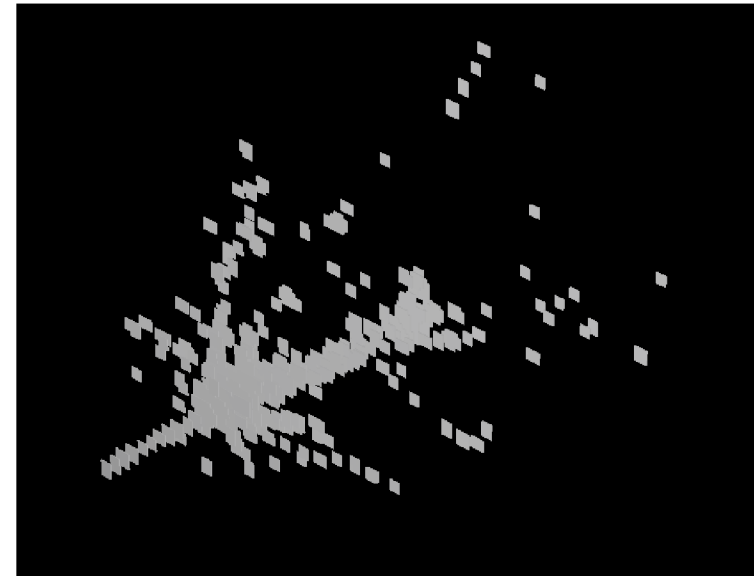


DHCAL Analysis & Simulation

Fermilab testbeam 2011 with Fe absorber

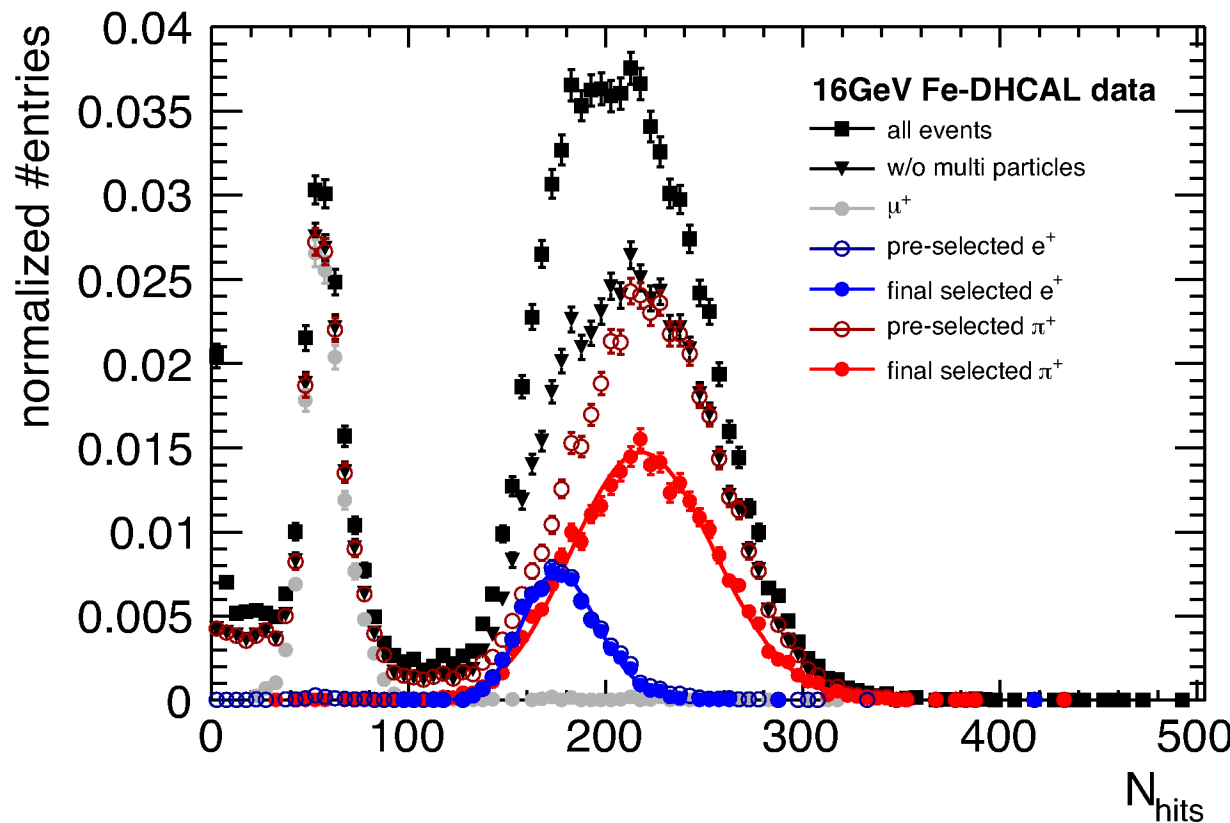


C. Neubüser, [K. Krüger](#)
CALICE meeting
Arlington, 16.09.16



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



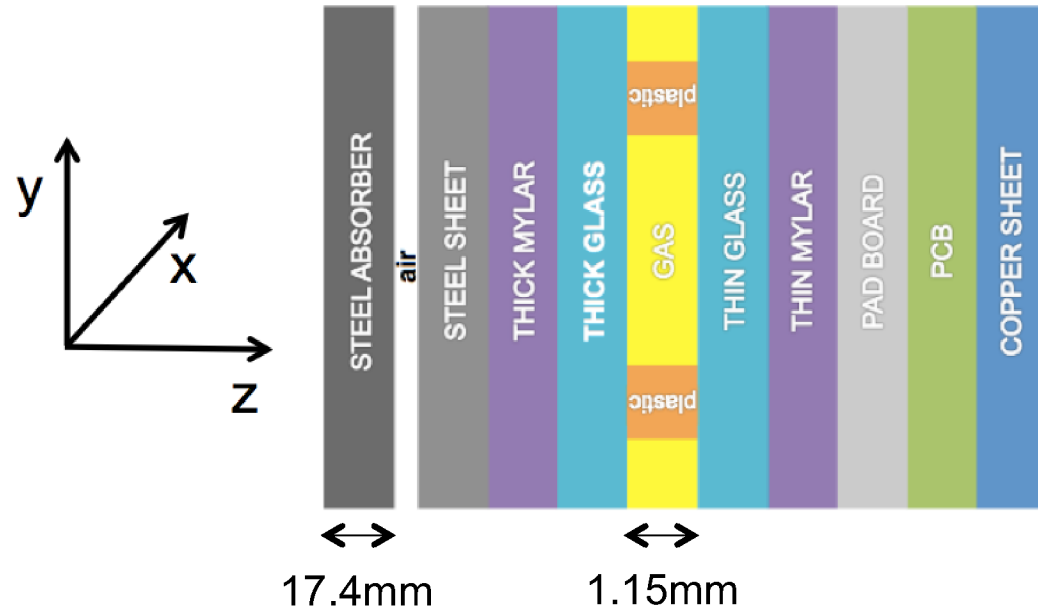
Data set has been calibrated and dead channels were identified, see talk at CLICdp meeting 2015:

https://indico.cern.ch/event/376800/contributions/1799923/attachments/751395/1030845/20150602_CLICdpMeeting_FeDHCAL.pdf



Fe-DHCAL simulation

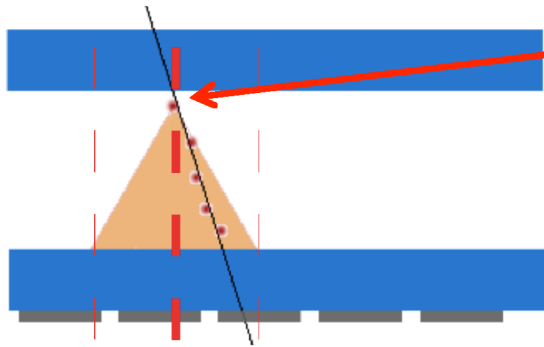
- > Geant4 10.01, Mokka v08-05
- > 10,000 events per run, including dead channels list per beam energy
- > Output: number of energy deposits in the RPC gas gap (strong dependence on Geant4 modeling)



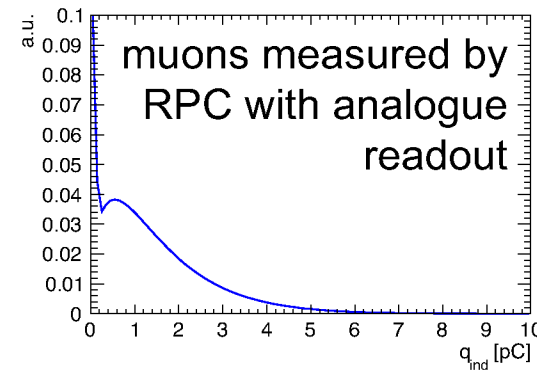
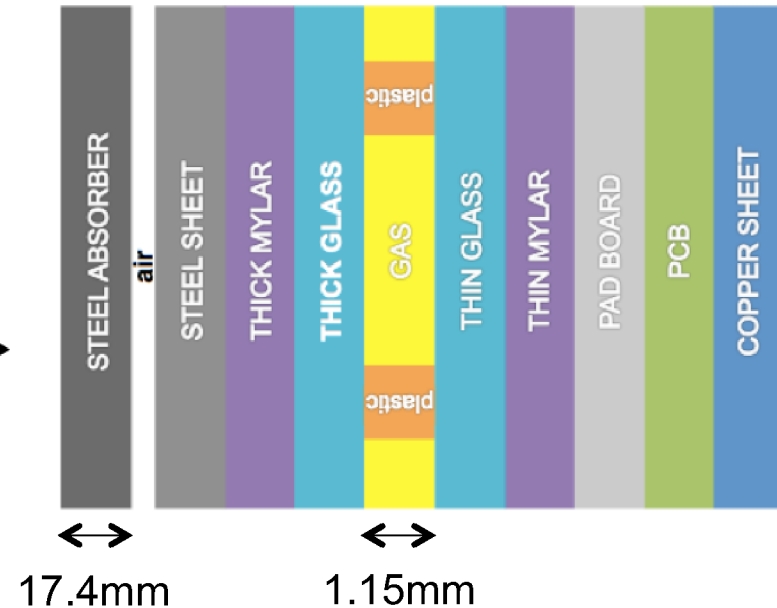
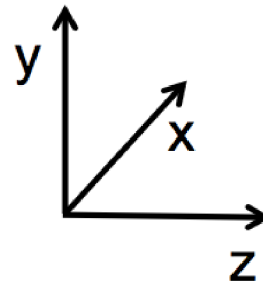
Fe-DHCAL simulation

