The status of the NICA project and Polish participation in the MPD Collaboration

A.Kisiel,

Warsaw University of Technology

(based in part on the talk of V. Kekelidze At CERN Detector Seminar)

Joint Institute for Nuclear Research (JINR) – International Intergovernmental Organization established through the Convention of March 26, 1956 by 11 founding States and registered with the United Nations on 1 February 1957

Governed by the
Committee of Plenipotentiary
*representing governments of **18** countries*

Synchrophasotron –10 GeV proton synchrotron (1957) ***pioneering research in RNP since '70-th;***

SC synchrotron- **Nuclotron (1993)** *based on superconducting fast cycling magnets developed at* ***LHE JINR***

Nuclotron ring (c= ***251,5*** *m)*

NICA (Nuclotron based Ion Colider fAcility)

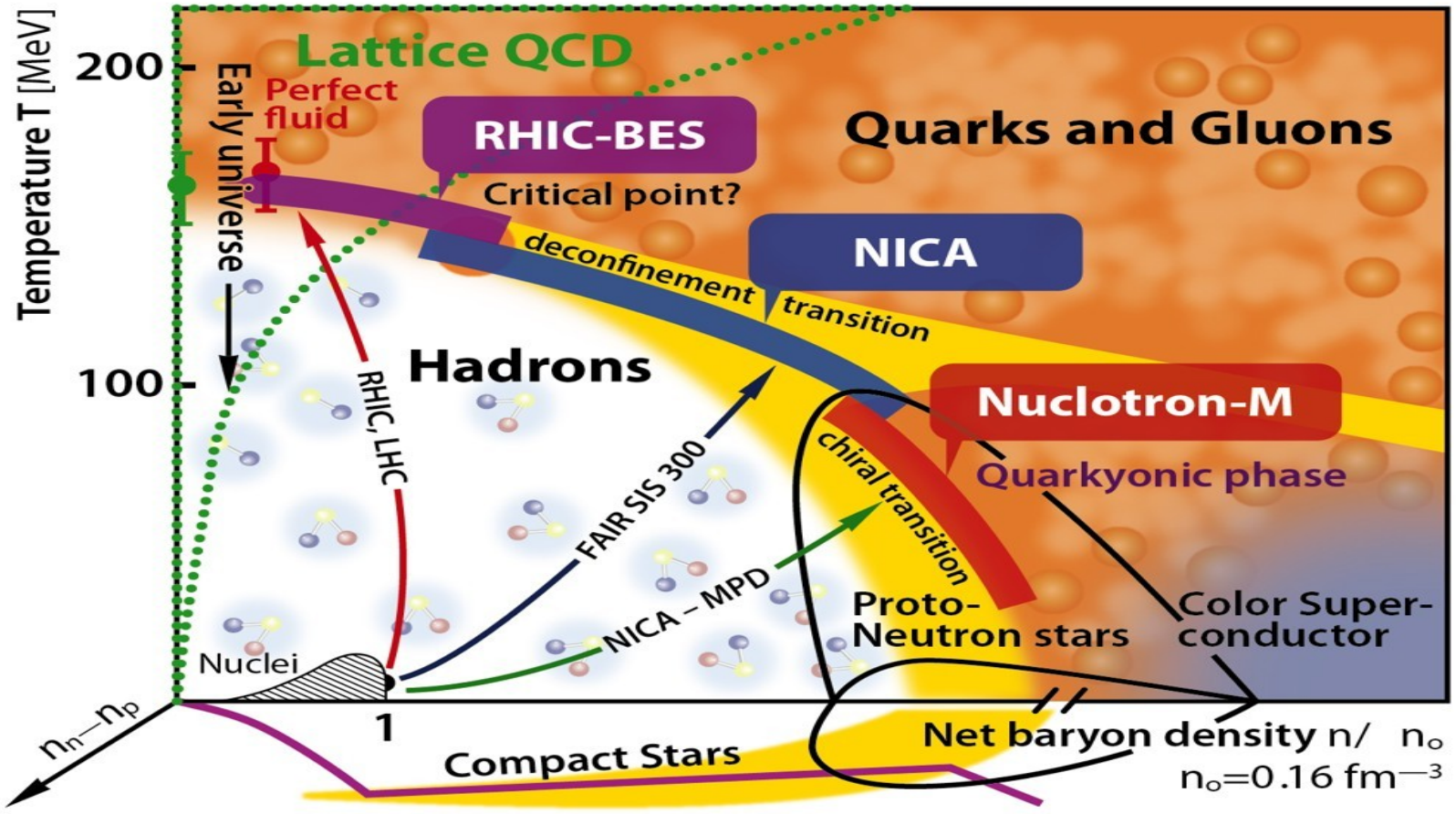
Main targets:

- *study of hot and dense baryonic matter at the energy range of max baryonic density*
- *investigation of nucleon spin structure, polarization phenomena*

- *development of accelerator facility for HEP @ JINR*
- *construction of Collider of relativistic ions from **p** to **Au**, polarized protons and deuterons*

with max energy up to $\sqrt{s_{NN}}$ = **11** *GeV* (Au^{79+}) *and* = **27** *GeV (p)*

NICA -dedicated QCD machine

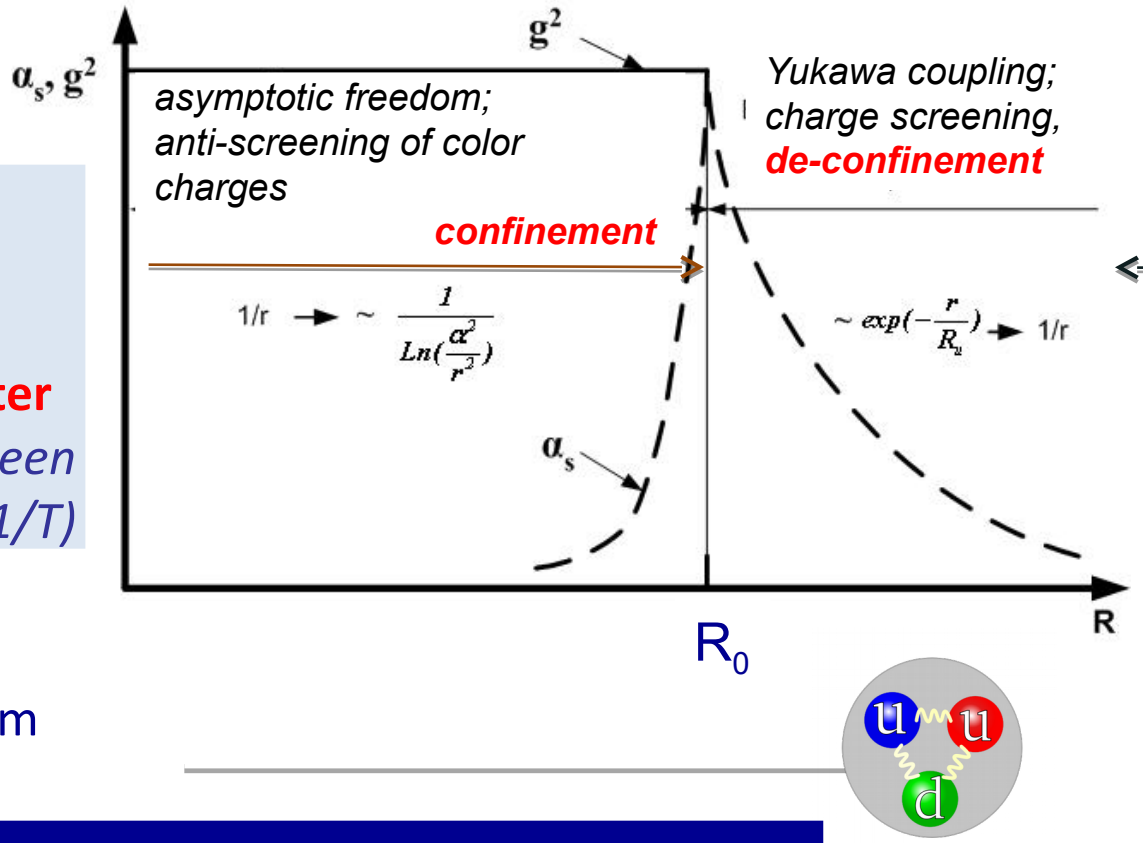


Asymptotic freedom of quarks

The regime of "asymptotic freedom" is reached in hard scattering processes at sufficiently high energies,

D.J.Gross, H.D.Politzer, F.Wilczek

however, this regime could be available already at rather low energies in **super dense nuclear matter** *(the distance between particles ~ 1/T)*



typical size $R_0 \sim 1$ fm $= 10^{-15}$ m

The super dense nuclear matter could be obtained in heavy ion collisions

«The only source of knowledge is experience»

A. Einstein

heavy ion collisions

particle physics: *most of discoveries in last decades have been obtained through research guided by the **Standard Model***

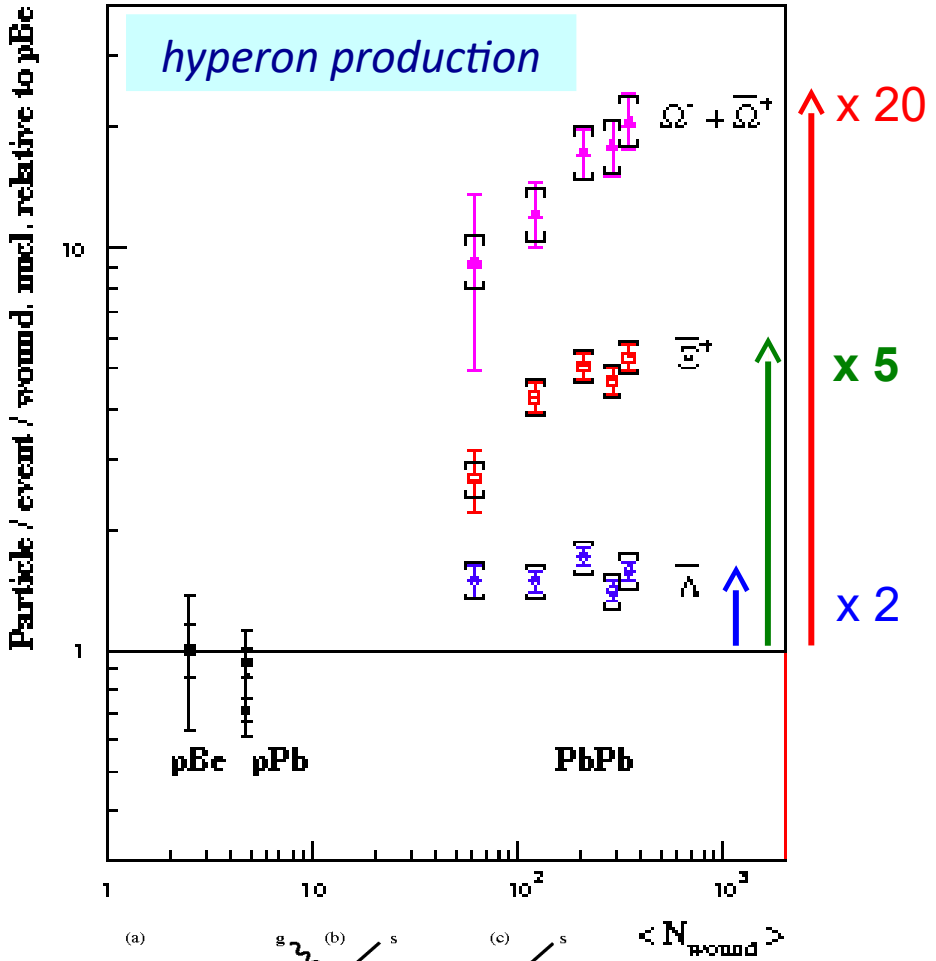
heavy ion collisions: *physics driven by **data***

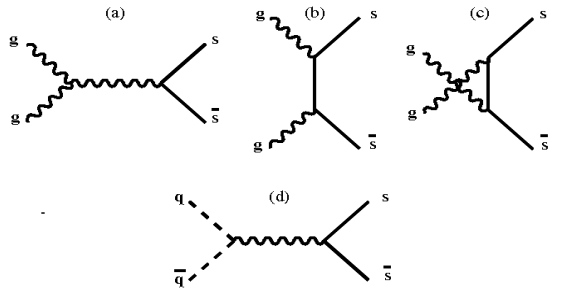
new data in less explored region of QCD phase diagram at **high baryon density**

are highly required and could lead to:

- *observation / discovery of new phenomena;*
- *development of theoretical models*

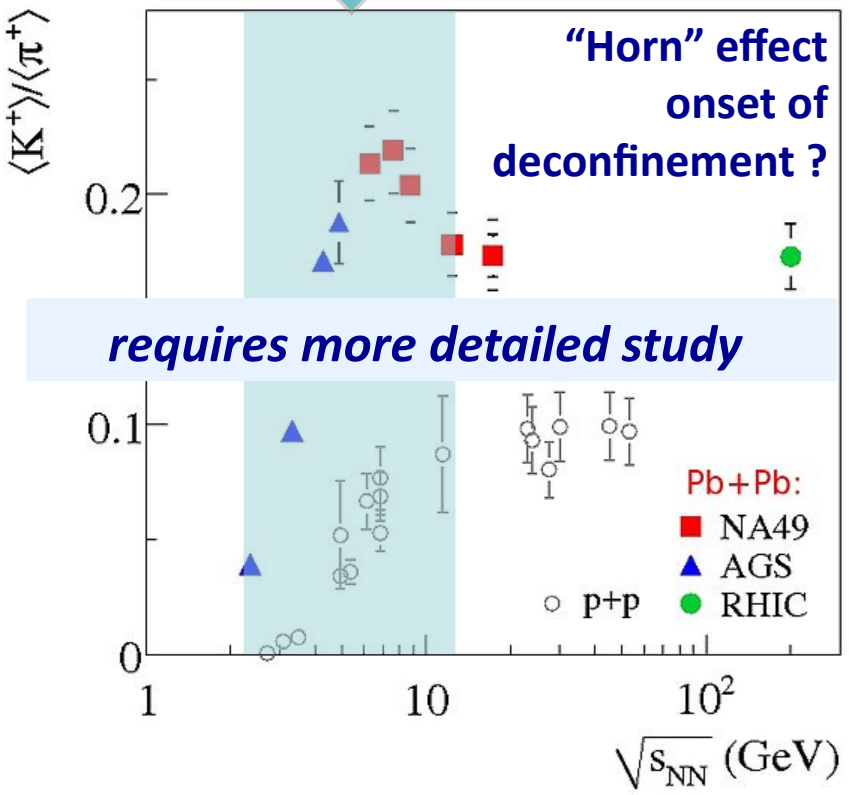
Strangeness Enhancement: *SPS CERN, RHIC*





Indication of chiral symmetry restoration

energy region of **NICA**

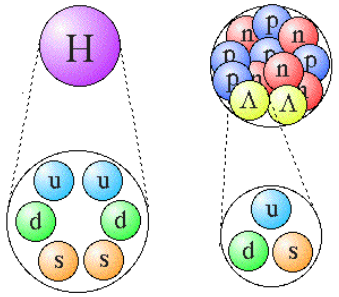


NA49 : *Phys. Rev. C 77, (2008)*

STAR : *QM2011 proceedings*

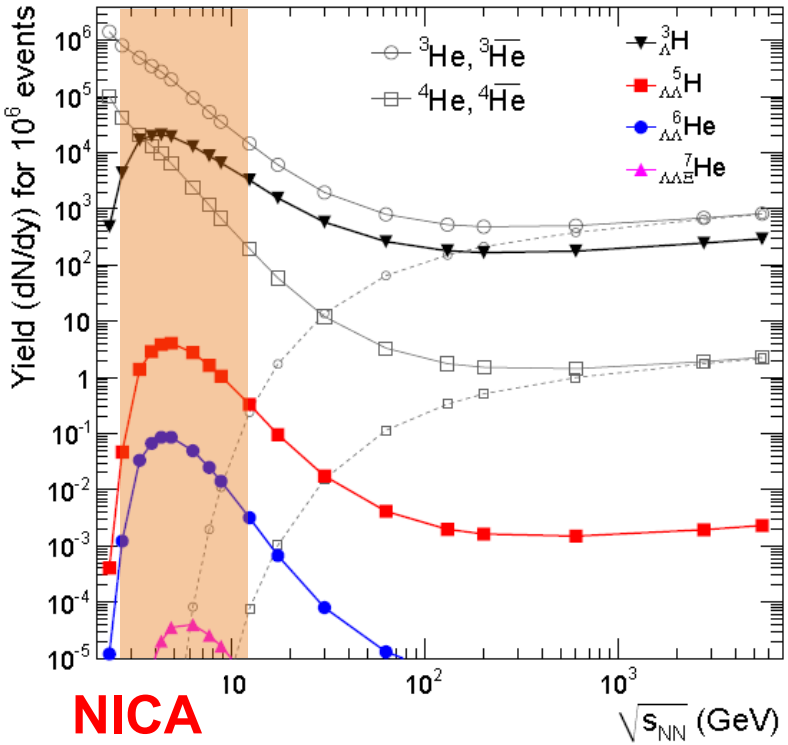
Hypernuclei

Hypernuclei provide unique opportunity to study the strange particle-nucleus interaction in a many-body environment.



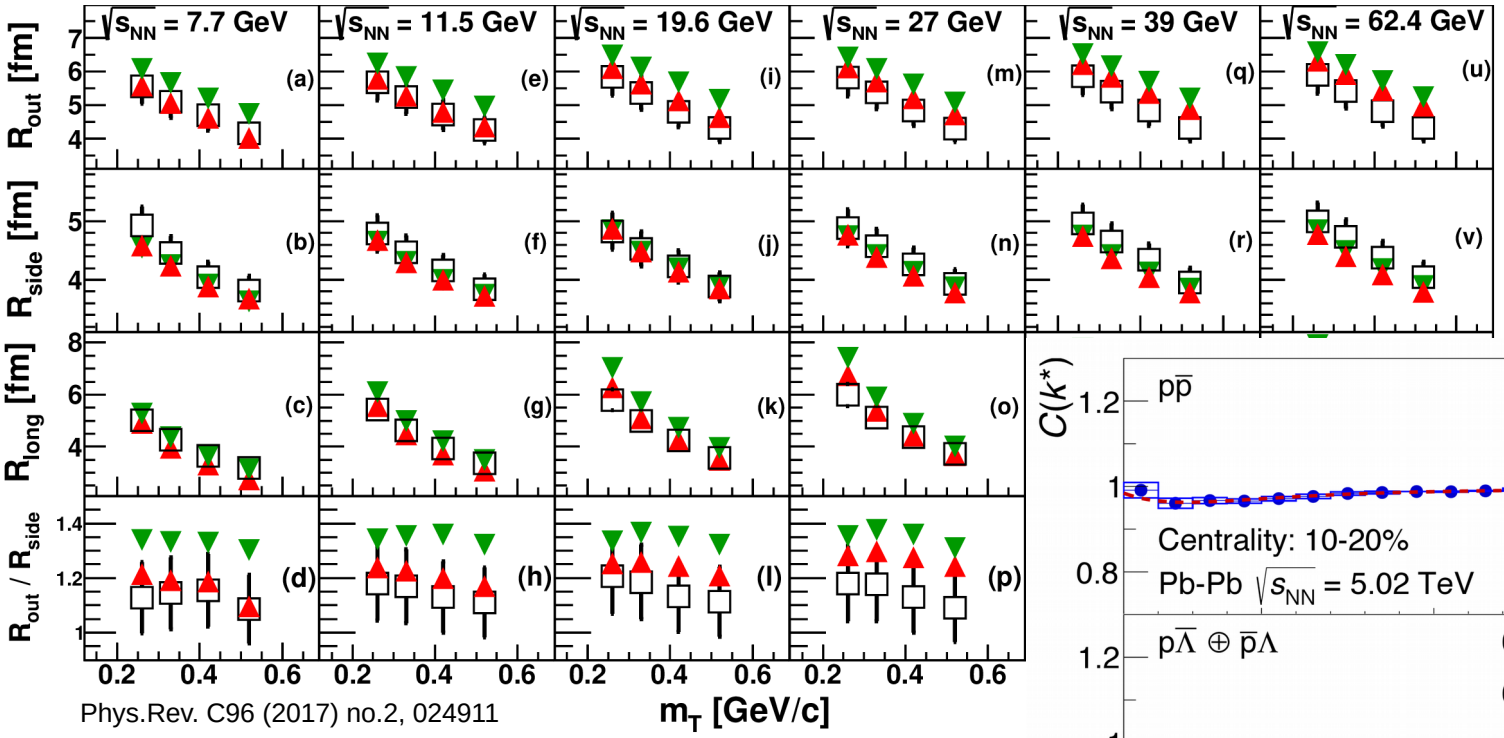
*astrophysical research indicates the appearance of hyperons in the dense core of a **neutron star***

