Comparison of data with Monte Carlo simulations at the ATLAS barrel Combined Test Beam 2004

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for the CTB pion analysis group
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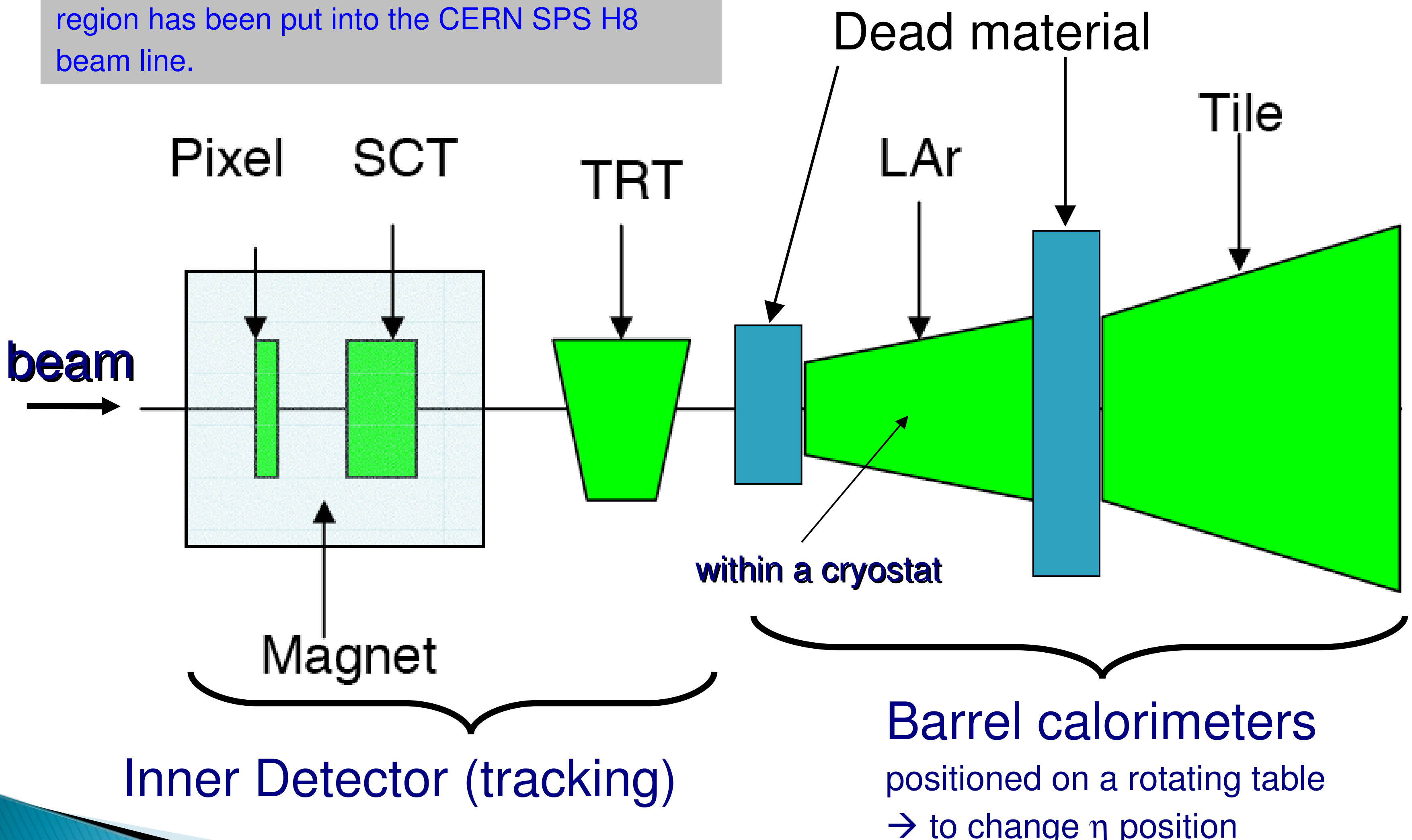
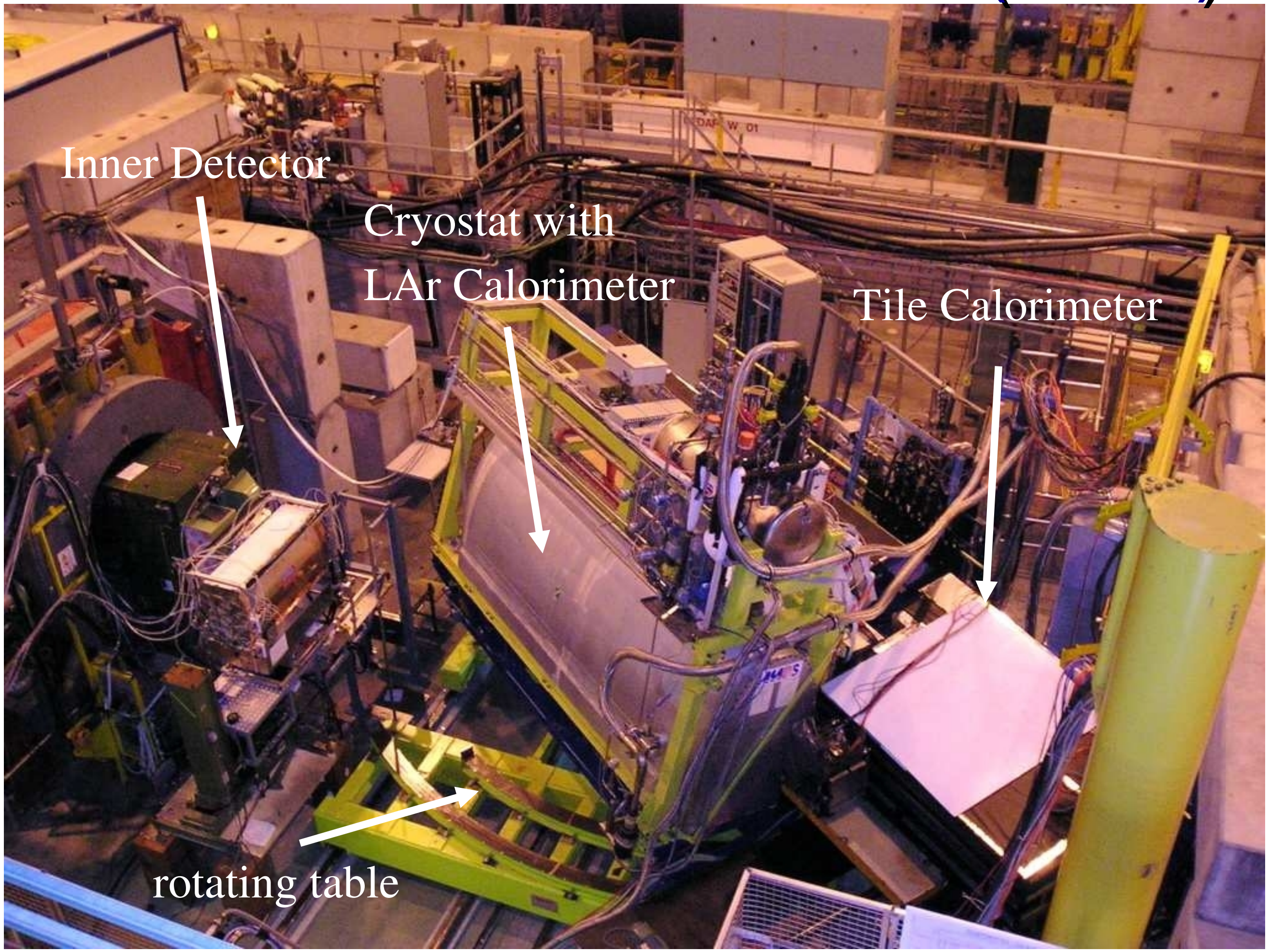
CALOR 2008

Combined Test Beam 2004 (CTB)