- 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

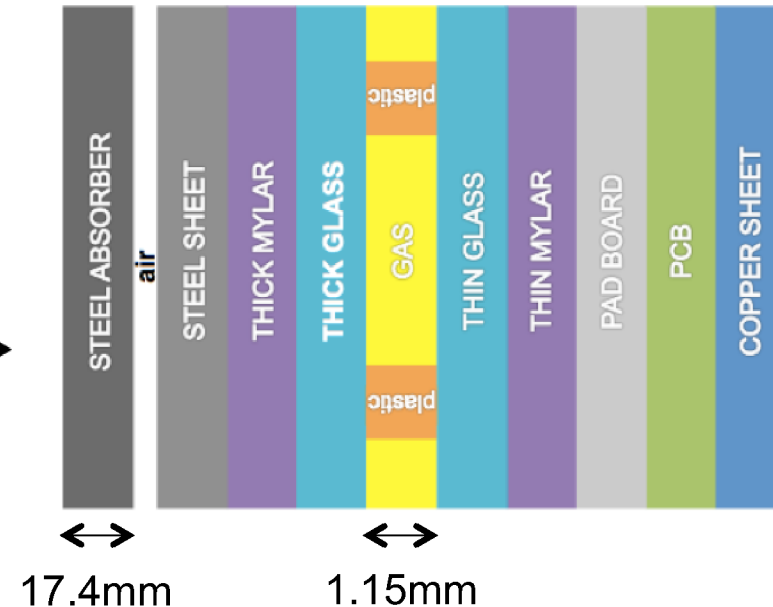
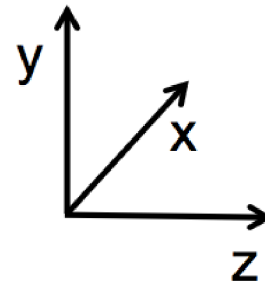


$$Q_{tot} = q_0 \cdot q_{ind}$$

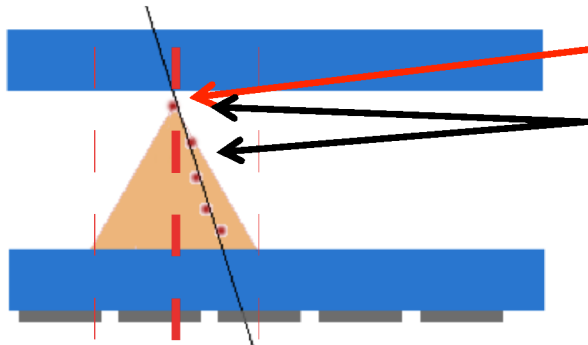


Fe-DHCAL simulation

- 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)

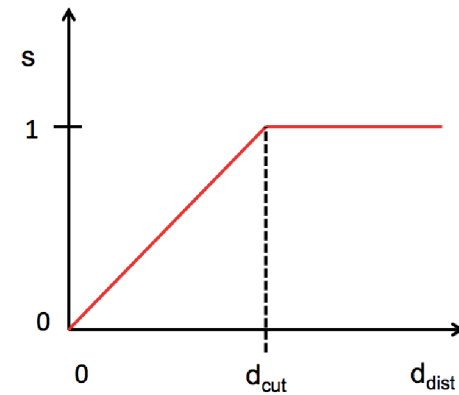


→ Digitisation



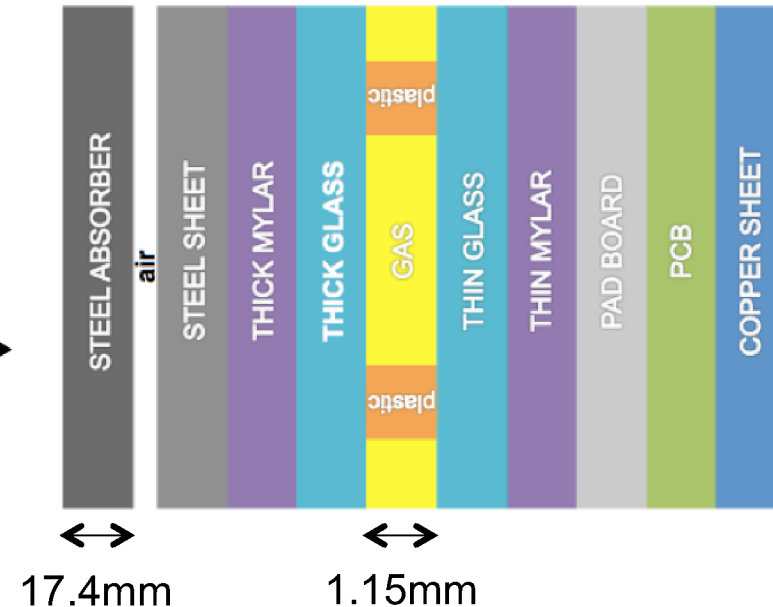
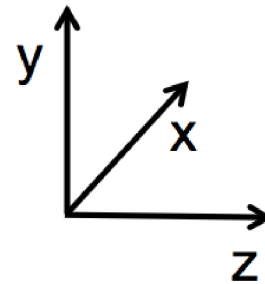
$$Q_{tot} = q_0 \cdot q_{ind}$$

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

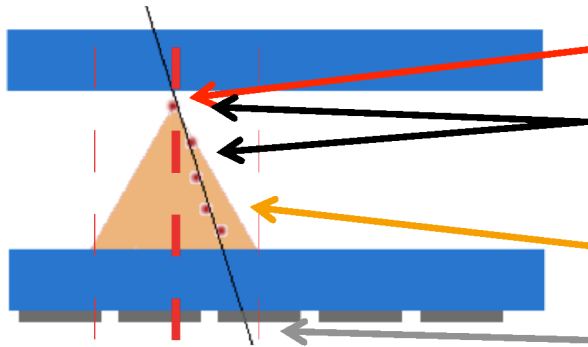


Fe-DHCAL simulation

- > 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

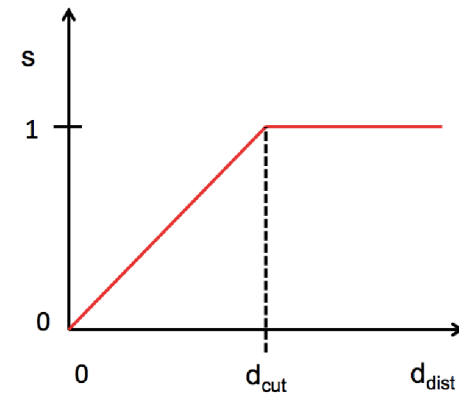


$$Q_{tot} = q_0 \cdot q_{ind}$$

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

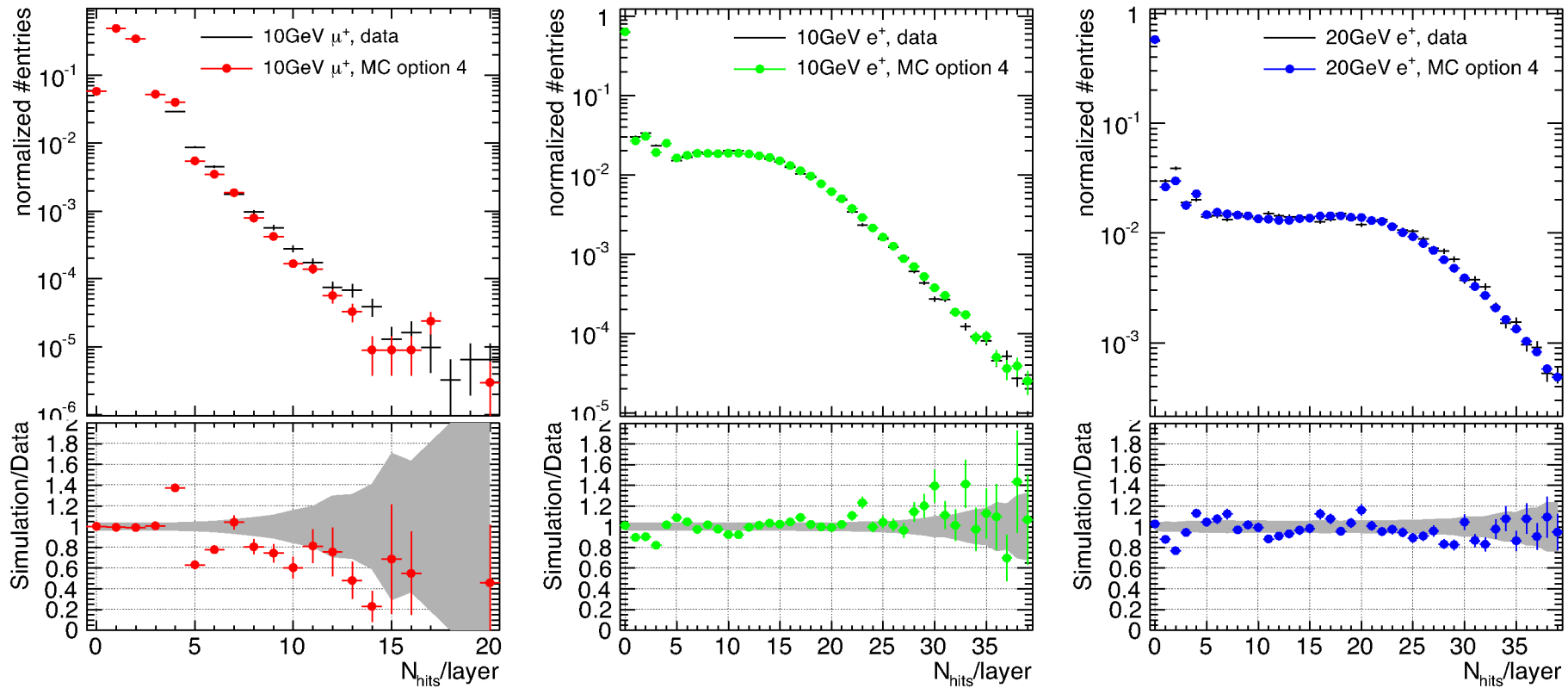
$$f(r) = (R-1) \cdot \exp\left(-\frac{r^2}{2\sigma_1}\right) + R \cdot \exp\left(-\frac{r^2}{2\sigma_2}\right)$$

