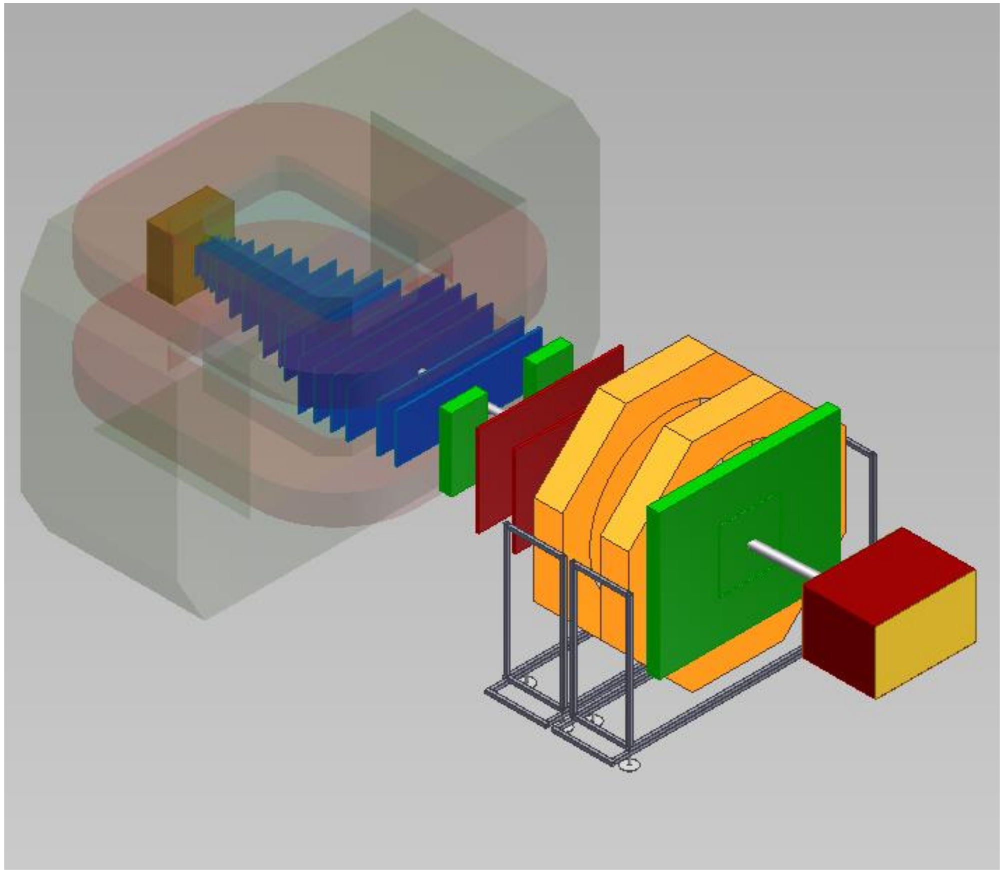
Status of Baryonic Matter at Nuclotron

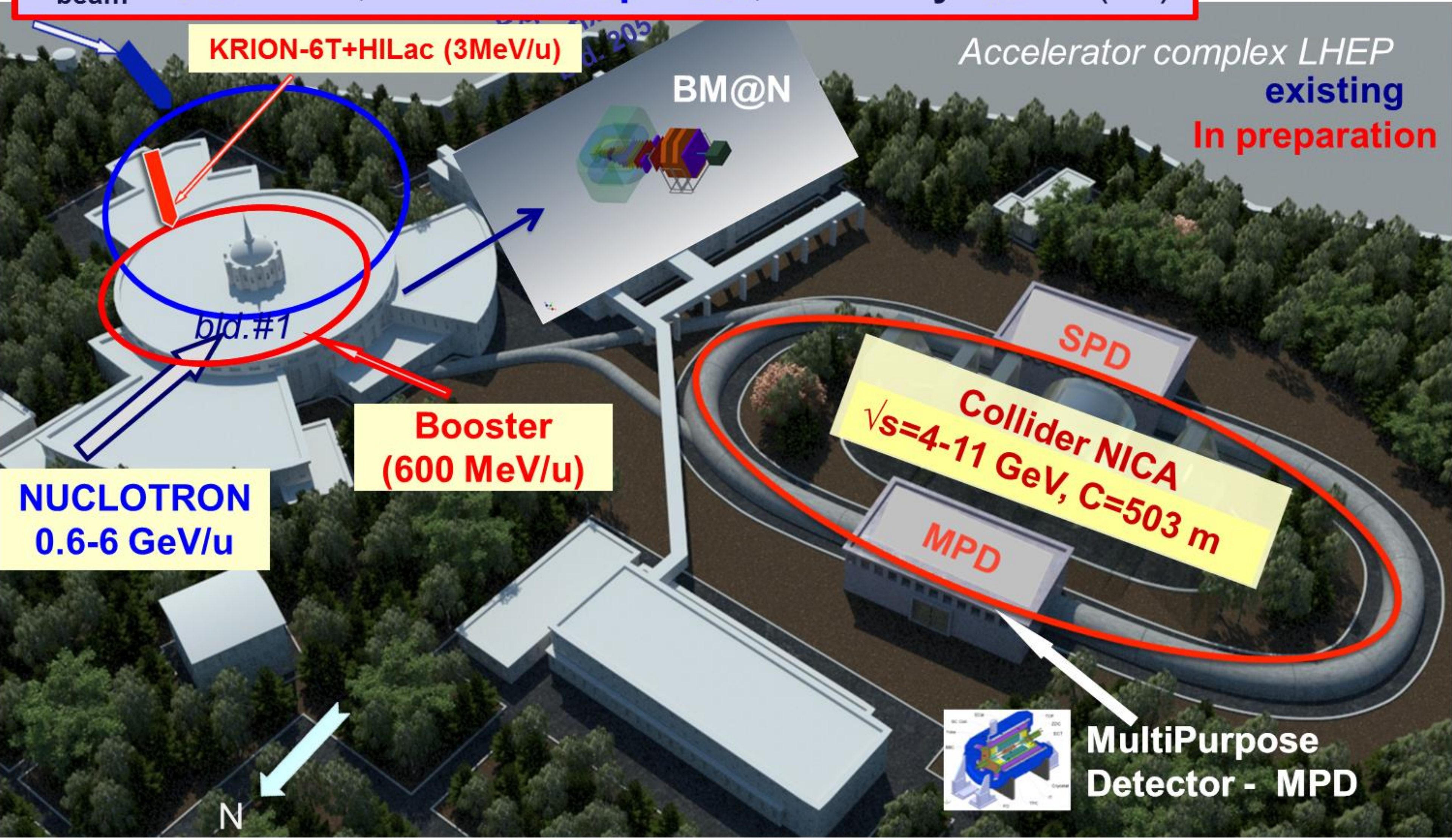
M.Kapishin



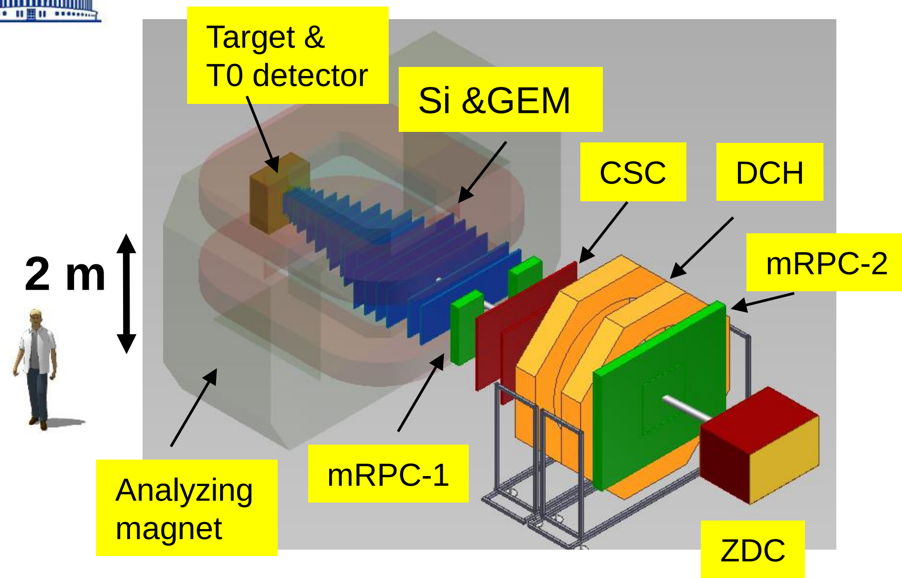
Complex NICA

Parameters of Nuclotron for BM@N experiment:

E_{beam} = **1-6** GeV/u; ***beams***: *from* **p** to **Au**; **Intensity~10^7** c^{-1} (Au)



BM@N setup



BM@N advantage: large aperture magnet (~1 m gap between poles)

→ fill aperture with coordinate detectors which sustain high multiplicities of particles

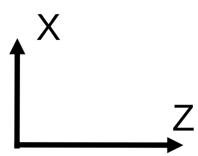
→ divide detectors for particle identification to “near to magnet” and “far from magnet” to measure particles with low as well as high momentum (p > 1-2 GeV/c)

→ fill distance between magnet and “far” detectors with coordinate detectors

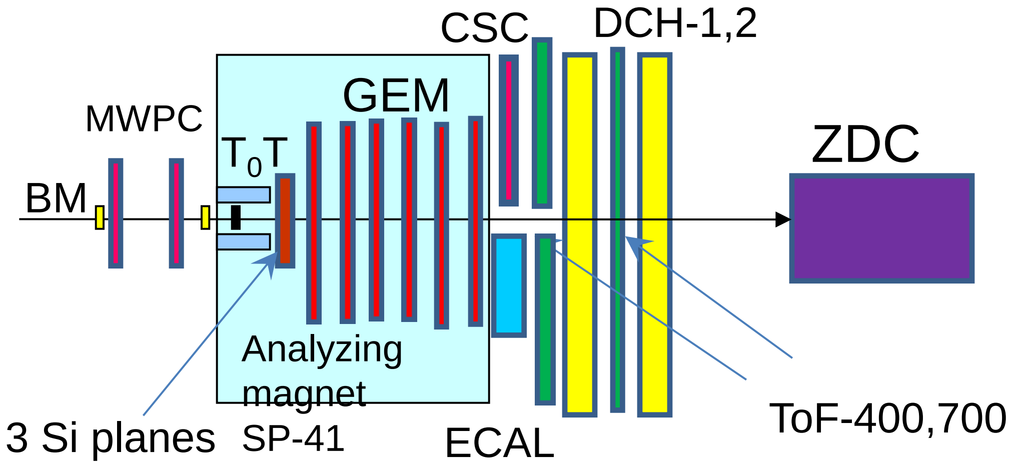
- Central tracker (Si + GEM) inside analyzing magnet to reconstruct AA interactions
- Outer tracker (CSC, DCH) behind magnet to link central tracks to ToF detectors
- ToF system based on mRPC and T0 detectors to identify hadrons and light nucleus
- ZDC calorimeter to measure centrality of AA collisions and form trigger
- Detectors to form T0, L1 centrality trigger and beam monitors
- Electromagnetic calorimeter for γ,e+e-

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 cm^2 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

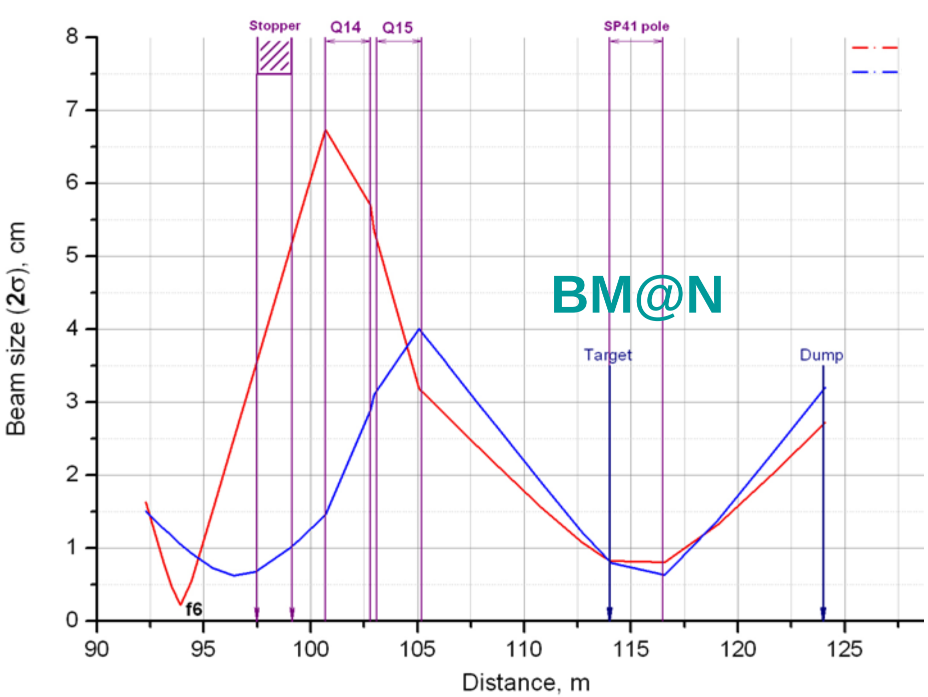
+ analyze data from previous technical run with Carbon beam of 3.5 - 4.5 GeV/n

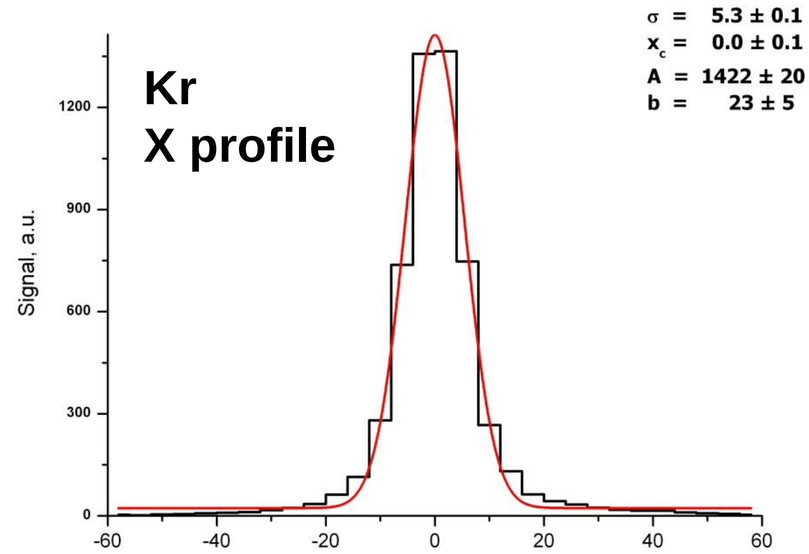
BM@N beam profile

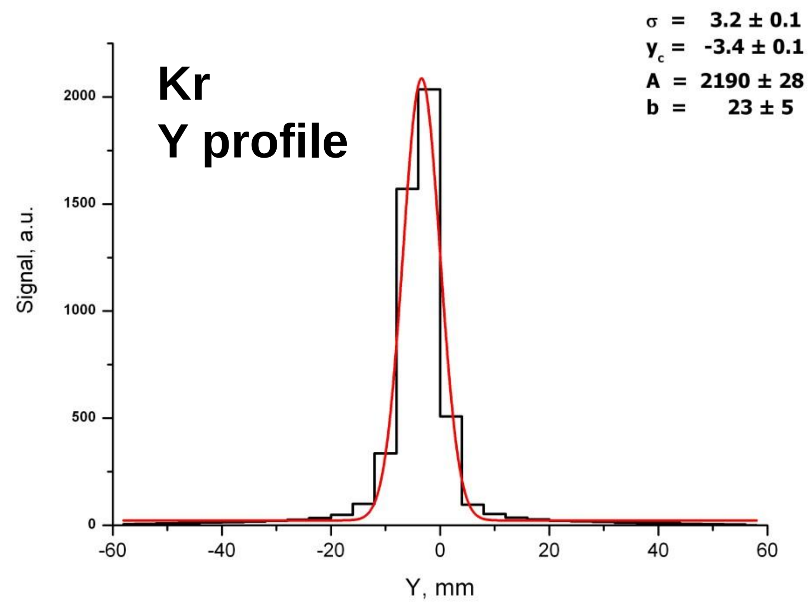
C^{12}, Ar, Kr beam profiles measured by Nuclotron beam group

