Hadronic shower models study using SDHCAL

Arnaud Steen

IPNL

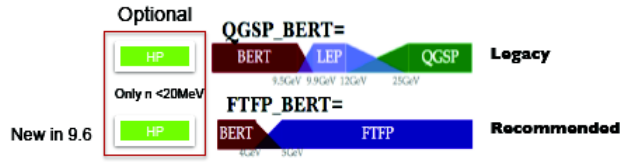
09/09/2013

Outline

Simulation/Digitizer Status

Simulation :

- Geant4 version 9.6.p01 is used
- FTFP_BERT_HP and QGSP_BERT_HP physics lists are used
- $\sim 20k$ events per energy point



Digitizer :

- Geant4 simulation gives information on the deposited energy $\Rightarrow$ need a Polya function to simulate the induced charge in RPC
- Charge spreading
  - $f_3(x,y) = \sum_{i=1}^{3} \alpha_i e^{\frac{(x_0-x)^2+(y_0-y)^2}{\sigma_i^2}}$
  -

Parameter	Value
α_1	1
α_2	0.00065
α_3	0.000057

Parameter	Value
σ_1	1
σ_2	9.5
σ_3	100

  - Integration of f_3 over the pads area
- Threshold : $0.114, 5.0, 10.0pC$ (0.114, 5.0, 15.0 pC for data)

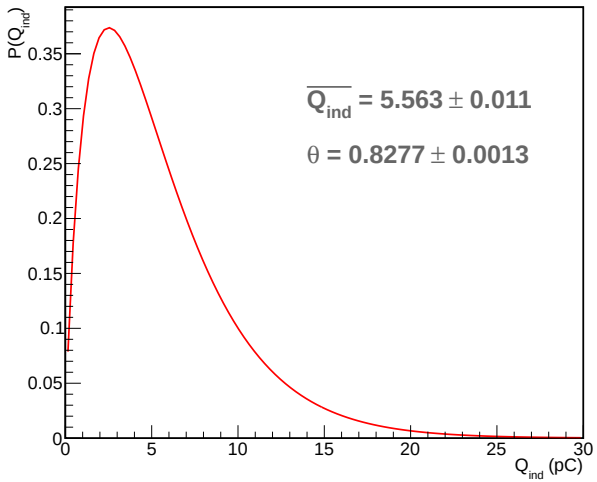
Threshold scan results

- Need to simulate the induced charge by an incoming particle in GRPC with a Polya distribution :

$$P(q) = (q\frac{(1+\theta)}{\bar{q}})^{\theta} e^{-\frac{q}{\bar{q}}(1+\theta)} \quad (1)$$

$\bar{q}$: mean charge

θ : free parameter related to the width of $P(q)$



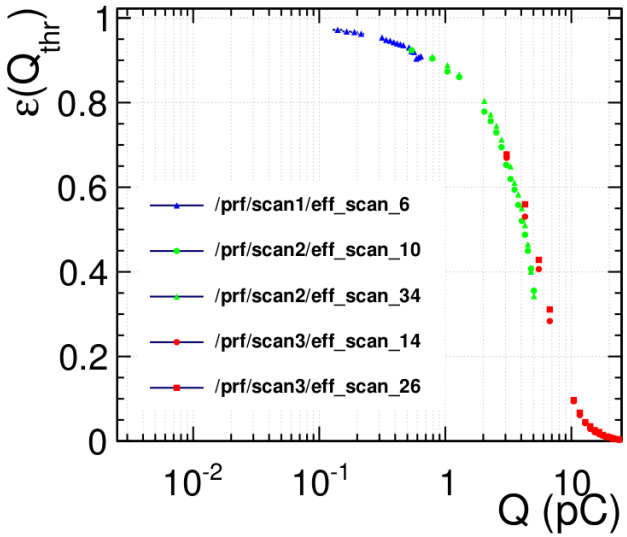
- 18 runs dedicated for a threshold scan in order to find Polya parameters
  - Change the threshold value in some chambers :

Threshold	Chamber no
1	6, 18, 30
2	10, 22, 34
3	14, 26, 38

  - Estimate the efficiency in those chambers
  - Fit the efficiency with

$$\epsilon(q) = \epsilon_0 - c\int_0^q P(q)dq \quad (2)$$

ϵ_0 : detector efficiency if $threshold = 0pC$



MIPs response

- Efficiency and multiplicity per layer estimated from reconstructed tracks from other layers
  - Efficiency = presence of at least one hit within $2cm$ radius around the expected impact point of the track $\bar{\varepsilon} \simeq 0.95$ for data
  - Multiplicity = number of hits per cluster $\bar{\mu} \simeq 1.73$ for data

