

Hadronic Validation - Geant4.9.6.p01: test48, test47, test19, test75

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General Remarks

- New tests added
- Regression tests(if applicable) include:
 - 4.9.5.p01, 4.9.6.b01, 4.9.6.p01 (current)
- From now on, **4.9.6.p01** is proposed to be the **reference point** for further validation
- Complete set of results will be available in a few days via Geant4 Validation Repository
- Focus on recent changes (regression) and/or new test results; other results are in backup slides



Test48: Capture/Annihilation Processes

- **Particles:** pi-, K-, Sigma-, pbar, mu- (**new - w/K.Genser**)
- **Data sets:**
 - R.Madey et al., Phys.Rev.C25,3050(1982) (pi-)
 - K.Larson et al., Phys.Rev.D47,799(1993) + ref.materials (K-)
 - M.Goossens et al., in Low and Intermediate energy physics, ed. E.Ferrari and G.Violini (Riedel, Holland, 1980, p.243 (Sigma-))
 - C. Amsler, Rev. Mod. Phys. 70, 1293 (1998) (pbar)
 - C.B. Dover et al., Prog. Part. Nucl. Phys., Vol.29, pp.87-173 (1992) (pbar)
 - P.Singer, Springer Tracts in Modern Physics, 71, 39 (1974) (mu-)
 - R.M.Sundelin et. Al., Phys.Rev.Lett., Vol.20, Number 21, 1198 (1968) (mu-)
- **Models:**
 - **Stopping (traditional), Bertini, FTF, CHIPS (last release)**
- **Regression tests (Bertini only): 4.9.5.p01, 4.9.6.b01, 4.9.6.p01**



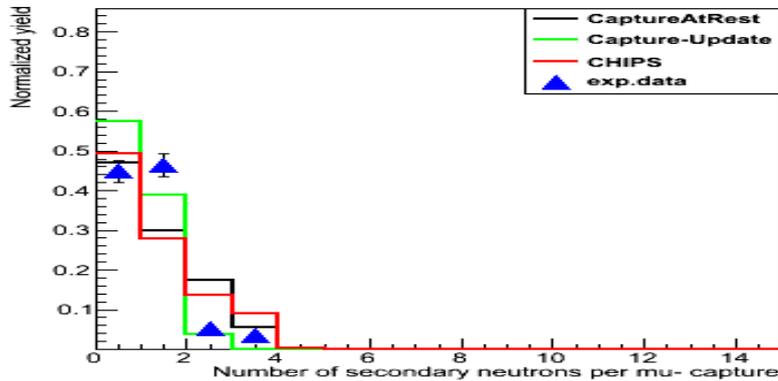
Test48: Results(I)

- Regression tests show small variation in Bertini for π^- on various targets; agreement with data better than CHIPS results (see backup slides)
- No changes between 9.6.b01 and 9.6.p01 in modeling K- and Sigma- capture on H by Bertini (not available in 9.5.p01); good agreement with data by Bertini (see backup plots)
- No changes in \bar{p} on H modeling w/FTF (plot in backup)
- New development for μ^- capture introduced last year
- **New set of plots for μ^- added (w/K.Genser);**
“1st and last” comparison vs CHIPS (see following slides)

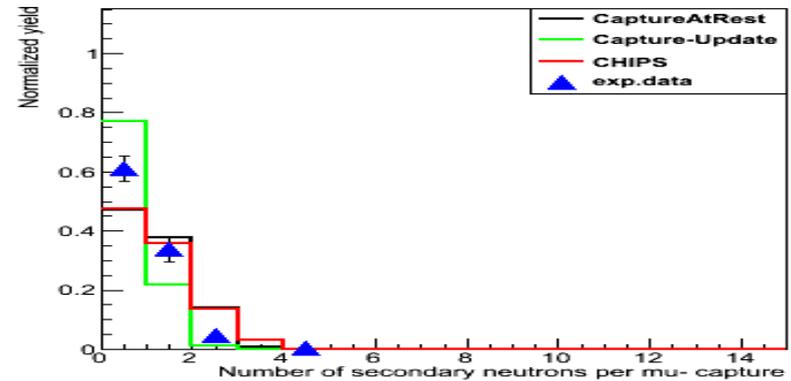


Test48: Results(II) mu- on various targets secondary neutrons multiplicity

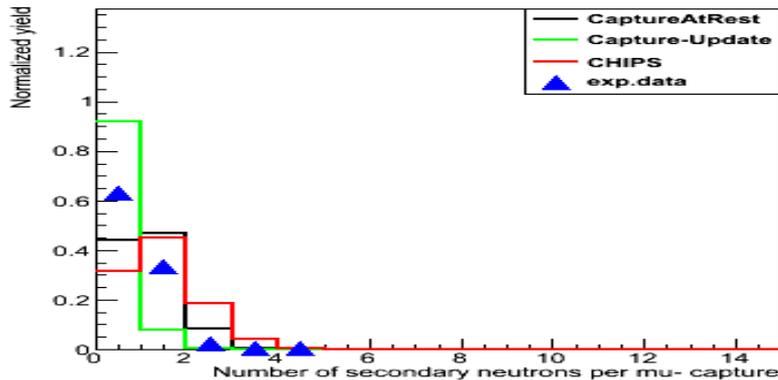
mu- on Al



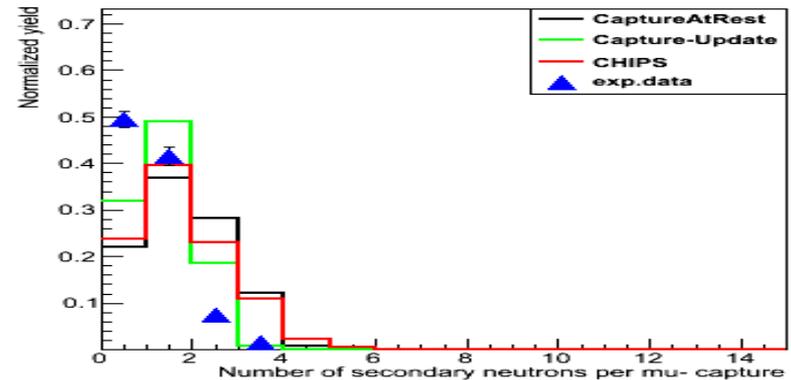
mu- on Si



mu- on Ca



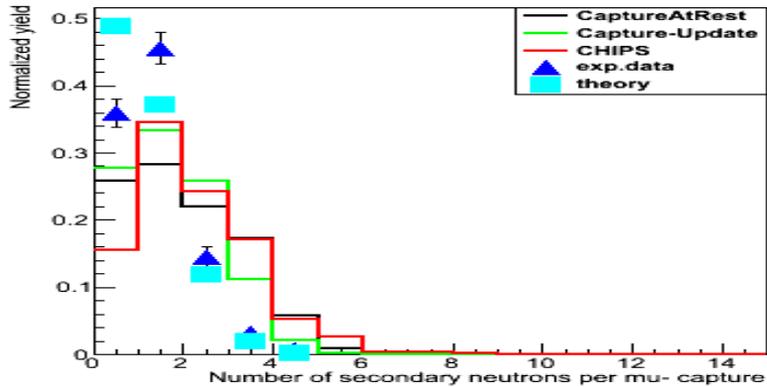
mu- on Fe



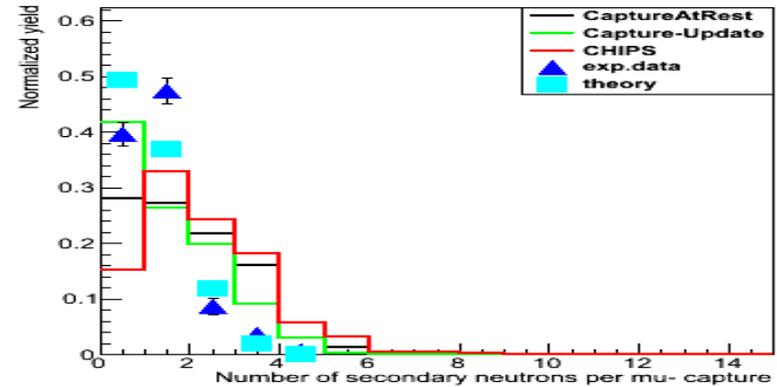


Test48: Results(III) mu- on various targets secondary neutrons multiplicity (cont.)

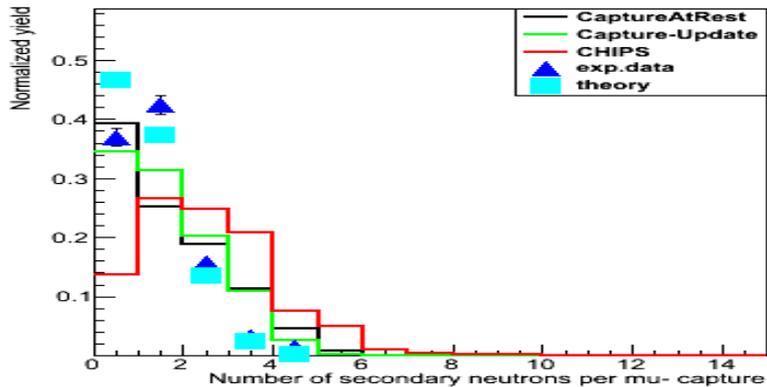
mu- on Ag



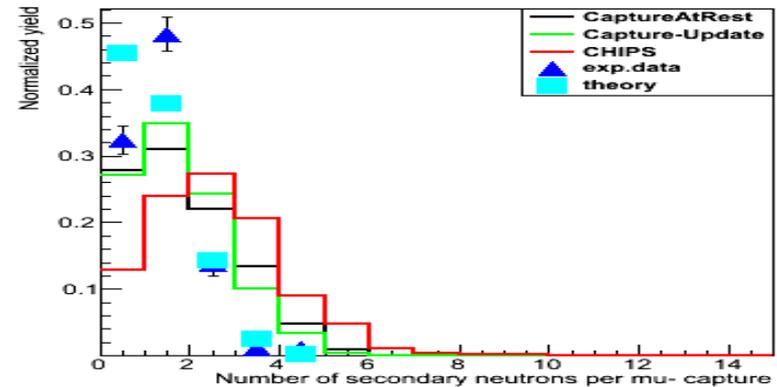
mu- on I



mu- on Au

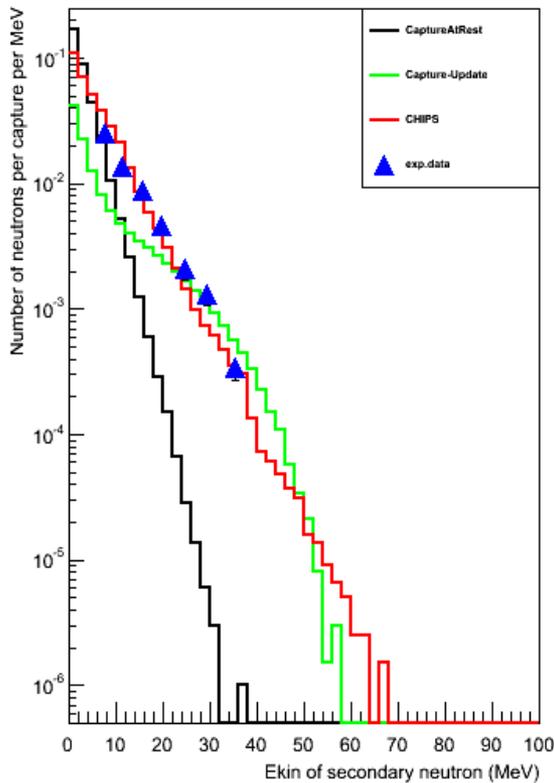


mu- on Pb

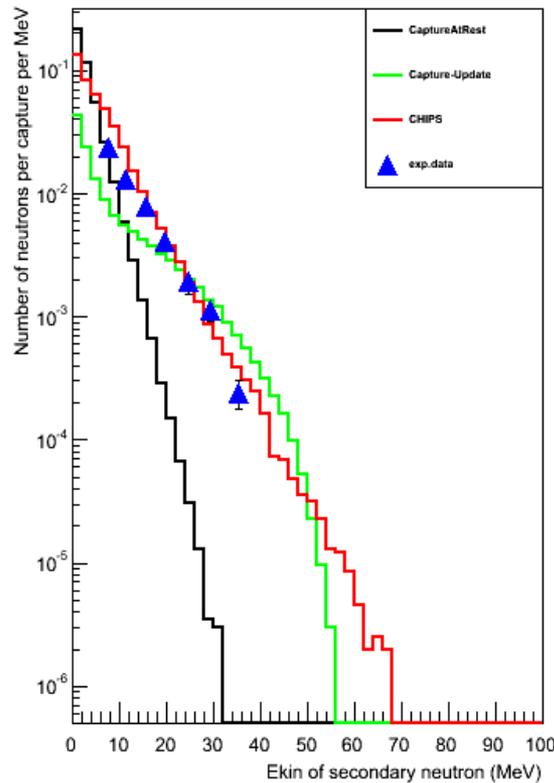


Test48: Results(III) mu- on various targets kinetic energy of secondary neutron

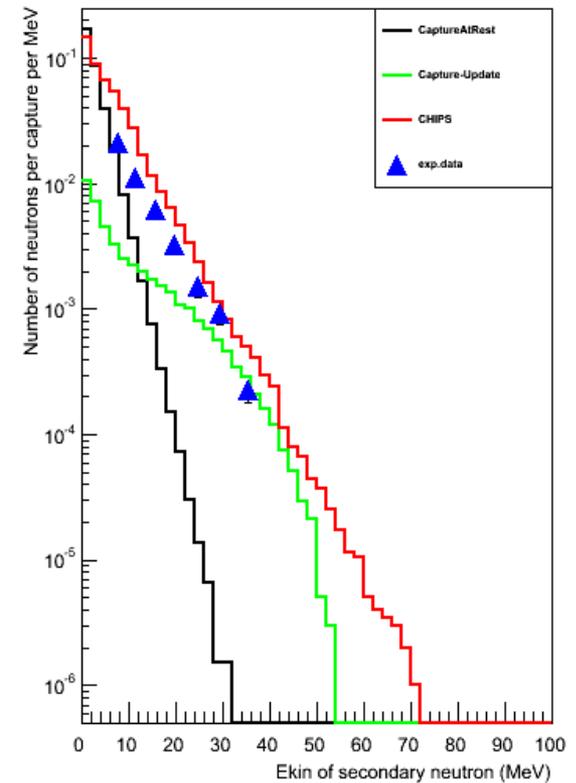
mu- on Si



mu- on S



mu- on Ca





Test48: Summary

- Bertini successfully replaces CHIPS and/or “traditional” code to model pi-, K-, Sigma- capture at rest
- FTF successfully replaces CHIPS and/or traditional code to model anti-baryons annihilation
- New development of mu- capture code has been introduced and is showing good results; comparable and/or better than traditional mu- capture code
- This is the last validation round showing CHIPS results



Test47: Intermediate Energy up to 7.5GeV

- **Beam:**
1.4GeV/c p, pi⁻, pi⁺, 5.GeV/c pi⁻, pi⁺, 7.5GeV p
- **Targets:** C and U
- **Data set:**
 - Yu.D. Bayukov et al., Sov.J.Nucl.Phys.42:116-121,1985
- **Models:** Binary, Bertini, CHIPS, QGSC, FTF(P)
- **NOTE-1:** Plans to include INCL++
- **NOTE-2:** Last validation round to include CHIPS/QGSC

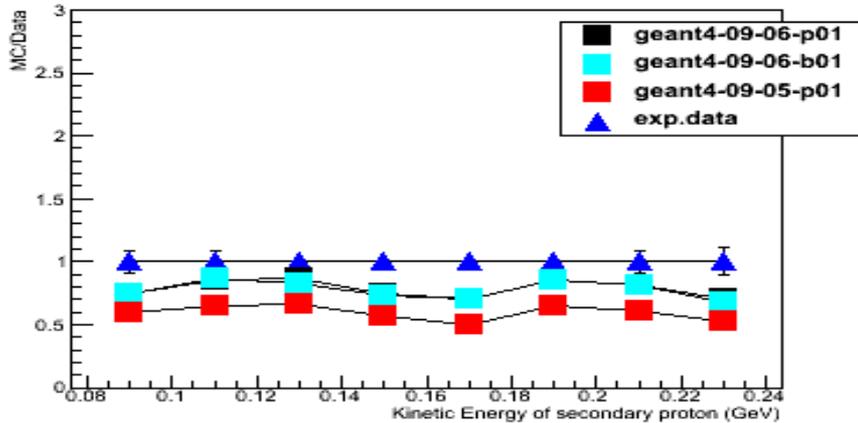


Test47: Results(I)

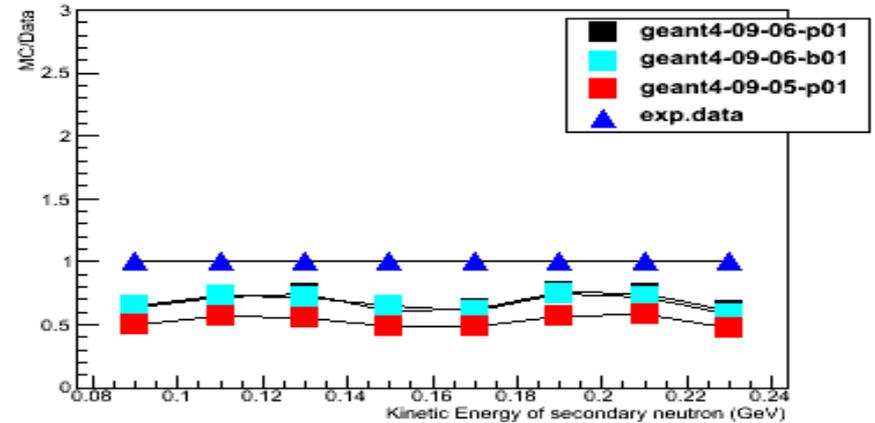
- Model comparison plots in backup (to save space/time)
- At 1.4GeV Bertini and Binary are two main players
- At 5-7.5GeV Bertini and/or FTF(P) is/are a reasonable choice
- Regression tests show improvements in Bertini vs 9.5.p01, but slight degradation in some cases in bck hemisphere; stable between 9.6.b01 and 9.6.p01 - see following sample plots; more plots in backup slides
- Regression tests show FTF mostly drifting AWAY from data between 9.6.b01 and 9.6.p01 - see following slides

Test47: Results(II) - Bertini

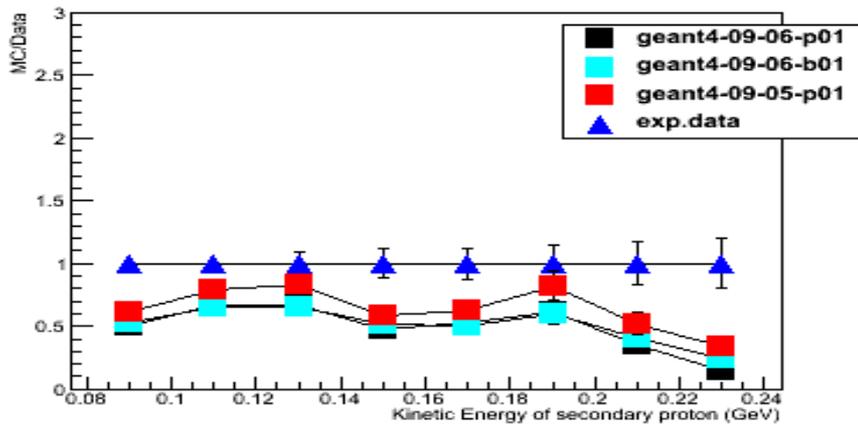
piplus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



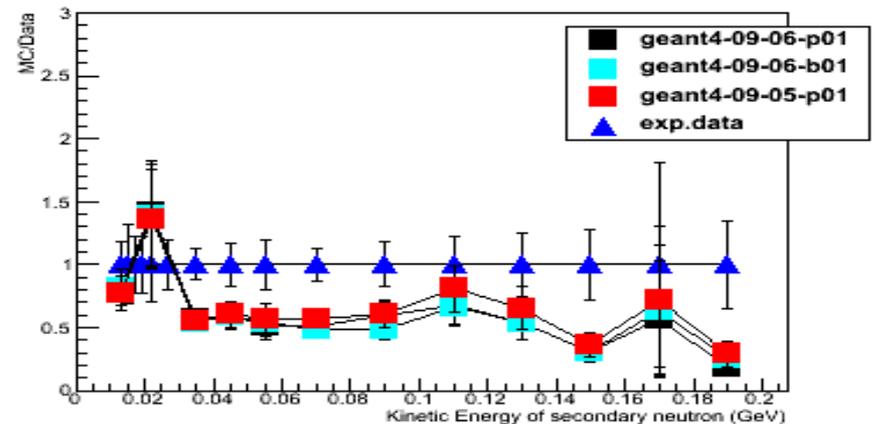
piplus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+C to p at 5.00 GeV (bertini) ($\theta = 119.00$)

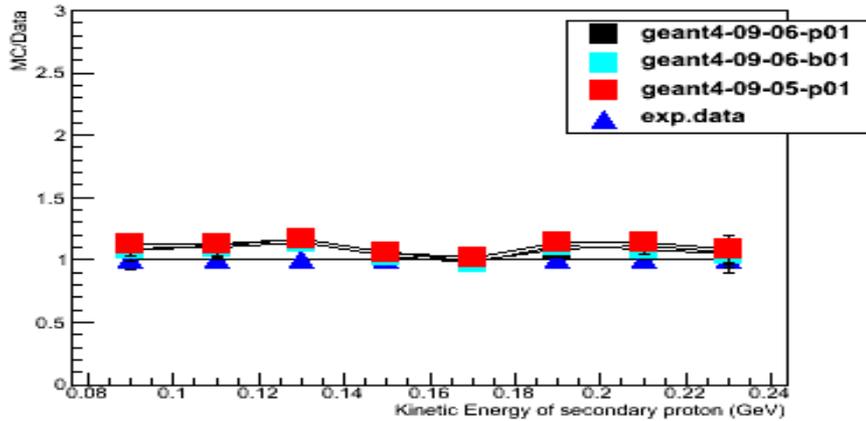


piplus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

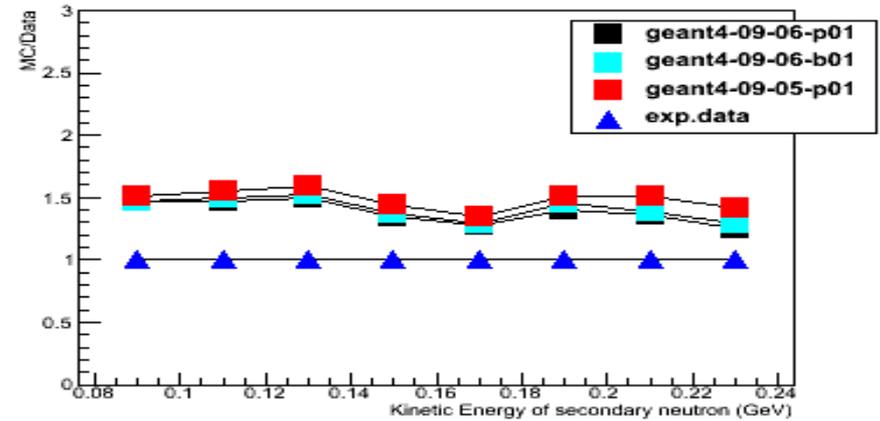


Test47: Results(III) - Bertini

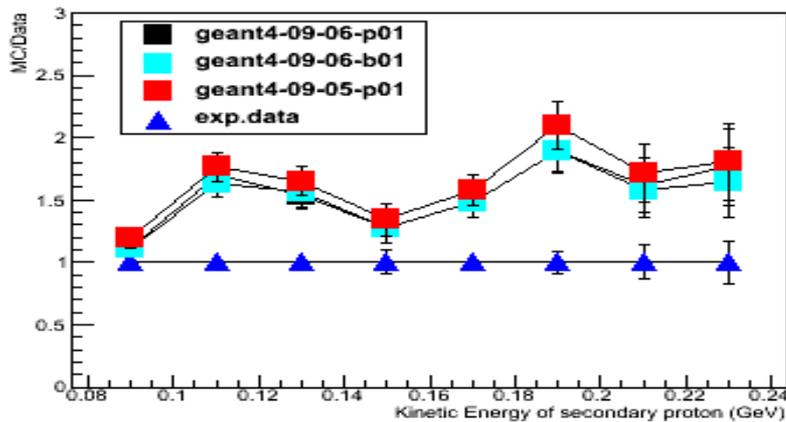
piplus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



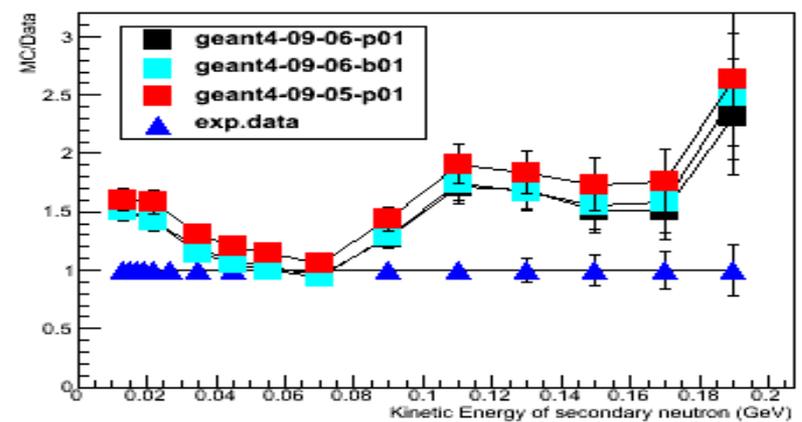
piplus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+U to p at 5.00 GeV (bertini) ($\theta = 119.00$)

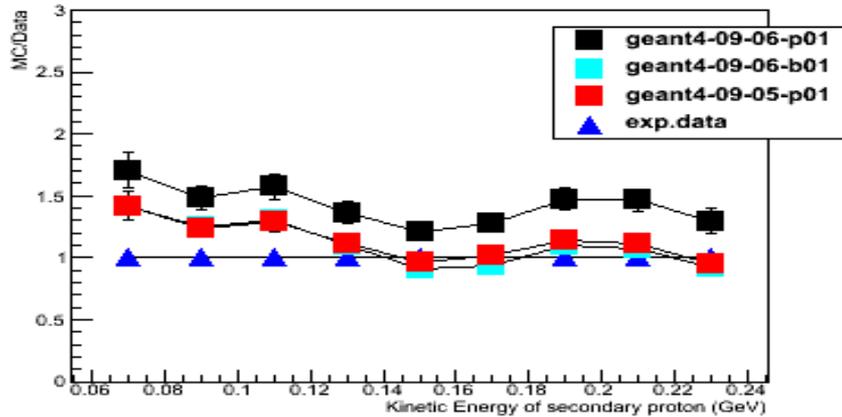


piplus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

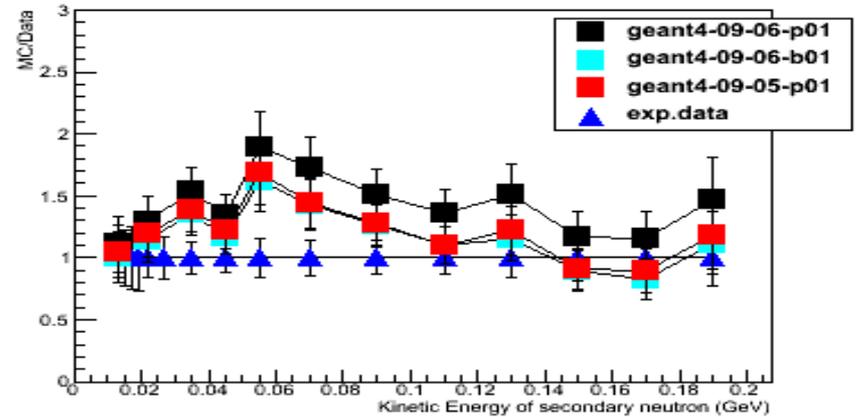


Test47: Results(IV) - FTF(P)

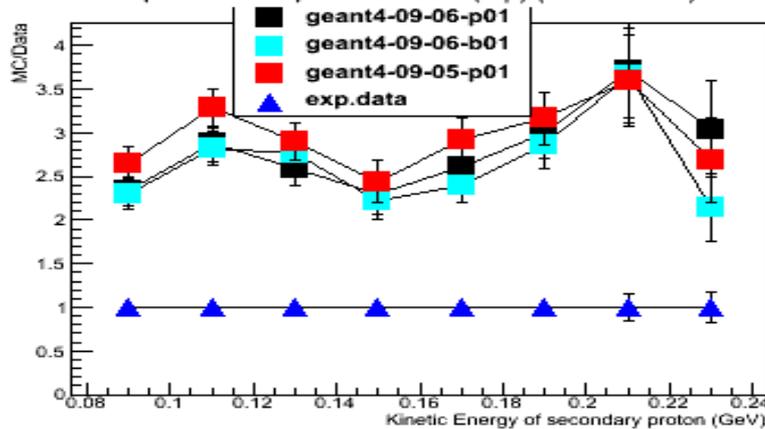
proton+C to p at 7.50 GeV (ftfp) ($\theta = 59.10$)



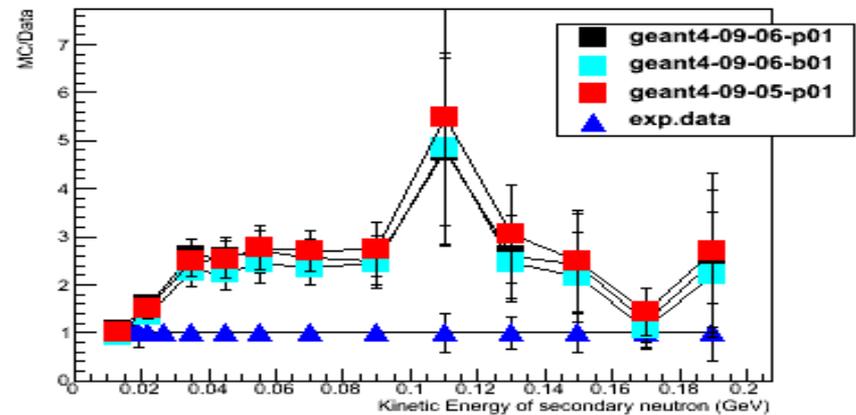
proton+C to n at 7.50 GeV (ftfp) ($\theta = 59.10$)



proton+C to p at 7.50 GeV (ftfp) ($\theta = 119.00$)

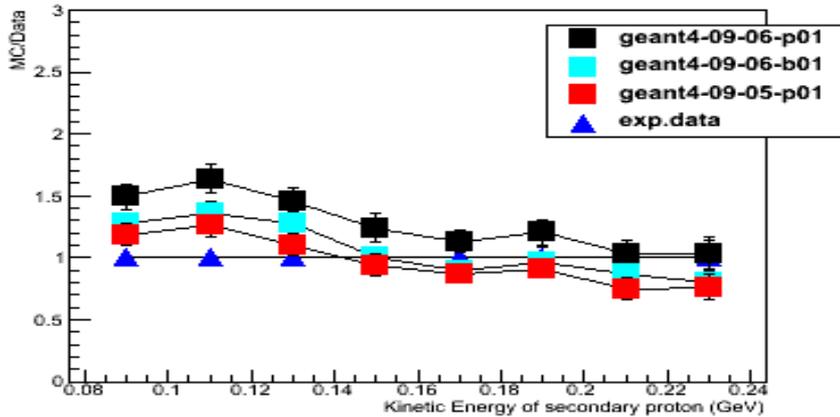


proton+C to n at 7.50 GeV (ftfp) ($\theta = 119.00$)

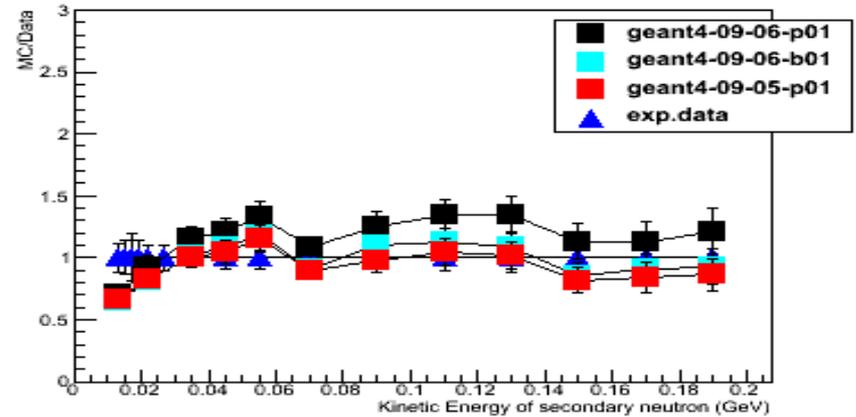


Test47: Results(V) – FTF(P)

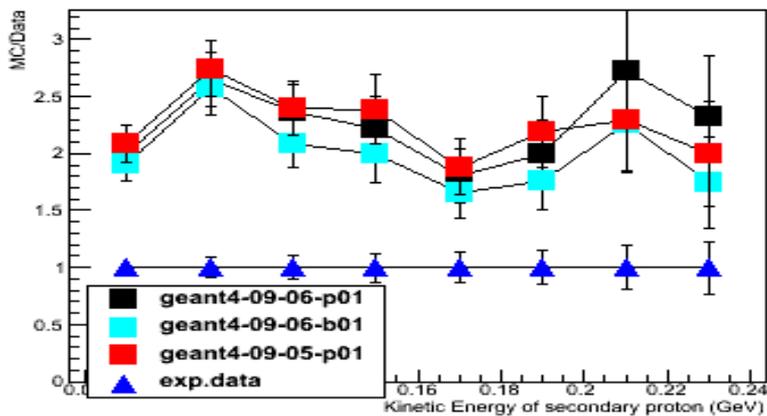
piminus+C to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



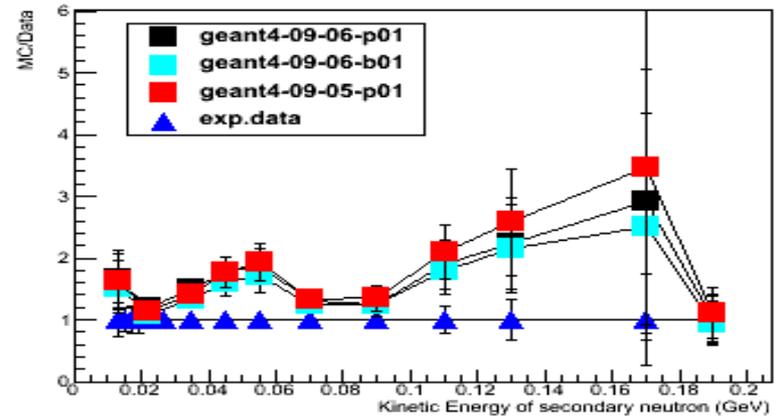
piminus+C to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



piminus+C to p at 5.00 GeV (ftfp) ($\theta = 119.00$)

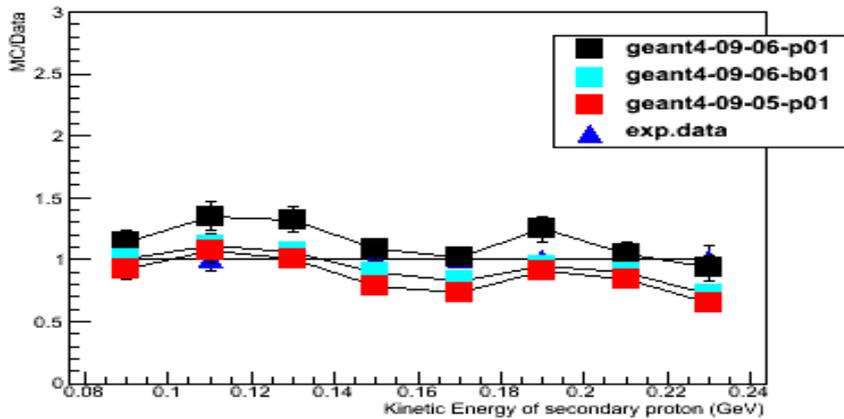


piminus+C to n at 5.00 GeV (ftfp) ($\theta = 119.00$)

