Dedicated to the memory of
Alexei Sissakian

NICA / MPD -status & perspectives
JINR accelerator facility to study DBM

V.Kekelidze at CPOD 2010 23 August 2010

Introduction

- The JINR Committee of Plenipotentiary (CP) accepted the Seven-Year Plan for the Development of JINR in 2010-2016, based on concentration of resources for updating the accelerator and reactor base of the Institute, and approved this plan taking into account the recommendations of the PACs and the Scientific Council

- The CP also supported the efforts being taken towards integration of the JINR basic facilities into the common European research infrastructure

- NICA / MPD is the JINR flagship project in HEP
  It was initiated and led by **A.N.Sissakian**

Introduction

- **The NICA/MPD project (Nuclotron based Ion Collider fAcility and Multi Purpose Detector)**

  is aimed to study of

  hot & dense baryonic matter at A=1-197, $\sqrt{S_{NN}}$ = 4 - 11 GeV/u

  and spin physics with polarized protons and deutrons

- **the study of DBM could provide us with information on**

  -in-medium properties of hadrons & nuclear matter equation of state

  -de-confinement and/or chiral symmetry restoration,

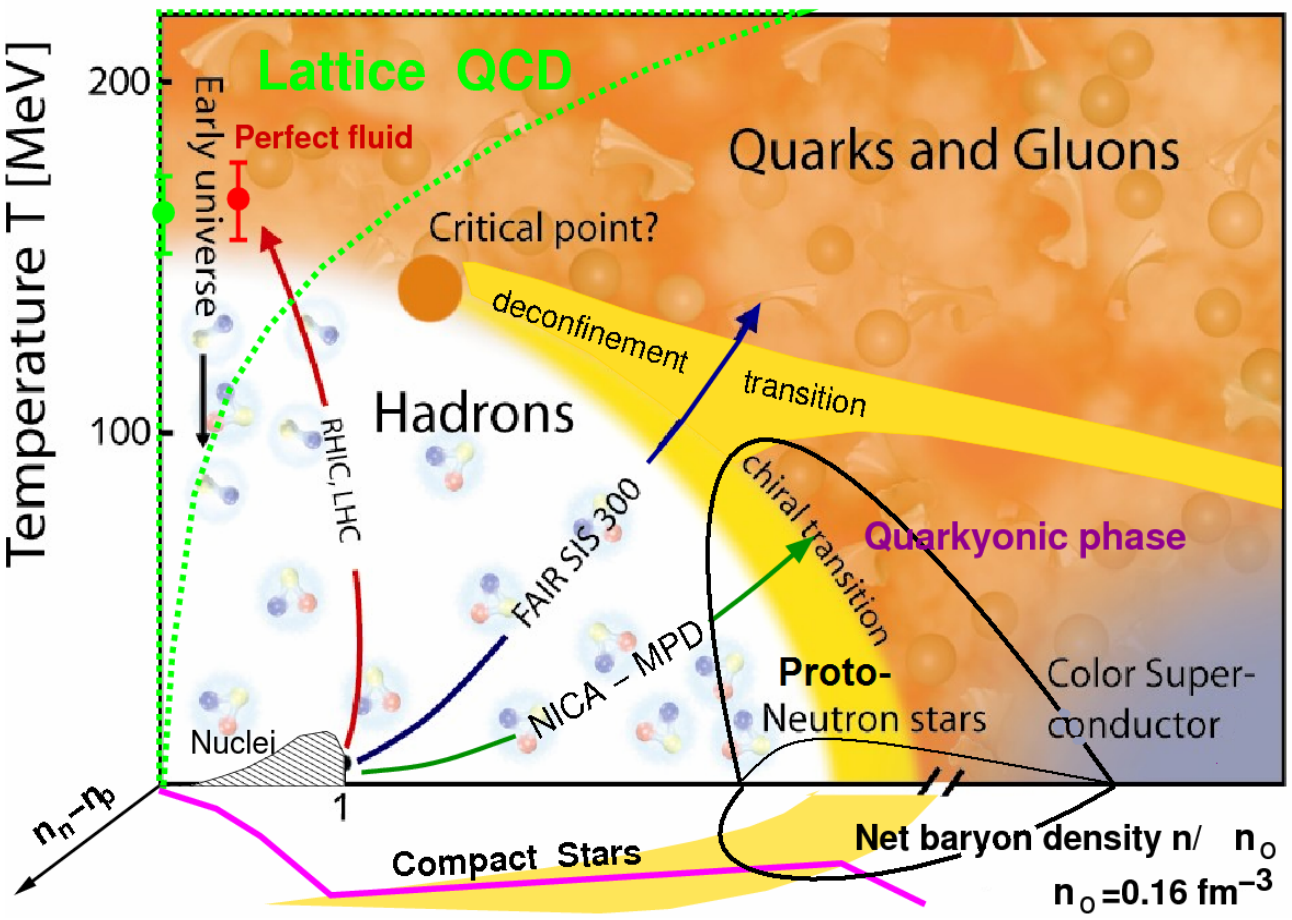
  -phase transition, mixed phase & critical end-point

  -possible strong P- & CP local violation

NICA physics program

Creation of the deconfined QGP state in HI collisions,
study of fundamental properties of QCD in various regions of QCD PD

QCD phase diagram

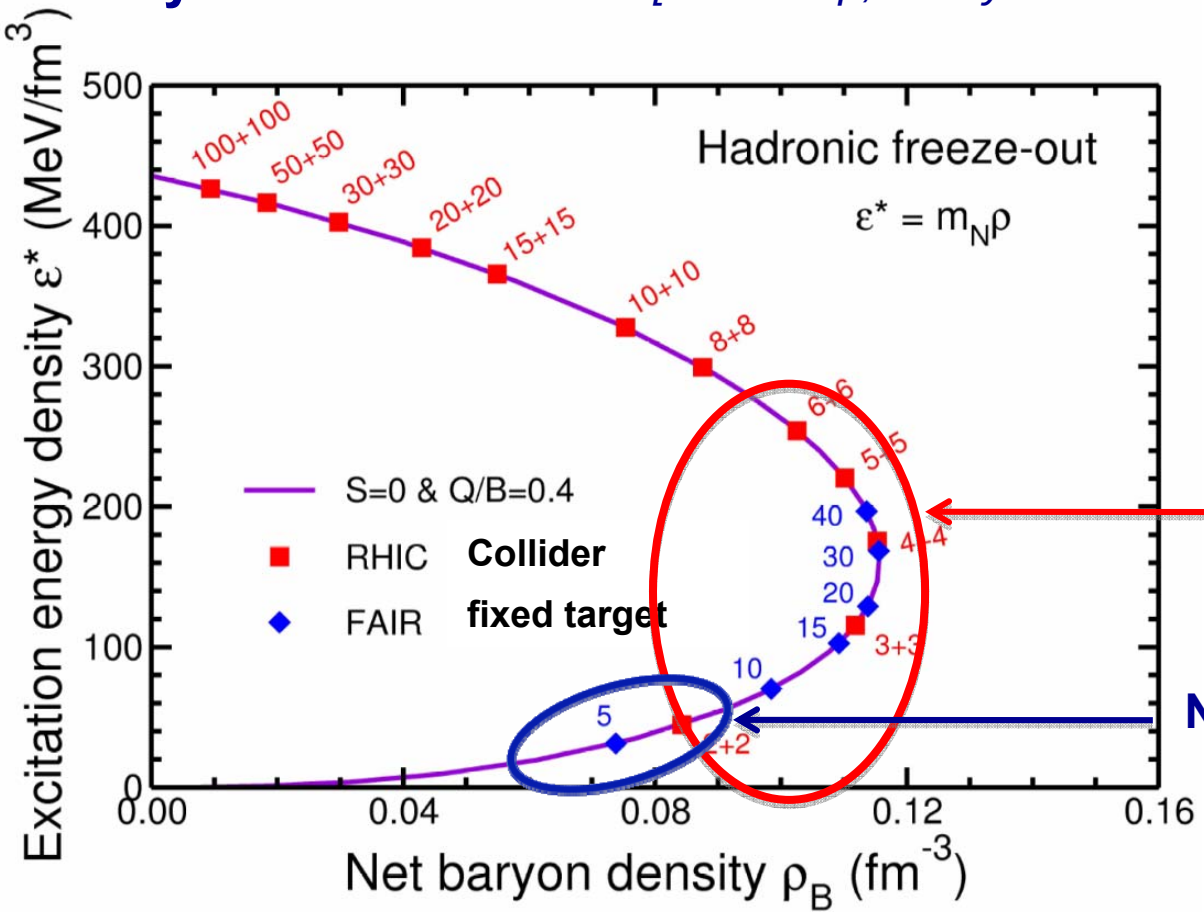


NICA energy region

J.Cleymans, M. Gazdzicki, M. Gorenstein , A. Sissakian, A. Sorin, V. Toneev, G. Zinovjev & others*: an optimal way to reach the highest possible baryon density*

→ **heavy ion collision at $\sqrt{S_{NN}}$ = 4 - 11 GeV/u**

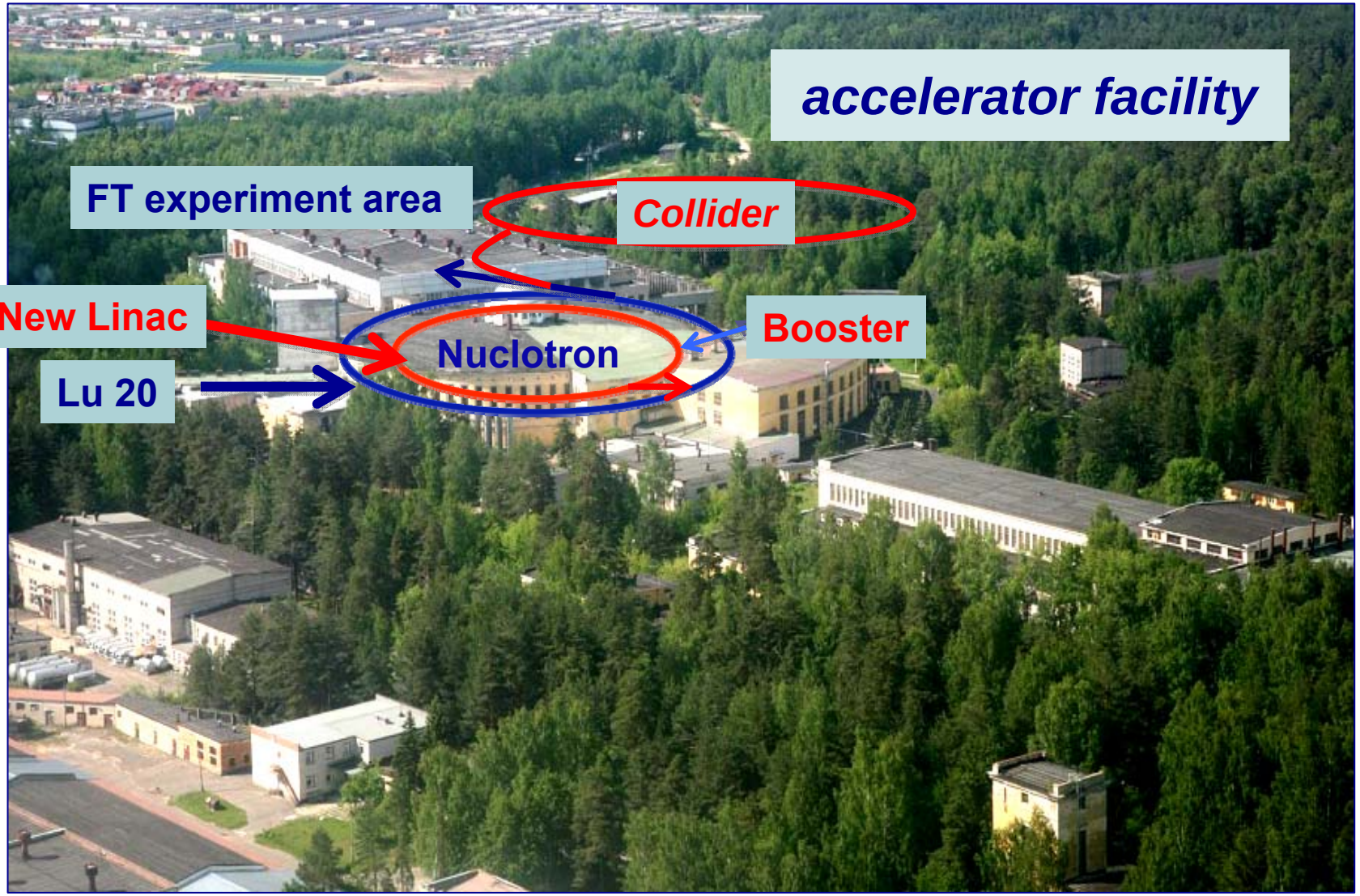
Baryon density in A+A collisions *[J.Randrup, J.Cleymans PR C74 (2006)047901]*



