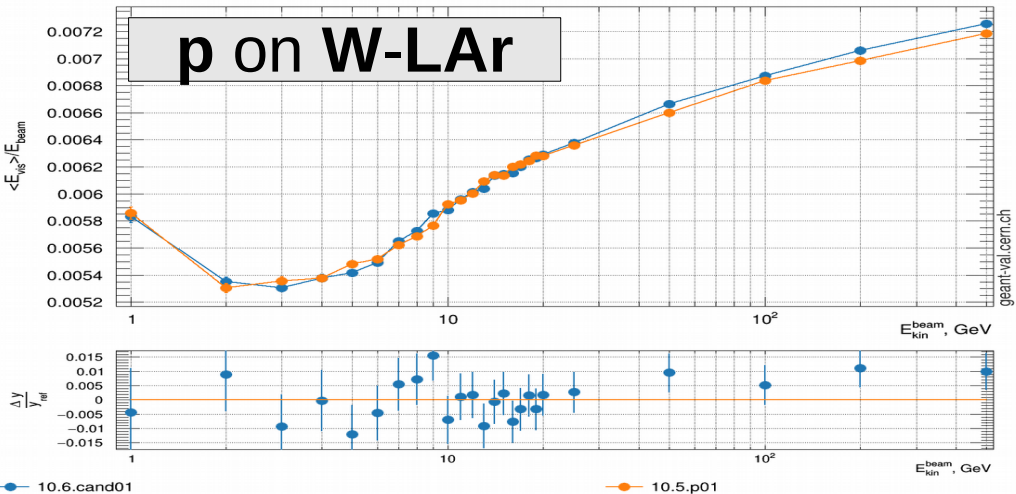
Energy response | Beam: proton | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 3.10499$



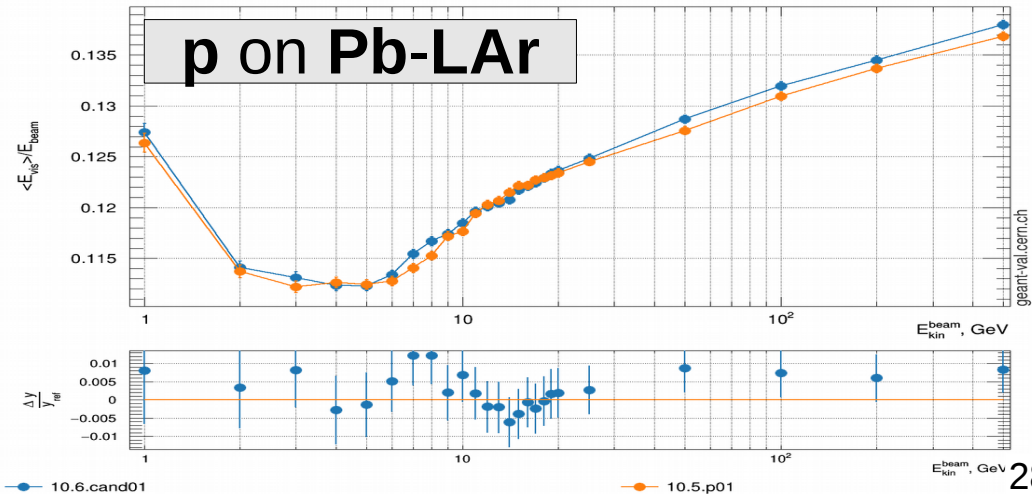
Energy response | Beam: proton | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 4.15127$



Energy response | Beam: proton | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 1.49027$

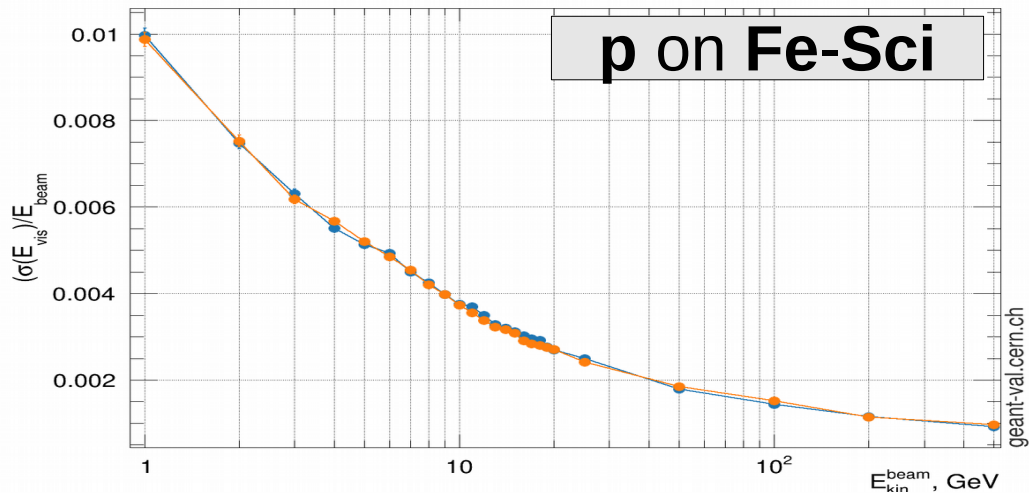


Energy response | Beam: proton | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 0.936064$

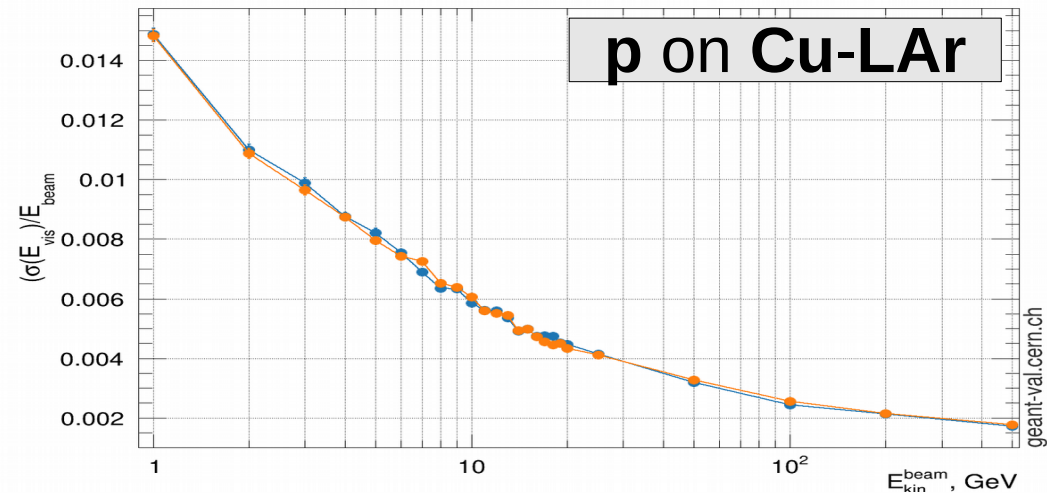


FTFP_BERT : Energy Width

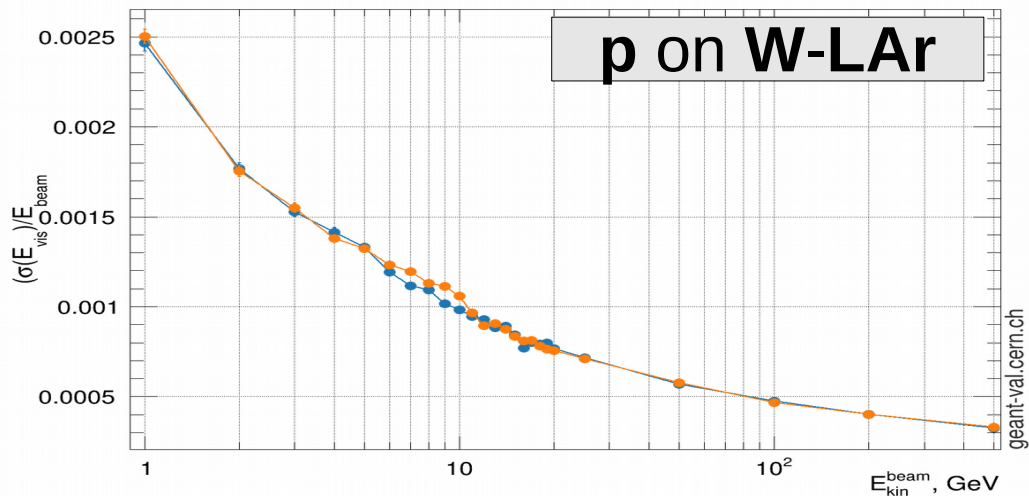
Normalized width | Beam: proton | Target: TileCal | FTFP_BERT



