Open charm simulation in p-Ni collisions at SIS-100 with CBM detector

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In this work we study the possibility of the reconstruction of D0-mesons in p-Ni collisions with interaction rate 10 MHz and proton energy E = 15 GeV with CBM detector. We evaluate the efficiency of D0 reconstruction and estimate the signal-to-background ratio. The complete electron CBM-detector setup including RICH and TRD detectors was used in our simulations.

High-energy heavy-ion collision experiments worldwide are devoted to the investigation of strongly interacting matter under extreme conditions. Fig. 1 illustrates the possible phases of nuclear matter and their boundaries in a diagram of temperature vs the baryon chemical potential (which is proportional to the net baryon density).

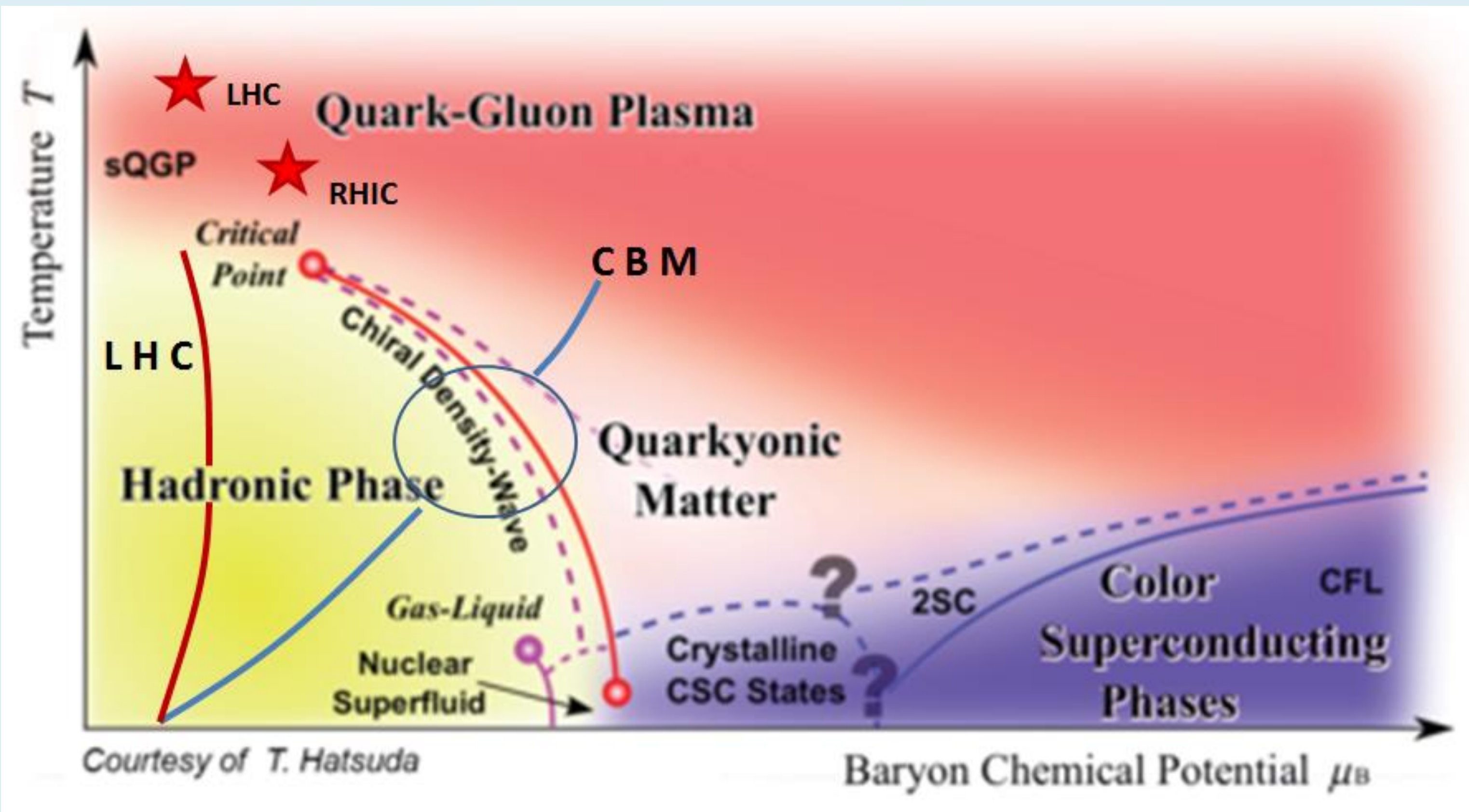


Fig. 1: Phase diagram for nuclear matter

