# Existing and future experiments at Nuclotron Based Ion Collider fAcility (NICA)


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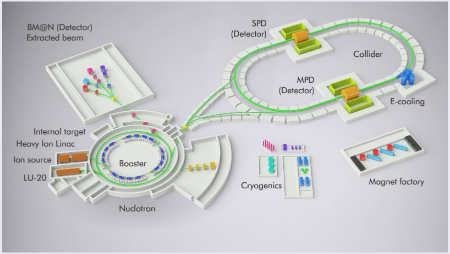
# NICA Complex




- Set of accelerators providing particle beams for fixed target and collider experiments
- Experimental facilities
- Line for assembling and cryogenic testing of SC-magnets
- Workshops for construction of the detector elements
- NICA innovation center

**Beams -** $p$**,** $d$ **...** $^{197}Au^{79+}$
**Collision energy:**
$\sqrt{s_{NN}}$ = **4 - 11 GeV** $E_{lab}$ = **1 - 6 AGeV**
**Luminosity:** $10^{27}\ cm^{-2}s^{-1}$ **(Au),** $10^{32}$ **(p)**

- **2 interaction points - MPD and SPD**
- **Fixed target experiment - BM@N**

- **2018:** extracted beams of heavy ions (Ar, Kr) are available within the BM@N experiment
- **2020-2021**: a first configuration of the MPD setup available.
- **2023**: commissioning of the fully designed NICA-complex is foreseen.

# Nuclotron (in operation since 1993)

## Modernized in 2010 - 2015

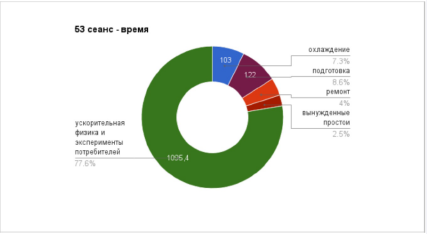
| Parameters | Nuclotron |
|---|---|
| type | SC synchrotron |
| particles | ↑p, ↑d, nuclei |
| injection energy [MeV/u] | 5 (↑p, ↑d), 570-685 (Au) |
| max. kin. energy [GeV/u] | 12.07 (↑p), 5.62 (↑d), 4.38 (Au) |
| magnetic rigidity [T · m] | 25 - 43.25 |
| circumference [m] | 251.52 |
| cycle for collider mode [s] | 1.5-4.2 (active), 5.0 (total) |
| vacuum [Torr] | $10^{-9}$ |
| intensity, Au [ions/pulse] | $1 \cdot 10^{9}$ |
| spill of slow extraction [s] | up to 10 |

- The project approved in 1986
- Commissioning & first beam, March 1993
- Slow extraction in 2000

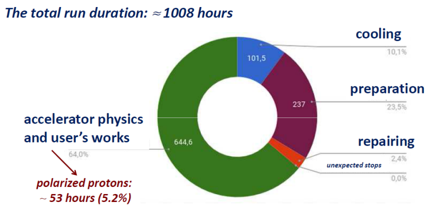
Ions from p to Xe
(C, Mg, Fe, Ar, Kr)
Polarized p & d beams

# Nuclotron

## Run № 53, 1450 h, the longest one

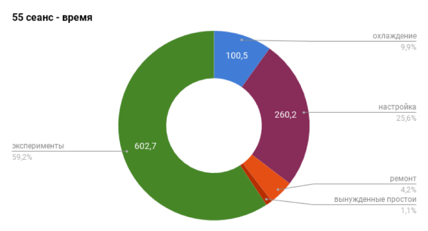



## Run № 54, 1150 h




- Run53 - Polarized, unpolarized deuterons, maximum energy of extracted beam 4.6 GeV/u
- Run54 - Carbon beam
- Run55 - Argon & Krypton beams

## Run55: Feb - Apr, 2018



# Booster

## Commissioning started in 2018

| Parameter | Booster |
|---|---|
| type | SC synchrotron |
| particles | ions $A/Z \leq 3$ |
| injection energy [MeV/u] | 3.2 |
| maximum energy [MeV/u] | 600 |
| magnetic rigidity [$\mathrm{T \cdot m}$] | 1.6 - 25.0 |
| circumference [m] | 210.96 |
| vacuum [Torr] | $10^{-11}$ |
| intensity [Au ions/pulse] | $1.5 \cdot 10^{9}$ |
| RF range [MHz] | 0.5 - 2.53 |


## Tunnel for Booster

- Fabrication of the magnetic system is completed.
- Start of assembly - September 2018.
- First (technological) run - May 2019.
- Commissioning - end of 2020

First magnet was installed on 19 September 2018!

## Line for assembling and cryogenic testing of SC-magnets

### Main production areas:

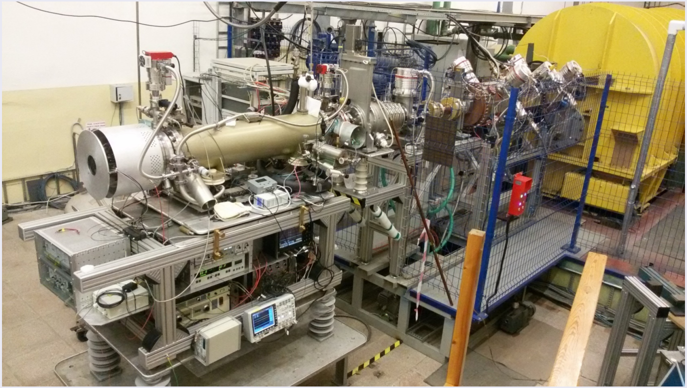
- Incoming inspection zone
- SC cable production hall
- SC coils production hall
- Area for assembling the magnets
- Area for the magnetic measurements under the room temperature
- Leakage test area
- Area for mounting the SC-magnets inside cryostats
- Cryogenic tests bench

**All of the Booster magnets are produced & tested**

**450 magnets for NICA and FAIR projects**

# KRION 6T - heavy ion source

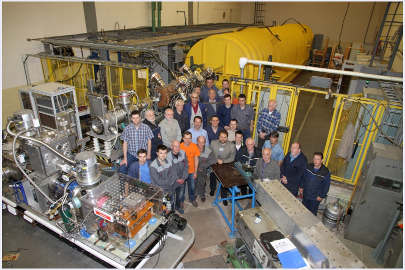
## Used during Nuclotron RUN №55



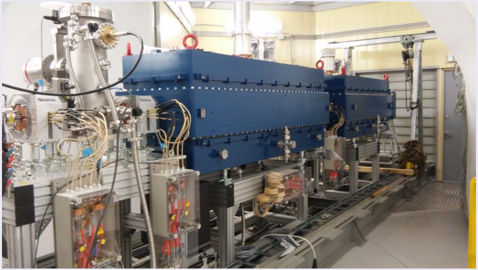
- **Cryogenic heavy ion source KRION - Electron String Ion Source (ESIS) - provides up to $2.5 \cdot 10^9\ Au^{31+}$ ion / cycle at repetition frequency up to 10 Hz**

# Linacs

## LU-20



## HILAC



- **LU-20 - JINR, INR, ITEP, MEPhI (Commissioning - May 2016)**
- **HILAC - BEVATECH OHG (Commissioning - October 2018)**

