The Spin Physics Detector (SPD) at NICA

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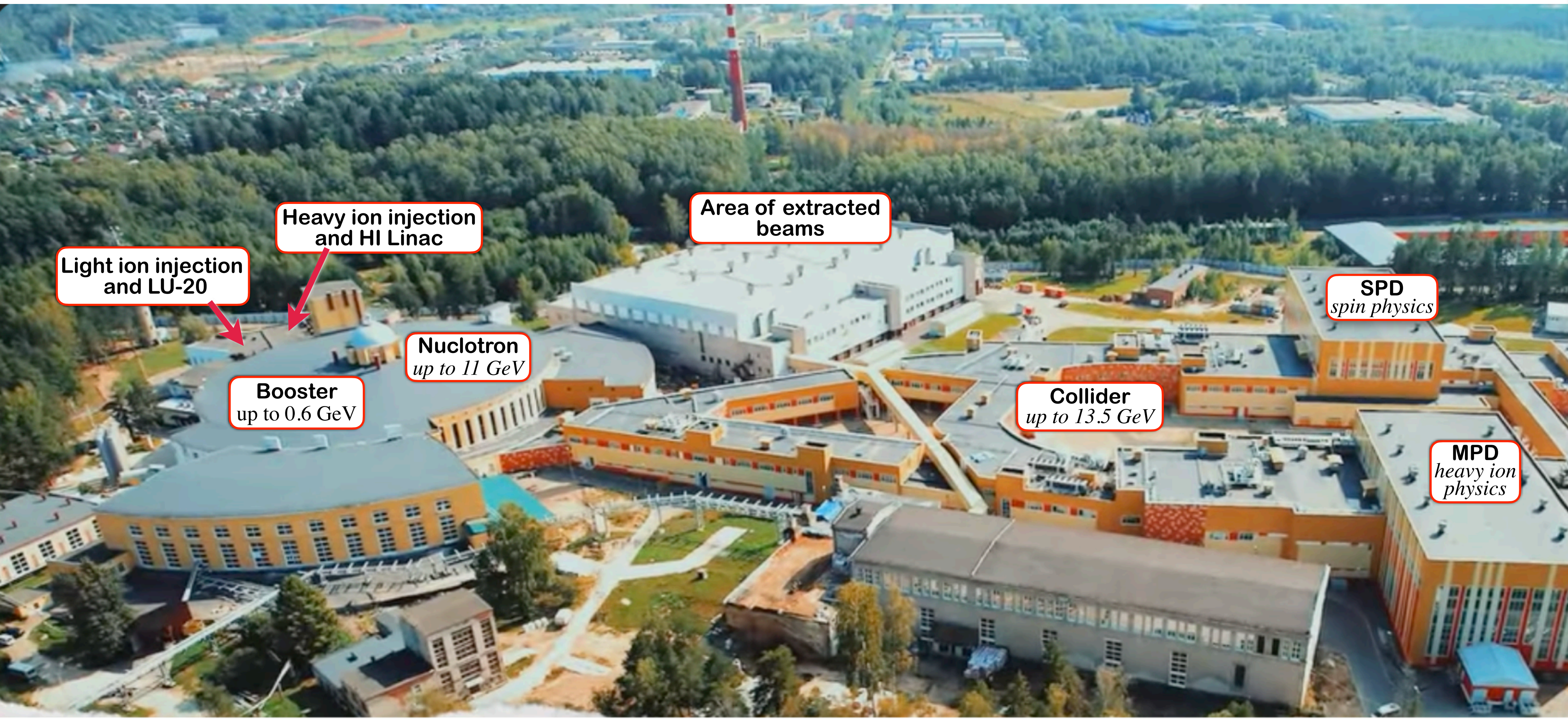
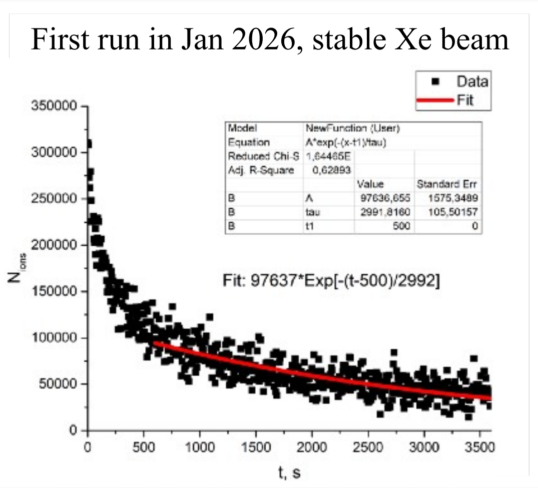
on behalf of the SPD Collaboration

