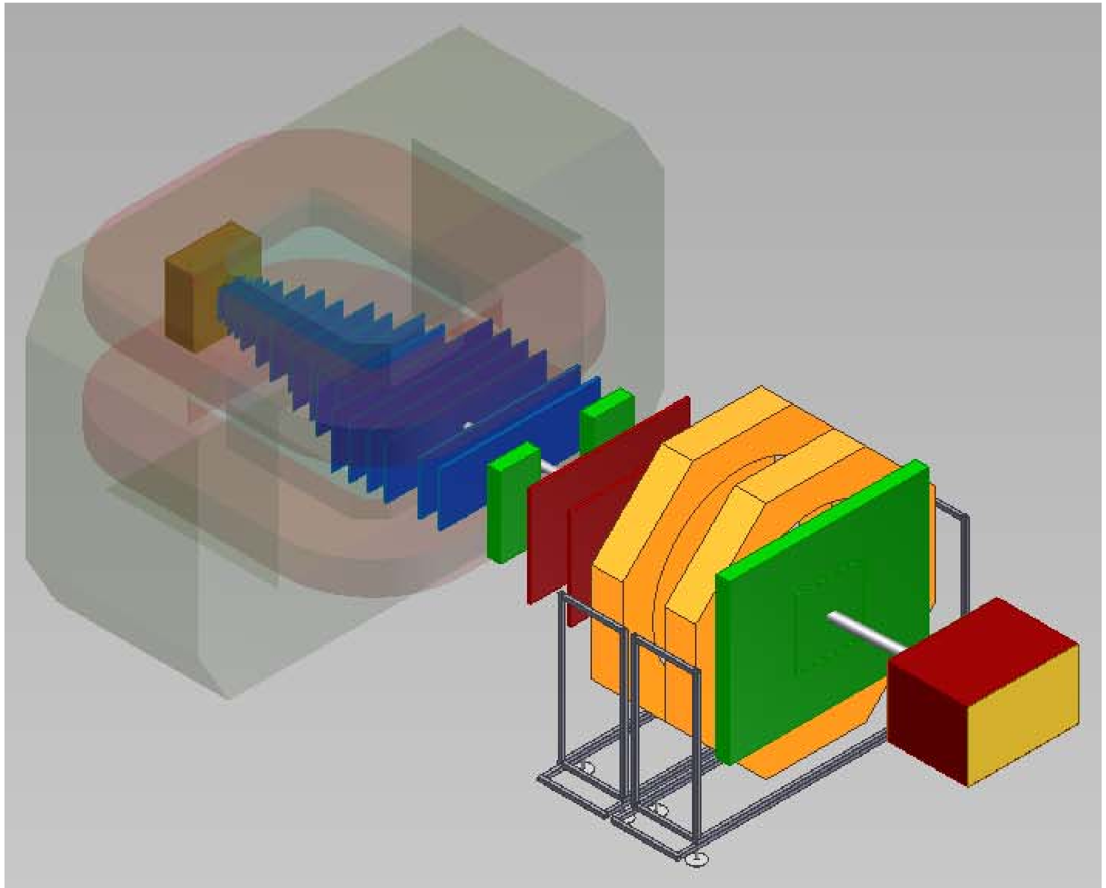
Status of Baryonic Matter at Nuclotron

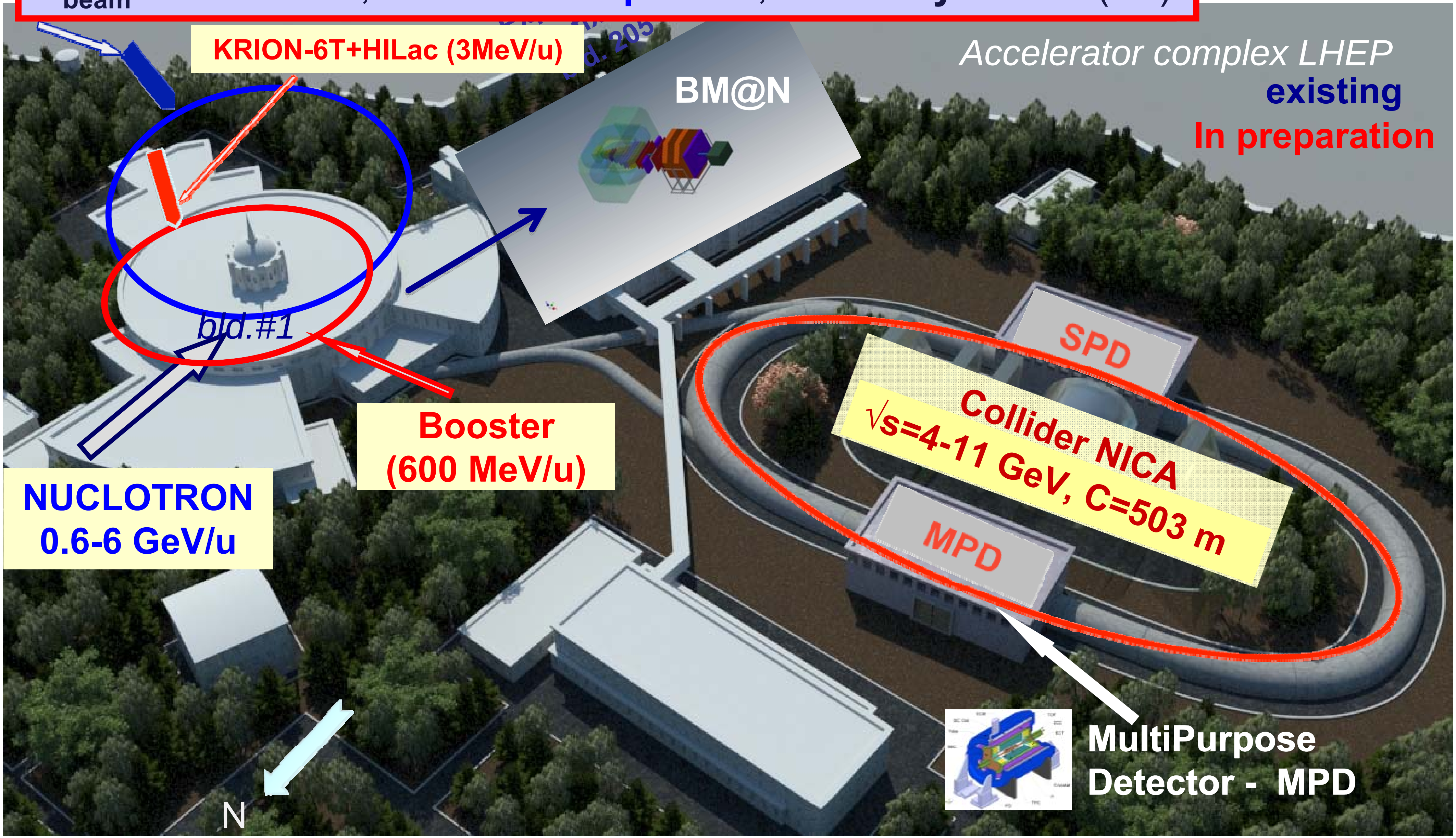
BM@N Project

M.Kapishin

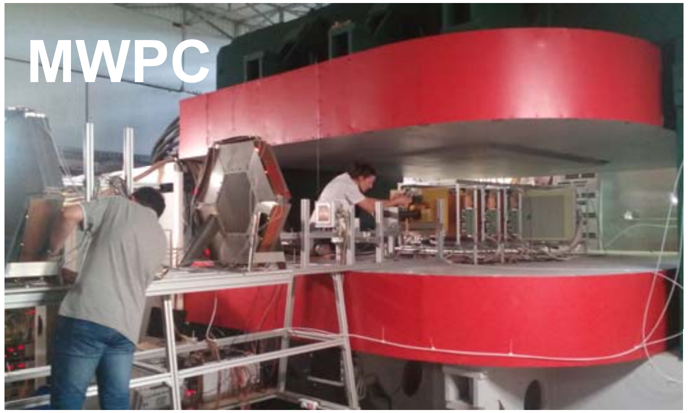


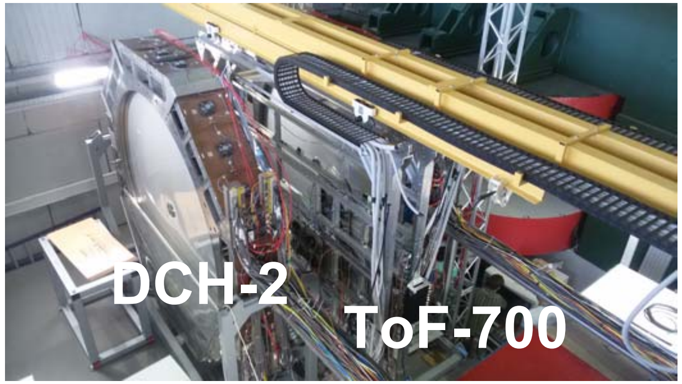
Complex NICA

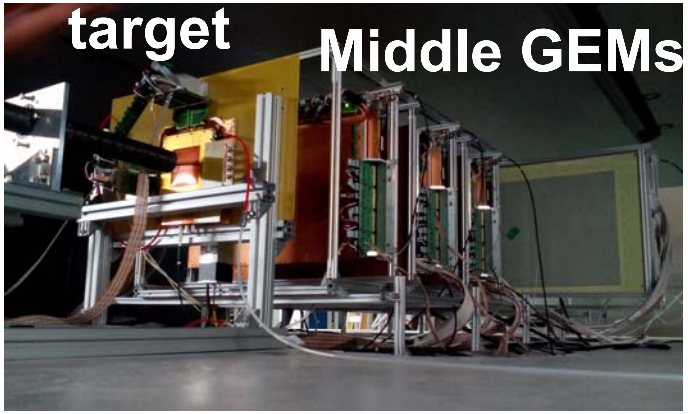
Parameters of Nuclotron for BM@N experiment:
E_{beam} = 1-6 GeV/u; *beams: from* p to Au; Intensity~10^7 c^{-1} (Au)

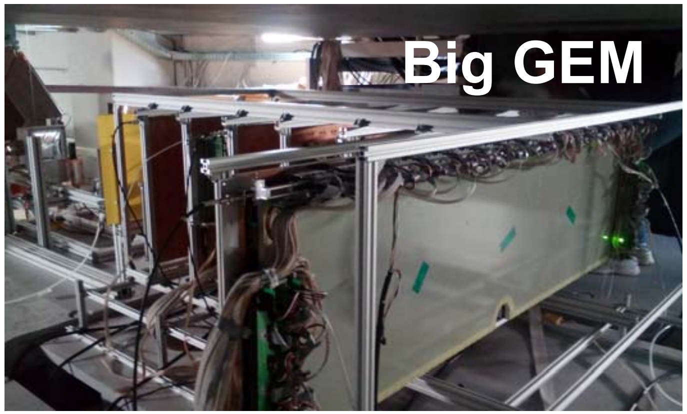


BM@N setup, séance 52 June 2016









- Deuteron beam (~$5 \cdot 10^5$ /cycle) with T_0= 2.94 GeV / nucleon
- Tests and commissioning of GEM central tracker situated inside analyzing magnet → 5 detectors 66 x 41cm2 + 1 detector 163 x 45 cm2
- only 3 hours of data taking

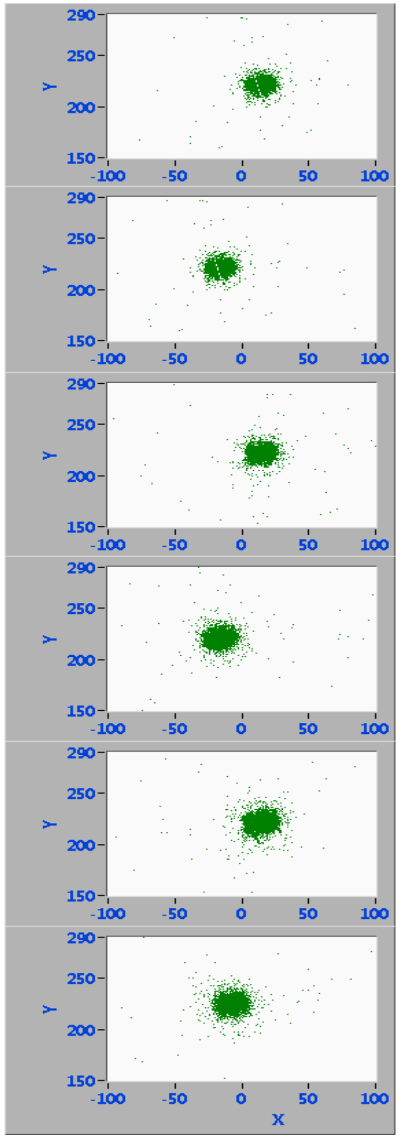
→ recorded beam events and beam interactions with target, GEM detectors at reduced HV

→ collected data without magnetic field and with reduced magnetic field (0.25 T)

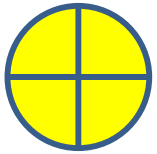
Performance of GEM tracker in séance 52, June 16

5 middle size and 1 big GEM detectors

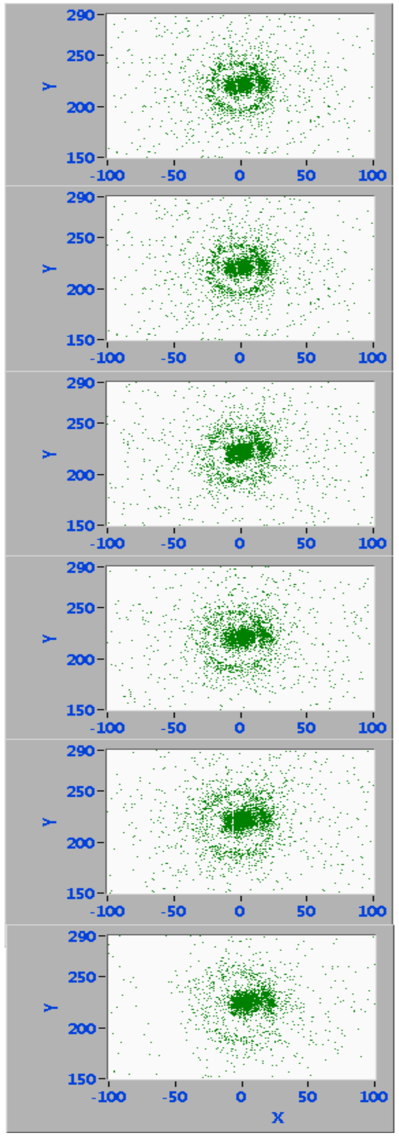
Beam spot, detectors are displaced to ±15 mm



