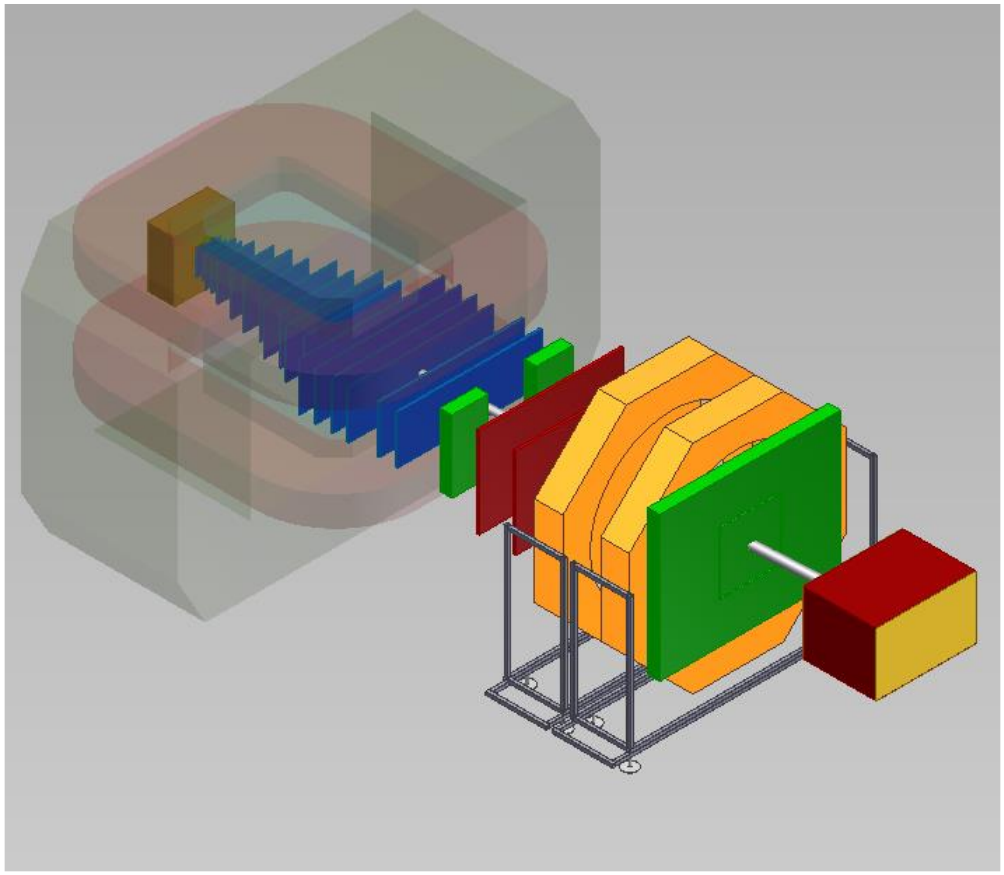
Progress of Baryonic Matter at Nuclotron

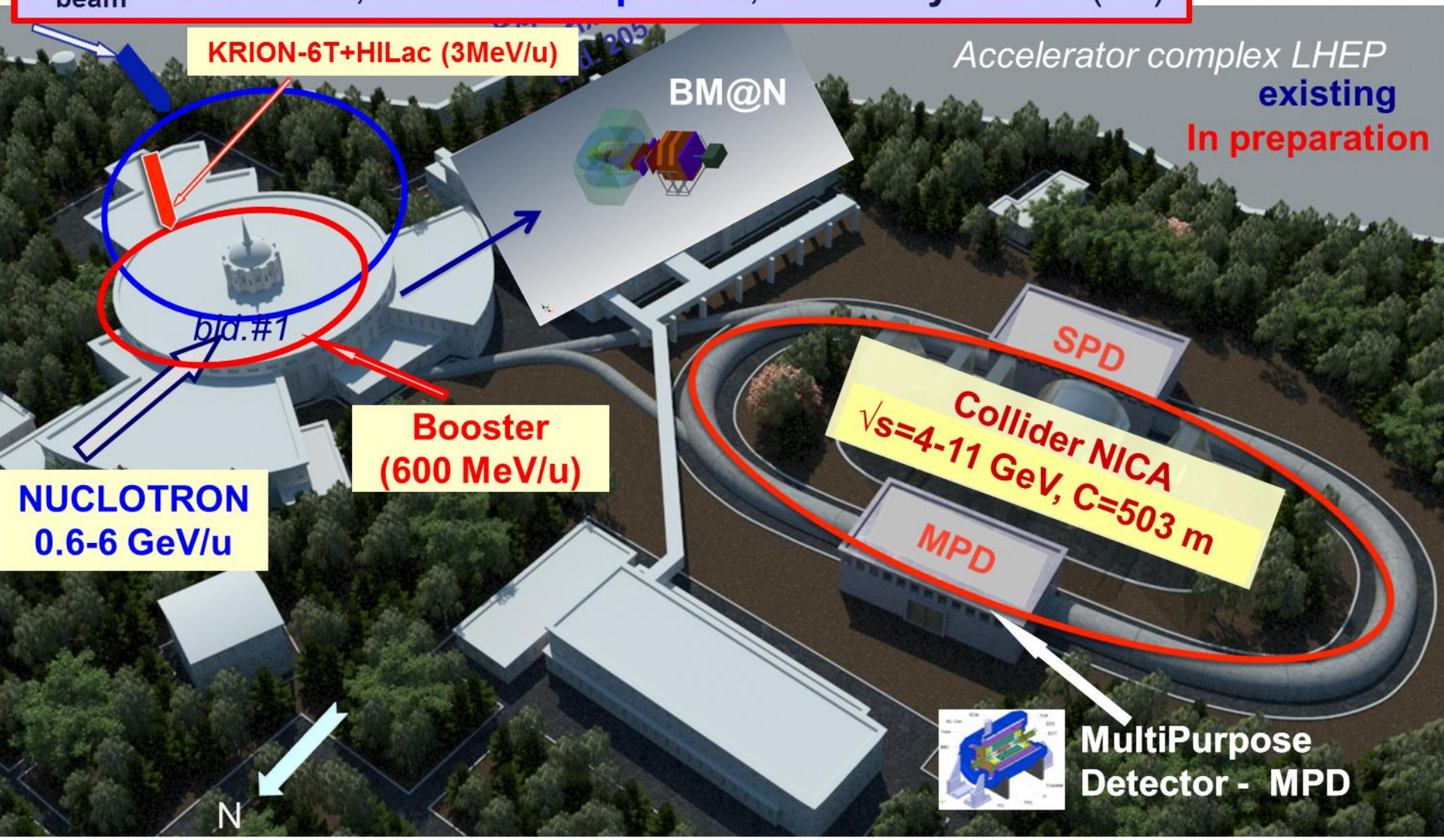
M.Kapishin

for BM@N Collaboration



Complex NICA

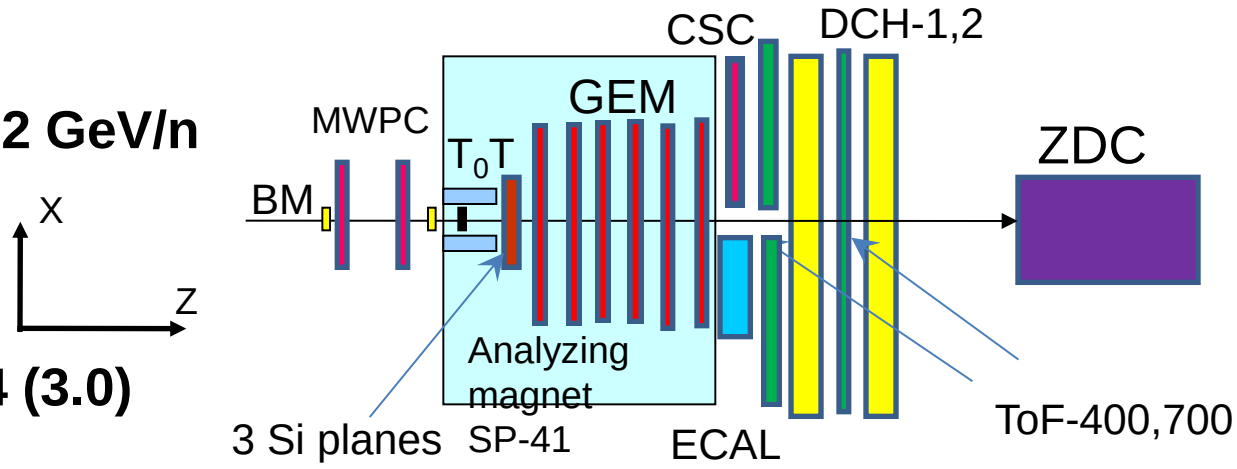
Parameters of Nuclotron for BM@N experiment:
E_{beam} = 1-6 GeV/u; *beams*: *from* p to Au; Intensity~10^7 c^{-1} (Au)



BM@N 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

→ 130 M events in Ar beam, 50 M events in Kr beam

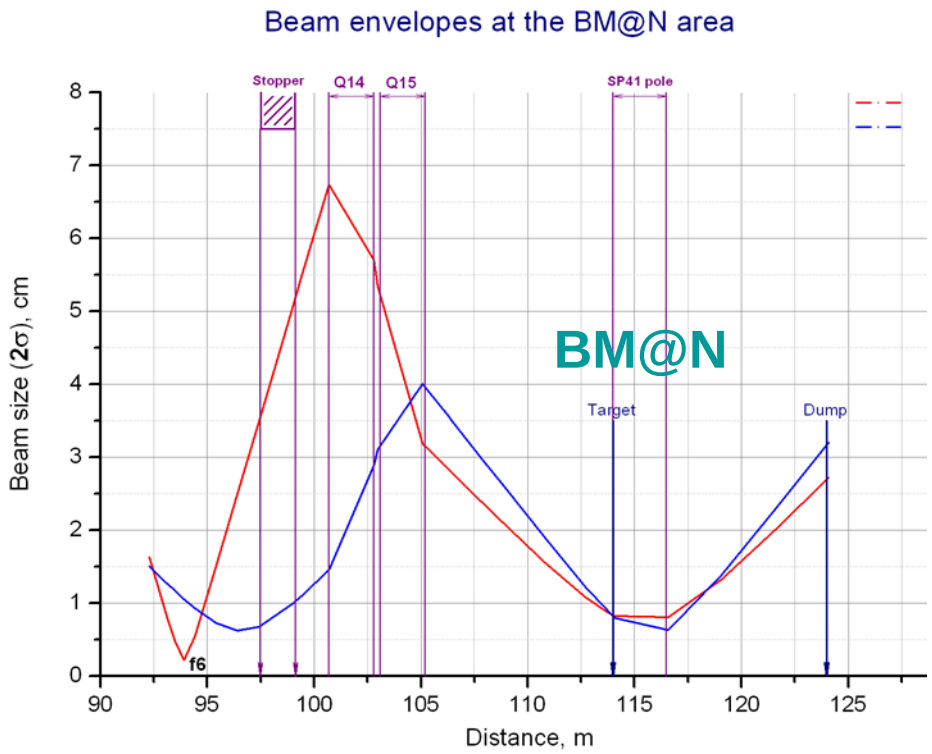
+ SRC program in Carbon beam with Liq H_2 target (talk of E.Piasetzky)

