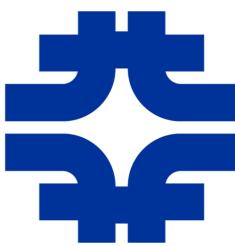


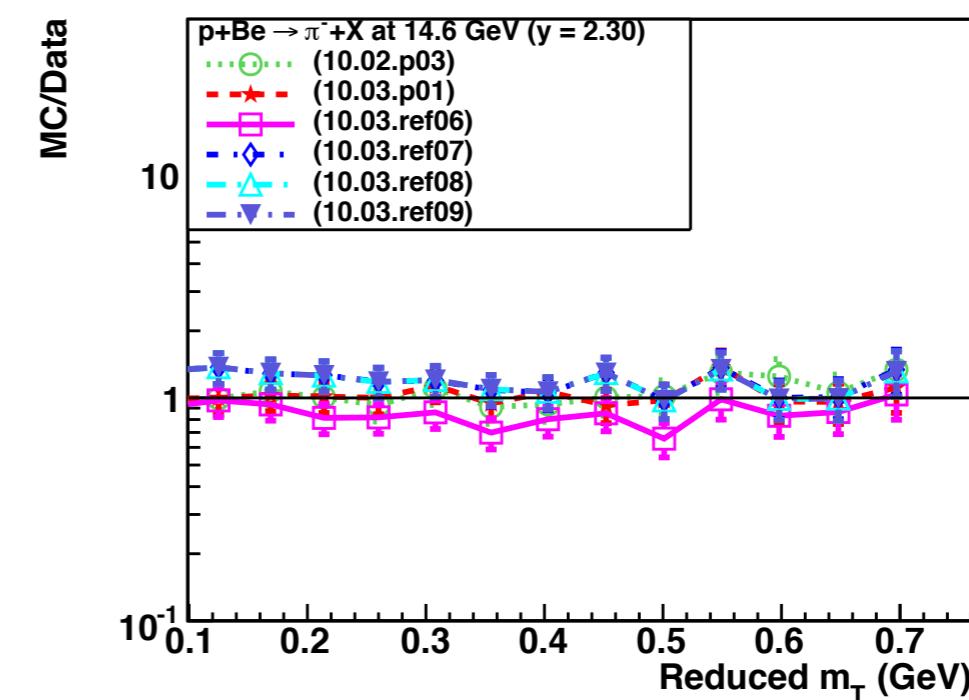
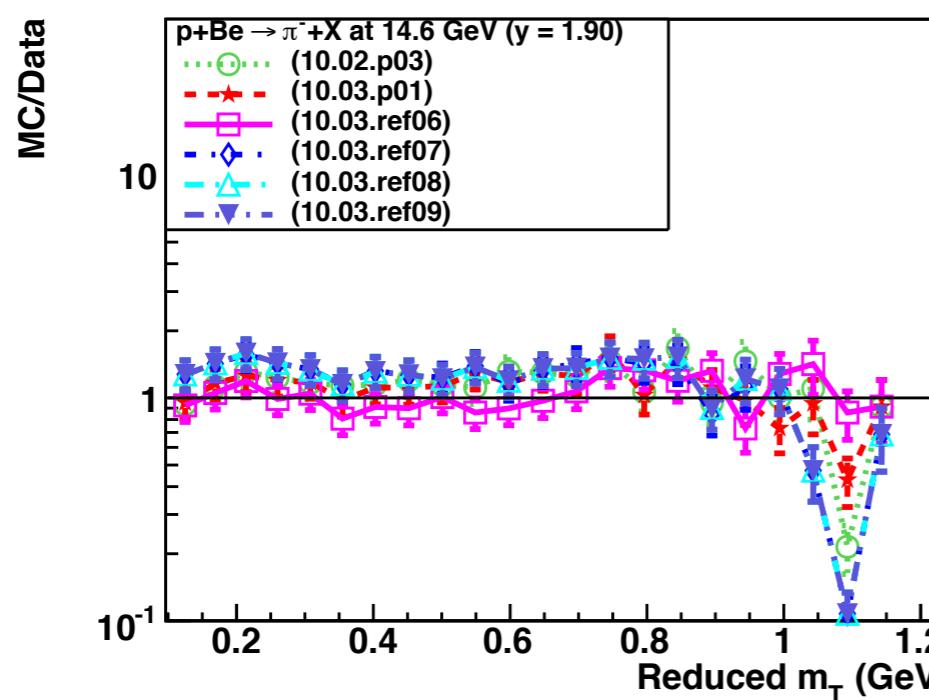
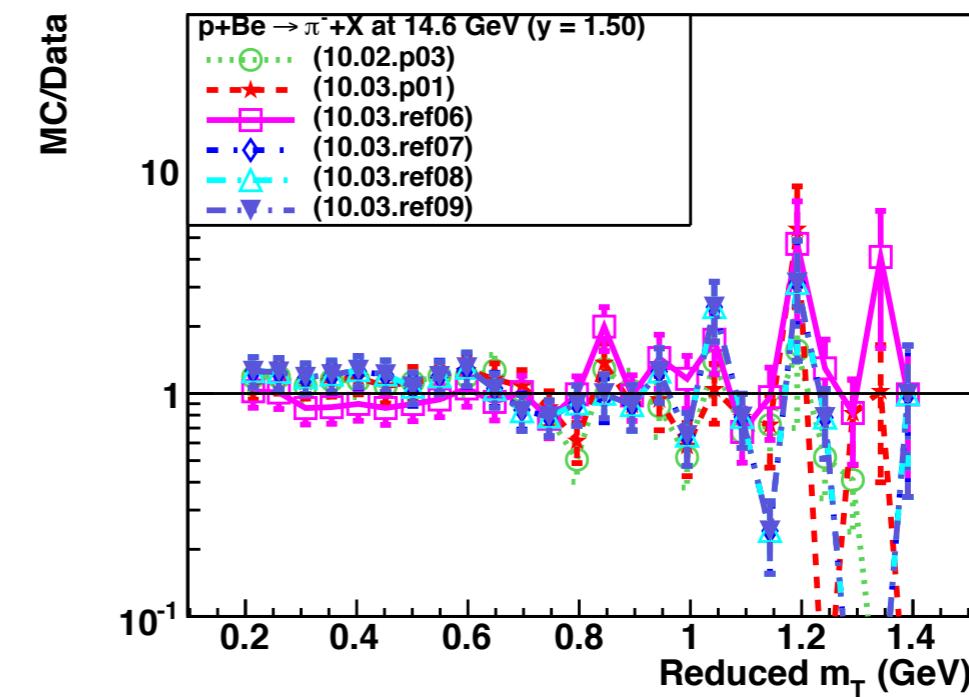
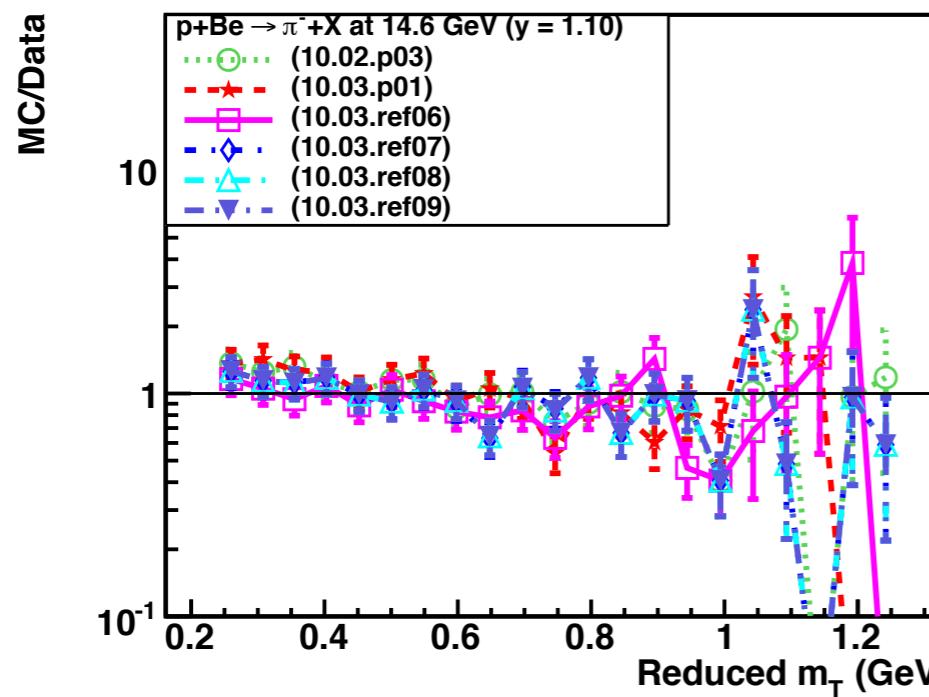
Validation of Hadronic Models using BNL E802 and MIAPP data

