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Highlights of the highlights of Geant4 10.3 and 10.2.p03 releases and evolution of selected physics lists

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January 30th, 2017

Geant4 10.3; released December 9th, 2016

- Technical forum: https://indico.cern.ch/event/596279/timetable/#20170111.detailed

16:00	**General introduction of version 10.3 and prospect**	*Makoto Asai*	*160-R-009, CERN*	16:00 - 16:12
	Highlights of version 10.3 - non–physics part	*Gabriele Cosmo*	*160-R-009, CERN*	16:12 - 16:24
	Highlights of version 10.3 – EM physics part	*Vladimir Ivantchenko*	*160-R-009, CERN*	16:24 - 16:36
	Highlights of version 10.3 – Hadronic physics part	*Alberto Ribon*	*160-R-009, CERN*	16:36 - 16:48
	Open requirements	*Marc Verderi*	*160-R-009, CERN*	16:48 - 17:00
17:00	**Status of Geant4 in CMS**	*Vladimir Ivantchenko*	*160-R-009, CERN*	17:00 - 17:15
	Validation of Physics Models of Geant4 using data from CMS Experiment	*Sunanda Banerjee*	*160-R-009, CERN*	17:15 - 17:30
	ATLAS	*John Derek Chapman et al.*	*160-R-009, CERN*	17:30 - 17:45

Release notes: http://geant4.web.cern.ch/geant4/support/ReleaseNotes4.10.3.html

Selected information from the general introduction

- Some minor changes may be needed:
  - An explicit call to G4SDManager::AddNewDetector() must now be added in order to register a sensitive-detector
    - The use of G4VUserDetectorConstruction::SetSensitiveDetector() no longer does this implicitly
  - A new application state G4State_Init is introduced. Geant4 enters this state during initialization of geometry and physics
    - Transparent to all who use G4RunManager or G4MTRunManager (usually the case)
  - Plus (not in that talk):
    - (rarely used directly) theParticleIterator needs to be replaced with auto theParticleIterator = GetParticleIterator();

Selected information from non-physics highlights

- Geometry/Geometrical primitives
  - Updated VecGeom library (USolids) (Optional replacement of original Geant4 solids)
    - Selection made at configuration
      - Possibility to choose replacement of all available shapes or only selected primitives; Selection specified at configuration by shape name
- Persistency
  - New GDML schema version 3.1.4
    - Added ability to automatically export names of sensitive detectors as auxiliary information
- Particles: Updated properties according to PDG-2015
- CLHEP: Added 'us' and 'ps' units, requiring new CLHEP library version 2.3.4.3

Selected information from EM & hadronic physics highlights

- Completed migration of EM parameters management via G4EmParameters class
- Hadronic Data Sets
  - Achieved consistent set of data in terms of energy levels and lifetimes of excited nuclides, and physics models that use these data
    - photon evaporation
    - de-excitation
    - radioactive decay

Selected information from hadronic physics highlights, cont'd

- The latest FTF improvements – driven by thin-target data – and fixes of FTF model are not producing better hadronic showers (i.e. higher energy response and narrower shapes)
- Therefore, as a temporary solution to provide to the experiments reasonable hadronic showers (e.g. for the jet-energy scale), we have decided to release a version of FTF which is expected to produce showers similar to those in G4 10.1
  - Starting from G4 10.2.p02, but with the treatment of the excited nuclear remnants more similar to the one in G4 10.1
    - The treatment of the excited nuclear remnants introduced in G4 10.2 was the main responsible of the worsening (i.e. higher energy response) of hadronic showers with respect to G4 10.1

Selected information from hadronic physics highlights, cont'd

- Bertini-like (BERT)
  - Improved the evaporation spectrum. This reduces the overproduction of low-energy neutrons and protons
  - Added 8- and 9-body final states to kaon-induced reactions
- Physics Lists
  - In FTFP_BERT and FTFP_BERT_HP changed the transition region between FTFP and BERT : [3, 12] GeV
    - Instead of [4, 5] GeV
      - For pions, kaons, proton and neutron
      - For hyperons, left unchanged: [2, 6] GeV
      - For anti-nucleons, FTFP is used at all energies
    - To smooth out unphysical kinks and to leverage more on BERT
      - BERT produces hadronic showers with lower energy response and wider with respect to FTFP

Selected information from hadronic physics highlights, cont'd

- Hadronic showers
  - FTFP_BERT hadronic showers in G4 10.3 are expected to be as good as, is not slightly better than, those of G4 10.1
  - Some differences – in particular smoother behavior and wider hadronic showers as a function of the projectile energy, especially between 4 and 12 GeV – are due to the change of transition region between FTFP and BERT
  - Energy response in Fe & Cu is similar to G4 10.1, i.e. a few % lower than in version 10.2
  - Energy response in heavier absorbers (W & Pb) is a few % lower than both versions 10.1 and 10.2

Geant4 10.2.p03

- Released on January 27, 2017
- http://geant4.web.cern.ch/geant4/support/Patch4.10.2-3.txt
  - models/particle_hp: Reintroduced cache of cross-section in GetIsoCrossSection(). Fixing CPU performance penalty introduced in release 10.2 on HP processes
    - This affected …_HP and Shielding(M) physics lists, increasing the execution time for some hadronic processes (the fix decreases the simulation time by ~40% in those cases)
  - Added method GetParticleIterator() in G4VPhysicsConstructor and in G4VUserPhysicsList.

Hadronic validation results on selected physics list evolution for versions 9.6-10.3 and comparison of physics lists for version 10.3 by Julia Yarba

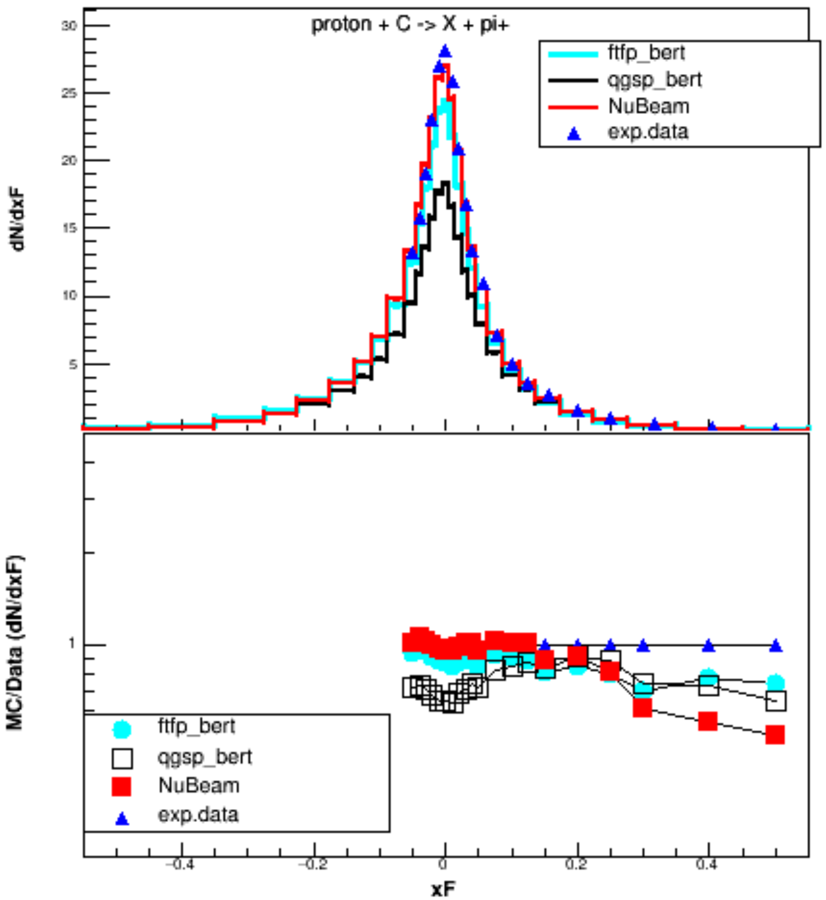
Physics lists and models

- High energy models, FTF and QGS, are being actively developed.
- Composition of the physics lists may change from one Geant4 release to another; in particular, the FTFP_BERT composition has changed substantially in 10.3 as the Bertini/FTF overlap region went from 4-5GeV to 3-12GeV.
- "Experimental" physics lists NuBeam has been part of Geant4 distribution since early 10.x series:
  - One needs to remember that its composition is largely motivated by the state of FTF, QGS, and Bertini as of releases 9.6 and 10.0.
  - We monitor the development in QGS and FTF, and as more progress is made, we may recompose NuBeam and/or recommend another physics list.

