Experiments at the Nuclotron beams.

E.A. Strokovsky, JINR (Dubna)

Plan

1. The origin …
2. What users have now
3. Selected experiments
   - Experiments at the Internal Target Station
   - Selected experiments at extracted beams
     - STRELA project
     - ALPOM-2 project
     - Applied physics (E&T RaW project)
4. Baryonic Matter at Nuclotron (the *BM@N* project)
5. User's policy at LHEP

The origin …

1944: Phase stability principle - V.I.Veksler; **70 years in 2014**

1945: independently - E.M.McMillan; **70 years in 2015**

Veksler-Baldin Laboratory of High Energy Physics

V.I.Veksler

with D.I.Blokhintsev, F. Joliot-Curie

A.M.Baldin

"Father" of the relativistic nuclear physics.

LHEP
ЛФВЭ

1944	***Phase stability principle*** **(V.I.Veksler; 1945 - E.M.McMillan)**
1949-1950	**Physics grounds of the Synchrophasotron, prototyped in Lebedev Physics Inst. of AS USSR; construction of the Synchrophasotron started.**
1953	**Electrophysics Lab. of AS USSR with the Synchrophasotron as a future basic facility**
1956, March 26	**Laboratory for High Energy of Joint Institute for Nuclear Research**
1957, April	**Synchrophasotron was put into operation.**

Research program was developed and performed under leadership of V.I.Veksler, M.A.Markov, I.V.Chuvilo, A.M.Baldin

1970	**Acceleration of deuterons in Synchrophasotron; later on – relativistic nuclei.**
1981	**Acceleration of polarized deuterons**
1993	**Nuclotron was put into operation; In mid 90' – Movable Polarized Proton Target in LHE.**

Synchrophasotron operated almost 50 years

time

1970’

1986’

1996’

2008’

2015’

Relativistic Ion Facilities from Synchrophasotron and AGS to NICA and FAIR

Over the last 30 years a lot of efforts have been made to provide the conditions for searching for new states of strongly interacting matter under extreme conditions.

Synchrophasotron: $E_{lab} \sim 4.2$ AGeV ($\sqrt{s_{NN}} = 3$ GeV)
1971 - 1999, pioneer experiments in the field of relativistic nuclear physics.

AGS: $E_{lab} \sim 11$ AGeV ($\sqrt{s_{NN}} = 5$ GeV)
1986 — 1992, study of compressed baryonic matter.

SPS: $E_{lab} \sim 158$ AGeV ($\sqrt{s_{NN}} = 18$ GeV)
1986- up to now,
study of compressed baryonic matter.

RHIC: $\sqrt{s_{NN}} = 200$ GeV ($E_{lab} \sim 80000$ AGeV)
1996 - up to now,

LHC: $\sqrt{s_{NN}} = 5520$ AGeV ($E_{lab} \sim 6.1 \cdot 10^7$ AGeV)

SIS 300 (FAIR): $E_{lab} \sim 34$ AGeV ($\sqrt{s_{NN}} = 8.5$ GeV),
full performance will be reached in 2015,
study of compressed baryonic matter.

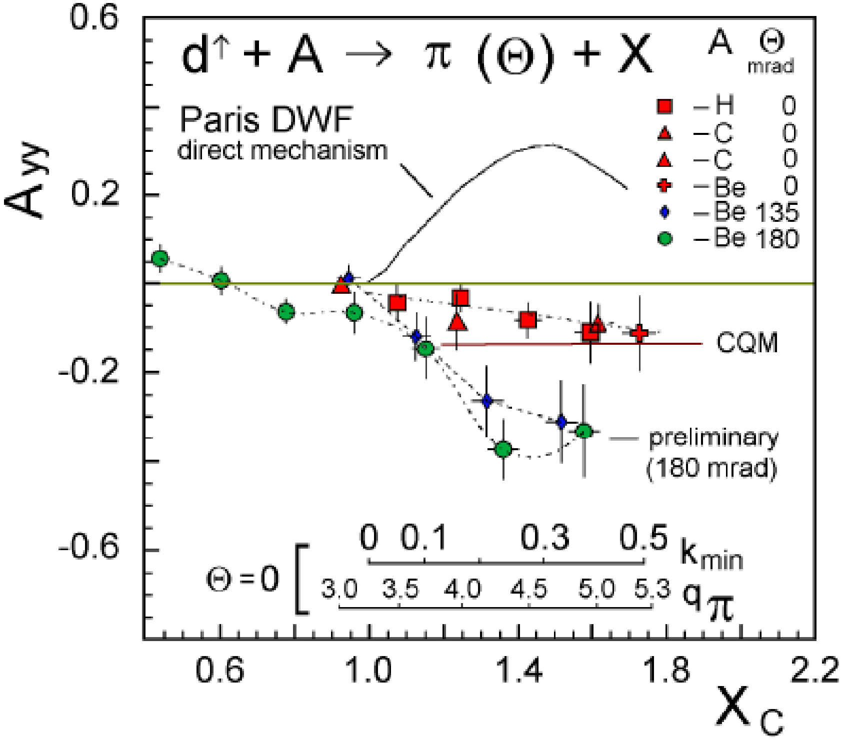
NICA: $\sqrt{s_{NN}} = 9$ GeV ($E_{lab} \sim 40$ AGeV).
full performance will be reached in 2013,
search for the mixed phase of strongly interacting matter.

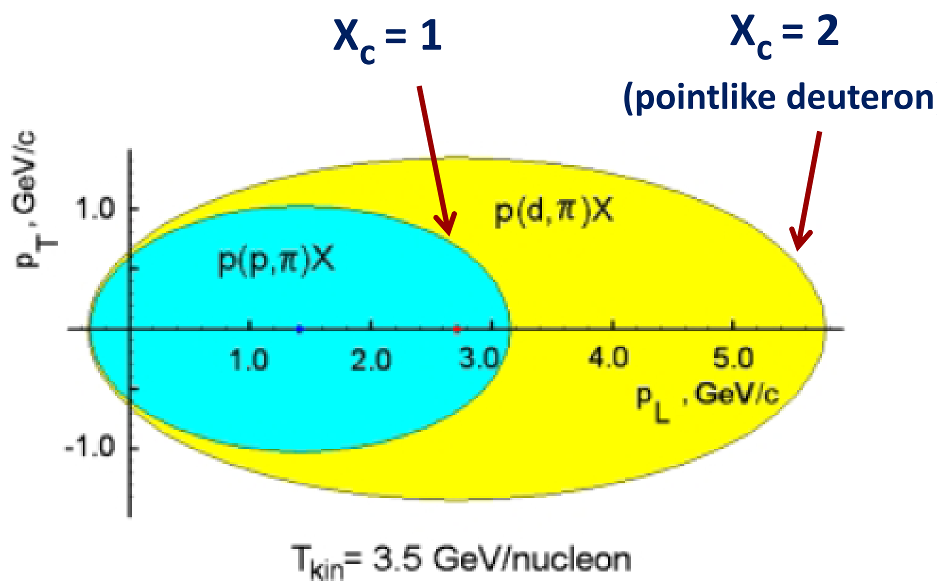
Selected examples
(cumulative particle production,
polarization phenomena,
few nucleon structure)

personal view

Polarization effects in cumulative particle production.

Example: pion production by polarized deuterons. L.Zolin et al, Nucl. Phys. A689 (2001) 414c





Pion lab. momentum ellipse

$$X_c = \frac{\left(\mathcal{P}_{targ}\mathcal{P}_{\pi} - m_{\pi}^2/2\right)}{\left(\mathcal{P}_{targ}\mathcal{P}_{beam}\right) - m_N^2 - \left(\mathcal{P}_{beam}\mathcal{P}_{\pi}\right)}$$

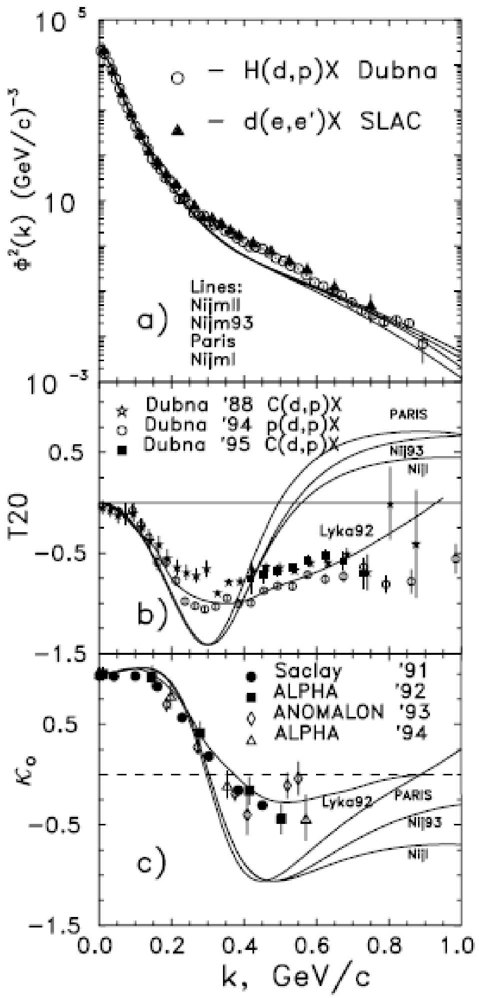
Few nucleon systems at short inter-nucleon distances

Unpolarized beam

Polarized beam

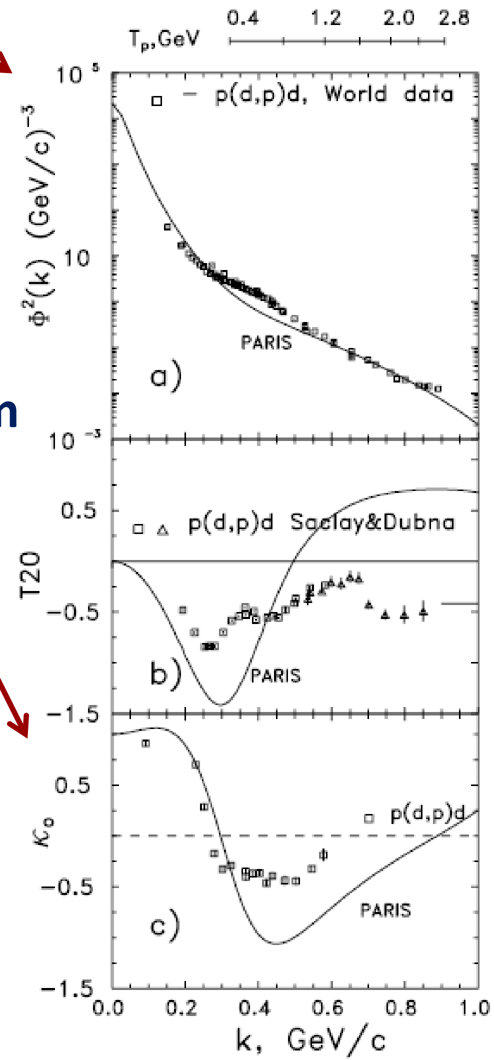
$\sigma_{pol} = \sigma_0 \cdot (1 - \frac{1}{2}\rho_{20} \cdot T_{20})$
$\kappa_0 = P_{prot}/P_z^d \quad when \quad P_{zz}^d = 0$

- The empirical momentum density (EMD) is independent on:
  - the probe
  - the initial T_{kin} (1.5 to 7.4 GeV)
  - the target
- The same for κ_0; T_{20} has 25% sensitivity to the type of target
- T_{20} tends to be a negative constant



- The EMD is the same as in $(d,p)X$ at 0°
- T_{20} has a new structure
- κ_0 and T_{20} differs from $(d,p)X$ at 0°
- the same track at the $\kappa_0 - T_{20}$ plot as for $(d,p)X$ at 0°

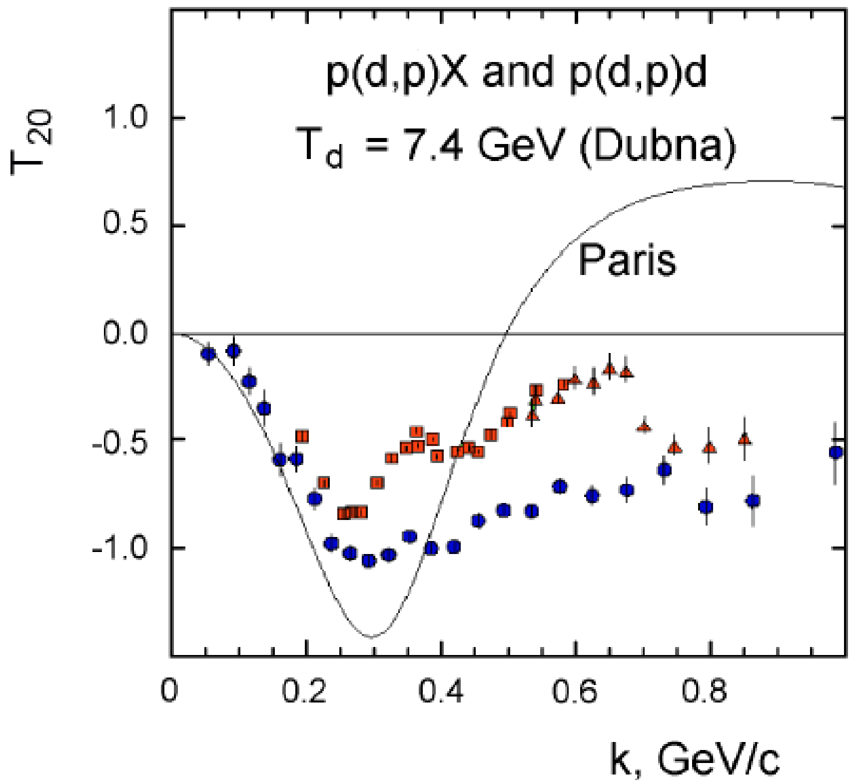
Summary of the elastic $p(d,p)d$ 180° results.

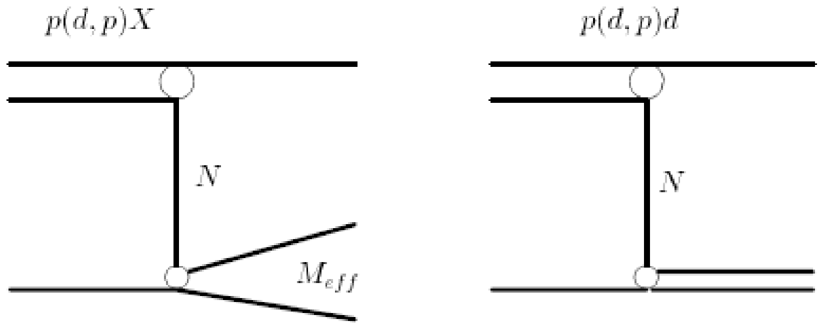


Deuteron breakup

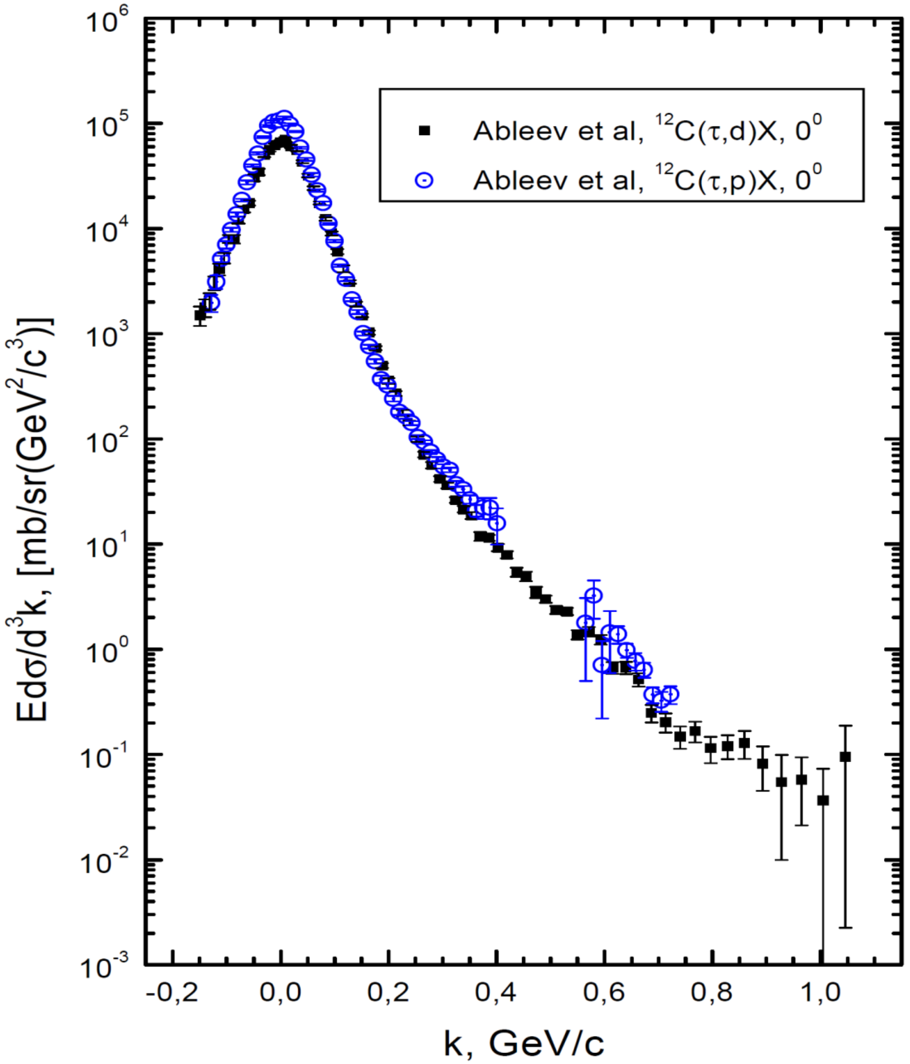
Elastic backward deuteron-proton scatteing

Deuteron structure at short distances: summary of the data (polarized beams)





- $M_{eff} = M_d$ $\Rightarrow$ elastic backward scattering
- $2\ M_N < M_{eff} < 2\ M_N + m_\pi$ $\Rightarrow$ "cold" breakup
- $M_{eff} > 2\ M_N + m_\pi$ $\Rightarrow$ "hot" breakup

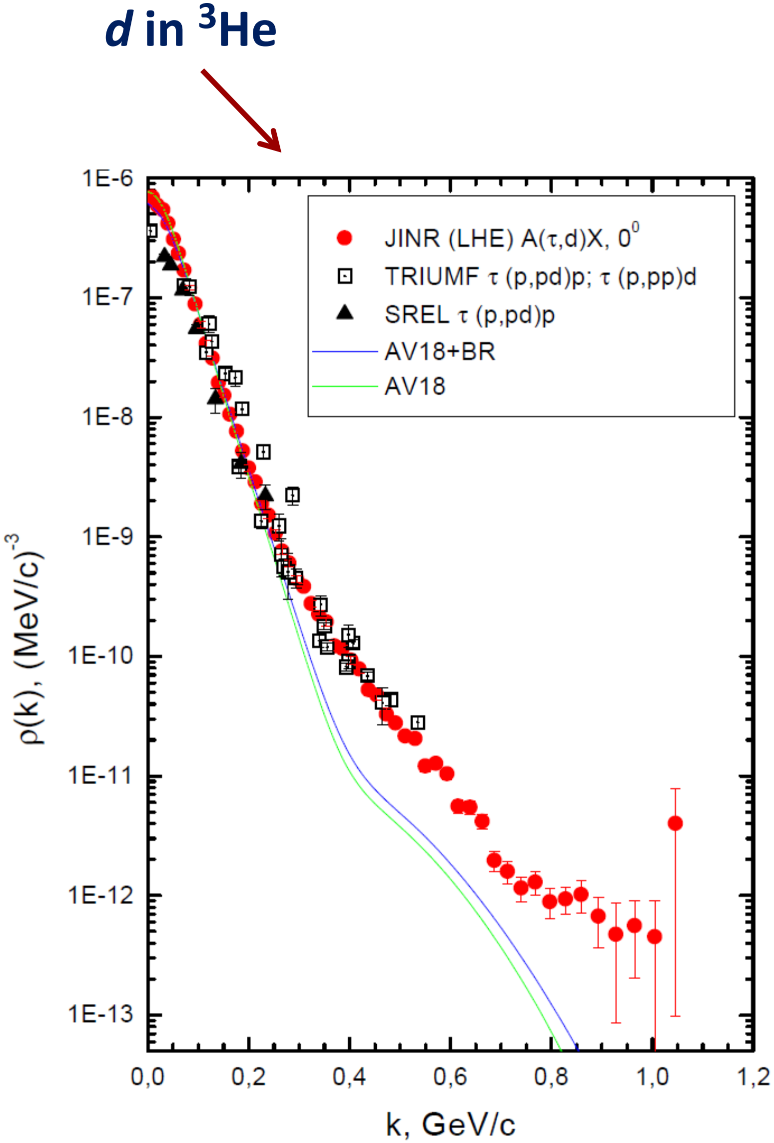


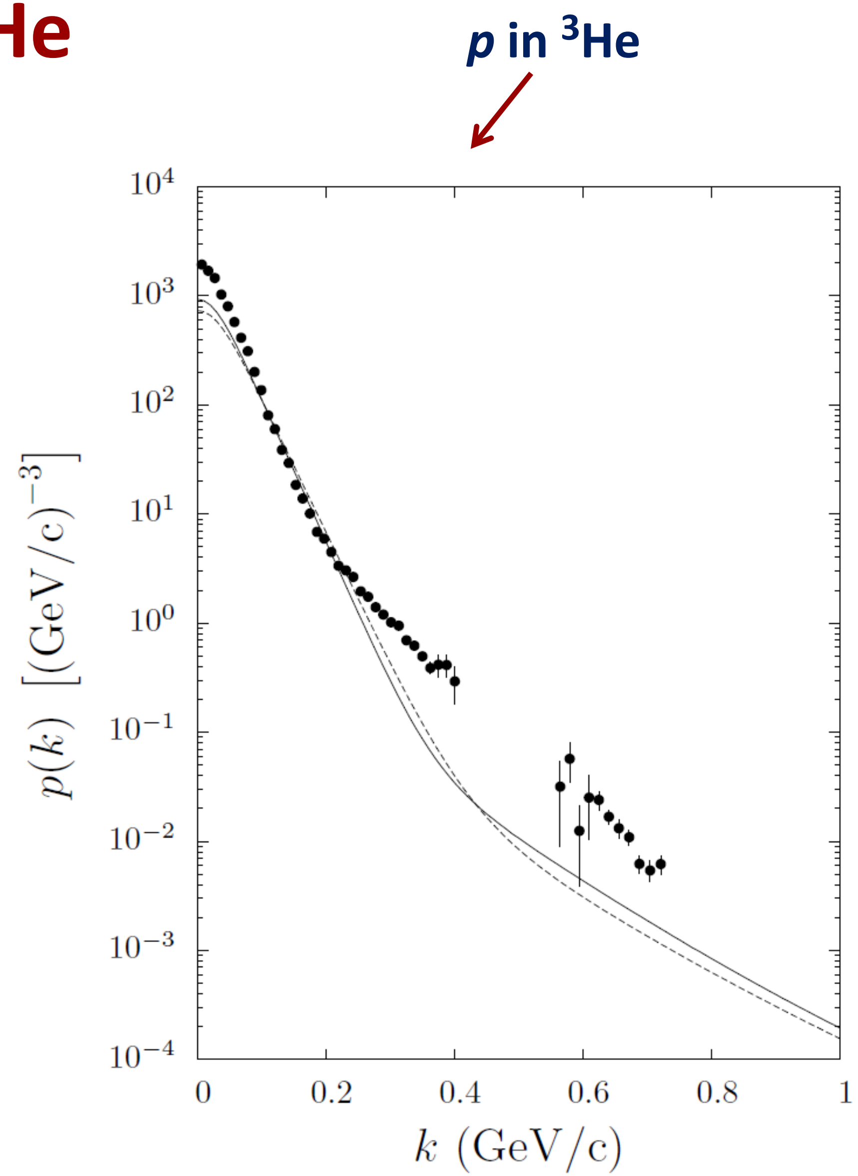
^{3}He

d and *p* in ^{3}He

Inclusive invariant cross sections for 3He breakup (0^0 in lab.syst.) into protons and deuterons versus the Light-Cone «internal» fragment momentum in 3He (see: Ableev V.G. et al, Pis'ma ZhETF 45 (1987) 467 (in Russian) and JETF Letters 45 (1987) 596 (in English)) .

