Mathematical modeling of experiments at the NUCLOTRON.

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The aim of this work is to present shortly the Monte Carlo Models:

Urqmd with nuclear fragments,
Fritiof in Geant4,
and
MCNPX code for calculations of experiments at the NUCLOTRON.

Monte Carlo Transport Codes for the simulation of the passage of particles through matter.

For modeling of interactions of heavy ions and calculations of hadron-hadron, hadron-nucleus, nucleus-nucleus interactions at high energies the following codes are used:

- **GEANT4(Fritiof…)**
- **MCNPX(LAQGSM, DPMJET…)**
- **SHIELD (QGSM, DCM)**

For modelling of experiments at the Nuclotron useful are the following codes:

- **Geant – collider;**
- **Mcnpx - fixed target;**

MONTE CARLO GENERATORS for NICA/FAIR physics

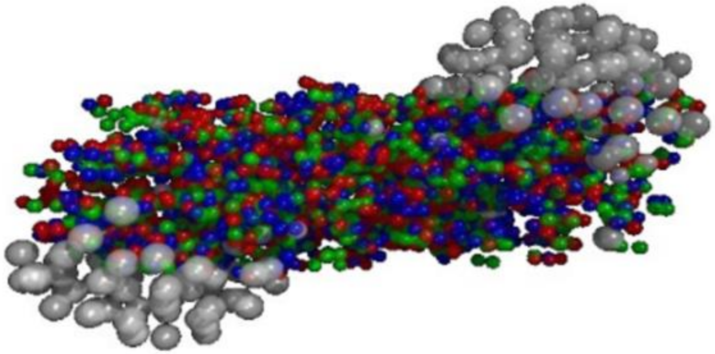
- Ultrarelativistic Quantum Molecular Dynamics (UrQMD)
- Quark Gluon String Model
- Shield
- Parton Hadron String Dynamics
- Hybrid UrQMD
- EPOS
- vHLLE UrQMD
- 3 Fluid Dynamics model

Nuclear fragments (Quark Gluon String Model, Shield)

Flows (Parton Hadron String Dynamics, Hybrid UrQMD, EPOS)

Femtoscopy (Hybrid UrQMD, EPOS)

baryon stopping power (3 Fluid Dynamics model)



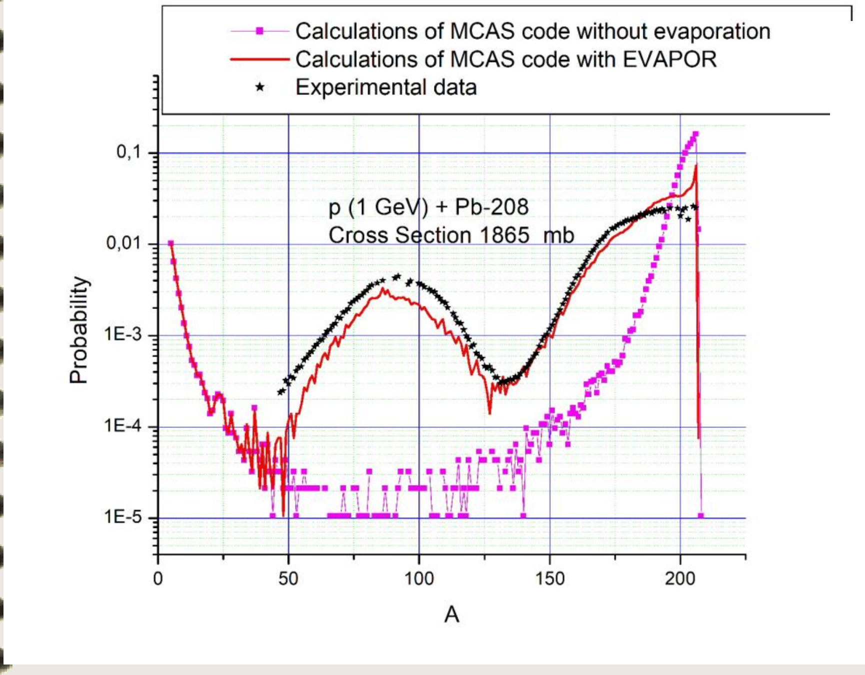
UrQMD with nuclear fragments

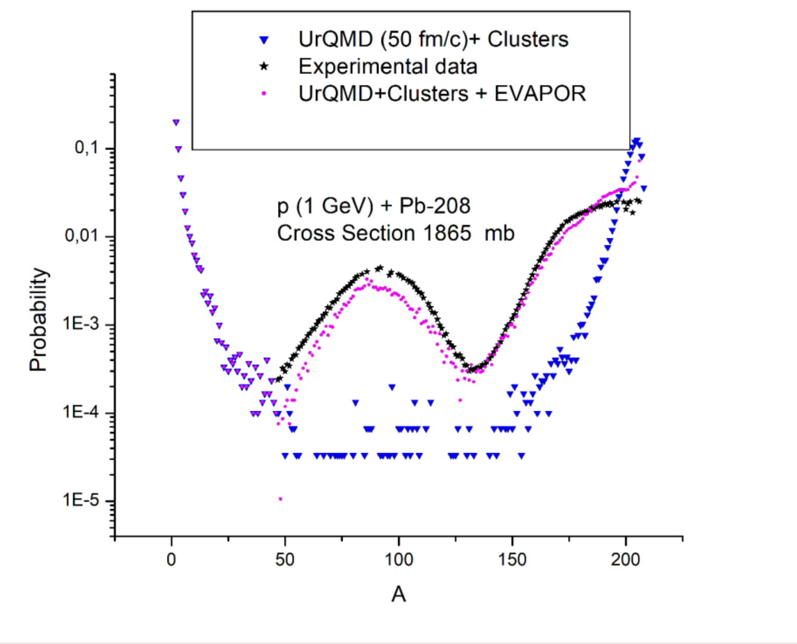
Implementation of the fragments and residue production in UrQMD are performed by the following manner.

