Fixed Targets physics @ Nuclotron

V.Kekelidze at RT-V, 2010

28 August 2010

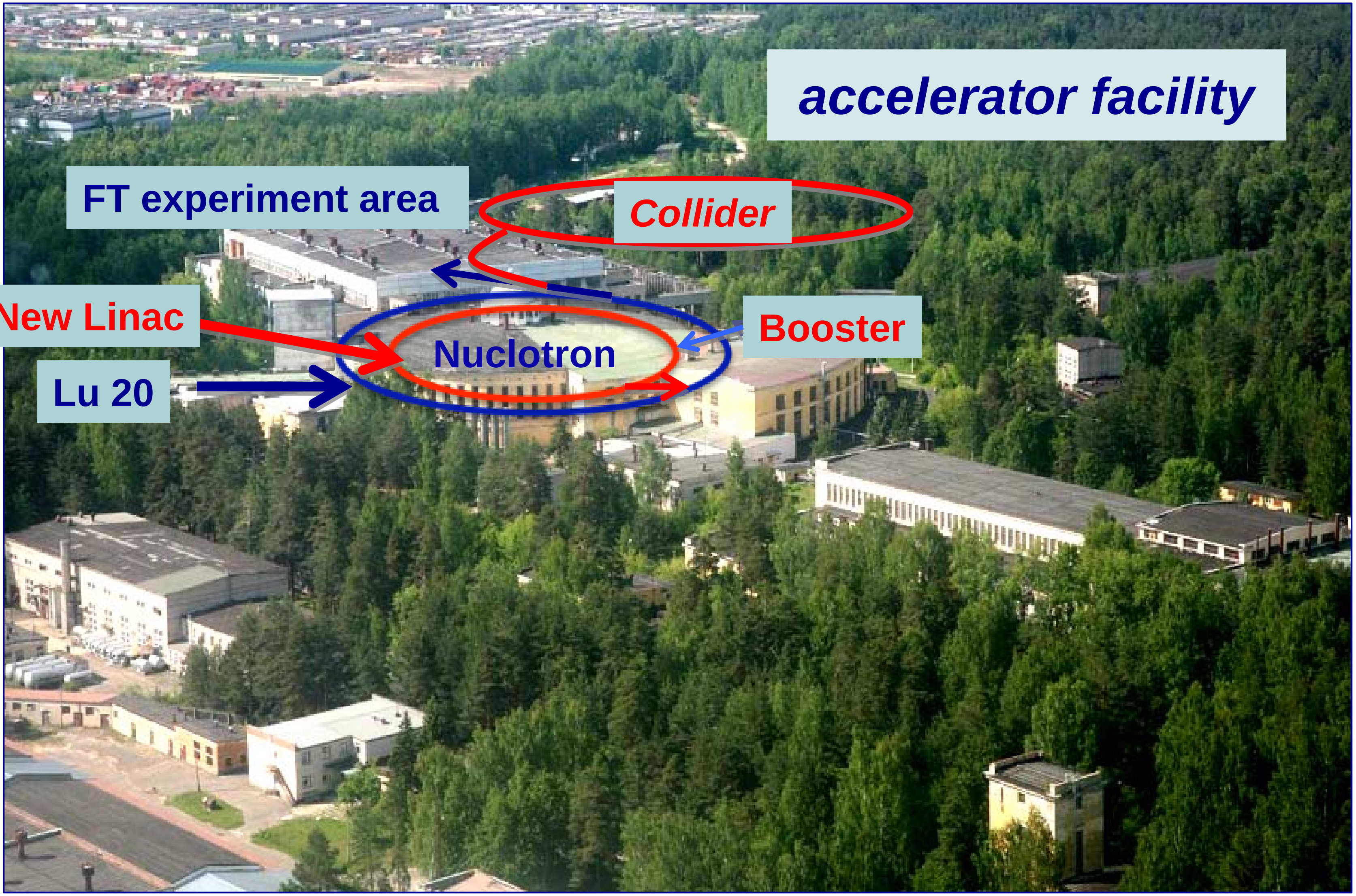
Nuclotron – the JINR basic facility in HEP

- *in operation since **1993***
  in Veksler & Baldin Laboratoty of High Energy Physics (VBLHEP)
- based on the unique technology of
  super-conducting fast cycling magnets *developed in JINR*
- provides proton, **polarized** deuteron & **multi charged** ion beams