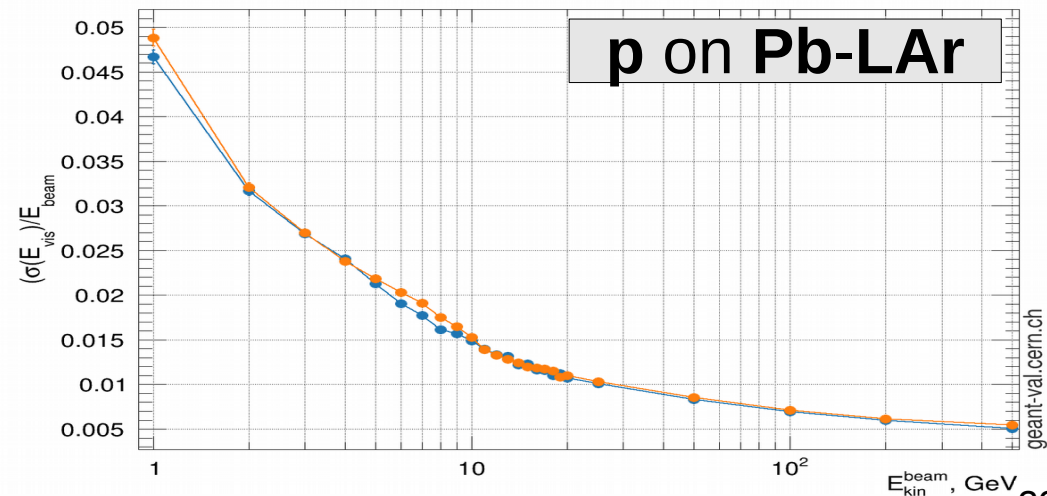
Normalized width | Beam: proton | Target: AtlasHEC | FTFP_BERT



Normalized width | Beam: proton | Target: AtlasFCAL | FTFP_BERT



Normalized width | Beam: proton | Target: AtlasECAL | FTFP_BERT



10.6.cand01

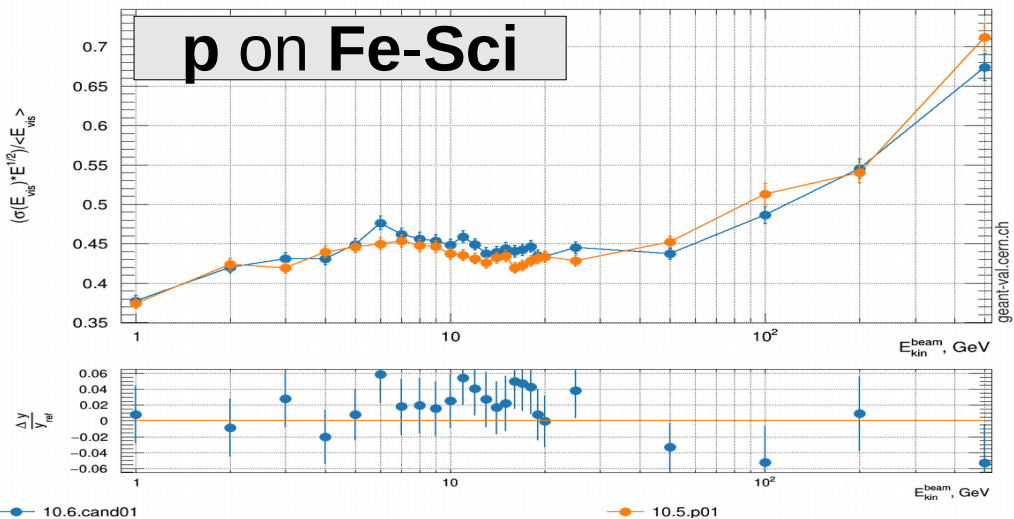
10.5.p01

10.6.cand01

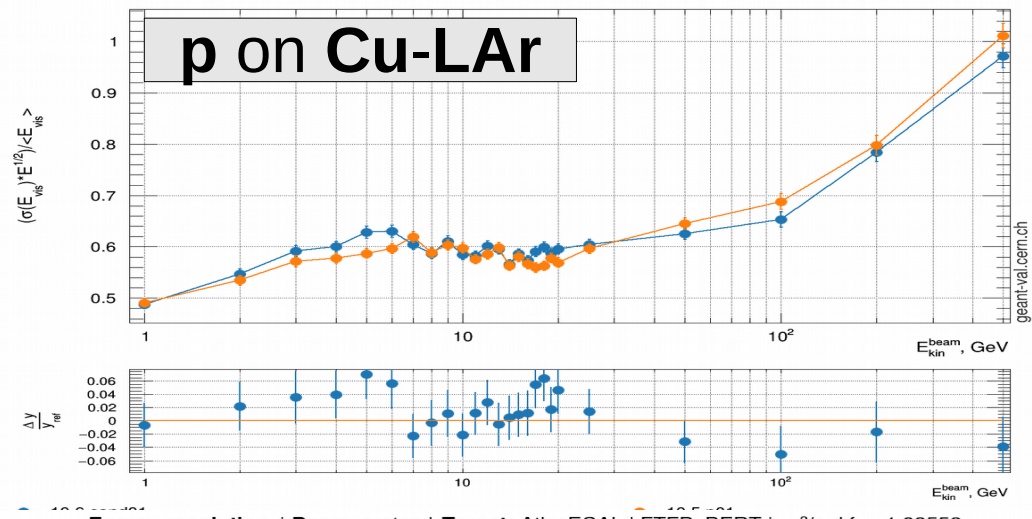
10.5.p01

FTFP_BERT : Energy Resolution

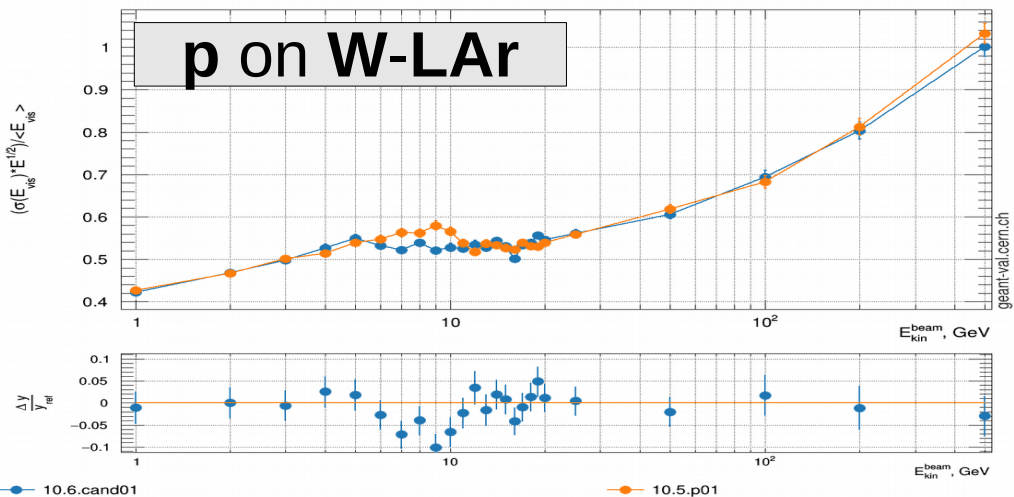
Energy resolution | Beam: proton | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 1.30845$



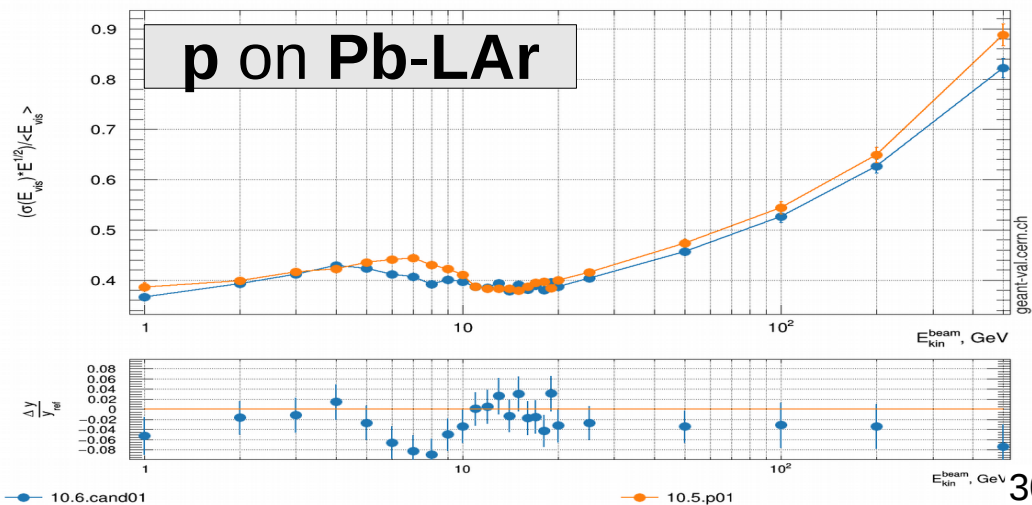
Energy resolution | Beam: proton | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 1.56676$



