

Improvements of QGS model and effects of alpha cluster structure in Carbon-12

V. Uzhinsky, 13 Dec. 2017

An essential bug was fixed in QGSM. After that parameters were tuned.

Good results were obtained for PP and Pi P interactions.

Though, a description of P C and Pi C interactions required a new idea!

Cluster structure of C-12!?

A stupid bug!

G4QGSParticipant.cc

// loop over nucleons to find collisions

```
if( rndNumber < Pprd )           {InteractionType = PrD; InteractionMode = WITHOUT_R;};
if( rndNumber < Pprd+Ptrd)       {InteractionType = TrD; InteractionMode = WITHOUT_R;};
if( rndNumber < Pprd+Ptrd+Pdd)   {InteractionType = DD; InteractionMode = WITHOUT_R;};
if( rndNumber < Pprd+Ptrd+Pdd+Pnd ) {InteractionType = NonD; InteractionMode = NON_DIFF;
                                   NcutPomerons = Regge->ncPomerons();};
if ( rndNumber < Pprd+Ptrd+Pdd+Pnd+Pnvr ) {InteractionType = Qexc; InteractionMode = ALL; }
```

G4QGSParticipant.cc

// loop over nucleons to find collisions

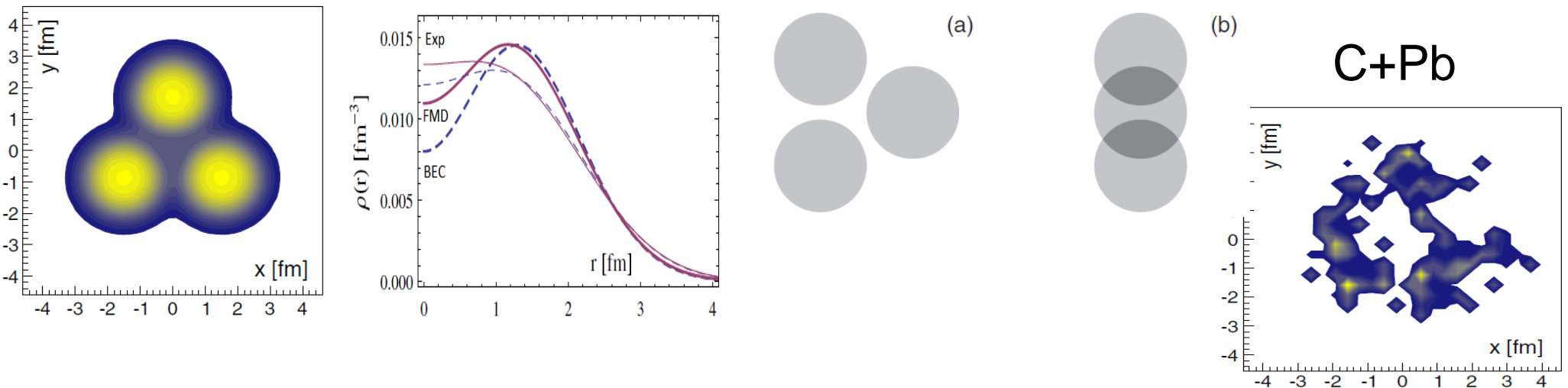
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if ( rndNumber < Pprd )           {InteractionType = PrD; InteractionMode = WITHOUT_R;}
else if( rndNumber < Pprd+Ptrd)   {InteractionType = TrD; InteractionMode = WITHOUT_R;}
else if( rndNumber < Pprd+Ptrd+Pdd) {InteractionType = DD; InteractionMode = WITHOUT_R;}
else if( rndNumber < Pprd+Ptrd+Pdd+Pnd ) {InteractionType = NonD; InteractionMode = NON_DIFF;
                                           NcutPomerons = Regge->ncPomerons(); }
else                               {InteractionType = Qexc; InteractionMode = ALL;}
```

α Clustering in C-12

Signatures of α Clustering in Light Nuclei from Relativistic Nuclear Collisions

W. Broniowski, E.R. Arriola

Phys. Rev. Lett. 112 (2014) 112501, arXiv:1312.0289



α clusters and collective flow in ultrarelativistic carbon–heavy-nucleus collisions

P. Bozek, W. Broniowski, E.R. Arriola, M. Rybeczynski

Phys. Rev. C90, 064902 (2014), arXiv:1410.7434

TABLE I. Parameters used in our Monte Carlo simulations for the distributions of nucleons in ^{12}C .

