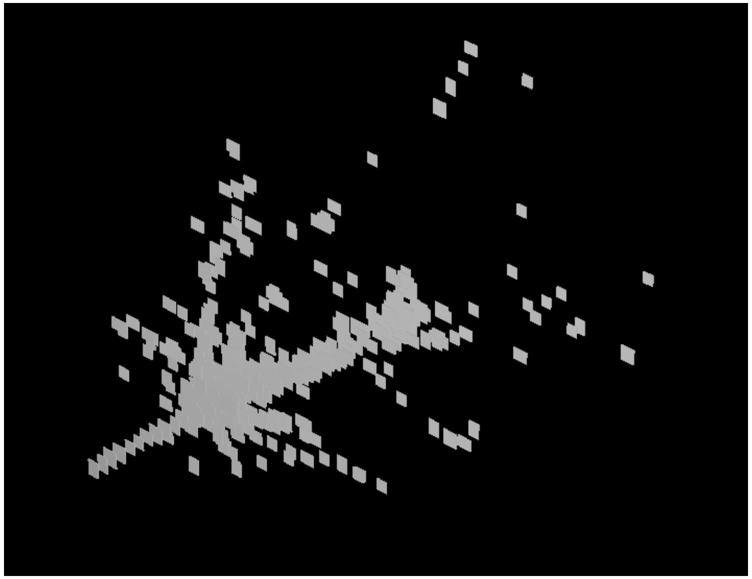
DHCAL Analysis & Simulation

Fermilab testbeam 2011 with Fe absorber



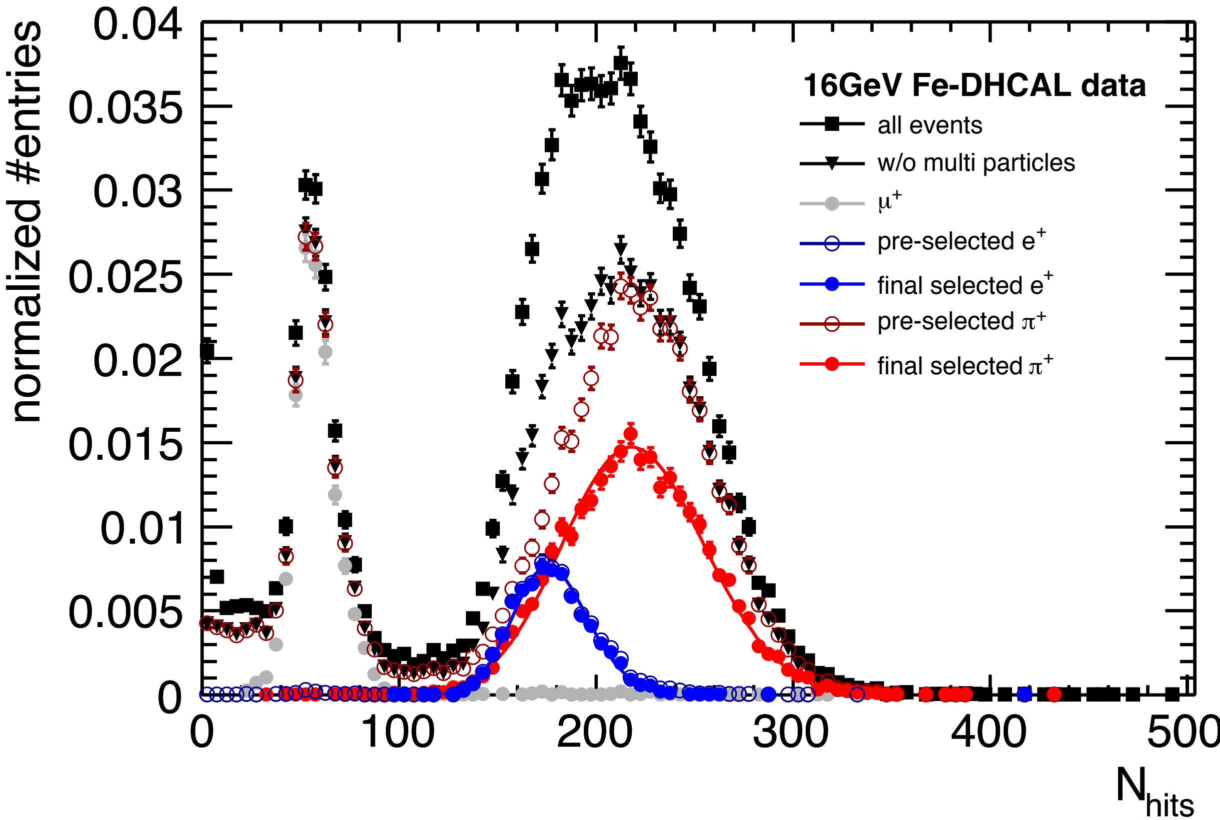
C. Neubüser, K. Krüger
CALICE meeting
Arlington, 16.09.16

Eine Partnerschaft der Universität Hamburg und DESY

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Fe-DHCAL testbeam data

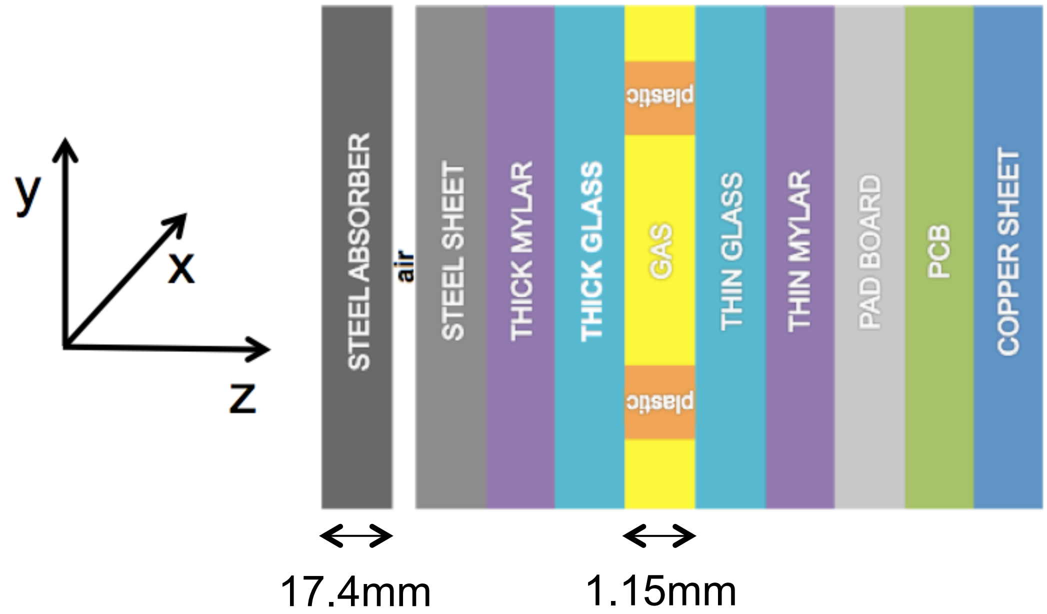
- Beam energies: 2-60GeV
- Mixed beam: μ^+, e^+, π^+ +multi-particle events
- Event selection: Cherenkov counter, shower start algorithm +topological cuts
- 237.062 e^+ events: 2-25GeV
- 135.312 π^+ events: 6-60GeV



Data set has been calibrated and dead channels were identified, see talk at CLICdp meeting 2015:
https://indico.cern.ch/event/376800/contributions/1799923/attachments/751395/1030845/20150602_CLICdpMeeting_FeDHCAL.pdf

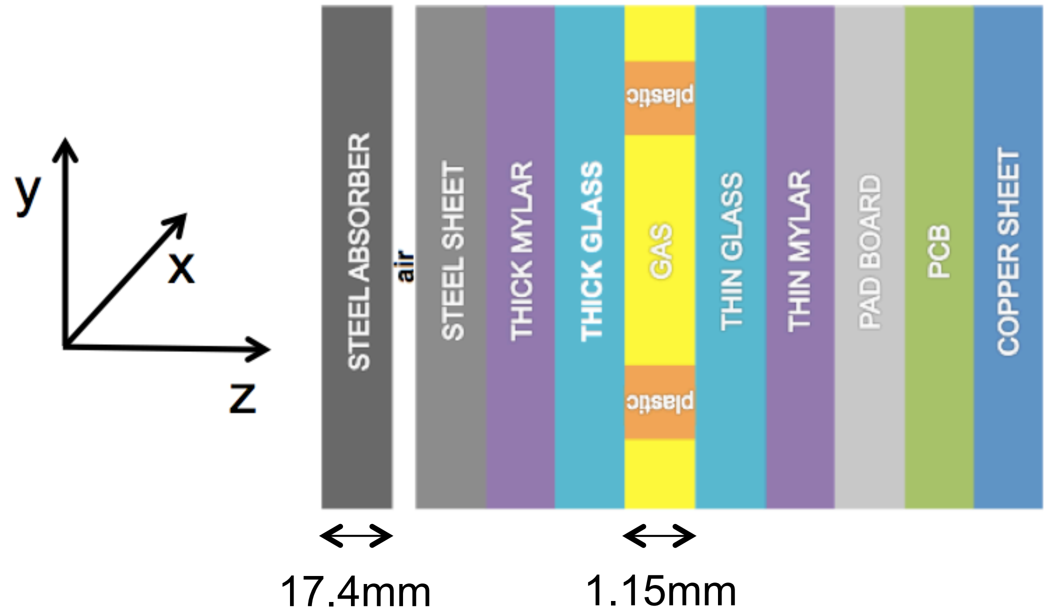
Fe-DHCAL simulation

- Geant4 10.01, Mokka v08-05
- 10,000 events per run, including dead channels list per beam energy
- Output: number of energy deposits in the RPC gas gap (strong dependence on Geant4 modeling)

