Data & Monte Carlo Comparison

Analysis of W-AHCAL CERN 2010 Data

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Contents

1. Previously...

➢ Last presentation ([1], concerning 2010 data):

- 2010 Data:
  - 1 – 10 GeV beam momentum
  - CERN T7: Dedicated muon runs
  - CERN T9: Mixed beam runs (e, π, μ, p)
- MIP calibrations — OK
- Temperature correction — OK
- Selection of events — Updated
- Energy resolution for electrons and pions (data) — Updated
- Comparison with Monte Carlo — This presentation

Intermezzo

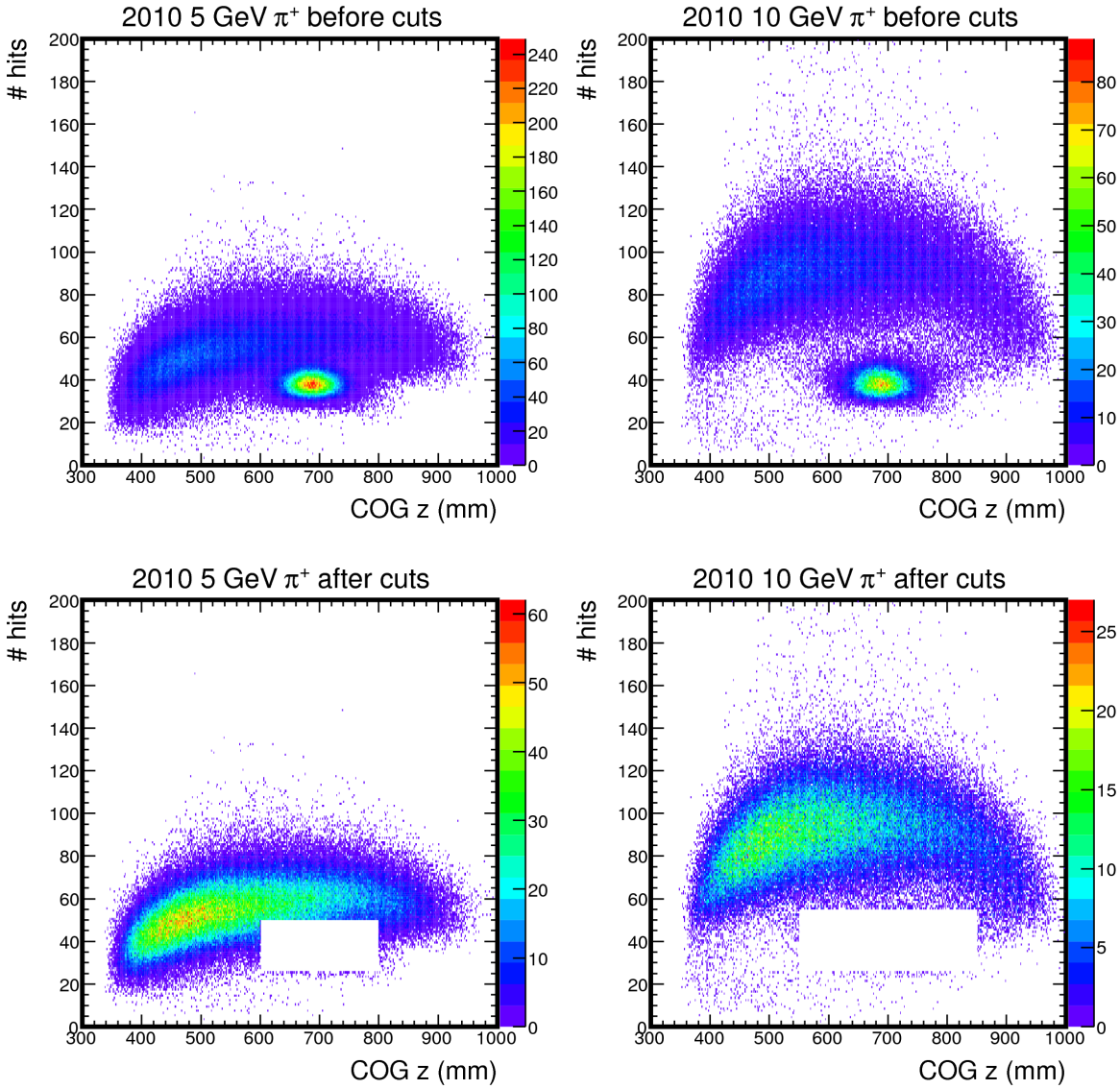
Work in progress: numbers and figures shown in this presentation are not final

2. Selection of events

Example: Pions

- Similar for electrons and protons

1. Identify particles based on Cherenkov triggers
2. Muon rejection: cut in COG z and number of hits
   - $\text{COG z} = \frac{\sum_i E_i z_i}{\sum_i E_i}$



2. Selection of events

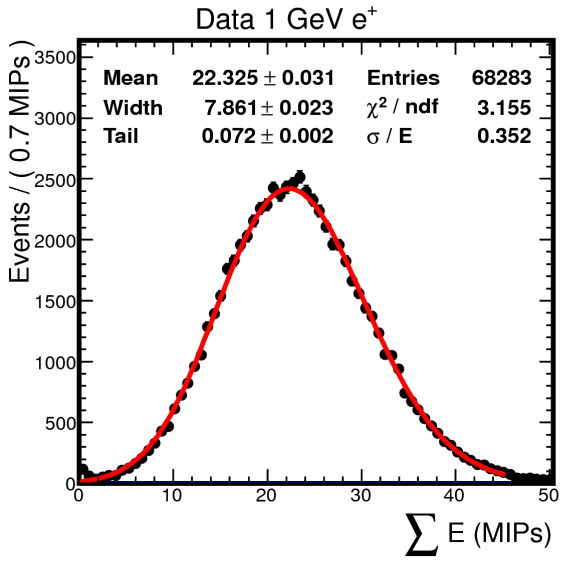
In addition for electrons, a cylinder cut is applied:

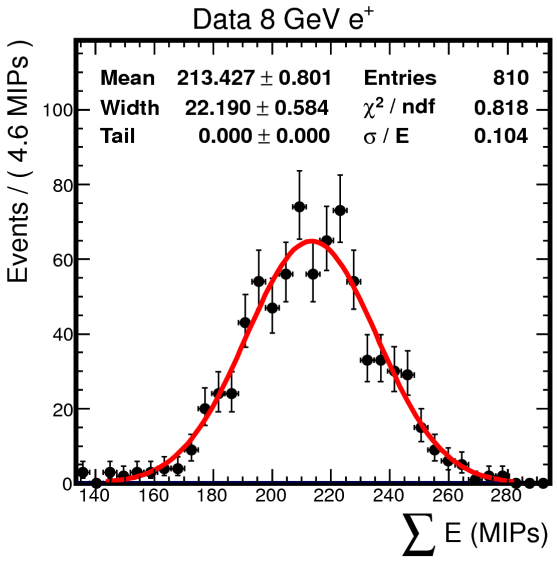
- Hit is in the first twenty layers
- Hit is within 50 mm distance w.r.t. track (50 mm $\approx$ 5.3 R_M)

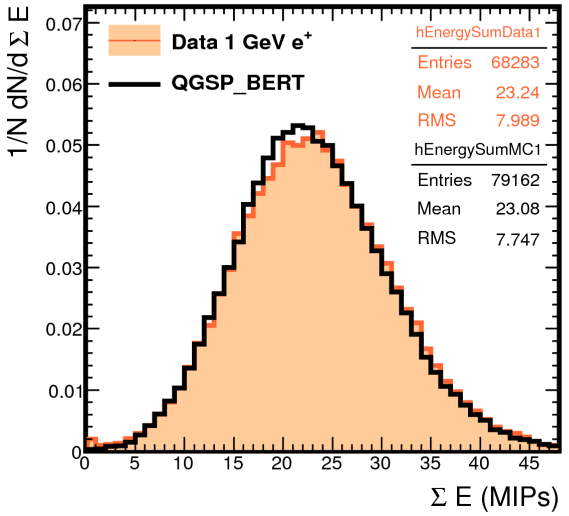
3. CERN 2010 e^+

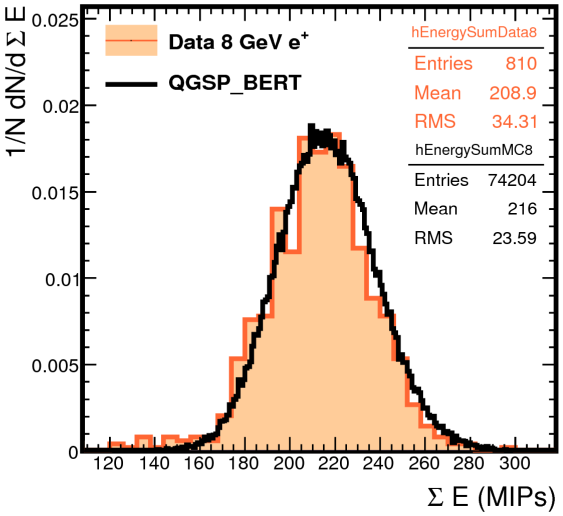
- Fit of data with Novosibirsk ([2], Gaussian with tail)
- Fit within $\pm 3\sigma$ of mean

