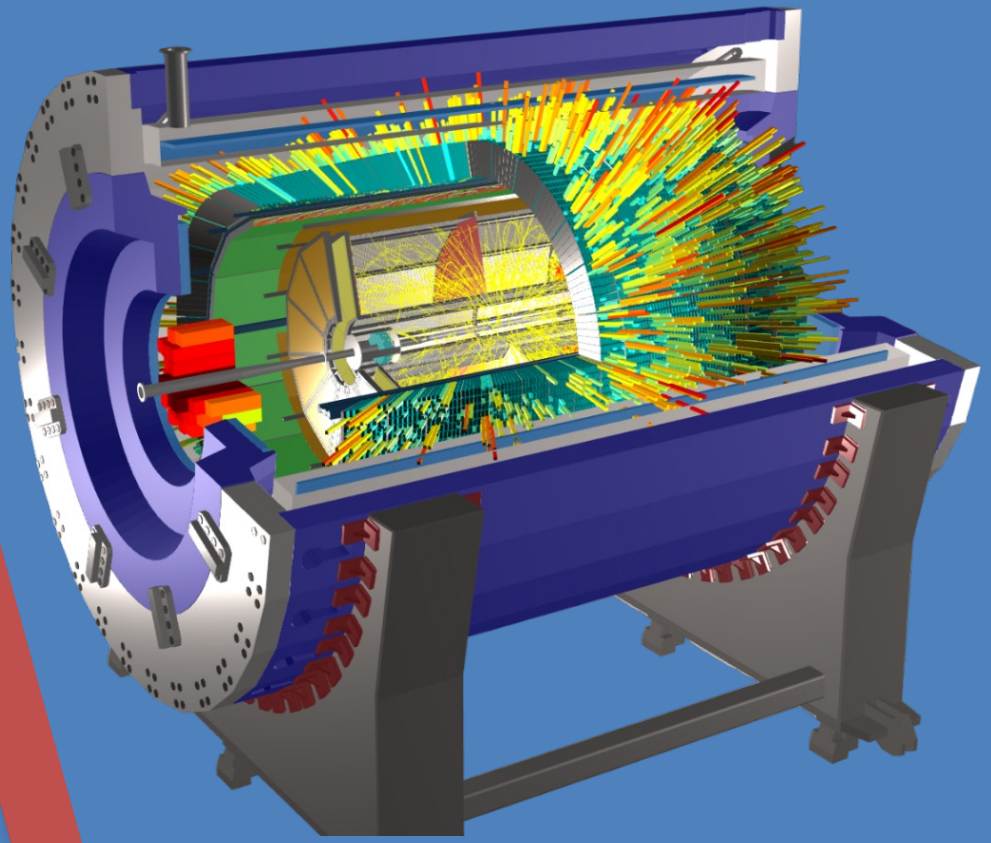
MPD - Многоцелевой Детектор коллайдера NICA



Степан Верещагин, по поручению коллаборации MPD, ОИЯИ

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

NICA

NICA MPD

Содержание:

Ускорительный комплекс NICA

https://nica.jinr.ru/

http://mpd.jinr.ru/

Коллаборация MPD

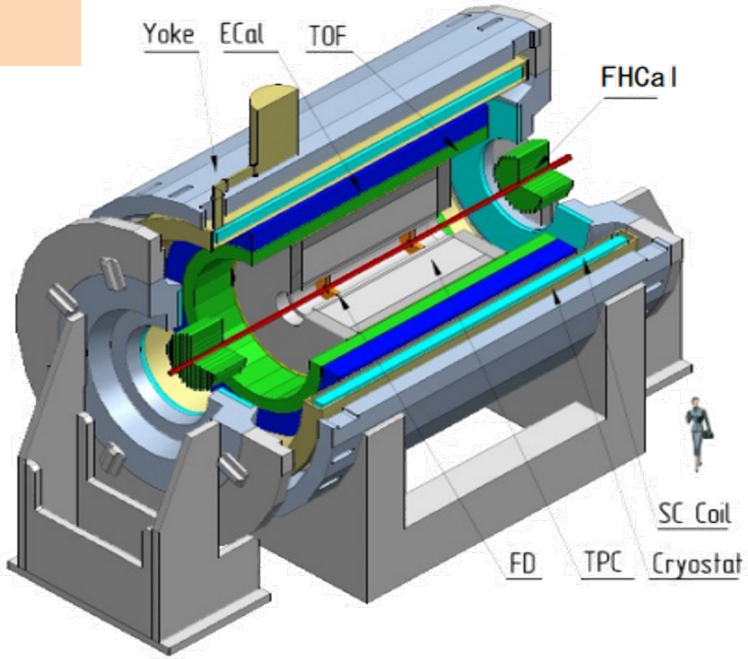
12** Countries, **>500** participants, **38** Institutes and **JINR

Organization

Acting Spokesperson:	***Victor Riabov***
Deputy Spokespersons:	***Zebo Tang, Arkadiy Taranenko***
Institutional Board Chair:	***Alejandro Ayala***
Project Manager:	***Slava Golovatyuk***

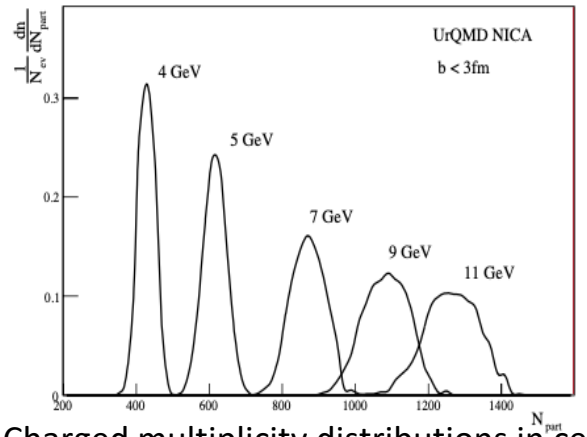
MPD** International Collaboration was established in **2018
to construct, commission and operate the detector

***Joint Institute for Nuclear Research, Dubna**;*
*A.Alikhanyan National Lab of Armenia, Yerevan, **Armenia;***
*SSI "Joint Institute for Energy and Nuclear Research – Sosny" of the National Academy of Sciences of Belarus, Minsk, **Belarus***
*University of Plovdiv, **Bulgaria;***
*Tsinghua University, Beijing, **China**;*
*University of Science and Technology of China, Hefei, **China**;*
*Huzhou University, Huzhou, **China**;*
*Institute of Nuclear and Applied Physics, CAS, Shanghai, **China**;*
*Central China Normal University, **China**;*
*Shandong University, Shandong, **China**;*
*University of Chinese Academy of Sciences, Beijing, **China**;*
*University of South China, **China**;*
*Three Gorges University, **China**;*
*Institute of Modern Physics of CAS, Lanzhou, **China**;*
*Tbilisi State University, Tbilisi, **Georgia**;*
*Institute of Physics and Technology, Almaty, **Kazakhstan**;*
*Benemérita Universidad Autónoma de Puebla, **Mexico**;*
*Centro de Investigación y de Estudios Avanzados, **Mexico**;*
*Instituto de Ciencias Nucleares, UNAM, **Mexico**;*
*Universidad Autónoma de Sinaloa, **Mexico**;*
*Universidad de Colima, **Mexico**;*
*Universidad de Sonora, **Mexico**;*
*Universidad Michoacana de San Nicolás de Hidalgo, **Mexico***
*Institute of Applied Physics, Chisinev, **Moldova**;*
*Institute of Physics and Technology, **Mongolia**;*



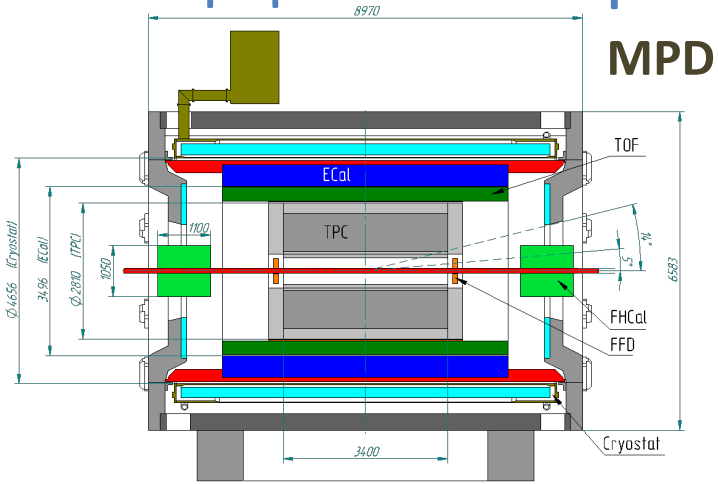
*Belgorod National Research University, **Russia**;*
*Institute for Nuclear Research of the RAS, Moscow, **Russia**;*
*High School of Economics University, Moscow, **Russia***
*National Research Nuclear University MEPhI , Moscow, **Russia**;*
*Moscow Institute of Science and Technology, **Russia**;*
*North Osetian State University, **Russia**;*
*National Research Center "Kurchatov Institute", **Russia**;*
*Peter the Great St. Petersburg Polytechnic University Saint Petersburg, **Russia**;*
*Plekhanov Russian University of Economics, Moscow, **Russia**;*
*St.Petersburg State University, **Russia**;*
*Skobeltsyn Institute of Nuclear Physics, Moscow, **Russia**;*
*Petersburg Nuclear Physics Institute, Gatchina, **Russia**;*
*Vinča Institute of Nuclear Sciences, **Serbia**;*
*Pavol Jozef Šafárik University, Košice, **Slovakia***

Многоцелевой Детектор MPD

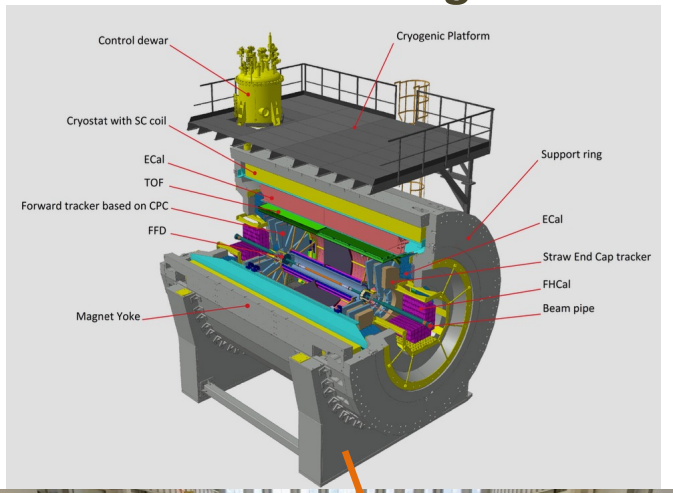


Charged multiplicity distributions in central Au + Au collisions (b < 3 fm) calculated by UrQMD.

