Heavy fragments (^3He and ^4He) identification using energy loss method in the STS detector of the CBM experiment

O.Yu. Derenovskaya[1], V.V. Ivanov[1,2], I.O. Vassiliev[3,4], Yu. V. Russov[2]

[1]Laboratory of Information Technologies, Joint Institute for Nuclear Research, Dubna, Russia

[2]National Research Nuclear University "MEPhI", Moscow, Russia

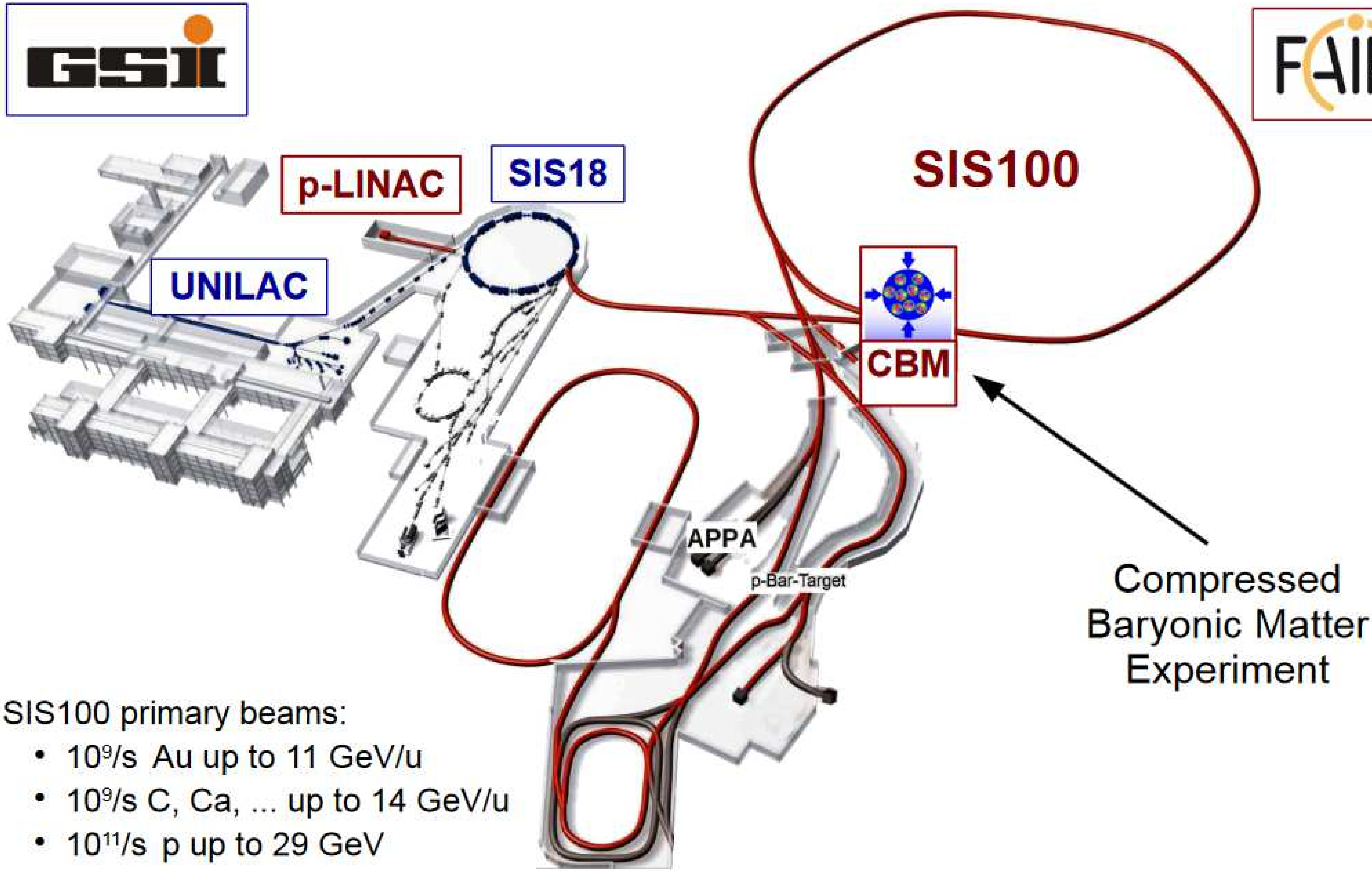
[3]Gesellschaft für Schwerionenforschung mbH, GSI, Darmstadt, Germany

