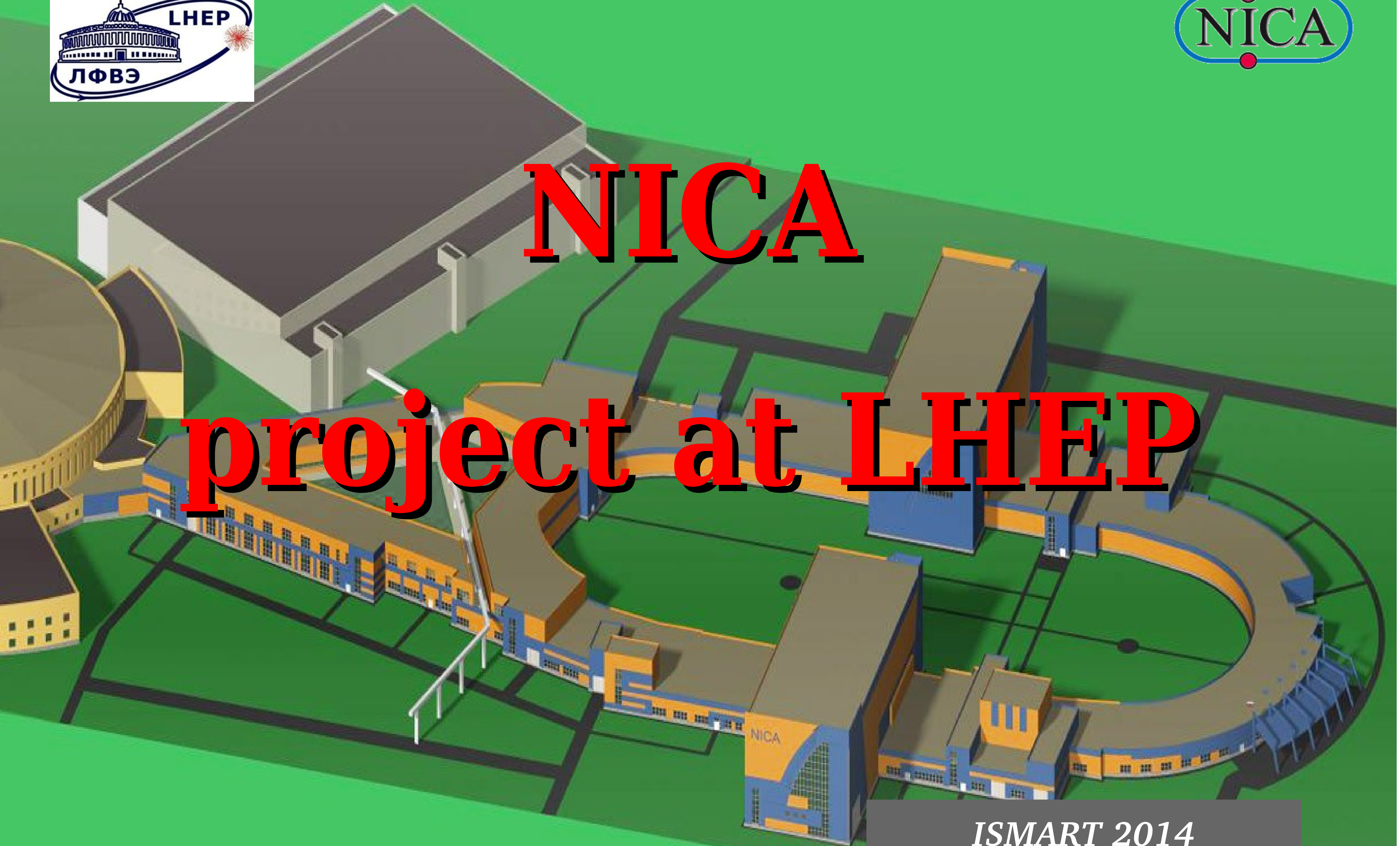
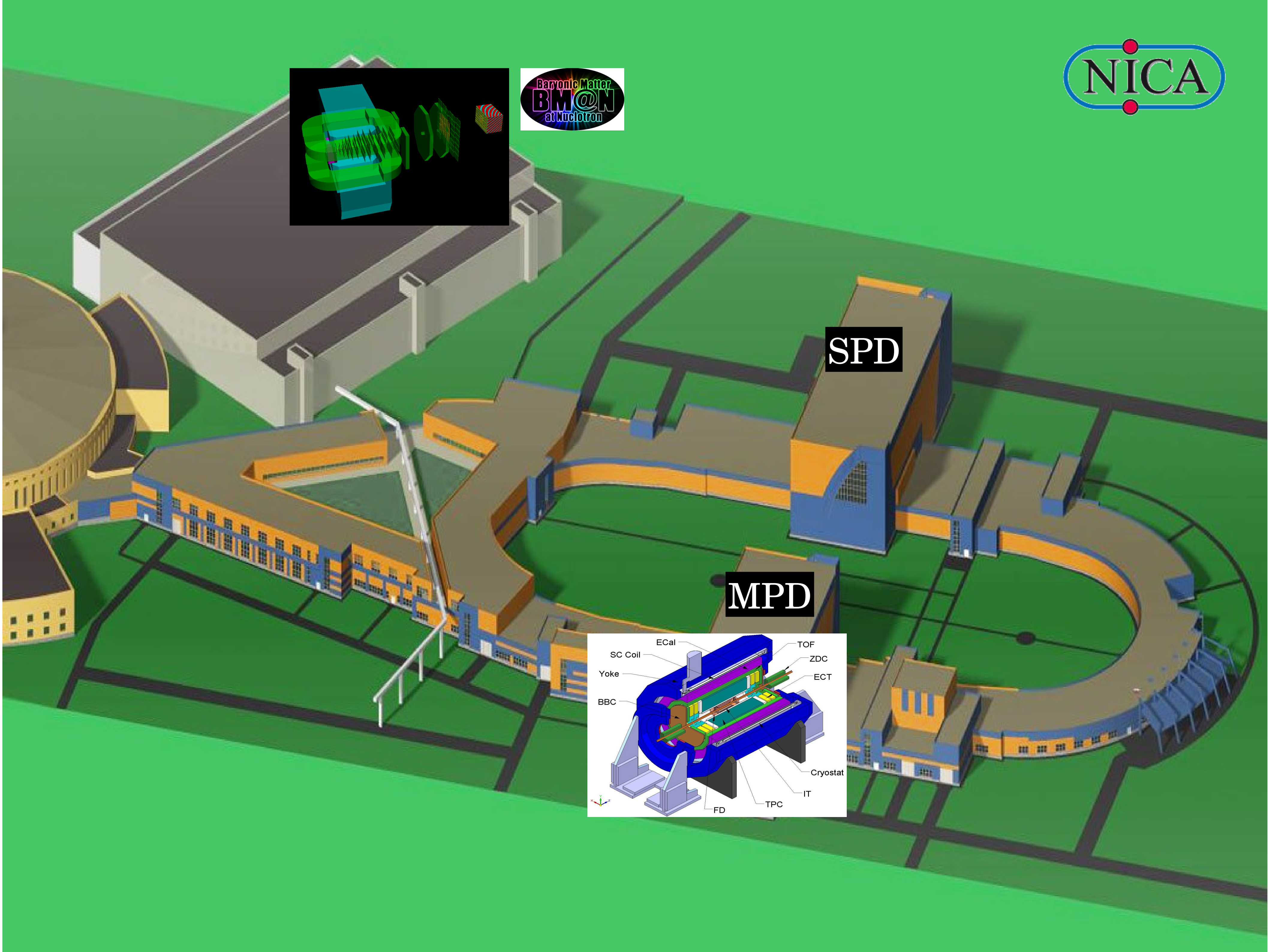
NICA project at LHEP

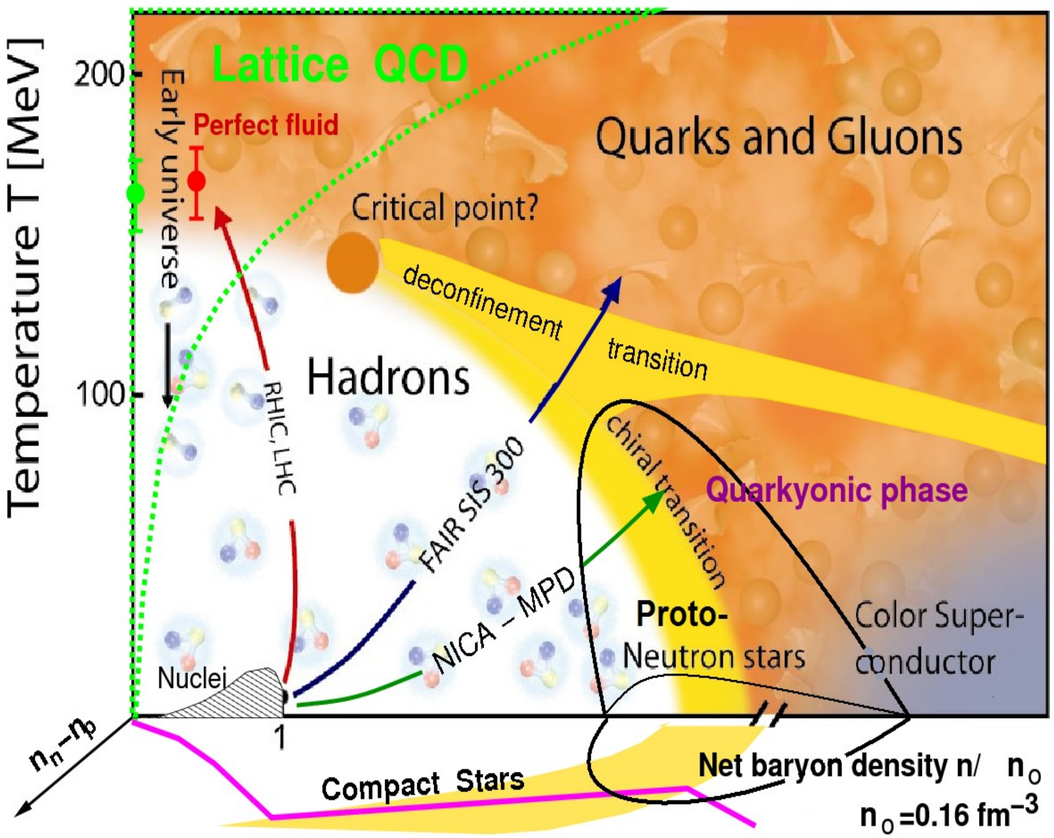


Rogachevsky Oleg
for MPD/BM@N team

ISMART 2014
Minsk
13.10.2014


NICA
Baryonic Matter
BM@N
at Nuclotron
SPD
MPD
ECal
SC Coil
Yoke
BBC
TOF
ZDC
ECT
Cryostat
IT
TPC
FD

QCD phase diagram



The collision of two heavy nuclei which approach and smash against each other with almost the speed of light. According to Einstein's theory of special relativity they look like thin pancakes. This "Little Bang" creates in the laboratory the primordial state of matter, called Quark-Gluon Plasma (QGP). The QGP expands like a fireball, cools and finally turns into ordinary matter.

. The thousands of particles produced will be recorded by detectors. The tracks that those particles leave in the detectors will be analysed by modern powerful software tools.

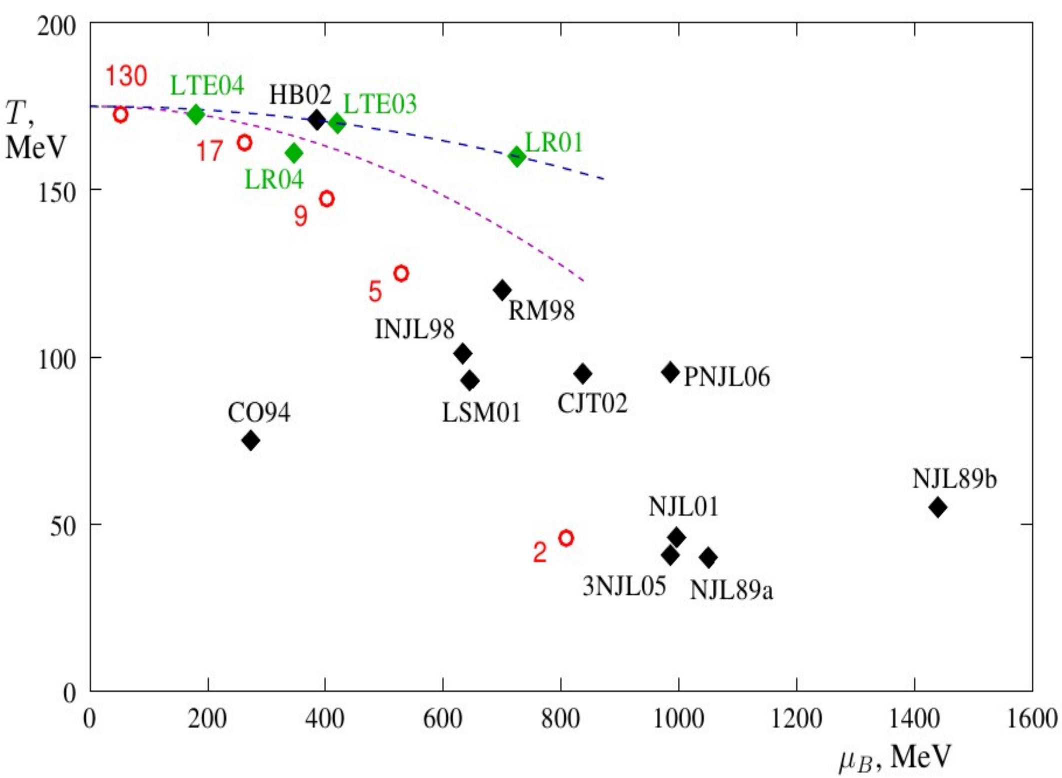
The challenge is to infer the properties of the QGP state of matter by studying the different particles that arrive in the detectors.

QCD Critical point quest

M. Stephanov

XXIV International Symposium on Lattice Field Theory
July 23-28 2006
Tucson Arizona, US

Comparison of predictions for the location of the QCD critical point on the phase diagram. Black points are model predictions: NJLa89, NJLb89 – [12], CO94 – [13, 14], INJL98 – [15], RM98 – [16], LSM01, NJL01 – [17], HB02 – [18], CJT02 – [19], 3NJL05 – [20], PNJL06 – [21]. Green points are lattice predictions: LR01, LR04 – [22], LTE03 – [23], LTE04 – [24]. The two dashed lines are parabolas with slopes corresponding to lattice predictions of the slope dT /d μB 2 of the transition line at μB = 0 [23, 25]. The red circles are locations of the freezeout points for heavy ion collisions at corresponding center of mass energies per nucleon (indicated by labels in GeV)



[13] A. Barducci, R. Casalbuoni, S. De Curtis, R. Gatto and G. Pettini, Phys. Lett. B 231 (1989) 463; Phys. Rev. D 41 (1990) 1610.
[14] A. Barducci, R. Casalbuoni, G. Pettini and R. Gatto, Phys. Rev. D 49 (1994) 426.
[15] J. Berges and K. Rajagopal, Nucl. Phys. B 538 (1999) 215 [arXiv:hep-ph/9804233].
[16] M. A. Halasz, A. D. Jackson, R. E. Shrock, M. A. Stephanov and J. J. M. Verbaarschot, Phys. Rev. D 58 (1998) 096007 [arXiv:hep-ph/9804290].
[17] O. Scavenius, A. Mocsy, I. N. Mishustin and D. H. Rischke, Phys. Rev. C 64 (2001), 045202 [arXiv:nucl-th/0007030].
[18] N. G. Antoniou and A. S. Kapoyannis, Phys. Lett. B 563 (2003) 165 [arXiv:hep-ph/0211392].
[19] Y. Hatta and T. Ikeda, Phys. Rev. D 67 (2003) 014028 [arXiv:hep-ph/0210284].
[20] A. Barducci, R. Casalbuoni, G. Pettini and L. Ravagli, Phys. Rev. D 72, 056002 (2005) [arXiv:hep-ph/0508117].
[21] S. Roessner, C. Ratti and W. Weise, arXiv:hep-ph/0609281.
[22] Z. Fodor and S. D. Katz, JHEP 0203 (2002) 014 [arXiv:hep-lat/0106002]; JHEP 0404, 050 (2004) [arXiv:hep-lat/0402006].
[23] S. Ejiri, C. R. Allton, S. J. Hands, O. Kaczmarek, F. Karsch, E. Laermann and C. Schmidt, Prog. Theor. Phys. Suppl. 153, 118 (2004) [arXiv:hep-lat/0312006].
[24] R. V. Gavai and S. Gupta, Phys. Rev. D 71, 114014 (2005) [arXiv:hep-lat/0412035].
[25] P. de Forcrand and O. Philipsen, arXiv:hep-ph/0301209; Nucl. Phys. B 673 (2003) 170 [arXiv:hep-lat/0307020]; Nucl. Phys. Proc. Suppl. 129, 521 (2004) [arXiv:hep-lat/0309109].