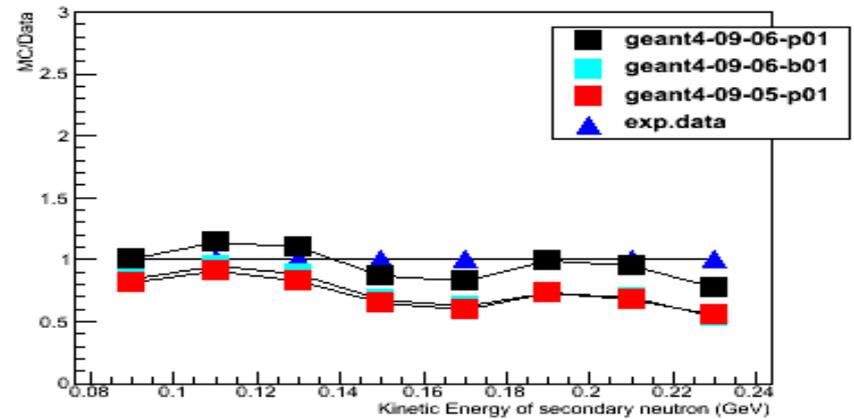


Test47: Results(VI) – FTF(P)

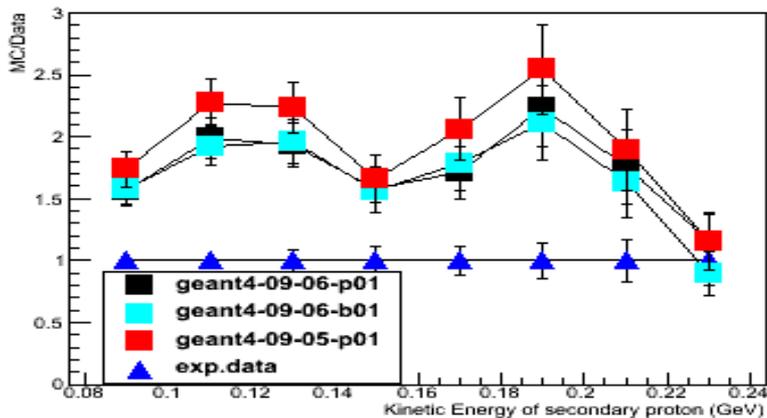
piplus+C to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



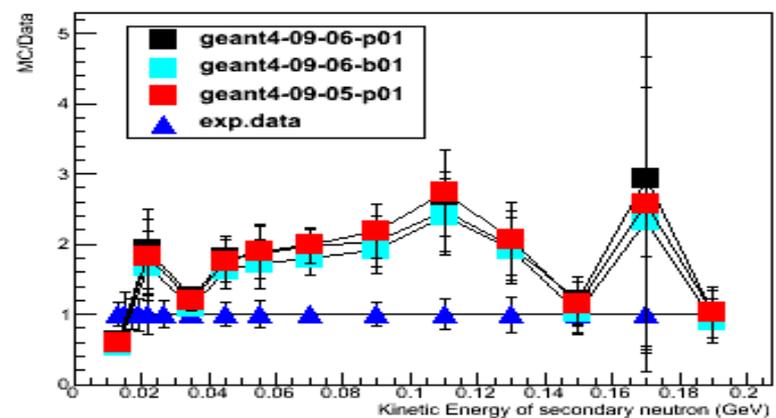
piplus+C to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



piplus+C to p at 5.00 GeV (ftfp) ($\theta = 119.00$)

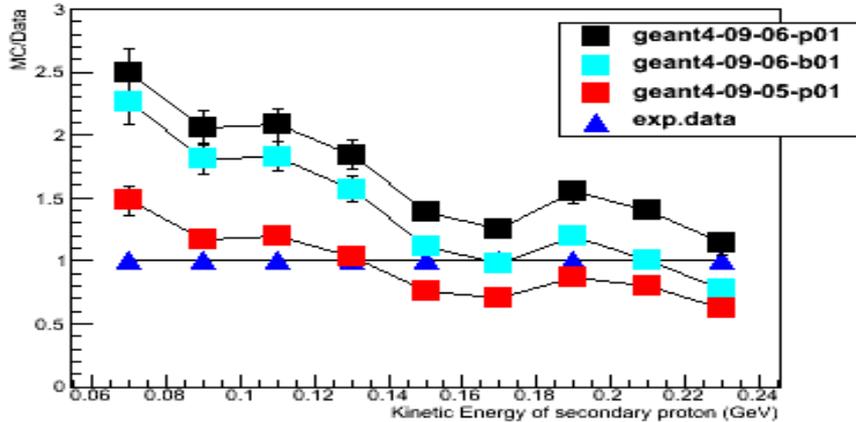


piplus+C to n at 5.00 GeV (ftfp) ($\theta = 119.00$)

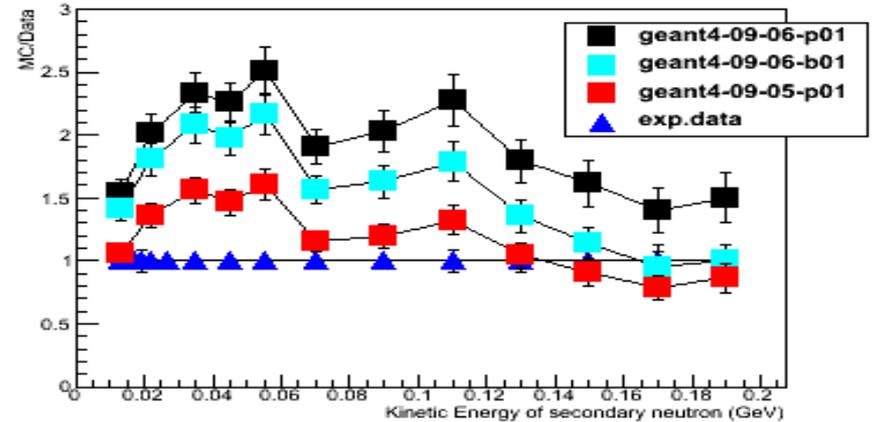


Test47: Results(VII) – FTF(P)

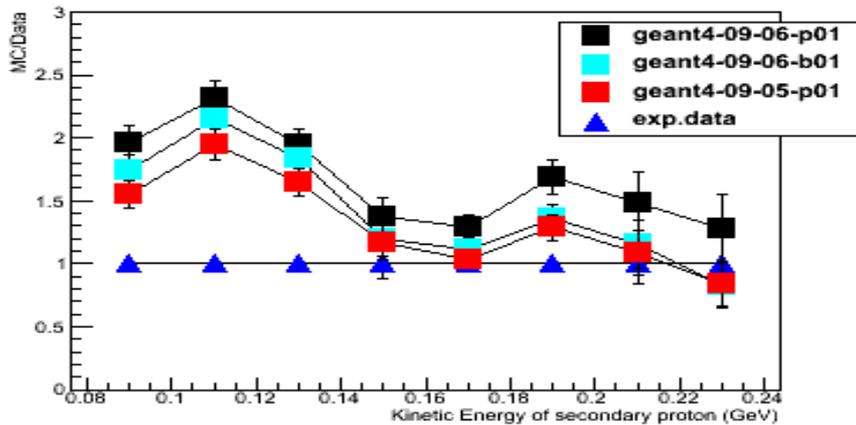
proton+U to p at 7.50 GeV (ftfp) ($\theta = 59.10$)



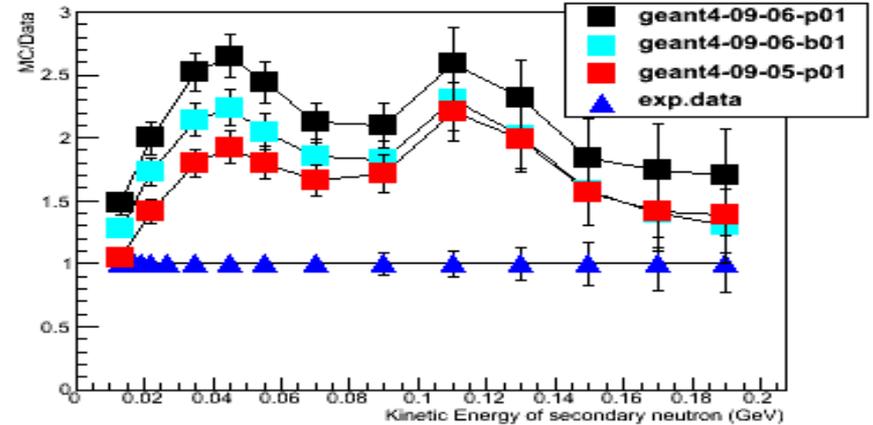
proton+U to n at 7.50 GeV (ftfp) ($\theta = 59.10$)



proton+U to p at 7.50 GeV (ftfp) ($\theta = 119.00$)

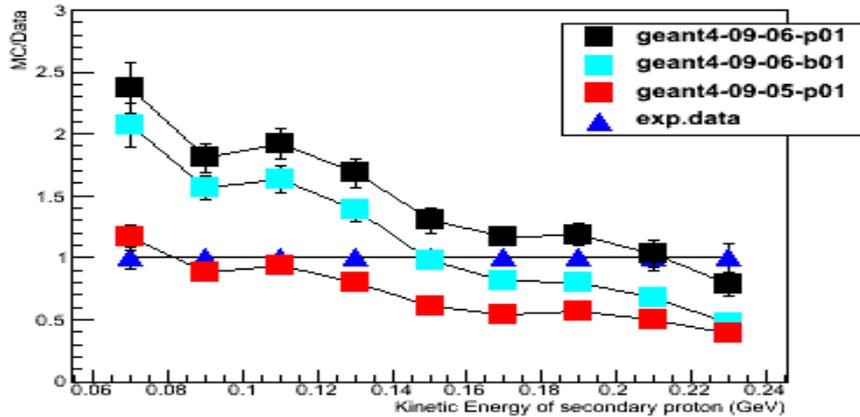


proton+U to n at 7.50 GeV (ftfp) ($\theta = 119.00$)

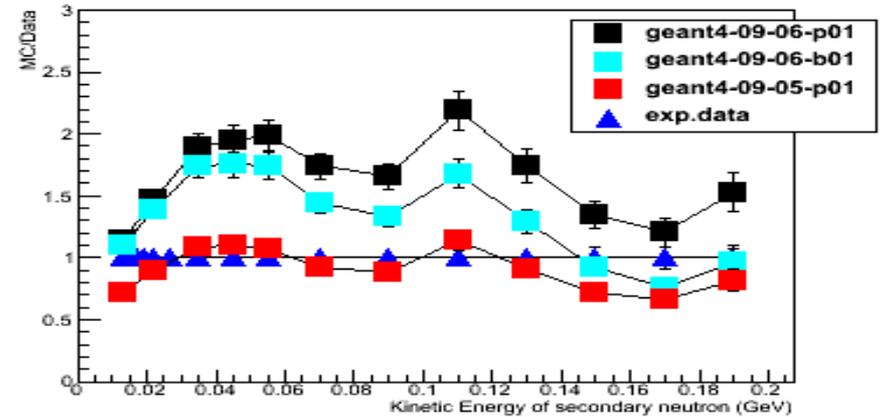


Test47: Results(VIII) – FTF(P)

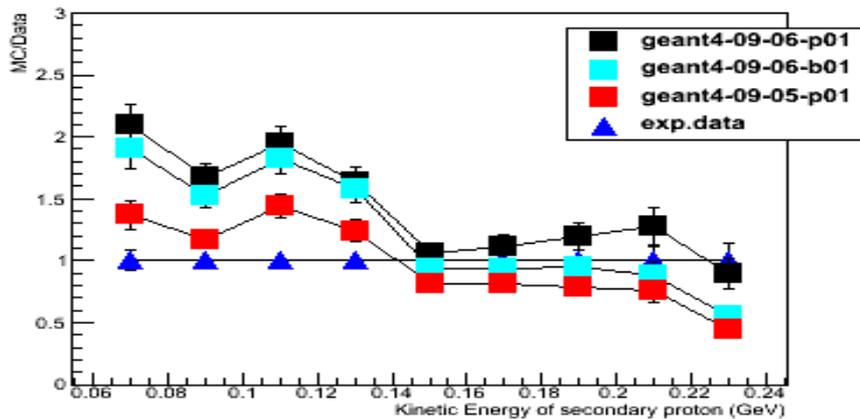
piminus+U to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



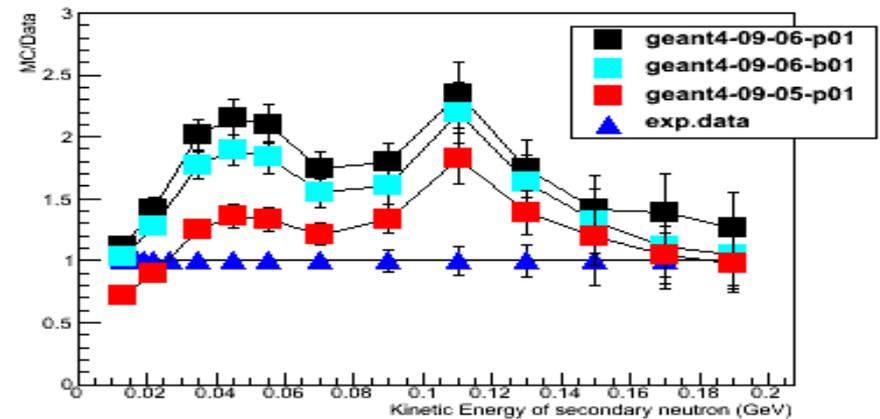
piminus+U to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



piminus+U to p at 5.00 GeV (ftfp) ($\theta = 119.00$)

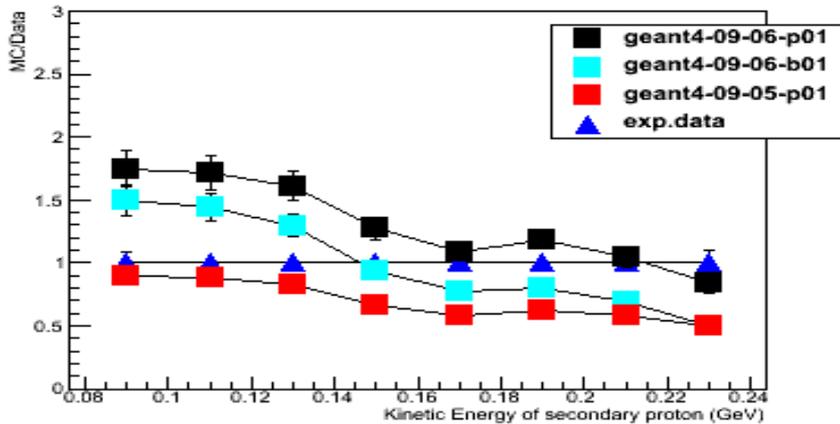


piminus+U to n at 5.00 GeV (ftfp) ($\theta = 119.00$)

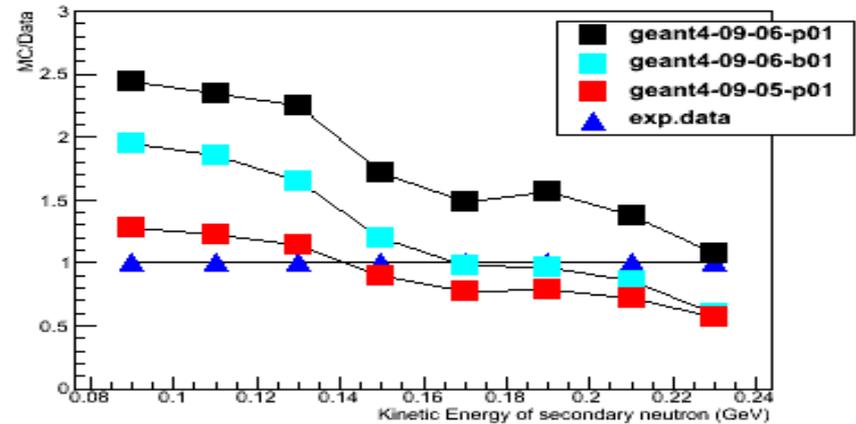


Test47: Results(IX) – FTF(P)

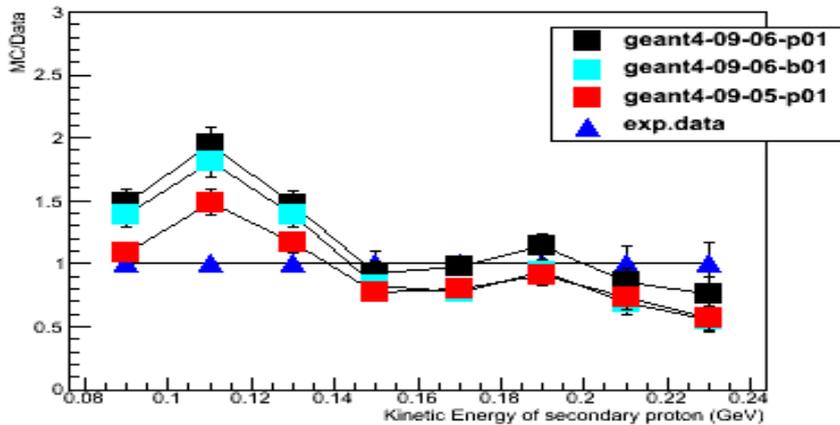
piplus+U to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



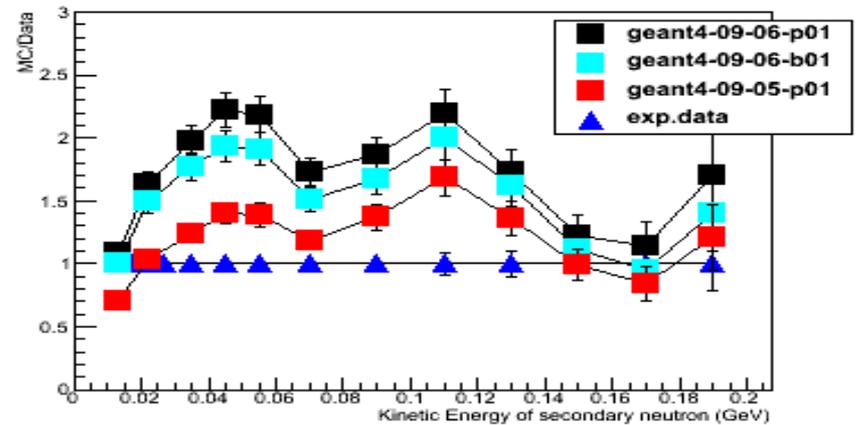
piplus+U to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



piplus+U to p at 5.00 GeV (ftfp) ($\theta = 119.00$)



piplus+U to n at 5.00 GeV (ftfp) ($\theta = 119.00$)





Test47: Summary

- None of the models is perfect at intermediate energy
- Bertini appears as most reliable across the range
- Bertini is relatively stable between 9.6.b01 and 9.6.p01, mostly improved over 9.5.p01
- FTF appears to be drifting away from the data between 9.6.b01 and 9.6.p01
- Plans to give more attention to INCL++ (and Binary)

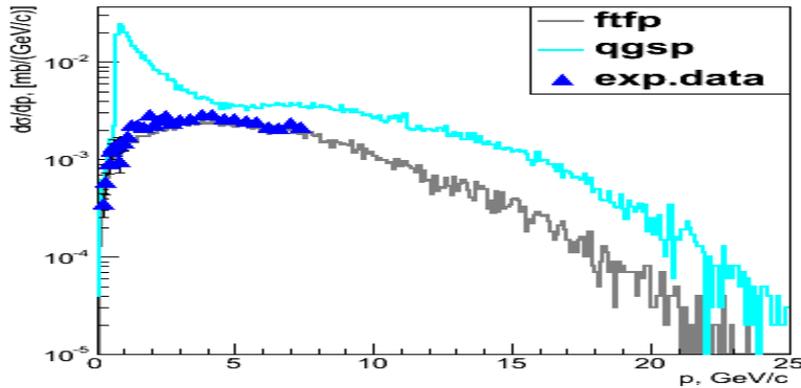


Test19: High(er) Energy Range 31 GeV/c (NA61) and 158 GeV/c (NA49)

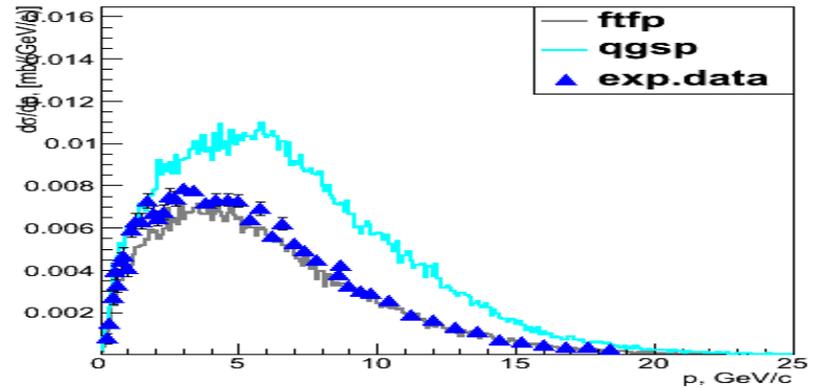
- **NEW TEST - WORK IN PROGRESS !!!**
- 31 GeV p on C, 158 GeV/c p on C
- Data sets:
 - N.Abgrall et al., Phys.Rev. C84, 034604 (2011) (NA61)
 - Communications with NA61 (proton data)
 - <http://spshadrons.web.cern.ch/spshadrons/> (NA49)
- NOTE-1: Only a portion of datasets incorporated so far; more will be added shortly
- NOTE-2: move MIPP data from test47 and into test19 ???
- Models: FTF(P) and QGS(P)
- Suggestions welcome - future improvements

Test19: Results(I) 31GeV p+C secondary pi- momenta in theta bins

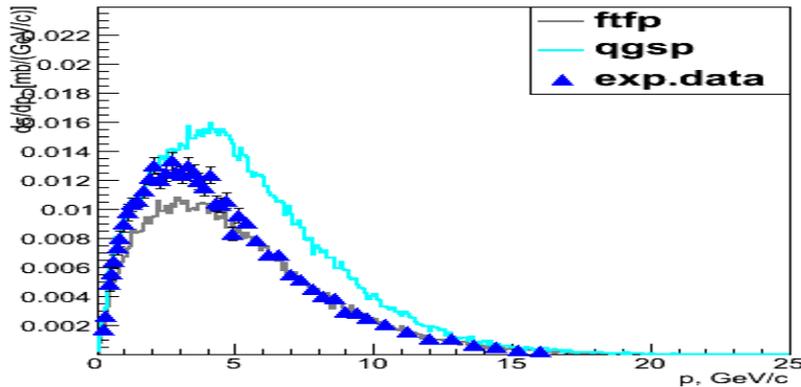
proton + C -> X + pi- (0<theta<20 (mrad))



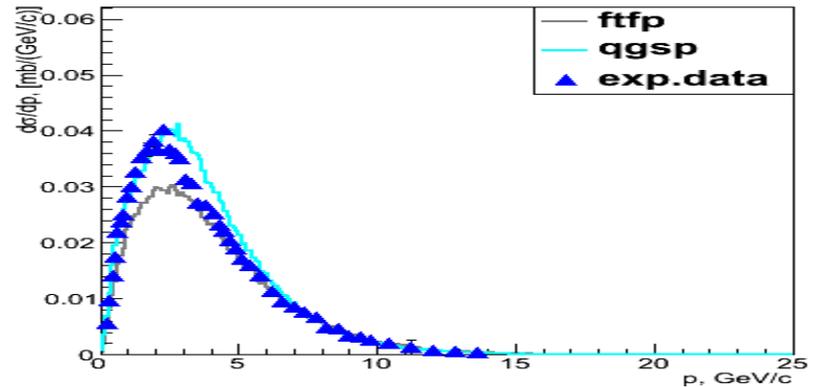
proton + C -> X + pi- (20<theta<40 (mrad))



proton + C -> X + pi- (40<theta<60 (mrad))

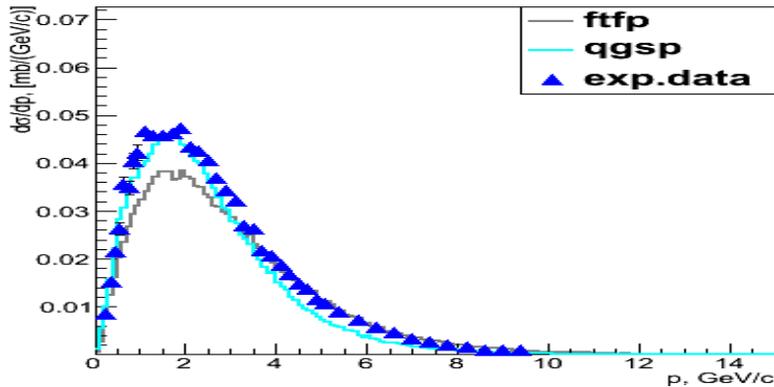


proton + C -> X + pi- (60<theta<100 (mrad))

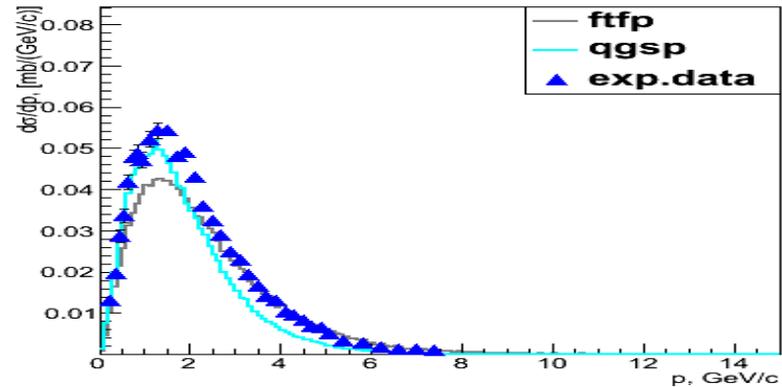


Test19: Results(II) 31GeV p+C secondary pi- momenta in theta bins (cont.)

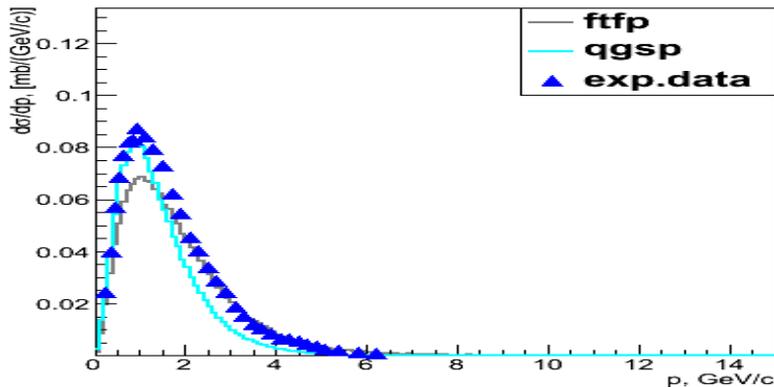
proton + C -> X + pi- (100<theta<140 (mrad))



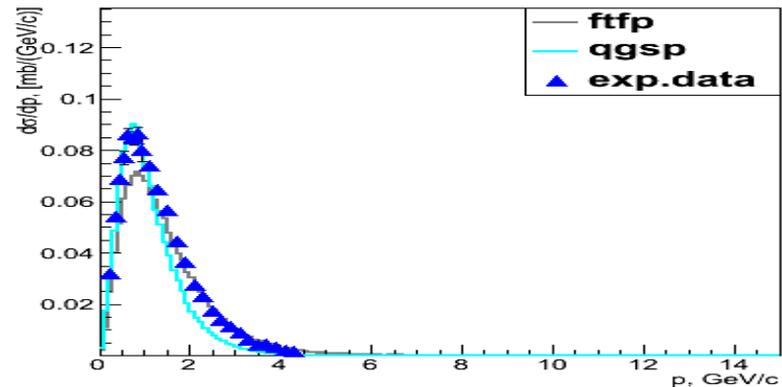
proton + C -> X + pi- (140<theta<180 (mrad))



proton + C -> X + pi- (180<theta<240 (mrad))

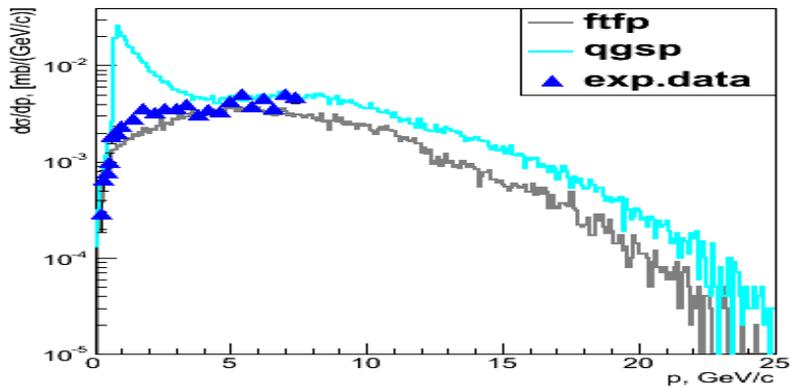


proton + C -> X + pi- (240<theta<300 (mrad))

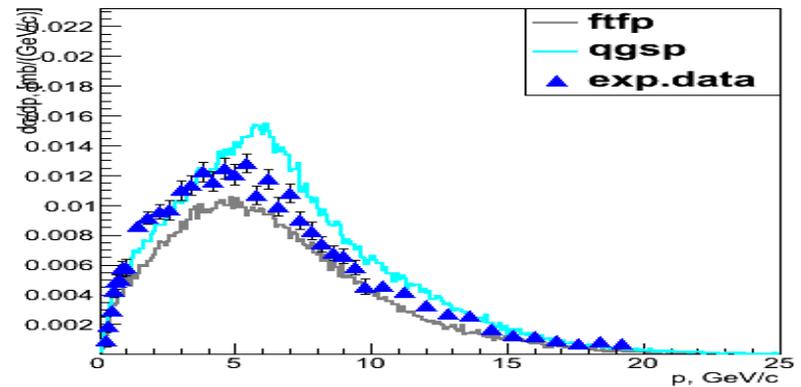


Test19: Results(III) 31GeV p+C secondary pi+ momenta in theta bins

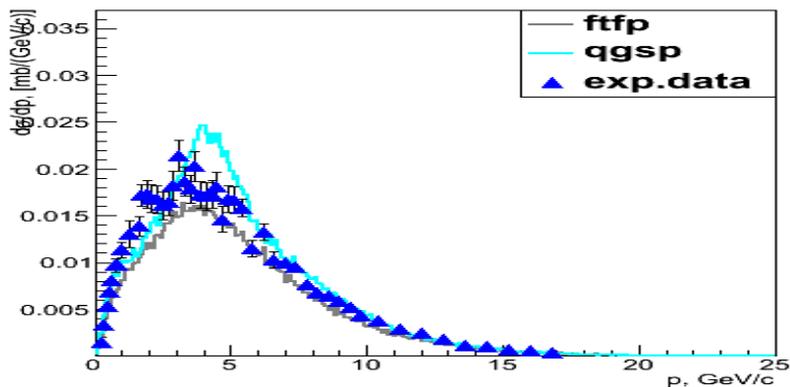
proton + C -> X + pi+ (0<theta<20 (mrad))



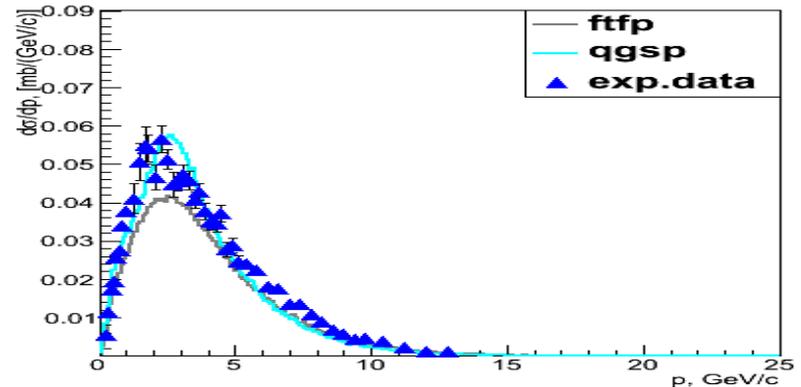
proton + C -> X + pi+ (20<theta<40 (mrad))



proton + C -> X + pi+ (40<theta<60 (mrad))

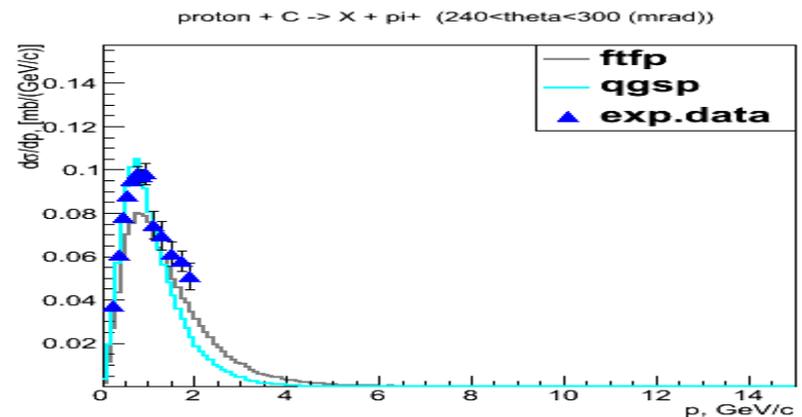
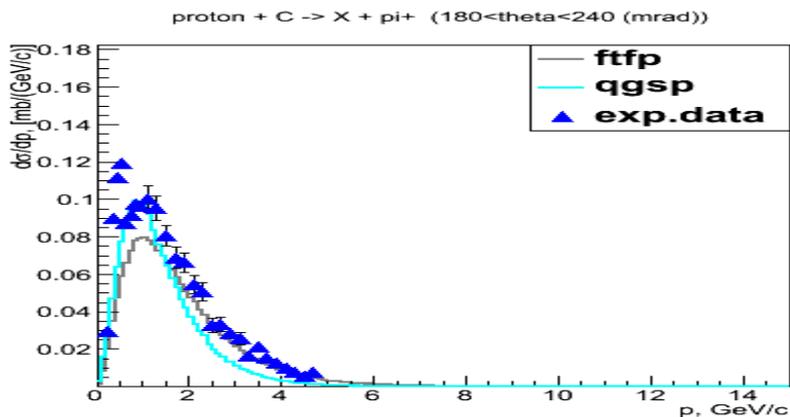
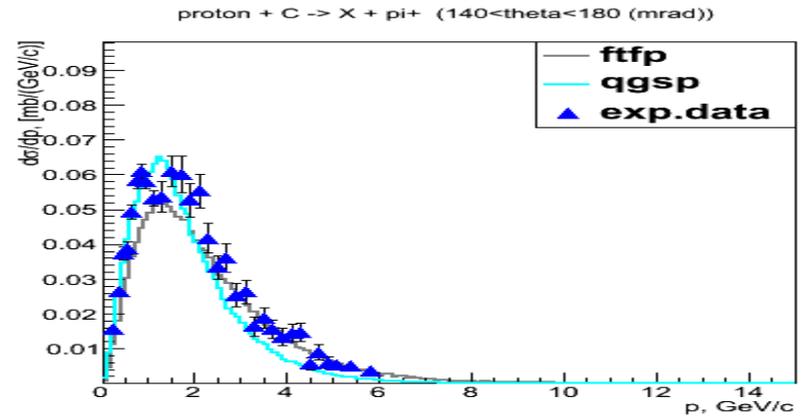
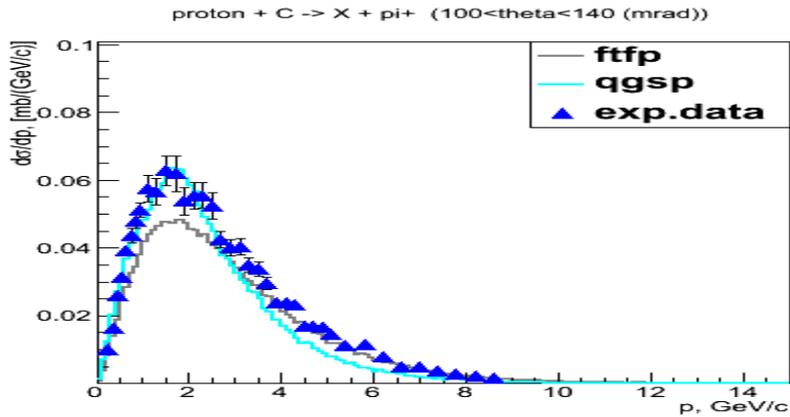


proton + C -> X + pi+ (60<theta<100 (mrad))

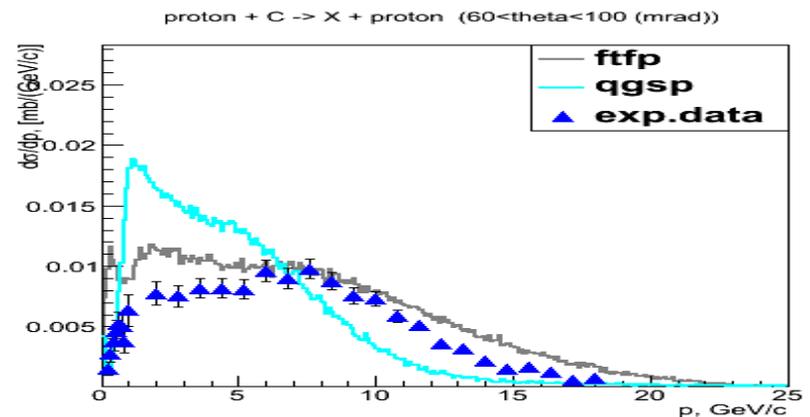
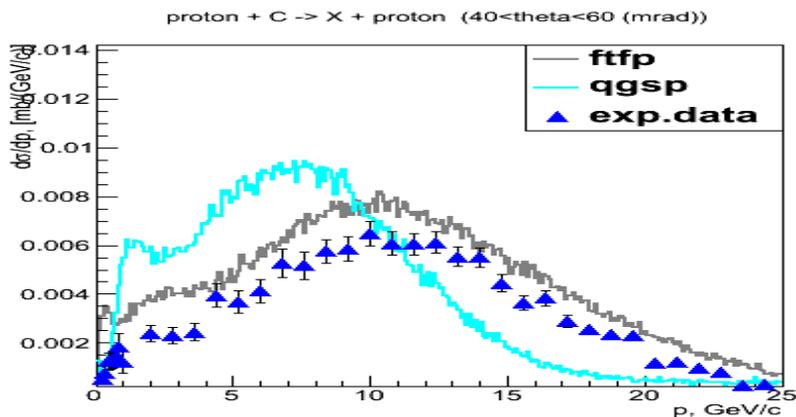
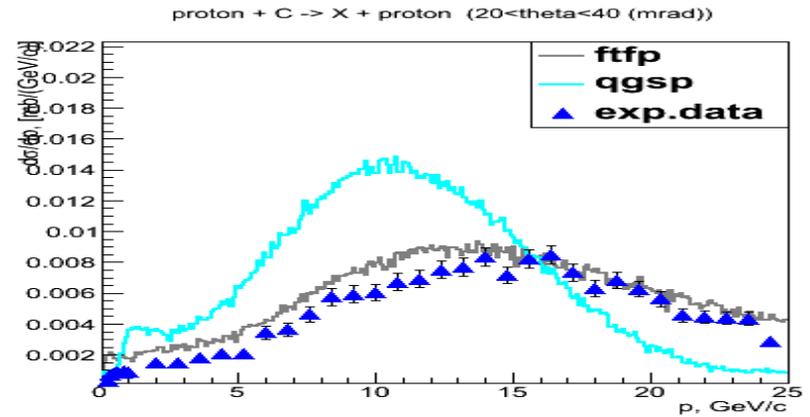
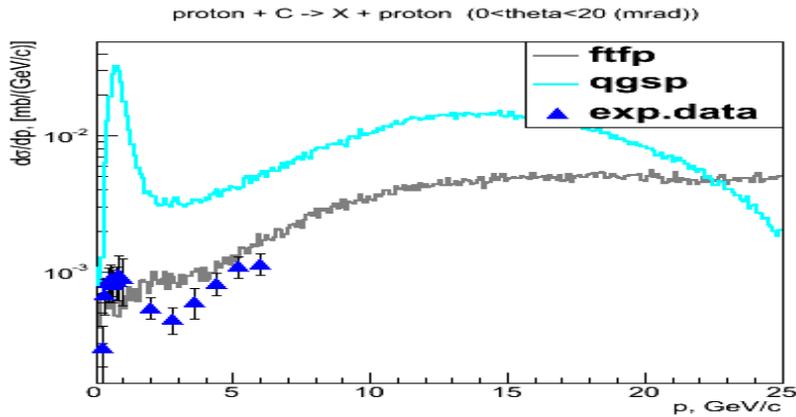




Test19: Results(IV) 31GeV p+C secondary pi+ momenta in theta bins (cont.)



