Validation of Geant4.10.2.p03, 10.3.p01, 10.3.ref01, and 10.3.ref02
- selected results -

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Geant4 Hadronic Group Meeting

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General Information (I)

- Focus on the state of FTF and QGS
- MC results compared vs exp.data:
  - NA49
  - SAS M6E – exp.data for light or heavy nuclear targets
    - D.S. Barton et al., Phys. Rev. D27, 2580 (1983)
  - NA61 – updated data from Run-2009
    - Abgrall, N. et al., Eur.Phys.J. C76, 84 (2016)
  - Selected comparisons vs HARP and ITEP771 data are also included to attest the state of FTF modeling at intermediate energies
    - For detailed benchmarking vs HARP data see talk by Vladimir I.
- Geant4 releases:
  - 10.3.ref01 and ref02
  - 10.2.p03 and 10.3.p01 for reference
- Apologies for inconsistent coloring scheme among different groups of comparisons !

General Information (II)

- QGS is used with the following string fragmentation components:
  - G4QGSMFragmentation – “traditional”
  - G4LundStringFragmentation – typically used with FTF but totally compatible with QGS
    - Improves agreement with the data in some corners of the phase space…
    - … but not everywhere
- Selected results obtained with both string fragmentation components will be shown to illustrate the case
- Most of results in this report are for “traditional” string fragmentation component
- Open question: when developing QGS, one may want to consider what string fragmentation component it should be used with

General Information (III)

- Large number of validation plots is available
  - Secondaries include charged pions, charged kaons, K0s, Lambda, protons, antiprotons, neutrons
- Only selected results are included in this report (due to the time constraints)
- If there's interest in a particular group of results, please let me know, and I'll make them available
- Populating DoSSiER with MC results is a task that remains of high priority (although "something always happens")

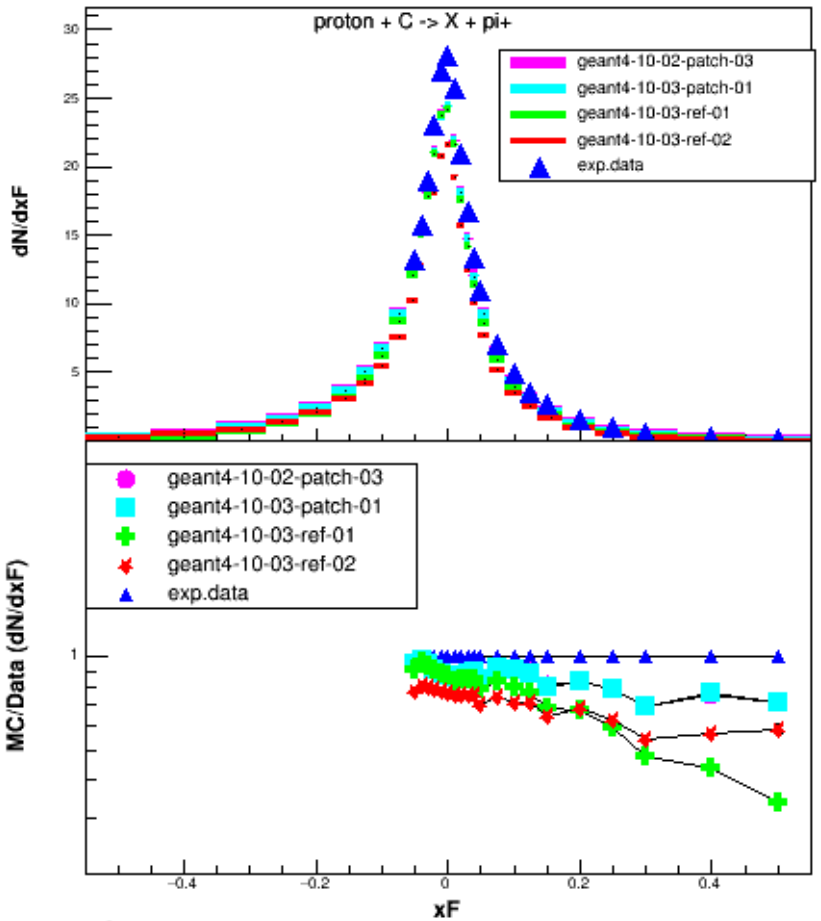
FTFP at High Energies as of 10.3.ref01/02 (I)

- Modeling pion+A interactions
  - Relatively stable results throughout releases in question
  - Some variations can be observed but they are smaller than in the case of proton beam
- Pion production in p+A
  - Trend to deviation from the data
    - <mult> vs xF
    - momentum spectra in diff. bins of pt
    - Momentum spectra in different bins of polar angle
  - Although <pt> vs xF appears to improve (at least, for C target)
- Kaon or Lambda production in p+A interactions
  - Relatively decent agreement with the data (updated NA61 data or SAS M6E)

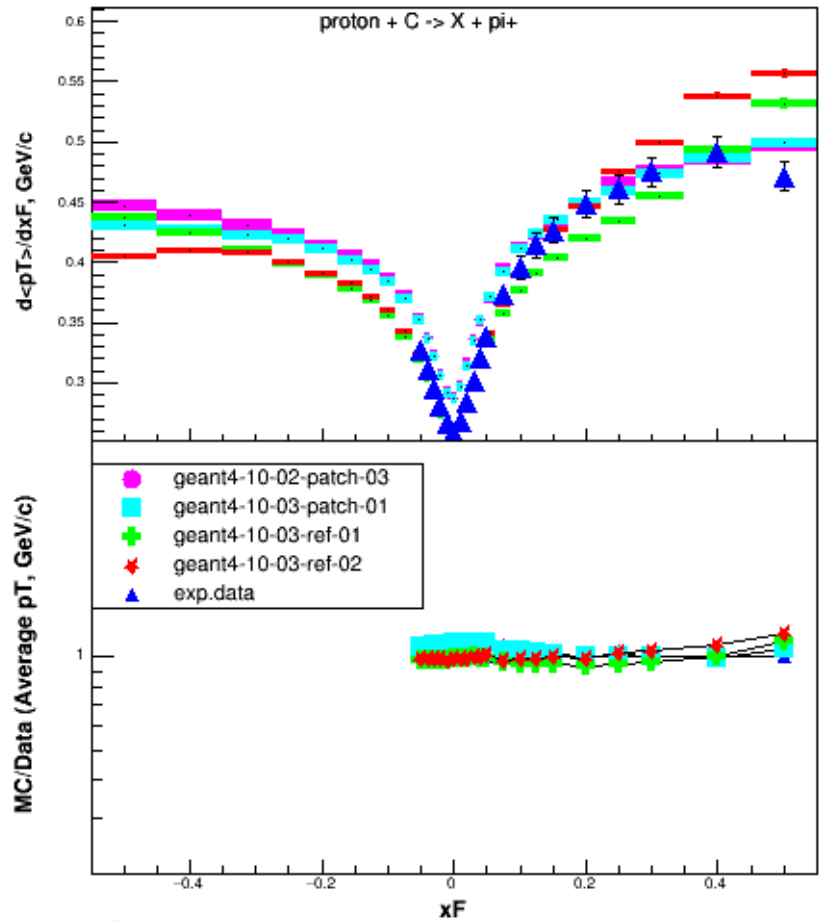
FTFP at High Energies as of 10.3.ref01/02 (II)

- Proton production in p+A
  - Substantial variations between ref01 and ref02 results
  - Maybe ref01 is better ?
- Pbar production in p+A
  - Obvious degradation of <mult> vs xF or <pt> vs xF spectra in 10.3.ref02
  - Relatively mild effects on momentum spectra in diff. bins of pt

FTFP: 158GeV/c p+C -> pi+

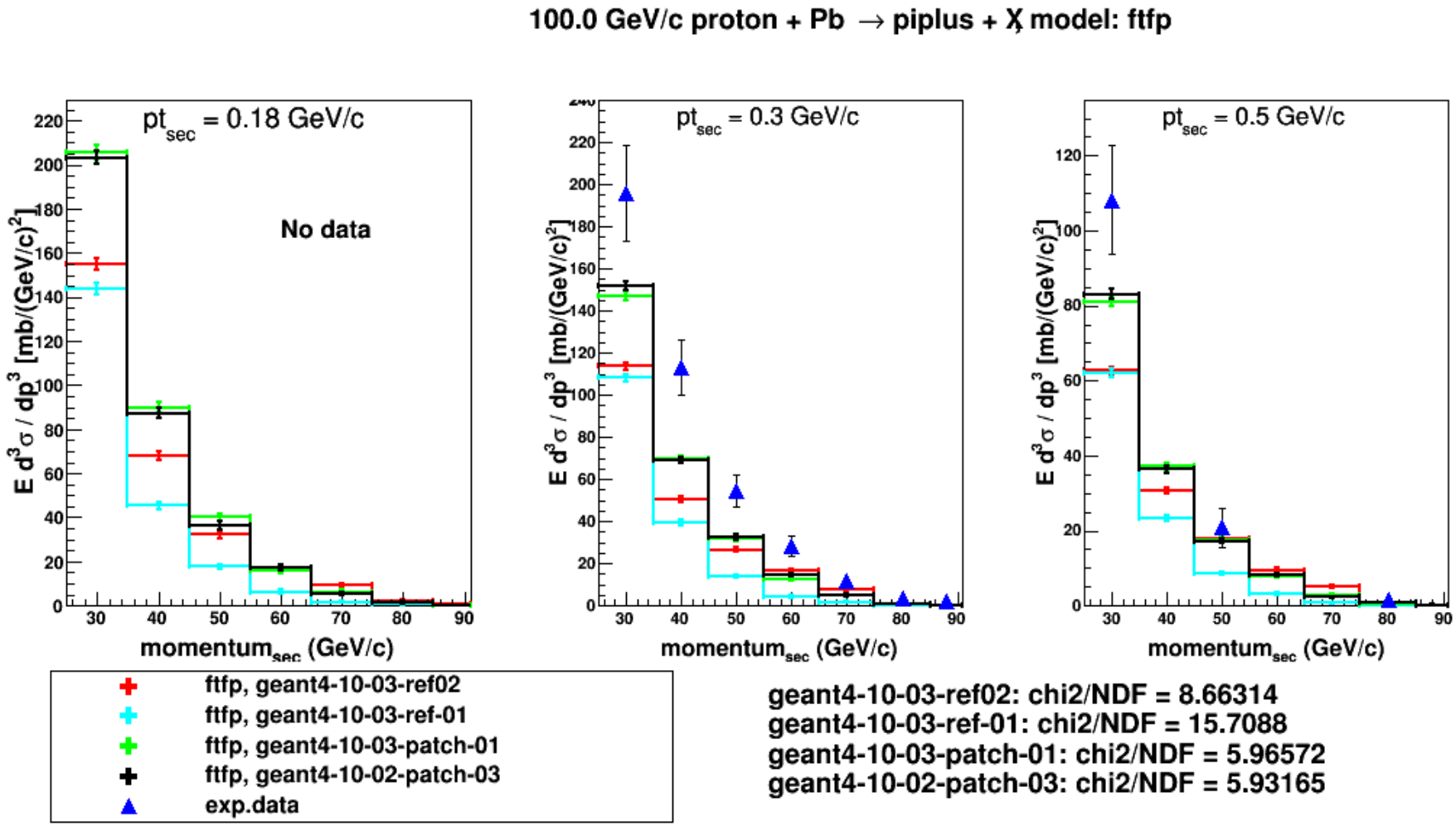


χ^2/NDF = 35.8255 for geant4-10-02-patch-03 vs NA49 Data
χ^2/NDF = 35.7028 for geant4-10-03-patch-01 vs NA49 Data
χ^2/NDF = 117.644 for geant4-10-03-ref-01 vs NA49 Data
χ^2/NDF = 130.255 for geant4-10-03-ref-02 vs NA49 Data