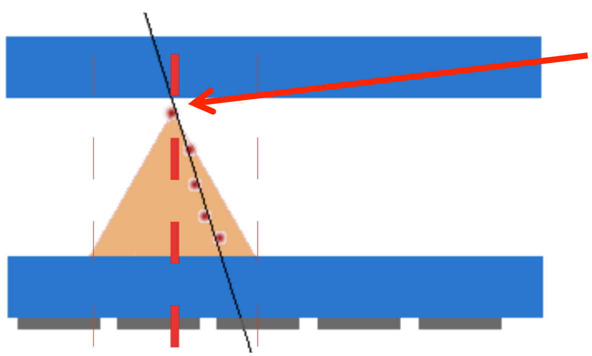


Fe-DHCAL simulation

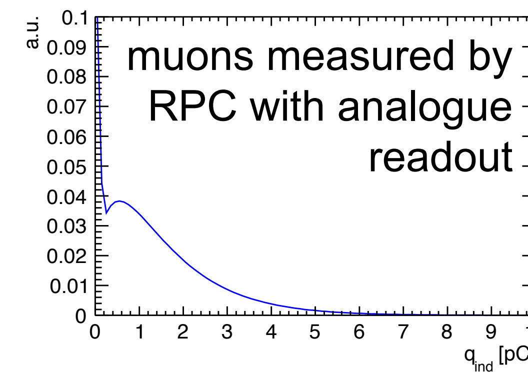
- Geant4 10.01, Mokka v08-05
- 10,000 events per run, including dead channels list per beam energy
- Output: number of energy deposits in the RPC gas gap (strong dependence on Geant4 modeling)



→ Digitisation

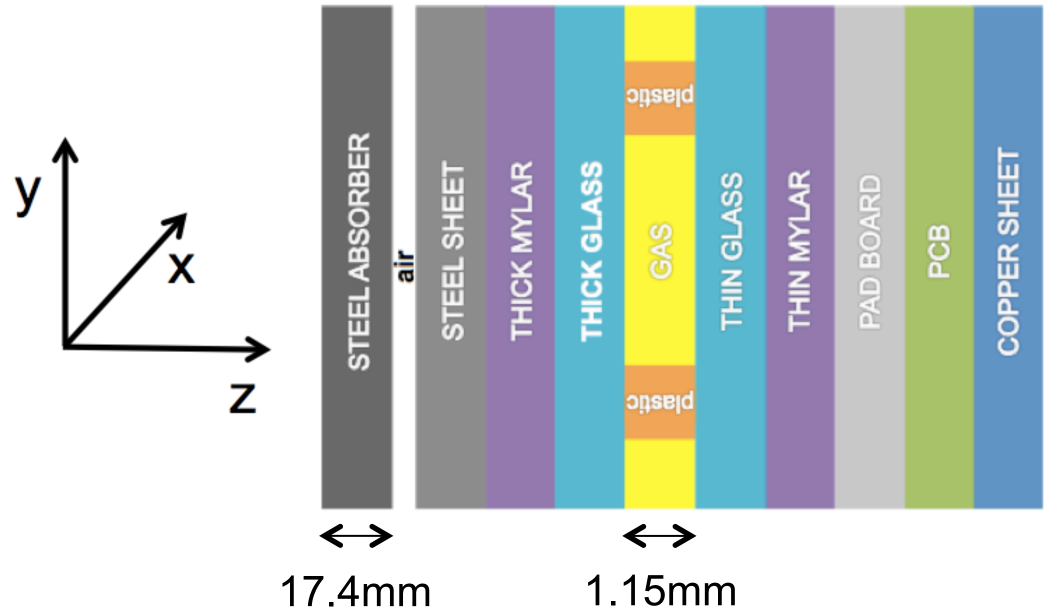


$$Q_{tot} = q_0 \cdot q_{ind}$$

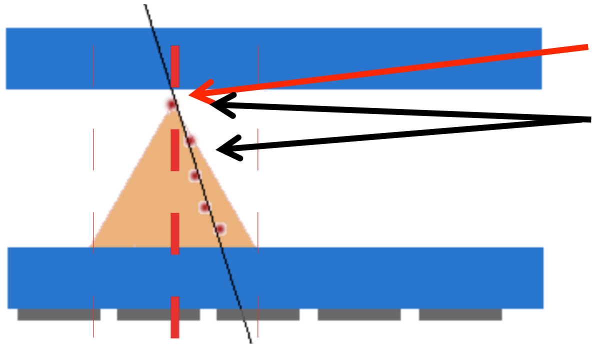


Fe-DHCAL simulation

- Geant4 10.01, Mokka v08-05
- 10,000 events per run, including dead channels list per beam energy
- Output: number of energy deposits in the RPC gas gap (strong dependence on Geant4 modeling)

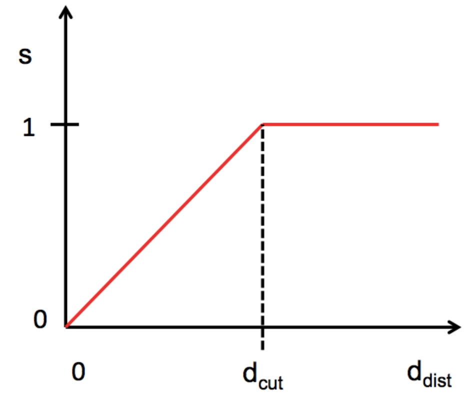


→ Digitisation



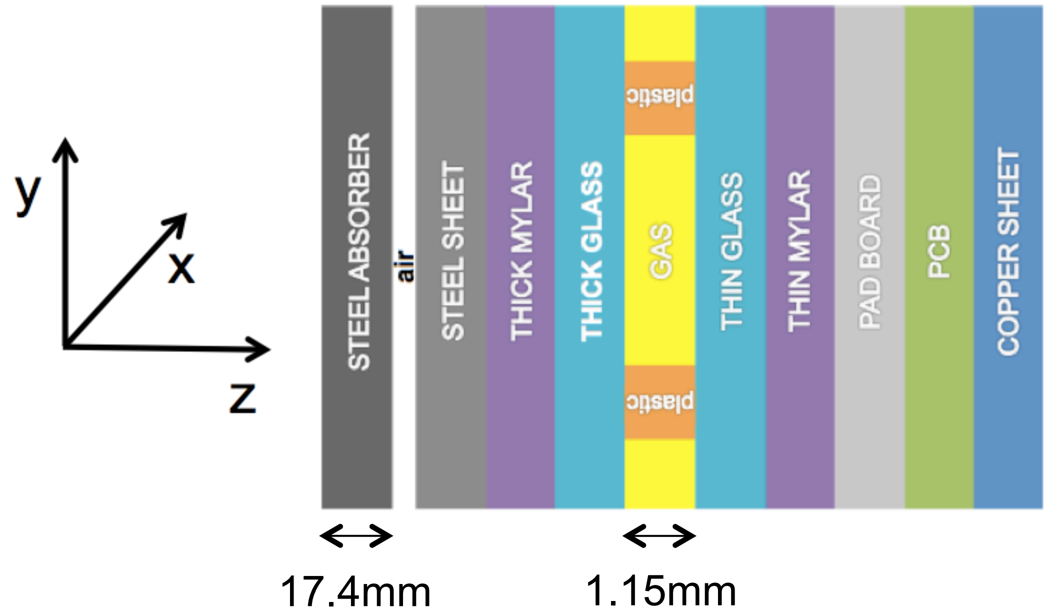
$$Q_{tot} = q_0 \cdot q_{ind}$$

$$d_{dist} < d_{cut} \rightarrow Q_{tot} \cdot s$$

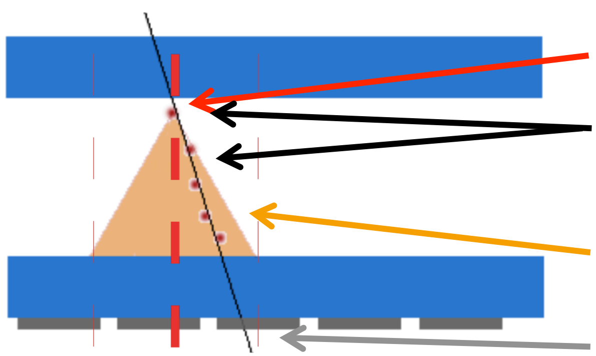


Fe-DHCAL simulation

- Geant4 10.01, Mokka v08-05
- 10,000 events per run, including dead channels list per beam energy
- Output: number of energy deposits in the RPC gas gap (strong dependence on Geant4 modeling)



