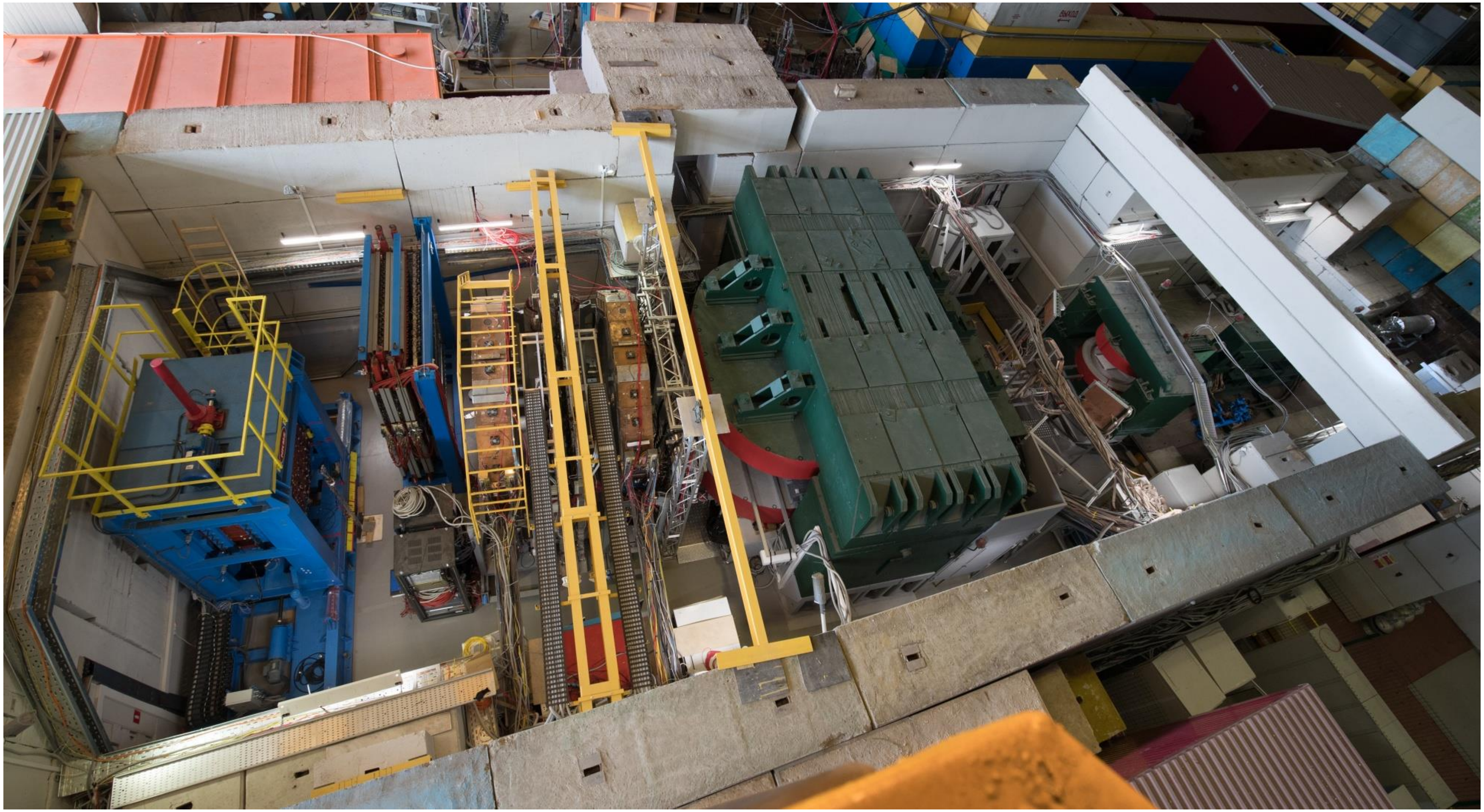
Status and plans of the BM@N experiment

M.Kapishin

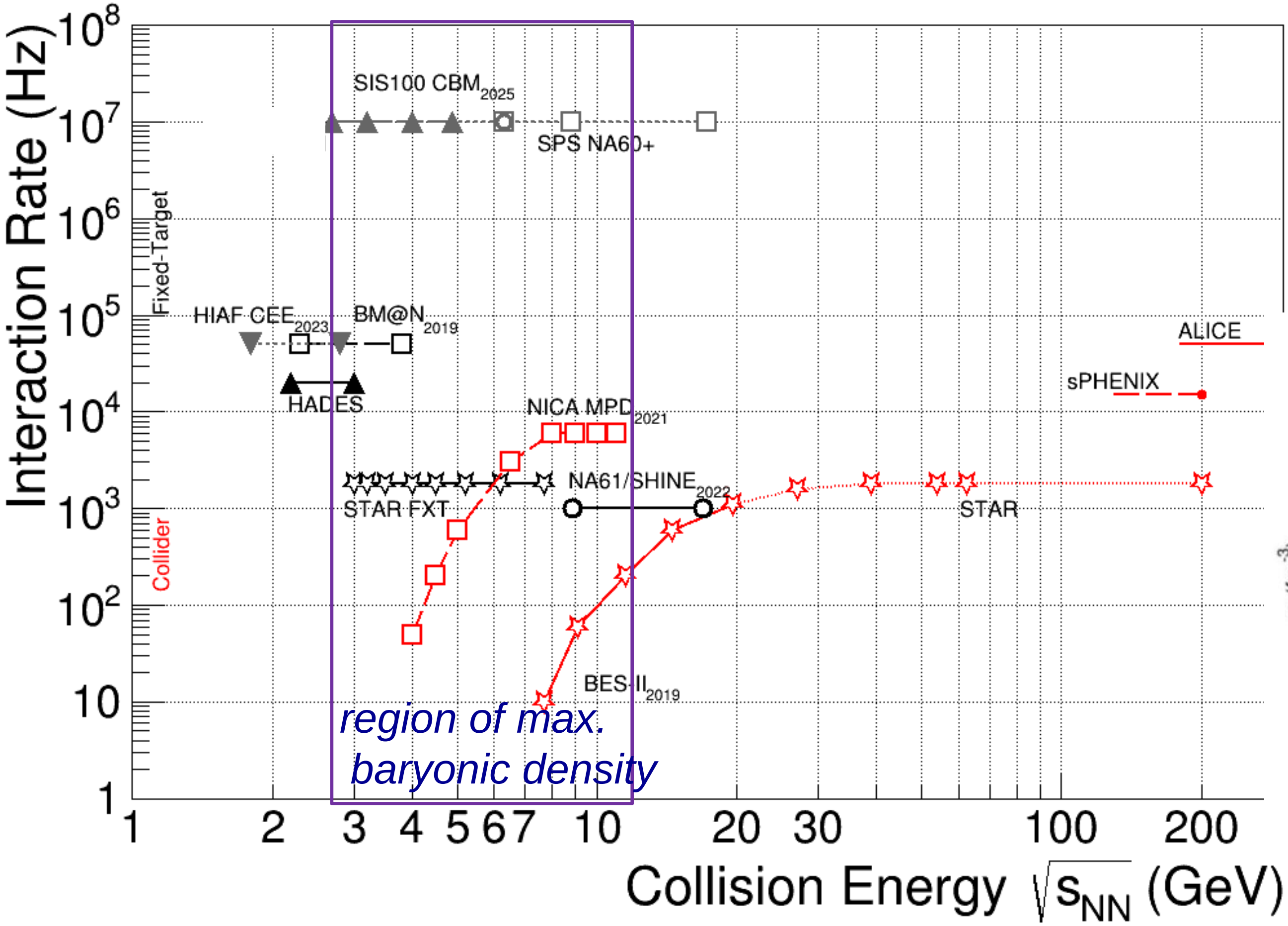


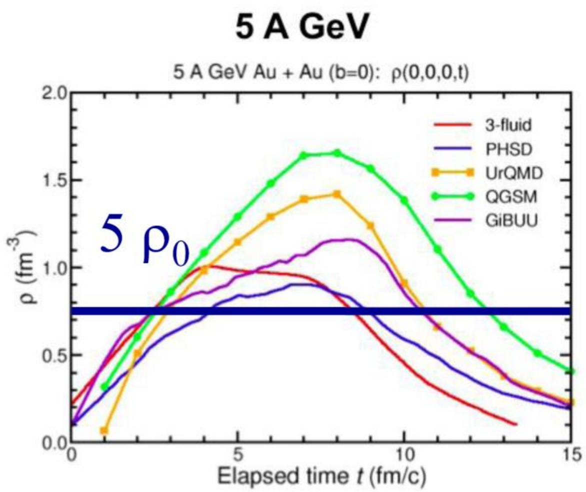
Baryonic Matter at Nuclotron (BM@N) Collaboration:

10 Countries, 20 Institutions, 240 participants

- *University of Plovdiv, Bulgaria → MoU signed;*
- *St.Petersburg University → MoU signed;*
- *Shanghai Institute of Nuclear and Applied Physics, CFS, China;*
- *Nuclear Physics Institute CAS, Czech Republic→ MoU signed;*
- *CEA, Saclay, France;*
- *TU Darmstadt, Germany;*
- *GSI & FAIR, Germany;*
- *Tubingen University, Germany → MoU signed;*
- *Tel Aviv University, Israel;*
- *Joint Institute for Nuclear Research;*