[4]Goethe-Universität, Frankfurt am Main, Germany

FAIR — Facility for Antiproton and Ion Research in Europe

Mathematical Modeling and Computational Physics
July1-5, 2019

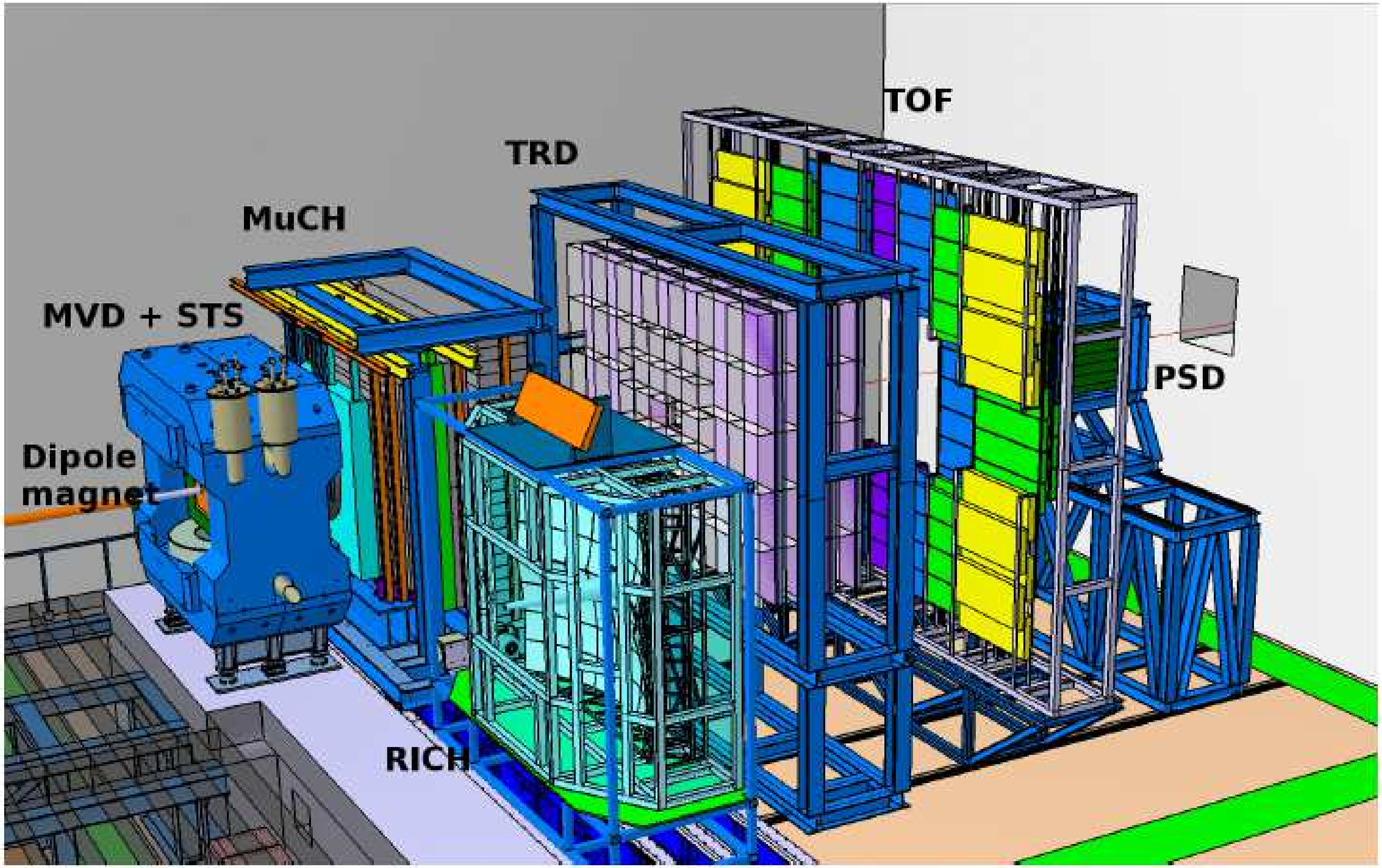
Facility for Antiproton and Ion Research



SIS100 primary beams:

- 10^9/s Au up to 11 GeV/u
- 10^9/s C, Ca, ... up to 14 GeV/u
- 10^{11}/s p up to 29 GeV

Compressed Baryonic Matter experiment



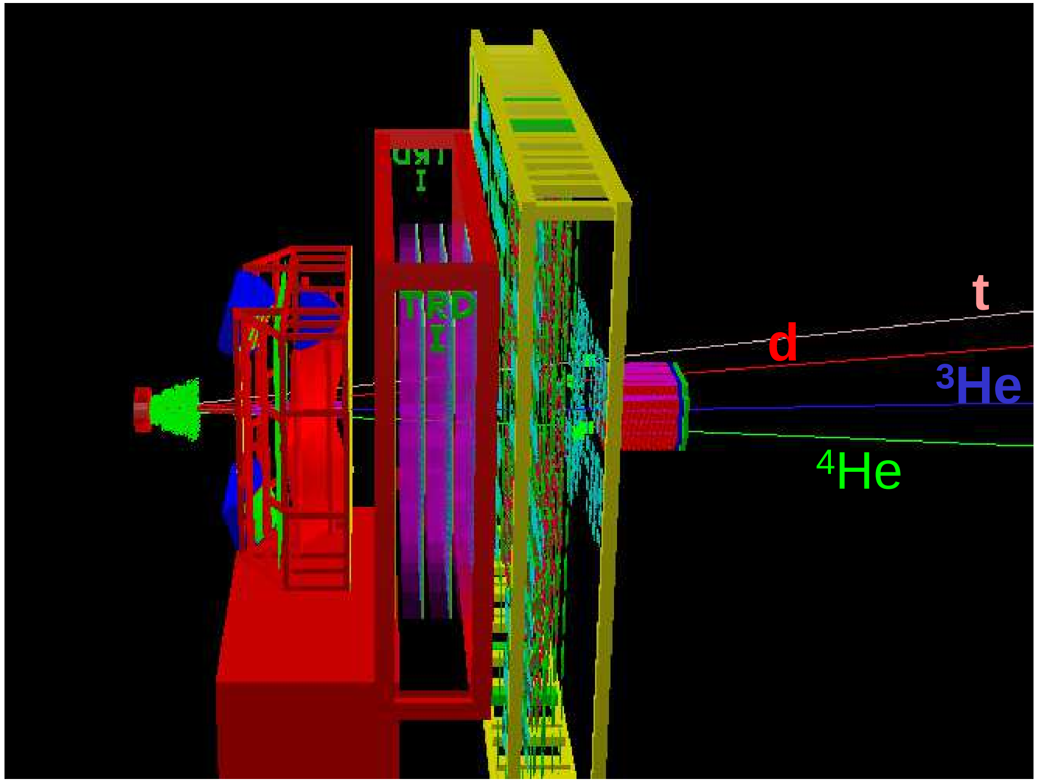
- Vertexing:
  MVD
- Tracking:
  STS, MUCH,
  TRD, ToF
- Particle ID:
  RICH, TRD, ToF
- Calorimetry:
  ECAL, PSD