At the high net baryon densities and low energies the phase transition between hadronic and partonic matter is expected to be first order, featuring a region of phase coexistence and a critical endpoint. The experimental discovery of these prominent landmarks of the QCD phase diagram would be a major breakthrough in understanding of the properties of nuclear matter. Equally important is quantitative experimental information on the properties of hadrons in dense matter which may shed light on chiral symmetry restoration and the origin of hadron masses. [1]

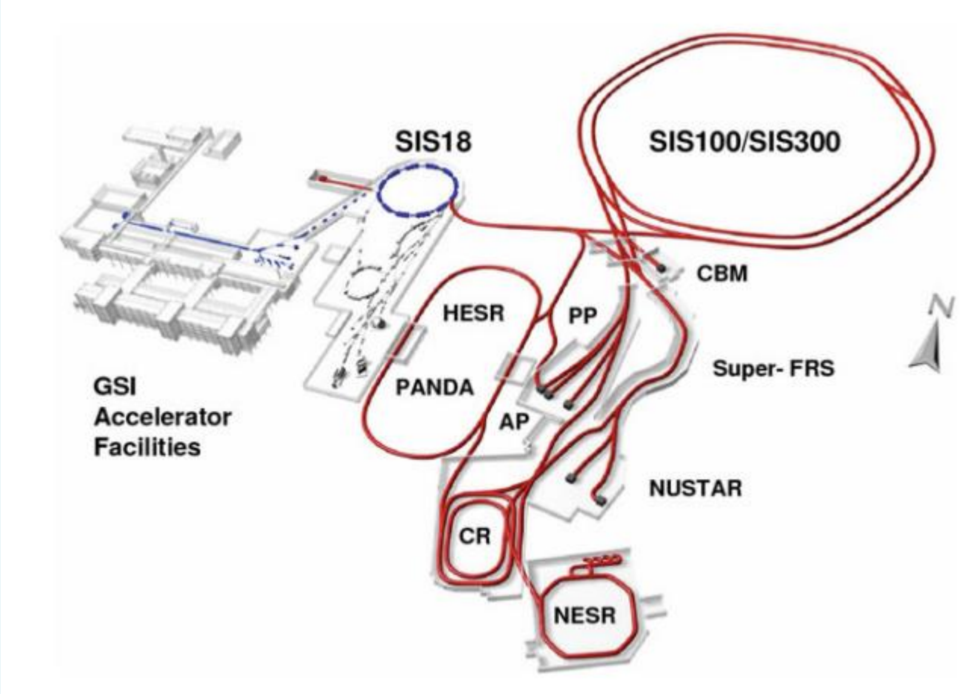


Fig.2: Facility for Antiproton and Ion Research

Compressed Baryonic Matter experiment

Silicon **T**racking **S**ystem - 8 layers of silicon micro-strip detectors. Track reconstruction and momentum determination.

Micro-**V**ertex **D**etector - 4 layers of Monolithic Active silicon Pixel Sensors. Close to target. High-precision determination of D-meson decay vertex.

