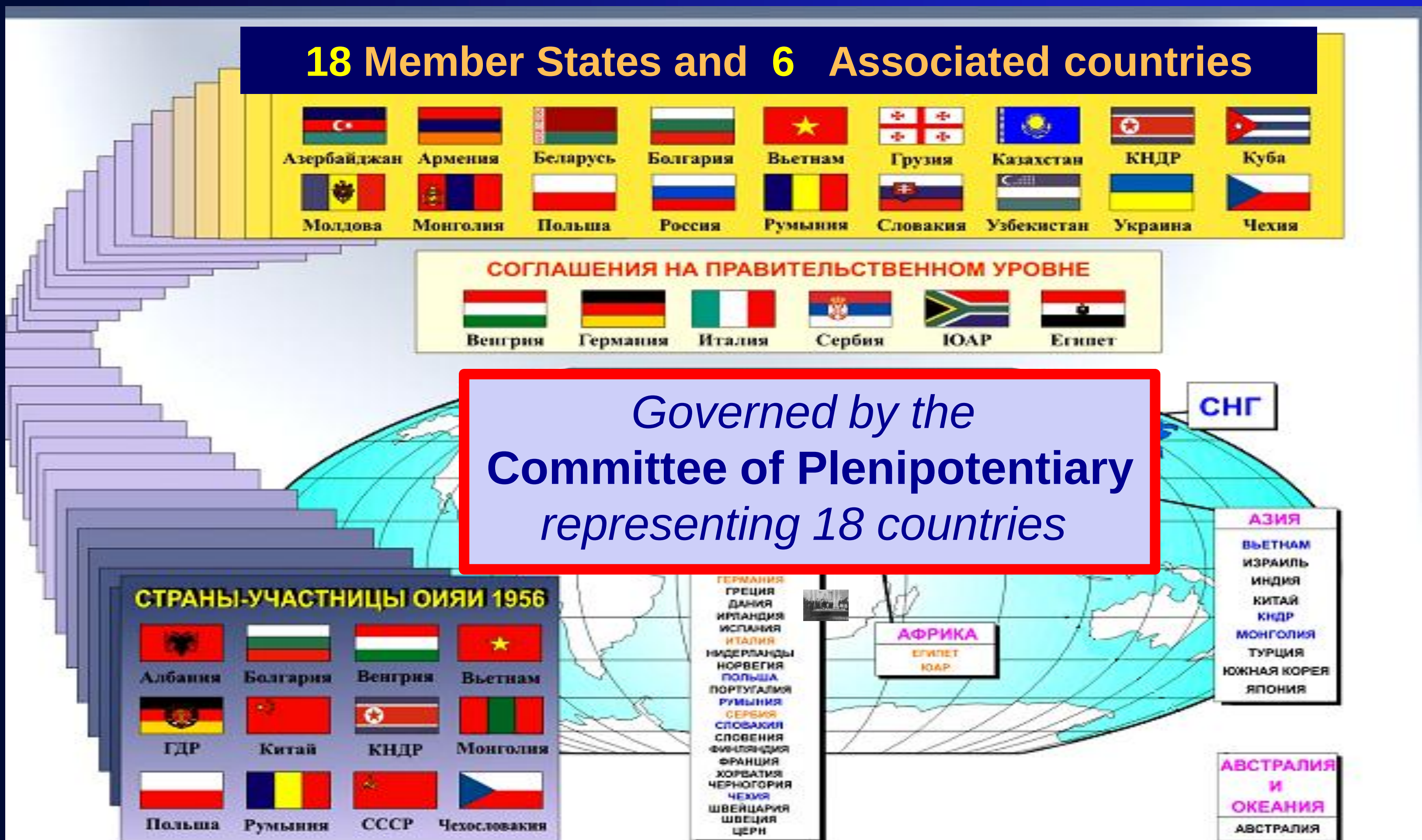
NICA/MPD project

Flagship HEP project at JINR

Joint Institute for Nuclear Research (JINR) –

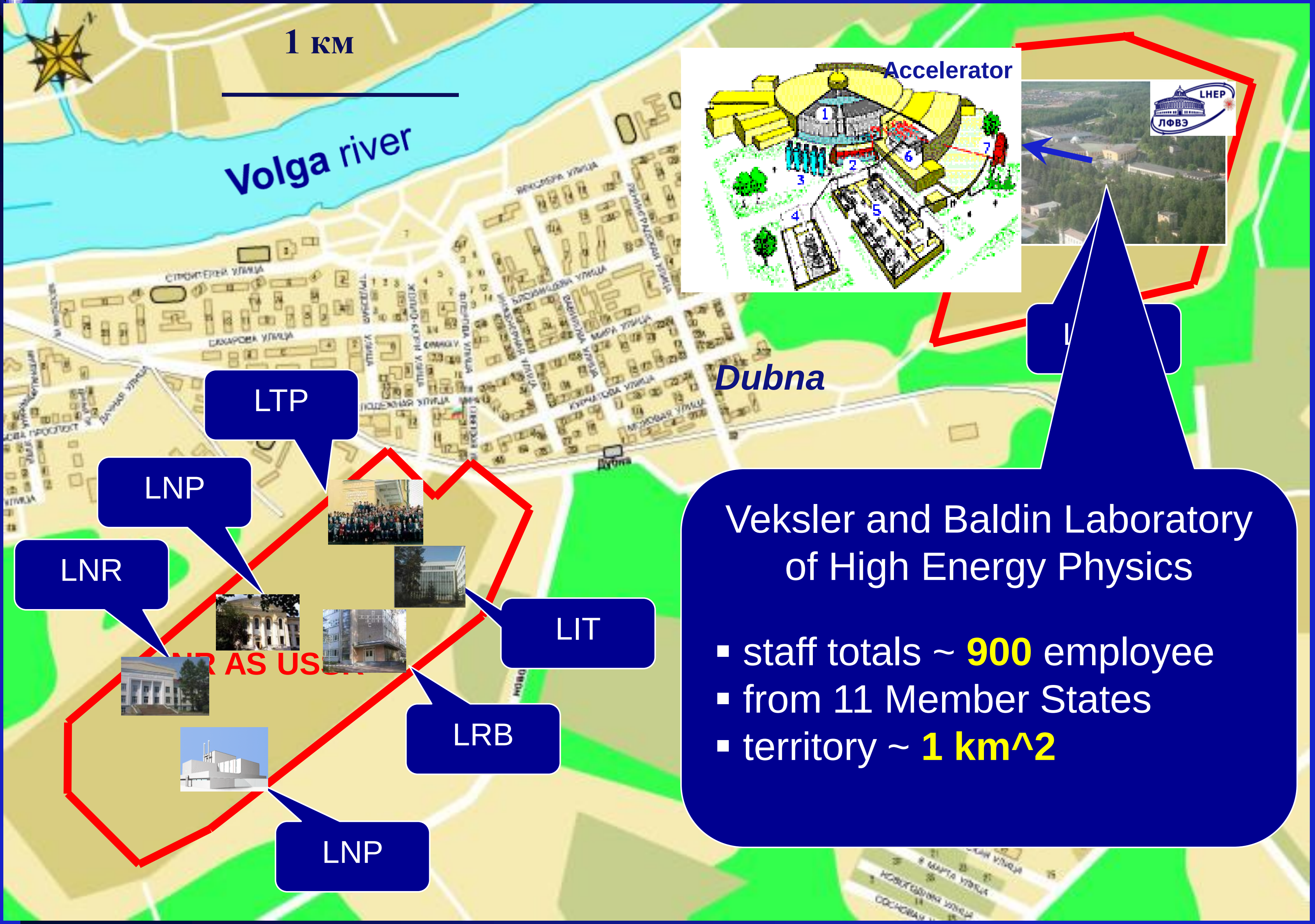
International Intergovernmental Organization established through the Convention signed on 26 March 1956 by eleven founding States and registered with the United Nations on 1 February 1957



H I S T O R Y

OF
High Energy Physics
BASIC INSTALLATIONS
at JINR

About history and structure of JINR

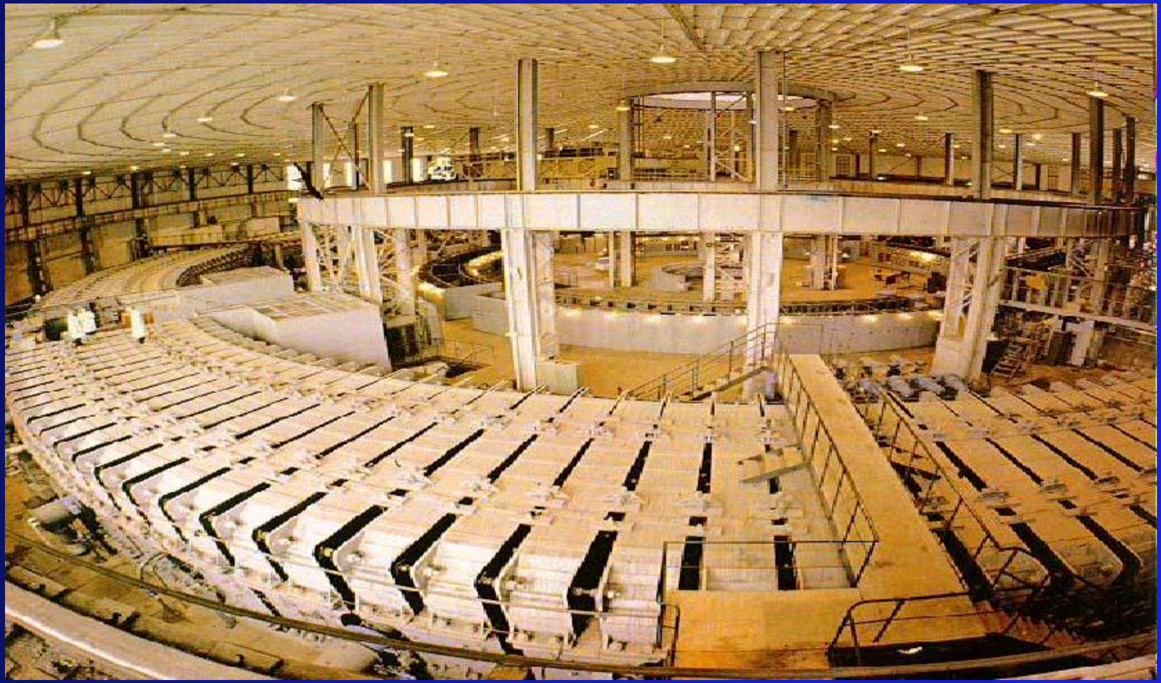


Veksler and Baldin Laboratory of High Energy Physics

- staff totals ~ **900** employee
- from 11 Member States
- territory ~ **1 km^2**

The pioneer accelerator for HEP: Synchrophasotron

- designed & constructed under the leadership of acad. V. I. Veksler
- put into operation in April, 1957
- the world largest accelerator at that time 10 GeV protons



Nuclotron

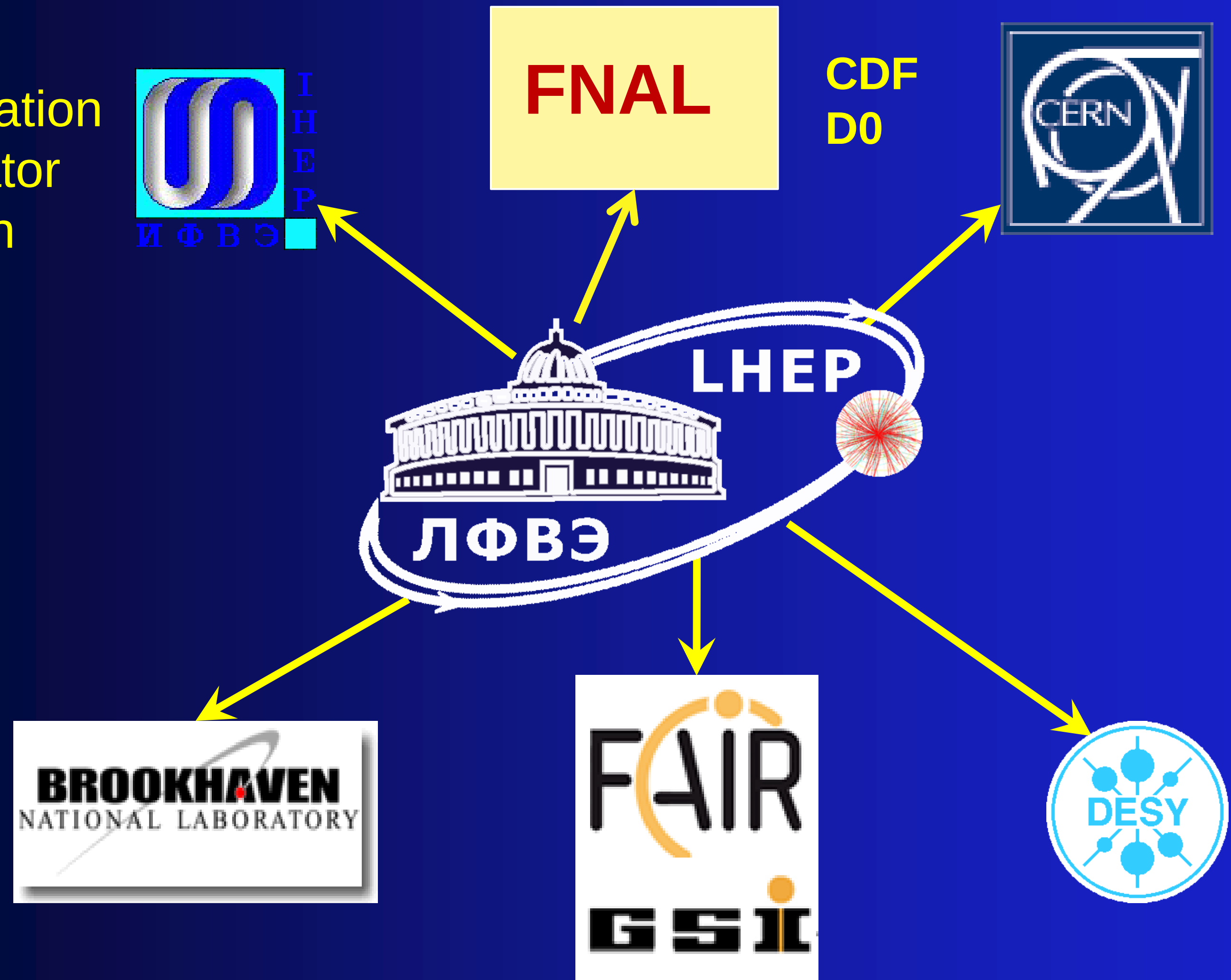
– the first **SC** accelerator of *heavy ions* (***p*** of **12 GeV**)
– was designed, constructed & put into operation under the leadership of acad. **A.M. Baldin**

