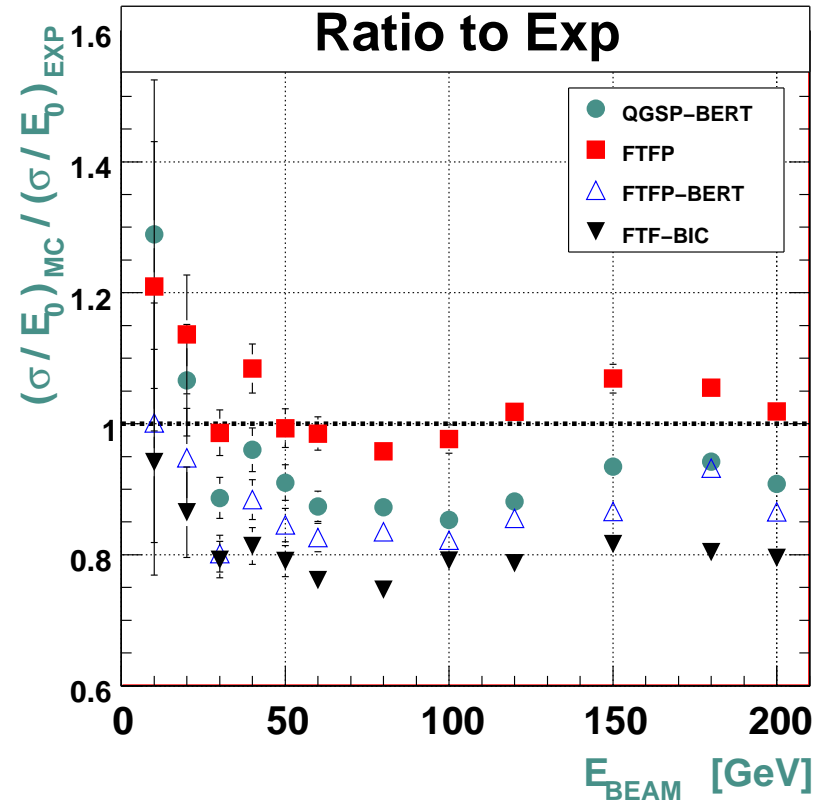
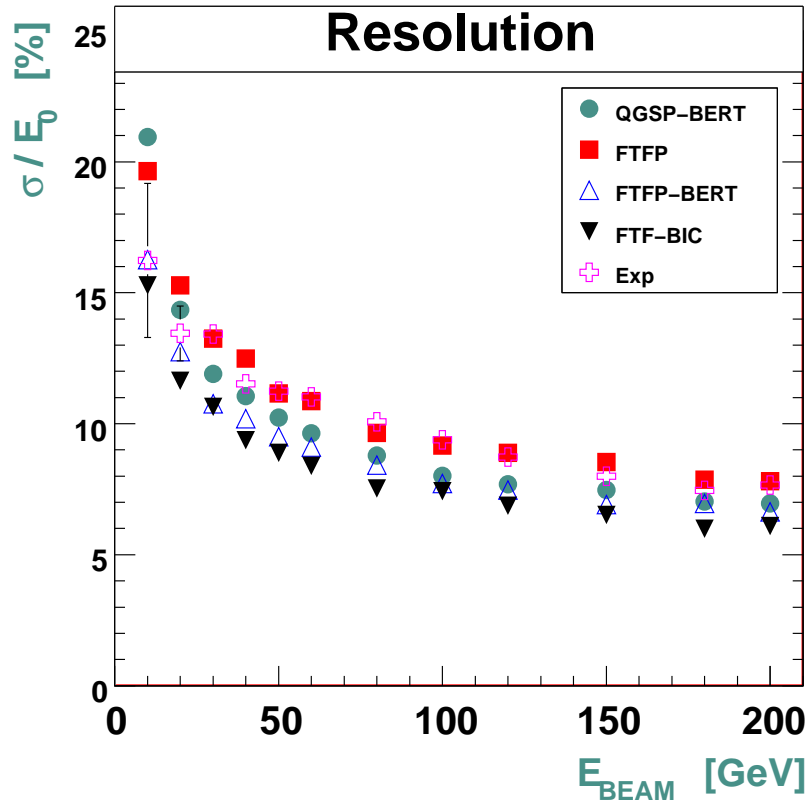


Pion energy resolution



- **FTFP** is the closest to experimental values of the energy resolution
- **FTF-BIC** demonstrates the worst behaviour