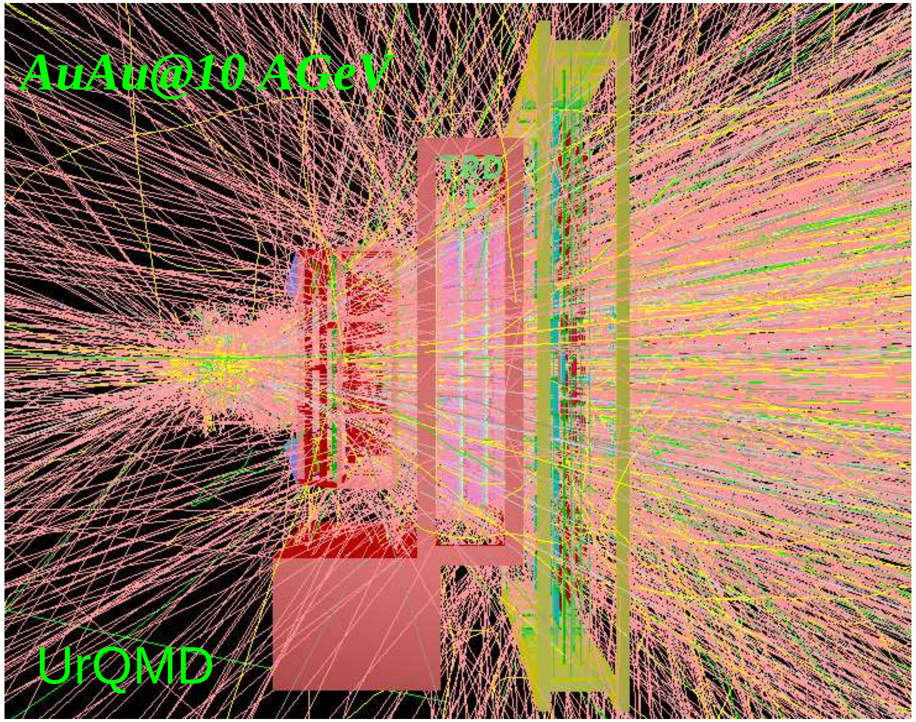
- fixed traget geometry with polar angle coverage [2.5°; 25°]
- electron and muon configuration
- free-streaming DAQ
- online event selection using high level triggers
- very high interaction rates of up to 10 MHz
- up to 1000 charged particles/collision

Motivation

One of the aims of the experiment is to study the production of hypernuclei. In order to accurately measure the yields of hypernuclei and their lifetime, it needs to identify their decay products including ^{3}He and ^{4}He with maximum significance.

PID detectors: RICH, TRD, TOF, STS



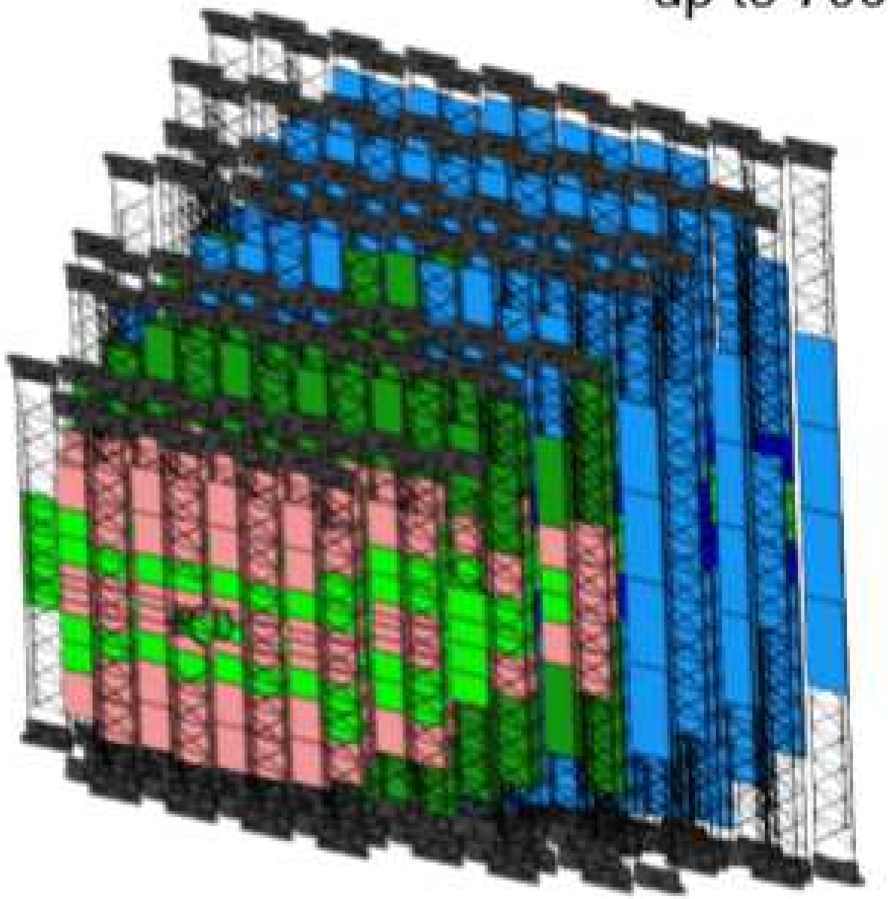


Input for simulation

- ✓ Two sets of data:
  - Siganl: ^{3}He, ^{4}He, d, t (simulated according to the thermal distribution)
  - background events (UrQMD)
- ✓ central AuAu collisions at 10 AGeV
- ✓ sis100_electron setup without MVD
- ✓ Cbmroot release Oct2018

Silicon Tracking System

STS is a main tracking detector that will reconstruct up to 700 charged particle per collision.