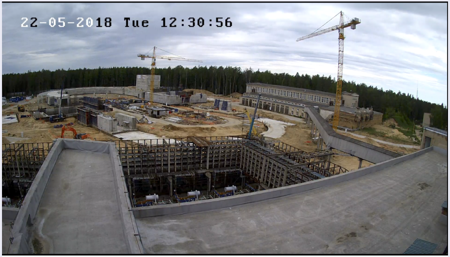
| | LU-20 | HILAC (NEW!) |
|---|---|---|
| Mass to charge ratio $A/Z$ | 1-3 | 1-6 |
| Injection energy [keV / a.m.u.] | 150 for A/Z 1-3 | 17 |
| Extraction energy [MeV / a.m.u.] | 5 (A/Z 1-3) | 3.24 (A/Z = 6) |

# Collider as the main ingredient of the kitchen:)

## Collider construction: Official start up of the construction is 25 March 2016

# Collider

### NICA site online
http://nucloweb.jinr.ru/nucloserv/205corp.htm




### Technical params:

| | |
|---|---|
| Ring circumference [m] | 503.04 |
| Number of bunches | 22 |
| $\Delta_{bunch\ length}$ [m] | 0.6 |
| Max. energy $\sqrt{s_{NN}}$ [GeV] | 11 |
| $\Delta p/p$ $[10^{-3}]$ | 1.6 |
| Luminosity $[cm^{-2} \cdot s^{-1}]$ | $10^{27}$ |

# Collider

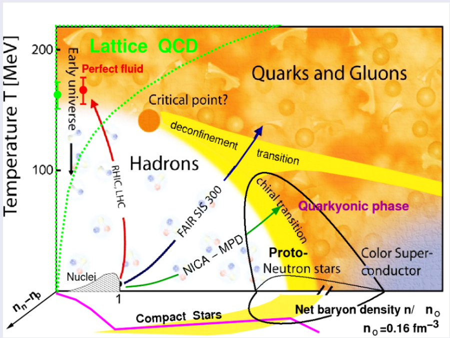
## September 2018

# Cryogenic facility

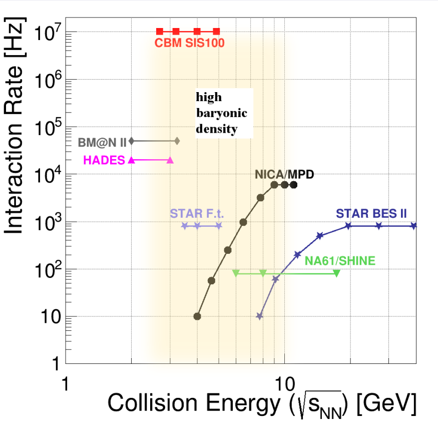
## New helium liquefier (1000 L/H)

**Finally the cooling power should be doubled from 4 kW to 8 kW @ 4.5K**

# QCD phase diagram




## Landscape of experiments exploring QCD phase diagram




### High energy:

- $N_{baryons} \approx N_{antibaryons}$
- Lattice QCD predicts crossover transition between hadronic and partonic matter
- ALICE, ATLAS, CMS, STAR, PHENIX

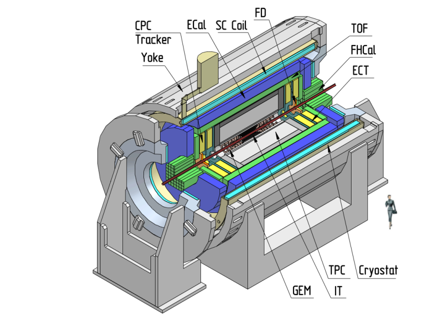
### High net-baryon density:

- $N_{baryons} >> N_{antibaryons}$
- Lattice QCD not applicable, models predict structures and exotic phases
- BES @ RHIC, NA61, CBM, NICA/MPD, BM@N

# Experiments in collider mode

# MultiPurpose Detector (MPD) for $A + A$ collisions @ NICA

## MPD Layout:




## Benefits:

- Hermeticity, $2\pi$-acceptance in azimuth
- 3D-tracking (TPC, ECT)
- Vertex high-resolution (IT)
- Powerful PID (TPC, TOF, ECAL)
  - $\pi$, $K$ up to 1.5 GeV/c
  - $K$, $p$ up to 3 GeV/c
  - $\gamma$, $e$ from 0.1 GeV/c up to 3 GeV/c
- Precise event characterization (FHCAL)
- Fast timing and triggering (FFD)
- Low material budget
- High event rate (up to 7 kHz)

## Participants:

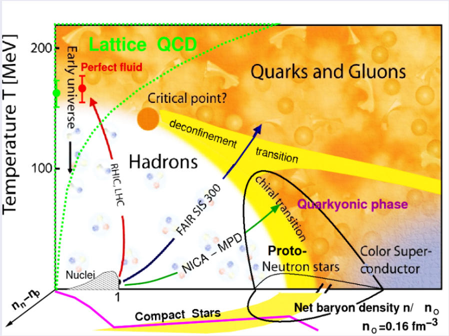
- Tsinghua University, Beijing, China
- GSI, Darmstadt, Germany
- WUT, Warsaw, Poland
- MEPhI, Moscow, Russia
- INR, RAS, Russia
- PPC BSU, Minsk, Belarus
- Dubna, JINR, Russia

## Realization progress:

- TDR - completed / close to completion
- Preparation for / start of mass production
- First stage - 2020 - 2021
- Second stage and full commissioning (IT + end-cups) - 2023

# MPD physics cases

## QCD phase diagram




## Deconfinement (chiral) phase transition at high baryonic density

enhanced strangeness production
Chiral Magnetic (vortical) effect,
$\Lambda$-polarization

## Bulk properties, EOS

particle yields & spectra, ratios,
femtoscopy, flow
measure: $\gamma$, $\pi$, $K$, $p$, $\Lambda$, $\Omega$,
(anti)-particles, light nuclei

## In-Medium modification of hadron properties

onset of low-mass dilepton
enhancement
measure: $\rho$, $\omega$, $\phi$, $e^+e^-$

## QCD Critical Point

event-by-event fluctuations and
correlations

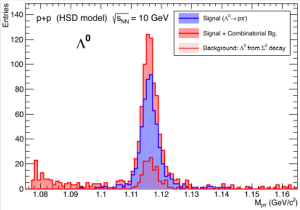
## Strangeness in nuclear matter

hypernuclei

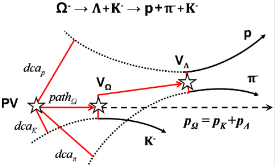
# Multi-strangeness @ MPD

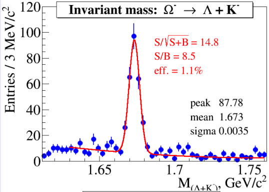
## Hyperon yields for 1 week of running (Stage 1)

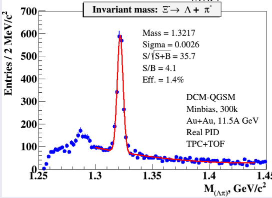
| Particle | Yield |
|---|---|
| $\Lambda^0$ | $3 \cdot 10^7$ |
| $\overline{\Lambda}^0$ | $3.5 \cdot 10^5$ |
| $\Xi^-$ | $1.5 \cdot 10^5$ |
| $\overline{\Xi}^+$ | $8.0 \cdot 10^3$ |
| $\Omega^-$ | $7 \cdot 10^3$ |
| $\overline{\Omega}^+$ | $1.5 \cdot 10^3$ |