T



6 digitisation parameters

Tuning of the digitisation parameters

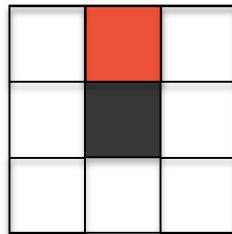


- 10GeV muons and positrons + 20GeV positrons
- Geant4 EM physics lists: standard, _EMY(option 3), _EMZ(option 4)
 - Each EM physics list independent tuning of digitisation parameters

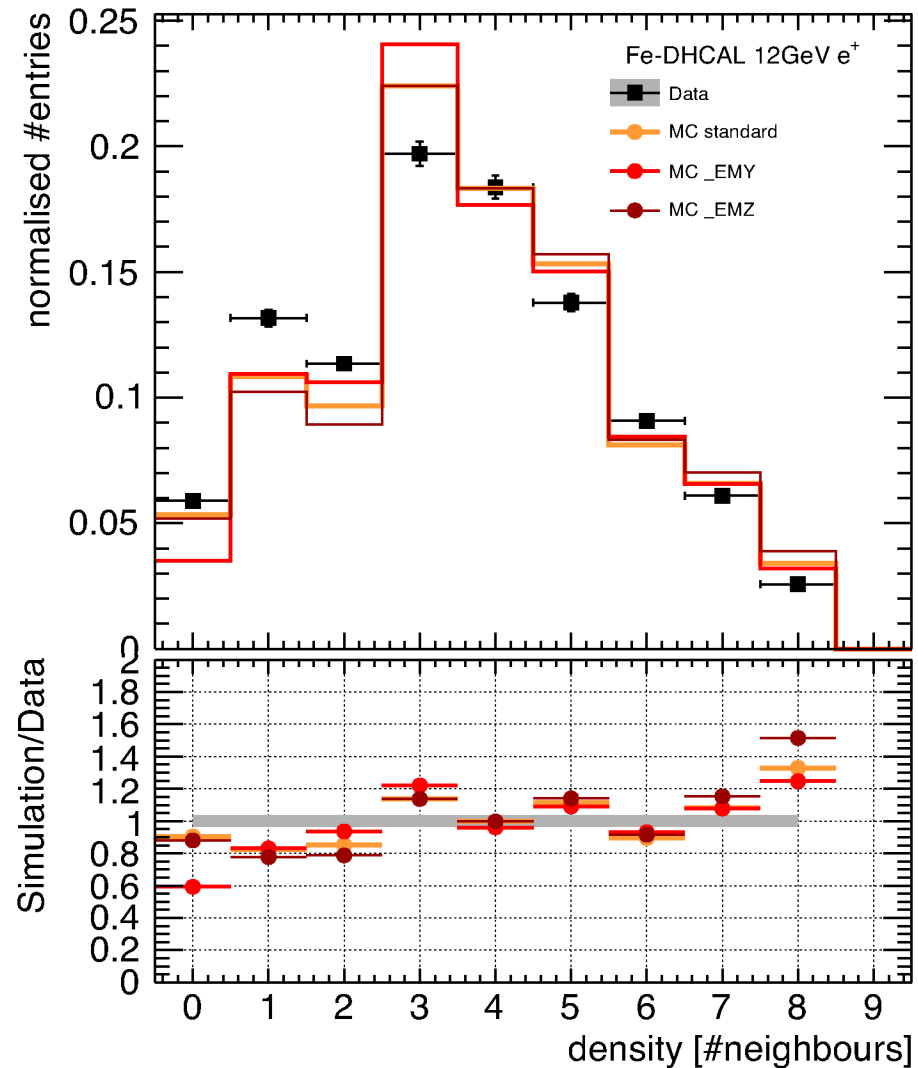
Positron shower analysis

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

density = 1



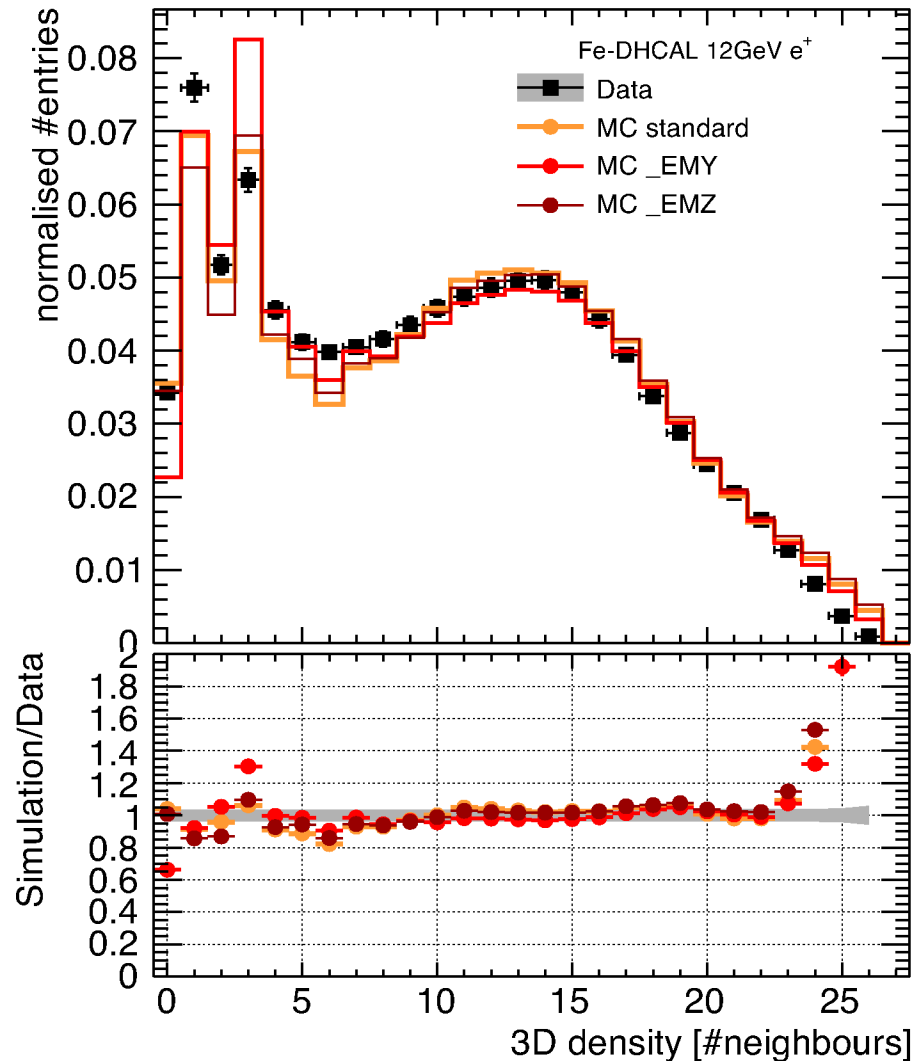
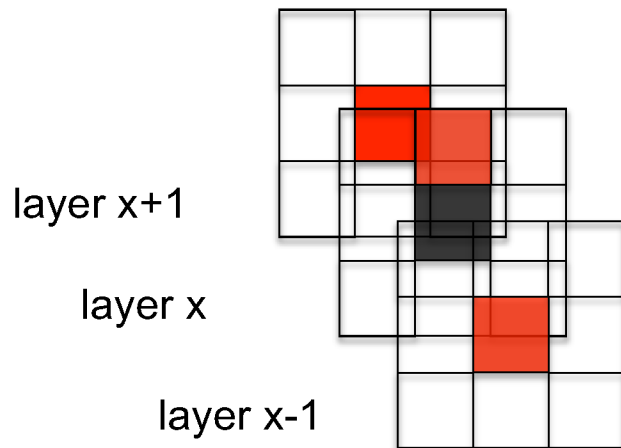
layer x