Features:

- located inside 1 Tm dipole magnet
- 8 tracking stations
- active area about 4 m^2
- 896 sensors installed onto 106 carbon fibre ladders
- low material budget $<1.5\% X_0$ per station
- fast self-triggering readout
- radiation tolerance up to $10^{14}\ n_{eq}cm^{-2}$

Requirements:

- fast and radiation hard detectors
- self-triggering electronics
- 4D event reconstruction

dE/dx calculation in STS

1. reconstruct a track;
2. for each cluster dE is defined as a total cluster charge. Since each track consists of several hits (points where particle passes through the STS planes), each of which consists of two clusters, there are $2xN_{hits}$ measurements of dE for a track.;
3. to estimate dx:

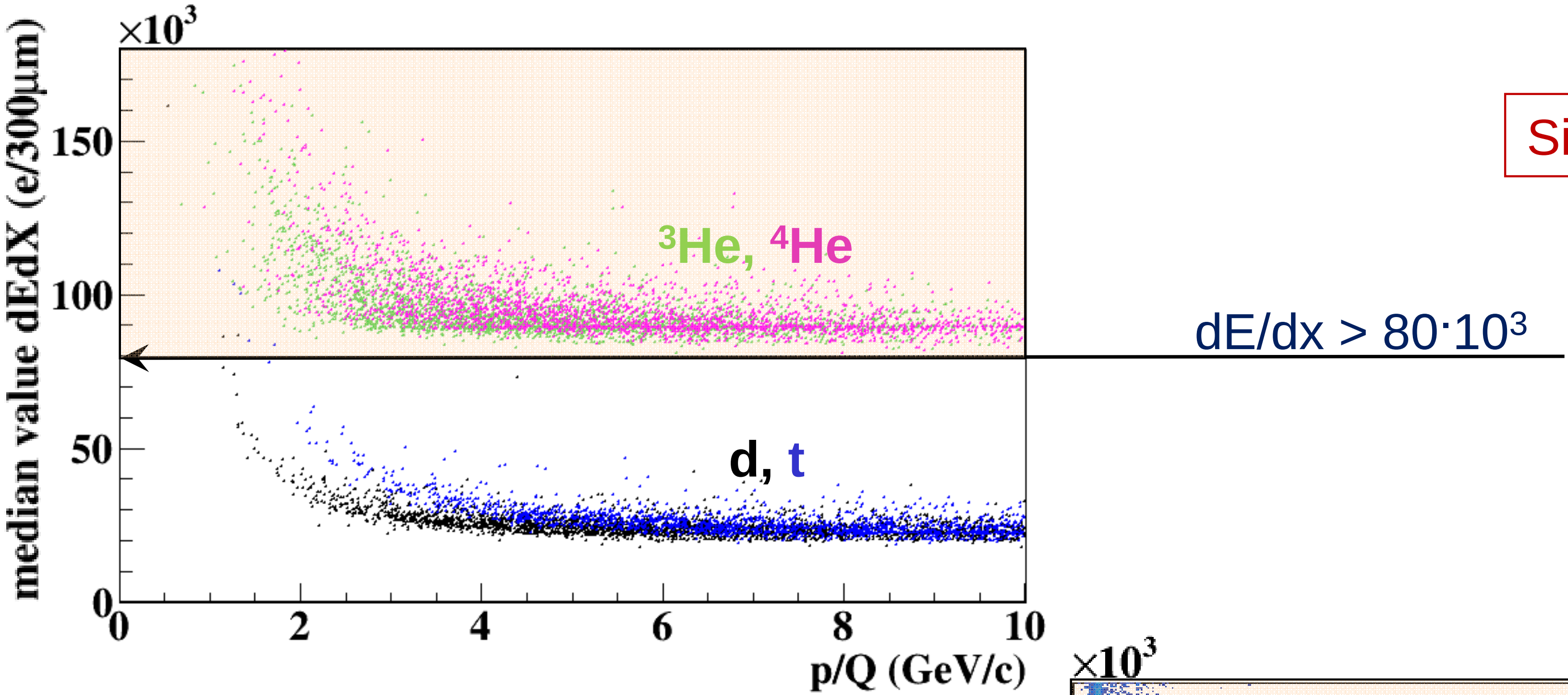
   3.1 track is assumed to be a straight line between the current hit and the hit in the next station;

   3.2 track inclination is calculated;

   3.3 dx is calculated from the track inclination.
4. take median value of dE/dx over remaining clusters.