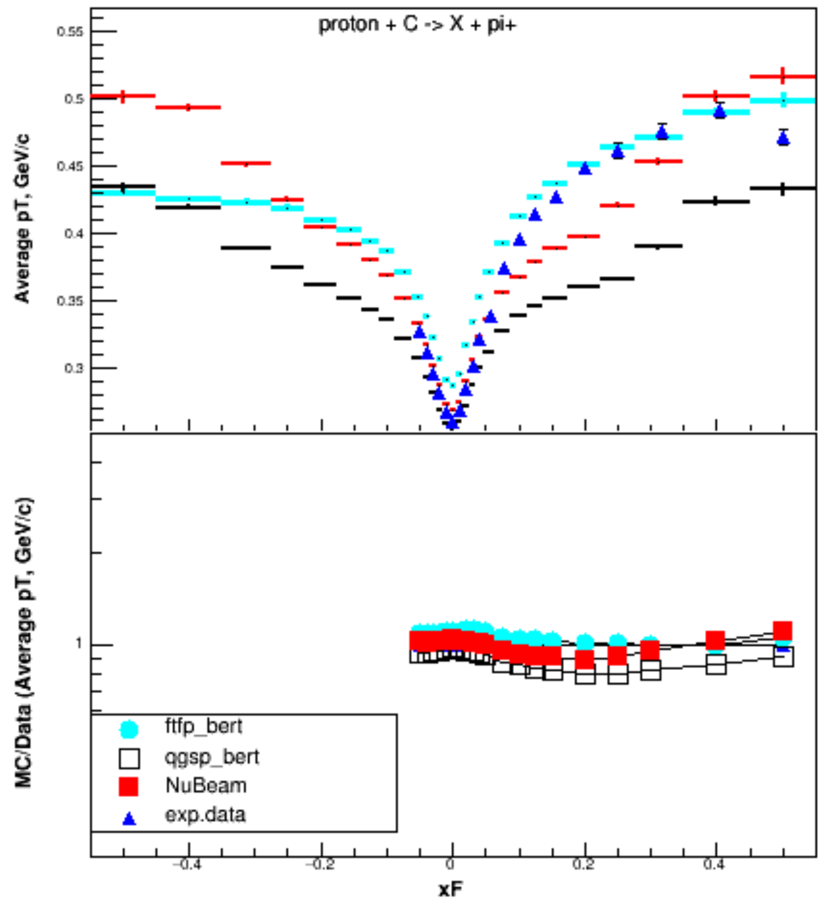
Physics lists and models validation

- Validation of Geant4 hadronic models and physics lists is an important part of the Geant4 development and release efforts
- We work on expanding collection of experimental data for validation:
  - Recently added benchmarking vs data on hadron production in π^++A and p+A at 100GeV/c (several target)
    - this complements earlier benchmarking vs data from p+C at 158GeV/c
  - Plan to add more high energy data on hadron production in hadron+A interactions
  - Incorporating more recent results from NA61 (run-2009), in order to better attest modeling of hadron production in the tens-GeV range

158GeV/c p+C -> π^+ + X
Different physics lists (4.10.3) vs NA49 data

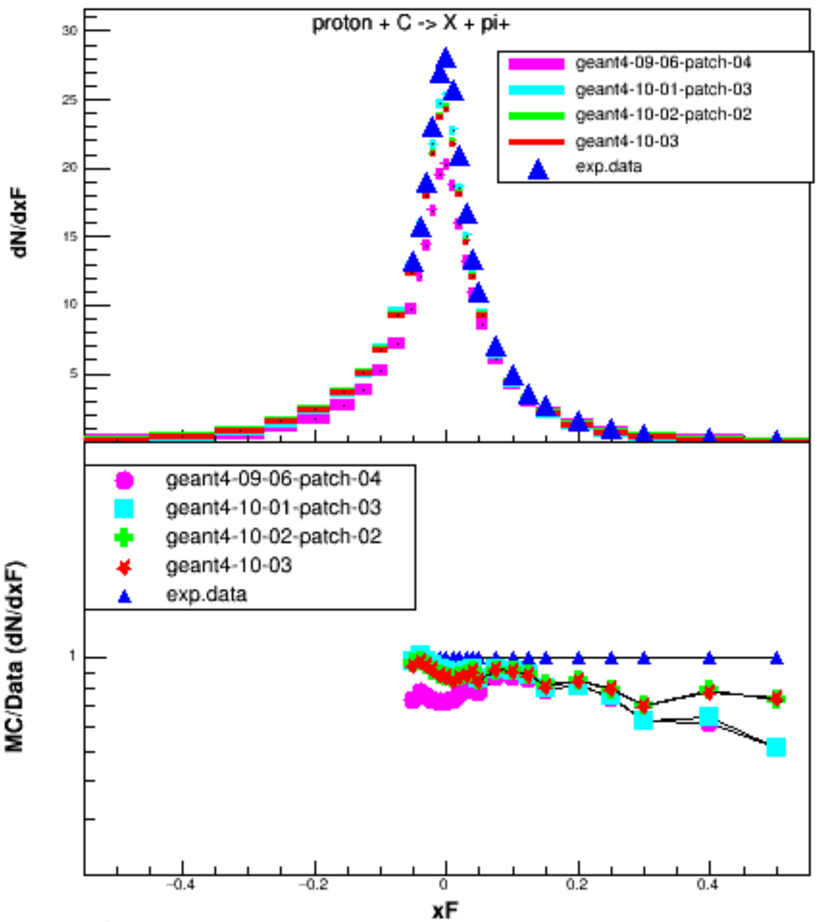


χ^2/NDF = 32.3 for ftfp_bert
χ^2/NDF = 103.9 for qgsp_bert
χ^2/NDF = 39.2 for NuBeam

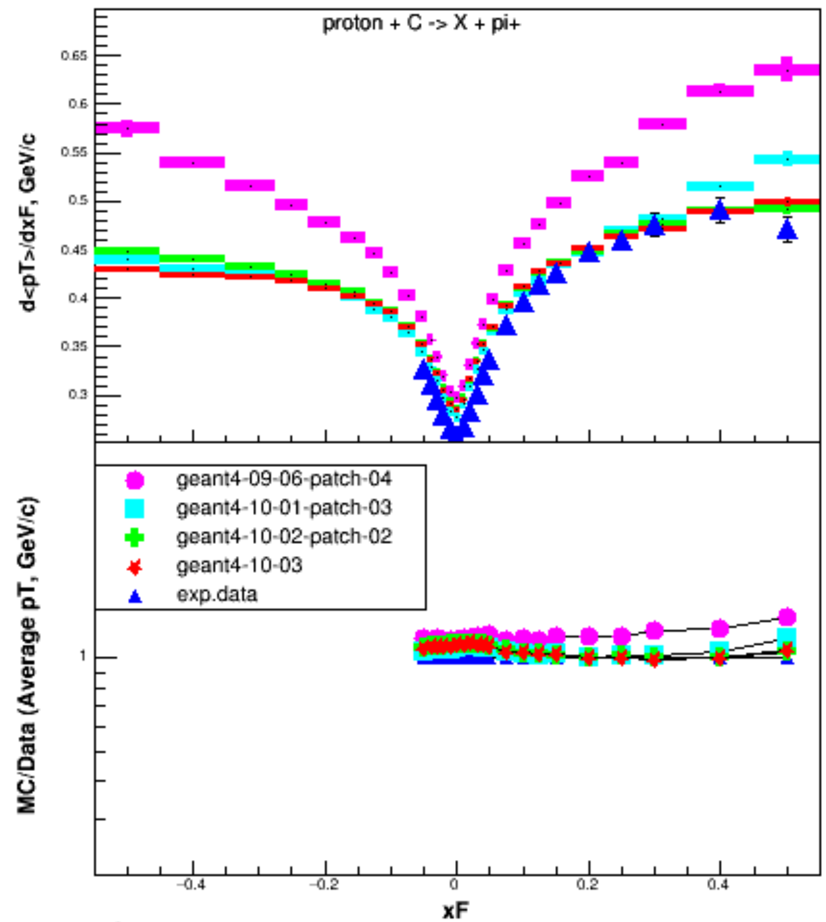


χ^2/NDF = 9.02 for ftfp_bert
χ^2/NDF = 20.3 for qgsp_bert
χ^2/NDF = 4.49 for NuBeam

158GeV/c p+C -> π^+ + X
FTFP_BERT regression vs NA49 data

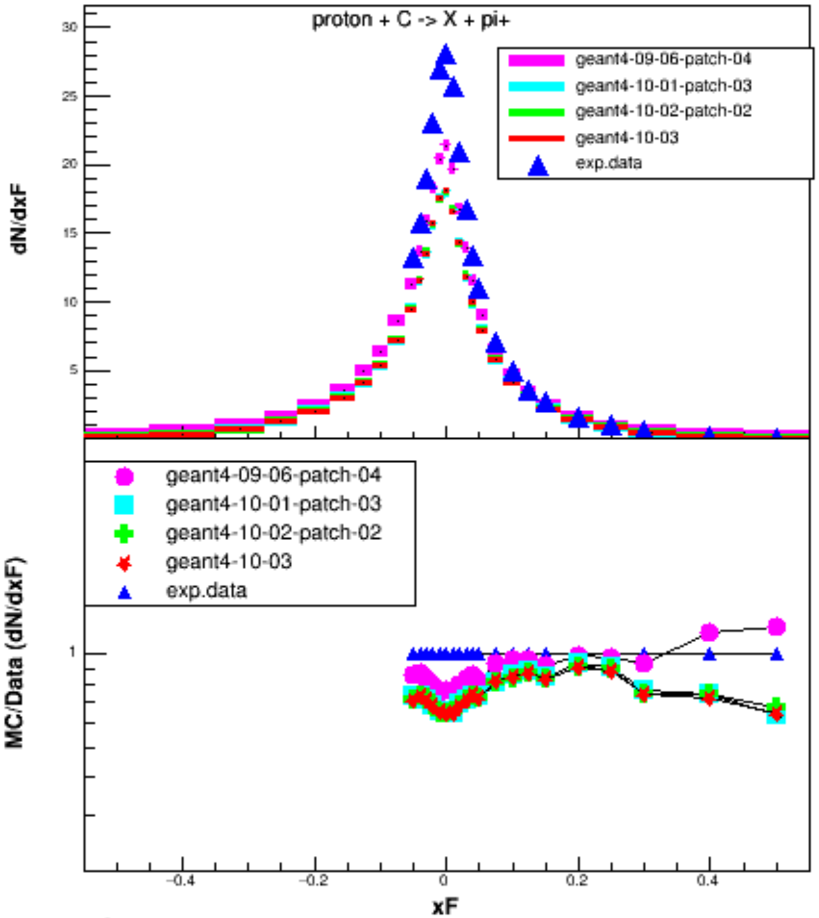


χ^2/NDF = 96.0786 for geant4-09-06-patch-04 vs NA49 Data
χ^2/NDF = 48.0921 for geant4-10-01-patch-03 vs NA49 Data
χ^2/NDF = 31.5786 for geant4-10-02-patch-02 vs NA49 Data
χ^2/NDF = 32.2511 for geant4-10-03 vs NA49 Data