Positron shower analysis

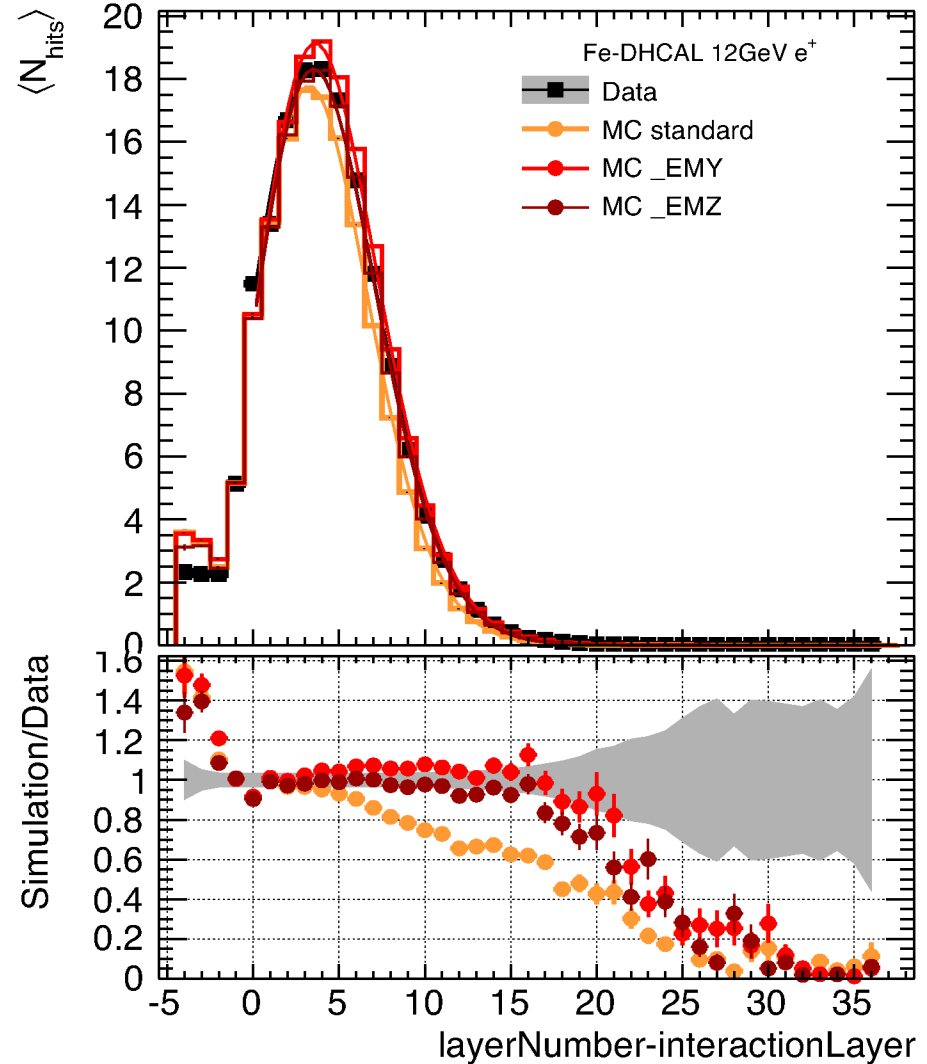
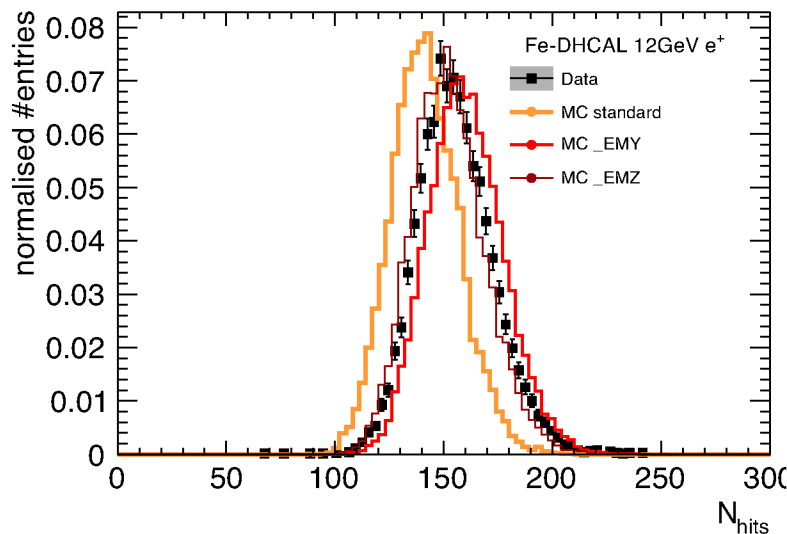
- > 3D hit density
- > All simulations show larger (smaller) number of very high (low) density hits

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}

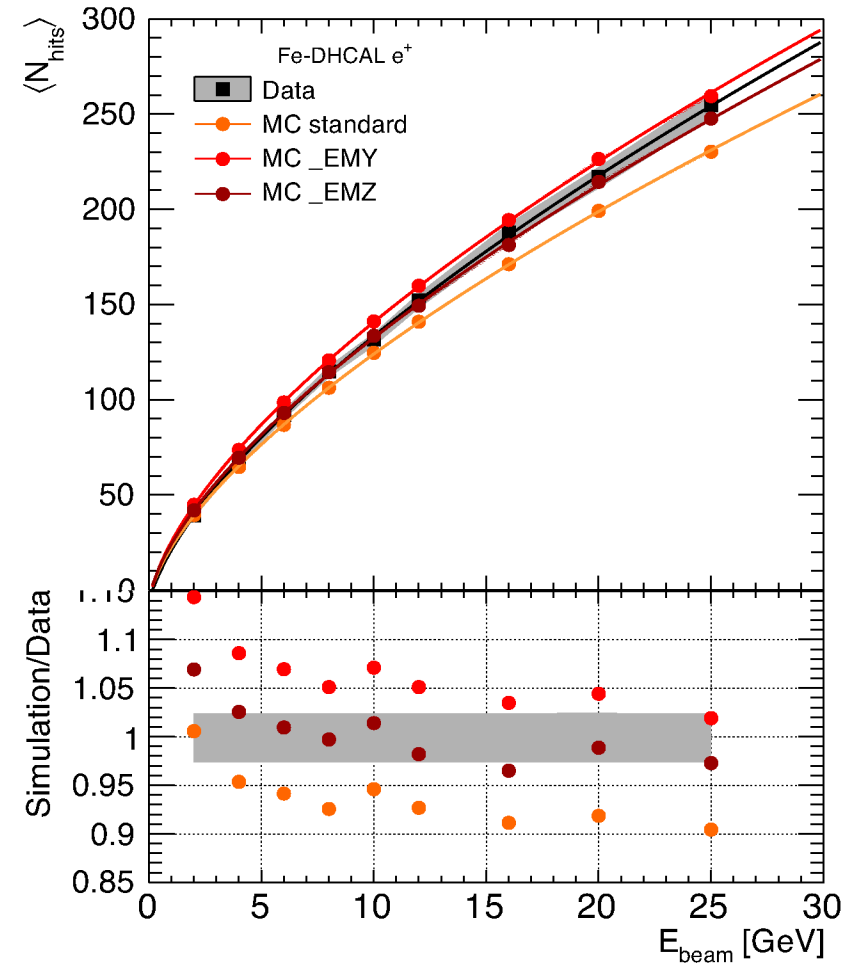
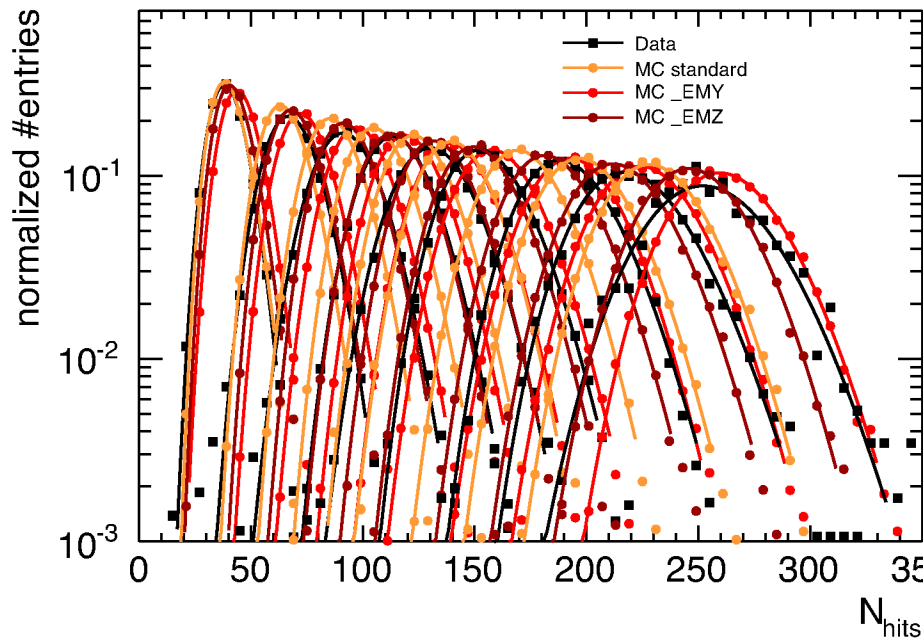


Positron energy reconstruction

- Power law fit of mean response in $\langle N_{\text{hits}} \rangle$ used for the correction of saturation