TIPP 2026, Mumbai, India
February 2, 2026

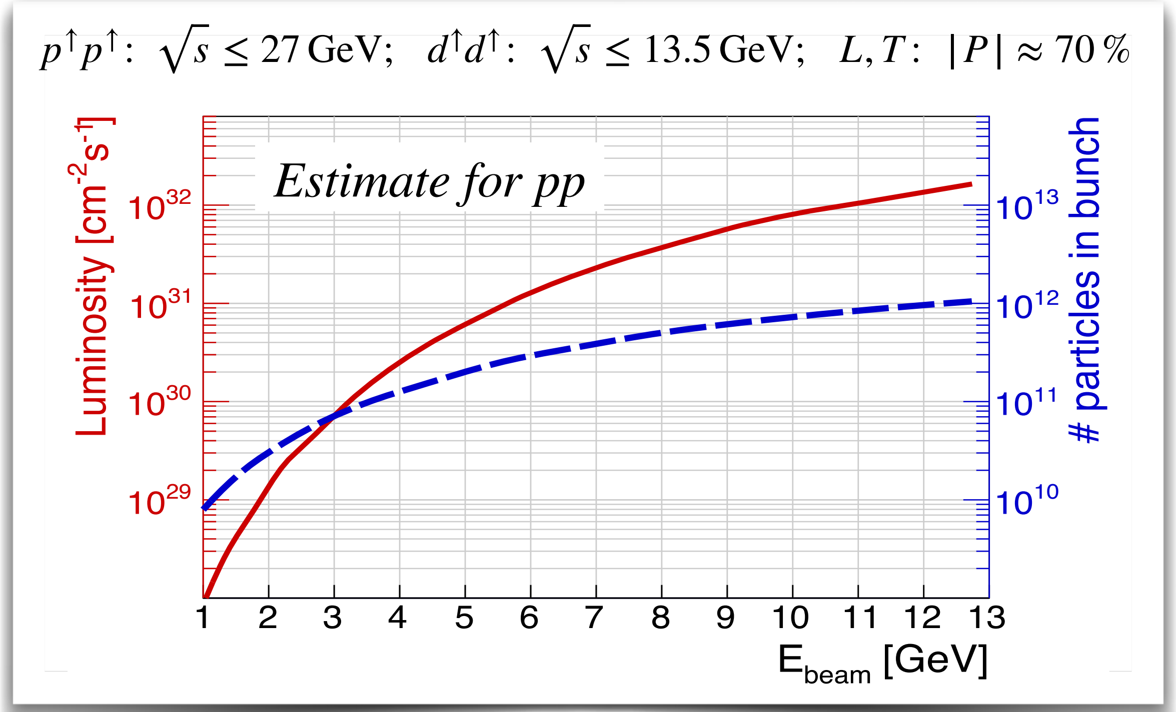
Accelerator complex NICA in JINR

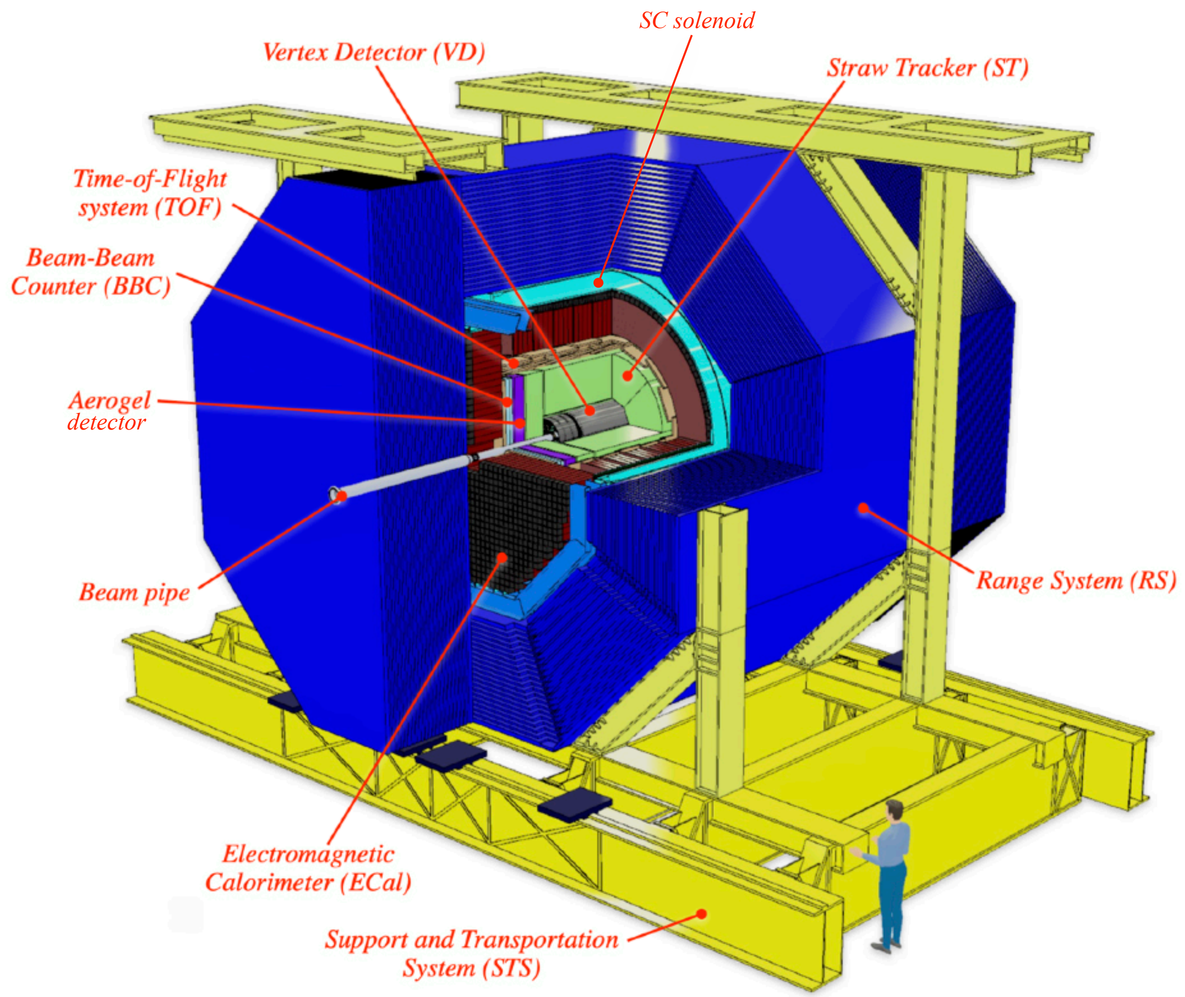




SPD project

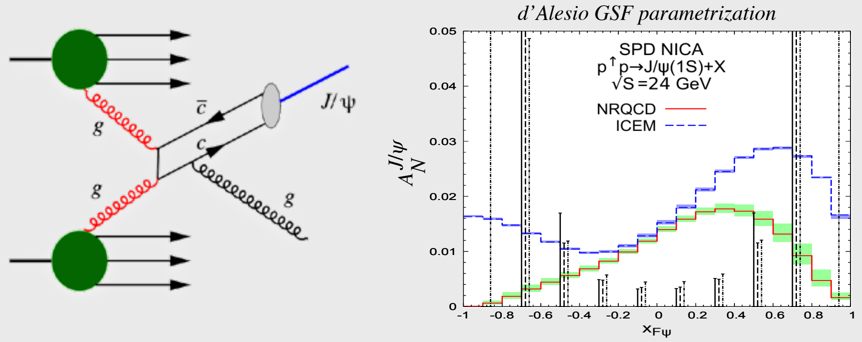
- SPD (Spin Physics Detector) is a universal facility with the primary goal to study *unpolarized and polarized gluon content of proton and deuteron*
