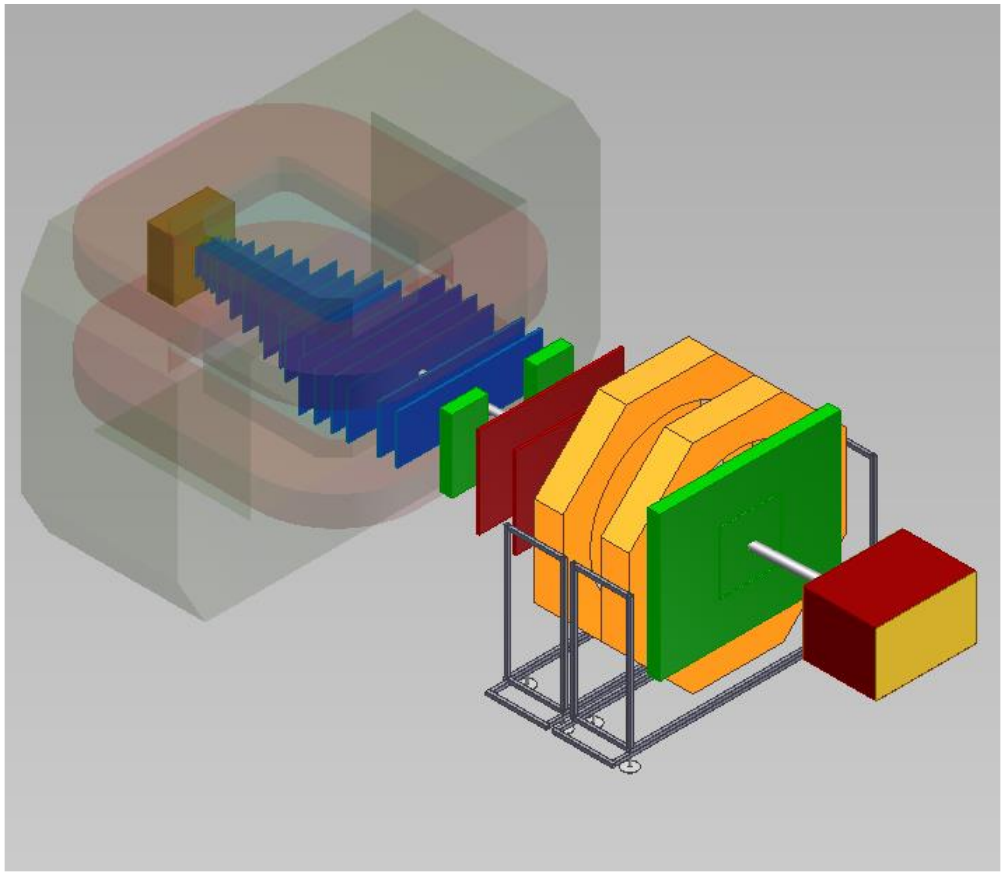
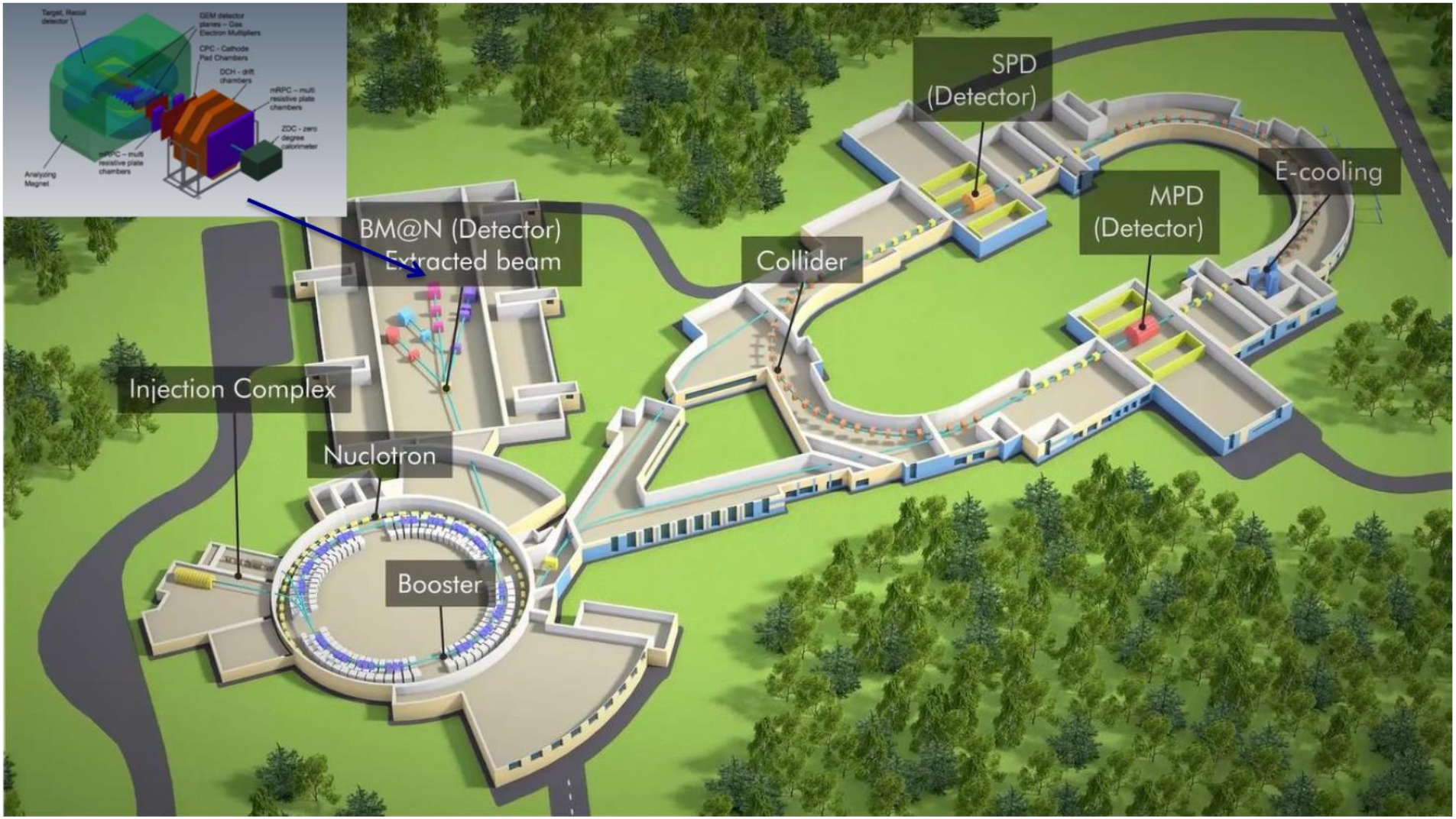
Progress of Baryonic Matter at Nuclotron

M.Kapishin



NICA Heavy Ion Complex

BM@N: heavy ion energy 1 - 4.5 GeV/n, beams: p to Au, Intensity up ~10^7 /s (Au)

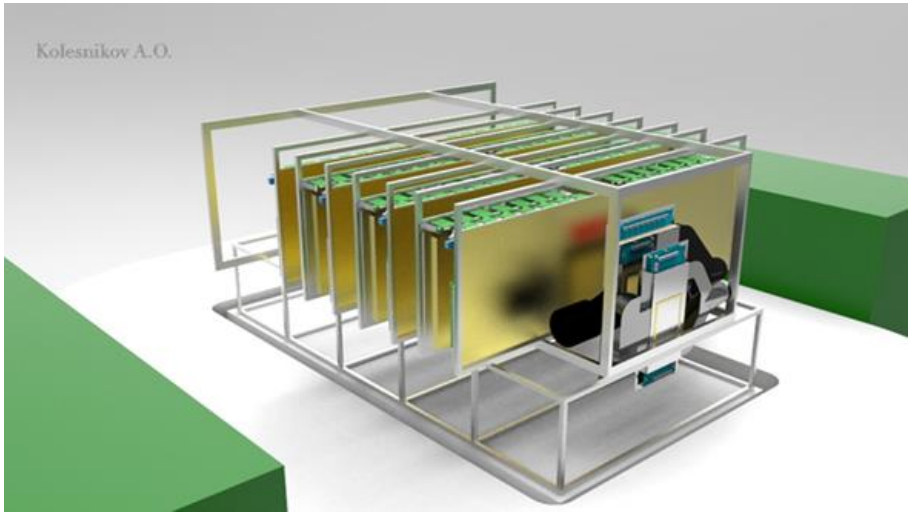


► BM@N runs with Ar and Kr beams and SRC measurement in March 2018

Forward silicon strip detectors in Ar / Kr runs

Central tracker in Ar / Kr runs, March 2018

Silicon detector group



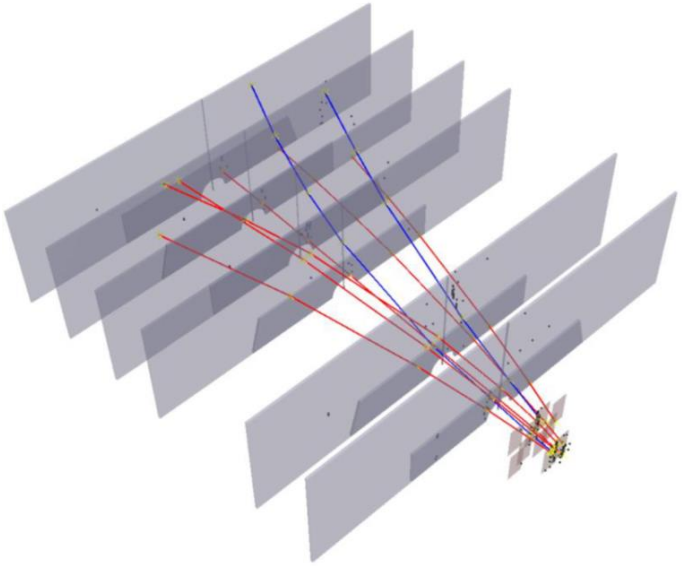
- **2-coordinate Si detector with strip pitch of 95/103 μm, full size of 25 x 25 cm^2**
- **Detector combined from 4 sub-detectors arranged around beam**

+ 2 smaller vertex detectors

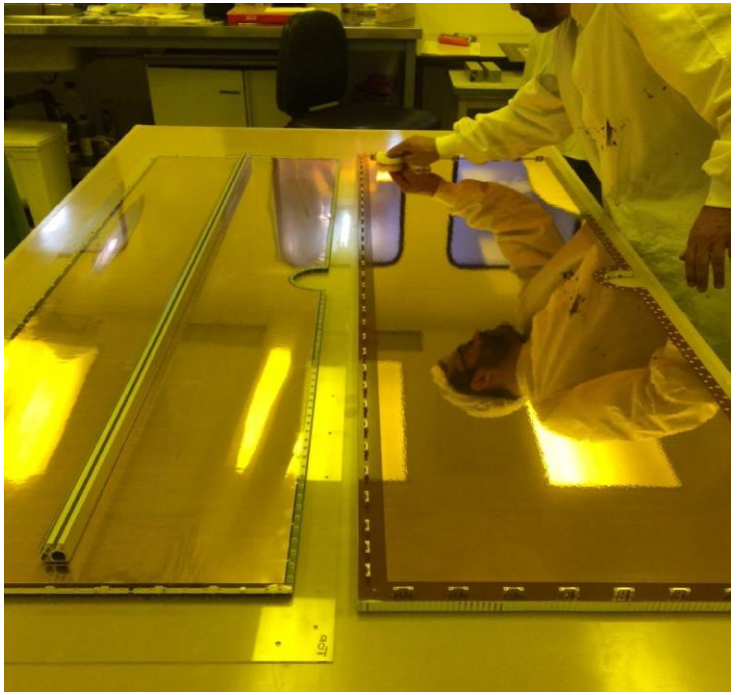
GEM detectors for central BM@N tracker

Ar / Kr runs, March 2018

Ar-target interaction reconstructed in central tracker



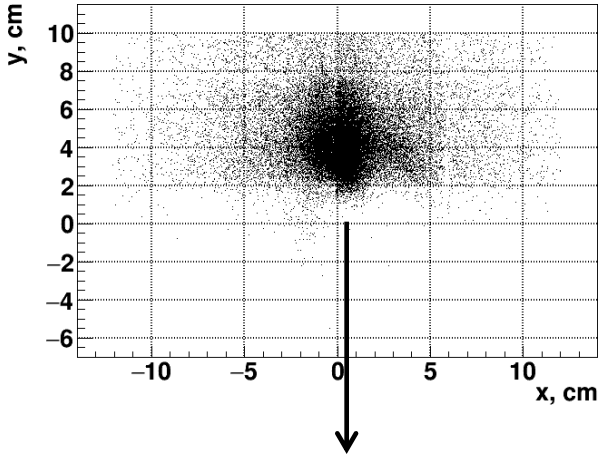
GEM production at CERN



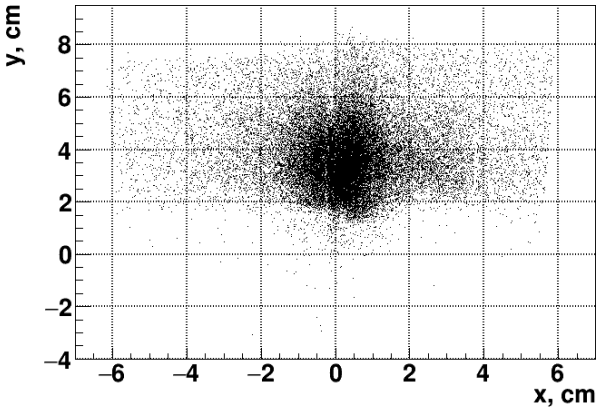
- **7 additional detectors of 163 x 39 cm^2 for lower part of GEM tracker are being produced at CERN workshop in 2019**

