JINR–GSI Collaboration in the Field of Relativistic Heavy-Ion Physics

V.Kekelidze

110 session of Scientific Council, 15-16 September 2011, Dubna

Research in Relativistic Heavy Ions

is one of intensively developing fields in the last two decades

many discoveries have been made,

interesting processes have been observed

and precisely measured in the series of experiments

at RHIC (BNL), SPS (CERN) and GSI (SIS18)

The researches are carried out at LHC,

in preparation at SIS100 (FAIR)

However the most interesting phenomena *as*

the mixed phase, critical endpoint, max. of baryonic density etc.

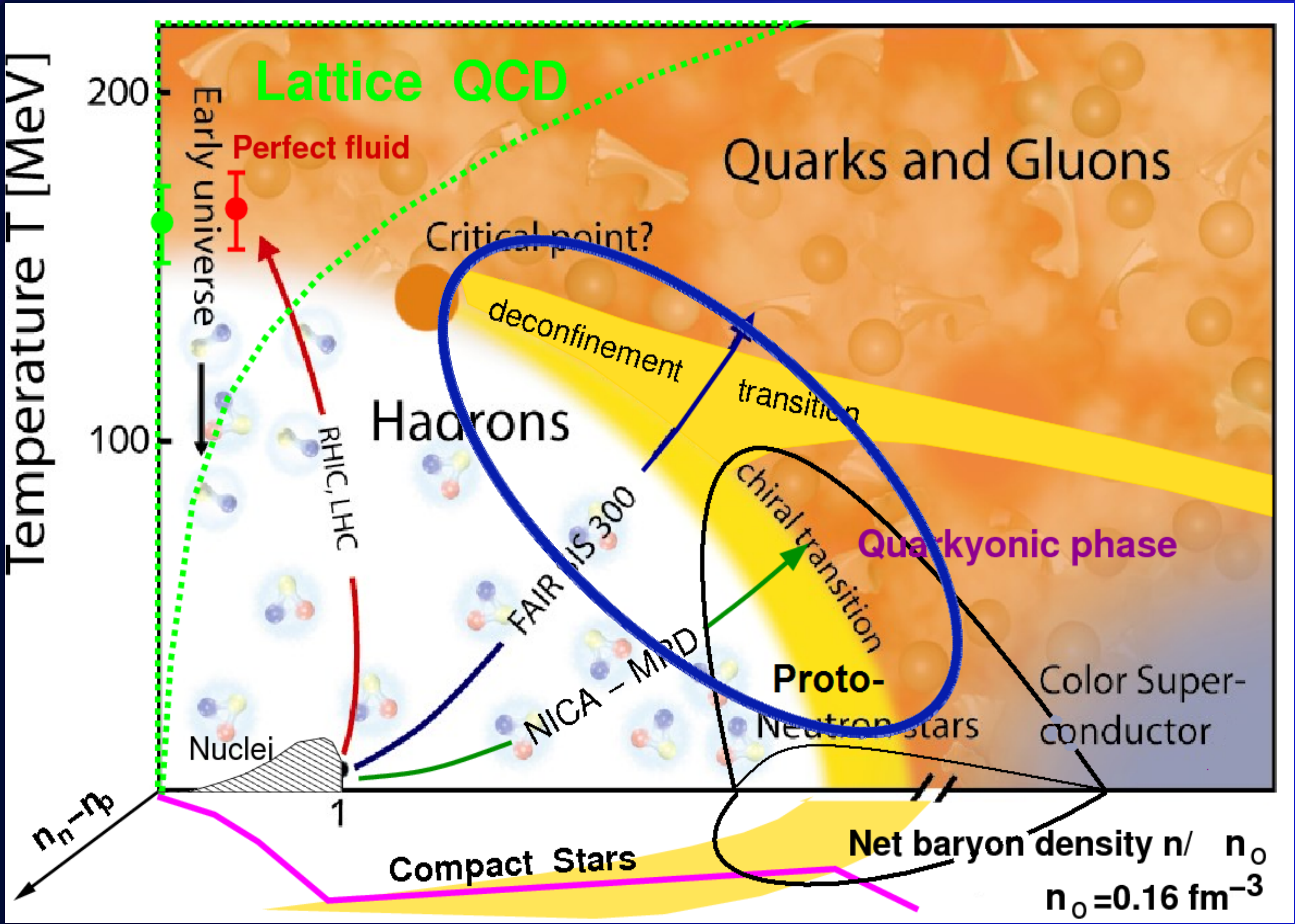
are not observed yet

in this view the energy scan in wide region - is the high priority task

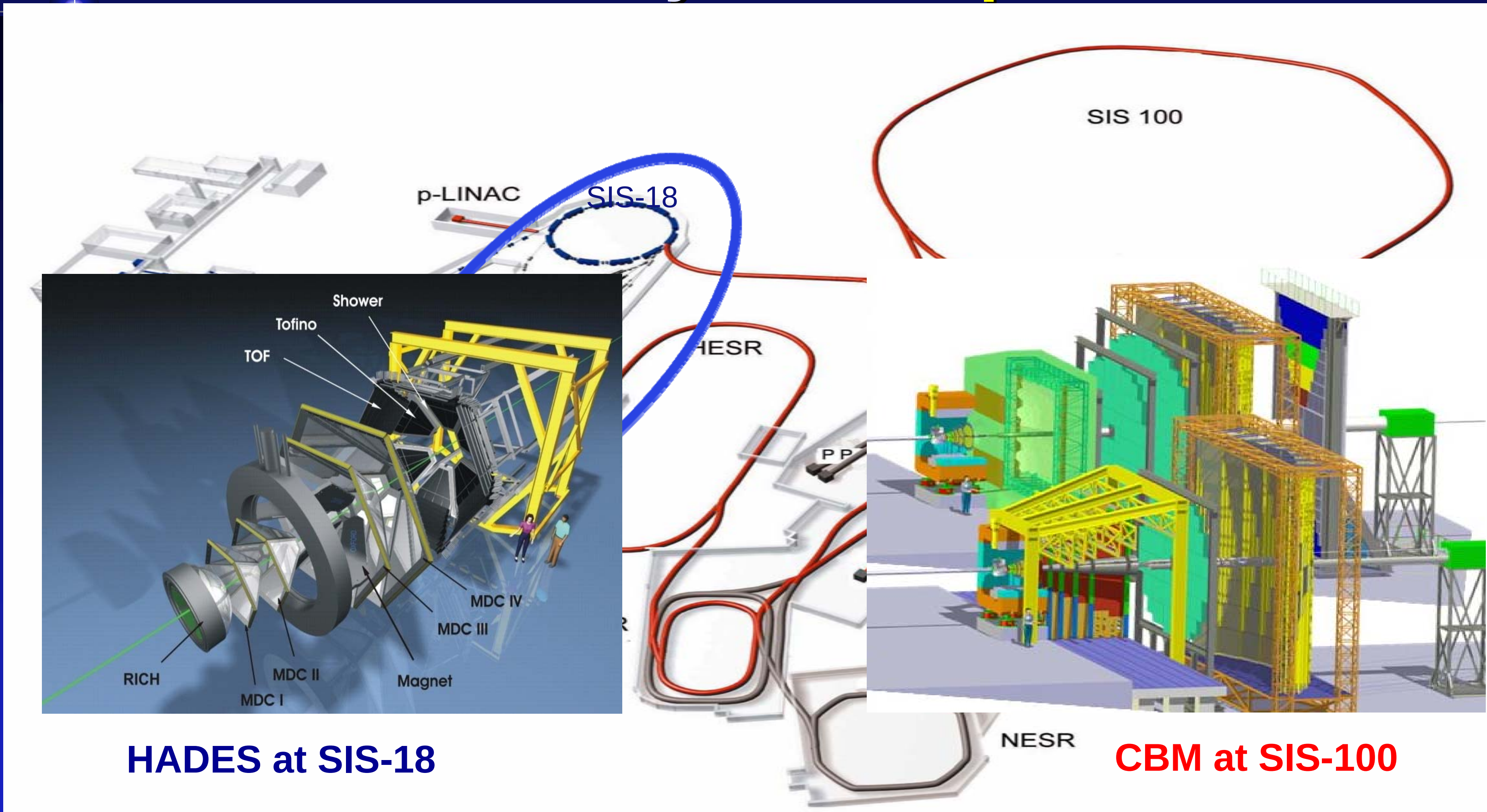
this report presents such a possibility at ***LHEP JINR***

and ***GSI*** *(briefly)*

QCD phase diagram

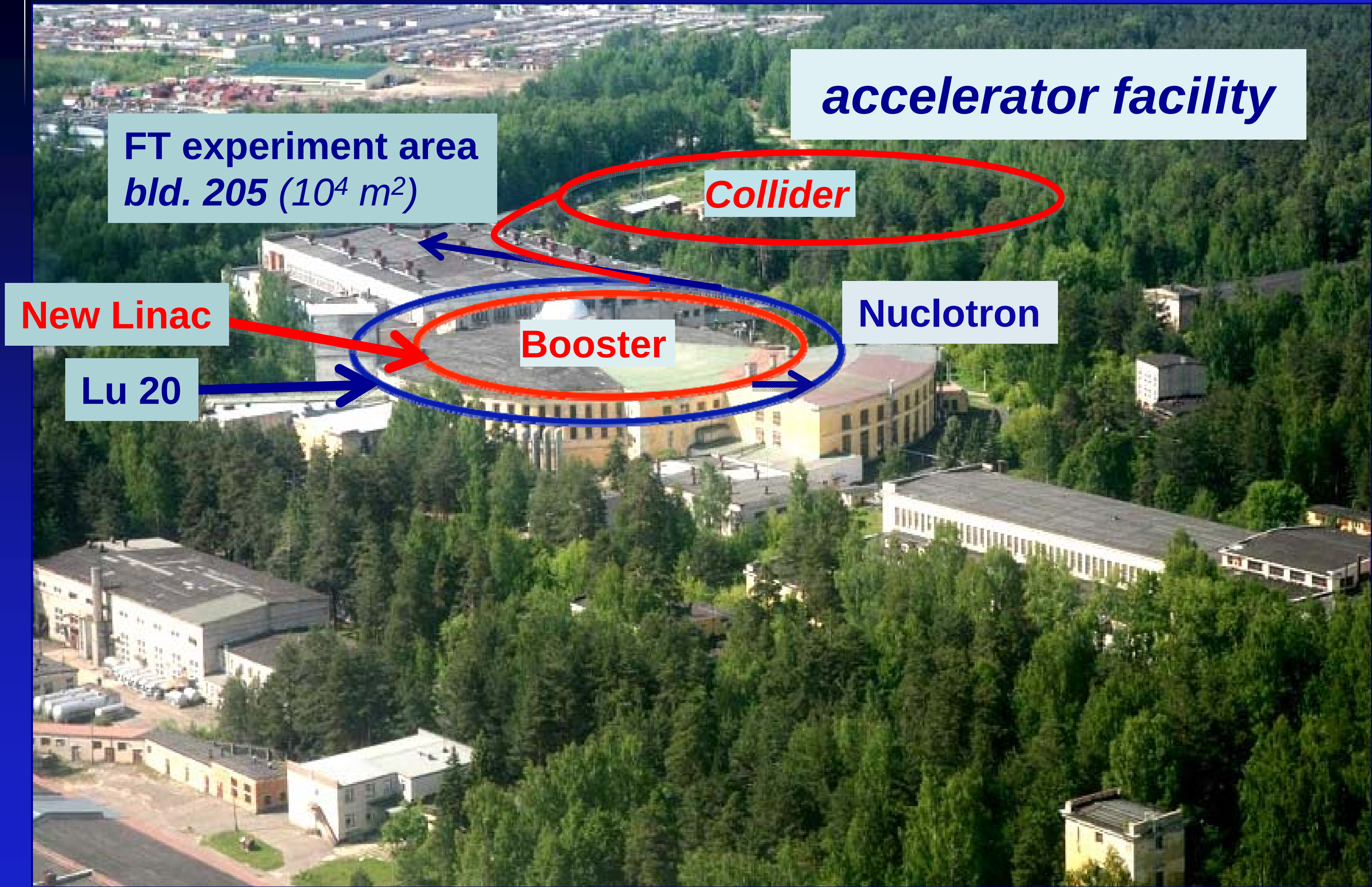


GSI facility & FAIR plans



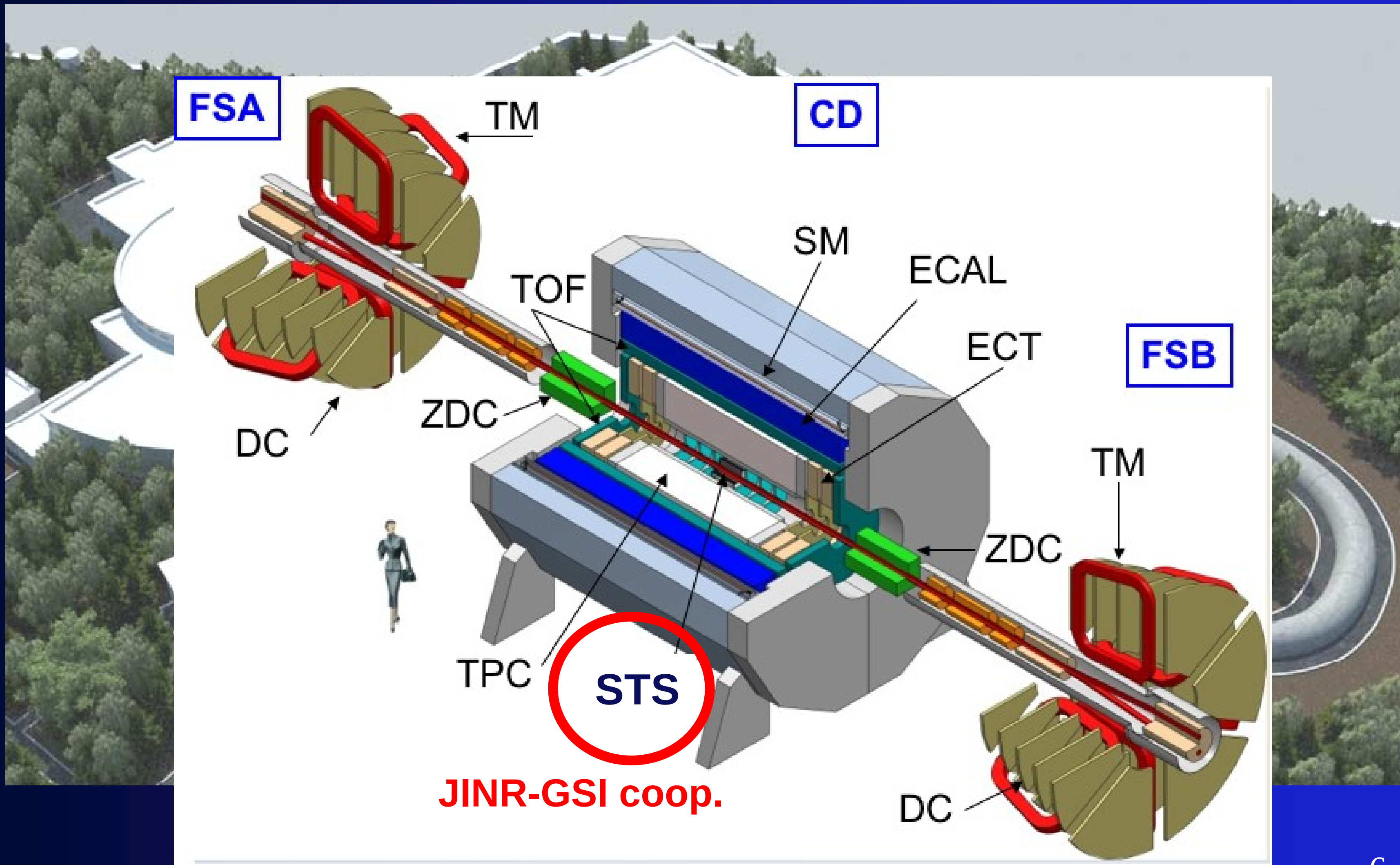
- Compressed Baryonic Matter (CBM) - experiment in preparation for the first stage of FAIR
- JINR cooperation in both experiments are supported by the BMBF