- On the first stage of the process of nuclear collision the time evolution of the spatial distributions of nucleons and mesons (pions, kaons, etc.) are traced by using UrQMD code (EOS=1)
- Then, taking into account relative spatial distributions and momenta of nucleons, the nucleon clusters are formed with the Cluster code
- On the next step the nuclear fragments are shaped from these clusters, and their kinetic energies, masses and binding energies are calculated
- On the last stage of the interaction the decay of the excited fragments to smaller ones with the usage of the EVAPOR of Modified CASCADE (MCAS code) are calculated.

Development of dynamical model for simulation of nuclear spallation. G.Musulmanbekov, A.Polański.

XXI International Baldin Seminar on High Energy Physics Problems, September 10-15, 2012 JINR, Dubna, Russia





The Dynamical model of spallation/fragmentation of nuclei in hadron-nucleus reactions in the framework UrQMD has been developed. Isotopes production calculated by Modified Cascade (MCAS) and Dynamical Models quite agree with experimental data. Thus, UrQMD which is very popular and effective in simulation of particle production in intermediate and high energies can be used for description of spallation/fragment formation, as well.

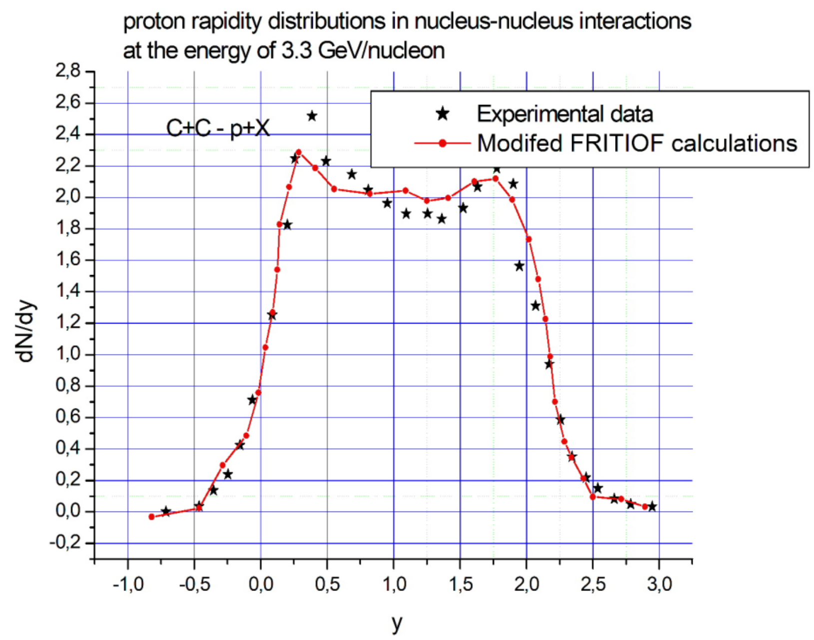
FRITIOF model adapted to low (NUCLOTRON) energies in a combination with the reggeon theory

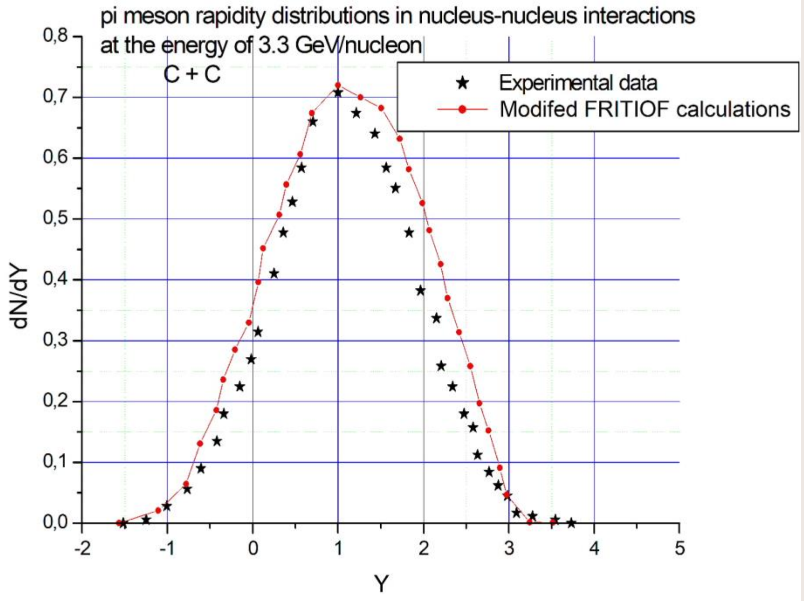
A Monte Carlo algorithm for estimation of the nuclear destruction in the nucleus nucleus interactions which corresponds to the model formulation, includes the following steps:

