Simulation of Anti-Nucleus – Nucleus and Nucleus-Nucleus interactions in GEANT-4

V. Uzhinsky, A. Galoyan, 3.03.2011

For the implementation it was needed:

1. **Cross sections of Abar A interactions**
   Class G4ComponentAntiNuclNuclXS

2. **Simulation of NbarN interactions**
   Class G4FTFAnnihilation

3. **Sampling of nucleus-nucleus interaction graph**
   Class G4FTFParticipants

4. **Simulation of NbarA and AbarA interactions**
   Class G4FTFAnnihilation + theBinary model of Geant4 or Precompound model of Geant4

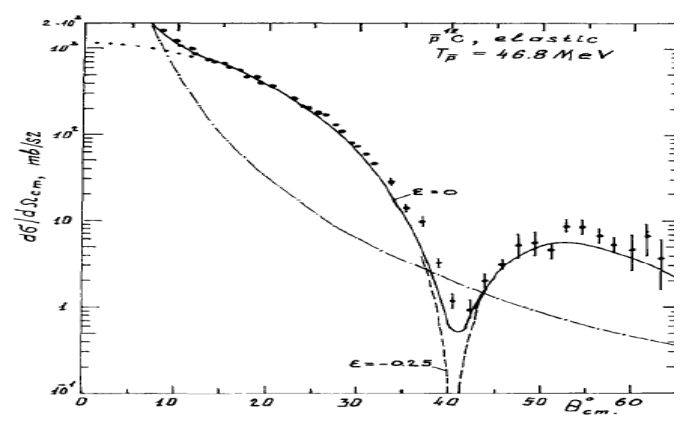
5. **Creation of the corresponding Physics Lists**
   QGSP_FTFP_BERT

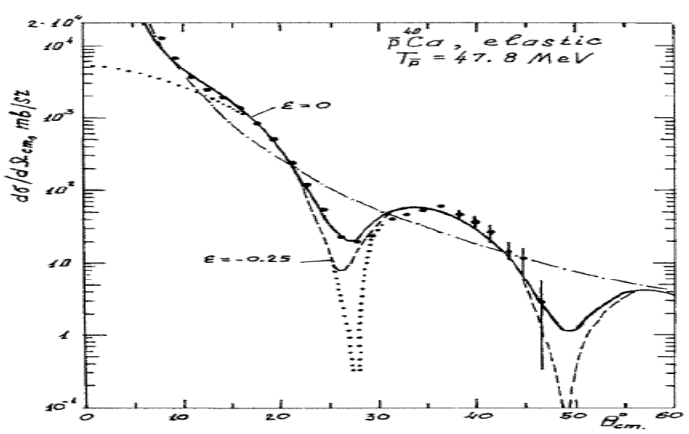
Reference tag: geant4-09-04-ref-02

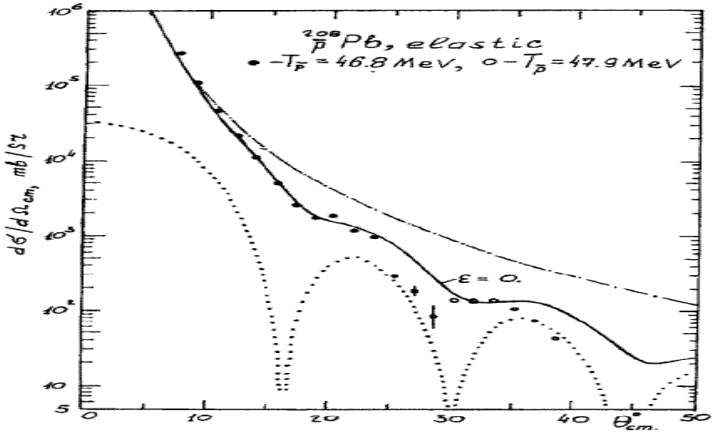
1. Cross sections of Abar A interactions

Class G4ComponentAntiNuclNuclXS

Scattering Of Low-Energy Anti-Protons From Nuclei.
O.D. Dalkarov, V.A. Karmanov Nucl.Phys.A445:579-604,1985.