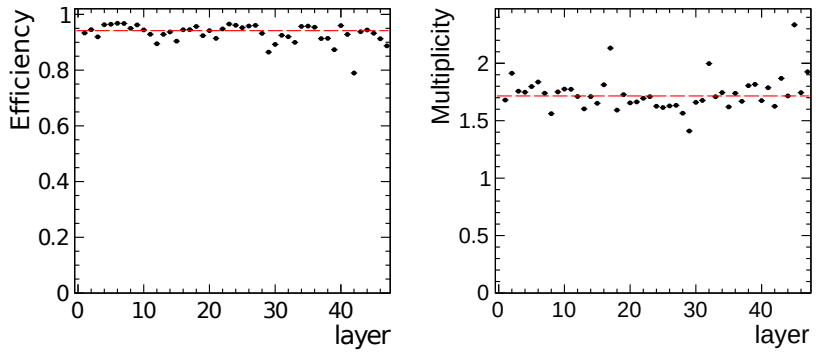


FIGURE: Efficiency (left) and multiplicity (right) per layer for data

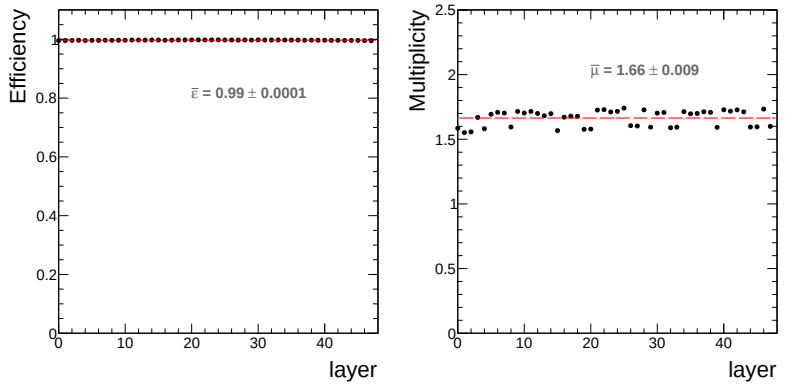


FIGURE: Efficiency (left) and multiplicity (right) per layer for simulation

Pion Selection

Data recorded with a trigger less mode : all events recorded until one ASIC's memory is full $\Rightarrow$ Pion selection only based on topological information.

- Beam/Cosmic muon rejection : $\frac{N_{hit}}{N_{layer}} > 3$
- Radiative muon rejection : $\frac{Radius}{LB} > 0.2$ (LB : longitudinal barycenter)
- Electron rejection : $FIP > 5$ or $N_{layer} > 30$ (FIP : first interaction plan $\equiv$ first layer with at least 4 hits and with the three following layers with at least 4 hits)

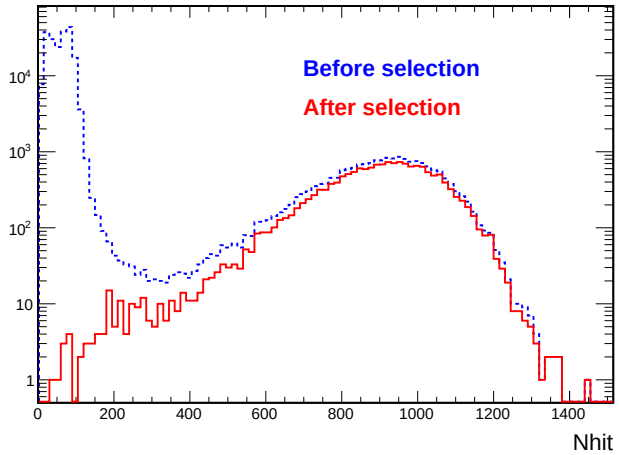
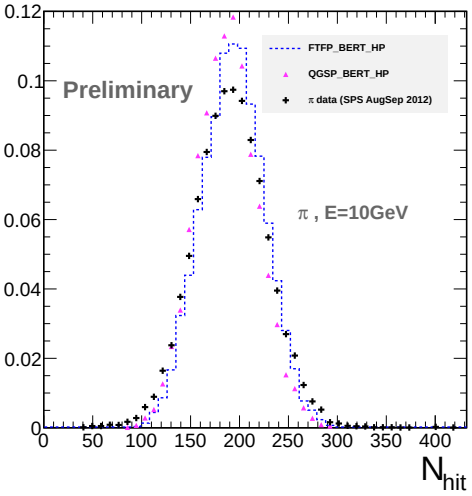
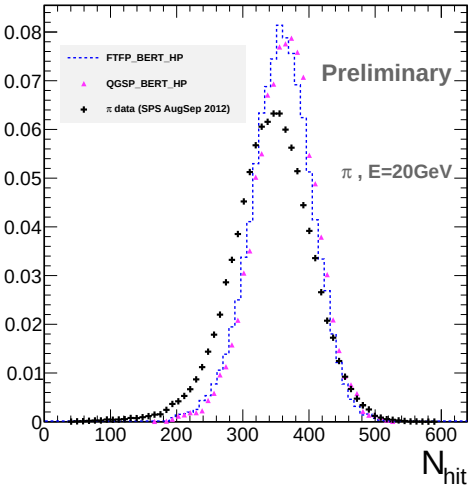
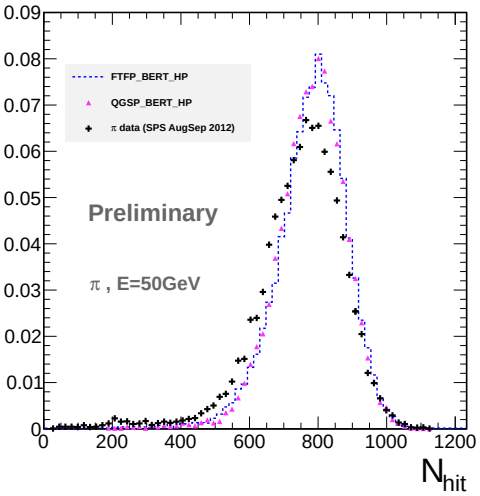