- *Warsaw University of Technology, Poland→ MoU signed;*
- *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 → MoU signed;*
- *Moscow Engineer and Physics Institute, Russia → MoU signed;*
- *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.*

Heavy Ion Collision Experiments





BM@N: $\sqrt{s_{NN}}$= 2.3 - 3.3 GeV
MPD: $\sqrt{s_{NN}}$= 4 - 11 GeV

BM@N competitors:

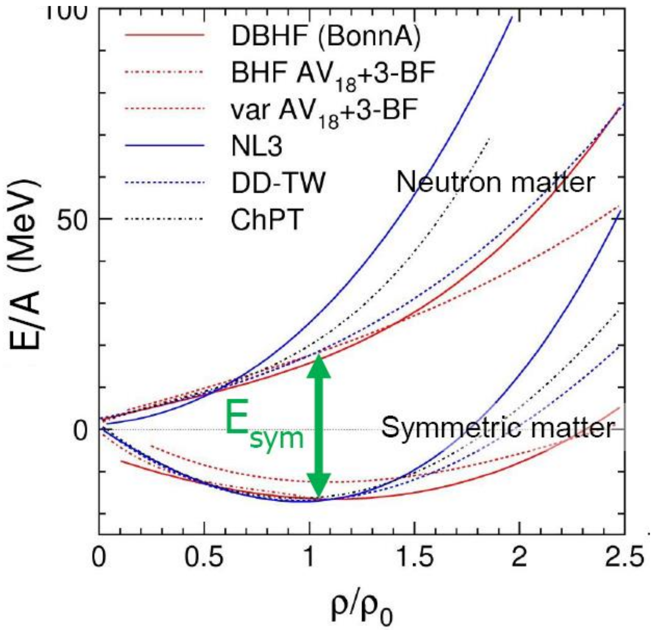
HADES BES (SIS): Au+Au at $\sqrt{s_{NN}}$ = 2.42 GeV, Ag+Ag at $\sqrt{s_{NN}}$ = 2.42 GeV, 2.55 GeV.

STAR BES (RHIC): Au+Au at $\sqrt{s_{NN}}$ = 3-200 GeV

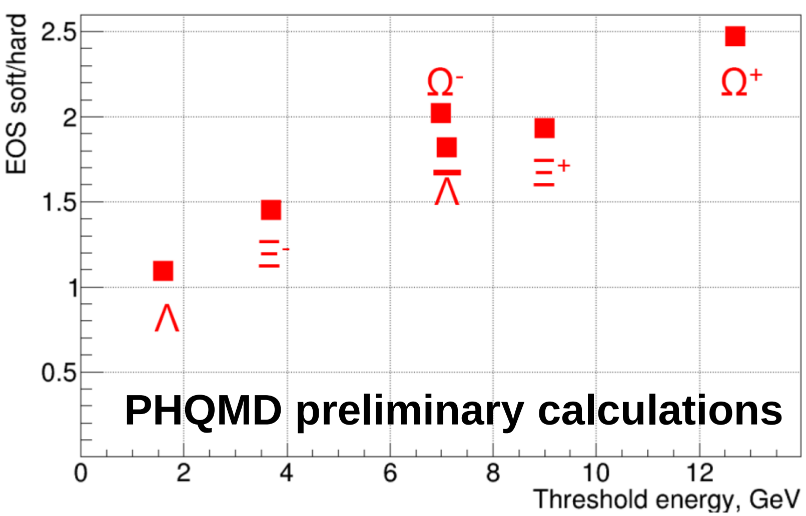
Future CBM experiment: Au+Au at $\sqrt{s_{NN}}$~ 2.7 – 4.9 GeV