Veksler & Baldin Laboratory of HEP

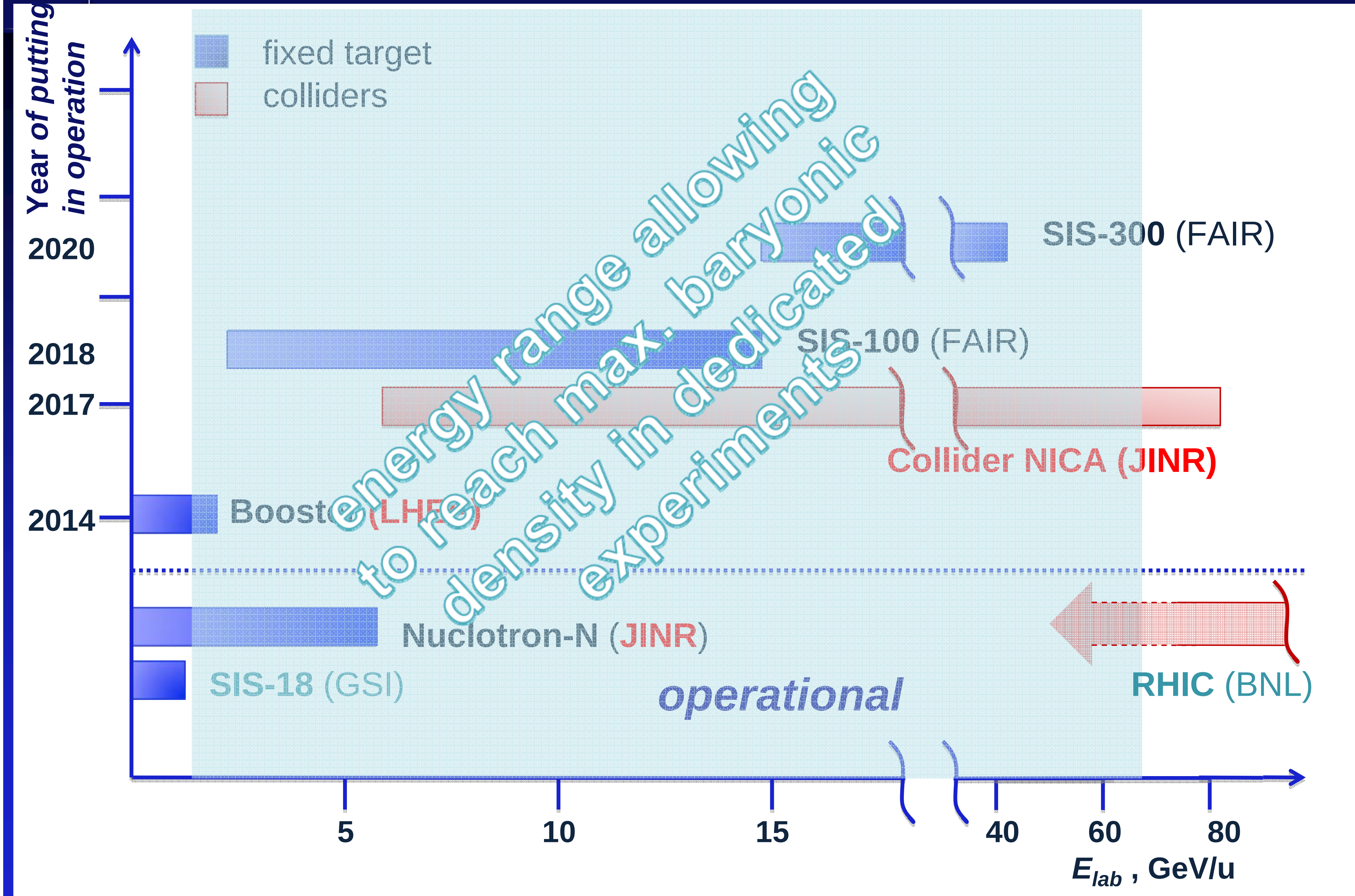


Veksler & Baldin Laboratory of HEP

present & future facility



Energy region covered by the LHEP and GSI facilities
(in deutron energy, recalculated for E_{lab})



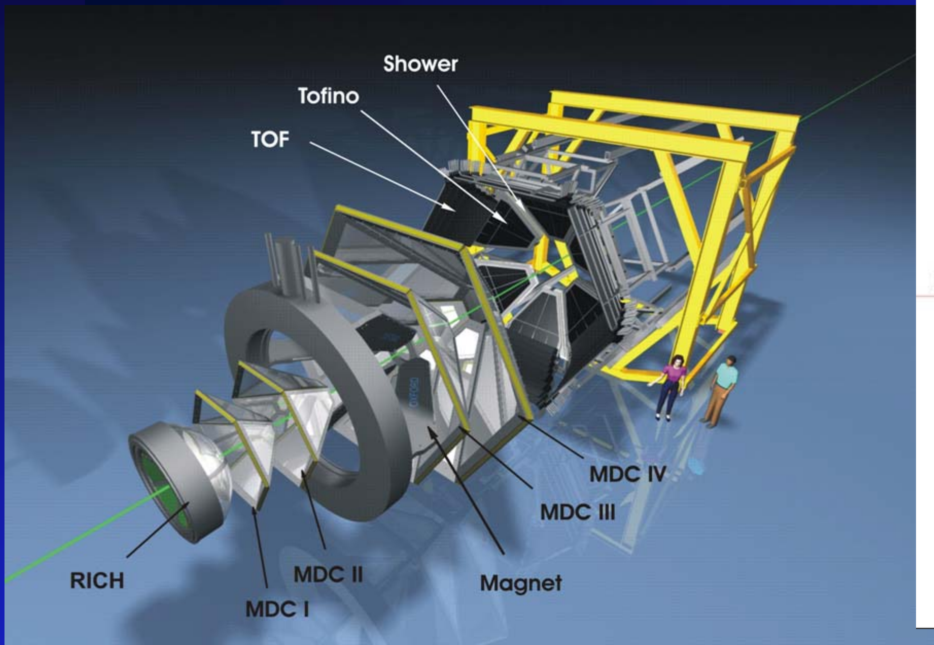
The beams at GSI (SIS18)

Energy & Intensities, particles per cycle

Beam	*Energy*	*Intensity per cycle*
p	4,5 GeV	**$2 \cdot 10^{10}$**
d	2,2 GeV	**$5 \cdot 10^{11}$**
$^{12}C^{6+}$	300 MeV	**$7 \cdot 10^{10}$**
$^{24}Mg^{12+}$	300 MeV	**$5 \cdot 10^{10}$**
$^{40}Ar^{18+}$	300 MeV	**$6 \cdot 10^{10}$**
$^{58}Ni^{26+}$	300 MeV	**$8 \cdot 10^{9}$**
$^{84}Kr^{34+}$	0,3 -1 GeV	**$2 \cdot 10^{10}$**
$^{124}Xe^{48/42+}$	0,3 -1 GeV	**$1 \cdot 10^{10}$**
$^{181}Ta^{61+}$	1 GeV	**$2 \cdot 10^{9}$**
$^{197}Au^{65/79+}$		**$3 \cdot 10^{9}$**
$^{238}U^{28+/73+}$	0,05-1 GeV	**$6 \cdot 10^{9}/2 \cdot 10^{10}$**

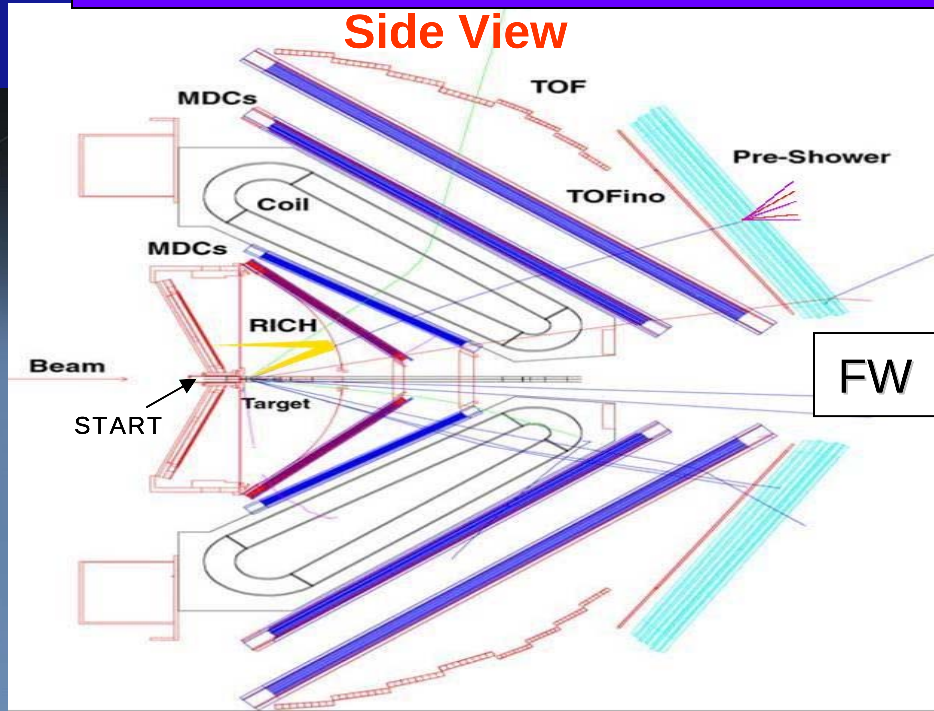
HADES- JINR participation

SIS 18, GSI Darmstadt
(p, π, A) + A collisions
ρ ≤ 3 ρ0, T ≤ 80 MeV



- in-medium modification of light vector mesons;
- dilepton continuum in the hot dense hadronic matter

HADES - 2nd generation dilepton spectrometer

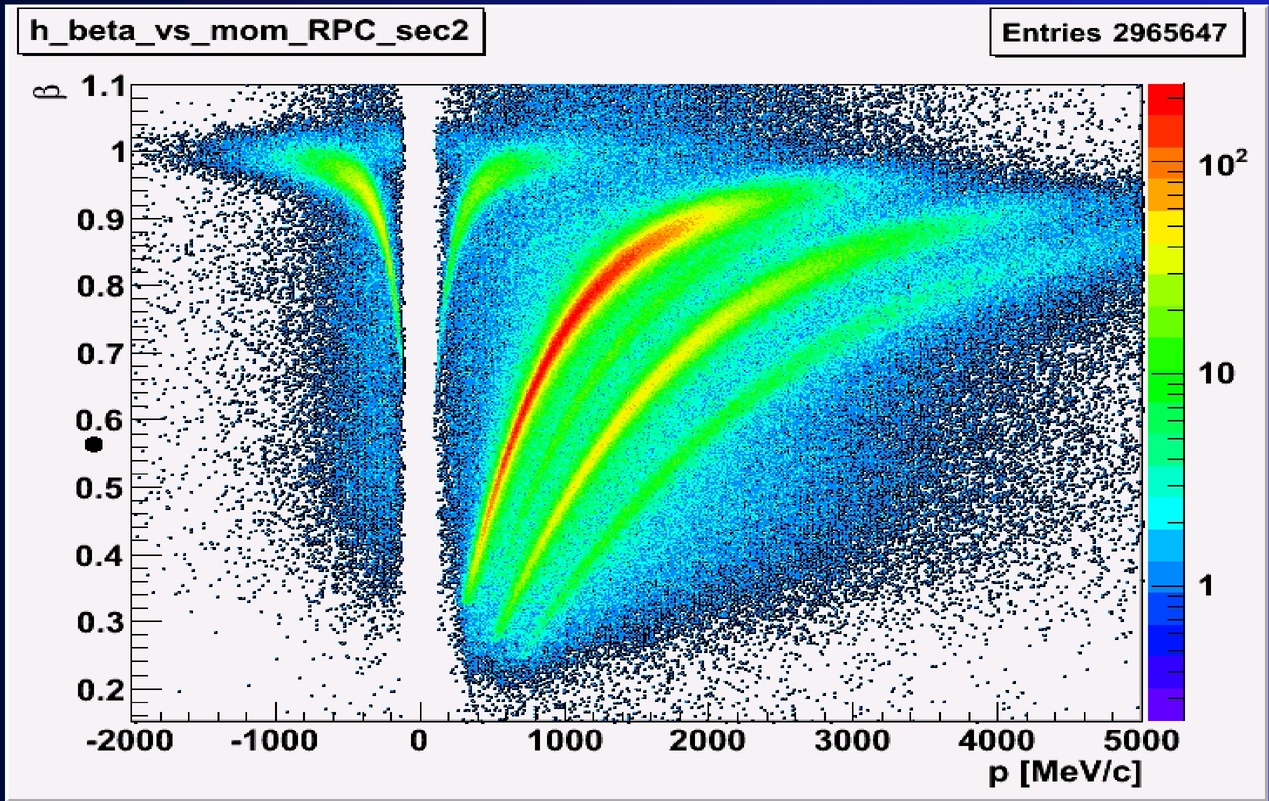


JINR contribution:

- 2-nd Drift Chambers station
- FEE for drift chambers
- Software algorithms
- Analysis for hadronic channels

Au+Au collisions at 1.25 A GeV

Particles identification for upgraded HADES from the commissioning run in August 2011

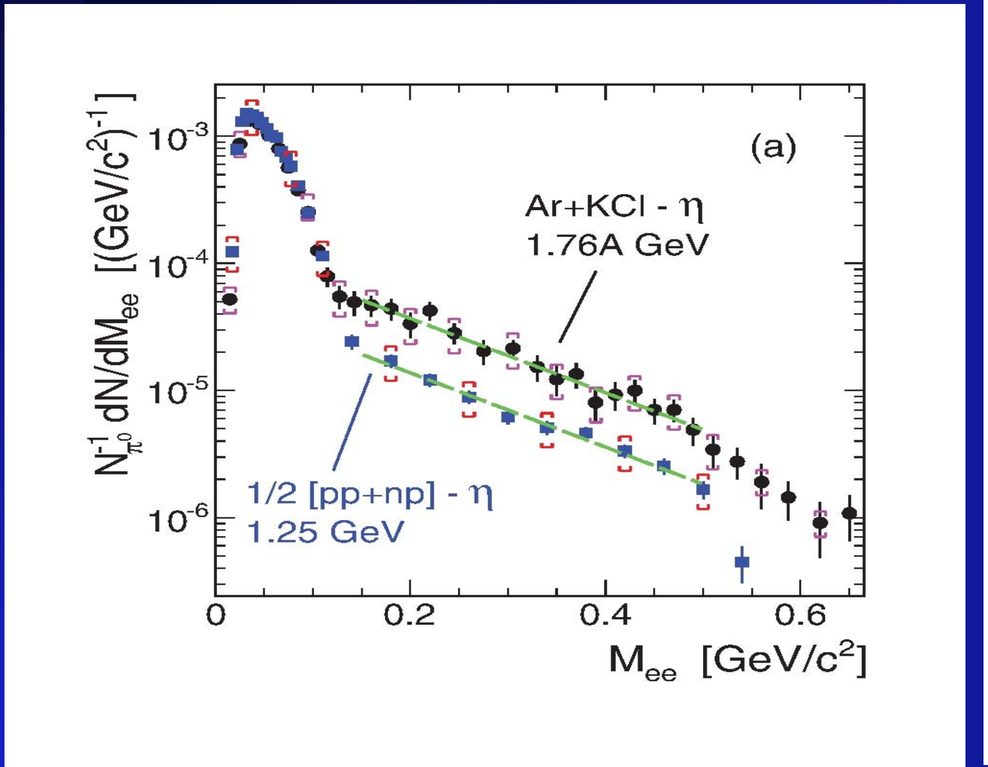


analysis performed by the JINR physicists

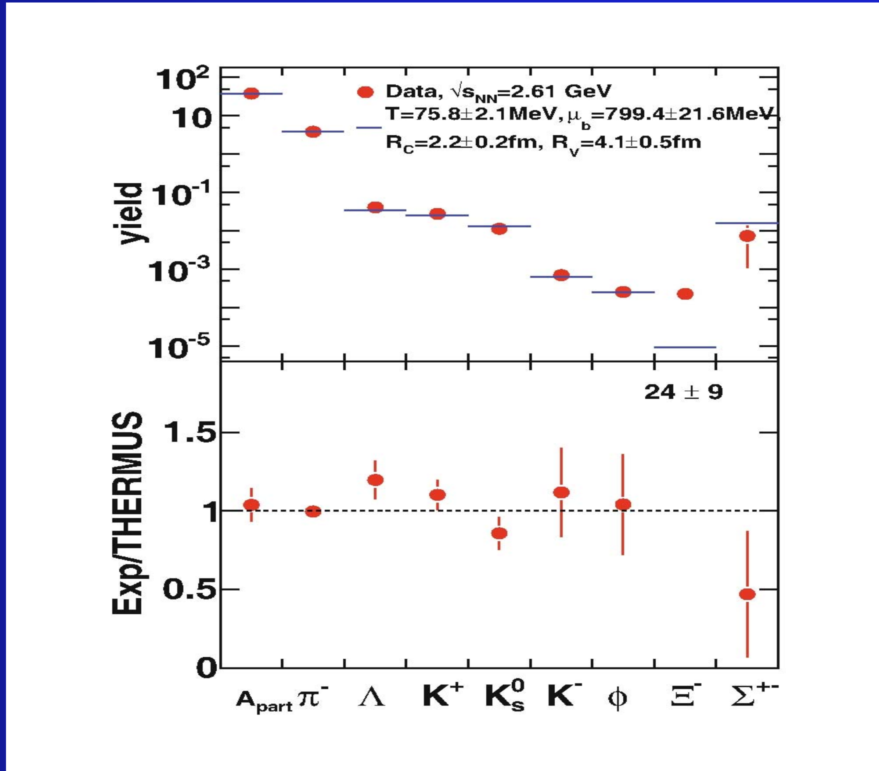
Data production run for Au+Au collisions is planned in 2012

Recent exciting results from HADES

Enhancement of the dilepton yield in Ar+KCl at 1.76 A GeV



Large excess of Ξ hyperons production (20 times)



Strong impact to the physics program at BM@N and MPD

Compressed Baryonic Matter (CBM) & CBM - JINR cooperation

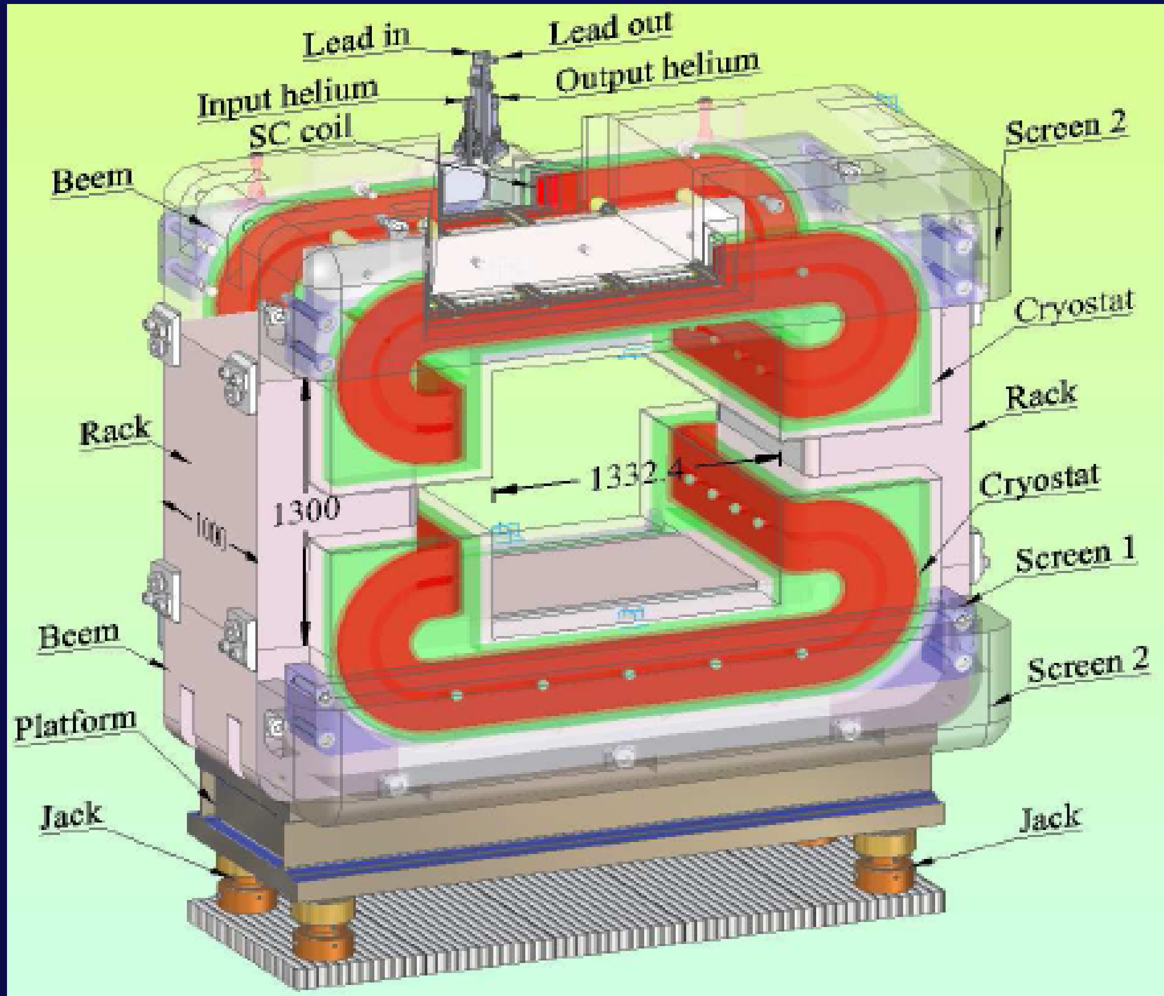
Experiment is dedicated to the study of the QCD phase diagram using variety of probes:

vector mesons, charm, strange & multi-strange objects etc.

CBM

- Physics program development
- R&D on detectors
- MC simulation

JINR contribution – SC Dipole Magnet



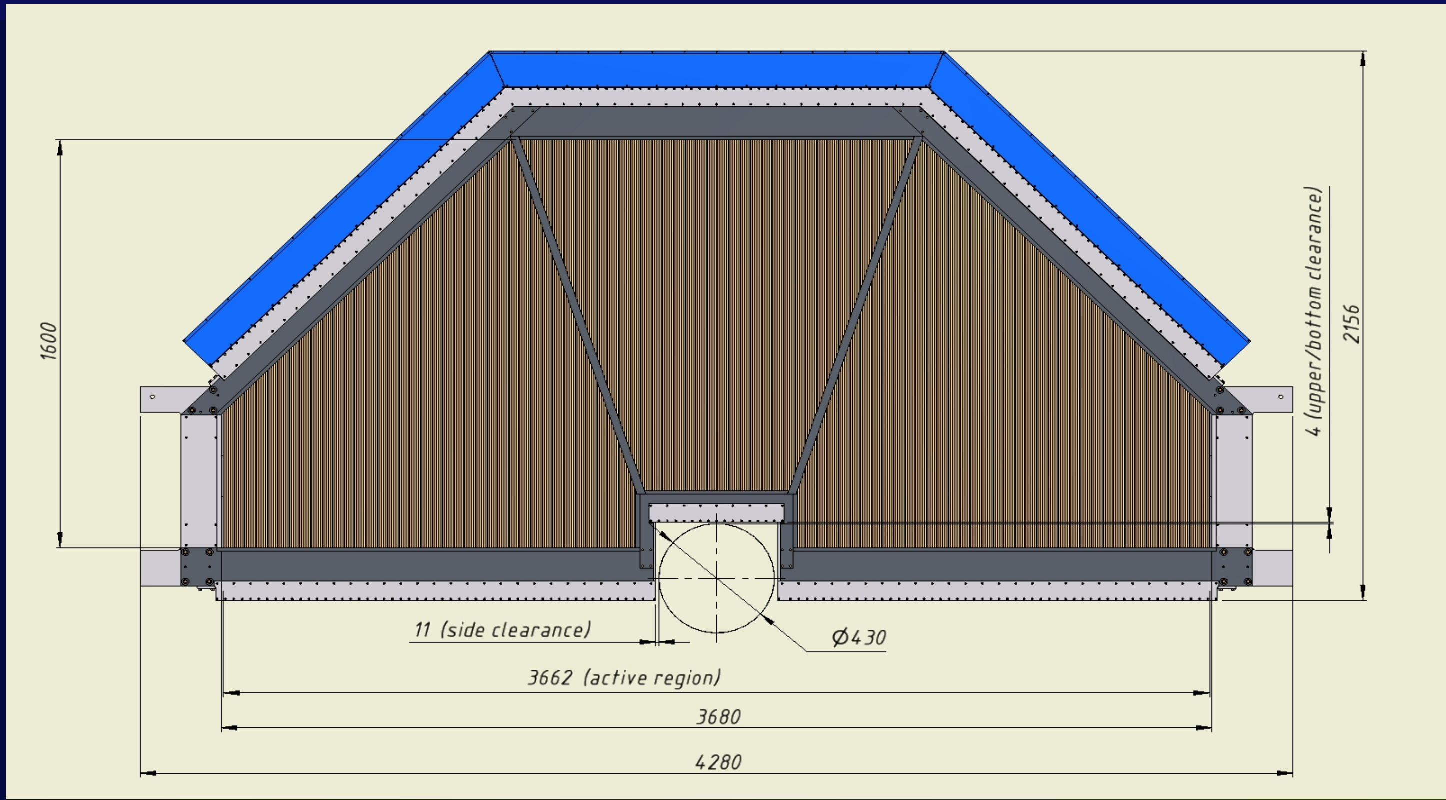
- Superconducting Dipole Magnet based on JINR technologies
- Algoritms of the track reconstruction and particles ID

JINR contribution -Transition Radiation Detectors

- The TRD is the part of the electron-positron ID system
- Large experience at LHEP JINR for ALICE@CERN