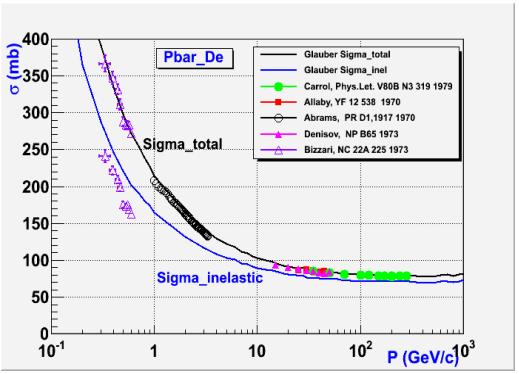


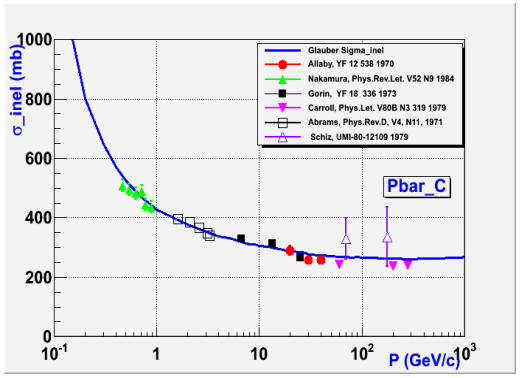


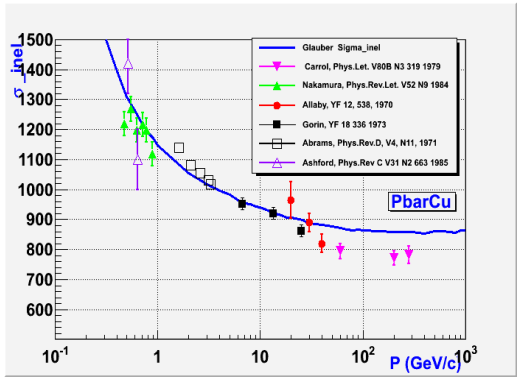


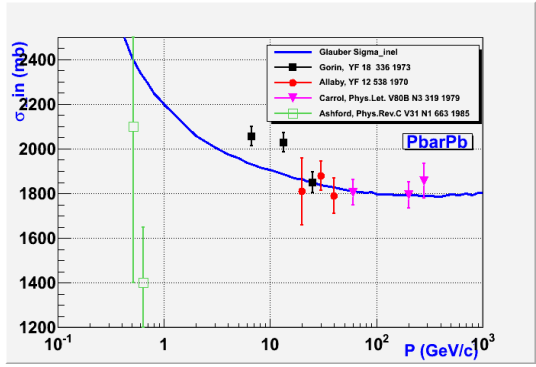
Main computational method

Generator of inelastic nucleus-nucleus interaction diagrams
Computer Physics Communications, V 54, 1989, Pages 125-135
S. Yu. Shmakov, V. V. Uzhinskii, A. M. Zadorozhny









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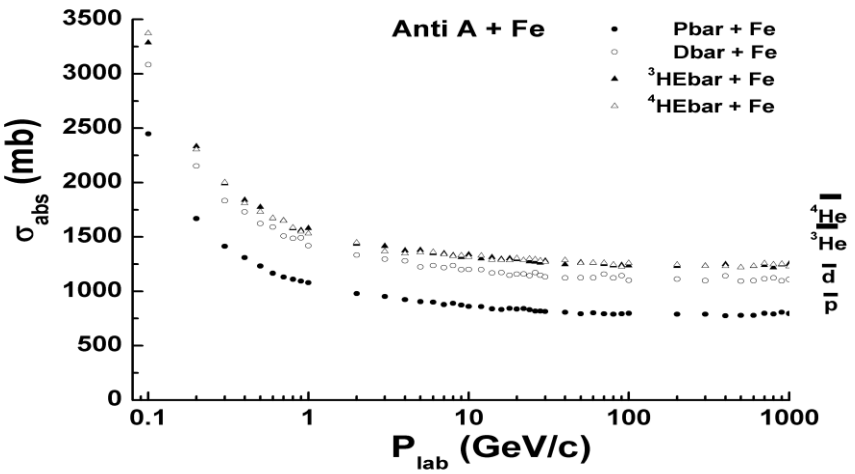
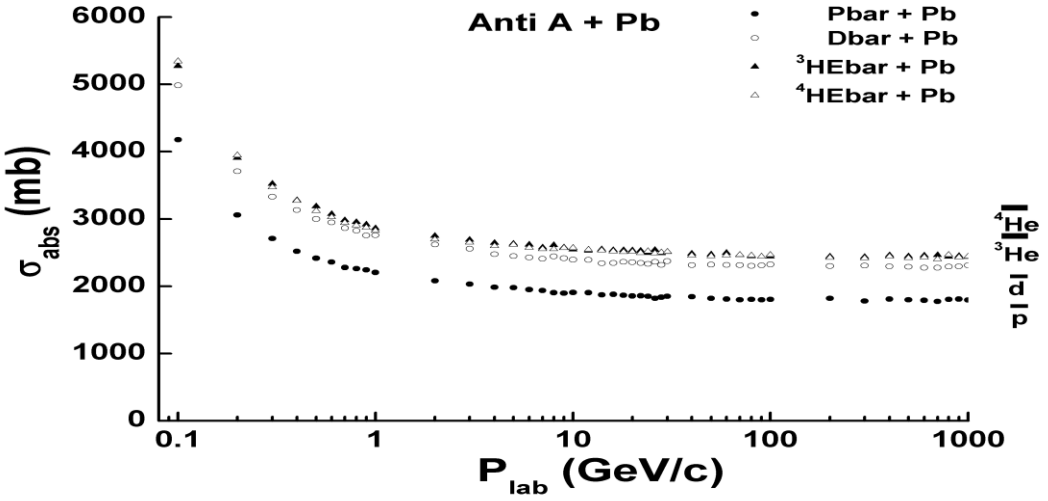
1. Cross sections of Abar A interactions

Class G4ComponentAntiNuclNuclXS





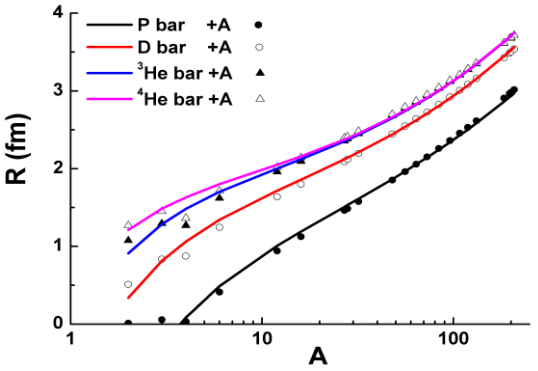
Parameterization of the cross sections

A simplified Glauber model for hadron-nucleus cross sections.
V.M. Grichine Eur.Phys.J. C62: 399-404, 2009.

A simple model for integral hadron-nucleus and nucleus-nucleus cross-sections.
V.M. Grichine, Nucl.Instrum.Meth. B267: 2460-2462, 2009

$$\sigma_{tot}^{A_pA_t} = 2\pi(R_p^2 + R_t^2)\ln\left[1 + \frac{A_pA_t\sigma_{tot}^{NN}}{2\pi(R_p^2 + R_t^2)}\right],$$

$$\sigma_{in}^{A_pA_t} = \pi(R_p^2 + R_t^2)\ln\left[1 + \frac{A_pA_t\sigma_{tot}^{NN}}{\pi(R_p^2 + R_t^2)}\right],$$



