Comparison of Geant4 simulation data with hadron shower data in the PAMELA experiment.

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Problem Statement

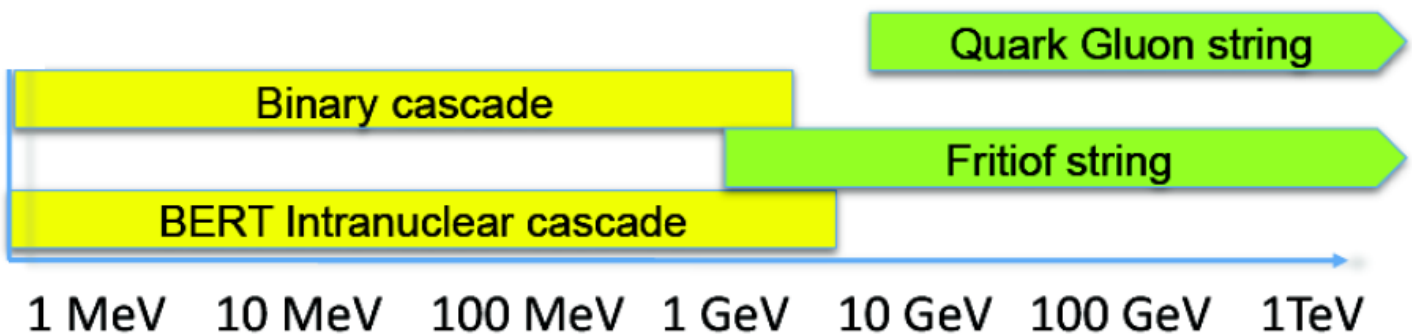
PAMELA calorimeter: 22 tungsten plates + 22×2 scintillating silicon layers each with 96 read-out strips, X and Y projections.

Goal: choose appropriate Geant4 hadronic cascade model for different energy ranges.

Geant4 Physics Lists

Simulation data (protons):

- QGSP_BERT – Quark-Gluon String model with Bertini cascade.
- FTFP_BERT – Fritiof model with Bertini cascade.
- QGSP_BIC – QGSP with binary cascade.
- QGSP_INCLXX – QGSP with Liege intranuclear cascade model.



Selection criteria

Basic criteria:

- anti-coincidence system;
- time-of-flight system;
- tracking system (correctly restored trajectory).

Cascade selection:

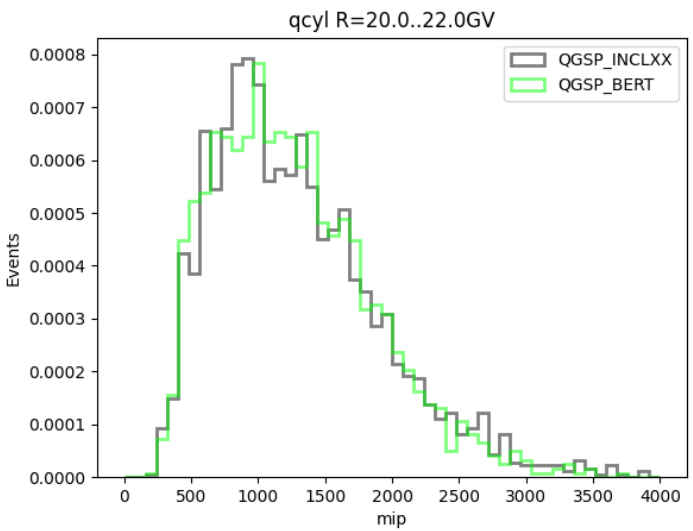
- at least 150 strips triggered in calorimeter;
- energy loss at least 500 mip.