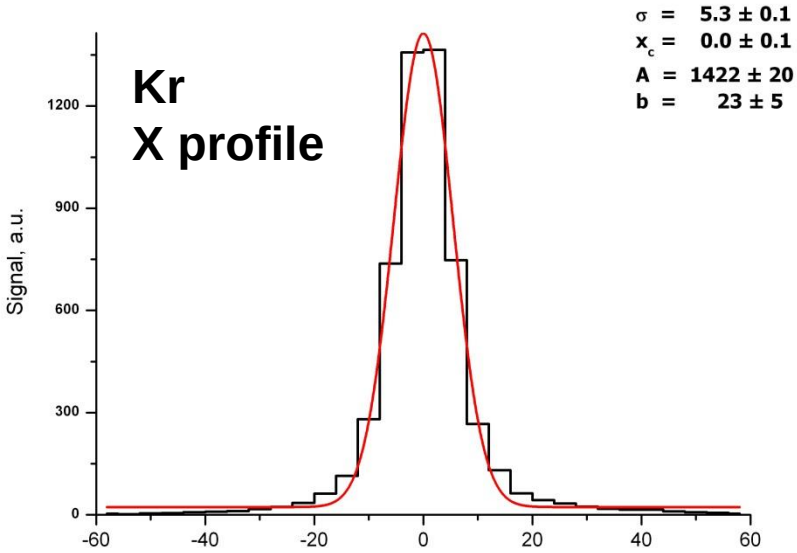
+ analyze data from previous technical runs with Deuteron and Carbon beams of 3.5 - 4.6 GeV/n

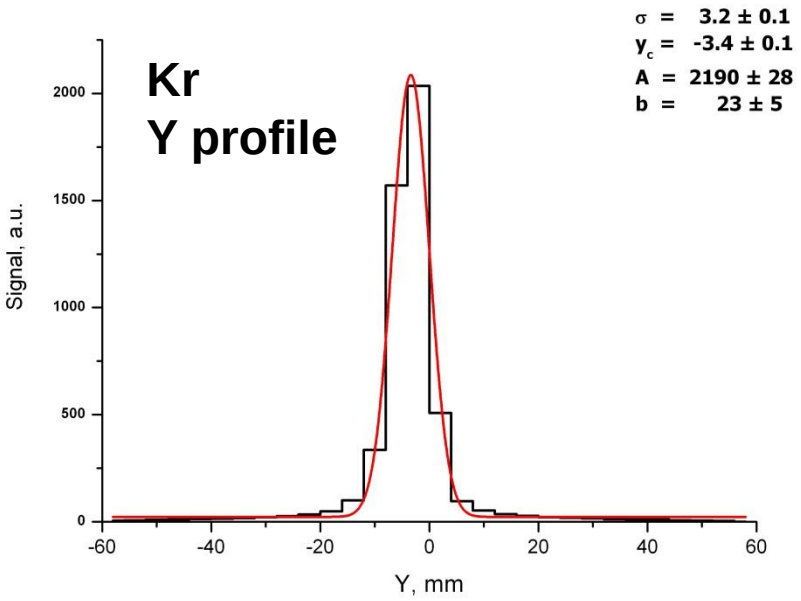
BM@N beam profile

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

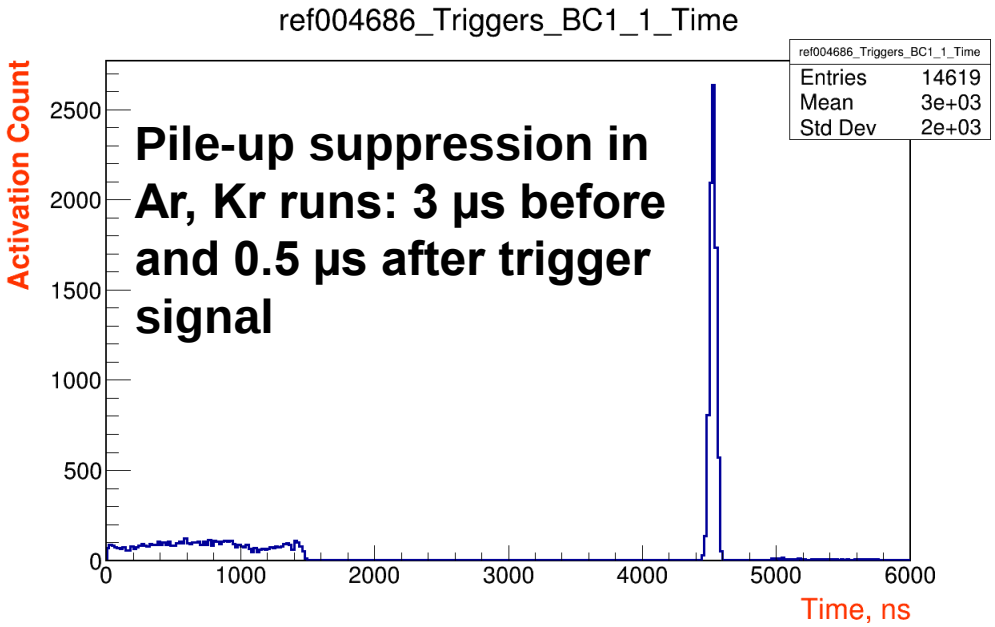
C^{12} 2017	Ar 2018	Kr 2018
σ_X = 6 mm	5 mm	5.3 mm
σ_Y = 4.9 mm	5 mm	3.2 mm