Parameter	BEC	VMC
l (fm)	3.05	2.84
r_α (fm)	0.96	1.15

α Clustering in nuclei

Signatures of α clustering in ultra-relativistic collisions with light nuclei

Maciej Rybczyński,^{1,*} Milena Piotrowska,^{1,†} and Wojciech Broniowski^{1,2,‡}

¹*Institute of Physics, Jan Kochanowski University, 25-406 Kielce, Poland*

²*H. Niewodniczański Institute of Nuclear Physics PAN, 31-342 Cracow, Poland*

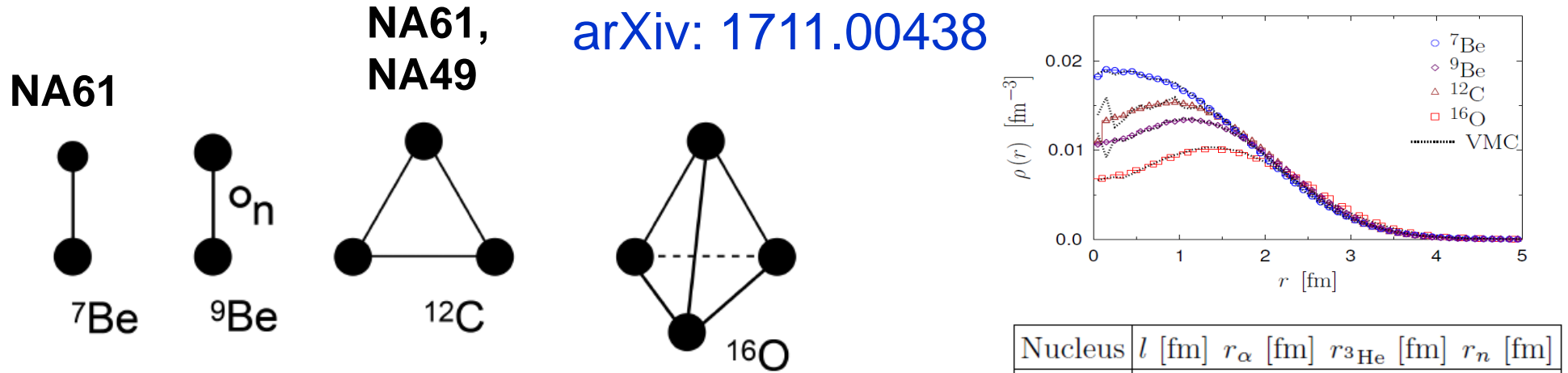
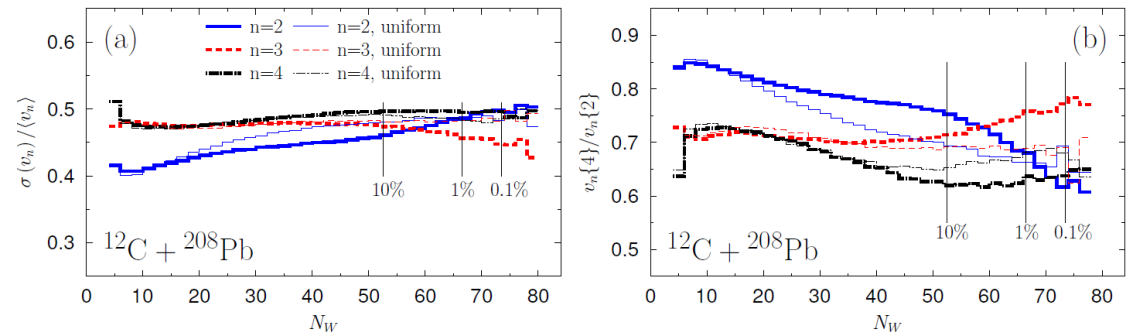
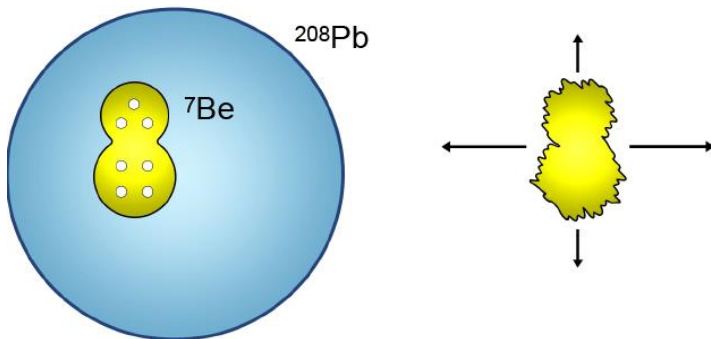
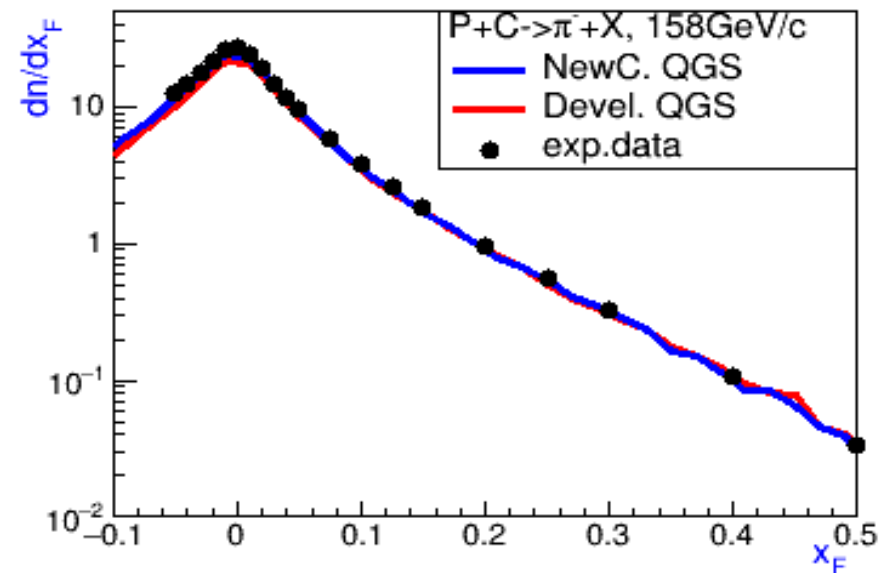
