The NICA Complex at JINR: status and plans

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JINR LHEP

NICA (Nuclotron dased Ion Colider fAcility) – the JINR flagship project in HEP

Main targets of "NICA Complex":

- ***study of hot and dense baryonic matter***
- *investigation of nucleon spin structure, polarization phenomena*

- *development of accelerator facility for HEP@JINR providing*

intensive beams of relativistic ions from p to Au with max energy up to $\sqrt{S_{NN}}$= ***11 GeV*** *and* **L=~10[27]** *cm*$^{-2}$ *c*$^{-1}$ ***(Au***$^{79+}$***)***

and polarized protons and deuterons with max energy up to ***26 GeV and L=~10[32]*** *cm*$^{-2}$ *c*$^{-1}$ ***(p)***

NICA accelerator opportunities

1: - Heavy ion colliding beams $^{197}Au^{79+}$ x $^{197}Au^{79+}$ at

$\sqrt{s_{NN}}$ = 4 ÷ 11 GeV (1 ÷ 4.5 GeV/u ion kinetic energy)

at $L_{average}$= 1x10^{27} cm^{-2}·s^{-1} (at $\sqrt{s_{NN}}$ = 9 GeV)

- Light-Heavy ion colliding beams of the same energy range and L

2: Polarized beams of protons and deuterons in collider mode:

p↑p↑ $\sqrt{s_{pp}}$ = 12 ÷ 27 GeV (5 ÷ 12.6 GeV kinetic energy)

d↑d↑ $\sqrt{s_{NN}}$ = 4 ÷ 13.8 GeV (2 ÷ 5.9 GeV/u ion kinetic energy)

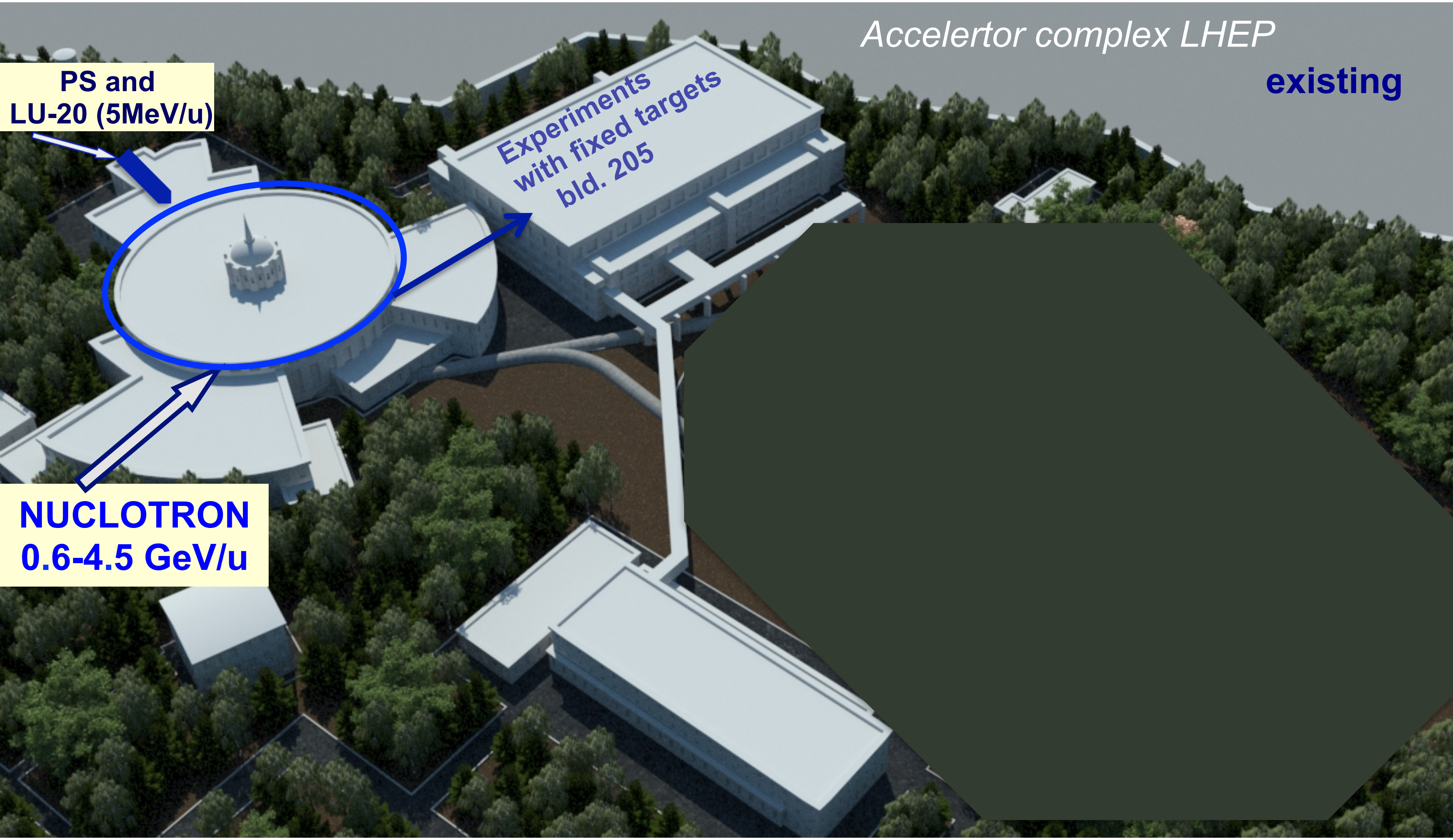
$L_{average}$ ≥ 1x10^{32} cm^{-2}·s^{-1} (at $\sqrt{s_{pp}}$ = 27 GeV)

3: The beams of light ions and polarized protons and deuterons for fixed target experiments:

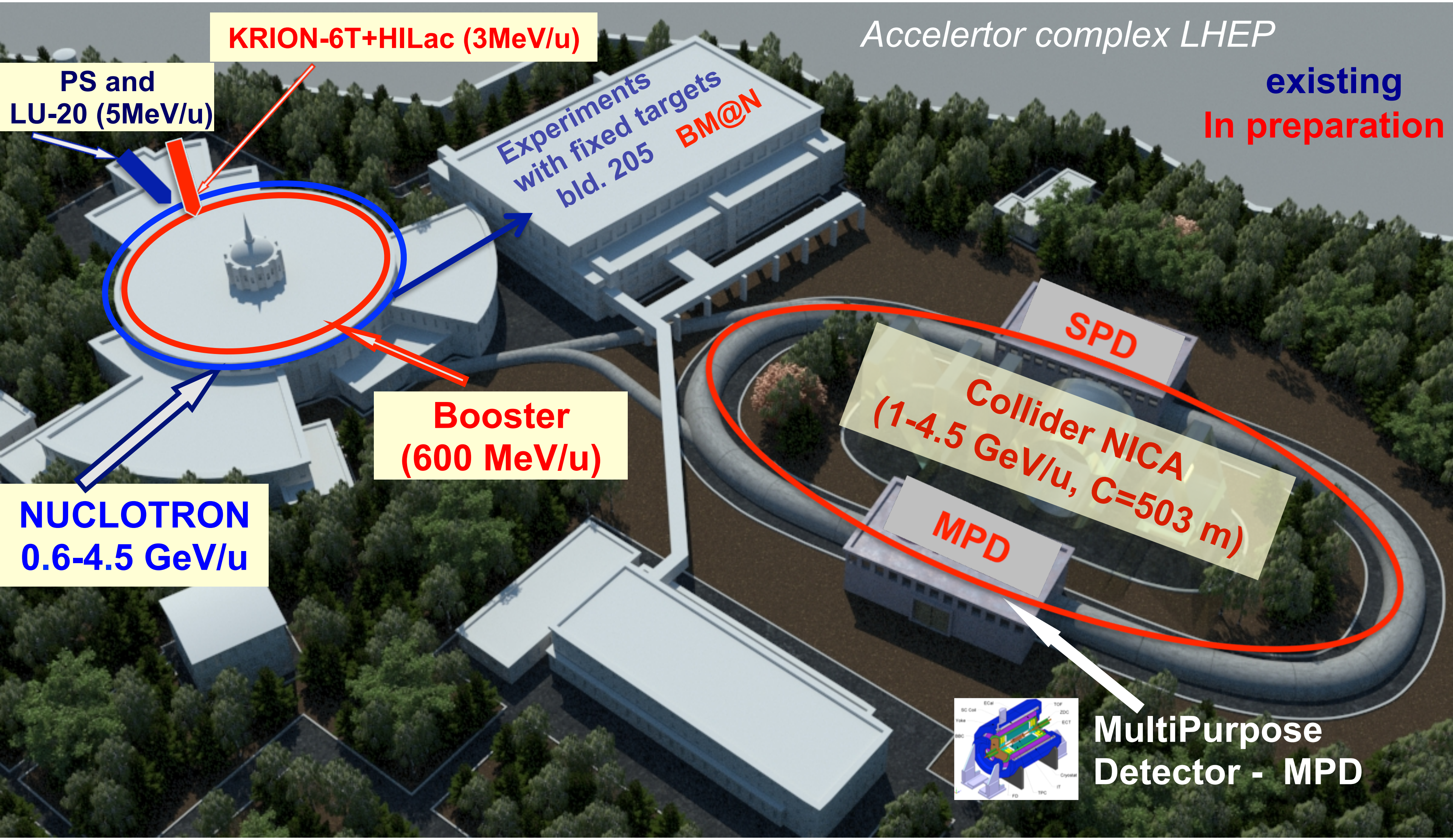
Li ÷ Au = 1 ÷ 4.5 GeV /u ion kinetic energy
p, p↑ = 5 ÷ 12.6 GeV kinetic energy
d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

4: Ion beams for applied researches at kinetic energy from 0.5 GeV/u up to 12.6 GeV (p) and 4.5 GeV /u (Au)

The NICA Complex



The NICA Complex



Complex NICA – civil construction

The project of the CV was done by the Moscow design firm “Kometa” and has passed through the State Expertise in 2013

For the first time at JINR an international tendering has been organized

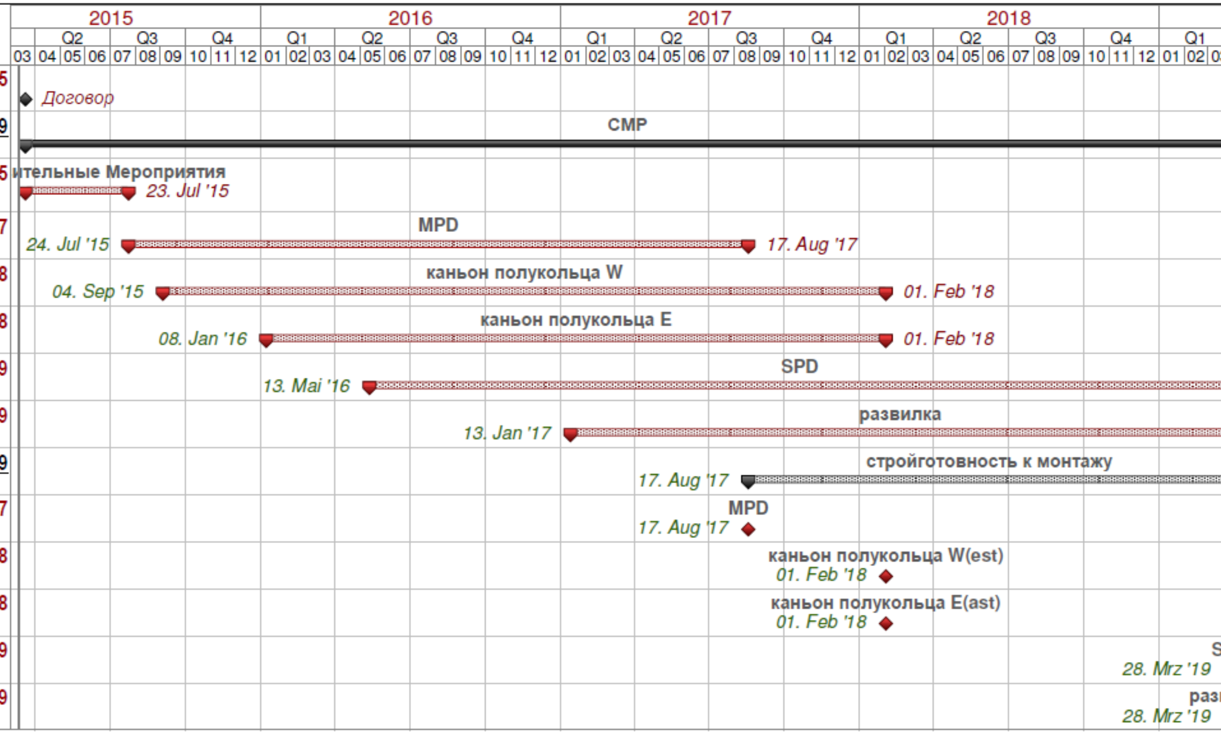
Contract for Working Documentation signed in August'14. Ready – mid 2015

In January 2015 20 test piles (up to 15 m) has been pushed and additional drilling for soil analysis for special vibration tests has been done

A Contract for Civil Construction

/MPD — Концептуальный график организаций работ — STRABAG

Notizen	Длит-сть	Anfang	Fertig stellen
Договор			Fr 20.03.15
CMP	1050 Tage	Fr 20.03.15	Do 28.03.19
Подготовительные Мероприятия	90 Tage	Fr 20.03.15	Do 23.07.15
MPD	540 Tage	Fr 24.07.15	Do 17.08.17
каньон полукольца W	630 Tage	Fr 04.09.15	Do 01.02.18
каньон полукольца E	540 Tage	Fr 08.01.16	Do 01.02.18
SPD	750 Tage	Fr 13.05.16	Do 28.03.19
развилка	575 Tage	Fr 13.01.17	Do 28.03.19
стройготовность к монтажу	420 Tage	Do 17.08.17	Do 28.03.19
MPD			Do 17.08.17
каньон полукольца W(est)			Do 01.02.18
каньон полукольца E(ast)			Do 01.02.18
SPD			Do 28.03.19
развилка			Do 28.03.19



A contract for General construction works is under very final agreement – planned to sign in July

NICA – basic milestones

- JINR 7-years plan (2010-2016) is approved **2009**
- NICA project is approved **2010**
- The *1-st stage of Nuclotron modernization*
  is completed **2010**
  9 runs are fulfilled in 2010-2015
- The projects have been approved for:
  - ✓ accelerator complex **2010 – 2019**
  - ✓ MPD (Multi-Purpose Detector, start-up) **2010 – 2019**
  - ✓ experiment with fixed target BM@N (I stage) **2012 – 2018**
- The project preparation for Spin Physics Detector (SPD) is going on

Last PAC on PP approved all existing project on the NICA complex up to 2020

Research in Relativistic Heavy Ions

is intensively developing fields in the last two decades

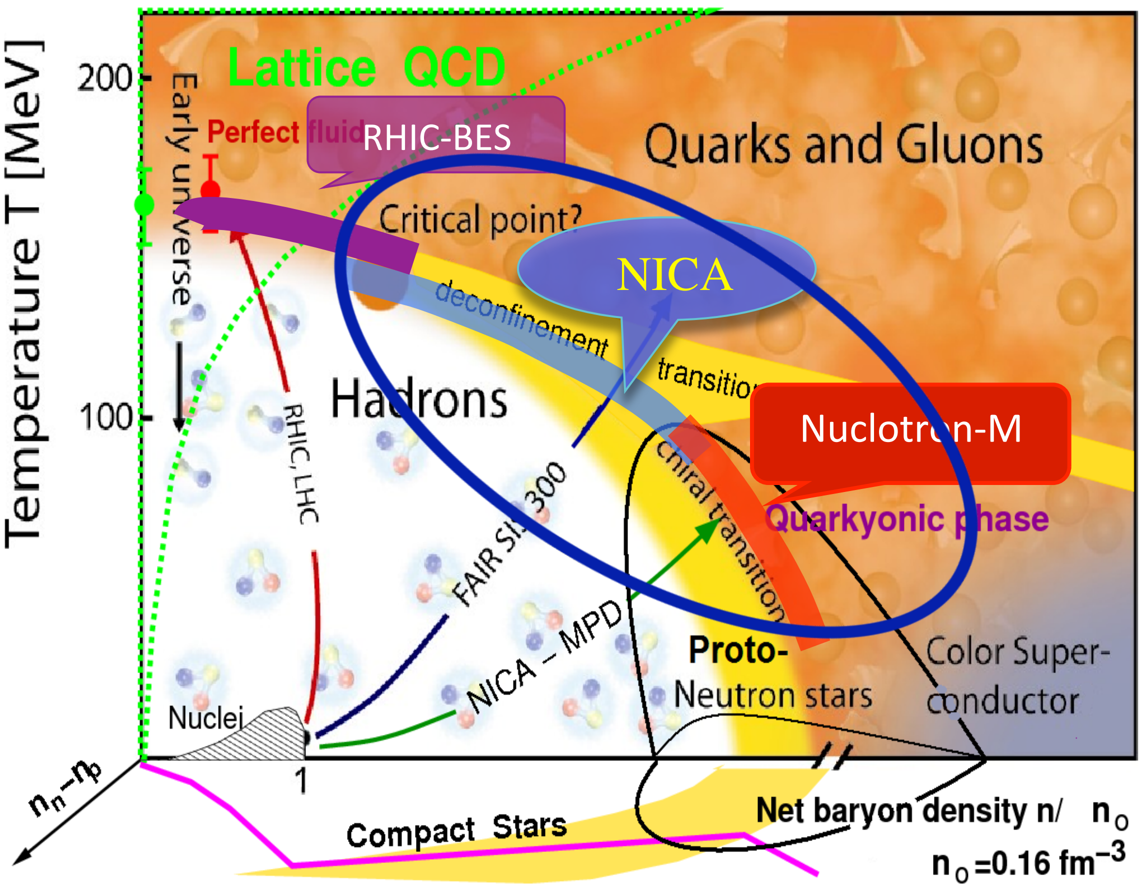
many discoveries have been made,
interesting processes have been observed
and precisely measured in the series of experiments
at ***RHIC*** *(BNL),* ***SPS*** *(CERN) and* ***SIS18*** *(GSI)*

The researches are carried out at ***LHC****,*
in preparation - at ***SIS100*** *(FAIR)*

However interesting phenomena *as*
the mixed phase, the critical endpoint, max. of baryonic density etc.
are not observed yet

In this view the energy scan in wide energy region
is a ***high priority*** *task*

QCD phase diagram - prospects for NICA



Energy Range of NICA is unexplored region of the QCD phase diagram:

- Highest net baryon density
- Onset of deconfinement phase transition
- Strong discovery potential:
  - a) Critical End Point (CEP)
  - b) Chiral Symmetry Restoration

NICA experimental programme is complementary to the RHIC/BES, FAIR and CERN and can be started already at Nuclotron-M

So, the NICA facilities provide unique capabilities for studying a variety of phenomena in a large region of the phase diagram

NICA White Paper – International Effort
(under preparation from 2010)

NICA

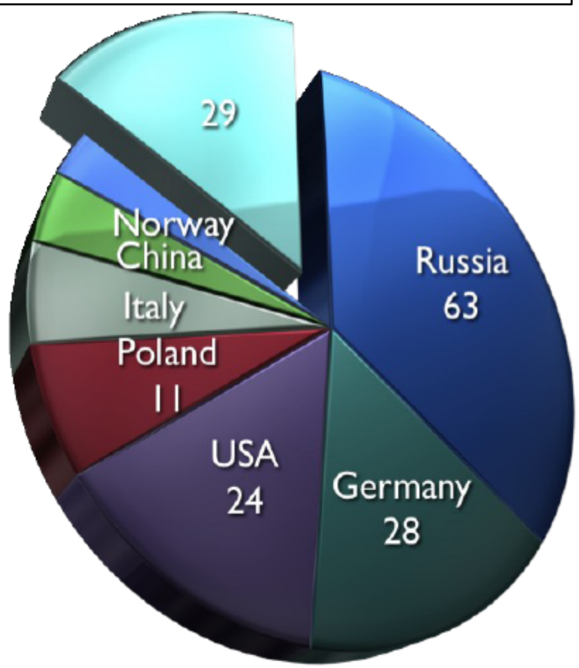
Draft v 8.03
January 24, 2013

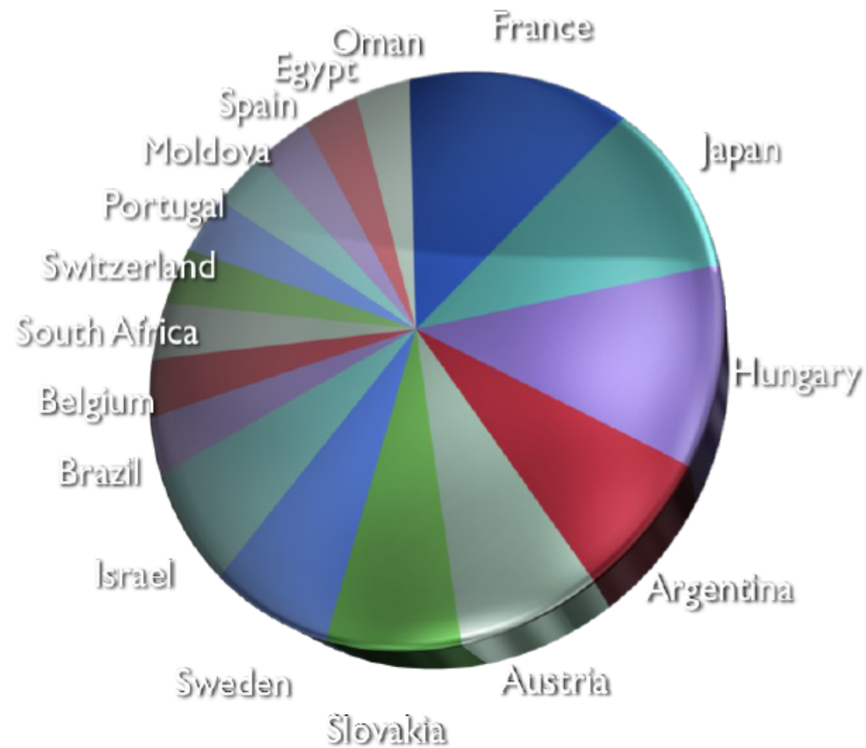
SEARCHING for a QCD MIXED PHASE at the
NUCLOTRON-BASED ION COLLIDER FACILITY
(NICA White Paper)

Statistics of White Paper Contributions

111 *contributions:*
188 *authors from* **70** *centers in* **24** *countries*

Indicates wide international interest
to the physics at MPD & BM@N





Research in Spin Physics

Physics tasks

- *Nucleon spin structure studies using the Drell-Yan (DY) mechanism*
- *New nucleon PDFs and J/Ψ production mechanisms*
- *Direct photons*
- *Spin-dependent high-pT reactions*
- *Spin-dependent effects in elastic ppand ddscattering*
- *Spin-dependent reactions in heavy ion collisions.*

Proposal (SPD):

- to perform *measurements of asymmetries of the DY pairs production in collisions of polarized protons and deuterons* which provide an access to all collinear and Transverse Momentum Dependent Parton Distribution Functions of quarks and anti-quarks in nucleons; a set of these measurements will supply complete information for tests of the quark-parton model of nucleons at the twist-two level with minimal systematic errors.
- to *perform measurements of asymmetries in production of J/Ψ simultaneously with DY* using dedicated triggers.

