

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:** π^- , K^- , Σ^- , $pbar$, μ^- (**new - w/K.Genser**)
- **Data sets:**
 - R.Madey et al., Phys.Rev.C25,3050(1982) (π^-)
 - 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 (Σ^-))
 - 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) (μ^-)
 - R.M.Sundelin et. Al., Phys.Rev.Lett., Vol.20, Number 21, 1198 (1968) (μ^-)
- **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)

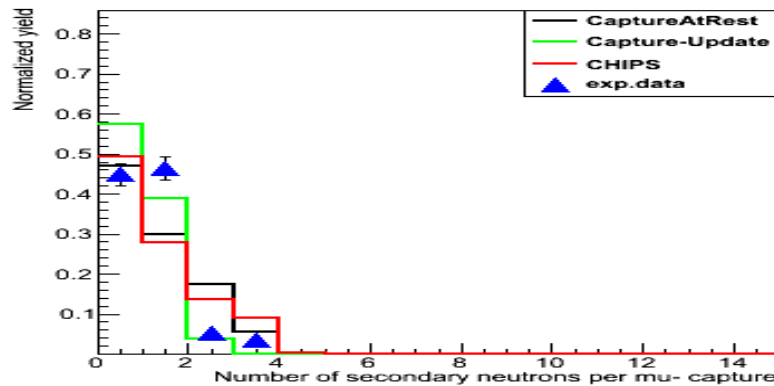
- Regression tests show small variation in Bertini for π^- on various targets; agreement with data better than CHIPS results (see backup slides)
- No changes between 9.6.b01 and 9.6.p01 in modeling K- and Sigma- capture on H by Bertini (not available in 9.5.p01); good agreement with data by Bertini (see 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)

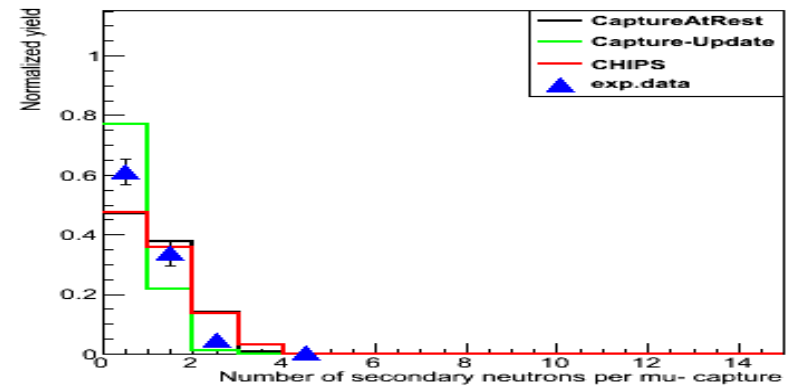
mu- on various targets

secondary neutrons multiplicity

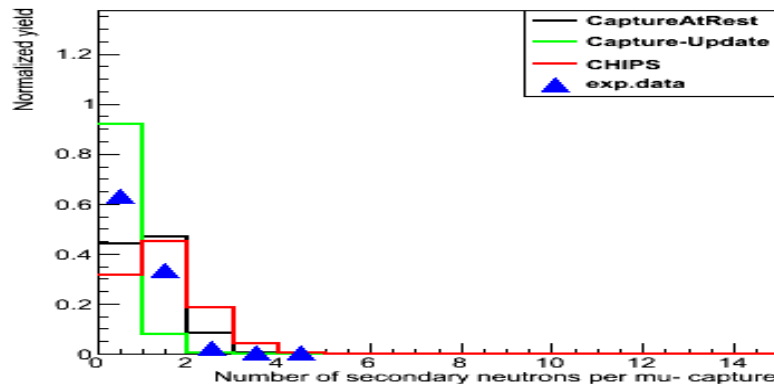
mu- on Al



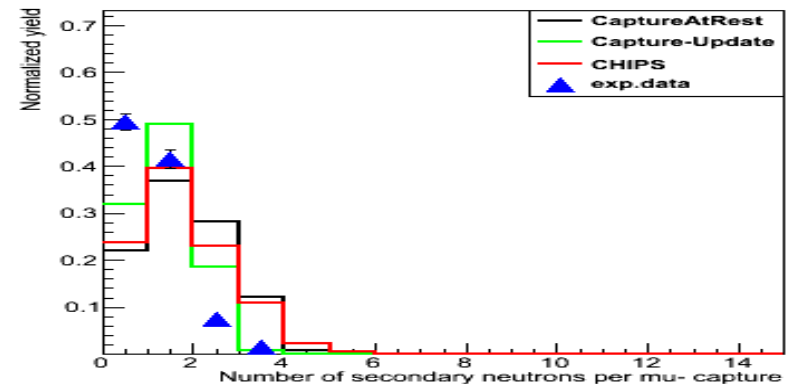
mu- on Si



mu- on Ca

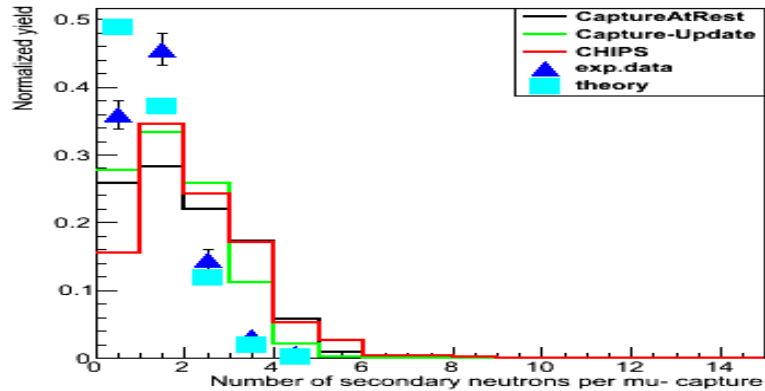


mu- on Fe

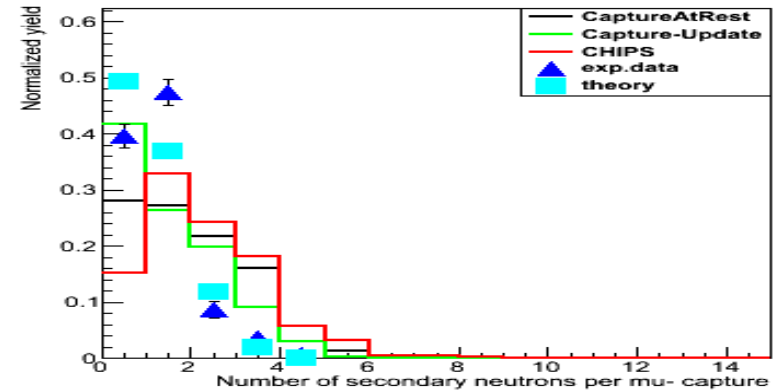


Test48: Results(III) mu- on various targets secondary neutrons multiplicity (cont.)

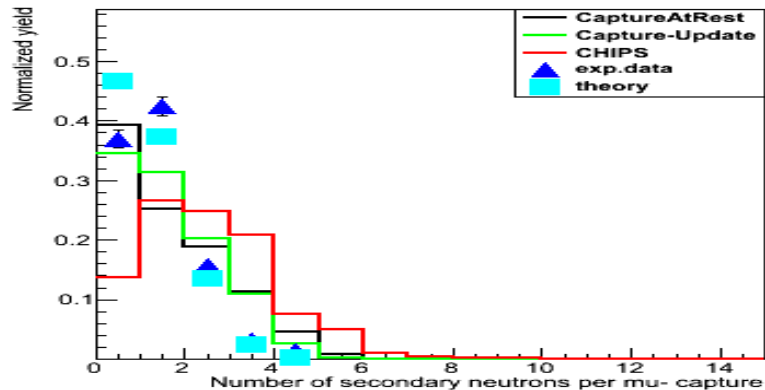
mu- on Ag



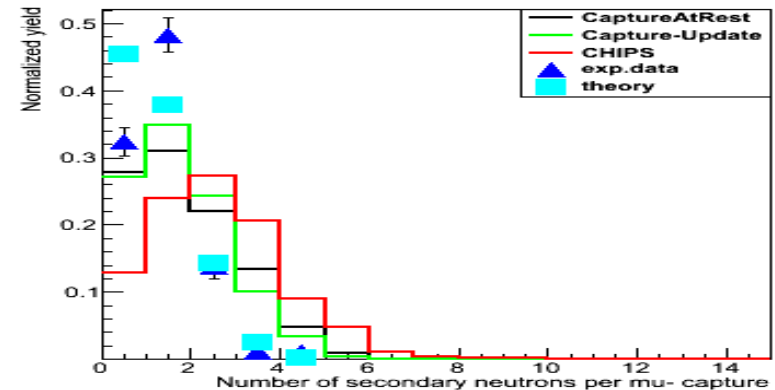
mu- on I



mu- on Au

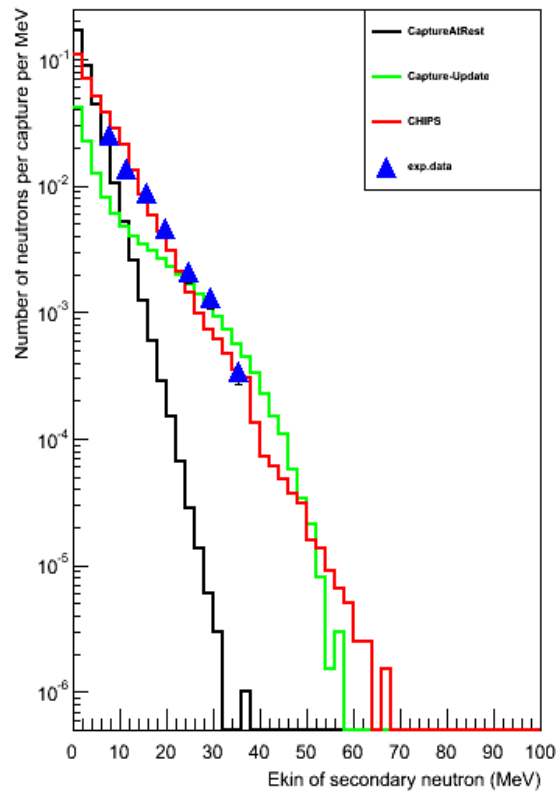


mu- on Pb

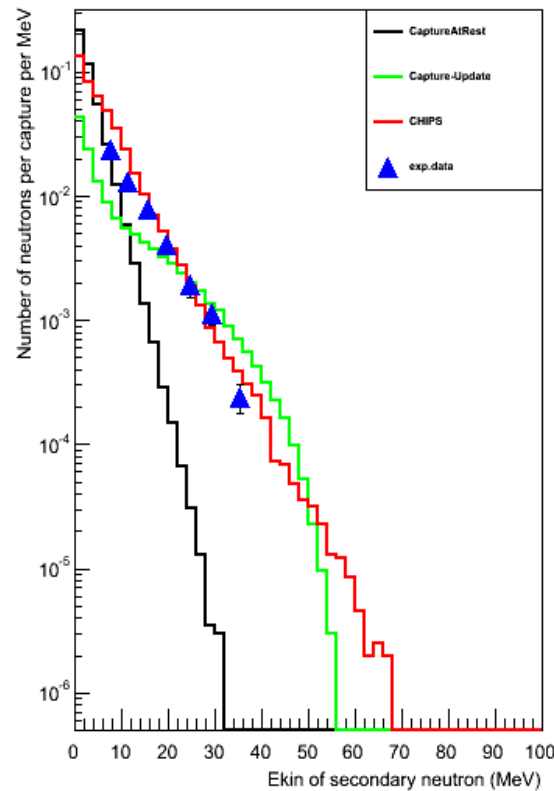


Test48: Results(III) mu- on various targets kinetic energy of secondary neutron

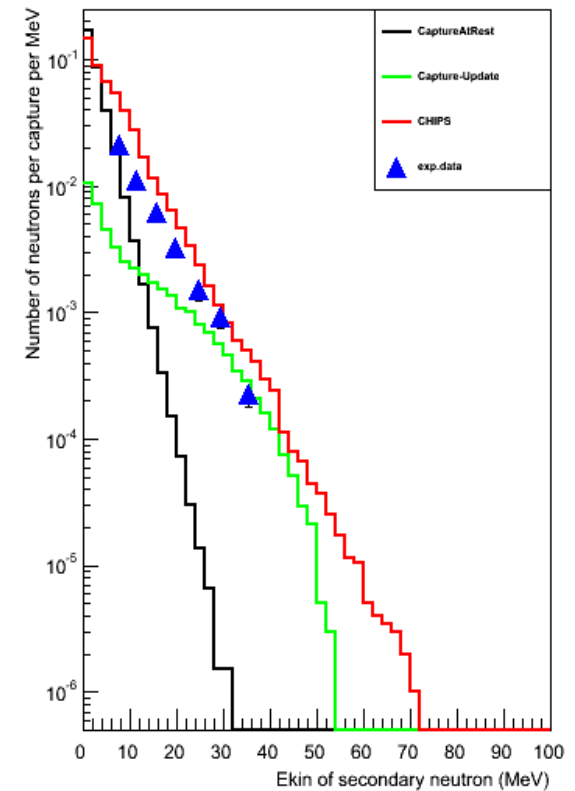
mu- on Si



mu- on S



mu- on Ca





Test48: Summary

- Bertini successfully replaces CHIPS and/or “traditional” code to model π^- , 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

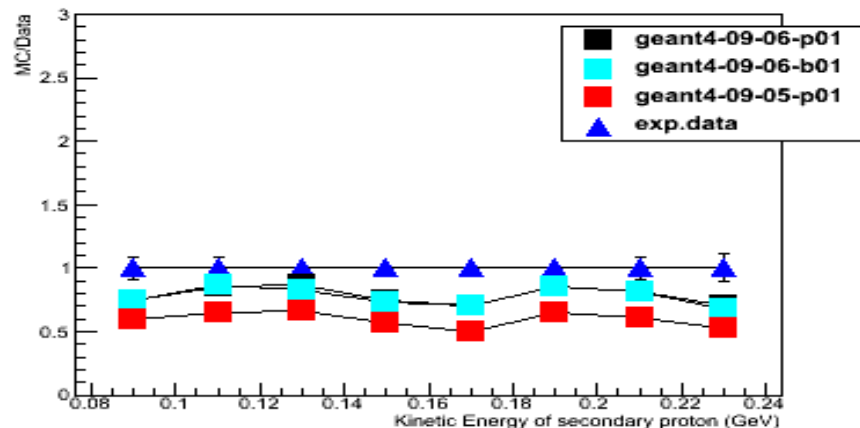


Test47: Results(I)

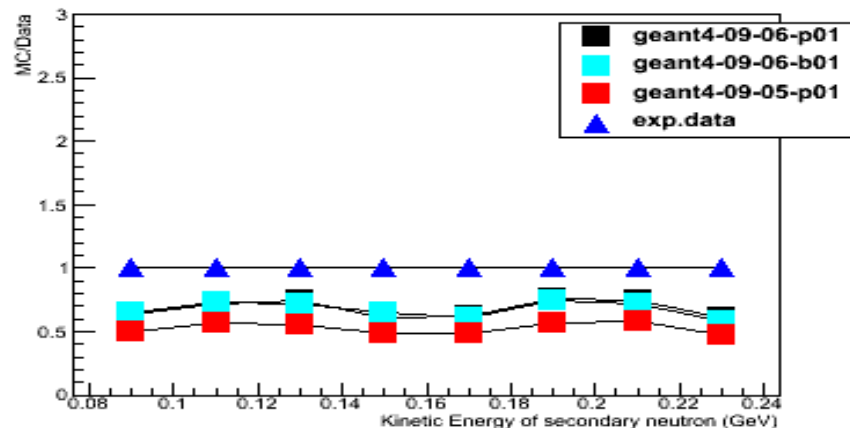
- Model comparison plots in backup (to save space/time)
- At 1.4GeV Bertini and Binary are two main players
- At 5-7.5GeV Bertini and/or FTF(P) is/are a reasonable choice
- Regression tests show improvements in Bertini vs 9.5.p01, but slight degradation in some cases in bck hemisphere; stable between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

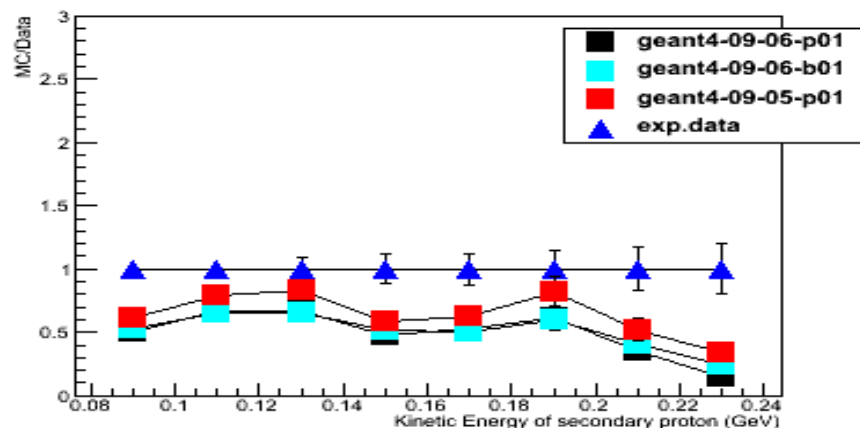
piplus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



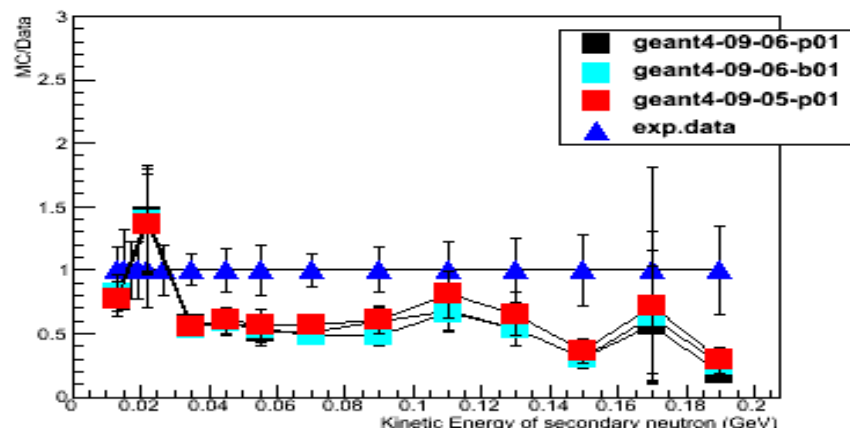
piplus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

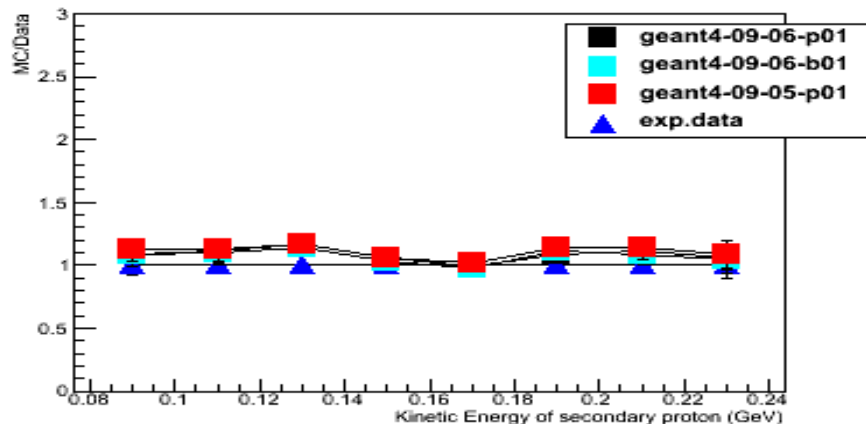


piplus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

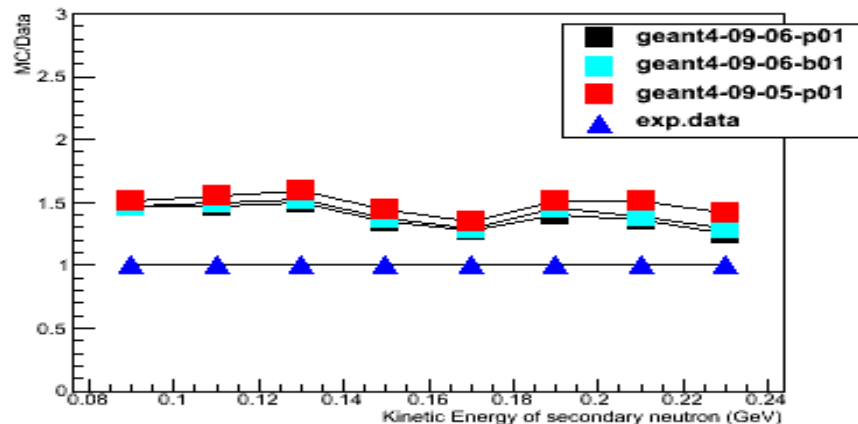


Test47: Results(III) - Bertini

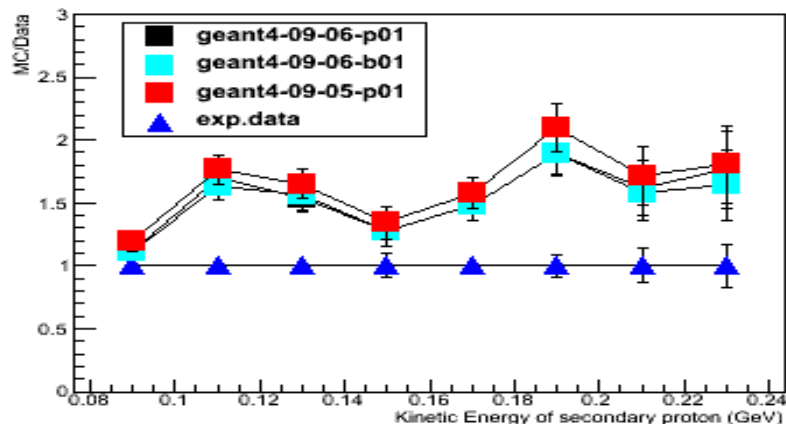
piplus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



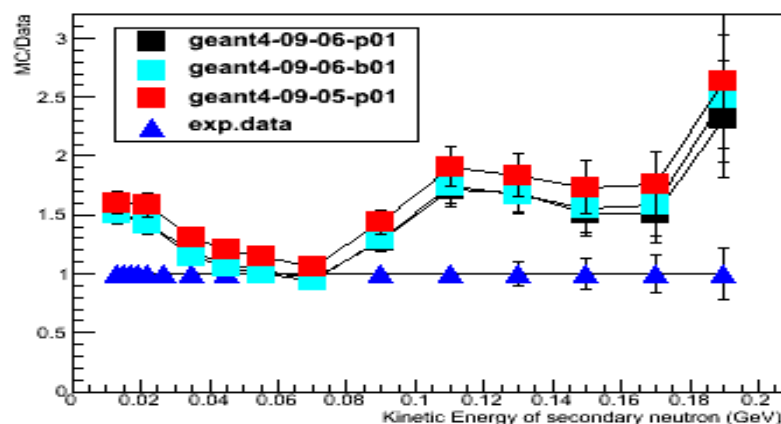
piplus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

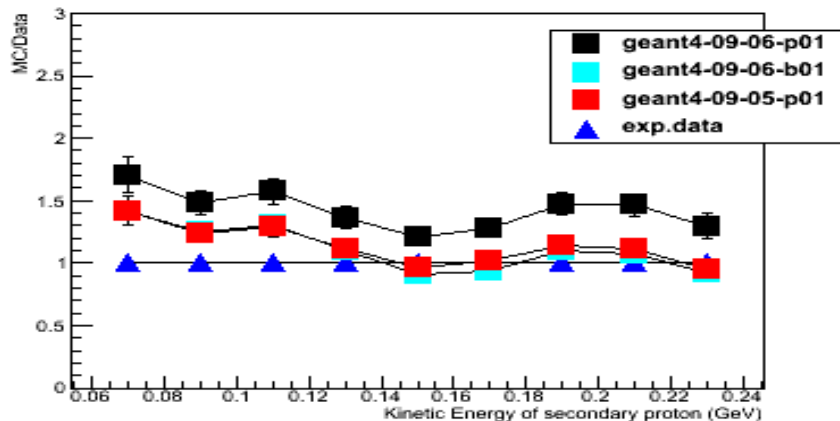


piplus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

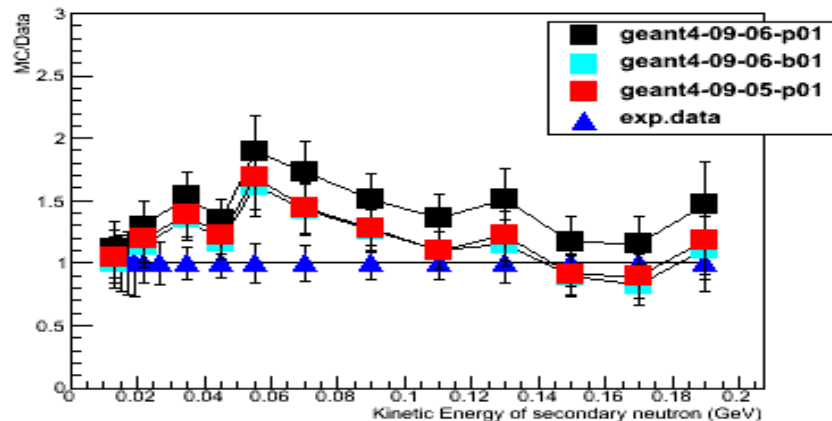


Test47: Results(IV) - FTF(P)

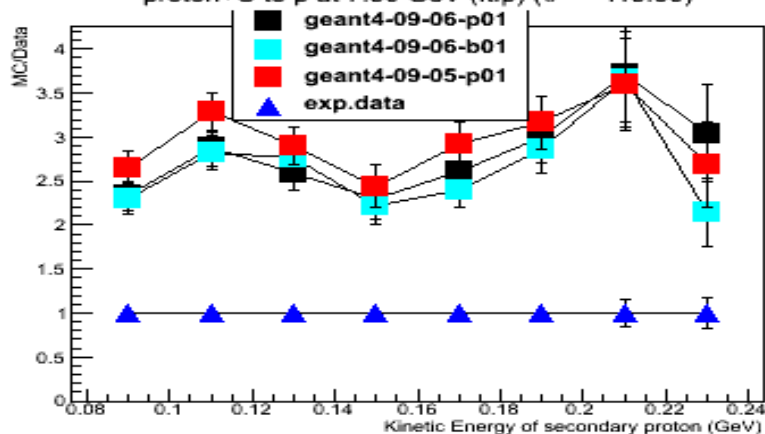
proton+C to p at 7.50 GeV (ftfp) ($\theta = 59.10$)



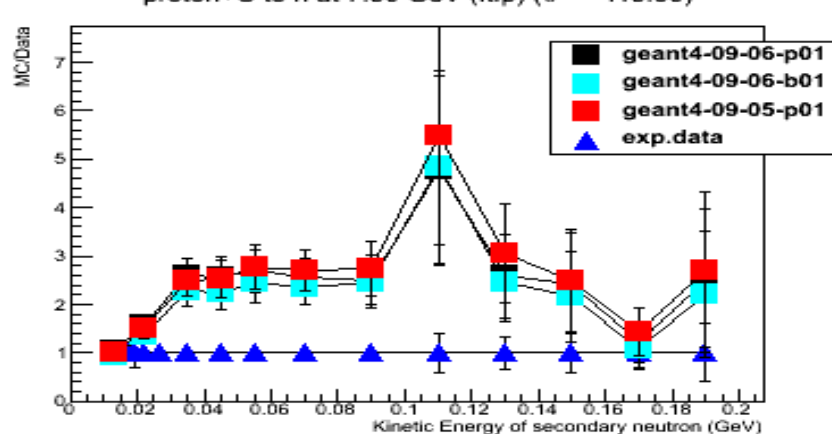
proton+C to n at 7.50 GeV (ftfp) ($\theta = 59.10$)



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

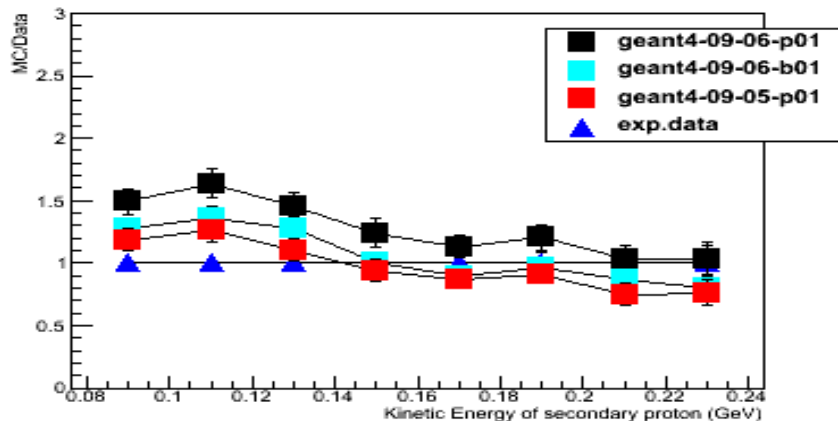


proton+C to n at 7.50 GeV (ftfp) ($\theta = 119.00$)

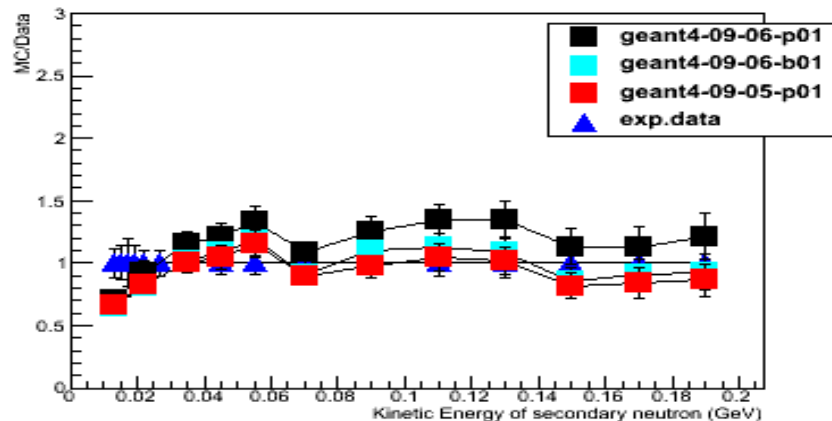


Test47: Results(V) – FTF(P)

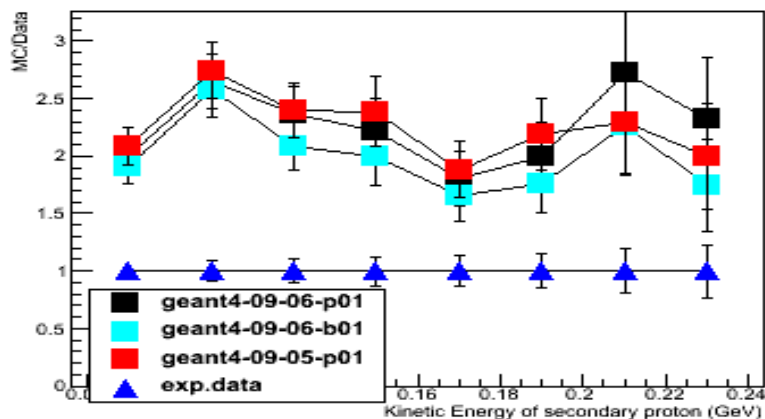
pimicus+C to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



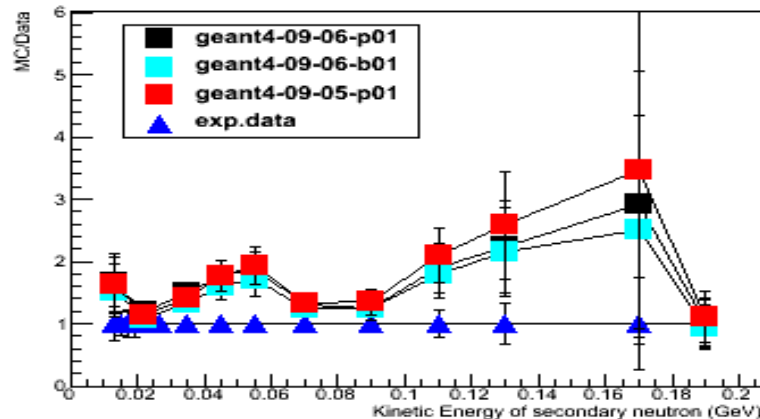
pimicus+C to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



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

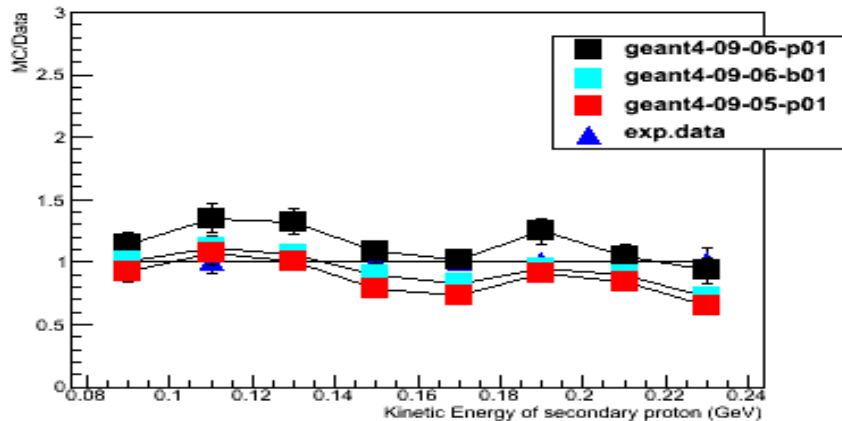


pimicus+C to n at 5.00 GeV (ftfp) ($\theta = 119.00$)

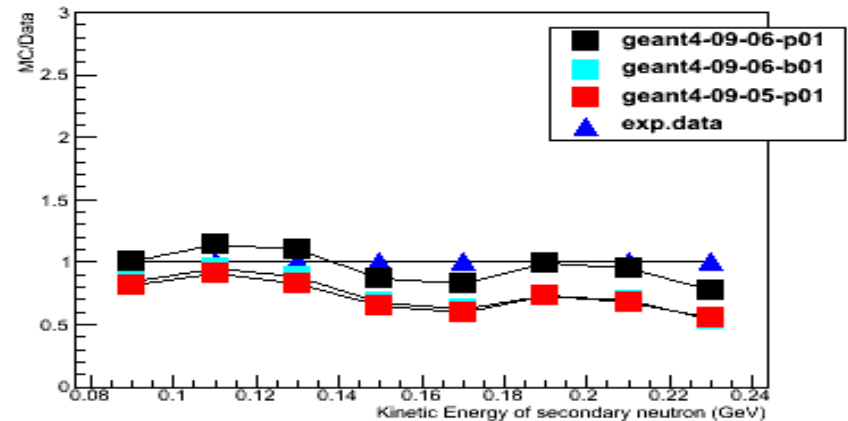


Test47: Results(VI) – FTF(P)

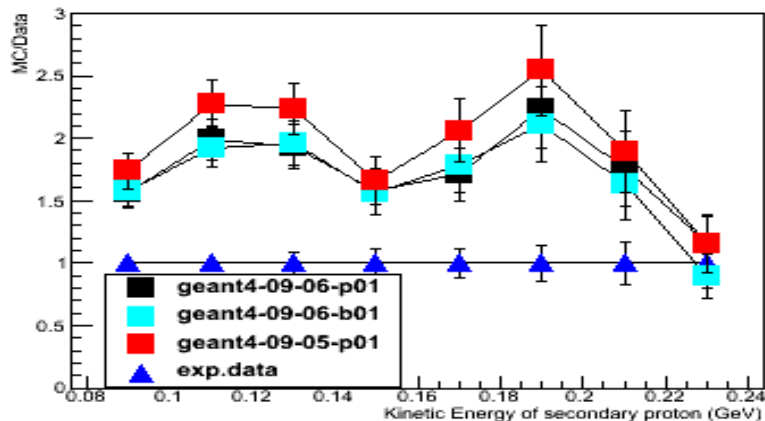
piplus+C to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