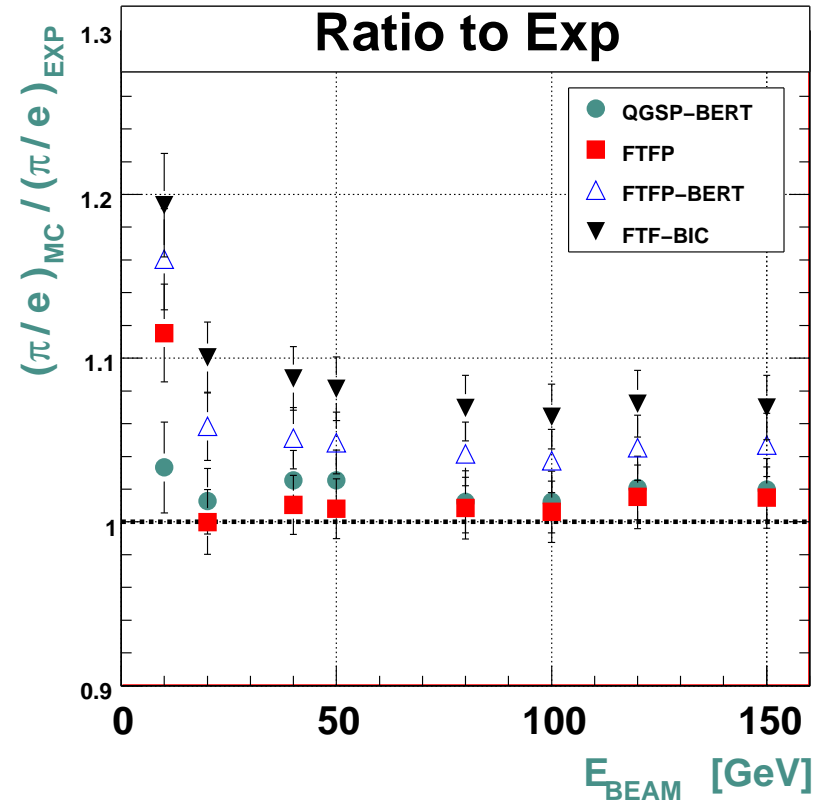
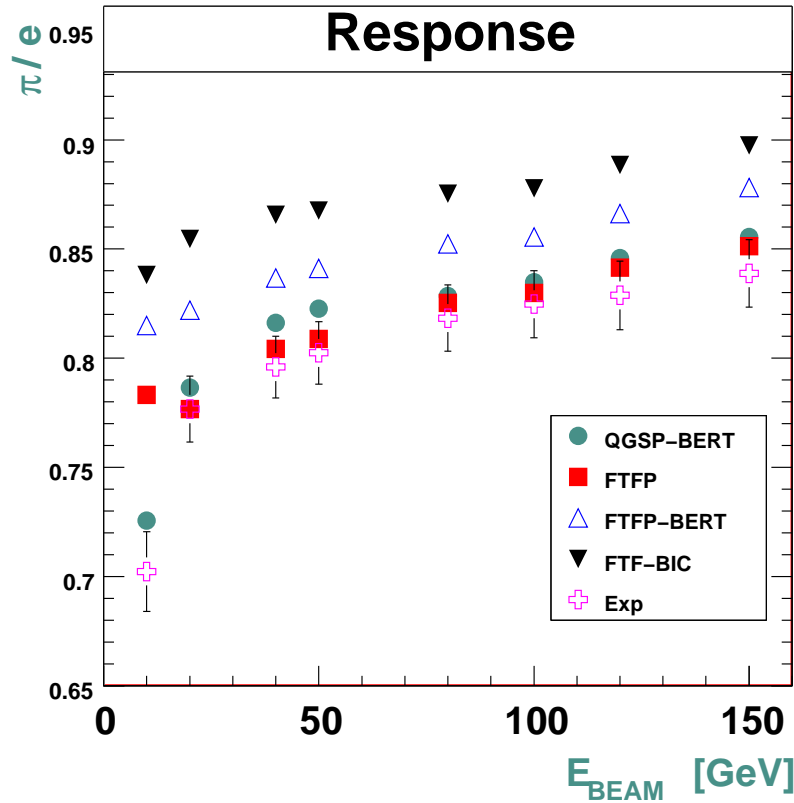
Pion energy resolution: Two-term parametrization

- $\sigma / E_0 = A / \sqrt{E_{BEAM}} \oplus B$
- Experimental values:
 $A = 69 \pm 1 \% \sqrt{GeV}$, $B = 5.8 \pm 0.1 \%$
- MC predictions:

Physics list	Terms of energy resolution	
	$A [\% \sqrt{GeV}]$	$B [\%]$
QGSP-BERT	60.2 ± 0.7	5.48 ± 0.09
FTFP	63.3 ± 0.8	6.61 ± 0.10
FTFP-BERT	51.5 ± 0.7	5.76 ± 0.08
FTF-BIC	49.5 ± 0.6	5.09 ± 0.08

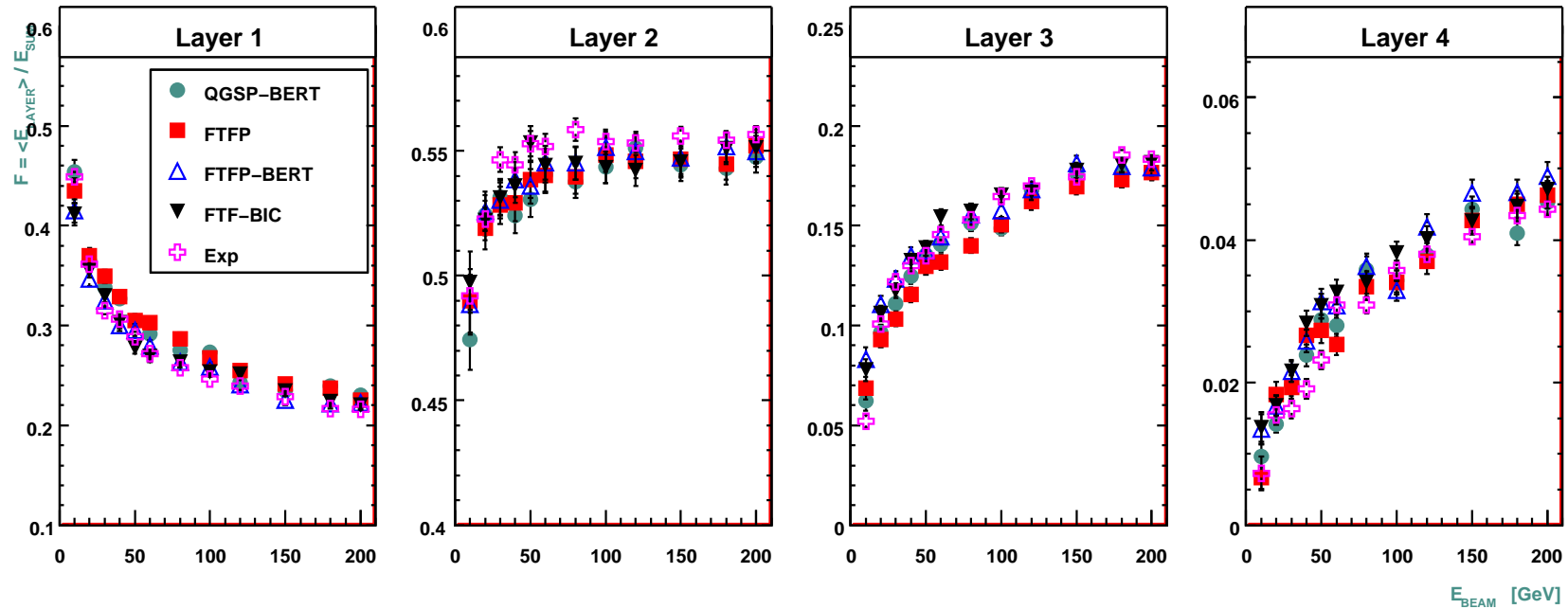
- Sampling term A of the energy resolution is better described by **FTFP**
- Physics lists with the Bertini cascade model (**QGSP-BERT** and **FTFP-BERT**) give better predictions of the constant term B

Pion response



- **FTFP** gives the best description of the pion response, *except the lowest beam energy*
- **FTF-BIC** and **FTFP-BERT** predict too high response to charged pions