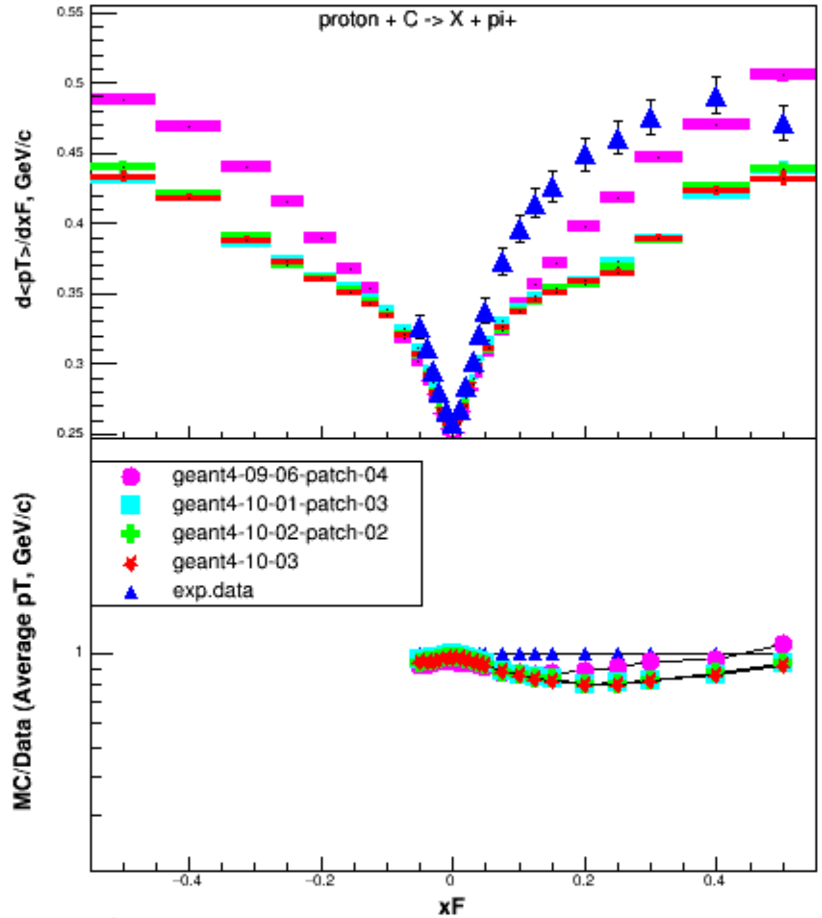


χ^2/NDF = 43.1789 for geant4-09-06-patch-04 vs NA49 Data
χ^2/NDF = 6.4867 for geant4-10-01-patch-03 vs NA49 Data
χ^2/NDF = 9.09161 for geant4-10-02-patch-02 vs NA49 Data
χ^2/NDF = 9.01598 for geant4-10-03 vs NA49 Data

158GeV/c p+C -> π^+ + X
QGSP_BERT regression vs NA49 data

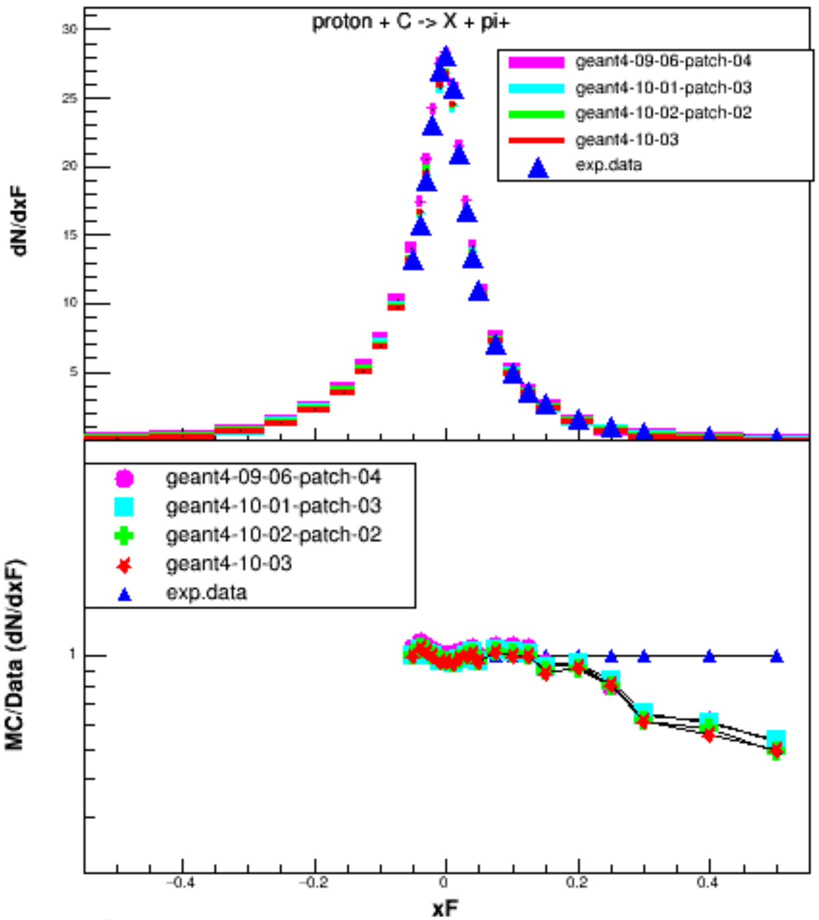


χ^2/NDF = 35.9442 for geant4-09-06-patch-04 vs NA49 Data
χ^2/NDF = 101.021 for geant4-10-01-patch-03 vs NA49 Data
χ^2/NDF = 103.643 for geant4-10-02-patch-02 vs NA49 Data
χ^2/NDF = 103.855 for geant4-10-03 vs NA49 Data

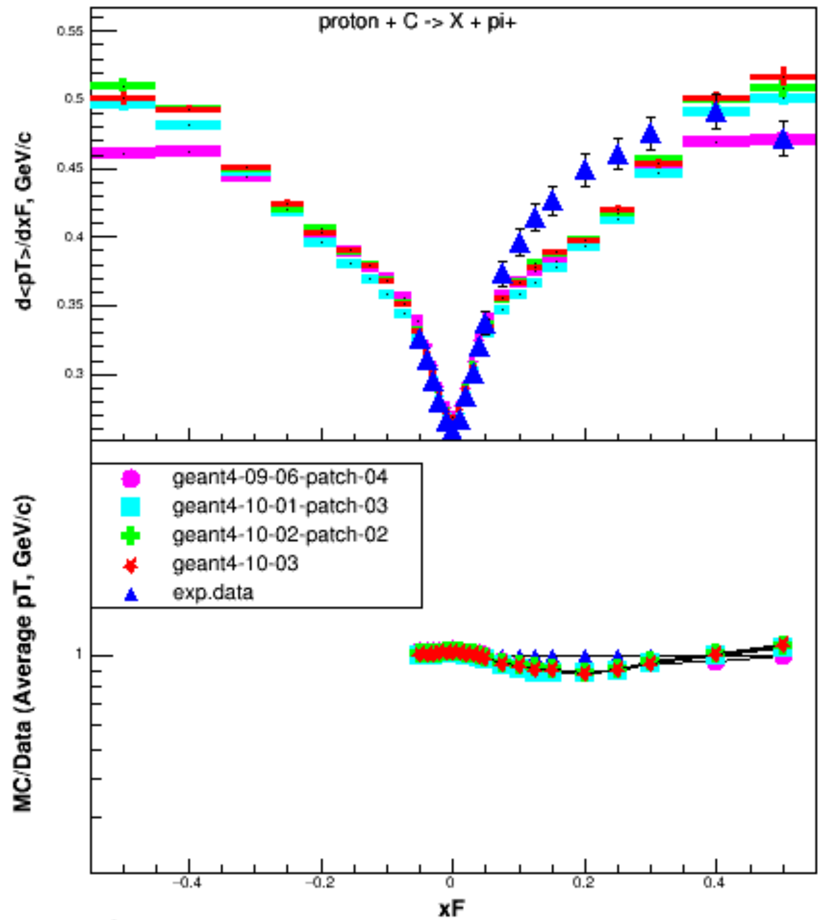


χ^2/NDF = 11.8178 for geant4-09-06-patch-04 vs NA49 Data
χ^2/NDF = 18.1344 for geant4-10-01-patch-03 vs NA49 Data
χ^2/NDF = 20.4153 for geant4-10-02-patch-02 vs NA49 Data
χ^2/NDF = 20.3343 for geant4-10-03 vs NA49 Data