Energy sum CERN 2010 e^+









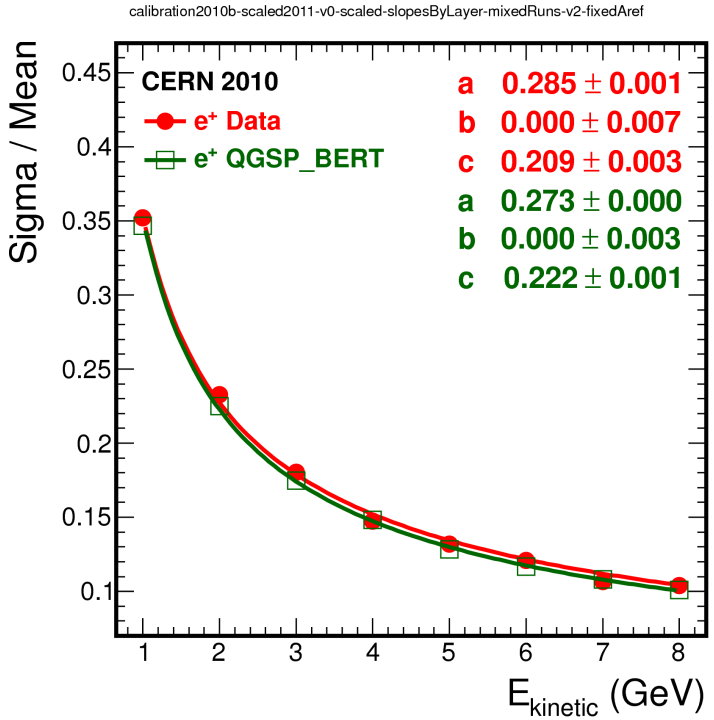
3. CERN 2010 e^+

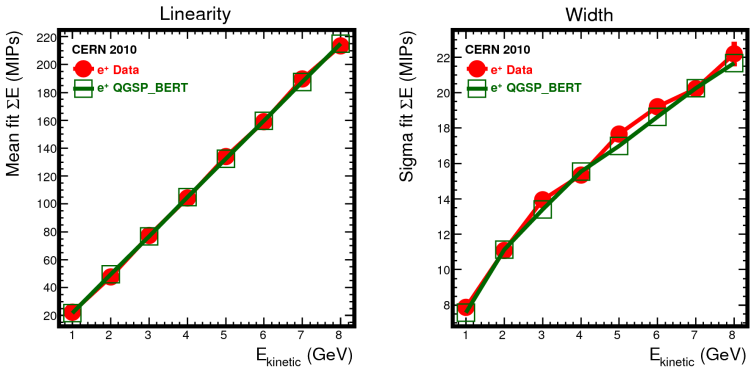
- Numbers in this presentation are not final
- Fit: noise term to be fixed in all energy resolution plots

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

	Data	QGSP_BERT
a (stochastic)	0.285 ± 0.001	0.273 ± 0.000
b (constant)	0.000 ± 0.007	0.000 ± 0.003
c (noise)	0.209 ± 0.003	0.222 ± 0.001

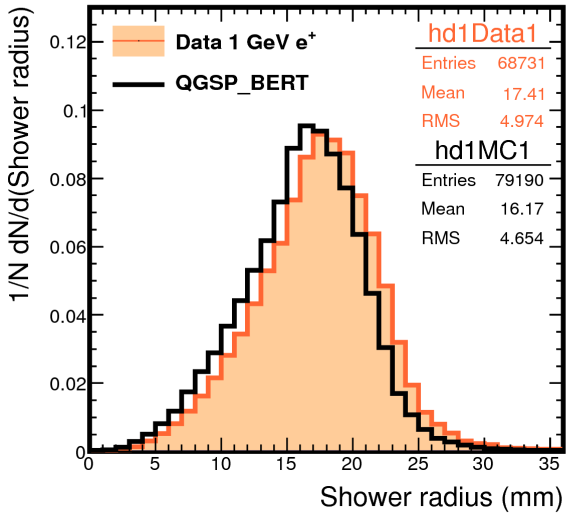
Energy resolution for CERN 2010 e^+

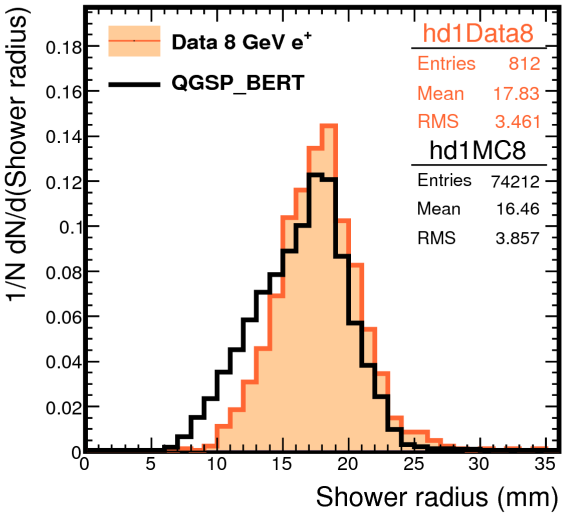




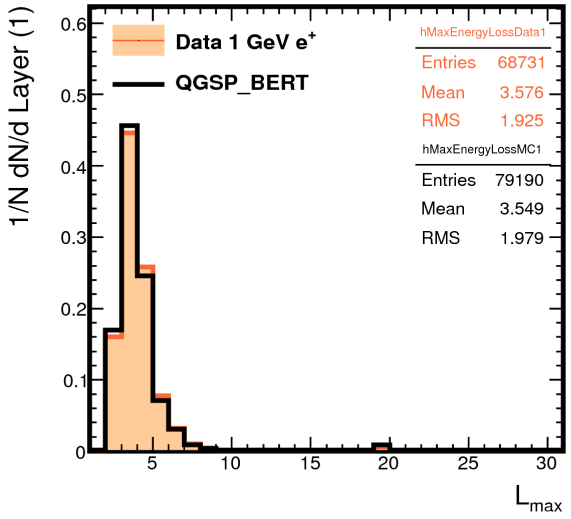
3. CERN 2010 e^+

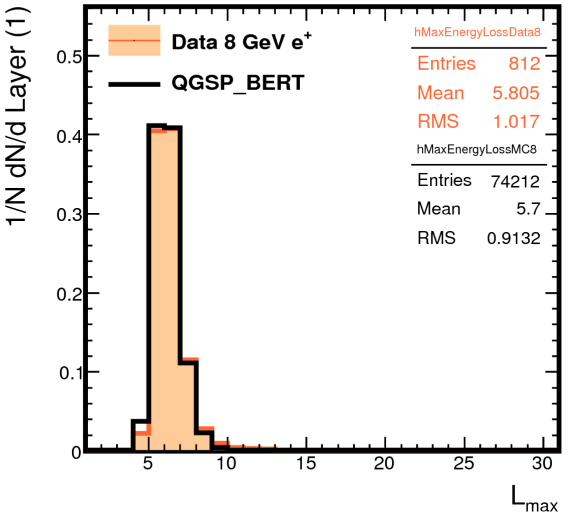
- Shower radius: energy weighted distance of hits w.r.t. track