## Decay topology

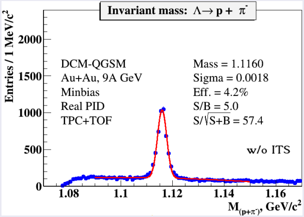


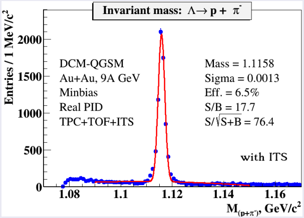




## Data & Analysis

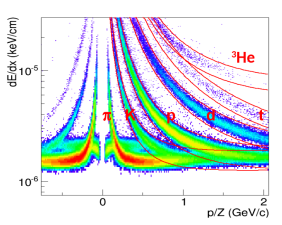
- $5 \cdot 10^5$ events, AuAu @ $\sqrt{s_{NN}} = 9$ GeV
- $\Lambda$-candidates are in inv. mass window $\pm 3\sigma$
- Topological cuts are optimized to improve significance

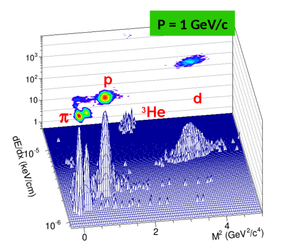


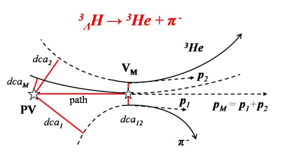
# Hypernuclei @ MPD

## Particle Identification



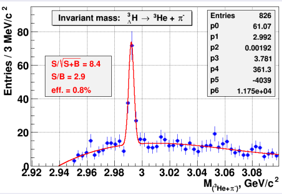

## Decay topology



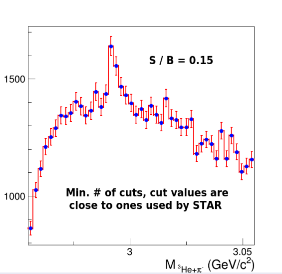

## Data & Analysis

- Particles are selected within $\pm 3\sigma$-cuts in $dE/dx$ or $dE/dx - M^2$
- $V_0$ finding is done with quality cuts for max. significance

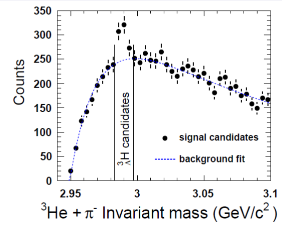
## "Strong" cuts




## "Soft" cuts

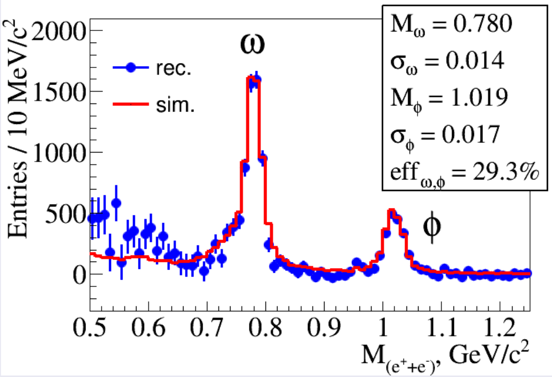



## STAR preliminary

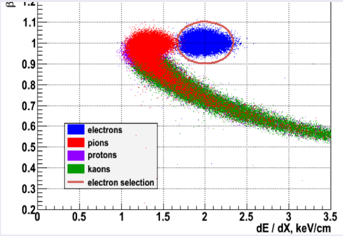


# Dileptons @ MPD

## Invariant mass of dileptons (background subtracted): red - MC, blue - reco

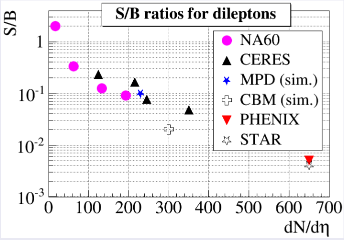



## PID




## MPD

$0.2 < M_{(e^+e^-)} < 1.1 GeV/c^2$

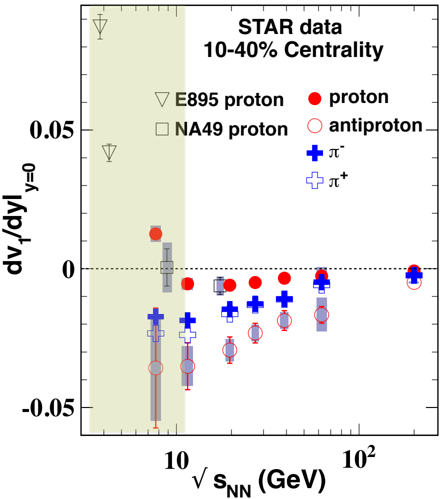



## Yield, decay modes ... for dileptons

| Particle | Yield | | Decay mode | BR | Eff. [%] | Yield [per 1 week] |
|---|---|---|---|---|---|---|
| | $4\pi$ | $y = 0$ | | | | |
| $\rho$ | **31** | **17** | $e^+e^-$ | $4.7 \cdot 10^{-5}$ | 35 | $7.3 \cdot 10^4$ |
| $\omega$ | **20** | **11** | $e^+e^-$ | $7.1 \cdot 10^{-5}$ | 35 | $7.2 \cdot 10^4$ |
| $\phi$ | **2.6** | **1.2** | $e^+e^-$ | $3 \cdot 10^{-4}$ | 35 | $1.7 \cdot 10^4$ |

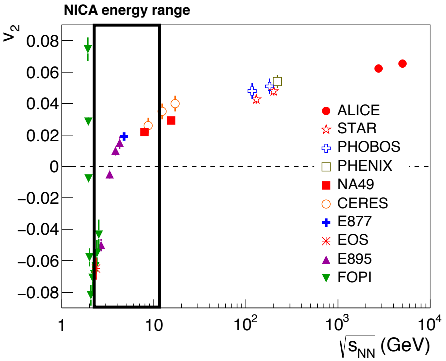
# Flow @ MPD

## Direct flow




Slope of $v_1$ changes sign in the NICA energy range

## Elliptic flow

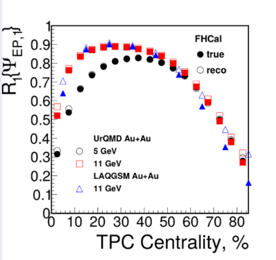


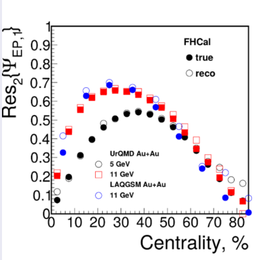

$v_2$ becomes very close to zero in the NICA energy range

- Large uncertainties in existing experimental data in the NICA energy range
- Non-monotonic $|dv_1/dy|_{y=0}$ behavior could be a signature of phase transition
- More differential (centrality classes) measurements required

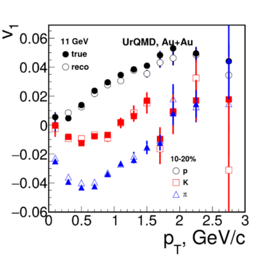
# Flow performance @ MPD: $v_n$ of charged hadrons