NICA/MPD

Nuclotron / BMN

Veksler & Baldin Laboratory of High Energy Physics



Nuclotron

- JINR HEP basic facility, *in operation* ***1993***
- based on the unique technology of **super-conducting fast cycling magnets** *developed in JINR*
- provides proton, **polarized** deuteron & **multi charged** ion beams

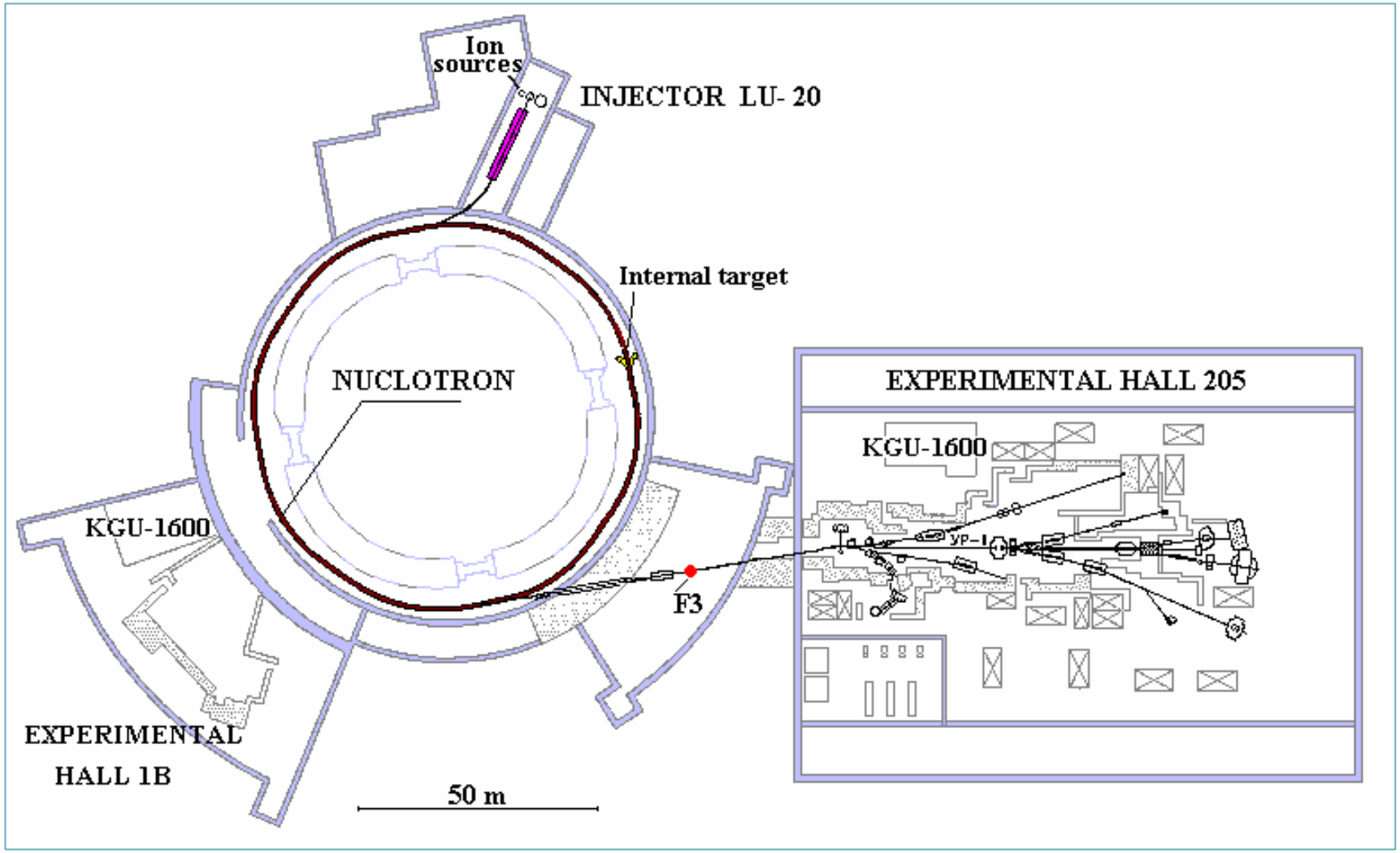
Nuclotron development plans:

- **Nuclotron-M** *(vac., PS, orbit corr.)* **2010**
- **Nuclotron-N** *(Krion-6, LU-20, RF)* **2012**
- **Nuclotron-N*** *(New Linac, Booster)* **2013**

Parameter	Design	Obtained
Accelerated ions	1<Z<92	1<Z<42
Energy, GeV/amu	6(A/Z=2)	5.2
Magnetic field, T	2.0	1.8
Inj. Energy, MeV/amu	5	5
Vacuum pressure,Torr	$1\cdot10^{-7}$	$2\cdot10^{-9}$
cold chamber	$1\cdot10^{-10}$	$1\cdot10^{-10}$
Repetition rate, (Hz)	0,5	0,2
Field ramp rate, (T/s)		
stand testing	4	2
in the ring	4,1	1,0

Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New ion source + booster (2013)
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↑	$2 \cdot 10^{8}$	ABS ("Polaris")	$1 \cdot 10^{10}$ *(SPI)*
^{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-2")	$5 \cdot 10^{10}$
^{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	-	--- ,, ---	$1 \cdot 10^{9}$

The plan of Nuclotron and experimental zones



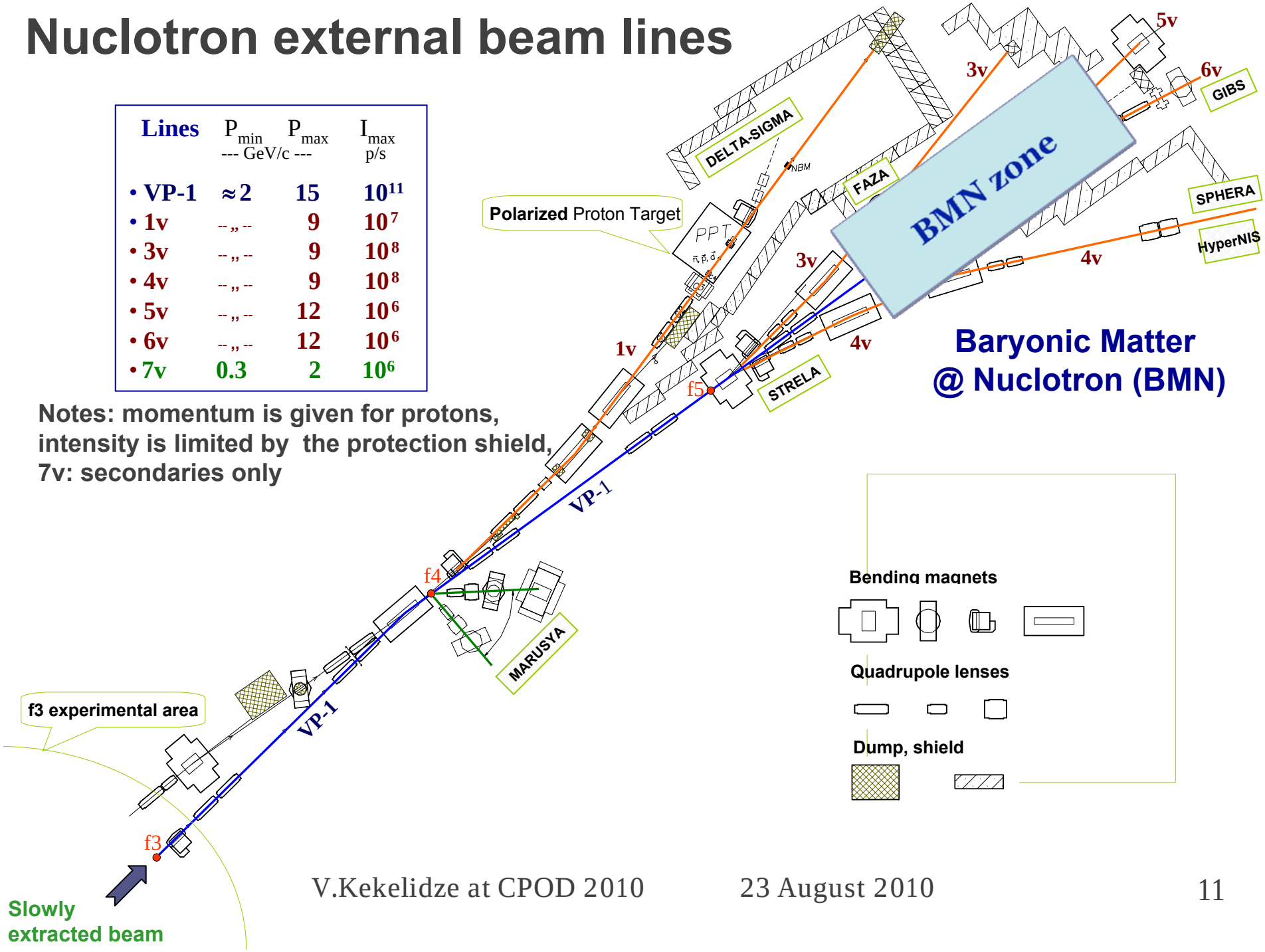
Nuclotron beam slow extraction

Parameter	Design	Obtained
Energy range, (GeV/amu)	0,2-6,0	0,2-2,2
Duration, (s) up to	10	10
Extraction efficiency, %		
at 0,2 GeV/amu	90	95
at 2,2 GeV/amu	95	95
Extraction angles, (mrad)		
horizontal	5	5
vertical	96±6	96±1
Nominal ES voltage, (kV)	200	200
Exploitation ES voltage, (kV)	up to 200	up to 150
LM supply current, (kA)	up to 6,3	6,3
Repetition rate, (Hz)	1,0	1,0

Nuclotron external beam lines

Lines	P_{min} --- GeV/c ---	P_{max}	I_{max} p/s
• VP-1	≈2	15	10^{11}
• 1v	-- „ --	9	10^{7}
• 3v	-- „ --	9	10^{8}
• 4v	-- „ --	9	10^{8}
• 5v	-- „ --	12	10^{6}
• 6v	-- „ --	12	10^{6}
• 7v	0.3	2	10^{6}