Tracks in forward silicon strip and GEM detectors in Ar run

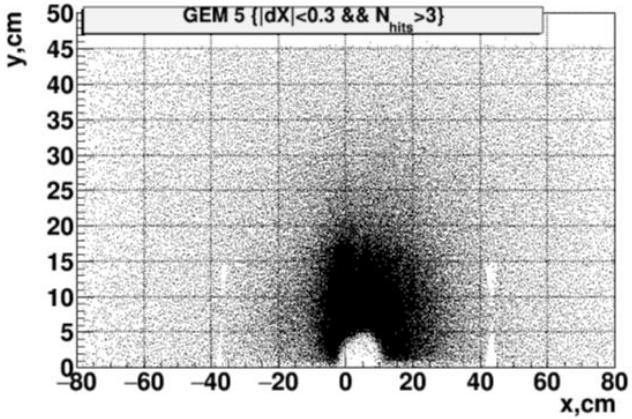
Si-3 track profile

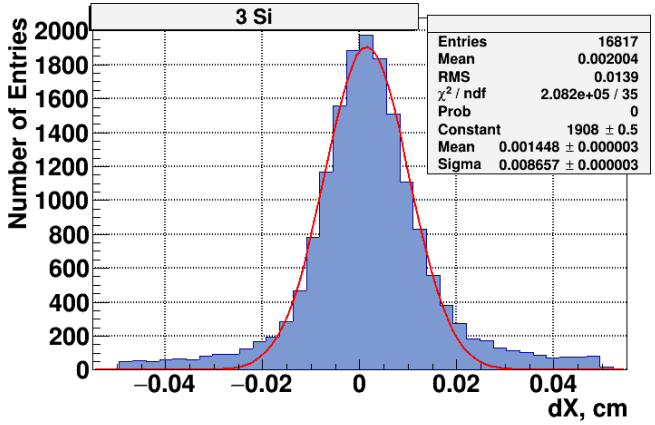


Si-2 track profile

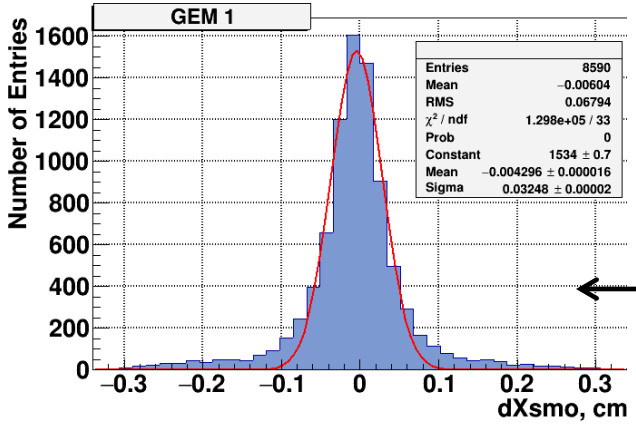


GEM-5 track profile

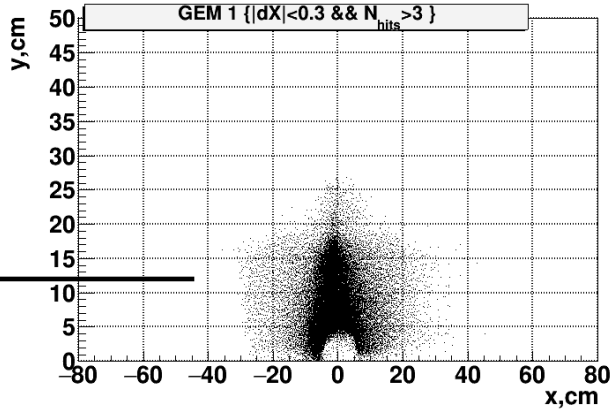




Si-3 detector residual vs GEM+Si track ~ 86 μm

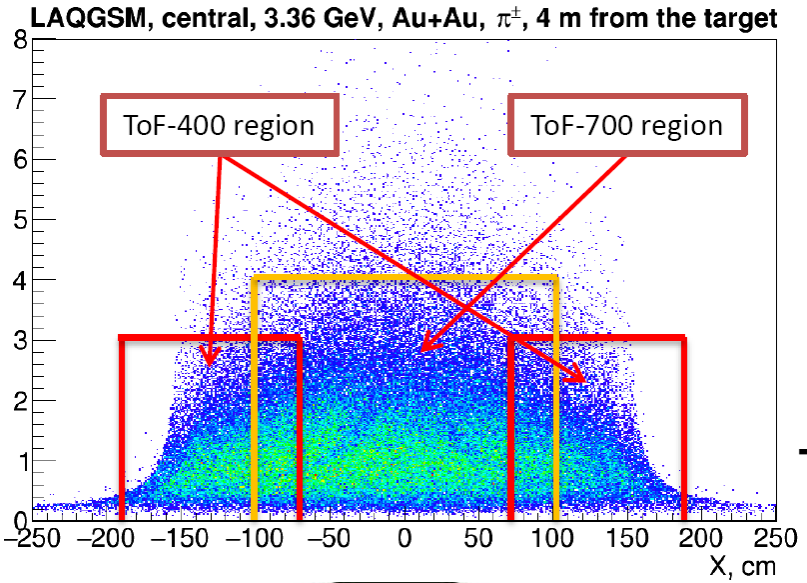


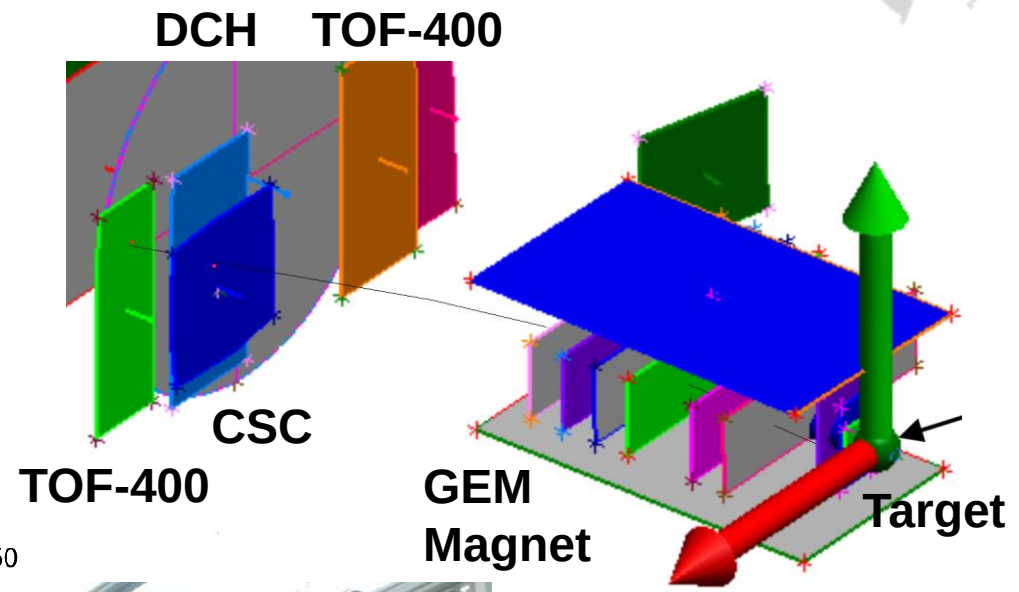
GEM-1 detector residual vs GEM+Si track ~ 320 μm

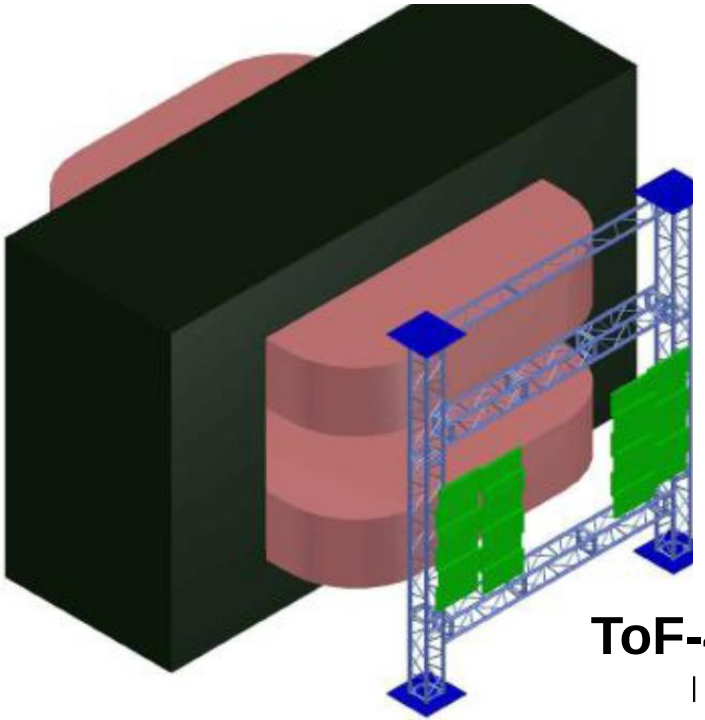


GEM-1 track profile

ToF-400 and ToF-700 based on mRPC







ToF-400 wall

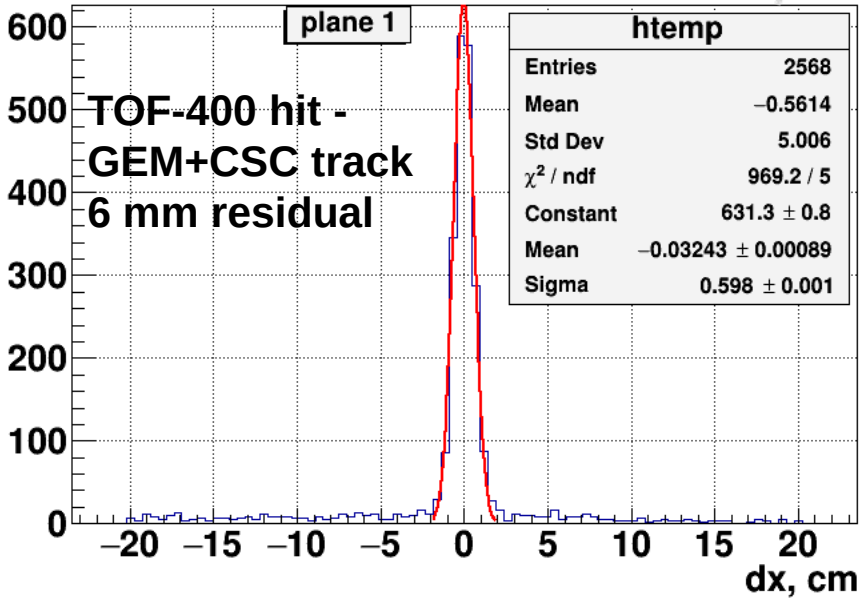
I experiment

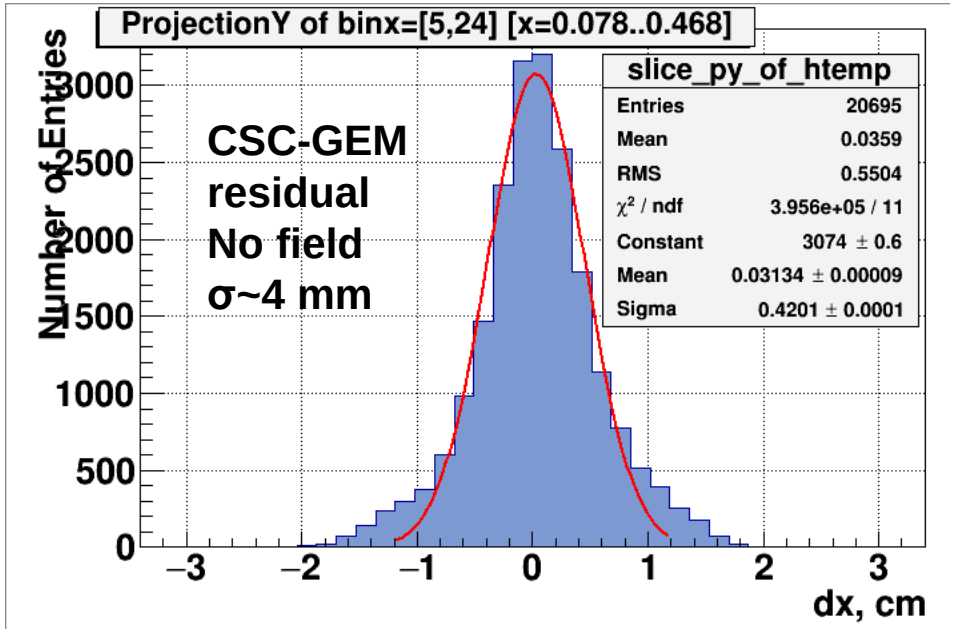
Link of GEM tracks to CSC and TOF-400

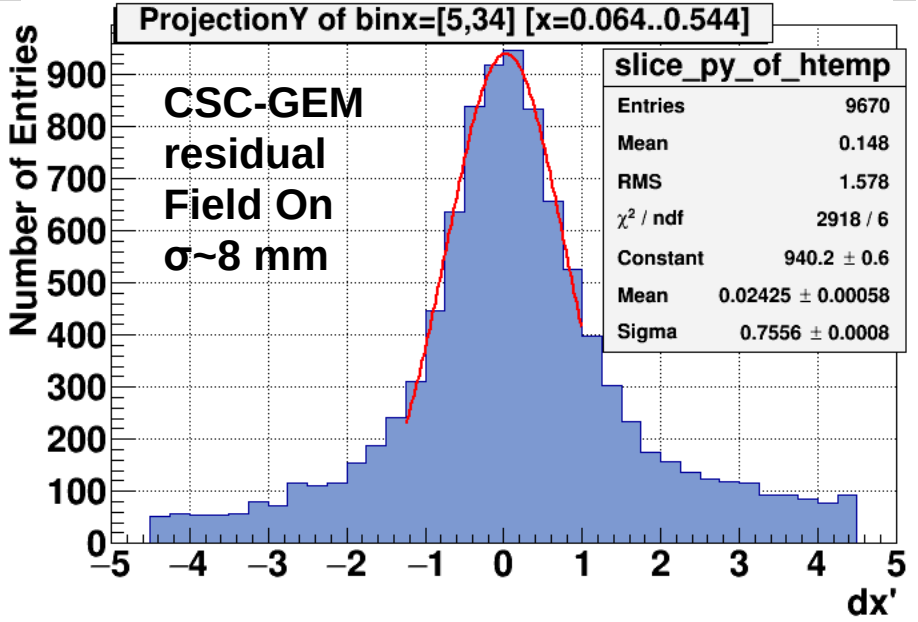
Interactions of Ar beam with targets:

Residuals of CSC hits to GEM tracks

Residuals of ToF-400 to CSC+GEM tracks



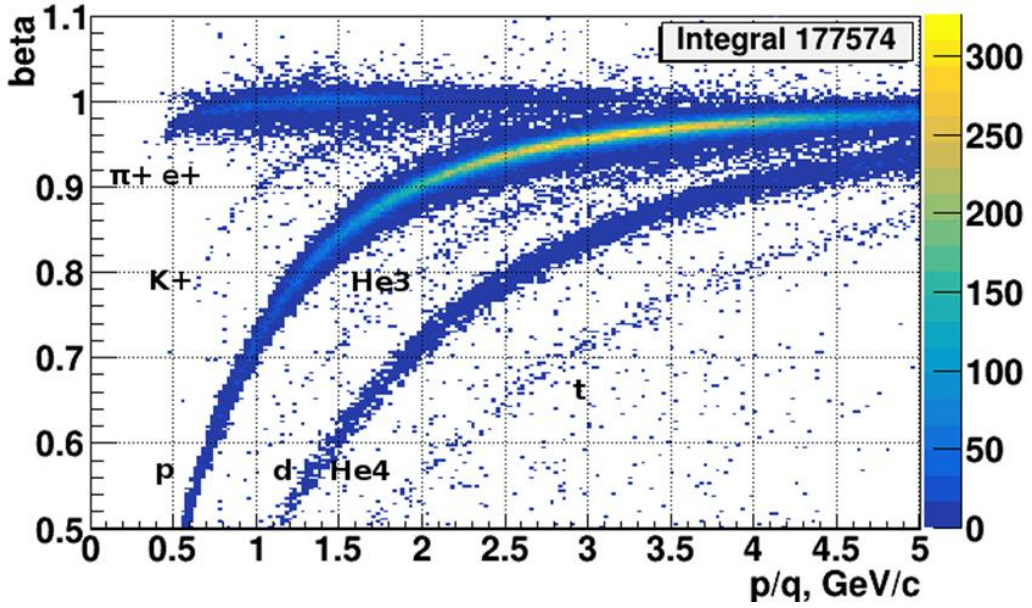


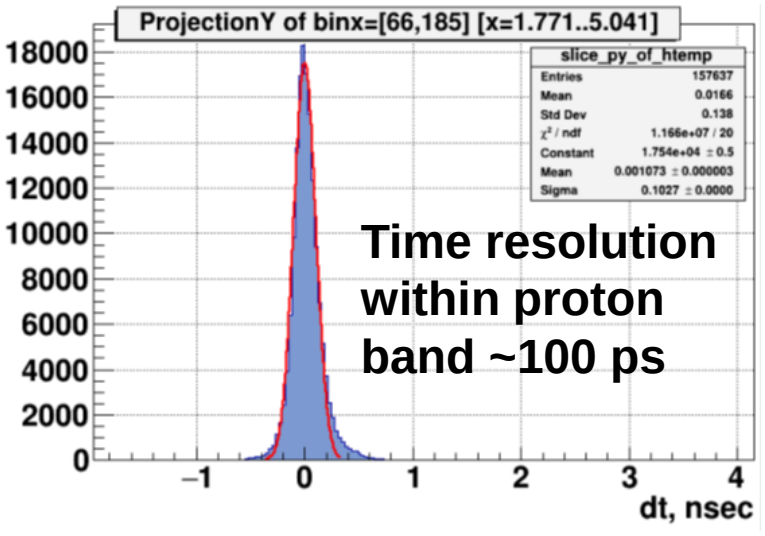


Present status of TOF-400 identification

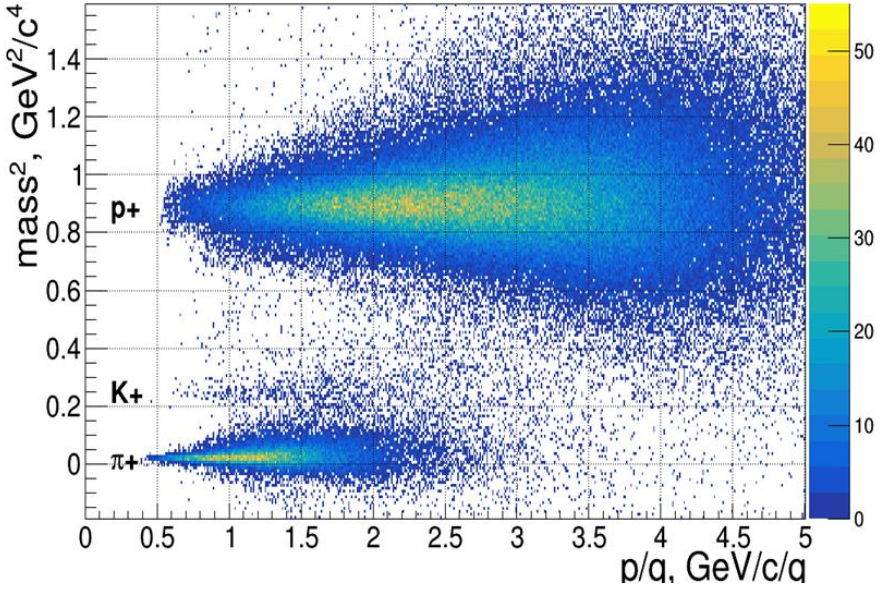
Ar beam , 3.2 AGeV , Ar + Al,Cu → X

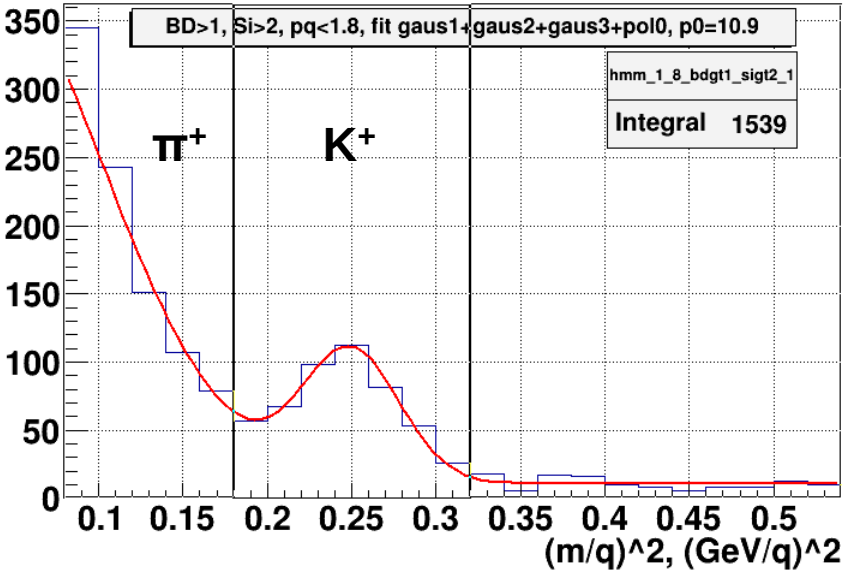
V.Plotnikov, M.Rumyantsev





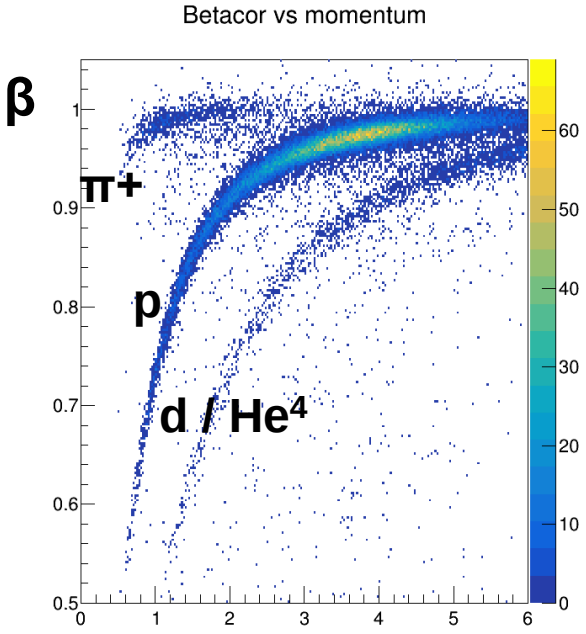
Time resolution within proton band ~100 ps