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

R E V I E W

OF
INTERNATIONAL COOPERATION

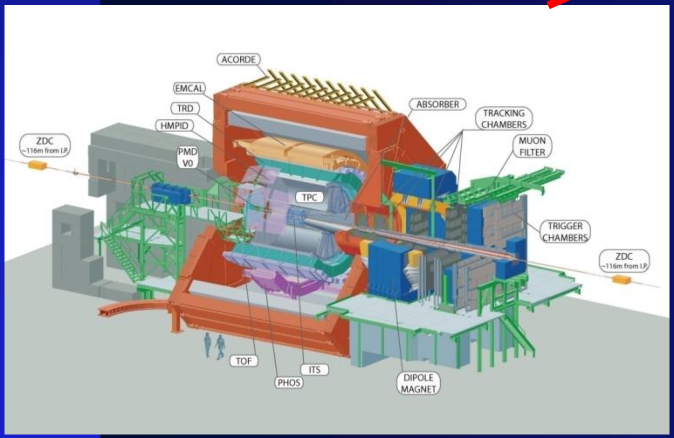
JINR HEP Scientific Links



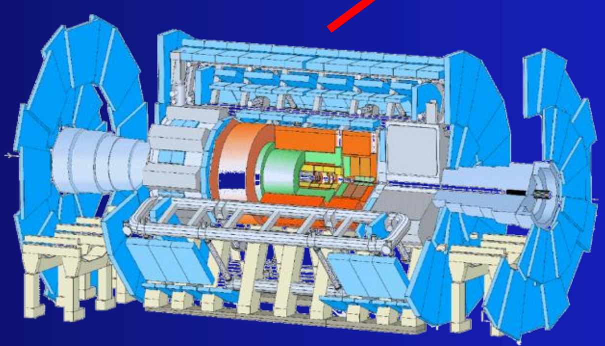
p+p @ 14 TeV

Pb+Pb @ 5.5A TeV

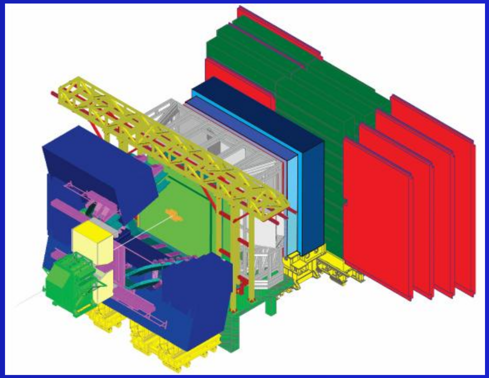
CMS



ALICE



ATLAS



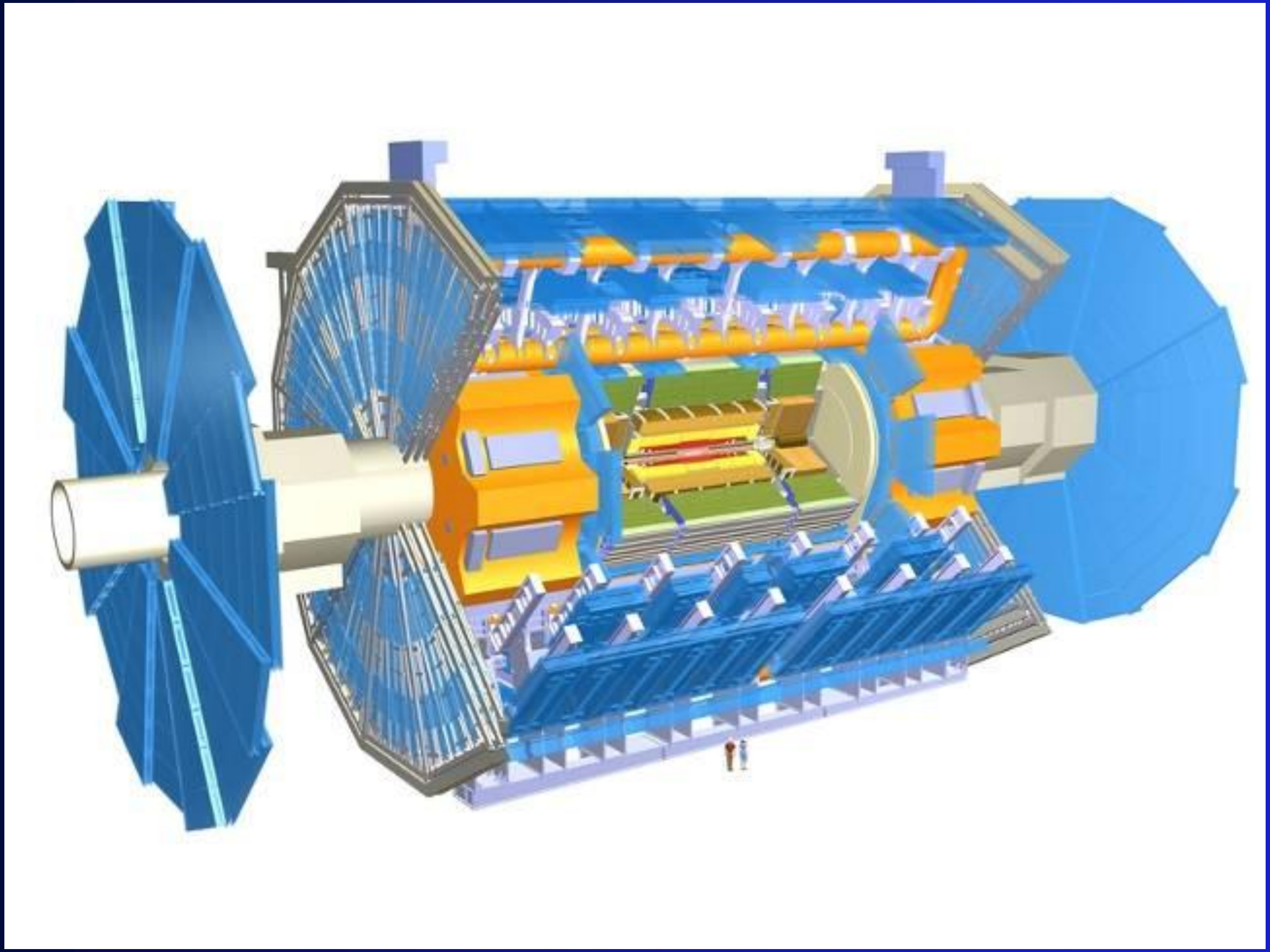
LHCb

ALICE Set-up

размер: 16 x 26 метров
вес: 10,000 тонн

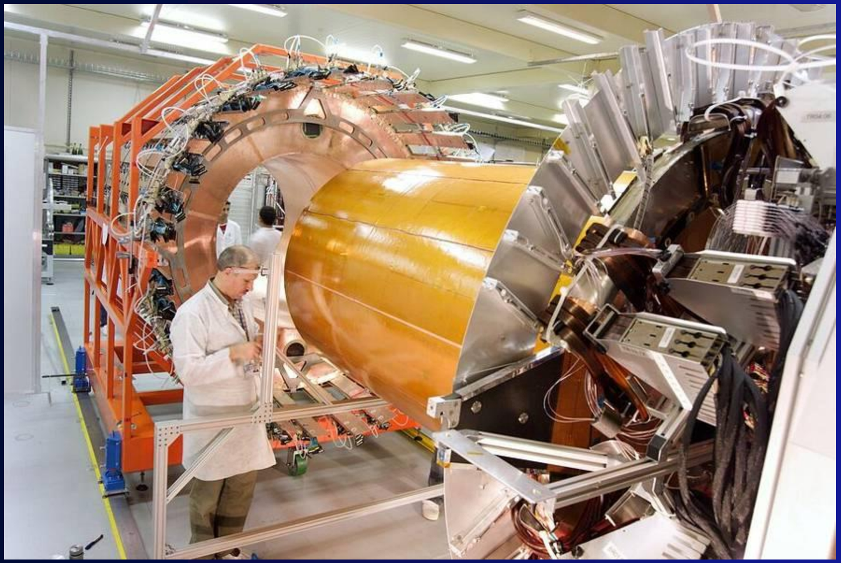
Largest dipole magnet (850 ton, 9×7×4.5 м) and particle detectors

ATLAS detector



Diameter	*25 m*
Barrel toroid length	*26 m*
End-cap end-wall chamber span	*46 m*
Overall weight	*7000 Tons*

JINR contribution to ATLAS

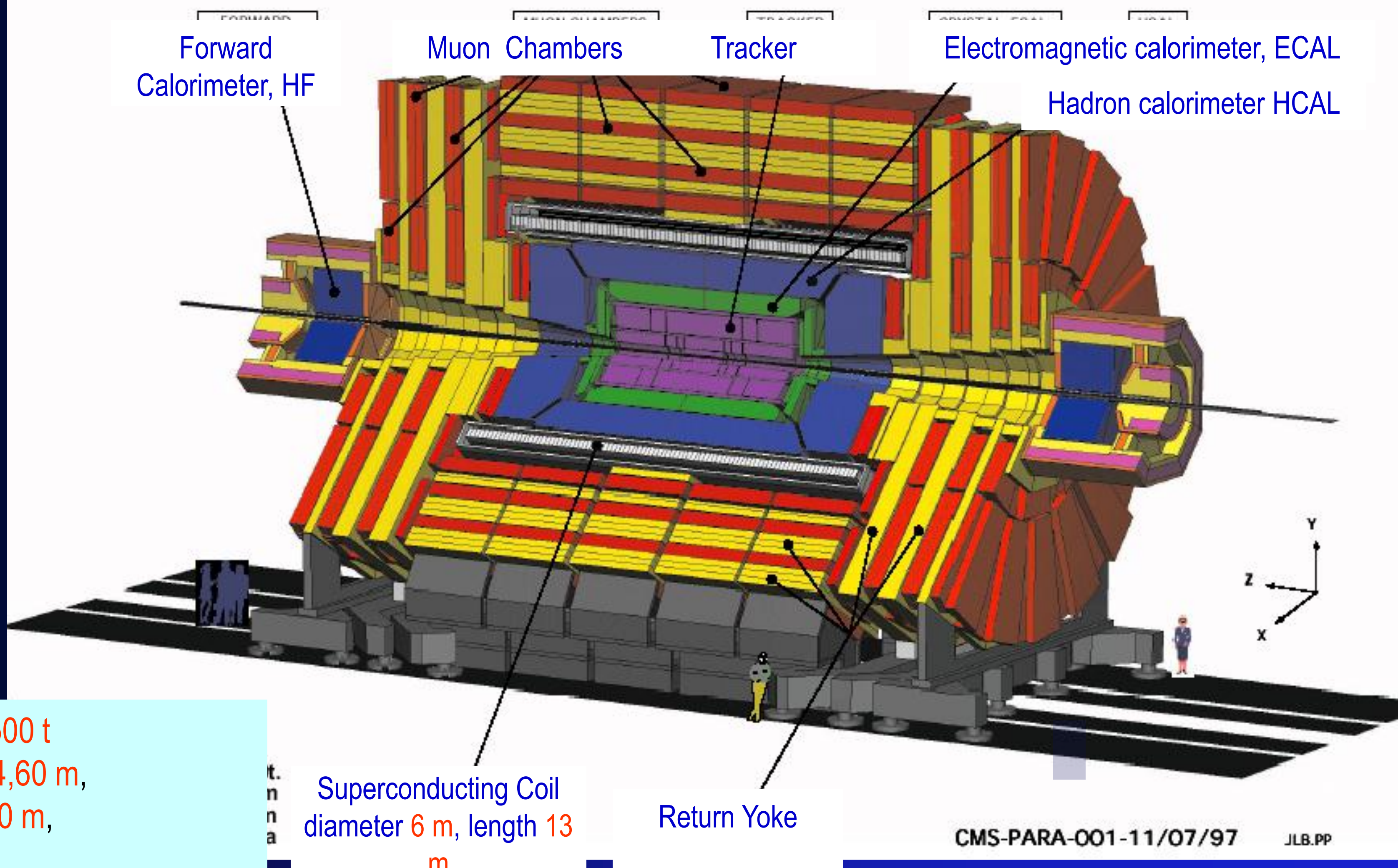


Transition Radiation Tracker based on straw tubes assembly

Barrel Tile Calorimeter;
LqAr Hadronic End-Cap Cal.
Muon Chambers

Compact Muon Solenoid- CMS

Detector subsystems are designed to measure: the energy and momentum of photons, electrons, muons, jets, missing E_T up to a few TeV



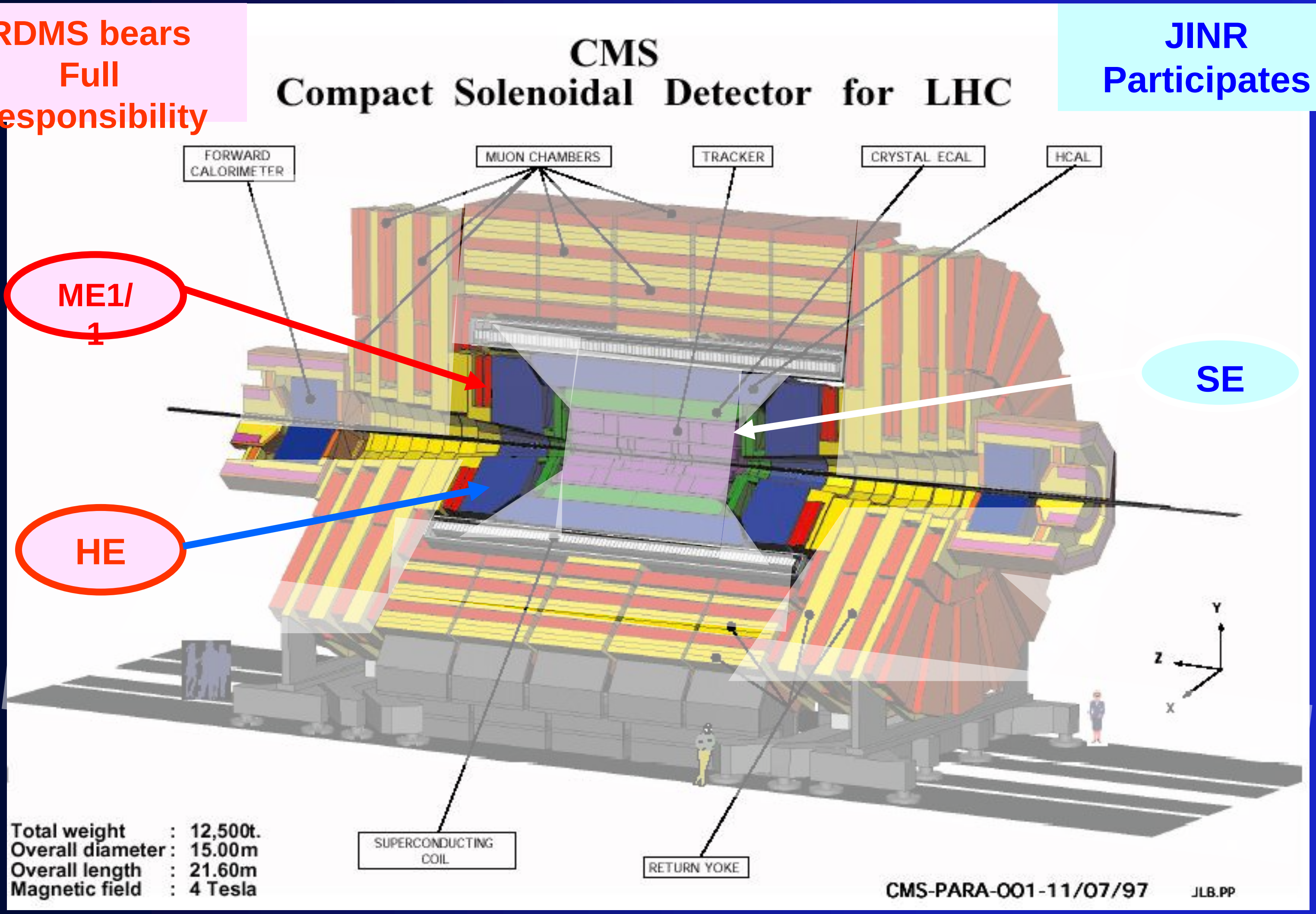
weight - 14500 t
diameter - 14,60 m,
length - 21,60 m,
B-field - 4 T

JINR Participation in CMS Construction

JINR participates in the CMS in a framework of the RDMS CMS Collaboration

RDMS bears Full Responsibility

JINR Participates



CURRENT AND FUTURE PROGRAMME

NICA/MPD project

http://nica.jinr.ru/

(continuous data base update)

In 2009 the JINR Committee of Plenipotentiary (CP) approved the 7-th Plan for the development of JINR, based on concentration of resources for updating the accelerator & reactor base of the Institute

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

The project NICA/MPD

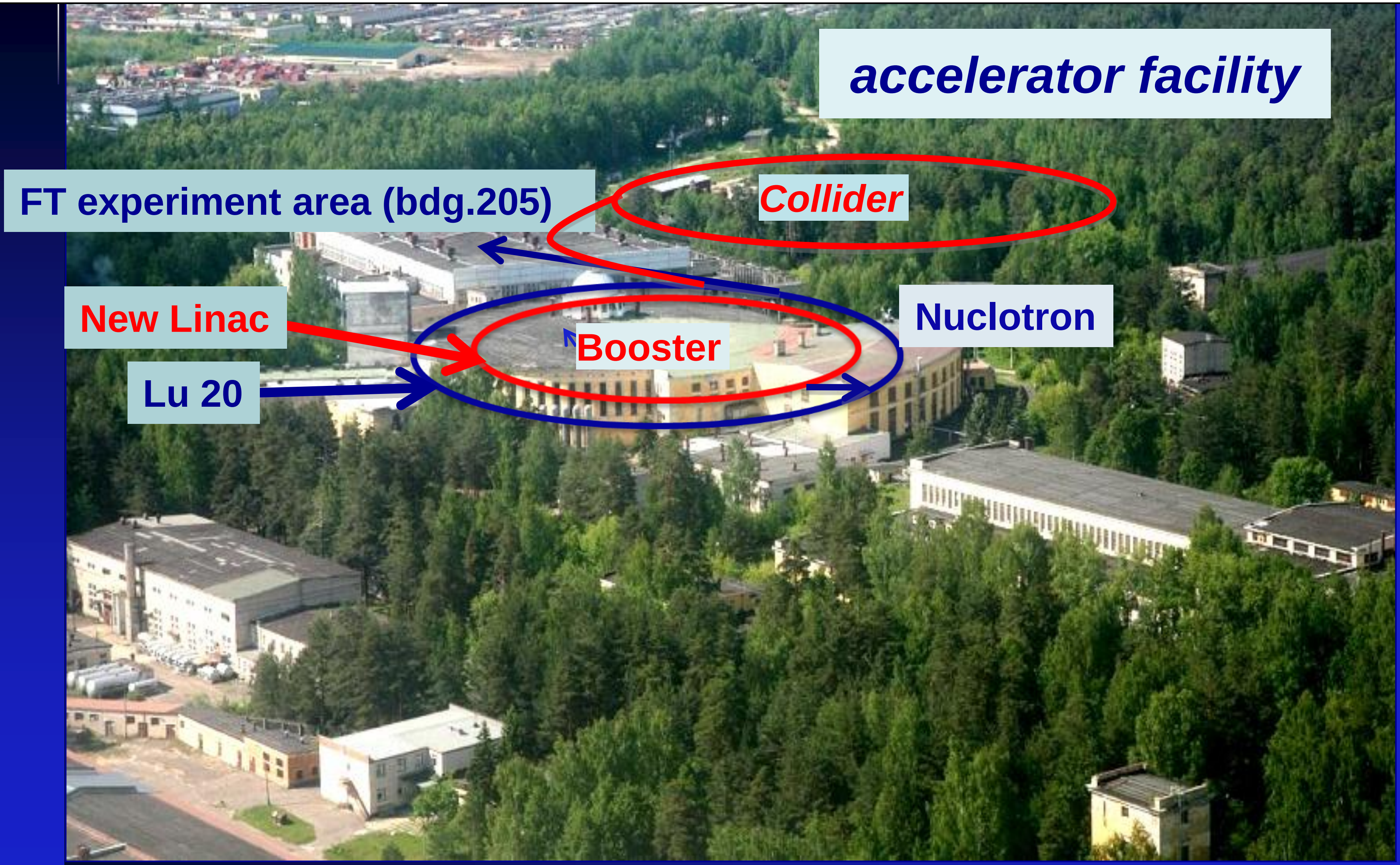
(Nuclotron based Ion Collider fAcility & Multi Purpose Detector)

aimed to study of hot & dense baryonic matter (DBM) & spin physics with polarized protons & deutrons