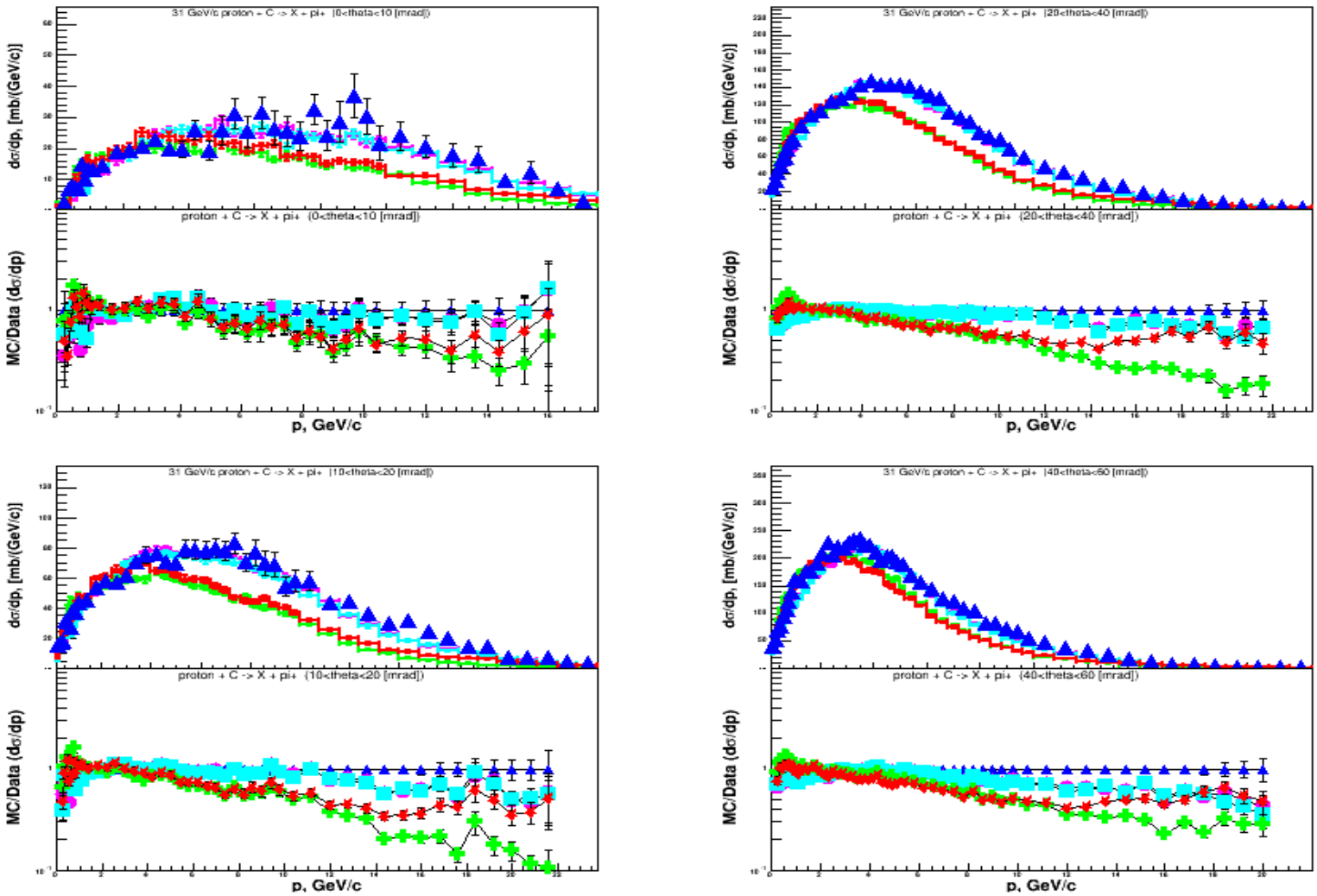


χ^2/NDF = 9.00193 for geant4-10-02-patch-03 vs NA49 Data
χ^2/NDF = 9.05905 for geant4-10-03-patch-01 vs NA49 Data
χ^2/NDF = 2.839 for geant4-10-03-ref-01 vs NA49 Data
χ^2/NDF = 3.2059 for geant4-10-03-ref-02 vs NA49 Data

FTFP: 100GeV/c p+Pb -> pi+



FTFP: 31GeV/c p+C -> pi+

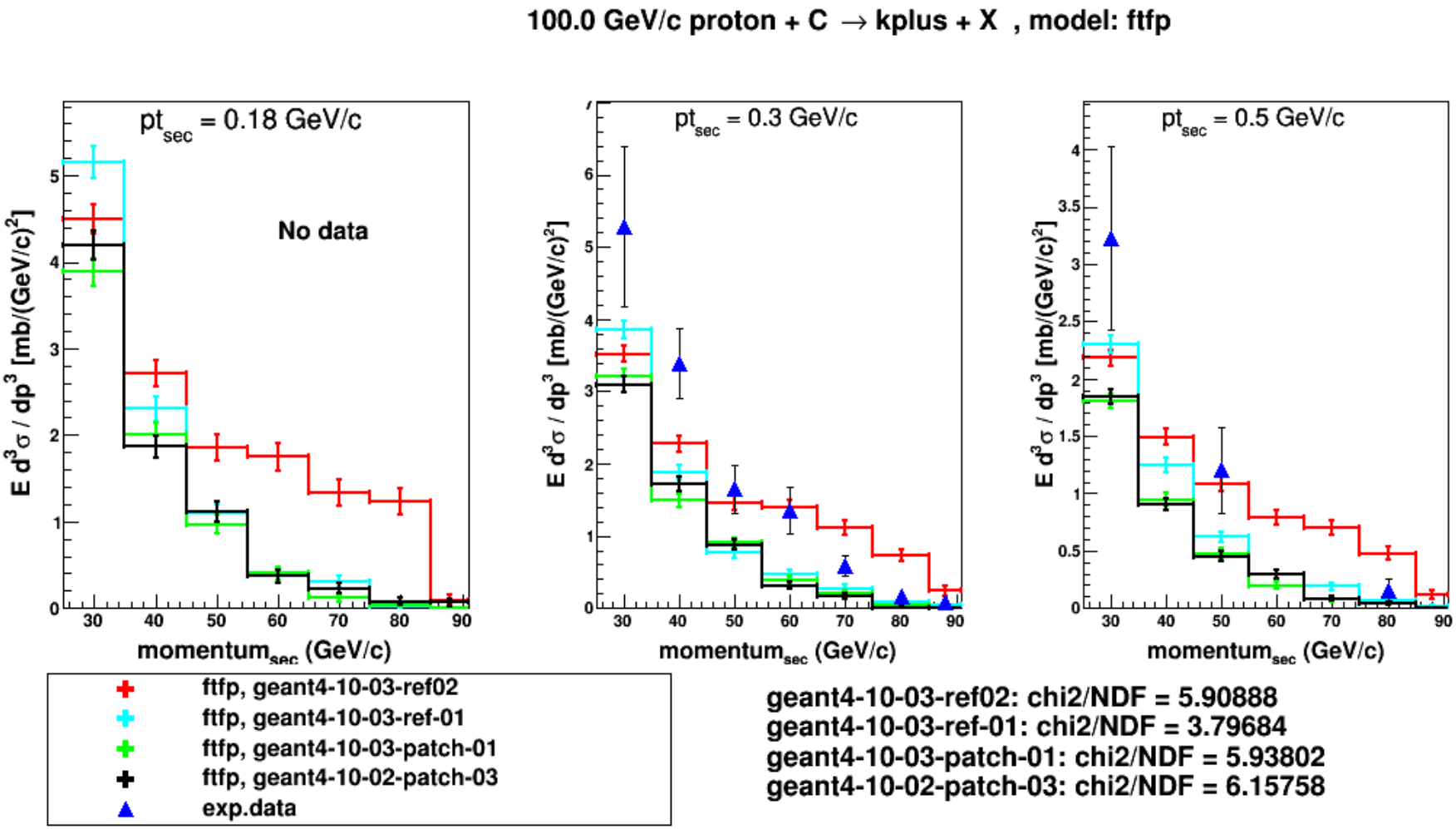


ftfp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

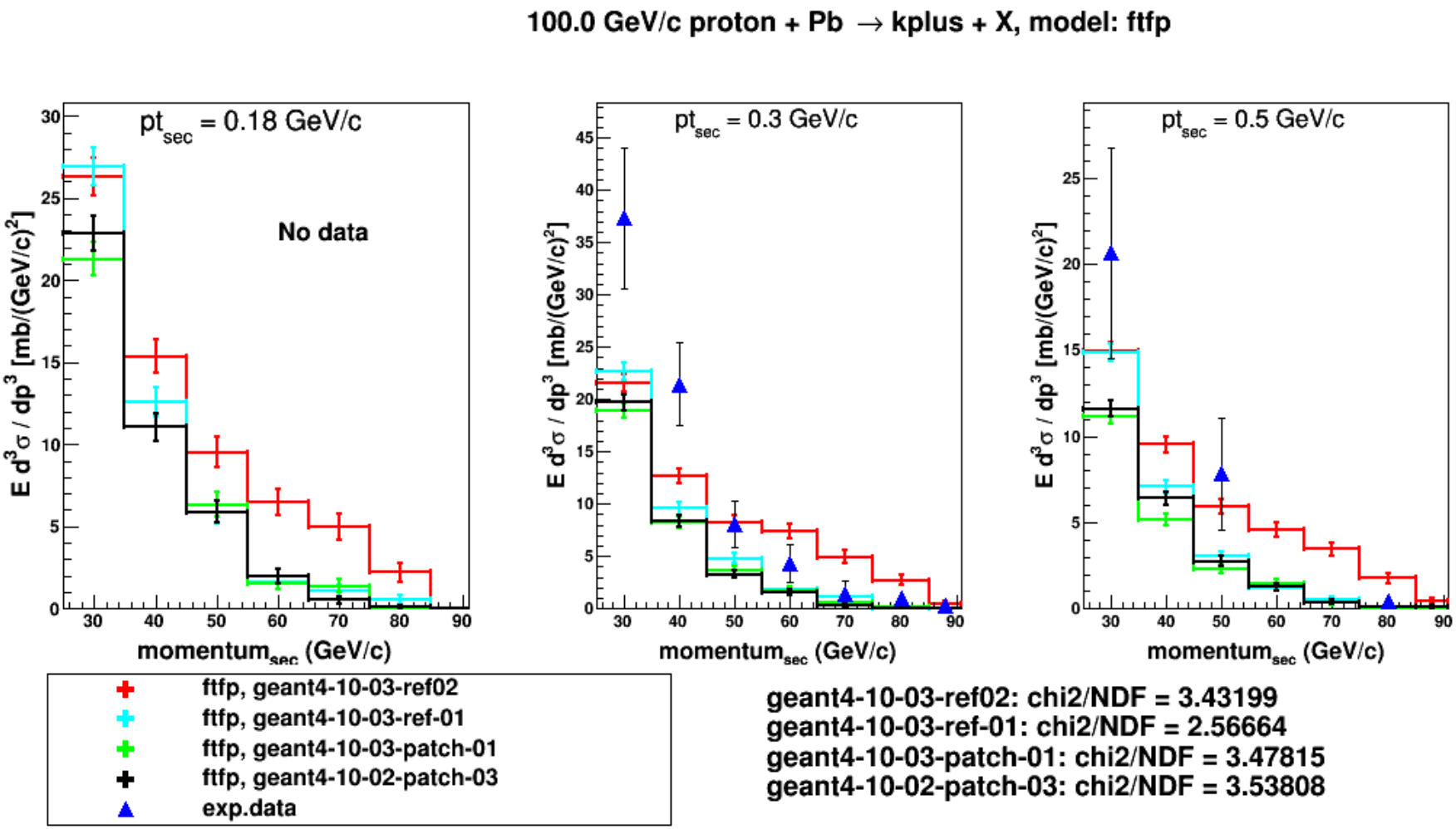
χ^2/NDF = 11.0307 for geant4-10-02-patch-03
χ^2/NDF = 11.2954 for geant4-10-03-patch-01
χ^2/NDF = 25.328 for geant4-10-03-ref-01
χ^2/NDF = 21.7705 for geant4-10-03-ref-02

- geant4-10-02-patch-03
- geant4-10-03-patch-01
- geant4-10-03-ref-01
- geant4-10-03-ref-02
- exp.data