- 1. The calculation of the impact parameter distribution in the framework of
- the Glauber theory;
- 2. The sampling of the impact parameter and the nucleon coordinates;
- 3. The determination of the wounded nucleons
- 4. The determination of the spectator nucleons involved in the ”cascade”
- by the wounded nucleons. If the number of the involved nucleons is
- equal to zero - exit;
- 5. If the number of the involved nucleons is not equal to zero, a possibility
- is considered to involve the other spectators nucleons by the involved
- ones. If the number of the new involved nucleons is equal to zero - exit.
- In other case - it is needed to repeat the step 5 taking into account only
- the new involved nucleons.

SIMULATION OF NUCLEUS-NUCLEUS INTERACTIONS IN THE FRAMEWORK OF THE FRITIOF MODEL

A. Polanski, A.S Galoyan, V.V. Uzhinsky. Conference: Int. Conf. on Advanced Monte Carlo on Radiation Physics, Particle Transport Simulation and Applications. Lisbon, Portugal, 23-26 Oct. 2000. p.1169. Springer-Verlag Berlin Heidelberg 2001,



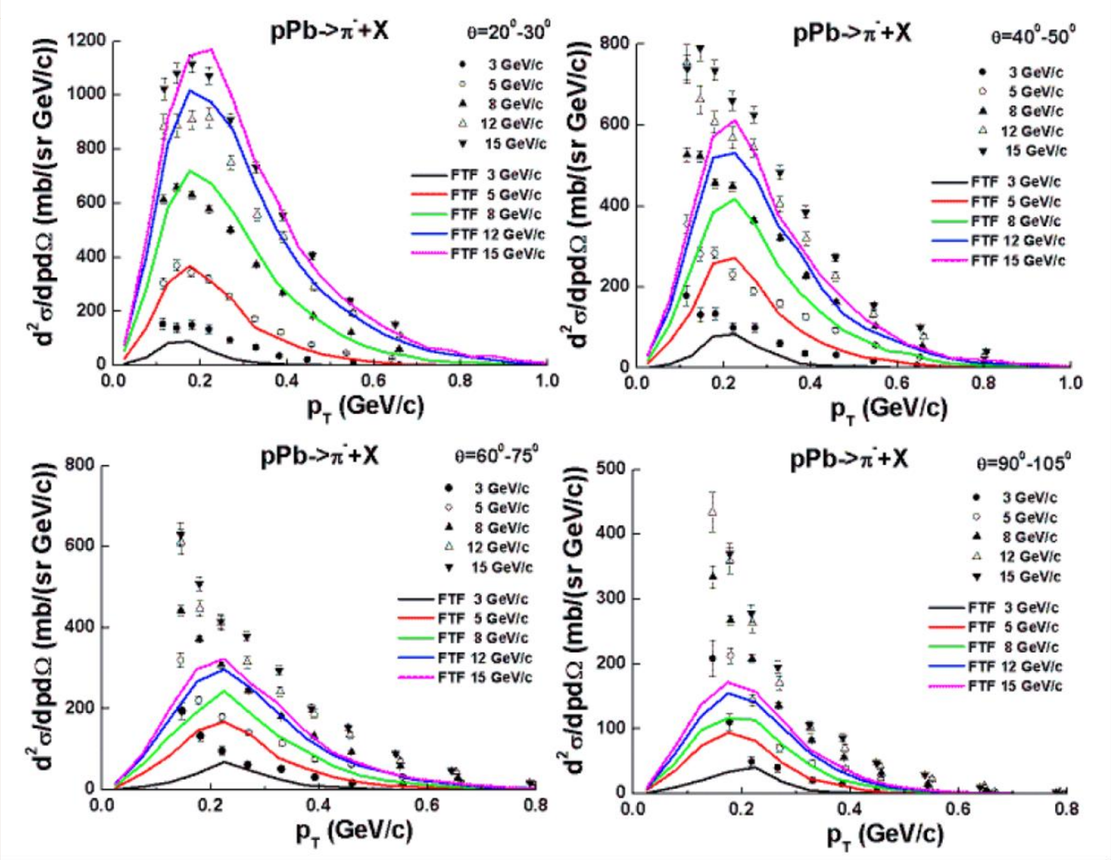


Summing up, we can conclude that we have reached a satisfactory description of the meson and nucleon production in the nucleus-nucleus interactions at the energy of 3.3 GeV/nucleon in the framework of the modified FRITIOF model. The model can be applied for calculations of hadron productions (multiplicity, Pt etc.) of nucleus-nucleus interactions.