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

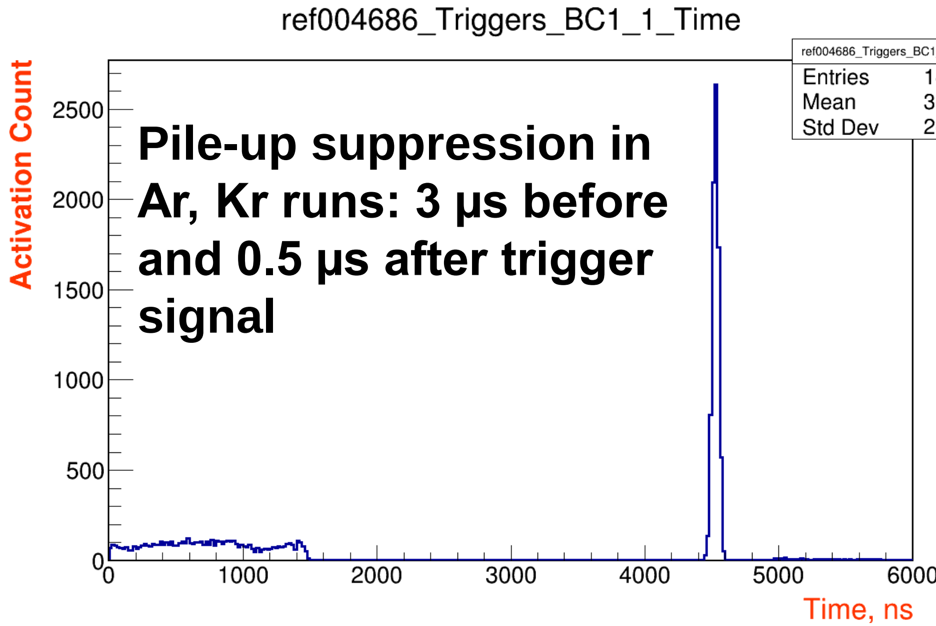
Beam envelopes at the BM@N area

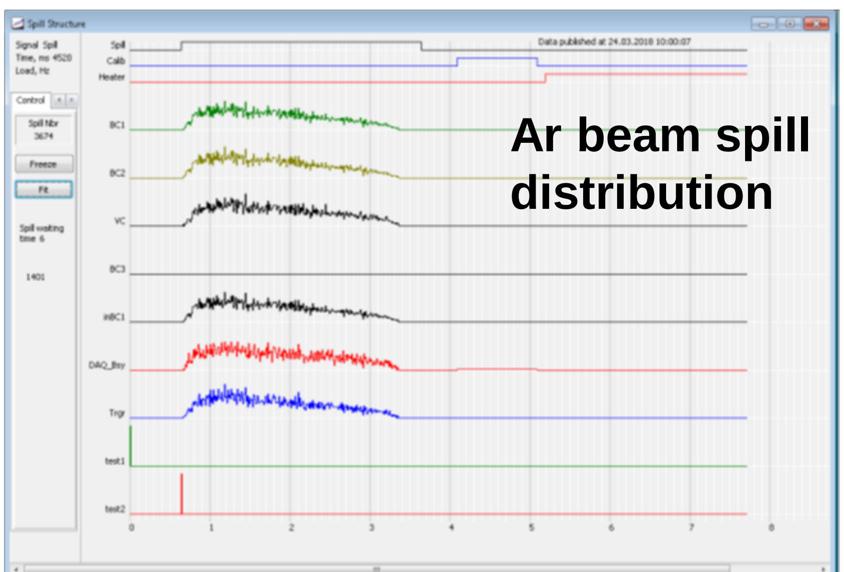




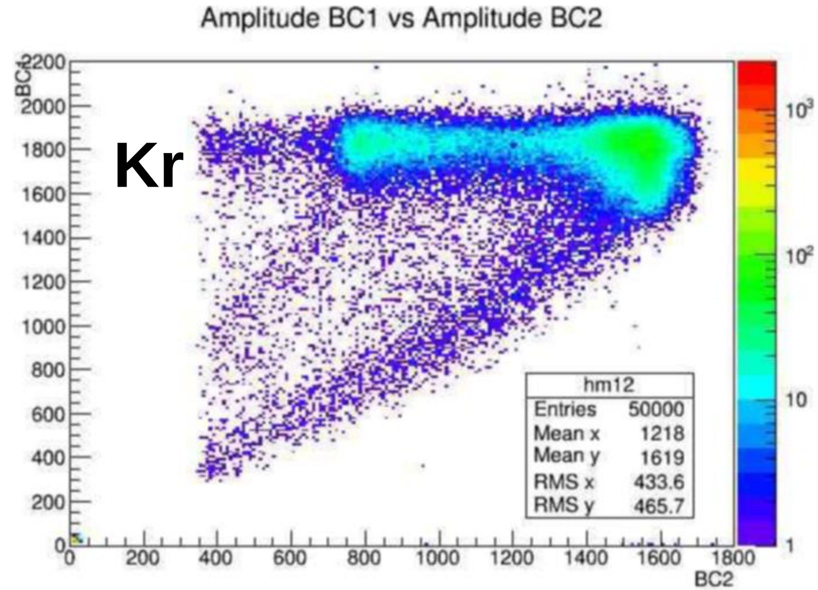


Beam structure & pile-up suppression

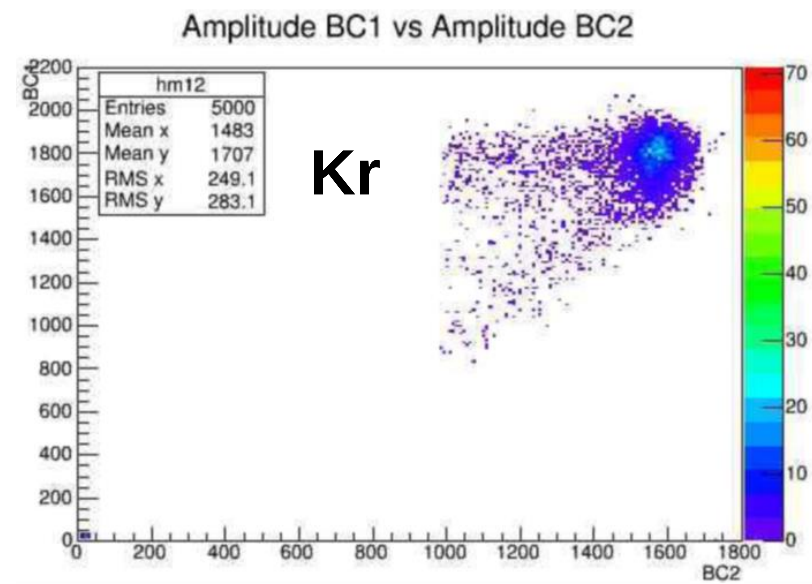




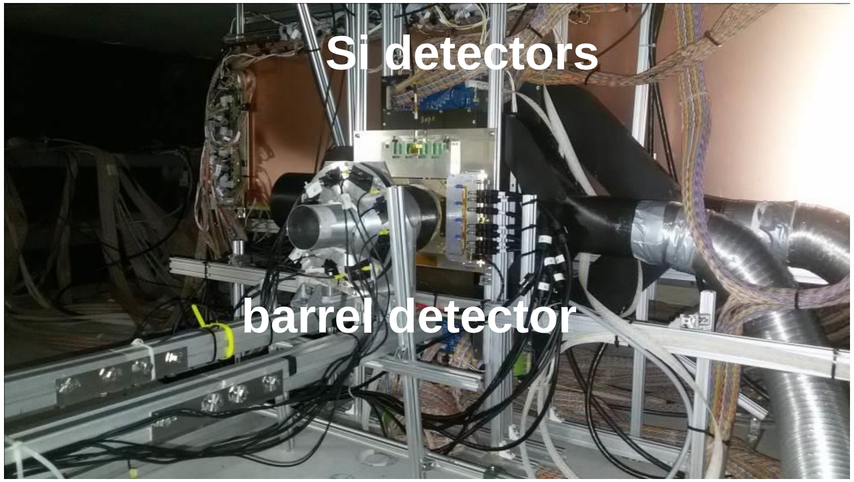
Low threshold in BC



High threshold in BC

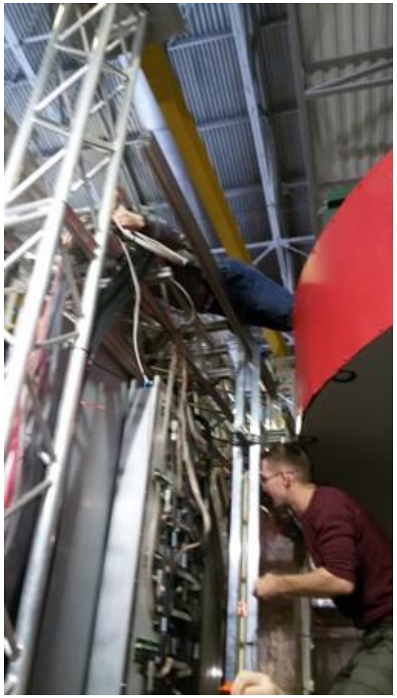


BM@N set-up in Ar, Kr run, March 2018



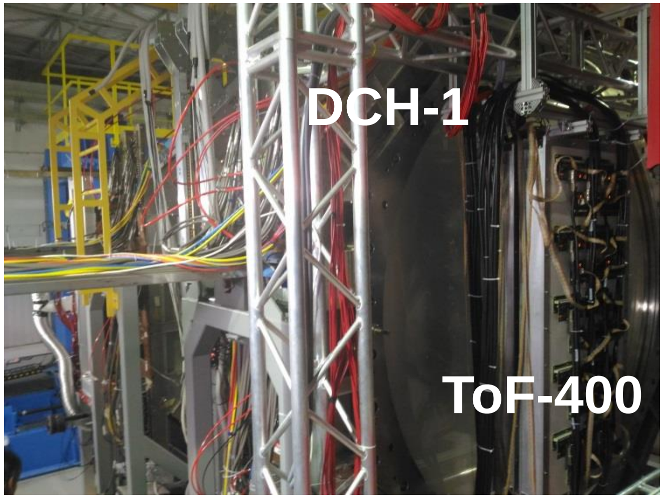
CSC chamber

ToF-400 installation

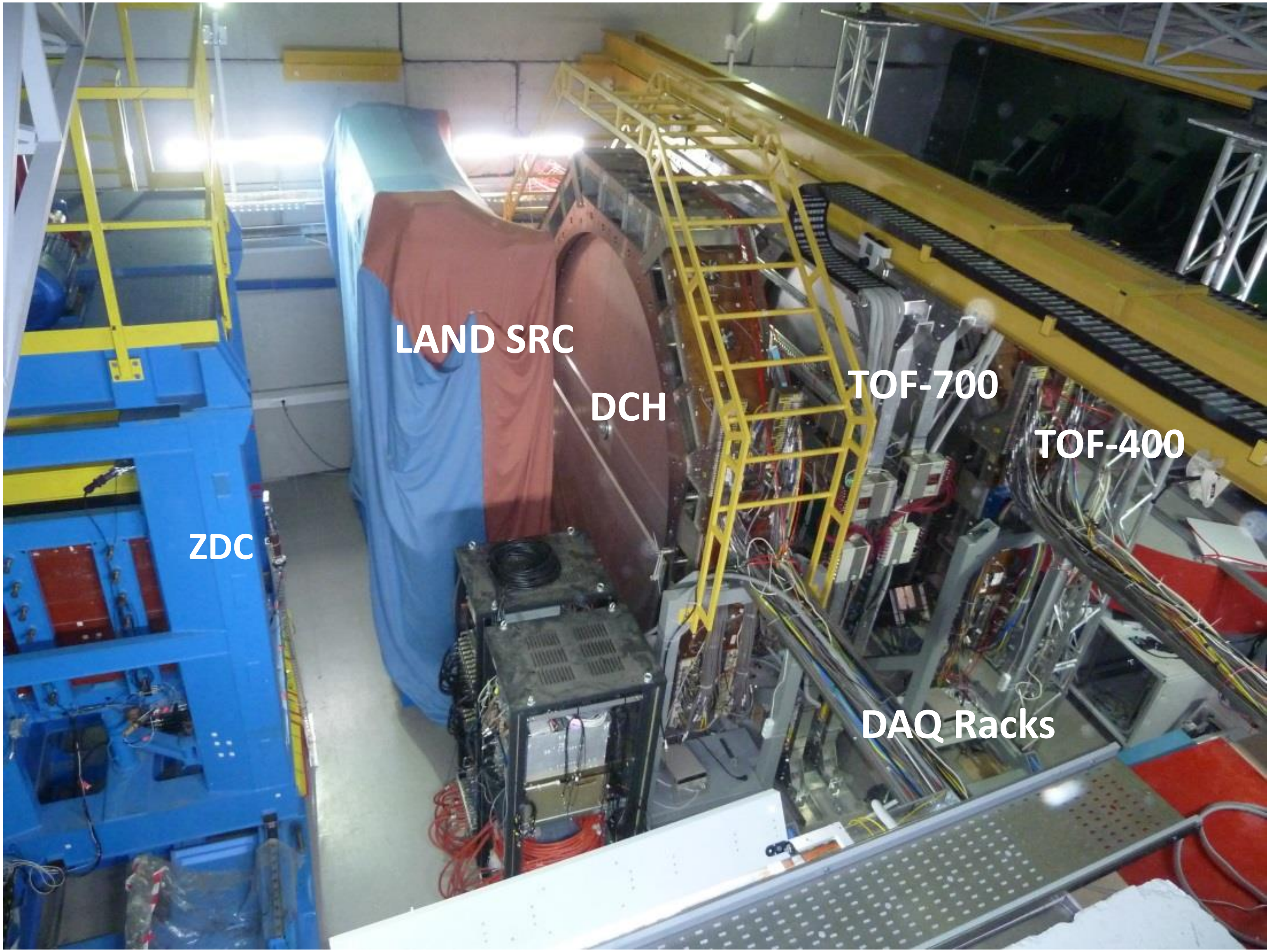


New detector components:

6 big GEMs, trigger detectors, 3 Si detectors, CSC chamber, full set of ToF detectors

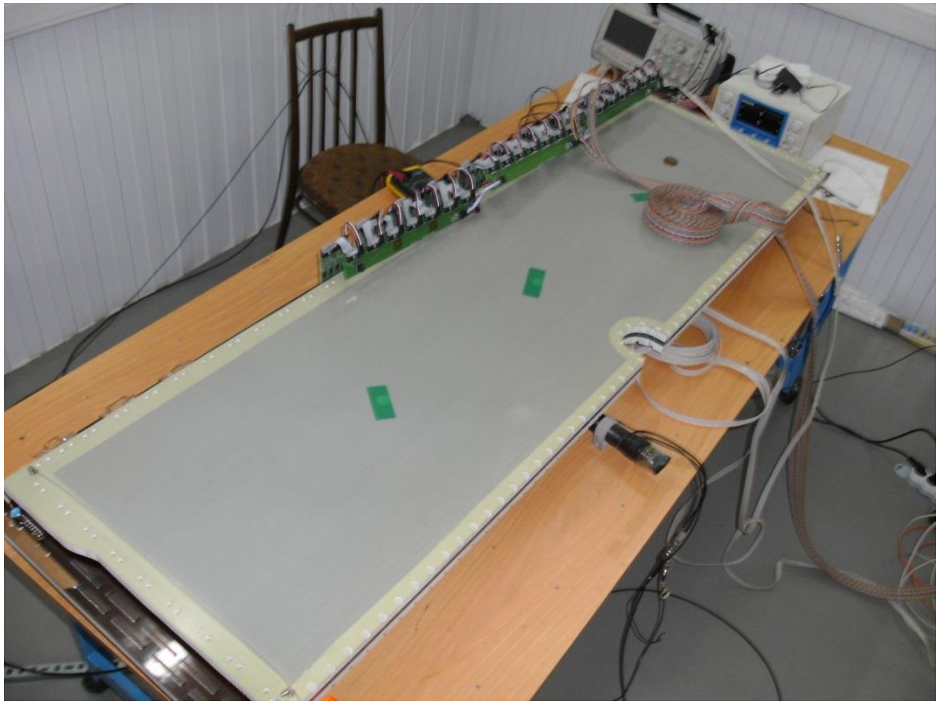


BM@N setup behind magnet, 2018

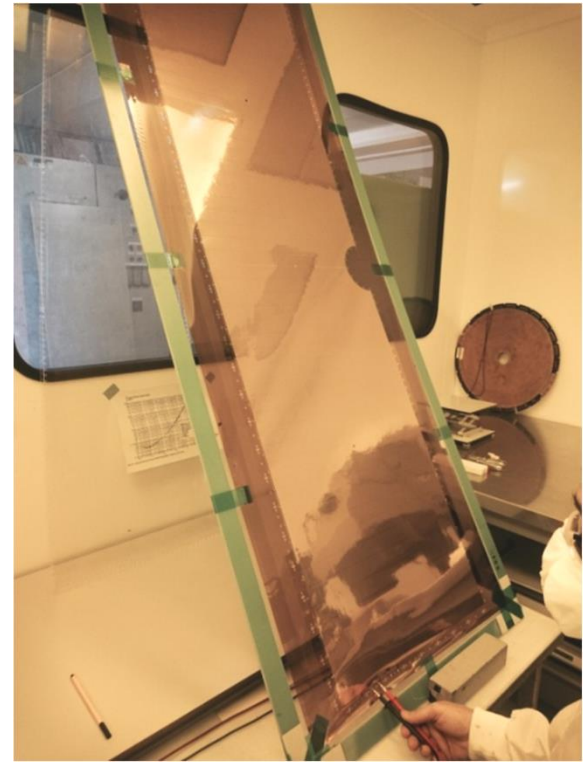


GEM detectors for central BM@N tracker

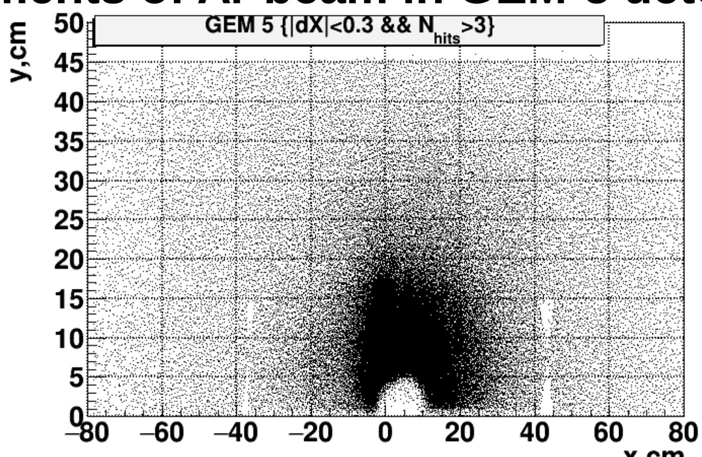
Tests of GEM detector 163 x 45 cm²



GEM group, see talk of A.Maksymchuk



Fragments of Ar beam in GEM-5 detector



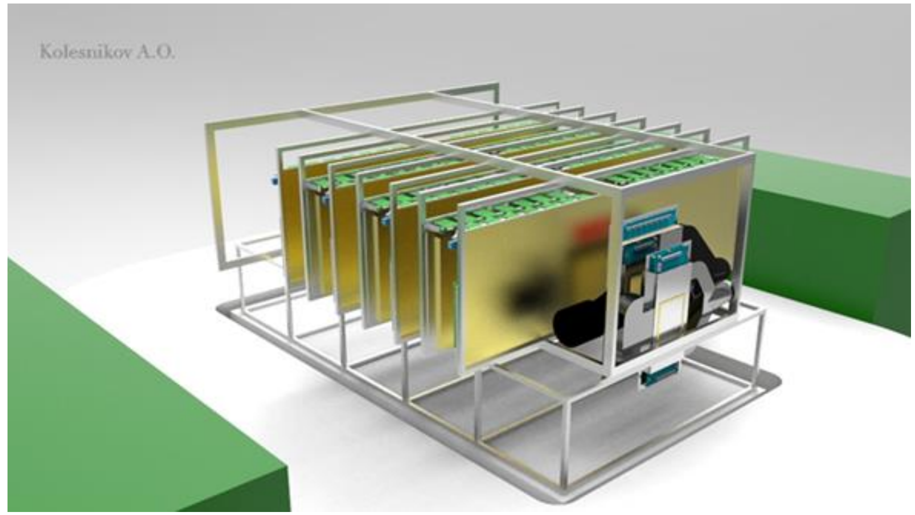
- **7 detectors of 163 x 45 cm² are produced at CERN workshop**
- **one detector is defected, has to be repaired**

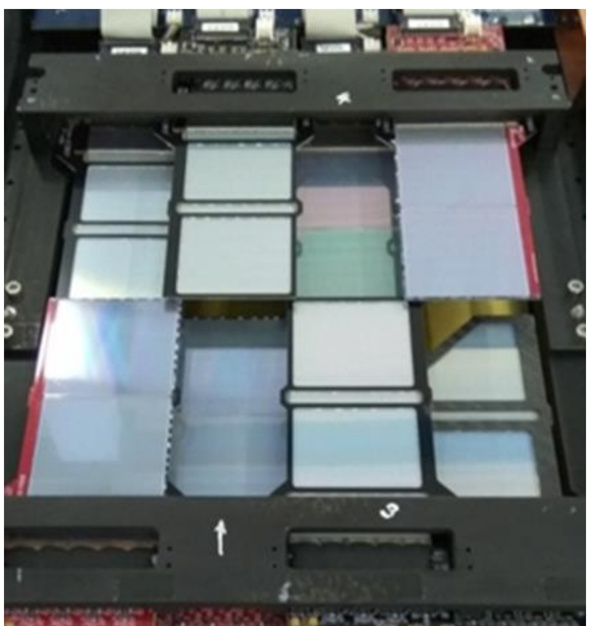
M.Kapishin

Forward silicon strip detectors

Central tracker in Ar / Kr runs

Silicon detector group,
see talk of N.Zamiatin





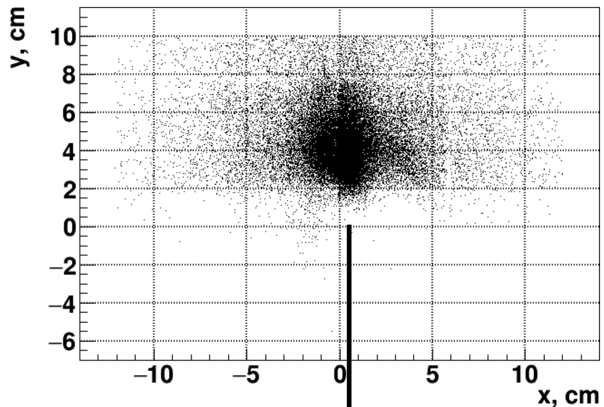
- 2-coordinate Si detector with strip pitch of 95/103 μm, full size of 25 x 25 cm^2
- Detector combined from 4 sub-detectors arranged around beam

+ 2 smaller vertex detectors → March 2018

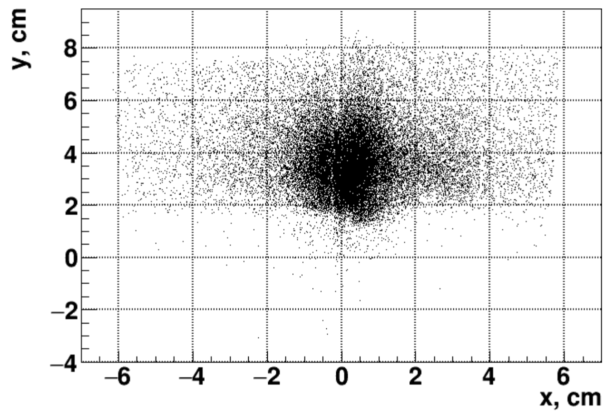
►Precise 3D measurement of all major components of BM@N setup ! (A.Kolesnikov + firm)

Tracks in forward silicon strip and GEM detectors in Ar run

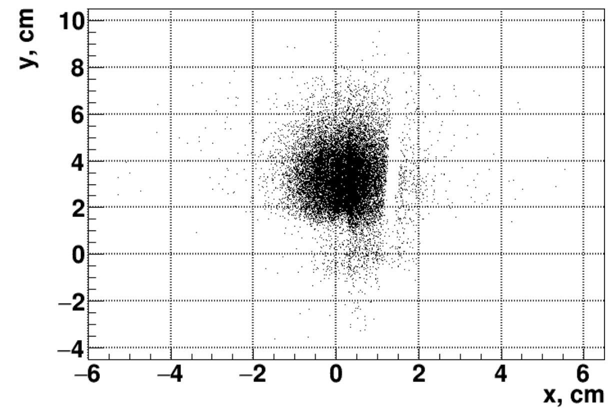
Si-3 track profile

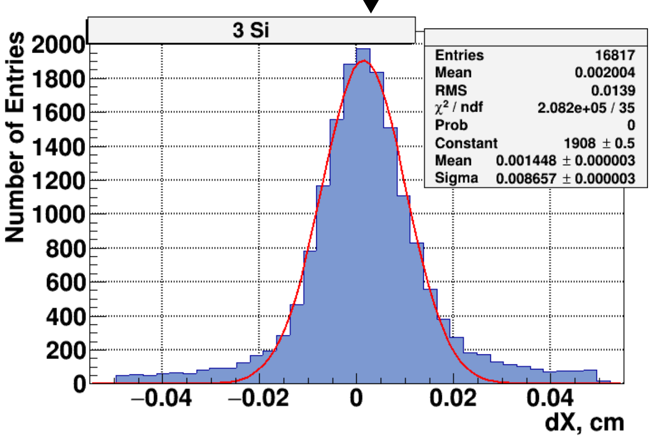


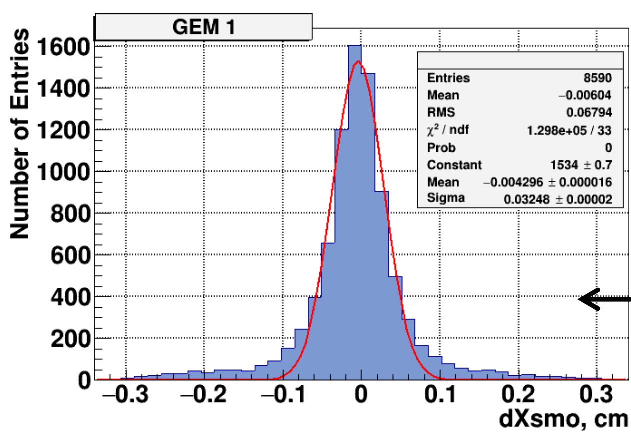
Si-2 track profile

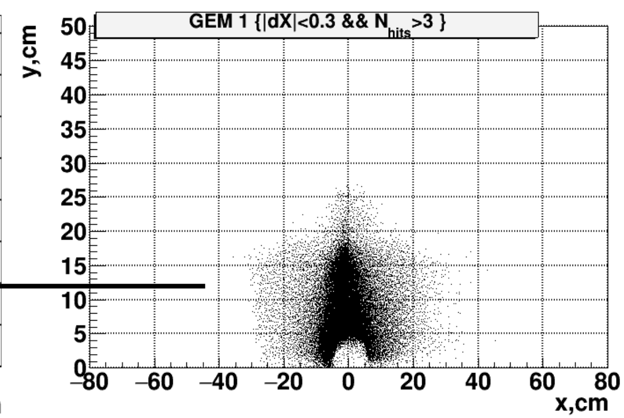


Si-1 track profile







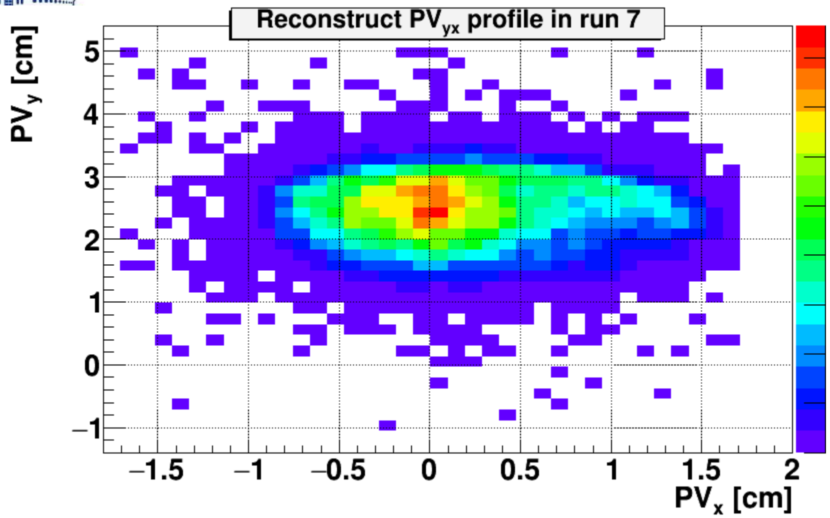


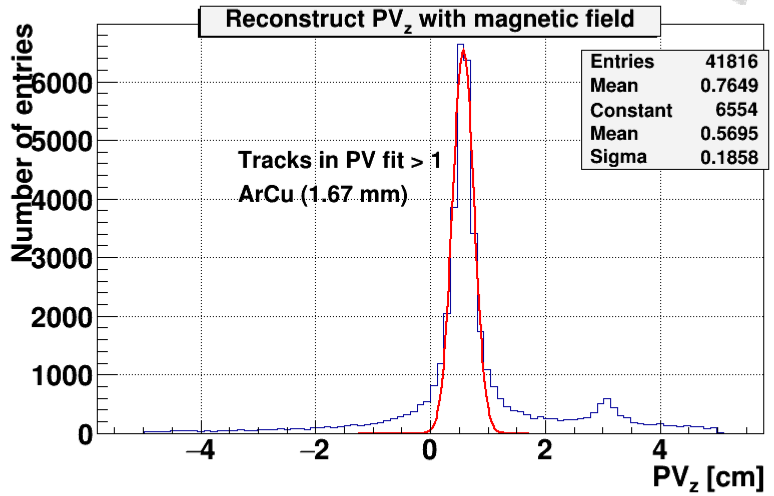
Si-3 detector residual vs GEM+Si track ~ 86 μm