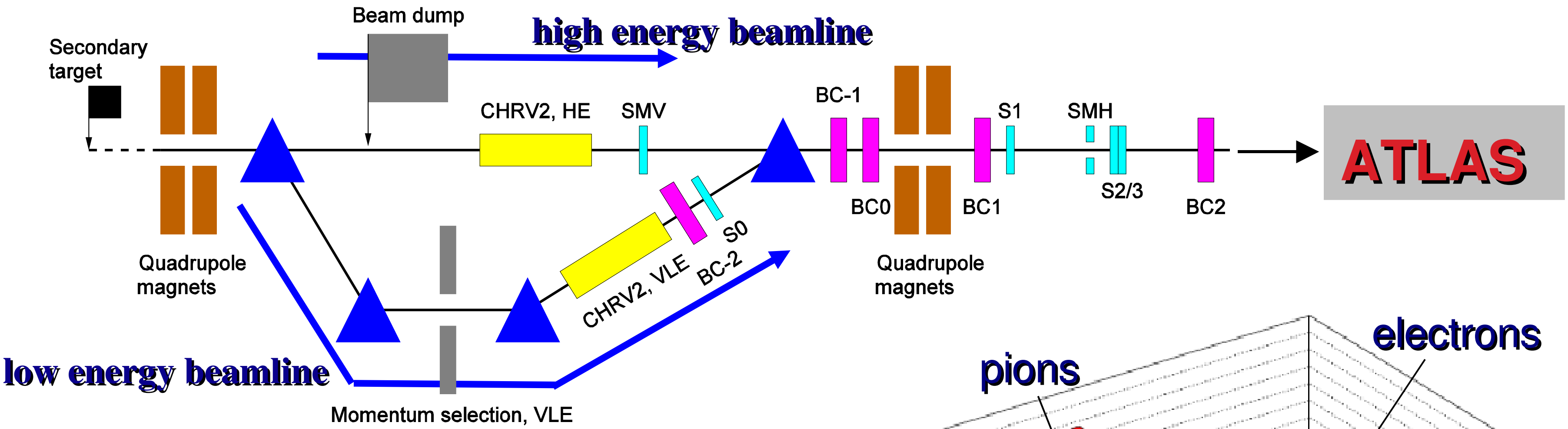
Slice of all the detectors of the ATLAS barrel region has been put into the CERN SPS H8 beam line.

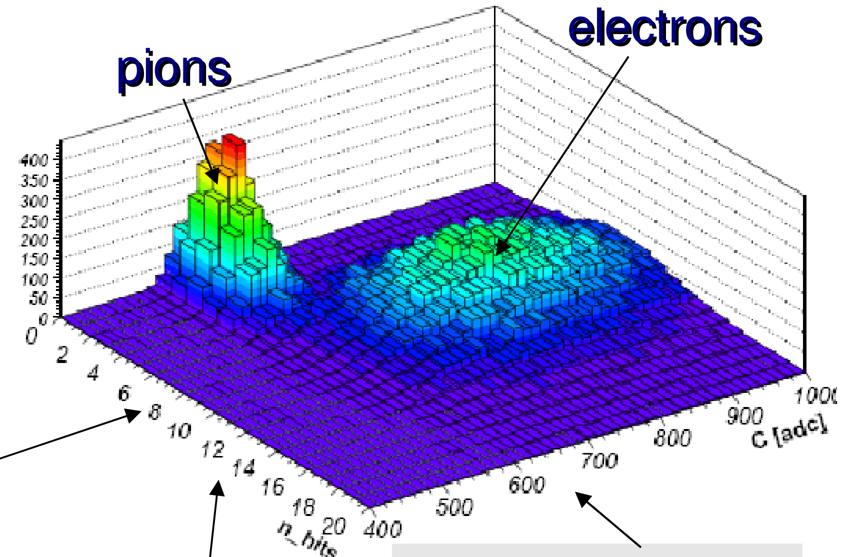


Combined Test Beam 2004 (CTB)



The beam line





strong cuts necessary to get clean beam:

- muon rejection:
  - high energy muons → timing, E_{TileD}-cut
  - Pion decays → included in systematic uncertainty
- e/π separation (e.g. TRT, Cherenkov)

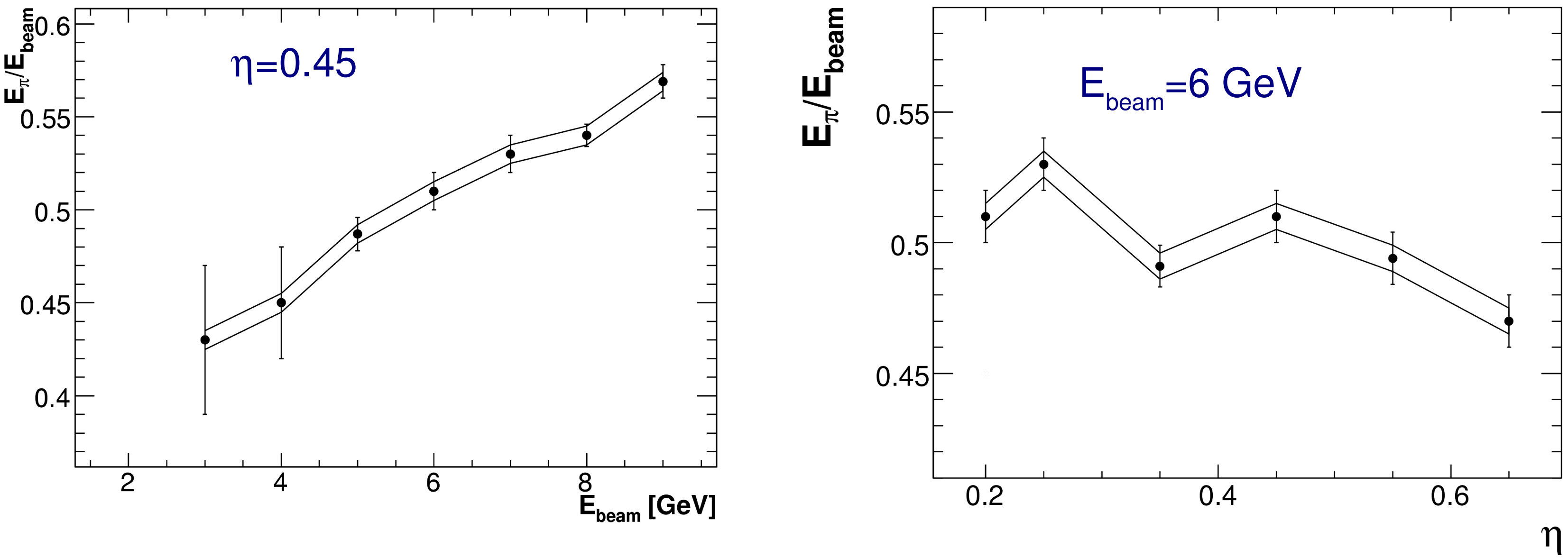
Large event rejection: (100k→1000)

signal in Cherenkov detector

number of hits produced by transition radiation in the TRT

Pion response for very low energy data (3 to 9 GeV)

examples:



full scan from E = 3 to 9 GeV and η = 0.20 to 0.65 analysed

full systematic error analysis:

•typical uncertainty: ~8% at 3 GeV/c to ~1% at 9 GeV (dominated by the statistical error)

•Uncertainty on the beam energy scale

Physics lists

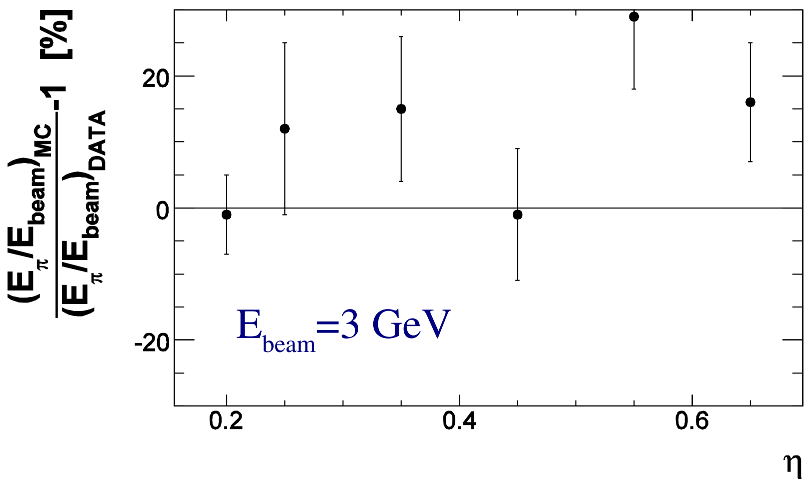
physics list: defines for all particle-types which physical model is used in each energy range.

