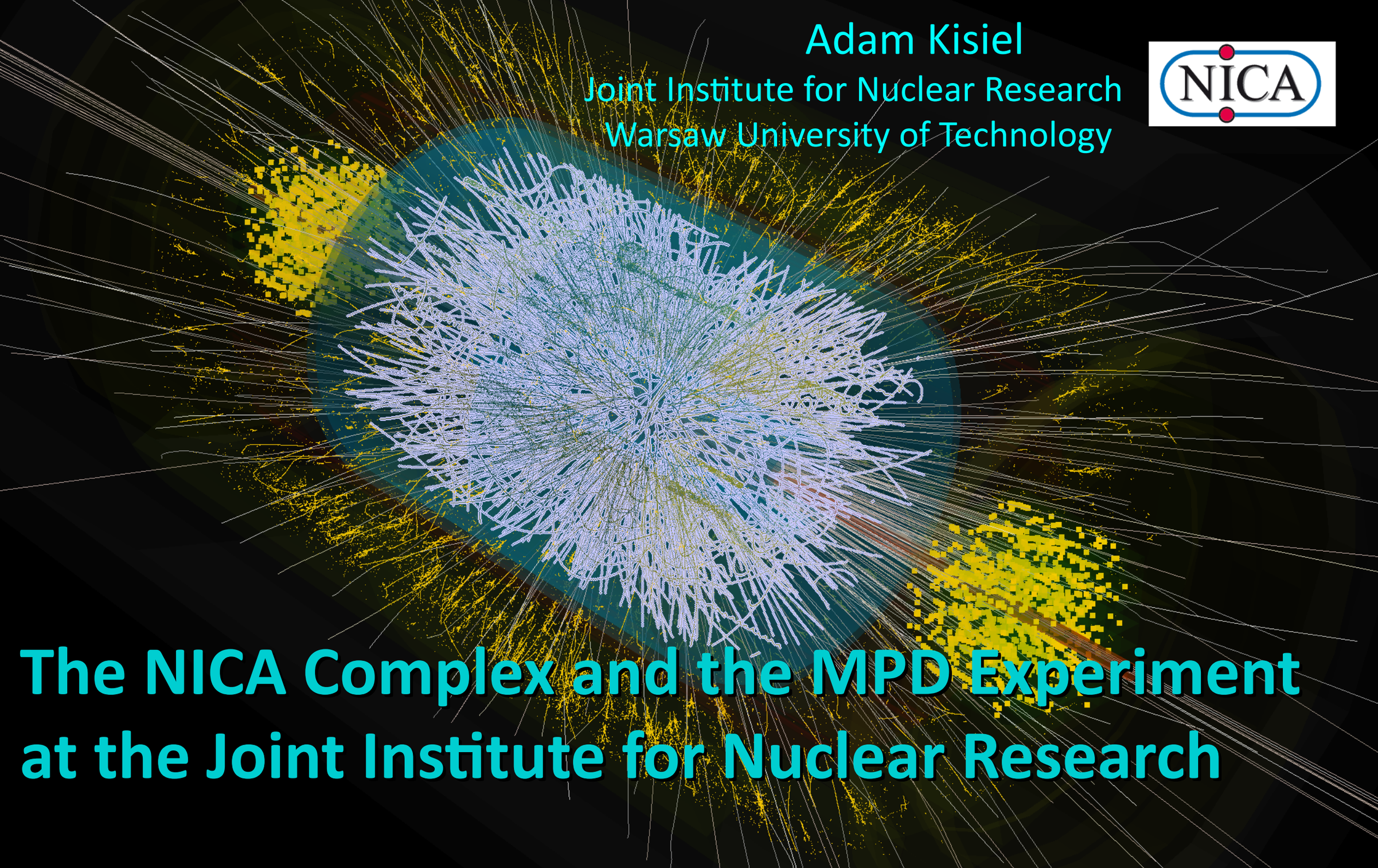
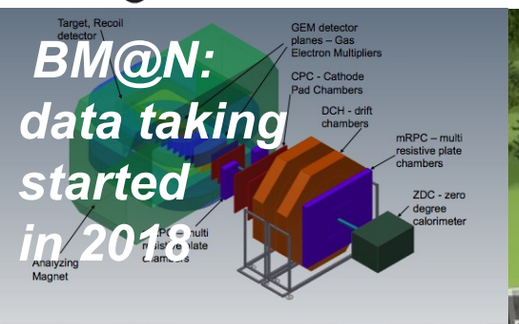


Adam Kisiel
Joint Institute for Nuclear Research
Warsaw University of Technology

The NICA Complex and the MPD Experiment at the Joint Institute for Nuclear Research

NICA Accelerator Complex in Dubna



BM@N: data taking started in 2018

SPD TDR - 2021

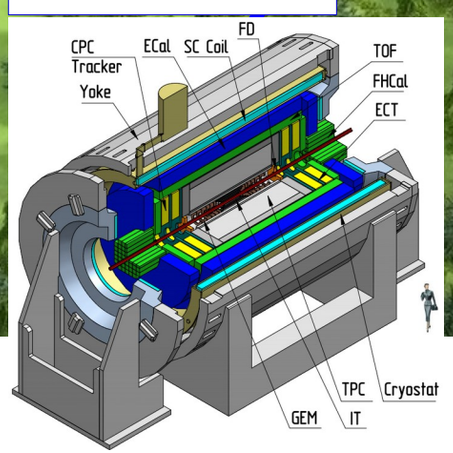
Collider - 2022

applied research infrastructure- 2021

Booster - 2020

Nuclotron (c=251,5 m)

MPD - 2021



NICA Center - 2022

Status of the Accelerator Complex

Linac HILac

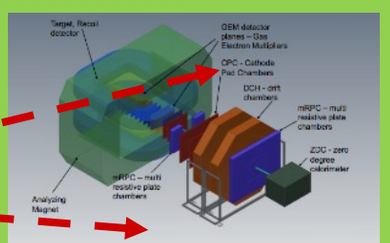
KRION

Ion sources

Linac LU-20

Booster (25 Tm)
1(2-3) single-turn injection, storage of (2 ÷ 4)×10⁹ ions, acceleration up to 100 MeV/u, electron cooling, acceleration up to 578 MeV/u

Fixed Target Area



BM@N *put in operation in 2018*

Stripping (80%) $^{197}Au^{31+}$ => $^{197}Au^{79+}$

Nuclotron (45 Tm)
injection of one bunch of ≤ 2×10⁹ ions, acceleration up to 1 - 4.5 GeV/u max.

Slow resonance extraction

Two SC collider rings

IP-2

$\sqrt{s_{NN}}$ = 4 – 11 GeV (Au+Au)

L = 1 x 10^{27} cm^{-2} s^{-1}

~ 2 x 22 injection cycles
22 bunches per ring

IP-1

work in progress	early commissioning	commissioned / existing

Recent video from NICA: https://youtu.be/mfOLT9XZOj0

NICA construction live

Main parameters of accelerator complex

Nuclotron

Parameter	SC synchrotron
particles	↑p, ↑d, nuclei (Au, Bi, ...)
max. kinetic energy, GeV/u	10.71 (↑p); 5.35 (↑d) **3.8** (Au)
max. mag. rigidity, Tm	38.5
circumference, m	251.52
vacuum, Torr	10^{-9}
*intensity, **Au** /pulse*	1 10^{9}

Booster

	value
ion species	A/Z ≤ 3
max. energy, MeV/u	**600**
magnetic rigidity, T m	1.6 – 25.0
circumference, m	210.96
vacuum, Tor	10^{-11}
*intensity, **Au** /p*	1.5 10^{9}

The Collider

Design parameters, Stage II

45 T*m, 11 GeV/u for Au^{79+}

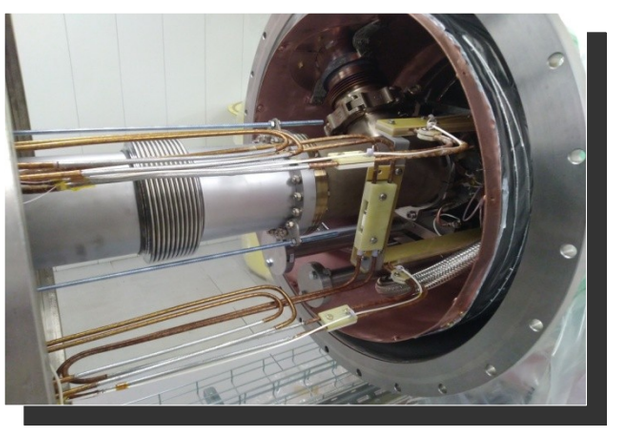
Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
Energy in c.m., Gev/u	**4-11**
r.m.s. Δp/p, 10^{-3}	**1,6**
IBS growth time, s	**1800**
Luminosity, cm^{-2} s^{-1}	**1x10^{27}**

Stage I:

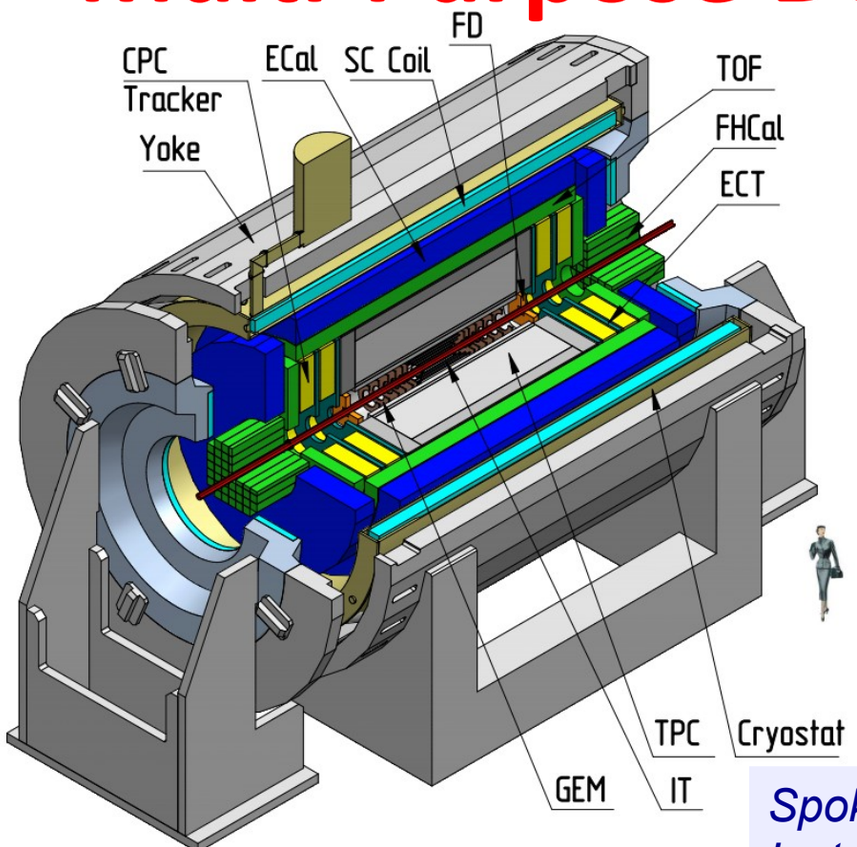
- ***without ECS***
- ***reduced number of RF***
- ***reduced luminosity***

Booster magnets inside Sychrophasotron

- ✓ ***all magnets in the tunnel***
- ✓ ***95% connected***
- ✓ ***ring He-system***
  assembled 95%, tested 50%
- ✓ ***beam pipe 55%***



Multi-Purpose Detector (MPD) Collaboration



11 *Countries,* ***>500*** *participants,*
39 *Institutes and* ***JINR***

NICA

Spokesperson: ***Adam Kisiel***
Inst. Board Chair: ***Fuqiang Wang***
Project Manager: ***Slava Golovatyuk***