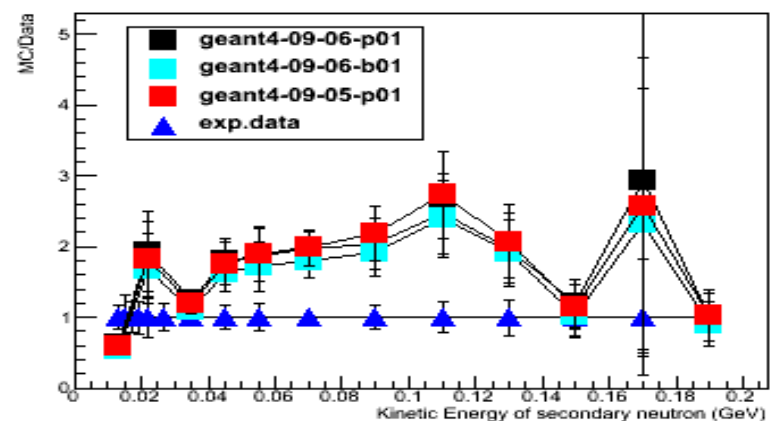
piplus+C to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



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

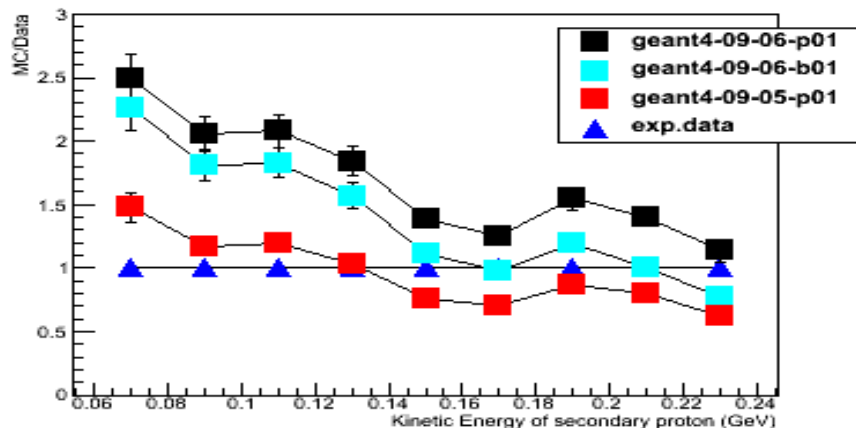


piplus+C to n at 5.00 GeV (ftfp) ($\theta = 119.00$)

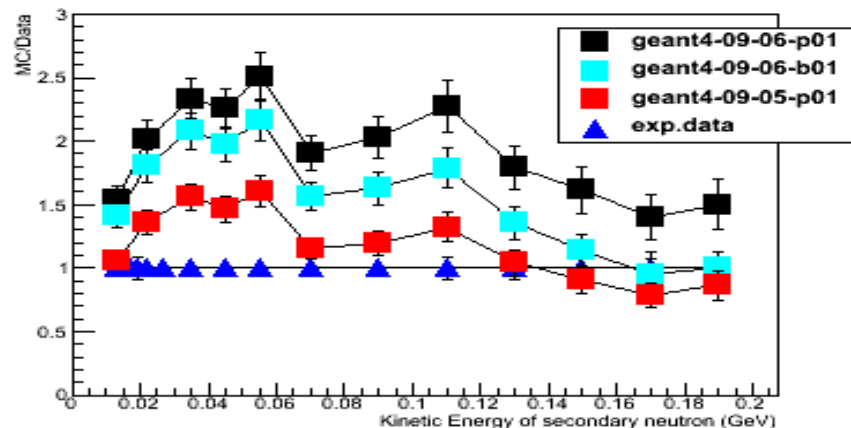


Test47: Results(VII) – FTF(P)

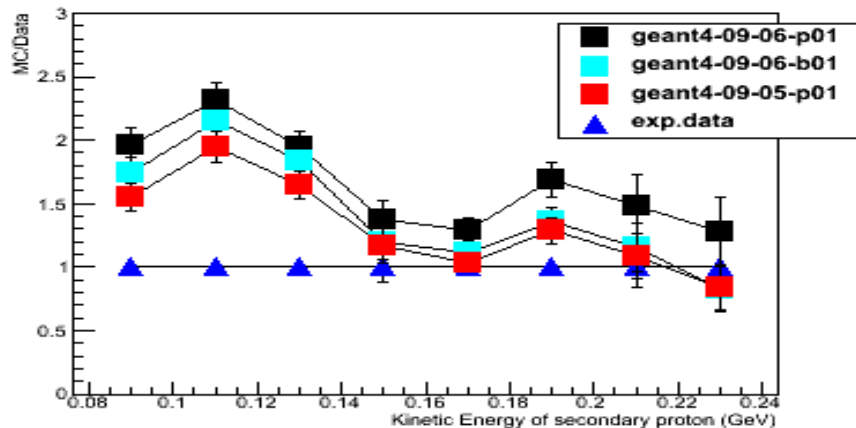
proton+U to p at 7.50 GeV (ftfp) ($\theta = 59.10$)



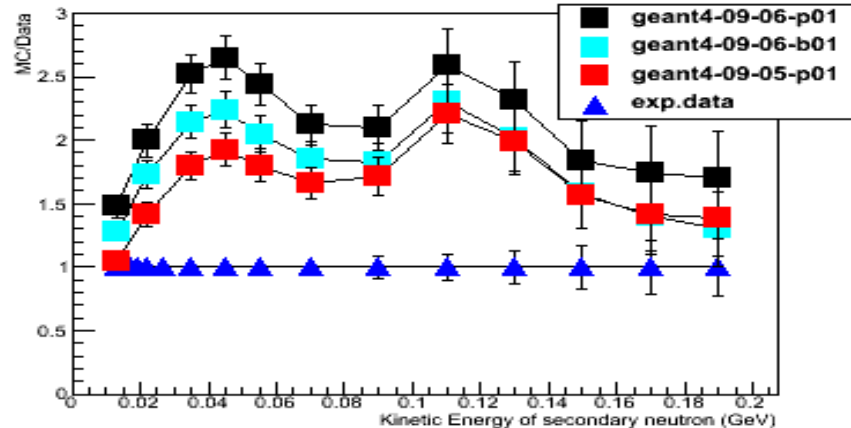
proton+U to n at 7.50 GeV (ftfp) ($\theta = 59.10$)



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

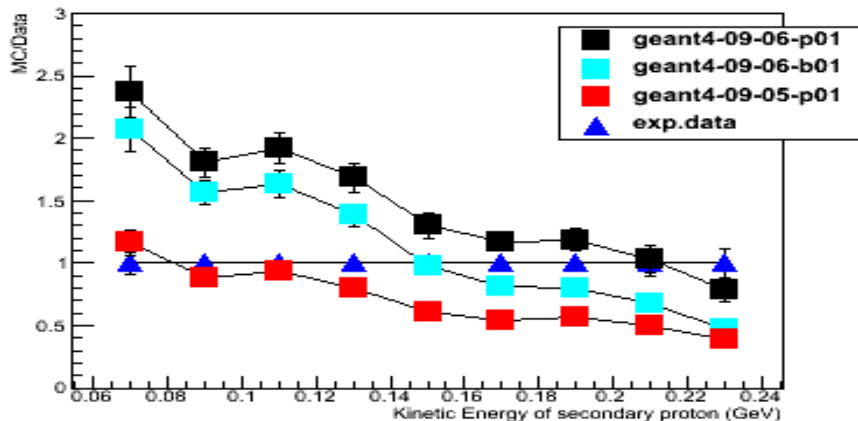


proton+U to n at 7.50 GeV (ftfp) ($\theta = 119.00$)

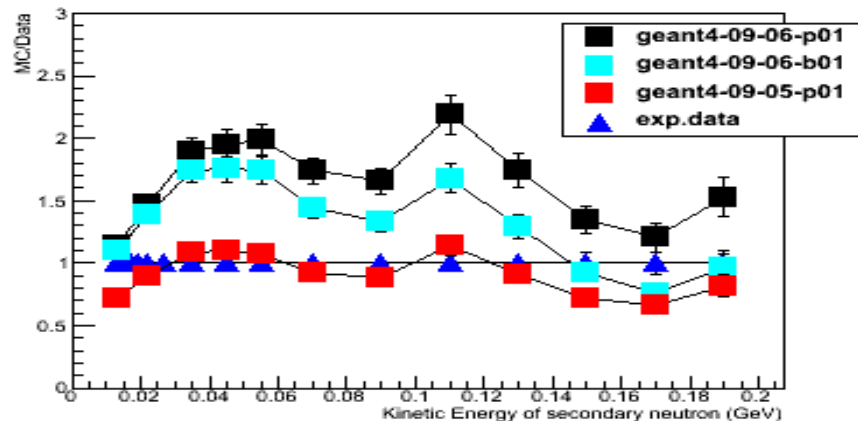


Test47: Results(VIII) – FTF(P)

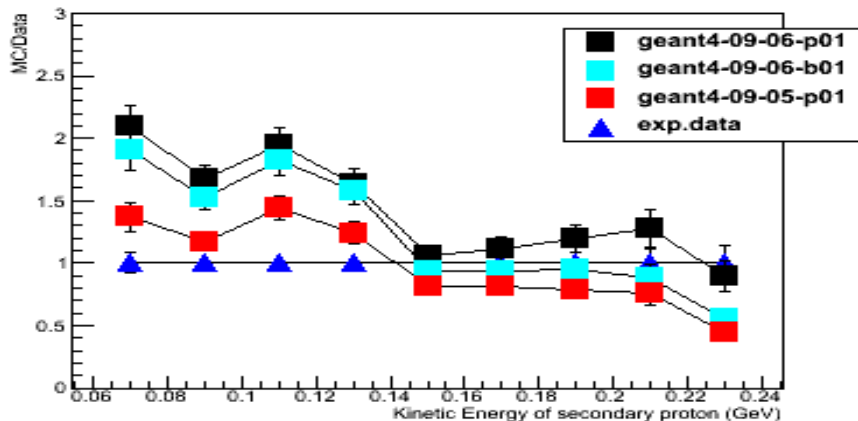
pimino+U to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



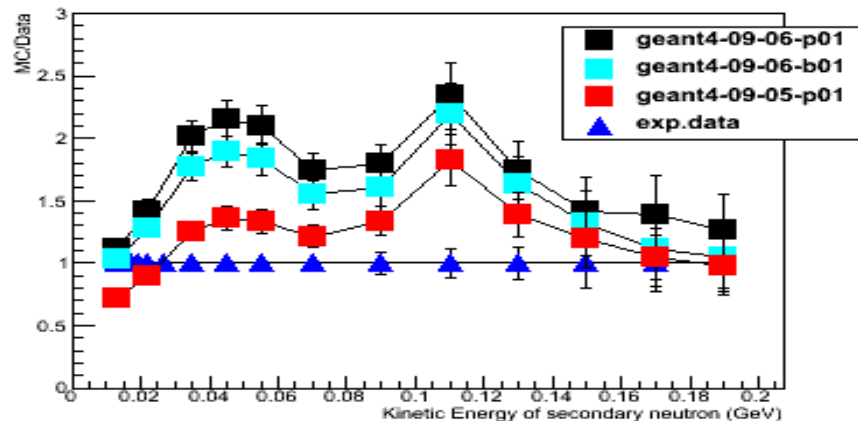
pimino+U to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



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

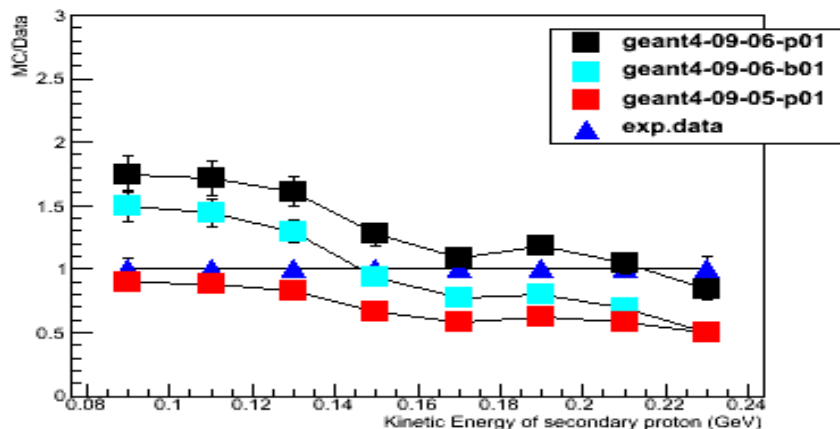


pimino+U to n at 5.00 GeV (ftfp) ($\theta = 119.00$)

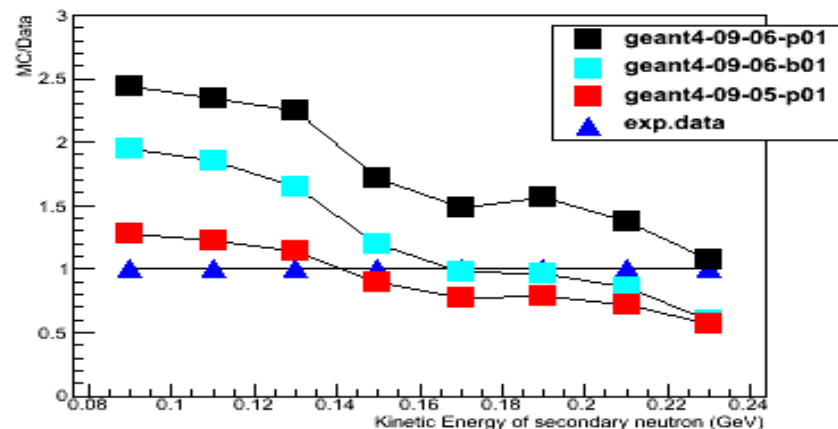


Test47: Results(IX) – FTF(P)

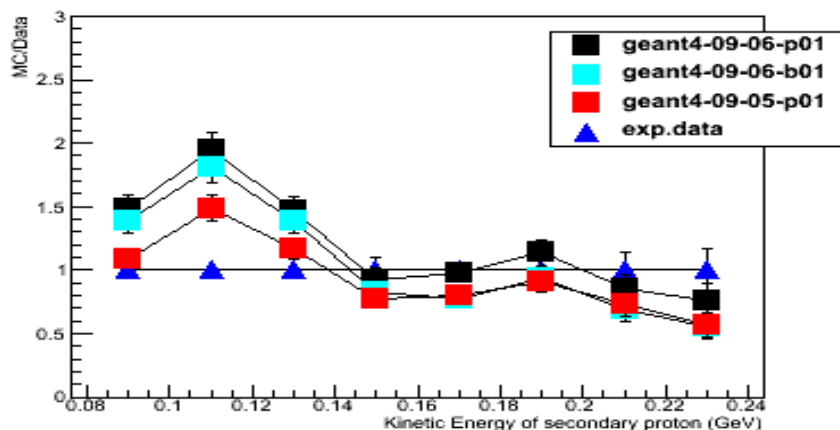
piplus+U to p at 5.00 GeV (ftfp) ($\theta = 59.10$)



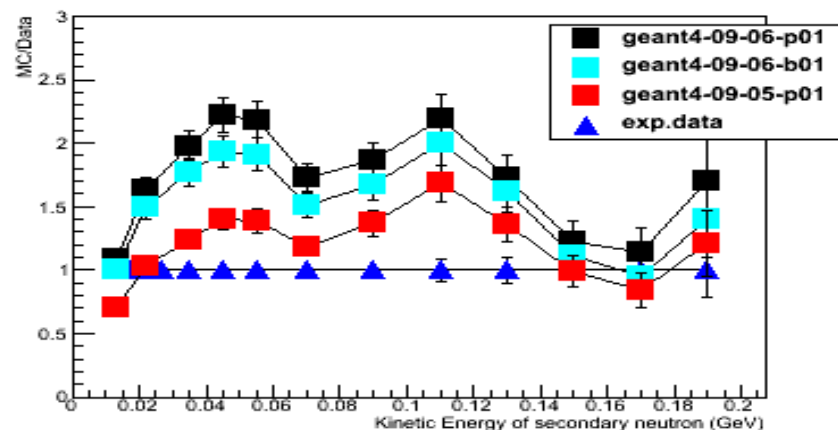
piplus+U to n at 5.00 GeV (ftfp) ($\theta = 59.10$)



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



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





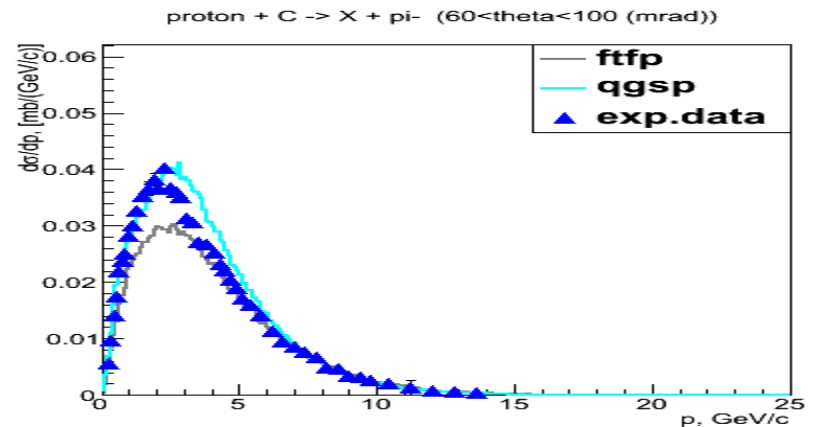
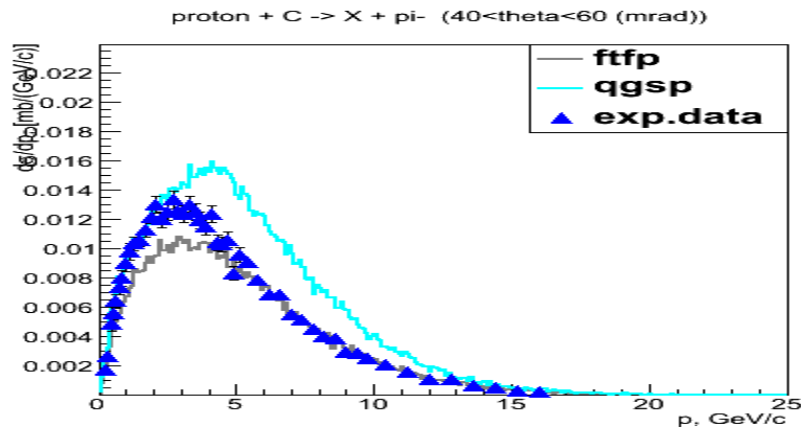
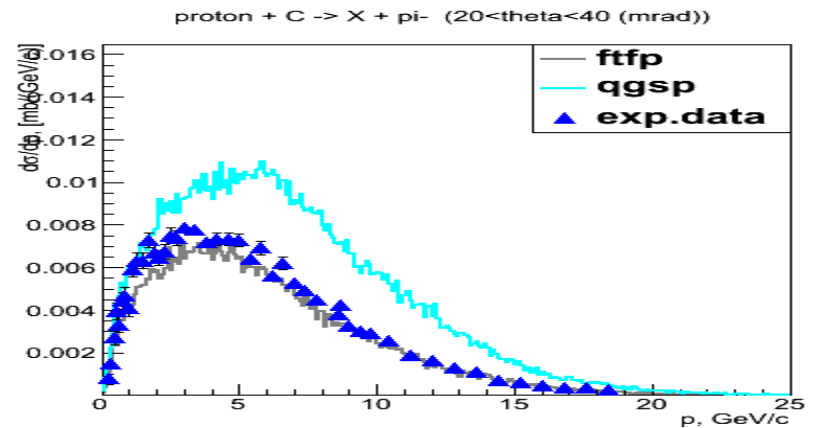
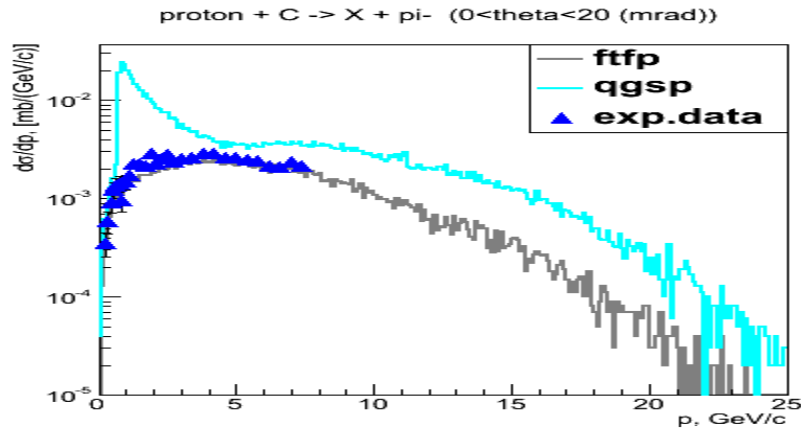
Test47: Summary

- 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 31GeV/c (NA61) and 158GeV/c (NA49)

- **NEW TEST** - WORK IN PROGRESS !!!
- 31GeV 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

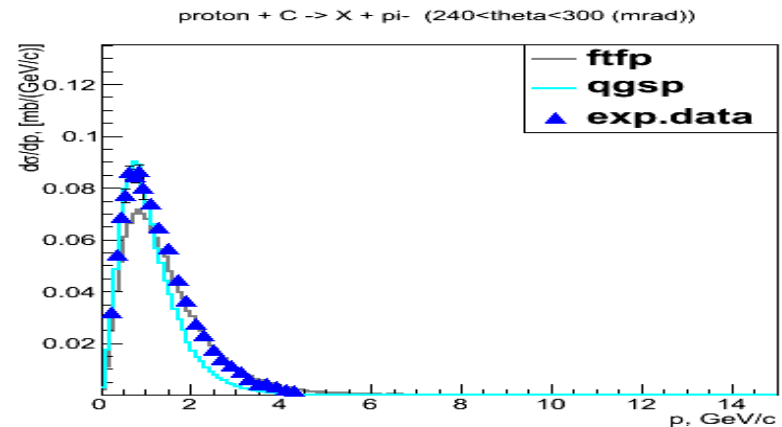
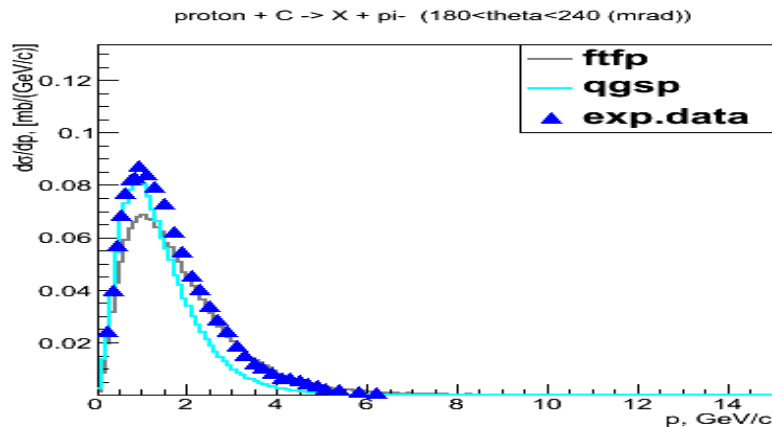
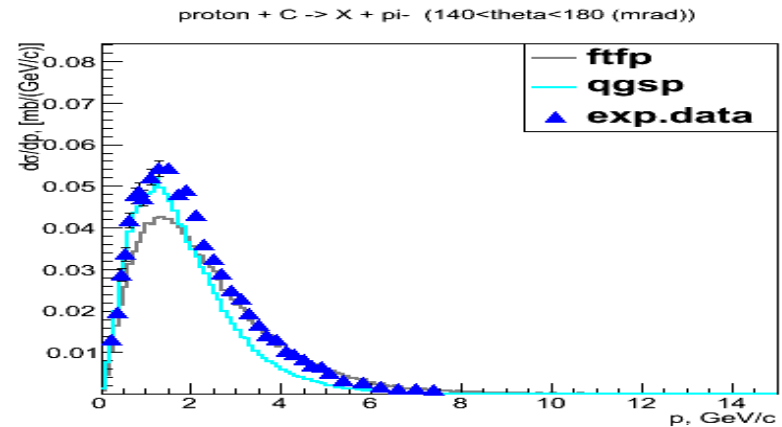
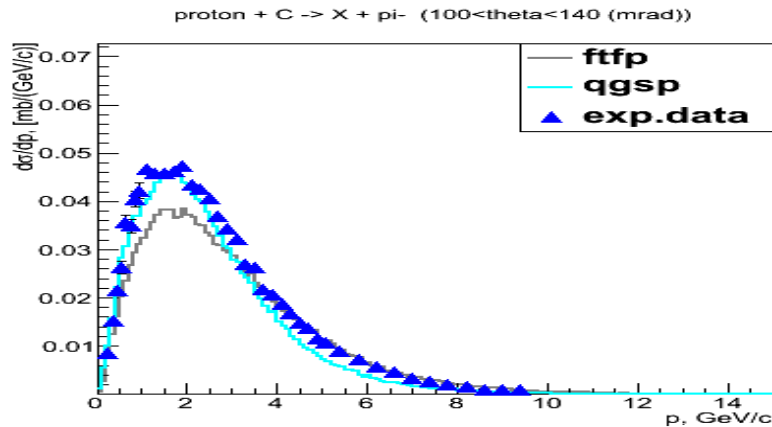
Test19: Results(I) 31GeV p+C secondary pi- momenta in theta bins



Test19: Results(II)

31GeV p+C

secondary pi- momenta in theta bins (cont.)

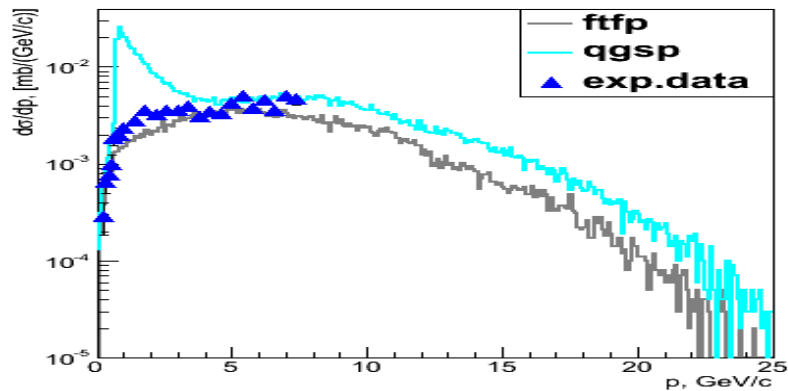


Test19: Results(III)

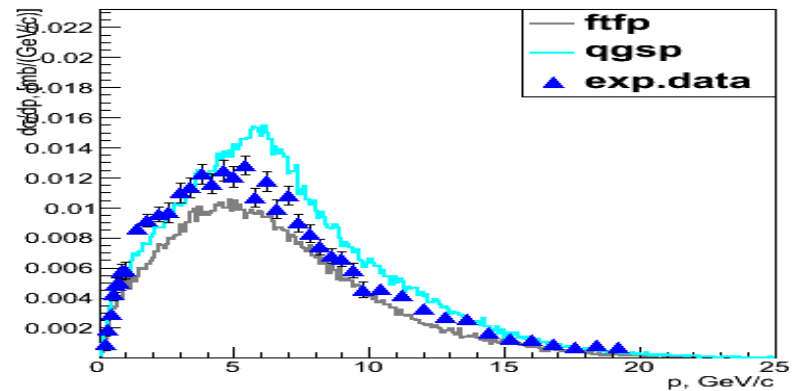
31GeV p+C

secondary pi+ momenta in theta bins

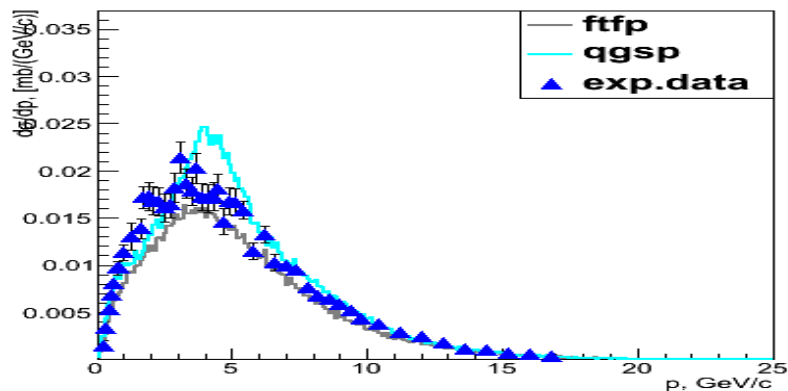
proton + C -> X + pi+ (0<theta<20 (mrad))



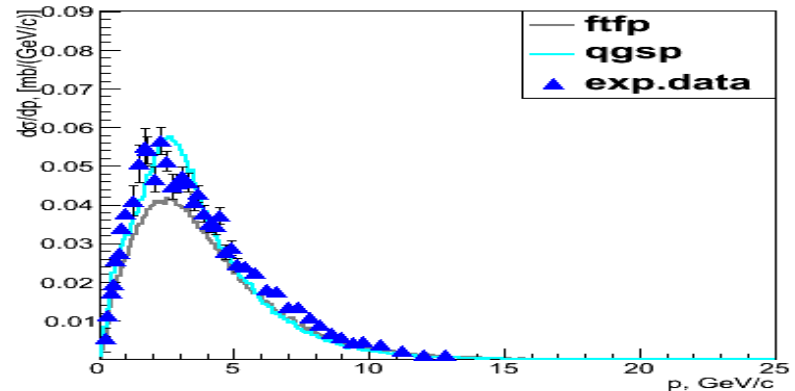
proton + C -> X + pi+ (20<theta<40 (mrad))



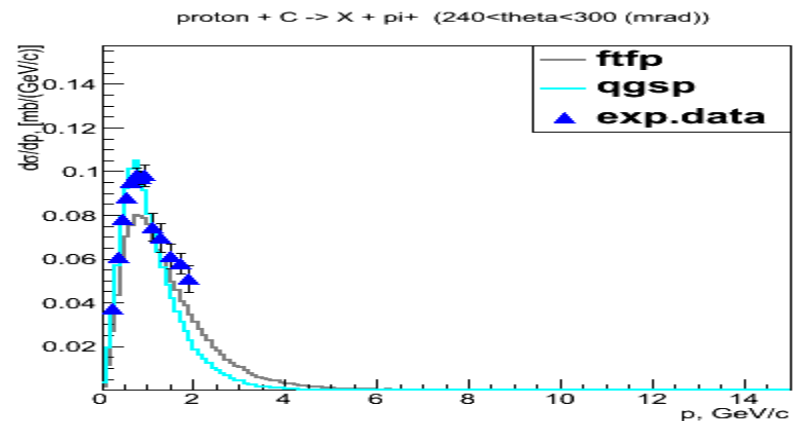
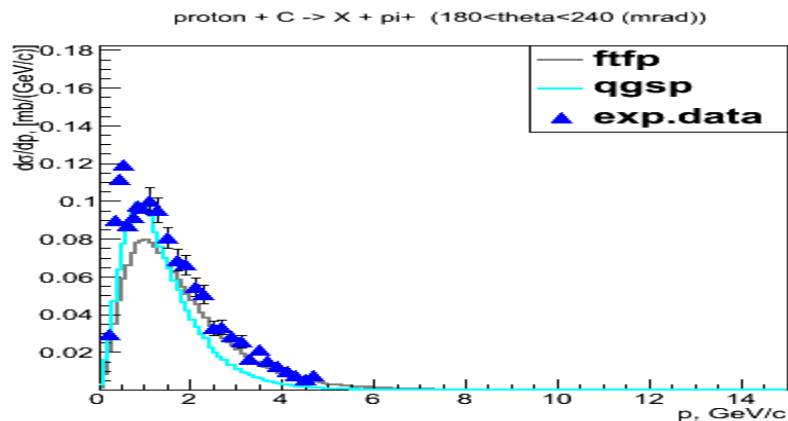
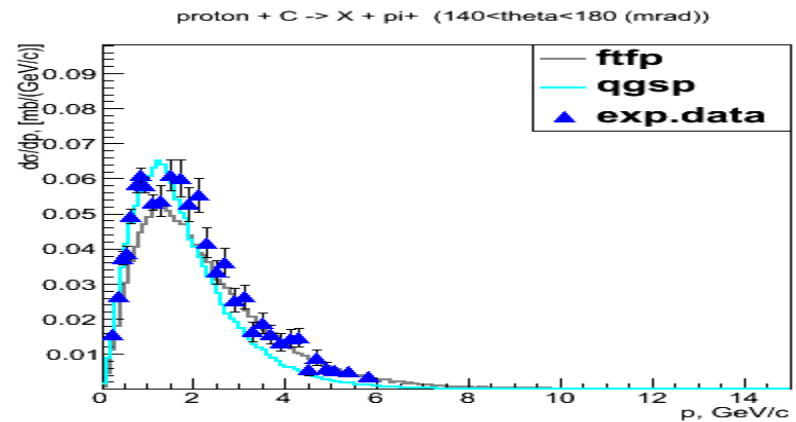
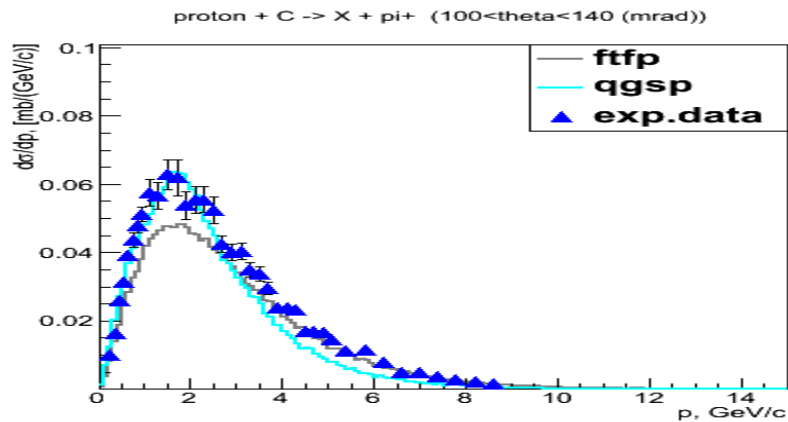
proton + C -> X + pi+ (40<theta<60 (mrad))