Energy resolution | Beam: proton | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 2.1244$

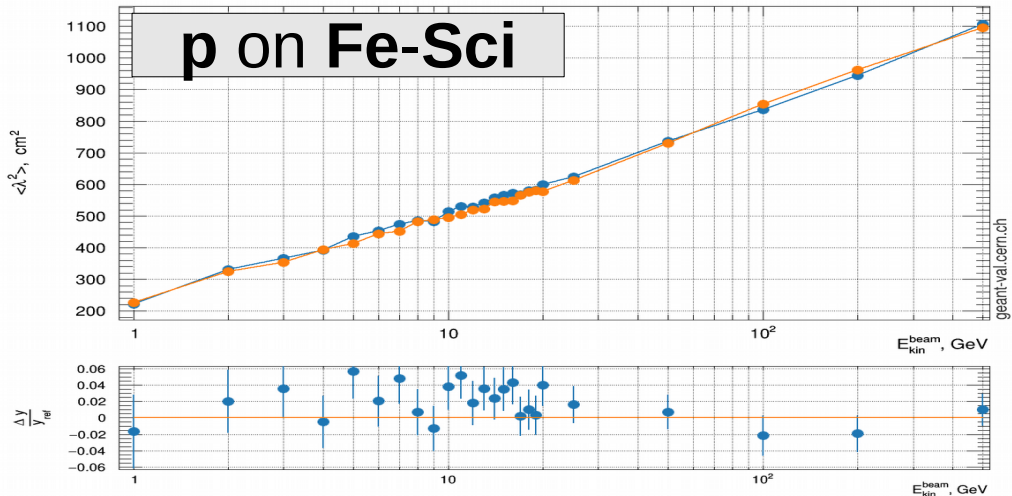


Energy resolution | Beam: proton | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 1.93552$

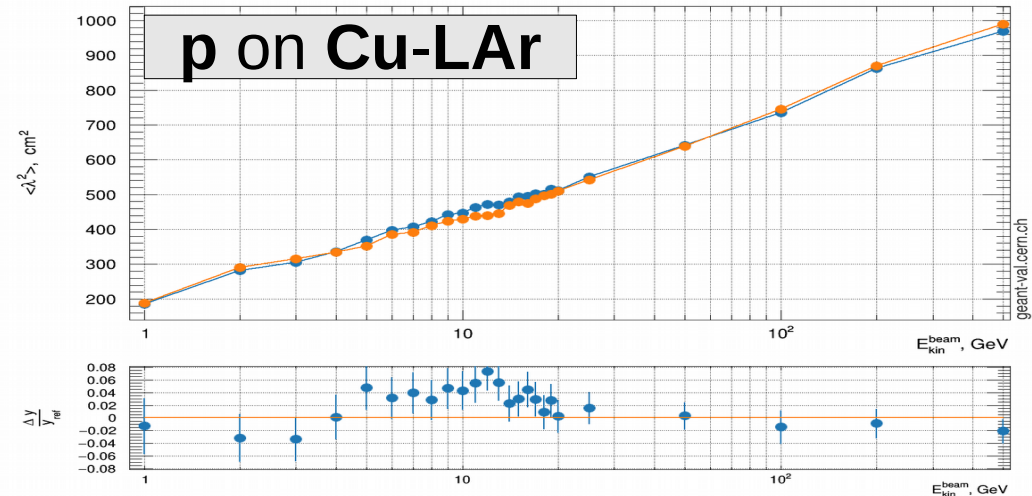


FTFP_BERT : Longitudinal Shape

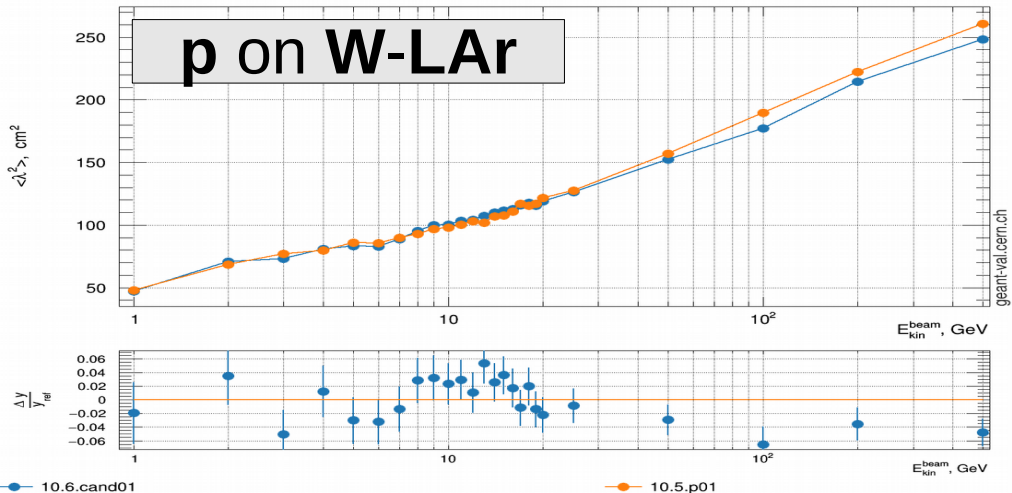
Longitudinal shower shape | Beam: proton | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 1.38953$



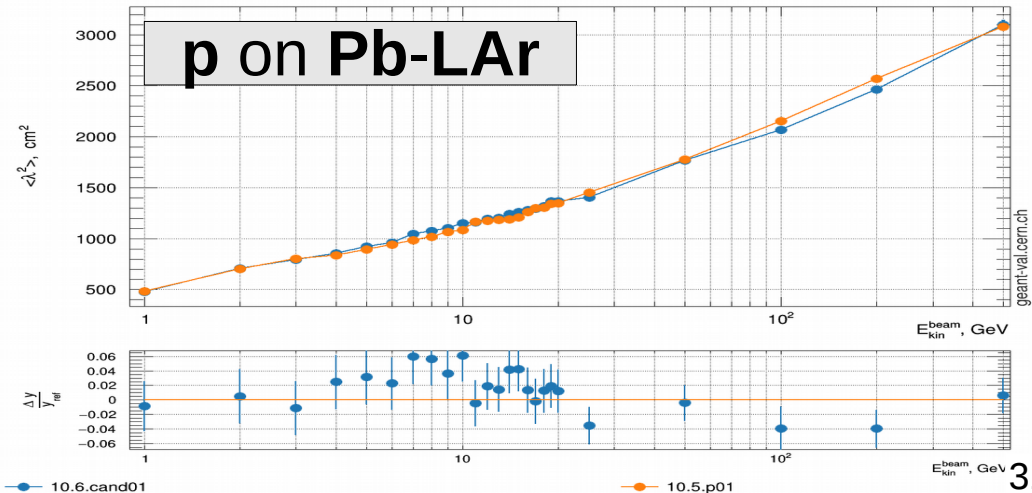
Longitudinal shower shape | Beam: proton | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 1.98357$



Longitudinal shower shape | Beam: proton | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 2.62181$

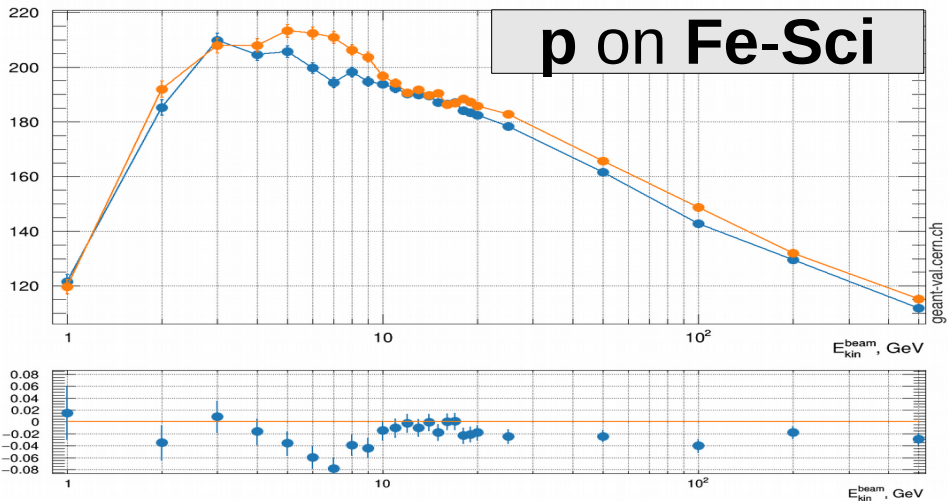


Longitudinal shower shape | Beam: proton | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 1.65668$

