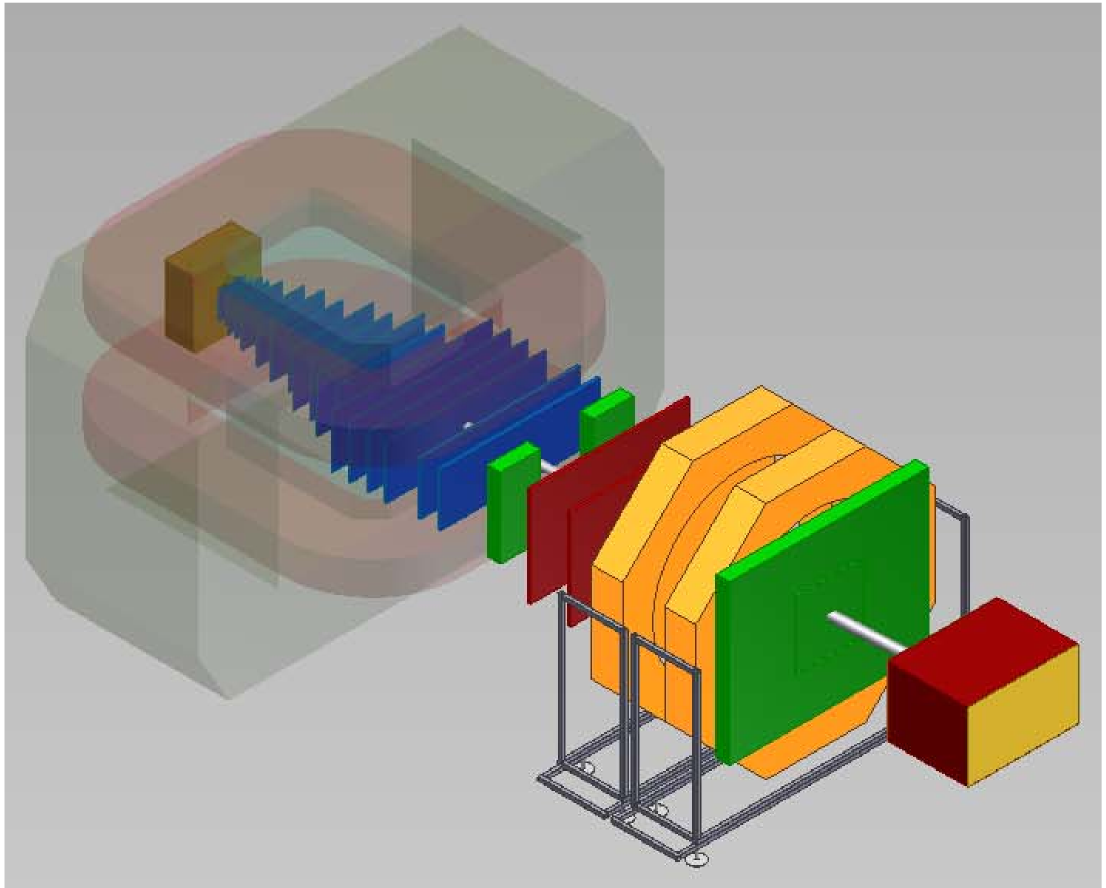
Status of Baryonic Matter at Nuclotron

BM@N Project

JINR (Dubna), IHEP (Protvino), INR RAS (Troitsk), ITEP (Moscow), SINR MSU

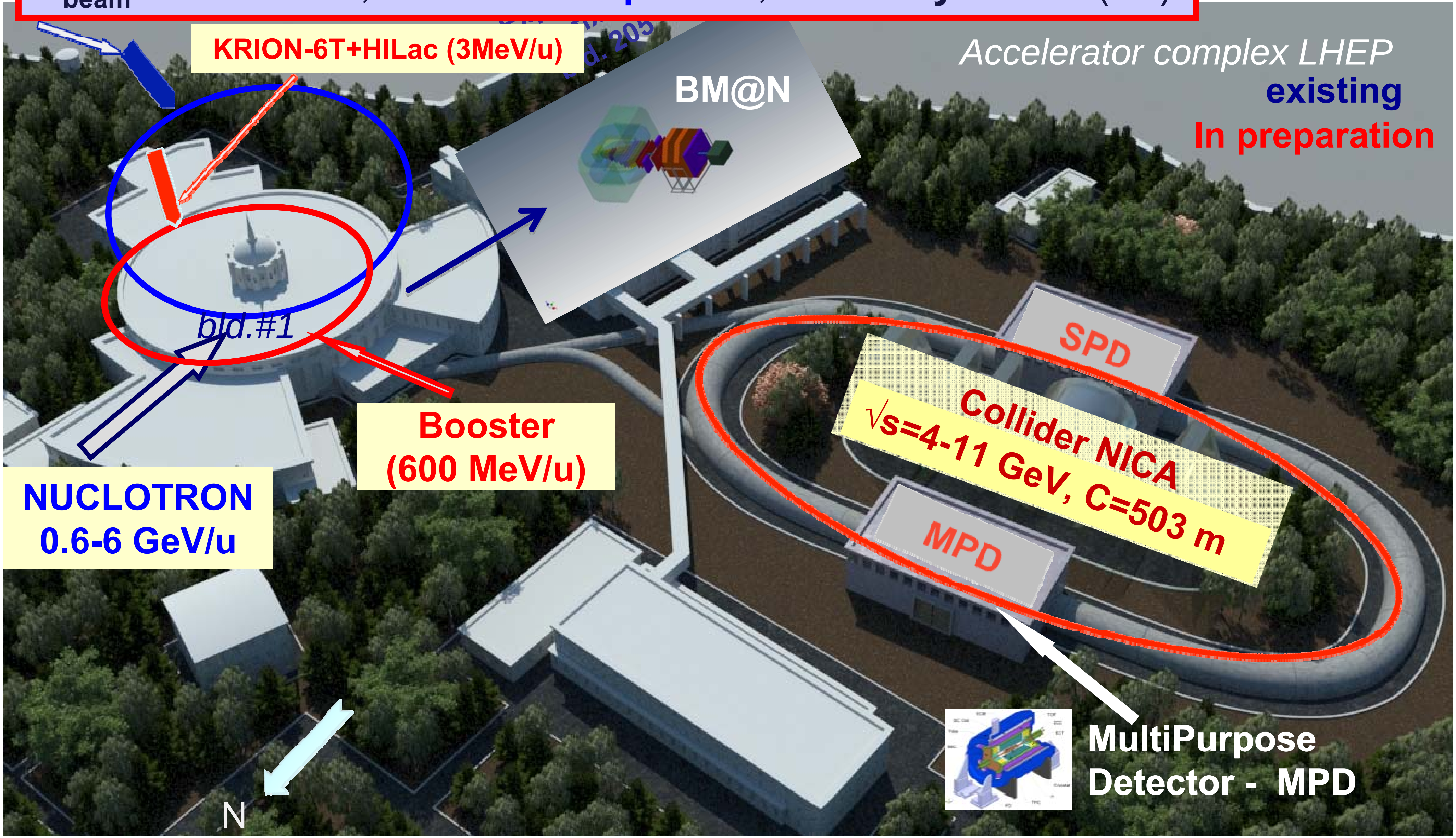
WUT (Warsaw), Goethe Uni (Frankfurt), MoU with GSI (Darmstadt)

M.Kapishin



Complex NICA

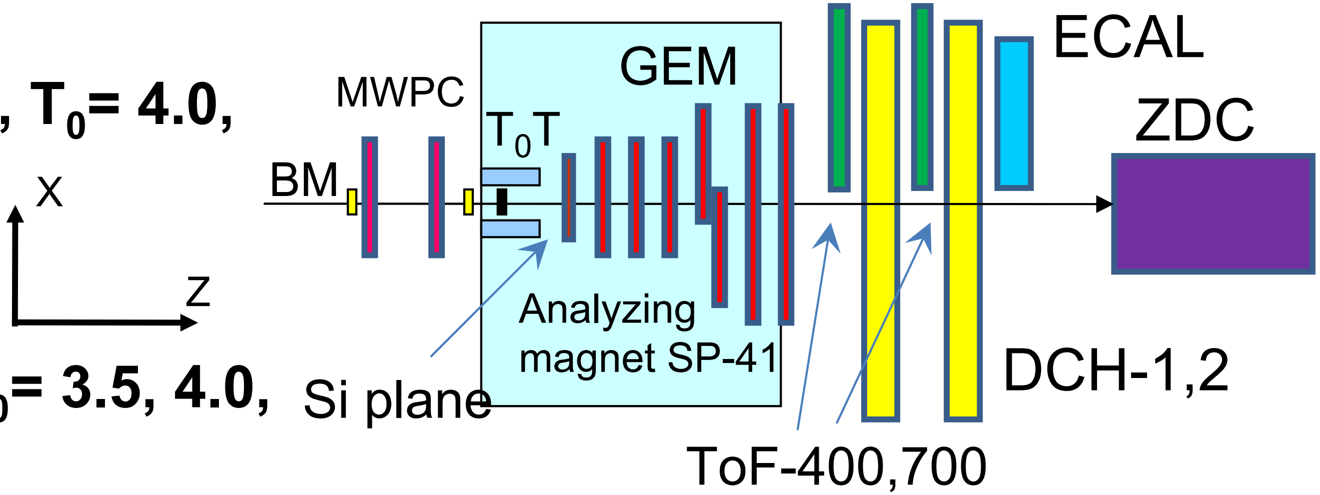
Parameters of Nuclotron for BM@N experiment:
E_{beam} = **1-6** GeV/u; ***beams**: from* **p** to **Au**; **Intensity~10^7** c^{-1} (Au)



BM@N in technical runs with deuteron and carbon beams

Deuteron beam, T_0= 4.0, 4.6 GeV/n

Carbon beam, T_0= 3.5, 4.0, 4.5, (5.14) GeV/n

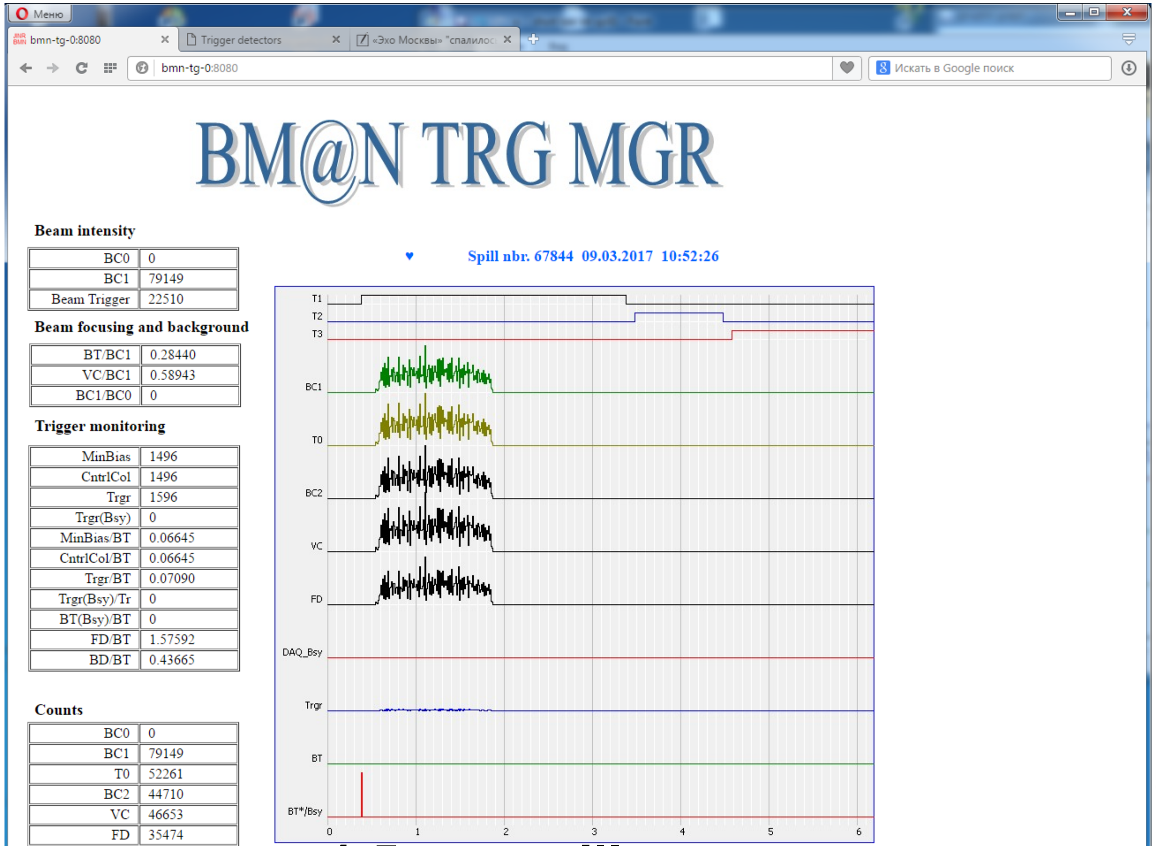


- **Focus on tests and commissioning of central tracker inside analyzing magnet → 5 GEM detectors 66 x 41cm^2 + 2 GEM detectors 163 x 45 cm^2 and 1 plane of Si detector for tracking**
- **Test / calibrate ToF, T0+Trigger barrel detector, full ZDC, part of ECAL**

Program:

- **Trace beam through detectors, align detectors, measure beam momentum in mag. field of 0.3 – 0.85 T**
- **Measure inelastic reactions d (C) + target → X with deuteron and carbon beam energies of 3.5 - 4.6 GeV/n on targets CH_2, C, Al, Cu, Pb**