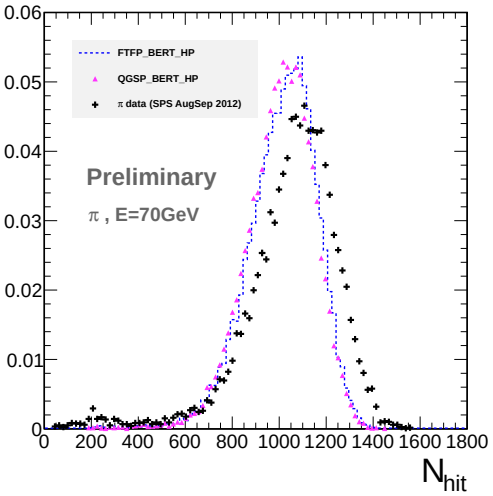
FIGURE: Distribution of total number of hits for a 60 GeV pion run

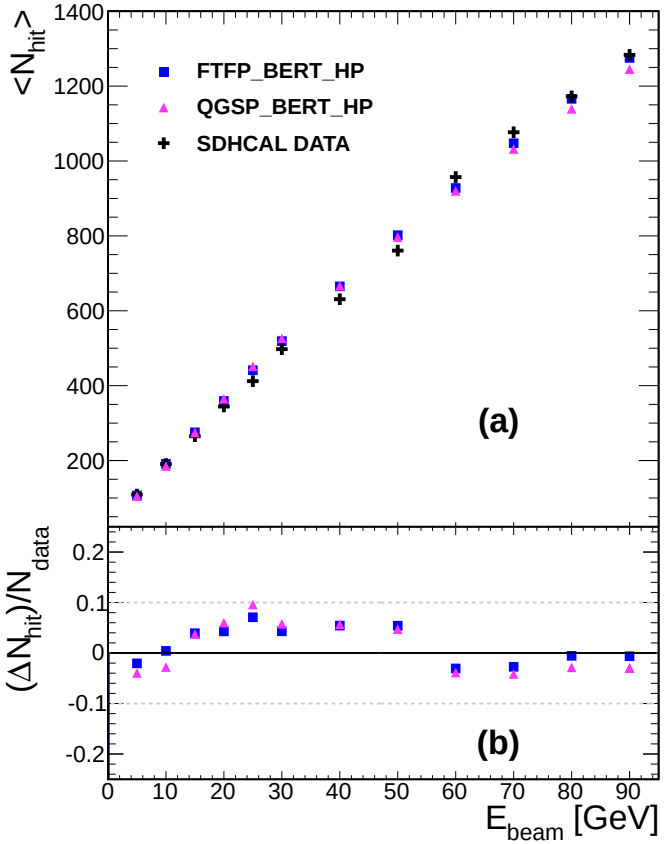
N_{hit} Result


FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=10GeV
N_hit

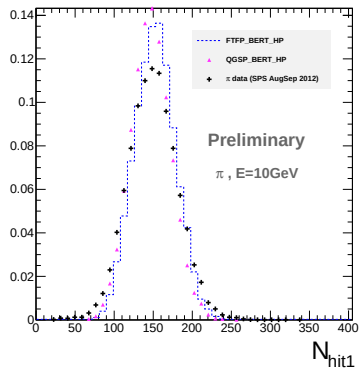

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=20GeV
N_hit

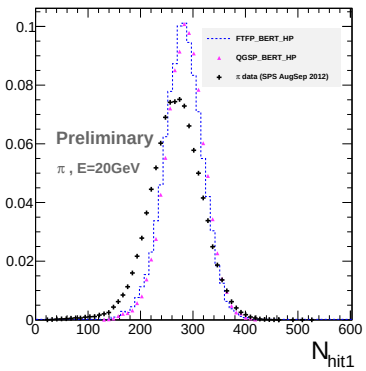

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=50GeV
N_hit

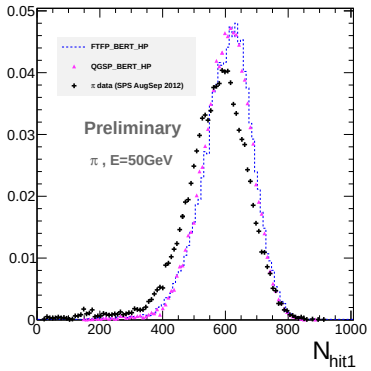

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=70GeV
N_hit

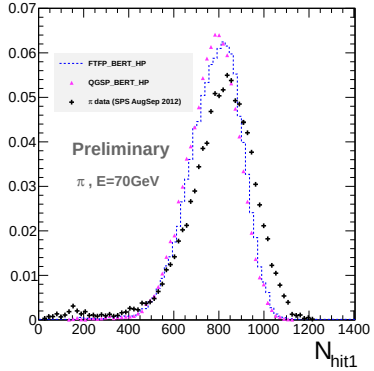

<N_hit>
FTFP_BERT_HP
QGSP_BERT_HP
SDHCAL DATA
(a)
(ΔN_hit)/N_data
(b)
E_beam [GeV]