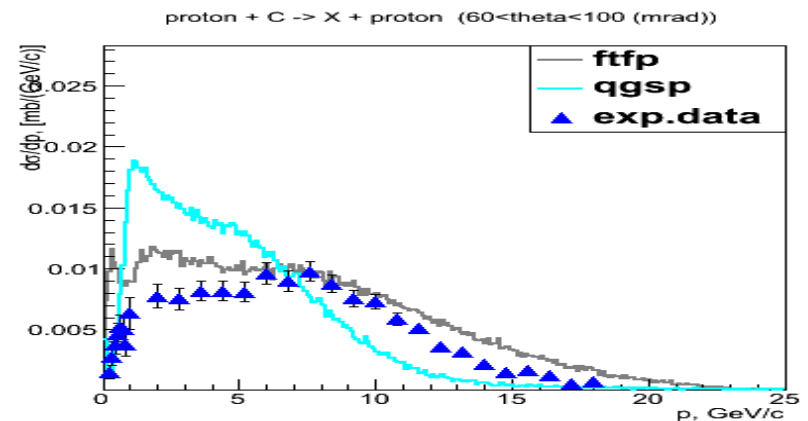
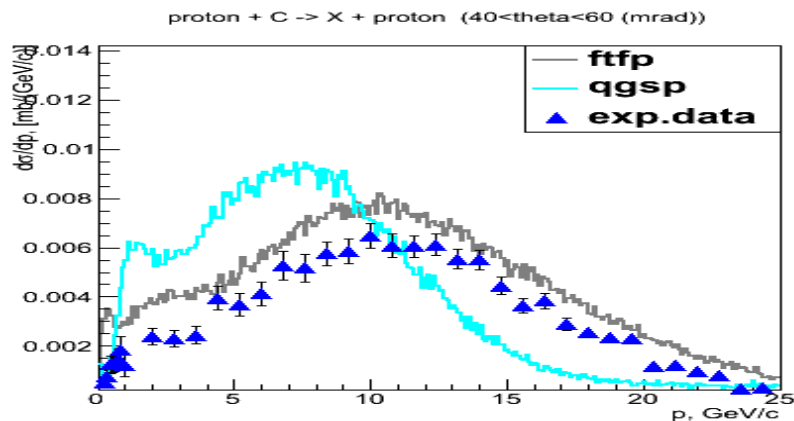
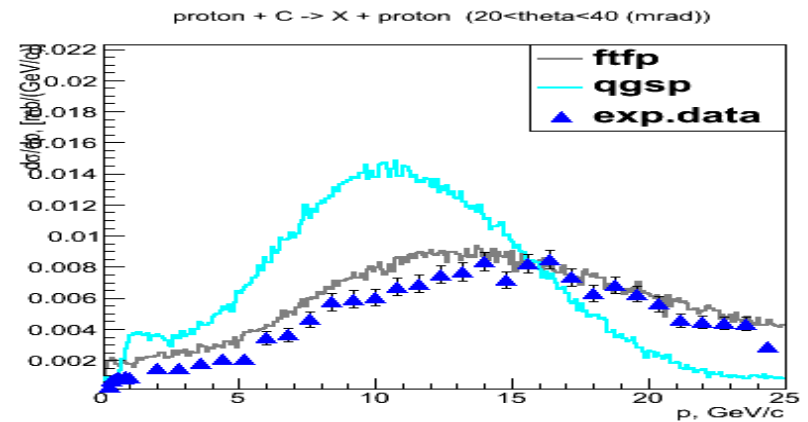
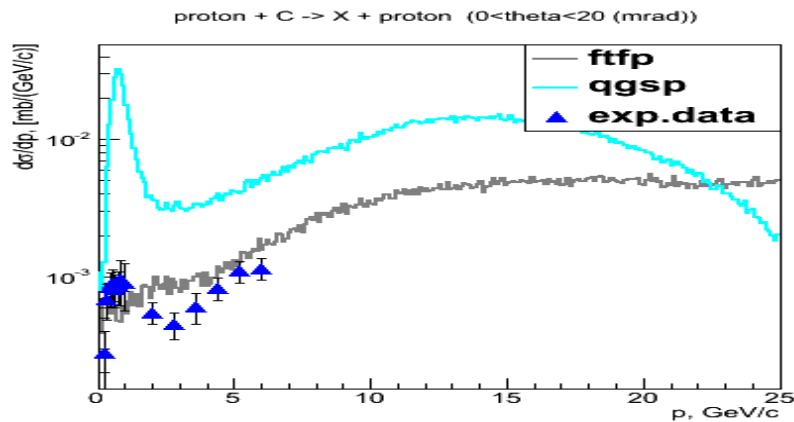
proton + C -> X + pi+ (60<theta<100 (mrad))



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



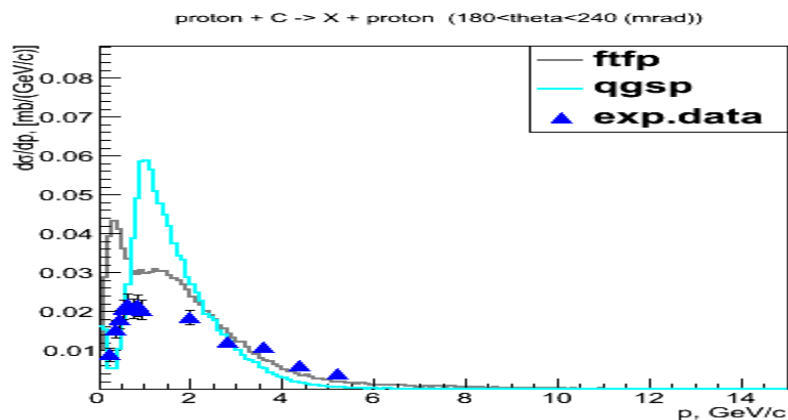
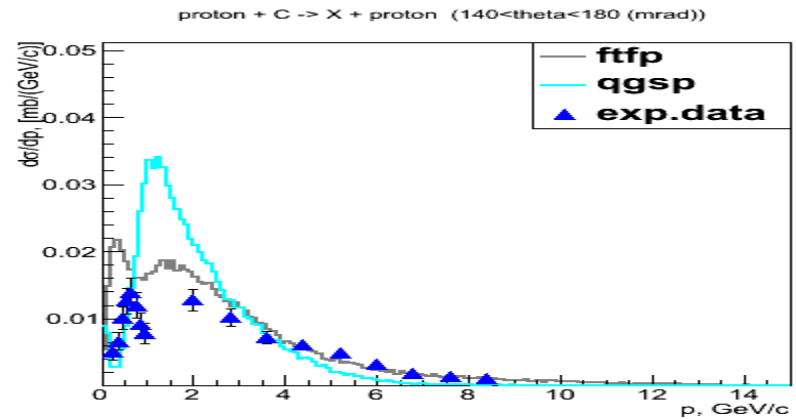
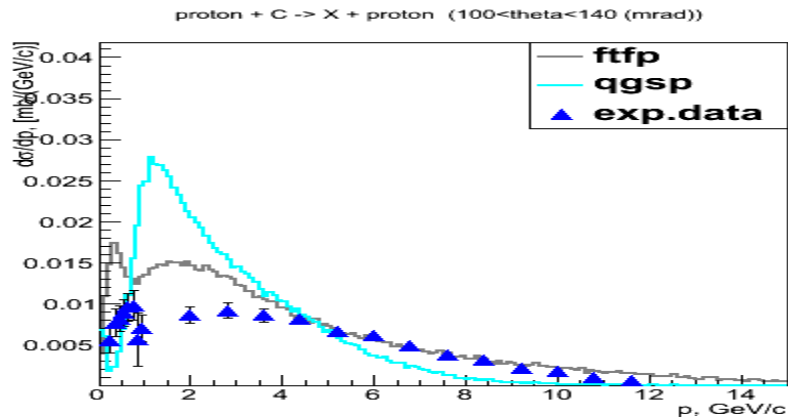
Test19: Results(V) 31GeV p+C secondary proton momenta in theta bins



Test19: Results(VI)

31GeV p+C

secondary proton momenta in theta bins (cont.)

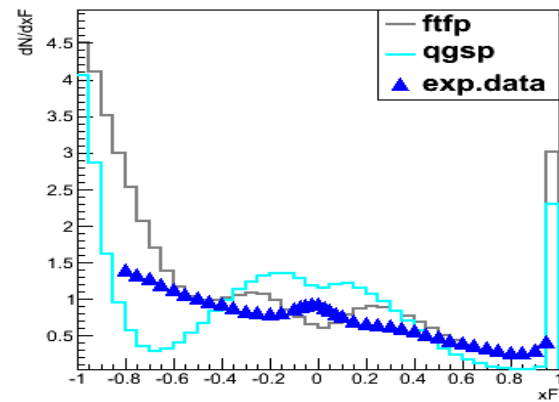


Test19: Results(VII)

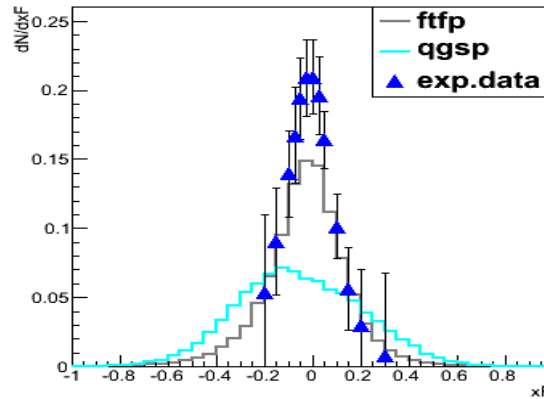
158 GeV p+C

dN/dxF for secondary p, pbar, n, pi+, pi-

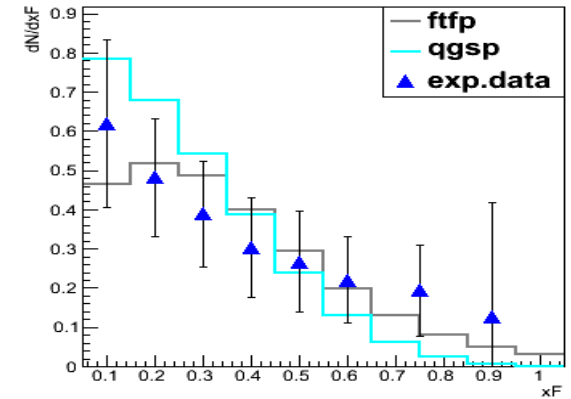
proton + C \rightarrow X + proton



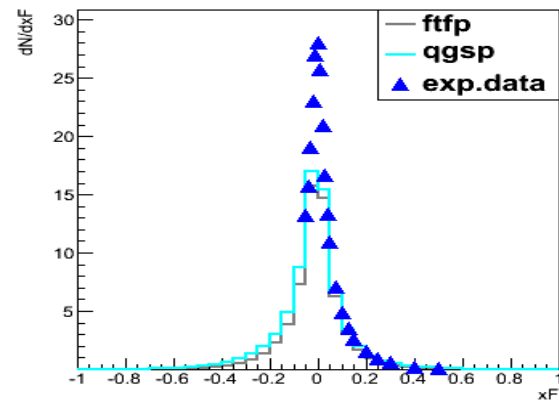
proton + C \rightarrow X + antiproton



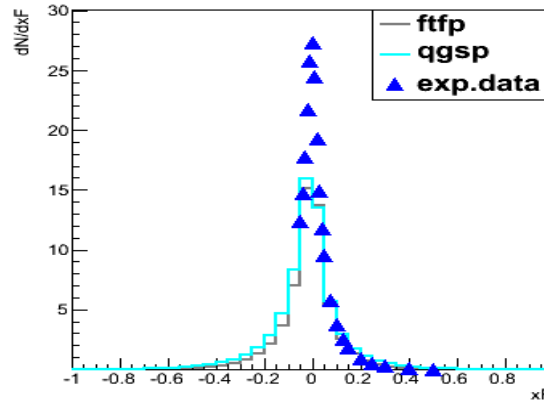
proton + C \rightarrow X + neutron



proton + C \rightarrow X + pi+

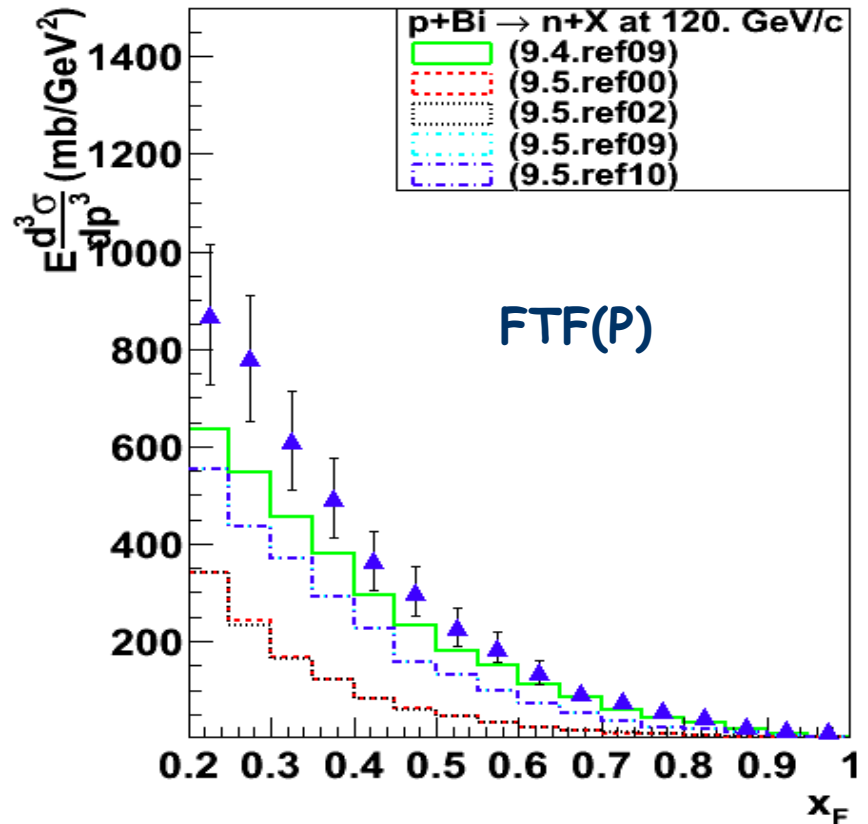
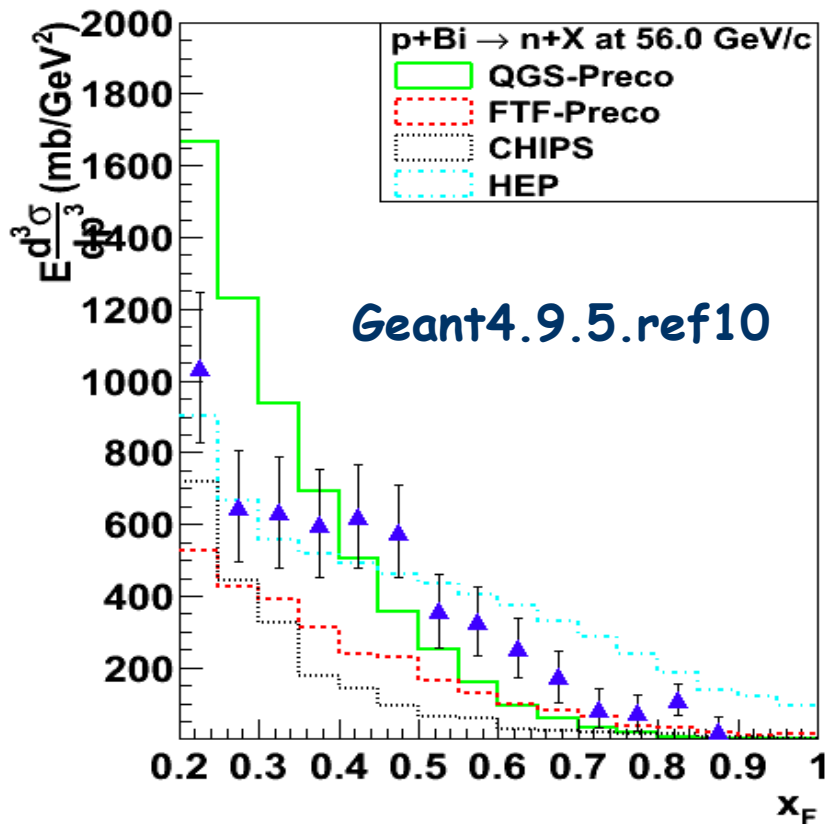


proton + C \rightarrow X + pi-



For reference:

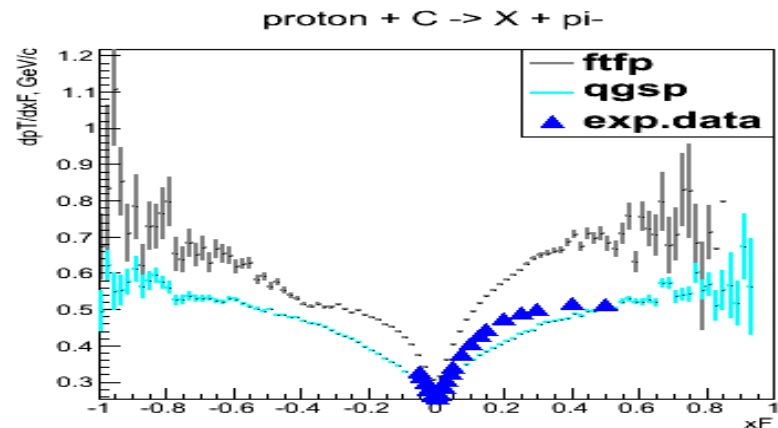
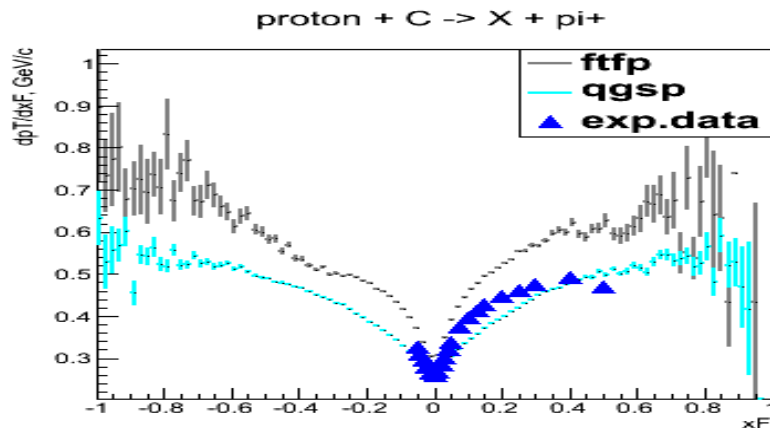
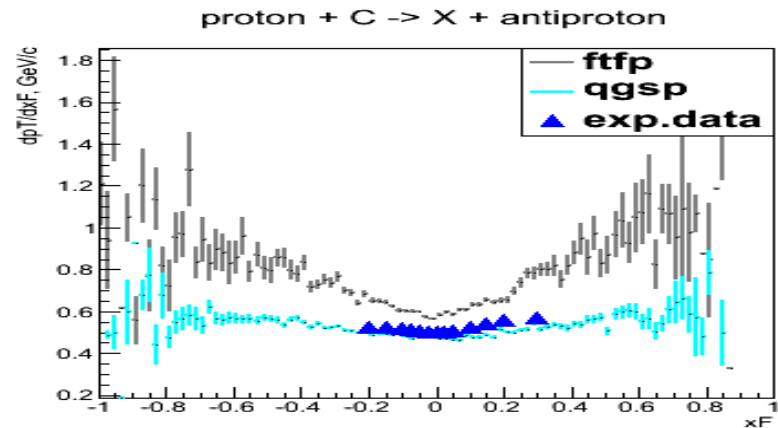
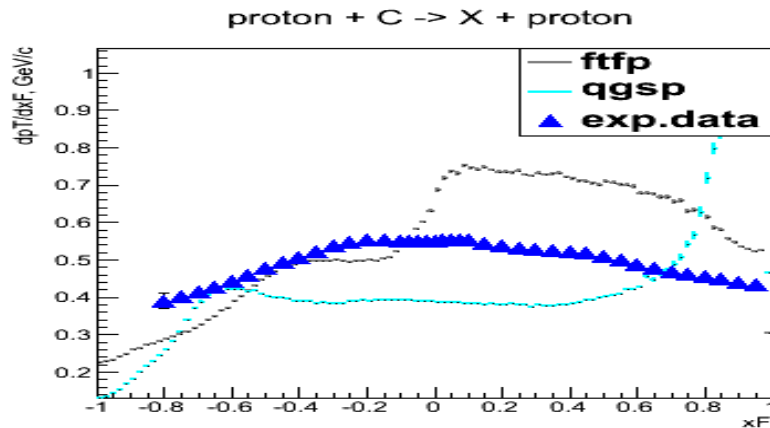
from Sunanda's talk on Nov.28, 2013
(comparison vs MIPP data on secondary neutrons)



Test19: Results(VIII)

158 GeV p+C

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





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)

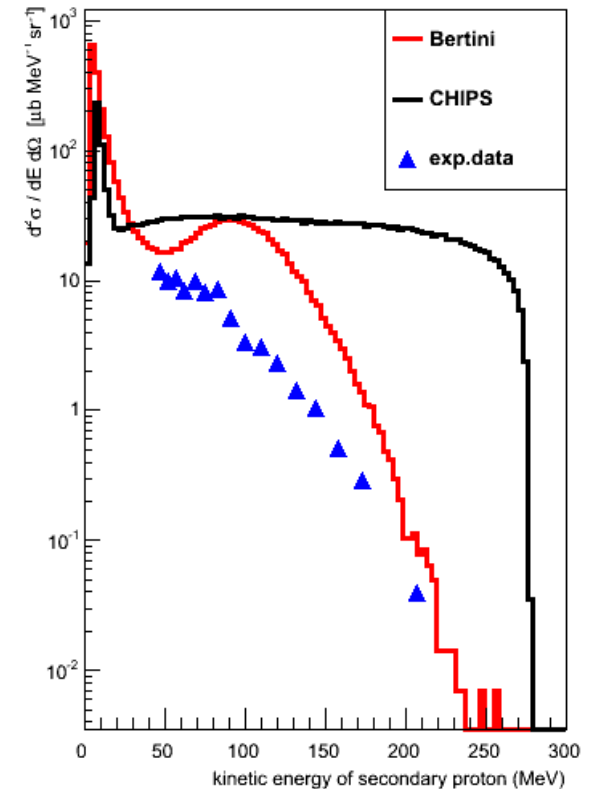
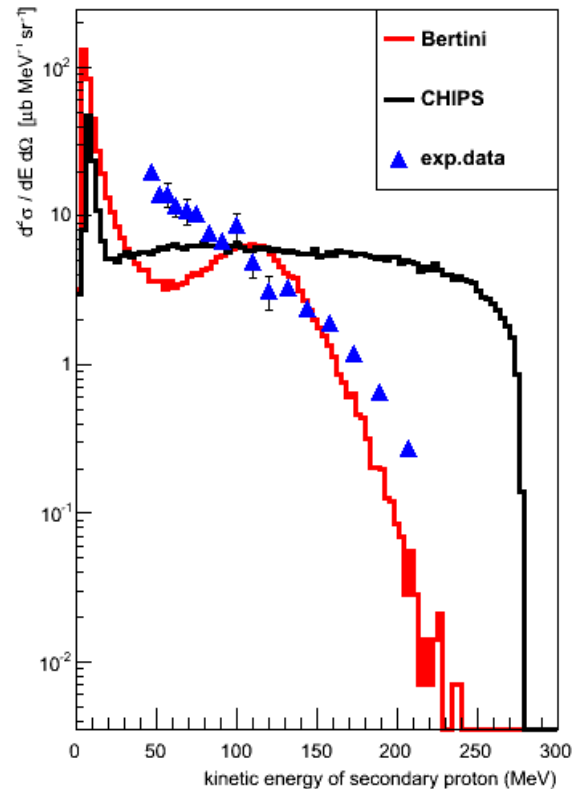
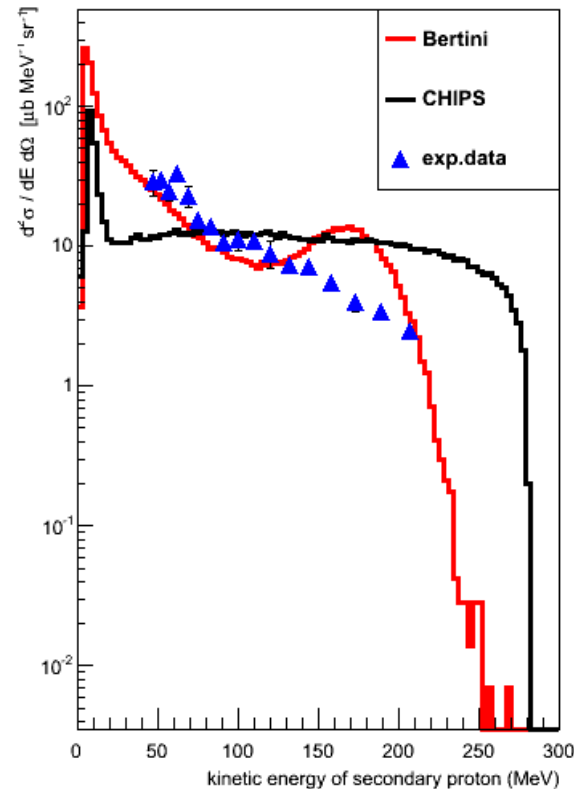
300MeV gamma + C

kinetic E of sec. proton (at different angles)

gamma + Cu \rightarrow X + proton (45deg)

gamma + Cu \rightarrow X + proton (90deg)

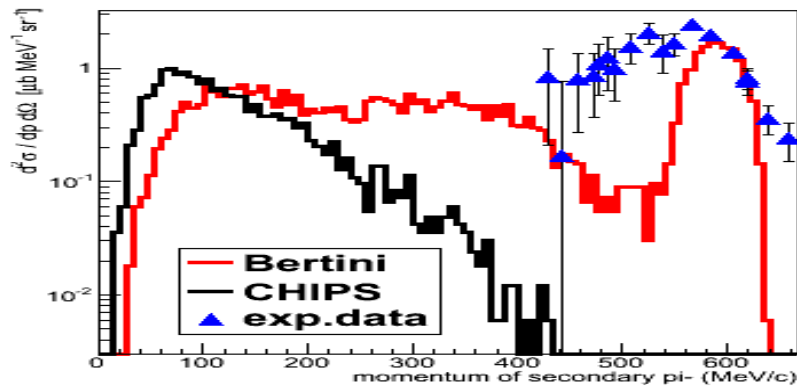
gamma + Cu \rightarrow X + proton (135deg)



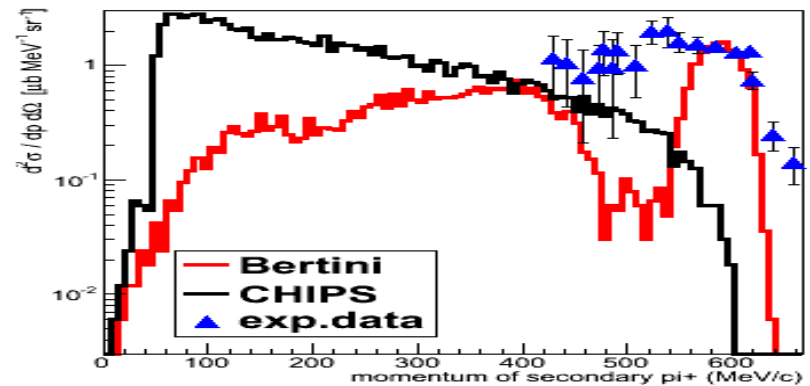
Test75: Results(II)

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

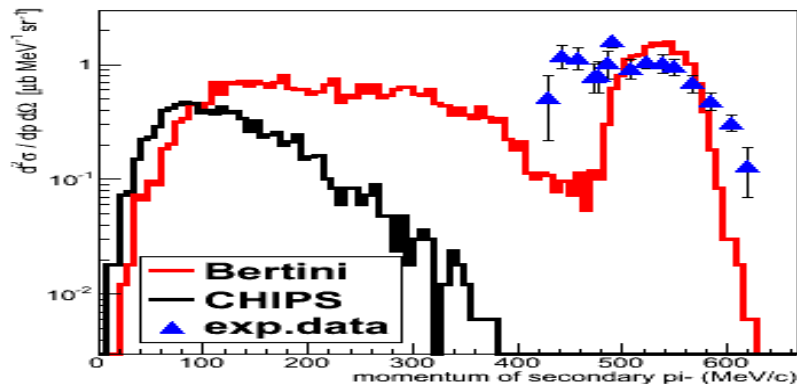
gamma + Cu \rightarrow X + pi- (28deg)



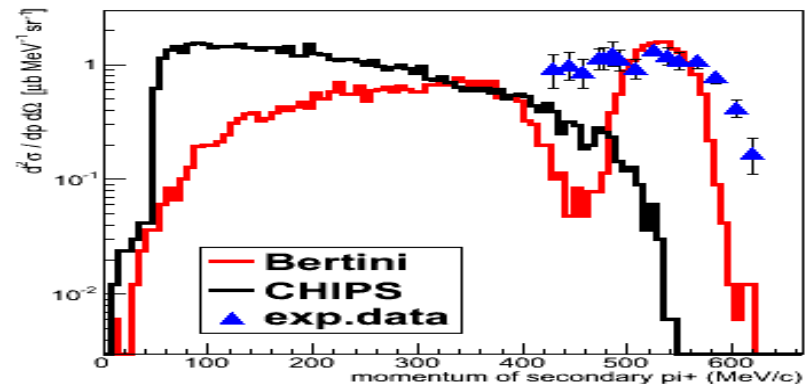
gamma + Cu \rightarrow X + pi+ (28deg)



gamma + Cu \rightarrow X + pi- (44deg)



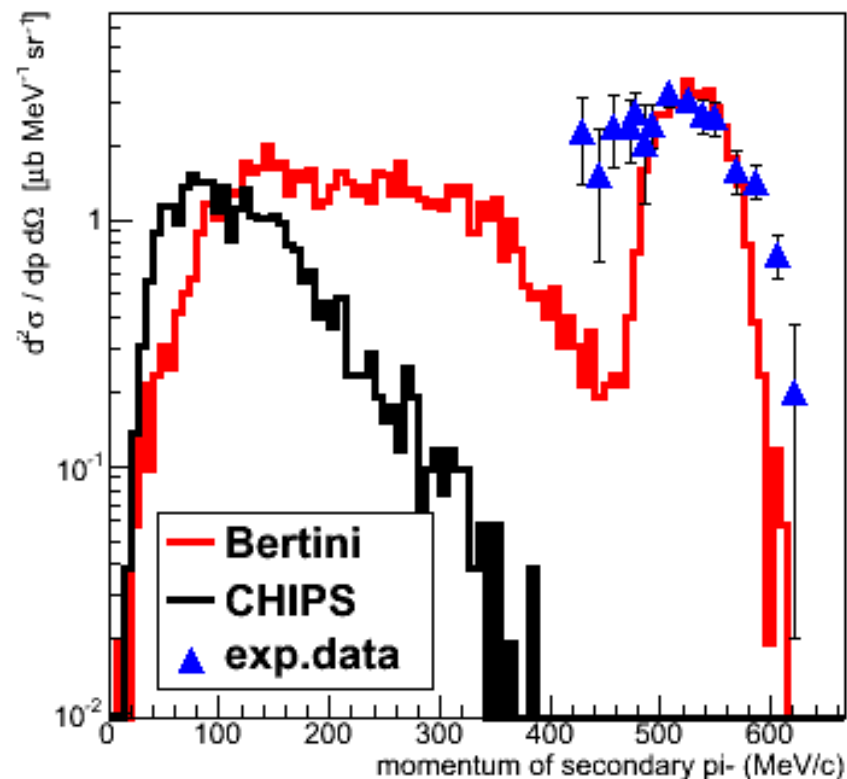
gamma + Cu \rightarrow X + pi+ (44deg)



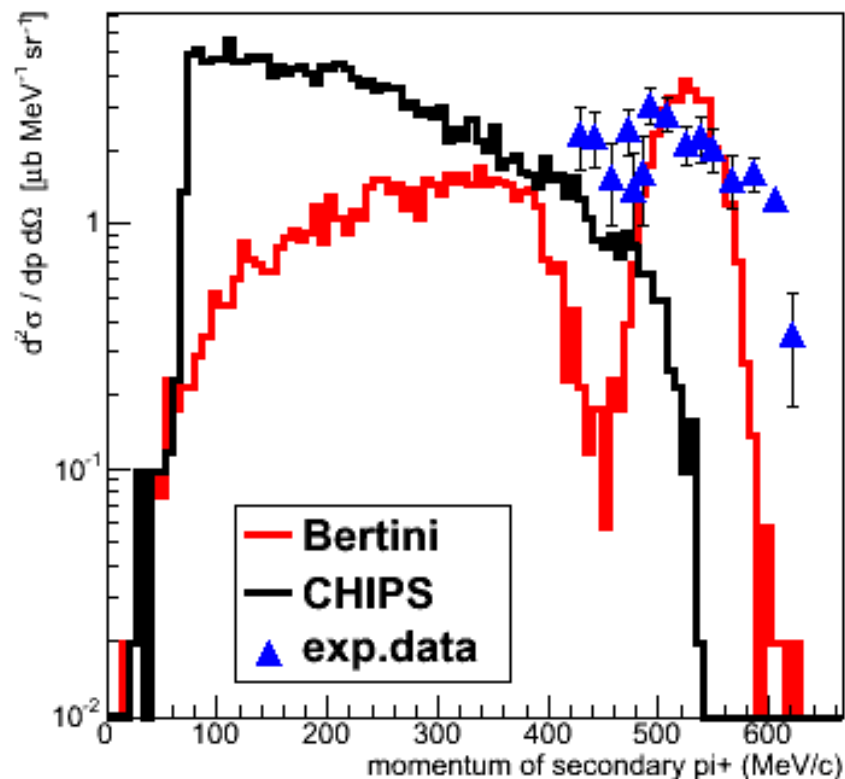
Test75: Results(III)

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

gamma + Pb \rightarrow X + pi- (44deg)



gamma + Pb \rightarrow 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



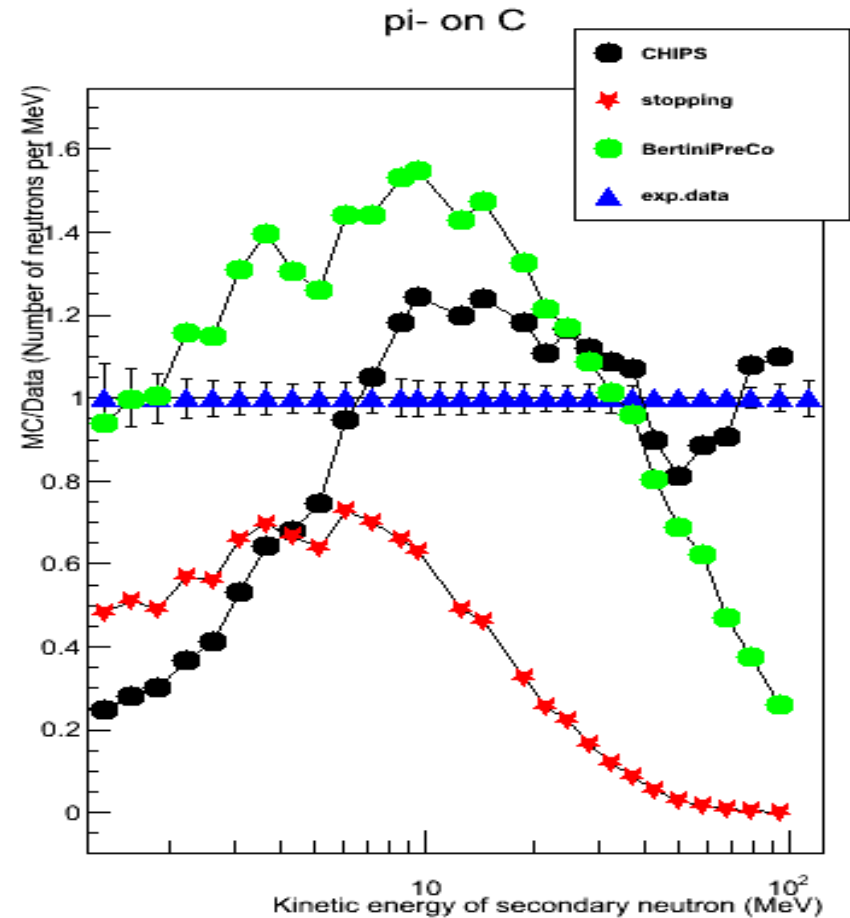
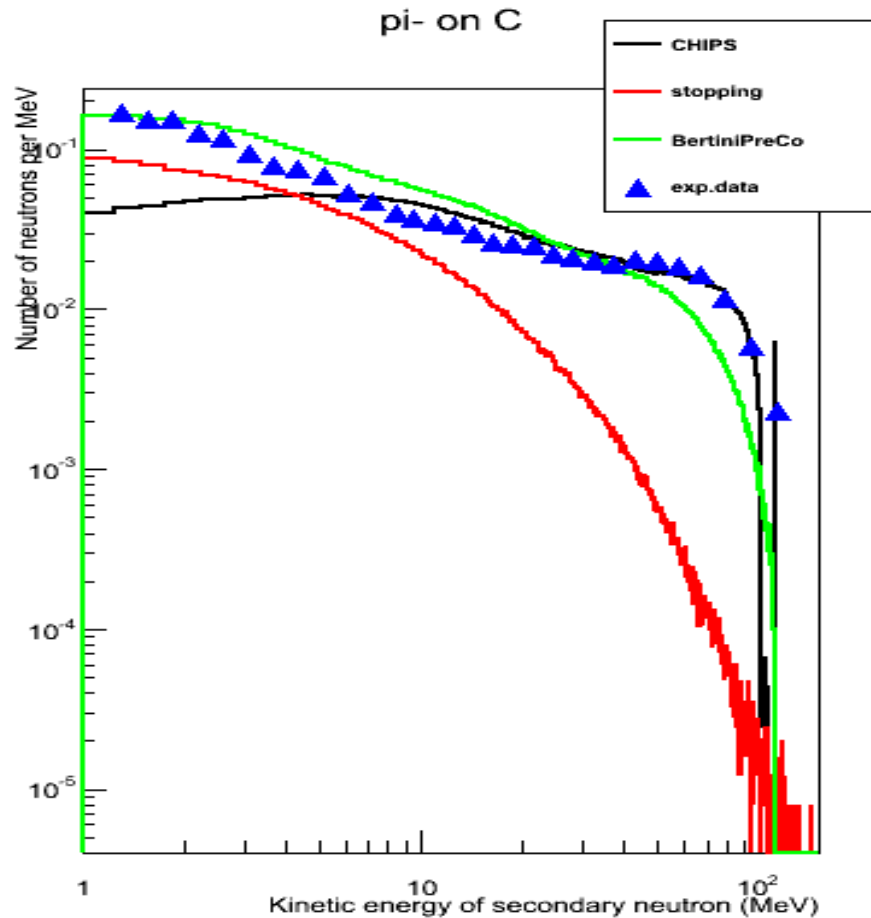
Summary