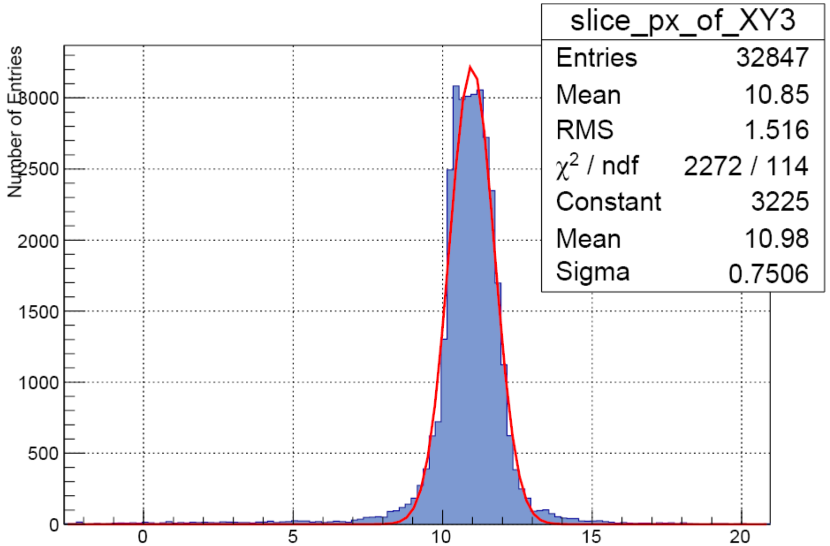
Deuteron / carbon beams at BM@N



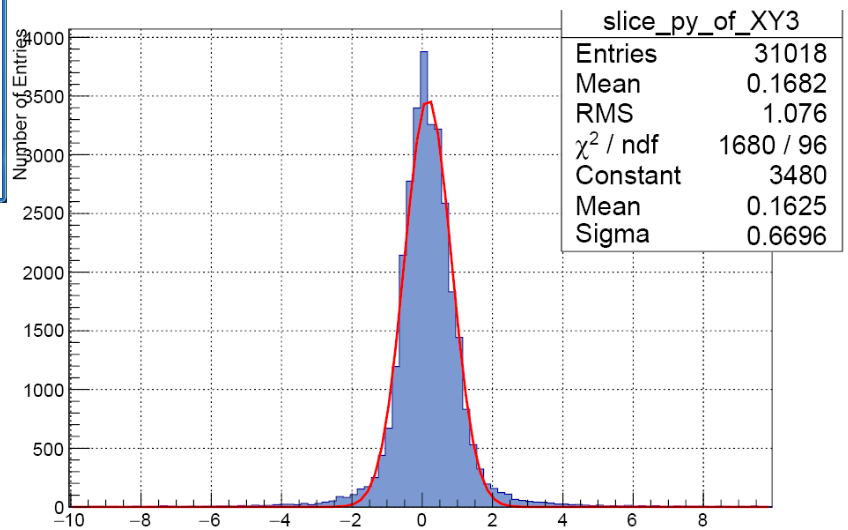
1.5 sec spill

- 10^5 - $3 \cdot 10^5$ per spill, but non-uniform spiky structure
  - ➢ Pileup in GEM detectors
  - ➢ Limits DAQ rate to 4-5 kHz

X, Y profiles of deuteron beam in 1st GEM

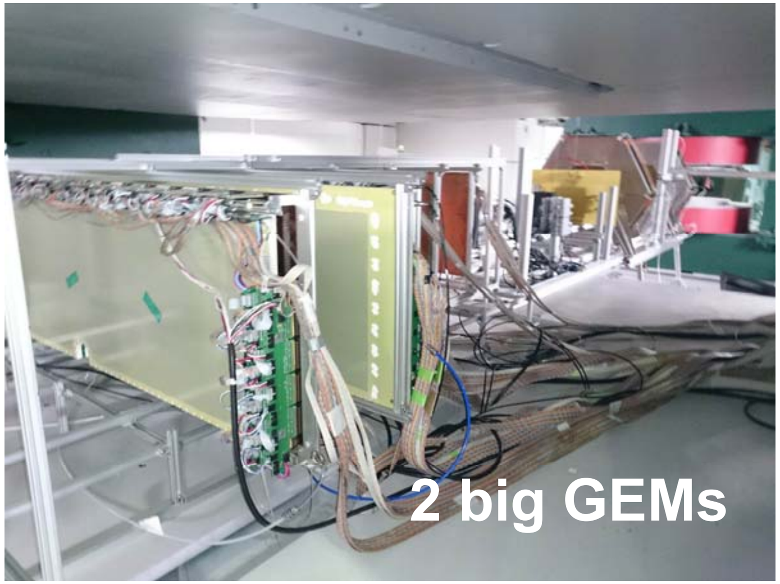


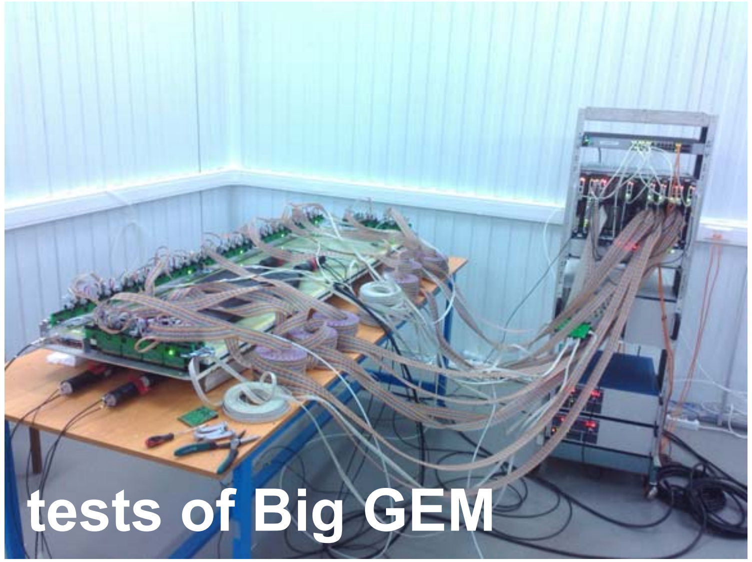
cm



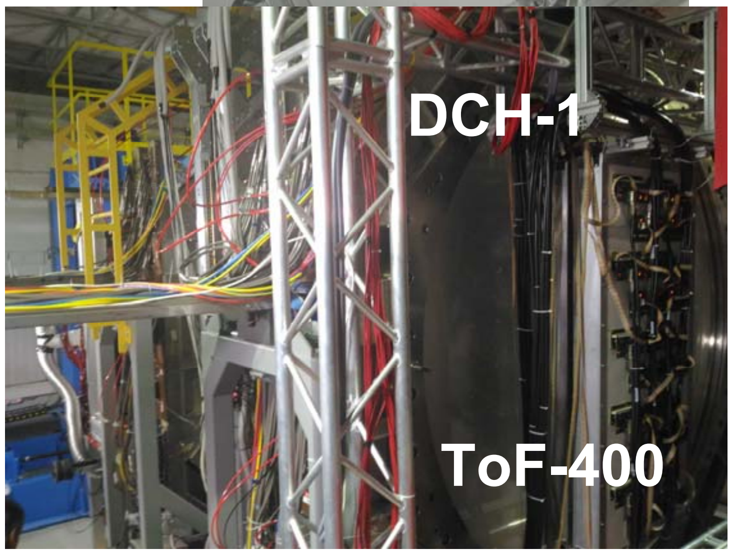
cm

BM@N experiment in carbon run, March 2017





New detector components:
2 big GEMs, trigger barrel detector, Si detector, ECAL



GEM detectors for central BM@N tracker

Tests of GEM detector 163 x 45 cm^2

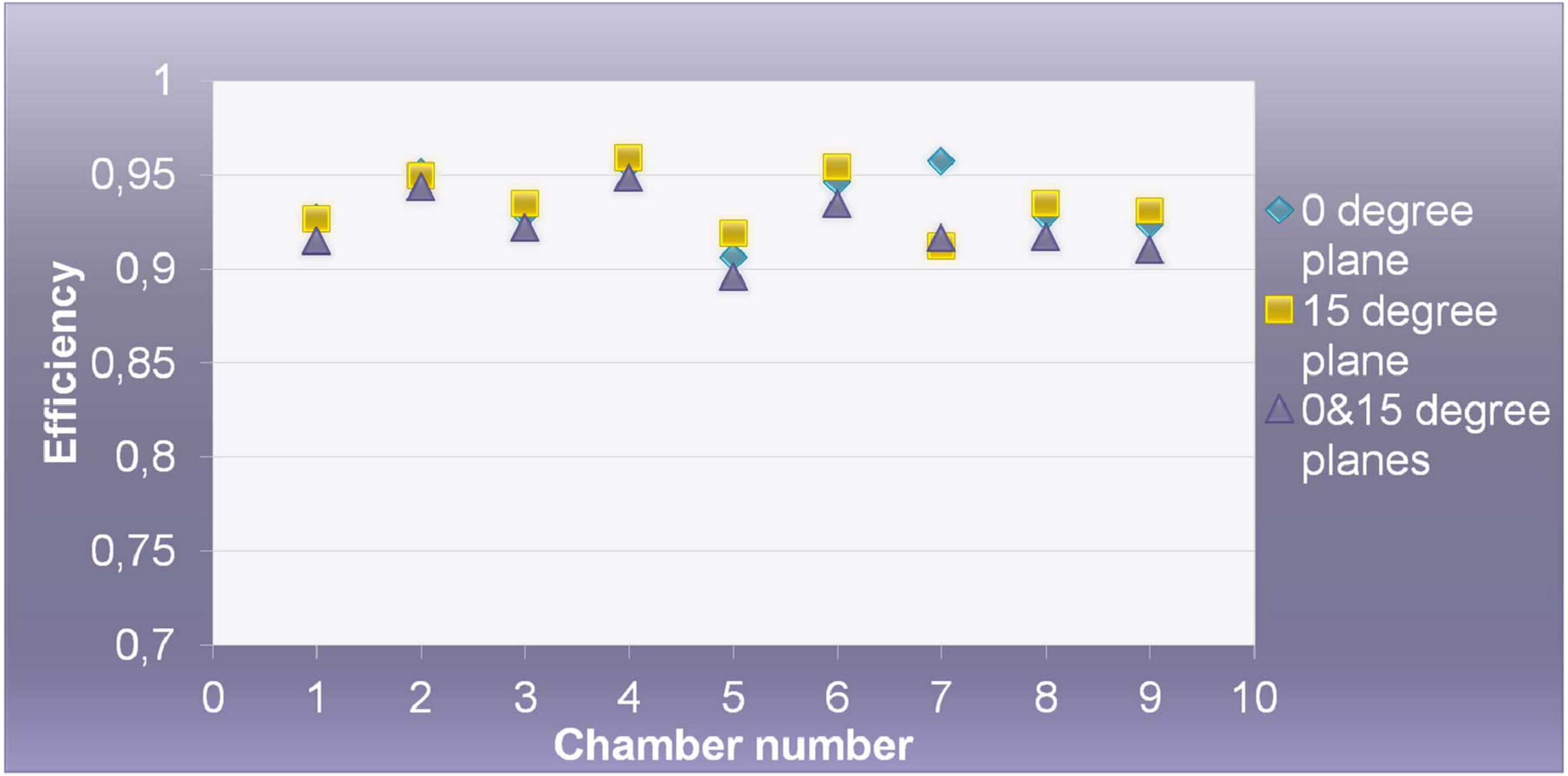
GEM group

- **for tracking in technical runs with deuteron and carbon beams in December 2016 and March 2017 used 5 detectors 66 x 41 cm^2 and 2 detectors 163 x 45 cm^2**

- **for BM@N run in autumn 2017 plan to produce 4 more detectors 163 x 45 cm2**

GEM detector efficiency in deuteron run

Plane efficiency calculated using reconstructed tracks of beam inclined at different angles



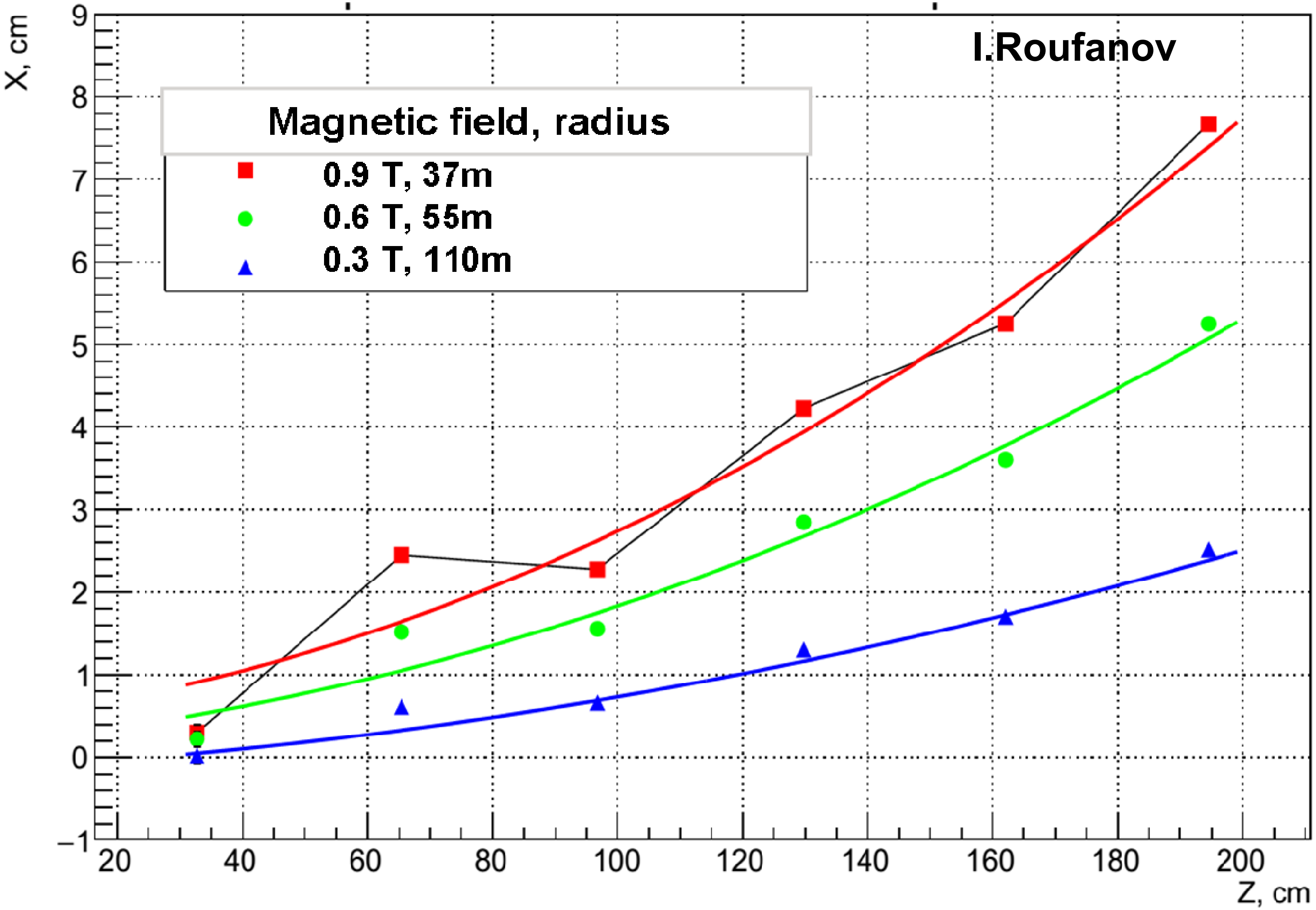
X plane

X‘ plane

X & X‘ planes

Beam in GEM detectors in deuteron run

Averaged positions of deuteron beam with T_0= 4 GeV/nucleon reconstructed in 6 GEM planes at different values of magnetic field