Deputy Spokespersons:
Victor Riabov, Zebo Tang

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

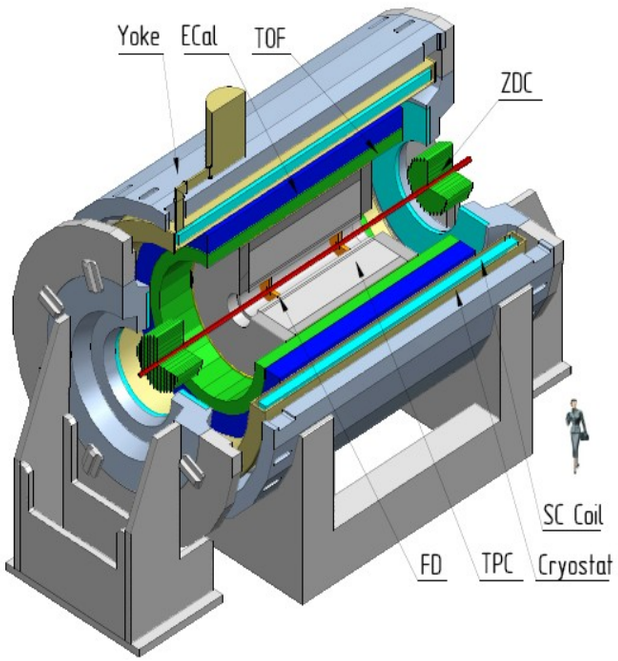
IHEP, Beijing, ***China****;*
University of South China, ***China****;*
Three Gorges University, ***China****;*
Institute of Modern Physics of CAS, Lanzhou, ***China****;*
Palacky University, Olomouc, ***Czech Republic****;*
NPI CAS, Rez, ***Czech Republic****;*
Tbilisi State University, Tbilisi, ***Georgia****;*
Joint Institute for Nuclear Research*;*
FCFM-BUAP (Mario Rodriguez) Puebla, ***Mexico****;*
FC-UCOL (Maria Elena Tejeda), Colima, ***Mexico****;*
FCFM-UAS (Isabel Dominguez), Culiacán, ***Mexico****;*
ICN-UNAM (Alejandro Ayala), Mexico City, ***Mexico****;*
CINVESTAV (Luis Manuel Montaño), Mexico City, ***Mexico****;*
Institute of Applied Physics, Chisinev, ***Moldova****;*

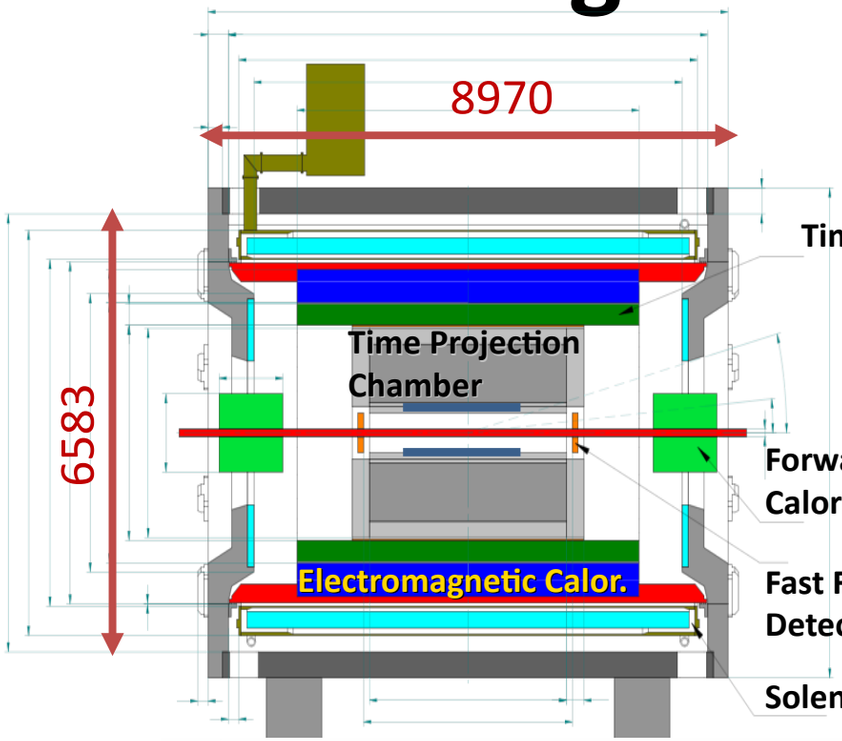
NICA-PL

WUT, Warsaw, ***Poland****;*
NCNR, Otwock – Świerk, ***Poland****;*
University of Wrocław, ***Poland****;*
University of Silesia, ***Poland;***
University of Warsaw, ***Poland****;*
Jan Kochanowski University, Kielce, ***Poland****;*

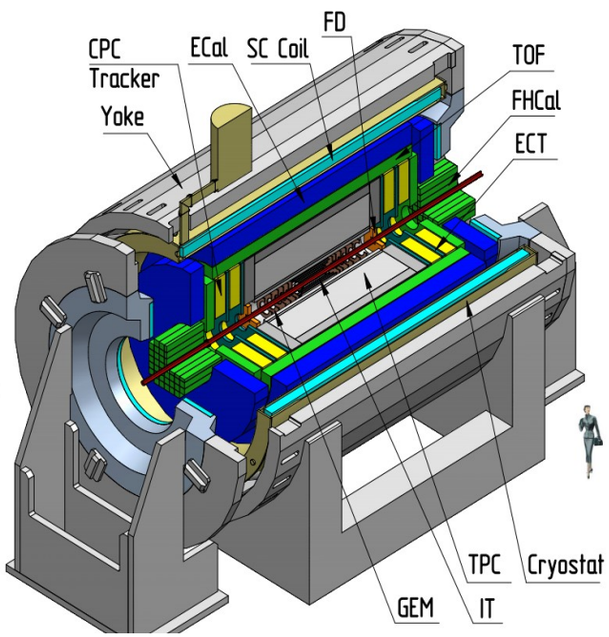
Belgorod National Research University, ***Russia****;*
INR RAS, Moscow, ***Russia****;*
MEPhI, Moscow, ***Russia****;*
Moscow Institute of Science and Technology, ***Russia****;*
North Osetian State University, ***Russia****;*
NRC Kurchatov Institute, ITEP, ***Russia****;*
Kurchatov Institute, Moscow, ***Russia****;*
St. Petersburg State University, ***Russia;***
SINP, Moscow, ***Russia****;*
PNPI, Gatchina, ***Russia****;*

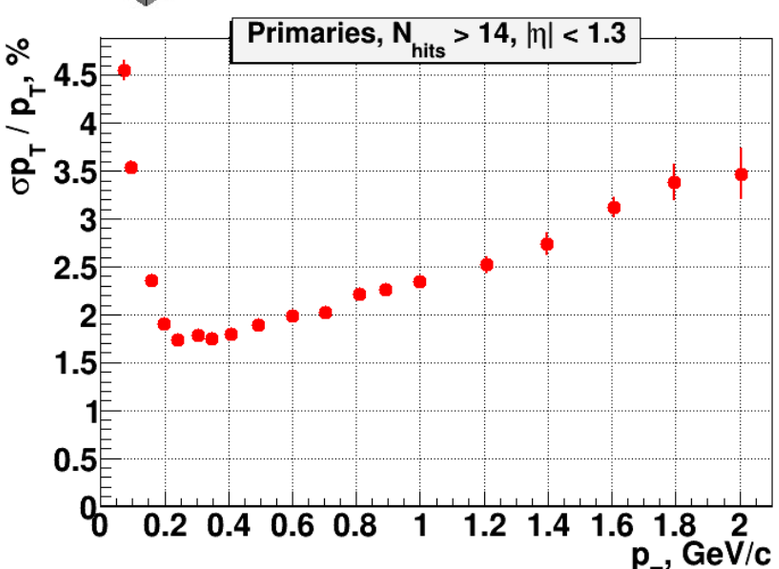
MPD - stage I and II



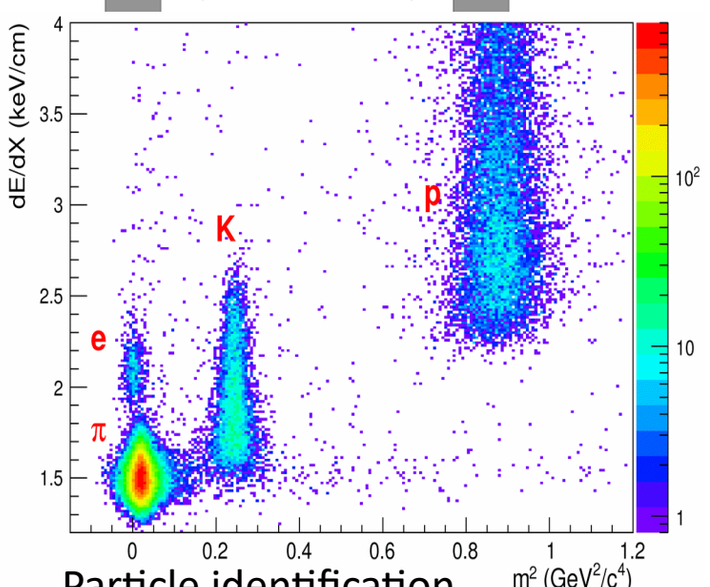


MPD - Stage II

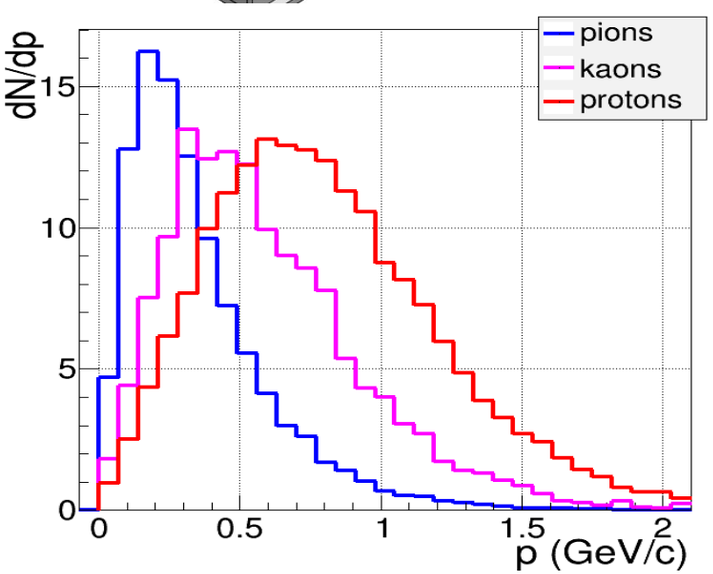




Momentum resolution with TPC



Particle identification



Momentum dist. of secondary particles

MPD Civil Construction status

- MPD Hall ready for limited scope of equipment installation, remaining works still ongoing