- SPD project was approved in JINR and had its first proto-collaboration meeting in June 2019
- Conceptual Design Report (CDR) was released in January 2021, [arXiv:2102.00442]
- Official birthday of the SPD collaboration in June 2021
- Technical Design Report (TDR) of SPD was released in January 2023, NSR 1 (2024) 1, [arXiv:2404.08317], *http://spd.jinr.ru*





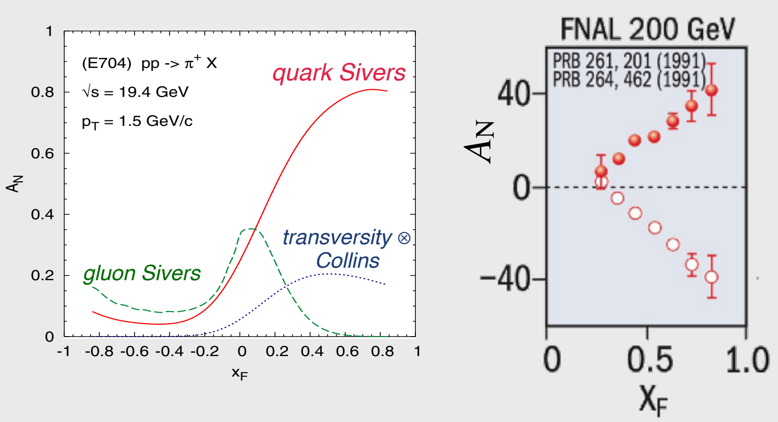
Detector requirements for the SSA measurements