Test19: Results(V) 31GeV p+C secondary proton momenta in theta bins

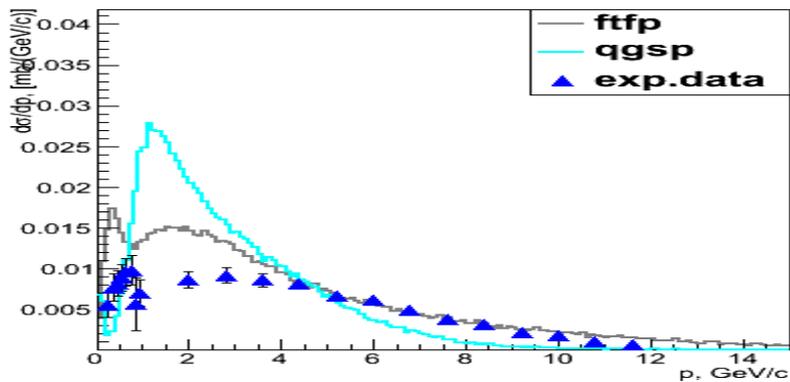


Test19: Results(VI)

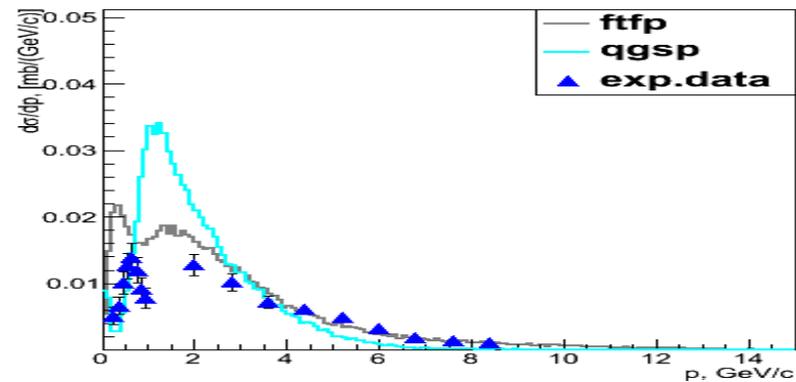
31GeV p+C

secondary proton momenta in theta bins (cont.)

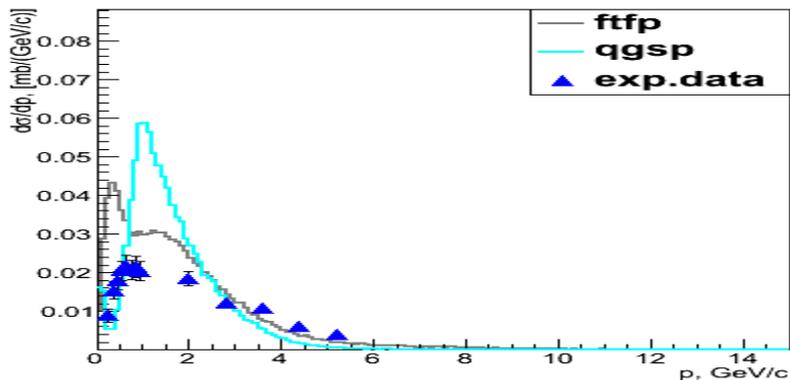
proton + C -> X + proton (100<theta<140 (mrad))



proton + C -> X + proton (140<theta<180 (mrad))

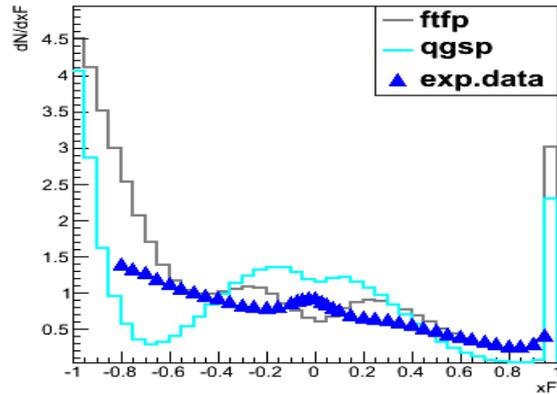


proton + C -> X + proton (180<theta<240 (mrad))

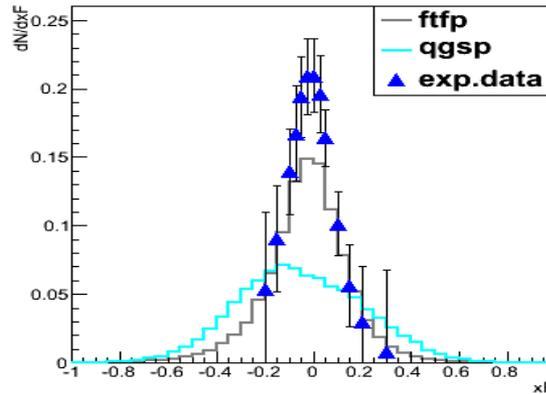


Test19: Results(VII) 158 GeV p+C dN/dxF for secondary p, pbar, n, pi+, pi-

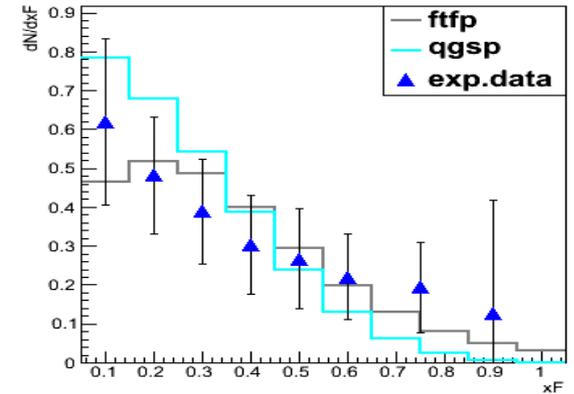
proton + C -> X + proton



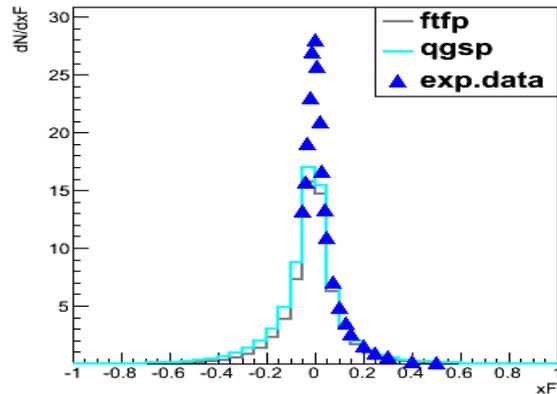
proton + C -> X + antiproton



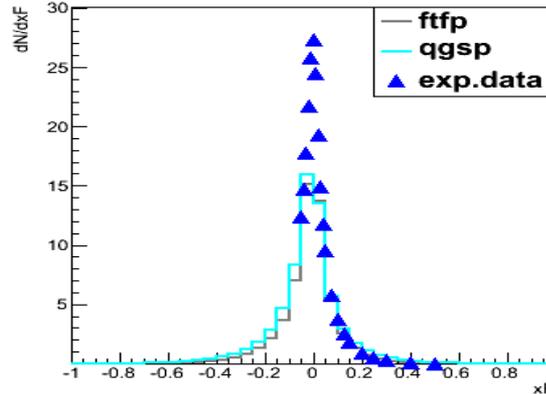
proton + C -> X + neutron



proton + C -> X + pi+



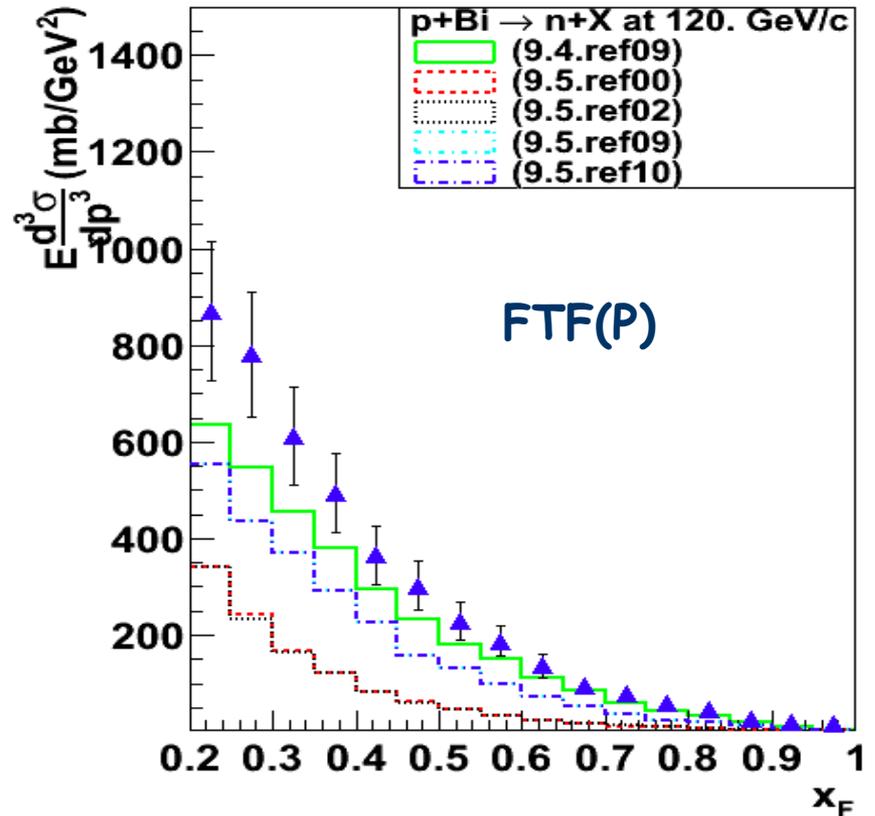
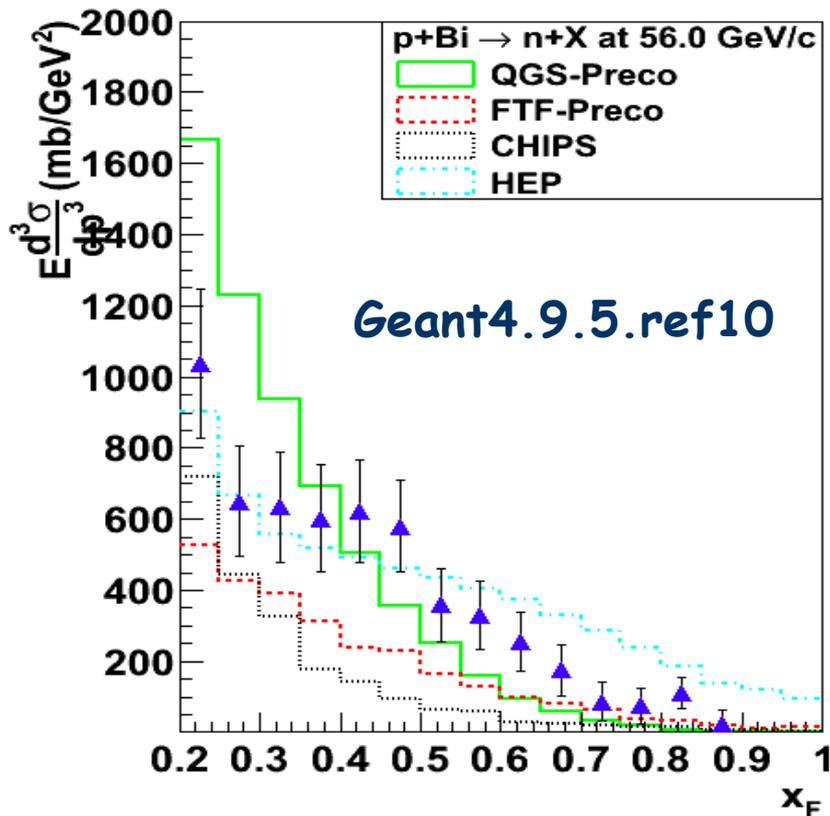
proton + C -> X + pi-





For reference:

from Sunanda's talk on Nov.28, 2013
(comparison vs MIPP data on secondary neutrons)

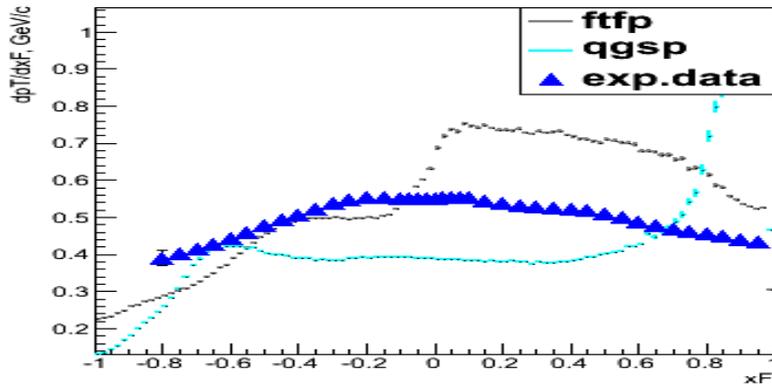


Test19: Results(VIII)

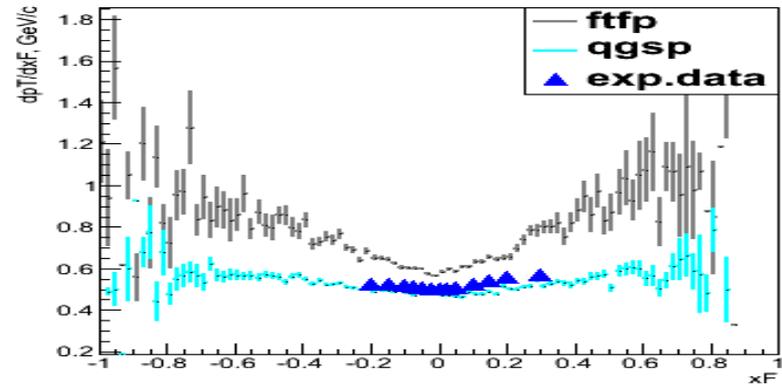
158 GeV p+C

$d\langle p_T \rangle / dx_F$ for secondary p, pbar, pi+, pi-

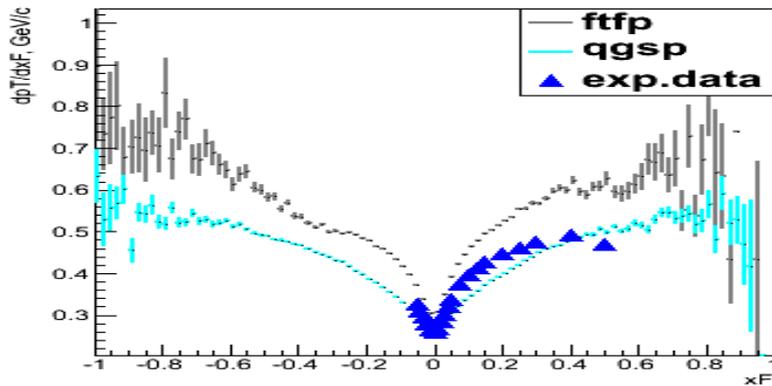
proton + C -> X + proton



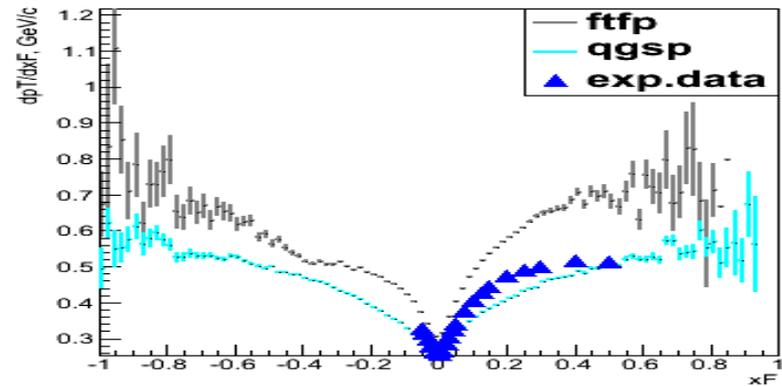
proton + C -> X + antiproton



proton + C -> X + pi+



proton + C -> X + pi-





Test19: Summary

- New test for High Energy (improvements to come)
- Comparison vs NA61, NA49 data; move MIPP data in ?
- Includes FTF(P) and QGS(P)
- Geant4.9.6.p01 is a “starting” point and will be a reference in upcoming validation rounds
- Neither model does a perfect job in this energy range; to an extent this confirms (conceptually) earlier observations from test47/MIPP



Test75: Gamma-Nuclear Interactions

- **New test** added for Gamma-Nuclear interactions
- Beam: 300 or 668MeV gamma
- Targets: Cu, Pb
- Data sets:
 - R.Schumacher et al., Phys.Rev. C25, 2269 (1982)
 - K.Baba et al., Nucl.Phys. A306, 292 (1978)
 - **NOTE: more datasets to be added**
- Models: Bertini (new), CHIPS (last release)

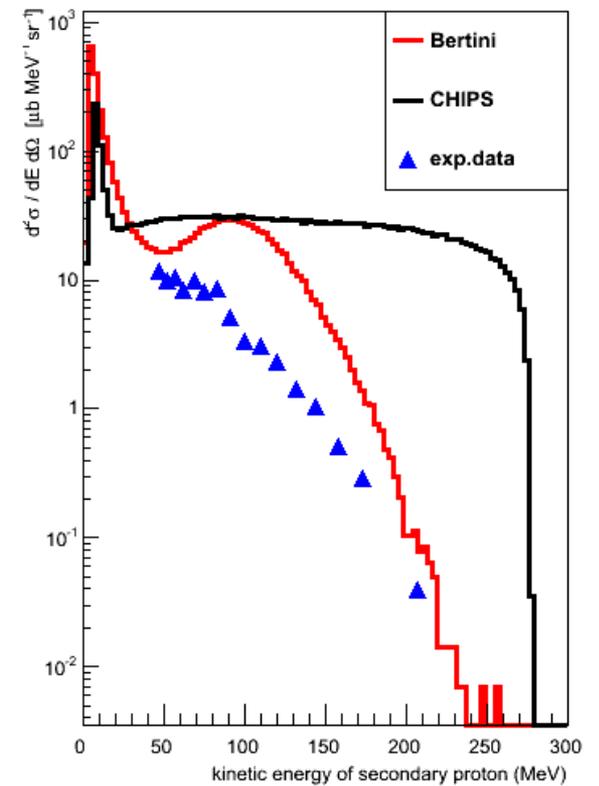
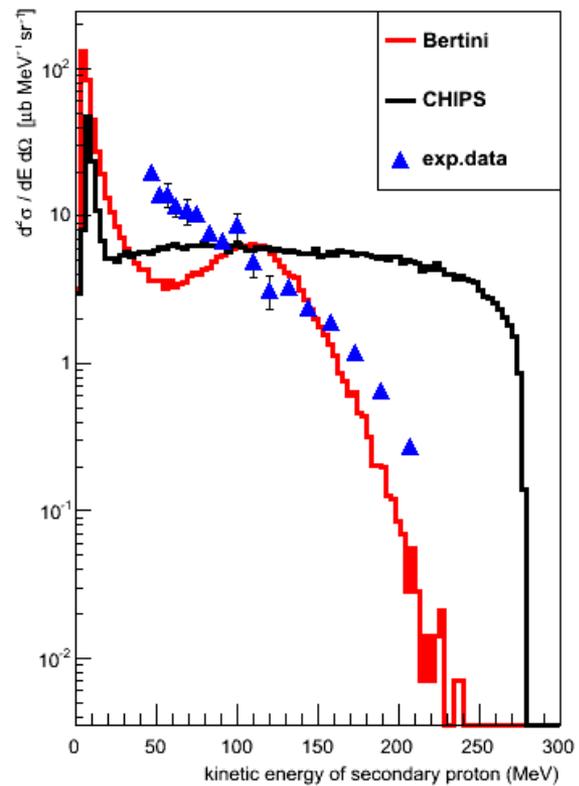
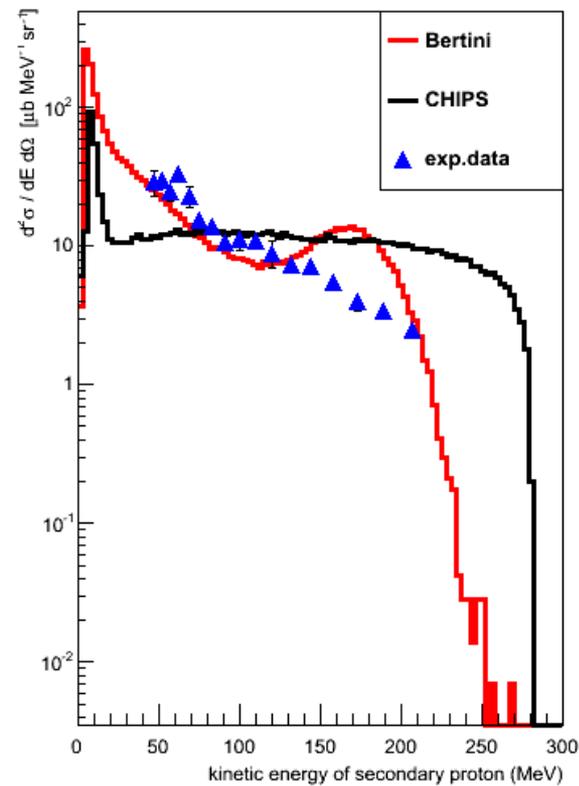


Test75: Results(I) 300MeV gamma + C kinetic E of sec. proton (at different angles)

gamma + Cu → X + proton (45deg)

gamma + Cu → X + proton (90deg)

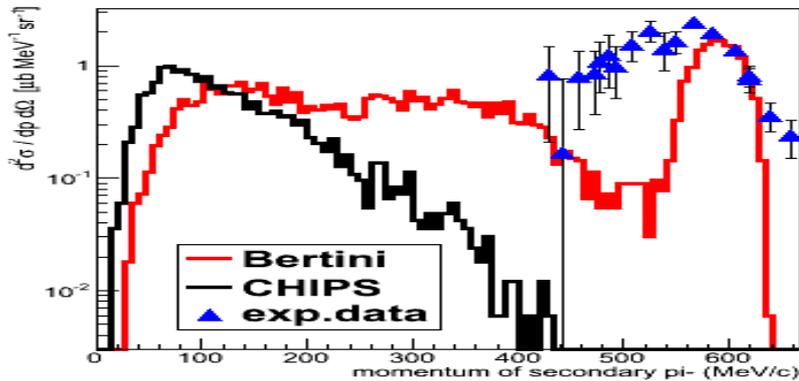
gamma + Cu → X + proton (135deg)



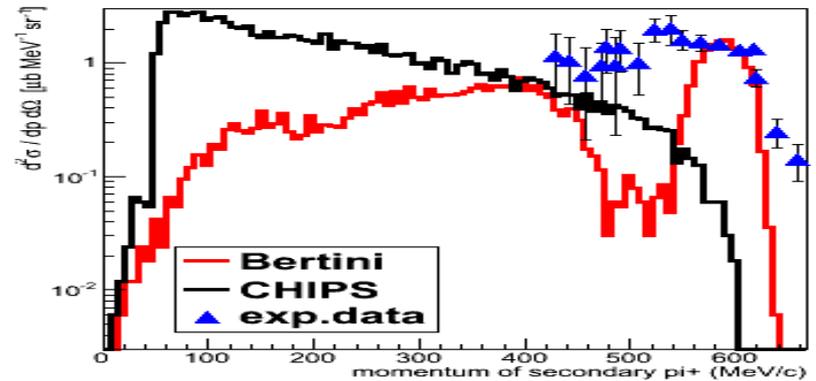
Test75: Results(II)

668MeV gamma + Cu
momentum of sec. pi- or pi+ (at different angles)

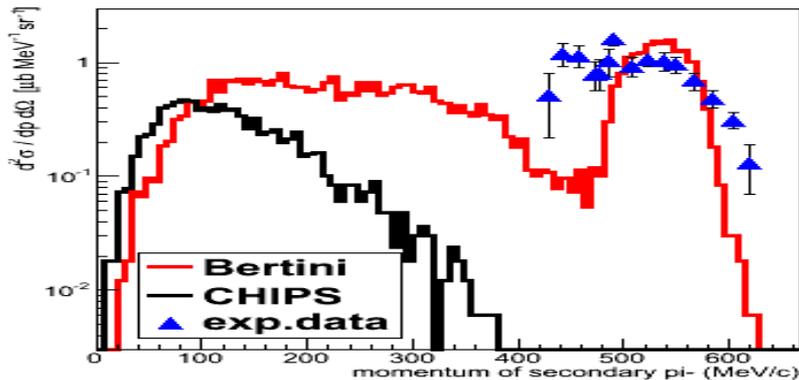
gamma + Cu → X + pi- (28deg)



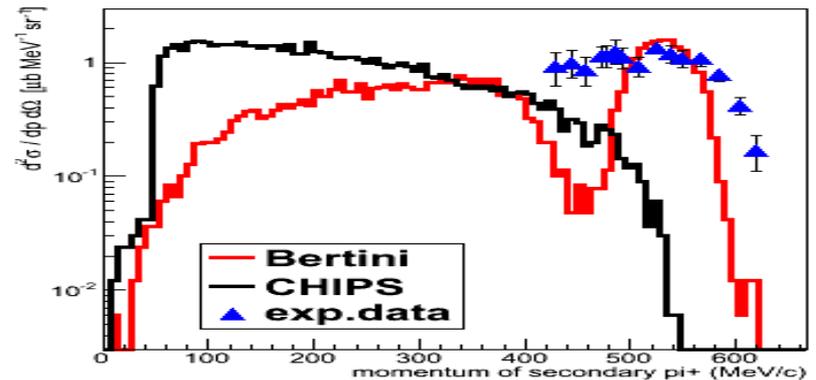
gamma + Cu → X + pi+ (28deg)



gamma + Cu → X + pi- (44deg)



gamma + Cu → X + pi+ (44deg)

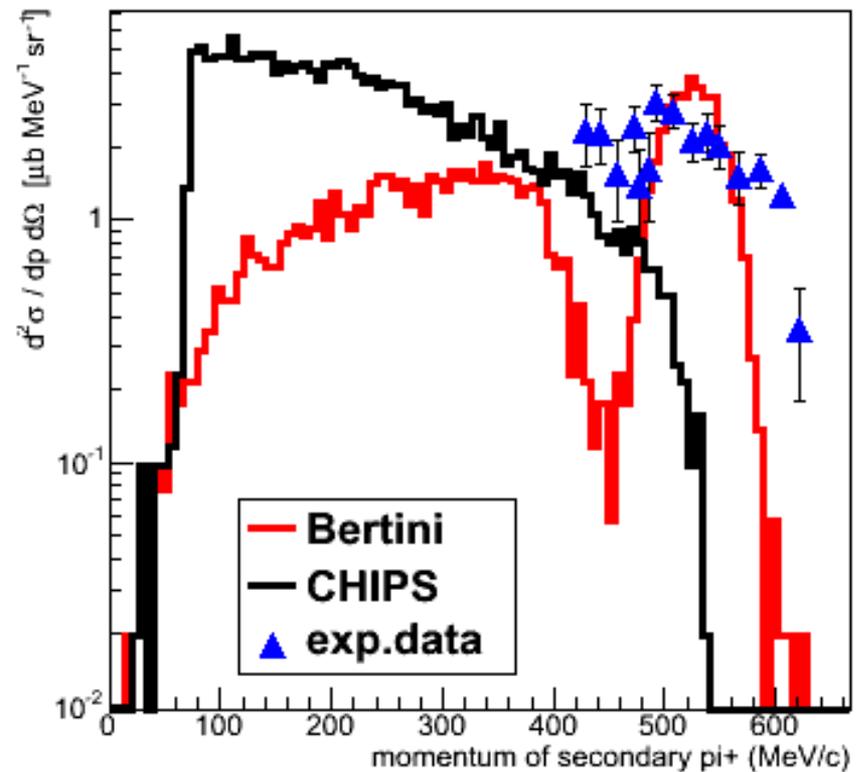
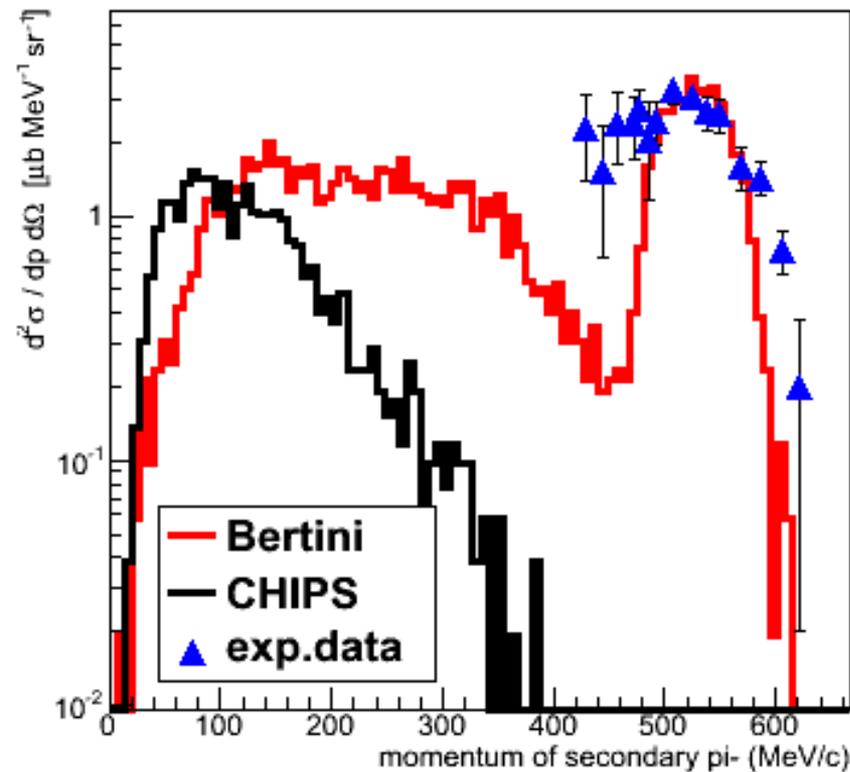


Test75: Results(III)

668MeV gamma + Pb
momentum of sec. pi- or pi+ (at 44.2 deg)

gamma + Pb → X + pi- (44deg)

gamma + Pb → X + pi+ (44deg)





Test75: Summary

- Addressed long-pending request for a test of gamma-nuclear interactions (improvements to come)
- Principal model Bertini; “1st and last” comparison vs CHIPS
- Geant4.9.6.p01 is a “starting point” and will be a reference for further developments/validation
- Results are sensible but fit with data isn't perfect - consider it as input for improvements