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

GEM-1 track profile

Vertex reconstruction in Ar run



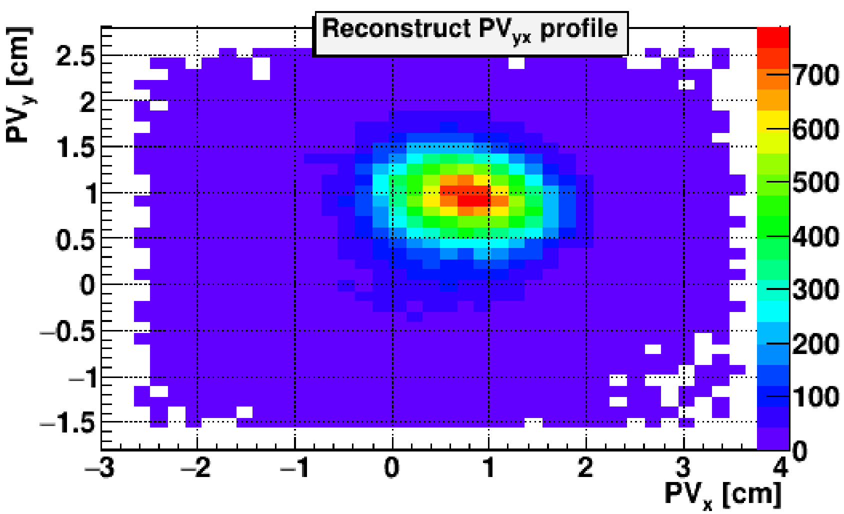


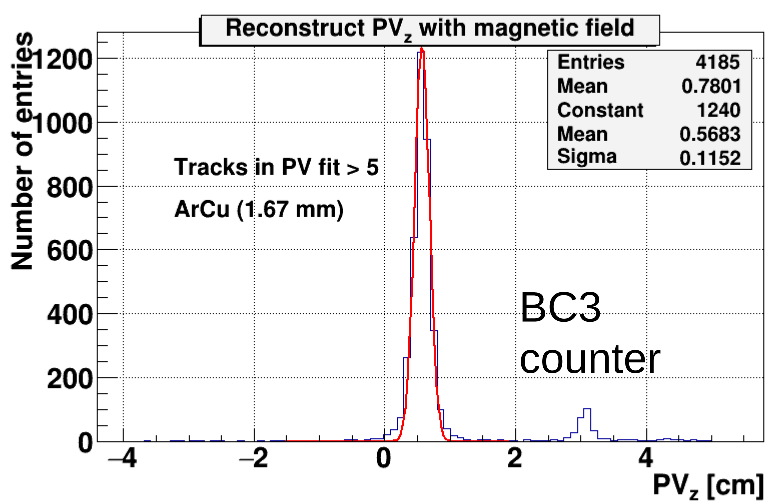
- Beam in Ar run ~1.8 cm higher in Y and has tail in X

Vertex sigma along beam ~1.8 mm comparable with target thickness

►Compare with vertex in Carbon run in March 2017

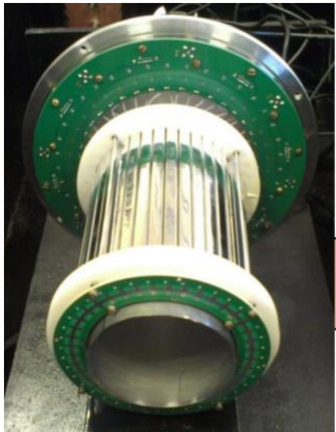
Vertex in high multiplicity events





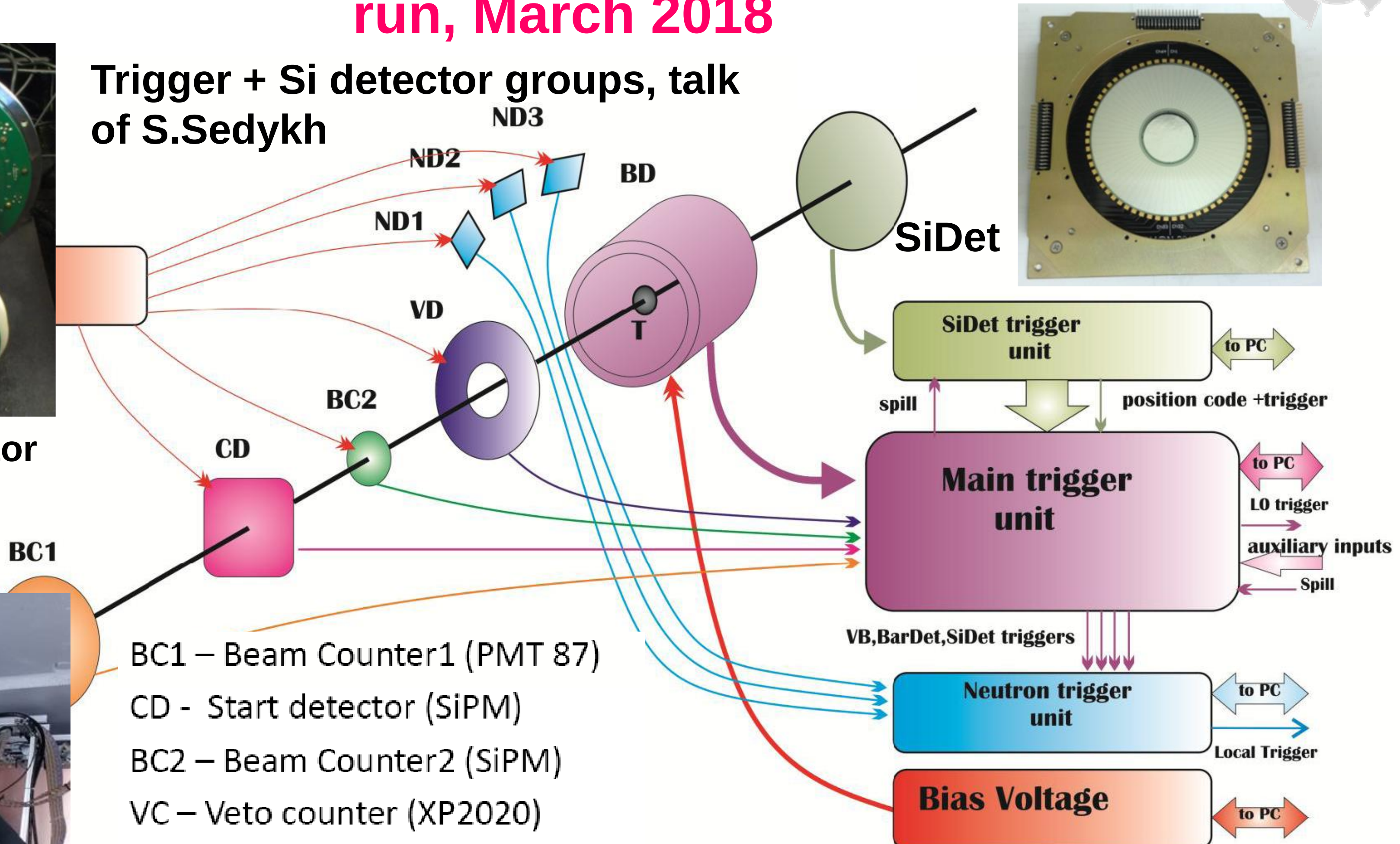
Trigger detectors and beam counters in Ar and Kr run, March 2018

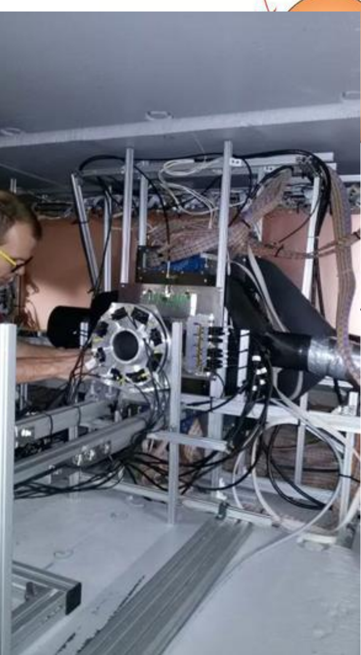
Trigger + Si detector groups, talk of S.Sedykh



Barrel detector

SiDet





BC1 – Beam Counter1 (PMT 87)

CD - Start detector (SiPM)

BC2 – Beam Counter2 (SiPM)

VC – Veto counter (XP2020)

BD – Barrel Detector – 40ch. SiPM

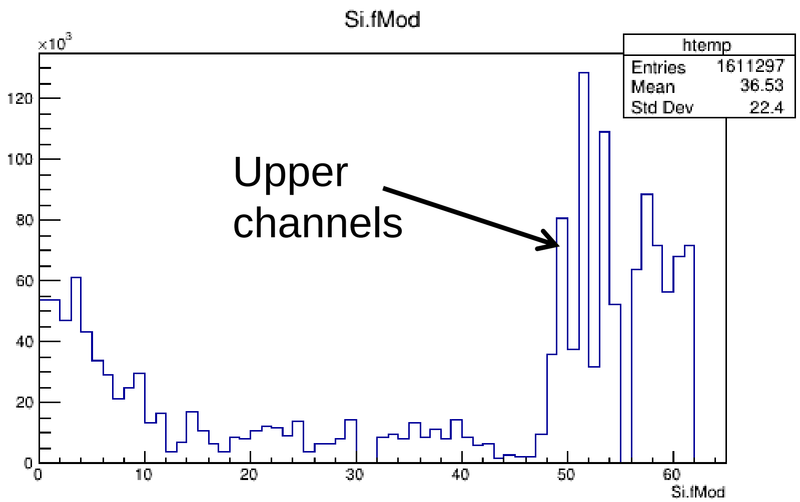
T – target

SiDet – Silicon Detector

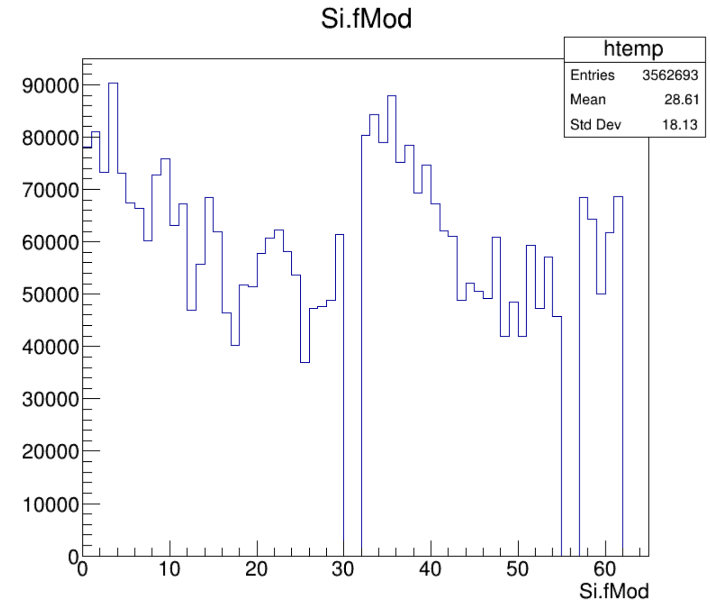
Selection of events with activity in barrel detector: BD >= N or forward Si detector: SiDet >= N