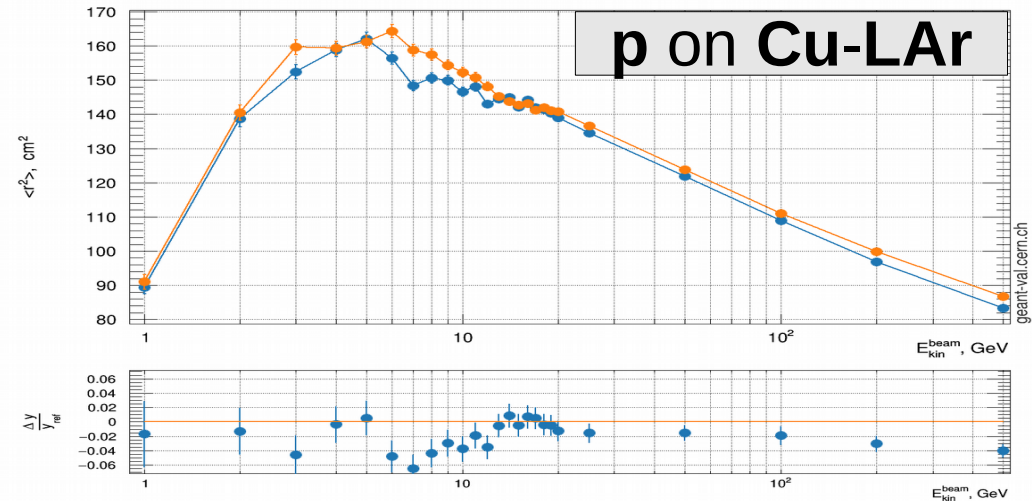


FTFP_BERT : Lateral Shape

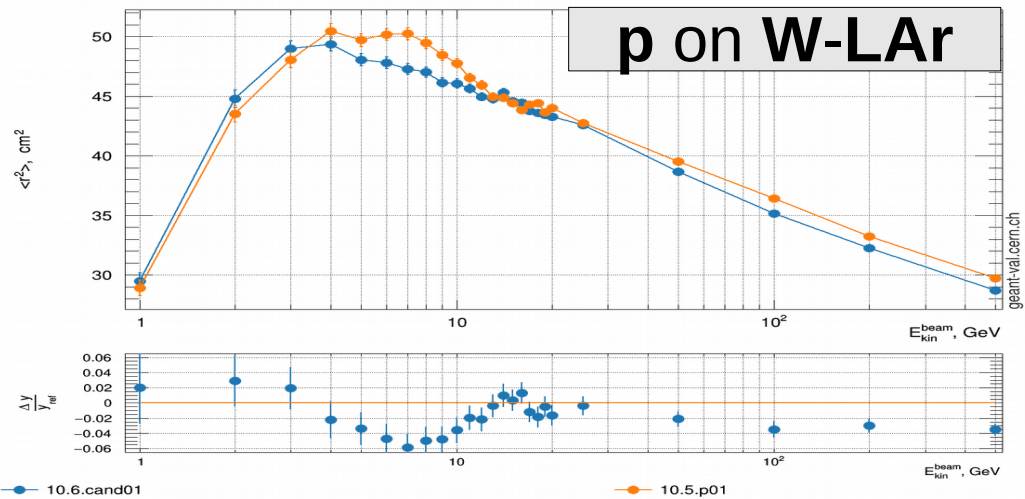
Lateral shower shape | Beam: proton | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 2.74129$



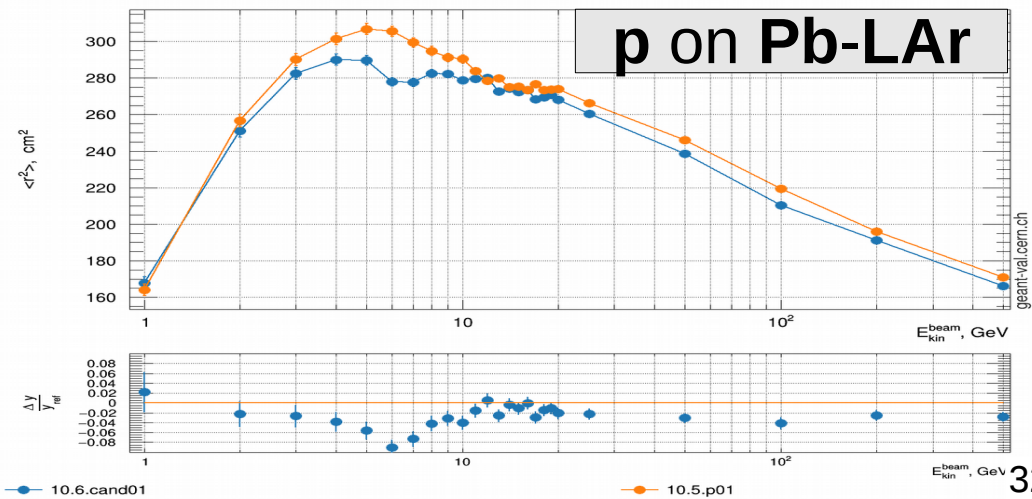
Lateral shower shape | Beam: proton | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 2.69971$



Lateral shower shape | Beam: proton | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 3.64423$



Lateral shower shape | Beam: proton | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 4.27329$



Antiproton showers: FTFP_BERT

G4 10.6

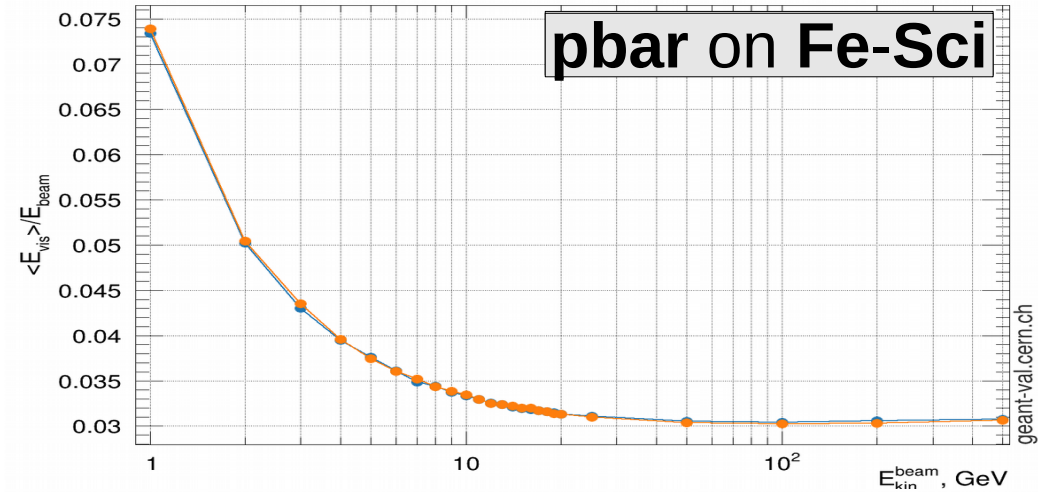
G4 10.5.p01

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

FTFP_BERT : Energy Response

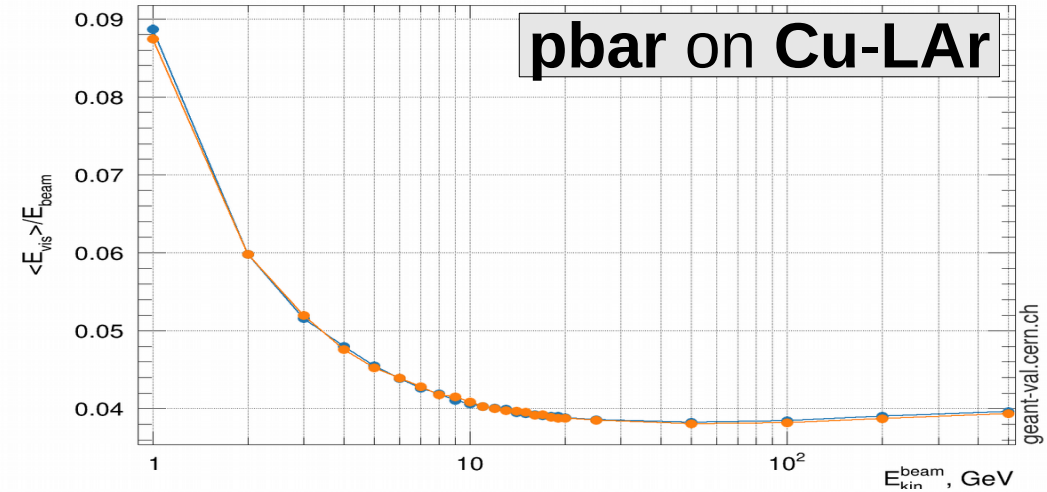
Energy response | Beam: anti_proton | Target: TileCal | FTFP_BERT