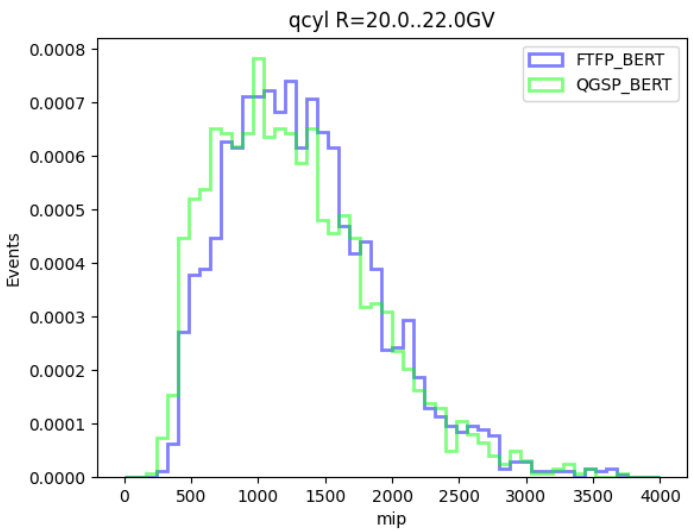
Hadronic shower descriptors

- `qcyl, ncyl` – energy loss and number of triggered strips in a cylinder around shower axis ($R = 8$ strips).
- `qtr, ntr` – energy loss and number of triggered strips in a cylinder around shower axis ($R = 4$ strips).
- `qcore, ncore` – energy loss and number of triggered strips in a cylinder around shower axis up to the shower maximum ($R = 2R_M$, R_M is Moliere radius)
- `planemaxy` – number of plane with maximal energy loss (Y projection).
- `nstrip` – total number of triggered strips.

Comparison of models

- Consider a narrow rigidity range.
- Calculate shower descriptors for simulation events in this range.
- Compare distributions for different models by two-sample goodness-of-fit test (KS – test or CvM – test).