CERN 2000

January 31, 2000

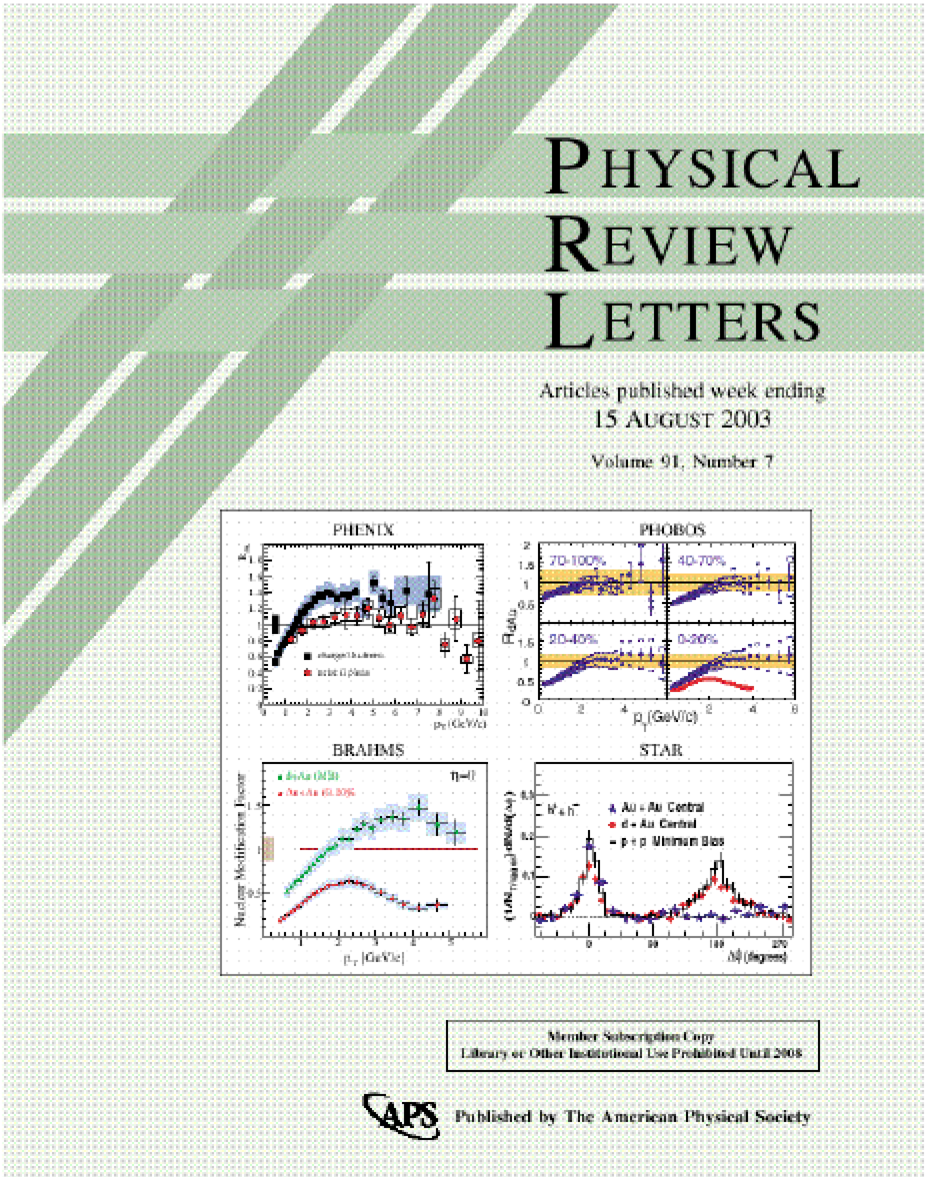
Evidence for a New State of Matter:
An Assessment of the Results from the CERN Lead Beam Programme

Ulrich Heinz and Maurice Jacob
Theoretical Physics Division, CERN, CH-1211 Geneva 23, Switzerland

A common assessment of the collected data leads us to conclude that we now have compelling evidence that a new state of matter has indeed been created, at energy densities which had never been reached over appreciable volumes in laboratory experiments before and which exceed by more than a factor 20 that of normal nuclear matter. The new state of matter found in heavy ion collisions at the SPS features many of the characteristics of the theoretically predicted quark-gluon plasma.

arXiv:nucl-th/0002042v1 16 Feb 2000

The Quark-Gluon-Plasma is Found at RHIC



3rd RHIC Milestone

RHIC White papers

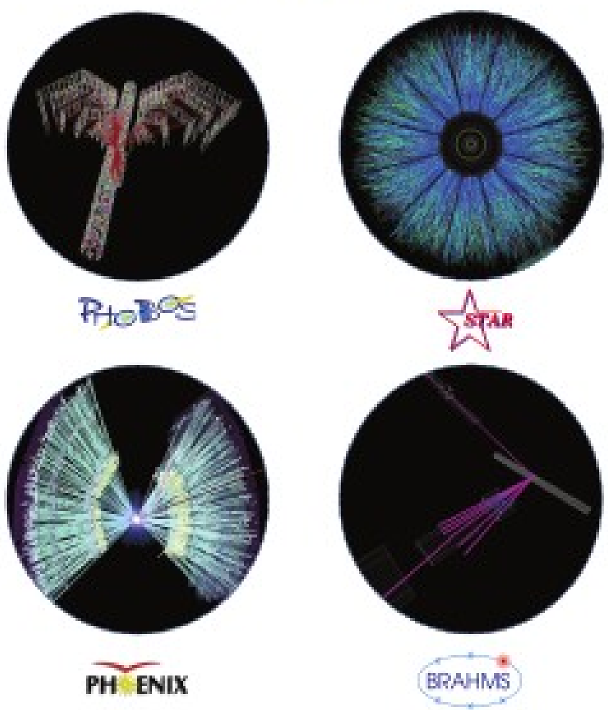
BNL -73847-2005
Formal Report

Hunting the Quark Gluon Plasma

Results from the first 3 years at RHIC

Assessments by the experimental collaborations

April 18, 2005



Relativistic Heavy Ion Collider (RHIC) • Brookhaven National Laboratory, Upton, NY 11974-5000

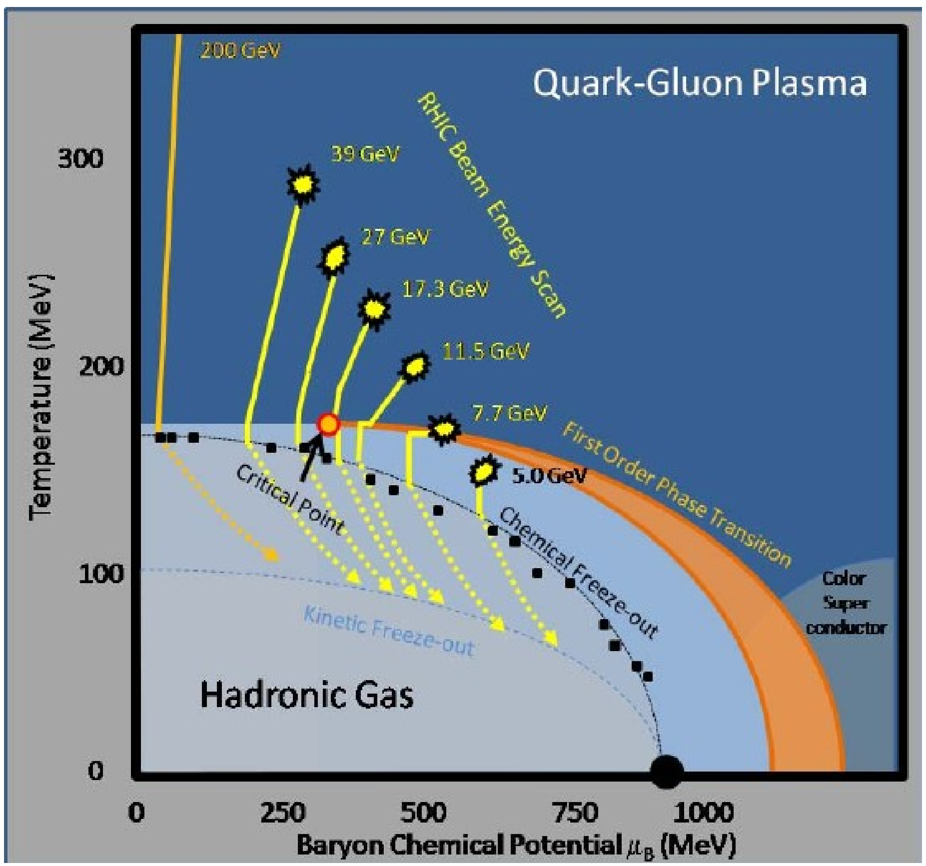
Office of Science U.S. Department of Energy

Brookhaven National Laboratory

Nuclear Physics A 757 (2005)

CONTENTS

STAR BES program



Experimental Study of the QCD Phase Diagram and Search for the Critical Point: Selected Arguments for the Run-10 Beam Energy Scan at RHIC

The STAR Collaboration (B. I. Abelev et al.)

Introduction & Summary

We present an overview of the main ideas that have emerged from discussions within STAR for the Beam Energy Scan (BES). The formulation of this concise and abridged document is facilitated by the existence of a much longer and more comprehensive companion document entitled *Experimental Exploration of the QCD Phase Diagram: Search for the Critical Point* [1]. The compelling arguments and motivations for the physics of our proposed Beam Energy Scan program, which have a particular role in guiding the run plan (see p. 13) as set out in our discussion of Tables 1 and 2, are (not in order of priority):

A. A search for turn-off of new phenomena already established at higher RHIC energies; QGP signatures are the most obvious example, but we define this category more broadly. If our current understanding of RHIC physics and these signatures is correct, a turn-off must be observed in several signatures, and such corroboration is an essential part of the "unfinished business" of QGP discovery [2]. The particular observables that STAR has identified as the essential drivers of our run plan are:

(A-1) Constituent-quark-number scaling of v_2, indicating partonic degrees of freedom;

(A-2) Hadron suppression in central collisions as characterized by the ratio R_{CP};

(A-3) Untriggered pair correlations in the space of pair separation in azimuth and pseudorapidity, which elucidate the ridge phenomenon;

(A-4) Local parity violation in strong interactions, an emerging and important RHIC discovery in its own right, is generally believed to require deconfinement, and thus also is expected to turn-off at lower energies.

B. A search for signatures of a phase transition and a critical point. The particular observables that we have identified as the essential drivers of our run plan are:

(B-1) Elliptic & directed flow for charged particles and for identified protons and pions, which have been identified by many theorists as highly promising indicators of a "softest point" in the nuclear equation of state;

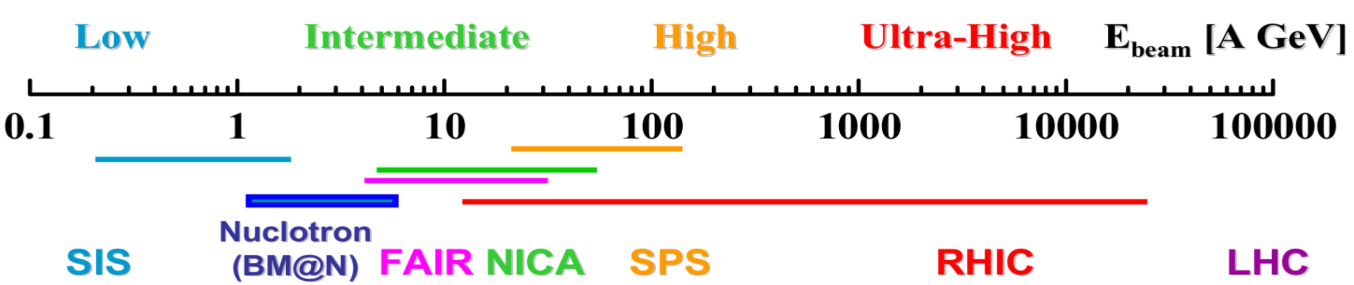
(B-2) Azimuthally-sensitive femtoscopy, which adds to the standard HBT observables by allowing the tilt angle of the ellipsoid-like particle source in coordinate space to be measured; these measurements hold promise for identifying a softest point, and complements the momentum-space information revealed by flow measurements, and

(B-3) Fluctuation measures, indicated by large jumps in the baryon, charge and strangeness susceptibilities, as a function of system temperature – the most obvious expected manifestation of critical phenomena.

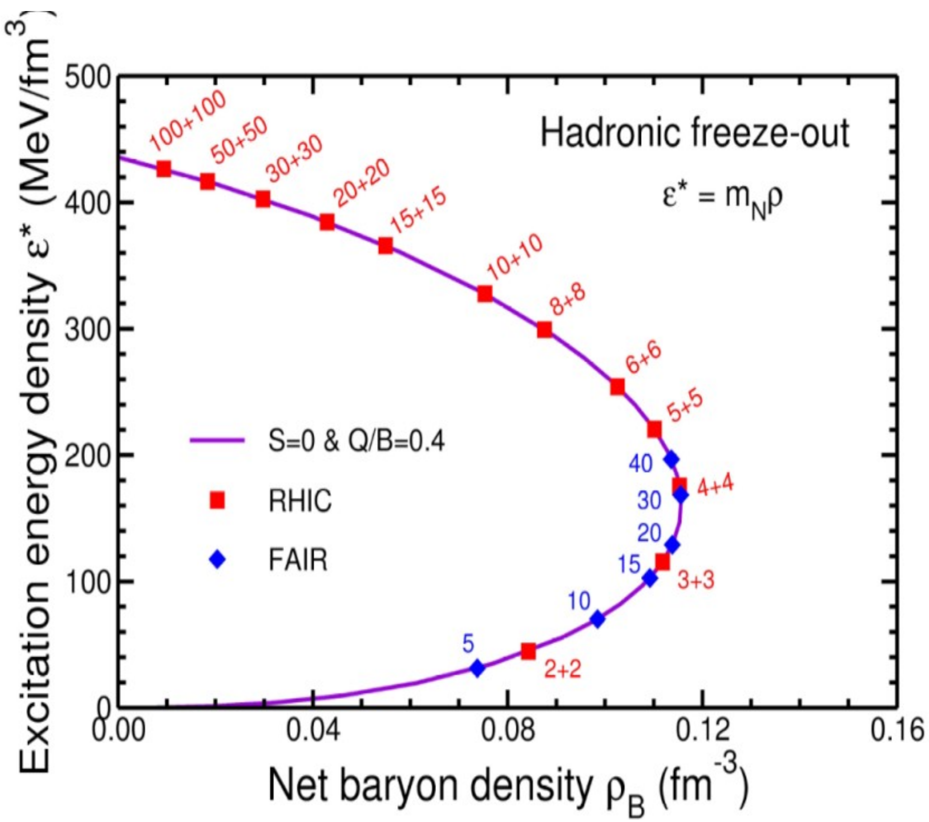
Current & future experiments

Facility	SPS	RHIC BES	Nuclotron -M	NICA	SIS/100 (300)	LHC
Laboratory	CERN Geneva	BNL Brookhaven	JINR Dubna	JINR Dubna	FAIR GSI Darmstadt	CERN Geneva
Experiment	NA61 SHINE	STAR PHENIX	BM@N	MPD	HADES CBM	ALICE ATLAS CMS
Start of data taking	2011	2010	2015	2019	2017/18	2009
CMC energy GeV/(N+N)	5.1 – 17.3	7.7 – 200	< 3.5	4 - 11	2.3 – 4.5	up to 5500
Physics	CP & OD	CP & OD	HDM	OD & HDM	OD & CP	PDM

CP — critical point
OD — onset of deconfinement, mixed phase, 1st order phase transition
HDM — hadrons in dense matter
PDM — properties of deconfined matter

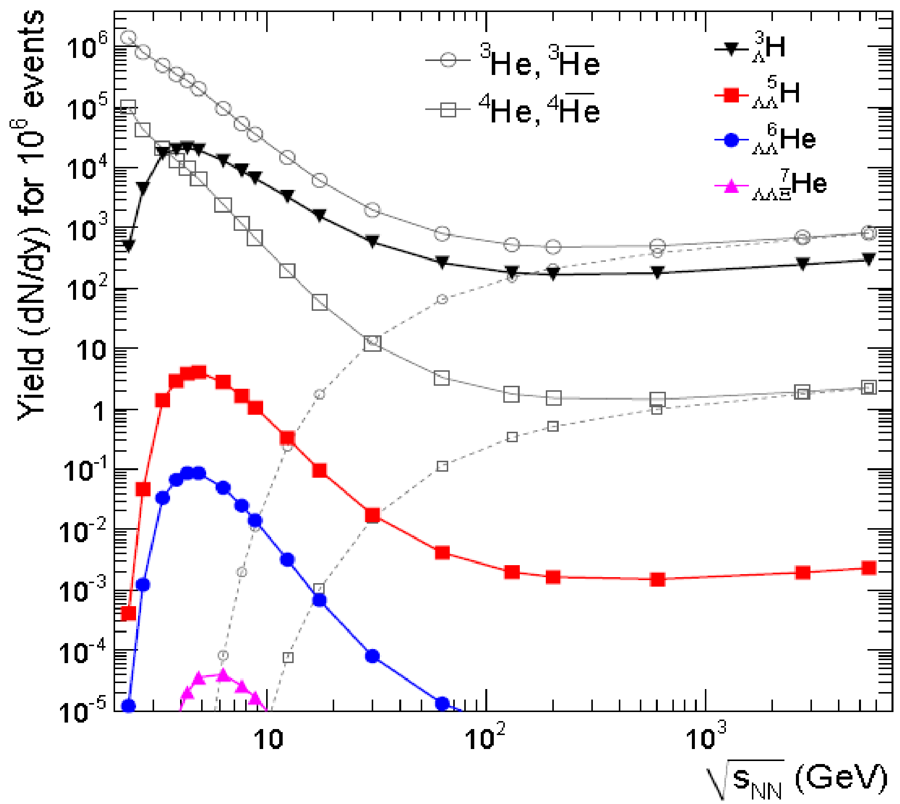


Barion density & hypernuclei production

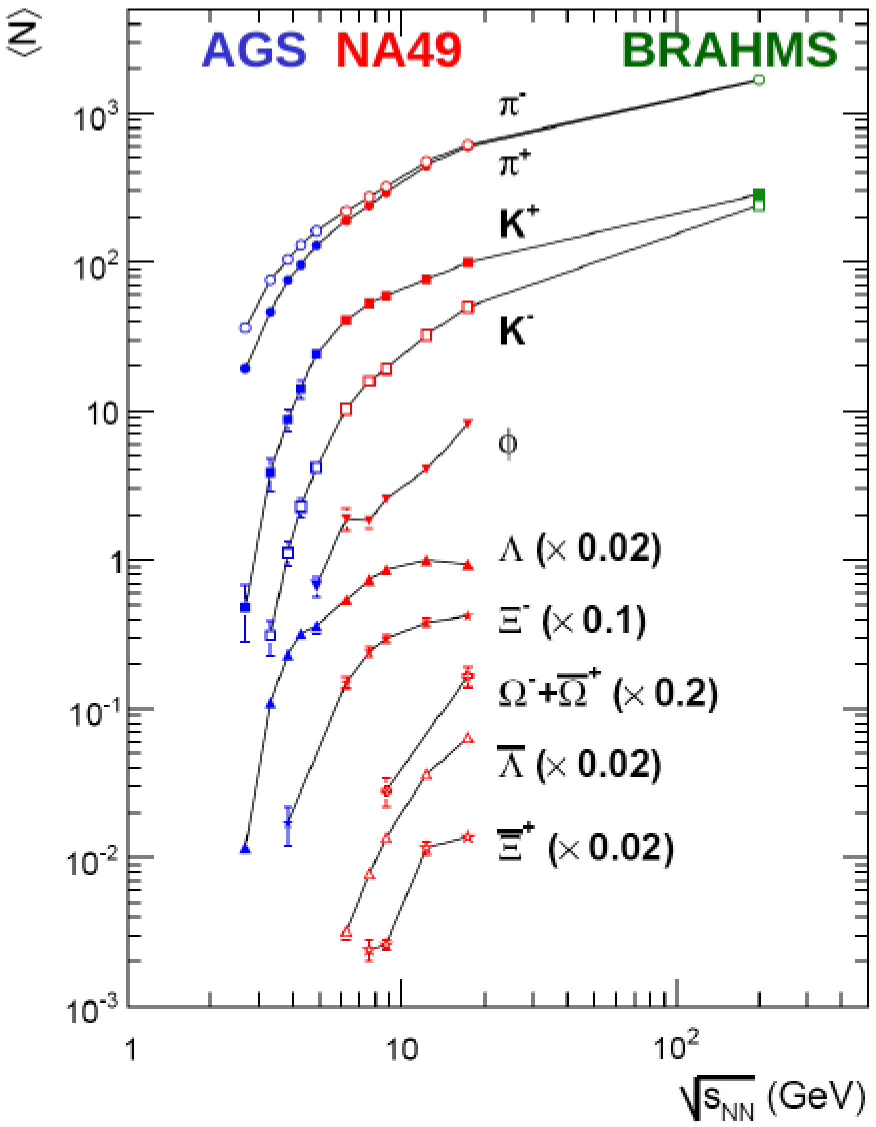


A.Andronic, P.Braun-Munzinger, J.Stachel, H.Stocker

Hypernuclei production enhanced at high baryon densities (NICA)