pbar on Fe-Sci



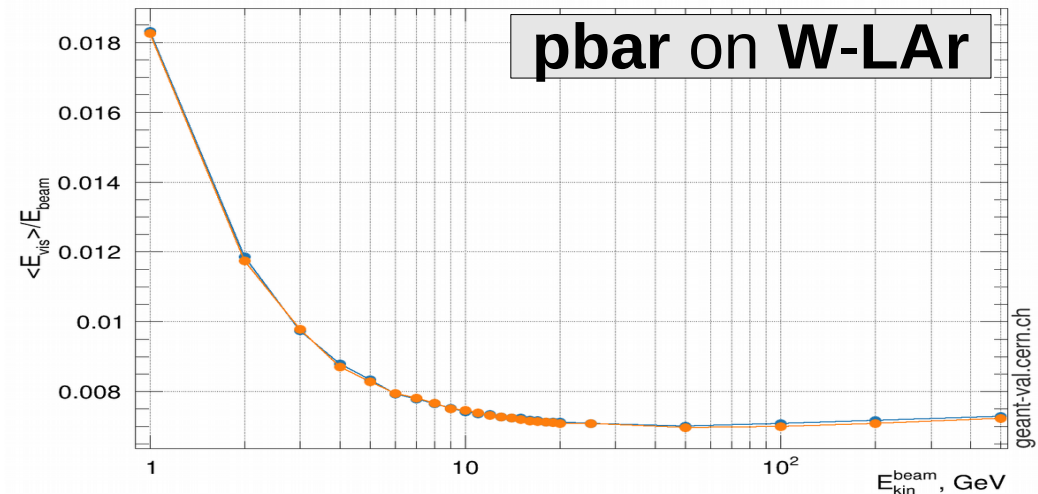
Energy response | Beam: anti_proton | Target: AtlasHEC | FTFP_BERT

pbar on Cu-LAr



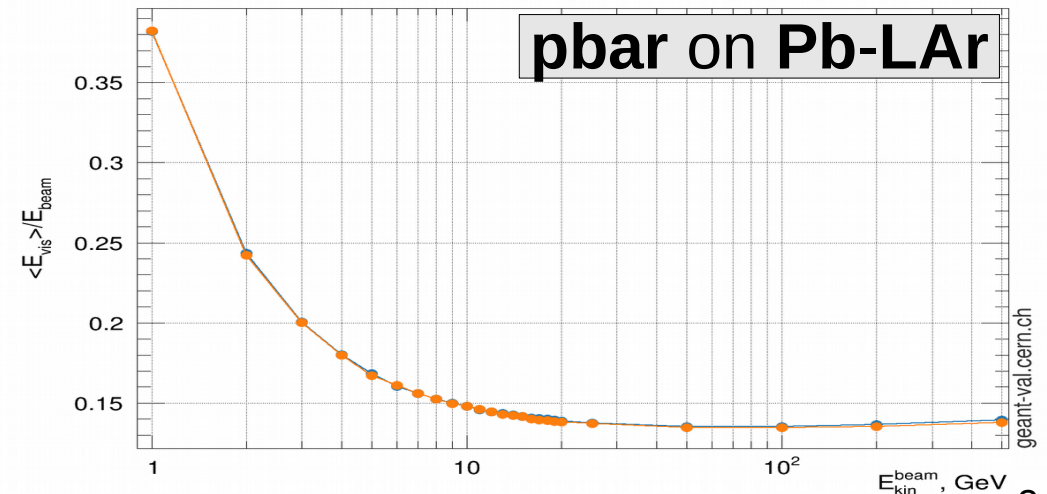
Energy response | Beam: anti_proton | Target: AtlasFCAL | FTFP_BERT

pbar on W-LAr



Energy response | Beam: anti_proton | Target: AtlasECAL | FTFP_BERT

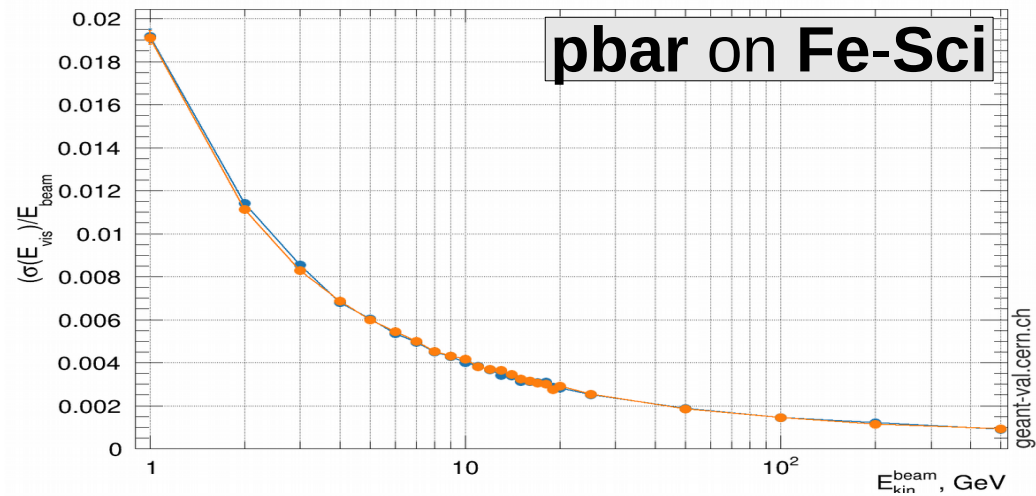
pbar on Pb-LAr



FTFP_BERT : Energy Width

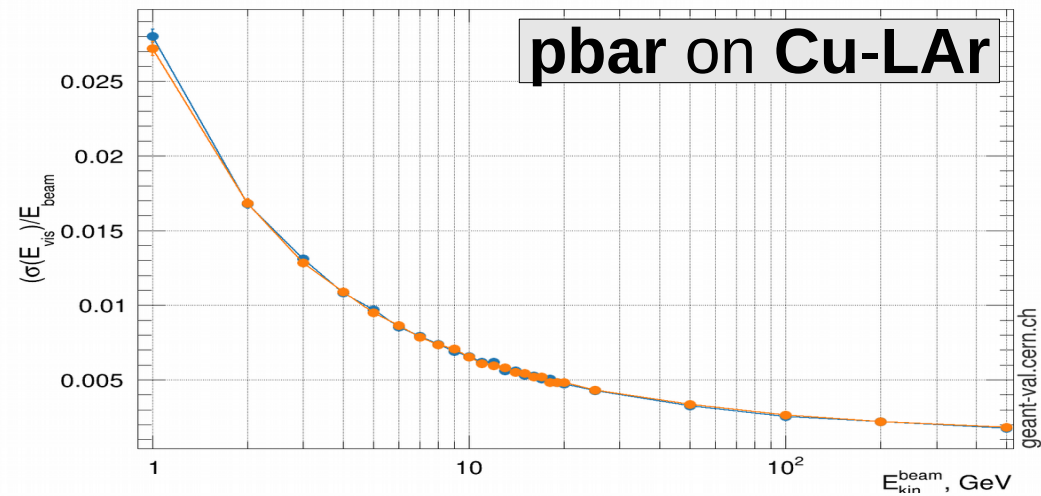
Normalized width | Beam: anti_proton | Target: TileCal | FTFP_BERT