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

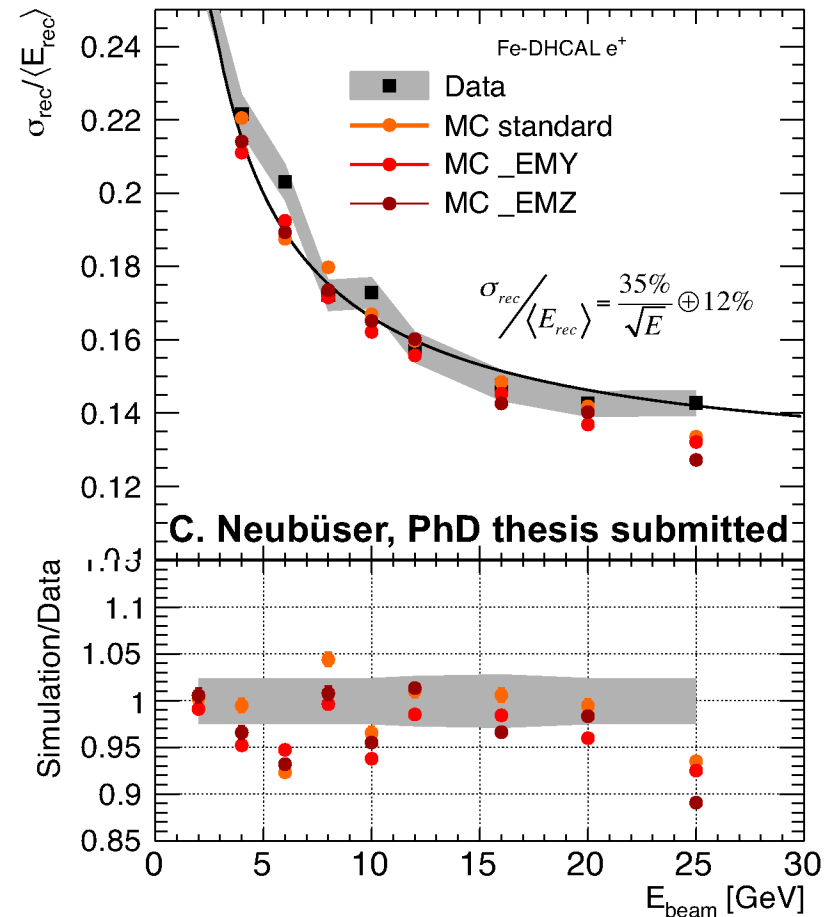
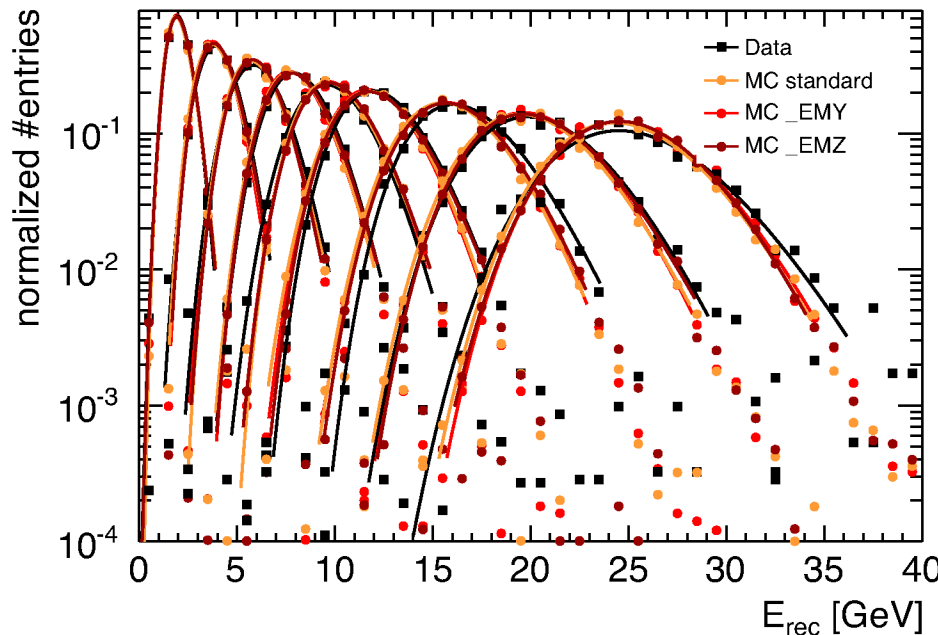
- Individual reconstruction for MCs



Positron energy resolution

> Energy resolution

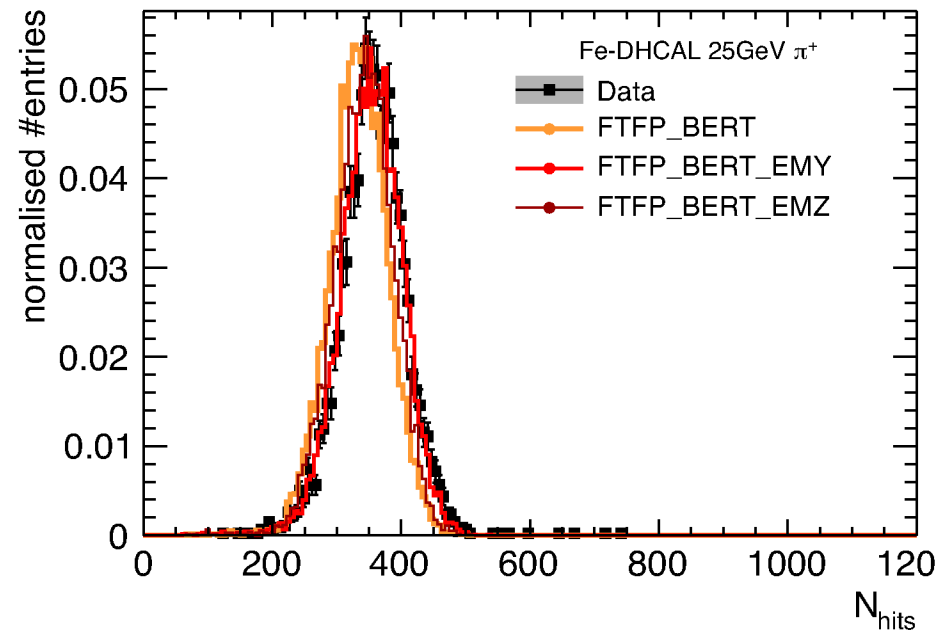
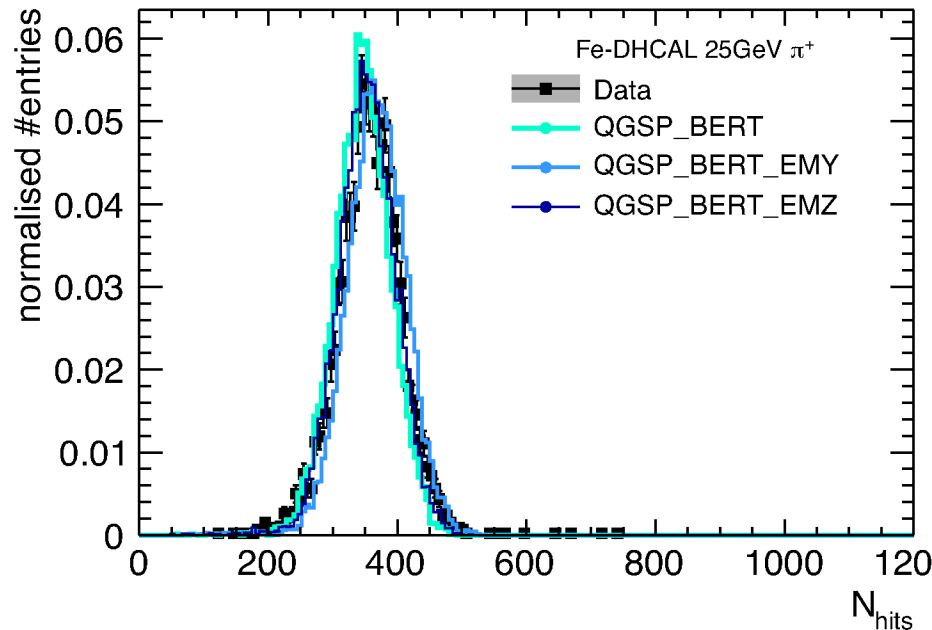
- Good agreement with all EM physics list options
- 25GeV e^+ statistics very limited in data
- Impact of saturation correction visible in shape of distributions