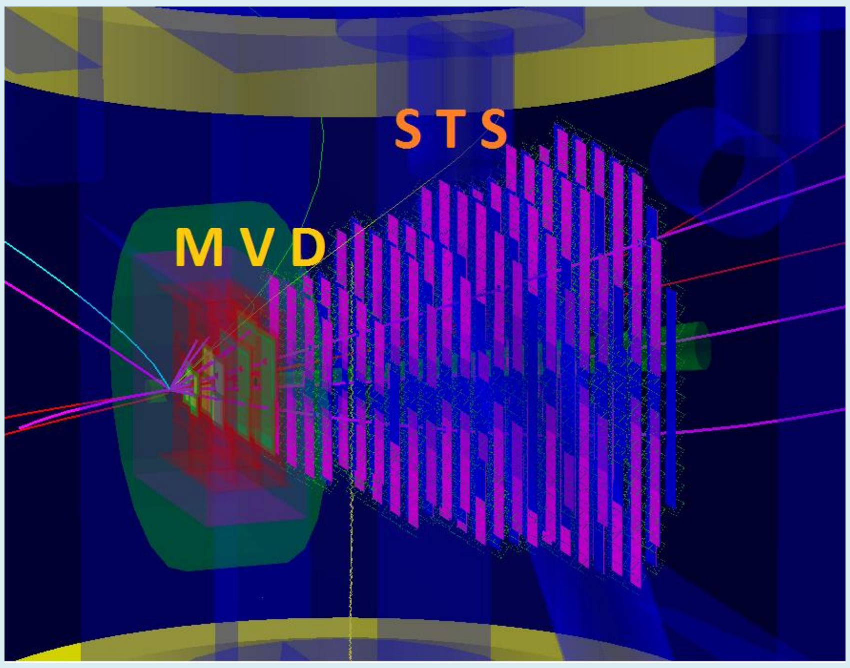


Fig.3: Reconstructed tracks in the detector system

Step 1: Simulation

- p-Ni collisions at E = 15 GeV, IR = 10^7 /s

- UrQMD-3.3-p2 (Ultrarelativistic Quantum Molecular Dynamics), [2, 3]

- CBM FairRoot (June 2016) framework; Geant-3 engine

- 5 * 10^7 events

Step 2: Reconstruction

- Particle identification via TOF (Time Of Flight) measurements.

$$m = \frac{p\sqrt{c^2t^2 - L^2}}{cL}$$

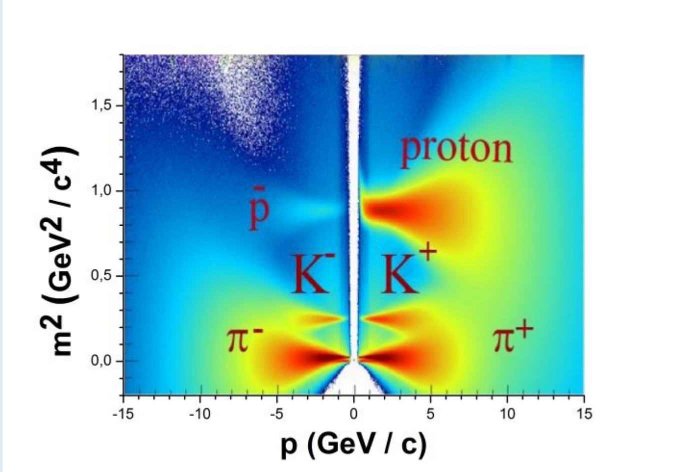


Fig.4 m^2-momentum diagram for particle ID

Step 3: Data analysis

In order to reconstruct the charmed mesons decay, a set of cuts is applied to single tracks as well as to the D0-meson reconstructed vertices.

Cuts to tracks:

$\chi^2_{prim} > 6.0$;

Impact Parameter < 0.5 mm;

Cuts to verteces:

$\chi^2_{GEO} < 3.0$;

$\chi^2_{TOPO} < 3.0$;

L / dL < 10.