*production enhanced at high baryon densities (**NICA**)*



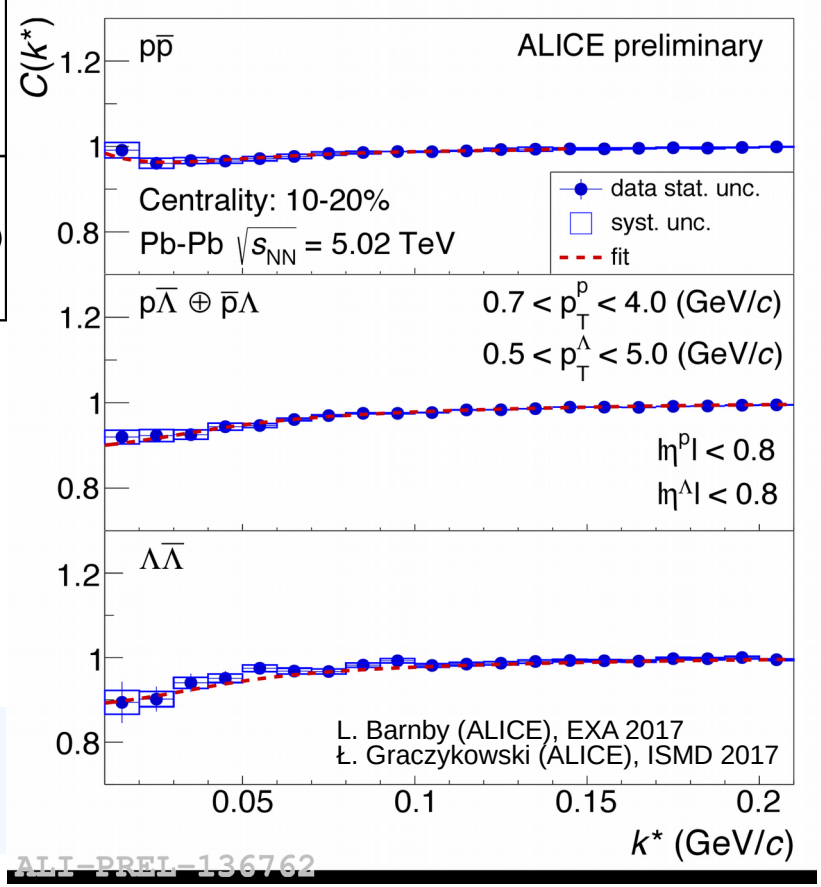
A. Andronic et al., Phys. Lett. B697 (2011) 203

Two-particle correlations



Phys.Rev. C96 (2017) no.2, 024911

System size sensitive to the presence of the first order phase transition

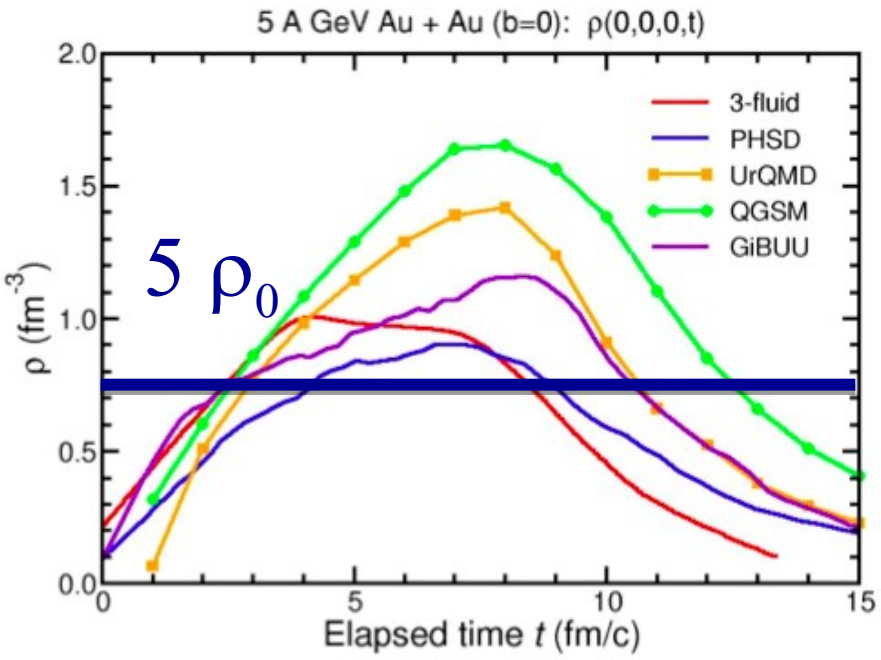


Baryon-(anti-)baryon correlation functions sensitive to strong interaction potentials

Net Baryonic density to be reached in Au + Au collisions

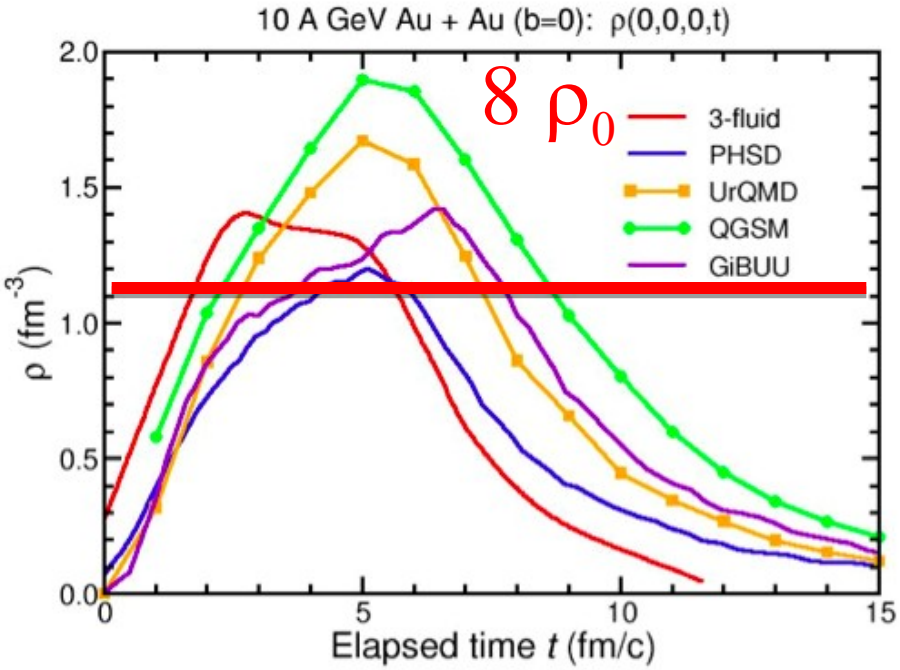
FAIR SIS-100

5 A GeV



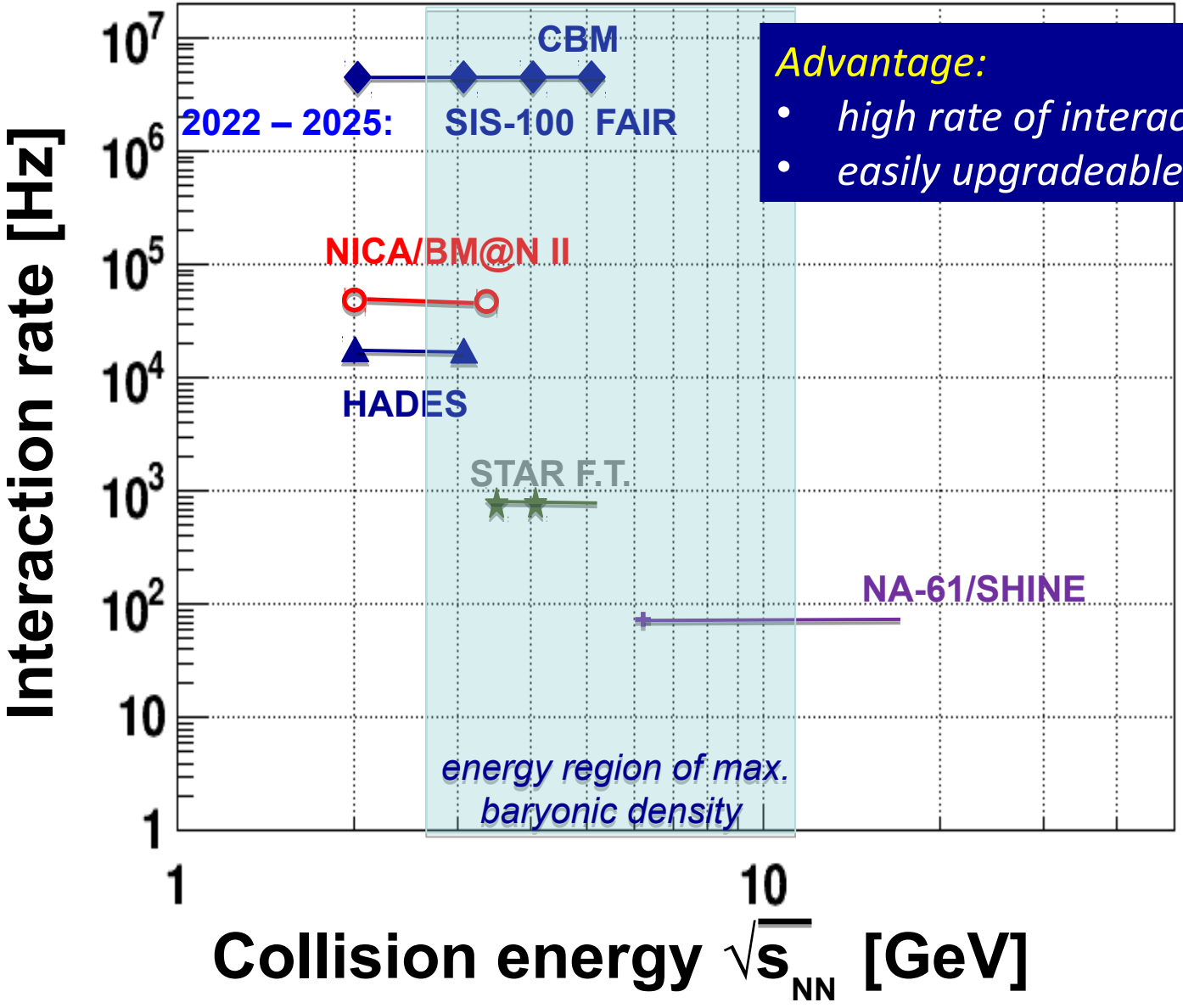
NICA

10 A GeV



I.C. Arsene at al., Phys. Rev. C75 (2007) 24902.

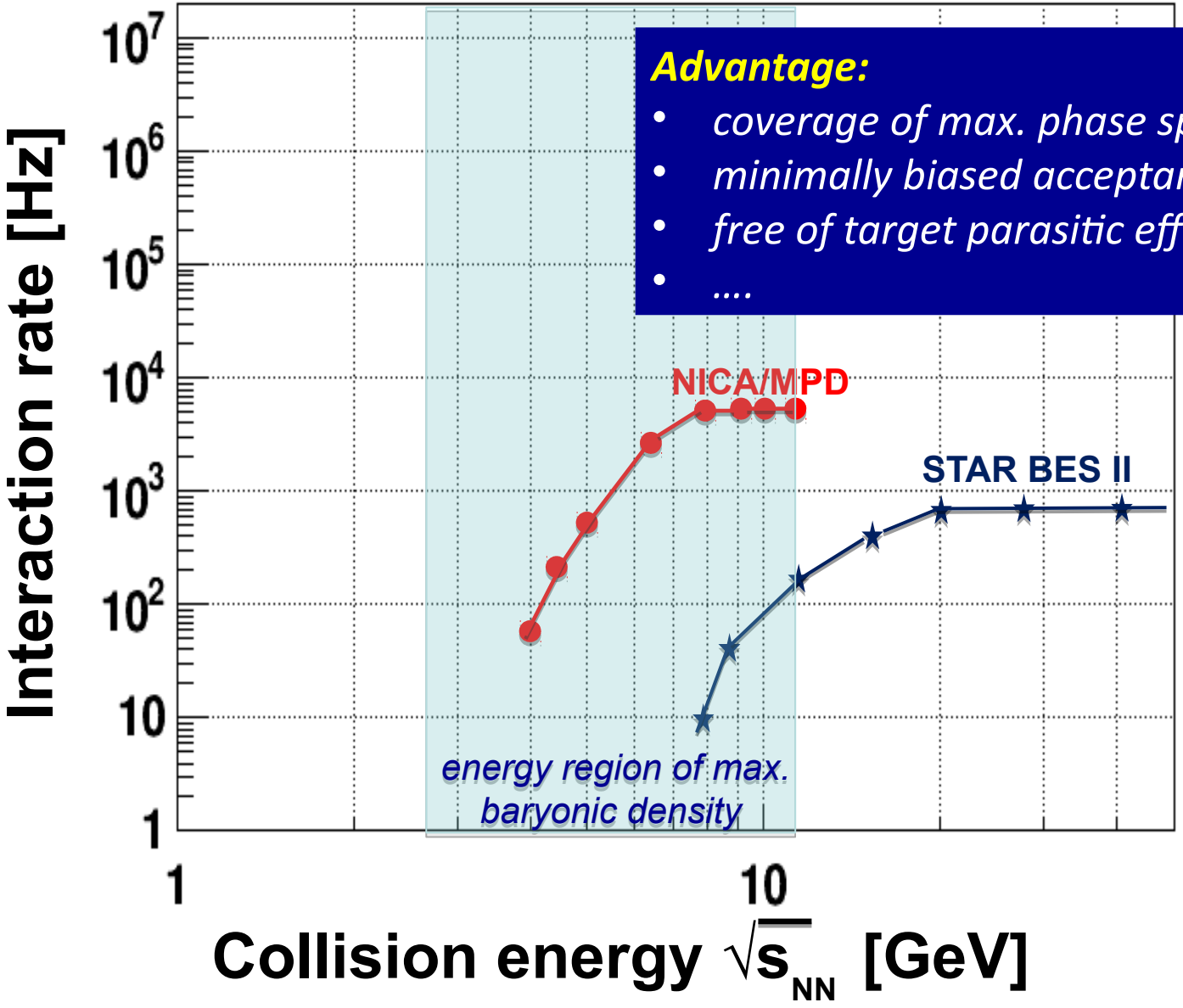
Present and future HI F.T. experiments



Advantage:

- *high rate of interactions*
- *easily upgradeable*

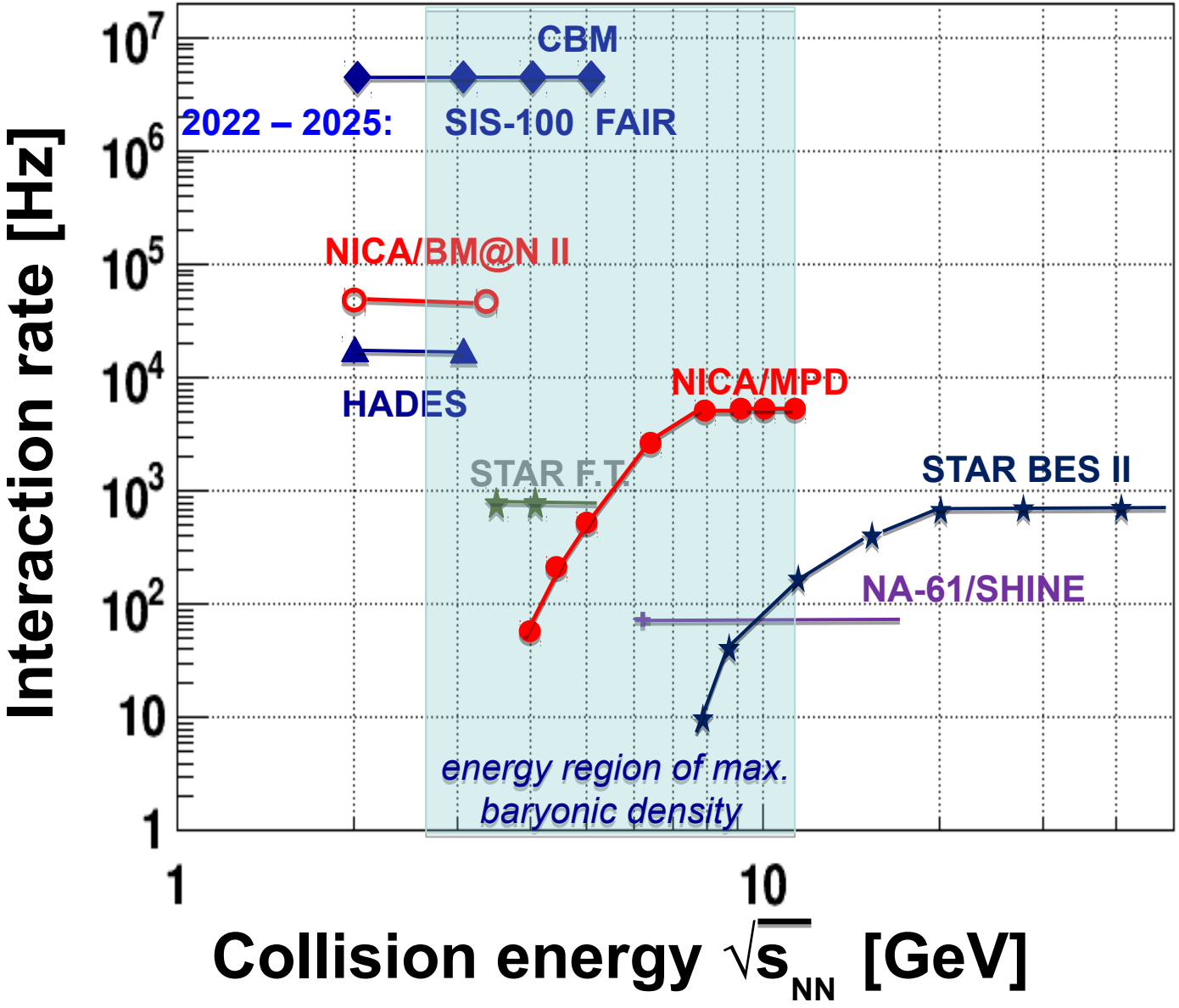
Present and future HI collider experiments



Advantage:

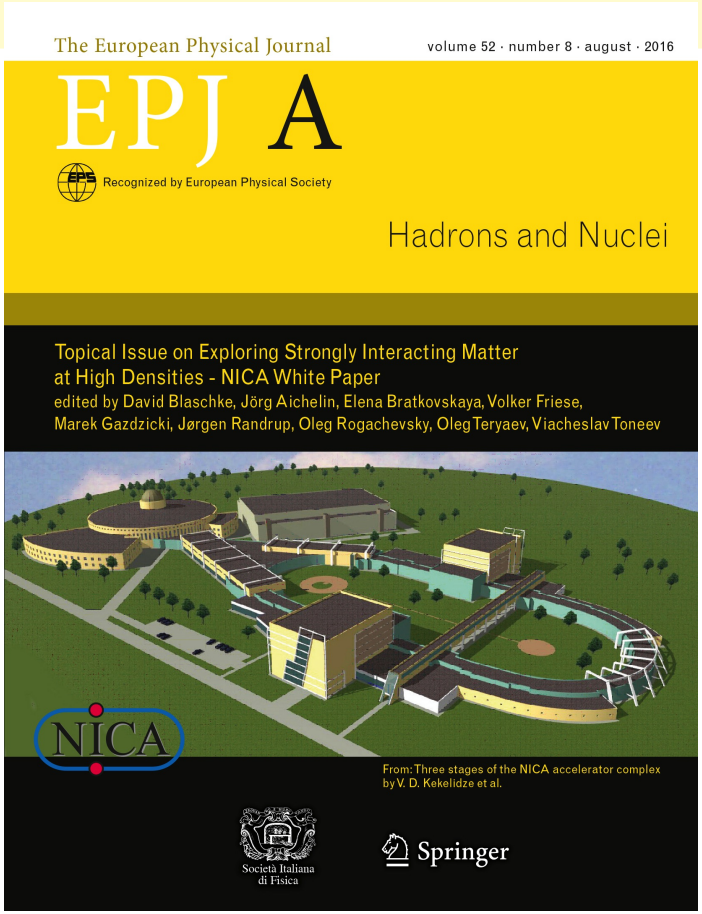
- *coverage of max. phase space*
- *minimally biased acceptance*
- *free of target parasitic effects*
- *....*