→ Digitisation

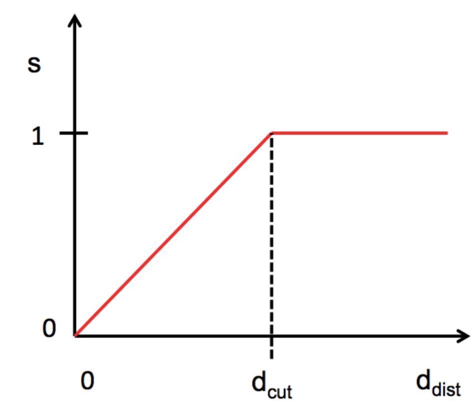


$$Q_{tot} = q_0 \cdot q_{ind}$$

$$d_{dist} < d_{cut} \rightarrow Q_{tot} \cdot s$$

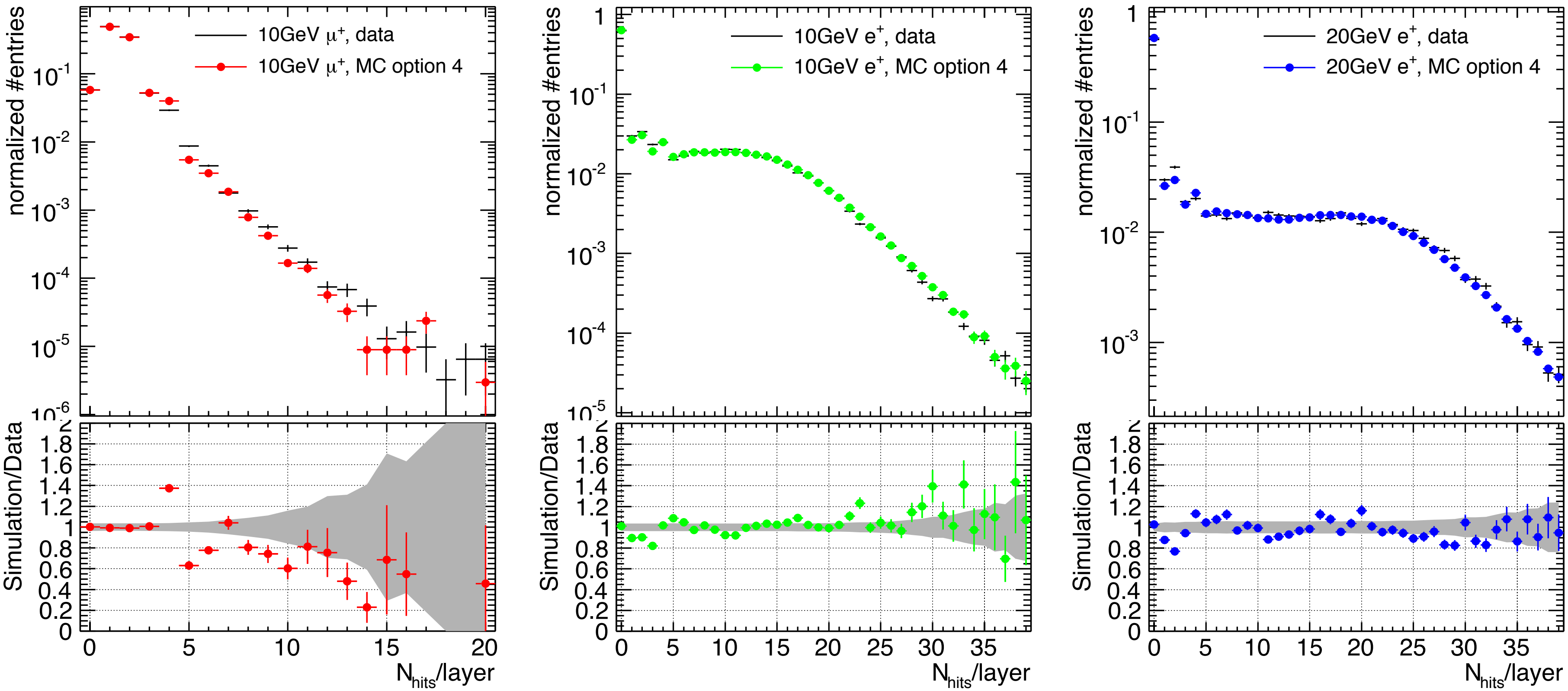
$$f(r) = (R-1) \cdot \exp\left(-\frac{r^2}{2\sigma_1}\right) + R \cdot \exp\left(-\frac{r^2}{2\sigma_2}\right)$$

$$T$$



6 digitisation parameters

Tuning of the digitisation parameters

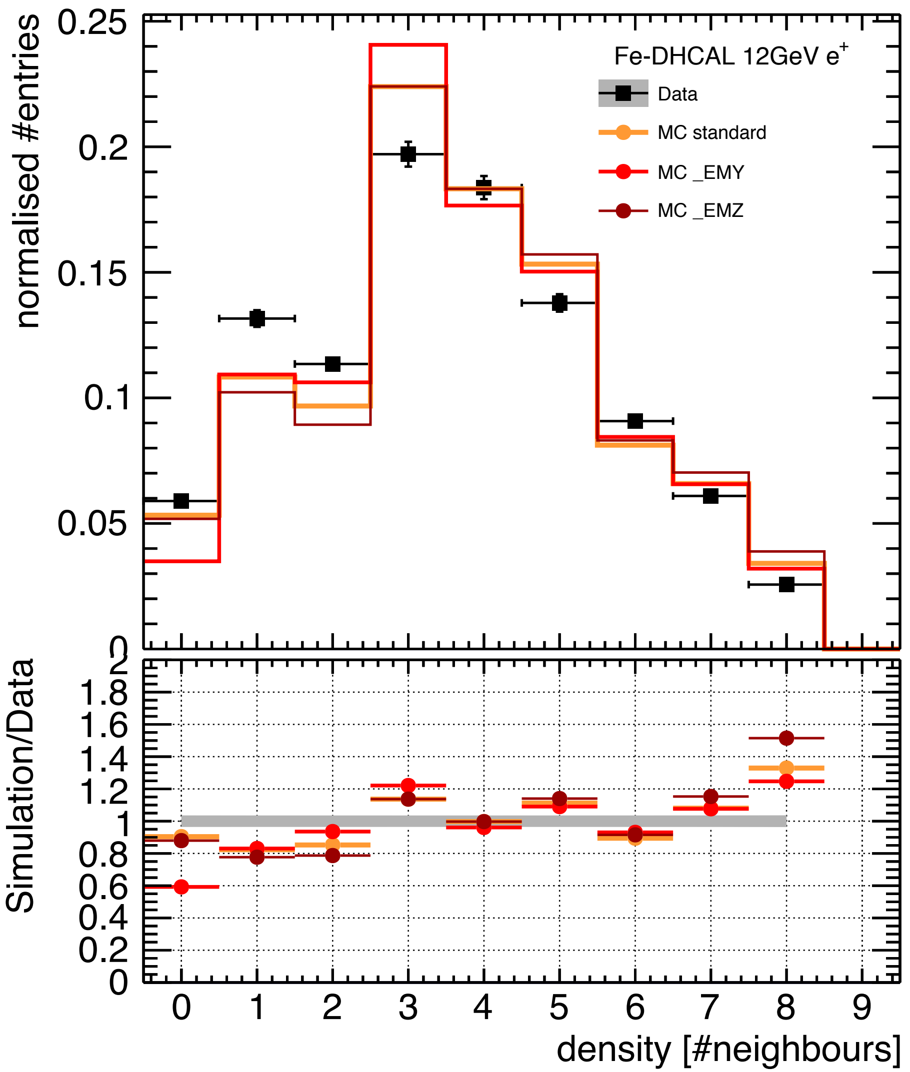


- 10GeV muons and positrons + 20GeV positrons
- Geant4 EM physics lists: standard, _EMY(option 3), _EMZ(option 4)
  - Each EM physics list independent tuning of digitisation parameters

Positron shower analysis

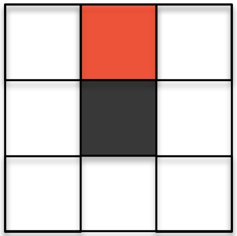
- Hit density

- All simulations show larger (smaller) number of high (low) density hits



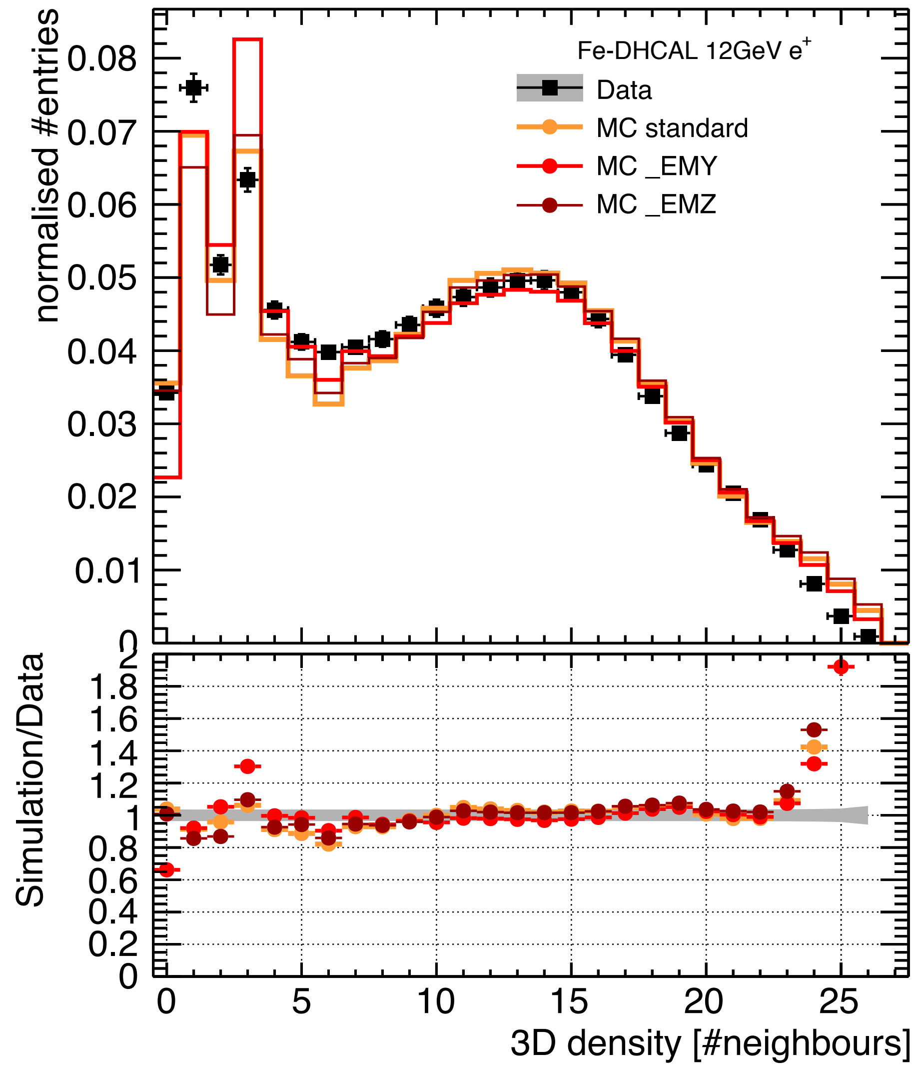
density = 1

layer x

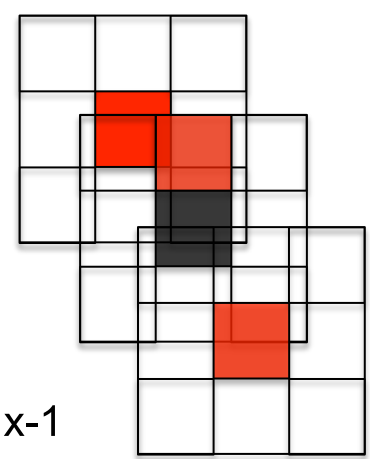


Positron shower analysis

- 3D hit density
- All simulations show larger (smaller) number of very high (low) density hits