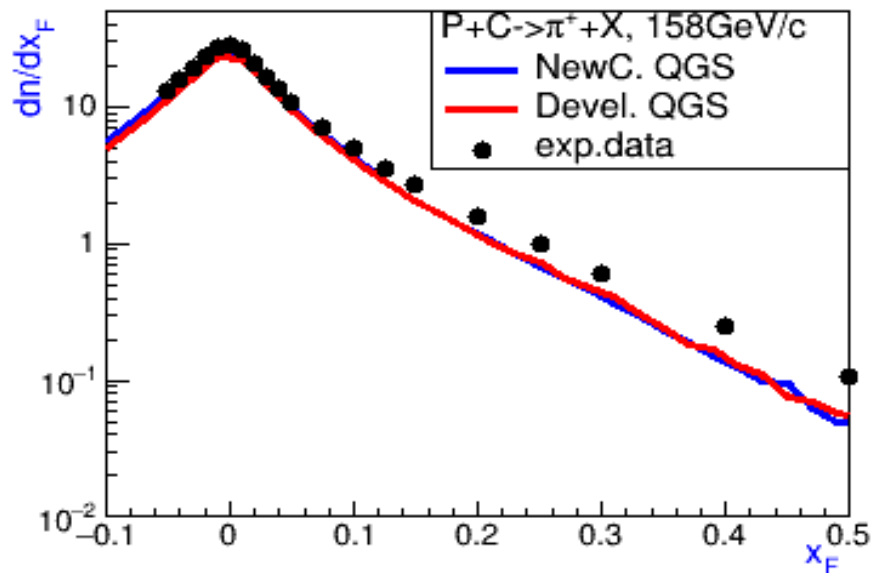
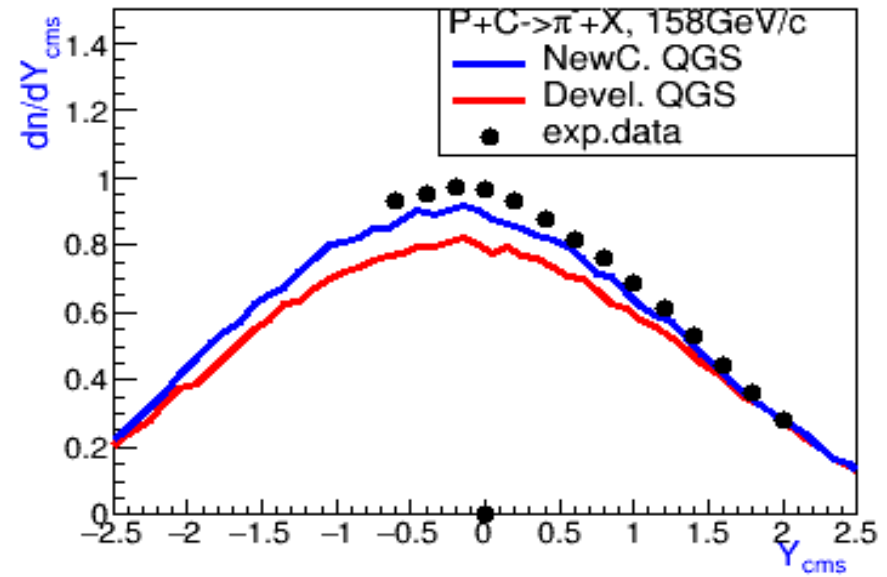
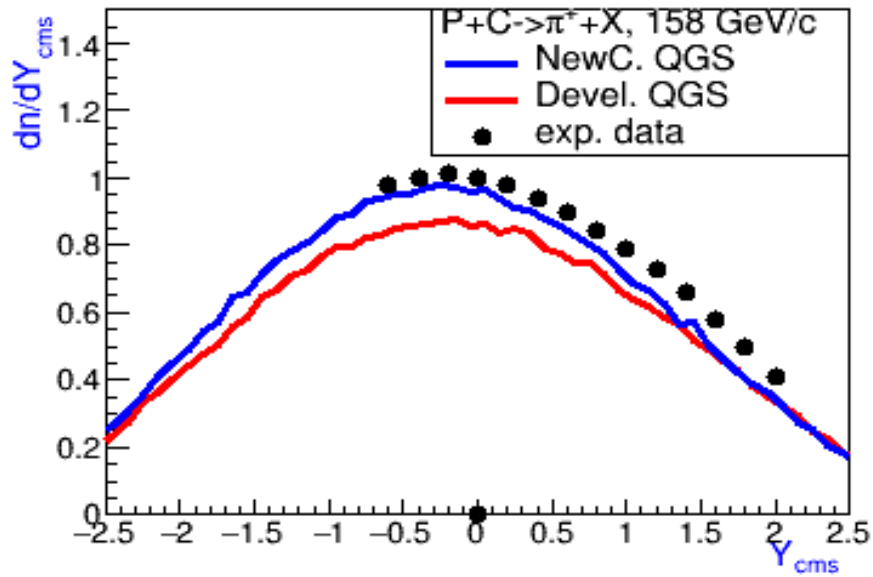


FIG. 1. Schematic view of the cluster structure of light nuclei. The dark blobs indicate α clusters (in the case of ${}^7\text{Be}$, also the ${}^3\text{He}$ cluster). The additional dot in ${}^9\text{Be}$ indicates the extra neutron.



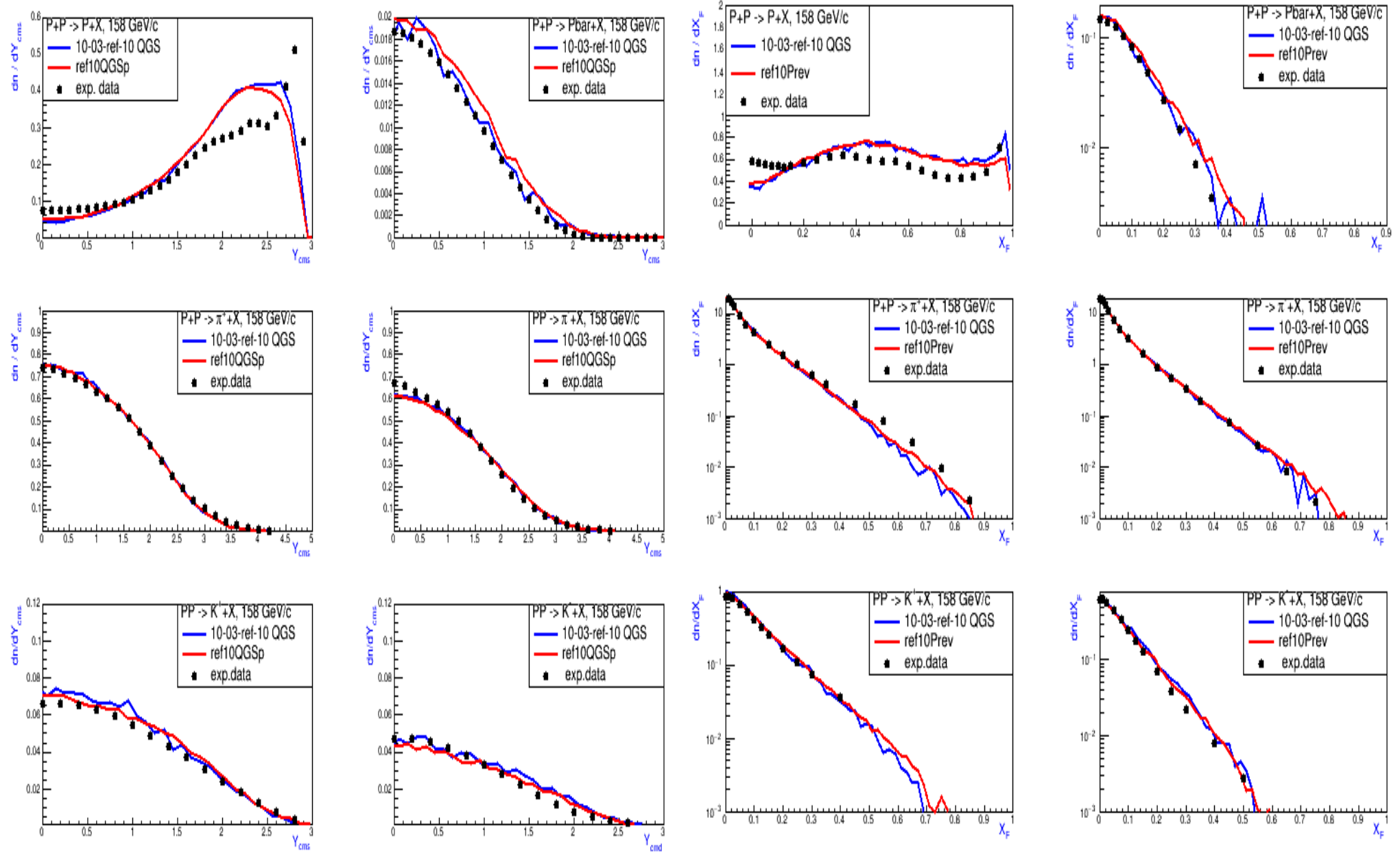
(Color online) Scaled standard deviations of rank- n flow coefficients (panel (a)) and ratios of the four-particle to two-particle