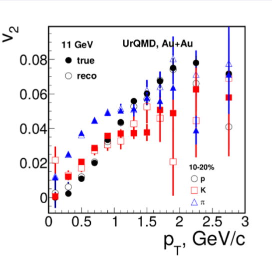
## Ev. plane resolution




## Flow harmonics




**Azimuthal flow coefficients:**

$$v_n = \frac{\langle \cos[n(\phi - \Psi_{EP,1})] \rangle}{R_{\Psi_{EP,1}}}$$

$\Psi_{EP,1}$ - event plane angle

$R_{\Psi_{EP,1}}$ - resolution correction factor

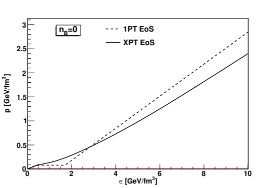
$\phi$ - azimuthal angle of produced particles

**Centrality with TPC estimator**

**Results indicate good precision of reaction plane reconstruction and sufficiently good reproducibility of generated events in a wide range of transverse momentum $p_T$**

# Femtoscopy @ MPD with vHLLE+UrQMD

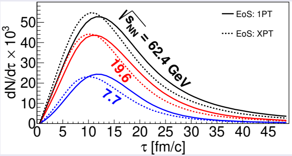
## Thermodynamic pressure as a function of energy density




## Parameters $\tau_0$, $R_\perp$, $R_\eta$ and $\eta/s$ adjusted using basic observables in the RHIC BES region.

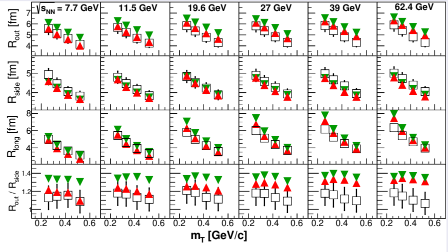
| $\sqrt{s_{NN}}$ [GeV] | $\tau_0$ [fm/c] | $R_\perp$ [fm] | $R_\eta$ [fm] | $\eta/s$ |
|---|---|---|---|---|
| 7.7 | 3.2 | 1.4 | 0.5 | 0.2 |
| 8.8 (SPS) | 2.83 | 1.4 | 0.5 | 0.2 |
| 11.5 | 2.1 | 1.4 | 0.5 | 0.2 |
| 17.3 (SPS) | 1.42 | 1.4 | 0.5 | 0.15 |
| 19.6 | 1.22 | 1.4 | 0.5 | 0.15 |
| 27 | 1.0 | 1.2 | 0.5 | 0.12 |
| 39 | 0.9 | 1.0 | 0.7 | 0.08 |
| 62.4 | 0.7 | 1.0 | 0.7 | 0.08 |
| 200 | 0.4 | 1.0 | 1.0 | 0.08 |

## Pion emission times at the last interaction




Phys. Rev. C 96, 024911 (2017)

## Comparison of extracted radii with the STAR data

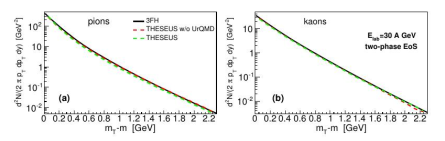



- EoS with a crossover in the fluid phase results in a quite reasonable reproduction of 3D pion femtoscopic radii measured by the STAR collaboration (empty squares).
- EoS with a first-order phase transition leads to fact that the "out" and "long" Gaussian femtoscopic radii are systematically larger if comparing with the crossover EoS; the "side" radii coincide for both types of EoS.

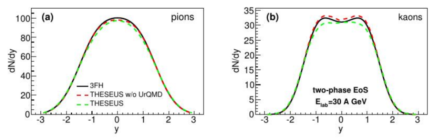
**Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS)**

3FH → PARTICLIZATION → UrQMD CASCADE

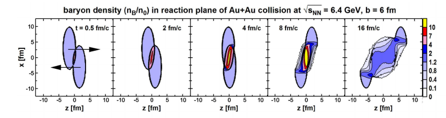
## $p_T$-spectra:




## Rapidity distribution:




## 3FH-model (see Phys. Rev. C 94, 044917 (2016)):



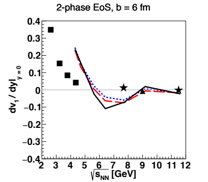

**Very high baryon densities are reached in the central region of the colliding system**

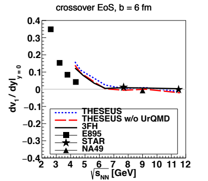
## UrQMD hadronic rescattering:

- leads to a slight steepening of the pion $p_T$-spectrum.
- smears the double-peak structure in the kaon rapidity spectrum.

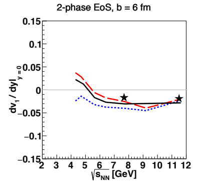
# Observables @ MPD with THESEUS

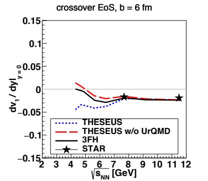
## $|dv_1/dy|_{y=0}$ protons



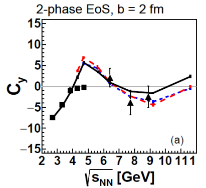



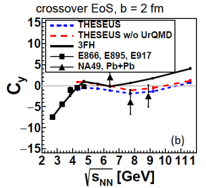

## $|dv_1/dy|_{y=0}$ pions



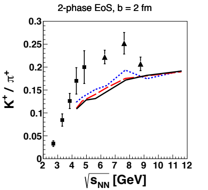



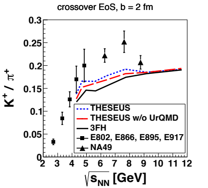

## Curvature of net-proton rapidity distribution




## The "horn" effect?




- Hadronic cascade has a small effect on $dv_1/dy$ for protons
- Hadronic cascade changes flow to antiflow for pions at low energies. The effect becomes weaker with the collision energy rise.

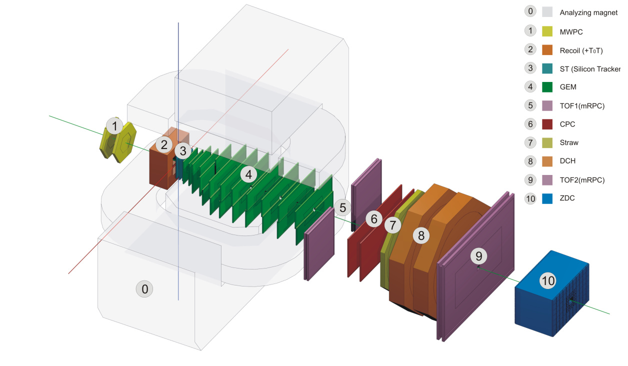
- The "wiggle" as a feature for the EoS with a 1-st order phase transition is robust against hadronic FSI.

- Turning the hadronic cascade on does not influence the kaon to pion ratio.