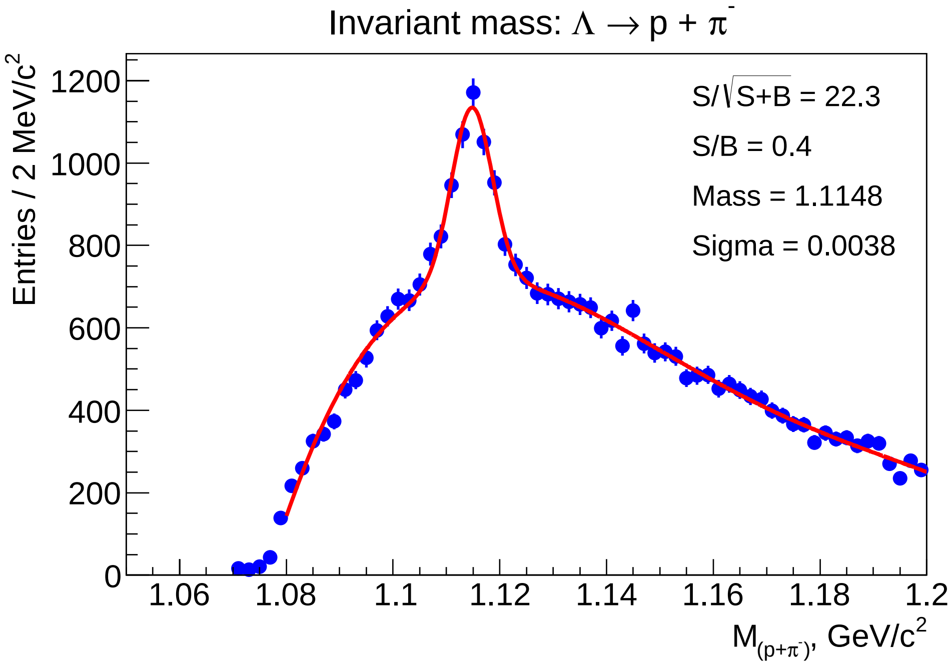
Results of Λ reconstruction with GEM detectors in deuteron beam interactions

A.Zinchenko, V.Vasendina

G.Pokatashkin, I.Roufanov

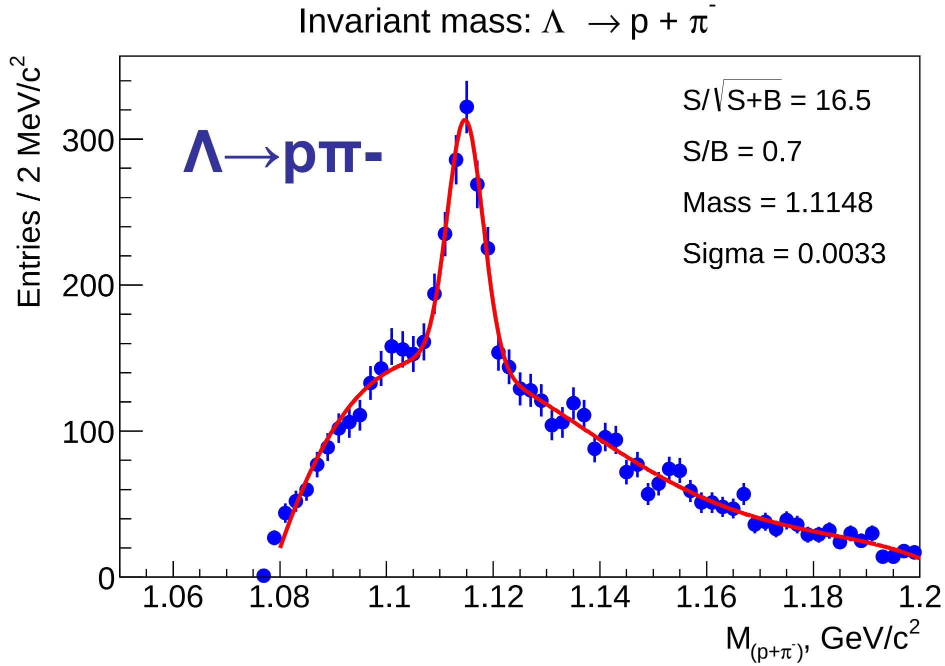
d + target → Λ + X

Soft selection



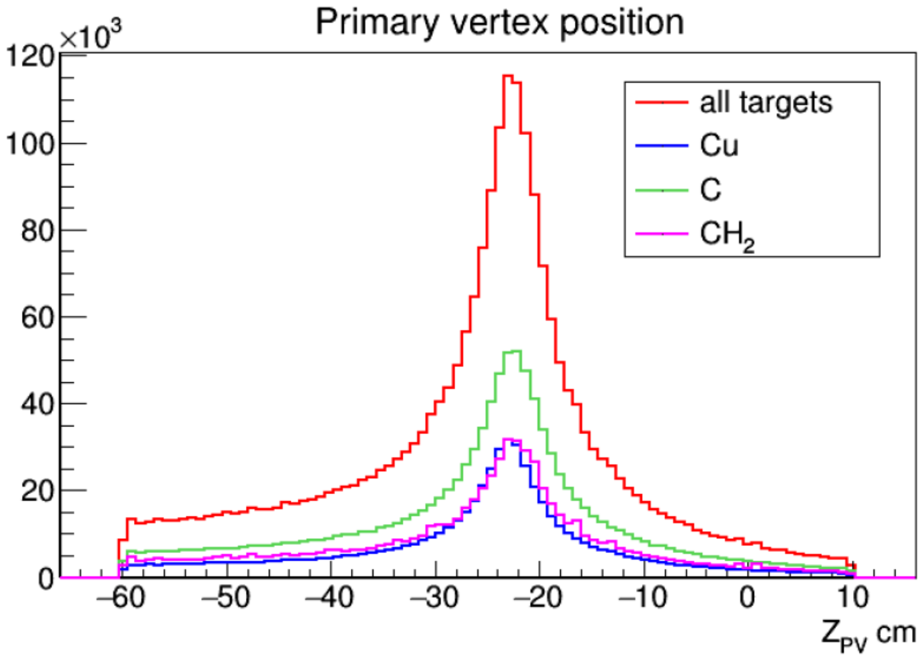
~1900 Λ, sigma ~3.8 MeV

Tight selection

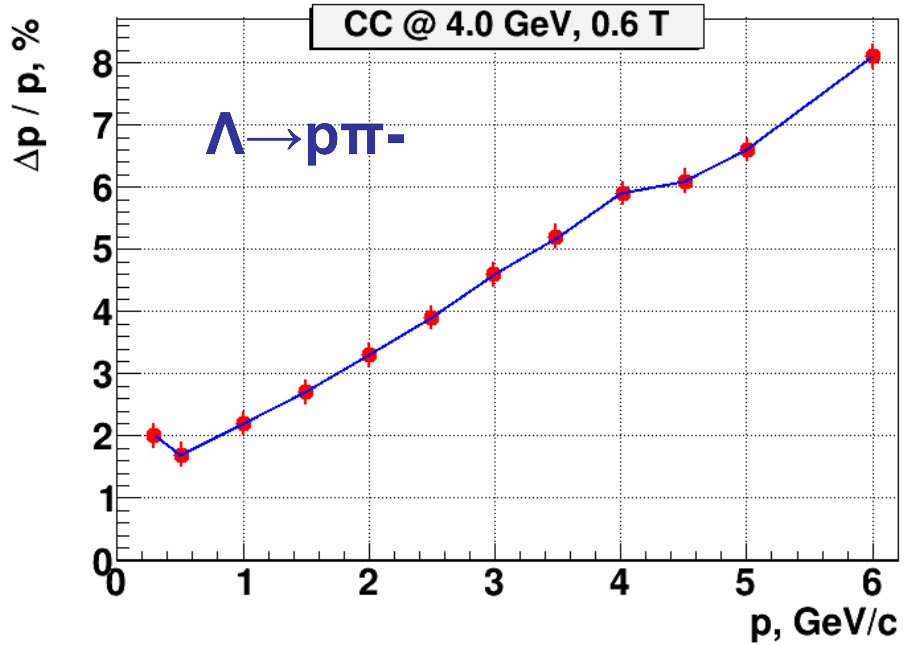


Vertex reconstruction with GEM detectors
Momentum resolution from Λ resolution

Z vertex in d + target interactions



MC: p, π⁻ momentum resolution corresponding to Λ resolution of 5 MeV



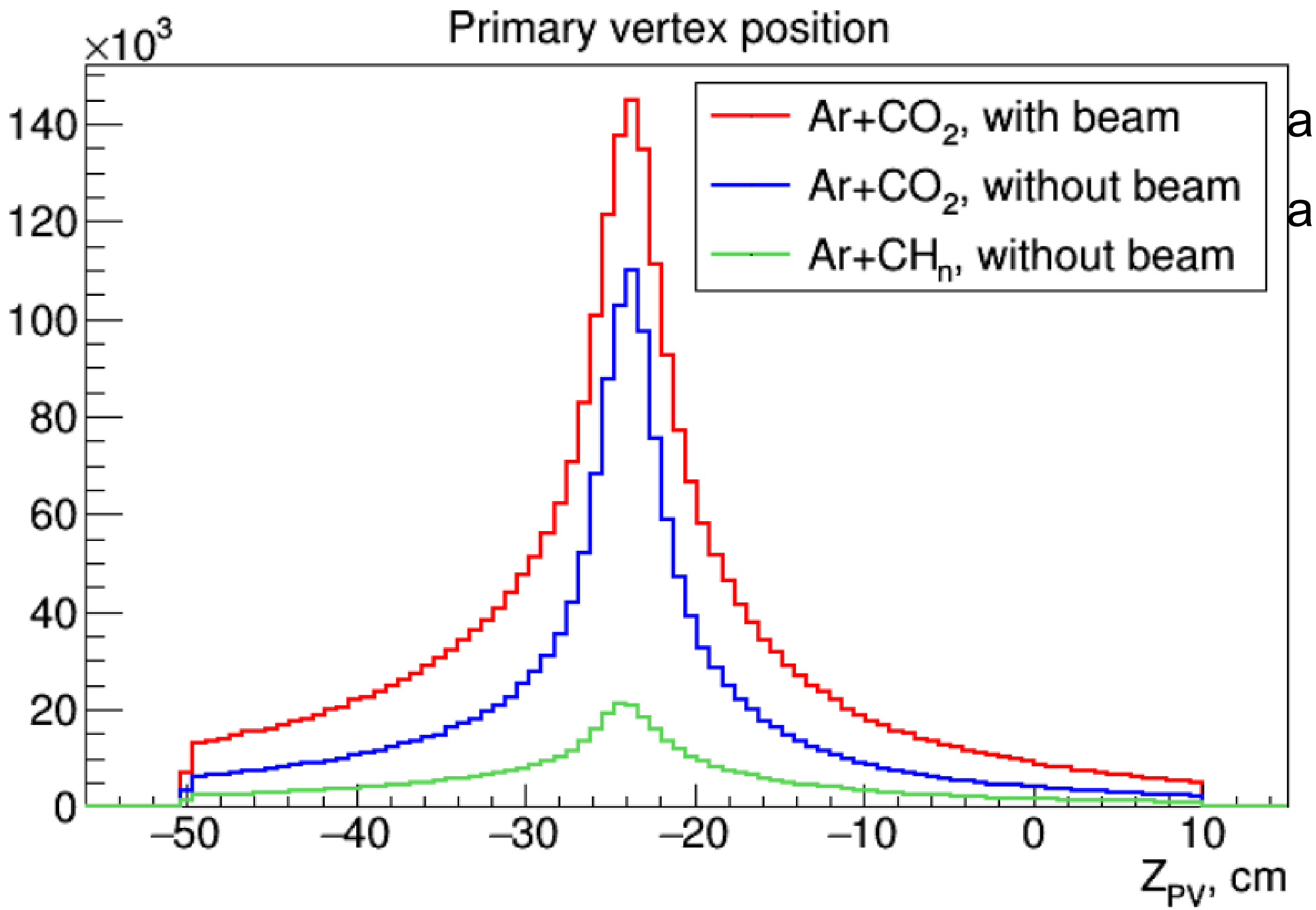
- **Need to improve vertex reconstruction → forward Silicon detector already implemented**
- **Need more GEM planes to improve track momentum reconstruction → plan to install 4 GEM planes in autumn 2017**