cumulants (panel (b)), plotted as functions of the total number of the wounded nucleons. Clustered nuclei (thick lines) are compared with the case where the nucleons are distributed uniformly with the same one-body radial distributions (thin lines). ${}^{12}\text{C} + {}^{208}\text{Pb}$ collisions. The vertical lines indicate the multiplicity percentiles (centralities) corresponding to the indicated values of N_w .

P+ C interactions at 158 GeV/c, NA49 data



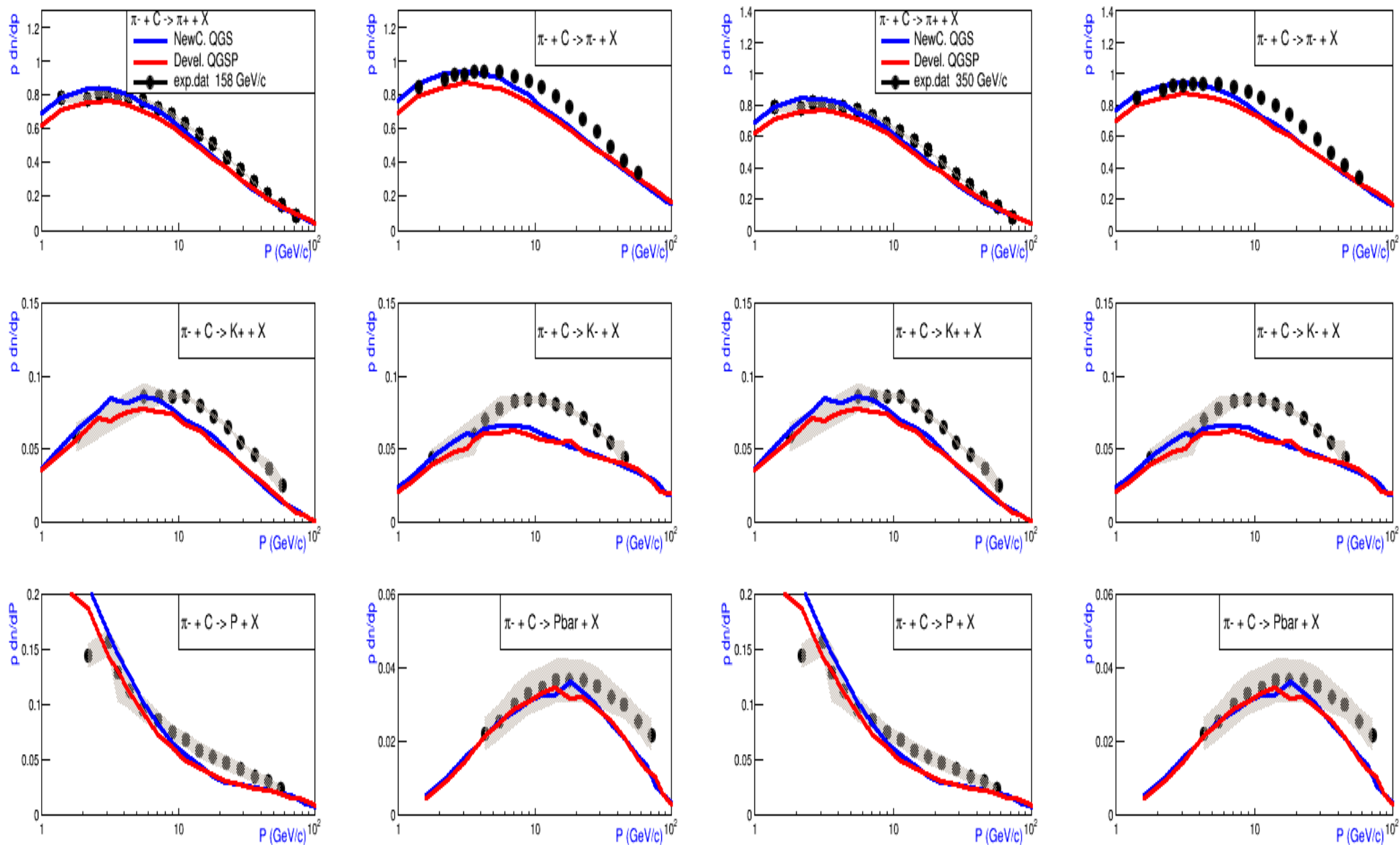
Clustered C-12 increased prediction on 20%!