Simulation of pion showers

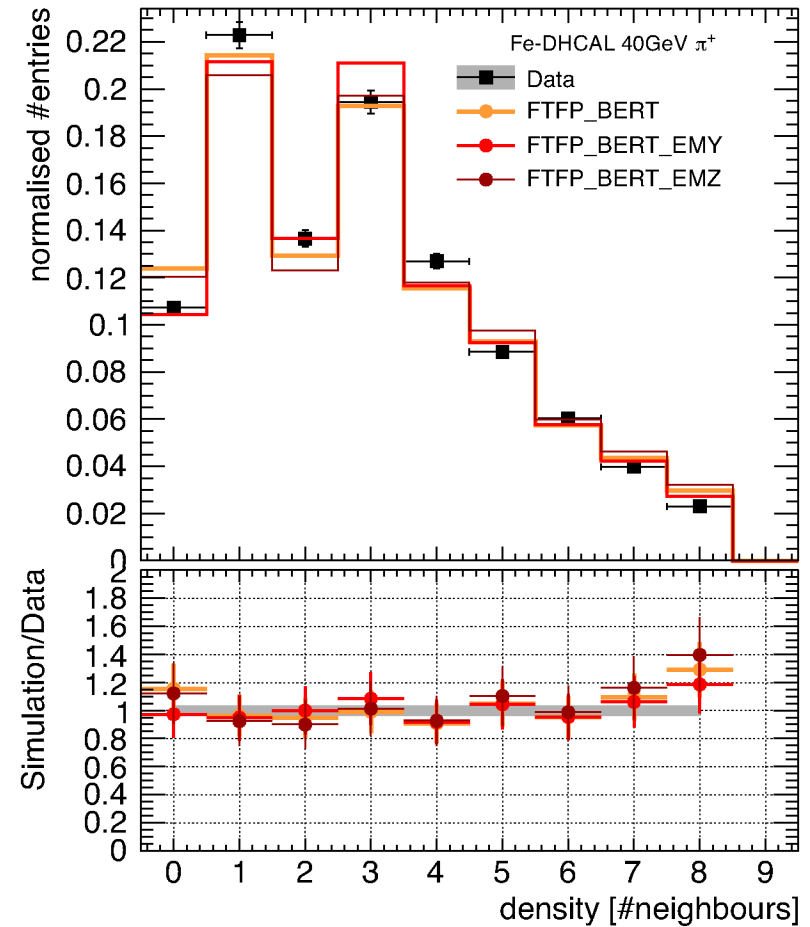
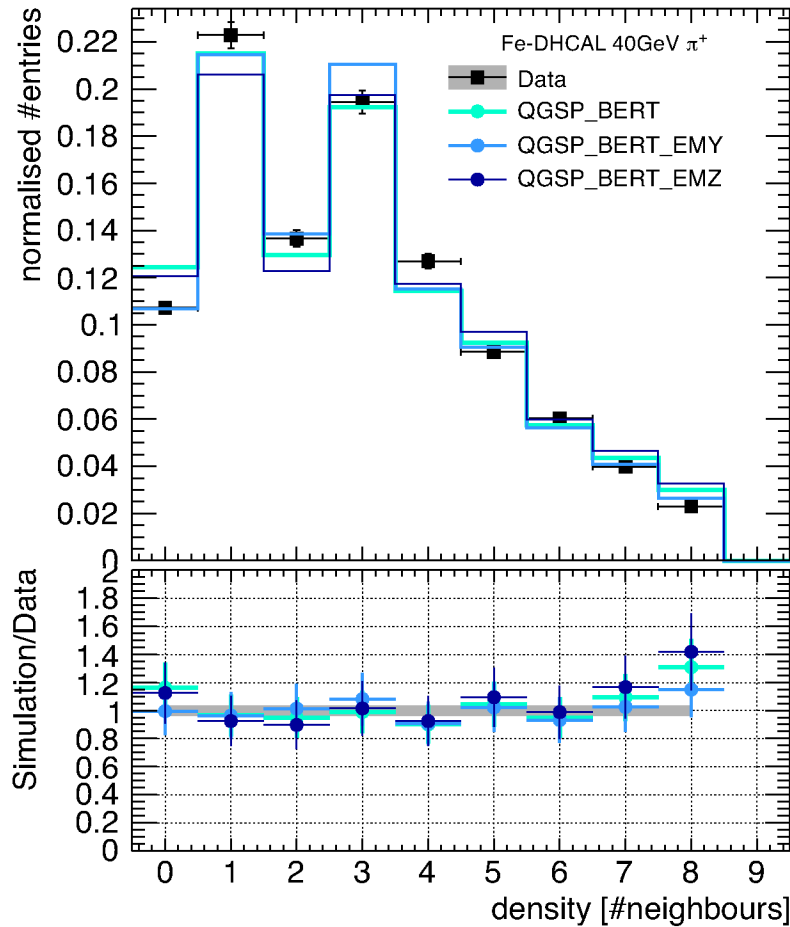
➤ Additionally to EM physics lists, hadronic physics lists:

- FTFP_BERT (+ standard, _EMY, _EMZ)
- QGSP_BERT (+ standard, _EMY, _EMZ)



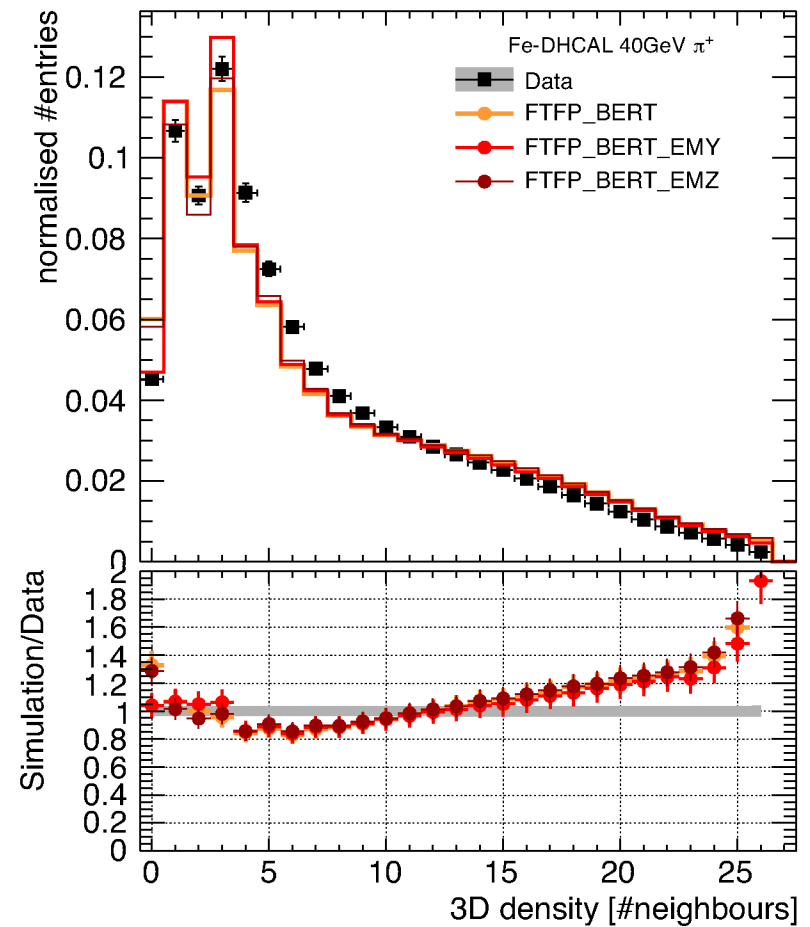
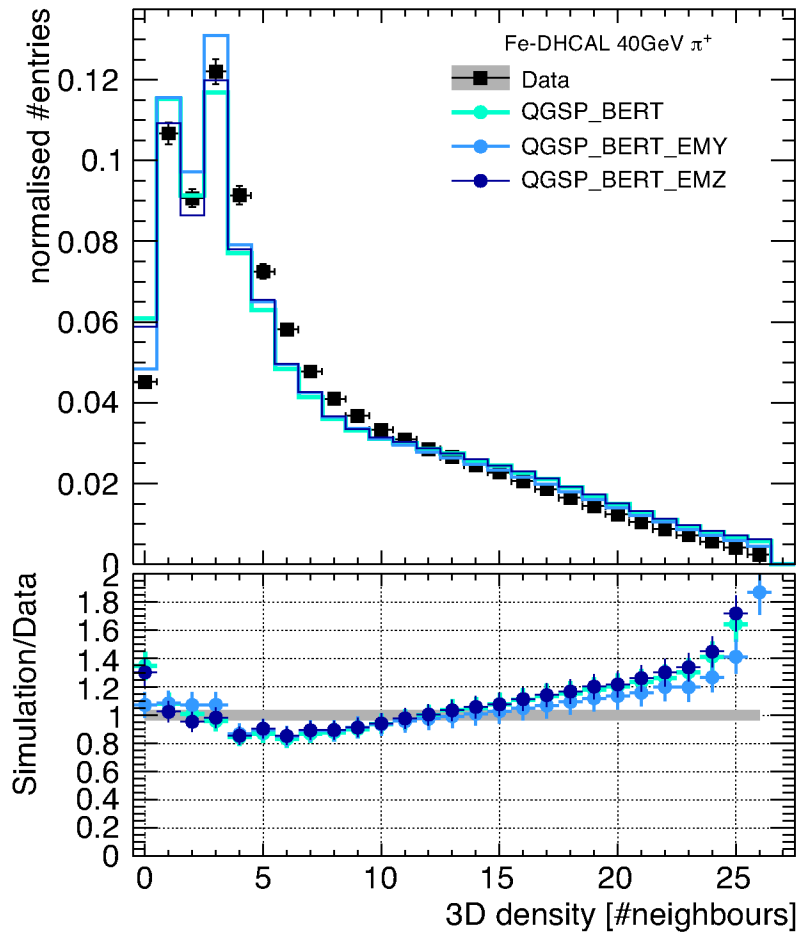
Pion shower analysis