Notes: momentum is given for protons, intensity is limited by the protection shield, 7v: secondaries only



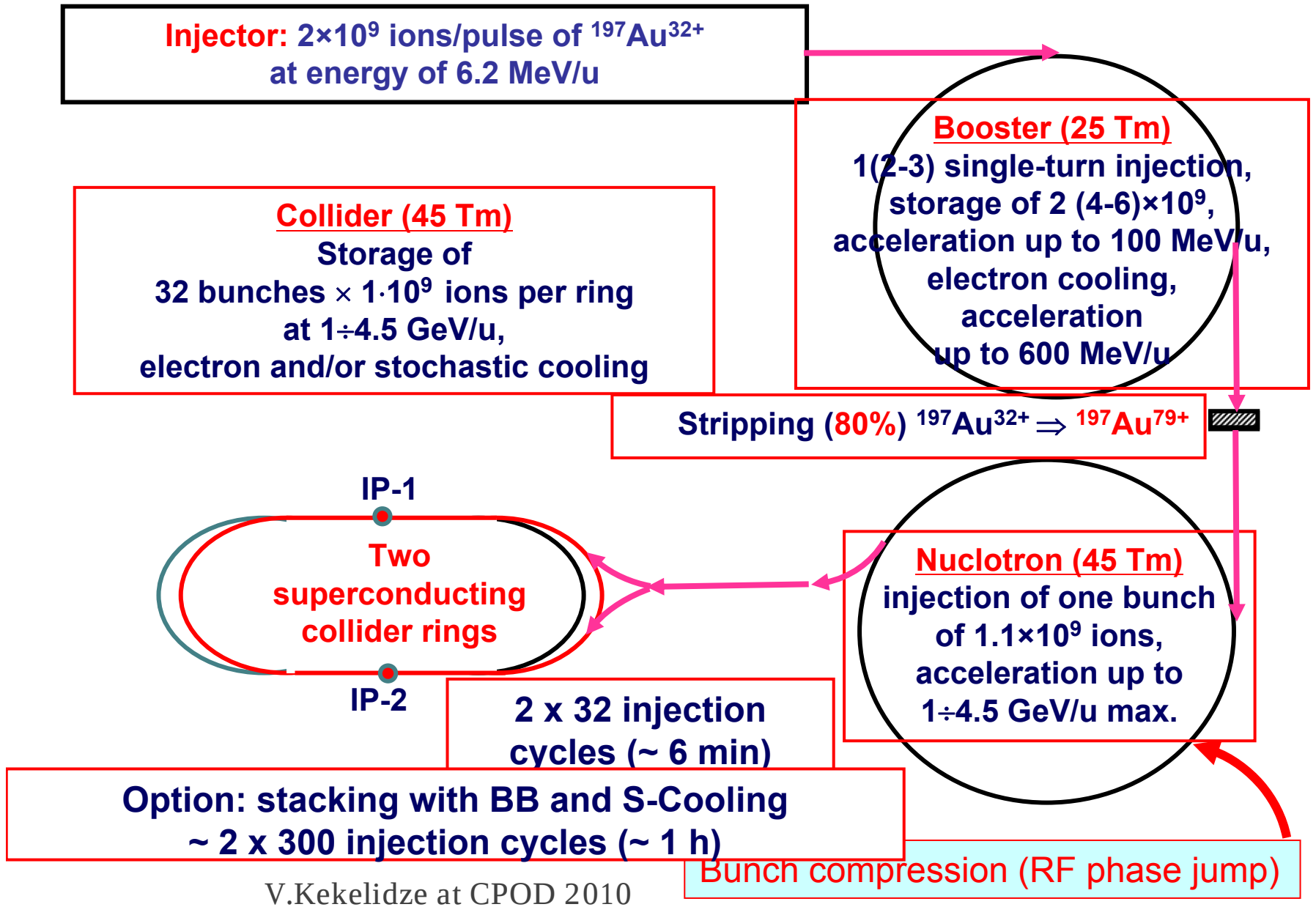
Baryonic Matter @ Nuclotron (BMN)

Baryonic Matter @ Nuclotron (BMN)

Schedule *(preliminary)*

- **Start of project preparation** **2010**
- **presentation for the consideration at PAC** **2011**
- **Experimental area preparation** **2012**
  major subdetector for the starting kit are prototyped and mounted
- **DMN starting kit commissioning** **2013**
- **Physics runs start up** **2014**

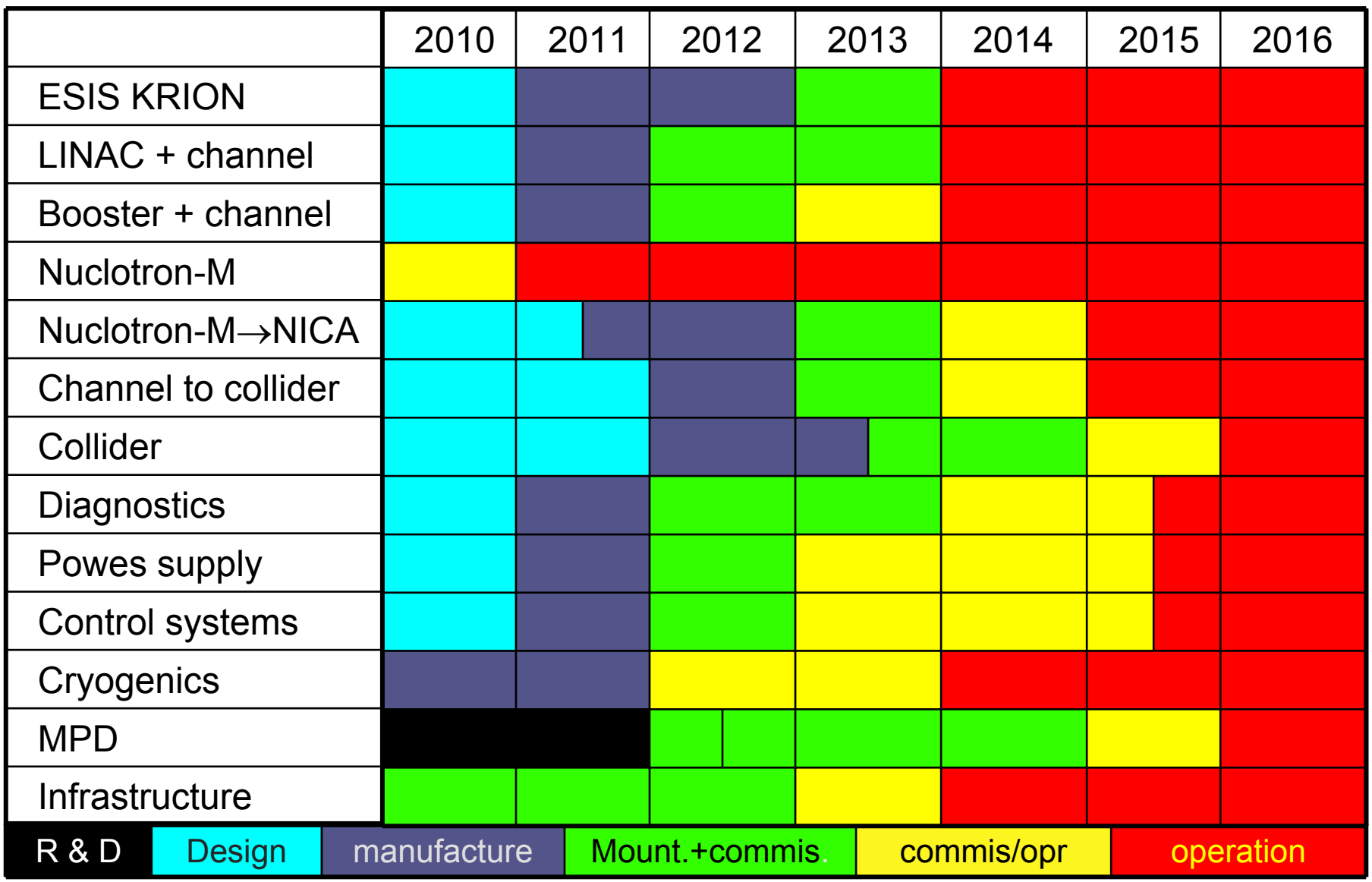
NICA operation regime & parameters



Collider–general parameters

Ring circumference, [m]	~ 450
Bρ max [T·m]	45.0
Ion kinetic energy (Au79+), [GeV/u]	1.0 ÷ 4.56
Dipole field (max), [T]	2.0
Free space at IP (for detector)	9 m
Beam crossing angle at IP	0
Vacuum, [Torr]	10^{-11}
Luminosity per one IP, $cm^{-2}·s^{-1}$	**0.75÷11 ·10^26**

NICA: works schedule



NICA TDR (vol. I & II)
August 209

Ускорительно-накопительный комплекс NICA

(Nuclotron-based Ion Collider fAcility)

Технический проект

Том I

Дубна, 2009

Ускорительно-накопительный комплекс NICA

(Nuclotron-based Ion Collider fAcility)

Технический проект

Том II

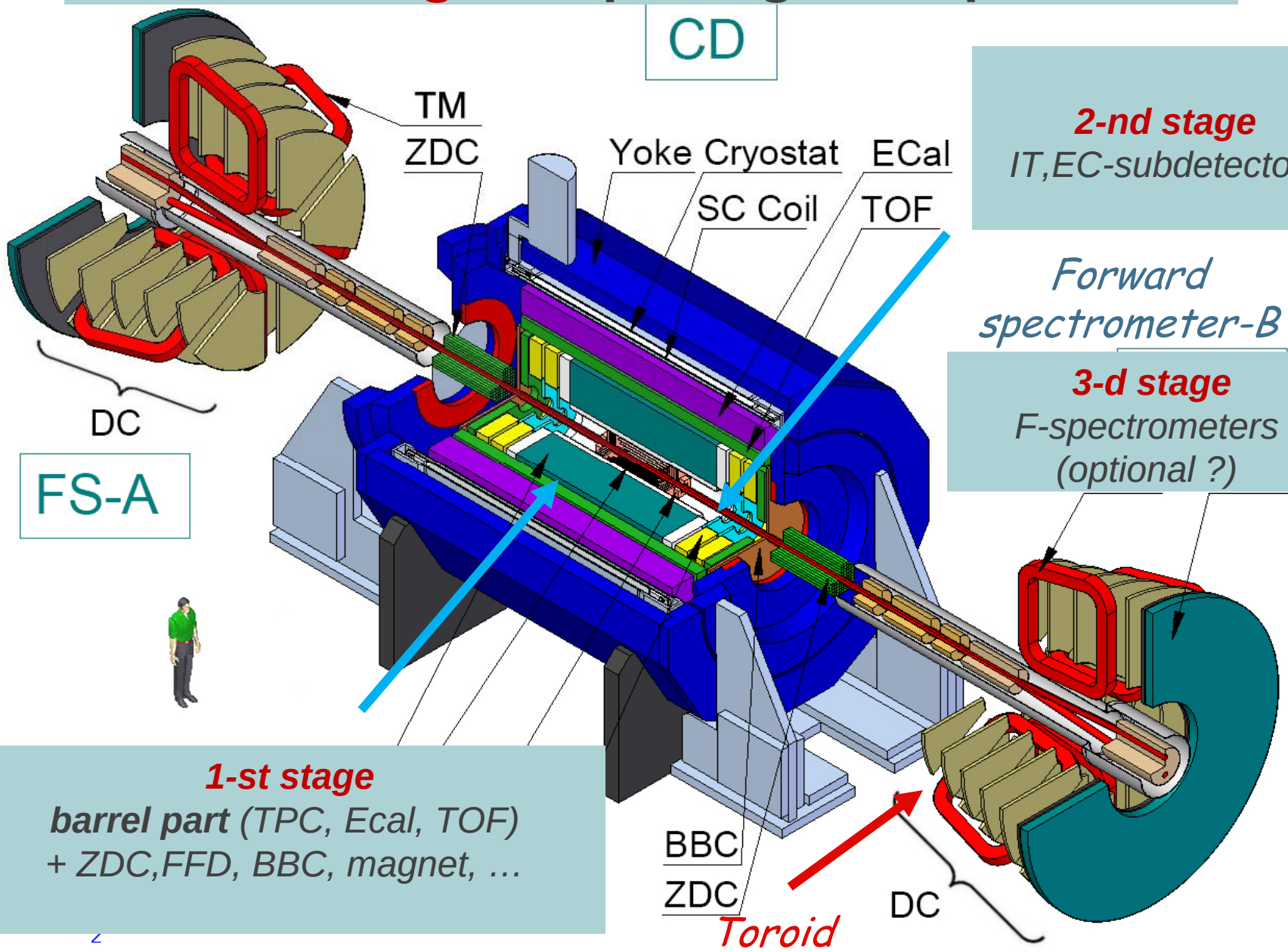
Дубна, 2009

Accelerator faci

- Machine advisory comm
  - *Boris Sharkov, ITEF*
  - *Pavel Beloshitsky, C*
  - *Sergei Ivanov, IHEF*
  - *Thomas Roser, BNL*
  - *Alexei Fedotov , BNL*