Description of p+p interactions at 158 GeV/c, NA49 data



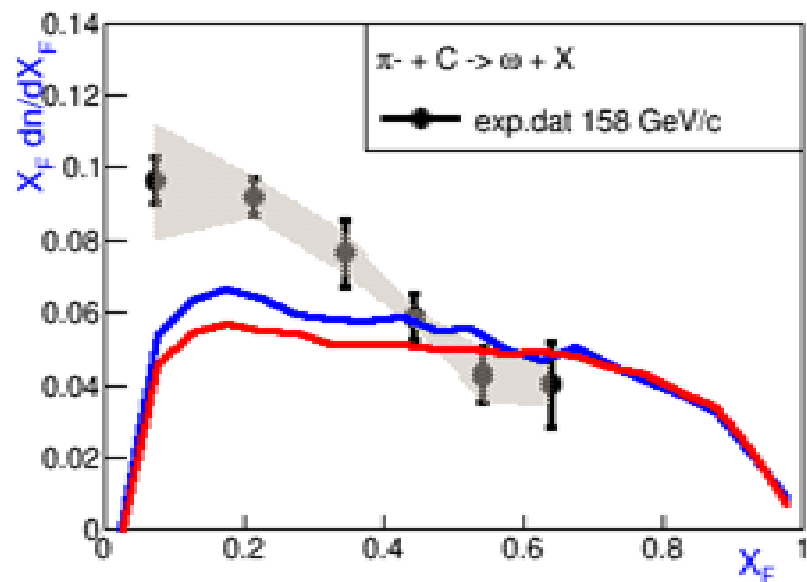
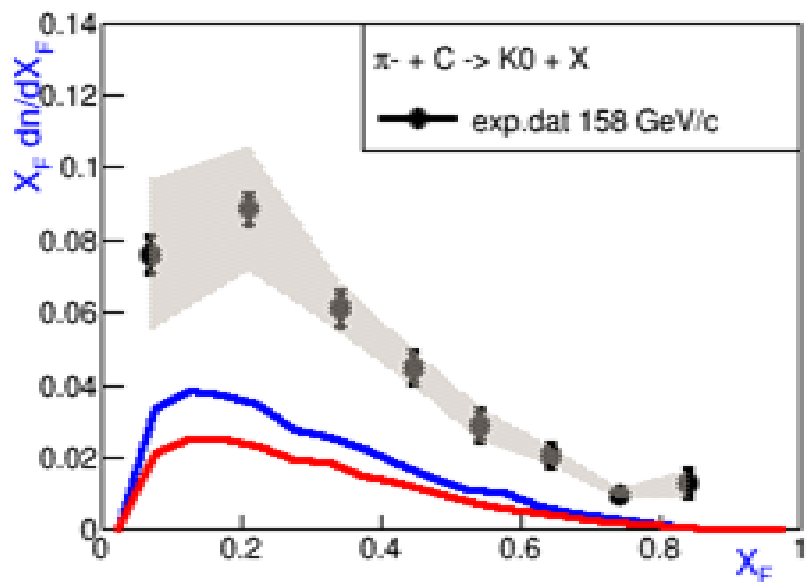
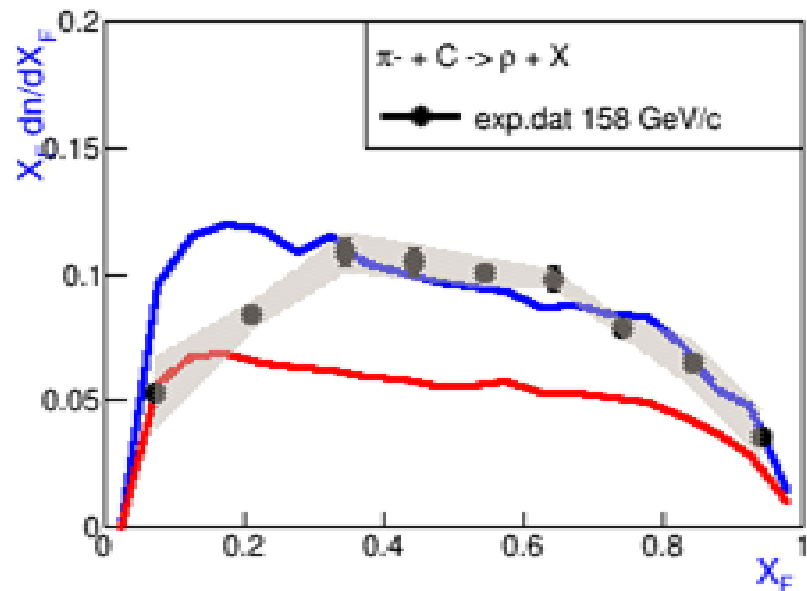
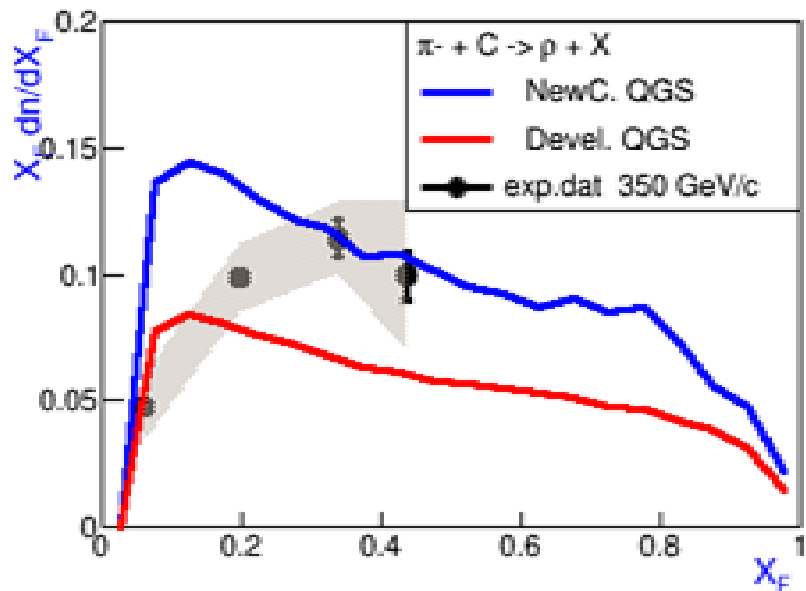
Pion production is reproduced! Stable and Devel. are equal.