Gluon TMD: Charmonia (J/ψ) production



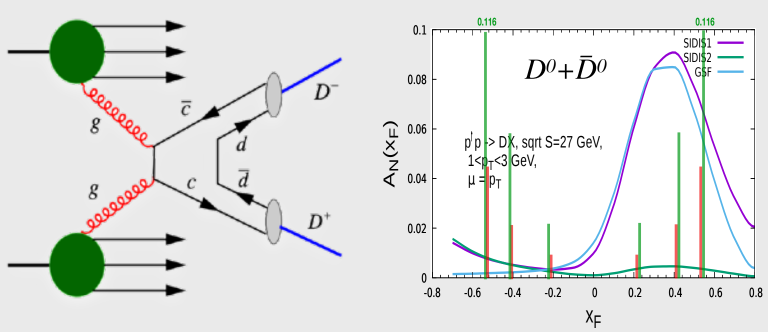
- Pair of muons from primary vertex to be identified
- **Range System** (iron interleaved by MDT detectors)
  - Thickness of $4\lambda_I$ or $4.5\lambda_I$ with ECal

Quark TMD: Light hadron π,K,p production



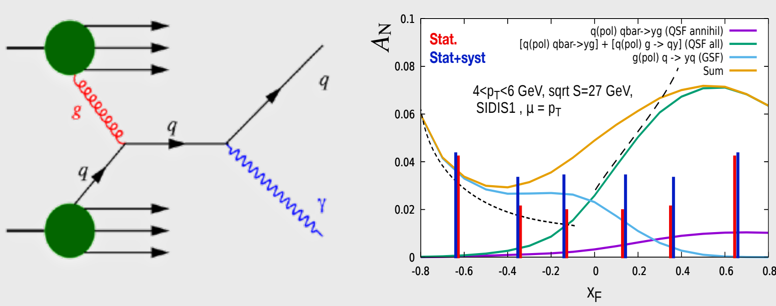
- High energy hadron identification (x_F>0.3)
- **FARICH** (Cherenkov photon detector)
  - Better than 3σ separation up to 6 GeV