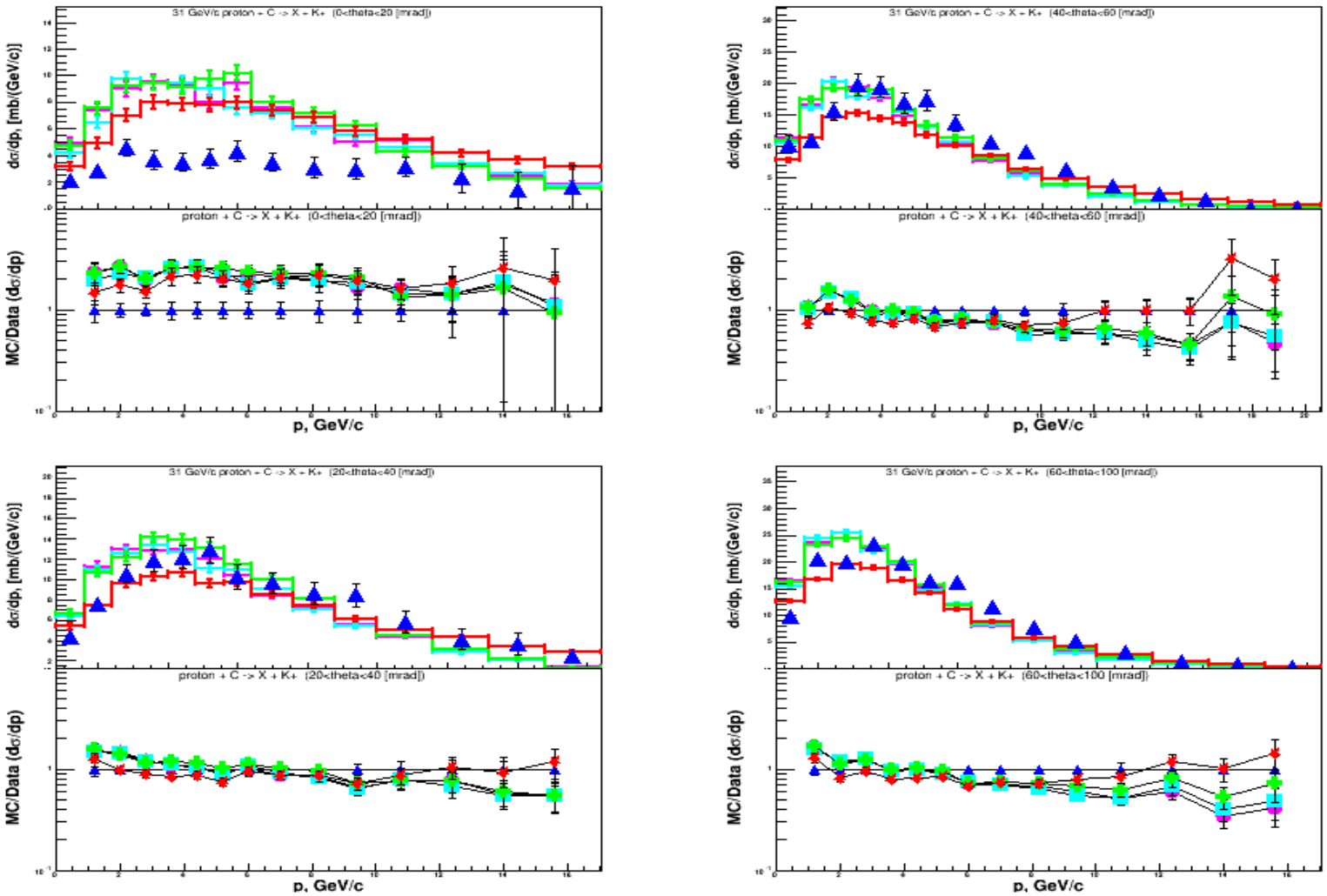
FTFP: 100GeV/c p+C -> K+



FTFP: 100GeV/c p+Pb -> K+

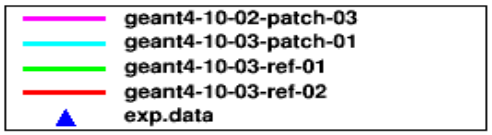


FTFP: 31GeV/c p+C -> K+

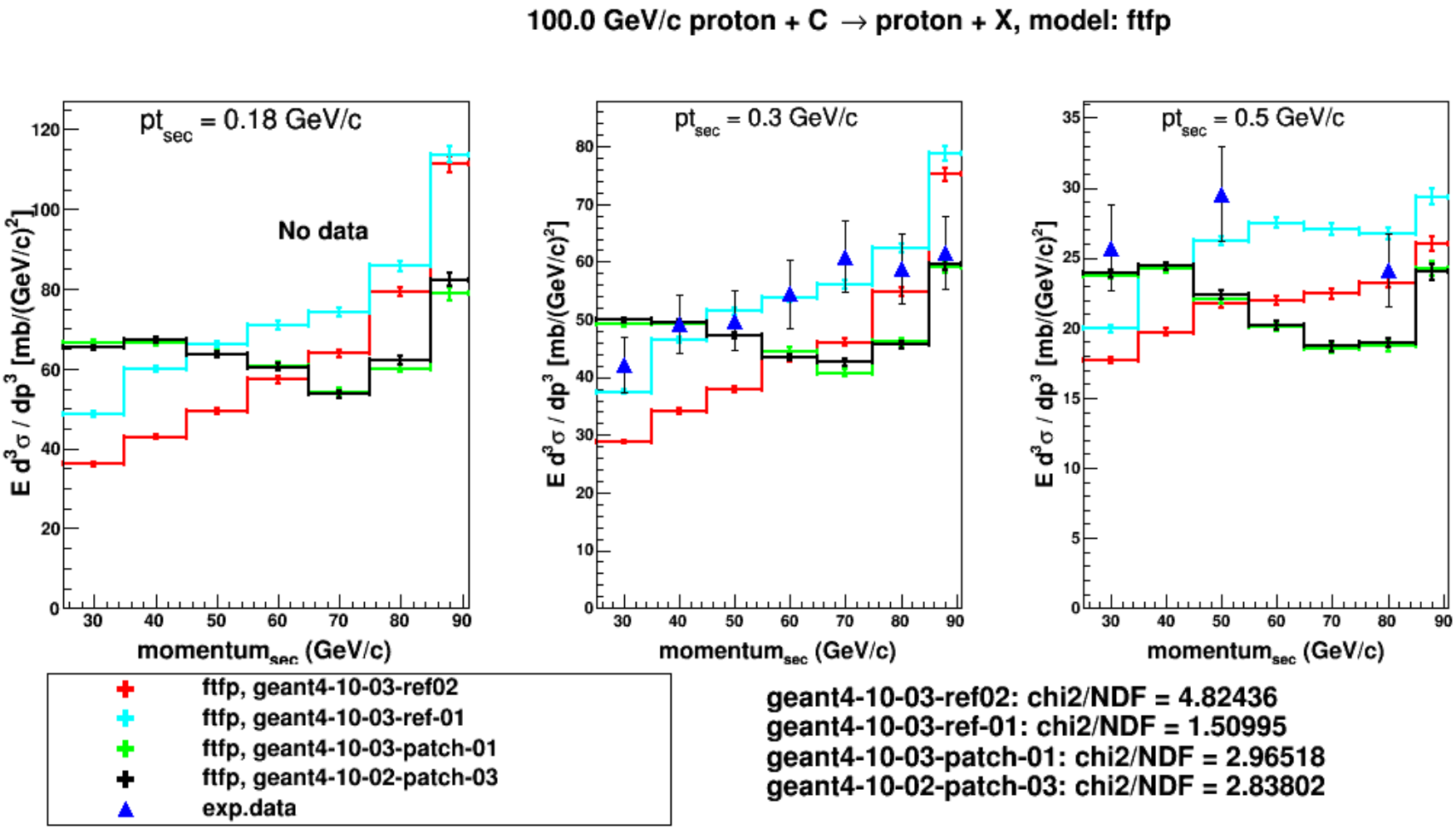


ftfp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

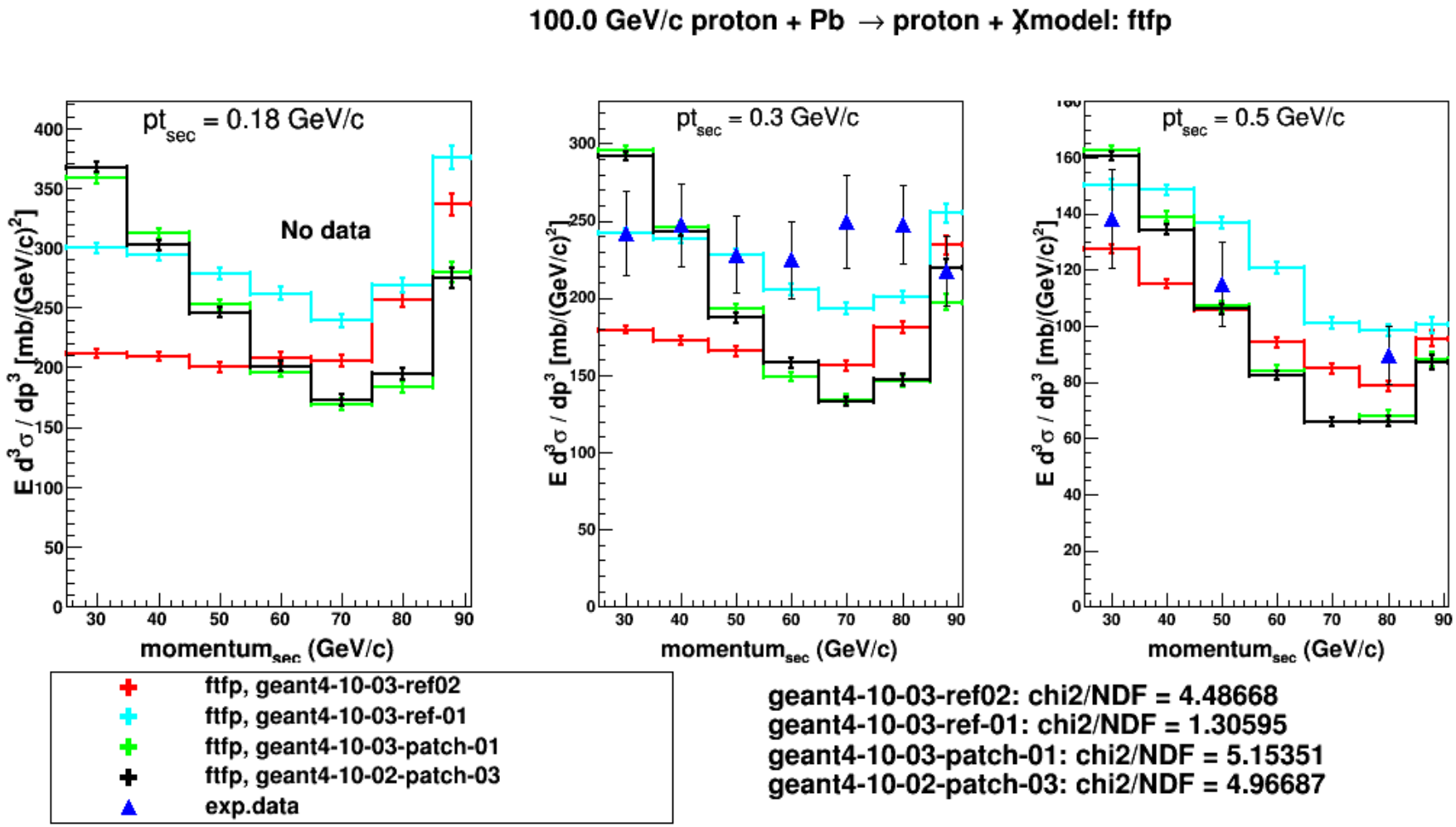
χ^2/NDF = 6.74957 for geant4-10-02-patch-03
χ^2/NDF = 6.48119 for geant4-10-03-patch-01
χ^2/NDF = 6.85449 for geant4-10-03-ref-01
χ^2/NDF = 4.59085 for geant4-10-03-ref-02



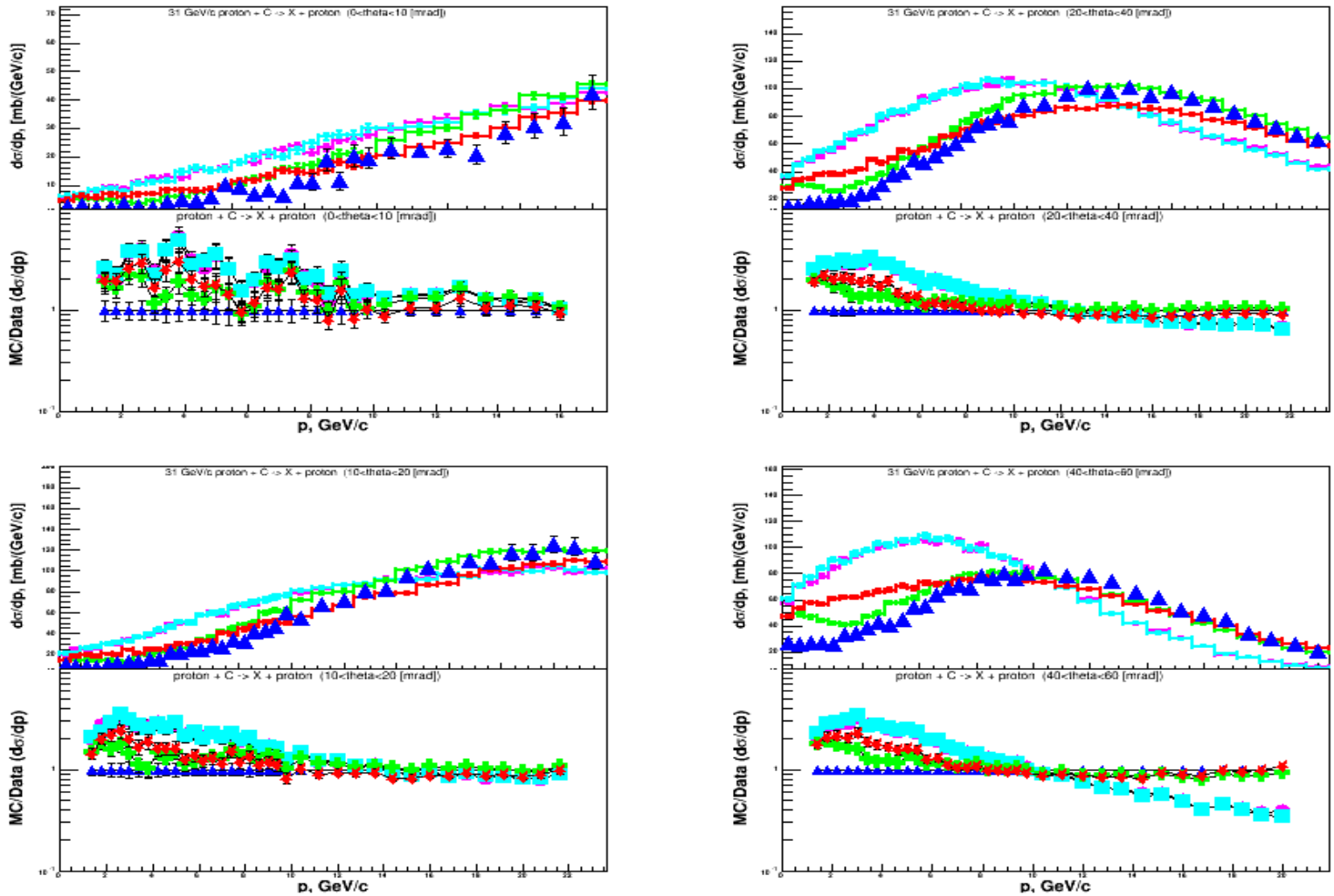
FTFP: 100GeV/c p+C -> p



FTFP: 100GeV/c p+Pb -> p



FTFP: 31GeV/c p+C -> p (I)

