THE CONCEPT OF THE FRITIOF (FTF) MODEL

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Abstract. *The FRITIOF model, or FTF for short, is used in Geant4 to model hadron-nuclear interactions with P_{lab} > 3-4 GeV/s, core-nuclear interactions with P_{lab} > 3-4 ГэВ/c/nucleon and anti-baryon-nuclear interactions, as well as anti-nuclear interactions without a low energy threshold. Since the model does not include multi-jet production in hadron-nucleon interactions, the upper limit of its reliability is about 1000 GeV/s. The main components of the model and its results are briefly described.*
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The FRITIOF model [1] assumes that all hadron-hadron interactions are binary reactions, $h_1 + h_2 \rightarrow h'_1 + h'_2$, where h'_1 and h'_2 are excited states of hadrons with discrete or continuous mass spectra (see Fig. 1, left part). If one of the finite hadrons is in its ground state ($h_1 + h_2 \rightarrow h'_1 + h'_2$), then the reaction is called "single diffraction dissociation", and if none of the hadrons is in its ground state, then it is called "double diffraction" interaction. Excited hadrons are considered as QCD strings, and the corresponding fragmentation model of LUND strings is used to model their decays.

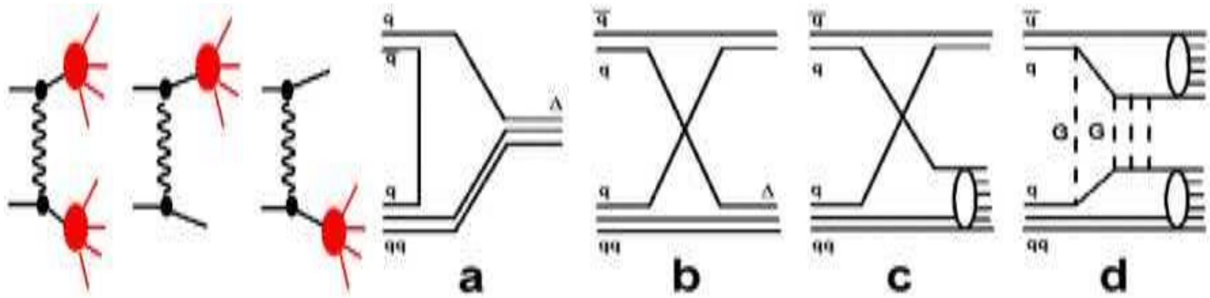

Fig. 1: Processes considered in the FTF model.

In the component quark model of hadrons, the creation of s-channel a-isobars, for example, in np interactions, is explained by quark-anti-quark annihilation (see Figure 1a). The formation of two mesons can be the result of quark exchange (see Fig.1b). The quark-di-quark (q-qq) system created in the process of Fig.1c can be in a resonant state (see Fig.1b) or in a state with a continuous mass spectrum. In the latter case, multi-season production is possible. The amplitudes of these two channels are associated by the intersection of symmetry with annihilation in the t-channel and with non-vacuum exchanges in elastic scattering in accordance with the phenomenology of reggeon. According to this phenomenology, the elastic scattering at high energies should be dominated by the pomeron exchange. In a simple approach, this corresponds to a two-gluon exchange between colliding hadrons. It is also reflected in one or many nonperturbative gluon exchanges in an inelastic reaction. Thanks to these exchanges, a state with separated colors is created (see Figure 1d). The state can break up into two colorless objects. The quark content of objects coincides with the quark content of primary hadrons, according to the FTF model, or it is a mixture of quarks of the primary hadron, according to the quark-gluon-string model (QGSM).

These processes are very important at low energies (<5-15 GeV). In order to extend the FRITIOF model to this energy domain, we include the processes Fig.1b, Fig.1c in a typical Geant4 site. The process of Fig.1a with quark annihilation is considered only in the case of anti-baryon-baryon interactions.

A key component of the FRITIOF model is the sampling of string masses. In general, the set of final states of interactions can be represented in Fig. 2 (left), where samples of possible string masses are shown. There is a point corresponding to elastic scattering, a group of points representing the final states of binary hadron-hadron interactions, lines corresponding to diffraction interactions, and various intermediate regions. The area populated by red dots is responsible for double diffraction interactions. In the model, the threshold for mass selection is set equal to the masses of ground-state hadrons, but in principle the threshold may be lower than these masses. The string masses are sampled in a triangular region bounded by a diagonal line corresponding to the kinematic limit $M_1 + M_2 = E_{cms}$, where M_1 and M_2 are the masses of hadrons h'_1 and h'_2, as well as threshold lines. If the point is below the threshold of the string mass, it shifts to the nearest diffraction line. The original model had no points corresponding to elastic scattering or binary end states.