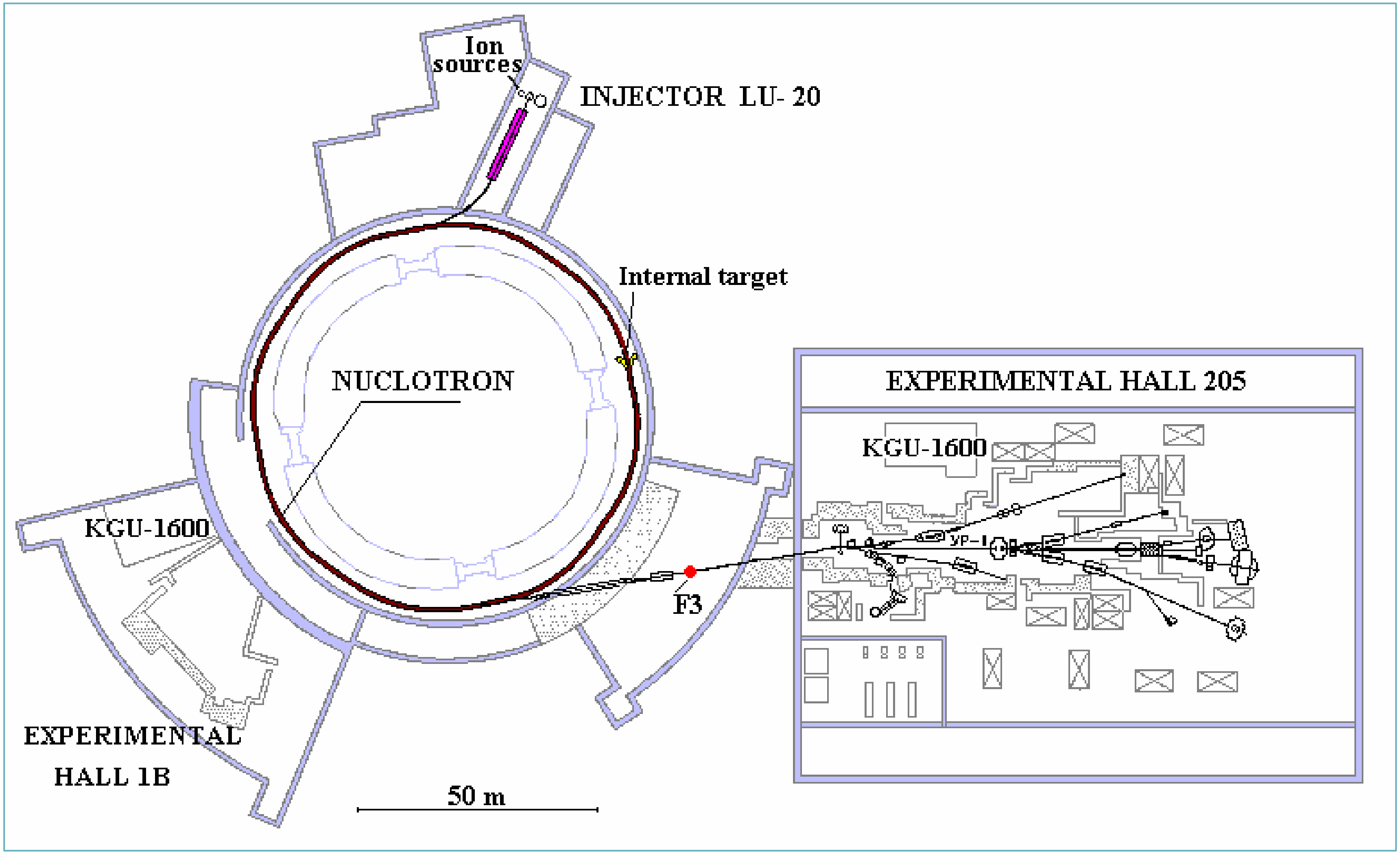
Nuclotron development plans:

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

Veksler & Baldin Laboratory of High Energy Physics



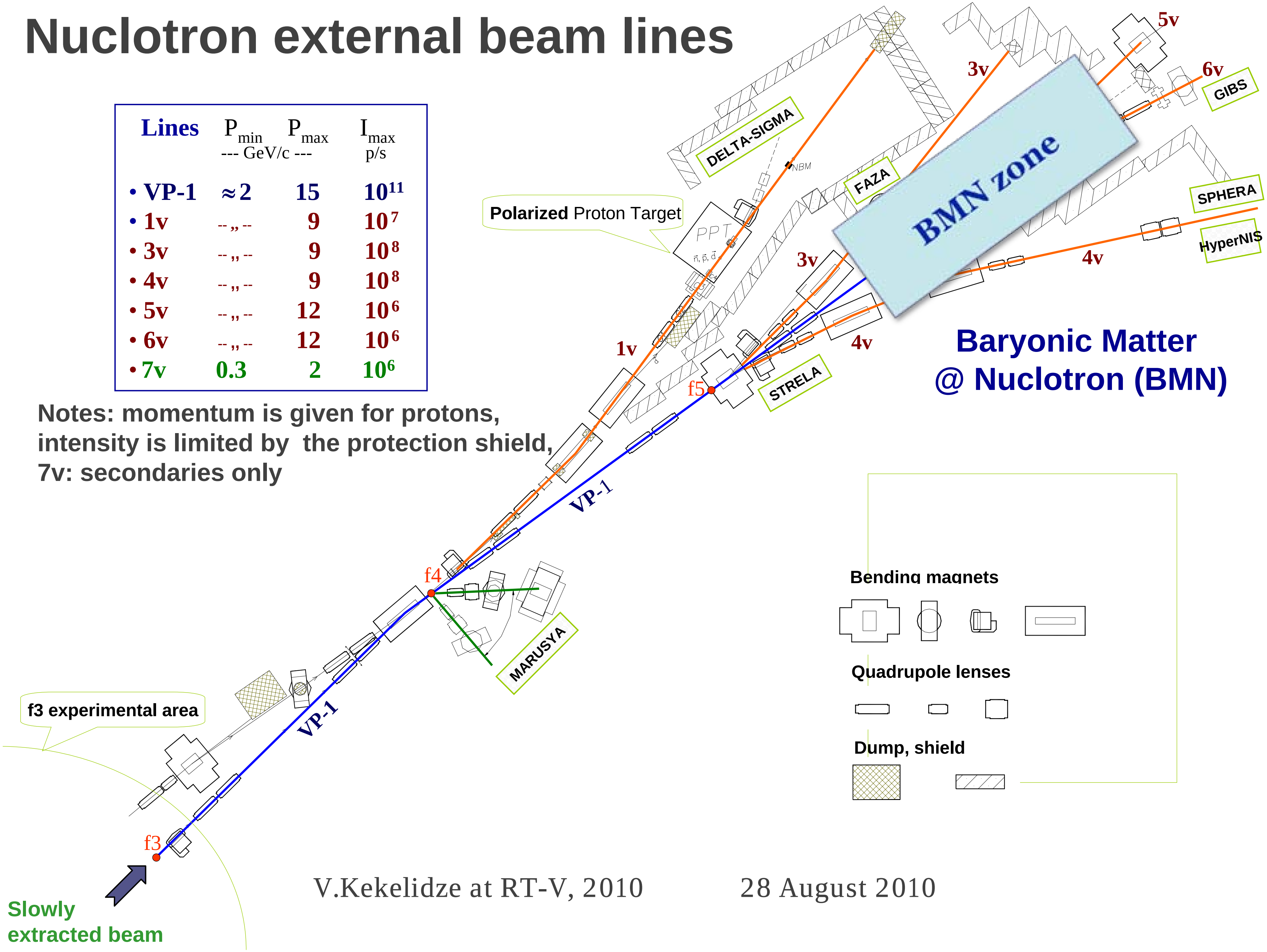
The plan of Nuclotron and experimental zones