^{3}He





Distribution of momentum density for constituents

^{4}He

t and *p* in ^{4}He

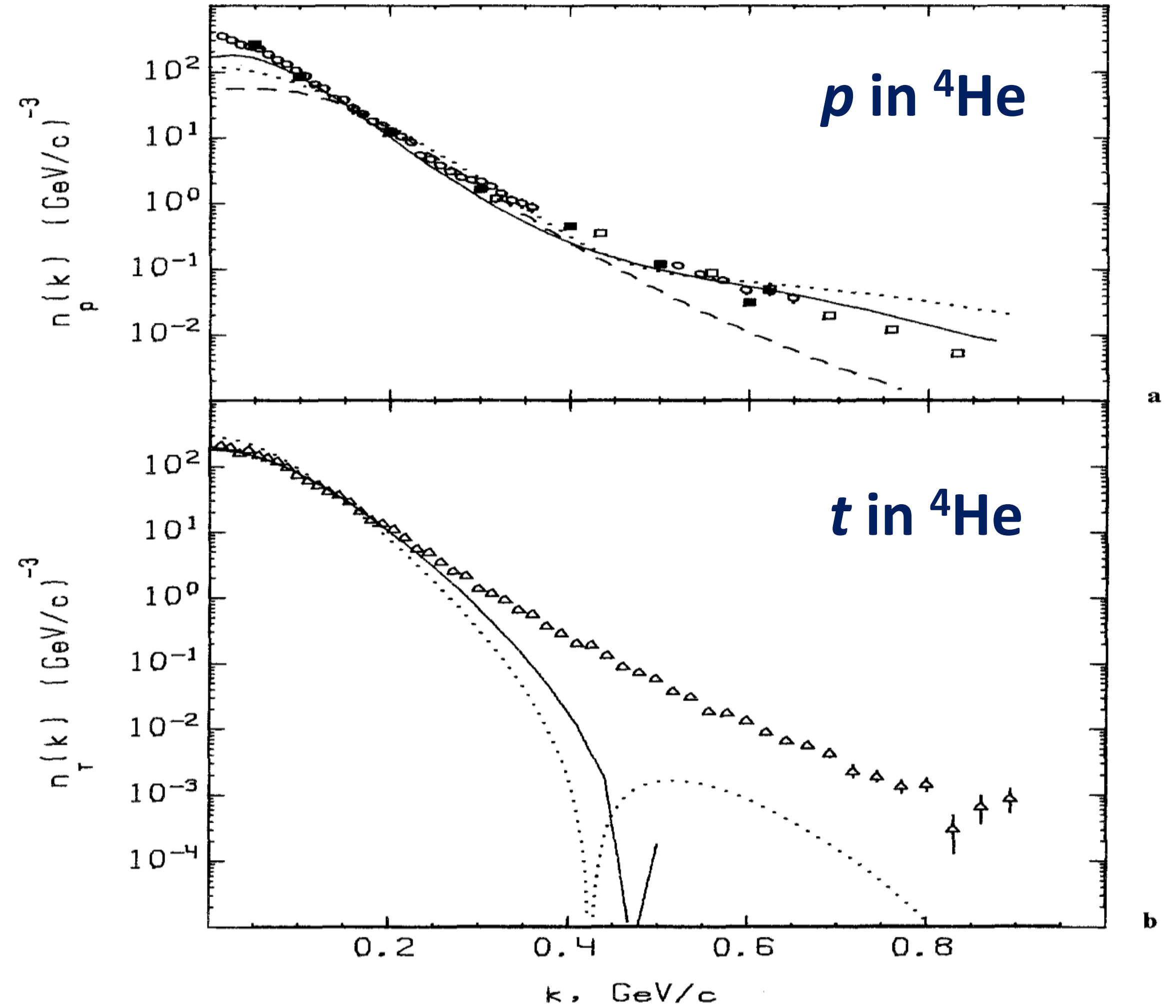


Fig. 3. a Comparison of the proton momentum distribution in ^{4}He from Fig. 2 (○ and □) with the data [13] (■), extracted from the ^{4}He(e, e') reaction, with the theoretical calculations [14] (solid line) and [15] (dotted line) using the Reid SC potential and with the flucton model calculations [16] (dashed line); **b** comparison of the triton momentum distribution in ^{4}He from Fig. 2 (△) with the theoretical calculations [11] (solid line) using the Urbana potential and [15] (dotted line) using the Reid SC potential

from the Synchrophasotron to the heavy ion collider

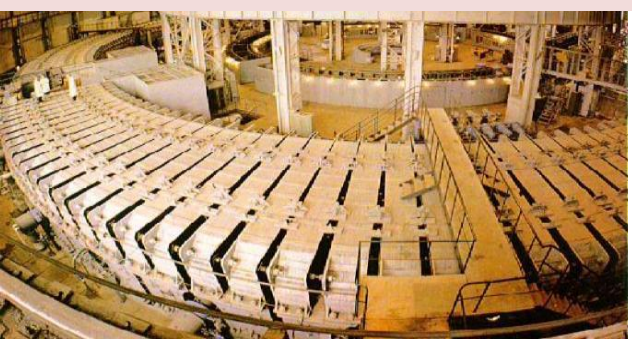
1957 Synchrophasotron	1993 Nuclotron	2020 NICA

10 GeV synchrotron (*p*) – leader in the energy

Origin of the high energy physics

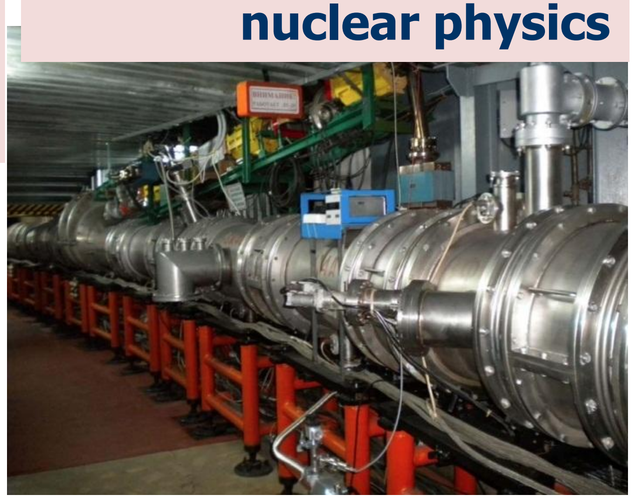
V.I.Veksler – the author of the *Phase Stability Principle*

(1944)



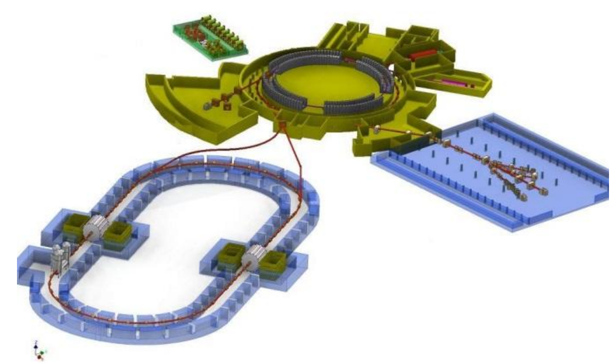
The first superconductive heavy ion accelerator

A.M. Baldin: pioneering studies in relativistic nuclear physics



Superconductive collider for heavy ions

Study of nuclear and baryonic matter at extremal densities



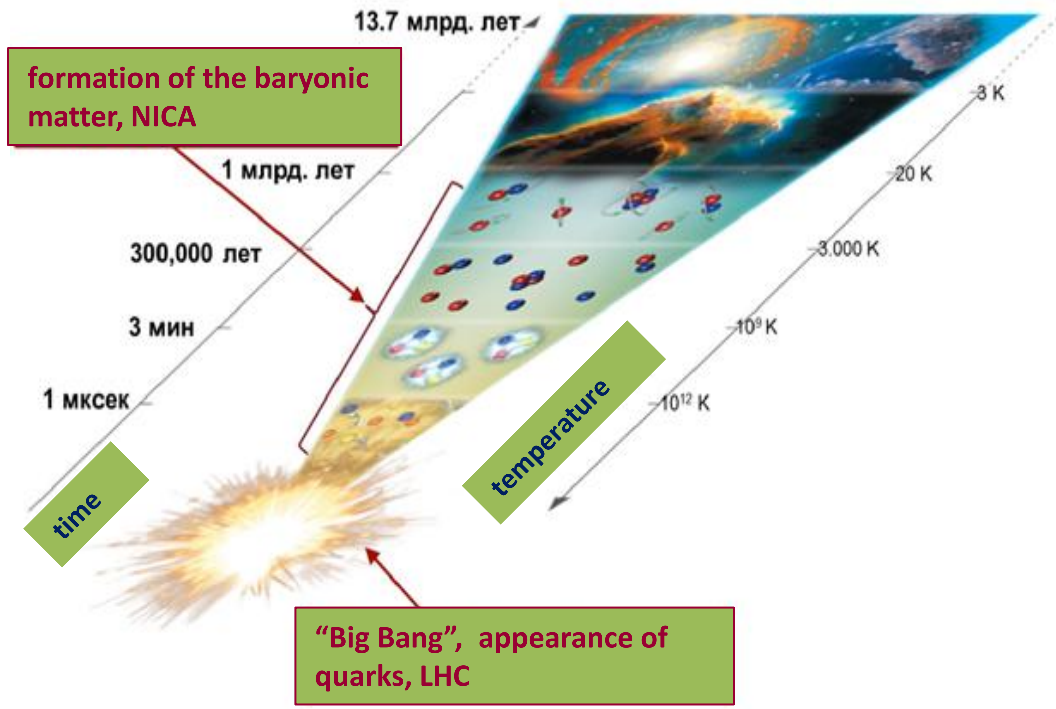
The main tasks of the NICA complex:

(see talks given on Monday by R. Lednicky, A. Sorin)

- ***study of hot and dense baryonic matter***
- ***study of the spin structure of nucleons and other polarization phenomena***

L H E P

J I N R

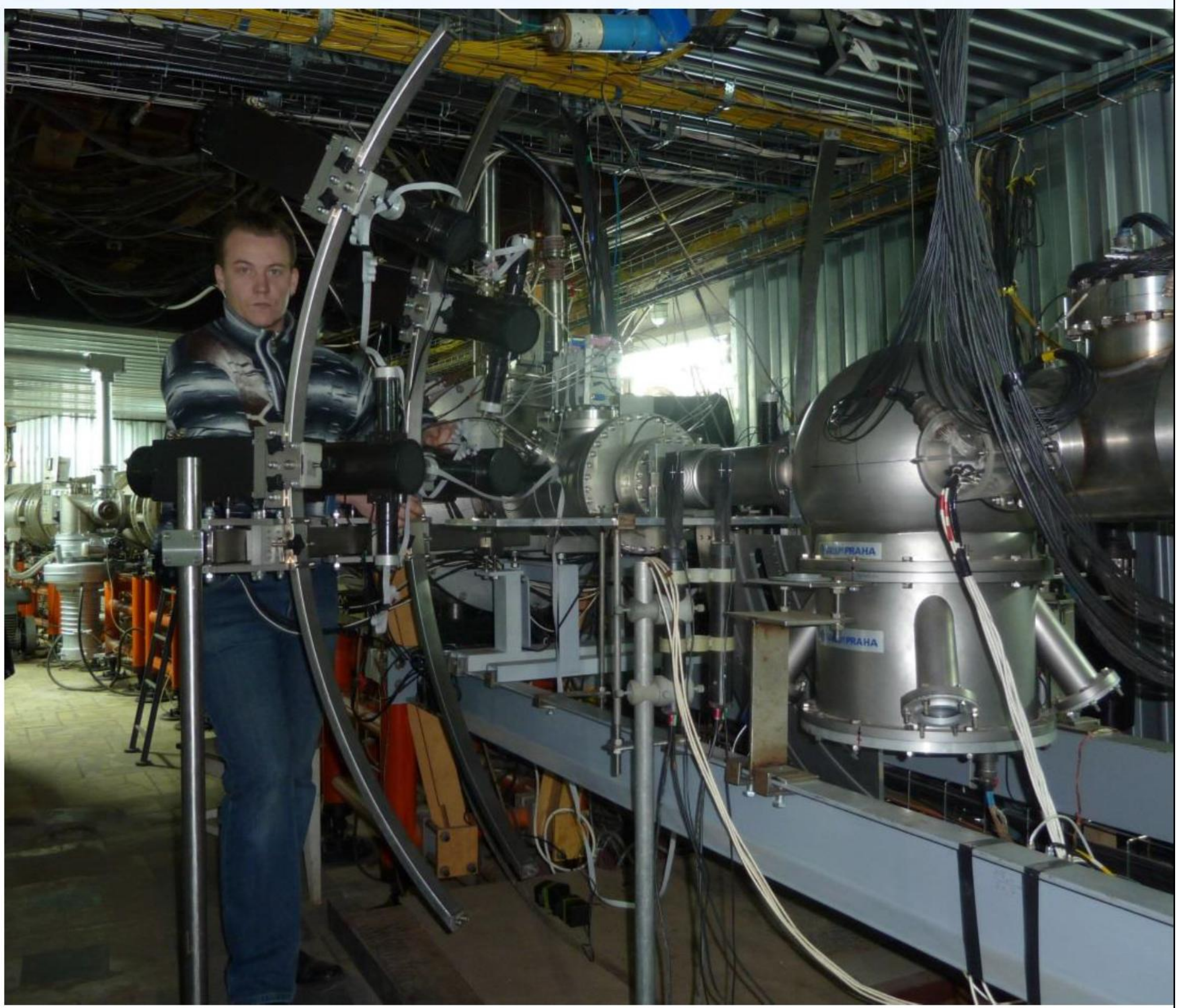


To do this, it is necessary:

- *to upgrade accelerator base in JINR, which is able to provide intensive beams from **p** to **Au** and polarized **protons and deuterons** with maximal energy up to* $\sqrt{S_{NN}}$ ***= 11 GeV (Au^{79+})*** *and* ***=27 GeV (p)***

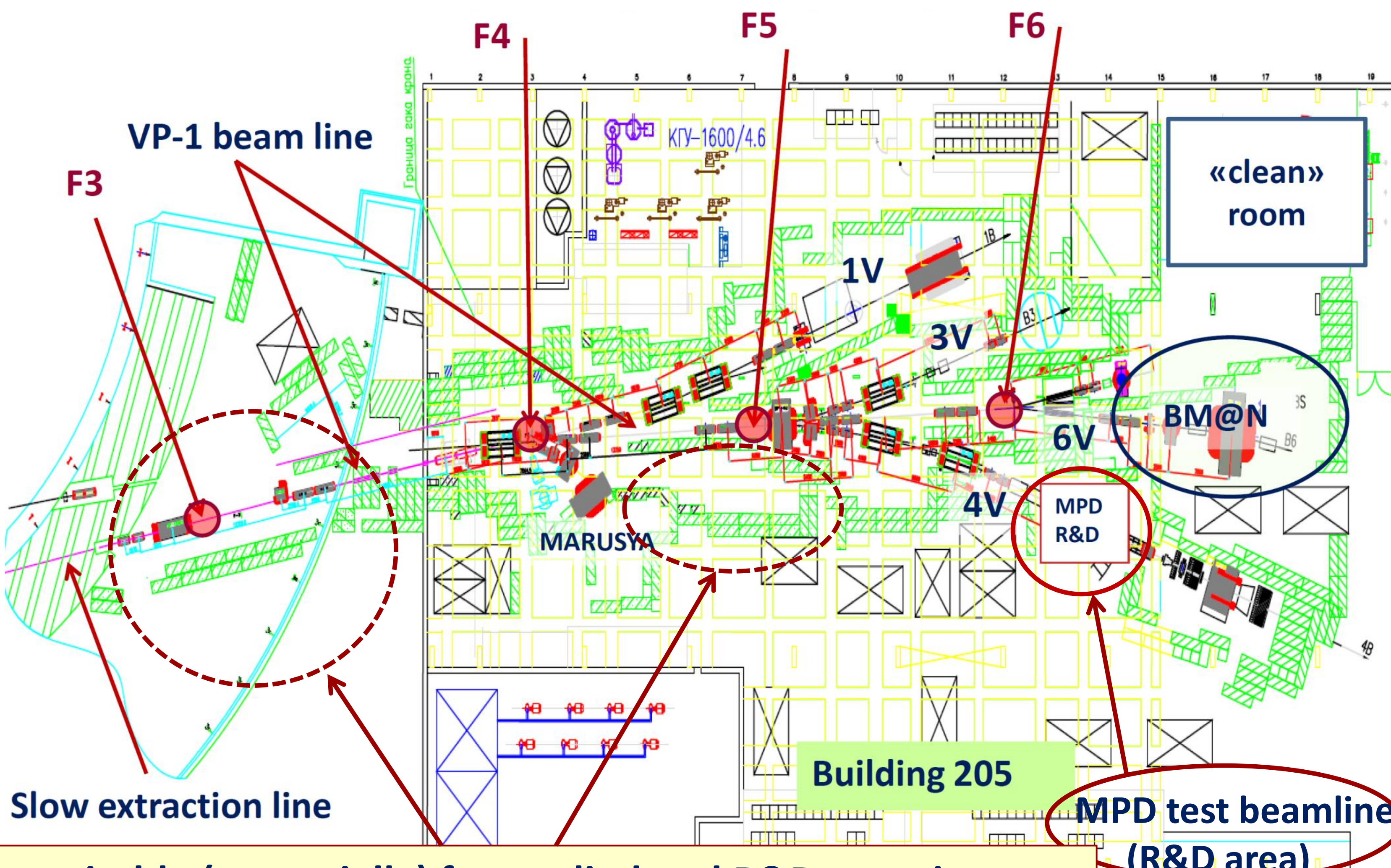
What users have now

Internal Target Station.



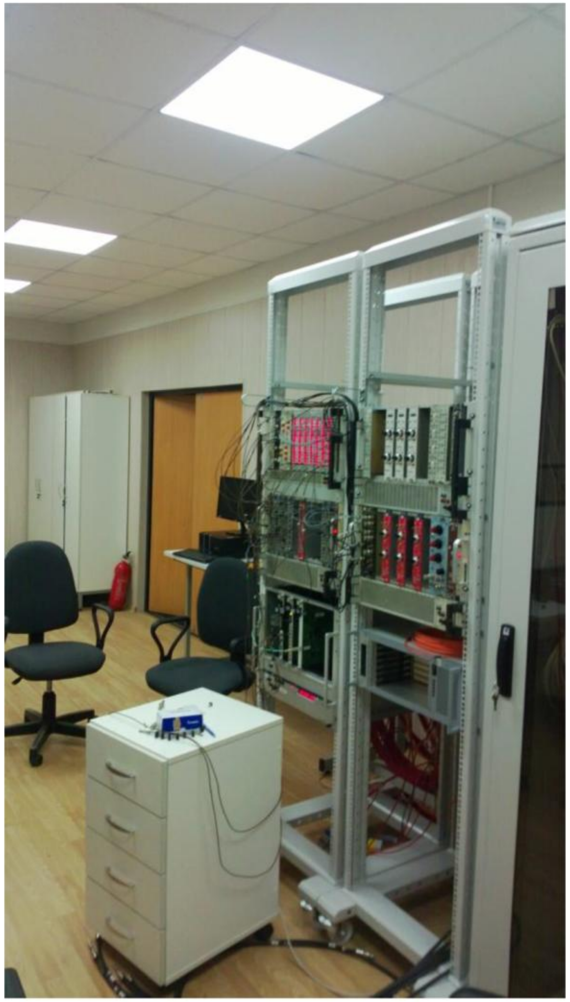
Extracted beams.