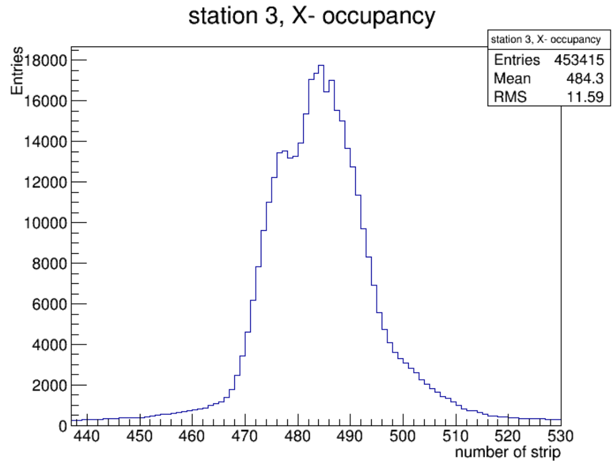
Beam



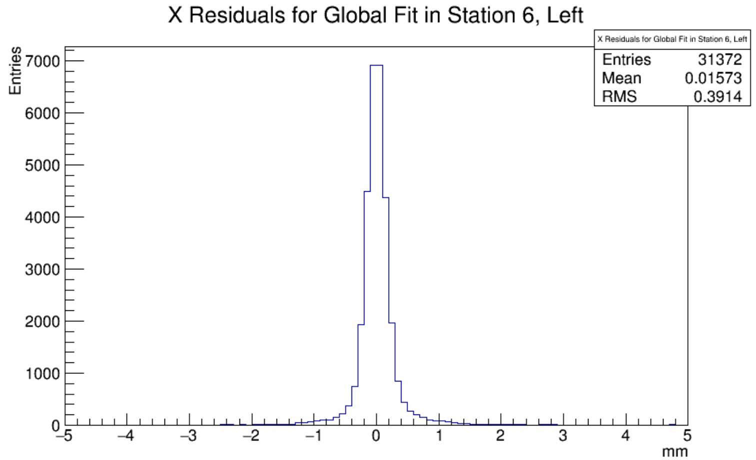
Products of interaction with target and proton spectators / pile-up events in center



Beam profile in middle GEM detector



Beam track residuals in big GEM detector

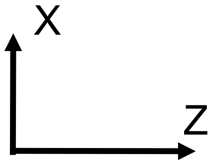


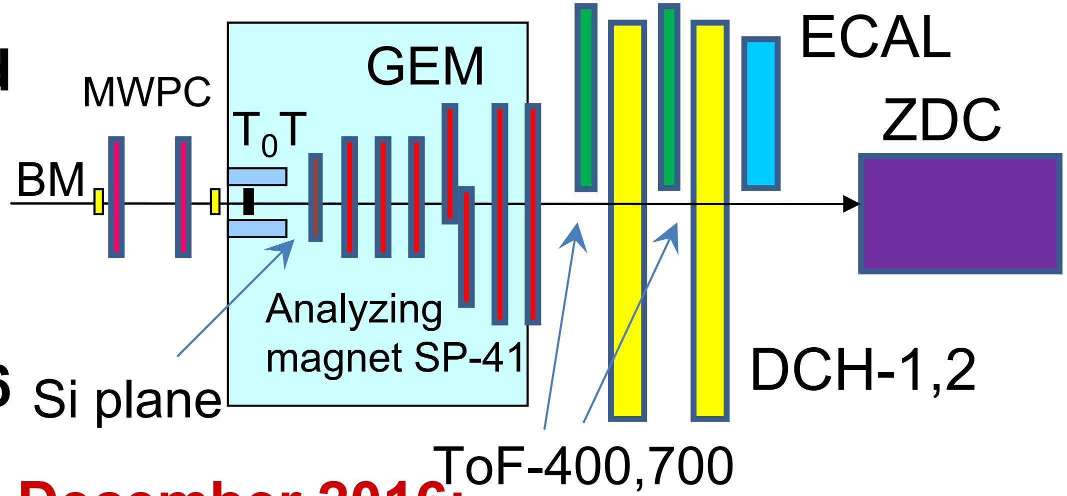
M.Kapishin

BM@N experiment

BM@N experiment in séance 53, December 2016

Deuteron beam, T_0= 4 and 4.6 GeV / nucleon





Configuration in end 2016

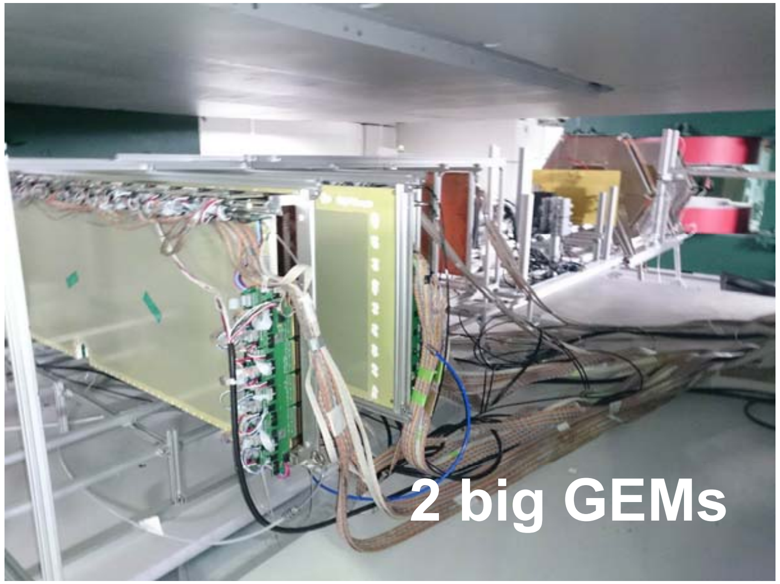
BM@N in technical run in December 2016:

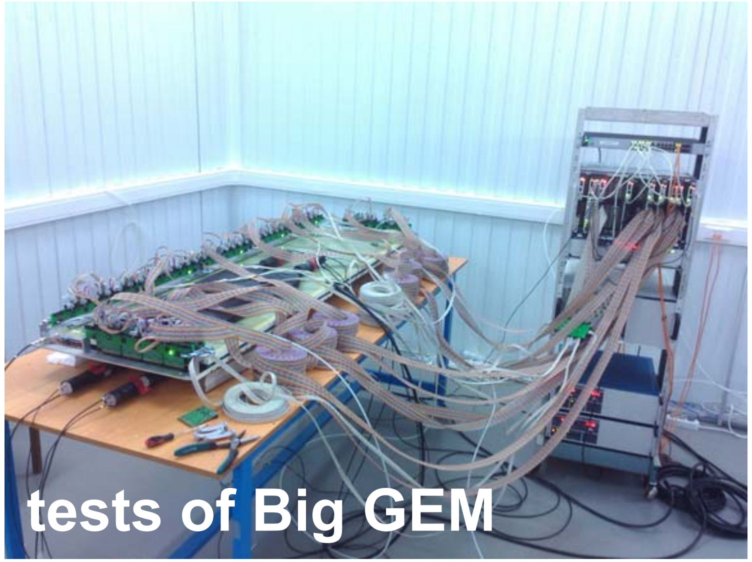
- **Deuteron beam (10^5-$3\cdot10^5$ /cycle) with T_0= 4 GeV / nucleon**
- **Focus on tests and commissioning of GEM central tracker inside analyzing magnet → 5 detectors 66 x 41cm^2 + 2 detectors 163 x 45 cm^2**
- **Install and test one plane of Si detector for tracking**
- **Test / calibrate ToF, T0+Trigger 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 + target → X in deuteron beam with energy T_0= 4.0 GeV / nucleon on targets (CH_2, C, Cu, Pb) in mag. field of 0.75 T**
- **Extract and trace to BM@N deuteron beam with maximal energy (4.6 GeV / nucleon), measure beam momentum and inelastic reactions d + C → X**

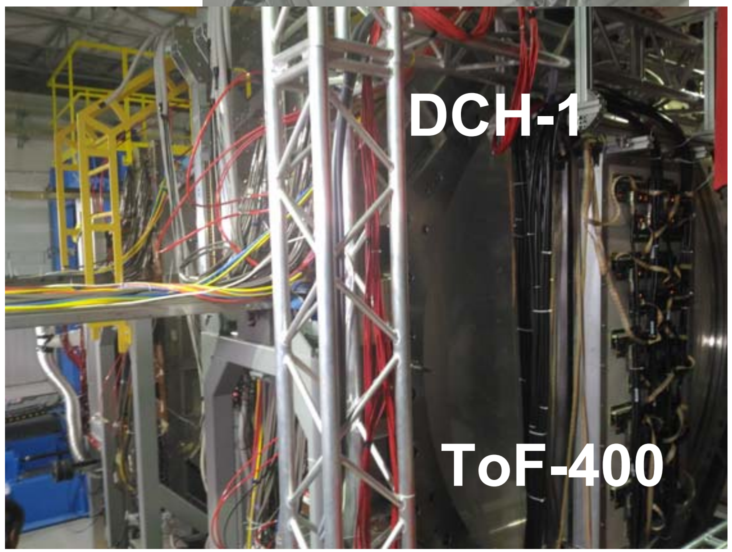
BM@N experiment in séance 53, December 2016





New detector components:

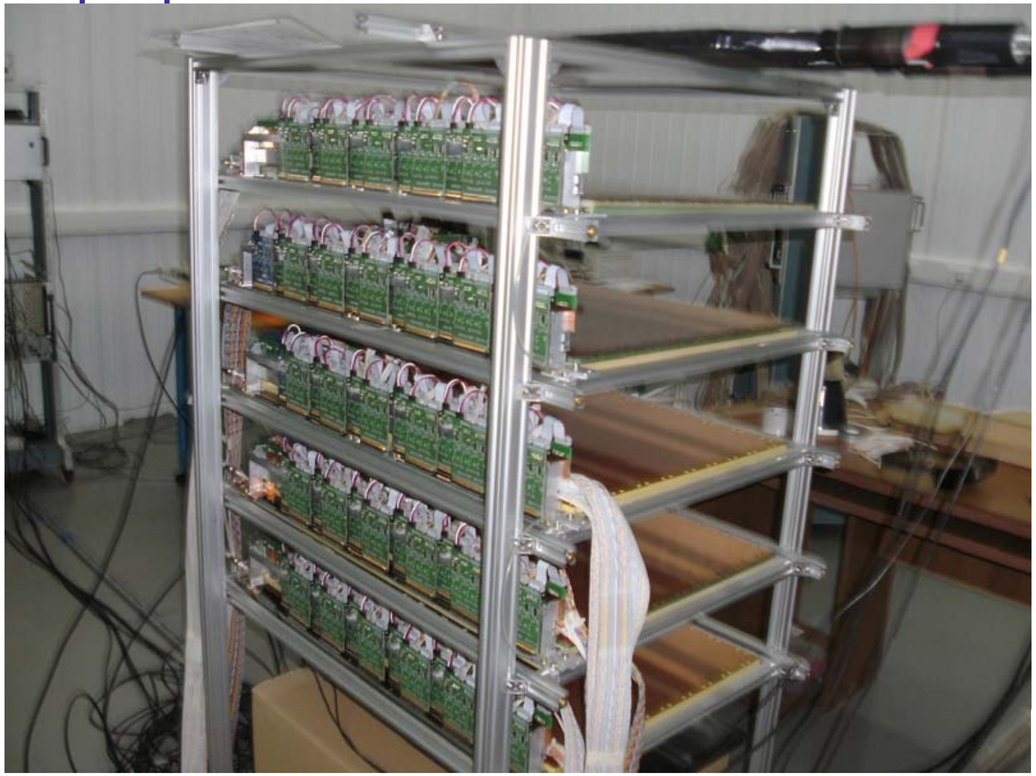
2 big GEMs, trigger barrel detector, Si detector, ECAL



GEM detectors for central BM@N tracker

Tests of GEM detector 163 x 45 cm^2

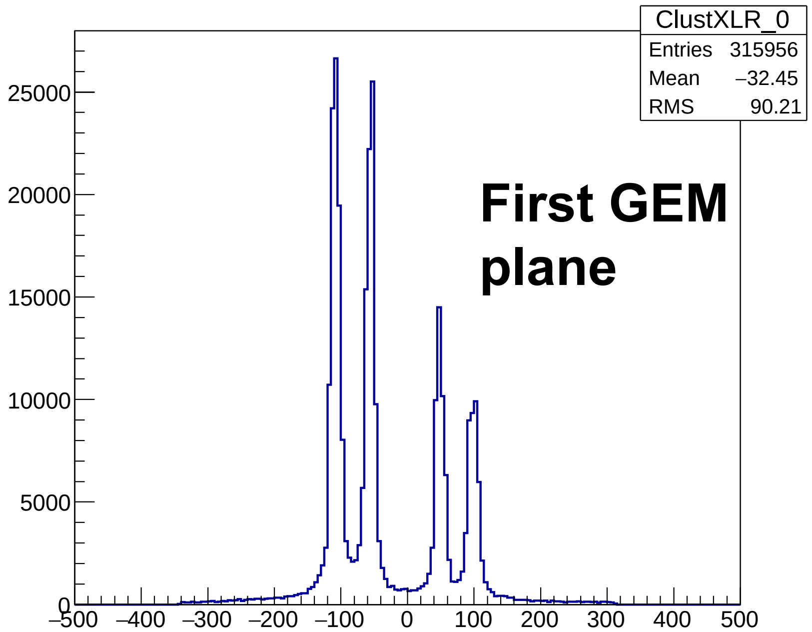
Set of 5 GEM detectors 66 x 41 cm^2 prepared for cosmic tests

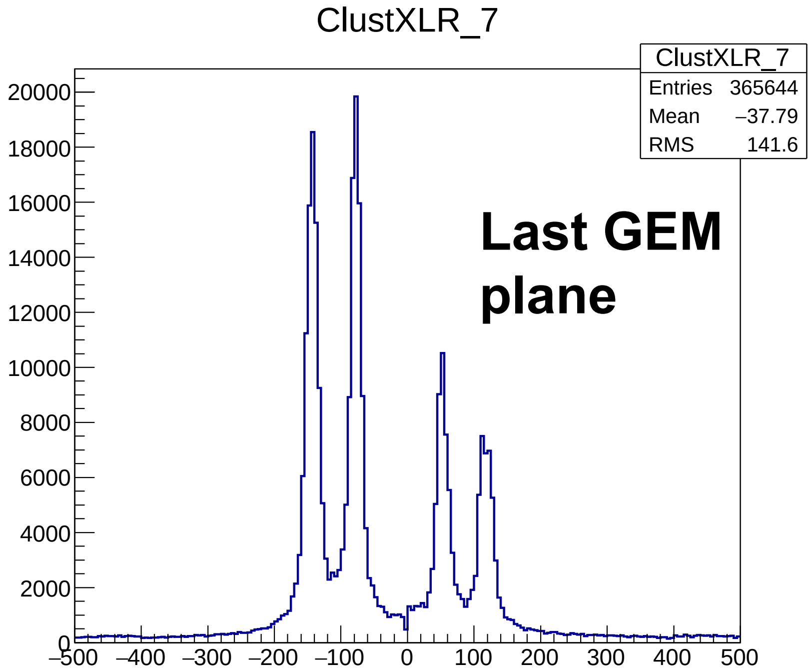


- for tracking in BM@N technical run in December 2016 used 5 detectors 66 x 41 cm^2 and 2 detectors 163 x 45 cm^2
- for BM@N run in autumn 2017 plan to produce 6 more detectors 163 x 45 cm2