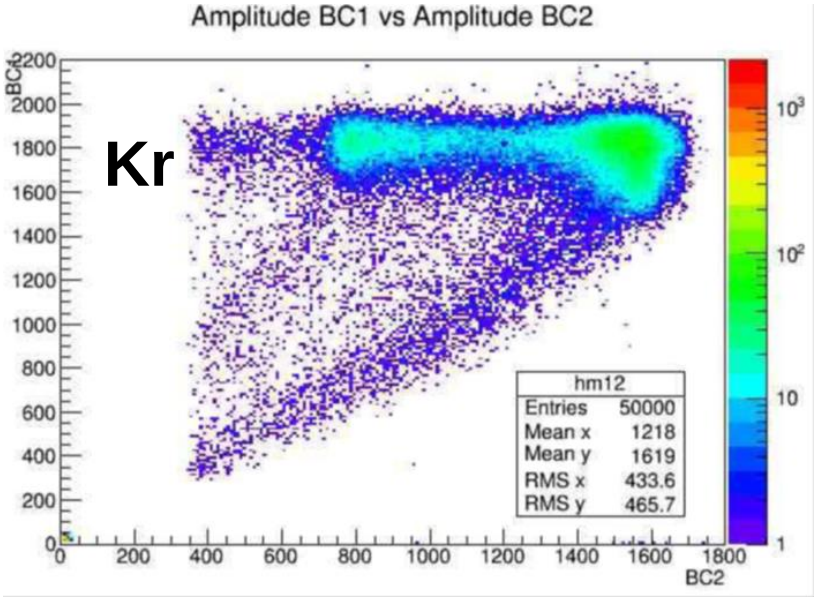


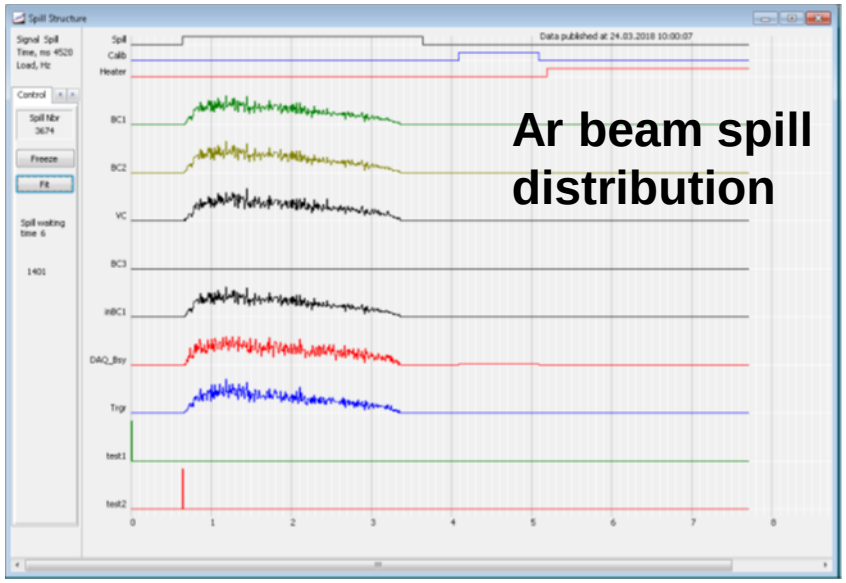


Beam structure & pile-up suppression

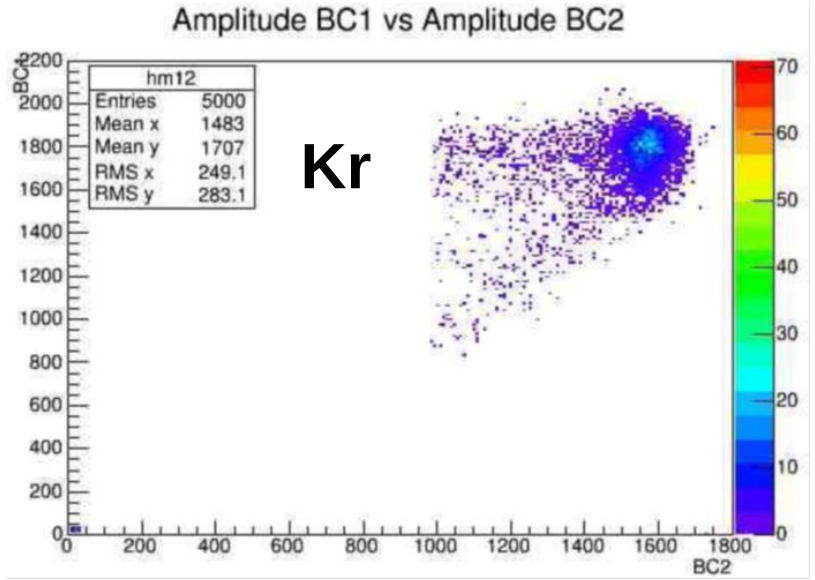


Low threshold in BC

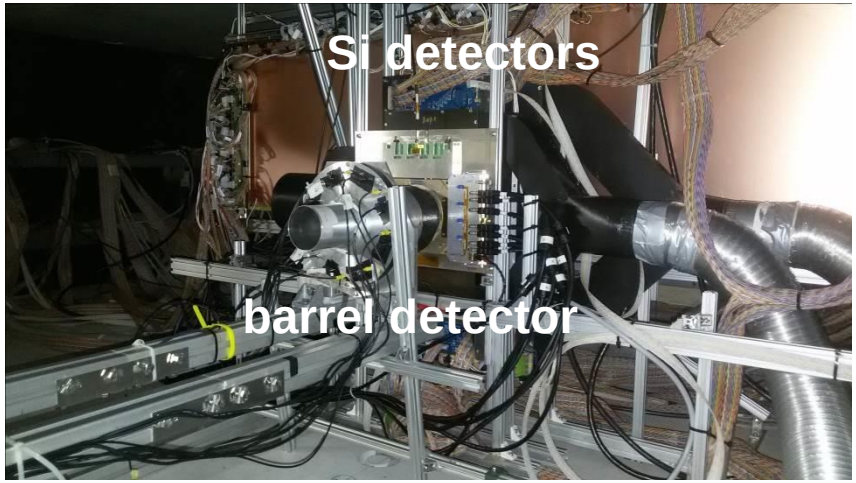




High threshold in BC

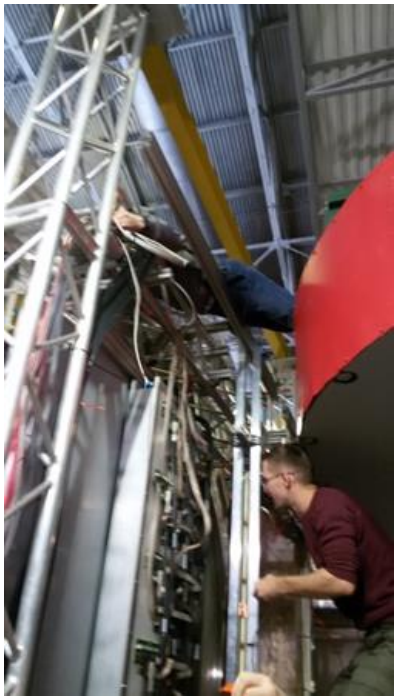


BM@N set-up in Ar, Kr run, March 2018



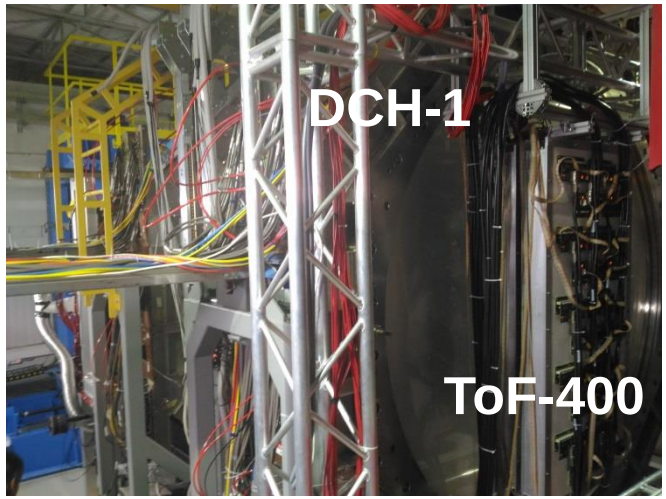
CSC chamber

ToF-400 installation

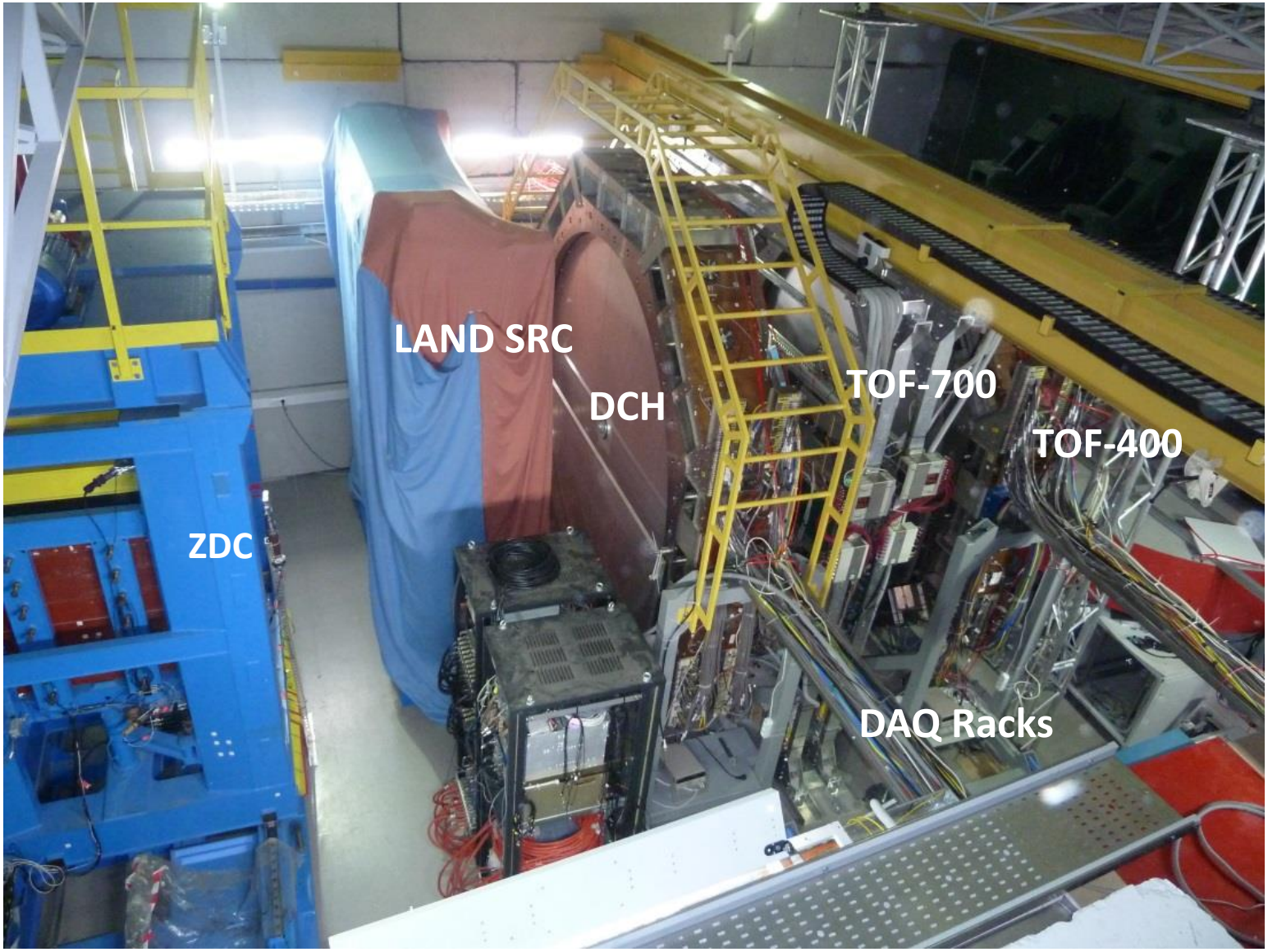


New detector components:

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



BM@N setup behind magnet, 2018

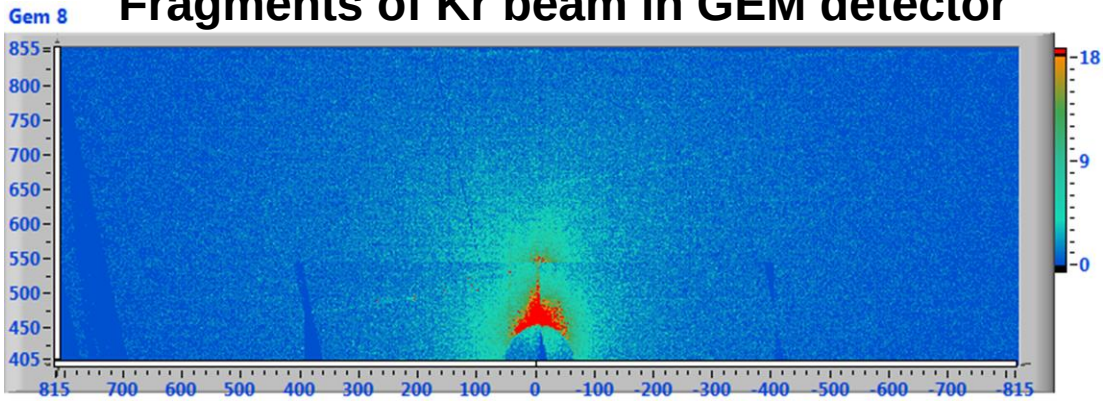


GEM detectors for central BM@N tracker

Tests of GEM detector 163 x 45 cm^2

GEM group

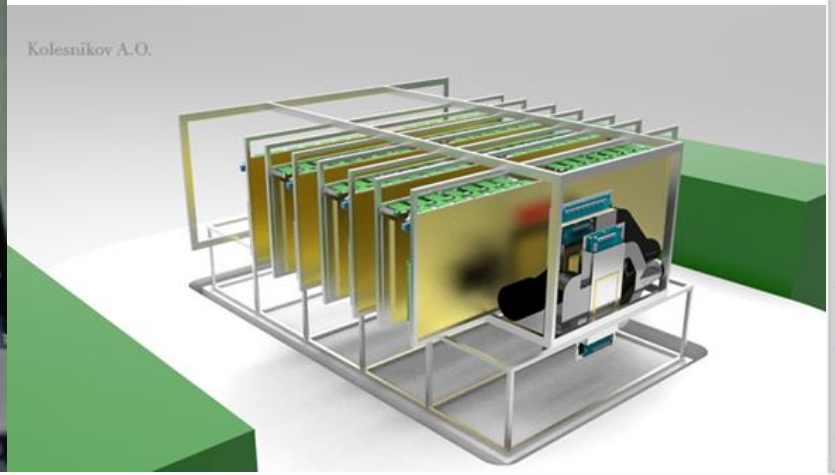
Fragments of Kr beam in GEM detector



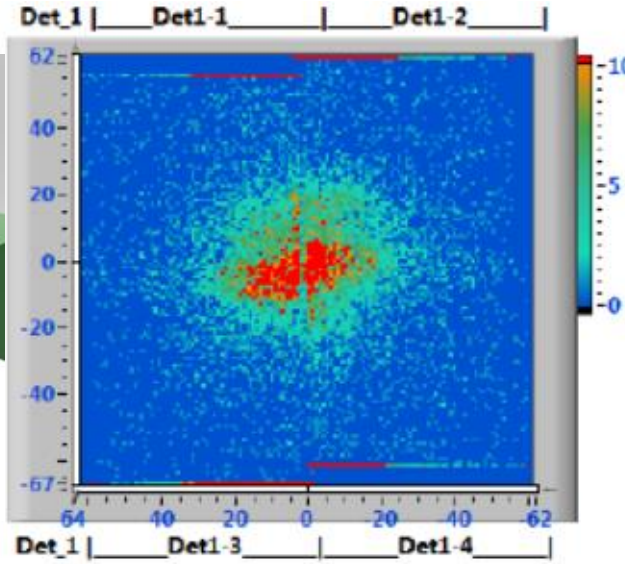
- 7 detectors of 163 x 45 cm^2 are produced at CERN workshop