# Experiments in fixed-target mode

# BM@N experiment

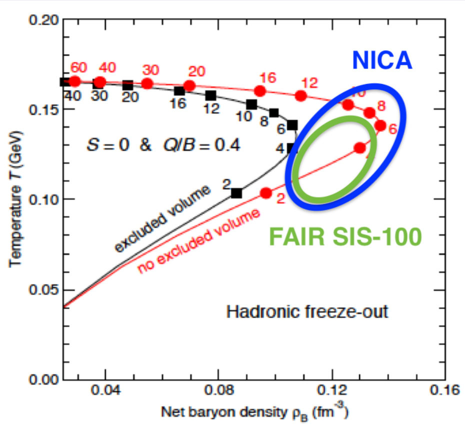
## Full setup, layout

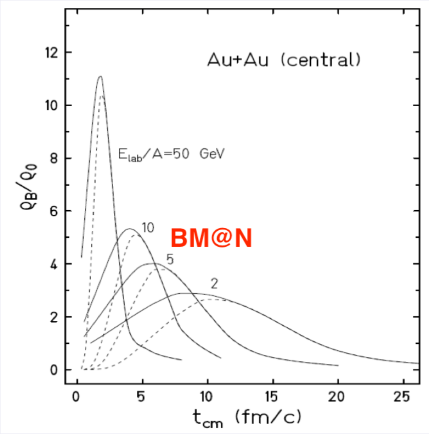



- Central tracker (Silicon tracker + GEM) inside analyzing magnet to reconstruct AA-interactions
- Outer tracker (CPC, DCH) behind magnet to link tracks from central tracker to ToF detectors
- TOF1 & TOF2 system based on mRPC and T0 detectors to identify hadrons and light nuclei
- Detectors to form T0 and beam monitors
- ZDC calorimeter to measure centrality of AA-collisions
- Electromagnetic calorimeter for $\gamma$, $e^+$, $e^-$

### BM@N advantages:

- large aperture analyzing magnet
- sub-detector systems are resistant to high multiplicities of charged particles
- PID: "near to magnet" (TOF1), "far from magnet" (TOF2)




**Nuclotron is well suited to study high density (dominantly baryonic) matter since at that energies baryon-dominated system exists comparatively long lifetime**

# Physics possibilities at the Nuclotron

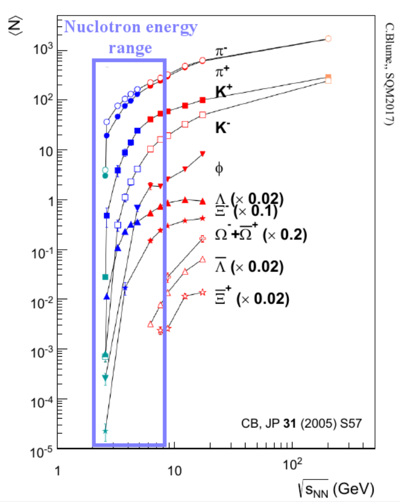
## $A + A$ collisions:

- strangeness at threshold
- Need more precise data for strange mesons, hyperons and hypernuclei, multi-variable distributions, unexplored energy range

## $p + p$, $p + n$, $p + A$ collisions:

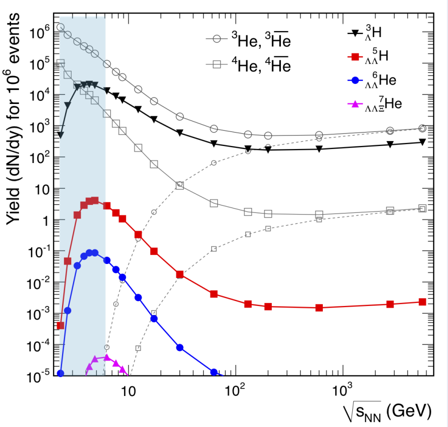
- Hadron production in elementary reactions and “cold” nuclear matter as a “reference” to determine exactly nuclear effects

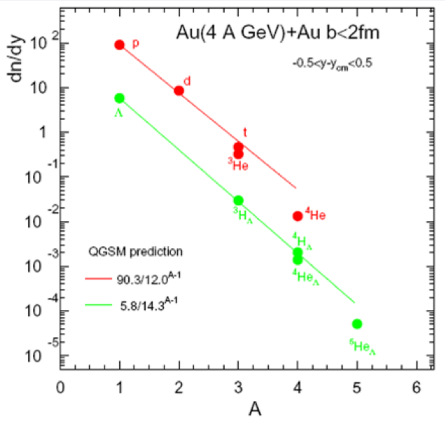
## AGS NA49 BRAHMS



# Heavy ions $A + A$: Hypernuclei production

A. Andronic et al., Phys. Lett. B697 (2011) 203




**BM@N energy range** is **suited** for the search of (double) hypernuclei

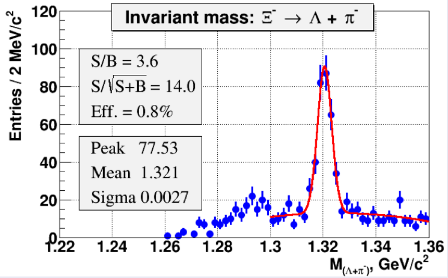
- **In heavy-ion collisions:** production of hypernuclei through coalescence of $\Lambda$ with light fragments enhanced at high baryon densities
- **Maximal yield** predicted for $\sqrt{s_{NN}} =$ 4 - 5 AGeV (stat. model)

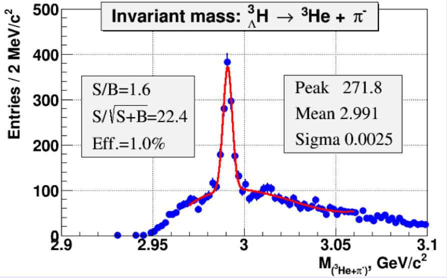
# BM@N feasibility study

**Simulation: UrQMD & DCM-QGSM, Au+Au, T = 4.5 AGeV**

**900k central events,**
**7.5M $\Xi^-$ in 1 month**
**20 kHz trigger**

**2.6M central events,**
**8.5M $^3_\Lambda H$ in 1 month**
**20 kHz trigger**



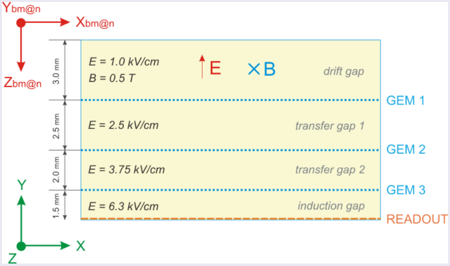

**The feasibility study indicates reliable reconstruction of cascades and hypernuclei of order of 10 millions per month**

# Towards realistic simulation of GEM tracker

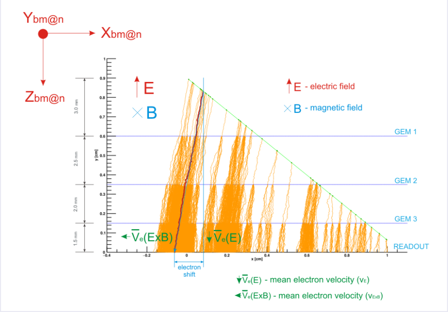
## Simulation of GEM response: Garfield++

- **Garfield++** is a framework for micro-simulation of physical processes in gas detectors
- A charge particle passing through GEM chamber detecting volume ionizes electrons in gas
- Multiplayer GEM-cascades form avalanches which drift to readout-plane and fire strips

