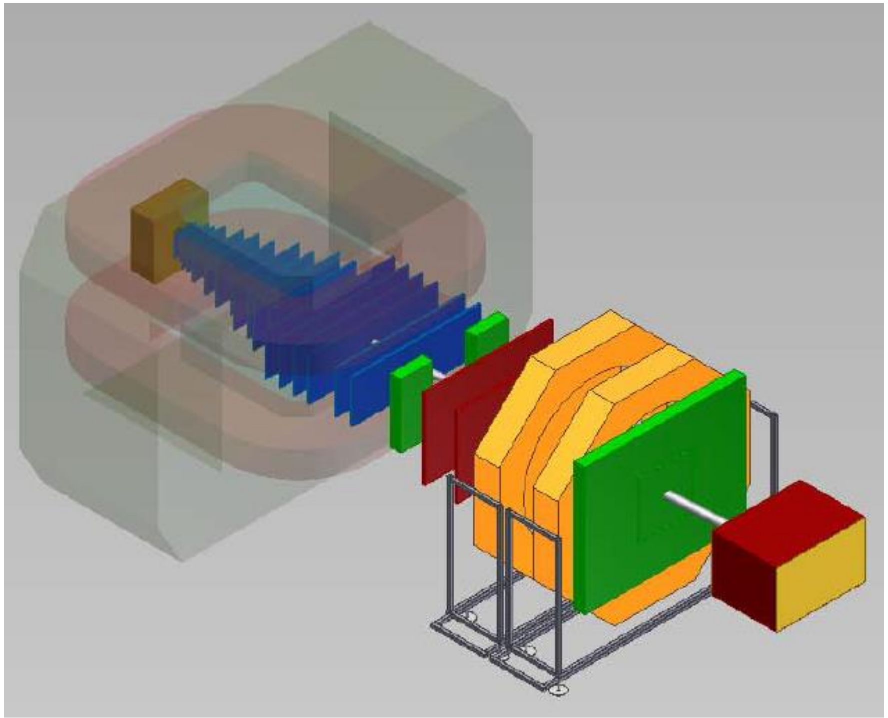
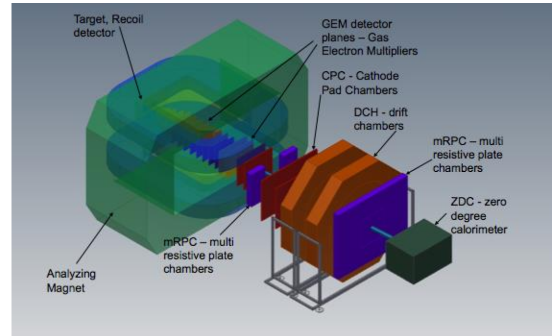
Status of the BM@N experiment

M.Kapishin



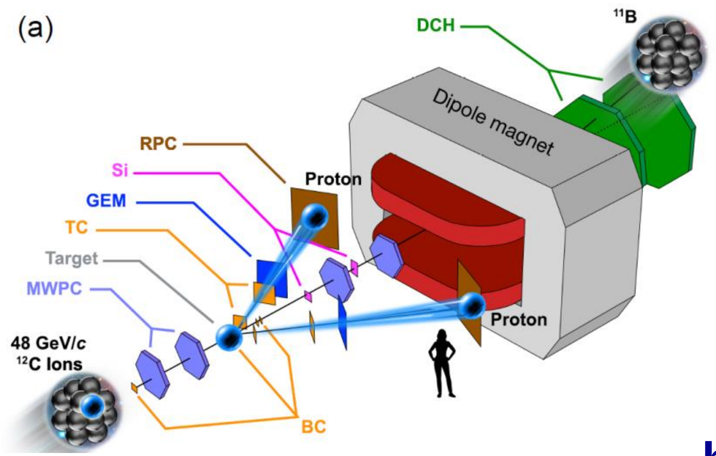
Baryonic Matter at Nuclotron (BM@N) Collaboration:

10 Countries, 20 Institutions, 246 participants

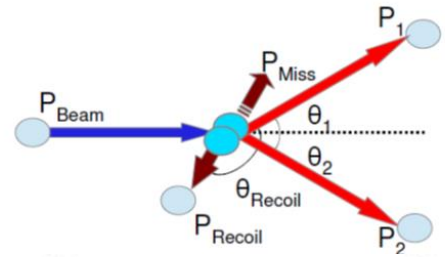


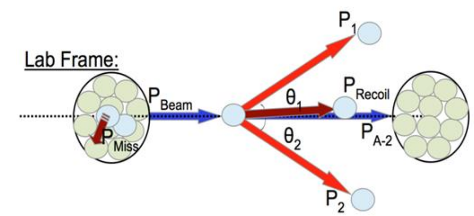
- *University of Plovdiv, Bulgaria → MoU signed;*
- *St.Petersburg University;*
- *Shanghai Institute of Nuclear and Applied Physics, CFS, China;*
- *Tsinghua University, Beijing, China;*
- *Nuclear Physics Institute CAS, Czech Republic→ MoU signed;*
- *CEA, Saclay, France;*
- *TU Darmstadt & GSI Darmstadt, Germany;*
- *Tubingen University, Germany → MoU signed;*
- *Tel Aviv University, Israel;*
- *Joint Institute for Nuclear Research;*
- *Institute of Applied Physics, Chisinev, Moldova;*
- *Warsaw University of Technology, Poland;*
- *University of Wroclaw, Poland → MoU signed;*
- *Institute of Nuclear Research RAS, Moscow, Russia → MoU signed;*
- *NRC Kurchatov Institute, Moscow;*
- *Institute of Theoretical & Experimental Physics, NRC KI, Moscow, Russia;*
- *Moscow Engineer and Physics Institute, Russia;*
- *Skobeltsin Institute of Nuclear Physics, MSU, Russia → MoU signed;*
- *Moscow Institute of Physics and Technics, Moscow, Russia → MoU signed;*
- *Massachusetts Institute of Technology, Cambridge, USA.*

BM@N: study Short Range Nucleon Correlations with hard inverse kinematic reactions