Map of beam lines for fixed target experiments at Nuclotron beams

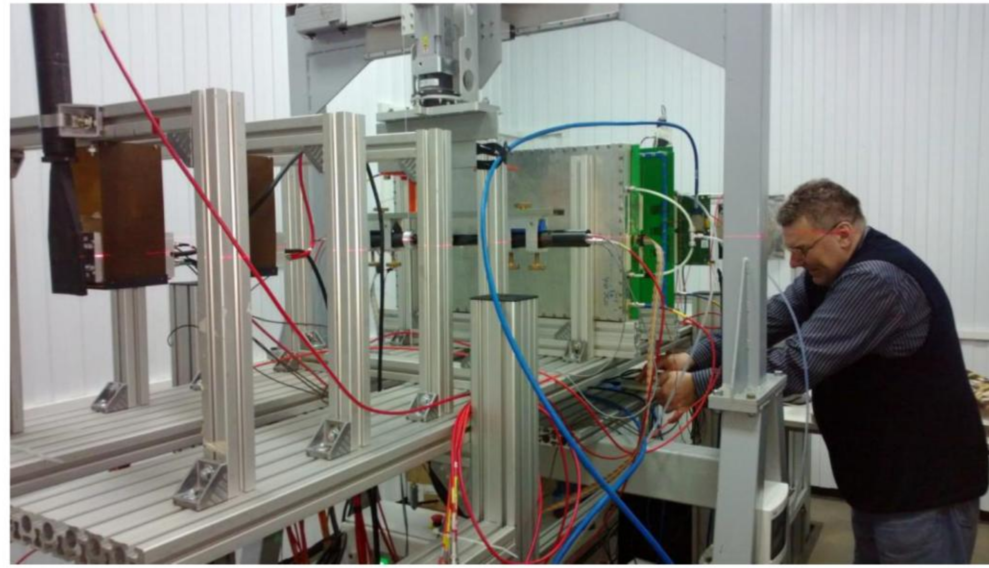


Areas suitable (potentially) for applied and R&D experiments

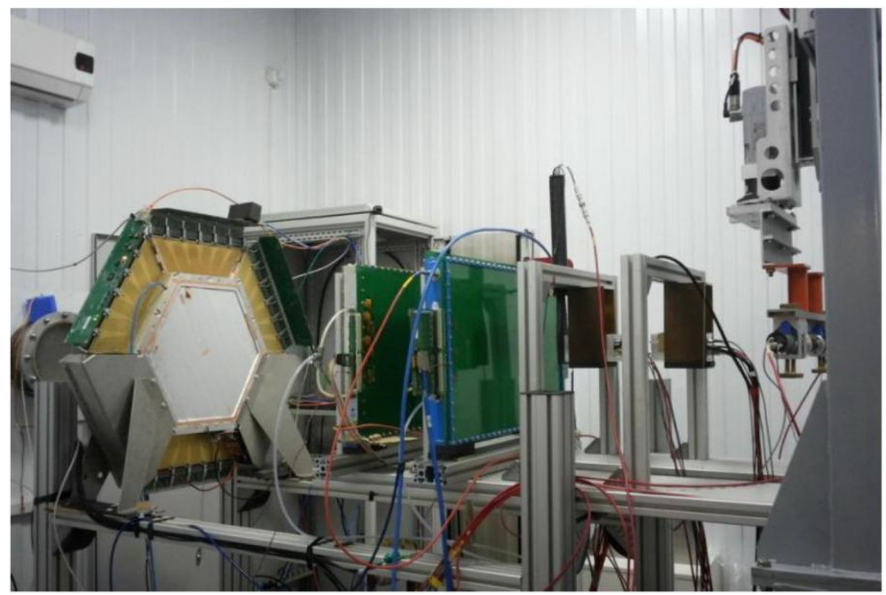
MPD test beamline:
new place to test detectors.



beam



beam

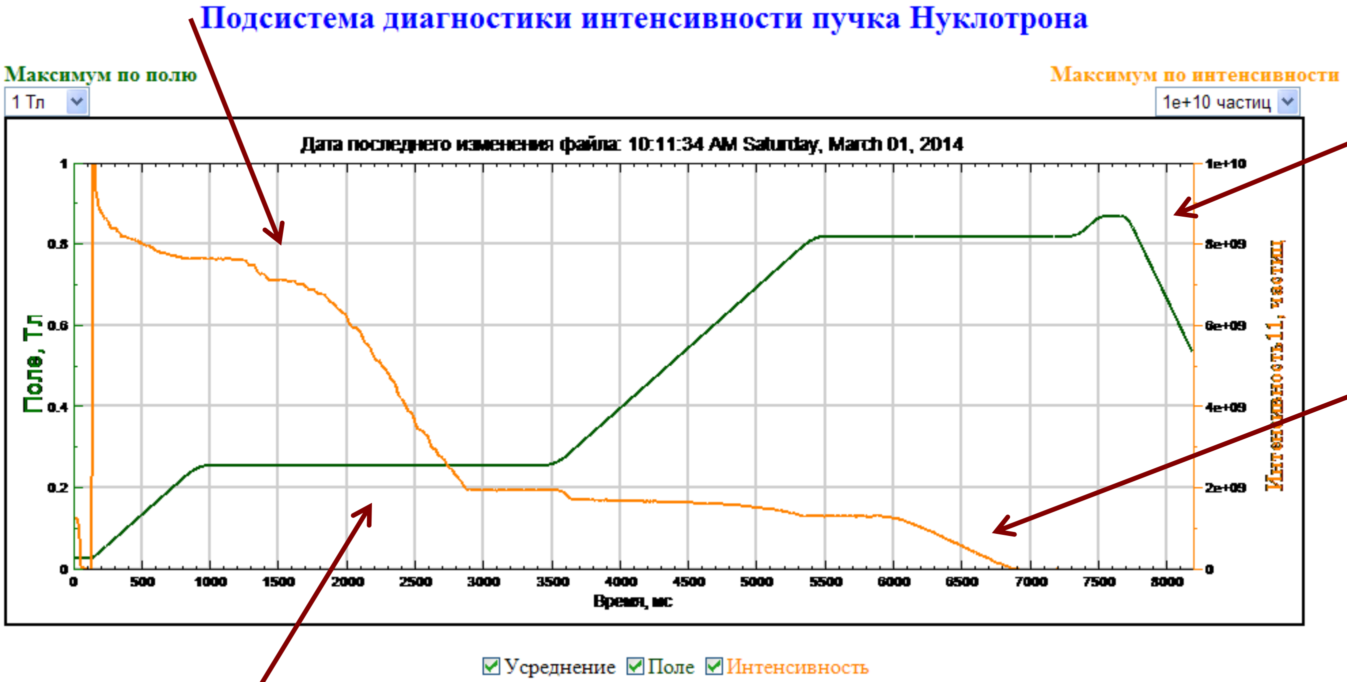


Control room

Area for beam tests of detectors

Internal beam intensity

Magnetic field of the machine



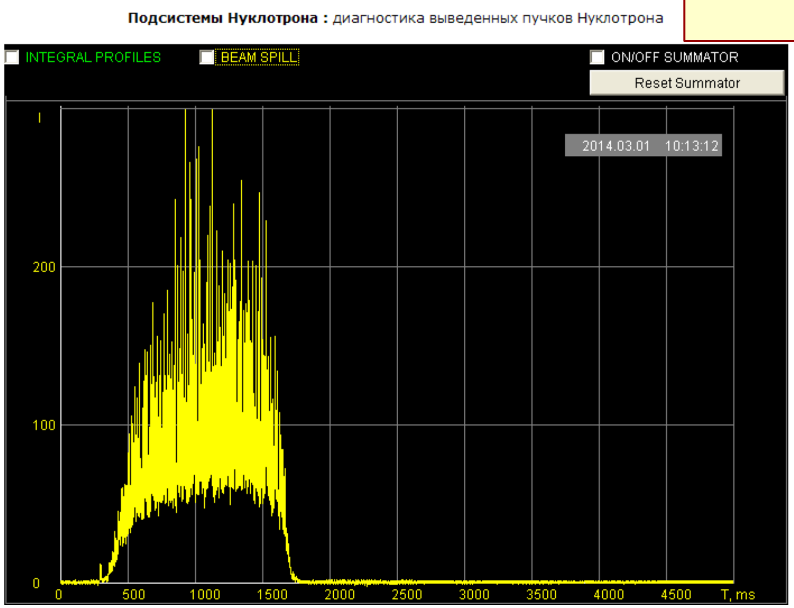
Extracted beam:

(MPD-test beamline)

Two flat-tops regime

Internal Target Station

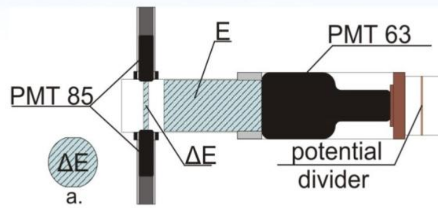
(the DSS project)



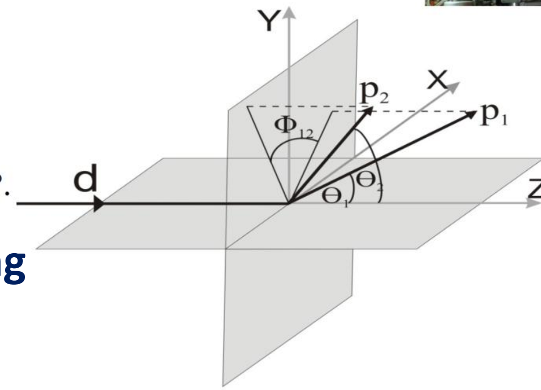
This regime is now a regular option.

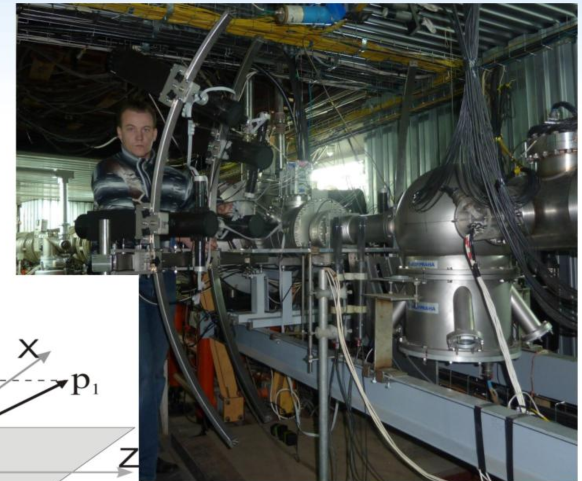
Selected experiments

Experiments at Internal Target Station.



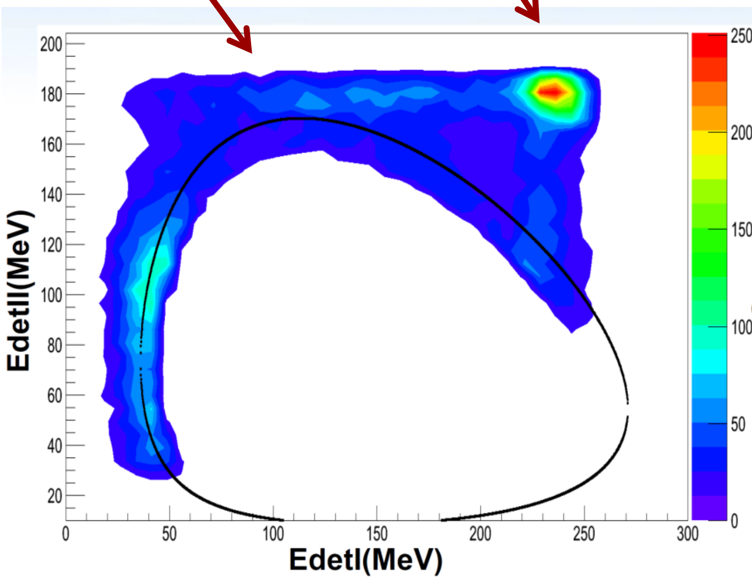
Θ (12°, 45°)
Φ (0°, 360°)
Space angle of
the detector 4.6°.





elastic dp scatering

dp→ppn breakup



Correlation of the two energies with the cut on missing mass.

Deuteron energy: 400 MeV.

Configuration: $\Theta_1=25^0, \Theta_2=43.6^0, \varphi_{12}=178.5^0$

dp-elastic scattering: 87^0 cms

Energy deuteron: 229.7MeV

Energy proton: 170.32MeV

Black curve – kinematic locus for dp-breakup reaction.

Internal Target Station.

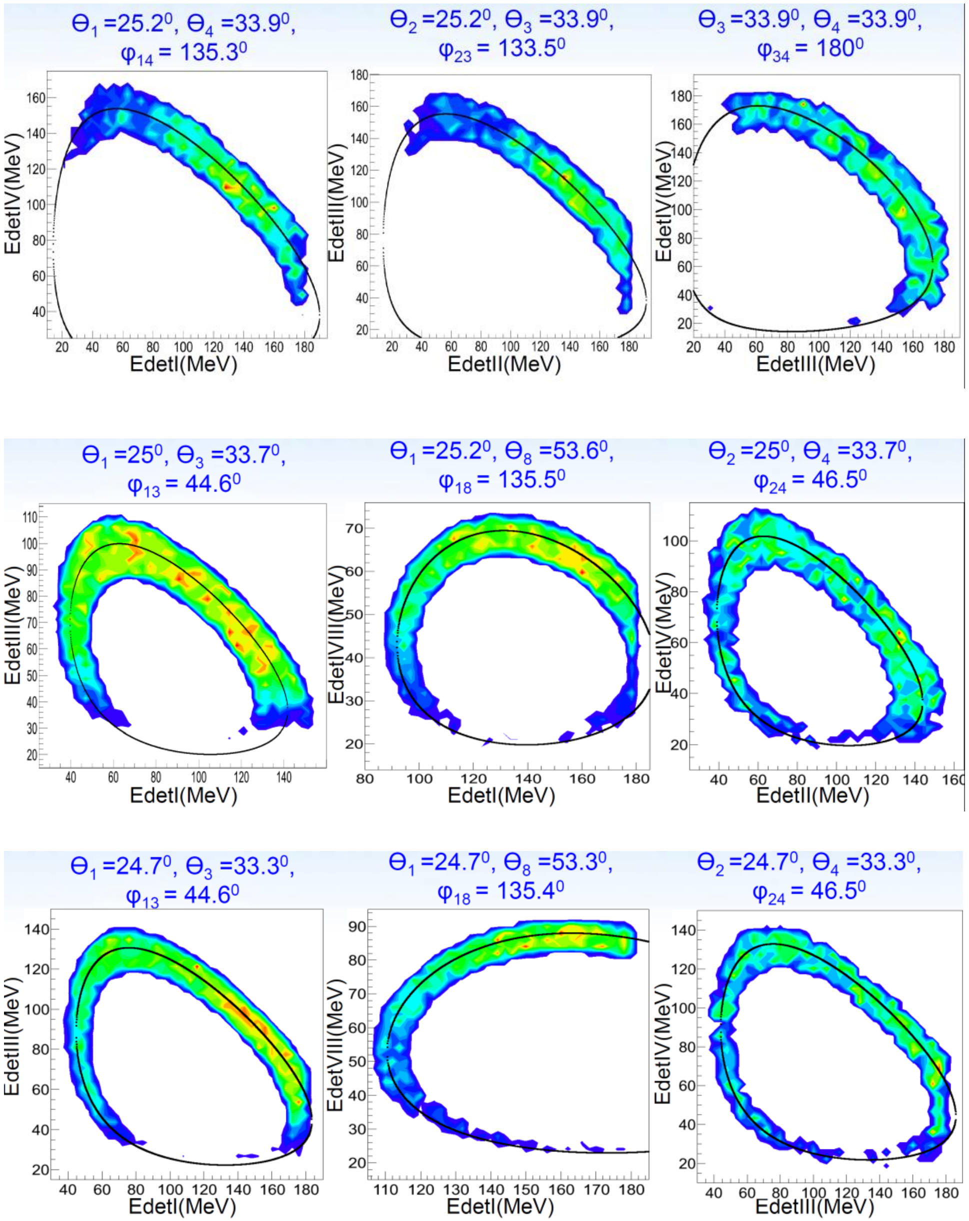
The DSS project: elastic dp scattering, dp→ppn breakup.

CH_2 - C method.

Next slides: after cut on the missing mass: M_{miss} within 940 ± 10 MeV/c^2

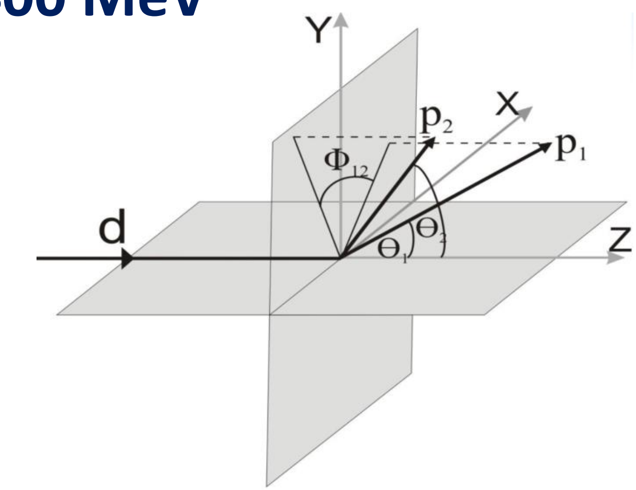
dp→ppn breakup

(reported at IBSHEPP-XXII, Sept. 2014)



T_d = 300 MeV

T_d = 400 MeV

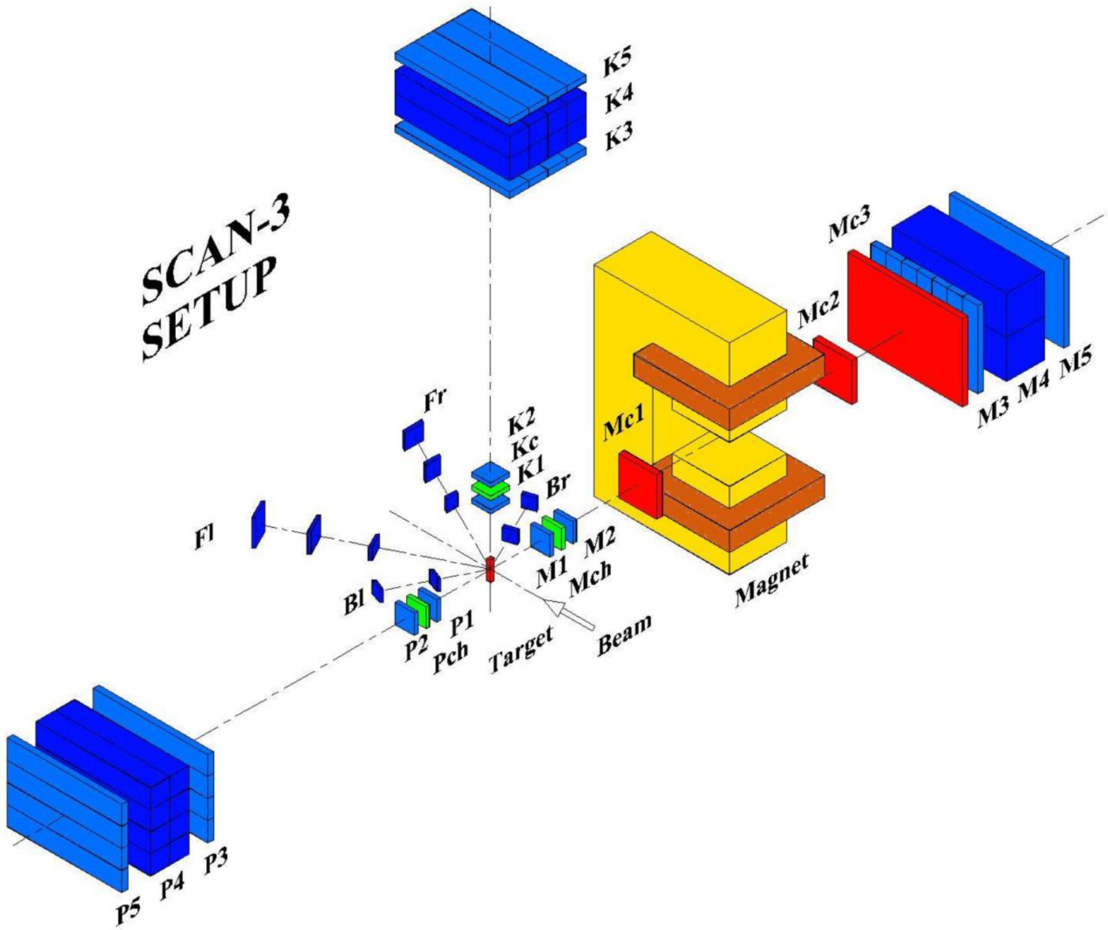


T_d = 500 MeV

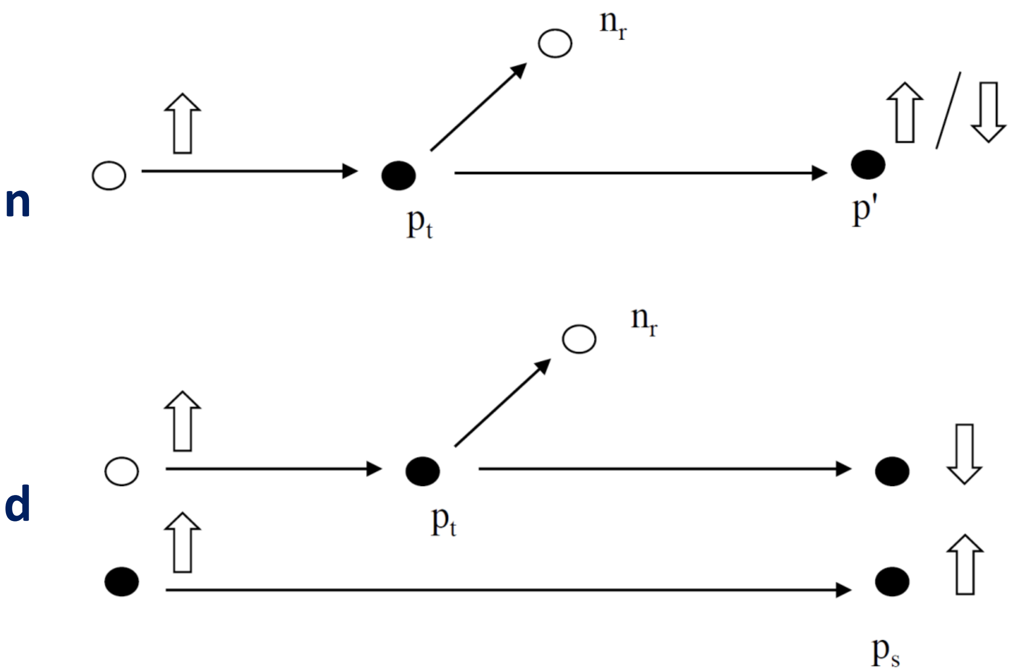
Analysis of new data is in progress

SCAN-3 (*under preparation*): *search for nuclei with η-meson as a constituent*; study of *np* and *pp* pair production, breakup of heavy nuclei into low energy fragments etc.