Reff (Pbar A) = 0.60 $A^{0.3}$ + 0.08/$A^{1/3}$ – 3.5/A

Reff (Dbar A) = 0.68 $A^{0.3}$ + 1.2/$A^{1/3}$ - 2.9/A

Reff (He3bar A) = 0.70 $A^{0.3}$ + 1.7/$A^{1/3}$ - 2.6/A

Reff (He4bar A) = 0.70 $A^{0.3}$ + 1.7/$A^{1/3}$ - 2.0/A

Reference tag: geant4-09-04-ref-02

1. Cross sections of Abar A interactions

Class G4ComponentAntiNuclNuclXS

New parameterization of total and elastic cross-sections of pbar-p interactions

J.R. Cudell et al. (COMPLETE collab.) Phys. Rev. **D65** (2002) 074024;
W.-M. Yao et al. (PDG), J. Phys. **G33** (2006) 337;
M. Ishida and K. Igi, Phys. Rev. **D79** (2009) 096003.

$$\sigma^{tot}_{ab,asmpt} = Z_{ab} + B \ \ (log(s/s_0))^2$$

Low energy extension

A.A. Arkhipov, **hep-ph/9909531** (1999), **hep-ph/9911533** (1999)

$$\sigma^{tot}_{\bar{p}p} = \sigma^{tot}_{asmpt}\left[1 + \frac{C}{\sqrt{s-4m_N^2}}\frac{1}{R_0^3}\left(1 + \frac{d_1}{s^{0.5}} + \frac{d_2}{s^1} + \frac{d_3}{s^{1.5}}\right)\right]$$

$$\sigma^{tot}_{asmpt} = 36.04 + 0.304 \ \ (log(s/33.0625))^2$$

New parameterization at all energies

$$\sigma^{tot}_{\bar{p}p} = \sigma^{tot}_{asmpt}\left[1 + \frac{C}{\sqrt{s-4m_N^2}}\frac{1}{R_0^3}\left(1 + \frac{d_1}{s^{0.5}} + \frac{d_2}{s^1} + \frac{d_3}{s^{1.5}}\right)\right]$$

$$\sigma^{tot}_{asmpt} = 36.04 + 0.304 \ \ (log(s/33.0625))^2$$

$$R_0 = \sqrt{0.40874044\,\sigma^{tot}_{asmpt} - B}$$

$$B = 11.92 + 0.3036 \ \ \left(log(\sqrt{s}/20.74)\right)^2$$

$$C = 13.55,\ d_1 = -4.47,\ d_2 = 12.38,\ d_3 = -12.43$$

$$\sigma^{el}_{\bar{p}p} = \sigma^{el}_{asmpt}\left[1 + \frac{C}{\sqrt{s-4m_N^2}}\frac{1}{R_0^3}\left(1 + \frac{d_1}{s^{0.5}} + \frac{d_2}{s^1} + \frac{d_3}{s^{1.5}}\right)\right]$$

$$\sigma^{el}_{asmpt} = 4.5 + 0.101 \ \ (log(s/33.0625))^2$$

$$R_0 = \sqrt{0.40874044\,\sigma^{tot}_{asmpt} - B}$$

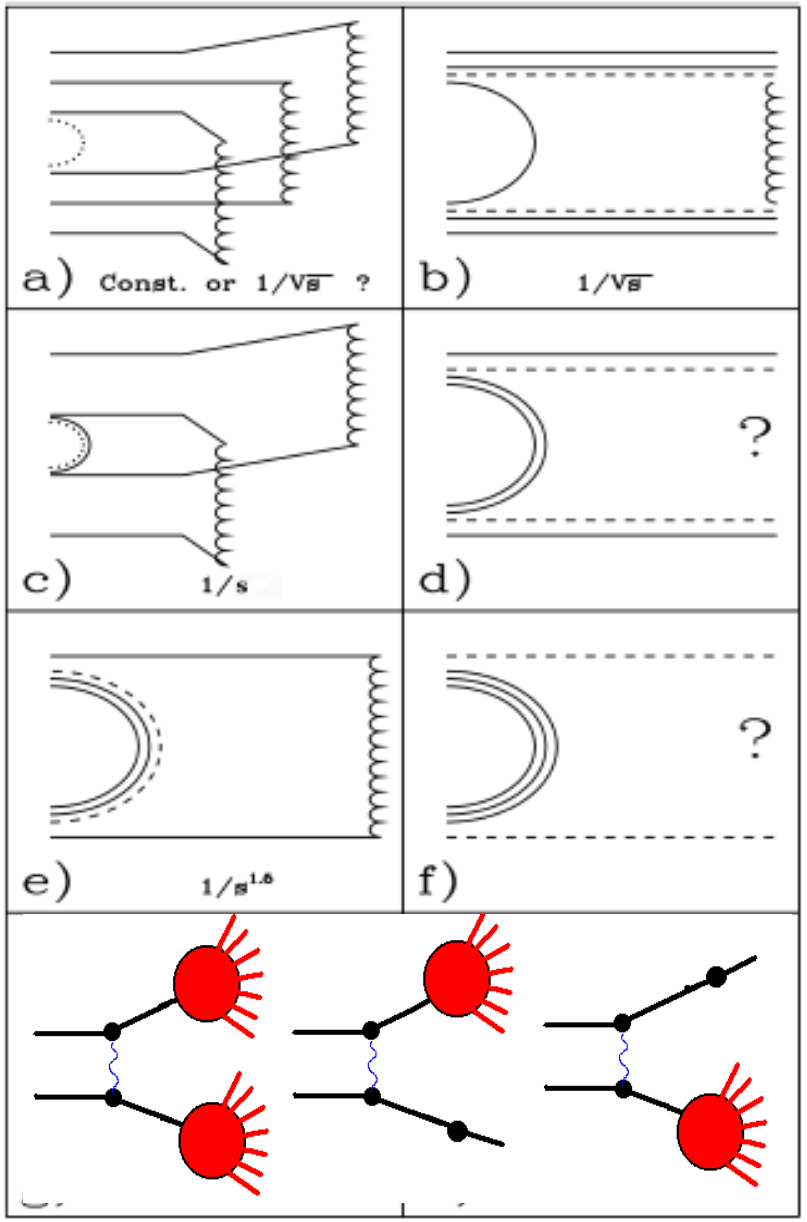
$$B = 11.92 + 0.3036 \ \ \left(log(\sqrt{s}/20.74)\right)^2$$

$$C = 59.27,\ d_1 = -6.95,\ d_2 = 23.54,\ d_3 = -25.34$$

Reference tag: geant4-09-04-ref-02

2. Simulation of NbarN interactions

Class G4FTFAnnihilation



The question marks mean that the corresponding estimations are absent.