Geant4 Hadronic Working Group Meeting
October 18, 2017

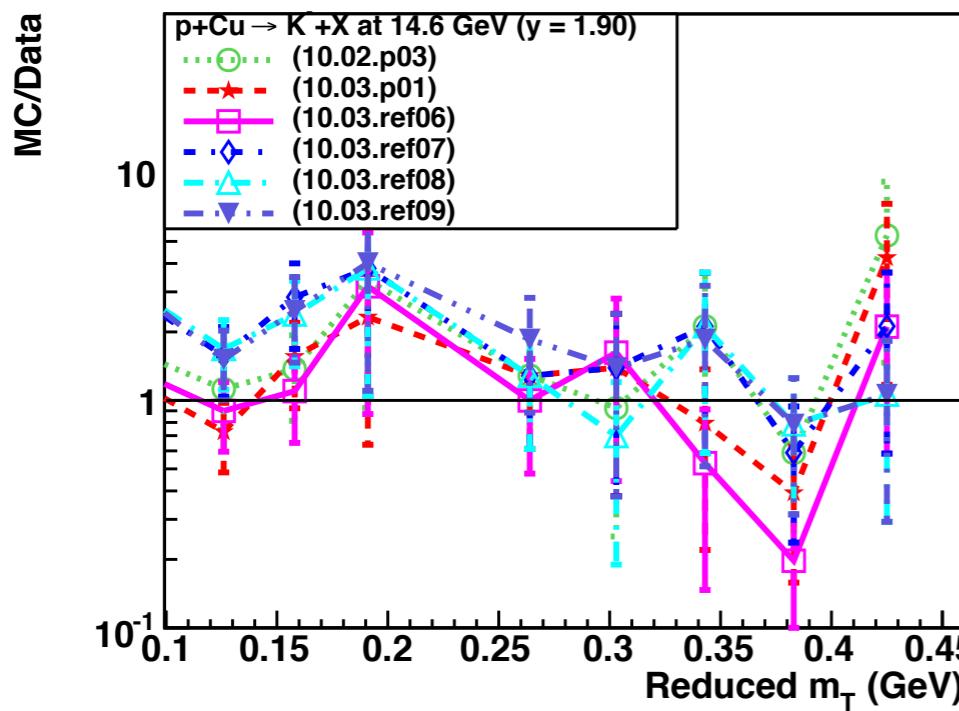
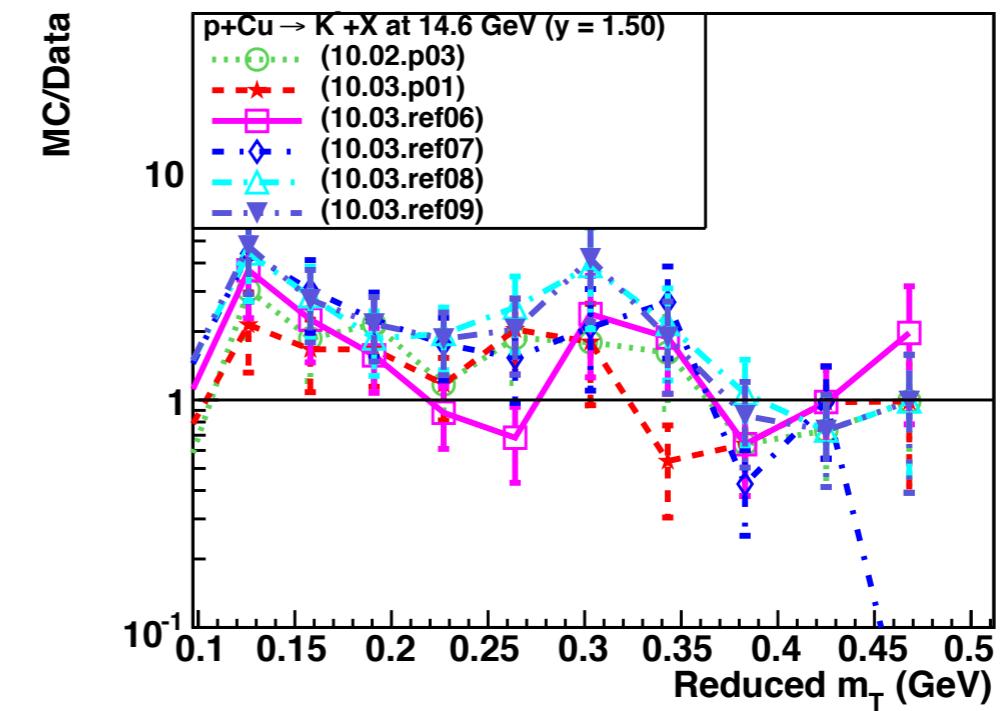
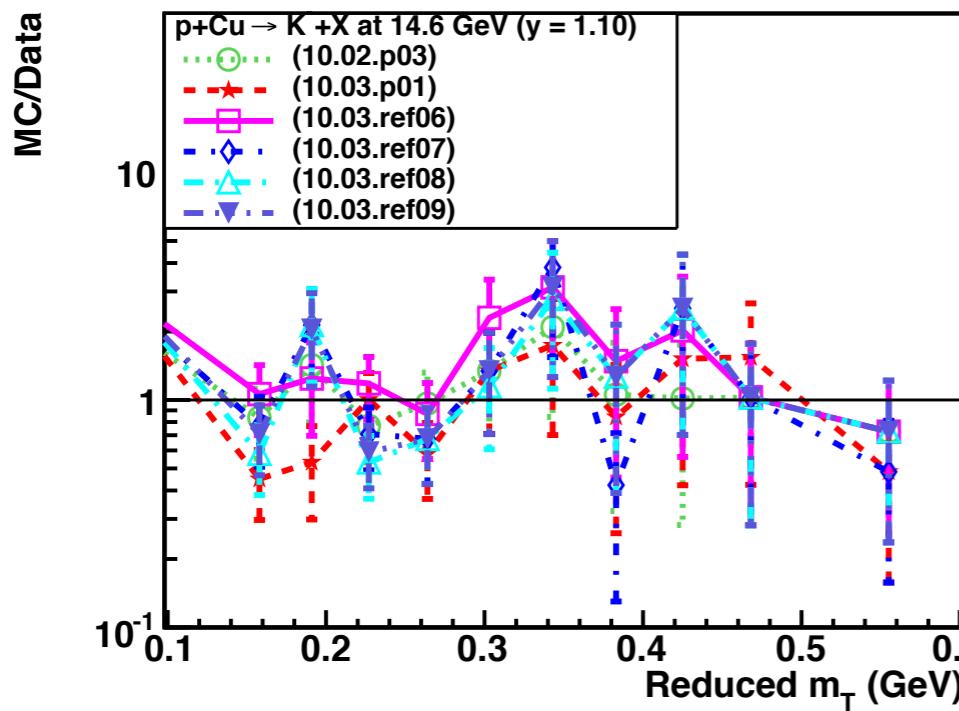
S. Banerjee
Fermilab



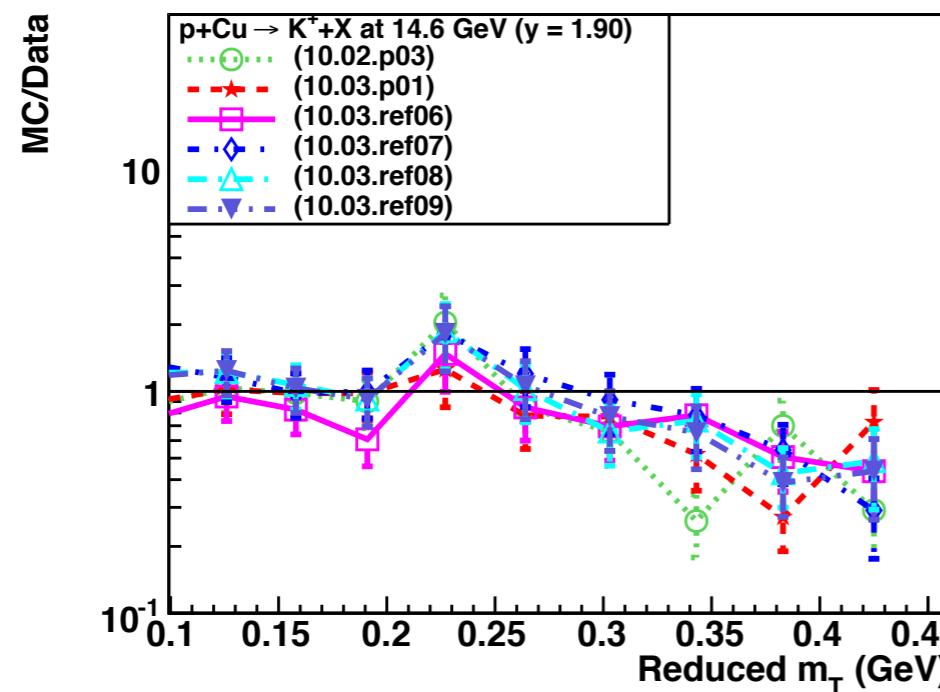
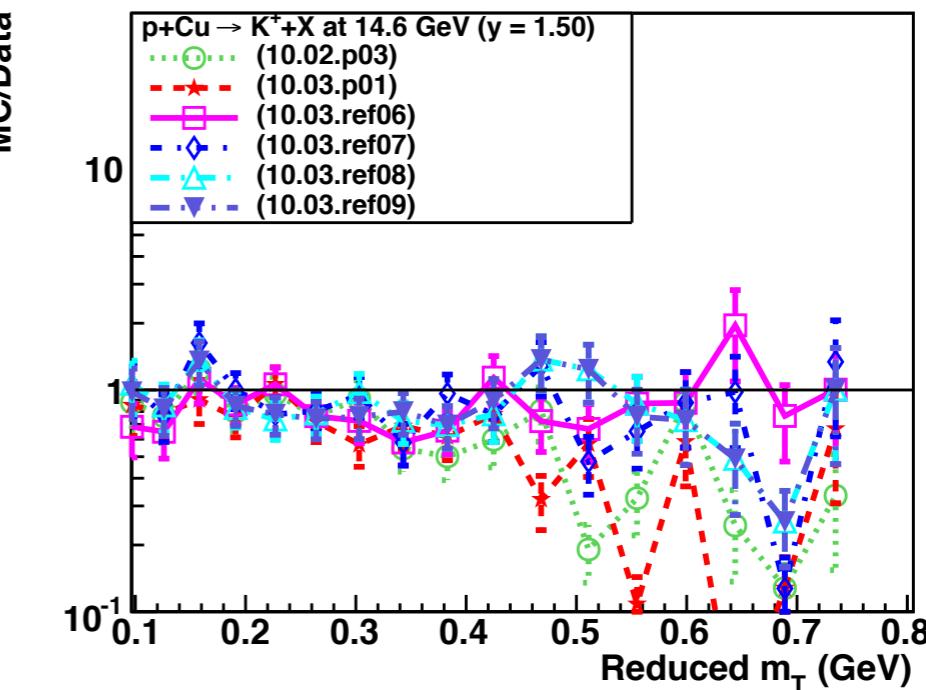
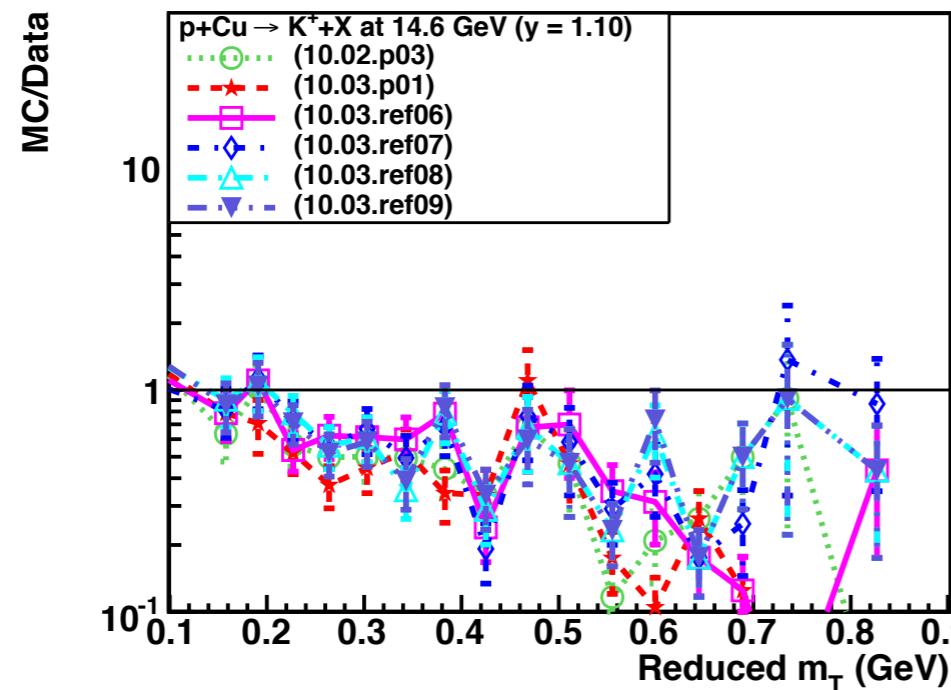
- Data set from BNL E802: (T. Abbott *et al.*, Phys. Rev. D45, 3906)
 - Inclusive π^\pm , K^\pm and proton production from p beams at 14.6 GeV/c on a variety of nuclear targets
 - Quantities measured are Lorentz invariant differential cross sections as a function of transverse mass (m_T) in bins of rapidity (y)
 - Data quality: statistical error 5-30%; systematic uncertainty 10-15%
 - Targets studied Be, Al, Cu, Au for all the final states available
- For calculation of invariant cross sections in the BNL data **constant bin width** of ($\Delta y = \pm 0.1$) is used
- Three Geant4 models are considered for the comparisons:
 - Bertini cascade, FTFP and QGSP models
- Five versions of Geant4 are used in the following plots:
 - 10.2.p02, 10.3.p01, 10.3.ref06, 10.3.ref07, 10.3.ref08, 10.3.ref09