Internal Target Station will be used.



Selected experiments at extracted beams



Unpolarized deuterons!

I. Pomeranchuk, DAN USSR LXXVIII, Issue 2 (1951) 249;
A.B. Migdal, ZhETP 28 (1955) 3;
L.I. Lapidus, ZhETP 32 (1957) 1437;
N.W. Dean, Phys. Rev. D5 (1972) 2832

$$\left(\frac{d\sigma}{dt}\right)_{dp\to(pp)n} = \left[1 - F_d\right]\left(\frac{d\sigma_{nf}}{dt}\right)_{np\to pn} + \left[1 - \frac{1}{3}F_d\right]\left(\frac{d\sigma_f}{dt}\right)_{np\to pn}$$

spin- nonflip **spin-flip**

$$\boxed{\left(\frac{d\sigma}{dt}\right)_{dp\to(pp)n} = \frac{2}{3}\left(\frac{d\sigma_f}{dt}\right)_{np\to pn}}$$

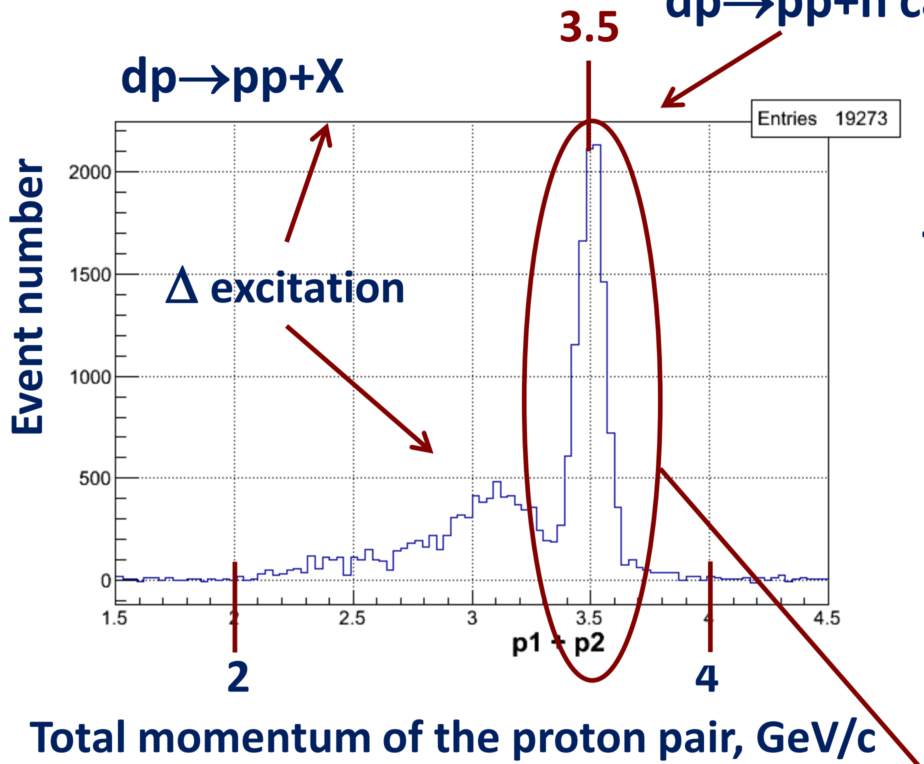
at $|t| \approx 0$

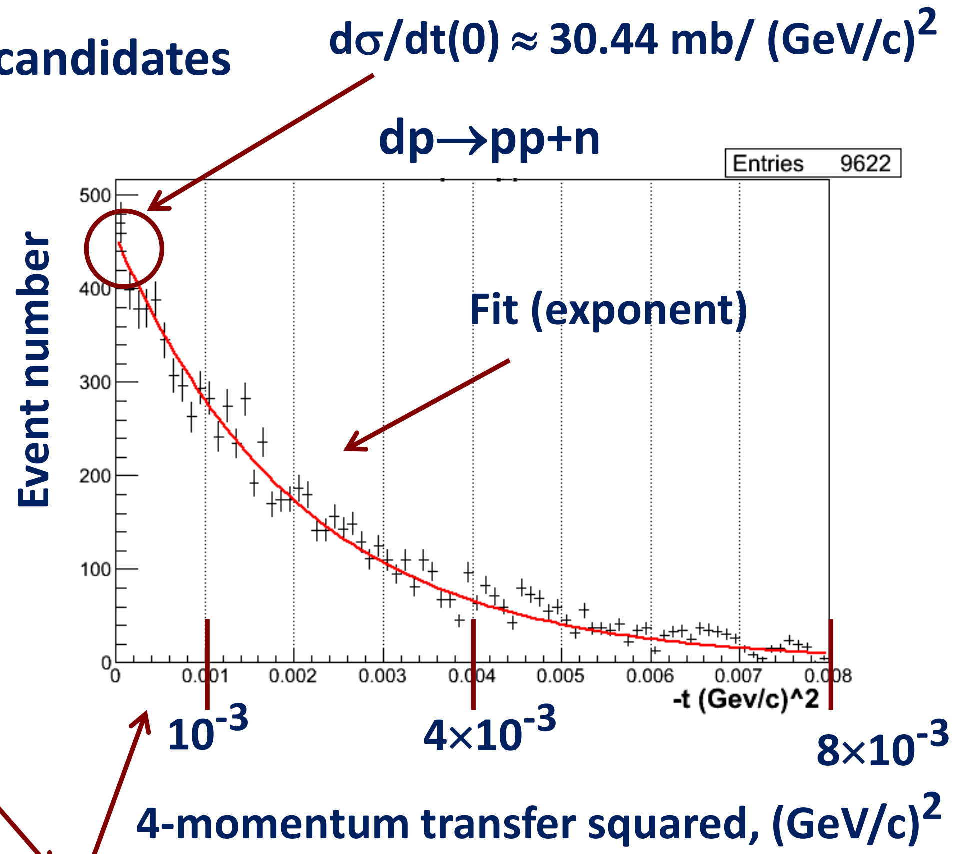
Project STRELA

Unpolarized deuterons!

2 protons emitted *at forward angles <2 deg.* were detected.

Deuteron momentum: 3.5 GeV/c. CH2-C subtraction.





Events from the peak selected by missing mass: must be around the neutron mass.

(Reported by V.V. Glagolev at IBSHEPP-XXII, Sept. 2014, Dubna)

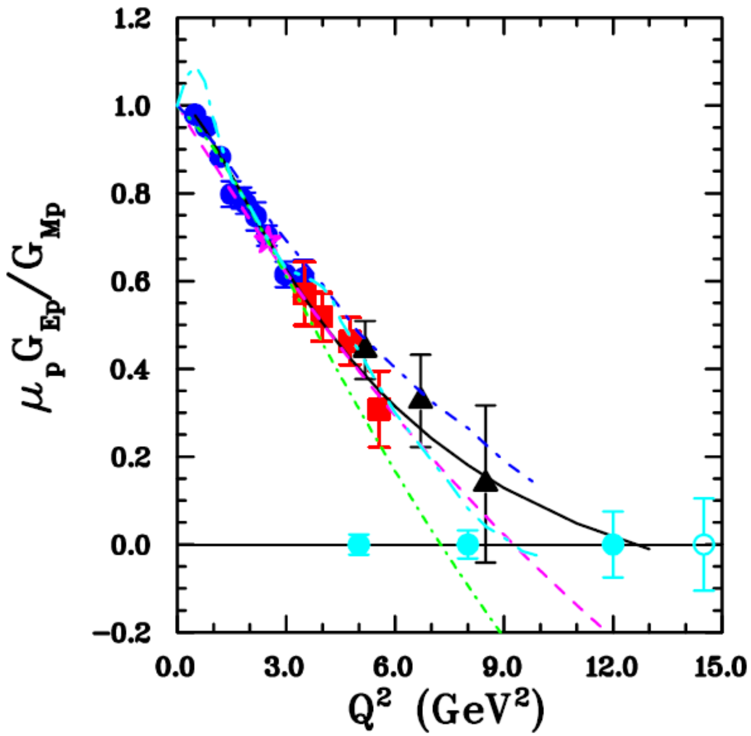
Other experiments (ongoing):

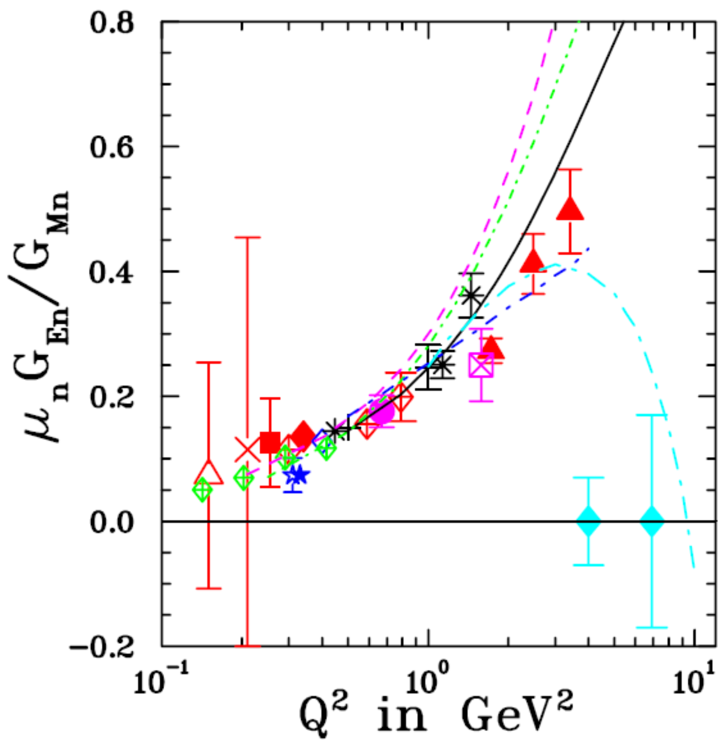
1. ***HyperNIS*** **(physics of hypernuclei, first of all – properties of loosely bound hypernuclei with neutron excess)**
2. ***FAZA*** **(nuclear multifragmentation and "liquid to fog" phase transition of the nuclear matter)**
2. ***MARUSYA*** **(cumulative production; currently – R&D of detectors for beam diagnostics)**
4. ***ALPOM-2*** **(needs polarized deuteron for calibrating of polarimeter for new G_E/G_M experiment at JLAB).**
5. ***Radiation biology*** **(by LRB of JINR)**
6. ***Applied physics (E&T RaW)***

ALPOM-2: measurements of analyzing powers for polarimeters with analyzing targets from CH_2 and CH (active target) measuring polarizations of scattered **protons and neutrons** in the new G_E/G_M (as for **protons**, as for **neutrons**) experiment at JLAB.

Proton lab. momentum up to 7.5 GeV/c

Neutron lab. momentum up to 4.5 GeV/c

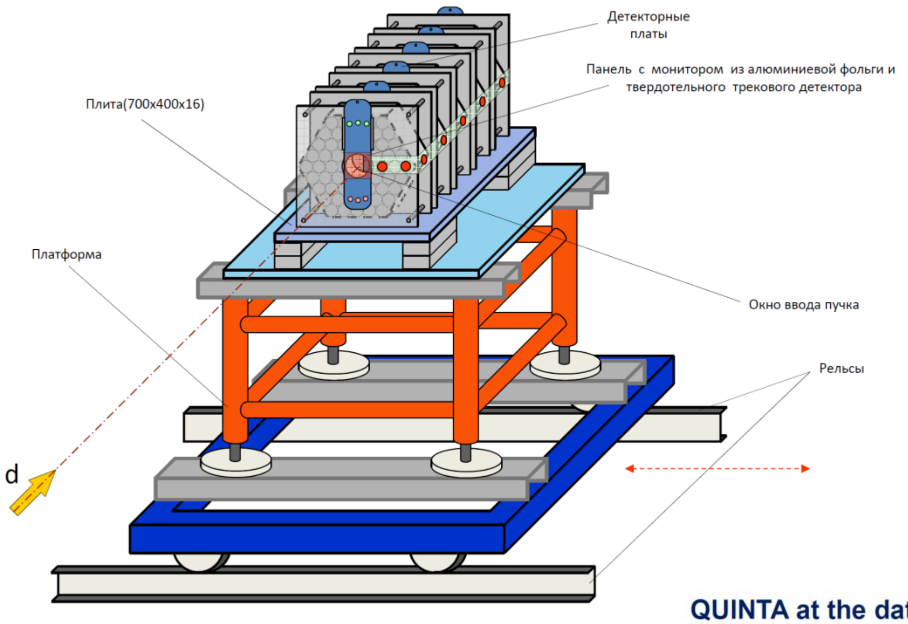




Applied physics

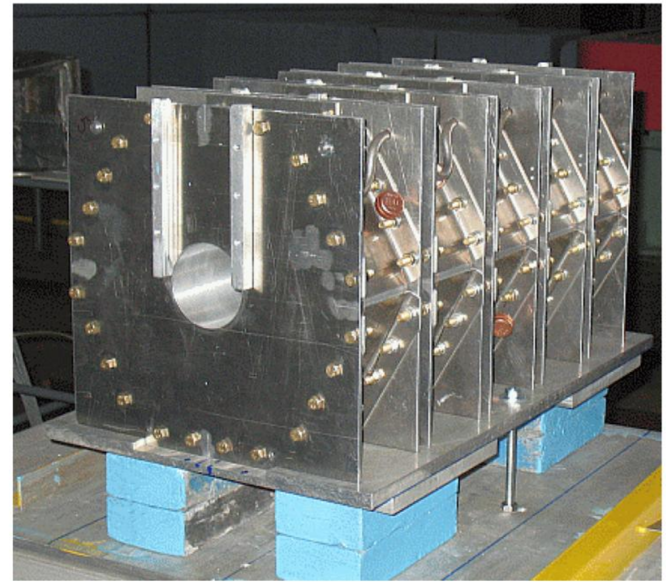
(E&T RaW project)

QUINTA at working position (extraction line, F3)

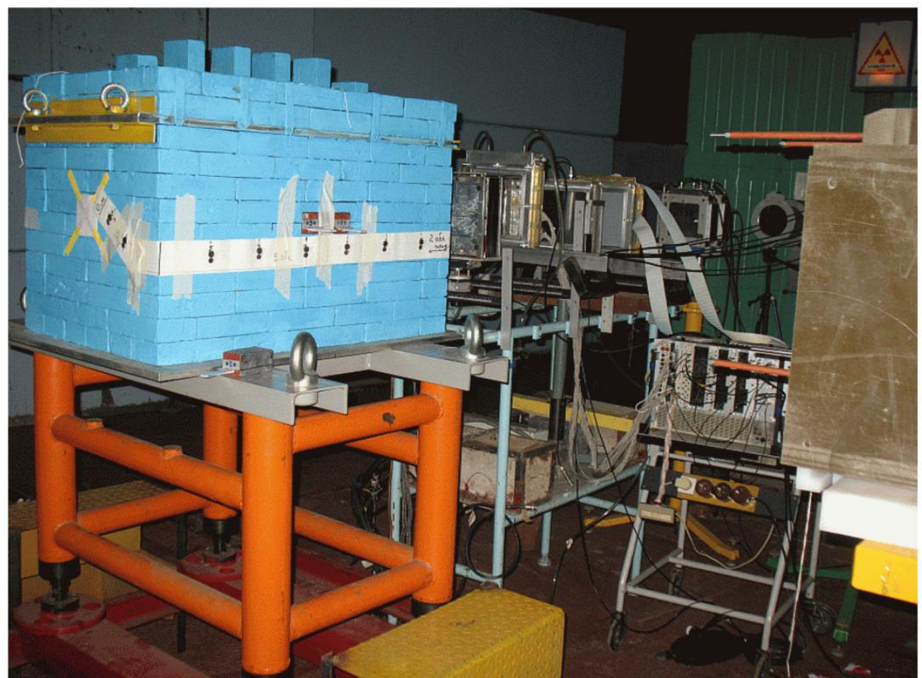


● - Точки расположения ТТД и АД на поверхности мишени «КВИНТА»

QUINTA target assembly



QUINTA at the data taking place (extraction line, F3) during runs 44 and 45

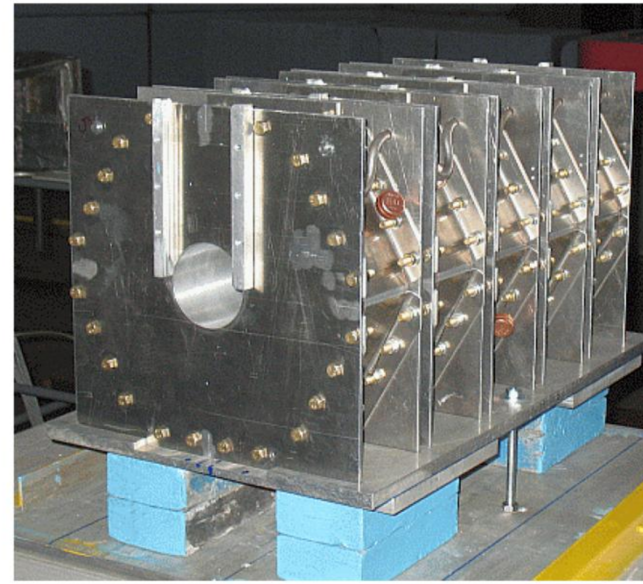


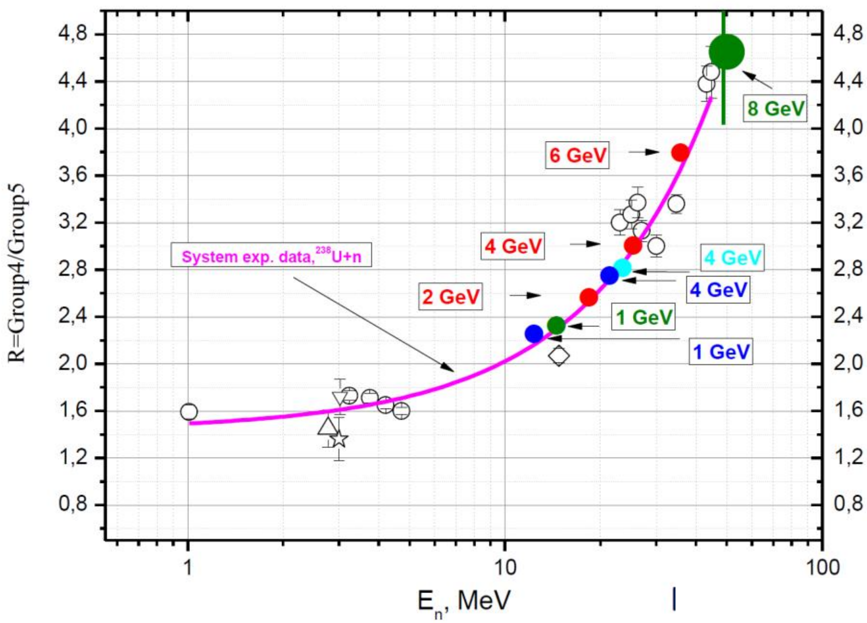
E&T RaW project

E.A. Strokovsky , 19 June 2015

For extended massive (500 kg, ø30cm x 65cm) uranium target assembly QUINTA irradiated by NUCLOTRON deuteron beams with energy from 1 to 8 GeV were firstly simultaneously measured the time spectra of delayed neutrons (DN) with aid of IZOMER-M detector and spatial distributions of ^{238}U fission rates. Beside that the first direct measurements of energy spectra of prompt leakage neutrons produced within the target assembly have been carried out by the liquid scintillation detector DEMON. These measurements revealed a large background of high energy neutrons... In contrary with previous calculations it was experimentally proved that in ADS with deep subcritical natural uranium target a total number of fissions increases linearly within studied incident energy range. The group analysis of DN time spectra indicates that fission of target ^{238}U nuclei is initiated by cascade neutrons with its mean energy growing with increase of the incident deuteron energy..