Pi- C interactions at 158 and 350 GeV/c, NA61 data



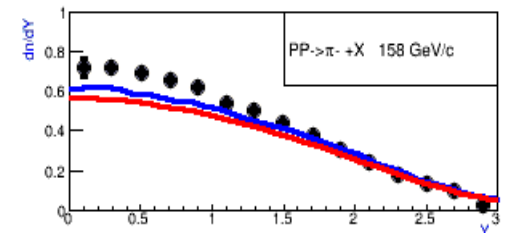
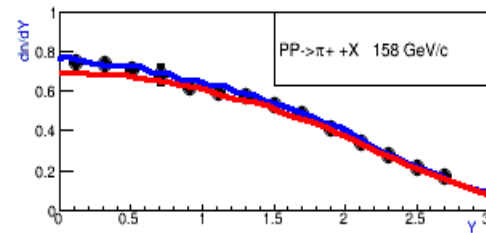
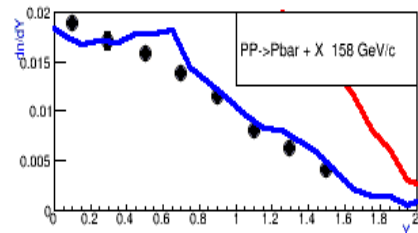
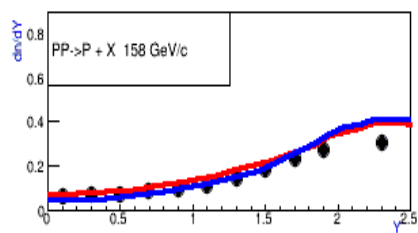
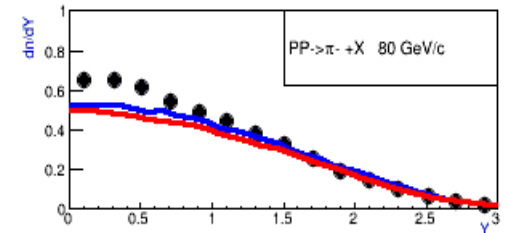
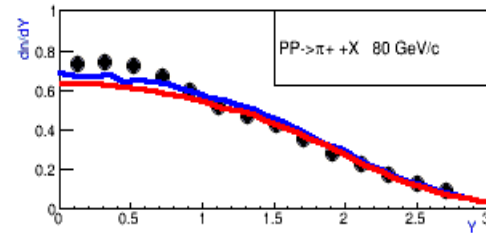
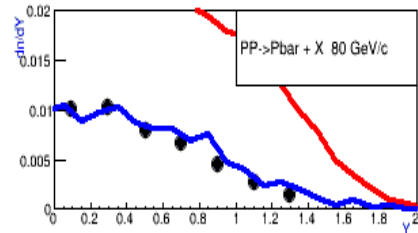
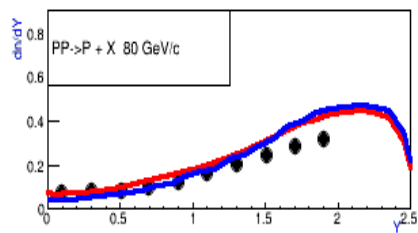
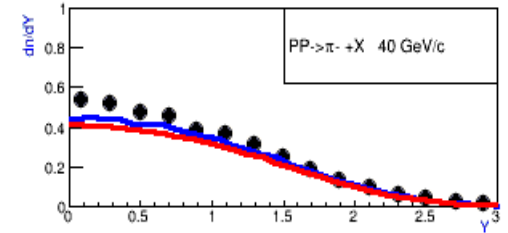
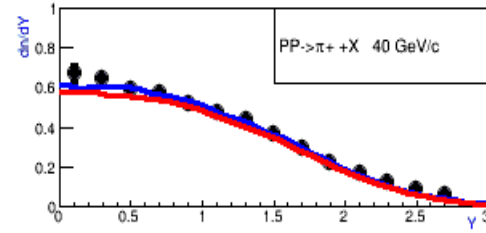
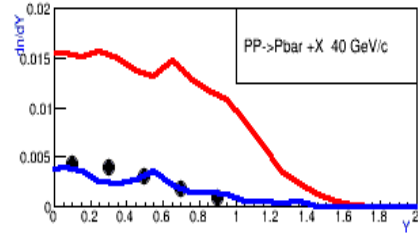
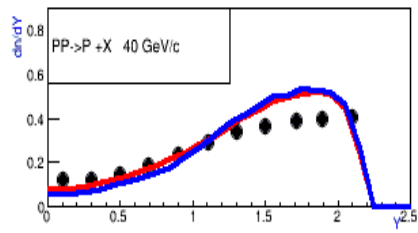
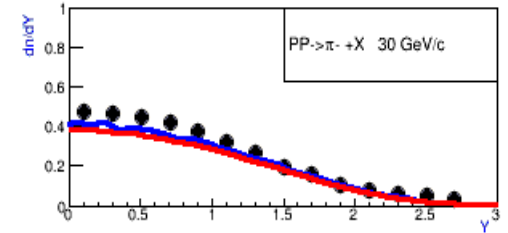
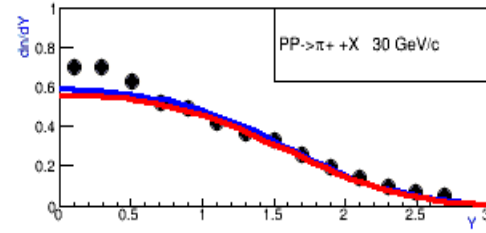
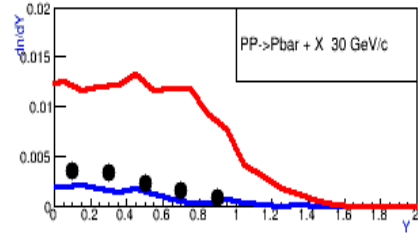
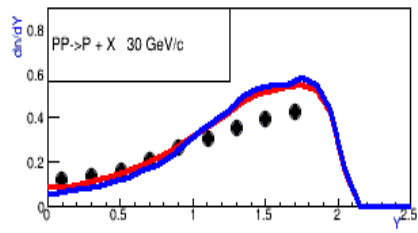
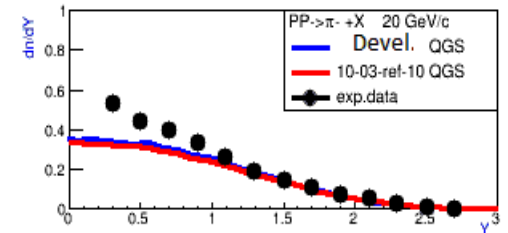
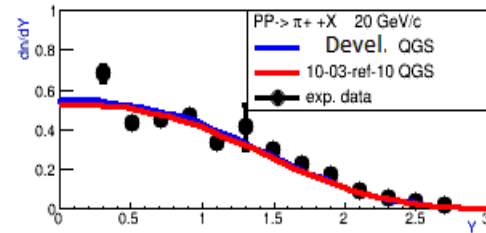
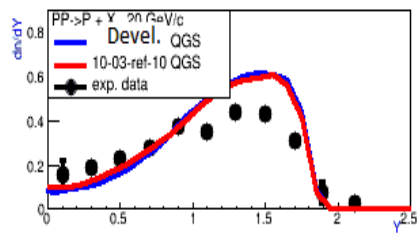
Pion production in the central region is reproduced!