Hanna Malygina, CBM Progress Report 2017, p. 160

Median value of dE/dx

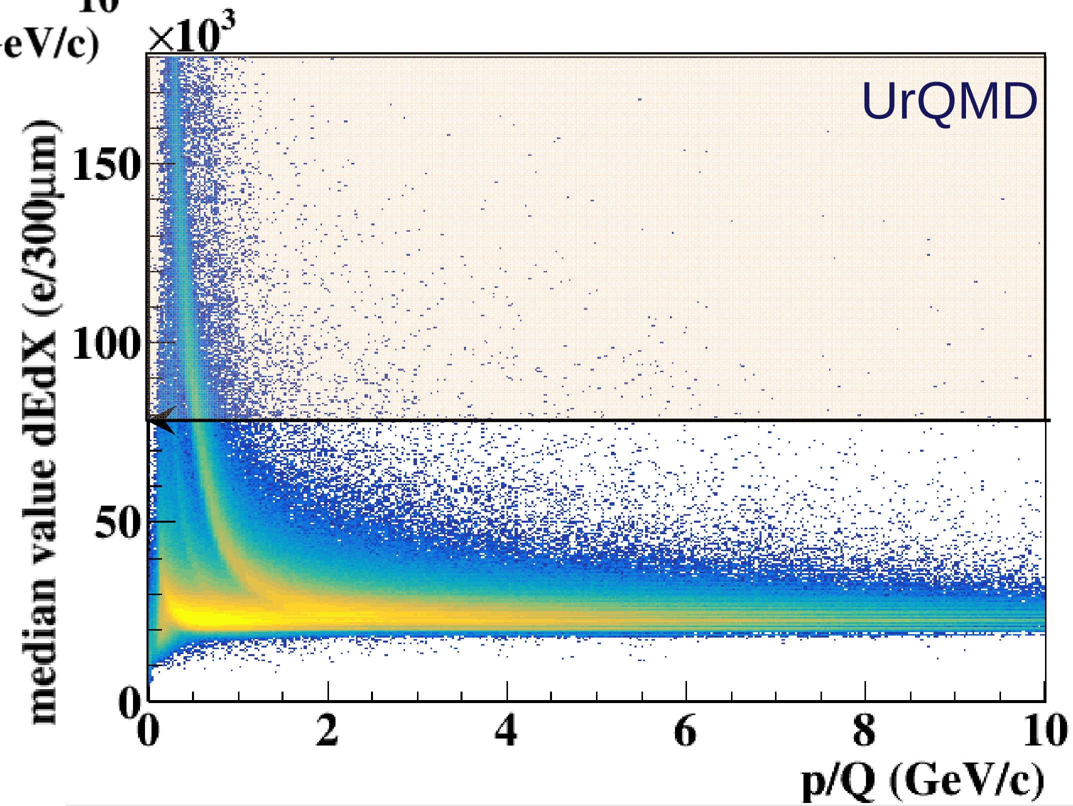


Signal loss: 0%

$$"Bg \text{ suppression}" = \frac{S_1}{S_2} = 158$$

S_1 - all tracks from UrQMD

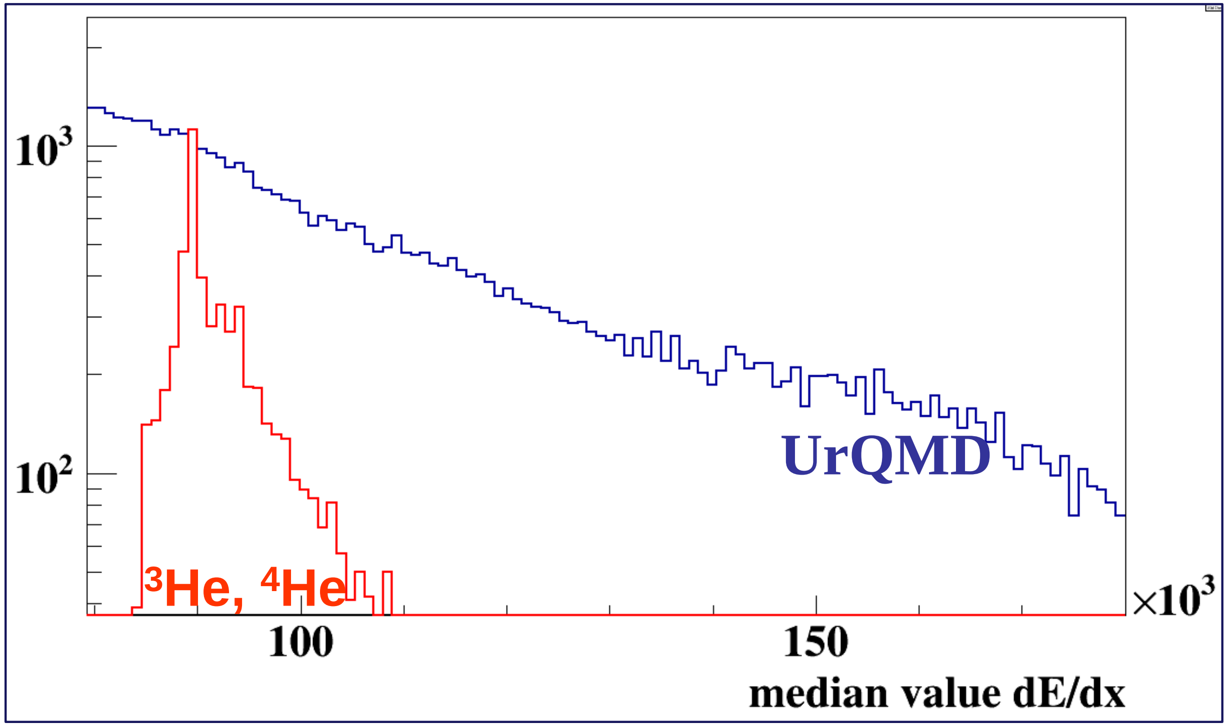
S_2 - tracks left after dE/dx cut



Particle identification

Each track is associated with a set of measurements of the particle energy losses.

With the help of ω^k_n, one should determine to which distribution (signal or background) these losses are related.