ECFA session in Dubna,
11 October 2009

MPD: 3 stages of putting into operation



2-nd stage
IT,EC-subdetectors

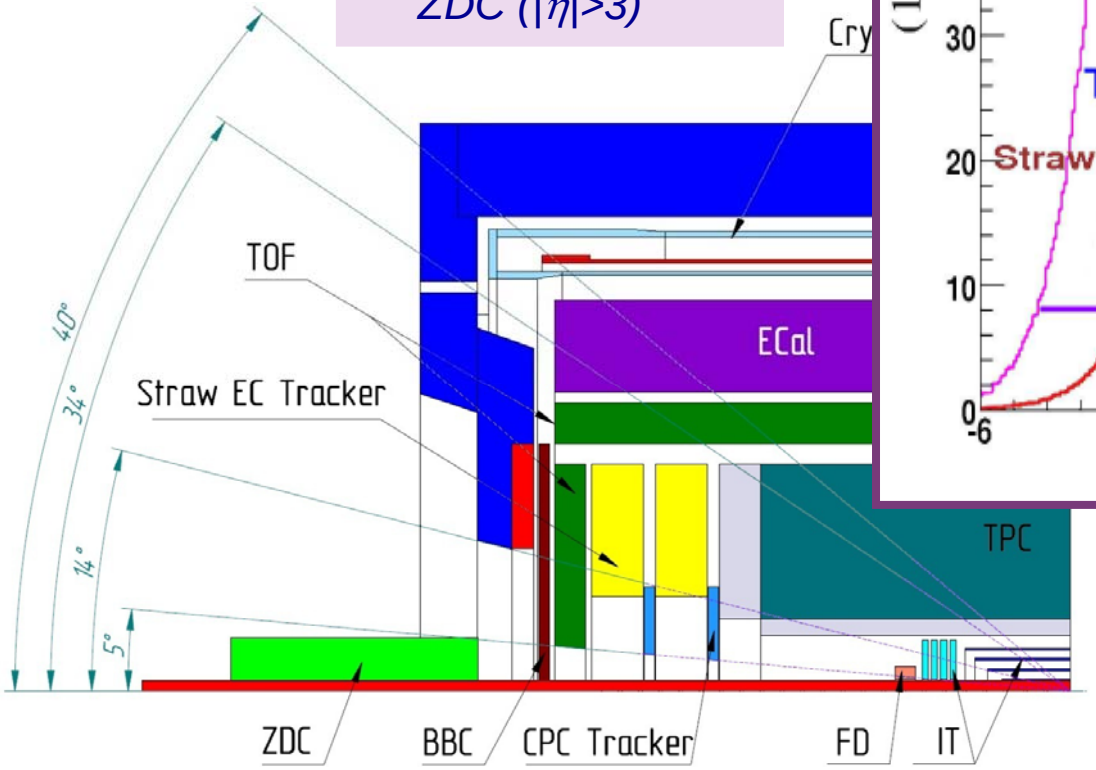
Forward spectrometer-B

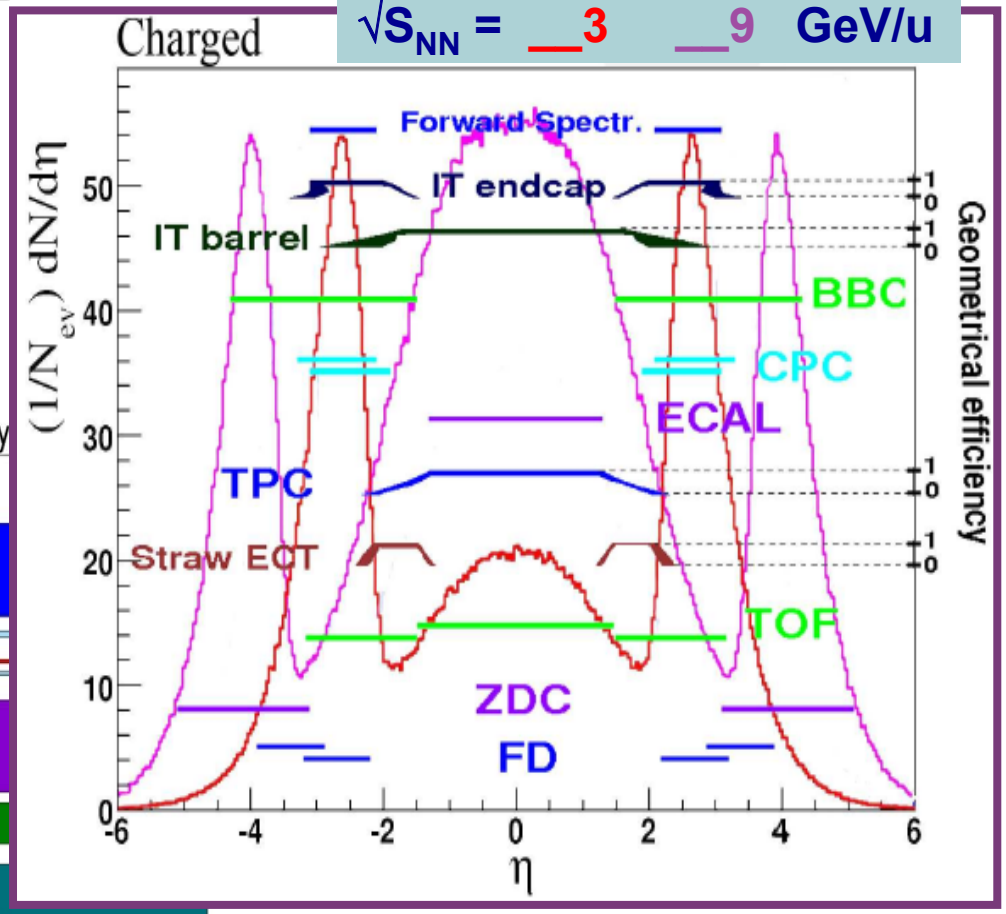
3-d stage
F-spectrometers (optional ?)

1-st stage
barrel part *(TPC, Ecal, TOF)*
+ ZDC,FFD, BBC, magnet, …

Angle coverage of MPD

TPC (|η| <2)
ECAL (|η|<1.2)
FD (2<|η|<4)
TOF (|η|<3)
IT (|η|<2.5)
ZDC (|η|>3)

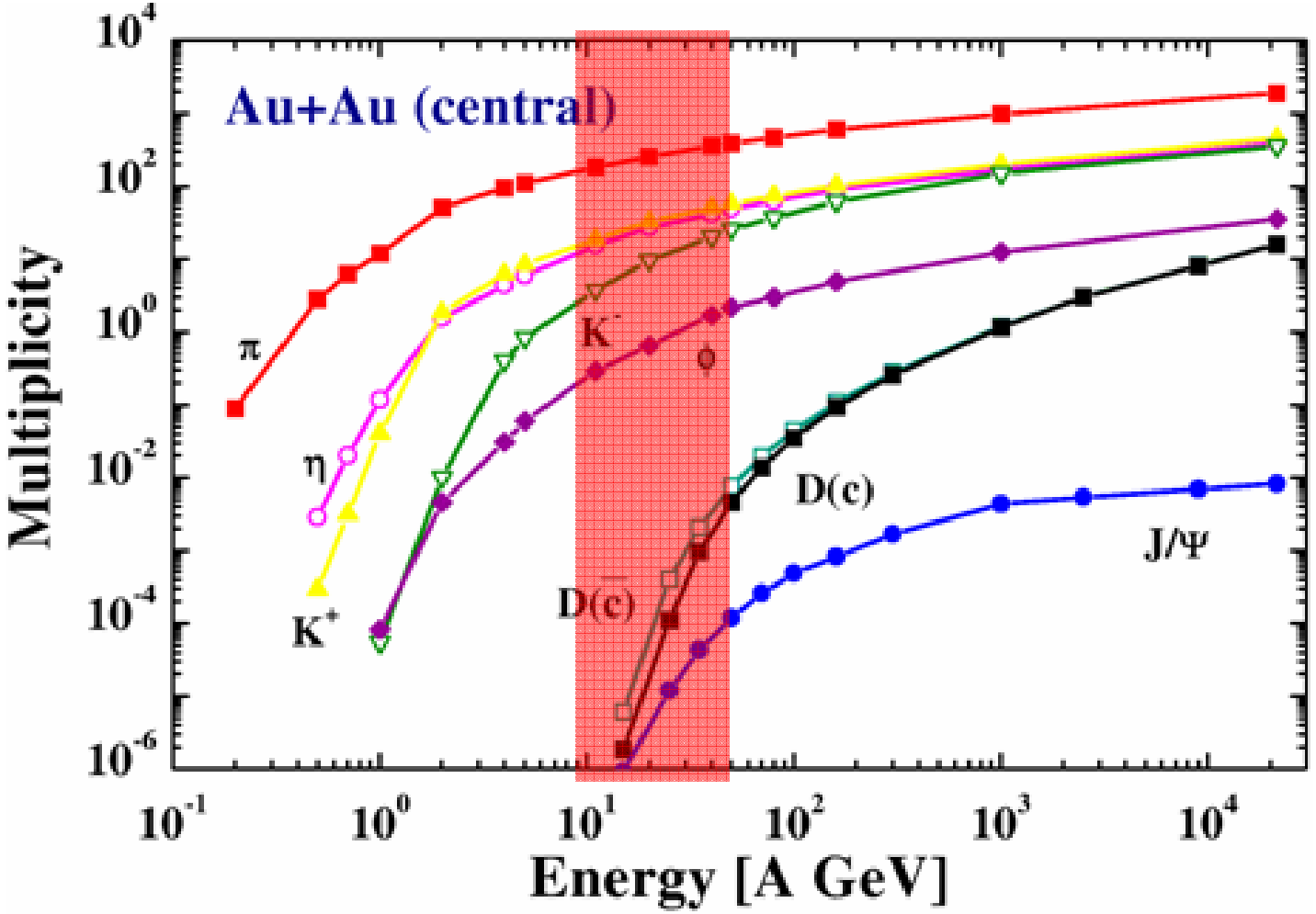




B = 0.5 T

Particle multiplicities in hadronic model (HSD)