158GeV/c p+C -> π^+ + X
NuBeam regression vs NA49 data

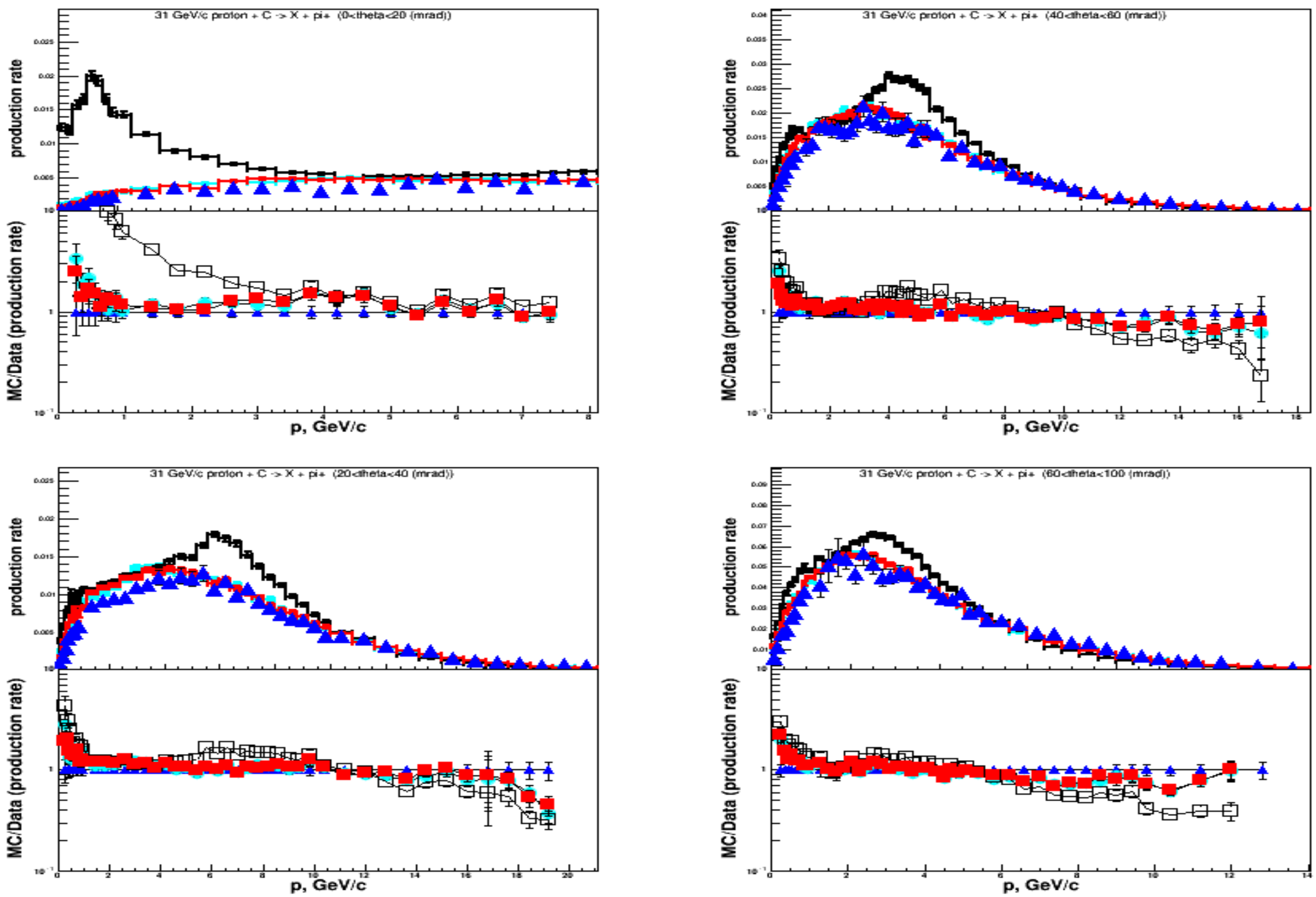


χ^2/NDF = 34.9058 for geant4-09-06-patch-04 vs NA49 Data
χ^2/NDF = 31.3844 for geant4-10-01-patch-03 vs NA49 Data
χ^2/NDF = 38.534 for geant4-10-02-patch-02 vs NA49 Data
χ^2/NDF = 39.2023 for geant4-10-03 vs NA49 Data

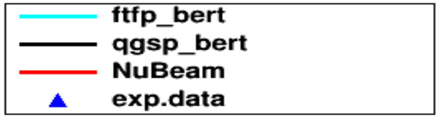


χ^2/NDF = 5.08824 for geant4-09-06-patch-04 vs NA49 Data
χ^2/NDF = 5.79514 for geant4-10-01-patch-03 vs NA49 Data
χ^2/NDF = 4.2806 for geant4-10-02-patch-02 vs NA49 Data
χ^2/NDF = 4.49066 for geant4-10-03 vs NA49 Data

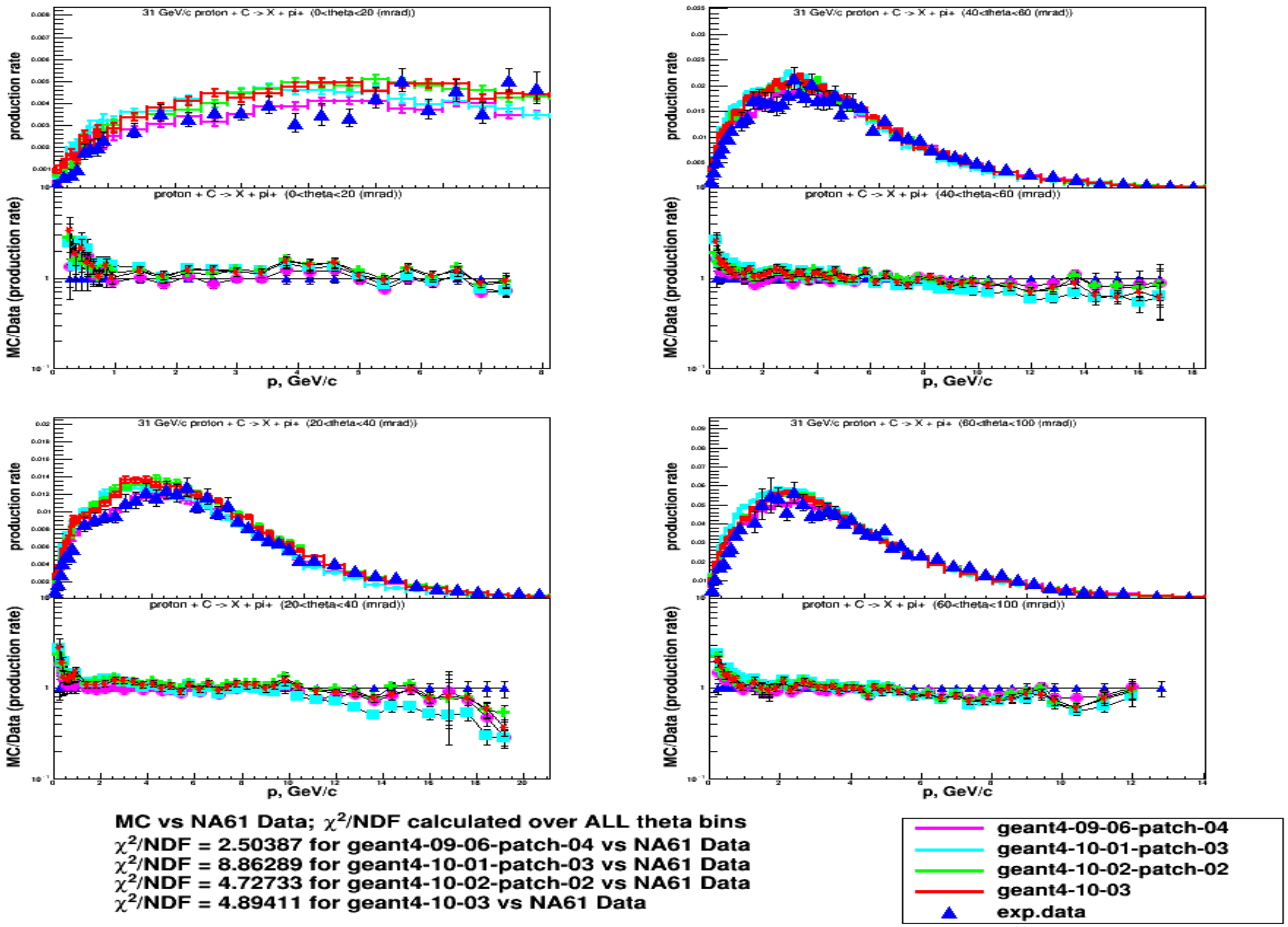
31GeV/c p+C -> π⁺ + X
Different physics lists (4.10.3) vs NA61 data



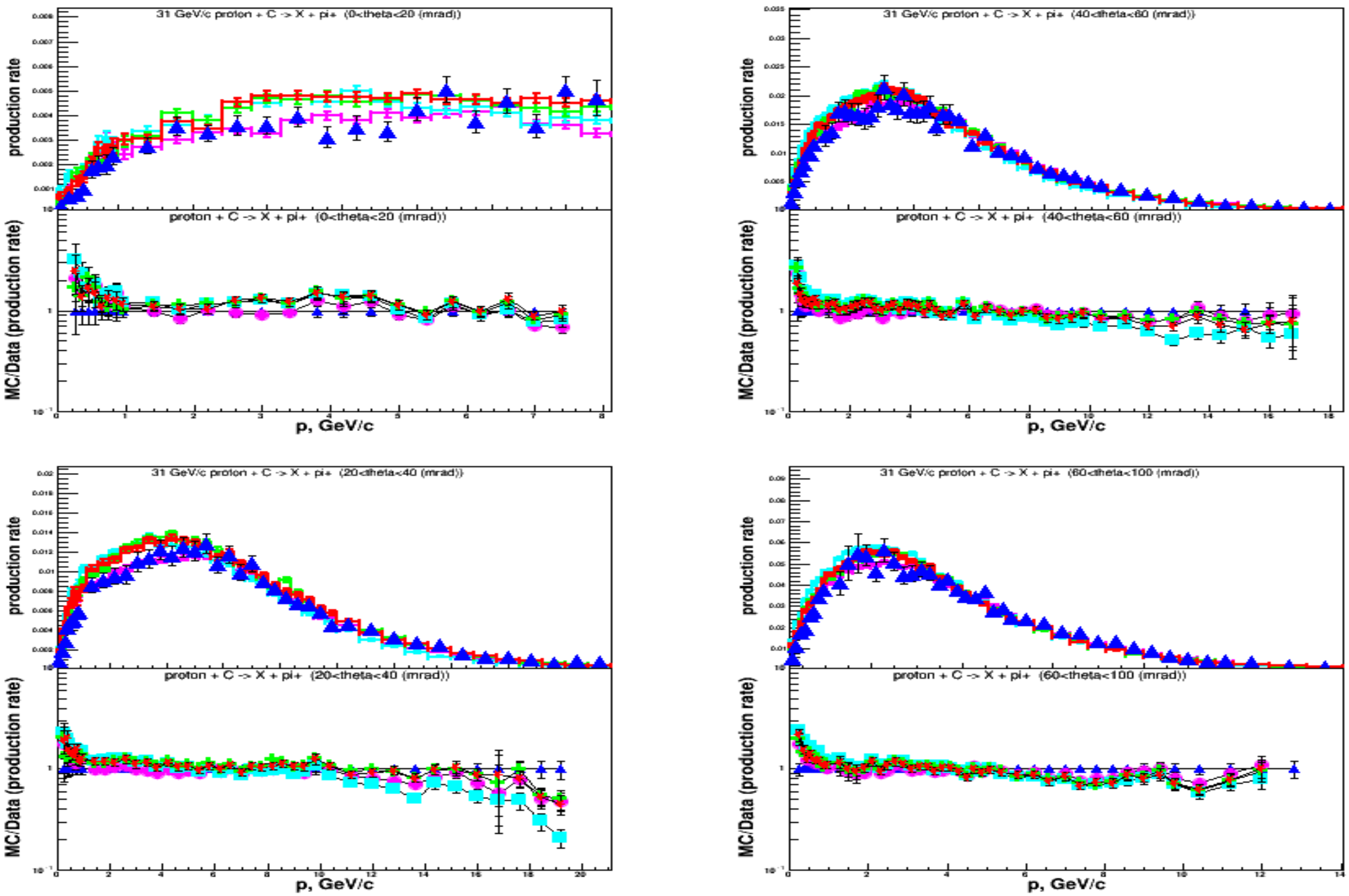
MC vs NA61 Data; χ^2/NDF calculated over ALL theta bins
χ^2/NDF = 4.89411 for ftfp_bert
χ^2/NDF = 27.9128 for qgsp_bert
χ^2/NDF = 4.53398 for NuBeam