Overlaying two histograms (blue – UrQMD, red - signal) after dE/dx cut

ω_n^k criterion

$$\omega_n^k = -\frac{n^{\frac{k}{2}}}{k+1}\sum_{j=1}^{n}\left\{\left[\frac{j-1}{n}-\phi(\lambda_j)\right]^{k+1}-\left[\frac{j}{n}-\phi(\lambda_j)\right]^{k+1}\right\},$$

where *k* is the criterion degree,

n is the sample size (number of dE/dx values),

$\phi(\lambda)$ is Landau distribution function (which describe H_0 hypothesis) with

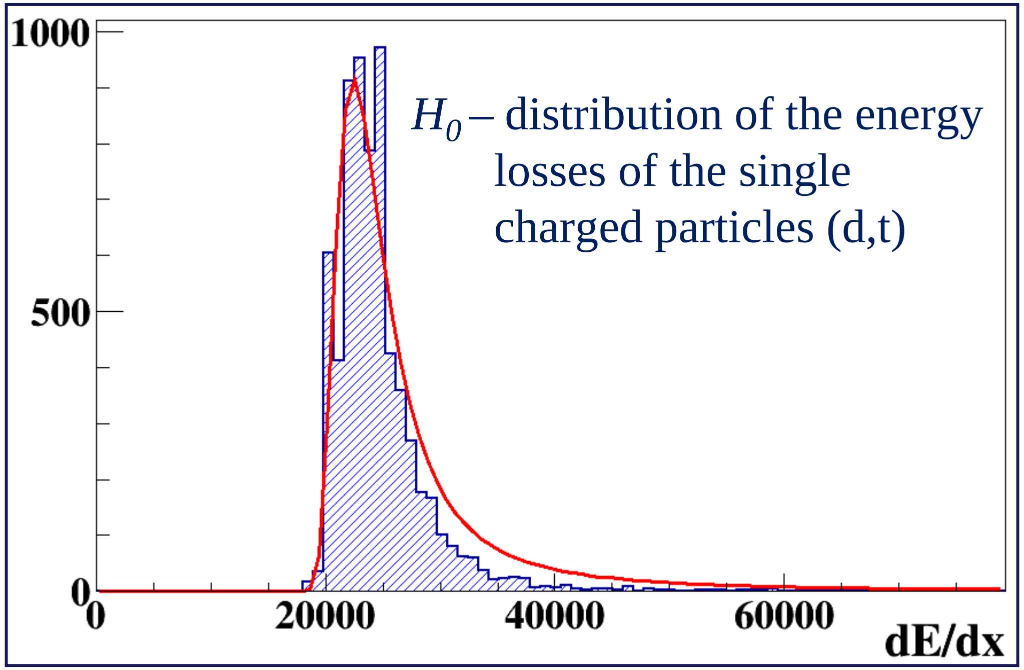
a new variable λ:

$$\lambda_i = \frac{\Delta E_i - \Delta E^i_{mp}}{\xi_i} - 0.225, \mathrm{i} = 1,2,\ldots,\mathrm{n},$$

ΔE_i – the energy loss in the i-th STS “layer”,

ΔE^i_{mp} – the value of most probable energy loss,

ξ_i =1/4.02 FWHM of distribution of the energy losses for H_0.



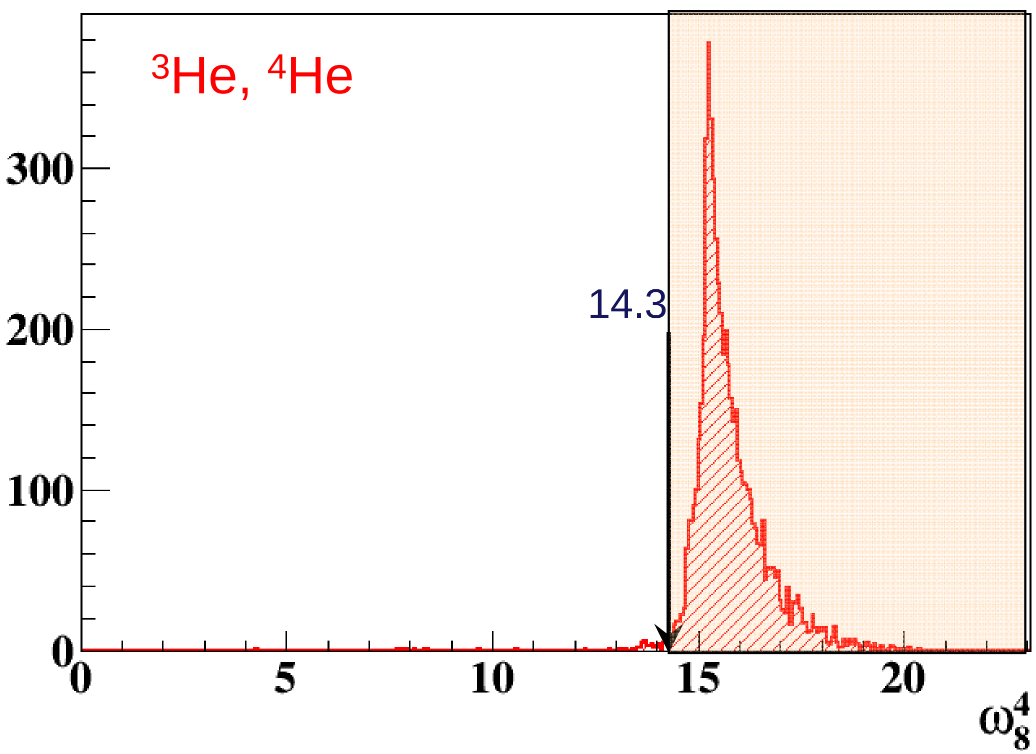
P.V. Zrelov and V.V. Ivanov, *Nucl. Instr. and Meth. in Phys. Res.*, **A310** (1991) pp. 623-630.