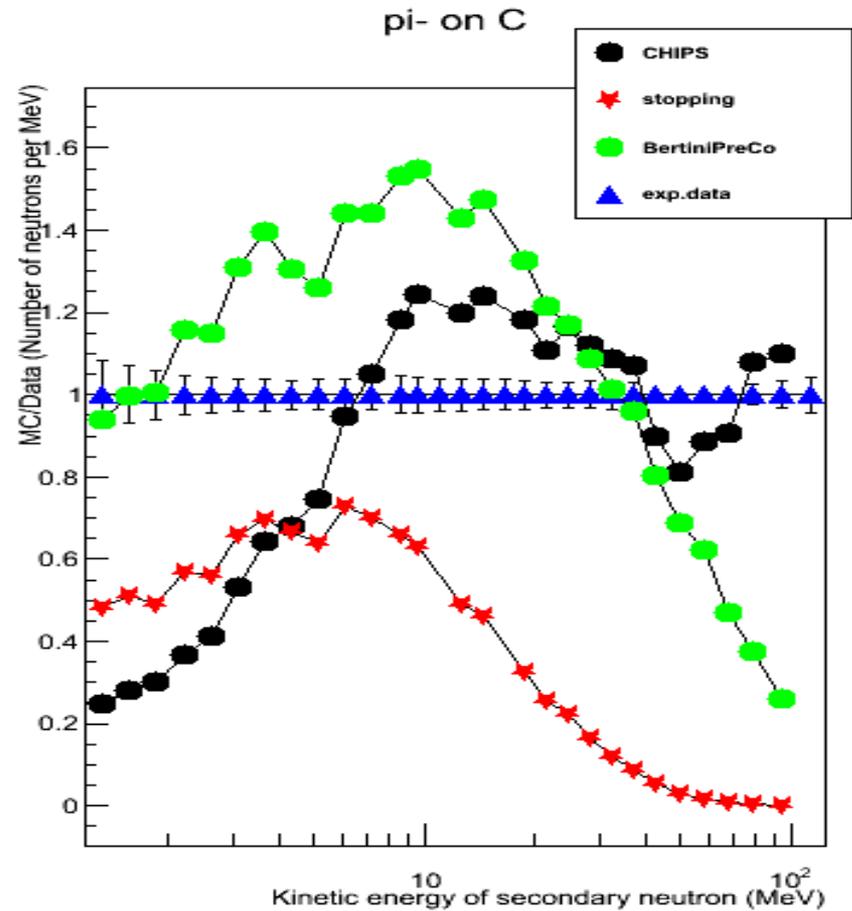
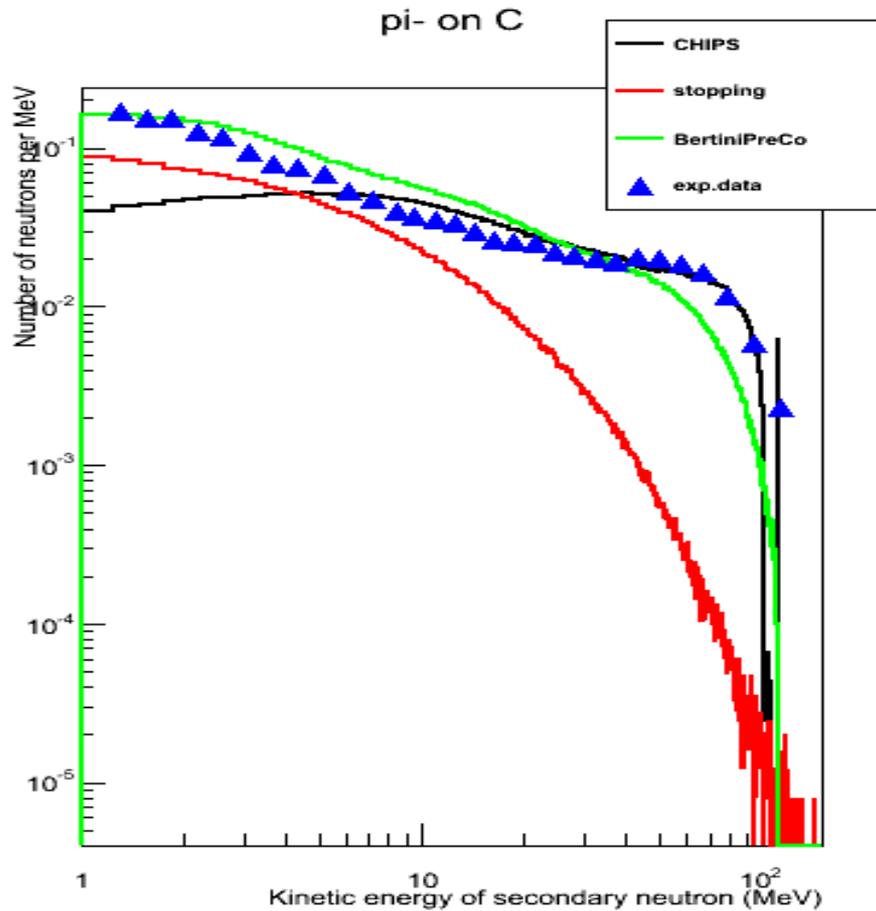
Summary

- Validation tests have been done on *Geant4.9.6.p01*, to evaluate performance of capture/annihilation models, cascade models at intermediate energies, high energy models, and gamma-nuclear interaction model
- Regression tests include public releases 9.5.p01 and 9.6.b01
- Results show Bertini stable, FTF drifting away from data
- Gamma-N, mu- capture, high energy tests are NEW - results will be used for benchmarking future developments.
- Room for improvements in all models (obviously)
- All results will be available via *G4 Validation Repository*

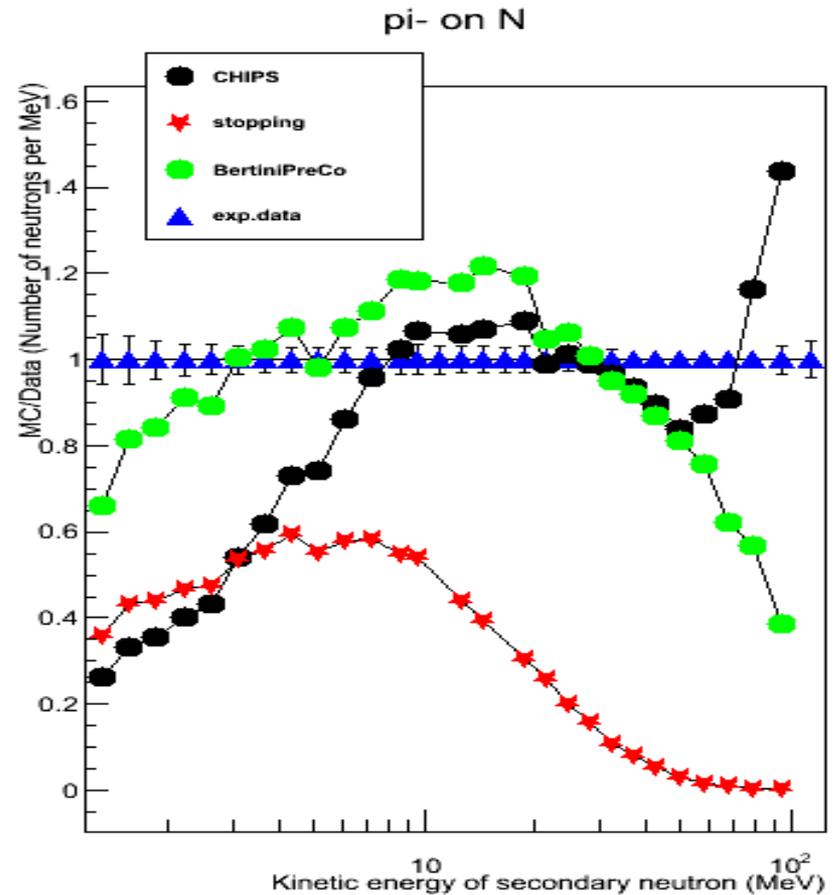
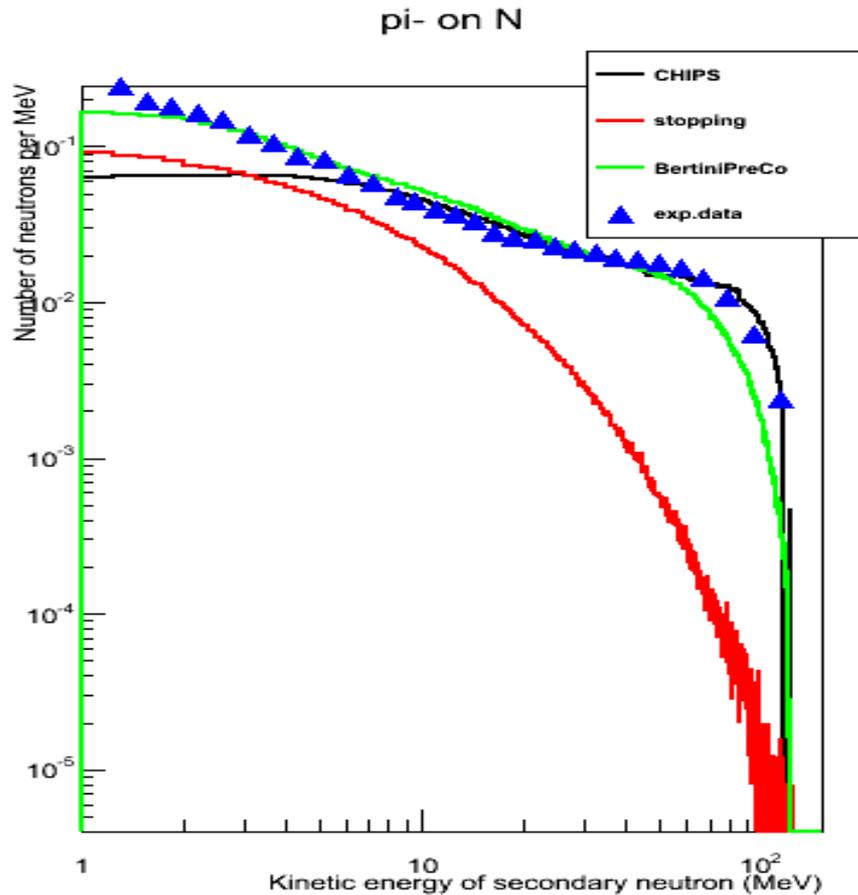


BACKUP SLIDES

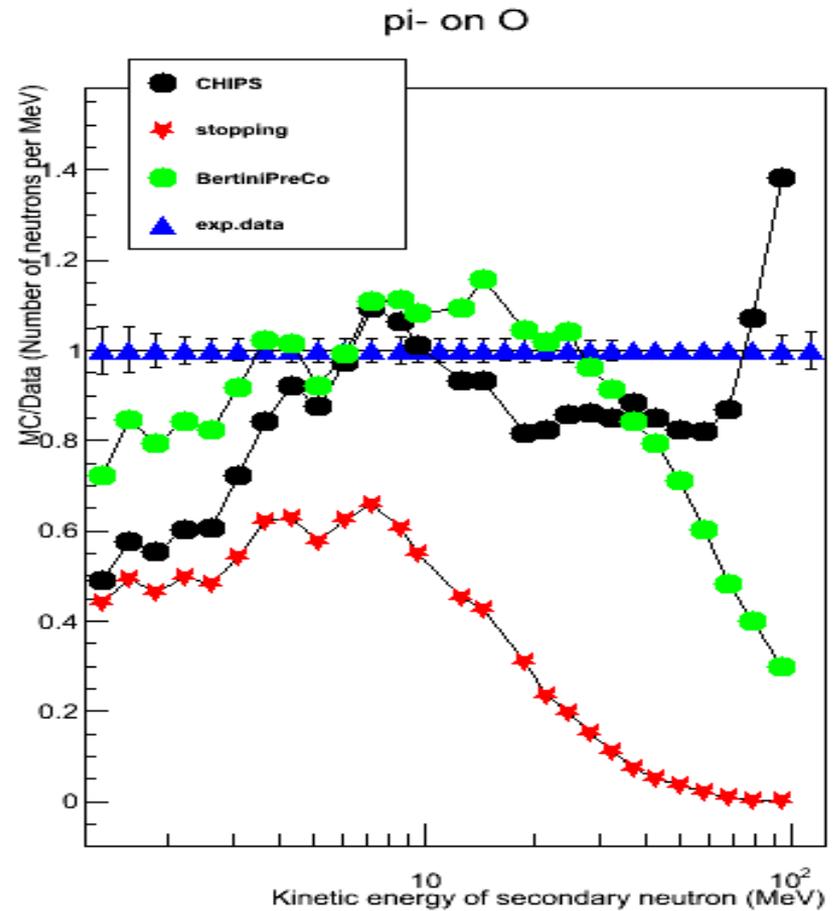
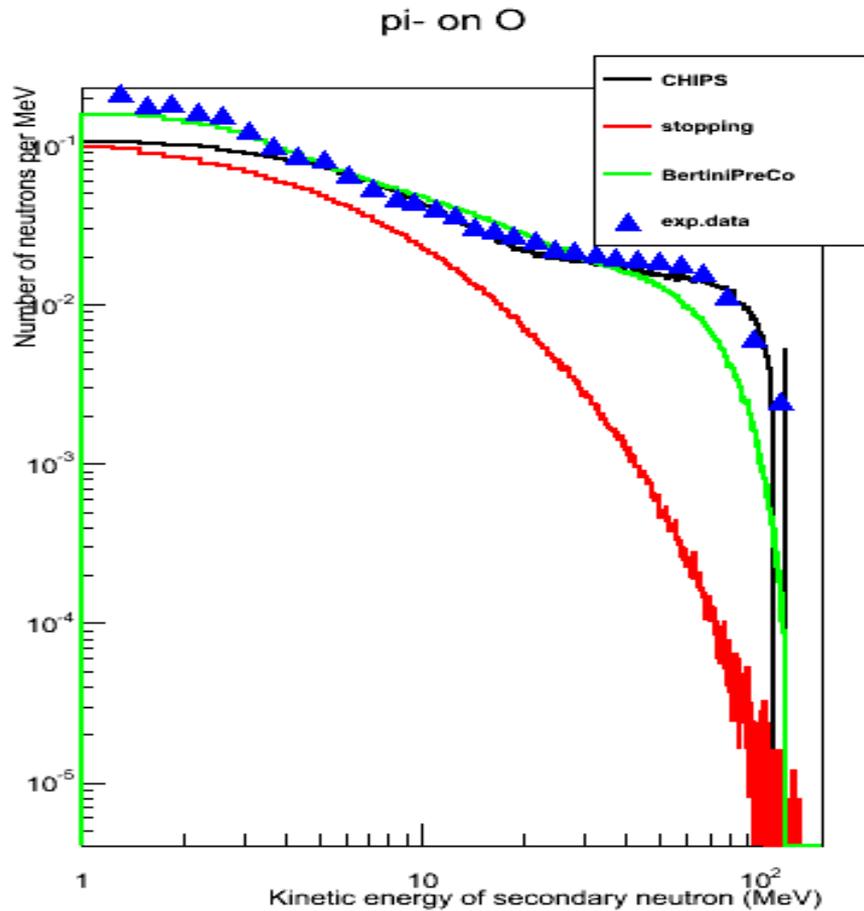
Test48: Models (I)



Test48: Models (II)

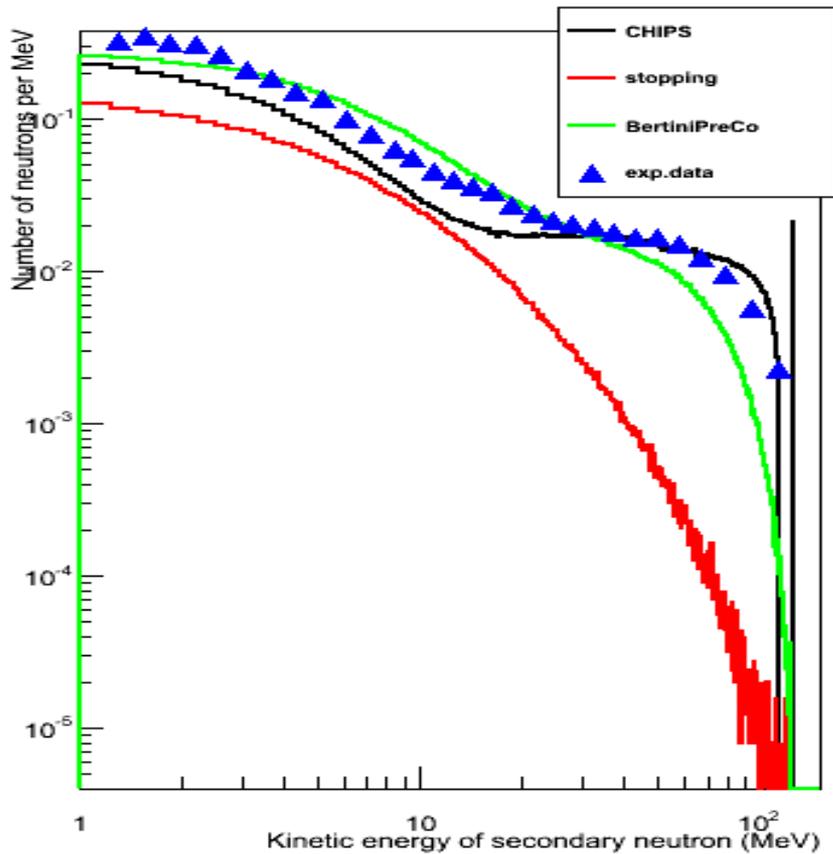


Test48: Models (III)

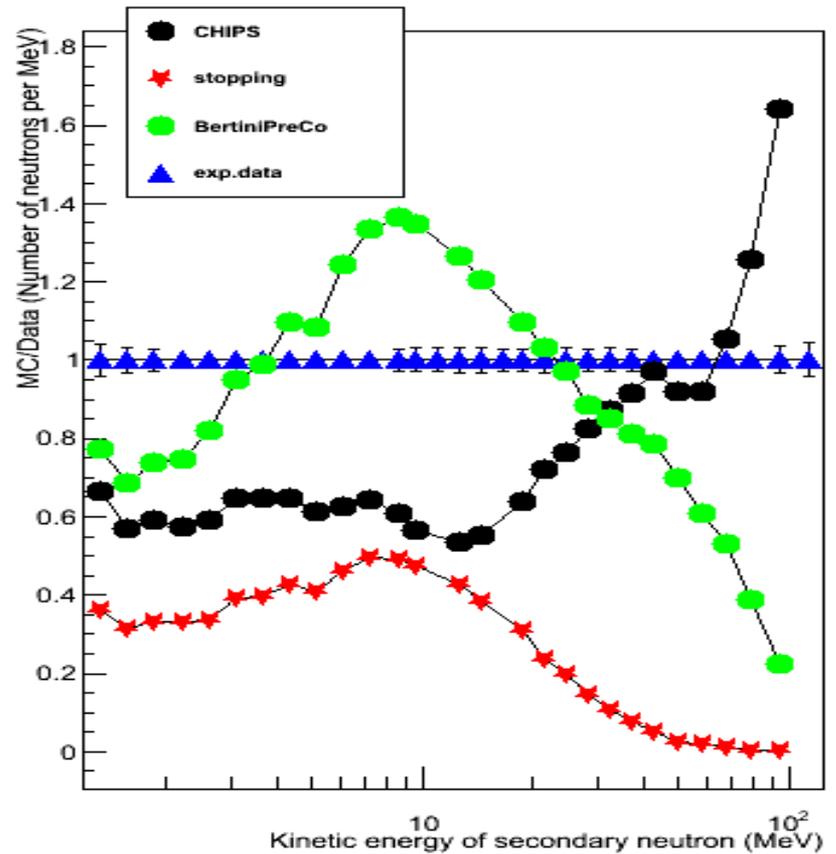


Test48: Models (IV)

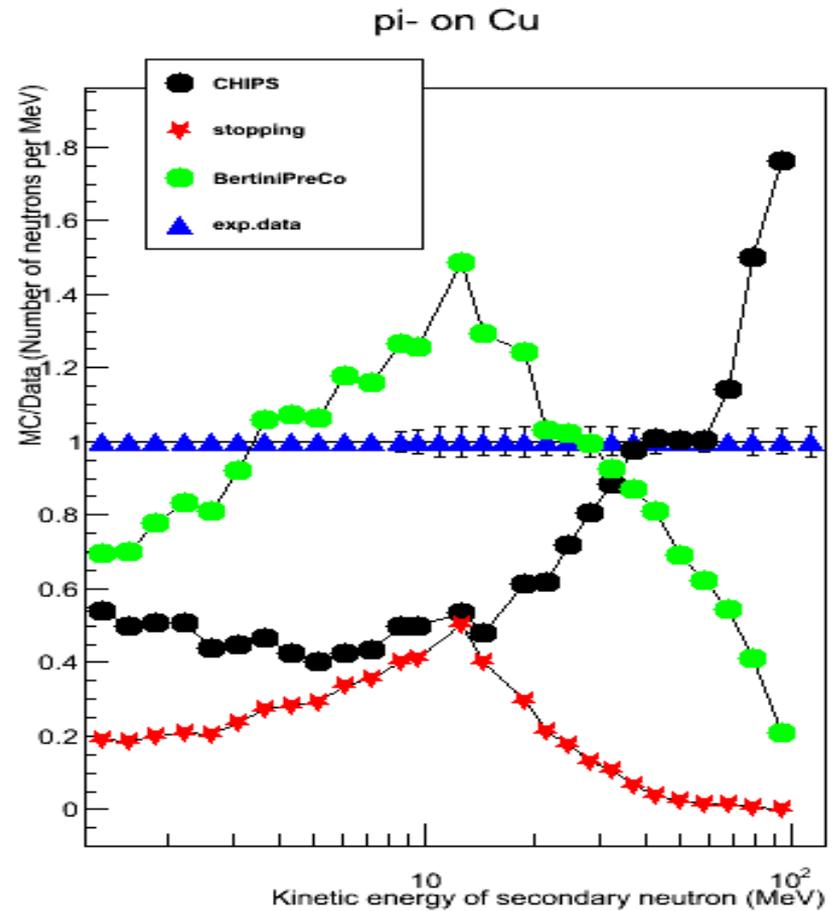
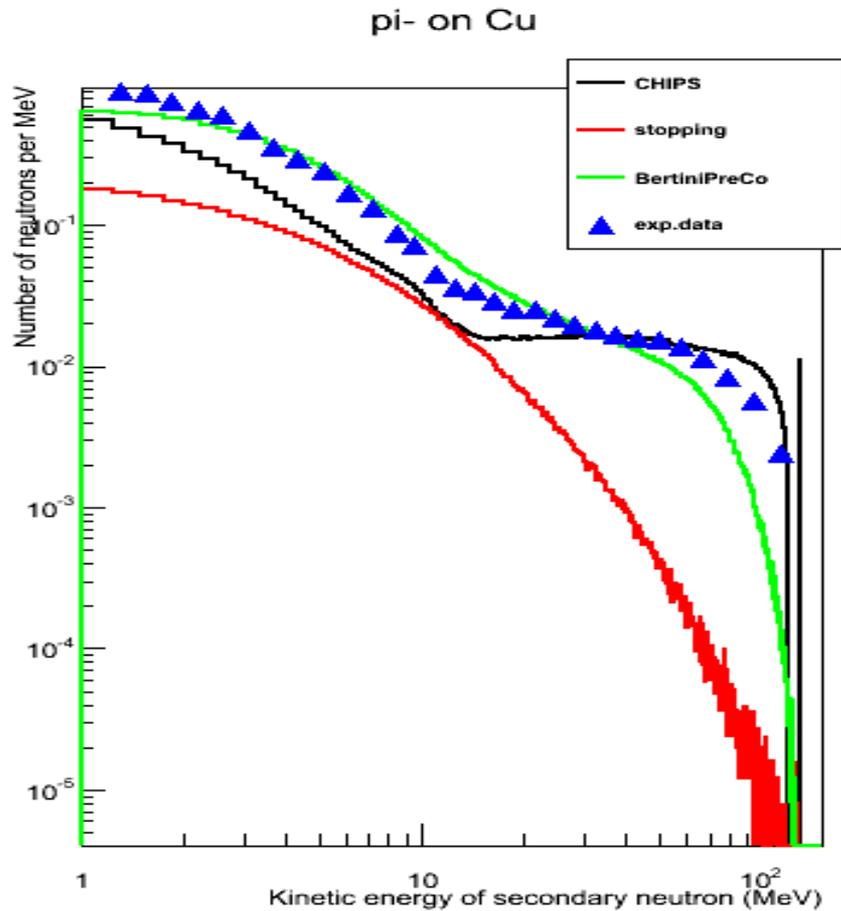
pi- on Al



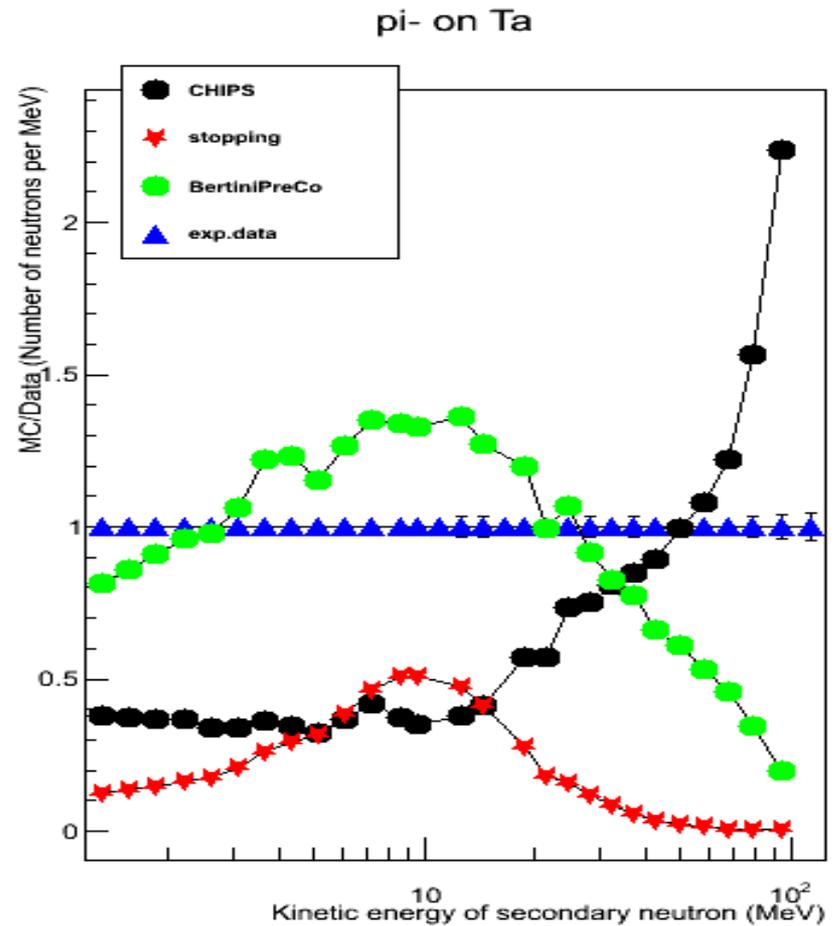
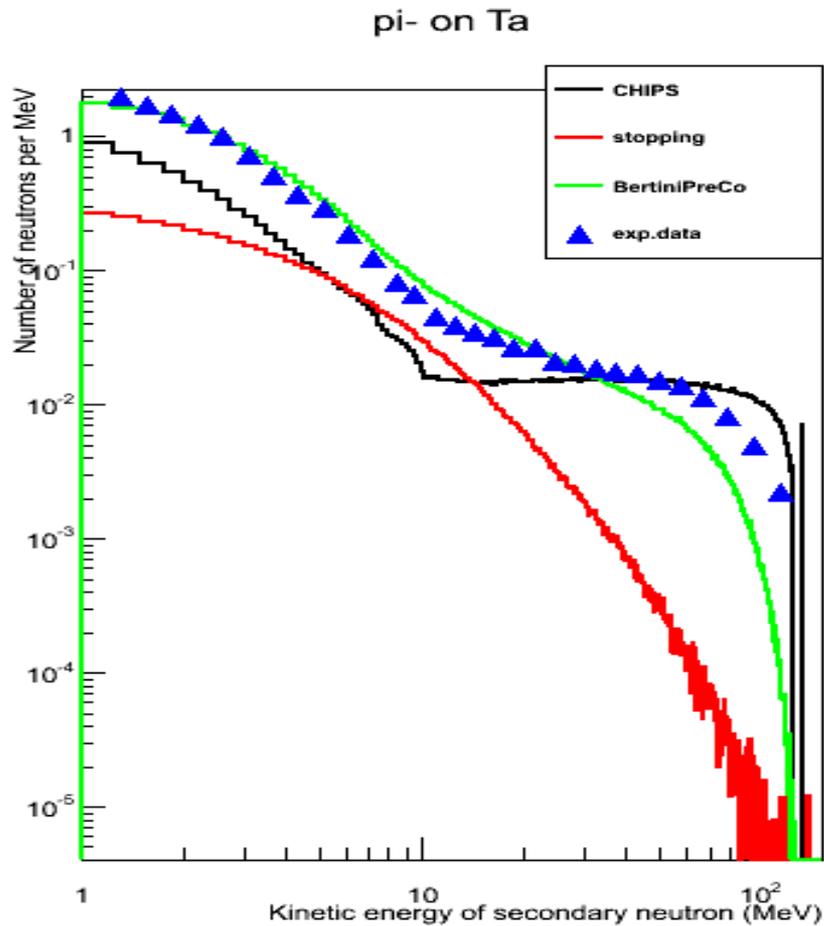
pi- on Al



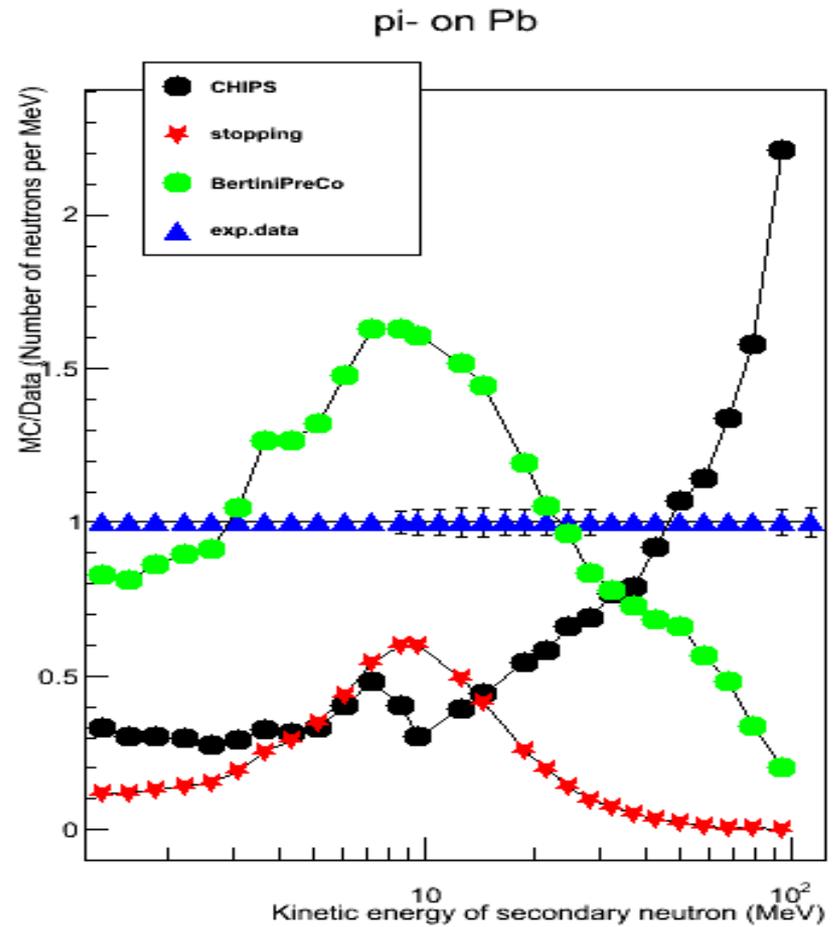
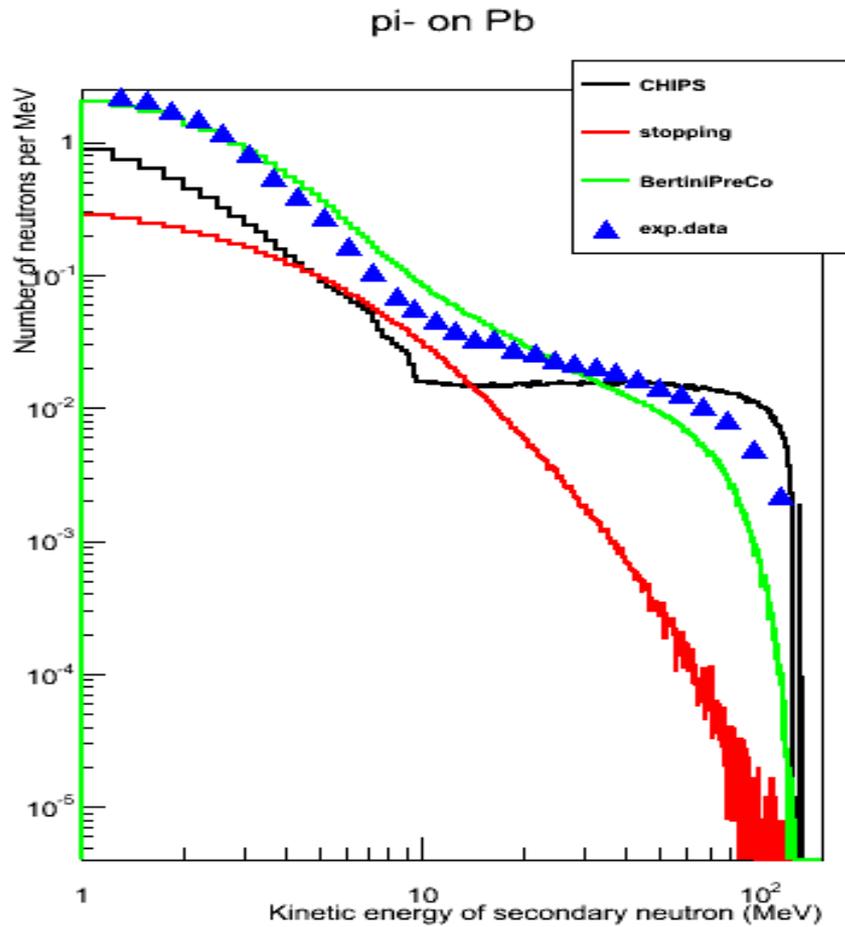
Test48: Models (V)



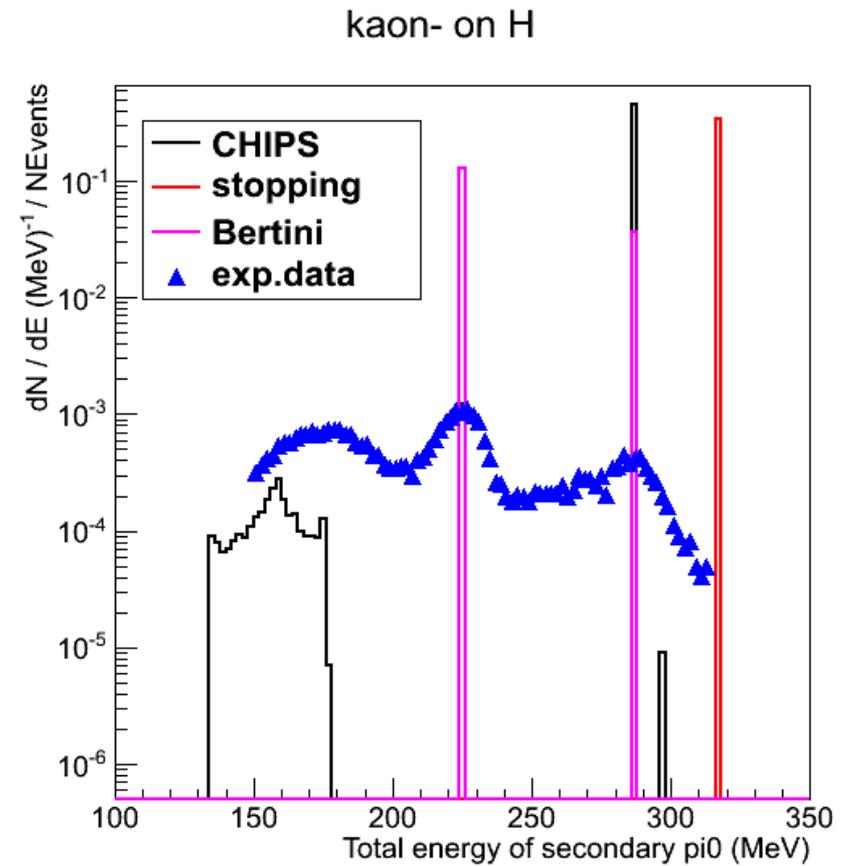
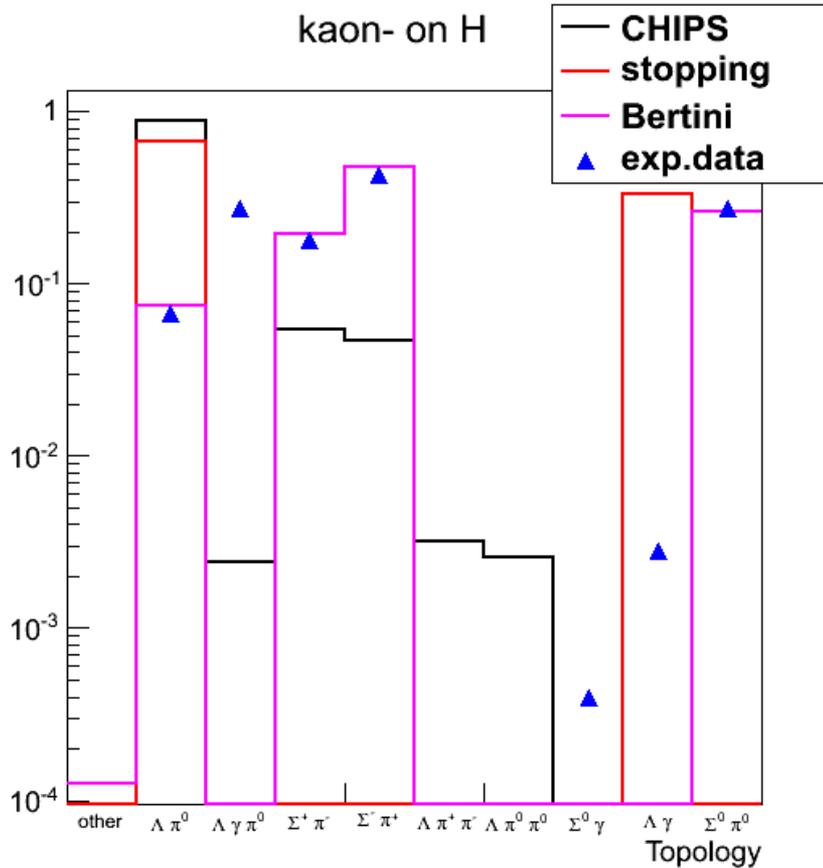
Test48: Models (VI)