Visits of Prof. H. Stoeker (GSI) , and Prof. R. Hoyer (CERN)

JINR contribution – Straw Tracker for muon system



- the Straw Tracker is considered as a part of muon system
- the construction is based on the technologies developed at LHEP JINR
- these technologies will be used also for MPD and BM@N

The CBM-MPD Consortium

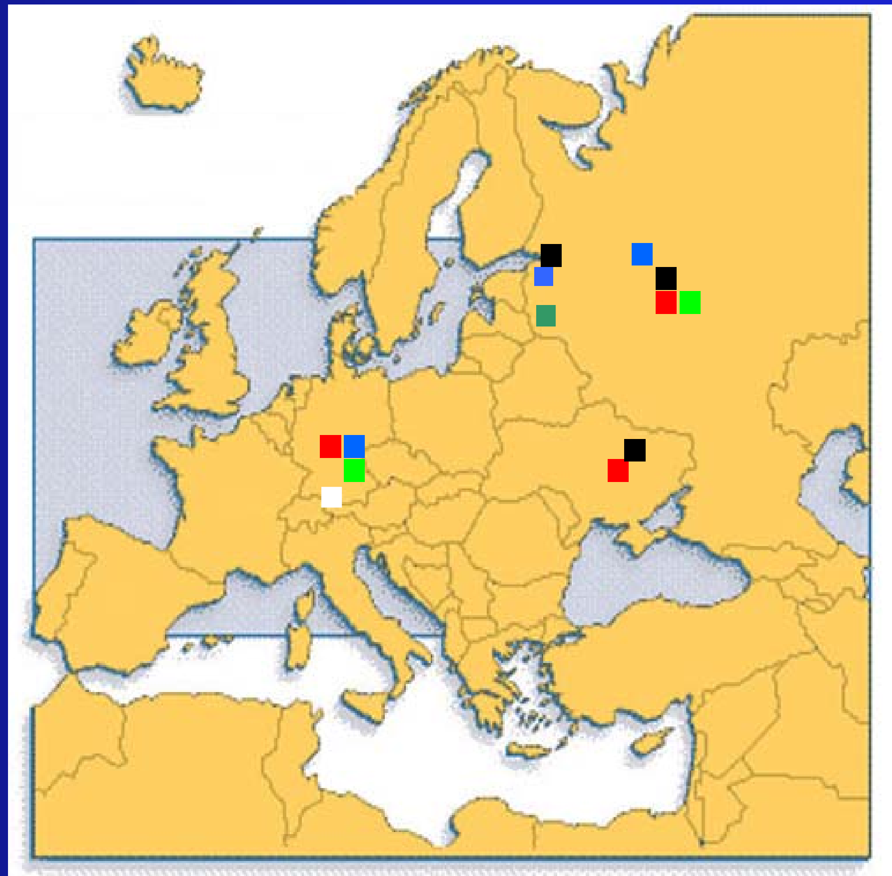
supported by the BMBF

- 7 institutes
- 3 countries

CBM @ FAIR (Darmstadt)

MPD @ NICA (Dubna)

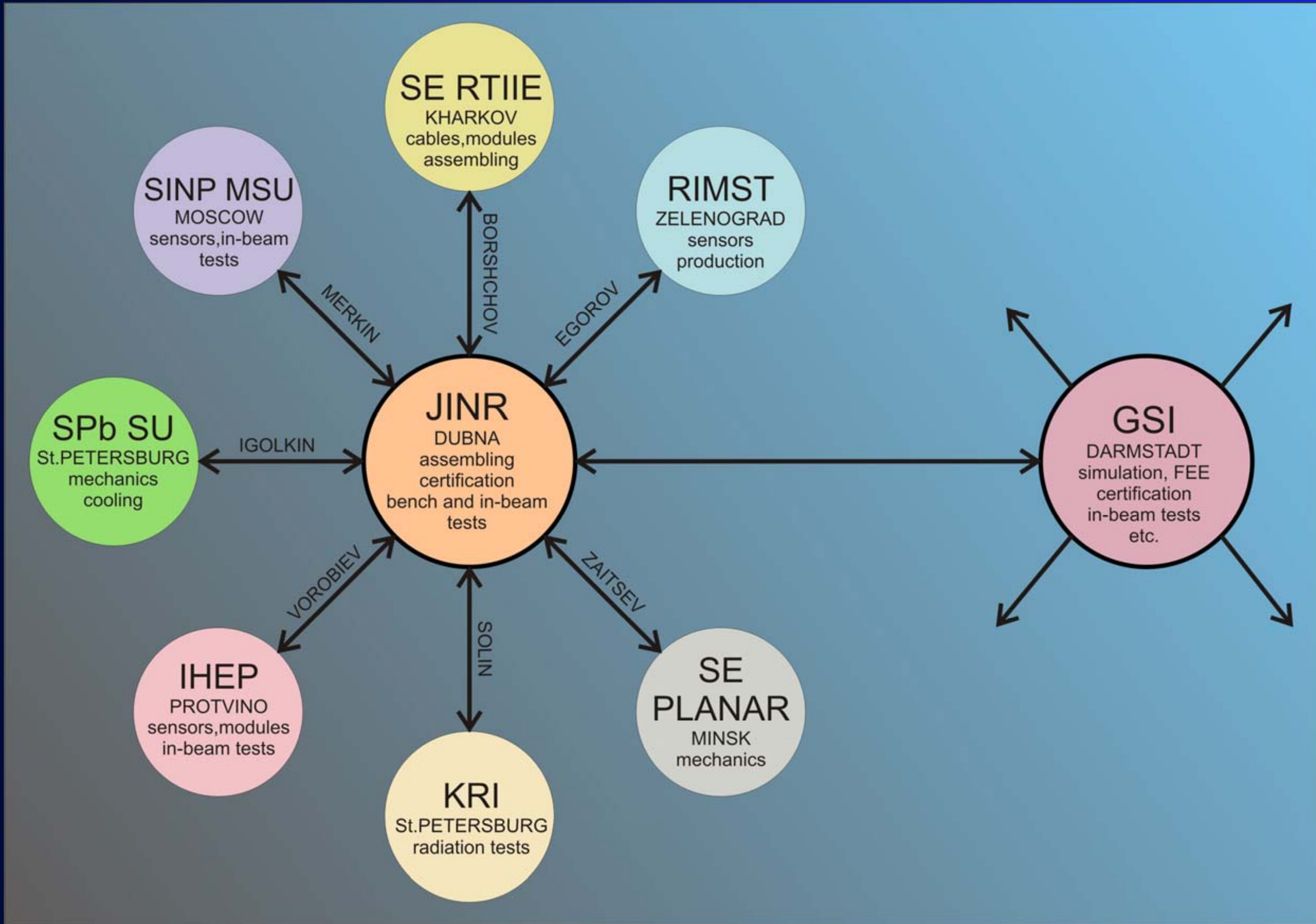
- **GSI**, Darmstadt, Germany
- **JINR**, Dubna, Russia
- IHEP, Protvino, Russia
- MSU, Moscow, Russia
- KRI, St.Petersburg, Russia
- University, St.Petersburg
- SE SRTIIE, Kharkov, Ukraine



- Modules assembly
- Components
- Ladder assembly
- Radiation tests
- In-beam tests

The CBM-MPD Consortium Structure

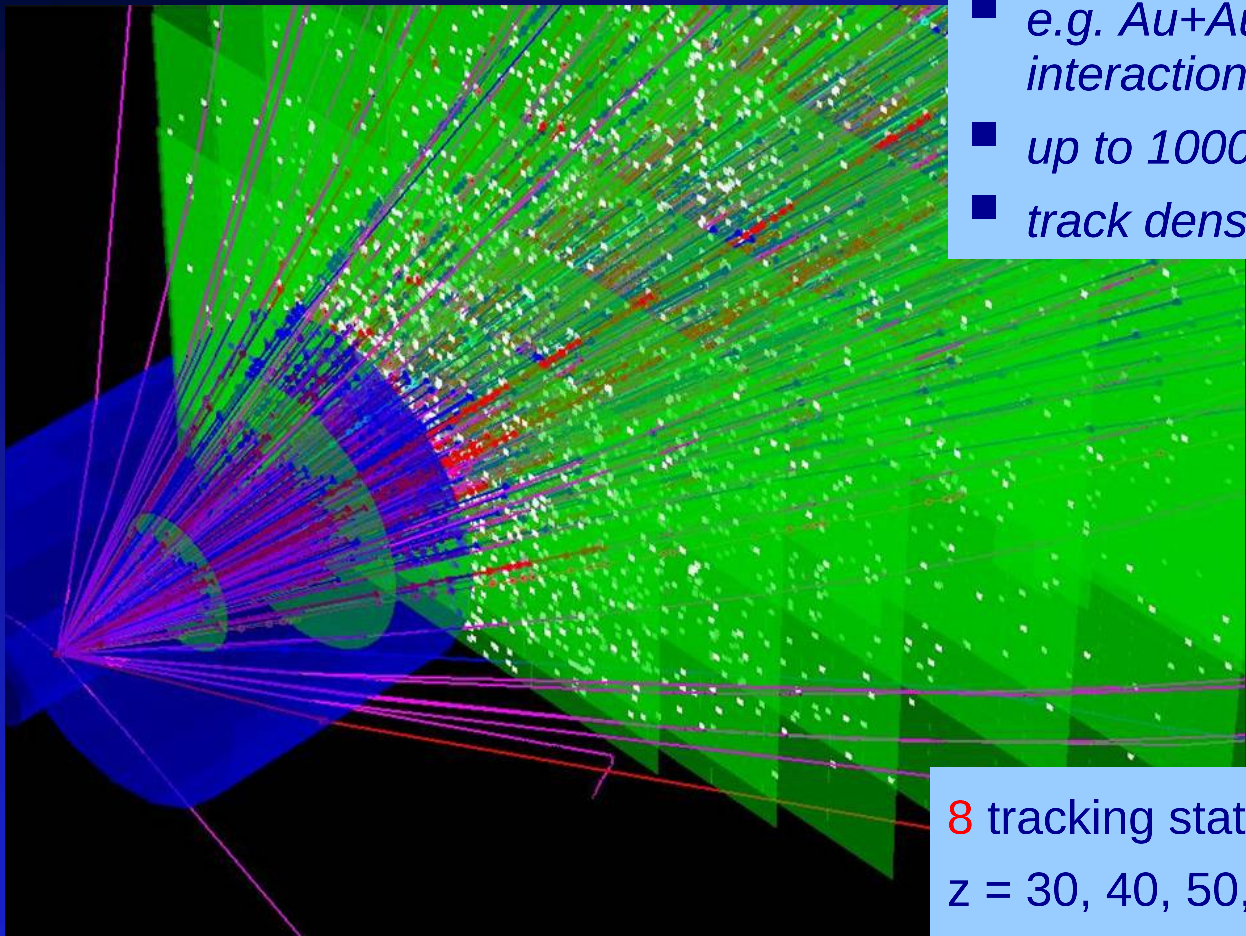
supported by the BMBF



CBM Silicon Tracking System

the mission ...

... tracking nuclear collisions



- *e.g. Au+Au collisions @ 25 GeV/u, interaction rates up to 10 MHz*
- *up to 1000 charged particles/event*
- *track densities up to 30 cm^{-2}*

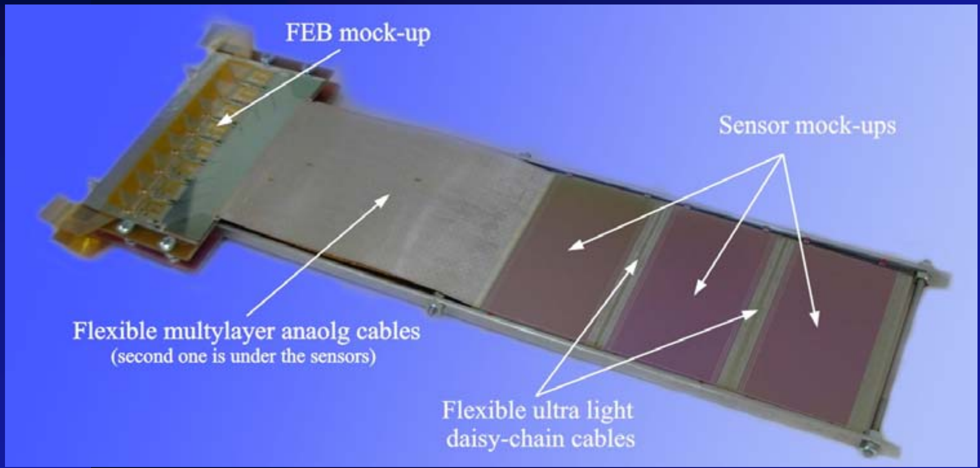
8 tracking stations at:

z = 30, 40, 50, 60, 70, 80, 90, 100 cm

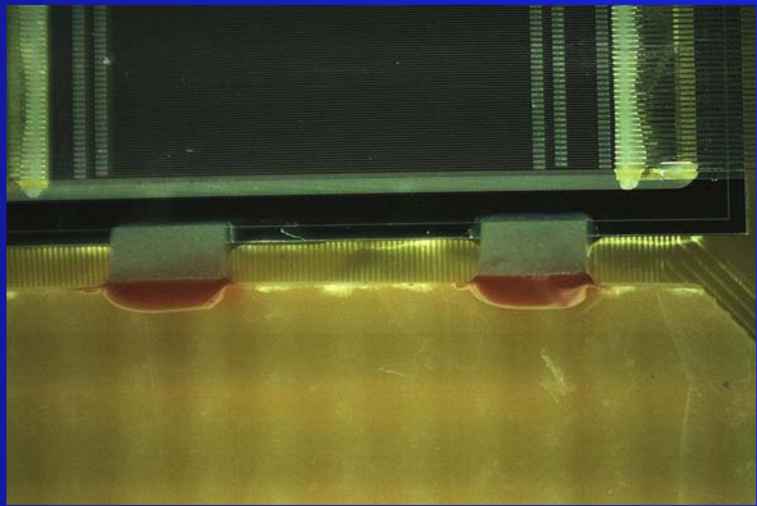
made from silicon microstrip detectors

activities towards new demonstrators & prototypes
(supported by the BMBF)

the first 3-sensor module mock-up: demonstrator -2a



demonstrator 2b = demo 0b, but on isolator



Nuclotron-M/NICA

- **JINR HEP** basic facility (*in operation since* **’93)** *based on the unique technology of* ***super-conducting fast cycling magnets*** *developed in JINR*
- provides proton, **polarized** deuteron *& multi charged ion beams*