- $L_{\max}$: Layer with maximum energy

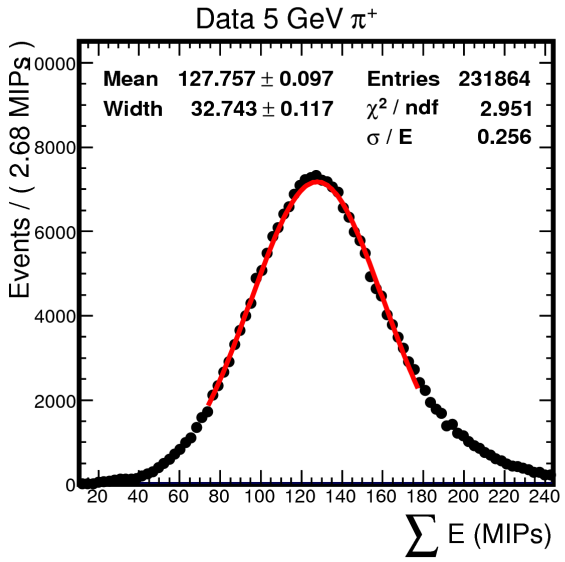


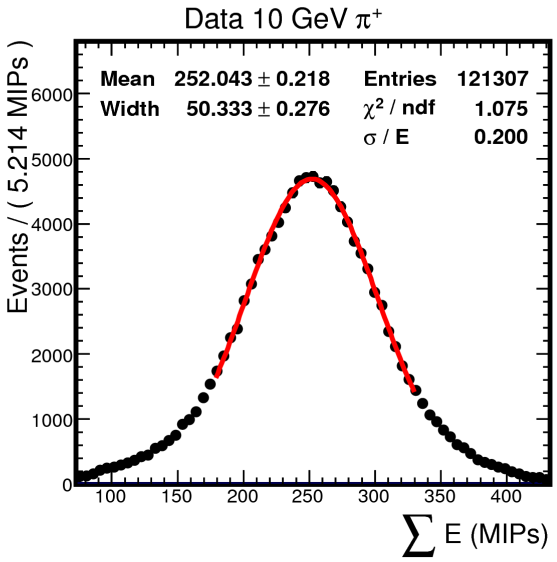


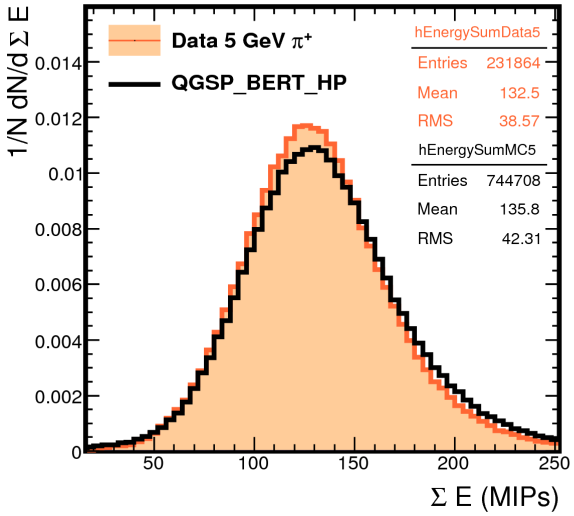
3. CERN 2010 π^+

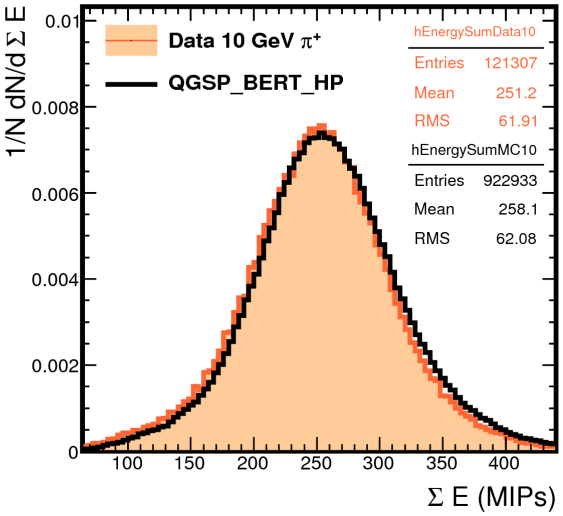
Energy sum CERN 2010 π^+

- Fit of data with Gaussian
- Fit within $\pm 1.5\sigma$ of mean









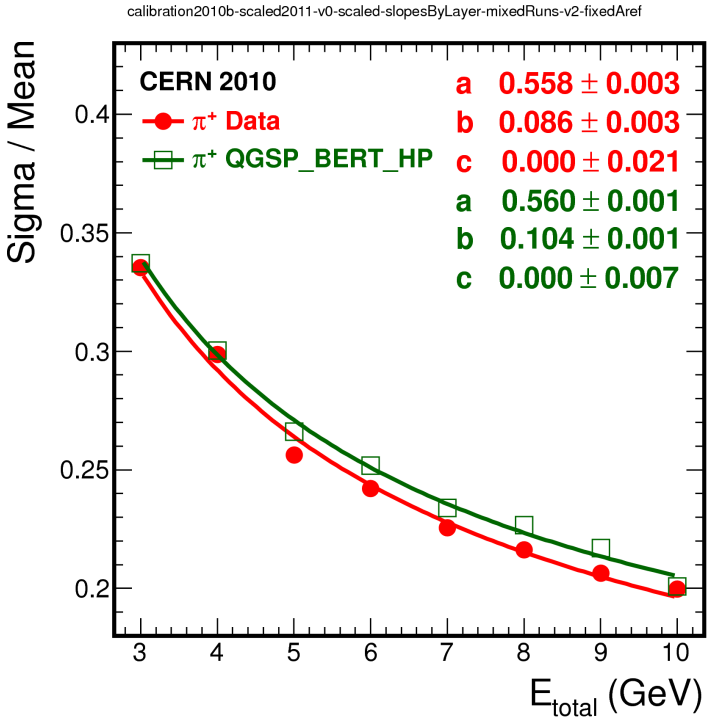
3. CERN 2010 π^+

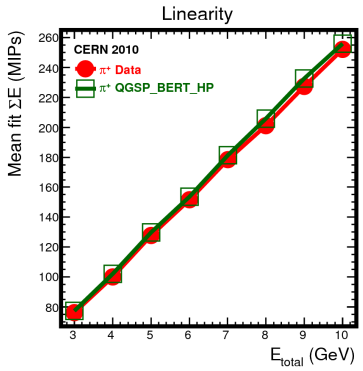
- Difference in sigma between data and MC:
  - Physics list changes from BERT to LEP between 9.5-9.9 GeV ([3])
  - First steps towards validation of MC physics lists with data. Started discussion with GEANT4 team.
  - Difference not yet understood

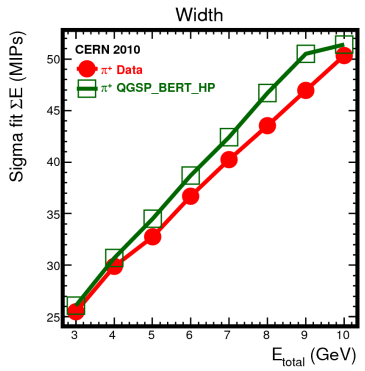
$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

	Data	QGSP_BERT_HP
a (stochastic)	0.558 ± 0.003	0.560 ± 0.001
b (constant)	0.086 ± 0.003	0.104 ± 0.001
c (noise)	0.000 ± 0.021	0.000 ± 0.007

Energy resolution for CERN 2010 π^+

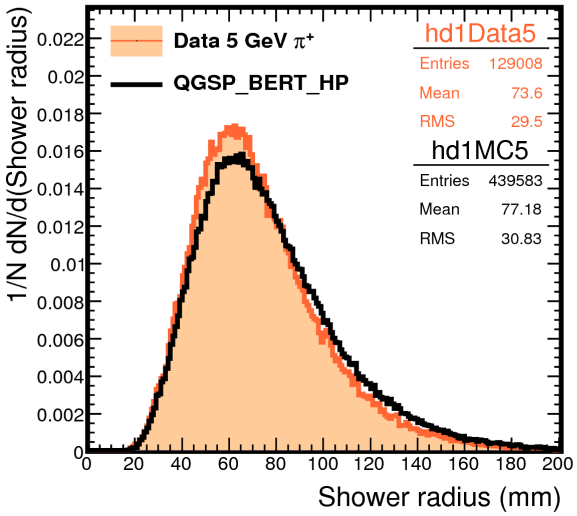


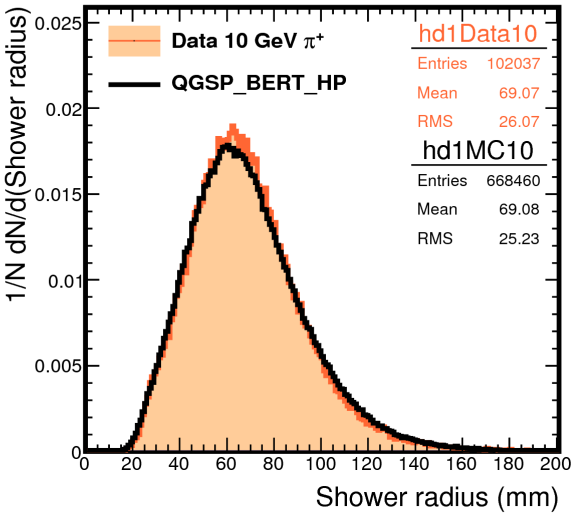




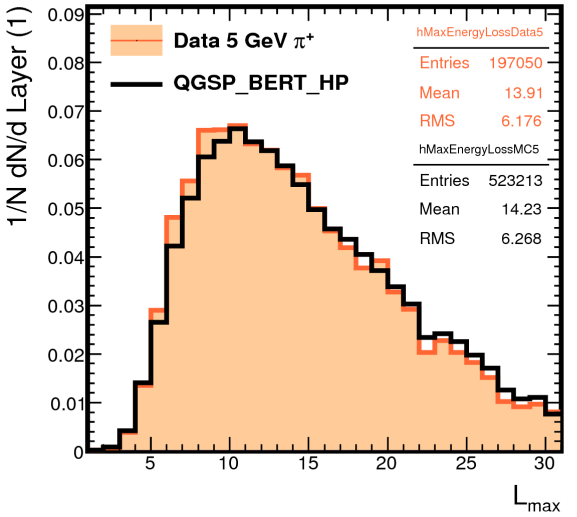
3. CERN 2010 π^+

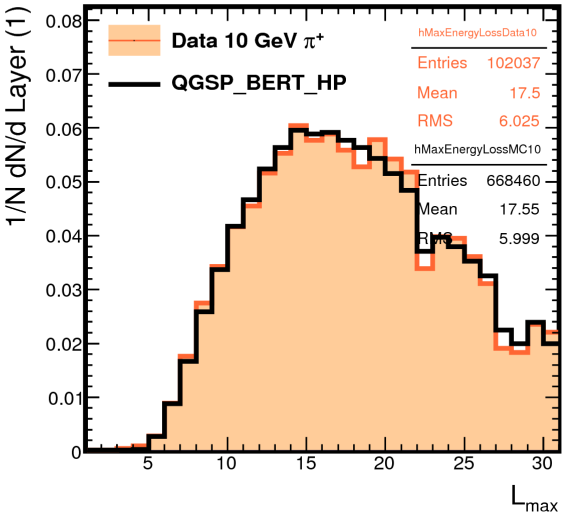
- Shower radius: energy weighted distance of hits w.r.t. track





- L_{max}: Layer with maximum energy
- Dips in layer 22, 27 & 28 are due to dead cells: same in data and MC