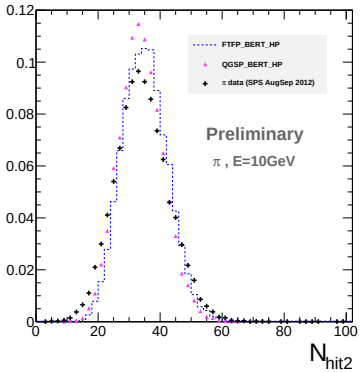
N_{hit} Result

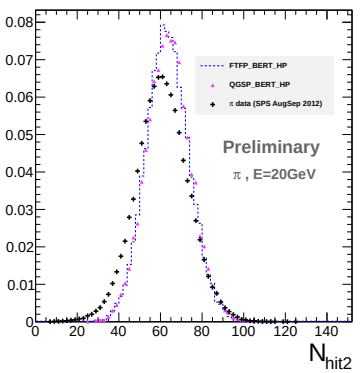

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=10GeV
N_hit1

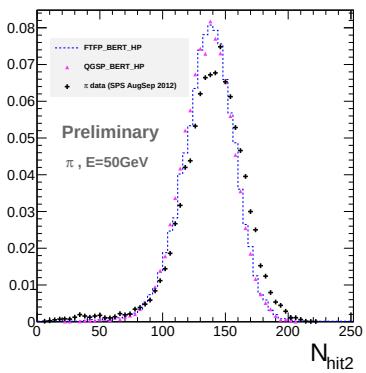

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=20GeV
N_hit1

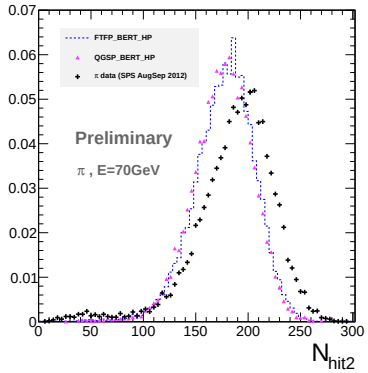

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=50GeV
N_hit1

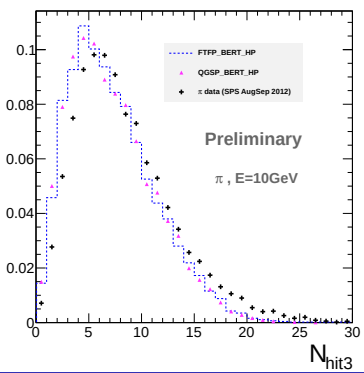

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=70GeV
N_hit1

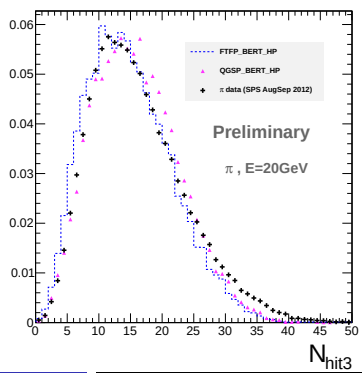

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=10GeV
N_hit2

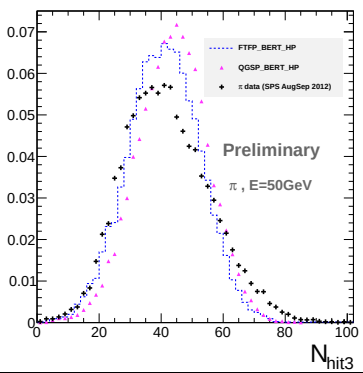

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=20GeV
N_hit2