The goal:

- *acceleration of heavy ions -> $^{197}Au^{79+}$*
- *energy ~ 4.5 GeV/u*
- *beam intensity ~ 10^9 A/cycle*

Nuclotron development:

- **Nuclotron-M** *(vacuum, PS, orbit corr. +…) completed in* **2010**
- **Nuclotron-NICA** *(Krion-6T, SPI, RF, new Linac +…) to be fulfilled in* ***2014***

Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New ion source + booster
p	$3 \cdot 10^{10}$	Duoplasmotron	$5 \cdot 10^{12}$
d	$3 \cdot 10^{10}$	--- ,, ---	$5 \cdot 10^{12}$
^{4}He	$8 \cdot 10^{8}$	--- ,, ---	$1 \cdot 10^{12}$
d↑	$2 \cdot 10^{8}$	SPI	$1 \cdot 10^{10}$
^{7}Li	$8 \cdot 10^{8}$	Laser	$5 \cdot 10^{11}$
$^{11,10}B$	$1 \cdot 10^{9,8}$	--- ,, ---	
^{12}C	$1 \cdot 10^{9}$	--- ,, ---	$2 \cdot 10^{11}$
^{24}Mg	$2 \cdot 10^{7}$	--- ,, ---	
^{14}N	$1 \cdot 10^{7}$	ESIS (“Krion-6T”)	$5 \cdot 10^{10}$
^{24}Ar	$1 \cdot 10^{9}$	--- ,, ---	$2 \cdot 10^{11}$
^{56}Fe	$2 \cdot 10^{6}$	--- ,, ---	$5 \cdot 10^{10}$
^{84}Kr	$1 \cdot 10^{4}$	--- ,, ---	$1 \cdot 10^{9}$
^{124}Xe	$1 \cdot 10^{4}$	--- ,, ---	$1 \cdot 10^{9}$
^{197}Au	-	--- ,, ---	$1 \cdot 10^{9}$

energy of beams extracted from Nuclotron

covers the gap between SIS-18 and AGS *(with some overlaps)*

	Z/A	max $\sqrt{s_{NN}}$ (GeV/n)	max. T_{kin} (GeV/n)
p	**1**	**≈ 5.2**	**≈ 12**
d	**1/2**	**≈ 3.8**	**≈ 5.7** *(including polarized deuterons)*
Au	**0.4**	**≈ 3.5**	**≈ 4.5** *(at **2T** in dipoles)*

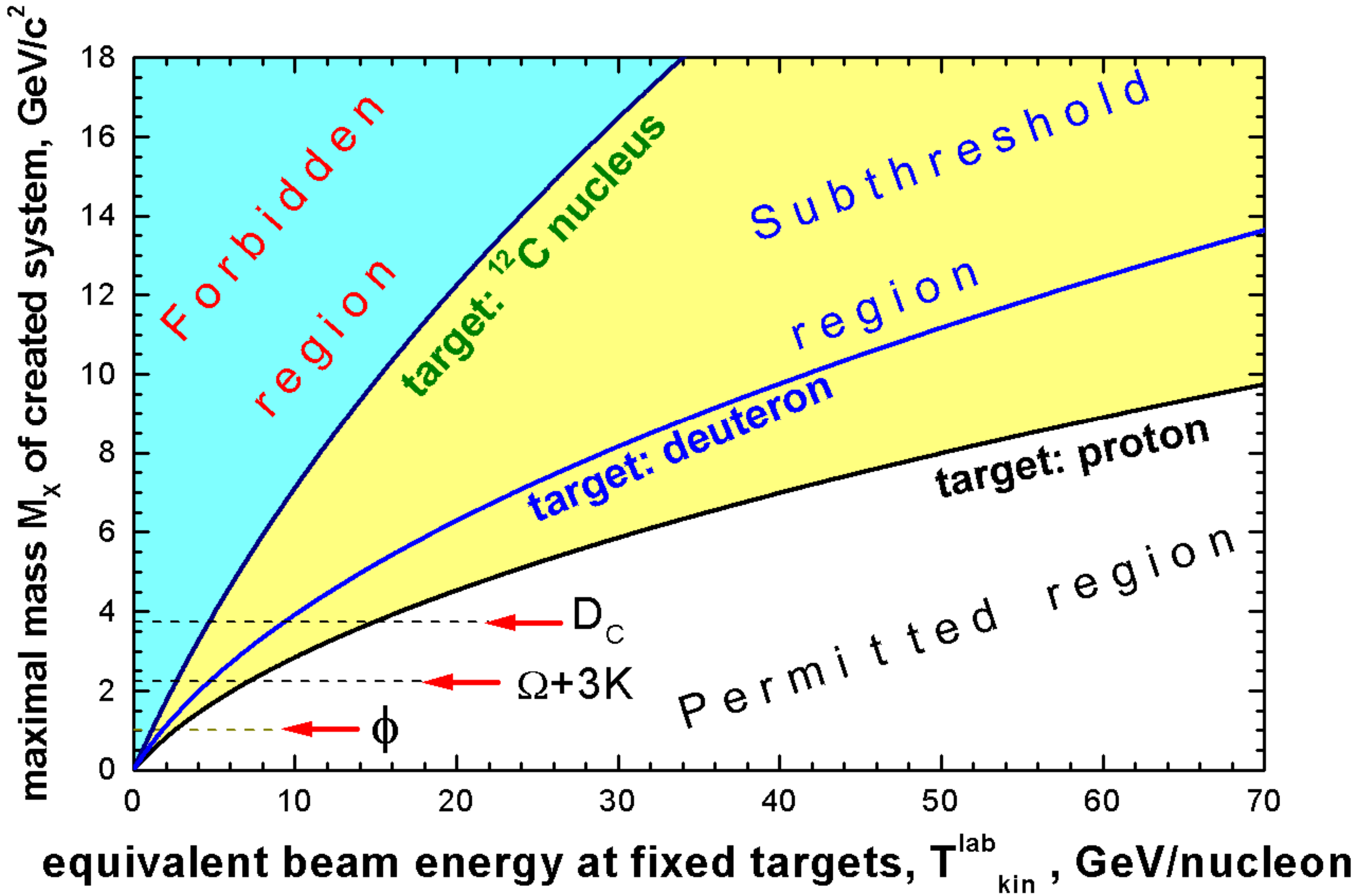
These allow:

- *study of dense baryonic matter at temperatures up to **100** MeV,*
- *(multi)-strangeness (open & hidden) production in dense baryonic matter,*
- *modification of particle properties in dense nuclear matter*

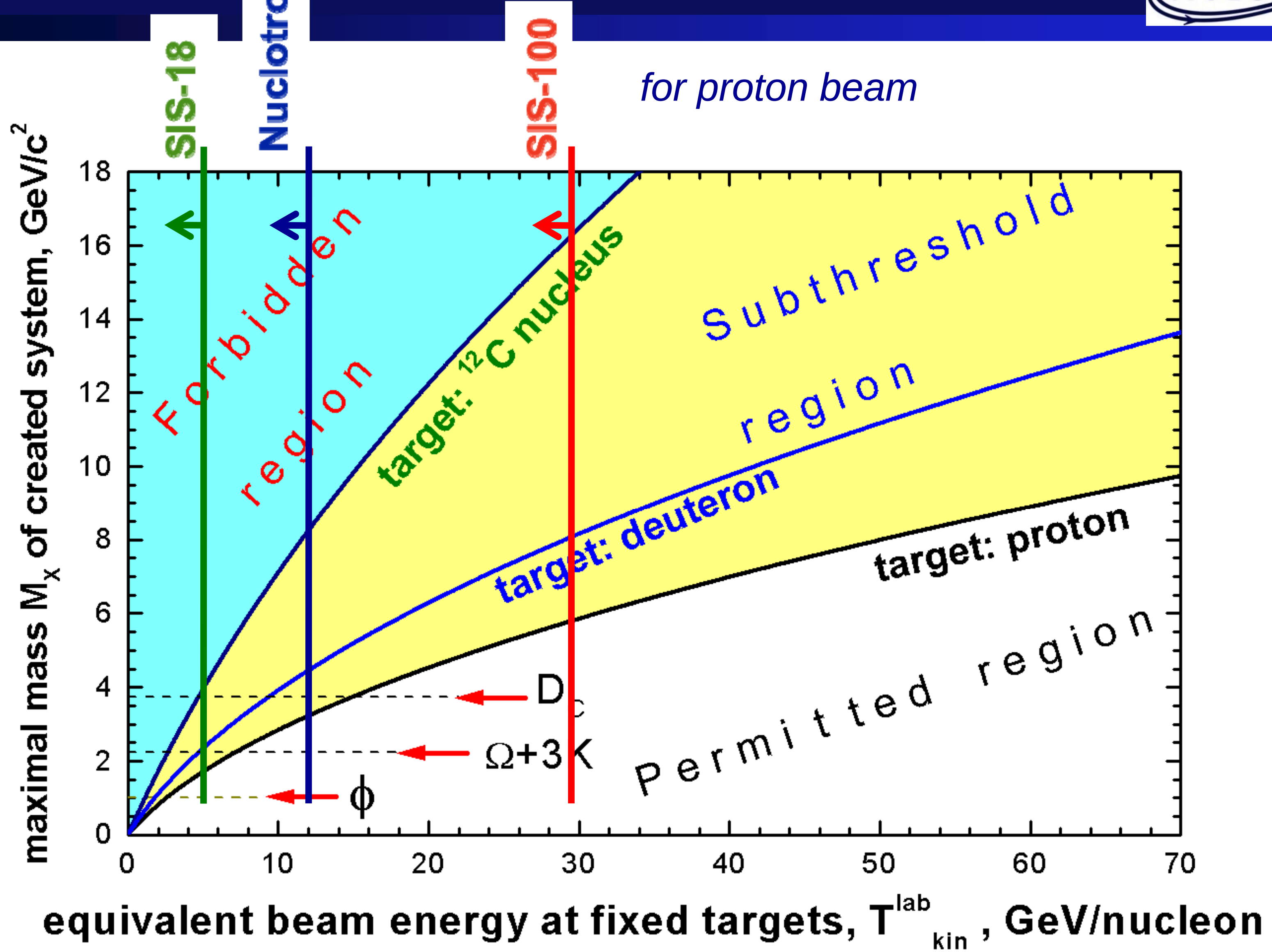
The corresponding multi-purpose setup

Baryonic Matter at Nuclotron (BM@N)