Particles yield



NICA physics

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

Draft v 10.01
January 24, 2014

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

Contents

Observables

I stage: ***: mid rapidity region*** *(good performance)*

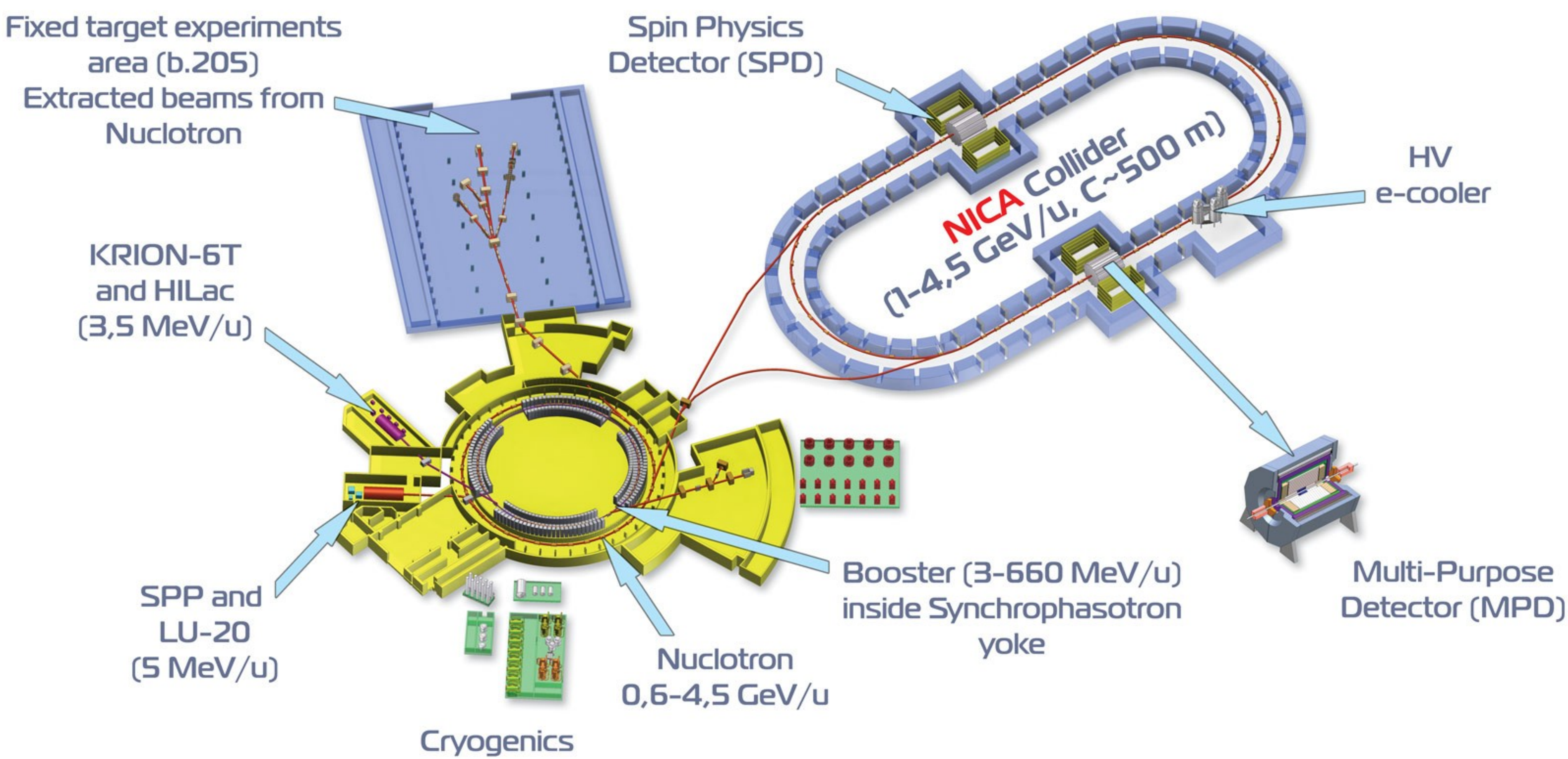
- ***Particle yields and spectra (π,K,p,clusters,Λ, Ξ ,Ω)***
- ***Event-by-event fluctuations***
- ***Femtoscopy involving π, K, p, Λ***
- ***Collective flow for identified hadron species***
- ***Electromagnetic probes (electrons, gammas)***

II stage: ***: extended rapidity + ITS***

- ***Total particle multiplicities***
- ***Asymmetries study*** *(better reaction plane determination)*
- ***Di-Lepton precise study*** *(Endcap Calorimeter)*
- ***Charm***
- ***Exotics (soft photons, hypernuclei)***

Measurements regarded as complementary to RHIC/BES and CERN/NA61,
However, higher statistics & (close to) the total yields for rare probes at MPD
No boost invariance at NICA – more accurate source parameters fit without rapidity cut
Rapidity dependence of the fireball thermal parameters will be possible at NICA

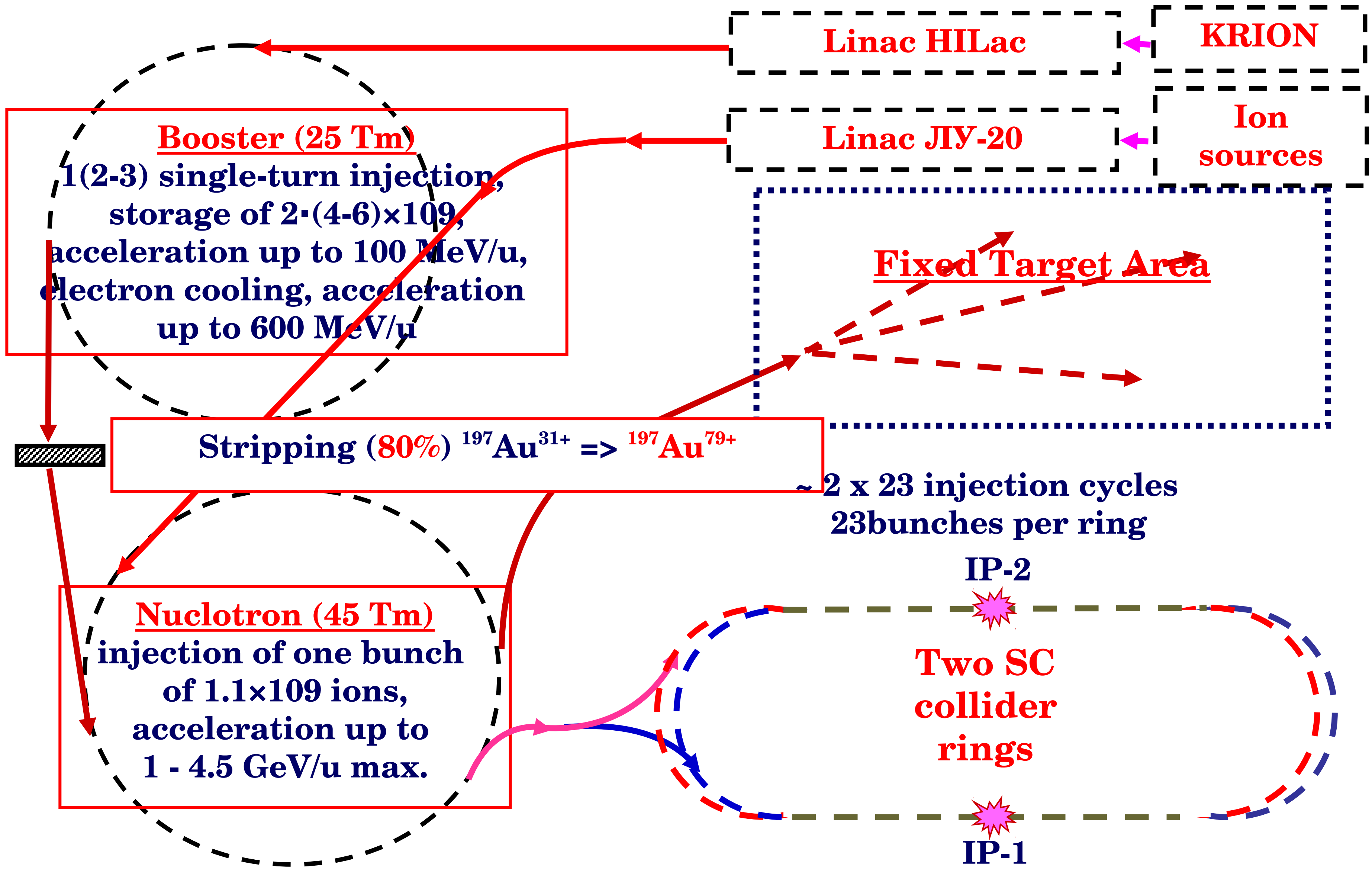
Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



NICA parameters:

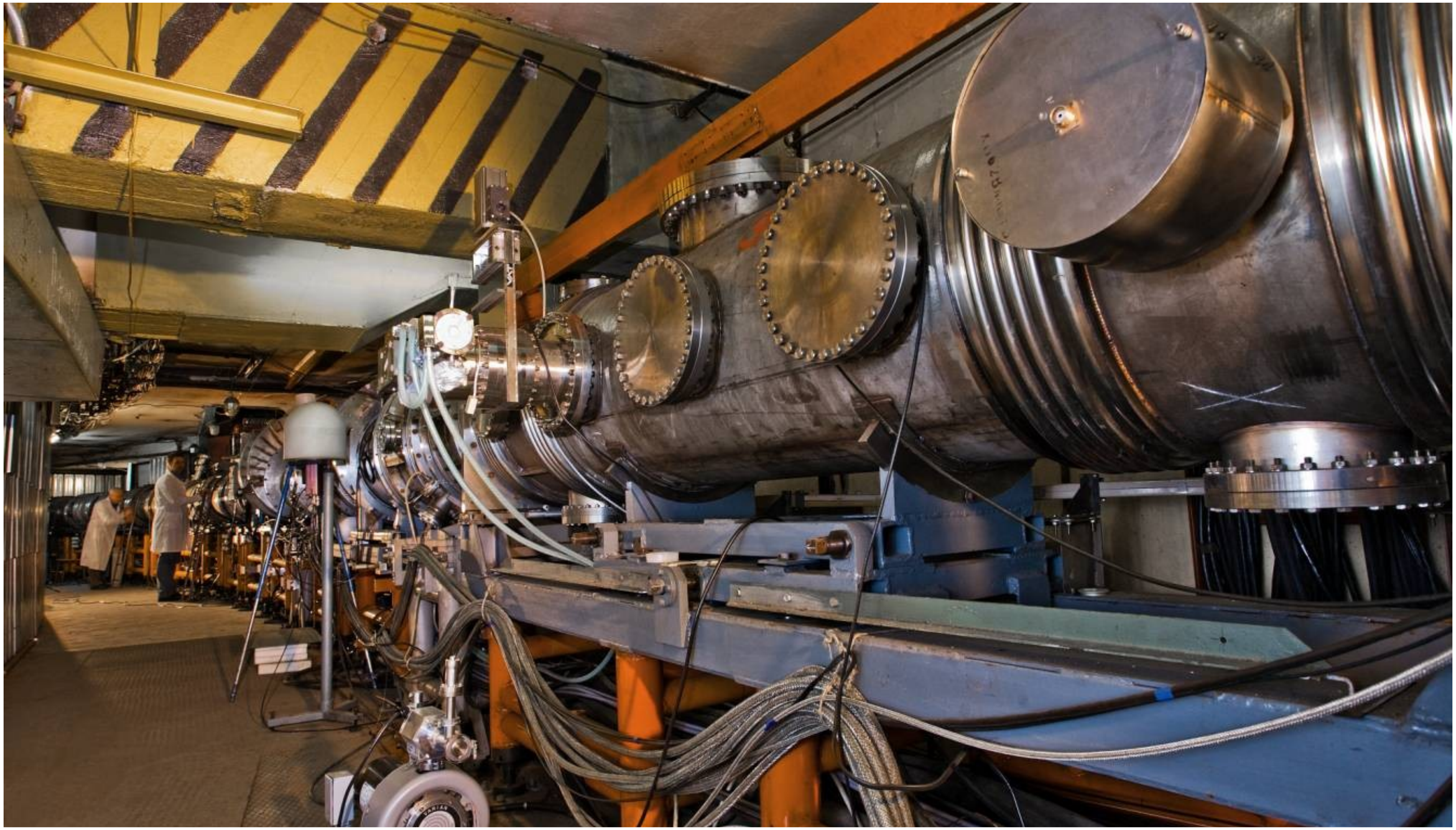
- Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV
- Beams: from p to Au
- Luminosity: L~10^{27} (Au), 10^{32} (p)
- Detectors: MPD (ions), SPD (spin physics)

Facility Operation Scenario



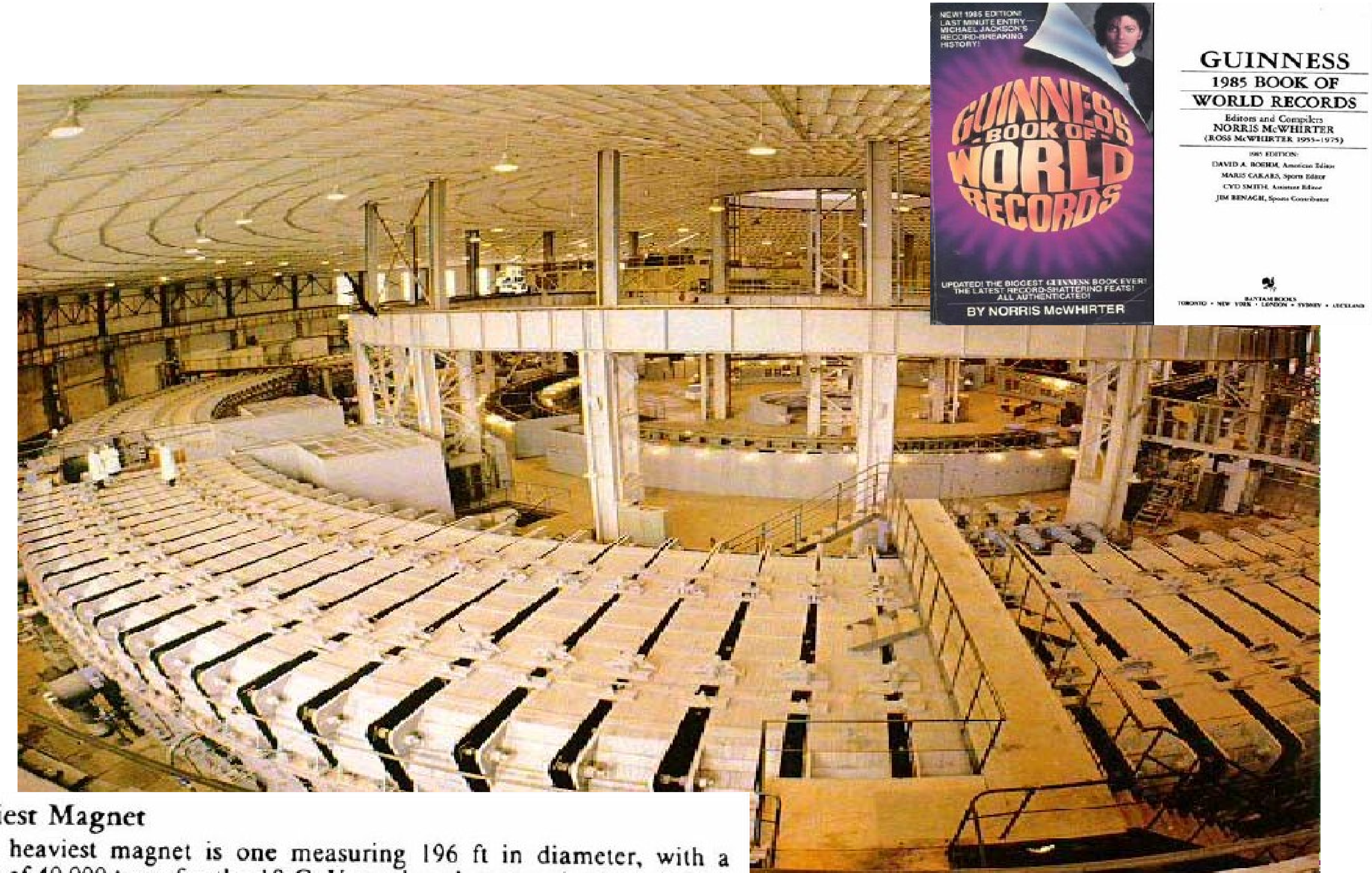
Nuclotron (1993)

– superconducting accelerator for ions and polarized particle
– physics of ultrarelativistic heavy ions, high energy spin physics



Nuclotron provides now performance of experiments on accelerated proton and ion beams (up to Xe^{42+}, $A=124$) with energies up to 6 AGeV (Z/A = 1/2)