Calculation procedure:

V.V. Uzhinsky and A.S. Galoyan, hep-ph/0212369

Cross-sections of various processes in anti-P P interactions.

Implementation:

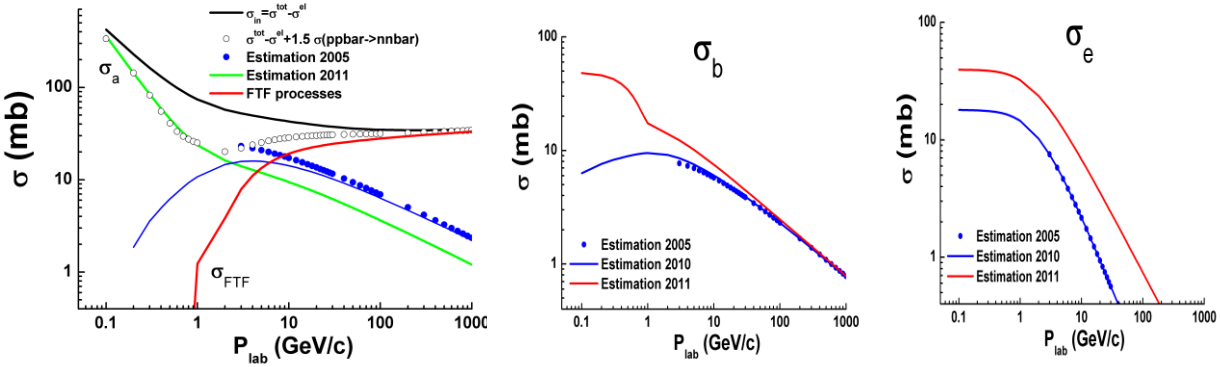
A.Galoian and V.Uzhinsky,AIP Conf.Proc.796:79,2005

New Monte Carlo implementation of quark-gluon string model of anti-p p interactions.

Physics Book of PANDA Collaboration,

Physics Performance Report for: PANDA (AntiProton Annihilations at Darmstadt) Strong Interaction Studies with Antiprotons