Kinematic thresholds

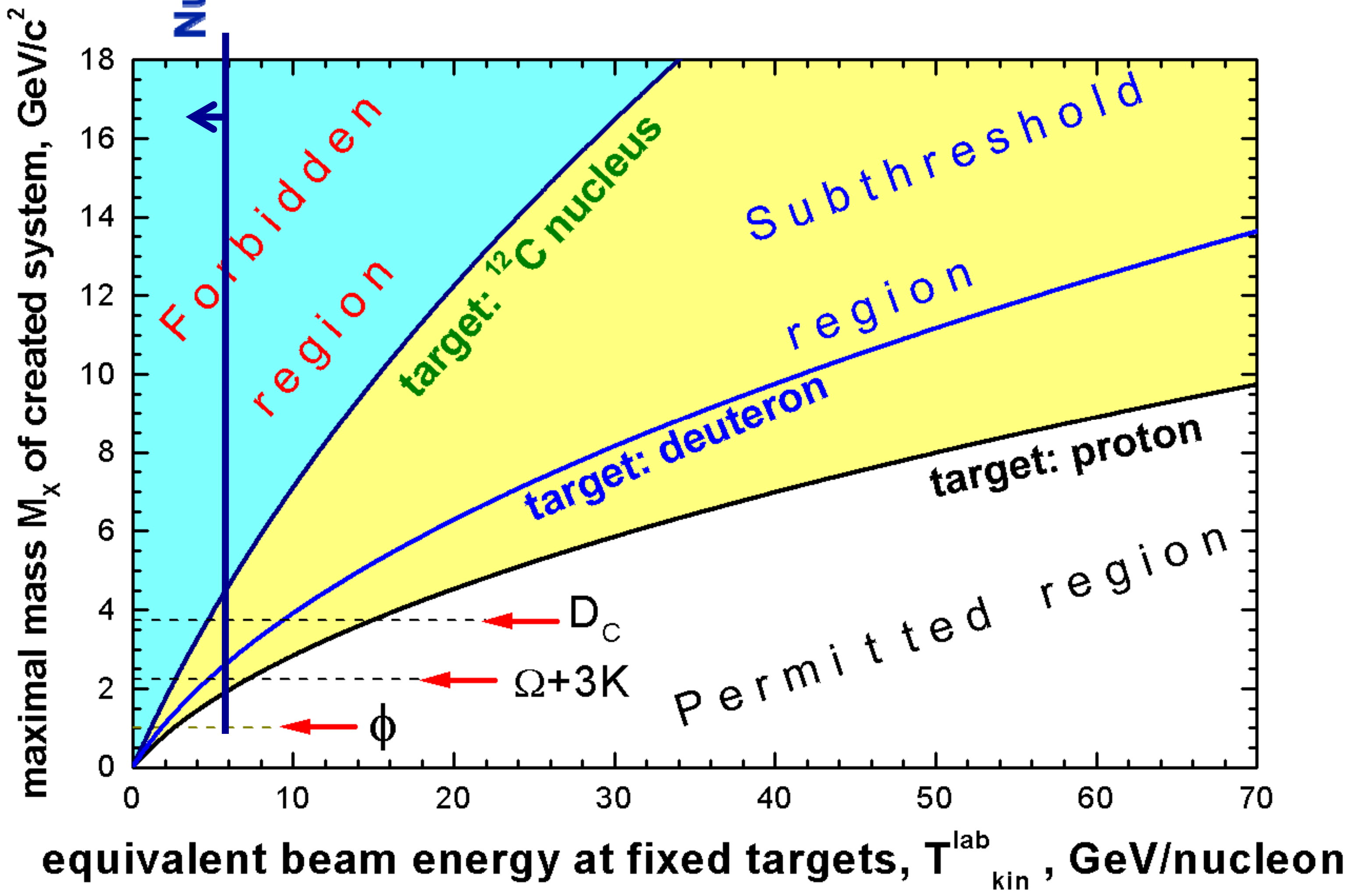


Kinematic thresholds

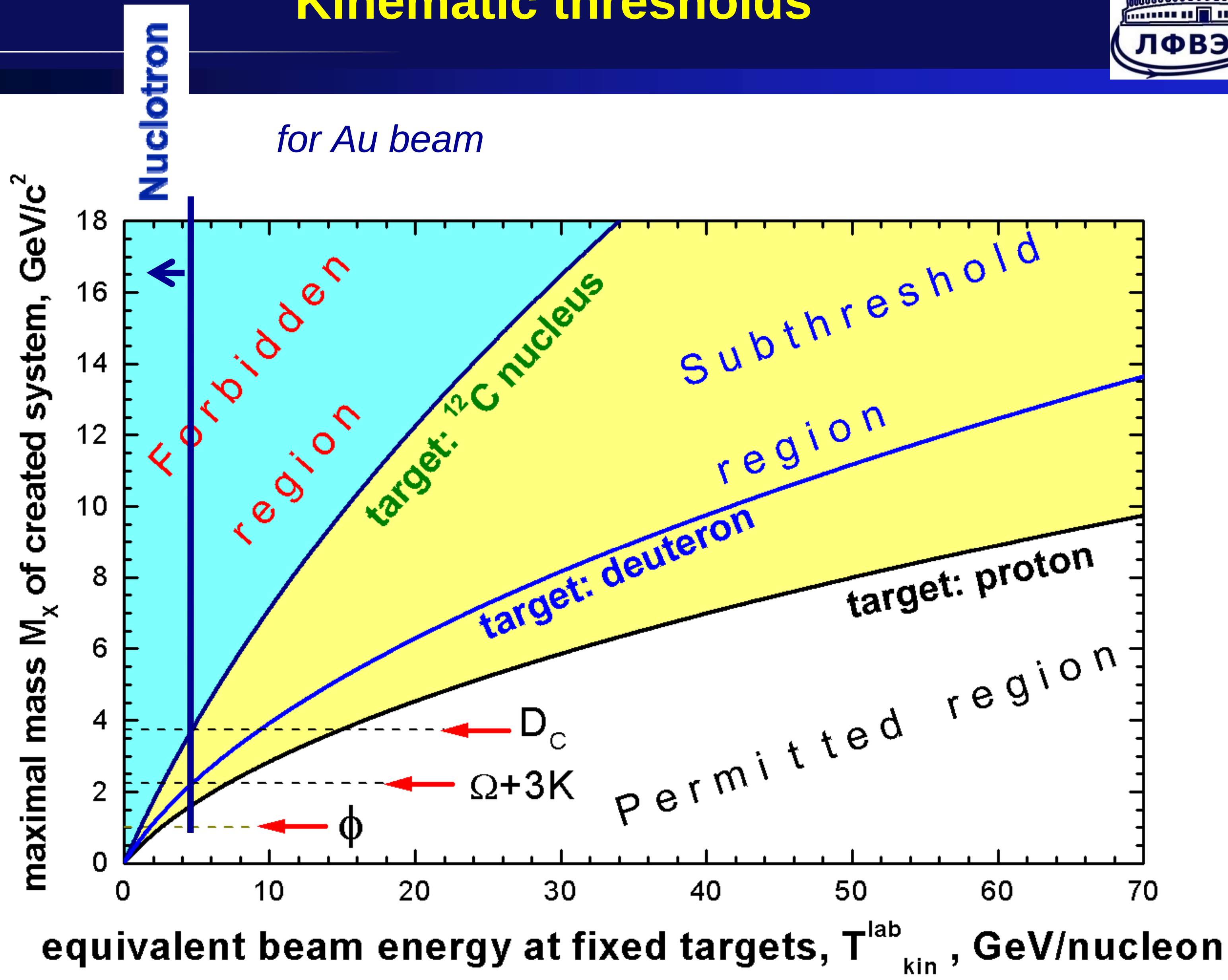


Kinematic thresholds

for deuteron beam



Kinematic thresholds



Study of dense baryonic matter at < 6 GeV/n

Physics is complementary to the MPD program
& will be actual even after start of the MPD runs:

- **AA interactions:**
  - particle production, incl. subthreshold one;
  - particle(collective) flows, event-by-event fluctuations, correlations;
  - multiplicities, phase space distributions of p, n, π, K, hyperons, light nuclear fragments, vector mesons, hadronic resonances, direct light hypernuclei production in central AA collisions.
  - ratios of yields (π/K etc) in different kinematical regions.

- **pA, nA, dA interactions in direct & inverse** (Ap, Ad) **kinematics:**
  - to get a "reference" data set for comparison with AA interactions,
  - to investigate particle modifications in hadronic matter advantages of the inverse kinematics (Ap, Ad collisions) may play significant role
  - to look for polarization effects in particle production off nuclear targets by polarized d, p, n.

Workshop

Fixed Target@Nuclotron-N and SIS100@FAIR

Detector R&D, Synergies and Physics Opportunities

GSI Helmholtz Centre, 2010 November 3rd

Wednesday, November 3rd

GSI WD-Zimmer

09:30 – 09:45 **Welcome and Goals of the Meeting**		H. Stöcker
Chair: A. Sorin		
09:45 – 11:00 **Technical Status of the Facilities**		
Nuclotron-M: Status of the Facility and the New Fixed Target Program		V. Kekelidze
Towards Nuclotron-N@JINR & SIS100@FAIR Physics Program		H. Stöcker /A. Sorin
Coffee Break		
Chair: G.Trubnikov		
11:15 – 12:15 **Nuclear Structure Physics**		
Nuclear Structure and Nuclear Astrophysics opportunities with RIBs		G. Martinez-Pinedo
Status of R3B		T. Aumann / H.Simon
Lunch Break (small Lunch incl. coffee / WD-Zimmer)		
Chair: V. Kekelidze		
13:00 – 15:00 **Nuclear Matter Physics**		
Status of the HADES Upgrade, recent results		R. Holzmann / J. Pietraszko
Status of FOPI, recent results		N. Herrmann
Nuclear Matter Physics at Nuclotron and SIS100 energies		P. Senger
Status of R&D CBM		W. Müller
The STS Consortium		J. Heuser
Coffee Break		
15:15 – 17:00 **Final Panel Discussion:**		
Synergies and Joint R&D Projects		Chair: H. Stöcker
17:30 *Dinner at the GSI Guesthouse*		

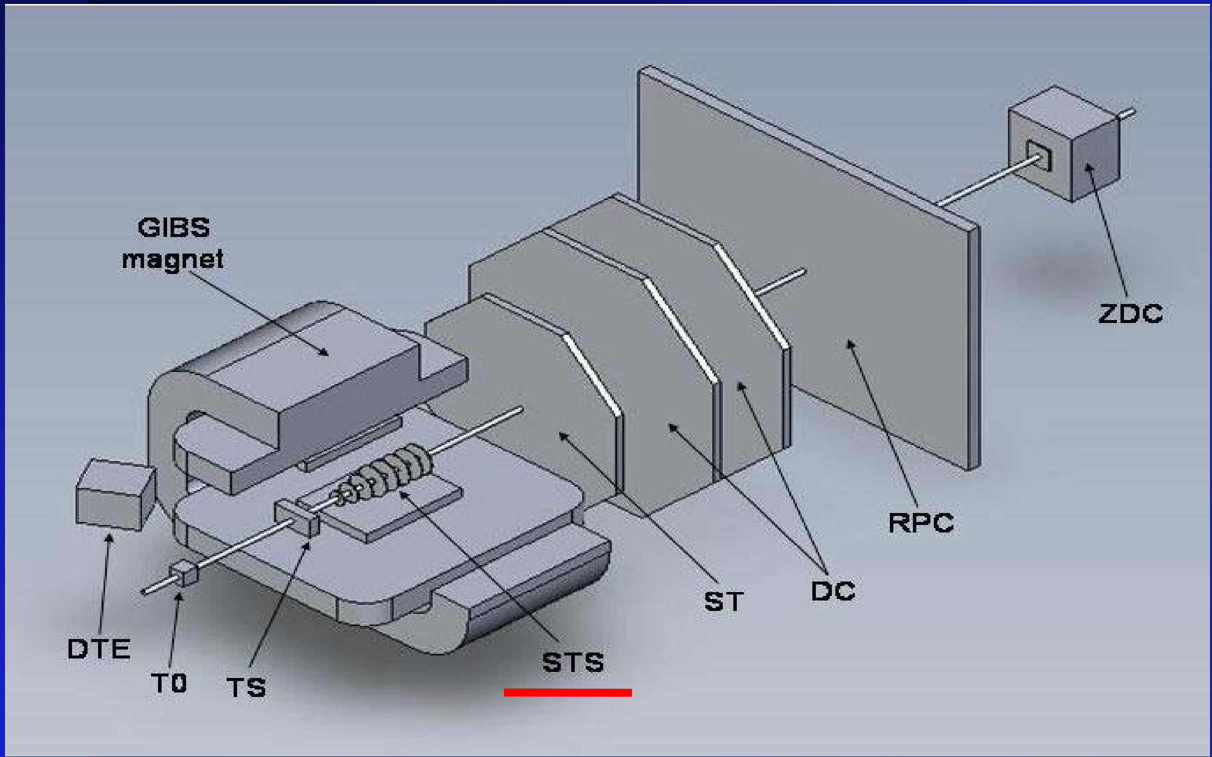
Preparation of the joint GSI - JINR experiment has started

in the study of baryonic matter production *at the **Nuclotron***

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

Goal of the BM@N experiment

- measurements of the mult-istrange objects (Ξ, Ω, exotics) & hypernuclei in HI collisions
- close to the threshold production in the region of high sensitivity to the models prediction



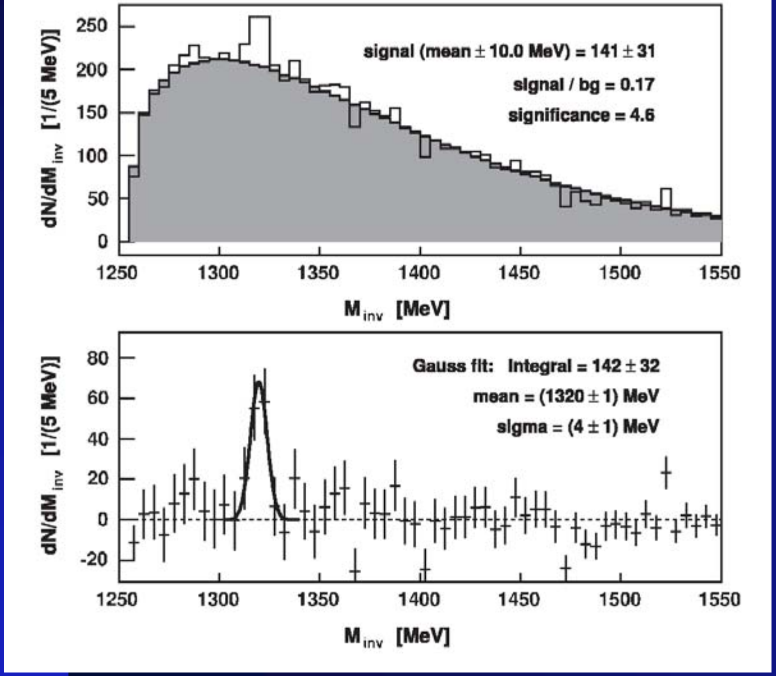
GIBS magnet (SP-41)

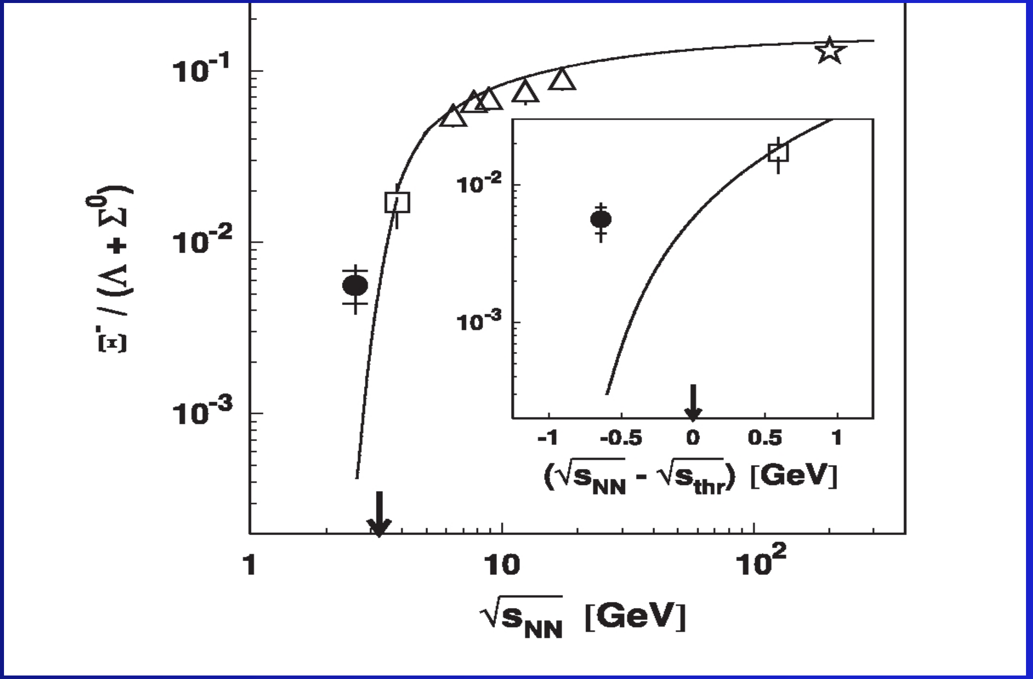
TS-target station,
T0- start diamond detector,
STS - silicon tracker,
ST- straw tracker,
DC- drift chambers,
RPC- resistive plate chambers,
ZDC- zero degree calorimeter,
DTE – detector of tr. energy.