Forward silicon strip detectors

Central tracker in Ar / Kr runs



Silicon detector group



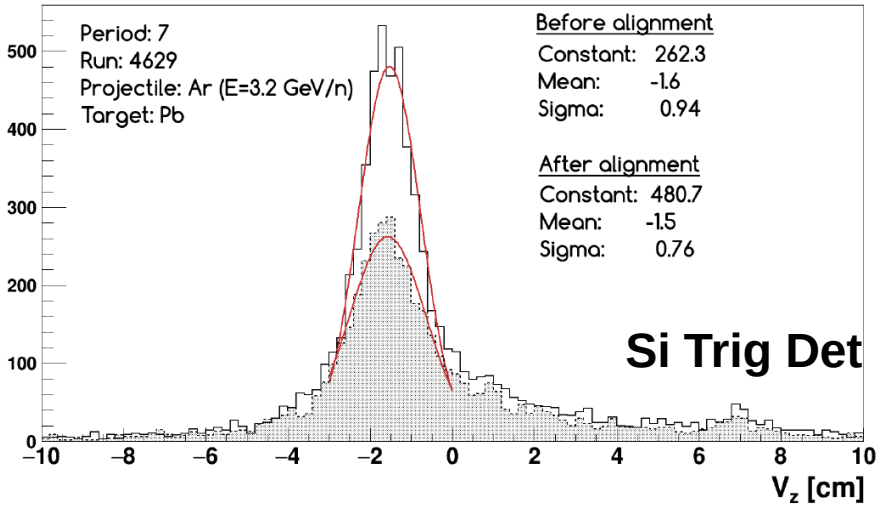
Kr beam fragments in Si Vertex detector

- 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

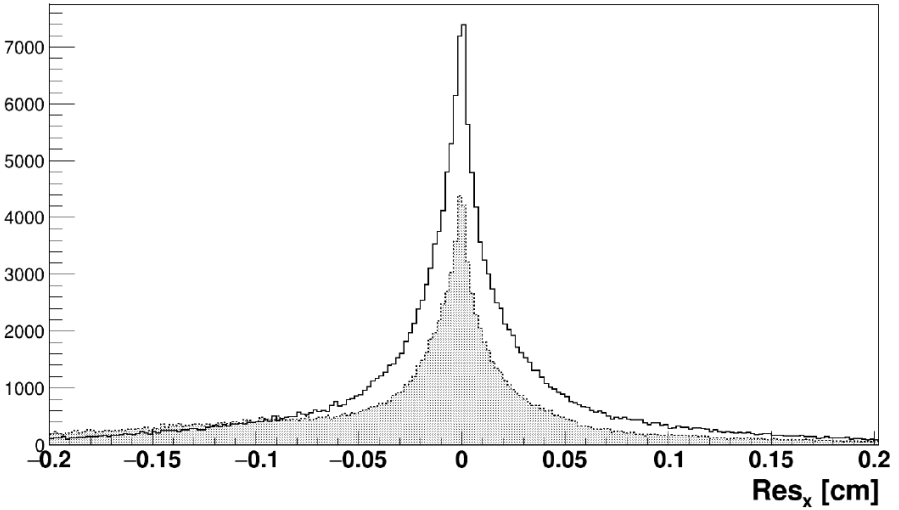
+ 2 smaller vertex detectors → March 2018

Alignment of GEM detectors in Ar / Kr runs

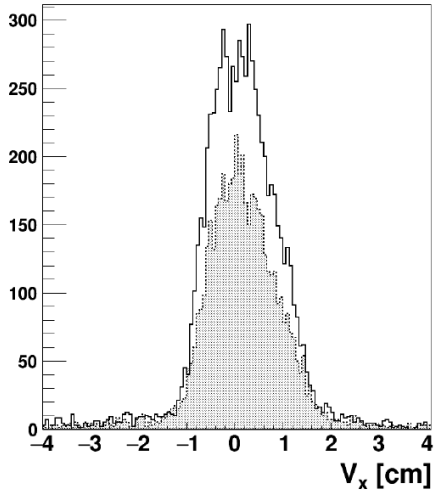
Track reconstruction + Milipede: P.Batyk, S.Merz

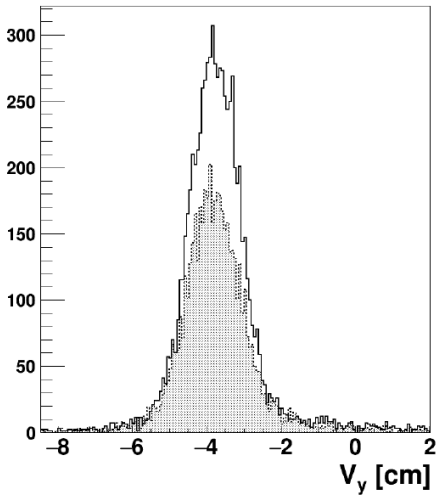


Vertex profile along beam

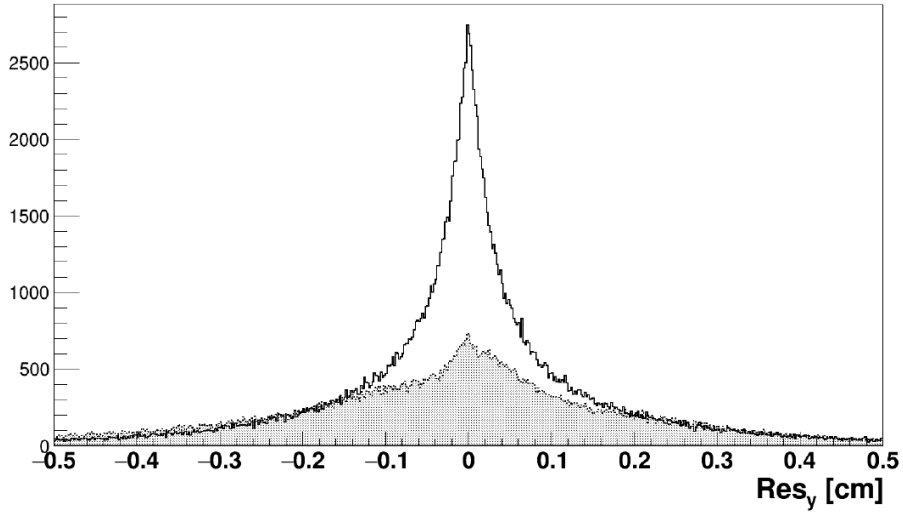


Track X residuals





X, Y vertex profiles

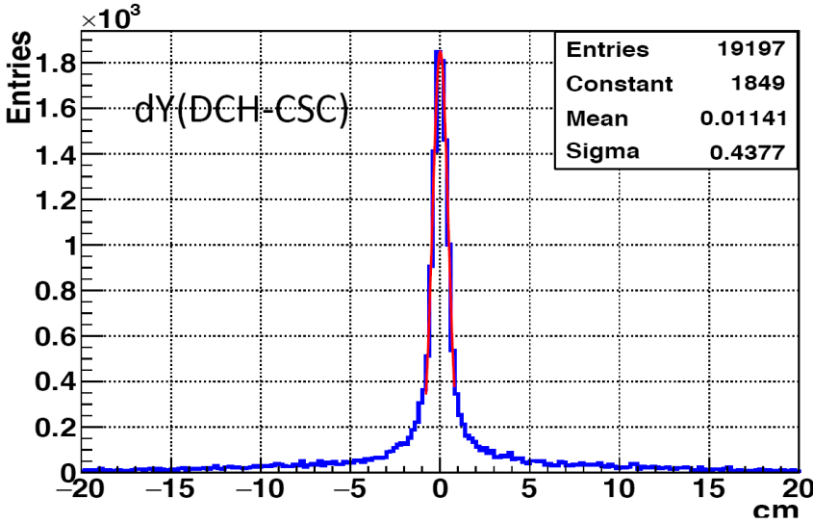


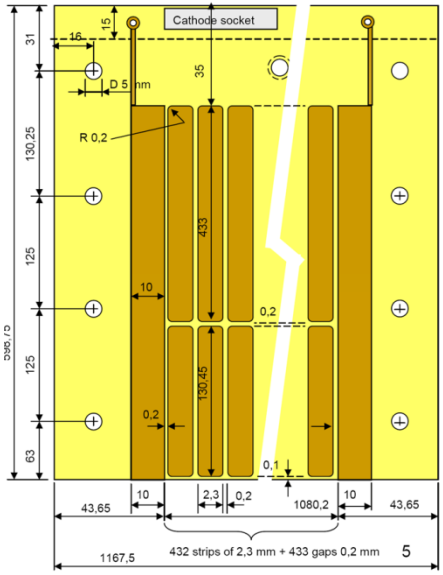
Track Y residuals

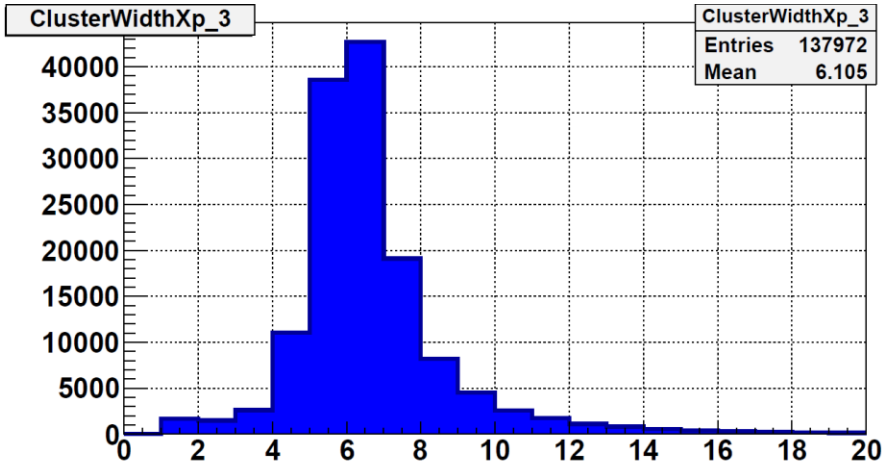
New Cathode Strip Chamber as Outer tracker