Present and future HI experiments



New issues: NICA White Paper, SQM proceedings

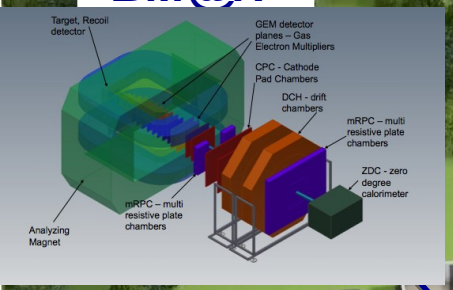
*Physics targets for the exploration of first order phase transitions in the region of the QCD phase diagram accessible to NICA & FAIR and possible observable effects of a "mixed phase" indicated in the release of the "NICA White Paper" as a Topical Issue of the **EPJ A** (July 2016).*



111 *contributions,*
188 *authors*
from **24** *countries*

NICA basic facility

BM@N



SPD (Detector)

E-cooling

MPD (Detector)

BM@N (Detector) Extracted beam

Collider

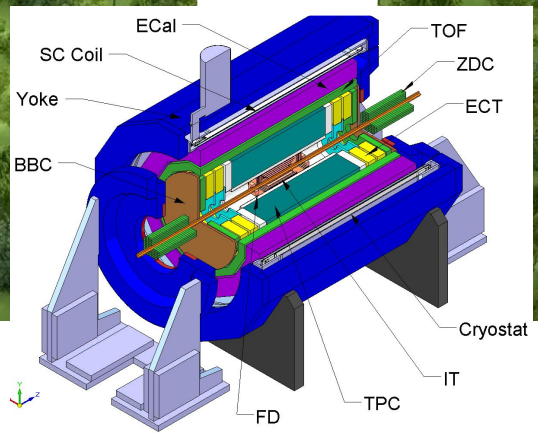
Injection Complex

Nuclotron

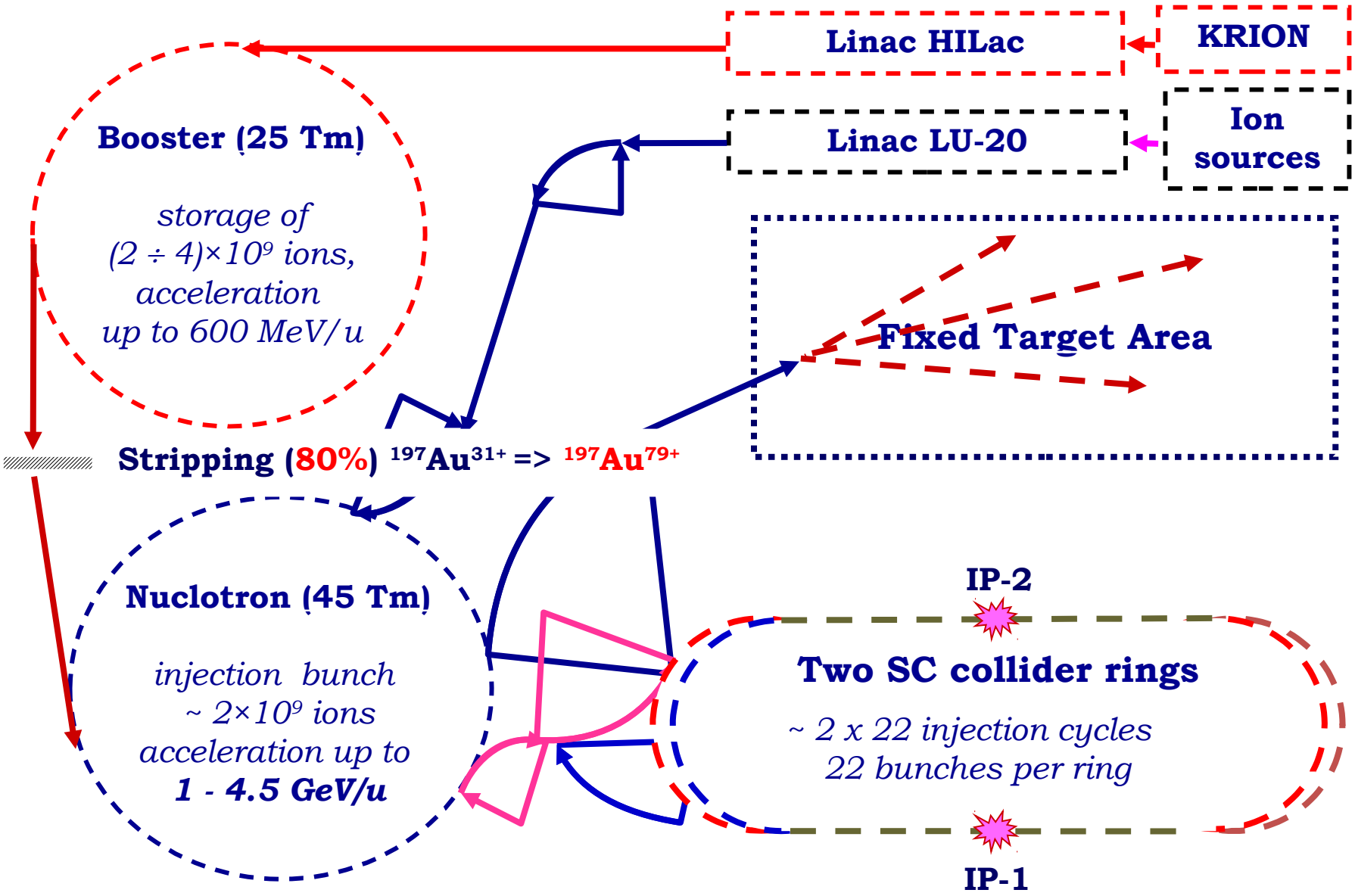
Booster

Nuclotron ring (c=251,5 m)

MPD



Structure of Accelerator Complex and Operation Regimes



Nuclotron:

superconducting synchrotron, put in operation in 1993

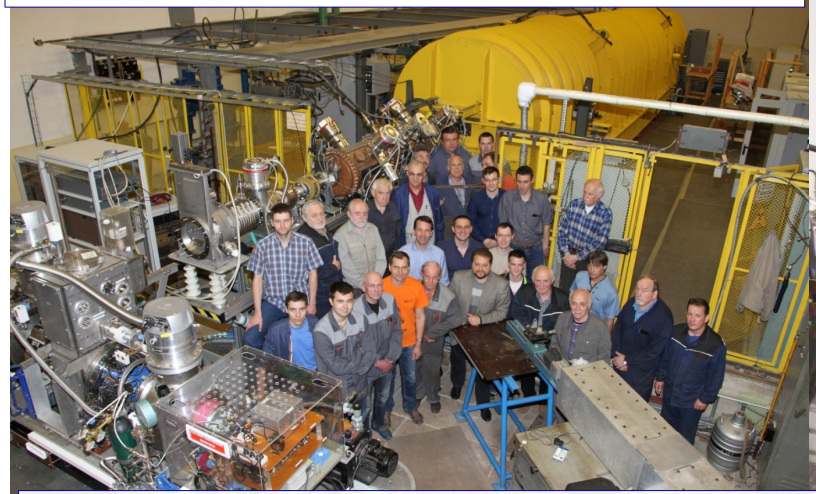
Parameters	Nuclotron
type	SC synchrotron
particles	↑p,↑d, nuclei
injection energy, MeV/u	5 (↑p,↑d) 570-685 (Au)
max. kin. energy, GeV/u	**12.07** (↑p); **5.62** (↑d) **4.38** (Au)
magnetic rigidity, T m	25 – 43.25
circumference, m	251.52
cycle for collider mode, s	1.5-4.2 (active); 5.0 (total)
vacuum, Torr	10^{-9}
*intensity, **Au** ions/pulse*	$1\ 10^{9}$
transition energy, GeV/u	7.0
RF range, MHz	0.6 -6.9 (p, d) 0.947 – 1.147 (nuclei)
spill of slow extraction, s	up to ↑10↑

*modernized in **2010-2015***

Linacs

Linac	LU-20	HILAC **new !**
structure (section number)	RFQ + Alvarez type	RFQ + IH DTL(2)
mass to charge ratio A/Z	1-3	1-6
injection energy, keV/amu	150 for A/Z 1-3	17
extraction energy, MeV/amu	**5** (A/Z 1-3)	**3.24** (A/Z=6)
input current, mA	up to 20	up to 10

***LU-20 – new for-injector**:*
*JINR, **INR, ITEP, MEPI***



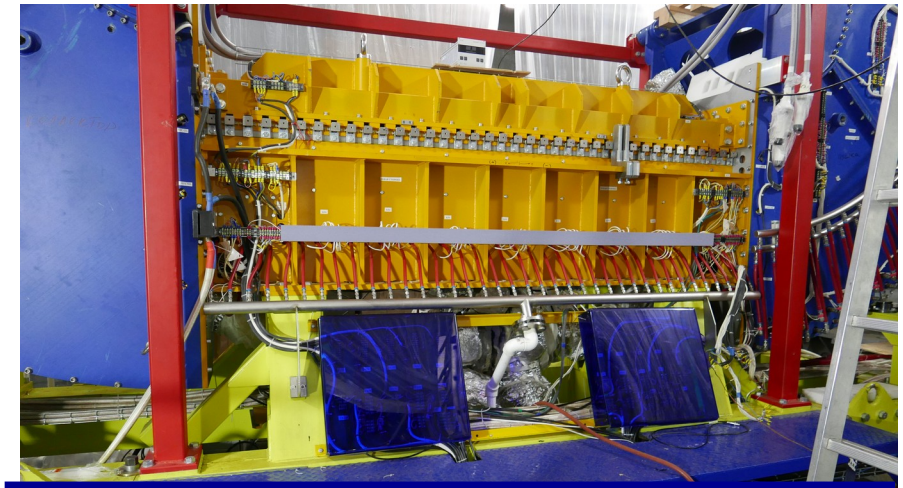
put in operation: May '16

HILAC: "BEVATECH OHG"

put in operation: Oct. .'16

Booster (*under construction*)

Parameter	Booster
type	SC synchrotron
particles	ions A/Z ≤ 3
injection energy, MeV/u	3.2
maximum energy, MeV/u	**600**
magnetic rigidity, T m	1.6 – 25.0
circumference, m	210.96
cycle for collider mode, s	4.02 (active); 5.0 (total)
vacuum, Torr	10^{-11}
*intensity, **Au** ions/pulse*	$1.5\ 10^{9}$
transition energy, GeV/u	3.25
RF range, MHz	0.5 -2.53
spill of slow extraction, s	up to 10



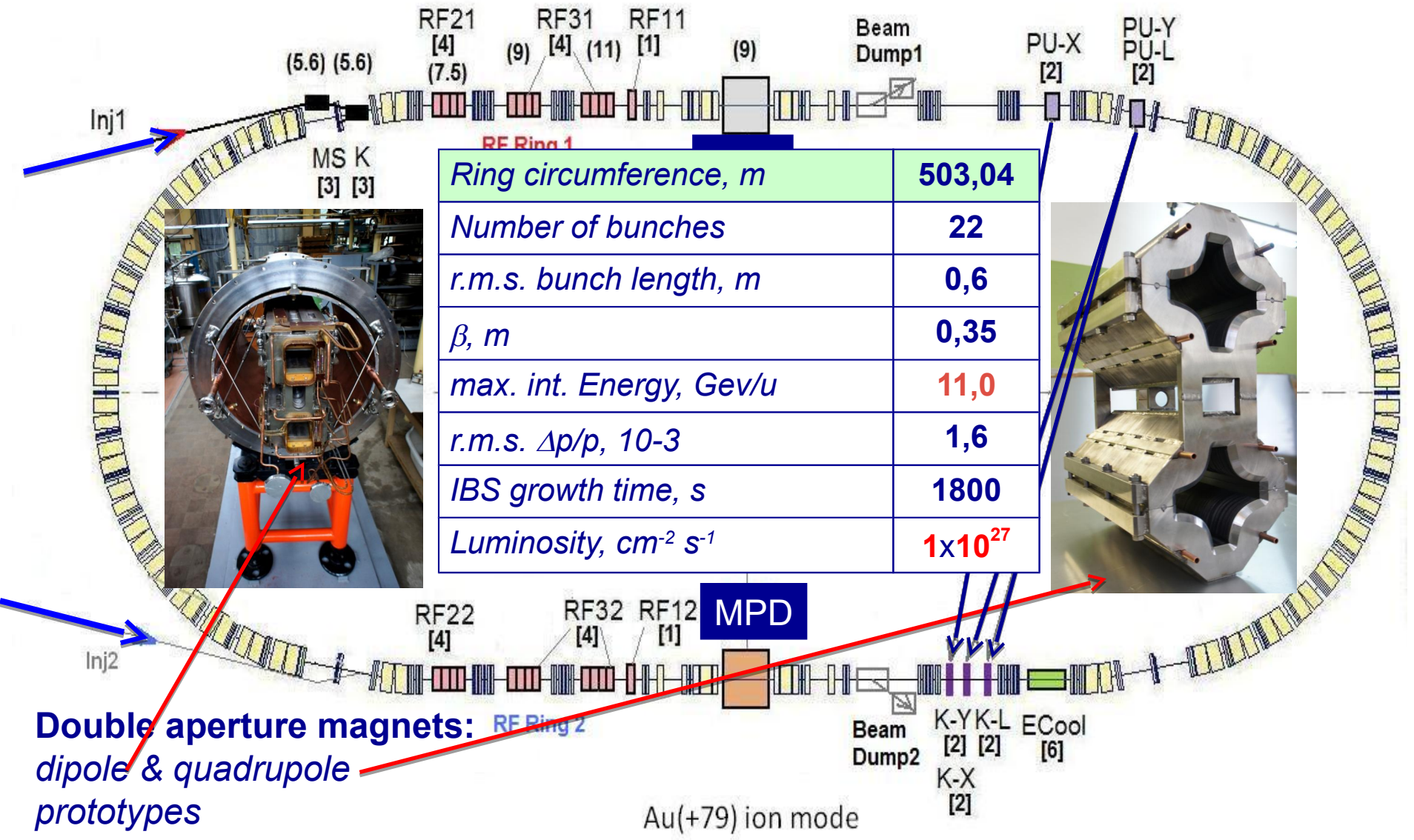
Electron Cooling System & 2 RF stations (Budker INP) - installed

tunnel is ready

Commissioning starts in Dec. 2018

The Collider

45 T*m, *4.5 GeV/u for* ***Au***$^{79+}$



Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
max. int. Energy, Gev/u	**11,0**
r.m.s. $\Delta p/p$, 10-3	**1,6**
IBS growth time, s	**1800**
Luminosity, cm^{-2} s^{-1}	**1×10^{27}**

Double aperture magnets:
dipole & quadrupole prototypes

Workshop at VBLHEP *(bld. 217)* for production of SC magnets for NICA & SIS-100/FAIR

was put in operation in Nov. 2016

all of the Booster magnets are produced & tested

Civil Construction, bld.17

June 2018

readiness for equipment installation in the MPD Hall - 2019

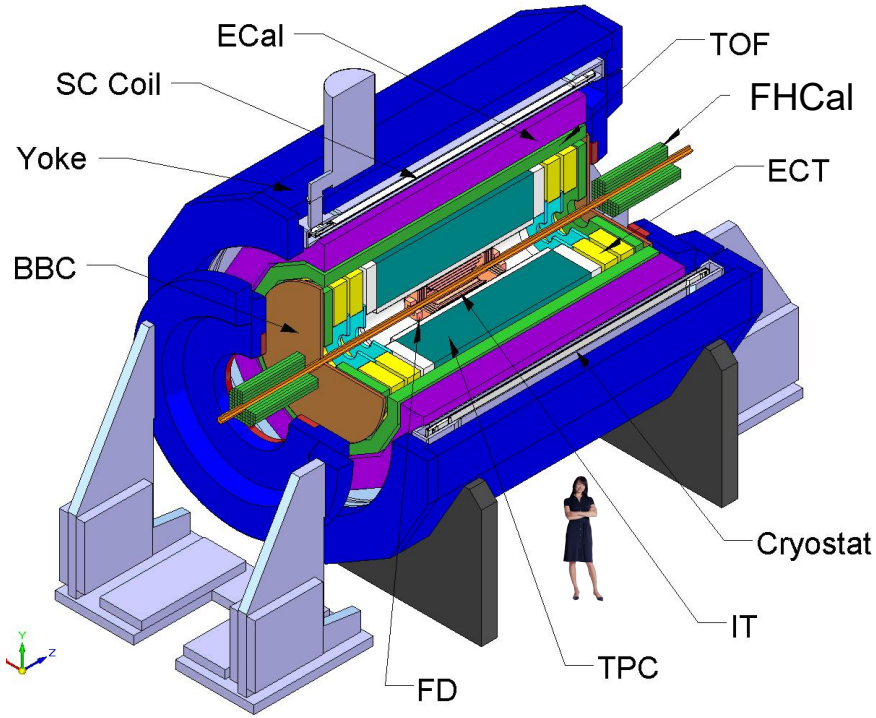
Civil Construction, bld.17

June 2018

readiness for equipment installation in the MPD Hall - 2019

Visit on site at 29 Oct 2018

MultiPurpose Detector (MPD) Collaboration:

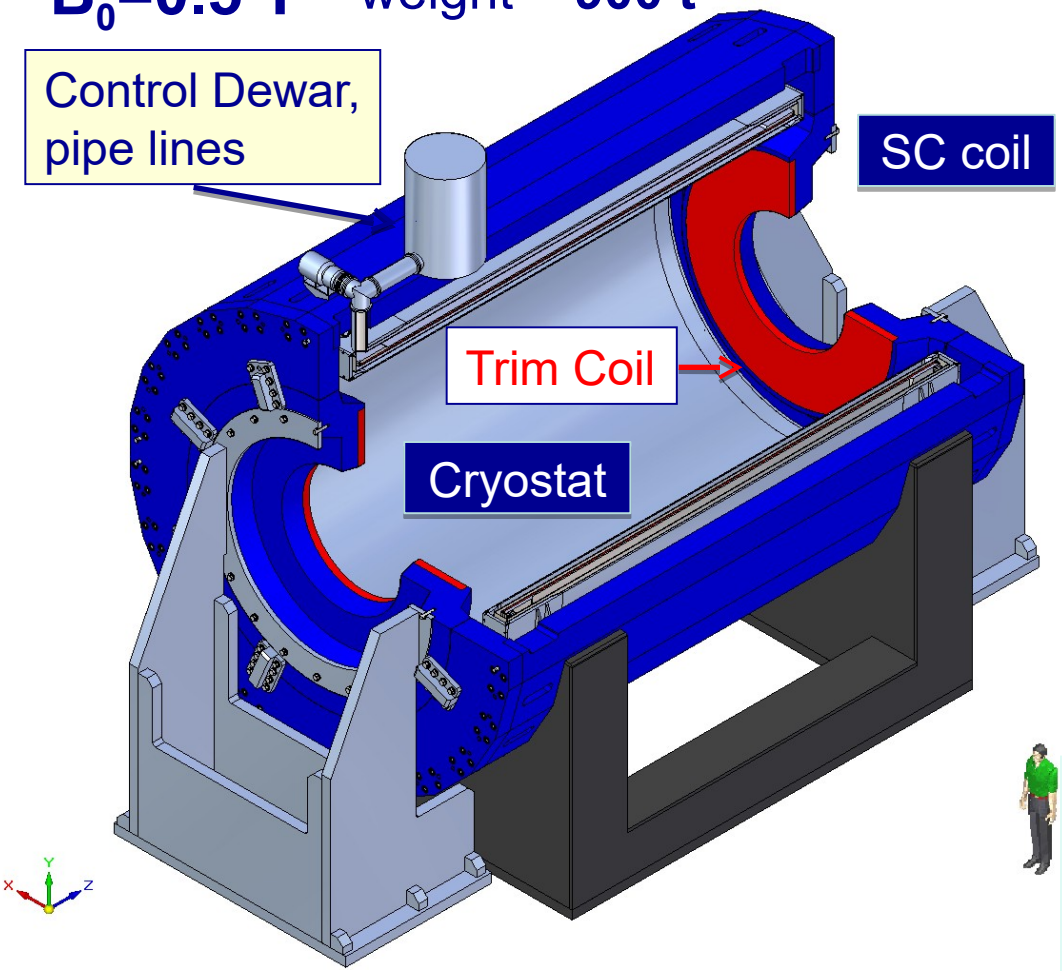


*Baku State University, NNRC, **Azerbaijan**;*
*University of Plovdiv, **Bulgaria;***
*University Tecnica Federico Santa Maria, Valparaiso, **Chile**;*
*Tsinghua University, Beijing, **China**;*
*USTC, Hefei, **China**;*
*Huizhou University, Huizhou, **China**;*
*Institute of Nuclear and Applied Physics, CAS, Shanghai, **China**;*
*Central China Normal University, **China**;*
*Shandong University, Shandong, **China**;*