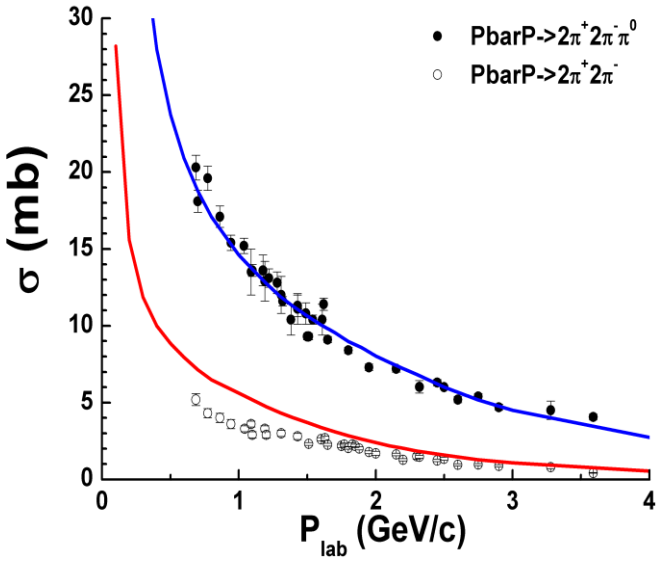
New estimation

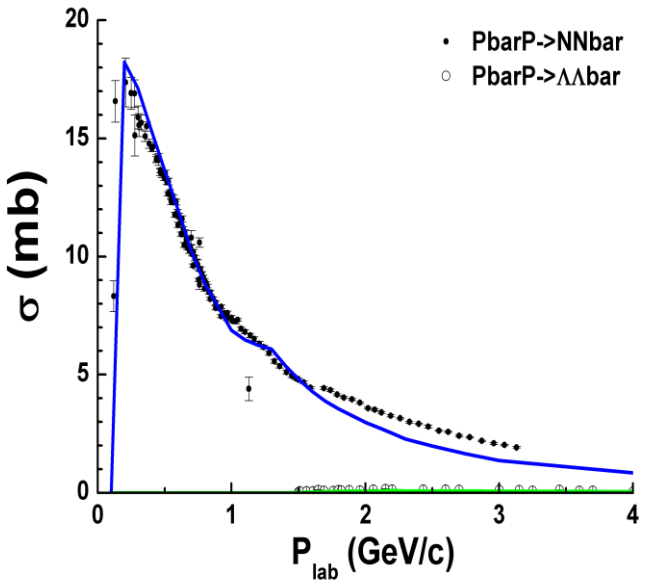


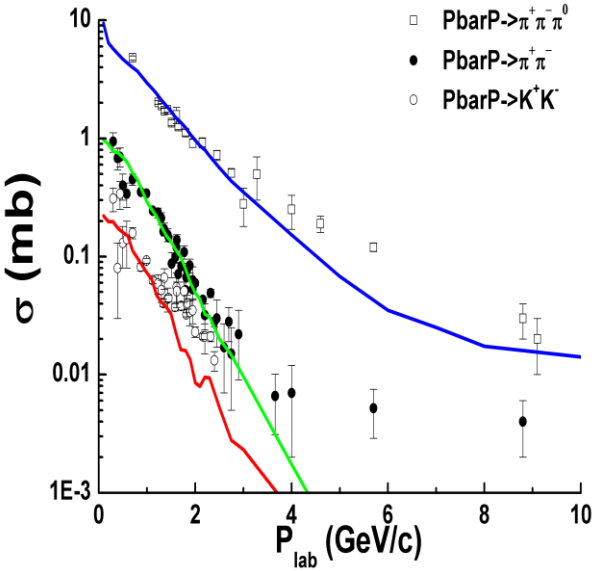
Reference tag: geant4-09-04-ref-02

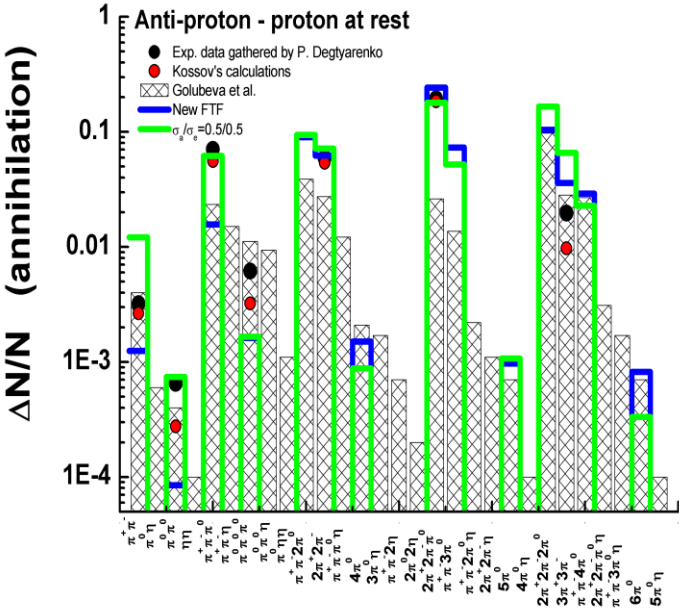
2. Simulation of NbarN interactions

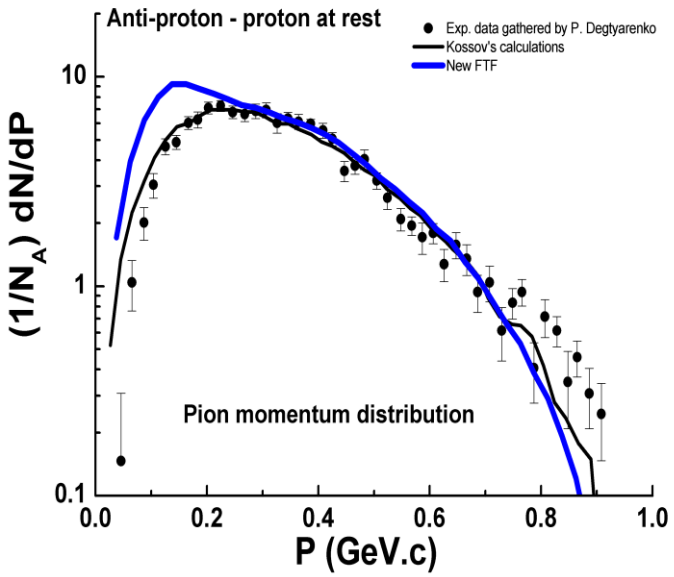
Class G4FTFAnnihilation

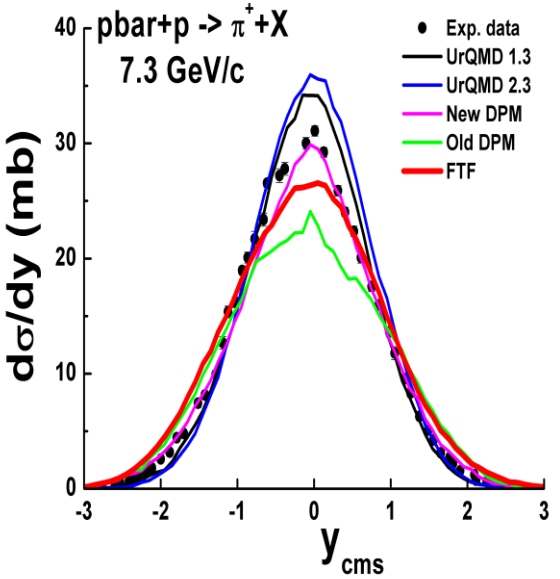












Reference tag: geant4-09-04-ref-02

3. Sampling of nucleus-nucleus interaction graph

Class G4FTFParticipants

We follow the method proposed in

Generator of inelastic nucleus-nucleus interaction diagrams
Computer Physics Communications, V 54, 1989, Pages 125-135
S. Yu. Shmakov, V. V. Uzhinskii, A. M. Zadorozhny

taking into account the annihilation processes.

4. Simulation of NbarA and AbarA interactions

Class G4FTFAnnihilation + theBinary model of Geant4 or Precompound model of Geant4

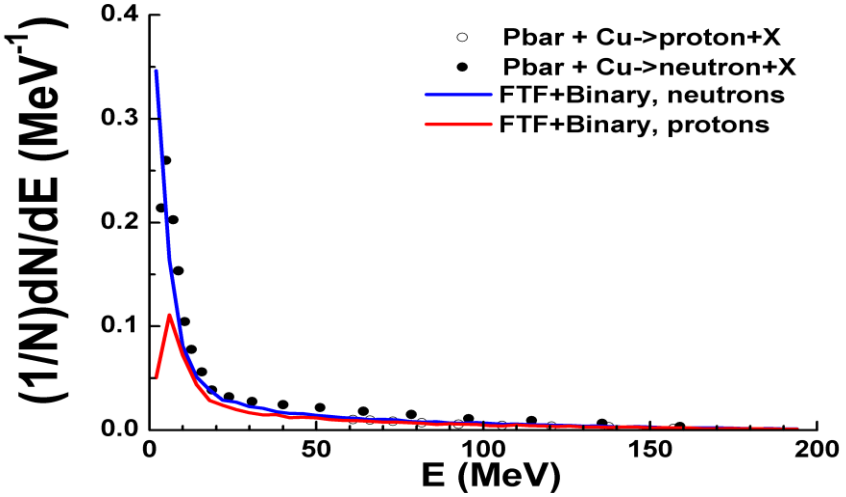
We use the wounded nucleon approximation.
The excitation energy per wounded nucleon is equal 75 MeV.