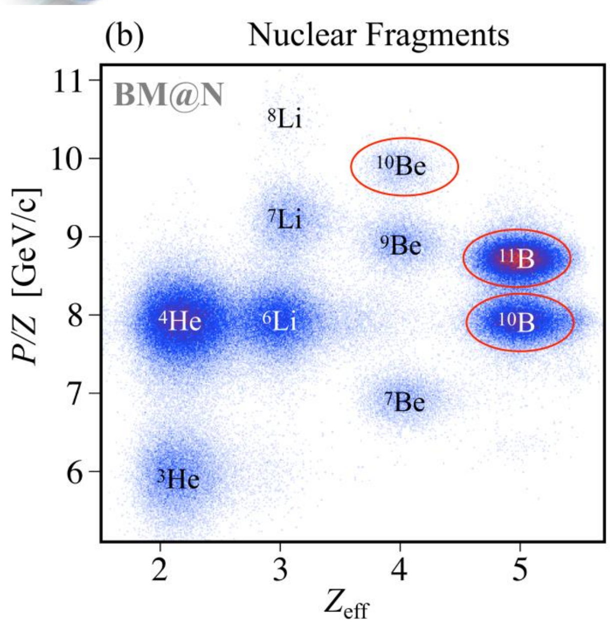
^{12}C Beam Frame | **Lab frame**





$$^{12}C + p \rightarrow 2p + {}^{10}_{5}B + n \qquad \text{np SRC}$$

$$^{12}C + p \rightarrow 2p + {}^{10}_{4}Be + p \qquad \text{pp SRC}$$



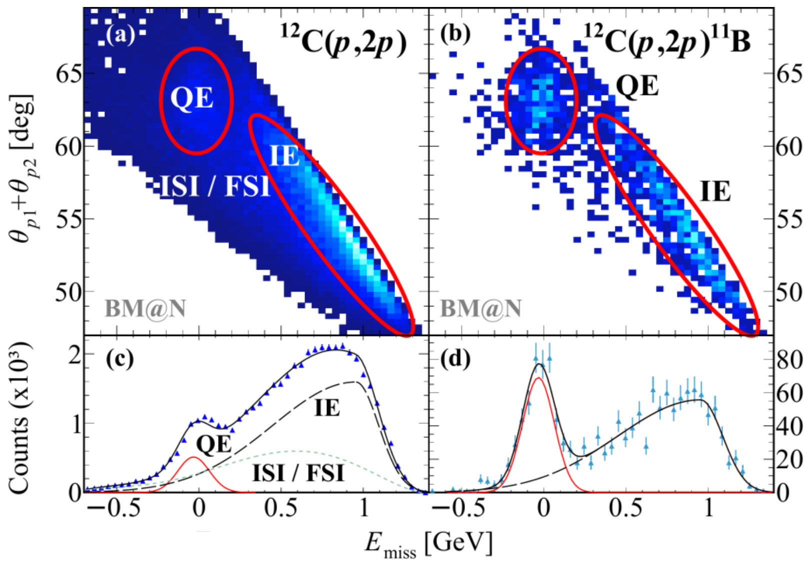
- high momentum ^{12}C beam: 4 GeV/c/nucleon
- (p,2p) ~90°c.m. scattering
- inverse kinematics
- detection of A-1 or A-2 system selects reactions with no multiple scattering

Goals:

→ extract missing-and recoil-momentum distributions for Quasi-Elastic scattering

→ identify SRC signal in inverse kinematics

First BM@N results on SRC and Single Proton Knockout

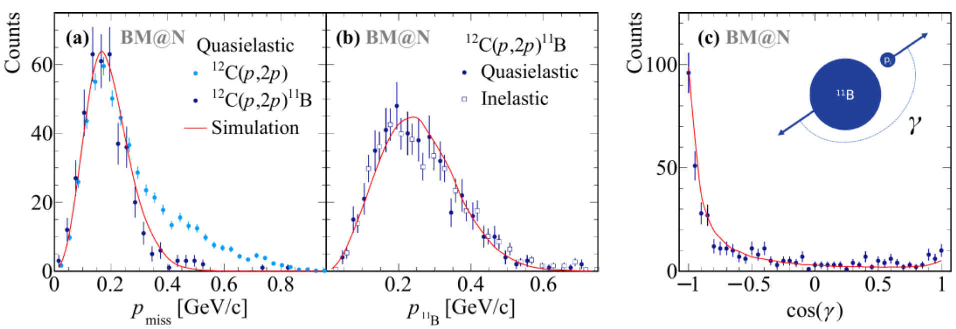


BM@N SRC paper:

"The Transparent Nucleus: unperturbed inverse kinematics nucleon knockout measurements with a 48 GeV/c carbon beam"

Single Proton Knockout:

- ►**exclusive $^{12}C(p,2p)^{11}B$ reaction**
- ►**Quasi-Elastic scattering (bound ^{11}B)**
- ►**tagging A-1 fragment removes ISI / FSI**



First observation of Final State Interaction suppression and single-step nucleon knockout selection using fragment detection in quasi-elastic reaction **$^{12}C + p \rightarrow 2p + {}^{11}B$**

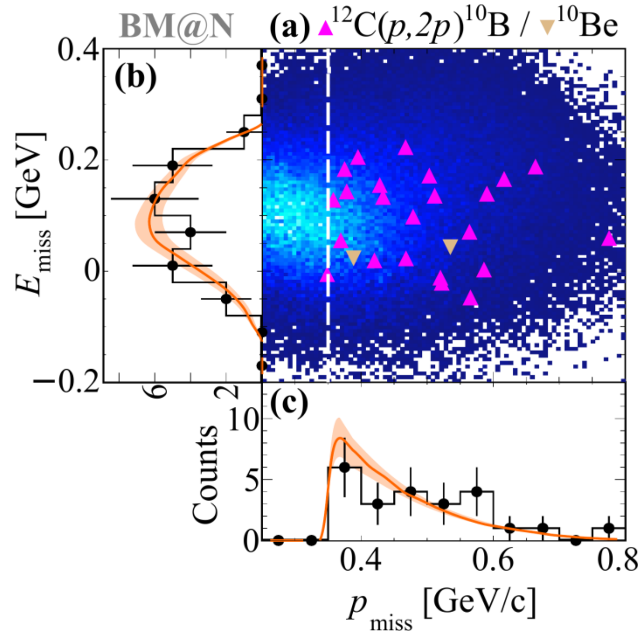
First BM@N result on Short Range Nucleon Correlations

- First observation of SRCs with bound residual A-2 system in reactions:

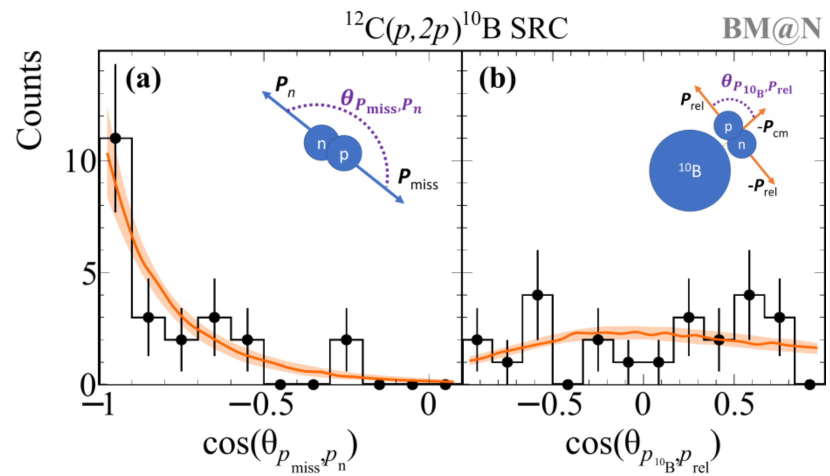
$^{12}C + p \rightarrow 2p + {}^{10}B \,/\, {}^{10}Be + (n\,/\,p)$