Development of the Fritiof Model in Geant4

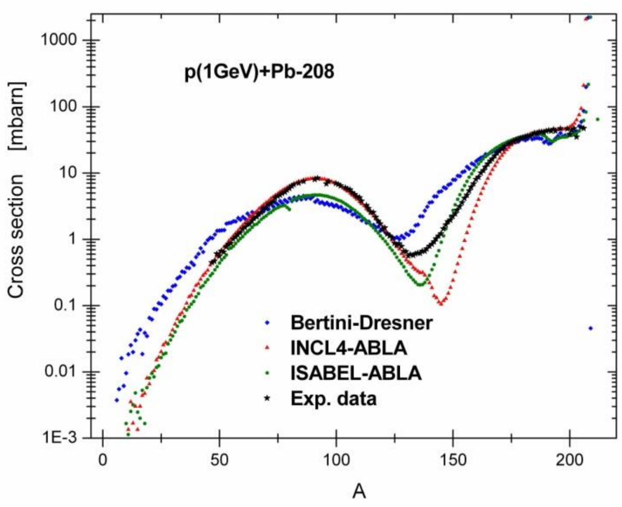
Vladimir UZHINSKY Joint International Conference on Supercomputing in Nuclear Applications and Monte Carlo 2010 (SNA + MC2010)

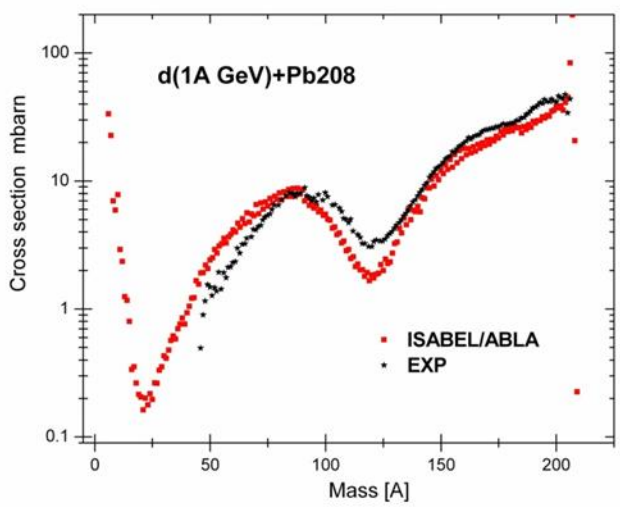
Hitotsubashi Memorial Hall, Tokyo, Japan, October 17-21, 2010



The Fritiof model of Geant4 has been improved. New ideas have been proposed and implemented. All of these allows one a good description of hadron-nucleus interactions at Plab 3 – 15 GeV/c.

Calculations of Mcnpx. Comparison of models for calculations of nuclear fragments