Si trigger performance in Ar and Kr runs

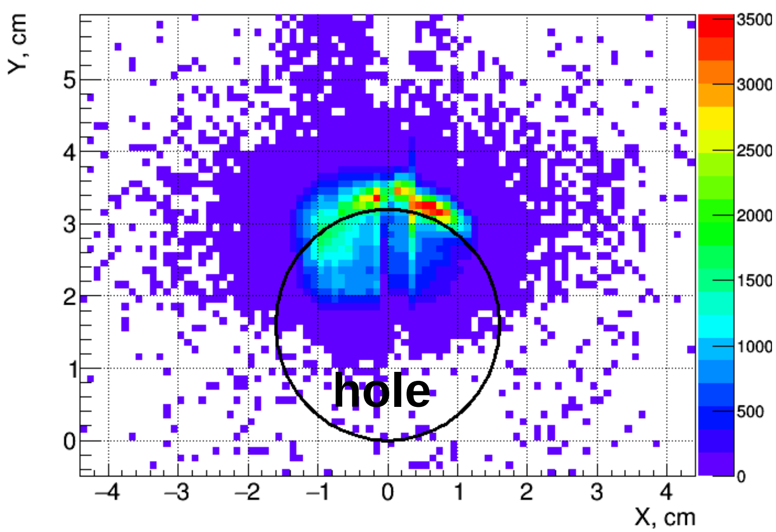
Si trigger detector profile, Ar run



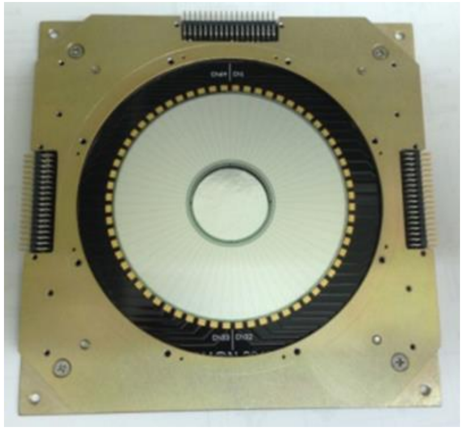
Si trigger detector profile, Kr run



Beam scrapes upper part of Si trigger detector in Ar run



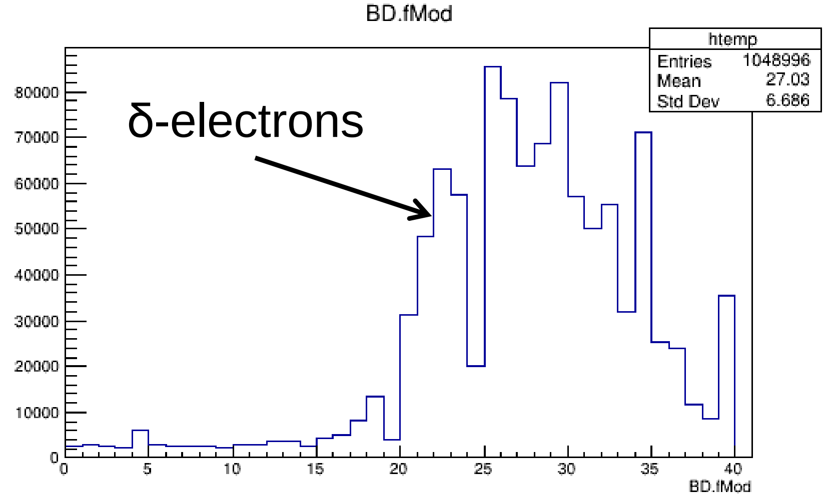
Si trigger detector



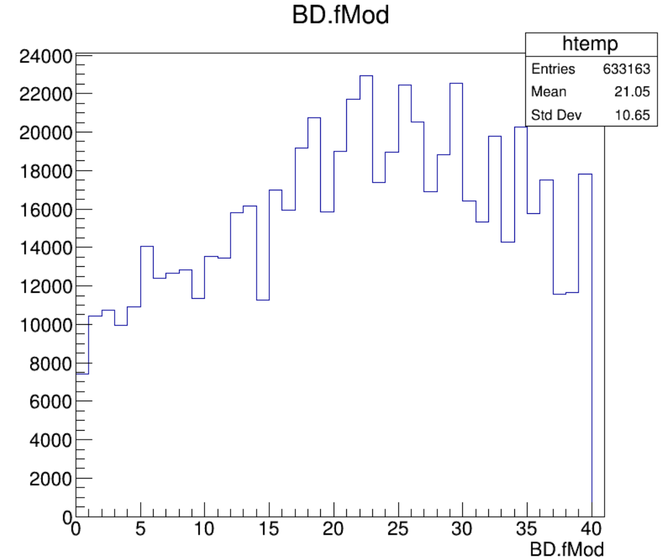
► **Adjusted beam position in Kr run**

Barrel detector trigger performance in Ar and Kr runs

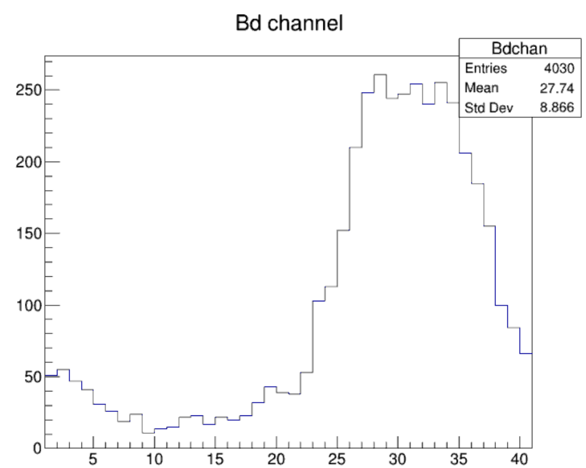
BD trigger detector profile, Ar run



BD trigger detector profile, Kr run



BD detector profile in Ar+Cu, GEANT4 simulation of δ-electrons

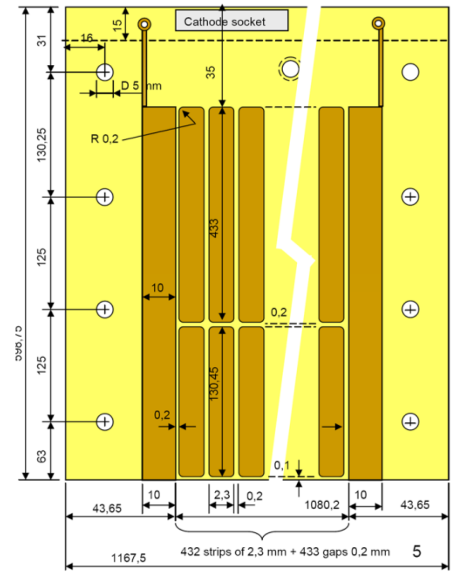


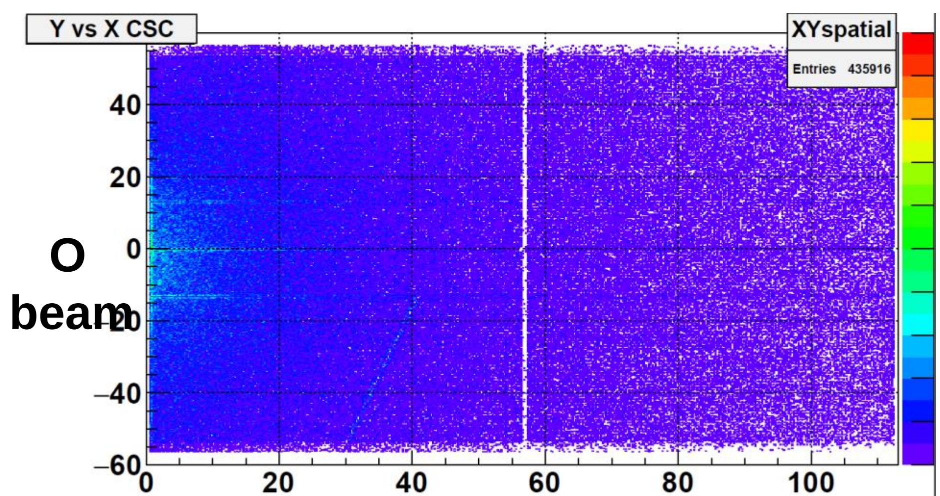
► **Implementation of 4 mm Pb shielding inside BD cylinder diminished δ-electron rate**

New Cathode Strip Chamber as Outer tracker

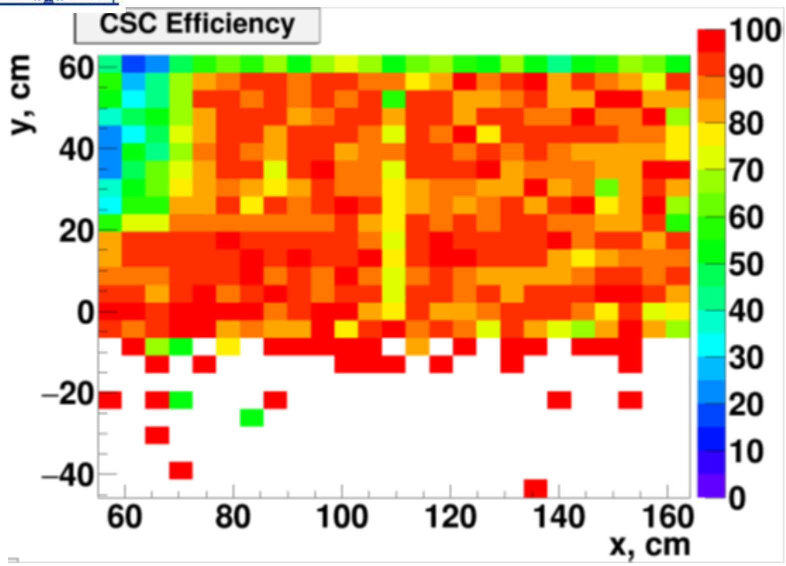
A.Vishnevsky + GEM team

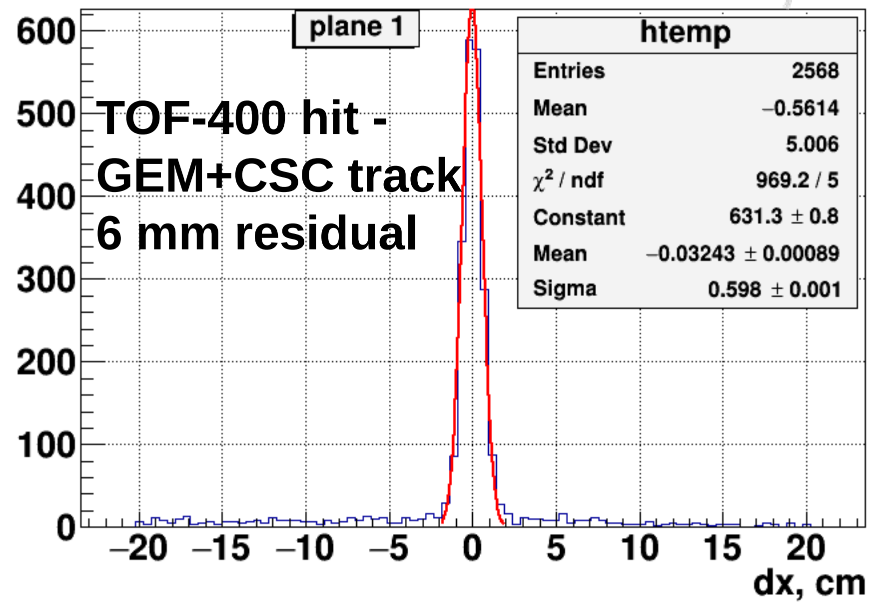
C, Ar and Kr runs in March 2018: CSC chamber installed in front of ToF-400 to check its performance as Outer tracker for heavy ions