26 ^{10}B events

3 ^{10}Be events → *np* pair dominance

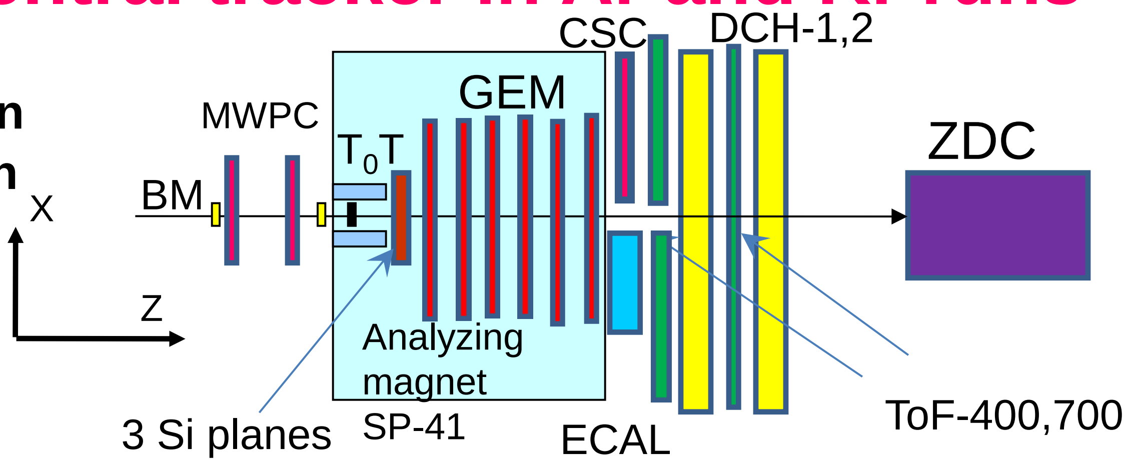


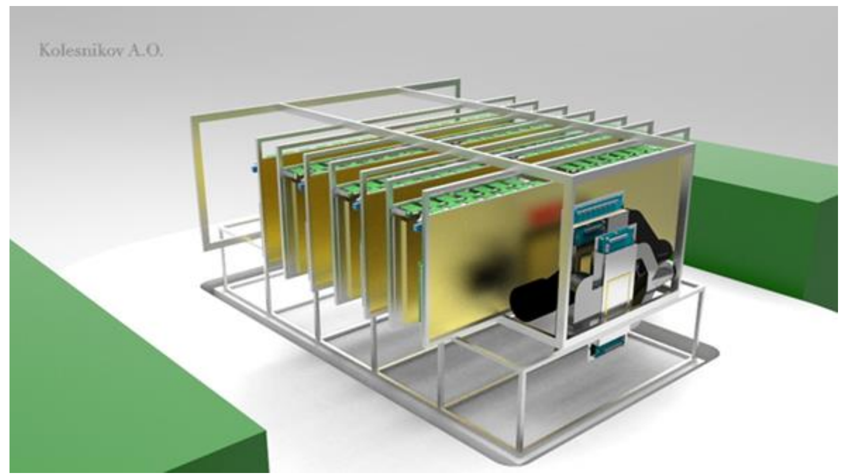
First SRC paper discussed and accepted by BM@N and sent to Nature Physics



BM@N central tracker in Ar and Kr runs

Ar beam, T_0= 3.2 GeV/n
Kr beam, T_0= 2.4 GeV/n

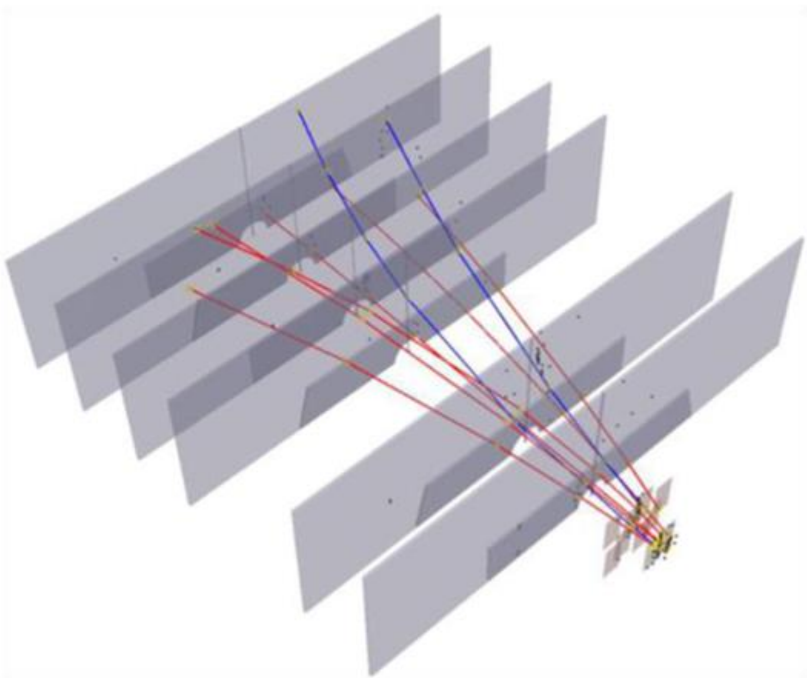




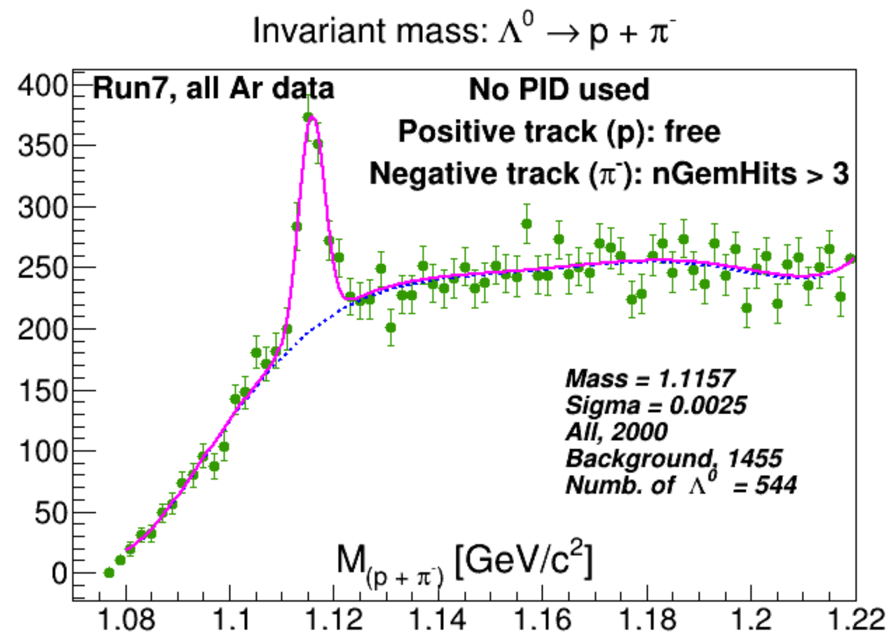
Central tracker: 3 Forward Si detectors and 6 GEM detectors

Λ hyperon signals in 3.2A GeV Argon-nucleus interactions

P.Batyuk, S.Merts



Ar+Cu interaction reconstructed in central tracker



Ar (3.2 AGeV) + Target → Λ + X
Λ signal width 2.5 MeV

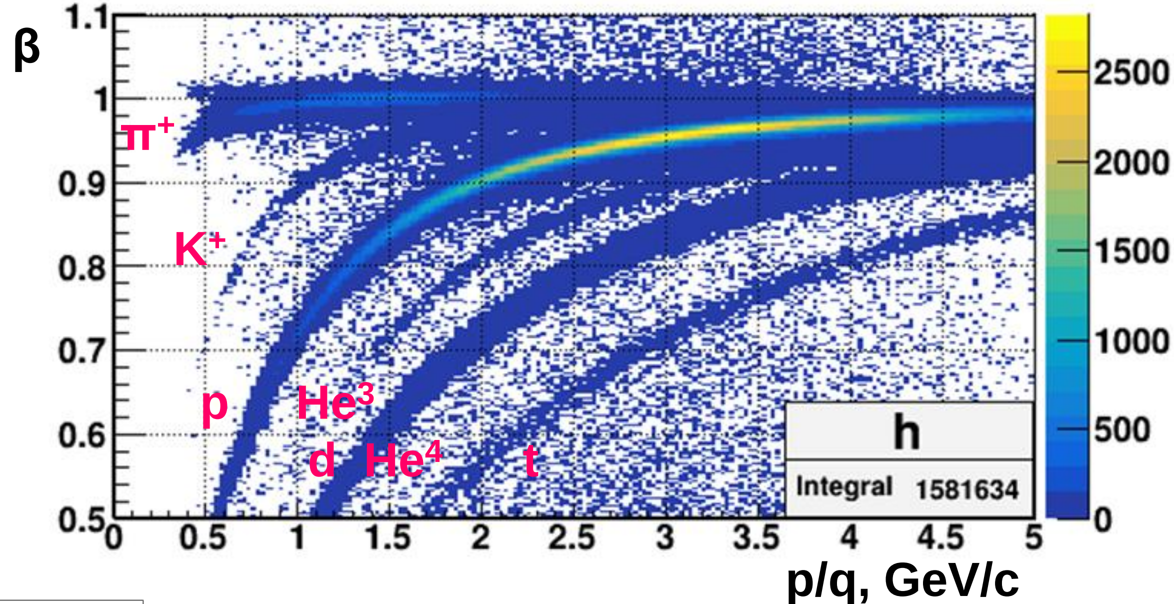
Status of TOF-400 particle identification

