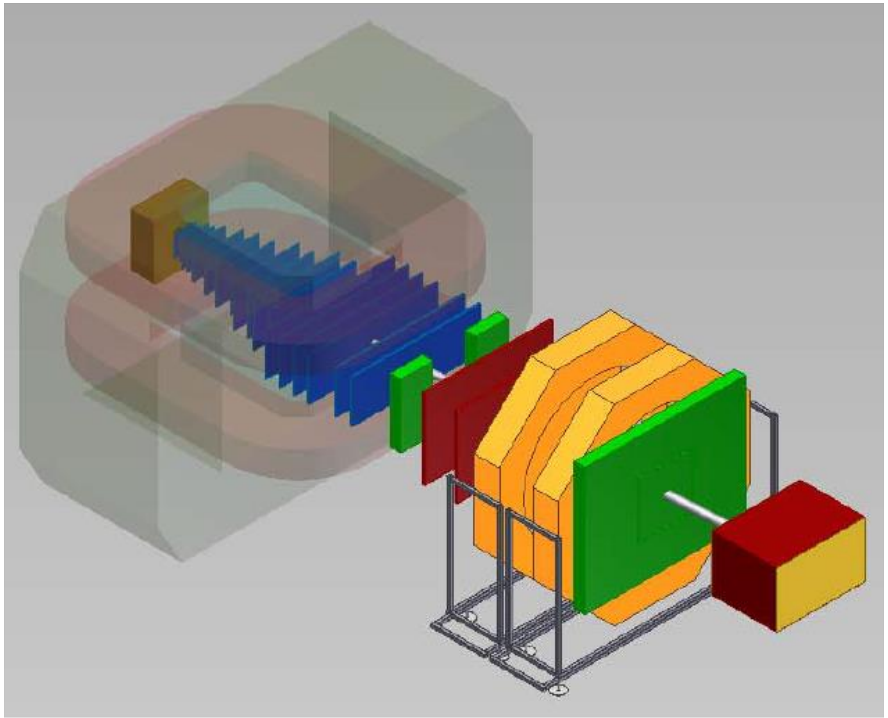
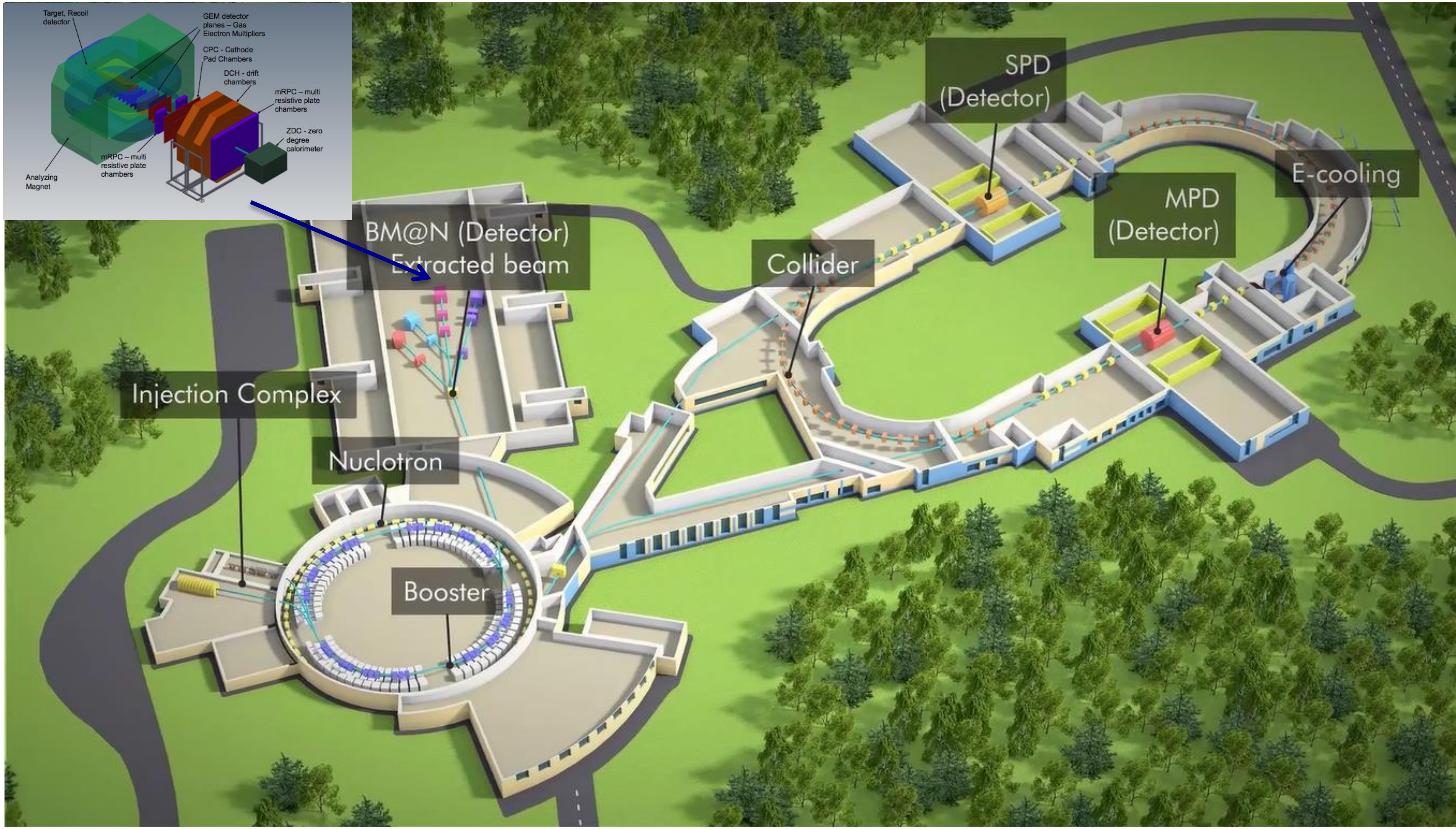
Status of the BM@N project

M.Kapishin



NICA Heavy Ion Complex

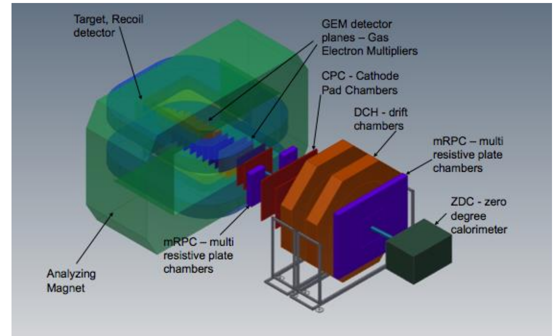
BM@N: heavy ion energy 1- 3.8 GeV/n, beams: p to Au, Intensity ~few 10^6 Hz (Au)



Baryonic Matter at Nuclotron (BM@N) Collaboration:

10 Countries, 19 Institutions, 255 participants

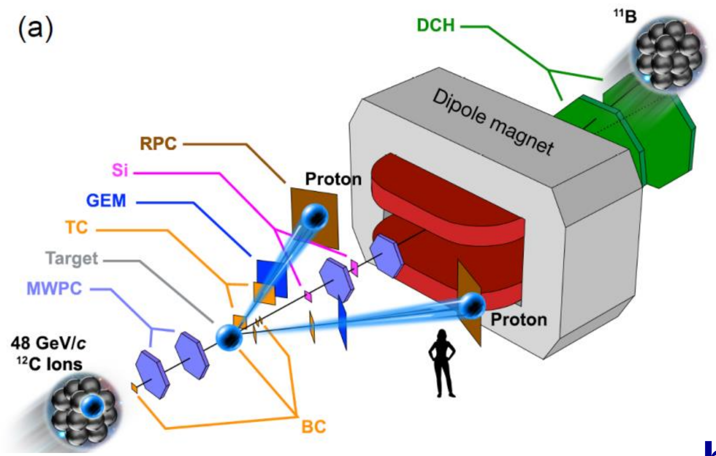
- ***University of Plovdiv, Bulgaria → MoU signed;***
- ***St.Petersburg University;***
- ***Shanghai Institute of Nuclear and Applied Physics, CFS, China;***
- ***Tsinghua University, Beijing, China → leave BM@N;***
- ***Nuclear Physics Institute CAS, Czech Republic→ MoU signed;***
- ***CEA, Saclay, France;***
- ***TU Darmstadt, Germany;***
- ***GSI & FAIR, Germany → joined BM@N;***
- ***Tubingen University, Germany → MoU signed;***
- ***Tel Aviv University, Israel;***
- ***Joint Institute for Nuclear Research;***
- ***Institute of Applied Physics, Chisinev, Moldova → leave BM@N, join JINR group;***
- ***Warsaw University of Technology, Poland;***



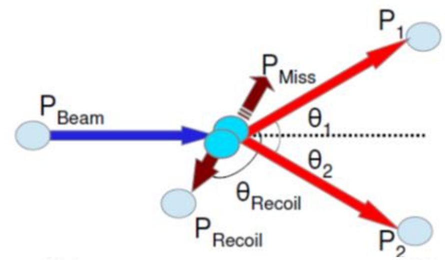
- ***University of Wroclaw, Poland → MoU signed;***
- ***Institute of Nuclear Research RAS, Moscow, Russia → MoU signed;***
- ***NRC Kurchatov Institute, Moscow;***
- ***Institute of Theoretical & Experimental Physics, NRC KI, Moscow, Russia;***
- ***Moscow Engineer and Physics Institute, Russia;***
- ***Skobeltsin Institute of Nuclear Physics, MSU, Russia → MoU signed;***
- ***Moscow Institute of Physics and Technics, Moscow, Russia → MoU signed;***
- ***Massachusetts Institute of Technology, Cambridge, USA.***

- **The 6th Meeting of the BM@N Collaboration took place on October 26-27 in JINR / online.**

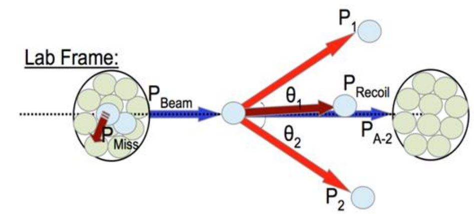
BM@N: study Short Range Nucleon Correlations with hard inverse kinematic reactions



^{12}C Beam Frame

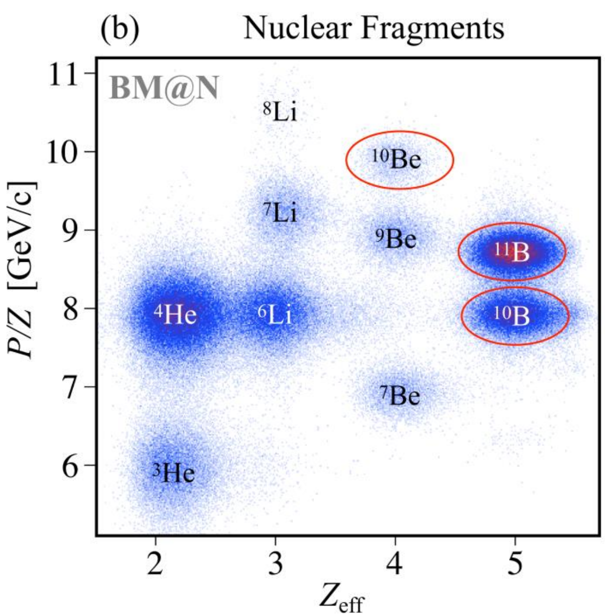


Lab frame



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

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

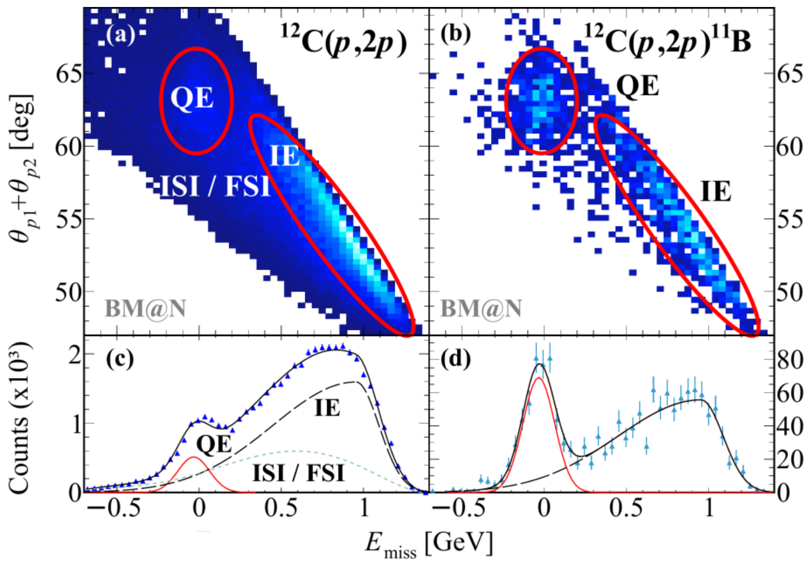


- high momentum ^{12}C beam: 4 GeV/c/nucleon
- (p,2p) ~90°c.m. scattering
- inverse kinematics
- detection of A-1 or A-2 system selects reactions with no multiple scattering