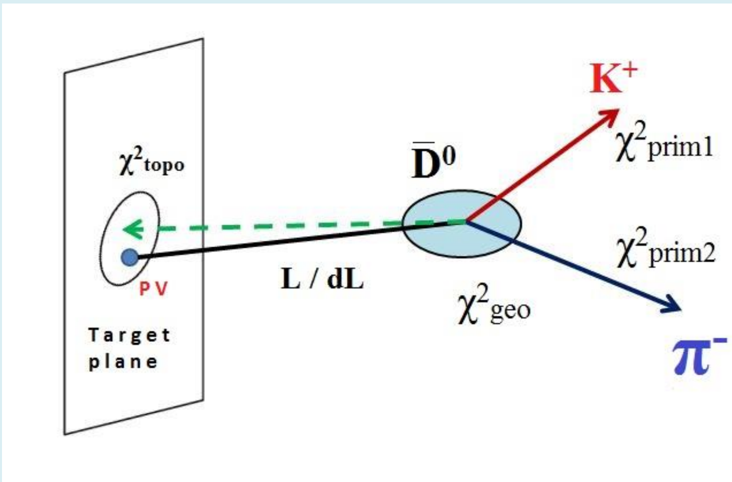


Fig.5: D-meson decay and cuts

Signal counts

$$N = N_0 \times \varepsilon \times M \times BR$$

$N_0 = 5 * 10^{11}$ – number of simulated events;

$M = 5.5 * 10^{-8}$ – multiplicity, taken from [4];

BR = 3.89% - branching ratio, taken from [5];

$\varepsilon = N_{REC0} / N_{GEN} = (3.3 \pm 0.2)\%$ - D0-meson reconstruction efficiency.