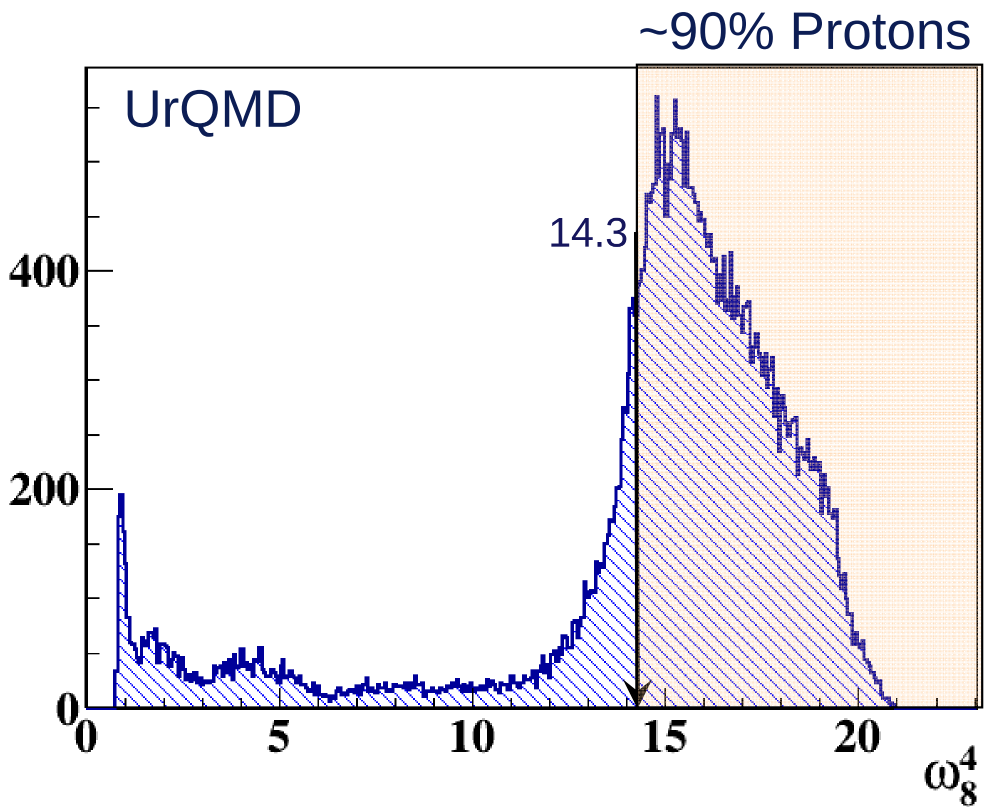
$$"Bg \text{ suppression}" = \frac{S_1}{S_2} = 1.3$$

S_1 - tracks left after dE/dx cut + cut on N_{hits}

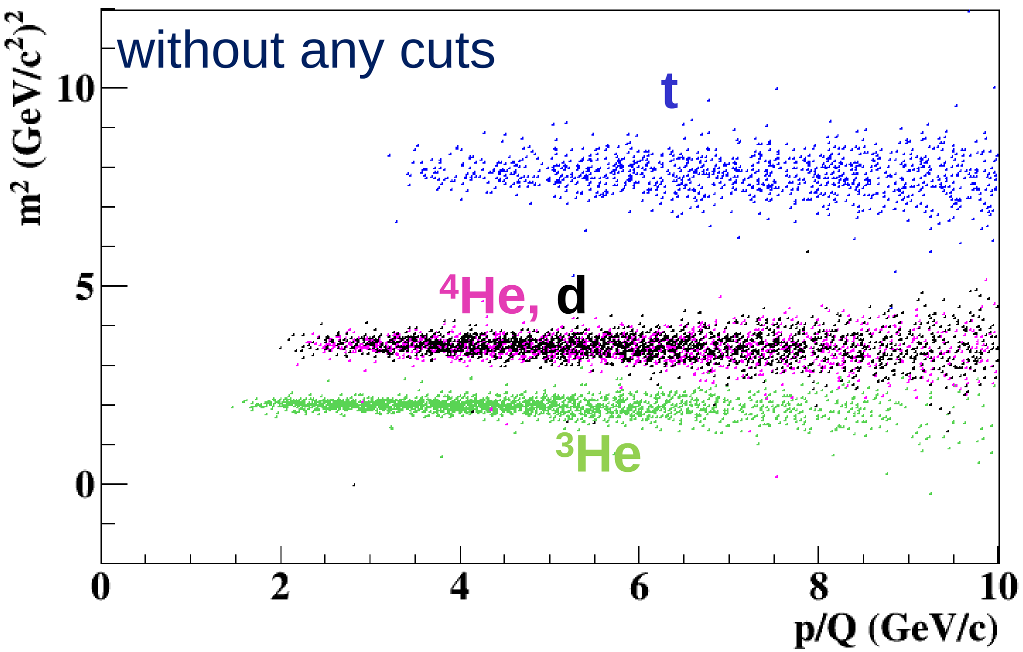
S_2 - tracks left after ω^4_8

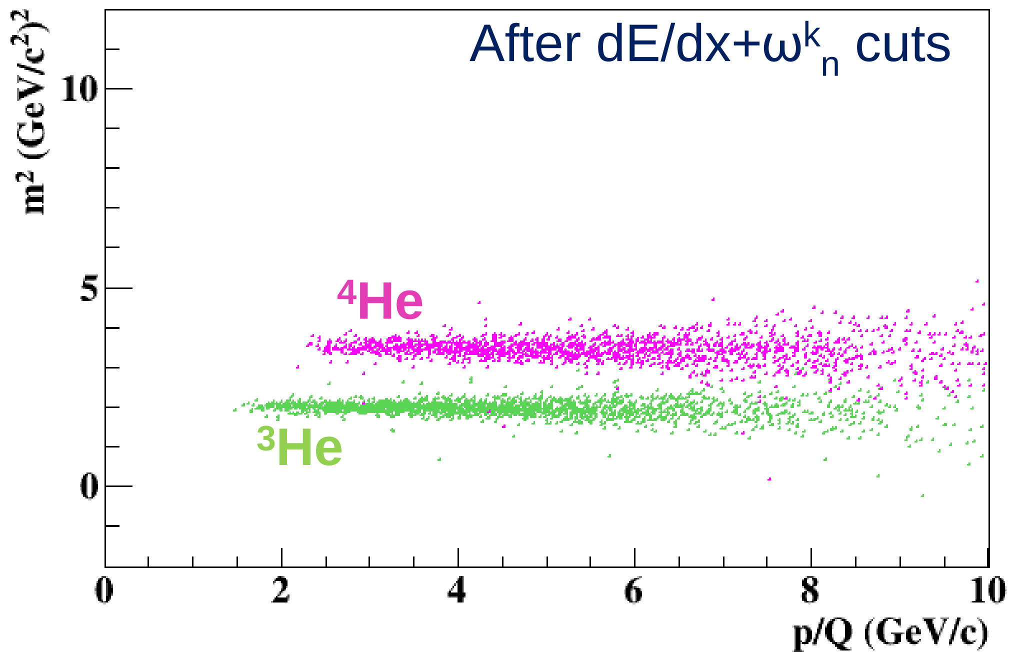
The background suppression factor corresponding to 1% signal losses for ω^4_8



