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Multiplicity fluctuations in interactions of light nuclei with carbon nuclei at momentum of 4.2 GeV/c per nucleon and their theoretical interpretation

Aida Galoyan

Joint Institute for Nuclear Research
D u b n a
Russian Federation

Multiplicity fluctuations in interactions of light nuclei with carbon nuclei at momentum of 4.2 GeV/c per nucleon and their theoretical interpretation

A.Galoyan, V.Uzhinsky
JINR, Dubna, 2008

Nontrivial dependence of a scaled variance of multiplicity distribution of produced particles in nucleus-nucleus interact.

NA49 Coll. (C. Alt et al.), Phys. Rev. C75 (2007) 064904; nucl-ex/0612010.
NA49 Coll. (M. Gazdzicki et al.), J. of Phys. G,30 (2004) S701; nucl-ex/0403023.
NA49 Coll. (M Rybczynski et al.), J. of Phys. Conf. Ser.5 (2005)74; nucl-ex/0409009.

String Fusion Model

L. Cunqueiro et al.,Phys. Rev. C72 (2005) 024907;
P. Brogueira1 and J. Dias de Deus, Phys. Rev. C72 (2005) 044903.

Statistical Model

M. Rybczynski, Z. Wlodarczyk, J. of Phys. Conf. Ser. 5 (2005) 74.

Experimental data

Experimental data were obtained by propane bubble chamber irradiated by light nuclei with momentum of 4.2 GeV/c per nucl

Statistics of registered events

pC3H8	12757	pC	8971
dC3H8	9016	dC	5807
4HeC3H8	22975	αC	13319
CC3H8	39544	CC	20594

π^- mesons were identified quite well .
Protons were identified up to 500 MeV/c. At larger momenta the separation of protons and π^+-mesons is complicated, but their momenta are defined well. The tracks of positive charged particles with momentum larger than 3 GeV/c and emission angle less than 4° were considered as spectator protons.
The evaporated protons with momentum less than 300 MeV/c and proton-participants with momentum larger than 300 MeV/c without

$Q = n_+ - n_- - n_{evap} - n_{strp}$, is measure of collision centrality

Used models

Modified FRITIOF

UrQMD+SMM

Cascade Evaporation Model (Dubna)

Modified FRITIOF model

$a + b \rightarrow a' + b'$ $\quad m_{a'} > m_a \quad m_{b'} > m_b$

a' and b' are excited states of initial hadrons a, b

In hadron-nucleus interactions -- a'+ b1->a''+b1' …

Probability of multiple collisions are considered in the Glauber approach. Modified FRITIOF takes into account inelastic scatterings and elastic re-scatterigns of nucleons. Modified FRITIOF uses reggeon cascade model. "Wounded" nucleon involve in the reggeon cascade nonintercating nucleon with probability $W=C_{nd}e^{-r2/r2nd}$.

The involved nucleon can involve another spectator nucleon.

$C_{nd} = 1$, $r_{nd}=1.2$ Фм. $\quad \Delta^+$ - and Δ^0– izobars in nucleus

UrQMD approach

S.A.Bass et al., Prog. Part. Nucl. Phys., 41 (1998) 225
M.Bleicher et al., J.Phys. G25 (1999) 1859

- UrQMD approach represents a Monte-Carlo solution of a large set of equations:

$$\frac{df_i(x,p)}{dt} \equiv \frac{\partial p}{\partial t}\frac{\partial f_i(x,p)}{\partial p} + \frac{\partial x}{\partial t}\frac{\partial f_i(x,p)}{\partial x} + \frac{\partial f_i(x,p)}{\partial t} = Stf_i(x,p),$$

$f_i(x,p)$ are phase space densities of particle species $i = N, \Delta, \Lambda$;
x and p are position and momentum of particle,
$Stf_i(x,p)$ denotes the collision term.

- Consideration of cross-section of various meson-meson, meson-baryon, and baryon-baryon interactions
  ~ 50 baryons, ~ 45 mesons;
- $Q\bar{Q}$ string creation a *la* FRITIOF model at $P_{lab} > 5GeV/c$;
- string fragmentation and formation time of particles;

Interactions if $r_{ij} < \sqrt{\sigma_{ij}/\pi}$

$r_{ij} \approx 1$ - 3 fm!

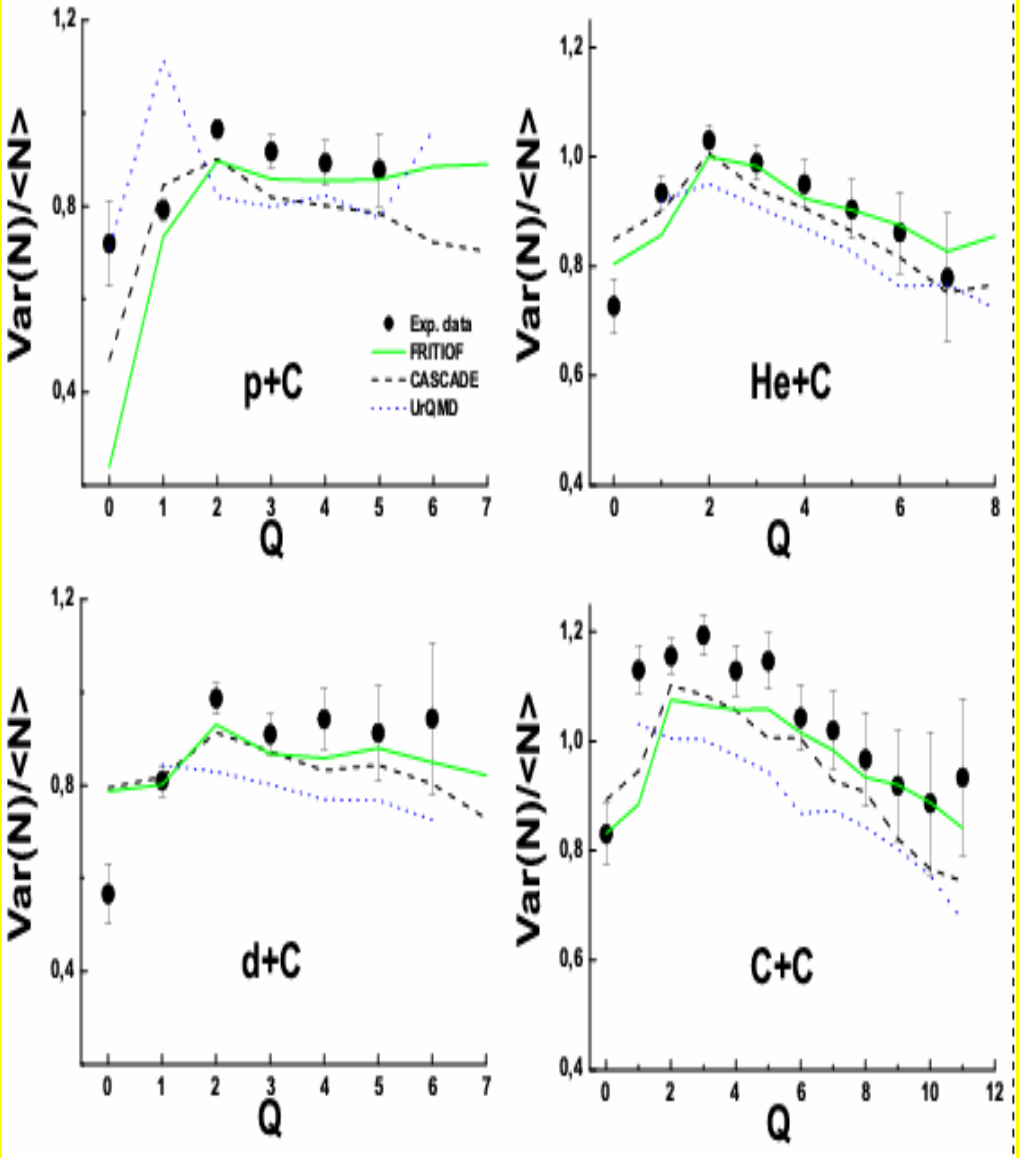
- At $P_{lab} < 5$GeV/c there are reaction channels:
  $N + N \to \Delta N, \Delta\Delta, N^*N, etc., M + N \to \Delta^0, \Lambda, ...$
- potential interactions between the particles: Yukawa, Coulumb, Pauli potentials.