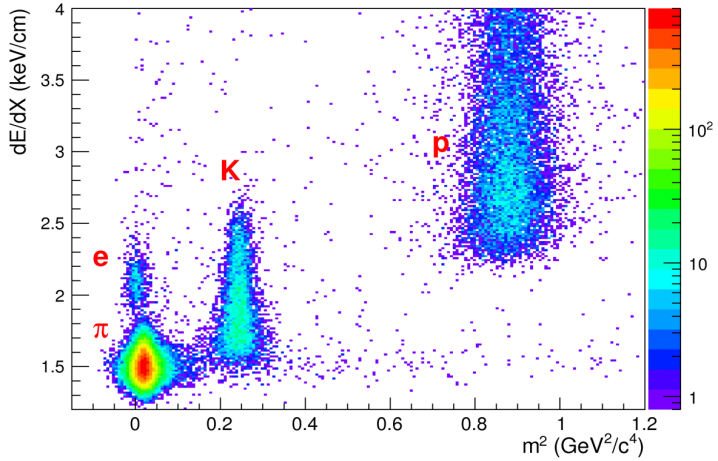
MPD - stage I



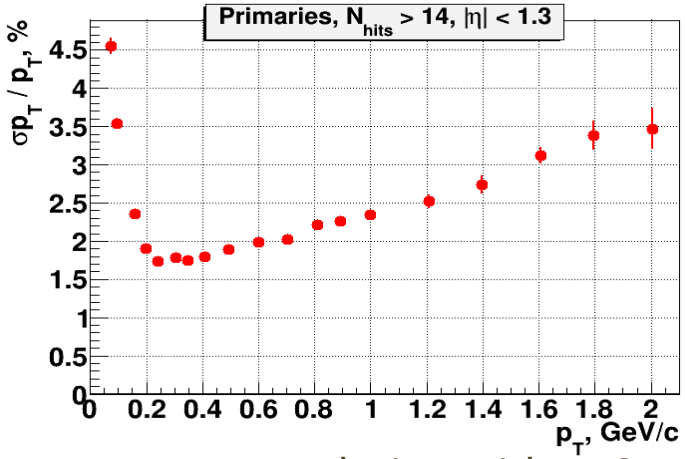
MPD - Stage II



Magnet assembly in the MPD Hall



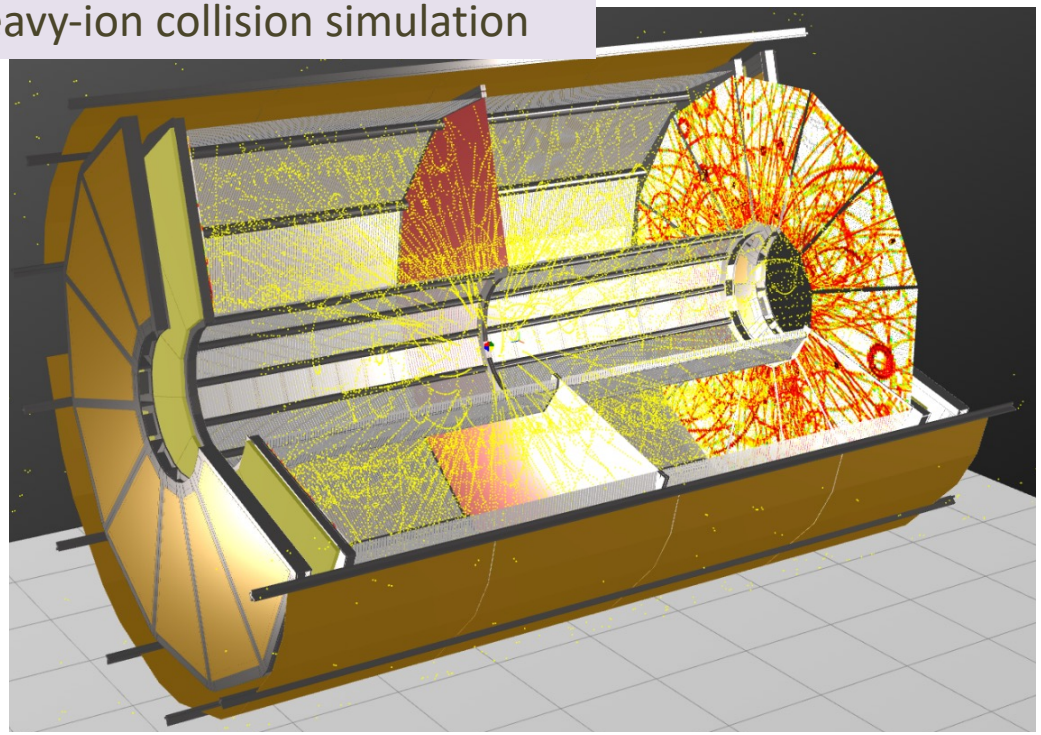
Particle identification with TPC, TOF & ECal



Momentum resolution with TPC

Время-Проекционная камера - TPC

Heavy-ion collision simulation



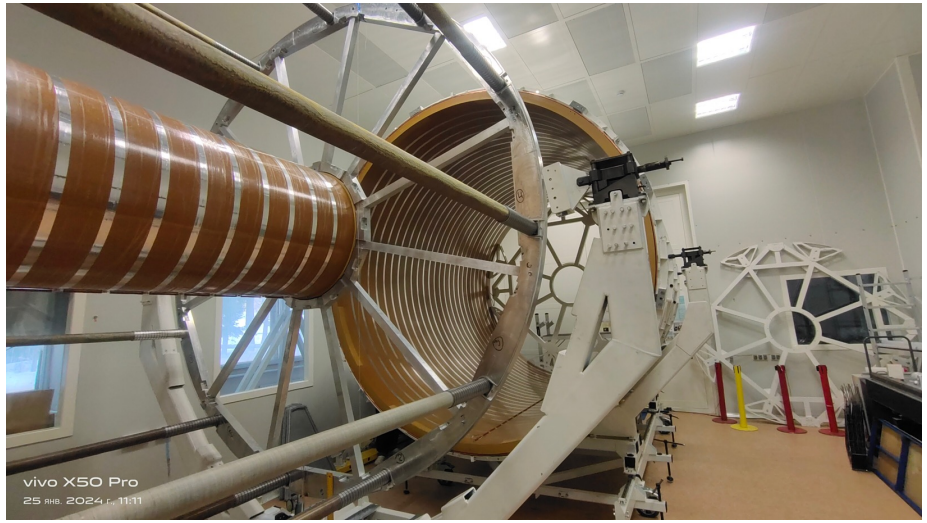
The TPC/MPD design requirements:

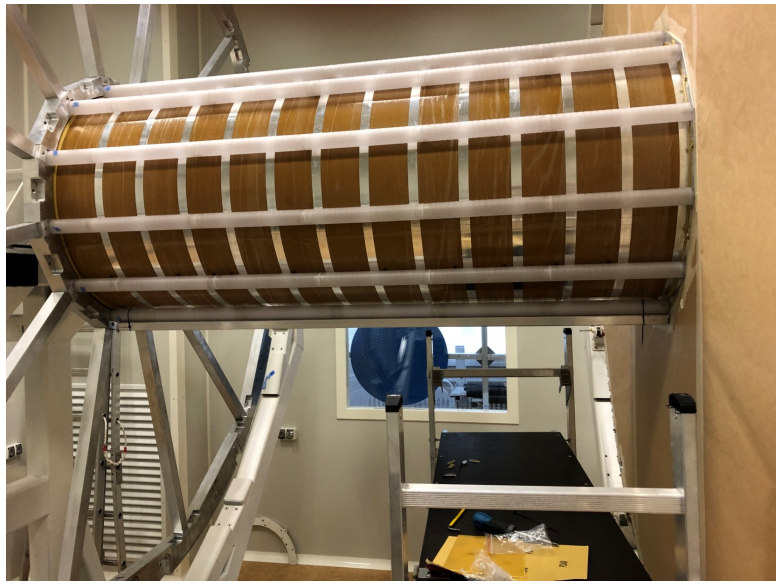
- The overall acceptance: η < 1.2
- The momentum resolution for charged particles is under 3% in the transverse momentum range 0.1 < pt < 1.5 GeV/c
- Two-track resolution is of about 1 cm
- Hadron and lepton identification by dE/dx measurements: with a resolution better than 8%
- Operation trigger rate: 7 KHz

Основные параметры TPC:

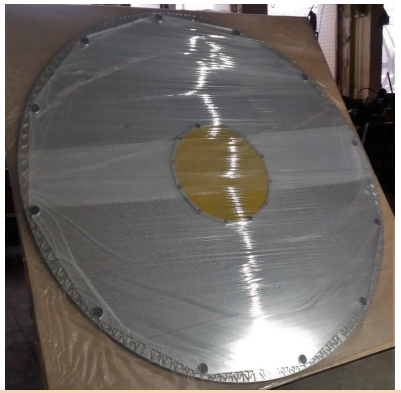
Item	Dimension
Length of the TPC	340cm
Outer radius of vessel	140cm
Inner radius of vessel	27 cm
Outer radius of the drift volume	133cm
Inner radius of the drift volume	34cm
Length of the drift volume	170cm (of each half)
HV electrode	Membrane at the center of the TPC
Electric field strength	~140V/cm;
Magnetic field strength	0.5 Tesla
Drift gas	90% Ar+10% Methane, Atmospheric pres. + 2 mbar
Gas amplification factor	~ 10^4
Drift velocity	5.45 cm/μs;
Drift time	< 30μs;
Temperature stability	< 0.5°C
Number of readout chambers	24 (12 per each end-plate)
Segmentation in ϕ	30°
Pad size	5x12mm^2 and 5x18mm^2
Number of pads	95232
Pad raw numbers	53
Pad numbers after zero suppression	< 10%
Maximal event rate	< 7 kHz (Lum. 10^{27})
Electronics shaping time	~180 ns (FWHM)
Signal-to-noise ratio	30:1
Signal dynamical range	10 bits
Sampling rate	10 MHz
Sampling depth	310 time buckets

Сборка корпуса TPC и ROC камеры

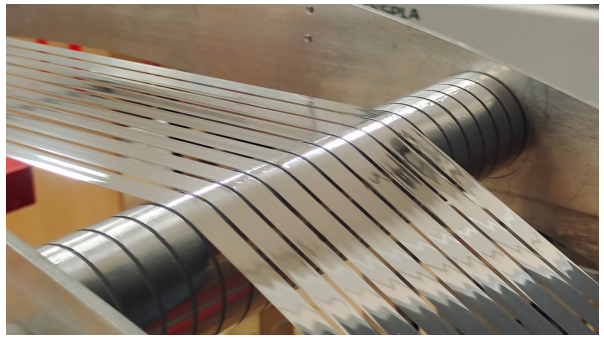




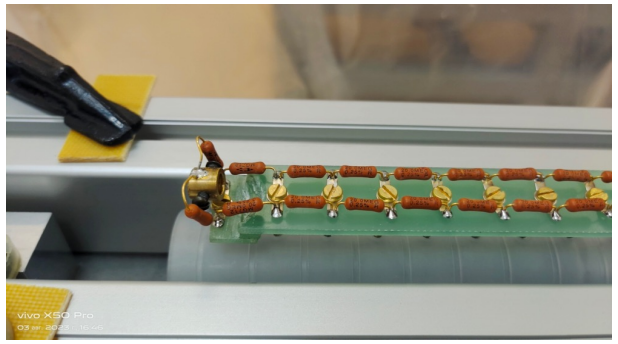
24 pc. of serial ROCs + 4 spare are READY



Central HV electrode

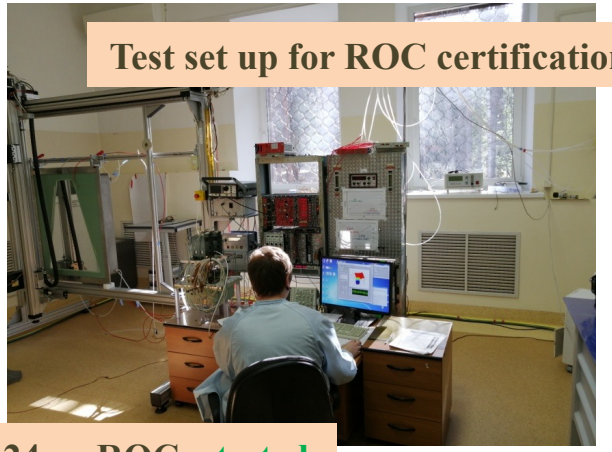


Field Cage strips



Rod with HV divider: 2 pc.