Nuclotron external beam lines

Lines	P_{min}	P_{max}	I_{max}
	--- GeV/c ---		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



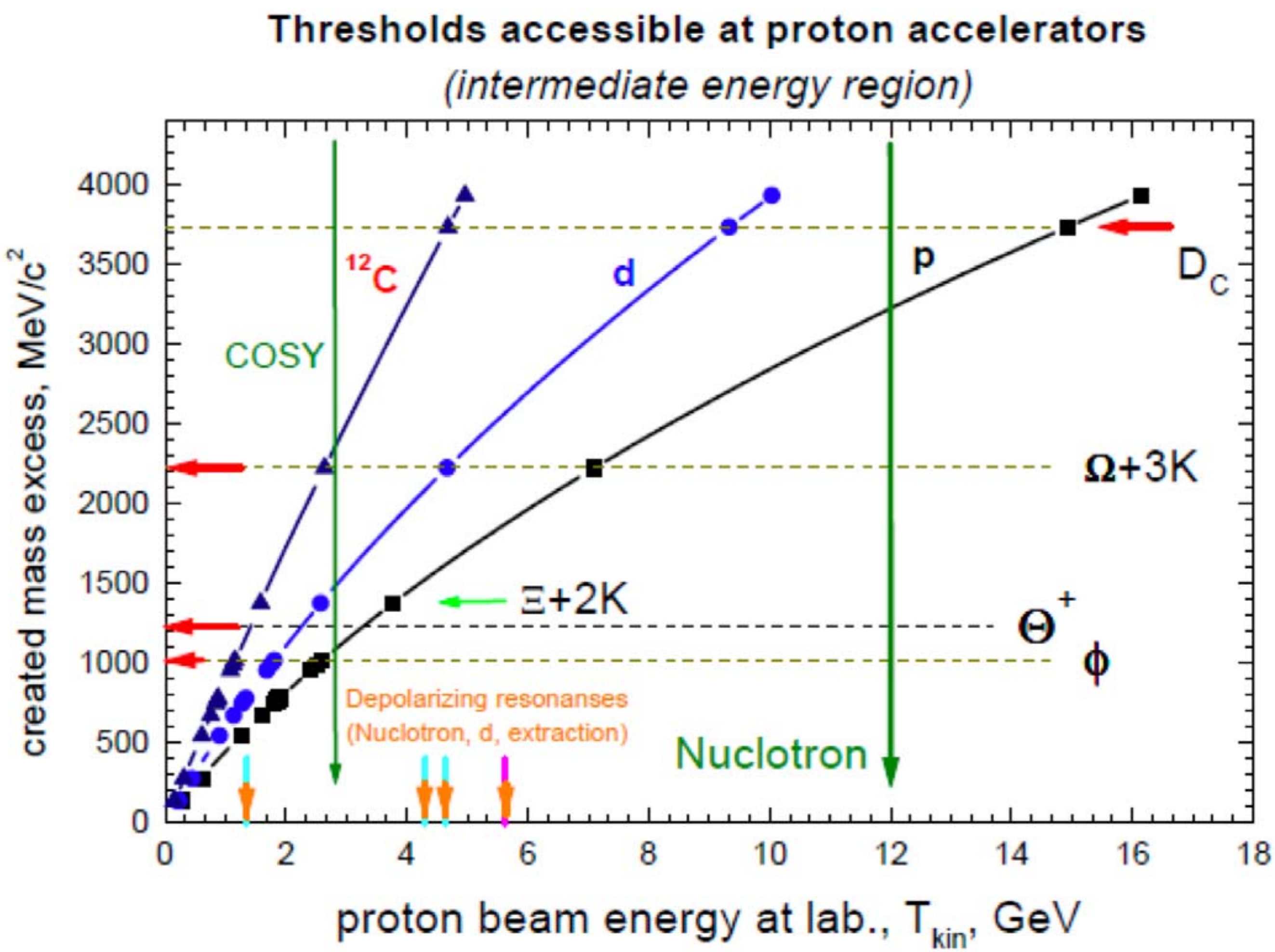
Experiments at Nuclotron-N* could cover the energy range between SIS-18 and AGS

Extracted beam	Max T_{kin} , GeV/u
proton (Z/A=1)	12.0
deutron (Z/A=1/2)	6.0
Au (Z/A=0.4)	4.56

The various beams extracted from Nuclotron are *(will be)* available:

protons, deutrons, neutrons, ions (up to Au),
polarized protons & deutrons
& (in principle) polarized neutrons

Physics program is complementary to ones at NICA/MPD, SPD


Thresholds accessible at proton accelerators
(intermediate energy region)
created mass excess, MeV/c²
proton beam energy at lab., T_kin, GeV
COSY
Nuclotron
¹²C
d
p
D_C
Ω+3K
Ξ+2K
Θ⁺
φ
Depolarizing resonanses
(Nuclotron, d, extraction)

➢ **BMN (Bronic Matter @ Nuclotron)**

The physics at BNM includes:

- ❑ ***AA-interactions***
  - *particle production, including sub-threshold production;*
  - *studies of particle (collective) flows,*
    even-by-event fluctuations, correlations
  - *phase space distribution of **p, n, pi, K**, **hyperon**s,*
    light nuclear fragments**, **vector mesons, resonances
  - *ratios of yields (**pi/K**) in different kinematic regions*