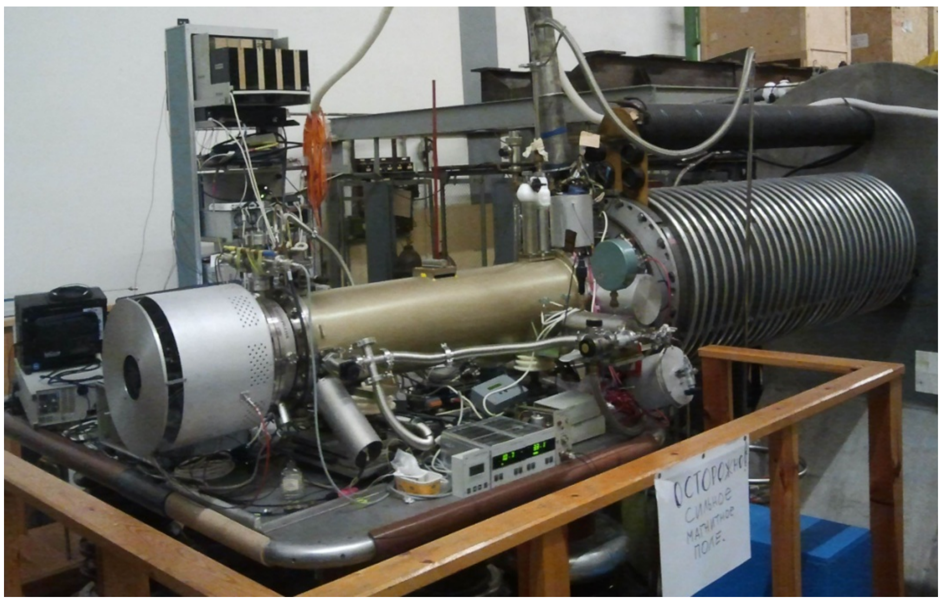
Status of the accelerator complex

Particle sources

Source	KRION-6T	Laser source	Duoplasmatron	SPI*)
Particles	Au^{31+}	Light ions up to Mg^{10+}	H^{+}, D^{+}, He^{2+}	↑H^{+}, ↑D^{+}
Particles per cycle	~ $2.5\cdot10^{9}$	~ 10^{11}	H^{+}, D^{+} ~ $5\cdot10^{12}$ He^{2+} ~ 10^{11}	$5\cdot10^{11}$
Repetition, Hz	up to 10	0.5	1	0.2

Unique Electron String Ion Source KRION-6T:

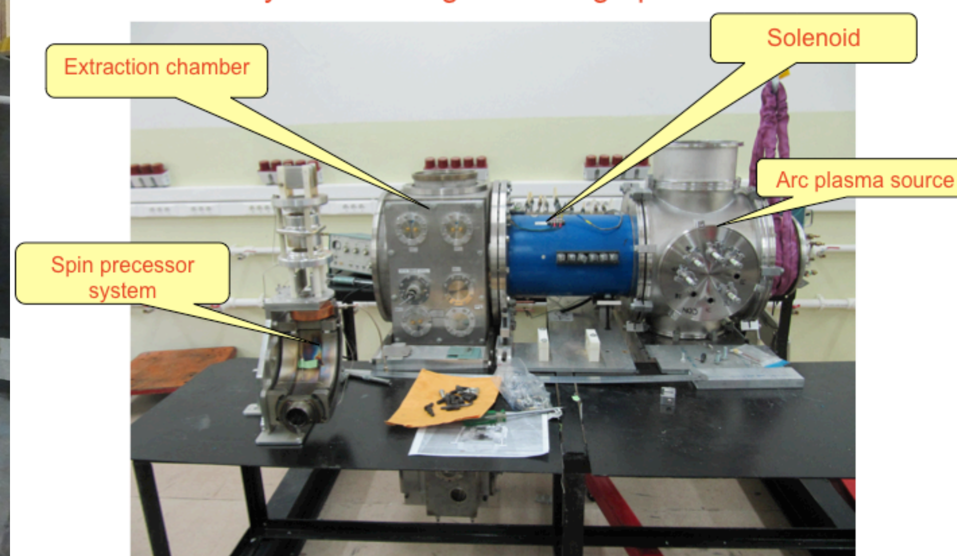
high intensity: Kr 28+, Xe 44+, Au 52+



Successfully tested in 2014 for light ions

High intensity polarized particle source: up to 10^{11} particles/s

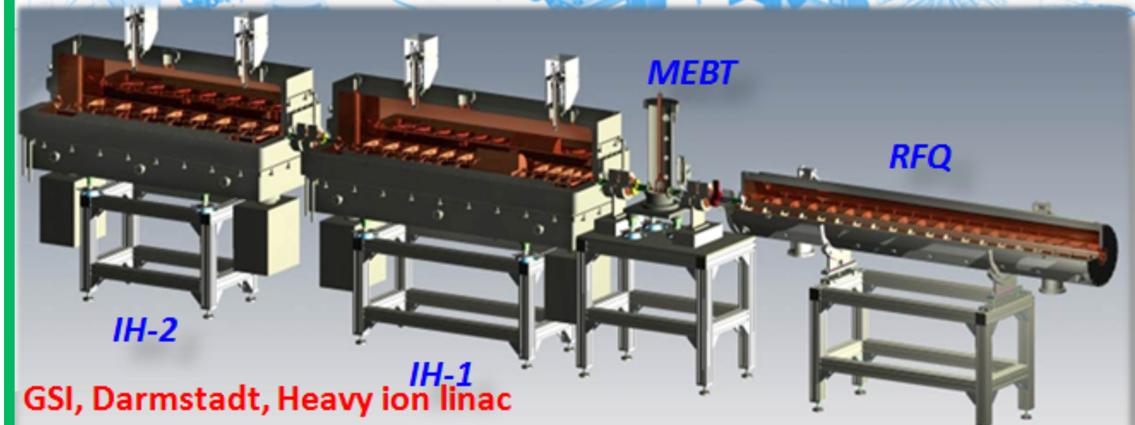
Assembly of the charge-exchange plasma ionizer

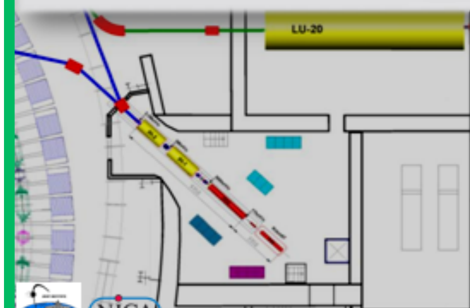


Successfully tested in 2012-2014 ready to use

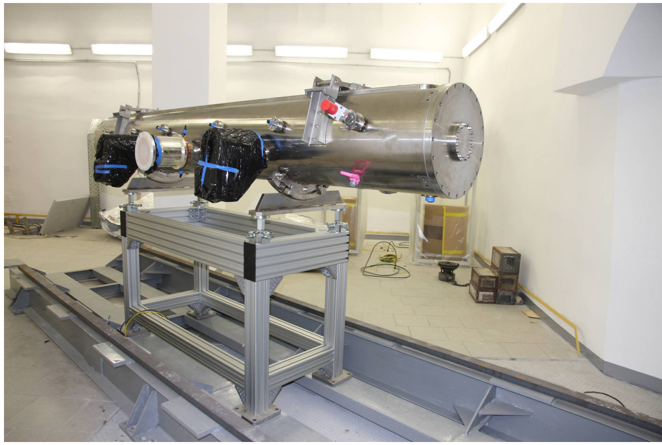
HILac: first in Russia high current (10 mA) heavy ion Linac, first Linac with transistor RF amplifier

NICA HILac: RFQ + IH1 + IH2





	Type	Weight	Length	RF power	Exit energy
RFQ	4 - rod	2000 kg	3.16 m	120 kW	0.3 MeV/u
MEBT	Two QD + buncher	500 kg	1.4 m	3 kW (buncher)	0.3 MeV/u
IH1	DTL + QT	4000 kg	2.3 m	296 kW	2 MeV/u
IH2	DTL	3900 kg	2.1 m	278 kW	3.2 MeV/u

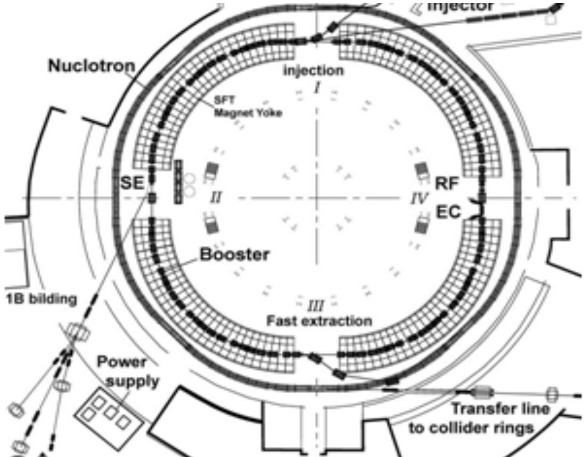


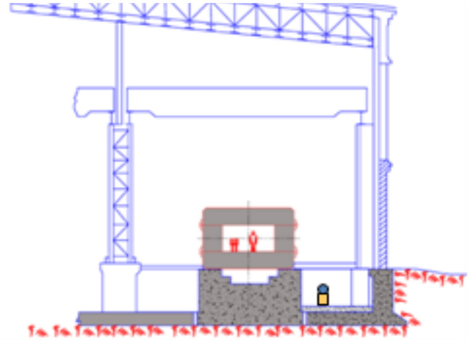
Design and fabrication under the contract with "BEVATECH OHG" Germany, Offenbach/Main,

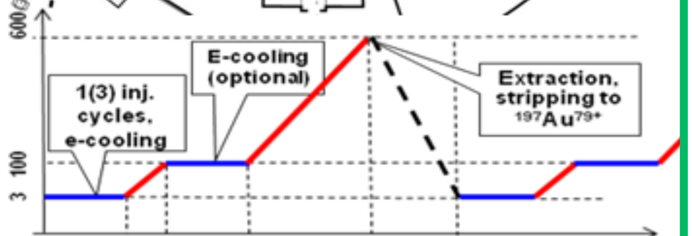
to be delivered at JINR in 2015

Booster and Nuclotron

Booster synchrotron, 211 m, with ultra high vacuum and electron cooling – inside the Synhrophasotron yoke



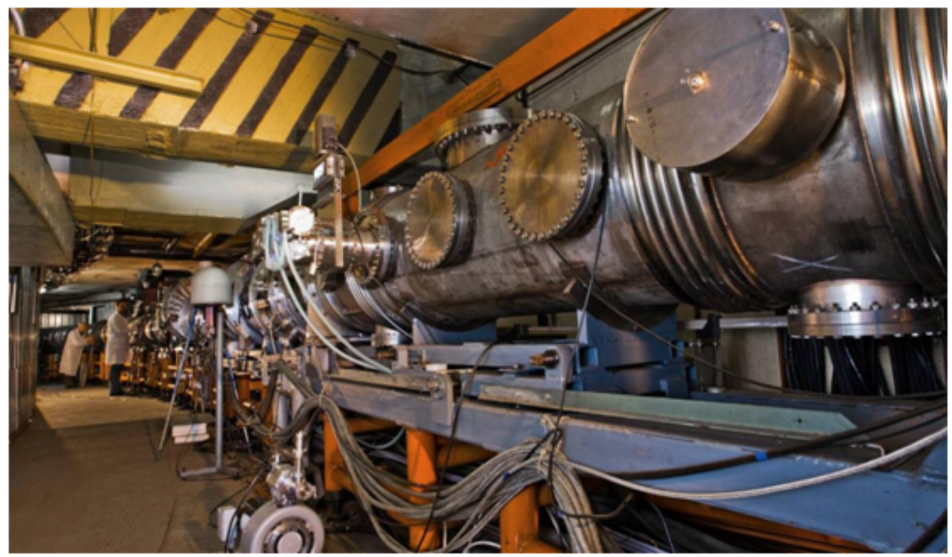




Dipole SC magnet

Quadruple SC magnet

Nuclotron



Nuclotron provides now performance of experiments on accelerated pro... beams (up to Fe^{24+}, A=56, *now Xe^{42+}, A=124*) with energies up to 6 AGeV (Z/A = 1/2)

RF system for booster

*In May **2014 2 RF** stations were assembled and tuned in BINP (Novosibirsk) in coop. with JINR specialists.*

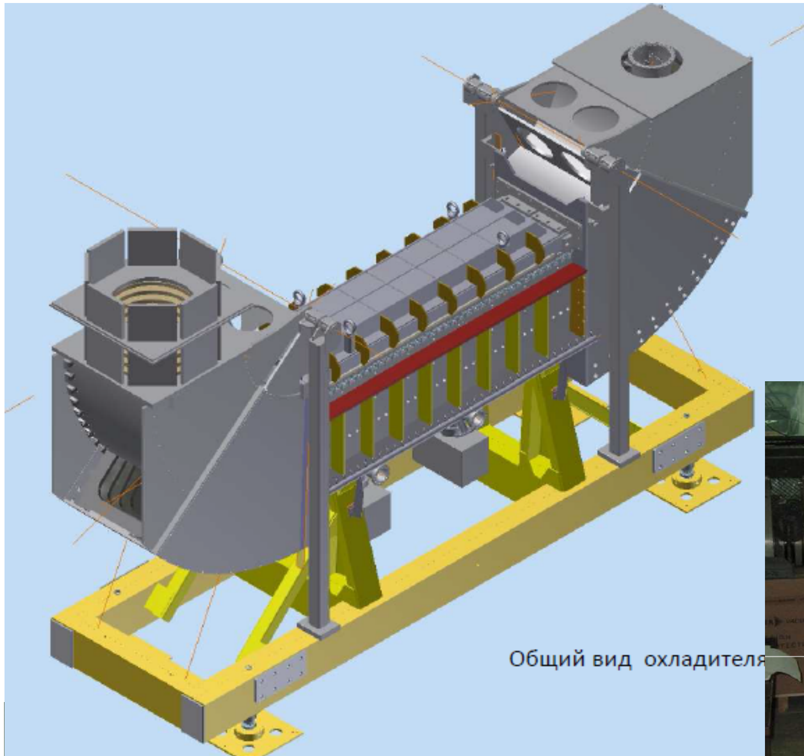
*In October **2014** the stations were delivered to Dubna, assembled and tested.*

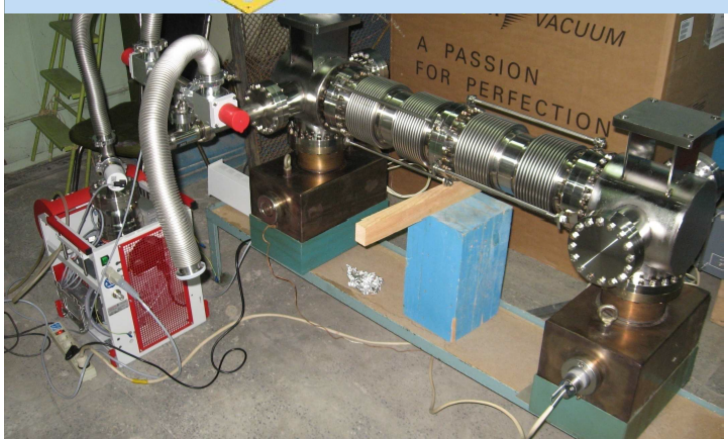
Project status:
all the works are performed in accordance with the plans.

The Booster RF station during commissioning at test bench at JINR

Commissioning is planed in **2017**

Electron cooling system for booster

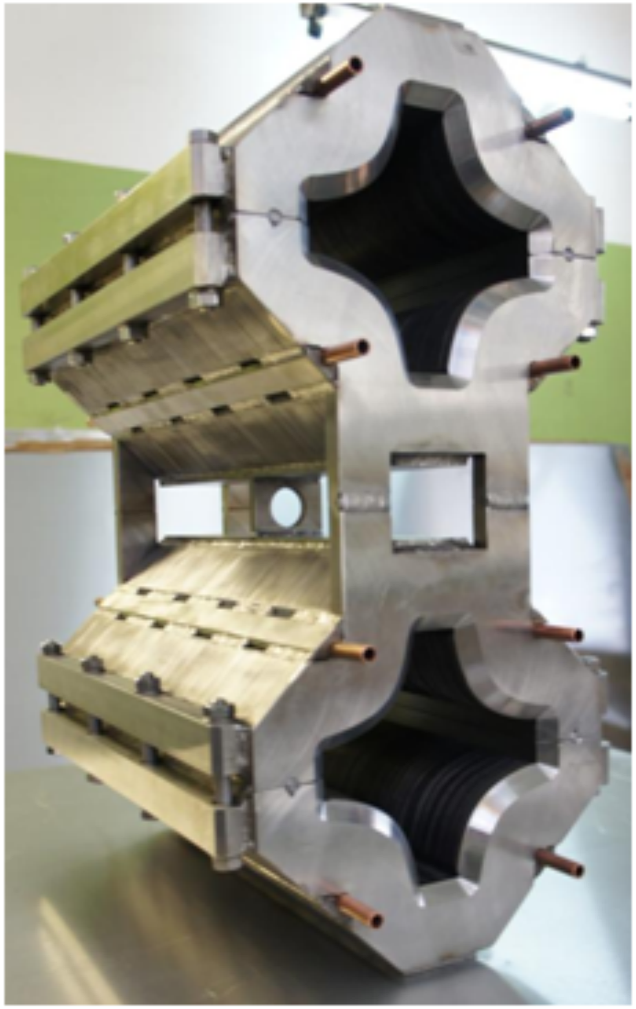




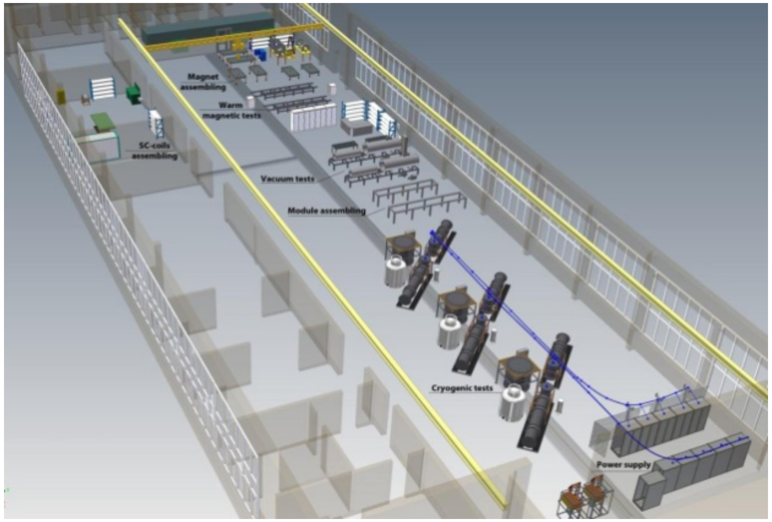
There are purchased 80% of materials
~ 70% of items are produced
in workshop
Commissioning is planed in ***2017***
Project status: *in schedule*

Collider: 2 aperture SC magnet

Test on vacuum tightness of the tubes for cooling the yoke

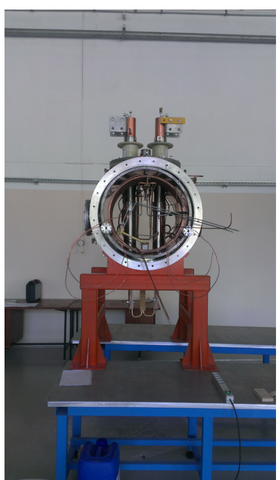


SC magnet assembling and testing area
(need to produce 450 magnets including magnet for SIS100)



SC cable (JINR) winding machine

HTSC current leads stand



He satellite refrigerator

Workshops for SC coil production

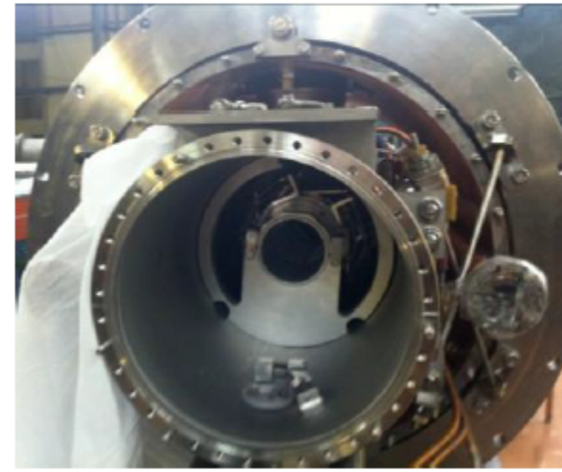
Magnet production plan

		2015				2016				2017				2018				2019				2020			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Booster																									
dipoles	**40+3**	■	■	■	■	■	■	■																	
quadrupoles	**48+6**	■	■	■	■	■	■	■	■																
multipole correctors	**40+4**					■	■	■	■																
Collider																									
dipoles	**80+5**					■	■	■	■	■	■	■	■	■	■	■	■								
quadrupoles	**86+5**					■	■	■	■	■	■	■	■	■	■	■	■								
multipole correctors																									
nonstructurals																									
SIS-100																									
pre-series quadrupole	**2**	■	■	■	■	■	■																		
pre-series sextupole correctors	**1**		■	■	■	■	■																		
pre-series dipole correctors	**2**			■	■	■	■	■																	
pre-series multipole correctors	**2**			■	■	■	■	■																	
quadrupole	**166**							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
sextupole correctors	**48**																								
dipole correctors	**83**																								
multipole correctors	**12**																								

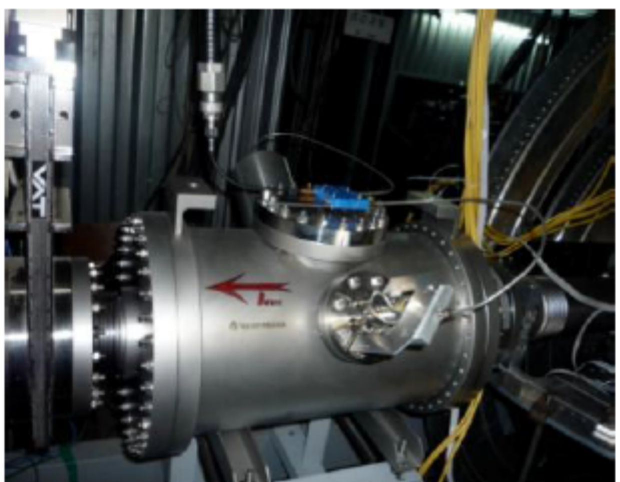
Booster in 2015:
- **16** *dipoles*
- **24** *quadrupoles*

Stochastic Cooling System

Stochastic Cooling System installed in Nuclotron is a prototype for Collider:
W=2-4 HGz, P=60 W
Collaboration JINR-IKP FZJ-CERN



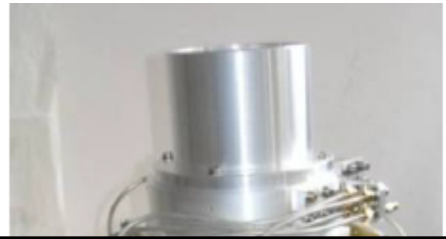
Slot-coupler RF structure (by IKP FZJ)



Kicker station

Pick-Up station

Stochastic Cooling System



Stochastic Cooling System installed in Nuclotron is a prototype f
W=2-4 HG
Collaboration
CE