➤ Hit density



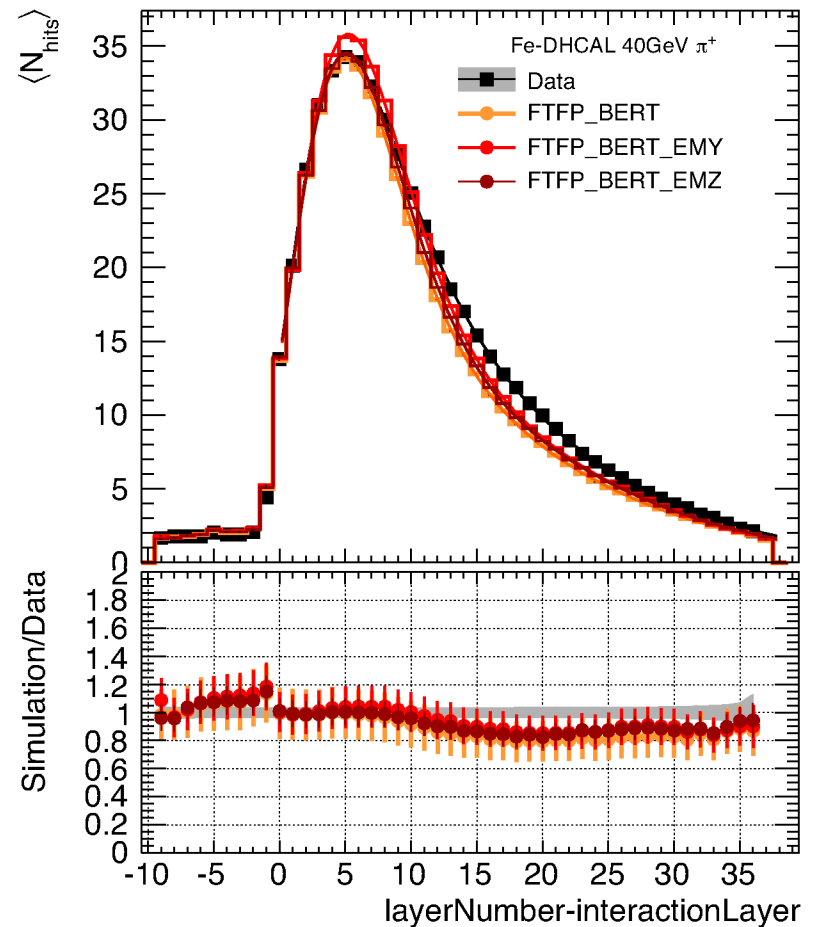
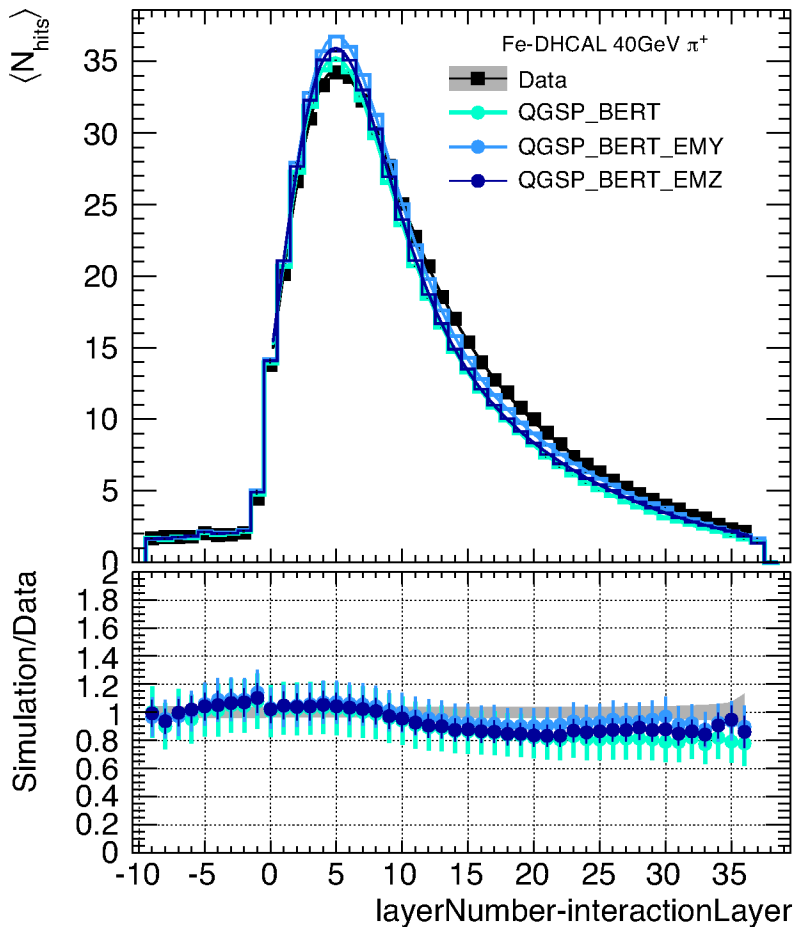
Pion shower analysis

➤ 3D hit density



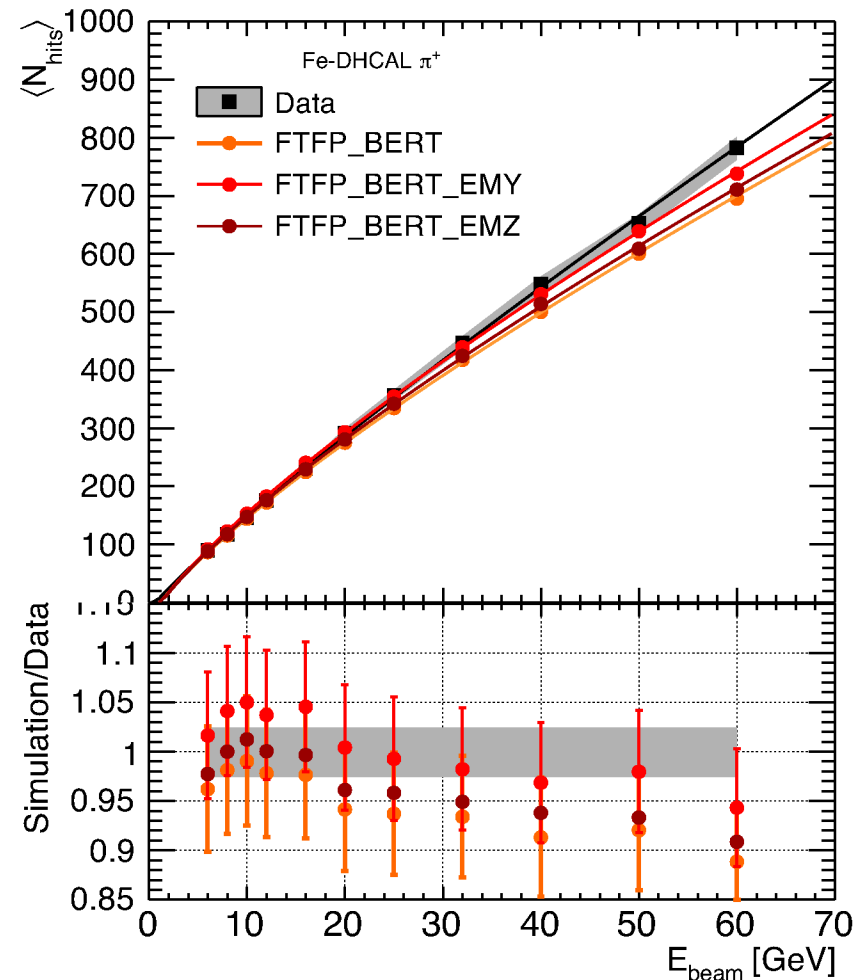
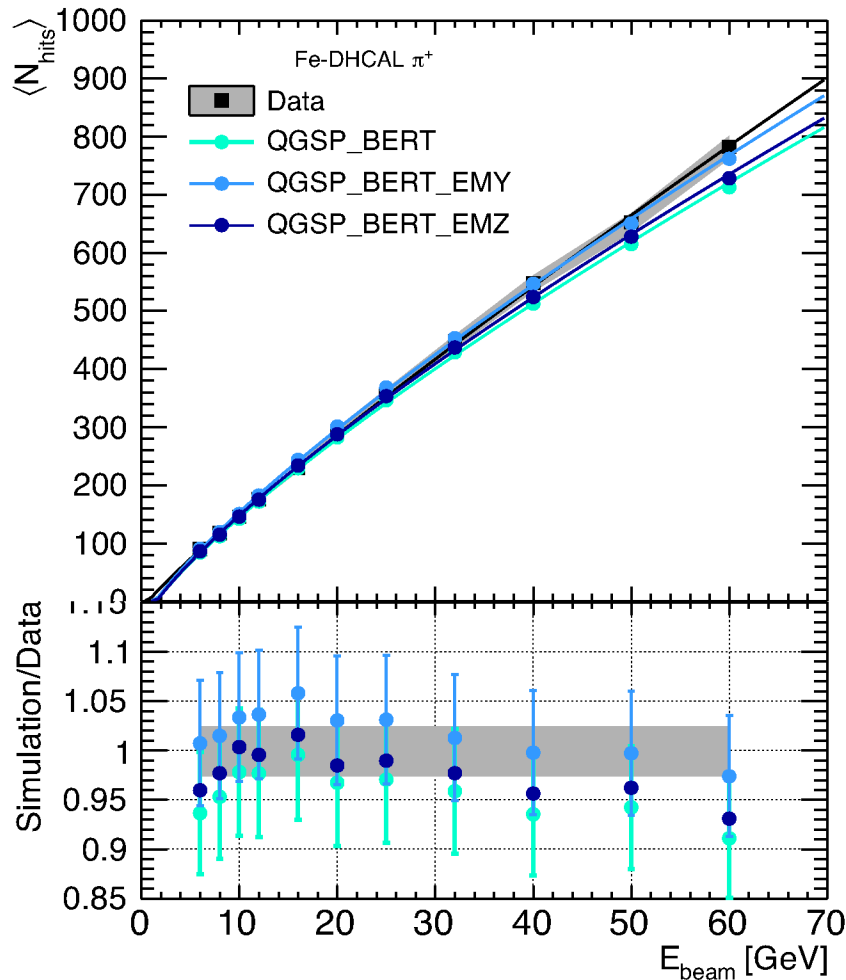
Pion shower analysis