Test48: Models (VII)

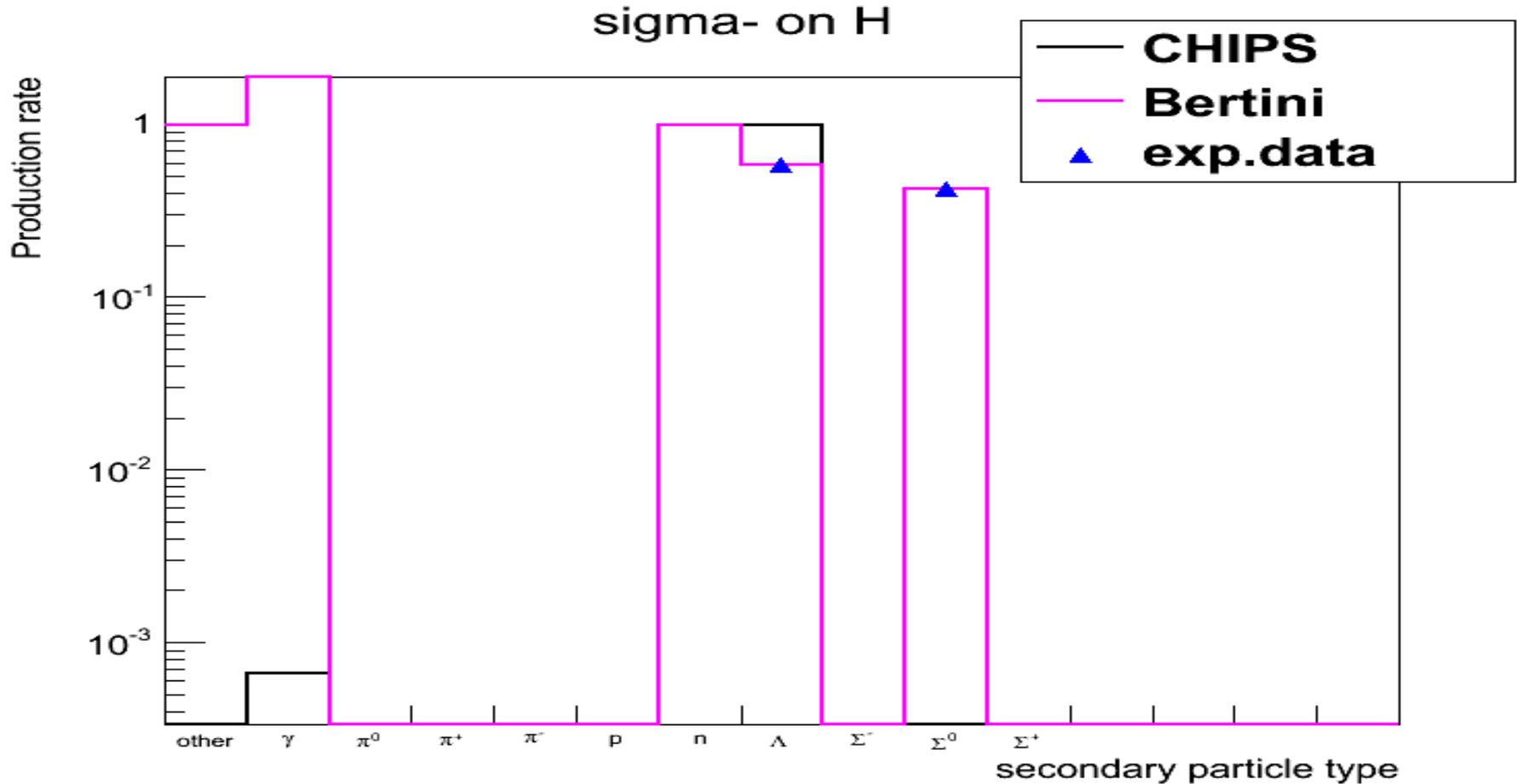


Test48: Models (VIII)



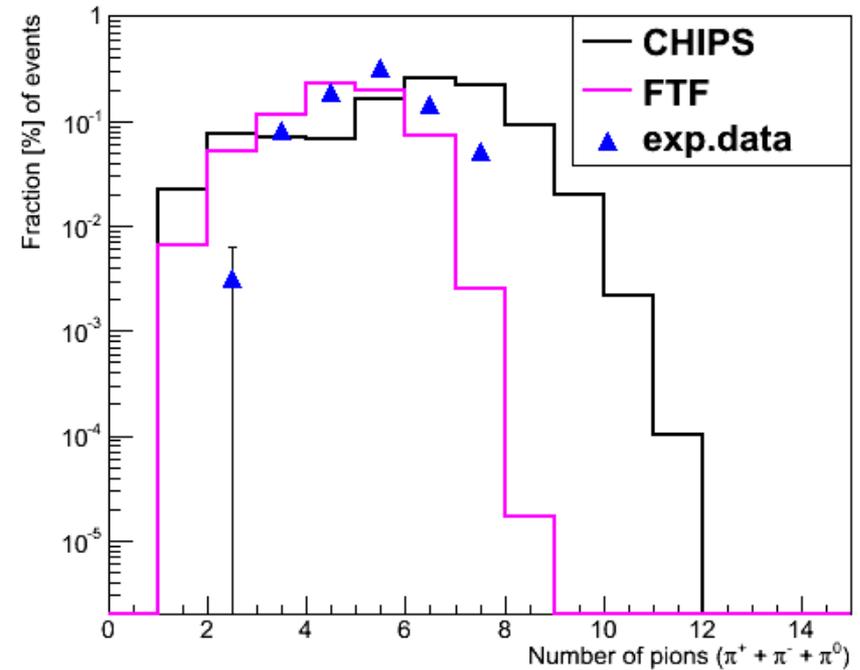
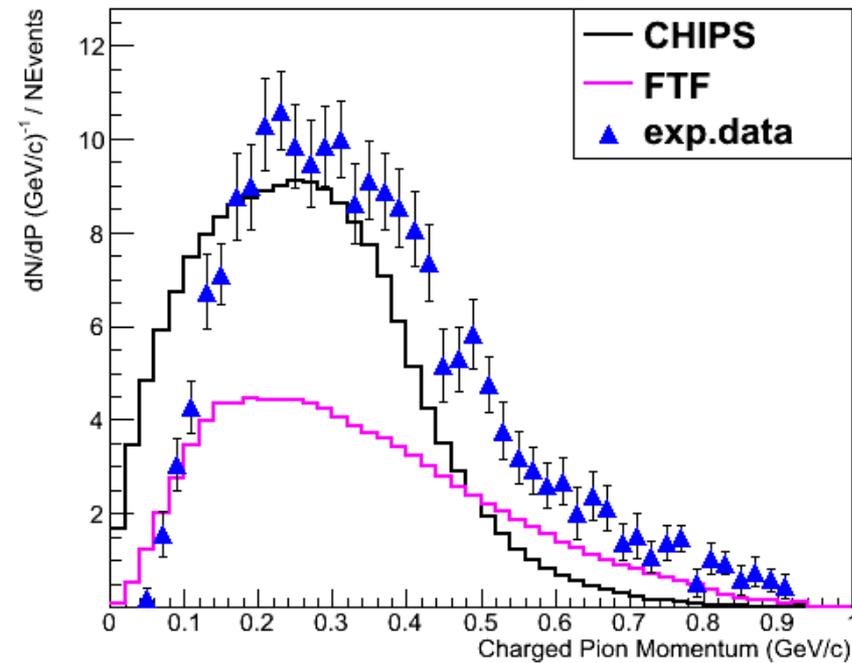


Test48: Models (IX)



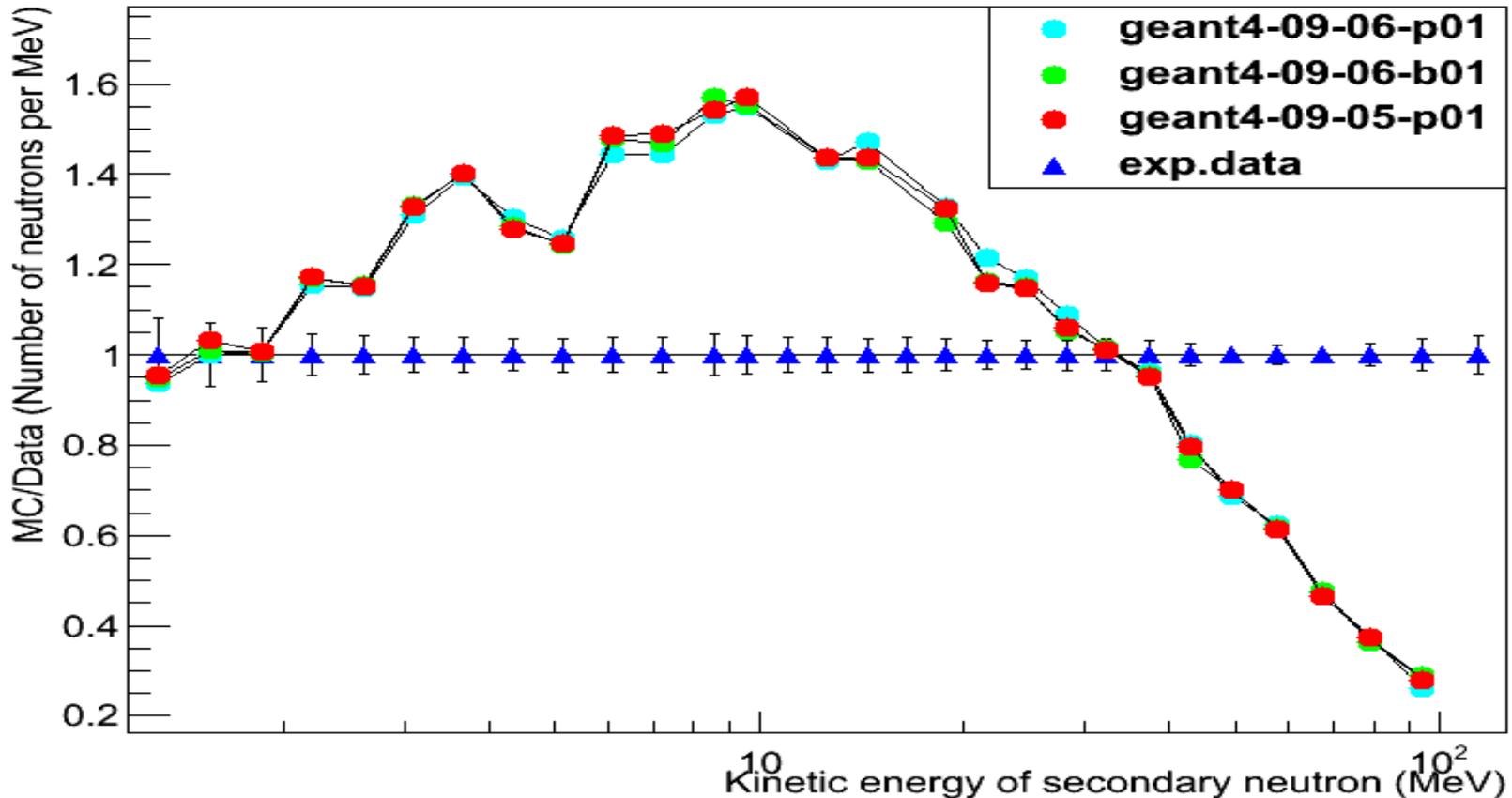
Test48: Models (X)

pbar annihilation on H



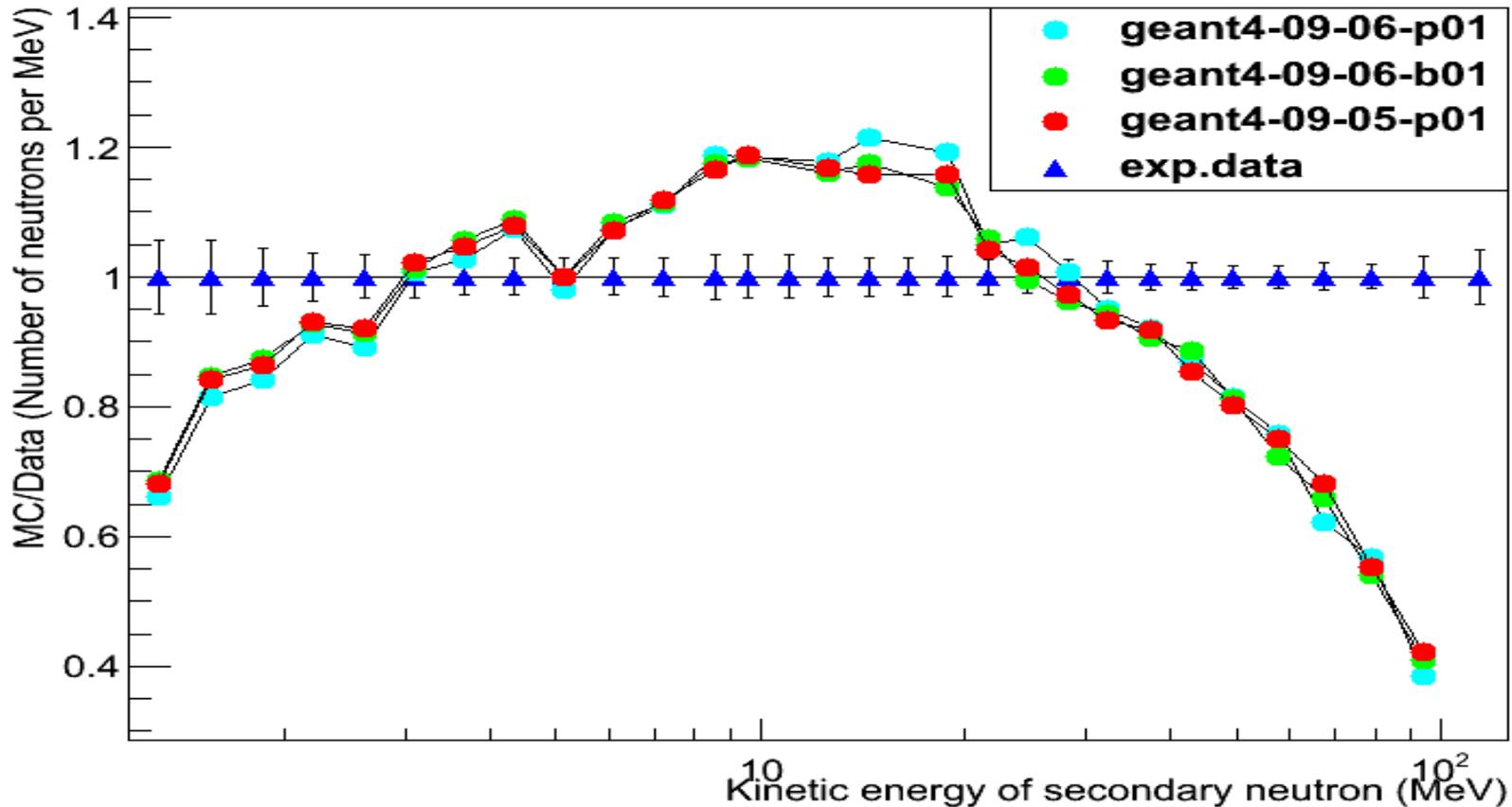
Test48: Bertini Regression (I)

π^- on C, BertiniPreCo



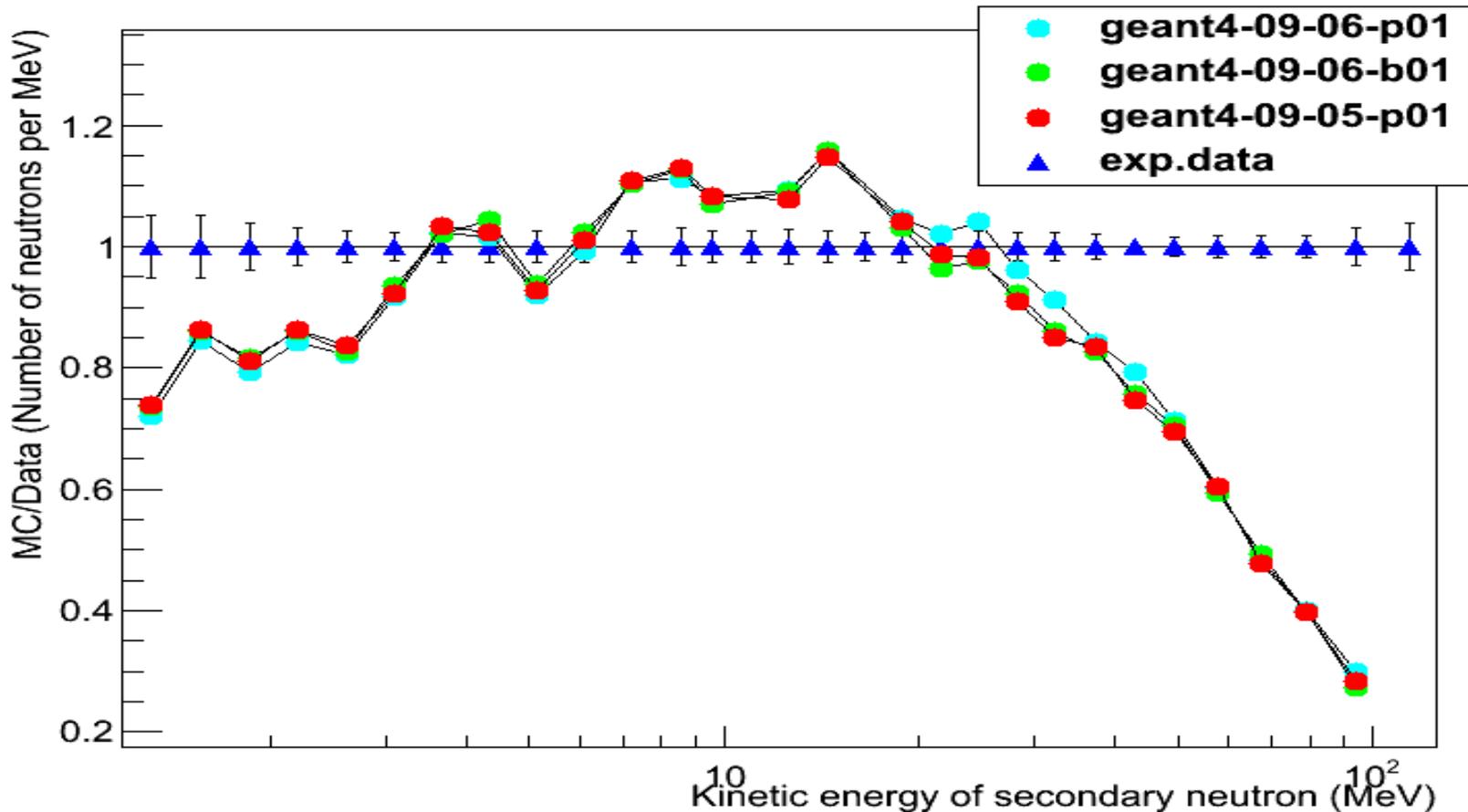
Test48: Bertini Regression (II)

pi- on N, BertiniPreCo



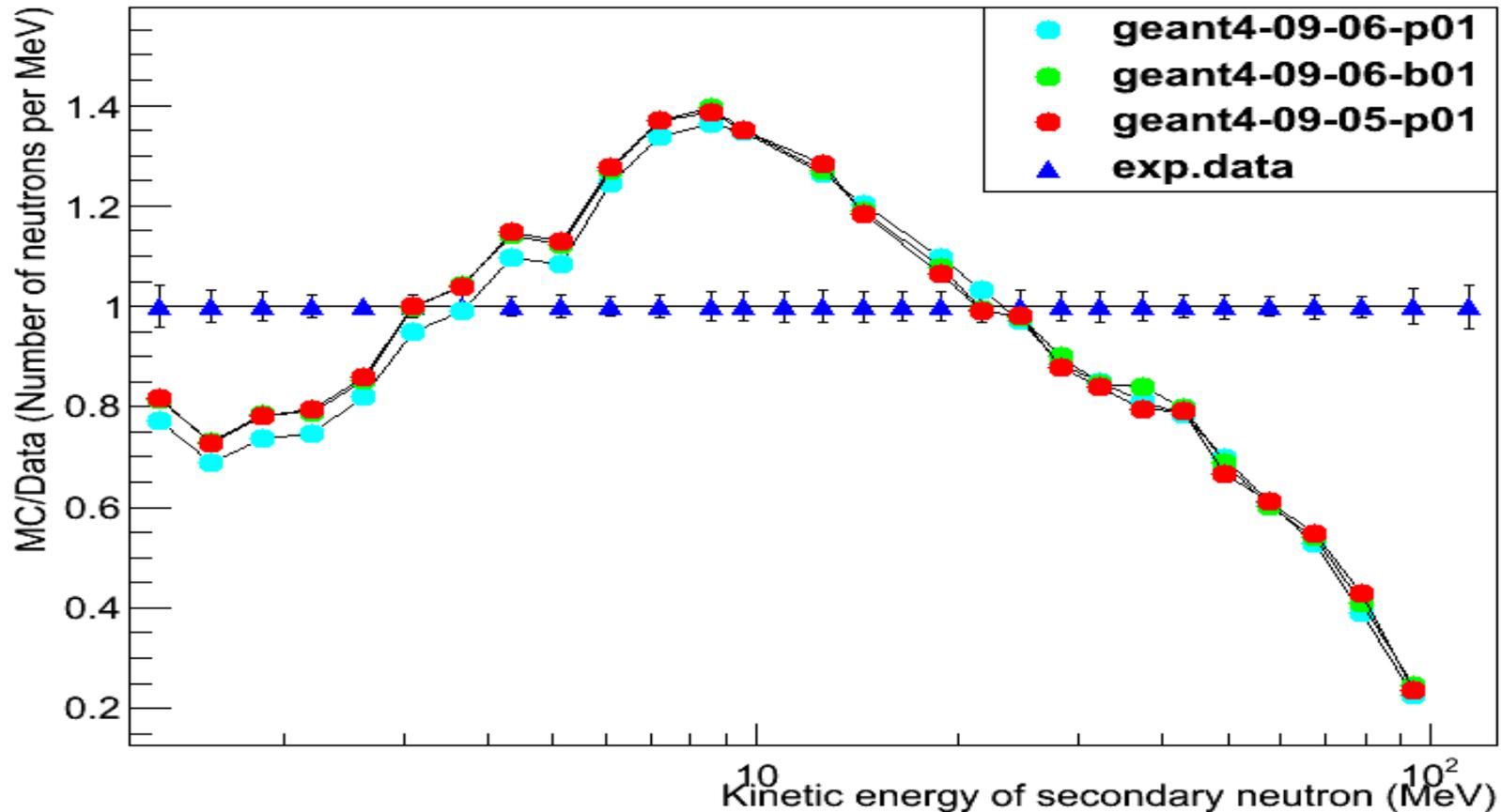
Test48: Bertini Regression (III)

pi- on O, BertiniPreCo



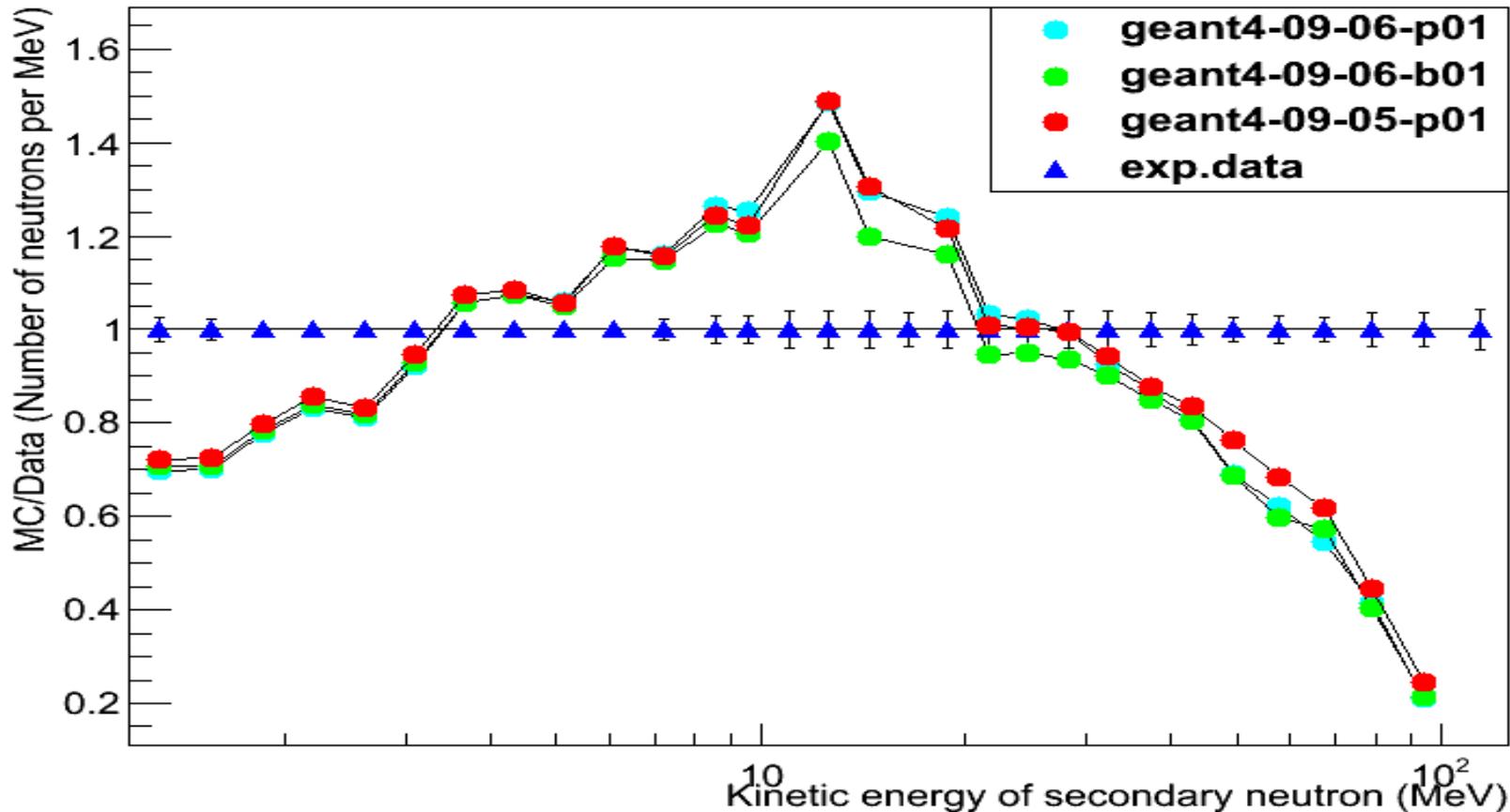
Test48: Bertini Regression (IV)

π^- on Al, BertiniPreCo



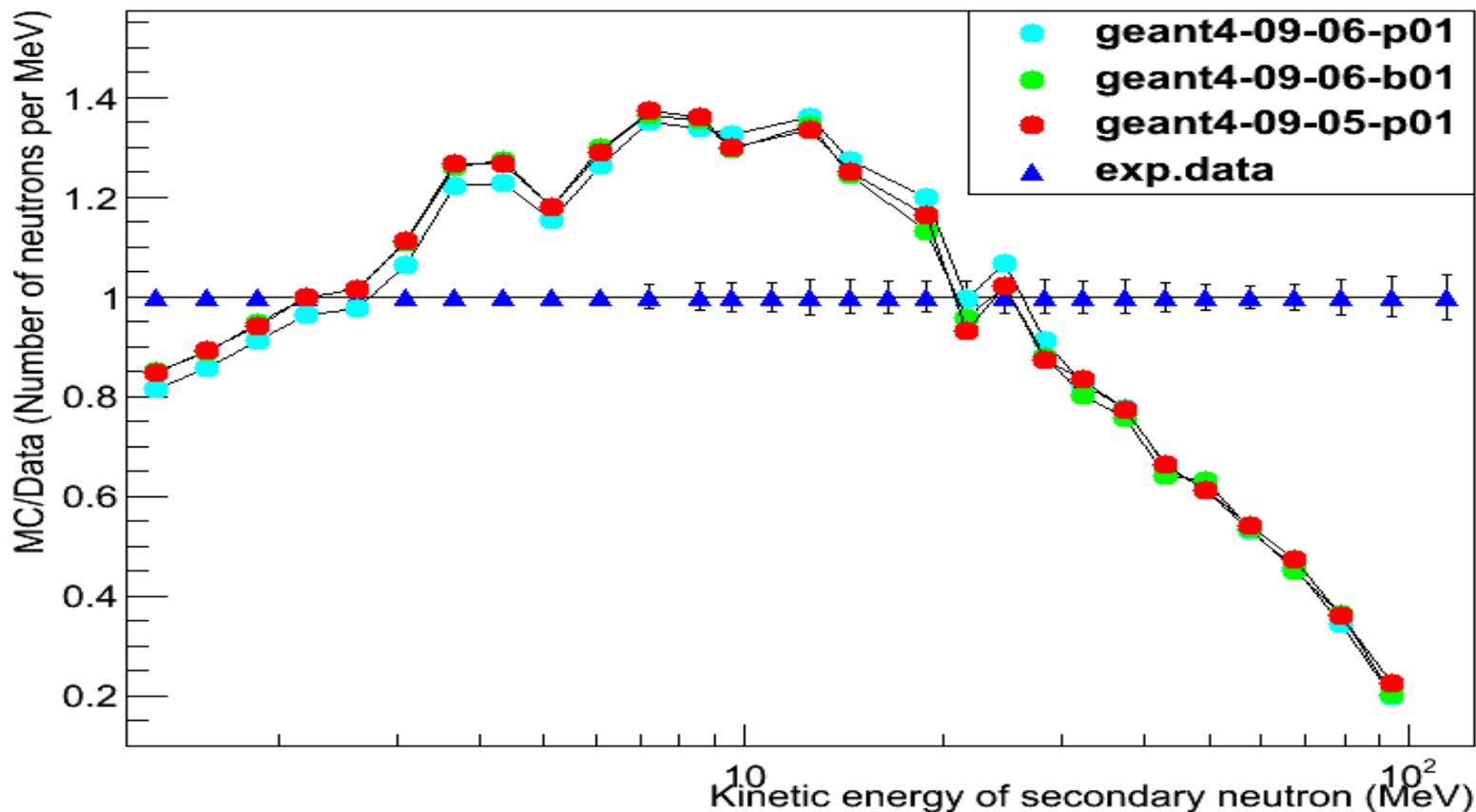
Test48: Bertini Regression (V)

pi- on Cu, BertiniPreCo



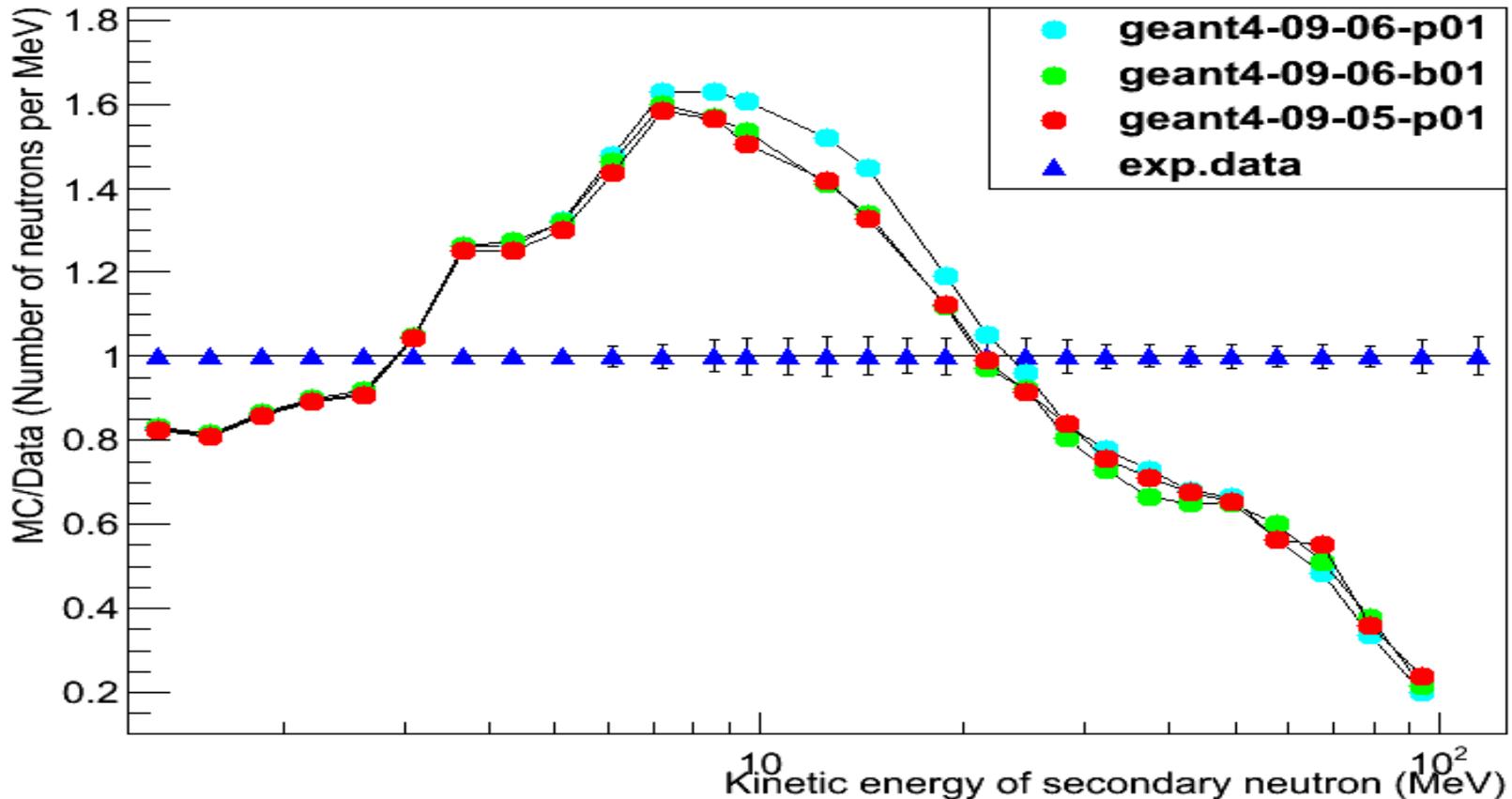
Test48: Bertini Regression (VI)

pi- on Ta, BertiniPreCo



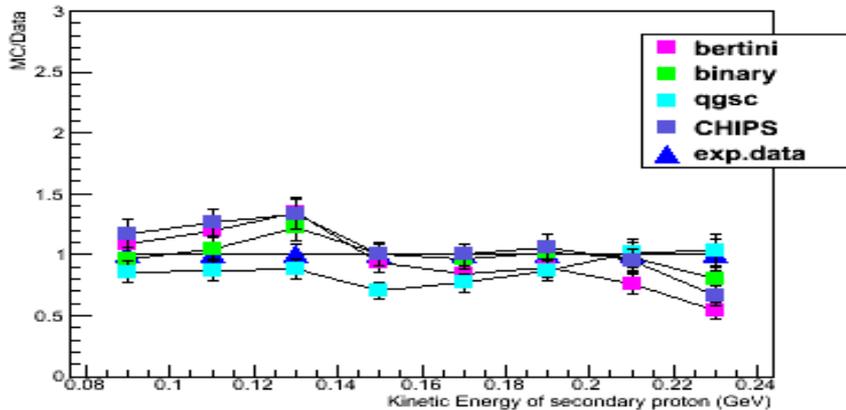
Test48: Bertini Regression (VII)

pi- on Pb, BertiniPreCo

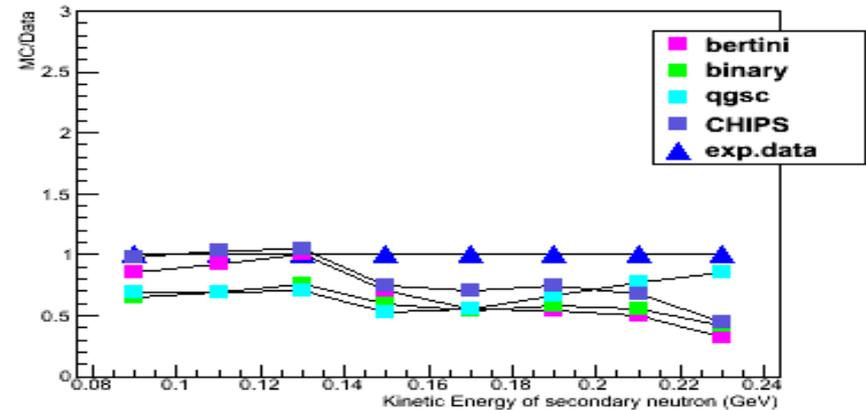


Test47: Models (I)