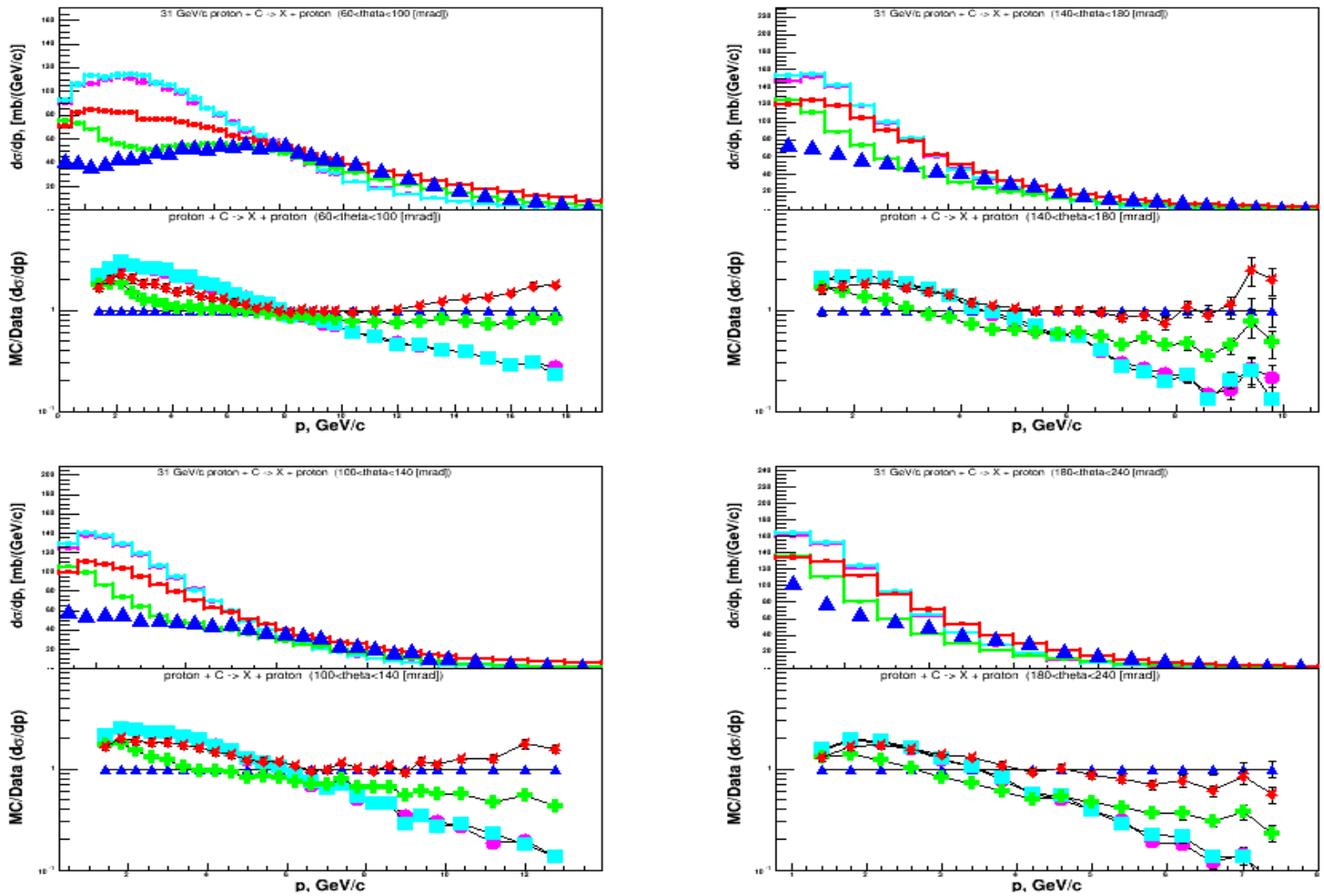


ftfp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

χ^2/NDF = 88.9198 for geant4-10-02-patch-03
χ^2/NDF = 92.7857 for geant4-10-03-patch-01
χ^2/NDF = 19.7226 for geant4-10-03-ref-01
χ^2/NDF = 28.3283 for geant4-10-03-ref-02

- geant4-10-02-patch-03
- geant4-10-03-patch-01
- geant4-10-03-ref-01
- geant4-10-03-ref-02
- exp.data

FTFP: 31GeV/c p+C -> p (II)

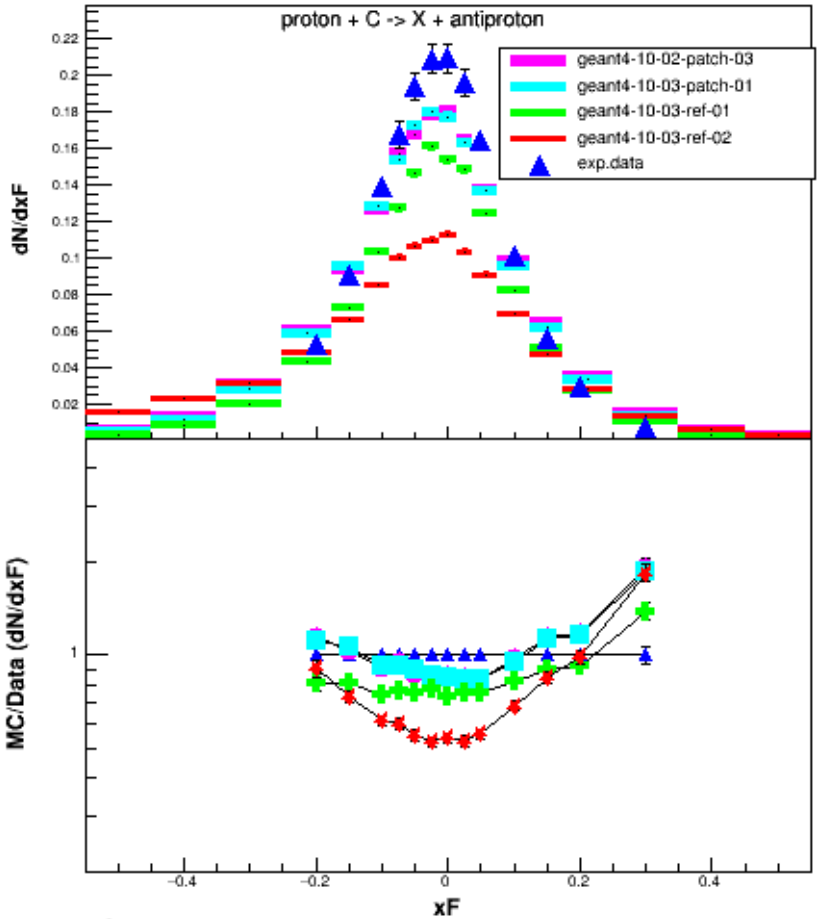


ftfp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

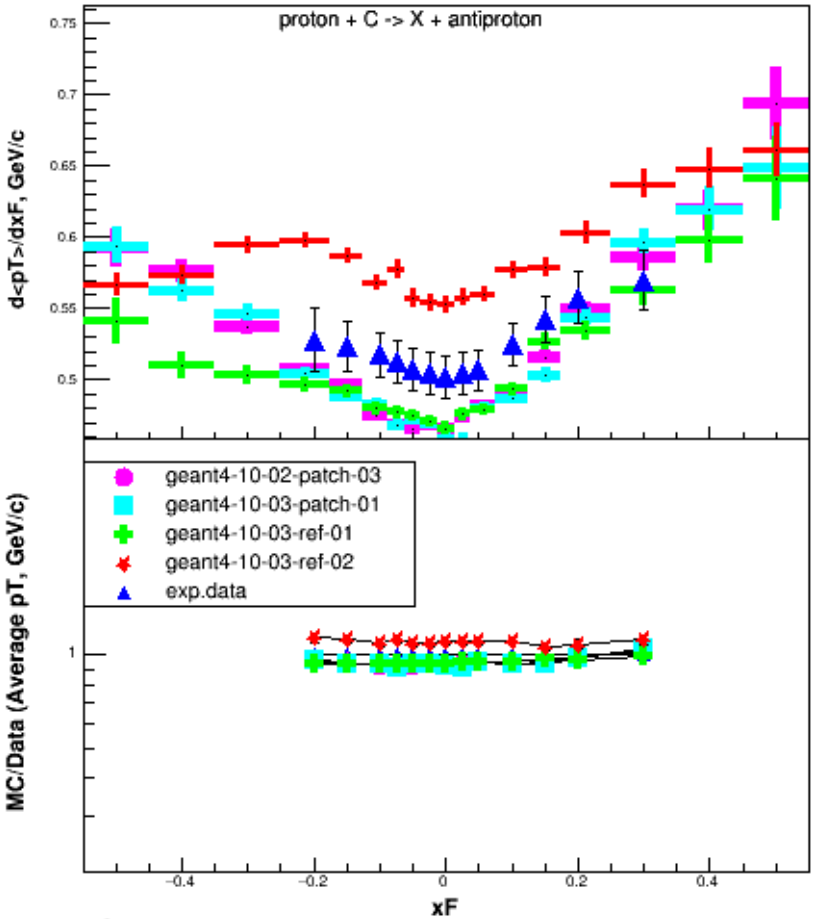
χ^2/NDF = 88.9198 for geant4-10-02-patch-03
χ^2/NDF = 92.7857 for geant4-10-03-patch-01
χ^2/NDF = 19.7226 for geant4-10-03-ref-01
χ^2/NDF = 28.3283 for geant4-10-03-ref-02

- geant4-10-02-patch-03
- geant4-10-03-patch-01
- geant4-10-03-ref-01
- geant4-10-03-ref-02
- exp.data

FTFP: 158GeV/c p+C -> pbar



χ^2/NDF = 18.08 for geant4-10-02-patch-03 vs NA49 Data
χ^2/NDF = 16.4491 for geant4-10-03-patch-01 vs NA49 Data
χ^2/NDF = 27.457 for geant4-10-03-ref-01 vs NA49 Data
χ^2/NDF = 87.868 for geant4-10-03-ref-02 vs NA49 Data

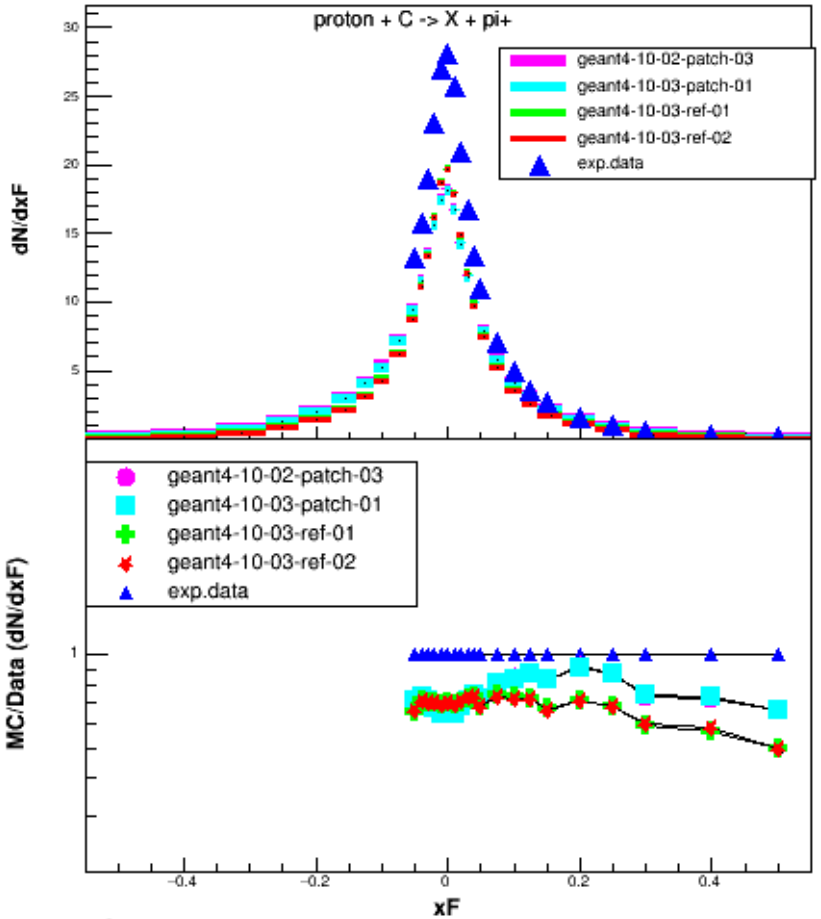


χ^2/NDF = 4.09394 for geant4-10-02-patch-03 vs NA49 Data
χ^2/NDF = 4.7744 for geant4-10-03-patch-01 vs NA49 Data
χ^2/NDF = 3.39065 for geant4-10-03-ref-01 vs NA49 Data
χ^2/NDF = 9.7682 for geant4-10-03-ref-02 vs NA49 Data

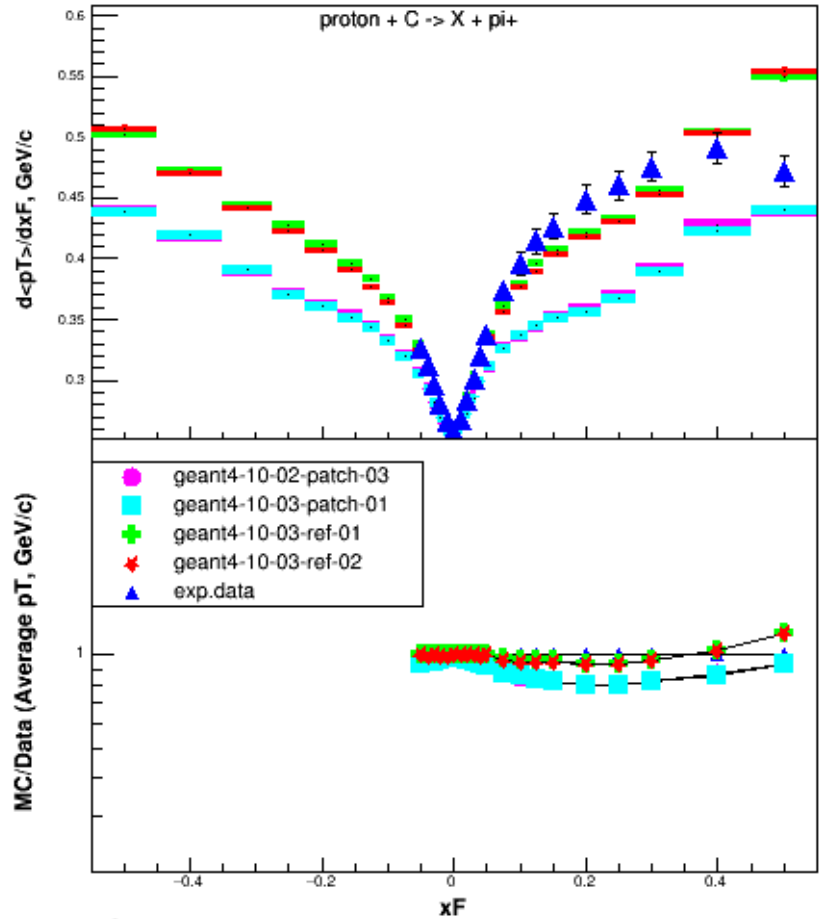
QGSP at High Energies as of 10.3.ref01/02