MPD Hall crane weight test

Exterior of the MPD Hall Building and high voltage connection housing

Epoxy floor finish ready in the MPD Hall

Magnet Yoke assembly

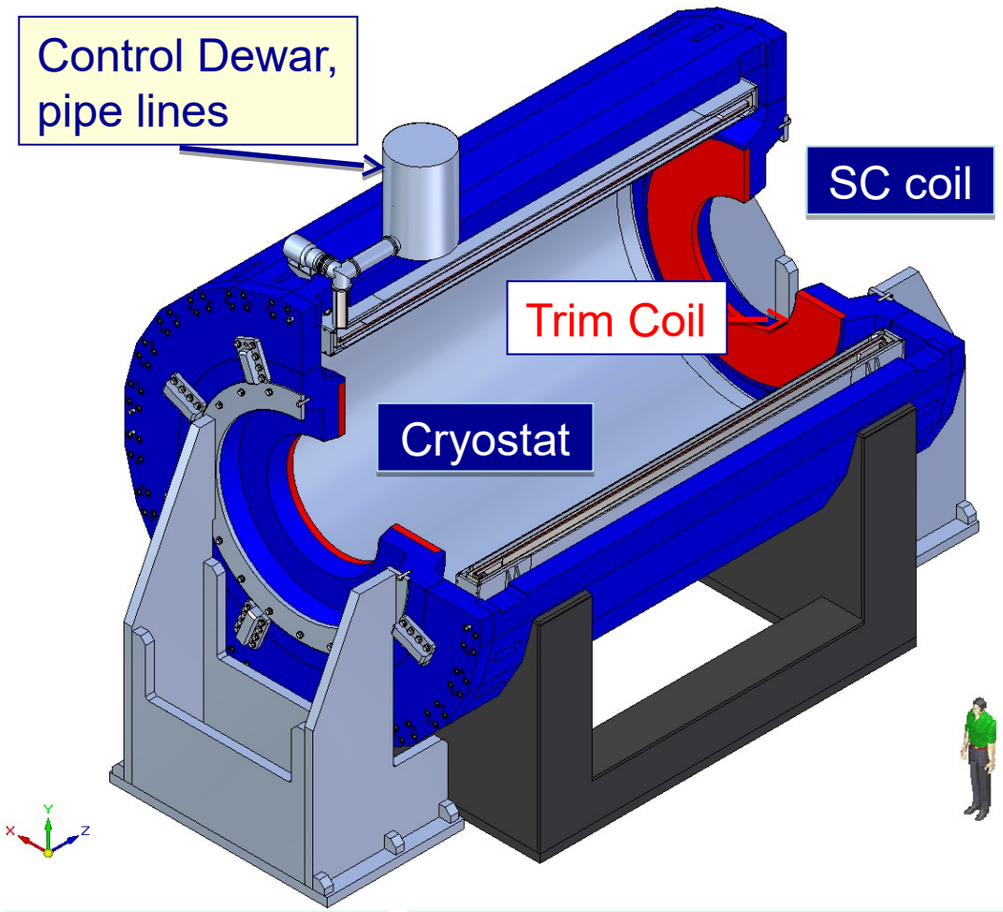
- Assembly of the magnet yoke started – 13 modules (out of 28) installed with average 200 µm precision
- Next step: assembly with solenoid in presence of manufacturer team
- Critical assembly path commenced

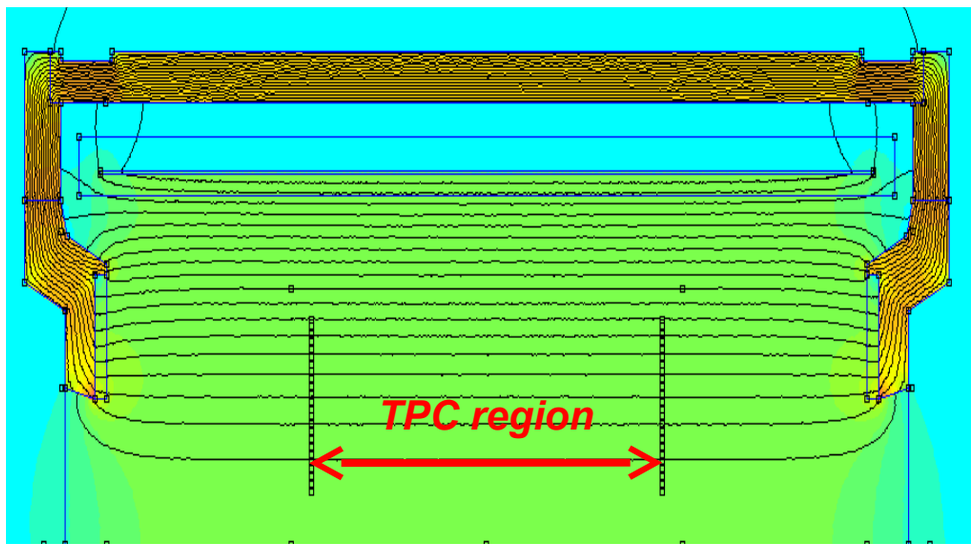
MPD Superconducting Solenoid

B_0=0.5 T

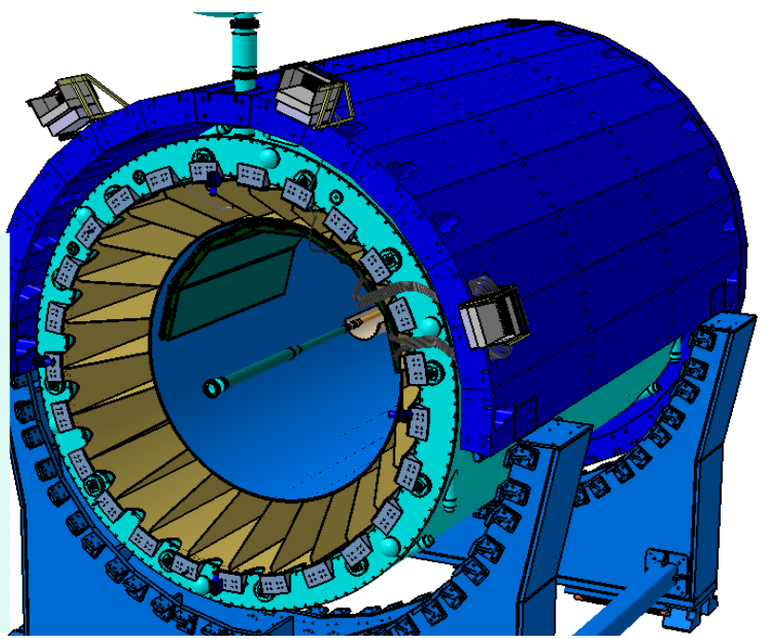
weight **~ 900 t**

*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*

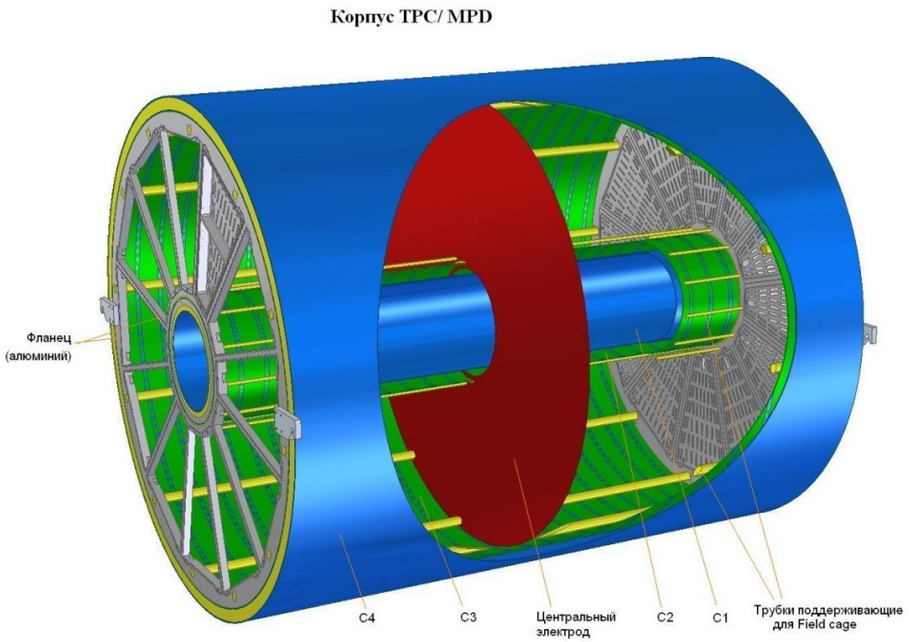
ASG superconductors, *Genova* ***general responsibility:*** *Cold Mass + Cryostat, Trim Coils Vacuum System, Control System*

The Central Research Institute for Special Machinery, *Khotkovo: Carbon Fiber support structure for all MPD subsystems*

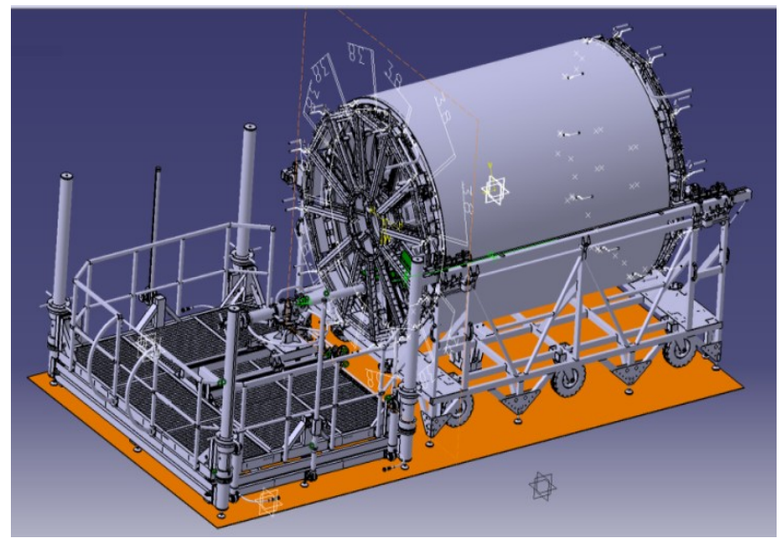
Solenoid in MPD Hall

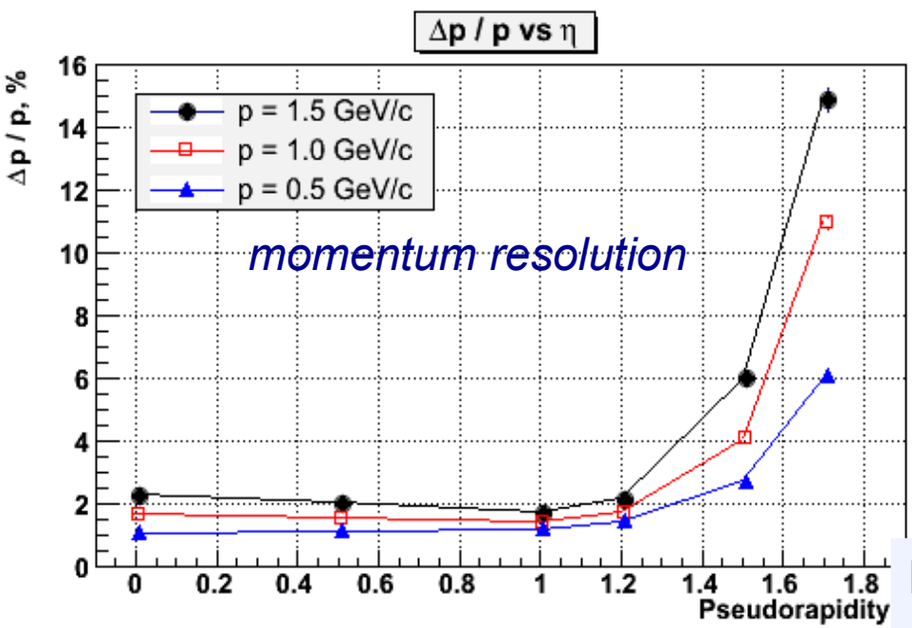
- On 6-th of November the MPD Solenoid delivered to MPD Hall

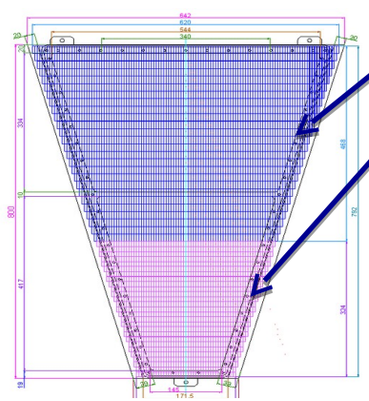
Time Projection Chamber (TPC): main tracker