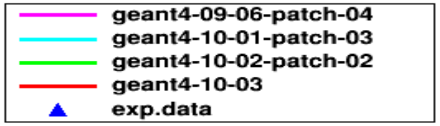
31GeV/c p+C -> π^+ + X
FTFP_BERT regression vs NA61 data



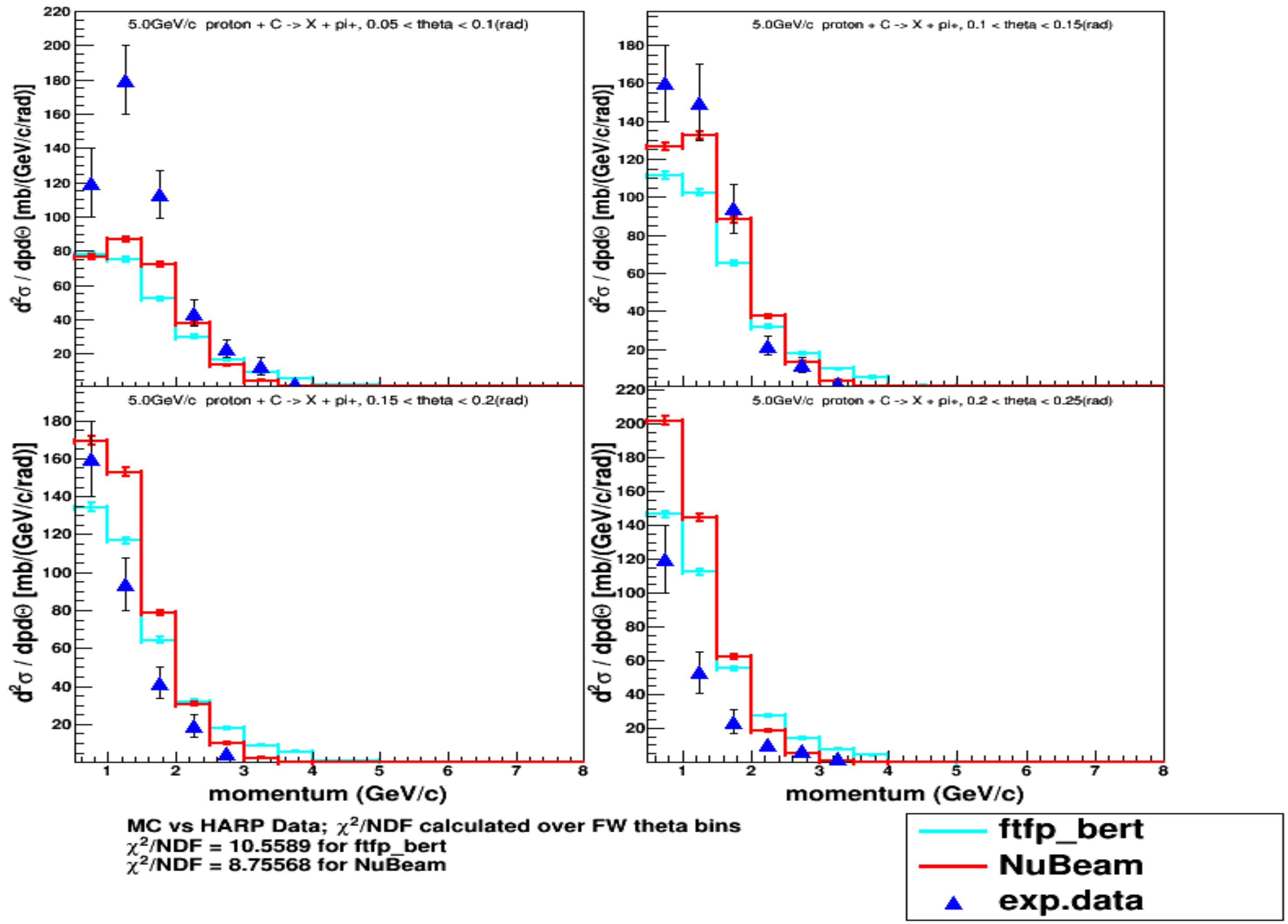
31GeV/c p+C -> π^+ + X
NuBeam regression vs NA61 data



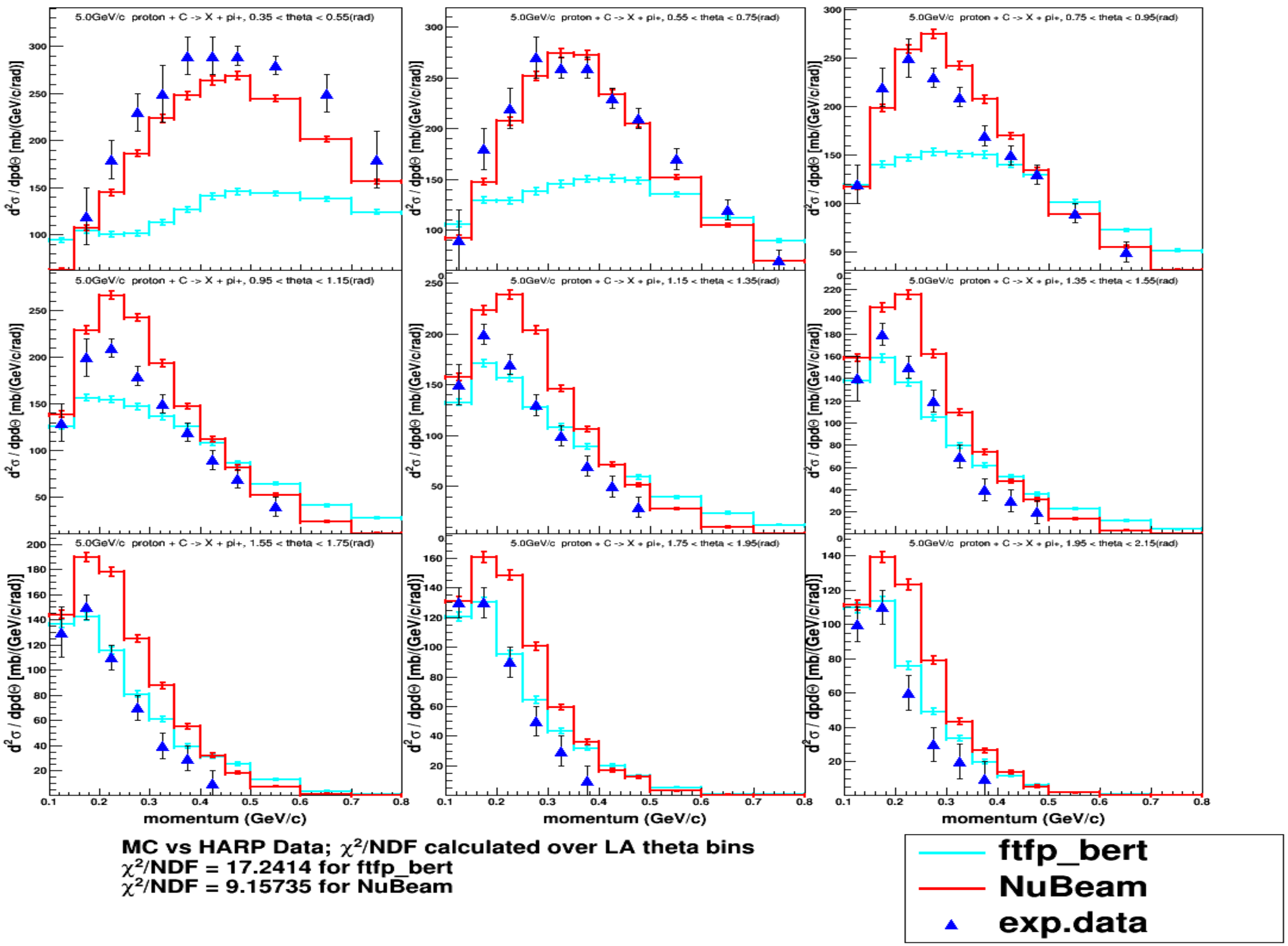
MC vs NA61 Data; χ^2/NDF calculated over ALL theta bins
χ^2/NDF = 2.74678 for geant4-09-06-patch-04 vs NA61 Data
χ^2/NDF = 8.85355 for geant4-10-01-patch-03 vs NA61 Data
χ^2/NDF = 4.51084 for geant4-10-02-patch-02 vs NA61 Data
χ^2/NDF = 4.53398 for geant4-10-03 vs NA61 Data