EOS of symmetric and asymmetric nuclear matter

Ch. Fuchs and H.H. Wolter, EPJA 30 (2006) 5



Hyperon yield in 4A GeV Au+Au:
soft EOS (K=240 MeV) / hard EOS (K=350) MeV



EOS: relation between density, pressure, temperature, energy and isospin asymmetry

$$E_A(\rho,\delta) = E_A(\rho,0)+E_{sym}(\rho)\cdot\delta^2$$

with $\delta = (\rho_n - \rho_p)/\rho$ $\quad E/A(\rho_o) = -16$ MeV

Curvature defined by nuclear incompressibility: $K = 9\rho^2\ \delta^2(E/A)/\delta\rho^2$

►Study symmetric matter EOS at ρ=3-5 ρ_0
→ elliptic flow of protons, mesons and hyperons
→ sub-threshold production of strange mesons and hyperons
→ extract K from data to model predictions
►Constrain symmetry energy E_{sym}
→ elliptic flow of neutrons vs protons
→ sub-threshold production of particles with opposite isospin

NICA main competitor → STAR experiment: BES Fixed Target program
Collected $2\cdot10^9$ interactions of Au+Au at $\sqrt{s}$ = 3 GeV in 2021

Plan for BM@N Experimental physics run for 800 hours (33 days) in spring 2022

BM@N: Estimated hyperon yields in Xe + Cs collisions

4 A GeV Xe+Cs collisions, multiplicities from PHSD model,
Beam intensity $2.5\cdot10^5$/s, DAQ rate $2.5\cdot10^3$/s, accelerator duty factor 0.25

$1.8\cdot10^9$ interactions
$1.8\cdot10^{11}$ beam ions

Particle	E_{thr}NN GeV	M b<10 fm	ε %	Yield/s b<10fm	Yield / 800 hours b<10 fm
Λ	1.6	1.5	3	220	$0.8\cdot10^8$
Ξ^-	3.7	$2.3\cdot10^{-2}$	1	1.1	$4\cdot10^5$
Ω^-	6.9	$2.6\cdot10^{-5}$	1	$1.3\cdot10^{-3}$	470
Anti-Λ	7.1	$1.5\cdot10^{-5}$	3	$2.2\cdot10^{-3}$	800

Plan for BM@N experimental physics run with Au (Bi) beam for 800 hours (33 days) in spring 2023

BM@N: Estimated hyperon yields in Au+Au collisions

4 A GeV min. bias Au+Au collisions, multiplicities from statistical model,
Beam intensity $2.5 \cdot 10^5$/s , DAQ rate $2.5 \cdot 10^3$/s, accelerator duty factor 0.25

Experimental run for 800 hours (33 days)

$1.8 \cdot 10^9$ interactions
$1.8 \cdot 10^{11}$ beam ions

Particle	E_{thr}NN GeV	M central	M m.bias	ε %	Yield/s m. Bias	Yield / 800 hours m. Bias
Ξ^-	3.7	$1 \cdot 10^{-1}$	$2.5 \cdot 10^{-2}$	1	2.5	$4.5 \cdot 10^5$
Ω^-	6.9	$2 \cdot 10^{-3}$	$5 \cdot 10^{-4}$	1	$5 \cdot 10^{-2}$	$0.9 \cdot 10^4$
Anti-Λ	7.1	$2 \cdot 10^{-4}$	$5 \cdot 10^{-5}$	3	$1.5 \cdot 10^{-2}$	2700
Ξ^+	9.0	$6 \cdot 10^{-5}$	$1.5 \cdot 10^{-5}$	1	$1.5 \cdot 10^{-3}$	270
Ω^+	12.7	$1 \cdot 10^{-5}$	$2.5 \cdot 10^{-6}$	1	$2.5 \cdot 10^{-4}$	45
					${}_{\Lambda}^{3}H$	$0.9 \cdot 10^5$

►To perform main BM@N physics program need 10 times more statistics → $2 \cdot 10^{10}$ interactions