pbar on Fe-Sci



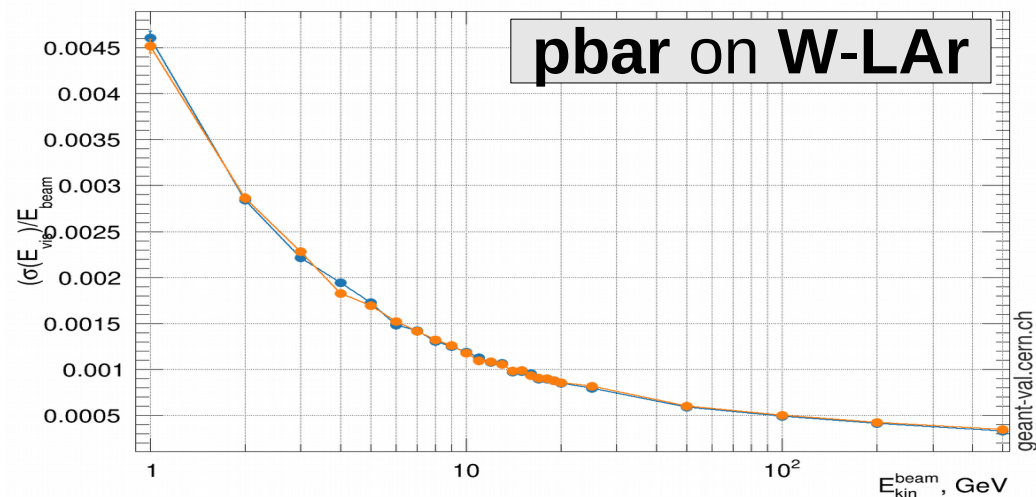
Normalized width | Beam: anti_proton | Target: AtlasHEC | FTFP_BERT

pbar on Cu-LAr



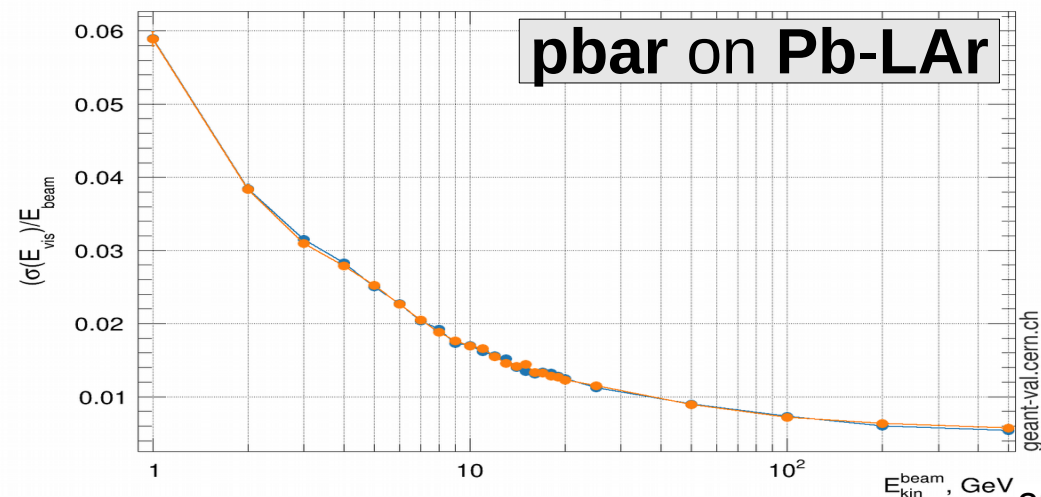
Normalized width | Beam: anti_proton | Target: AtlasFCAL | FTFP_BERT

pbar on W-LAr



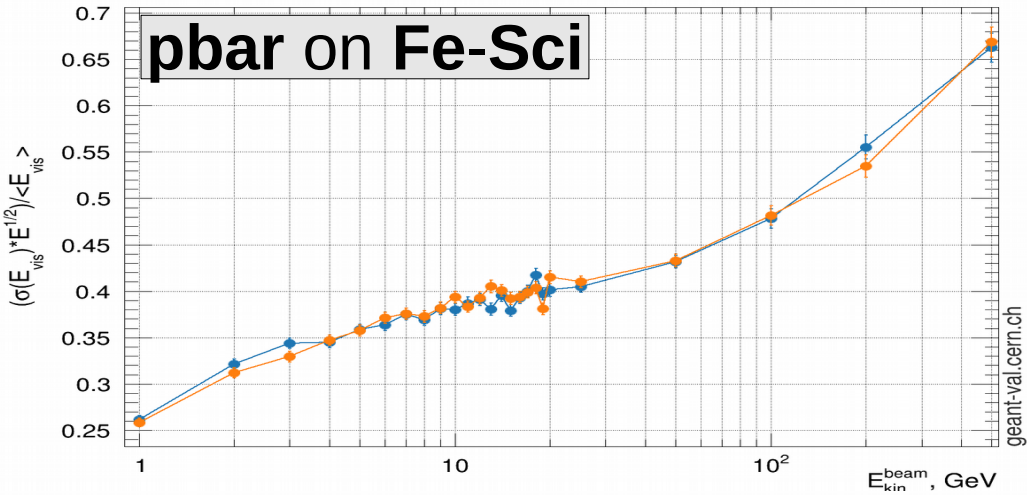
Normalized width | Beam: anti_proton | Target: AtlasECAL | FTFP_BERT

pbar on Pb-LAr

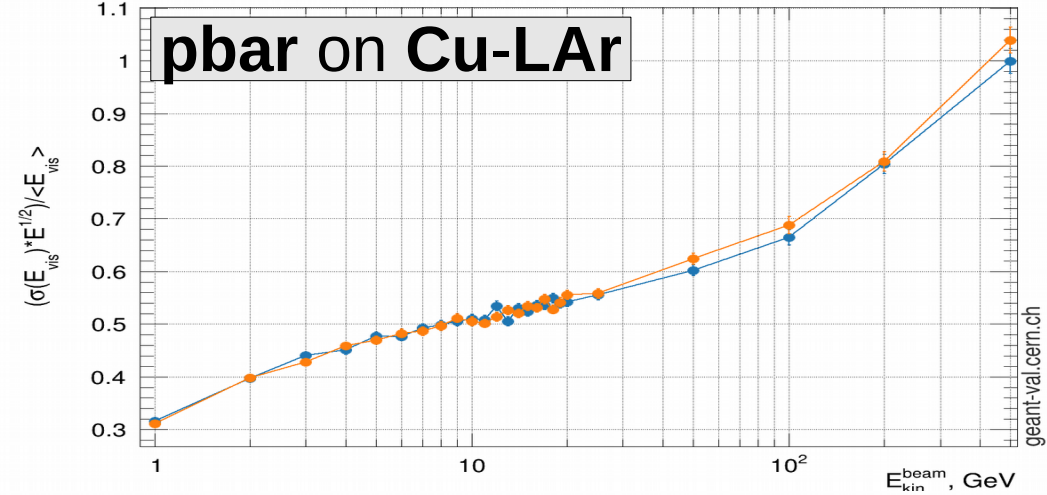


FTFP_BERT : Energy Resolution

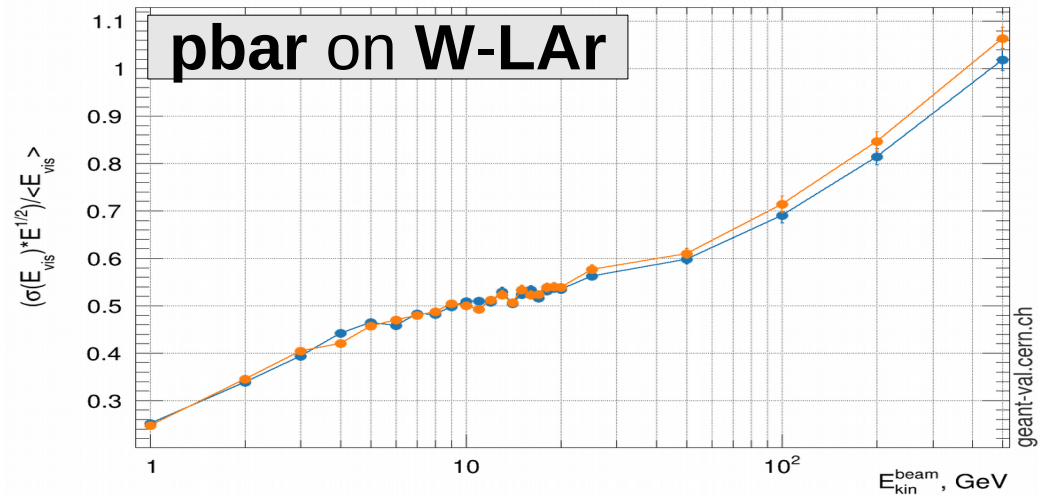
Energy resolution | Beam: anti_proton | Target: TileCal | FTFP_BERT