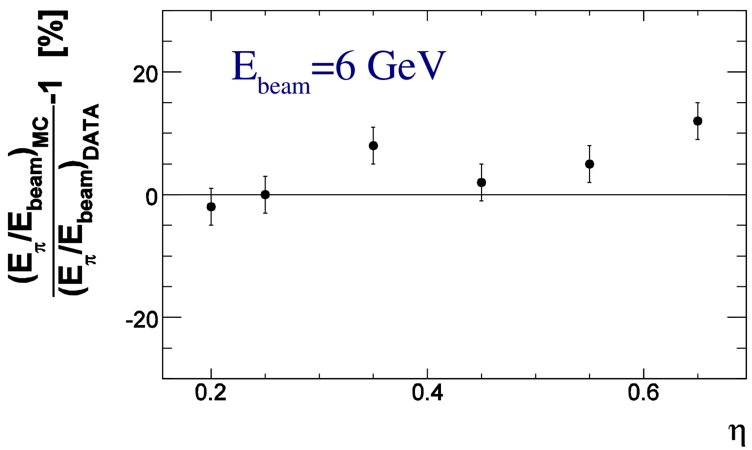
physics list	*low energy*	*high energy (fragmentation)*
QGSP	low energy paramet. (LEP) < 25GeV	quark gluon string (>12 GeV)
QGSP_BERT	0 GeV < Bertini cascade < 9.9 GeV 9.5 GeV < LEP < 25 GeV	quark gluon string (>12 GeV)
FTFP	0 GeV < LEP < 5 GeV	Fritiof (>4 GeV)
FTFP_BERT	0 GeV < Bertini cascade < 5 GeV	Fritiof (>4 GeV)

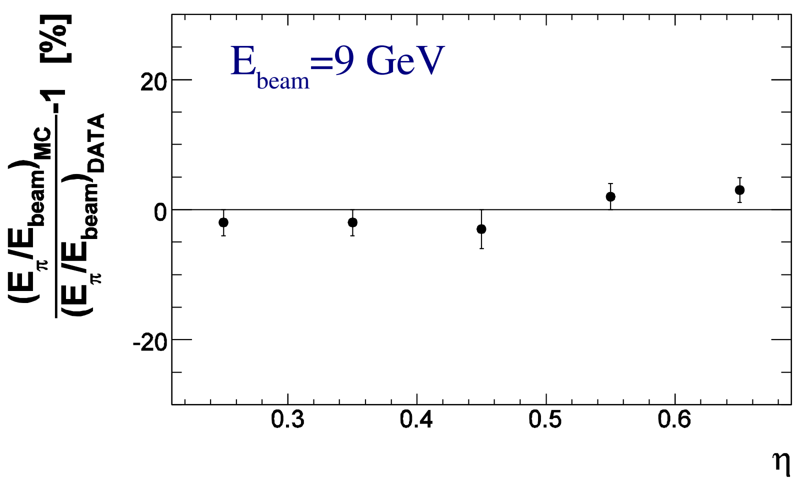
- newest version of simulation framework: Geant 4.91 (Dec. 2007).
- older version Geant 4.7 (Feb. 2005) is used for the hadronic calibration of the CTB (see talk by Francesco Spano)

(differences: new version has model for quasi-elastic scattering, and improvements of elastic scattering and multiple scattering)