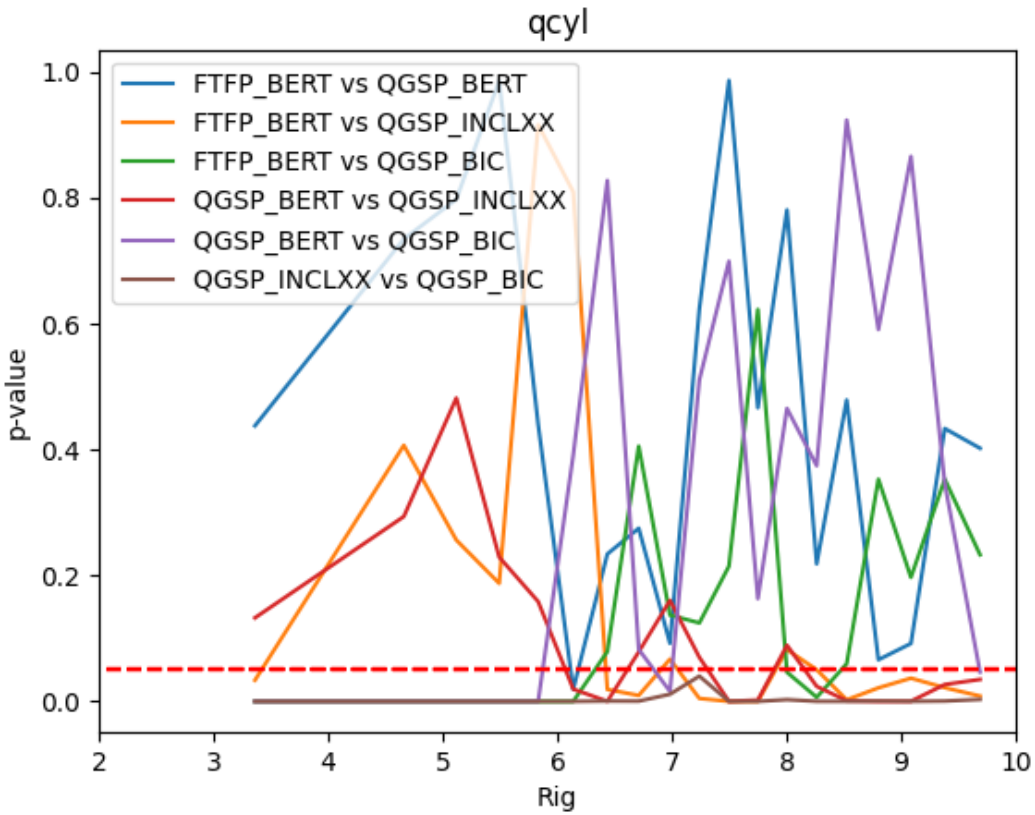




Comparison of models

R < 10 GV

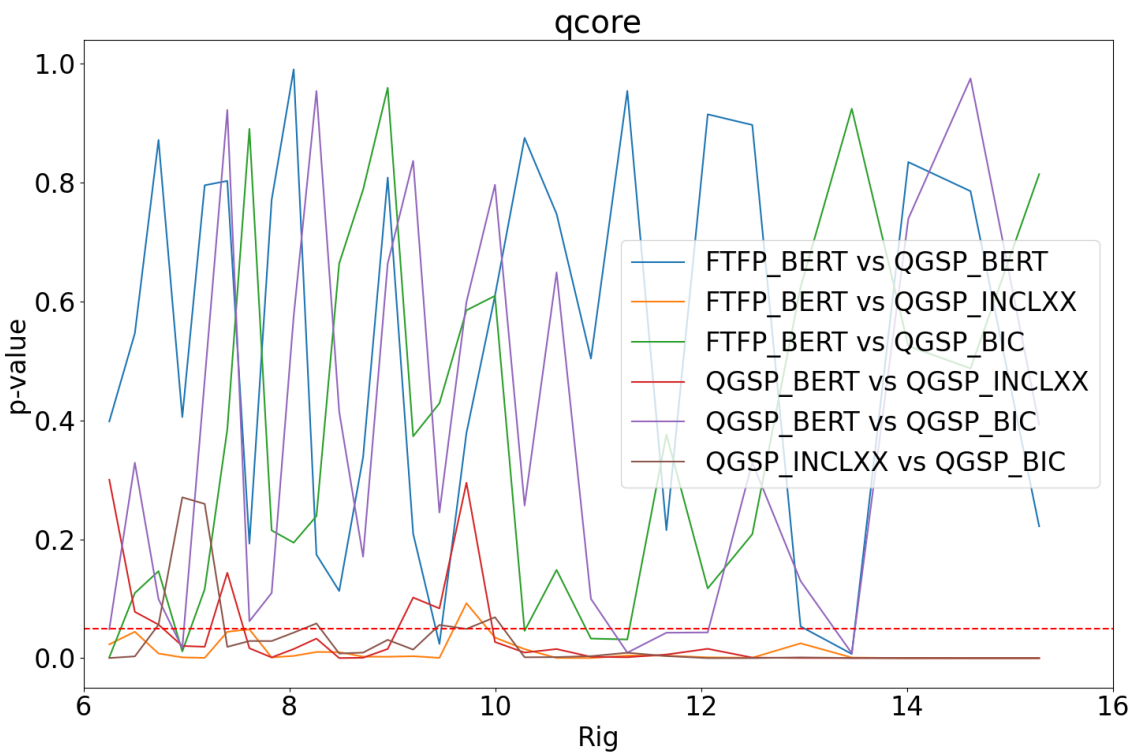
Rigidity < 10 GV: QGSP_BIC differs from other models.
On figure: p-value for KS-test ($\alpha = 0.05$).