➤ Longitudinal profiles

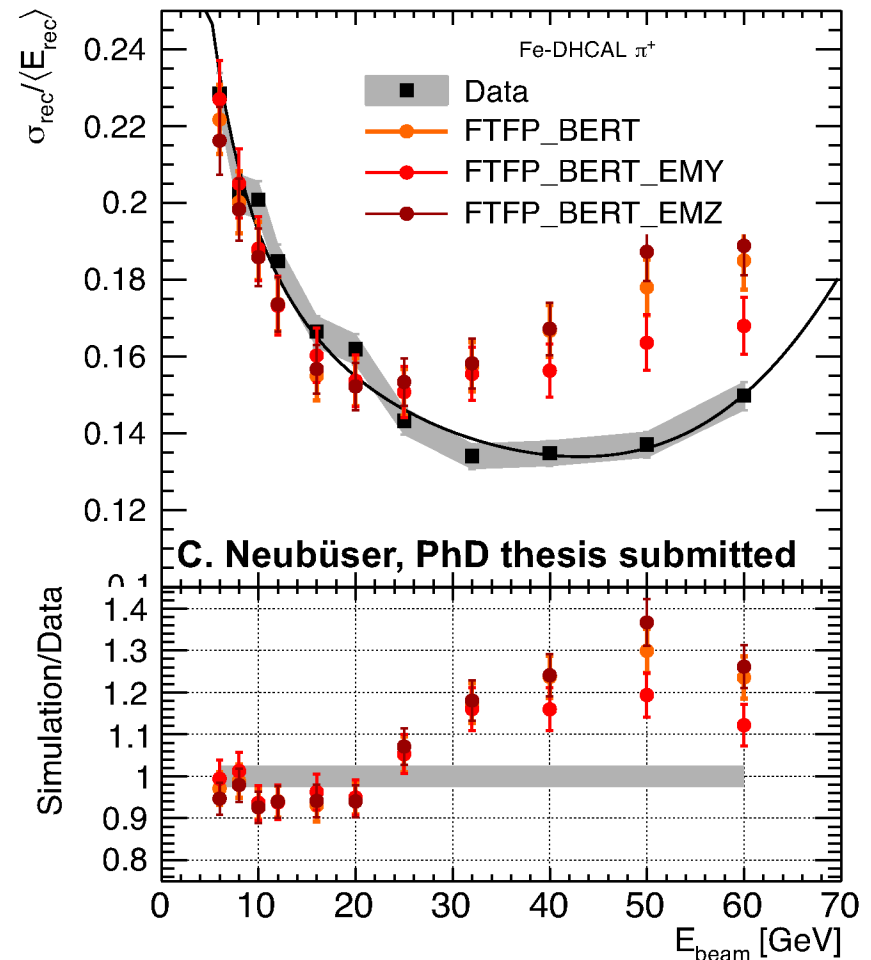
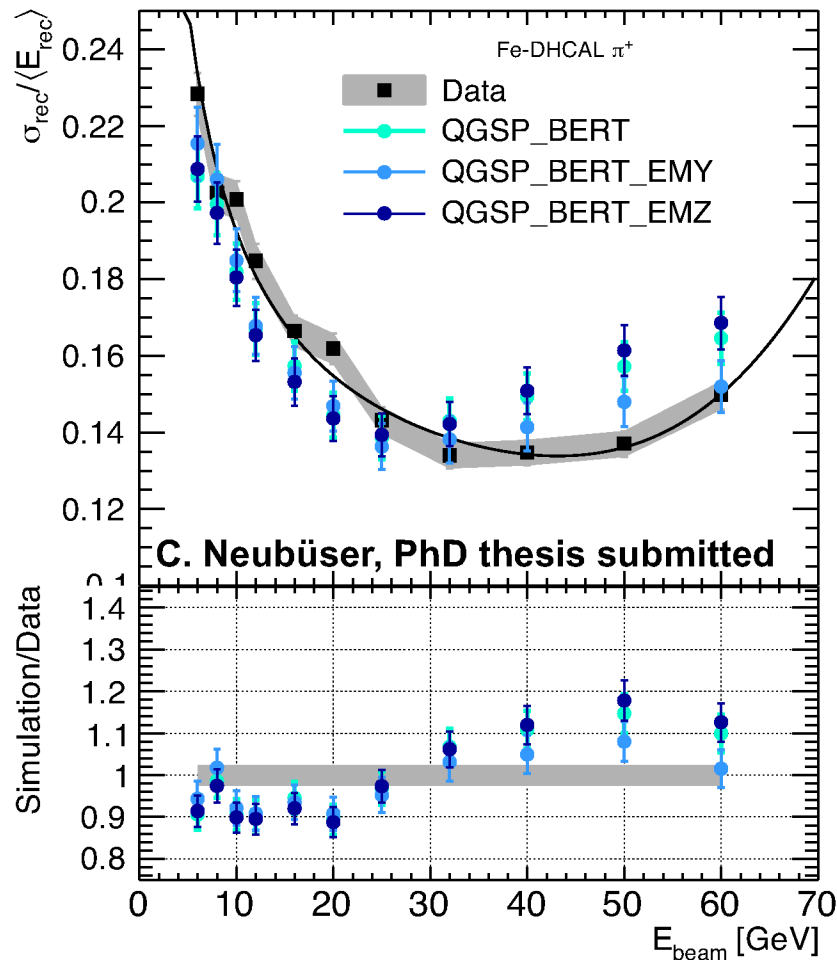


Pion energy reconstruction

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



Pion energy resolution



➤ QGSP_BERT_EMY physics list achieves best agreement with data

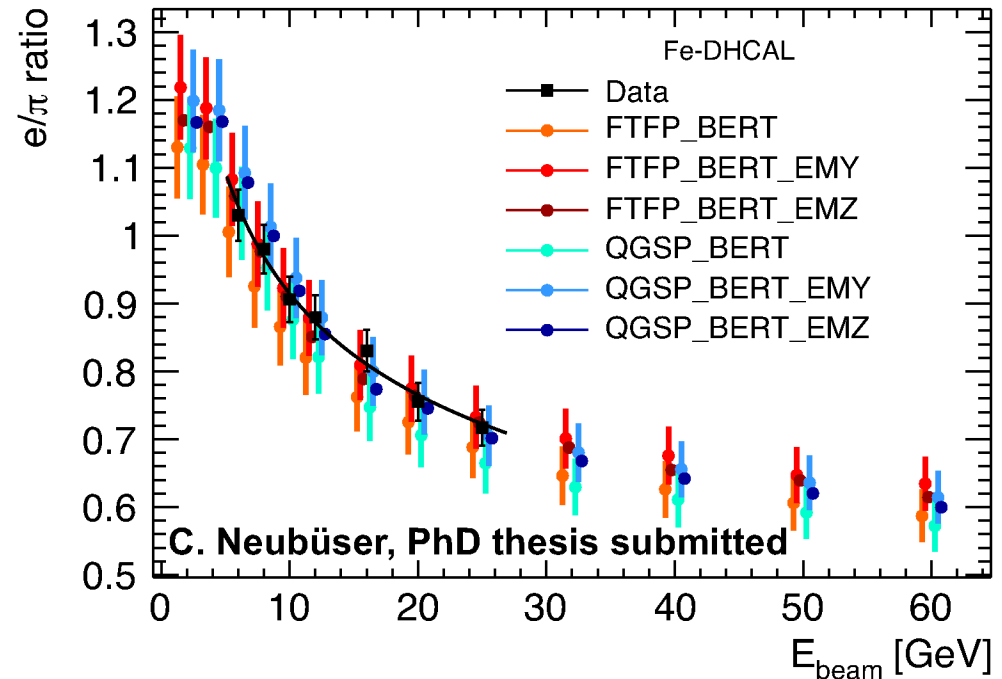
e/pi ratio

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

$$\frac{e}{h} = 0.62 \pm 0.04$$

- 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

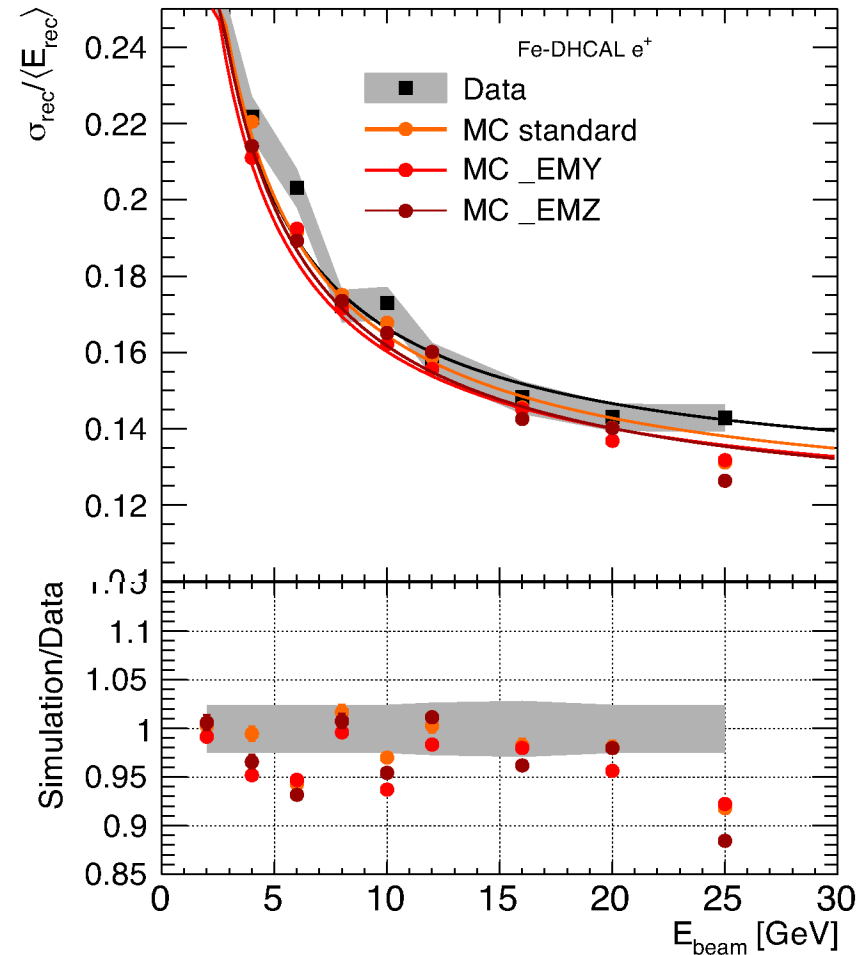
- Good agreement with all EM physics list options
- 25GeV e^+ statistics very limited in data
- Fit 0-100

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

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

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

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



Positron energy resolution

> Energy resolution

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

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

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

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

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