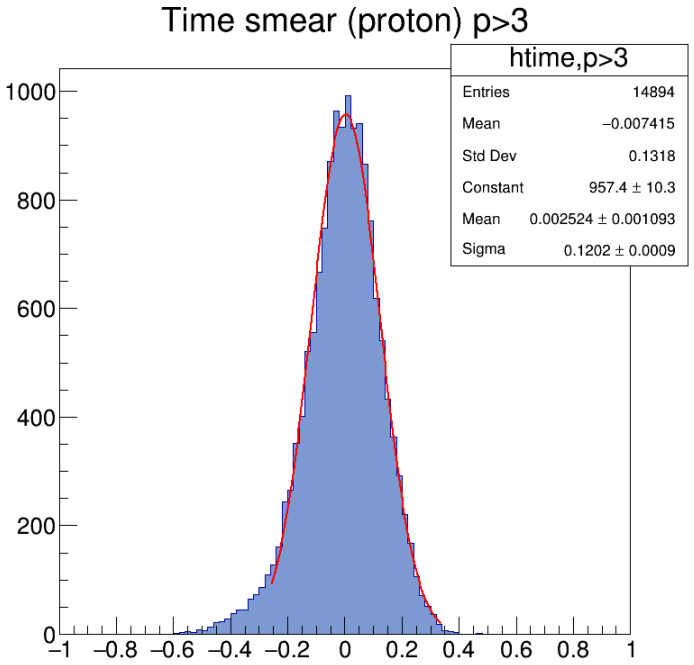


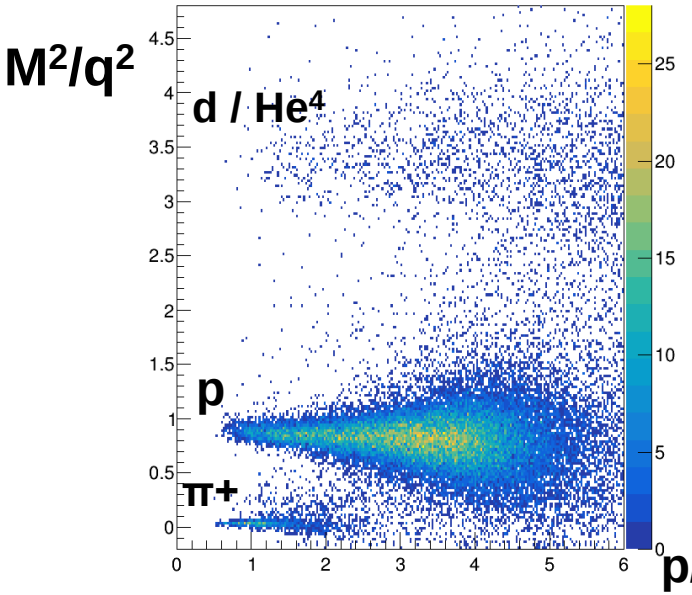


Present status of TOF-700 identification

Ar beam , 3.2 AGeV , Ar + Al,Cu → X



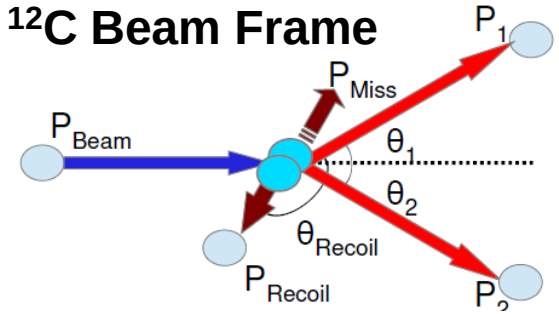


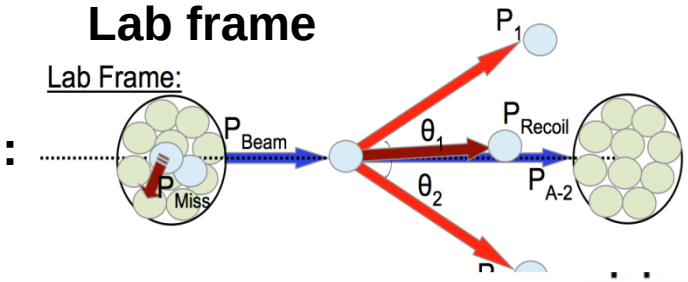


Time resolution within proton band ~120 ps

A proposal for BM@N experiment

to study SRC with hard inverse kinematic reactions

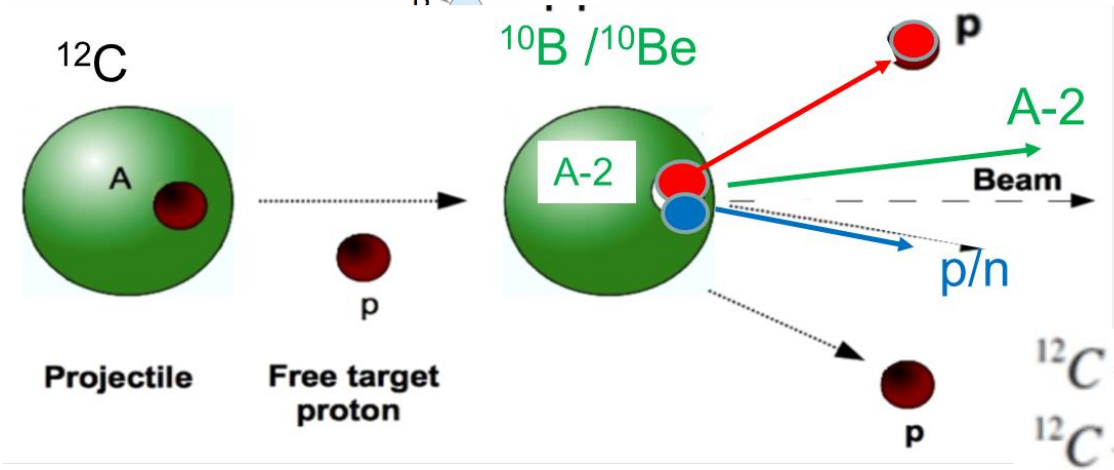




JINR (Dubna): BM@N
Israel: Tel Aviv University
Germany: TUD and GSI
USA: MIT
FRANCE: CEA

Objectives:

- identify 2N-SRC events with inverse kinematics
- study isospin decomposition of 2N-SRC
- study A-2 spectator nuclear system

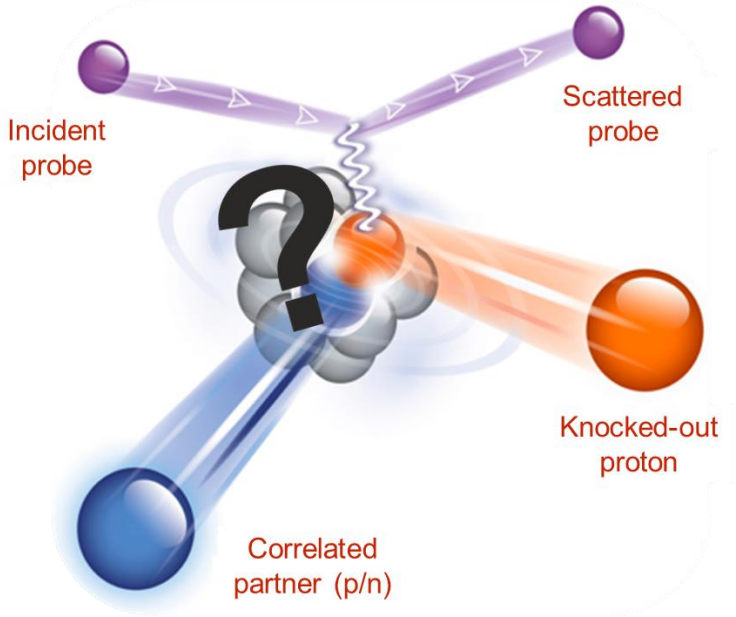


►First SRC @ BMN run in March 2018

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

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

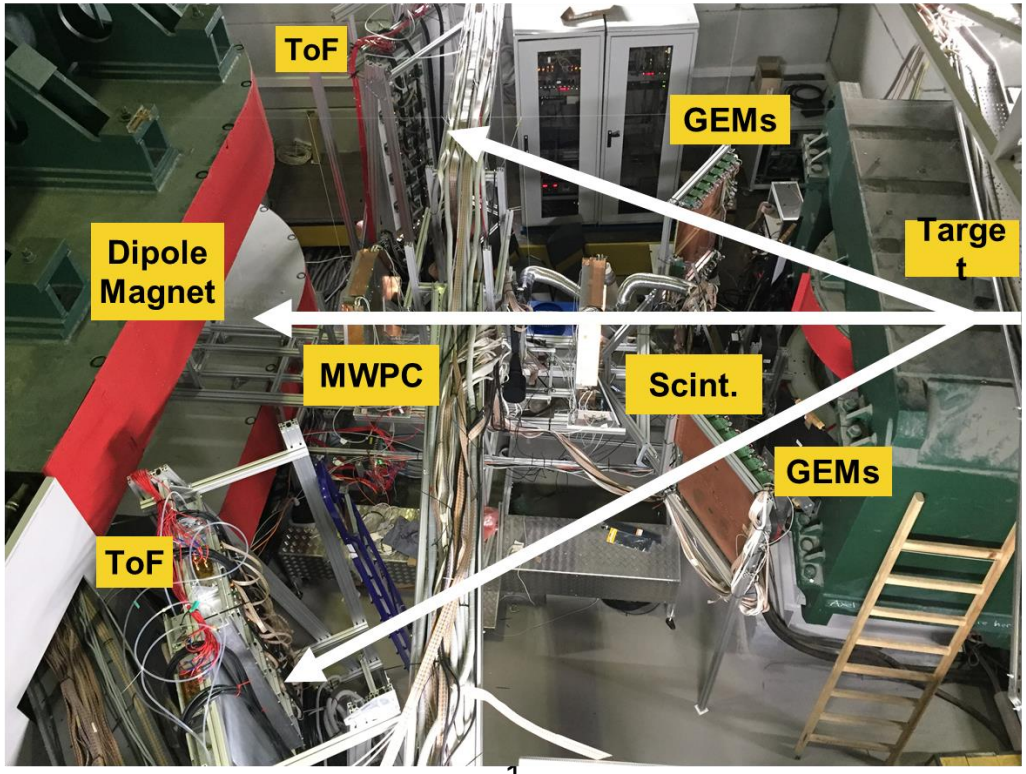
First Fully Exclusive Measurement of Short-Range Correlated Nucleons in Inverse Kinematics at JINR



Planned publications:

Identify quasi-elastic (p,2p) with 4GeV/c/u beam

Study A-2 residual system after SRC knockout

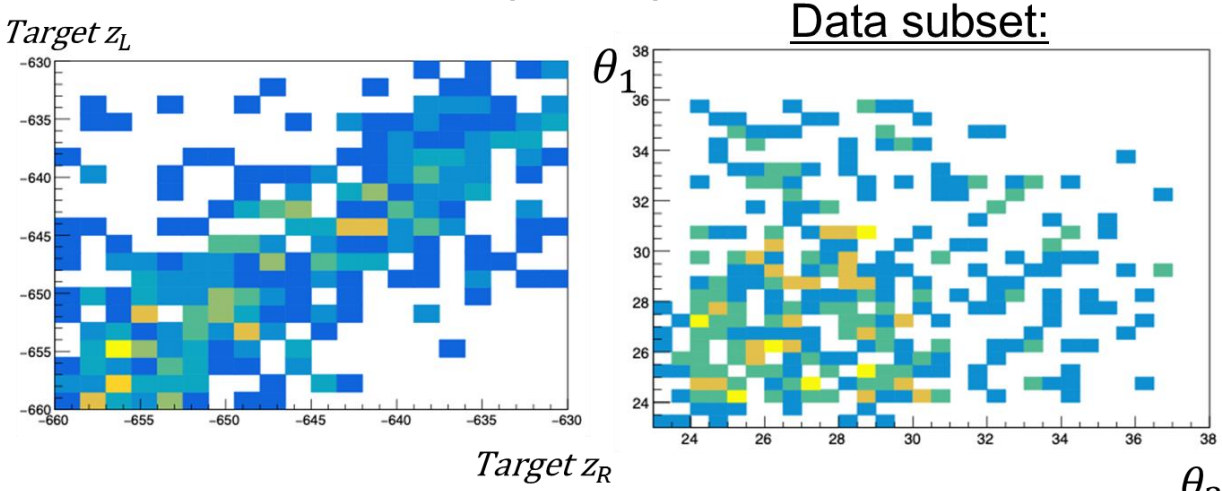


SRC@BMN Analysis Team

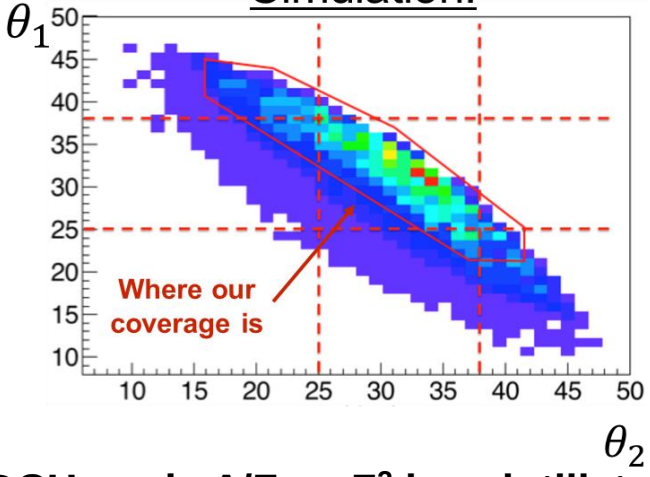
Overview of Analysis Achievements

Quasi-elastic C(p,2p)X

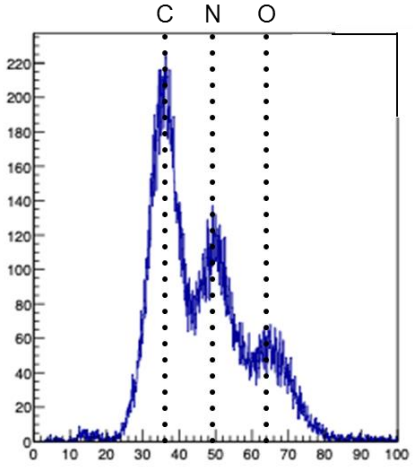
Data subset:

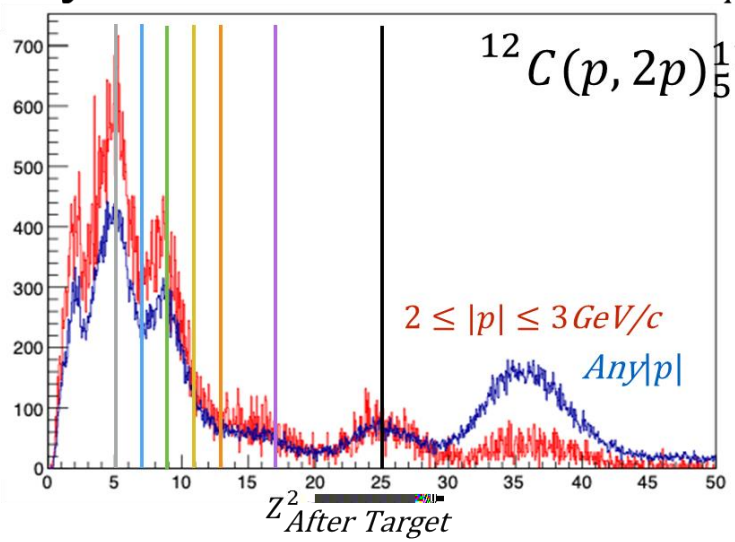


Simulation:

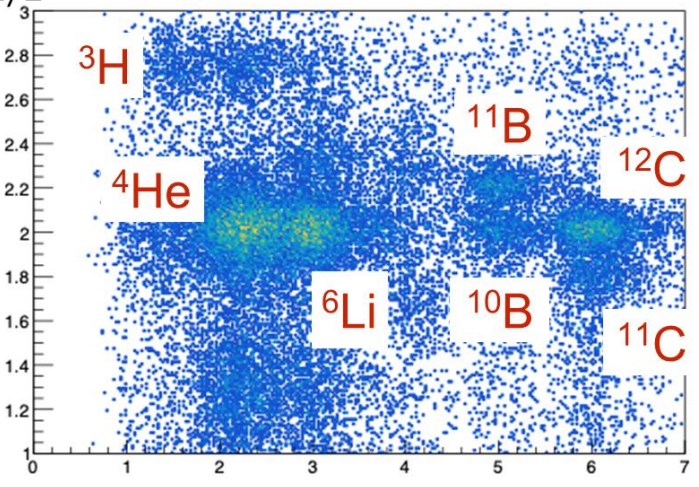


A-2 Residual System





DCH angle A/Z vs Z² in scintillator



What else is needed for first publications

Planned publications:

Identify quasi-elastic (p,2p) with 4GeV/c/u beam

Study A-2 residual system after SRC knockout

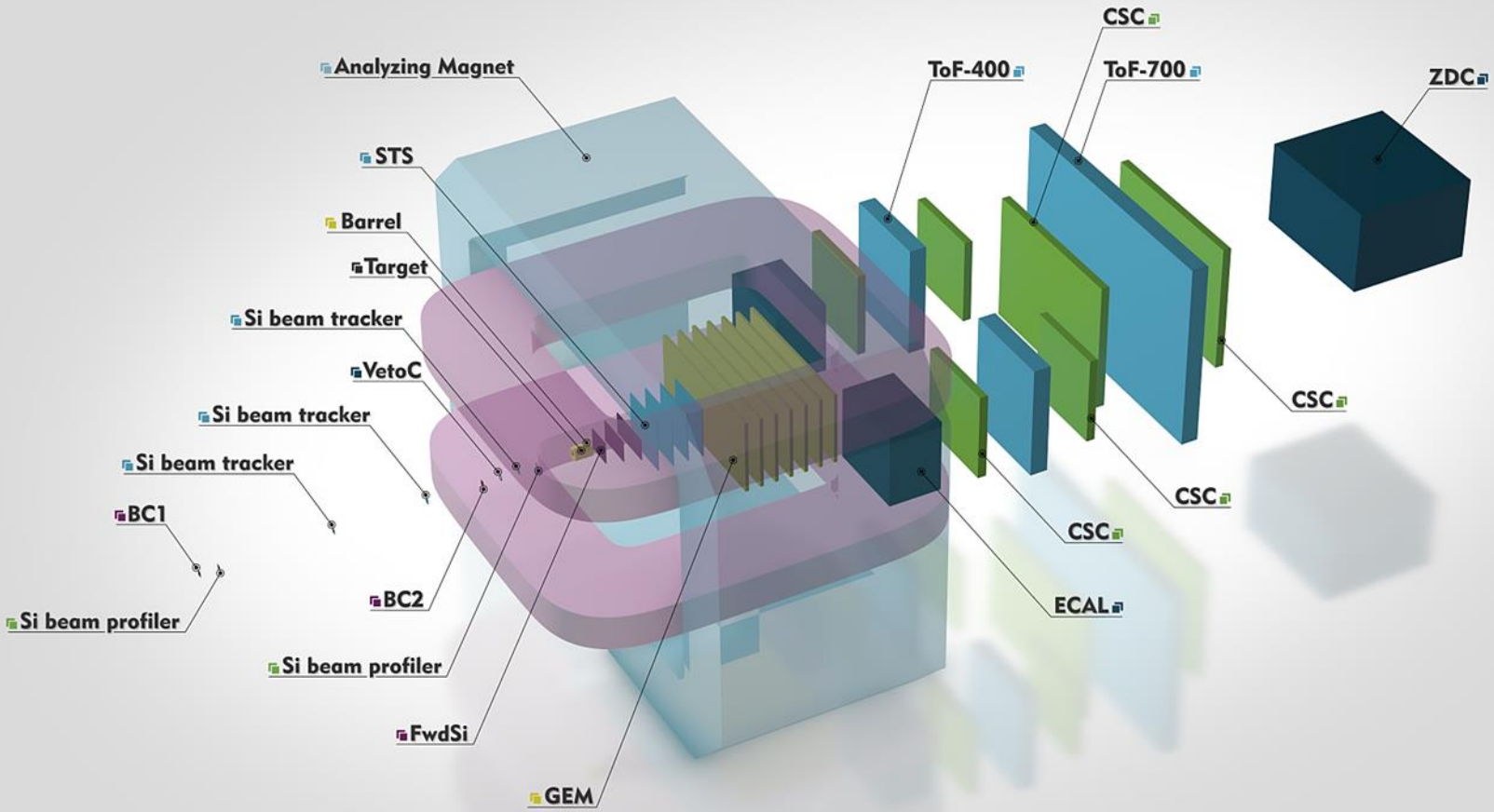
Quasi-elastic C(p,2p)X

- Purer event sample
- Optics calibration
- Understanding of GEMs with ToF system

A-2 Residual System

- No. of tracks discrimination
- Clean SRC event sample using ToF/GEM forward arms with beam tracking

Configuration of BM@N detectors (without beampipe)

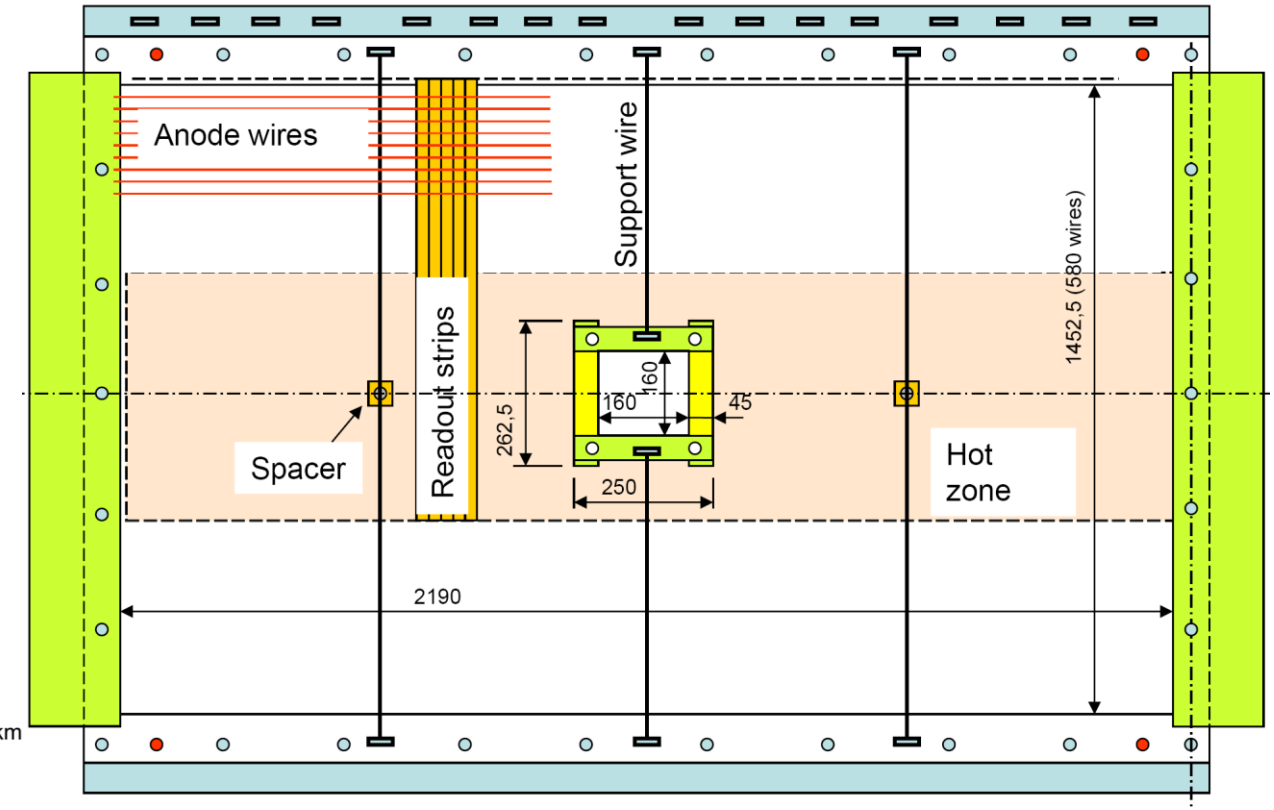


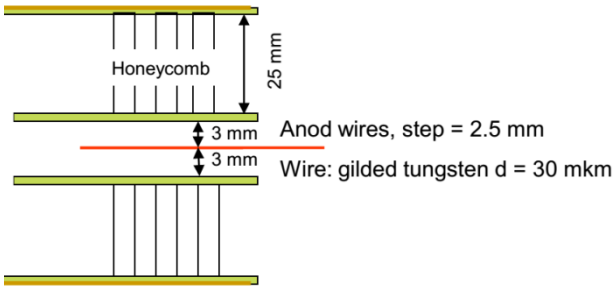
New Cathode Strip Chambers as Outer tracker

A.Vishnevsky + team

Need 4 CSC chambers in front and behind ToF-400

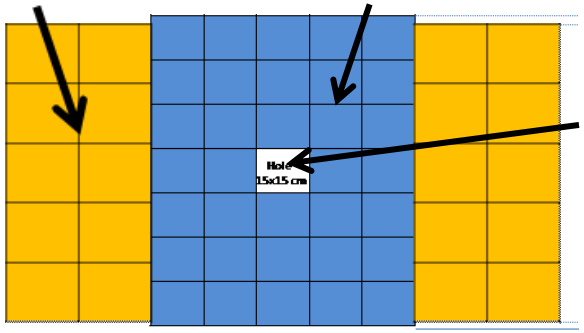
Design of 2 big CSC chambers in front and behind ToF-700



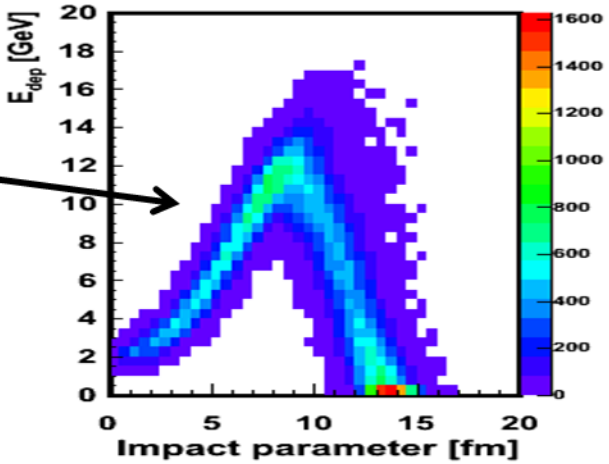


MPD / CBM hadron ZDC calorimeter

CBM modules MPD modules

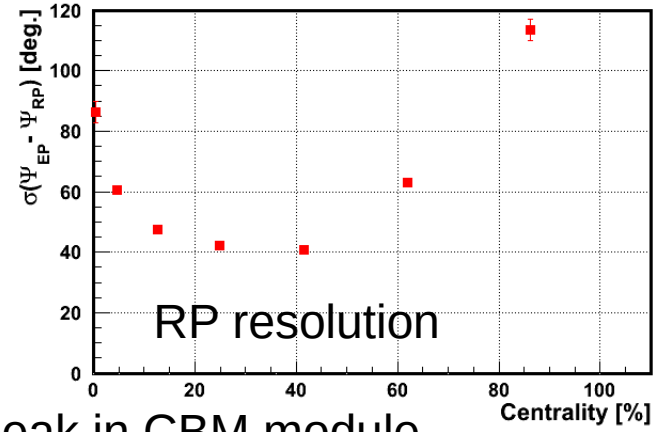


dE/dx detector to resolve central / peripheral interactions

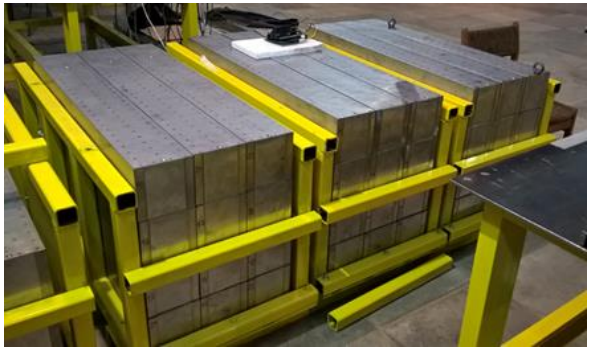


- **Modern technics;**
- **Light yield ~x10 higher;**
- **Detection of low energies;**
- **Stable operation at high count rates;**
- **Experience in operation for later MPD/CBM experiments**
- **Motivated team**