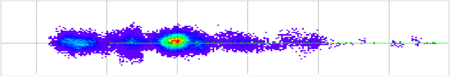
### Simulation parameters in Garfield++



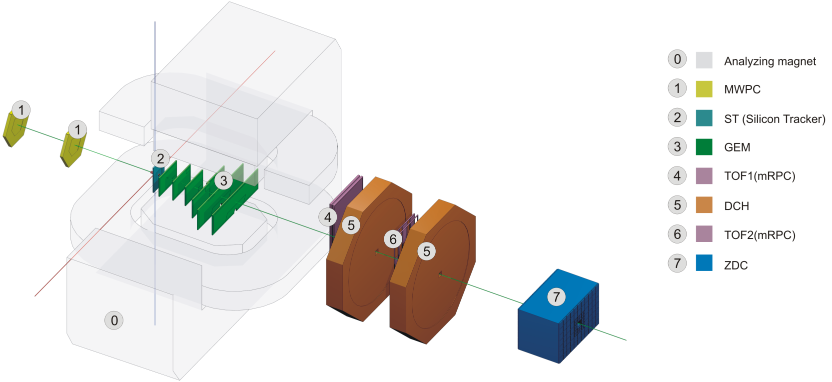

### Structure of BM@N GEM chamber and simulated electron avalanches




### Profile of electron avalanche at the readout-plane (cluster)



# BM@N, carbon run




## Input beams:

Deuteron beam (d),
$T = 4.0, 4.6$ **AGeV**
Carbon beam (C),
$T = 3.5, 4.0, 4.5$ **AGeV**

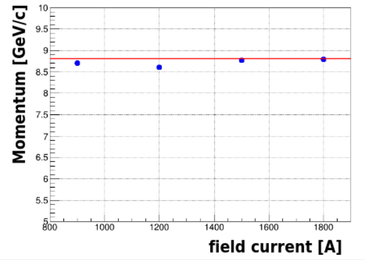
## Aims:

- Focus on tests and commissioning of central tracker inside analyzing magnet → GEM detectors and forward Si detector for tracking
- Test / calibrate ToF, trigger detectors, calorimeters

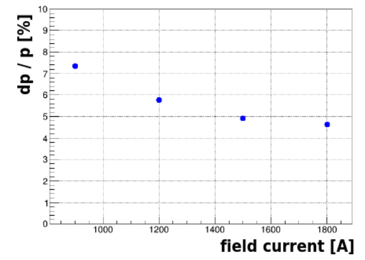
## Program:

- 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

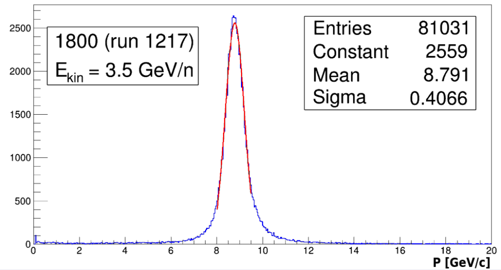
## $p$ vs. field current




## $\Delta p/p$ vs. field current



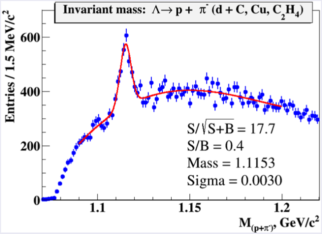

- Reconstruction of carbon beam trajectory and momentum in GEM detectors at different values of magnetic field
- Gas mixture: Ar + $CO_2$ (70:30)
- Carbon beam run, T = 3.5 AGeV



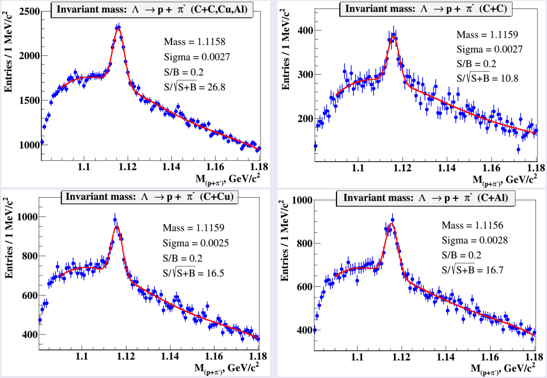
# $\Lambda^0$ in deutron and carbon runs

**d (C) + target → X**
**$\Lambda^0$-signal width ∼ 2.5-3 MeV**

## Deuteron run




## Carbon run, T = 4 AGeV



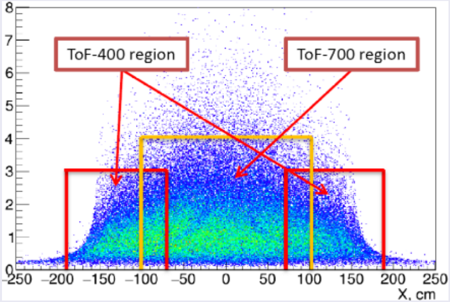

**PEPAN Lett., v.15, p.136, 2018(2): First results from BM@N technical run with deuteron beam**

To improve vertex and momentum resolution and reduce background under $\Lambda^0$:

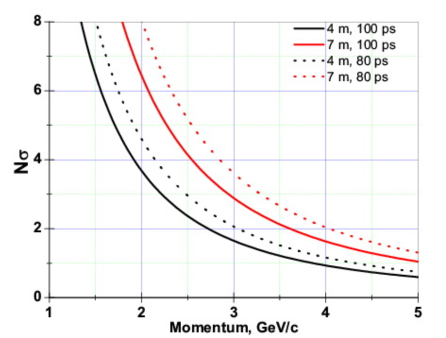
- Need few planes of forward Silicon detectors → 3 planes used in last run
- Need more GEM planes to improve track momentum reconstruction

# TOF1 and TOF2 based on mRPC

## AuAu @ T = 3.4 AGeV, $\pi^{\pm}$, 4m from target




## Separation of $\pi/K$ for different time resolution and bases



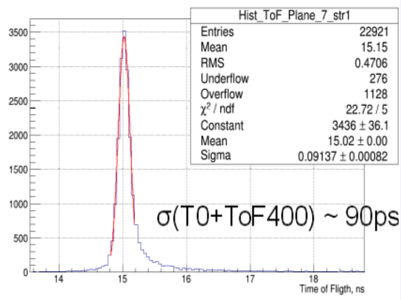

## Requirements to TOF system:

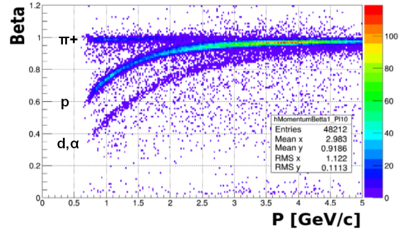
- high granularity to keep the overall system occupancy below 15% and minimize efficiency degradation due to double hits
- operation at high particle flux
- time resolution better then 80 ps
- high combined geometrical and detection efficiency (better than 95%)