Kicker st

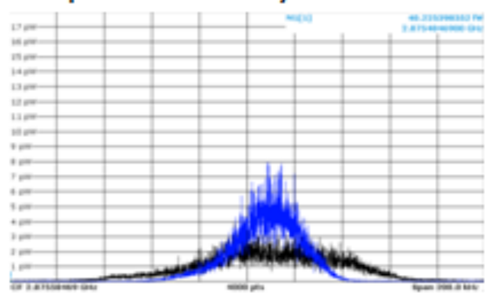
29 June 2015

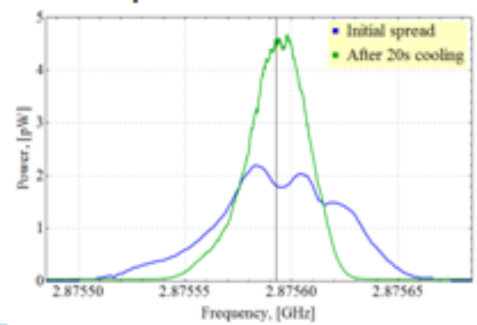
December 2013

Stochastic cooling of the carbon beam 2.5GeV/u

Spectrum analyzer | Computer reconstruction

Coasting beam



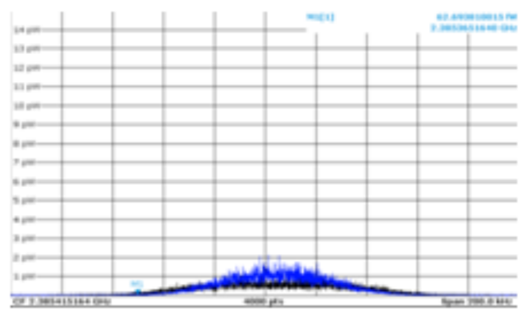


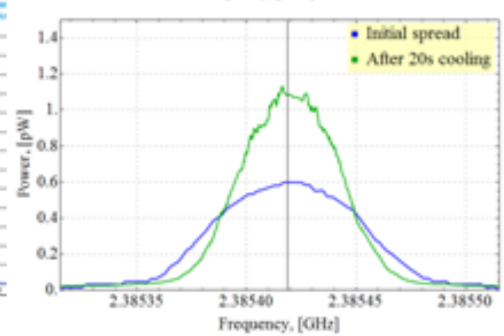
$\sigma_{init} = 0.15\times10^{-3}$

$\sigma_{final} = 0.07\times10^{-3}$

$\tau \approx 27s$

Bunched beam





$\sigma_{init} = 0.2\times10^{-3}$

$\sigma_{final} = 0.13\times10^{-3}$

$\tau \approx 64s$

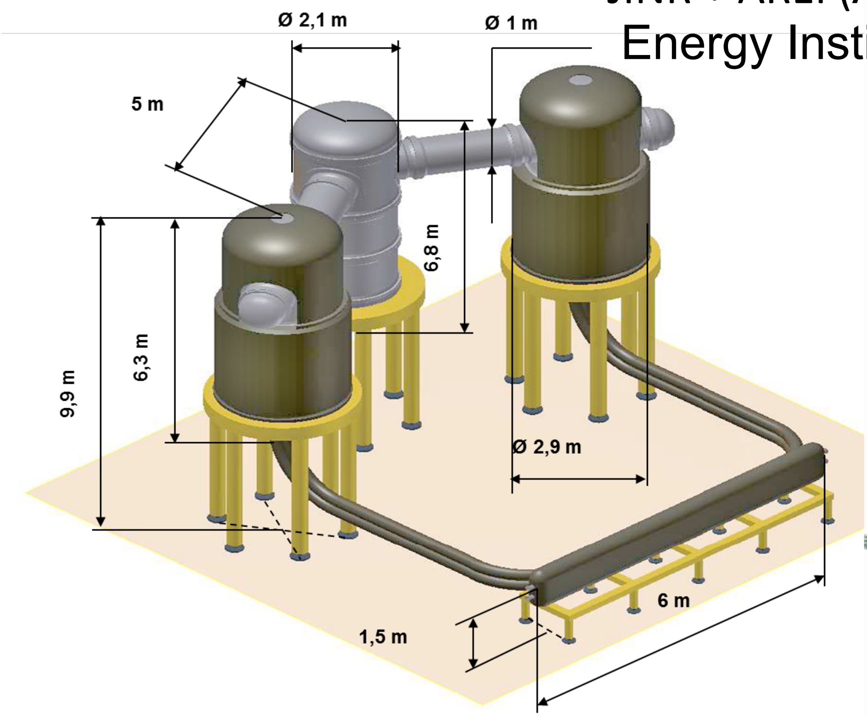
$\sigma_s = 4.2\ m$

RF voltage of 2 kV at plateau duration up to 25 sec, bunching factor (peak/mean current) ~ 5 (for NICA ~ 15)

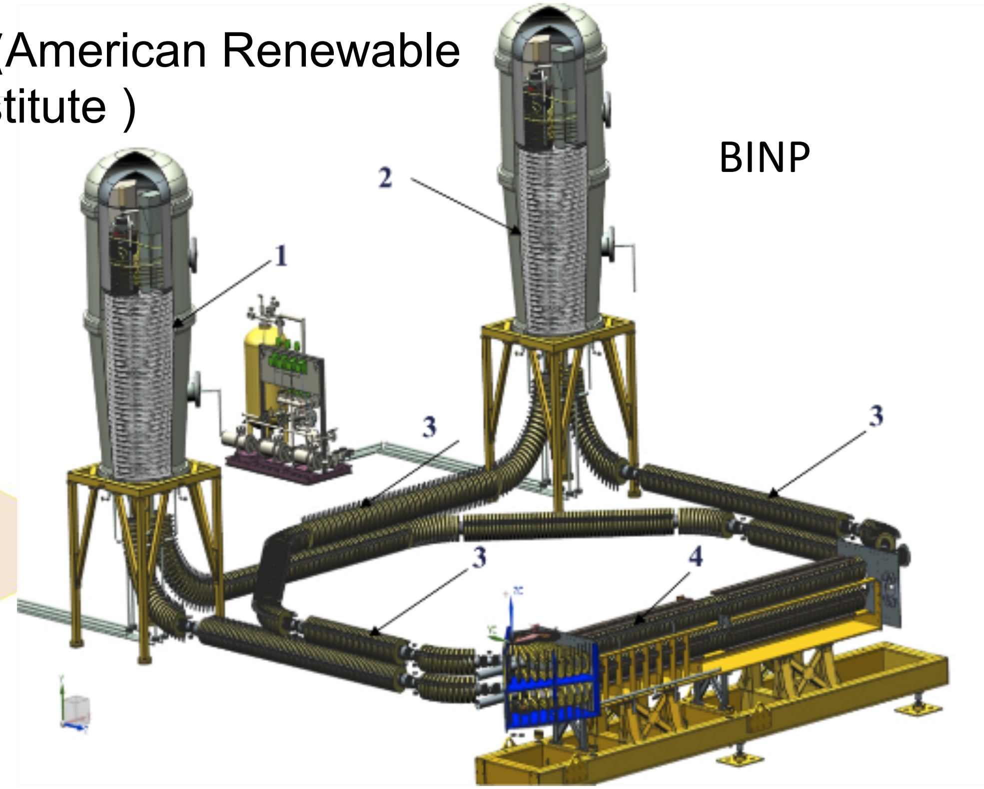
Nearest plans: heavy ions, large bunching factor

Collider Electron cooling

JINR + AREI (American Renewable Energy Institute)

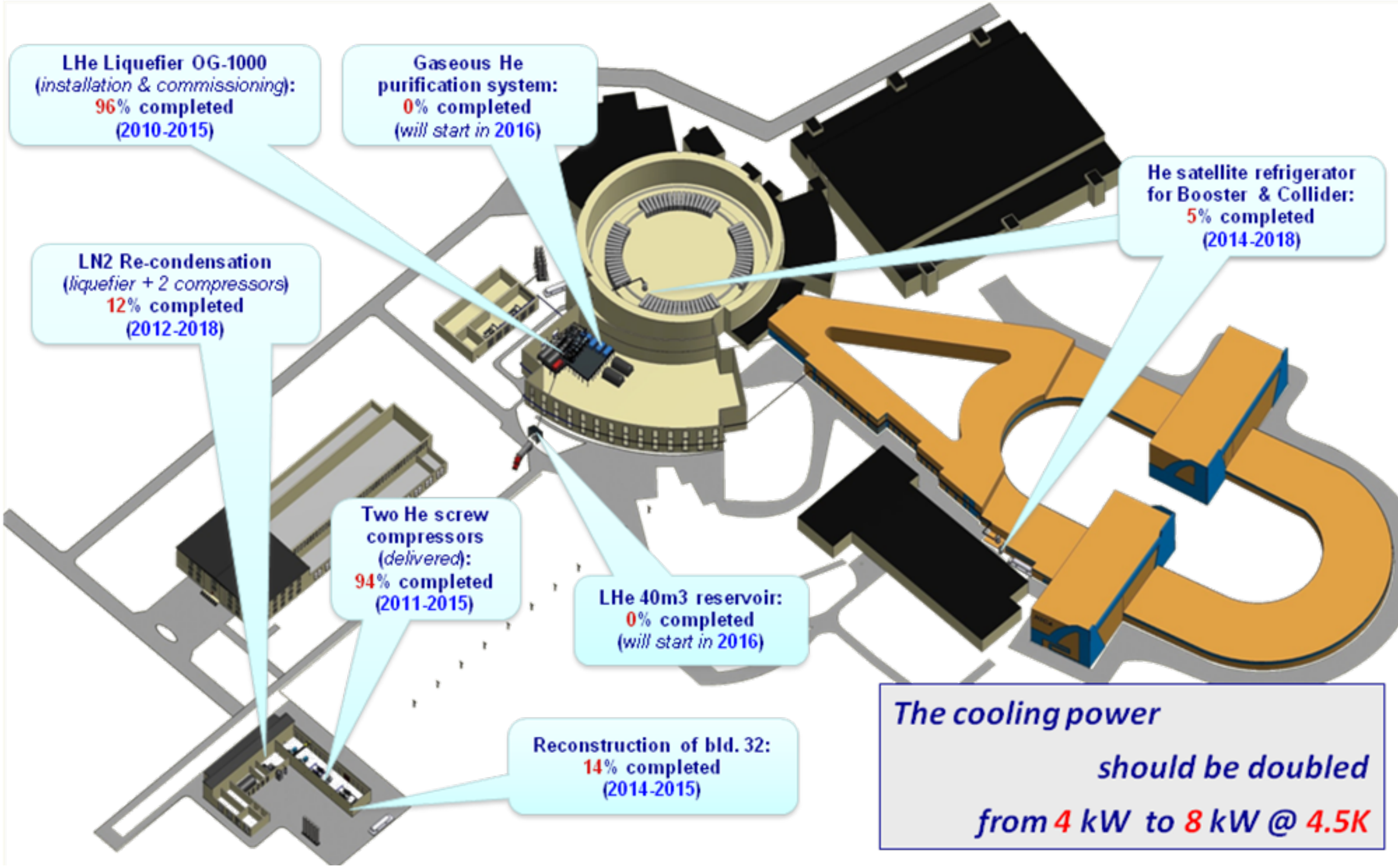


BINP



Maximum electron energy, MeV	2.5
Cooling section length, m	6.0
Electron beam current, A	0.5-1
Electron beam radius, cm	1
Magnetic field in cooling section, T	0.1-0.3

JINR cryogenic complex



Technical design project is in final stage. The goal is:
the cooling power will be doubled up to 8 kW @ 4.5K with new plant;
2 new screw compressors are under design

NICA MPD and BM@N experiments

The MultiPurpose Detector (MPD)

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)

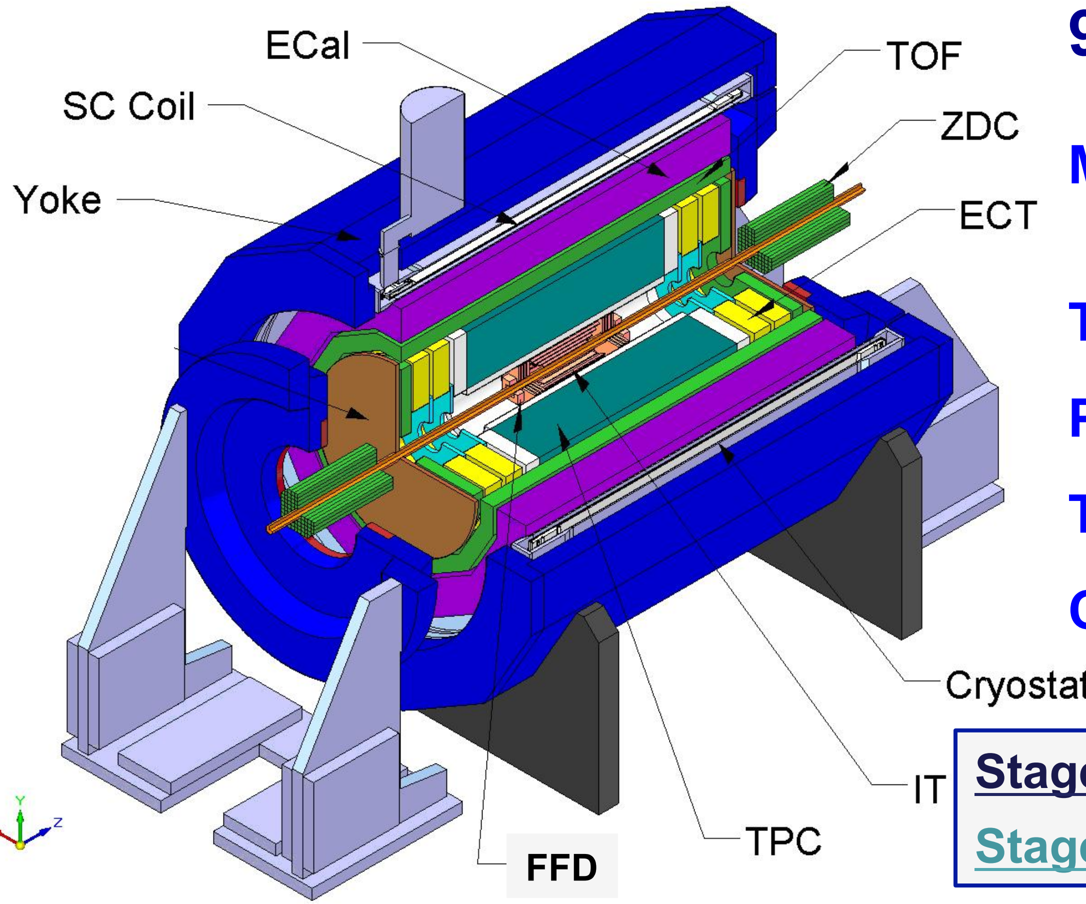
scanning over energy range: $\sqrt{S_{NN}}$ = 4 – 11 GeV *with fine steps ~ 10 MeV/u in selected regions*

at high Luminosity allowing the high statistic (*precision*) studies

MPD observables

- *Hadron multiplicities (4π particle yields :*
  π, K, p, Λ, Ξ, Ω)
- *Event-by-event fluctuations*
- *Femtoscopy involving π, K, p, Λ*
- *Collective flow for identified hadrons and resonances*
- *Electromagnetic probes:*
  electrons, gammas, vector meson decays
- *Hypernuclei & other exotic*

MultiPurpose Detector (MPD)



9 m length, 6 m in diameter

Magnet: ***0.5 T superconducting solenoid***

Tracking: ***TPC, IT, ECT***

ParticleID: ***TOF, ECAL, TPC***

T0, Triggering: ***FFD***

Centrality, Event plane: **ZDC**

Stage 1: ***TPC, barrel (TOF, ECAL), ZDC, FFD***

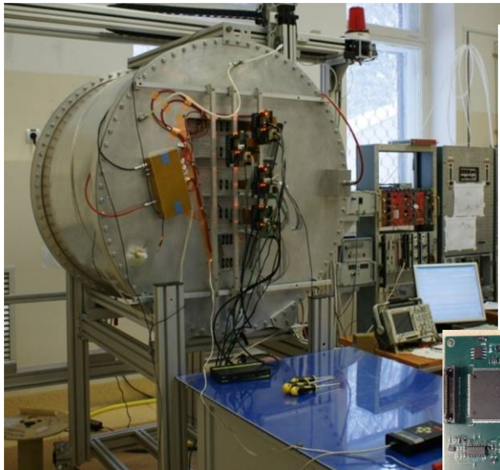
Stage 2: ***Endcaps (tracker, TOF, ECAL) + IT***

MPD potential advantages:

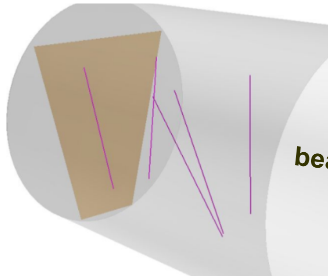
- *Hermetic & homogenous acceptance (2π in azimuth), low material budget*
- *Good tracking performance and powerful PID (nuclei, hadrons, e, γ)*
- *High event rate capability and reliable event separation*

Time Projection Chamber

TPC Prototype

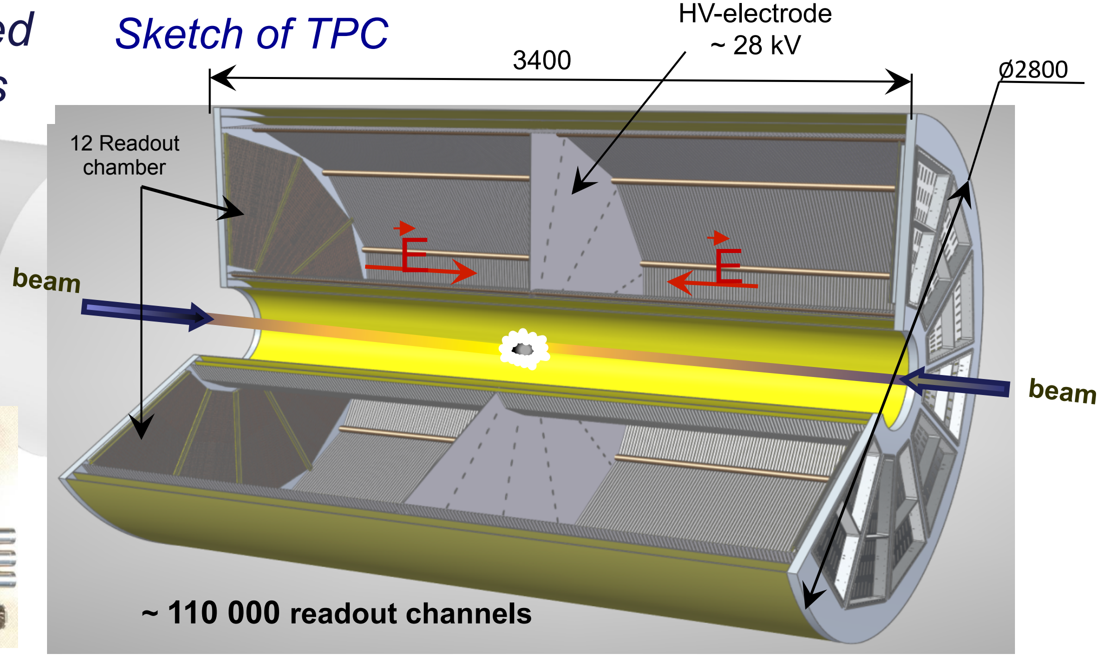


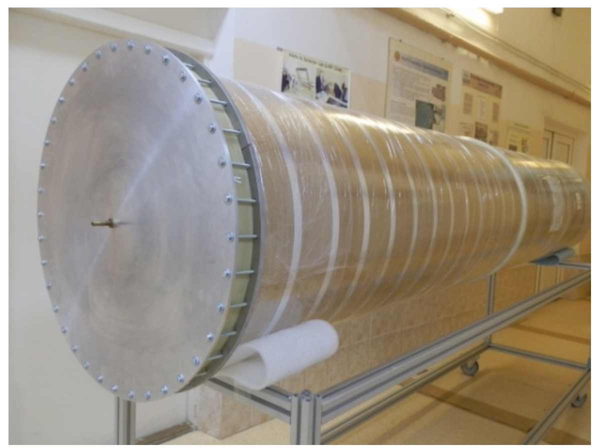
Reconstructed laser tracks



FEC-64 prototype

Sketch of TPC





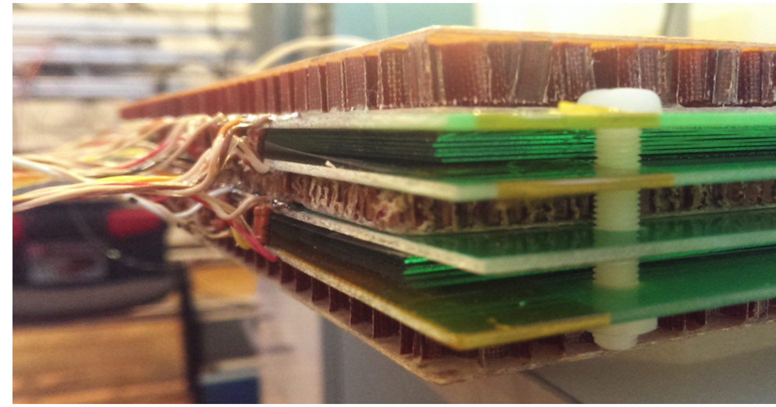
Momentum resolution – 3%,

dE/dX – 8%

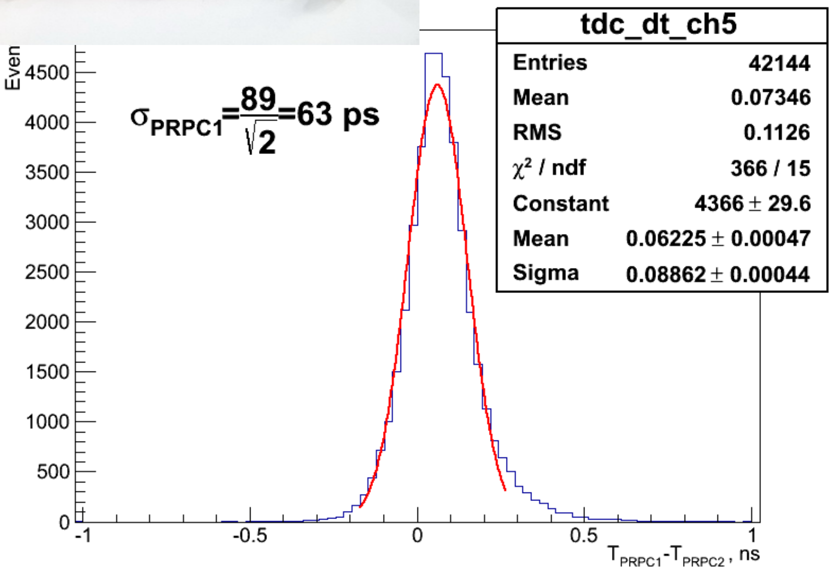
Detector production area is under construction

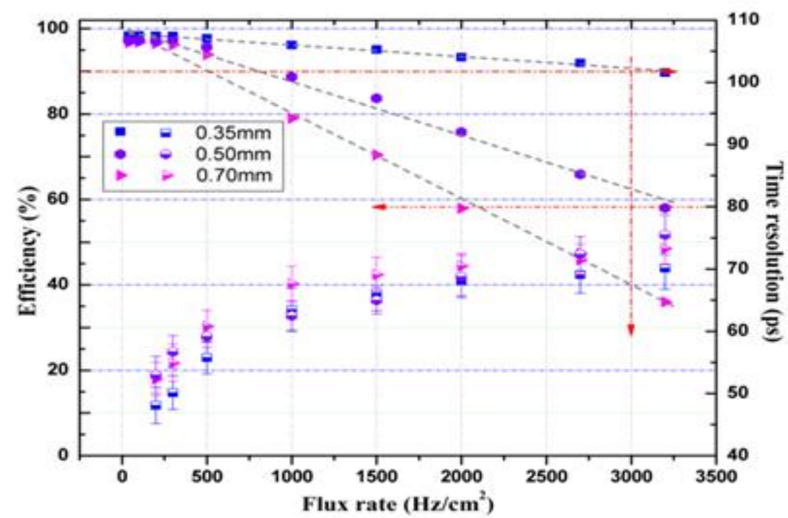
TOF

- TOF geometry & module based on multi-gap resistive plane design optimized
- Nuclotron test beam line upgraded
- mRPC performance: *required efficiency, rate capability & time resolution are reached*



*Zhu Weipinga, Wang Yi, Feng Shengqin, Wang Jingbo, Huang Xinjie, Shi Li, V. Babkin, V. Golovatyuk, M. Rumiantcev, G. Eppley, T. Nussbaum, **NIM A 735, 277–282, 2014***



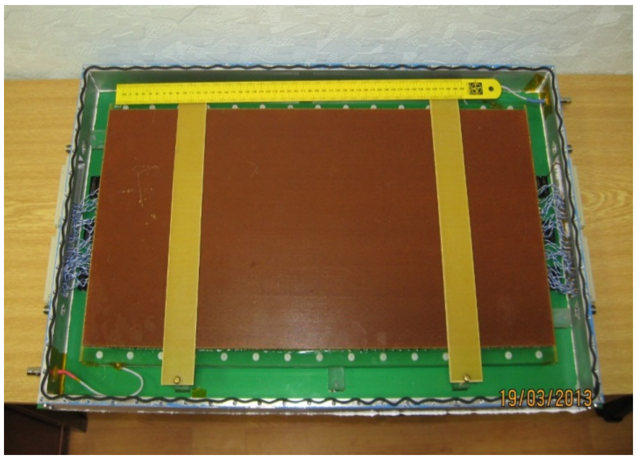


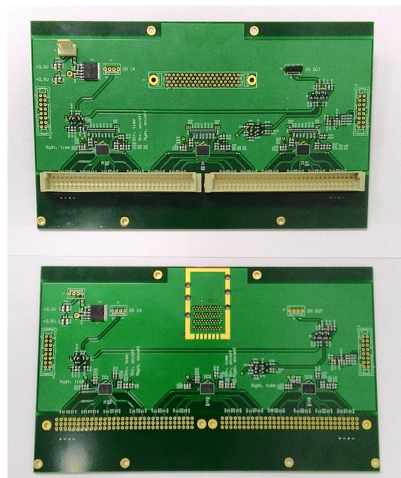
MPD TOF mRPC : Efficiency and time resolution versus flux rate for several glass thickness