Shape of hadronic showers: Fraction of energy in HEC longitudinal layers

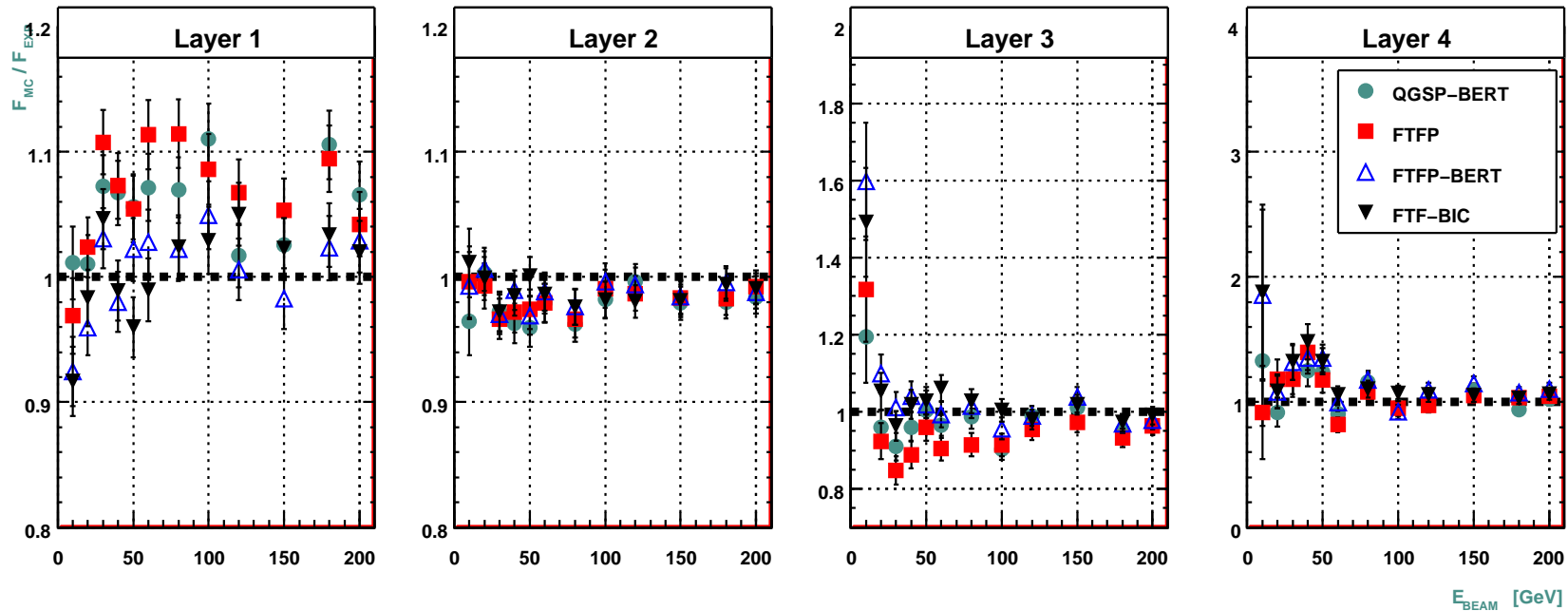


Four HEC longitudinal layers: 8/16/8/8 LAr gaps, 1.5/2.9/3.0/2.8 λ

$$F = \langle E_{LAYER} \rangle / E_{SUM}, \text{ where } E_{SUM} = \Sigma \langle E_{LAYER} \rangle$$

Shape of hadronic showers

Fraction of energy in HEC longitudinal layers: Ratio to experiment



- Fraction of energy in the second (main) layer is described within a few percent by all physics lists
- **FTFP-BERT** and **FTF-BIC**: good description of shower profiles, *except the lowest beam energy*
- **FTFP**: hadronic showers start earlier and are more compact (see layers 1 and 3)

Summary of the Comparison of MC Predictions and Experimental Results

- Ratio between simulated and experimental data as a function of the beam energy E_{BEAM}
- Maximal and minimal values of this dependence \Rightarrow

Deviation of MC predictions from experimental results [in %]

Physics list	Resolution ¹		Response ²		Fraction of energy in layers ²					
					Layer 1		Layer 2		Layer 3	
QGSP-BERT	-15	-4	+1	+3	+1	+11	-4	0	-10	+1
FTFP	-4	+8	0	+2	+2	+11	-3	-1	-15	-3
FTFP-BERT	-20	-7	+4	+6	-4	+5	-3	+1	-4	+10
FTF-BIC	-25	-18	+6	+10	-4	+5	-3	0	-4	+6

¹Data with $E_{BEAM} \geq 30$ GeV are used: Errors of the resolution are too large at smaller beam energies.

²Data with $E_{BEAM} = 10$ GeV are not used: Studied physics lists have problems to describe those parameters at this beam energy.

Conclusions

New round of GEANT4 based simulations with version 9.2 was carried out for the HEC stand-alone testbeam. Four different physics lists, namely: QGSP-BERT, FTFP, FTFP-BERT and FTF-BIC — were used for GEANT4 simulations. Comparison with experimental results was done.

None of these physics lists can describe the whole set of studied HEC performance parameters:

- The sampling term of the energy resolution is better described by the FTFP physics list and the constant term — by the BERT-based physics lists
- Pion response is well predicted by FTFP and QGSP-BERT, while FTFP-BERT and FTF-BIC predict too high response to charged pions
- FTFP-BERT and FTF-BIC give good description of longitudinal shower profiles, whereas FTFP predicts compact hadronic showers