- 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

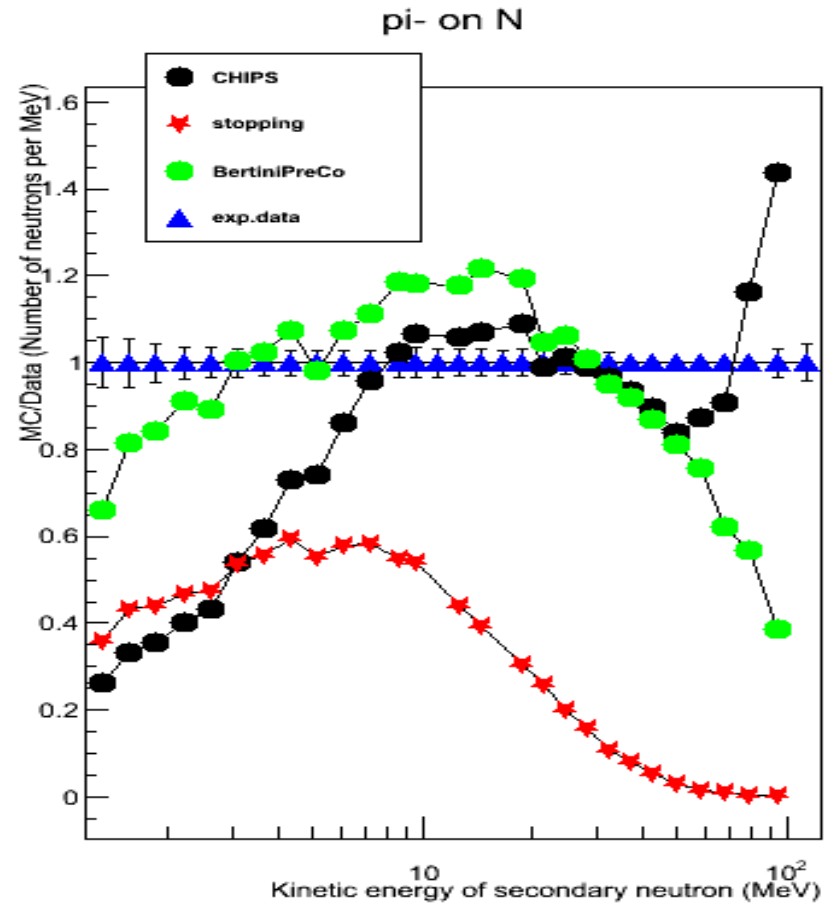
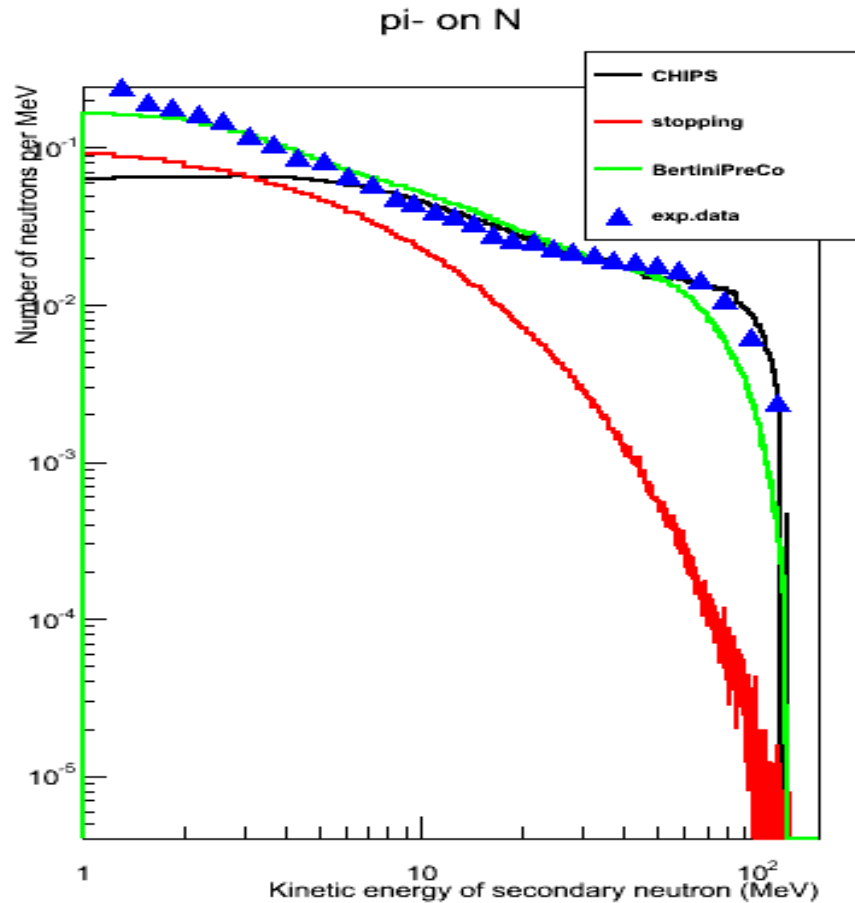


BACKUP SLIDES

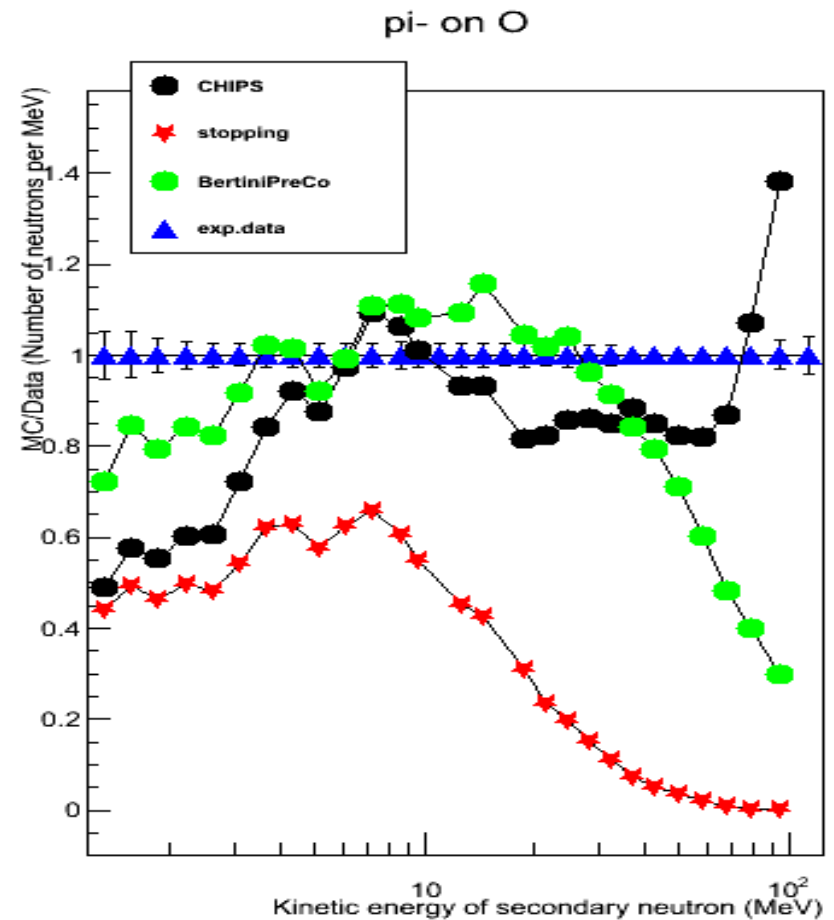
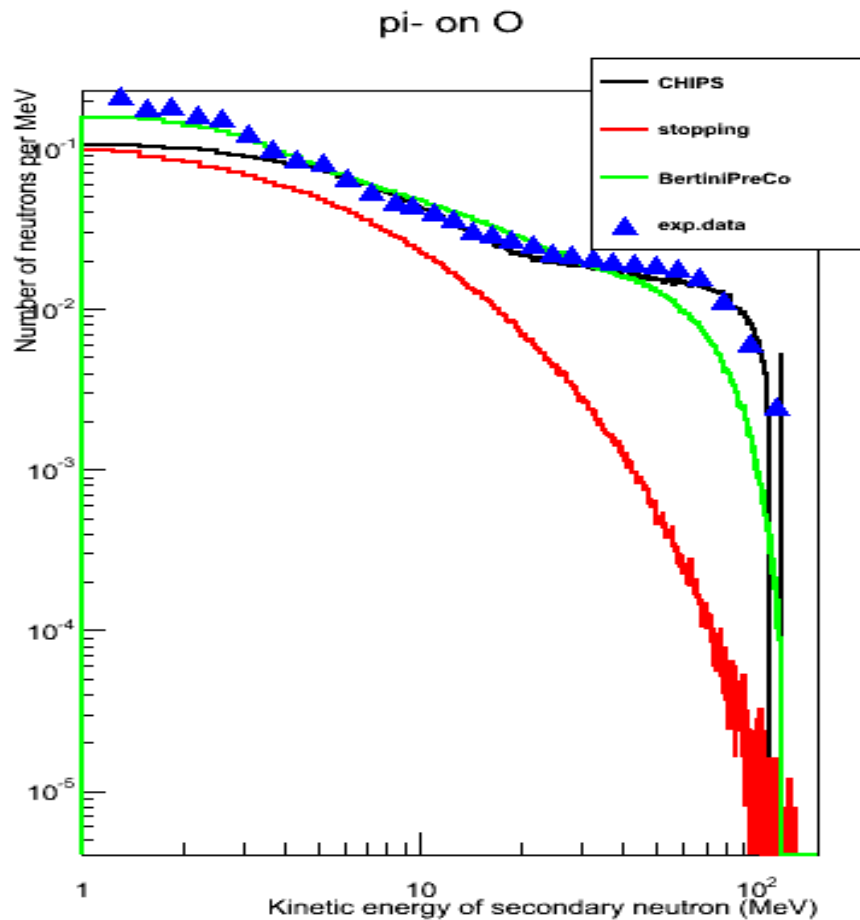
Test48: Models (I)



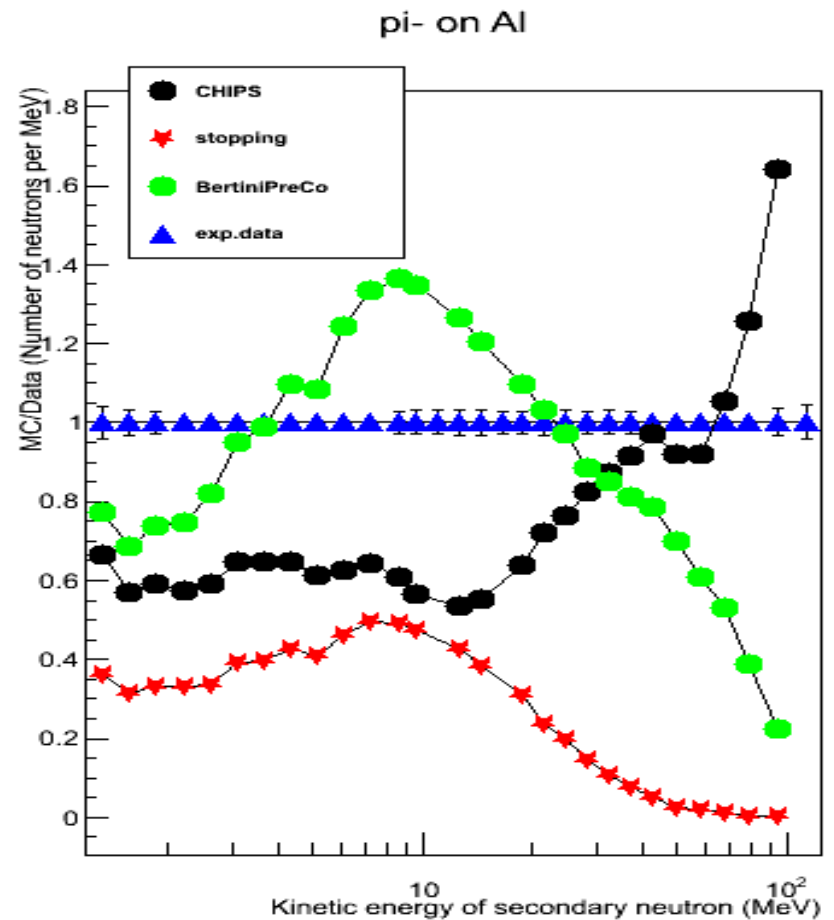
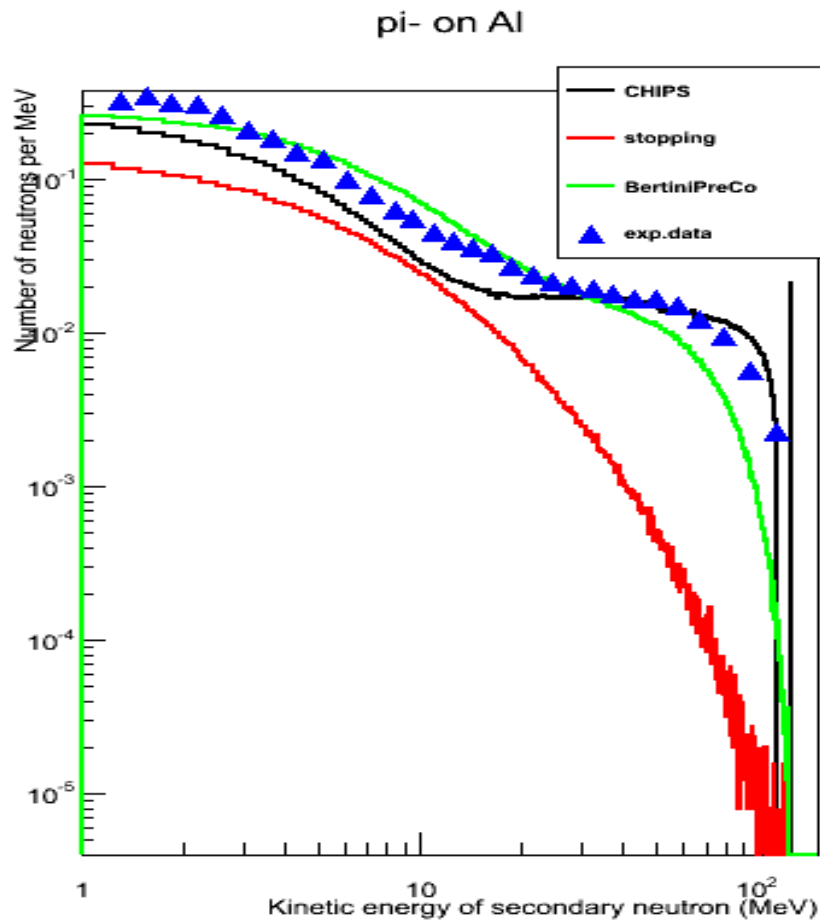
Test48: Models (II)



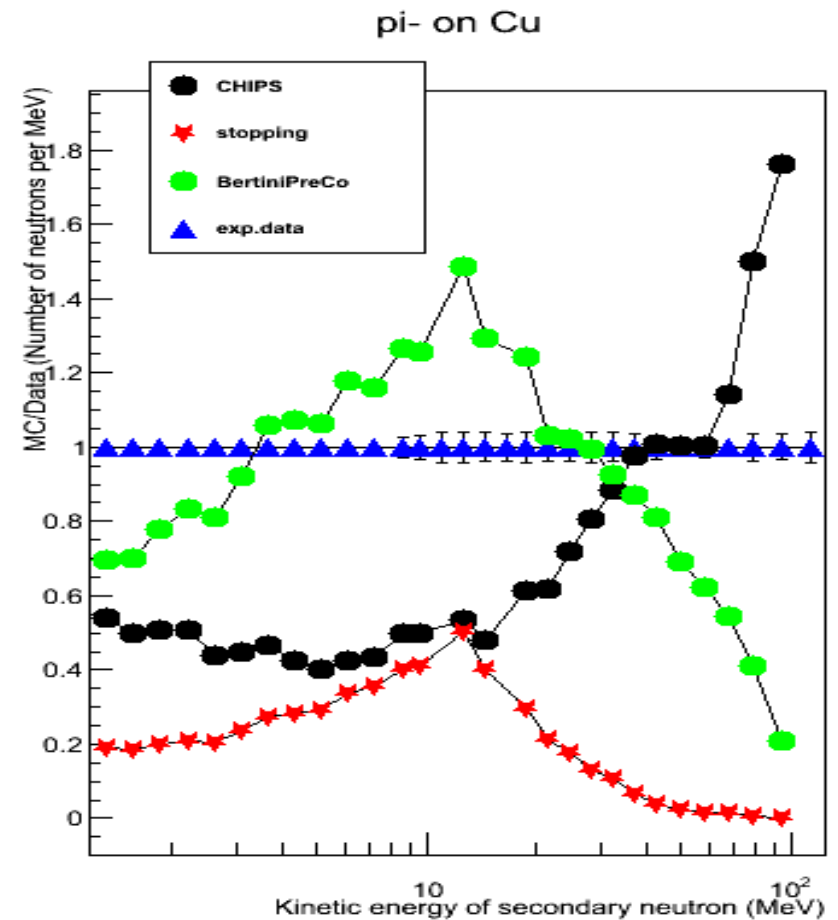
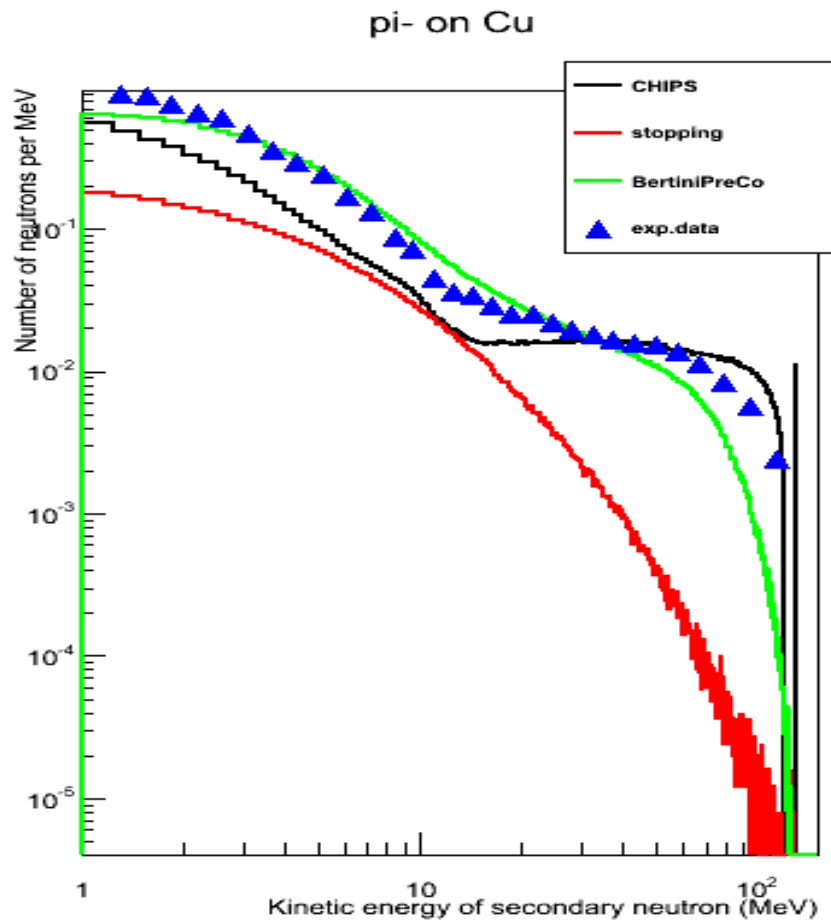
Test48: Models (III)



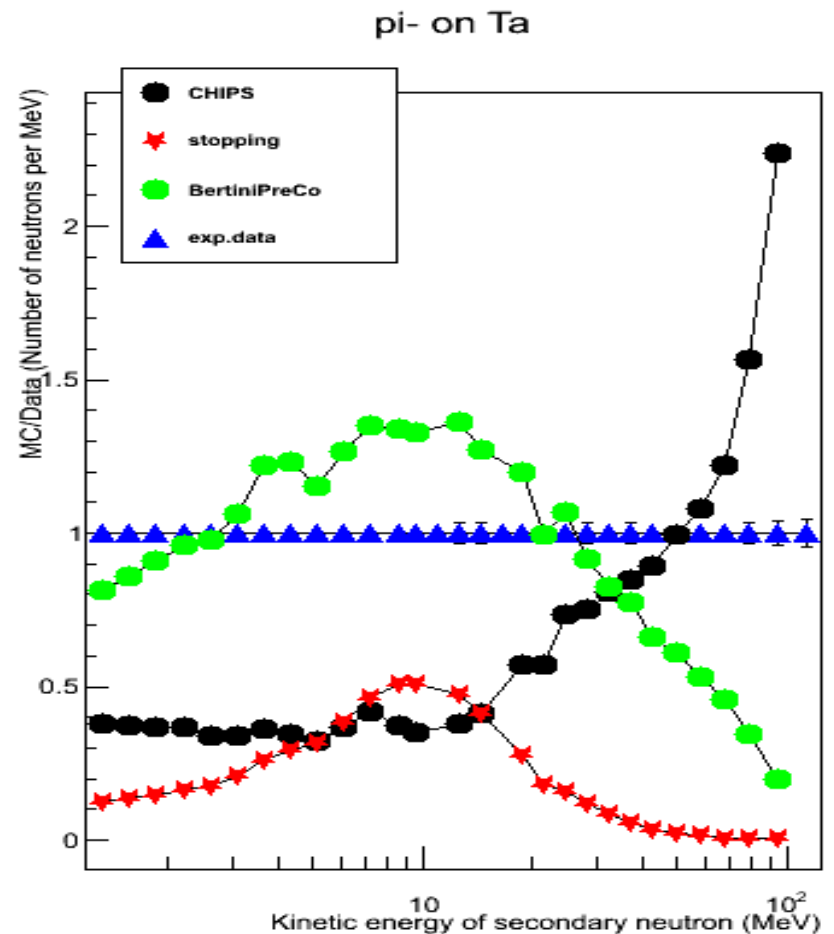
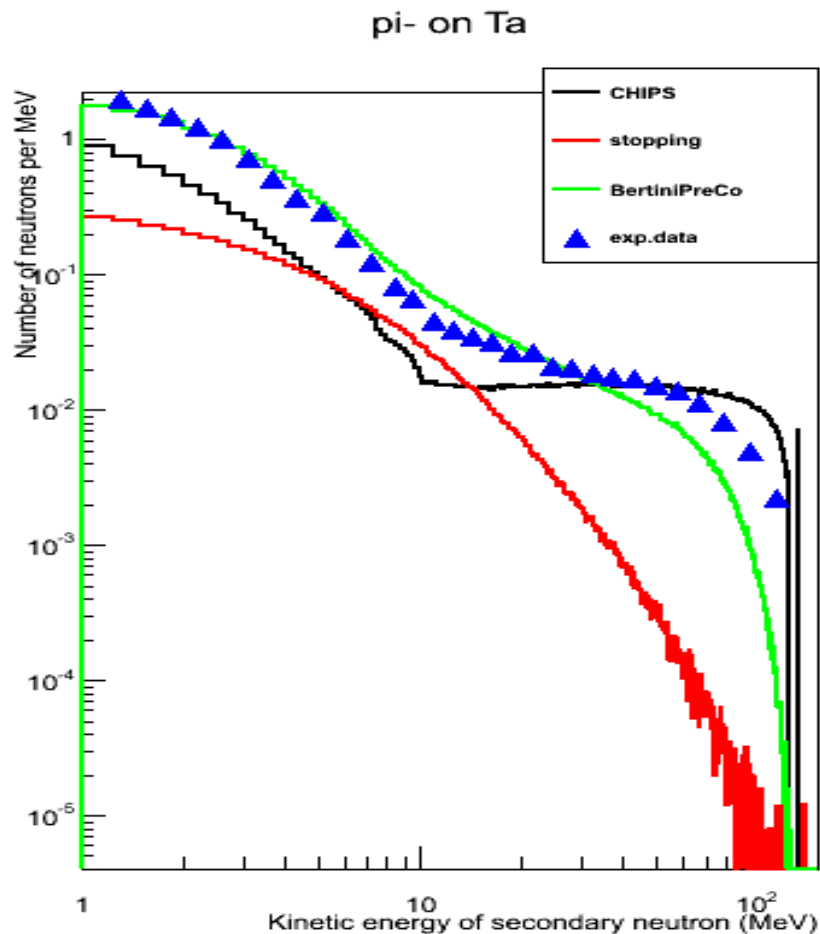
Test48: Models (IV)



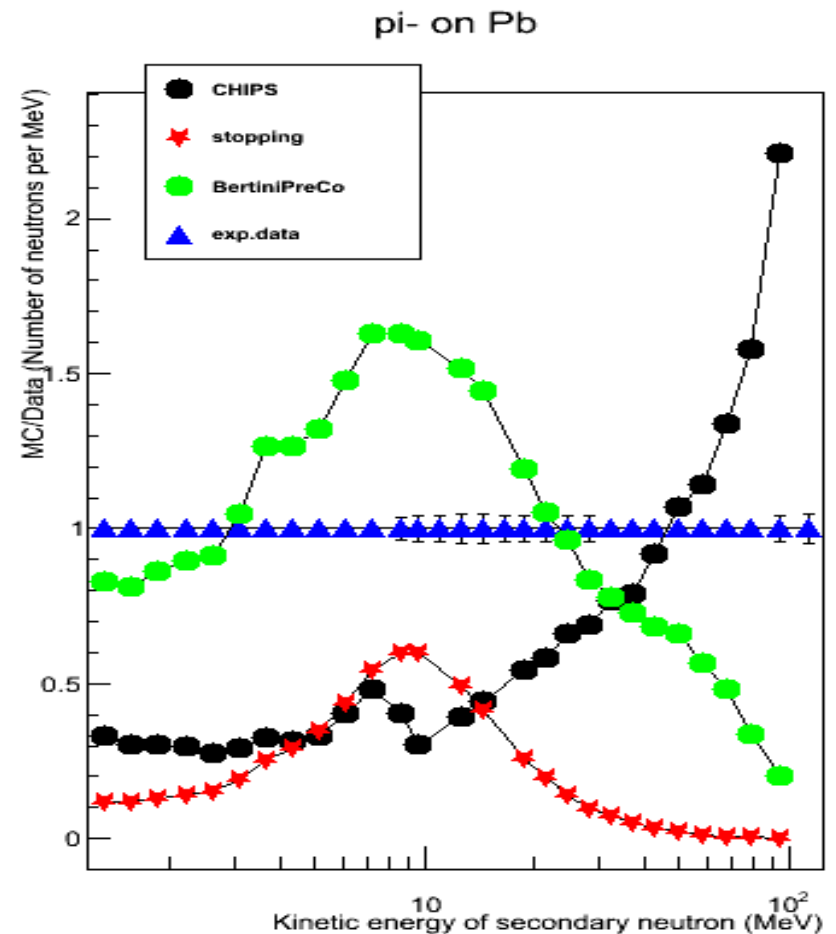
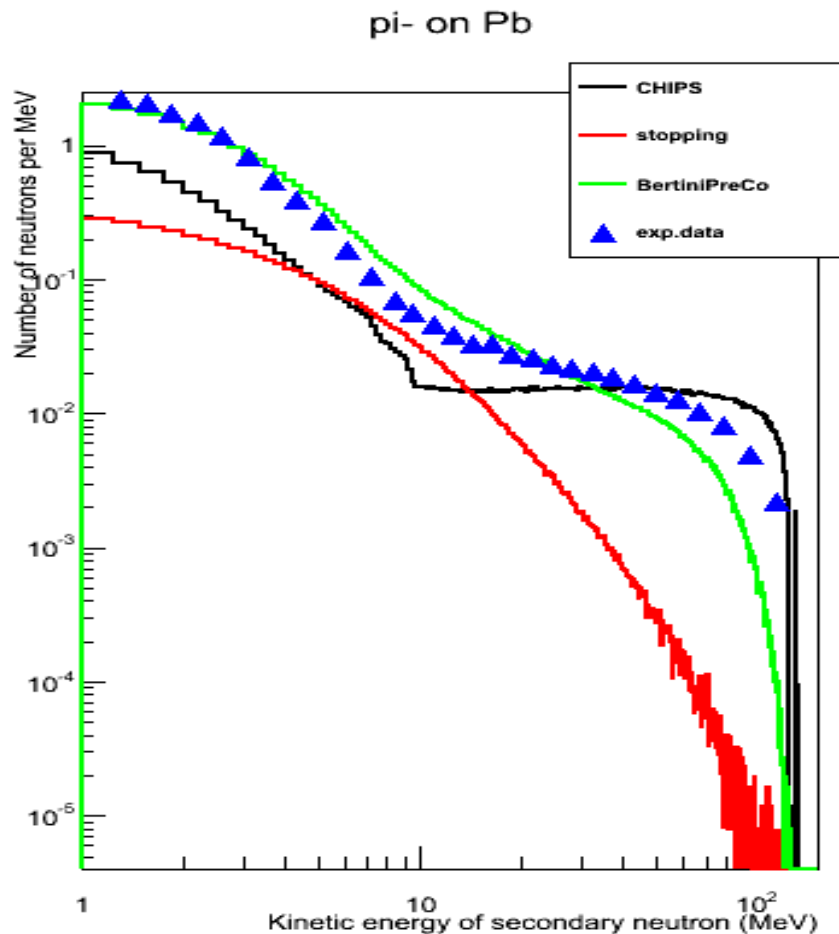
Test48: Models (V)



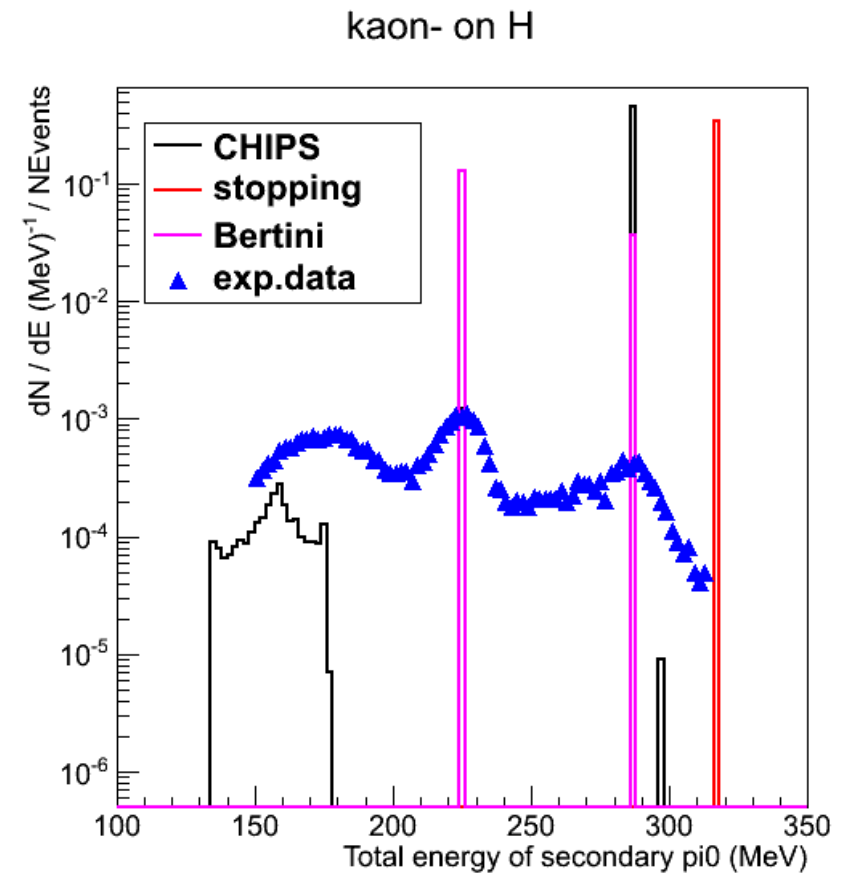
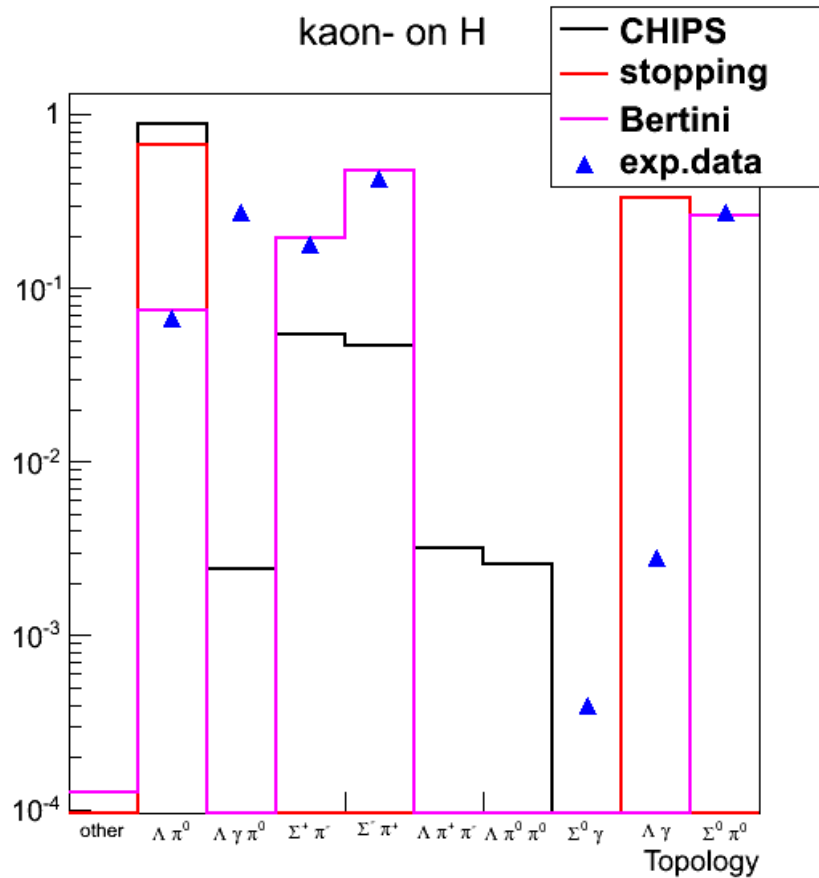
Test48: Models (VI)