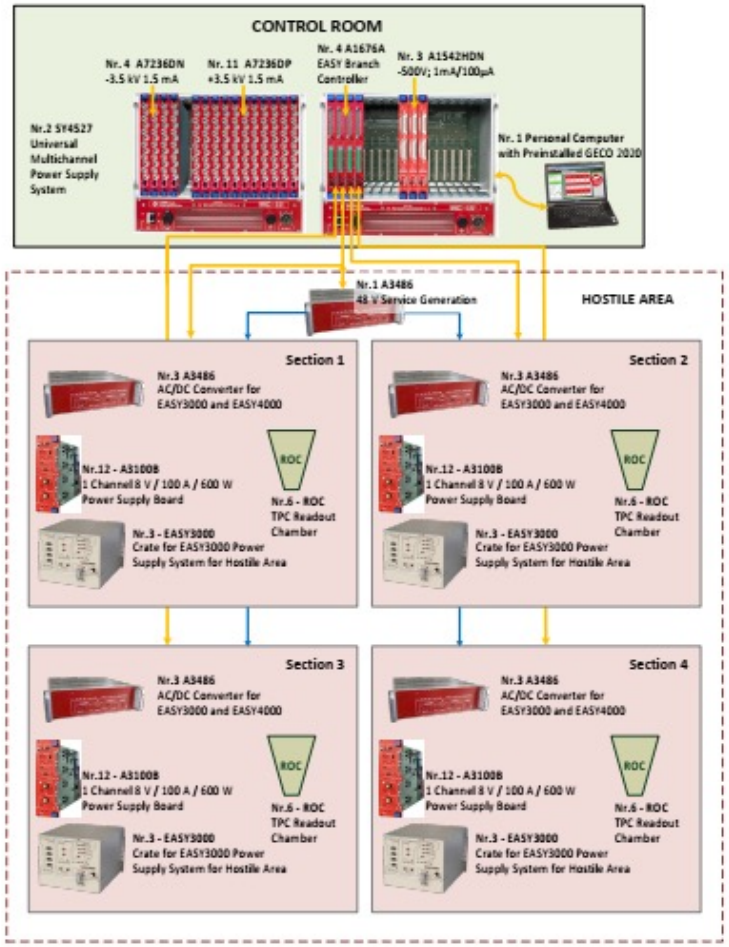
Test set up for ROC certification



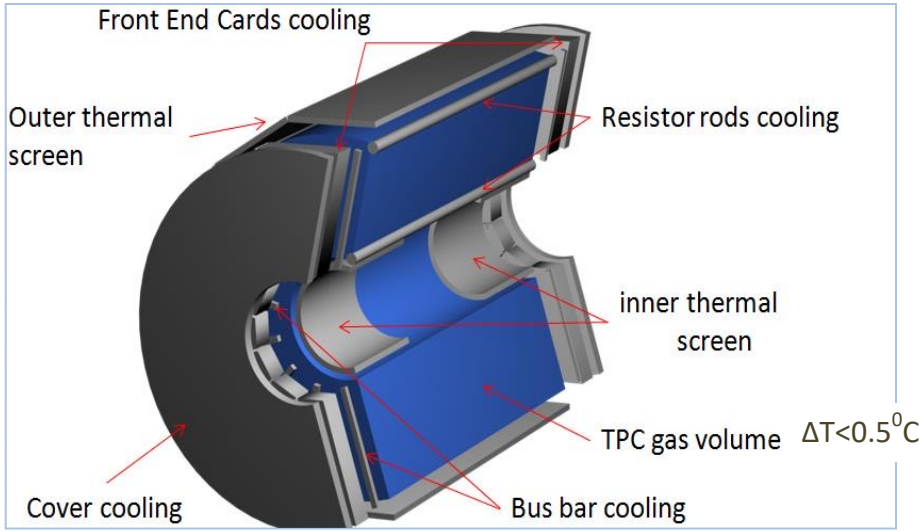
24 pc ROCs: tested

Подсистемы TPC

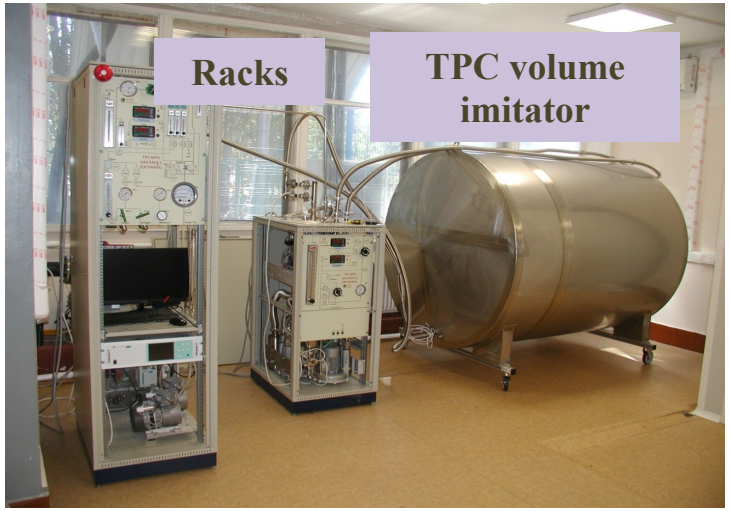
Low voltage and High voltage power supply



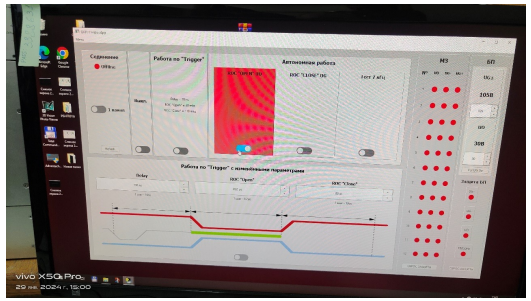
Cooling system



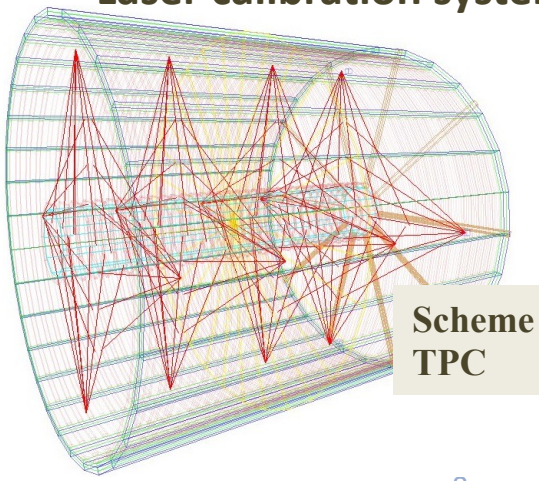
Gas system



Gating grid system

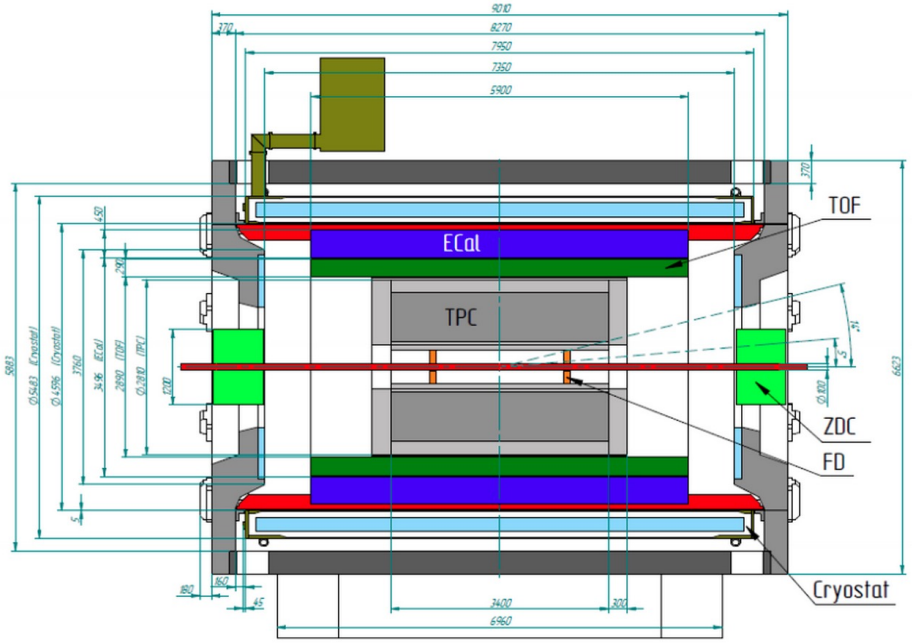


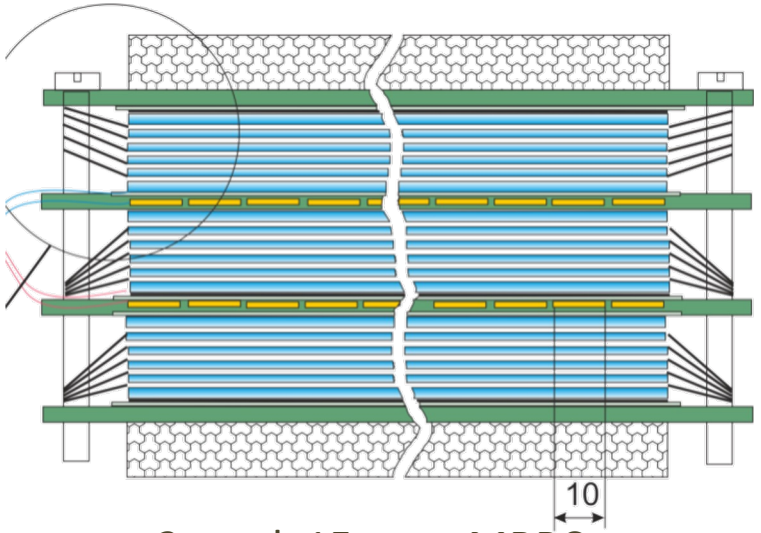
Laser calibration system



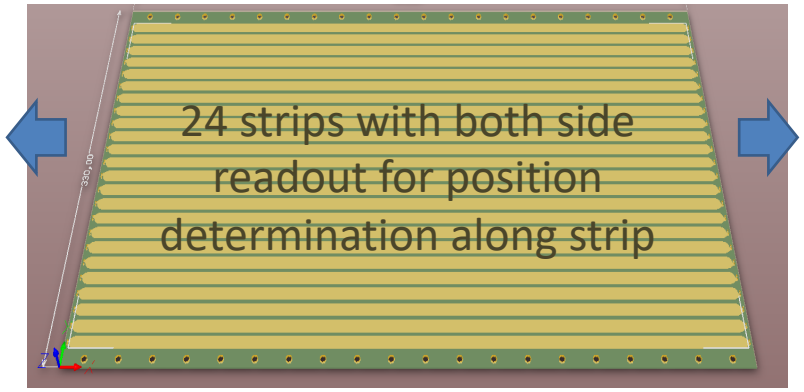
Scheme for ½ TPC

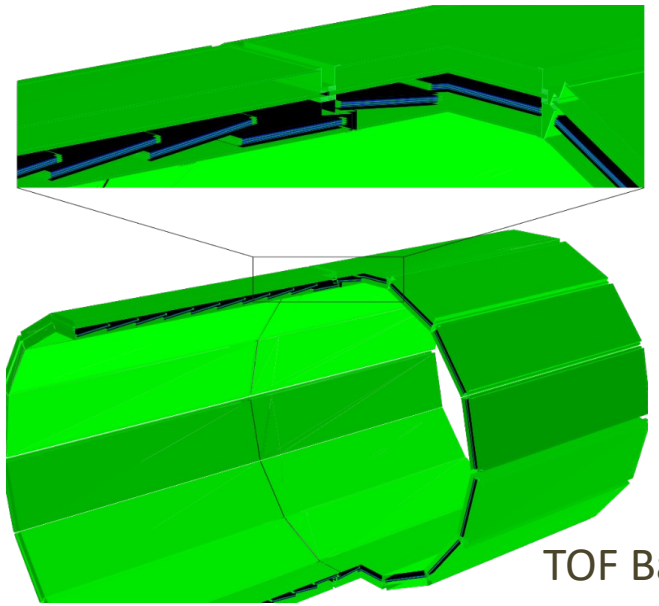
Время-Пролетный детектор TOF





3-stack 15-gaps MRPC





TOF Barrel

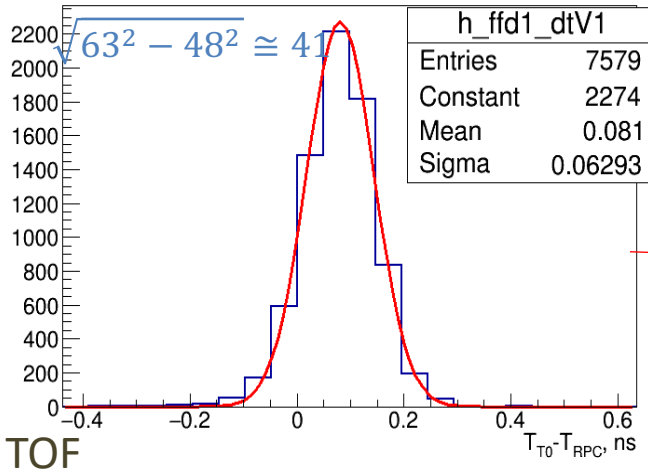
$|\eta| \leq 1.3$

Main parameters of the TOF system:

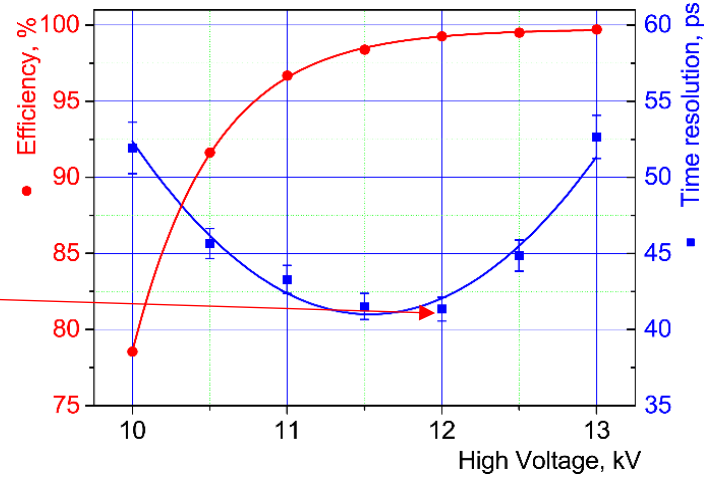
	Number of detectors	Number of readout strips	Sensitive area, m^2	Number of FEE cards	Number of FEE channels
MRPC	1	24	0.192	2	48
Module	10	240	1.848	20	480
Barrel (**28 modules**)	**280**	6720	**51.8**	560	**13440**

Идентификация частиц методом измерения времени пролета

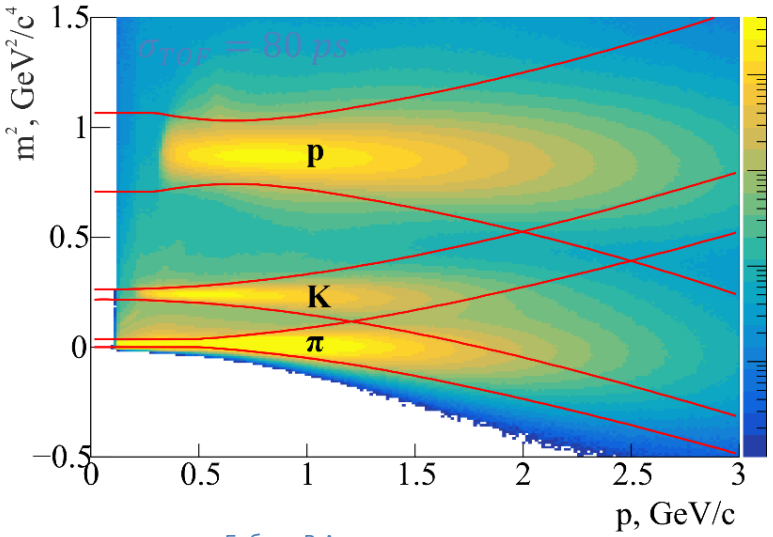
The best measured MRPC time resolution



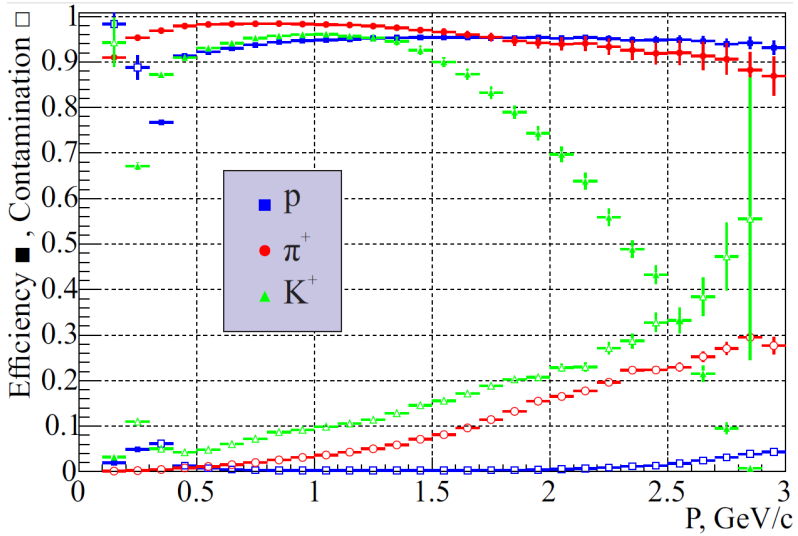
Efficiency vs applied HV



Squared mass of particles from TOF

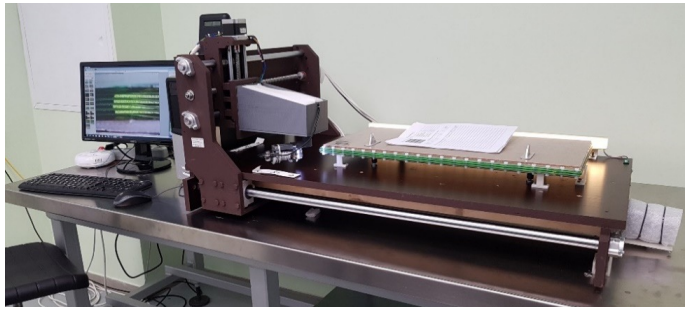


TOF PID efficiency

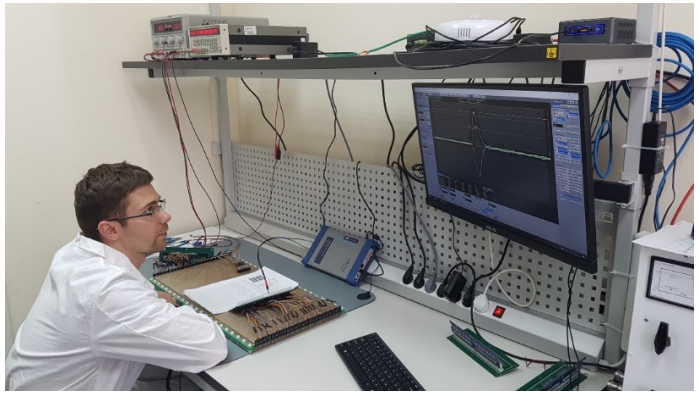


Массовое производство и тестирование модулей TOF

The production of MRPC detectors has been completed. Totally, to date, 300 (107%) MRPC detectors were produced. All 28 (100%) TOF MPD modules are already assembled, tested and stored. We have time to recheck and upgrade previously assembled modules. We are currently planning to make several additional spare modules.



Optical control (gap uniformity, cracks in glass)

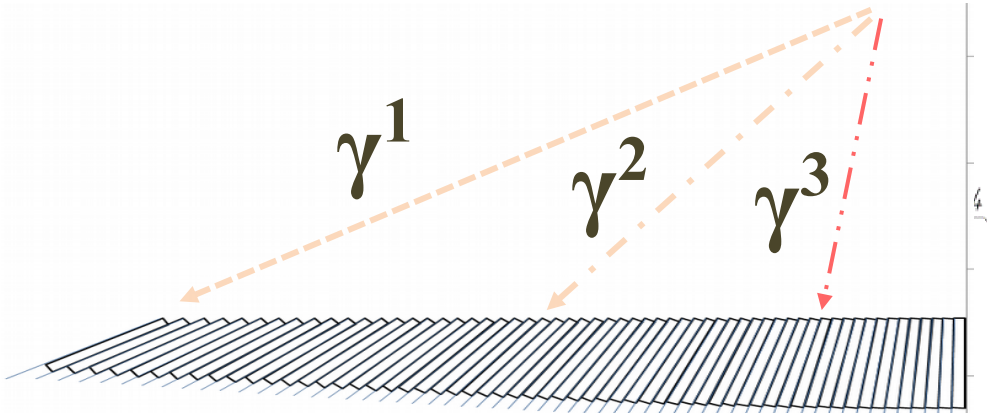


Transmission line impedance (reflection) control

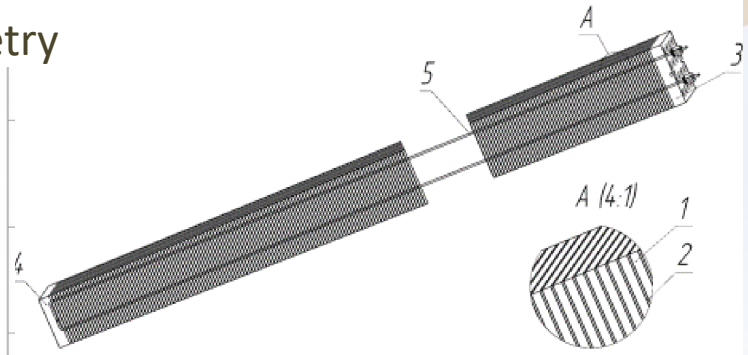
Стенд для тестирования модулей TOF космическим излучением

Электромагнитный калориметр ECal

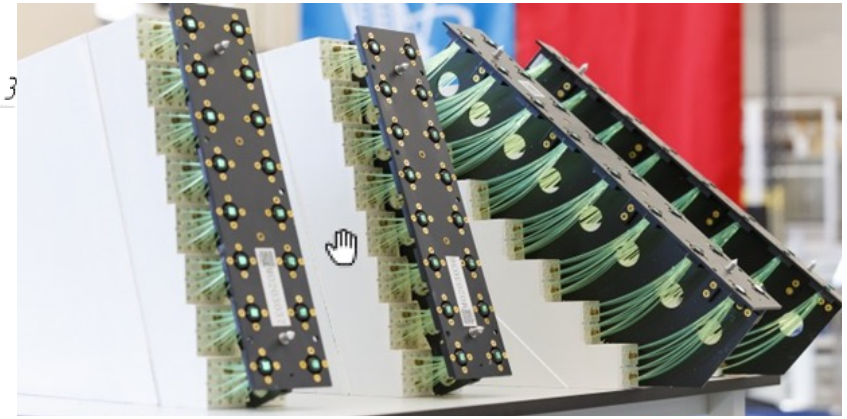
Main advantage and in the same time main construction complication of our ECal is it's projective geometry



+ Better energy and space resolution
- Many detector types with complicated shape



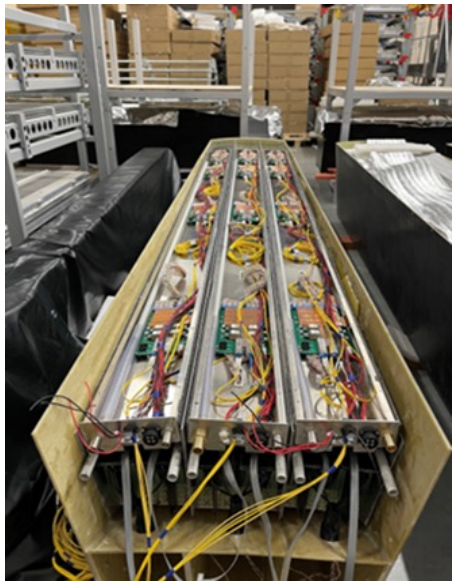
Construction of tower without WLS. 1 – scintillator plate, 2 - lead plate, 3 and 4 - pressure plates, 5 - pressure string.