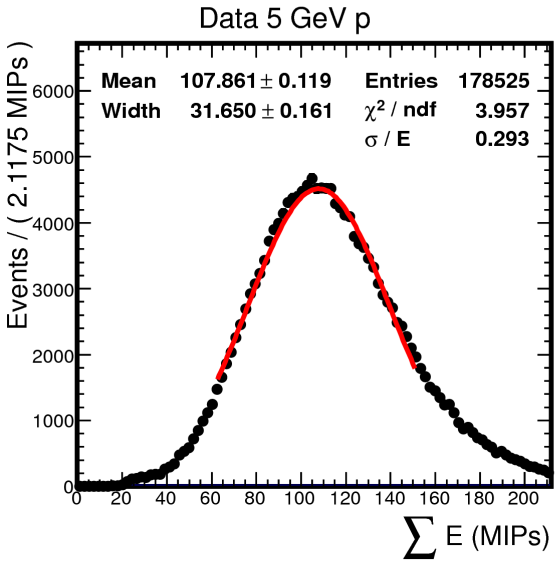


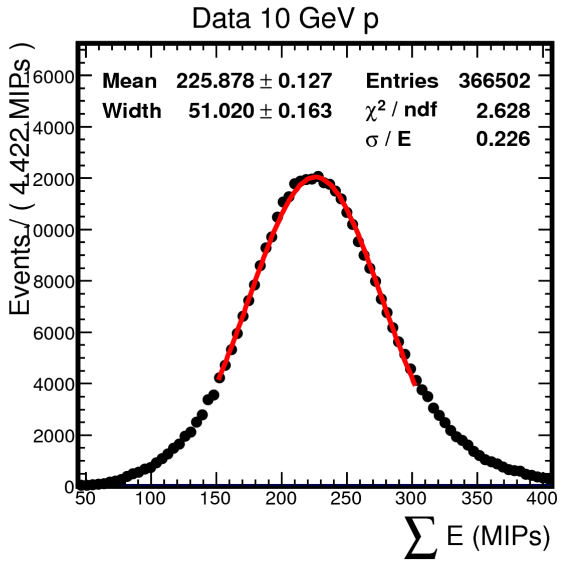


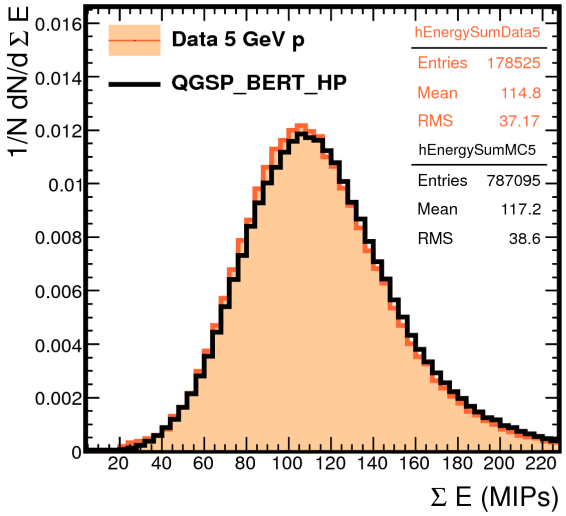
3. CERN 2010 p

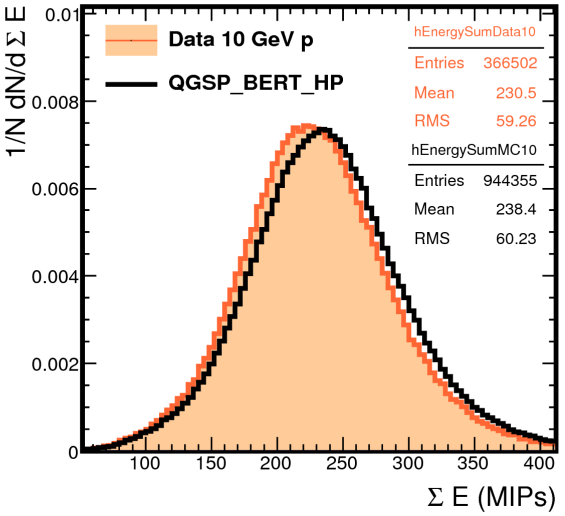
Energy sum CERN 2010 p

- Fit of data with Gaussian
- Fit within $\pm 1.5\sigma$ of mean





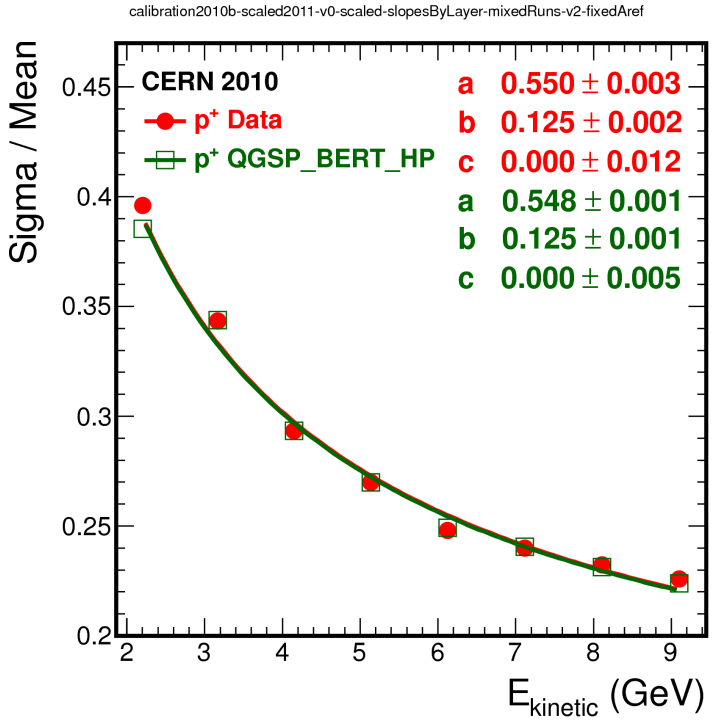




3. CERN 2010 p

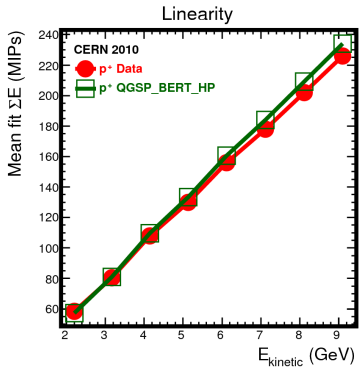
- Better agreement between data and Monte Carlo compared to pions: under investigation

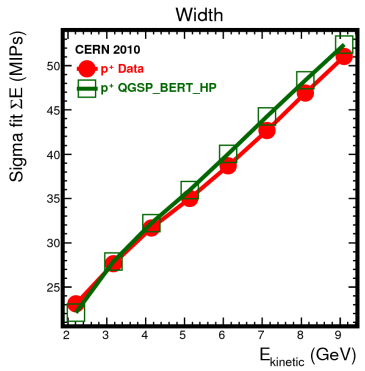
Energy resolution for CERN 2010 protons



$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

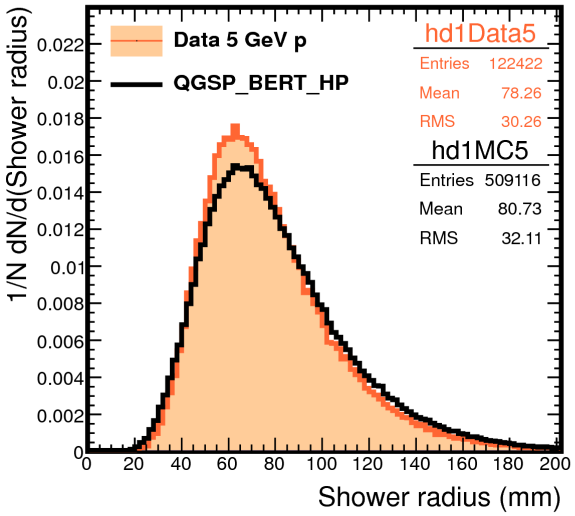
	Data	QGSP_BERT_HP
a (stochastic)	0.550 ± 0.003	0.548 ± 0.001
b (constant)	0.125 ± 0.002	0.125 ± 0.001
c (noise)	0.000 ± 0.012	0.000 ± 0.005

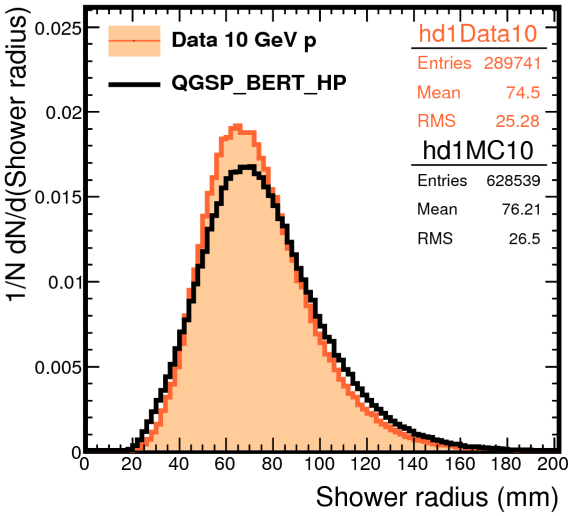




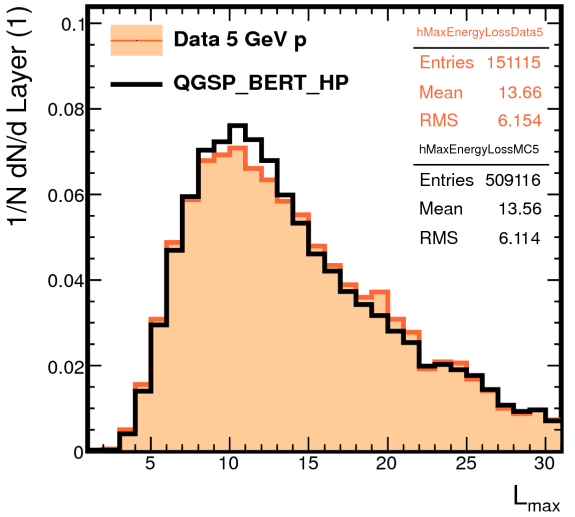
3. CERN 2010 p

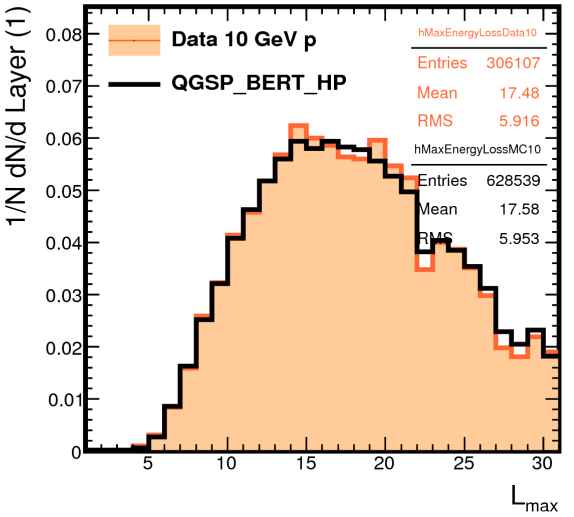
- Shower radius: energy weighted distance of hits w.r.t. track





- L_{max}: Layer with maximum energy
- Dips in layer 22, 27 & 28 are due to dead cells: same in data and MC