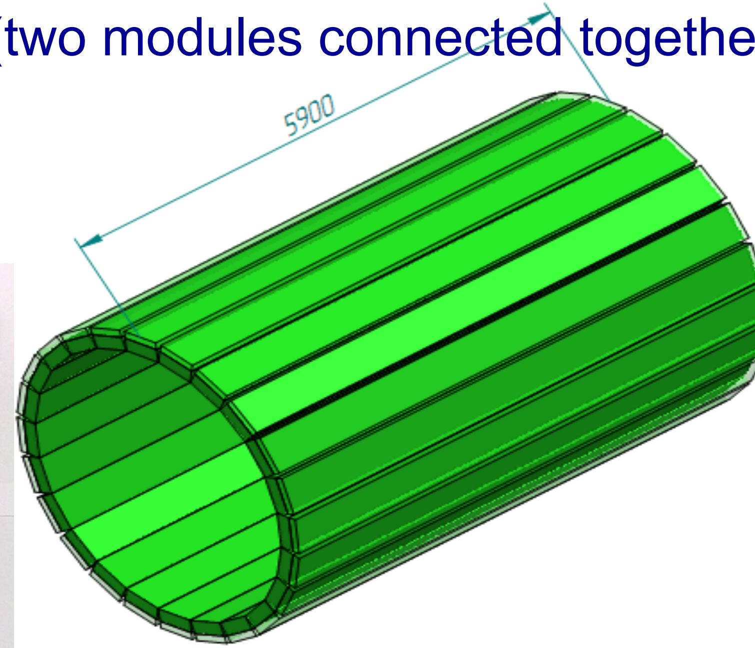
TOF Barrel Design

The barrel of consist of 12 super-modules (two modules connected together)

Active area of TOF barrel	~56 m^2
Number of channels	13 824

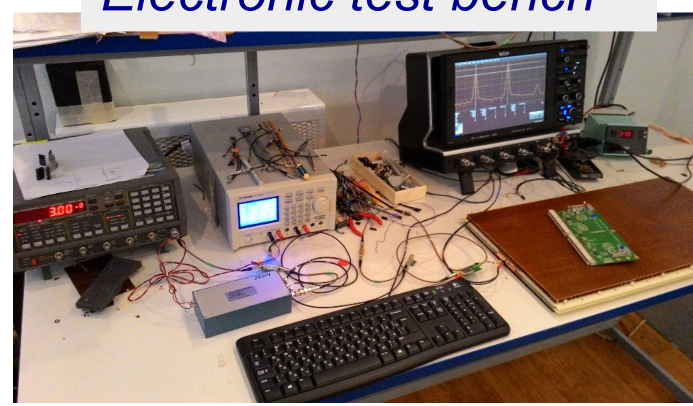






mRPC full scale prototype
& 24 ch. FEE based on NINO

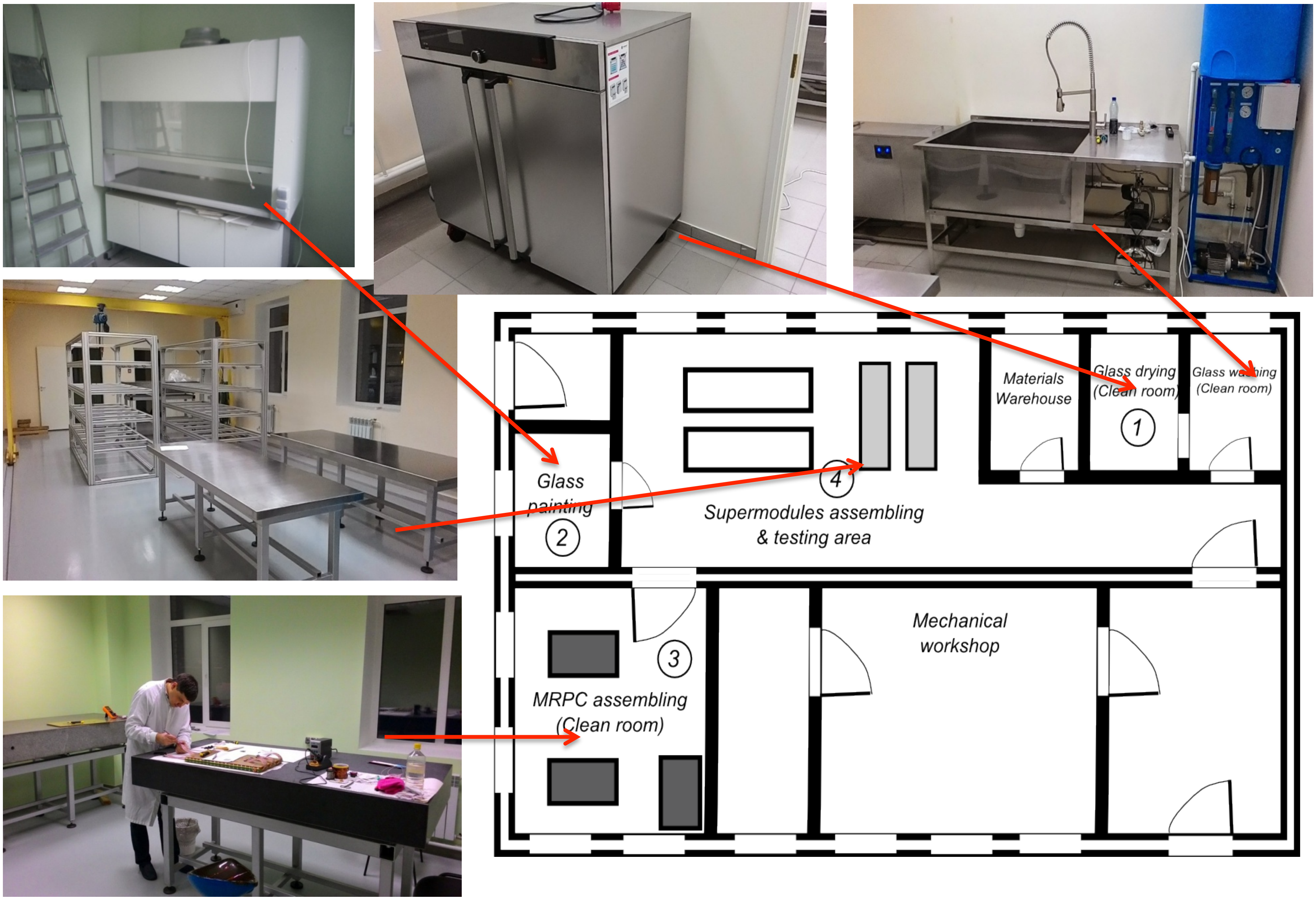
Electronic test bench



Project status:

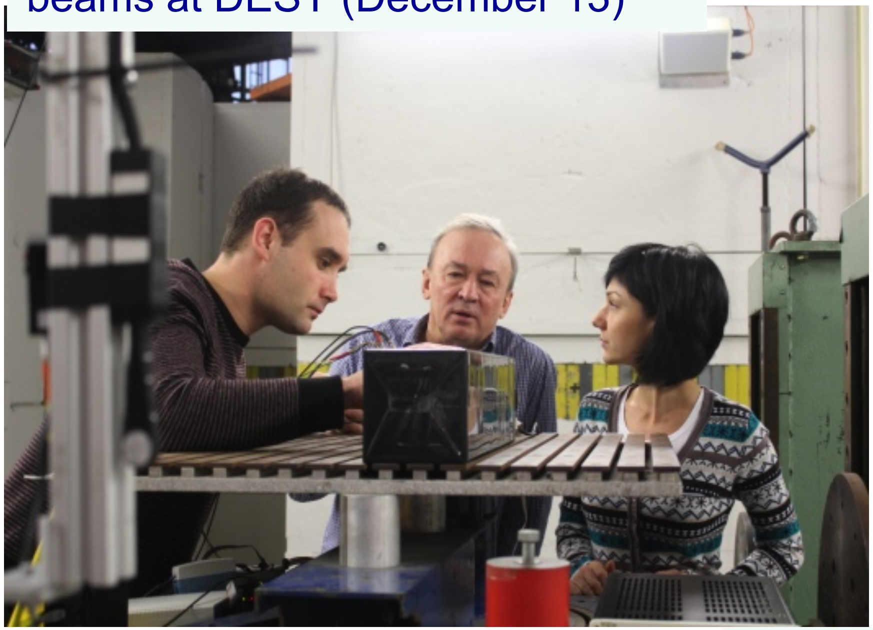
- *R&D and tests of prototypes are finished,*
- *80% readiness for the mass production*

Area for mass-production of the TOF mRPC



ECAL – TDR in preparation

Preparation for tests with electron beams at DESY (December'13)



ECAL tests with e beam *(December '13)*:

- performance study of two ECAL modules (35 cm length, 14 radiation length) with *different Wavelength Led Scintillator fibers*
- Tests of the ECAL read-out electronics *(amplifiers and ADCs)*
- Energy scan (E_e = 1 - 6 GeV)

Analysis of the recorded data indicates good performance:

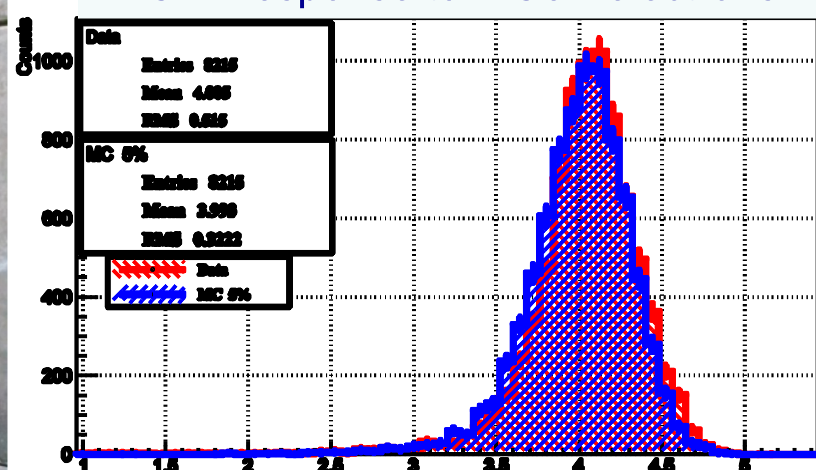
Energy resolution **2.5% / √E**

Time resolution **80 ps / √E**

fits the requirement

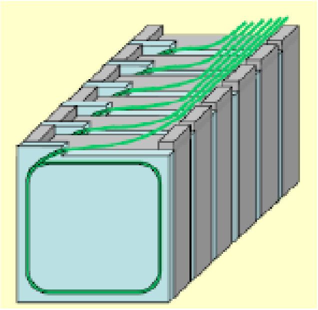
cosmic ray test

ECAL response to 4 GeV electrons



Zero Degree Calorimeter (ZDC)

ZDC coverage: $2.2<|\eta|< 4.8$



Together with the RAS Institute for Nuclear Research

Fig.1

Pb-scintillator sampling (5λ)
Read-out: fibers+ Avalanche PD

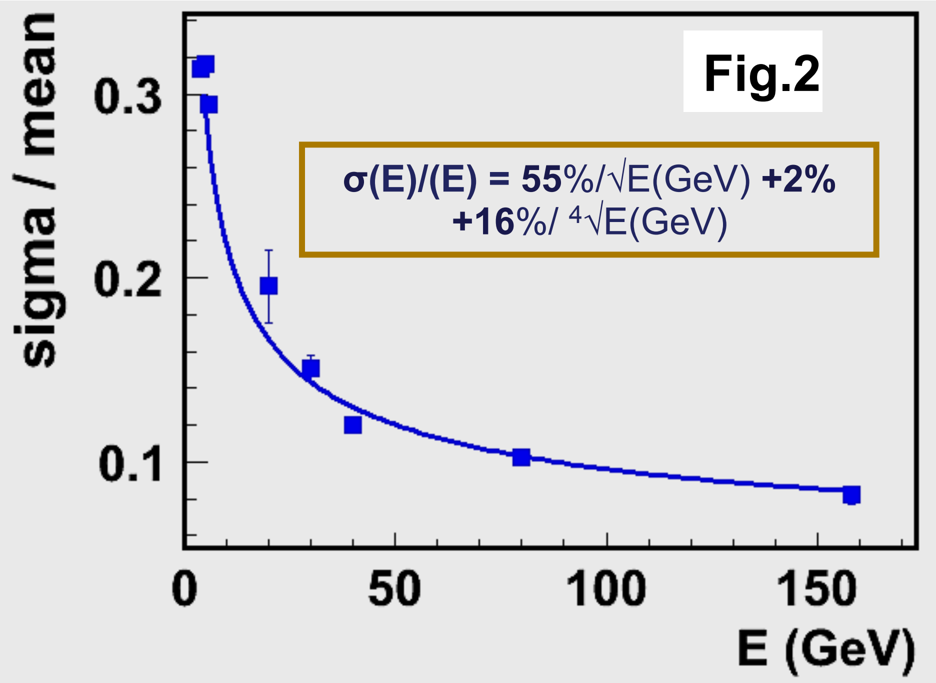
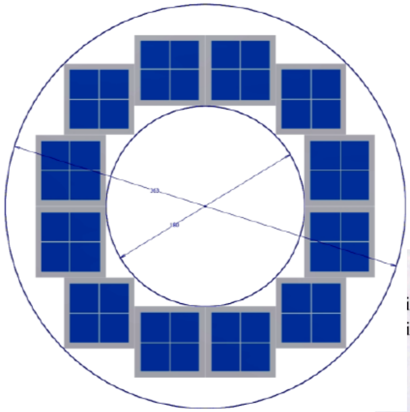


Fig.1. Beam tests of ZDC modules at PS/CERN

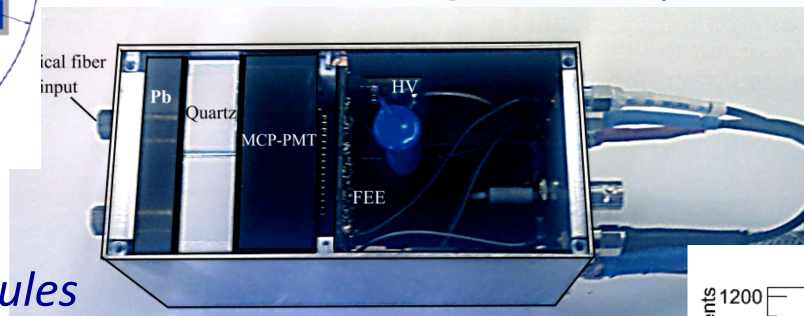
Fig.2. ZDC energy resolution

ZDC provides required resolution in deposited energy

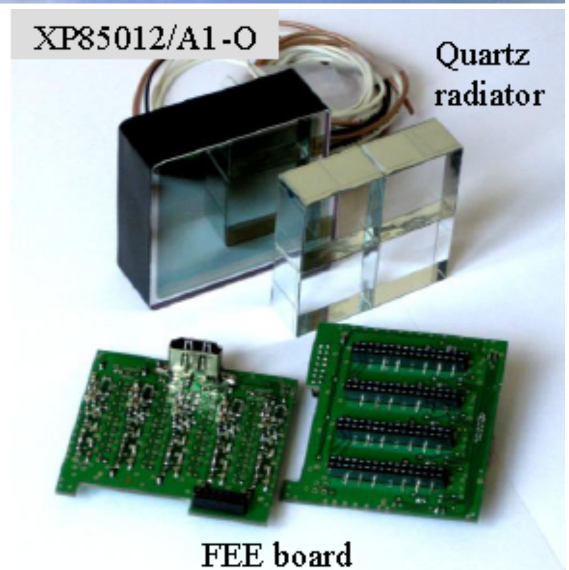
Fast Forward Detector (FFD)

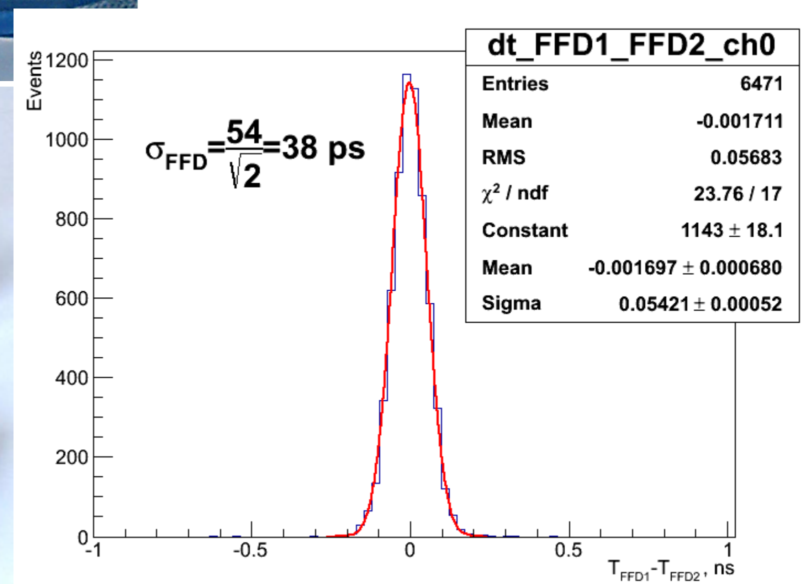


- Design and MC simulation
- Construction of prototypes and beam tests
- TDR preparation
- Ordering of components for mass production



FFD prototype modules



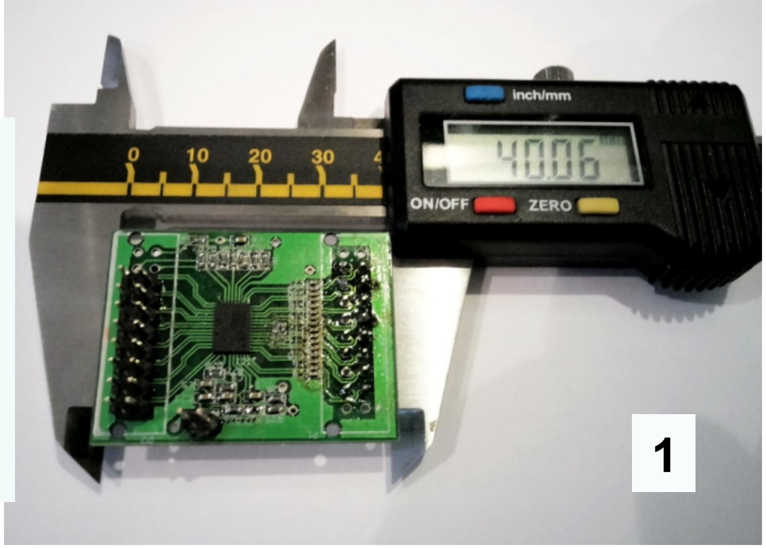


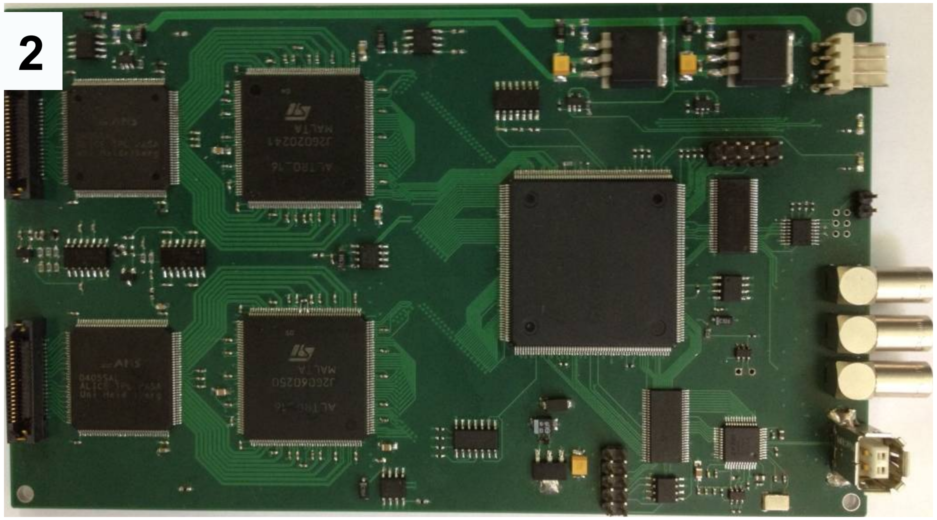
Based on Quartz radiators and Microchannel photomultiplier tube (MCP-PMT)

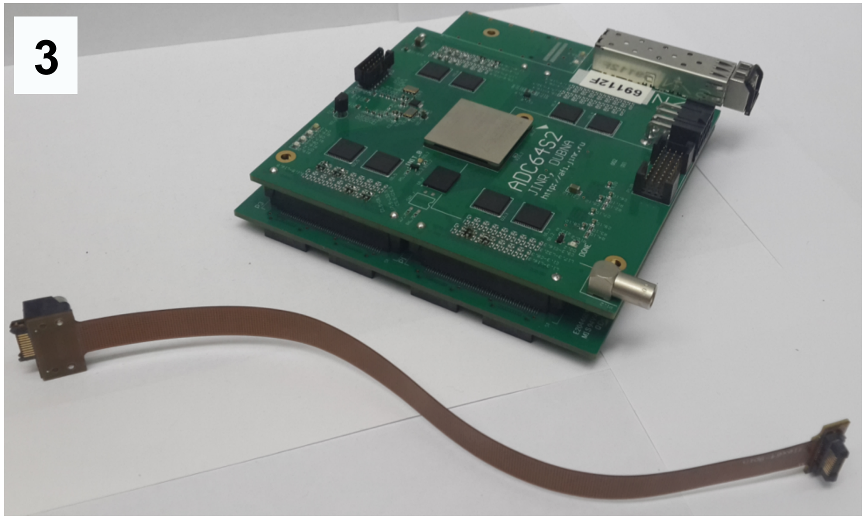
The achieved time resolution is better than required

Readout Electronics
have been developed for *TPC, TOF, and ECAL*

1. Ultra fast NINO pre-amplifier for mRPC readout:
   24- and 8-channel, rise time < 400 ps
2. ALTRO-based TPC Front-End card prototype.
3. High performance ADC for ECAL read-out:
   64 channels, 13-bit, 65 MSPS conversion rate







MPD Superconducting solenoid: challenging project

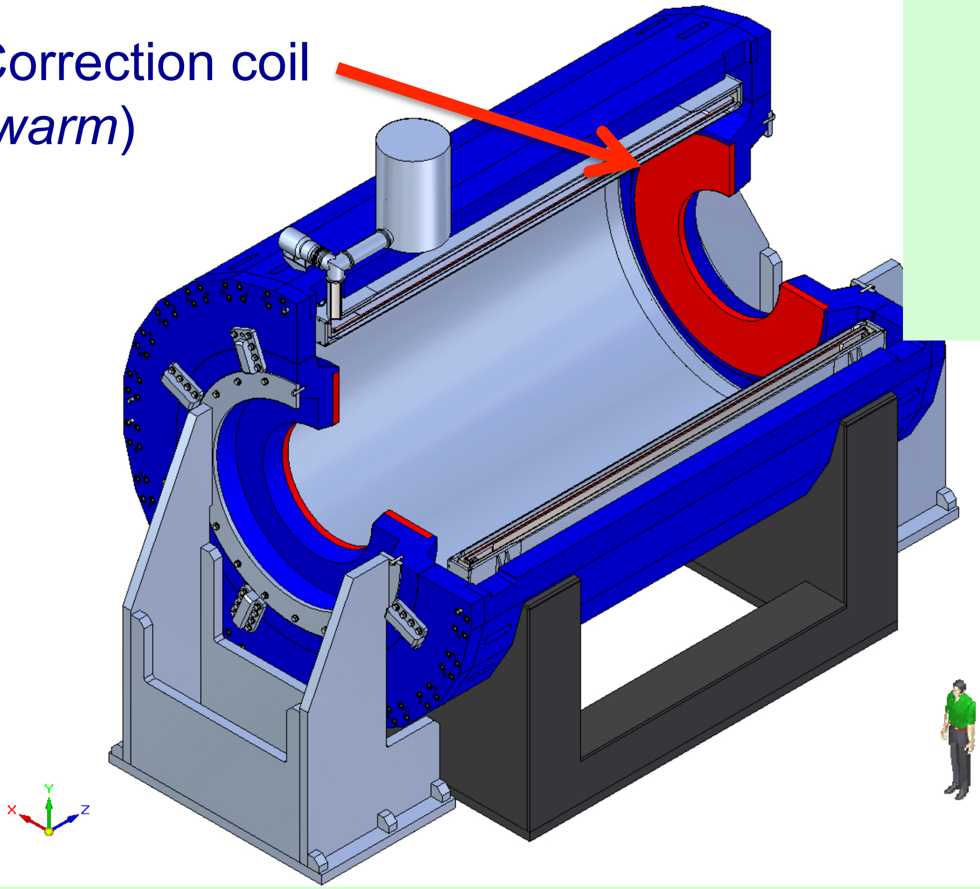
- to reach high level (~ 10^{-4}) of magnetic field homogeneity