Cascade model (V.S. Barashenkov, V.D. Toneev "Interactions of high energy particles and nuclei with nuclei", Moskow, Atomizdat, 1972)

$NN \to NN, NN \to NN + m\pi, \pi N \to \pi N,$
$\pi N \to N + m\pi, \pi + NN \to NN.$ $\omega, \eta, \rho, \Delta, \Lambda.$

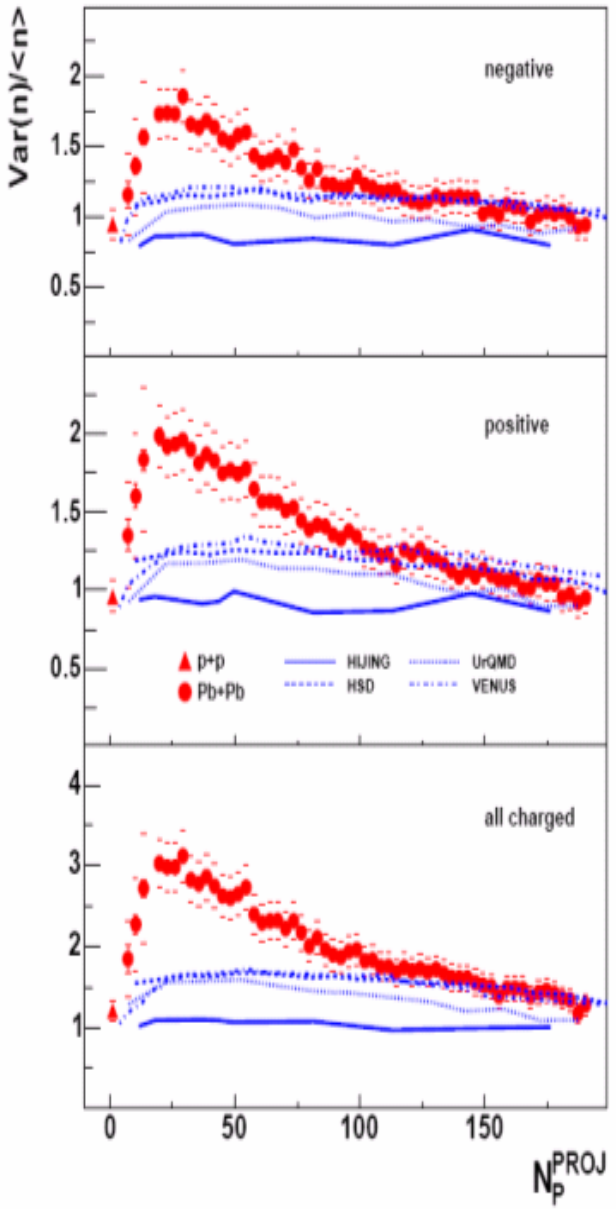
$$\sigma_{ann}^{\bar{p}p} = \sigma_0^N \frac{s_0}{s}\left[\frac{A^2 s_0}{(s-s_0)^2 + A^2 s_0} + B\right]$$

σ_0^N=120 mb, $s_0 = 4m_N^2$, $A = 50$MeV and $B = 0.6$.
Koch and Dover, P.R., C40, 1989, P.145



Scaled variances of negative particles multiplicity distributions in the light nuclei interactions with carbon

NA49 Collaboration (C. Alt et al.), Phys. Rev. C75 (2007) 064904; nucl-ex/0612010.



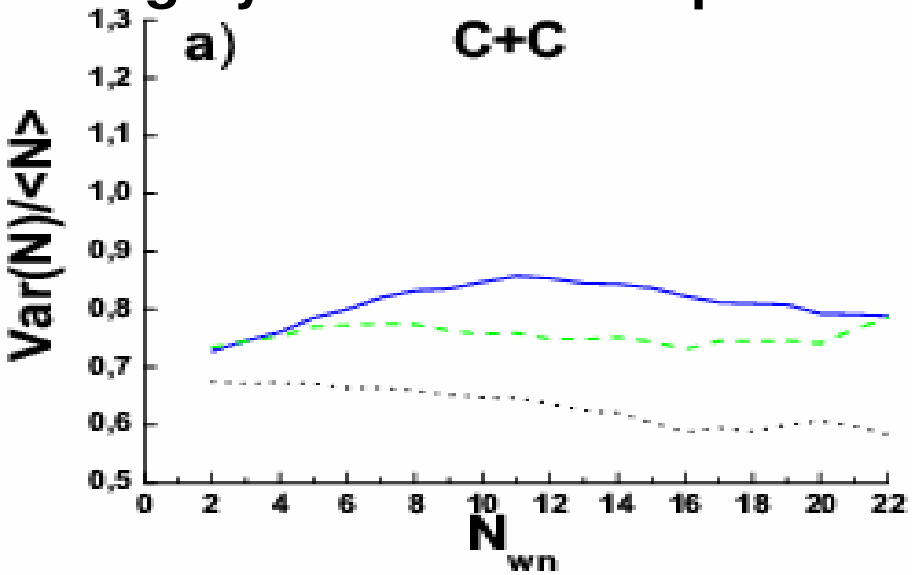
H. Heiselberg, Phys. Rep. **351** (2001) 161;
G. Baym and H. Heiselberg, Phys. Lett. **B469** (1999) 7.

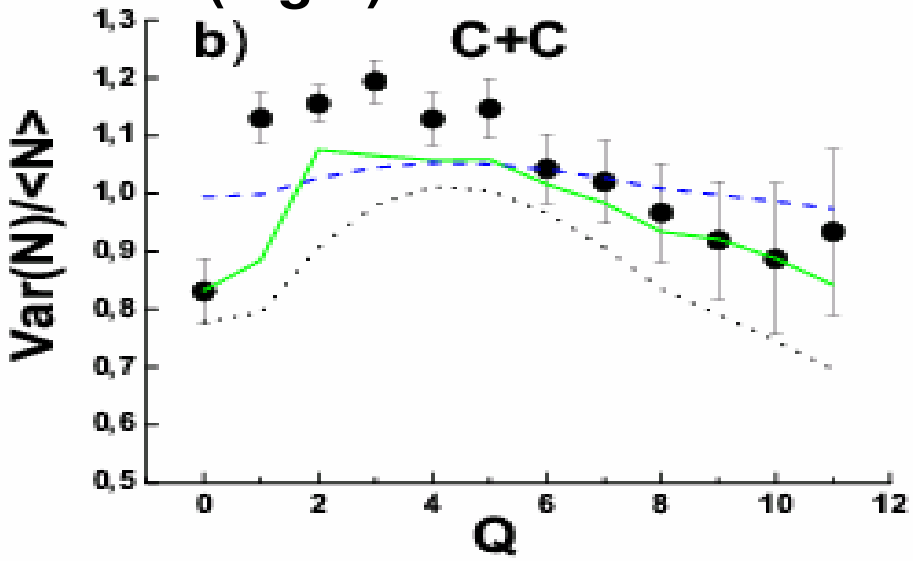
Scaled variance of multiplicity distribution is determined as

$$\omega = \frac{< n^2 > - < n >^2}{< n >} + < n > \frac{< N_s^2 > - < N_s >^2}{< N_s >}, \qquad (1)$$