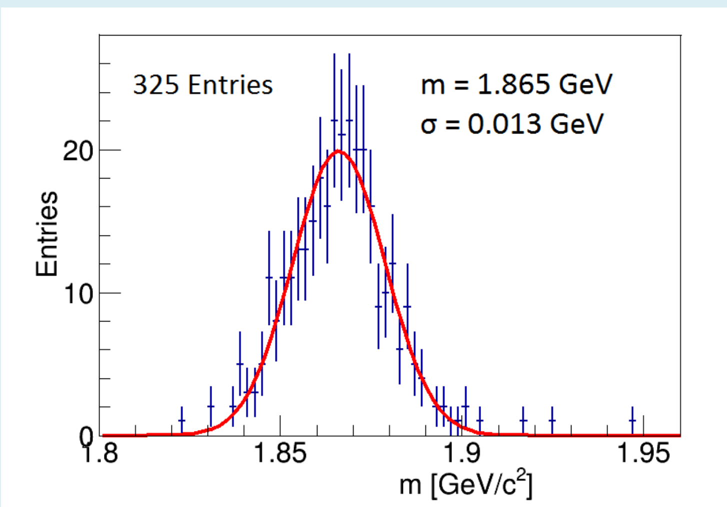


Fig.6: Distribution of invariant mass of D0

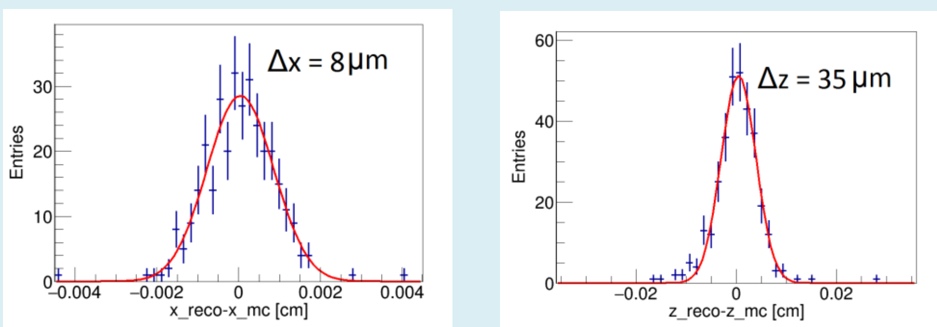
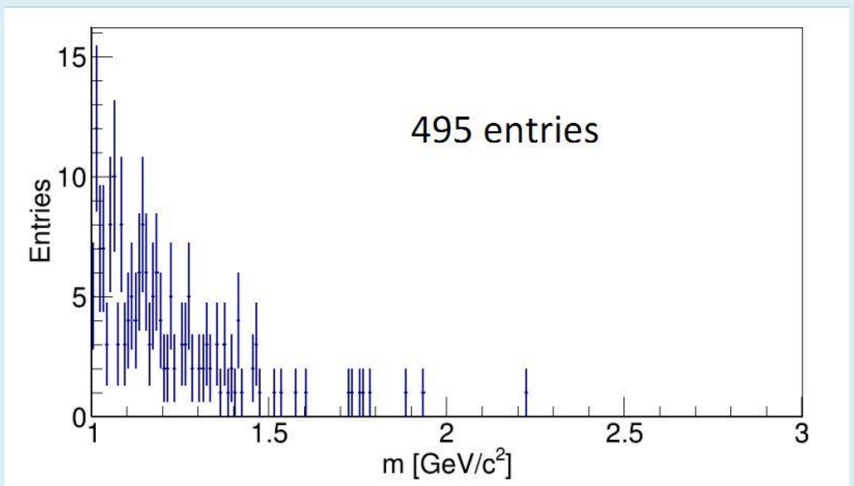


Fig.7, 8: D0-meson decay verteces resolution (along x and z-axis)

Background estimation



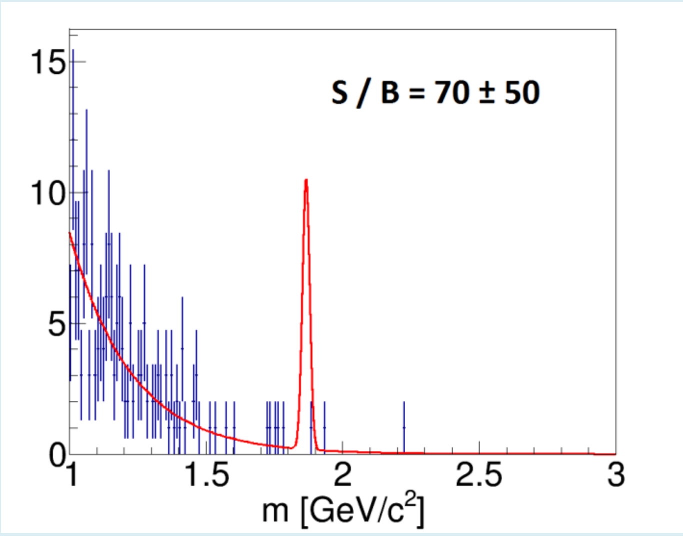
- 5 * 10^7 events – not enough statistics

→ mixed event analysis: N→N^2 events:

5000 * 10^4 → 5000 * 10^8 = 5 * 10^{11} “super-events”

Fig.9: Background distribution of D0-meson mass

Signal-to-background ratio



$S = 35 \pm 2$

$B = 0.9 \pm 0.6$

$S / B = 70 \pm 50$

blue bars – background;

red exponent and peak – Signal+background

Fig.10: Signal and combinatorial background

Conclusions:

- 10 weeks of measurements with IR = 10^7/s → 6 · 10^{13} events → about 3500 D-mesons
- CBM is well suited to make measurements of D-meson yields and spectra with high statistics
- Possibility to study charm production and propagation in hot and cold nuclear matter

Shortcomings:

- Pileup processes not considered
- Not clear, how many tracks from the primary vertex are produced, when $c\bar{c}$-pair is born

References:

[1] B.Friman et al.: CBM Physics Book

[2] S. A. Bass et al.: Microscopic Models for Ultrarelativistic Heavy Ion Collisions

[3] M. Bleicher et al.: Relativistic Hadron-Hadron Collisions in the Ultra-Relativistic Quantum Molecular Dynamics Model

[4] Thermal (J. Cleymans) model by V. Vovchenko

[5] Particle Data Group