- ❑ **pA, nA, dA interactions in direct & inverse (Ap, Ad) kinematics**
  - *to get a "reference" data set for comparison with **AA***
  - *to study particle modifications in hadronic matter*
  - *to study of polarization effects in particle production*
    *off nuclear target by polarized **d, p, n**.*

- **FAZA-3** **(running experiment, physics complementary to BMN)**
  - *study of phase transition: “liquid-fog” <--> “liquid-gas”*
  - *study of cold dense baryonic matter with a special cumulative trigger*
  - *correlation experiments on nuclear multifragmentation in coincidence with cumulative neutrals (including pions & photons)*

- **HyperNIS** ***(study of strangeness in nuclei & nucleons)***
  - *study of lightest hyper-nuclei & their properties*
  - *search for effects of hidden strangeness in nucleon*
  - *study of mechanisms of strangeness production near thresholds & low energy parameters for hyperon-nucleon interactions*
  - *study of binary reactions like pd 3He+meson (π, η, ω, ϕ) etc. using polarized* ***d*** *&* ***n*** *beams*
  - *study of strangeness propagation in hadronic medium (direct & inverse kinematics)*
  - *study of K-mesons in nuclear medium*

➢ Spin physics at Nuclotron:

- *Structure of light nuclei using spin-dependent observables (analyzing powers, spin-spin correlations)*
- *Polarization effects in sub-threshold particle production*
- *Polarization effects (asymmetries, spin-spin correlations) in inclusive particle production (π, K, hyperons etc.) in dependence on transverse momentum using polarized beams polarized target*
- *Polarization effects (asymmetries) in meson production in "cumulative" region*
- *Polarization effects in elastic & binary reactions (to complete the world NN data base)*
- *Use of polarized beams to calibrate polarimeters for multi-GeV region for other experiments*

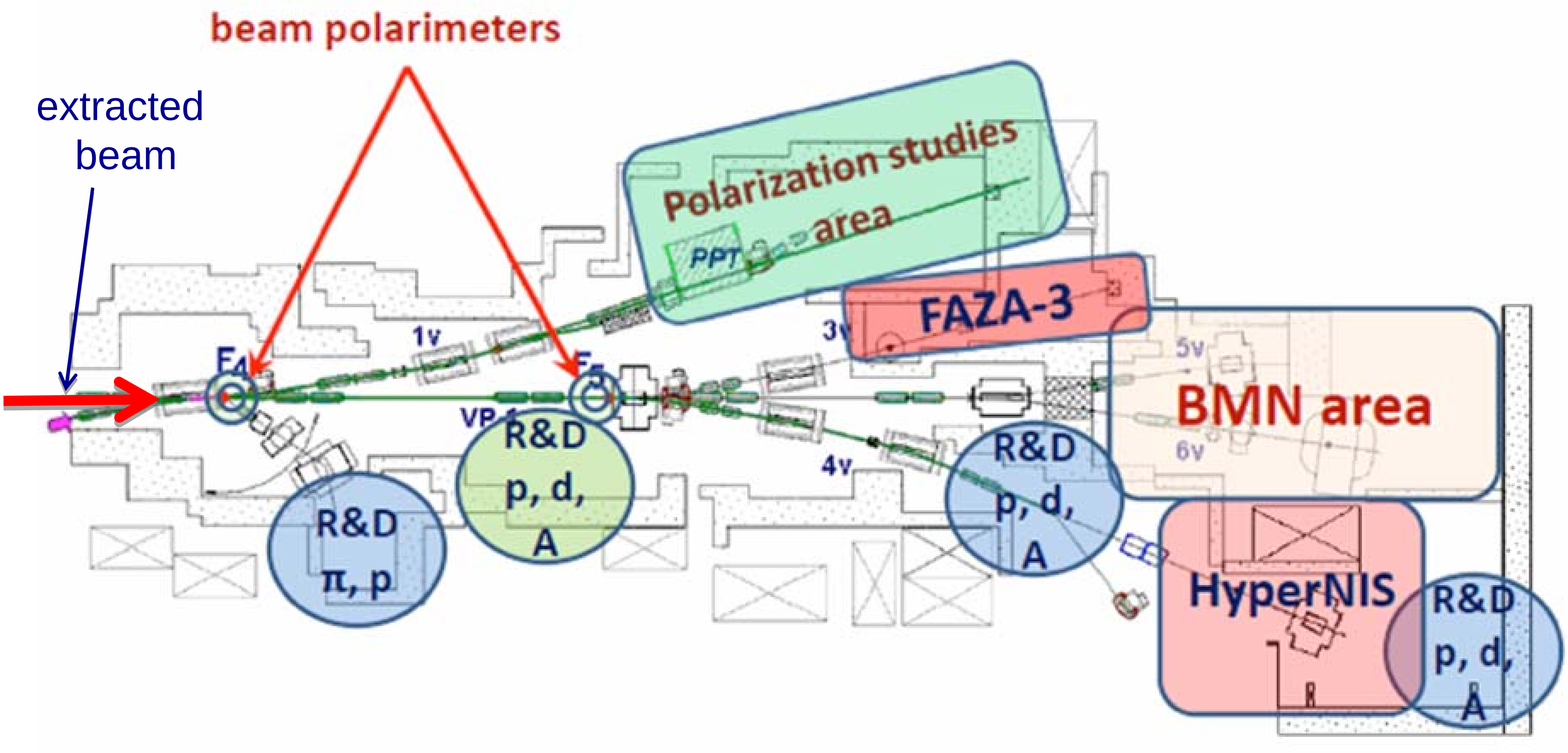
Baryonic Matter @ Nuclotron (BMN)