Comparison HADES, STAR FxT, BM@N

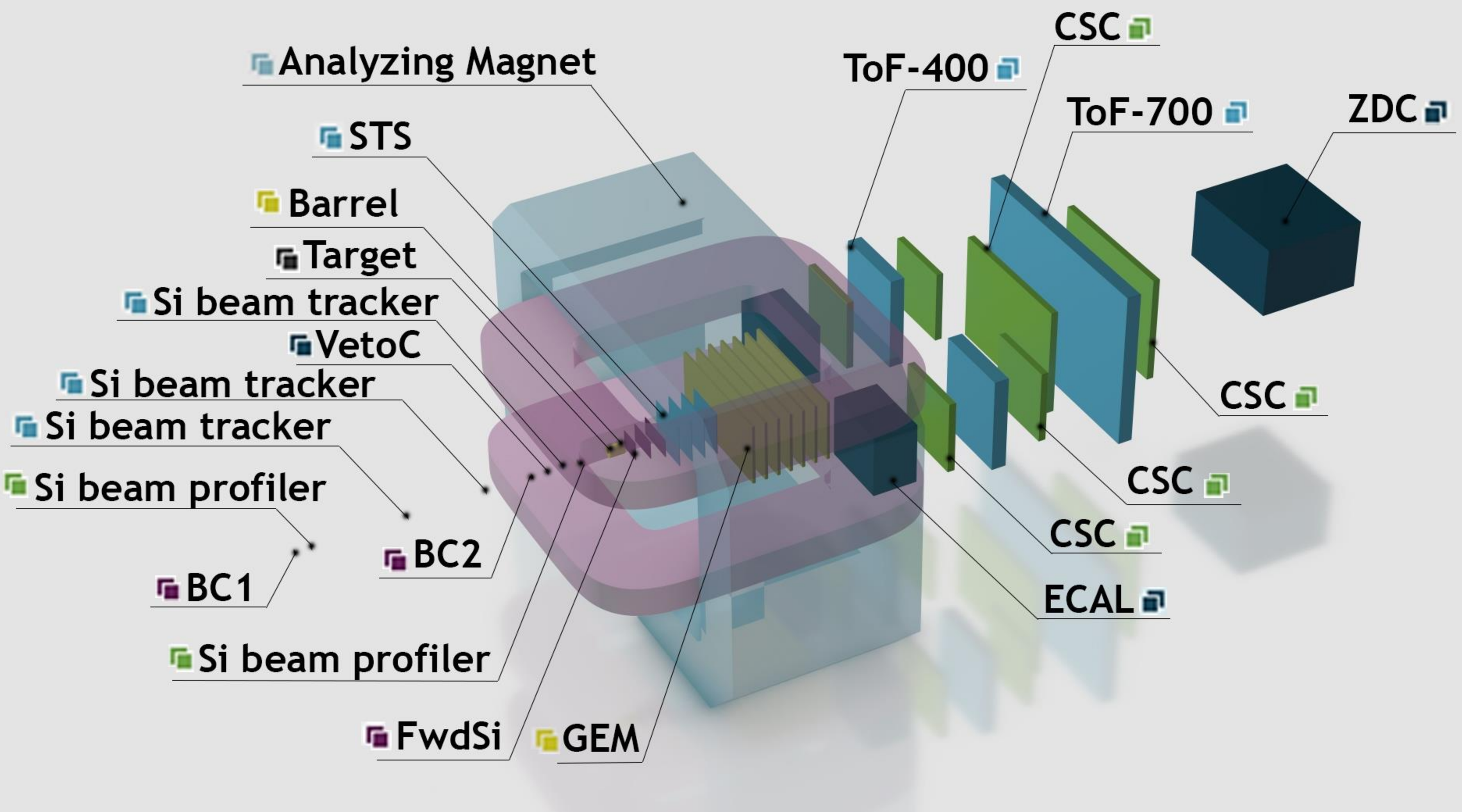
	year	A+A	E_{kin} A GeV	# Events	Rare Observables		
					e^+e^-	Ξ^-, Ω^-	hypernuclei
HADES	2012	Au+Au	1.23	$7\cdot10^9$	✓	---	---
HADES	2019	Ag+Ag	1.58	$1.4\cdot10^{10}$	✓	---	800 $^3_\Lambda$H
STAR FxT	2018	Au+Au	2.9	$3\cdot10^8$	---	10^4 Ξ^-	10^4 $^3_\Lambda$H, $6\cdot10^3$ $^4_\Lambda$H,
STAR FxT	2021 planned	Au+Au	2.9	$2\cdot10^9$	---	$7\cdot10^4$ Ξ^-, Ω^- ?	$7\cdot10^4$ $^3_\Lambda$H, $4\cdot10^4$ $^4_\Lambda$H, $^5_\Lambda$He, $^7_\Lambda$Li, $^7_\Lambda$He, ?
BM@N	simulated	Au+Au	3.8	$2\cdot10^{10}$	---	$5\cdot10^6$ Ξ^- Expected: 10^5 Ω^- $3\cdot10^4$ anti-Λ $5\cdot10^2$ Ω^+	10^6 $^3_\Lambda$H, $^4_\Lambda$H, $^5_\Lambda$He, $^7_\Lambda$Li, $^7_\Lambda$He, Expected: 10^2 $^5_{\Lambda\Lambda}$H

Reaction rates: HADES ≈ 20 kHz, BM@N ≈ 20 kHz, STAR FxT ≈ 2 kHz
Energy Au beams: HADES: 0.2 - 1.25 A GeV, BM@N: 1.5 – 3.8 A GeV, STAR FxT: > 2.9 A GeV

Conclusion:

HADES and BM@N are complementary , no cascade hyperons (Ξ^-,Ω^-) at HADES
Statistics at BM@N ≈70 times higher (Ξ^-) than at STAR FxT

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



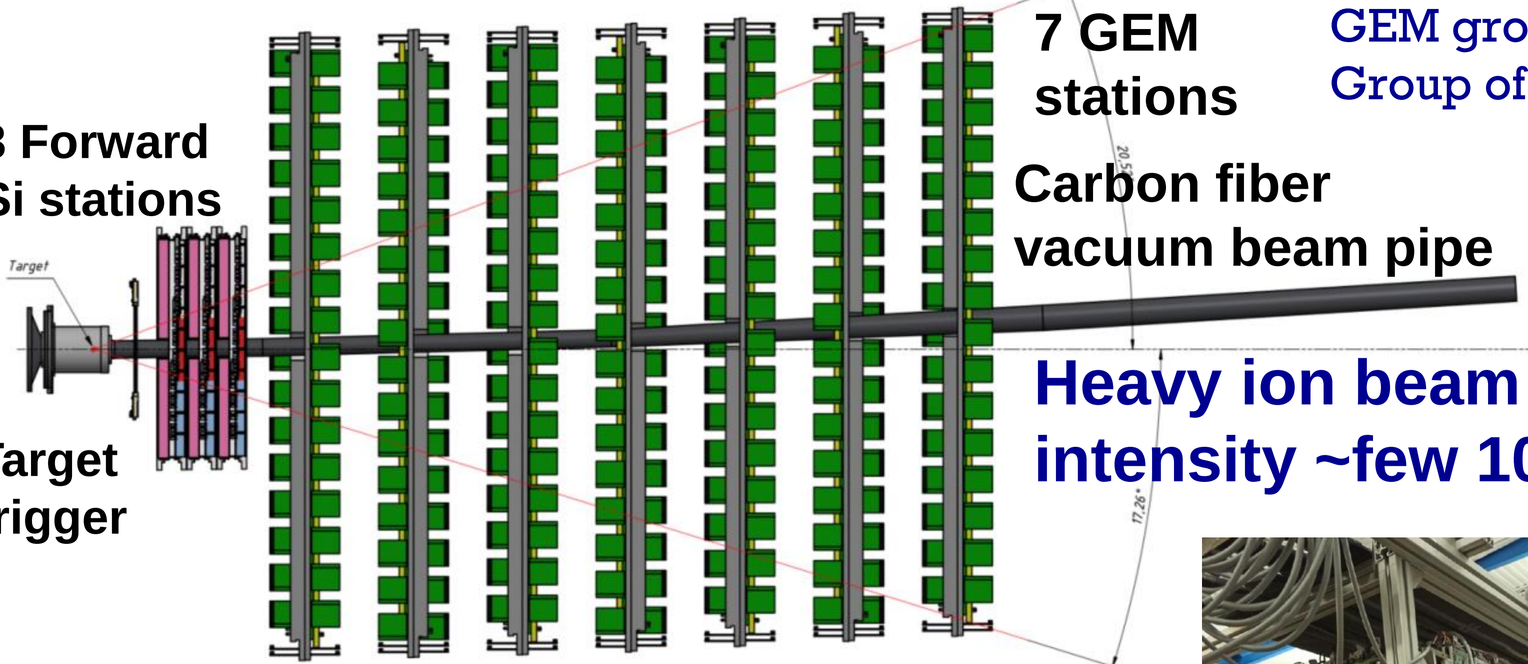
Initial Hybrid Central Tracker for heavy ion runs in 2022: Forward Si + GEM