*IHEP, Beijing, **China**;*
*University of South China, **China**;*
*Palacky University, Olomouc, **Czech Republic**;*
*NPI CAS, Rez, **Czech Republic**;*
*Tbilisi State University, Tbilisi, **Georgia**;*
*Tubingen University, Tubingen, **Germany;***
*Tel Aviv University, Tel Aviv, **Israel**;*
Joint Institute for Nuclear Research;
*IPT, Almaty, **Kazakhstan**;*
*UNAM, Mexico City, **Mexico**;*
*Institute of Applied Physics, Chisinev, **Moldova**;*
*WUT, Warsaw, **Poland**;*
*NCN, Otwock – Świerk, **Poland**;*
*UW, Wrocław, **Poland**;*
*Jan Kochanowski University, Kielce, **Poland**;*
*INR RAS, Moscow, **Russia**;*
*MEPhI, Moscow, **Russia**;*
*PNPI, Gatchina, **Russia**;*
*INP MSU, Moscow, **Russia**;*
*SPSU - Dept. of NP, **Russia;***
*St. Petersburg, **Russia**;*
*SPSU – Dept. of HEP, St. Petersburg, **Russia**;*
*KI NRS, Moscow, **Russia**;*

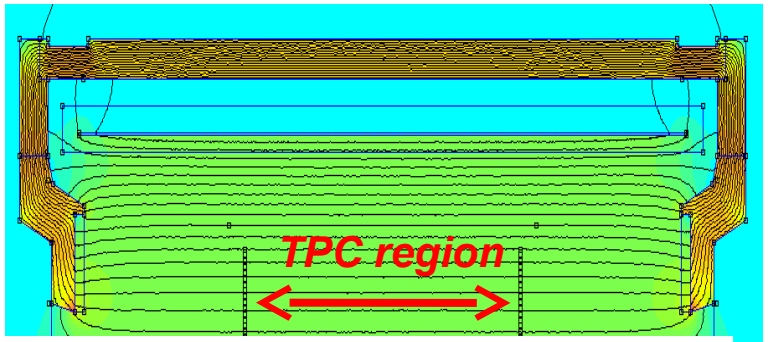
superconducting Solenoid

B_0=0.5 T weight **~ 900 t**



rated current: ***1790 A***

stored energy: ***14.6 MJ***



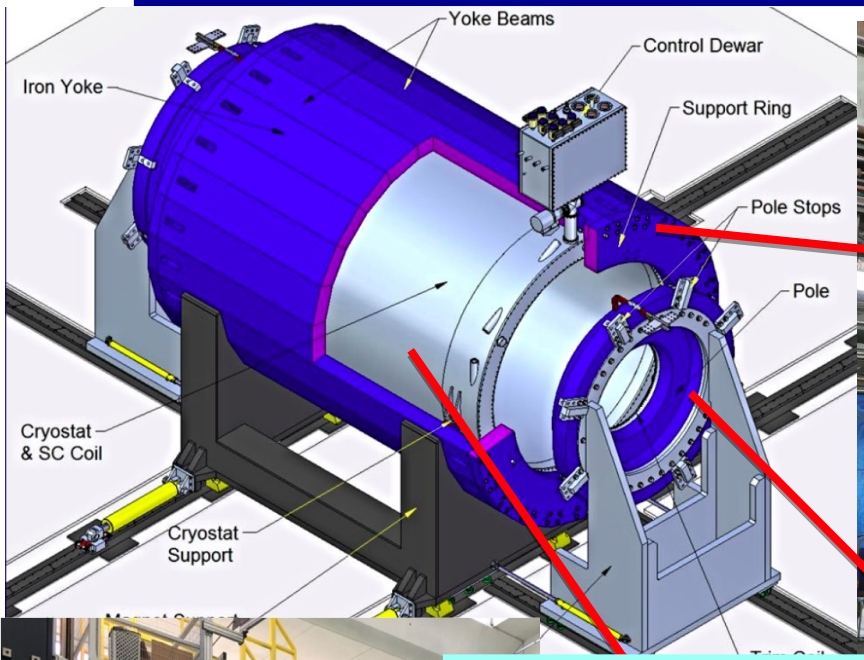
high level (~ ***3x10^{-4}****) of magnetic field homogeneity*

HM Vitkovice, *Czech Republic:*
fabrication of yoke & supports

ASG superconductors, *Genova*
general responsibility:

- *Cold Mass + Cryostat*
- *Trim Coils*
- *Vacuum System*
- *Control System + PS +…*

Magnet fabrication: *ASG (Genova) & Vitkovice HM*

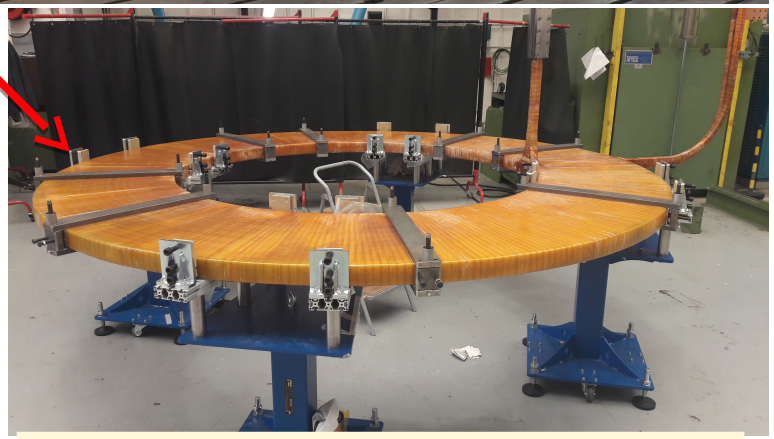


yoke control assembly at HM Vitkovice

*final assembly in the MPD hall - **June 2019***

winding machine

cryostat



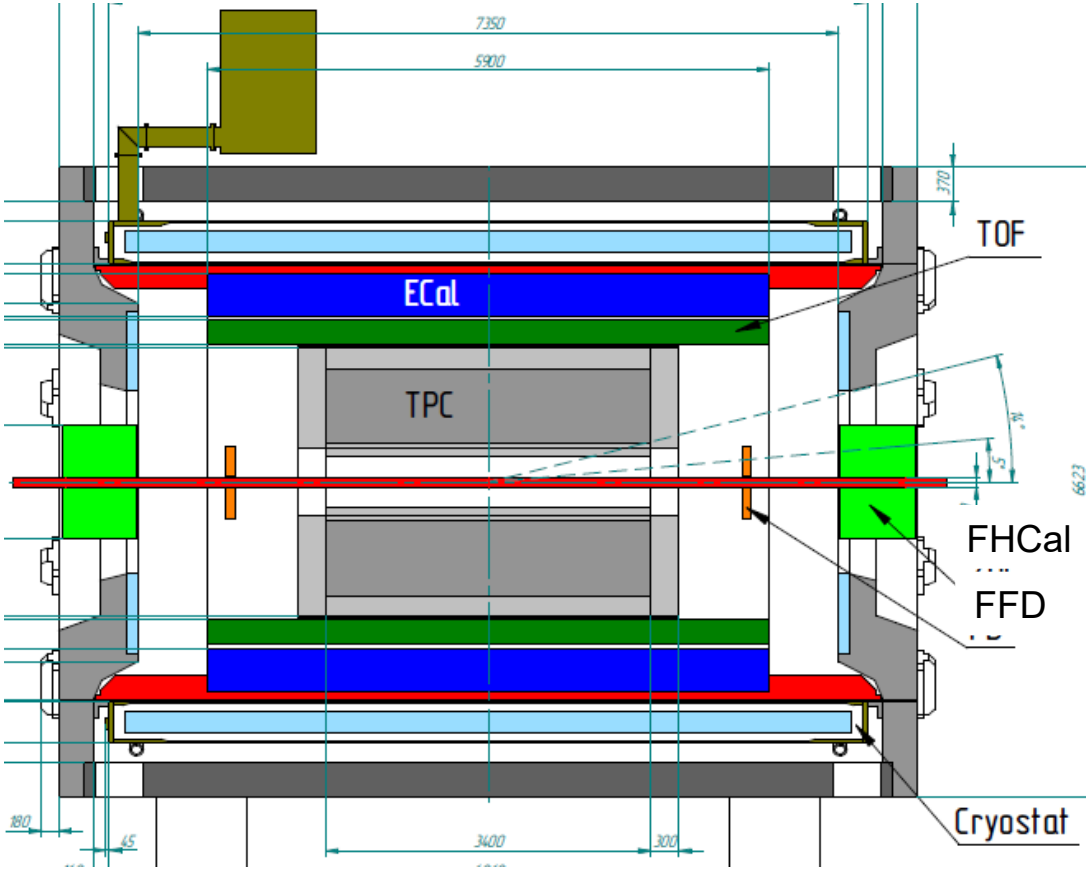
trim coil

Multi-Purpose Detector (MPD)

Stage 1: **TPC, TOF, ECAL, ZDC, FFD**

- **tracking**:
  up to $|\eta| < 1.8$ (**TPC**)
- **PID**:
  had., e, γ (**TOF**, **TPC**, **ECAL**)
- **Reaction:**
  centrality & plane determination (**FHCal**)

Plan:
overall commissioning starts in ***2020***



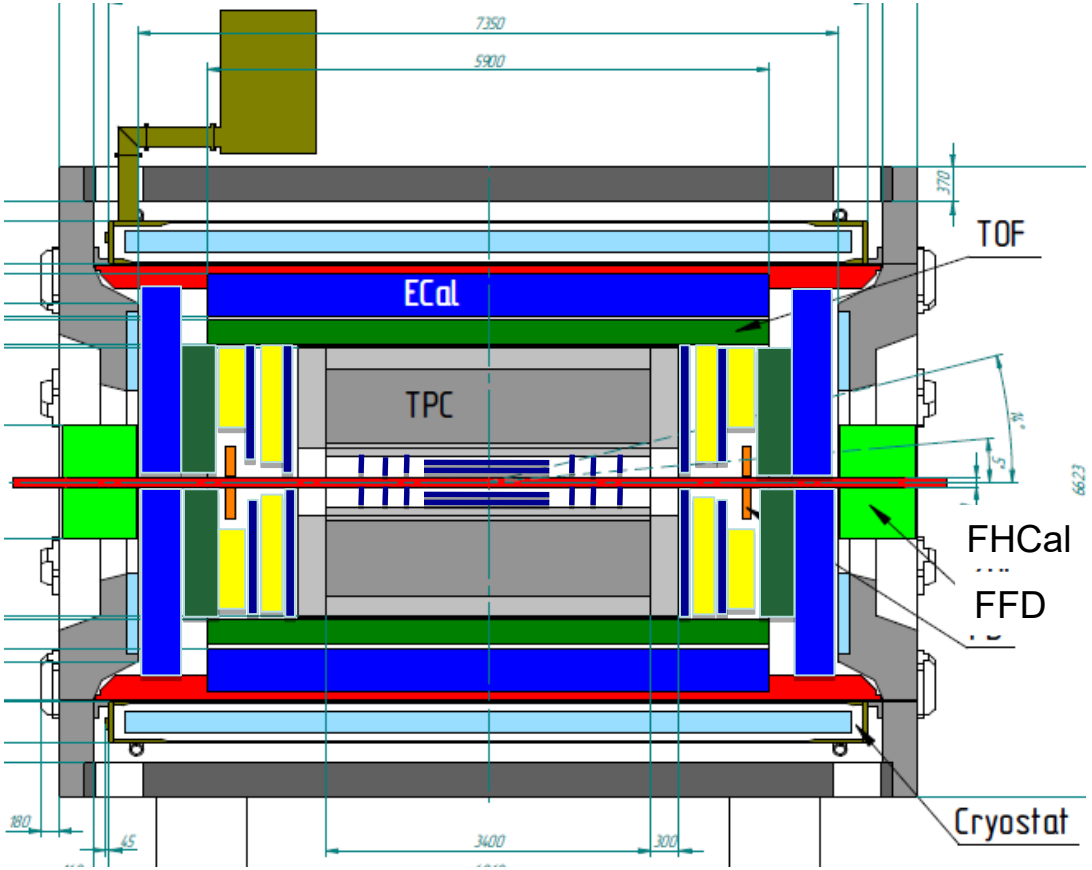
Multi-Purpose Detector (MPD)

Stage 1 (2020): TPC, TOF, ECAL, ZDC, FFD

Stage 2 (~2023): + ITS + EndCap (CPC, Straw, TOF, ECAL)

- **tracking**:
  up to $|\eta| < 1.8$ (**TPC**)
  $1.2 < |\eta| < 2.5$ (**CPC, Straw**)
- **PID**:
  had., e, γ (**TOF**, **TPC**, **ECAL**)
- **Reaction:**
  centrality & plane determination (**FHCal**)

Plan:
overall commissioning starts in **2020**

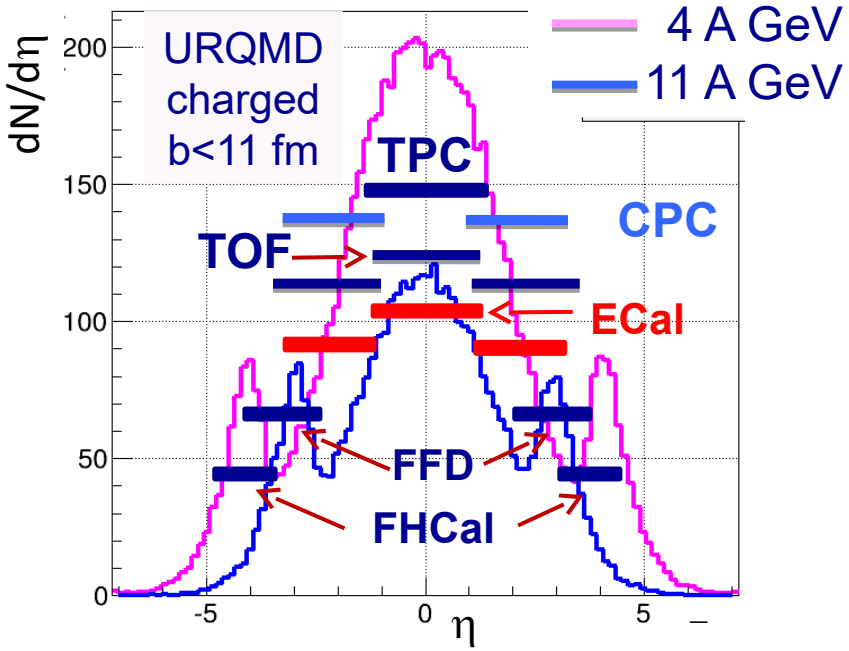


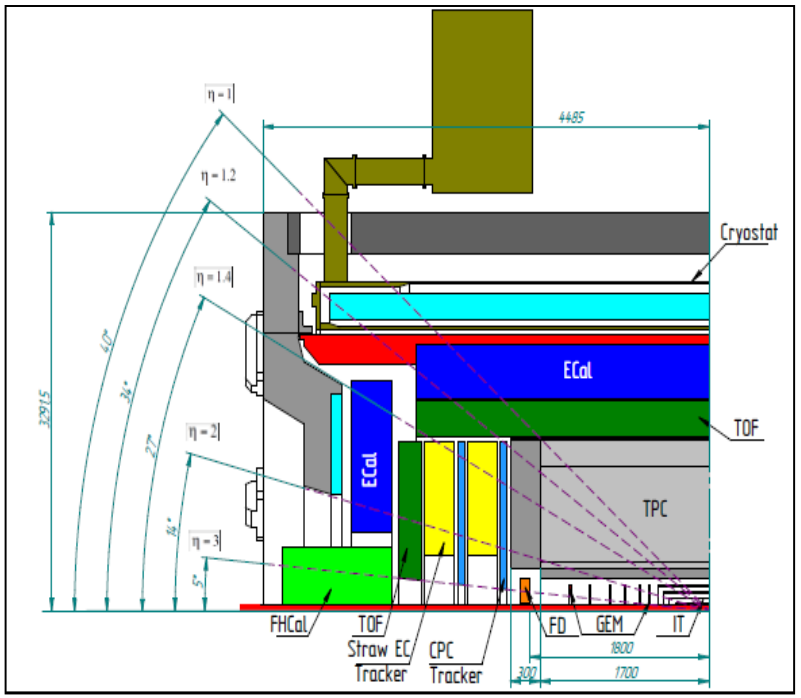
MPD (stage 1) detector status

- **Magnet** – *assembly & magnetic field measurement - **2019***
- **FHCal** – *production in progress*
- **TOF, FFD** – *production in progress*
- **TPC** – *production in progress*
- **ECAL** – *TDR completed*
- **Integration** – *TDR in preparation*

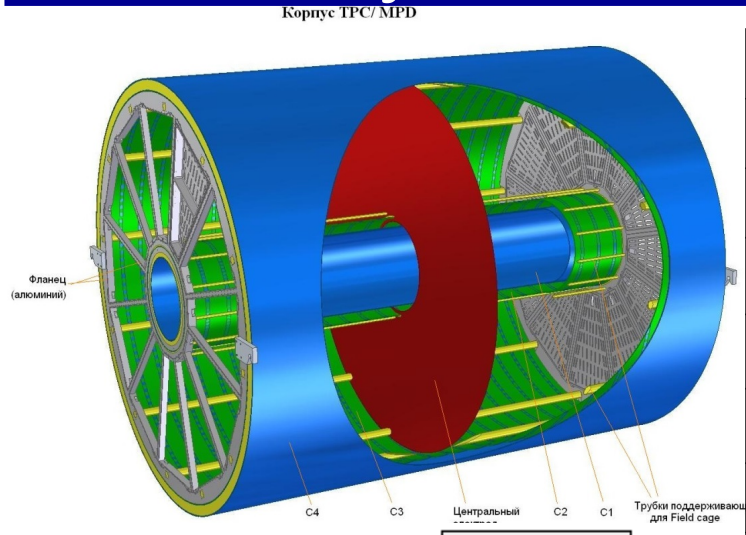
Stage II

MPD acceptance

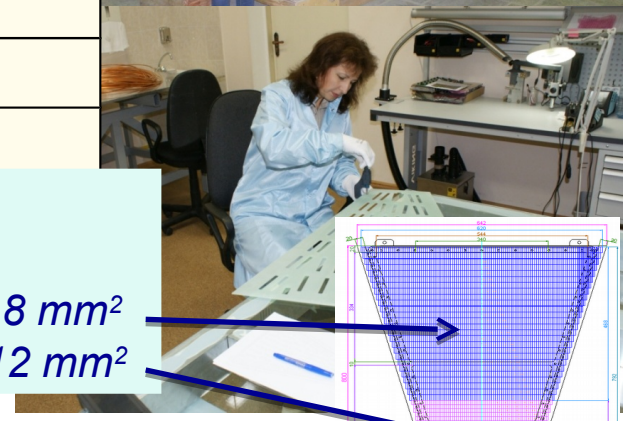




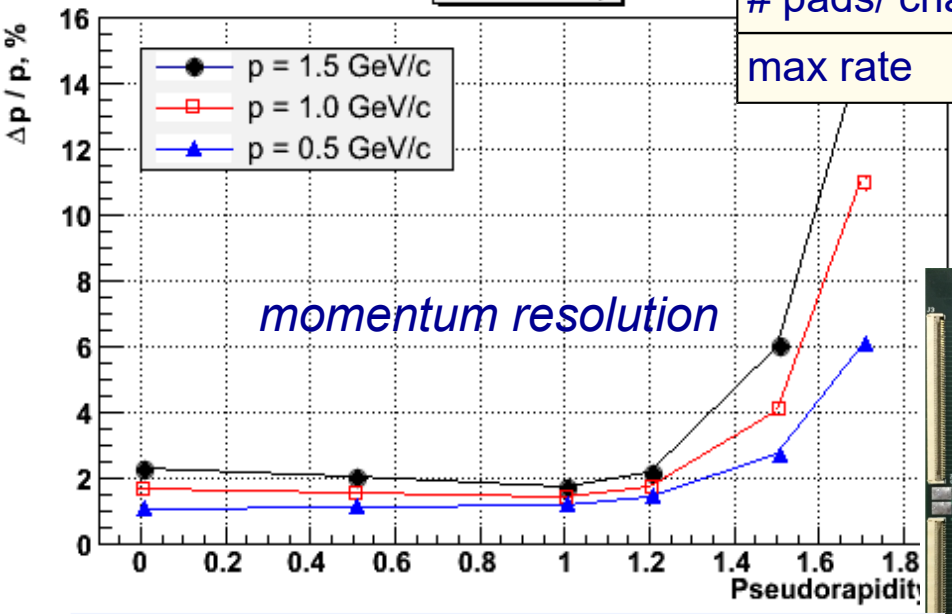
Time Projection Chamber (TPC) – basic tracker