Vertex reconstruction with GEM detectors in carbon beam interactions

A.Zinchenko, V.Vasendina

G.Pokatashkin, I.Roufanov

Z vertex in C + target interactions

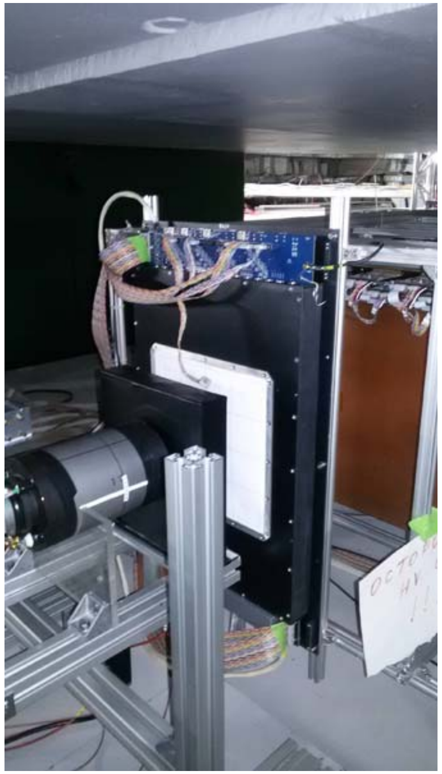


area

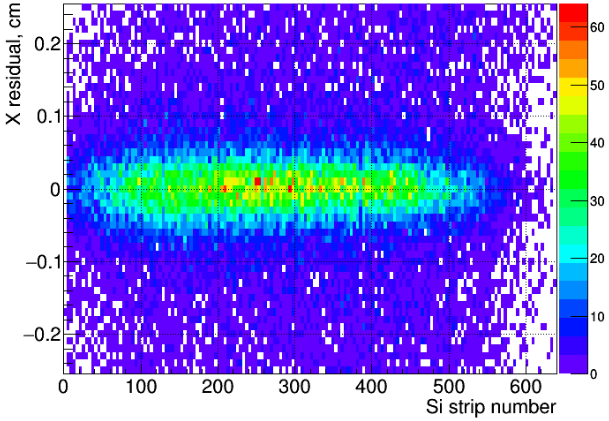
area

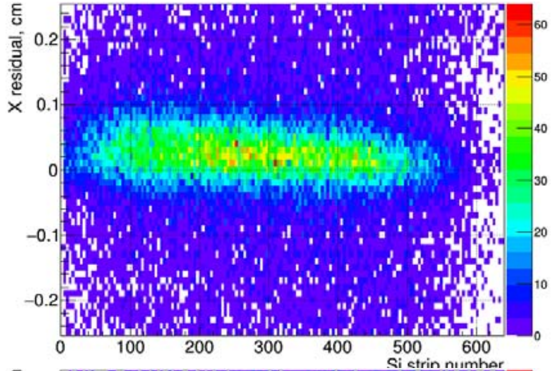
Forward silicon strip detector

Silicon detector group, N.Zamiatin



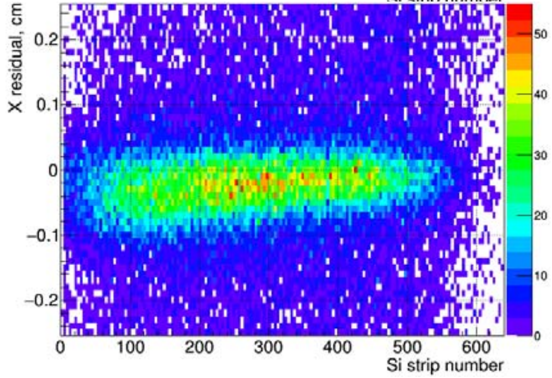
Si-GEM residuals (cm) vs strip number



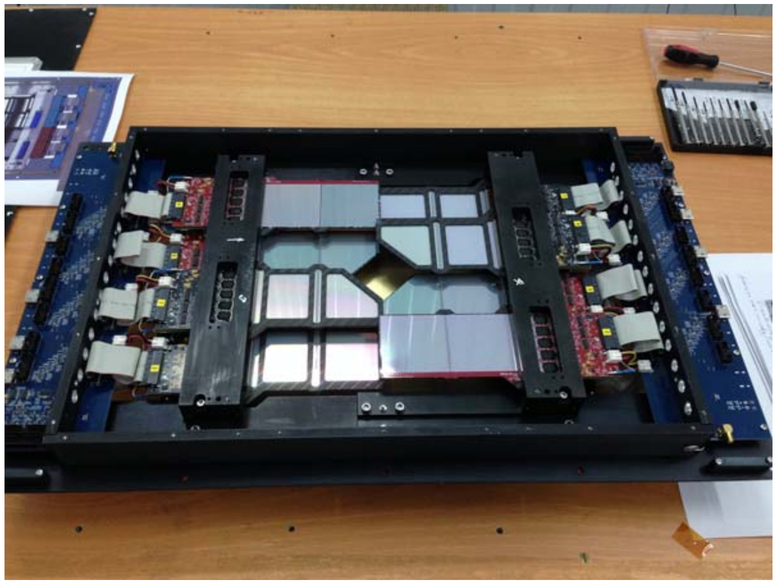


I.Roufanov

Z + 2mm misalignment



Z - 2mm misalignment



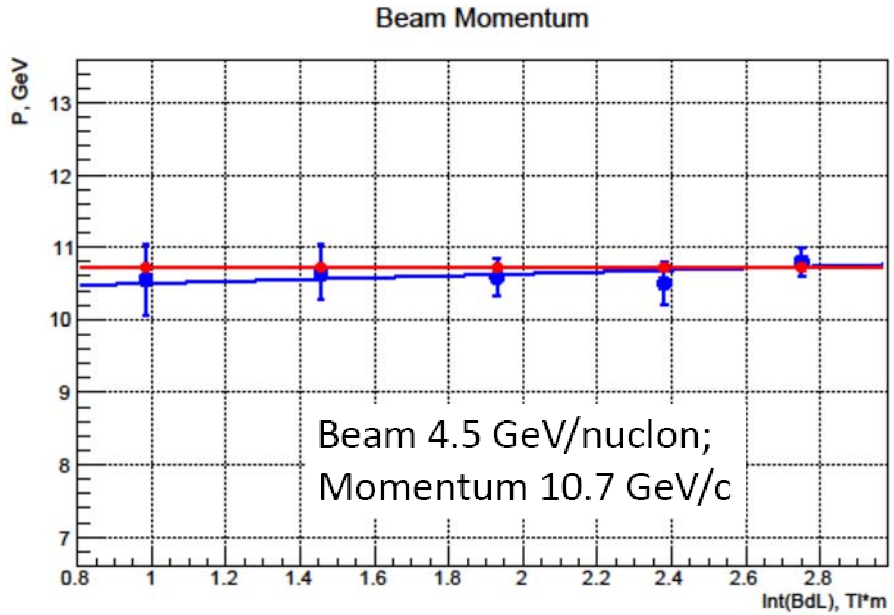
- **2-coordinate Si detector X-X'(±2.5°) with strip pitch of 95/103 µm, full size of 25 x 25 cm², 10240 strips**
- **Detector combined from 4 sub-detectors arranged around beam, each sub-detector consists of 4 Si modules of 6.3 x 6.3 cm²**
- **One plane installed in front of GEM tracker and operated in March 2017**

Beam Momentum measured with DCH outer tracker

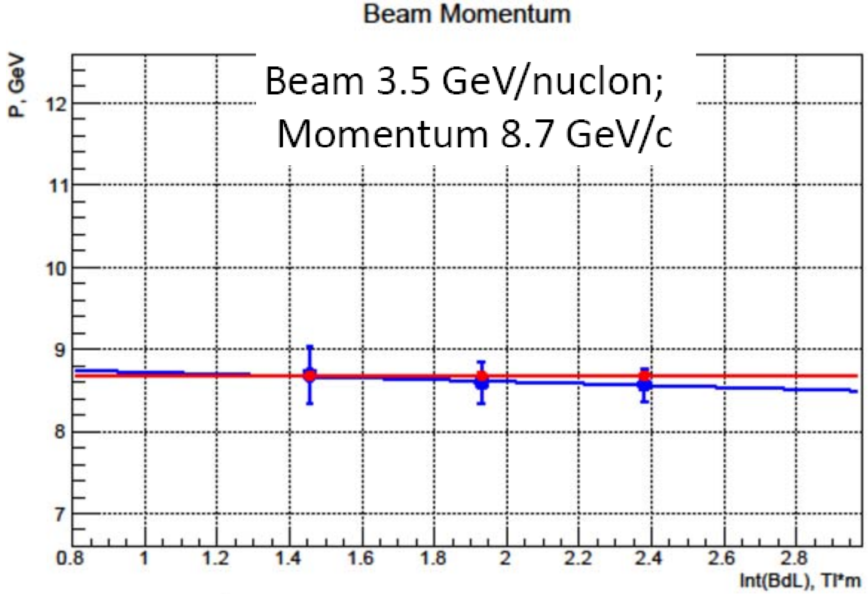
Momentum vs. Int(BdL)