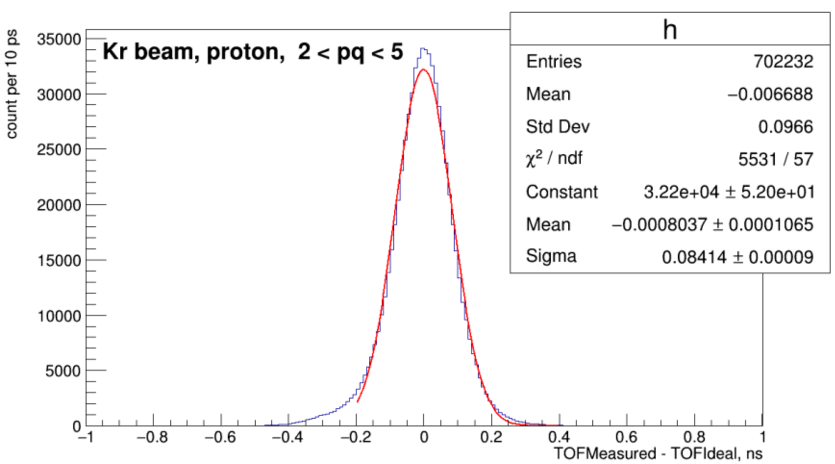
V.Plotnikov, M.Rumyantsev

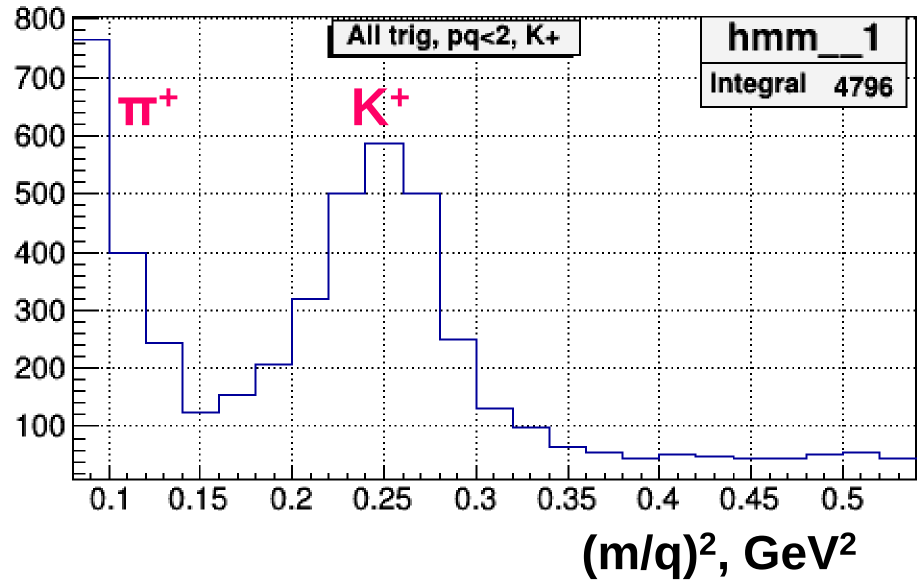
First expected results:

- **Ratio of K^+/π^+ in *argon - nucleus* interactions at beam kinetic energy of 3.2 AGeV**

Ar beam , 3.2 AGeV , Ar + C,Al,Sn,Cu → X

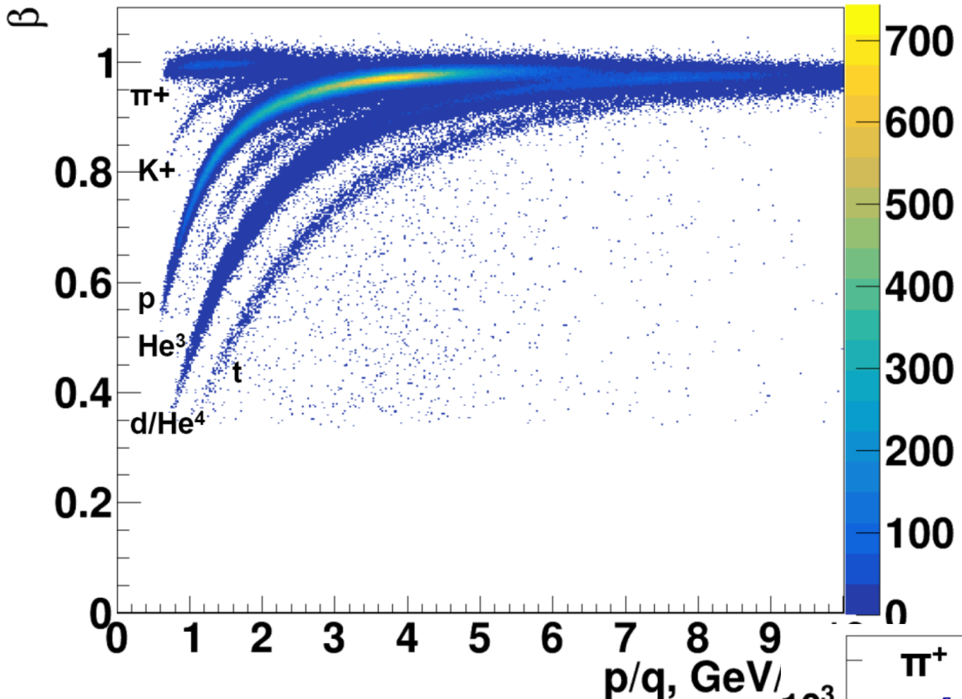






Time resolution within proton band ~85 ps

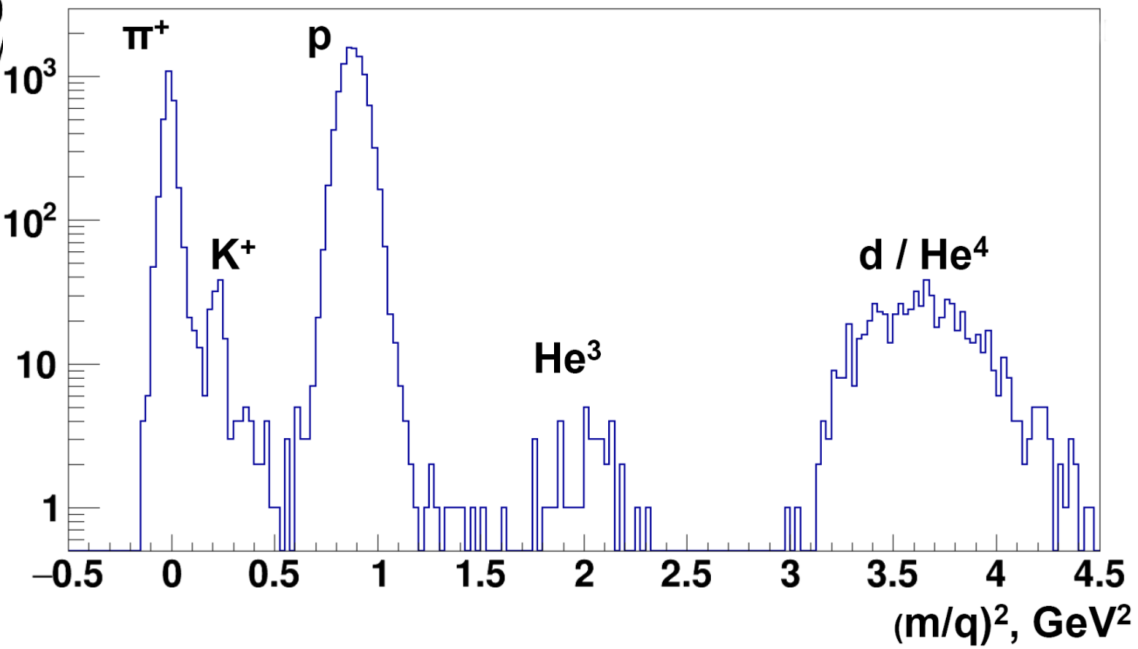
Status of TOF-700 particle identification