QUINTA target assembly

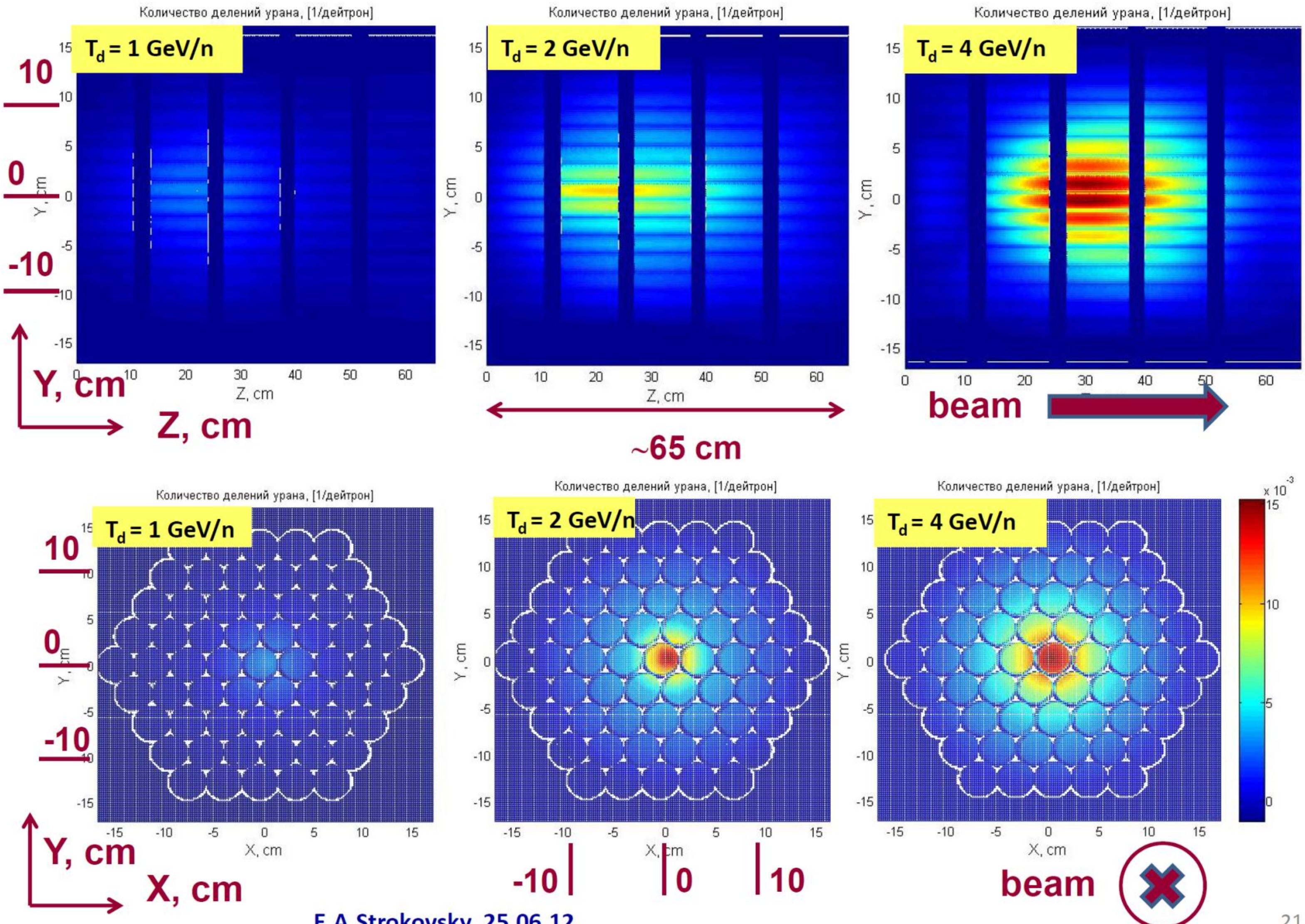




Run 03.2012	E_d = 1Gev	E_d = 4GeV	E_d = 8GeV
Method of measurement	Number of fission in QUINTA target assembly per 1 deuteron per 1Gev		
Track detectors	8.8 ±1.5	8.4 ±1.5	9.3 ±1.6
Activation method	9.6 ±1.6	8.8 ±1.3	9.8 ±1.6
Delayed neutrons	9.1 ±0.6 *Normalized*	8.5 ±0.6	11.5 ±0.9

Run 45 results

QUINTA , run 45: Number of fissions of U-238 in 1 cm^3 ; *colour scale: per 1 deutr.*



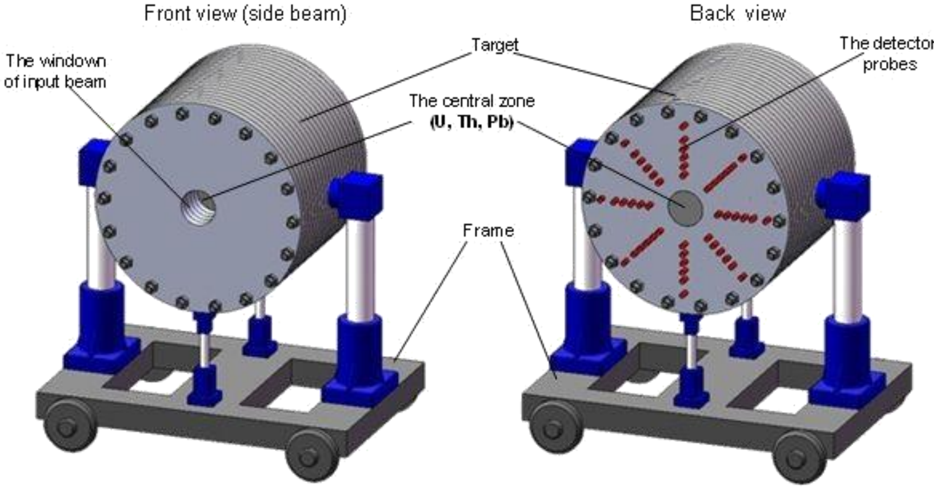
E.A.Strokovsky, 25.06.12

21

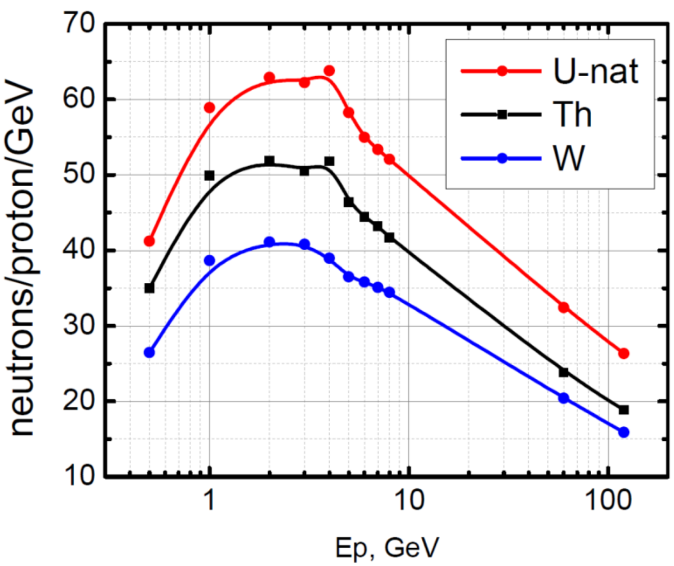
Next stage: new project "BURAN"

Fermilab-Conf-14-177-APC-TD
June 2014

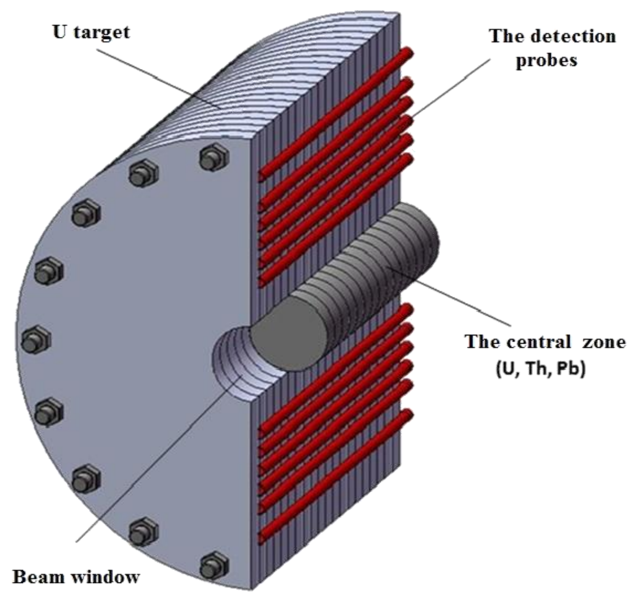
Calculated with MARS15 model

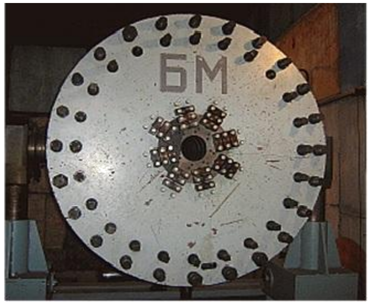


General view of the target setup BURAN at the transport-fixing platform.



Number of neutrons released per one proton per GeV in the target.





Back view

The scheme of longitudinal section of the TS BURAN with the mounted central zone (left) and general view photo (right).

Baryonic Matter at Nuclotron
(the *BM@N* project)

(The flagship “fixed target” experiment)

The Baryonic Matter at Nuclotron (BM@N) project

- approved in 2012

The goal:

Search for the mixed phase and phase transition of strongly interacting matter in processes:

AA, pA and pp interactions

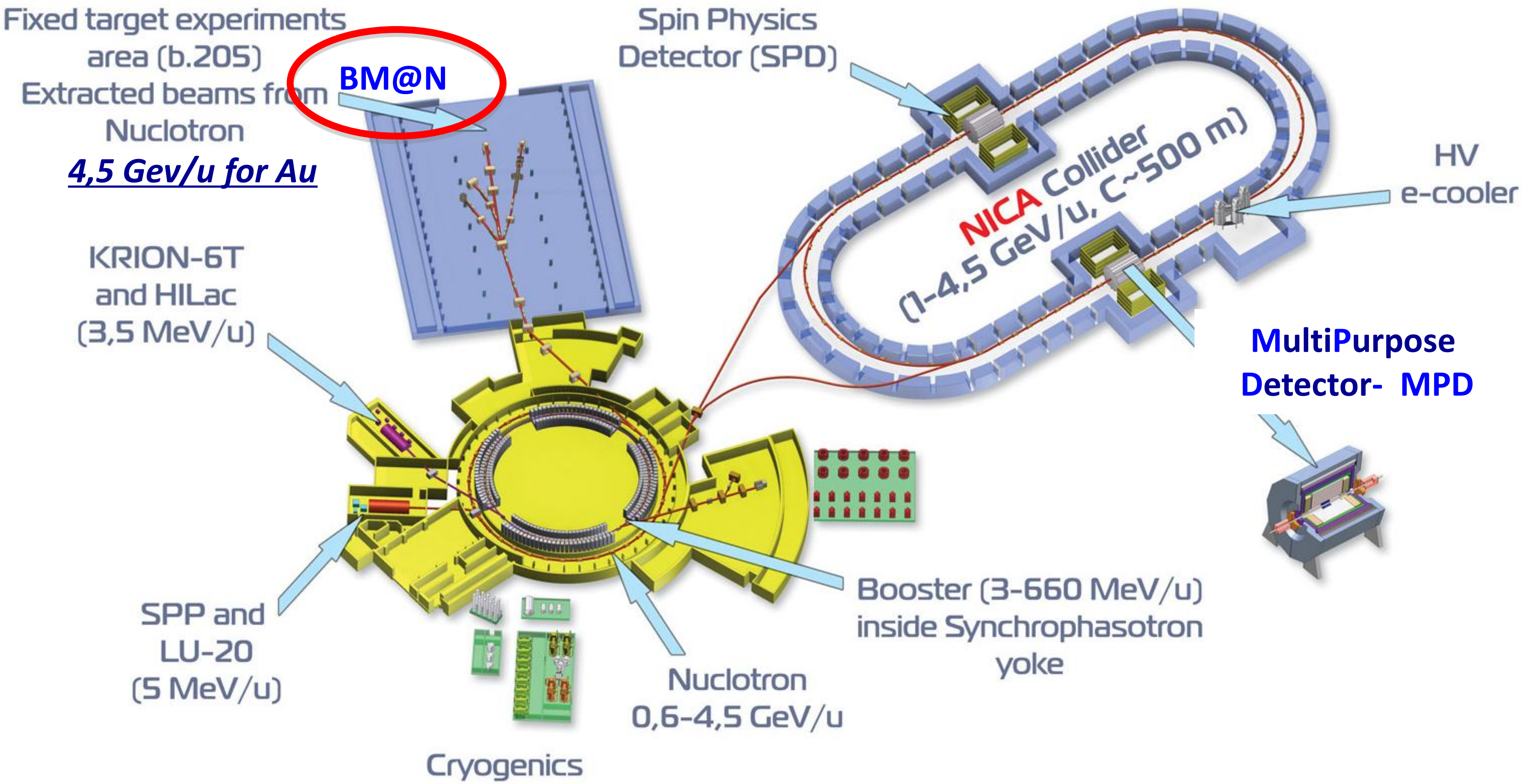
using variety of nuclei A (from p to Au)

scanning over energy range: E_{beam} = 1 – 6 GeV / nucleon

Strategy: beam energy & nucleus scan

19 scientific centers: INR, SINP MSU, IHEP + 2 Universities (Russia);
GSI, Frankfurt U., Gissen U. (Germany): + CBM-MPD IT-Consortium + **….** *expressed an interest*

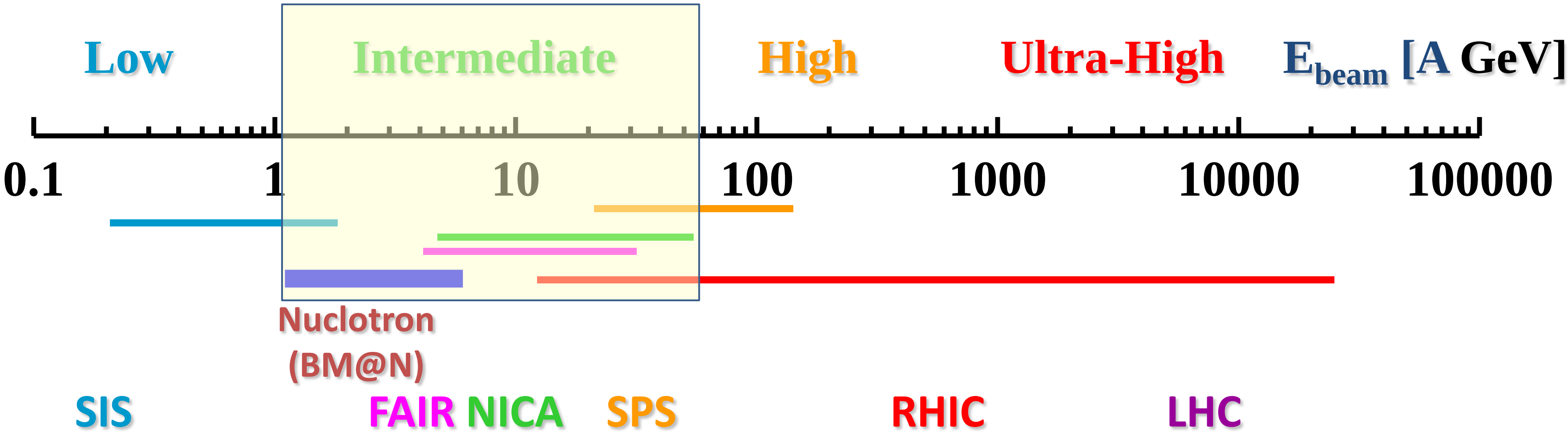
Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



Nuclotron parameters for BM@N:

- Energy range: Elab = 1-6 GeV /nucl
- Beams: from p to Au
- Intensity: 10^9 (Au), 10^{12} (p)

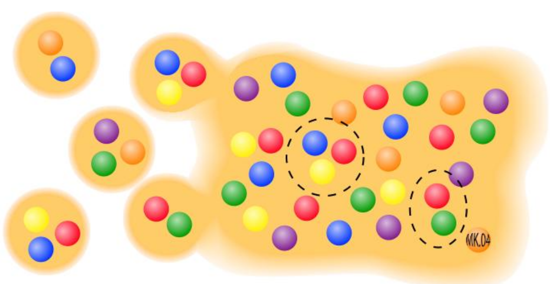
Heavy Ion Collision experiments



Baryonic matter
||
Meson and baryon spectroscopy
In-medium effects
EoS

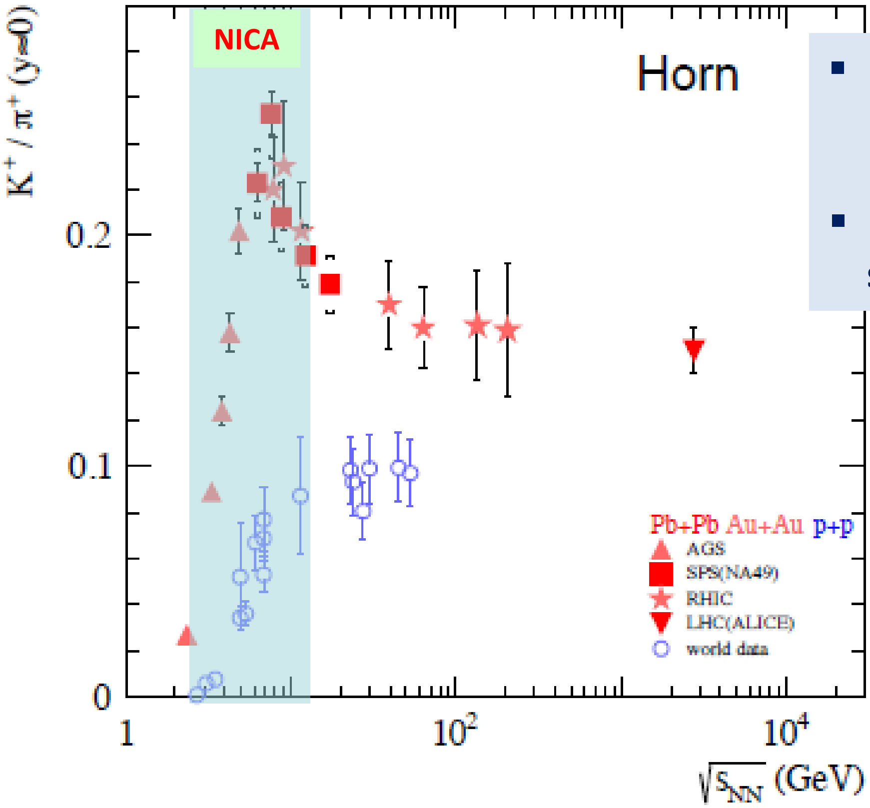
‚Mixed' phase:
hadrons (baryons, mesons) + quarks and gluons
||
In-medium effects
Chiral symmetry restoration
Phase transition to sQGP
Critical point in the QCD phase diagram

QGP: quarks and gluons
||
Properties of sQGP

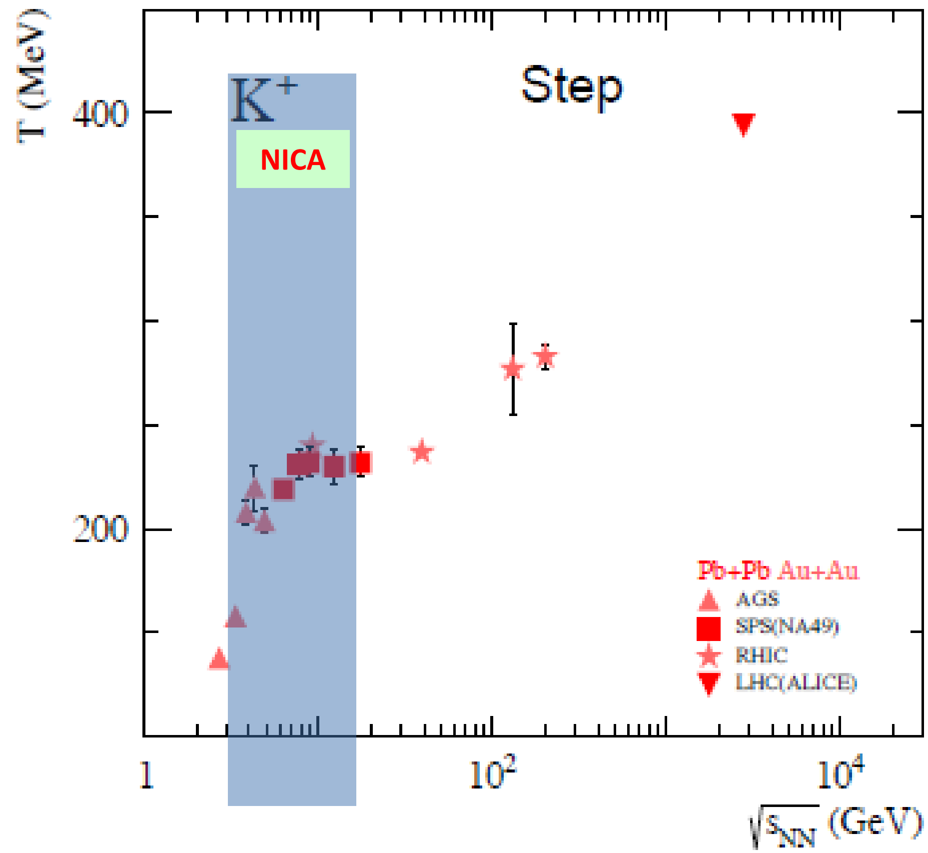


E.A. Strokovsky , 19 June 2015

Indications to onset of the deconfinement

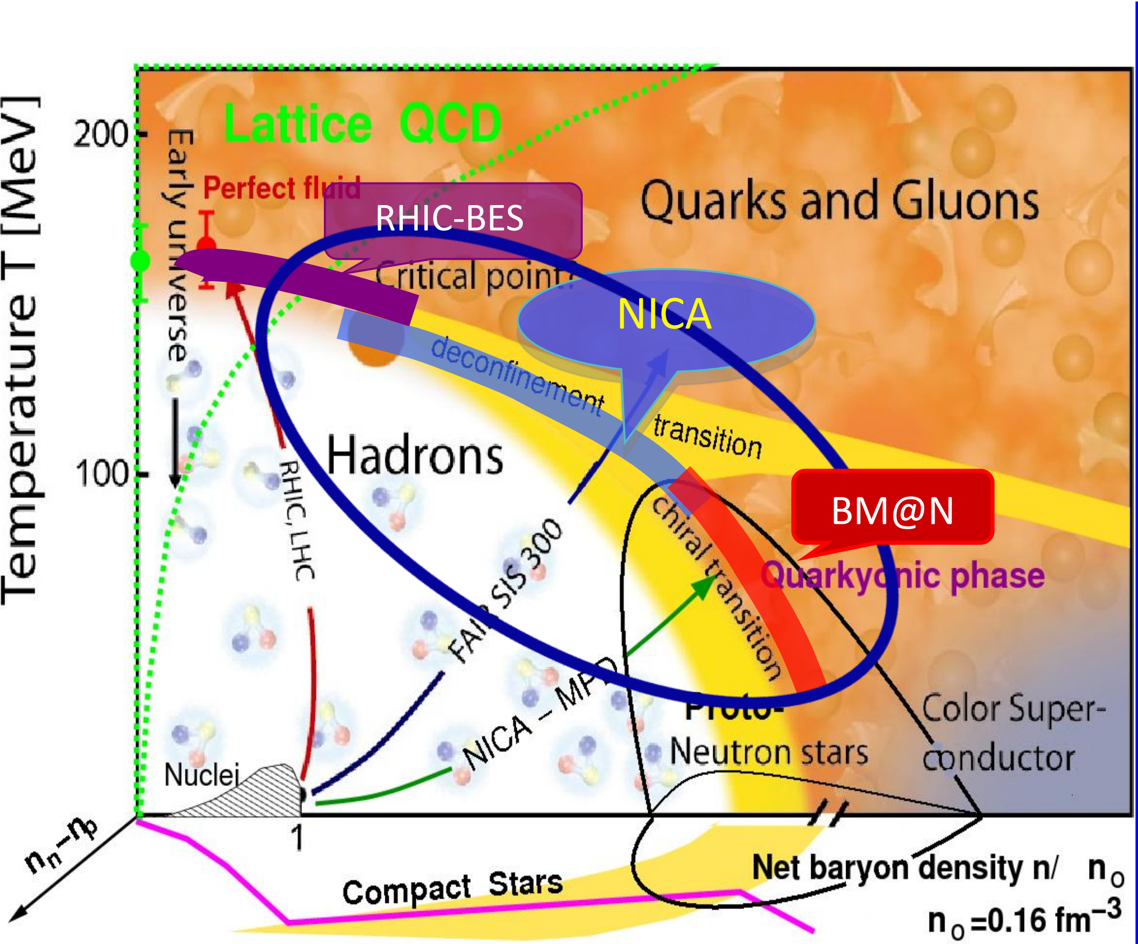


- Non-monotonic energy dependence of the K+/π+ ratio (the "Horn") – is it an onset of the deconfinement?
- Plateau in the apparent temperature of the kaon spectra ("Step") – possiblesignal of the mixed phase?