Pi- C interactions at 158 and 350 GeV/c, NA61 data



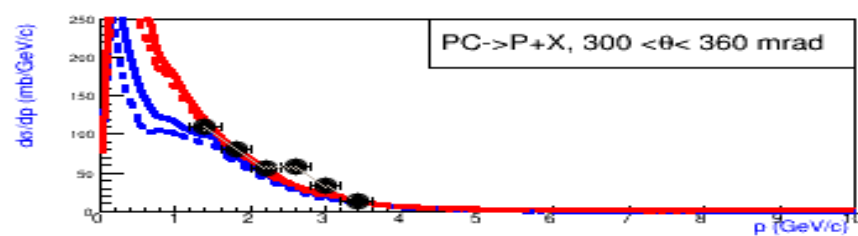
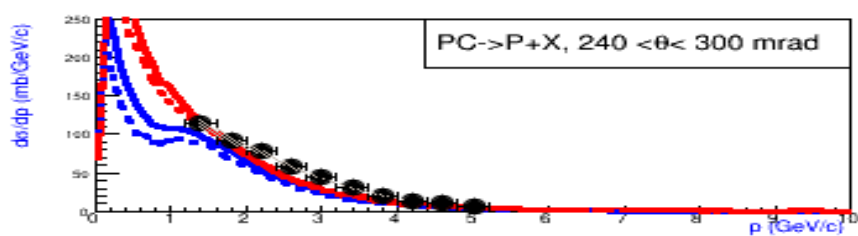
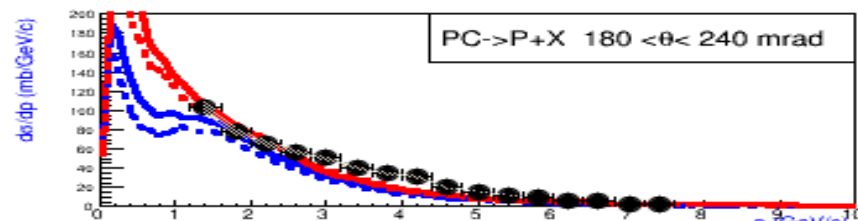
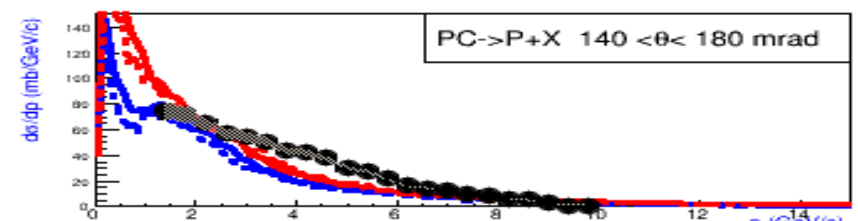
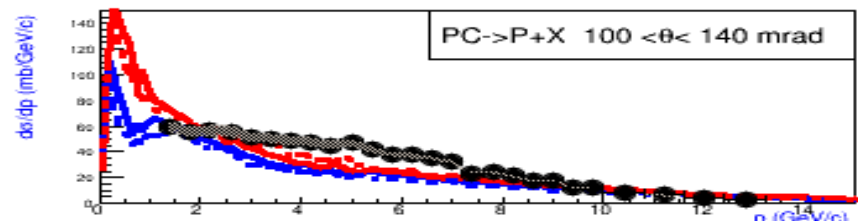
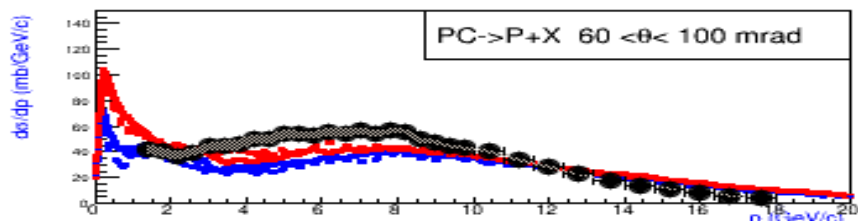
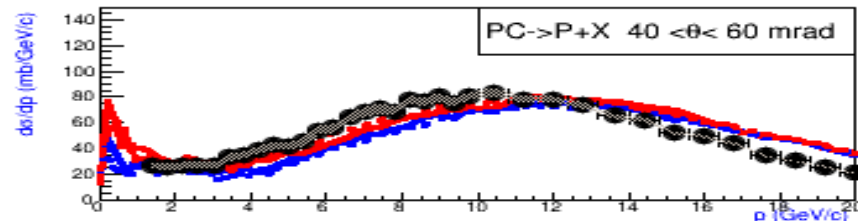
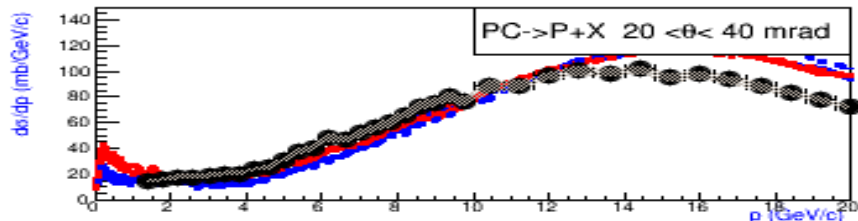
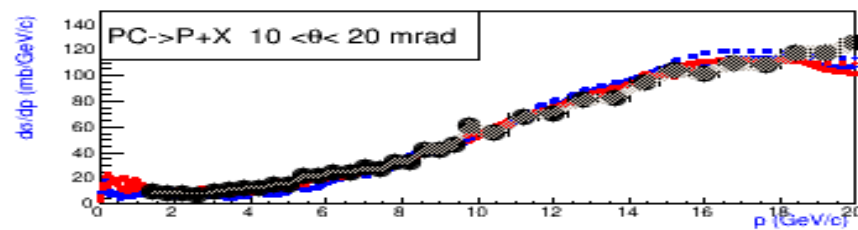
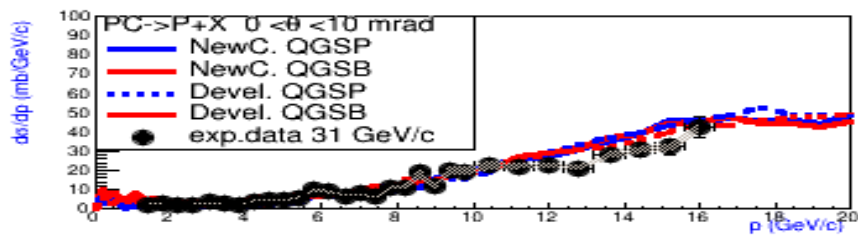
Probabilities Rho/omega 0.6/0.4! Standard 0.5/0.5

PP interactions, NA61 data