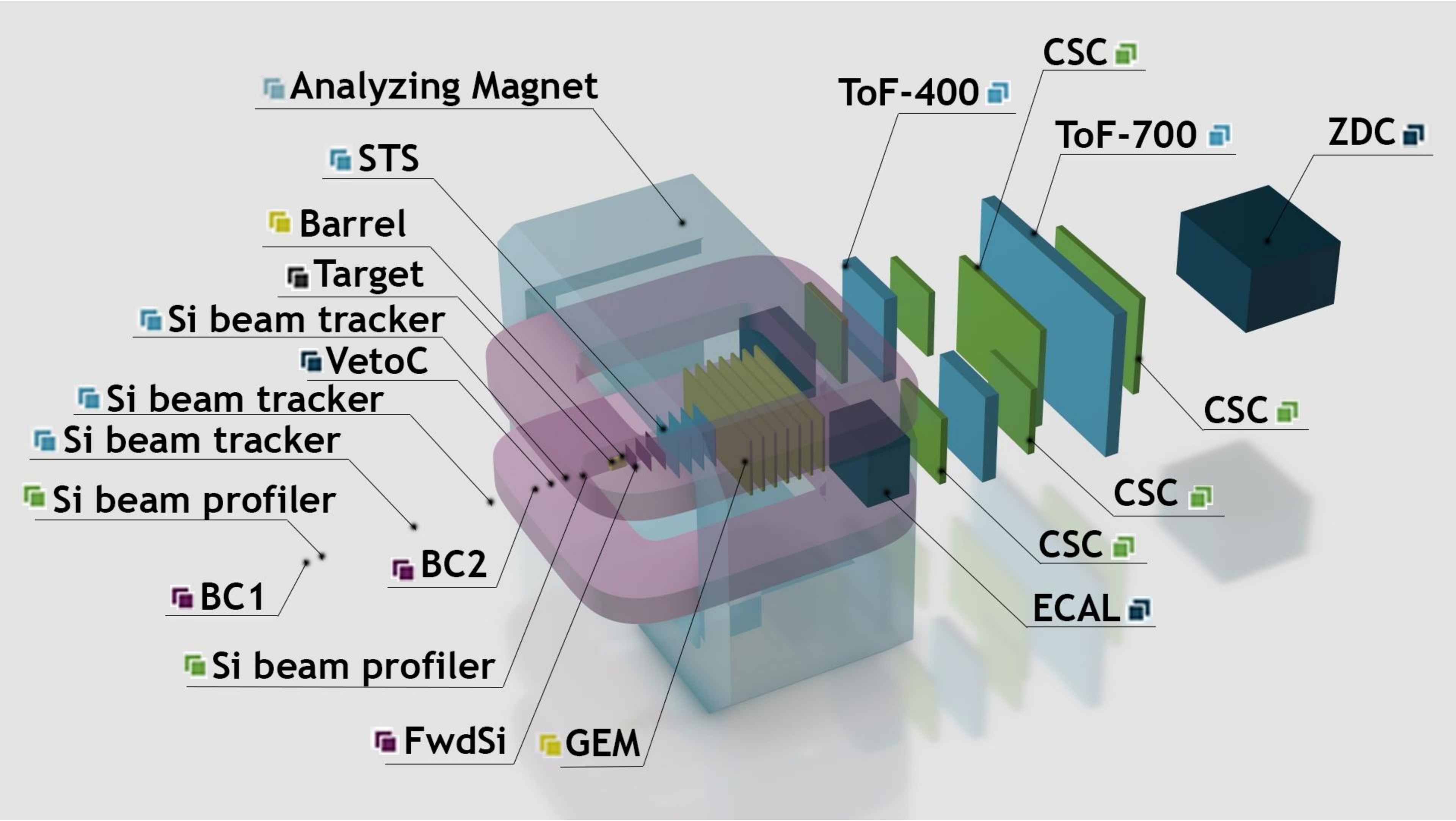
L.Kovachev, Yu.Petukhov

Ar beam , 3.2 AGeV ,
Ar + Al,Cu,Sn → X

Aim:
Yields of π, p, t, He^3, d/He^4 in *argon - nucleus* interactions (combination of ToF-400 and ToF-700)



Configuration of BM@N detector for heavy ion program (without beampipe)