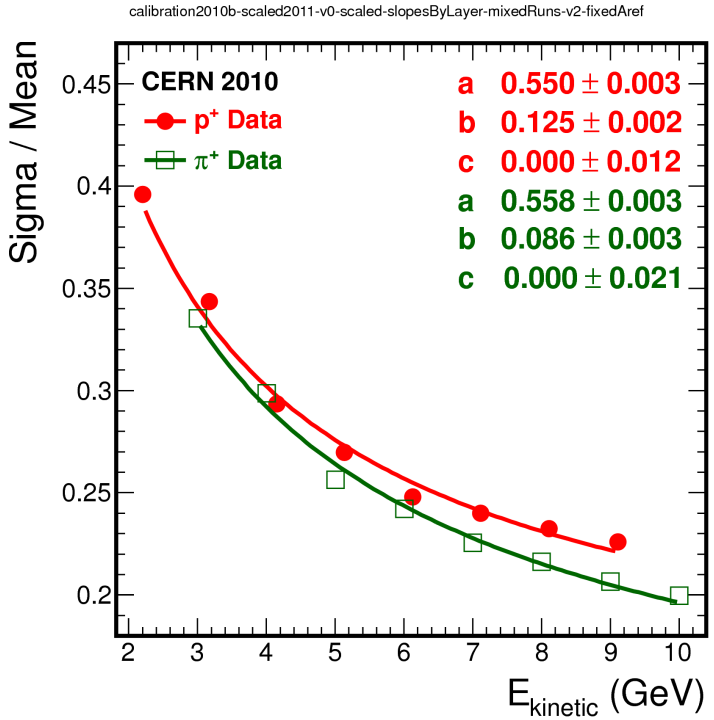




4. CERN 2010 p, π^+

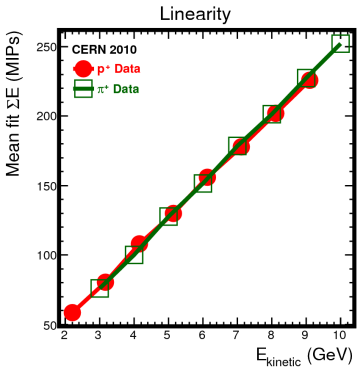
- Similar response, but broader sigma

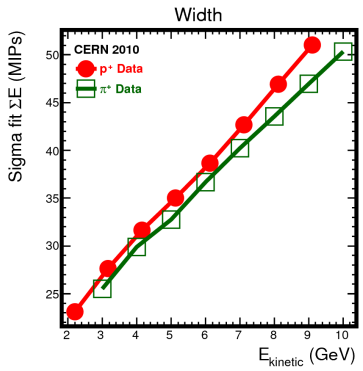
Energy resolution for CERN 2010 p & π^+



$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

	Data p	Data π^+
a (stochastic)	0.550 ± 0.003	0.558 ± 0.003
b (constant)	0.125 ± 0.002	0.086 ± 0.003
c (noise)	0.000 ± 0.012	0.000 ± 0.021





5. Summary

- Comparison between data and Monte Carlo
  - e^+ Good agreement between data and MC
  - π^+ Transition from BERT to LEP model between 9.5 and 9.9 GeV. Sigma is broader in MC → to be studied. Discussion started with GEANT4 team.
  - p Better agreement between data and Monte Carlo compared to pions → to be studied
- Comparison between data
  - p vs. π^+ Similar response, but broader sigma in proton data

and Outlook

- New physics list to compare with (from GEANT4 team, experimental): FTFP_BERT_HP
- Systematics to be done
- Work on CALICE Analysis Note has been continued

References

References

1. Lucaci-Timoce, A.; Lam, C.B.; "Analysis of W-AHCAL data," *CALICE Analysis and Software Meeting, 10 January 2012*

➢ Meeting PDF

2. Lam, C.B.; "Status of W-AHCAL data analysis," *CALICE Collaboration Meeting, Heidelberg, 14 September 2011*

➢ Meeting PDF

3. Ribon, A.; Apostolakis, J.; Dotti, A.; Folger, G.; Grichine, V.; Ivanchenko, V.; Kosov, M.; Uzhinsky, V.; Wright, D.H.; , "Transition between hadronic models in Geant4," *Nuclear Science Symposium Conference Record (NSS/MIC), 2009 IEEE* , vol., no., pp.526-529, Oct. 24 2009-Nov. 1 2009
doi: 10.1109/NSSMIC.2009.5401645

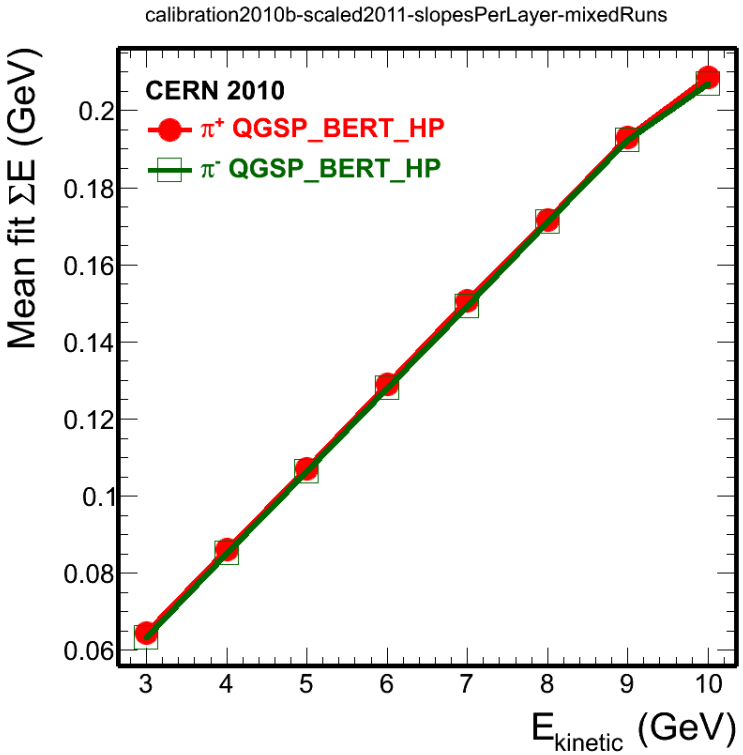
➢ IEEE PDF

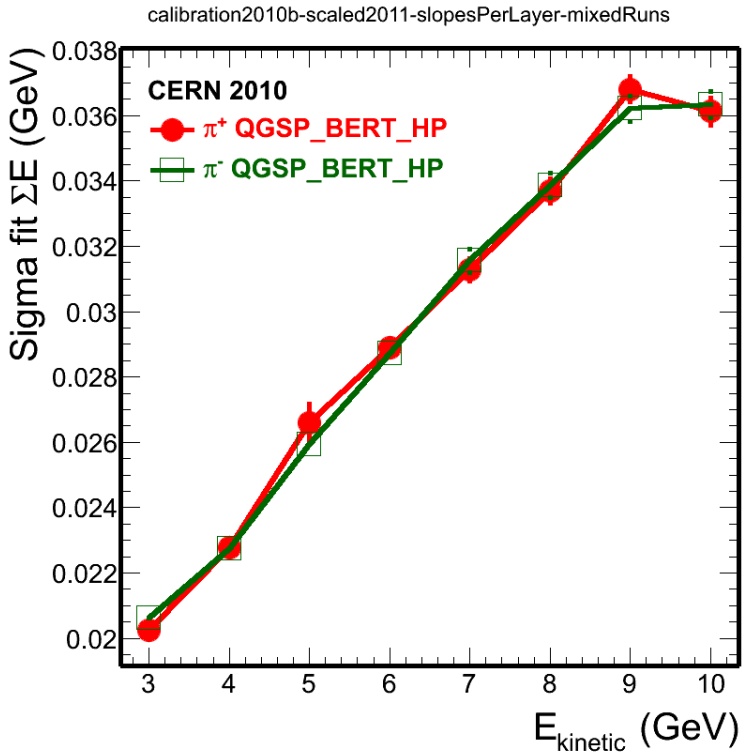
Backup slides

Linearity and Sigma plots: π^+ vs π^-

- Generator level

Particle	Monte Carlo
π^+	E_{kinetic} = 1 - 10 GeV
π^-	E_{kinetic} = 1 - 10 GeV

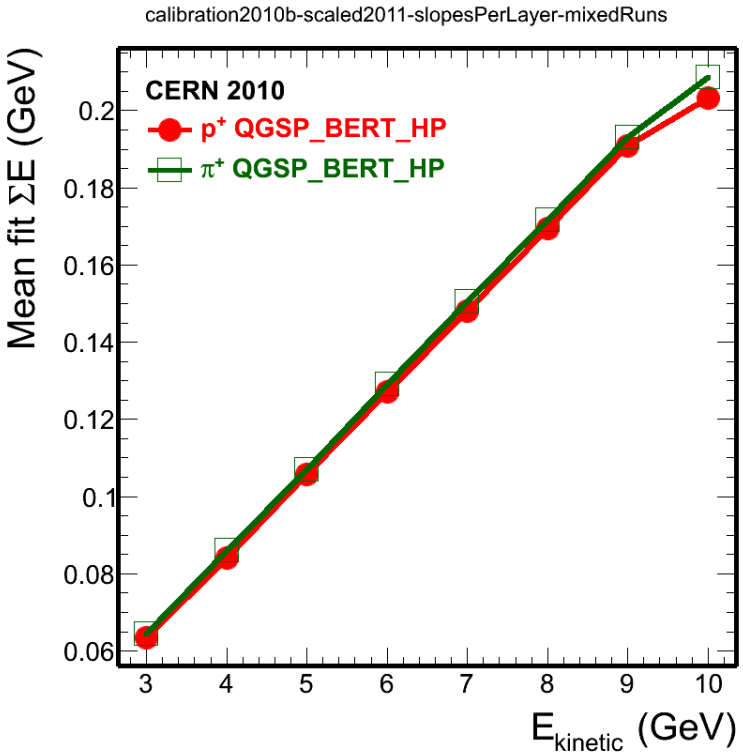


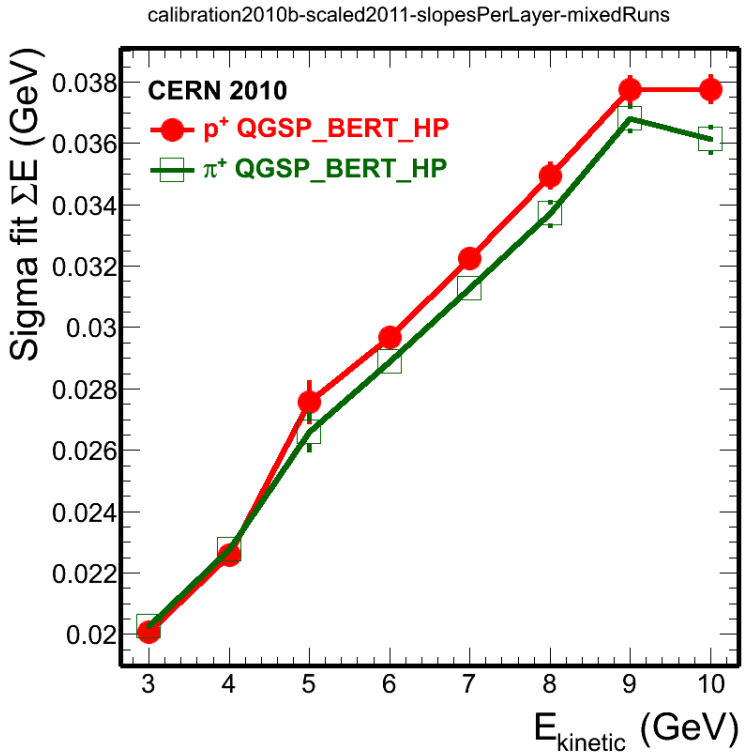


Linearity and Sigma plots: Protons vs π^+

- Generator level

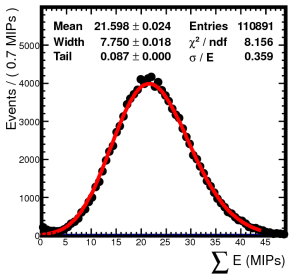
Particle	Monte Carlo
Protons	E_{kinetic} = 1 - 10 GeV
π^+	E_{kinetic} = 1 - 10 GeV