Schedule *(preliminary)*

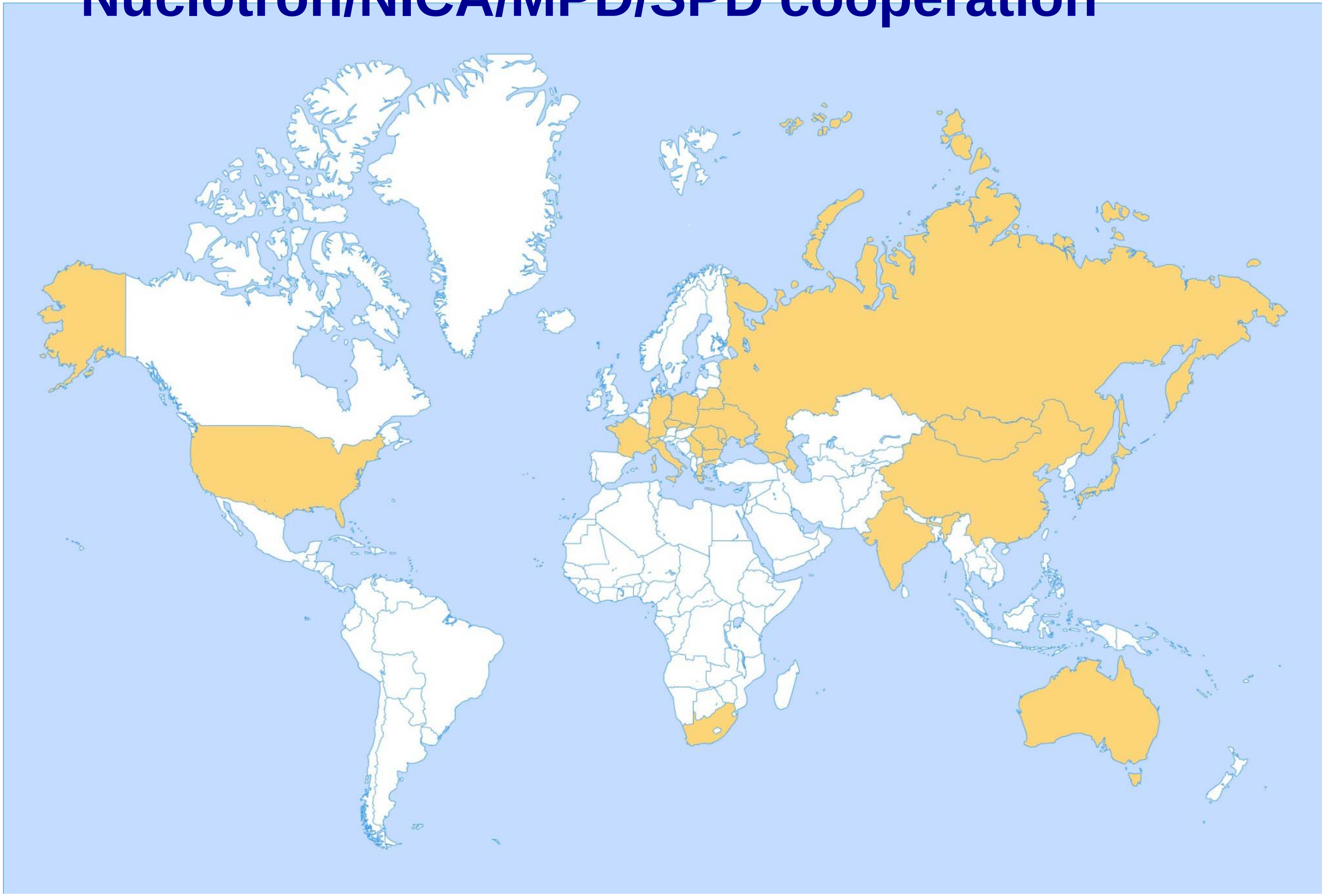
- Start of project preparation 2010
- presentation for the consideration at PAC 2011
- Experimental area preparation 2012

  major sub-detectors for the starting kit are prototyped and mounted
- DMN starting kit commissioning 2013
- Start of physics runs 2014

Fixed Target Experiment Area *(bld. 205)*



Nuclotron/NICA/MPD/SPD cooperation



Summary

- **Physics program to study baryonic matter at Nuclotron Fixed Target facility has started to develop**
  - *complementary to ones at **NICA/MPD**, **SPD***

- **The 1st stage of BMN could start running in 2014**

- **Some extracted beams are available already now *for both: physics & facility tests***

- **The interested groups are invited *to prepare proposals***

Thank you

Spares

Physical program of experiments at extracted Nuclotron beams has 2 blocks:

before NICA starts to operate *(considered here)*

after start of experiments with NICA/MPD

Therefore, as the main directions, the following options are being considered:

study of dense baryonic matter at temperatures up to 100 MeV,

(multi)-strangeness (open and hidden) production in dense baryonic matter,

modification of particle properties in dense nuclear matter.