Goals:

→ extract missing-and recoil-momentum distributions for Quasi-Elastic scattering
→ identify SRC signal in inverse kinematics

First BM@N results on SRC and Single Proton Knockout



BM@N SRC paper:

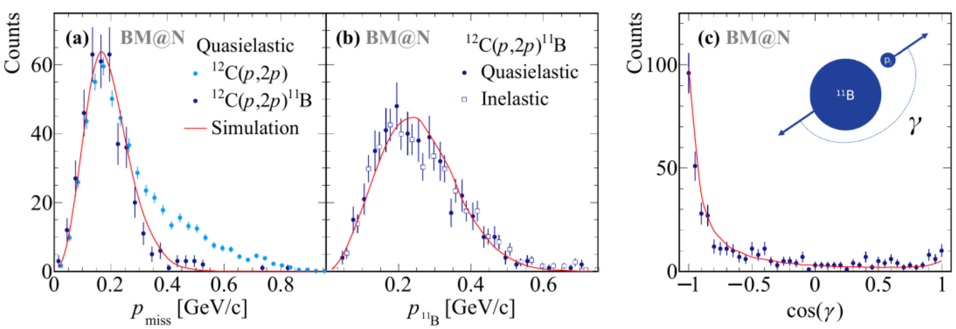
"The Transparent Nucleus: unperturbed inverse kinematics nucleon knockout measurements with a 48 GeV/c carbon beam"

Single Proton Knockout:

►exclusive ^{12}C(p,2p)^{11}B reaction

►Quasi-Elastic scattering (bound ^{11}B)

►tagging A-1 fragment removes ISI / FSI



First observation of Final State Interaction suppression and single-step nucleon knockout selection using fragment detection in quasi-elastic reaction **^{12}C + p → 2p + ^{11}B**

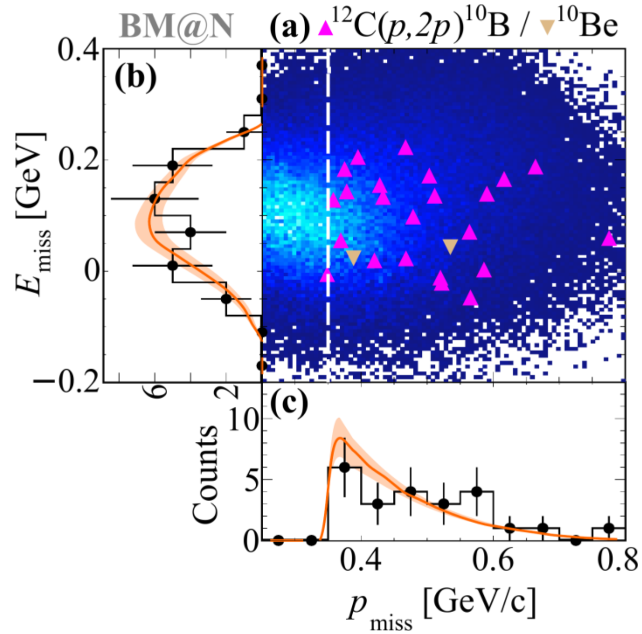
First BM@N result on Short Range Nucleon Correlations

- First observation of SRCs with bound residual A-2 system in reactions:

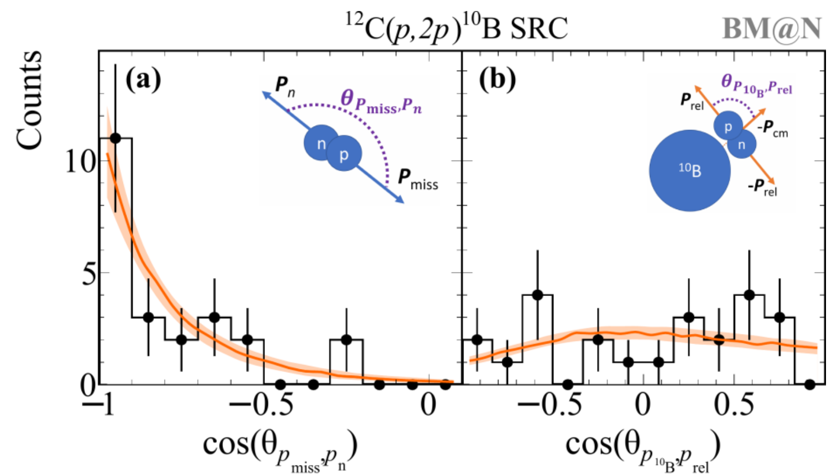
^{12}C + p → 2p + ^{10}B / ^{10}Be + (n / p)

26 ^{10}B events

3 ^{10}Be events → *np* pair dominance

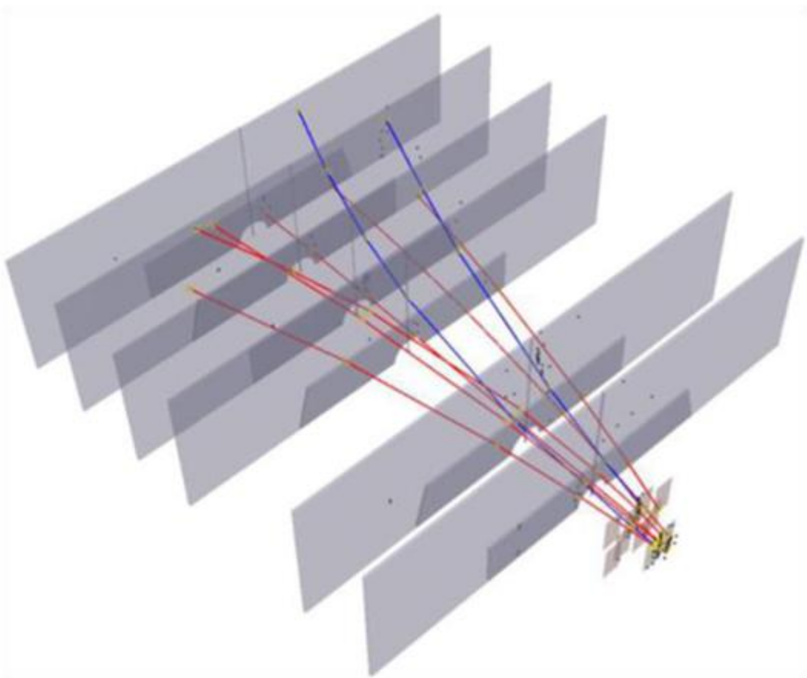


First SRC paper discussed and accepted by BM@N and sent to Nature Physics

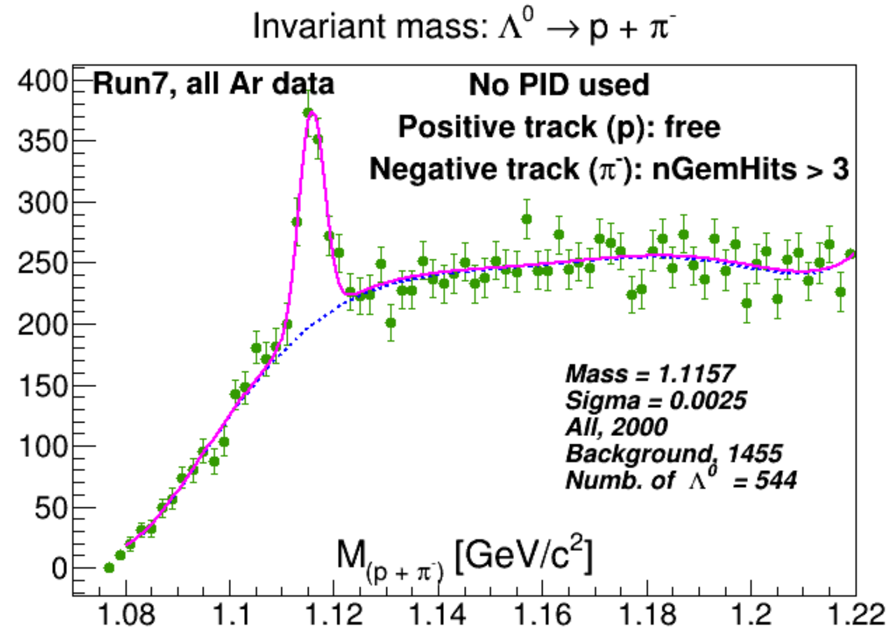


Λ hyperon signals in 3.2A GeV Argon-nucleus interactions

P.Batyuk, S.Merts

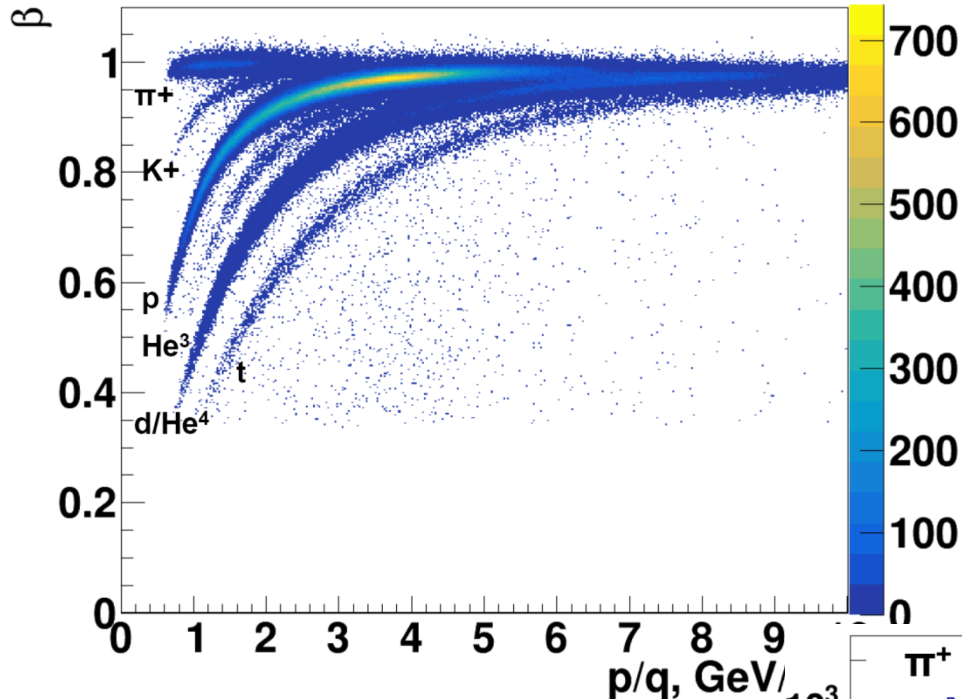


Ar+Cu interaction reconstructed in central tracker



Ar (3.2 AGeV) + Target → Λ + X
Λ signal width 2.5 MeV

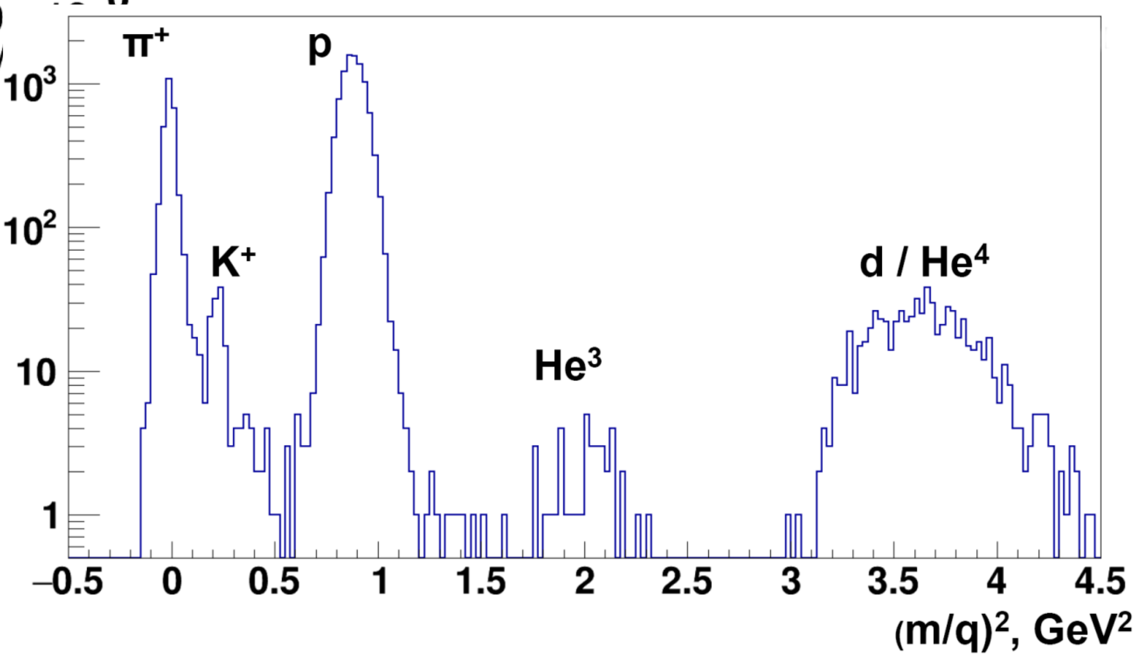
Status of TOF-700 particle identification