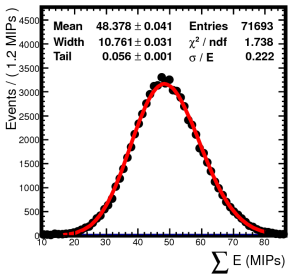


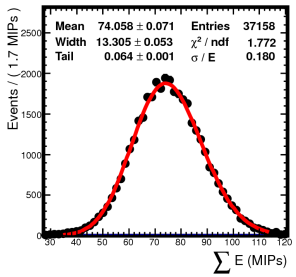


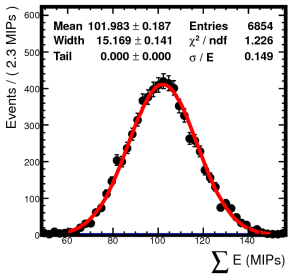
CERN 2010 Energy sum fits e^-

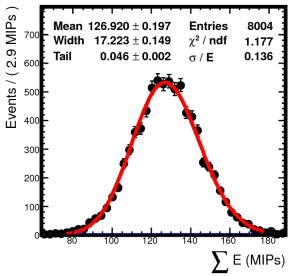
Energy sum fits CERN 2010 Data e-

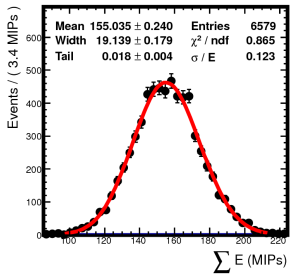


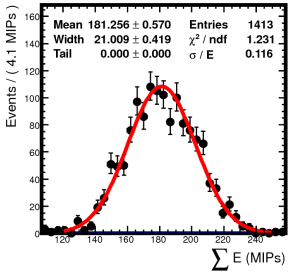


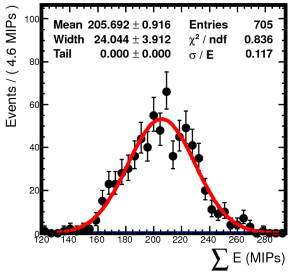




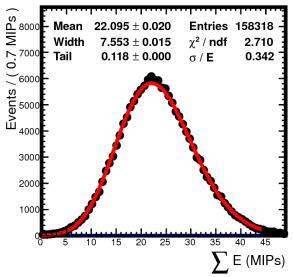


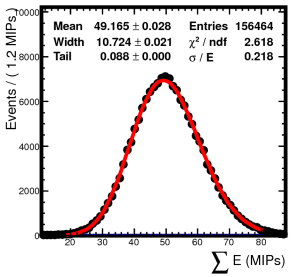


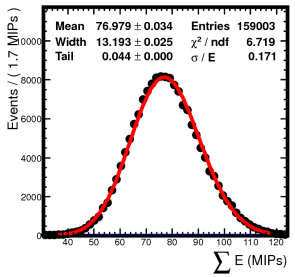


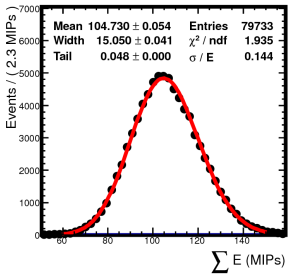


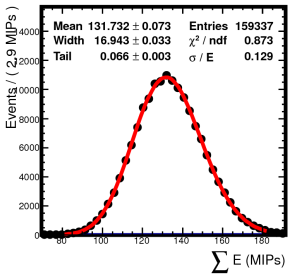
Energy sum fits CERN 2010 MC e-

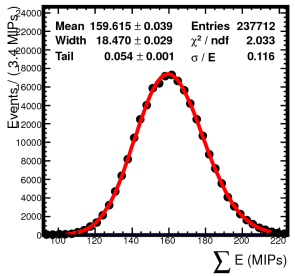


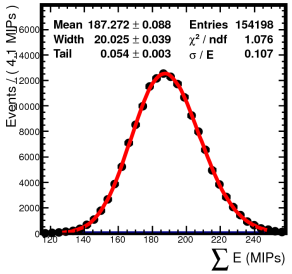


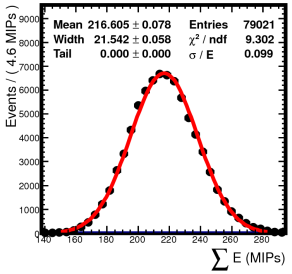






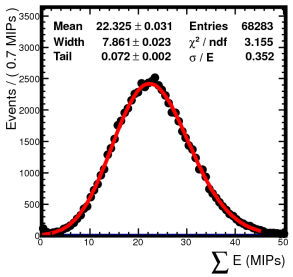


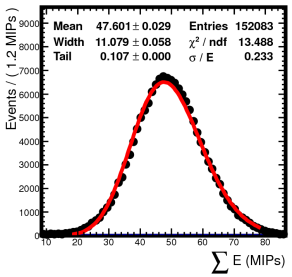


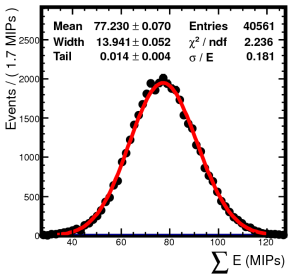