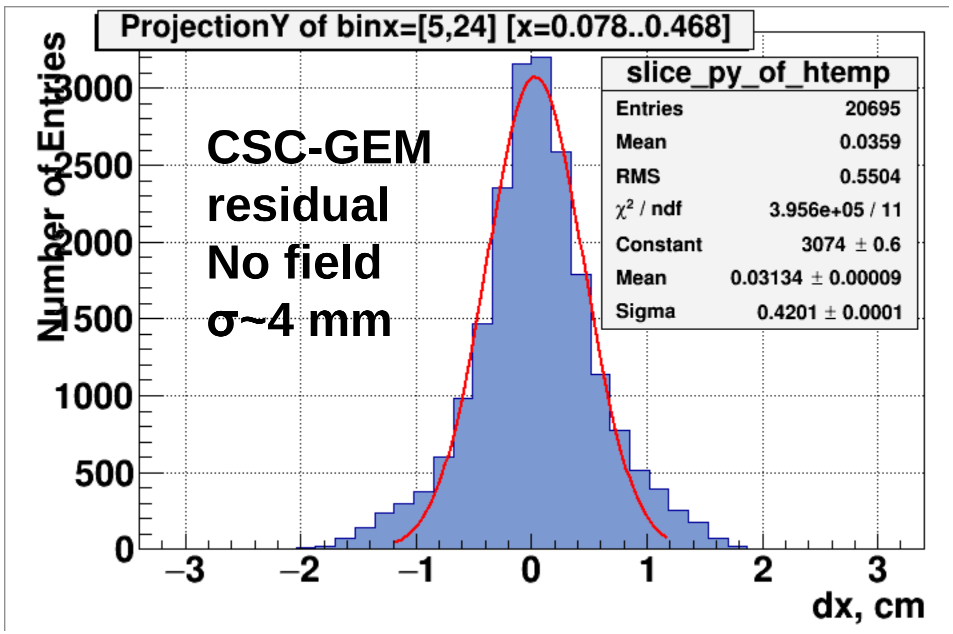


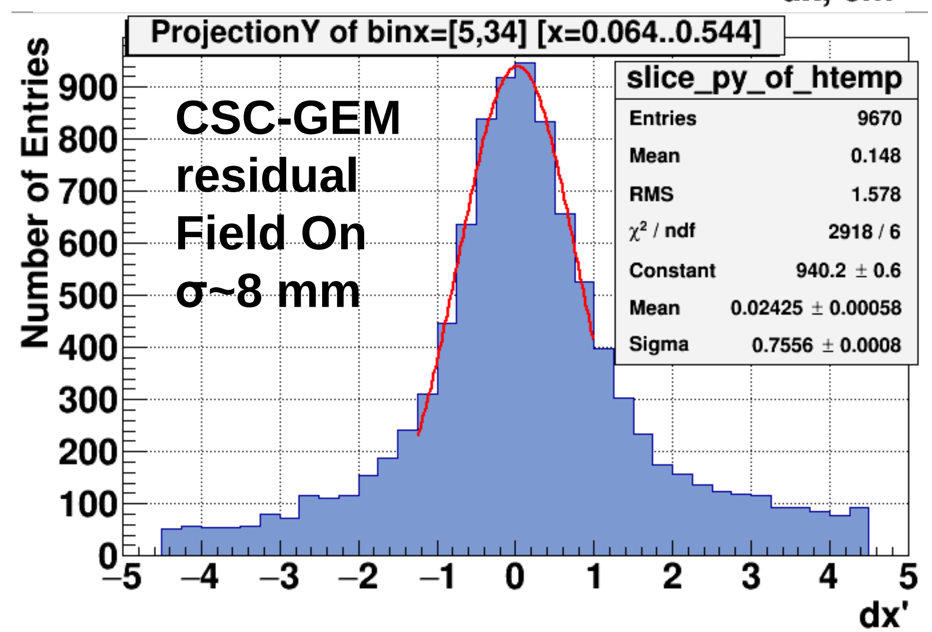


Link of GEM tracks to CSC and TOF-400

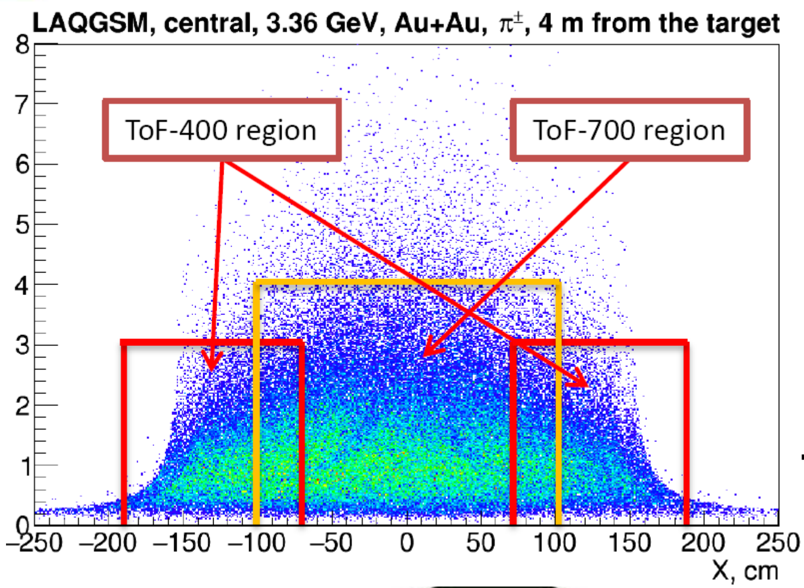


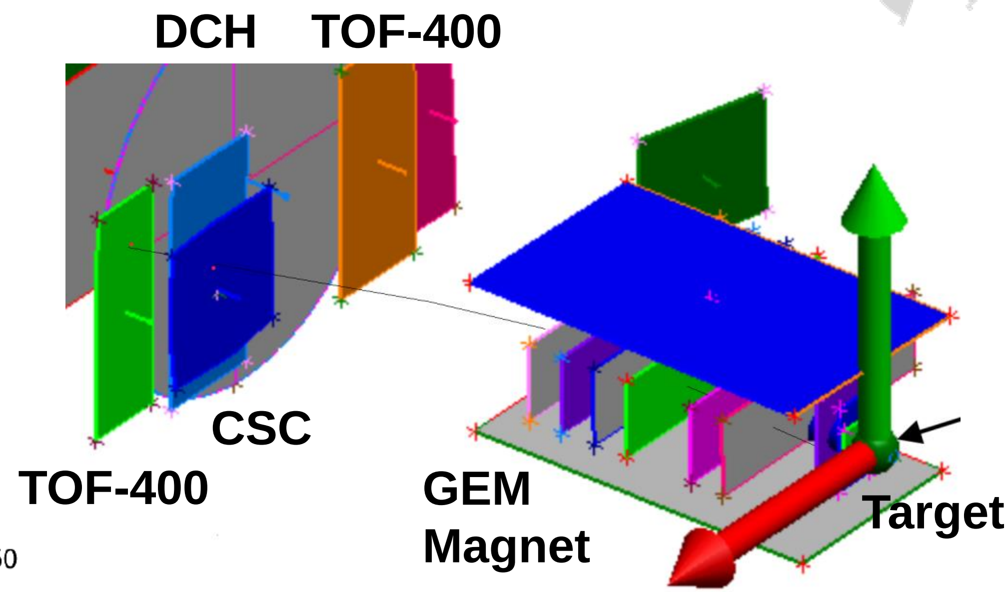


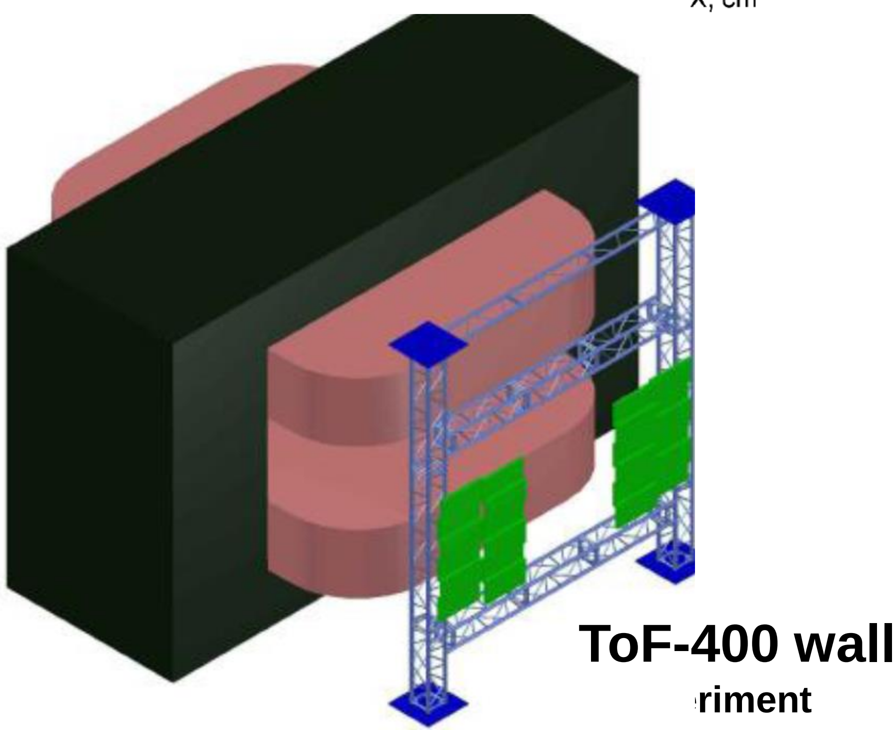


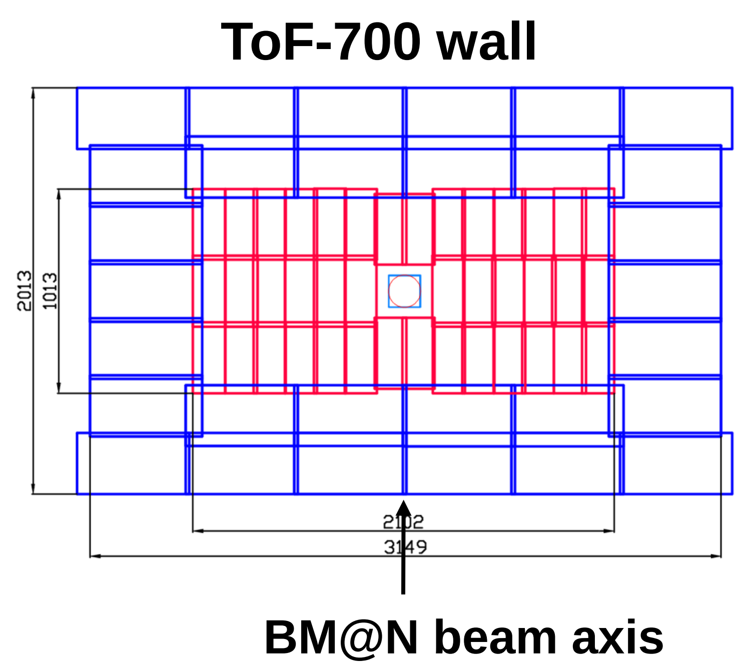


ToF-400 and ToF-700 based on mRPC

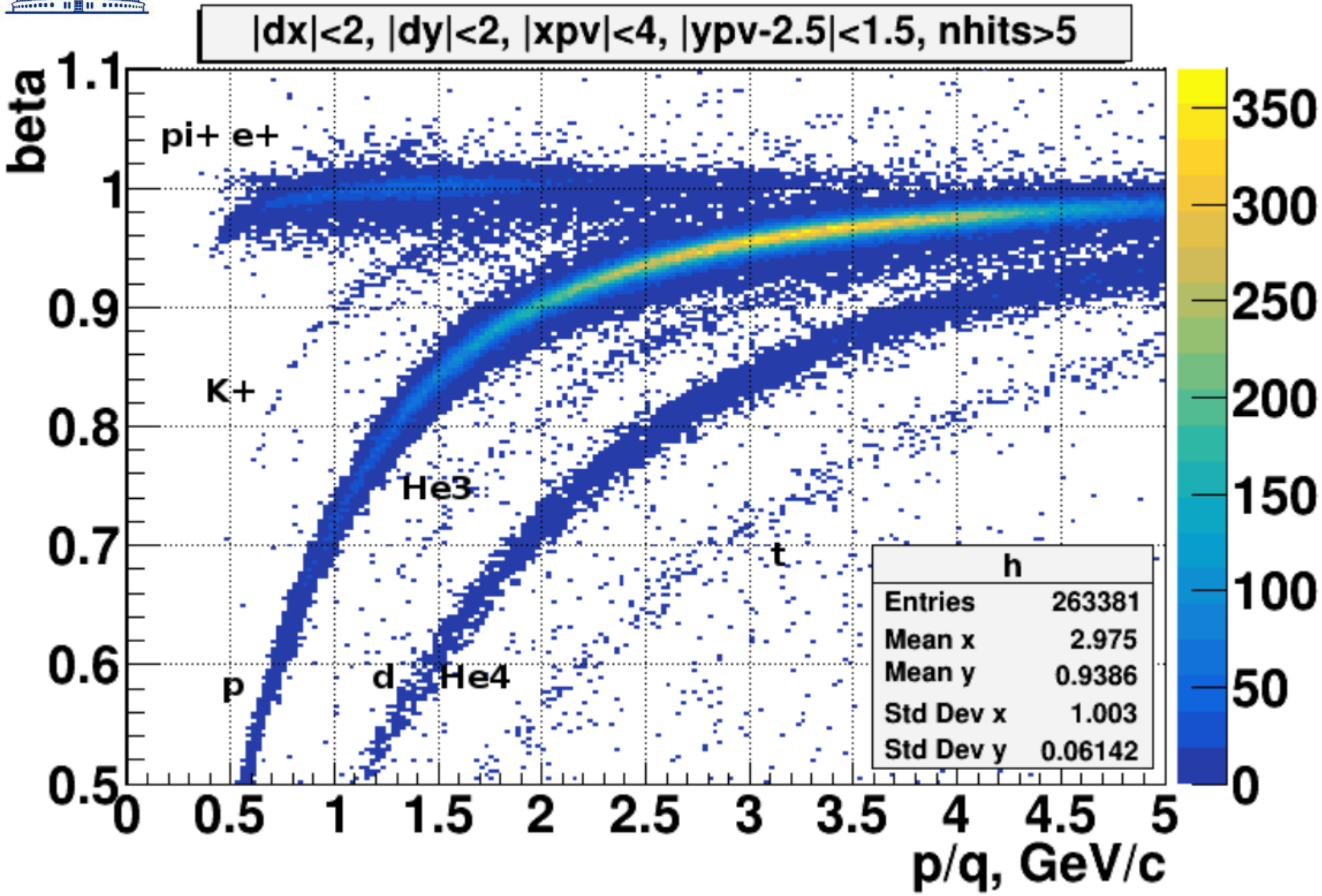








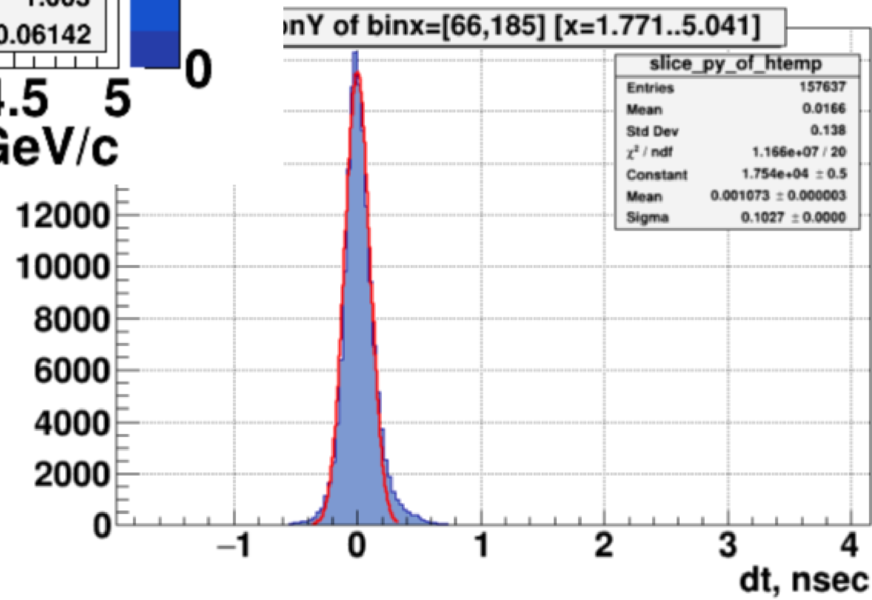
Present status of TOF-400 identification



V.Plotnikov,
M.Rumyantsev +
GEM tracking group

See talk of
M.Rumyantsev

Time resolution
within proton
band ~100 ps

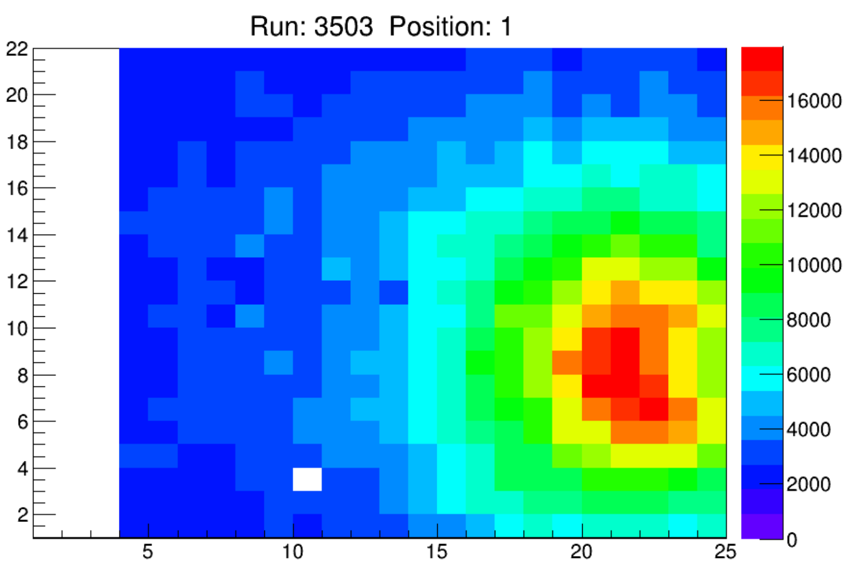


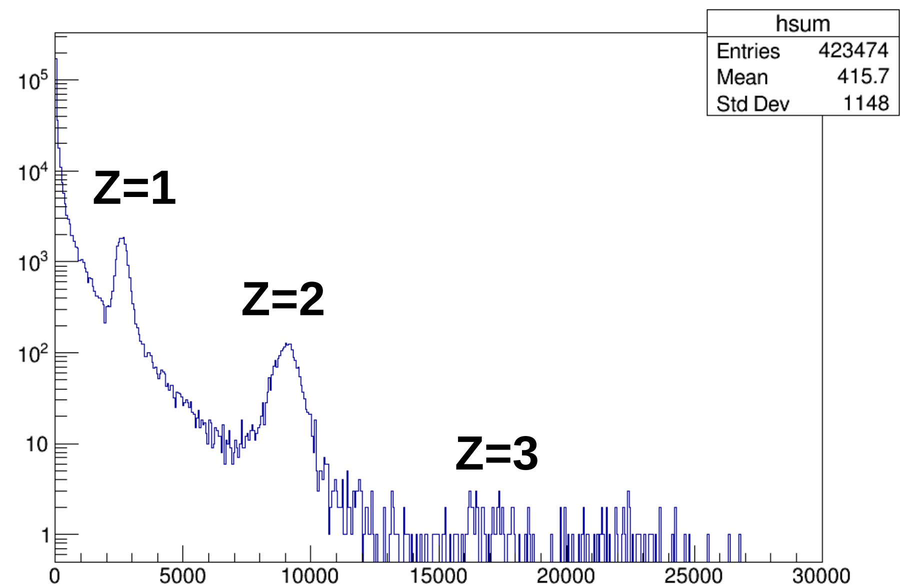
Electro-magnetic ECAL calorimeter

See talk of ECAL group, P.Alekseev

- **ECAL collected data in short runs in position close to C, Ar and Kr beams**
- **Calibration is being performed: response to Z=1, 2 particles in modules close to beam + response to cosmic particles**