7 GEM stations

GEM group
Group of N.Zaamiatin

3 Forward Si stations

Carbon fiber vacuum beam pipe

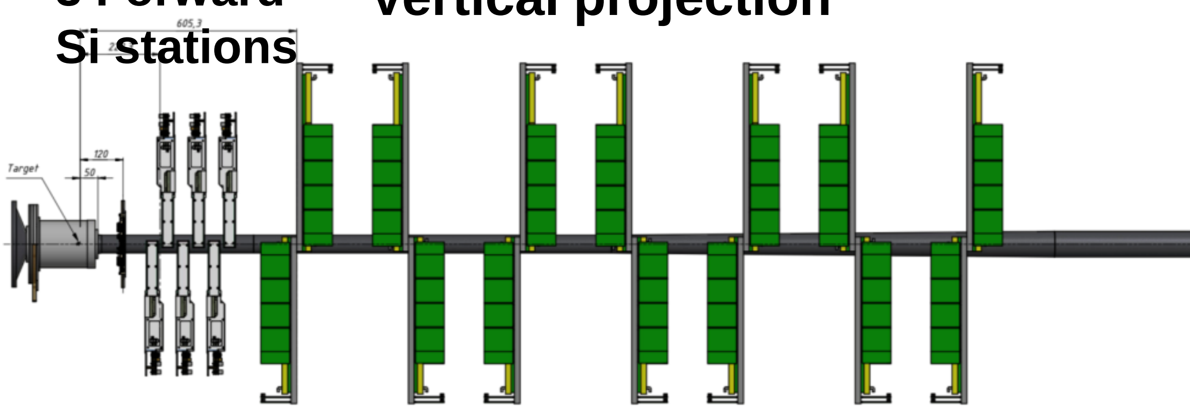


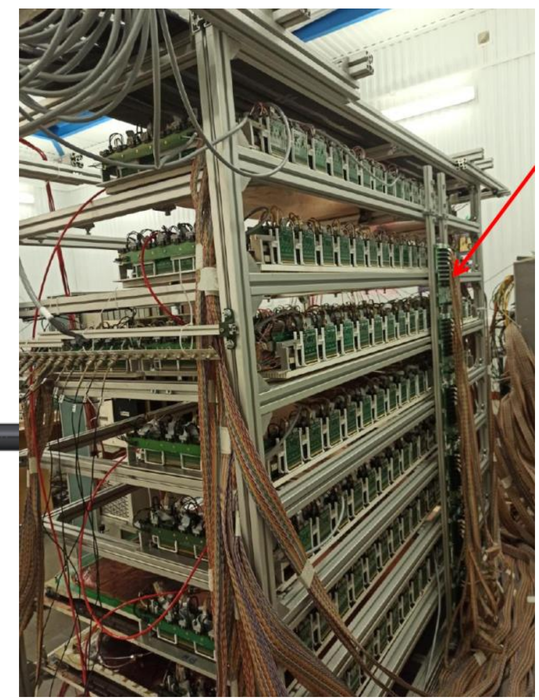
Heavy ion beam intensity ~few 10^5 Hz

Target trigger

3 Forward Si stations

Vertical projection

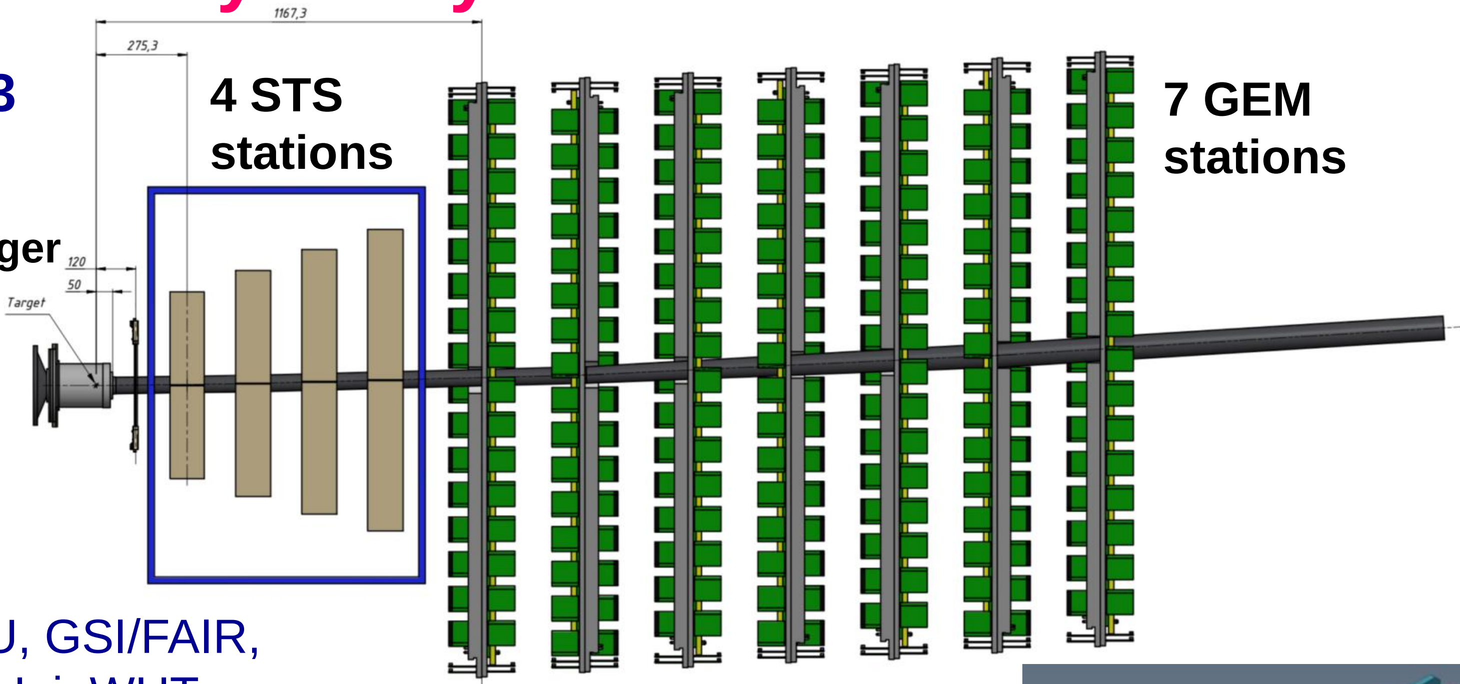




Stage2 Hybrid Central Tracker for high intensity heavy ion runs: STS +GEM

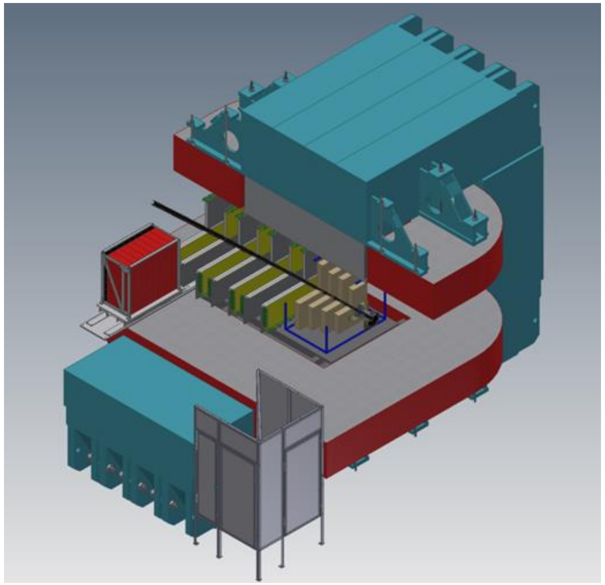
BM@N

after 2023



JINR, MSU, GSI/FAIR,
Tübingen Uni, WUT

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

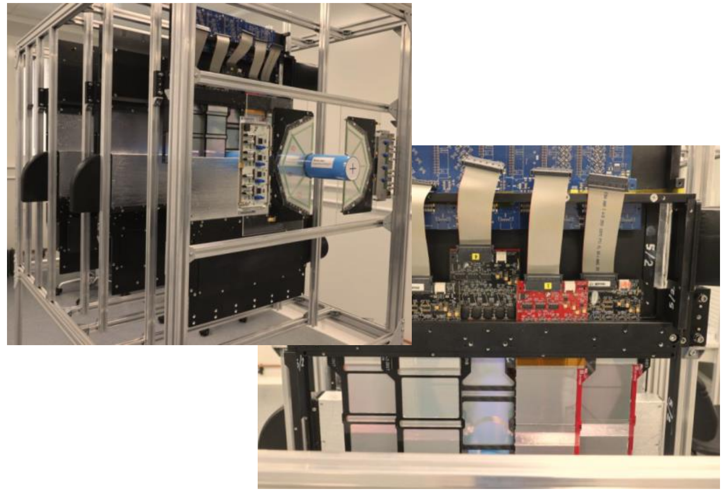


BM@N main detector activities towards heavy ion run

Central tracking system

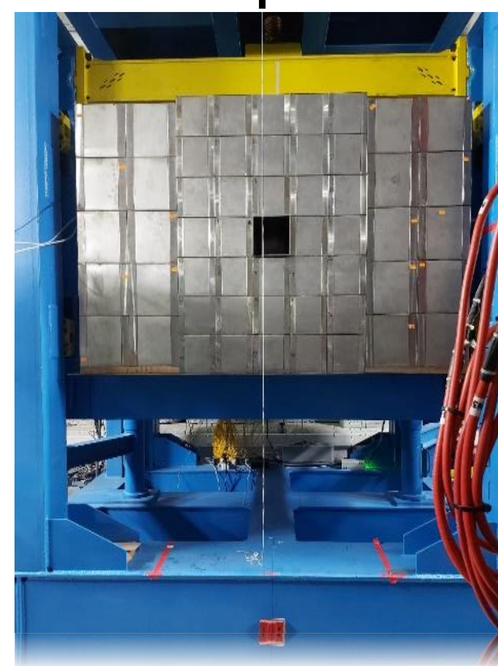
GEM detectors

Forward Silicon Tracker



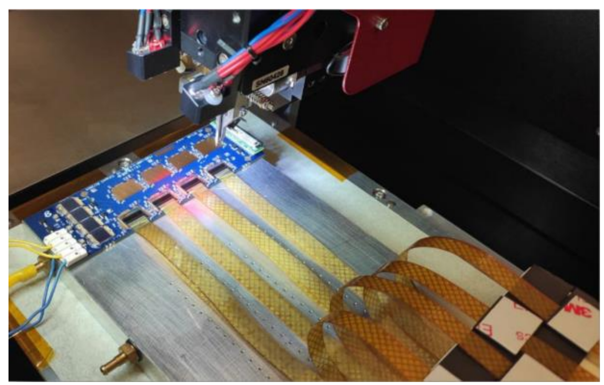
Carbon fiber vacuum beam pipe

Forward Hadron Calorimeter and Hodoscope



Outer tracker: Cathode Strip Chambers

Silicon Tracking System



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

Year	2016	2017 spring	2018 spring	2022 spring	2023	After 2023
Beam	d(↑)	C	Ar,Kr, C(SRC)	Xe	Au (Bi)	Au (Bi)
Max.intensity, Hz	0.5M	0.5M	0.5M	0.5M	0.5M	2M
Trigger rate, Hz	5k	5k	10k	10k	10k	up to 50k
Central tracker status	6 GEM half planes	6 GEM half planes	6 GEM half planes + 3 forward Si planes	7 GEM full planes + 3 forward Si planes	7 GEM full planes + 4 forward Si + 2 large STS planes	7 GEM full planes + 4 large STS planes
Experimental status	technical run	technical run	technical run+physics	stage 1 physics	stage1 physics	High rate stage 2 physics

SRC physics run with C12 beam (4 weeks of data taking)

- Only Nuclotron with laser source is sufficient

Limitations / requirements for BM@N physics run with Xe beam in spring 2022 (800 hours of physics data taking to collect $2 \cdot 10^9$ Xe + CsI interactions)