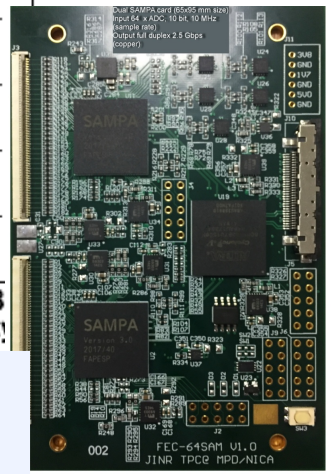


length	*340 см*
outer Radii	*140 см*
inner Radii	*27 см*
gas	*90%Ar+10%CH_4*
drift velocity	*5.45 см / μs;*
drift time	*< 30 μs;*
# R-O chamb.	*12 + 12*
# pads/ chan.	***95 232***
max rate	

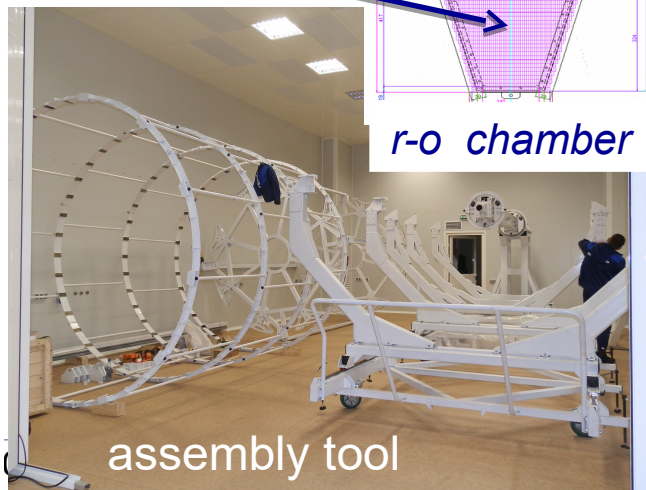


pad structure:
- *rows – 53*
- *large pads 5×18 mm²*
- *small pads 5×12 mm²*



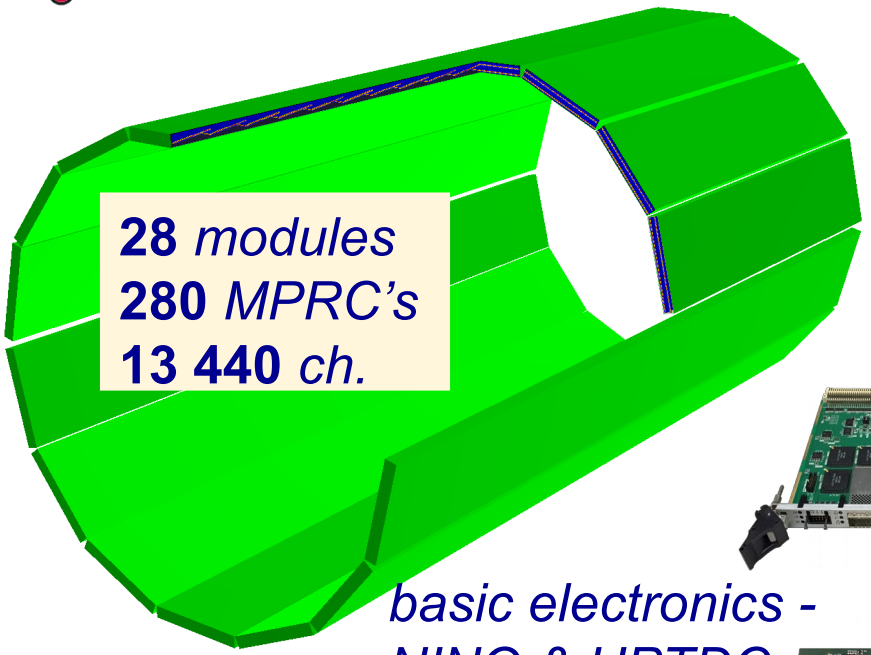


TPC/MPD Front-end card

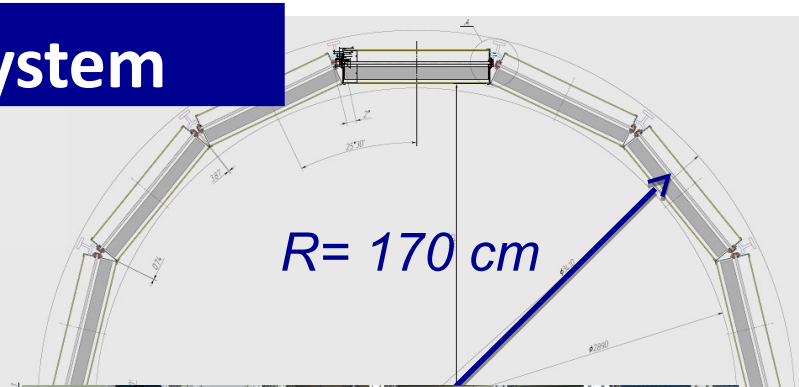


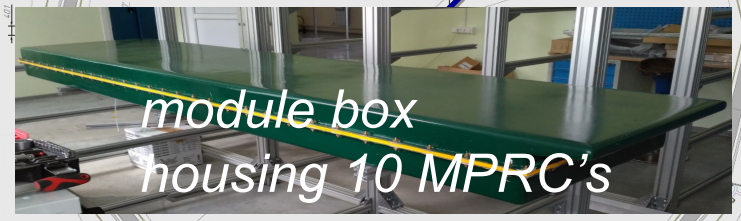
FE electronics: **FEC64SAM** – *dual **SAMPA** card (**ALICE** technology)*

Time of Flight (TOF) system

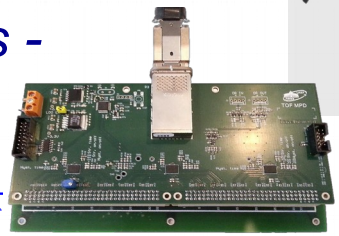


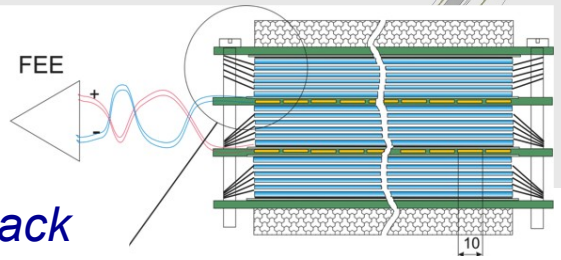
28 *modules*
280 *MPRC's*
13 440 *ch.*



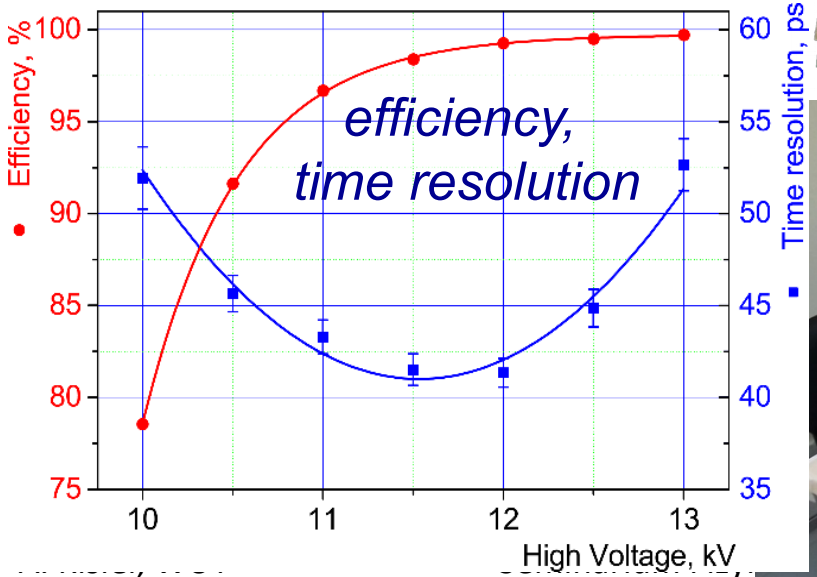


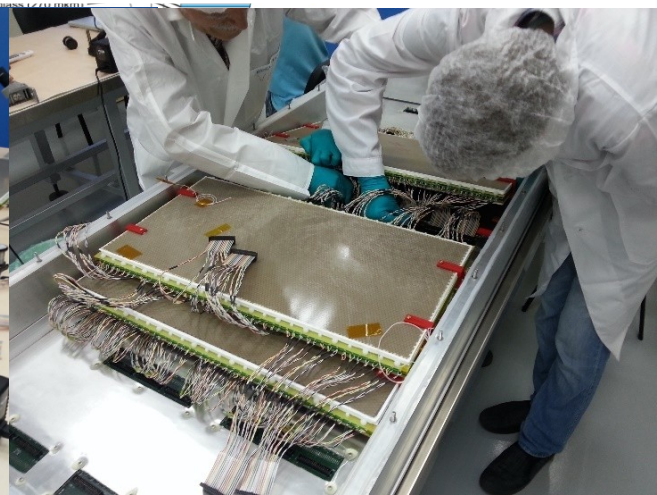
basic electronics -
NINO & HPTDC



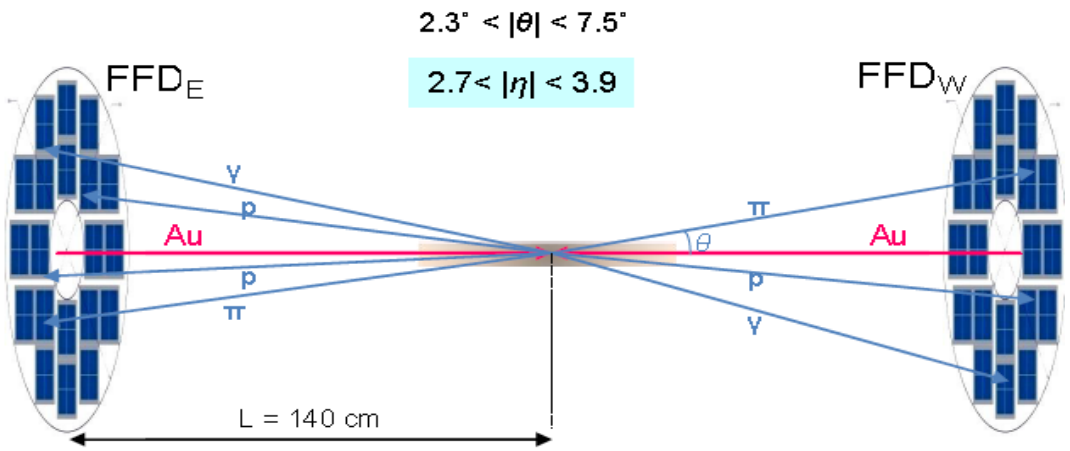


triple-stack
MRPC (5 gaps of 200 μm each)

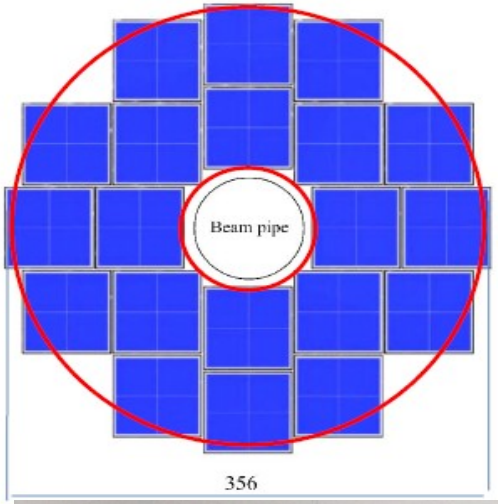




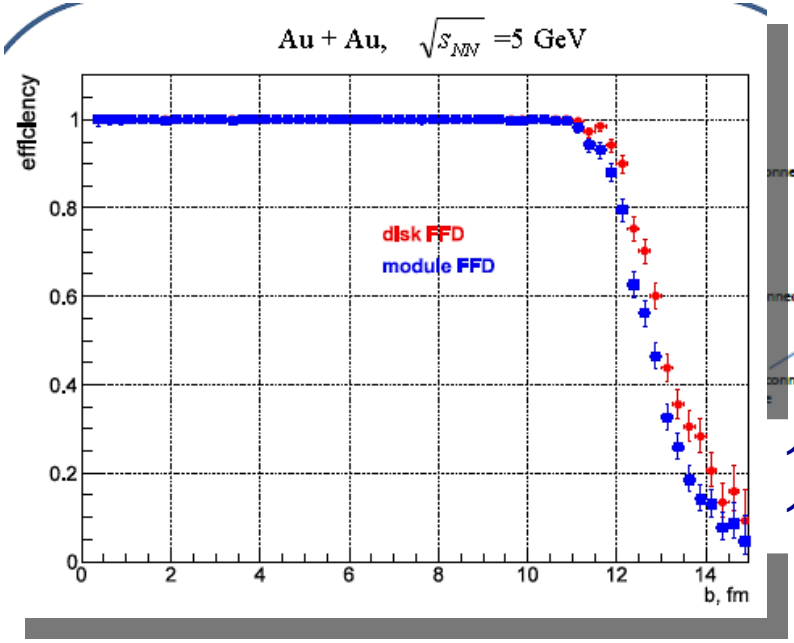
Fast Forward Detector – (FFD)

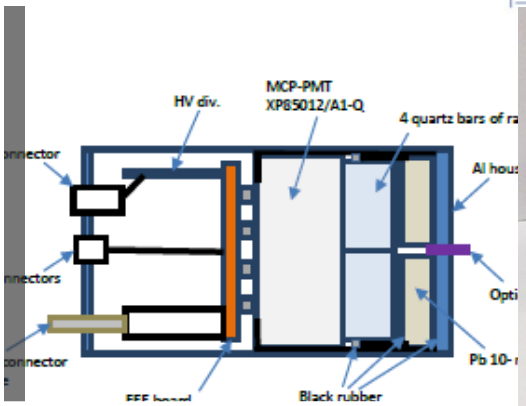


array of 20 modules
Planacon MCP-PMTs
80 +20 channels

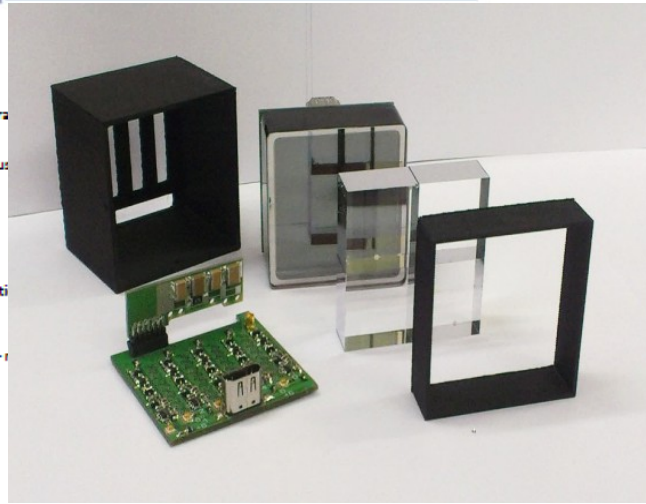


time resolution < 50 ps

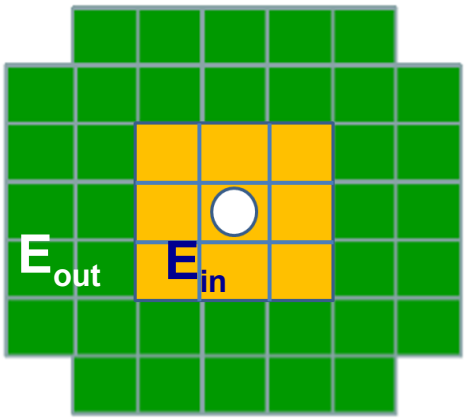


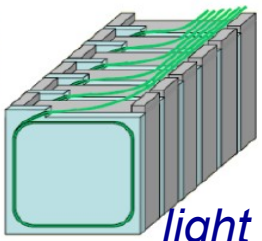


15 mm quartz radiator
10 mm lead converter



FHCAL: determination of reaction plane and centrality





light collection
WLS-fibers & SiPM

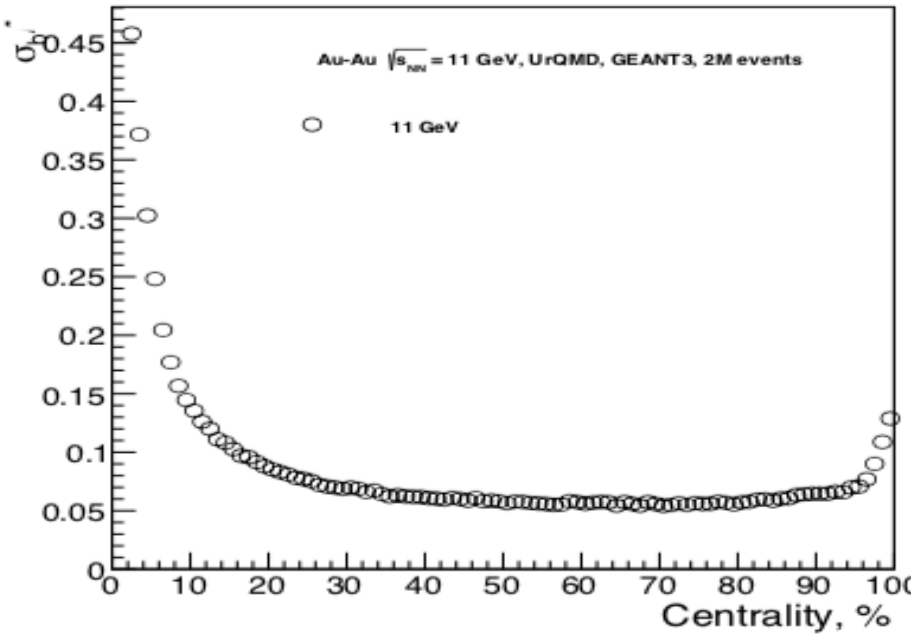
2 x **45** modules (15 x 15 cm^2 each)
located left and right at ~3.2 m from the **IP**)