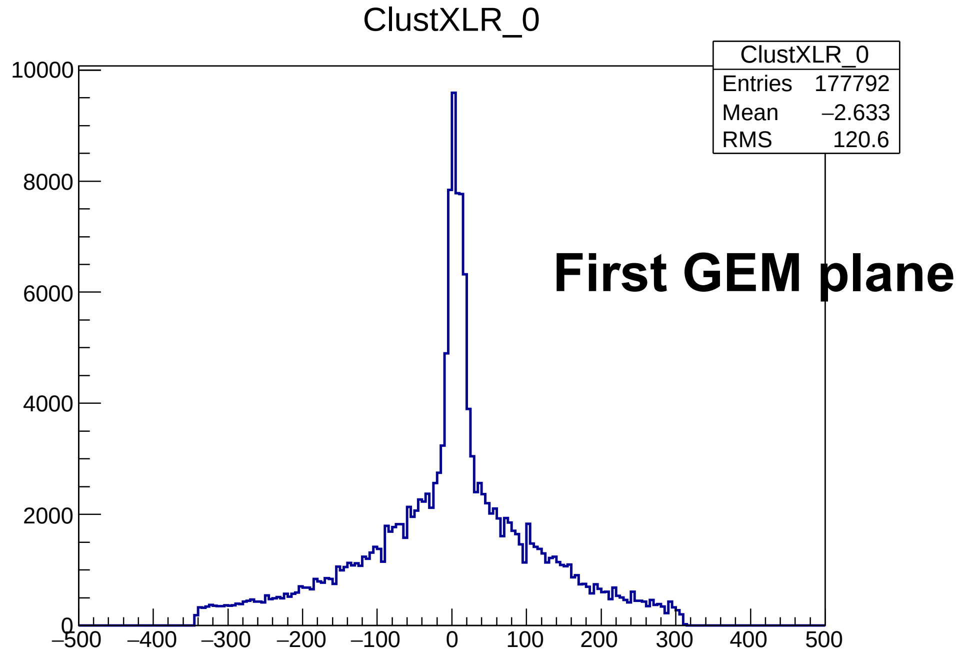
GEM performance in December run

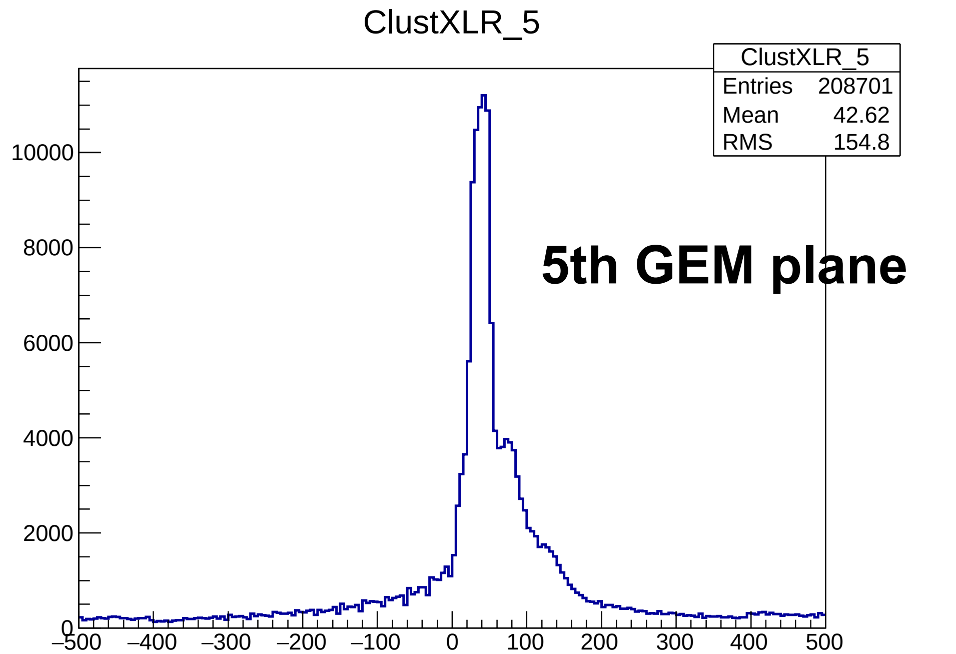
Profiles of beam inclined at different angles



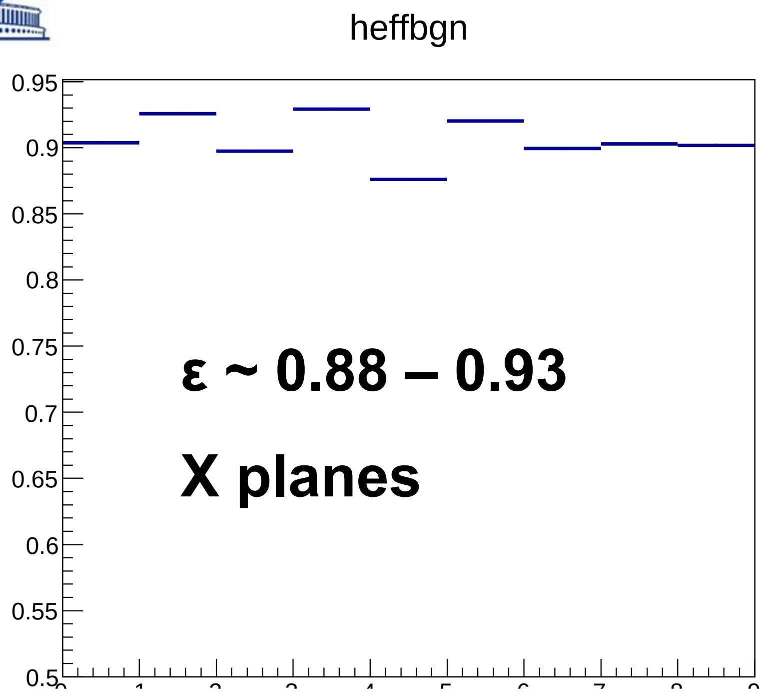


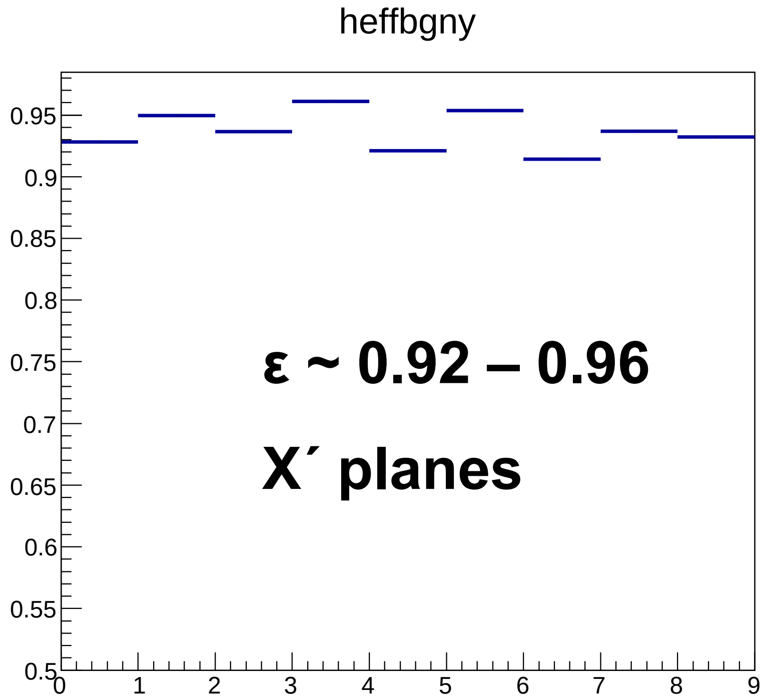
Min bias d + Cu interactions

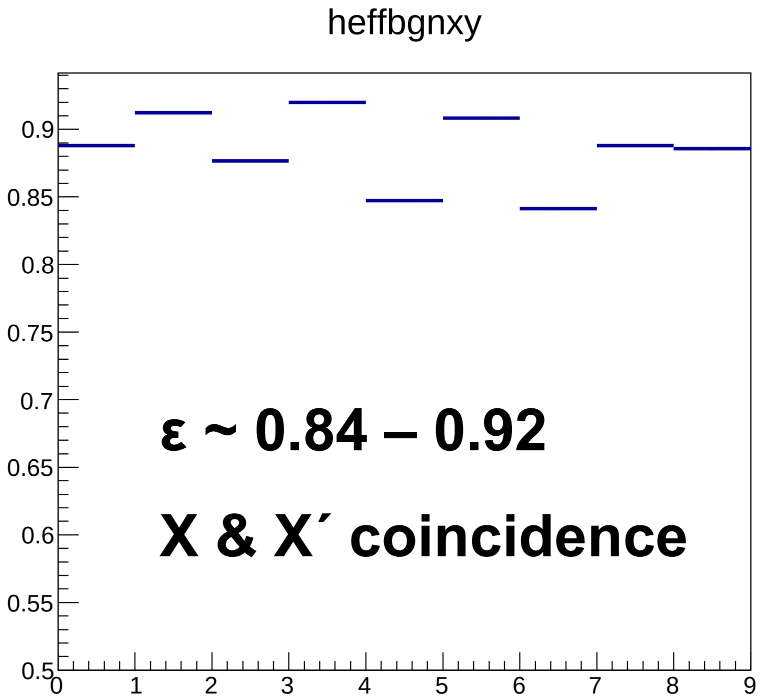




GEM detector efficiency in December run





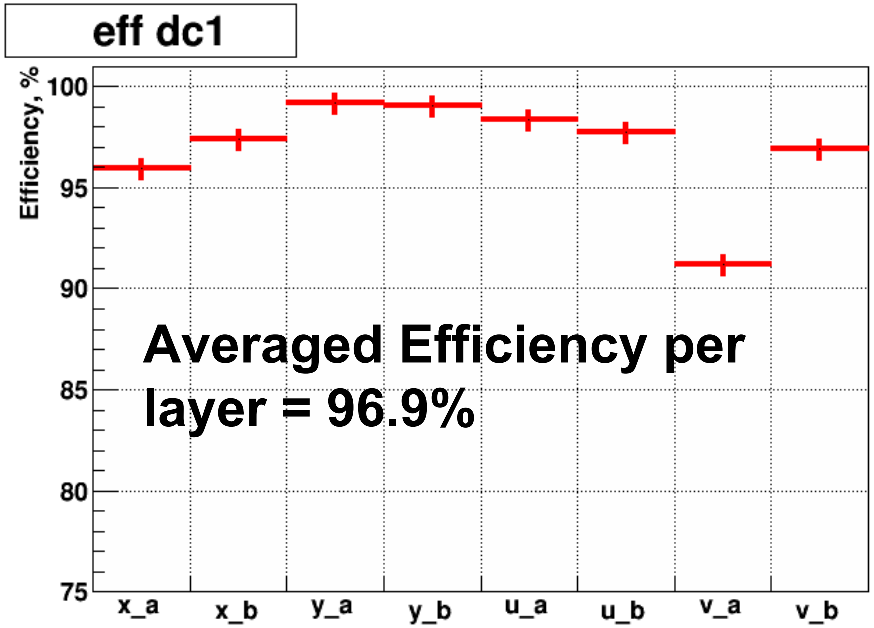


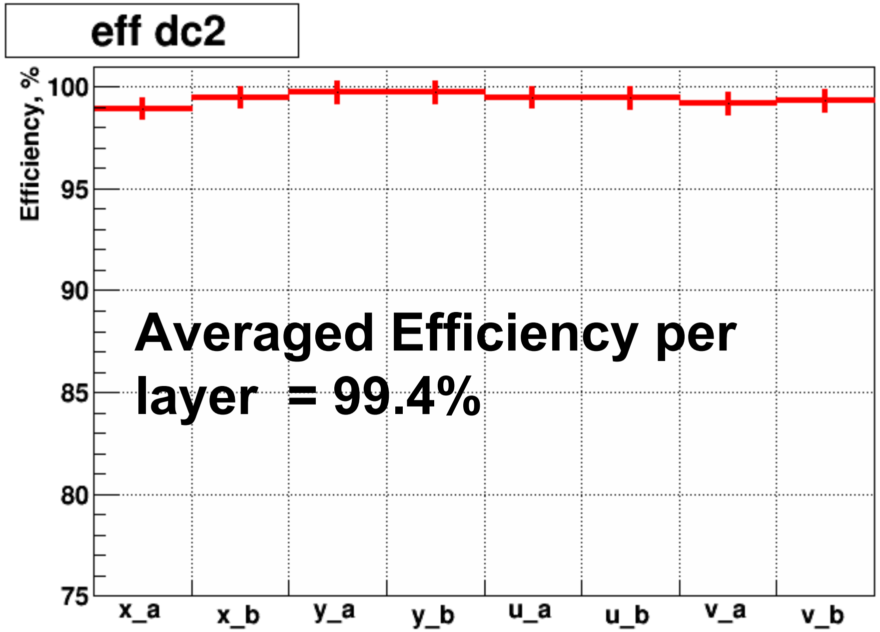
Plane efficiency calculated using reconstructed tracks of beam inclined at different angles

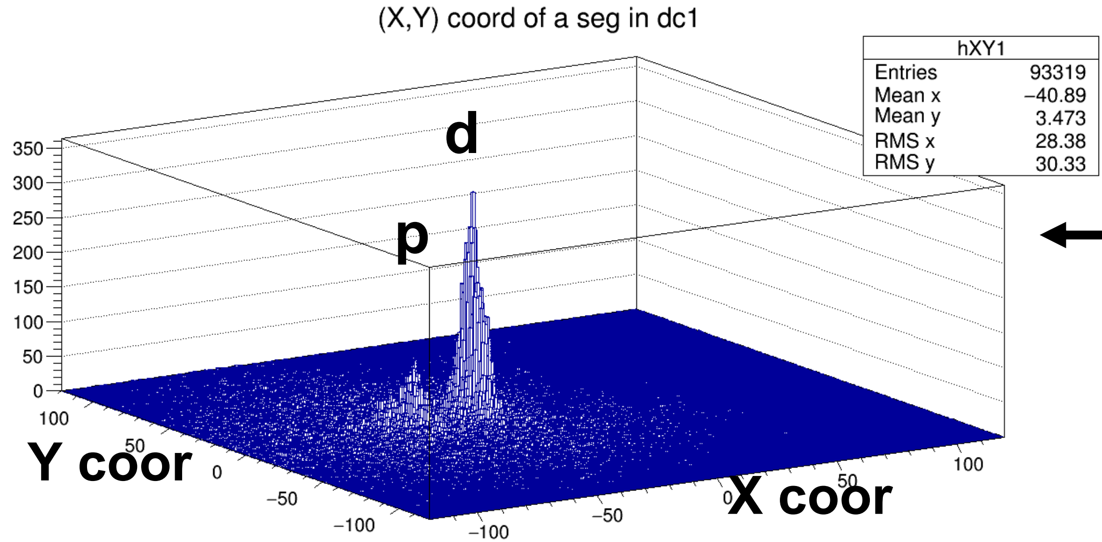
Performance of DCH tracker in December run