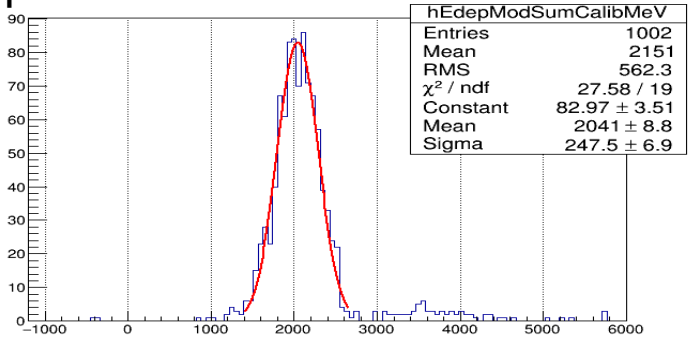
CBM module in BM@N



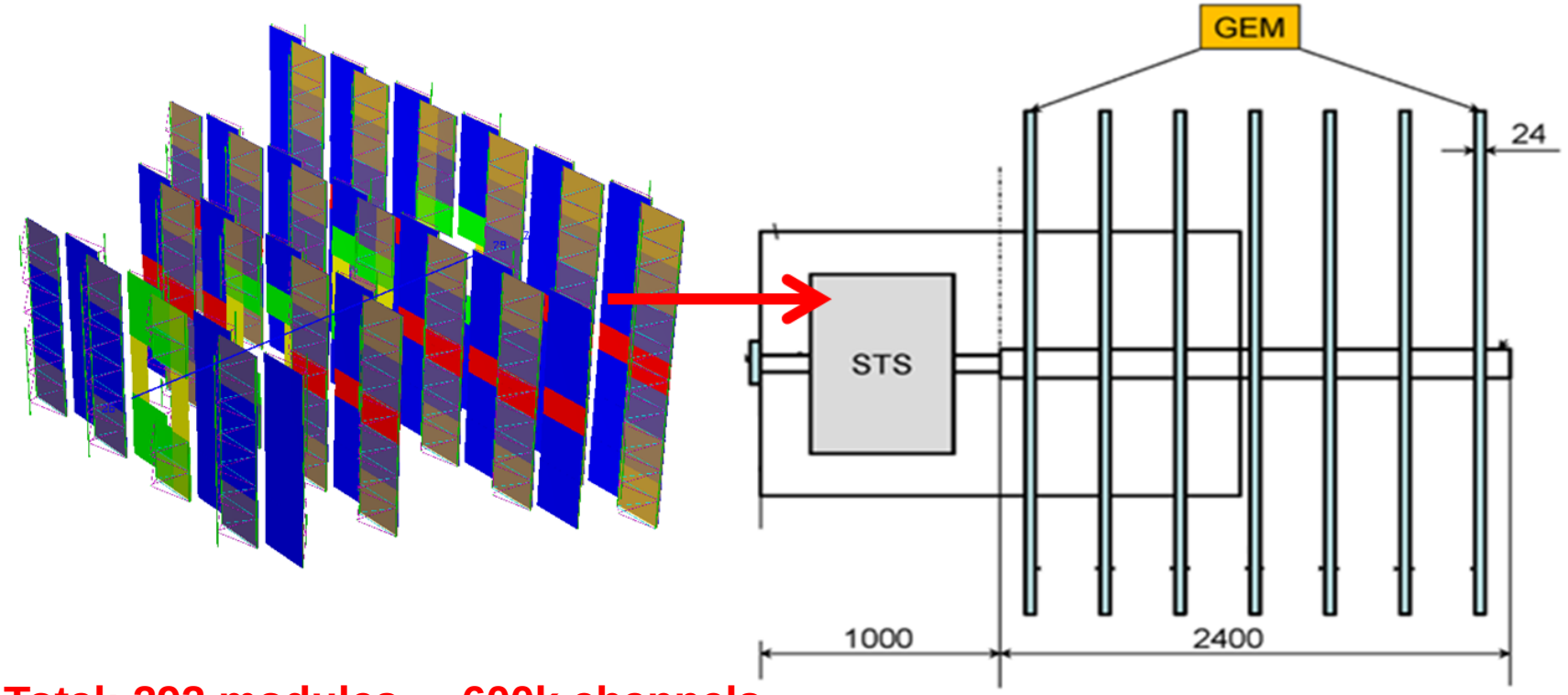
MPD FHCAL modules



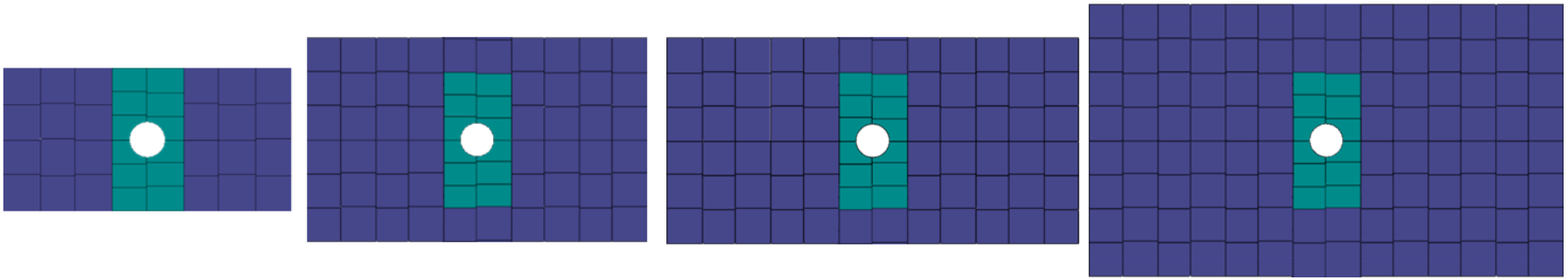
Ar peak in CBM module



Upgrade of central tracker with CBM STS



Total: 292 modules, ~600k channels



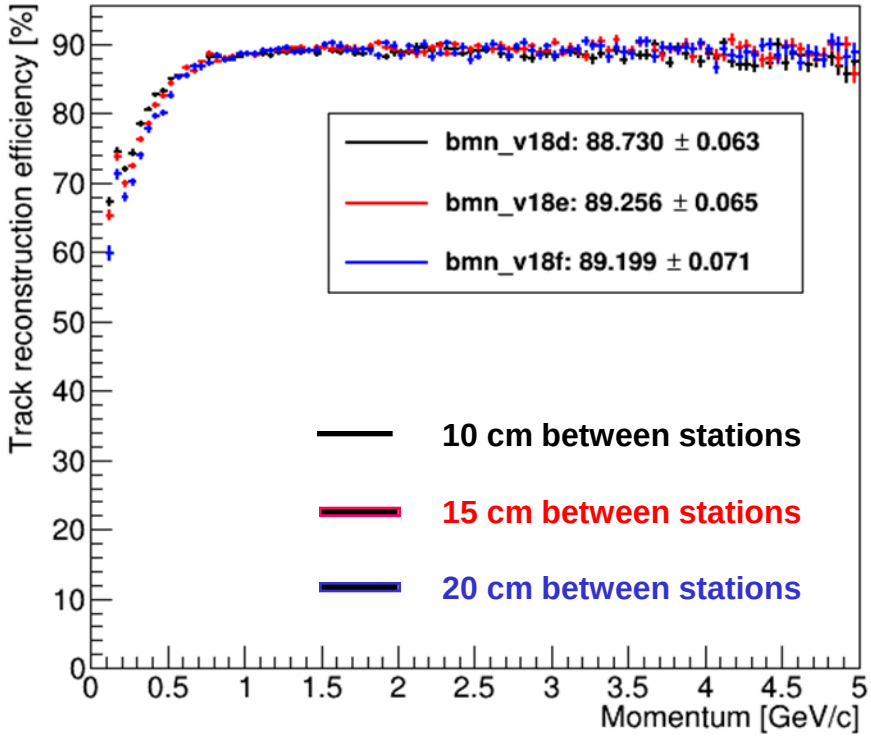
STS-1 **STS-2** **STS-3** **STS-4**

Simulation of BM@N STS tracker

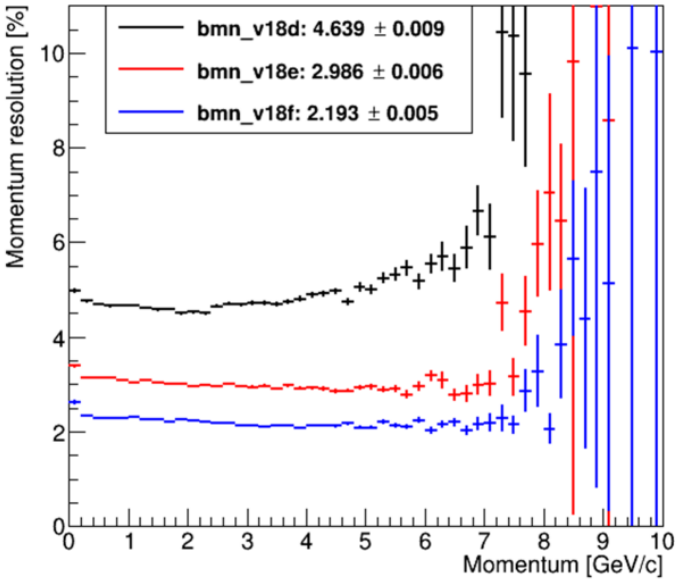
Eugeny Lavrik (GSI)

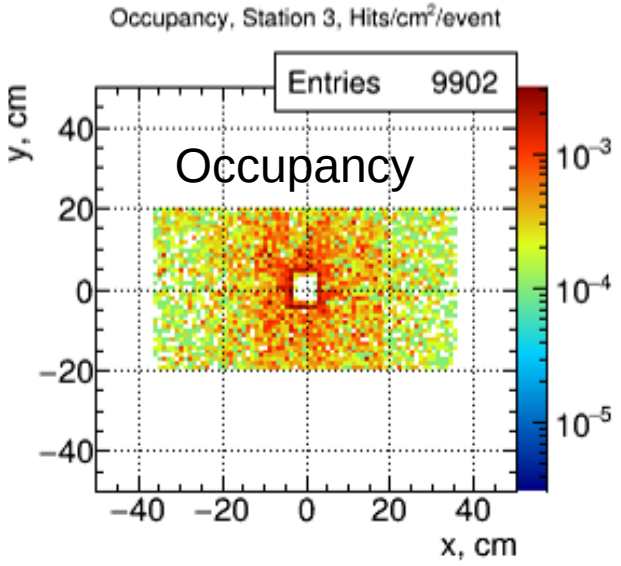
Simulations of min. bias Au+Au collisions at 4A GeV for B·L = 0.44 Tm

Track reconstruction efficiency



Momentum resolution



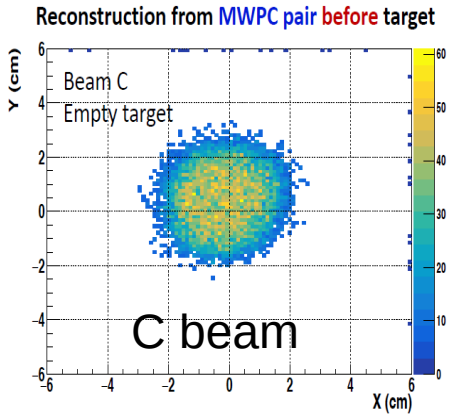


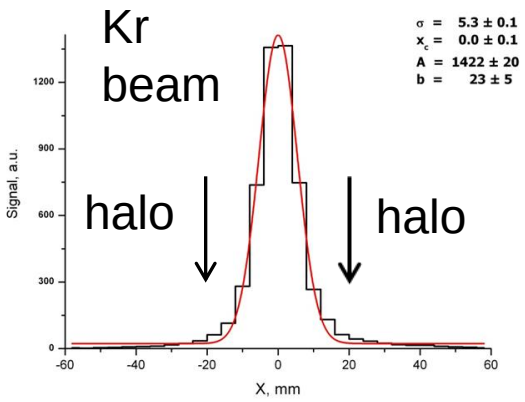
FLUKA simulation of BM@N beam line

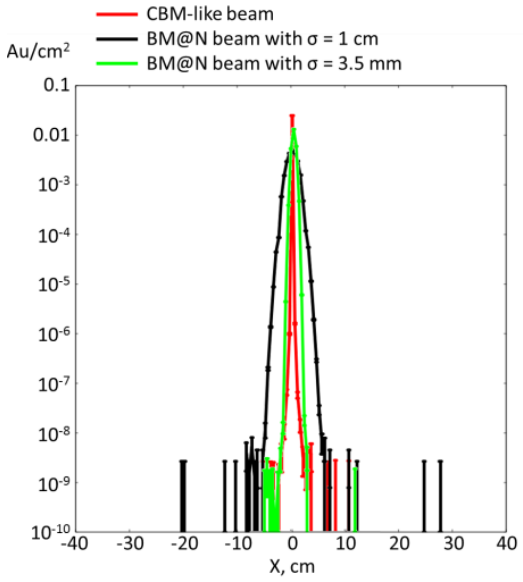
Anna Senger (GSI)

BM@N Setup with vacuum beam pipe downstream the target
Au-beam with energy of 5A GeV, 2x10^6 Au ions/s
Beam parameters:

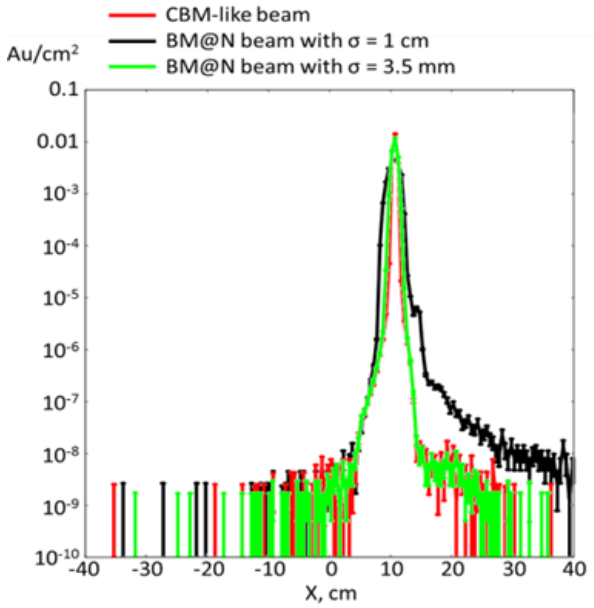
- To reproduce halo of Nuclotron beam: Gauss with sigma 1 cm, divergence 1.5 mrad
- Improved Nuclotron beam: Gauss with sigma 0.35 cm, divergence 1.5 mrad