→ Aim to reconstruct states decaying to γ



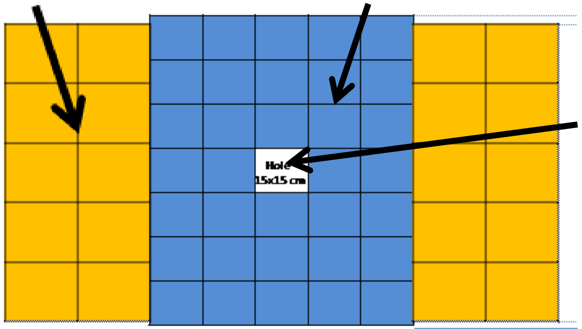


Interaction fragments inside ECAL

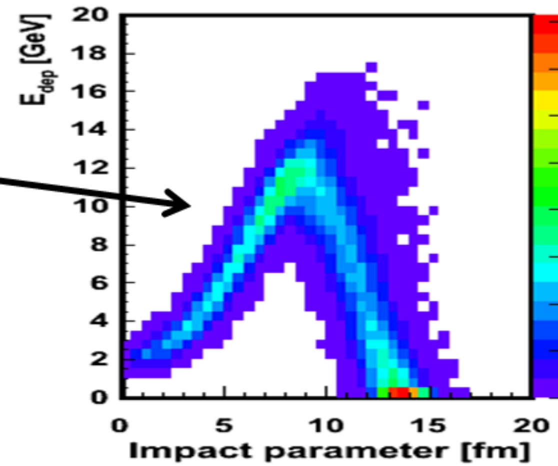
MPD / CBM hadron ZDC calorimeter

See talk of F.Guber

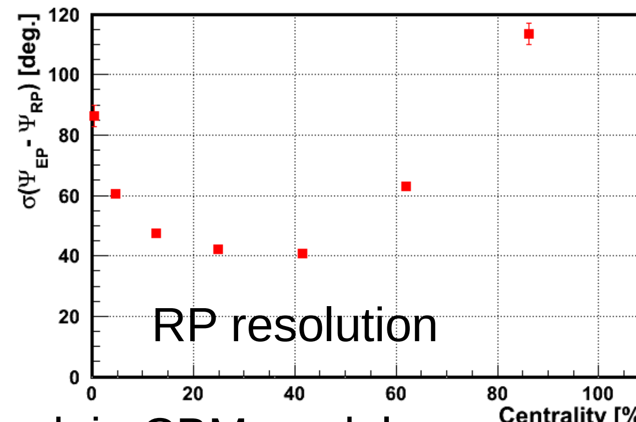
CBM modules   MPD modules



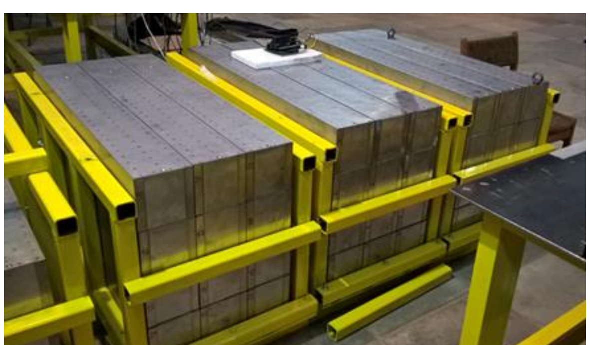
dE/dx scintillator to resolve central / peritheral interactions



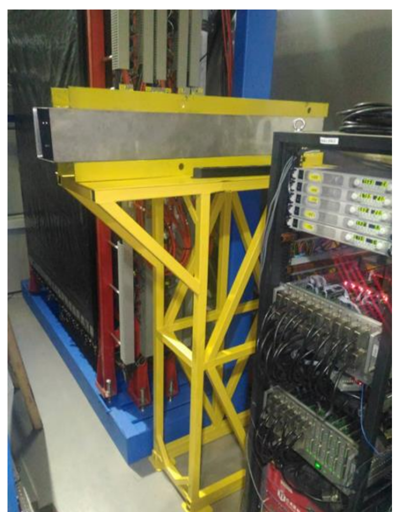
- **Modern technics;**
- **Light yield ~x10 higher;**
- **Detection of low energies;**
- **Stable operation at high count rates;**
- **Experience in operation for later MPD/CBM experiments**
- **Motivated team**



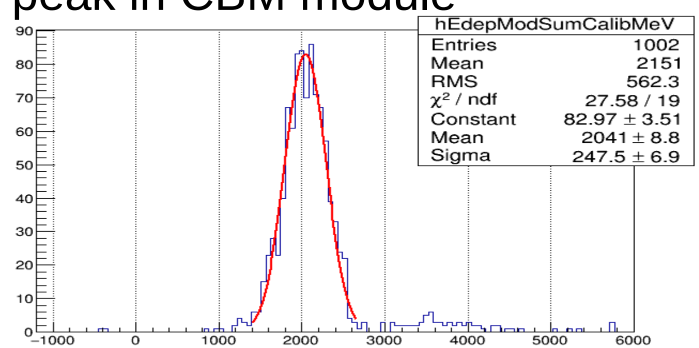
MPD FHCAL modules



CBM module in BM@N



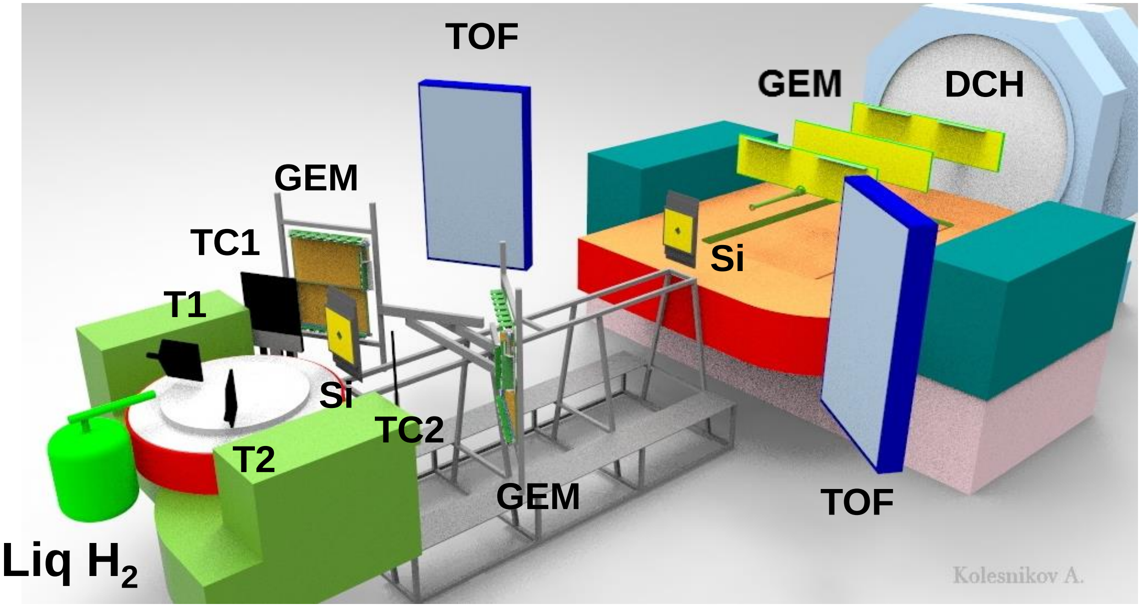
Ar peak in CBM module



BMN & SRC set-up

See talk of V.Panin

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



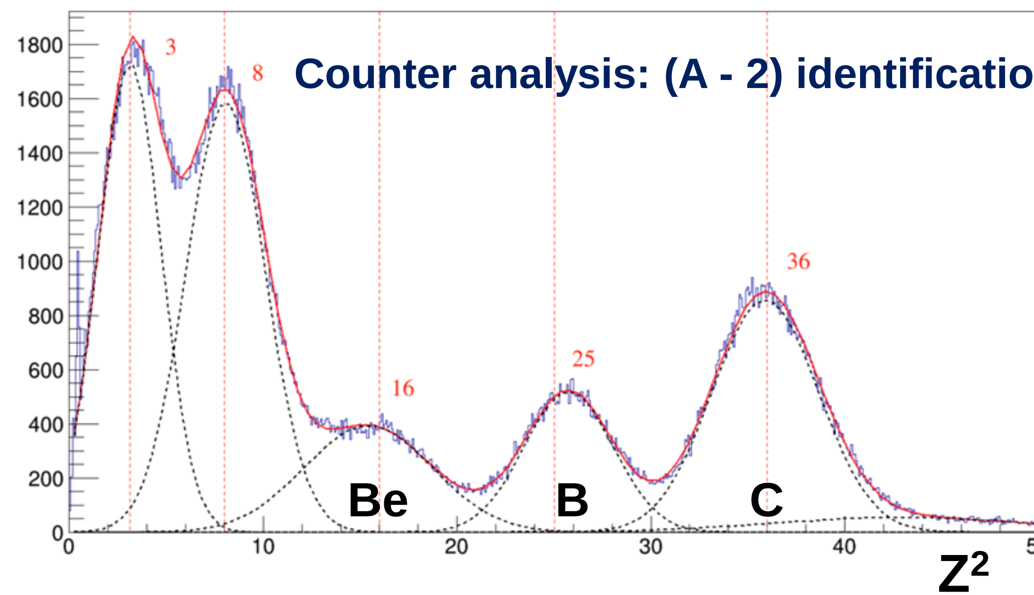
Trigger:

T0 · T1 · T2 · TC1 · TC2

Liq H_2

Signal rates for 14 days of data taking

Within LAND acceptance



First SRC @ BMN run in March 2018

Formation of working groups

Hyperon reconstruction, simulation and analysis
A.Zinchenko, G.Pokatashkin, V.Vasendina, I.Roufanov, Yu.Gornaya +

Particle identification, simulation and analysis
Yu.Petukhov, M.Rumyantsev, V.Plotnikov, N.Kuzmine, V.Babkin, N.Voitishin +

Track reconstruction and simulation
S.Merts, P.Batyuk, A.Zinchenko, G.Pokatashkin, I.Gabdrahmanov, D.Baranov +

BMNROOT software development
K.Gertsenberger, S.Merts, P.Batyuk, D.Baranov, A.Moshkin, G.Pokatashkin, A.Zinchenko +

Data quality analysis
P.Batyuk, G.Pokatashkin, I.Gabdrahmanov, I.Roufanov, S.Sedykh +

Detector simulation and reconstruction
S.Merts, P.Batyuk, A.Zinchenko, D.Baranov, E.Litvinenko +

ECAL: gamma data analysis and simulation
S.Afanasiev, A.Stavinsky, H.Abramyan + groups

SRC data analysis and simulation
M.Patsyk, V.Lenivenko, N.Voitishin, V.Palchik, M.Rumiantsev, Yu.Petukhov + MIT,CEA,Tel Aviv

ZDC: centrality / reaction plane data analysis and simulation
F.Guber + INR RAS team, O.Gavrischuk, E.Litvinenko +

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

Year	2016	2017 spring	2018 spring	2020	2021 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 + small + large Si planes	7 GEM full planes + small + large Si planes
Experimental status	technical run	technical run	technical run+physics	stage1 physics	stage2 physics

Nuclotron - BM@N beam line

Nuclotron beams for BM@N experiment: kin. energy of 1 - 4.5 AGeV, intensity few 10^6 per spill for Z/A~0.4 , beams from proton to Au

Need upgrade of Nuclotron - BM@N beam transport channel :

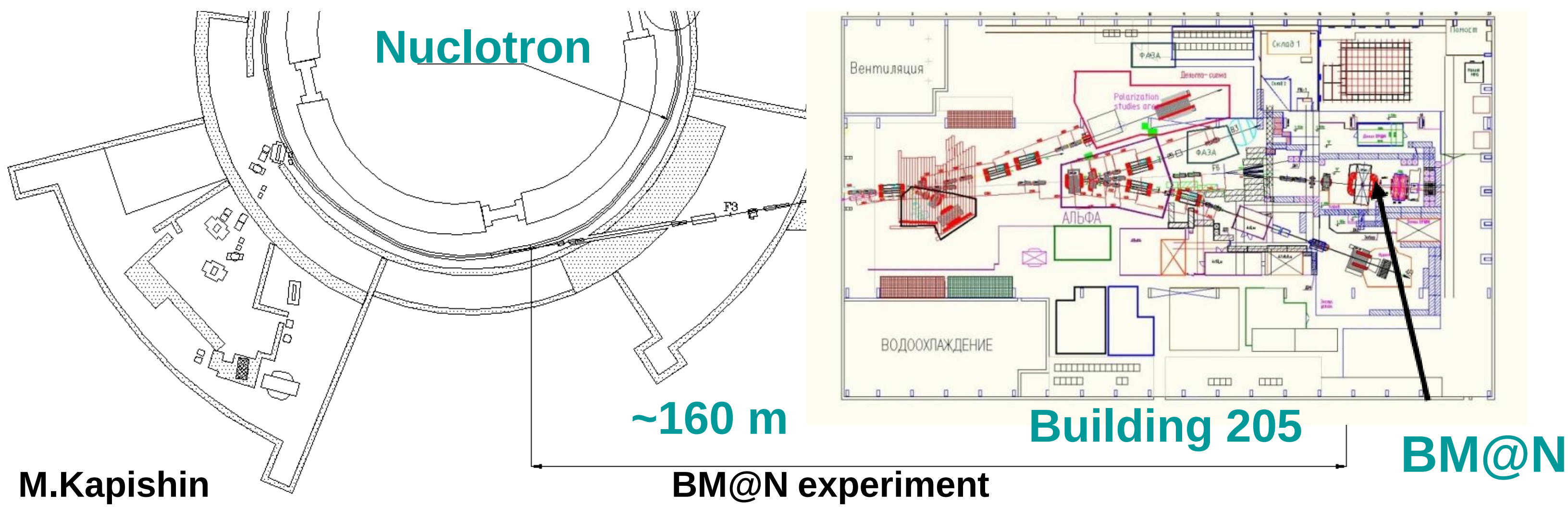
→ replace air intervals / foils with vacuum beam pipe along 160 m of BM@N transport line to get minimum dead material