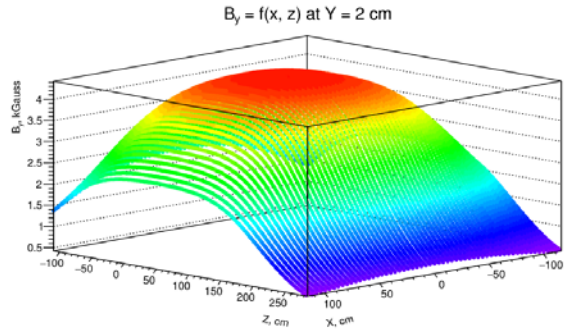
N.Voytishin, V.Palchik, LIT

Reconstructed beam tracks





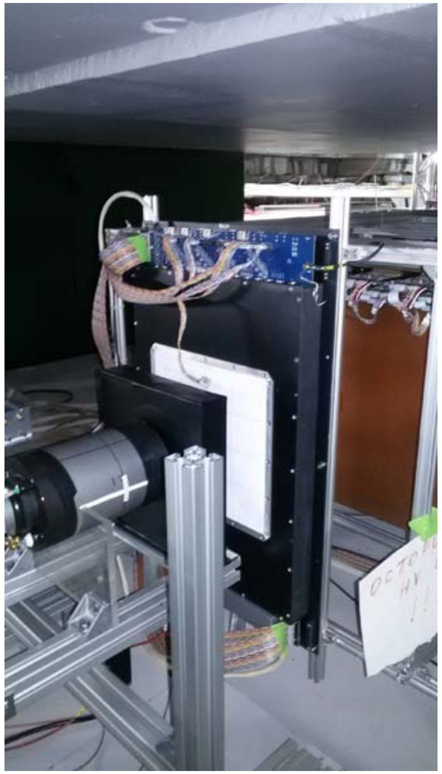


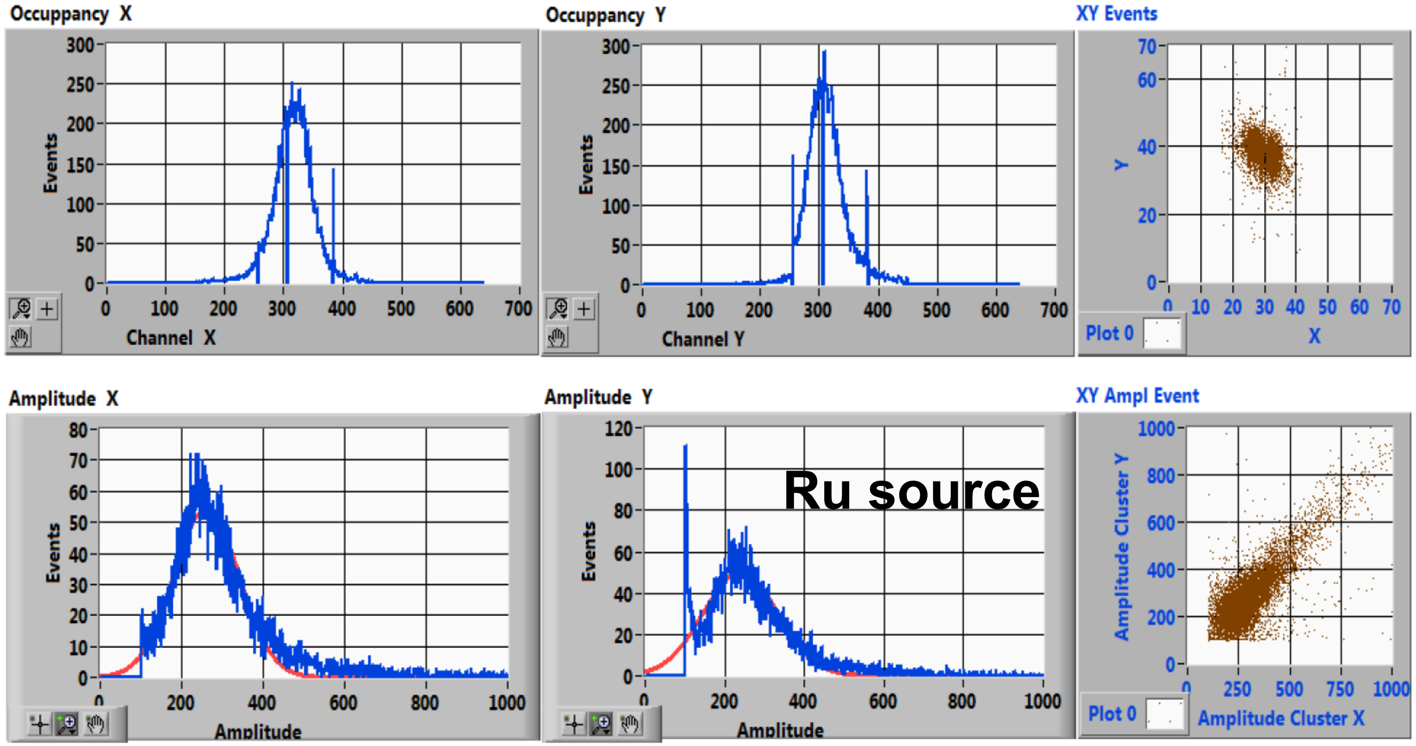


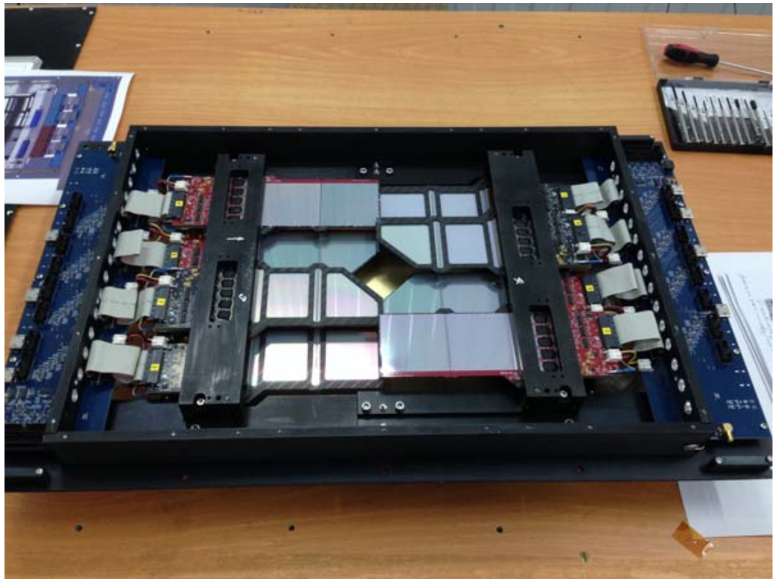
Magnetic field

Development of silicon strip detector

Silicon detector group, N.Zamiatin

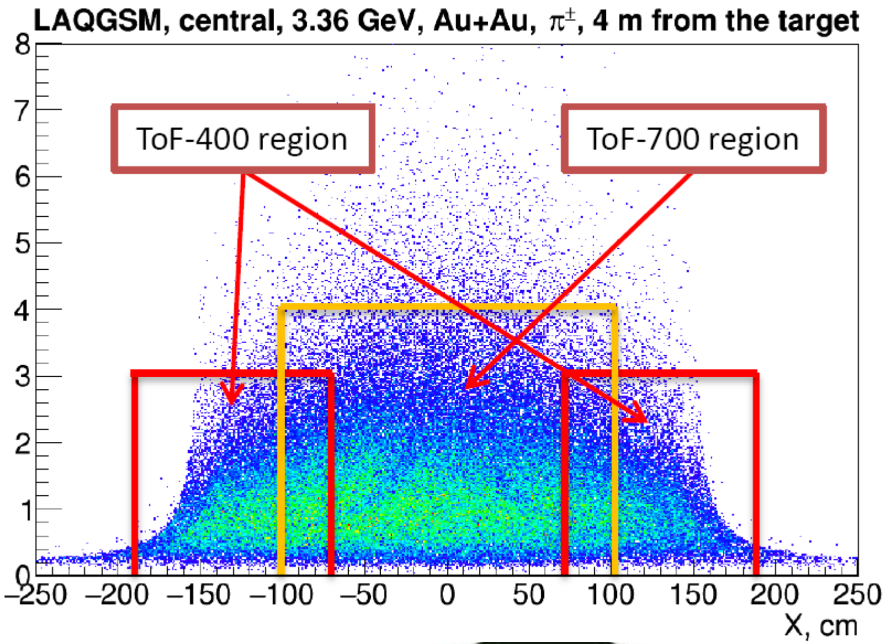




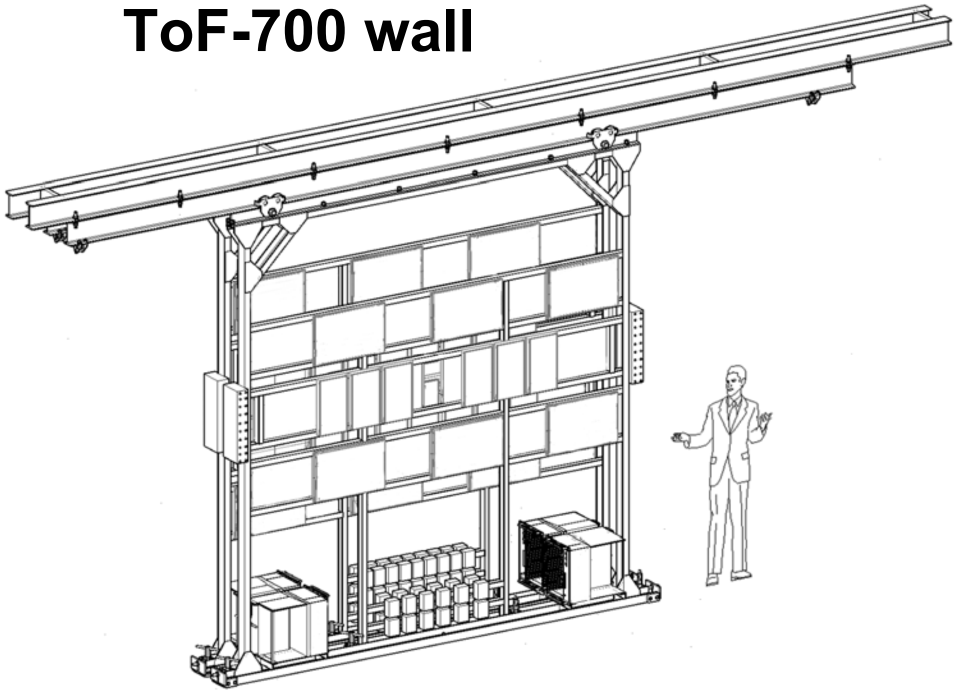


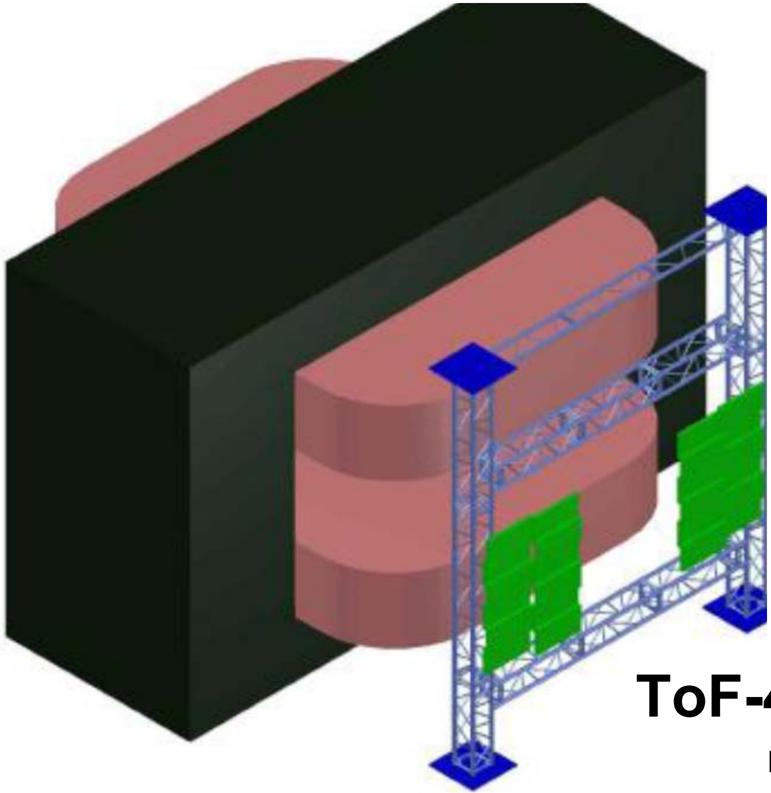
- 2-coordinate Si detector X-X’(±2.5°) with strip pitch of 95/103 μm, full size of 25 x 25 cm^2, 10240 strips
- Detector combined from 4 sub-detectors arranged around beam, each sub-detector consists of 4 Si modules of 6.3 x 6.3 cm^2
- One plane installed in front of GEM tracker in December 2016