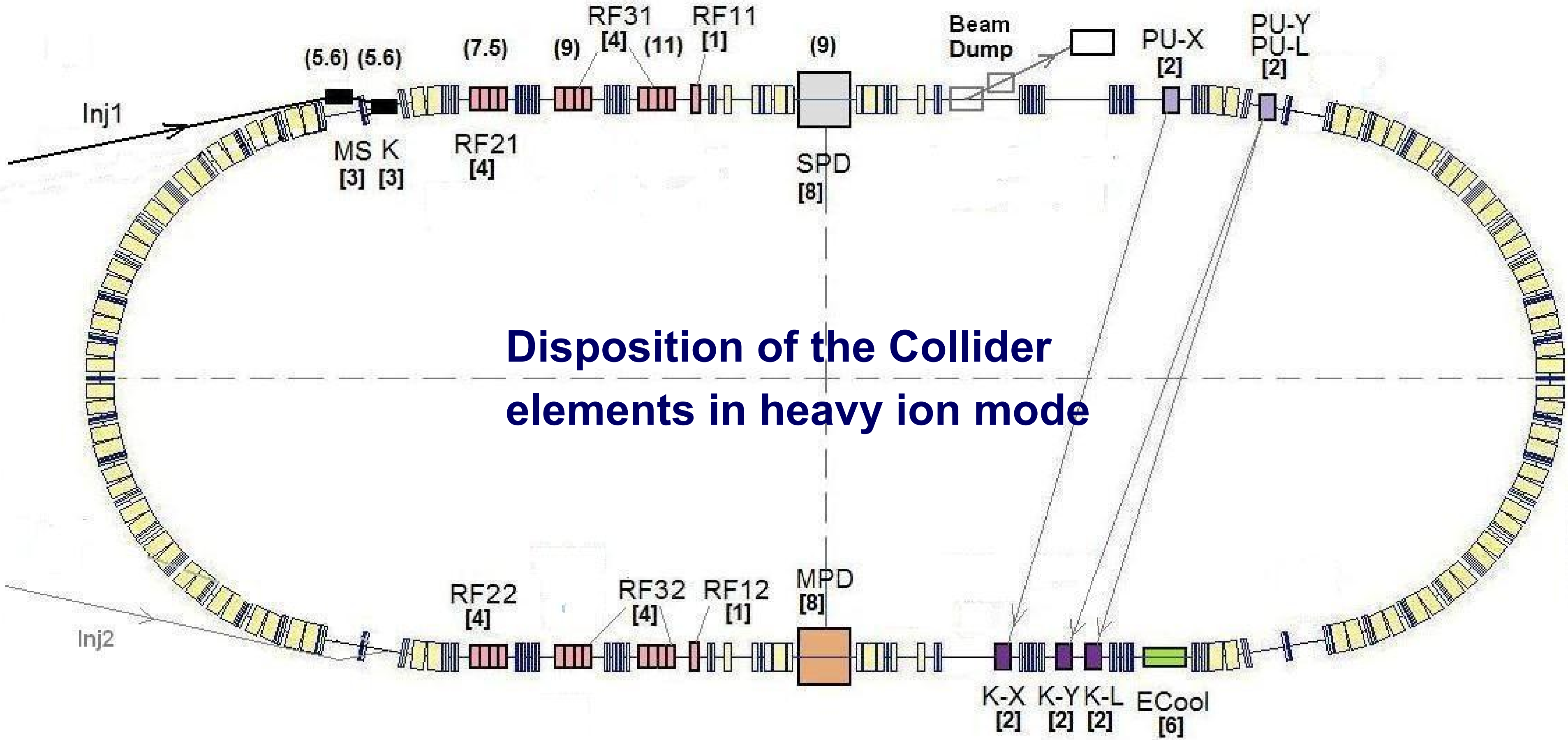
Booster (synchrophasotron (1957-2002))



Heaviest Magnet

The heaviest magnet is one measuring 196 ft in diameter, with a weight of 40,000 tons, for the 10 GeV synchrophasotron in the Joint Institute for Nuclear Research at Dubna, near Moscow.

Collider — heavy ion mode



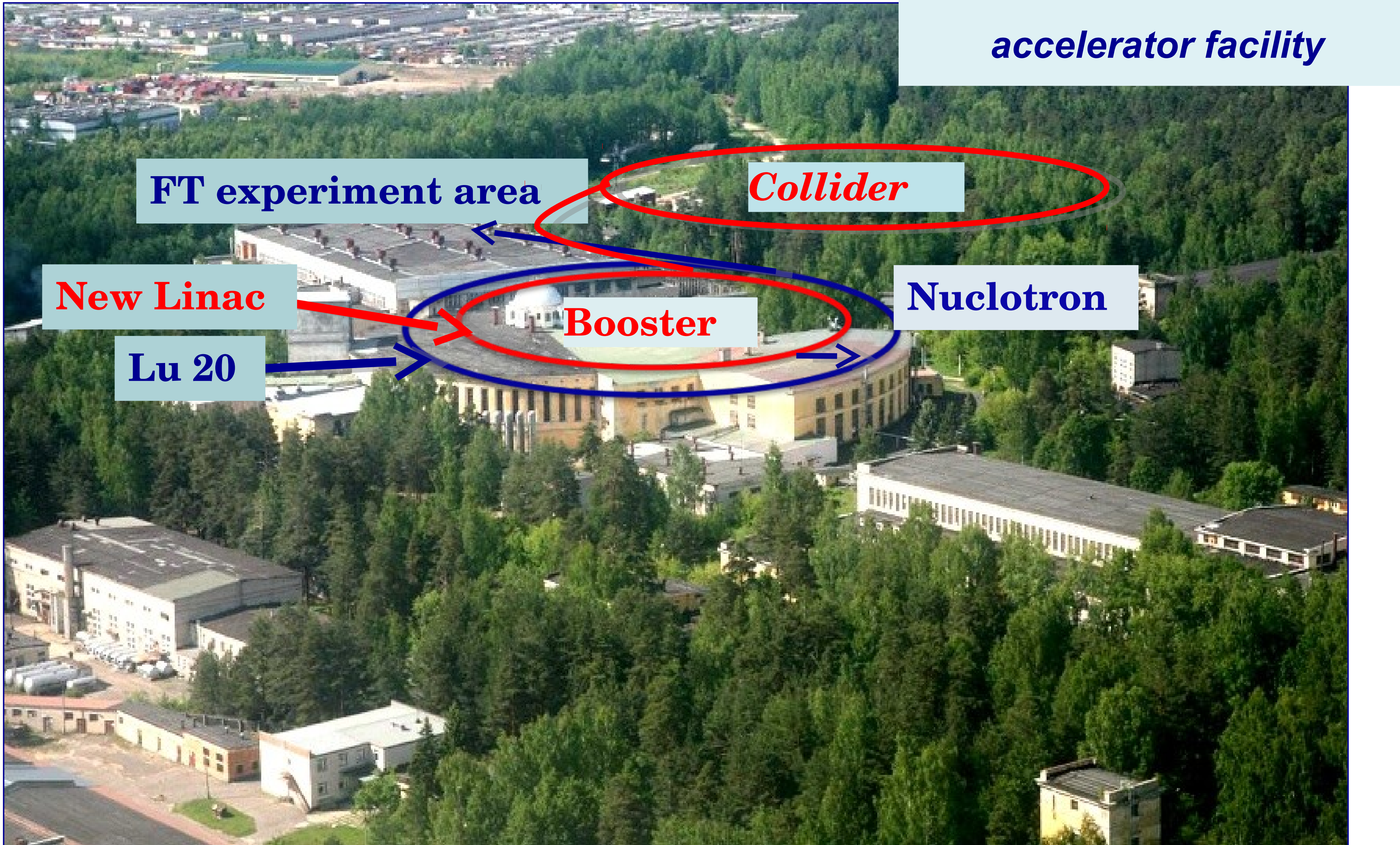
Au(+79) ion mode

[ ] - element length

( ) - distance between elements

Veksler & Baldin Laboratory of High Energy Physics, JINR

accelerator facility



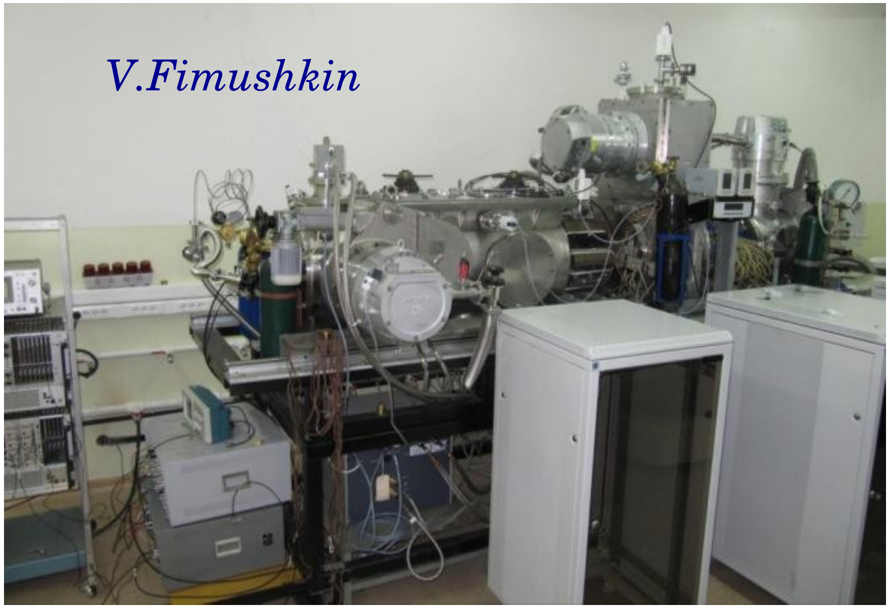
Unique SC heavy ion source

Heavy ion source: Krion-6T ESIS
5.4 Tesla magnetic field was reached

E.D.Donets, E.E.Donets

Test gold ion beams have been produced
$Au^{30+} \div Au32^{32+}$, $6{\cdot}10^8$ ppp, $T_{ioniz} = 20$ ms
Ion beams $Au^{51+} \div Au^{54+}$ are produced.
New goal : $Au^{65+} \div Au^{69+}$

V.Fimushkin



Source for polarized particles the goal:
10^{10} deuterons per pulse

The booster inside Synchrophasotron yoke

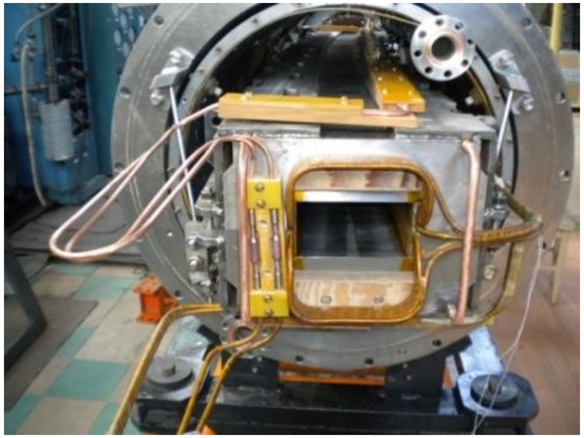
I.N.Meshkov

V.V.Putin

Nuclotron beams

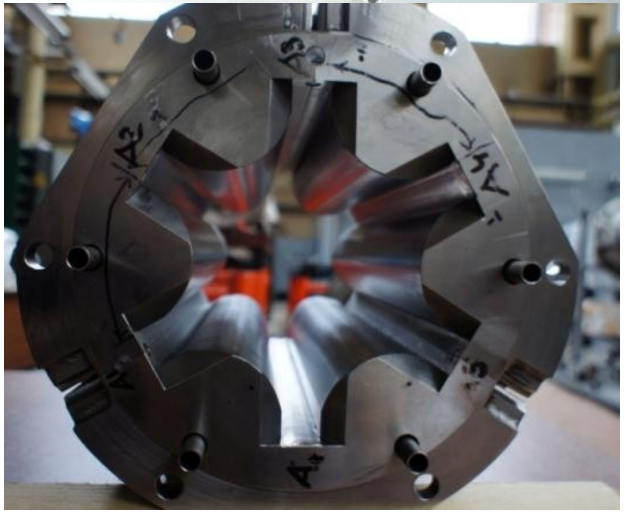
Parameter	Project (2017)		Achieved	
Magnetic field, T	2.0 (Bρ = 42.8 T·m)		2.0	
Field ramp, T/s	1.0		0.8	
Repetition period, s	5.0		8.0	
	Energy, GeV/u	Ions/ cycle	Energy, GeV/u	Ions/ cycle
Light ions ⇒ d	6.0	$5{\cdot}10^{10}$	5.6	$1{\cdot}10^{10}$
Heavy ions	*With KRION-6T & Booster*		*Without KRION-2*	
$^{40}Ar^{18+}$	4.9	$2{\cdot}10^{10}$	3.5	$5{\cdot}10^{6}$
$^{56}Fe^{26+}$	5.4	$1{\cdot}10^{10}$	2.5	$2{\cdot}10^{6}$
$^{124}Xe^{48/42+}$	4.0	$2{\cdot}10^{9}$	1.5	$1{\cdot}10^{3}$
$^{197}Au^{79+}$	4.5	$2{\cdot}10^{9}$	---	---
Polarized beams	*With SPI & Siberian snake*		*With POLARIS*	
p↑	11.9	$1{\cdot}10^{10}$	---	---
d↑	5.6	$1{\cdot}10^{10}$	2.0	$5{\cdot}10^{8}$

Magnets for the booster



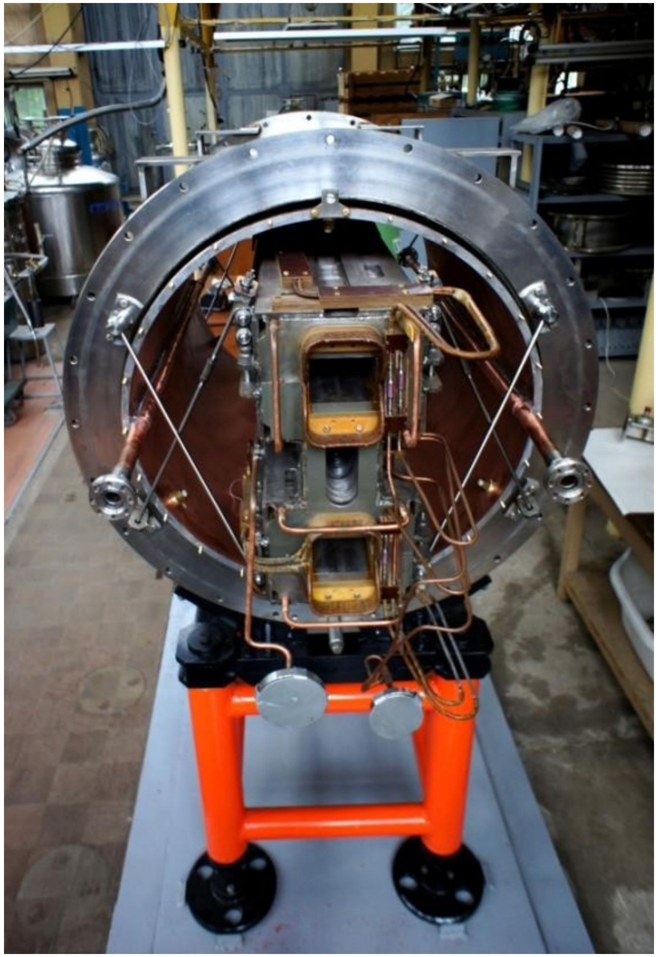
Booster dipole at cryo-test (9690A) and magnetic measurements