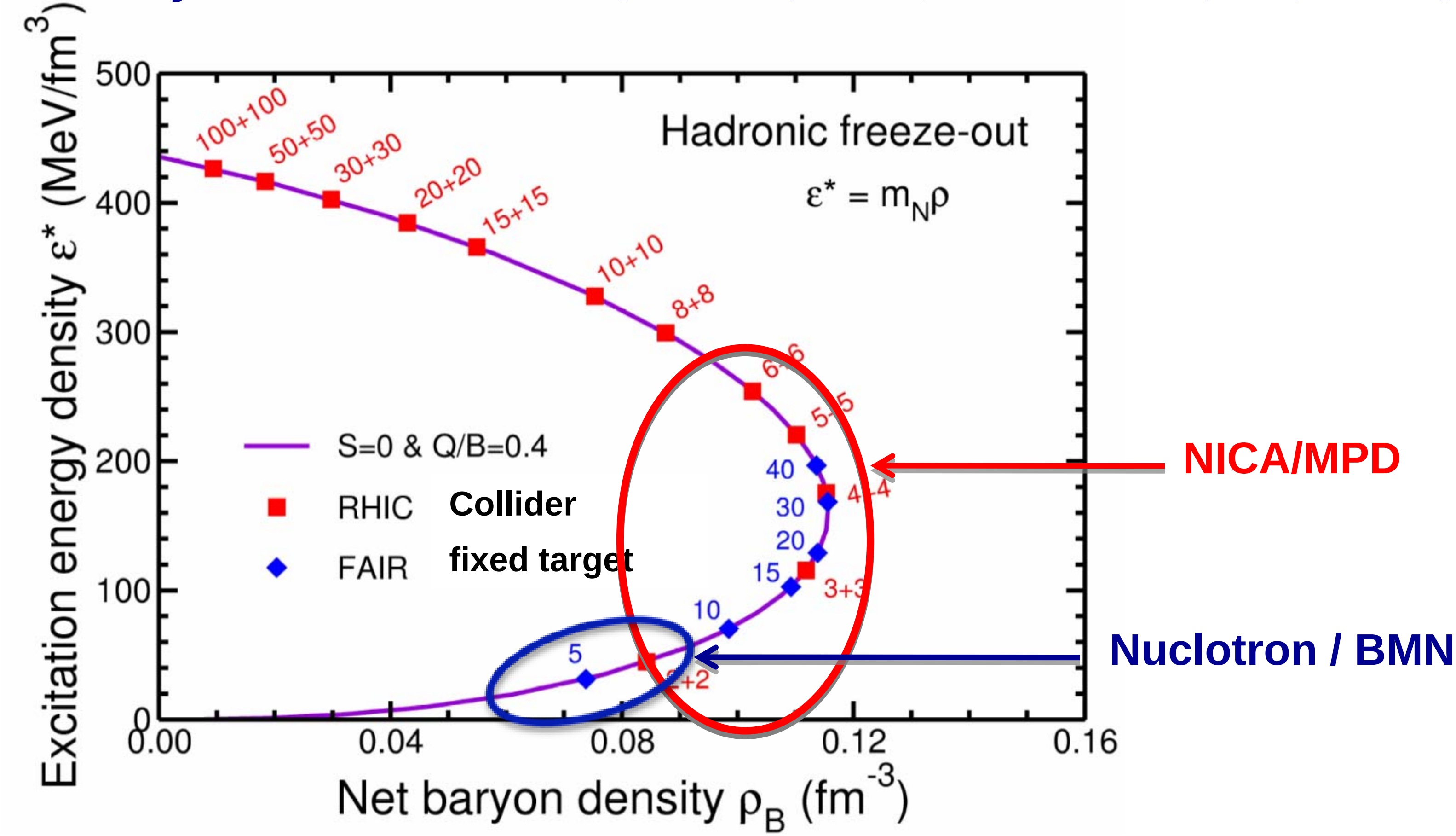
The corresponding multi-purpose setup (Baryonic Matter at Nuclotron, or BMN)
will be used as the main instrument.
Some of experiments presently running in the building 205
could be used for some specific physics tasks

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*

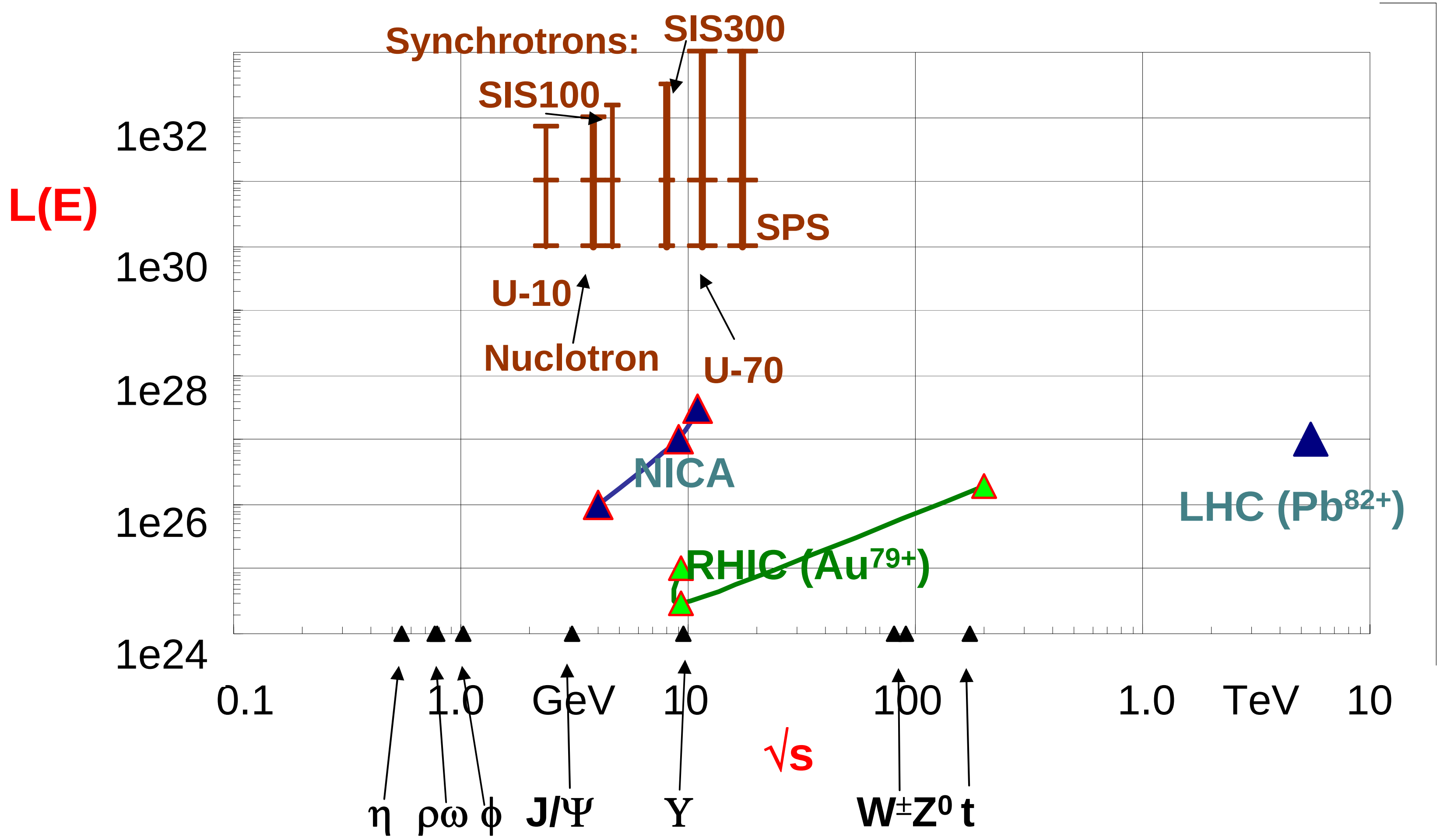
→ **heavy ion collision at $\sqrt{S_{NN}}$ = 4 - 11 GeV/u**