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	*< 7kGz (L= 10^{27})*





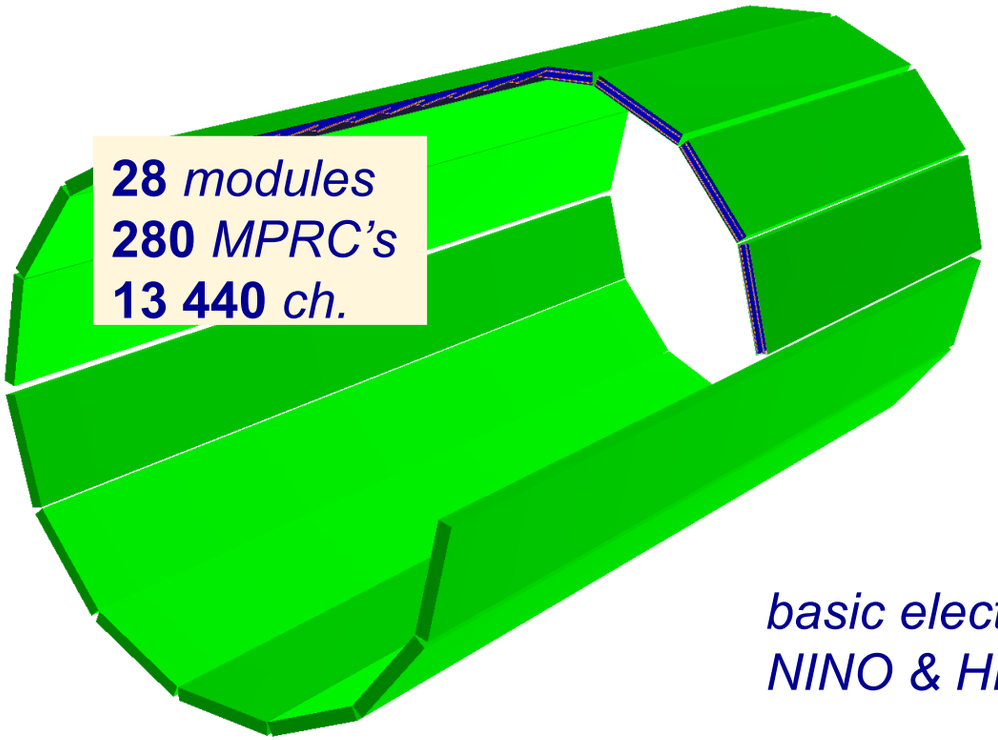


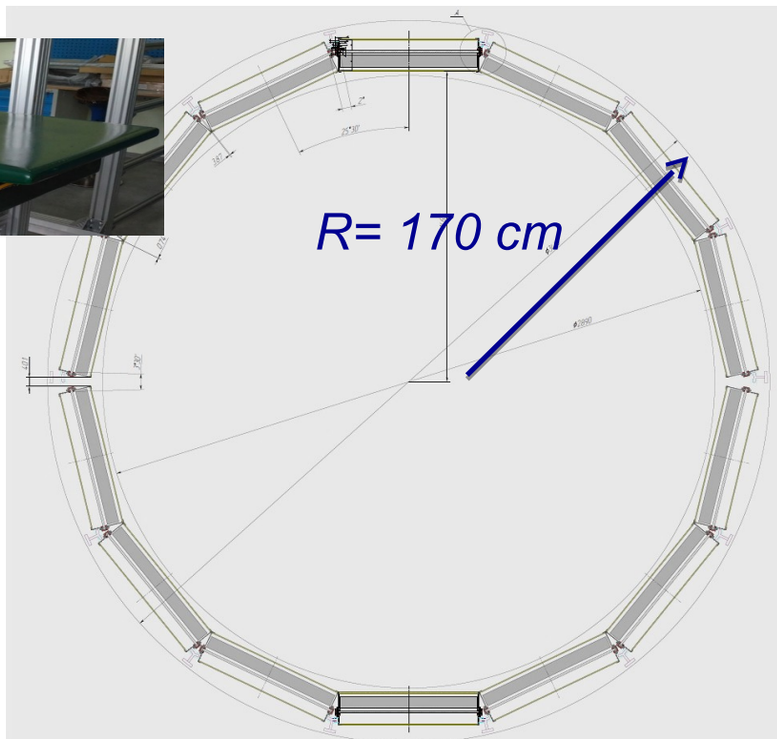
r-o chamber

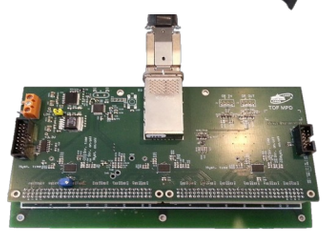
pad structure:
- *rows – 53*
- *large pads 5×18 mm²*
- *small pads 5×12 mm²*

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

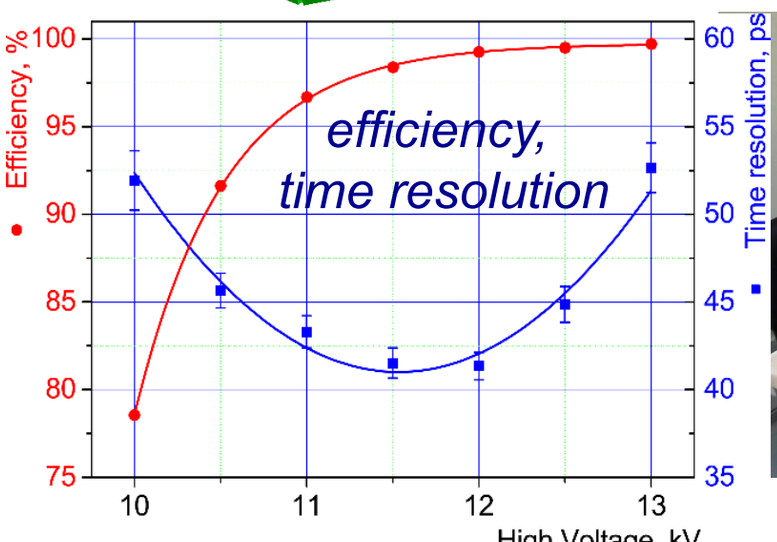
Time-of-Flight (TOF): particle identification

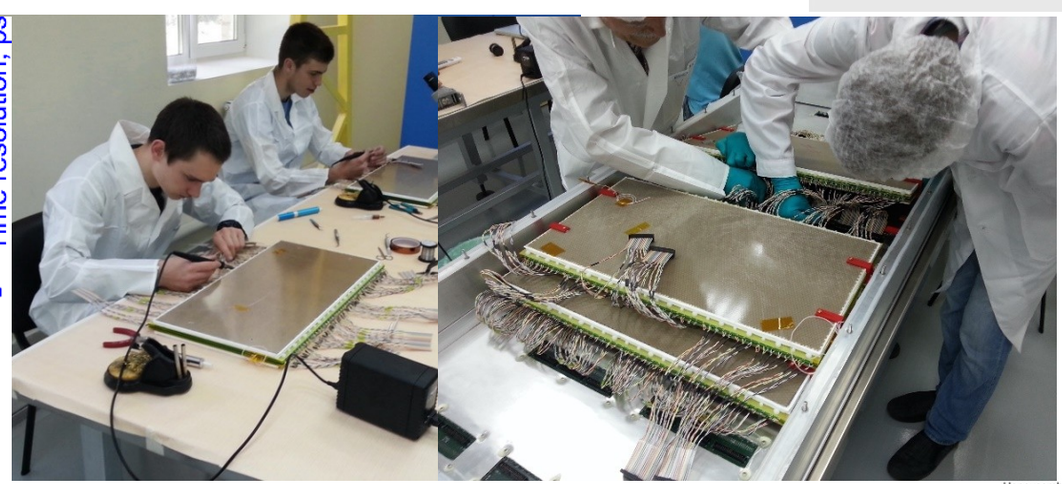




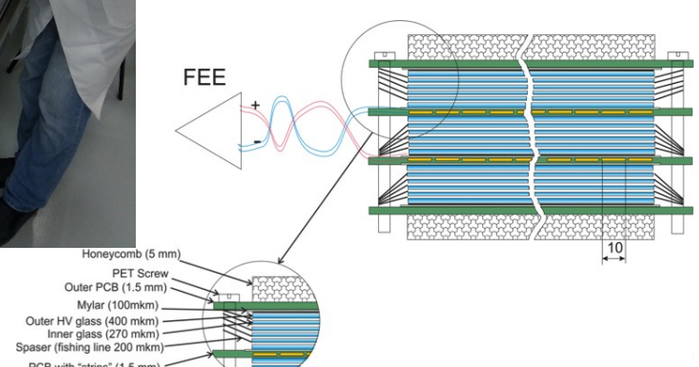


basic electronics -
NINO & HPTDC





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



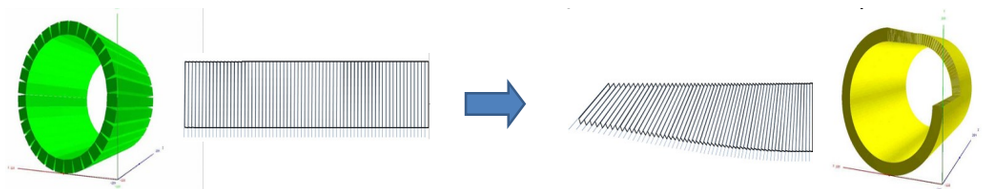
Electromagnetic Calorimeter (ECAL)

Pb+Sc "Shashlyk" | *read-out: WLS fibers + MAPD* | *L ~35 cm (~ 14 X_0)*

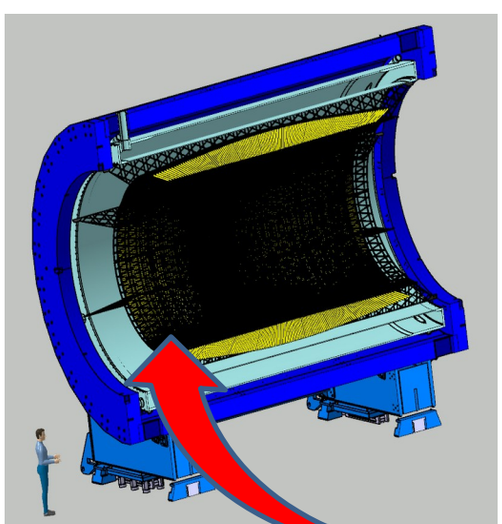
Segmentation (4x4 cm²) | *σ(E) better than 5% @ 1 GeV* | *time resolution ~500 ps*

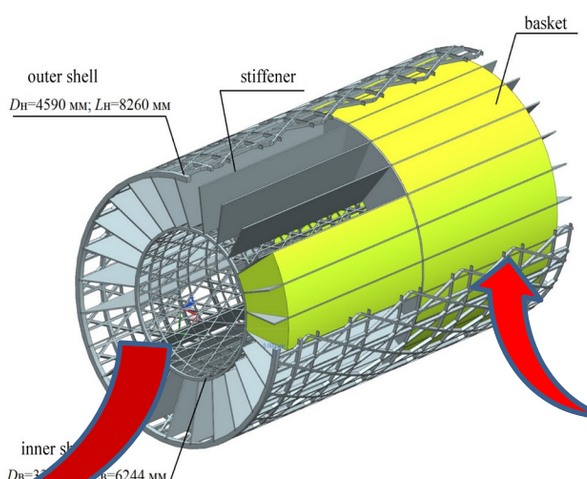
Barrel ECAL ~ 38400 ECAL modules

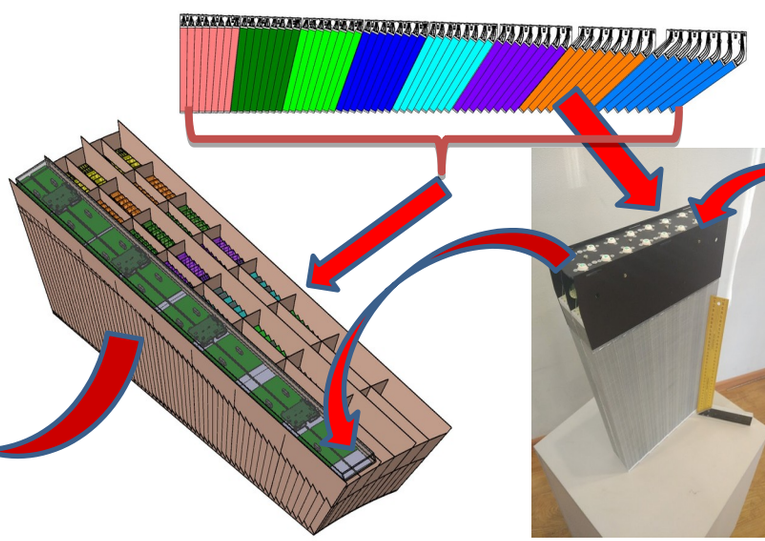
ECal is organized into 25 sectors (50 half-sectors). Each half-sector contains 48 modules.