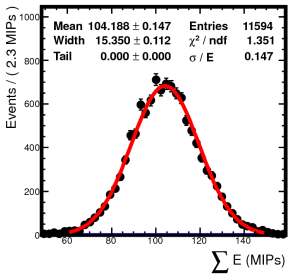
CERN 2010 Energy sum fits e^+

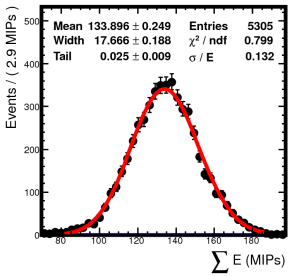
Energy sum fits CERN 2010 Data e+

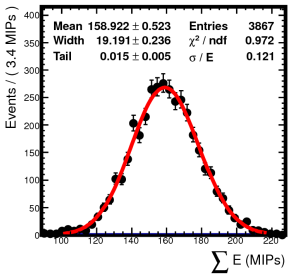


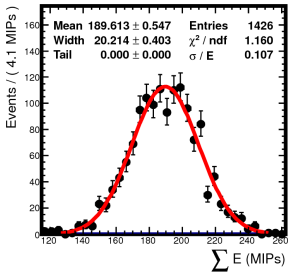


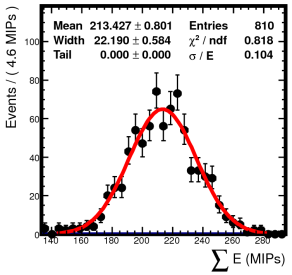




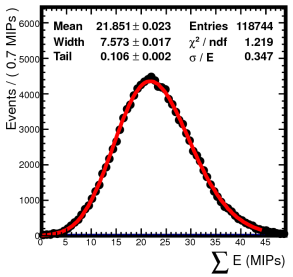


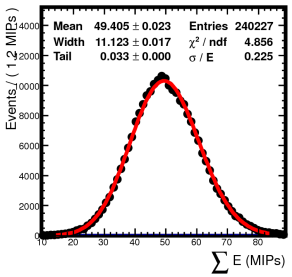


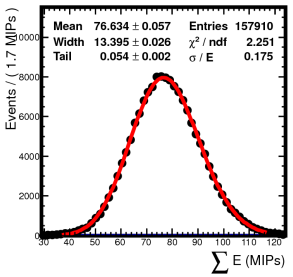


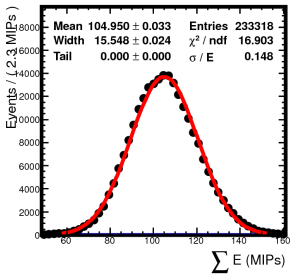


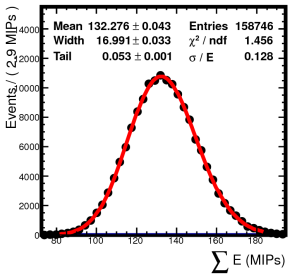
Energy sum fits CERN 2010 MC e+

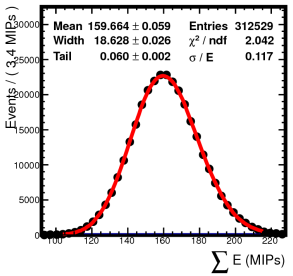


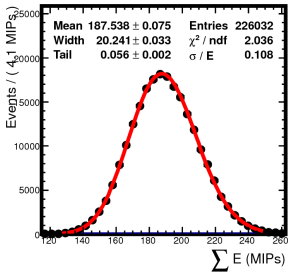


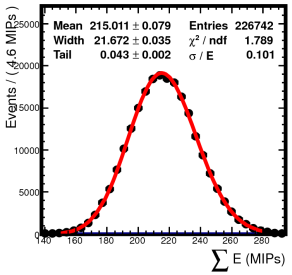




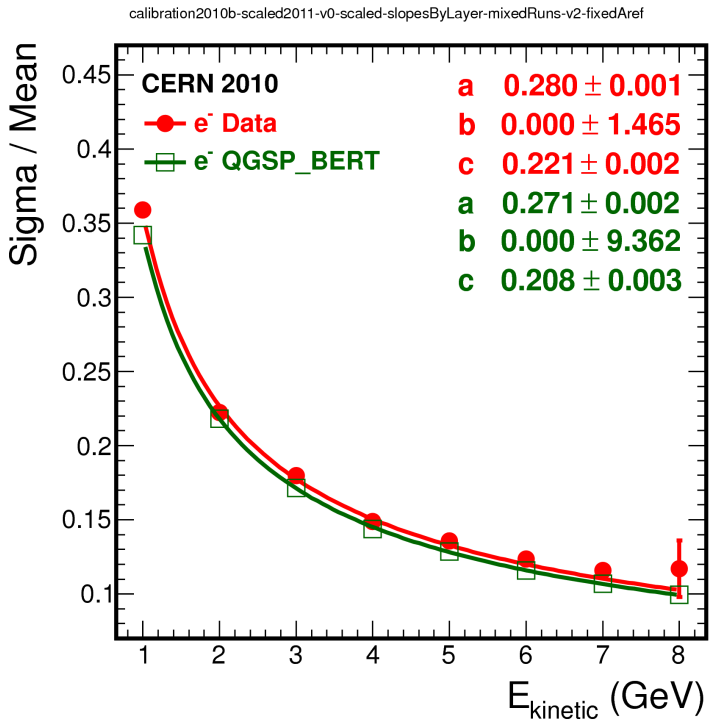


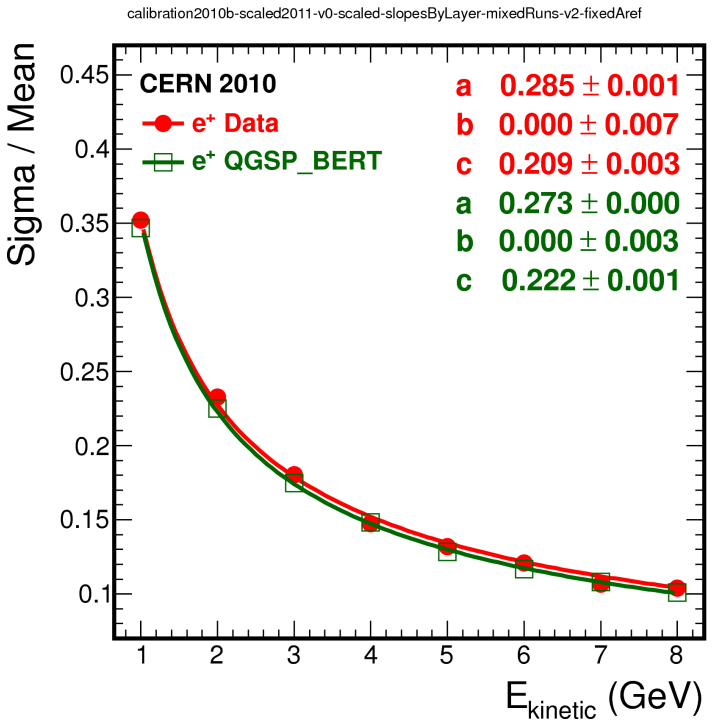


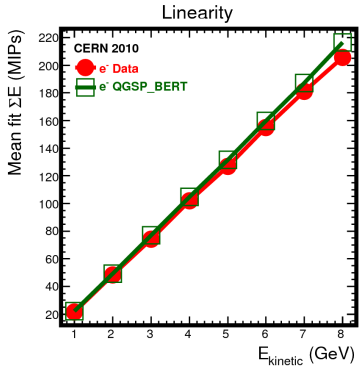


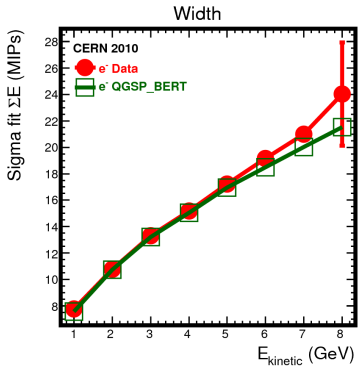


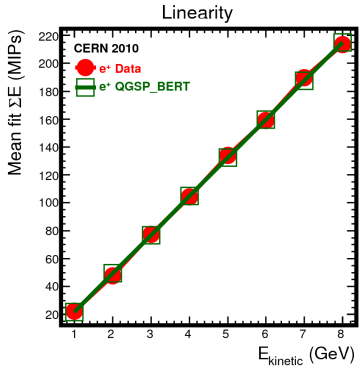
CERN 2010 Energy Resolution e^-, e^+