O. Linnyk, E.L. Bratkovskaya,
W. Cassing, H. Stöcker,
Nucl.Phys.A786:183-200,2007



Particle yields in Au+Au collisions

$\sqrt{s_{NN}}$ = 7.1 GeV (10% central)

Luminosity L = $10^{27}cm^{-2}s^{-1}$
Event rate (central) 700 Hz

Particle (mass)	Multi-plicity	decay mode	yield (s^{-1})	yield 10w
K^+ (494)	55	--	$7.7 \cdot 10^{3}$	$4.6 \cdot 10^{10}$
K^- (494)	16	--	$2.2 \cdot 10^{3}$	$1.3 \cdot 10^{10}$
ρ (770)	23.6	e^+e^-	$1.6 \cdot 10^{-2}$	$9.4 \cdot 10^{4}$
ω (782)	14.2	e^+e^-	$1.4 \cdot 10^{-2}$	$8.6 \cdot 10^{4}$
φ (1020)	2.7	e^+e^-	$1.1 \cdot 10^{-2}$	$6.8 \cdot 10^{4}$
Ξ^- (1321)	2.4	$\Lambda\pi^-$	67	$4.0 \cdot 10^{8}$
Ω^- (1672)	0.16	ΛK^-	1.5	$9.2 \cdot 10^{6}$
D^0 (1864)	$7.5 \cdot 10^{-4}$	$K^+\pi^-$	$2.0 \cdot 10^{-4}$	1200
J/ψ (3097)	$3.8 \cdot 10^{-5}$	e^+e^-	$8.0 \cdot 10^{-5}$	480

List of Tasks for MPD

.. To measure a large variety of signals systematically changing collision parameters (energy, centrality, system size).

Reference data (i.e. p+p) will be taken at the same experimental conditions.

- **bulk observables (hadrons): 4π particle yields (OD, EOS)**
- **multi-strange hyperon production : yields & spectra (OD, EOS)**
- **electromagnetic probes (CSR, OD)**
- **azimuthal charged-particle correlations (LPV)**
- **event-by-event fluctuation in hadron productions (CEP)**
- **correlations involving π, K, p, Λ (OD)**
- **directed & elliptic flows for identified hadron species (EOS,OD)**
- **…….**

OD – Onset of Deconfinement
CEP – Critical End Point
CSR – Chiral Symmetry Restoration
LPV – Local Parity Violation in strong interaction
EOS – Equation Of State

NICA White Paper (http://nica.jinr.ru)
Round Table materials (http://jinr.ru/theor/)

MPD working packages

- Magnet
- TPC *(+prototyping)*
- ECal
- TOF
- ZCal
- FFD
- CPC
- Straw wheels

- EC DC
- IT
- DAQ
- Slow Control
- Infrastructure & Integration
- Soft ware
- Physics performance

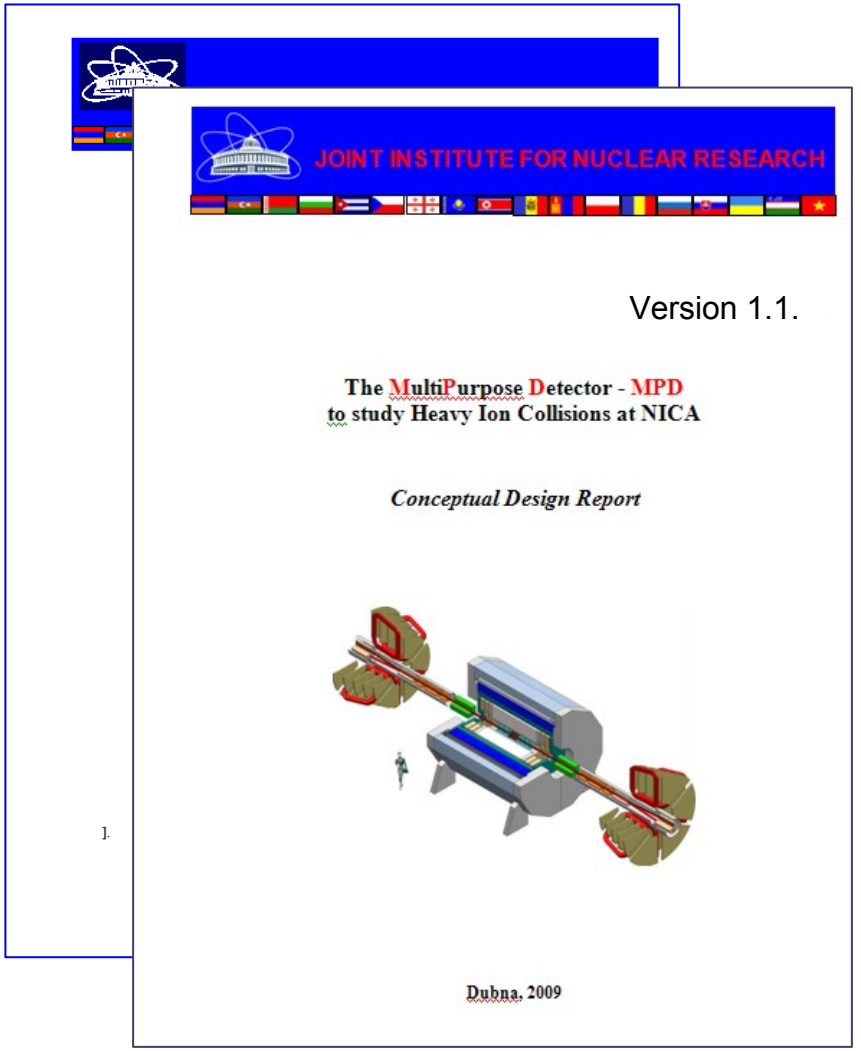
The CBM-MPD SSD consortium:
GSI – JINR – IHEP - … in IT silicon module development is well progressing

Timetable MPD

	Stage/Year	2009	2010	2011	2012	2013	2014	2015	2016
1	MPD Conceptual Design Report								
2	MPD TDR								
3	**R&D program**								
	TPC								
	TOF								
	ZDC								
	Si inner tracker								
	EMC								
	Straw Tracker								
	DAQ								
4	**Production and tests (the 1st stage detectors)**								
	Superconducting Magnet of MPD								
	TPC								
	EMC								
	ZDC								
	TOF barrel								
	Slow Control								
	DAQ								
	Installation& Commissioning								
	Si inner tracker								
5	**Production and tests (the 2nd stage detectors)**								
	TOF(EndCap)								
	Straw Tracker								
	DAQ								
	Slow Control								
	Installation								
6	**Production and tests (the 3rd stage, Forward Spectrometer)**								
	Toroidal Magnet construction								
	Coordinate detectors production								
	Coordinate detector testing								
	Installation& Commissioning								

Status of MPD project & physics

- *MPD LoI - the first version February 2008*
- *MPD CDR - the first version June 2009*
- *the last update version 1.1 in July 2010*
- *White Book (89 authors from 39 centers) the first version June 2009*
- *MPD project (1st stage) was considered at PAC of PP (107 session in January 2010) & recommended for approval*



MPD Collaboration

+ Nuclotron-M/NICA/MPD/SPD cooperation

Members of the Collaboration

- JINR ~100
- Other Institutes 54

Institutions

- JINR 1
- 12 Institutes from 7 countries

- **Joint Institute for Nuclear Research**
- Institute for Nuclear Research, RAS, **RF**
- Bogolyubov Institute for Theoretical Physics, NAS, **Ukraine**
- Nuclear Physics Institute of MSU, **RF**
- Institute Theoretical & Experimental Physics, **RF**
- St.Petersburg State University, **RF**
- Institute of Applied Physics, AS, **Moldova**
- Institute for Nuclear Research & Nuclear Energy BAS, Sofia, **Bulgaria**
- Institute for Scintillation Materials, Kharkov, **Ukraine**
- State Enterprise Scientific & Technolog
  Research Institute for Apparatus construction, Kharkov, **Ukraine**
- Particle Physics Center of Belarusian State University, **Belarus**
- Department of Engineering Physics, Tsinghua University, Beijing, **China**
- Physics Institute Az.AS, **Azerbaidjan**

The Collaboration is permanently growing

New participants – are welcome !

NICA Round Table IV *(9 September 2009)*

Summary

- **NICA/MPD** project to study hot & dense baryonic matter is well progressing
- The 1st stage **of MPD** conception is completed & the project is recommended for realization
- The scientific program in DBM will be extended for low energy region by FT facility - **BMN**
- Project schedules are properly followed for both **NICA** & **MPD**
- The **MPD Collaboration** is growing New members are welcome !

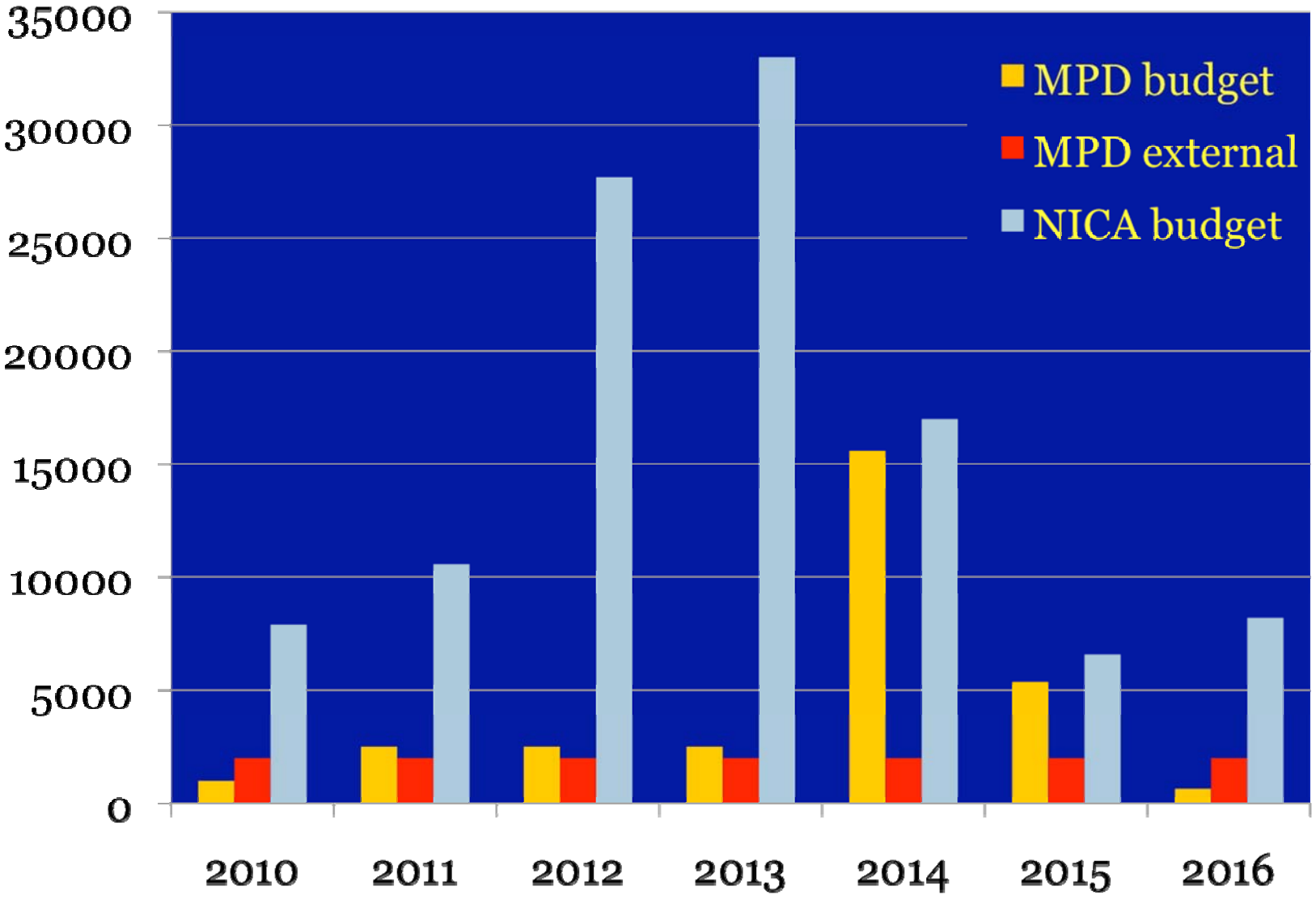
Detailed information on the NICA / MPD projects will be presented at the conference by