# TOF1 and TOF2 performance in carbon run

## $T = 3.5$ GeV/n, $C + Al \to X$

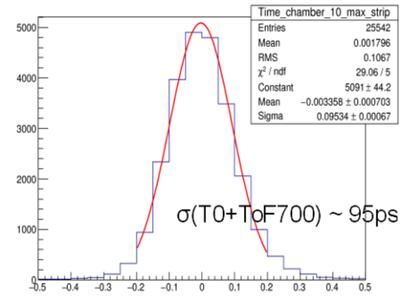
**Includes inf. from GEM tracking**

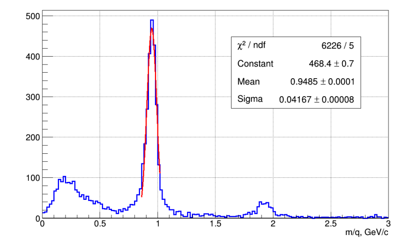


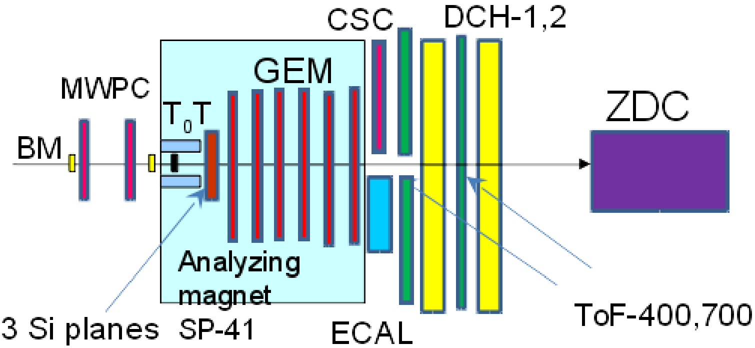

## $T = 4.5$ GeV/n, $C + Cu \to X$

**Includes inf. from GEM and DCH trackings**



# BM@N, Argon & Krypton runs




**Input beams:**

**Ar beam,** $T = 3.2$ **AGeV**
**Kr beam,**
$T = 2.4, 3.0$ **AGeV**

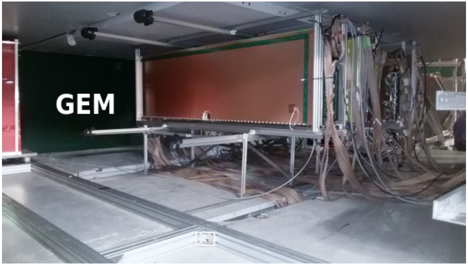
**Aims:**

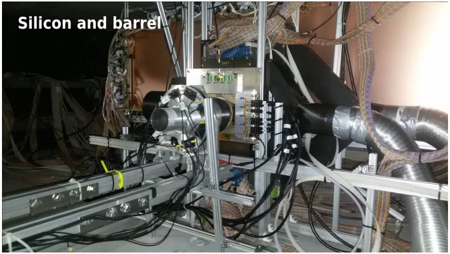
- Central tracker inside analyzing magnet → 6 GEM detectors $163 \cdot 45 cm^2$ and forward Si strip detectors for tracking
- Test ToF system, trigger detectors, hadron and EM calorimeters, outer tracker supplemented by CSC

**Program:**

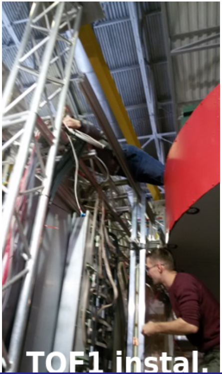
- Measure inelastic reactions Ar (Kr) + target → X on targets Al, Cu, Sn, Pb
- Hyperon production measured in central tracker (Si + GEM)
- Charged particles and nuclear fragments identified with ToF
- Gamma and multi-gamma states identified in ECAL

# BM@N setup in the last run (before magnet)



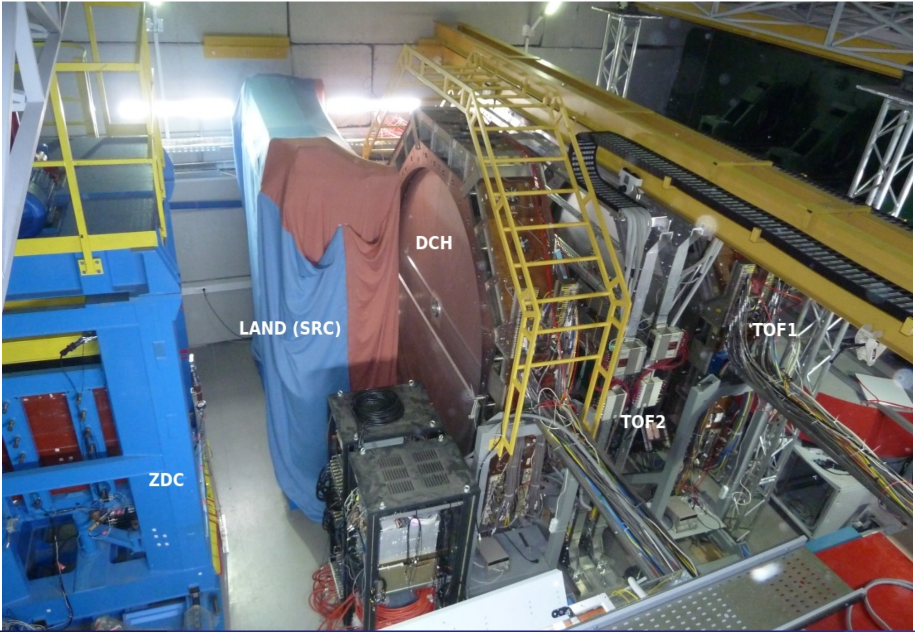





## New detector components:

- Six big GEMs
- Trigger detectors
- Three Si detectors
- CSC chamber
- Full set of TOF detectors

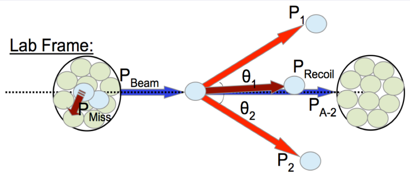
# BM@N setup in the last run (behind magnet)



# Short Range Correlation (SRC) programme as an extension to the BM@N experiment

# How to study SRC?

## Inverse kinematics




$^{12}_{6}\mathrm{C} + \mathrm{p} \rightarrow 2\mathrm{p} + {}^{10}_{5}\mathrm{B} + \mathrm{n}$ **(np SRC)**

$^{12}_{6}\mathrm{C} + \mathrm{p} \rightarrow 2\mathrm{p} + {}^{10}_{4}\mathrm{Be} + \mathrm{p}$ **(pp SRC)**

## Participants

- **JINR: BM@N**
- **Israel: Tel Aviv University**
- **Germany: TUD and GSI**
- **USA: MIT**
- **France: CEA**