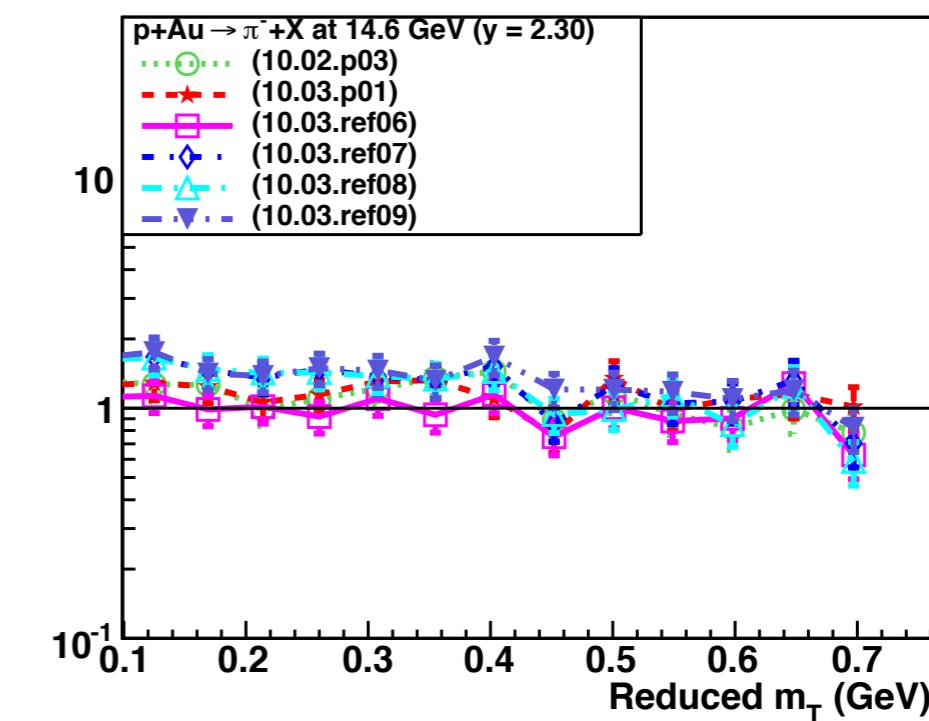
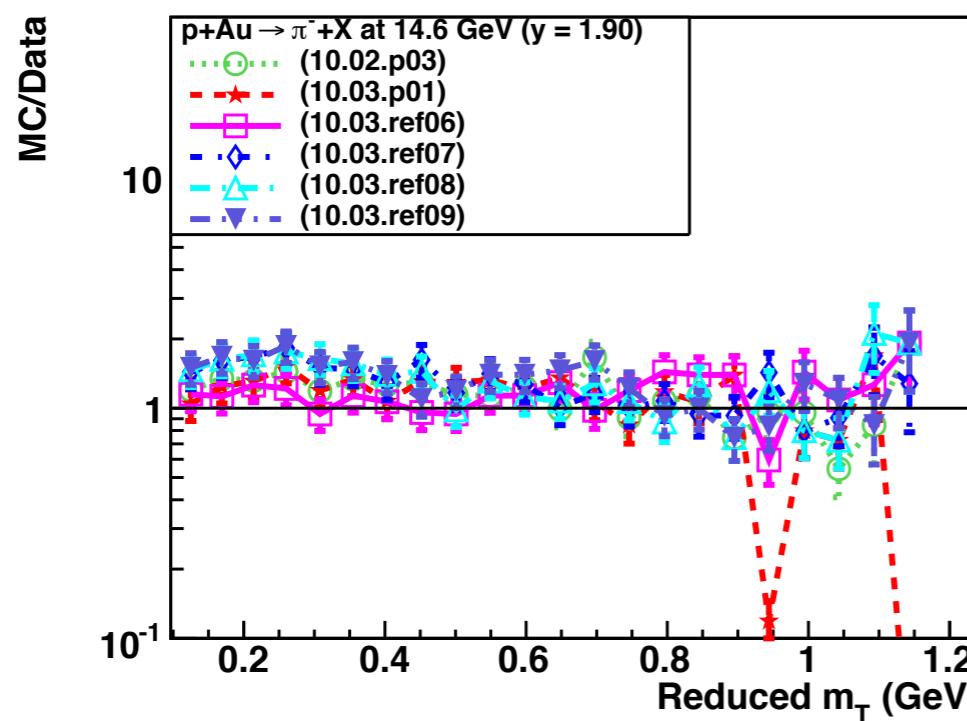
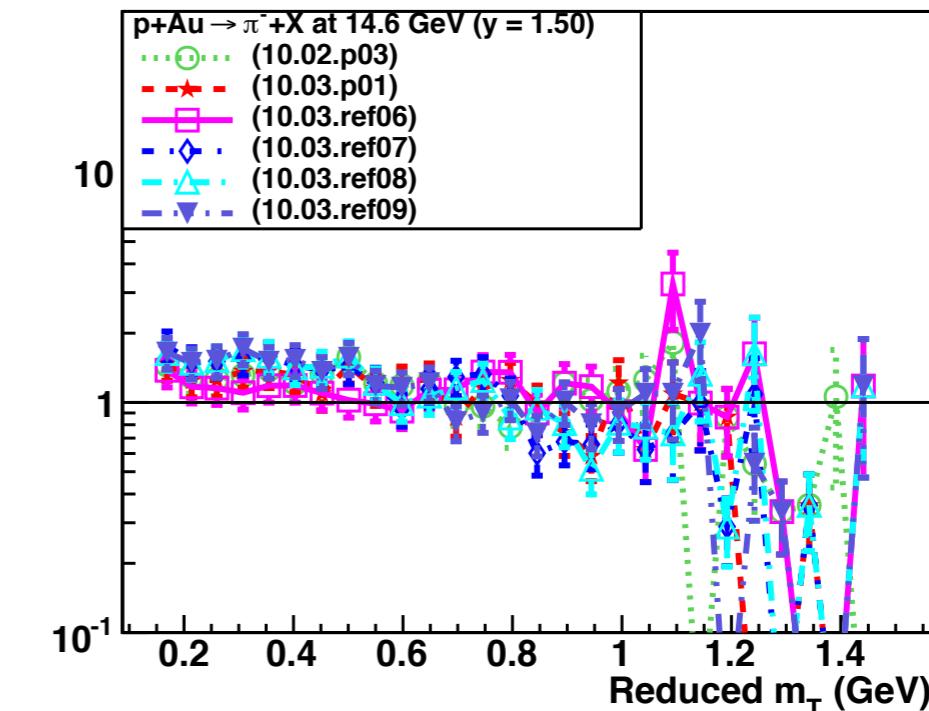
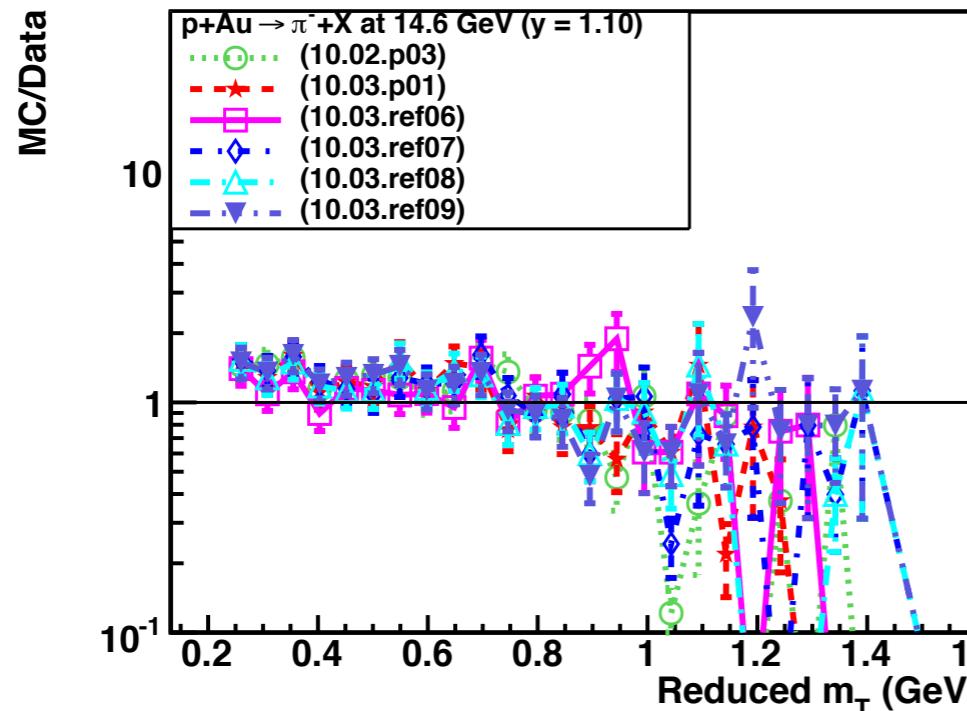
- No significant difference in the prediction of FTFP models from 9.6 till 10.3.ref08.



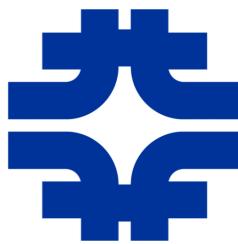
- FTFP models provide reasonable predictions for K^- production



- FTFP model predictions for K^+ production are similar among all these versions

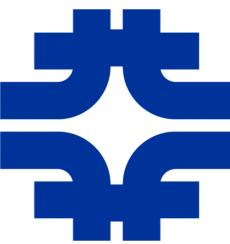


- No significant improvement in the prediction of FTFP models in the recent releases



- Using a flat systematic uncertainty for all measurements:

	10.2.p03	10.3.p01	10.3.r06	10.3.r07	10.3.r08	10.3.r09
Be π^+ (1.1)	1.36	1.65	0.44	1.32	1.34	1.34
Be π^+ (1.5)	1.73	2.48	3.42	2.93	2.77	2.77
Be π^+ (1.9)	0.73	0.79	0.99	1.49	1.57	1.57
Be π^+ (2.3)	0.73	1.08	2.07	1.18	1.17	1.17
Be π^- (1.1)	1.15	2.23	2.16	1.27	1.26	1.26
Be π^- (1.5)	1.31	3.69	4.19	2.75	2.78	2.78
Be π^- (1.9)	2.36	1.85	0.95	4.27	4.42	4.42
Be π^- (2.3)	0.53	0.37	0.91	2.11	2.08	2.08
Au π^+ (1.1)	1.88	2.03	1.22	1.53	1.40	1.44
Au π^+ (1.5)	3.12	3.15	2.15	4.43	3.83	3.47
Au π^+ (1.9)	3.16	1.95	2.30	3.68	3.59	4.56
Au π^+ (2.3)	1.13	0.86	2.09	2.71	2.72	2.80
Au π^- (1.1)	2.87	2.98	1.81	2.50	2.40	2.47
Au π^- (1.5)	2.42	2.60	2.61	4.61	4.48	4.51
Au π^- (1.9)	2.57	3.08	1.71	5.35	6.00	6.29
Au π^- (2.3)	1.71	1.61	0.67	6.75	6.26	7.15