Projective geometry







We need Containers for sectors

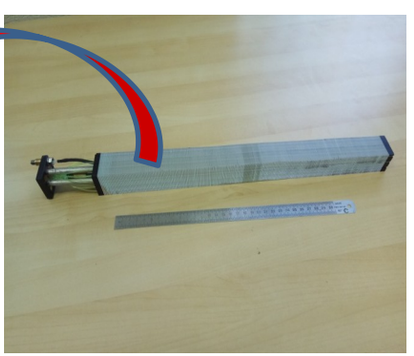
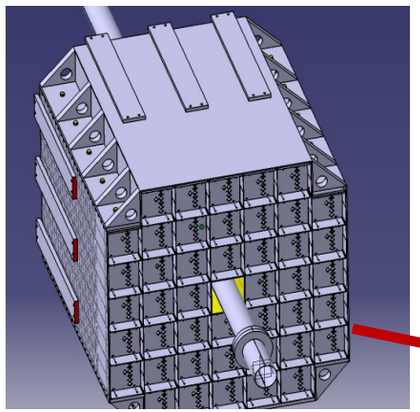
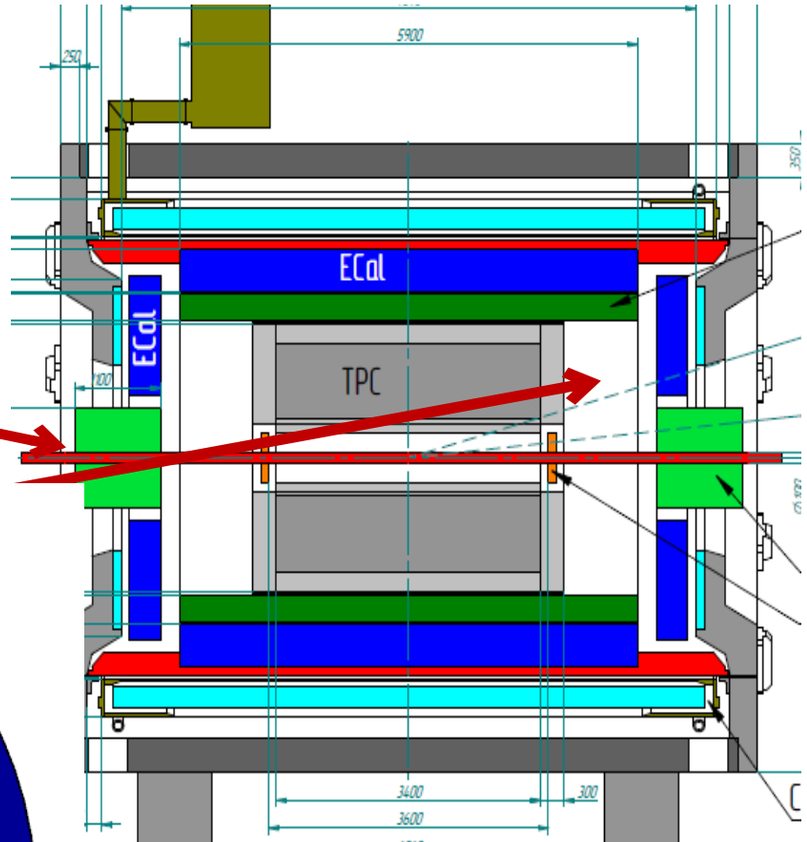
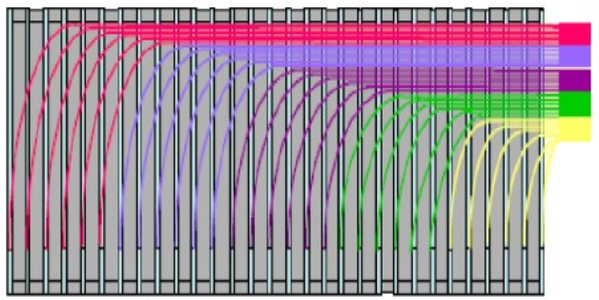


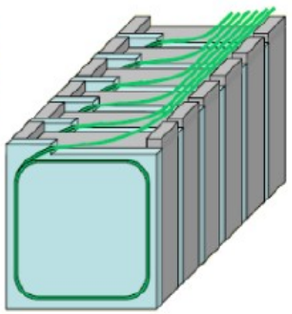
Photo of one element

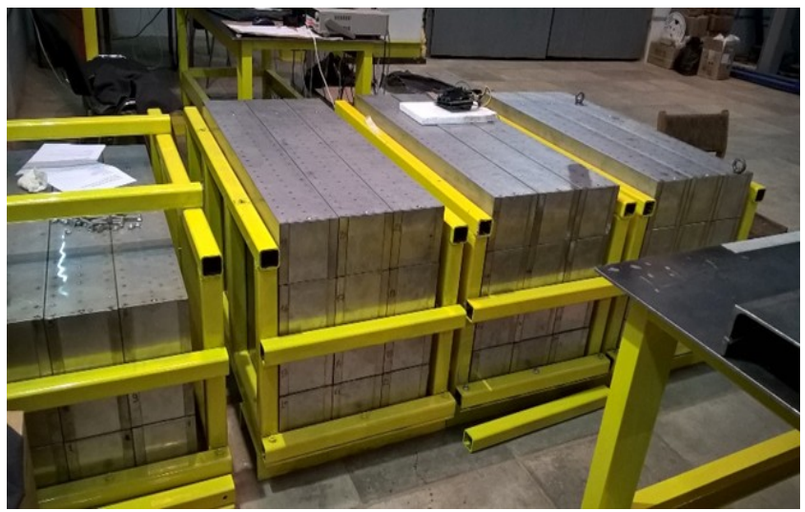
Forward Hadron Calorimeter (FHCal)

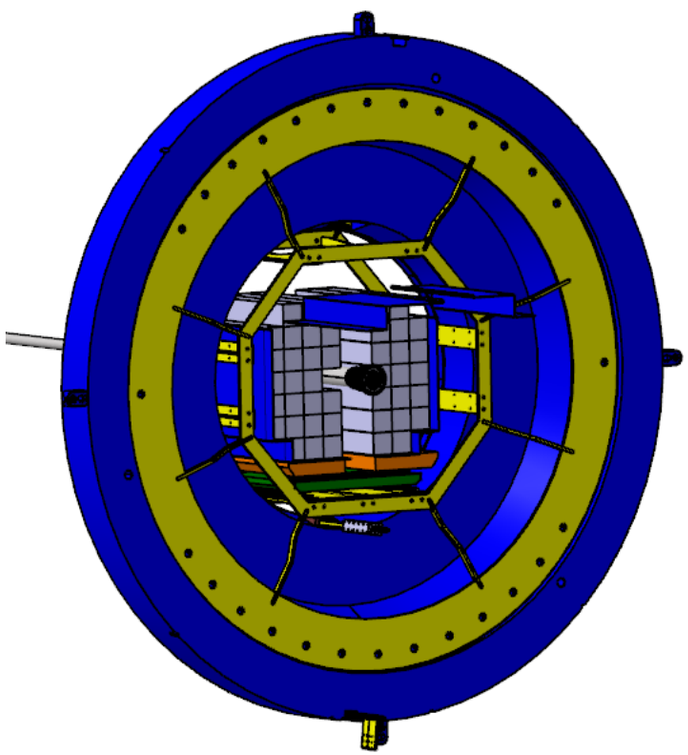






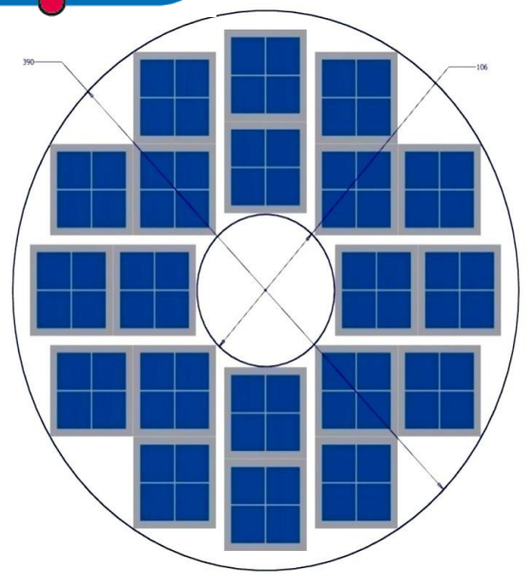


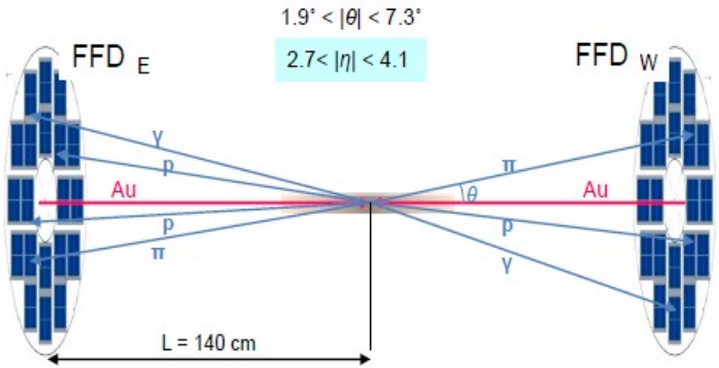




- Two-arms at ~3.2 m from the interaction point.
- Each arm consists of 44 individual modules.
- Module size 150x150x1100cm^3 (42 layers)
- Pb(16mm)+Scint.(4mm) sandwich
- 7 longitudinal sections
- 6 WLS-fiber/MAPD per section
- 7 MAPDs/module

FFD - Fast Trigger L_0 for MPD





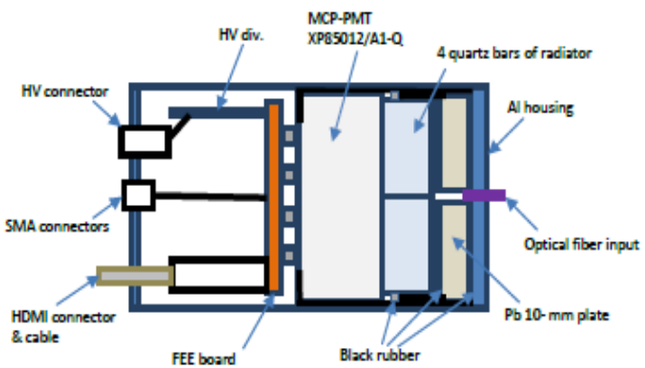


Fig. 4-1. A scheme of the FFD module.