Comparison of models

$6 < R < 16$ GV

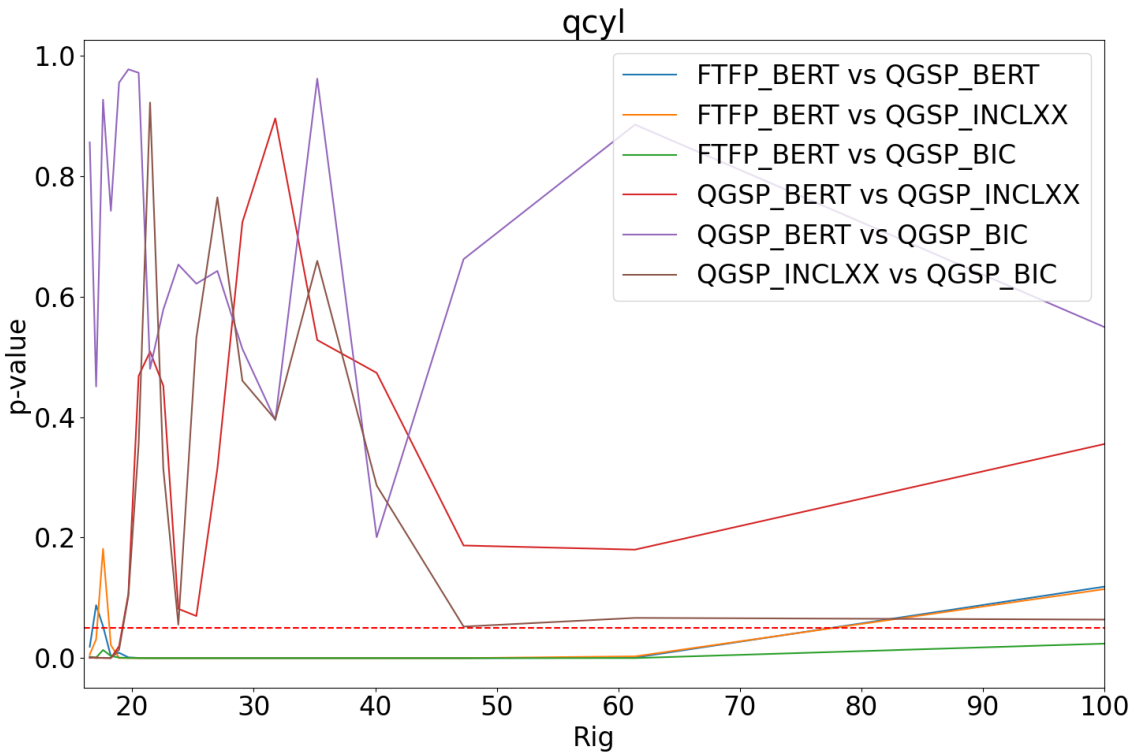
Rigidity 6..16 GV: QGSP_INCLXX differs from other models.
On figure: p-value for KS-test ($\alpha = 0.05$).



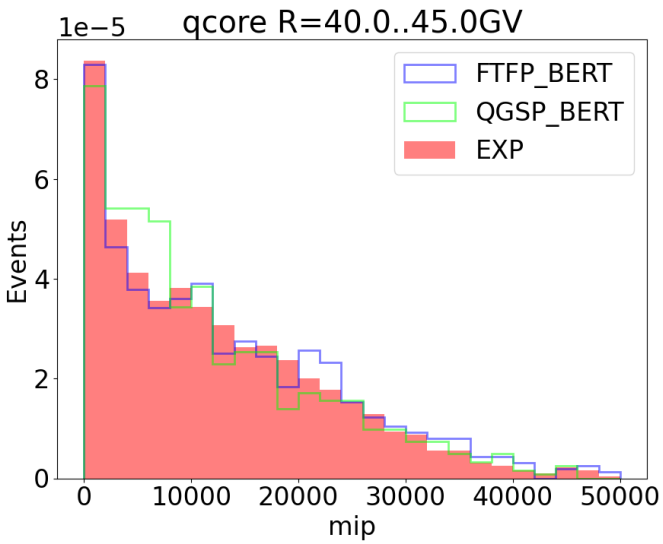
Comparison of models

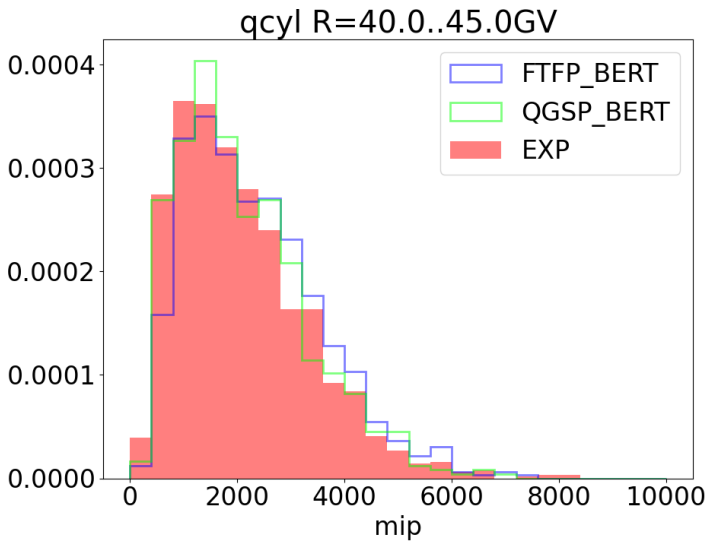
R > 16 GV

Rigidity > 16 GV: FTFP_BERT differs from other models.
On figure: p-value for KS-test ($\alpha = 0.05$).