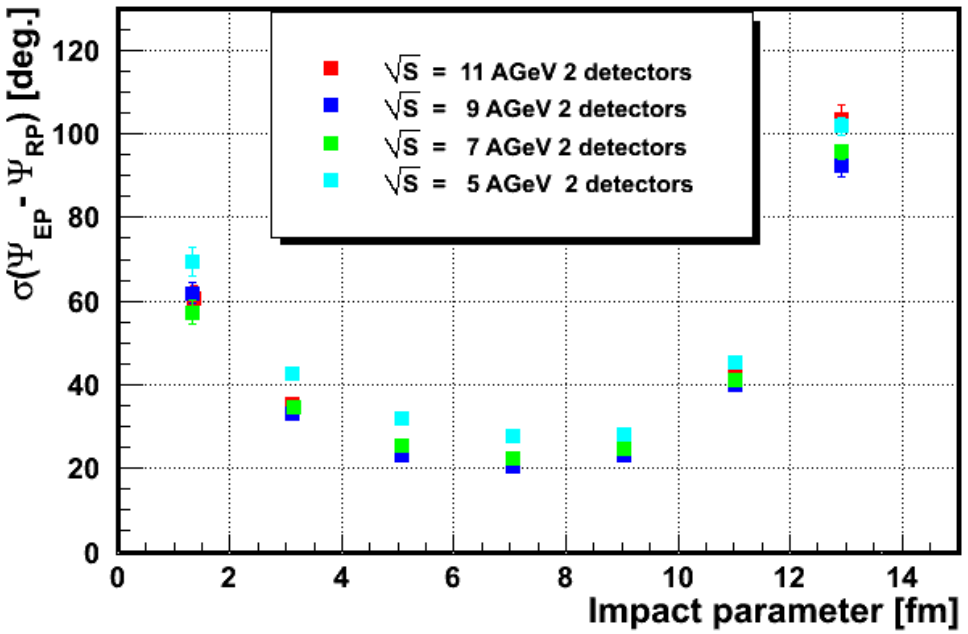
acceptance: 2.2<|η|< 4.8

σ(E)/(E) = 53%/√E(GeV) +10%

transverse granularity allows to measure:

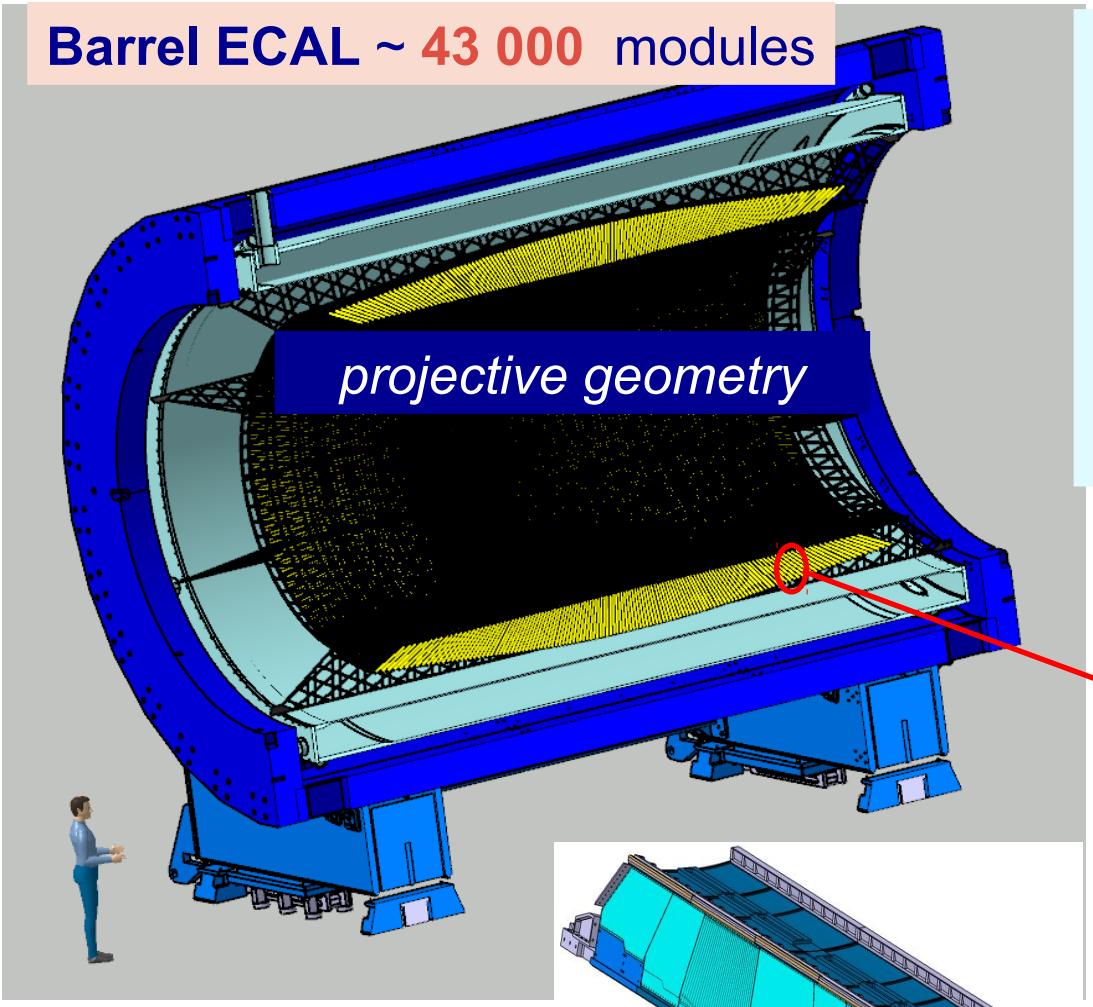
- *the reaction plane with accuracy* **~ 20^0-30^0**
- *the centrality with accuracy below* **10%.**



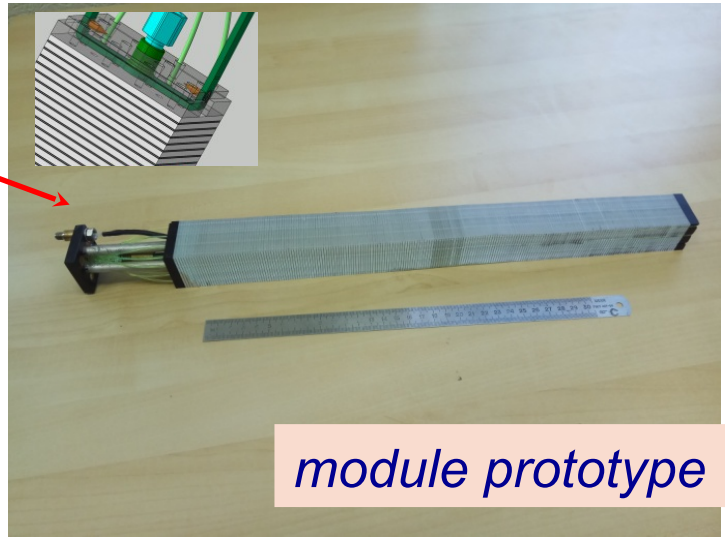


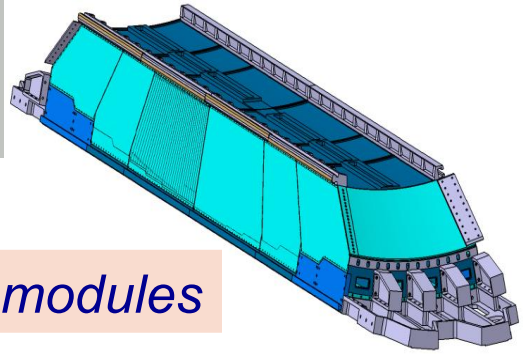
Electromagnetic calorimeter: ECAL

Barrel ECAL ~ 43 000 modules



- *Pb+Sc "Shashlyk"*
- *read-out: WLS fibers + MAPD*
- *L ~35 cm (~ 14 X_0)*
- *Segmentation (4x4 cm^2),*
- *σ(E) better than 5% @ 1 GeV;*
- *time resolution ~500 ps*

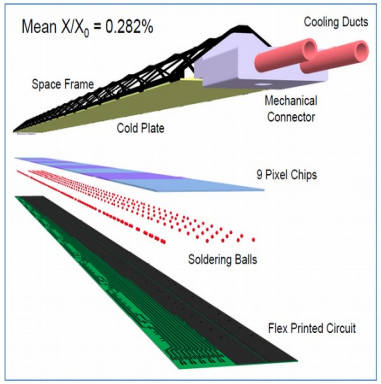


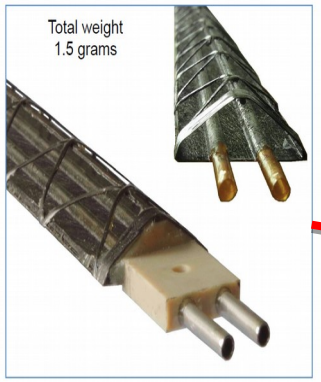


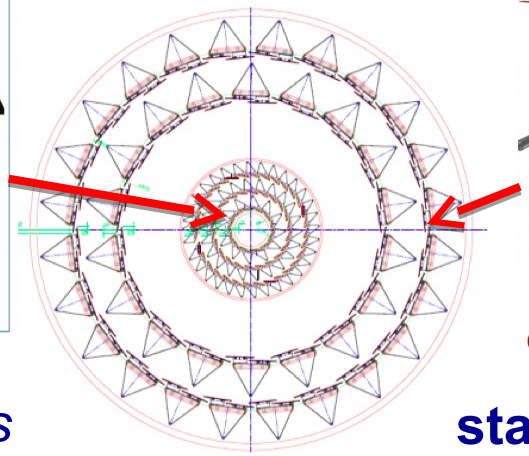
block of modules

Inner Tracker System *(MPD stage II)*

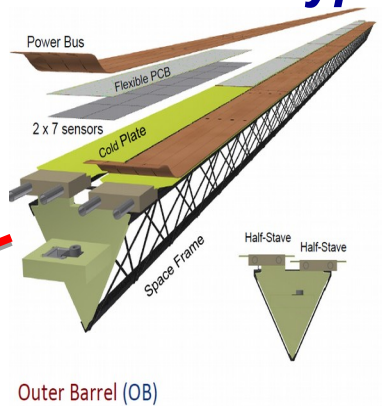
Inner Barrel (IB) – 3 layers
modified staves

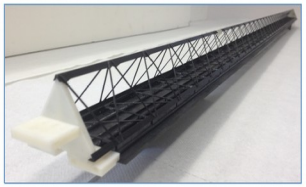


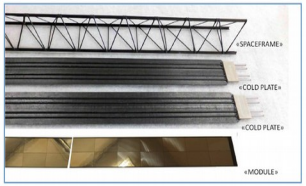




Outer Barrel (OB) – 2 layers
ALICE type staves







stave: ***2*** *modules x* ***9*** *chips*

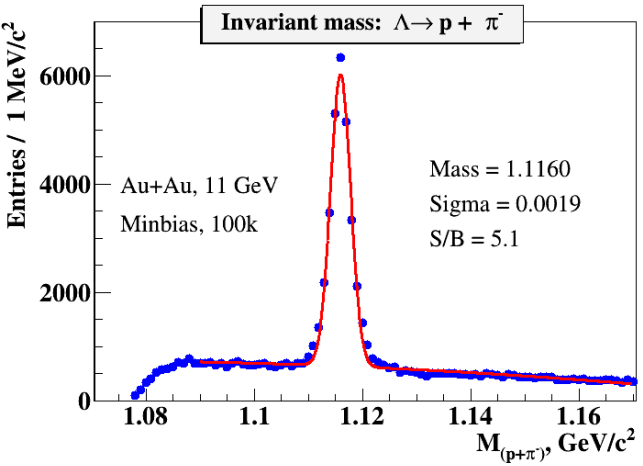
stave: ***14*** *modules x* ***14*** *chips*

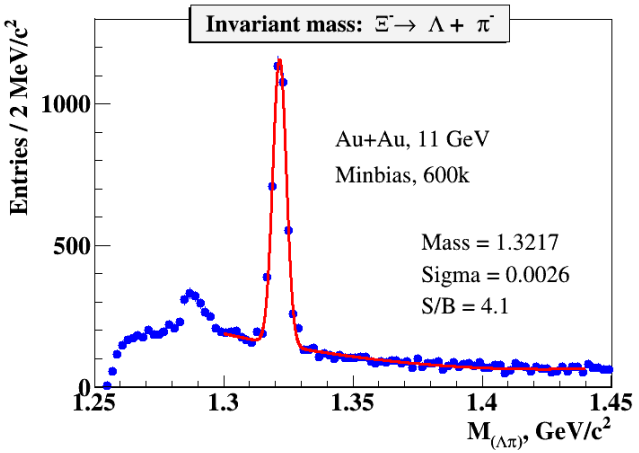
layer #	type	staves /layer	Rmin, mm	Rmax, mm	length, mm	chips /layer	X0, %
1	IB	12	22,4	26,7	540	216	0,3
2	IB	22	40,7	45,9	540	396	0,3
3	IB	32	59,8	65,1	540	576	0,3
4	OB	18	144,1	147,9	1470	3528	1,0
5	OB	24	194,1	197,6	1470	4704	1,0
total		**108**				**9420**	**2,9**

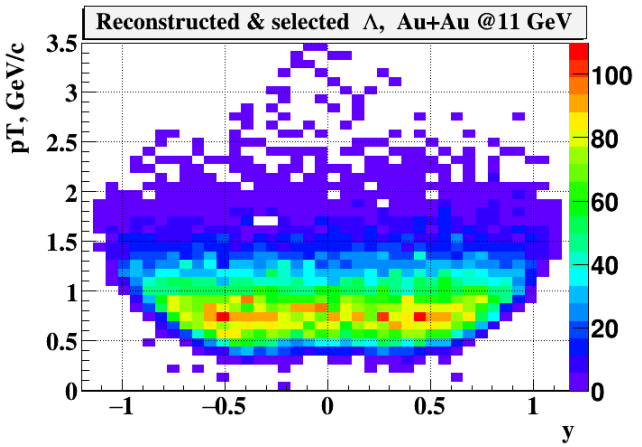
Strange and multi-strange baryons

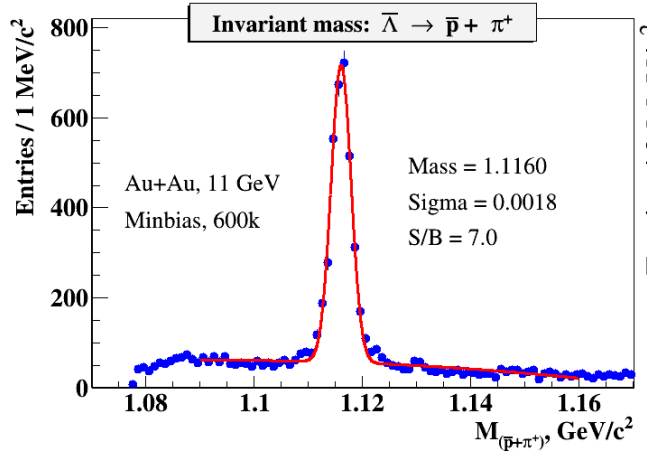
Stage'1 (TPC+TOF): Au+Au @ 11 GeV, UrQMD

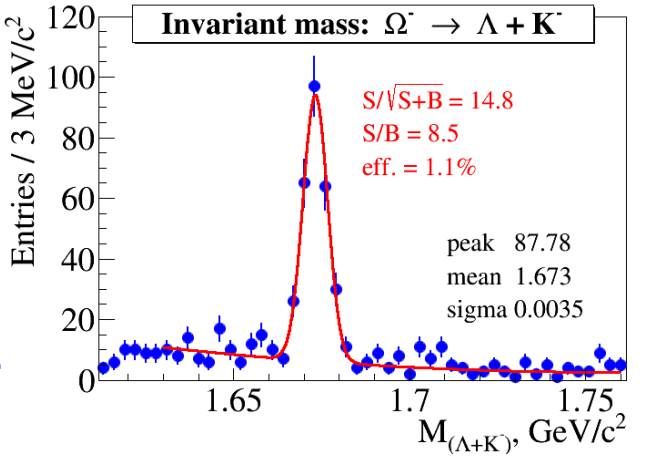
phase-space

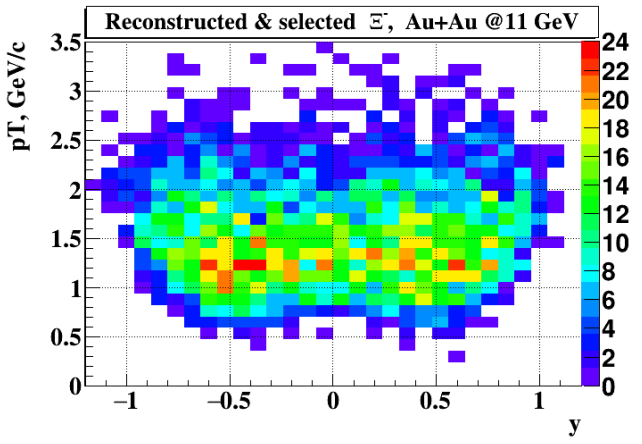








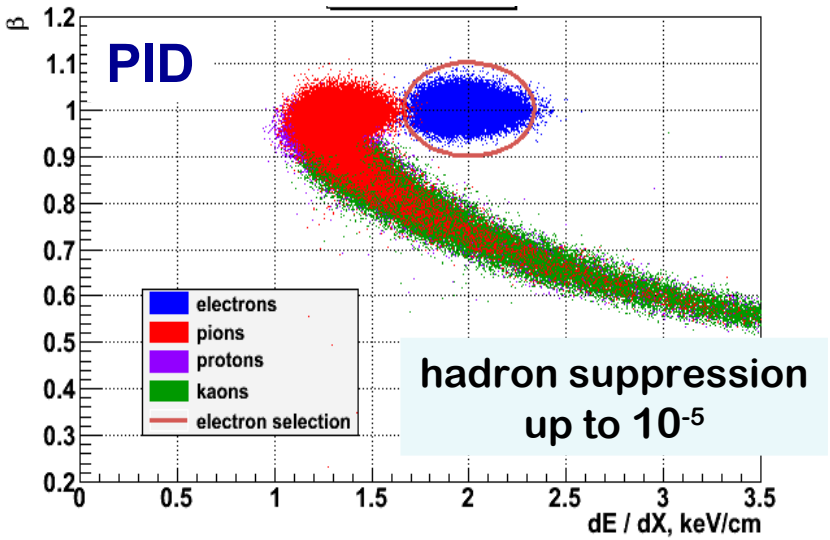


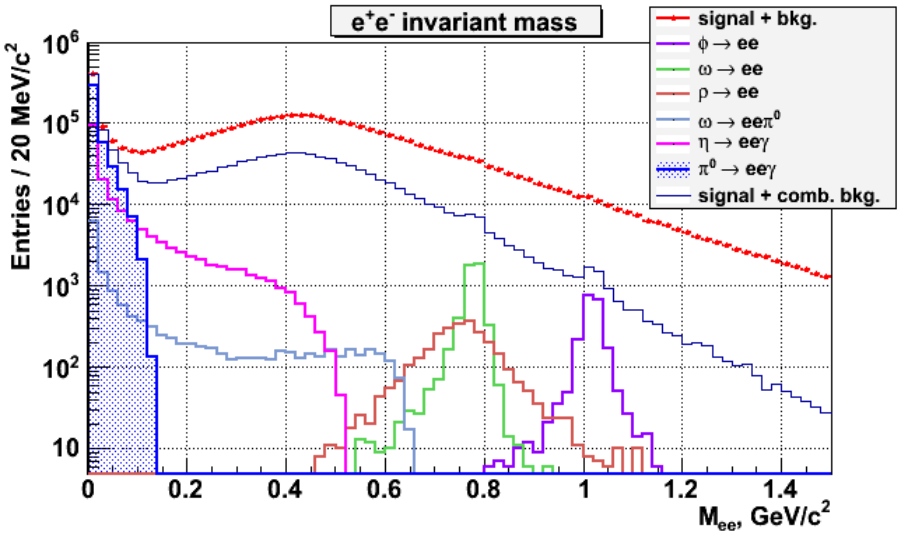


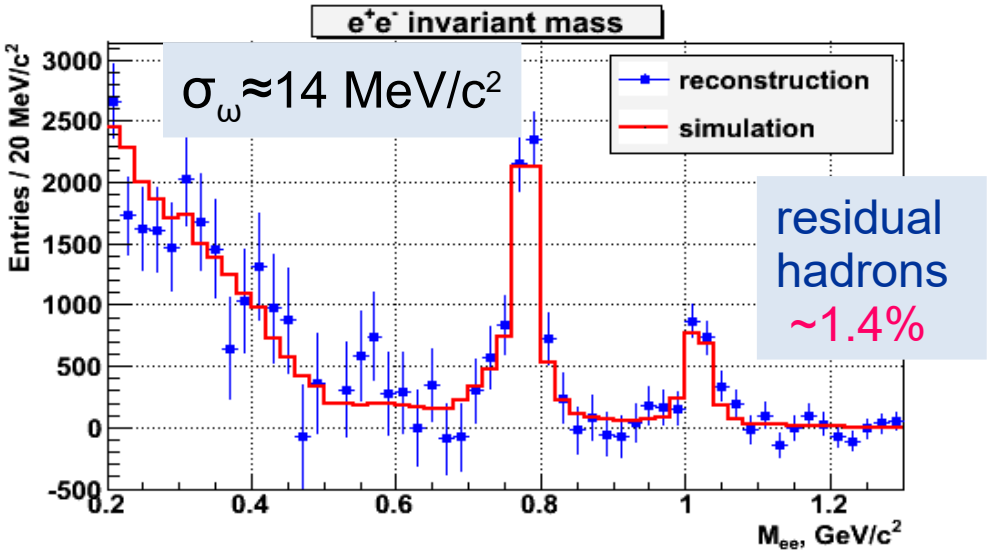
particle	Λ	anti-Λ	Ξ⁻	anti-Ξ⁺	Ω⁻	anti–Ω⁺
yield in 10week	$3 \cdot 10^8$	$3.5 \cdot 10^6$	$1.5 \cdot 10^6$	$8.0 \cdot 10^4$	$7 \cdot 10^4$	$1.5 \cdot 10^4$