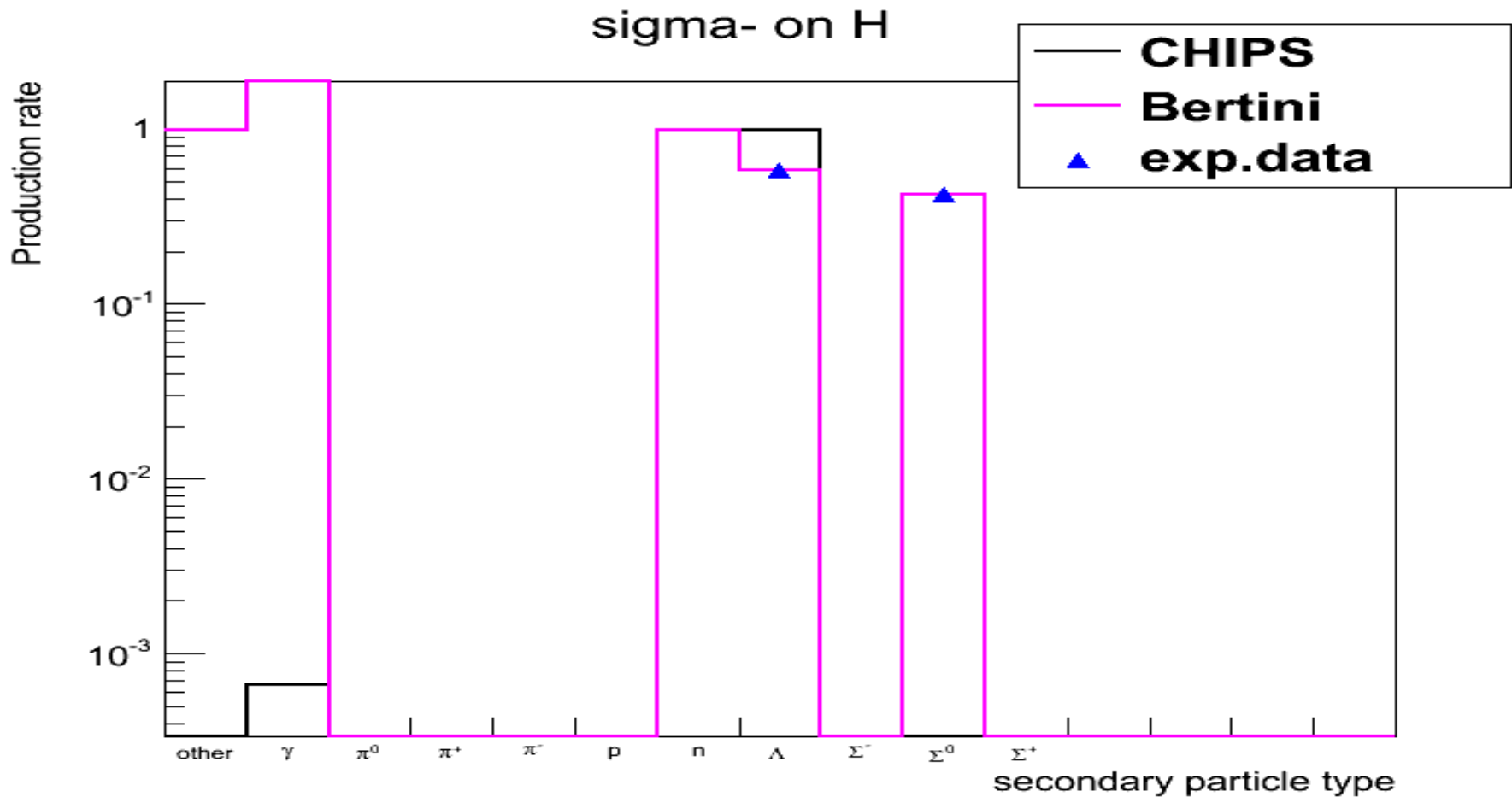
Test48: Models (VII)



Test48: Models (VIII)

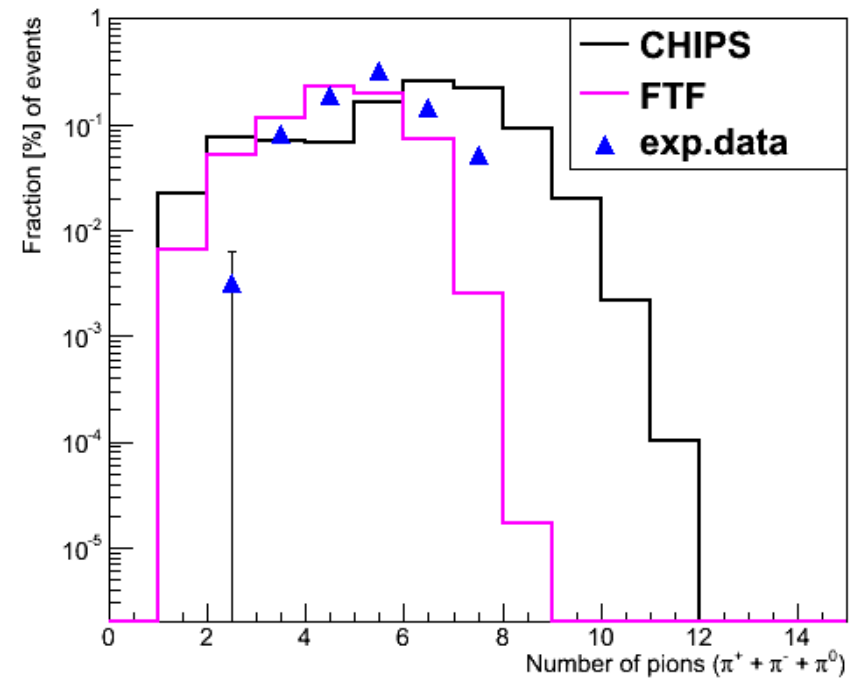
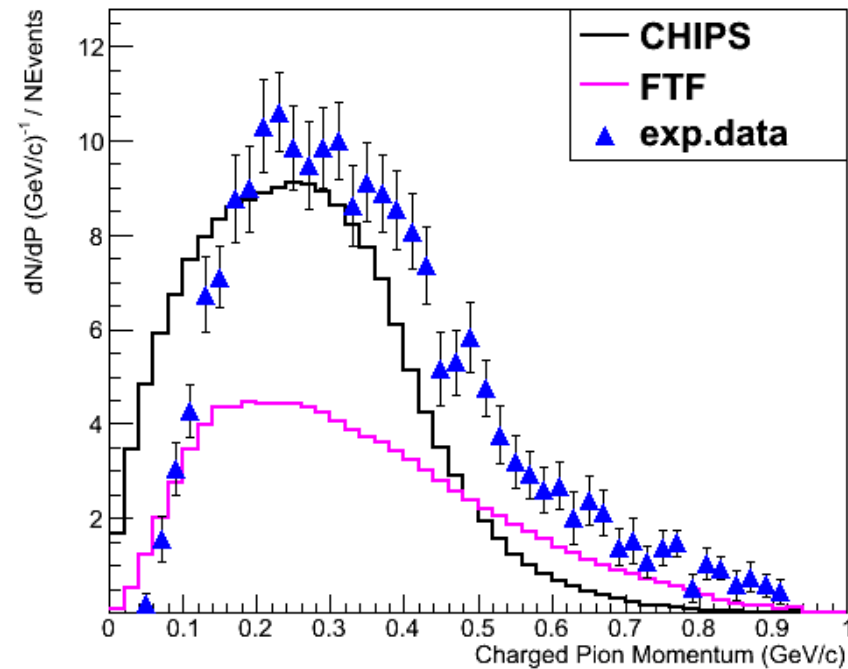


Test48: Models (IX)



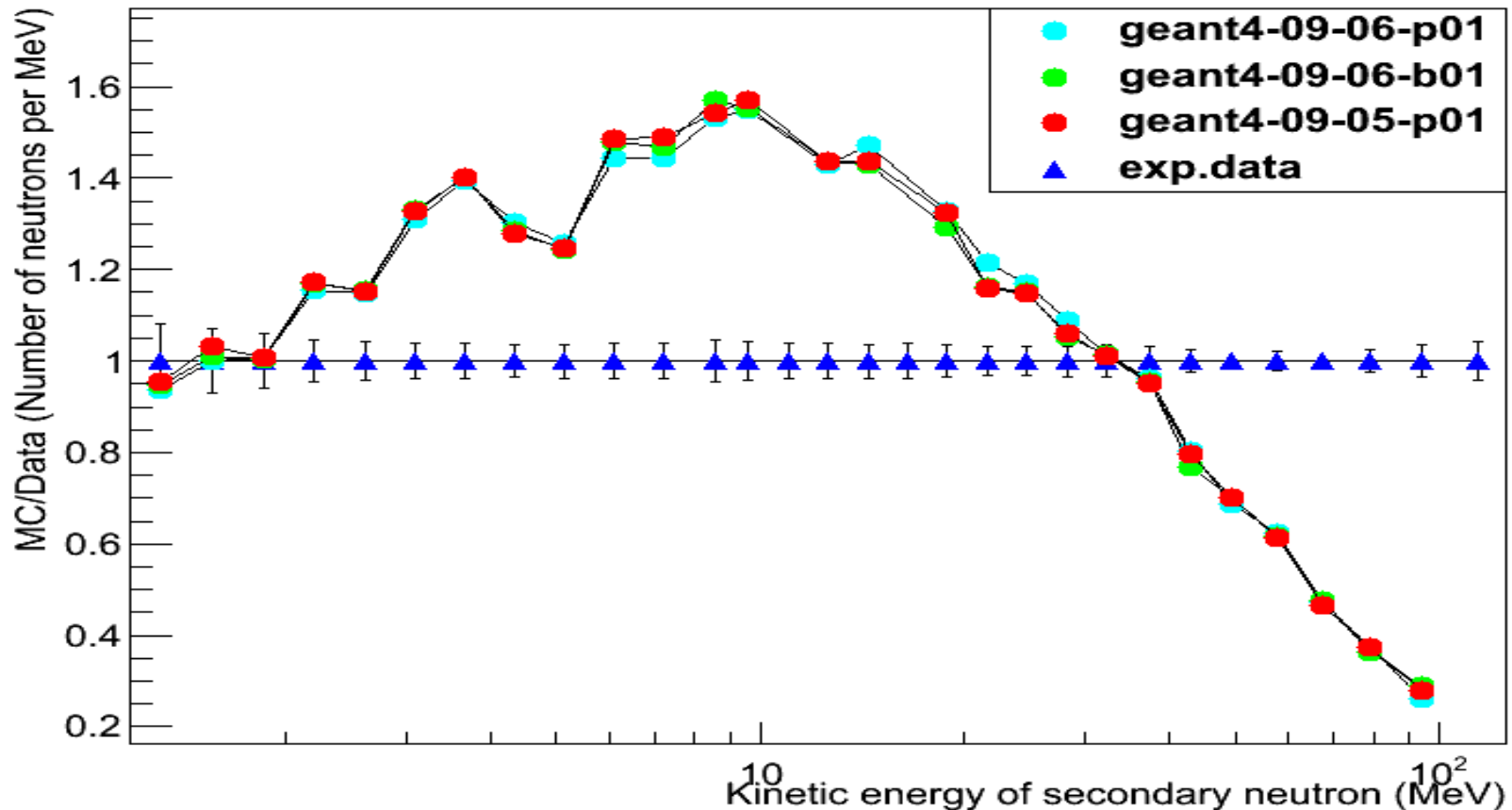
Test48: Models (X)

pbar annihilation on H



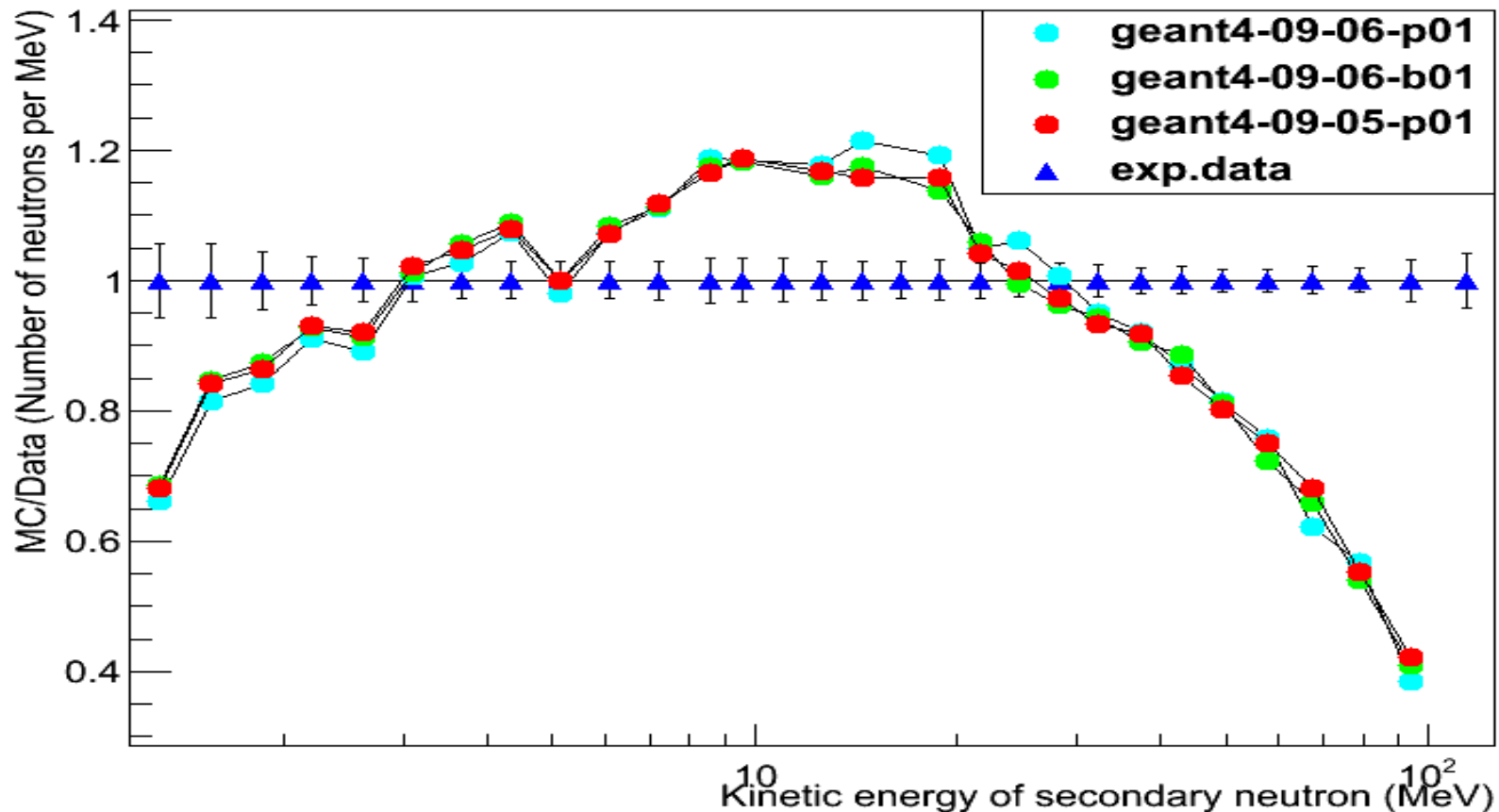
Test48: Bertini Regression (I)

pi- on C, BertiniPreCo



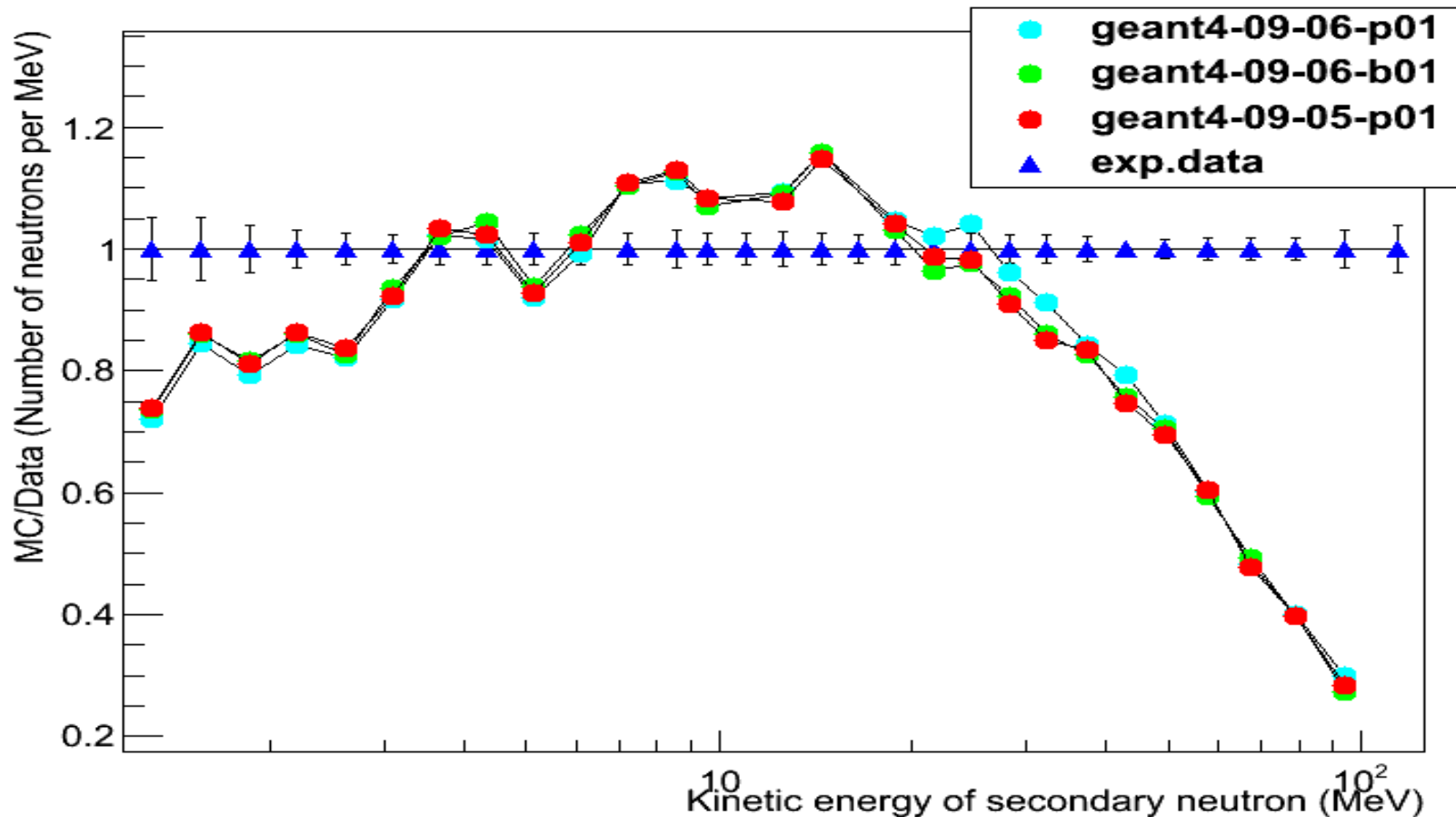
Test48: Bertini Regression (II)

pi- on N, BertiniPreCo



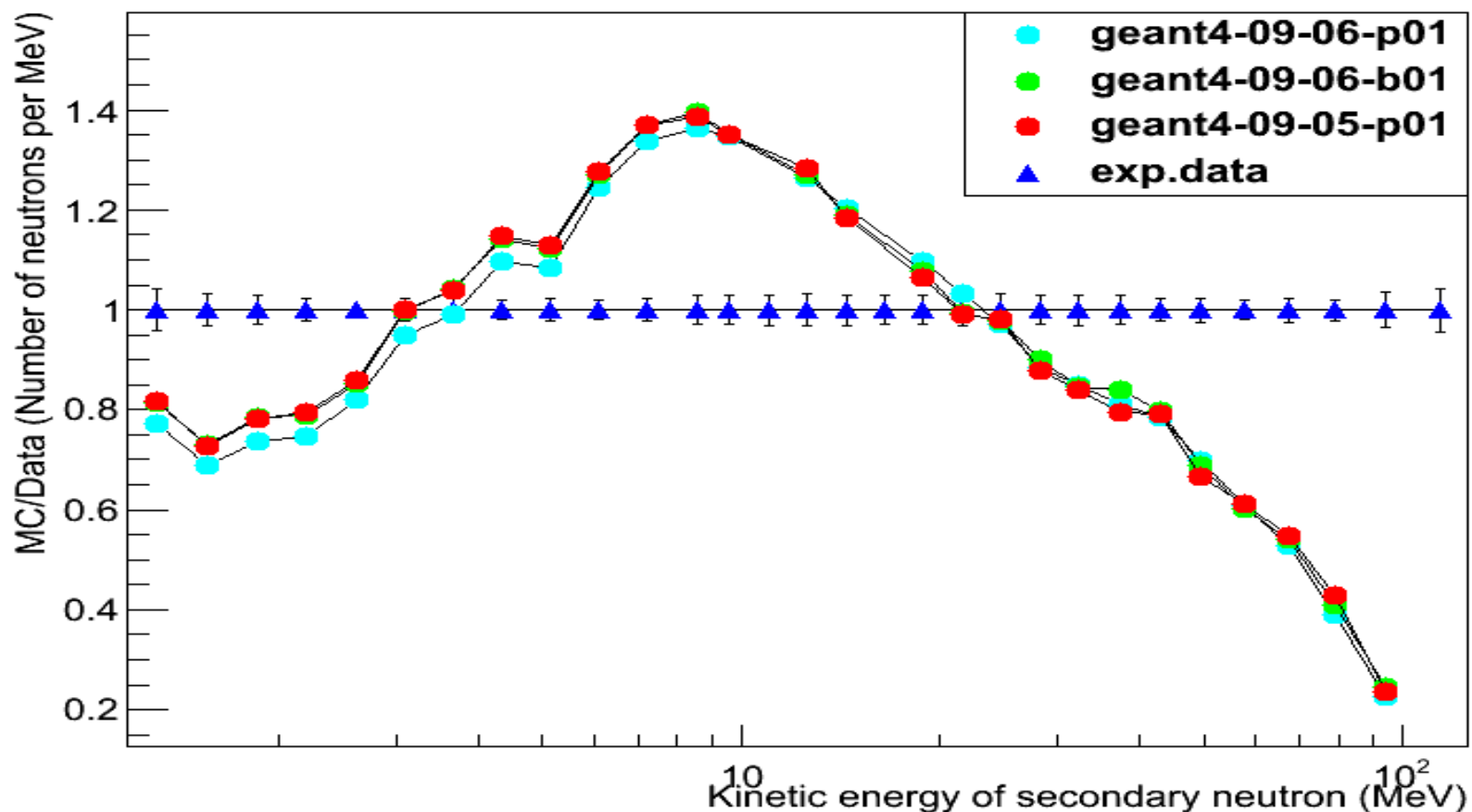
Test48: Bertini Regression (III)

pi- on O, BertiniPreCo



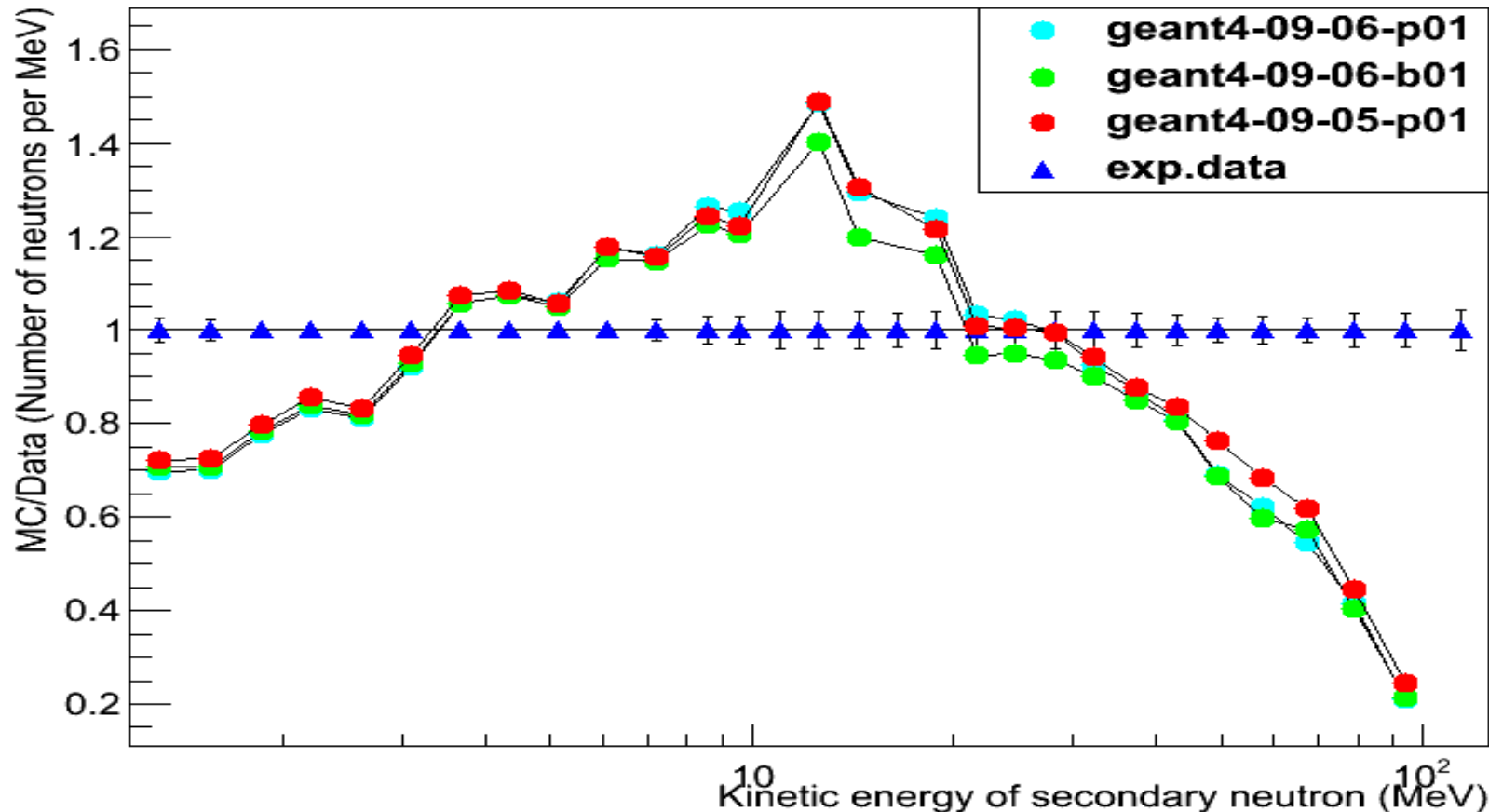
Test48: Bertini Regression (IV)

pi- on Al, BertiniPreCo



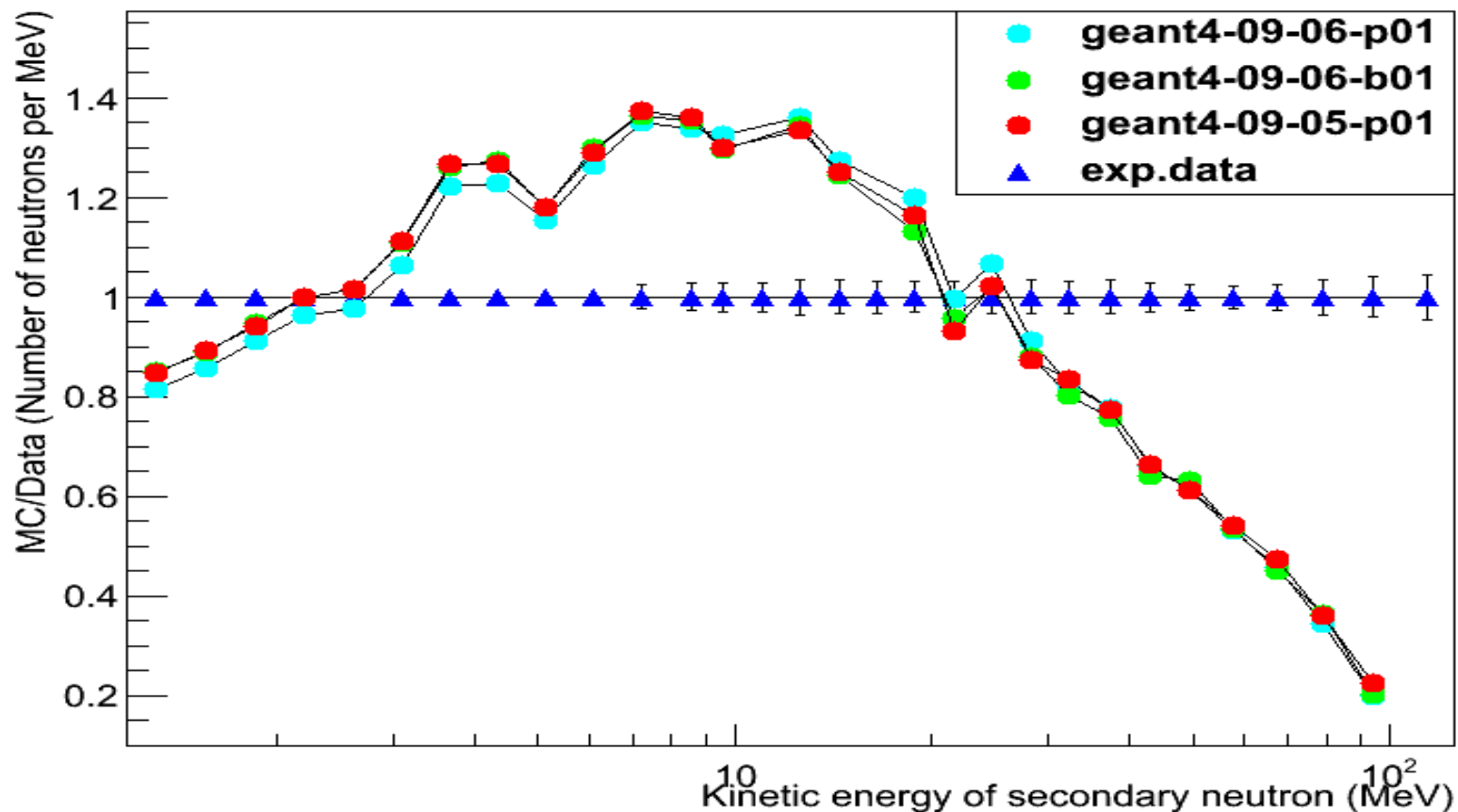
Test48: Bertini Regression (V)

pi- on Cu, BertiniPreCo



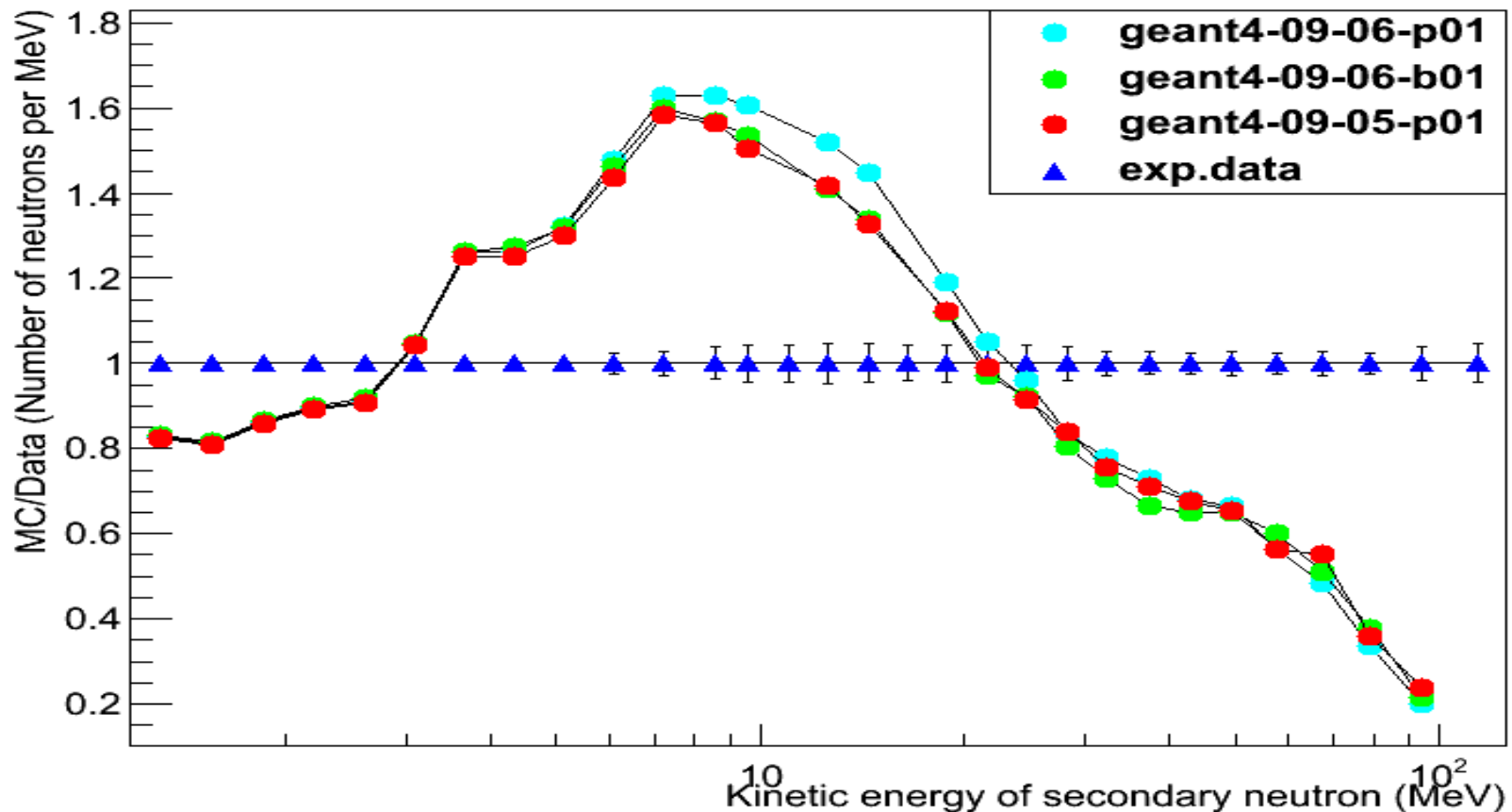
Test48: Bertini Regression (VI)

pi- on Ta, BertiniPreCo



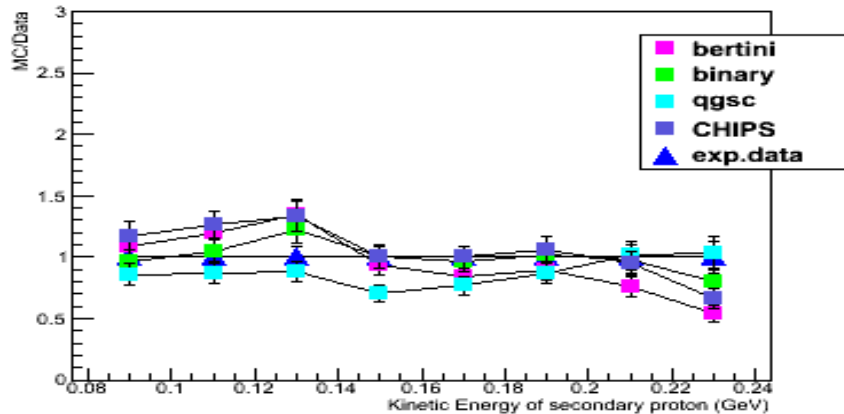
Test48: Bertini Regression (VII)

pi- on Pb, BertiniPreCo

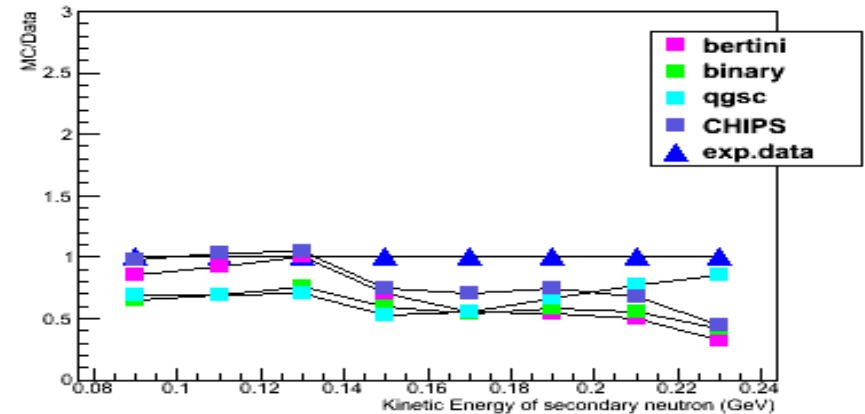


Test47: Models (I)