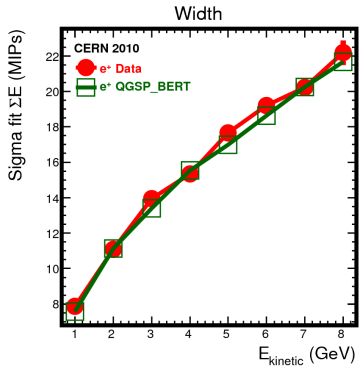






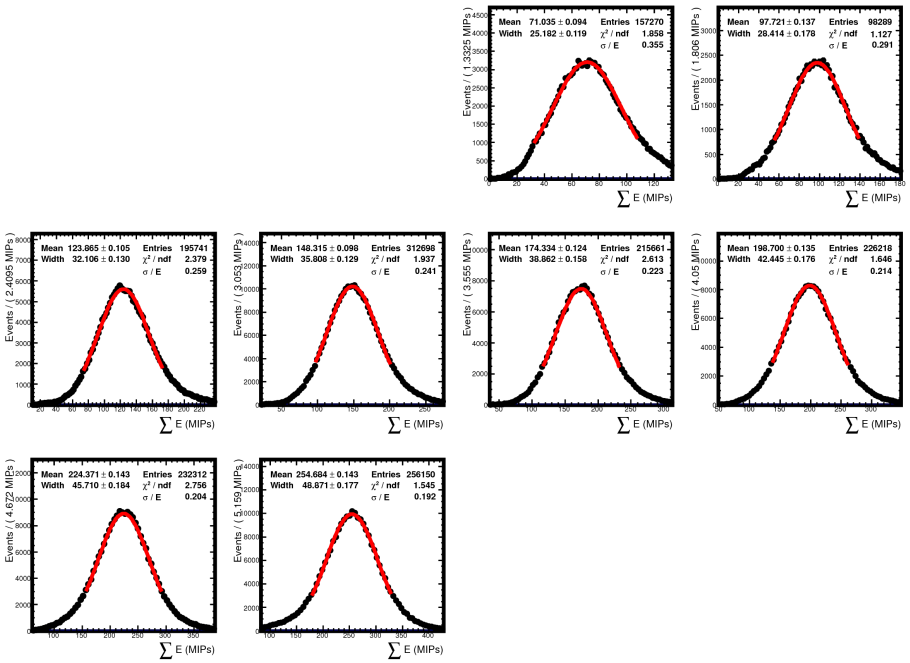




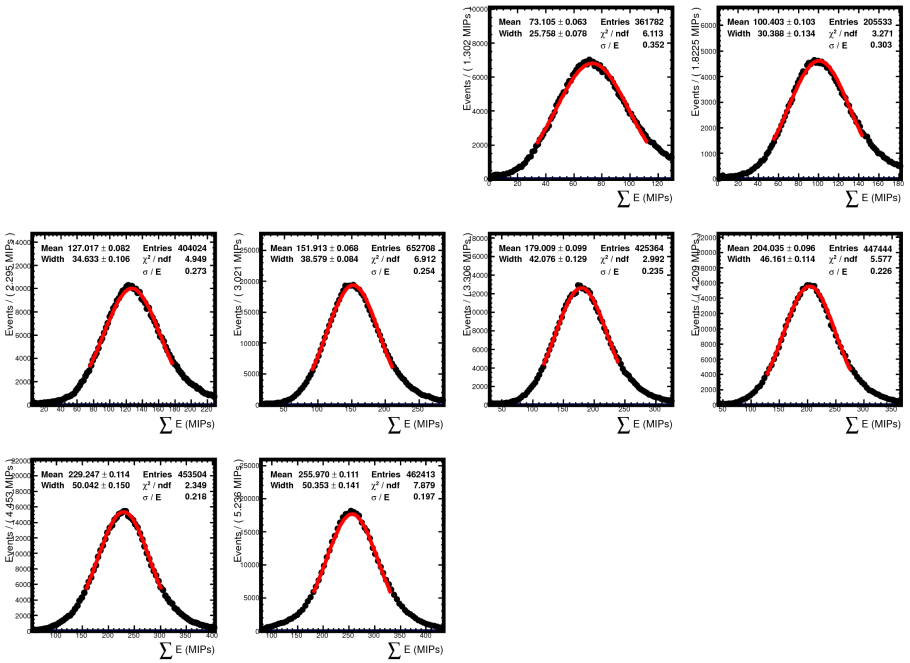


CERN 2010 Energy sum fits π^-

Energy sum fits CERN 2010 Data π^-

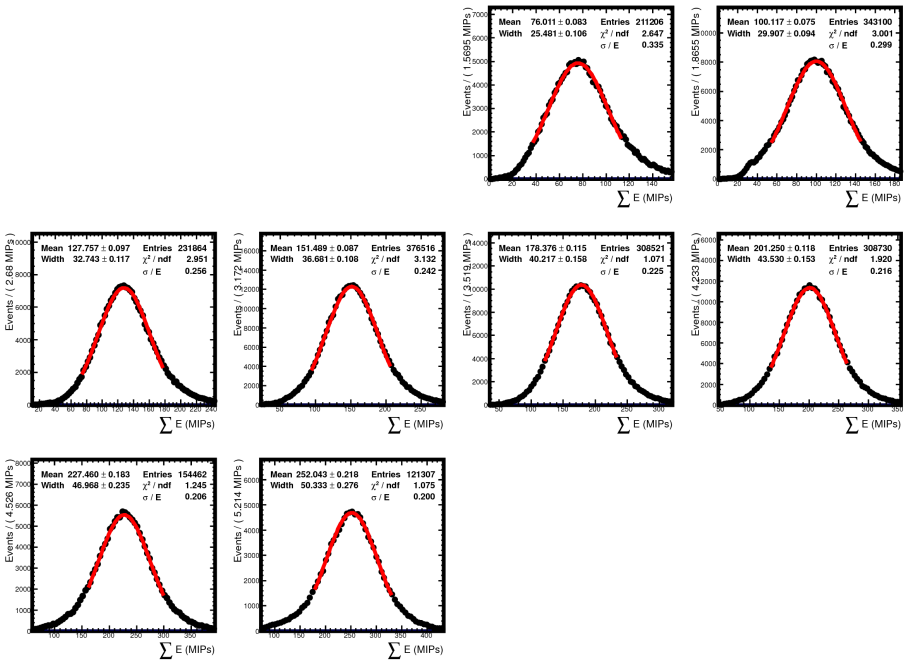


Energy sum fits CERN 2010 MC π^-

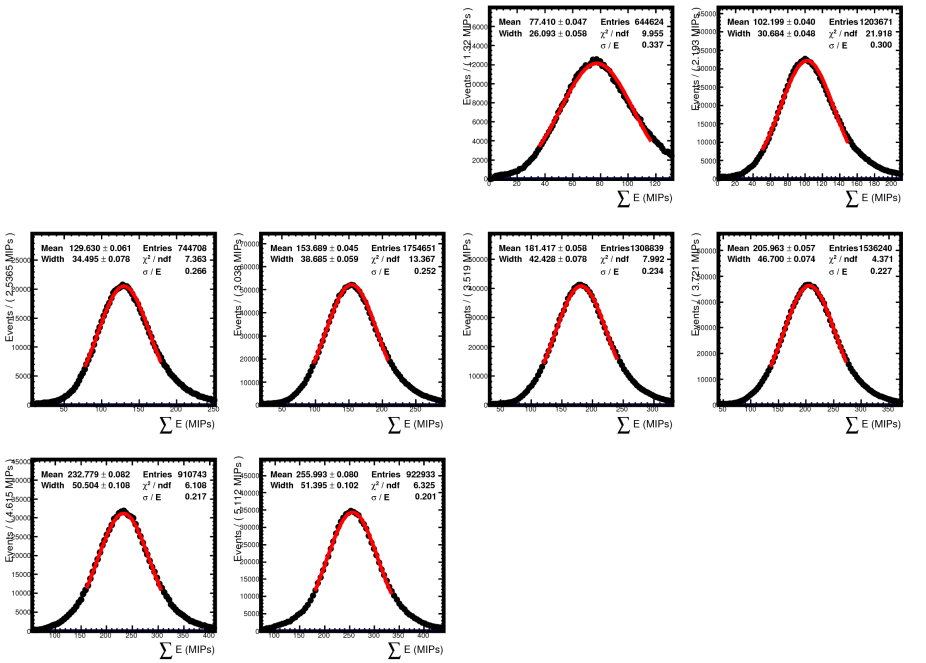


CERN 2010 Energy sum fits π^+

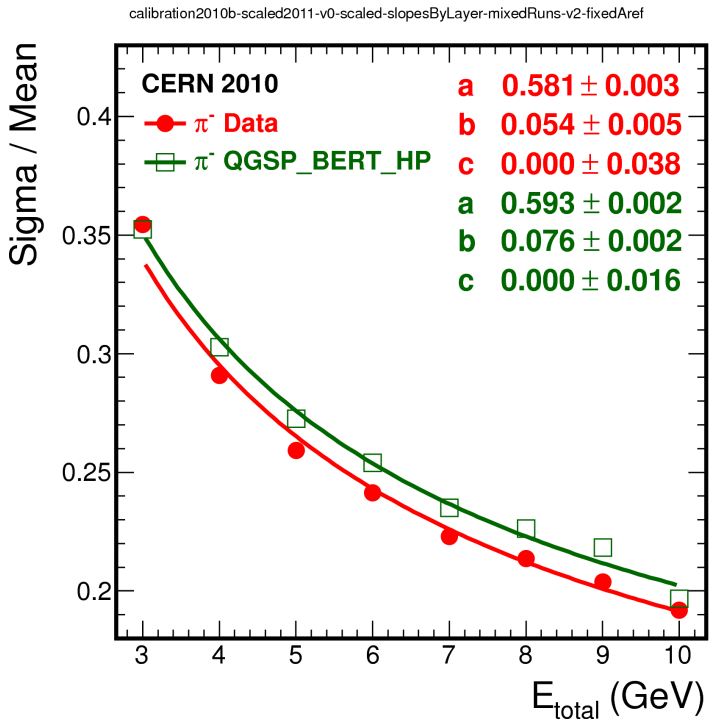
Energy sum fits CERN 2010 Data π^+

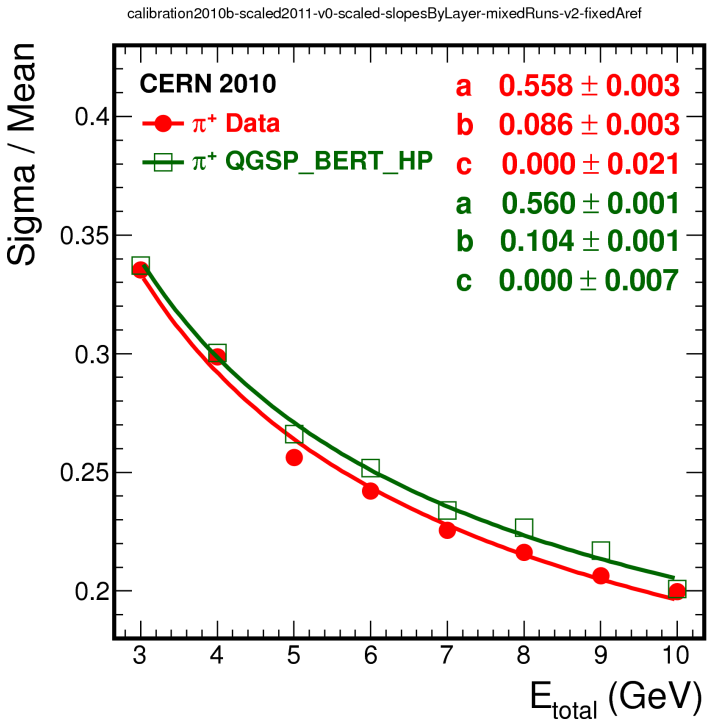


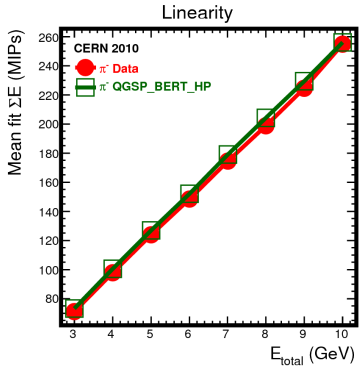
Energy sum fits CERN 2010 MC π^+

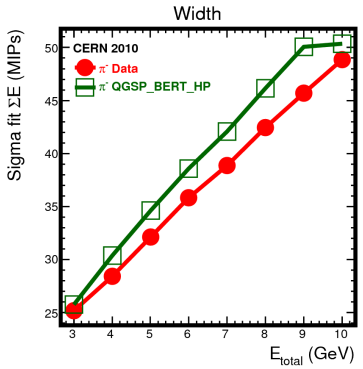


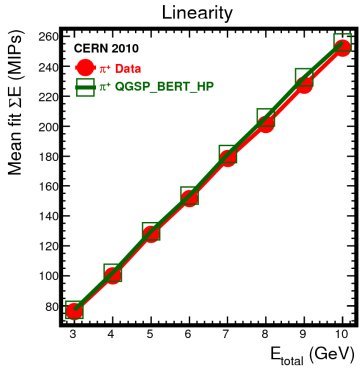
CERN 2010 Energy Resolution π^-, π^+

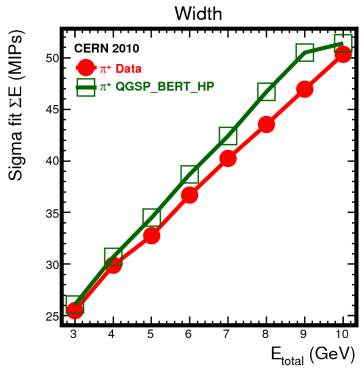






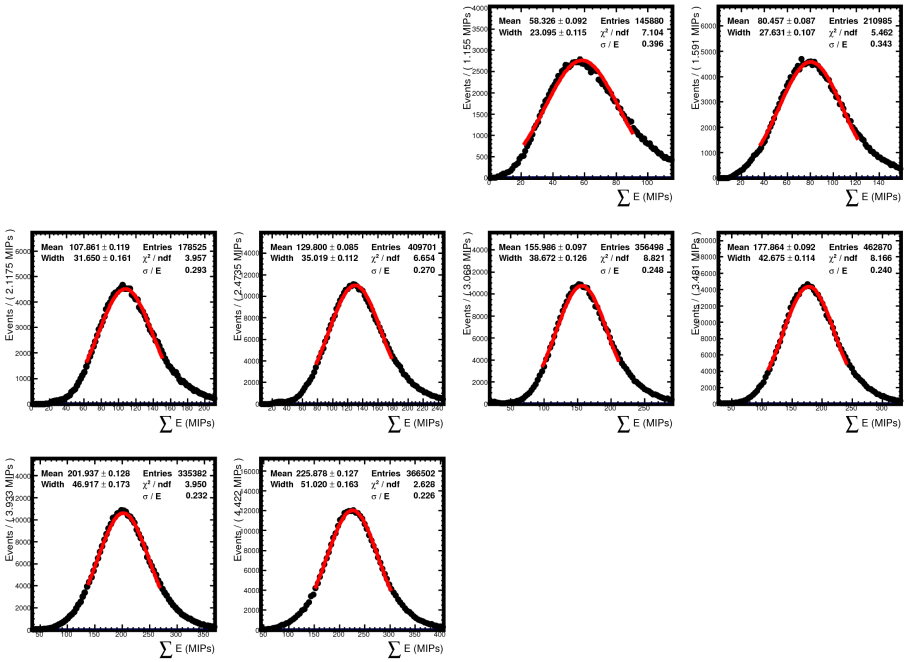






CERN 2010 Energy sum fits p

Energy sum fits CERN 2010 Data Protons



Energy sum fits CERN 2010 MC Protons