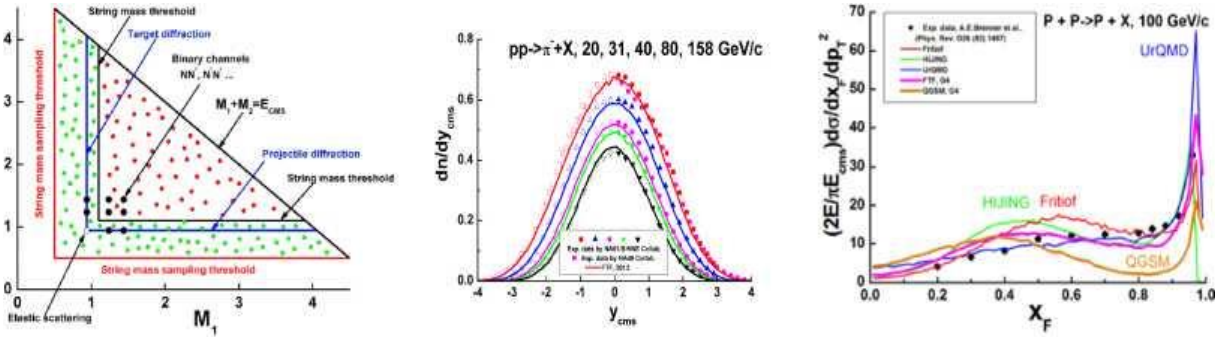

Fig. 2: (left) diagram of the final states of the FTF model. (center) description of the formation of n-mesons in pp interactions. (right) description of the proton spectrum. The points are experimental data [2].

All this allowed us to satisfactorily describe, from our point of view, the formation of mesons in P-, K±p-, pp- and pp-interactions. As an example, we will show in Fig. 2 (center) our calculations in comparison with the data of the NA61/SHINE and NA49 collaborations [2]. However, there are some problems with the description of the baryon spectra (see 2 (right)).

A simple cascade model takes into account only pions and nucleons. Because of this, it cannot work when resonance production is the dominant process in hadron interactions. But if the energy is small enough, the resonances may fade before the next possible collision, and the model may be correct. Let p be the pulse of the produced resonance (Δ). The average lifetime of the resonance in its resting frame is 1/G. In the laboratory system, the time is E_Δ/Gm_Δ. During this time, the resonance will fly the distance $\bar{l} = vE_\Delta/Gm_\Delta = p/Gm_\Delta$. If the distance is less than the average distance between nucleons in nuclei (d ~ 2fm), then the model can be applied. From the condition we have: $p \leq \bar{d}Gm_\Delta \sim 1.5$ (GeV/s).

Modeling hadron-nucleon interactions in the FTF model includes modeling elastic scattering, binary reactions such as $NN \rightarrow N\Delta$, $\pi N \rightarrow \pi\Delta$ on single diffraction and nonmetallic diffraction events, and annihilation in anti-baryon-nucleon interactions. It is assumed that unstable objects created during Hadron-core and core-core collisions may have similar reactions.

Recently, modeling of internuclear interactions at RHIC and LHC energies was implemented in the FTF model. Some preliminary results [3] are shown in Fig. 3.

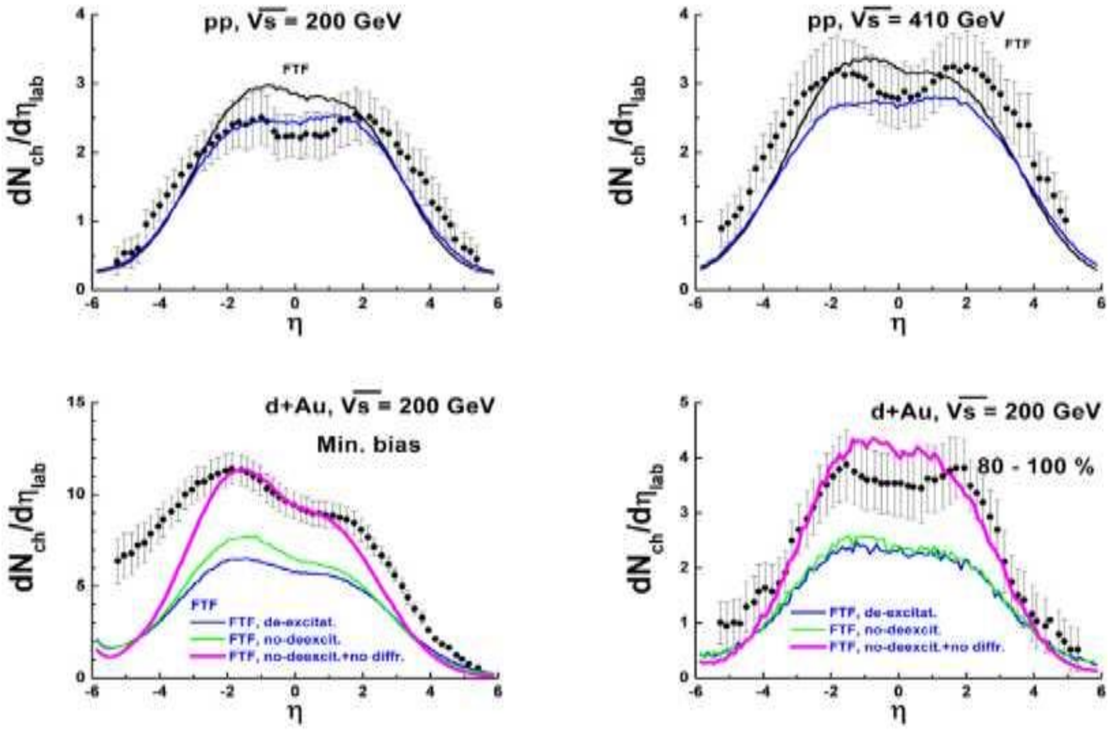

Fig.3: Preliminary results of modeling FTF core-nuclear interactions at RHIC energies. The lines are the calculations of the model[4,5,6]. Points are experimental data.

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