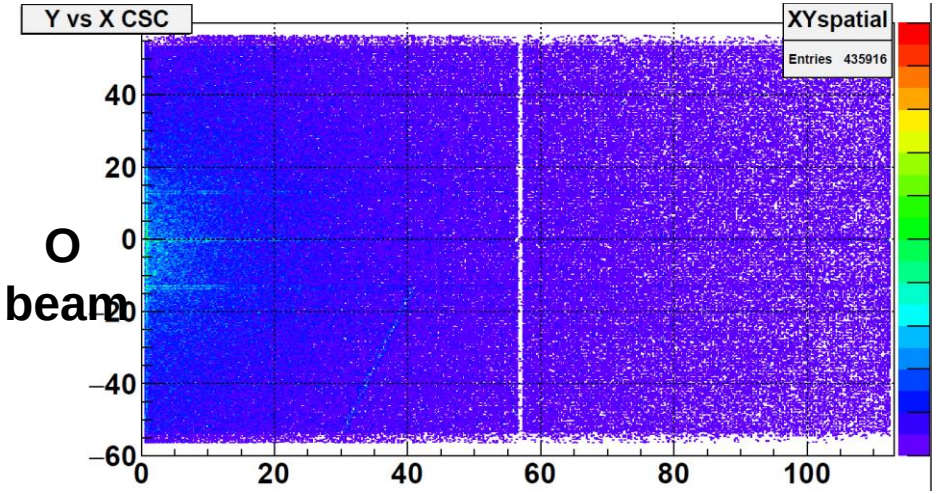
C, Ar and Kr runs in March 2018: CSC chamber installed in front of ToF-400 to check its performance as Outer tracker for heavy ions

A.Vishnevsky + GEM team
V.Palichik and analysis team







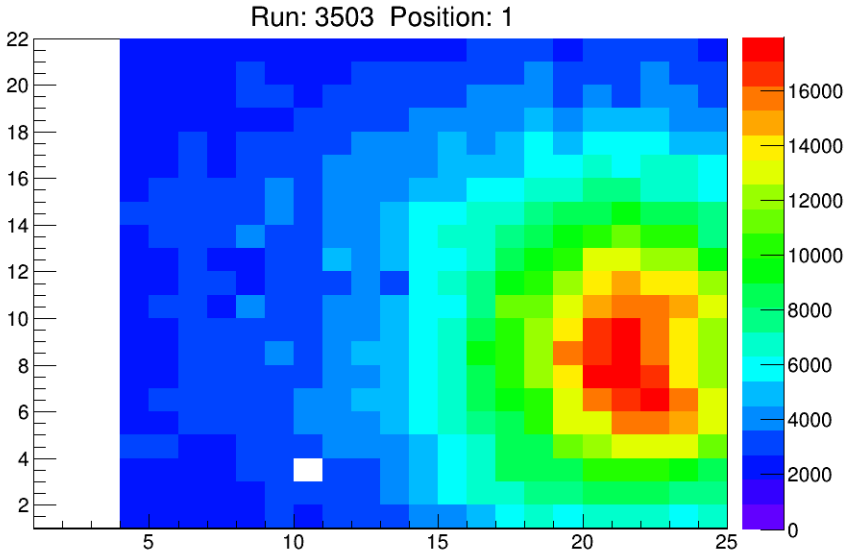


Electro-magnetic ECAL calorimeter

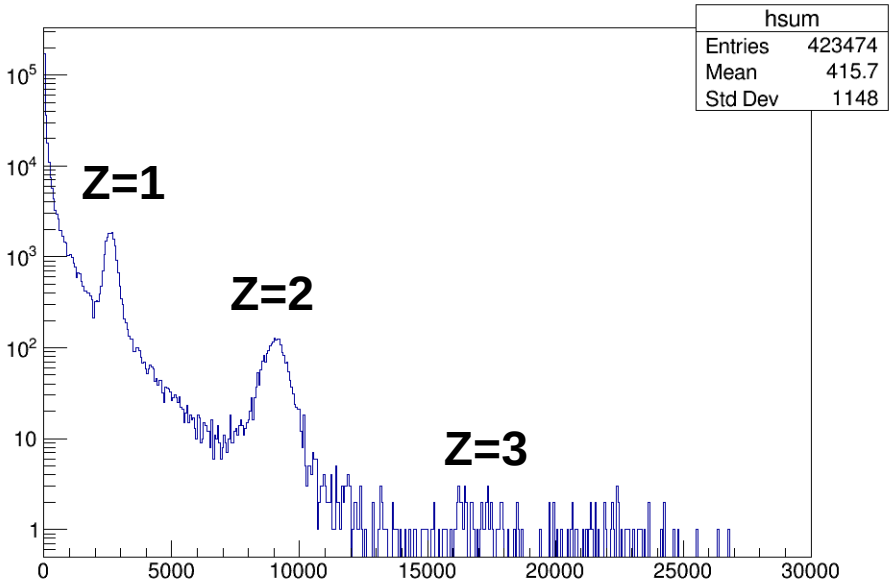
ECAL group

- **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

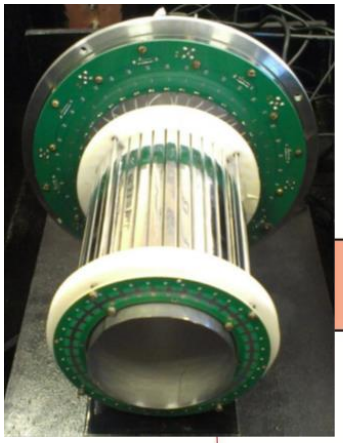


Interaction fragments inside ECAL

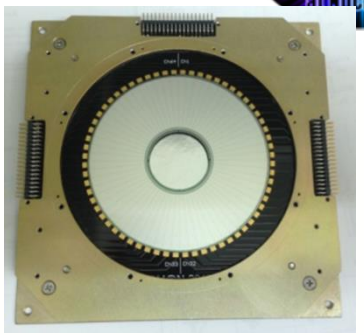


Trigger detectors and beam counters in Ar and Kr run, March 2018

Trigger + Si detector groups



Barrel detector



FD

BC1 – Beam Counter1 (PMT 87)

CD - Start detector (SiPM)

BC2 – Beam Counter2 (SiPM)

VC – Veto counter (XP2020)