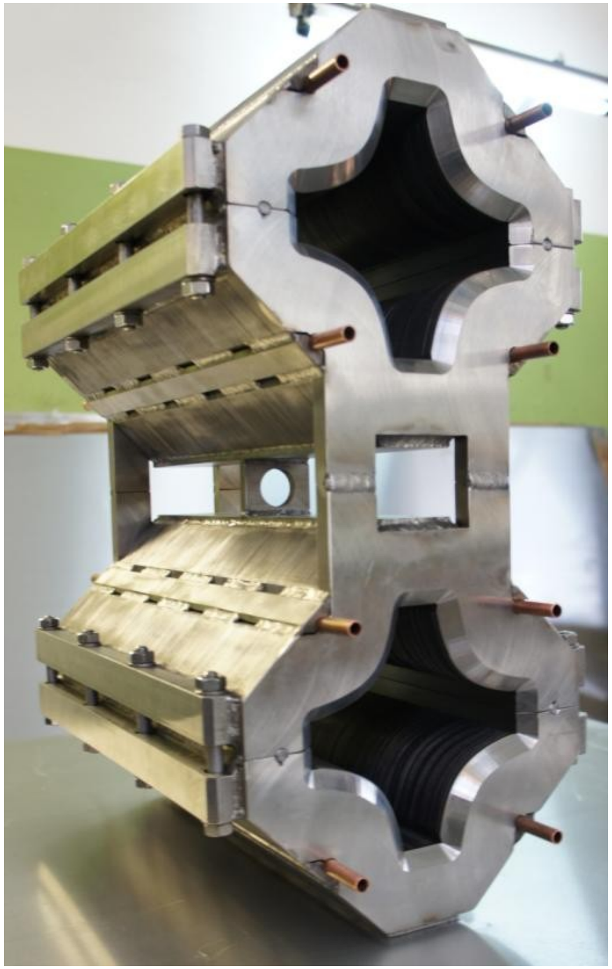
Quadrupole lense



Sextupole corrector prototype (for SIS100 and NICA booster) at assembly

Magnets for the collider

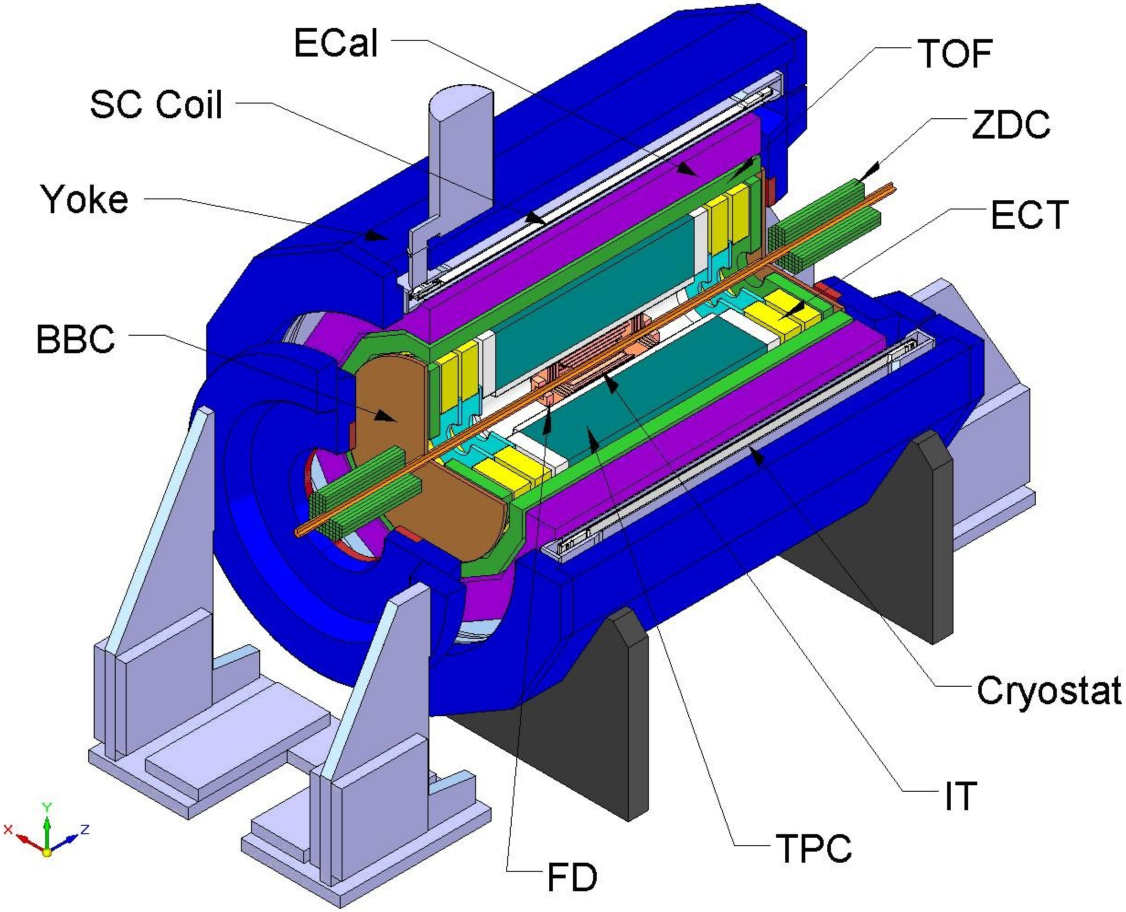


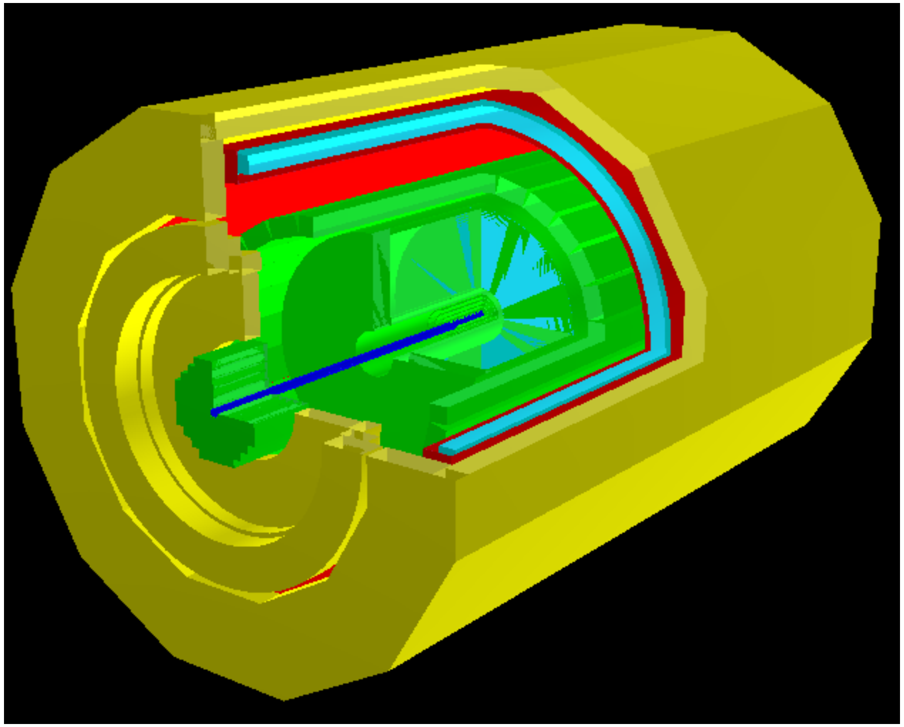


Cryo-tests (autumn 2012), magnetic measurements, new cryo-plant at b.217 (power convertors, cryogenics, etc.)serial production…

NICA experiments

Multi Purpose Detector





MPD Conseptual Design Report

http://nica.jinr.ru

Version 1.4

The MultiPurpose Detector – MPD

to study Heavy Ion Collisions at NICA
(Conceptual Design Report)

Project leaders: **A.N. Sissakian,** **A.S. Sorin, V.D. Kekelidze**

Editorial board:
V.Golovatyuk, V.Kekelidze, V.Kolesnikov, D.Madigozhin, Yu.Murin, V.Nikitin, O.Rogachevsky

Internal referee board:
N.Gorbunov, V.Kolesnikov, I.Meshkov, A.Olshevski, Yu.Potrebenikov, N.Topilin, I.Tyapkin, Yu.Zanevsky, A.Kurepin

The MPD Collaboration:[1]

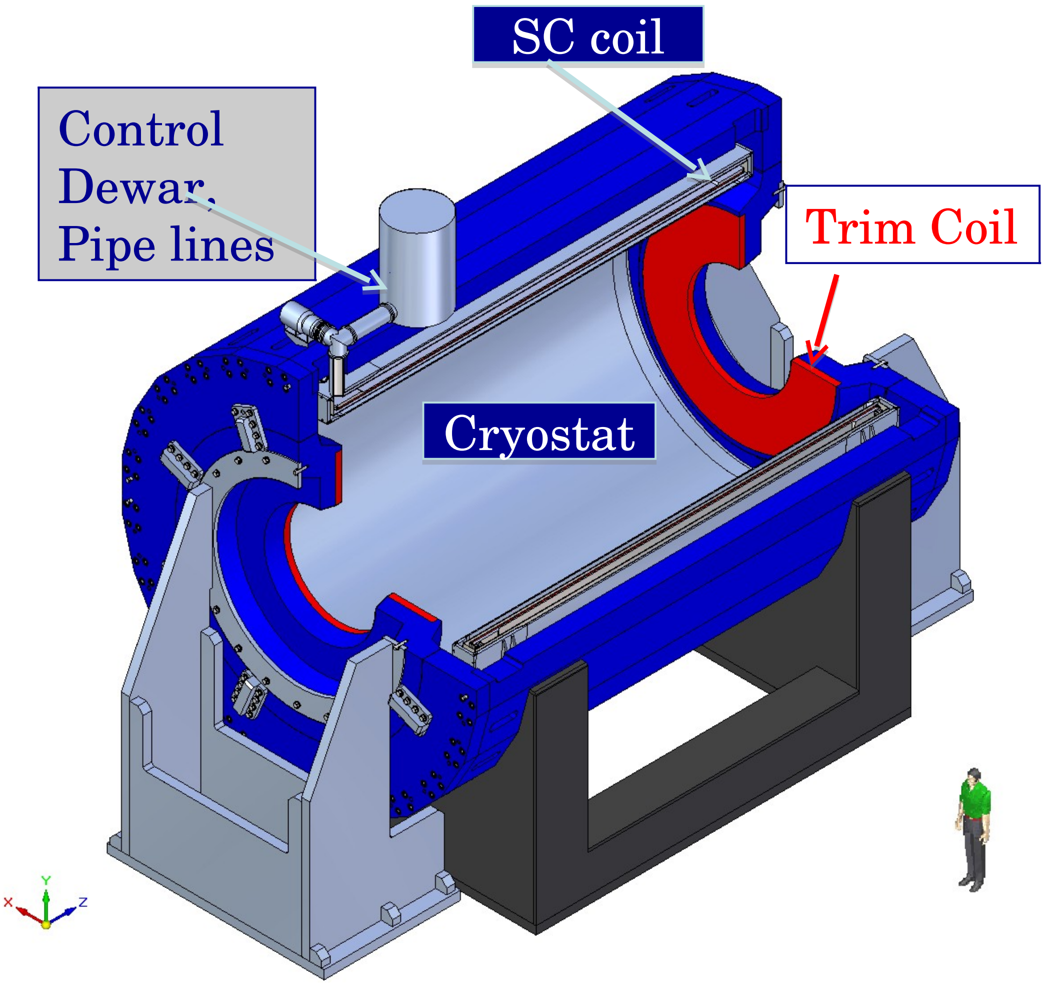
Kh.U.Abraamyan, S.V.Afanasiev, V.S.Alfeev, N.Anfimov, D.Arkhipkin, P.Zh.Aslanyan, V.A.Babkin, S.N.Bazylev, D.Blaschke, D.N.Bogoslovsky, I.V.Boguslavski, A.V.Butenko, V.V.Chalyshev, S.P.Chernenko, V.F.Chepurnov, Vl.F.Chepurnov, G.A.Cheremukhina, I.E.Chirikov-Zorin, D.E.Donetz, K.Davkov, V.Davkov, D.K.Dryablov, D.Drnojan, V.B.Dunin, L.G.Efimov, A.A.Efremov, E.Egorov, D.D.Emelyanov, O.V.Fateev, Yu.I.Fedotov, A.V.Friesen, O.P.Gavrischuk, K.V.Gertsenberger, V.M.Golovatyuk, I.N.Goncharov, N.V.Gorbunov, Yu.A.Gornushkin, N.Grigalashvili, A.V.Guskov, A.Yu.Isupov, V.N.Jejer, M.G.Kadykov, M.Kapishin, A.O.Kechechyan, V.D.Kekelidze, G.D.Kekelidze, H.G.Khodzhibagiyan, Yu.T.Kiryushin, V.I.Kolesnikov, A.D.Kovalenko, N.Krahotin, Z.V.Krumshtein, N.A.Kuz'min, R.Lednicky, A.G.Litvinenko, E.I.Litvinenko, Yu.Yu.Lobanov, S.P.Lobastov, V.M.Lysan, L.Lytkin, J.Lukstins, V.M.Lucenko, D.T.Madigozhin, A.I.Malakhov, I.N.Meshkov, V.V.Mialkovski, I.I.Migulina, N.A.Molokanova, S.A.Movchan, Yu.A.Murin, G.J.Musulmanbekov, D.Nikitin, V.A.Nikitin, A.G.Olshevski, V.F.Peresedov, D.V.Peshekhonov, V.D.Peshekhonov, I.A.Polenkevich, Yu.K.Potrebenikov, V.S.Pronskikh, A.M.Raportirenko, S.V.Razin, O.V.Rogachevsky, A.B.Sadovsky, Z.Sadygov, R.A.Salmin, A.A.Savenkov,W. Scheinast, S.V.Sergeev, B.G.Shchinov, A.V.Shabunov, A.O.Sidorin, I.V.Slepnev, V.M.Slepnev, I.P.Slepov, A.S.Sorin, O.V.Teryaev, V.V.Tichomirov, V.D.Toneev, N.D.Topilin, G.V.Trubnikov, I.A.Tyapkin, N.M.Vladimirova, A.S.Vodop'yanov, S.V.Volgin, A.S.Yukaev, V.I.Yurevich, Yu.V.Zanevsky, A.I.Zinchenko, V.N.Zrjuev, Yu.R.Zulkarneeva
Joint Institute for Nuclear Research, Dubna, RF

V.A.Matveev, M.B.Golubeva, F.F.Guber, A.P.Ivashkin, L.V.Kravchuck, A.B.Kurepin, T.L.Karavicheva, A.I.Maevskaya, A.I.Reshetin, E.A.Usenko
Institute for Nuclear Research, RAS, Troitsk, RF

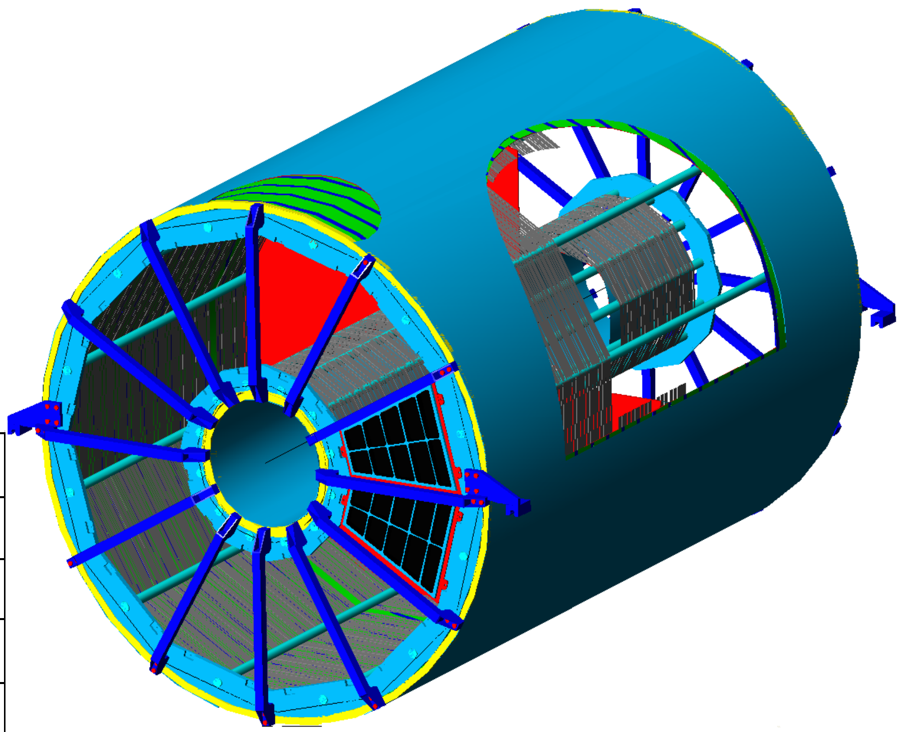
[1]The list of participating Institutes is currently a subject of update.

Contents

MPD solenoid

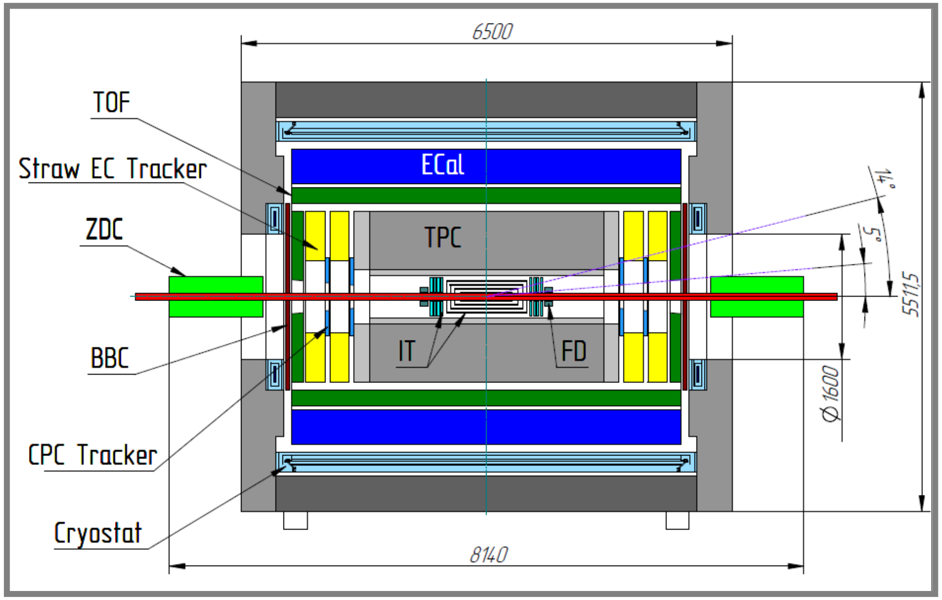


MPD TPC

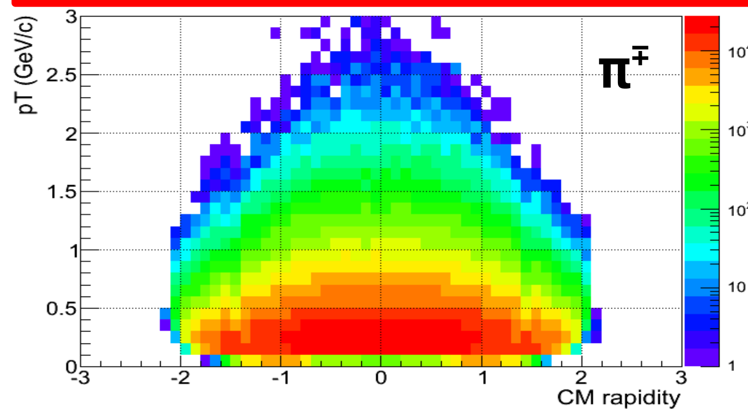


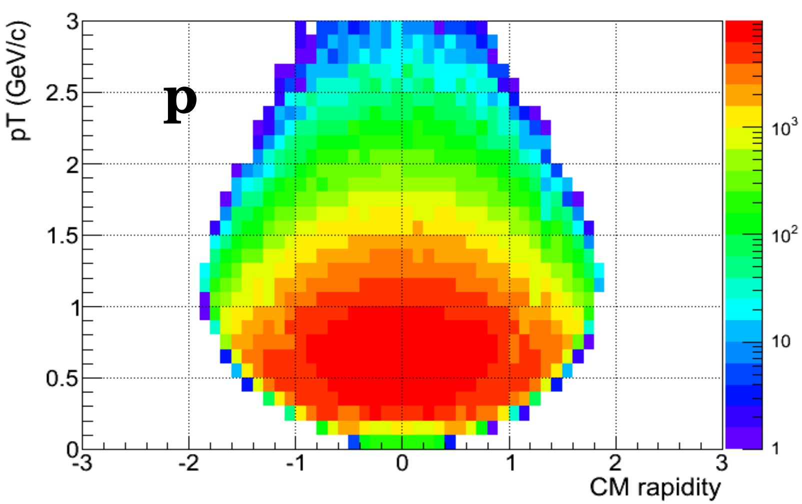
Length of the TPC	340 cm | Full length : 400cm
Outer radius of vessel	140cm
Inner radius of vessel	27 cm
Length of the drift volume	170cm (of each half)
Magnetic field strength	0,5 Tesla
Electric field strength	~140V/cm;
Drift gas	90% Ar+10% Methane, Atmospheric pres. + 2 mbar
Gas amplification factor	~ 10^4
Drift velocity	5,45 cm/μs;
Drift time	≤ 31μs
Temperature stability	< 0.1°C
Pad size	$4x12mm^2$ and $5x18mm^2$
Number of pads	~ 110 000
Pad raw numbers	53
Maximal event rate	≤ 5 kHz (Lum. 10^{27})
Signal to noise ratio	30:1