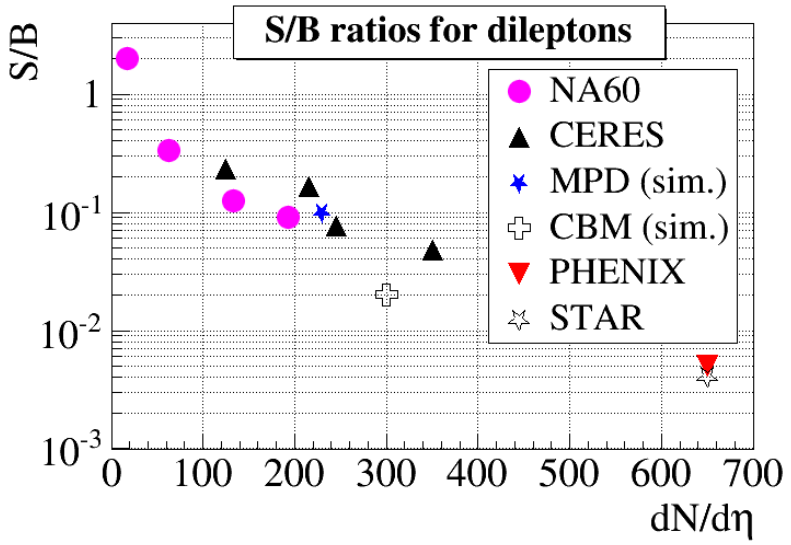
Prospects for study of dileptons

- **Event generator:** *UrQMD+Pluto (for the cocktail) central Au+Au @ 8 GeV*
- **PID**: *dE/dx (from TPC) + TOF (s ~100 ps) + ECAL*





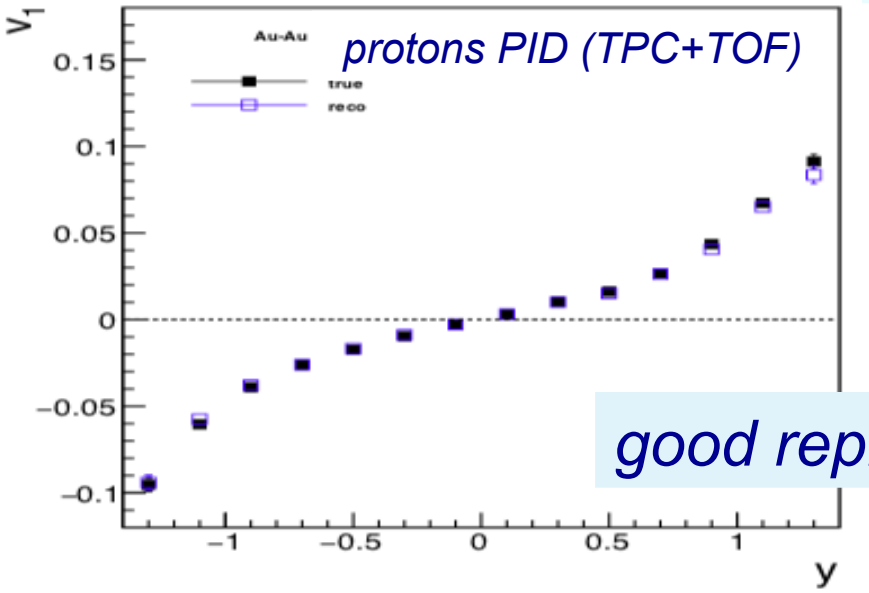


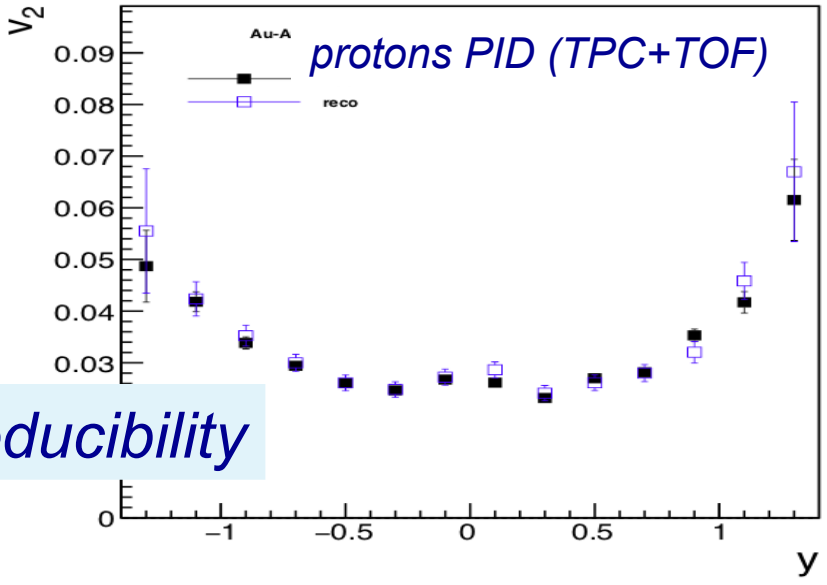


Performance study of elliptic flow

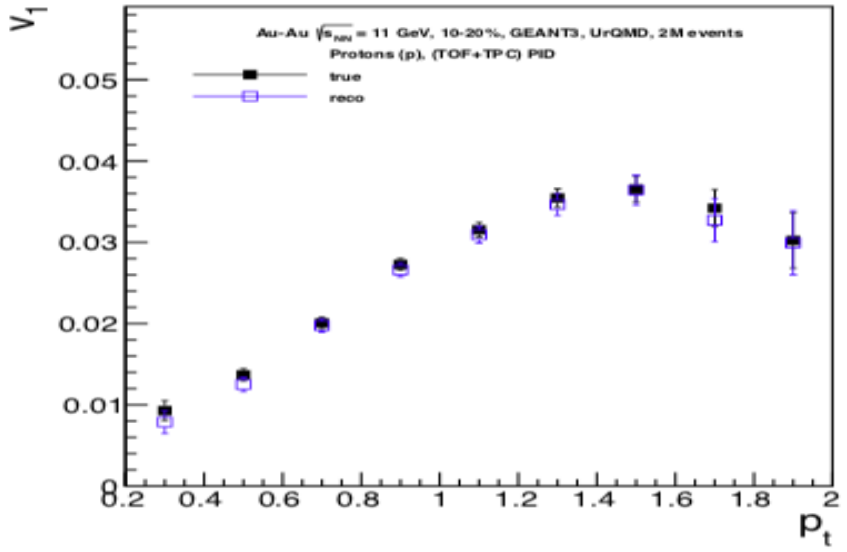
P.Parfenov, A.Taranenko, I.Selyuzhenkov, A.Mudrokh, V.Kireyeu

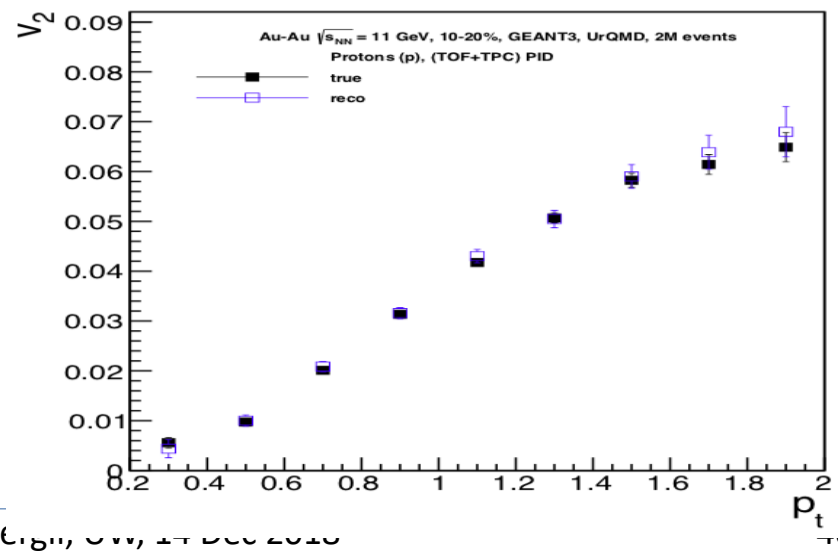
Au+Au, $\sqrt{s_{NN}}$ = 11 GeV, 10-20%, UrQMD, GEANT3, MPDROOT, 2M ev.





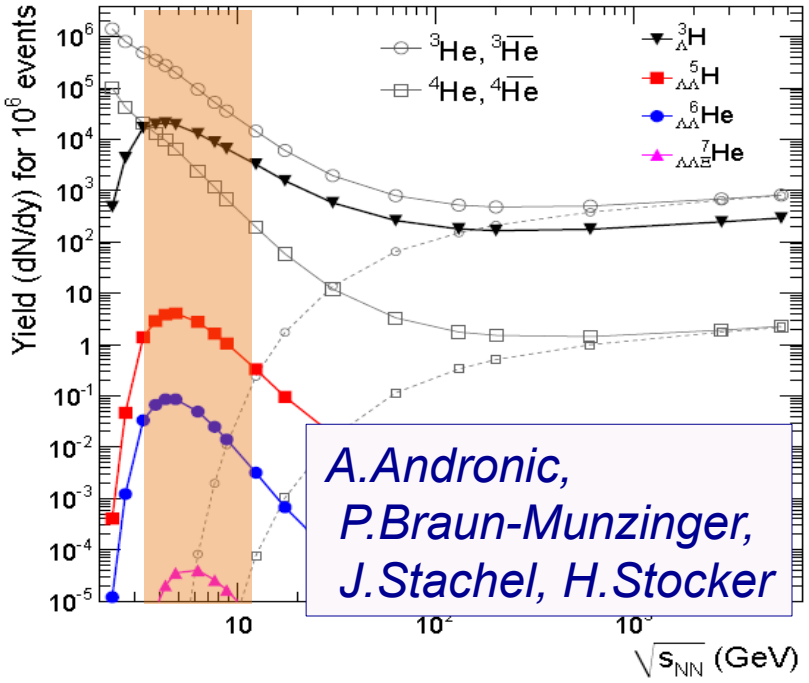
good reproducibility



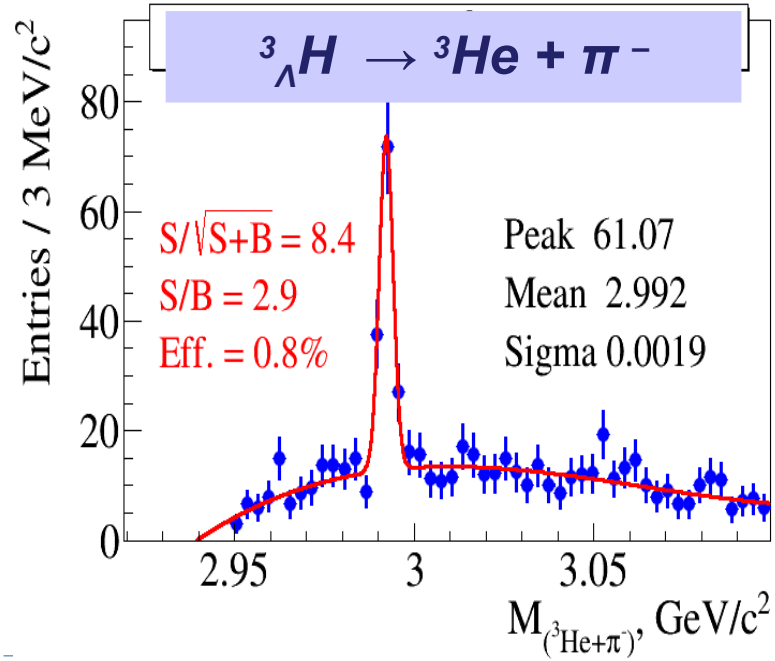


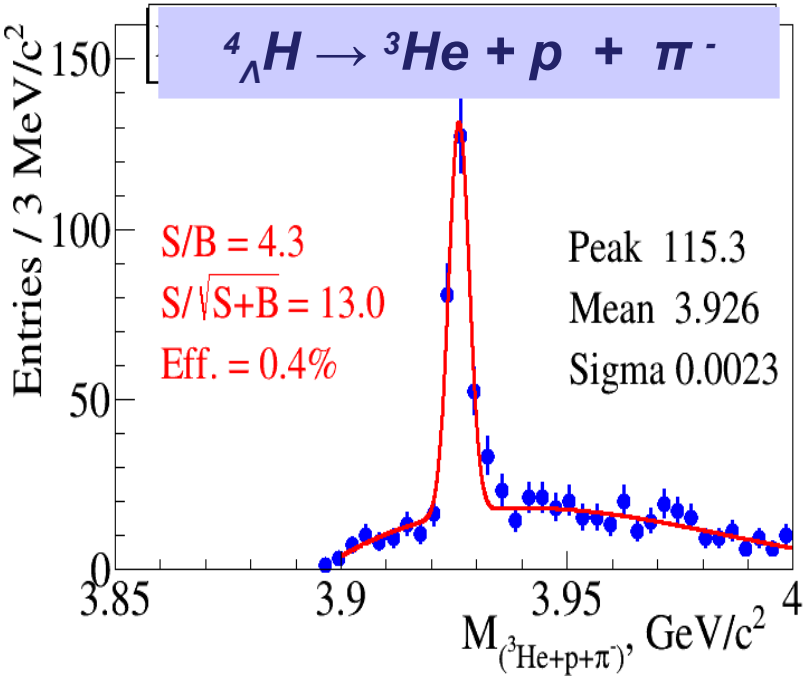
Hyper nuclei

Stage 2: *central* ***Au+Au*** *@* ***5*** *AGeV; DCM-QGSM*



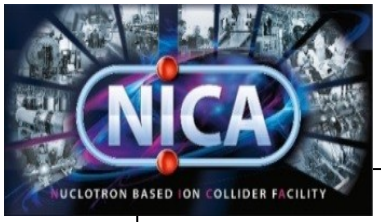
hyper nucleus	yield in 10 weeks
$^3_\Lambda$He	$9 \cdot 10^5$
$^4_\Lambda$He	$1 \cdot 10^5$



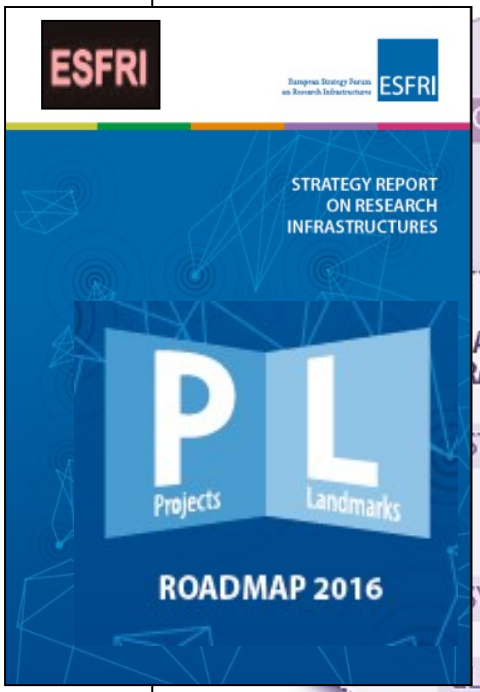


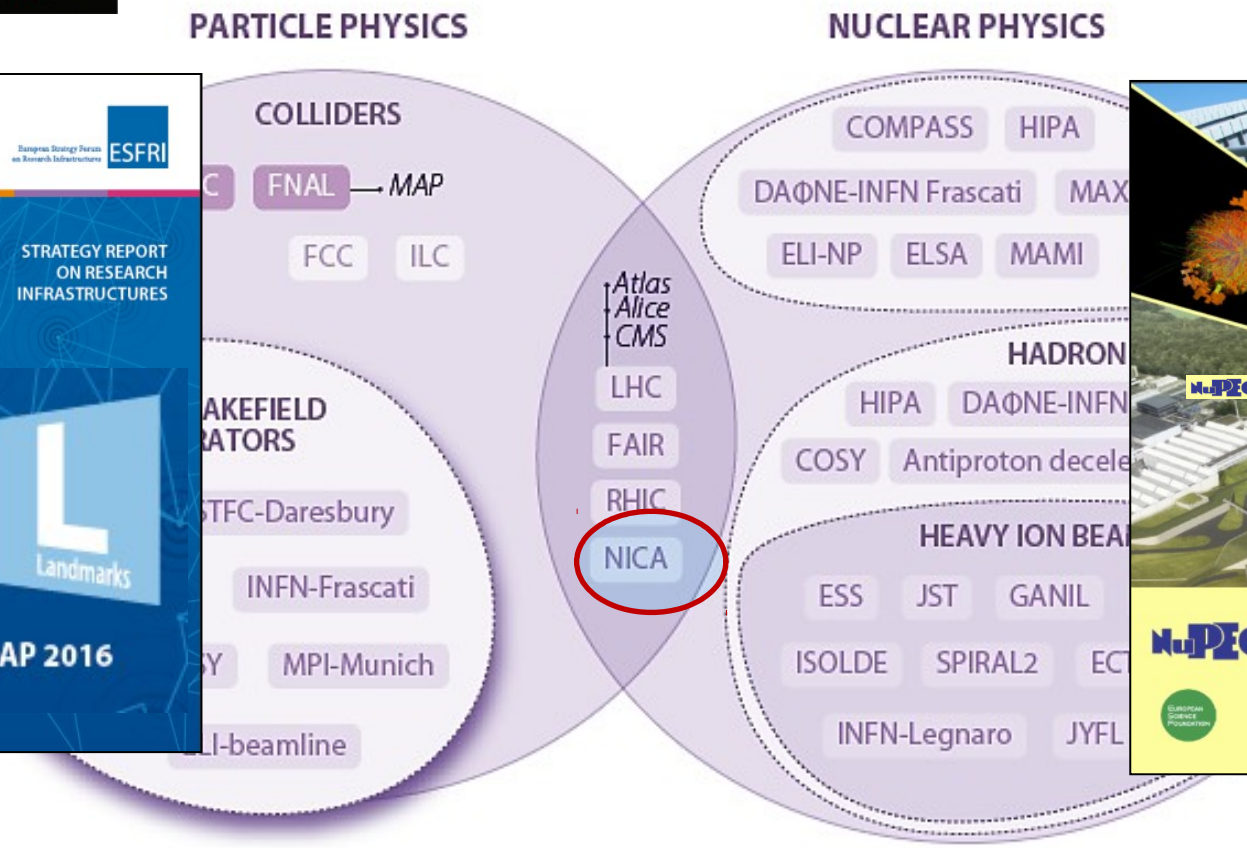
BARYONIC MATTER DENSITY FRONTIER

NICA is included in the ESFRI ROADMAP-2016 and in the NuPECC Long Range Plan 2017 - Perspectives in Nuclear Physics