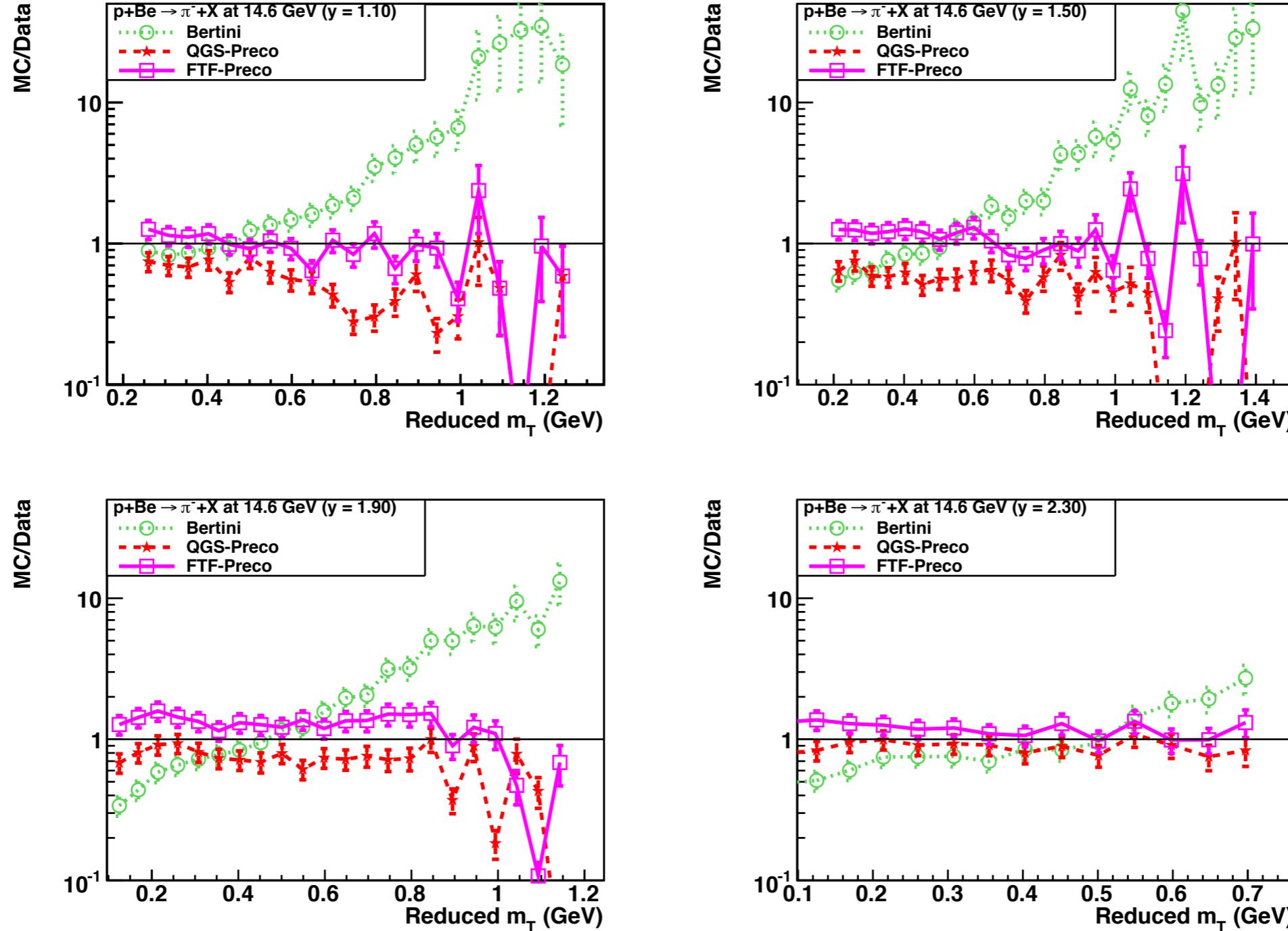


- Using a flat systematic uncertainty for all measurements:

	10.2.p03	10.3.p01	10.3.r06	10.3.r07	10.3.r08	10.3.r09
Cu K ⁺ (1.1)	3.04	3.73	2.50	2.20	2.21	2.23
Cu K ⁺ (1.5)	2.68	2.60	1.26	2.47	2.08	2.33
Cu K ⁺ (1.9)	2.04	0.95	1.15	1.55	1.78	1.77
Cu K ⁺ (2.3)	80.75	80.84	120.30	23.50	16.98	28.52
Cu K ⁻ (1.1)	1.01	1.90	3.60	4.40	3.71	3.88
Cu K ⁻ (1.5)	4.37	2.43	6.29	16.83	16.77	17.47
Cu K ⁻ (1.9)	5.20	2.76	1.49	7.86	8.25	9.22
Cu K ⁻ (2.3)	16.66	16.89	98.70	10.39	3.23	18.65
Cu p (1.1)	9.81	10.20	4.08	6.79	6.77	6.52
Cu p (1.5)	11.18	11.77	3.98	2.10	2.16	2.02
Cu p (1.9)	4.26	4.23	2.21	1.52	1.35	1.20
Cu p (2.3)	7.66	6.81	0.65	0.39	0.38	0.48

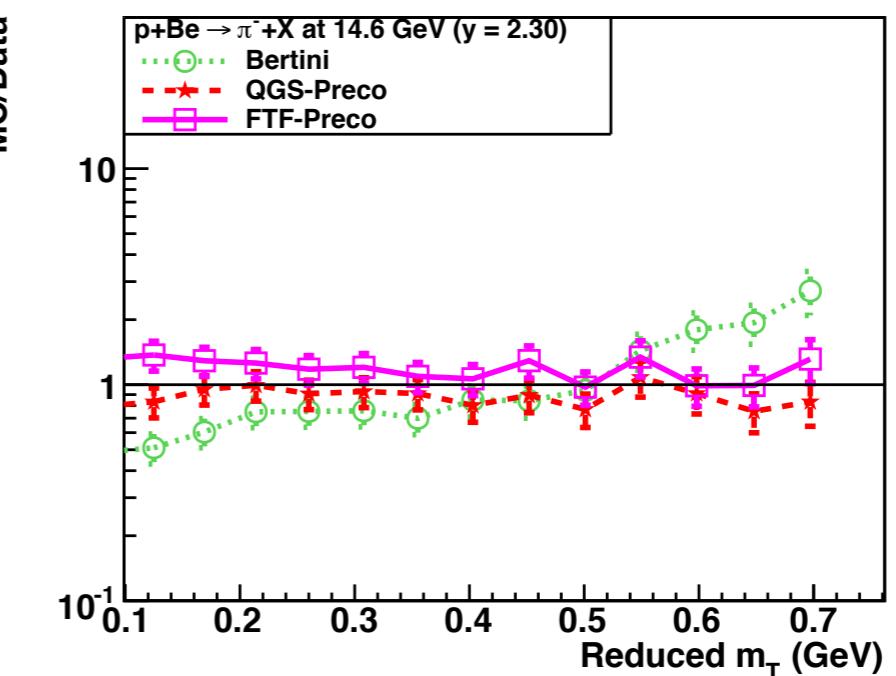
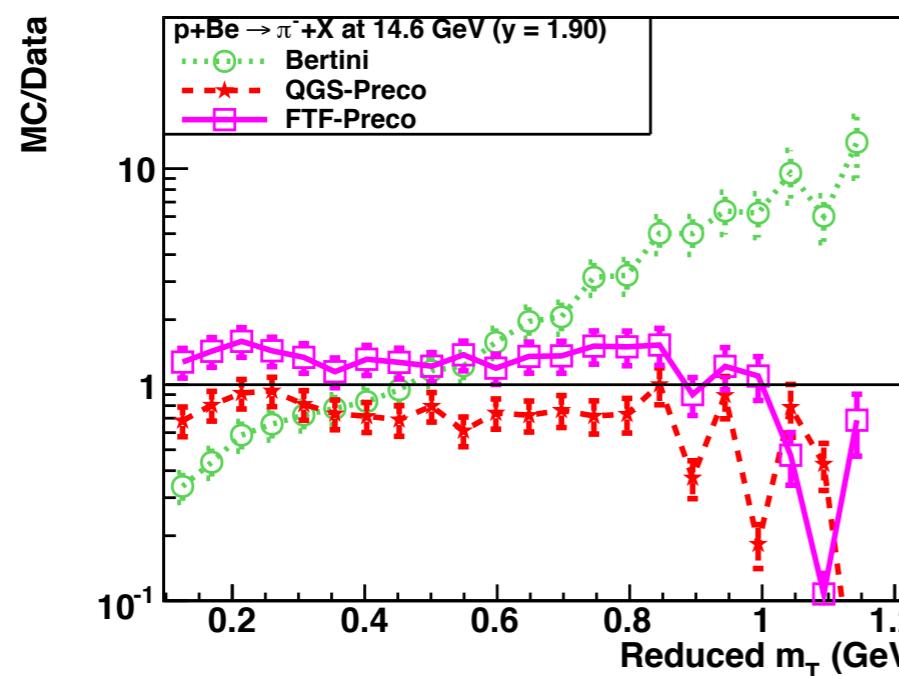
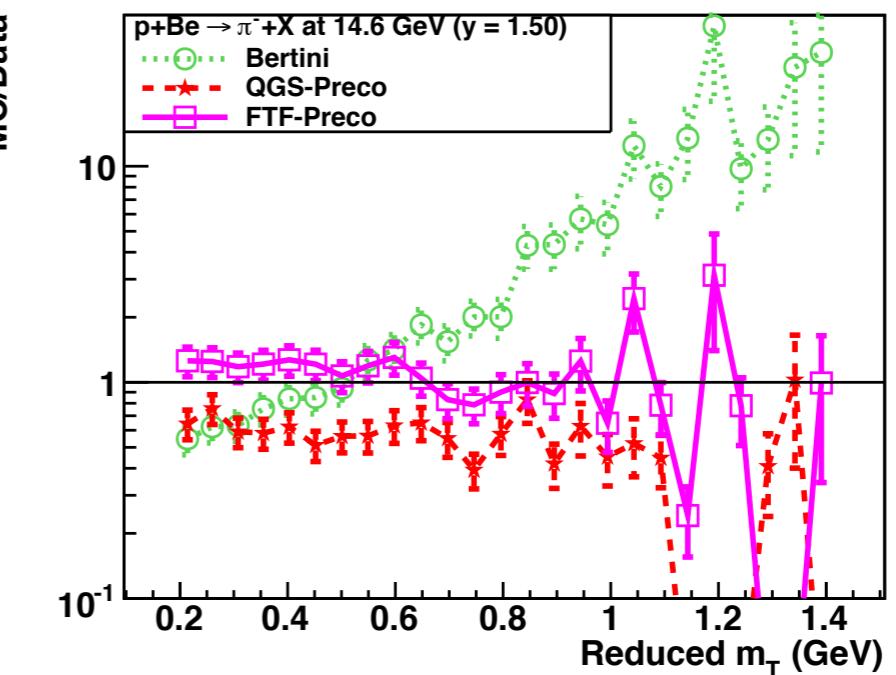
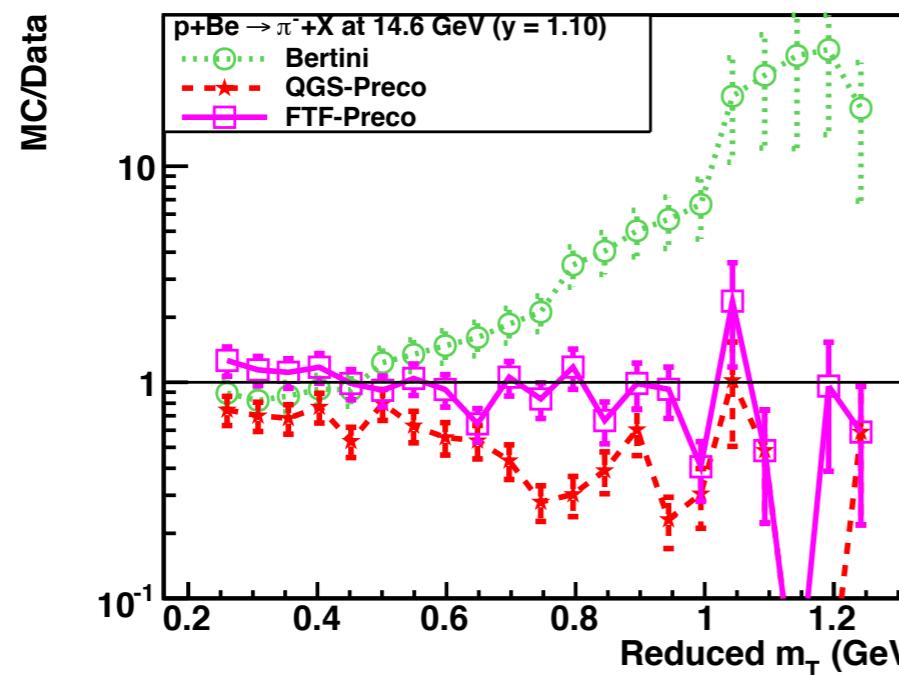
* Only one data point