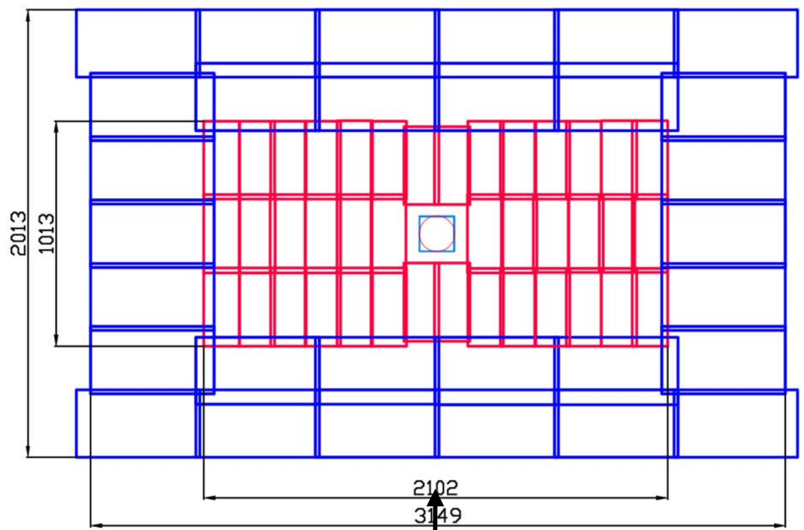
ToF-400 and ToF-700 based on mRPC



ToF-700 wall







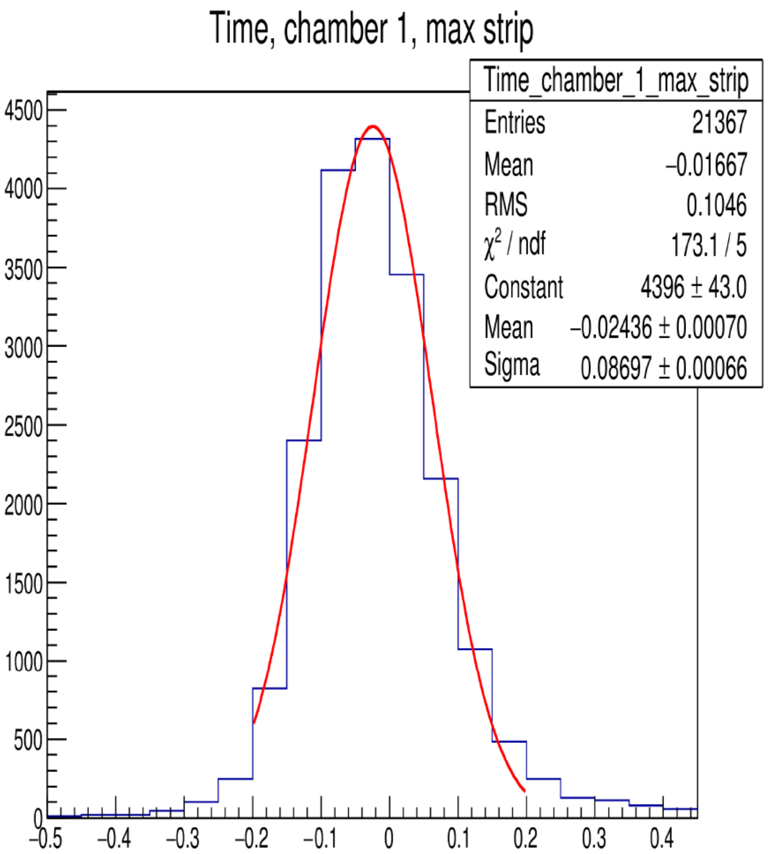
ToF-400 wall

BM@N beam axis

ToF system performance in December run

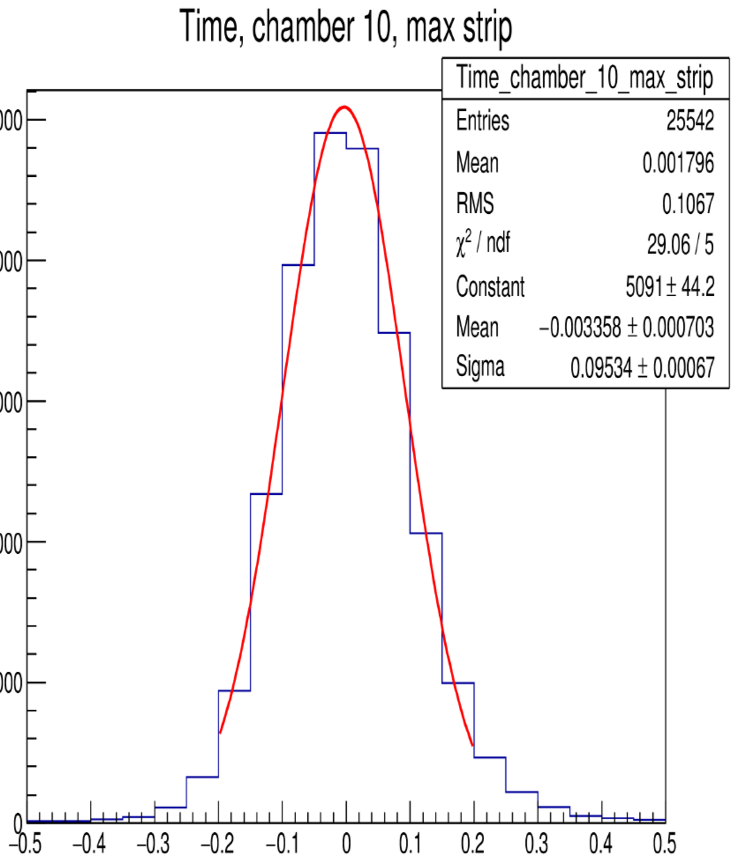
Yu.Petukhov, SNEO

Time resolution between ToF-400 and T0



TOF400 - T0

Time resolution between ToF-700 and T0



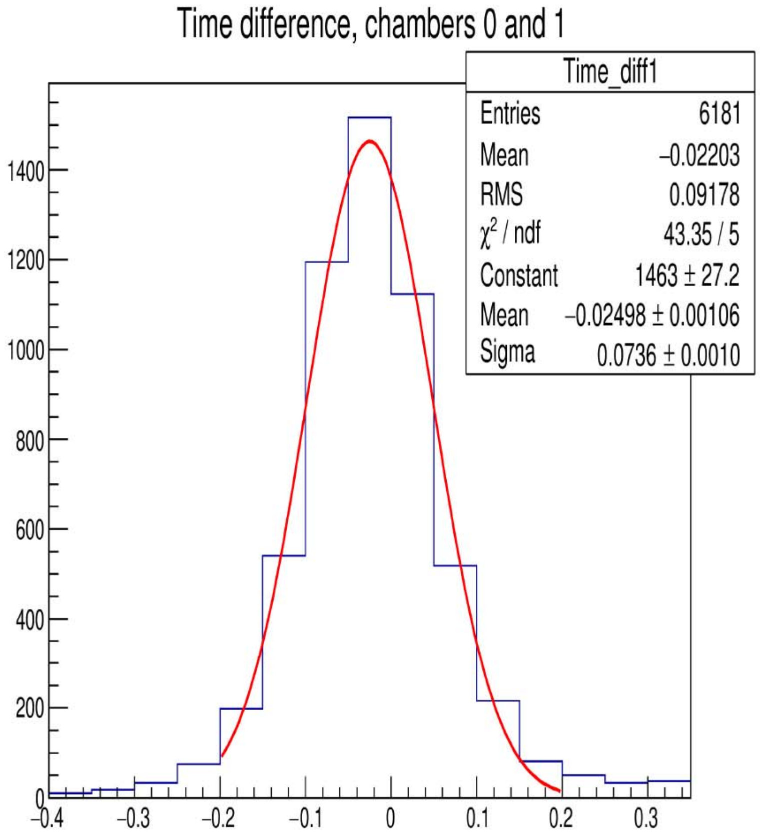
TOF700 - T0

- **Time resolution of T0 detector ~70 ps**

ToF system performance in December run

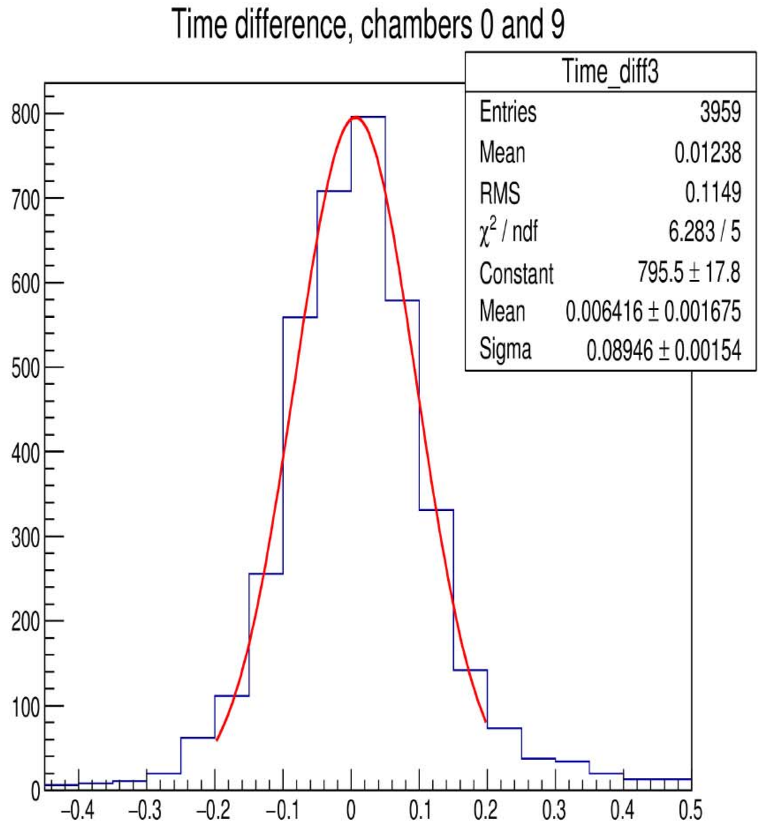
Yu.Petukhov, SNEO

Time resolution between two ToF-400 chambers



TOF400_1 - TOF400_2

Time resolution between ToF-700 and ToF-400 chambers



TOF700 - TOF400

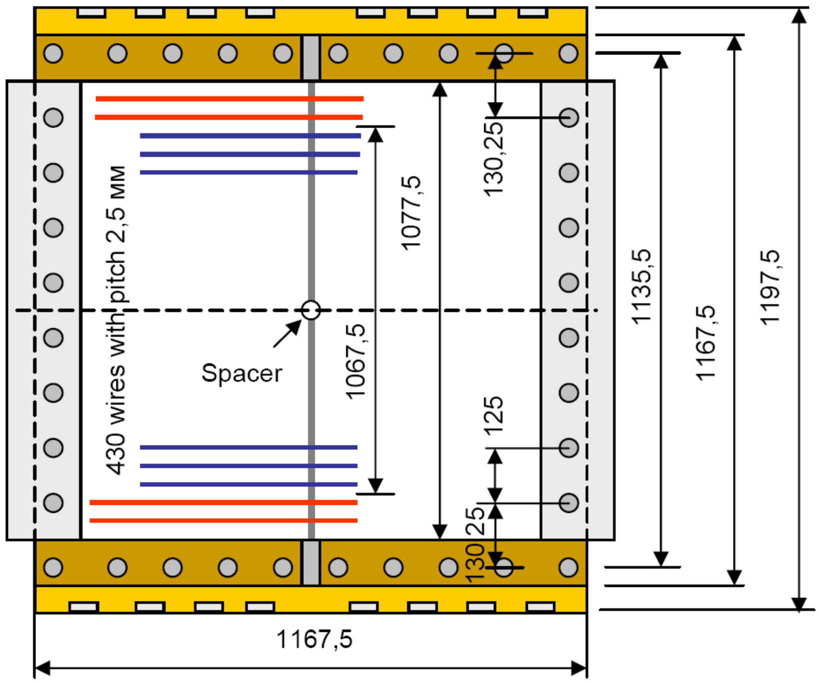
- **Time resolution of ToF-700 chamber ~65 ps**
- **Time resolution of ToF-400 chamber ~53 ps**