I. Meshkov & O. Rogachevsky

Thank you

Spares

Resources for NICA & MPD, in k$



Extracted beam	Max T_{kin} , GeV/u	Max $\sqrt{S_{NN}}$, GeV/u
proton (Z/A=1)	11.0	5.0
deutron (Z/A=1/2)	5.1	3.6
Au (Z/A=0.4)	3.9	3.3

STAR Run10 Physics Programs

Beam Energy (GeV)	29 cryo-week	STAR BUR In days	Physics
200	11 1/2 - 3/18	56	
62.4	4 3/20 - 4/17	0	
39	1.5 4/8 – 4/21	5 (24M)	BES programs (1) QCD T_E (2) QCD phase boundary
27		15 (33M)	
18		16 (15M)	
11.5	2 6/7 - 21	19 (5M)	
7.7	4 4/21 – 5/31	56 (5M)	
5.5	0.5 6/2 - 5	5 (0.1M)	

Weekly planning info: *http://www.c-ad.bnl.gov/esfd/RMEM_10/rhic_planning.htm*

Round Table IV & the NICA White Paper

86 authors *from* **39 scientific centers** *in* **15 Countries (8 JINR members)**

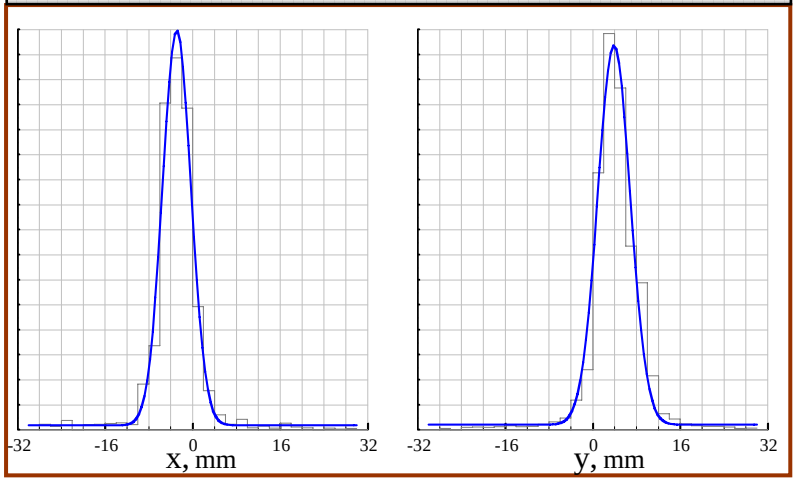
Arizona State University, USA

NICA Round Table IV (9 September 2009)

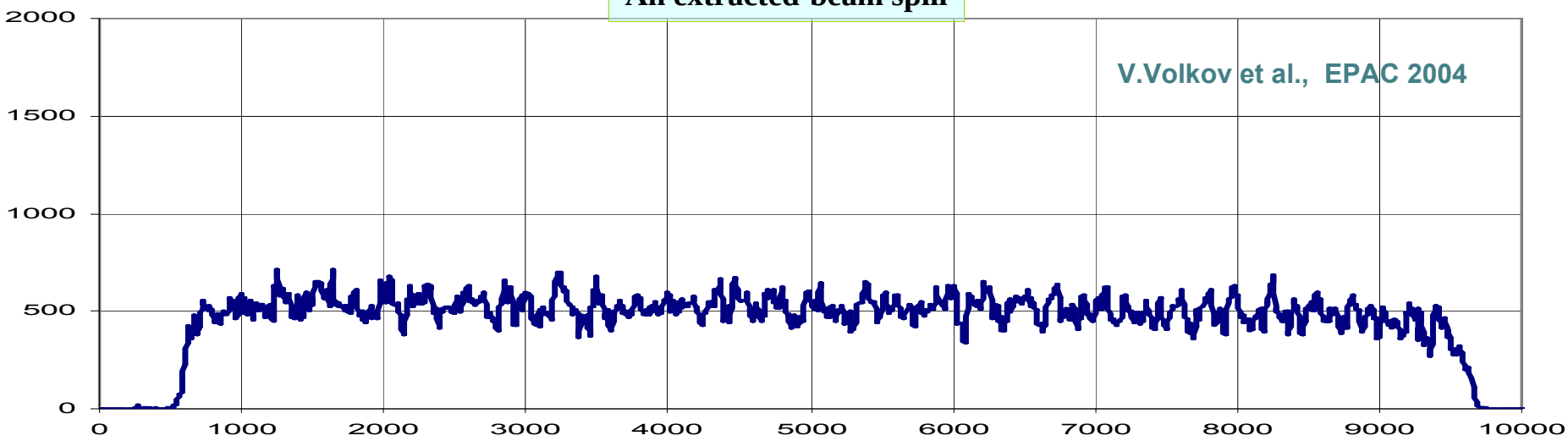
Nuclotron slow extraction

Parameter	@	Units	Value
Momentum range	Z/A = 1/2	Gev/c/amu	0.6 – 6.8
Momentum spread, σ		%	0.04 – 0.08
Extraction time		sec	10
Beam emittance	P_{max}	mm·mr	2π
Beam size in a waist, σ	P_{max}	mm	≤ 1
Extraction efficiency		%	> 90
Beams	p, d, d↑, α, ^{6,7}Li, ^{10,11}B, ^{12}C, ^{14}N, ^{24}Mg, ^{56}Fe		

Beam profiles at the F_5 focus.
Deuterons, p_{beam} = 4.3 GeV/c, σ_x = 2.6 mm, σ_y = 3.0 mm

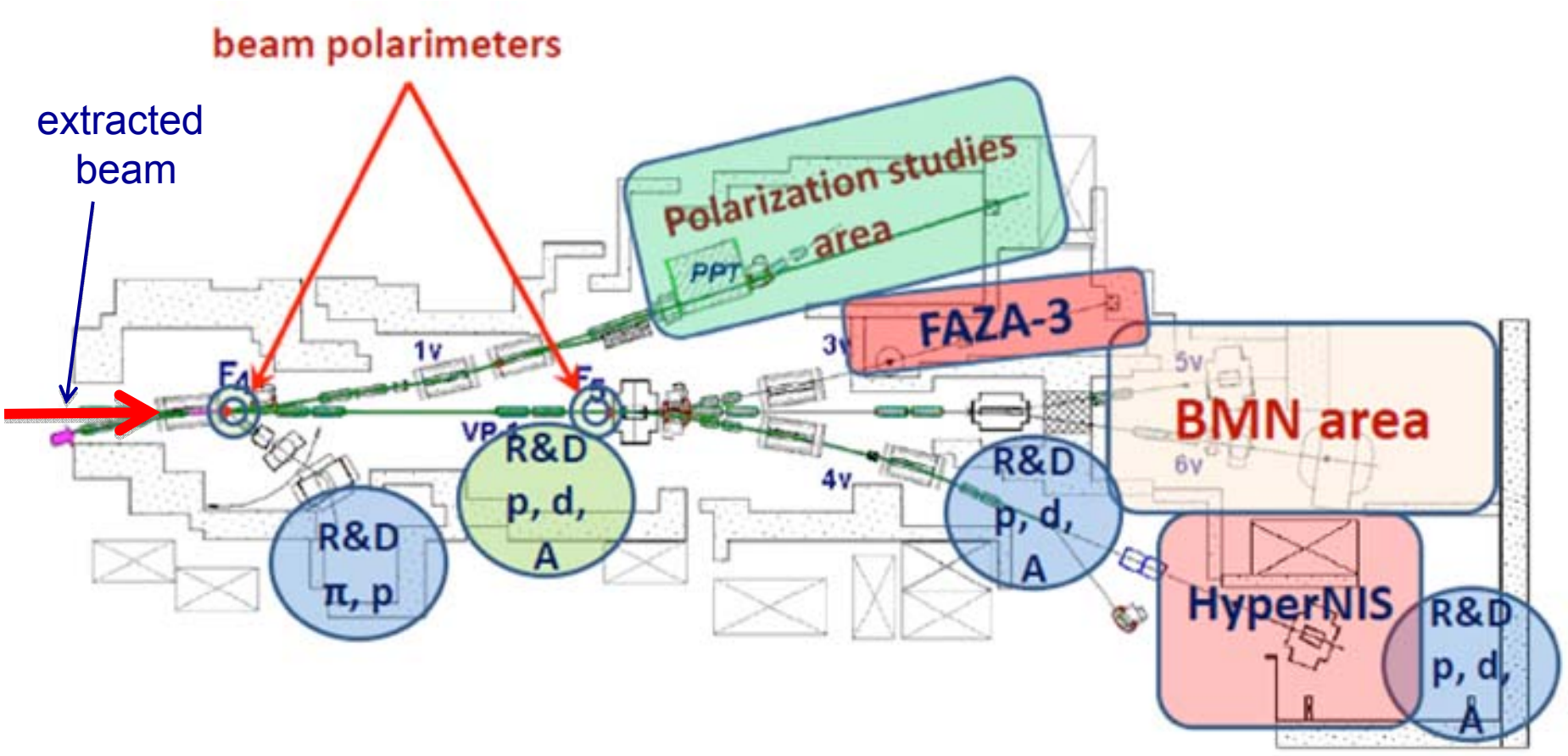


An extracted beam spill



Slide from P.Rukoyatkin

Fixed Target Experiment Area *(bld. 205)*



Femtoscopy correlation studies @ NICA

play a crucial role in the study of space-time aspects of the system:

- **high statistics, uniform acceptance, excellent PID required**
- **multidimensional fit technique has to be applied**

STAR

- **$4 \cdot 10^6$ min. bias events (200k central) in 2010 LES run**
  →10% precision for $\pi\pi$ correlation