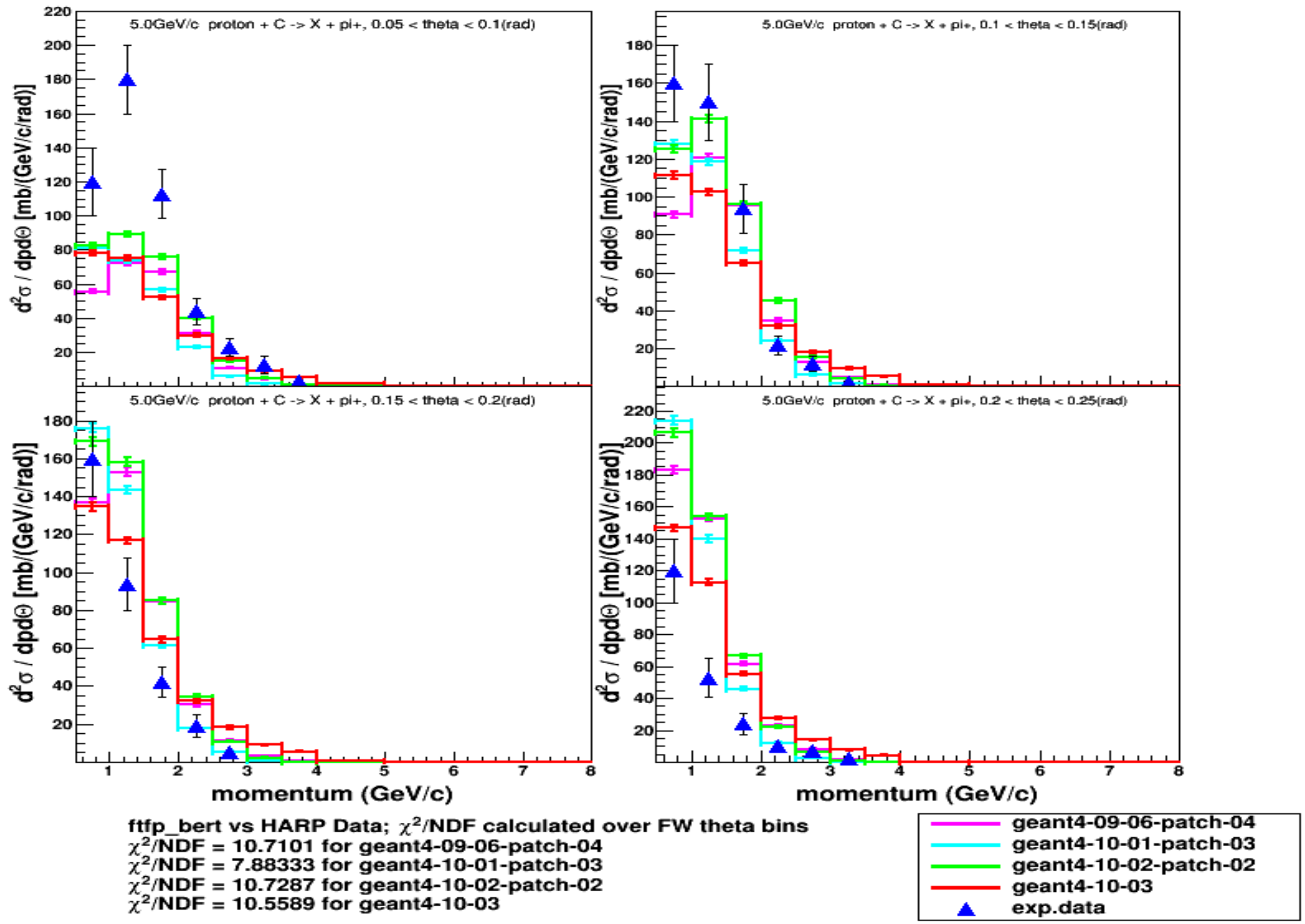
5GeV/c p+C -> π⁺ + X (forward production) Different physics lists (4.10.3) vs HARP data



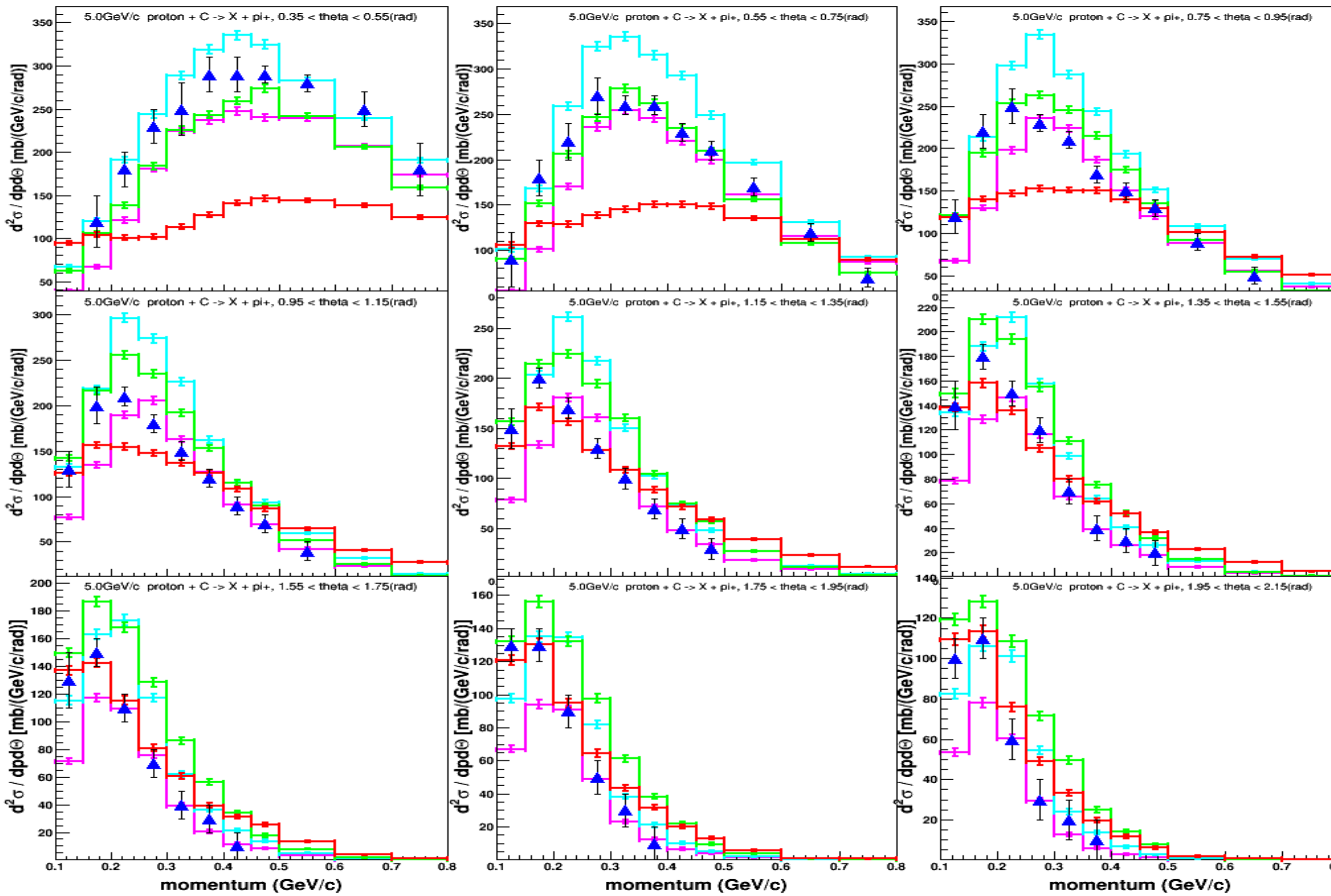
5GeV/c p+C -> π^+ + X (large angle production) Different physics lists (4.10.3) vs HARP data