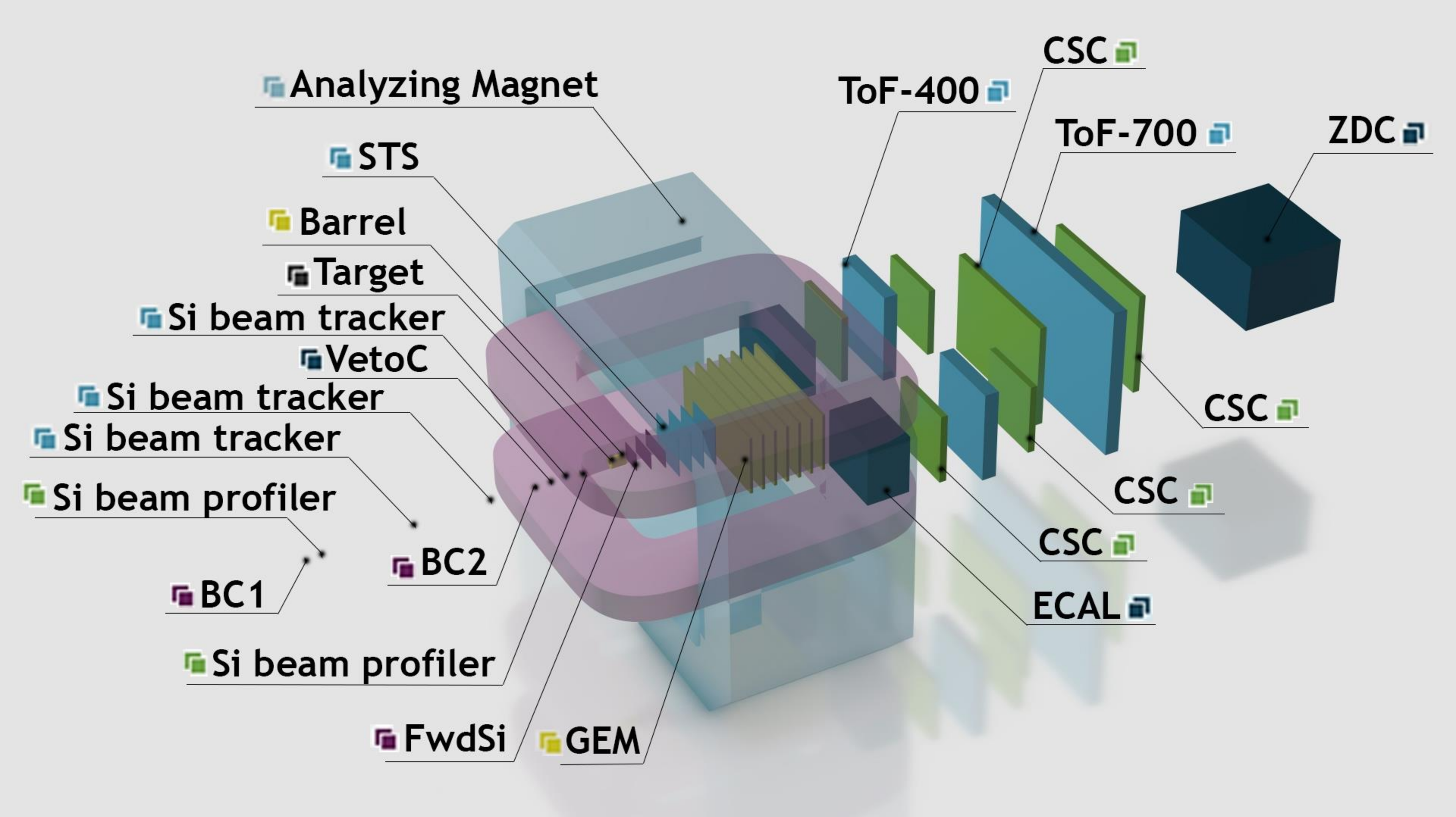
L.Kovachev, Yu.Petukhov

Ar beam , 3.2 AGeV ,
Ar + Al,Cu,Sn → X

Aim:
Yields of π, p, t, He^3, d/He^4 in *argon - nucleus* interactions (combination of ToF-400 and ToF-700)



Configuration of BM@N detector for heavy ion program (without beampipe)



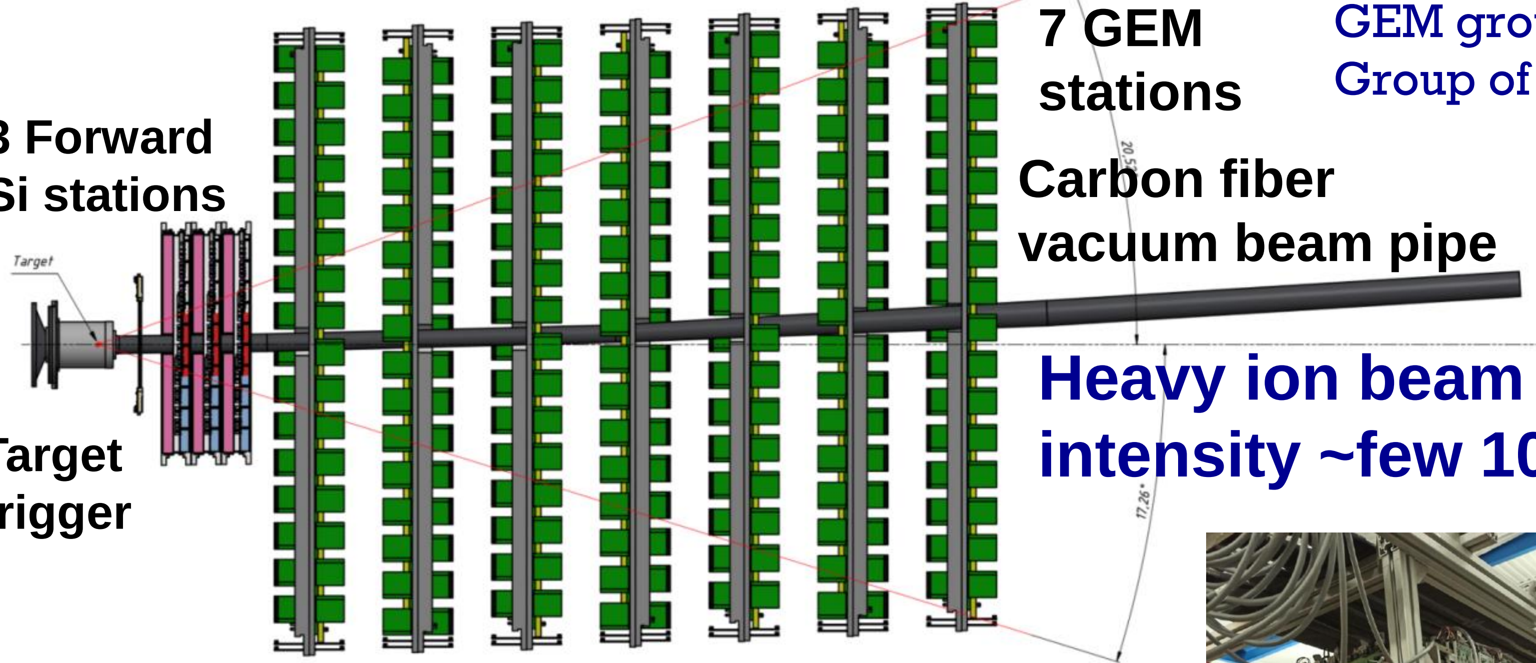
Initial Hybrid Central Tracker for heavy ion runs in 2022: Forward Si + GEM