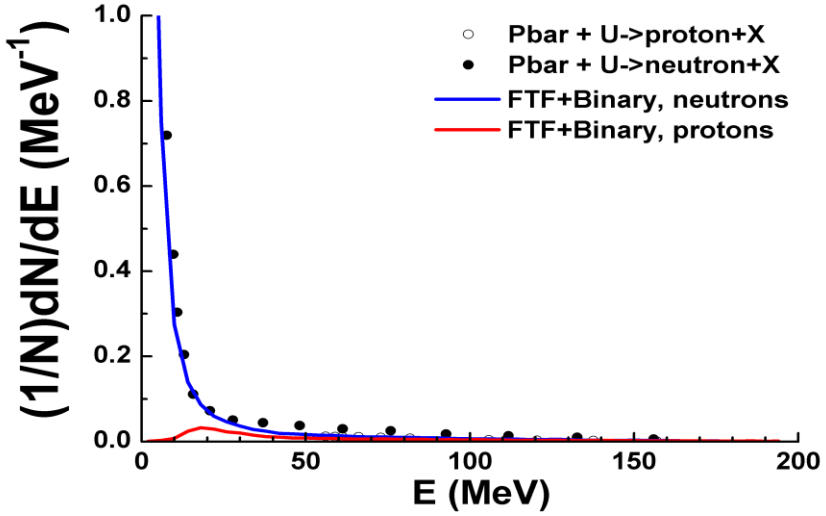
Reference tag: geant4-09-04-ref-02

4. Simulation of NbarA and AbarA interactions

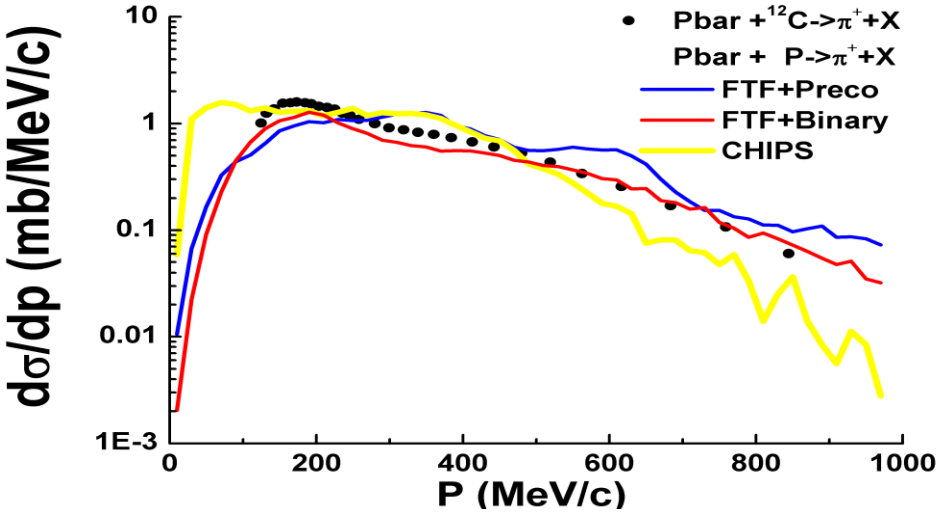
Class G4FTFAnnihilation + theBinary model of Geant4 or Precompound model of Geant4

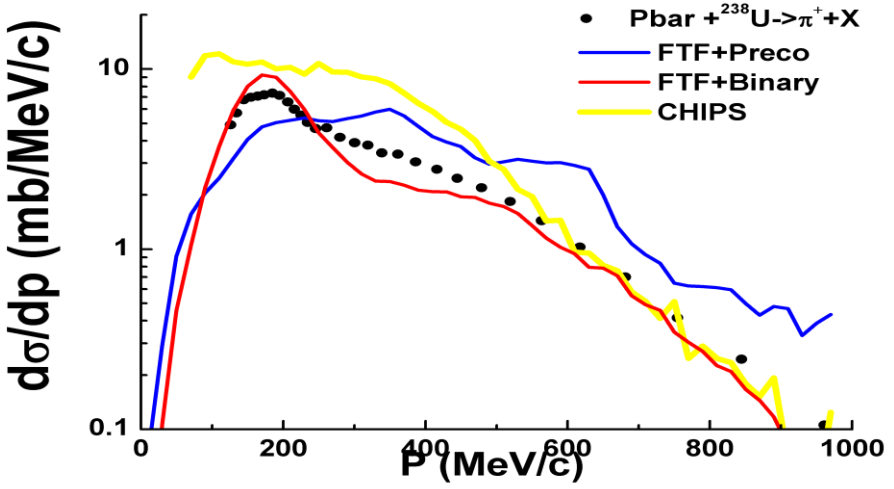
Annihilation pbar-A at rest.