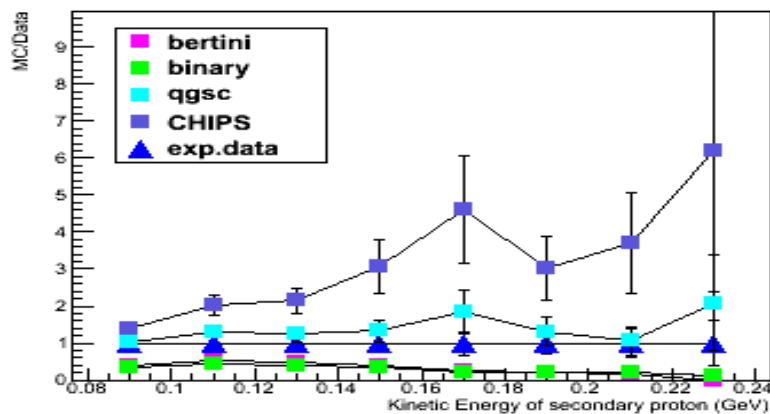
proton+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



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

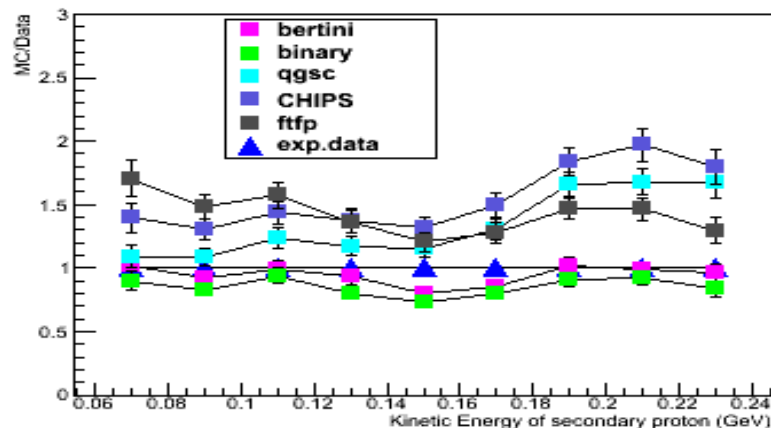


proton+C to p at 1.40 GeV (bertini) ($\theta = 119.00$)

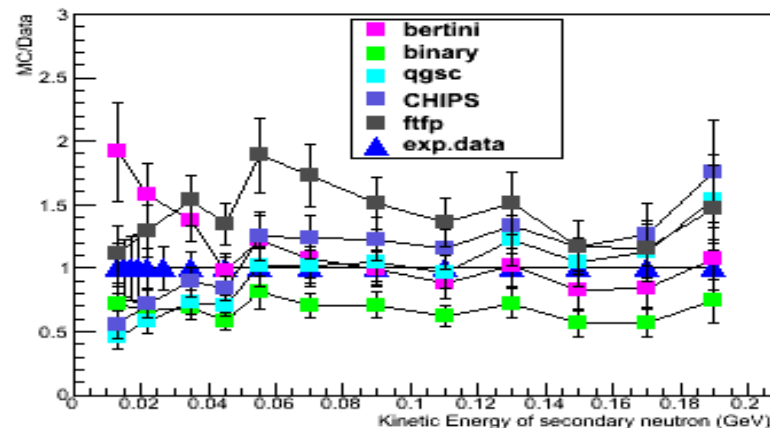


Test47: Models (II)

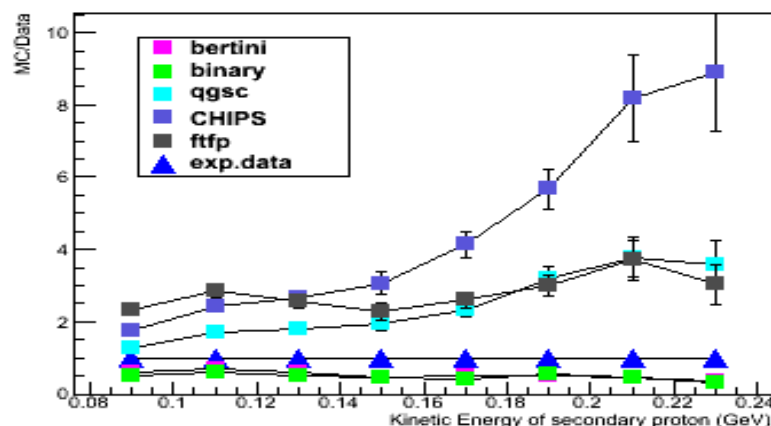
proton+C to p at 7.50 GeV (bertini) ($\theta = 59.10$)



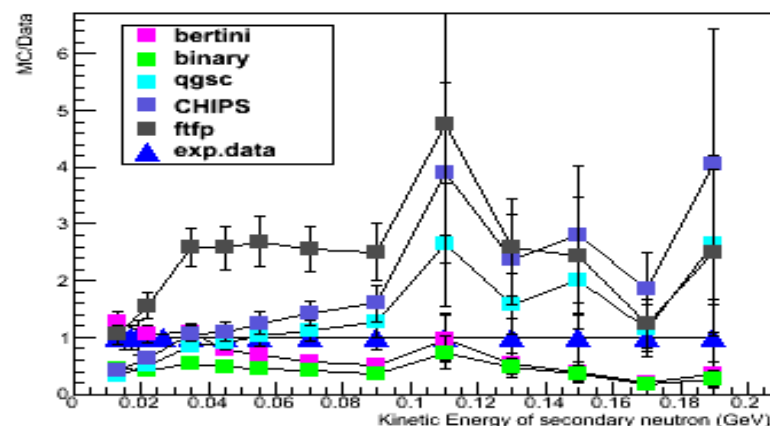
proton+C to n at 7.50 GeV (bertini) ($\theta = 59.10$)



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

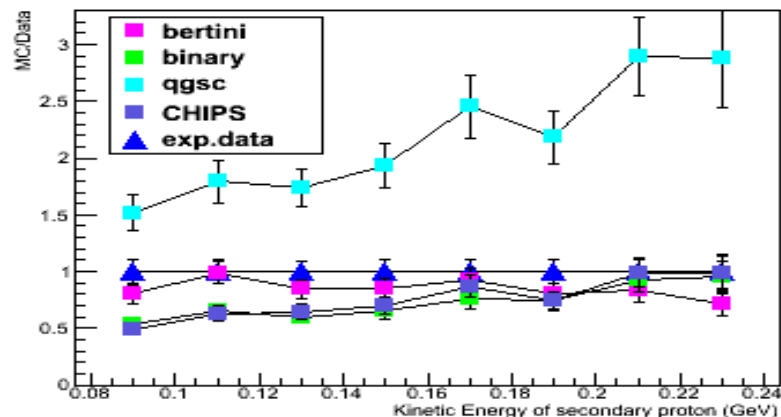


proton+C to n at 7.50 GeV (bertini) ($\theta = 119.00$)

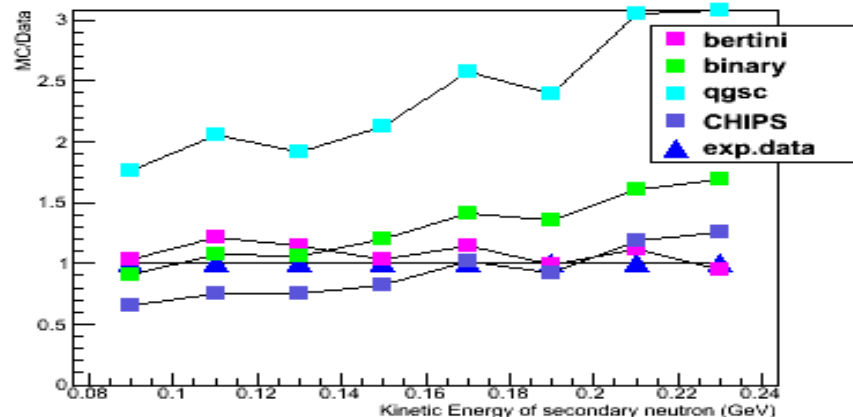


Test47: Models (III)

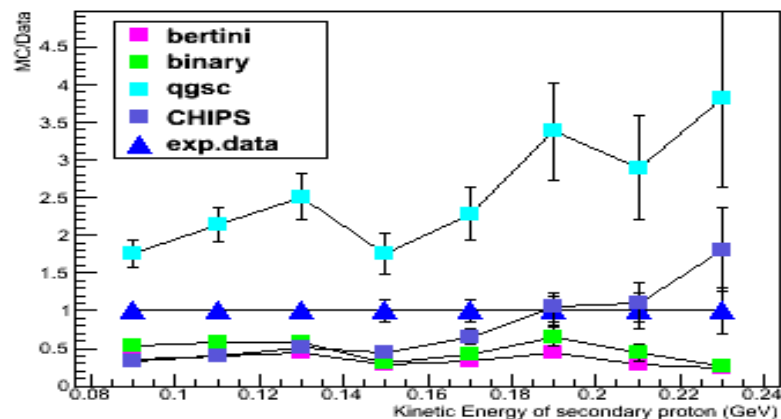
piminus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



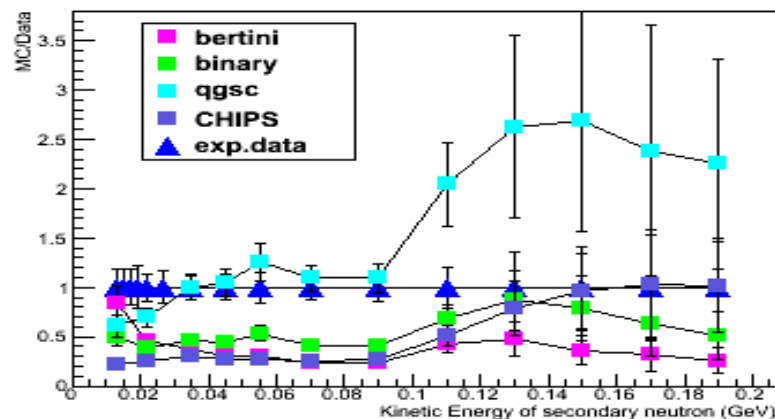
piminus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

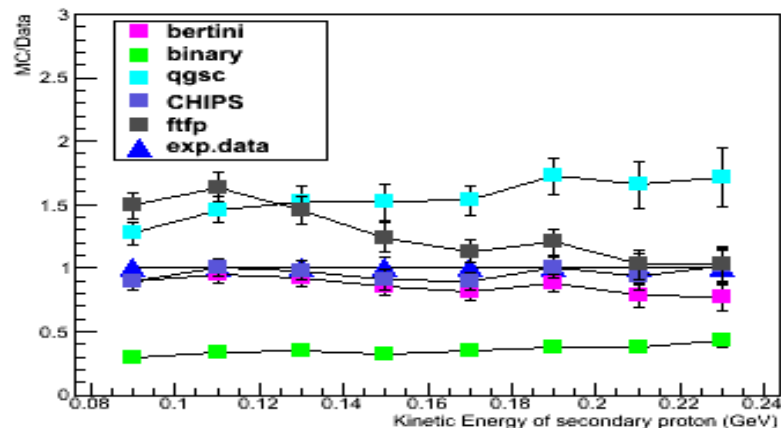


piminus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

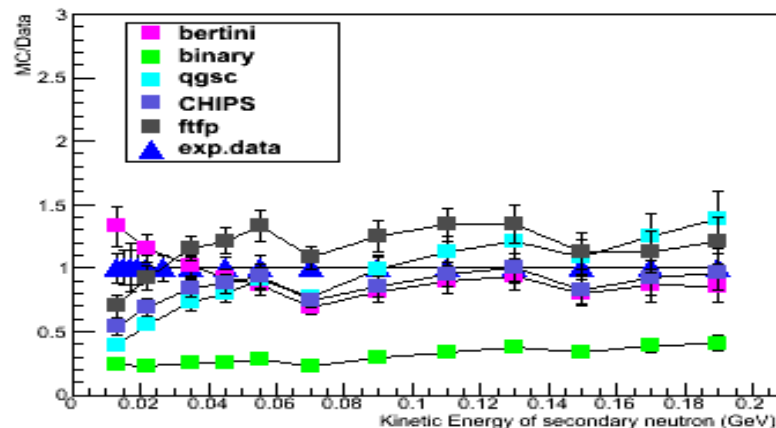


Test47: Models (IV)

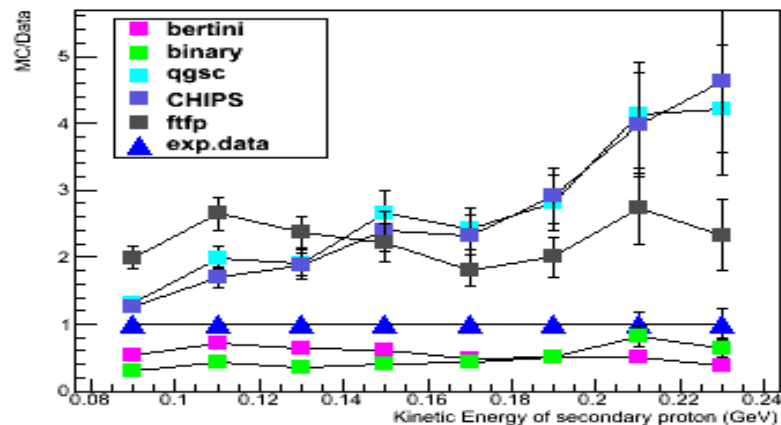
piminus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



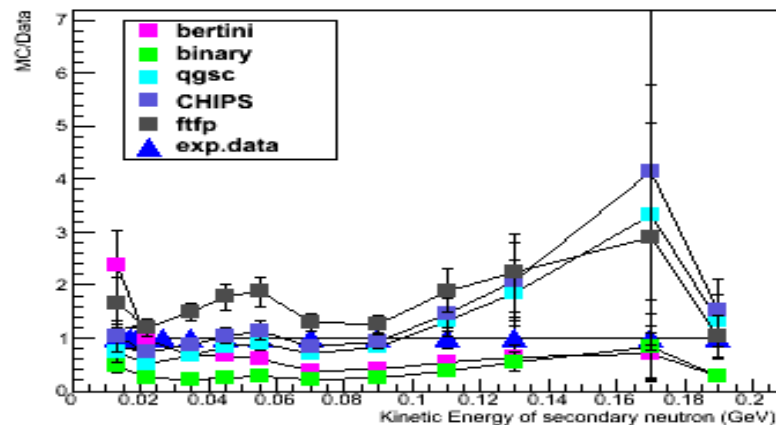
piminus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

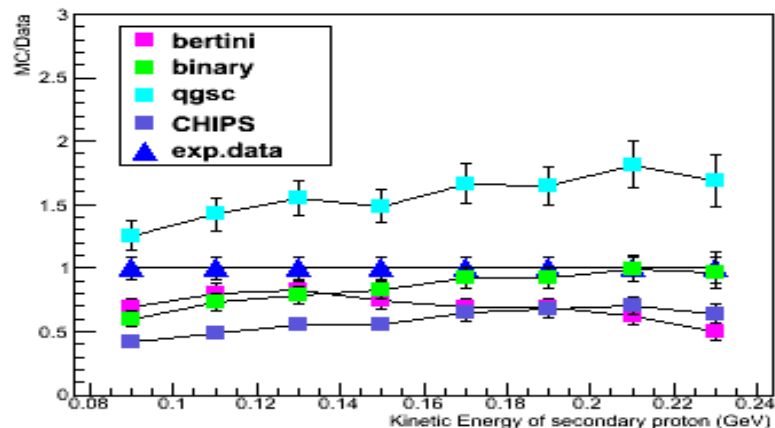


piminus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

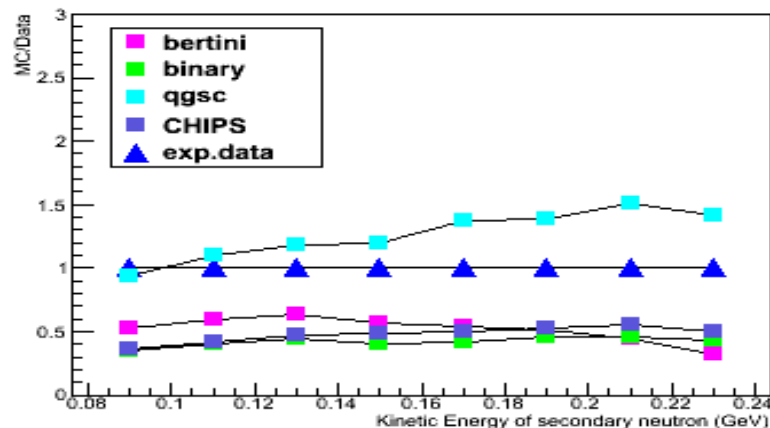


Test47: Models (V)

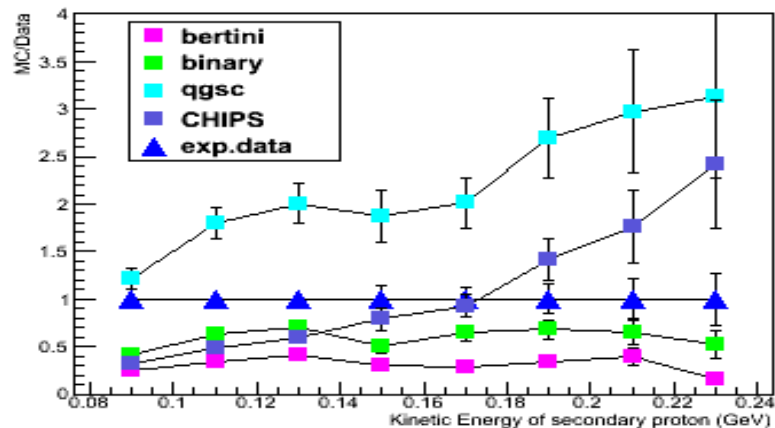
piplus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



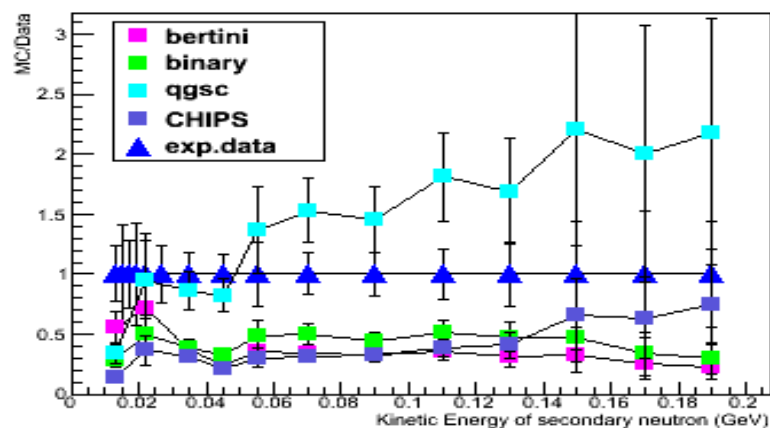
piplus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

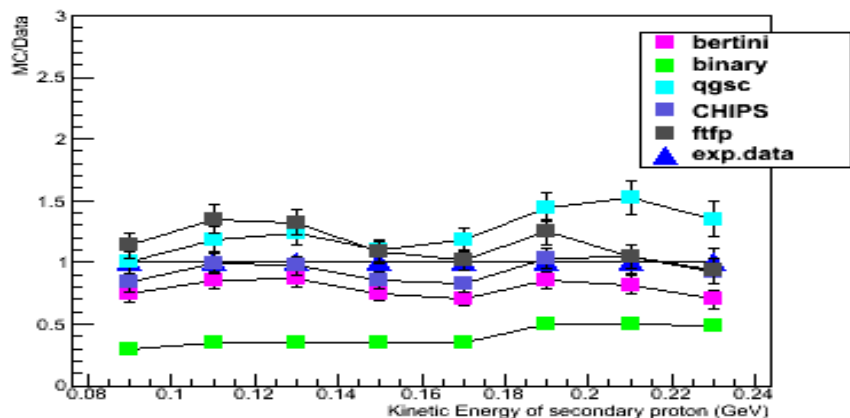


piplus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

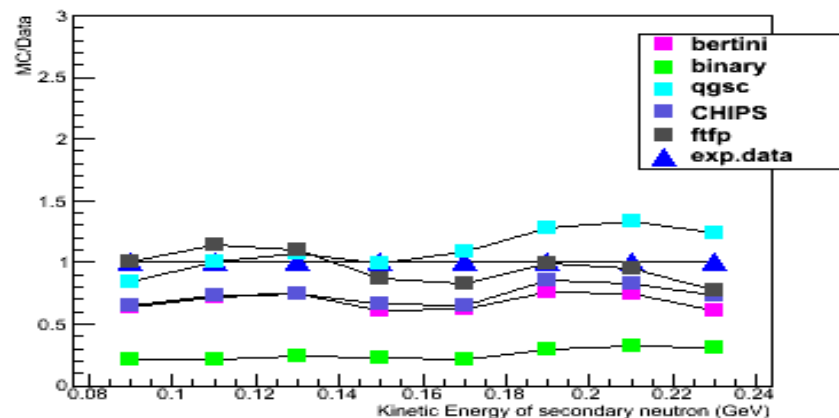


Test47: Models (VI)

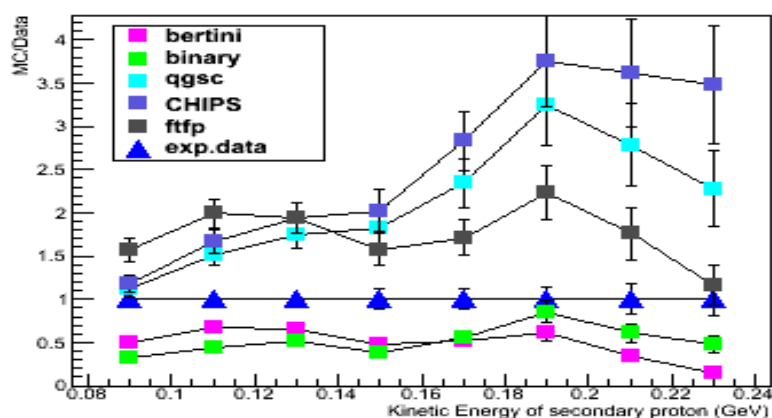
piplus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



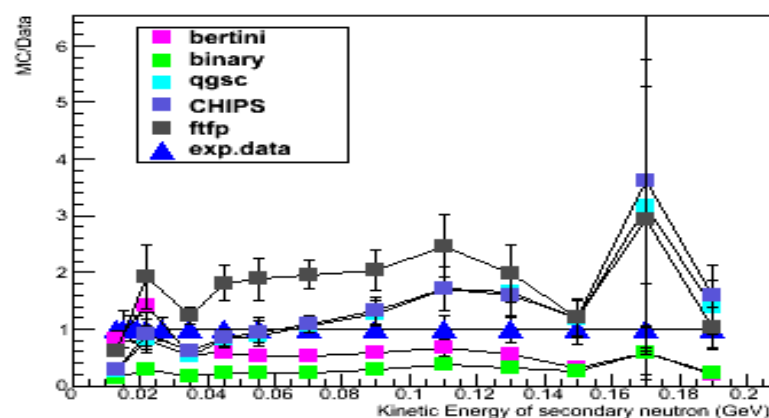
piplus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

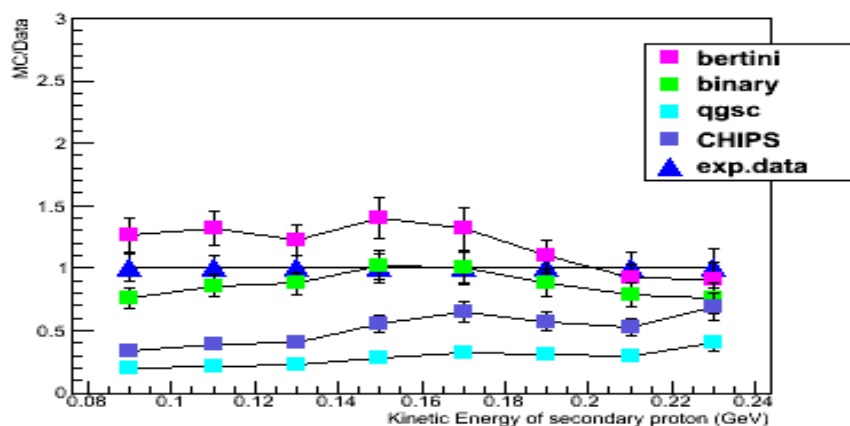


piplus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

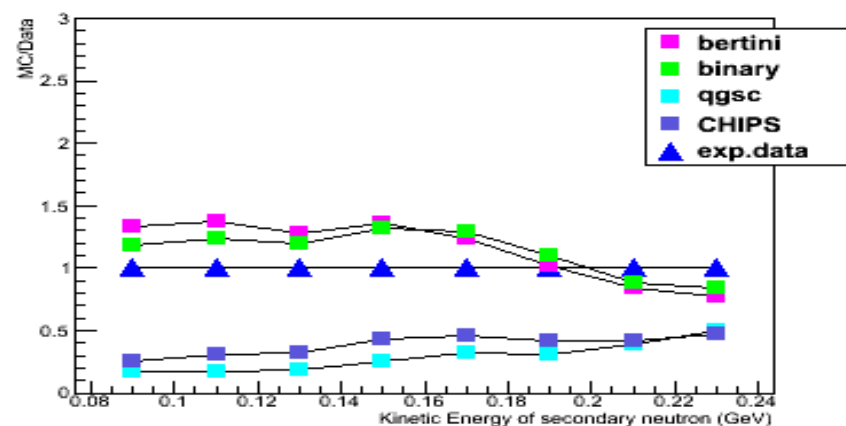


Test47: Models (VII)

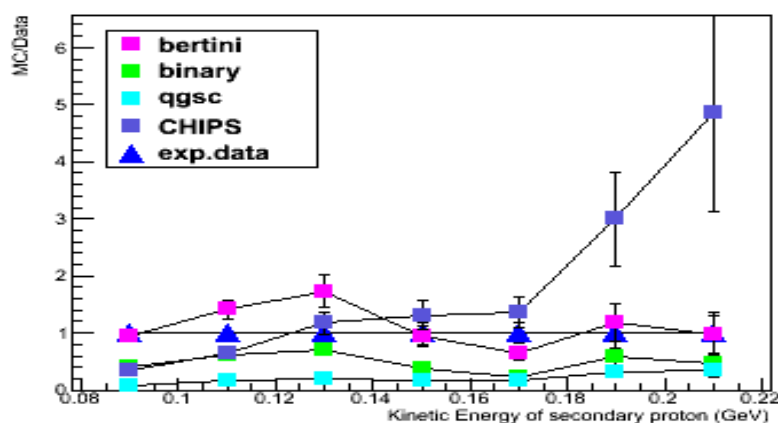
proton+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



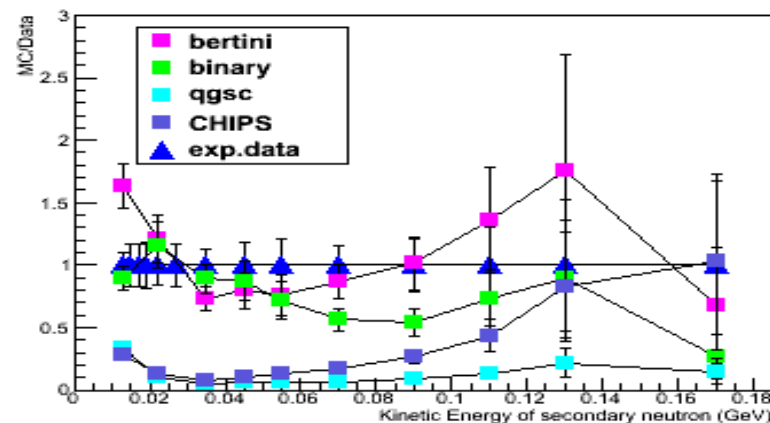
proton+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

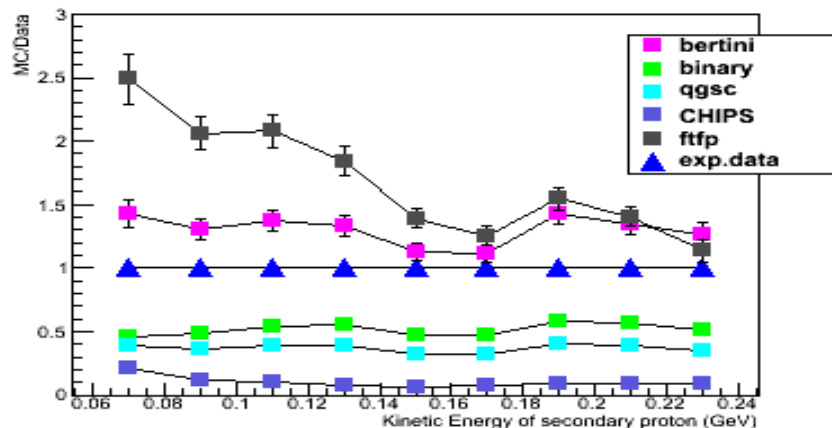


proton+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

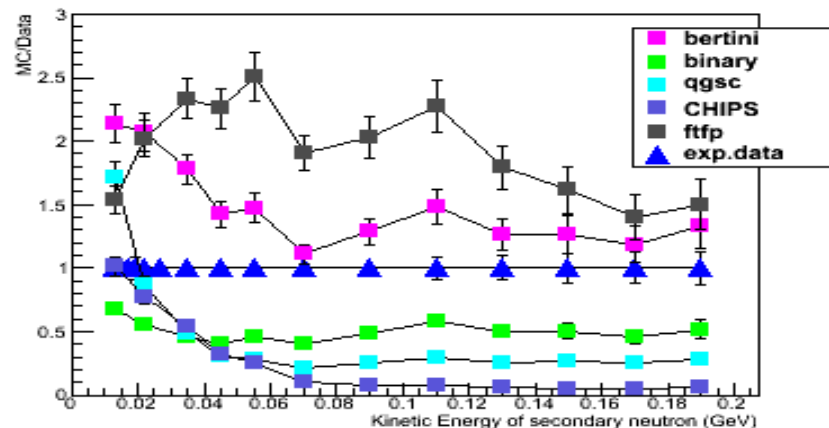


Test47: Models (VIII)

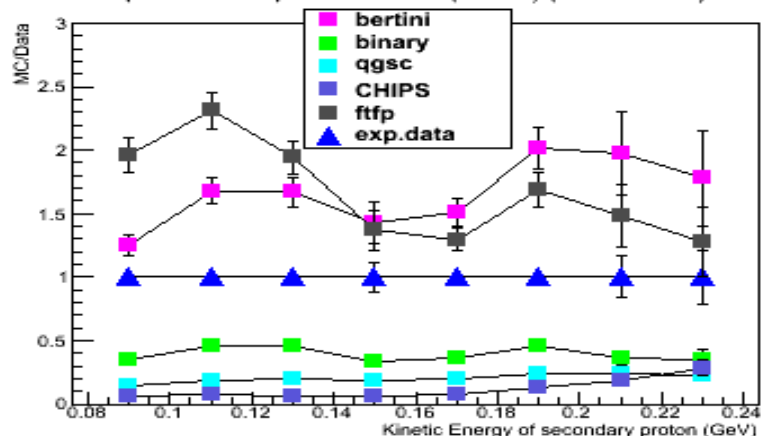
proton+U to p at 7.50 GeV (bertini) ($\theta = 59.10$)



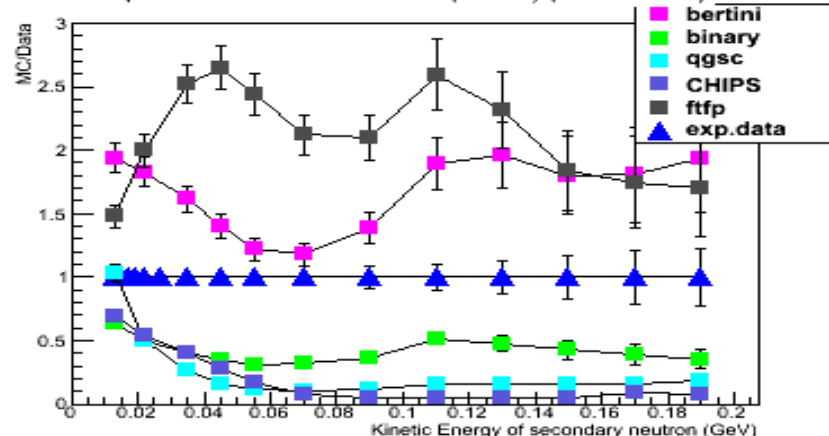
proton+U to n at 7.50 GeV (bertini) ($\theta = 59.10$)



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

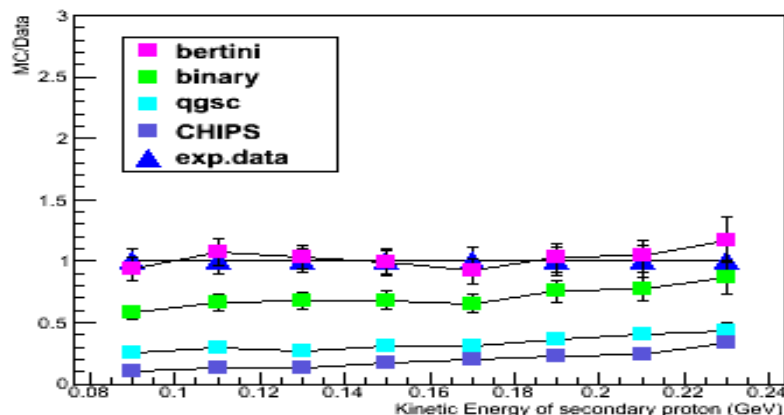


proton+U to n at 7.50 GeV (bertini) ($\theta = 119.00$)

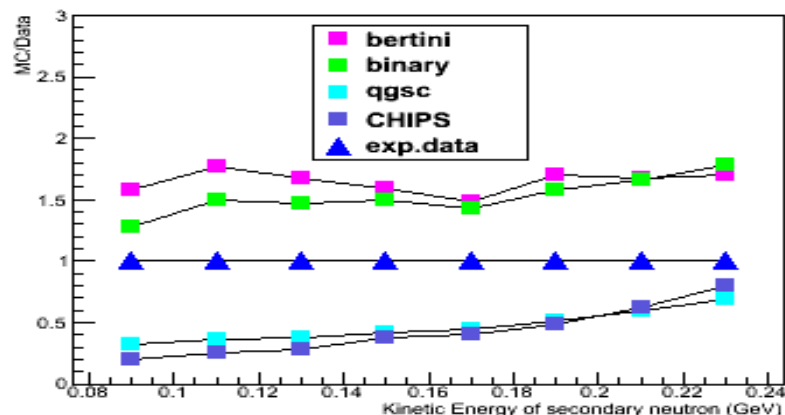


Test47: Models (IX)