Mean pion response ratio of data to Monte Carlo







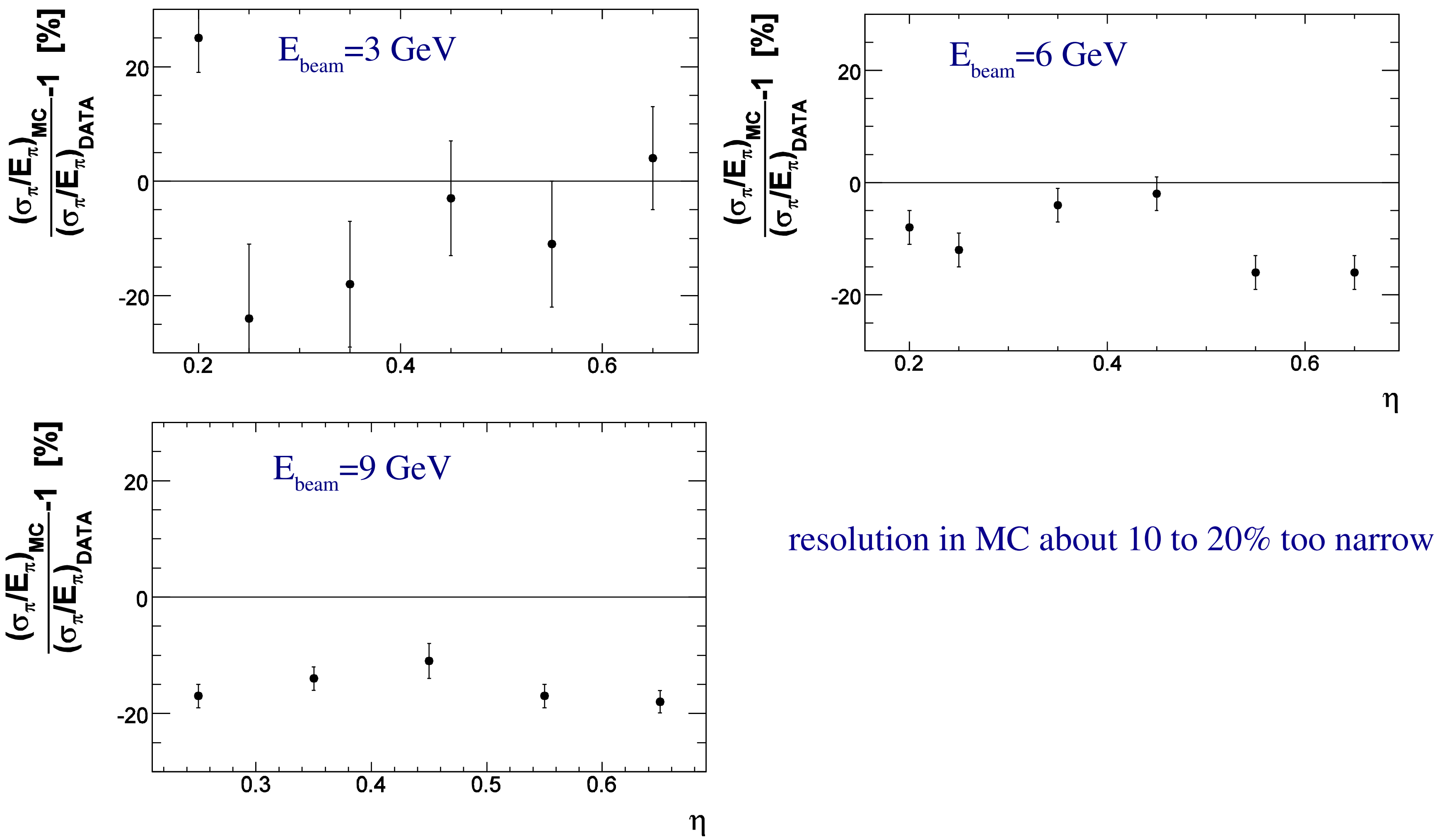
MC: Geant4.91 QGSP_BERT

9 GeV: ~±5%

6 GeV: ~±10%

3 GeV: ~±20%

Pion resolution ratio of data and Monte Carlo

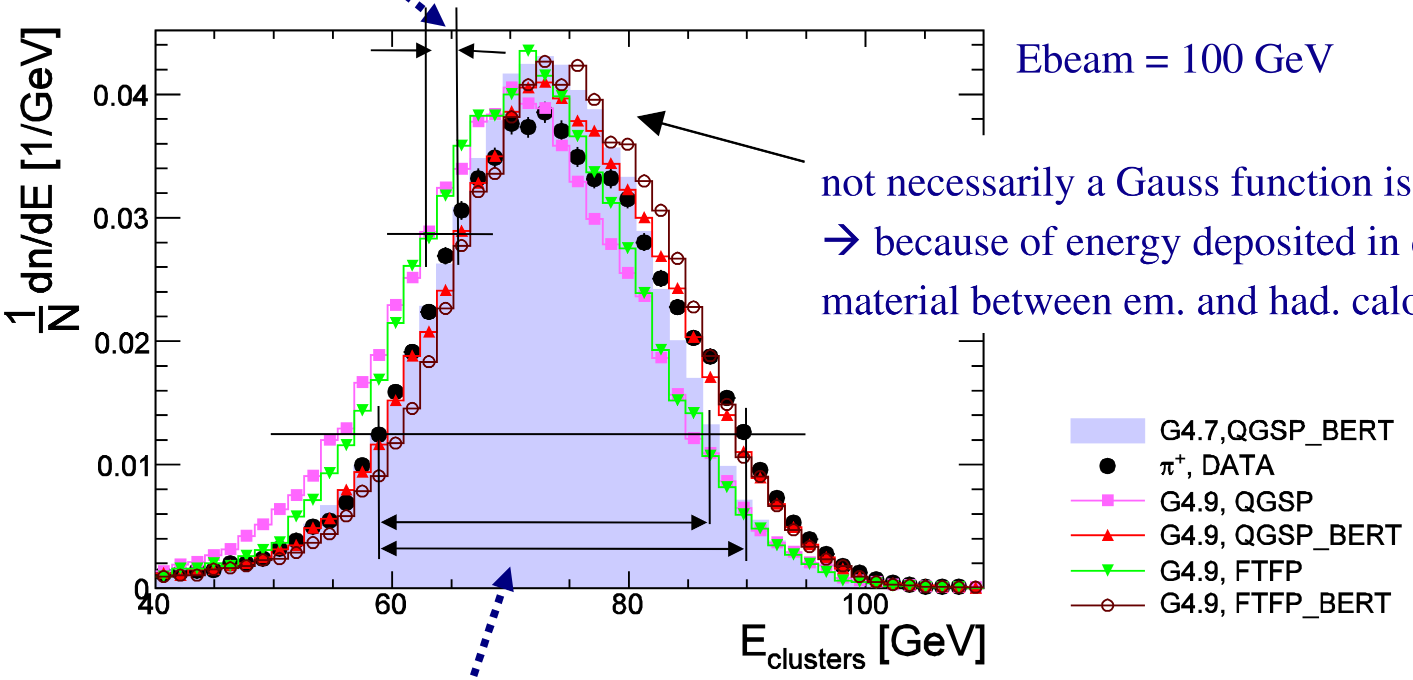


resolution in MC about 10 to 20% too narrow

total energy distribution deposited in the calorimeters

with Bertini cascade: more energy is deposited (shift to higher energies)

leads to a better agreement with data



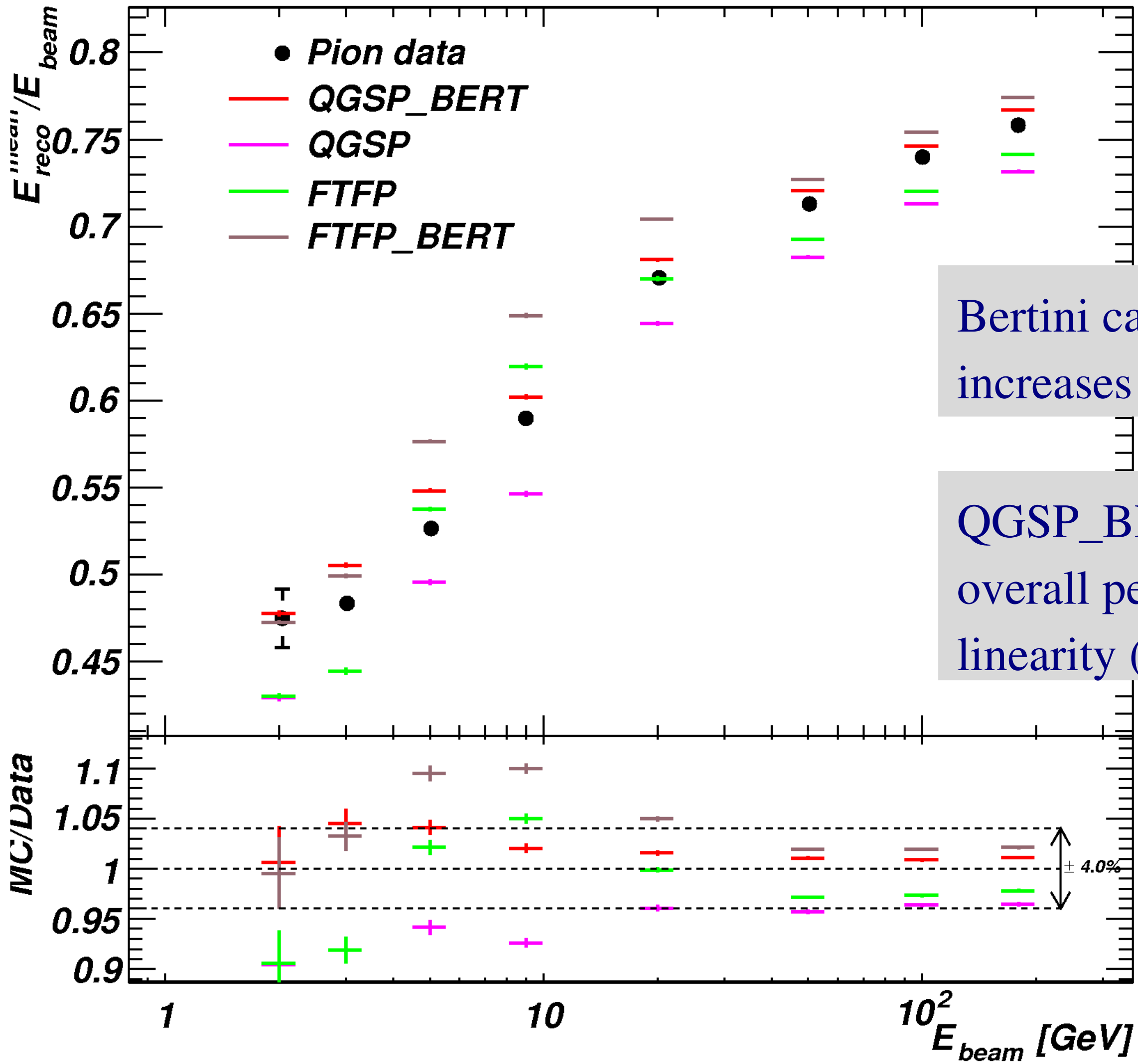
Ebeam = 100 GeV

not necessarily a Gauss function is expected
→ because of energy deposited in dead material between em. and had. calorimeters

width of distribution is too narrow for Geant4.7 compared to data

width of distribution of data better described in latest version of Geant (Geant 4.91)