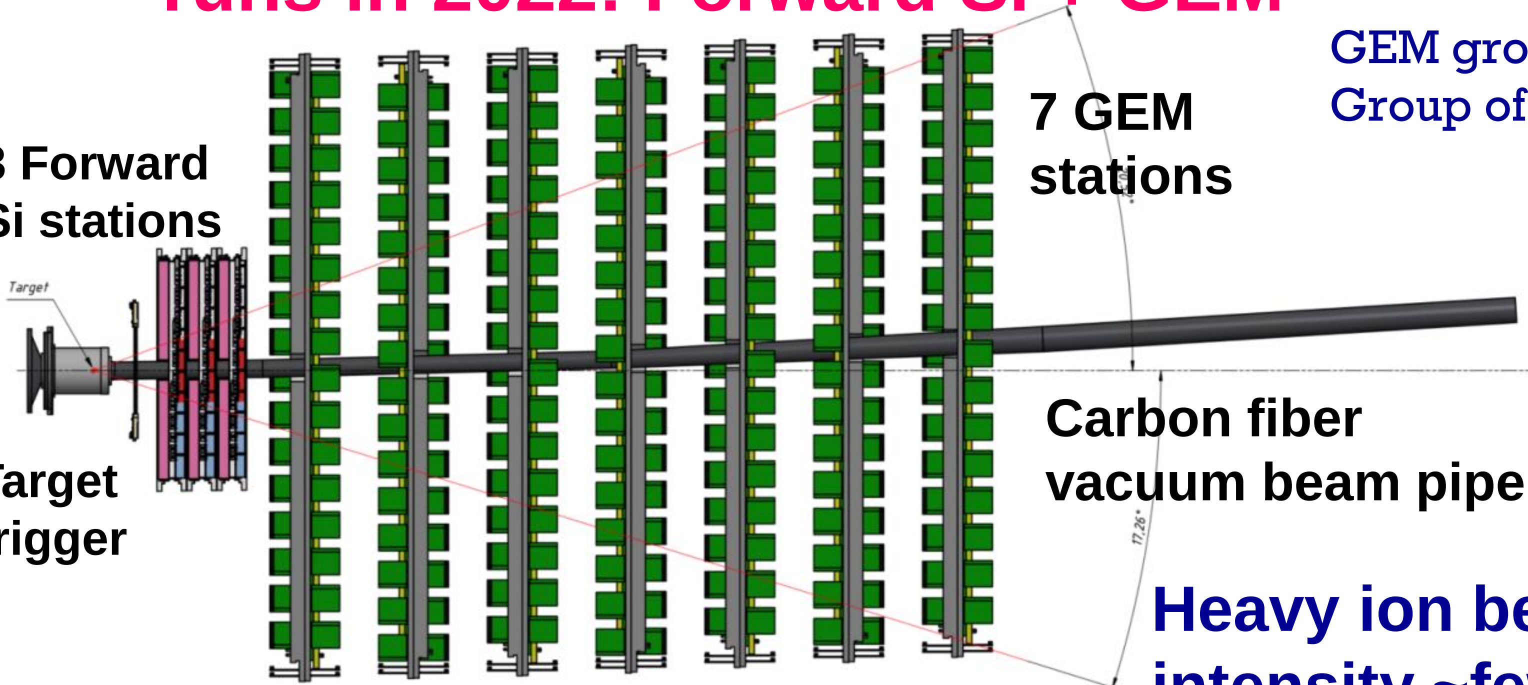


Initial Hybrid Central Tracker for heavy ion runs in 2022: Forward Si + GEM

GEM group
Group of N.Zamiatin

3 Forward Si stations

7 GEM stations

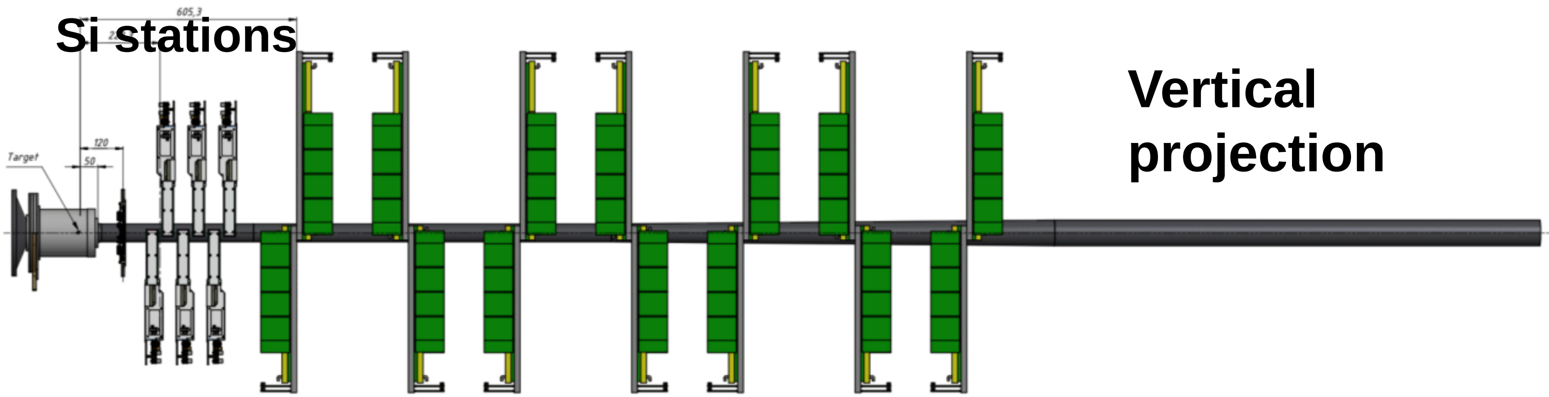


Target trigger

Carbon fiber vacuum beam pipe

Heavy ion beam intensity ~few 10^5 Hz

3 Forward Si stations

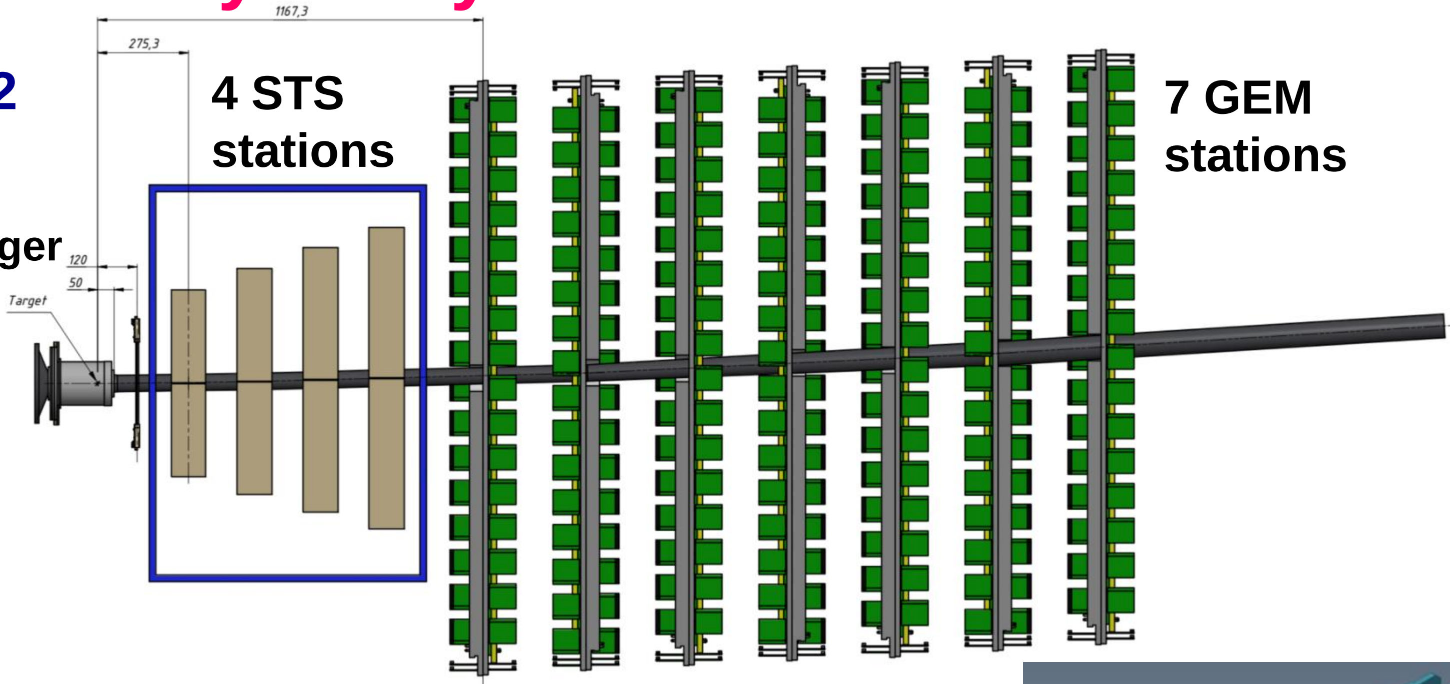


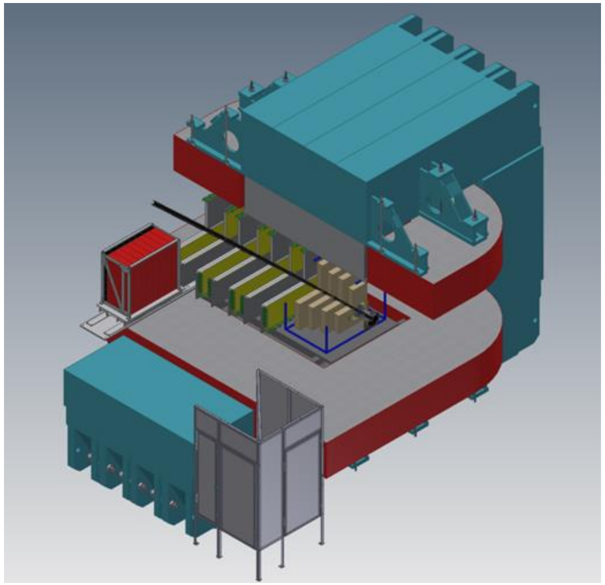
Vertical projection

Stage2 Hybrid Central Tracker for high intensity heavy ion runs: STS +GEM

after 2022

Target + trigger detectors





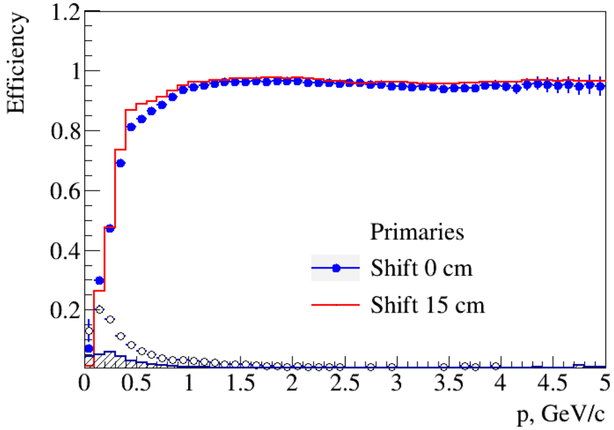
For heavy ion beam intensities of few 10^6 Hz