Geant4 p + Be \rightarrow π^- + X at 14.6 GeV/c (10.3.ref08)



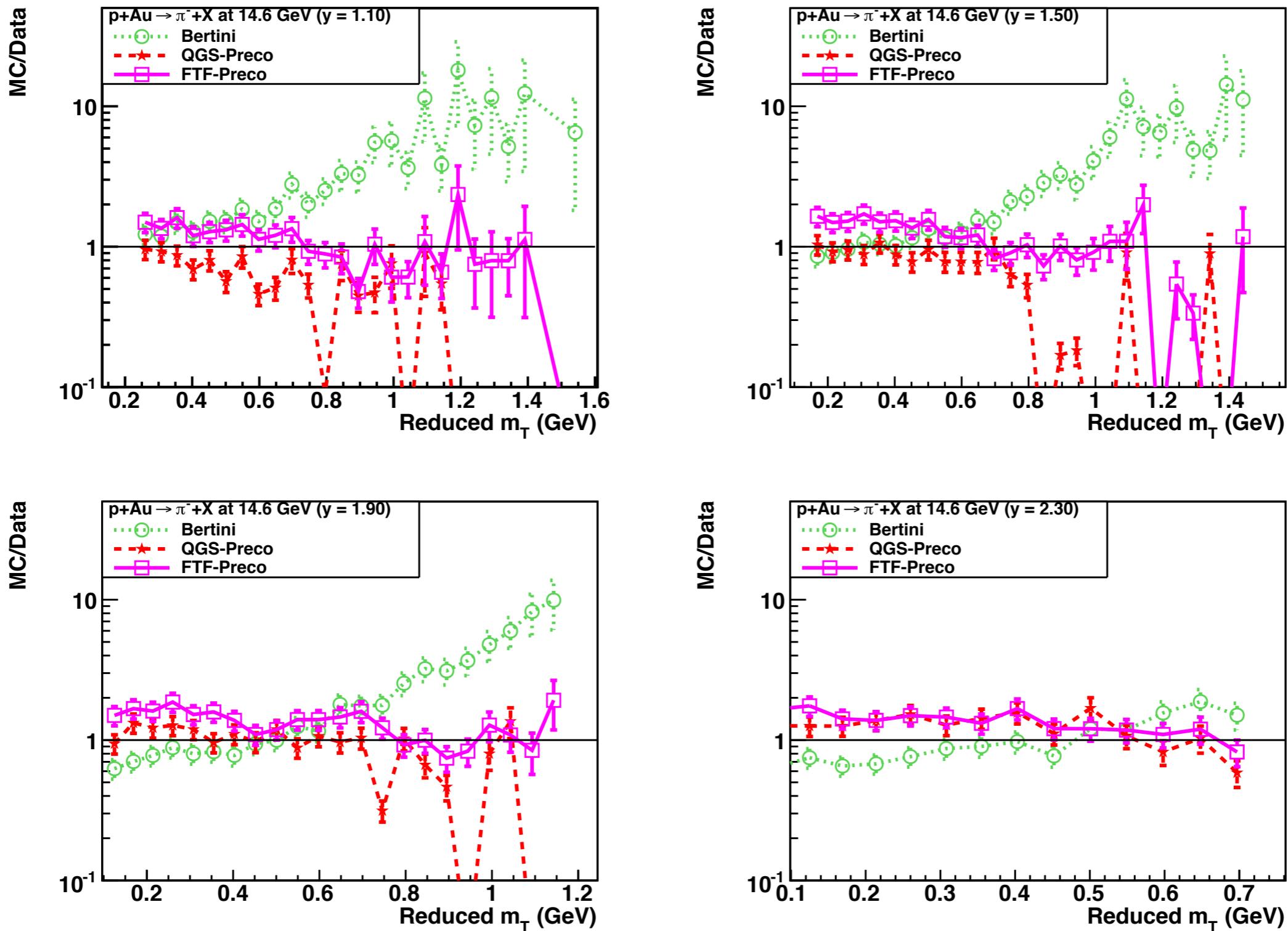
- Bertini Cascade model needs an improvement (?) - particularly in the backward hemisphere

Geant 4 p + Be $\rightarrow \pi + X$ at 14.6 GeV/c (10.3.ref09)

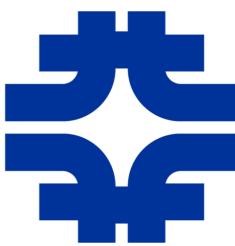


- Not much changes between 10.3.ref08 and 10.3.ref09

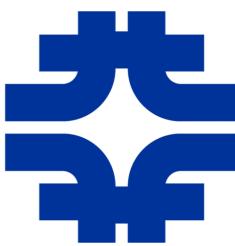
Geant4 p + Au → π + X at 14.6 GeV/c (10.3.ref09)



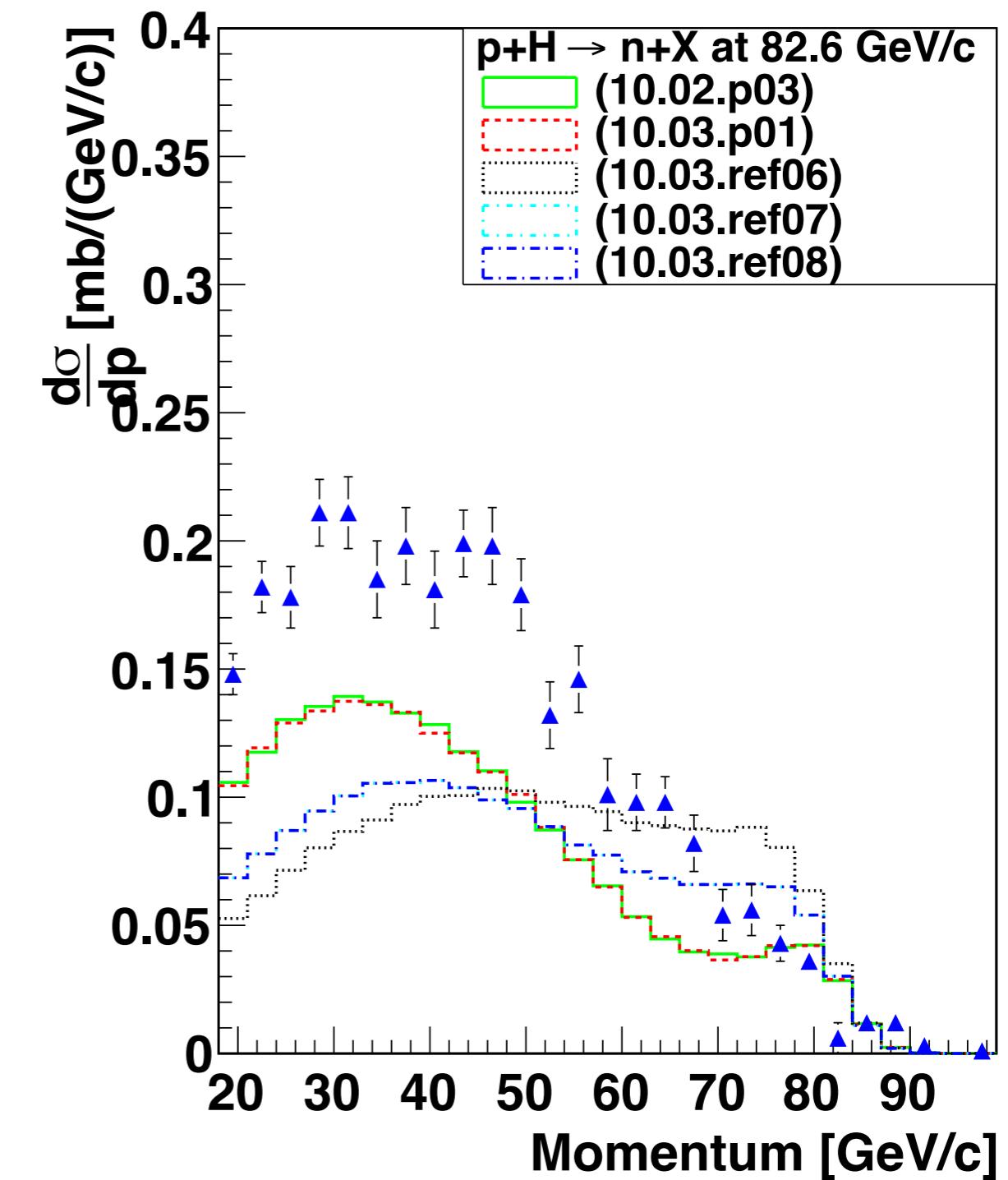
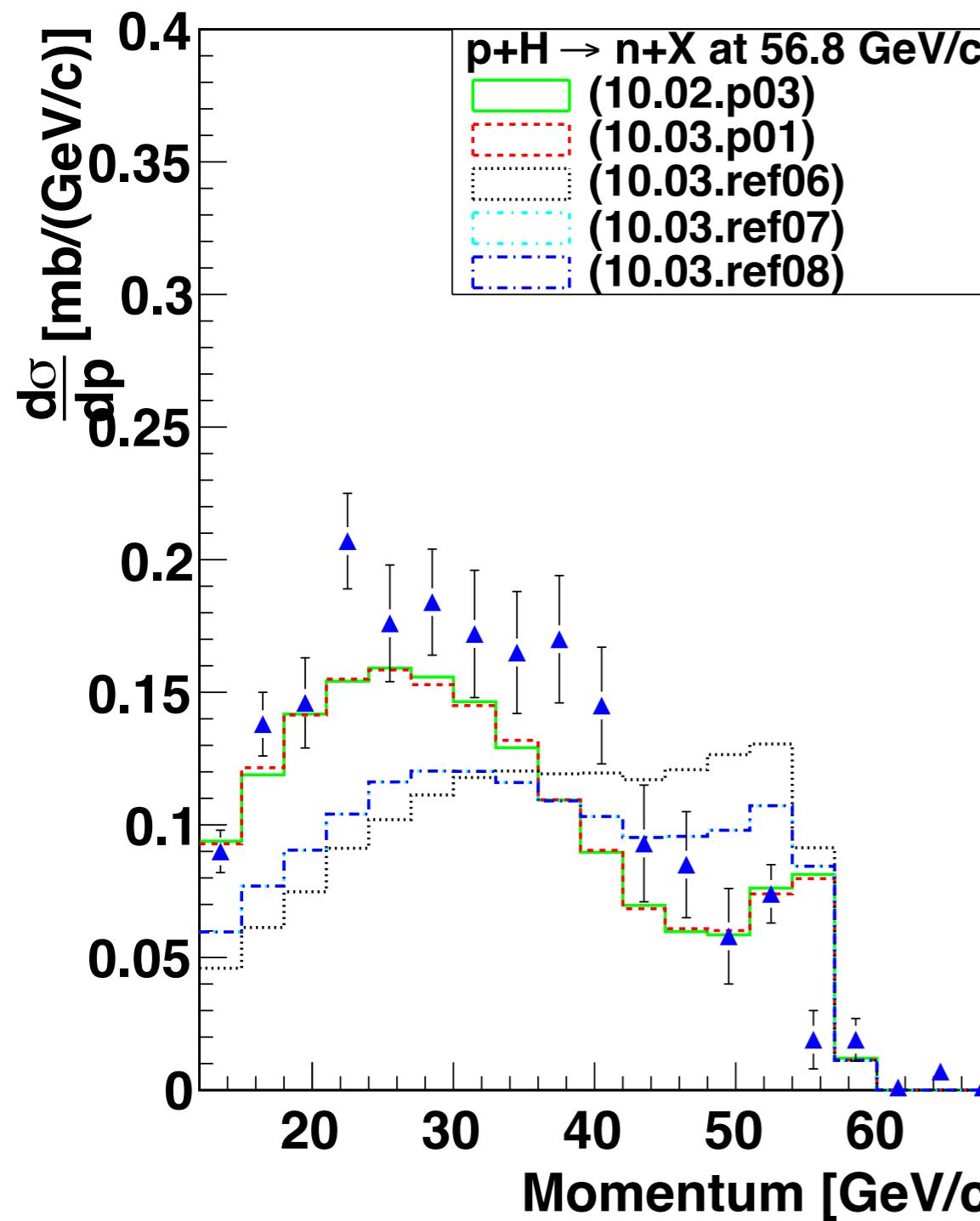
- Similar effect is observed for heavier targets