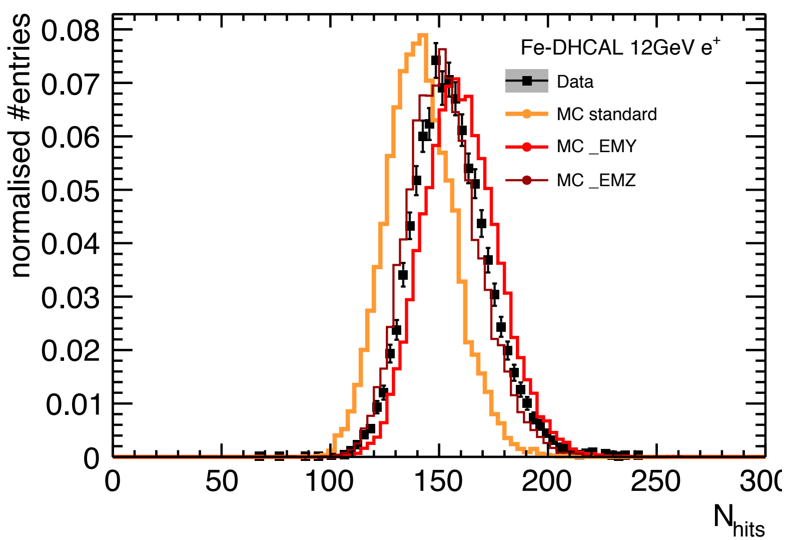


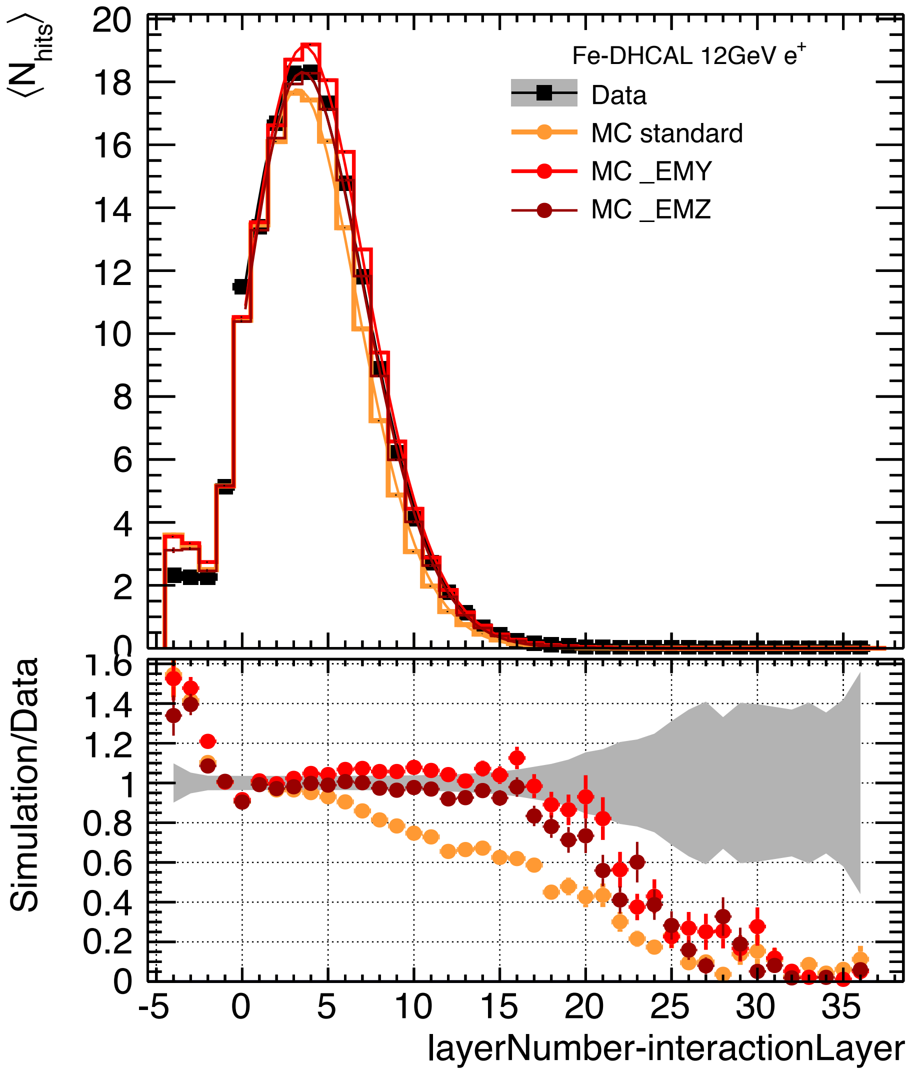
3D density = 3



Positron shower analysis

- Longitudinal profile
  - Fitted with Gamma Distribution
- Strong differences between EM physics lists
- Impact of longitudinal description on N_{hits}



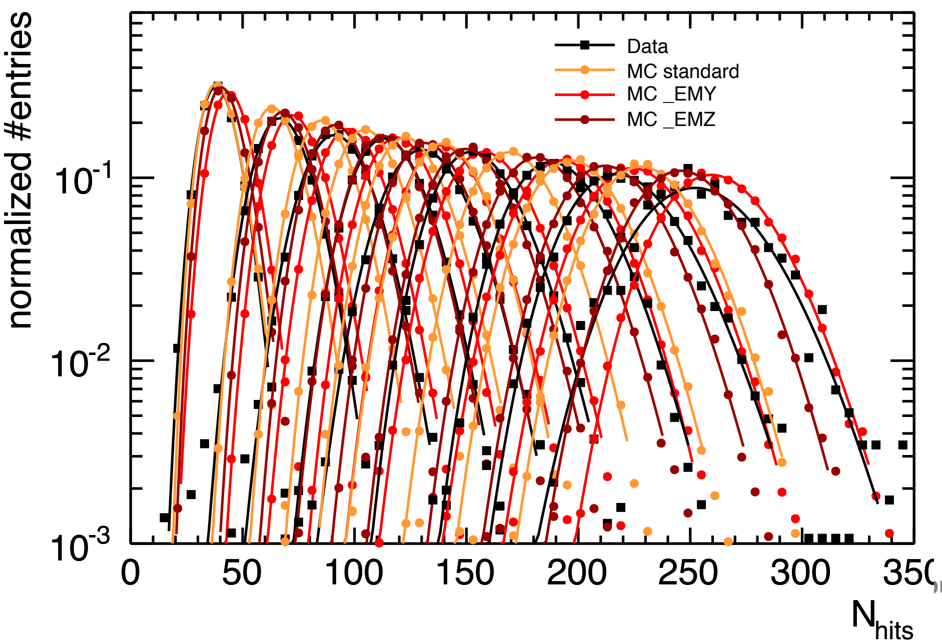


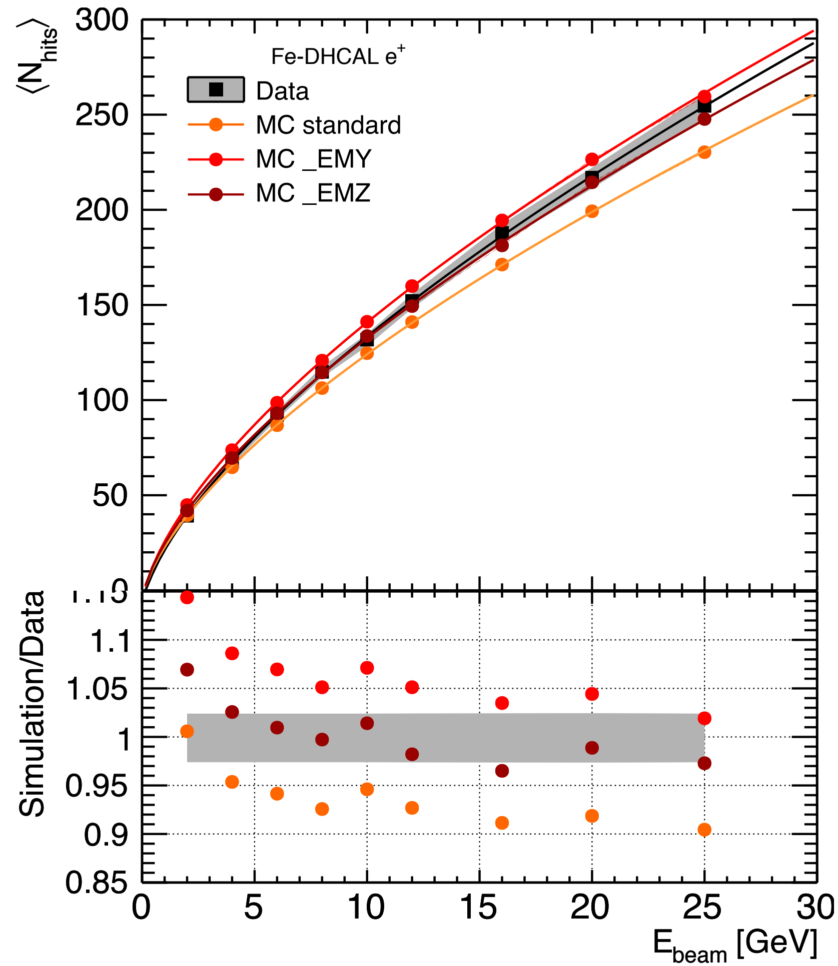
Positron energy reconstruction

- Power law fit of mean response in <N_{hits}> used for the correction of saturation