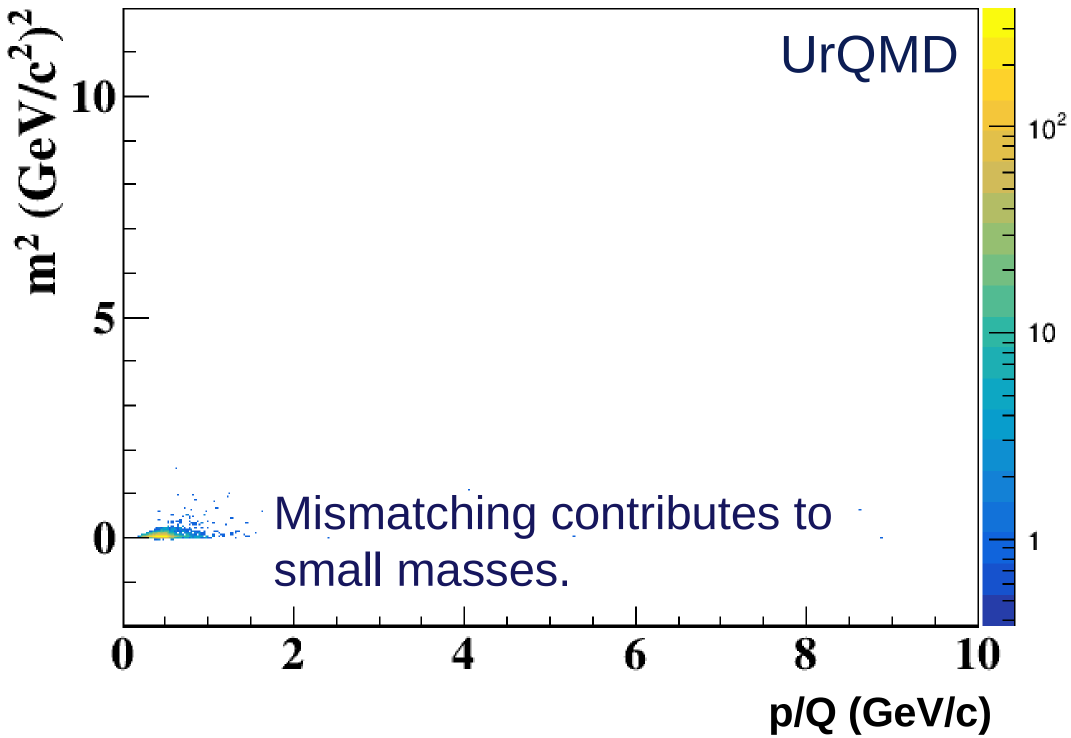


Particle identification in TOF





TOF+STS allow significantly suppress the background and clearly highlight ^{3}He and ^{4}He.



Conclusions

1. The energy loss method was used for particlele identification in the STS.
2. The $\omega^k{}_n$ criterion was successfully adapted for the STS detector. It allows to separate doubly charged particles from the single one.
3. The combination of dE/dx cut and $\omega^k{}_n$ criterion has shown high level of the background suppression. The $\omega^k{}_n$ gives the additional background suppression 1.3.
3. The combination of TOF + STS allows to separate ^{3}He and ^{4}He from the deuteron background.

Plans

Apply the proposed procedure to hypernuclei reconstruction.

The CBM Collaboration: 55 institutions, 413 members

China
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang

Czech Republic
CAS, Rez
Techn. Univ.Prague

France
IPHC Strasbourg

Hungary
KFKI Budapest
Budapest Univ.

Germany
Darmstadt TU
FAIR
Frankfurt Univ. IKF
Frankfurt Univ. FIAS
Frankfurt Univ. ICS
GSI Darmstadt
Giessen Univ.
Heidelberg Univ. P.I.
Heidelberg Univ. ZITI
HZ Dresden-Rossendorf
KIT Karlsruhe
Münster Univ.
Tübingen Univ.
Wuppertal Univ.
ZIB Berlin

India
Aligarh Muslim Univ.
Bose Inst. Kolkata
Panjab Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
IOP Bhubaneswar
IIT Kharagpur
IIT Indore
Gauhati Univ.

Korea
Pusan Nat. Univ.

Romania
NIPNE Bucharest
Univ. Bucharest

Poland
AGH Krakow
Jag. Univ. Krakow
Warsaw Univ.
Warsaw TU

Russia
IHEP Protvino
INR Troitzk
ITEP Moscow
Kurchatov Inst., Moscow
MEPHI Moscow
PNPI Gatchina
SINP MSU, Moscow

Ukraine
T. Shevchenko Univ. Kiev
Kiev Inst. Nucl. Research

JINR
VBLHEP, Dubna
LIT, Dubna

30th CBM Collaboration Meeting, 24-28 September 2017, Wuhan, China

Thank you for your attention ☺