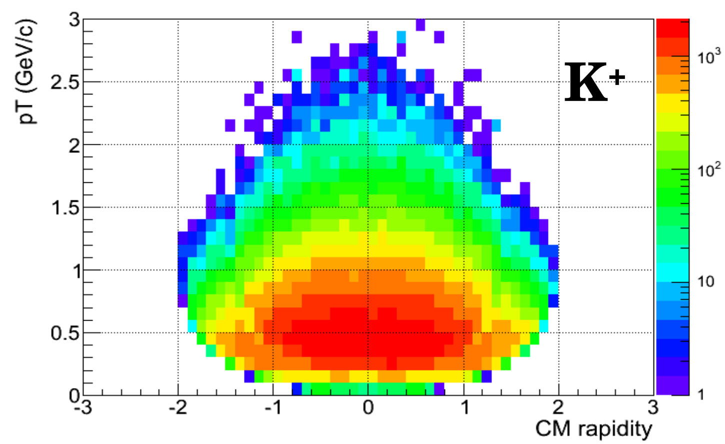
Phase space



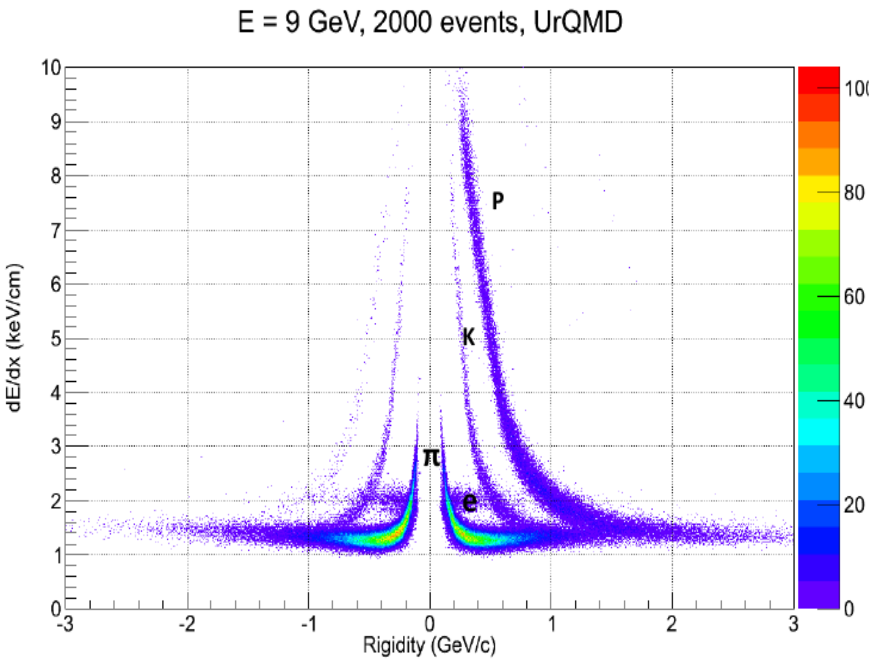
MPD registers on average :
~380 charged pions
~85 protons
~30 K+
in an event (central Au+Au at 8 GeV)







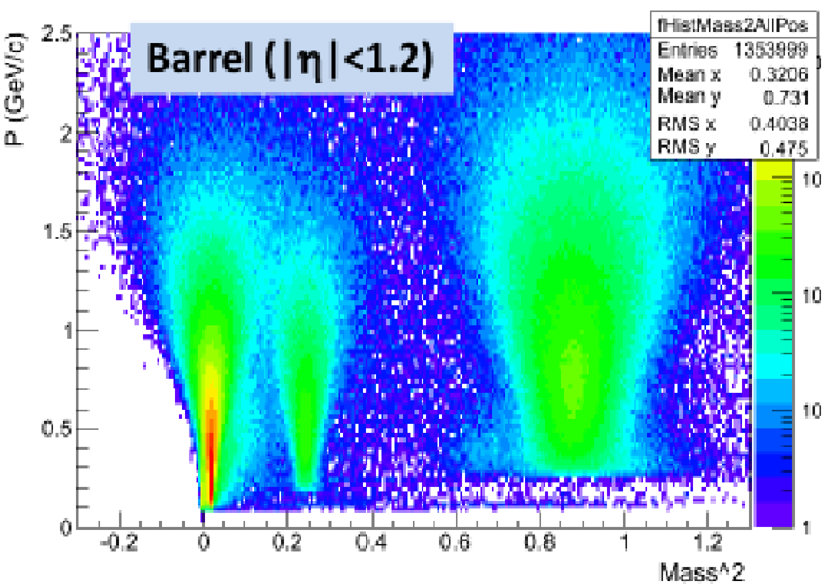
Charged Particle ID

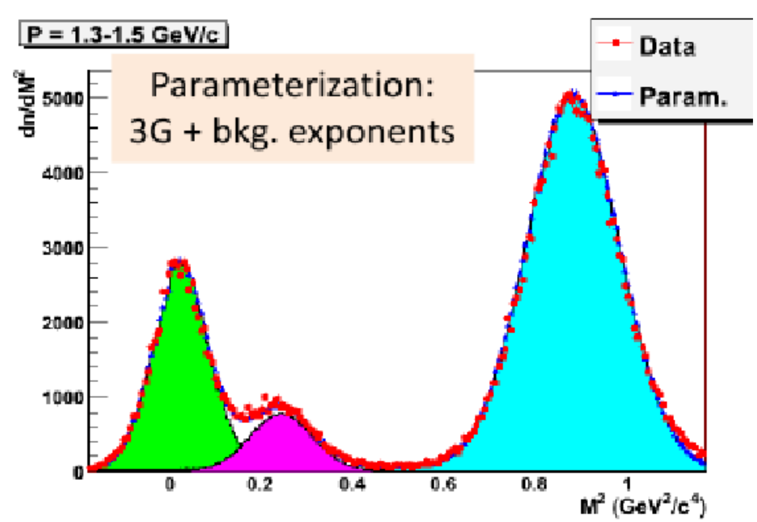


TPC
PID: Ionization loss (dE/dx) Separation:
e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

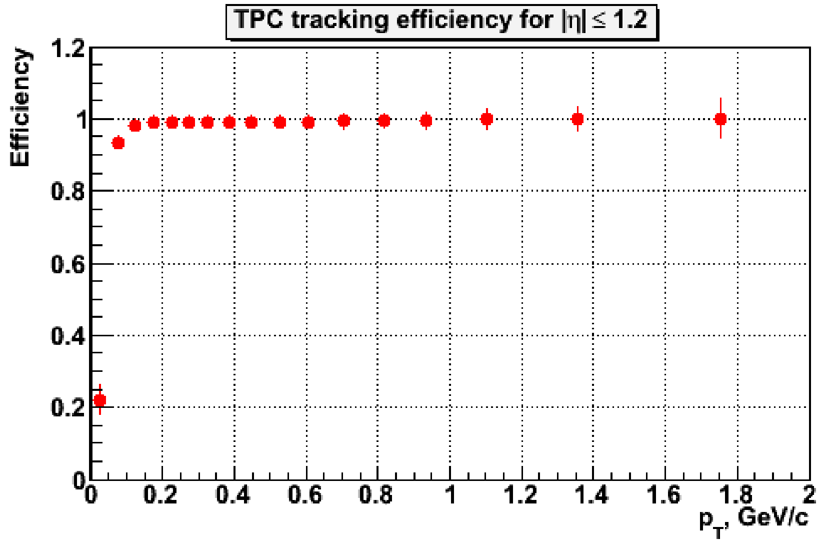
MPD PID (TOF):

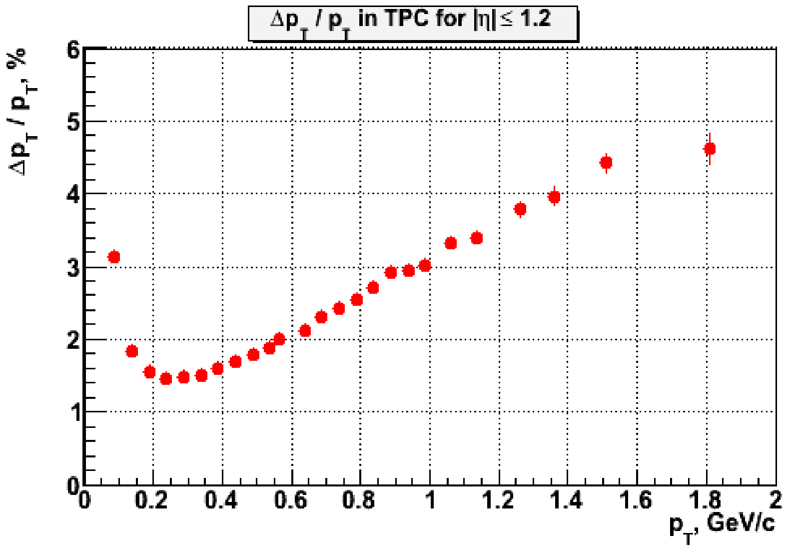
- π/K separation up to p=1.7 GeV/c, above 2 GeV/c - extrapolating the fitted 3G parameters
- Protons up to 3 GeV/c
- dE/dx provide extra PID capability for electrons and low momentum hadrons



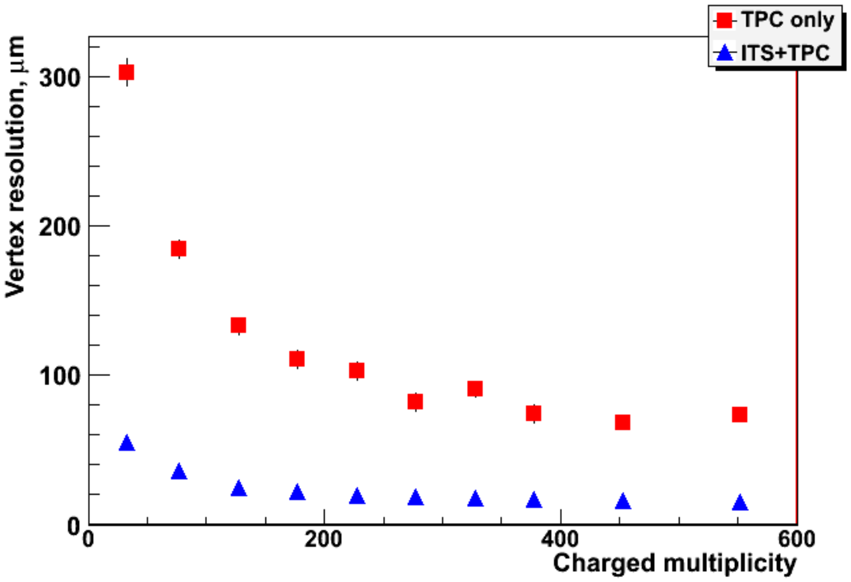


Tracking

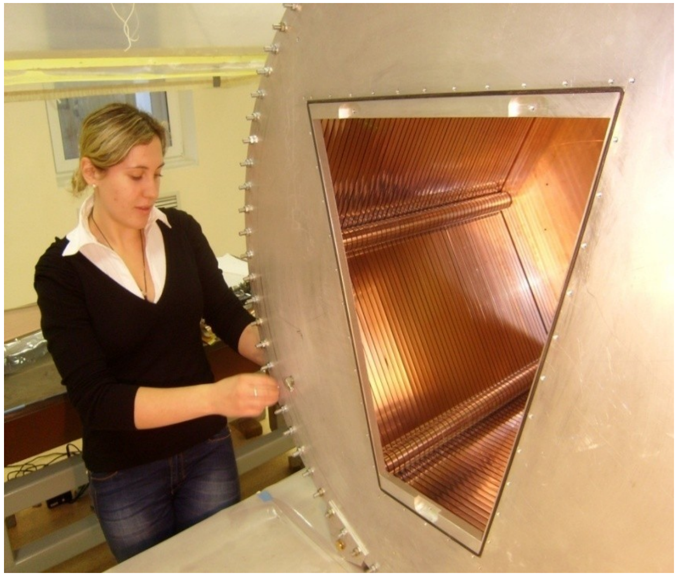




Low-p cutoff ~ **100 MeV**
for a **0.5 T** magnetic field



TPC prototype

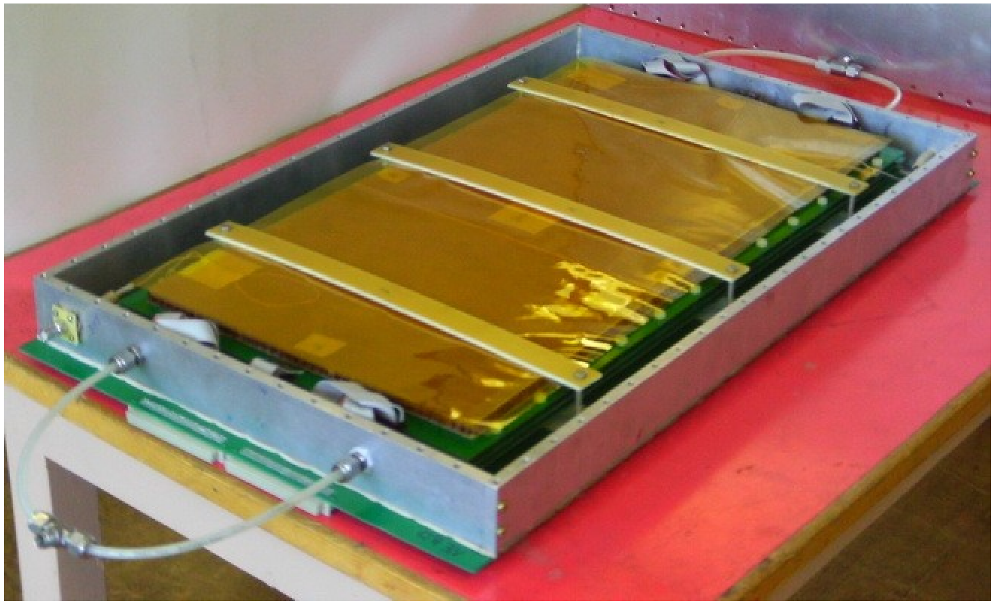


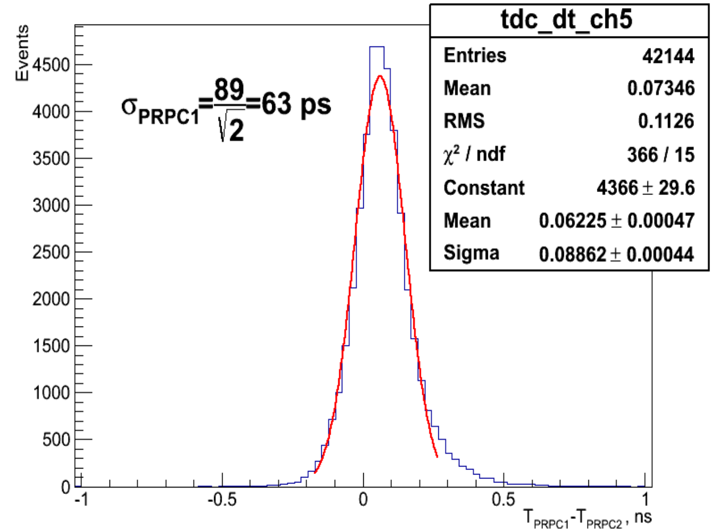
Test with laser beam

Field cage

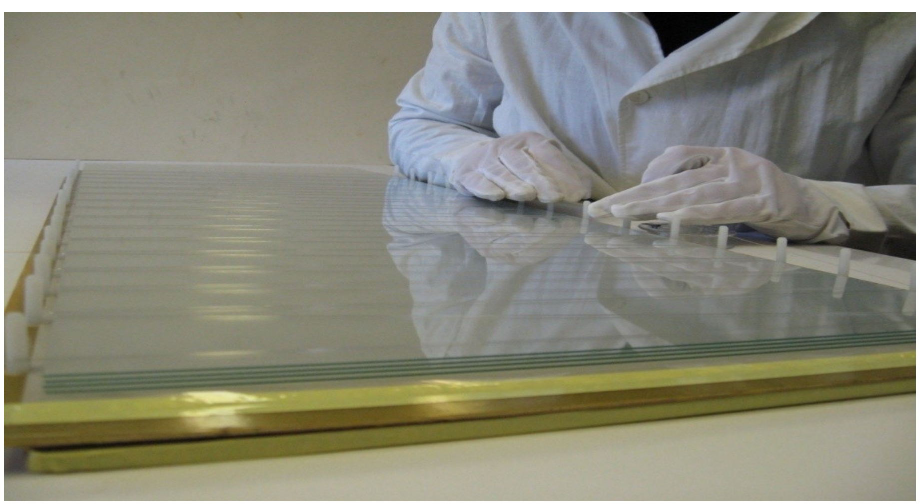
Time of Flight detector

mRPC prototype with a strip





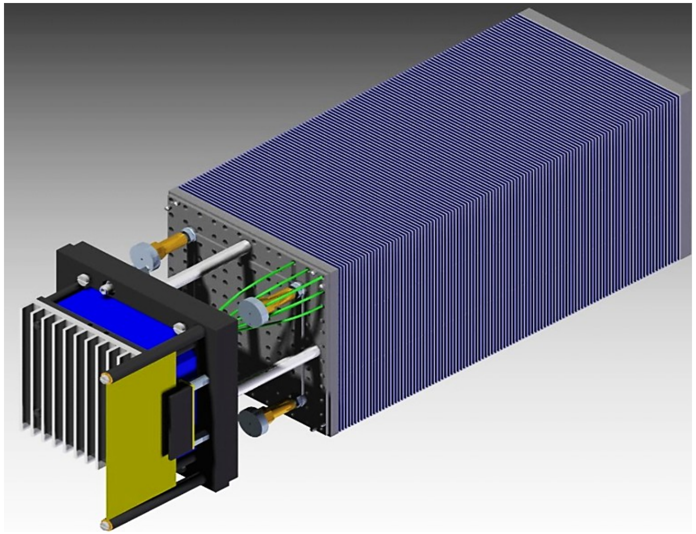
(T1 - T2) for two mRPCs



Full scale mRPC prototype with a strip

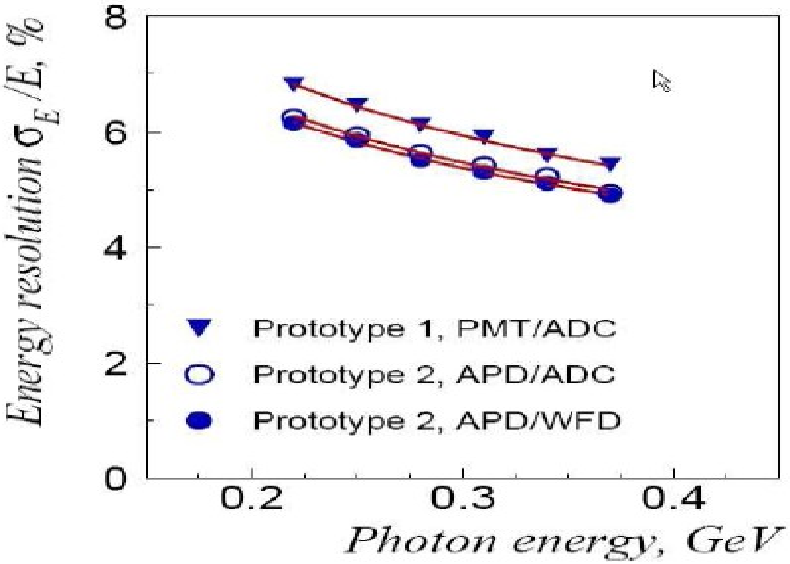
Electromagnetic calorimeter

Design of the ECAL module.