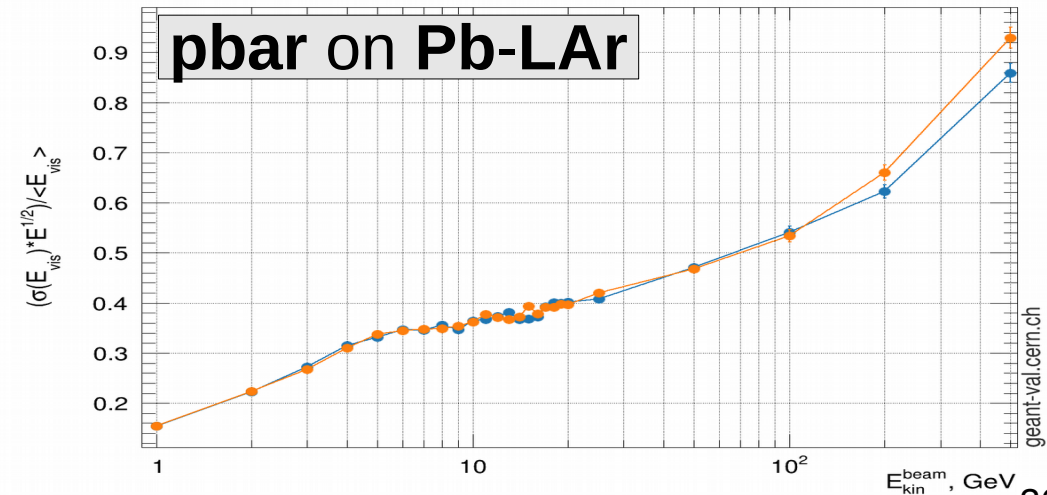
Energy resolution | Beam: anti_proton | Target: AtlasHEC | FTFP_BERT



Energy resolution | Beam: anti_proton | Target: AtlasFCAL | FTFP_BERT



Energy resolution | Beam: anti_proton | Target: AtlasECAL | FTFP_BERT



10.6.cand01

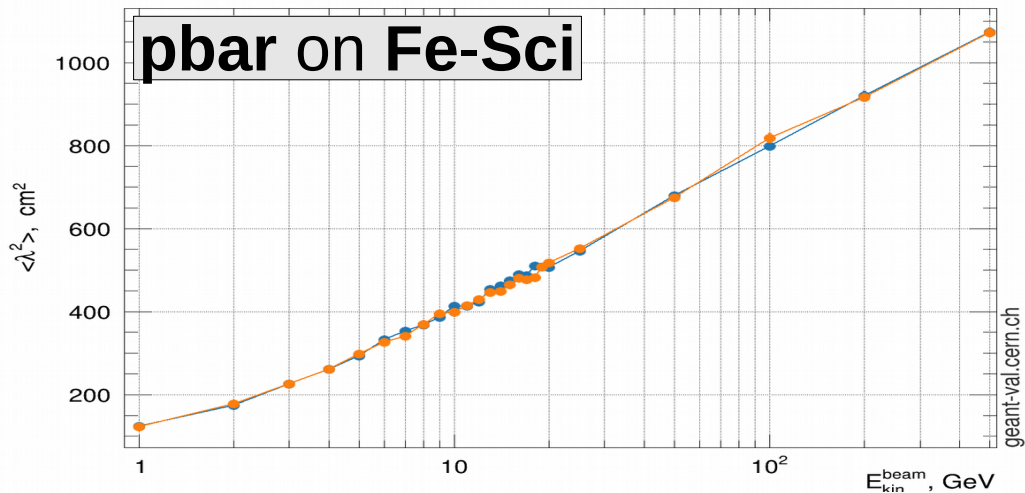
10.5.p01

10.6.cand01

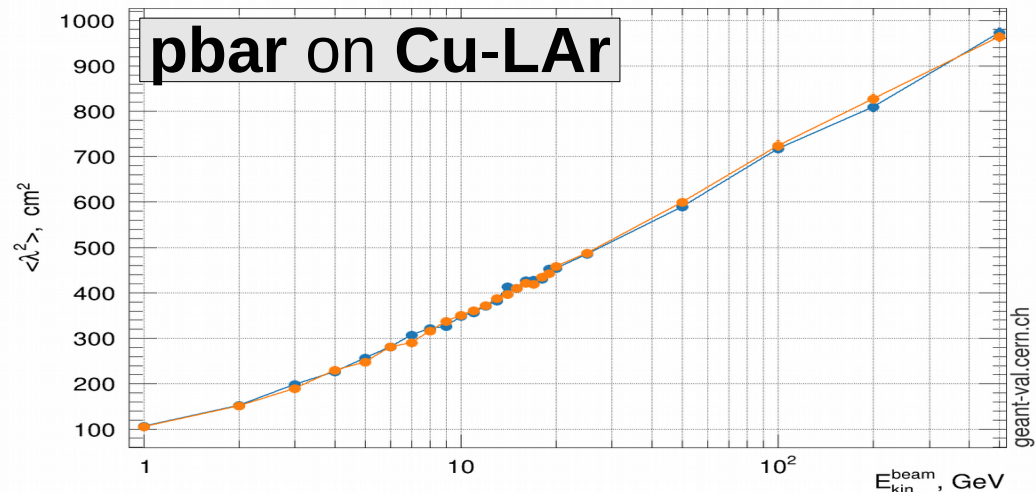
10.5.p01

FTFP_BERT : Longitudinal Shape

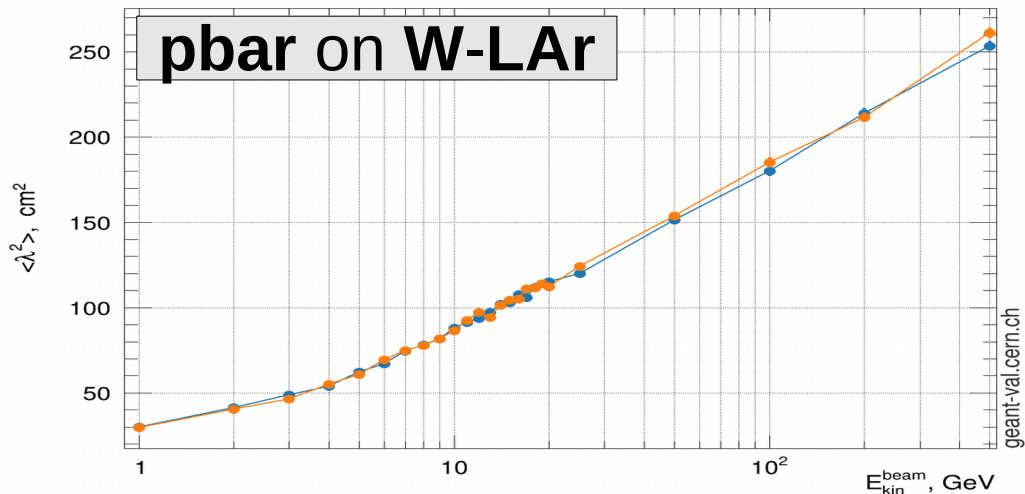
Longitudinal shower shape | Beam: anti_proton | Target: TileCal | FTFP_BERT



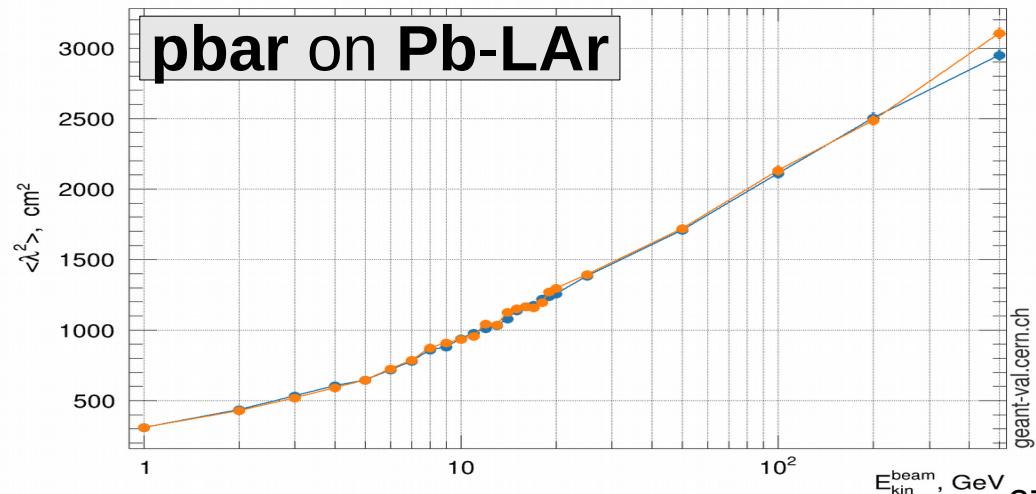
Longitudinal shower shape | Beam: anti_proton | Target: AtlasHEC | FTFP_BERT