FFD provides information on
- interaction rate (luminosity adjustment)
- bunch crossing region position

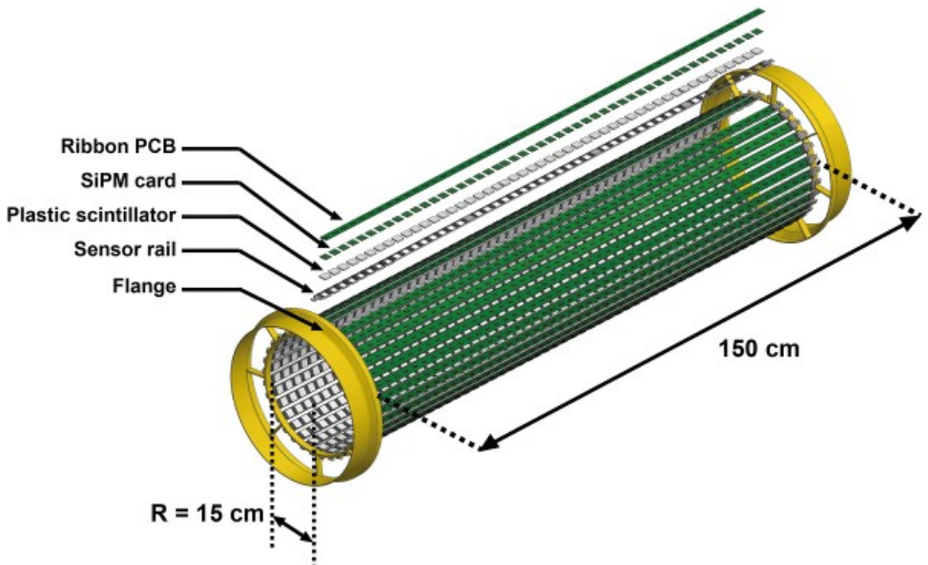
15 mm quartz radiator
10 mm Lead converter

The FFD sub-detector consists of
20 modules based on
Planacon multianode MCP-PMTs
80 independent channels

MPD trigger group is created on the basis of FFD team
Beside FFD we consider the signals from FHCal to be implemented into trigger L0
The FHCal team have produced trigger electronics.
Monte Carlo studies will be used to optimize the properties of the L0 trigger

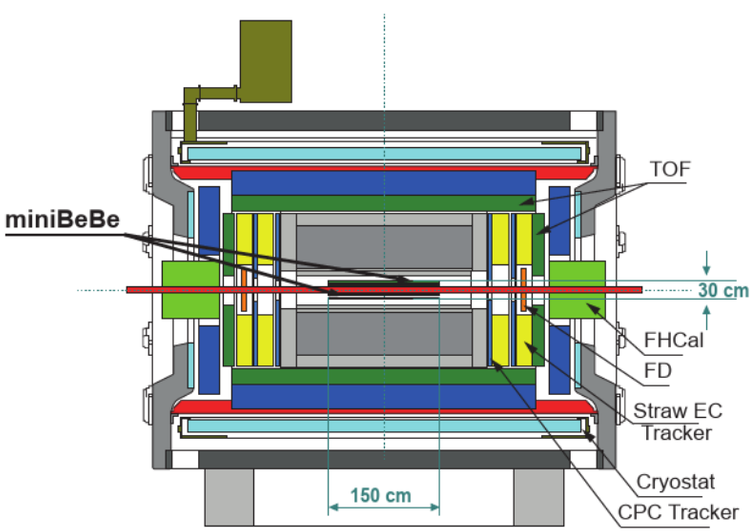
MiniBeBe (Mini Beam-Beam Counter)

MexNICA Collaboration



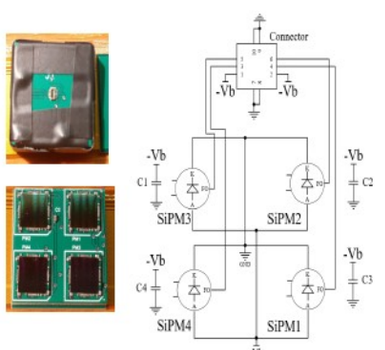
Main requirement:

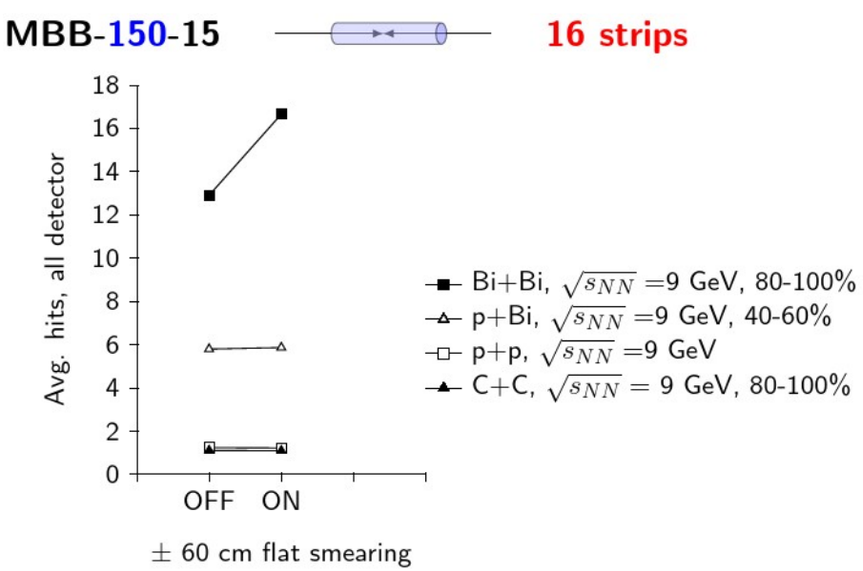
- Provide fast wake-up signal for TOF and reference time for TOF measurement with time resolution of ~30 ps
- Improve trigger efficiency for p+p, p-A and low multiplicity A-A
- Provide possibility to perform luminosity measurements at Phase 0 of NICA operation



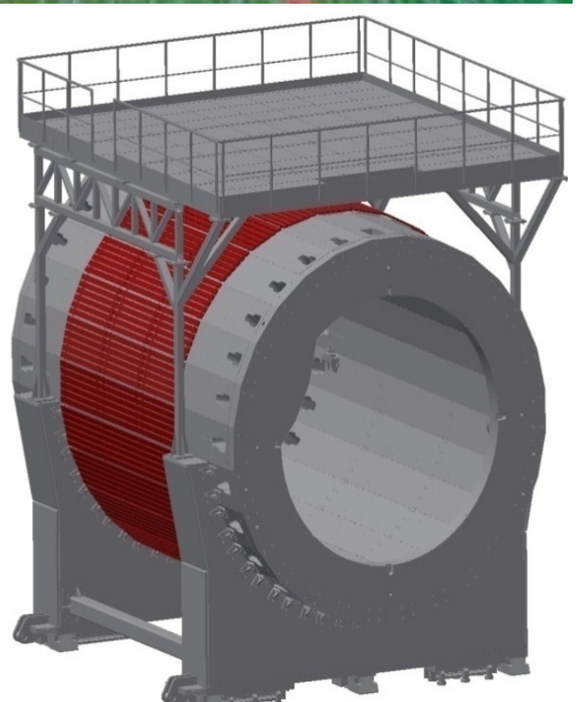
Basic cell with four SiPMs & electronics

- 20x20 mm²
- 4 SiPMs card attached to BC404 plastic scintillator
- Fast outputs to "connector" (micro mezzannine)
- DC decoupling capacitors





MPD Cosmic Ray Detector (MCORD)



NCBJ, Świerk - WUT, Warsaw (Poland) 18 scientists+12 engineers

Project leader: M. Bielewicz (NCBJ)

As soon as possible - start tests of MPD subsystems before Collider operation

Cosmic Ray Detector required for Commissioning and tests of the MPD.

The signals from MCORD will be used for TPC and TOF tests after their installation.

We'll need the elements of MCORD (scintillation panels with readout electronics) in March 2021

CDR for MCORD under evaluation of the MPD DAC

Cosmic Ray Detector consists of plastic scintillators with SiPM (Phototubes) light converters

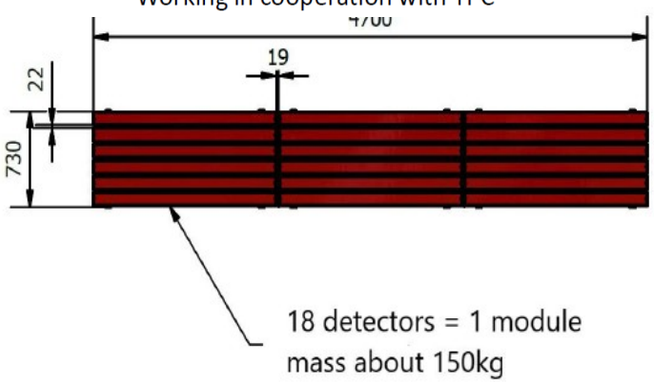
a) Trigger (for testing or calibration)
- testing before completion of MPD (testing of TOF, ECAL modules and TPC)
- calibration before experimental session

b) Veto (normal mode - track and time window recognition) Mainly for TPC and eCAL

Additionally

c) Astrophysics (muon shower and bundles)
- unique for horizontal events

Working in cooperation with TPC



5. MCORD Detector

SCINTILLATORS

Number of scintillators:	660 pcs
Dimensions of scintillators:	95x25x1500 [mm]
Dimensions of detector:	100x30x1554 [mm]
Scintillators are placed in the rectangle profile	10x30x2.5 [mm]
Weight of detector:	6.5 kg
Material of scintillators casing:	Aluminum alloy

MODULES

Number of detector in one module:	18
Number of Modules:	28
Dimensions of module:	730x90x4700 [mm]
Weight of one module:	150 kg

SiPM/MMPC

Number of SiPMs (Chanels)	1320
Number of SiPMs (with two fibers)	2640

RESOLUTION

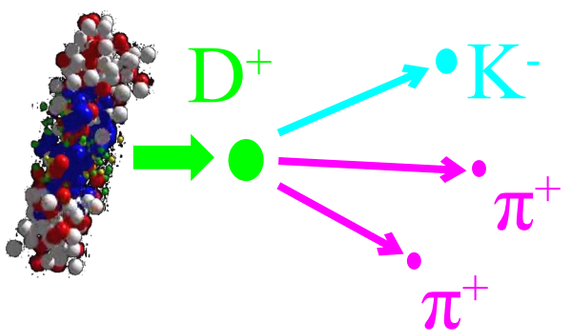
Position resolution: In X axis – up to 5 cm, In Y axis – 5-10 cm

Time Resolution – about 300-500 ps

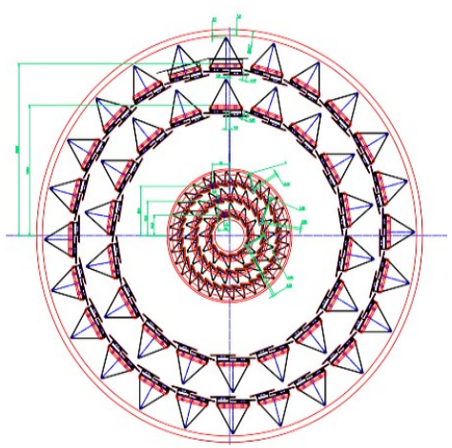
Number of events (particles):	about 100-150 per sec per m2
Calculated Coincidence factor:	about 98%

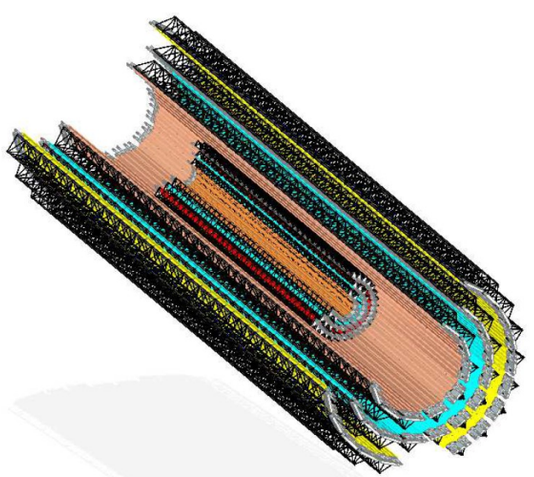
Inner Tracker System (ITS): precise tracking

Consortium includes JINR, NICA (BM@N & MPD) , **FAIR, Russian, Poland and Ukraine Institutes + CCNU Central China Normal Univ., IMP- Institute of Modern Physics, USTC – Hefei**



Protocol # 134 between CERN and JINR states the legal terms for transaction of CERN developed novel technology and the know-how for building the MPD-ITS on the basis of Monolithic Active Pixel Sensors *(the **MAPS***) ALPIDE, signed in 2018. This document laid a clear road towards the MPD ITS.