Pb(0.35 mm)+Scint.(1.5 mm)
4x4 cm², L ~35 cm (~ 14 X_0)
read-out: WLS fibers + MAPD

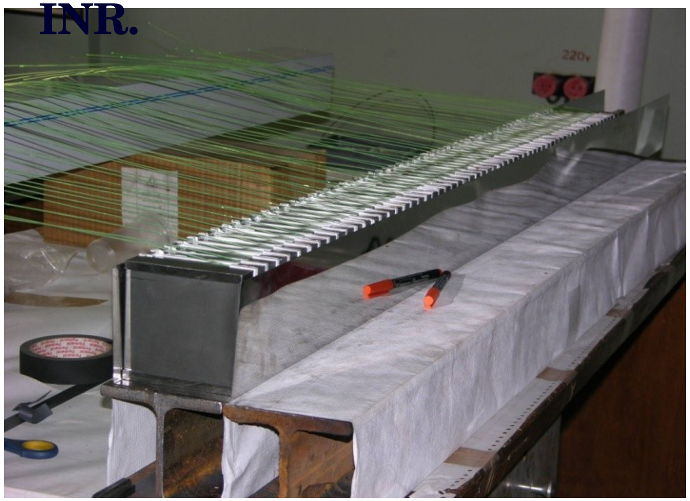
Setup for testing ECAL prototypes

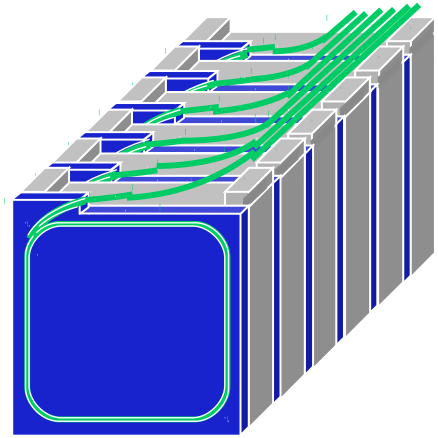


Energy resolution

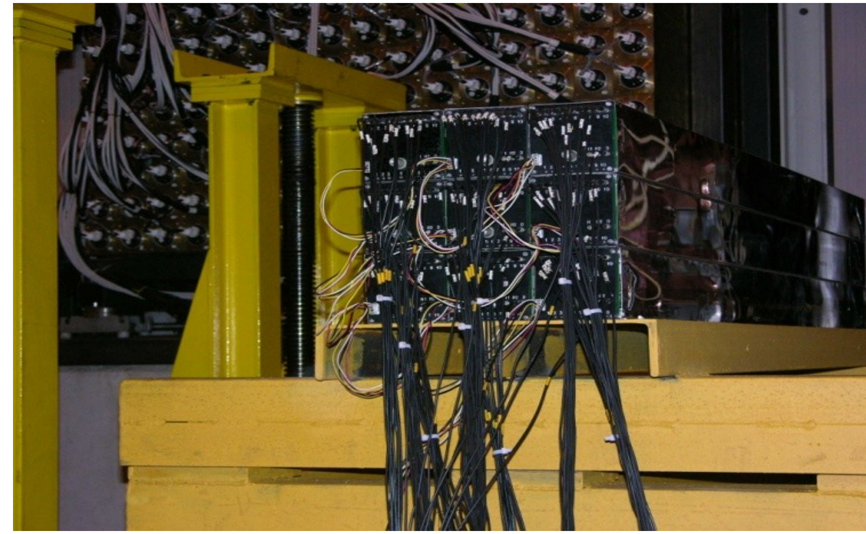
Zero Degree Calorimeter

Module assembling at INR.

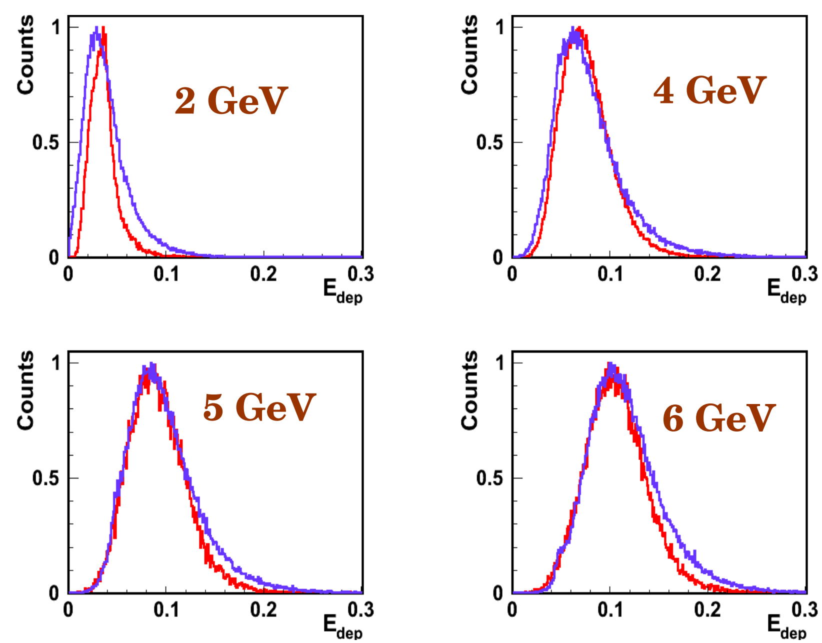




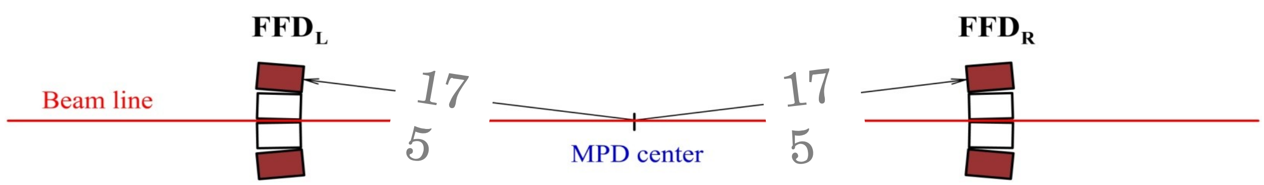
Transverse size 10x10 cm^2, length~160 cm, weight ~120 kg.
60 lead/scintillator sandwiches.
6 fiber/MAPD
10 MAPDs/module

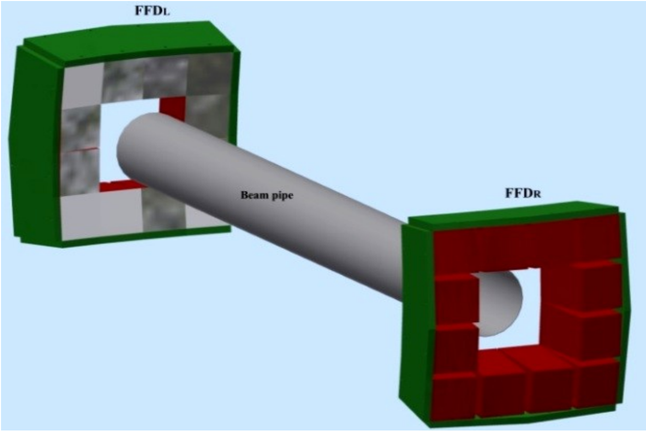


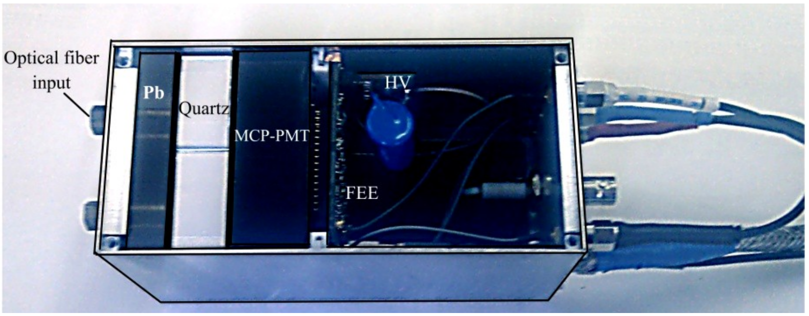
Beam test at *CERN*



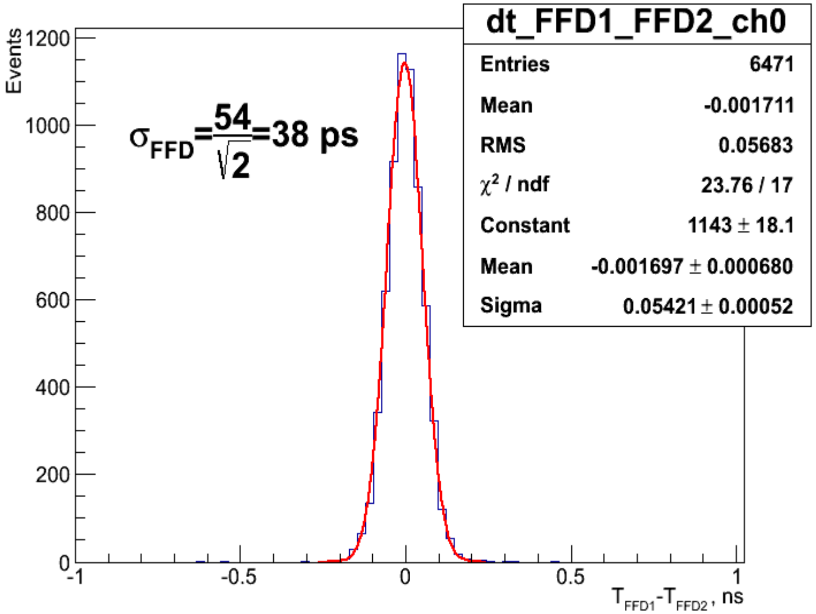
Fast Forward Detector (FFD)