Longitudinal shower shape | Beam: anti_proton | Target: AtlasFCAL | FTFP_BERT



Longitudinal shower shape | Beam: anti_proton | Target: AtlasECAL | FTFP_BERT



10.6.cand01

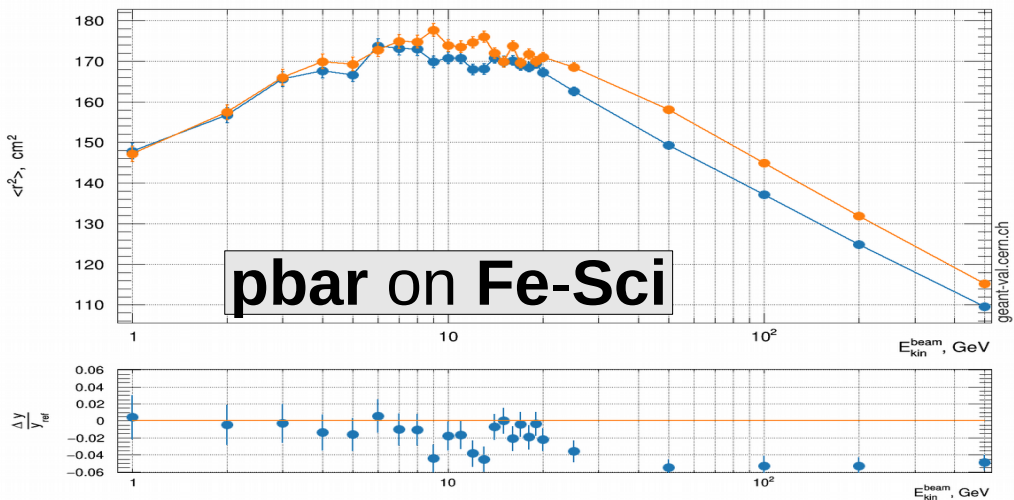
10.5.p01

10.6.cand01

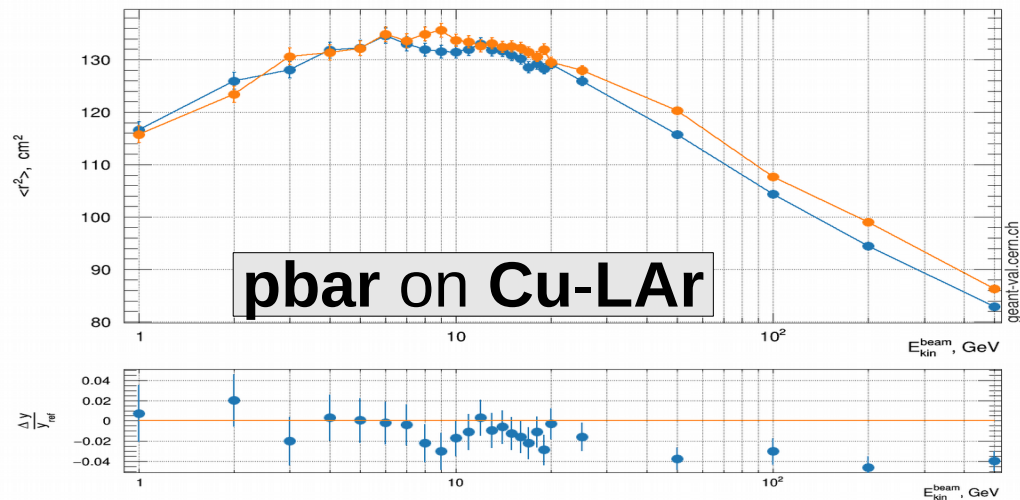
10.5.p01

FTFP_BERT : Lateral Shape

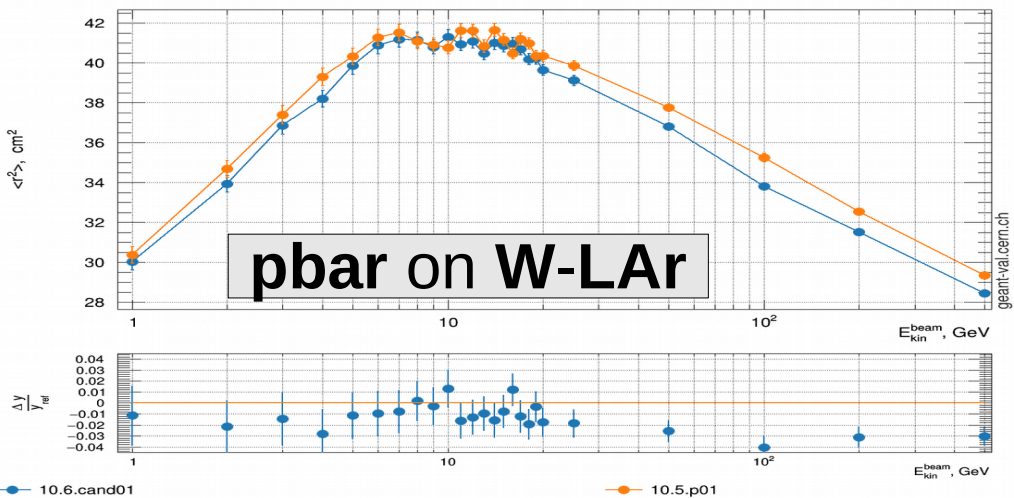
Lateral shower shape | Beam: anti_proton | Target: TileCal | FTFP_BERT | $\chi^2/n.d.f. = 4.67309$



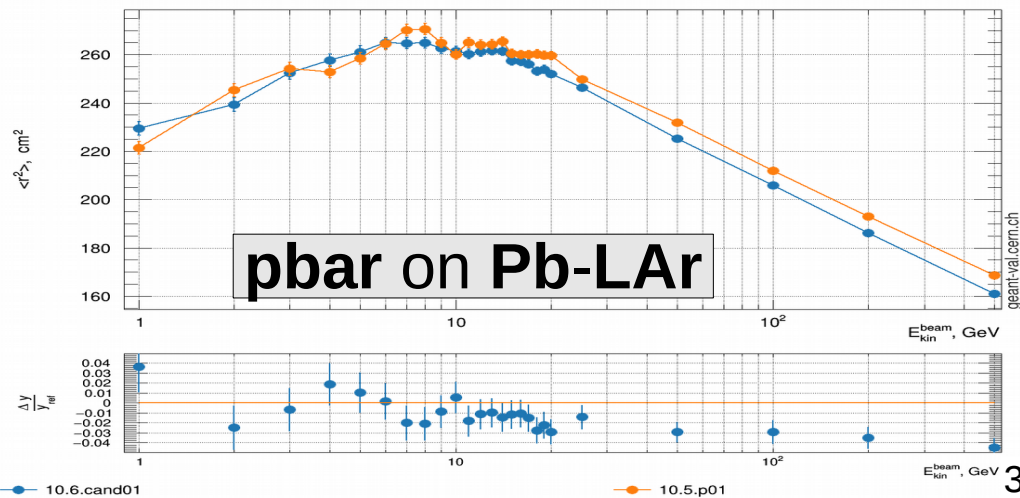
Lateral shower shape | Beam: anti_proton | Target: AtlasHEC | FTFP_BERT | $\chi^2/n.d.f. = 2.55634$



Lateral shower shape | Beam: anti_proton | Target: AtlasFCAL | FTFP_BERT | $\chi^2/n.d.f. = 2.01233$



Lateral shower shape | Beam: anti_proton | Target: AtlasECAL | FTFP_BERT | $\chi^2/n.d.f. = 2.89206$



Conclusions: Hadronic Showers in G4 10.6

- **FTFP_BERT** 10.6 vs. 10.5 : higher energy response and narrower, in particular for projectile energies between ~ 5 and ~ 25 GeV
- **QGSP_BERT** 10.6 vs. 10.5 : similar trend as for **FTFP_BERT**
 - Transition region between FTFP and QGSP is unchanged: $[12, 25]$ GeV
- **QGSP_BERT** vs. **FTFP_BERT** : higher energy response, more energy fluctuations, longer and narrower shapes
- Similar trend for **pions**, **kaons** and **nucleons** showers, whereas **antibaryons'** showers stay nearly the same as in G4 10.5
 - For antibaryons, FTFP is used for all energies
- We recommend to fit the **Birks quenching coefficient** from e/h data; else use **FTFP_BERT_ATL** whose showers remain similar as in 10.5
 - Transition region in FTFP_BERT_ATL is unchanged: $[9, 12]$ GeV