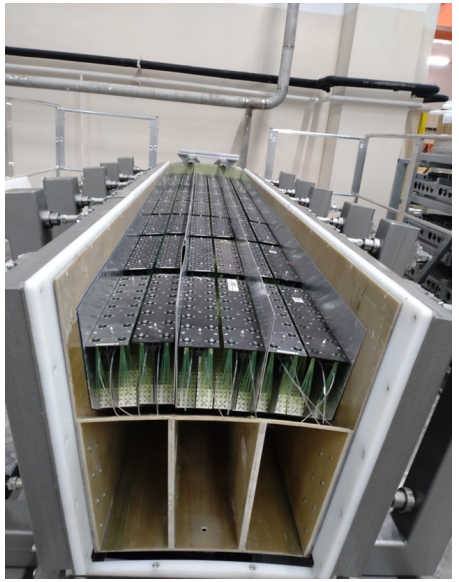


Main parameters of ECal

Parameters	
Maximum transverse dimensions of the tower, mm²	40x40
Maximum transverse dimensions of the module, mm²	80x320
Number of layers	219 ÷ 221
Paint free lead absorber thickness, mm	0.3
Paint lead absorber thickness, mm	0.4
Thickness of scintillator plate, mm	1.5
Effective radiation length, mm	32.4
Moliere radius, mm	62
Radiation length, X_0	11.8

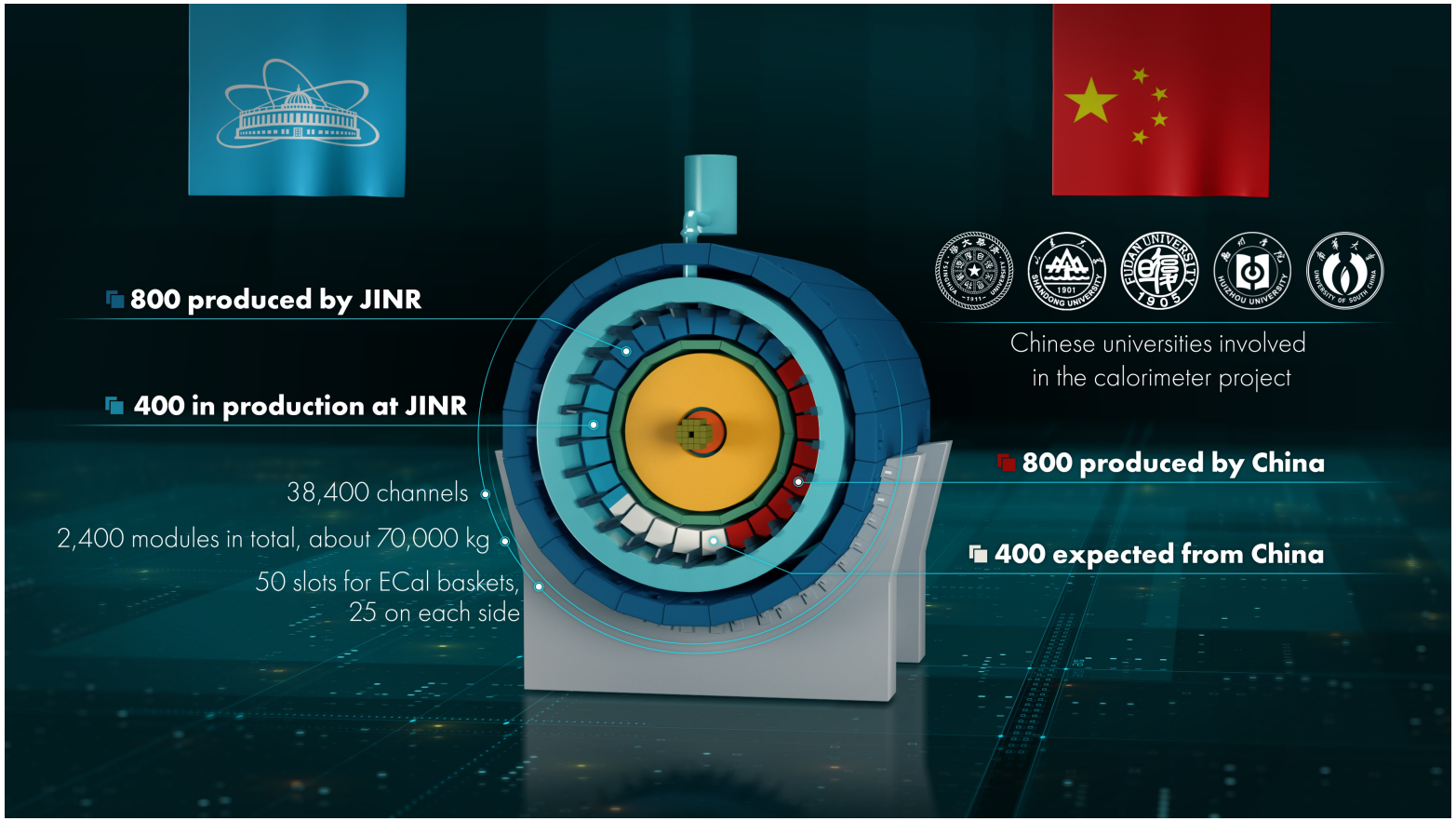
ECal consist of 50 baskets (2400 modules)





Материалы предоставил Тяпкин И.А.

Производство модулей ECal



ECal – Tsinghua University., Yi Wang
Shandong University
Fudan University
South China University
Huzhou University
JINR – production in IHEP (Protvino) and Tenzor (Dubna)

ECal consist of 50 baskets (2400 modules)

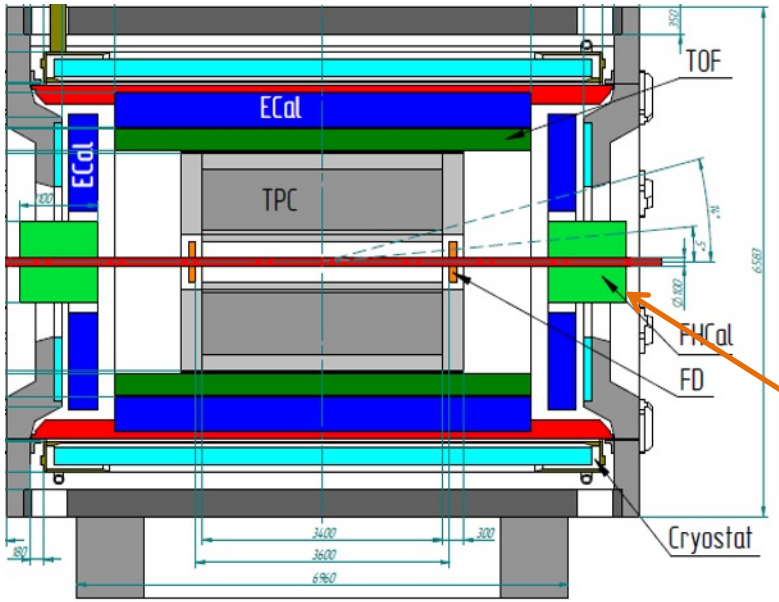
At the moment 1600 modules out of 2400 have been produced (66%) by JINR and
China (Tsinghua – supervisor)
Production of additional 800 modules in Russia is going on. For these modules we use Russian made wave shifters which have acceptable characteristics

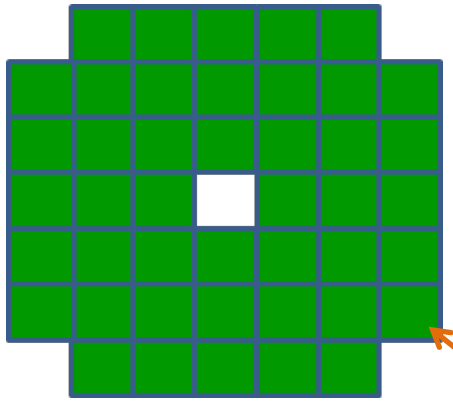
A mass assembly of half-sector baskets has begun.

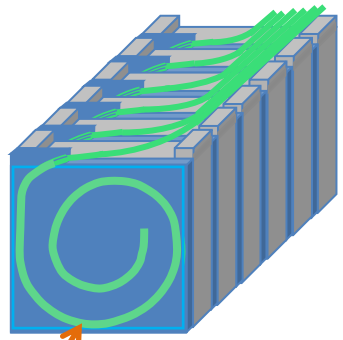
Материалы предоставил Тяпкин И.А.

Передний Адронный калориметр FHCal

Institute for Nuclear Research RAS







FHCal

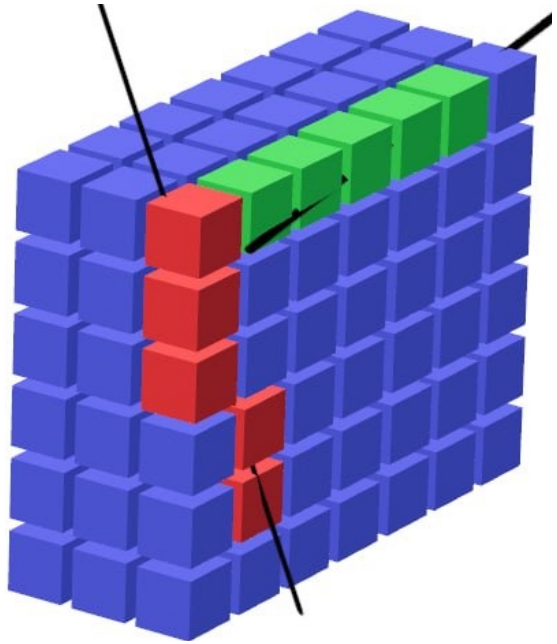
FHCal modules

- Two arms of hadron calorimeter at opposite sides in forward regions.
- At the distance 3.2 meters from the interaction point.
- Available acceptance corresponds to pseudorapidity $2.0<\eta<5.0$

- FHCAL consists of 2x44 modules.
- ~1x1 m^2 each part.
- Beam hole 15x15 cm^2.
- Lead/scintillator sampling calorimeter.
- Longitudinal segmentation;
- Light readout- WLS-fibers;
- 7 sections/photodetectors in each module.

Производство и тестирование модулей FHCal

- **All (90+spare) FHCal modules are assembled and tested with cosmic rays.**
- **Modules are ready for the delivery at MPD site.**
- **Mini-FHCal is operating now at INR.**



Modules in stockroom

The activities with modules:

- **Calibration with cosmic muons;**
- **Development of readout;**
- **Development of FHCal trigger;**
- **Development of Detector Control System;**
- **Monitoring system.**

Материалы Ивашкина А.

Быстрый Передний детектор FFD

The main aims of FFD are:

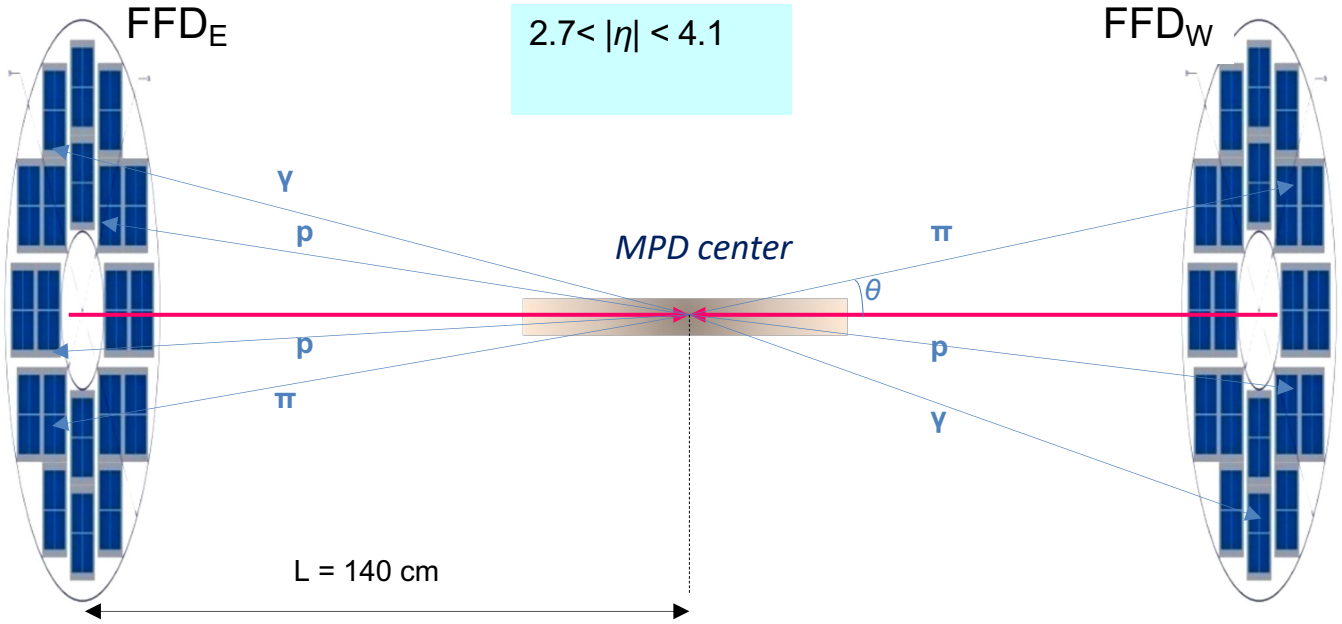
- ✓ Fast and effective triggering of nucleus – nucleus collisions in center of the MPD setup
- ✓ Generation of the start pulse T0 for the TOF detector