$$E_{rec,digital} = \left(\frac{N_{hits} - c}{a}\right)^{1/b}$$

- Individual reconstruction for MCs

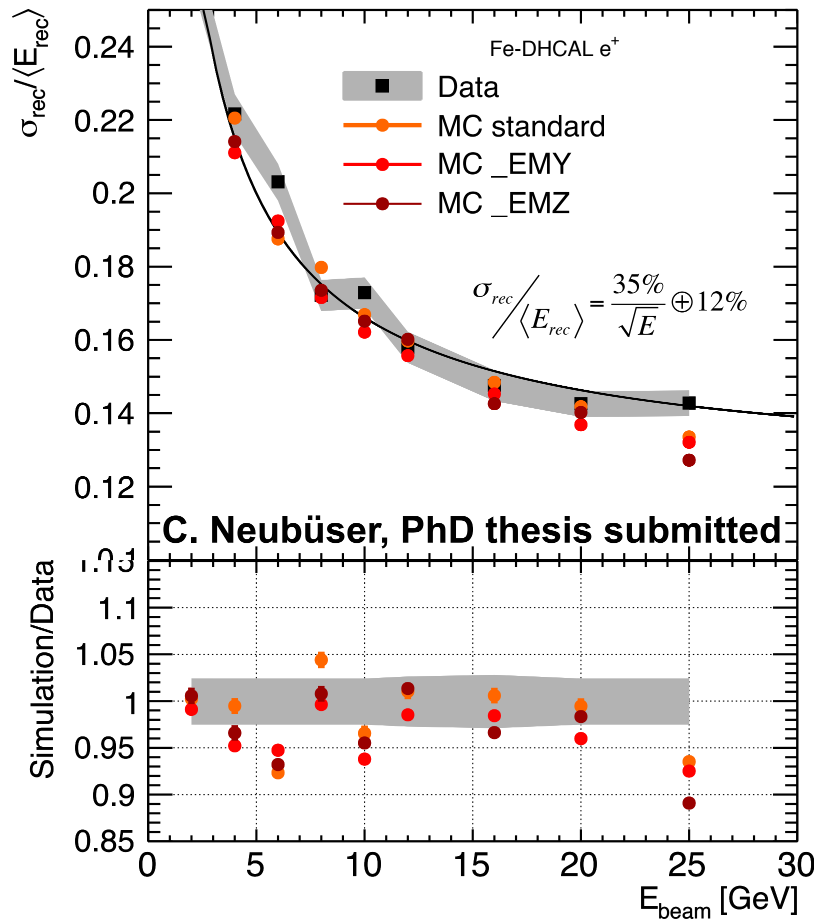


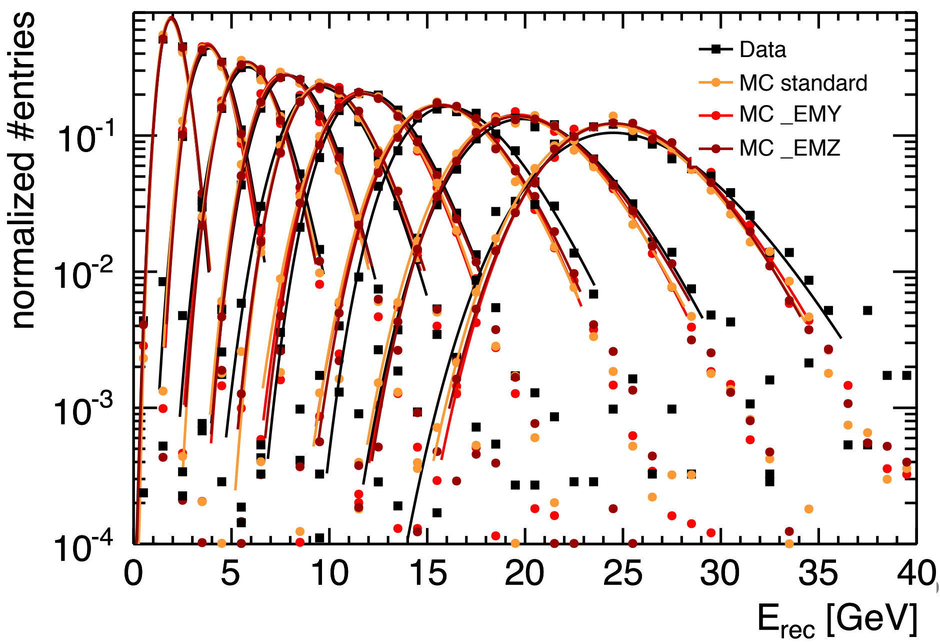


Positron energy resolution

> Energy resolution

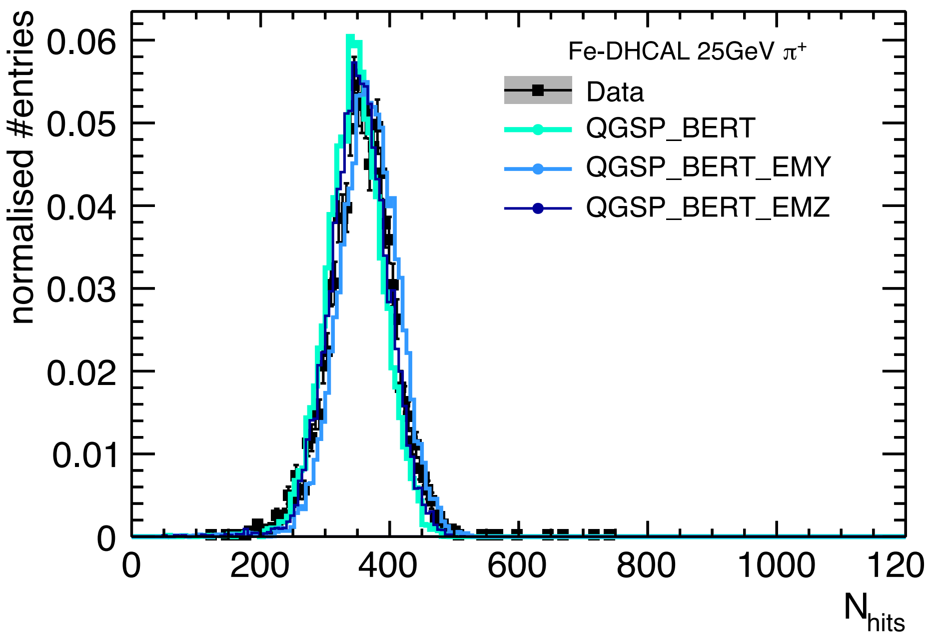
- Good agreement with all EM physics list options
- 25GeV e^+ statistics very limited in data
- Impact of saturation correction visible in shape of distributions