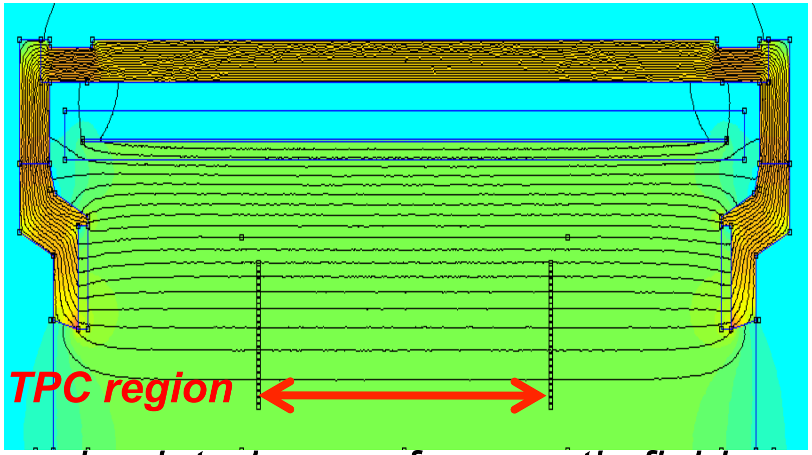
B_0=0.66 T
Weight – 800 ton

Correction coil (*warm*)

Technical design – *completed*;
Survey for contractors:

- *the cold coil / cryostat;*
- *cryo infrastructure;*
- *the warm coil;*
- *the yoke;*
- *PS;*
- *engineering infrastructure*





simulated map of magnetic field

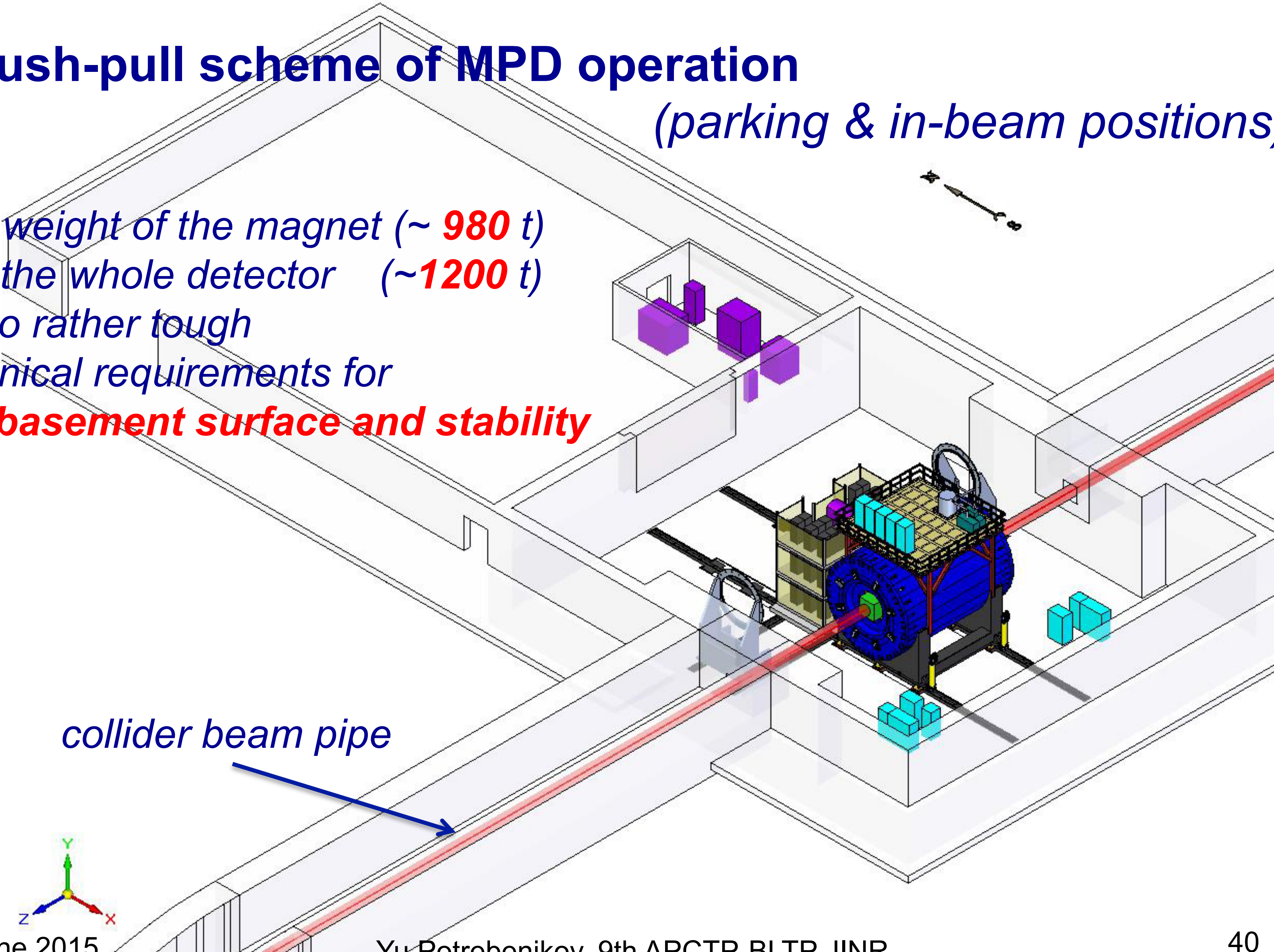
Design: "Neva-Magnet" (***Russia***); production: ASG SC (Italy),TOSHIBA (Japan)

The MPD Hall

push-pull scheme of MPD operation

(parking & in-beam positions)

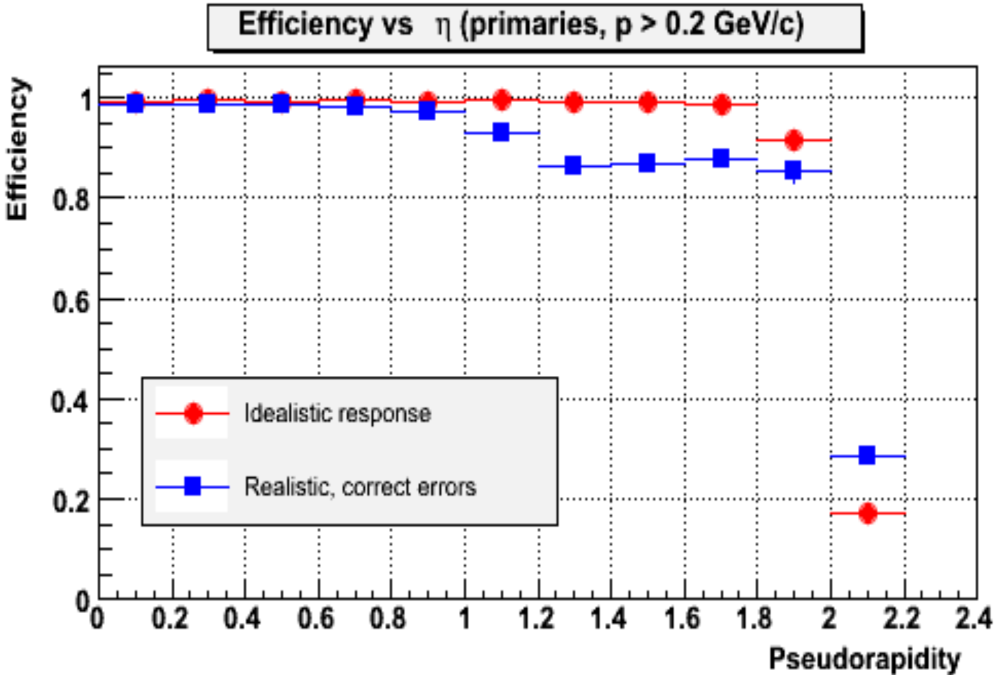
*The weight of the magnet (~ **980** t)*
*and the whole detector (~**1200** t)*
led to rather tough
technical requirements for
the basement surface and stability



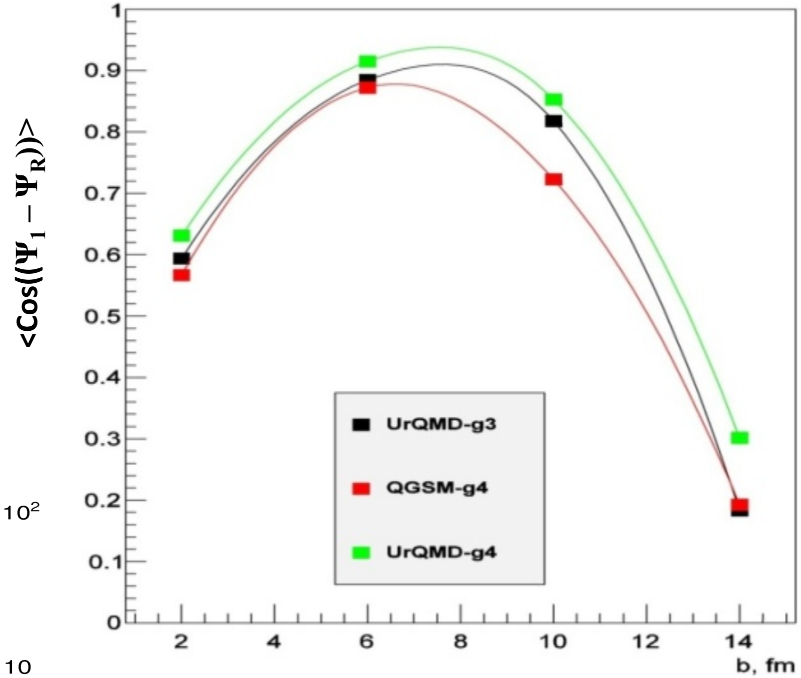
Study of MPD performance

MPD performance

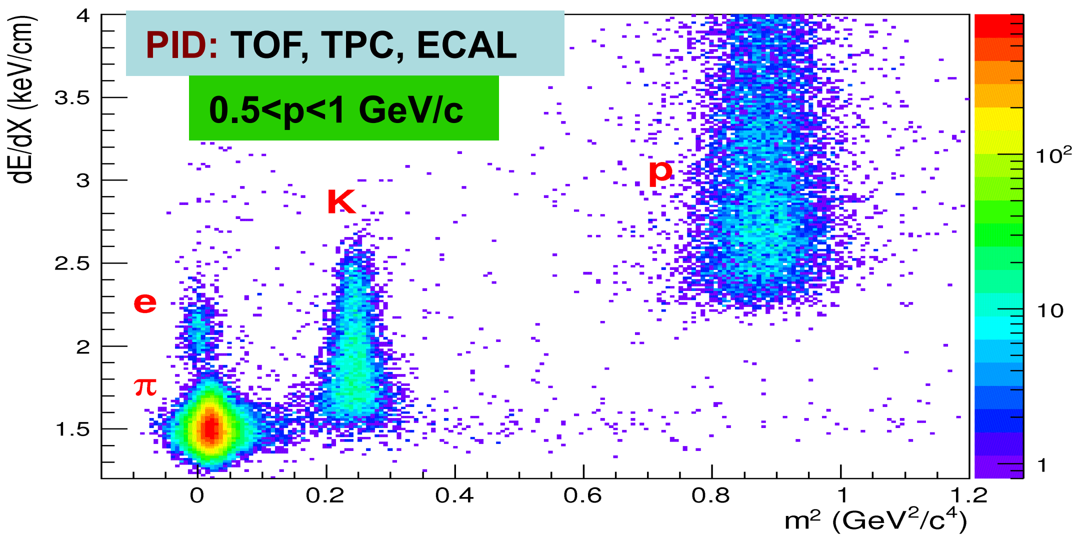
Tracking: *up to $|\eta|<2$ (TPC)*
PID: *hadrons, e, g (TOF, TPC, ECAL)*
Event characterization:
centrality & event plane (ZDC)



Reaction plane & impact parameter definitions



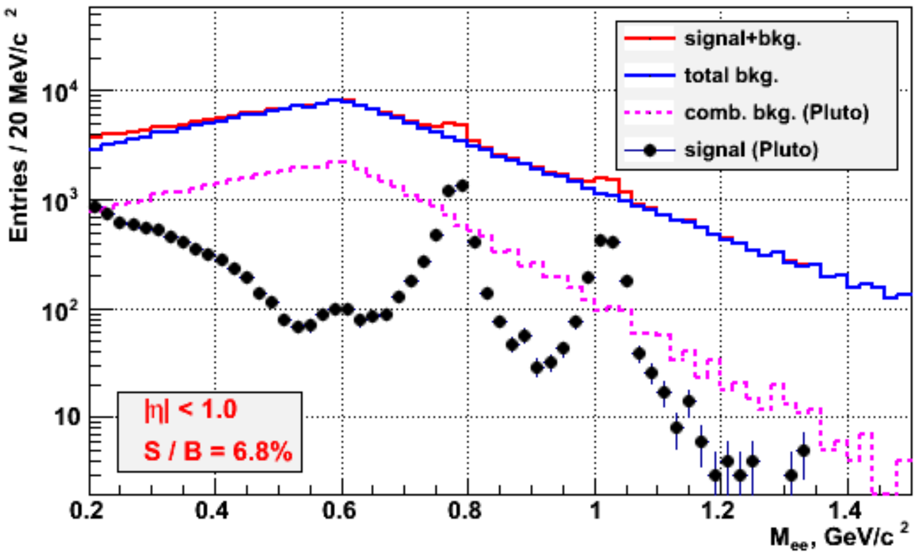
b, fm



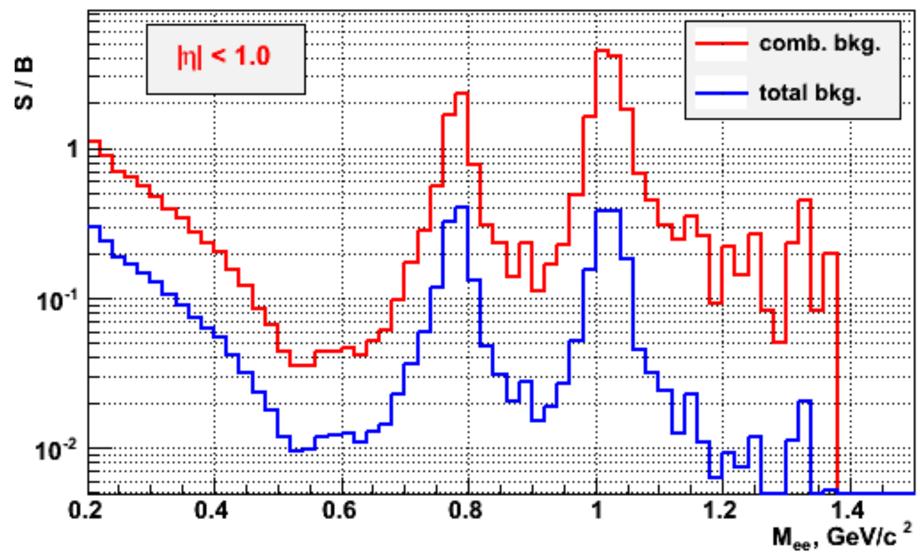
Study of electron-positron pairs

dileptonic decays of vector mesons ρ, ω, ϕ

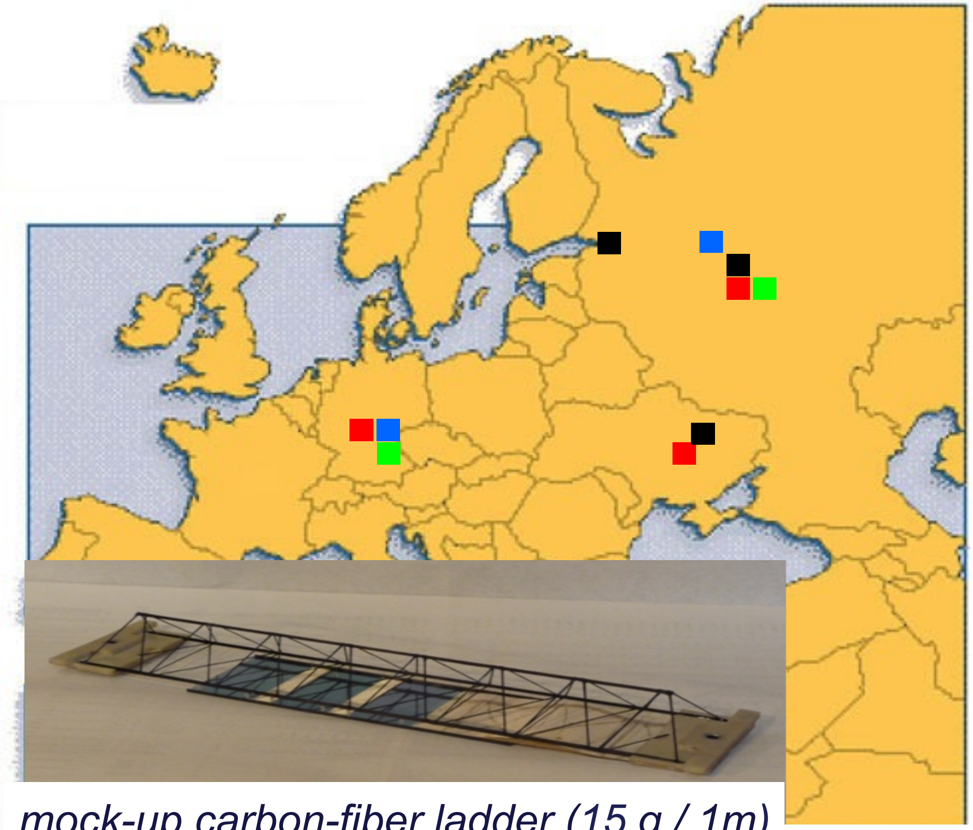
signal-to-background ratios in M(e+e-)



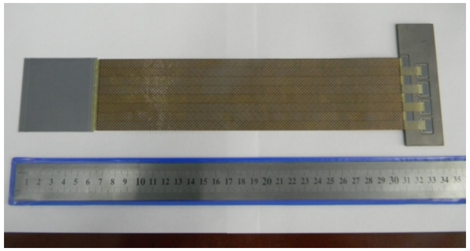
integrated signal-to-background ratios after identification

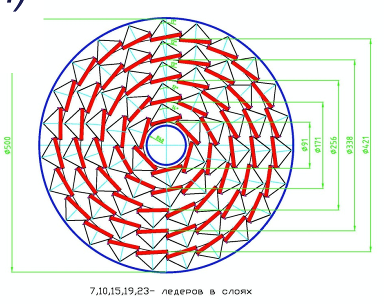


The CBM - MPD consortium:
*development & production of STS for **CBM** (FAIR), **MPD** & **BM@N***



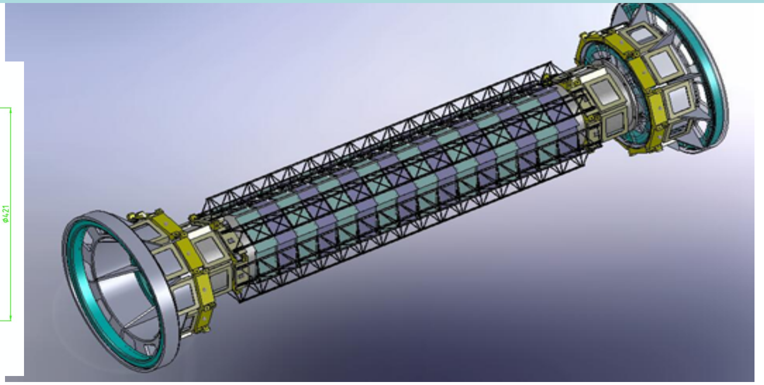
mock-up carbon-fiber ladder (15 g / 1m) and module circuit board



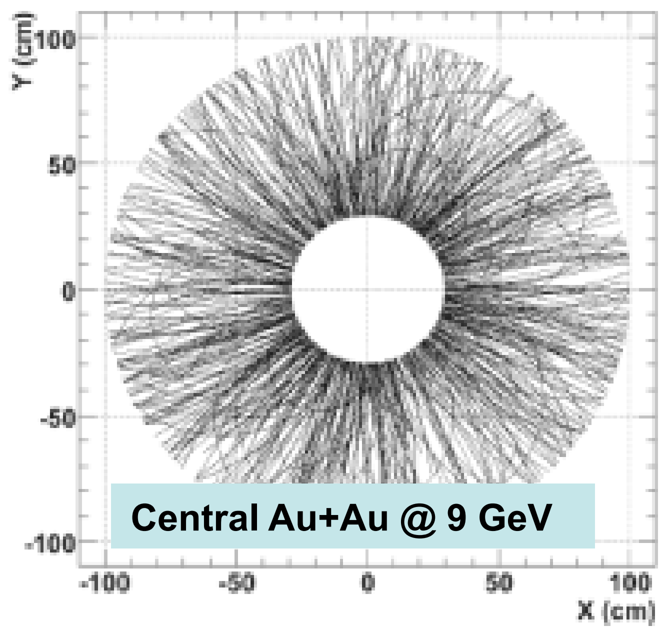


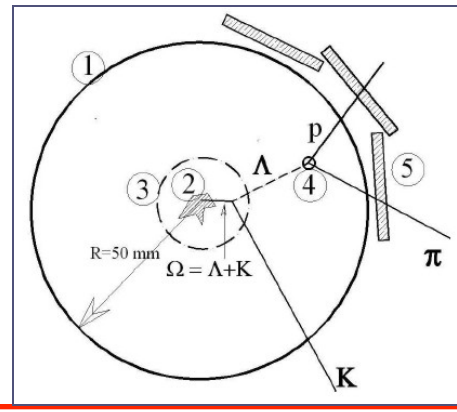
The **clean room** for assembling of STS modules is designed and constructed at LHEP