- Substantial improvement in most areas in modeling p+A
  - Results on pion or proton production in ref01/02 are much closer to the data than in 10.2.p03 or 10.3.p01
  - Modeling of kaon or Lambda production still has room for improvement
    - FTF appears to give better overall agreement with data
- Modeling of pion+A still has some room for improvement
  - Based on comparison with limited data
  - Exploring if more datasets can be added
- Use of G4LundStringFragmentation may substantially improve agreement with data in some areas, but at the same time it may pull MC results away from the data in some other areas

QGSPP: 158GeV/c p+C -> pi+

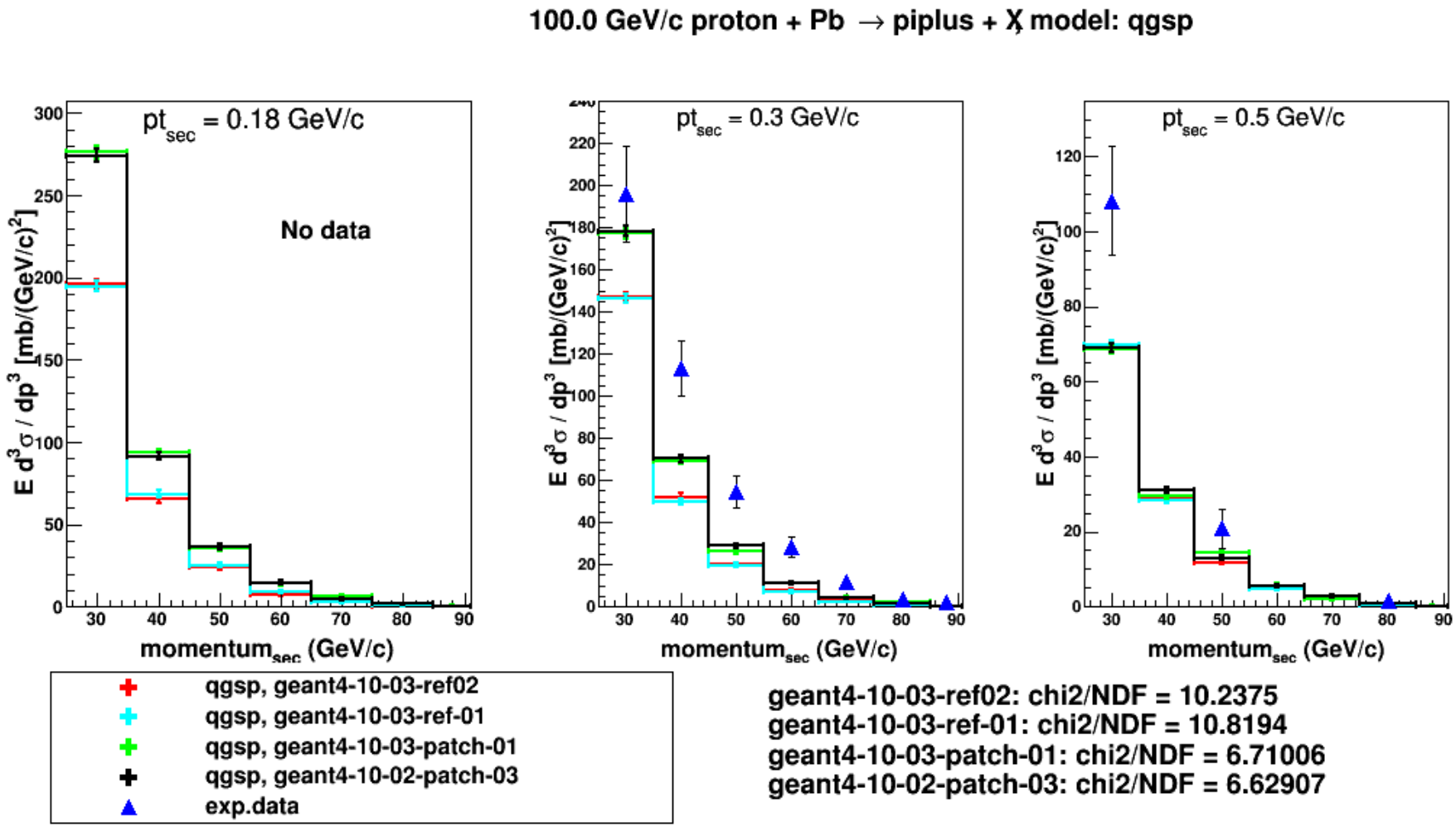


χ^2/NDF = 107.85 for geant4-10-02-patch-03 vs NA49 Data
χ^2/NDF = 107.507 for geant4-10-03-patch-01 vs NA49 Data
χ^2/NDF = 153.995 for geant4-10-03-ref-01 vs NA49 Data
χ^2/NDF = 153.031 for geant4-10-03-ref-02 vs NA49 Data

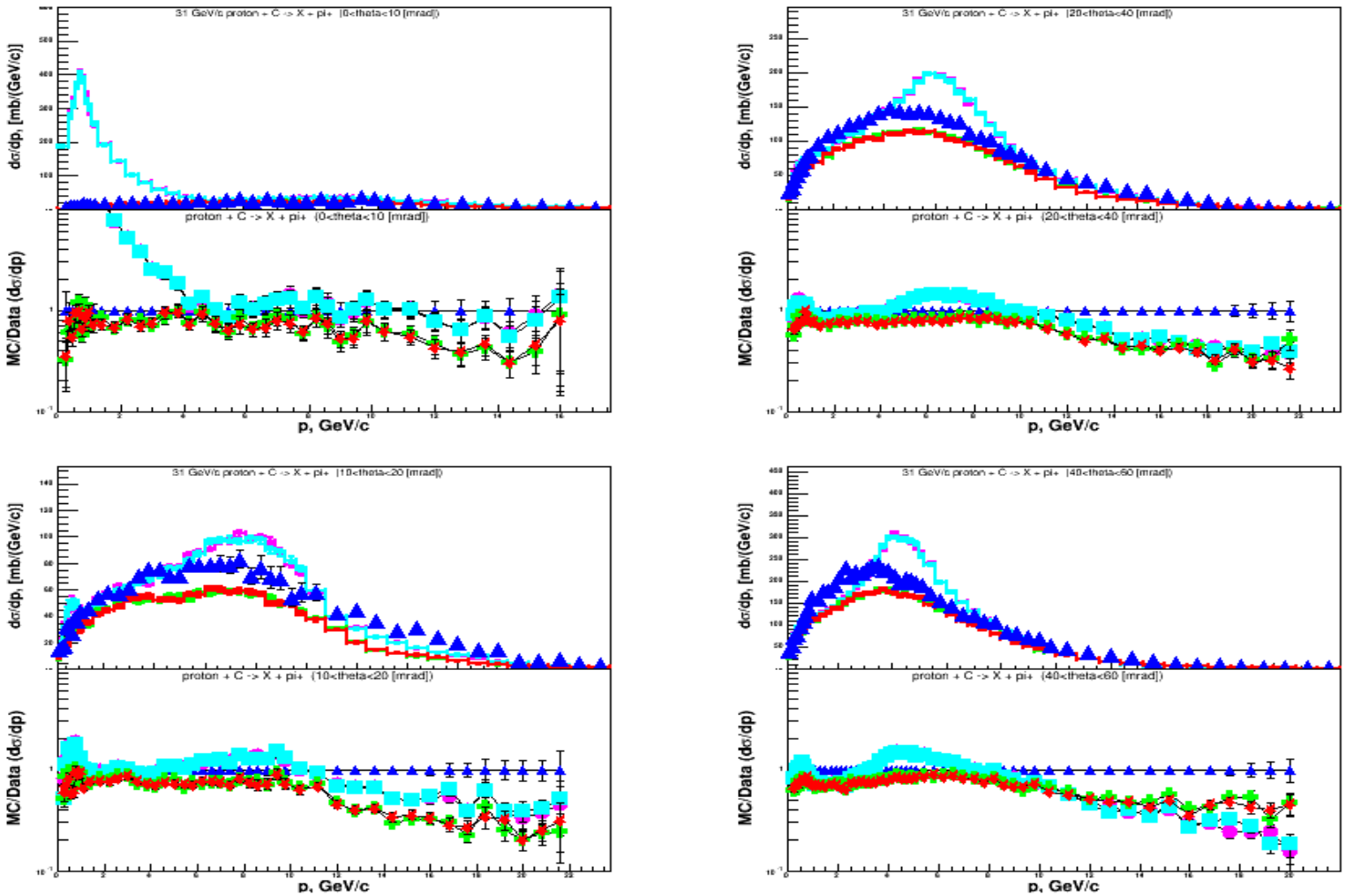


χ^2/NDF = 20.3901 for geant4-10-02-patch-03 vs NA49 Data
χ^2/NDF = 20.6476 for geant4-10-03-patch-01 vs NA49 Data
χ^2/NDF = 3.06864 for geant4-10-03-ref-01 vs NA49 Data
χ^2/NDF = 3.67801 for geant4-10-03-ref-02 vs NA49 Data

QGSPP: 100GeV/c p+Pb -> pi+



QGSPP: 31GeV/c p+C -> pi+

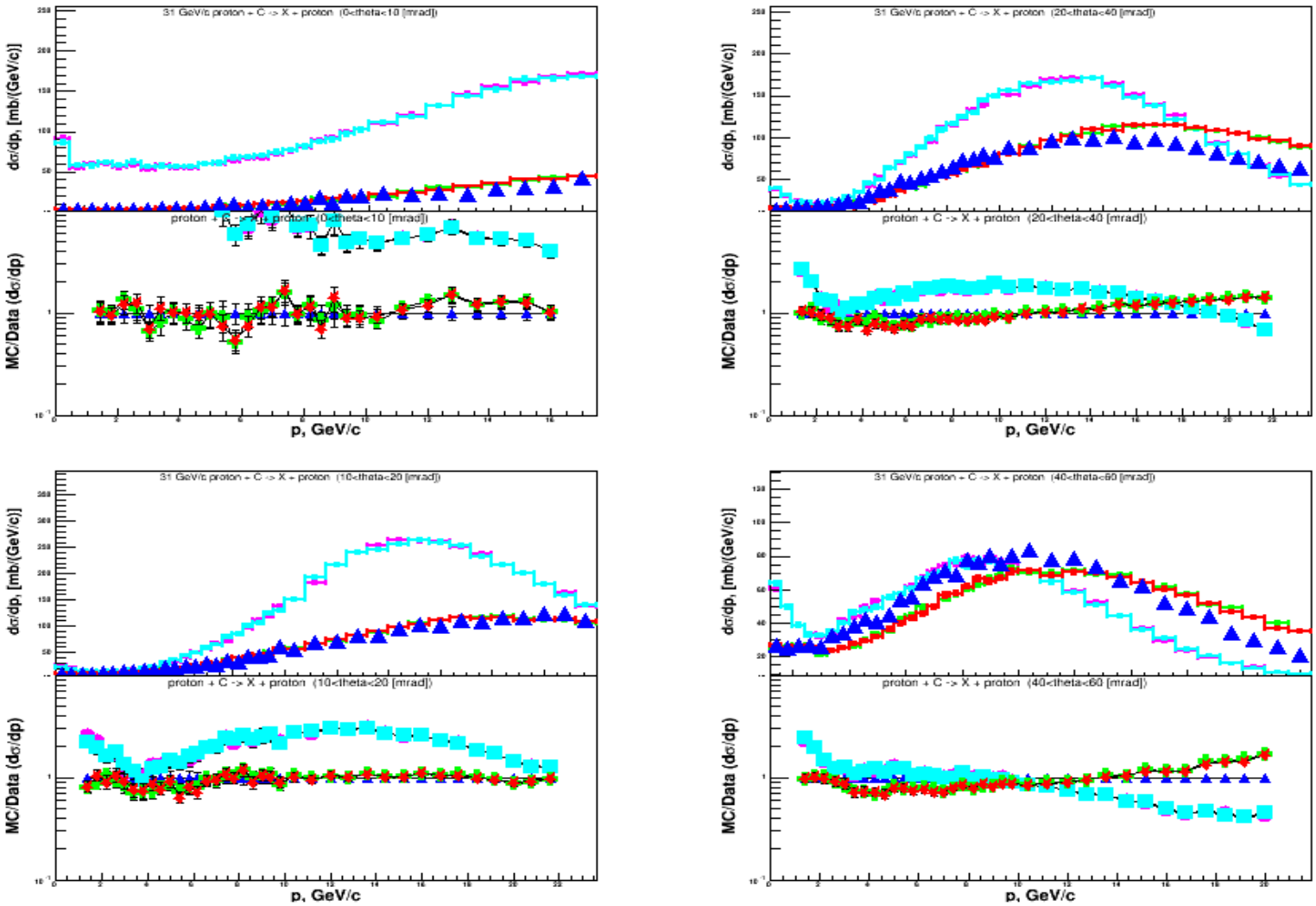


qgsp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

χ^2/NDF = 72.8259 for geant4-10-02-patch-03
χ^2/NDF = 72.2718 for geant4-10-03-patch-01
χ^2/NDF = 24.2353 for geant4-10-03-ref-01
χ^2/NDF = 24.1461 for geant4-10-03-ref-02

- geant4-10-02-patch-03
- geant4-10-03-patch-01
- geant4-10-03-ref-01
- geant4-10-03-ref-02
- exp.data