GEM group
Group of N.Zamiatin

7 GEM stations

3 Forward Si stations

Carbon fiber vacuum beam pipe

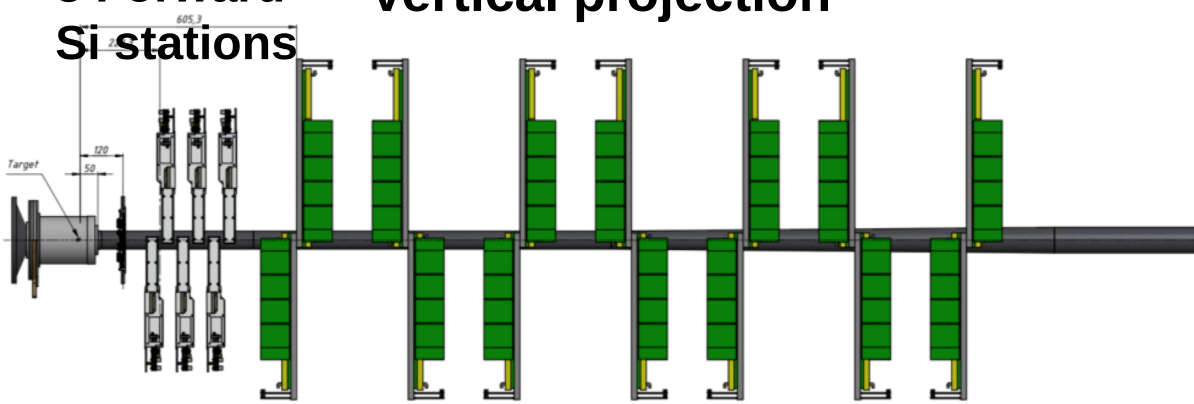


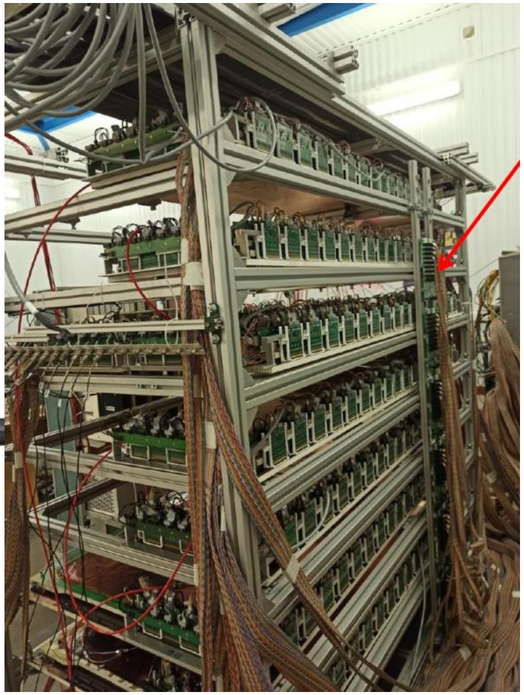
Target trigger

Heavy ion beam intensity ~few 10^5 Hz

3 Forward Si stations

Vertical projection





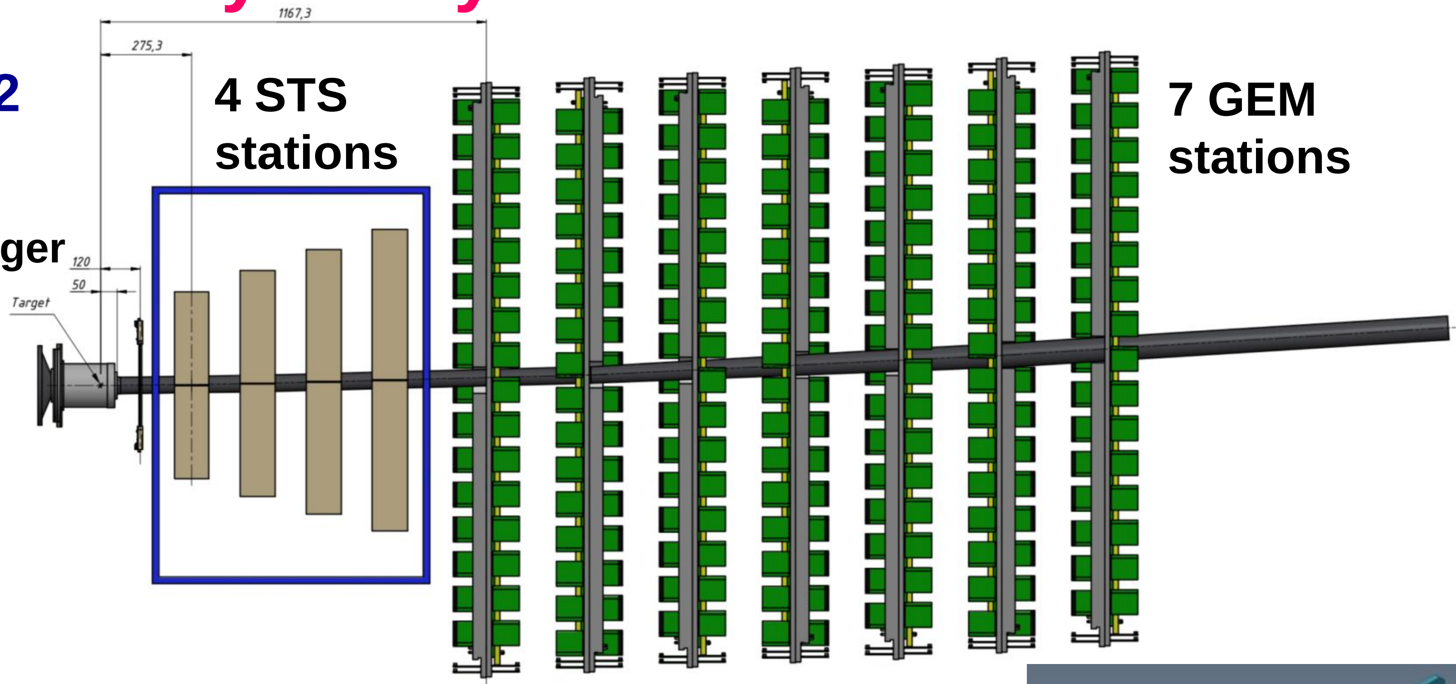
Stage2 Hybrid Central Tracker for high intensity heavy ion runs: STS +GEM

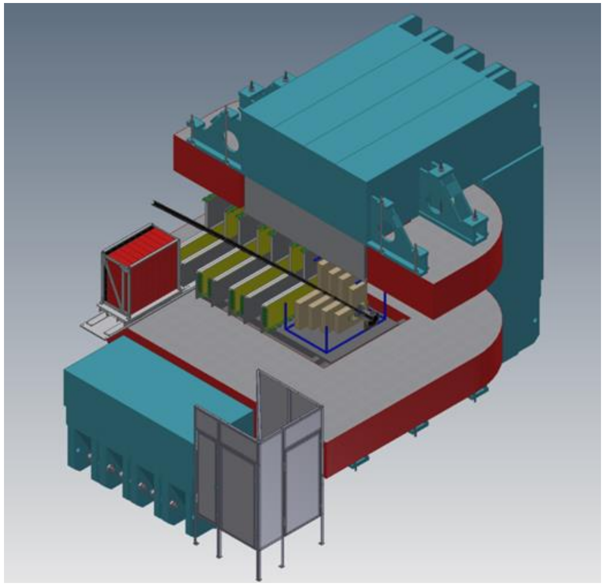
after 2022

Target + trigger detectors

4 STS stations

7 GEM stations

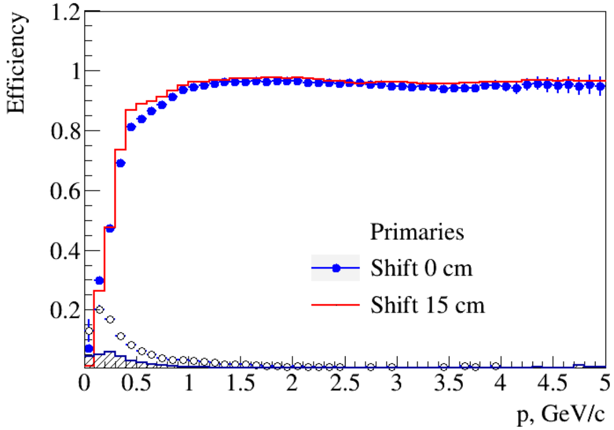


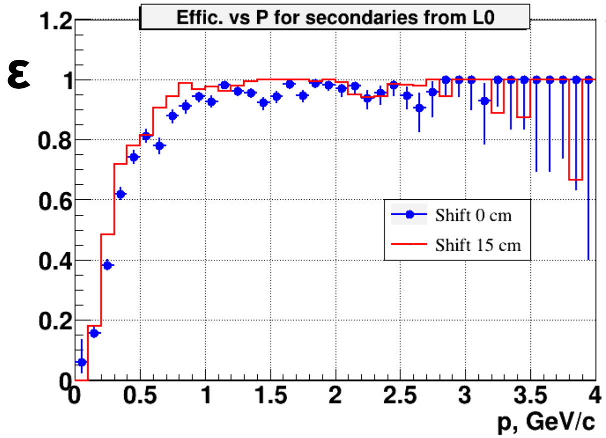


For heavy ion beam intensities of few 10^6 Hz
→ keep 4 STS + 7 GEM
→ fast FEE and readout electronics

Simulation of 1st stage of hybrid central tracker: 3 Forward Si + GEM

A.Zinchenko, V.Vasendina



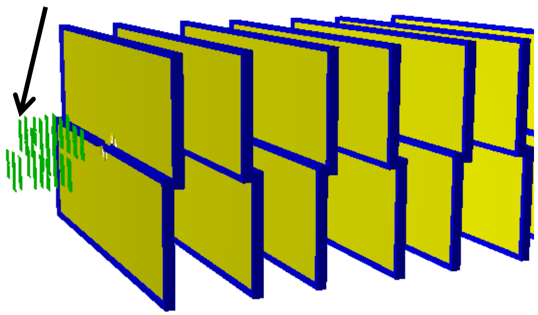


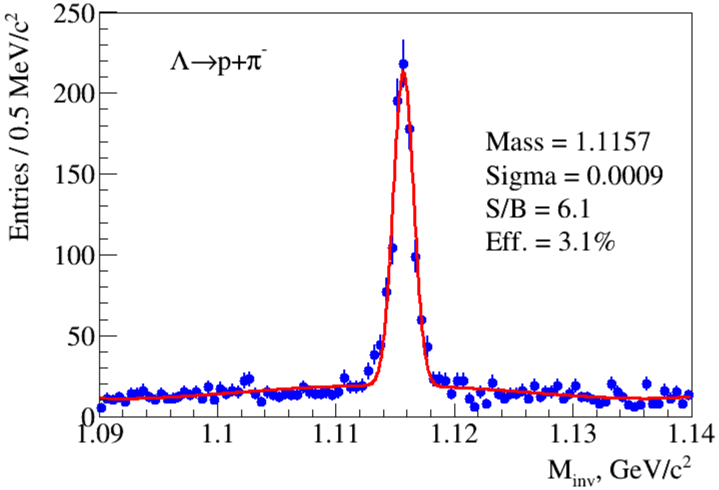
DCM-QGSM model
Kr + Pb , T_0= 2.4 AGeV

Aim:

- **Optimization of detector positions and rotation angle of Forward Si stations**
- **Estimation of track reconstruction efficiency and momentum resolution**

3 Forward Si + 7 GEM

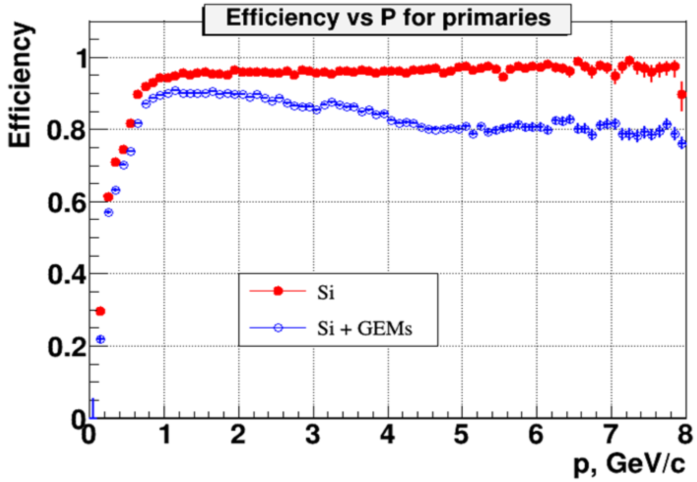


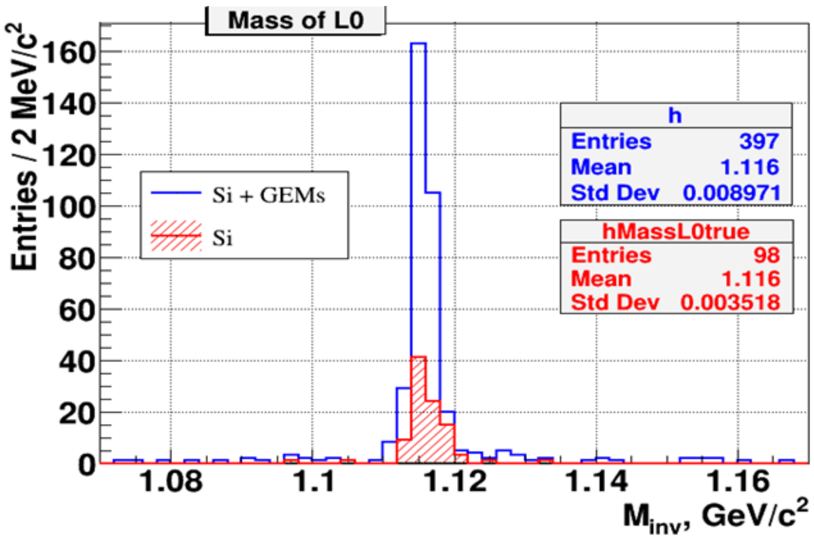


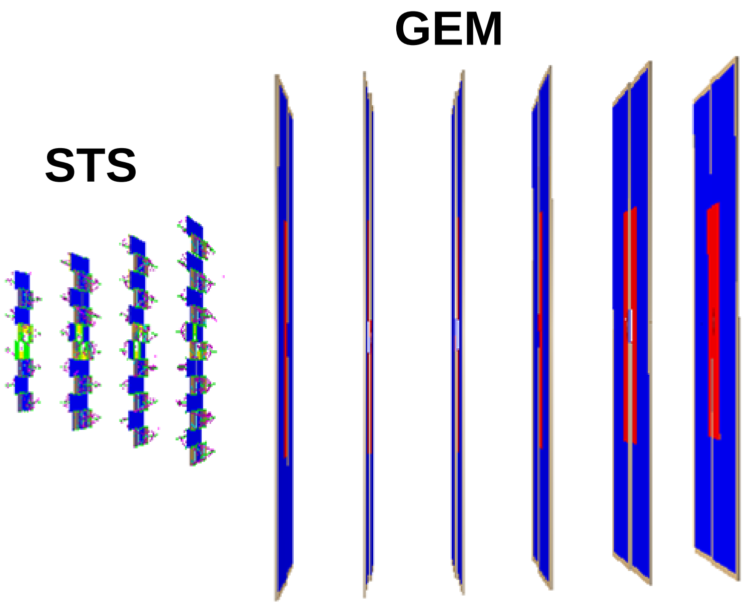
Simulation of hybrid central tracker for heavy ion runs: STS +GEM