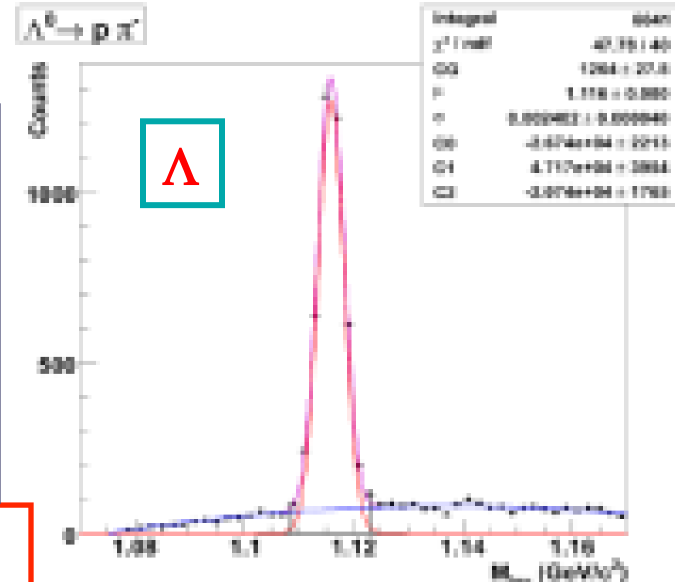
*Design of super-module for **IT MPD***



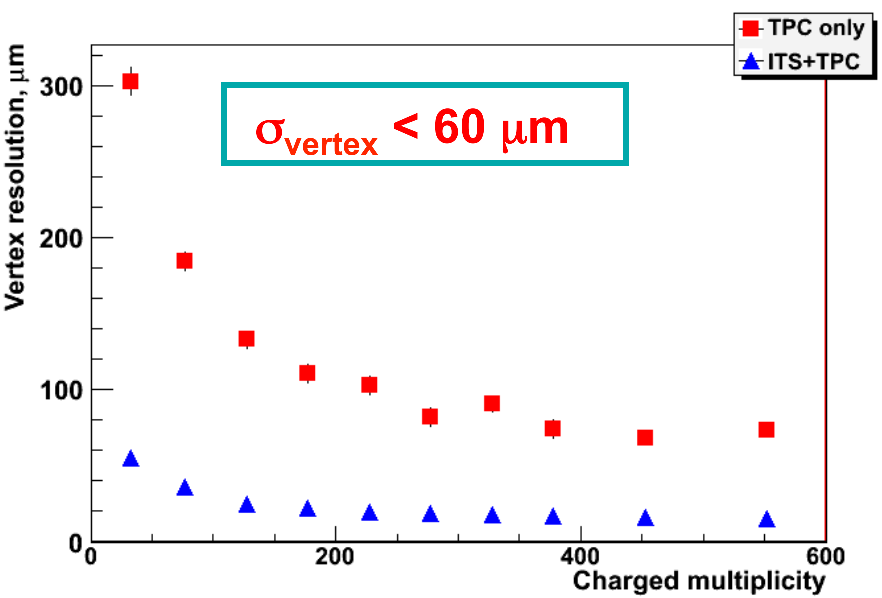
V0 performance (TPC+SIT)

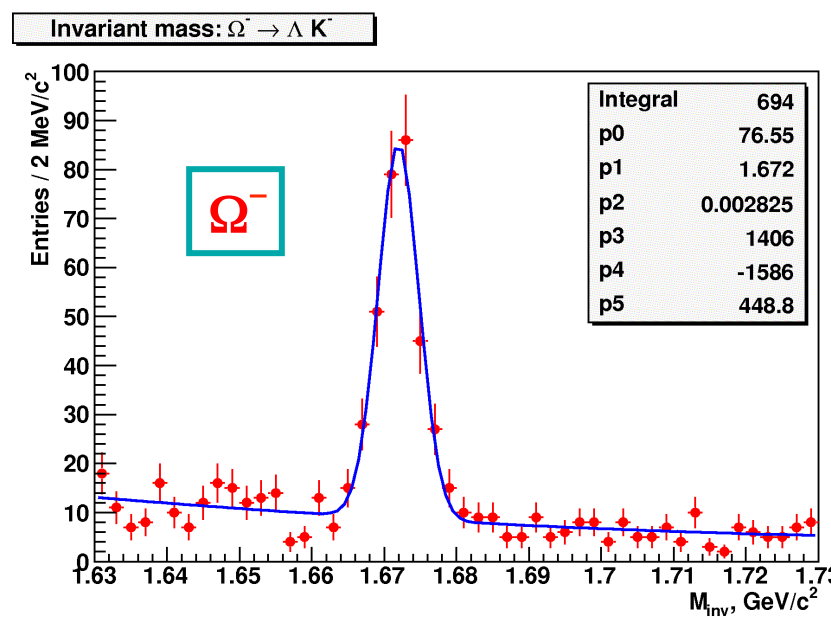






Improved Sg-to-Bg ratio (S/B) with the vertex IT detector

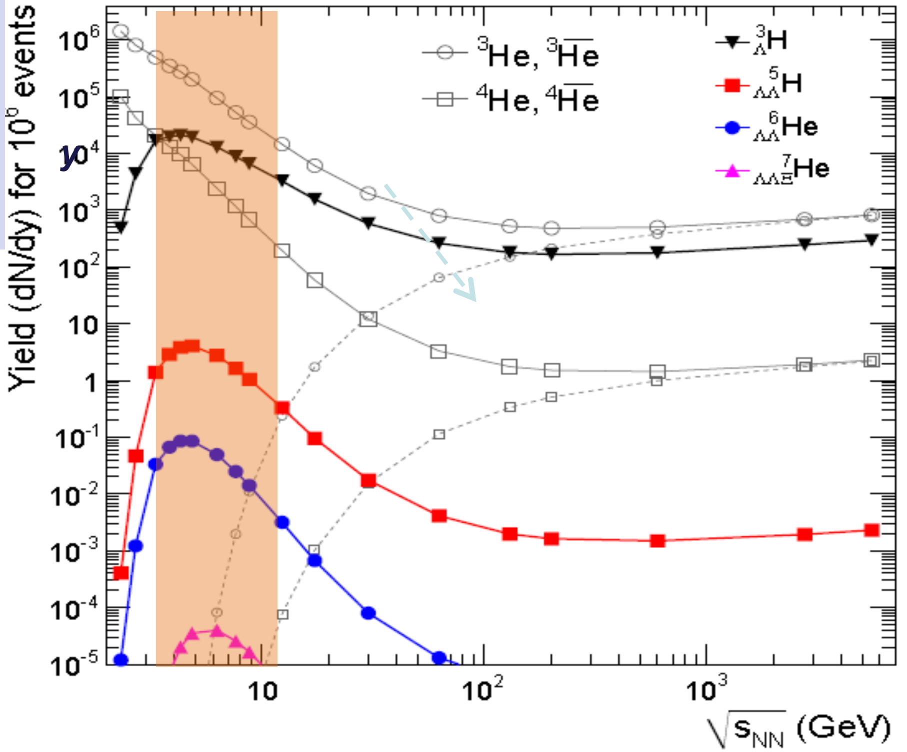




Hypernuclei @ MPD

- **Precise information on Y-N interaction:**
  nuclear EOS, astrophysics
- **Hypernuclei ground, excited states and life times:**
  critical assessments for QCD calculations and model predictions
- **Production mechanism of bound states with hyperons:**
  coalescence versus spectators-participants interactions, exotic states, dibaryons

Hypernuclei production enhanced at high baryon densities (NICA)



Requirements MPD detector has to fulfill:

- *efficient PID for hadrons and nuclei*
- *ability of precise reconstruction of secondary vertex*

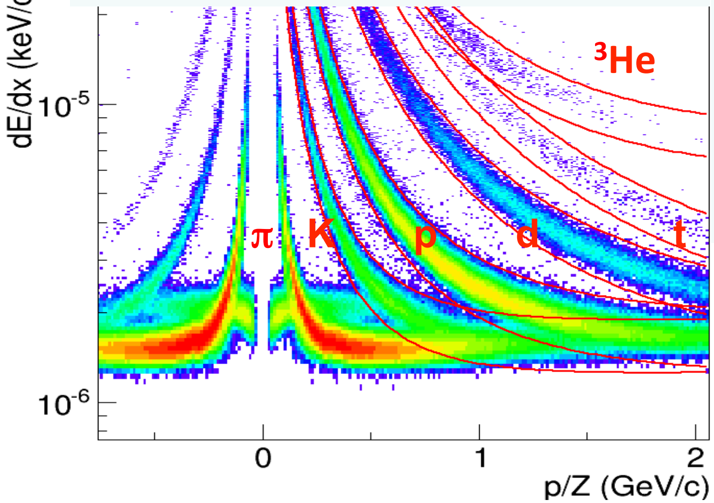
Hypertritons at NICA-MPD. Feasibility study

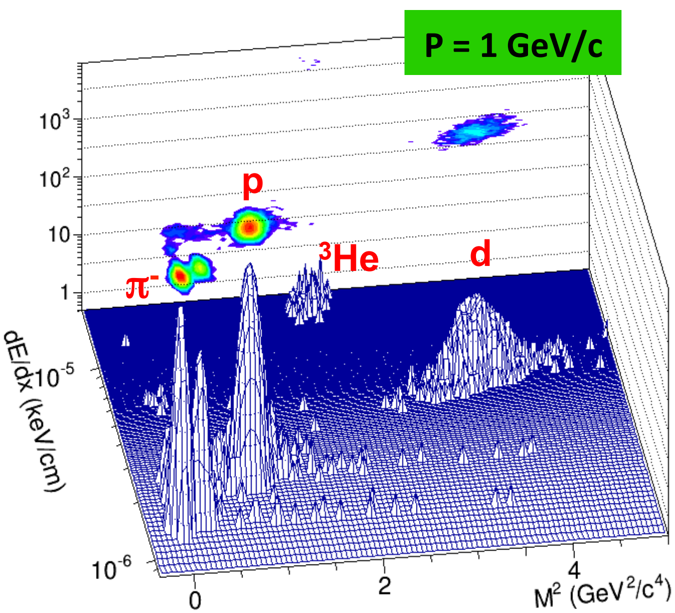
PID is achieved by dE/dx (TPC) and time-of-flight (TOF) measurements

$$m^2 = p^2\left(\frac{c^2T^2}{L^2} - 1\right)$$

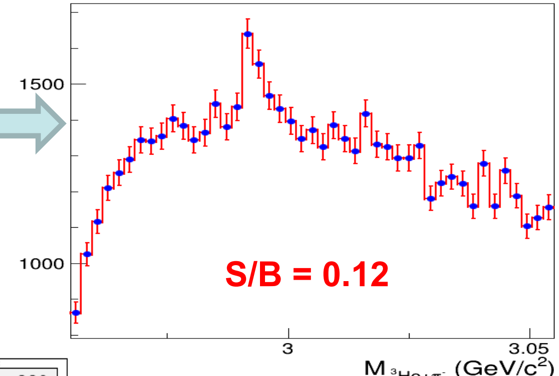
- ***Mass square from momentum (p), time-of-flight (T) and trajectory length (L)***
- ***Particles are selected within 3σ cuts in dE/dx or dE/dx (m^2) in momentum bins***
- ***Secondary vertex technique***
- ***Quality cuts to maximize significance***

Central Au+Au @ 5A GeV (DCM-QGSM)

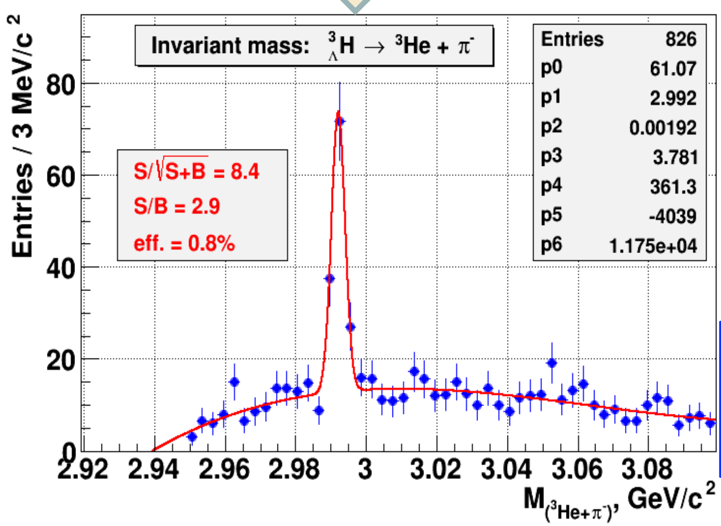




Min. # of cuts
(values ~ used by STAR)



Max. # of cuts
(tuned for max. significance)



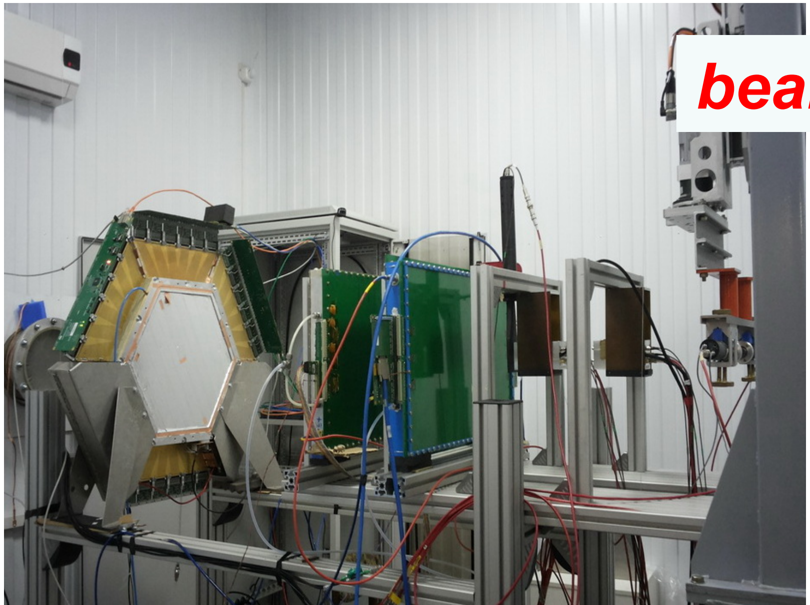
We expect ~10^6 $^{3}_{\Lambda}H$ for 10 weeks @ 5 AGeV

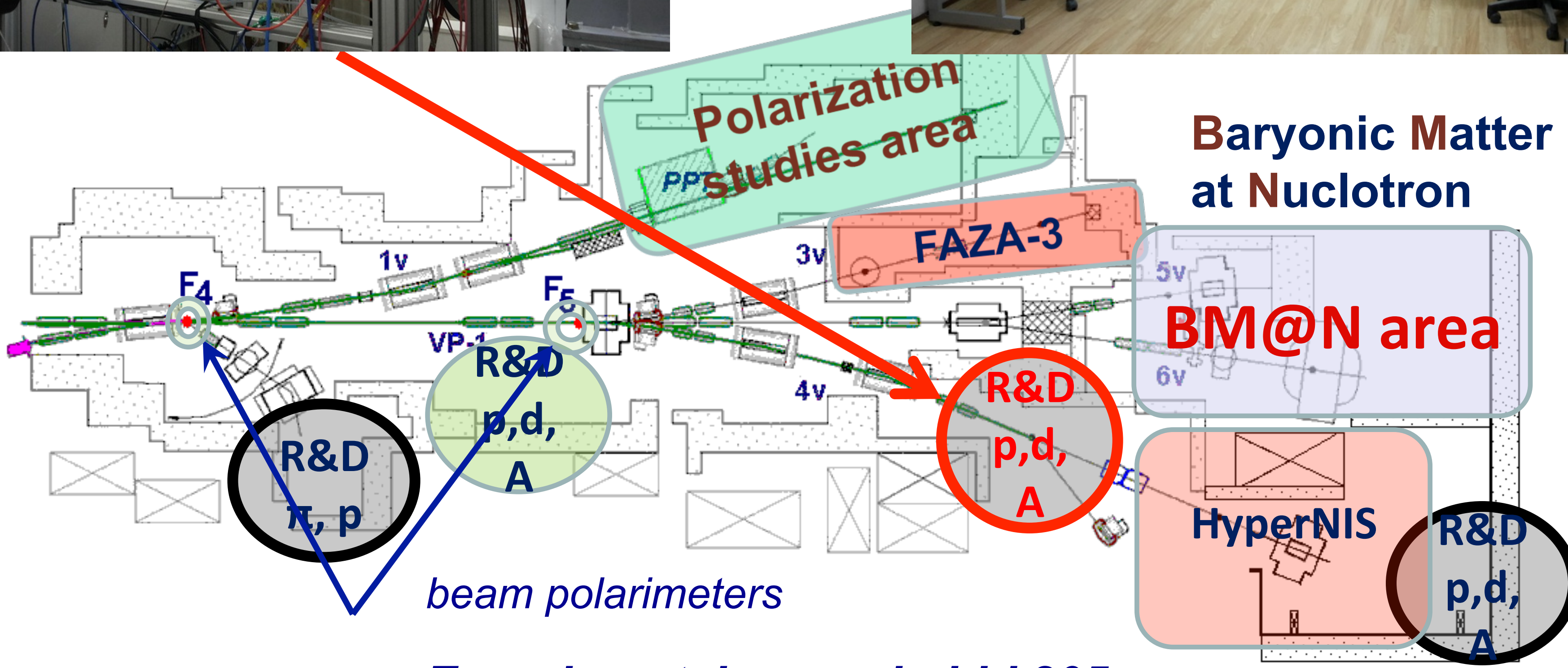
Experiment with the extracted beam:

B**aryonic **M**atter at **N**uclotron - **BM@N

project approved in 2012

beam test facility

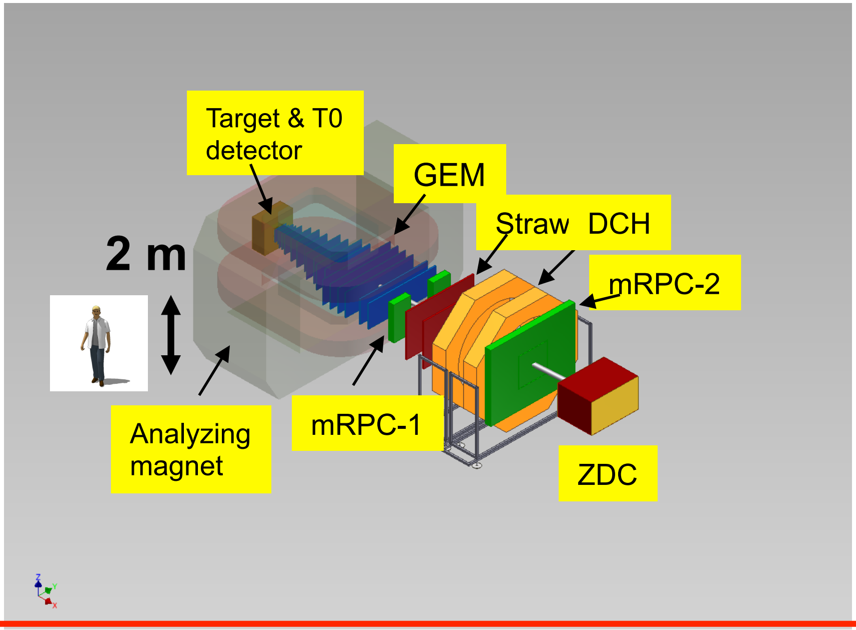




Experimental zones in bld.205

Beam	Intensities, particles per cycle				
	Energy	*GSI (SIS18)*	*Nuclotron-M (2011)*	*Planned with Nuclotron-N (2015)*	*Planned with new ion source and booster (after 2016)*
p	4,5 GeV	$2 \cdot 10^{10}$	-	$5 \cdot 10^{11}$	$1 \cdot 10^{12}$
d	2,2 GeV	$5 \cdot 10^{11}$	$6 \cdot 10^{10}$	$5 \cdot 10^{11}$	$1 \cdot 10^{12}$
^{4}He			$2 \cdot 10^{9}$	$3 \cdot 10^{10}$	$5 \cdot 10^{11}$
d↑			$2 \cdot 10^{8}$	$2 \cdot 10^{10}$ *(SPI)*	$2 \cdot 10^{10}$ *(SPI)*
$^{7}Li^{6+}$			$7 \cdot 10^{9}$	$3 \cdot 10^{10}$	$1 \cdot 10^{11}$
$^{12}C^{6+}$	300 MeV	$7 \cdot 10^{10}$	$6 \cdot 10^{9}$	$3 \cdot 10^{10}$	$1 \cdot 10^{11}$
$^{24}Mg^{12+}$	300 MeV	$5 \cdot 10^{10}$	$7 \cdot 10^{8}$	$4 \cdot 10^{9}$	$5 \cdot 10^{10}$
$^{40}Ar^{18+}$	300 MeV	$6 \cdot 10^{10}$	$8 \cdot 10^{6}$	$2 \cdot 10^{9}$	$2 \cdot 10^{10}$
$^{56}Fe^{28+}$			$4 \cdot 10^{6}$	$2 \cdot 10^{9}$	$2 \cdot 10^{10}$
$^{58}Ni^{26+}$	300 MeV	$8 \cdot 10^{9}$			
$^{84}Kr^{34+}$	0,3 -1 GeV	$2 \cdot 10^{10}$	$2 \cdot 10^{5}$	$1 \cdot 10^{8}$	$1 \cdot 10^{9}$
$^{124}Xe^{48/42+}$	0,3 -1 GeV	$1 \cdot 10^{10}$	$1 \cdot 10^{5}$	$7 \cdot 10^{7}$	$1 \cdot 10^{9}$
$^{181}Ta^{61+}$	1 GeV	$2 \cdot 10^{9}$			
$^{197}Au^{65/79+}$		$3 \cdot 10^{9}$		$1 \cdot 10^{8}$	$1 \cdot 10^{9}$
$^{238}U^{28+/73+}$	0,05-1 GeV	$6 \cdot 10^{9}/2 \cdot 10^{10}$			

BM@N: *the 1st stage*



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

Physics :

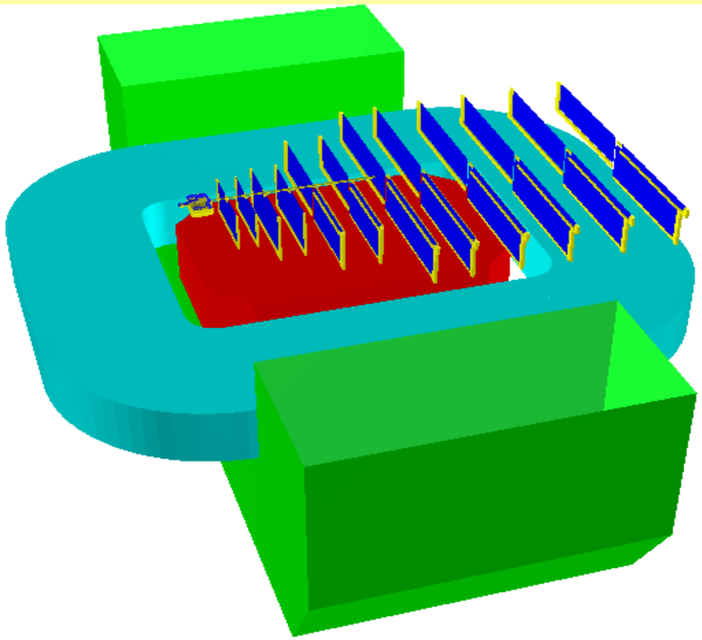
- *in-medium effects for strangeness and vector mesons decaying in hadron modes*
- *hyperon production*
- *hadron femtoscopy*
- ***pp** and **pA** reactions as reference for **AA** interactions*
- *electromagnetic probes (optional)*

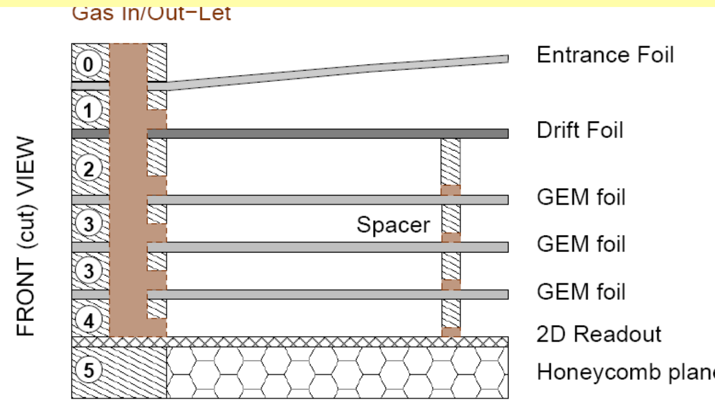
Required setup:

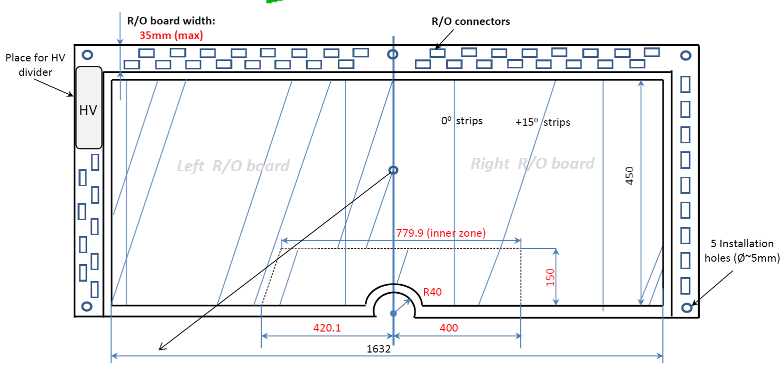
- *central tracker inside analyzing magnet to reconstruct AA interactions*
- *outer tracker behind magnet to link central tracks to the ToF detector*
- *ToF system based on RPC and T0 detectors to identify hadrons and light nucleus*
- *ZDC calorimeter to measure centrality of AA collisions and to trigger*
- *ECAL to identify γ,e*