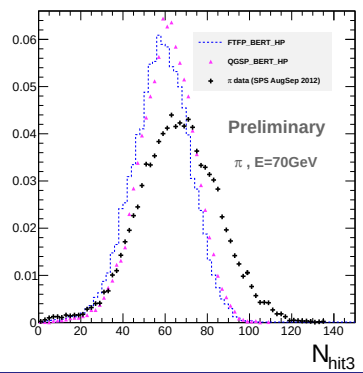

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=50GeV
N_hit2


FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=70GeV
N_hit2

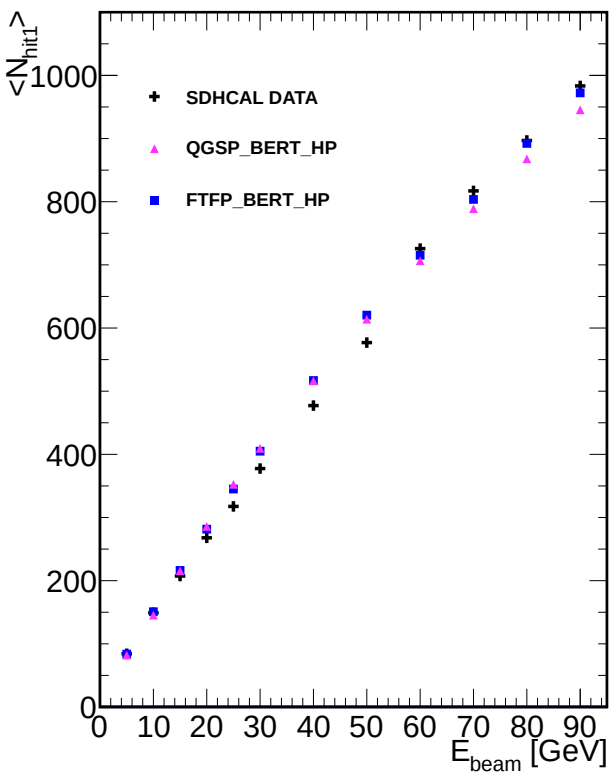

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=10GeV
N_hit3

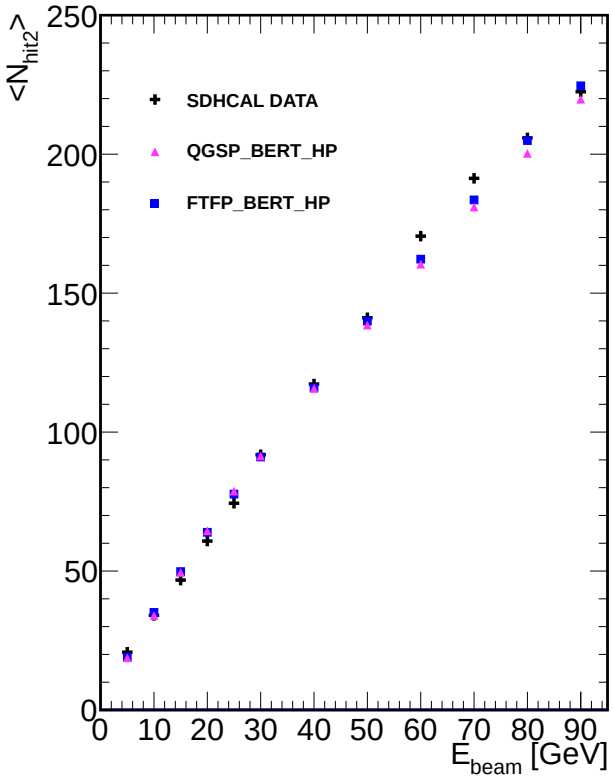

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=20GeV
N_hit3

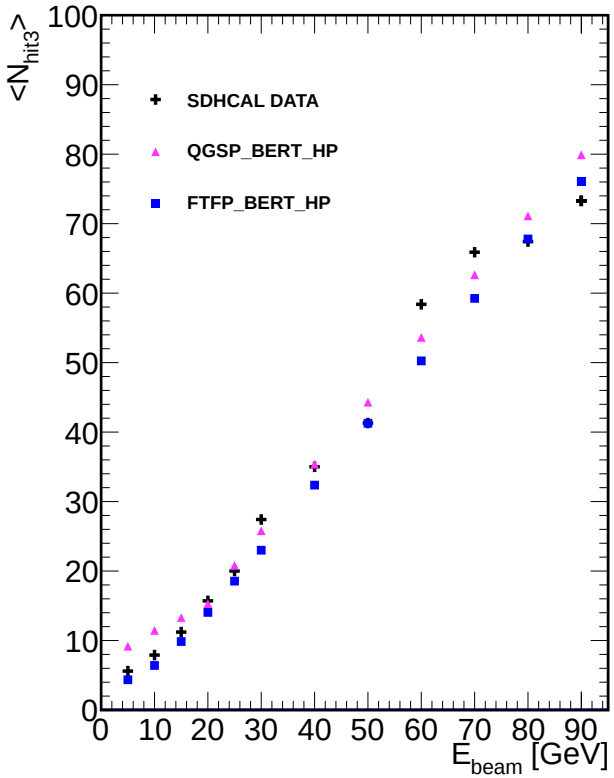

FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=50GeV
N_hit3


FTFP_BERT_HP
QGSP_BERT_HP
π data (SPS AugSep 2012)
Preliminary
π , E=70GeV
N_hit3

N_{hit} Result


$<N_{hit1}>$
SDHCAL DATA
QGSP_BERT_HP
FTFP_BERT_HP
E_{beam} [GeV]


$<N_{hit2}>$
SDHCAL DATA
QGSP_BERT_HP
FTFP_BERT_HP
E_{beam} [GeV]