Models vs experiment

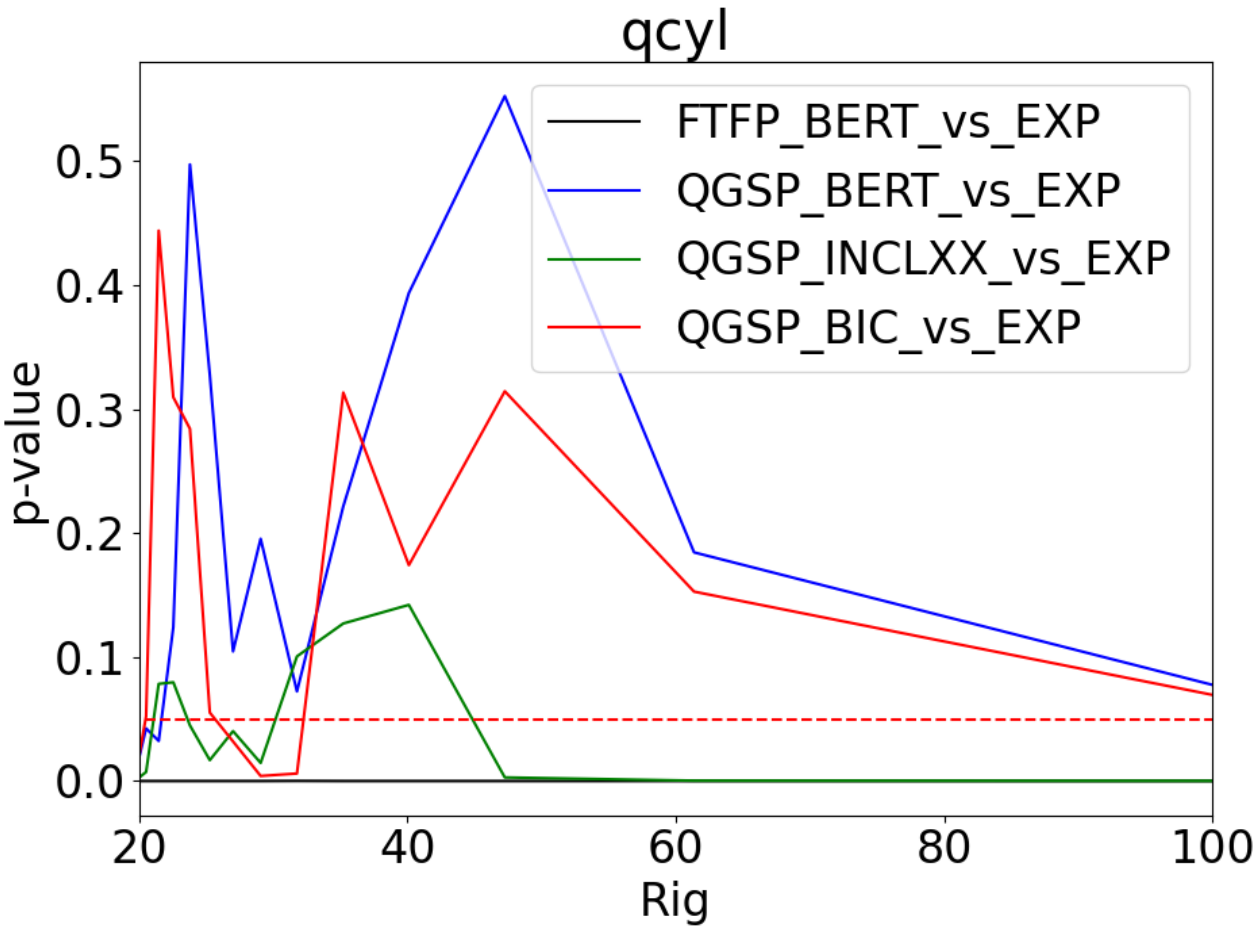




Models vs experiment

Two-sample agreement test