- the detector based on the sub-detectors developed for CBM, MPD & SPD

Motivation

- The multistrange objects (Ξ, Ω, exotics) & hypernuclei in HI collisions bring the information on the early stage of nuclei-nuclei interaction

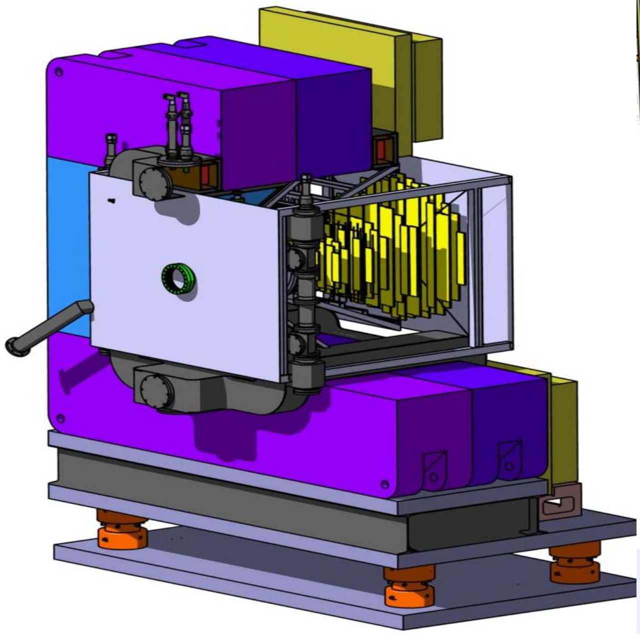


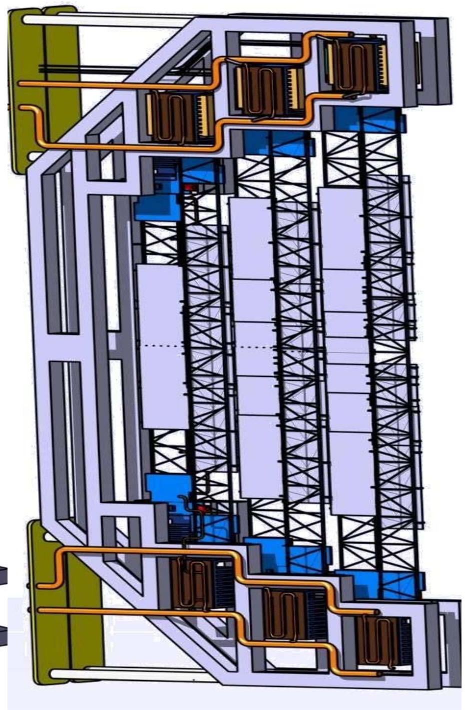


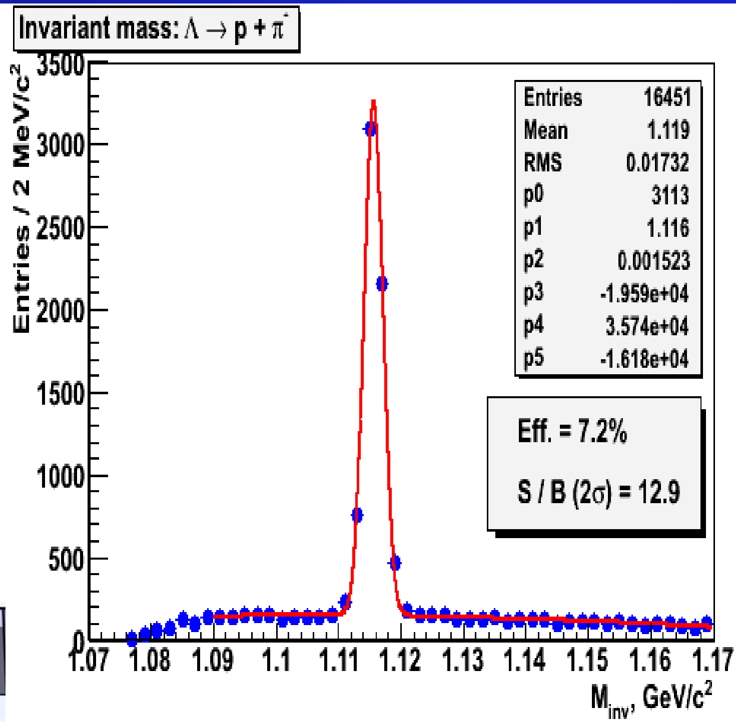
- Recent HADES (GSI) data on the deep subthreshold Ξ production demonstrated high sensitivity to the details of the nuclei-nuclei interactions description

CBM-MPD Silicon Tracker System

- The major part of the BM@N detector to select strange particles is the 8 stations Silicon Tracker System (STS) based on the technologies developed for CBM and MPD







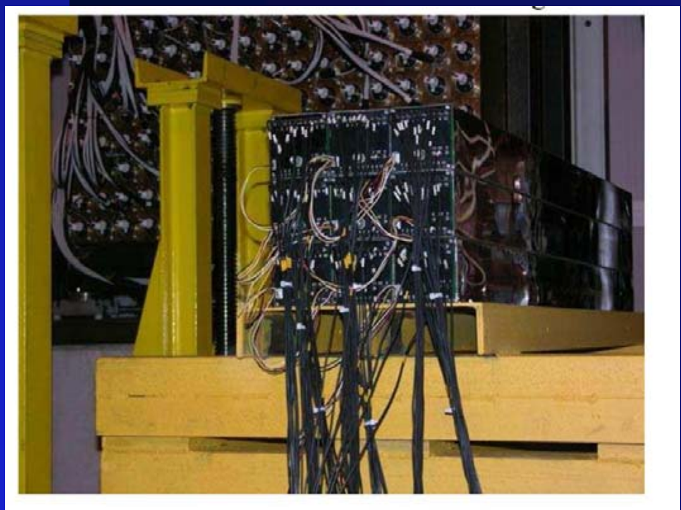
- The simulation demonstrated the feasibility of the hyperons selection at Nuclotron

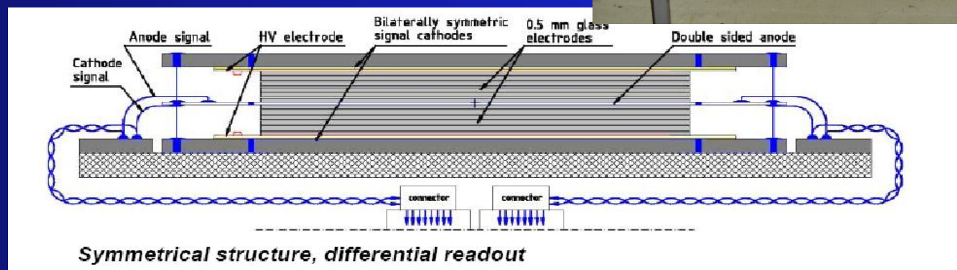
Tracking, particle ID & centrality measurements

Straw tracker
(CBM/MPD)

NA48 drift chambers
(NA48 – CERN/JINR)

RPC TOF



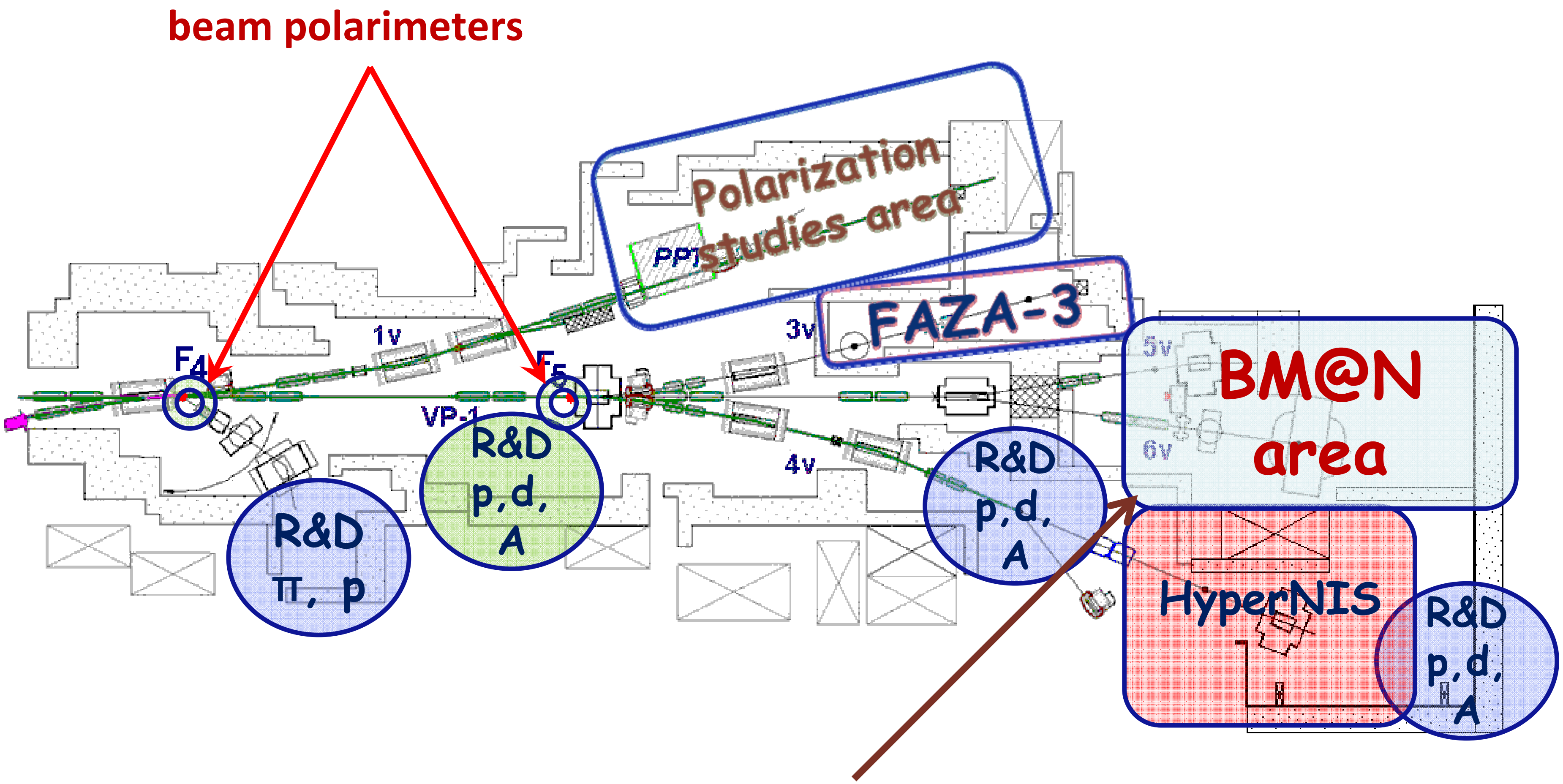


ZDC (CBM/MPD -INR,JINR)

Infrastructure development in fixed target area

(bld. 205, 10 000 m^2)

Bld. 205: planned structure of research zones



Baryonic Matter at Nuclotron (DBM@N)

Roof reparation *(new technology)*


K-2


КАНАЛ
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From CERN to

Fixed target experiment area

Should be properly developed in parallel with
Nuclotron upgrade & NICA collider construction

This is the high priority task, because it provides:

- relevant experimental *program* in BM, *(could be started in 2014)*
- proper *monitoring* of Nuclotron performance & beam parameters
- highly required beams - *to test MPD & SPD various subsystems*
- development of modern experimental *infrastructure,*
  organization of necessary services,
  & training of corresponding personal
- better *integration* of the JINR HEP facility into
  the common European research infrastructure

Conclusion

- essential progress is achieved in the development of HEP basic facility – Nuclotron-M -> NICA
- the proper preparation of FT area is going well since last decade
- that allow to start up a challenging research program already at the Nuclotron
  attractive for wide international collaborations
- the joint project of JINR & GSI - **BM@N** has been initiated for preparation
- this indicates the new stage of JINR - GSI cooperation in RHIP

Conclusion

- *participants from Russian Institutions started cooperation in physics program development + R&D activities*

- *further progress in this cooperation is very desirable but it requires both:*

  - more active works for RF Institution involvements

  - essential recourses which could be available in case of dedicated State Program

RF Prime Minister V.V. Putin at NICA, 5 July 2011

Thank you !