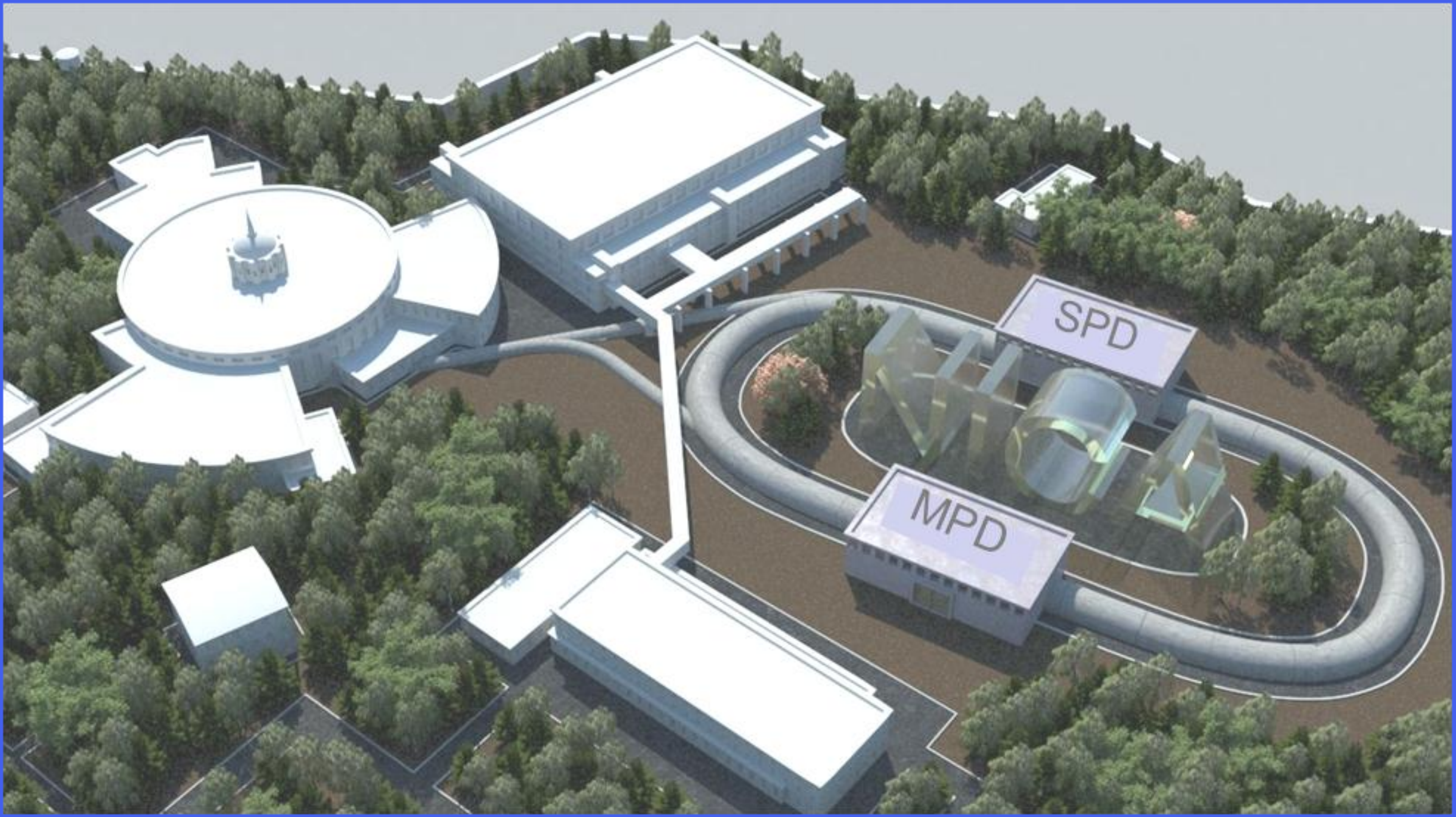
- is the JINR flagship project in HEP

It was initiated & led by **A.N.Sissakian**

Veksler & Baldin Laboratory of High Energy Physics



Veksler & Baldin Laboratory of High Energy Physics (future)



Fields of research

- **the study of Dence Barionic Matter could provide us with information on**

  -in-medium properties of hadrons

  & nuclear matter equation of state (EOS)

  -onset of deconfinement (OD) & chiral symmetry restoration (CSR),

  -phase transition, mixed phase & critical end-point (CEP)

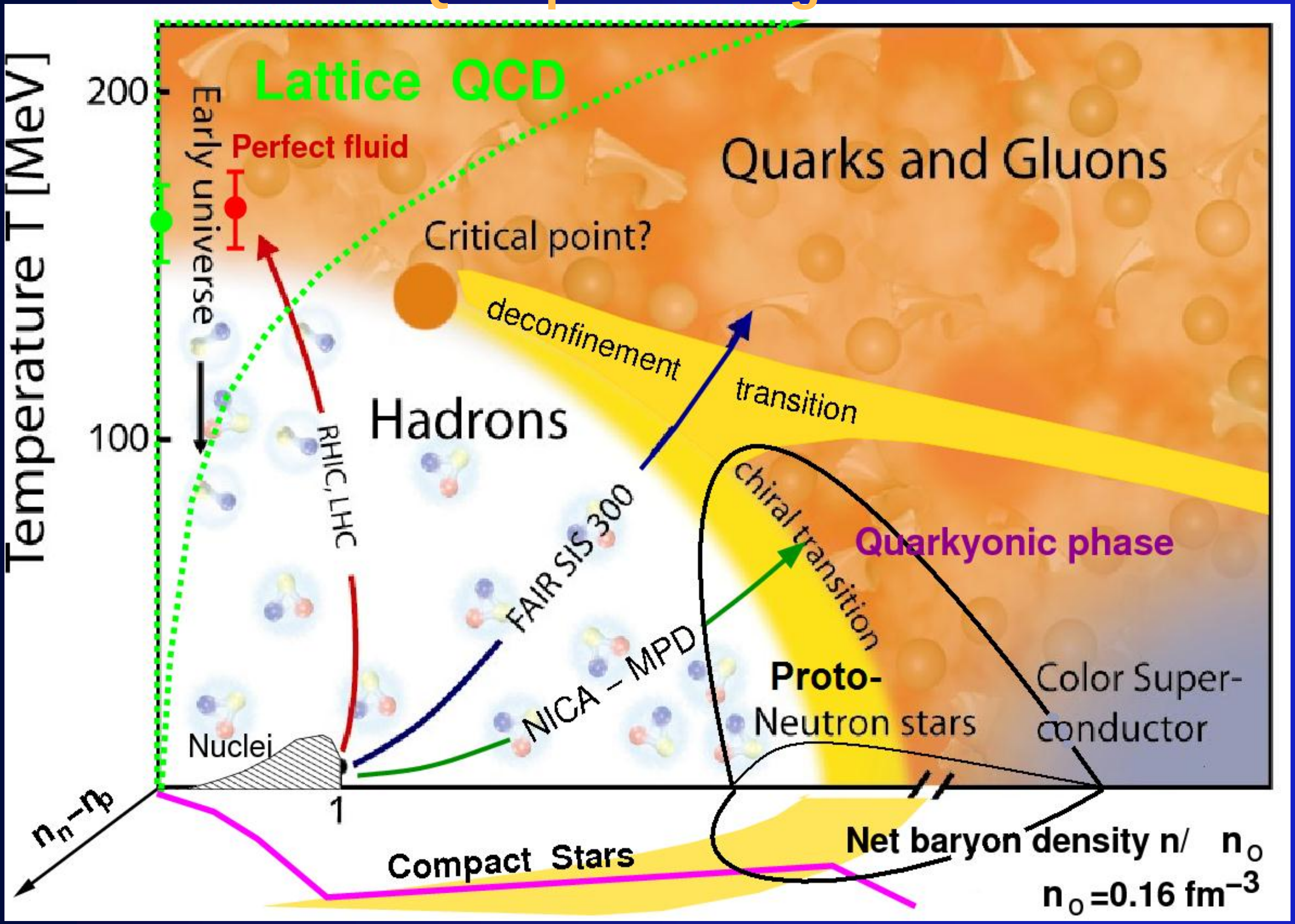
  -possible local parity violation in strong interaction (LPV)

- **the study of spin physics is aimed**
  - ***to shed light on the origin of spin***
  - ***to define the nucleon spin structure***

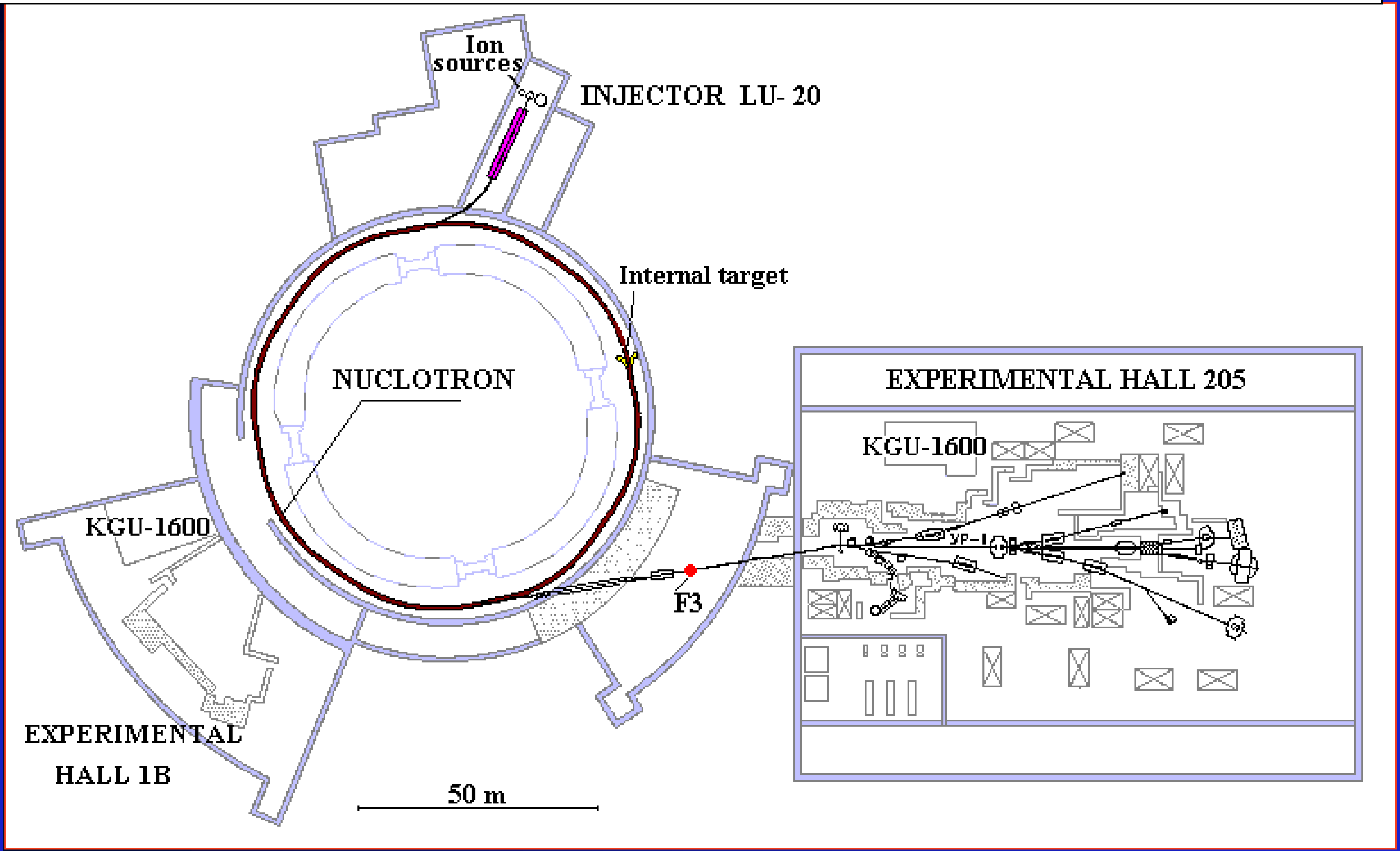
NICA/MPD physics *(at $\sqrt{S_{NN}}$ = 4 - 11 GeV)*

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

QCD phase diagram



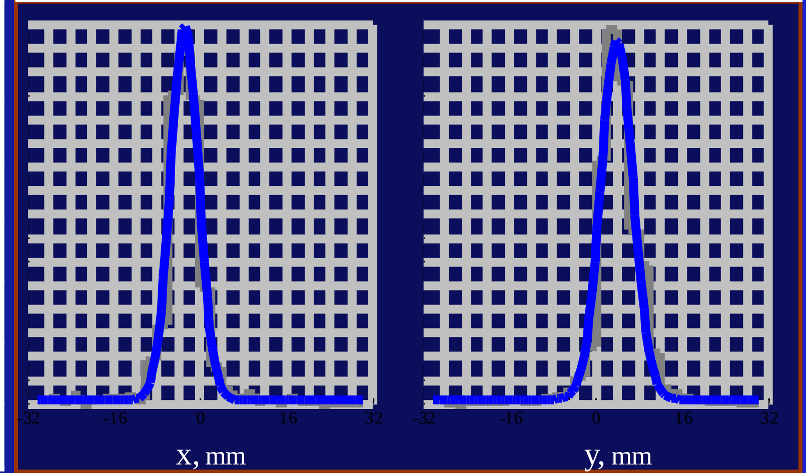
The plan of Nuclotron and experimental zones



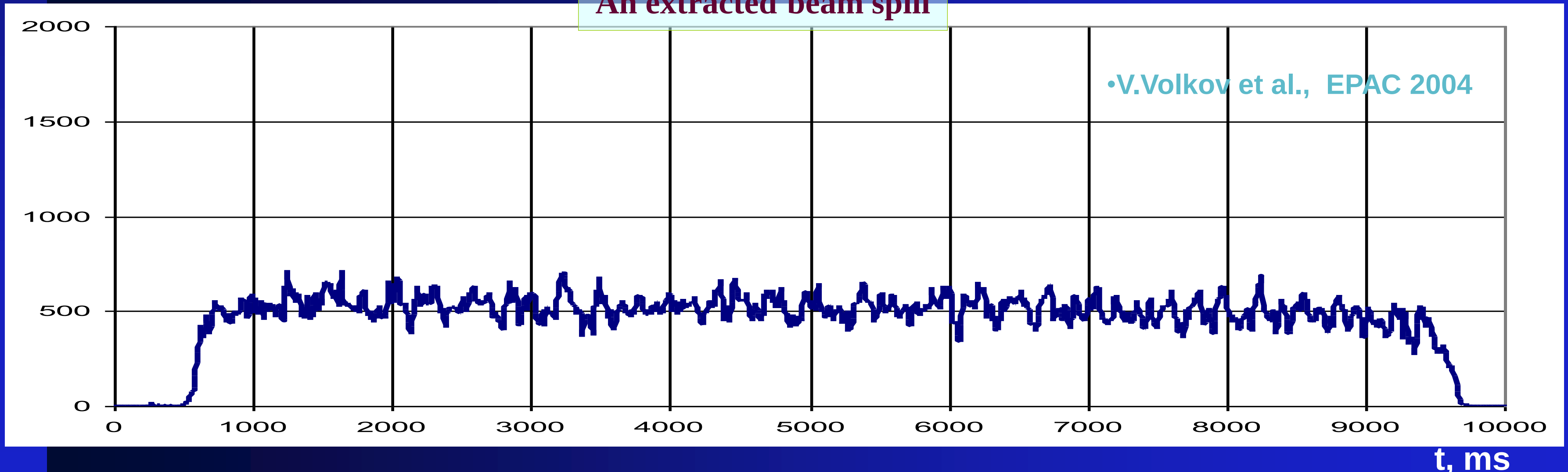
Nuclotron slow extraction

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



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

Three stages of Nuclotron development

- **Nuclotron-*M*** **2010**

cryogenic syst. modernization, linac corr., new ions (->Xe),
vacuum x10^-2 impr., PS, magnetic field (-> 1.9T),
beam adiabatic capture, beam diagnostic, orbit correction, RF
*run #42 (completing) under preparation (**DONE**)*

- **Nuclotron-N** + *Krion-6T, LU-20M, RF* **2012**
- **Nuclotron-N*** + *New Linac, Booster* **2014**