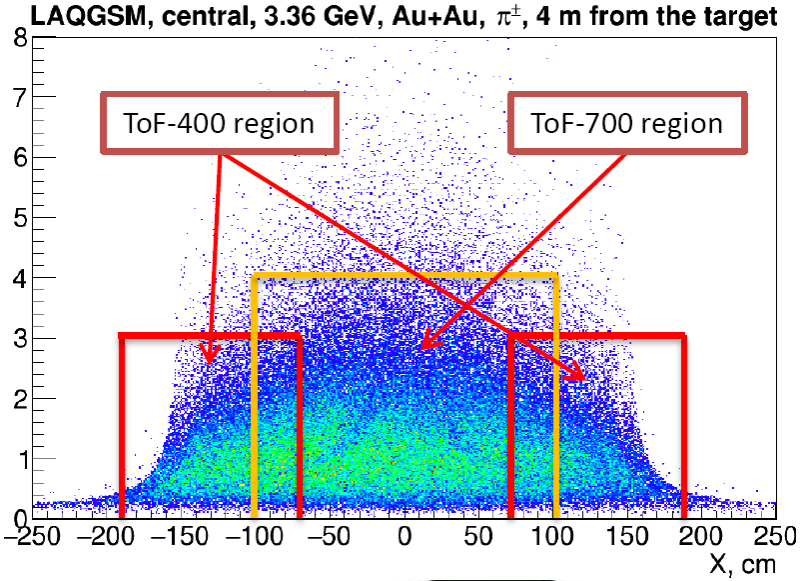
BD – Barrel Detector – 40ch. SiPM

T – target

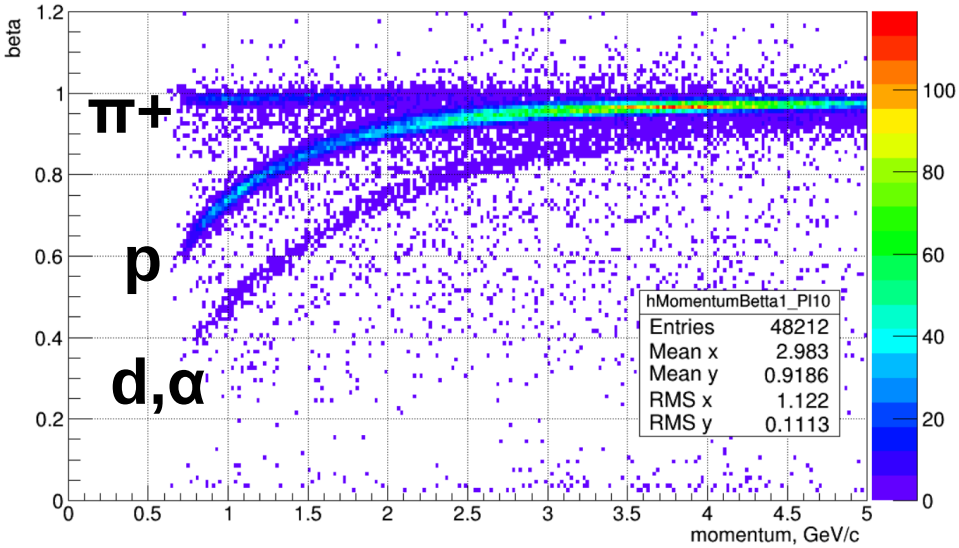
SiDet – Silicon Detector

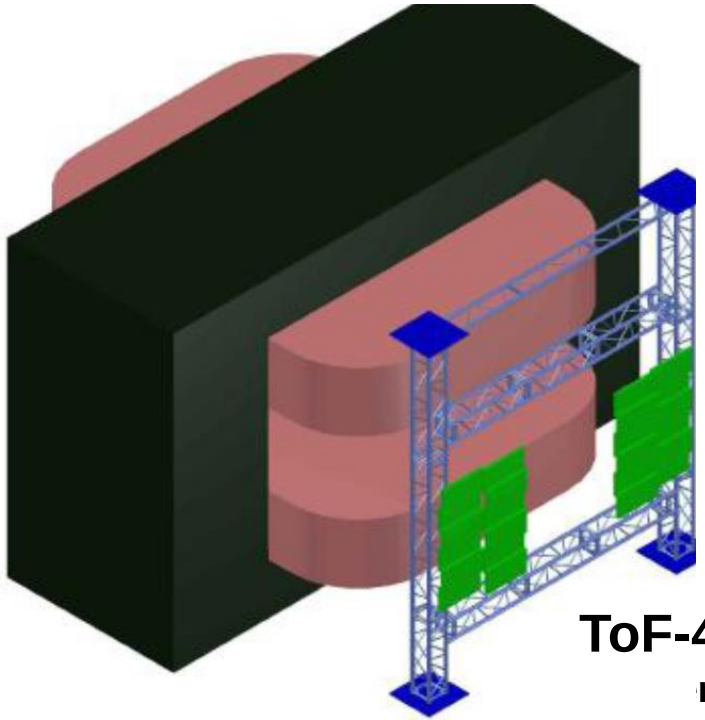
Selection of events with activity in barrel detector: BD >= N or forward Si detector: FD >= N

ToF-400 and ToF-700 based on mRPC



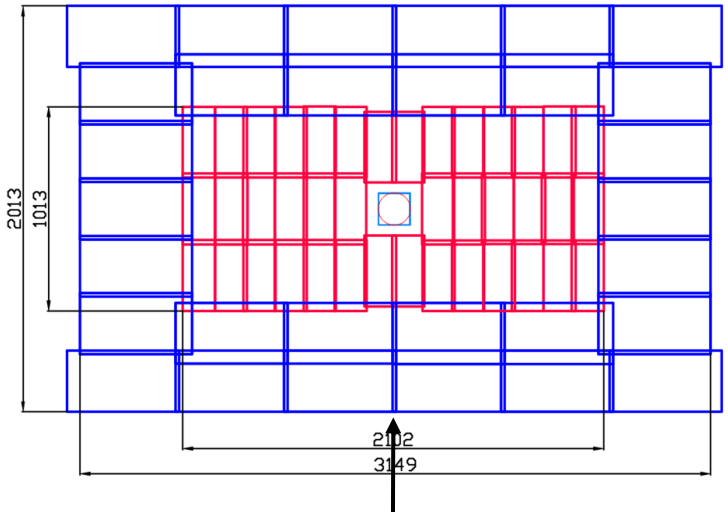
Carbon beam , 3.5 AGeV , C + Al → X





ToF-400 wall

ToF-700 wall



BM@N beam axis

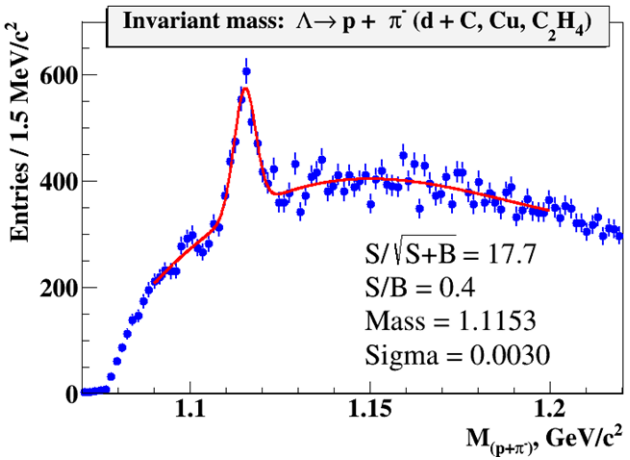
Λ in deuteron and carbon beams

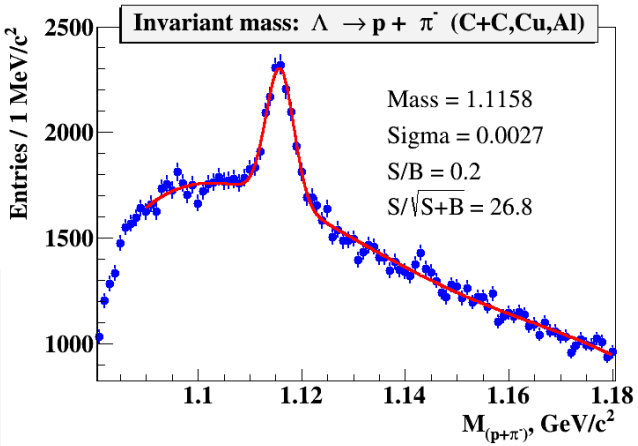
Carbon beam run, 4 AGeV

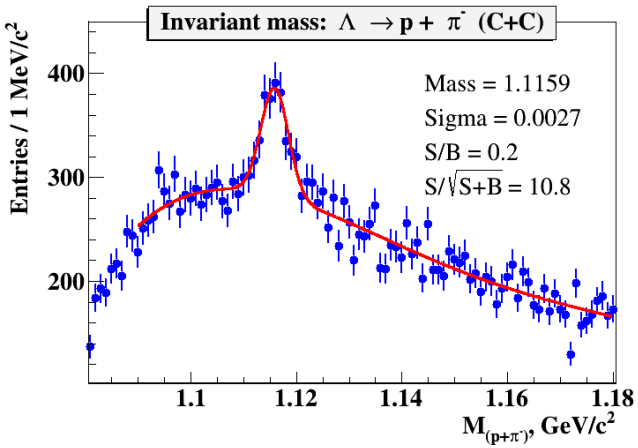
d (C) + target → X

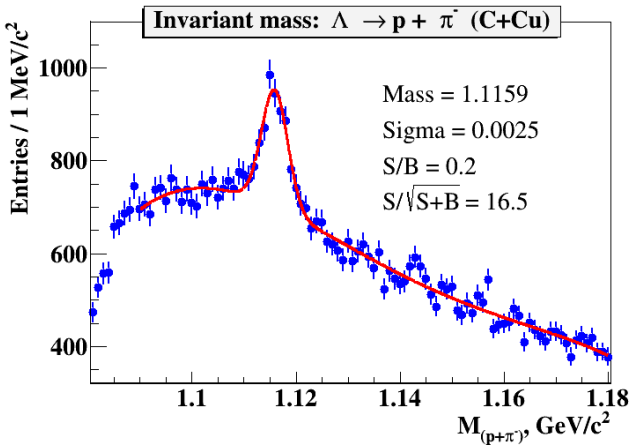
Λ signal width ~ 2.5-3 MeV

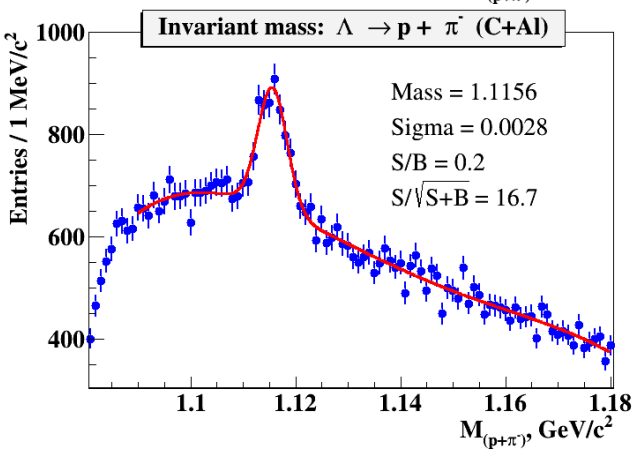
Deuteron Data











A.Zinchenko + analysis team

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

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	5M
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

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
- **First meeting of BM@N / MPD experiments** held in April to form Collaborations

Major BM@N plans for Au+Au to start in 2020:

- 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
- Implement vacuum / helium beam pipe through BM@N setup

Thank you
for attention!

Backup slides

Nuclotron and 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 magnet power system and BM@N beam line:

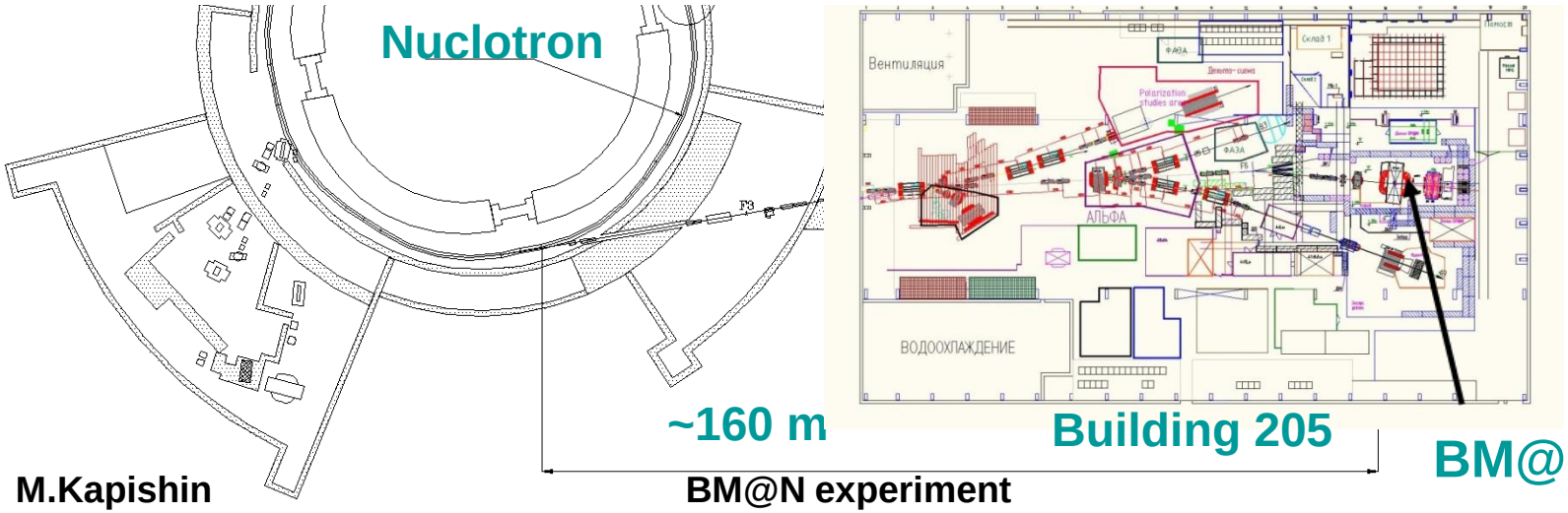
→ extend power of ring, septum, transport magnets to accelerate and transport ions of Z/A~0.4 (Kr, Xe, Au) with energy of 4.5 AGeV, increase beam spill up to 10 sec