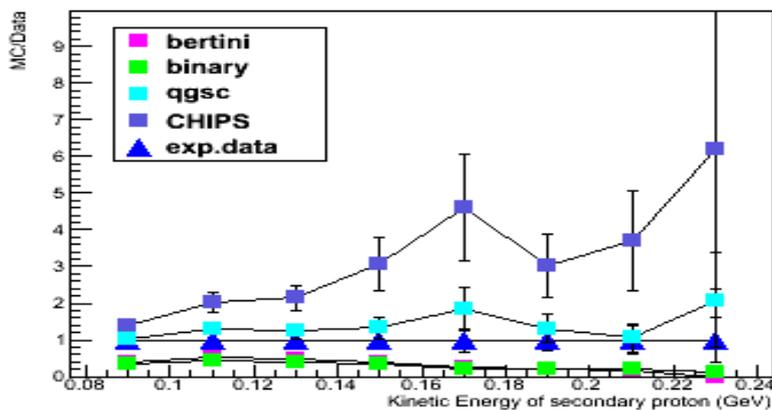
proton+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



proton+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)

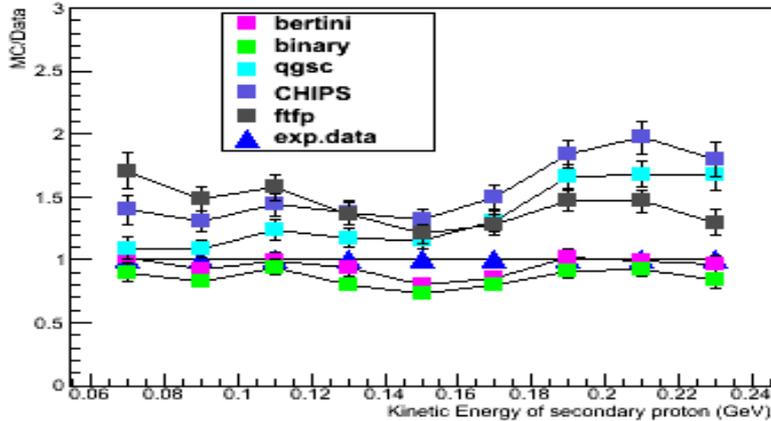


proton+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

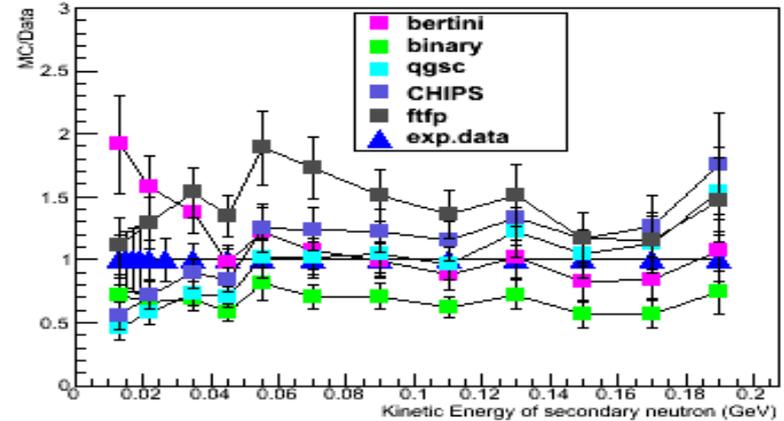


Test47: Models (II)

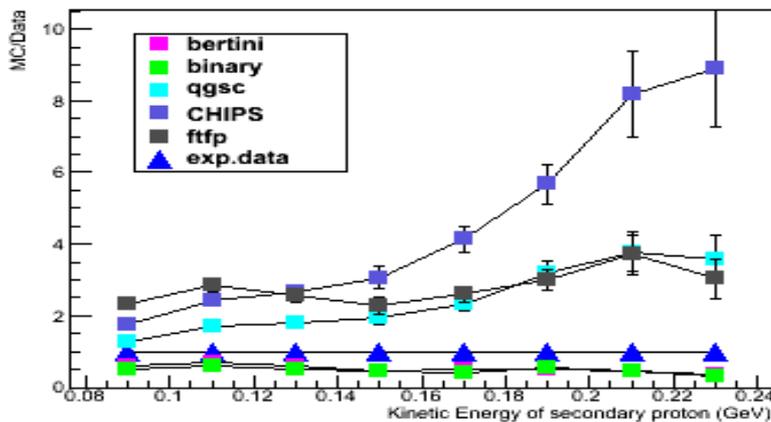
proton+C to p at 7.50 GeV (bertini) ($\theta = 59.10$)



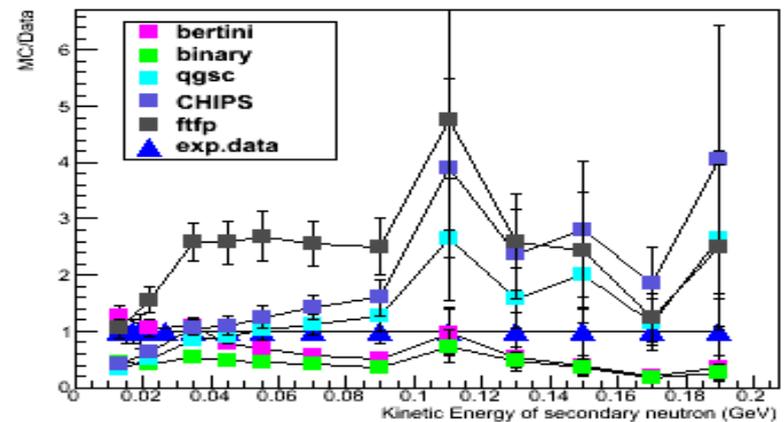
proton+C to n at 7.50 GeV (bertini) ($\theta = 59.10$)



proton+C to p at 7.50 GeV (bertini) ($\theta = 119.00$)

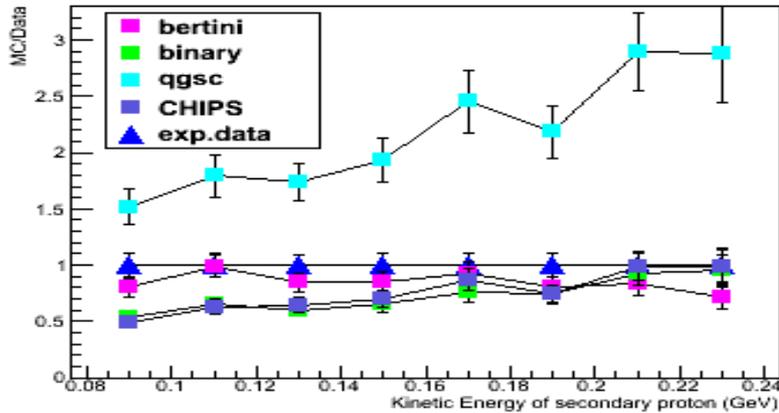


proton+C to n at 7.50 GeV (bertini) ($\theta = 119.00$)

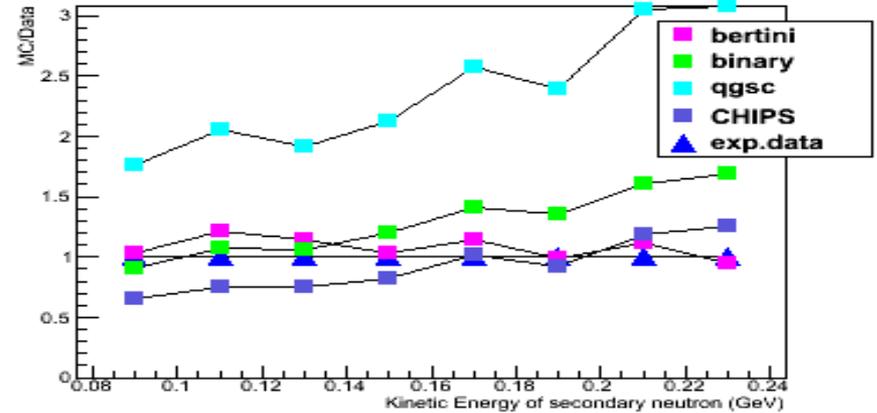


Test47: Models (III)

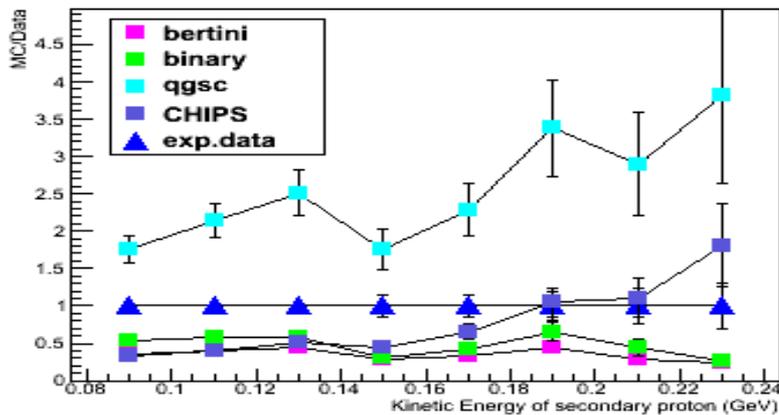
piminus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



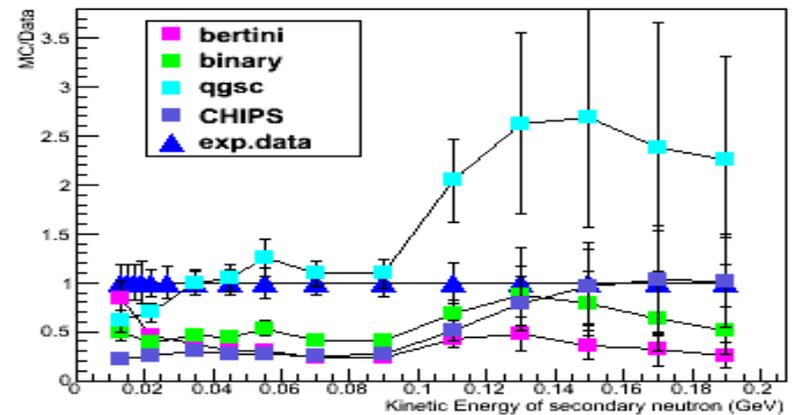
piminus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piminus+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

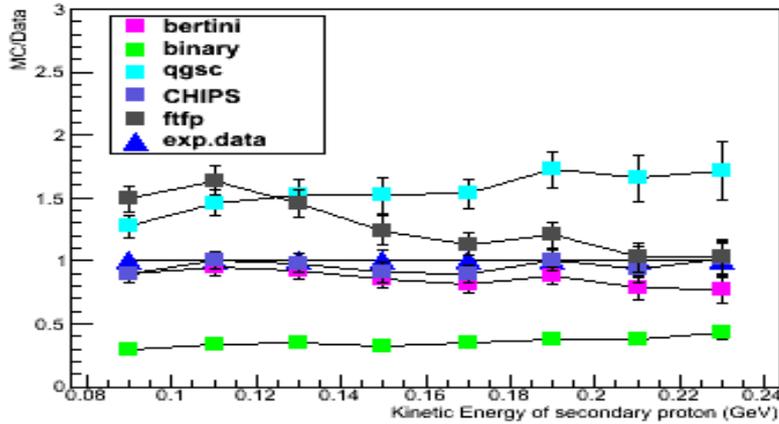


piminus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

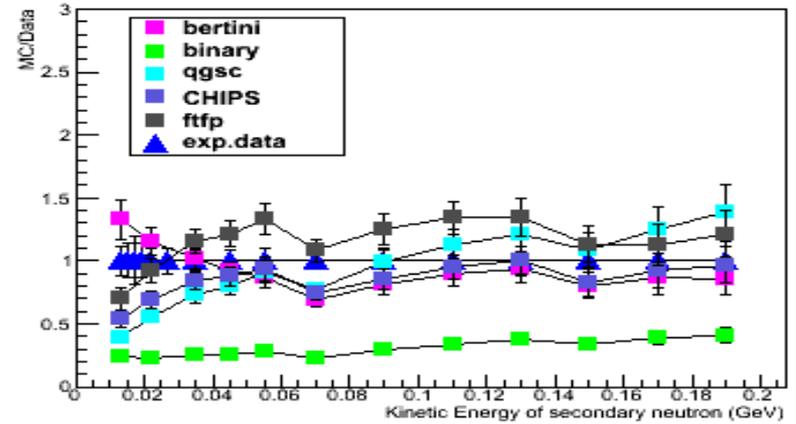


Test47: Models (IV)

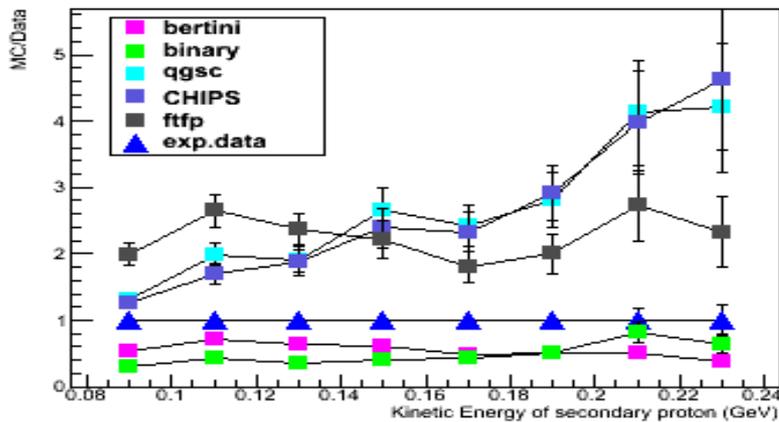
piminus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



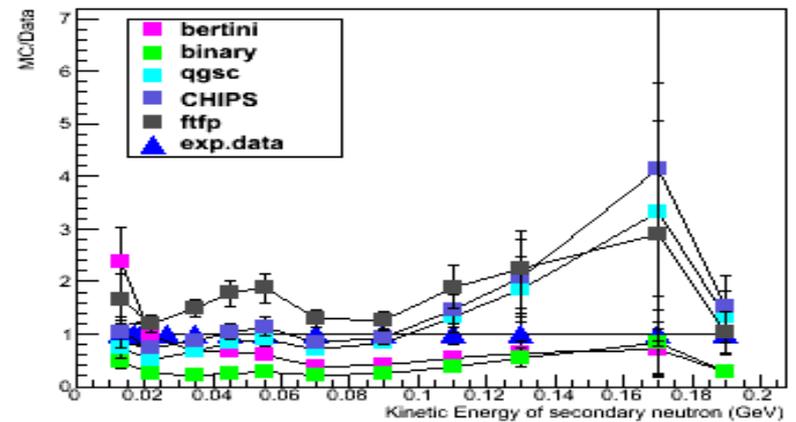
piminus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piminus+C to p at 5.00 GeV (bertini) ($\theta = 119.00$)

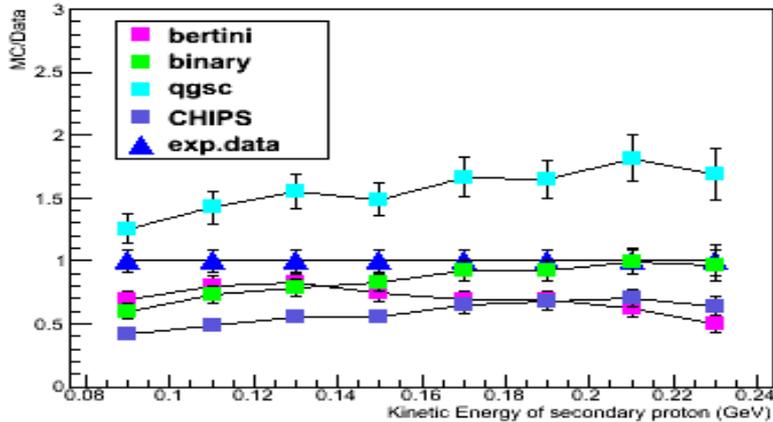


piminus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

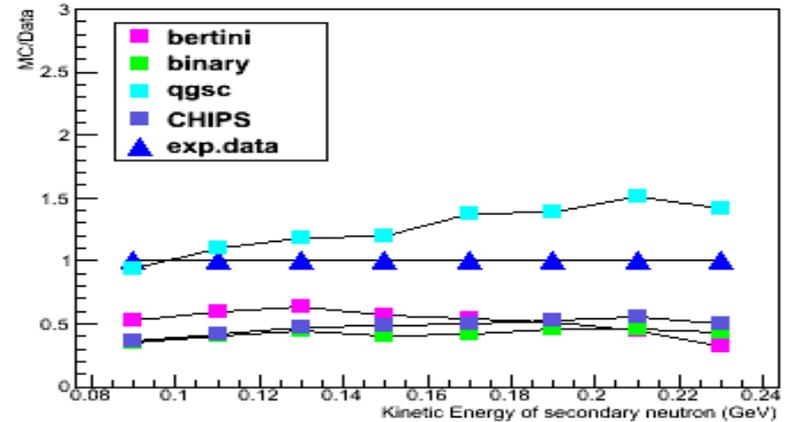


Test47: Models (V)

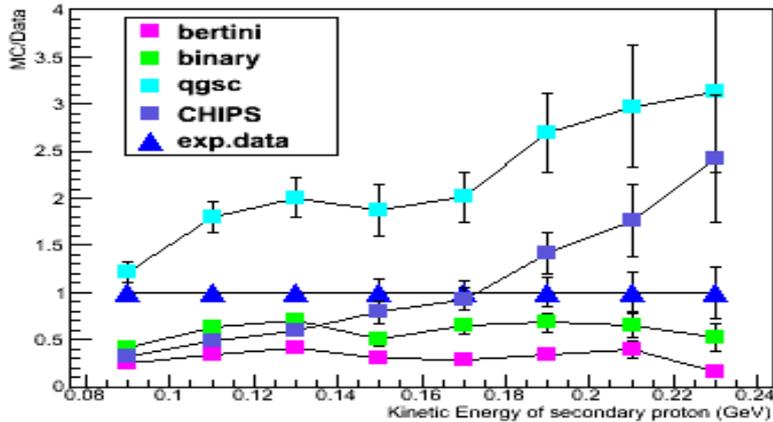
piplus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



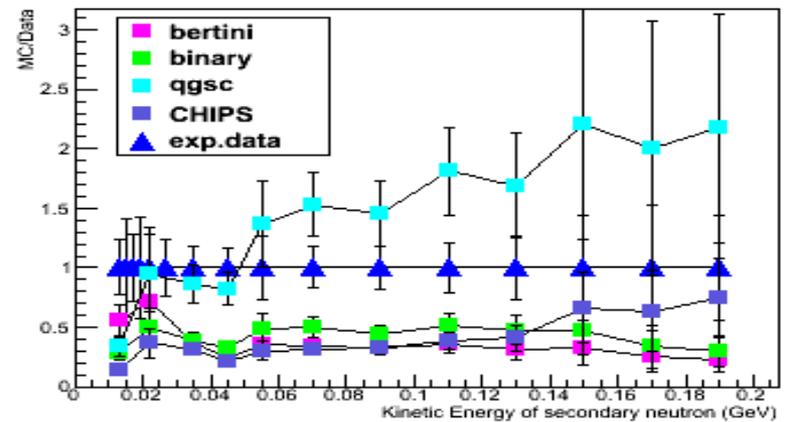
piplus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piplus+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

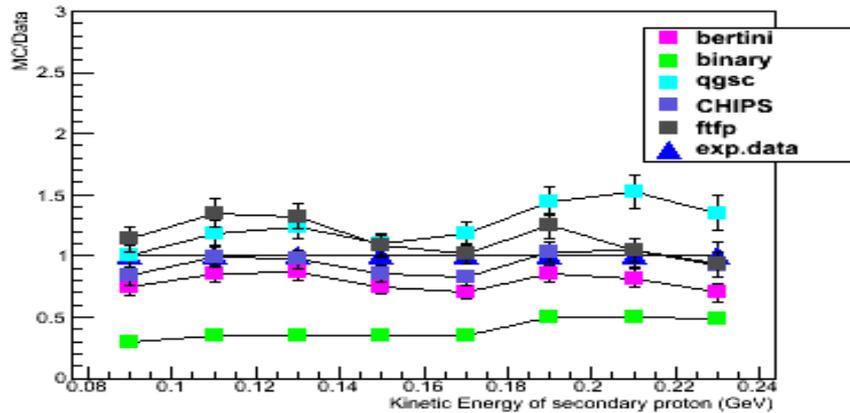


piplus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

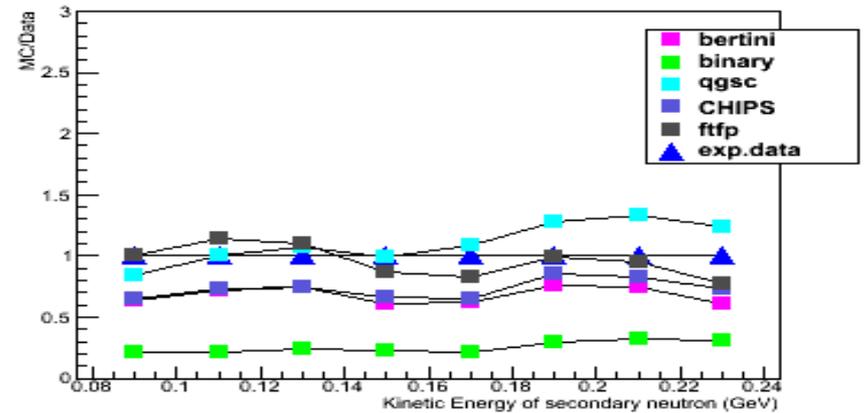


Test47: Models (VI)

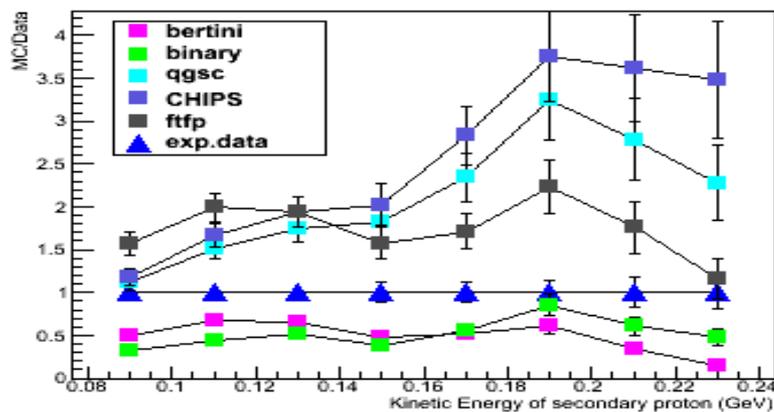
piplus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



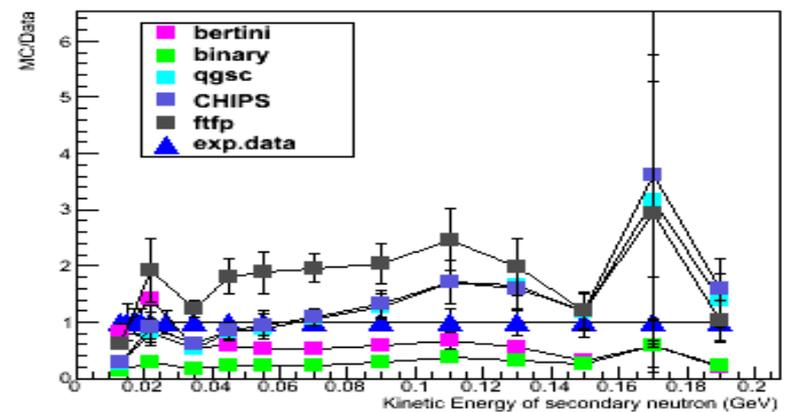
piplus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+C to p at 5.00 GeV (bertini) ($\theta = 119.00$)

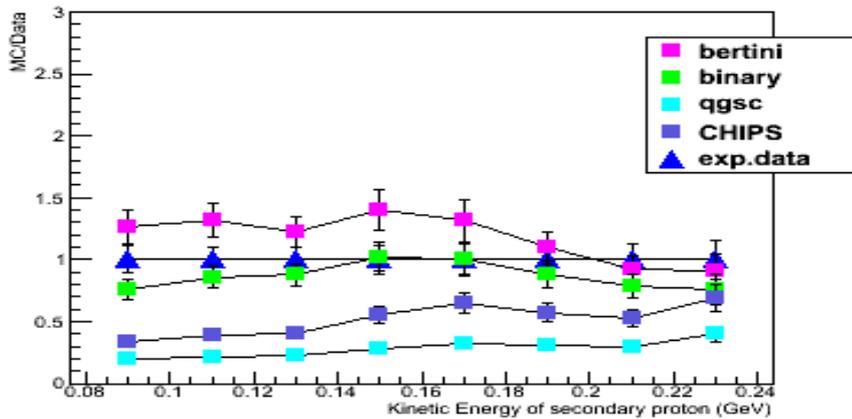


piplus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

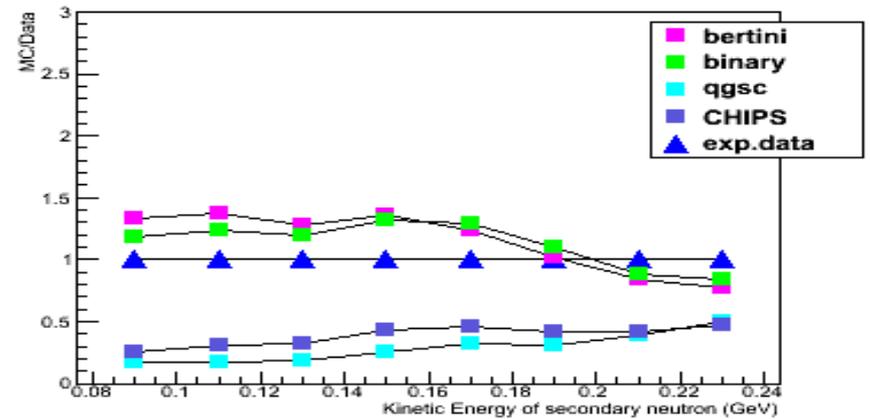


Test47: Models (VII)

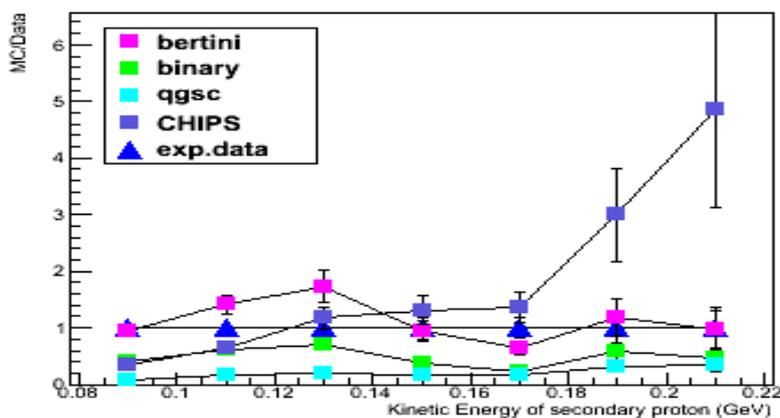
proton+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



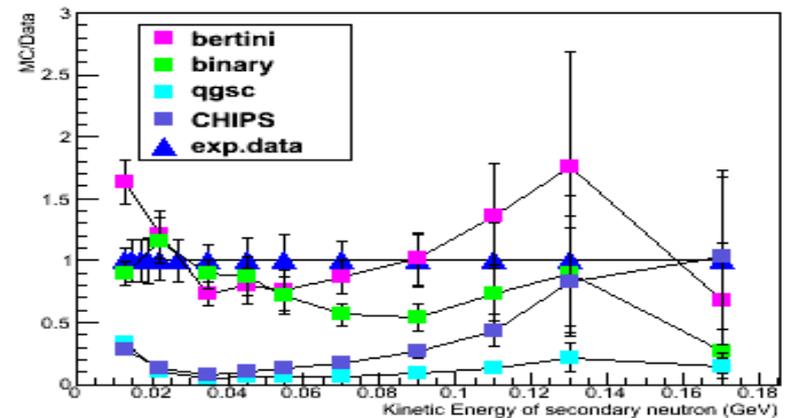
proton+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



proton+U to p at 1.40 GeV (bertini) ($\theta = 119.00$)

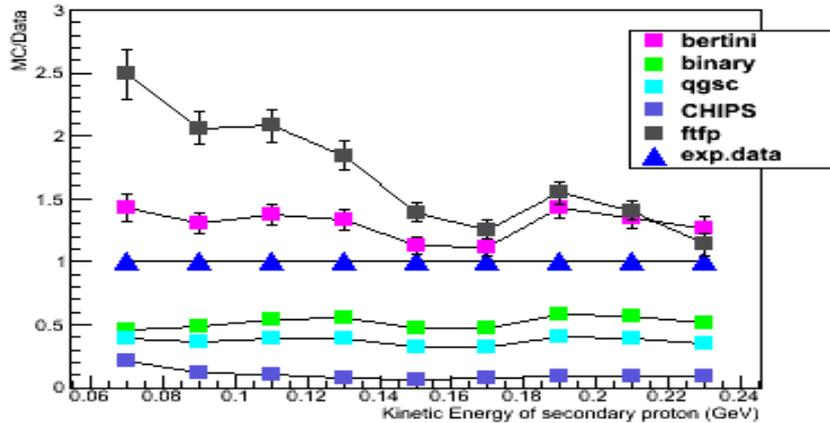


proton+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

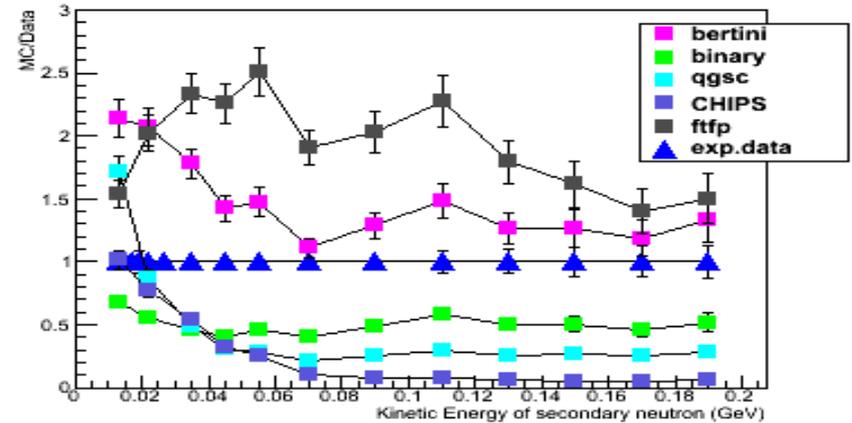


Test47: Models (VIII)

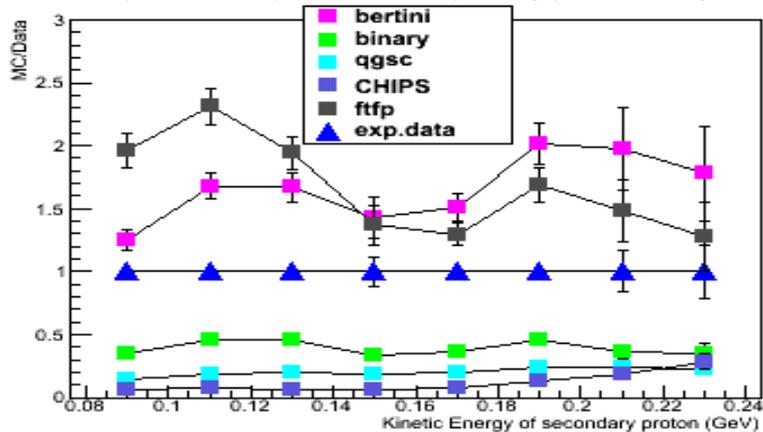
proton+U to p at 7.50 GeV (bertini) ($\theta = 59.10$)



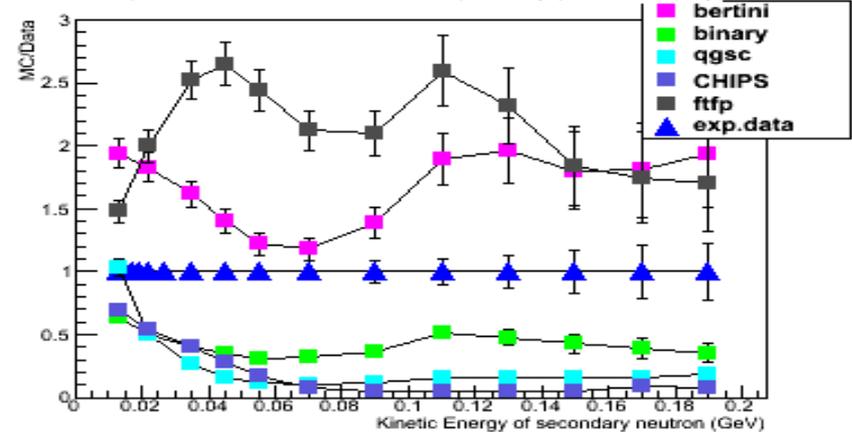
proton+U to n at 7.50 GeV (bertini) ($\theta = 59.10$)



proton+U to p at 7.50 GeV (bertini) ($\theta = 119.00$)

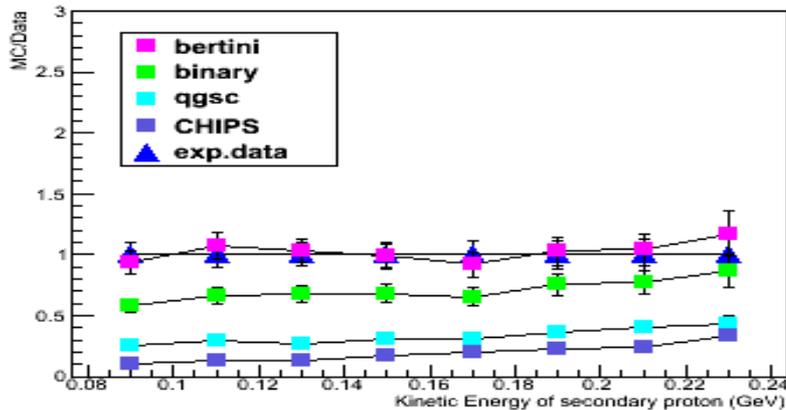


proton+U to n at 7.50 GeV (bertini) ($\theta = 119.00$)