A.Zinchenko, V.Vasendina

QGSM model, Au+Au, T_0 = 4 AGeV

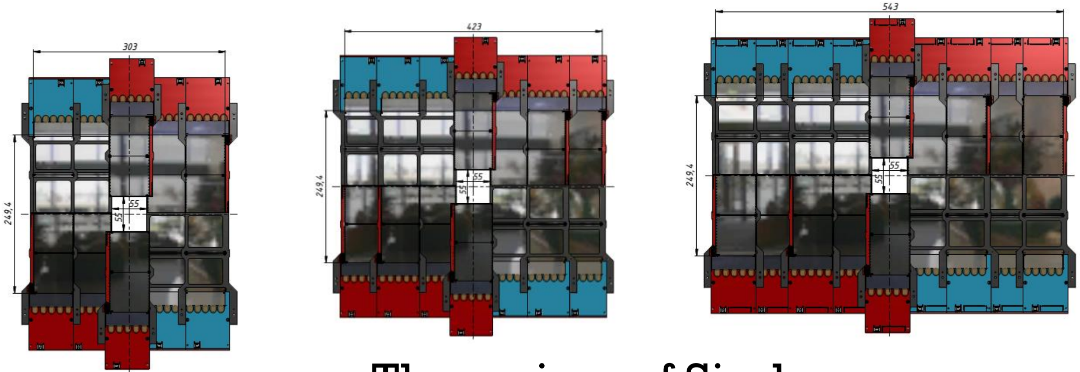






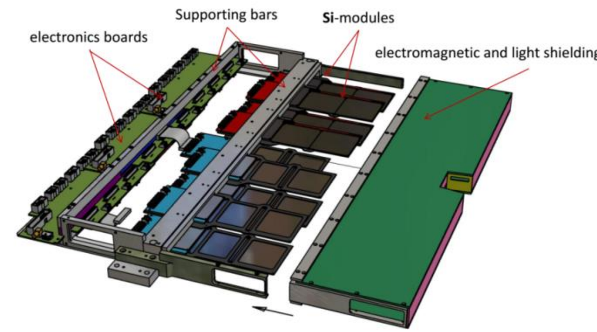
Hybrid STS + GEM tracker:
► 4 times increase in number of reconstructed tracks and Λ hyperons

Forward Si tracking detectors

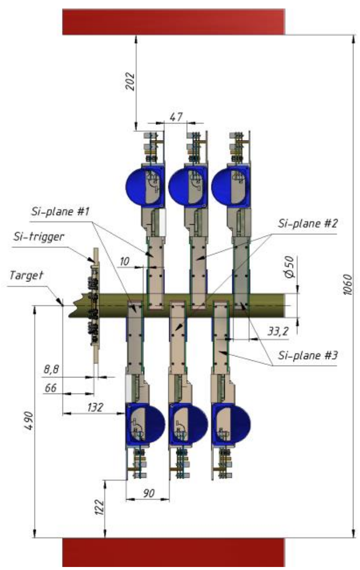


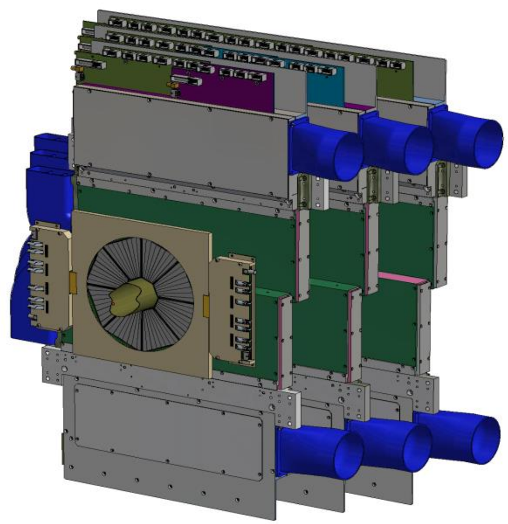
Three sizes of Si-planes

Group of N.Zamiatin



Half-plane design





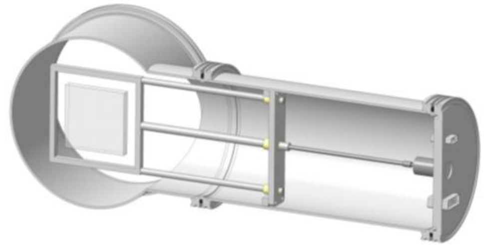
Design of the Si-planes
on the BM@N beam-channel

ASICs VATAGP7.1 (IDEAS, Norway)

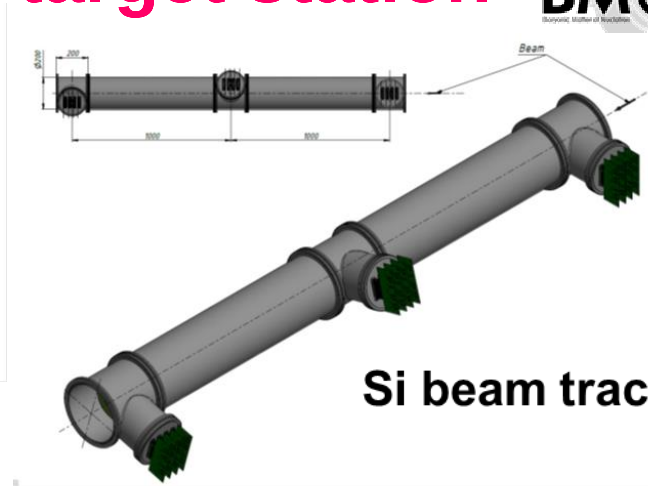
- **Proven technology and FEE readout electronics → used in C, Ar, Kr runs**
- **Development, production, tests and installation according to time schedule → by middle 2021**

Beam, Si tracking detectors and target station

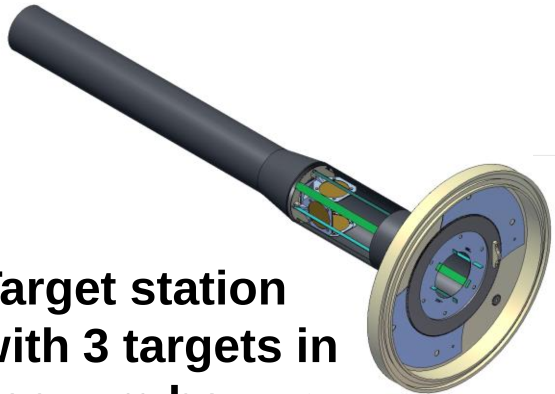
S.Piyadin, Yu.Gusakov
A.Kubankin group (Belgo
Group of N.Zaiamtin



Movable beam profile detector

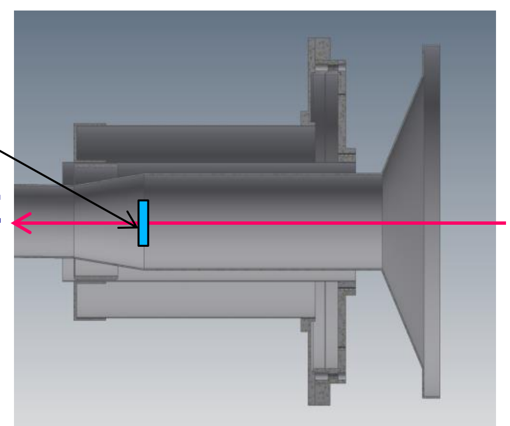


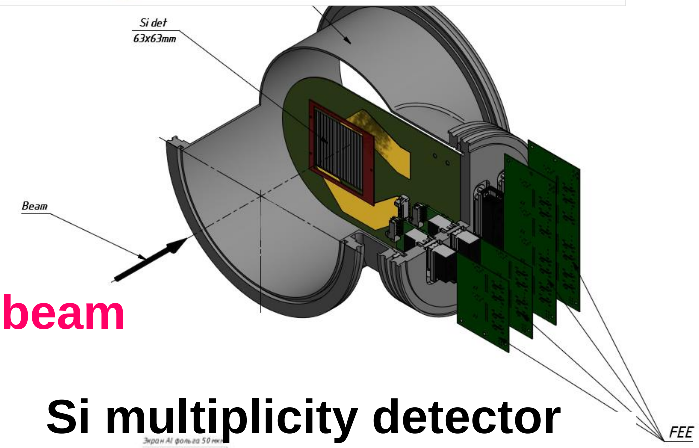
Si beam tracker



Target station with 3 targets in vacuum box

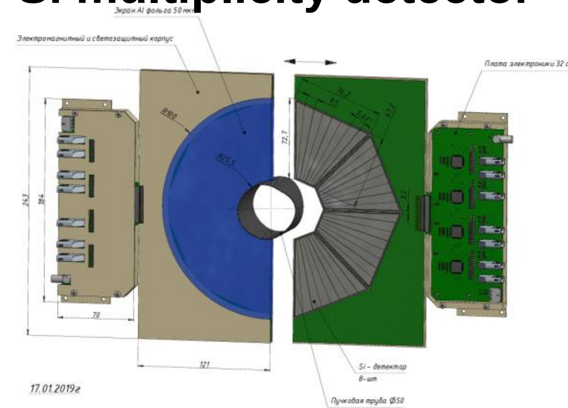
Barrel detector around target





beam

Si multiplicity detector

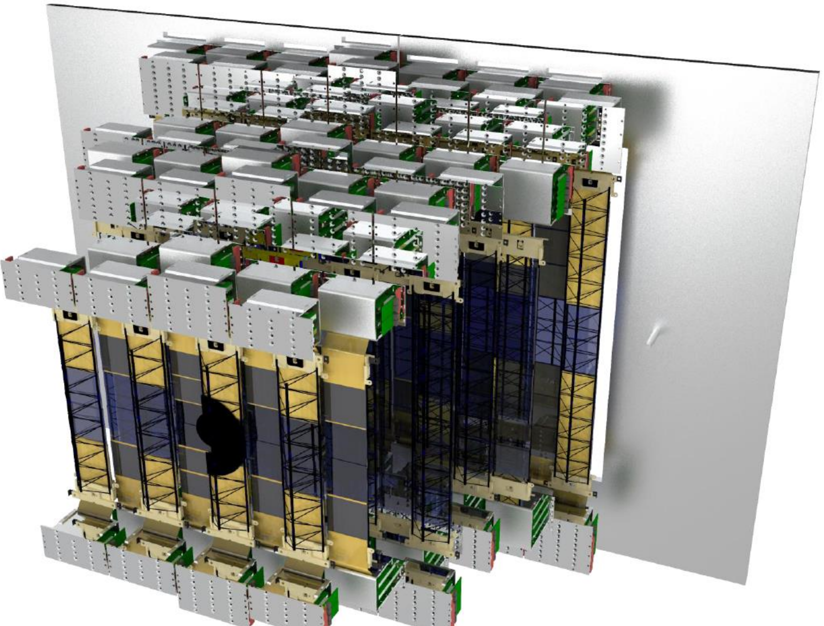


► All detectors and target station to be ready by middle 2021

► Detector performance in heavy ion beam should be tested in first run

Development of STS tracking system

4 STS stations



JINR, MSU, GSI, WUT groups

Current activities:

- **Module & ladder assembly**
  Delay of component delivery from GSI
- **Mainframe development**
- **STS-XYTER ASIC certification**
- **FEB v2.1 development**
- **Readout electronics development**
  GBT x EMU board
  FEB to GBTxEMU connectors

34 ladders
292 modules

Status of BM@N upgrade and possible risks

Forward Si tracking detectors:
►Proven technology and FEE readout electronics → used in C, Ar, Kr runs
►Development, production, tests and installation → middle 2021

Beam, Si tracking detectors and target station:
►All detectors and target station to be ready in middle 2021

GEM tracking detectors:
►All detectors produced at CERN, → tested in C, Ar, Kr runs
►No proven fast FEE for high intensity run

Trigger and T0 detectors:
► Detector performance in heavy ion beam should be tested in first run

Large aperture STS tracker:
►Complicated module, readout cables and ladder assembly → probable delay and long commissioning phase

CSC chambers for Outer tracker:
►4 chambers to be ready by end of 2020
►Risk of delay in production of 2 big CSC chambers

Time of Flight identification system:
►Detectors and readout electronics are in operation since 2018

Carbon fibre beam pipe inside BM@N:
►Vacuum beam pipe should be produced and tested by middle 2021

Beam pipe in front of target:
► Beam pipe elements and detector boxes are delivered to BM@N

New FHCAL hadron calorimeter:
►FHCAL assembled and installed into BM@N setup, need dE/dx hodoscope

Plans for 2021 – 22 experimental runs

Uncertainties for launching of heavy ion physics program:

- **Vacuum transport channel from Nuclotron to BM@N is critical for operation with middle and heavy ion beams**
- **Accelerator team need time to put Booster – Nuclotron system into routine operation**