MPD/NICA

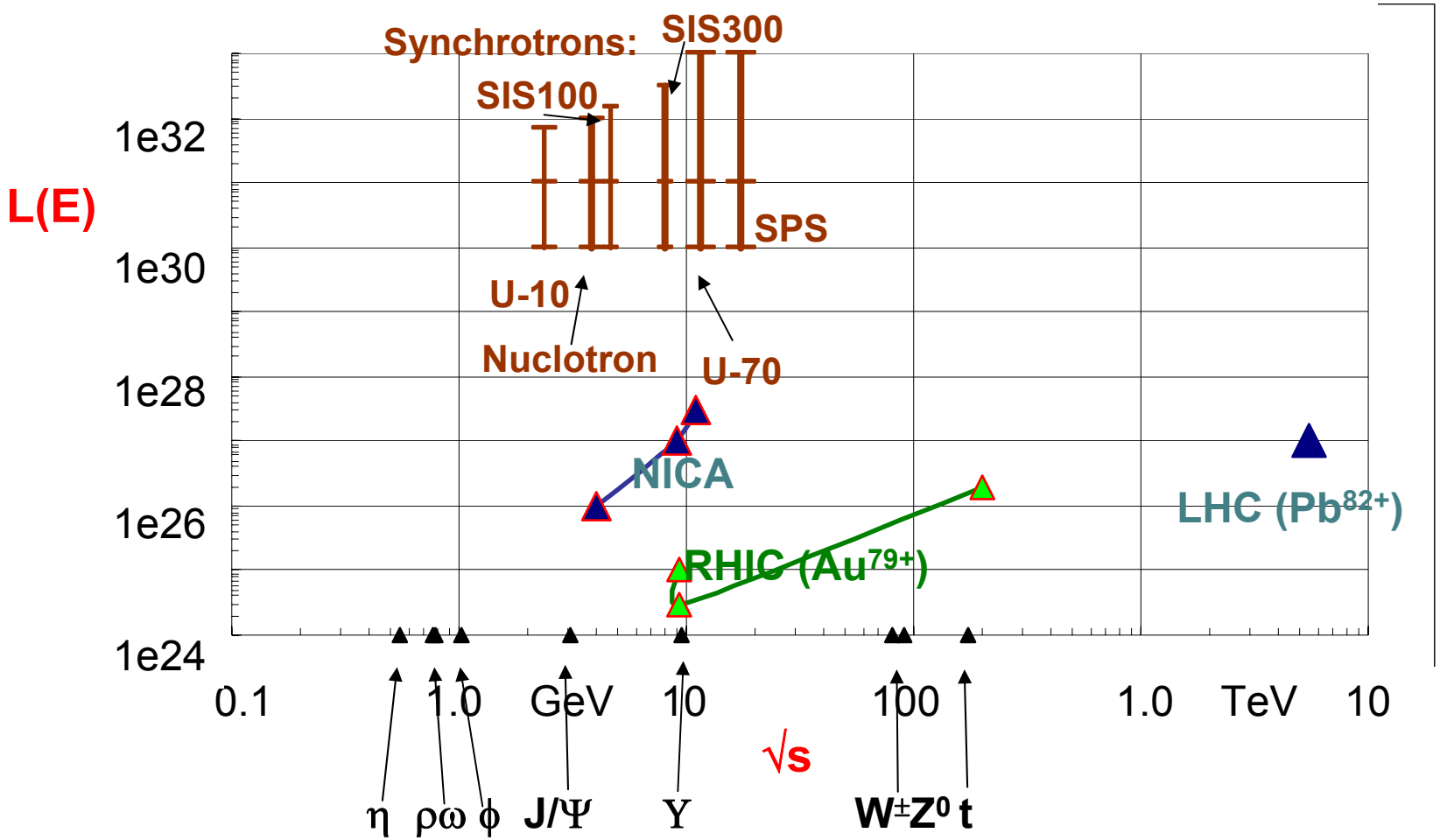
- **10^9 min. bias events/week (10^8 central) best precision for:**
  - **femtoscopy with respect to RP**
  - **correlation of multistrange particles**

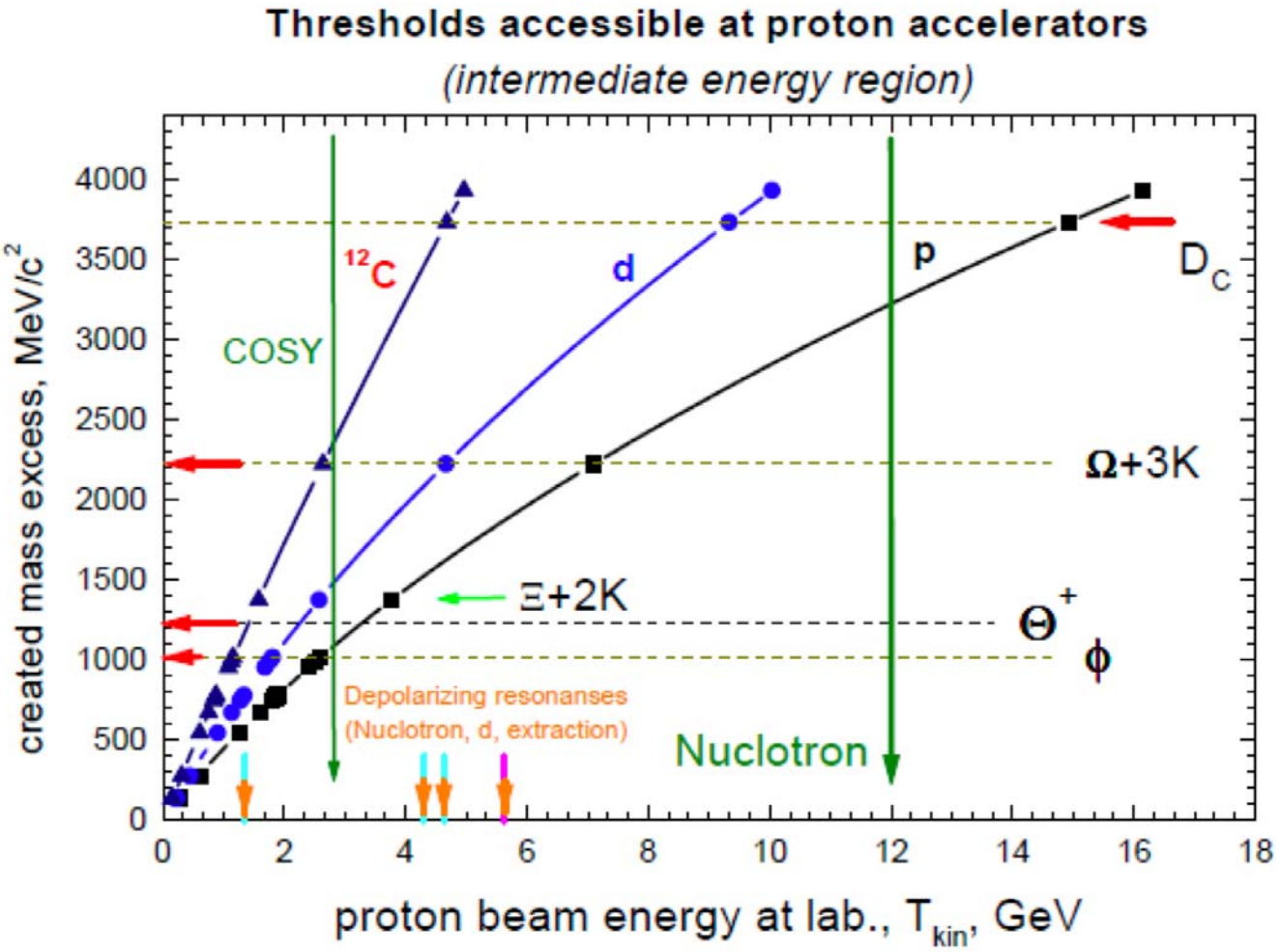
Table 1.3: Two-particle systems which, in principle, can be measured in the NICA energy range.

	π^+	π^-	π^0	K^+	K^-	K^0	p	n	Λ	$\overline{\Lambda}$	Ξ
π^+	+	+	+	+	+	+	+	+	+	+	+
π^-		+	+	+	+	+	+	+	+	+	+
π^0			+	+	+	+	+	+	+	+	+
K^+				+	+	+	+	+	+		
K^-					+	+	+	+	+		
K^0						+	+	+	+		
p							+	+	+		
n								+	+		
Λ									+		
$\overline{\Lambda}$											
Ξ											

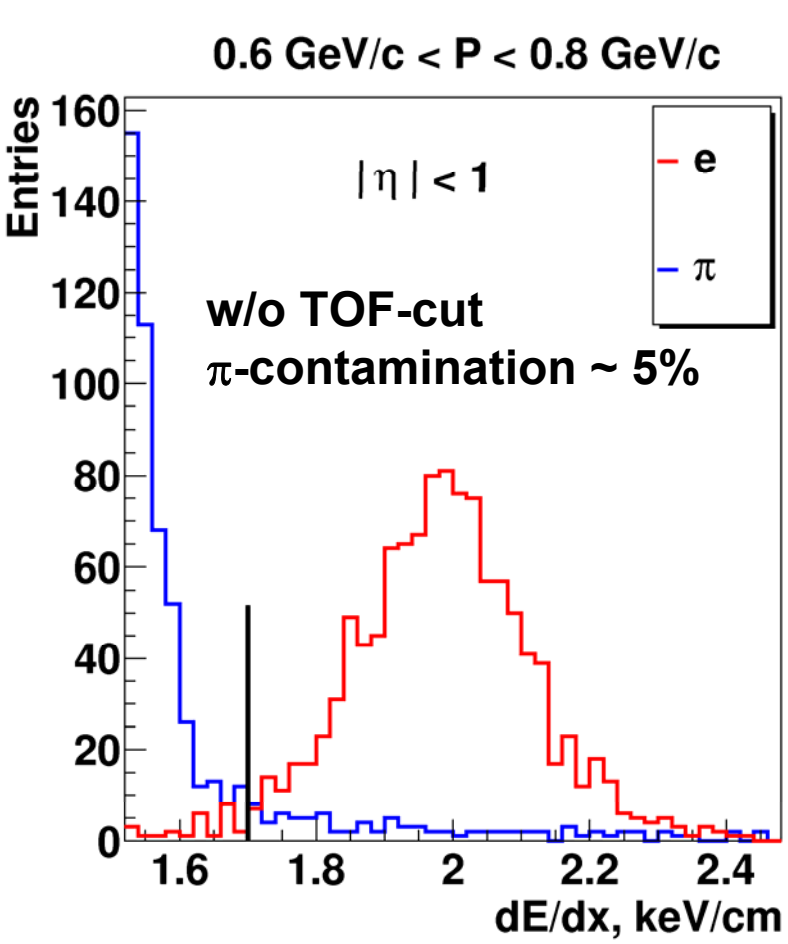
Relativistic Nuclear Physics

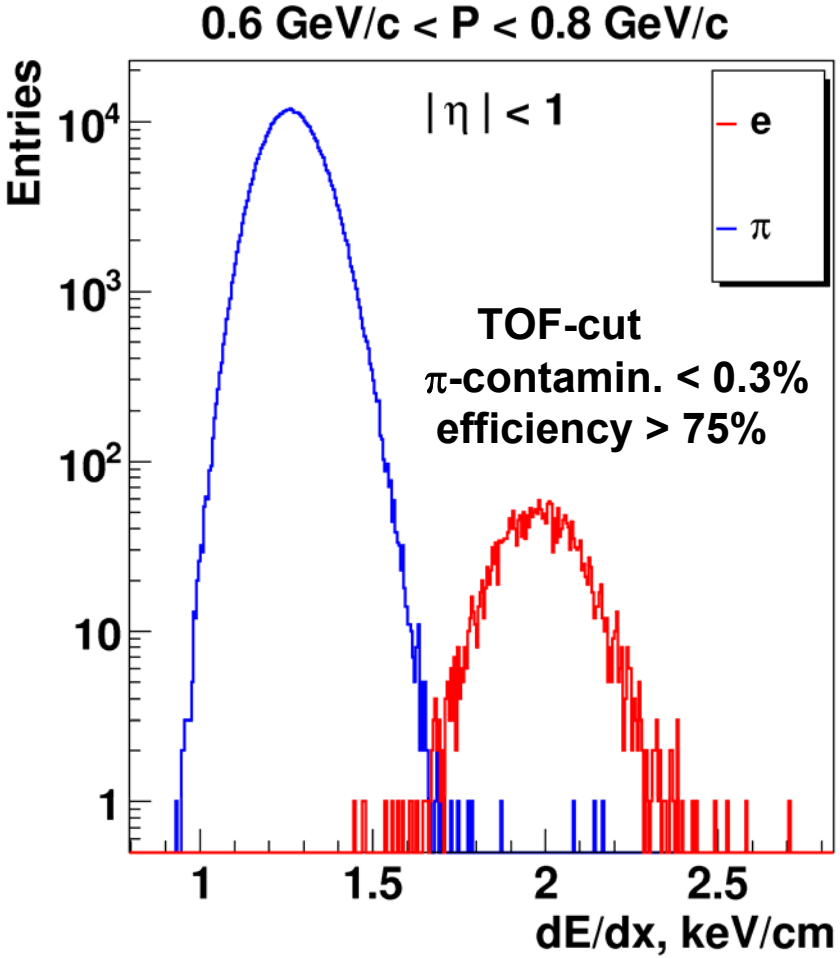
Colliders & Synchrotrons: Luminosity vs Energy (√s)