$<N_{hit3}>$
SDHCAL DATA
QGSP_BERT_HP
FTFP_BERT_HP
E_{beam} [GeV]

Longitudinal profile

- Pure digital study : thresholds information is not used

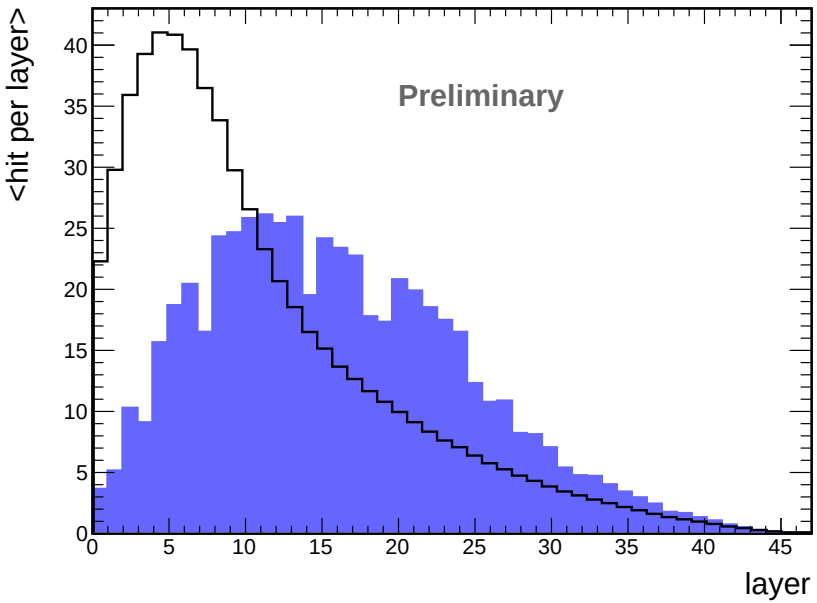
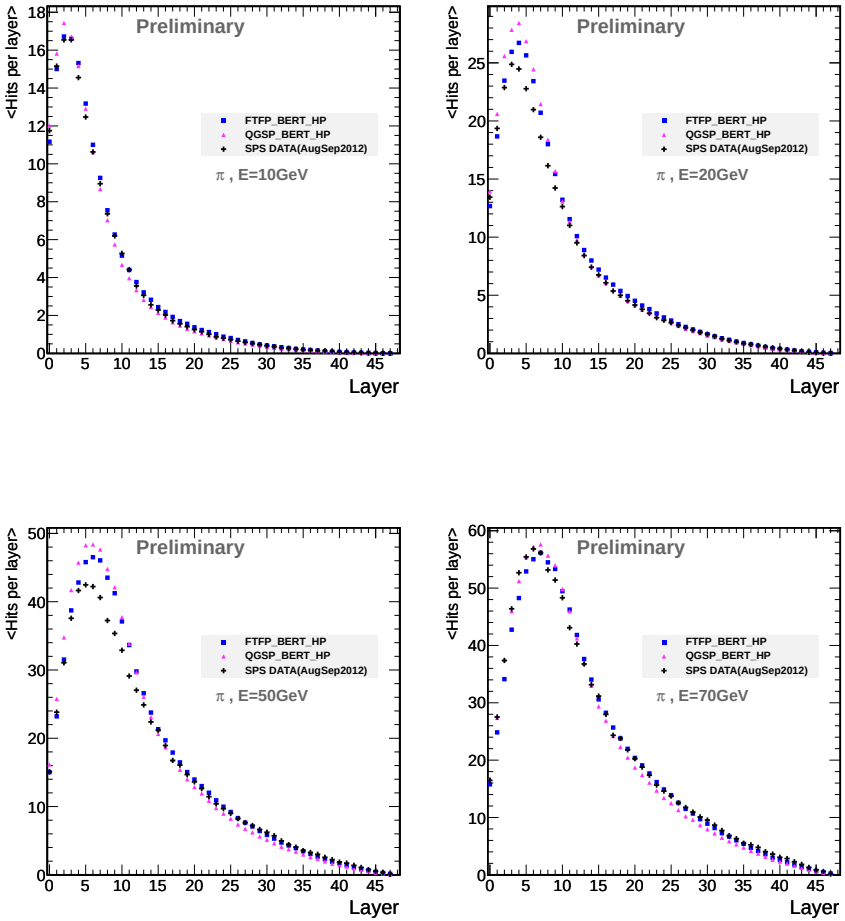