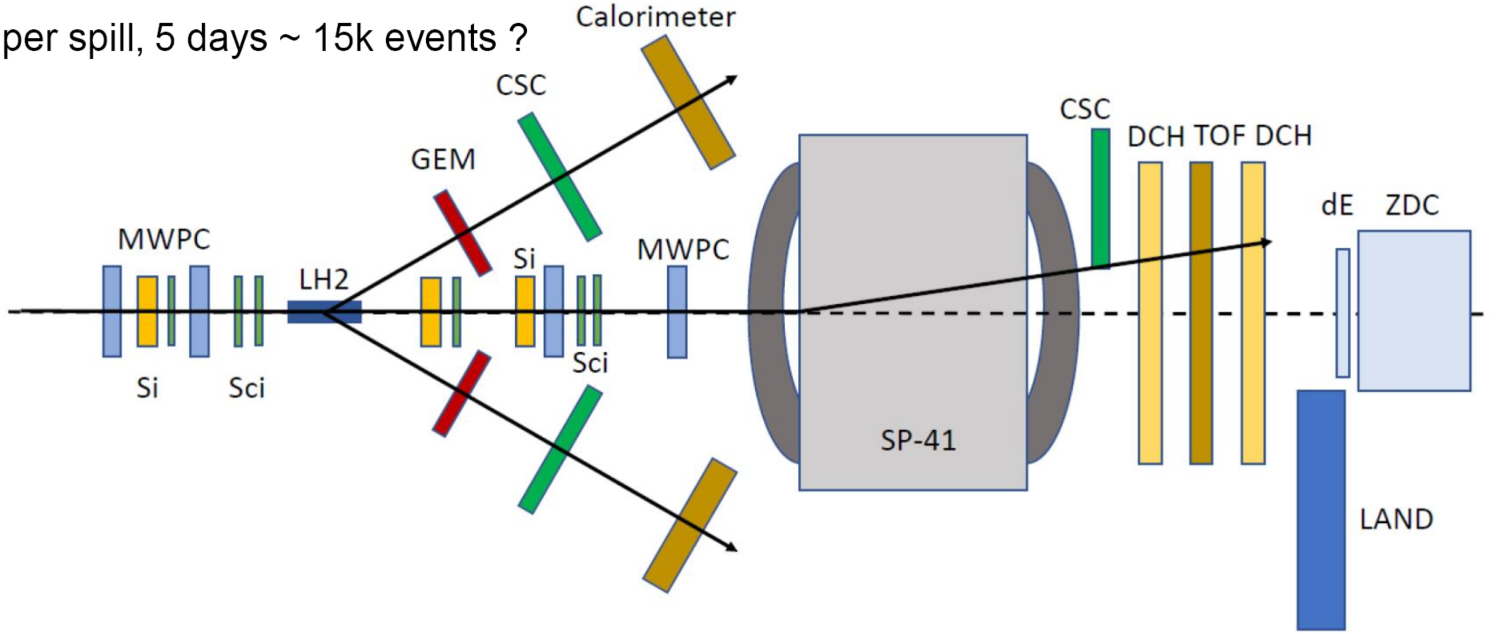
► Plan to start with a new SRC run in November-December 2021 with carbon beam, which could be provided by Booster-Nuclotron or Nuclotron alone
► critical is a new detector to separate protons from pions in the proton arms to improve data quality

We consider BM@N experimental run with a middle weight ion beam (Kr, Xe) in Spring 2022

►need two months to install and align vacuum carbon beam pipe and target, beam track Si, Forward Si, GEM, CSC, FHCAL, trigger detectors
► operate 1st stage of hybrid tracker (3 Fwd Si + 7 GEM)

Preparation for a new SRC run in 2021

- ^{12}C at 3.5 GeV/c/u (+ 2.5 GeV/c/u?)
- beam intensity $5x10^5$ ions/s (based on detector limit)
- beam momentum + profile measurement using 2 T0s
- deuteron beam: 10^6 per spill, 5 days ~ 15k events ?



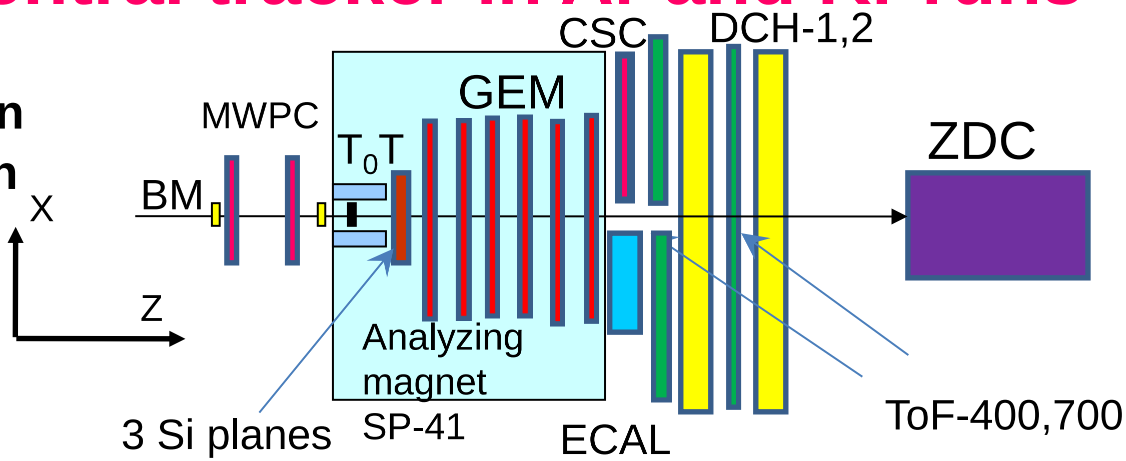
Configuration is based on 2018 run detectors with important improvements:

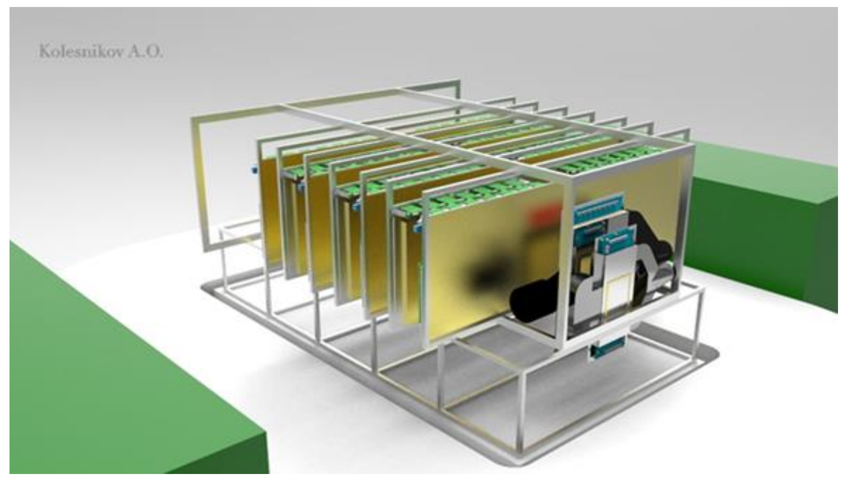
- **New detector (calorimeter) to separate p/pi and provide ToF in 2-arm spectrometer, laser calibration system**
- **2-arm tracking is based on GEM + CSC + Calorimeter**
- **New dE/dx counters for beam and fragment charge measurement: increase efficiency 85% → >95%**
- **New T0 counters: 125 ps → 50 ps**
- **New LH_2 target (4 x 35 cm)**

Thank you
for attention!

BM@N central tracker in Ar and Kr runs

Ar beam, T_0= 3.2 GeV/n
Kr beam, T_0= 2.4 GeV/n

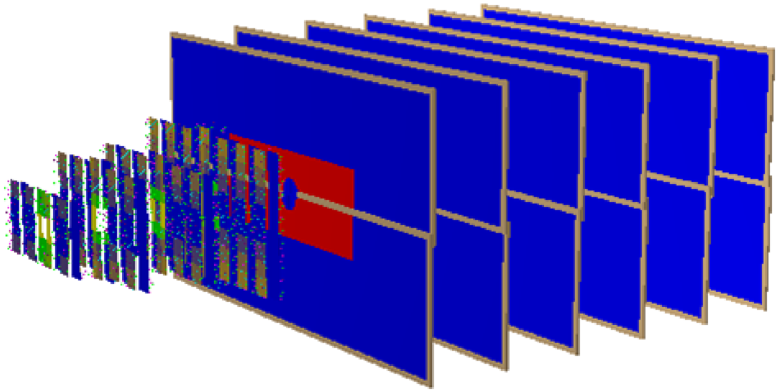




Central tracker: 3 Forward Si detectors and 6 GEM detectors

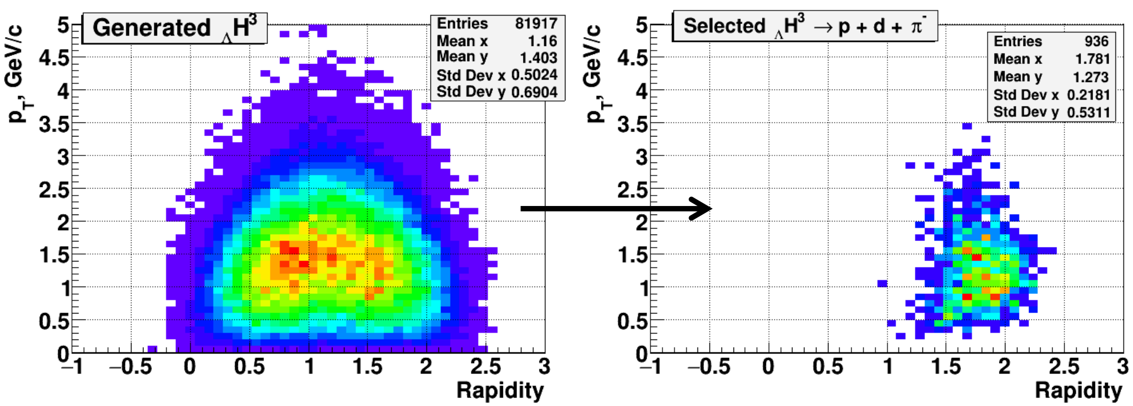
Simulation of hybrid central tracker for heavy ion runs: Ξ^- and $_{\Lambda}H^3$ reconstruction

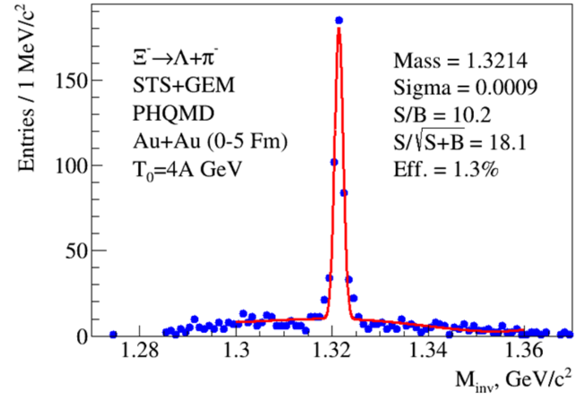
A.Zinchenko, V.Vasendina

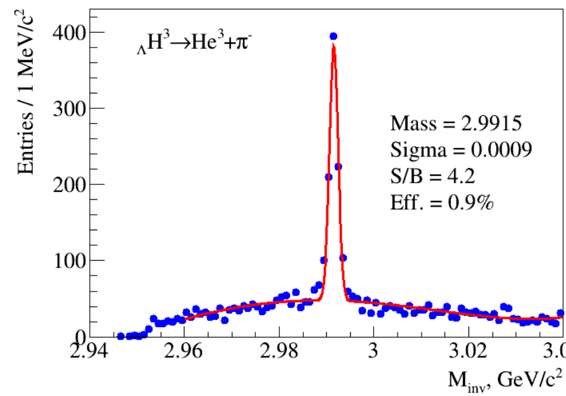


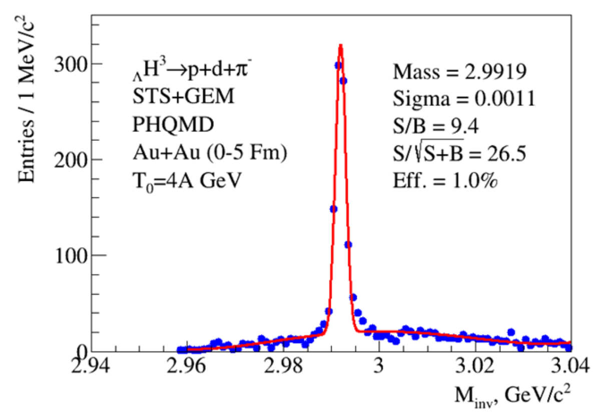
PHQMD model, Au+Au, T_0 = 4A GeV, b = 0-5 fm, 500k events