Mean pion response for 2 to 180 GeV

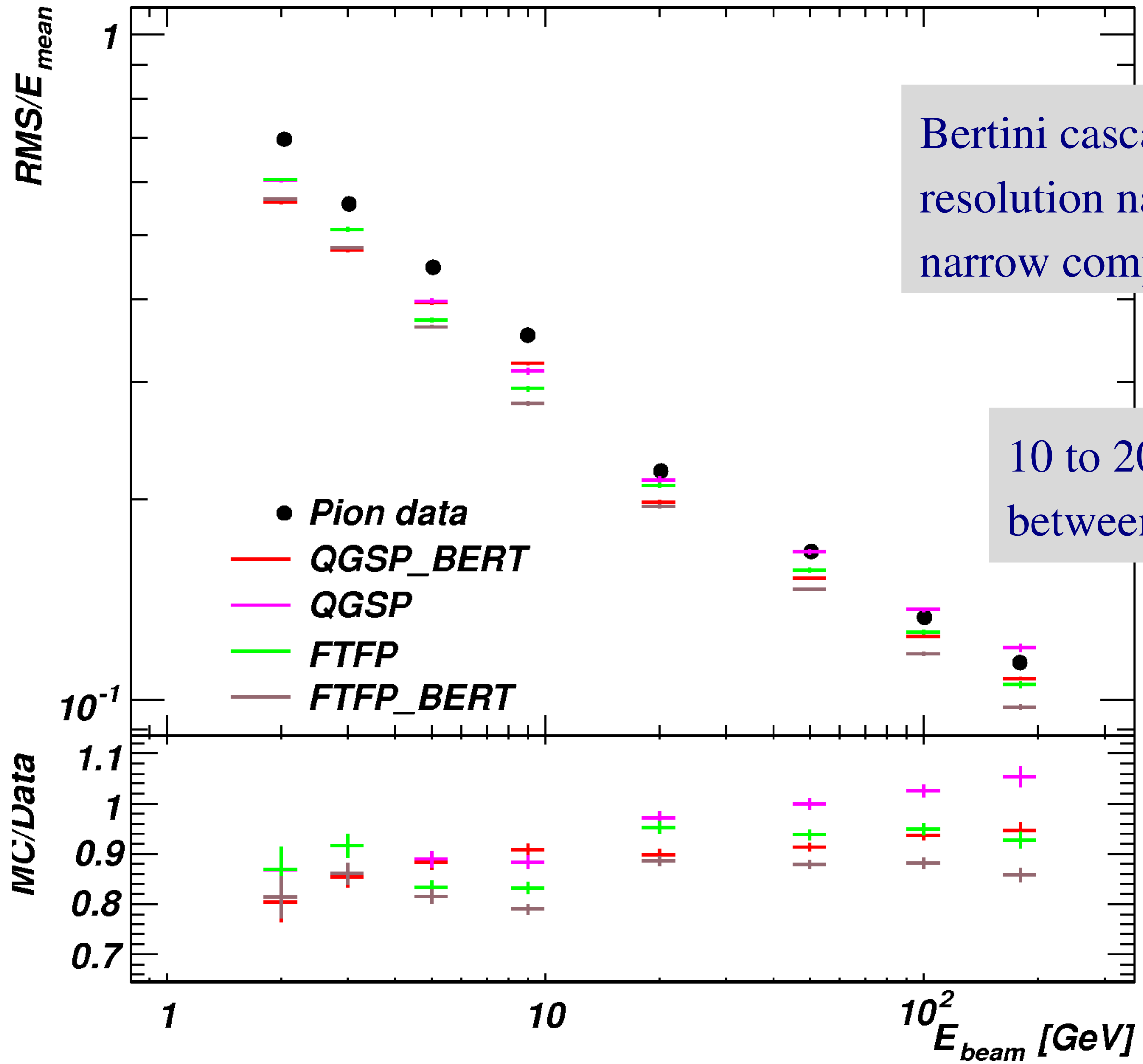


Bertini cascade model increases the energy response

QGSP_BERT shows the best overall performance for the linearity (within 4%)

- Slightly different event selection with respect to previous results
- No systematic uncertainty included

Pion resolution for 2 to 180 GeV



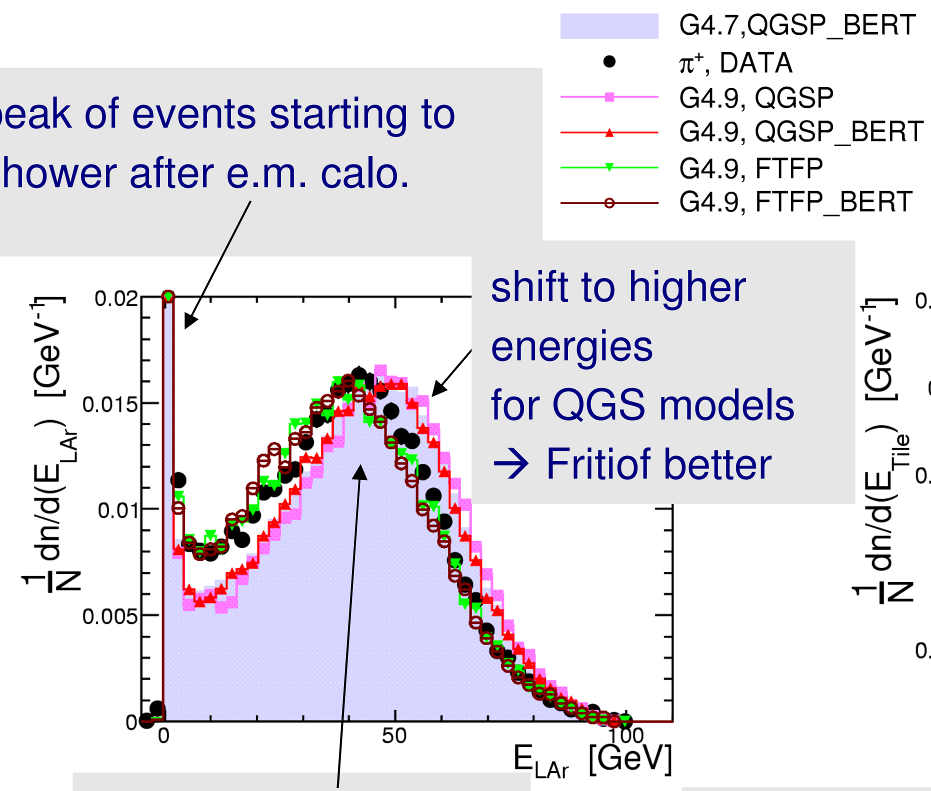
Bertini cascade makes resolution narrower (too narrow compared to data)

10 to 20% disagreement between MC and data

energy sharing: e.m. (LAr), had. (Tile) calorimeters, E_{beam} = 100 GeV

peak of events starting to shower after e.m. calo.

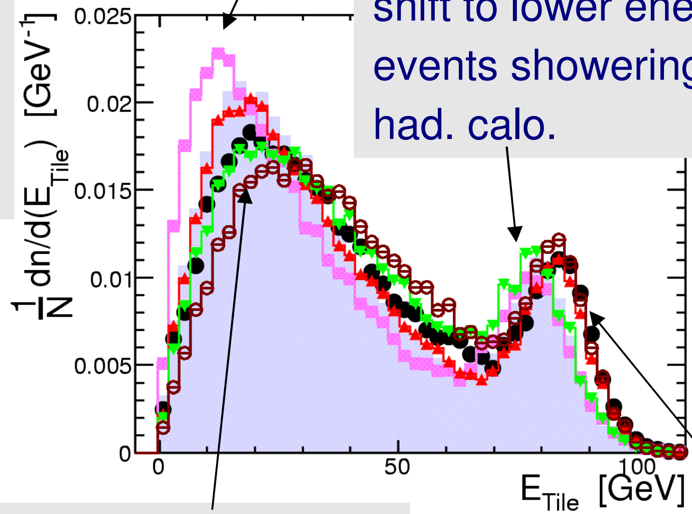
shift to higher energies for QGS models → Fritiof better



peak of events starting to shower in e.m. calo.