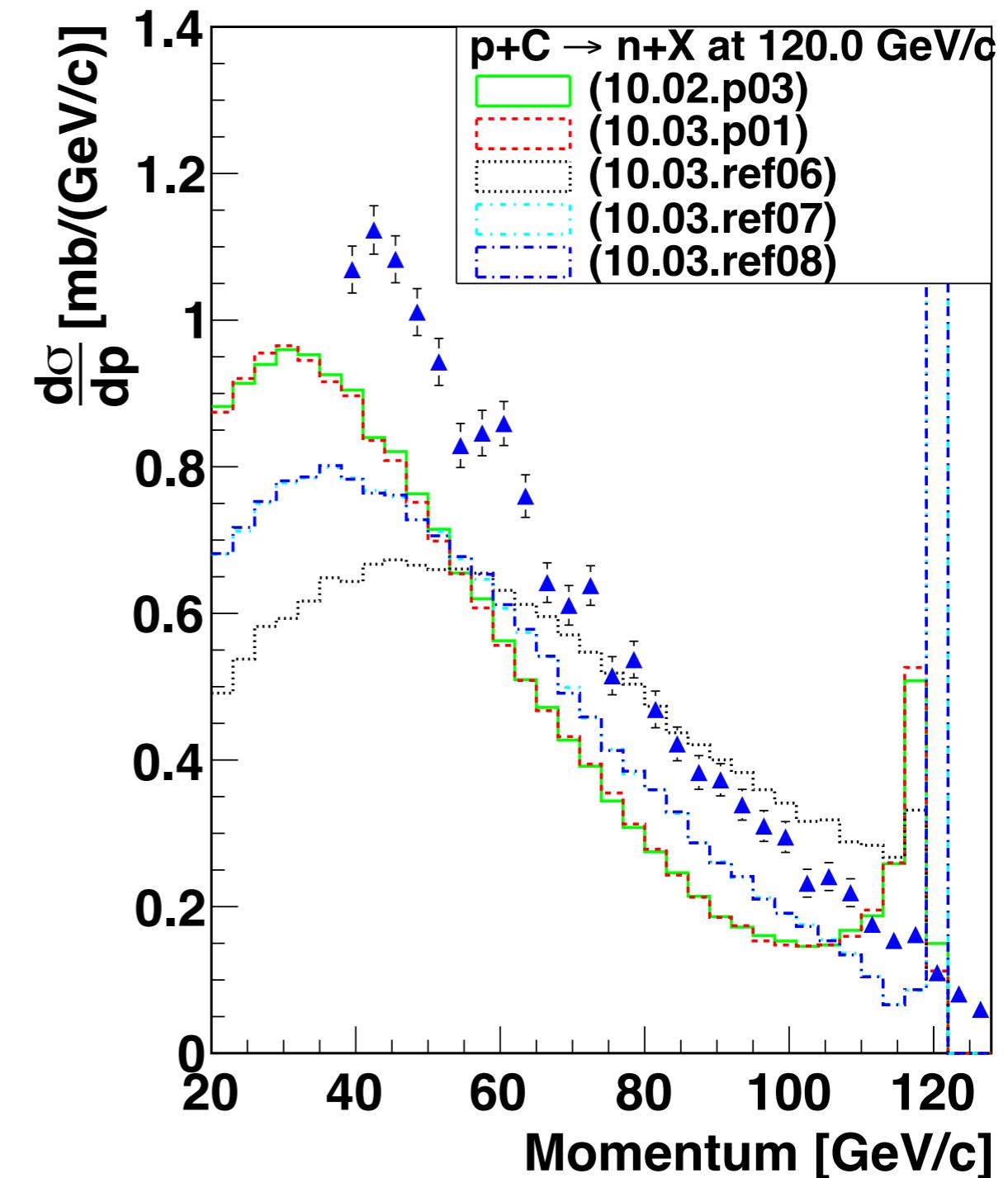
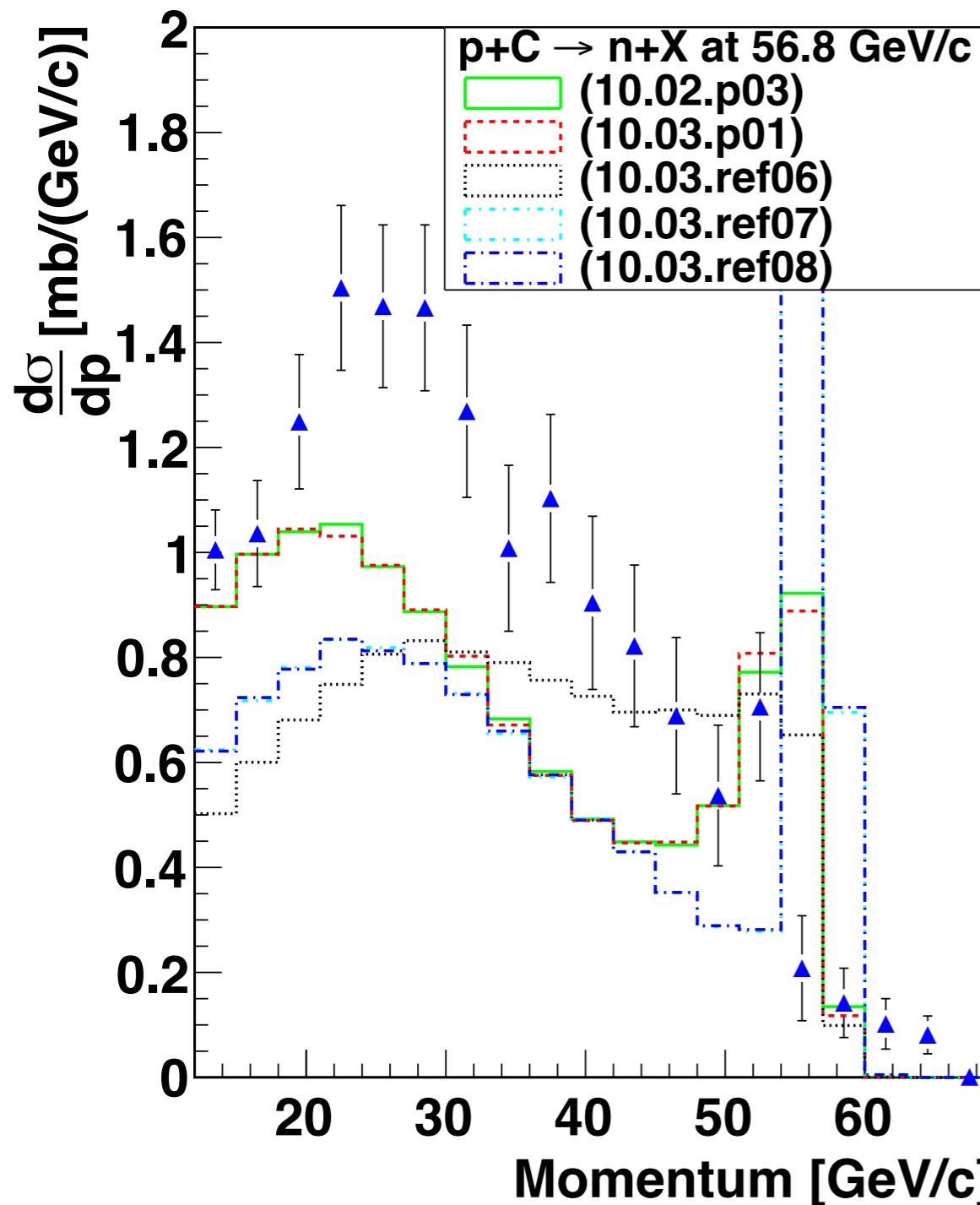
- Data set from Fermilab E907: (T.S. Nigmanov *et al.*, Phys. Rev. D83, 012002)
 - Inclusive neutron production with proton beams at high energies on a number of nuclear targets
 - Targets used: Hydrogen, Beryllium, Carbon, Bismuth, Uranium
 - Projectile: proton beam at: 56.8, 57.3, 82.6 and 120 GeV/c. Beam momentum and impact point at the target are measured using an upstream spectrometer
 - Neutrons detected in the hadron calorimeter and its energy is measured by subtracting energies of charged particles within the geometric acceptance of calorimeter
 - Inclusive neutron momentum distribution and Lorentz invariant cross section for neutron as a function of x_F without any geometric acceptance correction
- For calculation of invariant cross sections, finite target size, beam orientation, acceptance cut of the detector, beam momentum spread, etc. are taken into account
- Two Geant4 models are considered for the comparisons:
 - FTFP and QGSP models
- Five versions of Geant4 are used in the following plots:
 - 10.2.p02, 10.3.p01, 10.3.ref06, 10.3.ref07, 10.3.ref08, 10.3.ref09



- Corrections done to the data
 - Inefficiency for triggering on neutron events
 - Use Monte Carlo and cross checked with data - good agreement
 - Efficiency of neutron selection requirements (vertex position and Δp_T cuts)
 - Very smooth dependence on neutron momentum
 - Neutron losses due to interactions with material in the spectrometer
 - Use MC to estimate the losses (~10%)
 - Contamination of K^0_L , secondary neutrons and photons
- Corrections not done and applied in the MC samples
 - Geometrical acceptance
 - Effect due to finite target size, beam orientation, beam momentum spread