MPD ITS based on ALICE type staves

Milestones of MPD assembling in 2020-2022

Year 2020

1. July 15th - MPD Hall and pit are ready to store and unpack Yoke parts
2. August - The first 13 plates of Magnet Yoke are assembled for alignment checks
3. Sept 15th - Oct 1st - Solenoid is ready for transportation from ASG (Italy)
4. November 10th - Solenoid is in Dubna
5. Nov-Dec - Assembling of Magnet Yoke and Solenoid at JINR

Year 2021

6. Jan- April - Preparation for switching on the Solenoid (Cryogenics, Power Supply et cet.)
7. May - June - Magnetic Field measurement
8. July - Installation of Support Frame
9. Jul- Dec - Installation of ECal and TOF, Electronics Platform, Cabling

Year 2022

11. Jan- Mar - Installation of TPC, Electronics Platform, Cabling
12. March - Installation of beam pipe, FHCal, Cosmic Ray test system
13. April-Dec - Cosmic Ray tests
14. December - Commissioning

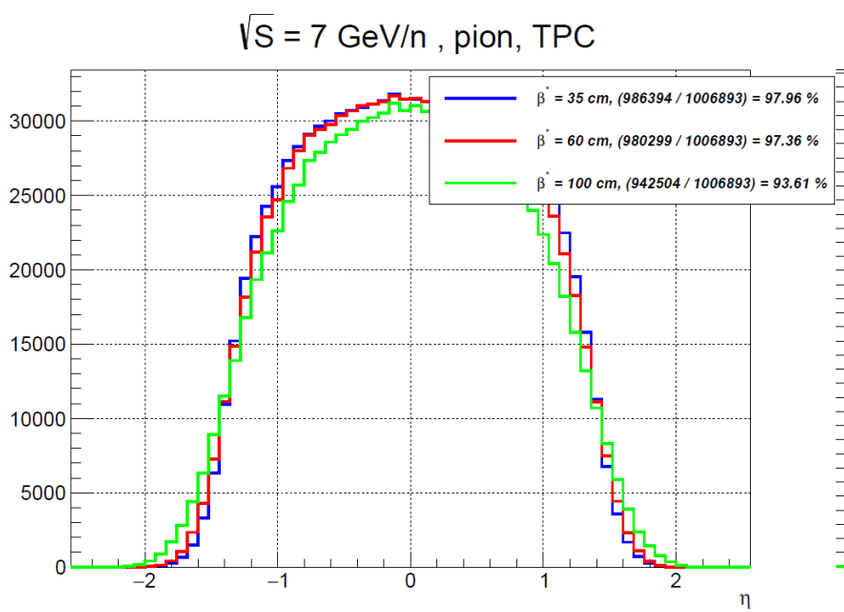
Year 2023

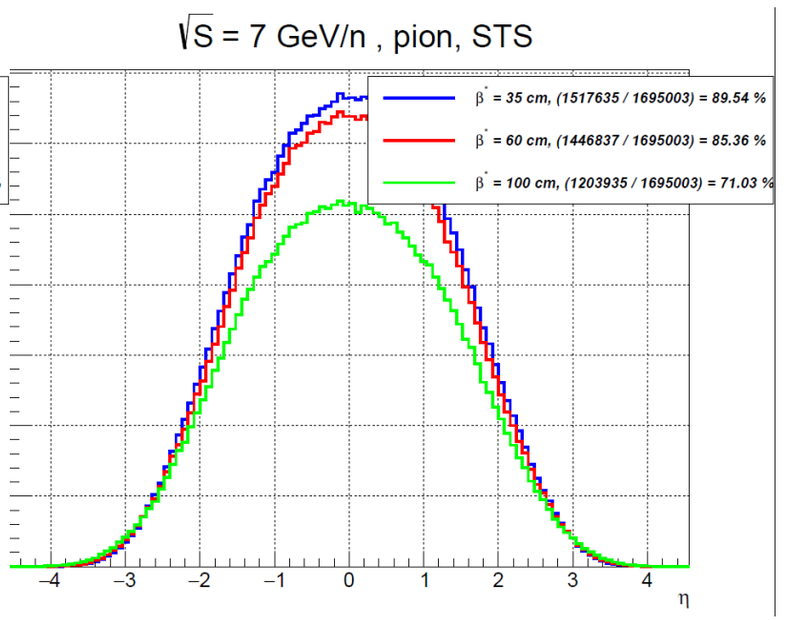
15. March - Run on the beam

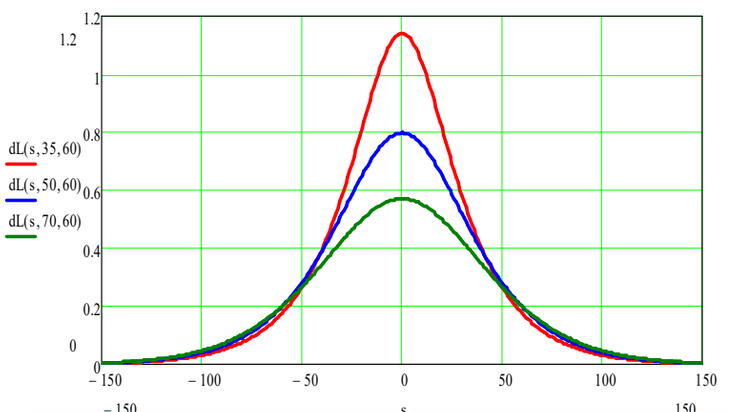
First beams at NICA

- Initial collision system will not be Au (difficult to produce efficient enough ion source). Bi beams are planned, as Bi source is practically ready.
- Initial running will not use acceleration in NICA. Beam momentum is limited to the one provided by Nuclotron, resulting in sqrt(s_{NN}) of 9.46 AGeV
- No electron cooling
- Not clear how efficient RFs will be in creating bunches
- Result: reduced luminosity – 10^{24} at the beginning, realistic 10^{25} soon after start of operation

Part of the secondary particles in one event from Au-Au beam collisions emitted in the acceptance of Inner tracker (ITS) and TPC (preliminary)







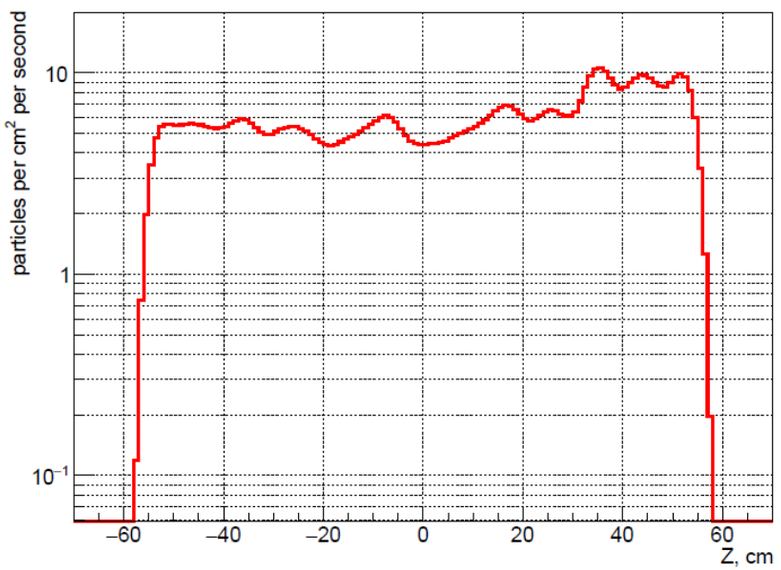
β* = 35, 60, 100 cm, σ_s = 60 cm

7 GeV/n pions	β 35 cm	β 60 cm	β 100 cm
Inner tracker	90,0%	85,4%	71%
TPC	98%	97,4%	93,6%

The background from the Beam – Rest gas interaction
Geant with real geometry and materials of all elements
(preliminary resilts)