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

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

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

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



M.Kapishin

Present status and next plans

- **BM@N technical runs performed with deuteron and carbon beams at energies T_0 = 3.5 - 4.6 AGeV and recently with Ar beam of 3.2 AGeV and Kr beam of 2.4 AGeV**
- **Measurement of Short Range Correlations performed with inverse kinematics: C beam + H_2 target**
- **Major sub-systems are operational, but are still in limited configurations**
- **Algorithms for event reconstruction and analysis are being developed, signals of Λ hyperon decays are reconstructed**

Major BM@N plans for Au+Au run in 2020-2021:

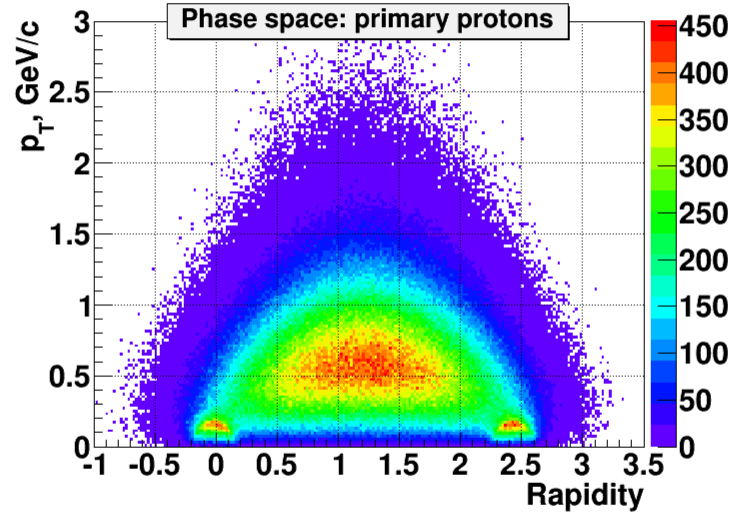
- **Collaborate with CBM to produce and install large aperture STS silicon detectors in front of GEM setup**
- **Extend GEM central tracker and CSC outer tracker to full configuration**
- **Install MPD / CBM type of hadron ZDC calorimeter**
- **Implement vacuum / helium beam pipe through BM@N setup**

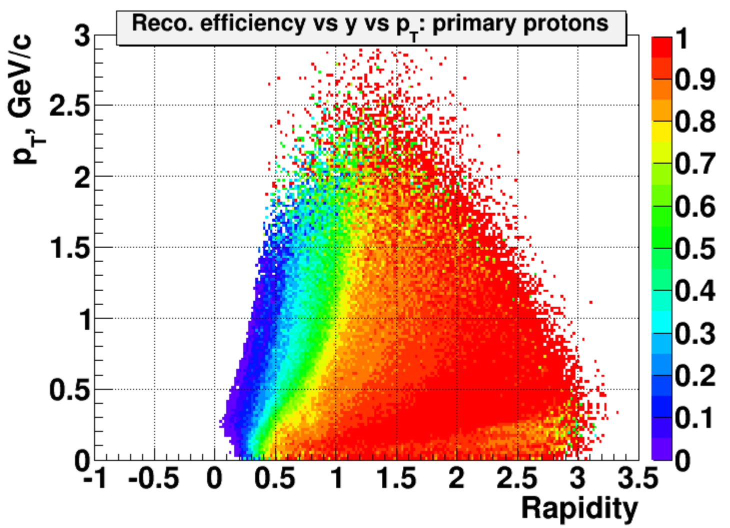
Thank you for attention!

Backup slides

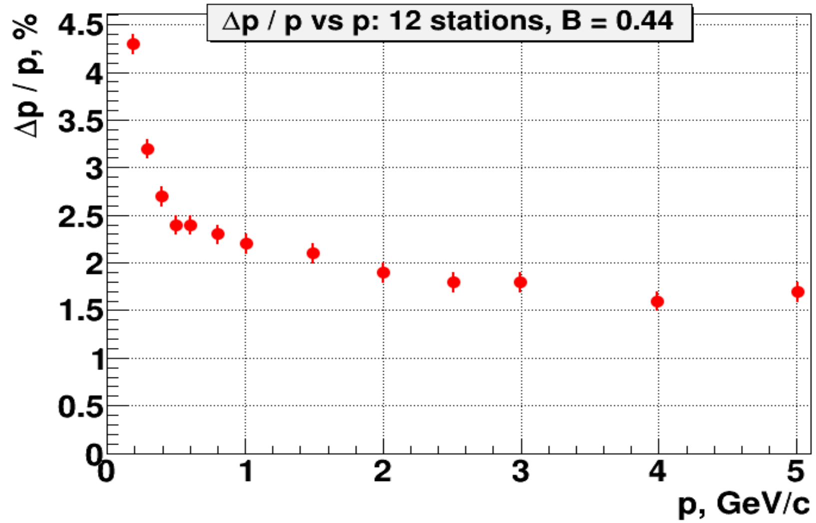
GEM tracker: acceptance / momentum resolution / detection efficiency

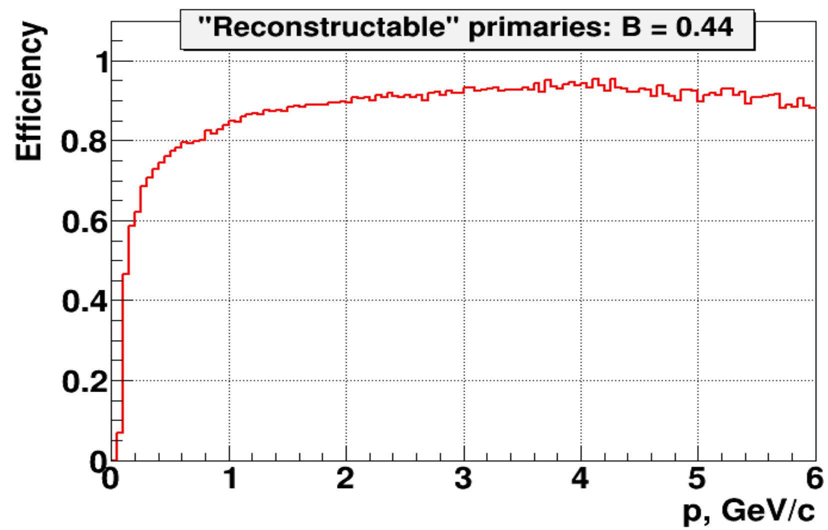
Phase space / acceptance to primary protons: Au+Au, 4.5 AGeV





Momentum resolution / detection efficiency





Λ in deuteron and carbon beams

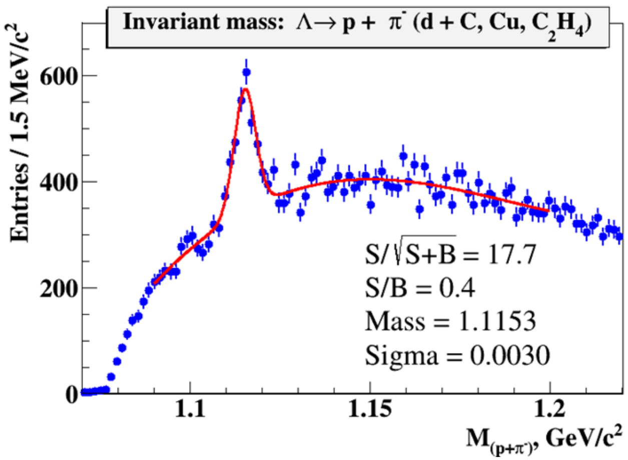
BM@N

talk of A.Zinchenko

d (C) + target → X

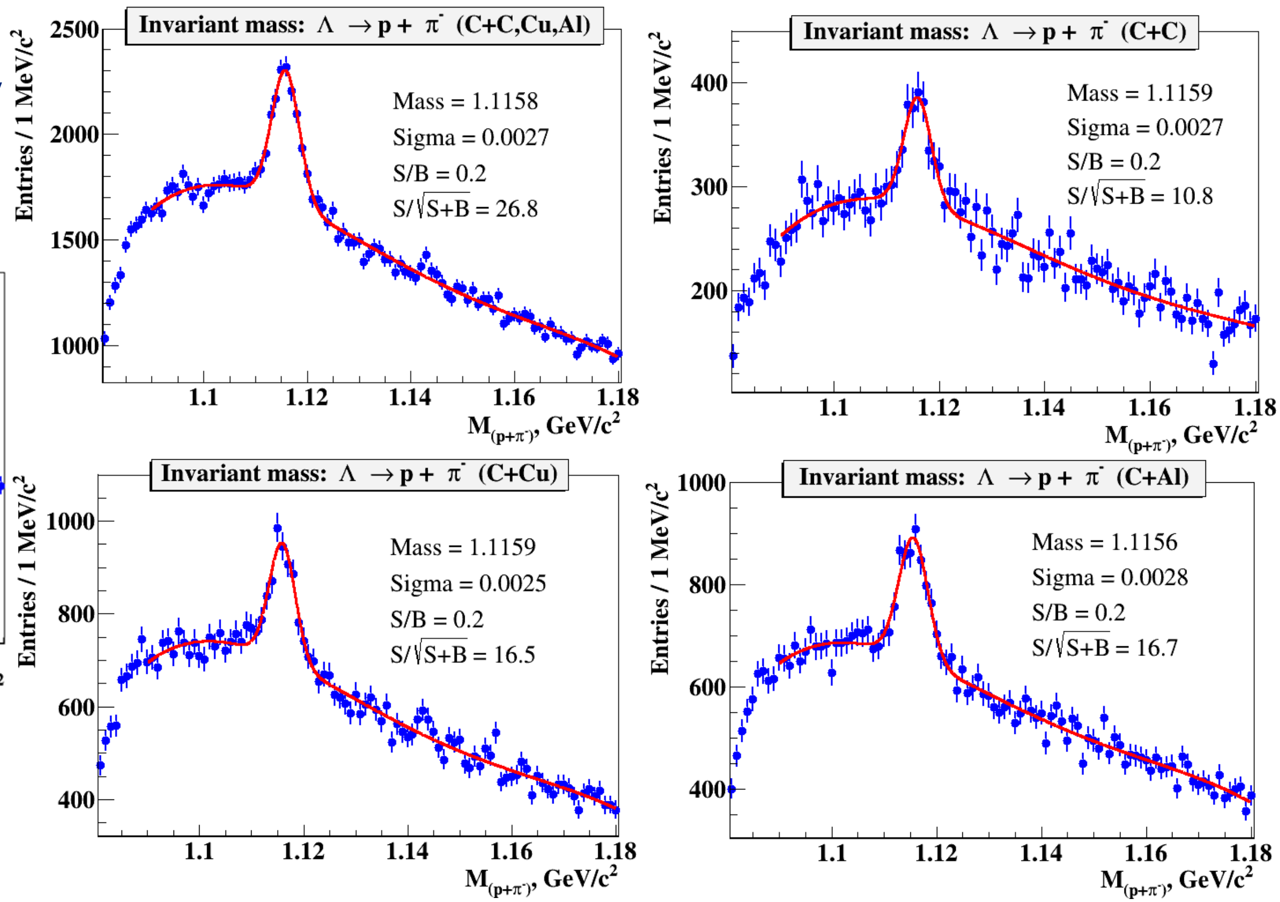
Λ signal width ~ 2.5-3 MeV

Deuteron Data



A.Zinchenko + analysis team

Carbon beam run, 4 AGeV



To improve vertex and momentum resolution and reduce background under Λ:

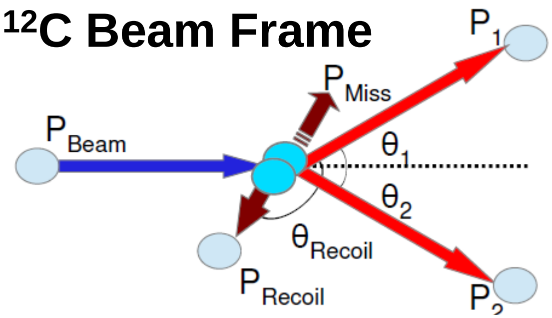
- **Need few planes of forward Silicon detectors → 3 planes used in last run**
- **Need more GEM planes to improve track momentum reconstruction**

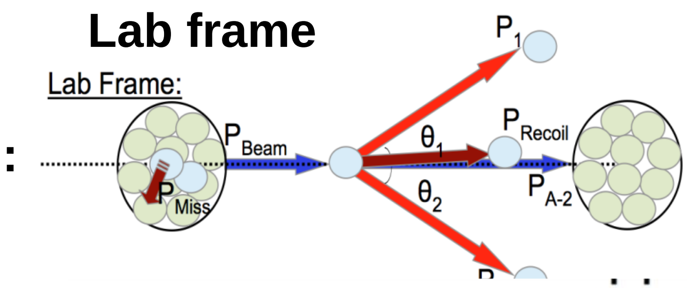
Methodical Paper published in PEPAN Letters, v.15, p.136, 2018(2): First results from BM@N technical run with deuteron beam

A proposal for BM@N experiment

to study SRC with hard inverse kinematic reactions

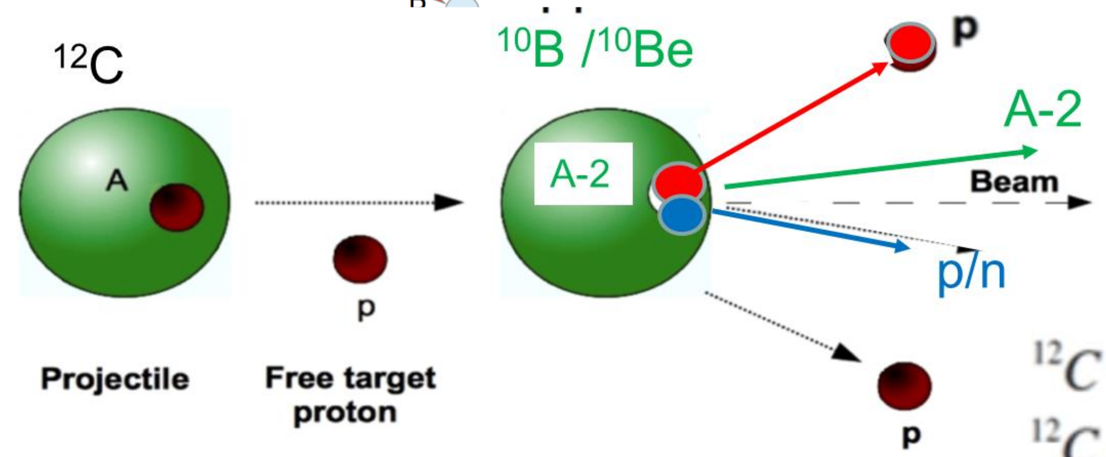
JINR (Dubna): BM@N
Israel: Tel Aviv University
Germany: TUD and GSI
USA: MIT
FRANCE: CEA





Objectives:

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



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

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