QGSPP: 31GeV/c p+C -> p

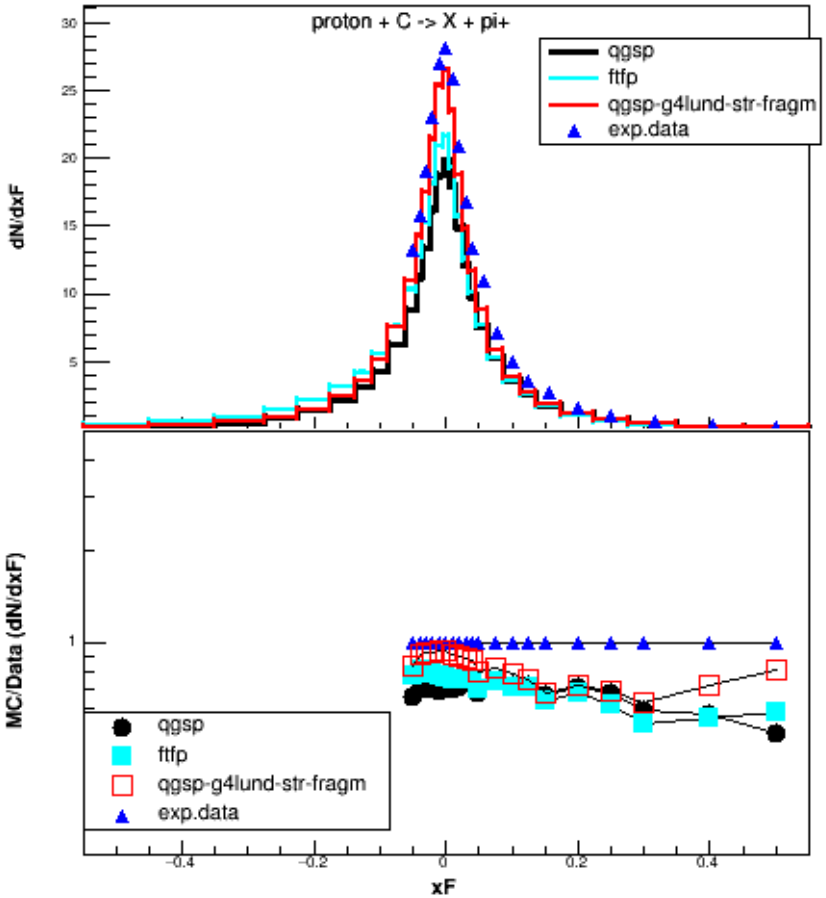


qgsp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

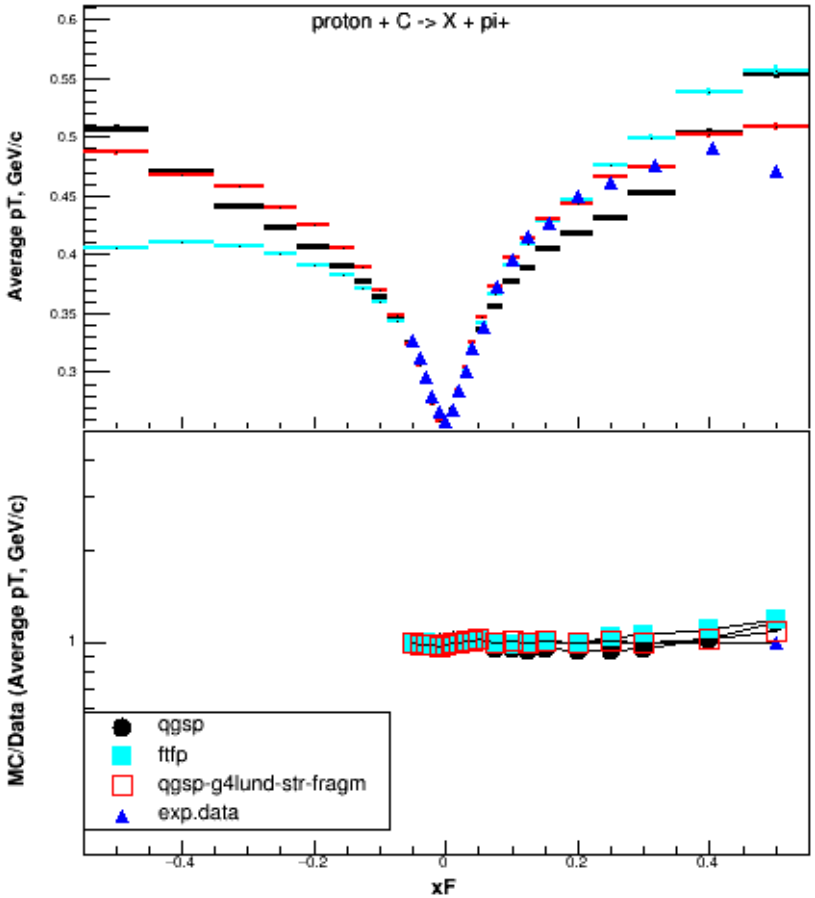
χ^2/NDF = 155.851 for geant4-10-02-patch-03
χ^2/NDF = 156.461 for geant4-10-03-patch-01
χ^2/NDF = 13.1912 for geant4-10-03-ref-01
χ^2/NDF = 13.0215 for geant4-10-03-ref-02

- geant4-10-02-patch-03
- geant4-10-03-patch-01
- geant4-10-03-ref-01
- geant4-10-03-ref-02
- exp.data

Models comparison: 158GeV/c p+C -> pi+

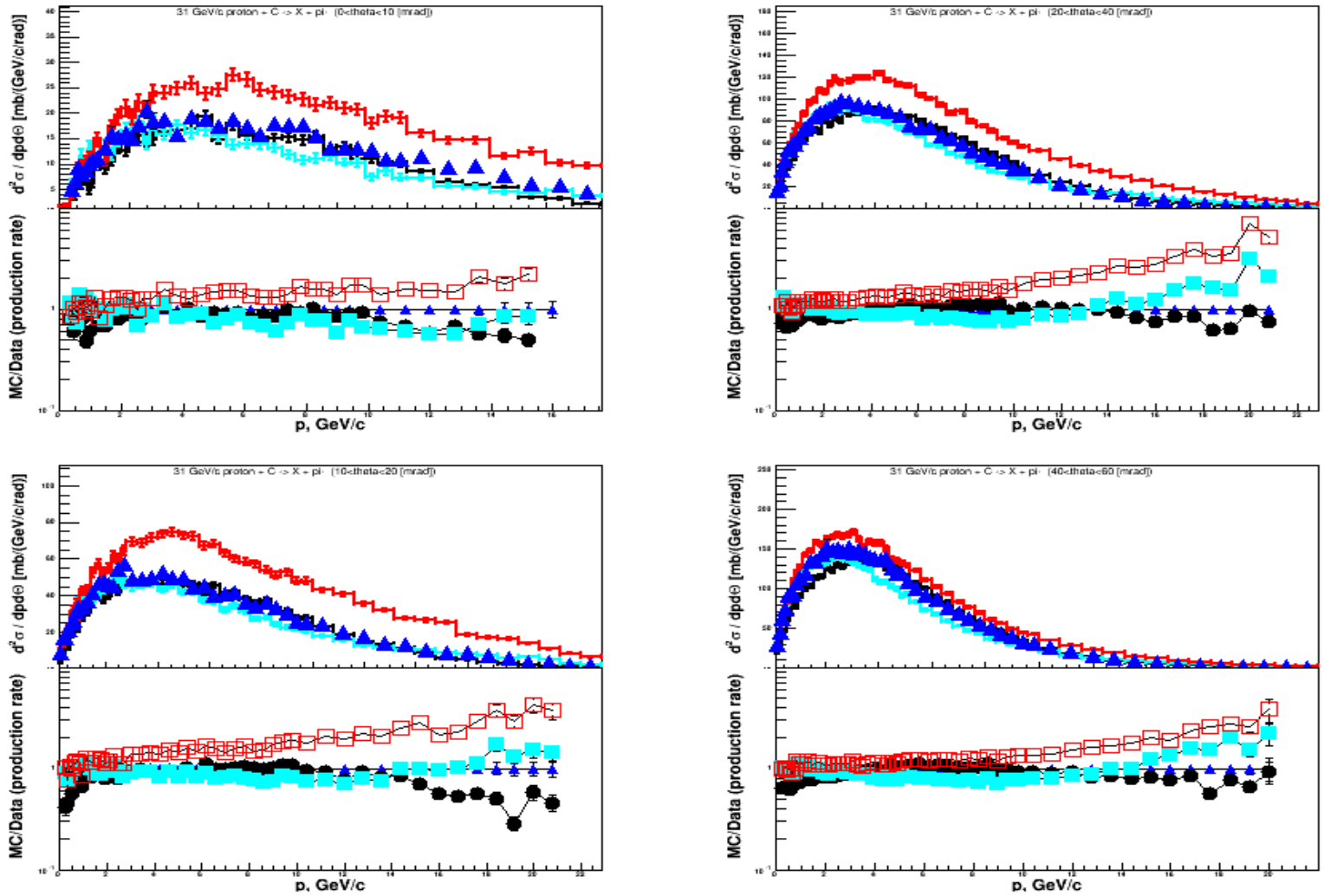


χ^2/NDF = 153 for qgsp
χ^2/NDF = 130.3 for ftfp
χ^2/NDF = 59.1 for qgsp-g4lund-str-fragm



χ^2/NDF = 3.68 for qgsp
χ^2/NDF = 3.21 for ftfp
χ^2/NDF = 0.775 for qgsp-g4lund-str-fragm

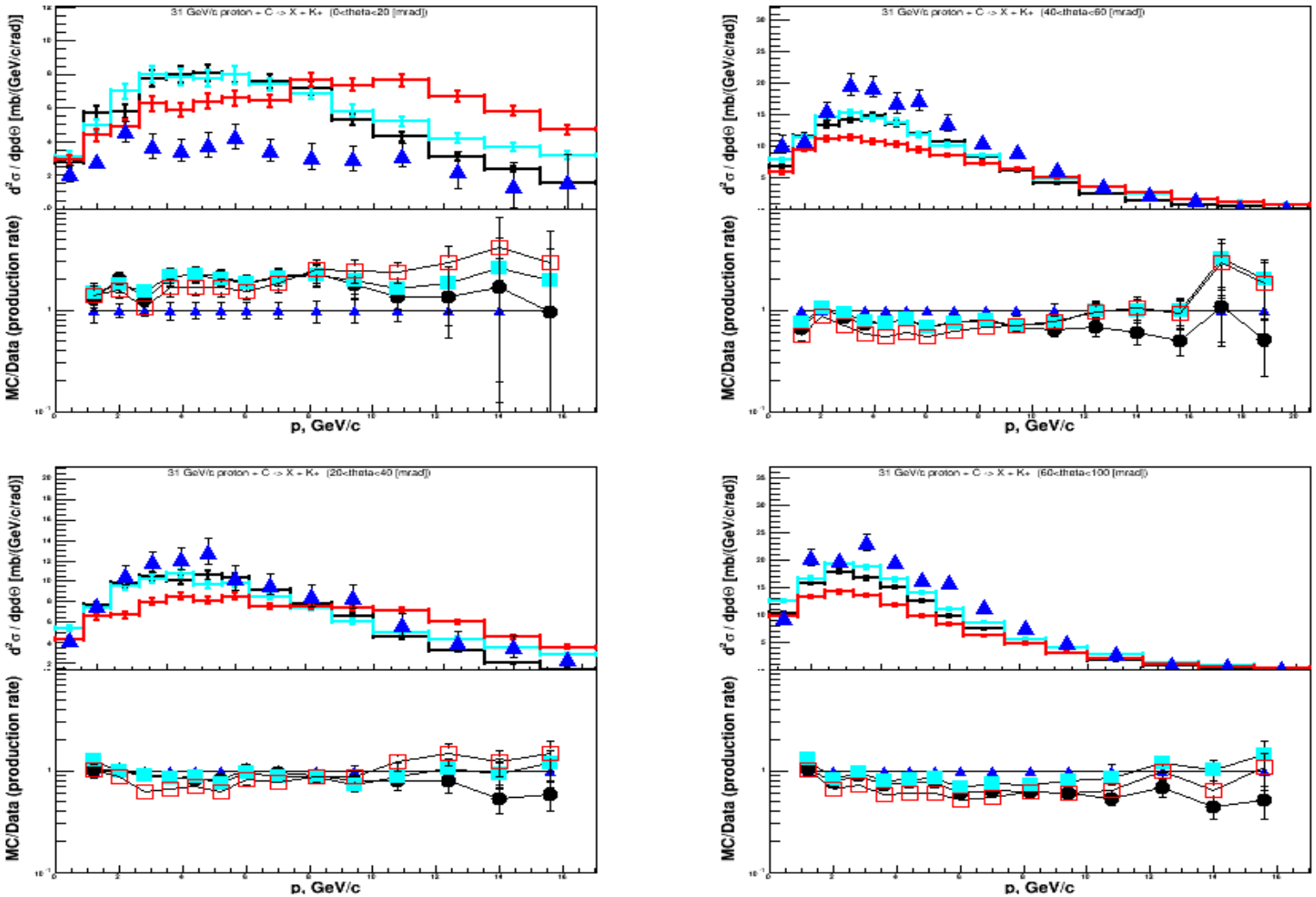
Models comparison: 31GeV/c p+C -> pi-



MC vs NA61 Data; χ^2/NDF calculated over ALL theta bins
χ^2/NDF = 28.2651 for qgsp
χ^2/NDF = 8.67256 for ftfp
χ^2/NDF = 17.7057 for qgsp-g4lund-str-fragm