Beam profiles at 30 cm downstream target

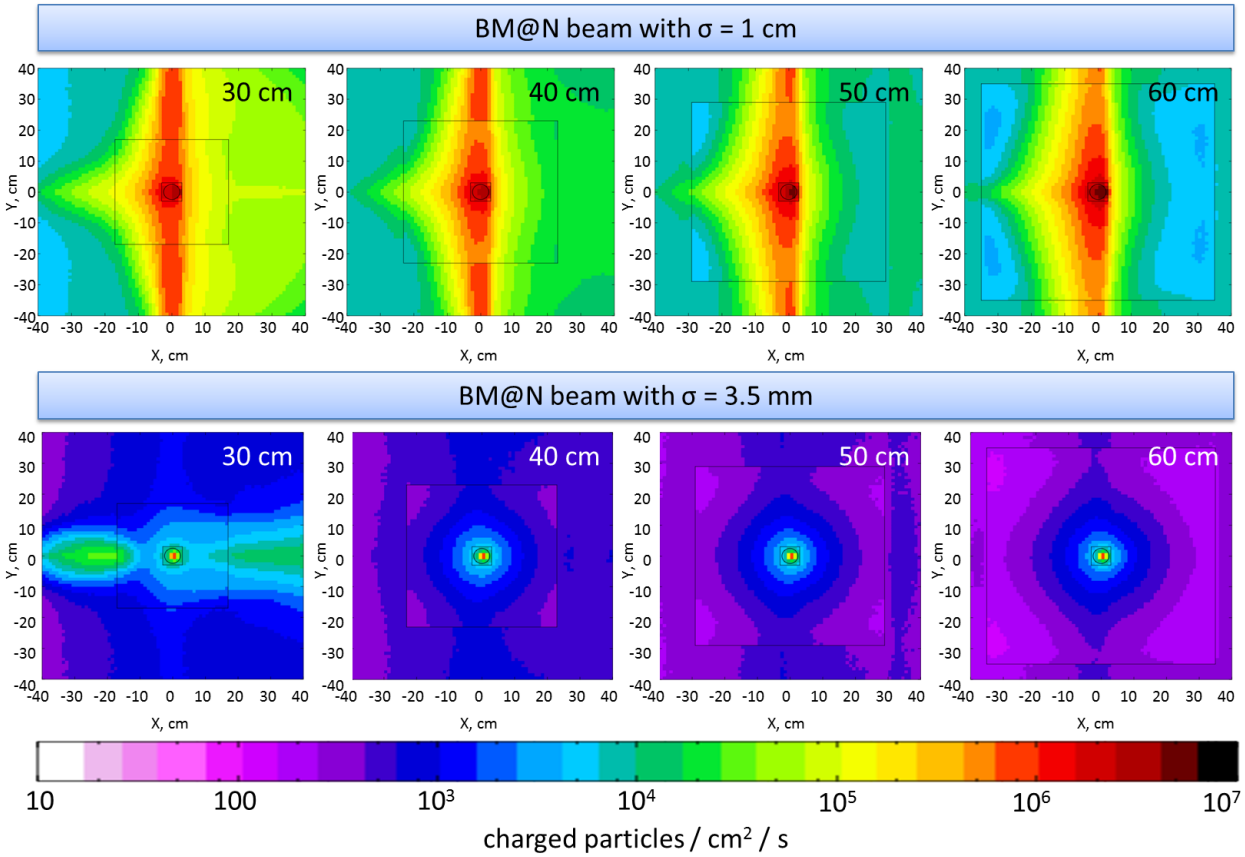


Beam profiles at 420 cm downstream target

FLUKA simulation of BM@N beam line

Charged particle densities in 4 STS stations

Anna Senger (GSI)



Nuclotron beam $2x10^6$ Au ions/s	STS radiation damage (2 months)	GEMs radiation damage (2 months)	STS channel inefficiency	GEMs Channel Inefficiency
Gauss σ = 1 cm	severe	mild	$3 \cdot 10^{-3}$	48 -96 %
Gauss σ = 0.35 cm	no	no	$1.5 \cdot 10^{-4}$	0.5 – 1 %

Nuclotron - BM@N beam line

Need upgrade of Nuclotron - BM@N transport channel for heavy ion program:

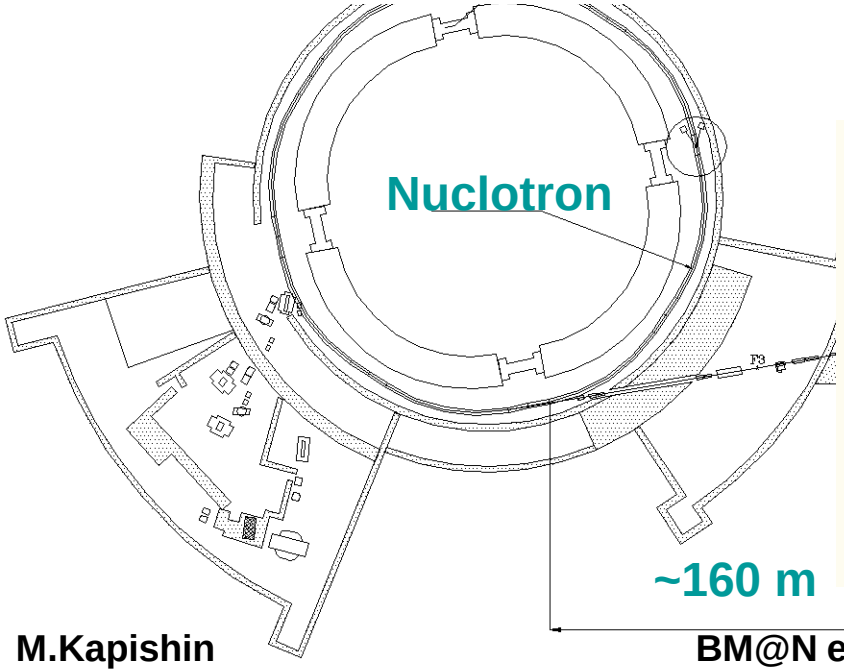
→ replace air intervals / foils with vacuum beam pipe along 160 m of BM@N transport line to get minimum dead material

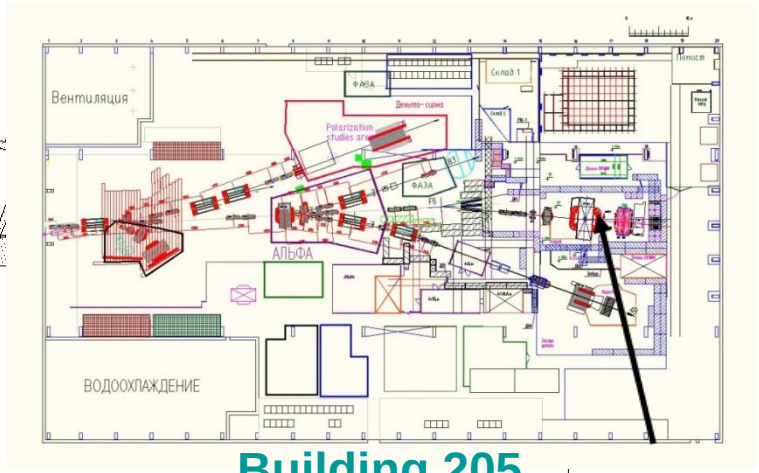
→ implement non-destructive beam position monitoring on movable vacuum inserts

→ implement instruments to limit beam size and spread at BM@N target

→ implement vacuum beam pipe inside BM@N from target to end

►BM@N can not start stage 1 heavy ion runs until the beam transport channel upgrade is done





~160 m

Building 205

BM@N

BM@N experiment

Beam parameters and setup at different stages of BM@N experiment

Year	2016	2017 spring	2018 spring	2020	2022 and later
Beam	d(↑)	C	Ar,Kr, C(SRC)	Au	Au,p
Max.intensity per spill	0.5M	0.5M	0.5M	1M	2M
Trigger rate, Hz	5k	5k	10k	10k	20k→50k
Central tracker status	6 GEM half planes	6 GEM half planes	6 GEM half planes + 3 small Si planes	7 GEM full planes + 3 small Si planes	7 GEM full planes + small + large Si planes
Experimental status	technical run	technical run	technical run+physics	stage1 physics	stage2 physics

►Need upgrade of Nuclotron
- BM@N transport channel

Present status and next plans

- Reconstruction and analysis of interactions of Ar 3.2 AGeV , Kr 2.4 (2.9) AGeV beams with targets and SRC data are progressing
- Simulation of upgraded configuration for heavy ion program is going on

BM@N plans for heavy ion runs in 2020-2022:

- Collaborate with CBM to produce and install large aperture STS silicon detectors in front of GEM setup
- Extend GEM central tracker and CSC outer tracker to full configuration
- Install MPD / CBM type of hadron ZDC calorimeter
- Implement vacuum beam pipe through BM@N setup

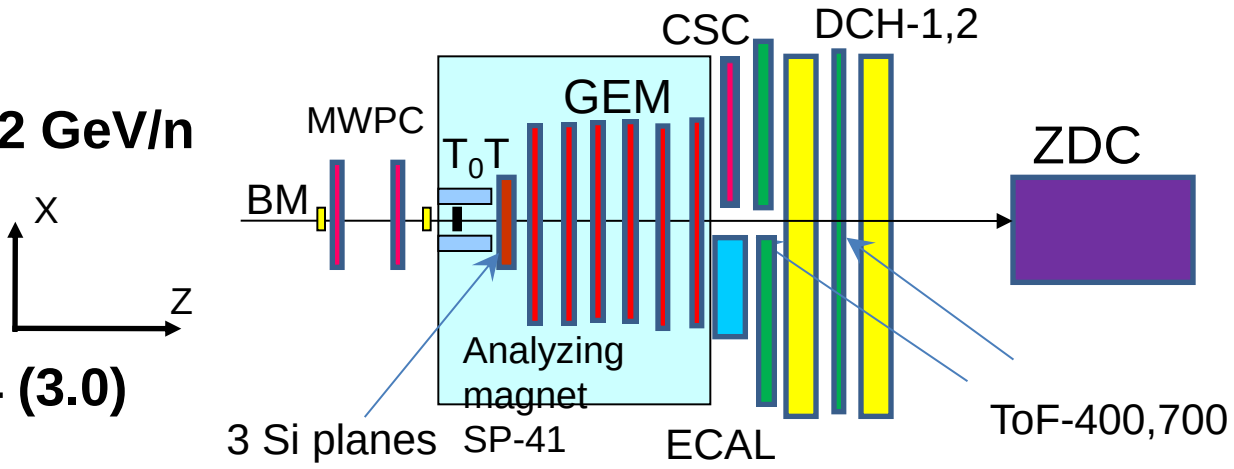
Thank you
for attention!

Backup slides

BM@N run with Ar and Kr beams in March 2018

Ar beam, T_0= 3.2 GeV/n

Kr beam, T_0= 2.4 (3.0) GeV/n



- **Central tracker inside analyzing magnet → 6 GEM detectors 163 x 45 cm² and forward Si strip detectors for tracking**
- **ToF system, trigger detectors, hadron and EM calorimeters, outer tracker**

Program:

- **Measure inelastic reactions Ar (Kr) + target → X on targets Al, Cu, Sn, Pb**

→ Hyperon production measured in central tracker (Si + GEM)

→ Charged particles and nuclear fragments identified with ToF

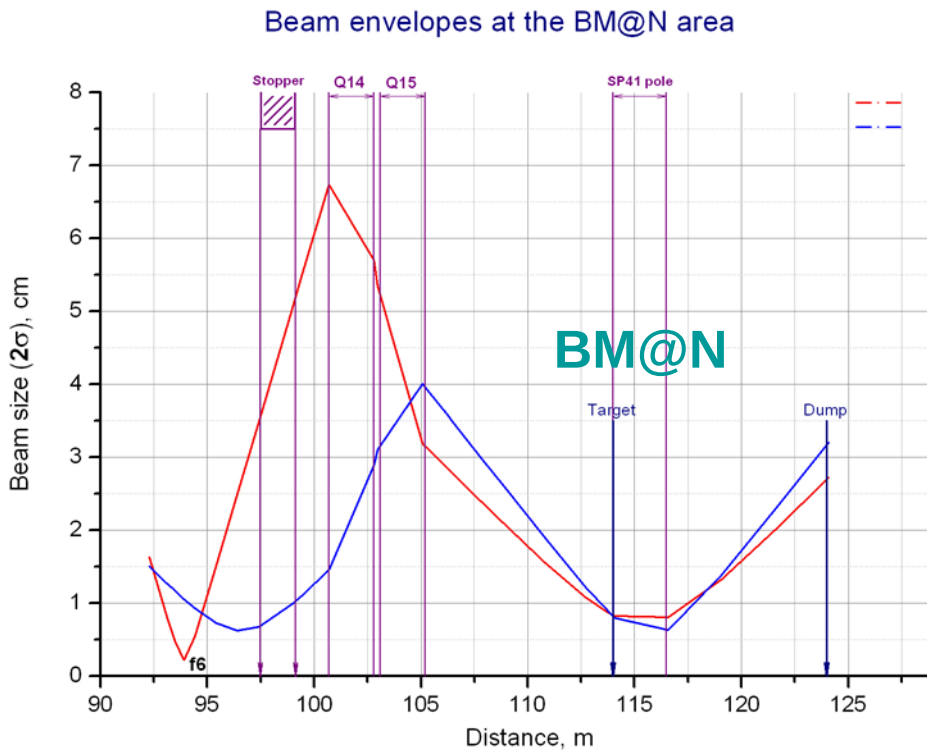
→ Gamma and multi-gamma states identified in ECAL