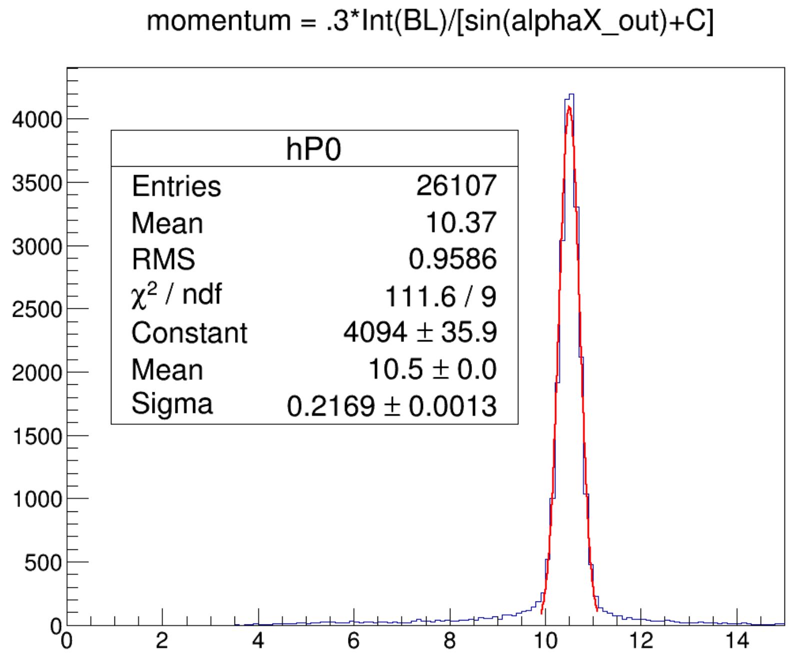
LIT: V.Pal'chik, N.Voitishin

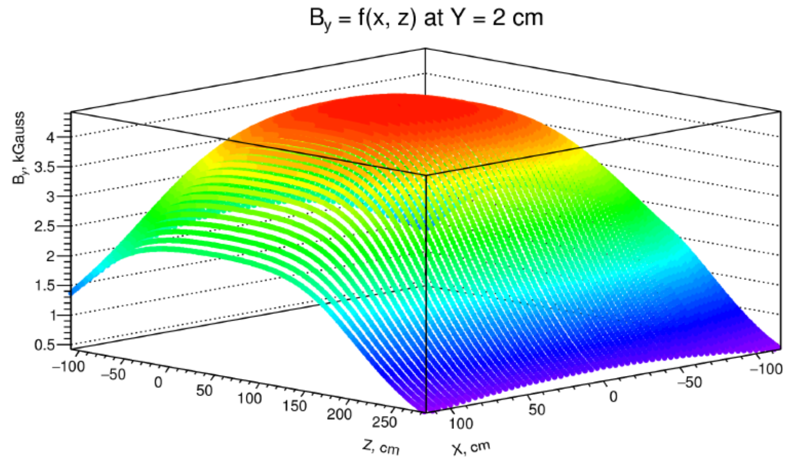
V.Lenivenko



Errors → momentum resolution



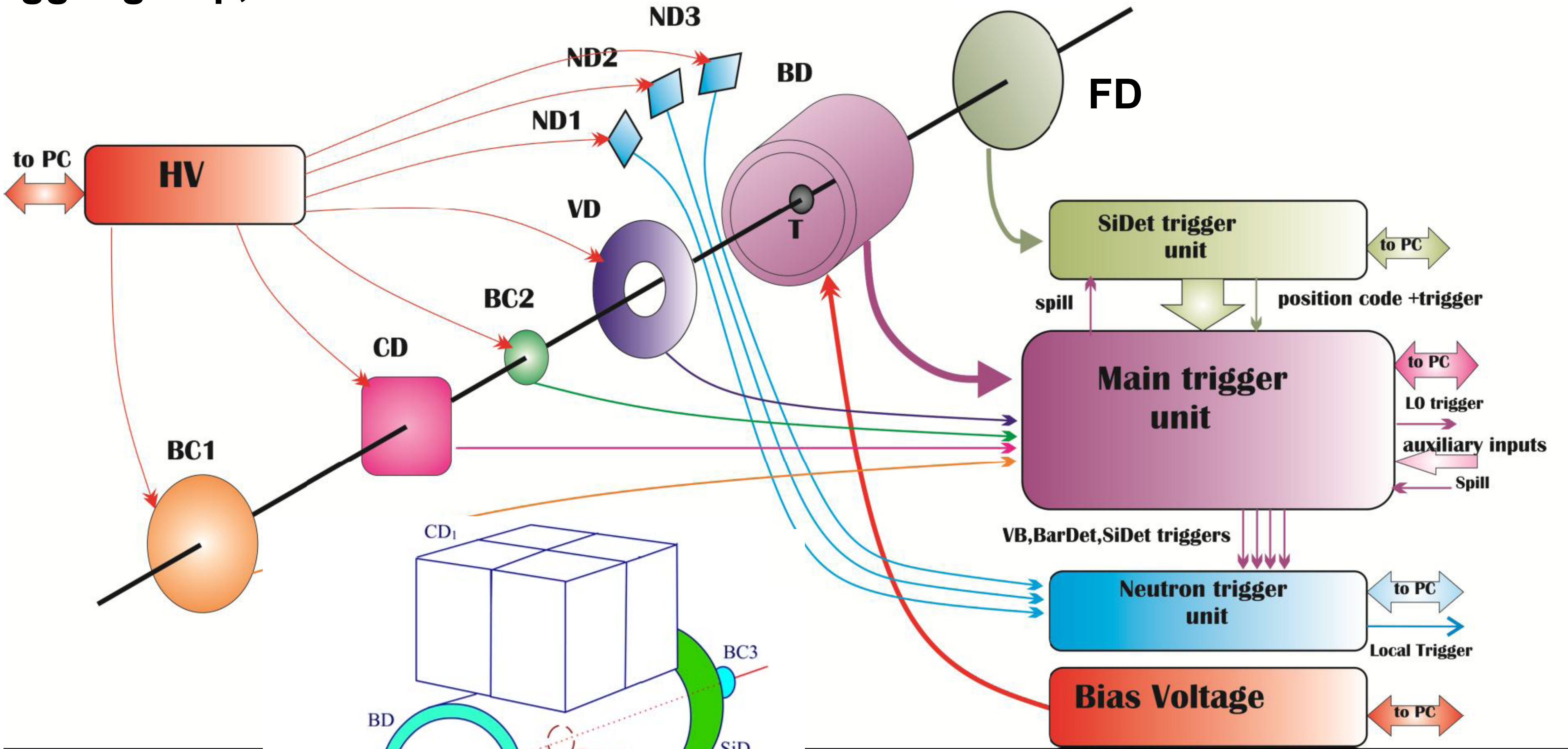


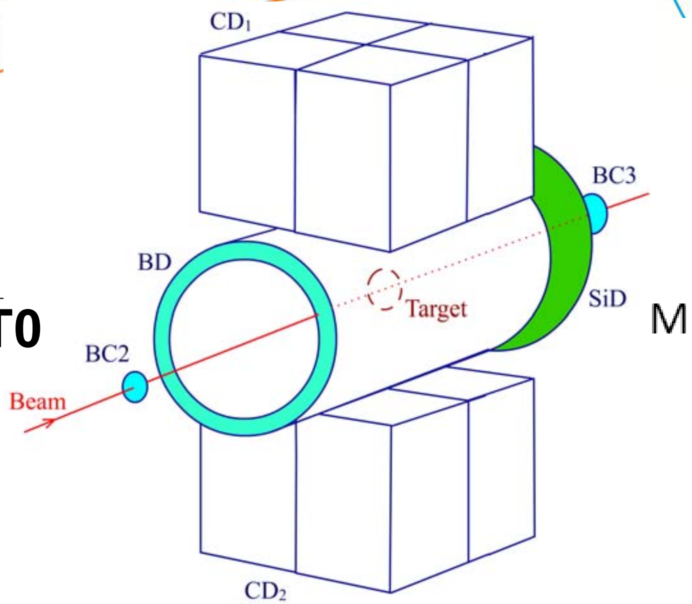


Magnetic field

Trigger detectors: beam counters and barrel detector in carbon run (March 2017)

Trigger group, V.Yurevich



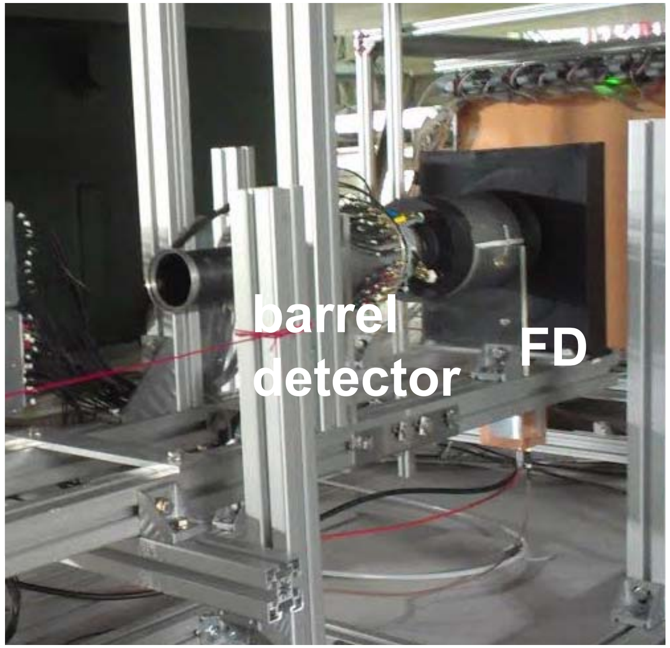


Trigger and T0 detectors for heavy ions

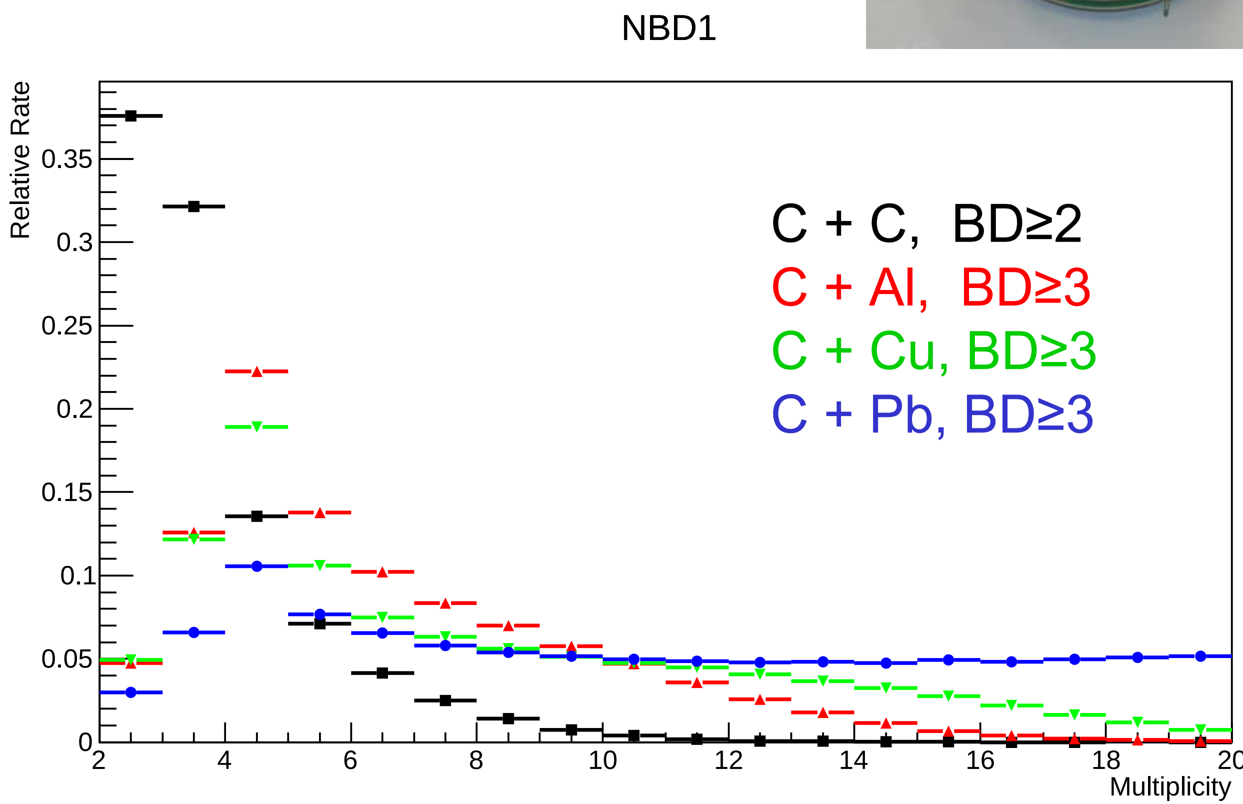
Selection of events with activity in barrel detector: BD >= 2, >= 3

Trigger barrel and Si detectors in BM@N setup

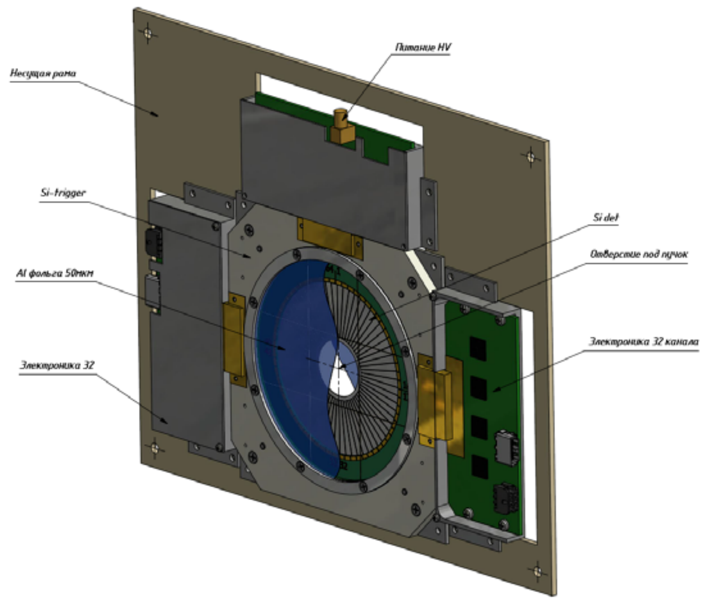
Trigger group, V.Yurevich



Barrel Detector multiplicity in carbon beam interactions with different targets



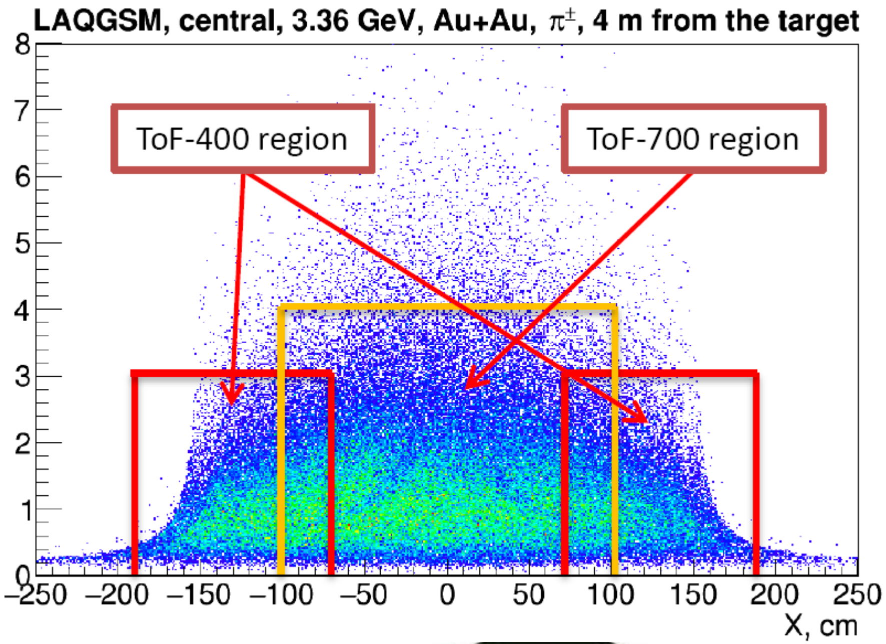
Forward Si trigger detector development, N.Zamiatin group