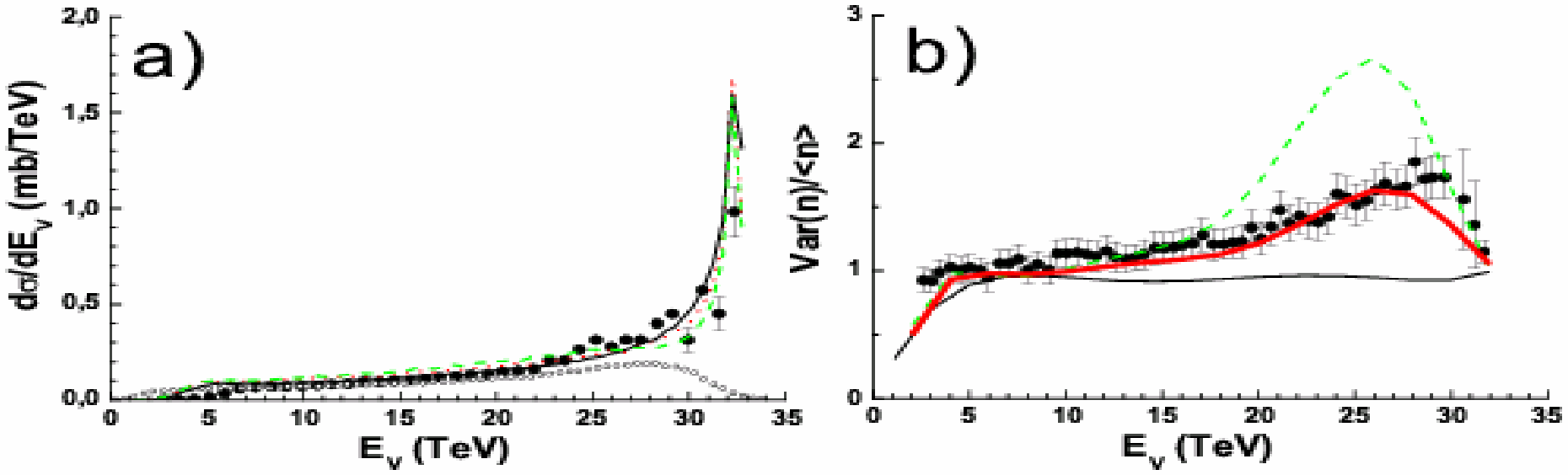
where $< n >$ is the average multiplicity of particles produced by a source, and $< N_s >$ is the average multiplicity of the sources.

Inserting the calculated "wounded" nucleon multiplicity in Eq.1 and using (<n2>-<n>2)/<n>=0.8 and <n>=0.25 we have result roughly close to the experimental data (Fig b)





Turning back to the NA49 data and difficulties in their description using UrQMD, HSD, VENUS, HIJING models, we note that the multiplicity of the "wounded" nucleons was estimated from Veto-calorimeter measuring the total energy of particles in the narrow region along beam direction.



Energy distribution in Veto calorimeter (lower points Fig a) given by *NA49 Coll. (C. Alt et al.), Phys. Rev. C75 (2007) 064904; nucl-ex/0612010* **is strongly different from the one for minimal bias events (upper points Fig b) given by** *NA49 Coll. (Afanasiev et al.) NIM, A 430, 210, (1999).* The last distribution is well described by VENUS and FRITIOF models.

NA49 data and calculations in the FRITOF model

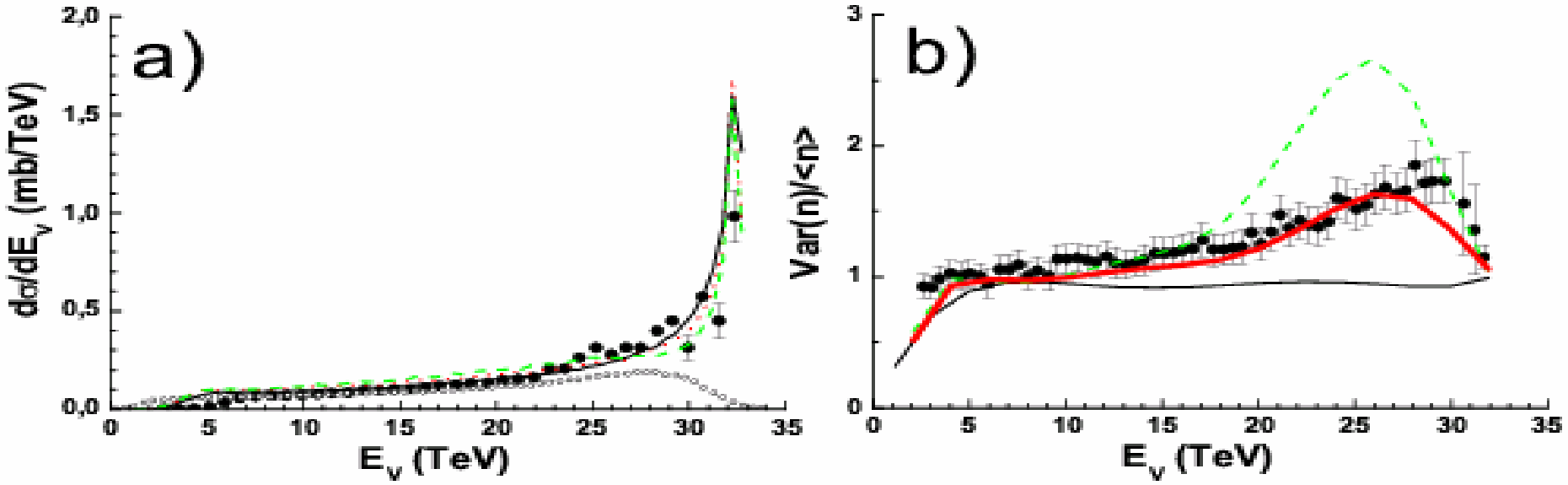
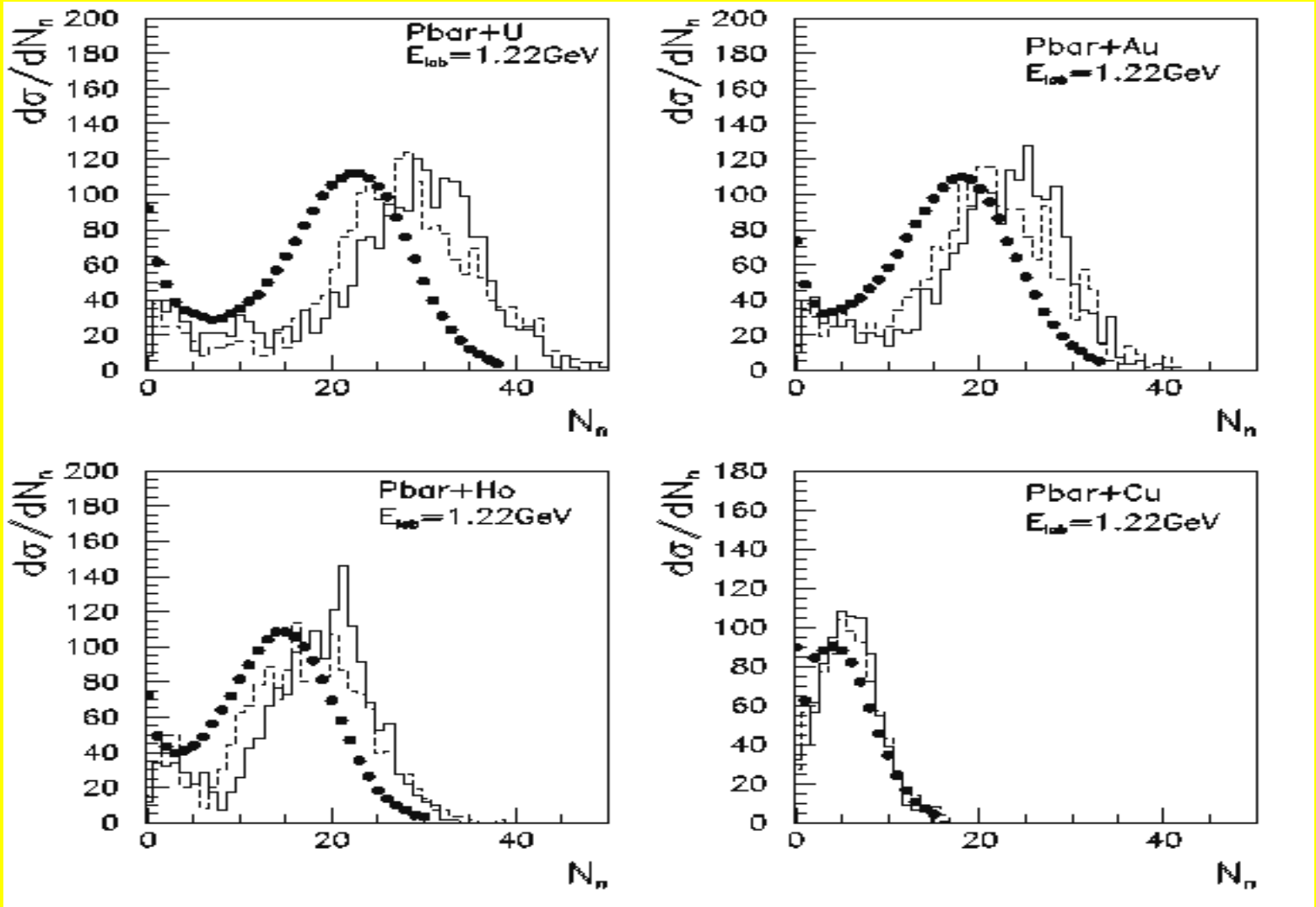