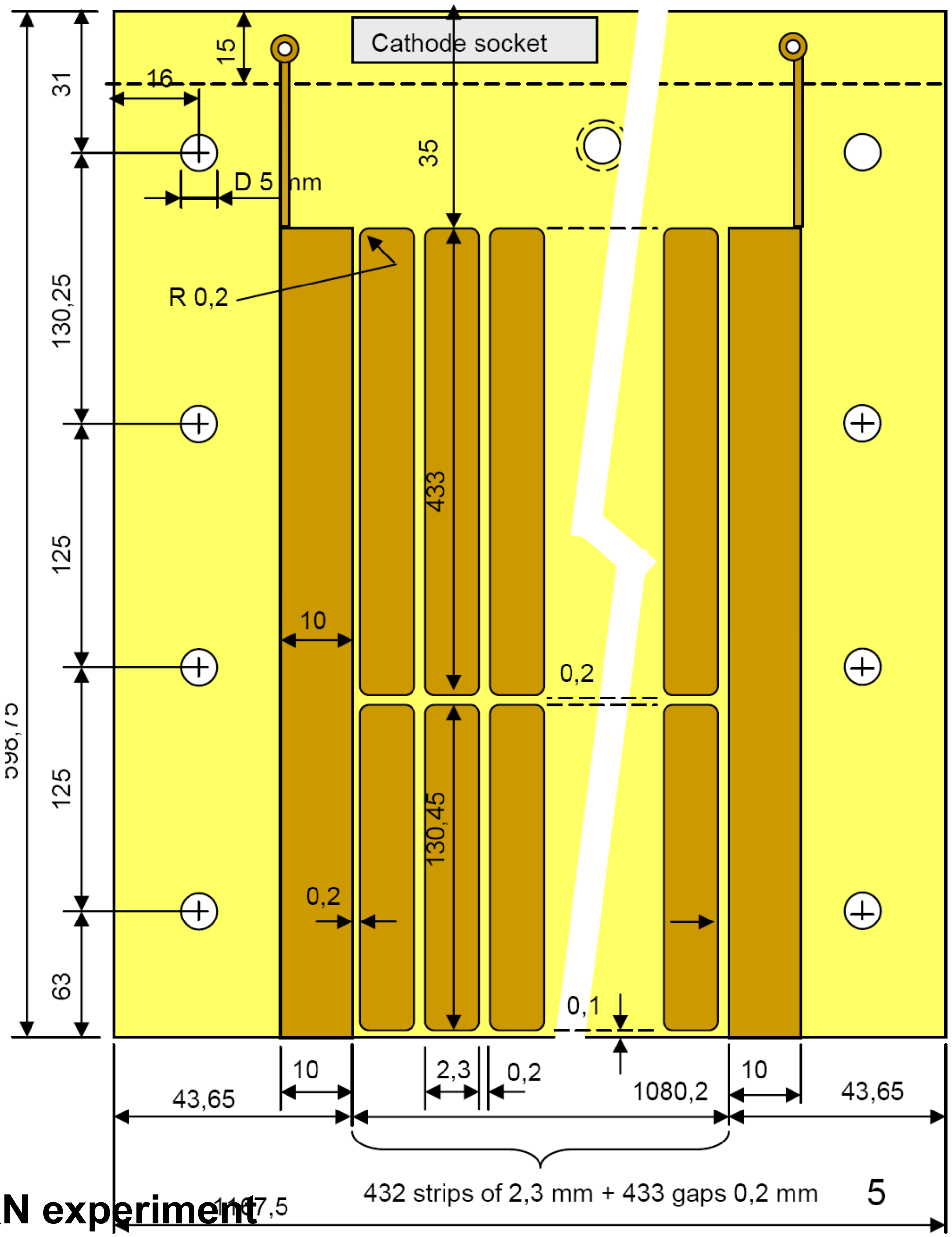
CPC chamber design

Al. Vishnevsky

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

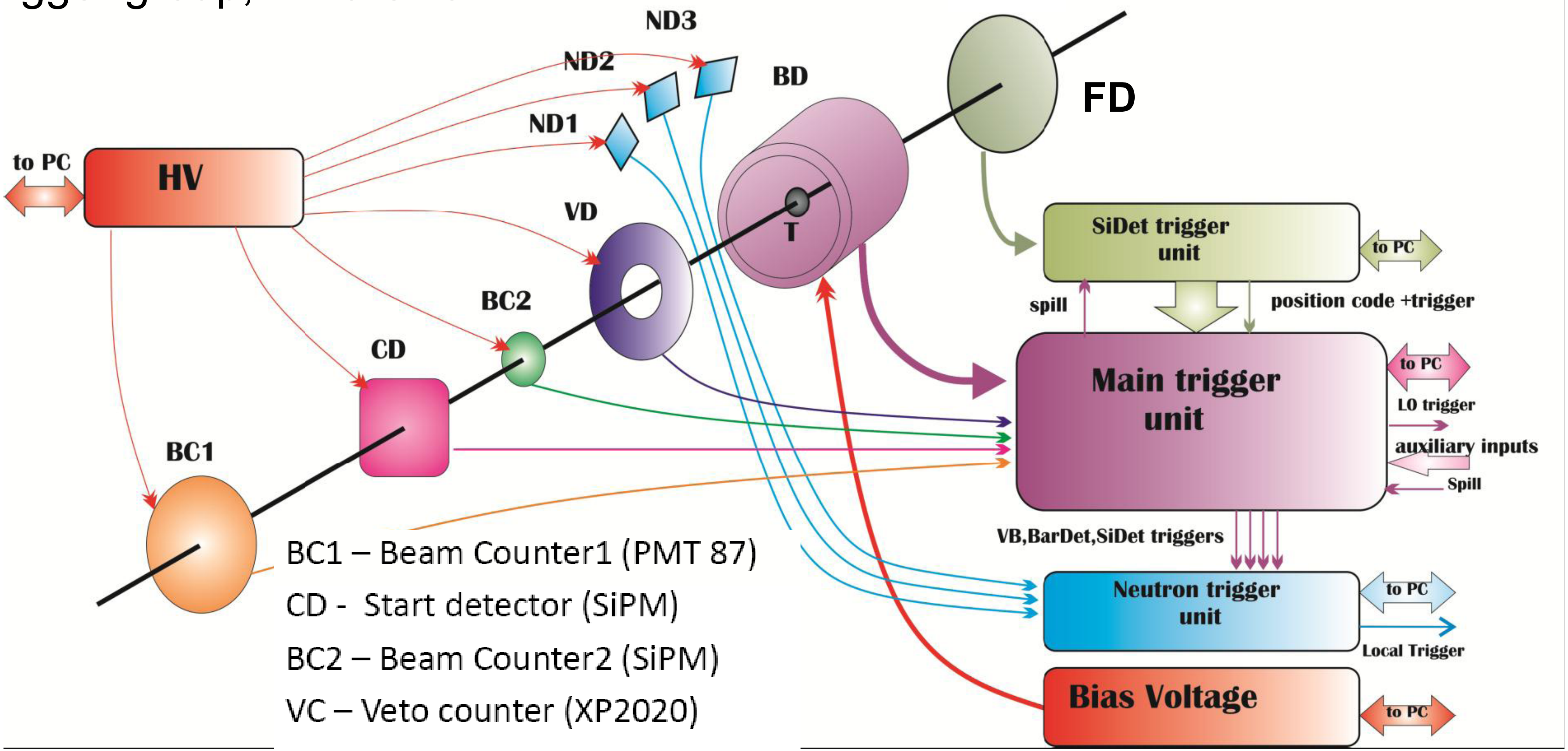
Cathode printed board #1





Trigger detectors: beam counters and barrel detector in December run

Trigger group, V.Yurevich

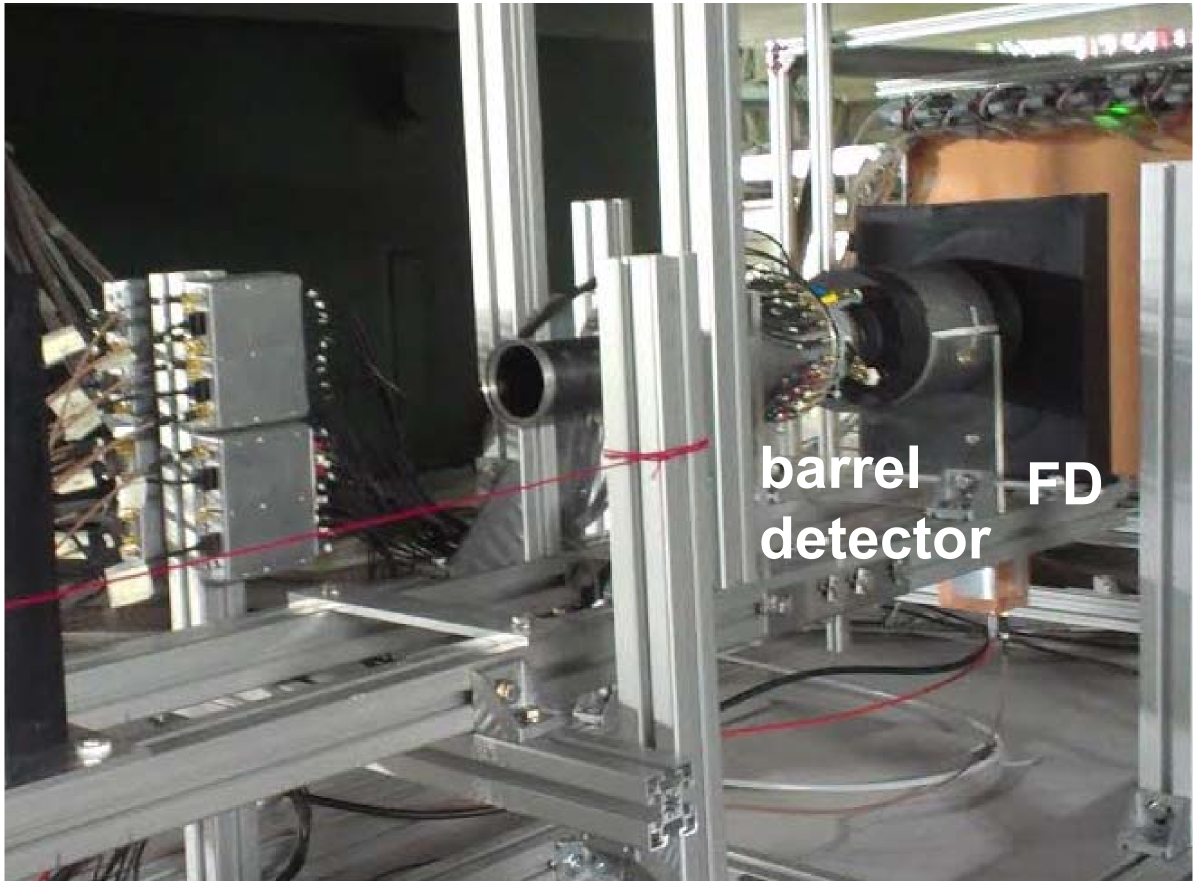


BC1 – Beam Counter1 (PMT 87)
CD - Start detector (SiPM)
BC2 – Beam Counter2 (SiPM)
VC – Veto counter (XP2020)
BD – Barrel Detector – 40ch. SiPM
T – target
SiDet – Silicon Detector

Selection of events with activity in barrel detector: BD > 0, > 1 or forward detector (with beam hole) FD