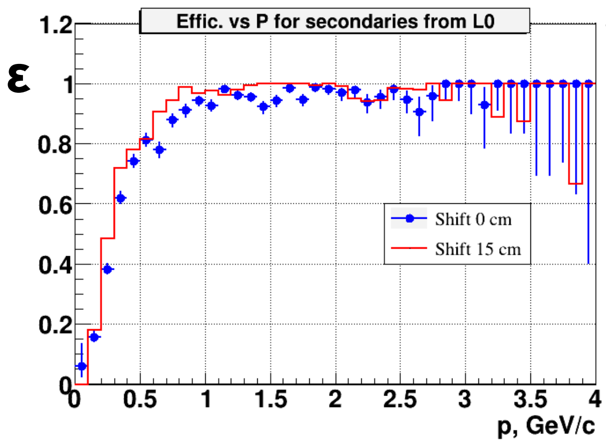
→ keep 4 STS + 7 GEM

→ fast FEE and readout electronics

Simulation of 1st stage of hybrid central tracker: 3 Forward Si + GEM

A.Zinchenko, V.Vasendina



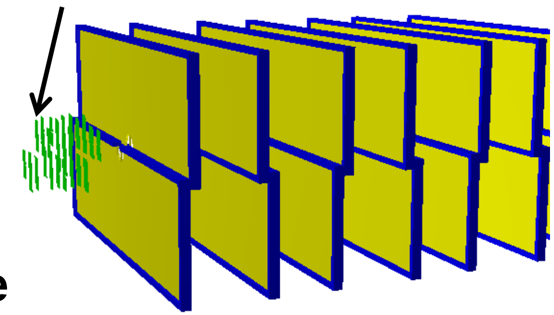


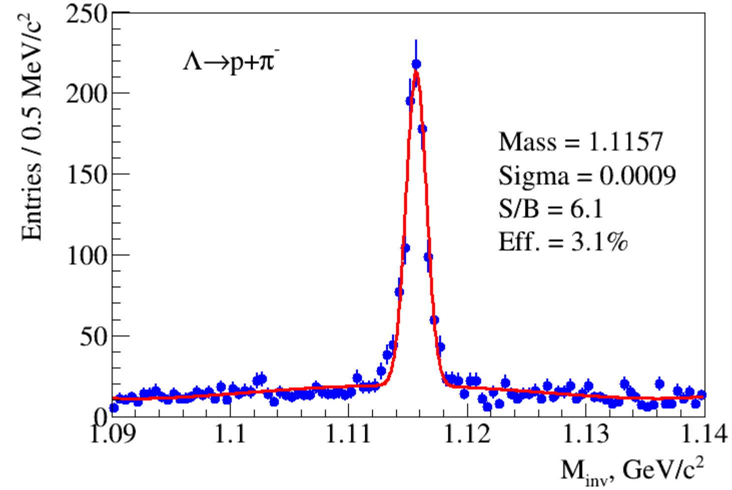
DCM-QGSM model
Kr + Pb , T_0= 2.4 AGeV

Aim:

- **Optimization of detector positions and rotation angle of Forward Si stations**
- **Estimation of track reconstruction efficiency and momentum resolution**

3 Forward Si + 7 GEM



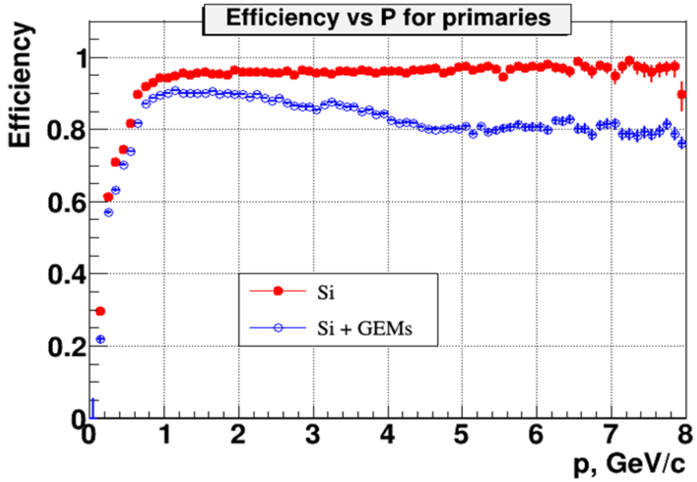


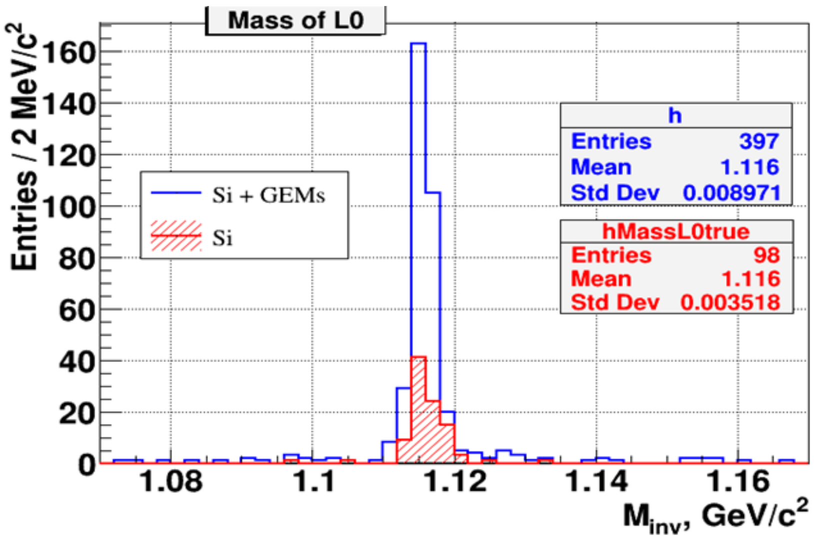
More details in talk of Alexander Zinchenko: Performance evaluation of the upgraded BM@N set-up for the strangeness production studies

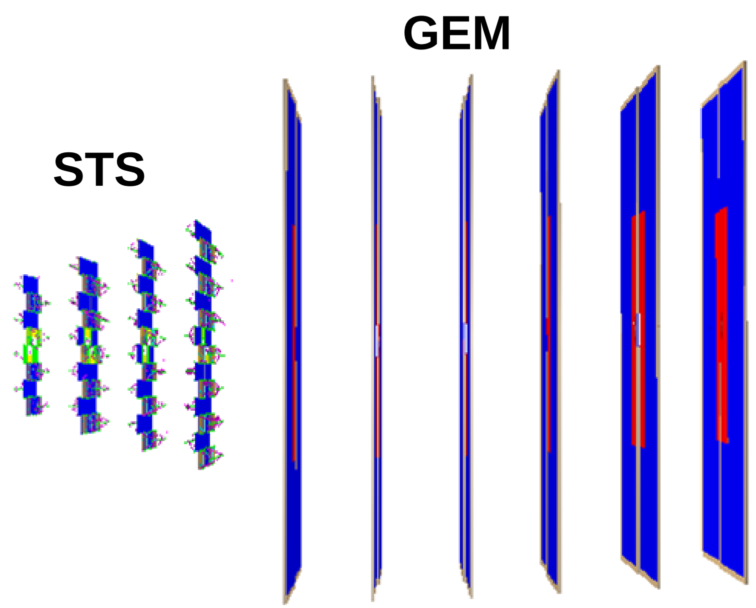
Simulation of hybrid central tracker for heavy ion runs: STS +GEM

A.Zinchenko, V.Vasendina

QGSM model, Au+Au, T_0 = 4 AGeV



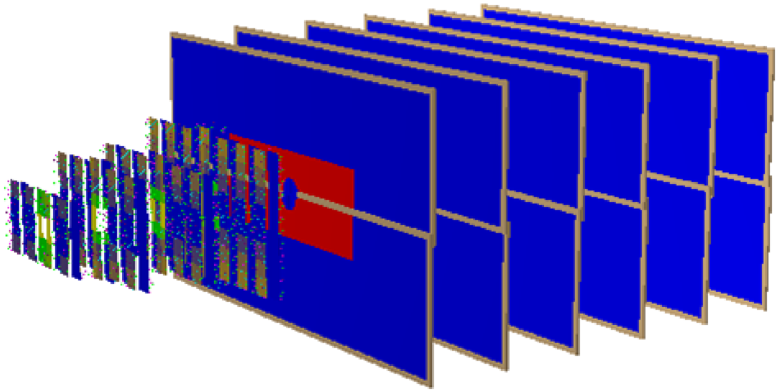




Hybrid STS + GEM tracker:
► 4 times increase in number of reconstructed tracks and Λ hyperons