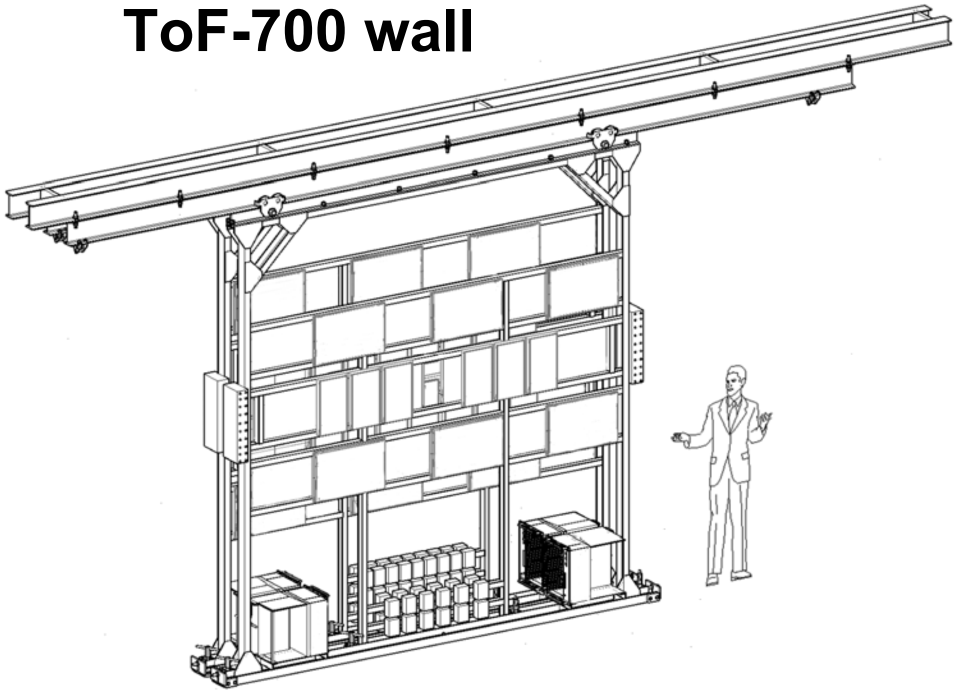
M.Kapishin

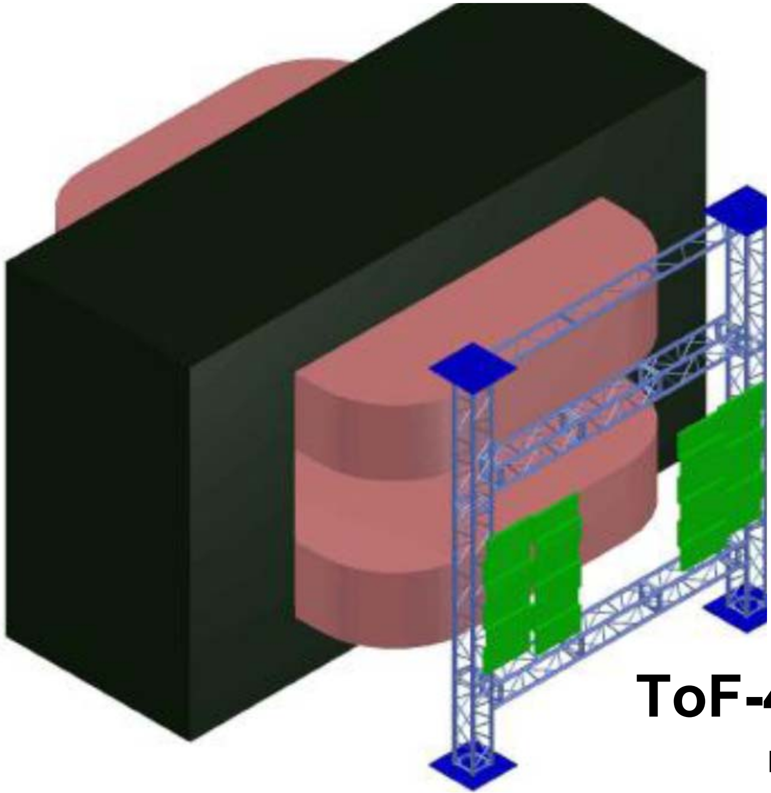
BM@N experiment

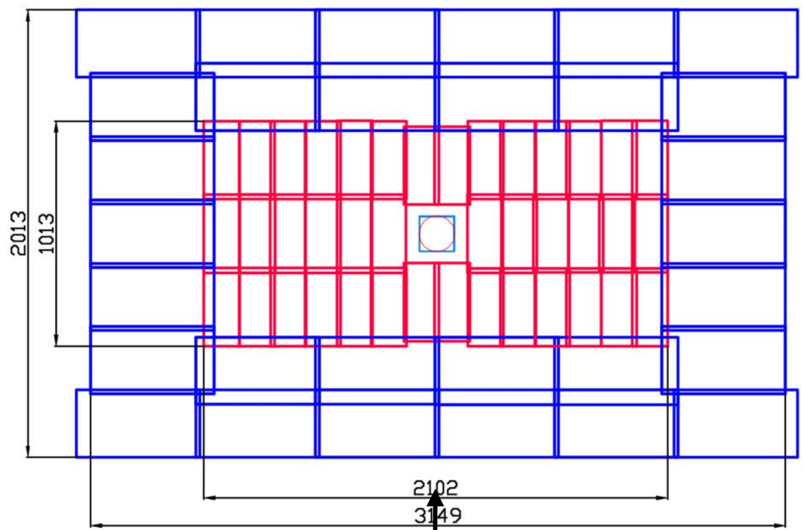
ToF-400 and ToF-700 based on mRPC



ToF-700 wall







ToF-400 wall

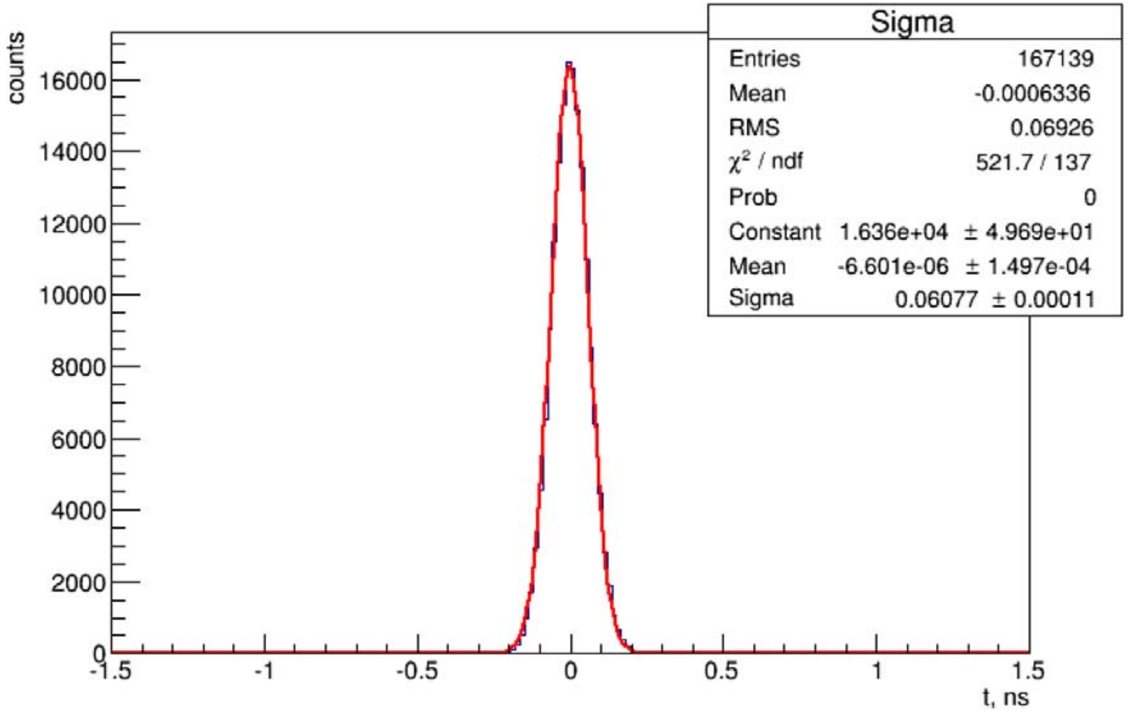
BM@N beam axis

M.K… …riment

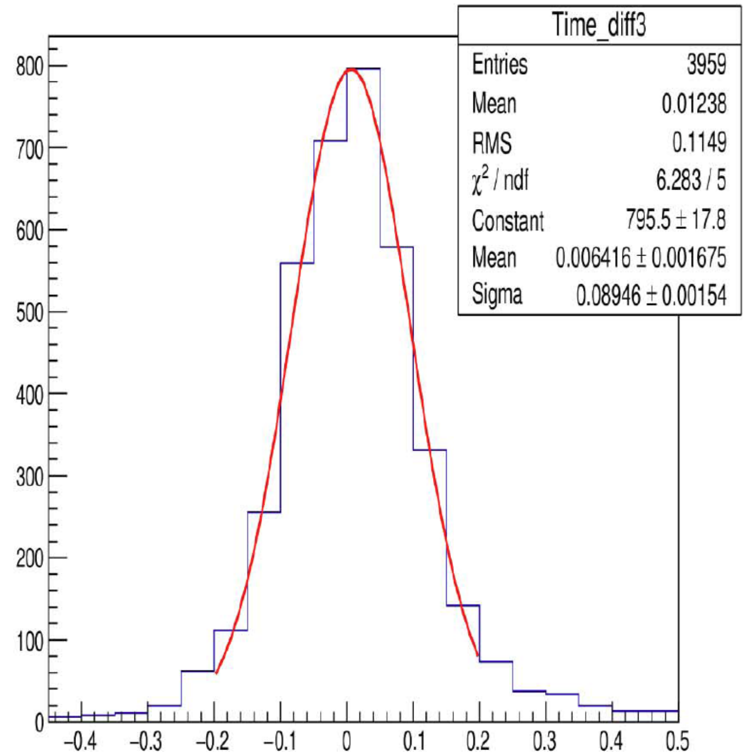
ToF system in deuteron and carbon beams

Trigger and ToF groups

Time resolution between T0 and BC2 counters



Time resolution between ToF-700 and ToF-400 chambers



TOF700 - TOF400

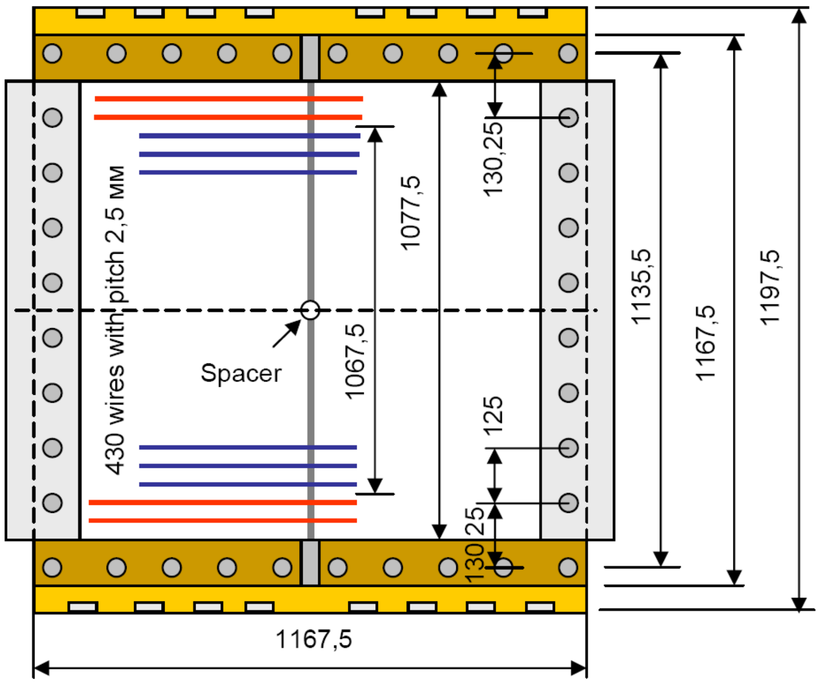
- **Time resolution of T0 counter ~43 ps**
- **Time resolution of ToF-700 chamber ~65 ps**
- **Time resolution of ToF-400 chamber ~53 ps**

CPC chamber design

Plan to produce in LHEP and install in autumn 2017 two CPC chambers in front and behind ToF-400 to check their performance as Outer tracker for heavy ion beams

Al. Vishnevsky

Cathode printed board #1



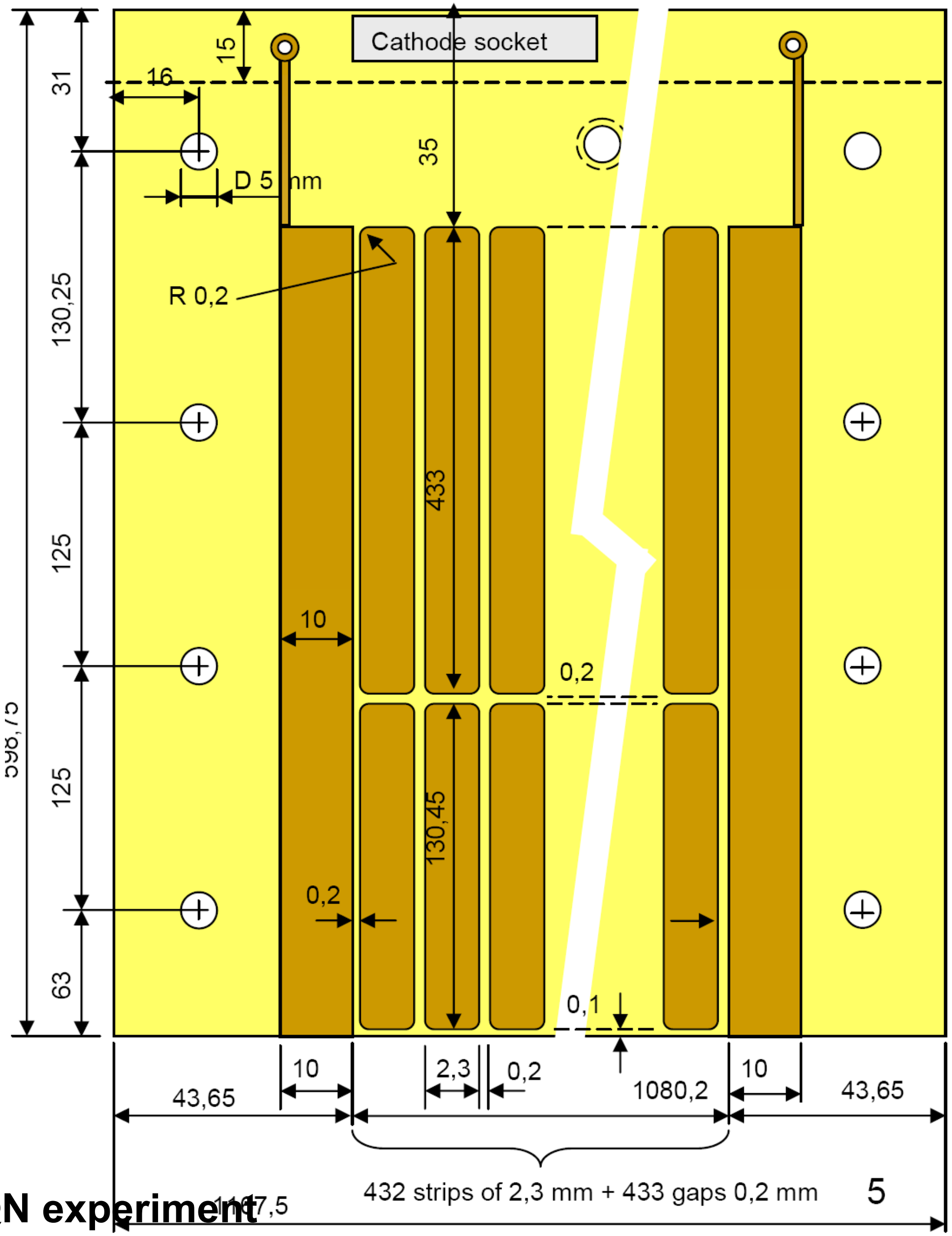


Table 1. Beam parameters and setup at different stages of the experiment

year	2016	2017 spring	2017 autumn	2019	2020 and later
beam	d(↑)	C	Kr, Ar	Au	Au, p
max.intensity, Hz	0.5M	0.5M	0.5M	1M	10M
trigger rate, Hz	5k	5k	5k	10k	20k→50k
central tracker status	6 GEM half pl.	6 GEM half pl.	10 GEM half pl.	8 GEM full pl.	10 GEMs + Si planes
experim. status	techn. run	techn. run	techn. run	stage 1 physics	stage 2 physics

Concluding remarks and next plans

- BM@N technical runs performed in December 2016 and March 2017 with deuteron and carbon beams at energies: T0 = 3.5 - 4.6 AGeV
- BM@N collected data to check efficiencies of sub-detectors and develop algorithms for event reconstruction and analysis
- Major sub-systems are operational, but are still in limited configurations: GEMs, forward Silicon detector, Outer tracker, ToF, ZDC, trigger, DAQ, slow control, online monitoring
- Limited qualified man power for data analysis

BM@N plans for run in November- December 2017:

- Beams provided by heavy ion source: Ar, Kr, extracted to BM@N setup

BM@N setup: extended GEM tracker (+ 4 detectors) , forward Silicon detector (+ 2 planes), extended trigger system, ToF, DAQ configurations, extended Outer tracker (2 new CPC chambers)

BM@N future plans for Au+Au: collaborate with CBM to produce and install large aperture STS silicon detectors in front of GEM setup

Thank you
for attention!