5GeV/c p+C -> π^+ + X (forward production) FTFP_BERT regression vs HARP data



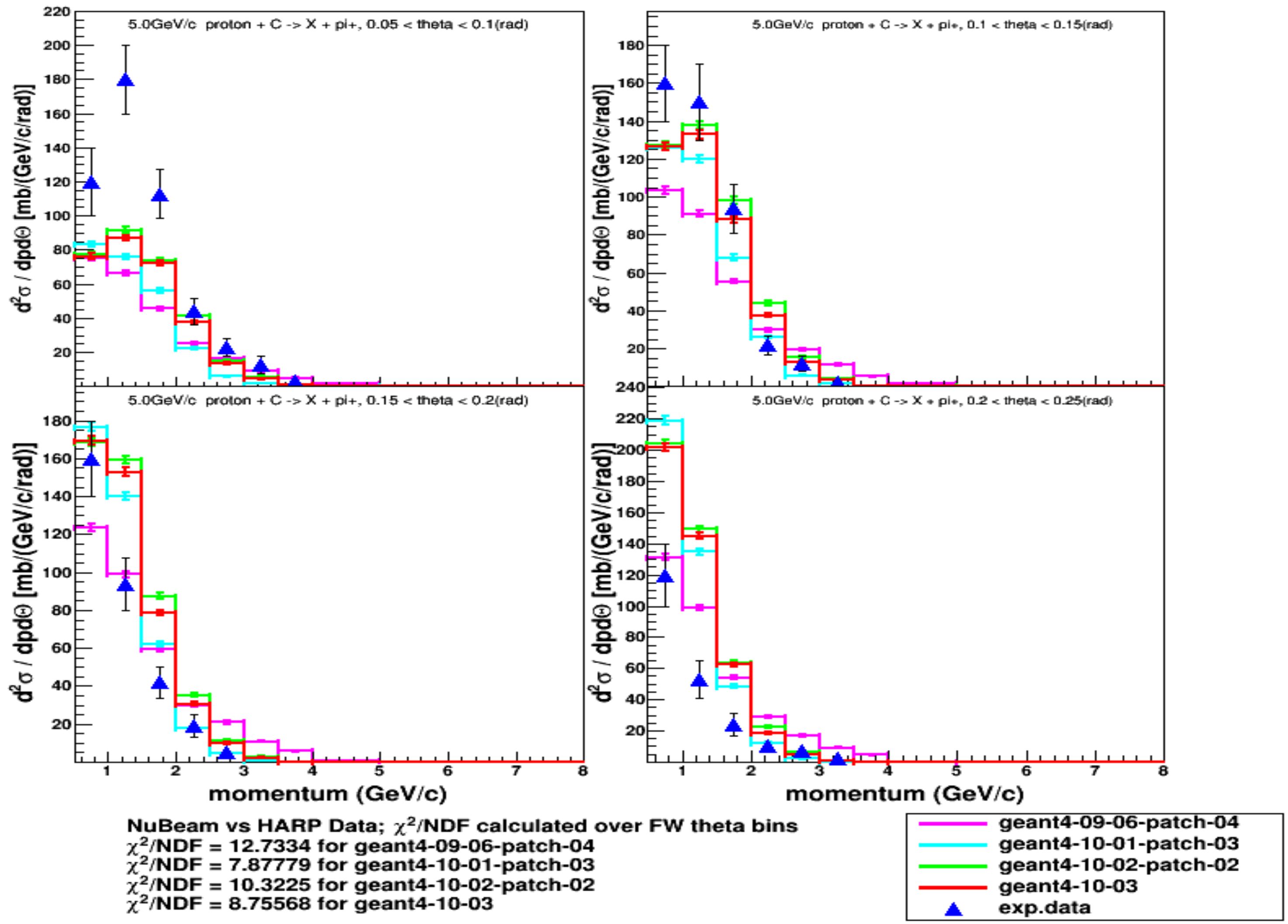
5GeV/c p+C -> π^+ + X (large angle production) FTFP_BERT regression vs HARP data



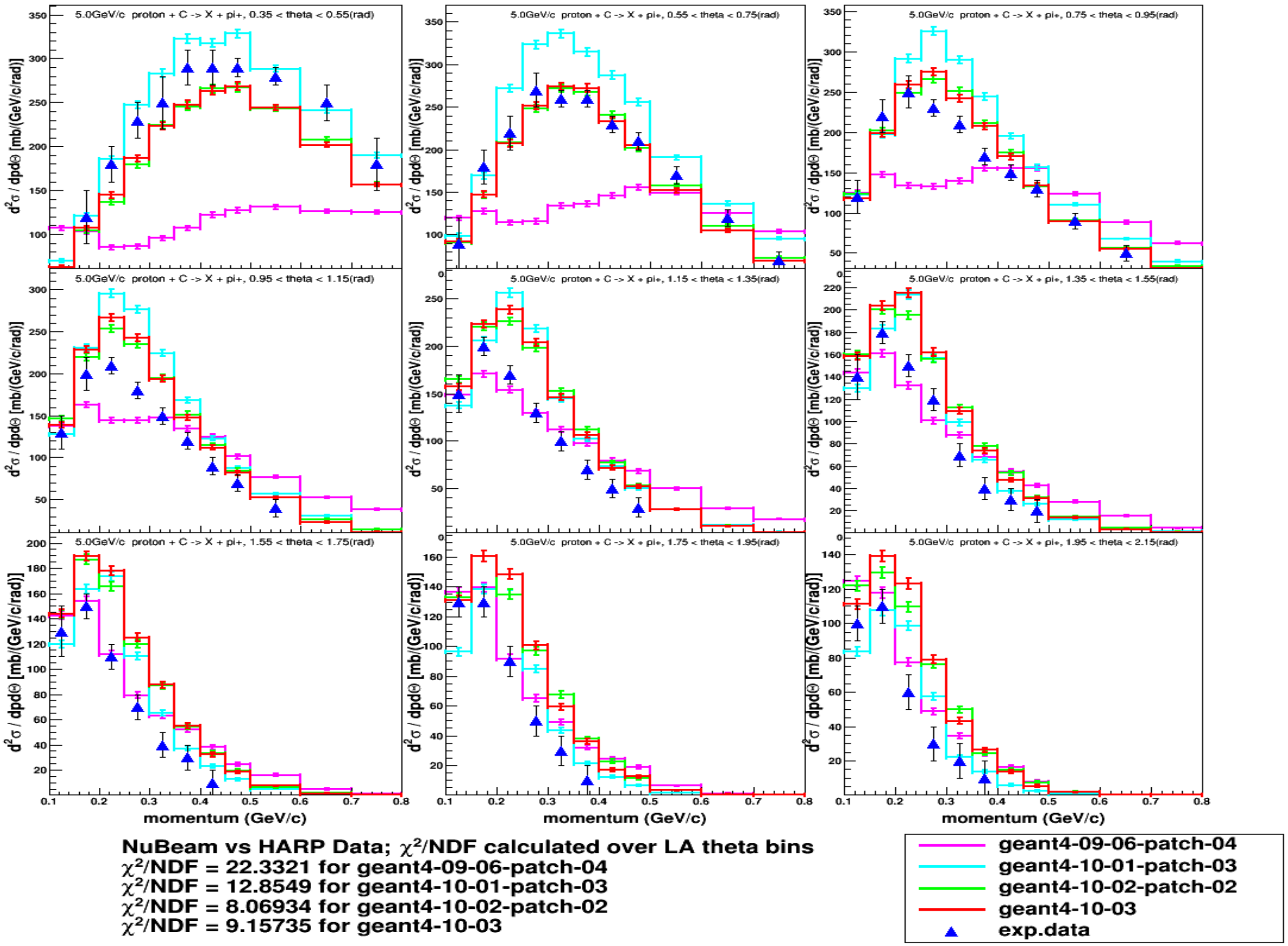
ftfp_bert vs HARP Data; χ^2/NDF calculated over LA theta bins
χ^2/NDF = 5.02515 for geant4-09-06-patch-04
χ^2/NDF = 12.8735 for geant4-10-01-patch-03
χ^2/NDF = 7.93419 for geant4-10-02-patch-02
χ^2/NDF = 17.2414 for geant4-10-03

- geant4-09-06-patch-04
- geant4-10-01-patch-03
- geant4-10-02-patch-02
- geant4-10-03
- exp.data