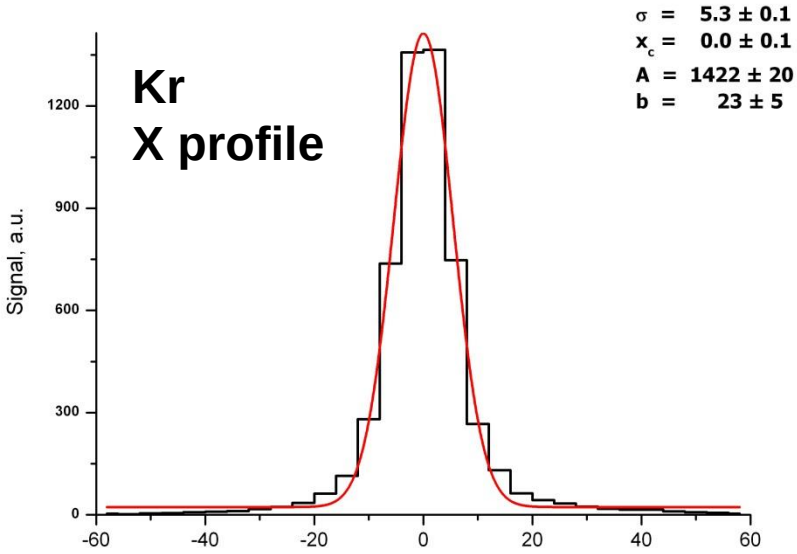
+ analyze data from previous technical run with Carbon beam of 3.5 - 4.5 GeV/n

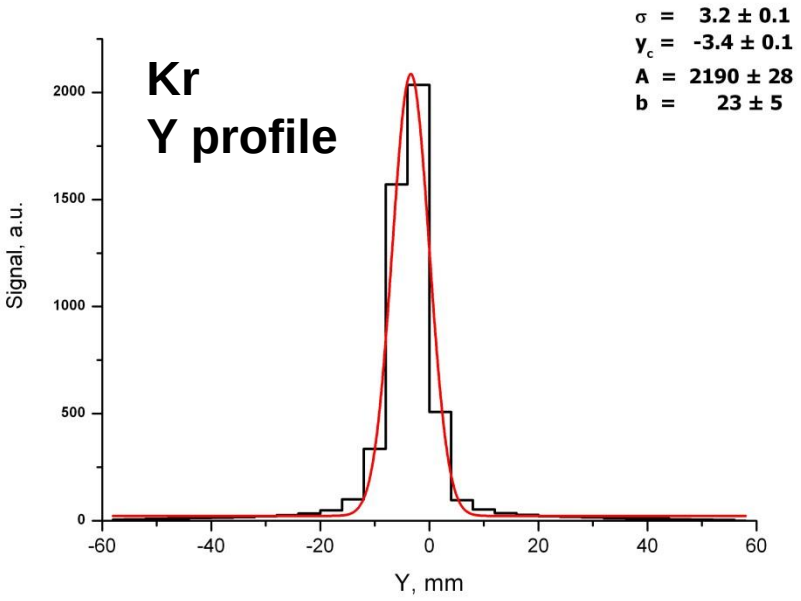
BM@N beam profile

C^{12} , Ar, Kr beam profiles measured by Nuclotron beam group

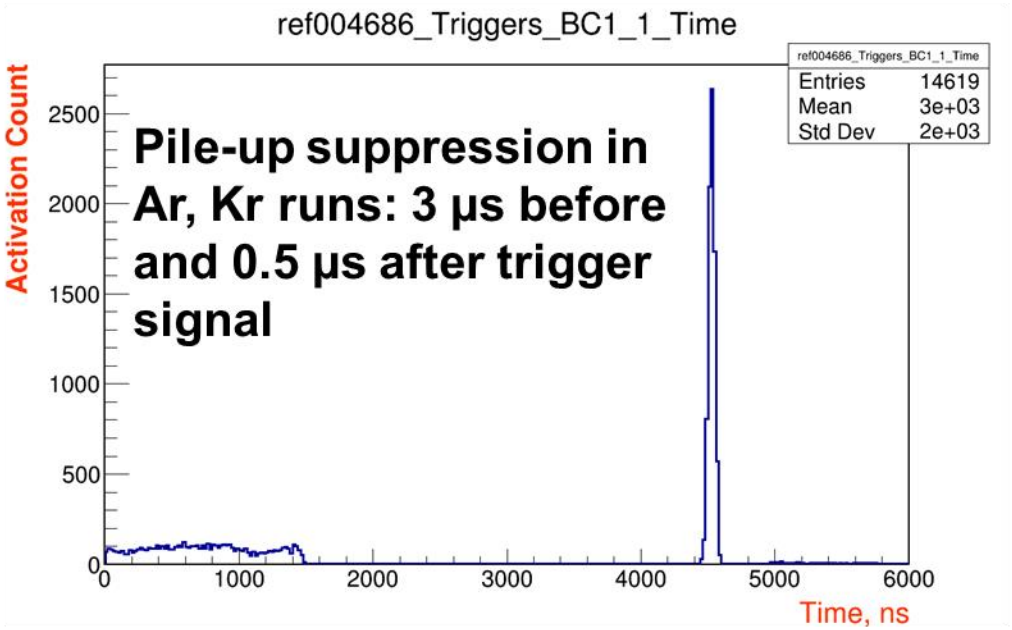
C^{12} 2017	Ar 2018	Kr 2018
σ_X = 6 mm	5 mm	5.3 mm
σ_Y = 4.9 mm	5 mm	3.2 mm



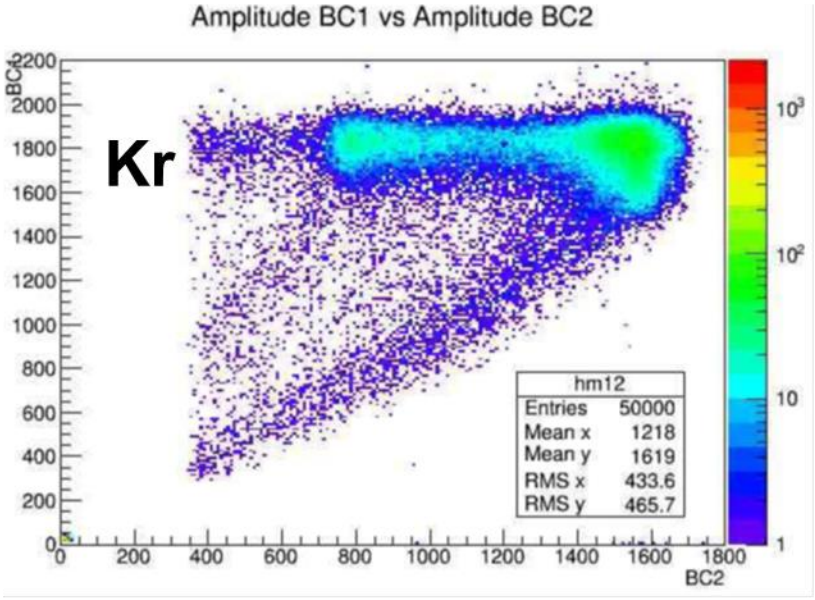


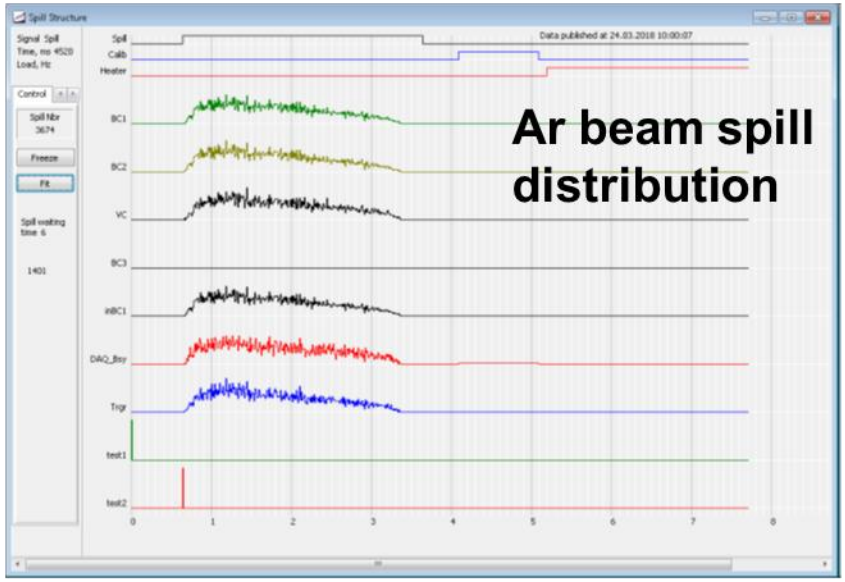


Beam structure & pile-up suppression

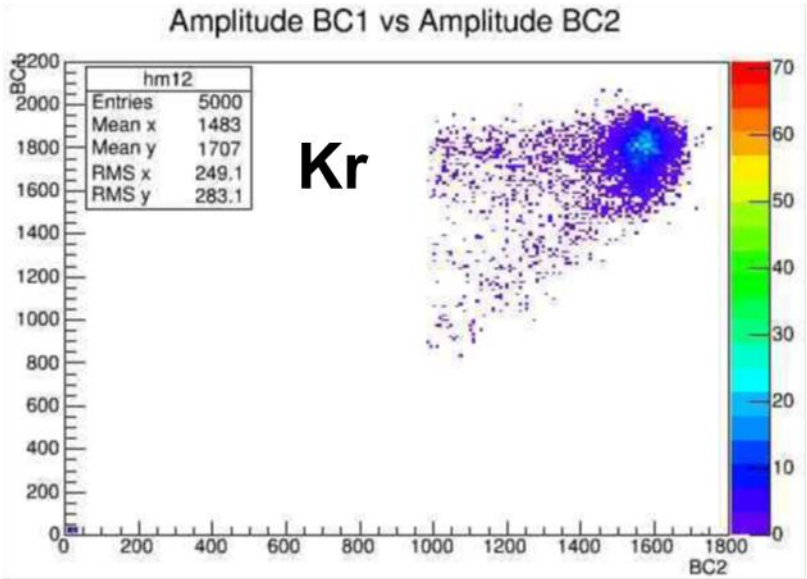


Low threshold in BC





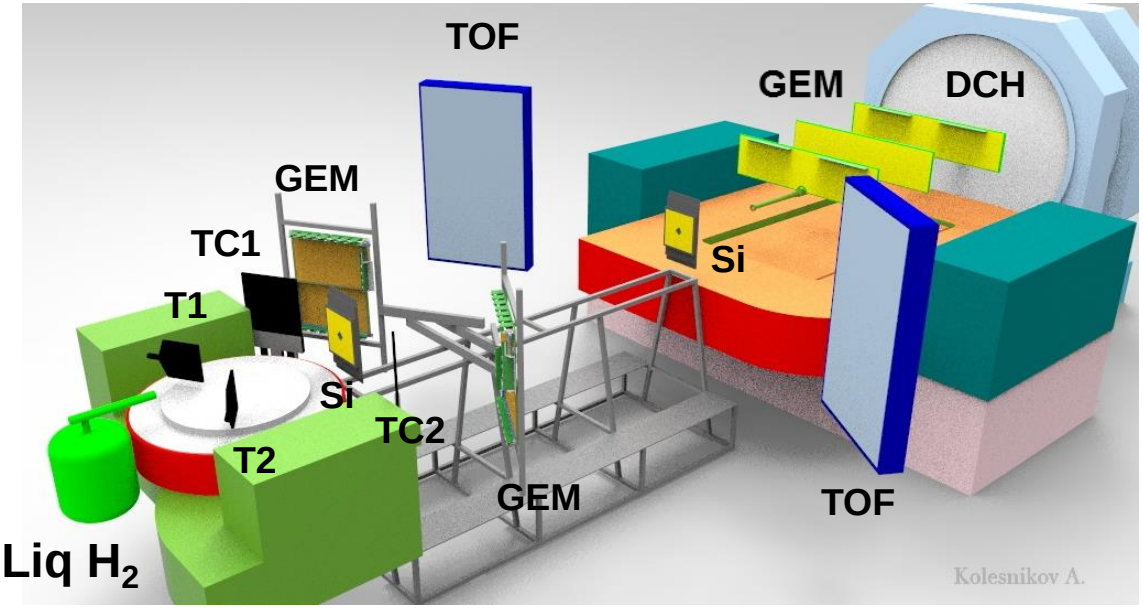
High threshold in BC



BMN & SRC set-up

Cuts
$\|\theta_{1,2}-30^o\|<6.5^o$
$\|\Delta\varphi_{1,2}\|<7.5^o$
$\|s,t,u\|>2$ (GeV/c)^2
$P_{miss}>0.275$ GeV/c

Trigger:
T0 · T1 · T2 · TC1 · TC2



Signal rates for 14 days of data taking

Within LAND acceptance

First SRC @ BMN run in March 2018