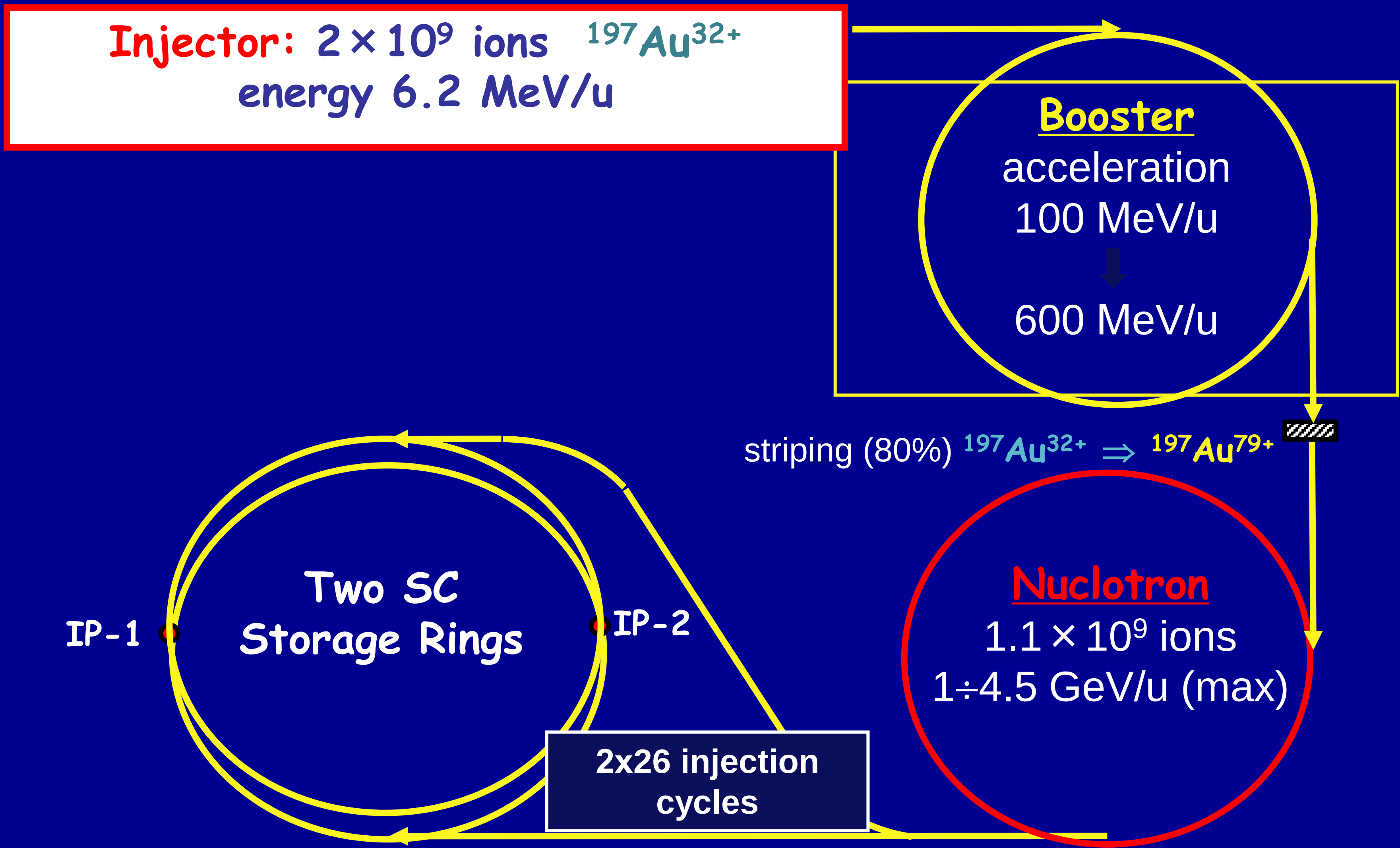
The beams to be provided by Nuclotron-N* *(ion kinetic energy in GeV /u):*

p, p↑:	**5 ÷ 12.6**
d, d↑:	**2 ÷ 5.9**
Li ÷ Au:	**1 ÷ 4.5**

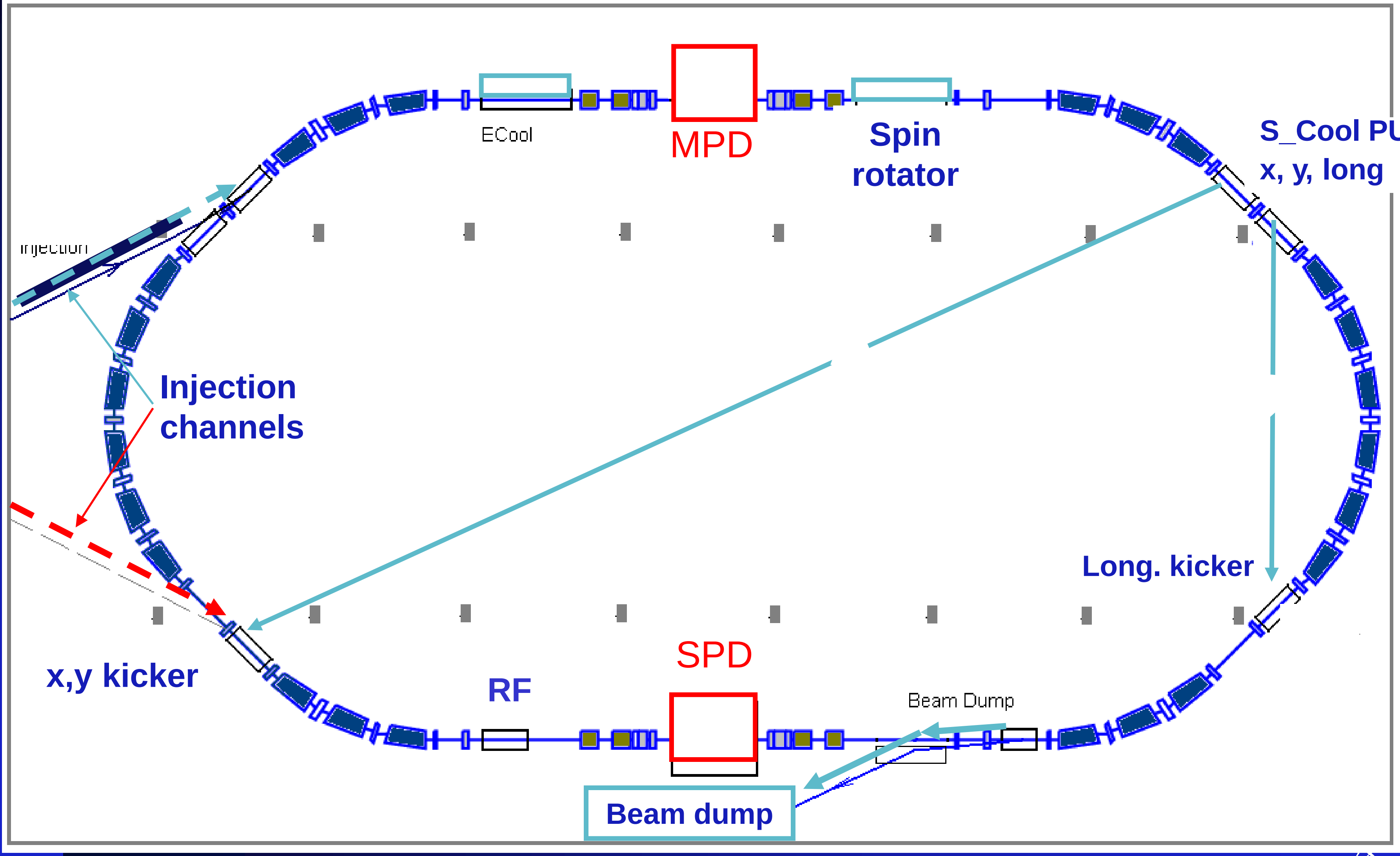
N I C A

Nuclotron based Ion Collider fAcility

NICA working schema (preliminary)



Collider NICA



Collider–general parameters *(preliminary)*

Bρ max [T·m]	45.0
Ion kinetic energy (Au79+), [GeV/u]	1.0 ÷ 4.56
Dipole field (max), [T]	1.8
Free space at IP (for detector)	9 m
Beam crossing angle at IP	0
Vacuum, [Torr]	10^{-11}
Luminosity per one IP, $cm^{-2} \cdot s^{-1}$	0.02÷5.0 ·10^27

Structure & details of the storage rings
- subject of discussion & consideration by the ***MAC***

Accelerator expertise

by the **Machine Advisory Committee (MAC)**

Members ->

MAC meetings:

- previous meetings in Dubna
  - January 2010,
  - October 2010
  - June 2011
- regular meetings via video-conference

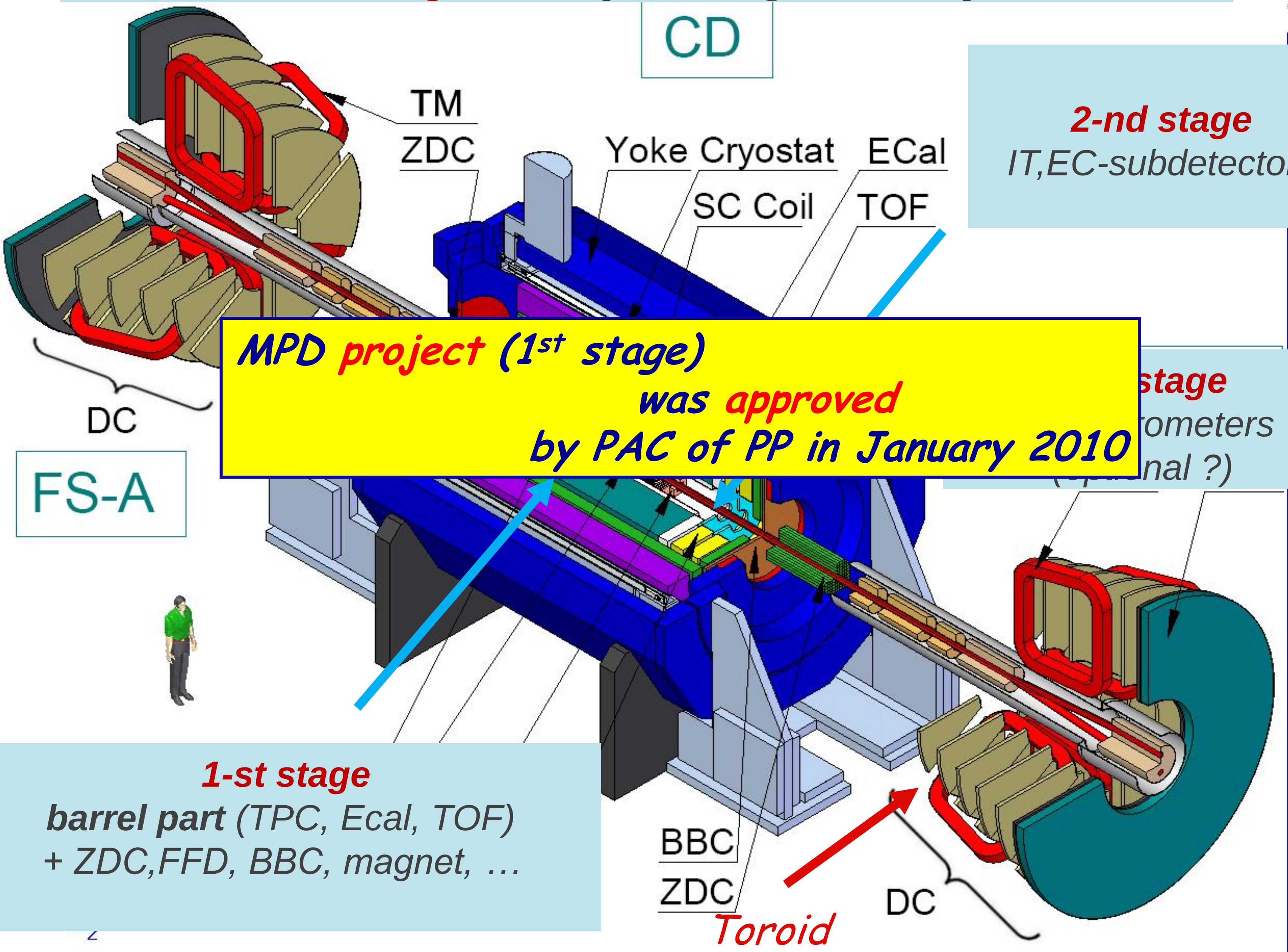
NICA TDR (vol. I & II) is available since August 2009

- *Boris Sharkov, FAIR & ITEP, chair*
- *Pavel Beloshitsky, CERN*
- *Sergei Ivanov, IHEP*
- *Thomas Roser, BNL*
- *Alexei Fedotov , BNL*
- *Markus Steck, GSI*
- *Nicholas Walker, Desy*
- *Sergei Nagaitsev, FNAL*
- *Alexander Zlobin, FNAL*
- *Takeshi Katayama, Tokyo Univ.*
- *Rolf Stassen, FZJ*
- *Yuri Senichev, FZJ*
- *Evgeny Levichev, BINP*
- *Victor Yarba, FNAL*
- *Pavel Zenkevich, ITEP*
- *Valeri Lebedev, FNAL*

M P D

Multi-Purpose Detector

MPD: 3 stages of putting into operation



MPD project (1st stage)
was approved
by PAC of PP in January 2010

2-nd stage
IT,EC-subdetectors

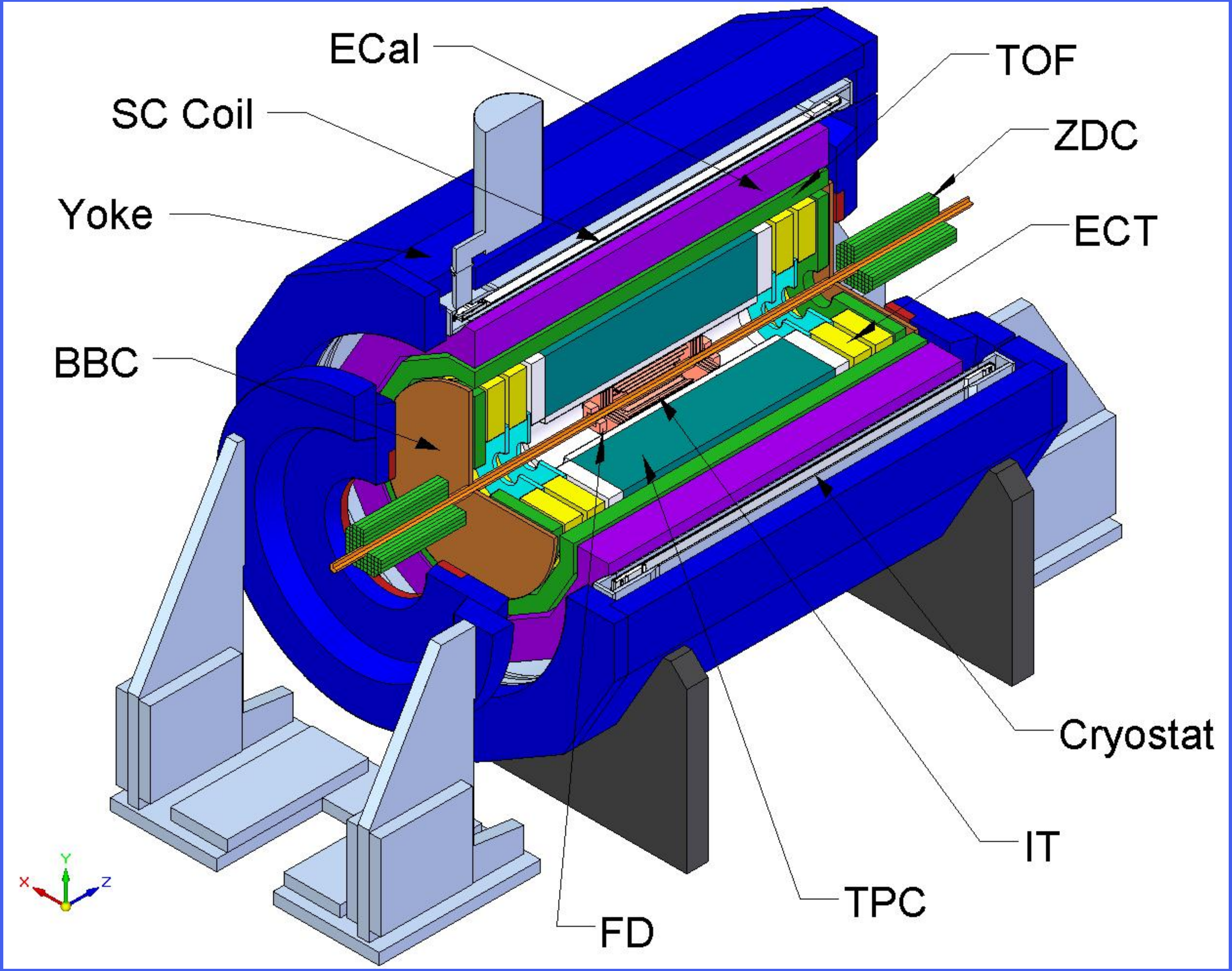
1-st stage
***barrel part** (TPC, Ecal, TOF)*
+ ZDC,FFD, BBC, magnet, …

MPD work packages & corresponding groups

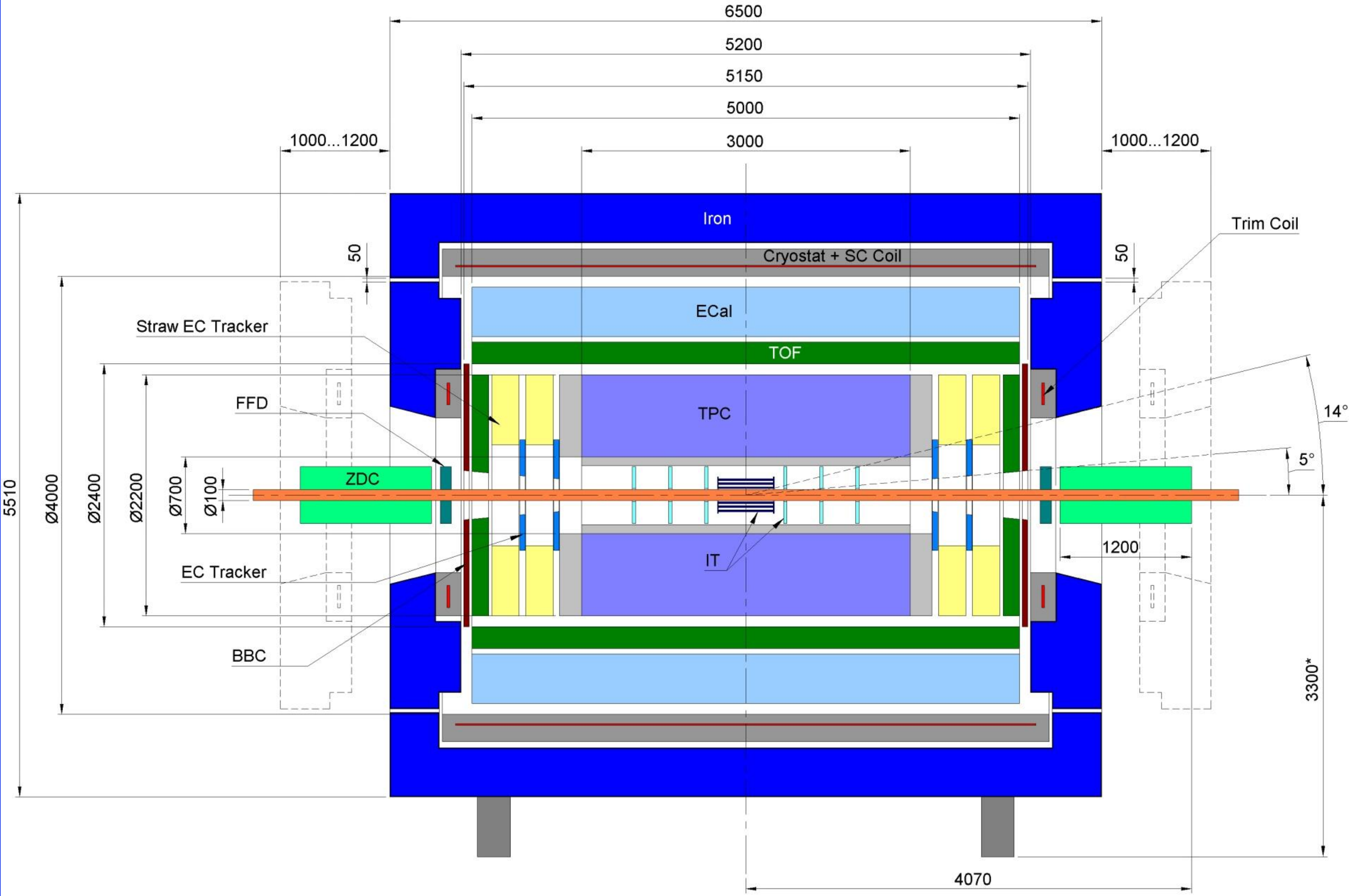
- Magnet
- TPC (+prototyping)
- ECal
- TOF
- ZCal
- FFD
- CPC
- Straw wheels