too many events with small energies in had. calo. for QGSP

without cascade model: shift to lower energies for events showering only in had. calo.



shift to higher energies for FTFP_BERT for events starting to shower in e.m. calo.

with cascade model: events showering in had. calo. agree with data

barycenter of the shower (center_lambda)

E_{beam}=100 GeV

most of the energy is deposited in the e.m. calorimeter

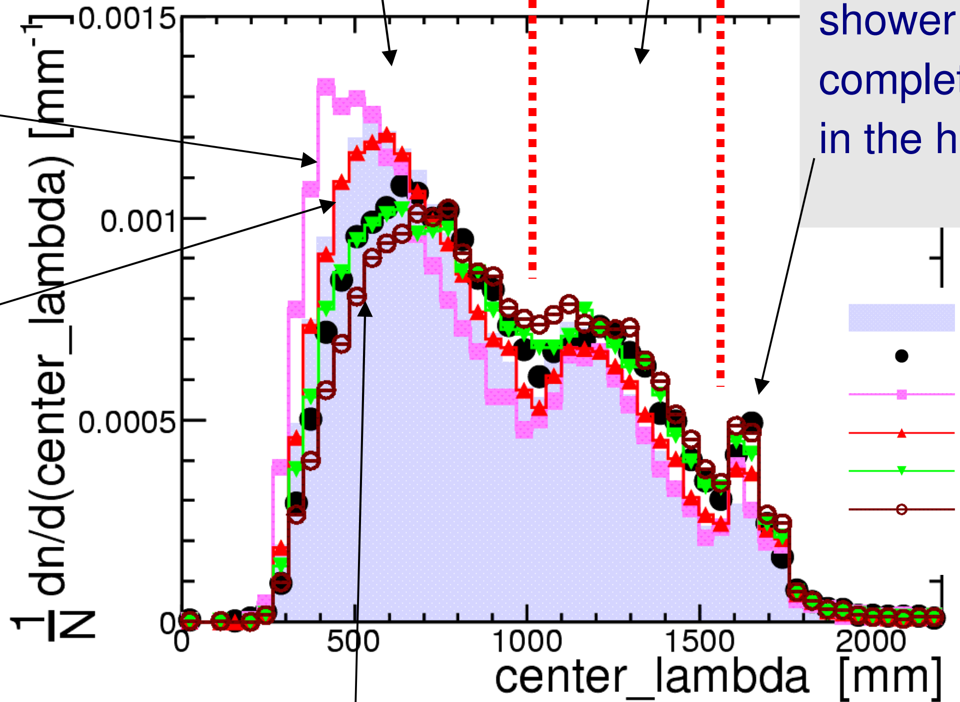
most of the energy is deposited in the had. calorimeter

shower is nearly completely contained in the had. calorimeter

QGSP → barycenter too "early"

QGSP_BERT→ barycenter is "later", but still too "early"

FTFP follows data well



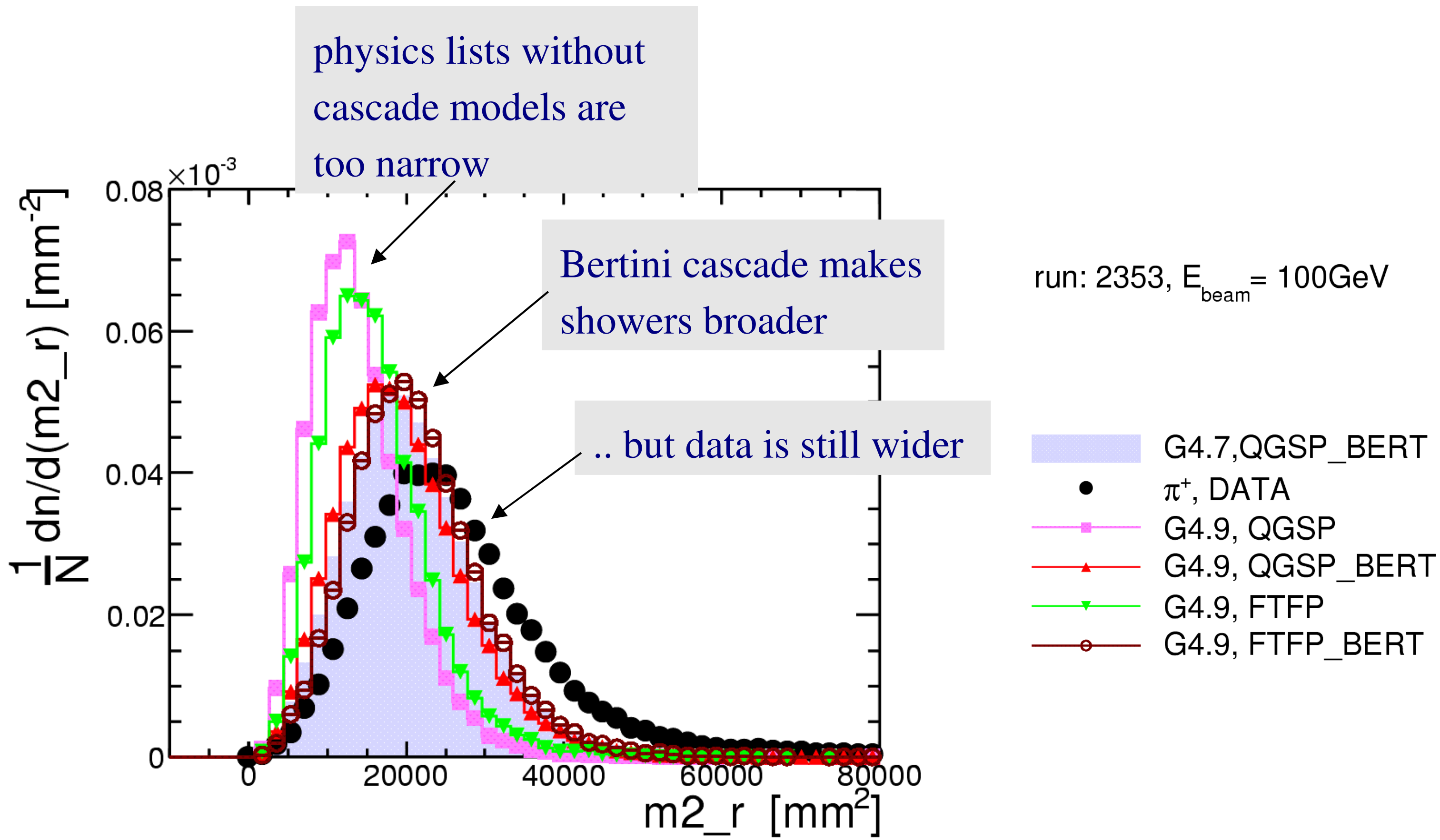
FTFP_BERT → barycenter "too late"