Backup slides

Nuclotron and BM@N beam line

26 elements of magnetic optics:

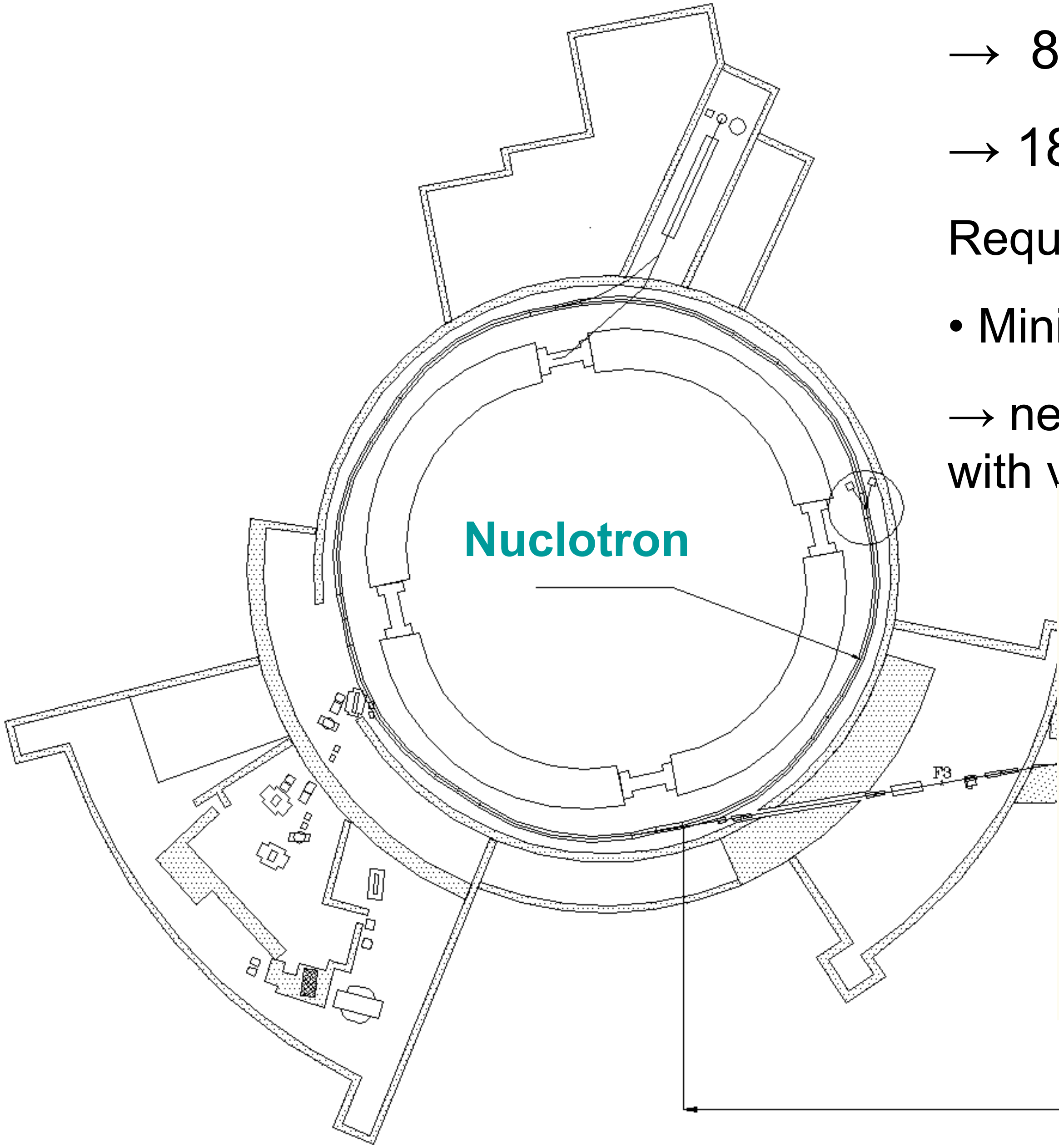
→ 8 dipole magnets

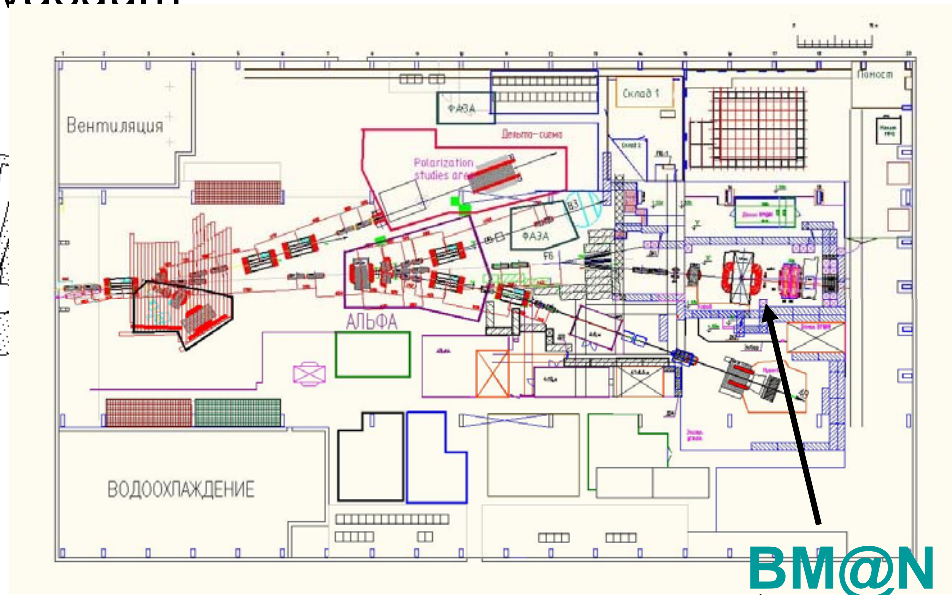
→ 18 quadruple lenses

Requirements for Au beam:

• Minimum dead material

→ need to replace 40 m air intervals / foils with vacuum

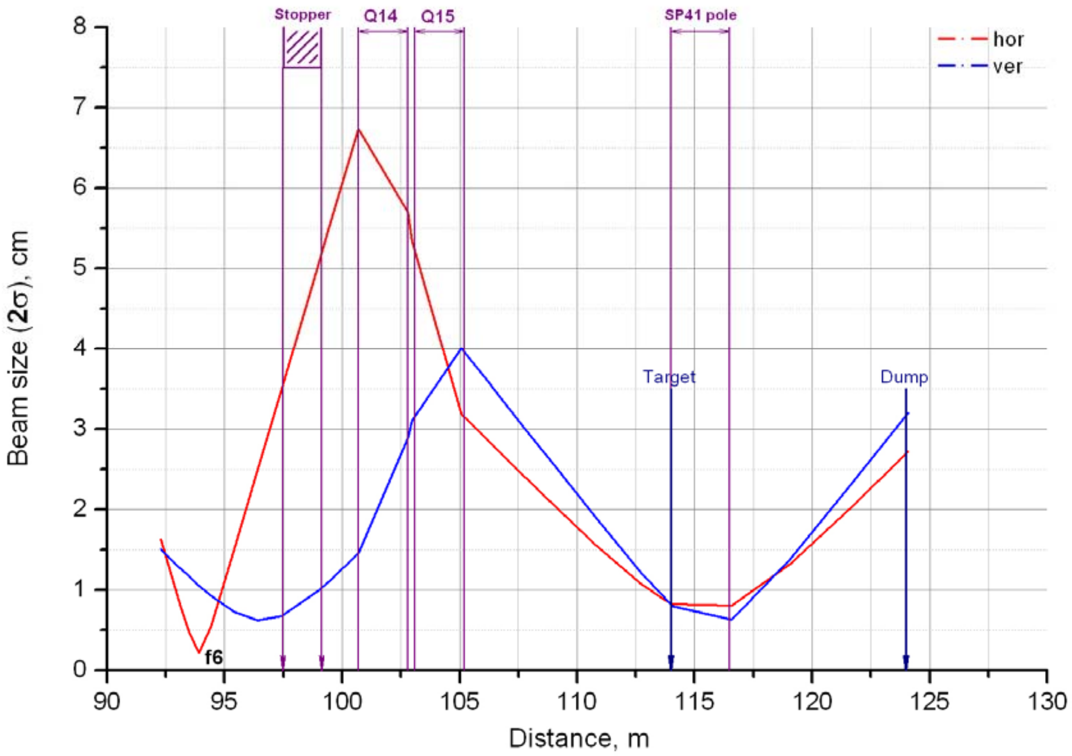




Building 205

BM@N beam line

Beam envelopes at the BM@N area



Beam	Planned intensity of Nuclotron + booster (per cycle)
p , d	$5{\cdot}10^{12}$
^{12}C	$2{\cdot}10^{11}$
^{40}Ar	$2{\cdot}10^{11}$
^{131}Xe	10^7 at BM@N
^{197}Au	10^7 at BM@N

Targets: ^{12}C, ^{64}Cu, ^{197}Au, liquid H_2, $^2H_2$

Plans for extensive upgrade of BM@N beam line:

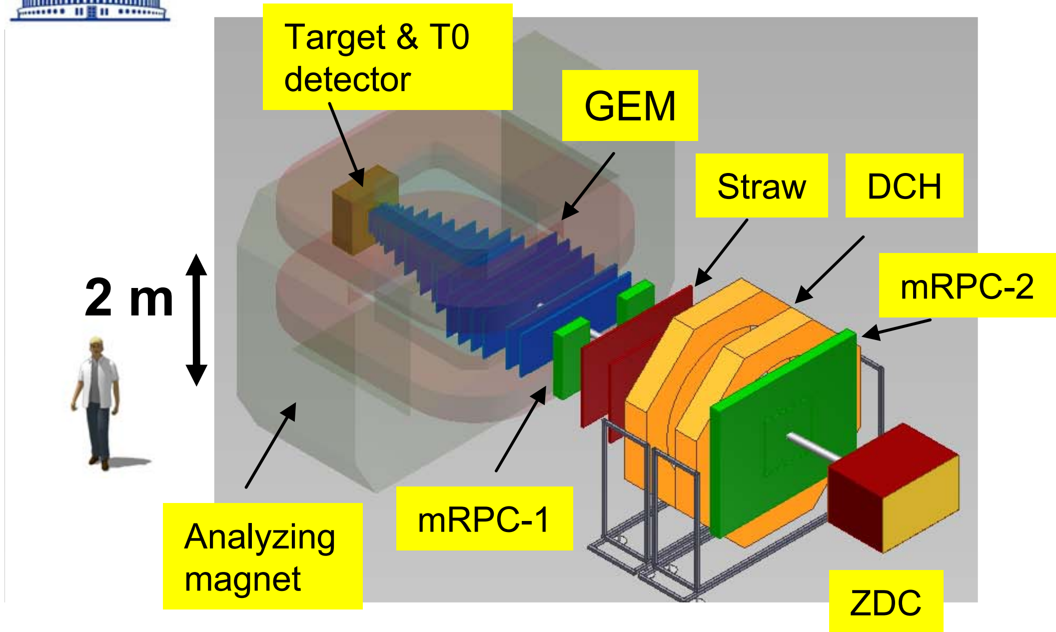
→ new stable power supplies for dipole magnets

→ stabilization circuits for existing power supplies for quadruples and dipoles

→ non destructive beam position monitoring on movable vacuum inserts

→ carbon fiber vacuum beam pipe inside BM@N from the target to the 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)

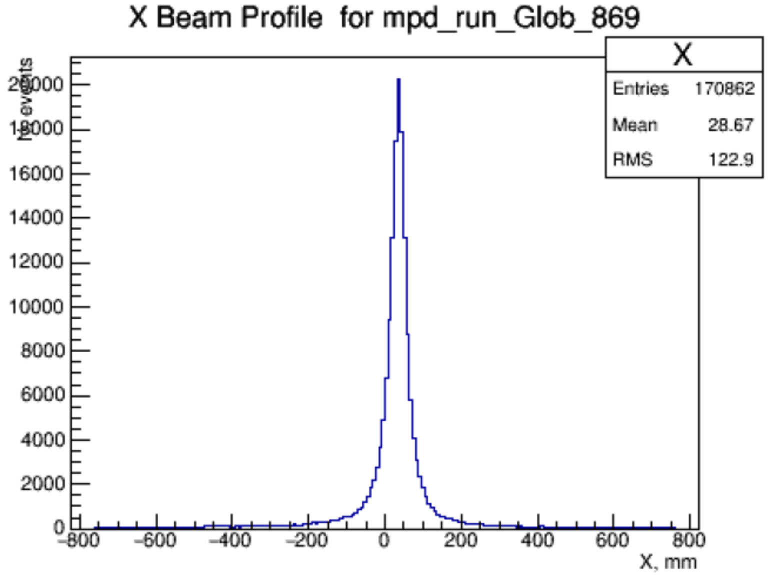
→ fill distance between magnet and "far" detectors with coordinate detectors