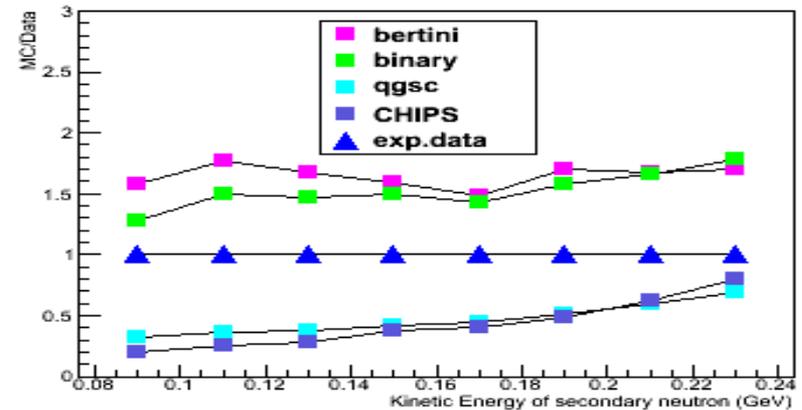


Test47: Models (IX)

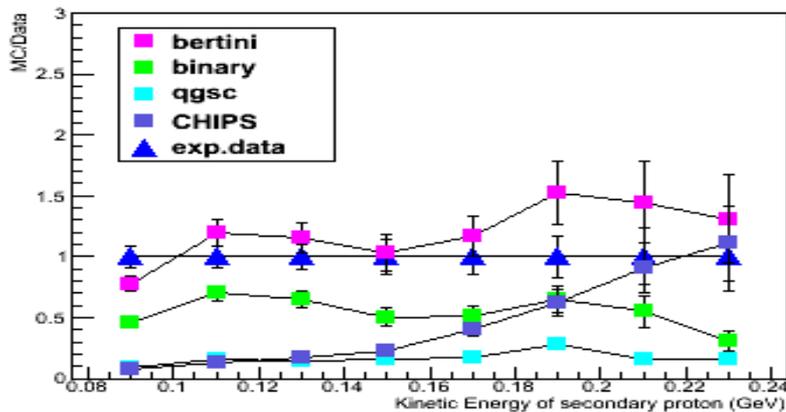
pimus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



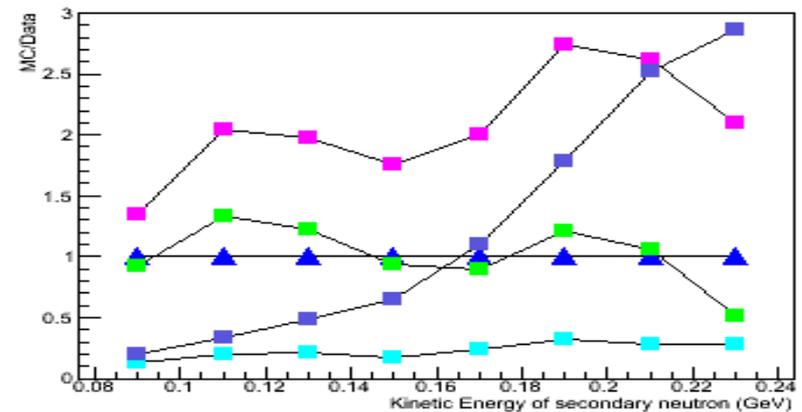
pimus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



pimus+U to p at 1.40 GeV (bertini) ($\theta = 119.00$)

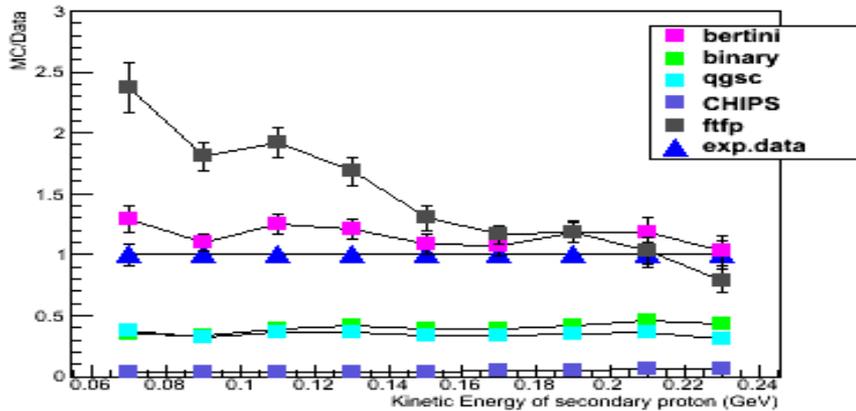


pimus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

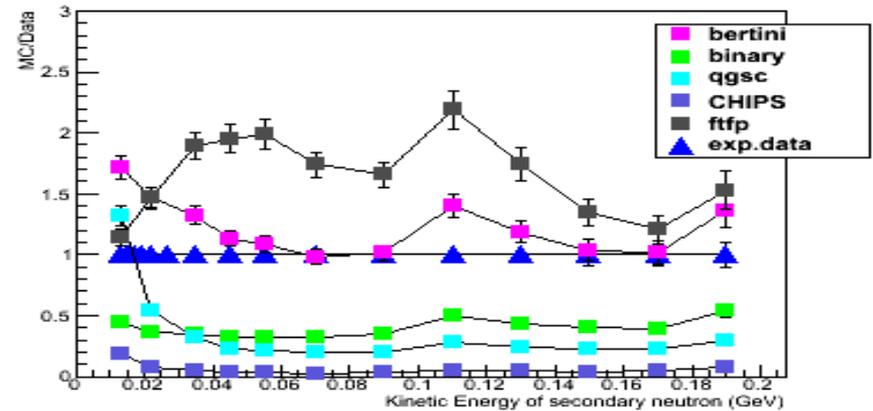


Test47: Models (X)

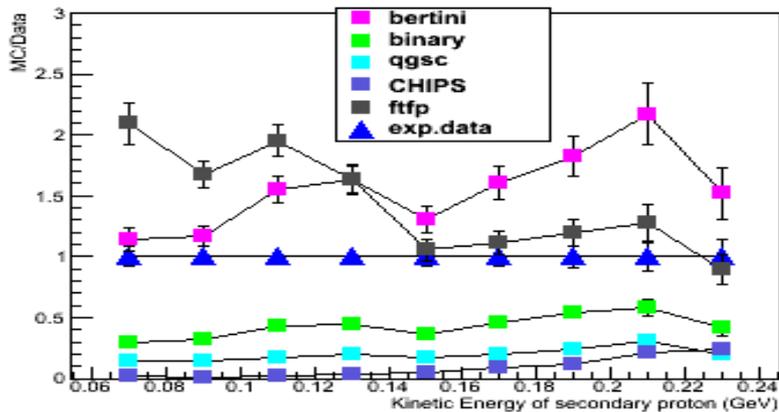
piminus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



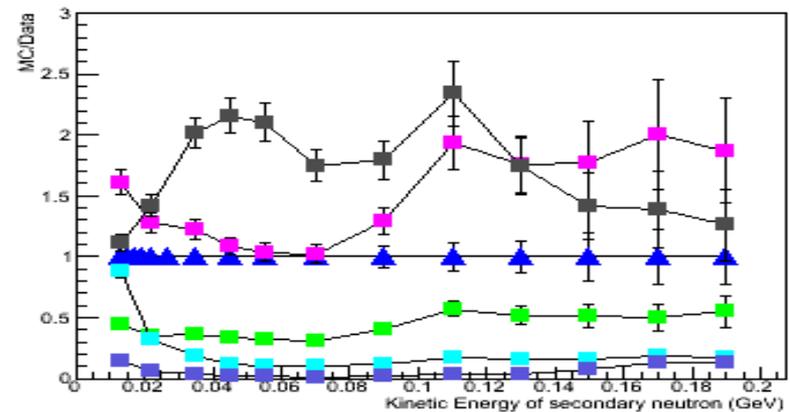
piminus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piminus+U to p at 5.00 GeV (bertini) ($\theta = 119.00$)



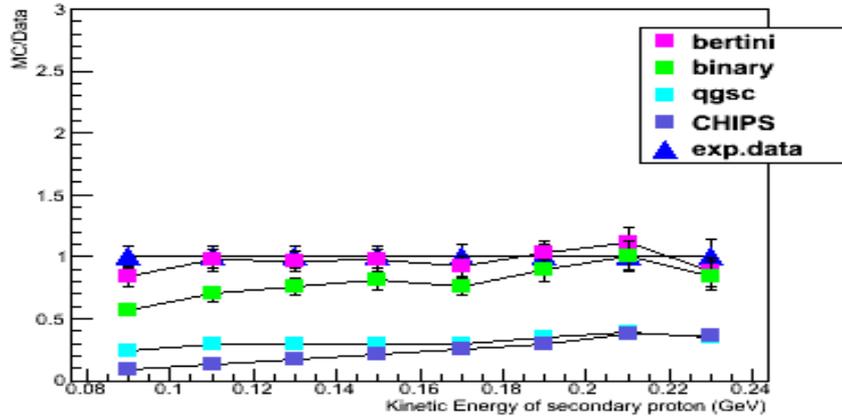
piminus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)



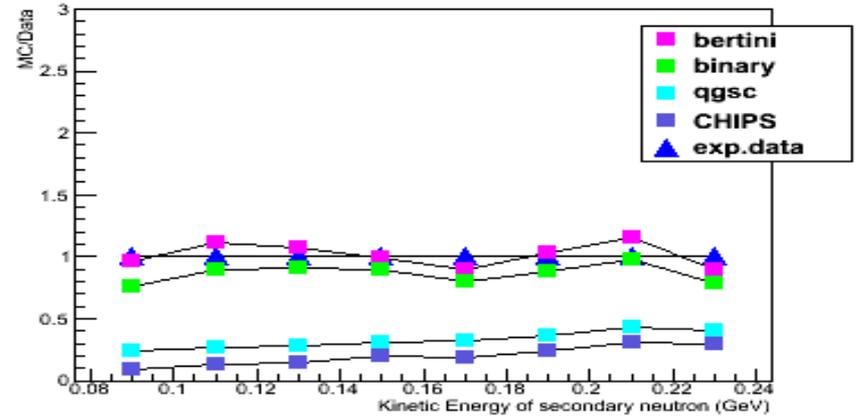


Test47: Models (XI)

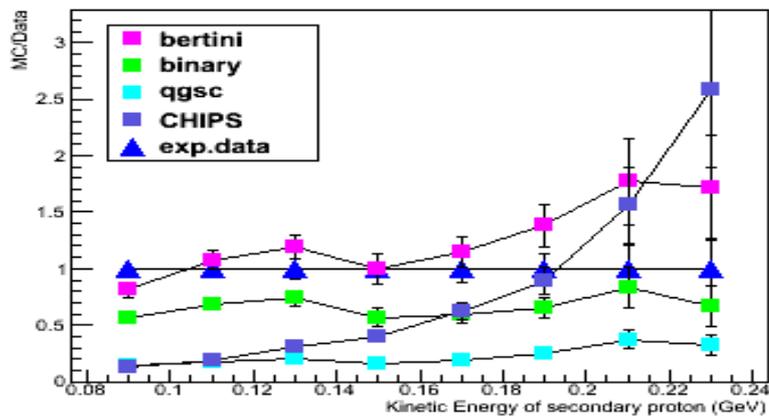
piplus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



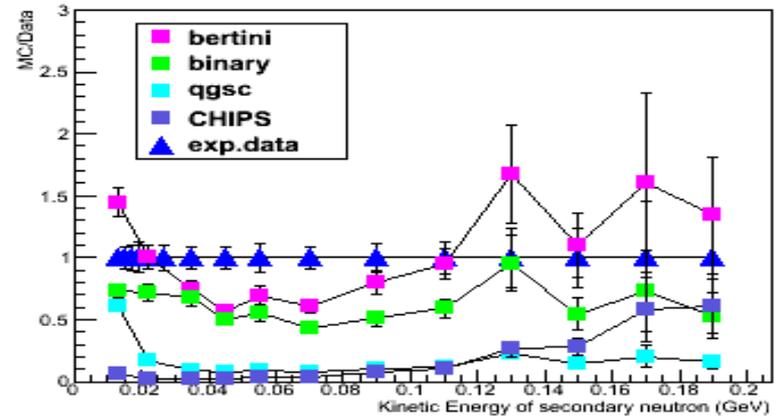
piplus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piplus+U to p at 1.40 GeV (bertini) ($\theta = 119.00$)

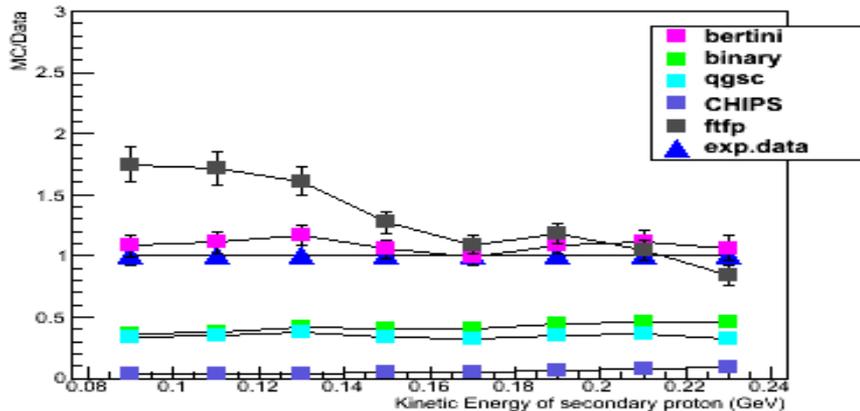


piplus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

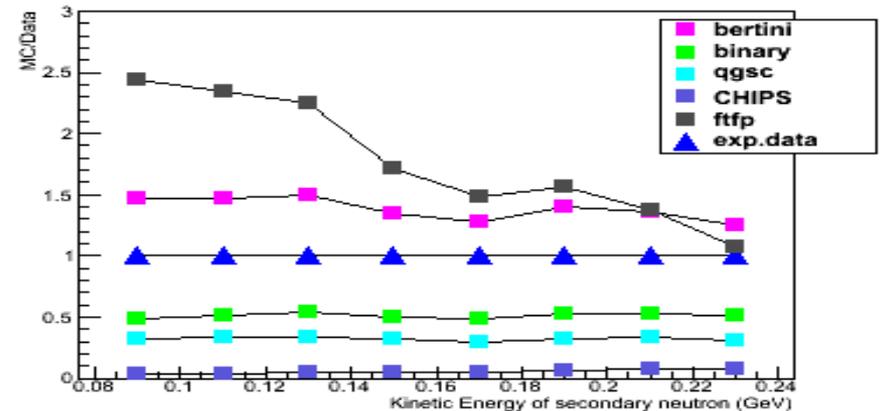


Test47: Models (XII)

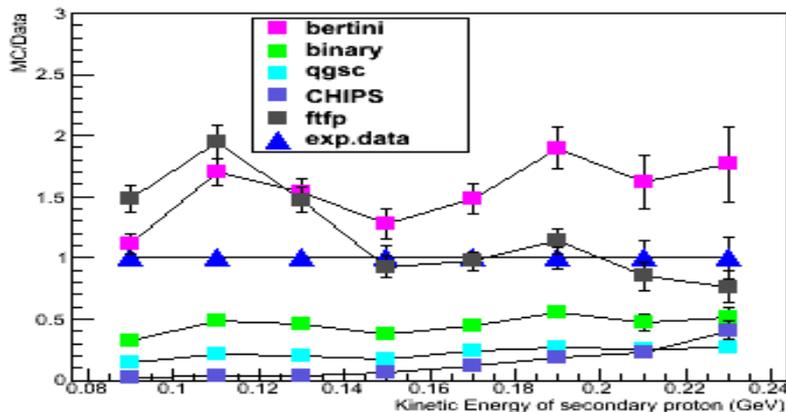
piplus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



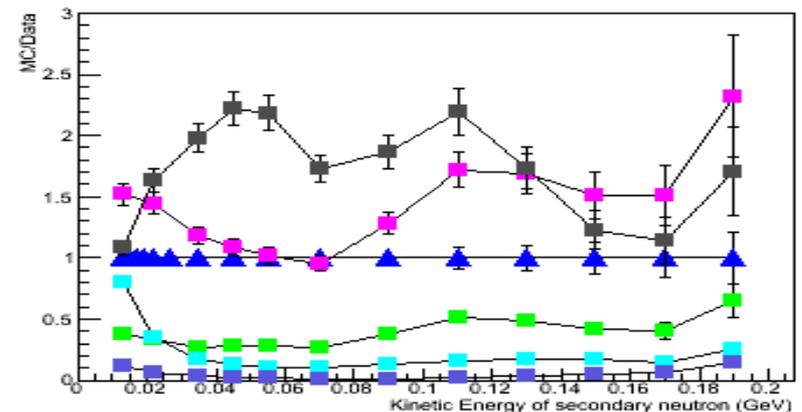
piplus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+U to p at 5.00 GeV (bertini) ($\theta = 119.00$)

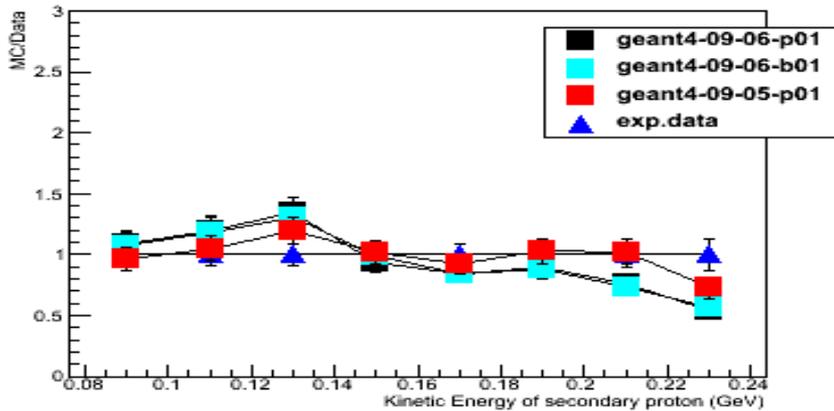


piplus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

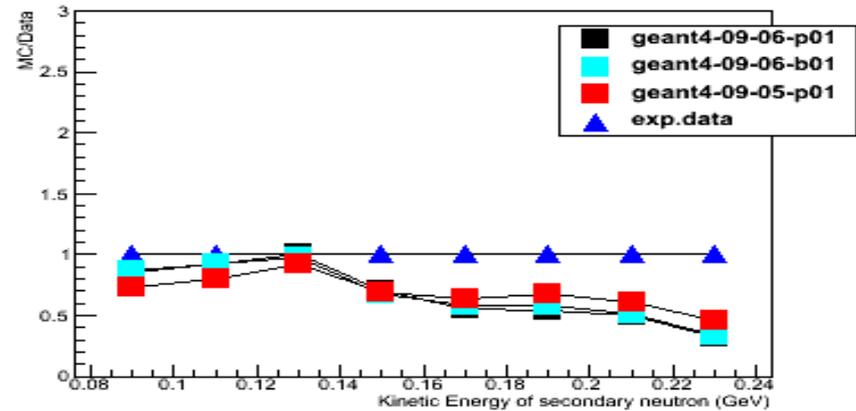


Test47: Bertini Regression (I)

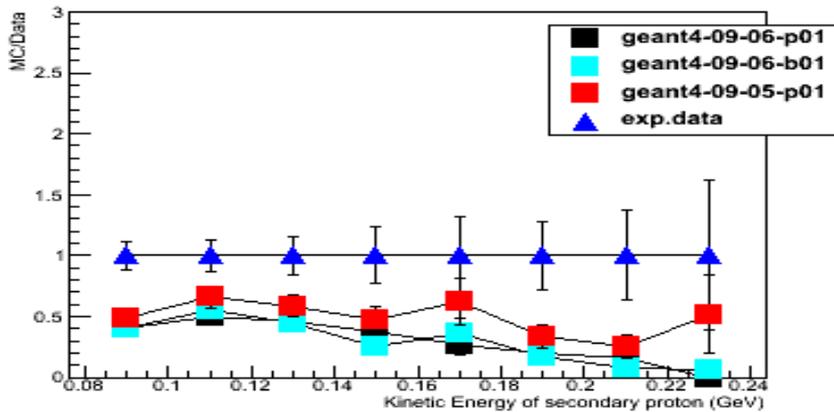
proton+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



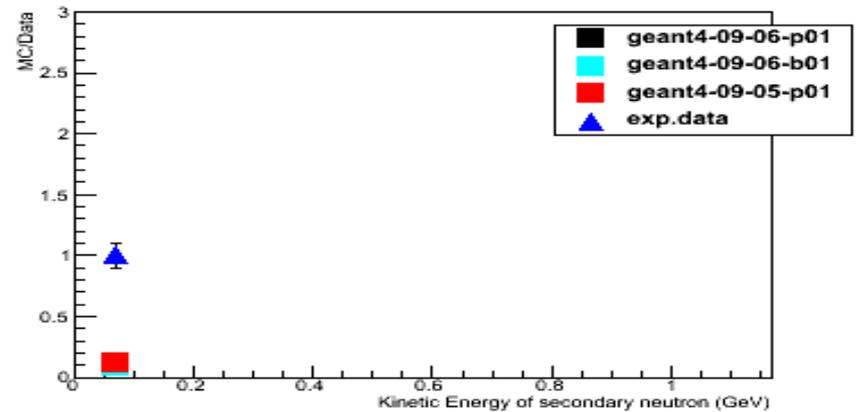
proton+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



proton+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

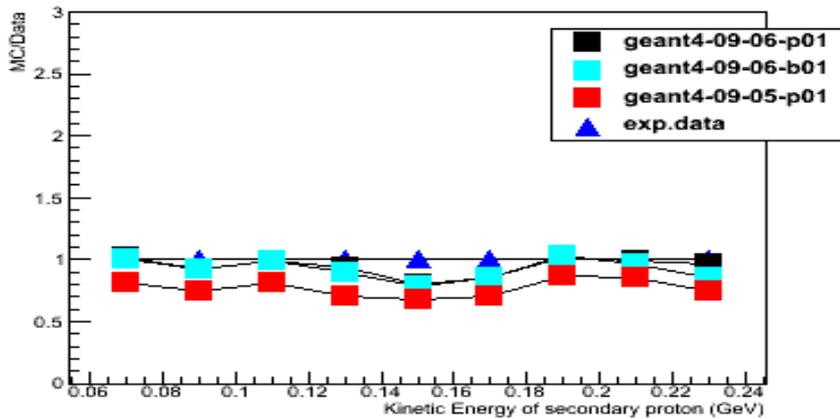


proton+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

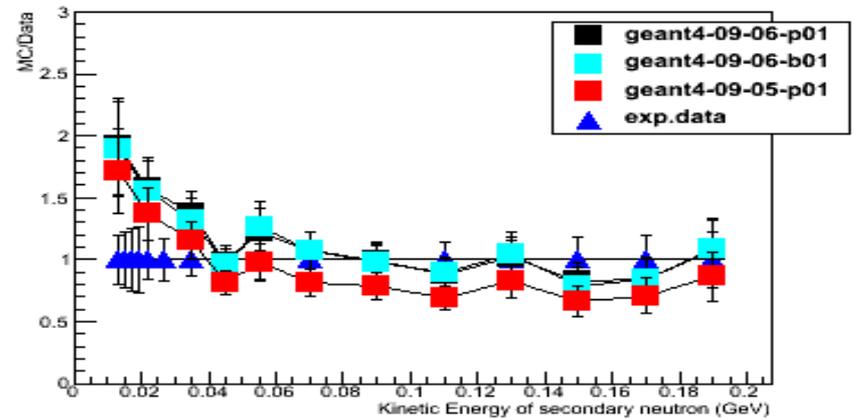


Test47: Bertini Regression (II)

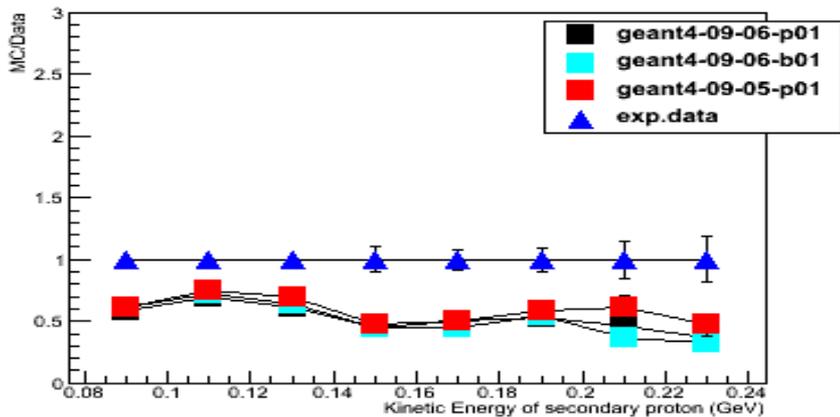
proton+C to p at 7.50 GeV (bertini) ($\theta = 59.10$)



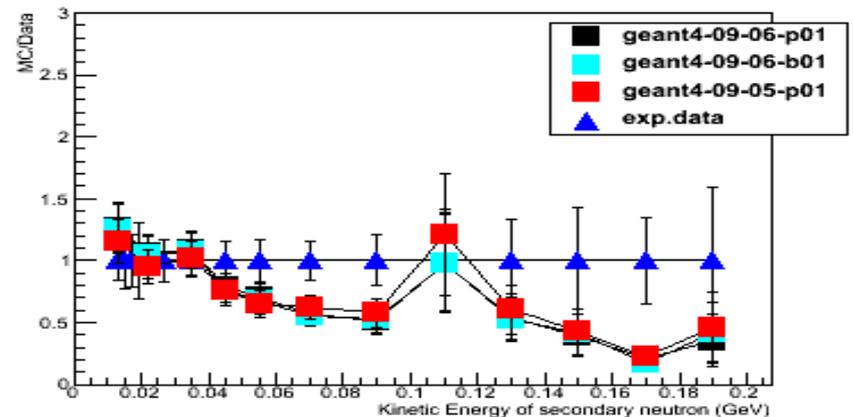
proton+C to n at 7.50 GeV (bertini) ($\theta = 59.10$)



proton+C to p at 7.50 GeV (bertini) ($\theta = 119.00$)

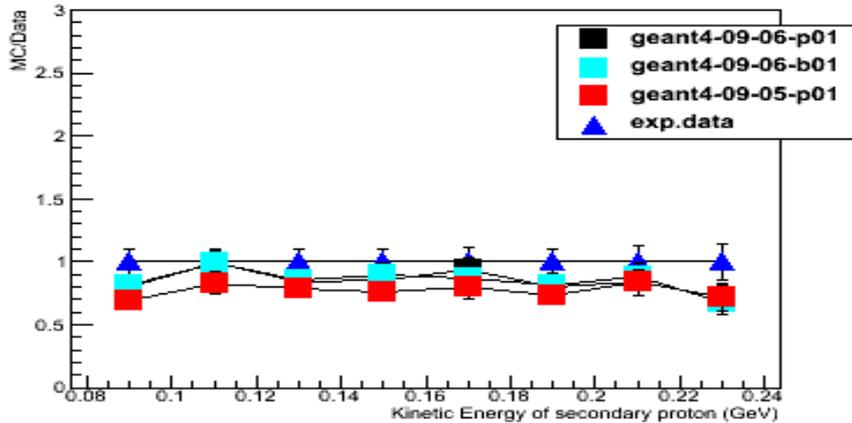


proton+C to n at 7.50 GeV (bertini) ($\theta = 119.00$)

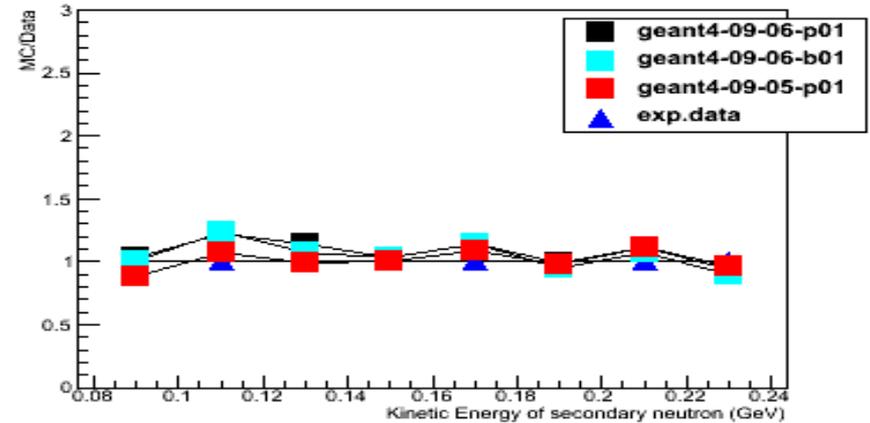


Test47: Bertini Regression (III)

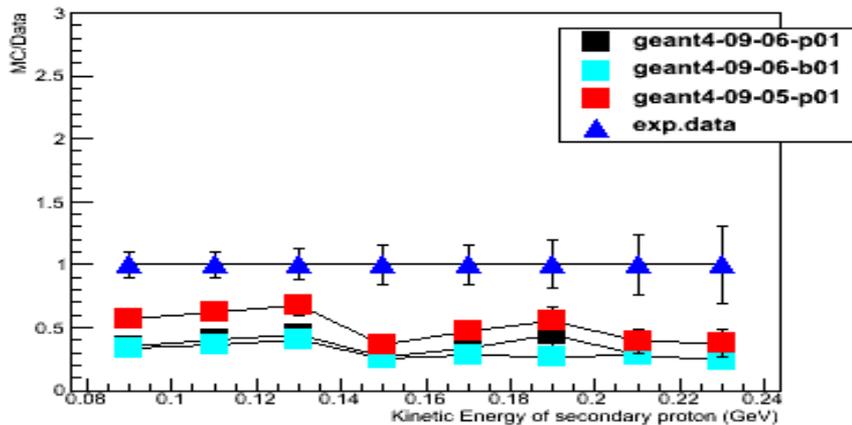
piminus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



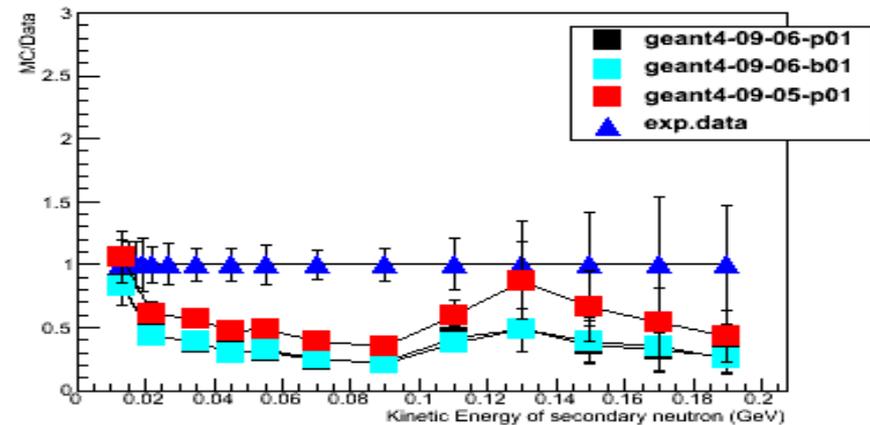
piminus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piminus+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

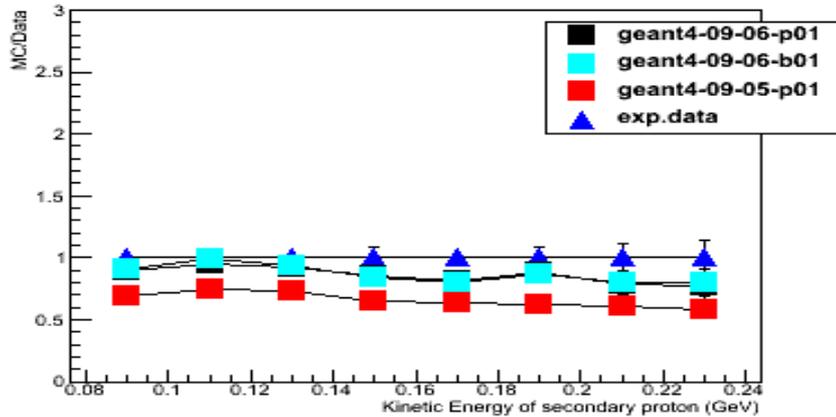


piminus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

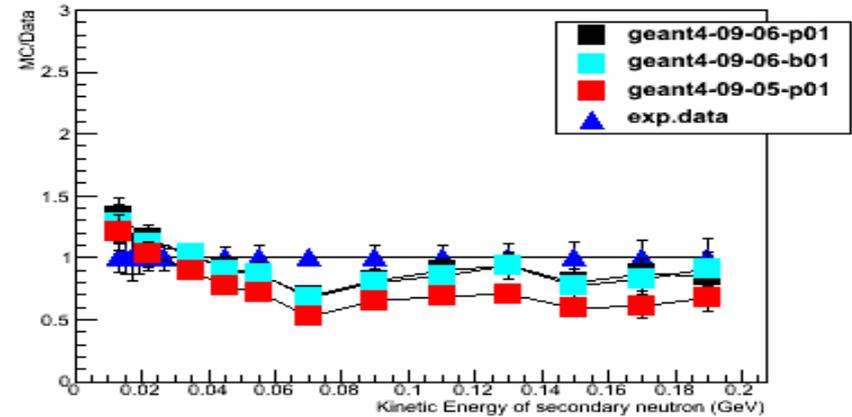


Test47: Bertini Regression (IV)

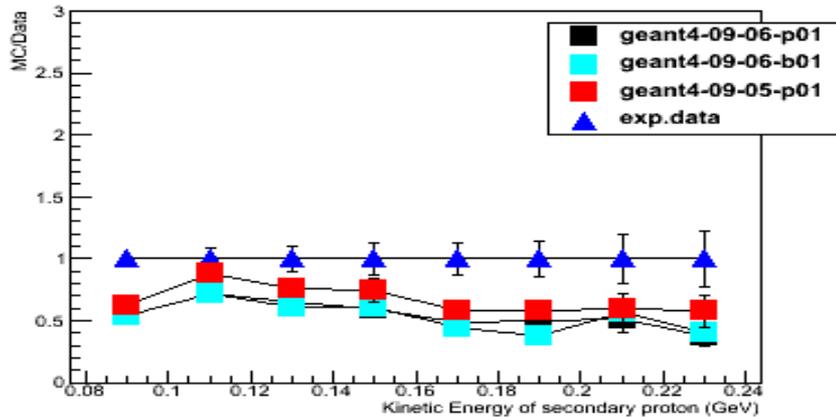
piminus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



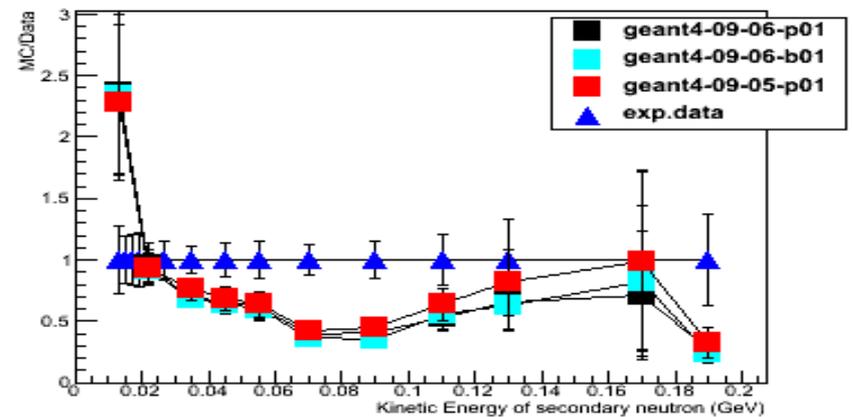
piminus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piminus+C to p at 5.00 GeV (bertini) ($\theta = 119.00$)