Time resolution per FFD channel is 40 ps

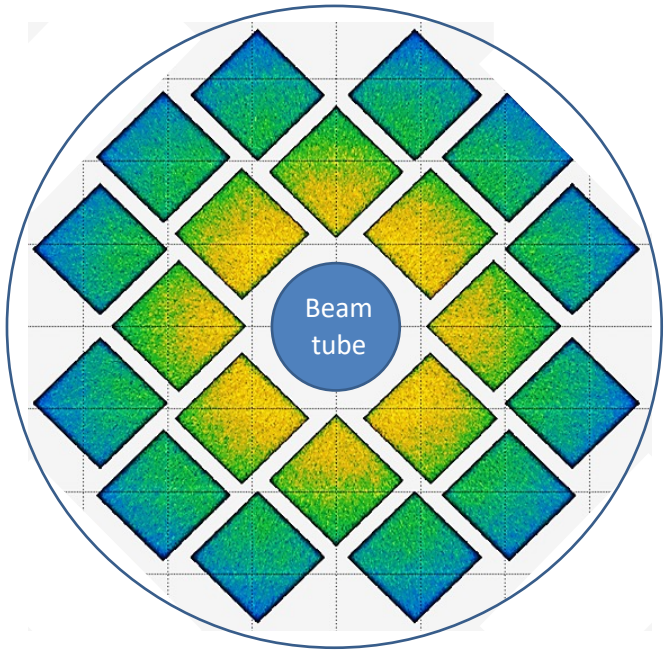
FFD design

Two Cherenkov detectors FFD_E and FFD_W
20 modules & 80 cells / channels
L = 140 cm from MPD center

FFD detects relativistic charged particles and high-energy photons

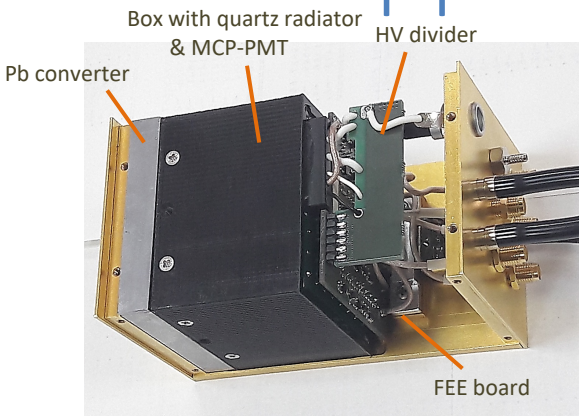


A schematic view of FFD detector



Distribution of incoming particles on the front of FFD modules

Модули FFD, их механика и система охлаждения



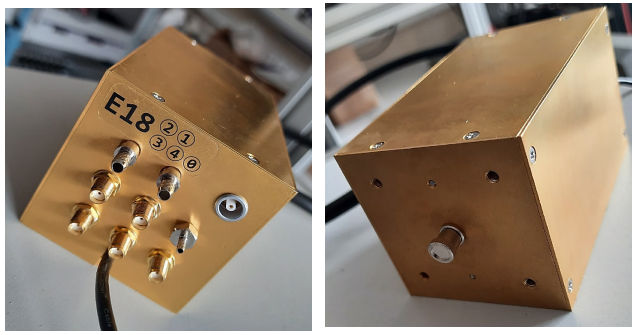
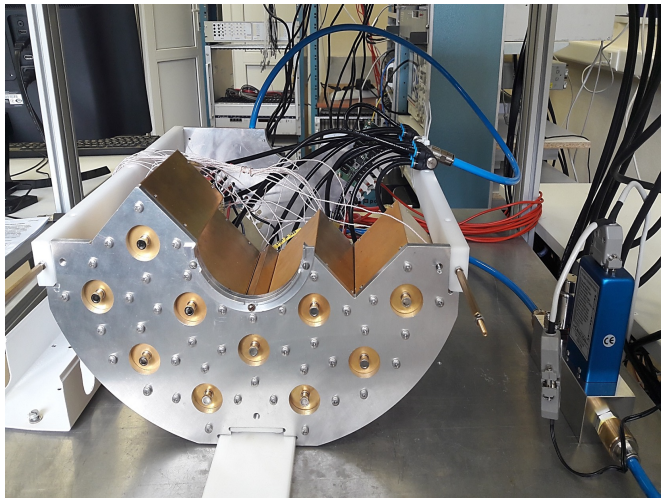
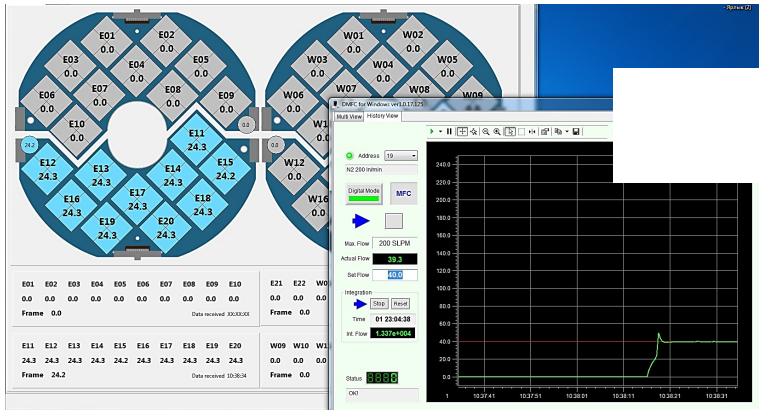


Photo of FFD module



Assembly of FFD mechanics in laboratory

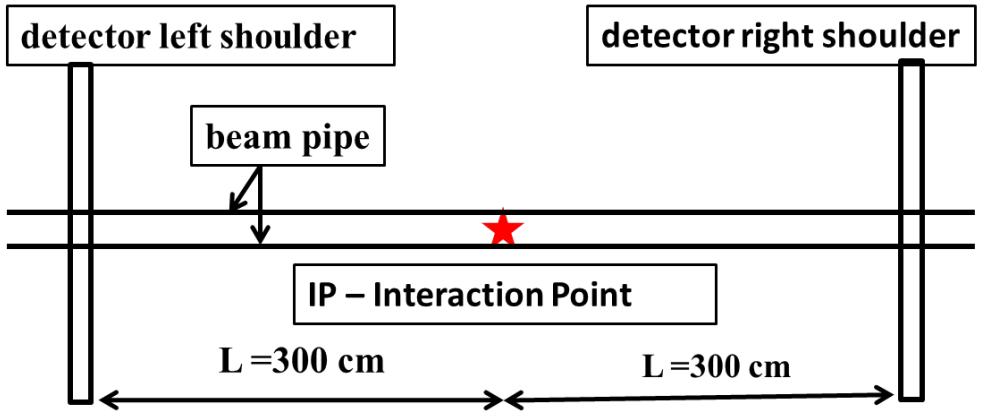


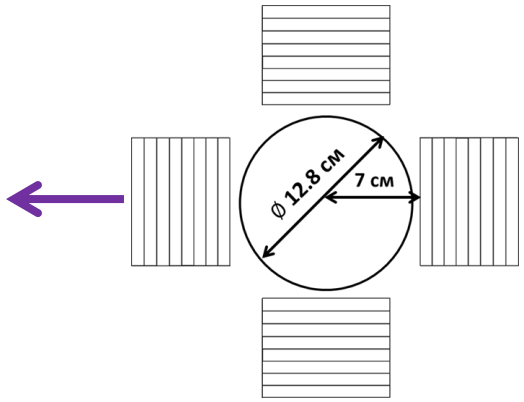
Test of cooling system with air flow

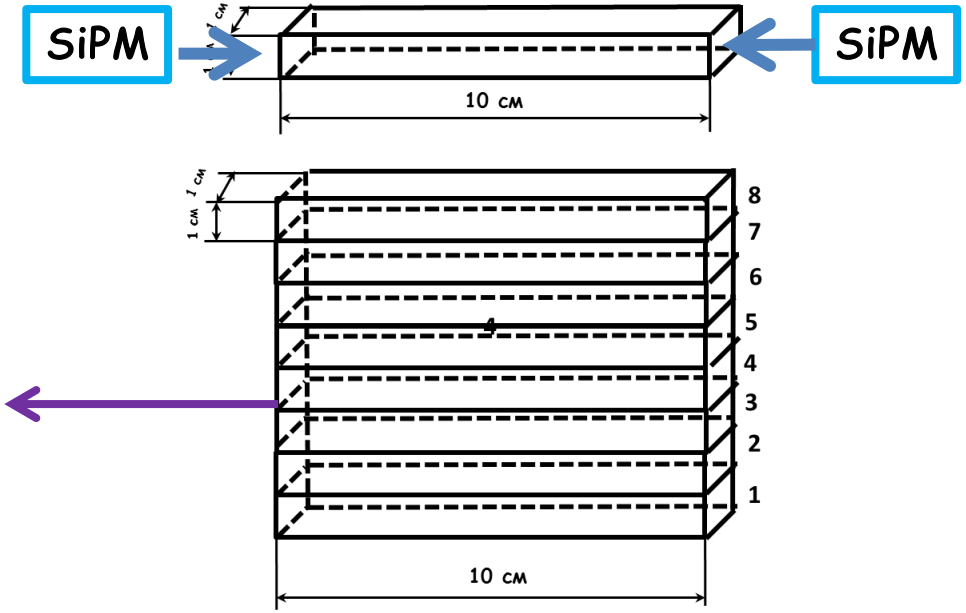
Детектор Светимости

Tasks which have to be solved by the detector

1. Assistance in controlling the transverse sizes of the bunches
2. Assistance in setting up transvers convergence of bunches
3. Assistance in setting up longitudinal convergence of bunches
4. Control of the distribution of vertices in the longitudinal direction.





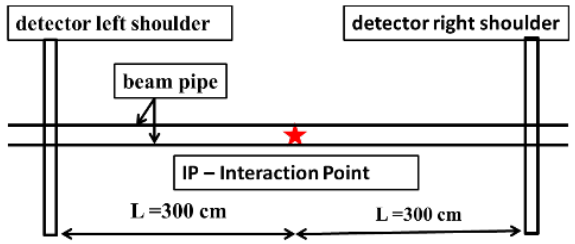


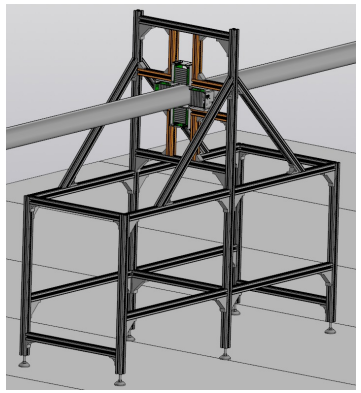
$I_b(1/bunch)$	$\mathcal{L}\ (cm^{-2}s^{-1})$	$N_{AuAu}(1/s)$	$N_{\mathcal{L}D}\ (1/s)$	B/S
$2 \cdot 10^9$	10^{27}	6000	4900	$< 10^{-5}$
$2 \cdot 10^8$	10^{25}	60	49	$< 10^{-4}$
$2 \cdot 10^7$	10^{23}	0.6	0.49	$< 10^{-3}$
$2 \cdot 10^6$	10^{21}	0.006	0.0049	$< 10^{-2}$

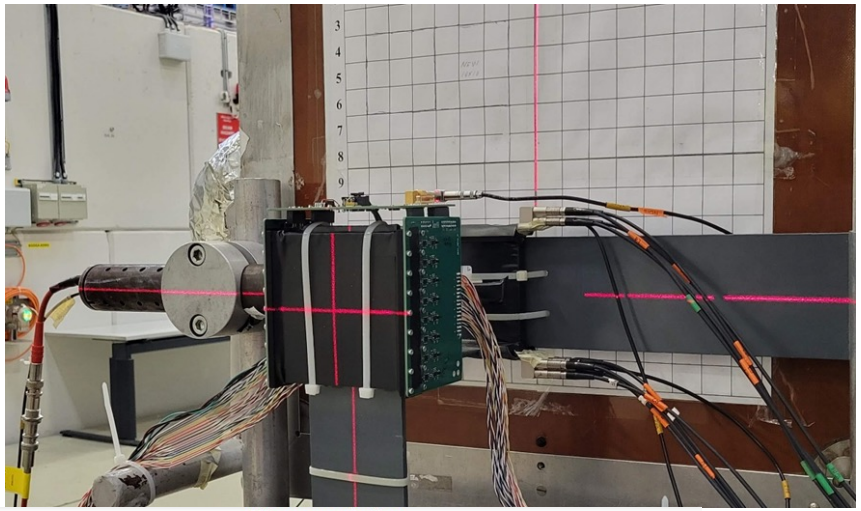
The detector consists of $100x10x10\ mm^3$ plastic scintillator strips viewed from both sides with silicon photomultipliers (SiPM)

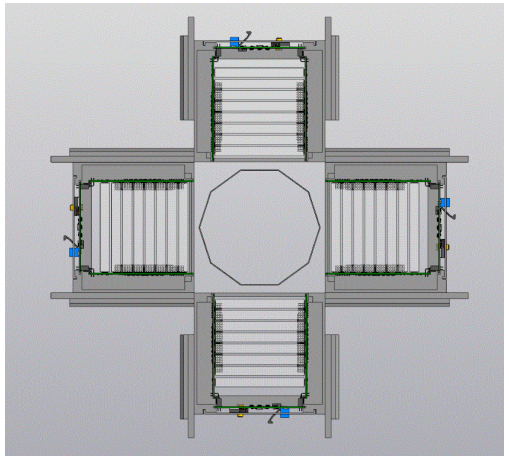
Материалы Литвиненко А.