Conclusions

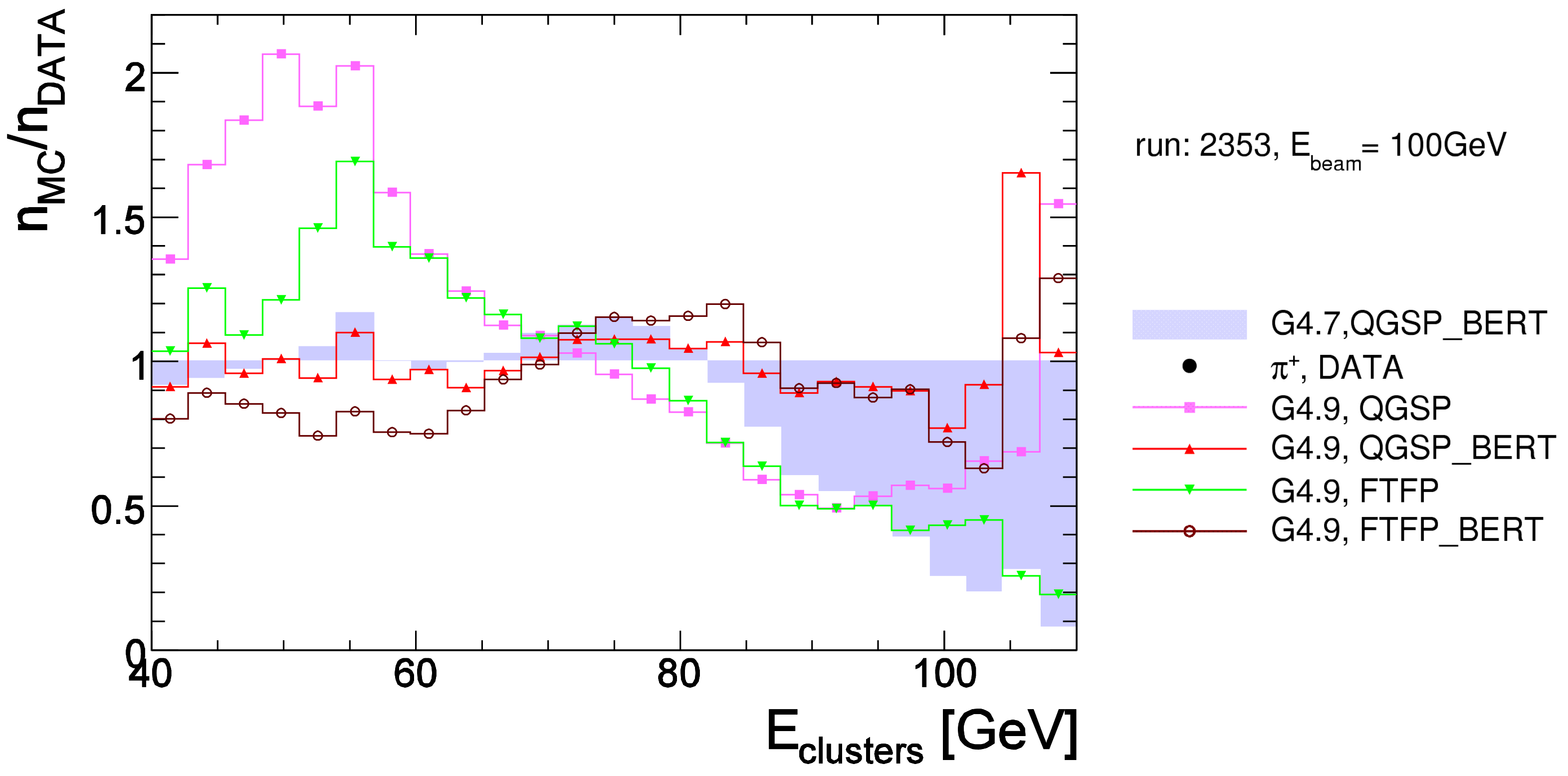
- ATLAS barrel calorimeter has been exposed to test-beam.
- Data analysis with full systematic uncertainty available for 3 to 9 GeV and full η-scan.
- Pion response within a few percent described by QGSP_BERT, but resolution too narrow (10 to 20%).
- Cascade model makes resolution of energy response narrower.
- Shower starts and ends too early for QGSP.
    - Bertini cascade makes shower longer (but not long enough).
- Fritiof describes the longitudinal shower development.
    - but with Bertini cascade, shower is too long.
- For the first simulation of ATLAS data QGSP_BERT is used.

backup

Lateral extension (radius) of the showers

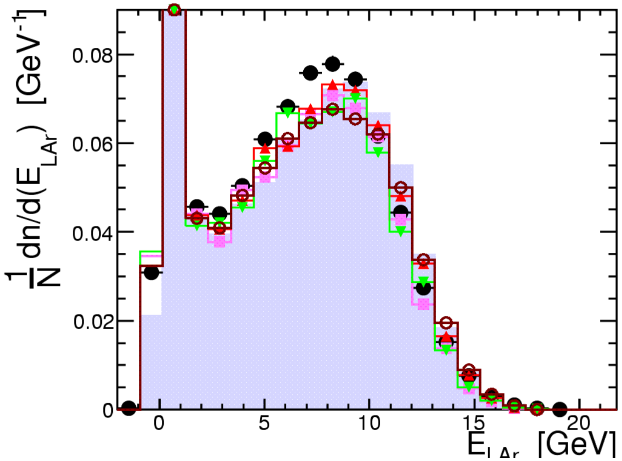


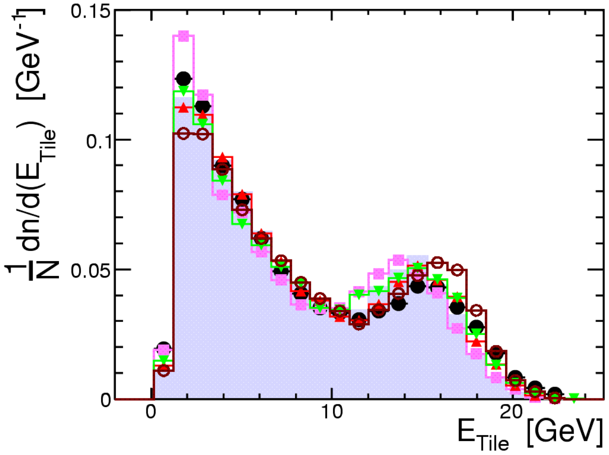
ratio of total energy distribution of MC and data