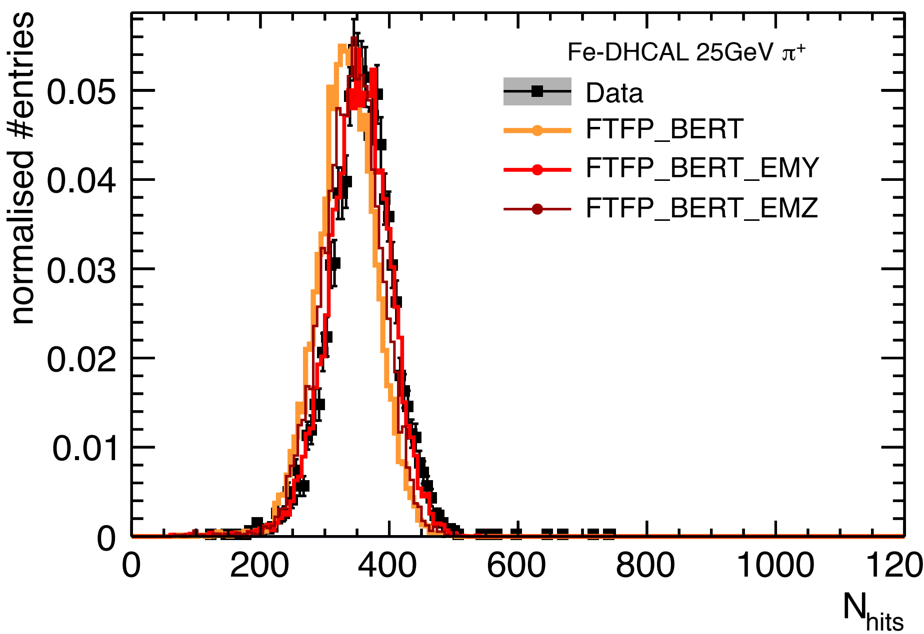




Simulation of pion showers

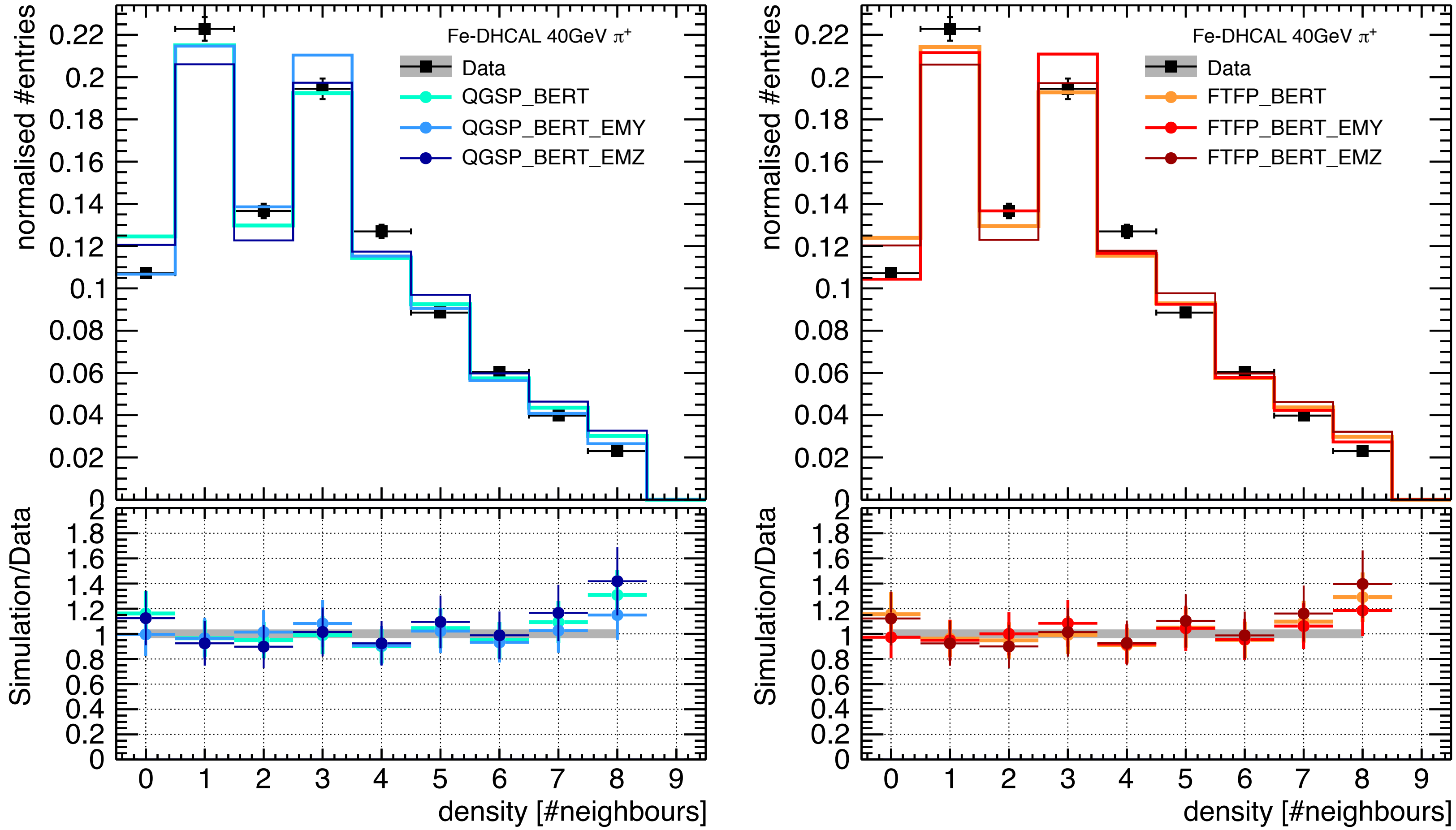
- Additionally to EM physics lists, hadronic physics lists:
  - FTFP_BERT (+ standard, _EMY, _EMZ)
  - QGSP_BERT (+ standard, _EMY, _EMZ)