Fig b) present normalized fluctuations in multiplicities of negatively charged particles. The points are the exp.data

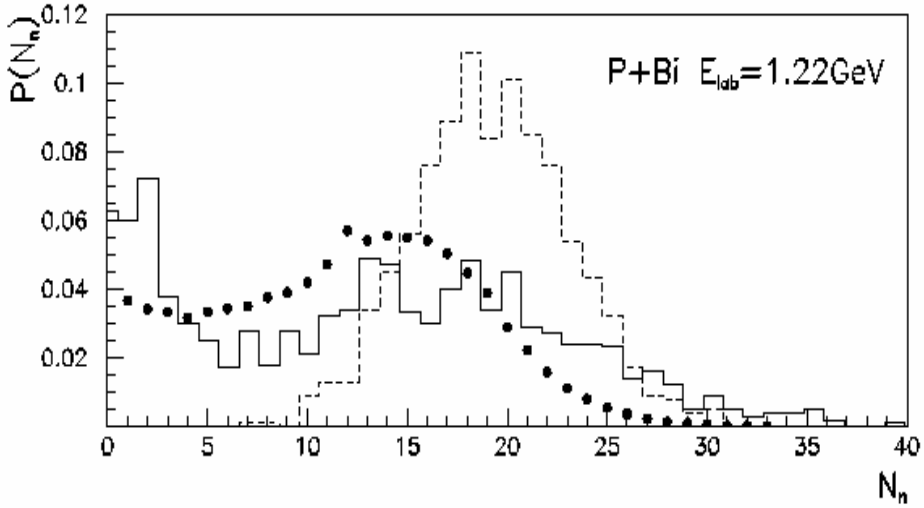
NA49 Coll. (C. Alt et al.), Phys. Rev. C75 (2007) 064904; nucl-ex/0612010

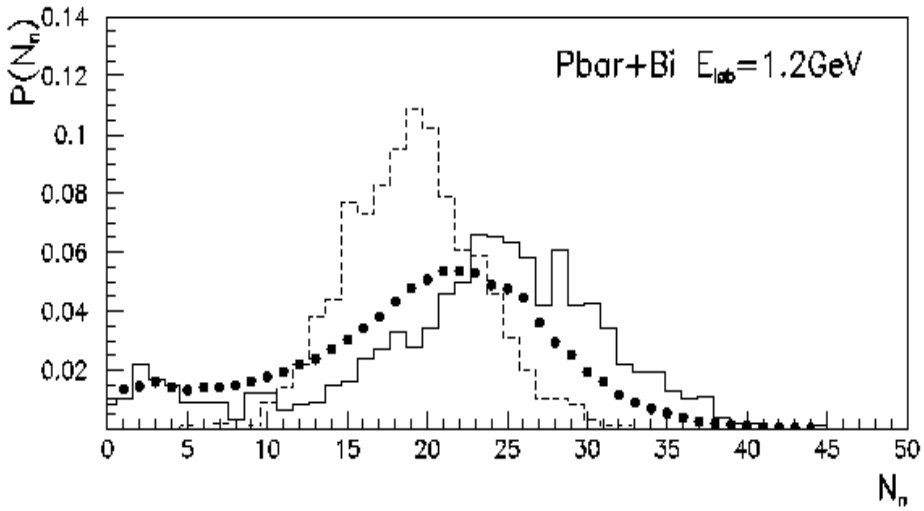
The curves are the calculations in the FRITOF model at parameter of reegeon model of nuclear disintegration Cnd=0 (solid)