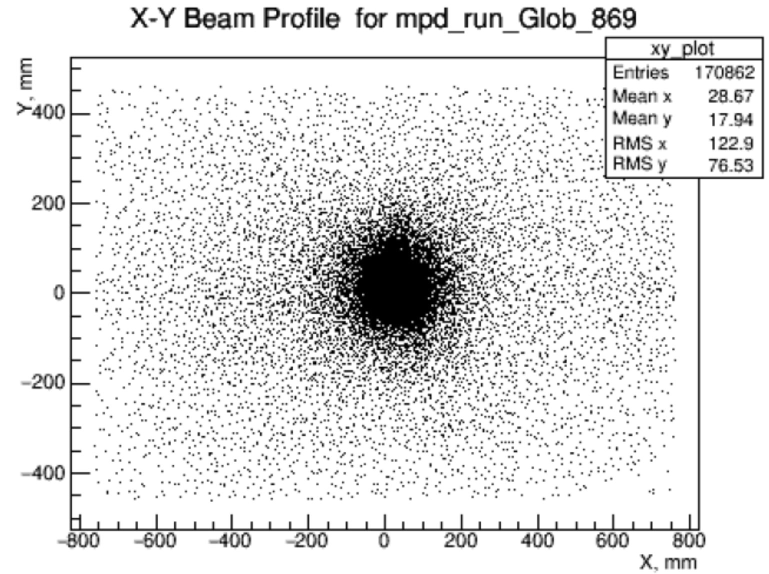
- Central tracker (GEM+Si) inside analyzing magnet to reconstruct AA interactions
- Outer tracker (DCH, Straw / CPC) behind magnet to link central tracks to ToF detectors
- ToF system based on mRPC and T0 detectors to identify hadrons and light nucleus
- ZDC calorimeter to measure centrality of AA collisions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

ZDC performance in December run

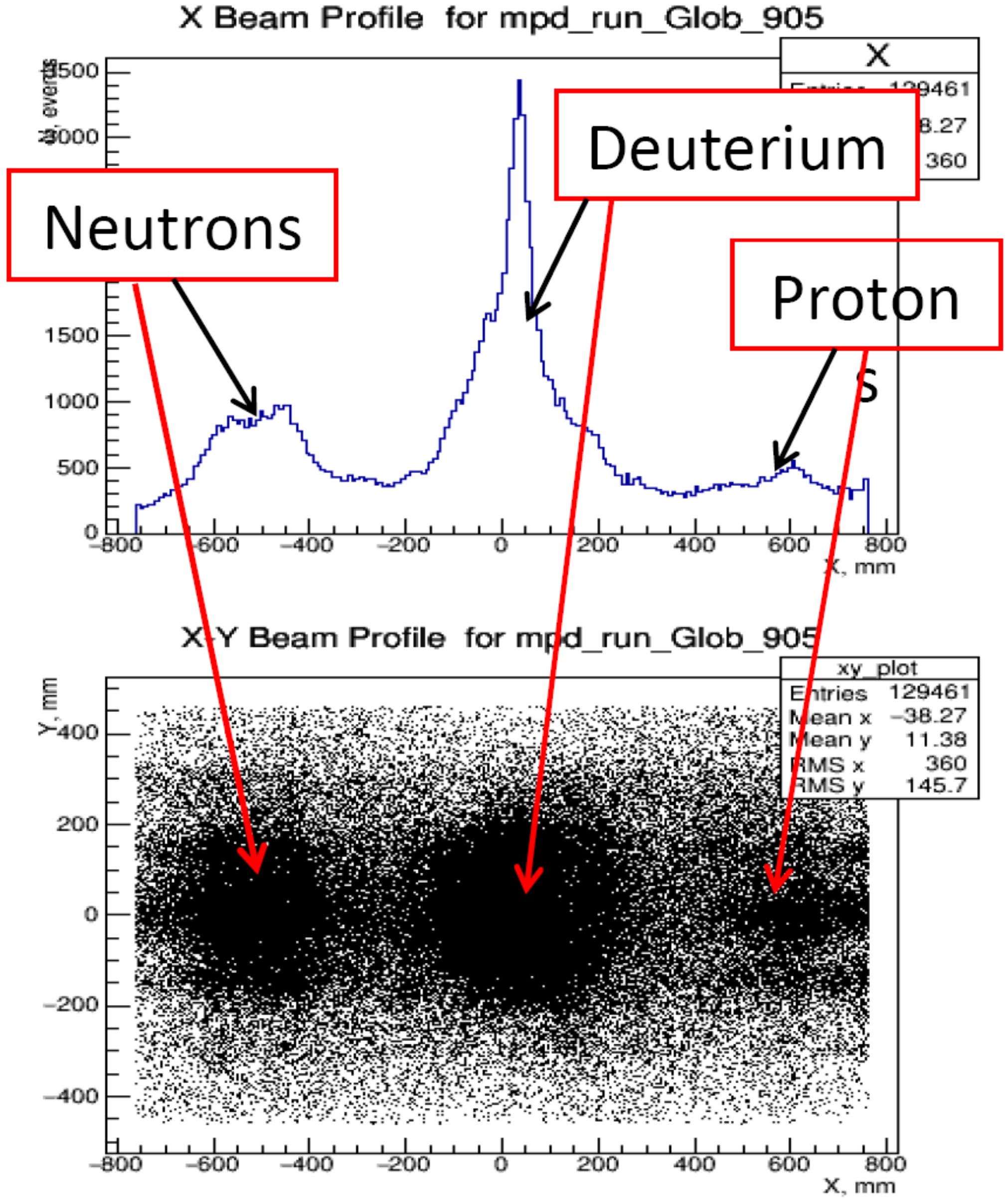
O.Gavrischuk, SNEO

Profile of deuteron beam in ZDC

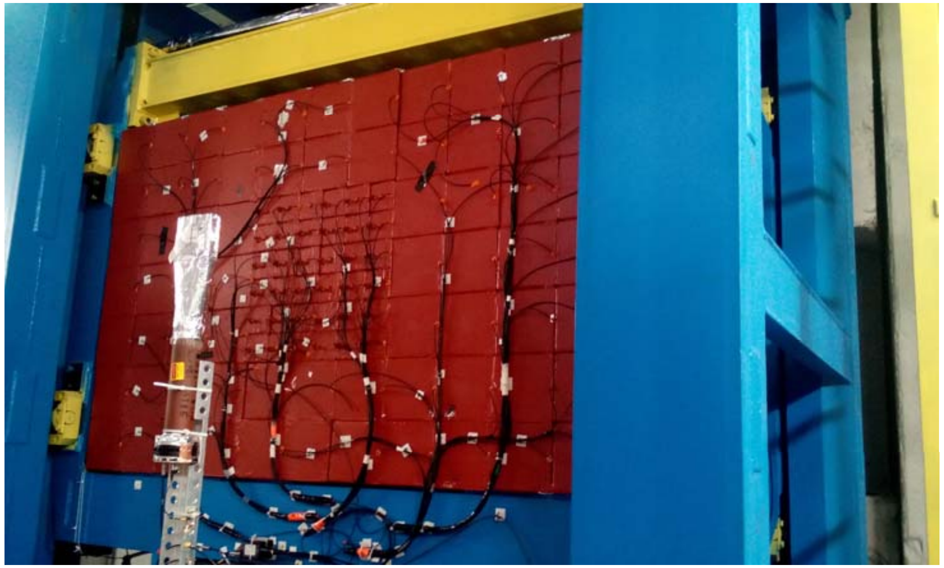




ZDC response to deuterons and products of d+CH_2 interactions

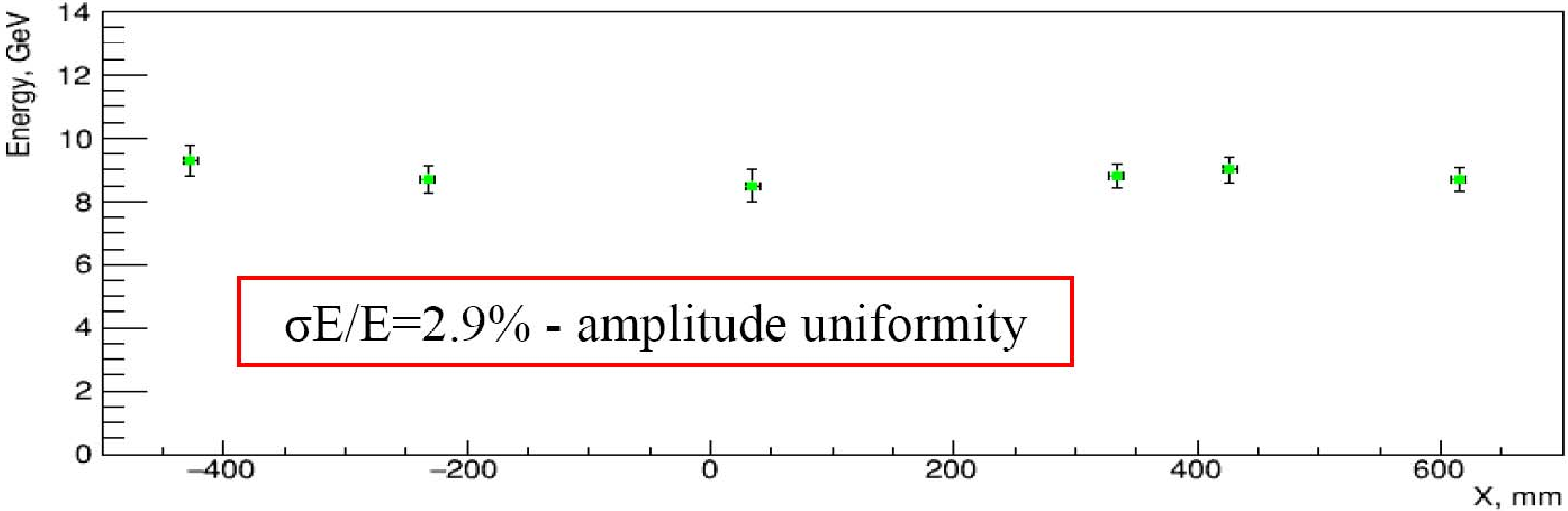


Calibration of ZDC calorimeter



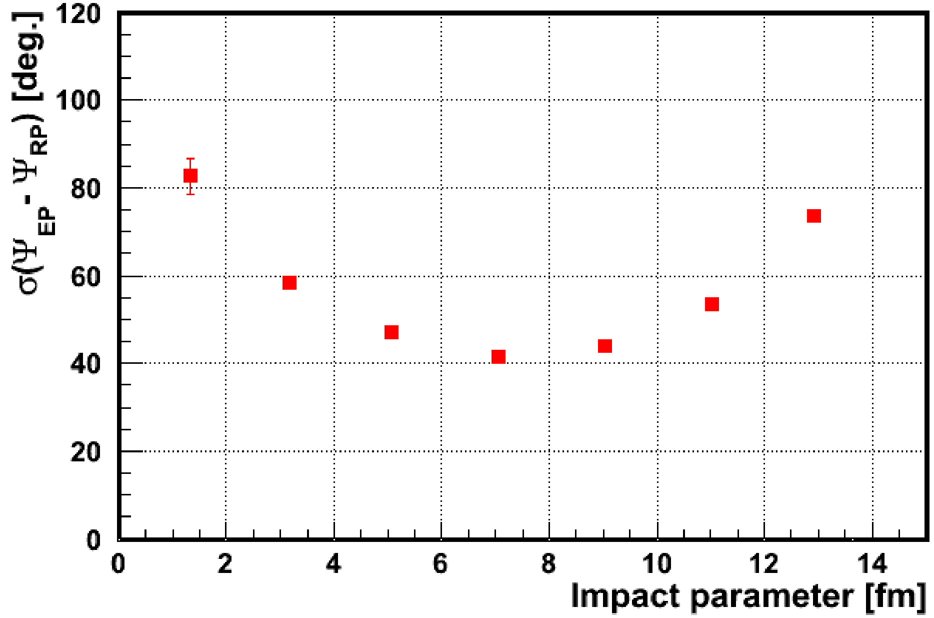
O.Gavrischuk, SNEO

- **Collect deuteron beam data with ZDC at different positions**
- **Calibration of cell amplitudes to get beam energy in cluster**
- **Spread of energies reconstructed at different ZDC positions ~3%**



New ZDC calorimeter for Au+Au

RP resolution Au+Au

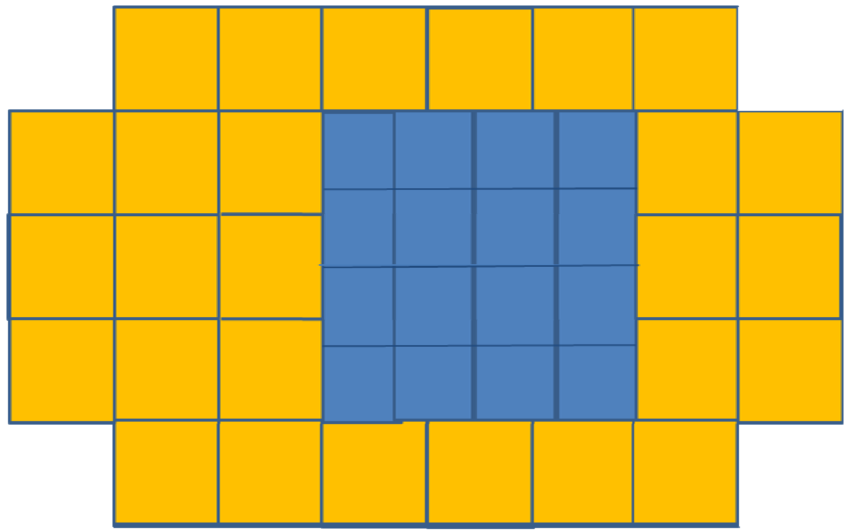


LAQGSM GEANT4 simulation

New BM@N ZDC for Au+Au: 43 modules

Yellow – CBM modules – 20x20 cm, 27 modules

– NICA MPD modules – 15x15 cm, 16 modules



INR RAS, Troitsk

Time schedule for BM@N project development