qgsp
ftfp
qgsp-g4lund-str-fragm
exp.data

Models comparison: 31GeV/c p+C -> K+



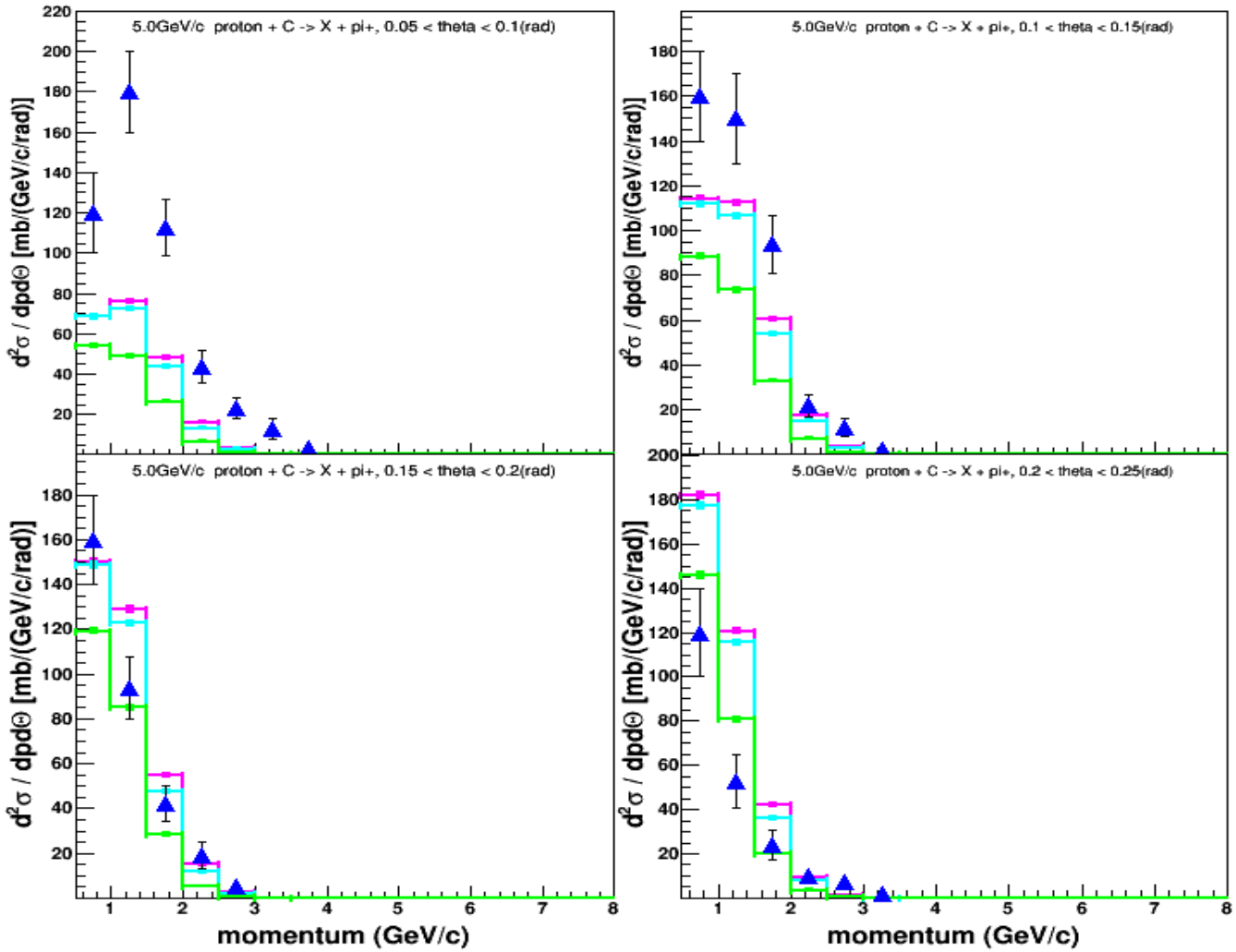
MC vs NA61 Data; χ^2/NDF calculated over ALL theta bins
χ^2/NDF = 8.37824 for qgsp
χ^2/NDF = 4.59085 for ftfp
χ^2/NDF = 12.3031 for qgsp-g4lund-str-fragm

qgsp
ftfp
qgsp-g4lund-str-fragm
exp.data

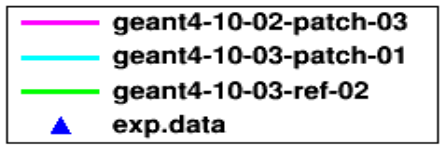
FTFP at Intermediate Energies

- Some variations in ref02 observed when modeling hadron+A -> pions
  - Mild for light targets
  - More obvious for heavy targets
- Certain variations among releases in question are observed when modeling hadron+A -> p/n
  - Effect is obvious for light targets
  - No significant effect for heavy targets

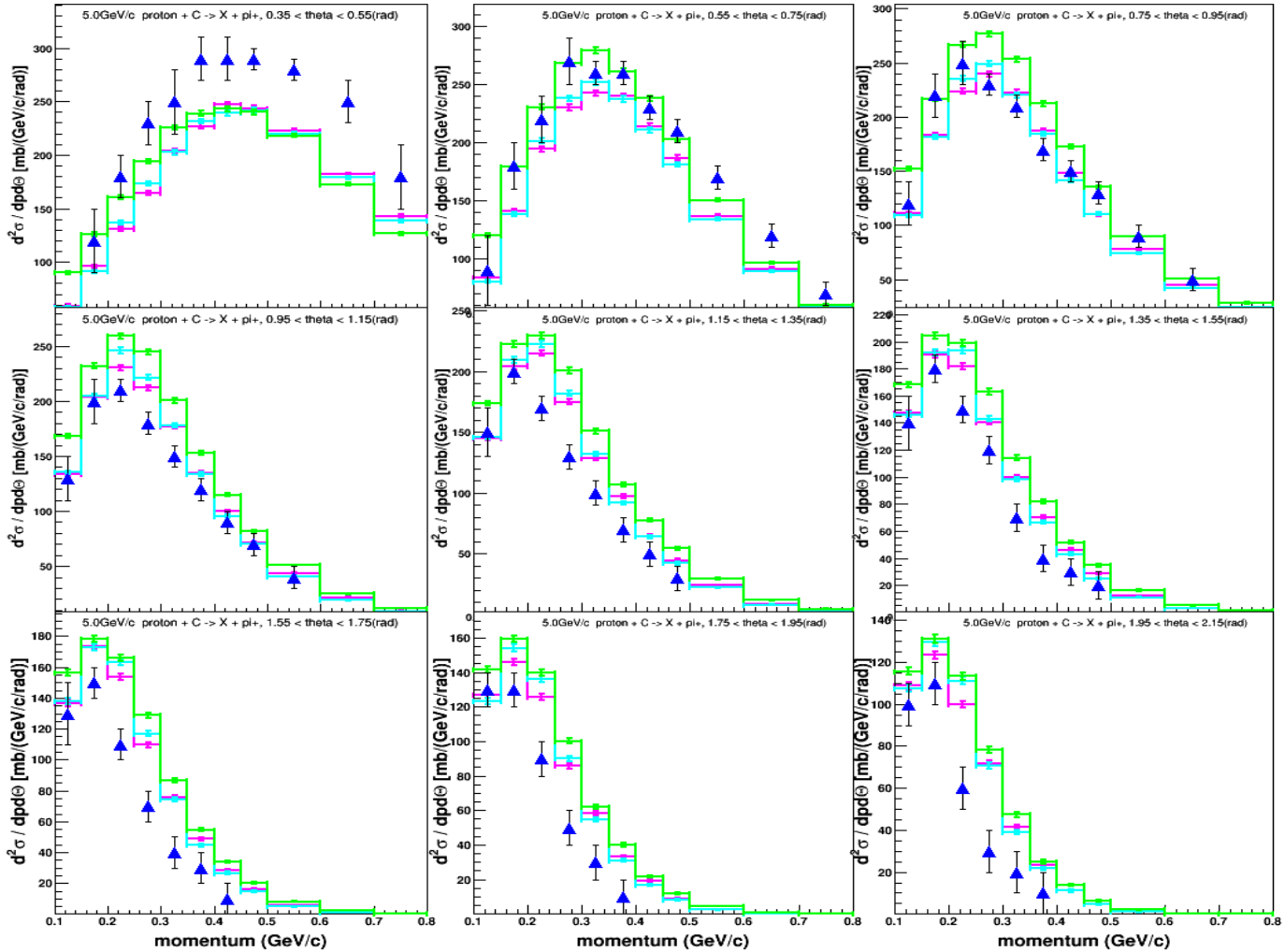
FTFP: 5GeV/c p+C -> pi+ (FW)



ftfp vs HARP Data; χ^2/NDF calculated over FW theta bins
χ^2/NDF = 7.47993 for geant4-10-02-patch-03
χ^2/NDF = 7.6837 for geant4-10-03-patch-01
χ^2/NDF = 10.1818 for geant4-10-03-ref-02



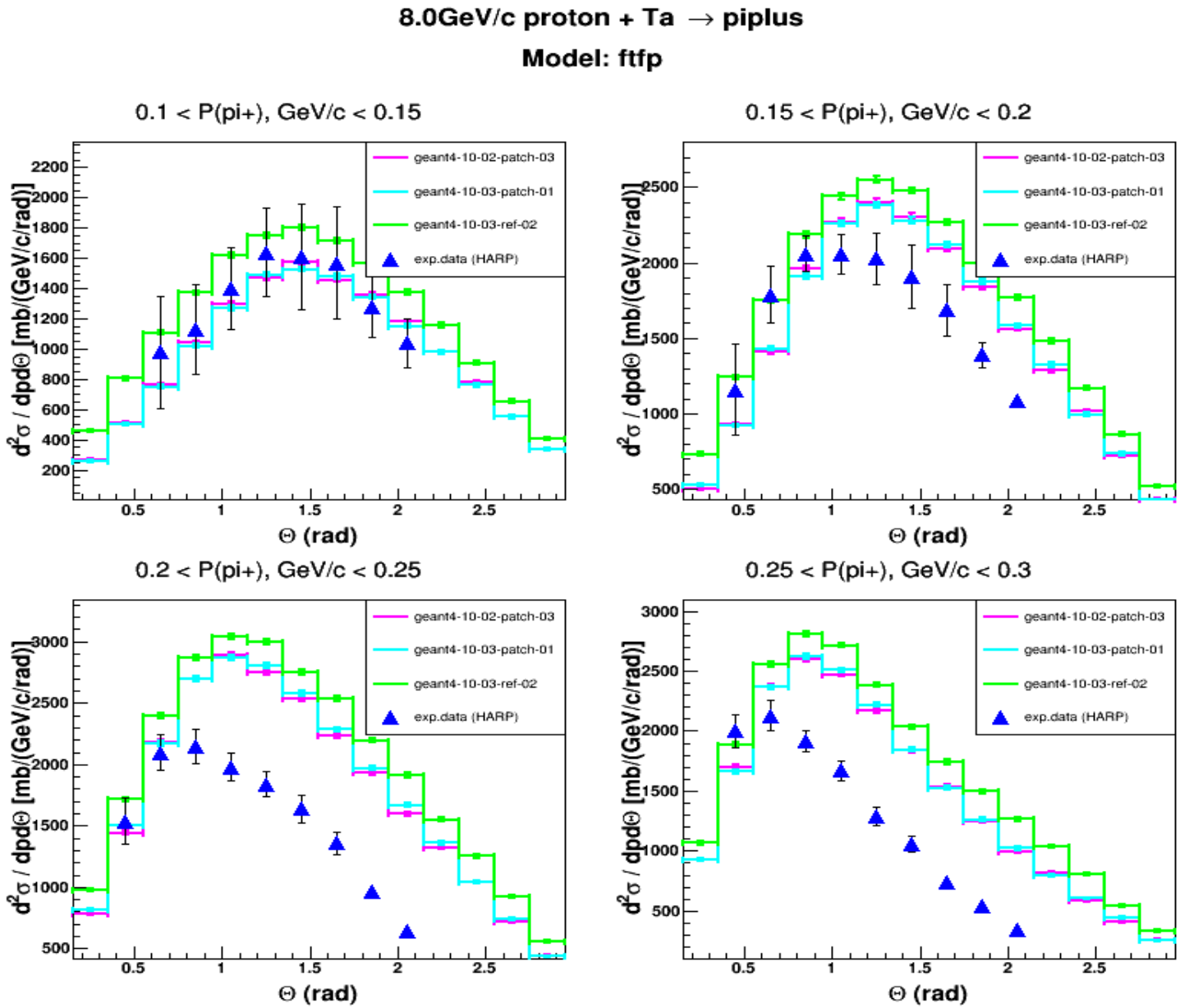
FTFP: 5GeV/c p+C -> pi+ (LA)