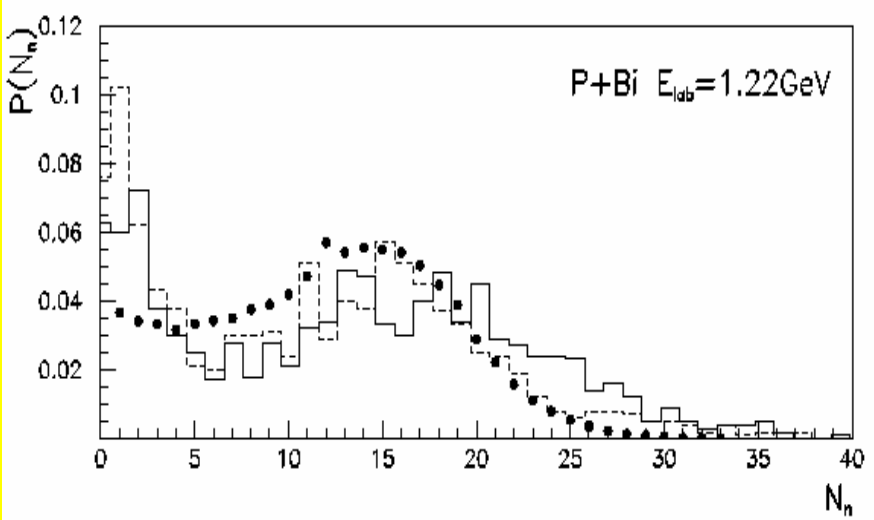
Results of calculations by UrQMD+SMM and UrQMD+Evaporation (Exp. Data - PS208 Collab.,LEAR)

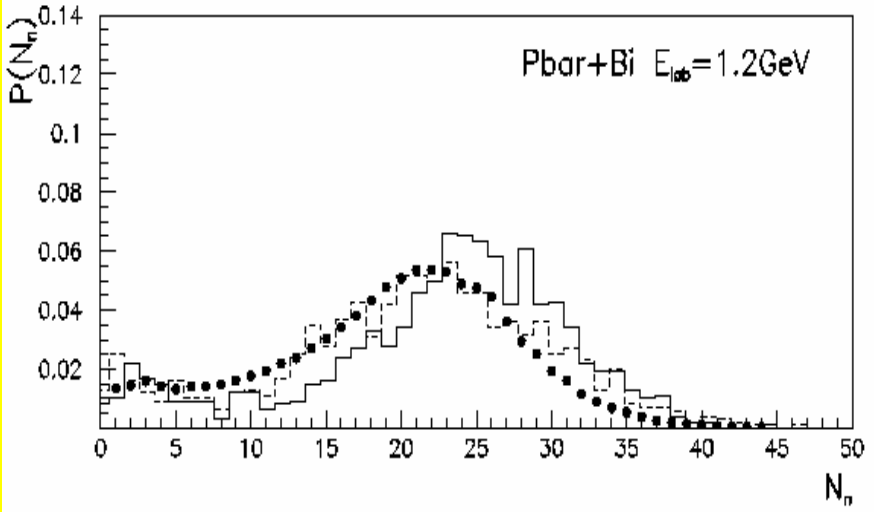


Results of calculations by UrQMD by UrQMD+SMM and UrQMD+Evaporation (Exp. Data - PS208 Collab.,LEAR)