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

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


ECal
SC Coil
Yoke
BBC
TOF
ZDC
ECT
Cryostat
IT
TPC
FD
Y
X
Z

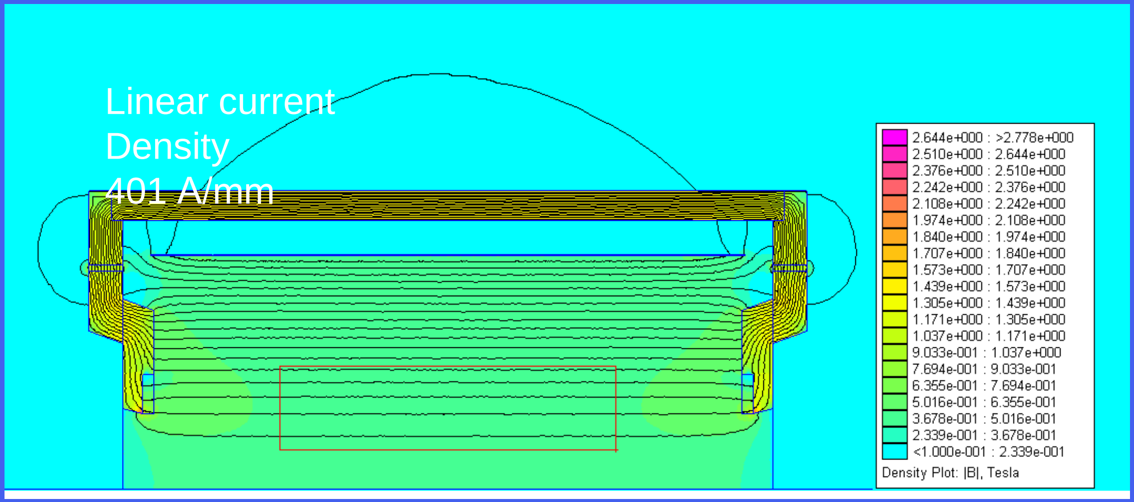
Integration of the Solenoid Magnet



MAIN PARAMETERS OF THE SOLENOID

Central field, T	0.5
Ampere-turns of the solenoid coil, MA	2.186
Design current density, MA/m^2	64.5
Stored energy, MJ	7.53
Nominal operational current, kA	1.36
Weight of the magnet, ton	440

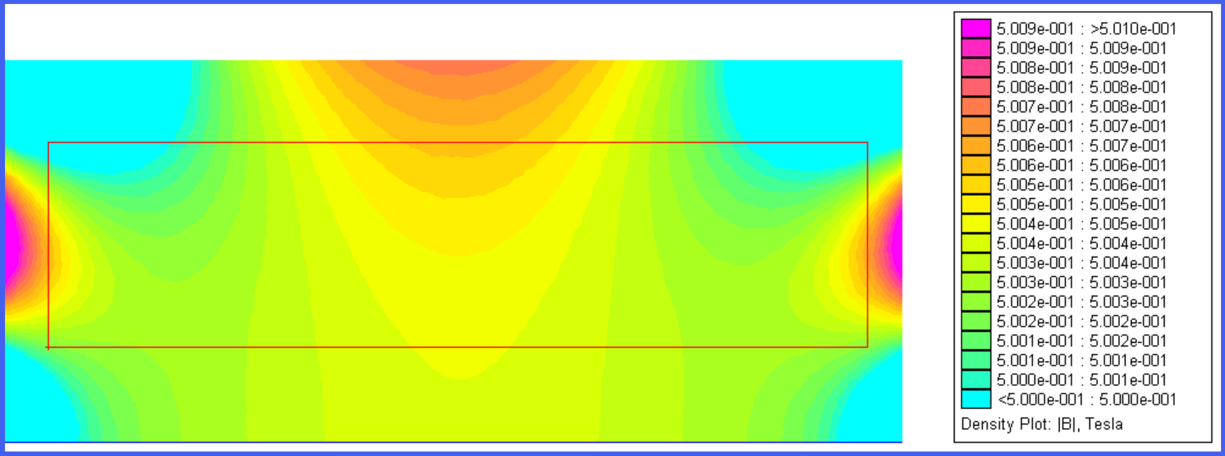
Magnetic Field Distribution



B_{max}=0.65 T

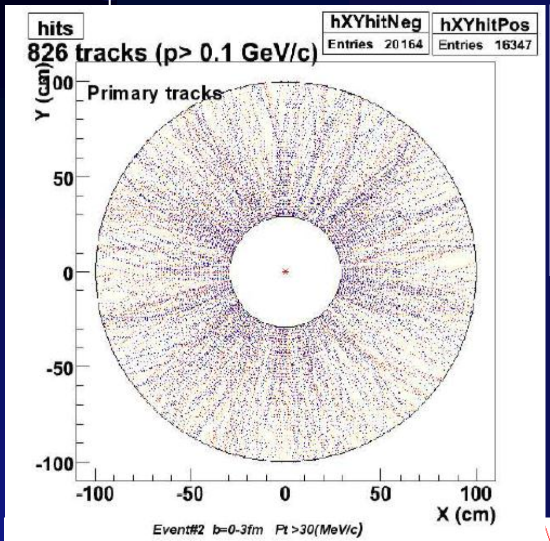
B_{iron}=1.47 T

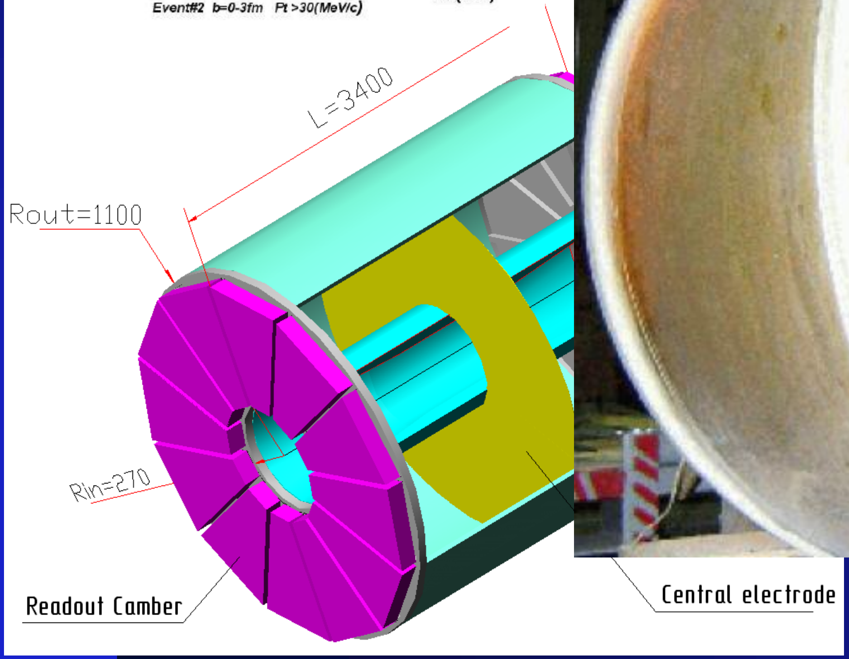
Distribution of the magnetic induction in the magnet structural parts

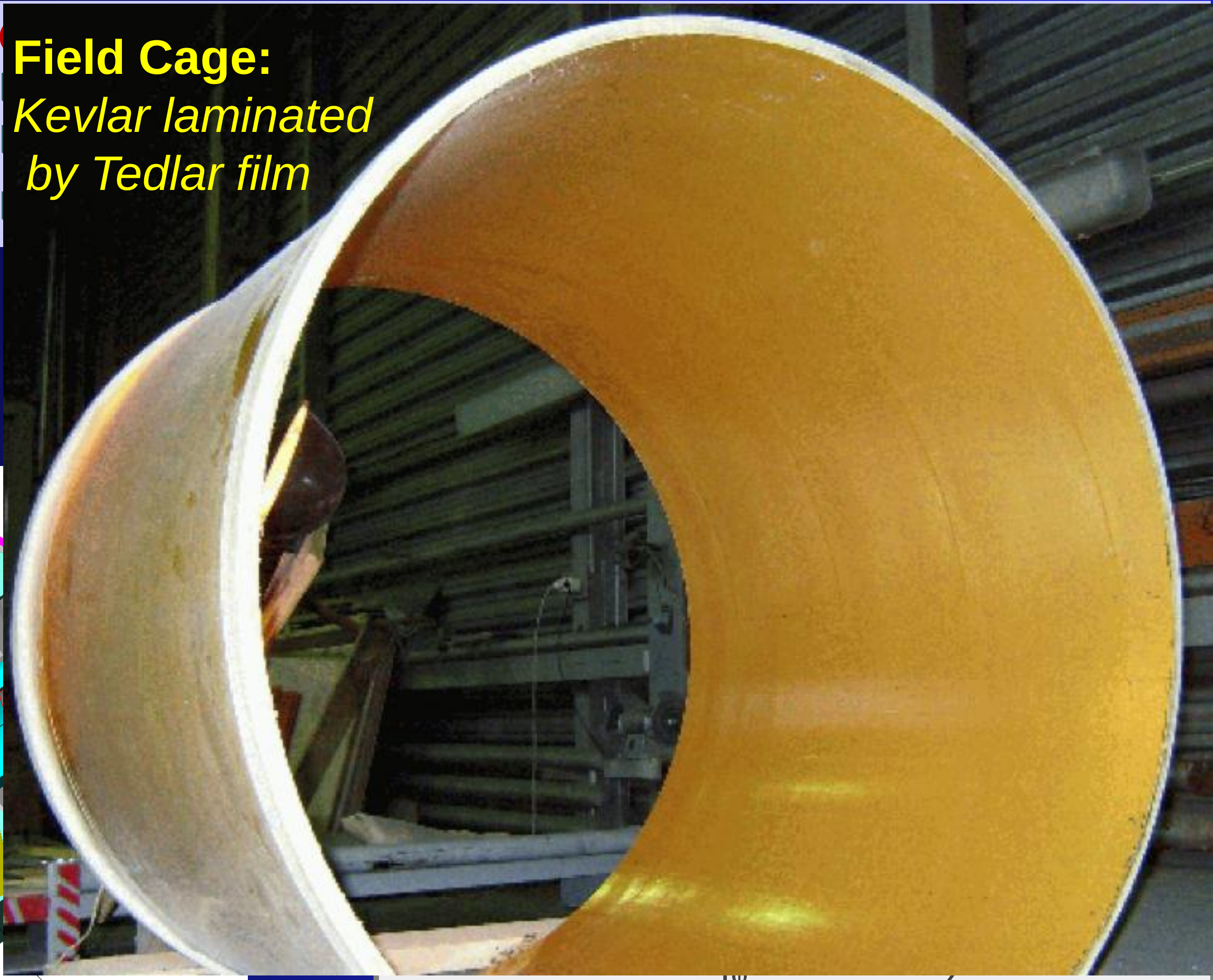


Distribution of the magnetic induction in the area of tracker

Time Projection Chamber (TPC)





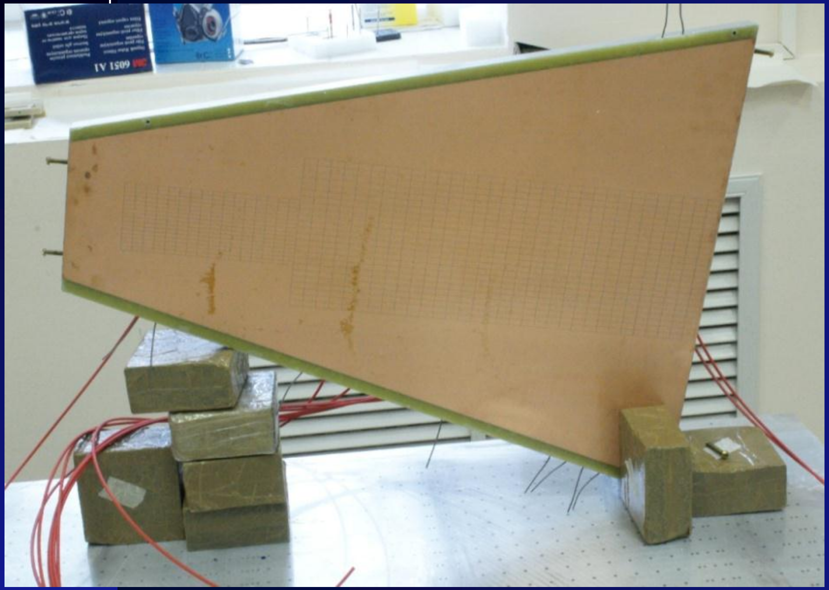


two track resolution < 1 cm

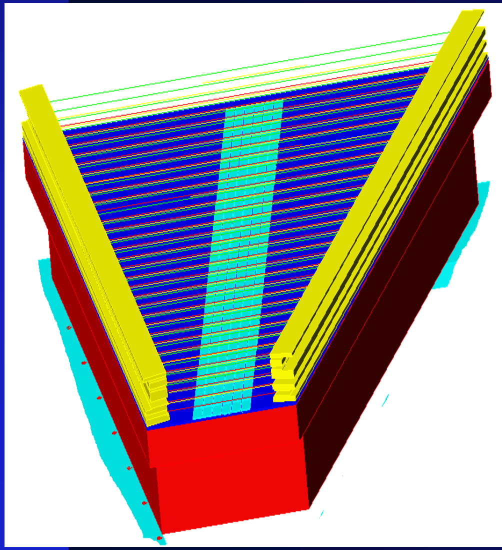
Mom. resolution Δp/p < 3% (0.2<p<1 GeV/c)

dE/dx resolution < 8%

TPC Readout Chamber

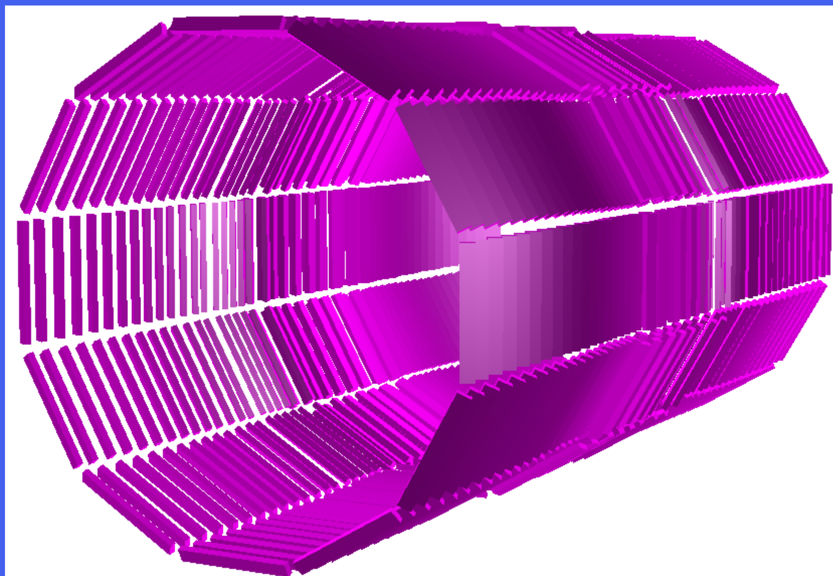


Pad Plane:
- *2 sets of 4x10 mm & 6x12mm pads*
- *256 channels of readout electronics*



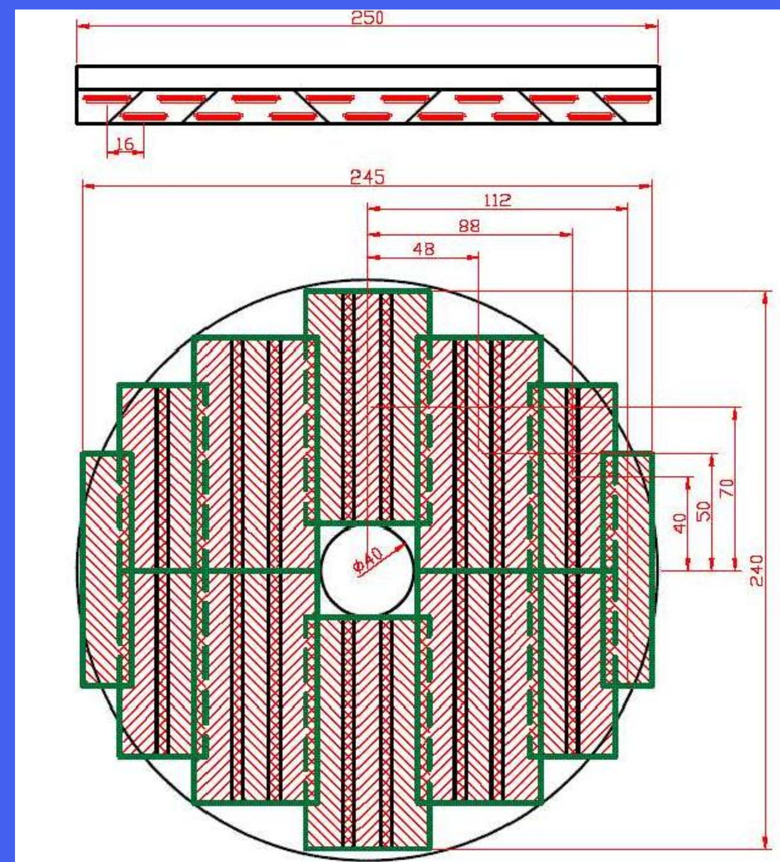
FEE :
- *Amplifier/Shaper – PCA16/ILC and PASA*
- *12 bits ADC – ADC12EU050*
- *FPGA VIRTEX5*