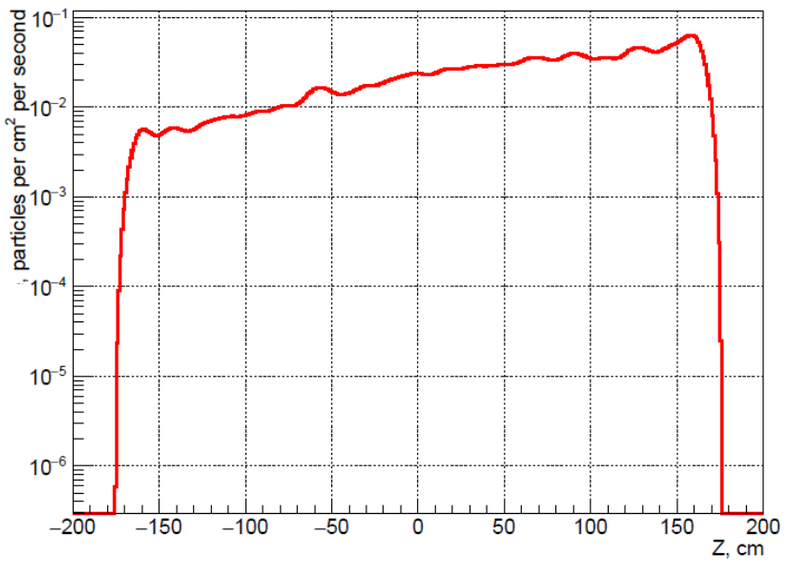
First Layer of Inner Tracker R=5,5 cm

The number of interactions/cm^{2*} s

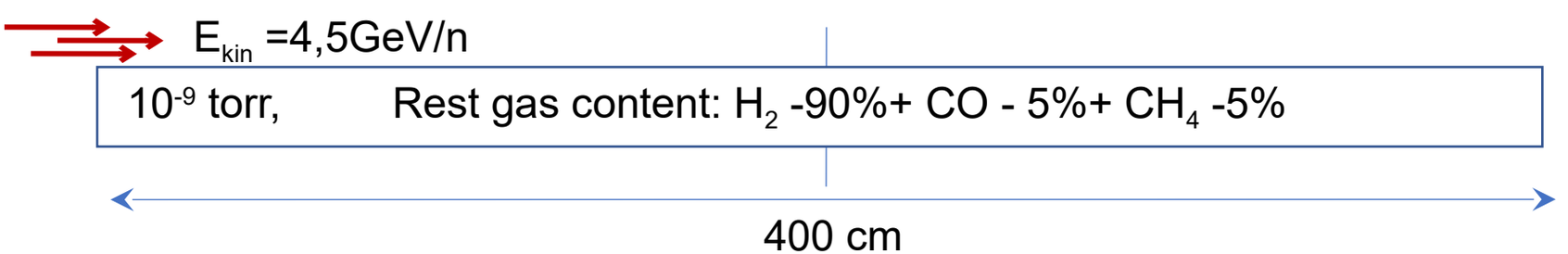


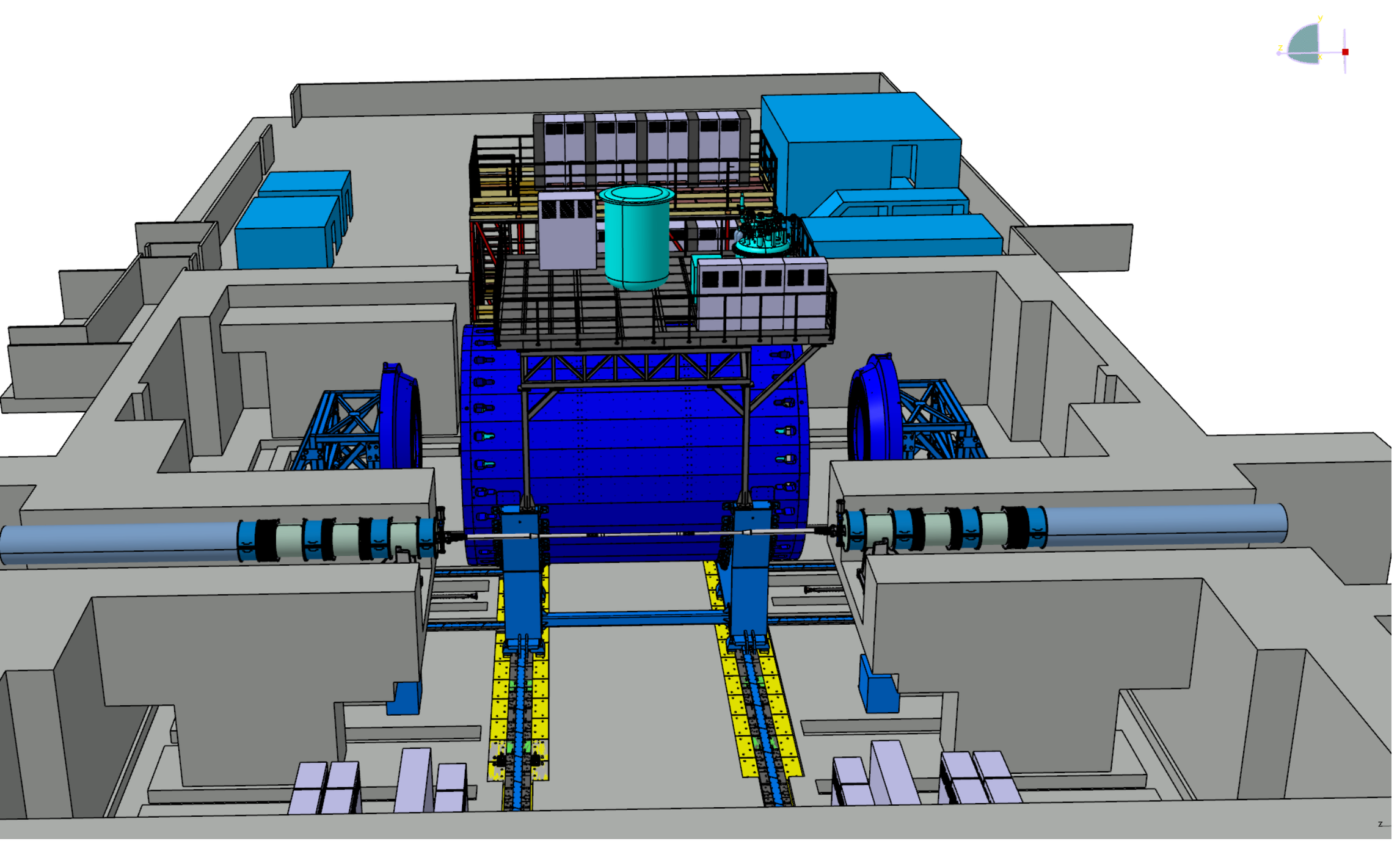
Inner Layer of TPC R=38 cm

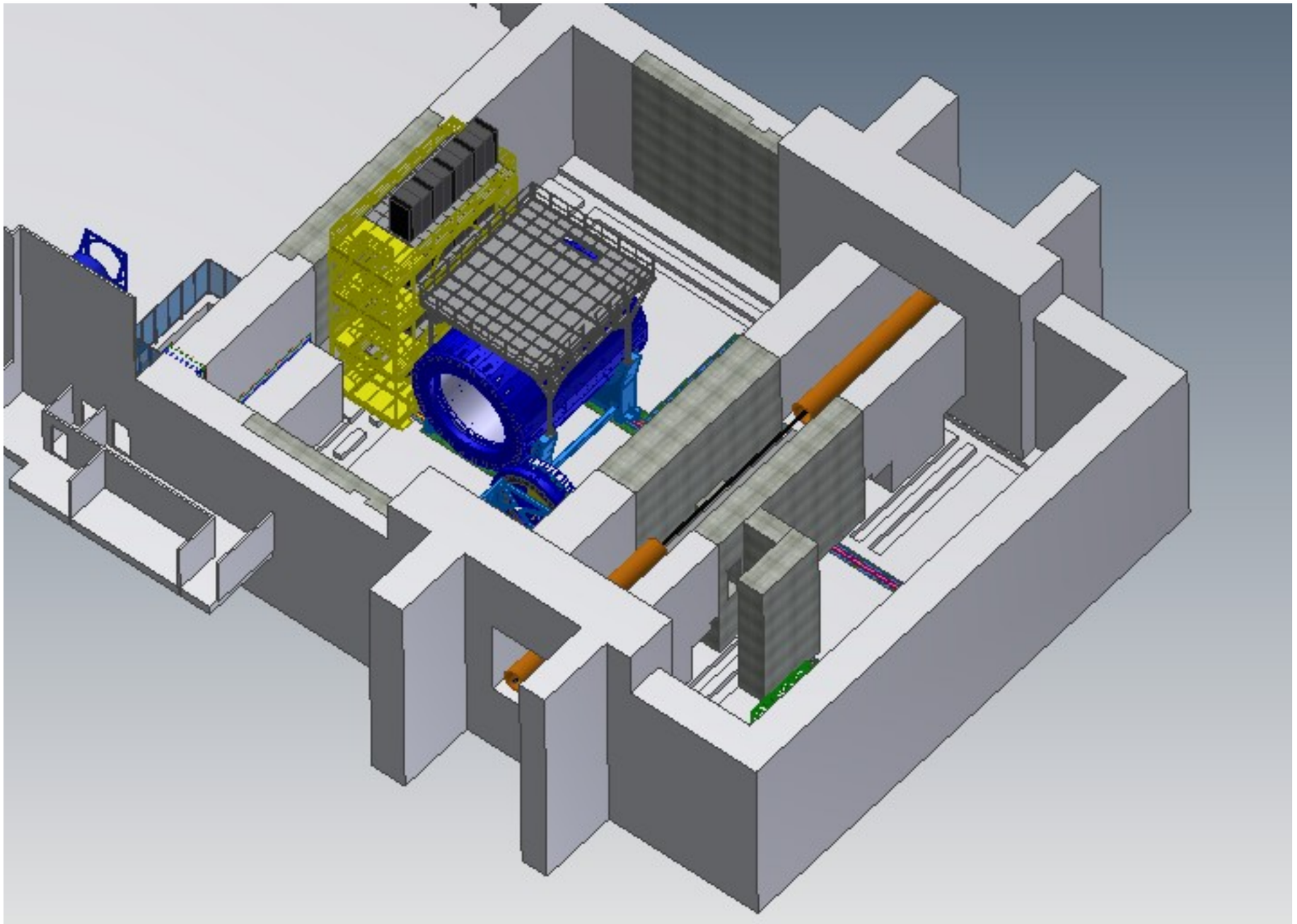
The number of interactions/cm^{2*} s

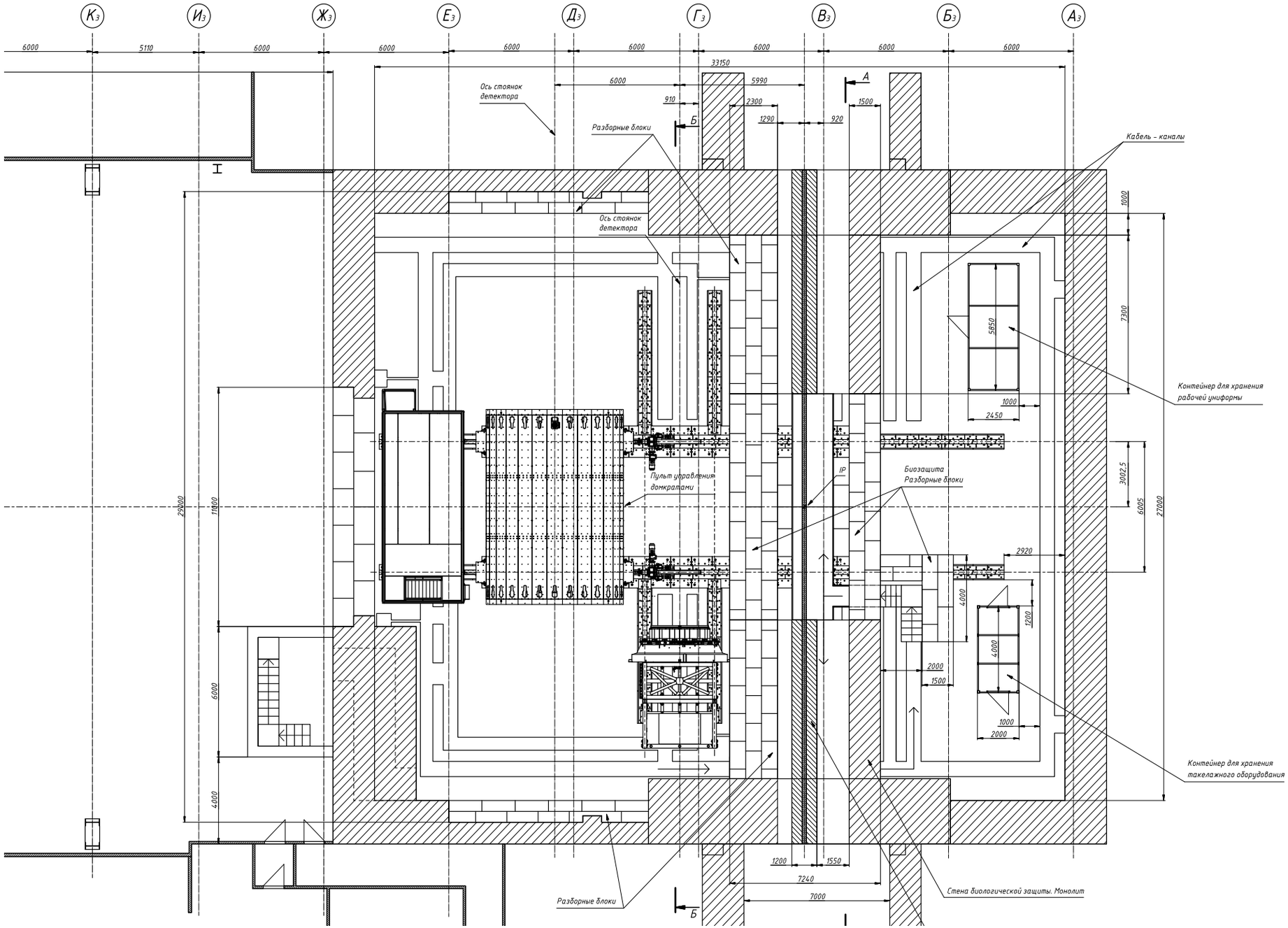


Beam from one side - 22 banches per 1,5*10^{-6} sec








К3
И3
Ж3
Е3
Д3
Г3
В3
Б3
А3
6000
5110
33150
5990
910
2300
1290
920
1500
Ось стоянок детектора
Разборные блоки
Кабель – каналы
Ось стоянок детектора
Пульт управления домкратами
IP
Биозащита
Разборные блоки
Контейнер для хранения рабочей униформы
Контейнер для хранения такелажного оборудования
Разборные блоки
Стена биологической защиты. Монолит
1000
7300
5850
2450
3002.5
6005
27000
29000
11000
6000
4000
2920
1200
2000
1500
1550
7240
7000

MPD Physics Programme

G. Feofilov, A. Ivashkin

Global observables

- Total event multiplicity
- Total event energy
- Centrality determination
- Total cross-section measurement
- Event plane measurement at all rapidities
- Spectator measurement

V. Kolesnikov, Xianglei Zhu

Spectra of light flavor and hypernuclei

- Light flavor spectra
- Hyperons and hypernuclei
- Total particle yields and yield ratios
- Kinematic and chemical properties of the event
- Mapping QCD Phase Diag.

K. Mikhailov, A. Taranenko

Correlations and Fluctuations

- Collective flow for hadrons
- Vorticity, Λ polarization
- E-by-E fluctuation of multiplicity, momentum and conserved quantities
- Femtoscopy
- Forward-Backward corr.
- Jet-like correlations

V. Riabov, Chi Yang

Electromagnetic probes

- Electromagnetic calorimeter meas.
- Photons in ECAL and central barrel
- Low mass dilepton spectra in-medium modification of resonances and intermediate mass region

Wangmei Zha, A. Zinchenko

Heavy flavor

- Study of open charm production
- Charmonium with ECAL and central barrel
- Charmed meson through secondary vertices in ITS and HF electrons
- Explore production at charm threshold

Summary

- The NICA Accelerator Complex in construction with important milestones achieved and clear plans for 2021 and 2022
- All components of the MPD 1st stage detector advanced in production, commissioning expected for 2021 and 2022
- Need for dedicated phase in MPD preparation – Phase 0, before MPD is placed on the beam