- Need Booster – Nuclotron accelerator system
- Need 2 months for transition from SRC set-up to heavy ion setup + 0.5 month for magnetic field map measurement
- Full vacuum transport channel from Nuclotron to BM@N
- Xe beam of maximal possible energy (up to 3.9 AGeV)
- Need few days for technical run before physics run to prove beam quality and detector response, in case of problems → postpose physics run
- If SRC run extends to January 2022:
  → only chance to shift BM@N physics run to April - May 2022

Requirements for BM@N physics run with Bi beam in spring 2023 (800 hours of physics data taking to collect $2 \cdot 10^9$ Bi + Bi interactions)

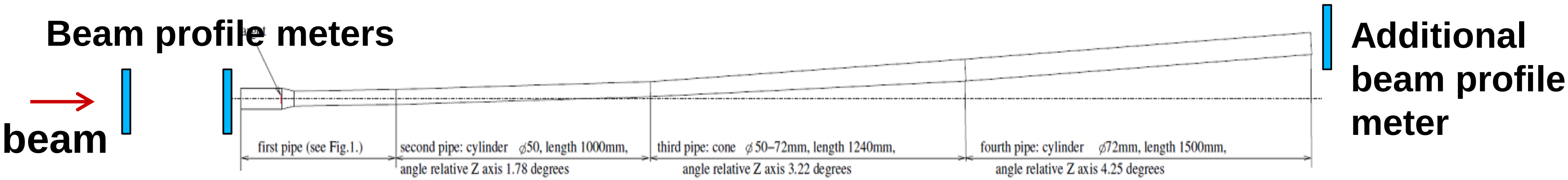
- Full vacuum transport channel from Nuclotron to BM@N
- Bi beam energy of maximal possible energy (up to 3.8 AGeV)

►To perform main BM@N physics program need 10 times more statistics → $2 \cdot 10^{10}$ Bi+Bi interactions with beam energies from 1.5 AGeV up to 3.8 AGeV

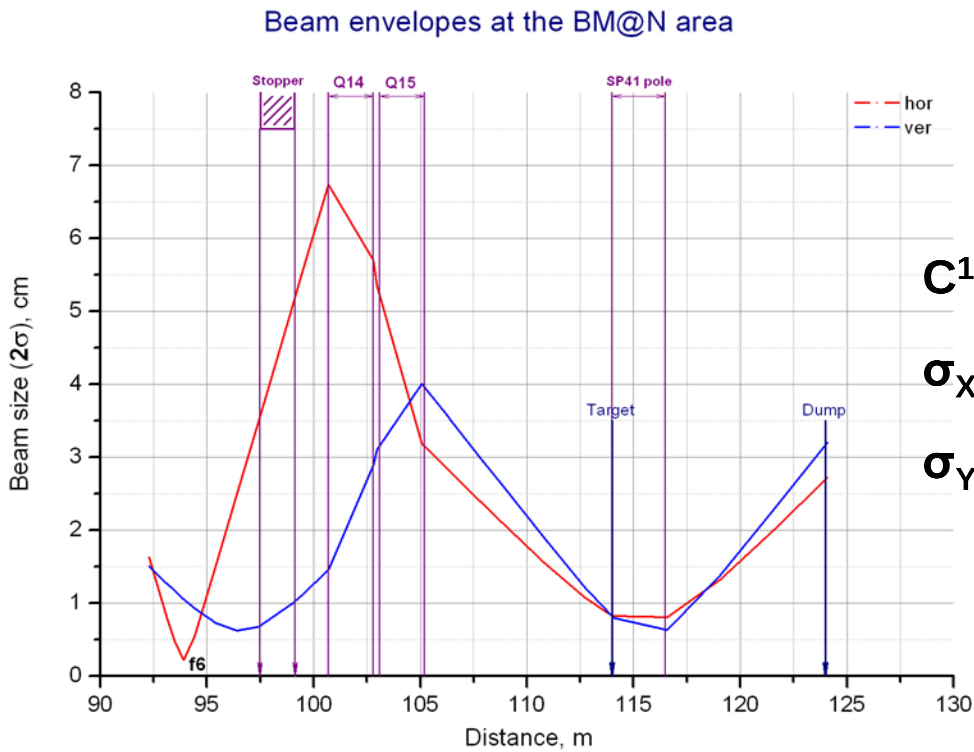
► Need also C + C and Xe + CsI interactions at these energies for reference

Thank you
for attention!

Beam tracing through BMN beam pipe and profile monitoring



First task of the next run → trace beam and monitor its profile in the end of the setup (try to find optimal trajectory to reduce background)



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

Nuclotron and BM@N beam line

26 elements of magnetic optics:

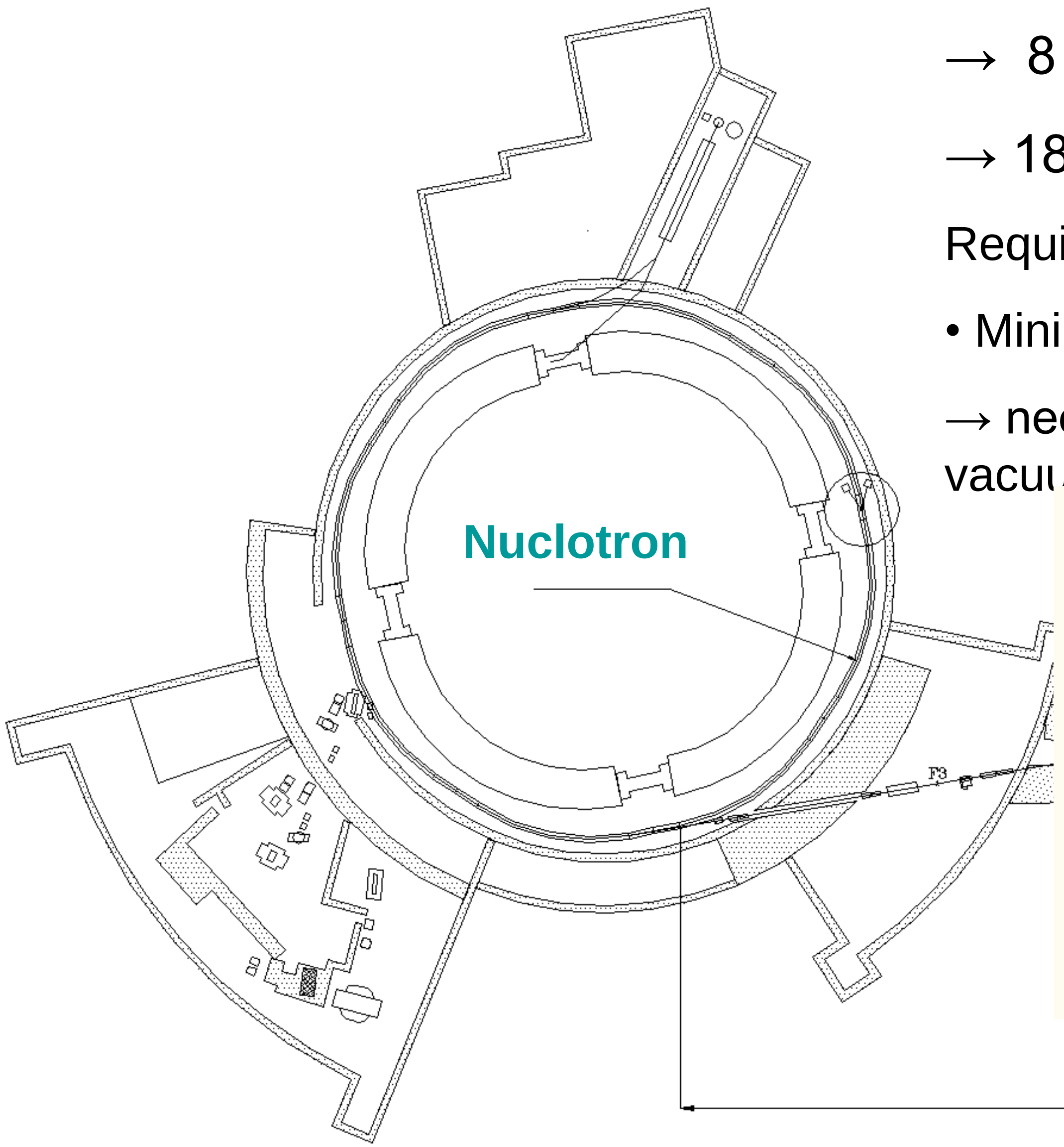
→ 8 dipole magnets

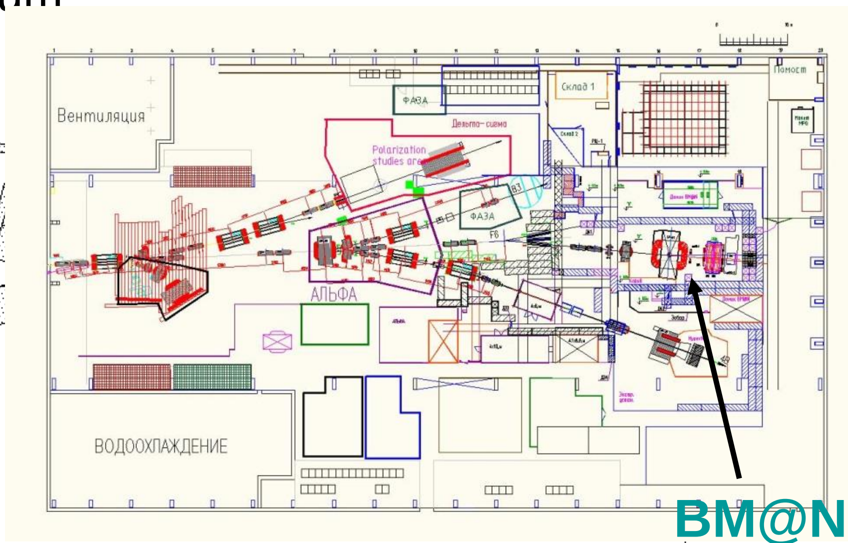
→ 18 quadruple lenses

Requirements for Au beam:

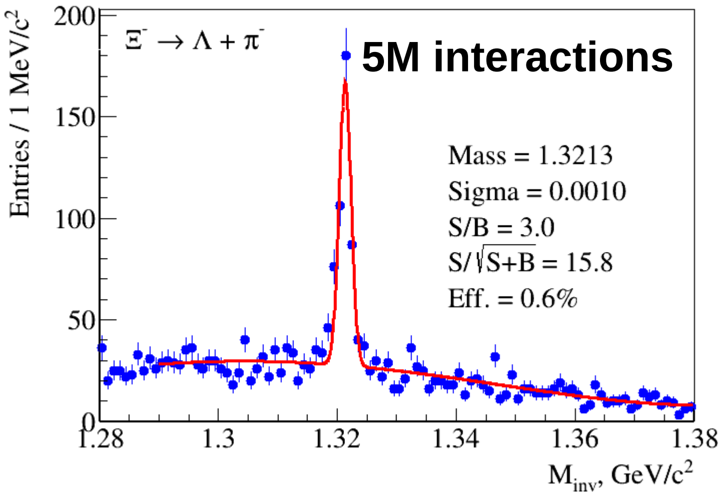
• Minimum dead material

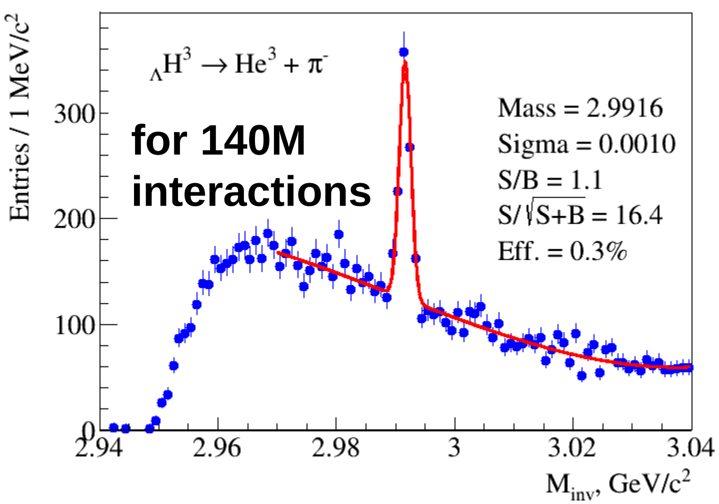
→ need to replace air intervals / foils with vacuum





Feasibility studies for first physics run: Ξ^- and $_\Lambda H^3$ reconstruction in Xe +A interactions: 3 Forward Si + GEM





DCM-SMM model: Xe + Sn , T_0= 3.9 AGeV

phase space of reconstructed Ξ^-