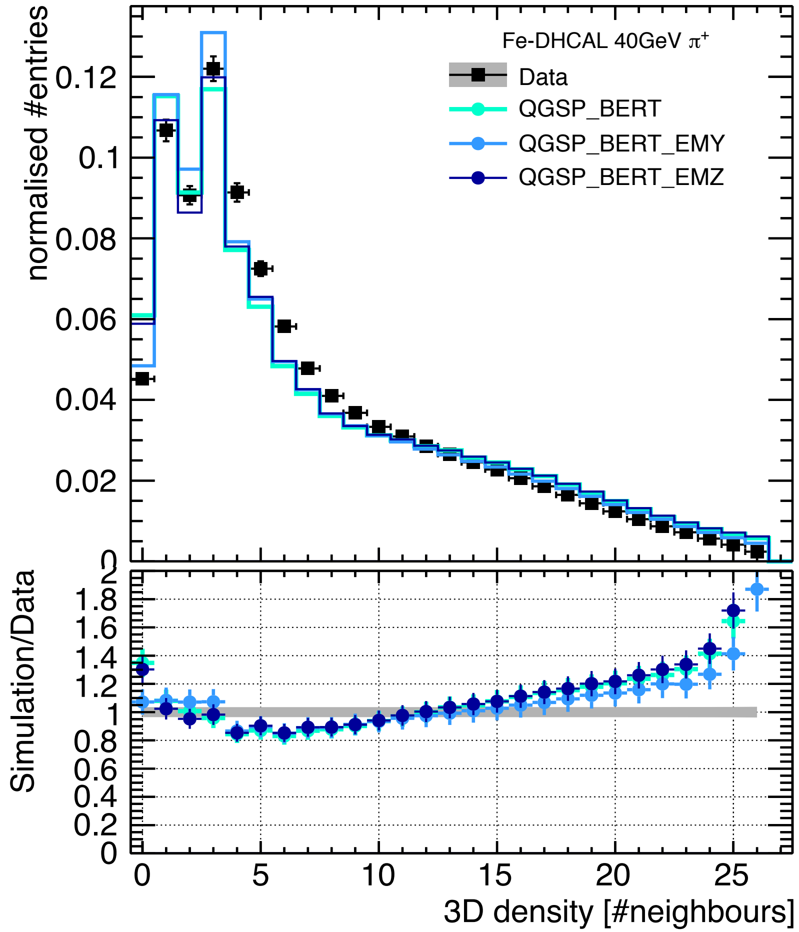
Pion shower analysis

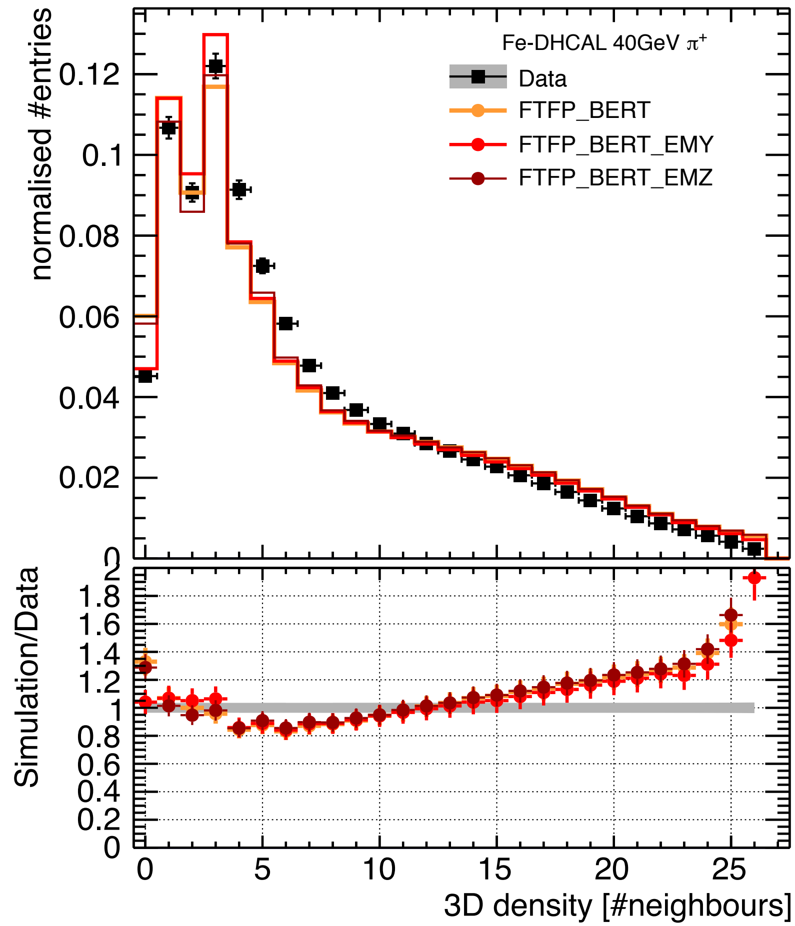
- Hit density



Pion shower analysis

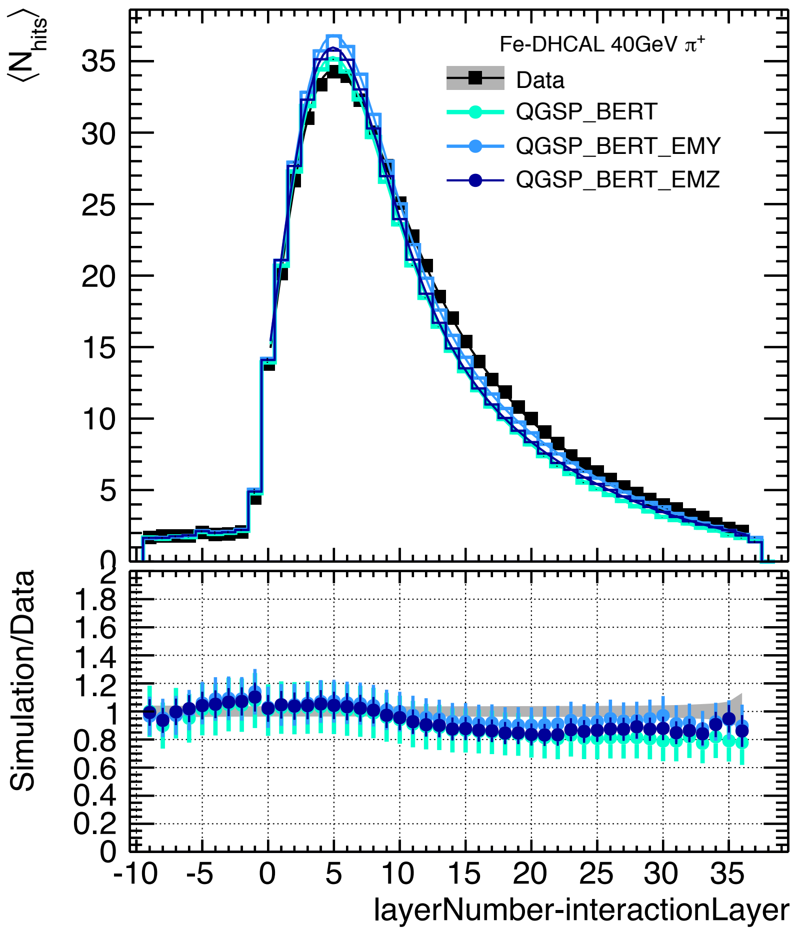
> 3D hit density

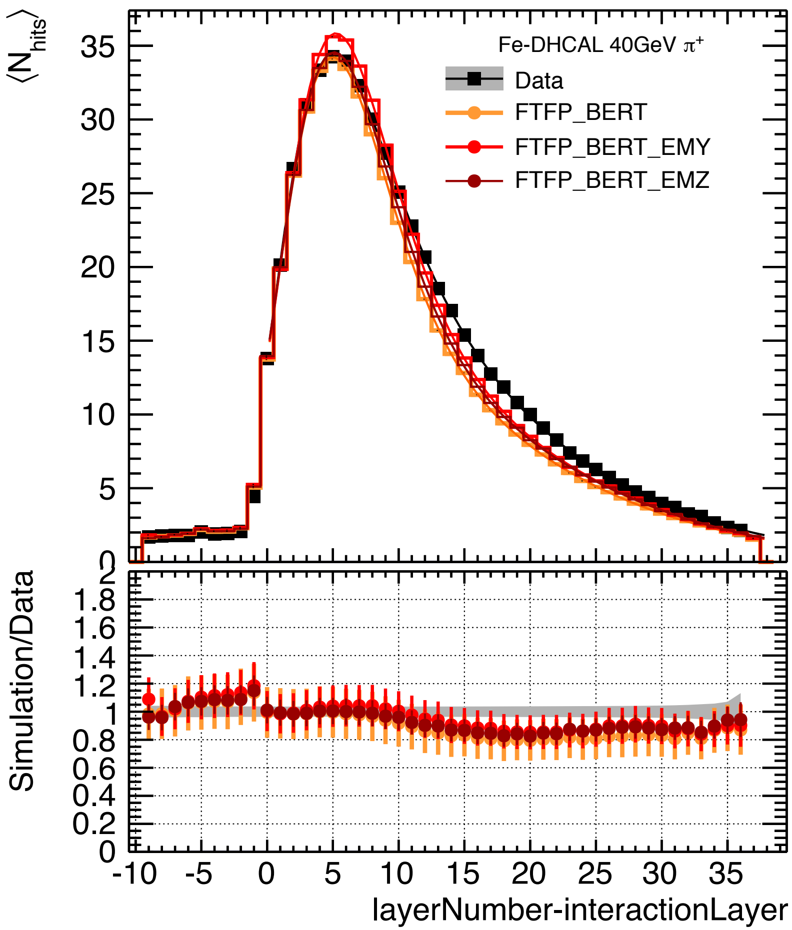




Pion shower analysis

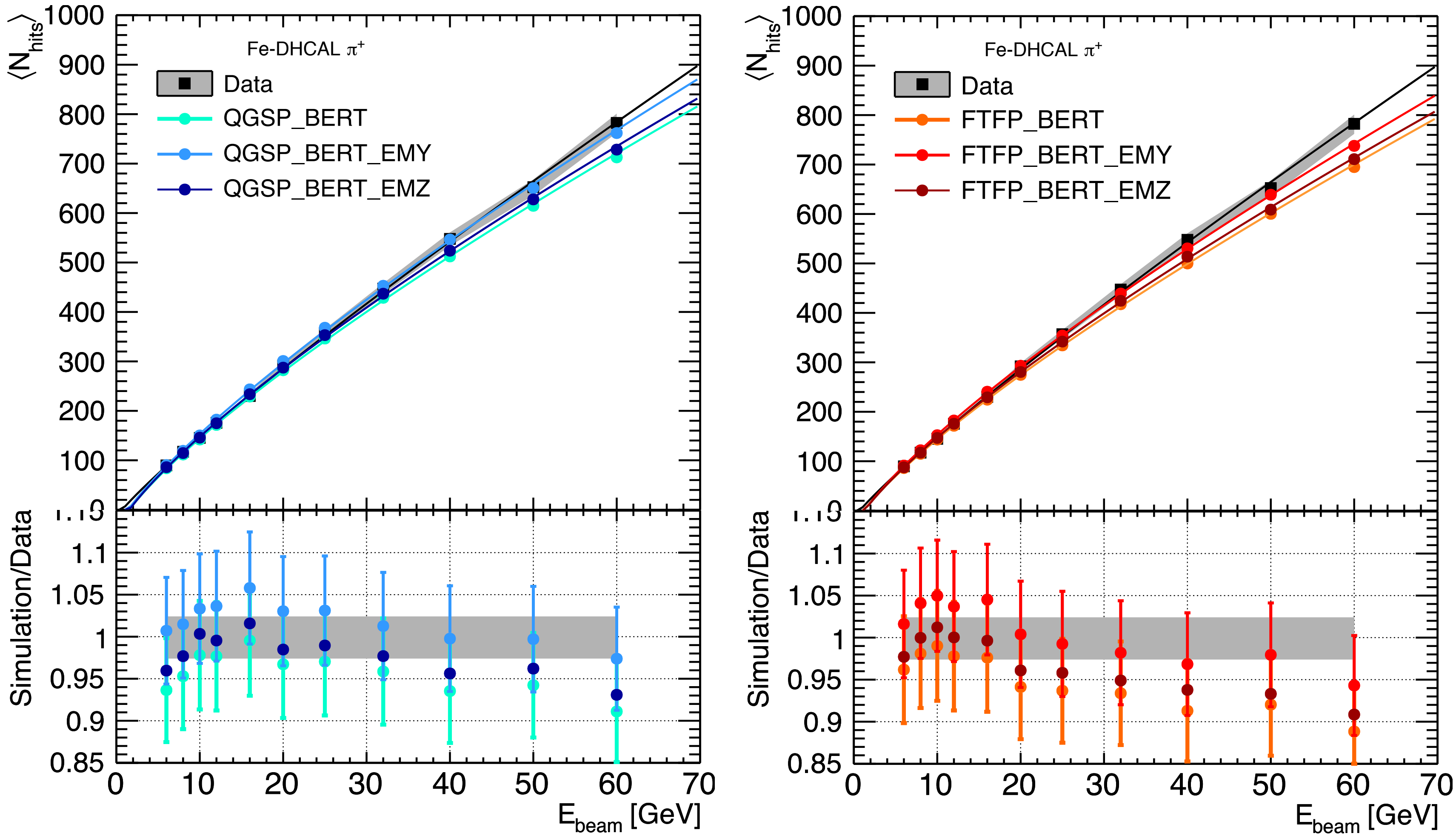
> Longitudinal profiles



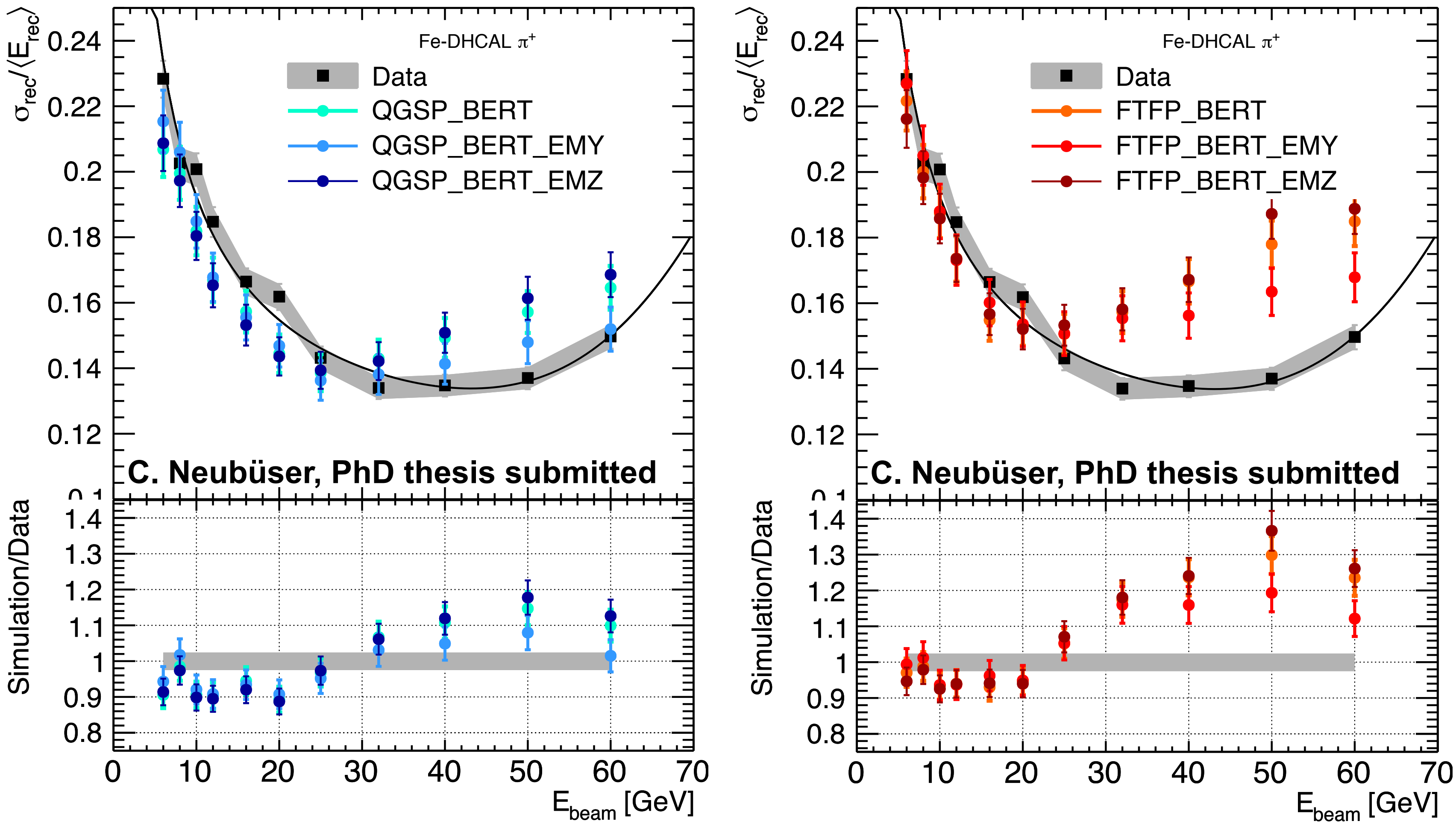


Pion energy reconstruction

> Mean Response, fitted with power law (→ correction for saturation)