Simulation of pbar-A at Plab= 608 MeV/c



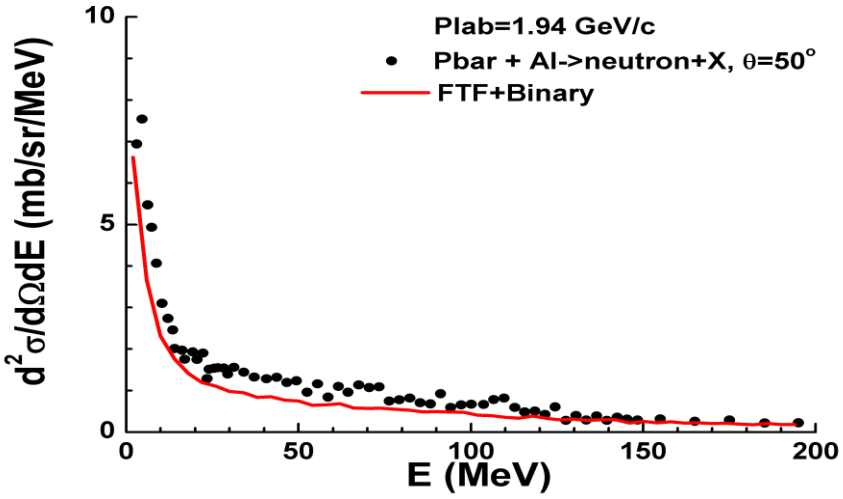


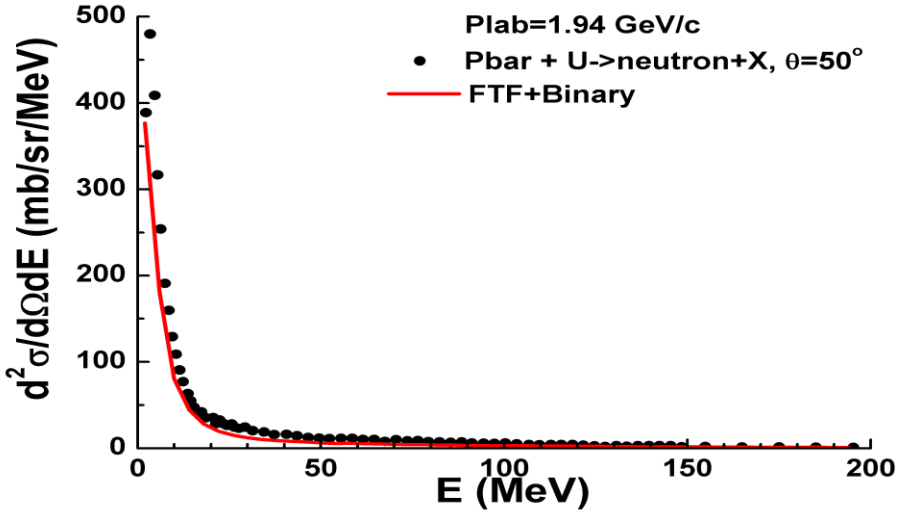
Reference tag: geant4-09-04-ref-02

4. Simulation of NbarA and AbarA interactions

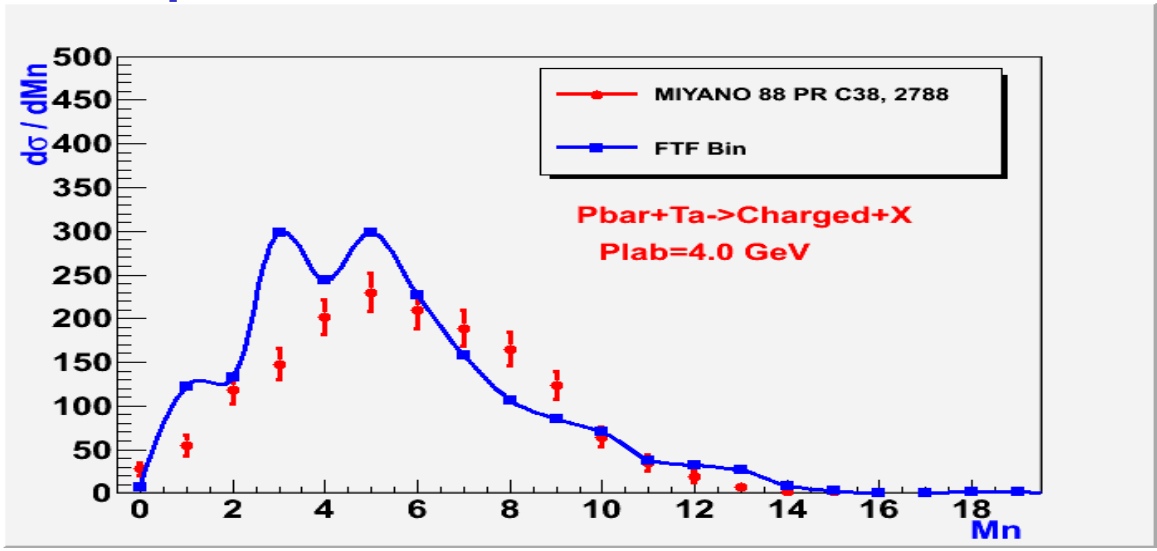
Class G4FTFAnnihilation + theBinary model of Geant4 or Precompound model of Geant4

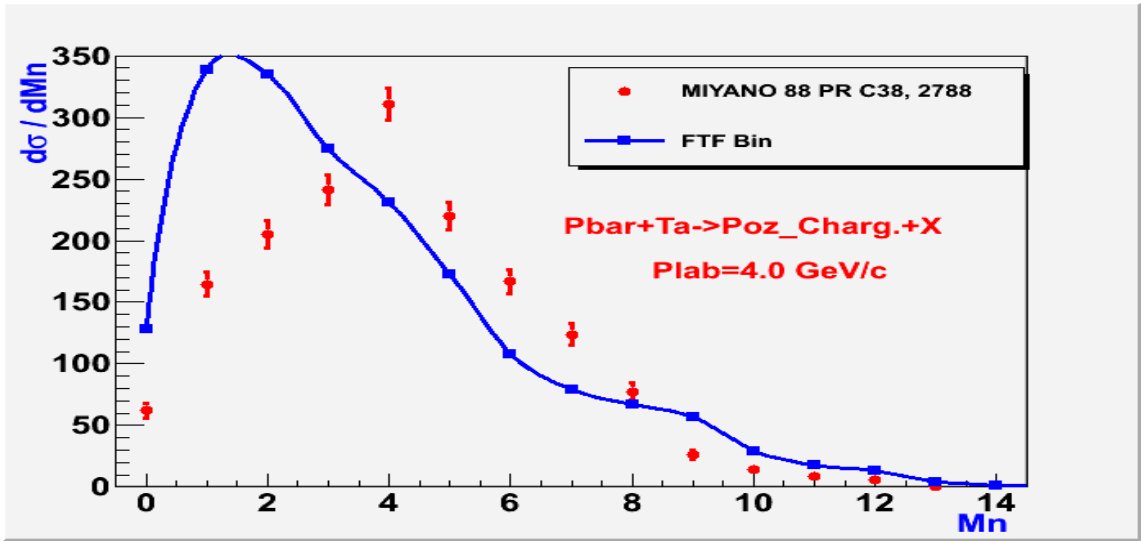
Plab= 2 GeV/c, 50 deg.