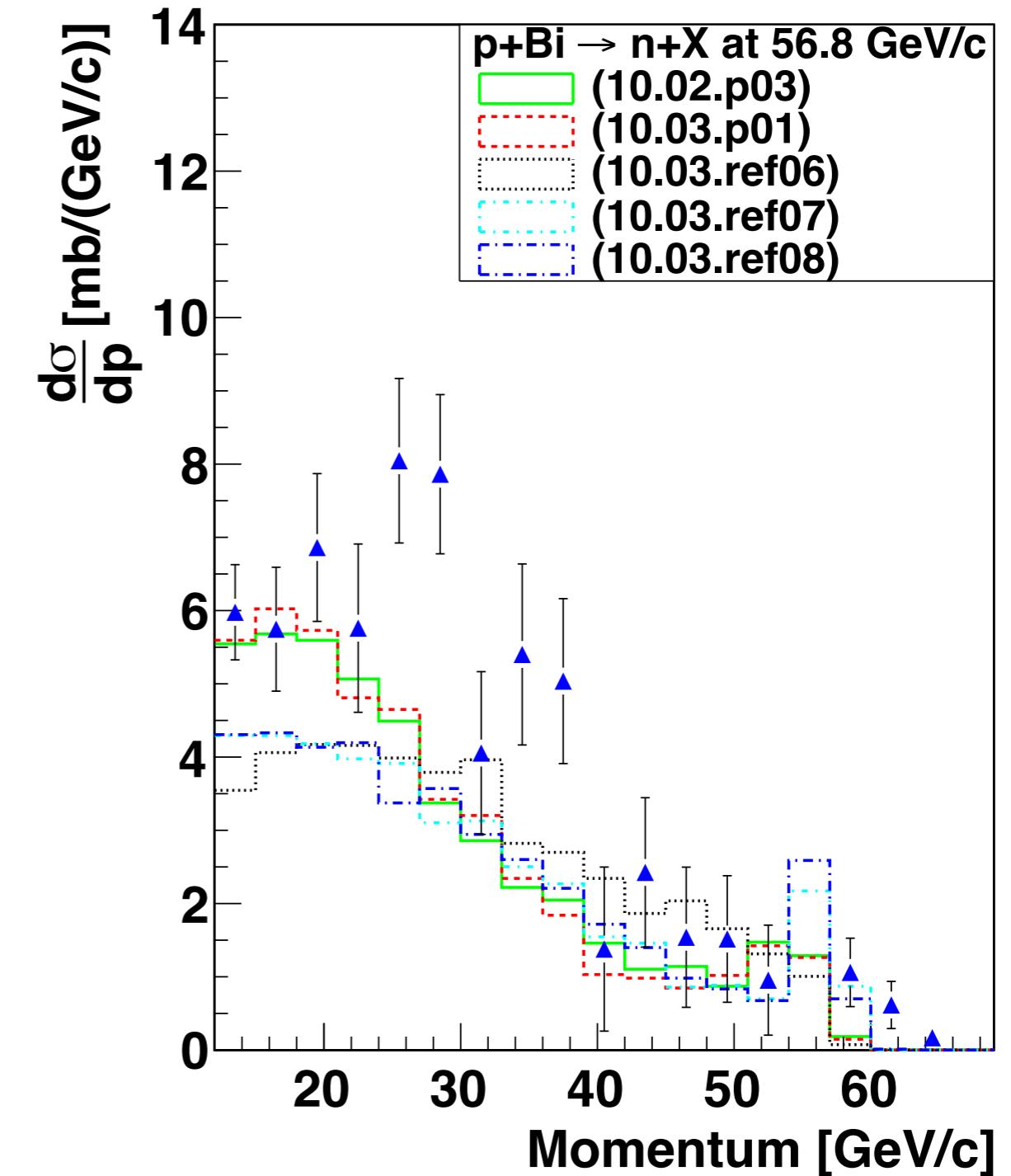
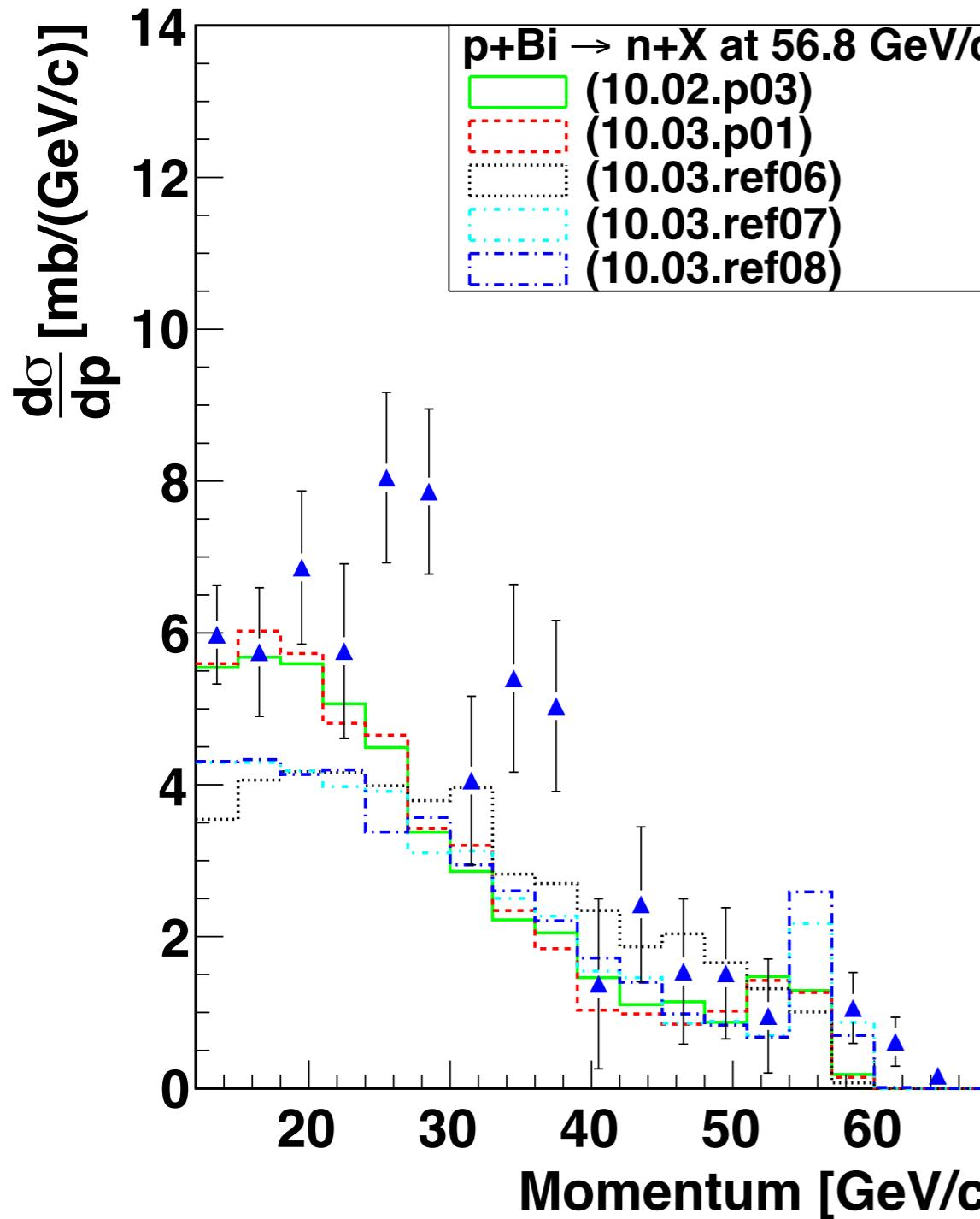


- FTFP predictions were better in 10.2 and 10.3 versions



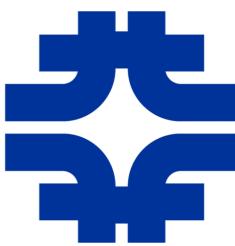
- FTFP model predictions show a spike at the highest energy which is more prominent in the most recent Geant4 version

Geant 4 $p + Bi \rightarrow n + X$ at 56.8 and 120.0 GeV/c

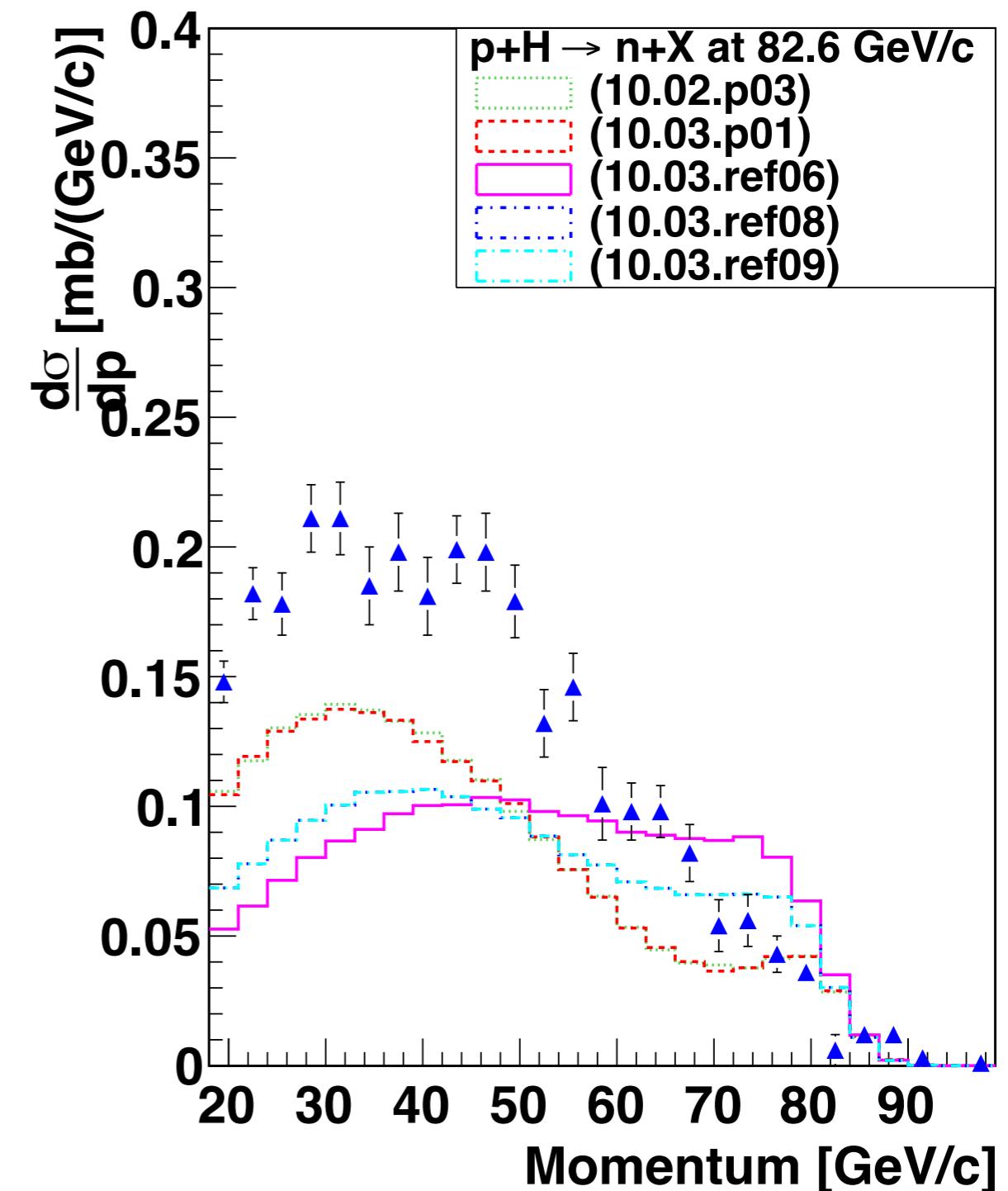
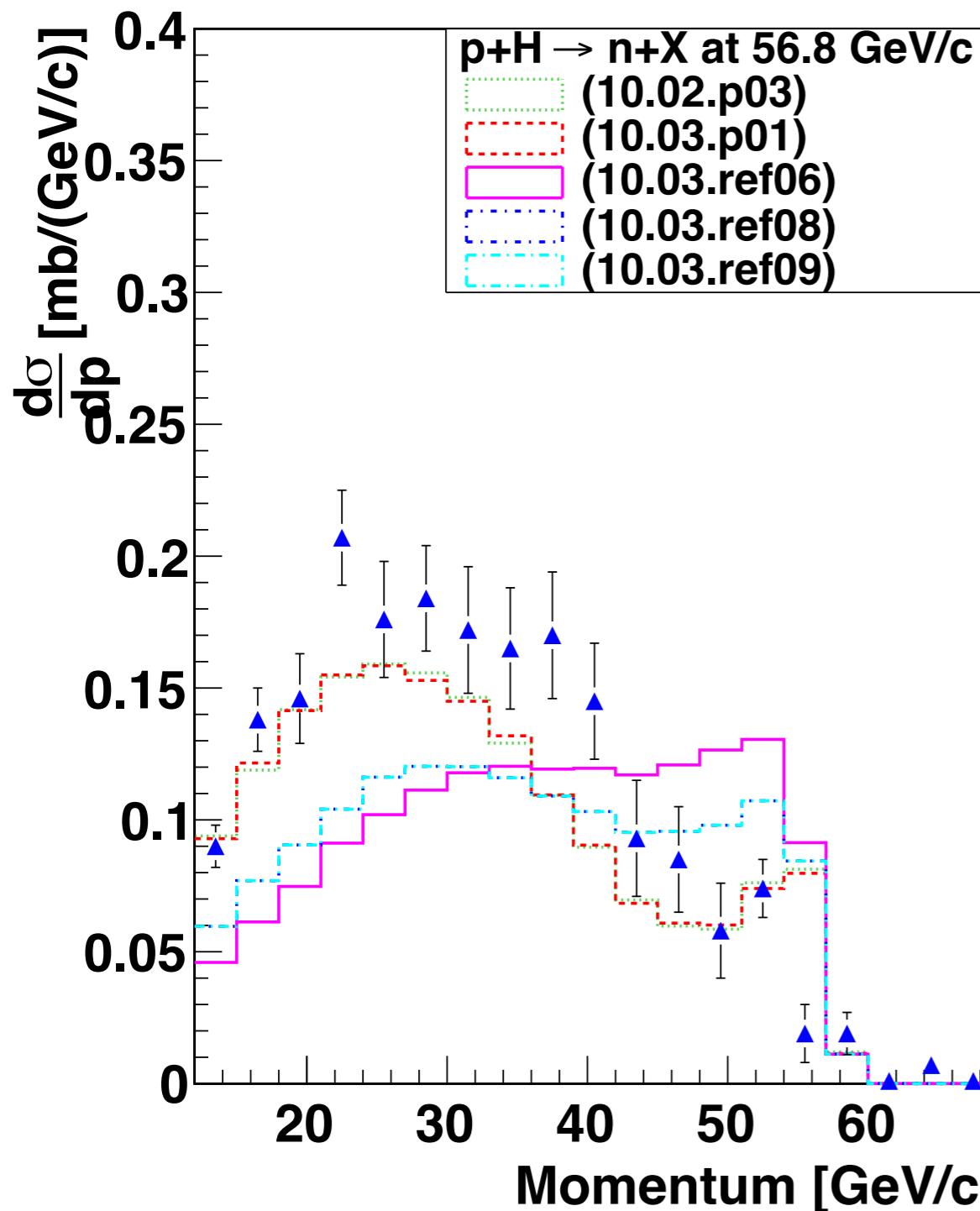