Main Research Infrastructures in Particle and Nuclear Physics





kick-off meeting on formation of the MPD and BM@N Collaborations

carried out in Dubna on 11-13 April, 2018

https://indico.jinr.ru/conferenceDisplay.py?ovw=True&confId=385

Second MPD Collaboration Meeting
29-30 October 2018

http://jinrmag.jinr.ru/pdf2/18num45-46.pdf

http://mpd.jinr.ru/experiment/

New member institutes (now 32 institutes from 10 countries)
Spokesperson election: Adam Kisiel (WUT, Poland)
IB Board Chair election: Fuqiang Wang (ZJHU, China)
Project manager endorsement: Slava Golovatyuk (JINR)

The NICA-PL Consortium

Warsaw University of Technology

National Center for Nuclear Research in Świerk

University of Warsaw

Jan Kochanowski University in Kielce

NICA-PL Consortium

- Agreement of the four Polish institutions (Warsaw University of Technology, Warsaw University, National Center of Nuclear Research in Świerk, Jan Kochanowski University of Kielce) "to carry out scientific research, specialist education, design and construction of the scientific and control equipment for the purpose of the NICA research complex at the Joint Institute of Nuclear Research in Dubna".
- Consortium is open for new members and foresees the addition of more polish institutions
- Members of the Consortium show explicit desire to join MPD and/or BM@N Collaborations
- Consortium can be a common vehicle for application for funding in various funding agencies (national and European)

Recent activities

- Group of Marek Peryt very active in the NICA Project:
  - Gas system for the MPD TOF detector
  - Slow Control System for MPD and BM@N
  - Engineering Support group leadership
  - EqDB Database Environment
  - MPD Experimental Platform
- Rapidly expanding group
  - 1 staff full-time at JINR (more soon)
  - Two PhDs permanently at JINR full-time
  - Intensive summer practices (2 weeks, 4 weeks)
  - "Team for the future of NICA" programme – 3-month, student stays at JINR, this year extended to 12-month stays

Expansion of possibilities

- Strong interest from Faculty of Electronics and Information Technology
  - Experience in electronics for HEP experiments (CMS muon trigger)
  - Experience in industrial system automation and control, SCADA
  - Strong software group (databases, computer graphics, event visualization, machine learning, big data)
- Interest in participation in the development, design and construction of the MPD and BM@N Slow Control
- Interest in participation in preparation of the cosmic ray detector (high-level trigger system, electronics)
- Possibility for three-way collaboration JINR-WUT-FAIR in MPD-CBM

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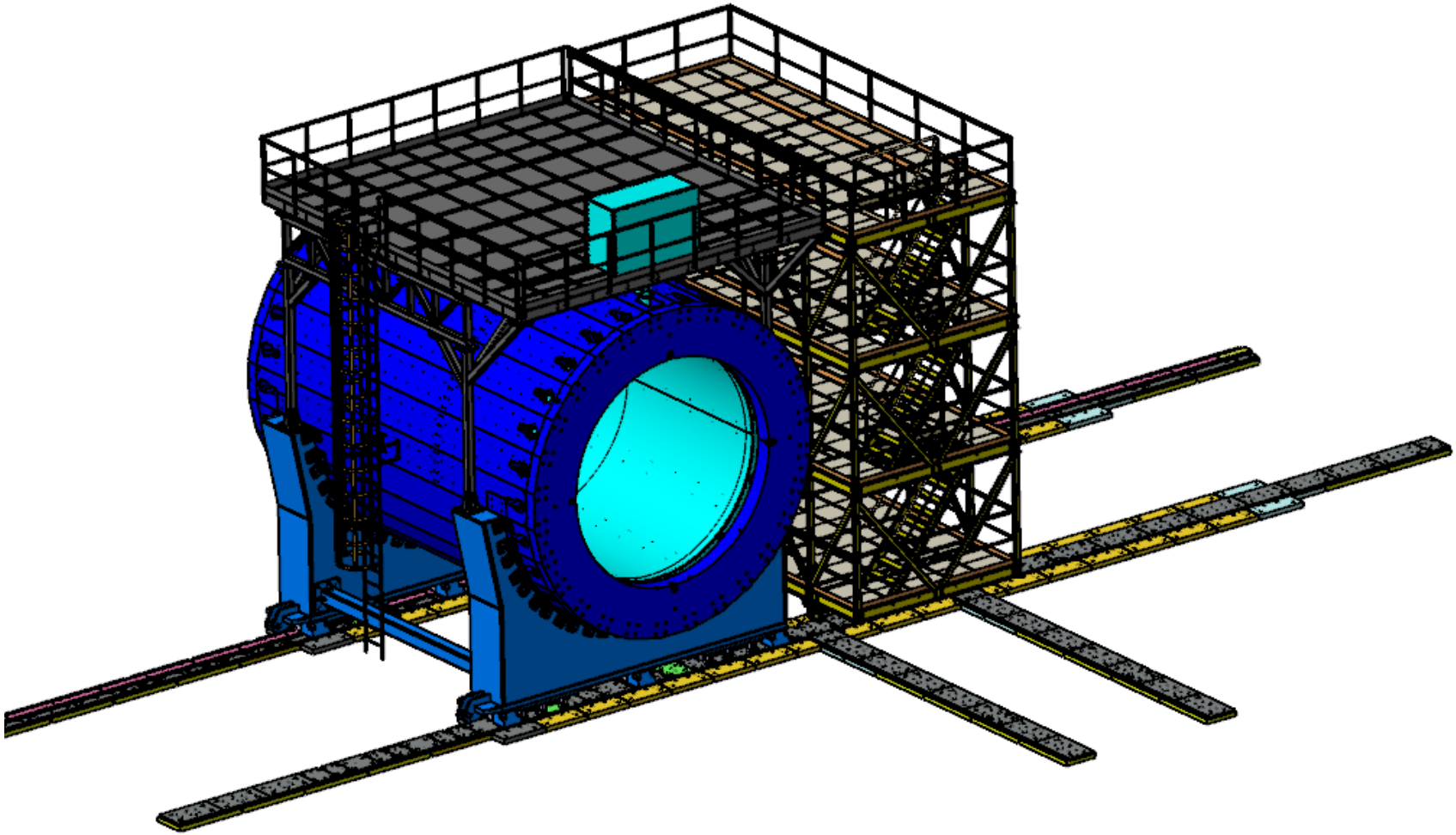
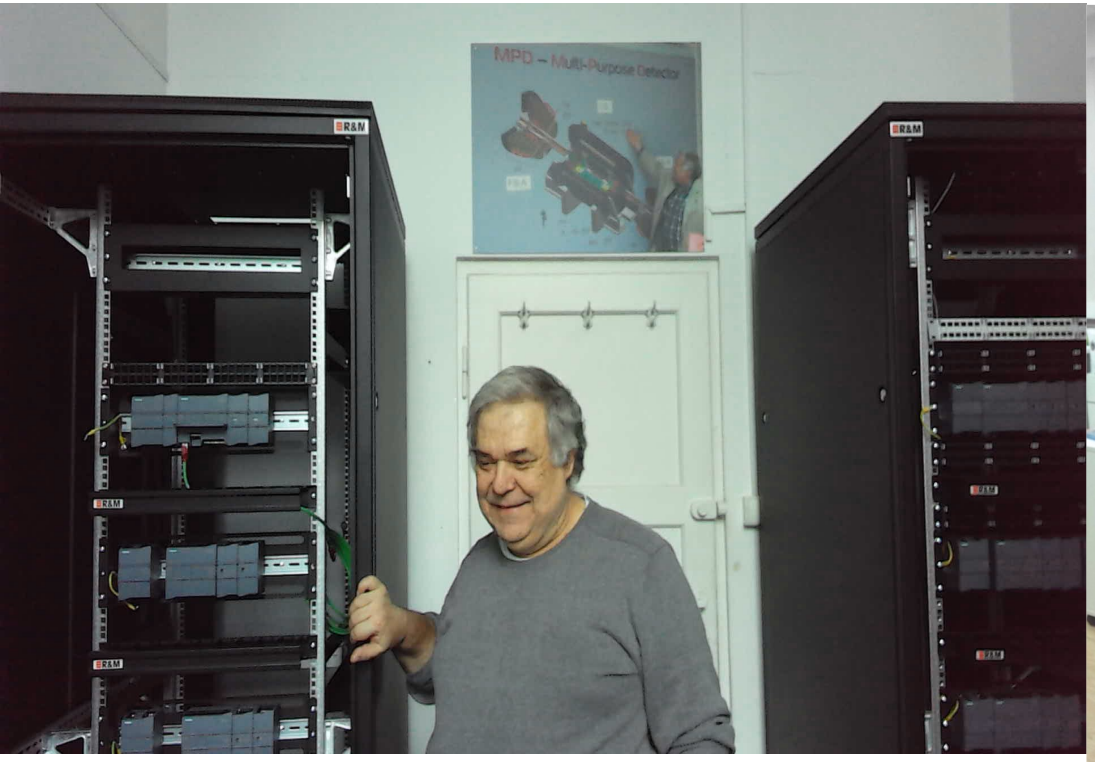
NICA Multi Purpose Detector – Engineering Support Platform



Slow Control System

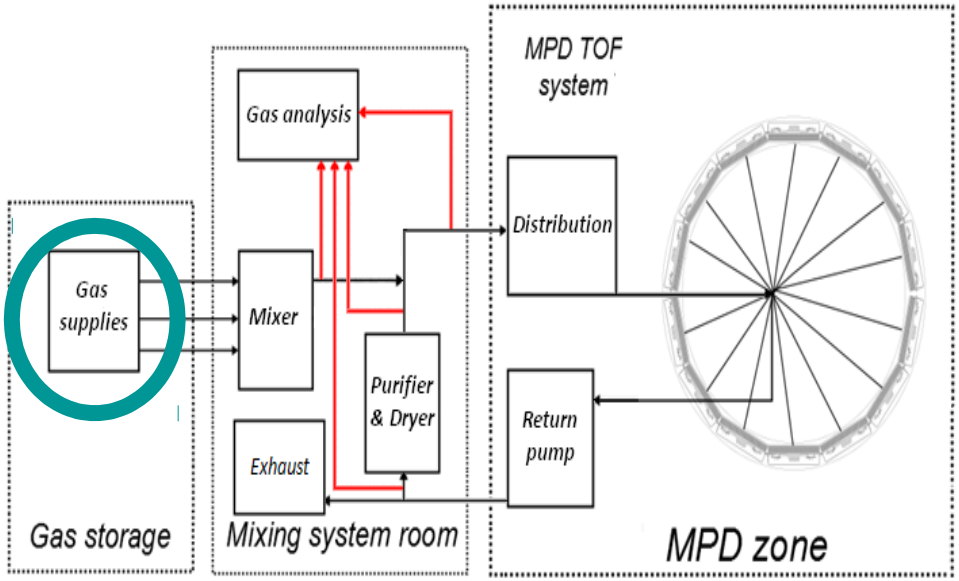
–IMPLEMENTATION; BASE UNIT 42U;

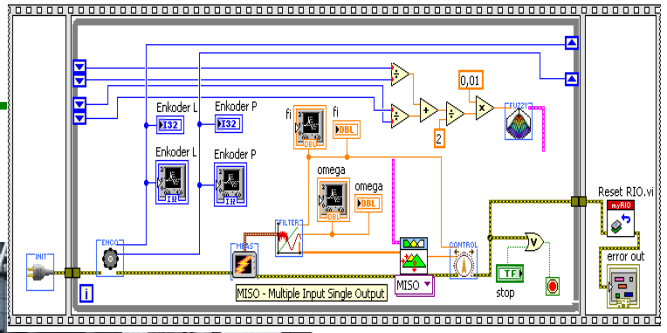


Gas System for the TOF detectors

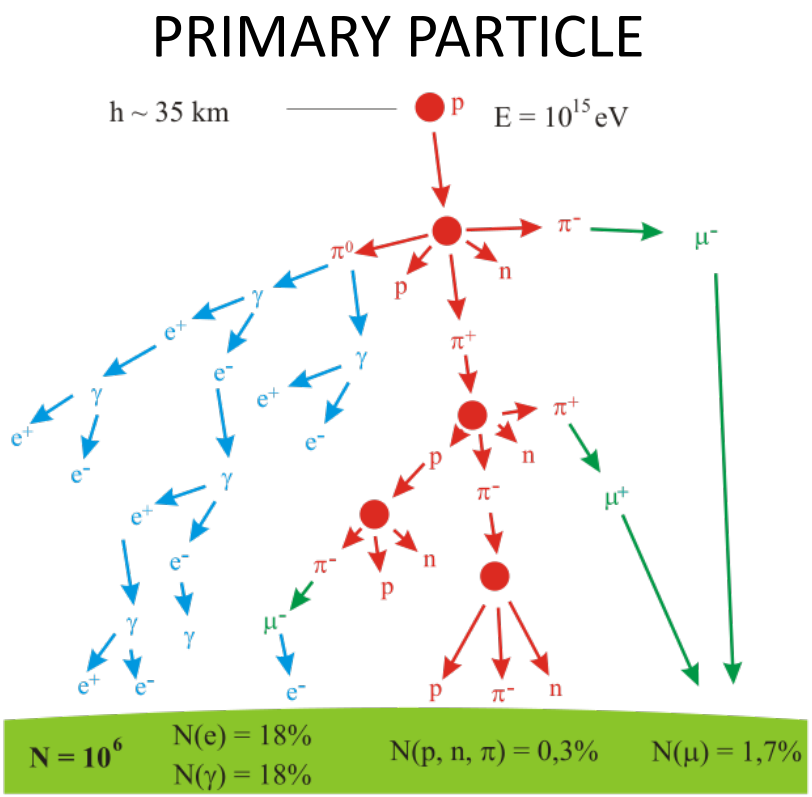
90% $C_2H_2F_4$ + 5% i-C_4H_{10} + 5% SF_6

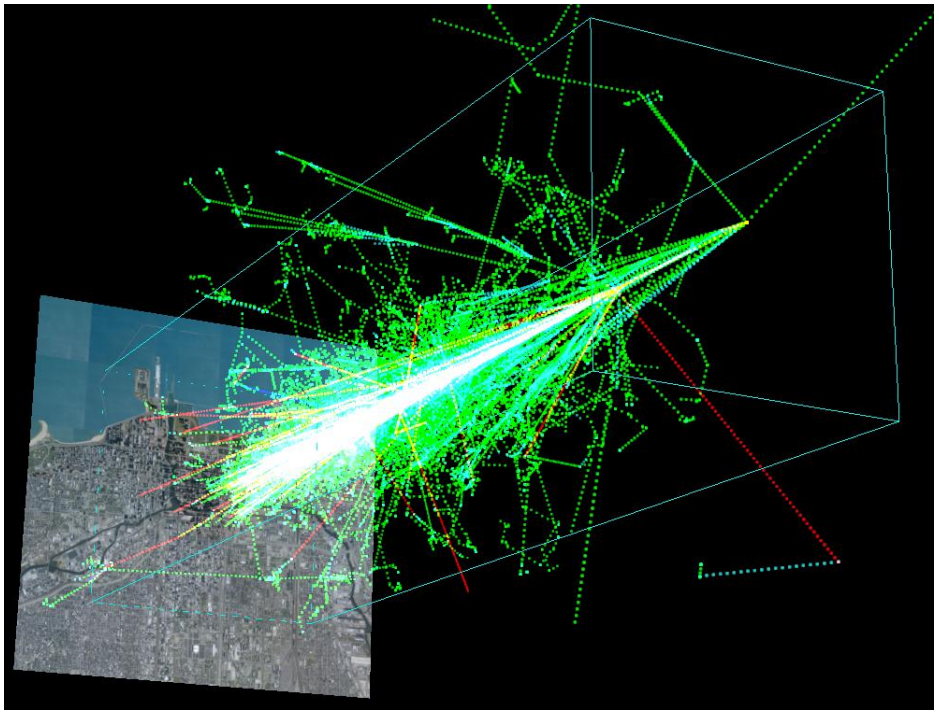
Gas system description





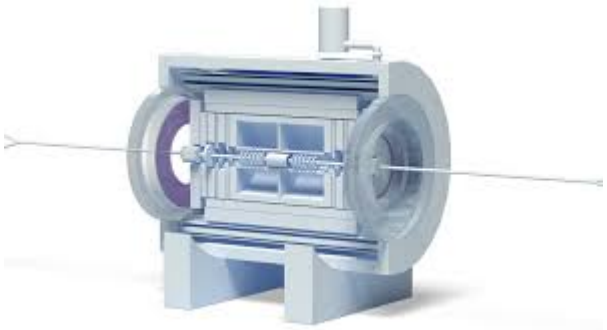
Cosmic Ray Detector – Goals

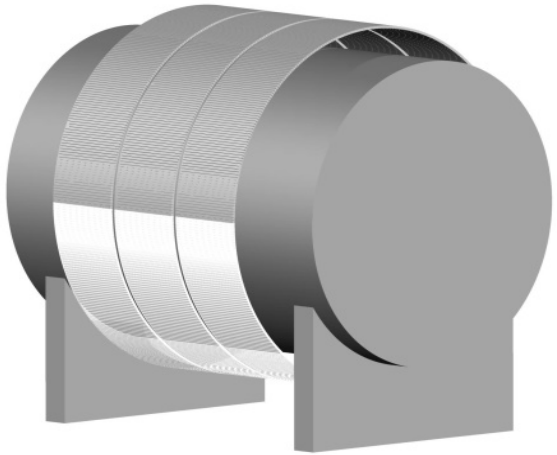


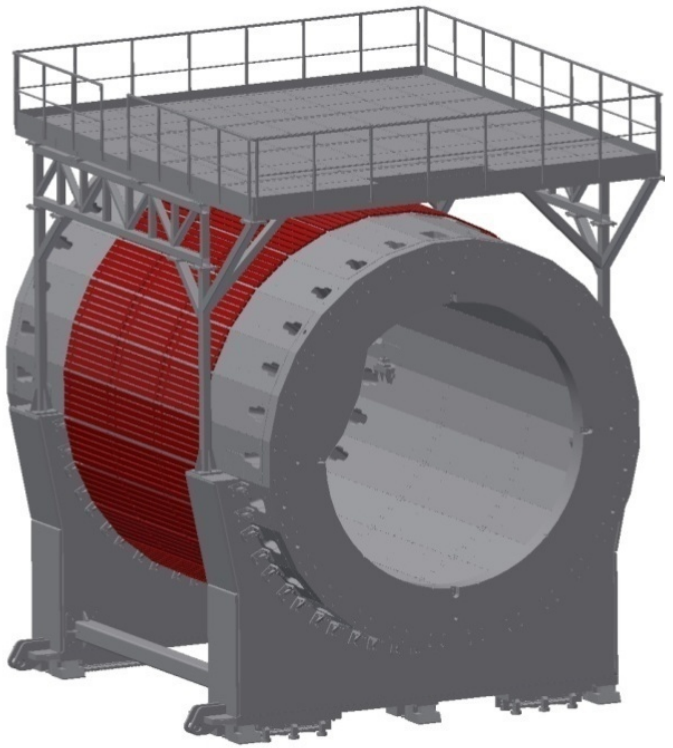


Cosmic ray air shower created by a 1TeV proton hitting the atmosphere 20 km above the Earth. The shower was simulated using the AIRES package.

MPD Cosmic Ray Detector (MCORD) - proposition



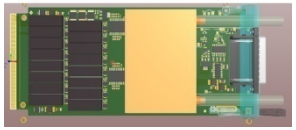




Single surface on full circumference
Scintillator slabs read out by SiMP modules (both ends)

MCORD - MicroTCA configuration

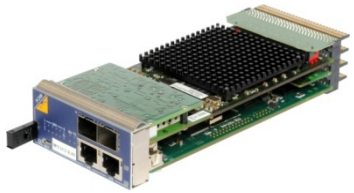
Analog Front-End module



FPGA mezzanine card (FMC)

AMC FMC carrier board

MTCA Carrier Hub



Standard MTCA crate
5 or 12 AMC modules
Crate number depends on channel count and sampling speed

At 250MS/s: 192 channels / crate
At 125MS/s: 384 channels / crate
At 80MS/s: 576 channels / crate
At 50MS/s: 768 channels / crate

For several MTCAs one main MCH concentrates data from slave MHCs to generate final muon trigger

Exemplary Collaboration

- JINR Directorate at WUT
- WUT visits at JINR

“Team for the future of NICA”

- Student internship program co-financed by JINR and WUT attracting young dedicated staff to the NICA project (more than 30 participants in 2017 and 2018, more planned)