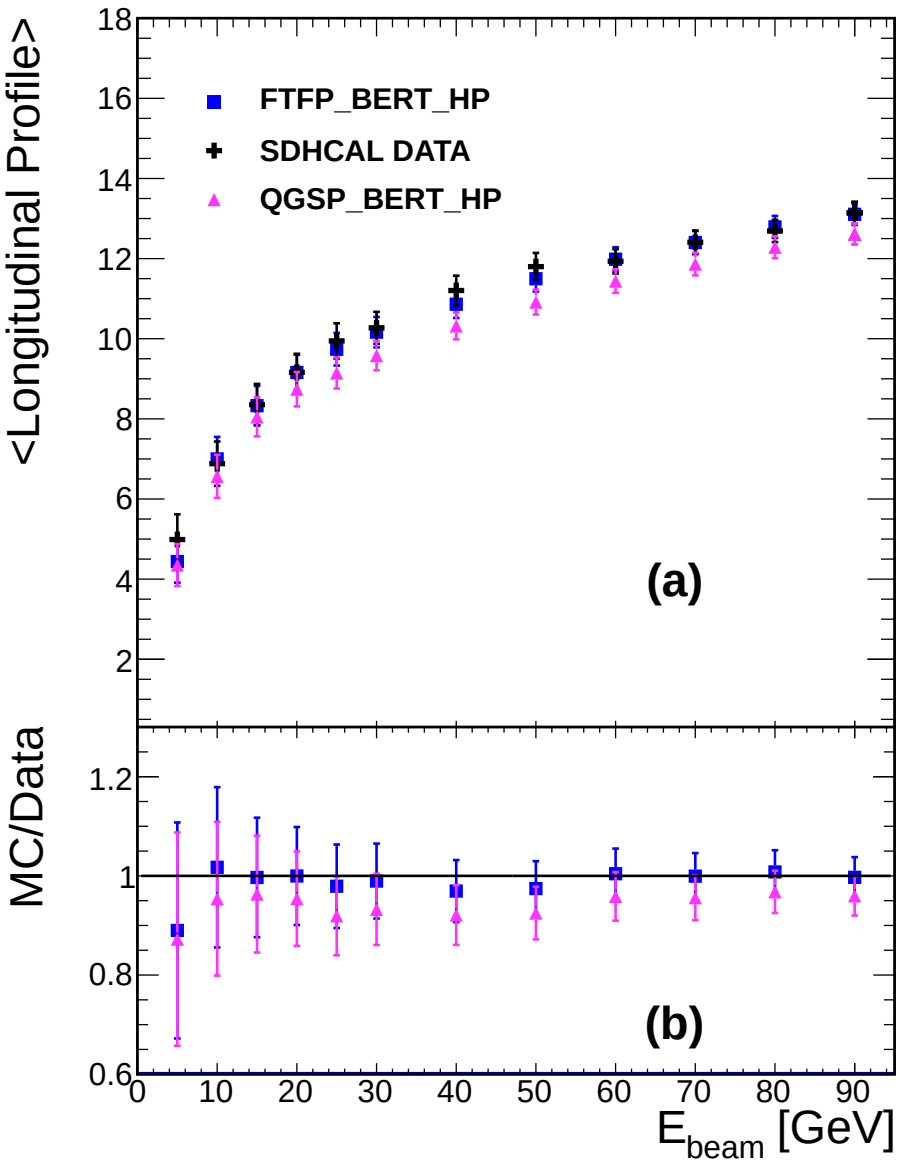
FIGURE: Longitudinal profile for 40 *GeV* π^- simulation (*FTFP_BERT_HP*) relative to the calorimeter front (blue filled histogram) and relative to the shower starting point (black line)



Longitudinal profile

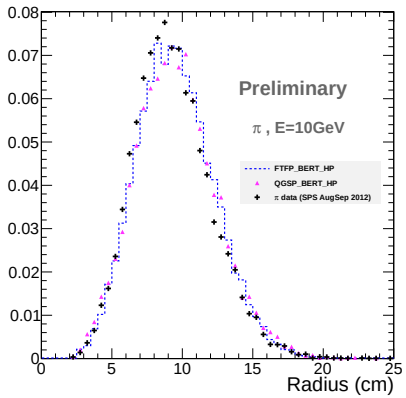
Longitudinal profile conclusion

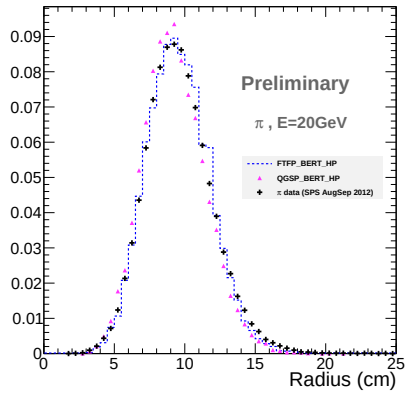
- Good agreement between data and *FTFP_BERT_HP*
- *QGSP_BERT_HP* creates shorter hadronic shower