NA49 findings are confirmed by STAR and ALICE

QCD phase diagram - Prospects for NICA/BM@N



▪ **NICA/BM@N is complementary to RHIC/BES, FAIR, CERN experimental programs**

Search for the mixed phase of partons and hadrons:

- Signatures of deconfinement phase transition at high net baryon densities ρ_b

→ enhanced strangeness production (baryons and mesons)

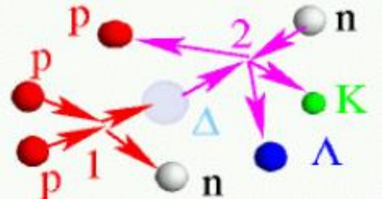
- Study of the Equation of State (EoS) at high ρ_b and temperatures

→ strange particle yields & ratios at thresholds, collective flows

- In-medium modification of hadron properties as a sign of chiral symmetry restoration at high ρ_b

→ onset of a low-mass di-lepton enhancement

- Y-N interactions in the dense nuclear matter and hyper-nuclei production



Study of „in-medium“ K$^+$ and K$^-$ properties in heavy-ion collisions at thresholds

- **baryon-baryon collisions:**

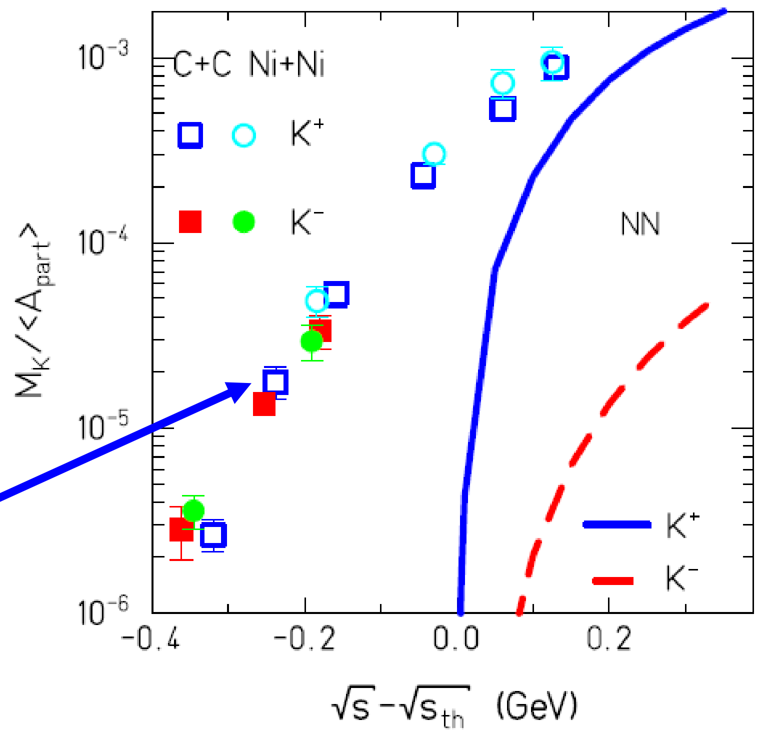
$$B+B \to B+Y+K$$
$$B+B \to B+B+K+\overline{K}$$
$$B+Y \to B+B+\overline{K}$$

$K=(K,K^0)$
$\overline{K}=(K^-,\overline{K}^0)$
$B=(N,\Delta,...)$
$Y=(\Lambda,\Sigma)$

- **meson-baryon collisions:**

$$\pi+B \to Y+K$$
$$\pi+B \to B+K+\overline{K}$$
$$\boxed{\pi+Y \to B+\overline{K}}$$

dominant channel for low energy K$^-$ production!



- **meson-meson collisions:** $\pi+\pi \to K+\overline{K}$

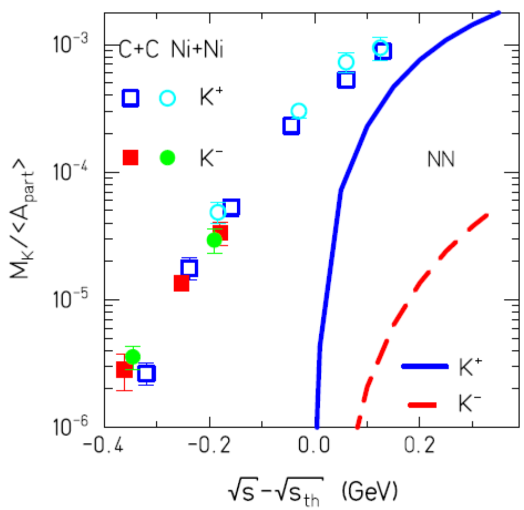
Opportunities at the Nuclotron

I. In A+A collisions at Nuclotron energies:

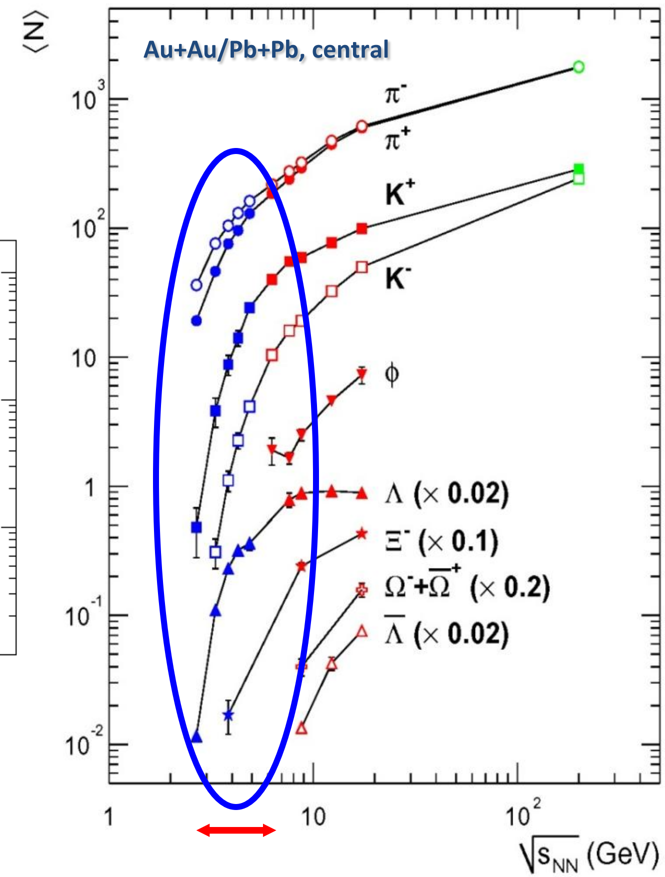
❑ Opening thresholds for strange and multi-strange hyperon production

➔ strangeness at thresholds

➔ More precise data for strange mesons and hyperons, multi- variable distributions, in the unexplored energy range are needed.



AGS NA49 BRAHMS



Nuclotron energies

II. In *p+p, p+n, p+A* collisions:

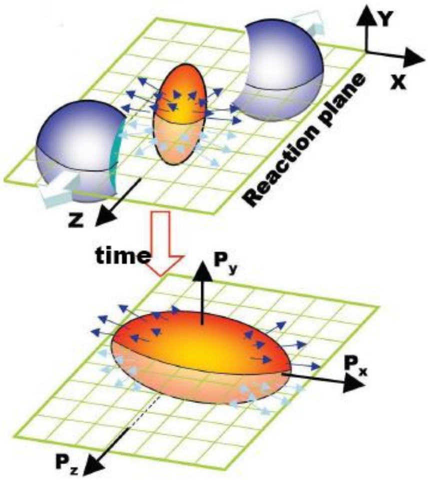
➔hadron production in elementary reactions and "cold" nuclear matter as a "reference" to pin down nuclear effects .

Heavy-ions A+A: in-medium effects

➔ **BM@N** can study the „in-medium“ effects for strangeness by measurements of a variety of observables for different energies and centralities in heavy-ion collisions in order to find an „anomalous“ behavior in comparison with theory

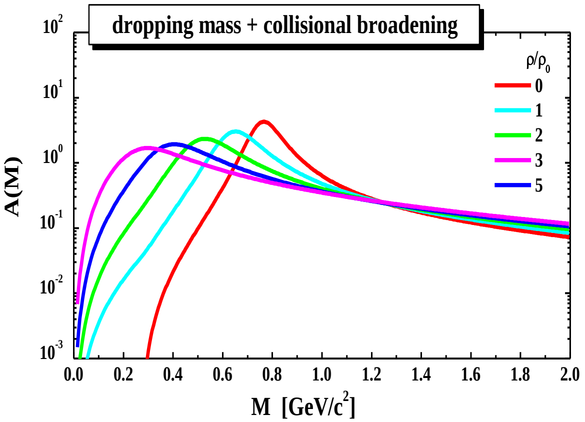
Observables sensitive to the „in-medium“ effects:

particle yields and ratios ;
p_T - (m_T)- spectra ;
rapidity distributions;
angular distributions;
collective flow (v_1,v_2,…)

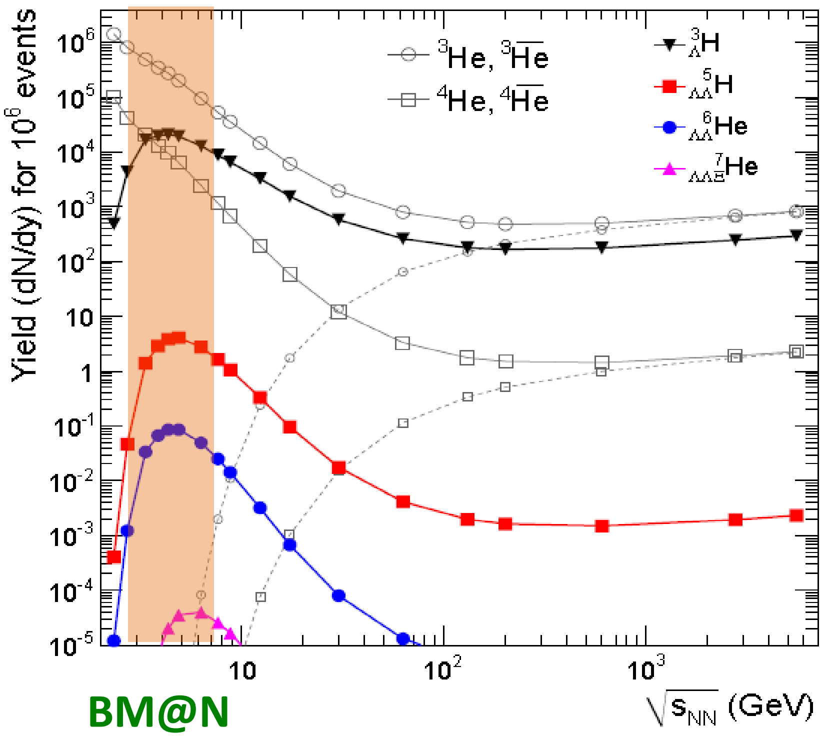


➔**BM@N (perspectives):** measurements of the „in-medium“ effects for vector mesons (V= ρ, ω, ϕ)

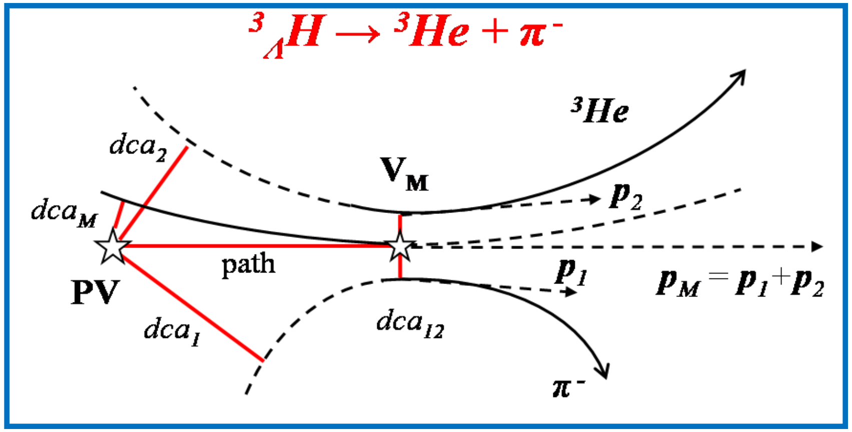
Optimal way – use “dilepton“ mode:
V➔e+e- or photon mode: $\omega \rightarrow \gamma\pi^0$.
Possible alternative: $\phi \rightarrow K^+K^-$ strong decay



Heavy-ions A+A: Hypernuclei production



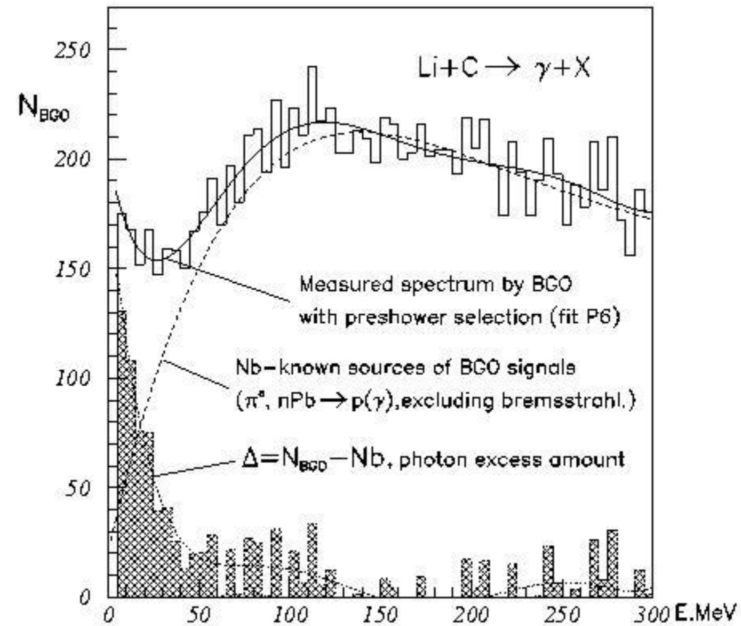
BM@N



- **In heavy-ion reactions:** production of hypernuclei through coalescence of Λ with light fragments enhanced at high baryon densities
- **Maximal yield** predicted for √s=4-5A GeV (stat. model) (interplay of Λ and light nuclei excitation function)

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

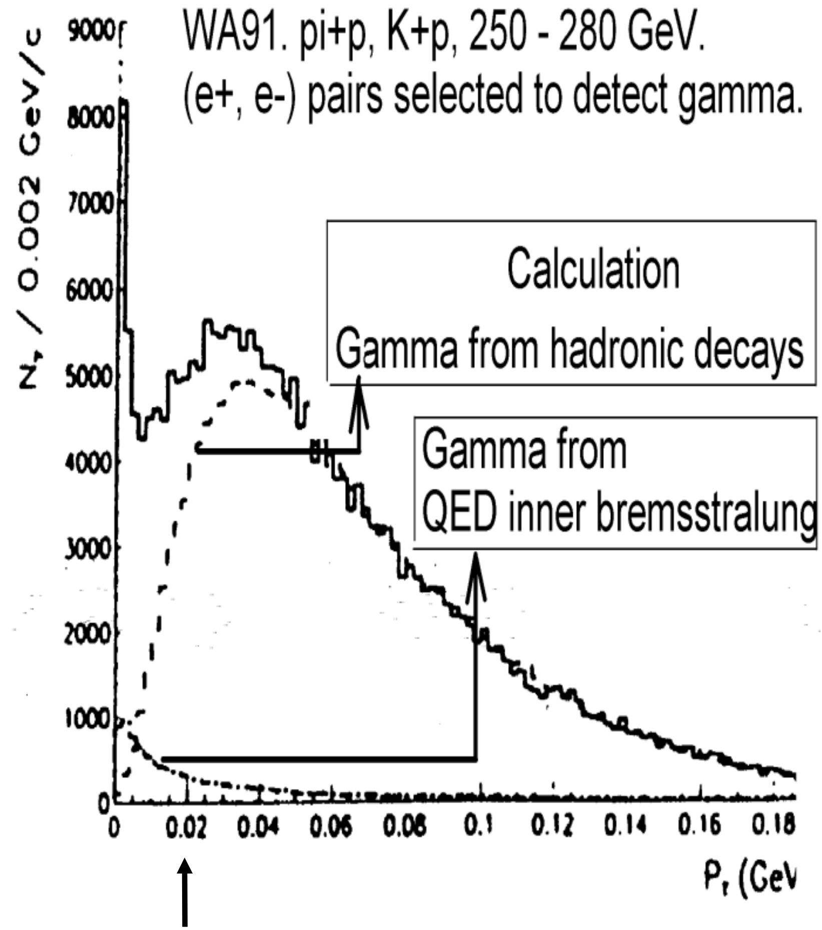
Complementary studies: Spectrum of soft photons



LiC→γ, T(Li)=3.5GeV/nucl, dNγ/(dEdΩ),dΩ=0.60e-02sr, dE=5MeV,Θ=17°

14.06.14, Runs163,165,166 BGO49 calorimeter, N300=11450 (Eγ<300MeV)

Δ/N300=0.05, Nb−approximation of sum of known γ−sources, LiCnb5M.eps

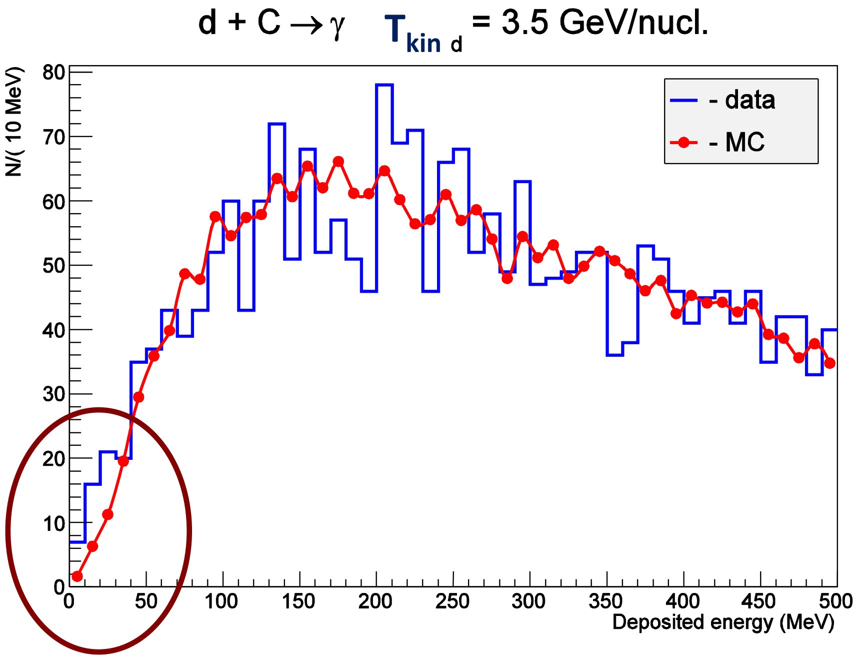


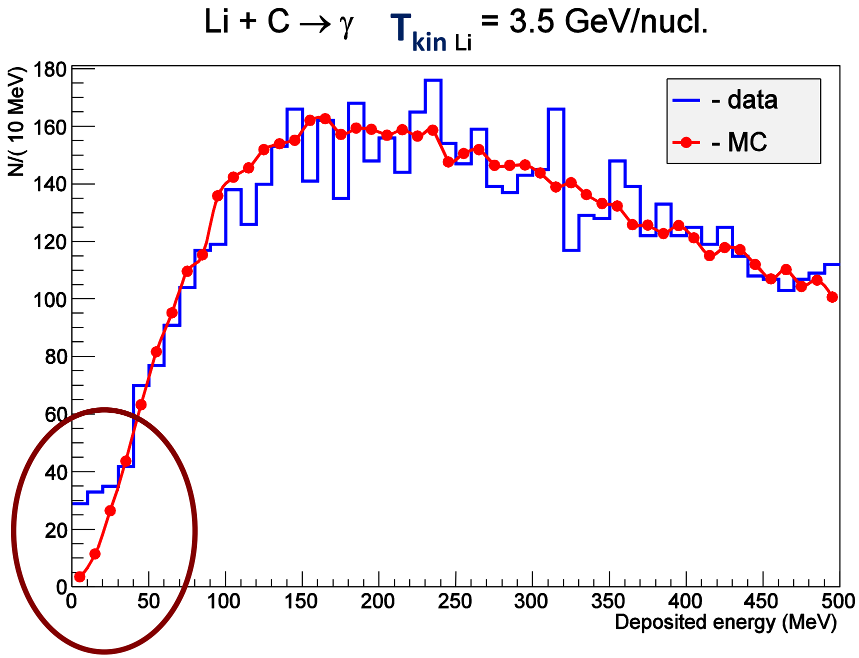
$P_T = 20$ MeV

- Result from 7x7 modules of BGO calorimeter, NIS-GIBS setup, June 2014
- To check feasibility of soft photon studies needs full simulation of BGO calorimeter in the BM@N setup