Simulated **GEM tracker** configuration

12 stations: Z = 30 – 45 – 60 – 80 – 100 – 130 – 160 – 190 – 230 – 270 – 315 – 360
Stereo angles: 0 – 7.5 deg in stat. 1-4; 0 – 15 deg in stat. 5 - 12
Pitch: 400 um in stat. 1-4, 800 um in stat. 5-12

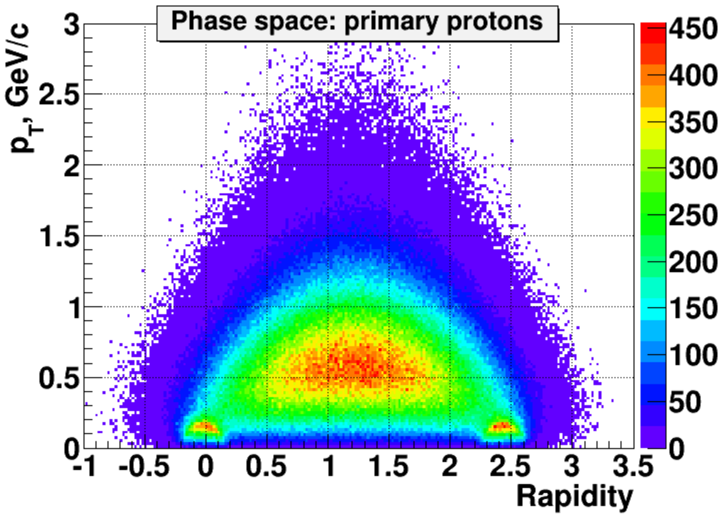




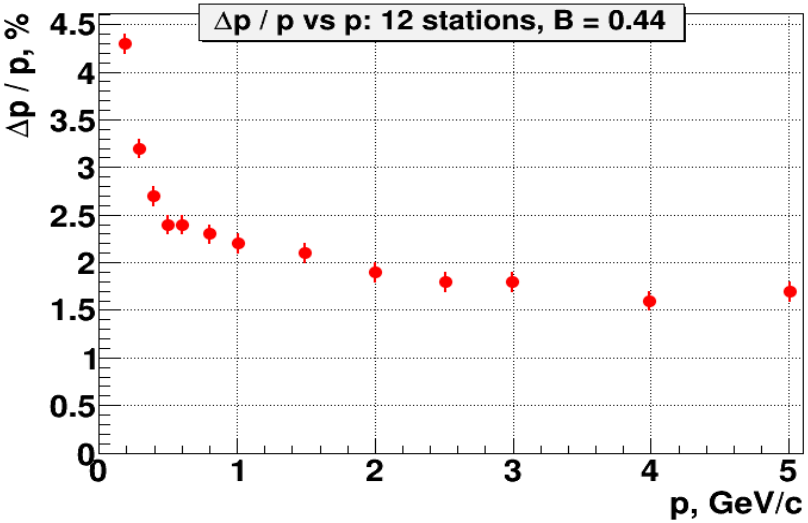


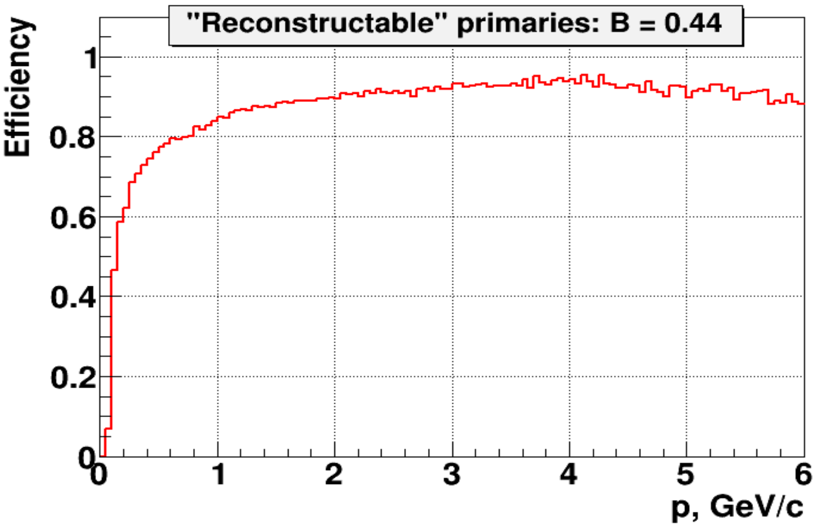
GEM tracker: acceptance / momentum resolution / detection efficiency

Phase space / acceptance to primary protons:



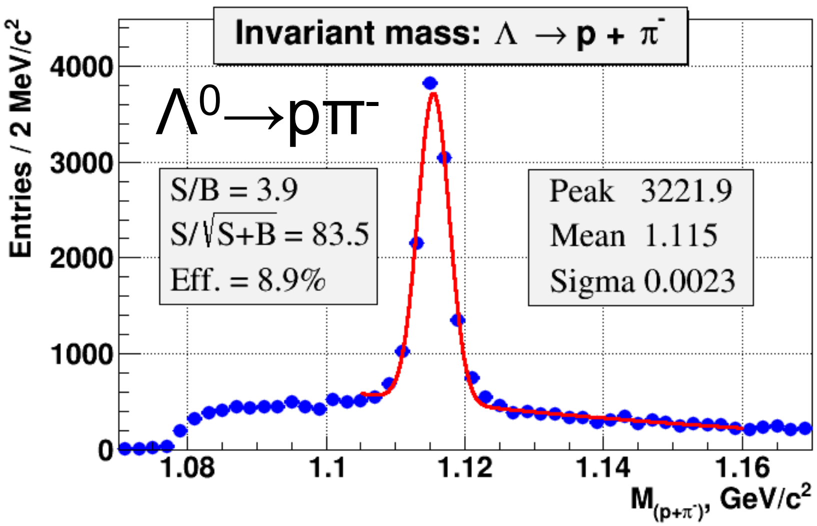
Momentum resolution / detection efficiency

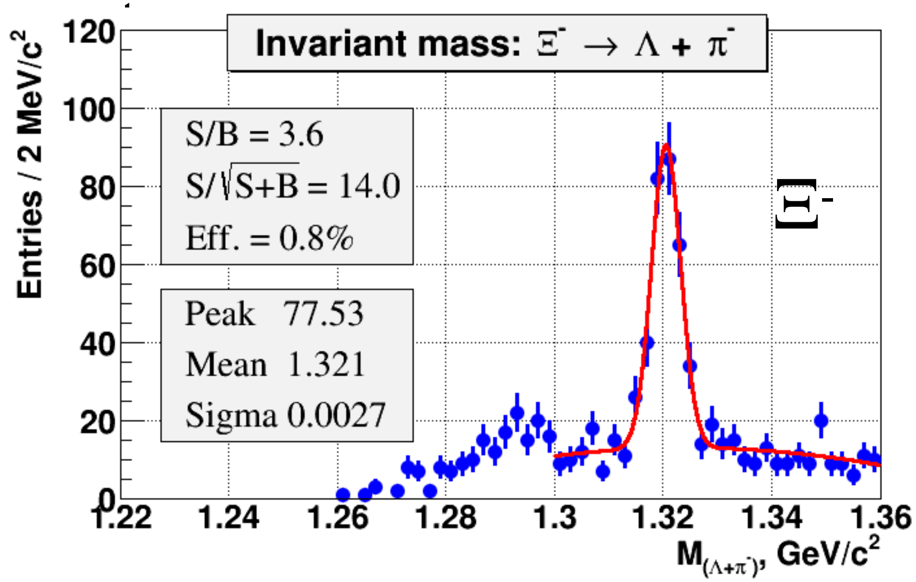




GEM tracker: Λ^0, Ξ^- , $^3H_\Lambda$ reconstruction

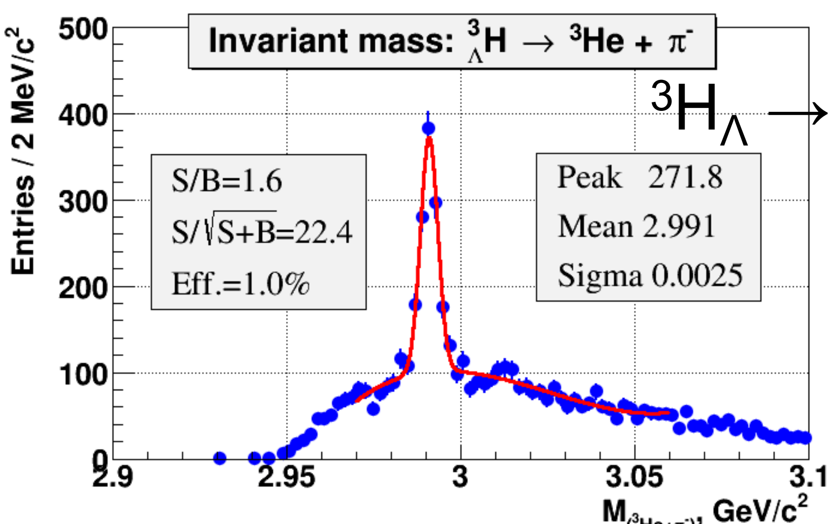
Au+Au, 4.5 AGeV, UrQMD, 900k central



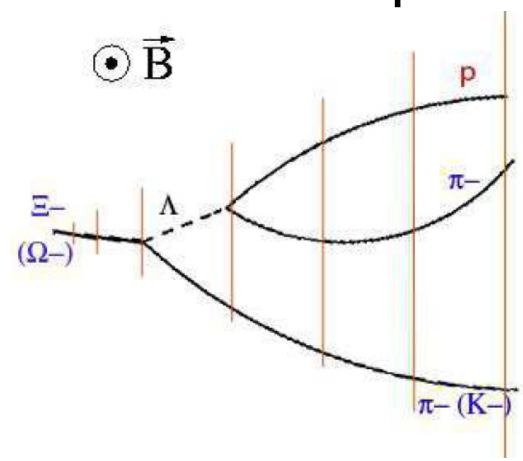


Au+Au, 4.5 AGeV, 2M central events

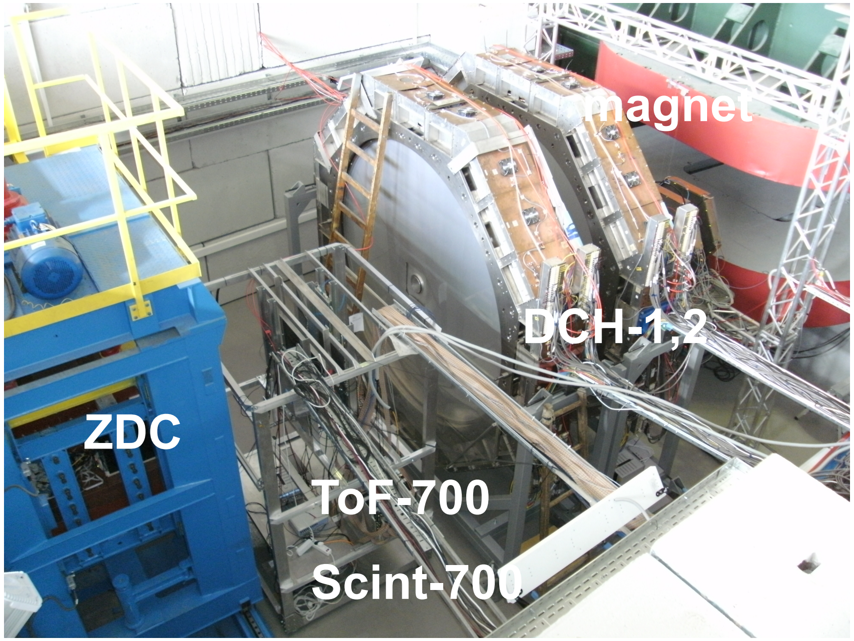
$\Xi^- \rightarrow \pi^- + \Lambda^0 \rightarrow p\pi^-$

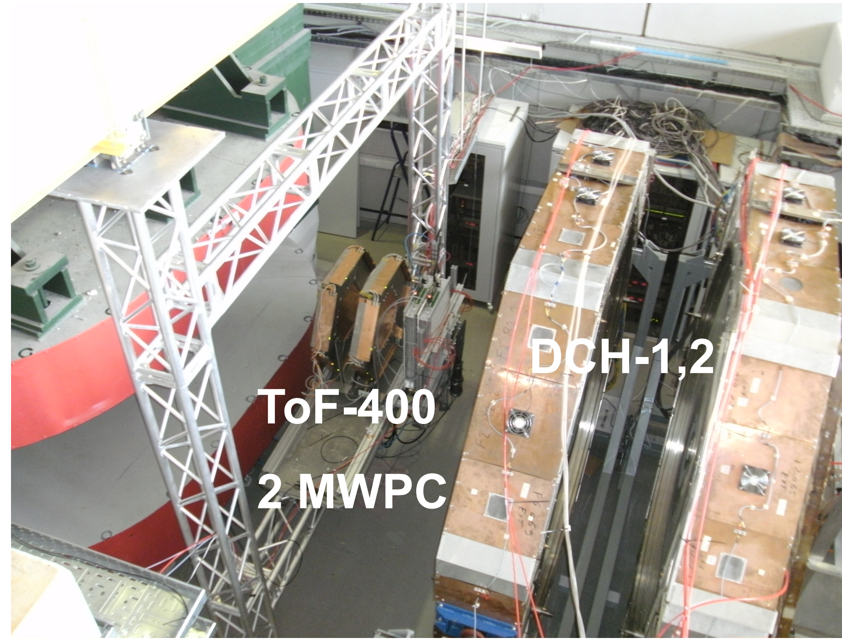


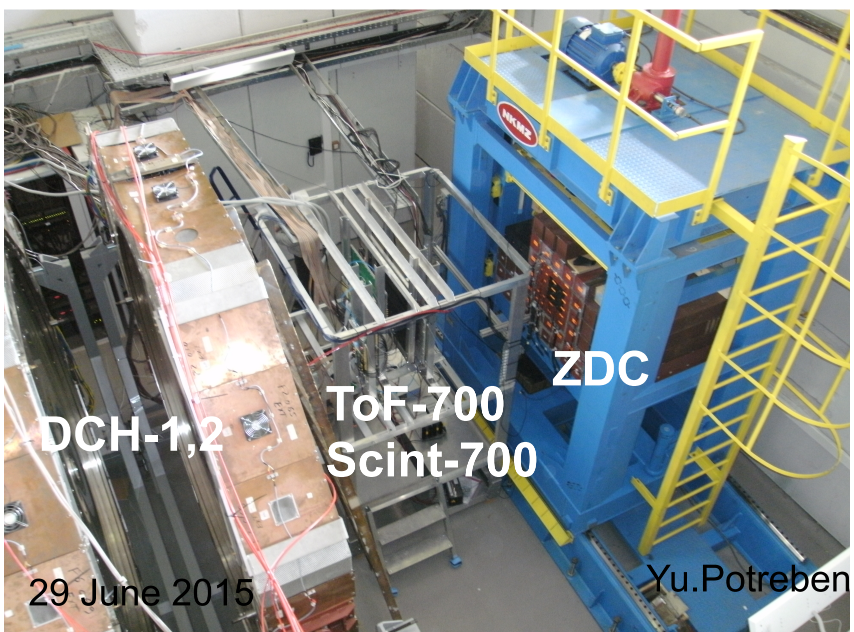
$^3H_\Lambda \rightarrow {}^3He\ \pi^-$



BM&N setup in the first technical run in February-March 2015





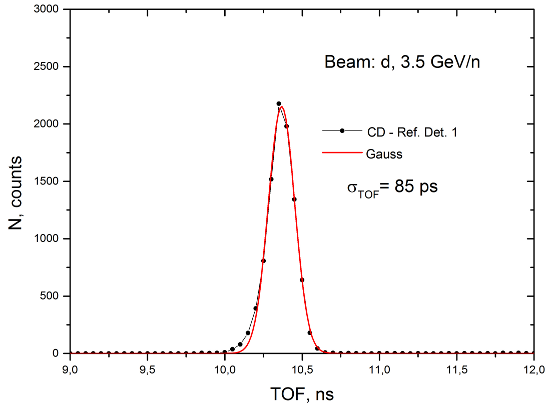


Tasks for BM@N technical run:

- deuteron 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

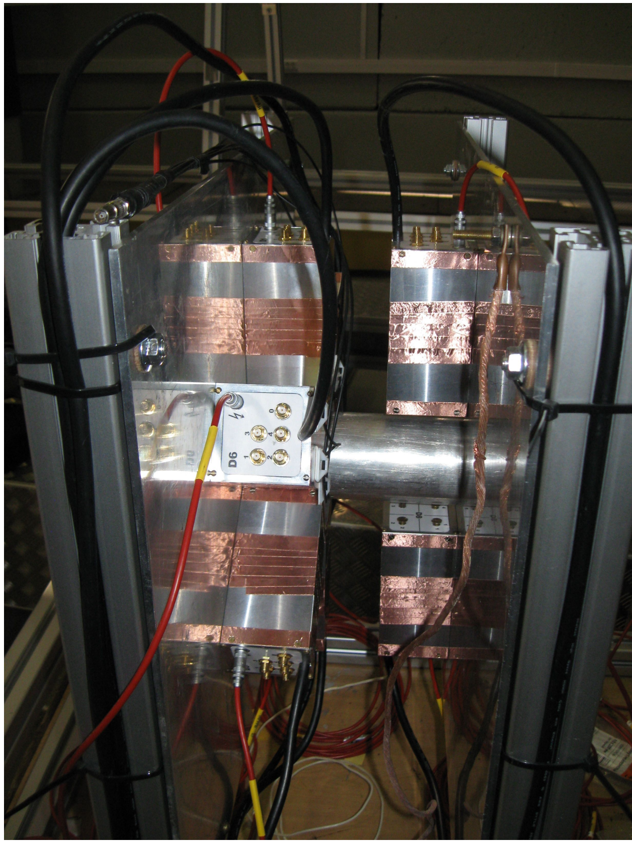
Start Cherenkov detector and T0+Tr detectors in technical run

BM@N trigger group



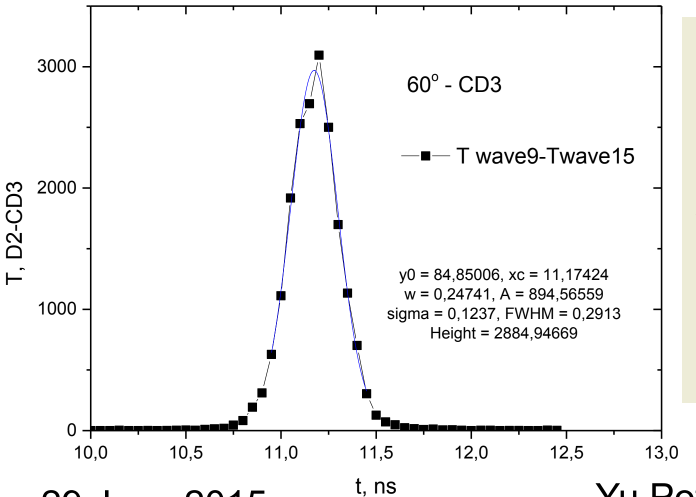
Time resolution of start CD detector measured using standalone readout electronics:

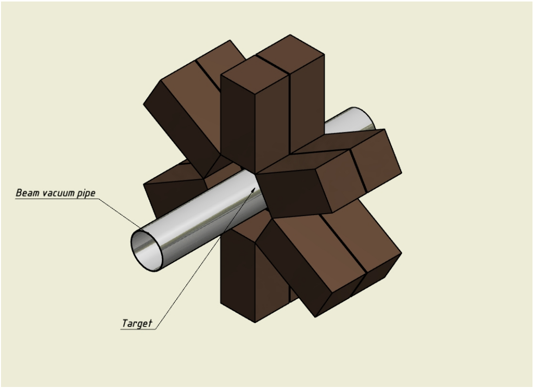
- 85 ps for deutron beam
- 27 ps for carbon beam



Time resolution of T0+Tr detector arranged at different angles to dipole magnetic field of SP-41:

T0+Tr(0°,180°): σ_{TOF} = 72 ps , T0+Tr(60°,120°): σ_{TOF}=124 ps

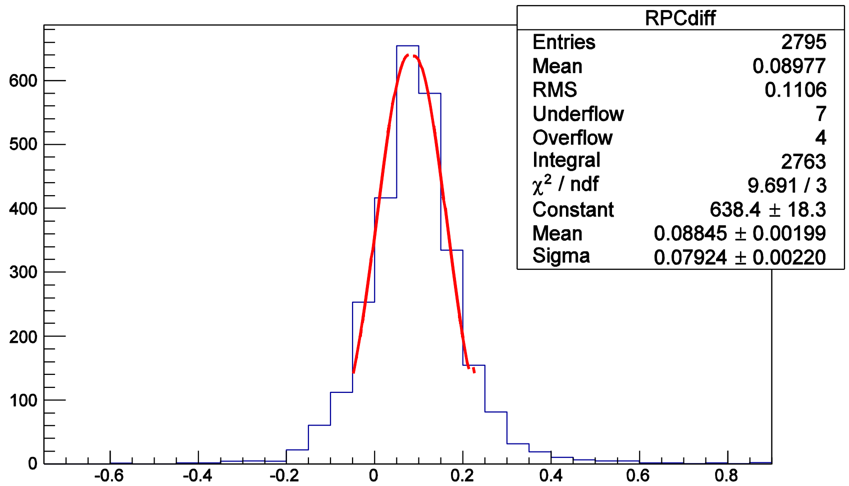




ToF system performance in technical run

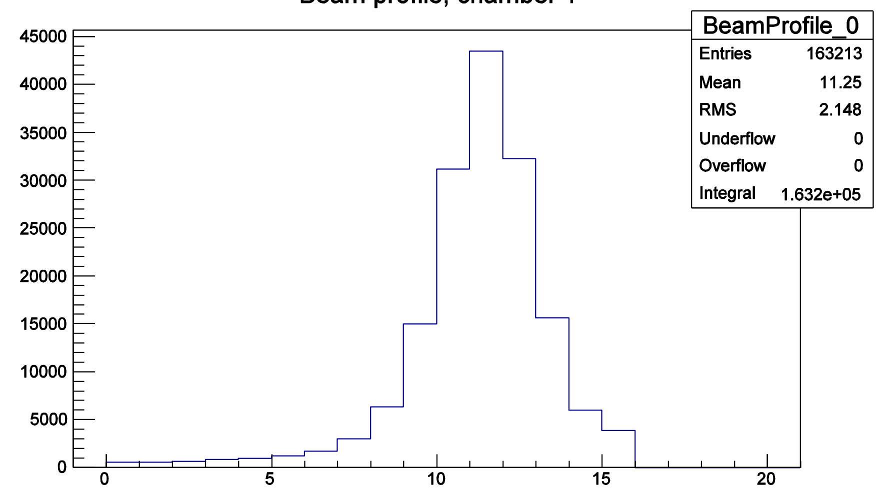
BM@N ToF-400 and ToF-700 groups

Time difference chambers 1 (chans (43+52)/2) and 2 (chans (107+116)/2)