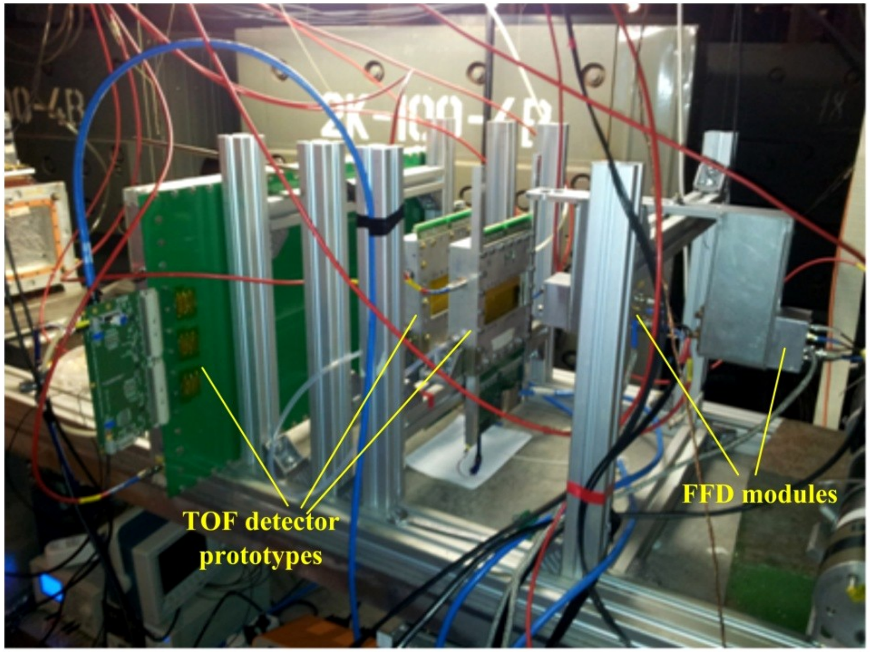




FFD prototype module

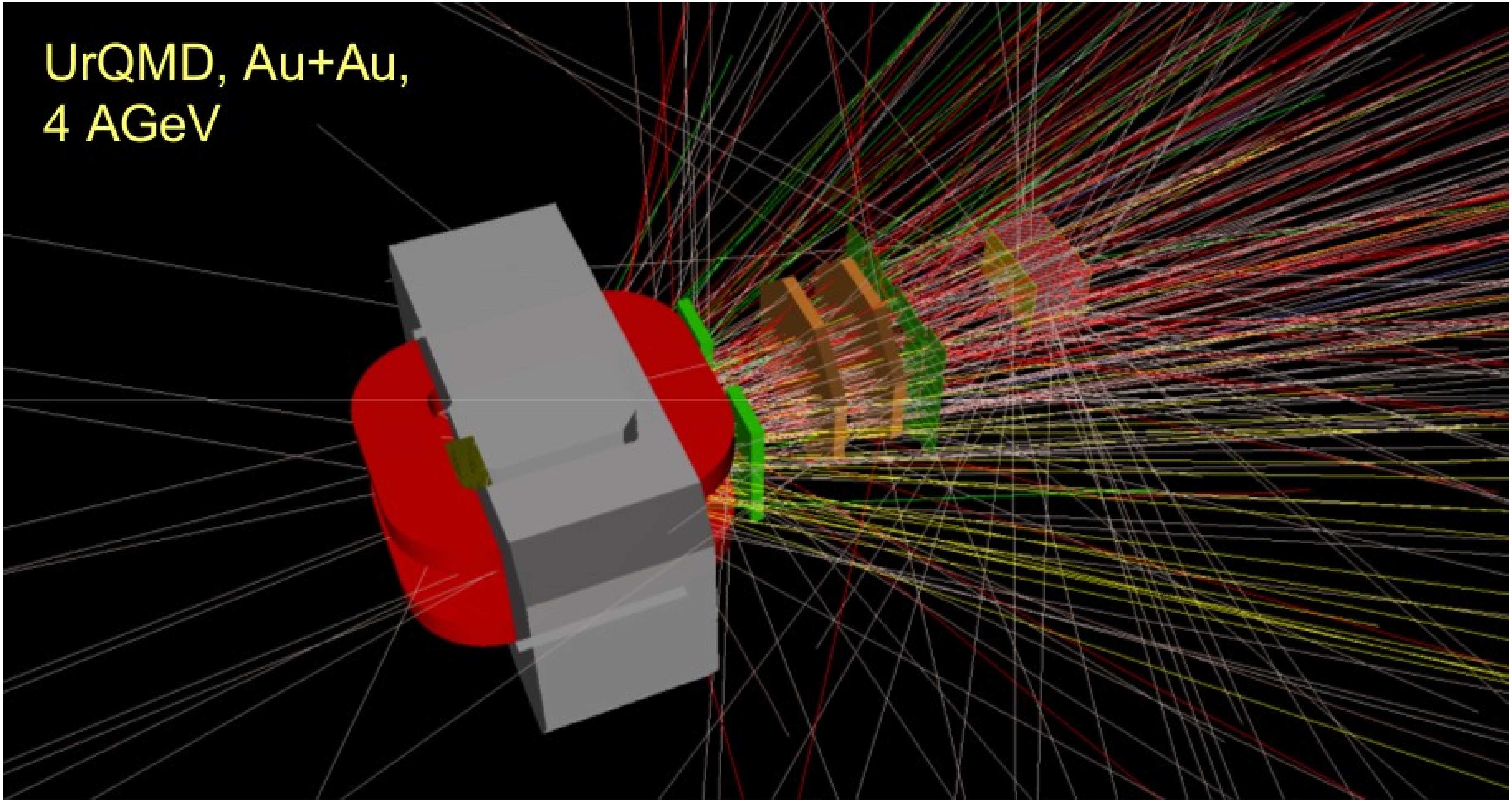


Time difference (T1-T2) for 2 FFD modules measured in Dec'12



Test facility at Nucltron

Barionic Matter at Nuclotron



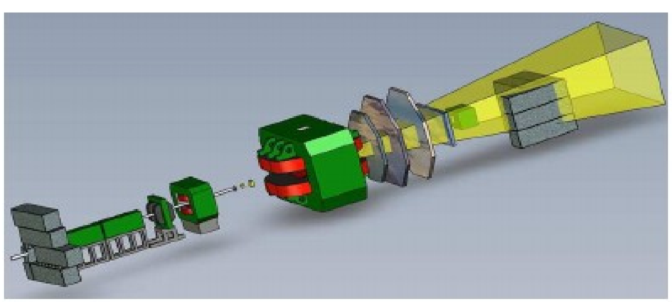
BM@N Conseptual Design Report

http://nica.jinr.ru

Conceptual Design Report

BM@N — Baryonic Matter at Nuclotron

Study of Strange Matter Production in Heavy-Ion Collisions at the Nuclotron



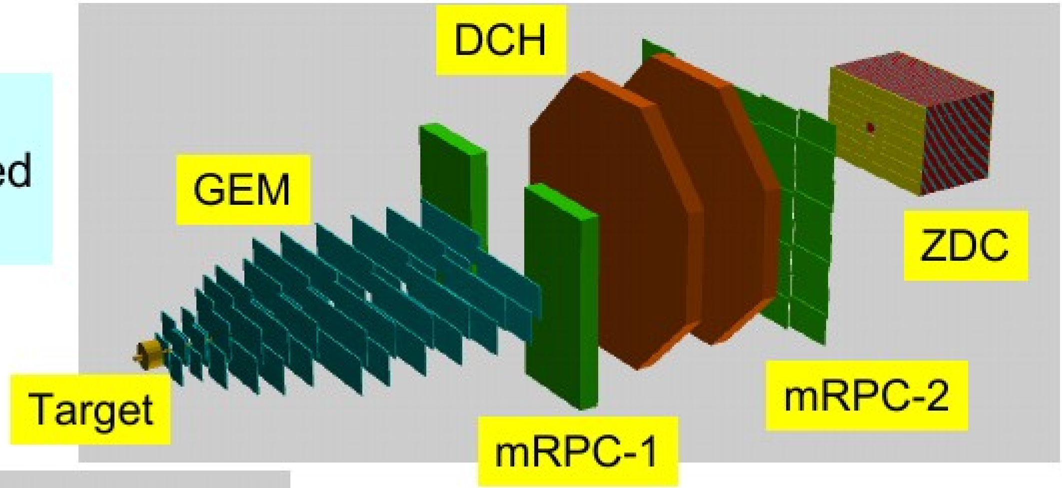
Contents

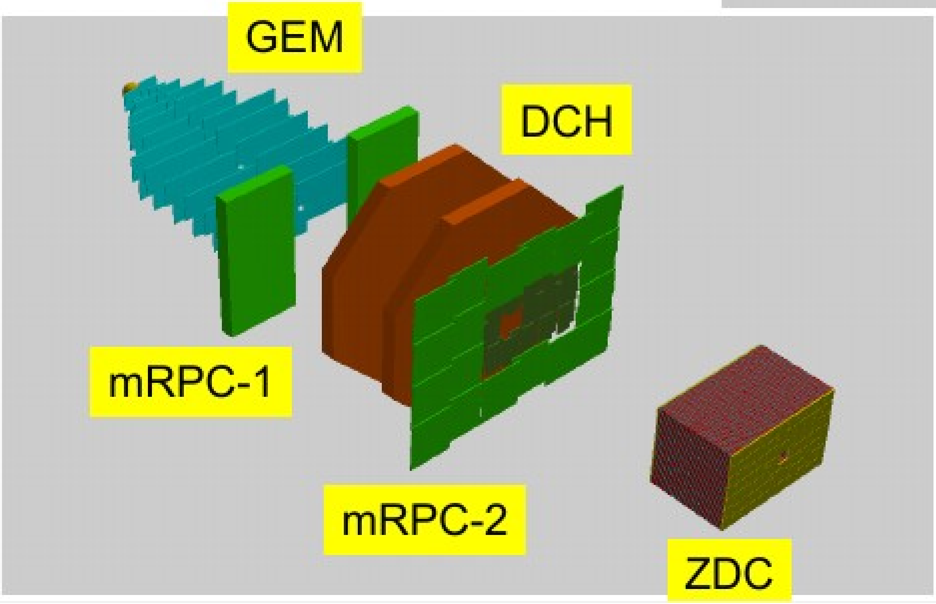
Experimental cave

counting rooms

BM@N detectors

• Tracking is based on 12 GEM detector planes placed at 30 - 360 cm from target

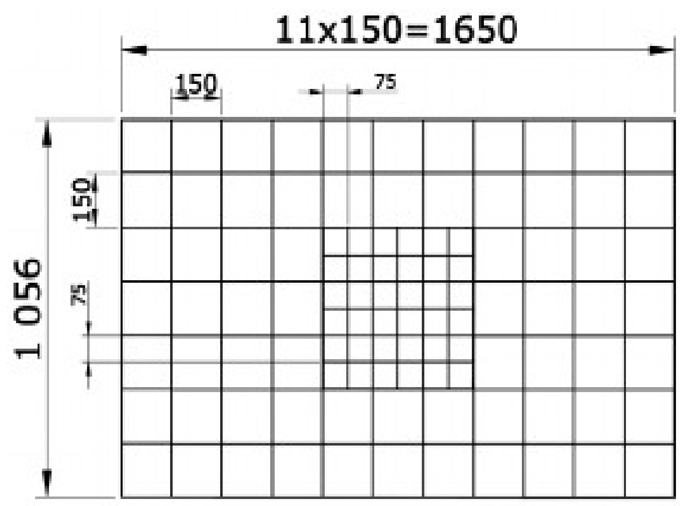


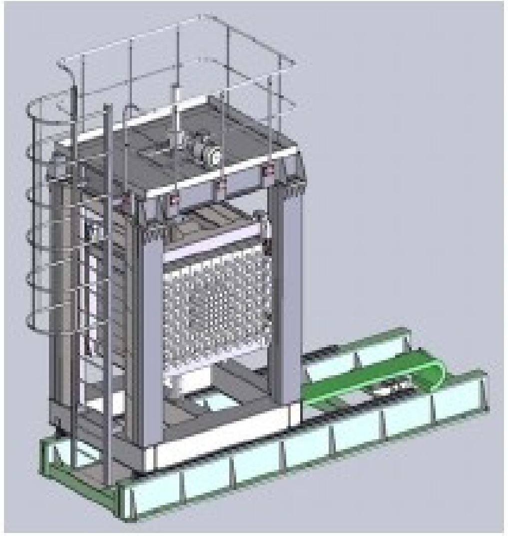


• GEM plane size is optimized for detection of $\Xi^- \to \Lambda\pi^-$, $\Lambda \to p\pi$-
• Strip pitch 400 μm in planes 1-4, 800 μm in planes 5-12
• Strip inclination 0, +15◦ in odd, 0, -15◦ in even planes

BM@N drift chambers

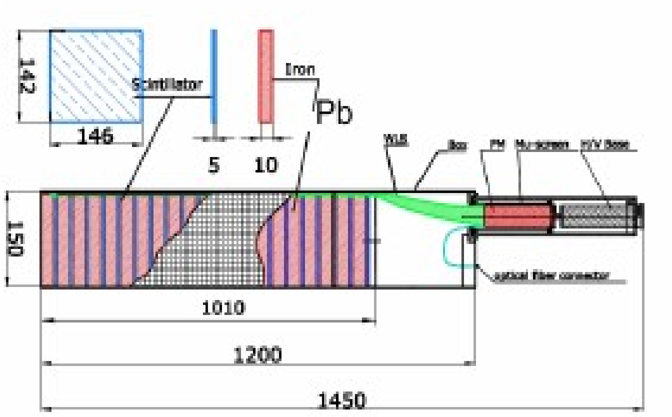
Zero Degree Calorimeter



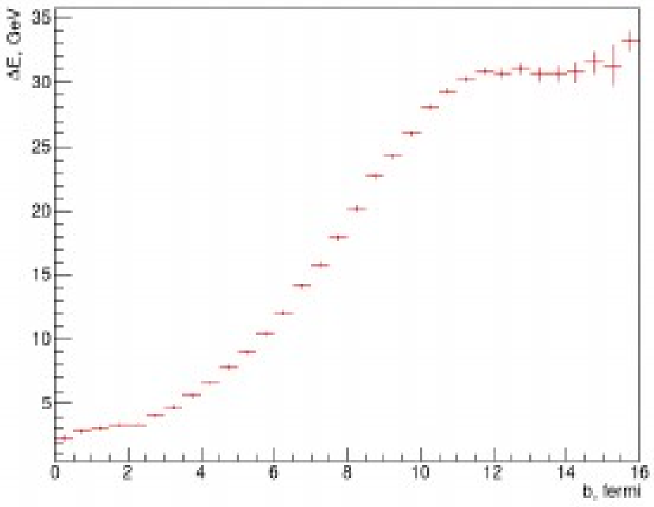


ZDC platform test in Kramatorsk

Sci-Pb sandwich calorimeter with PMT readout, 104 modules

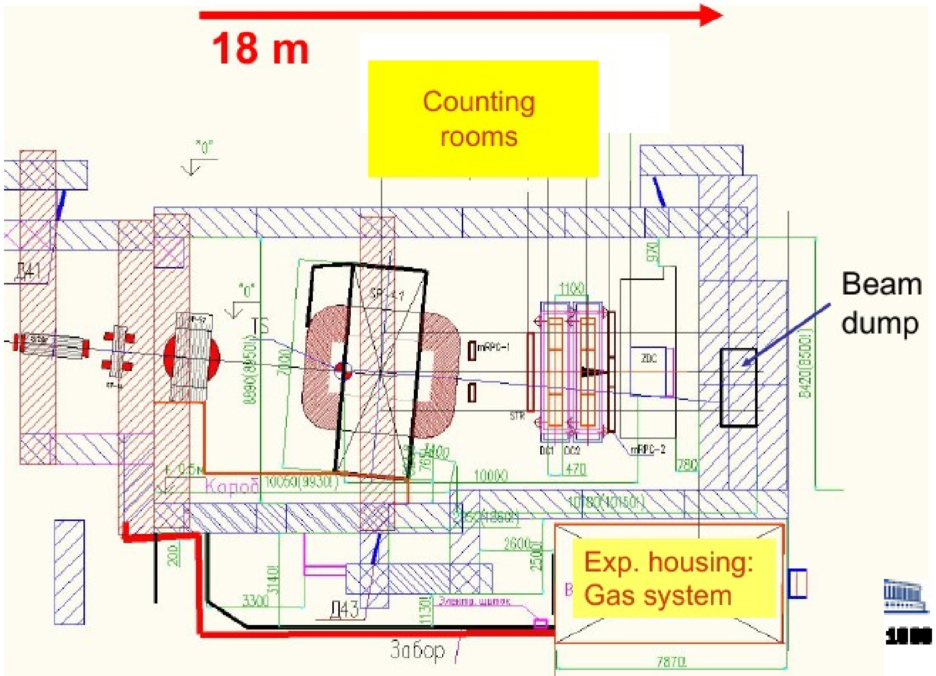


• Energy deposited in ZDC vs collision impact parameter

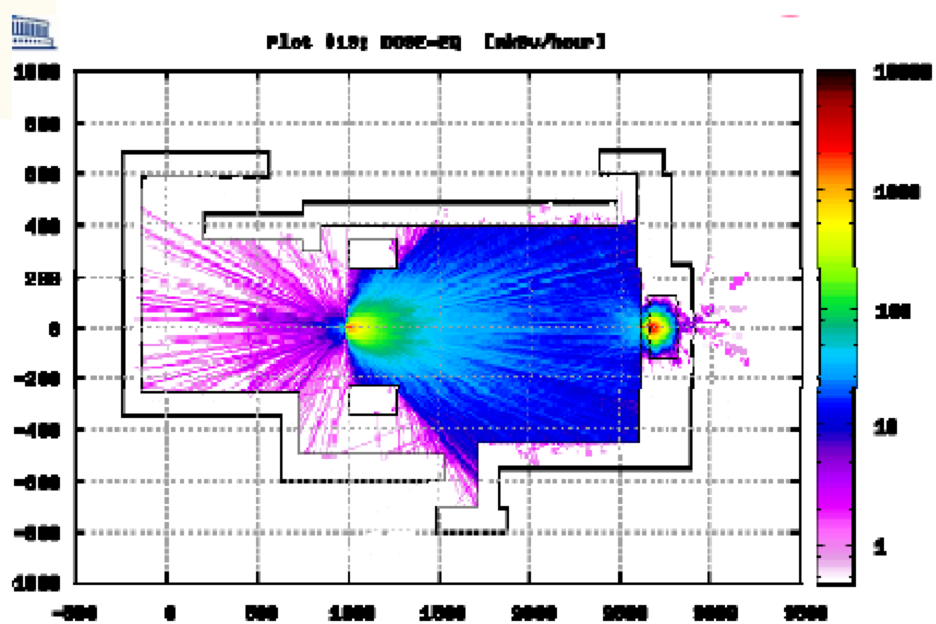


31

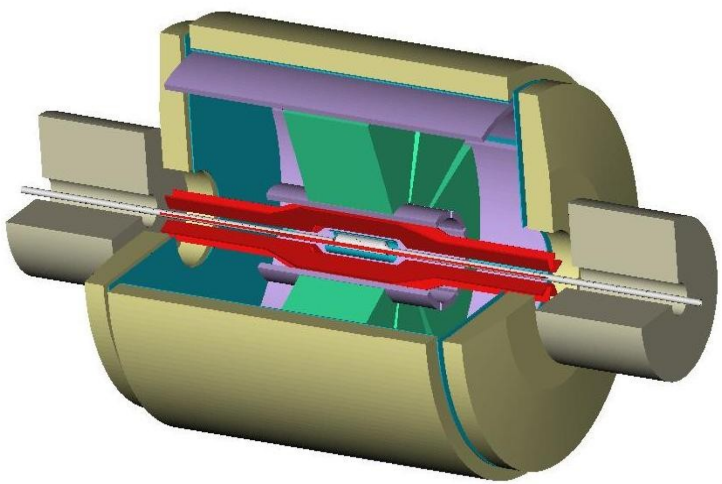
Radiation doses at BM@N



Equivalent Doses (mkSv/hour):
FLUKA simulation, Au+Au,
4 GeV/nuclon, intensity 10^7
Au/sec, Vacuum beam line



Spin Physics Detector



draft version 2.1
14.06.2010

THE SPIN PHYSICS DETECTOR- SPD
to study spin structure of the nucleon and polarization effects at NICA
(Conceptual Design Report)

JINR Dubna 2010

Contents

NICA – basic milestones

The project of NICA complex was approved	2010
The 1-st stage of Nuclotron modernization was completed	2010
The project	approval – completion
NICA accelerator complex	2010 – 2019
MPD (MultiPurpose Detector)	2010 – 2019
BM@N (Barionic Matter at Nuclotron) I stage	2012 - 2017
SPD (Spin Physics Detector)	is in progress

NICA Complex Civil Engineering

The State Expertise – Oct. 2013
International tender – 2013

Preparatory works completed - 2014
1-st contract with General Contractor – 2014

Civil construction will be completed by 2018
Start up version of NICA Collider:
commissioning is foreseen in 2019

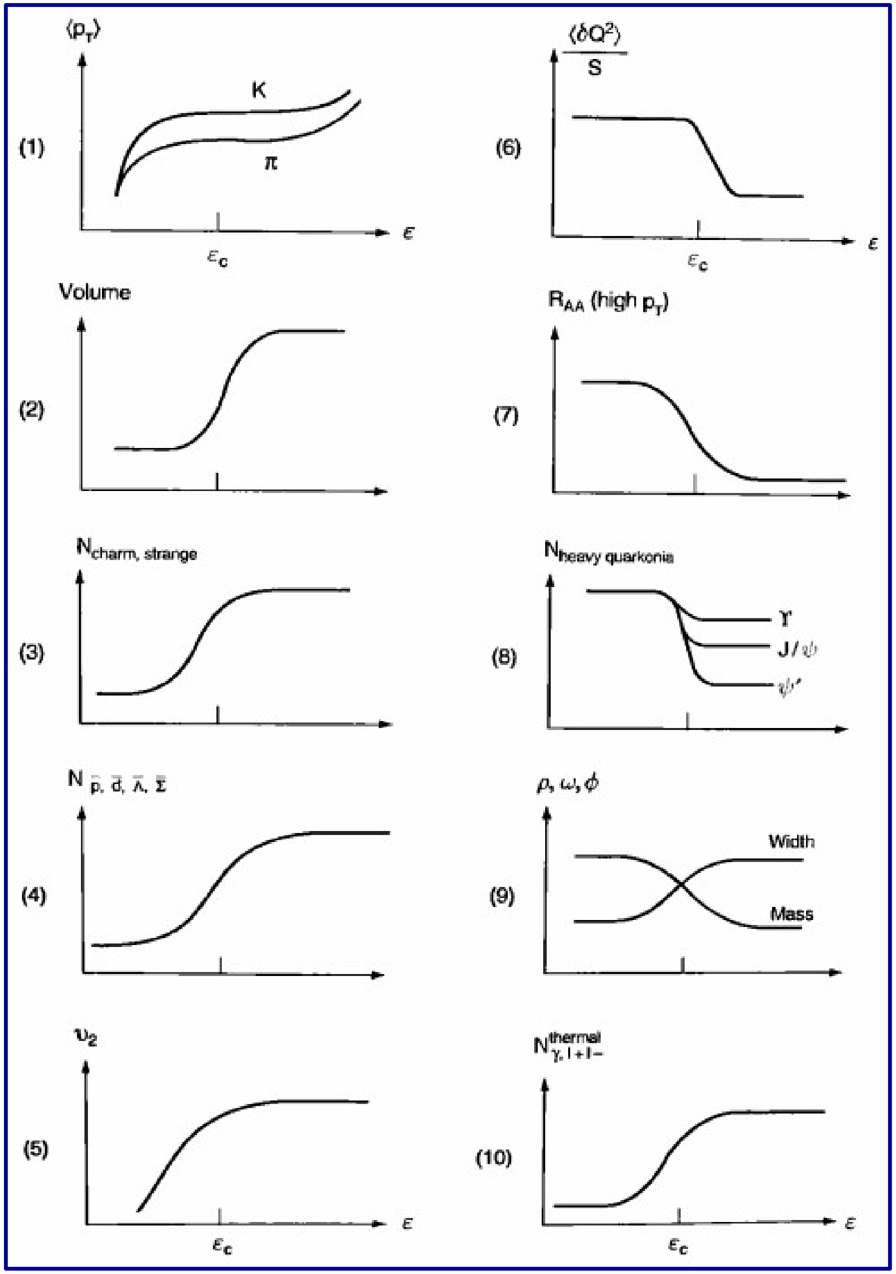
International Cooperation
@ Nuclotron-M / NICA experiments

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

Thank you for attention

Back up

QGP signatures



QUARK–GLUON PLASMA

From Big Bang to Little Bang

(1) A second rise in the average transverse momentum of hadrons due to a jump in entropy density at the phase transition.

(2) Measurement of the size. of the fireboll by particle interferometry with identical hadrons (Hanbury-Brown and Twiss effect).

(3) Enhanced production of strangeness and charm from QGP.

(4) Enhanced production of anti-particles in QGP.

(5) An increase of an elliptic flow of hadrons from early thermalization of an anisotropic initial configuration.

(6) Suppression of the event-by-event fluctuations of conserved charges

(7) Suppression of high-p_T hadrons due to the energy loss of a parton in QGP

(8) ??dification of the ?????ti?s of heavy mesons (J/Ψ, Ψ', Υ, Υ'} due to the color Debye screening in QGP.

(9) Modifications of the mass and width of the light vector ??sons due to chiral symmetry restoration.

(10) Enhancement of thermal photons and diieptons due to the emission from deconfined QCD plasma

Experiments

Pioneering ideas/experiments:

- 1980/00: AGS/SPS experiments with heavy ions discovery of strongly interacting matter (large volume, in ≈ equilibrium)
- 2000: M.Gazdzicki, M. Gorenstein statistical model predictions of the phase transition at the SPS energies
- 2000: NA49 at the CERN SPS discovery of phase transition of strongly interacting matter
- 2000-...: RHIC experiments study the properties of QGP