- FTFP model provides better agreement for heavier targets.
- Prediction worsens in the most recent versions

Summary

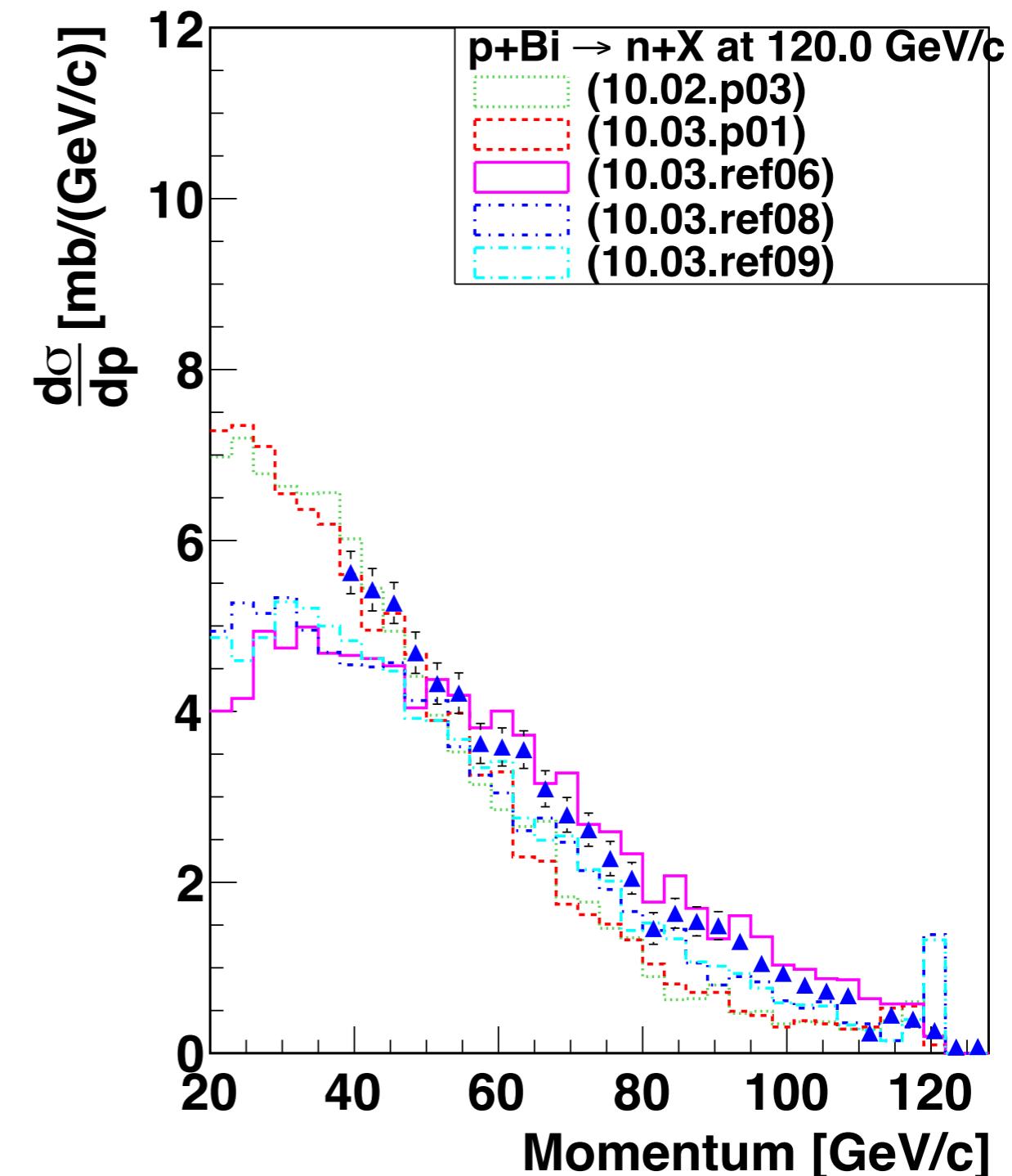
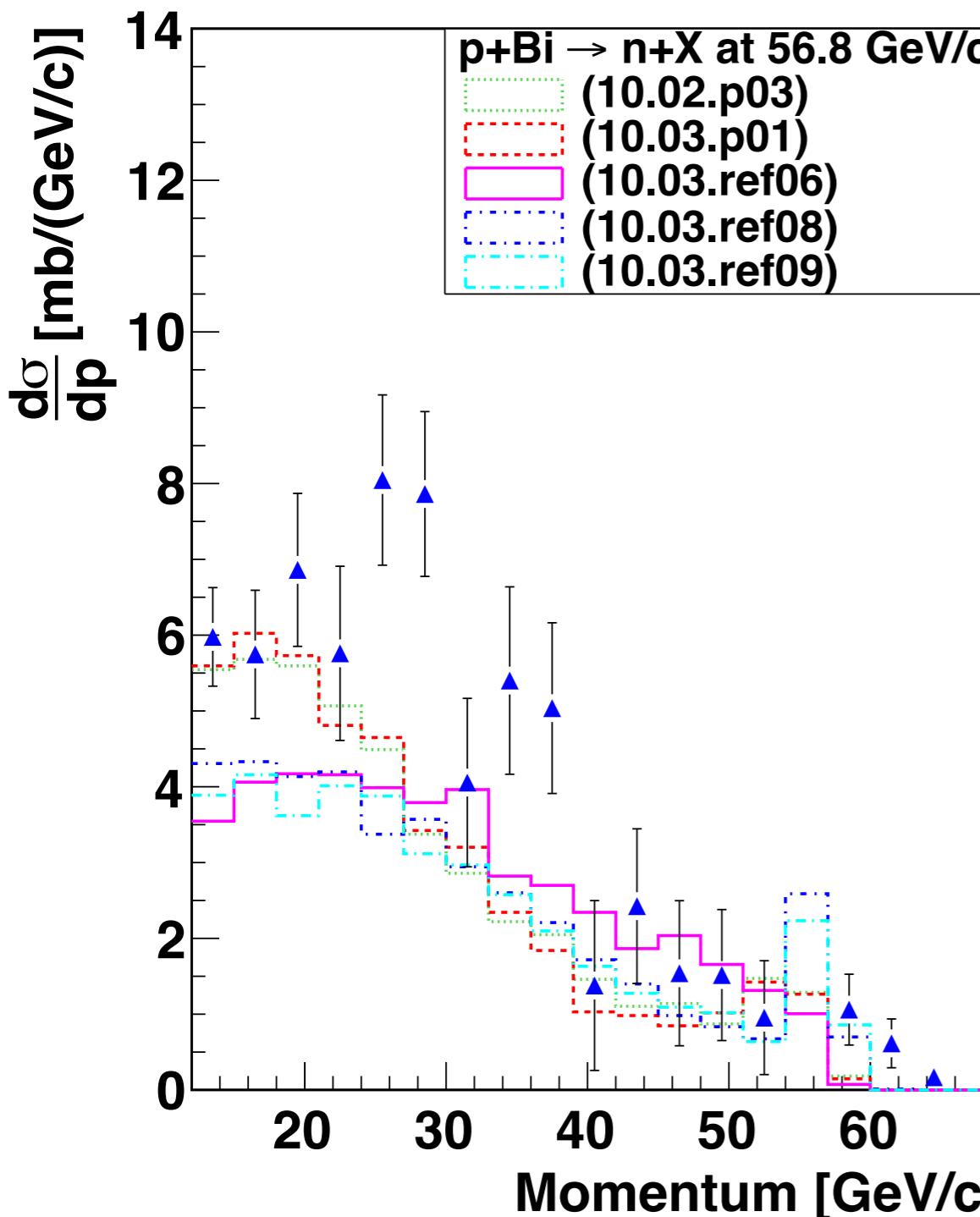


- Validation effort has been restarted with BNL E802 and MIPP experimental data
- Predictions from FTFP model provide good agreement with the BNL data while Bertini Cascade model needs some work to provide better agreement
- FTFP model shows some short comings in matching the MIPP data for inclusive neutron production

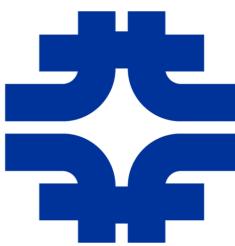


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