Time Of Flight (TOF) system



Basic requirements

- Coverage: barrel > 30 m^2,
- Endcap covers down to $|\eta|<3$
- σ ~ 80 ps (100 ps overall)



Dimensions

barrel: 5 m (length), 2.5 m (diameter)
endcap: 2 x 2.5 m (diameter) disks
Gas: 90% $C_2H_2F_4$ + 5% iC_4H_{10} + 5% SF_6

Segmentation (barrel)

12 sectors
module: 10-gap RPC, 48 pads 2.5x3.5 cm^2
or 30-50 cm long and 1-2 cm wide strips

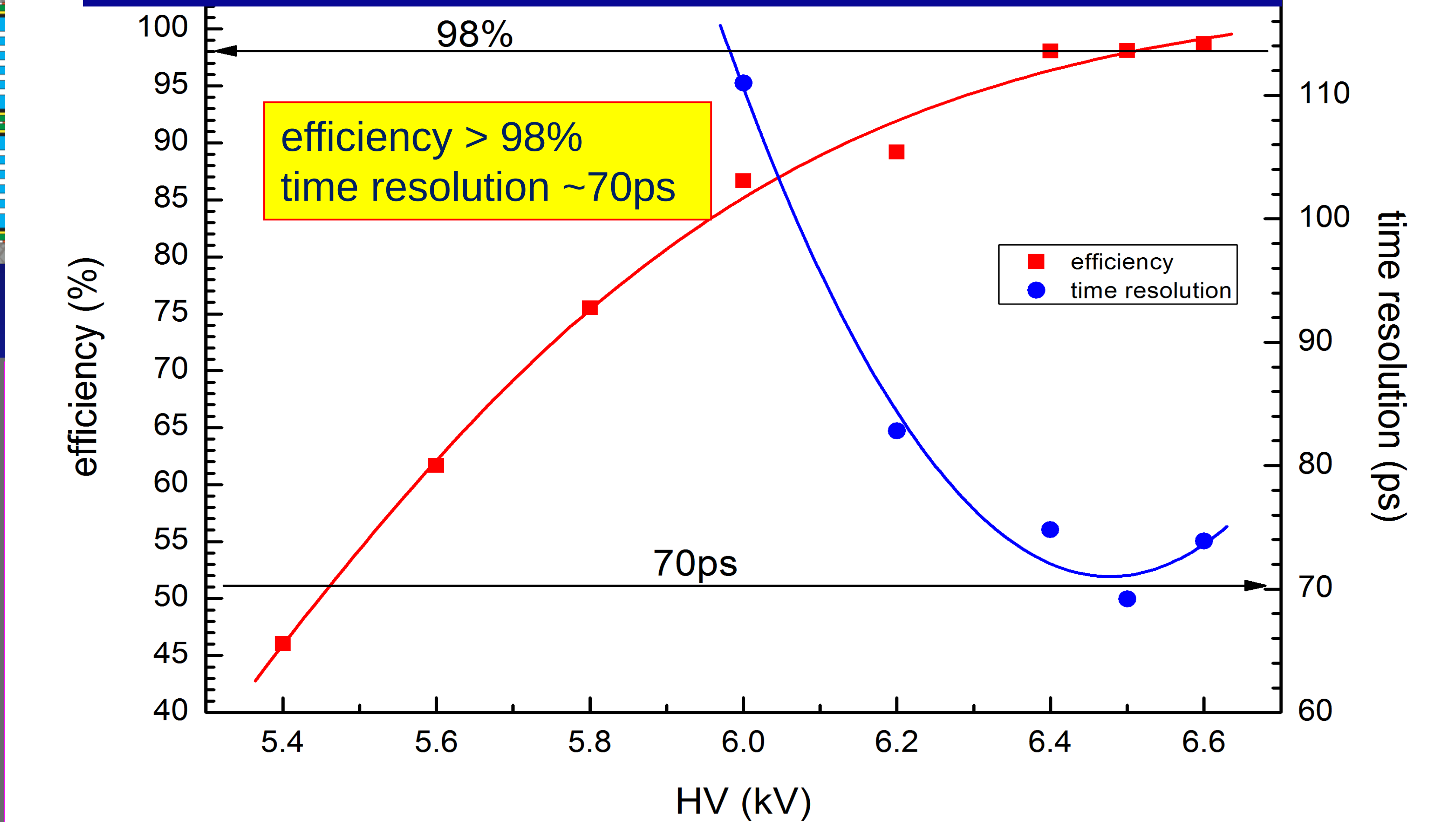
endcaps

24 mRPC 53,37,21x80-100 cm^2
pad size : 4x4 cm^2
geom. efficiency ~ 95%

RPC prototype *(China group)*

Plan to continue optimization

& tests at Nuclotron beam



cm3

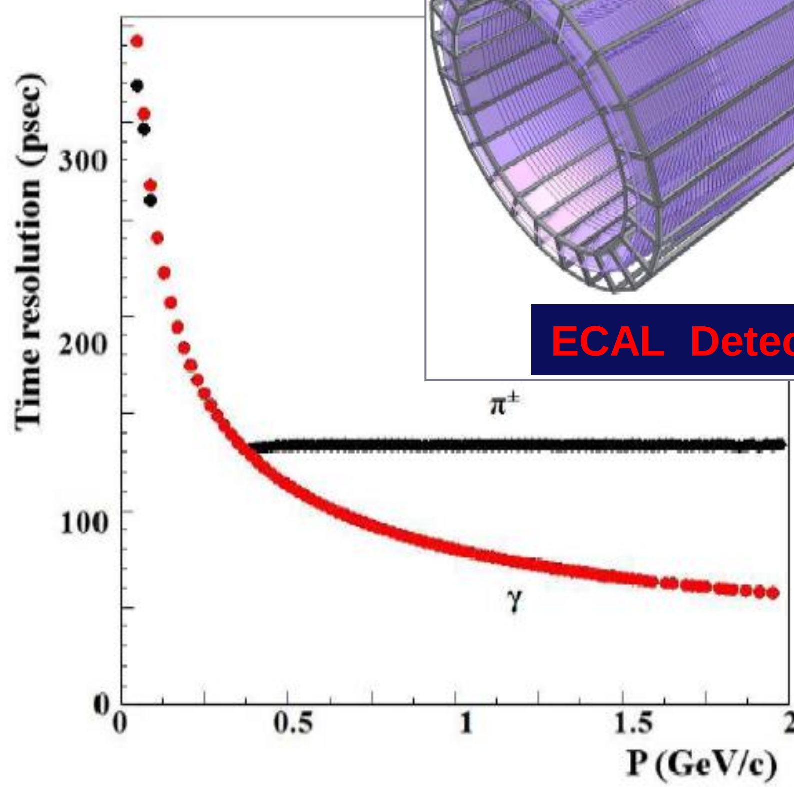
MΩ/□

by cosmic ray

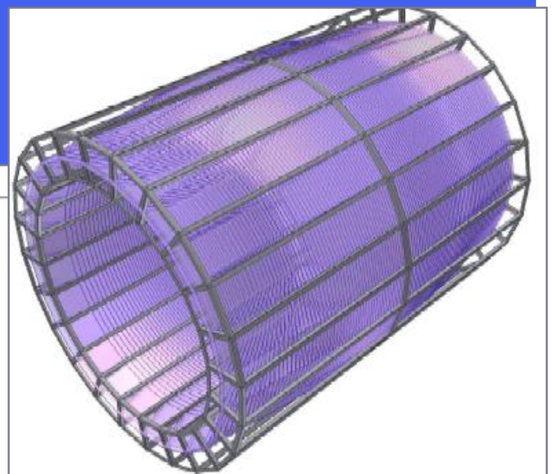
ECAL – “shashlyk” type modules with APD readout

(Lead plates (0.275 mm) and plastic scintillator (1.5 mm), the radiation length of tower $18X_0$ (40 cm))

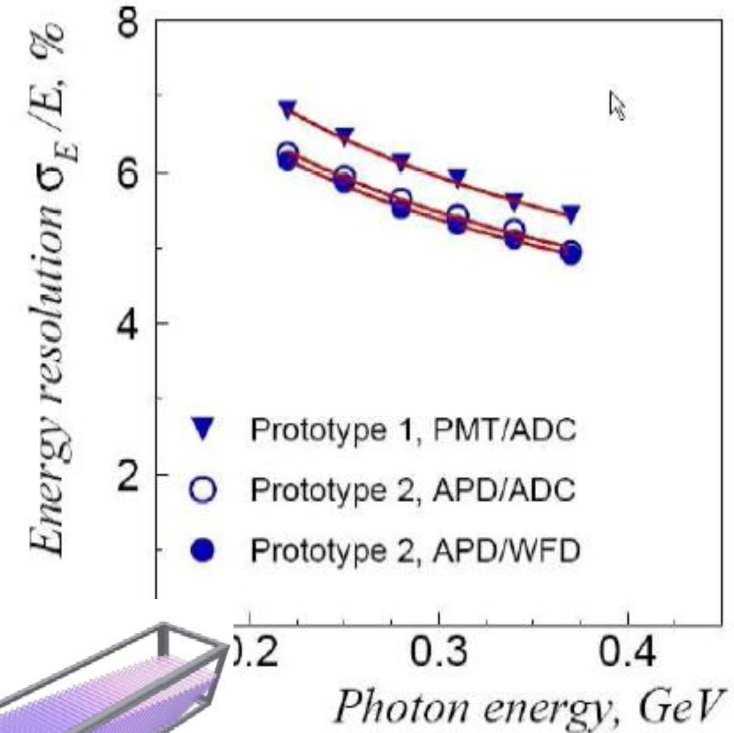
The active area of APD- 3x3 mm; density of pixels in APD – $10^4/mm^2$

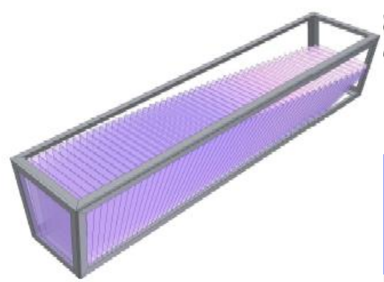


ECAL time resolution VS particle momentum



ECAL Detector





Energy resolution 2.5%/√E

Time resolution 80 psec/√E

MPD performance for physics tasks

was evaluated using a powerful tool based on

***MPDRoot** software including various physics generators,*

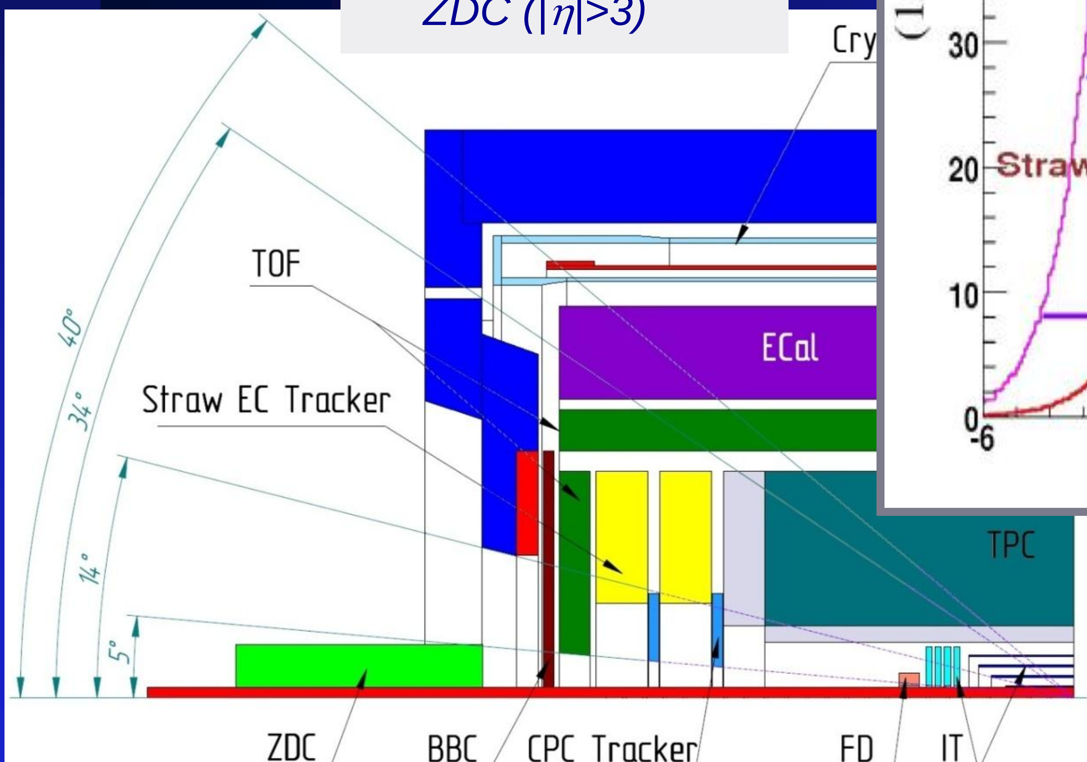
Detector simulation, event reconstruction

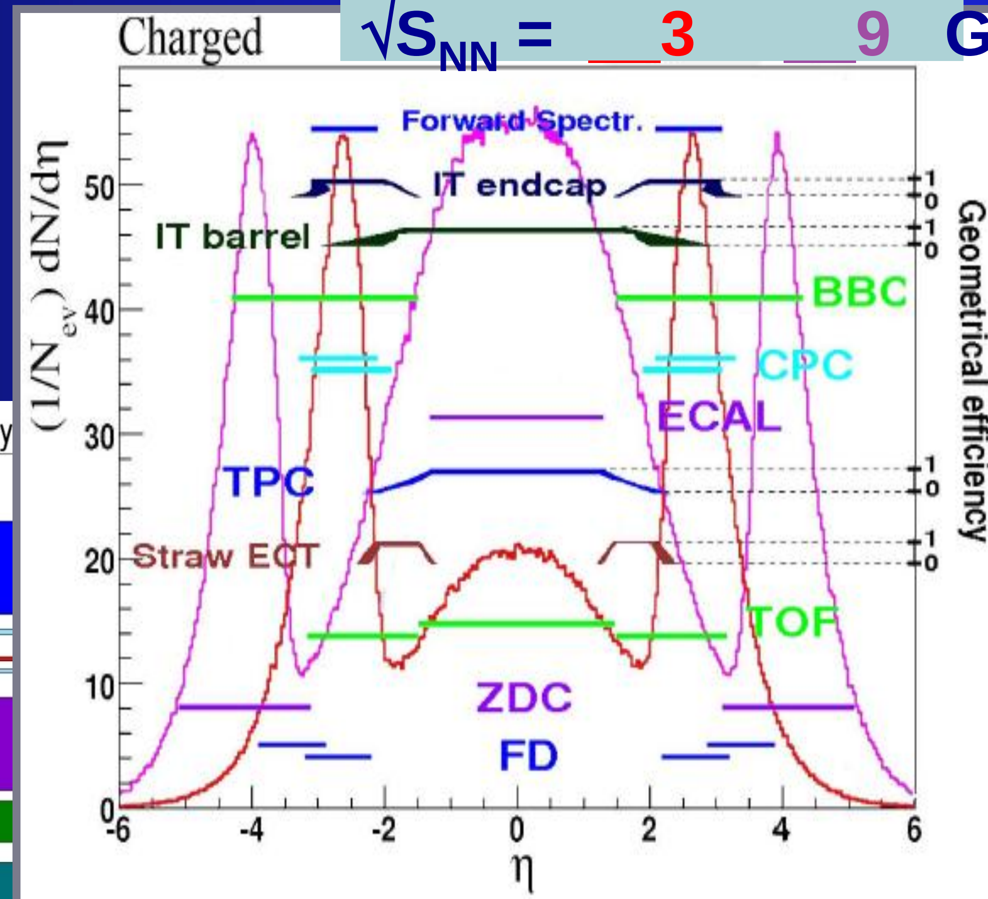
& analysis

Angle coverage of MPD

$\sqrt{S_{NN}}$ = __3 __9 Ge

- *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

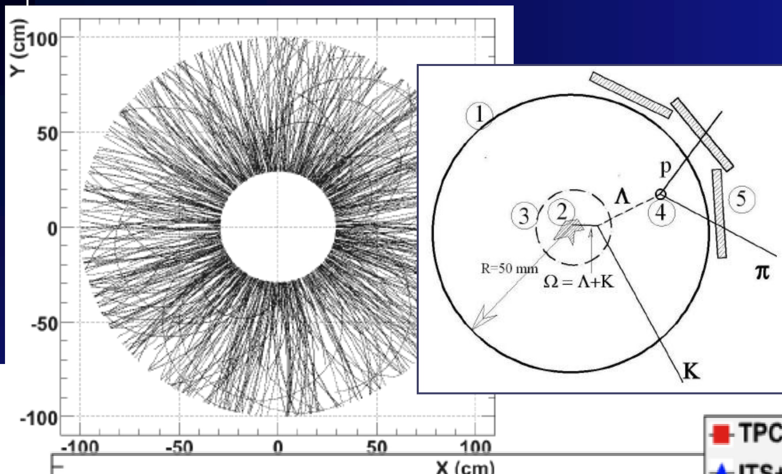
Particle yields in Au+Au collisions

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

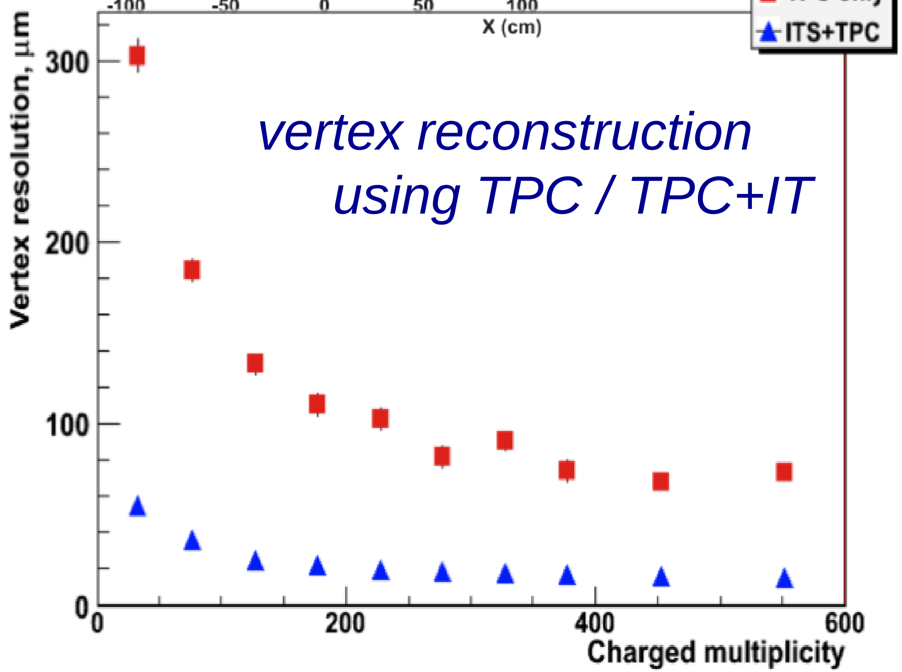
Luminosity L = 10^{27} cm^{-2}s^{-1}
Event rate (central) 700 Hz