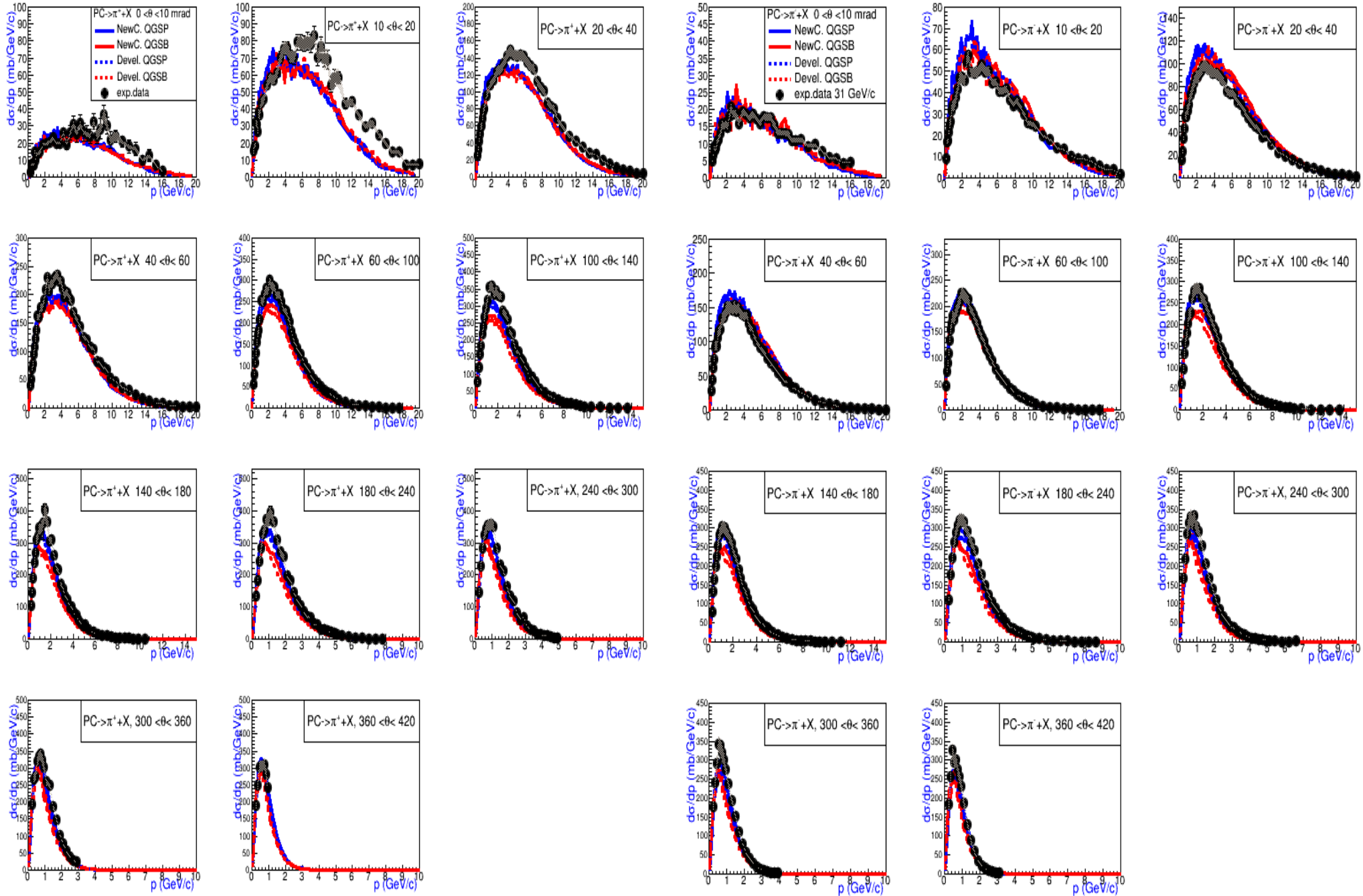
Improved!

P C->p interactions at 31 GeV/c, NA61 data



Results of the “stable” and developer versions are coincided.

P C \rightarrow Pi $^{+-}$ interactions at 31 GeV/c, NA61 data



Conclusion

The results of the “stable” and developer versions of QGSM coincide now!.

Essential bug is fixed in QGSM!

Accounting of the cluster structure of C-12 helps a lot! Effect on the level of 20%.

Unsolved problems:

Meson cloud of nucleon and pions?

High mass diffraction on nuclei?

Nucleus-nucleus interactions?

Hard processes?