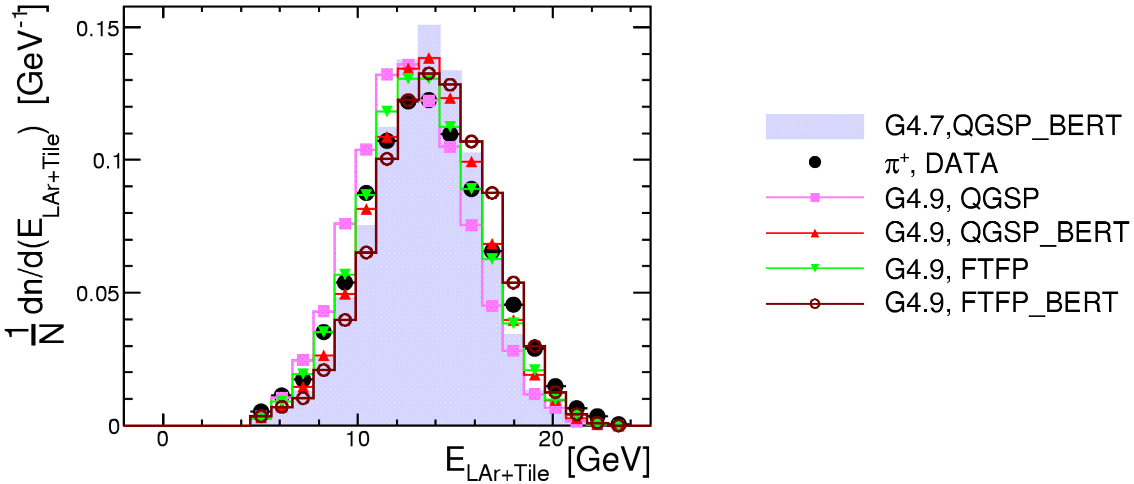


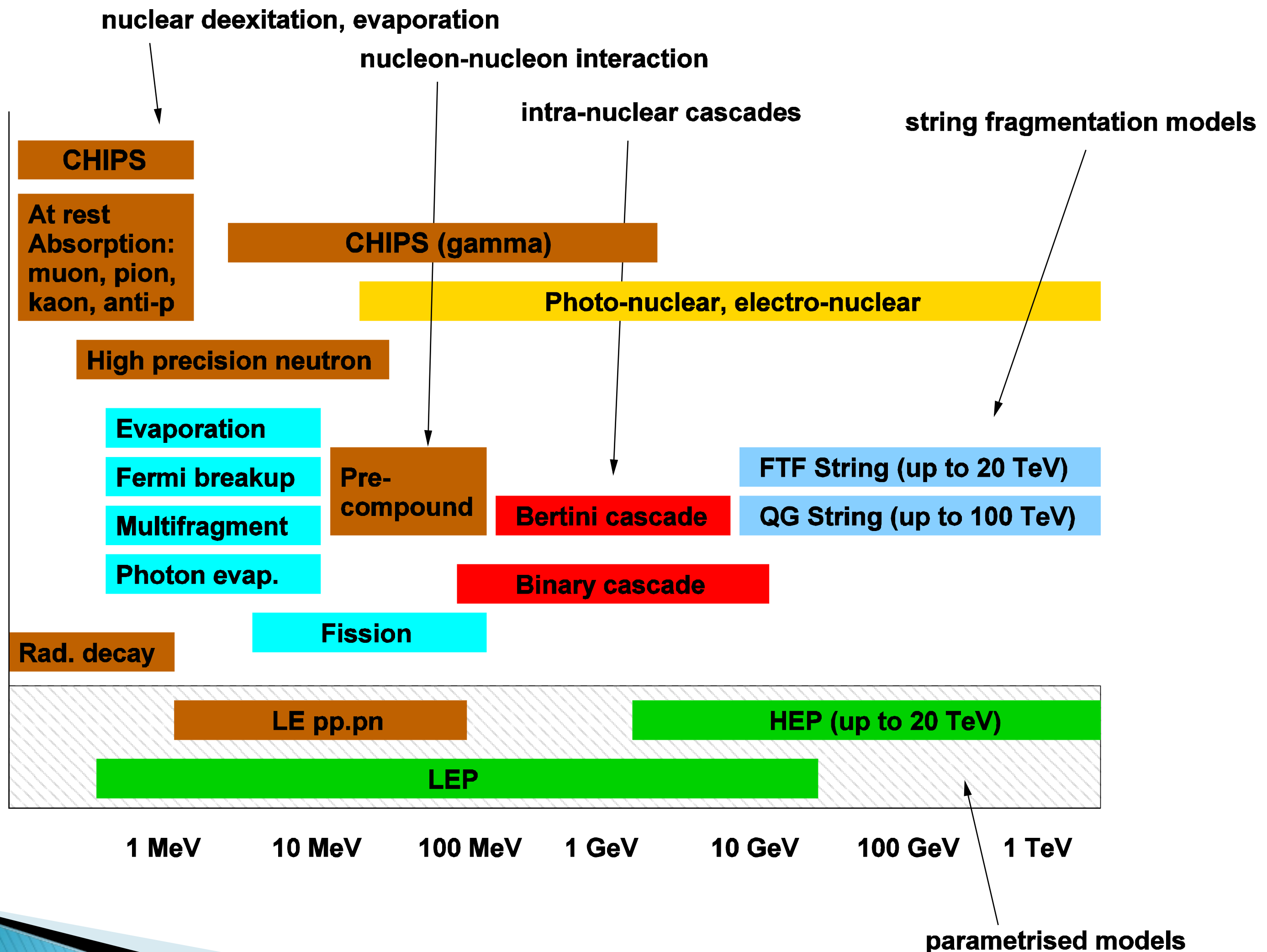
energy sharing: LAr, Tile calorimeters

E_{beam} = 20 GeV

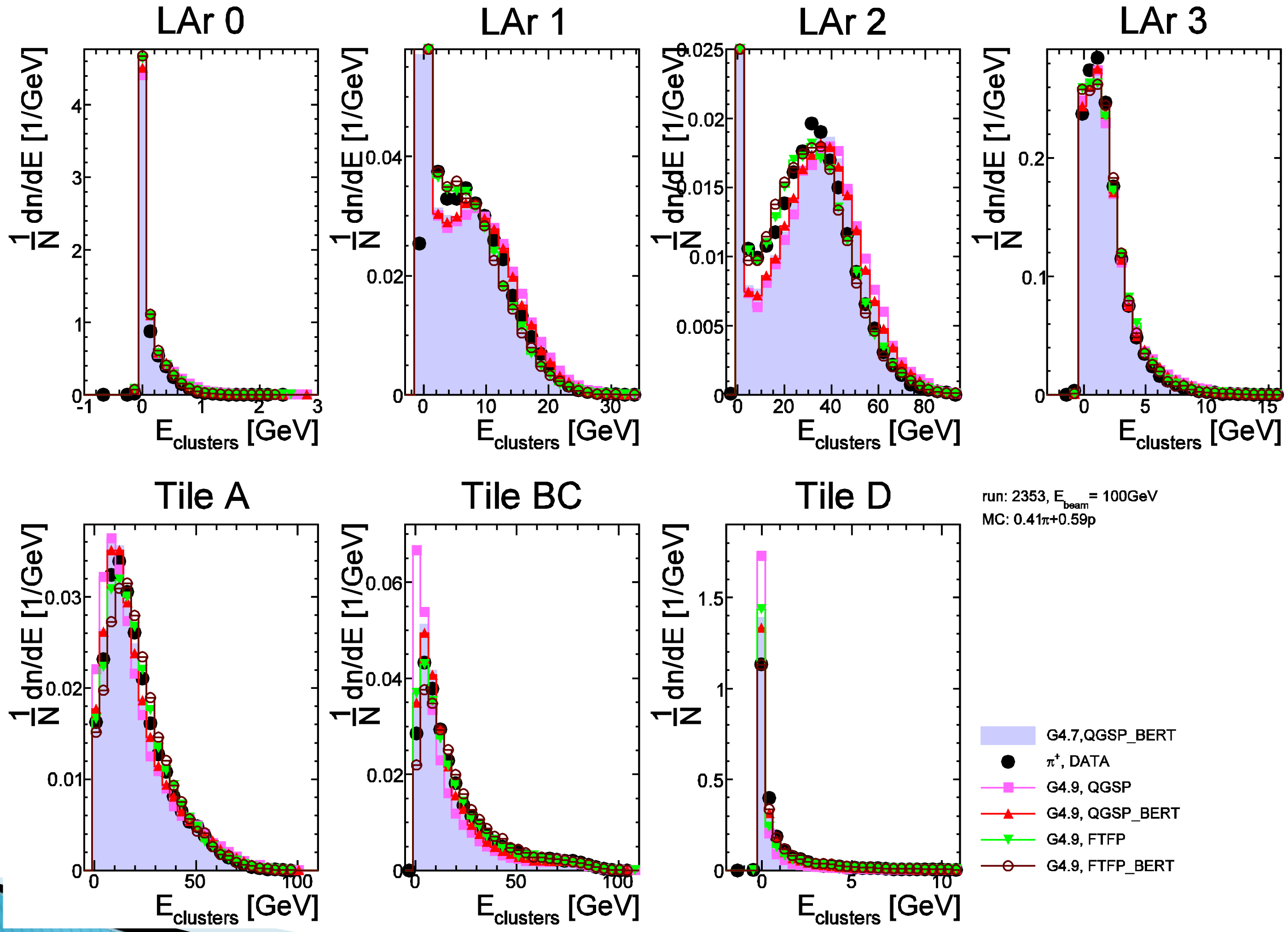







nuclear deexitation, evaporation
nucleon-nucleon interaction
intra-nuclear cascades
string fragmentation models
CHIPS
At rest Absorption: muon, pion, kaon, anti-p
CHIPS (gamma)
Photo-nuclear, electro-nuclear
High precision neutron
Evaporation
Fermi breakup
Multifragment
Photon evap.
Pre-compound
Bertini cascade
FTF String (up to 20 TeV)
QG String (up to 100 TeV)
Binary cascade
Fission
Rad. decay
LE pp.pn
HEP (up to 20 TeV)
LEP
1 MeV
10 MeV
100 MeV
1 GeV
10 GeV
100 GeV
1 TeV
parametrised models

distributions of energies deposited in the calorimeter layers



ratios of energy distributions of MC and data for layer 2 of the e.m. calo. and layer BC of the had. calo.