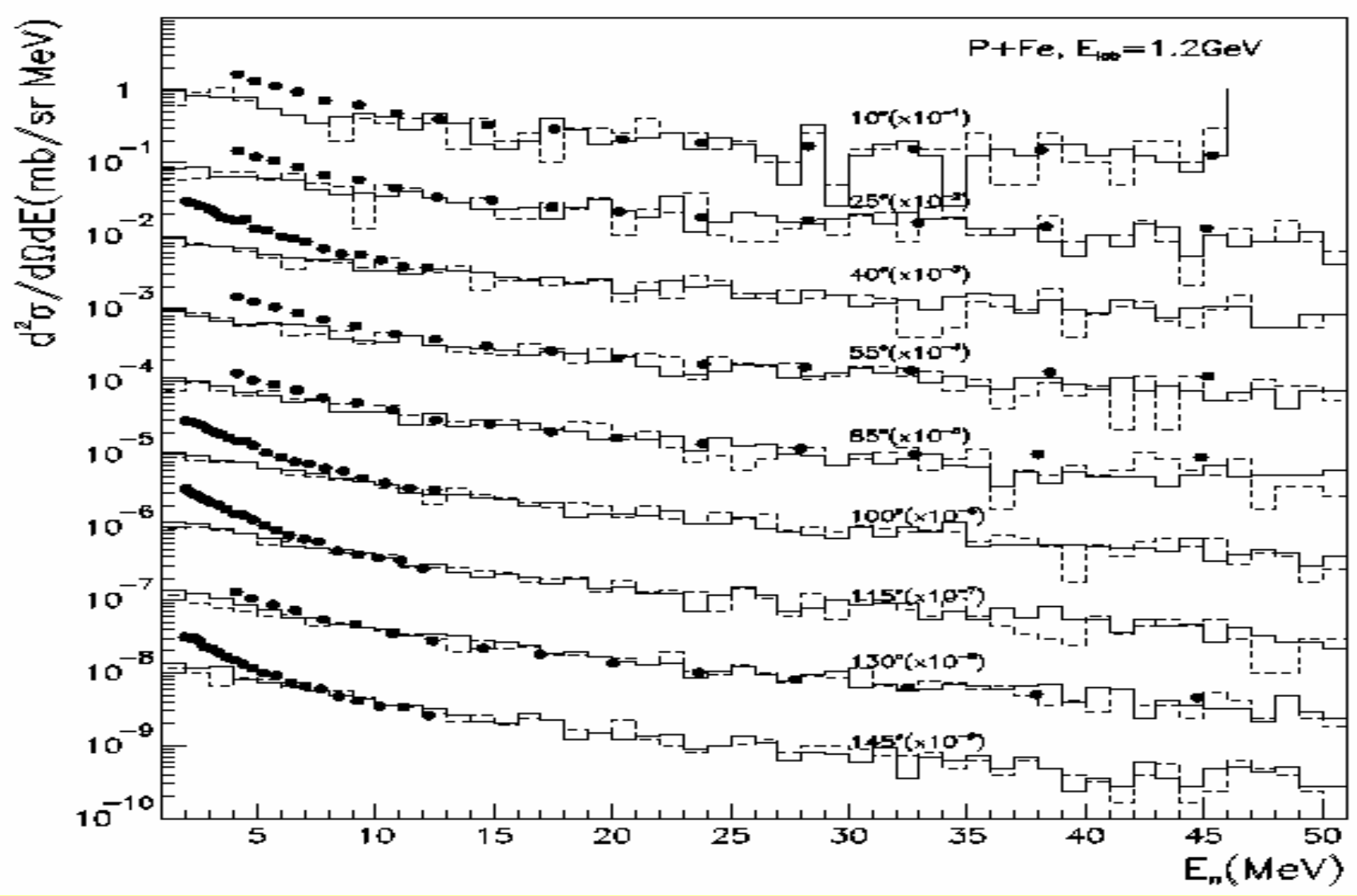




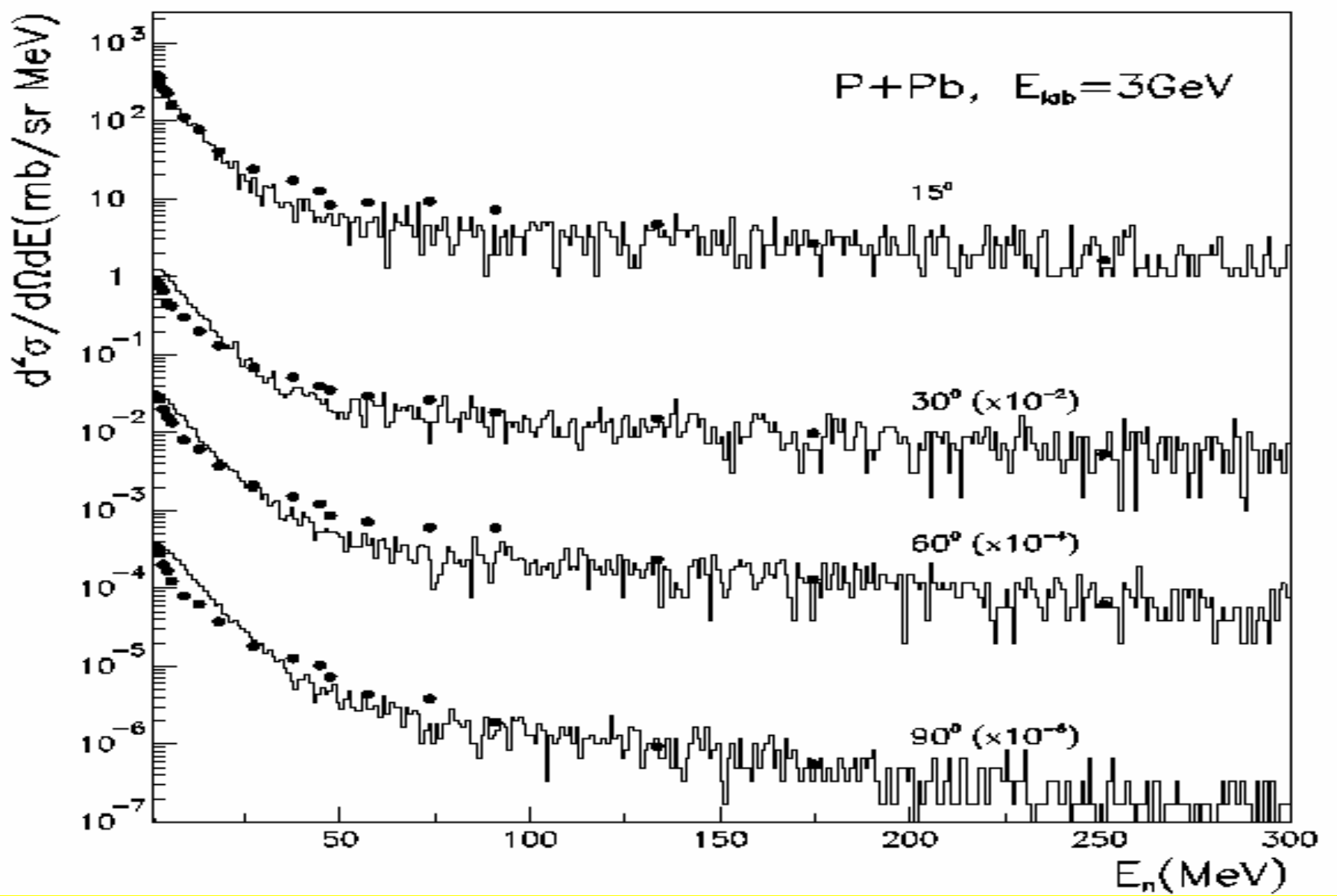




Results of calculations by UrQMD+SMM and UrQMD+Evaporation



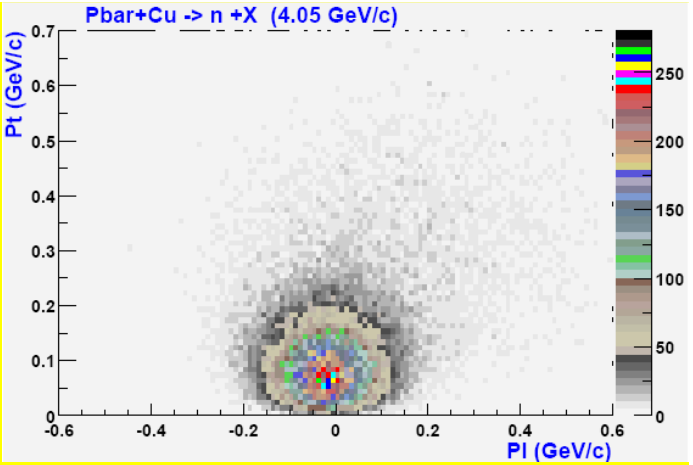
Results of calculations by UrQMD+SMM



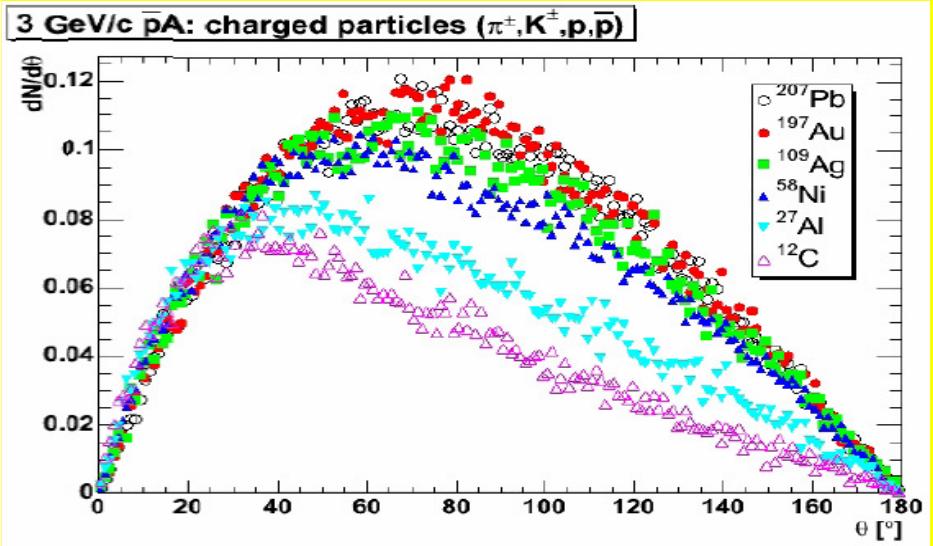
UrQMD+SMM

Target	N_n	N_p	N_π
^{12}C	2.3	2.6	6.6
^{63}Cu	9.3	7.0	6.4
^{197}Au	33.4	10.0	5.9

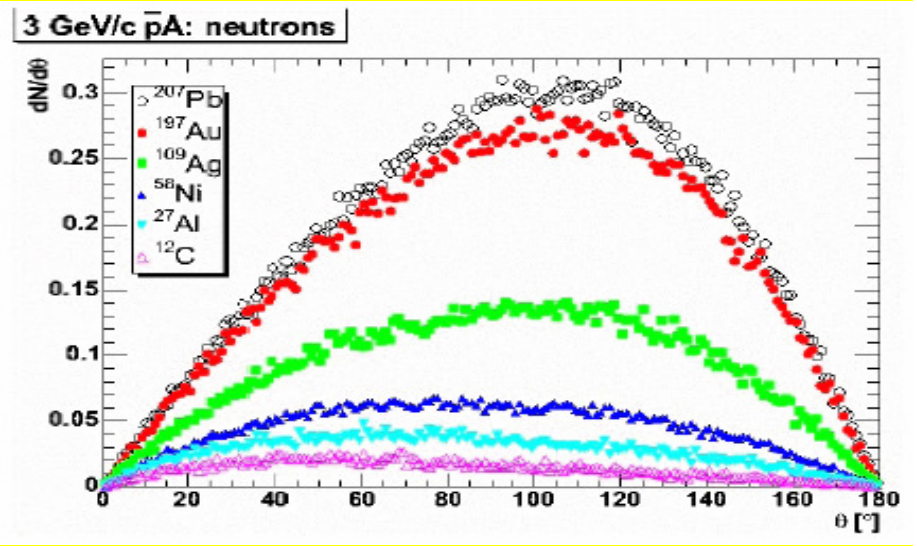
Multiplicities per collision of neutrons Nn, protons Np and pions N obtained in a UrQMD simulation of 10000 events for 4.05 GeV/c p + 12C, 63Cu, and 197Au. Particles from evaporation processes are included.