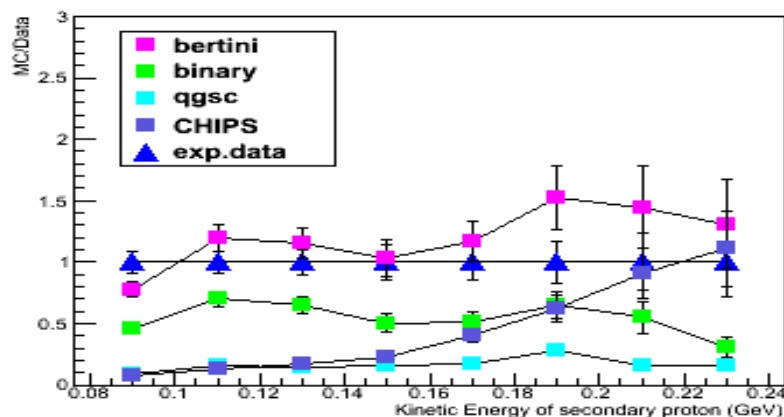
piminus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



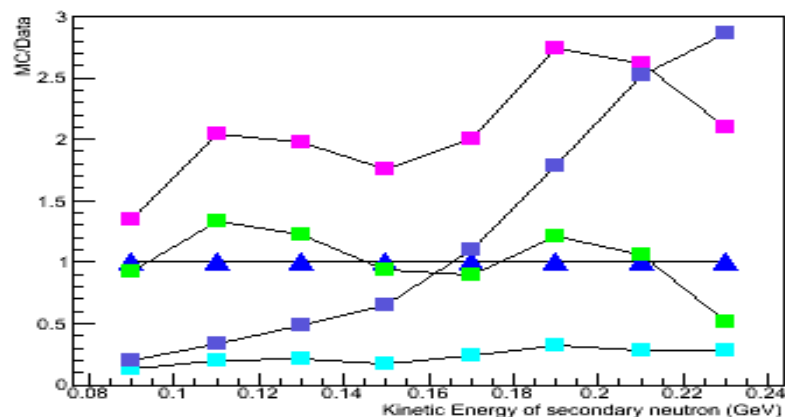
piminus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

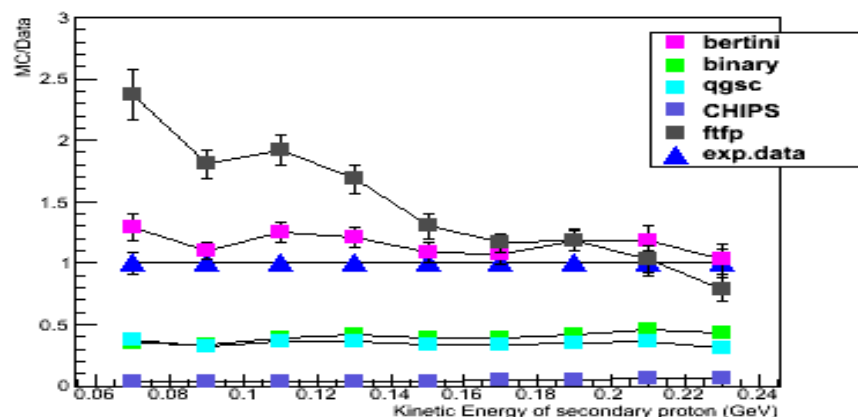


piminus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

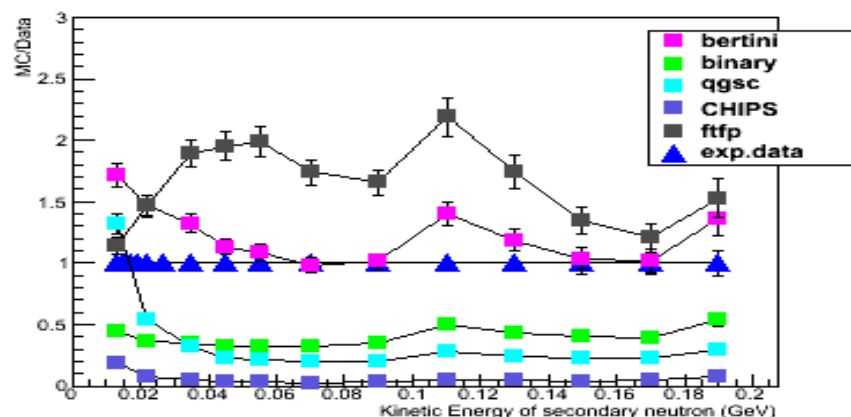


Test47: Models (X)

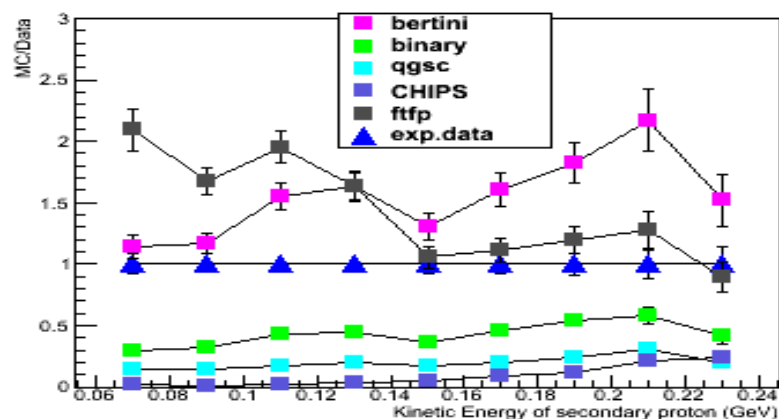
piminus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



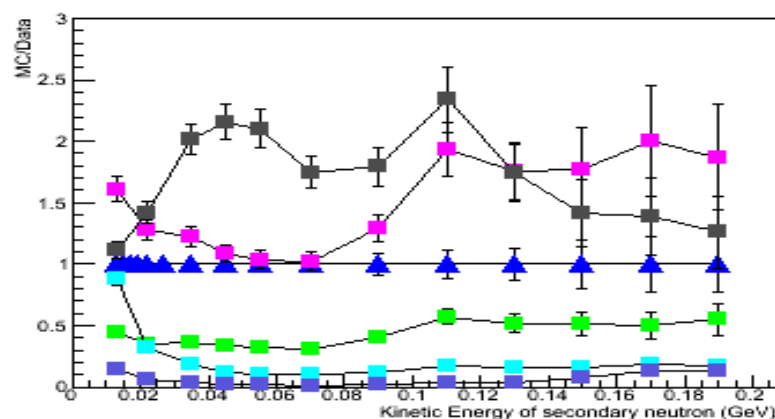
piminus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

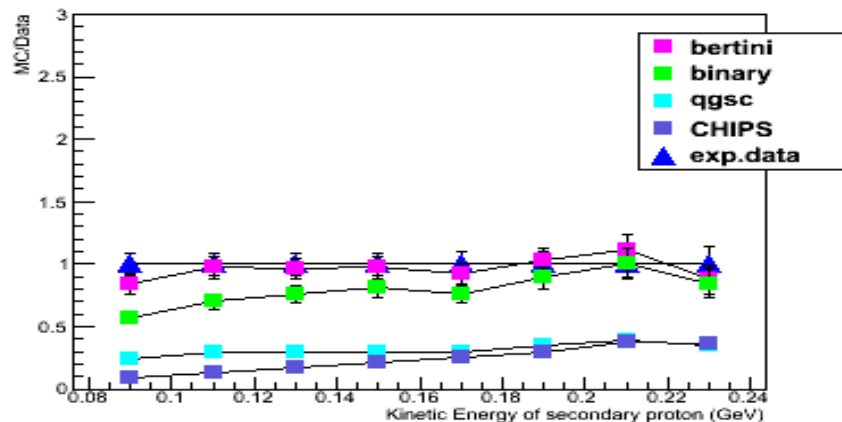


piminus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

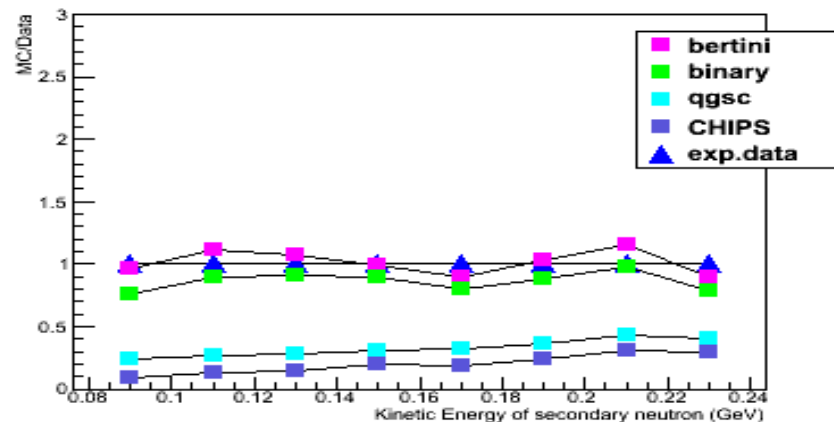


Test47: Models (XI)

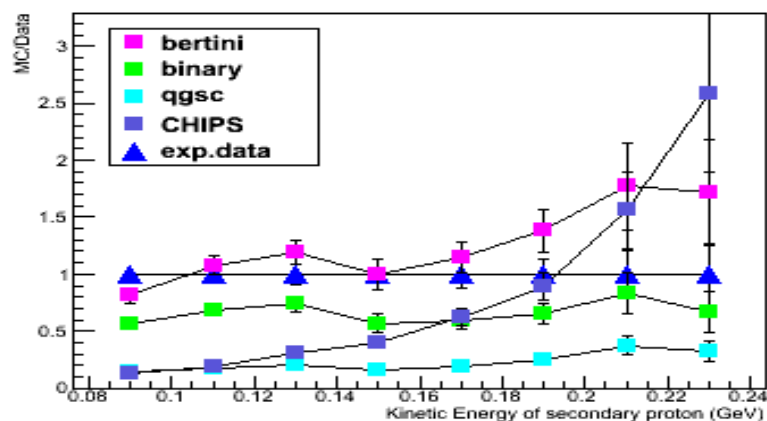
piplus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



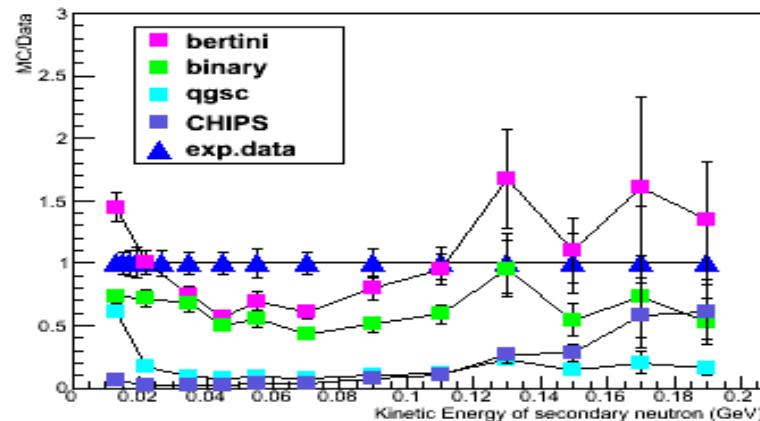
piplus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

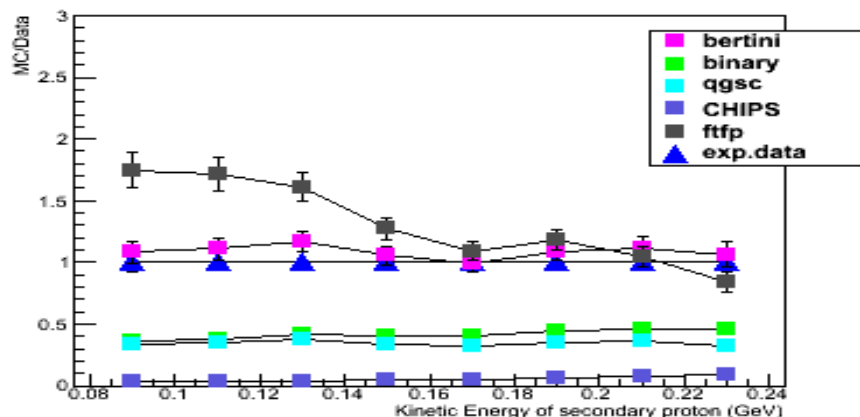


piplus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

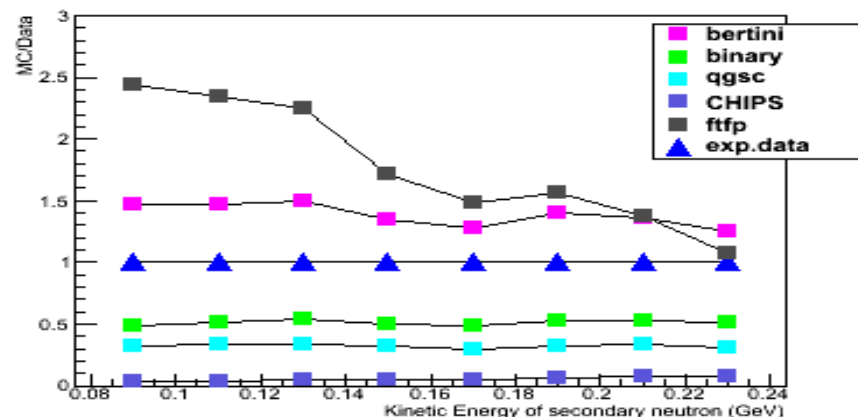


Test47: Models (XII)

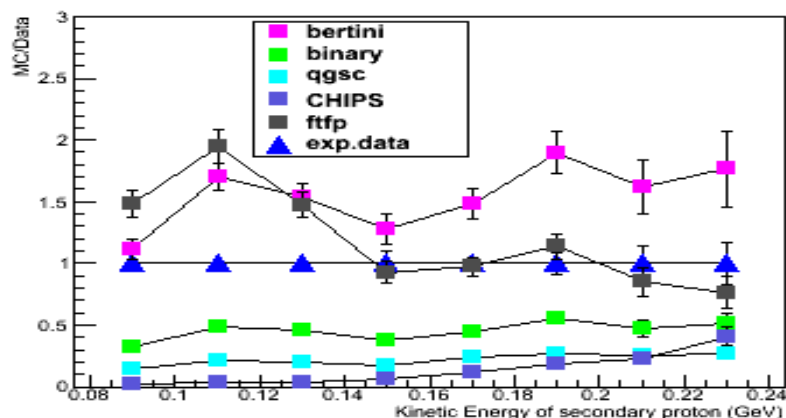
piplus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



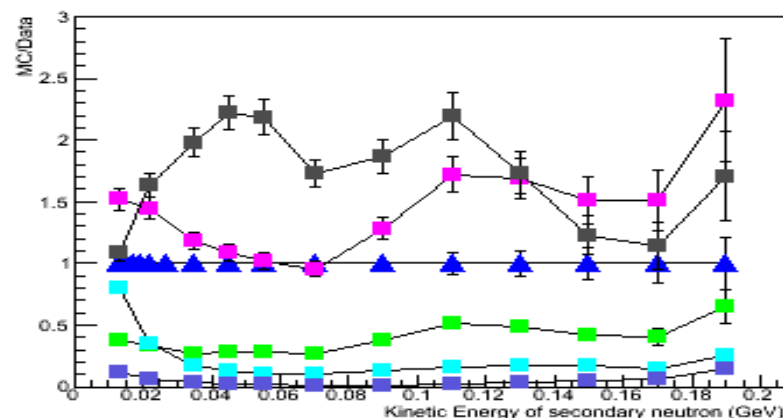
piplus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

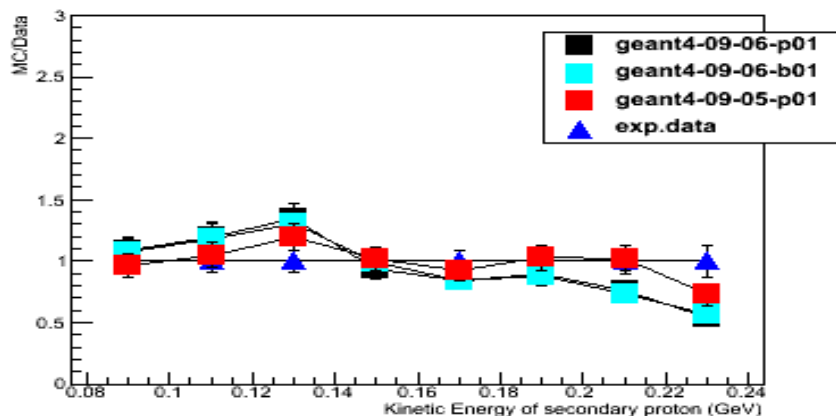


piplus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

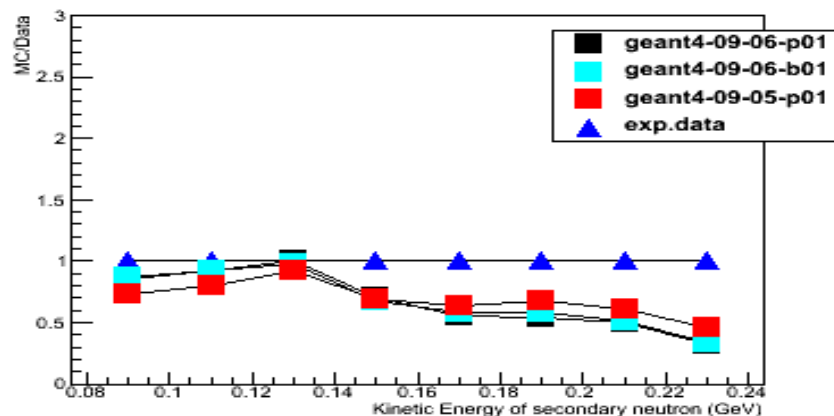


Test47: Bertini Regression (I)

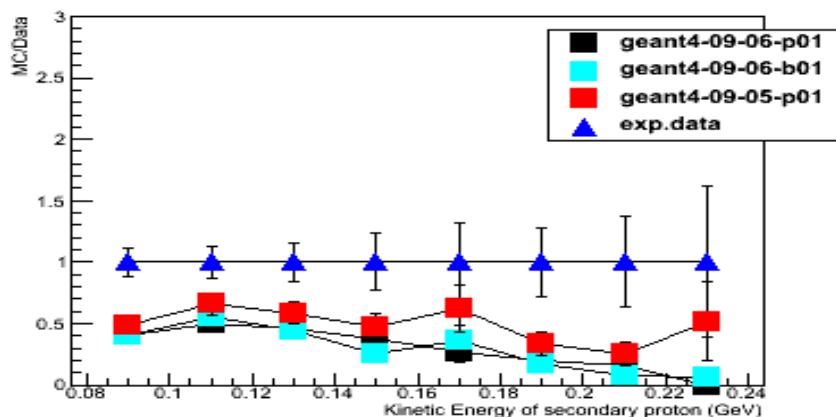
proton+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



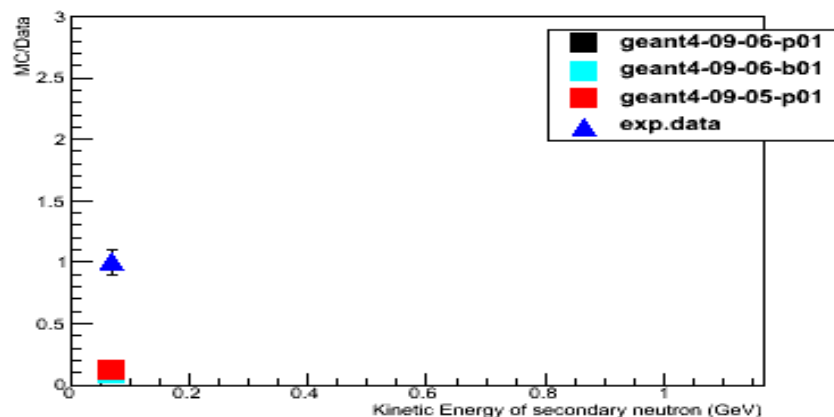
proton+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

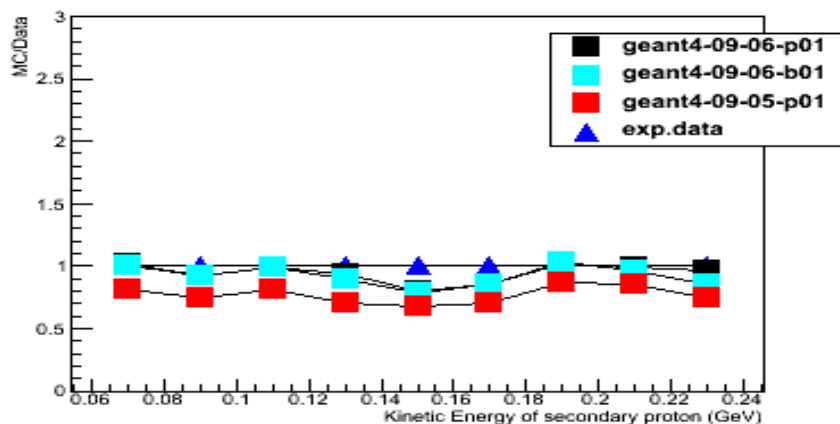


proton+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

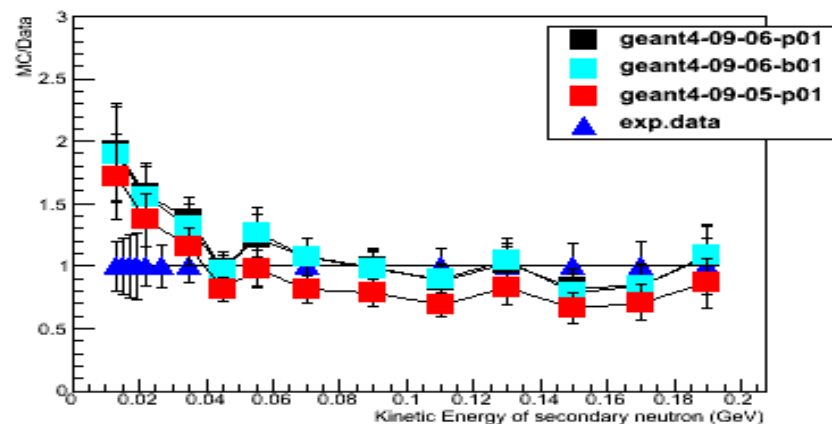


Test47: Bertini Regression (II)

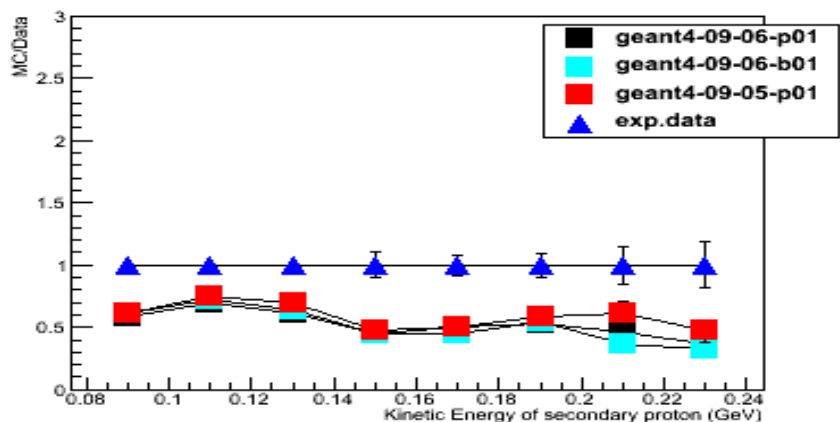
proton+C to p at 7.50 GeV (bertini) ($\theta = 59.10$)



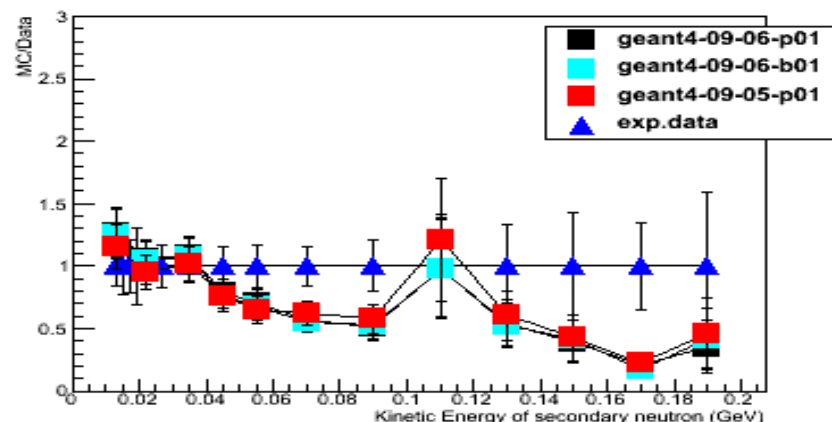
proton+C to n at 7.50 GeV (bertini) ($\theta = 59.10$)



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

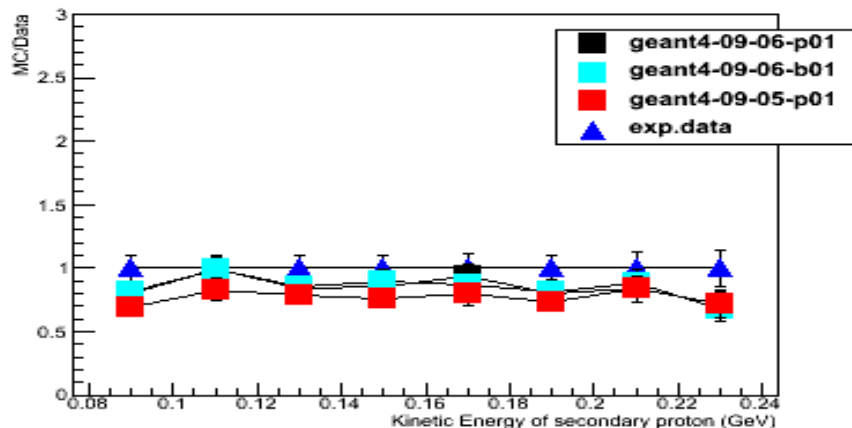


proton+C to n at 7.50 GeV (bertini) ($\theta = 119.00$)

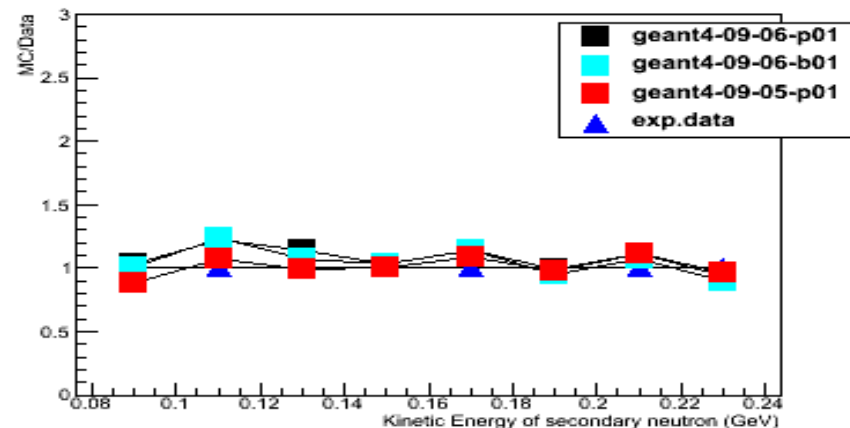


Test47: Bertini Regression (III)

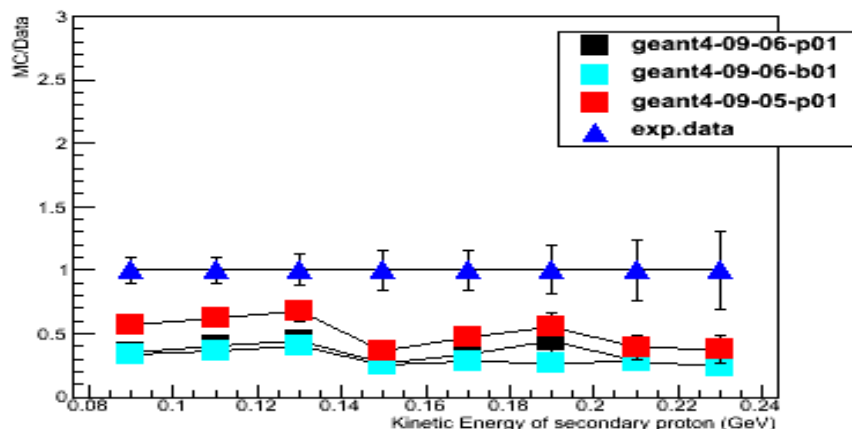
piminus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



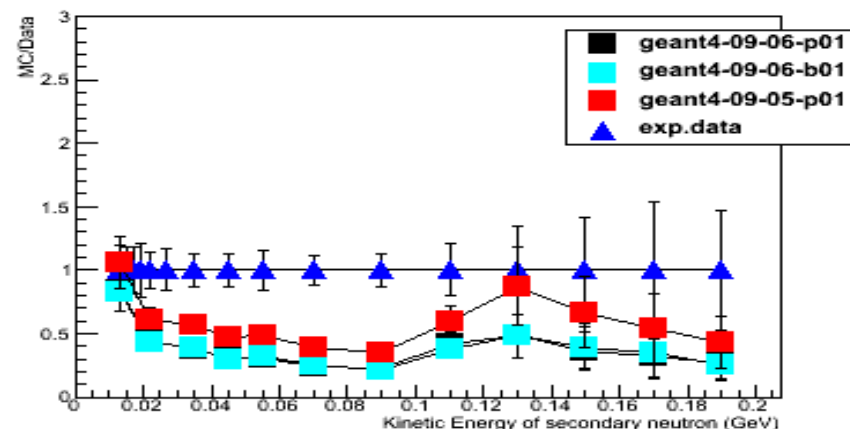
piminus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

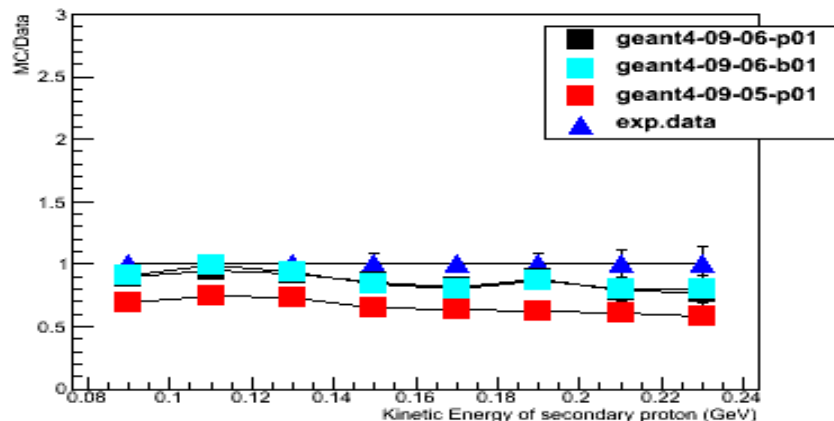


piminus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

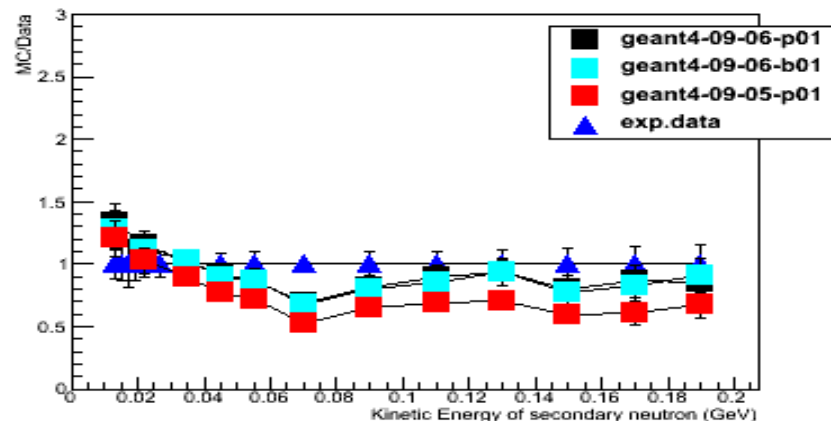


Test47: Bertini Regression (IV)

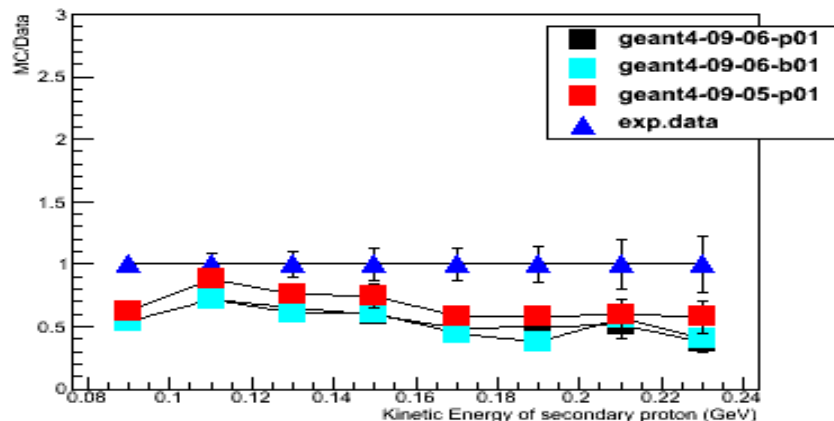
piminus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



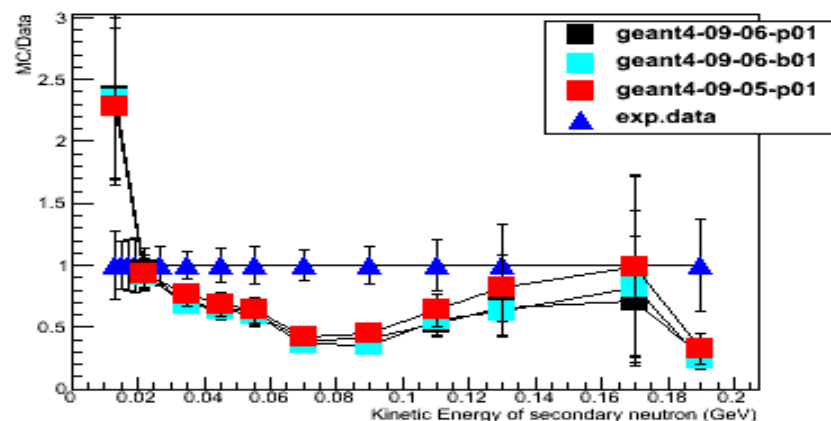
piminus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