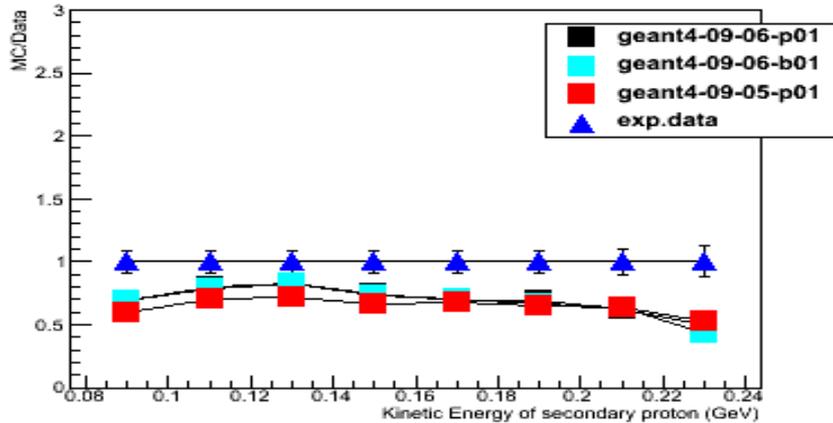


piminus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

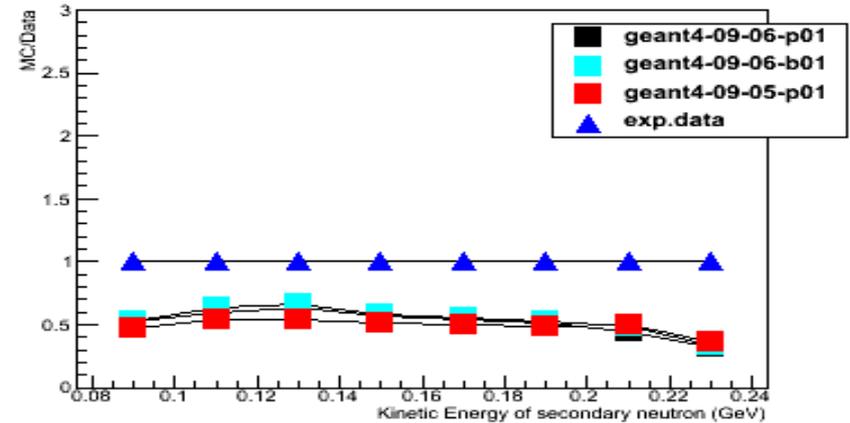


Test47: Bertini Regression (V)

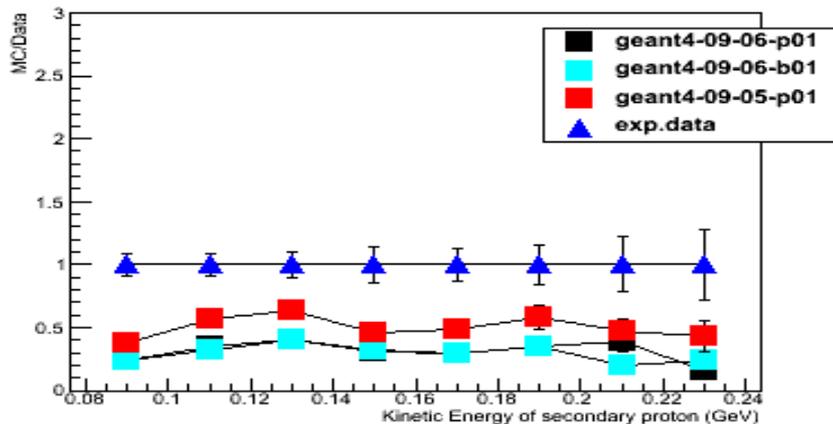
piplus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



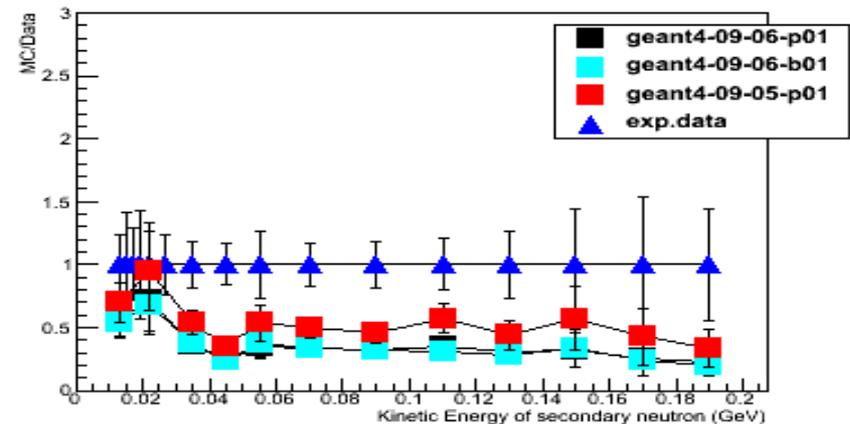
piplus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piplus+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

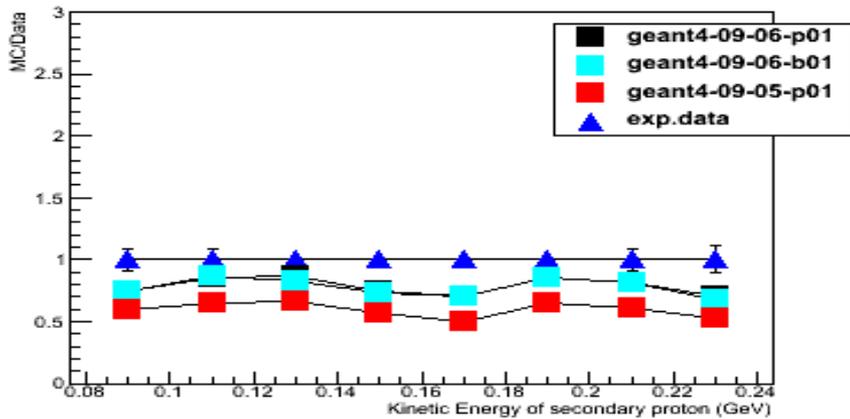


piplus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

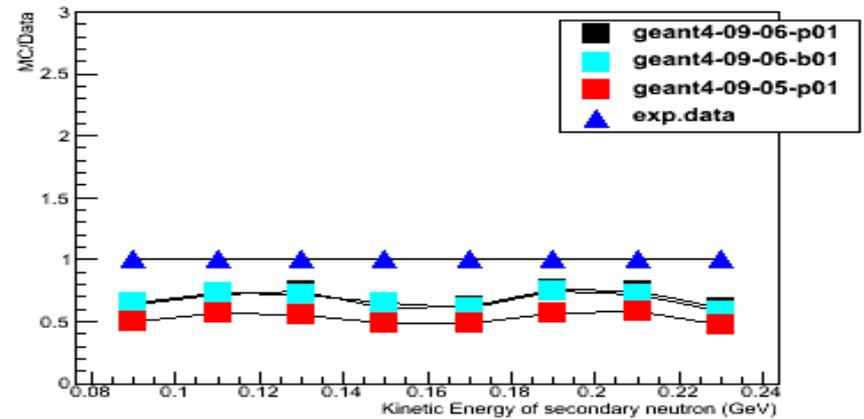


Test47: Bertini Regression (VI)

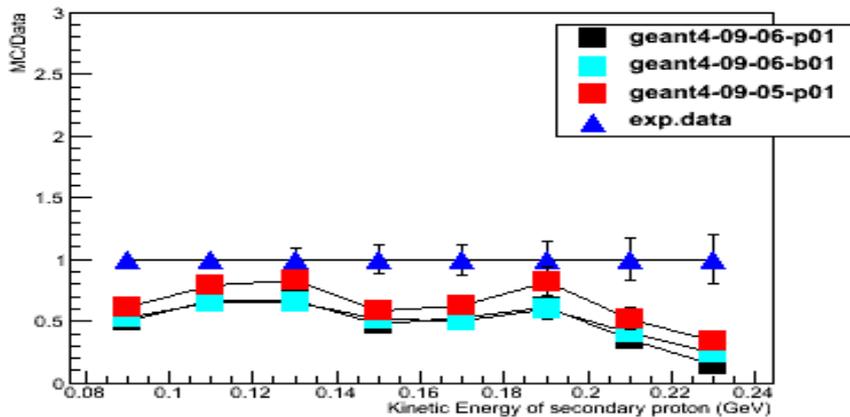
piplus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



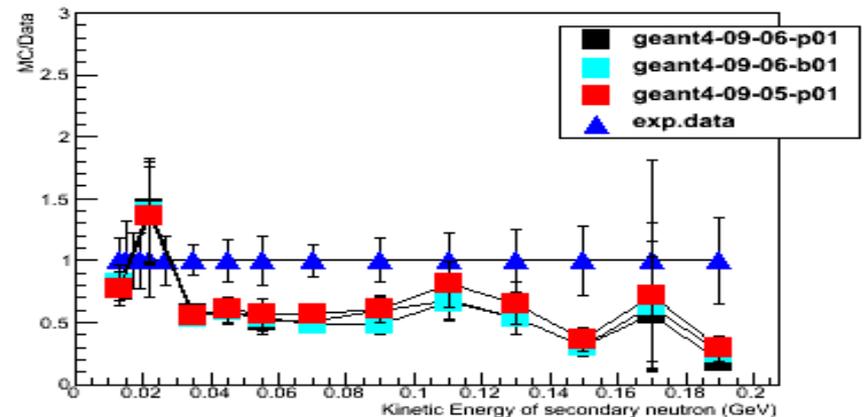
piplus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+C to p at 5.00 GeV (bertini) ($\theta = 119.00$)

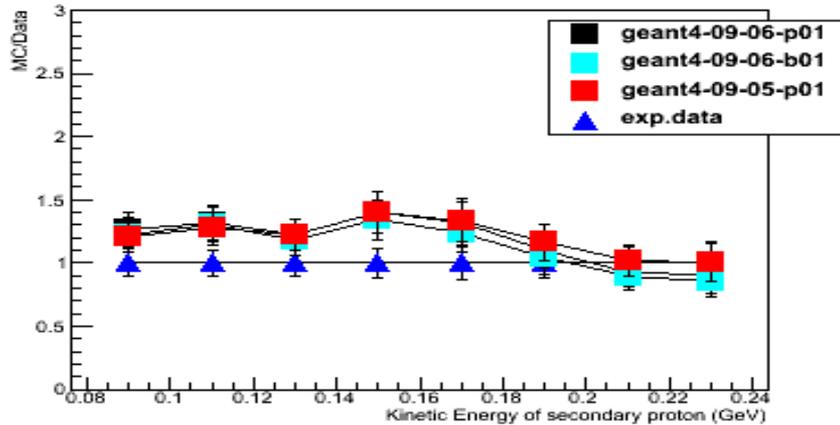


piplus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

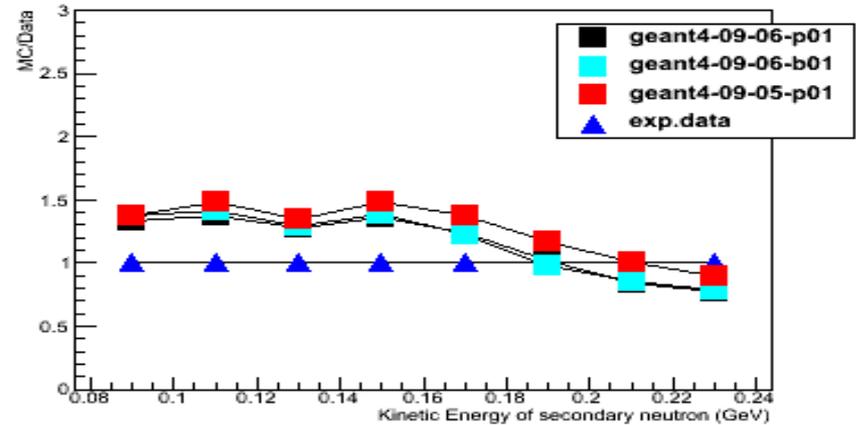


Test47: Bertini Regression (VII)

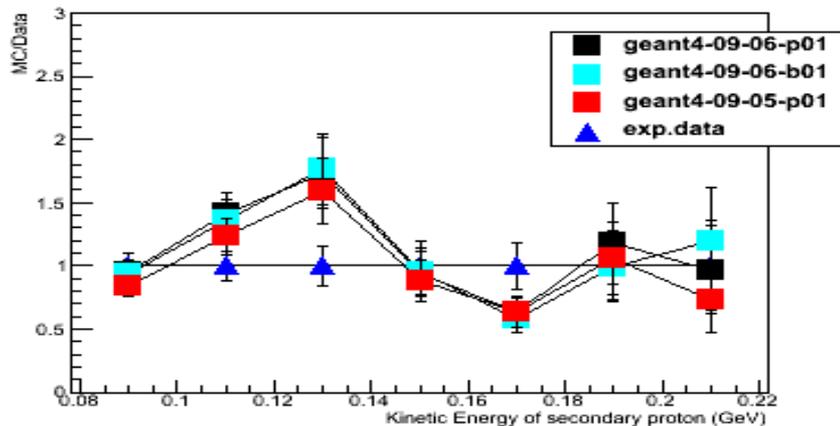
proton+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



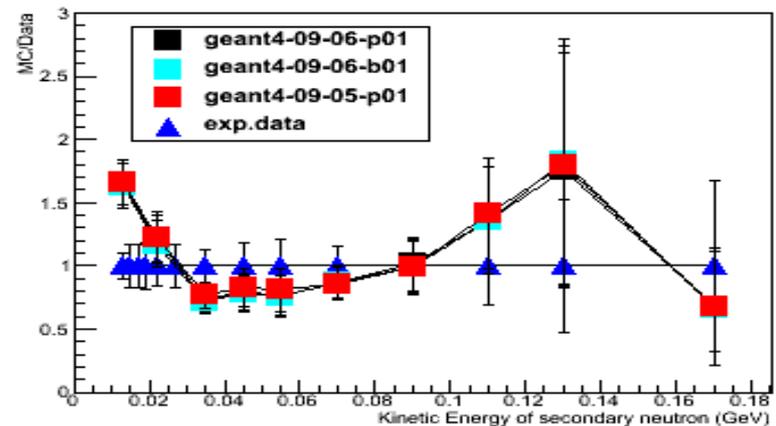
proton+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



proton+U to p at 1.40 GeV (bertini) ($\theta = 119.00$)

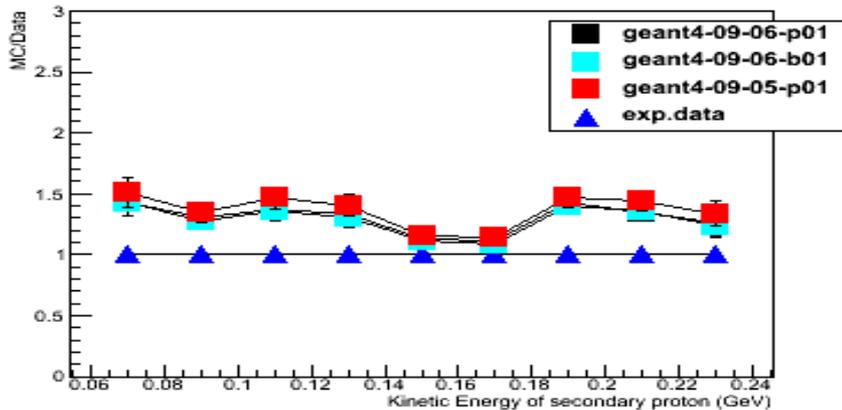


proton+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

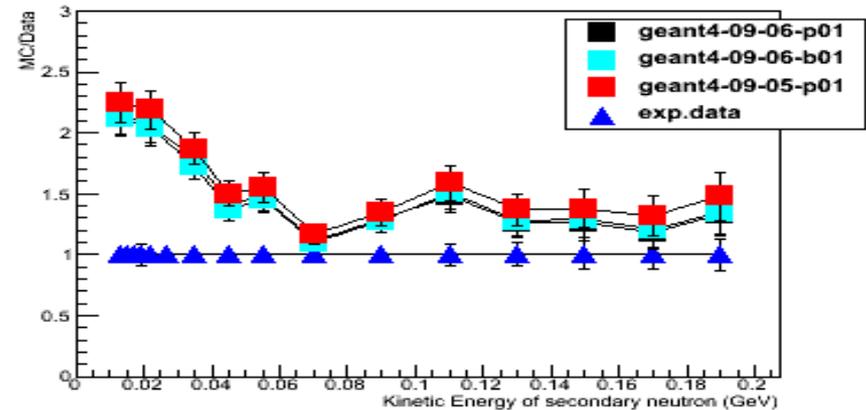


Test47: Bertini Regression (VIII)

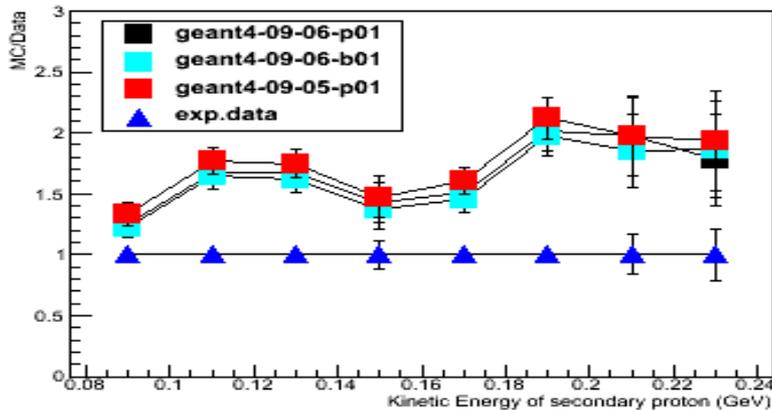
proton+U to p at 7.50 GeV (bertini) ($\theta = 59.10$)



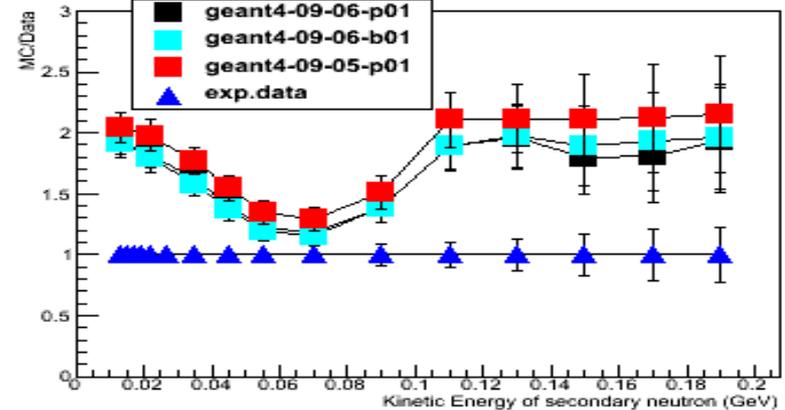
proton+U to n at 7.50 GeV (bertini) ($\theta = 59.10$)



proton+U to p at 7.50 GeV (bertini) ($\theta = 119.00$)

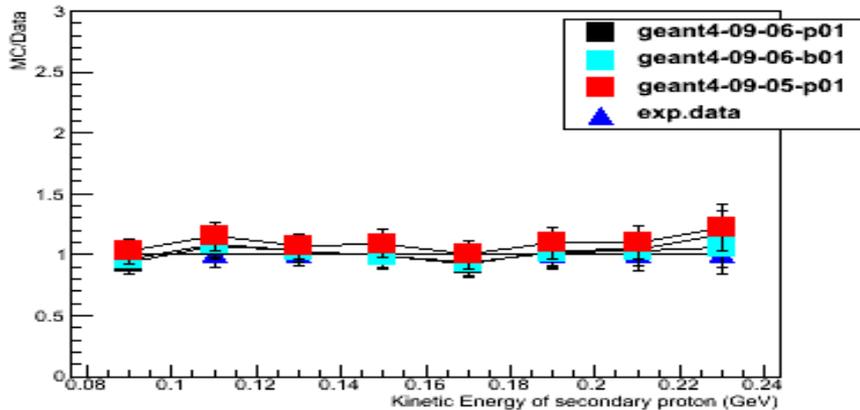


proton+U to n at 7.50 GeV (bertini) ($\theta = 119.00$)

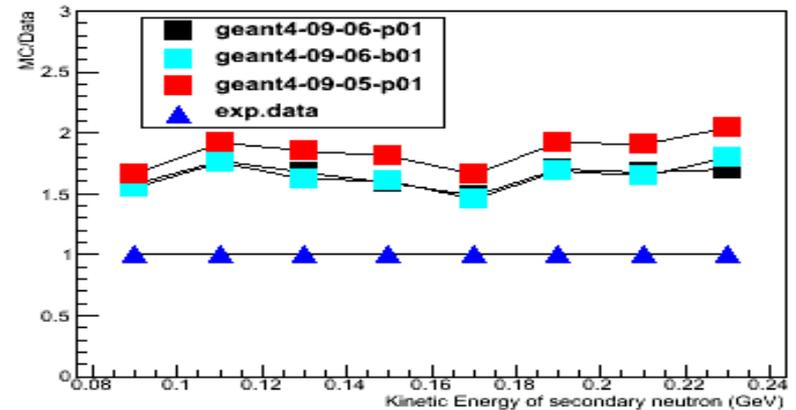


Test47: Bertini Regression (IX)

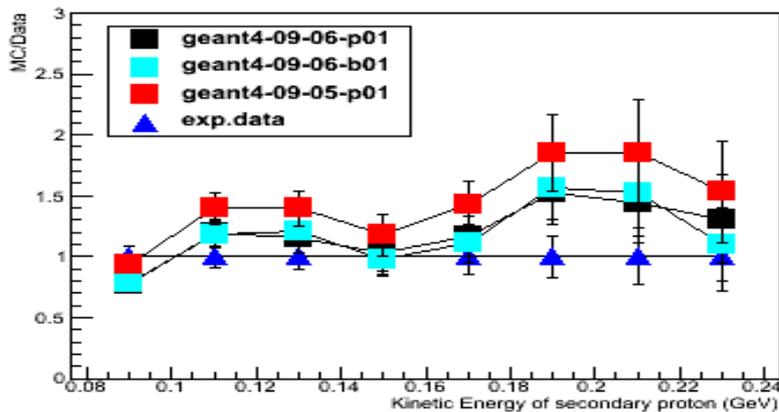
piminus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



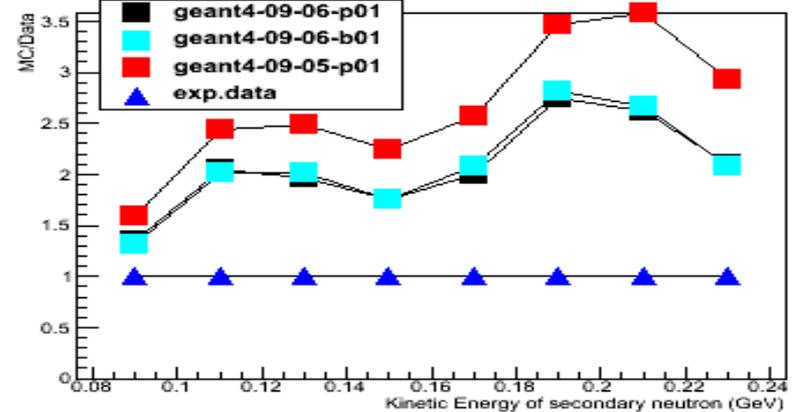
piminus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piminus+U to p at 1.40 GeV (bertini) ($\theta = 119.00$)

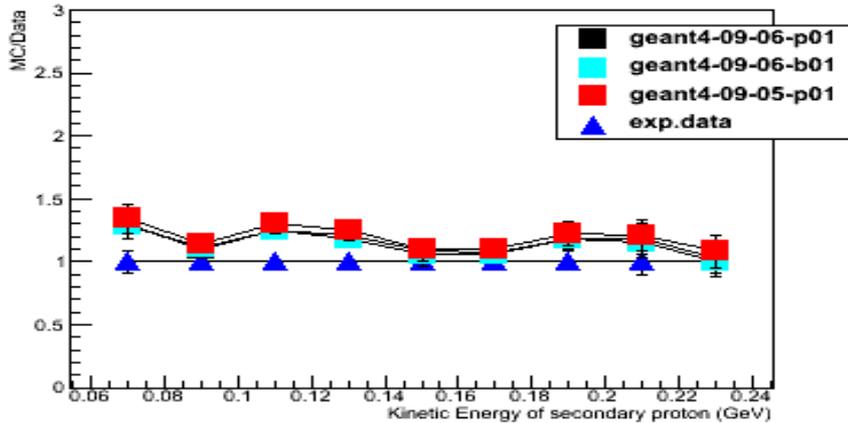


piminus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

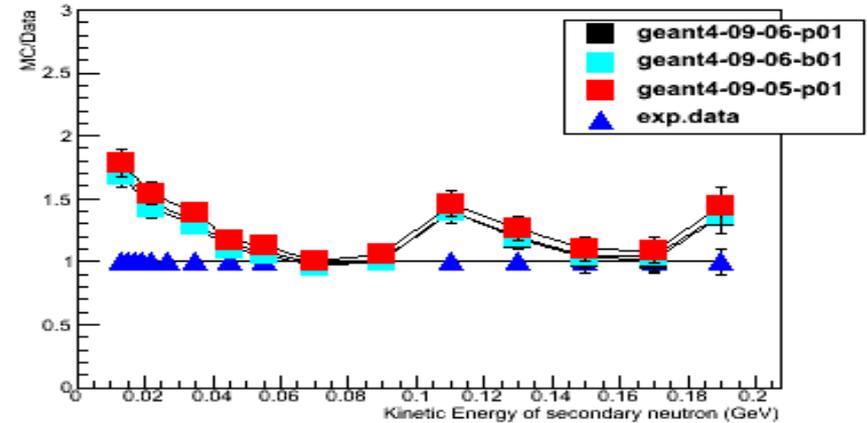


Test47: Bertini Regression (X)

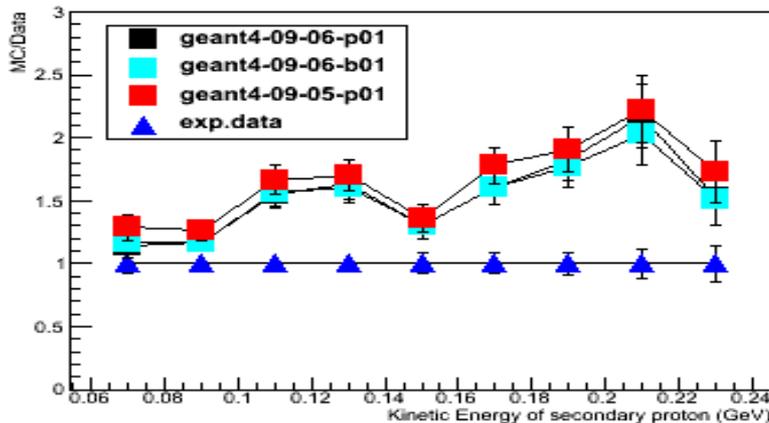
piminus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



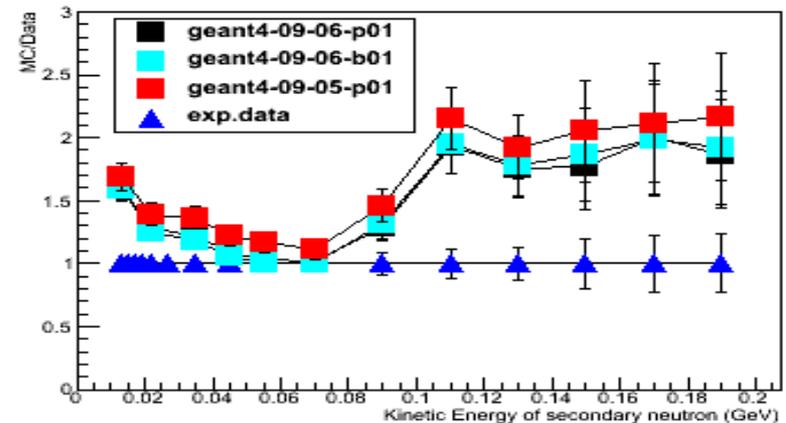
piminus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piminus+U to p at 5.00 GeV (bertini) ($\theta = 119.00$)

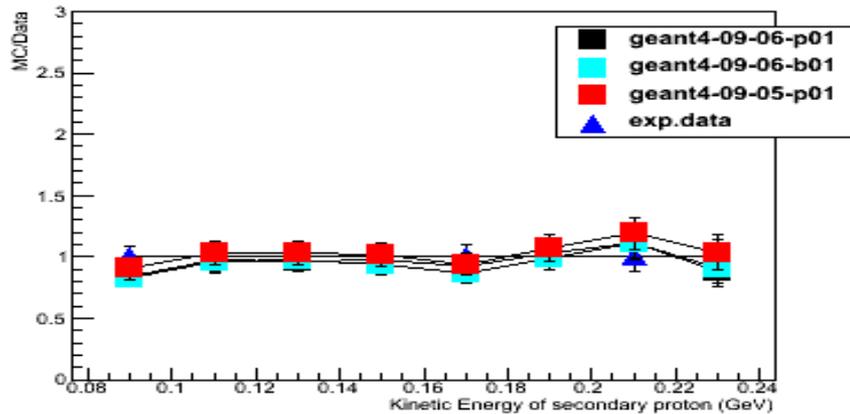


piminus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

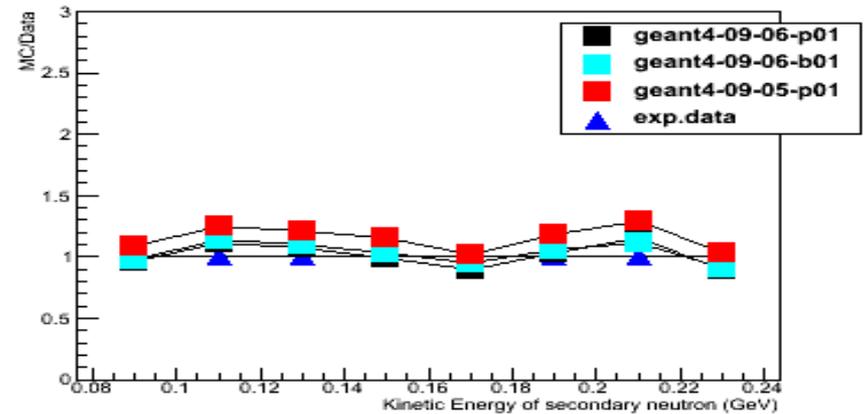


Test47: Bertini Regression (XI)

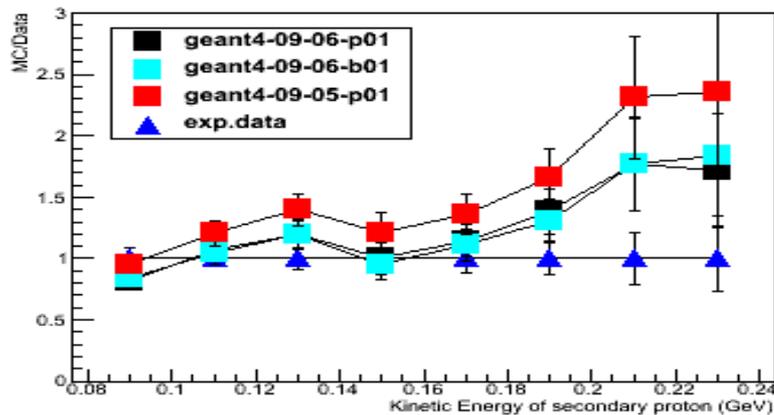
piplus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



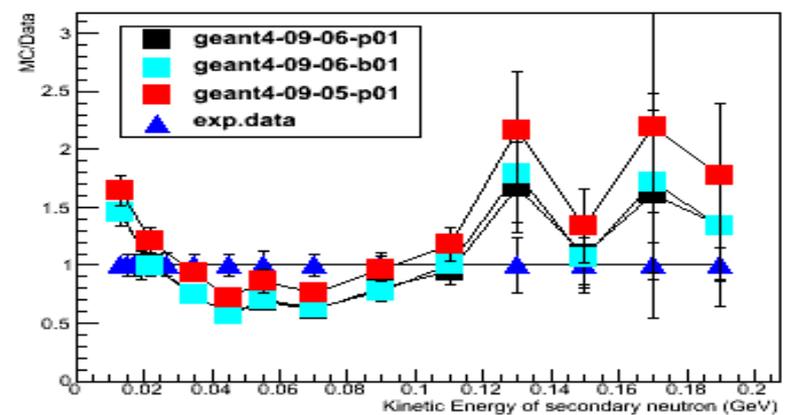
piplus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



piplus+U to p at 1.40 GeV (bertini) ($\theta = 119.00$)

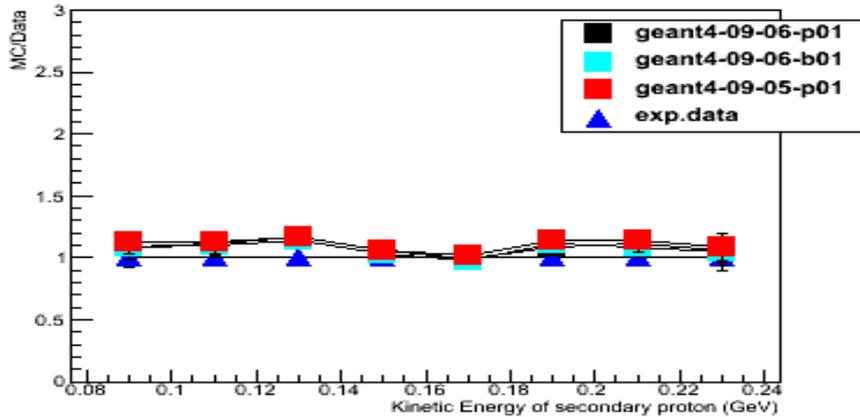


piplus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

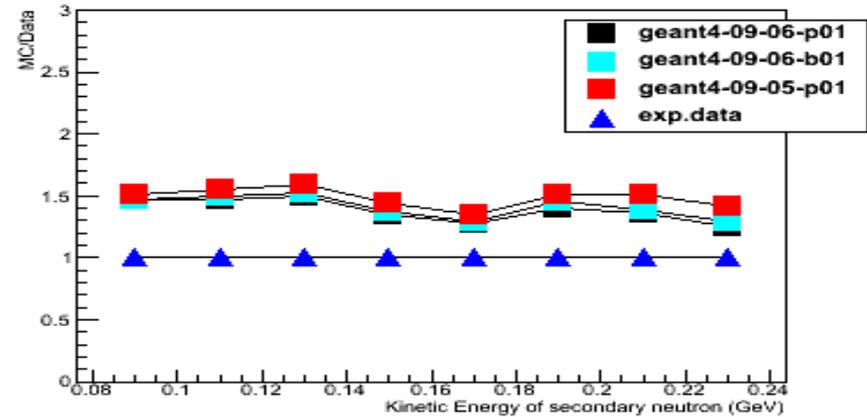


Test47: Bertini Regression (XII)

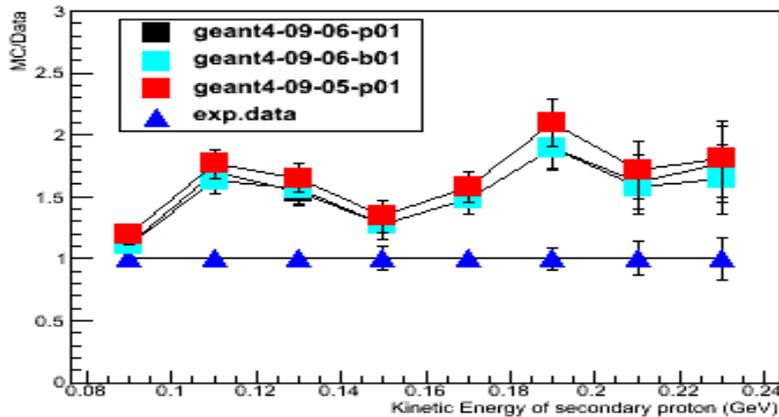
piplus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



piplus+U to p at 5.00 GeV (bertini) ($\theta = 119.00$)



piplus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