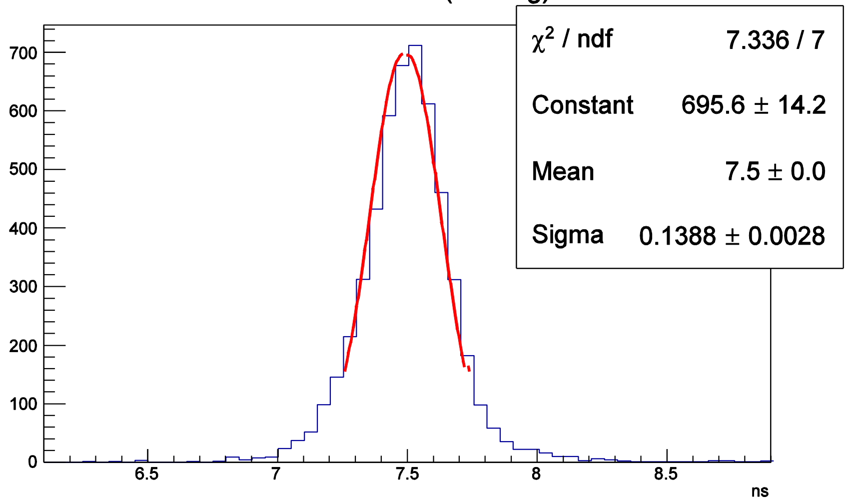
Deutron beam profile in ToF-700

Beam profile, chamber 1



Strips along horizontal axis, strip width 1 cm

Time RPC1+RPC2 (slewing) - T0

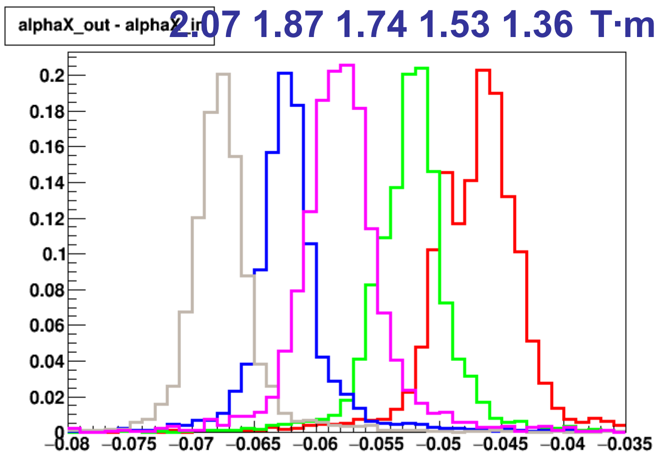


BM@N DAQ readout electronics:

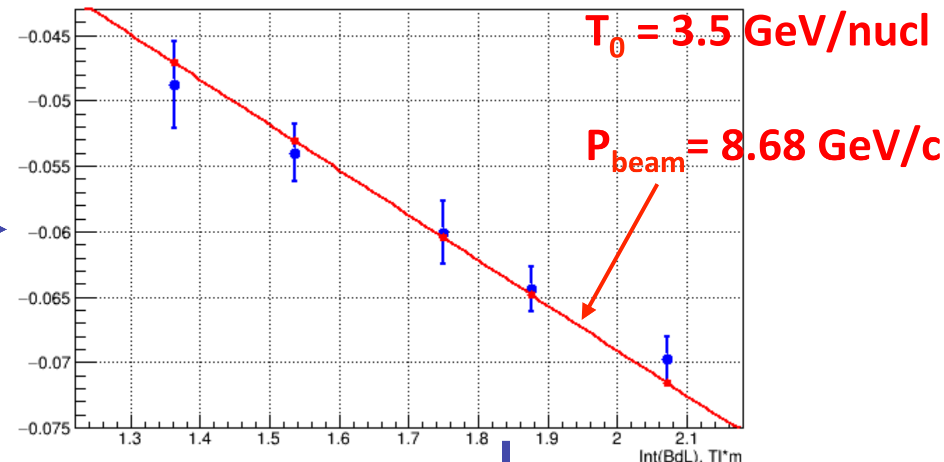
- Time spread between two ToF-700 chambers: 80-90 ps, time resolution of one chamber → ~60 ps
- Time resolution of ToF-400 chamber ~50 ps
- Time resolution of ToF-400, ToF-700 relative to start CD detector (T0) → ~140 ps

Deuteron tracks and momentum reconstruction in Drift Chambers

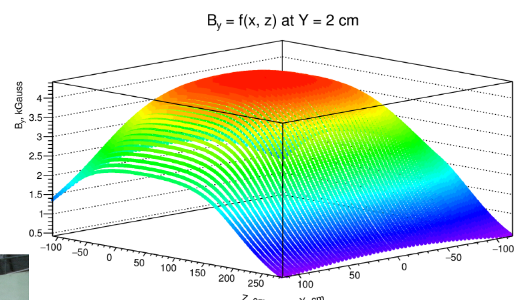
Deutron beam inclination at different values of magnetic field

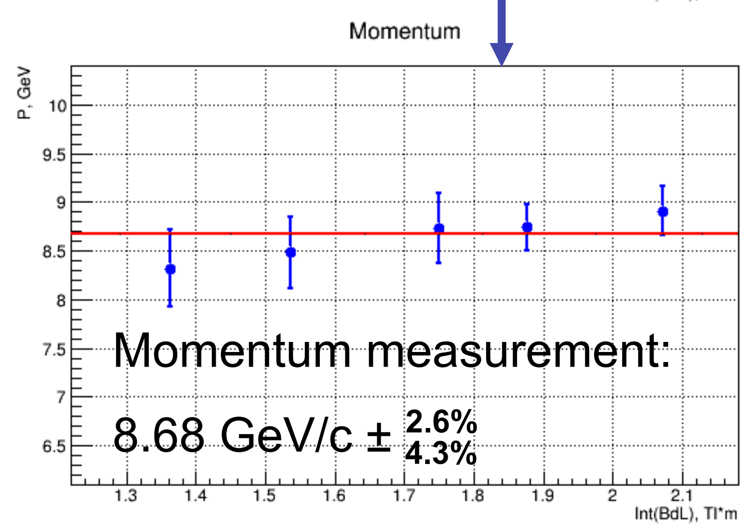


Inclination angle vs magnetic field

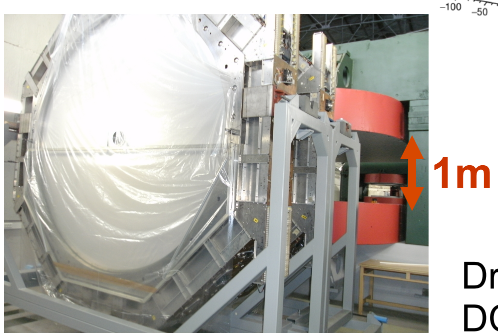


Vertical component of magnetic field →



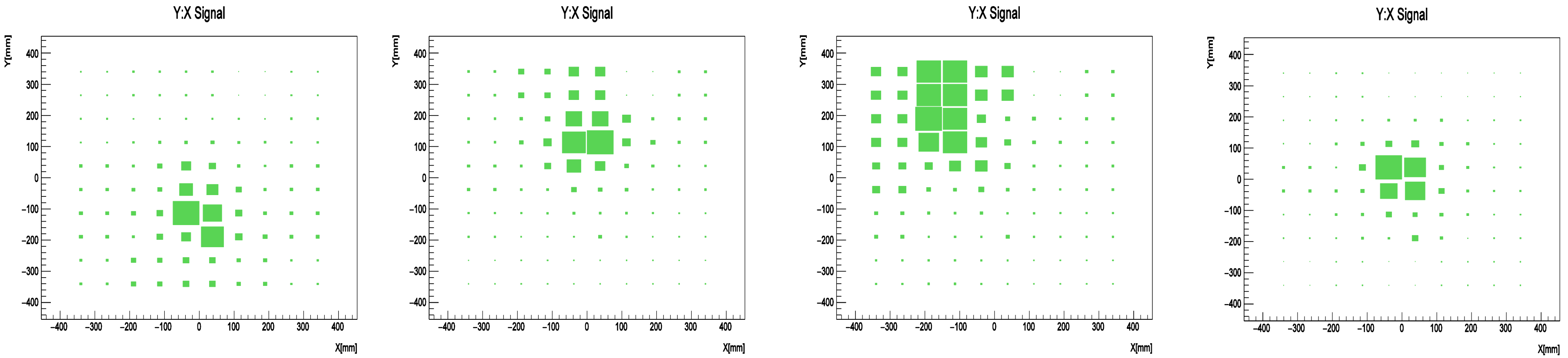


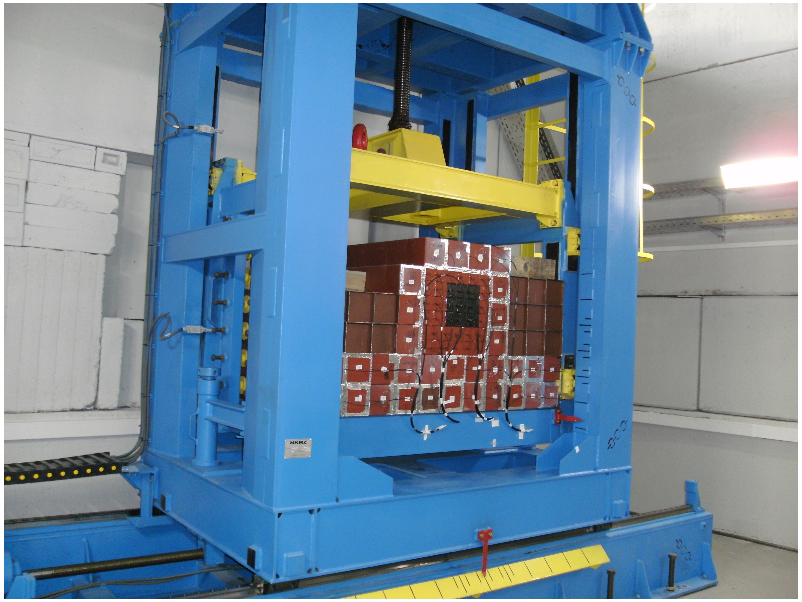
Integral of magnetic field, Tl·m



Drift chambers DCH-1,2

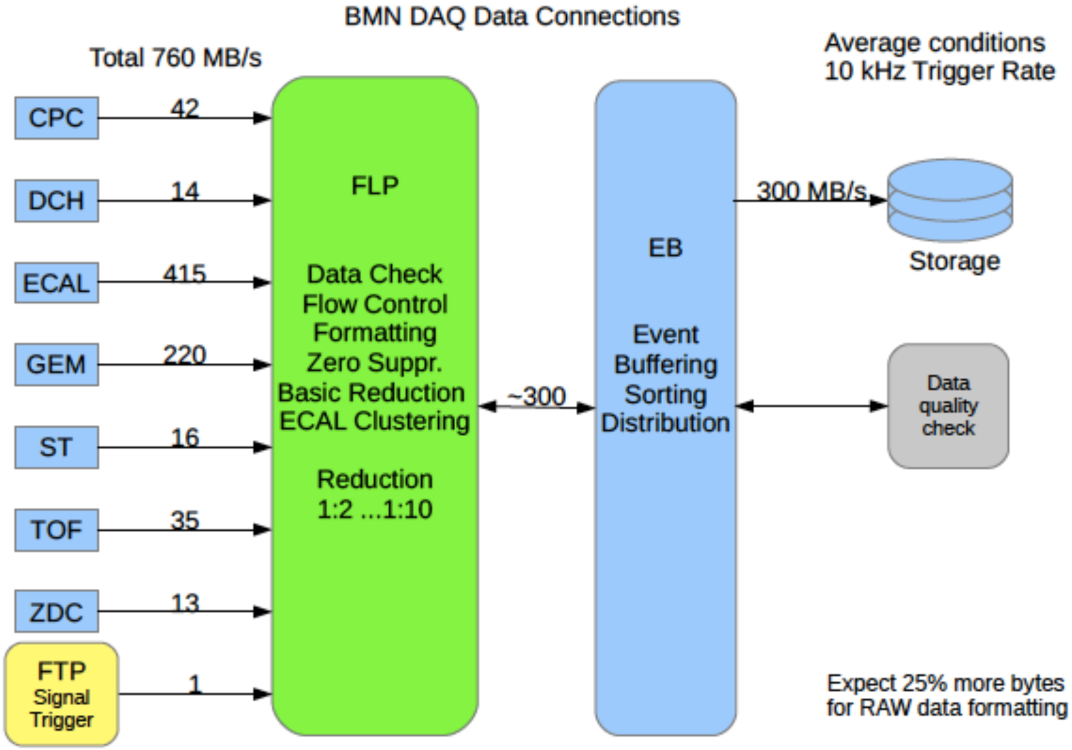
Calibration of ZDC calorimeter





- 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%

BMN Data Flows, 2017



- 80 kB/event
- 10 kHz trigger rate
- 60% beam on time
- 20% DAQ standby time
- 950 MB/s readout rate (4800 MB/s peak)
- 25 TB RAW data per day
- Up to 5 PB RAW data per year

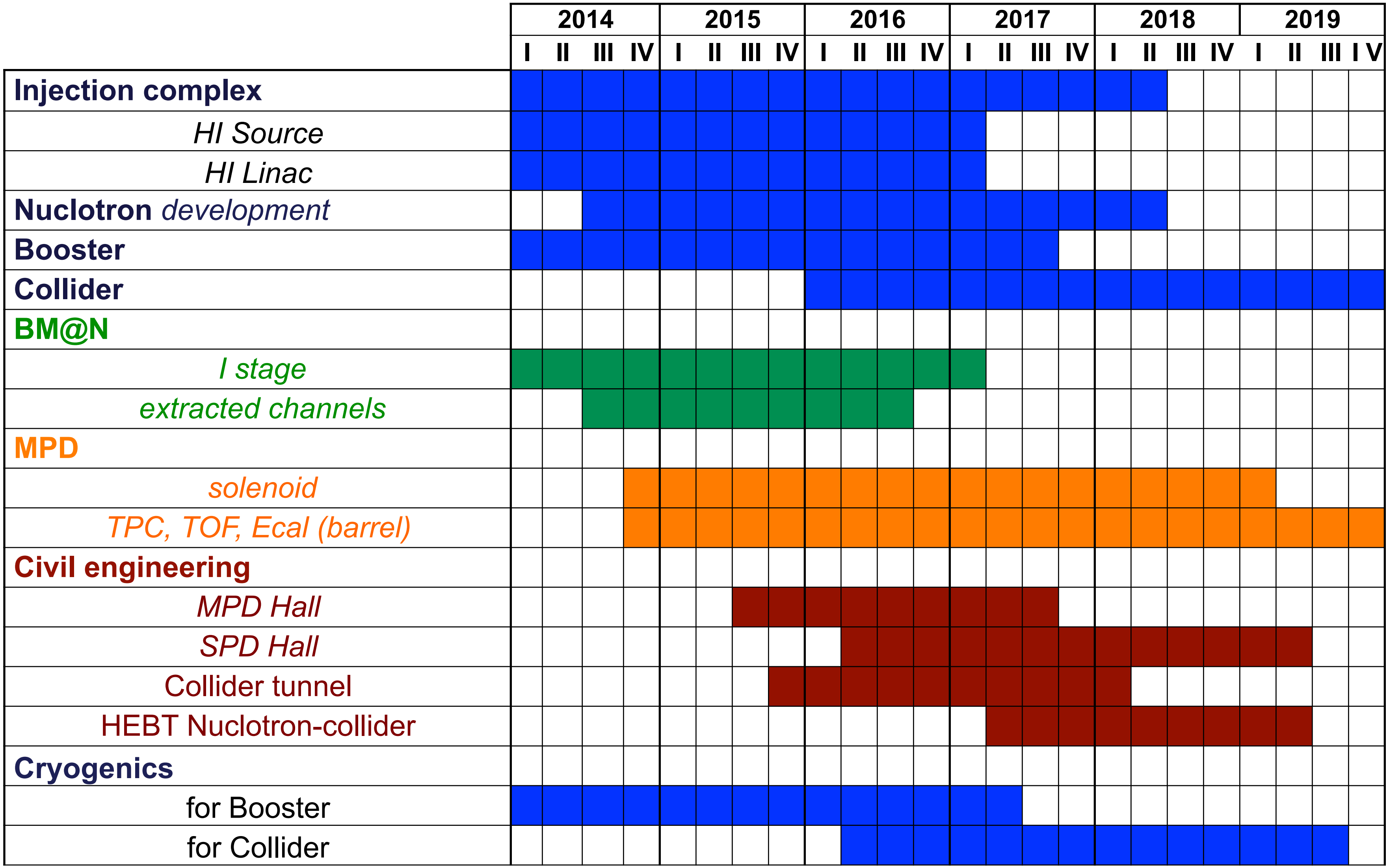
Together with MPD (2020) - more than 10 PB RAW data per year

Needs:

- Comp. CPU – 5 000 GHz
- Cpmp. CPU cores – 1 600
- Comp. RAM – 10 000 GB

- Disc storage – 2 200 TB
- Mass storage – 20 PB/year

Tentative schedule for NICA



Scientific cooperation of VBLHEP on the NICA projects

Belarus
NC PHEP BSU (Minsk)
GSU (Gomel)
…
…

Germany
GSI (Darmstadt)
JLU (Giessen)
UR (Regensburk)
Frankfurt/Main Univ.
FIAS
FZJ (Julich)
FAU(Erlangen)

Bulgaria
INRNE BAS (Sofia)
TU-Sofia
SU
ISSP BAS
LTD BAS
SWU
PU (Plovdiv)
TUL (Blagoevgrad)

Ukraine
BITP NASU (Kiev)
KhNU, KFTI NASU (Kharkov)

Russia
INR RAS (Moscow)
KI (Moscow)
BINP RAS (Novosibirsk)
MSU (Mscow)
LPI RAS (Moscow)
St.Pet. Univ ersity
RI (St.Petersbug)
…
…

Poland
Tech.University (Warsaw)
Warsaw University
Fracoterm (Krakow)
Wroclaw University
INP (Krakow)

Australia
Azerbaijan
CERN
China
France
Georgia
Greece
India

Czech Republic
TUL (Liberec)
CU (Prague)

RSA
UCT (Cape Town)
UJ (Johannesburg)
iThemba Labs

Italy
Japan
Moldova
Mongolia
Romania
Serbia
Slovakia
USA

Scientific cooperation of VBLHEP on the NICA projects

The MoU’s in cooperation are signed with:

Germany *(BMBF, GSI) – tech. lines for SC magnets & Si trackers;*
China *(ASIPP, Univ.) – NTSC current guides , SC magnets, RPC’s;*
USA *(FNAL) – systems for e- and stochastic- cooling;*
CERN *– systems for BM@N and MPD;*
RSA *– cryostats, diagnostic for SC ion sources.*

6 of them + JINR signed the Protocol

PROTOCOL

of the International Meeting on Prospects for Collaboration in the Mega-Science Project "Complex of Superconducting Rings for Heavy Ion Colliding Beams" — the NICA Complex

Dubna, 8 August 2013

1. The Participants of the Meeting representing:

- the State Committee of Science and Technology of the Republic of Belarus;
- the Nuclear Regulatory Agency of the Republic of Bulgaria;
- the Federal Ministry of Education and Research (BMBF) of the Federal Republic of Germany;
- the Atomic Energy Committee of the Ministry of Industry and New Technologies of the Republic of Kazakhstan;
- the Ministry of Education and Science of the Russian Federation;
- the State Agency for Science, Innovation and Informatization of Ukraine;
- the Joint Institute for Nuclear Research (JINR), an international research organization,

hereinafter referred to as the Parties,
have discussed the possibilities of collaboration in the mega-science project "Complex of Superconducting Rings for Heavy Ion Colliding Beams" — the NICA Complex.

2. The Parties take note of the information concerning the proposal for the new accelerator
and experimental comp
and quality of ion beam
NICA Complex will be
research, as well as to
scientists.

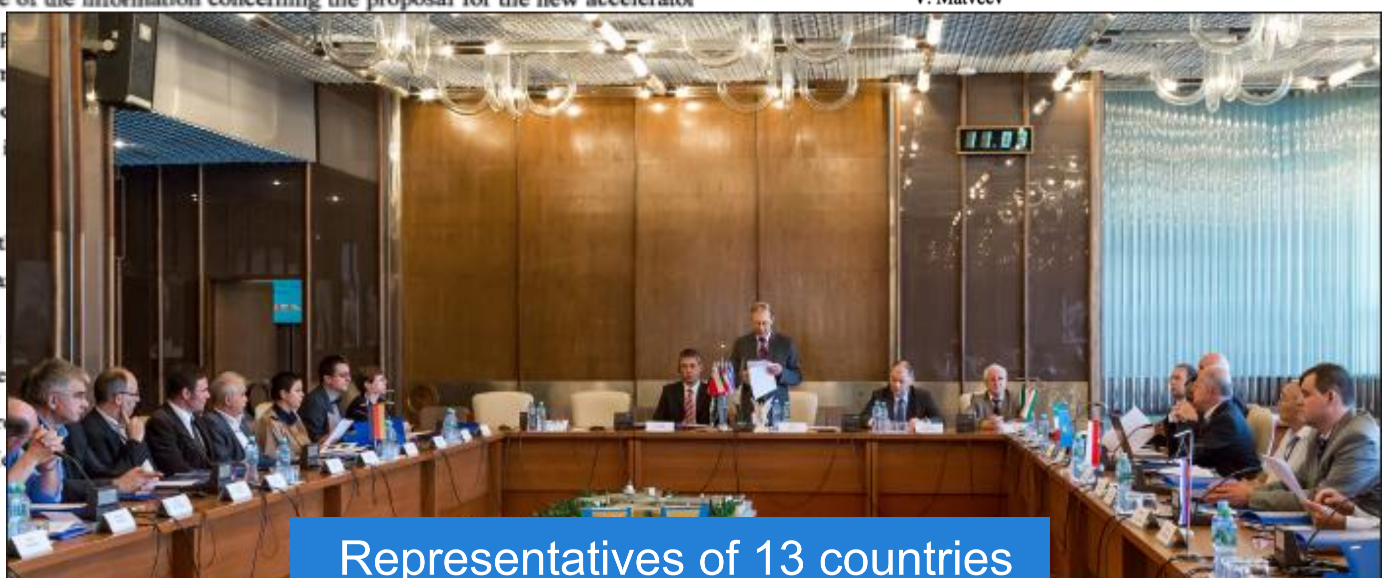
3. The Parties express t
aimed at construction a

4. The Parties note the
countries and their pote

5. The Parties have agr
Collaboration in the M

Signed:

F. Krylov	for the State Committee of Science and Technology of the Republic of Belarus
L. Kostov	for the Nuclear Regulatory Agency of the Republic of Bulgaria
B. Vierkorn–Rudolph	for the Federal Ministry of Education and Research (BMBF) of the Federal Republic of Germany
N. Burtebaev	for the Atomic Energy Committee of the Ministry of Industry and New Technologies of the Republic of Kazakhstan
A. Povalko	for the Ministry of Education and Science of the Russian Federation
B. Grynyov	for the State Agency for Science, Innovation and Informatization of Ukraine
V. Matveev	for the Joint Institute for Nuclear Research



Representatives of 13 countries

PROTOCOL

of the International Meeting on Prospects for Collaboration in the Mega-Science Project "Complex of Superconducting Rings for Heavy Ion Colliding Beams" — the NICA Complex

6 of them + JINR signed the Protocol

5. The Parties have agreed to inform their Governments about the Meeting on Prospects for Collaboration in the Mega-Science Project "Complex of Superconducting Rings for Heavy Ion Colliding Beams" – the NICA Complex and to express their interest in preparing a corresponding multilateral Agreement and in taking steps towards its approval by their countries

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NICA Com...
research, a...
scientists...

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5. The Parties have agr...
Collaboration in the Me...

Signed:

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B. Grynyov	for the State Agency for Science, Innovation and Informatization of Ukraine
V. Matveev	for the Joint Institute for Nuclear Research

Representatives of 13 countries

The meeting with EU experts in Brussels on 19-th June 2013

*"The fact that **NICA/JINR** is a part of the European research infrastructure landscape has already been recognized by **ESFRI**.*
***The Expert Group** recommends that the **NICA project** be fully taken into account in the forthcoming discussions on the next update of the **ESFRI** Roadmap"*

*In **2015** the **NICA project*** is presented ***by Bulgaria (***supported ***by Czech*** and ***Poland)*** *to be include to the next update of the **ESFRI** Roadmap*

Concluding remarks

- NICA complex has ***a potential for competitive research*** *in the field of* ***dense baryonic matter***
- a construction of the ***accelerator complex and its elements*** is ***in progress***
- both detectors **BM@N** & **MPD** are in preparation for experiments *at the* ***extracted Nuclotron beam*** & ***at the NICA collider***
- the R&D phase of MPD is ***practically completed***
- the BM@N **project** ***is progressing since 2012***
- The SPD project ***is under prepration***

Thank you!