$_{\Lambda}$H^3 phase space









SRC setup vs BM@N heavy ion setup

► Need improved detector setup, in particular, identification of arm protons

► SRC configuration is not consistent with the BMN setup for heavy ions:

• beam pipe within BM@N magnet, Si, GEM central tracker are obstacles for SRC nuclear fragments

• vacuum beam pipe from quadruple should be dismounted to install H_2 target, beam and fragment detectors

• DCH chambers are used for SRC, but are not suitable for heavy ions

→ need a couple of months between SRC and heavy ion run to reconfigure and align BM@N detectors

►Accelerator team are interested first of all to run Booster + Nuclotron with heavy ions, but BM@N needs vacuum transport channel for heavy ion run

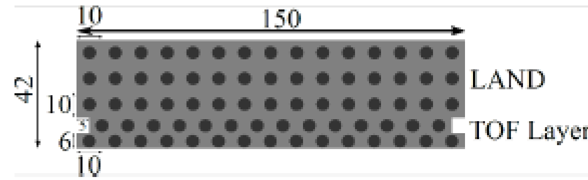
► If there is delay with Booster + Nuclotron operation → run only Nuclotron with laser ion source

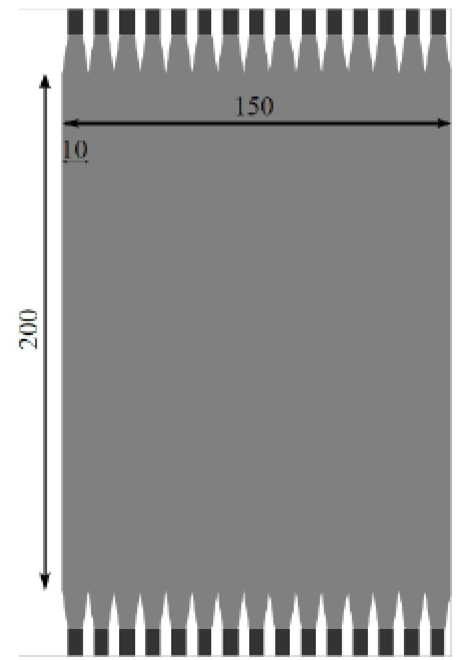
New detector for p/pi separation in SRC run

BM@N

- **Use existing LAND layers and new TOF layers**

Feature	2018	New 2021
p_{miss} resolution	60 MeV/c	35 MeV/c
Efficiency	85%	>95%
Proton-pion separation	Fast pions only by beta	- Segmented dE - Survival probability





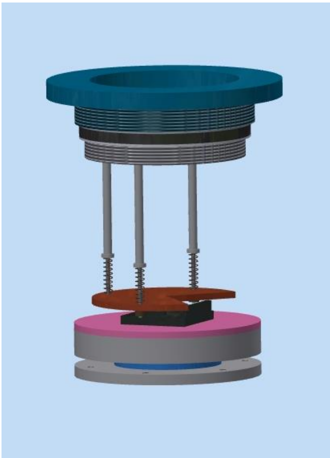
- 2 timing scintillator arrays (15+14 bars):
  - 200cm x 10cm x 6cm BC-408, PMT R13435
  - ToF resolution <80ps:
    improve momentum resolution by factor 2
- 3 layers of dE scintillator
  (15 LAND paddles per layer)
- active area 200cm (Y) x 150cm (X)

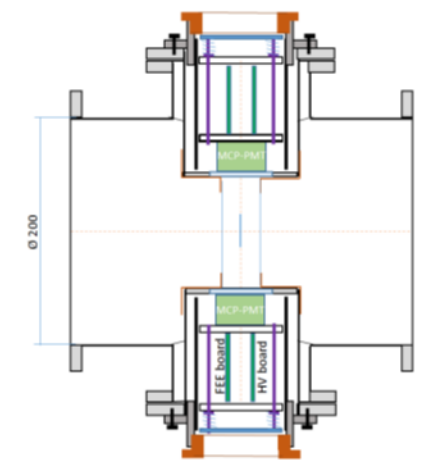
Trigger and T0 detectors for heavy ions

Trigger group

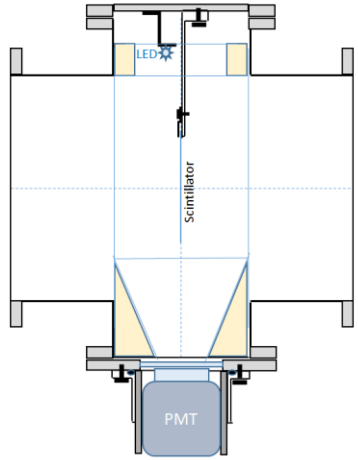
Box for BC2 counter

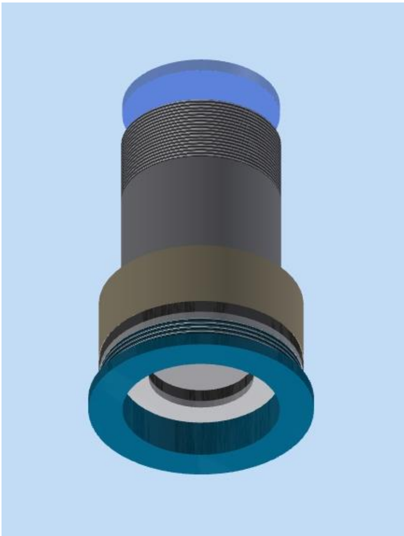
Box for BC1, Veto

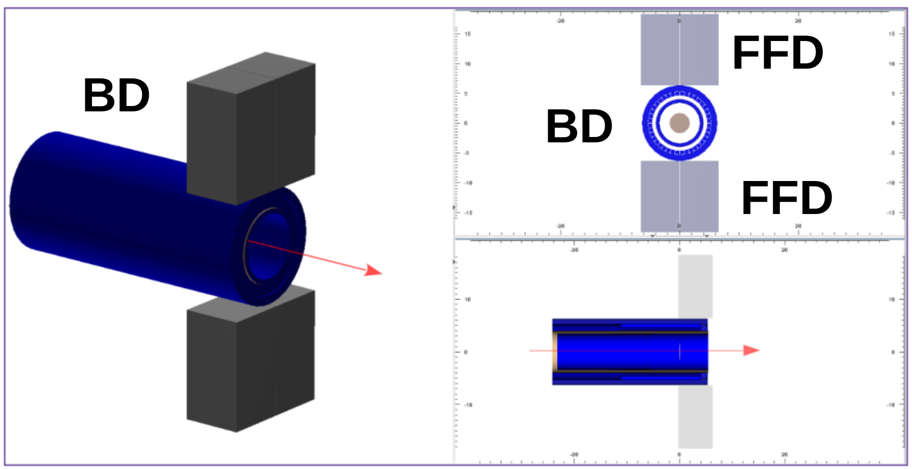




← beam







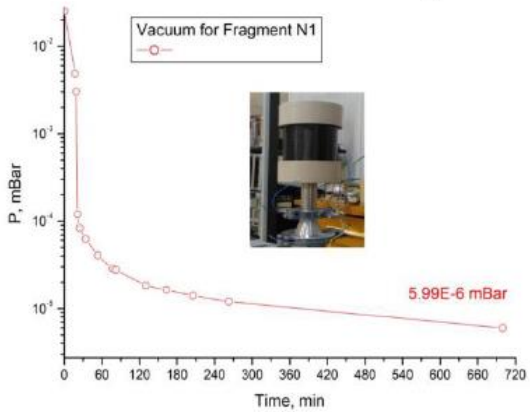
Fast quartz FFD detectors for high intensity heavy ions

- **T0 and beam scintillator film counters for heavy ion beam intensities < 10^6 Hz**
- **FFD T0 detectors and Si beam detectors for higher intensities**
- **Detector performance and efficiency in heavy ion beam should be tested in first run**

Design and tests of the carbon vacuum beam pipe

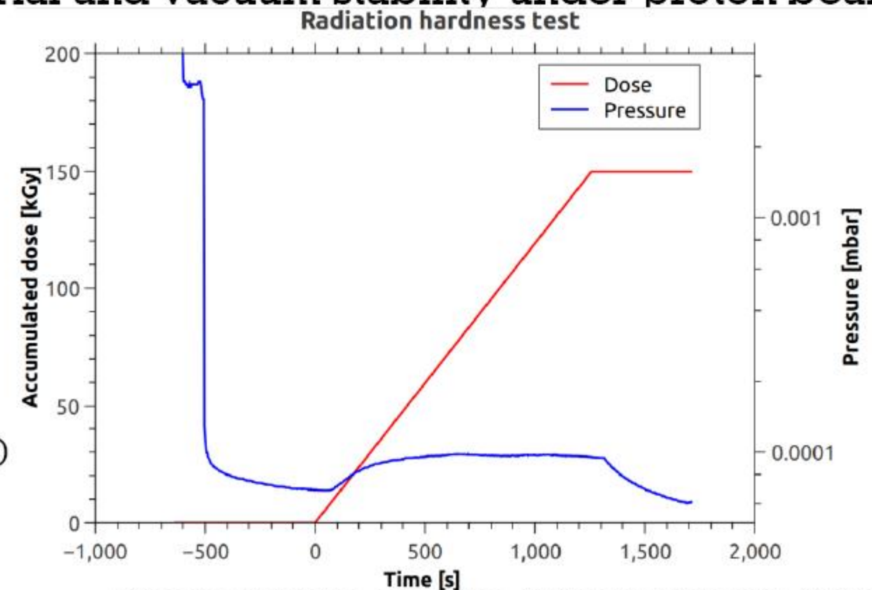
Faculty of Mechanical Engineering of the Czech Technical University
Nuclear physics institute, The Czech Academy of Sciences

Test of vacuum compatibility

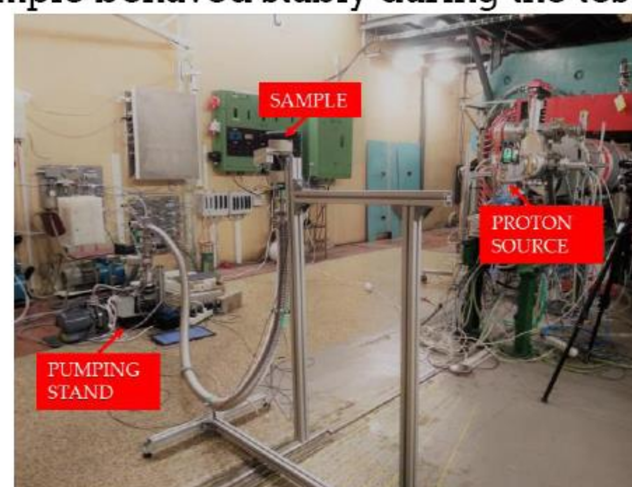


The ultimate pressure 6 x 10^{-6} hPa (scroll pump and turbomolecular pump)