5GeV/c p+C -> π^+ + X (forward production) NuBeam regression vs HARP data

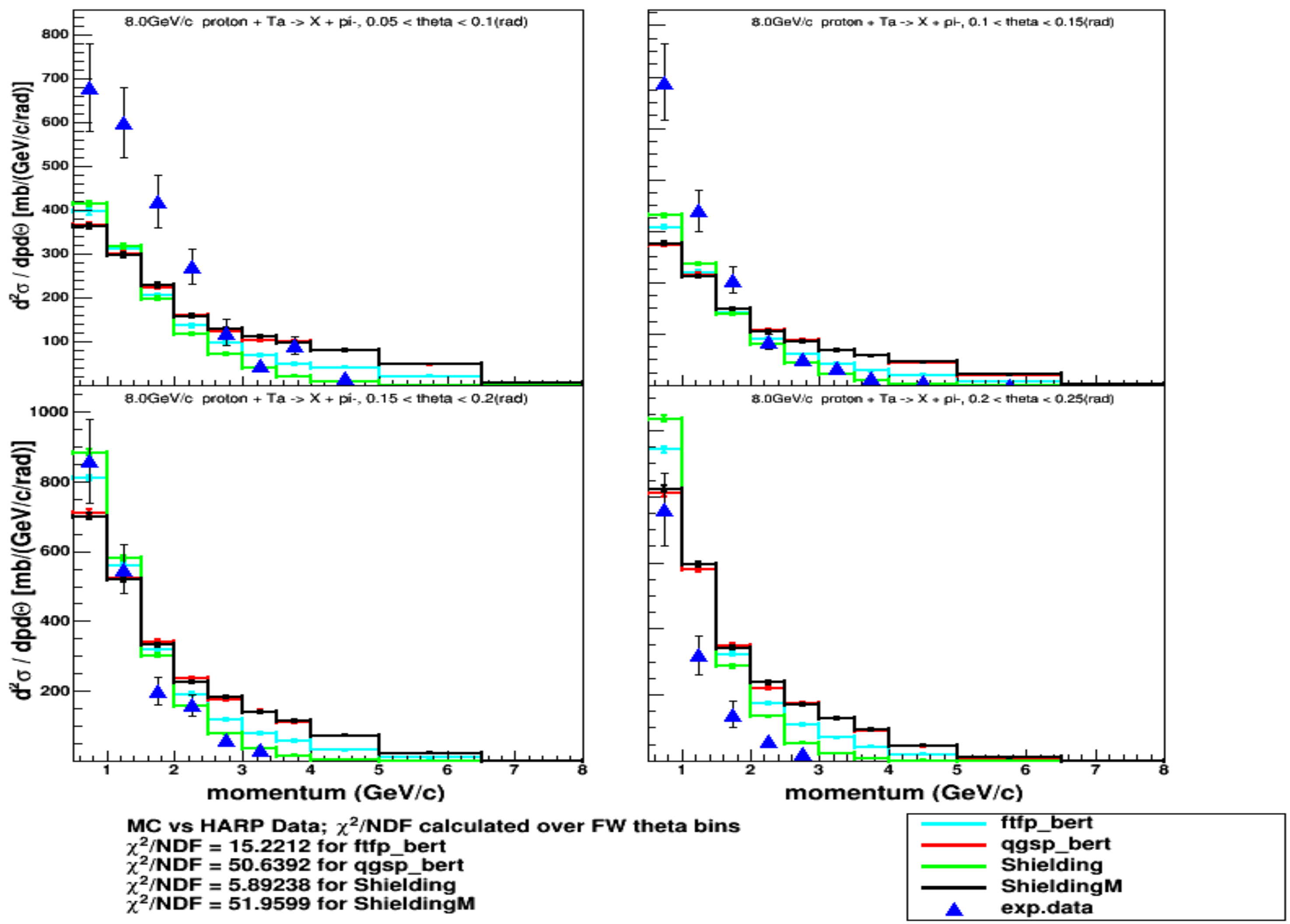


5GeV/c p+C -> π^+ + X (large angle production) NuBeam regression vs HARP data

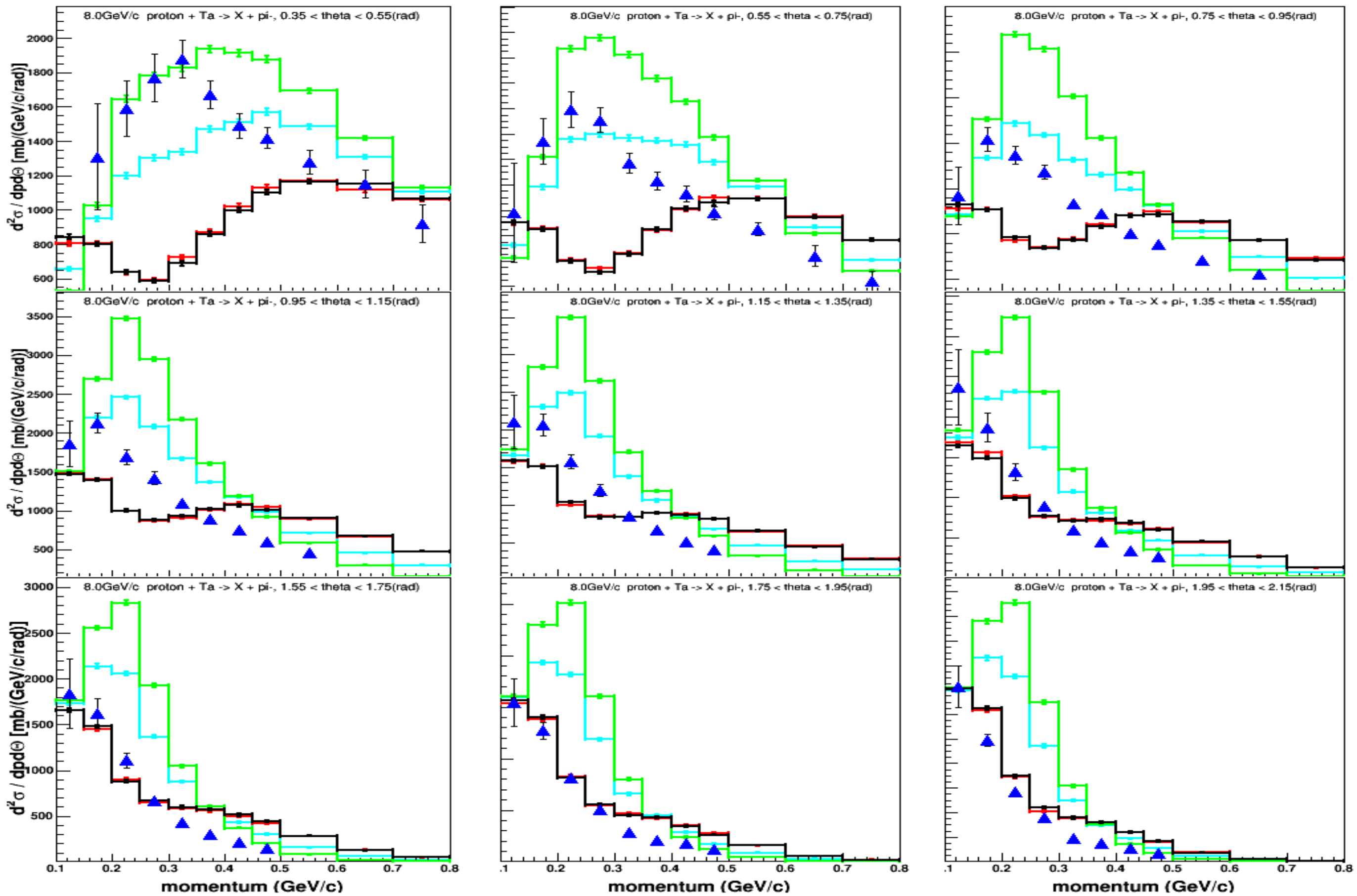


NuBeam vs HARP Data; χ^2/NDF calculated over LA theta bins
χ^2/NDF = 22.3321 for geant4-09-06-patch-04
χ^2/NDF = 12.8549 for geant4-10-01-patch-03
χ^2/NDF = 8.06934 for geant4-10-02-patch-02
χ^2/NDF = 9.15735 for geant4-10-03

8GeV/c p+Ta -> π + X (forward production)
Different physics lists (4.10.3) vs HARP data



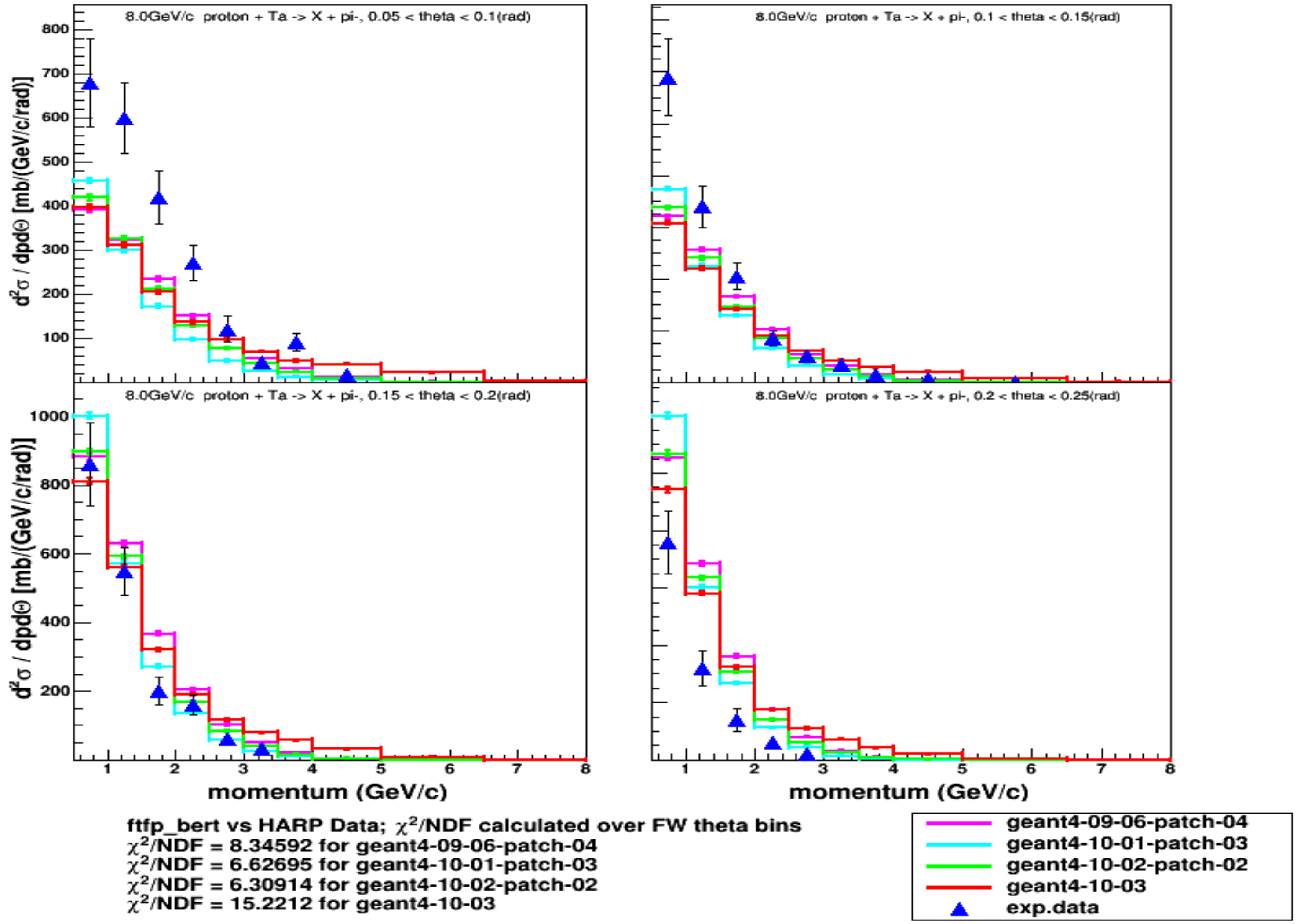
8GeV/c p+Ta -> π + X (large angle production) Different physics lists (4.10.3) vs HARP data



MC vs HARP Data; χ^2/NDF calculated over LA theta bins

χ^2/NDF = 78.3945 for ftfp_bert
χ^2/NDF = 58.2012 for qgsp_bert
χ^2/NDF = 168.509 for Shielding
χ^2/NDF = 59.8985 for ShieldingM

8GeV/c p+Ta -> π + X (forward production) FTFP_BERT regression vs HARP data



ftfp_bert vs HARP Data; χ^2/NDF calculated over FW theta bins
χ^2/NDF = 8.34592 for geant4-09-06-patch-04
χ^2/NDF = 6.62695 for geant4-10-01-patch-03
χ^2/NDF = 6.30914 for geant4-10-02-patch-02
χ^2/NDF = 15.2212 for geant4-10-03

8GeV/c p+Ta -> π + X (large angle production) FTFP_BERT regression vs HARP data