Multiplicity distribution of charg. particles at Plab=4 GeV/c



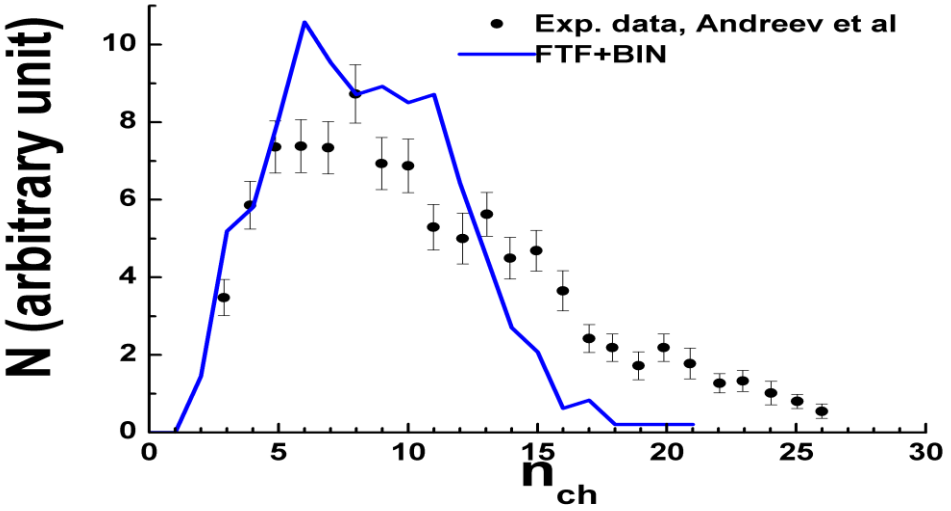


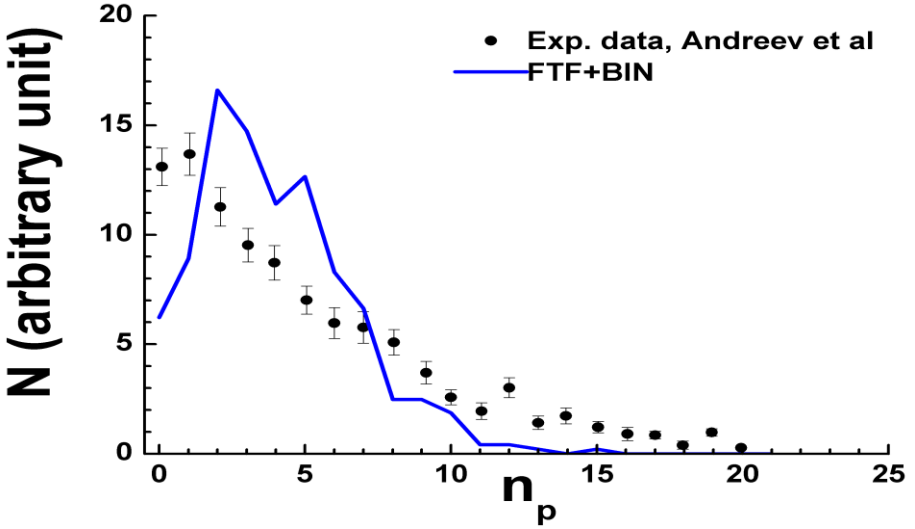
Reference tag: geant4-09-04-ref-02

4. Simulation of NbarA and AbarA interactions

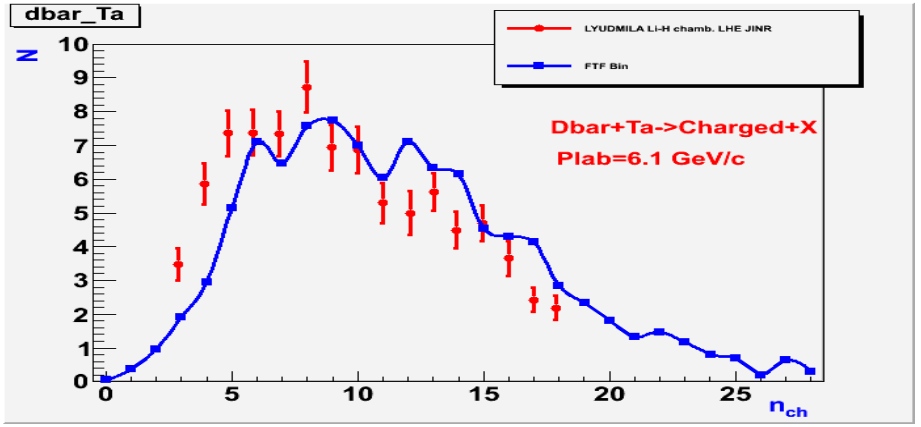
Class G4FTFAnnihilation + theBinary model of Geant4 or Precompound model of Geant4

Anti-deuteron momentum 12.2 GeV/c





Parameter variations.



Reference tag: geant4-09-04-ref-02

Conclusion

1. New implementation of the quark-gluon-string model of baryon annihilation is created.
   Validation region: 0 – 1000 GeV/c.

2. First code for simulation of anti-nucleus – nucleus interactions is created.
   Validation region: 0 – 1000 GeV/c/nucleon.

3. Code for simulation of high energy nucleus-nucleus interactions is proposed.
   Validation region: 3 – 1000 GeV/c/nucleon.

Geant4 allows now a simulation of anti-matter – matter interaction!

Reference tag: geant4-09-04-ref-02

5. Creation of the corresponding Physics Lists

QGSP_FTFP_BERT

Reference tag: geant4-09-04-ref-02