Thresholds accessible at proton accelerators
(intermediate energy region)
created mass excess, MeV/c²
proton beam energy at lab., T_kin, GeV
¹²C
d
p
D_C
COSY
Ω+3K
Ξ+2K
Θ⁺
ϕ
Depolarizing resonanses
(Nuclotron, d, extraction)
Nuclotron
0
500
1000
1500
2000
2500
3000
3500
4000
0
2
4
6
8
10
12
14
16
18

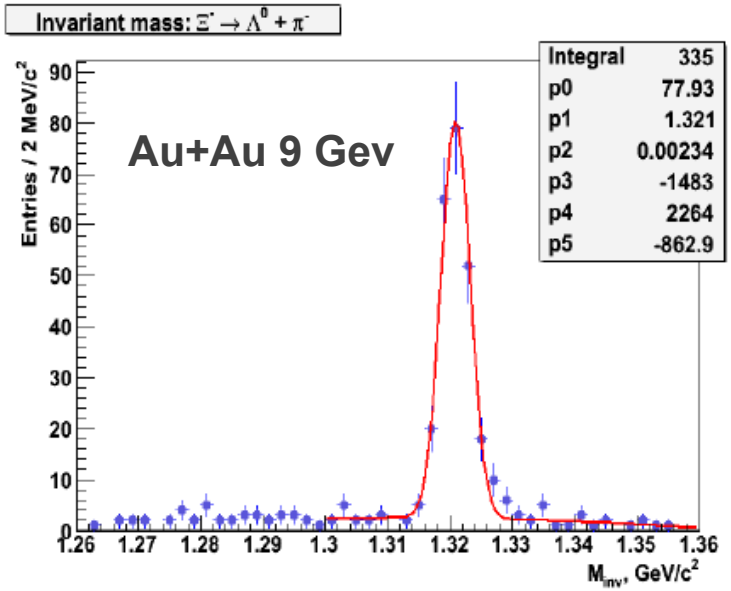
Electron identification



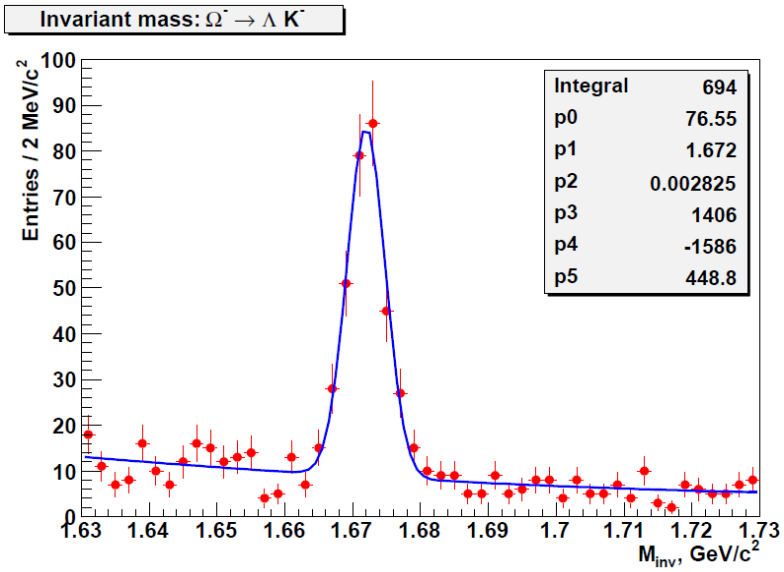


- Rejection of protons, kaons and most of pions by TOF
- π contamination in the e^{+-} sample < 0.3%
- ECAL provides extra suppression factor

Hyperon reconstruction



Eff. ≈ 3.8%
S / B (±3σ) = 245 / 18 ≈ 13.7
S / √(S+B) ≈ 15.1



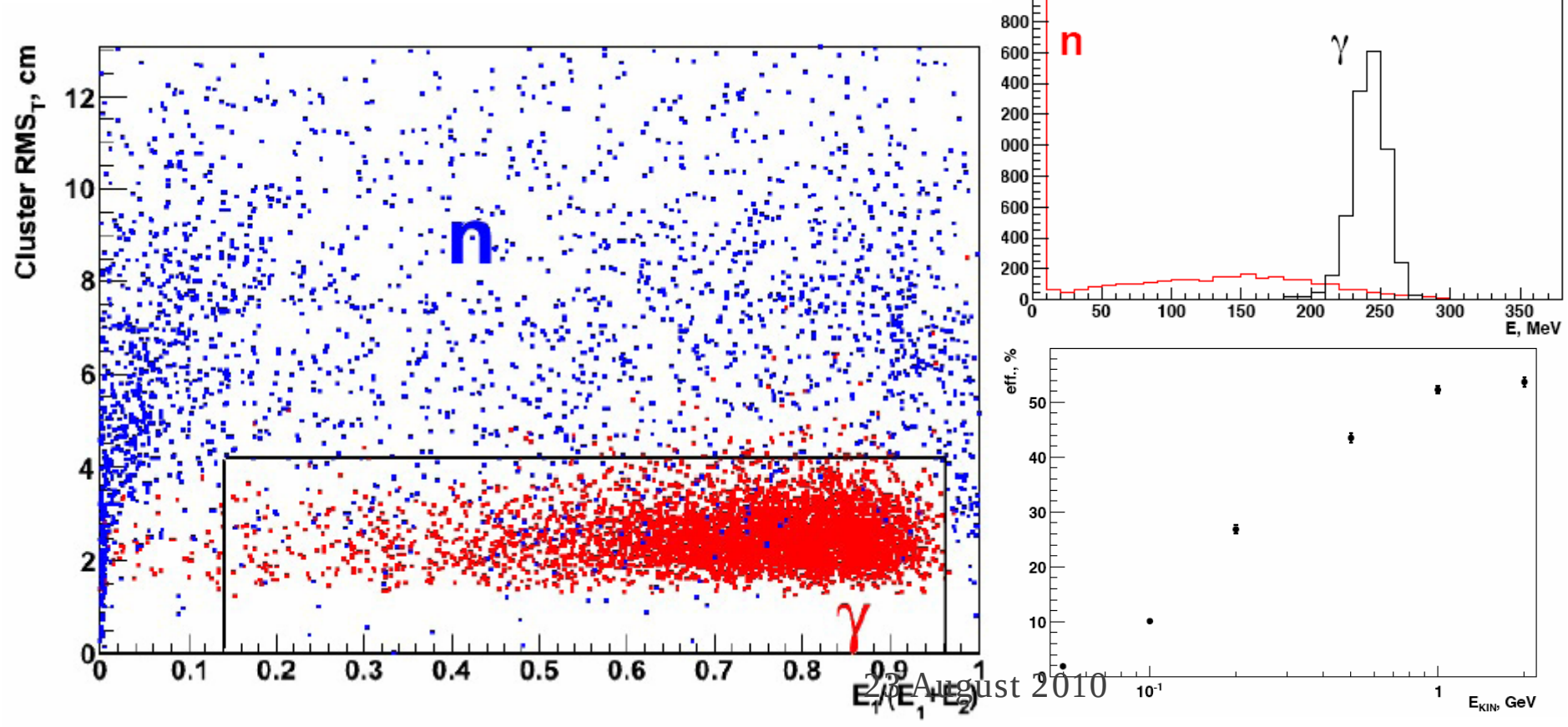
Eff. ≈ 2.1%
S / B (±3σ) = 286 / 59 ≈ 4.9
S / √(S+B) ≈ 15.4

Excellent capabilities for hyperon measurements!

n/γ separation efficiency

by using information on X-Y(transverse) and Z (longitudinal) shapes of profiles of the cluster in the ECal

Efficiency of neutron identification - 95% with 3% admixture of photons



Beam	Nuclotron beam intensity (particle per cycle)				
	Current	Ion source type	Nuclotron-M (2010)	Nuclotron-N (2012)	New ion source + booster (2013)
p	$3 \cdot 10^{10}$	Duoplasmotron	$8 \cdot 10^{10}$	$5 \cdot 10^{11}$	$5 \cdot 10^{12}$
d	$3 \cdot 10^{10}$	--- ,, ---	$8 \cdot 10^{10}$	$5 \cdot 10^{11}$	$5 \cdot 10^{12}$
^{4}He	$8 \cdot 10^{8}$	--- ,, ---	$3 \cdot 10^{9}$	$3 \cdot 10^{10}$	$1 \cdot 10^{12}$
d↑	$2 \cdot 10^{8}$	ABS ("Polaris")	$2 \cdot 10^{8}$	$1 \cdot 10^{10}$ *(SPI)*	$1 \cdot 10^{10}$ *(SPI)*
^{7}Li	$8 \cdot 10^{8}$	Laser	$5 \cdot 10^{9}$	$3 \cdot 10^{10}$	$5 \cdot 10^{11}$
^{11,10}B	$1 \cdot 10^{9,8}$	--- ,, ---	$2 \cdot 10^{9,8}$	$2 \cdot 10^{10,9}$	
^{12}C	$1 \cdot 10^{9}$	--- ,, ---	$3 \cdot 10^{9}$	$2 \cdot 10^{10}$	$2 \cdot 10^{11}$
^{24}Mg	$2 \cdot 10^{7}$	--- ,, ---	$2 \cdot 10^{8}$	$1 \cdot 10^{9}$	
^{14}N	$1 \cdot 10^{7}$	ESIS ("Krion-2")	$3 \cdot 10^{7}$	$3 \cdot 10^{8}$	$5 \cdot 10^{10}$
^{24}Ar	$1 \cdot 10^{9}$	--- ,, ---	$3 \cdot 10^{9}$	$2 \cdot 10^{10}$	$2 \cdot 10^{11}$
^{56}Fe	$2 \cdot 10^{6}$	--- ,, ---	$6 \cdot 10^{6}$	$1 \cdot 10^{8}$	$5 \cdot 10^{10}$
^{84}Kr	$1 \cdot 10^{4}$	--- ,, ---	10^{5}	$1 \cdot 10^{7}$	$1 \cdot 10^{9}$
^{124}Xe	$1 \cdot 10^{4}$	--- ,, ---	10^{5}	$1 \cdot 10^{7}$	$1 \cdot 10^{9}$
^{197}Au	-	--- ,, ---		$1 \cdot 10^{7}$	$1 \cdot 10^{9}$