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

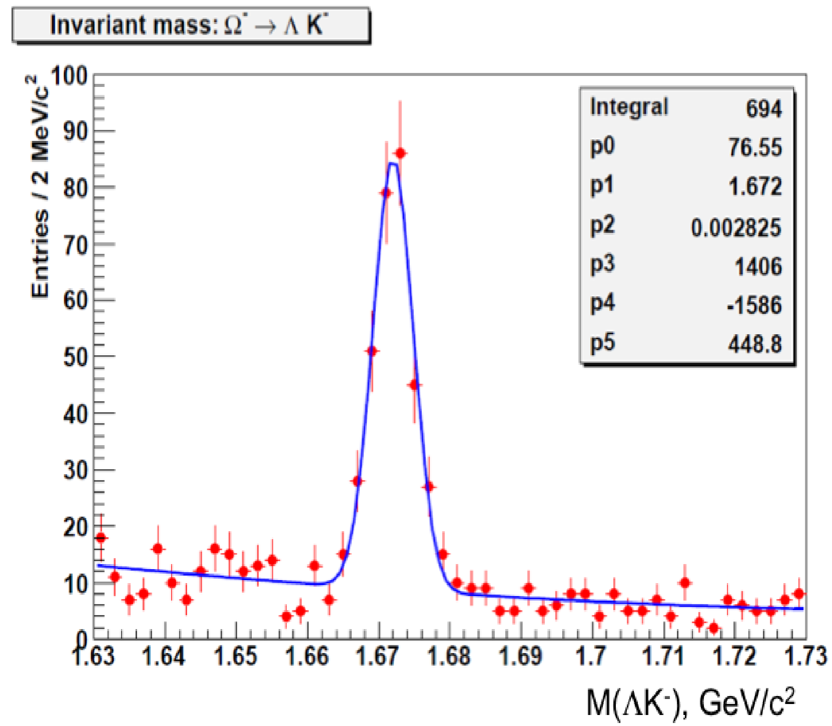
Vertex & hyperon decay reconstructions



Ω -> ΛK^- *decay reconstruction (vertex + particle ID)*

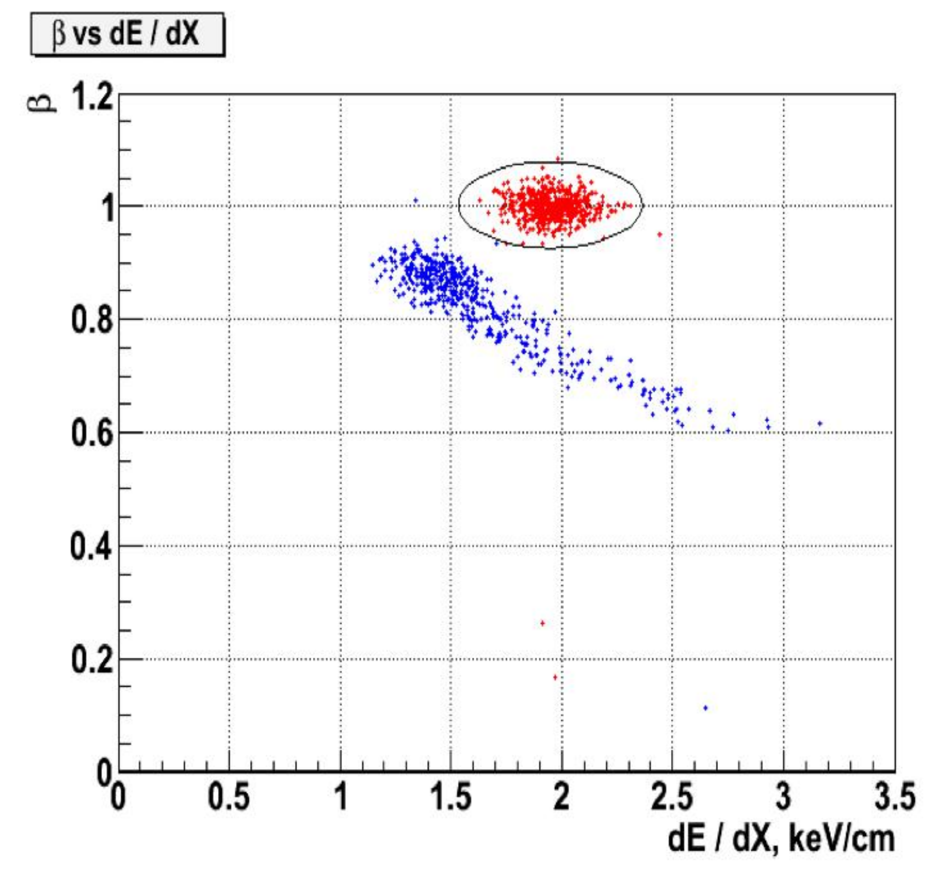


vertex reconstruction using TPC / TPC+IT

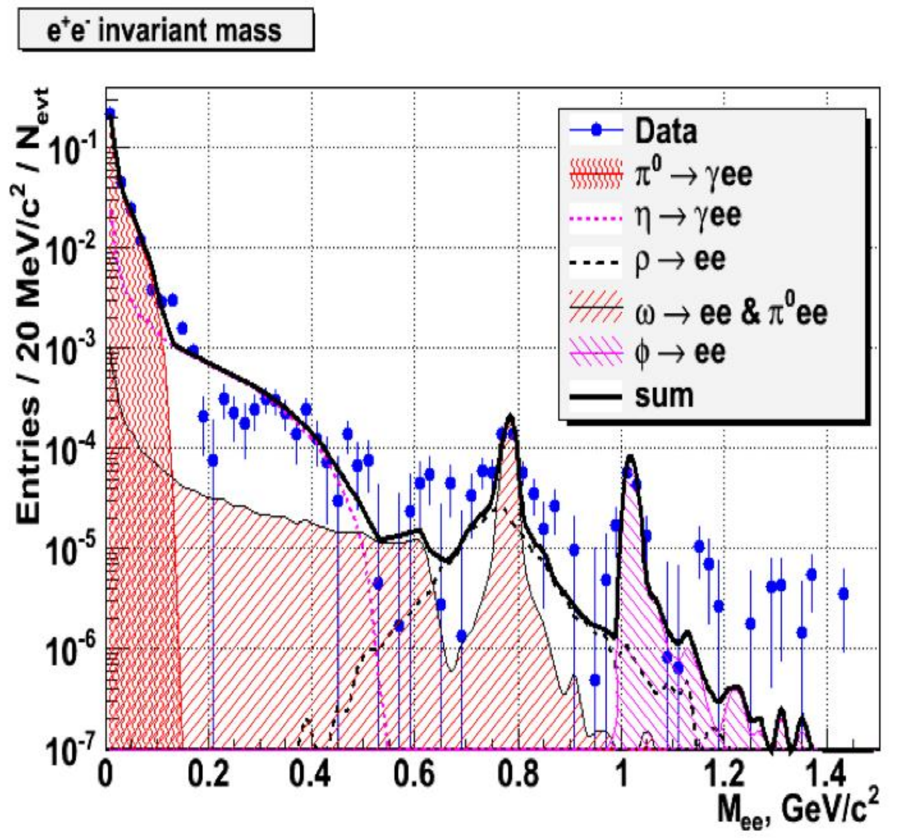


Lepton pairs (e^+e^-) reconstruction

e / π separation (using TPC + RPC)



Signal = (+-) - 2√(++)(--)



F I X E D TARGET

P R O G R A M

(DISCUSSION STARTED SPRING 2010)

Fixed target experimental area

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

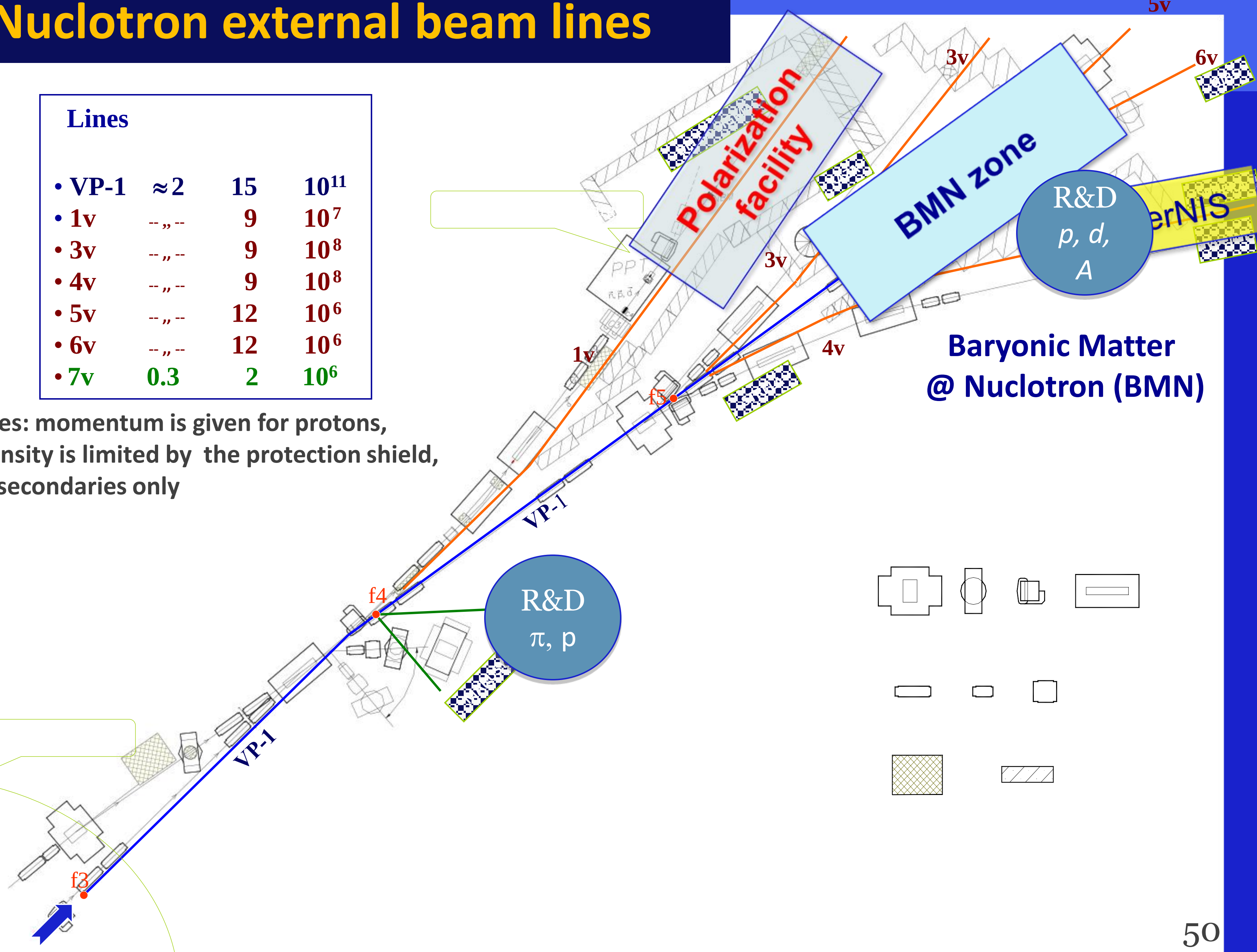
This is the high priority task, because it provides:

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

Nuclotron external beam lines

Lines			
• 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)

Slowly extracted beam

Baryonic Matter @ Nuclotron (BM@N)

Schedule *(preliminary)*

- **Start of project preparation 2010**
- **presentation for the consideration at PAC 2012**
  choice of magnet (?) & start its modernization
  working on the project
- **experimental area preparation 2012**
  major subdetector for the starting kit
  are prototyped & mounted
- **BMN starting kit commissioning 2013**
- **Start of physics runs 2014**

Fixed target area working plans *(very preliminary draft)*

2011 **2012** **2013** **2014** **2015** **2016**

bld.205 reparation + infrastructure

extracted beam channels update

BMN infrastructure preparation

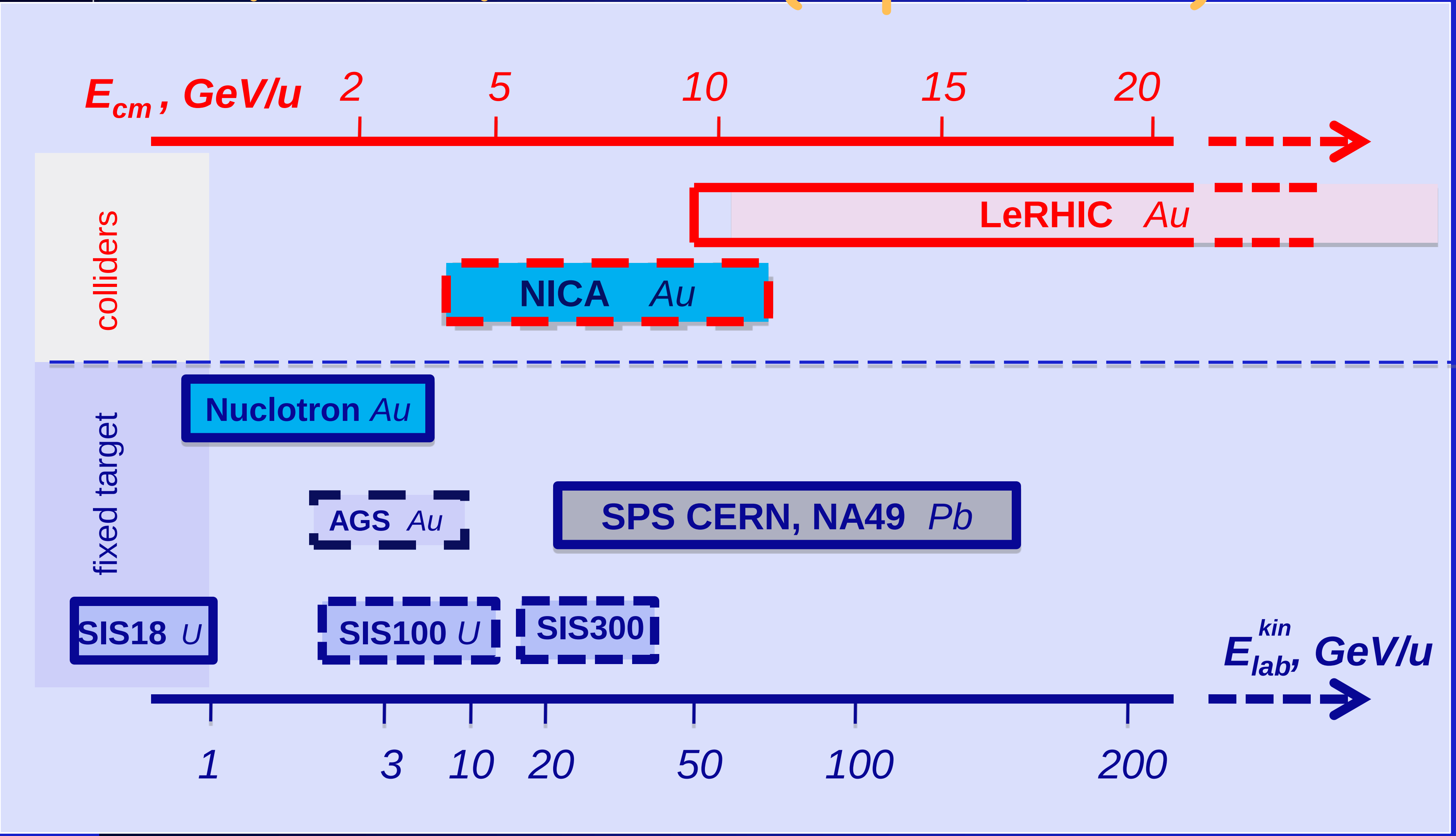
BM@N magnet putting in operation

BM@N detector assembly & commissioning (*min. configuration*)

runs with **BM@N** detector

test beams for detector elements **R&D**

Energy regions covered by present & future facilities (experiments)