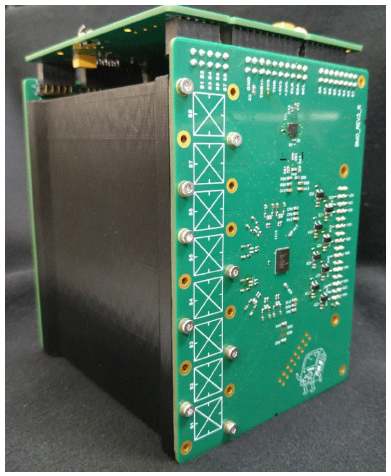
Испытания Детектора Светимости



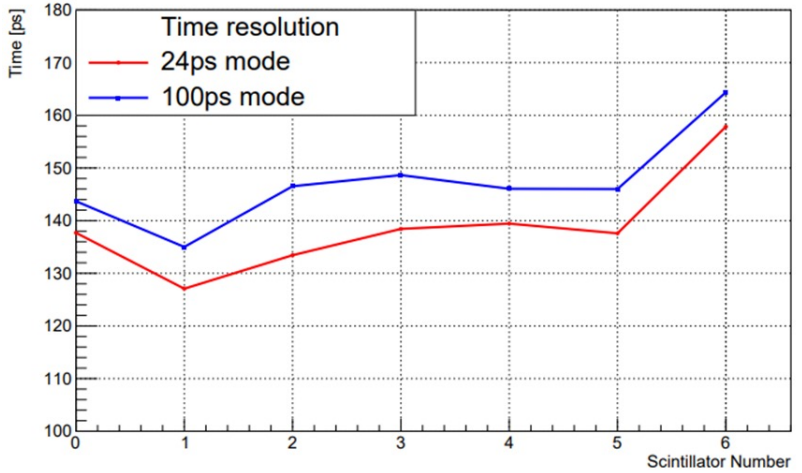






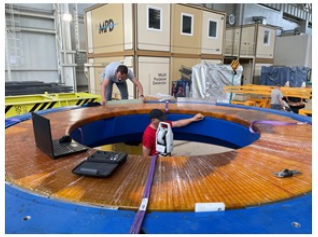


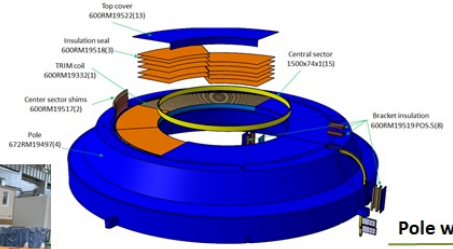
Time resolution



Материалы Литвиненко А.

Соленоидальный магнит MPD





Parameters of the magnet	
Magnetic field	0,57 T
Cryostat weight and size (diameter/length) mm	66 tons 5443/7910
Yoke weight and size (diameter/length) mm	630 tons 6583/8970
Current Voltage	1790 A 10V
Each pole weight	45 tons
Total weight with support equipment	800 tons

The magnet consists of Solenoid inside Iron Yoke and two correction coils inside of Endcaps

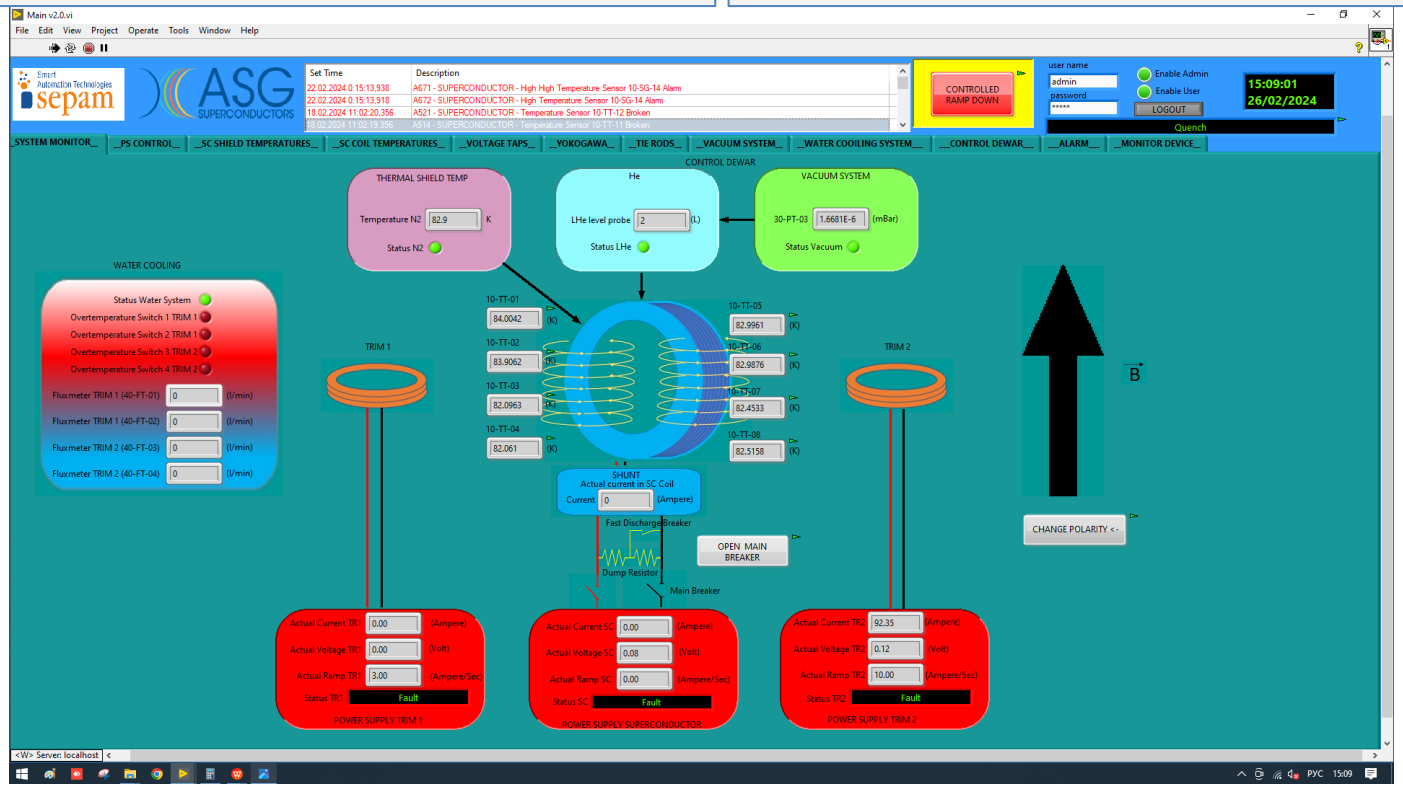
Данные предоставлены Мухиным К.А.

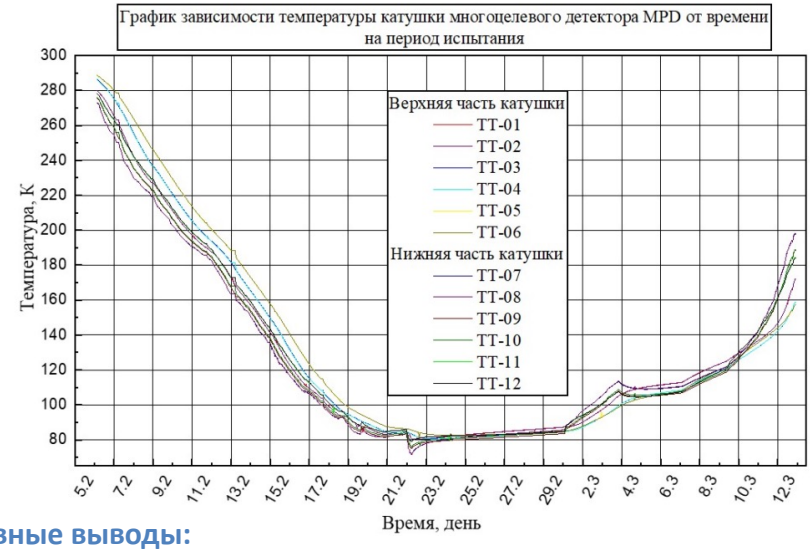
Первое охлаждение магнита MPD

В феврале – марте 2024 года было проведено первое охлаждение соленоида ***до температуры 72 К***

Охлаждение было выполнено по постоянной схеме, с циркуляцией азота в экранах и газообразного гелия в трубопроводах катушки.

В процессе охлаждения были отработаны два основных режима работы – до температур жидкого азота и переход на охлаждение двухфазным гелием.



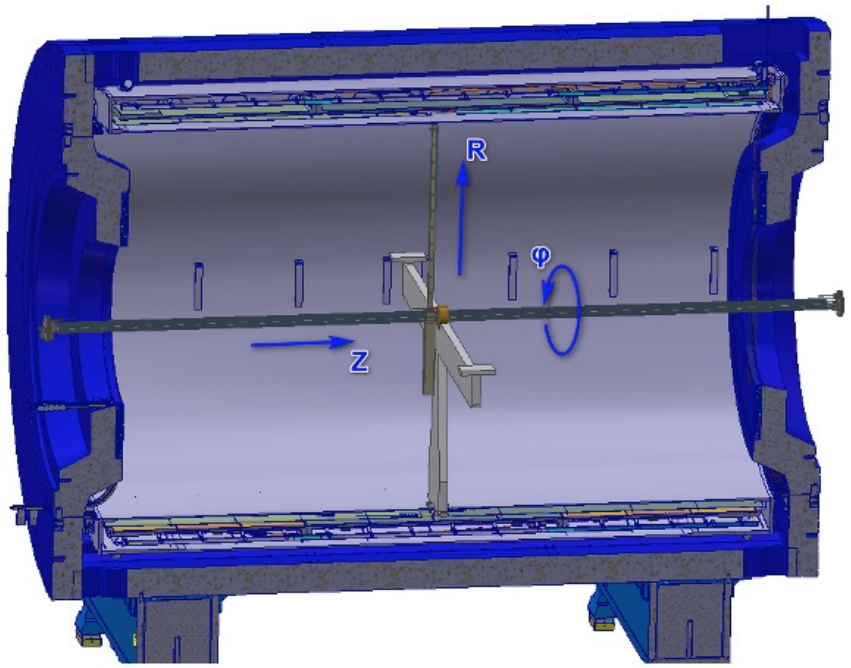


Основные выводы:

- Криогенная система охлаждения собрана и функционирует удовлетворительно.
- Проведено охлаждение соленоида без превышения проектных параметров (0,6 К/ч, проектная 1-3 К/ч).
- Холодных течей на уровне 80 К не обнаружено.
- Цикл охлаждения до 80 К занял 15 дней.
- Успешно проведено испытаний удержания температуры соленоида только азотными экранами.
- Успешно, без скачков давления, выполнен переход с режима охлаждения жидким азотом на двухфазный гелий.
- Успешно проведено перемещения магнита без остановки охлаждения из положения «Сервис» в положение «Пучок» (12 метров).

Данные предоставлены Мухиным К.А.