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

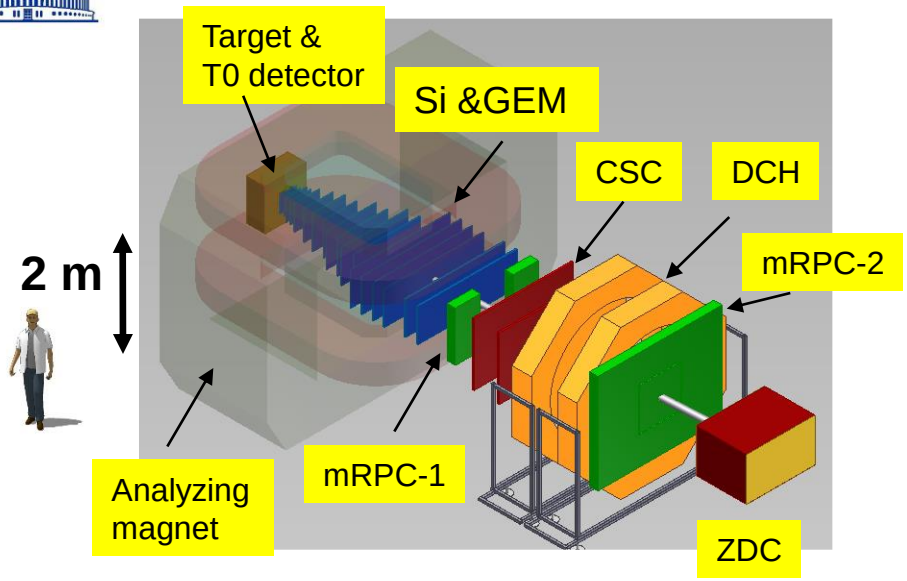
→ implement non-destructive beam position monitoring on movable vacuum inserts

→ implement instruments to limit beam size and spread at BM@N target (collimators ?)

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



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

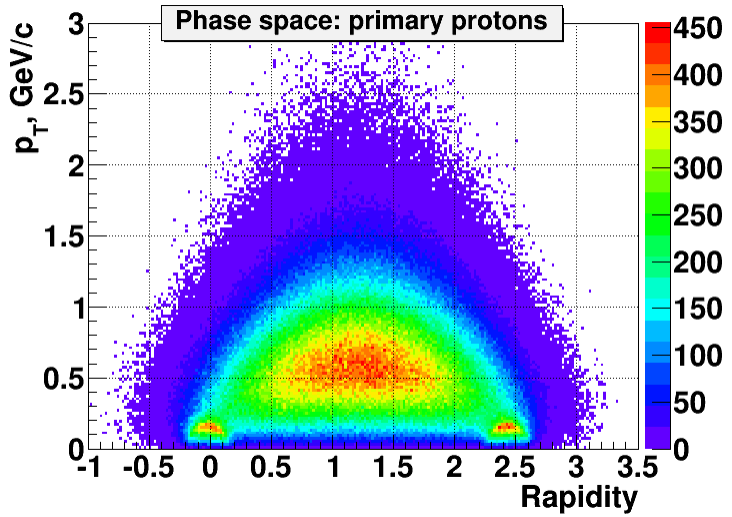
→ divide detectors for particle identification to “near to magnet” and “far from magnet” to measure particles with low as well as high momentum (p > 1-2 GeV/c)

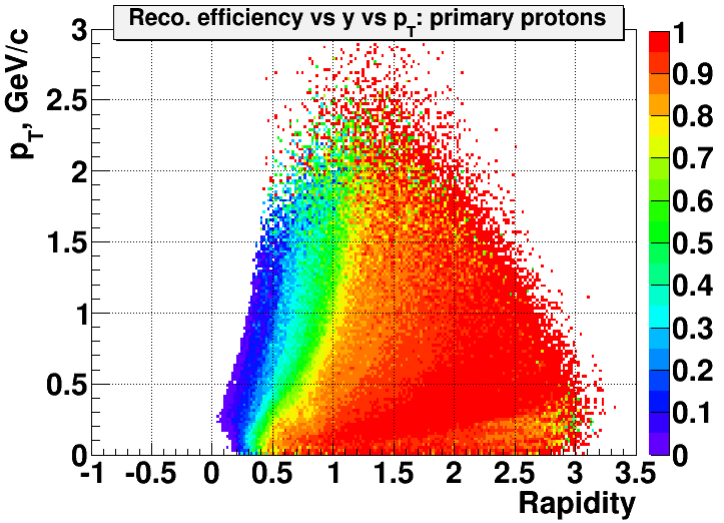
→ fill distance between magnet and “far” detectors with coordinate detectors

- 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-

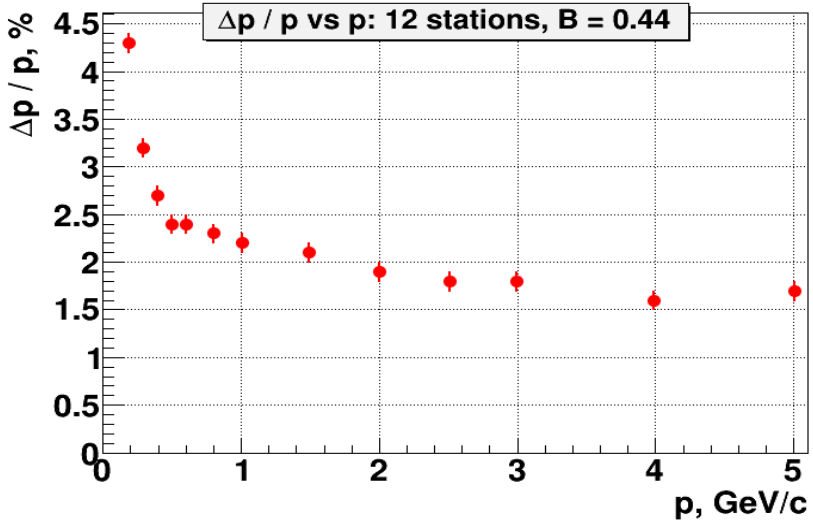
GEM tracker: acceptance / momentum resolution / detection efficiency

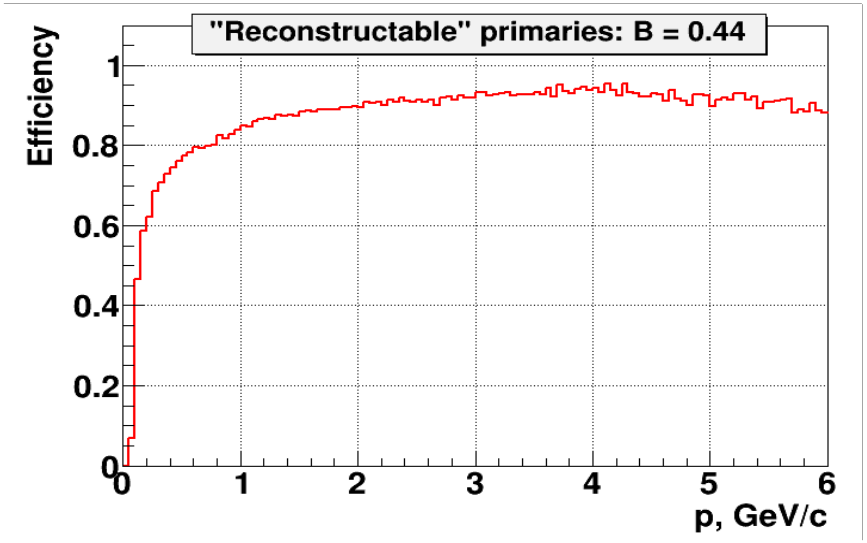
Phase space / acceptance to primary protons: Au+Au, 4.5 AGeV





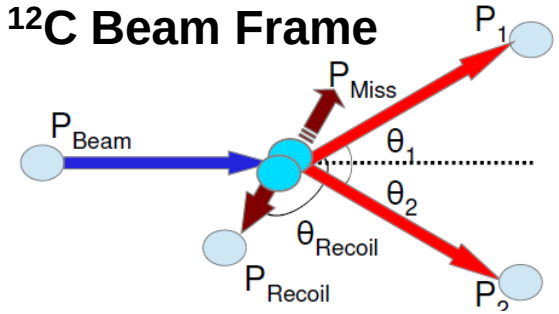
Momentum resolution / detection efficiency