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



Relativistic Nuclear Physics

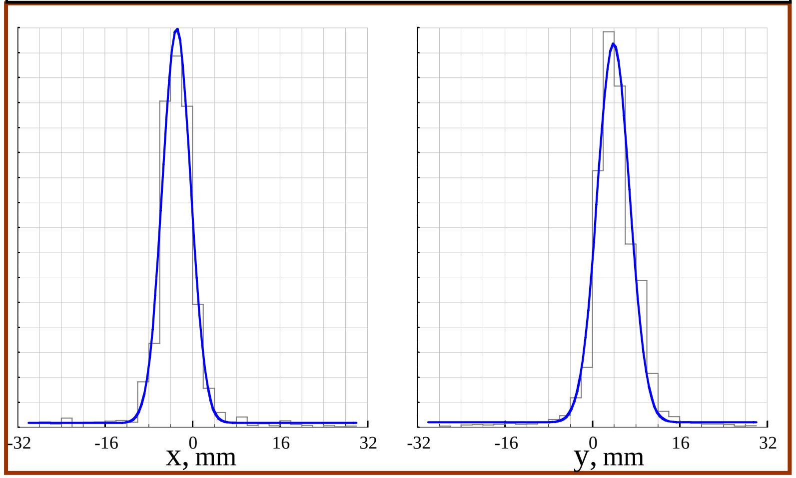
Colliders & Synchrotrons: Luminosity vs Energy (√s)