Измерение магнитного поля

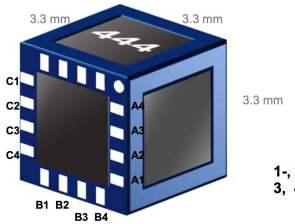


HE Hoeben Electronics

HE444

HE444 series 3D Analog Hall sensors

3 separate, totally independent axes, central crossing point

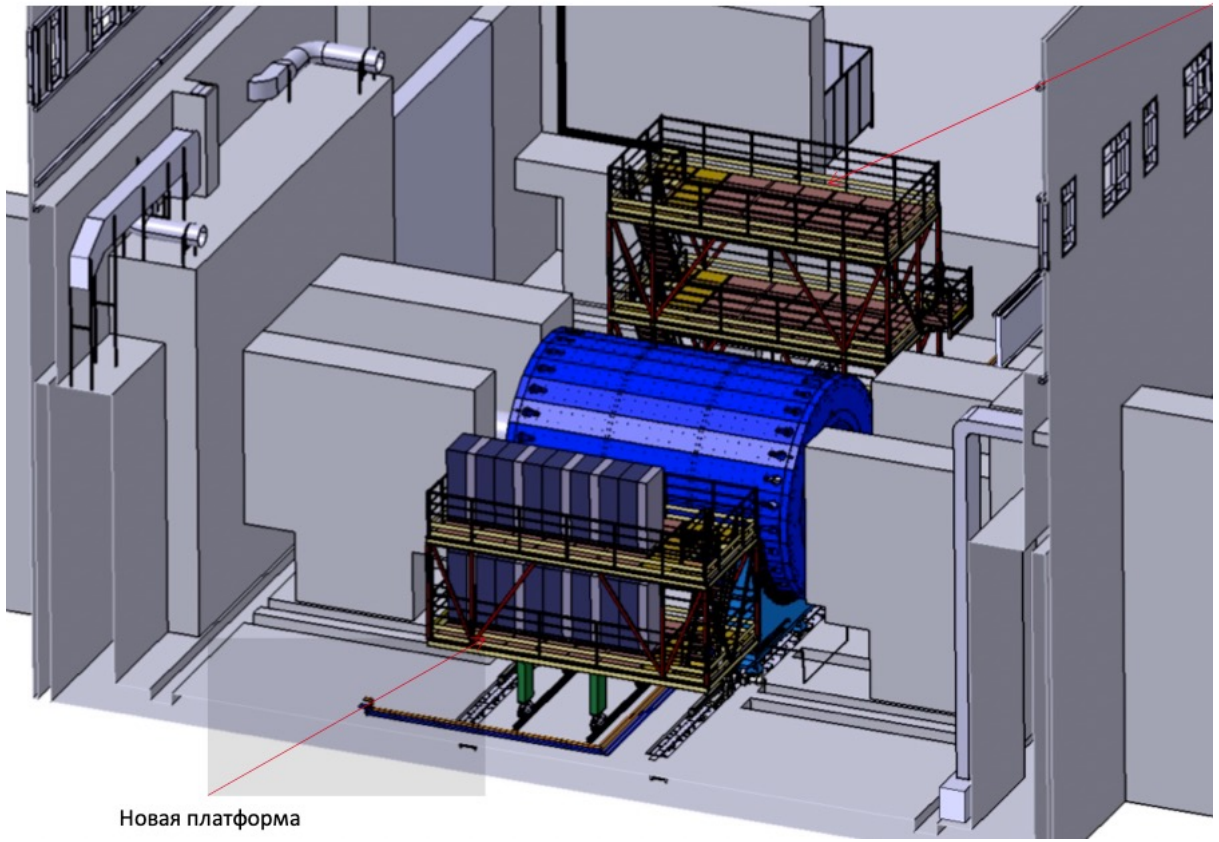


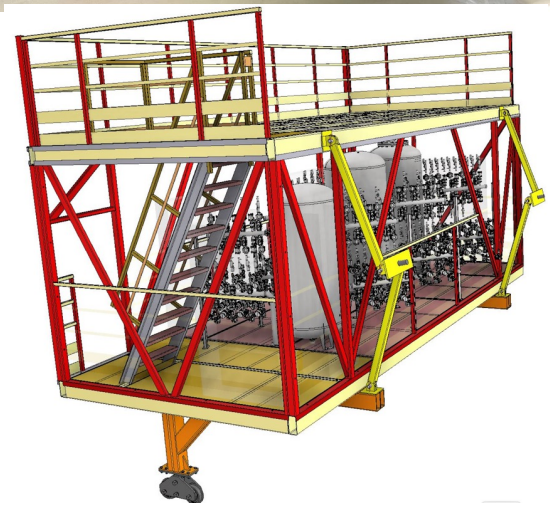
1-, 2+: Supply current
3, 4: Hall voltage

Note: component laser marking '444', or user defined, with date code, dimensions are in mm, this picture shows the solder / bond pads at the bottom, marking can be at the top, this picture does not show all details

Concept of **Novosibirsk INP** mapper:
1 Hall 3D probe moves in 3 directions: z , R and φ
Accuracy: ~1 Gs
Range of fields: 0.2-0.57 T
Range of measurement: from R = 0 cm to 2,0 m (It is able to do measurements in the volume of TPC when Ecal and TOF are mounted in the Support structure inside of the Magnet Yoke

Платформа MPD

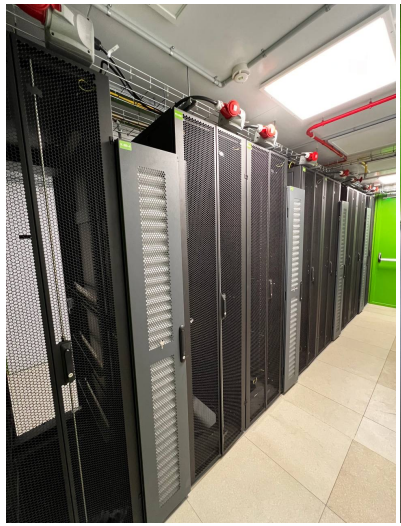

Новая платформа

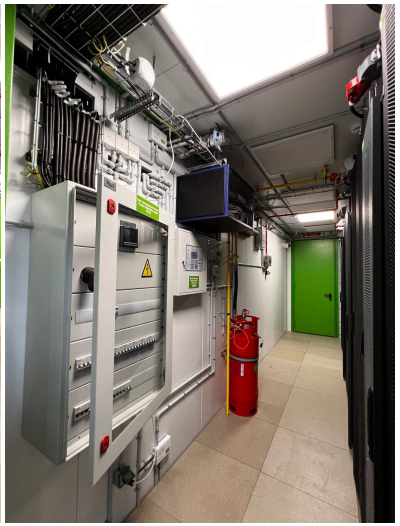


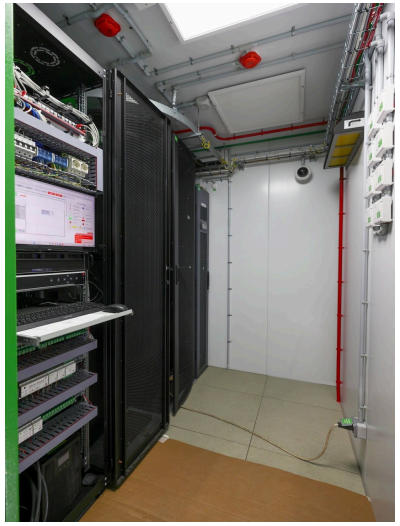
To provide optimal condition for the TPC cooling system we have decided to construct additional platform on the south side of MPD. Besides Cooling system of TPC one floor of this platform is planned for ITS electronics which is the second stage of detector (basic configuration).

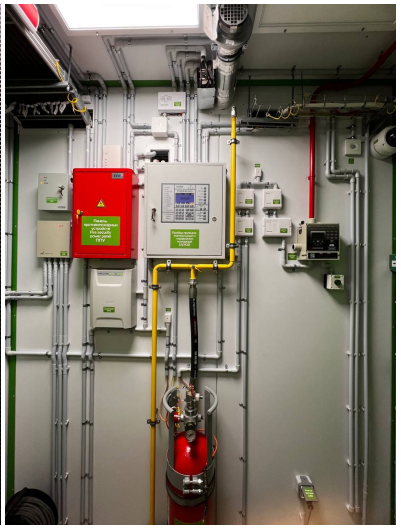
Платформа MPD

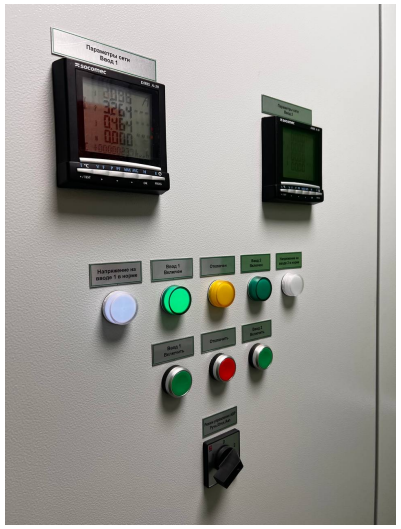
NMP PARTS	
1	IT RACKS on the NMP
2	Cooling System
3	Main electrical distribution board
4	Structed Cabling(fiber optic)
5	Access control and management system
6	CCTV video surveillance system
7	Aautonomous fire extinguishing system
8	Monitoring system
9	Testing of all NMP systems





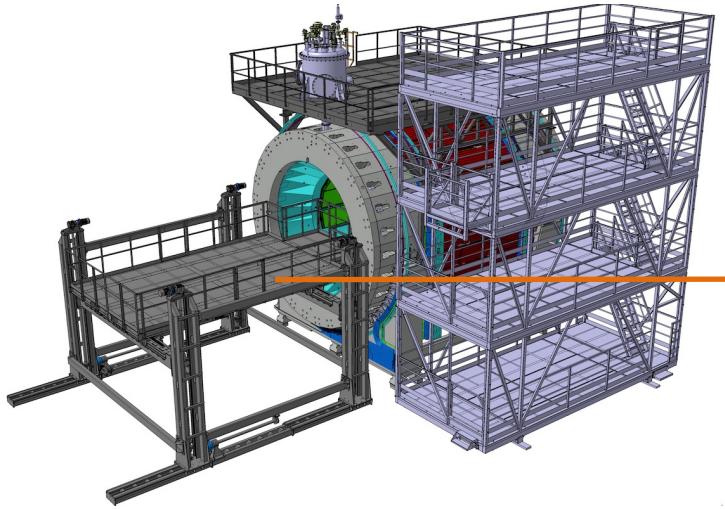






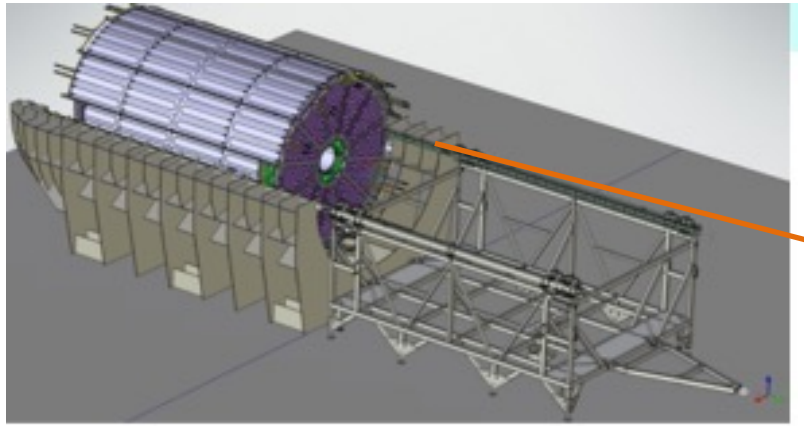
Материалы предоставил Федюнин А. А.

Приспособления для интеграции детекторов MPD

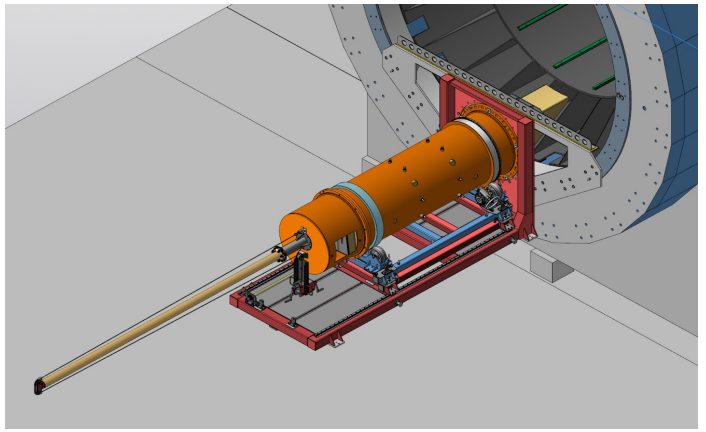


Lifting platform

The TOF installation bench is fully assembled and stored in the VBLHEP



TPC transport frame



ECAL tooling

Резюме

- Детекторы MPD первой очереди находятся в завершающей стадии изготовление либо уже изготовлены.
- В феврале – марте 2024 года было проведено первое охлаждение соленоида до температуры 72 К
- Инженерная инфраструктура MPD находится в высокой степени готовности
- Установка MPD в рабочее положение и приемка детекторов первой очереди намечена на начало 2025 г.