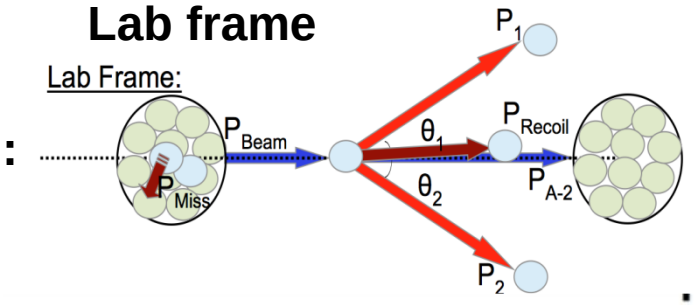




A proposal for BM@N experiment

to study SRC with hard inverse kinematic reactions

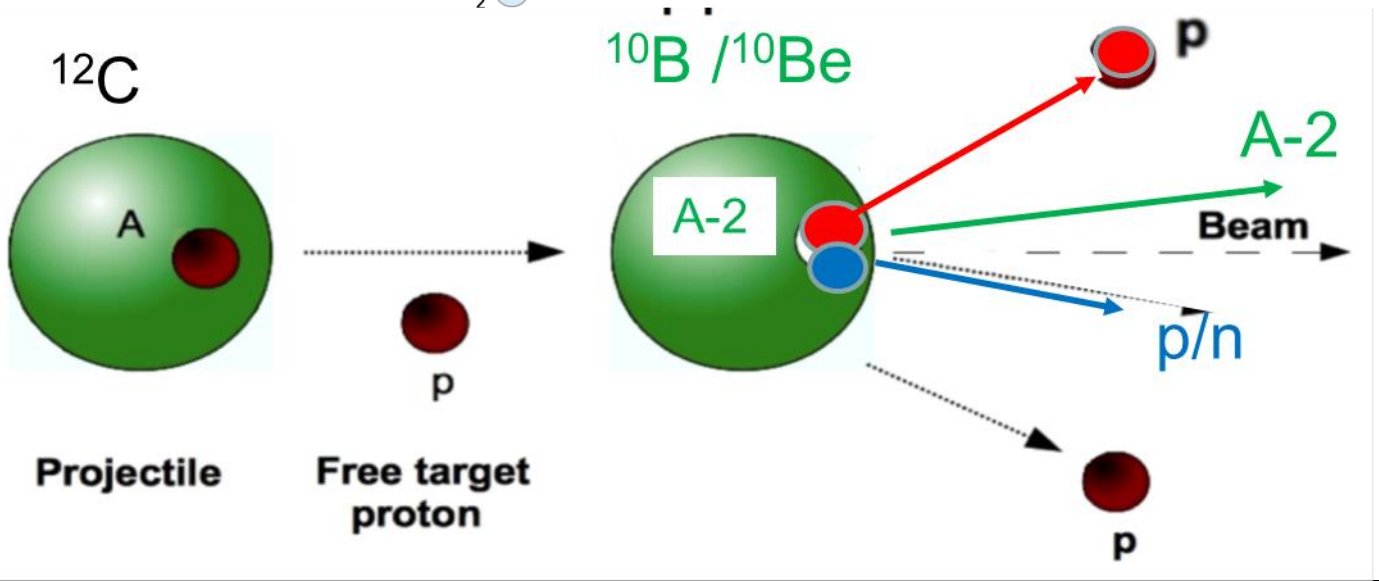




JINR (Dubna): BM@N
Israel: Tel Aviv University
Germany: TUD and GSI
USA: MIT
FRANCE: CEA

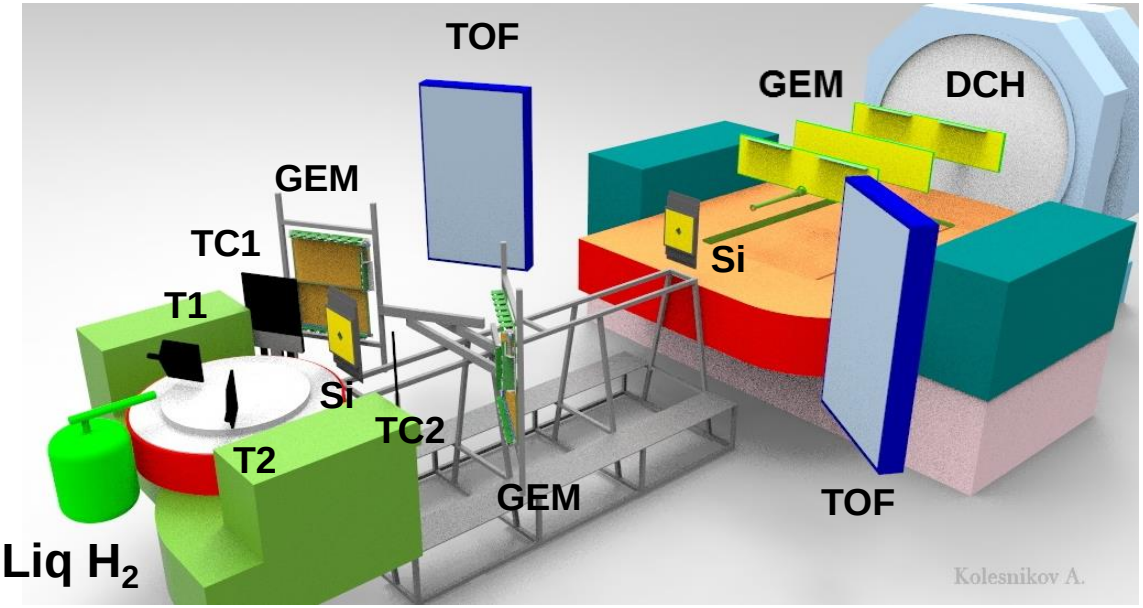
Objectives:

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



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

T0 +Target + T1

Signal rates for 14 days of data taking

Within LAND acceptance

$^{12}C + p \rightarrow {}^{10}B + pp$ np SRC

$^{12}C + p \rightarrow {}^{10}Be + pp$ pp SRC

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

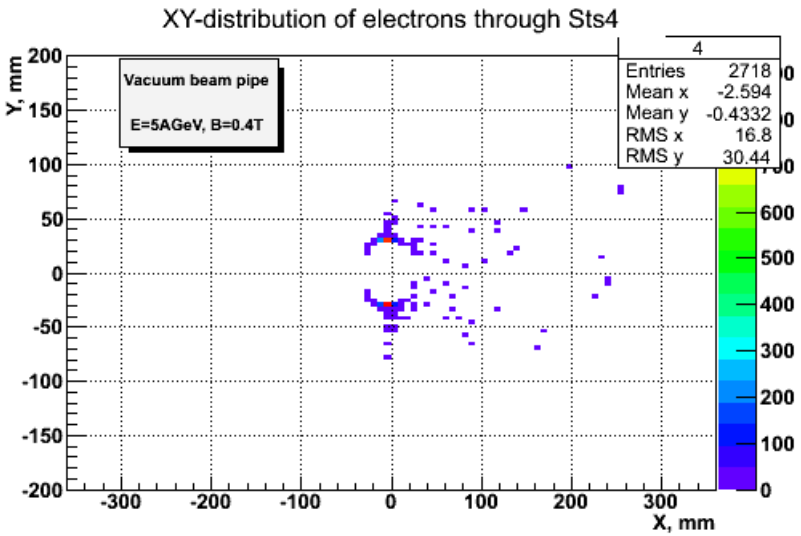
$^{12}C + p \rightarrow 2p + {}^{10}_{4}Be + p$ pp SRC

→ First SRC @ BMN run in March 2018: collected 8 M events

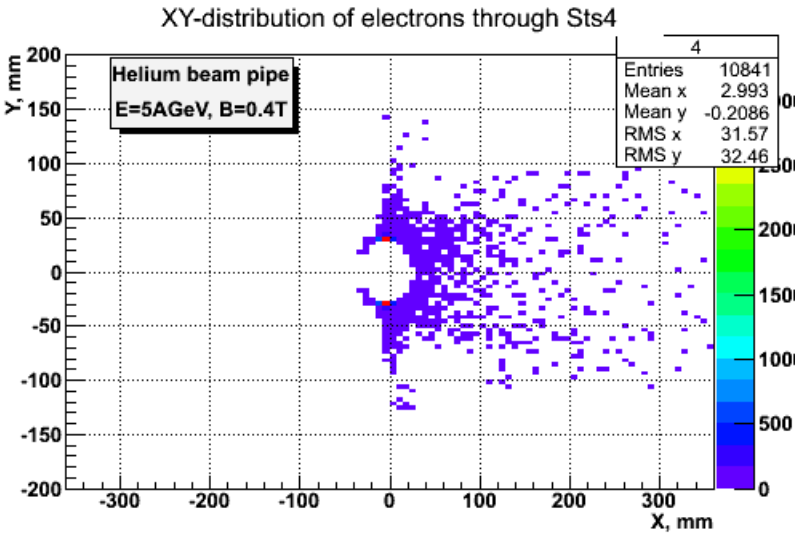
Distributions of Δ electrons in STS4 and GEM4

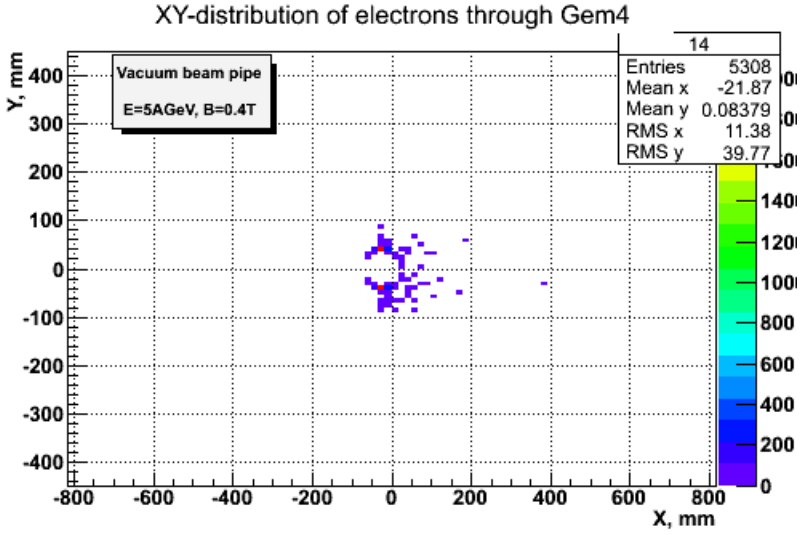
Au beam, GEANT simulation

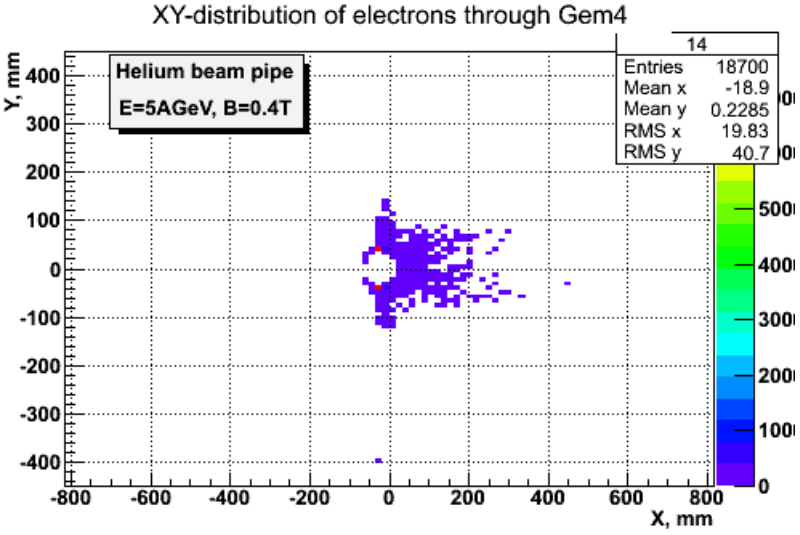
Vacuum beam pipe



Helium beam pipe







Conclusions for beam pipe selection

- **Rate of Δ electrons is factor 3.5 higher for helium beam pipe relative to vacuum beam pipe taking into account interactions of diffuse beam in gas and beam pipe elements**

- **Beam pile-up suppression before and after trigger signal eliminate beam induced background**

- **Helium beam pipe is much simpler technologically and in installation / adjustment procedure**

→ We prefer helium beam pipe