## Super exclusive measurement!

**Four particles detected:**

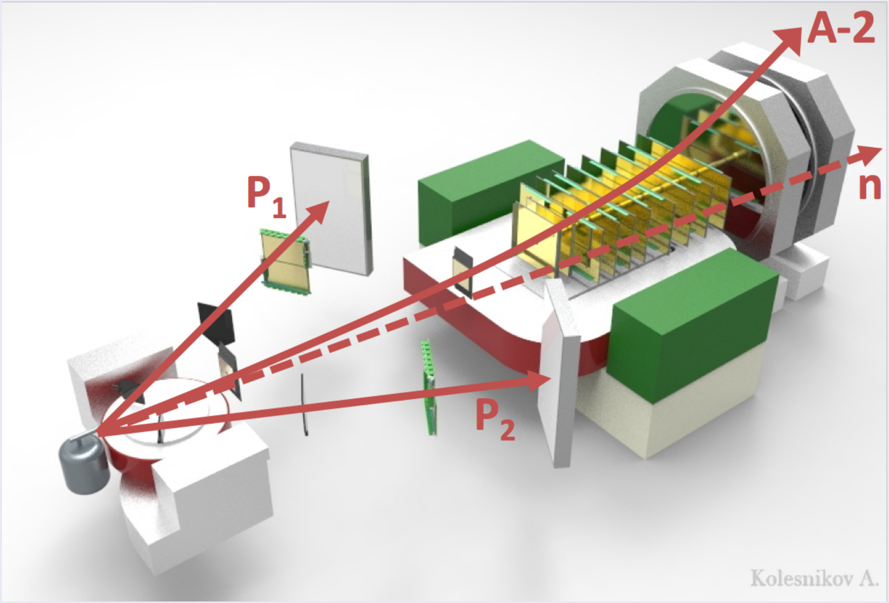
- **scattered probe**
- **knocked-out nucleon**
- **recoil**
- **(A-2)-fragment system**

## Objectives

- **identifying 2N-SRC events with inverse kinematics**
- **studying isospin decomposition of 2N-SRC**
- **studying (A-2) spectator nuclear system**

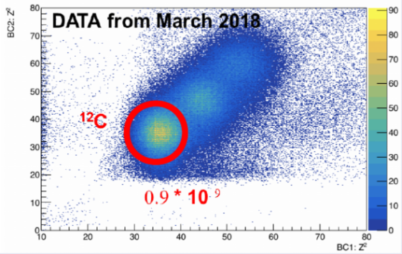
**First BM@N SRC program run in March 2018: ∼ 30 MEvents collected**

# Experimental setup

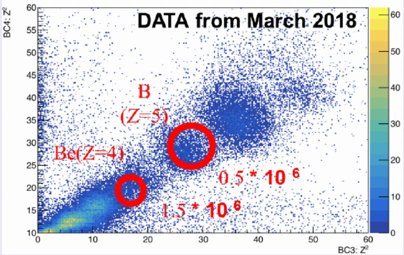


# Counter analysis (A - 2) identification

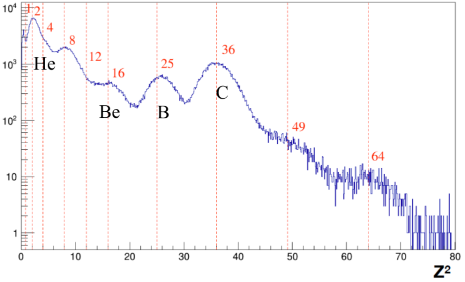
## Before target:

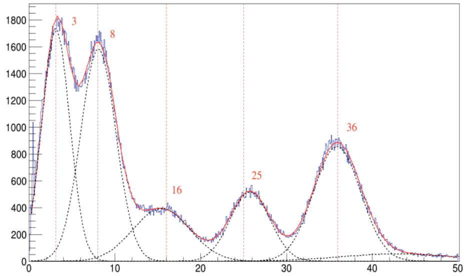



## After target:




## Nuclear fragment identification



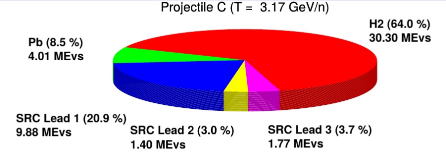
**SRC:**

- One beam energy available for C-beam
- More than half of the collected statistics can be used for analysis

**BM@N:**

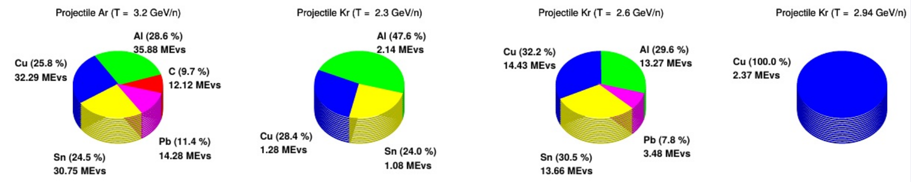
- One beam energy available for Ar-beam and three - for Kr-beam
- Wide set of targets used ($C$, $Al$, $Cu$, $Sn$, $Pb$)

## SRC




**Data analysis is in progress ...**

## BM@N



# BM@N: past & future, status & plans

## Beam parameters and setup at different stages of the experiment

| Year | 2016 | 2017 | 2018 | 2020 | 2021 and later |
|---|---|---|---|---|---|
| Experim. status | techn. run | techn.run | techn. run | stage 1, phys. | stage 2, phys. |
| Beam | d(↑) | C | Ar, Kr, C | Au | p, Au |
| Max. intensity [MHz] | 0.5 | 0.5 | 0.5 | 1 | 10 |
| Trigger rate [kHz] | 5 | 5 | 10 | 10 | 20-50 |
| Central tracker | | | | | |
| GEM | 6 (half planes) | 6 (half planes) | 6 (half planes) | 7 | 7 |
| SI | - | 1 (small plane) | 3 (small planes) | 4 | 4 |

## Status:

- Technical runs with deuteron and carbon beams (T = 3.5 - 4.6 GeV/n), argon beam (T = 3.2 GeV/n) and krypton beam (T = 2.3 GeV/n) performed
- Measurement on Short Range Correlations with inverse kinematics: C + $H_2$-target performed
- Major sub-systems are operational, but are still in limited configurations: GEMs, forward Silicon detectors, Outer tracker, ToF, ZDC, ECAL, trigger, DAQ, slow control, online monitoring
- Algorithms for event reconstruction and analysis are being developed

## Plans:

- Collaborate with CBM to produce and install large aperture silicon detectors in front of GEM-tracker
- Extend the GEM central tracker and the CSC outer tracker to full configuration
- Implement beam detectors into vacuum beam pipe, implement vacuum / helium beam pipe through the BM@N setup

- The 1st collaboration meeting (April, 11-13 2018)

**The 2nd collaboration meeting (October, 29-30 2018)**


**At present:**

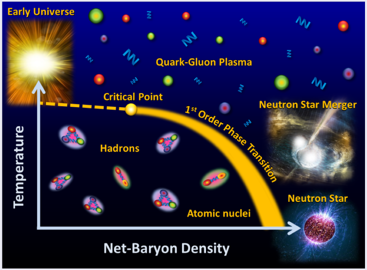
**BM@N:**
10 Countries,
17 Institutions,
216 Participants

**MPD:**
10 Countries,
26 Institutions,
436 Participants

- N. B.: The 3rd collaboration meeting is coming **April, 16-17**

## NICA energy region:

- Maximum in $K^+/\pi^+$-ratio
- Maximum in $\Lambda/\pi$-ratio
- Maximum yield of hypernuclei
- Maximum in the net-baryon density
- Transition from a Baryon dominated system to a Meson dominated one
- Maximum of $\Lambda$-polarization
- 1st order ph. transition & mixed phase creation
- Critical end-point???




- The construction of accelerator complex and both detectors BM@N & MPD are going close to the schedule
- NICA got a recognition as a part of European research infrastructure
- You are kindly invited to join the BM@N or/and MPD Collaborations