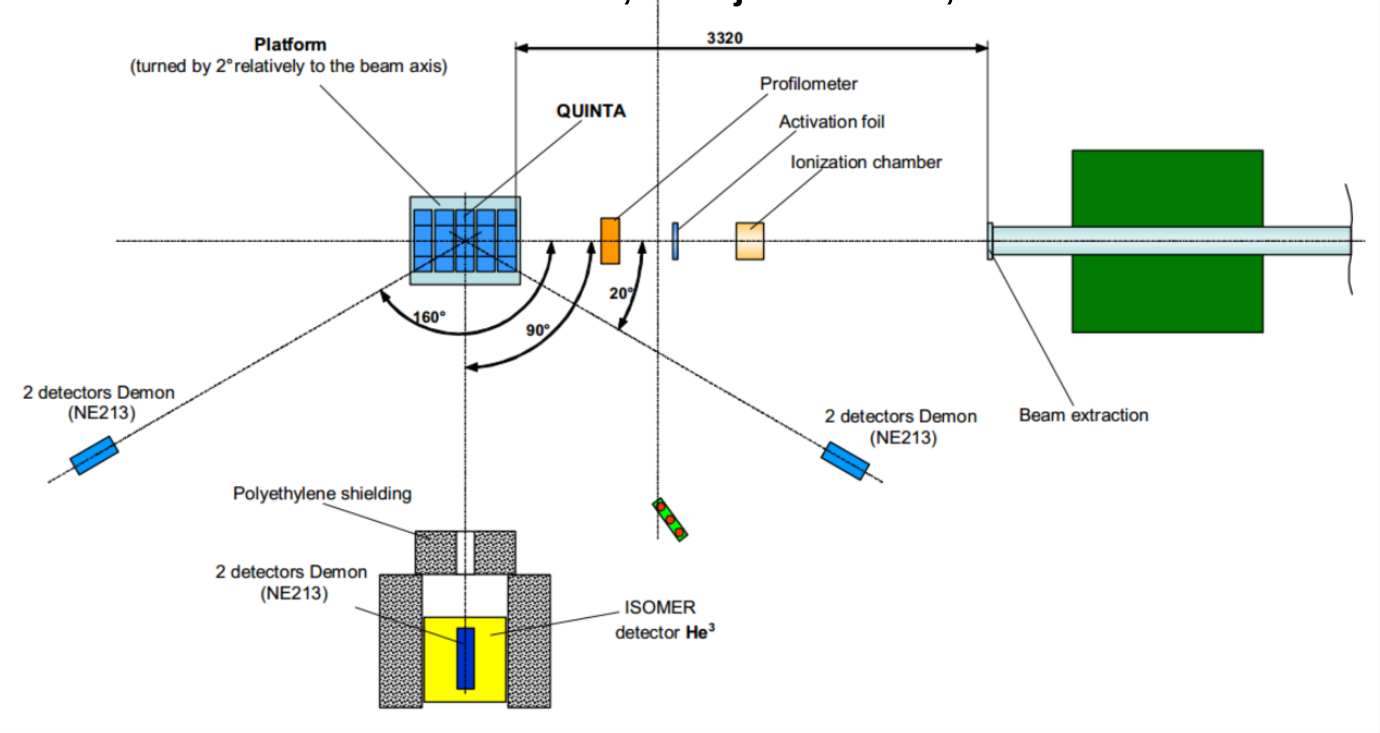




Isotopes production calculated by INCL4,ISADEL models conetted with ABLA model quite agree with experimental data for medium mass of fragments

Experimental study uranium target assembly QUINTA irradiated by deuterons with energies from 1 to 8 GeV at JINR NUCLOTRON

W. Furman, J. Adam, A. Baldin, A. Berlev, N. Gundorin, Zh. Hushvaktov,M. Kadykov, Yu. Kopatch, E. Kostyukhov, Kudashkin, A. Makan'kin, I. Mar'in, A.Polanski, V. Pronskikh, A. Rogov, V. Schegolev, A. Solnyshkin, V. TsupkoSitnikov, S.Tyutyunnikov, A. Vishnevsky, N. Vladimirova, A.Wojciechowski, L. Zavorka



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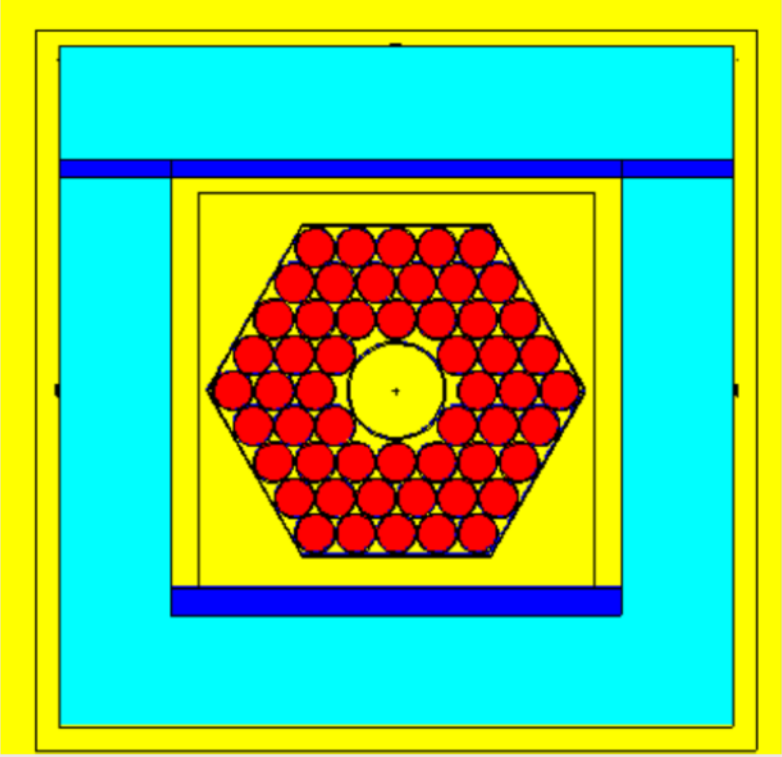
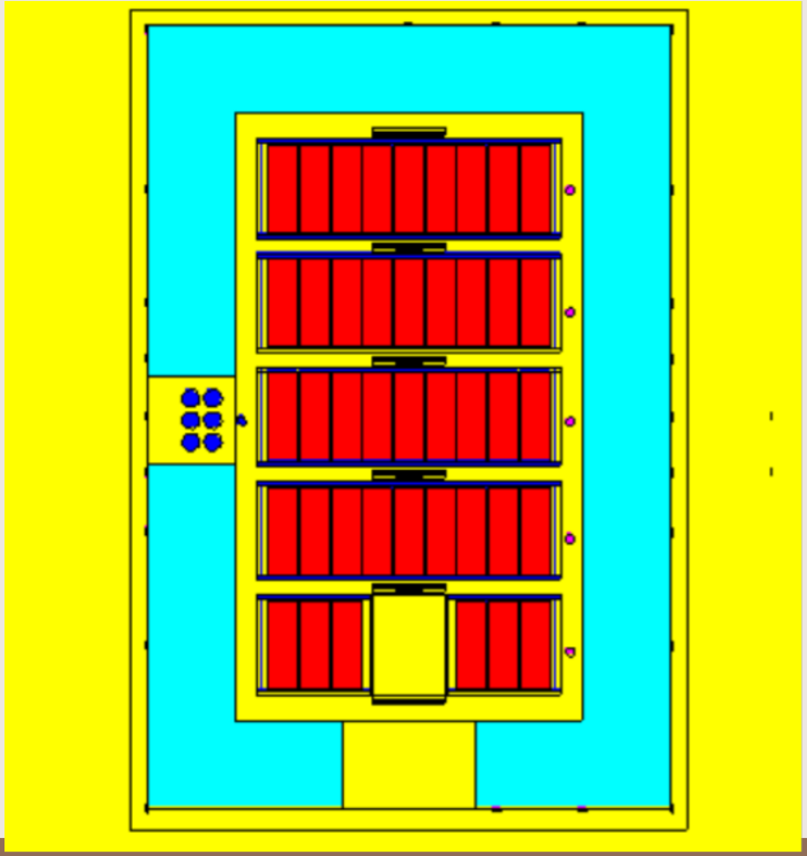
Modeling of experiments at the Nuclotron. Quinta target