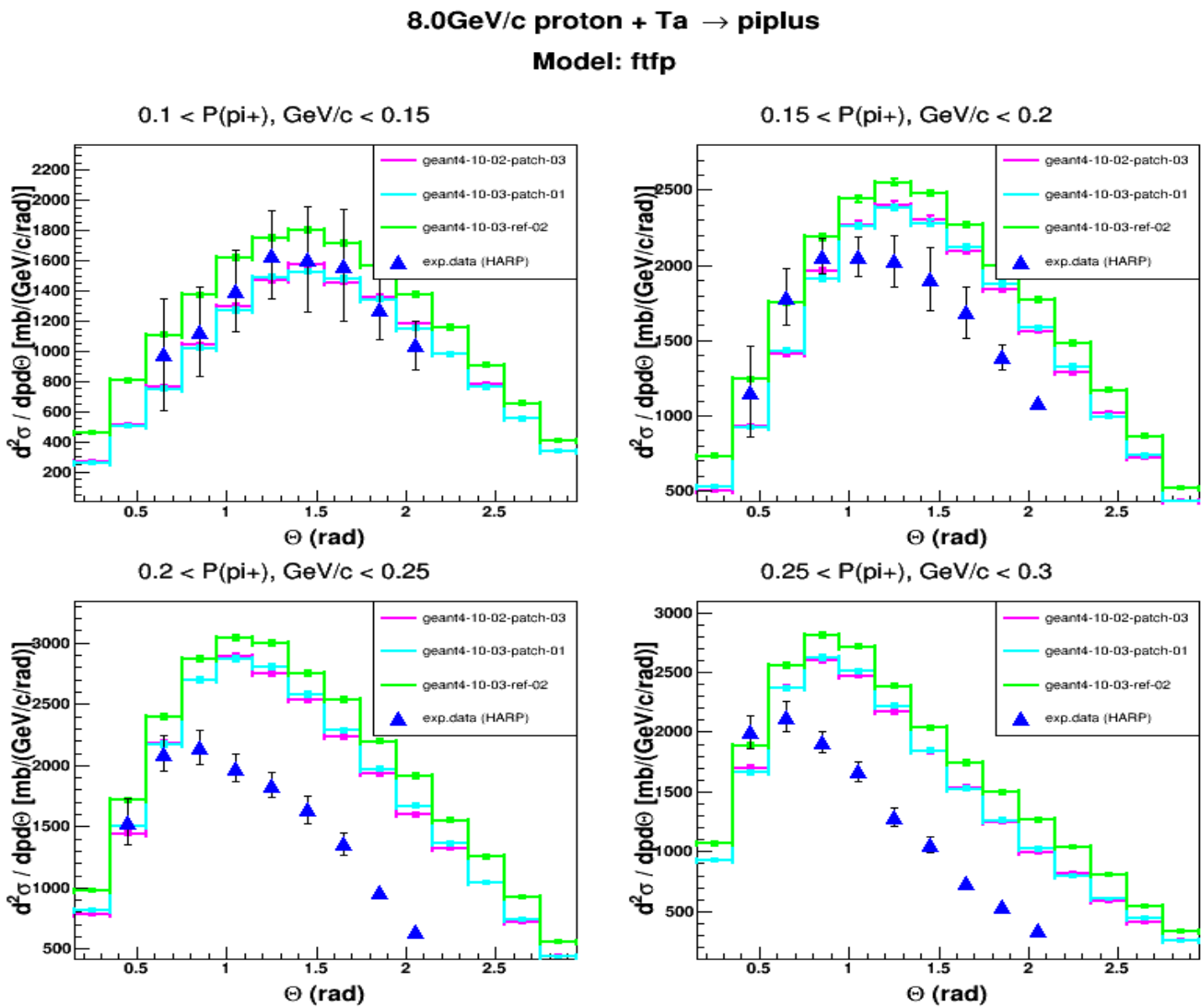
ftfp vs HARP Data; χ^2/NDF calculated over LA theta bins
χ^2/NDF = 5.68895 for geant4-10-02-patch-03
χ^2/NDF = 6.70567 for geant4-10-03-patch-01
χ^2/NDF = 10.4274 for geant4-10-03-ref-02

geant4-10-02-patch-03
geant4-10-03-patch-01
geant4-10-03-ref-02
exp.data

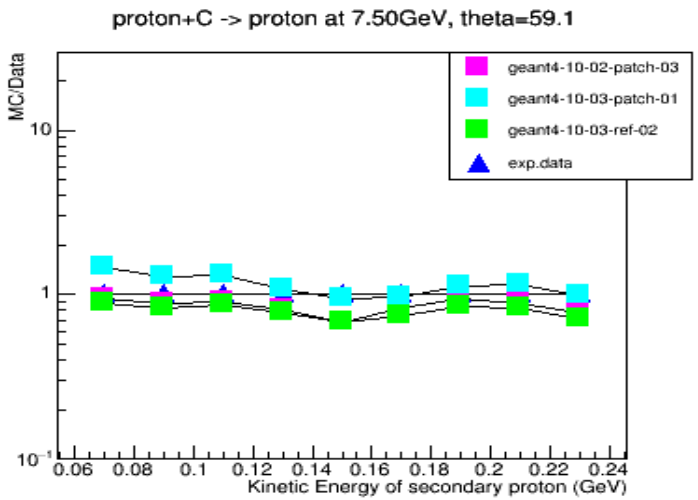
FTFP: 8GeV/c p+Ta -> pi+

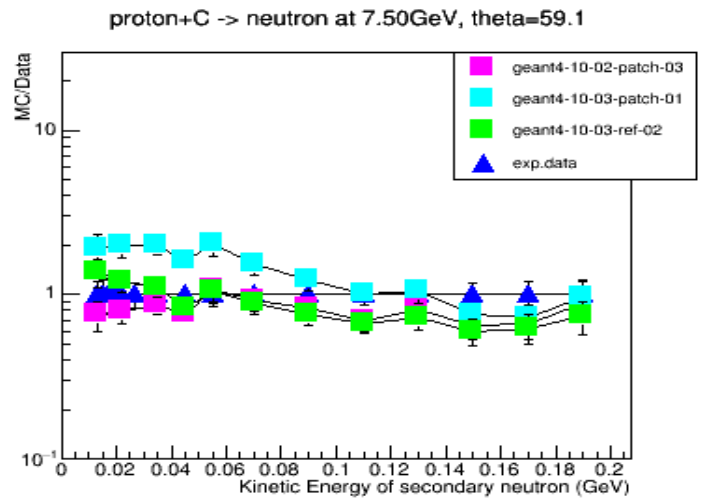


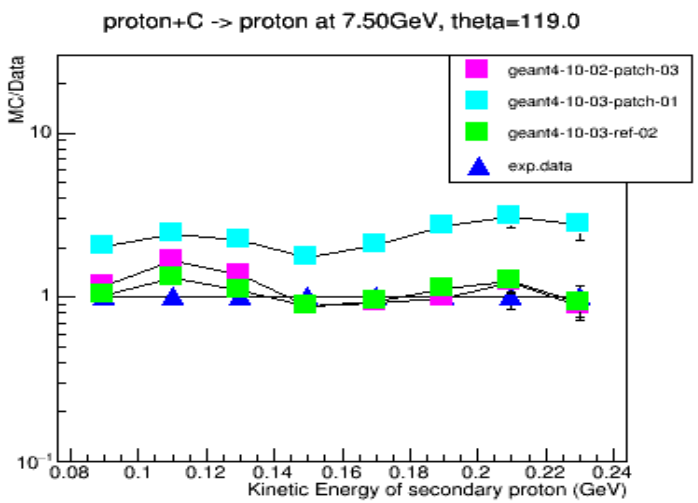
FTFP: 8GeV/c p+Ta -> pi-

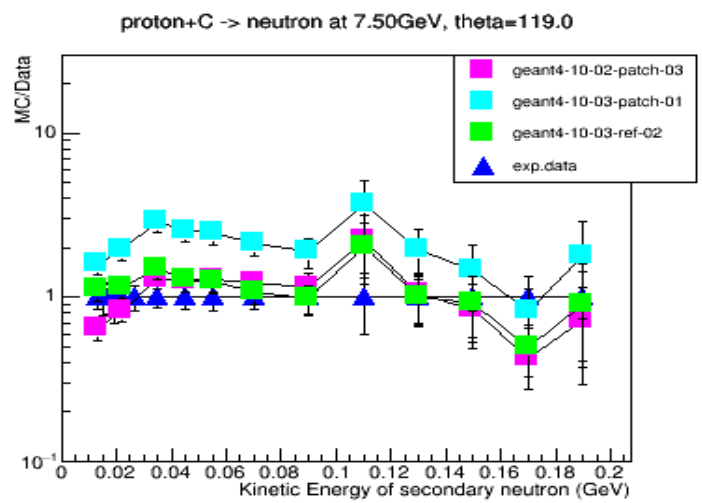


FTFP: 7.5GeV/c p+C -> p/n





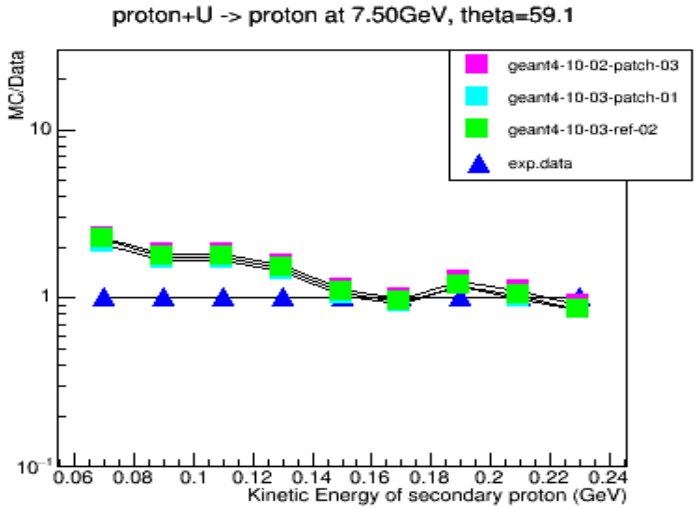


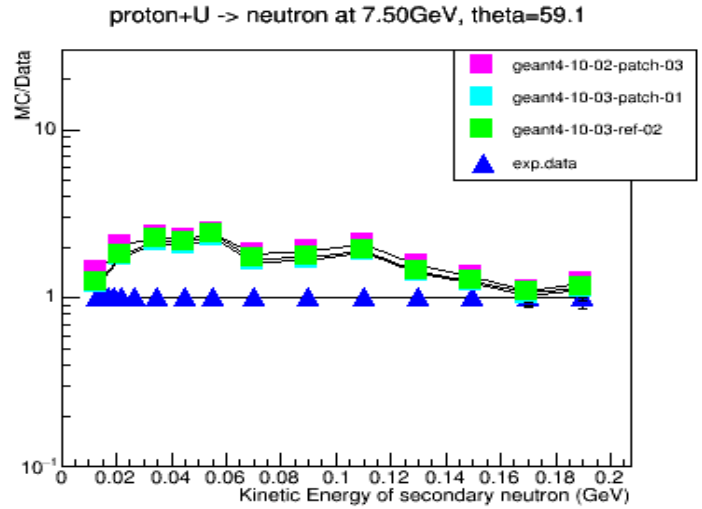


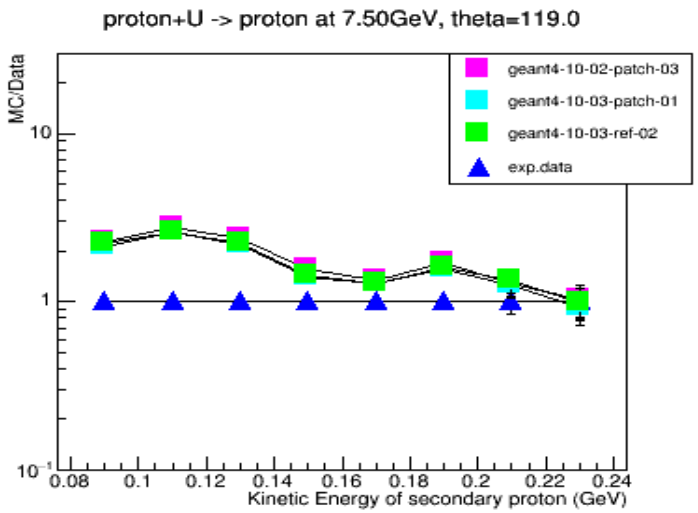
ftfp vs (ITEP) Data
χ^2/NDF = 8.7144 for geant4-10-02-patch-03
χ^2/NDF = 59.2975 for geant4-10-03-patch-01
χ^2/NDF = 6.73799 for geant4-10-03-ref-02

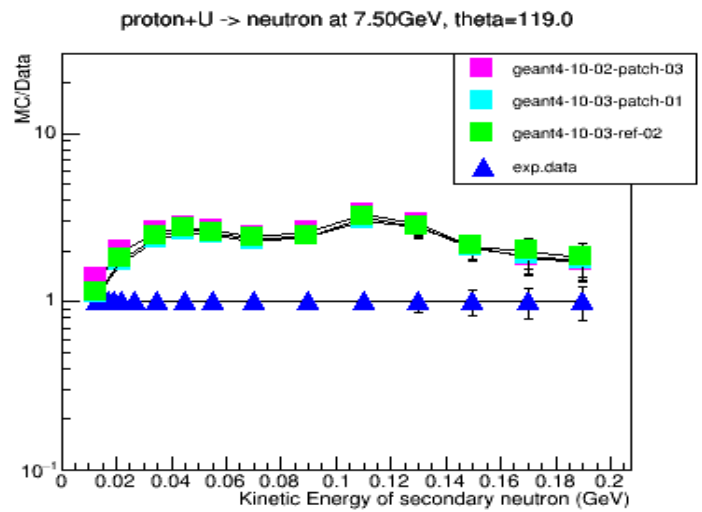
ftfp vs (ITEP) Data
χ^2/NDF = 2.30408 for geant4-10-02-patch-03
χ^2/NDF = 31.3598 for geant4-10-03-patch-01
χ^2/NDF = 2.45192 for geant4-10-03-ref-02

FTFP: 7.5GeV/c p+U -> p/n









ftfp vs (ITEP) Data
χ^2/NDF = 128.036 for geant4-10-02-patch-03
χ^2/NDF = 96.5196 for geant4-10-03-patch-01
χ^2/NDF = 107.58 for geant4-10-03-ref-02

ftfp vs (ITEP) Data
χ^2/NDF = 221.769 for geant4-10-02-patch-03
χ^2/NDF = 161.497 for geant4-10-03-patch-01
χ^2/NDF = 185.447 for geant4-10-03-ref-02

Summary

- Validation Geant4.10.2.p03, 10.3.p01, 10.3.ref01, and 10.3.ref02 has been performed; results compared vs various exp.data
- As of 10.3.ref02, in a number of areas FTF tends to move away from the data as compared to results of 10.2.p03 or 10.3.p01,
- Or even 10.3.ref01
  - Behavior is mainly similar for light or heavy targets
- As of 10.3.ref02, QGS results definitely improve in many areas
  - In particular, modeling of pions or protons production in hadron+A interactions has improved
  - Room for improvement remains in modeling of kaons production
  - Behavior appears similar for light or heavy targets
  - Use of G4LundStringFragmentation component with QGS improves agreement with the data in some areas, but results may degrade in some other areas