Summary

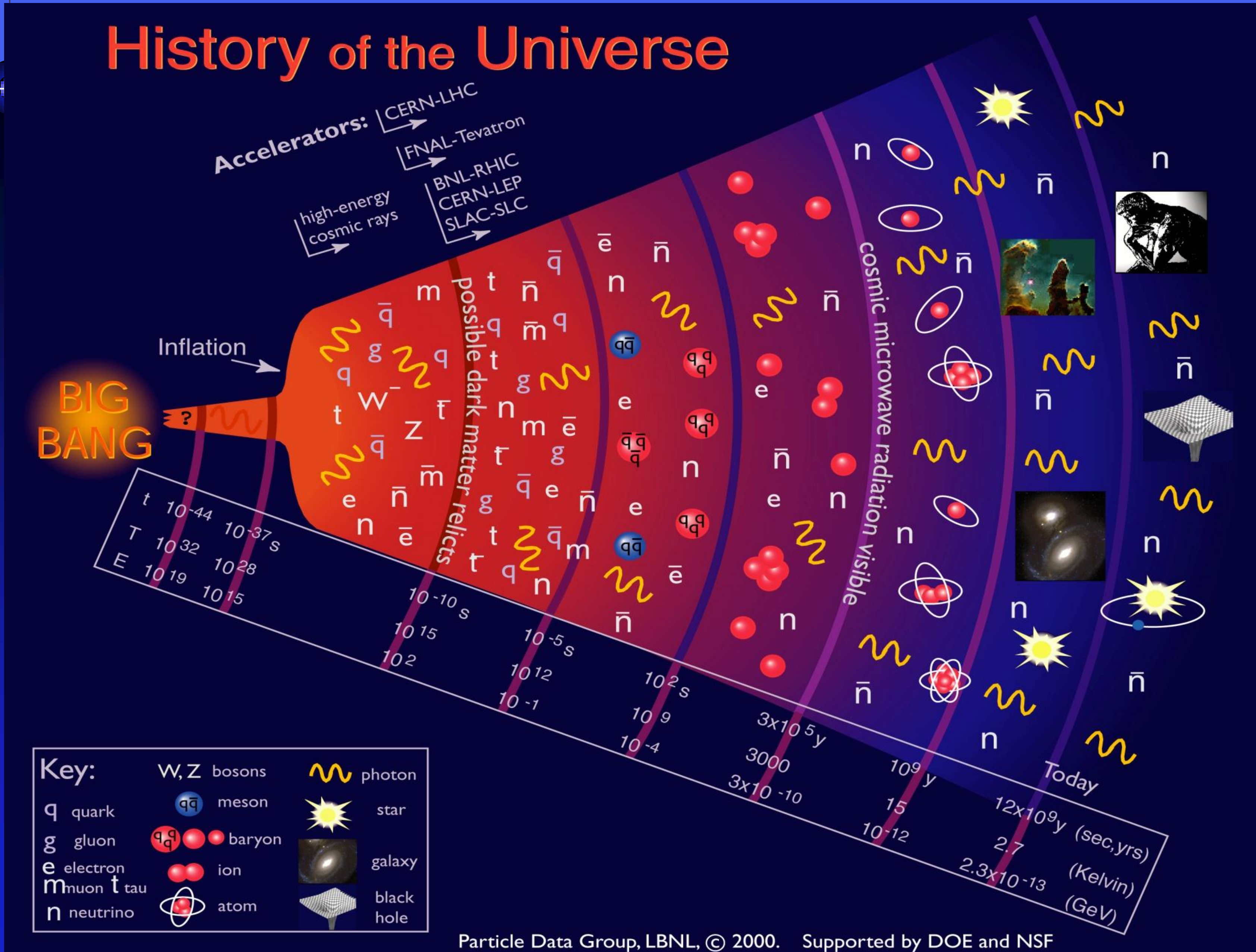
- ***NICA/MPD*** *project to study hot & dense baryonic matter is progressing well*
- *sub-project* ***Nuclotron-M*** *completed !*
- *new sub-**project Nuclotron-N** presented for the consideration at PAC in 2011 (**APPROVED!**)*
- *the 1st stage **of MPD** conception is completed, & the project is recommended for realization by PAC in 2010*
- *the scientific program in **Dense Baryonic Matter** will be extended by **Fix Target** facility – **BM@N***
- *new collaborations **are invited** to present proposals*

good reasons to start the joint program in DBM

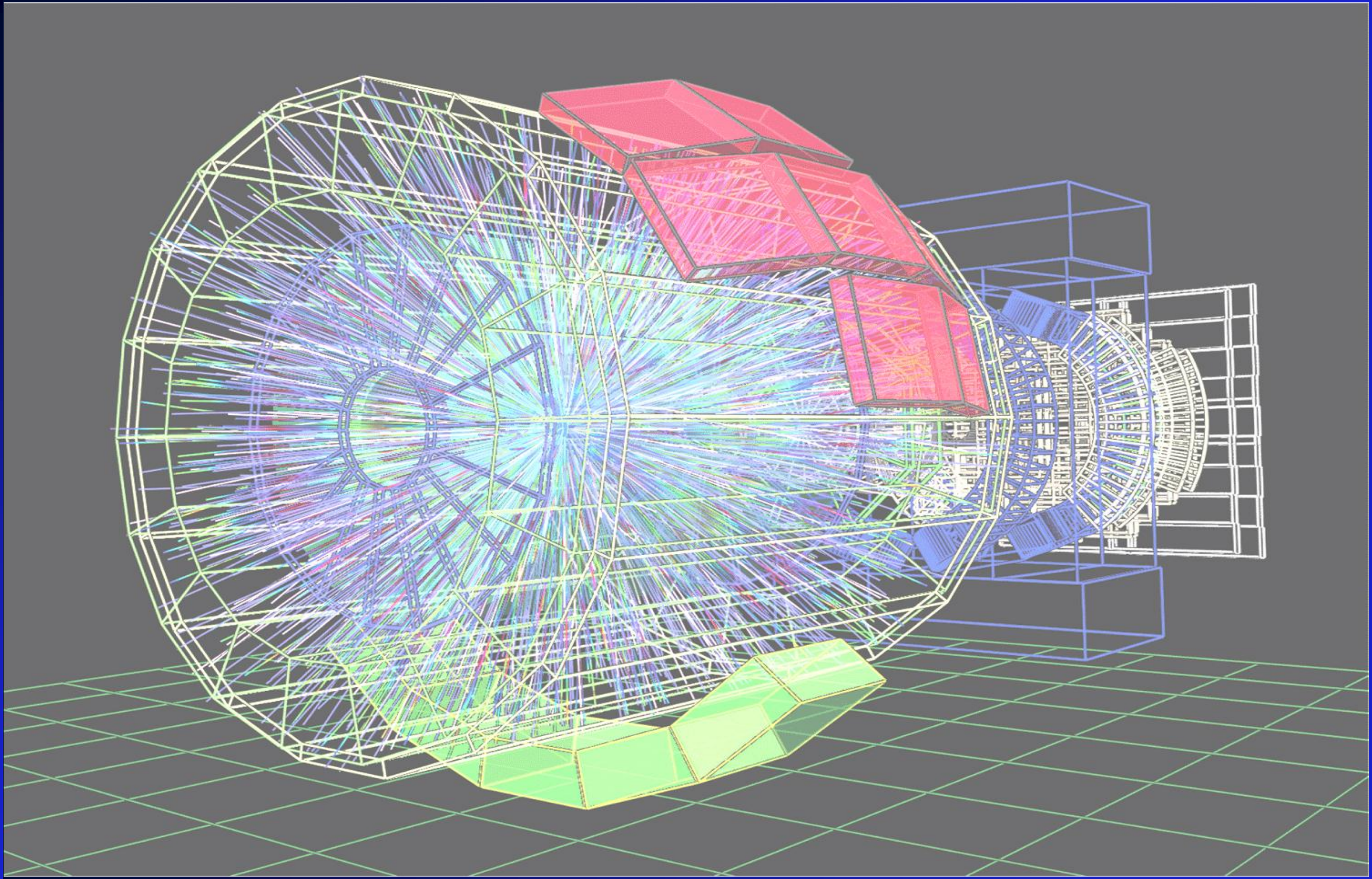
RF Prime Minister V.V. Putin at NICA, 5 July 2011

THANK YOU
FOR YOUR ATTENTION

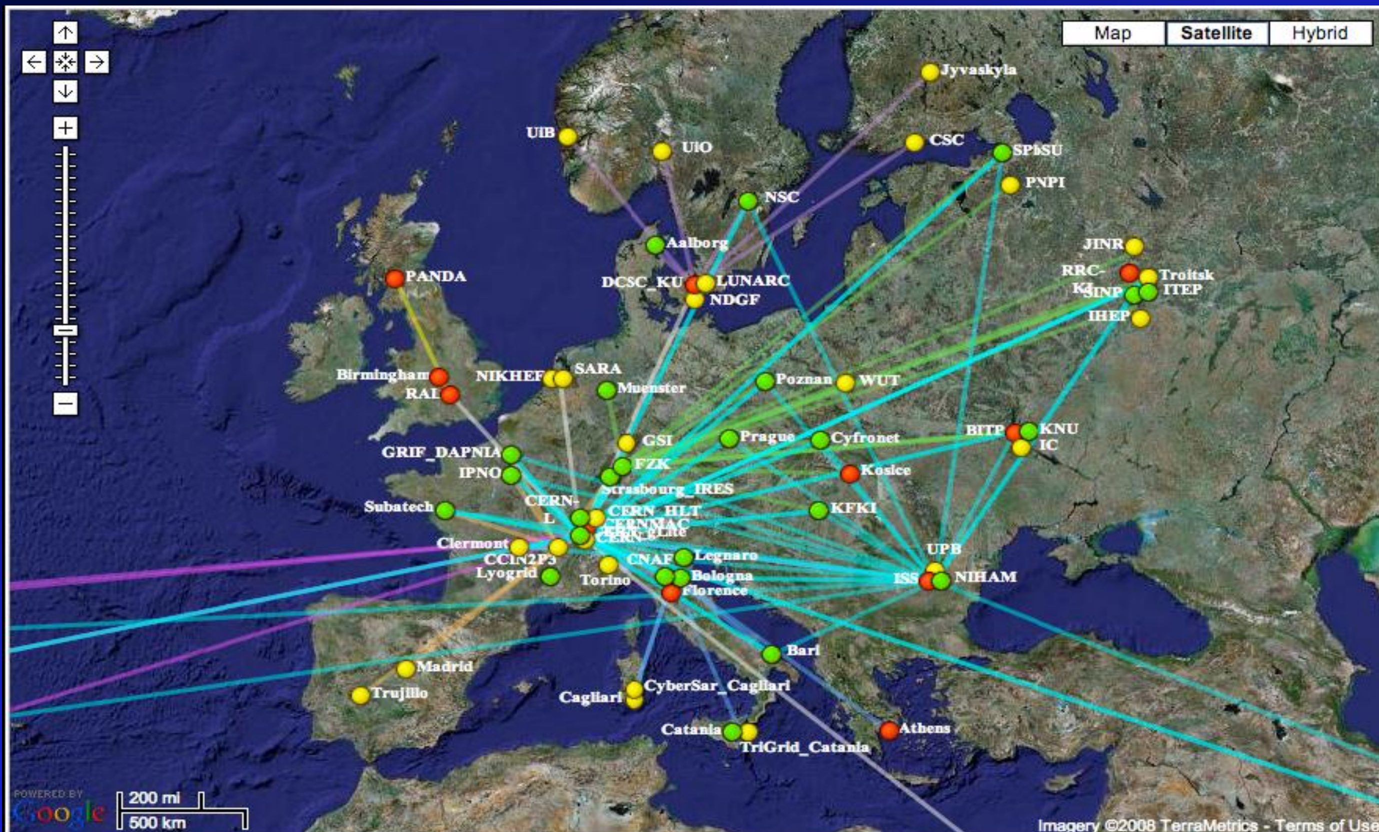
SPARES

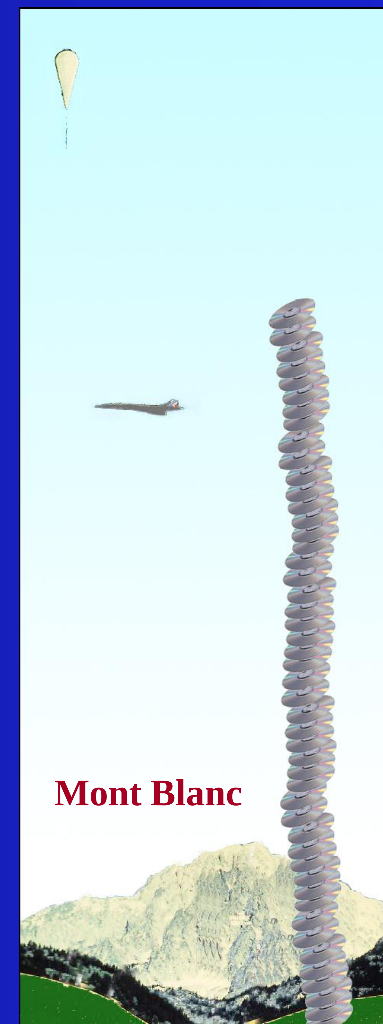

History of the Universe
Accelerators:
CERN-LHC
FNAL-Tevatron
BNL-RHIC
CERN-LEP
SLAC-SLC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10^-44 10^-37 s 10^-10 s 10^-5 s 10^2 s 3x10^5 y 10^9 y 12x10^9 y (sec,yrs)
T 10^32 10^28 10^15 10^12 10^9 3000 15 2.7 (Kelvin)
E 10^19 10^15 10^2 10^-1 10^-4 3x10^-10 10^-12 2.3x10^-13 (GeV)
Today
Key:
q quark
g gluon
e electron
m muon t tau
n neutrino
W, Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

Модель события Pb-Pb взаимодействия



ALICE-GRID: Распределенная сеть обработки экспериментальных данных от США и Мексики до Японии

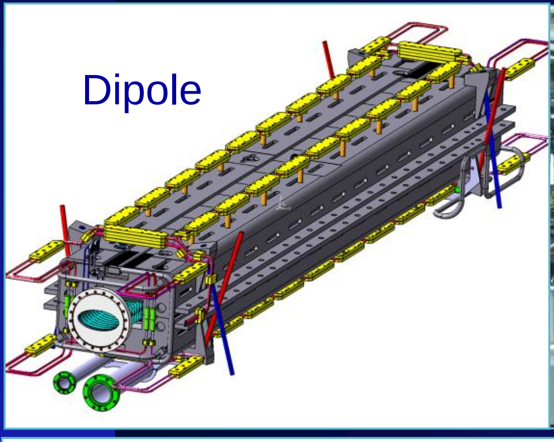


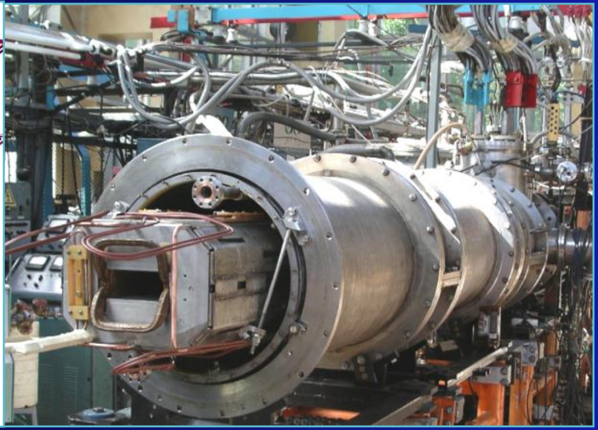


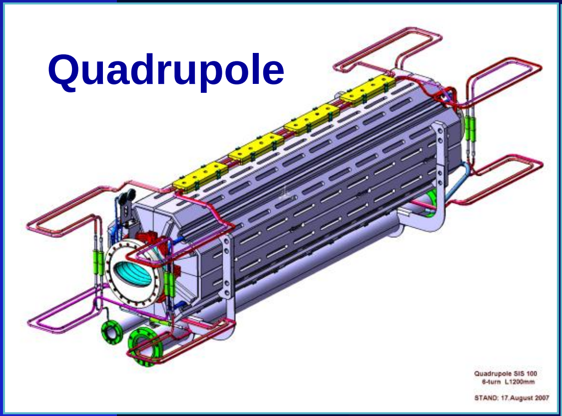
R&D магнита «суперферик»

2008 – подготовлен полный модуль для ускорителя SIS100 в GSI
(работа профинансирована Европейским грантом)

Созданная технология может быть использована в бустере & коллайдере при поле 2Т







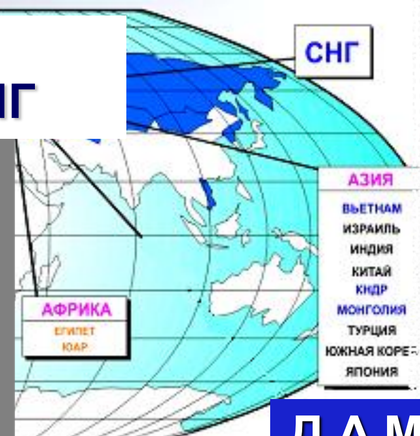
Объединенный Институт Ядерных Исследований
Международная Межправительственная организация на территории Московской области,
созданная в 1956 году Соглашением 11 стран

ОИЯИ

В.В.Путин, 02.01.2000 - закон о Соглашении между ОИЯИ и Российской Федерацией

18 стран-участниц + 6 ассоциированных

НУКЛОТРОН - единственный сверхпроводящий ускоритель в СНГ



Д.А.Медведев, А.Н.Сисакян апрель 2008 г., Дубна, ОИЯИ

Коллайдер НИКА на базе НУКЛОТРОНа
7-летка в бюджете ОИЯИ ⇒ $ 148 M