d (4 GeV) + U

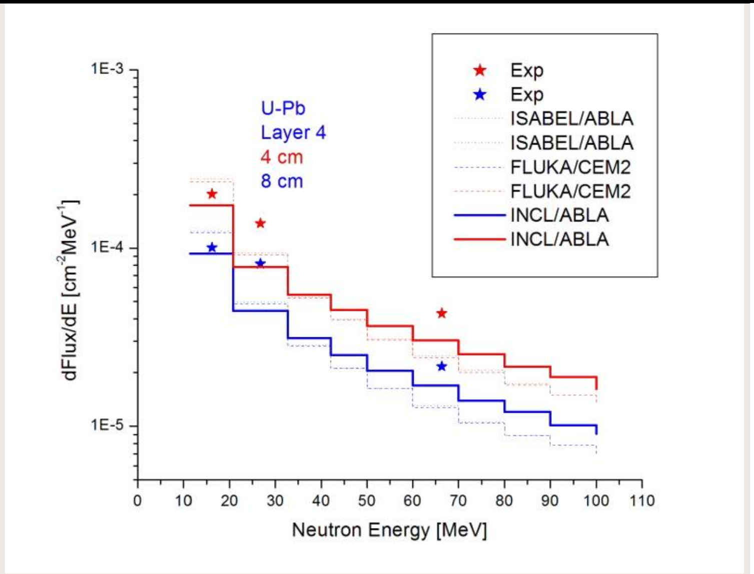
- Nat U –red
- Pb – blue
- Air -yellow

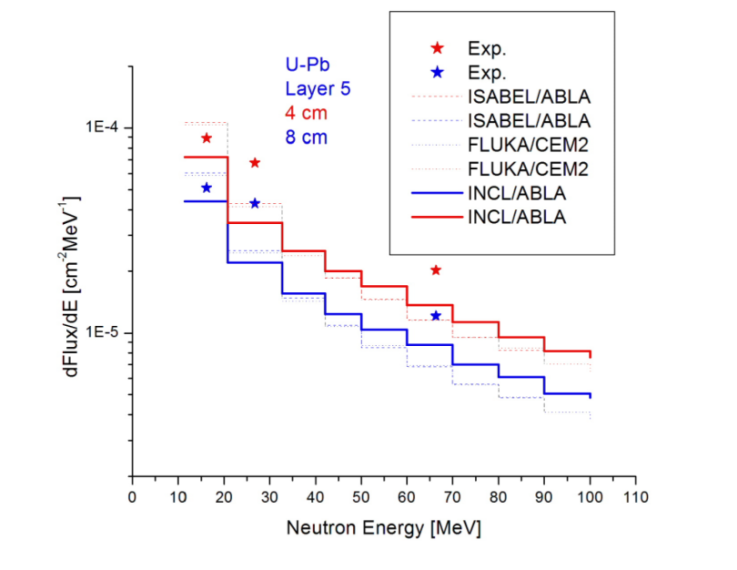


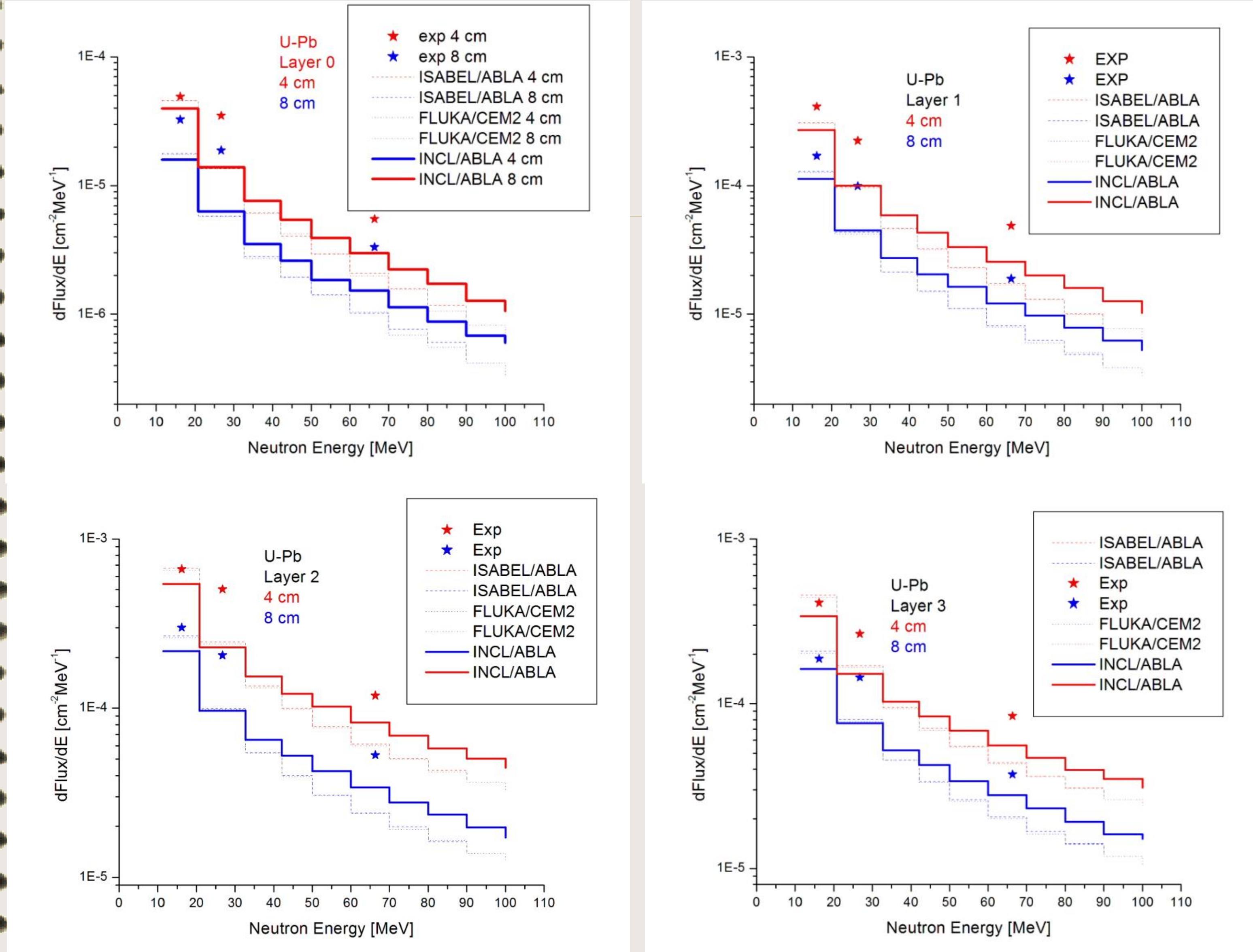


Calculations of neutrons using Mcnpx code
Comparison of models d(4 GeV) +U-238

	EXP	INCL ABLA	INCL BIBL238.21	ISABEL ABLA	FLUKA CEM2	LAQGSM ISABEL
escape	204 (40)	173.26	167.87	168.89	179.50	148.28
capture	43.2(6.4)	40.11	39.02	39.55	42.85	35.12
loss to n2n (n,xn)	6.8 (0.8)	13.48	21.72	14.89	14.44	12.34
loss to fission	34(5.6)	27.98	26.90	28.58	30.49	25.20
multiplicity creation	229 (40)	275.93	263.98	270.52	284.48	235.40