Trigger barrel detector in BM@N setup

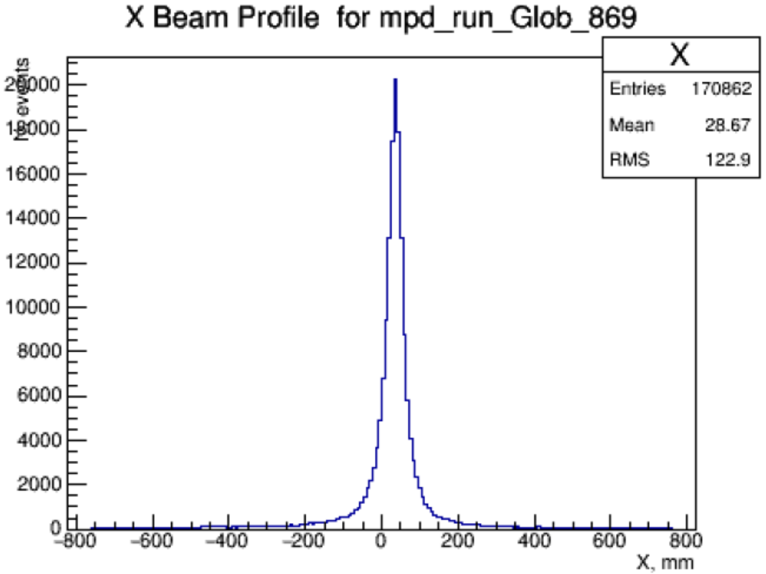
Trigger group, V.Yurevich

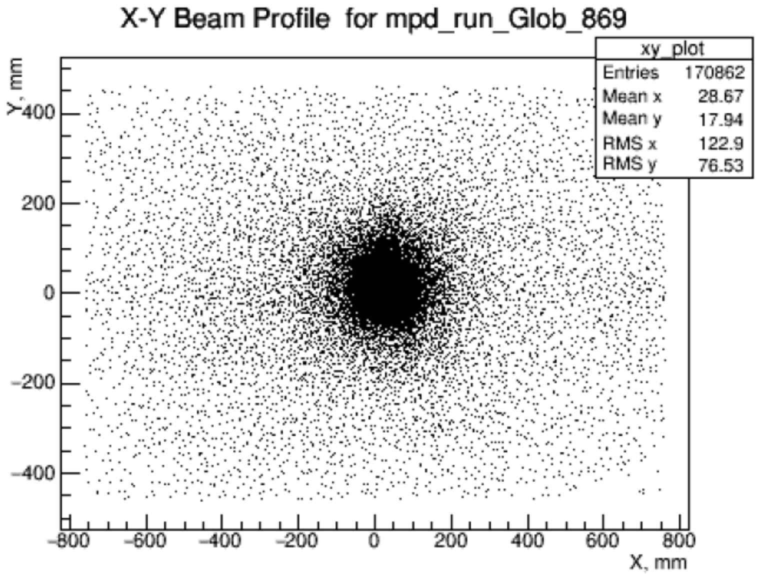


ZDC performance in December run

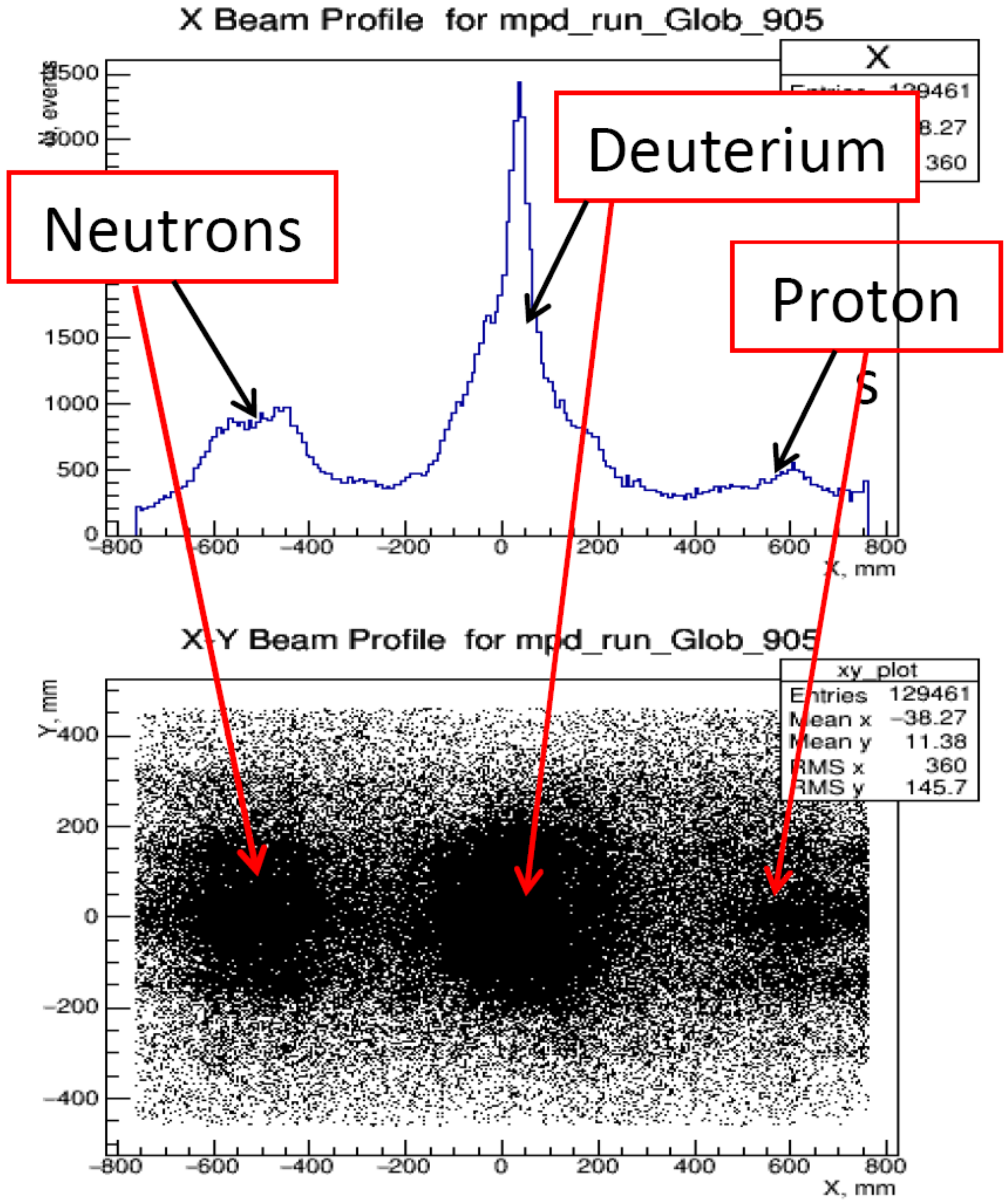
O.Gavrischuk, SNEO

Profile of deuteron beam in ZDC



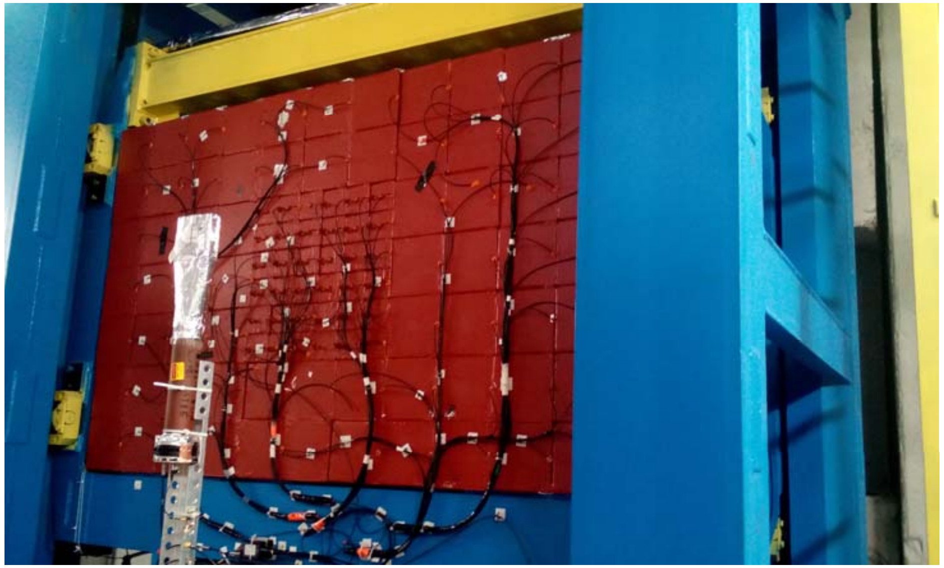


ZDC response to deuterons and products of d+CH_2 interactions

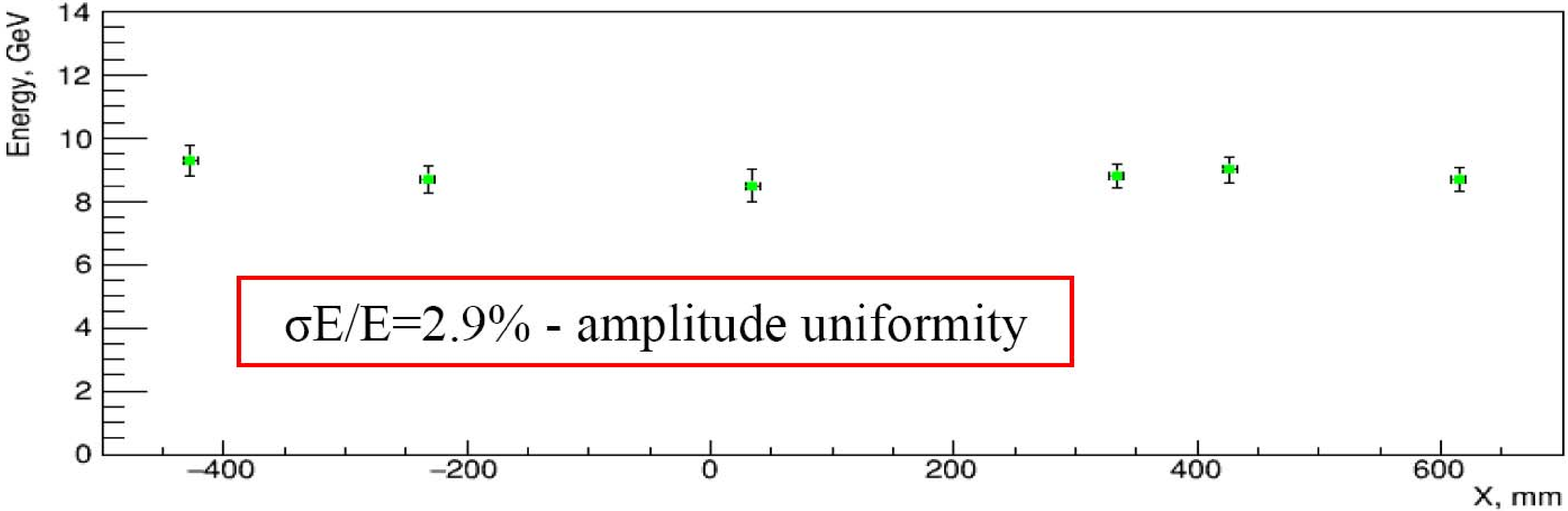


Calibration of ZDC calorimeter

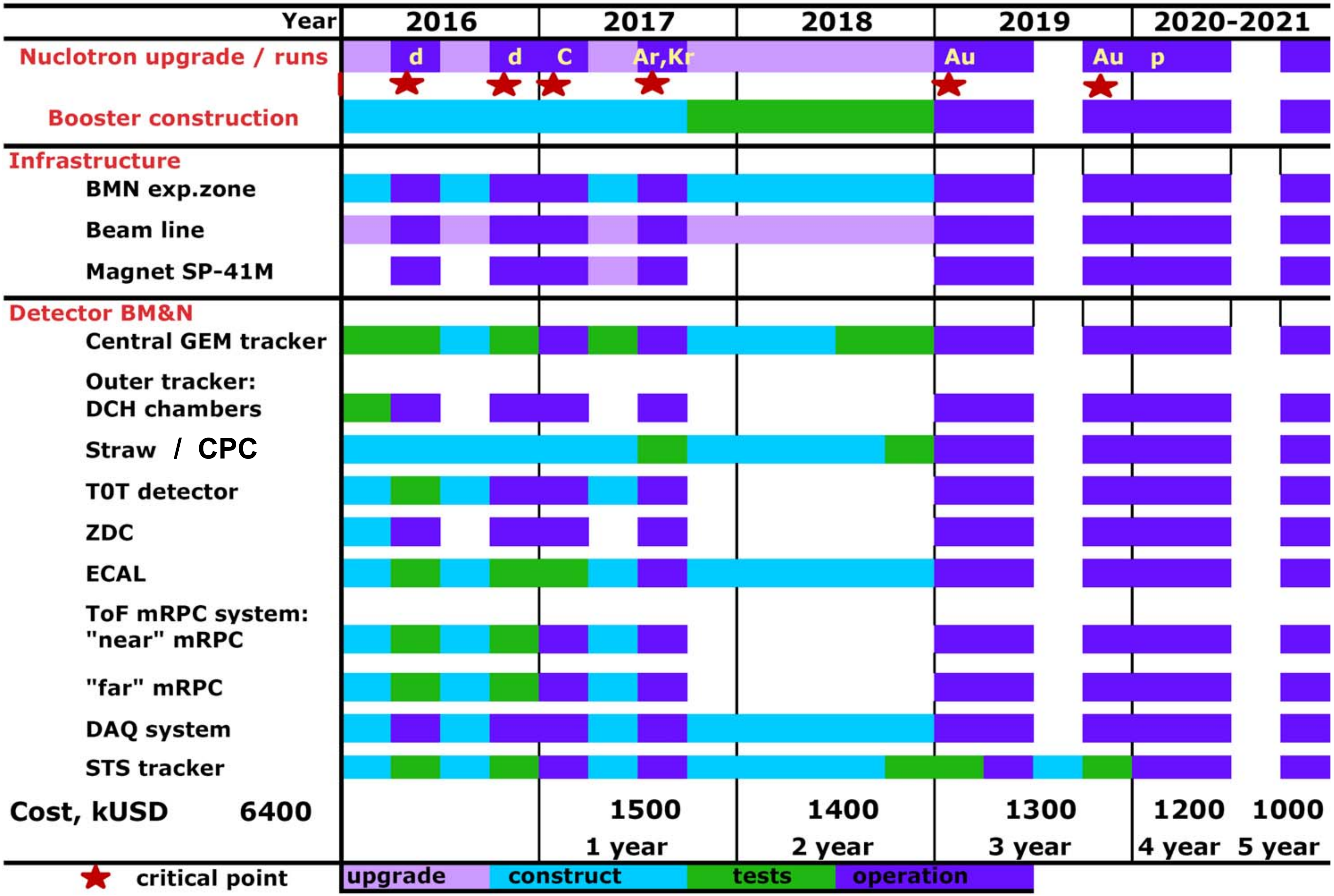
O.Gavrischuk, SNEO



- 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%



Time schedule for BM@N project development



Concluding remarks and next plans

• Finally 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: GEM, DCH, ToF-400, ToF-700, ZDC, trigger, DAQ, slow control, online monitoring

• New sub-detectors are putting into operation: Si detector plane, ECAL

• Low priority in getting beams and non-regular paying for contracts delayed project realization for about half of year

BM@N plans for 2017:

• Technical run in February-March with heaviest beams provided by laser ion source: C (O), make beam energy scan: 3.5, 4.0, 4.5 AGeV

BM@N setup: existing GEM tracker, modified trigger system, extended ToF-400, ToF-700, DCH, DAQ configurations, Si detector plane in full setup

• Technical run in November-December with beams provided by heavy ion source: Ar, Kr, extracted and traced to BM@N setup

BM@N setup: extended GEM tracker, trigger system, ToF-400, ToF-700; two new CPC chambers in front and behind ToF-400

Thank you for attention!

Backup slides

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, Ar	Kr	Au	Au, p
max.intensity, Hz	1M	1M	1M	1M	10M
trigger rate, Hz	10k	10k	20k	20k	50k
central tracker status	6 GEM half pl.	8 GEM half pl.	10 GEM half pl.	8 GEM full pl.	12 GEMs or 8 GEMs + Si planes
experim. status	techn. run	techn. run	physics run	stage 1 physics	stage 2 physics

Form 26

Time schedule and requested resources for the realization of the project: Studies of Baryonic Matter at the Nuclotron (BM@N)

Detectors / subsystems / facilities	ADB2 items	Cost of components, kUSD / required resources	2017	2018	2019	2020	2021
Detector prototypes	6.1.1	**130**	30	30	30	20	20
Central GEM tracker	6.1.2	**1920**	470	610	630	190	20
Outer tracker	6.1.3	**240**	100	100	20	10	10
ToF system	6.1.4	**260**	220	10	10	10	10
ZDC calorimeter	6.1.5	**50**	10	10	10	10	10
T0 detector	6.1.6	**60**	20	10	10	10	10
Si detector	6.1.7	**260**	110	80	50	10	10
ECAL calorimeter	6.1.8	**230**	90	90	30	10	10
Trigger system	6.1.9	**50**	10	10	10	10	10
Recoil detector	6.1.10	**50**	10	10	10	10	10
STS detector	6.1.11	**1830**	150(*)	150(*)	200(*)	680(*)	650(*)
Experimental zone	6.2	**280**	80	80	80	20	20
DAQ system + computing	6.3	**490**	90	100	100	100	100
Control system	6.4	**50**	10	10	10	10	10
Total costs, kUSD		**5900**	**1400**	**1300**	**1200**	**1100**	**900**
JINR budget							
Nuclotron, hours		10500	1500	-	3000	3000	3000
Labor OP, hours		5000	1000	1000	1000	1000	1000
Labor KB, hours		2500	500	500	500	500	500

(*) plus resurces from Mega Science project and grants

Nuclotron and BM@N beam line

26 elements of magnetic optics:

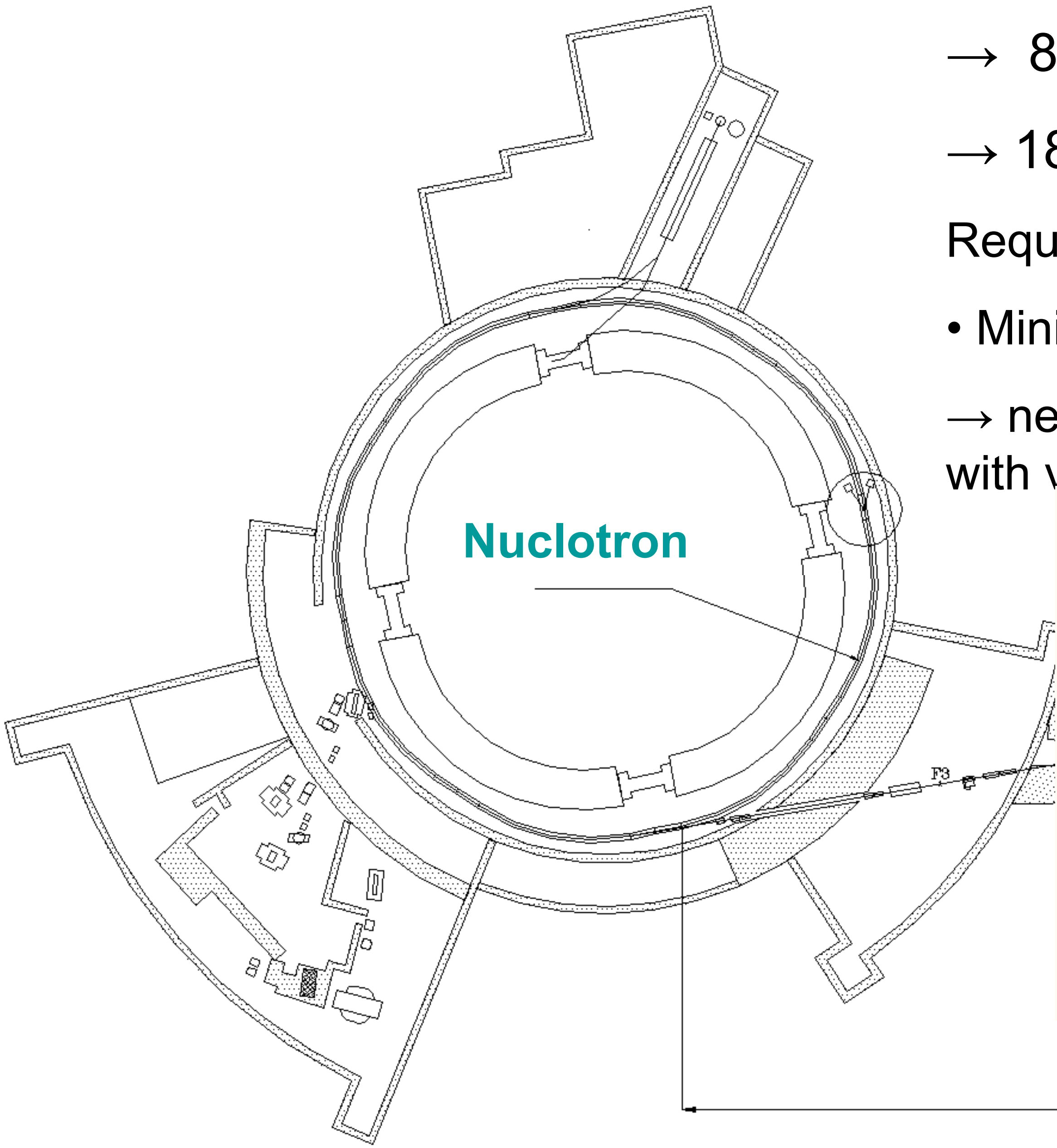
→ 8 dipole magnets

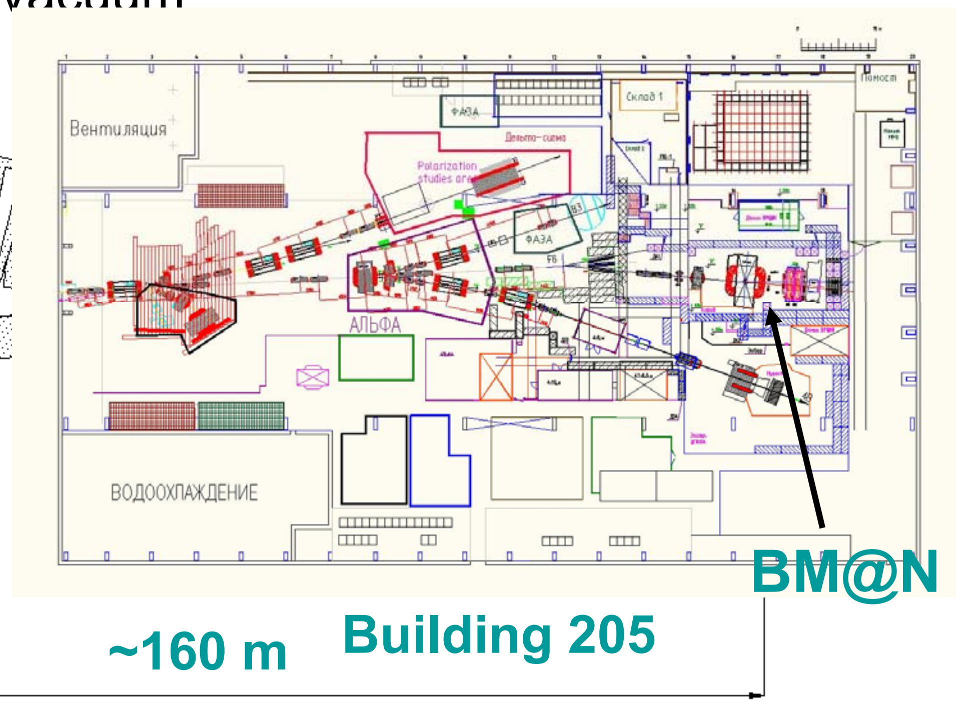
→ 18 quadruple lenses

Requirements for Au beam:

• Minimum dead material

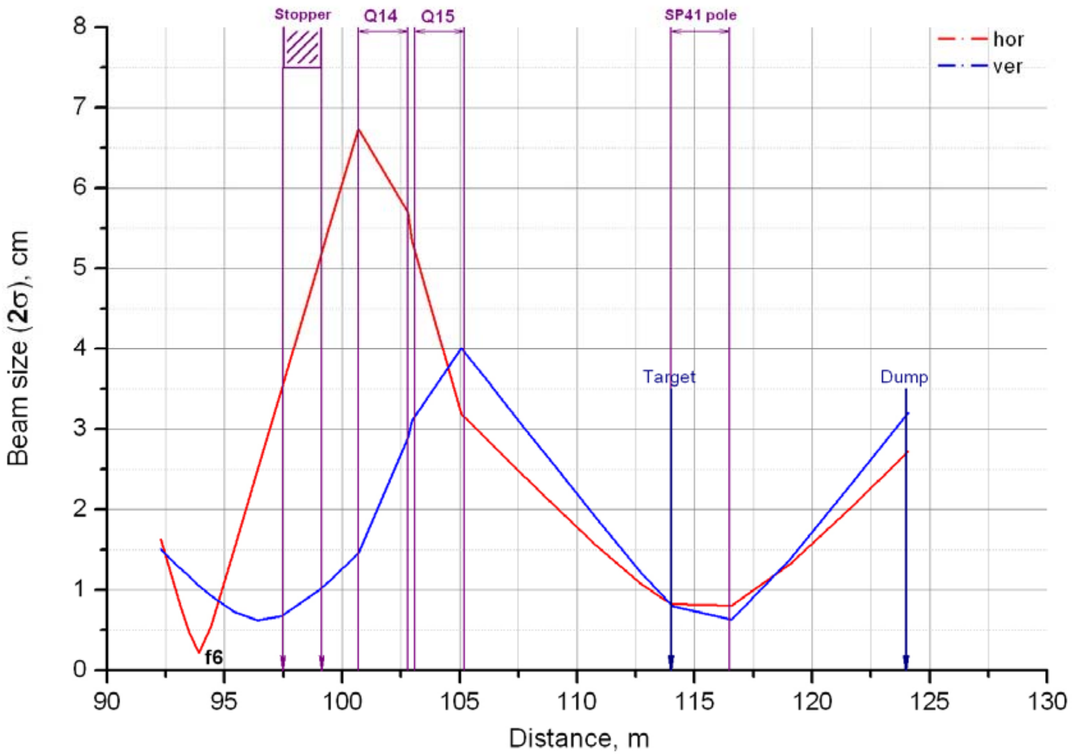
→ need to replace 40 m air intervals / foils with vacuum





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, $^{2}H_2$

Plans for extensive upgrade of BM@N beam line:

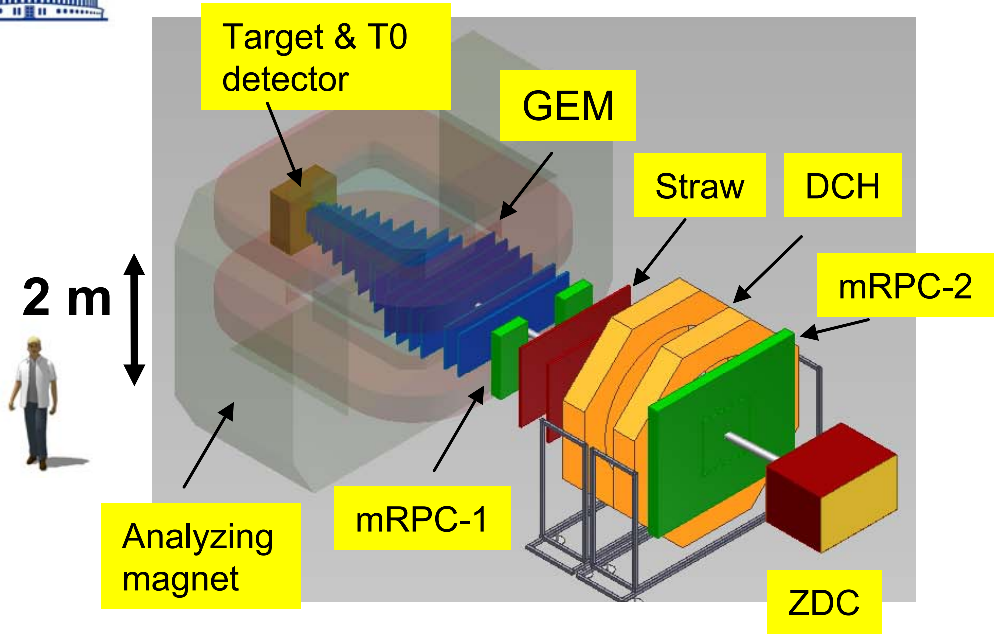
→ new stable power supplies for dipole magnets

→ 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

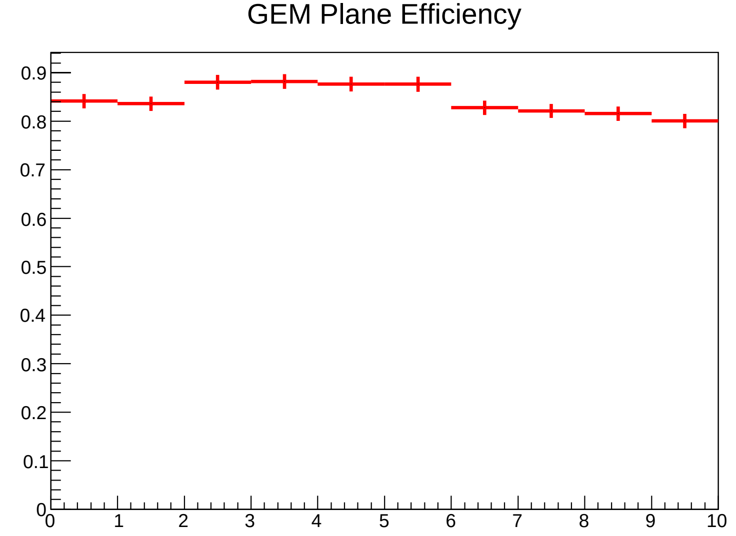
- Central tracker (GEM+Si) inside analyzing magnet to reconstruct AA interactions
- Outer tracker (DCH, Straw / CPC) behind magnet to link central tracks to ToF detectors
- ToF system based on mRPC and T0 detectors to identify hadrons and light nucleus
- ZDC calorimeter to measure centrality of AA collisions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

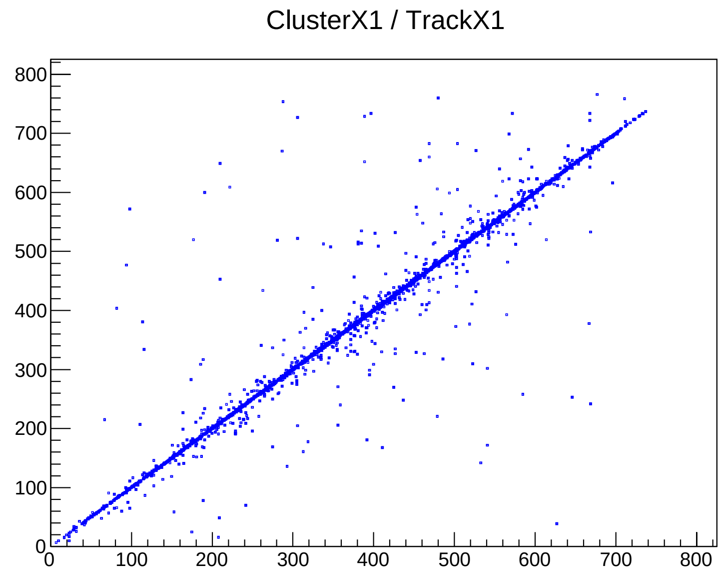
Tests of GEM detectors with cosmic particles

BMN GEM and DAQ groups

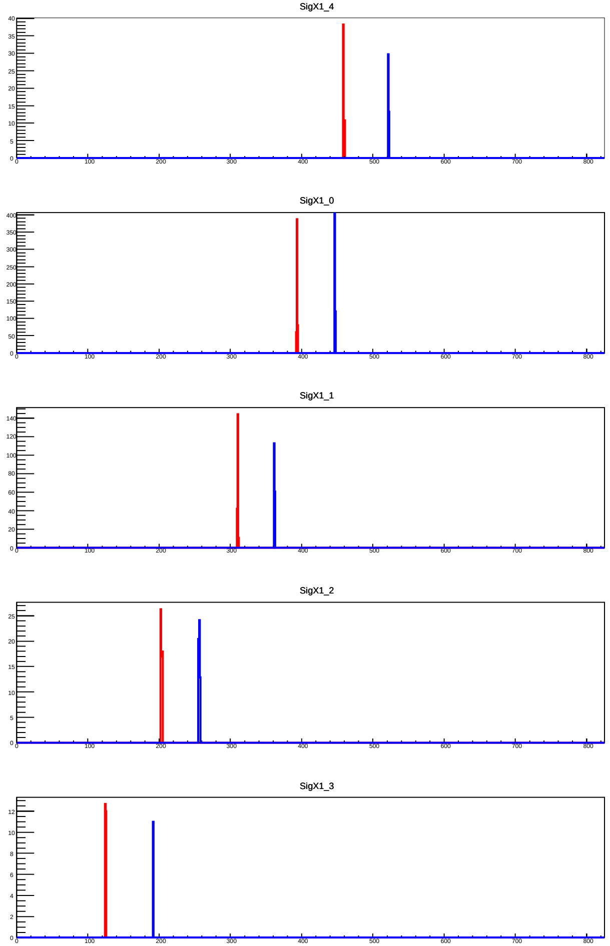
5 GEM detectors 66 x 41 cm^2

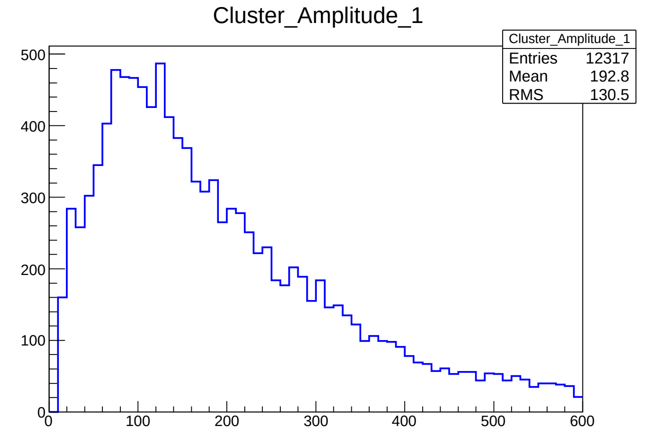
GEM plane Efficiency

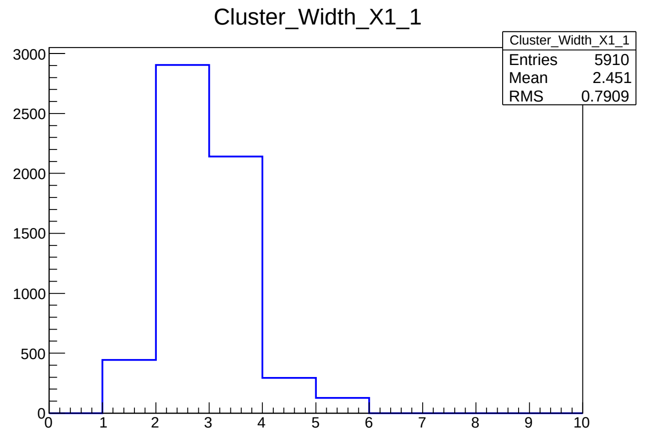




Cosmic event in 5 GEM detectors

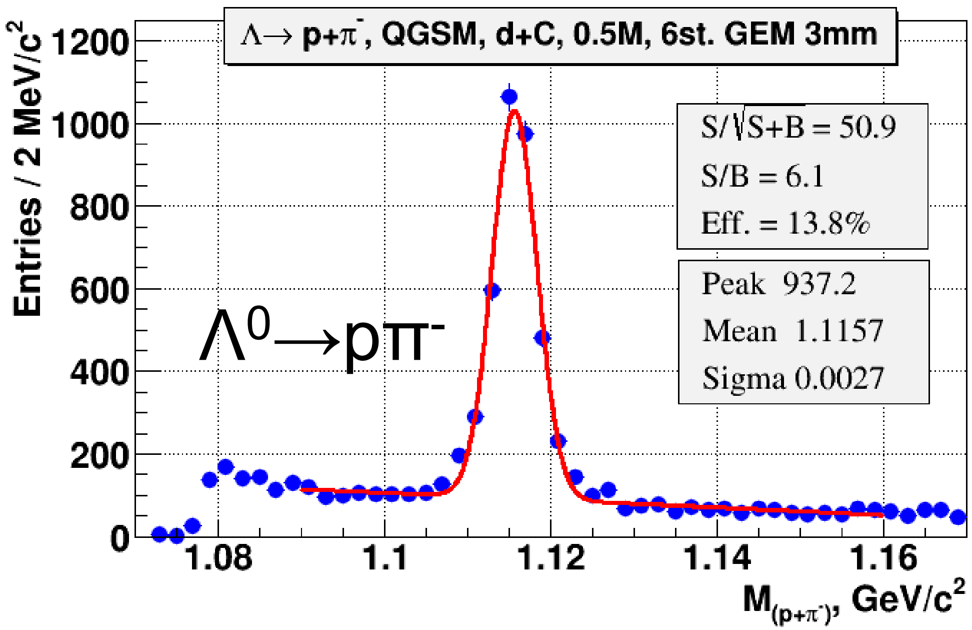


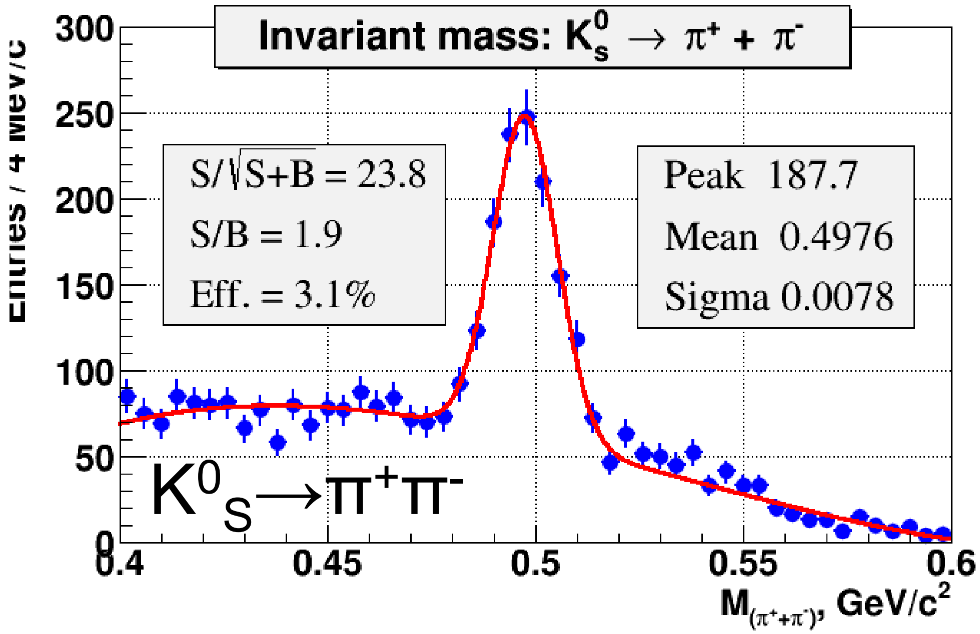




GEM tracker: Λ^0, K^0_S reconstruction

Simulation d+C, 4 AGeV, 500k events





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Configuration with 6 GEM stations for next BM@N runs in 2016