Transverse vs. longitudinal momentum distribution of neutrons obtained with an UrQMD calculation for 4.05 GeV/c p + Cu, including low energy evaporation processes.

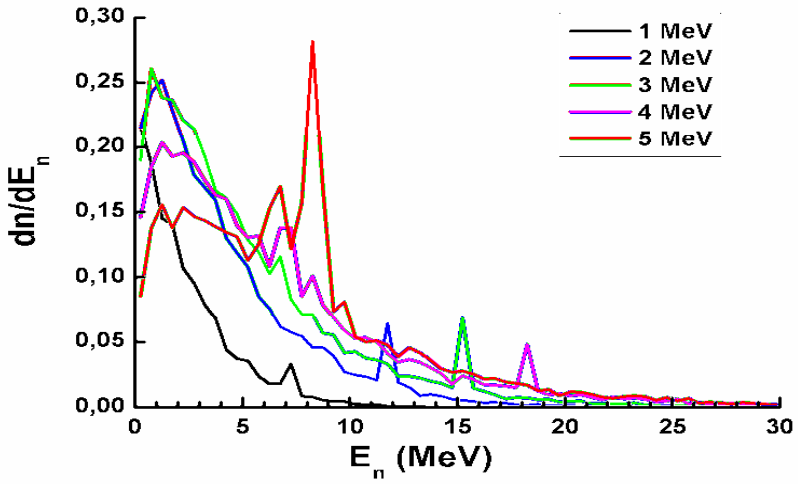


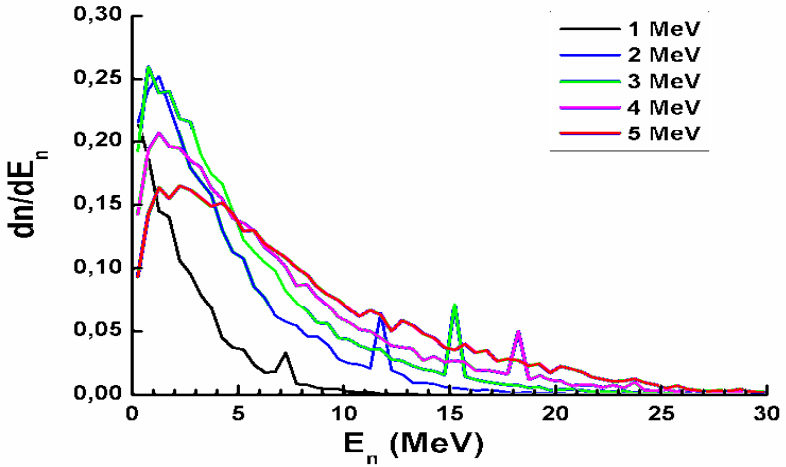
UrQMD predictions for the differential multiplicity of charged particles per interacting antiproton for various target nuclei at 3GeV/c incident momentum.

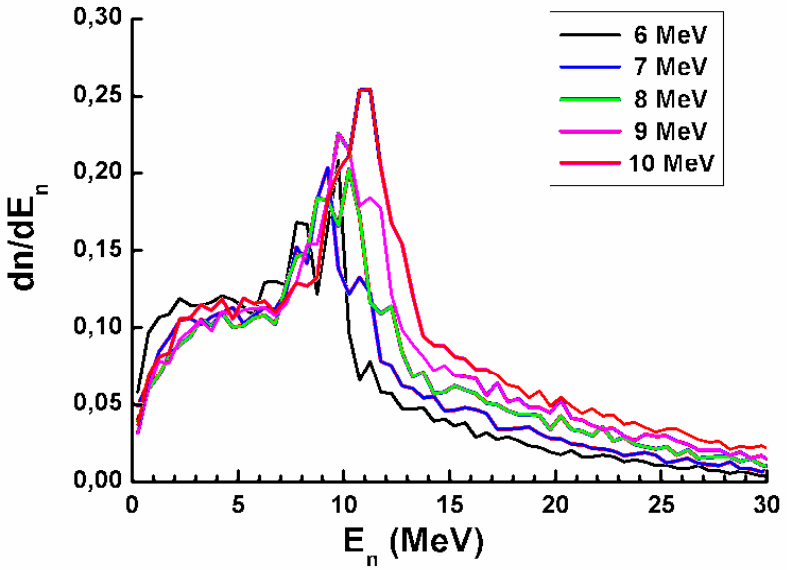


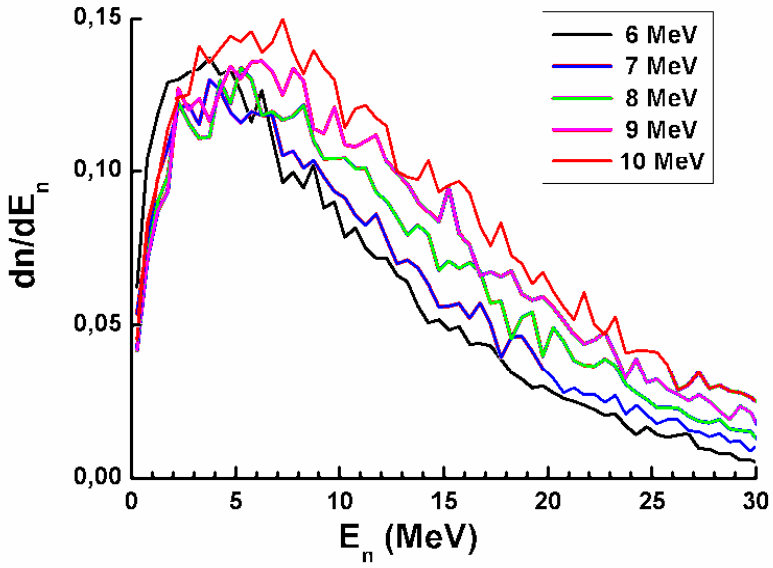
UrQMD predictions for the differential multiplicity of neutral particles per interacting antiproton for various targets at 3 GeV/c incident momentum.