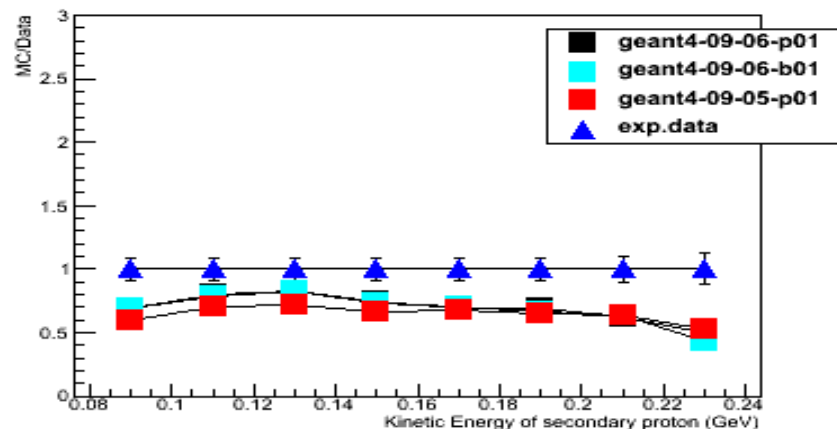


piminus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

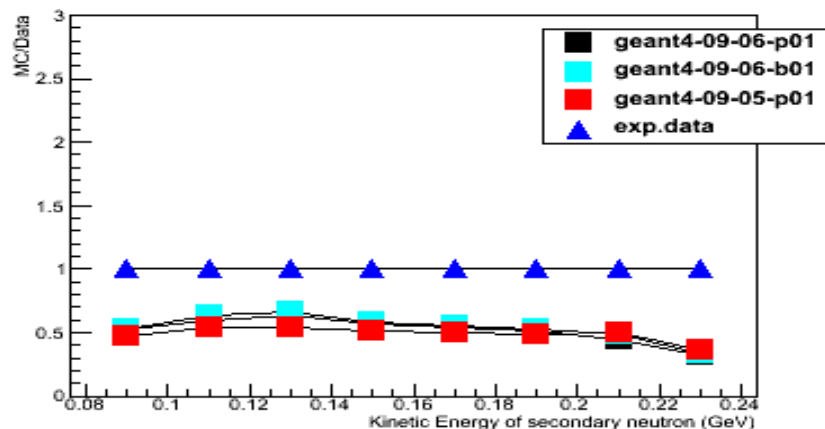


Test47: Bertini Regression (V)

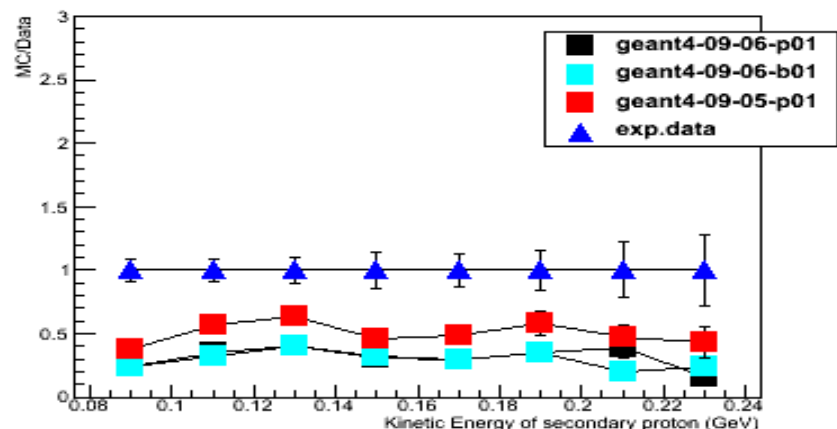
piplus+C to p at 1.40 GeV (bertini) ($\theta = 59.10$)



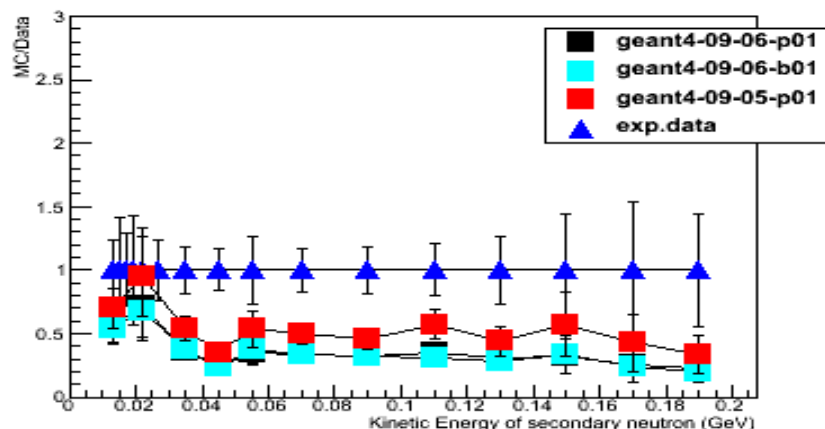
piplus+C to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

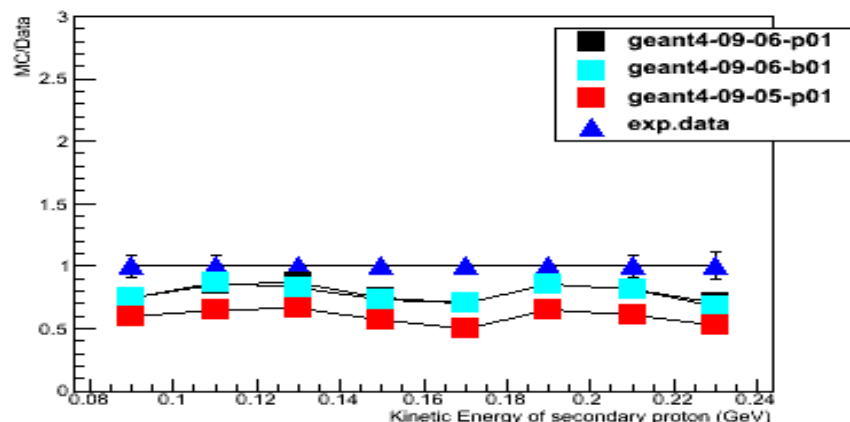


piplus+C to n at 1.40 GeV (bertini) ($\theta = 119.00$)

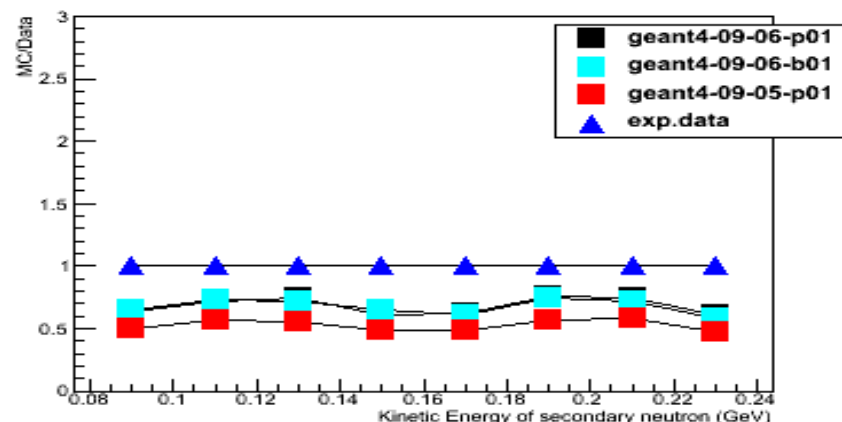


Test47: Bertini Regression (VI)

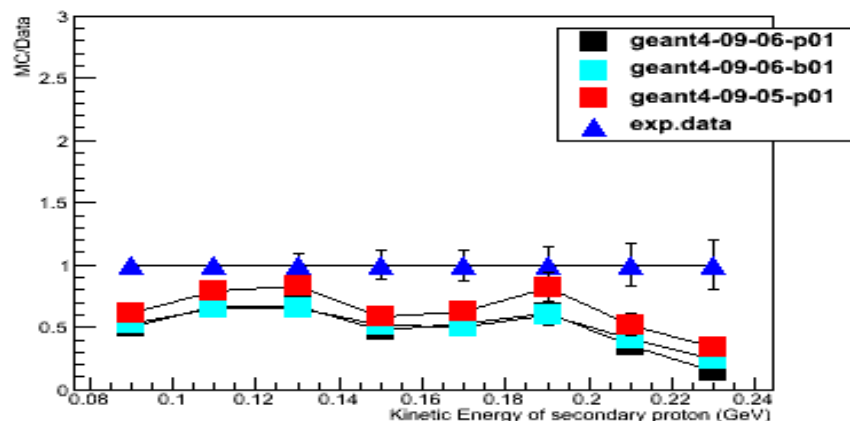
piplus+C to p at 5.00 GeV (bertini) ($\theta = 59.10$)



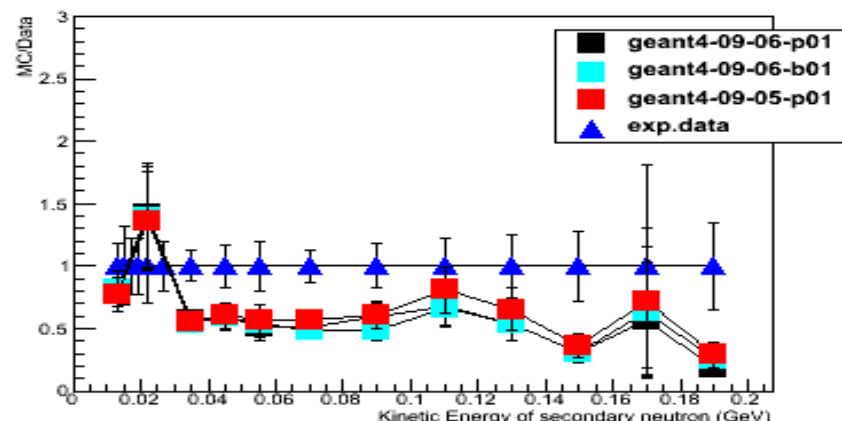
piplus+C to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

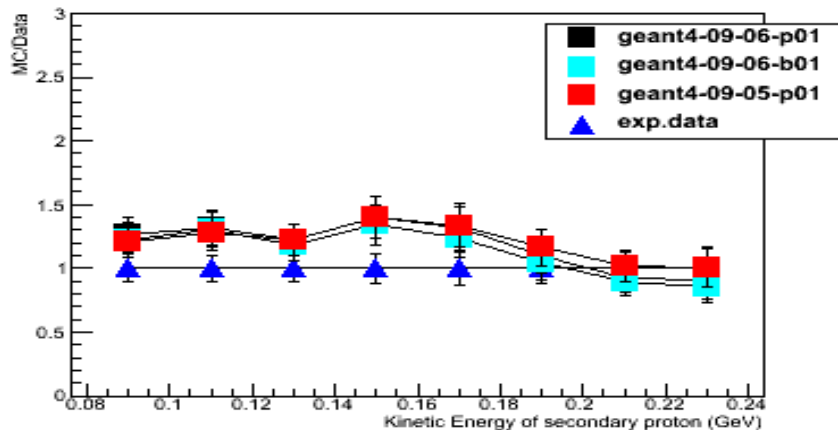


piplus+C to n at 5.00 GeV (bertini) ($\theta = 119.00$)

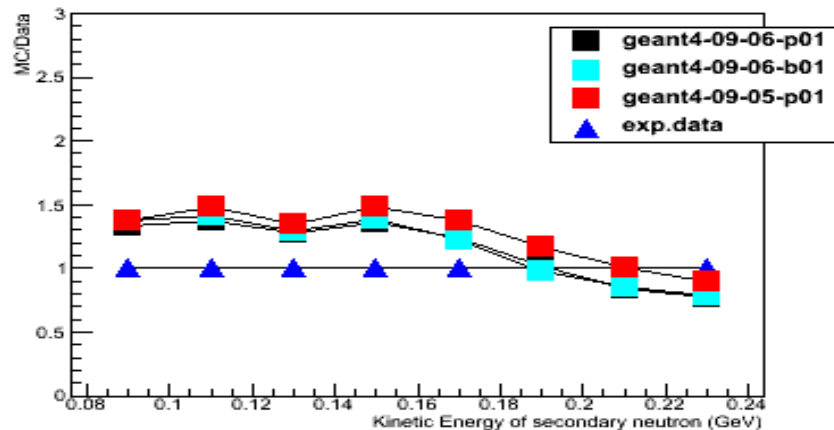


Test47: Bertini Regression (VII)

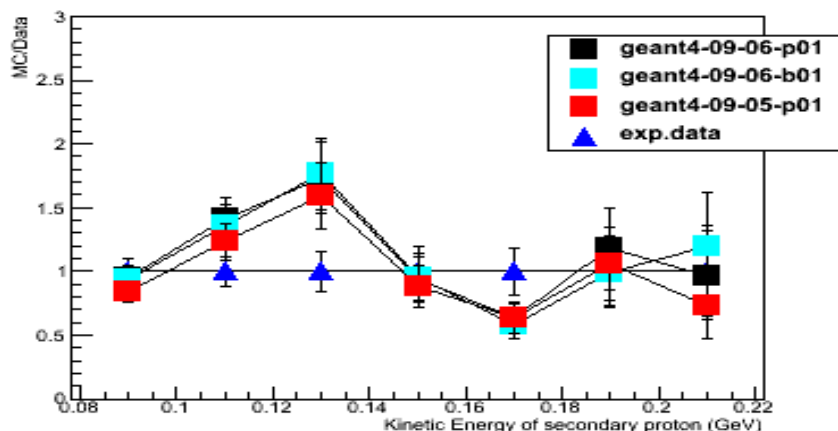
proton+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



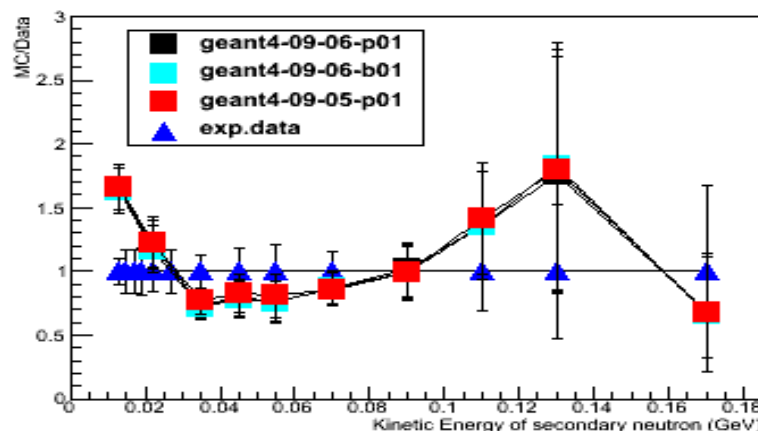
proton+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

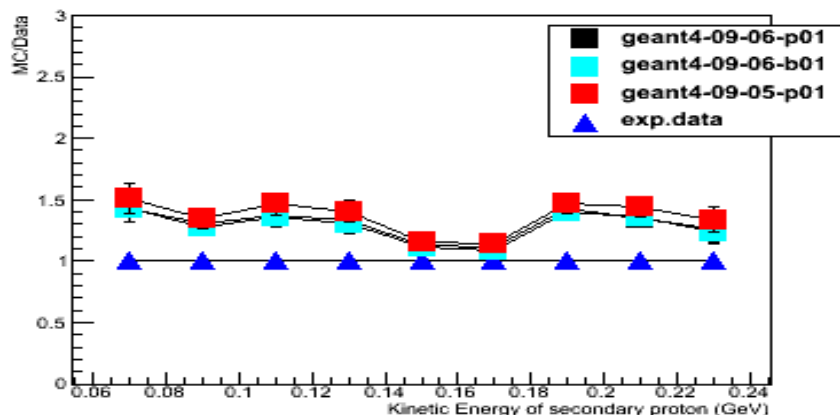


proton+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

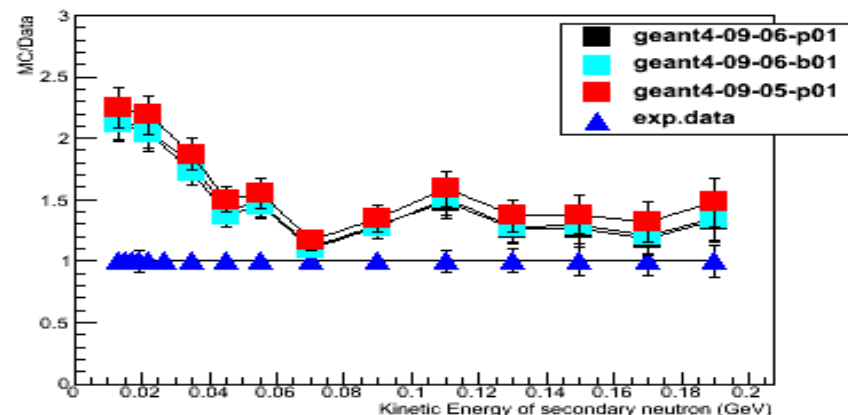


Test47: Bertini Regression (VIII)

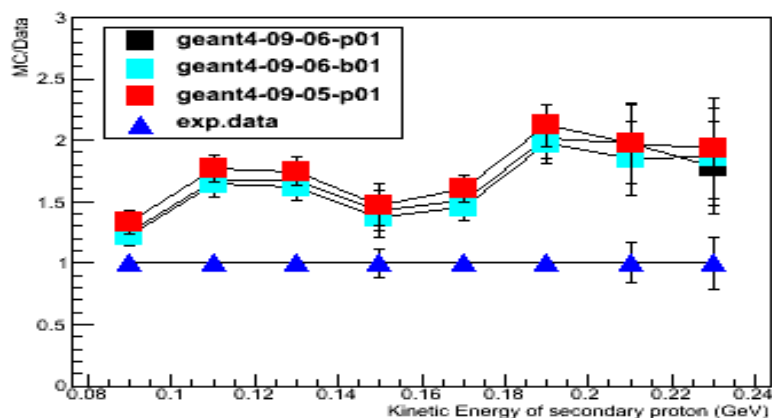
proton+U to p at 7.50 GeV (bertini) ($\theta = 59.10$)



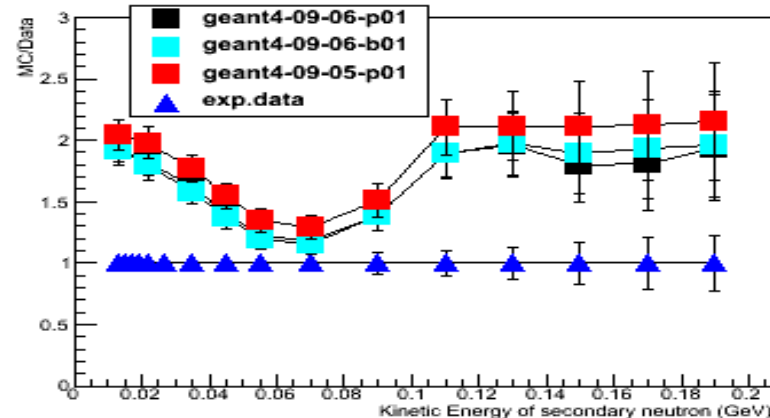
proton+U to n at 7.50 GeV (bertini) ($\theta = 59.10$)



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

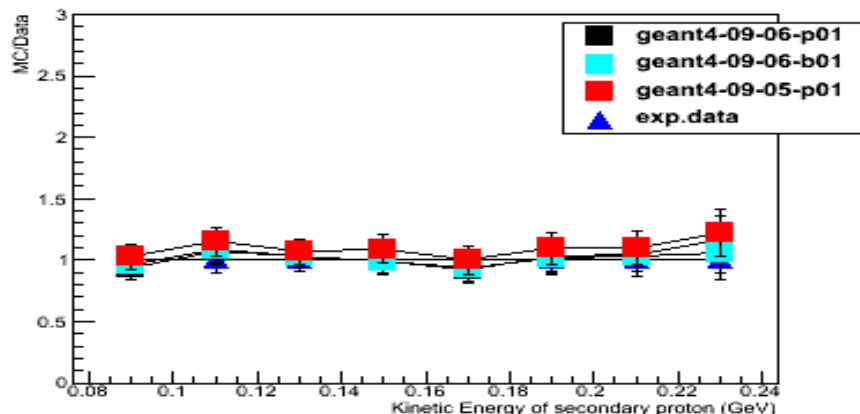


proton+U to n at 7.50 GeV (bertini) ($\theta = 119.00$)

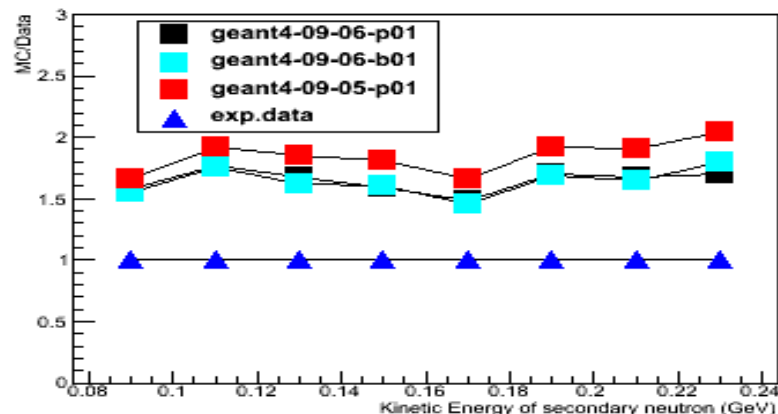


Test47: Bertini Regression (IX)

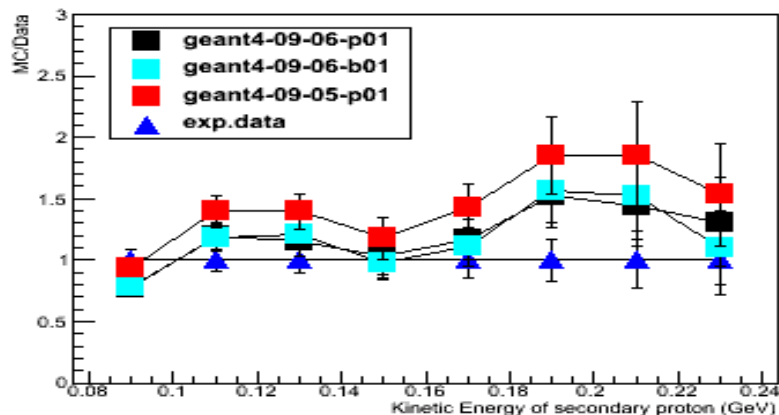
piminus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



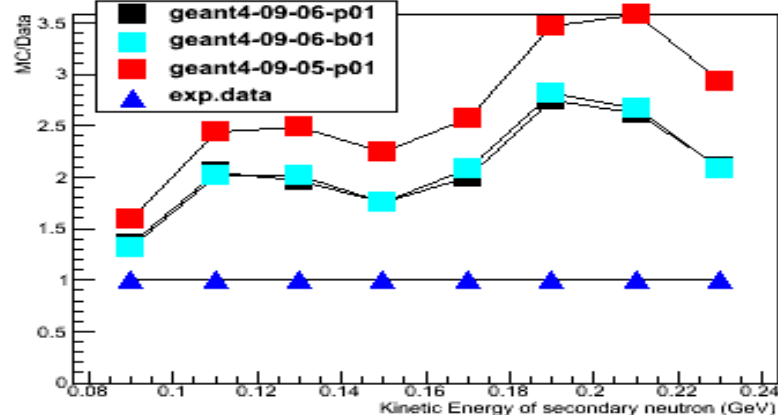
piminus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

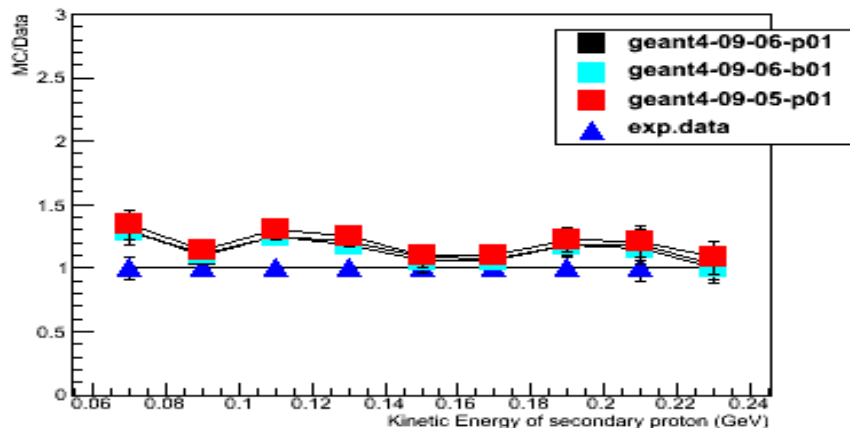


piminus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

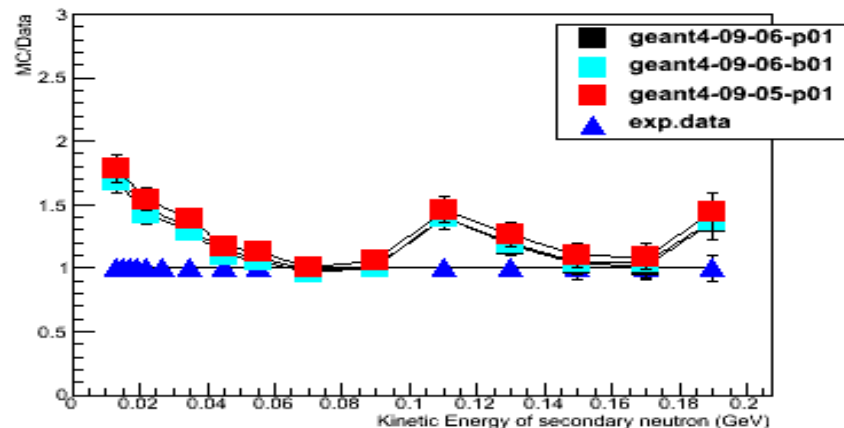


Test47: Bertini Regression (X)

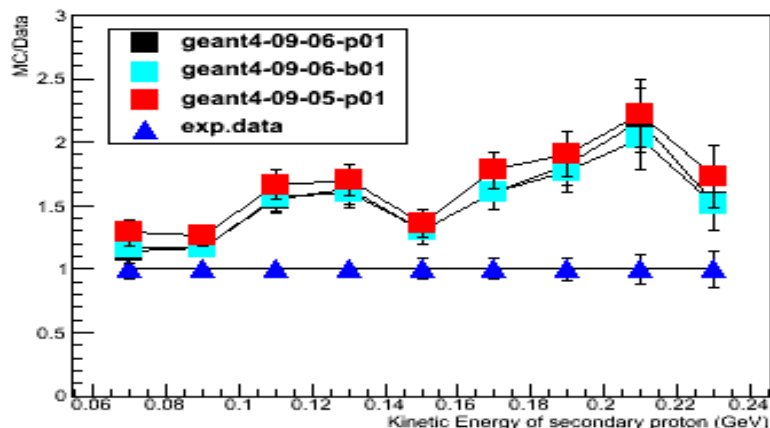
piminus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



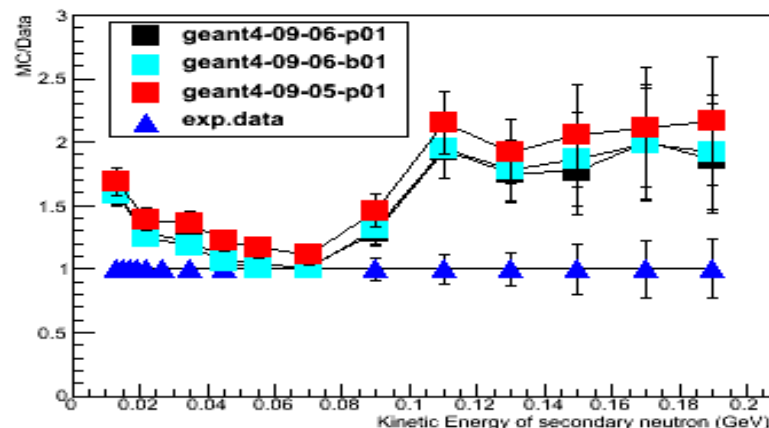
piminus+U to n at 5.00 GeV (bertini) ($\theta = 59.10$)



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

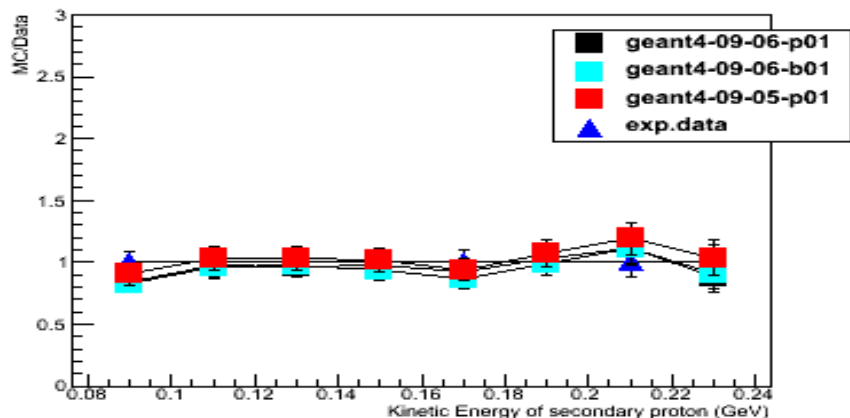


piminus+U to n at 5.00 GeV (bertini) ($\theta = 119.00$)

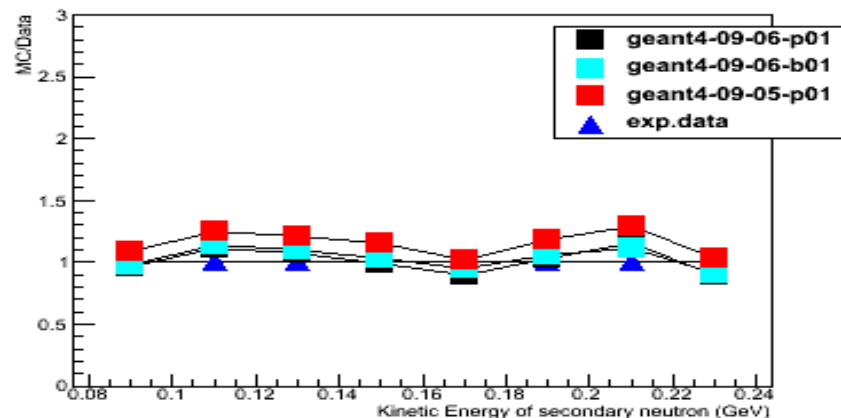


Test47: Bertini Regression (XI)

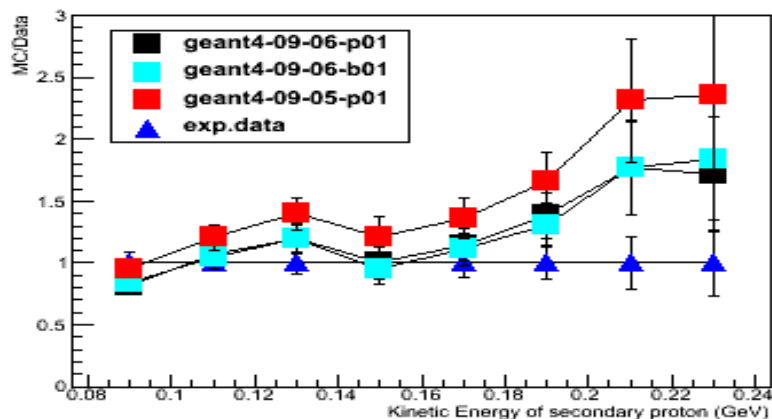
piplus+U to p at 1.40 GeV (bertini) ($\theta = 59.10$)



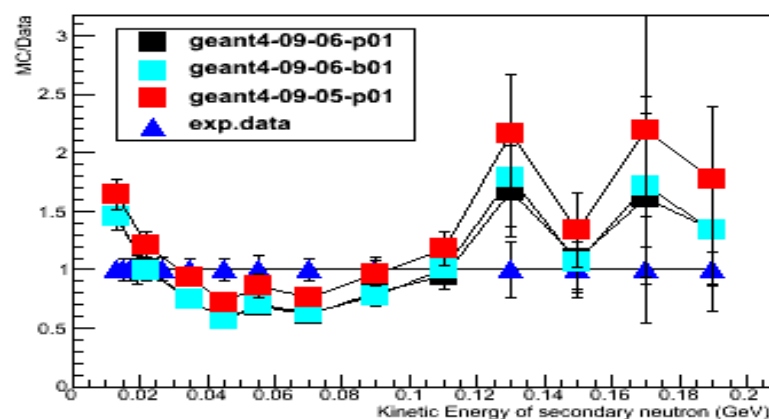
piplus+U to n at 1.40 GeV (bertini) ($\theta = 59.10$)



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

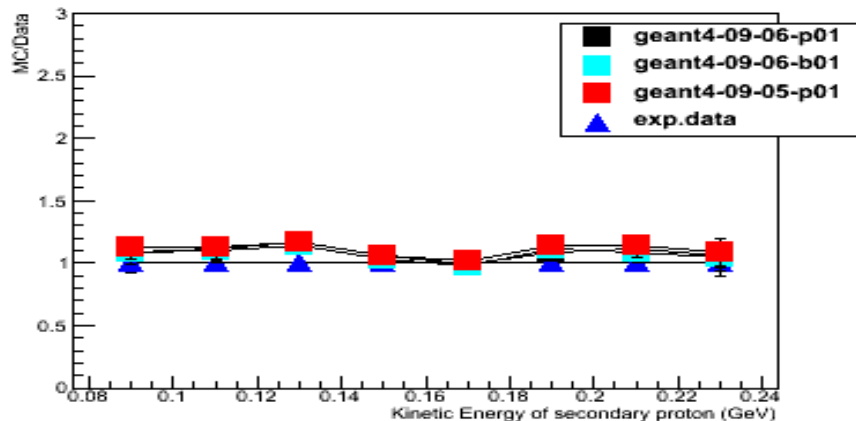


piplus+U to n at 1.40 GeV (bertini) ($\theta = 119.00$)

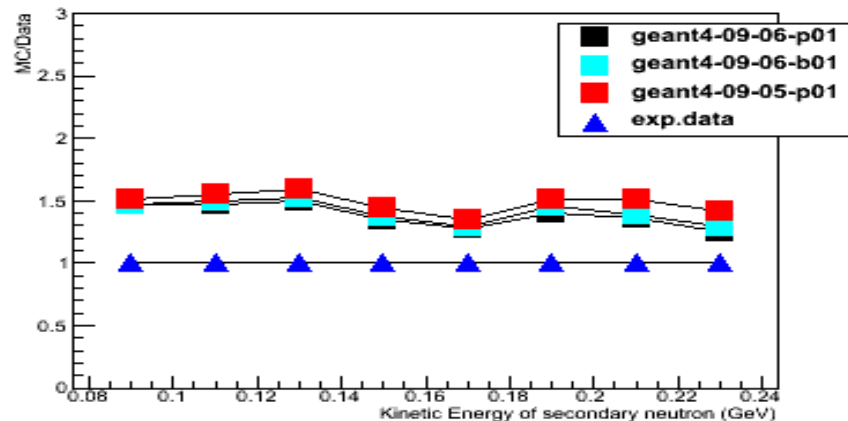


Test47: Bertini Regression (XII)

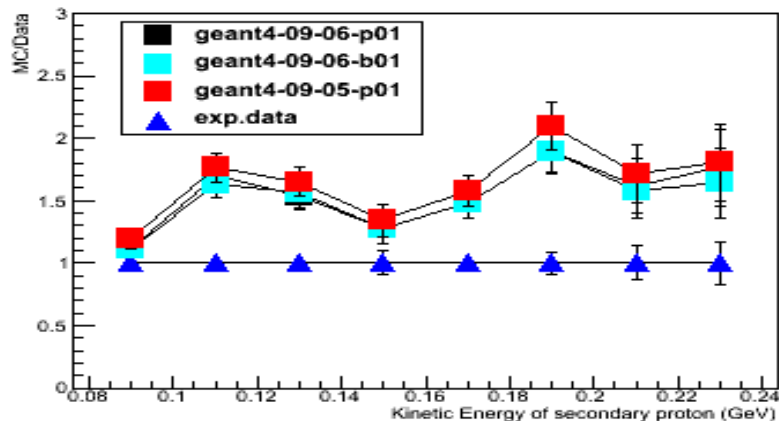
piplus+U to p at 5.00 GeV (bertini) ($\theta = 59.10$)



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) ($\theta = 119.00$)