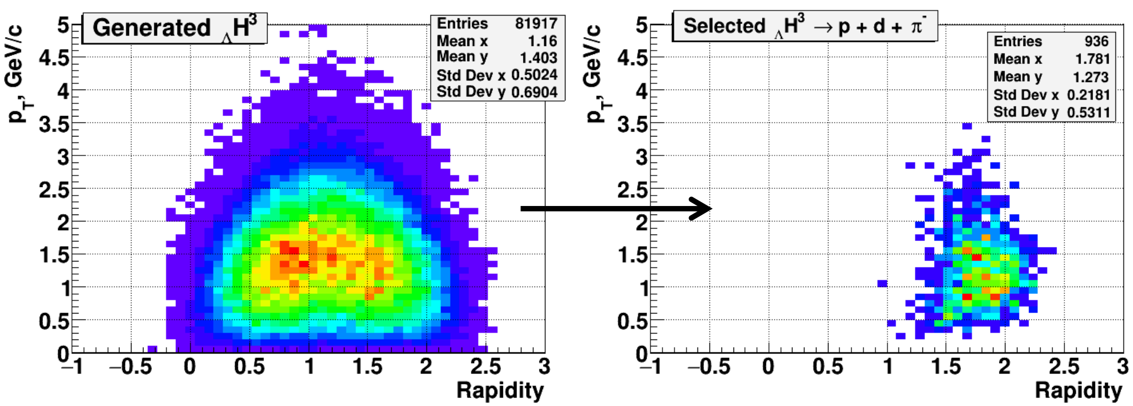
Simulation of hybrid central tracker for heavy ion runs: Ξ^- and $_\Lambda H^3$ reconstruction

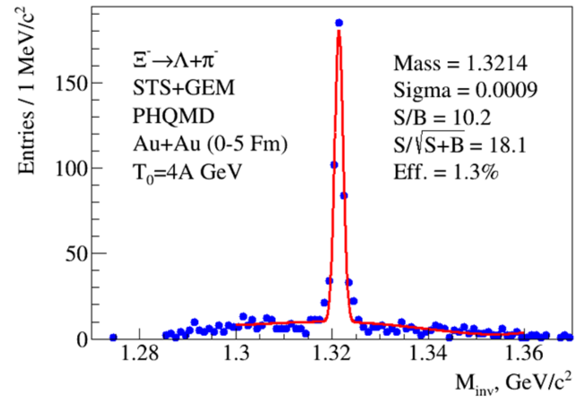
A.Zinchenko, V.Vasendina

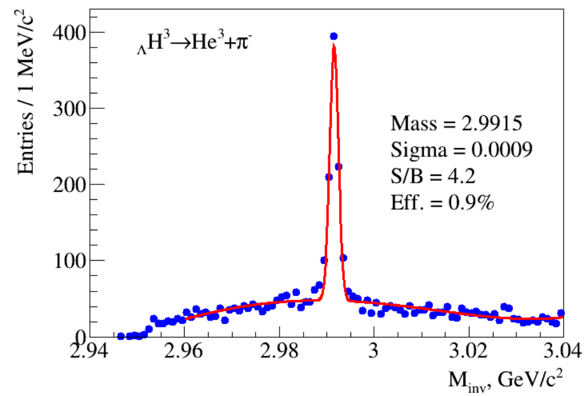


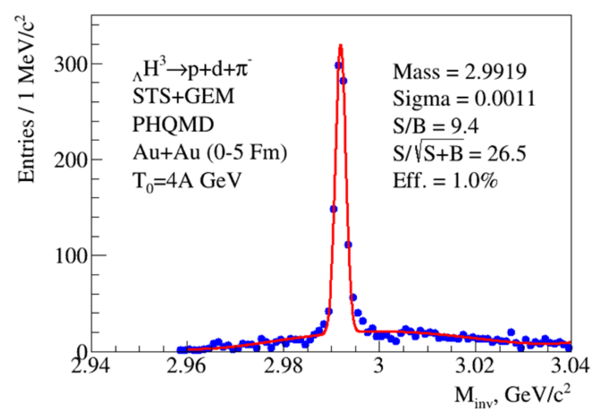
PHQMD model, Au+Au, T_0 = 4A GeV, b = 0-5 fm, 500k events

$_\Lambda H^3$ phase space









Status of BM@N upgrade and possible risks

Forward Si tracking detectors:
►Proven technology and FEE readout electronics → used in C, Ar, Kr runs
►Development, production, tests and installation → spring 2021

Beam, Si tracking detectors and target station:
►All detectors and target station to be ready in spring 2021

GEM tracking detectors:
►All detectors produced at CERN, → tested in C, Ar, Kr runs
►No proven fast FEE for high intensity run

Trigger and T0 detectors:
► Detector performance in heavy ion beam should be tested in first run

Large aperture STS tracker:
►Complicated module, readout cables and ladder assembly → probable delay and long commissioning phase

CSC chambers for Outer tracker:
►4 chambers to be ready by end of 2020
►Risk of delay in production of 2 big CSC chambers

Time of Flight identification system:
►Detectors and readout electronics are in operation since 2018

Carbon fibre beam pipe inside BM@N:
►Vacuum beam pipe should be produced and tested by middle 2021

Beam pipe in front of target:
► Beam pipe elements and detector boxes are delivered to BM@N

New FHCAL hadron calorimeter:
►FHCAL assembled and installed into BM@N setup, need dE/dx hodoscope

Hanging tasks related to STS and tracking

Combine STS and BM@N DAQ

- **Readout clock synchronization between BM@N and STS: 10 MHz vs 40 MHz**
- **Realization of trigger mode for STS readout**

► These tasks are hanging, need to find groups responsible for these developments (JINR, MSU, WUT, GSI)

► As soon as the above tasks are solved, need to test STS & BM@N readout (at least with one STS detector + GEM / Si detectors)

Need to improve tracking algorithms for the hybrid STS+GEM and global tracking (+ outer tracker and ToF)

►Presently use CBM tracking algorithm adapted for GEM tracking

Plans for 2021 – 22 experimental runs

- **We do not expect that vacuum transport channel from Nuclotron to BM@N is fully equipped by Autumn 2021**
- **It is critical for operation with middle and heavy ion beams**
- **Accelerator team need time to put Booster – Nuclotron system into routine operation**

► Plan to start with a new SRC run in November-December 2021 with carbon and deuteron beams (need deuterons for calibration), which could be provided by Nuclotron alone

► critical is a new detector to separate protons from pions in the proton arms to improve data quality

►if SRC setup is not ready by Autumn, switch to technical carbon run to test new BM@N detectors (vacuum carbon beam pipe and target, beam track Si, Forward Si, GEM, CSC, FHCAL, trigger detectors) → need two months to install and align beam pipe and detectors

We consider BM@N experimental run with a middle weight ion beam (Kr, Xe) in Spring 2022

► 1st stage of hybrid tracker (3 Fwd Si + 7 GEM)

► it is desirable to re-measure magnetic field map in an extended (X,Z) range but need power in building 205 to supply magnet

►in case of Booster-Nuclotron run in late spring 2021 with inner target, use this opportunity to test beam detectors at DSS

SRC setup vs BM@N heavy ion setup

► Need improved detector setup, in particular, identification of arm protons

► SRC configuration is not consistent with the BMN setup for heavy ions:

• beam pipe within BM@N magnet, Si, GEM central tracker are obstacles for SRC nuclear fragments

• vacuum beam pipe from quadruple should be dismounted to install H_2 target, beam and fragment detectors

• DCH chambers are used for SRC, but are not suitable for heavy ions

→ need a couple of months between SRC and heavy ion run to reconfigure and align BM@N detectors

►Accelerator team are interested first of all to run Booster + Nuclotron with heavy ions, but BM@N needs vacuum transport channel for heavy ion run

► If there is delay with Booster + Nuclotron operation → run only Nuclotron with laser ion source

Thank you
for attention!