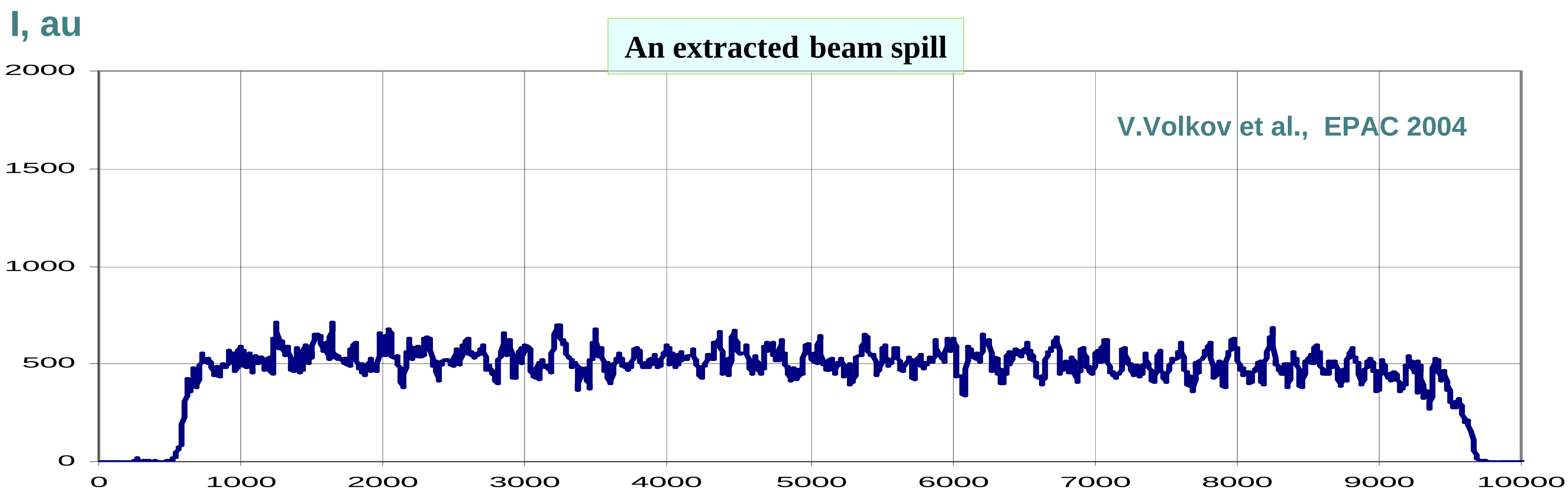


Nuclotron slow extraction

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





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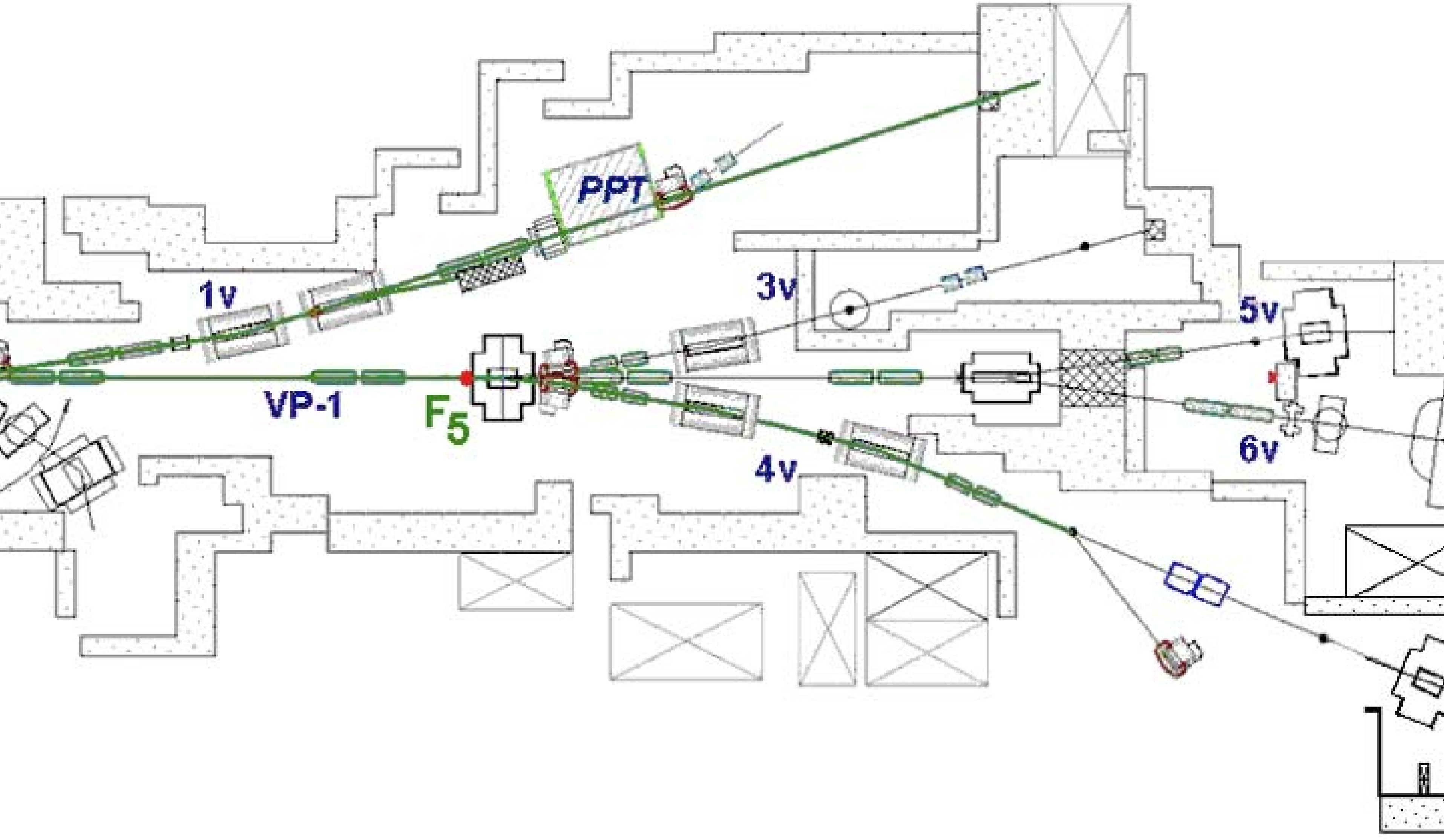
Slide from P.Rukoyatkin

Beam	Nuclotron beam intensity (particle per cycle)				
	Current	Ion source type	Nuclotron-M (2010)	Nuclotron-N (2012)	New ion source + booster (2013)
p	$3\cdot10^{10}$	Duoplasmotron	$8\cdot10^{10}$	$5\cdot10^{11}$	$5\cdot10^{12}$
d	$3\cdot10^{10}$	--- „ ---	$8\cdot10^{10}$	$5\cdot10^{11}$	$5\cdot10^{12}$
^{4}He	$8\cdot10^{8}$	--- „ ---	$3\cdot10^{9}$	$3\cdot10^{10}$	$1\cdot10^{12}$
d↑	$2\cdot10^{8}$	ABS ("Polaris")	$2\cdot10^{8}$	$1\cdot10^{10}$ *(SPI)*	$1\cdot10^{10}$ *(SPI)*
^{7}Li	$8\cdot10^{8}$	Laser	$5\cdot10^{9}$	$3\cdot10^{10}$	$5\cdot10^{11}$
^{11,10}B	$1\cdot10^{9,8}$	--- „ ---	$2\cdot10^{9,8}$	$2\cdot10^{10,9}$	
^{12}C	$1\cdot10^{9}$	--- „ ---	$3\cdot10^{9}$	$2\cdot10^{10}$	$2\cdot10^{11}$
^{24}Mg	$2\cdot10^{7}$	--- „ ---	$2\cdot10^{8}$	$1\cdot10^{9}$	
^{14}N	$1\cdot10^{7}$	ESIS ("Krion-2")	$3\cdot10^{7}$	$3\cdot10^{8}$	$5\cdot10^{10}$
^{24}Ar	$1\cdot10^{9}$	--- „ ---	$3\cdot10^{9}$	$2\cdot10^{10}$	$2\cdot10^{11}$
^{56}Fe	$2\cdot10^{6}$	--- „ ---	$6\cdot10^{6}$	$1\cdot10^{8}$	$5\cdot10^{10}$
^{84}Kr	$1\cdot10^{4}$	--- „ ---	10^{5}	$1\cdot10^{7}$	$1\cdot10^{9}$
^{124}Xe	$1\cdot10^{4}$	--- „ ---	10^{5}	$1\cdot10^{7}$	$1\cdot10^{9}$
^{197}Au	-	--- „ ---		$1\cdot10^{7}$	$1\cdot10^{9}$

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



PPT
1v
3v
5v
VP-1
F5
6v
4v

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