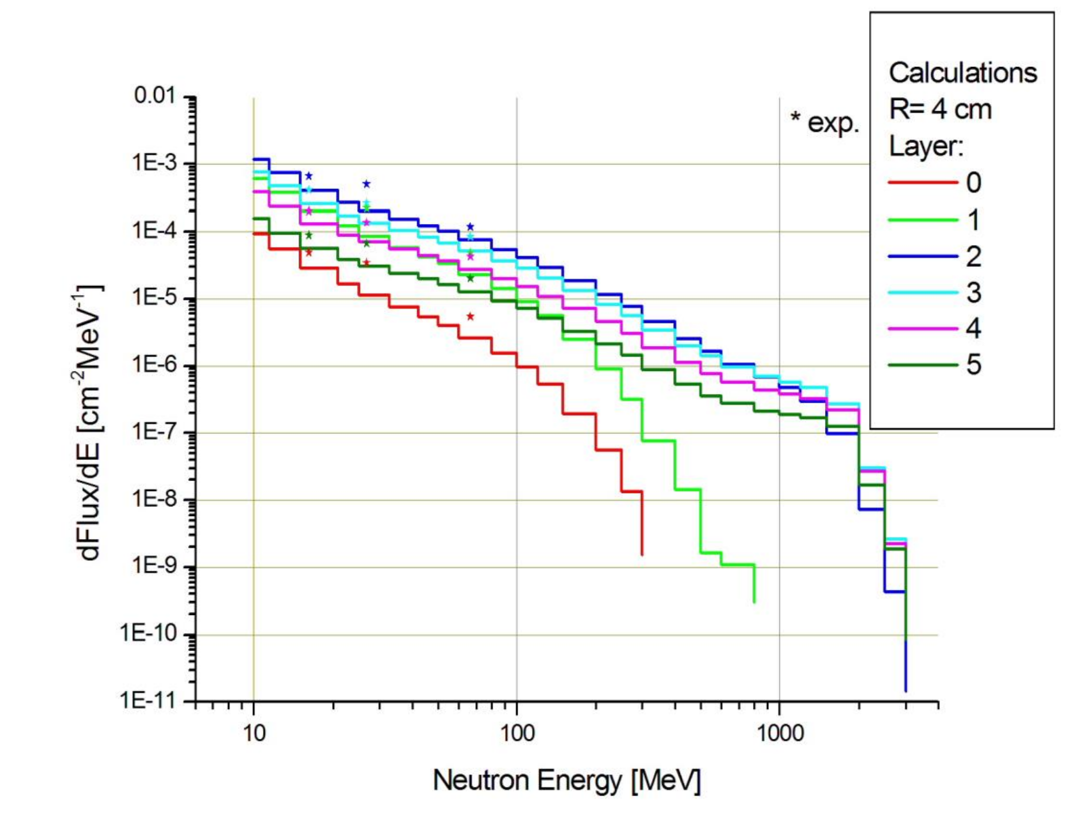






Of the models presented best describes the experimental data INCL+ABLA.
All calculated data are lower than the experimental data

The energy spectra of neutrons inside the Quinta set-up



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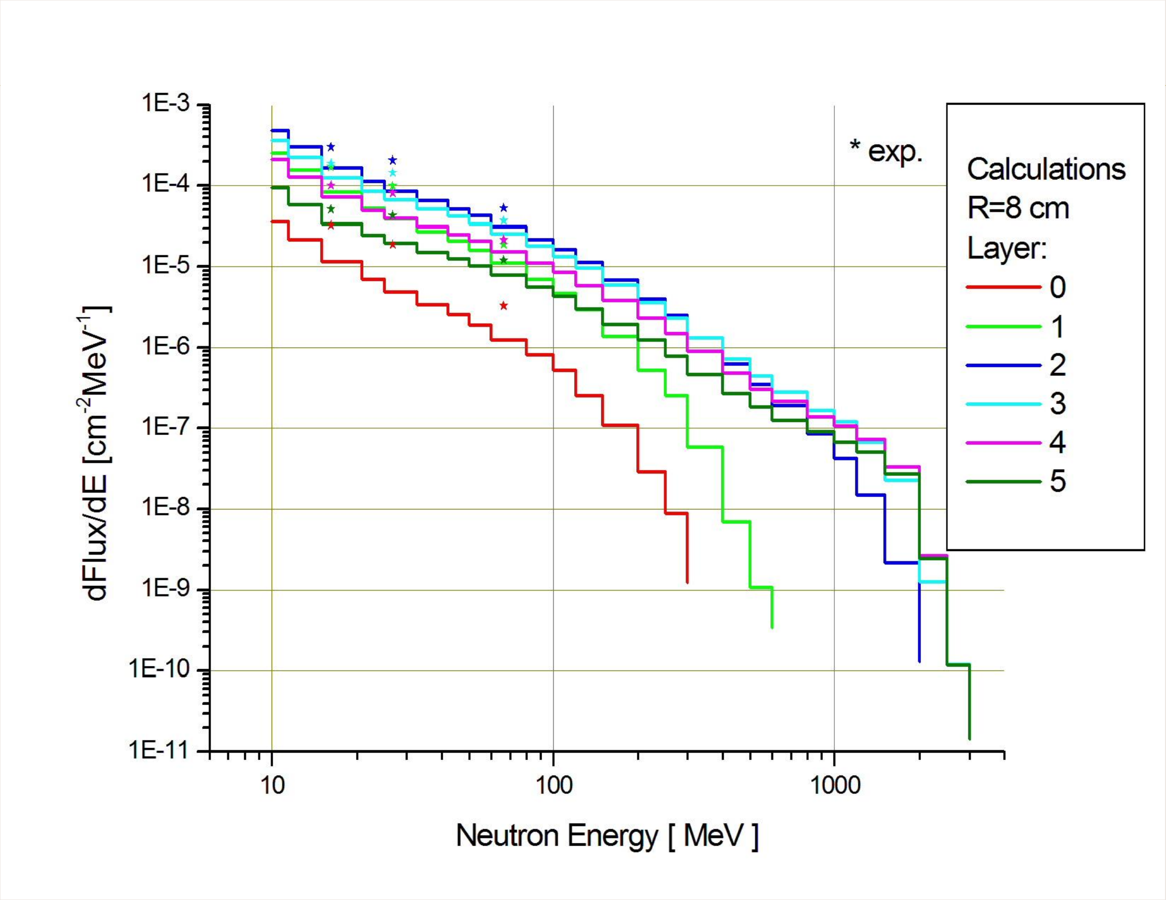

The energy spectra of neutrons depend on the position of the detectors inside the Quinta set-up

Conclusions

It appear the perspectives of using of Geant4 (FRITIOF) code and MCNPX code for calculations of construction of Nuclotron-based Ion Collider and calculations of detectors of secondary particles (protons, neutrons,gamma, mesons etc.)