Pion energy resolution

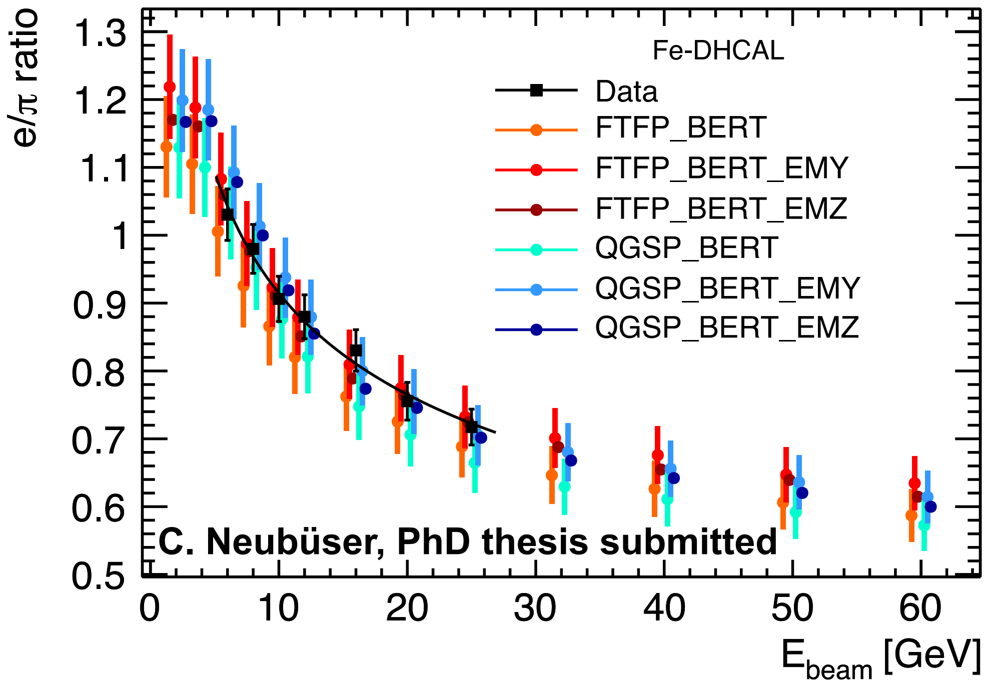


> QGSP_BERT_EMY physics list achieves best agreement with data

e/pi ratio

- e/pi ratio estimated from mean response to e^+ and pi^+ showers
- Data and all simulations agree within error bands
- From fit estimated ratio of EM and hadronic shower parts:

$$e/h = 0.62 \pm 0.04$$



→ Clear indication for possibility to improve resolutions by Software Compensation → see talk at CALICE meeting KEK 2015

https://agenda.linearcollider.org/event/6557/contributions/31752/attachments/26182/40131/20150420_CaliceMeetingKEK_SCforDHCAL.pdf

Conclusions

- Fe-DHCAL simulation strongly effected by the EM physics lists of Geant4
- Good agreement with _EMZ option for EM showers
- Good agreement with QGSP_BERT_EMY for π^+ showers

→ Paper with these results is in preparation

→ The validation of the RPC based DHCAL simulation allows further studies for a better understanding of the influences on the energy resolution (pad size, sampling fraction) and an implementation in full-size detector model → PFA performance

Thank you!

BACKUP

Positron energy resolution

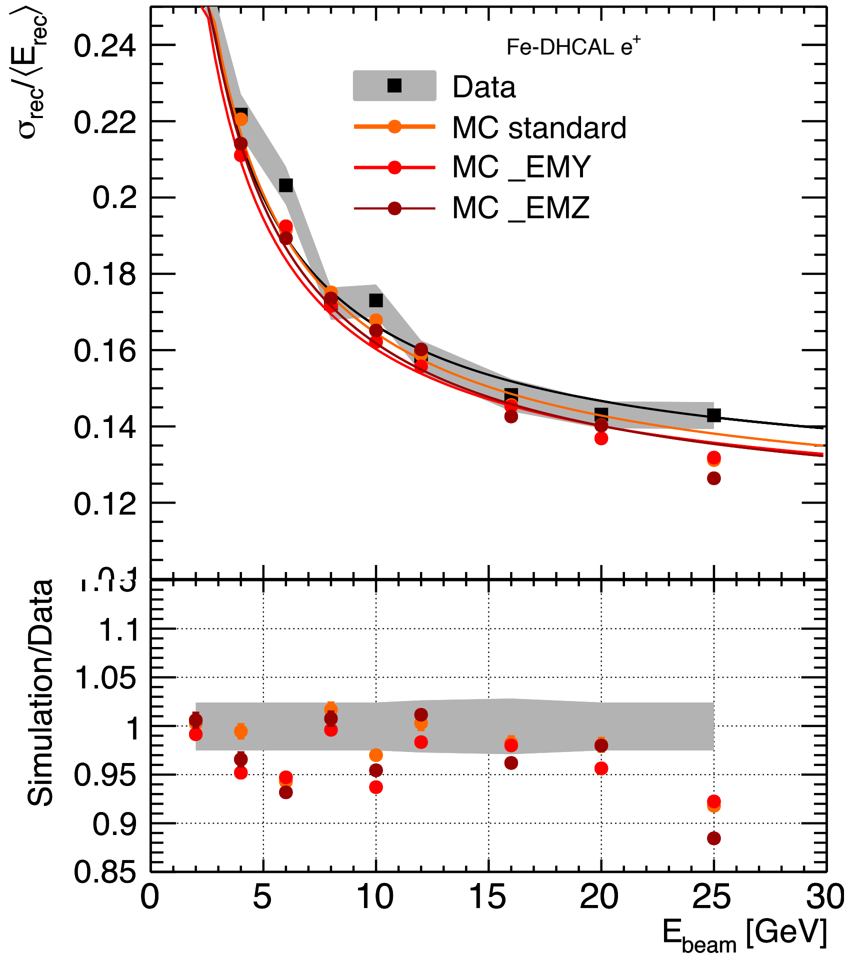
- Energy resolution
  - Good agreement with all EM physics list options
  - 25GeV e^+ statistics very limited in data
  - Fit 0-100

$$\sigma_{rec} / \langle E_{rec} \rangle = \frac{35.1\%}{\sqrt{E}} \oplus 12.4\%$$

$$\sigma_{rec} / \langle E_{rec} \rangle = \frac{36.4\%}{\sqrt{E}} \oplus 11.7\%$$

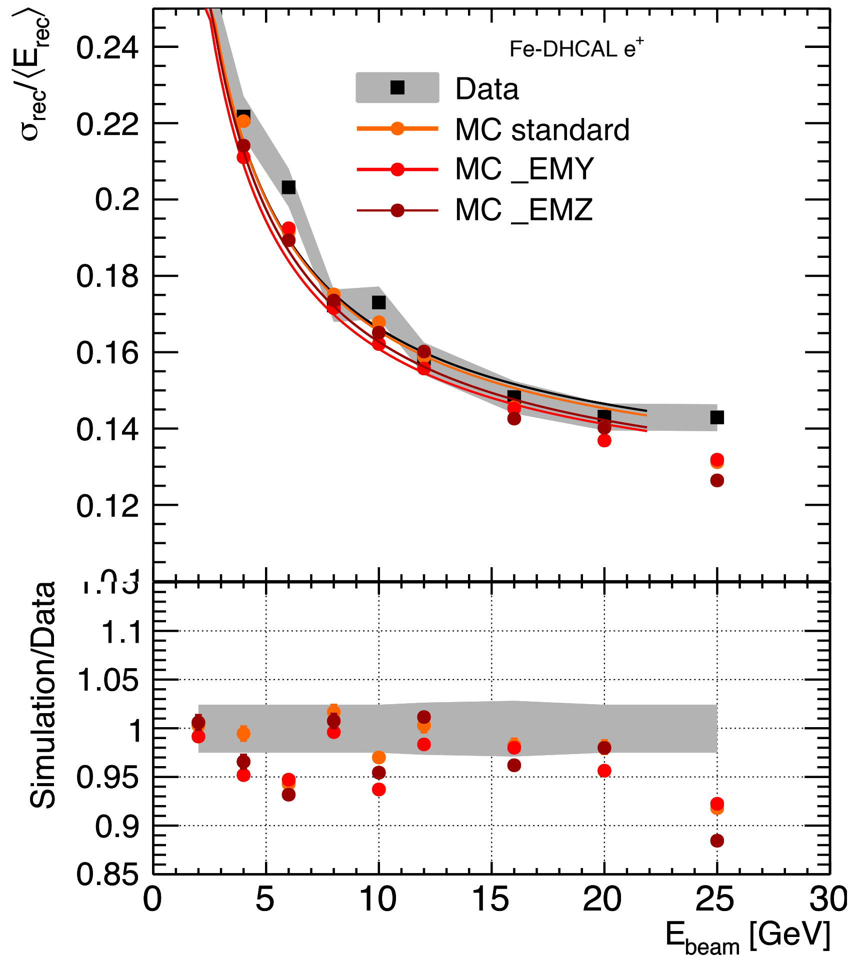
$$\sigma_{rec} / \langle E_{rec} \rangle = \frac{34.8\%}{\sqrt{E}} \oplus 11.6\%$$

$$\sigma_{rec} / \langle E_{rec} \rangle = \frac{36.1\%}{\sqrt{E}} \oplus 11.4\%$$



Positron energy resolution

- Energy resolution
  - Good agreement with all EM physics list options
  - 25GeV e^+ statistics very limited in data
  - Fit 0-22



$$\sigma_{rec}/\langle E_{rec}\rangle = \frac{35.2\%}{\sqrt{E}} \oplus 12.4\%$$

$$\sigma_{rec}/\langle E_{rec}\rangle = \frac{35.4\%}{\sqrt{E}} \oplus 12.2\%$$

$$\sigma_{rec}/\langle E_{rec}\rangle = \frac{34.5\%}{\sqrt{E}} \oplus 11.8\%$$

$$\sigma_{rec}/\langle E_{rec}\rangle = \frac{35.3\%}{\sqrt{E}} \oplus 11.8\%$$