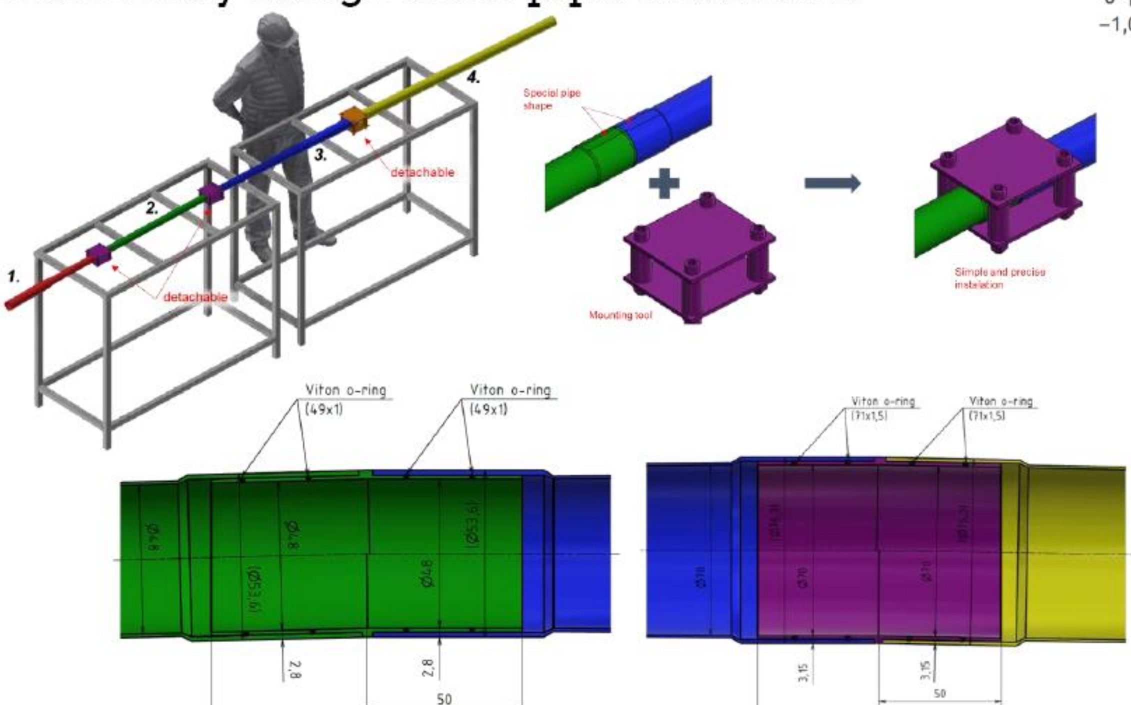
Test of material and vacuum stability under proton bea



The test was performed September 3, 2020
The sample behaved stably during the tes



Preliminary design of the pipe connectors



Carbon fibre beam pipe for heavy ion runs

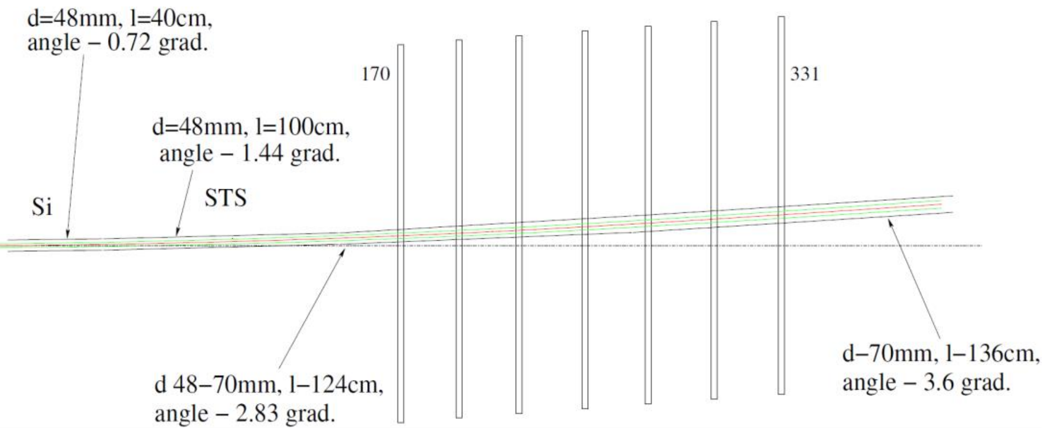
Status and plans:

• Carbon fiber vacuum beam pipe consist of several sections to provide bending of the beam

• Possibility to reassemble sections → use thin removable tube connectors

• Vacuum tests of 1m test sample performed in LHEP JINR

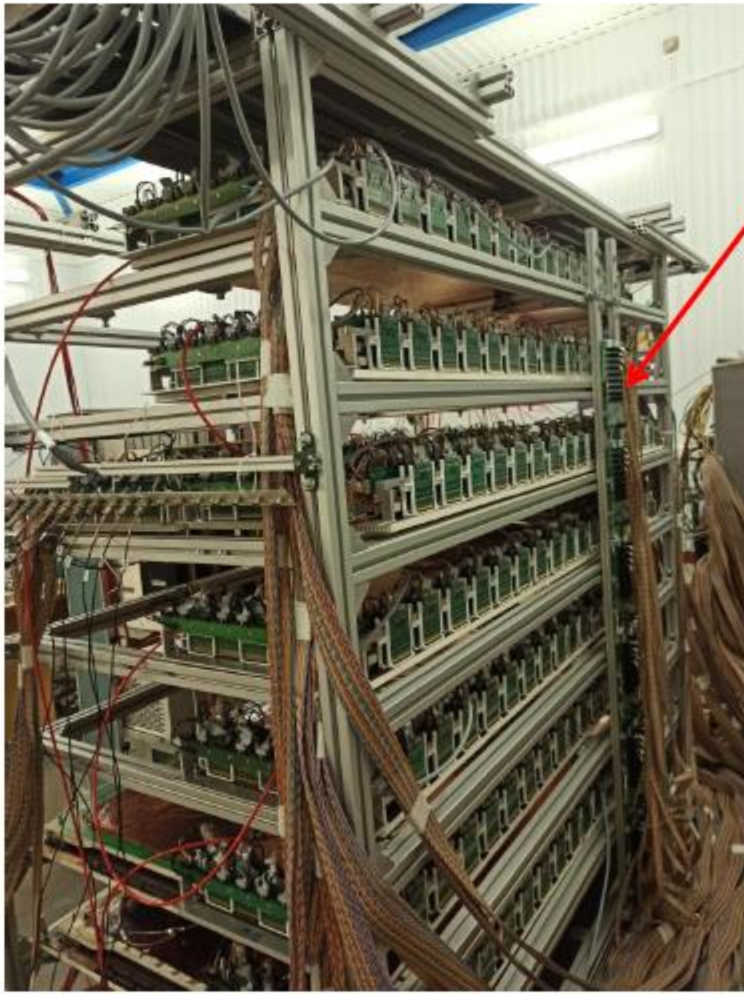
• Irradiation hardness tests performed by NPI CAS Rez group, need irradiation tests of tube connectors



• Vacuum beam pipe should be produced and tested by middle of 2021

GEM central tracking system status

Assembly of the stand for long-term GEM tests



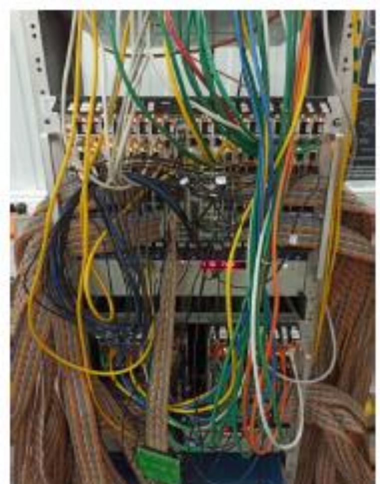
S. Khabarov

First stage – tests of 1632*390 mm^2 detectors
Second stage – tests of 1632*450 mm^2 detectors

A. Kuznecov

Trigger system – ten 10*200 cm^2 scintillation detectors

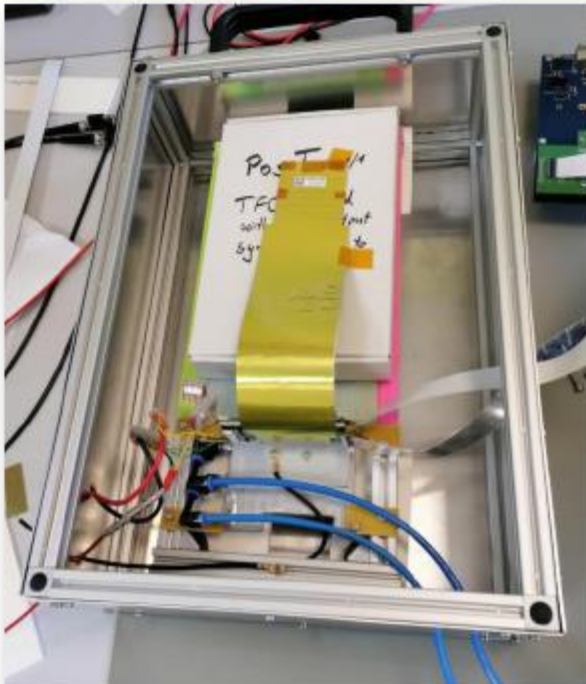
DAQ group

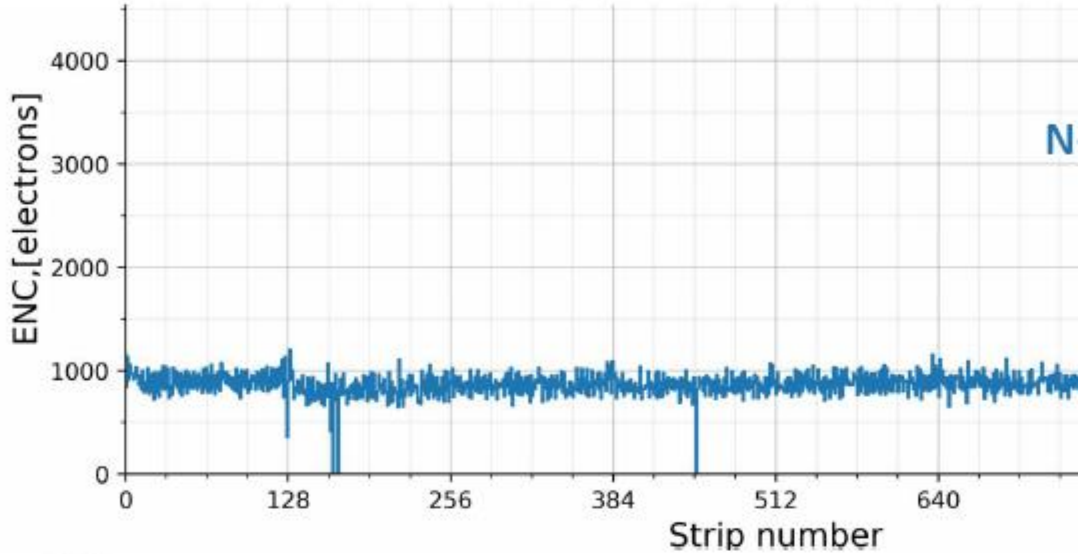


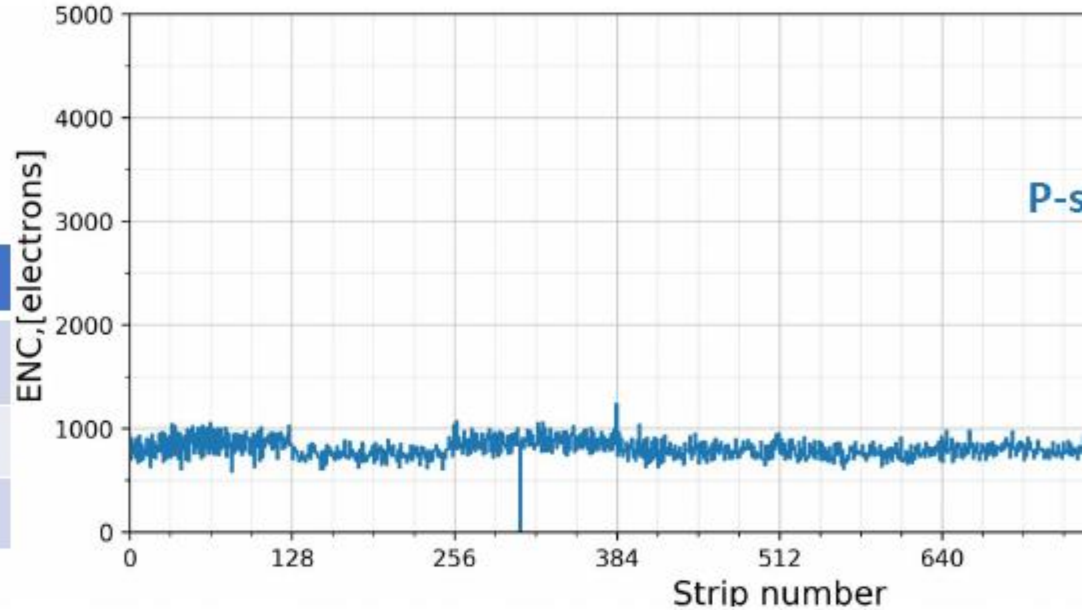
S. Novozhilov

Frames for FEE electronics

Assembled modules







% of not-operable channels per side :

Module	N-side	P-side
M294-6R-212-D001	40 (4%)	23 (2,3%)
M294-2R-212-D003	5 (0.5%)	10 (1%)
M294-2R-212-D004	7 (0.7%)	11 (1.1%)