Spares

RF Prime Minister V.V. Putin at NICA, 5 July 2011

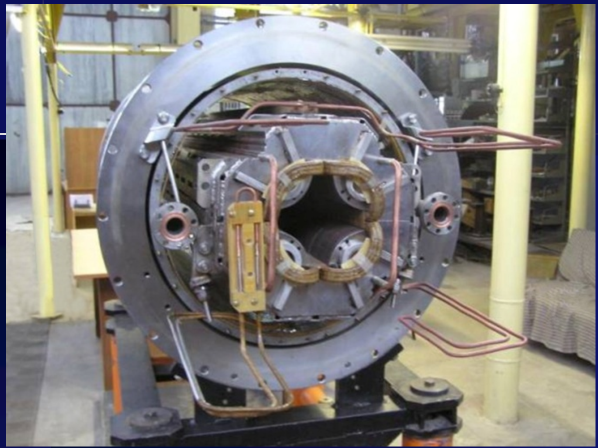
Experiments & activities at Nuclotron

- ALPOM → ALPOM-2
- STRELA (finished)
- LNS, pHe3 → DSS
- DELTA-2 (finished)
- DELTA-SIGMA (→2011, finished)
- NIS, GIBS → HyperNIS
- TPD (to be completed)
- MARUSYA (test beams of secondaries)
- η- nuclei (work in parasitic mode)
- PHASA → PHASA-3
- BECQUEREL (work in parasitic mode)
- Thermalisation (IHEP) (to be completed)

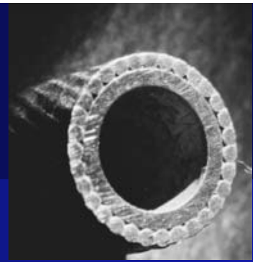
- Energy & transmutation
- DVIN (to be completed)

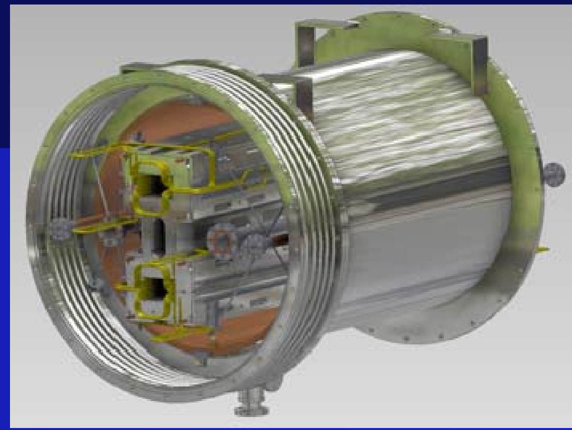
→ new encouraging results

- Compact electron & ion accelerators
- Straw detectors



Премия Правительства РФ в 2010 году
(совместно с ИТЭФ)





Уникальные Дубненские технологии сверхпроводящих магнитов, испытанные в ходе нескольких десятков сеансов на Нуклотроне и выбранные базовыми при создании комплексов

НИКА (ОИЯИ, Россия) и ФАИР (Германия)

Проект НИКА в ОИЯИ, (Дубна, Россия)

Проект ФАИР (Дармштадт, Германия

Beam	***GSI (SIS18)*** **Energy & Intensities, particles per cycle**				
	Energy		*Nuclotron-M (2010)*	*Planned with Nuclotron-N (2012)*	*Planned with new ion source and booster (2014-2015)*
p	4,5 GeV	$2\cdot10^{10}$	$8\cdot10^{10}$	$5\cdot10^{11}$	$5\cdot10^{12}$
d	2,2 GeV	$5\cdot10^{11}$	$8\cdot10^{10}$	$5\cdot10^{11}$	$5\cdot10^{12}$
^{4}He			$2\cdot10^{9}$	$3\cdot10^{10}$	$1\cdot10^{12}$
d↑			$2\cdot10^{8}$	$7\cdot10^{10}$ *(SPI)*	$7\cdot10^{10}$ *(SPI)*
$^{7}Li^{6+}$			$7\cdot10^{9}$	$3\cdot10^{10}$	$5\cdot10^{11}$
$^{12}C^{6+}$	300 MeV	$7\cdot10^{10}$	$6\cdot10^{9}$	$3\cdot10^{10}$	$3\cdot10^{11}$
$^{24}Mg^{12+}$	300 MeV	$5\cdot10^{10}$	$7\cdot10^{8}$	$4\cdot10^{9}$	$5\cdot10^{10}$
$^{40}Ar^{18+}$	300 MeV	$6\cdot10^{10}$	$8\cdot10^{6}$	$2\cdot10^{9}$	$2\cdot10^{10}$
$^{56}Fe^{28+}$			$4\cdot10^{6}$	$2\cdot10^{9}$	$5\cdot10^{10}$
$^{58}Ni^{26+}$	300 MeV	$8\cdot10^{9}$			
$^{84}Kr^{34+}$	0,3 -1 GeV	$2\cdot10^{10}$	$2\cdot10^{5}$	$1\cdot10^{8}$	$1\cdot10^{9}$
$^{124}Xe^{48/42+}$	0,3 -1 GeV	$1\cdot10^{10}$	$1\cdot10^{5}$	$7\cdot10^{7}$	$1\cdot10^{9}$
$^{181}Ta^{61+}$	1 GeV	$2\cdot10^{9}$			
$^{197}Au^{65/79+}$		$3\cdot10^{9}$		$1\cdot10^{8}$	$1\cdot10^{9}$

Major projects in physics

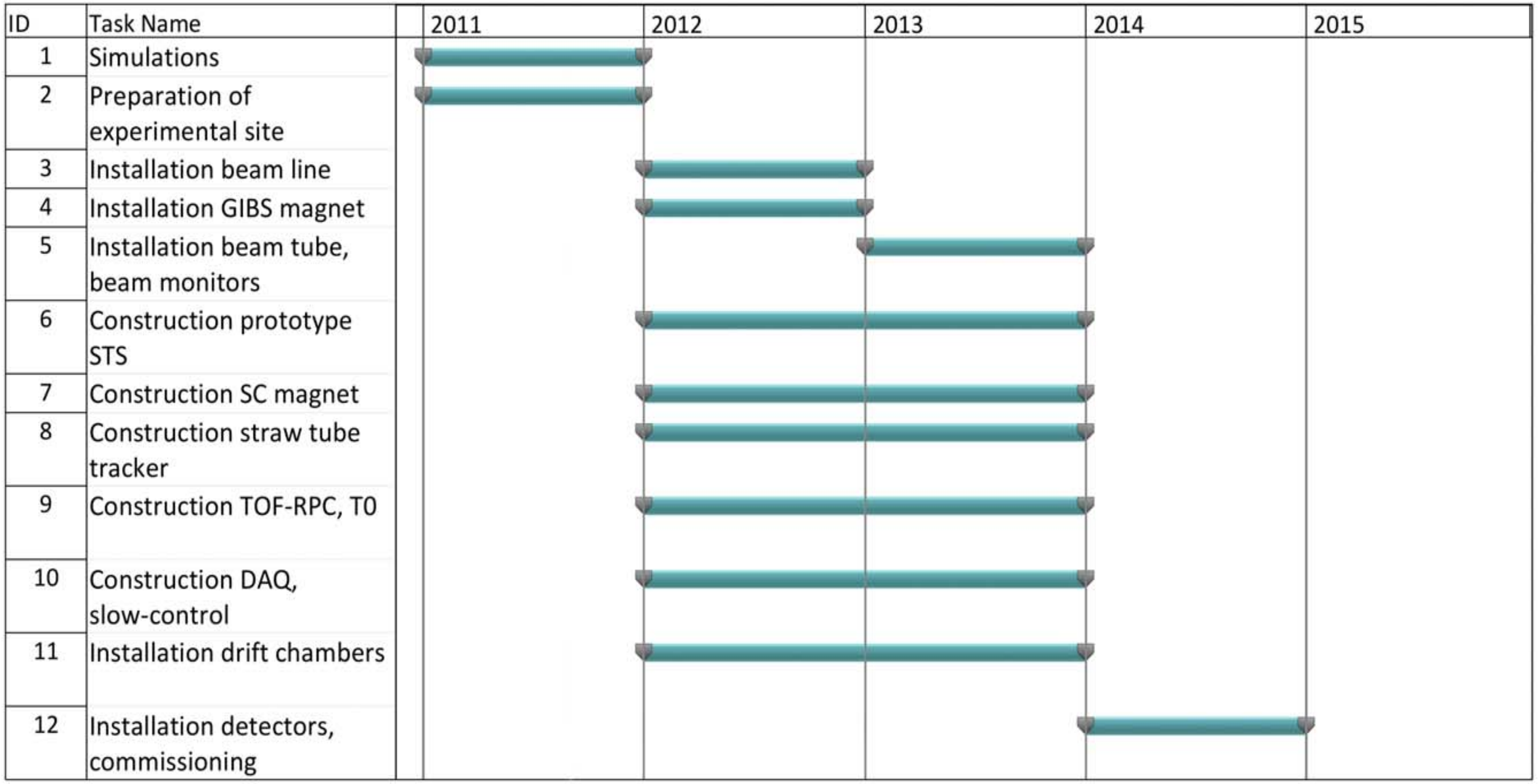
RHIP	SP	PP
▪ MPD (NICA)	▪ SPD (NICA)	
▪ **PHASA-3** ▪ **BM@N** **(Nuclotron-M/N)**	▪ **ALPOM-2, DSS** ▪ **SPRINT*)** **(Nuclotron-M/N)**	▪ **HyperNIS** **(Nuclotron-M/N)**
▪NA61 (CERN, SPS) ▪ ALICE (CERN, LHC)	▪ COMPASS (CERN,SPS)	▪NA62 (CERN, SPS)
▪ STAR (BNL, RHIC)	▪ STAR (BNL, RHIC)	▪CMS (CERN, LHS)
▪ HADES/CBM (GSI, SIS-18/100/300)	*)-**S**pin **P**hysics **R**esearch **I**nfrastructure at **N**uclo**T**ron-NICA	

New proposals

Coordination of works

Accelerator operation (~ 2000h in '12) ⟷ Run Coordinator *A.E.Strokovsky* ⟷ Experiments at Nuclotron

Time table and resources



Total cost of the project is about 10 M$

International Cooperation at Nuclotron-M/N

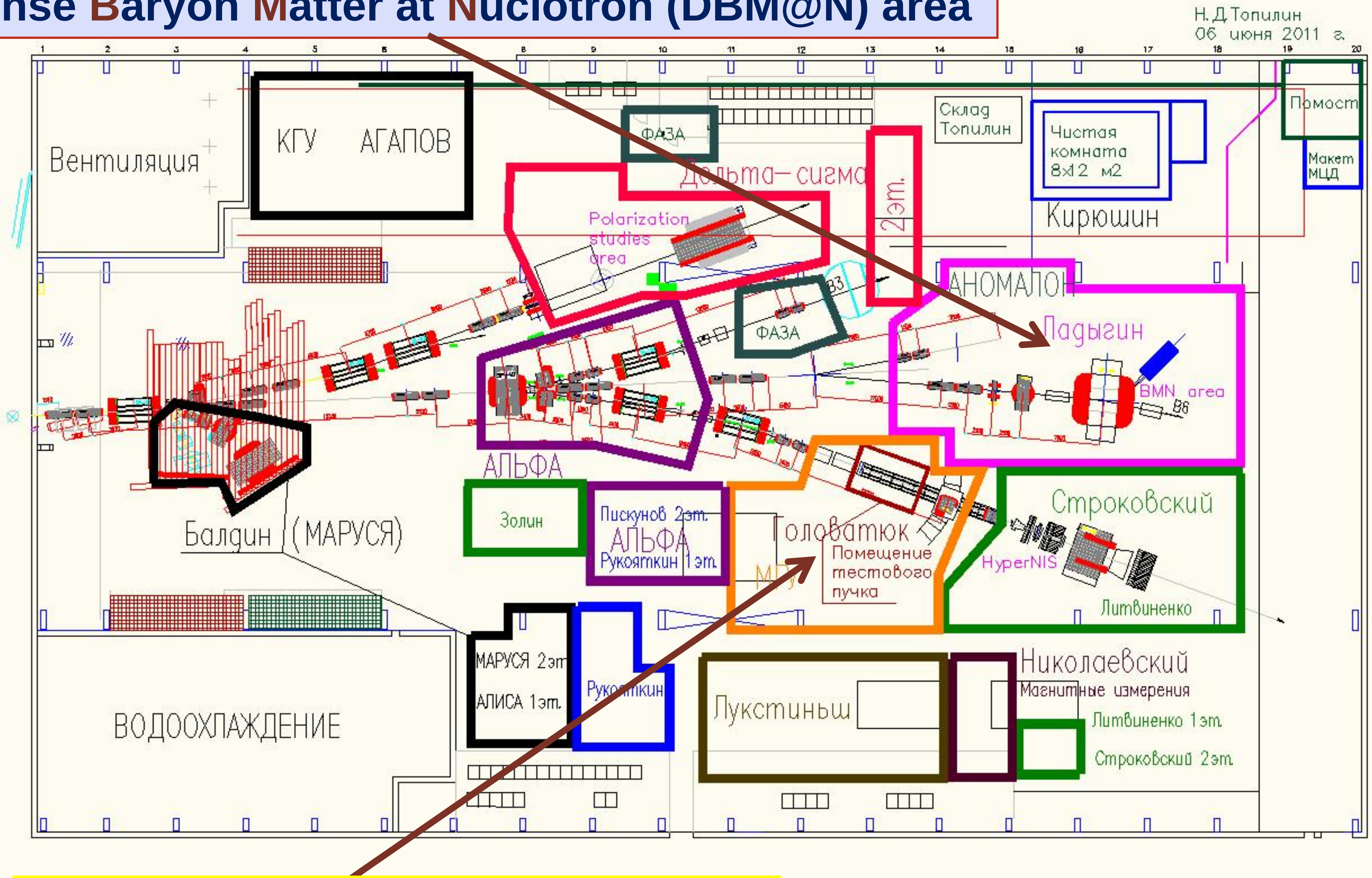
- **Joint Institute for Nuclear Research**
- Institute for Nuclear Research, RAS, **RF**
- Nuclear Physics Institute of MSU, **RF**
- Institute Theoretical & Experimental Physics, **RF**
- St.Petersburg State University, **RF**
- Bogolyubov Institute for Theoretical Physics, NAS, **Ukraine**
- Institute for Scintillation Materials, Kharkov, **Ukraine**
- State Enterprise Scientific & Technology Research Institute for Apparatus construction, Kharkov, **Ukraine**
- Institute of Applied Physics, AS, **Moldova**
- Particle Physics Center of Belarusian State University, **Belarus**
- Physics Institute Az.AS, **Azerbaijan**
- Institute for Nuclear Research & Nuclear Energy BAS, Sofia, **Bulgari**a
- Aristotel University of Thessaloniki, **Greece**
- GSI, **Germany**
- Institute of Physics & Technology of MAS, University of **Mongolia**
- Department of Engineering Physics, Tsinghua University, Beijing, **China**
- University of Science and Technology of China, Hefei, **China**
- Osaka University, **Japan**
- RIKEN, **Japan**
- The University of Sidney, **Australia**
- TJNAF (Jefferson Laboratory), **USA**
- University of Cape Town, **RSA**

Organizational issues

- *the new team dedicated to the maintenance of experimental area infrastructure in the bld. 205 is created*
- *this team led by N.Topilin started active works in the area*
- *in addition dedicated weekly meetings are organized & chaired by the chief engineer N.Agapov*
- *all experimental set-up's will be carefully revised in accordance with the technical inspection requirement*
- *preparation of areas for the new experimental set-ups has started*

Bld. 205: present layout
+ 2 areas under preparation

Dense Baryon Matter at Nuclotron (DBM@N) area



Area for R&D of MPD subdetectors