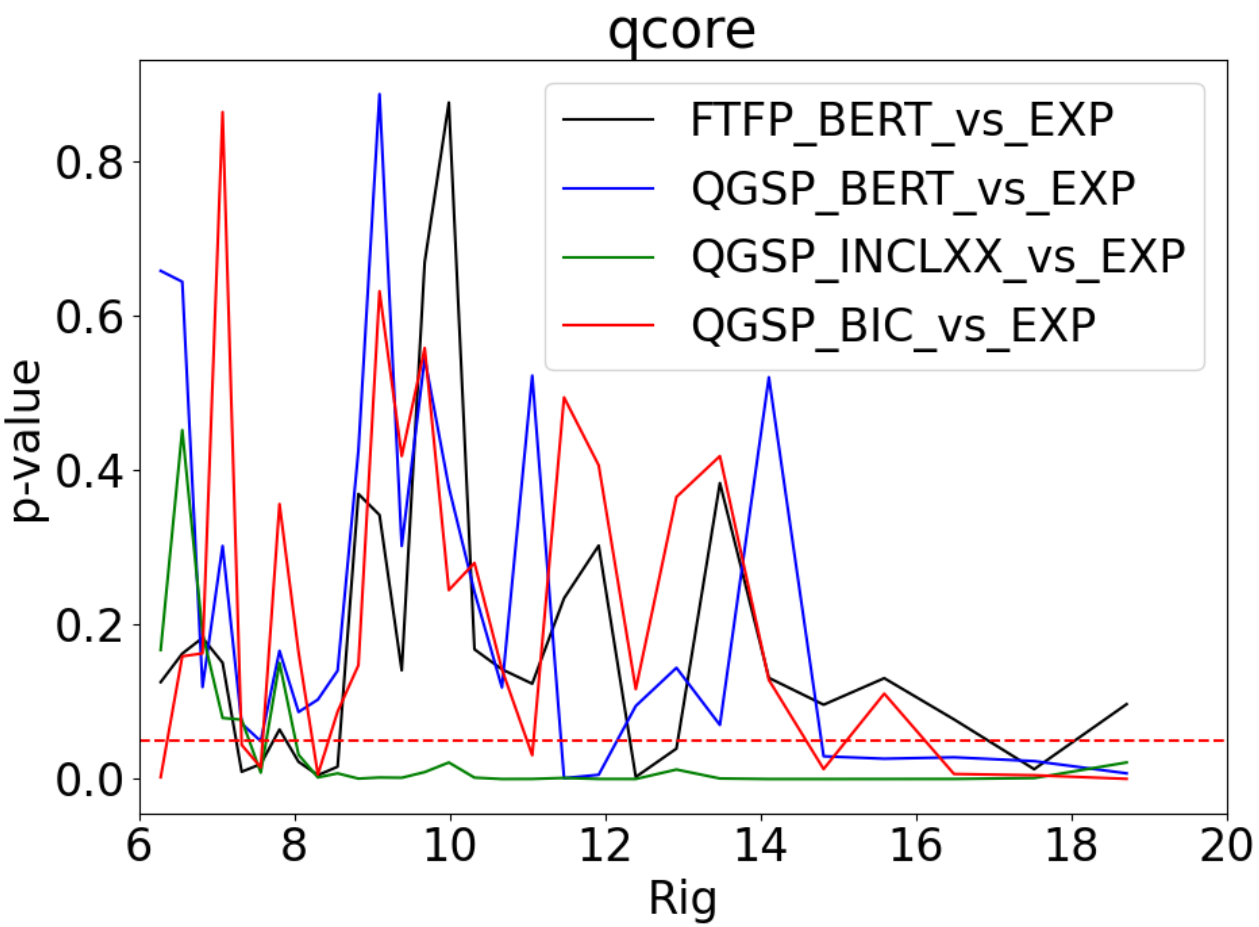
$R >$ 20GV: QGSP_BERT model agrees with experiment.