New SMM from 18.02.2005 by A.Botvina

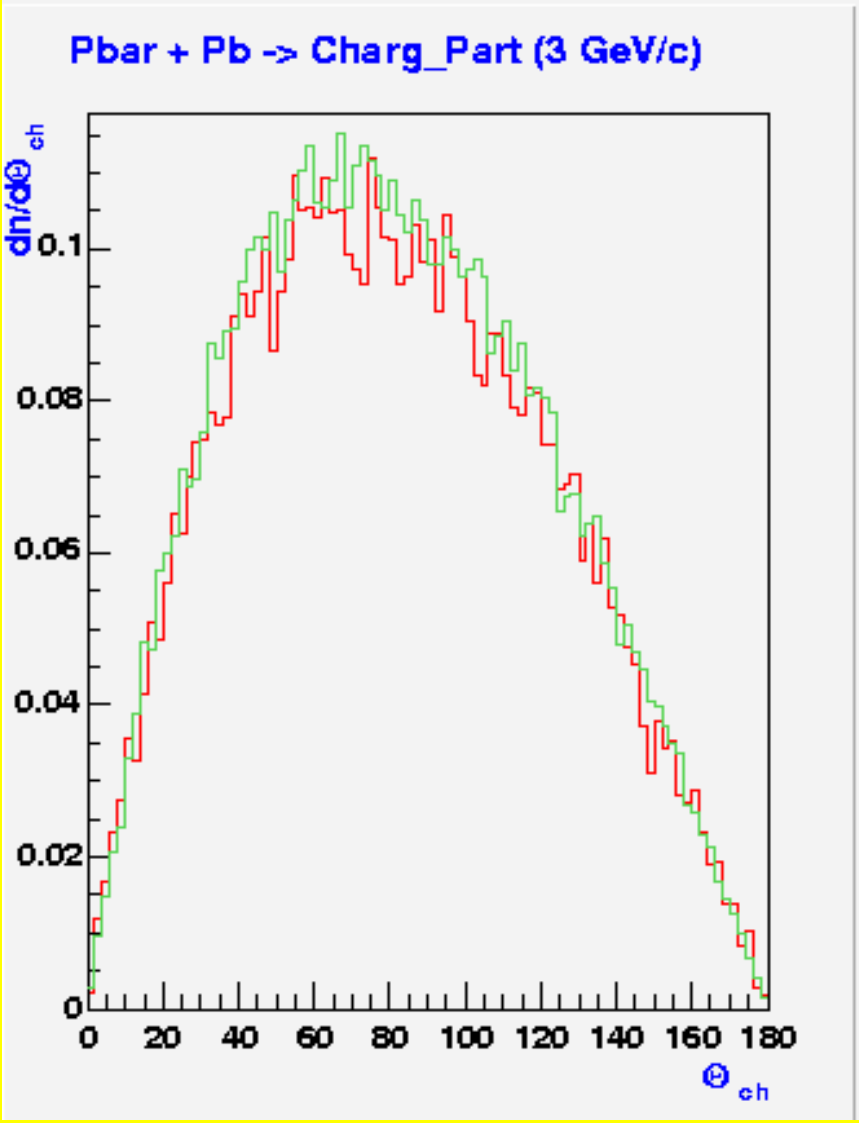


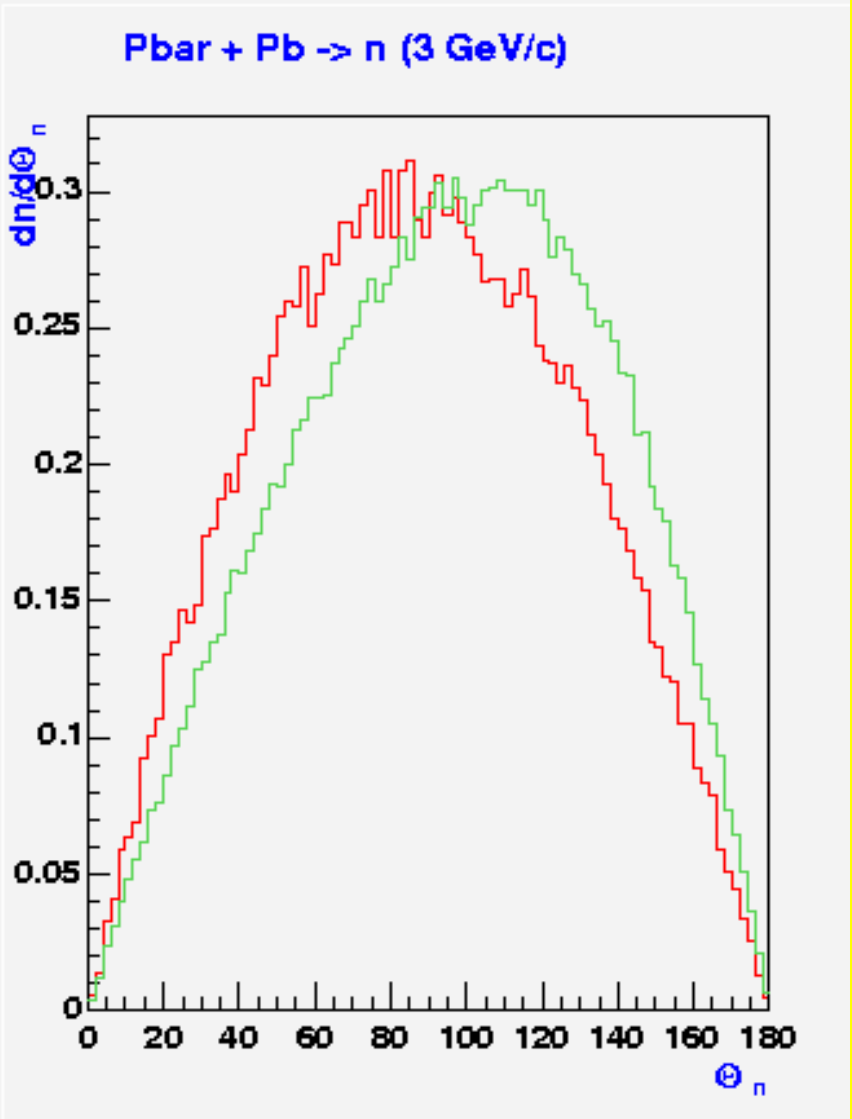






Recent calculations by UrQMD + SMM (new version)





Conclusion

1. New version of Statistical Multifragmentaion model has been coupled with UrQMD model to further use in PANDA software. Additional testing of the UrQMD + SMM is needed.
2. Lorentz- transformation is improved.
3. Kinetical energy spectra and angular distributions of neutrons became better.

Problems:

- Choice between the versions : UrQMD_1.3 or UrQMD_1.2
- Calculation of radiation doses.
- Calculations using UrQMD+SMM model require too many computer time for antiproton+heavy nuclei reactions.

UrQMD approach

S.A.Bass et al., Prog. Part. Nucl. Phys., 41 (1998) 225
M.Bleicher et al., J.Phys. G25 (1999) 1859

- UrQMD approach represents a Monte-Carlo solution of a large set of equations:

$$\frac{df_i(x,p)}{dt} \equiv \frac{\partial p}{\partial t}\frac{\partial f_i(x,p)}{\partial p} + \frac{\partial x}{\partial t}\frac{\partial f_i(x,p)}{\partial x} + \frac{\partial f_i(x,p)}{\partial t} = Stf_i(x,p),$$

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- Consideration of cross-section of various meson-meson, meson-baryon, and baryon-baryon interactions ~ 50 baryons, ~ 45 mesons;
- $Q\bar{Q}$ string creation a *la* FRITIOF model at $P_{lab} > 5GeV/c$;
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- At $P_{lab} < 5$GeV/c there are reaction channels: $N + N \to \Delta N, \Delta\Delta, N^*N, etc., M + N \to \Delta^0, \Lambda, ...$
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M.Bleicher et al., J. Phys. G25 (1999) 1859.

- Consideration of cross-section of various meson-meson, meson-baryon, and baryon-baryon interactions. It takes into account 50 baryons, 45 mesons, and medium modification of the cross-sections (elastic scattering only).
- It considers string creation a la FRITIOF model at
- Plab > 5GeV/c.
- It also considers string fragmentation and formation time of particles.
- At lower energies, Plab < 5GeV/c there are reaction with mesons, izobars, hyperons, etc.