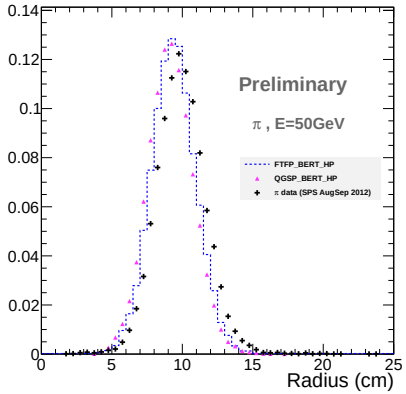


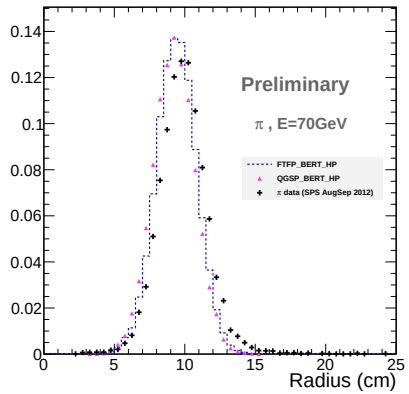
Lateral shower shape

- Pure digital study : thresholds information is not used
- $Radius = \sqrt{\sum_{i=0}^{n} \frac{(x_i - X_0)^2 + (y_i - Y_0)^2}{n}}$





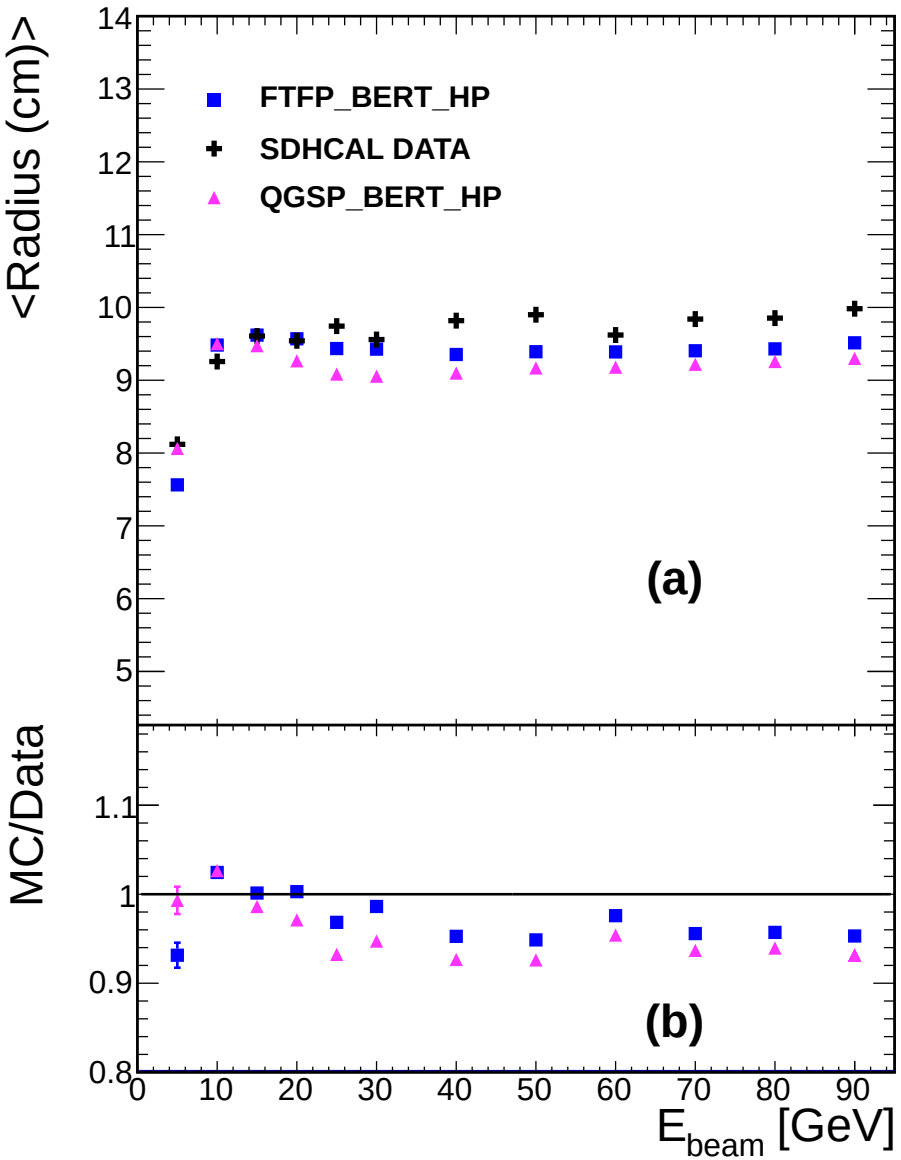




Lateral shower shape

Radius conclusion

- Simulation creates narrower hadronic shower than data.
- *FTFP_BERT_HP* makes hadronic shower wider than *QGSP_BERT_HP*



Conclusion

- The digitizer provides a good agreement between data and MC for MIPs and hadronic shower response for each threshold.
- *QGSP_BERT_HP* physic list creates more hits for the 3^{rd} threshold may be due to the bigger range for Bertini's model.
- *FTFP_BERT_HP* physic list provides better result from the topological point of view : longer and wider showers.
- Next step : find appropriate weights to apply on different thresholds for the topological variables.

Back-up

High precision for neutron : Effect on topological variables