Models vs experiment

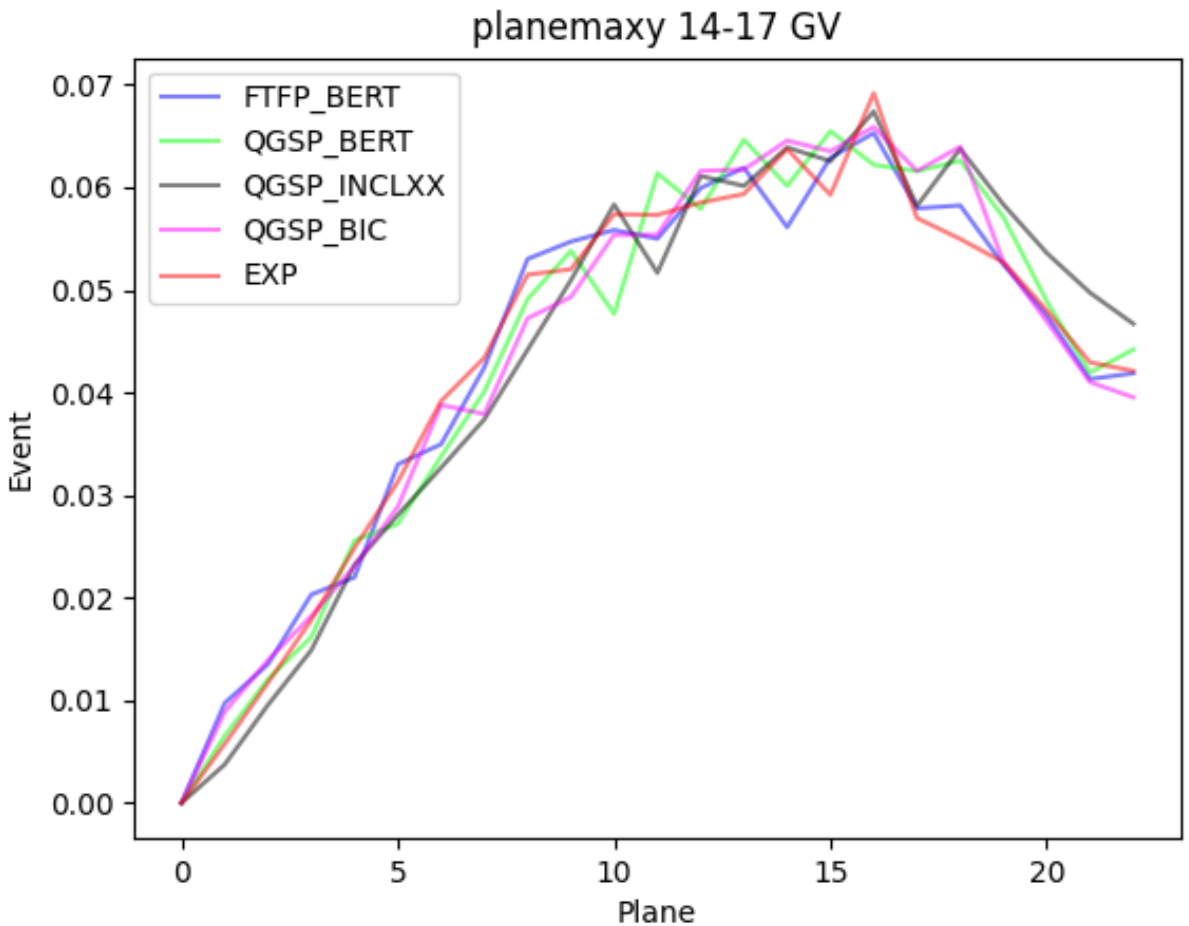
Two-sample agreement test

$8 < R < 20$GV: QGSP_INCLXX model disagrees with experiment.



Depth of cascade development

`planemaxy` – number of plane with maximal energy loss (Y projection).
All models agree with experiment.



Results

- Low rigidities (up to 6GV): the binary cascade simulation gives distributions of parameters, which are not agree with Bertini and Liege cascades.
- For R = 6..15 GV: physics lists QGSP and FTFP do not agree with QGSP_INCLXX model, then (supposing agreement between BERT and INCLXX) we conclude that INCLXX and QGSP / FTFP are different in cascade simulation.
- At the large (> 20 GV) rigidities we observe the difference between QGS and FTF models.

Results

From comparison with experiment we conclude:

- For the high energies statistical agreement is reached for QGSP_BERT model.
- For the medium energies (6..15 GV) there is no statistical difference between FTFP and QGSP models.
- For the low energies agreement is reached for Bertini cascade.
- Liege cascade model agrees with experimental data for rigidities up to 6-7 GV, despite of it is used for rigidities $<$ 20GV.