SPECTRA of SOFT PHOTON in d+C and Li+C INTERACTIONS AT NUCLOTRON

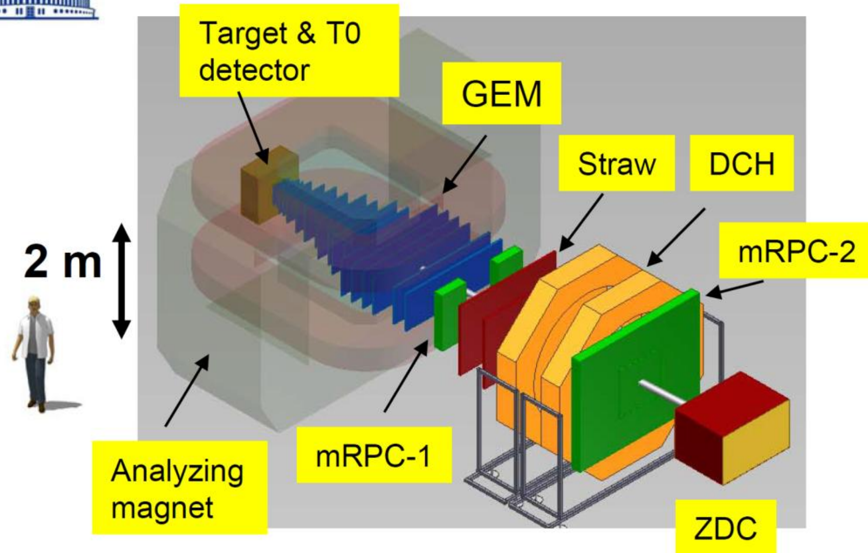
Results from runs 49 and 50.





d+C and C+C data from run 51 are being analyzed.

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

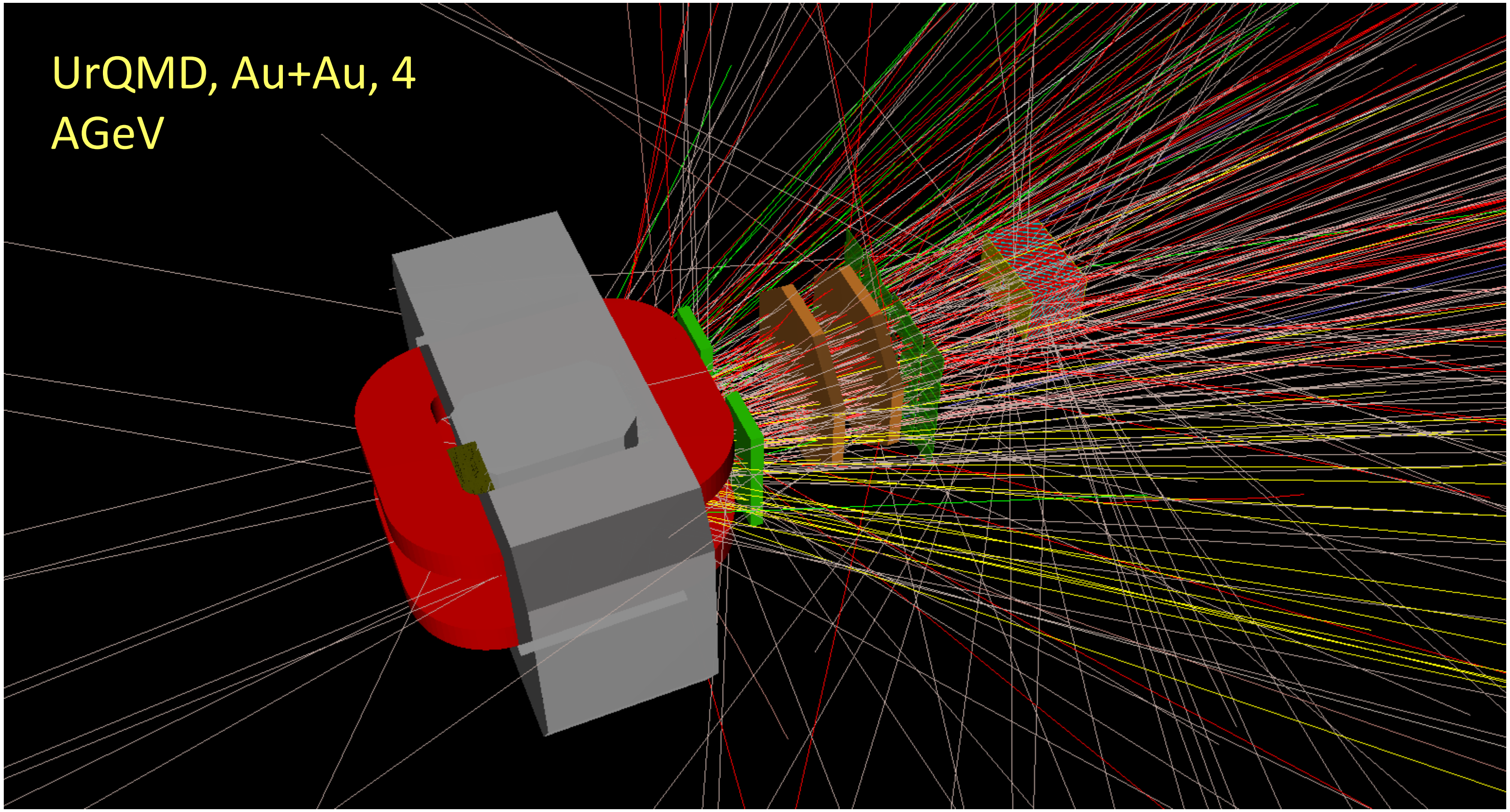
→ divide detectors for particle identification to "near to magnet" and "far from magnet" to measure particles with low as well as high momentum ($p > 1\text{-}2$ GeV/c)

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

- Central tracker (GEM) inside analyzing magnet to reconstruct AA interactions
- Outer tracker (DCH, Straw) 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-

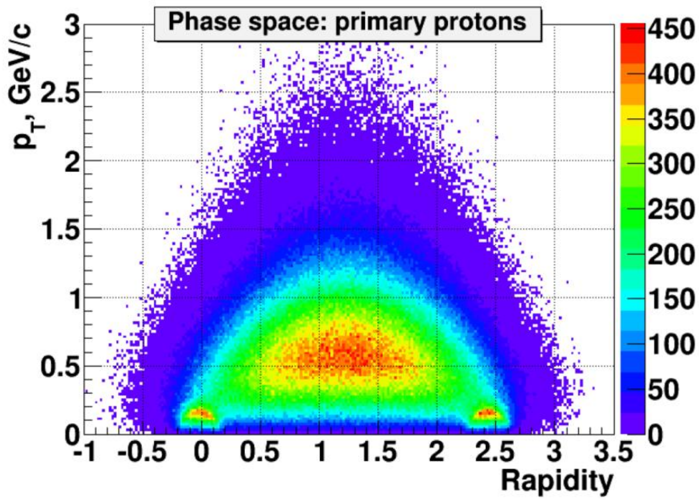
BMNROOT software framework

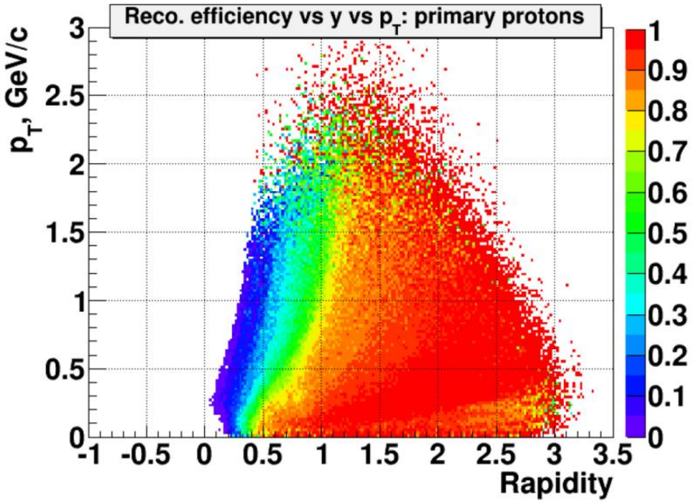
- Detector geometry
- A+A event generators
- GEANT simulation
- Track reconstruction
- Particle identification
- Physics analysis



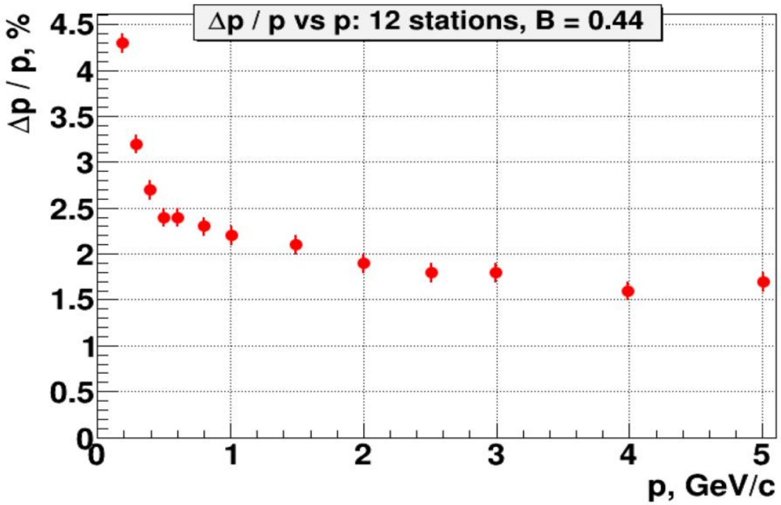
GEM tracker: acceptance / momentum resolution / detection efficiency

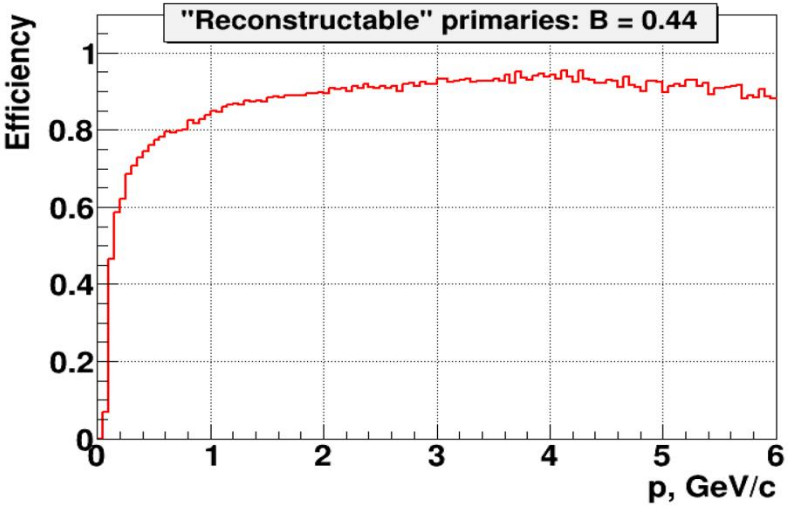
Phase space / acceptance to primary protons:





Momentum resolution / detection efficiency





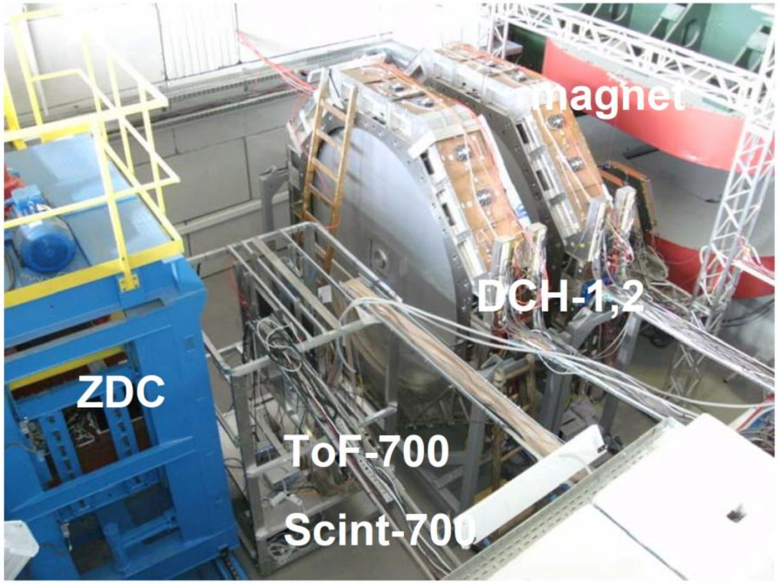
E.A. Strokovsky , 19 June 2015

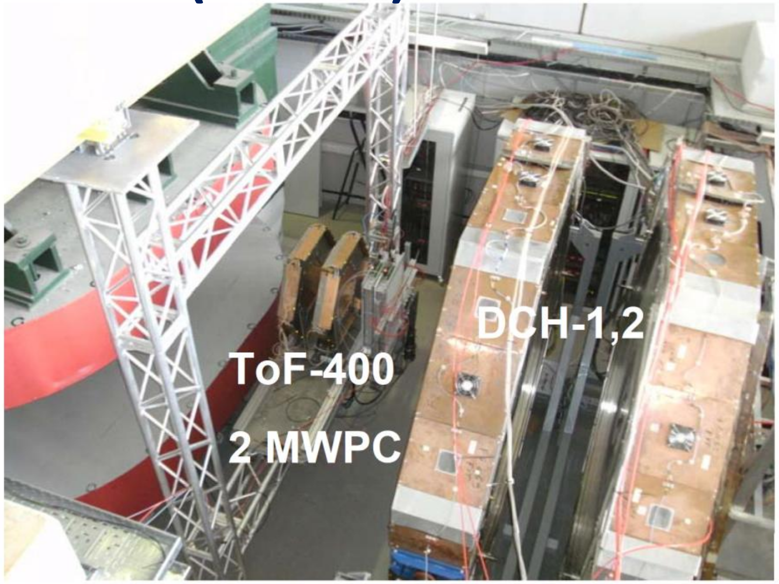
- Statistical model, Au+Au collisions @ 4A·GeV
- Beam intensity 10^7, 1% interaction length target

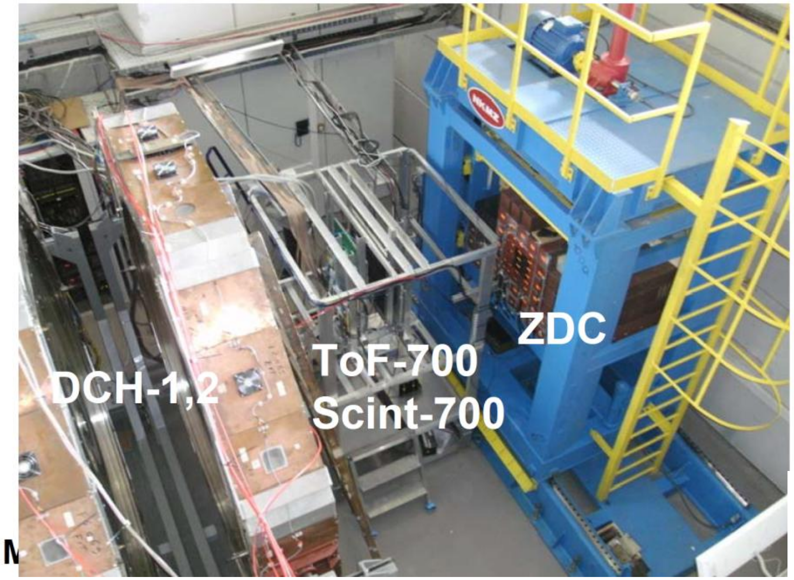
Particle	$E_{\mathrm{thr}\,NN}$, GeV	Multiplicity central	Multiplicity min.bias	ϵ, %	Yield/s min.bias	Yield/week min.bias
Ξ^-	3.7	$1\cdot10^{-1}$	$2.5\cdot10^{-2}$	3	75	$4.5\cdot10^{7}$
Ω^-	6.9	$2\cdot10^{-3}$	$5.0\cdot10^{-4}$	3	1.5	$9.0\cdot10^{5}$
$\bar{\Lambda}$	7.1	$2\cdot10^{-4}$	$5.0\cdot10^{-5}$	15	0.75	$4.5\cdot10^{5}$
Ξ^+	9.0	$6\cdot10^{-5}$	$1.5\cdot10^{-5}$	3	$4.5\cdot10^{-2}$	$2.7\cdot10^{4}$
Ω^+	12.7	$1\cdot10^{-5}$	$2.5\cdot10^{-6}$	3	$7.5\cdot10^{-3}$	$4.5\cdot10^{3}$

Hyper-nuclei	Multiplicity central	ϵ, %	Yield/s central	Yield/week central
${}^{3}_{\Lambda}\mathrm{H}$	$2\cdot10^{-2}$	8	160	$1.0\cdot10^{8}$
${}^{5}_{\Lambda\Lambda}\mathrm{H}$	$1\cdot10^{-6}$	1	$1\cdot10^{-3}$	$6\cdot10^{2}$
${}^{6}_{\Lambda\Lambda}\mathrm{He}$	$3\cdot10^{-8}$	1	$3\cdot10^{-5}$	18

BM&N setup in the first technical run in February-March 2015 **(Run 51)**





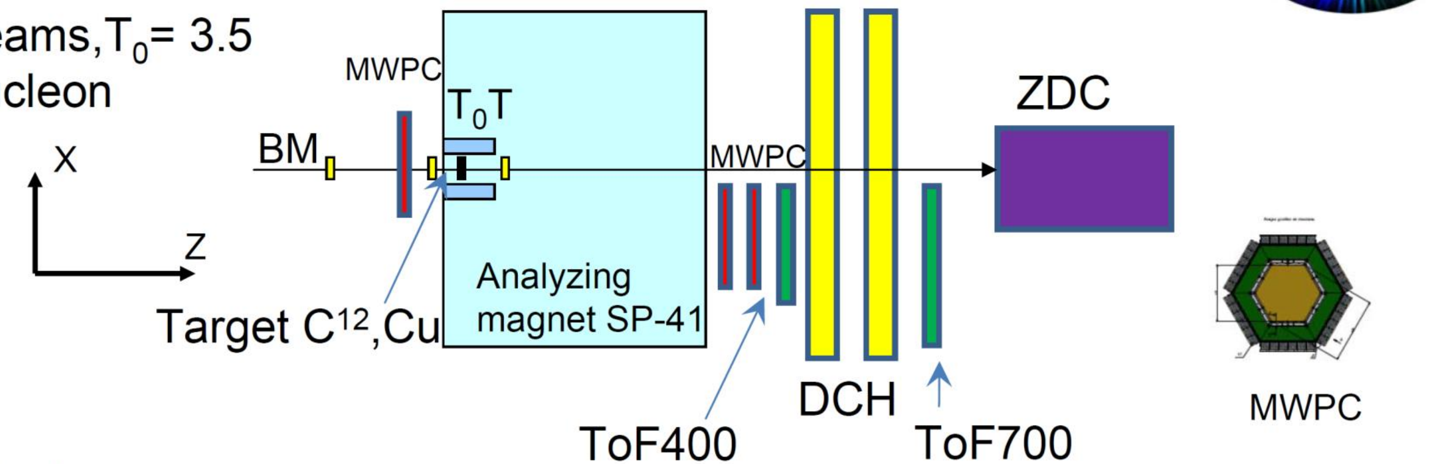


Tasks for BM@N technical run:

- deutron and C^{12} beams with T_0= 3.5 AGeV
- Trace beams, measure beam profile and time structure
- Test detector response: ToF-400, ToF-700, T0+Trigger, DCH-1,2, ZDC, ECAL modules, Beam monitors BM
- Test integrated DAQ and trigger system

BM@N technical run in February-March 2015

d, C^{12} beams, T_0= 3.5 GeV / nucleon



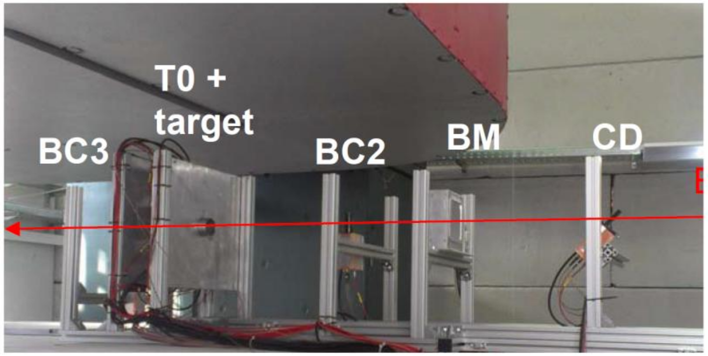
Results of technical run:

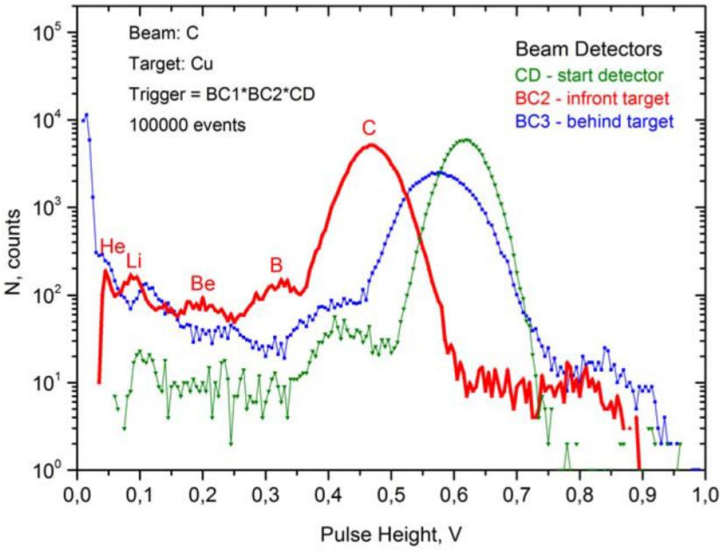
- Deutron beam ($2{\cdot}10^4$ - 10^5 /cycle) and C^{12} (10^5 - 10^6/cycle) beams with T_0= 3.5 GeV / nucleon are delivered and used in BM@N experiment
- Functionality of integrated DAQ for detectors: ToF-400, ToF-700, T_0T, DCH-1,2, ZDC, ECAL modules, 3 MWPC is proven; → DAQ system showed reliable behavior
- Data with beam-target interactions are recorded using several trigger logics
- Deutron beam is traced through detectors at different values of magnetic field to test momentum reconstruction
- Resolution of T0T and ToF-400,700 detectors is tested
- Special runs are collected with different positions of ZDC to calibrate detector response

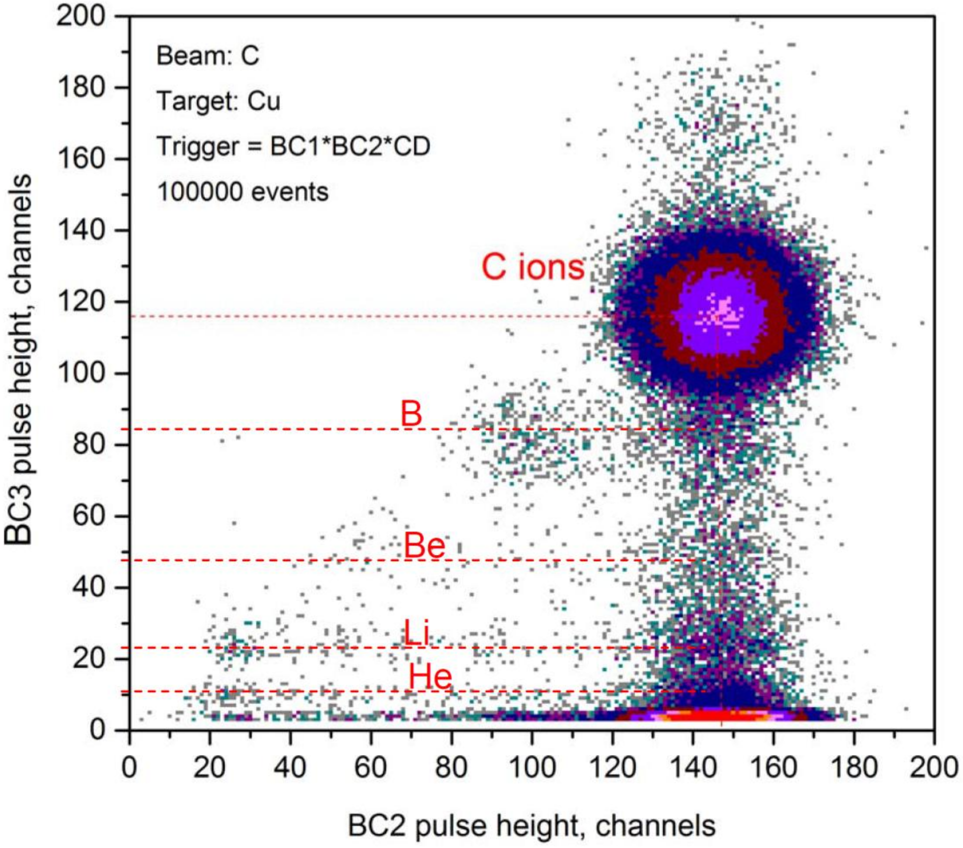
BM@N beam monitor, trigger counters and T0 counter for ToF system

BM@N trigger group

Components of carbon beam measured in counters BC2 (in front of target) and BC3 (behind target) using standalone readout electronics



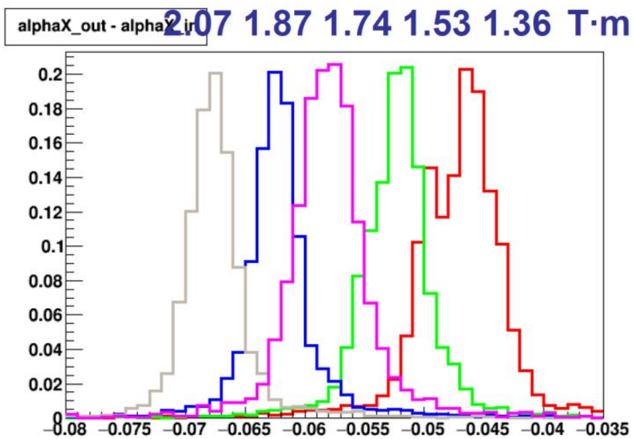




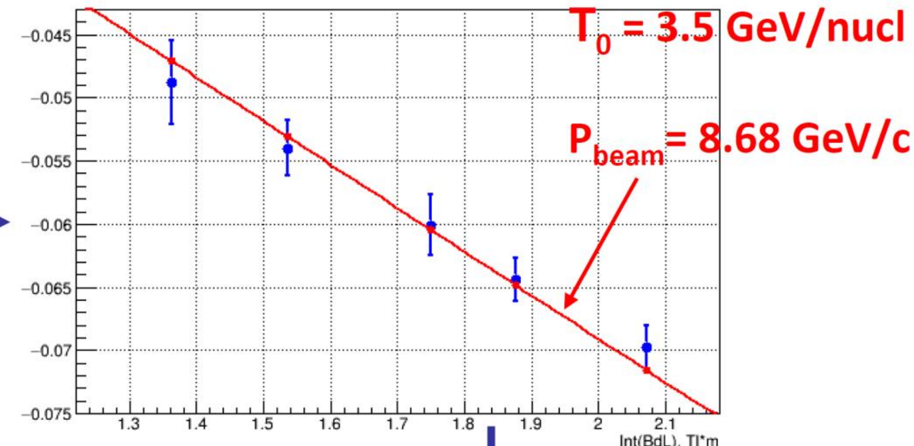
E.A. Strokovsky , 19 June 2015

Deutron tracks and momentum reconstruction in Drift Chambers

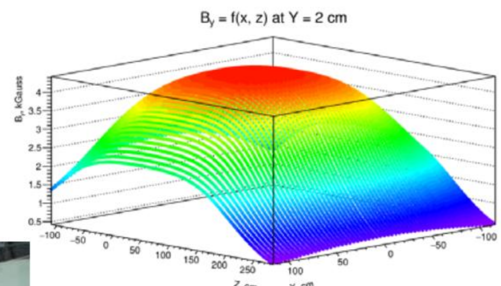
Deutron beam inclination at different values of magnetic field



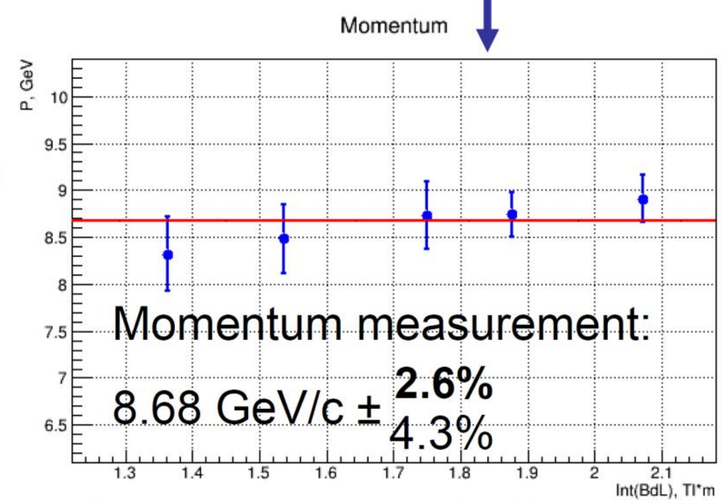
Inclination angle vs magnetic field



Vertical component of magnetic field →

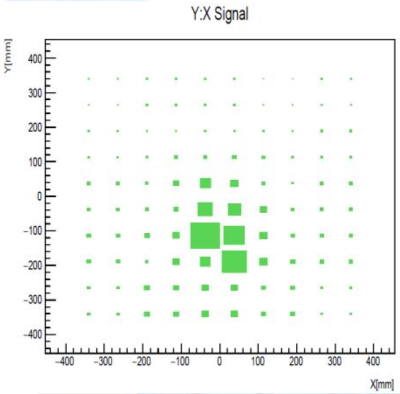


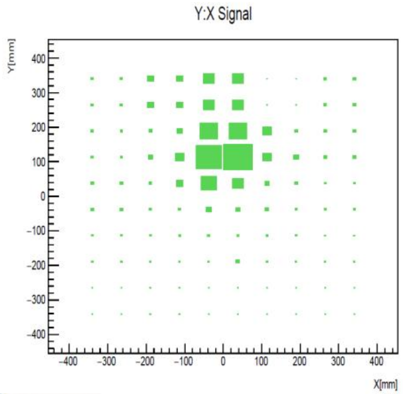
Drift chambers DCH-1,2

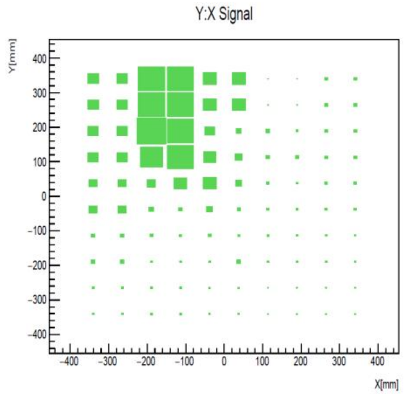


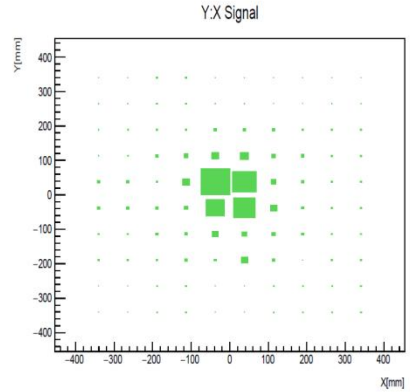
Integral of magnetic field, Tl·m

Calibration of ZDC calorimeter

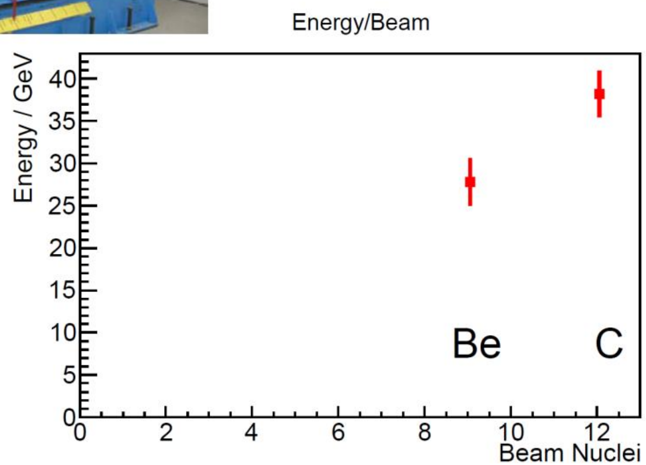


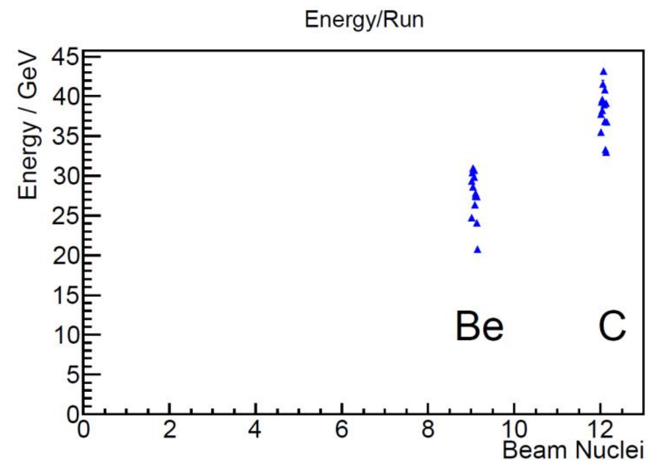




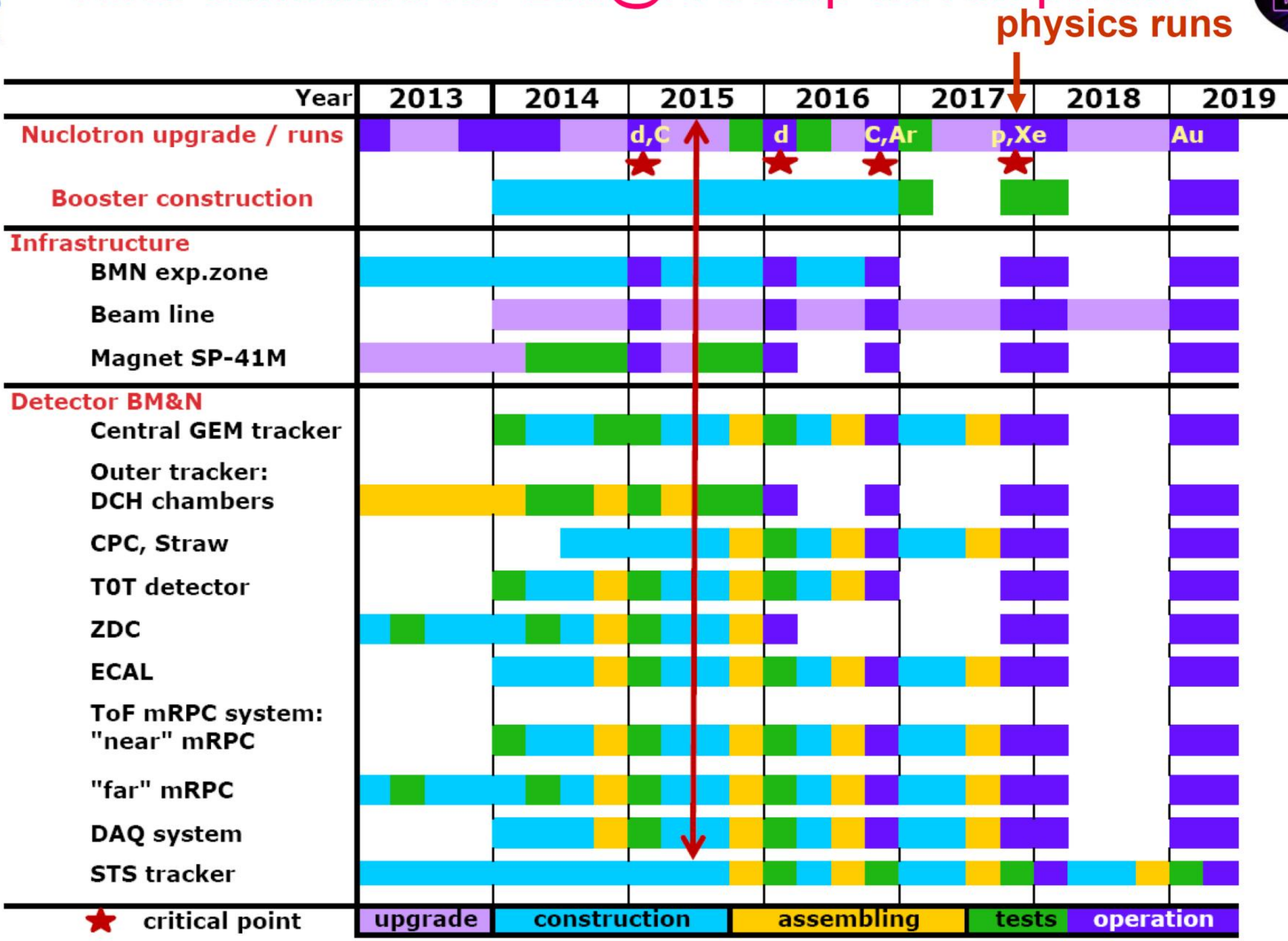


- Special runs with carbon beam with ZDC at different positions
- Calibration of cell amplitudes to get beam energy in cluster
- Spread of energies reconstructed in different runs ~7%
- Cross check linearity with fraction of Be in carbon beam



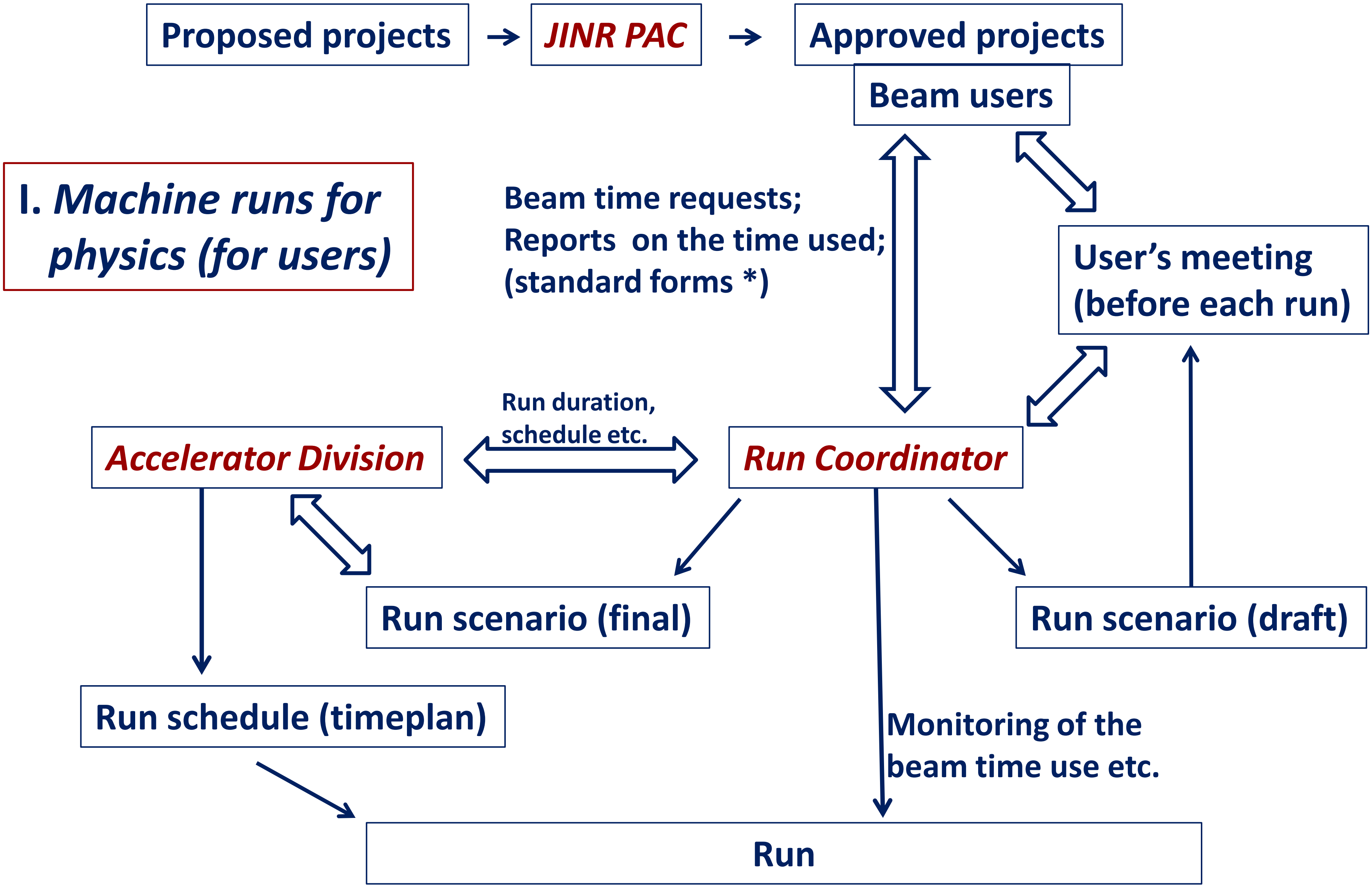


Time schedule for BM@N setup development



Plan for central tracker: 8 GEM + 2 Si planes for physics run at end 2017,
12 GEM + 2 Si planes for physics run in 2019

User's policy at LHEP



*(All forms can be found at the Nuclotron site.)

II. Annual Workshop of the Nuclotron beam users (international)

Permanent topics:

- Run coordinator report
- Machine representative report
- Reports of users about results obtained and quality of the beam
- Proposed schedule of runs for the next year and its discussion
- ….
- General discussion
- Fixing of user's needs and interests for the next year in the Concluding document.

In 2015 **the III "Annual user's Workshop" is planned for** ***Oct. 8-9***

Thank You!