Gluon TMD: Open charm ($D^{0,\pm}$) production



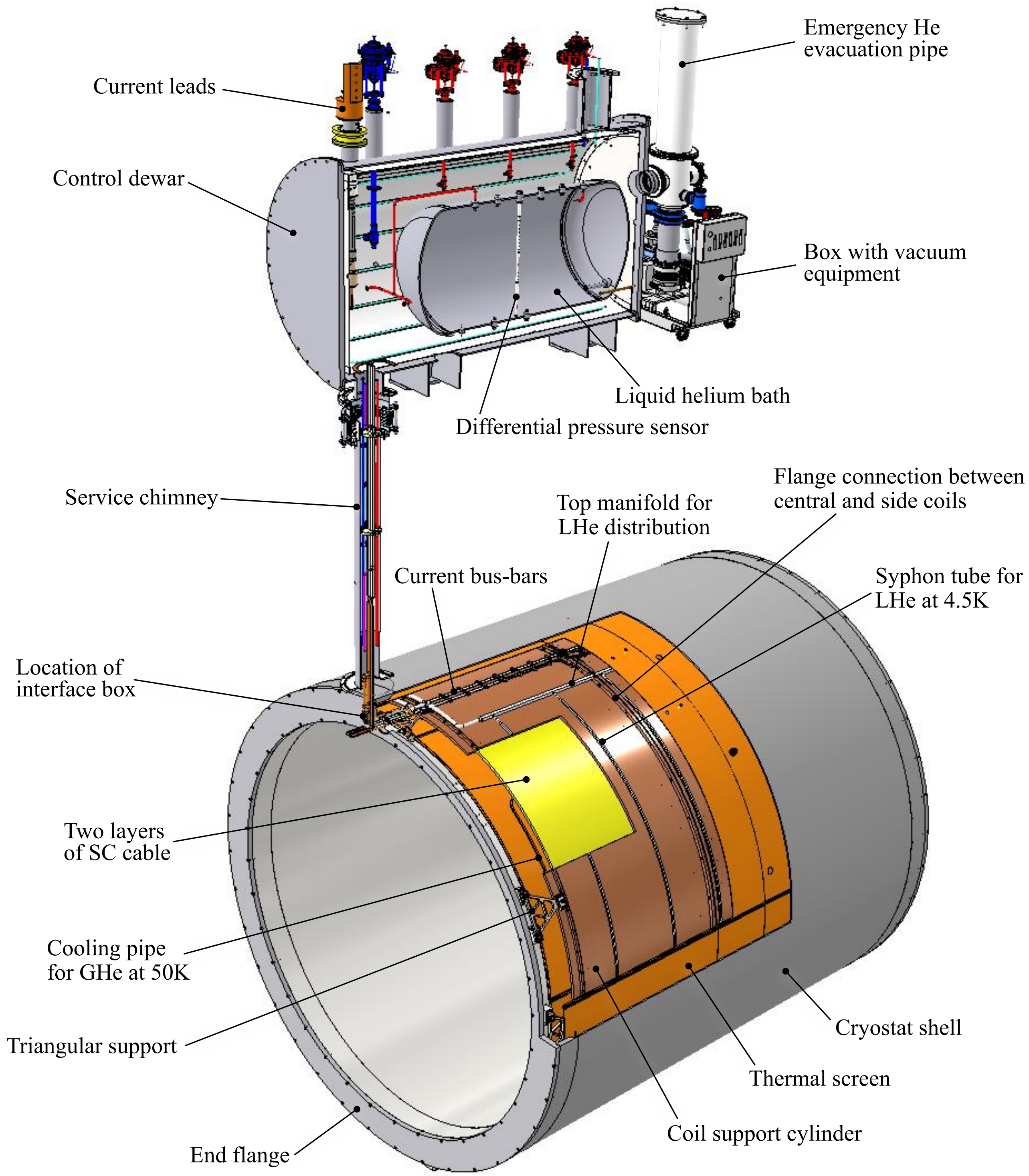
- Distinction of D-decay from primary vertex
  - Silicon detector (**DSSD** or **MAPS**)
- Identification of kaon from D-decay
  - **TOF** and **FARICH**

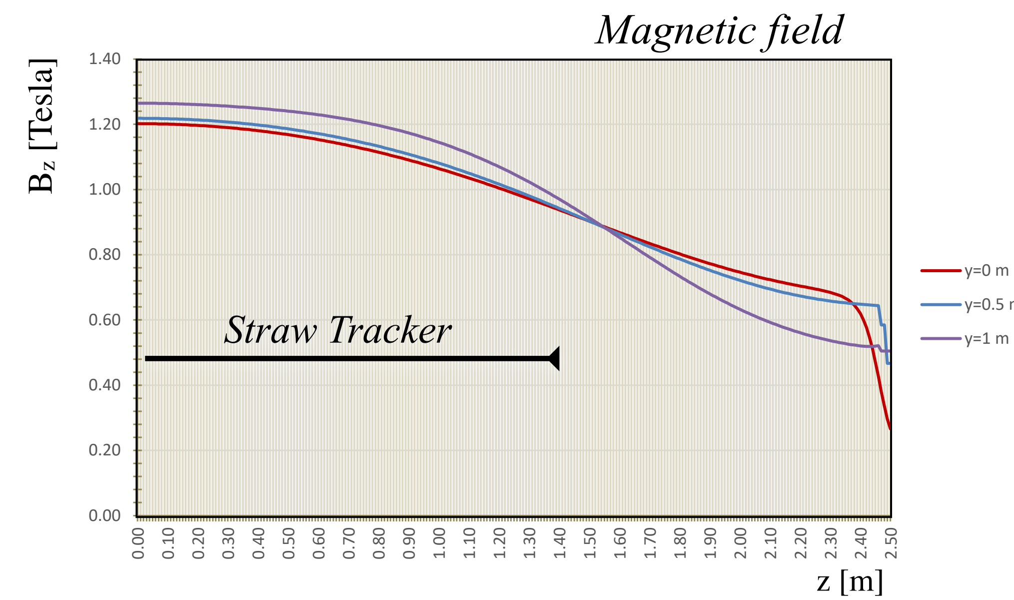
Gluon TMD: Prompt photon production



- High energy photons E>4 GeV to be detected
- **Electromagnetic calorimeter (ECal)**
  - 40 cm long cell = 200 layers of lead and scintillator
  - Thickness of $18.6X_0$

Superconductive solenoid magnet





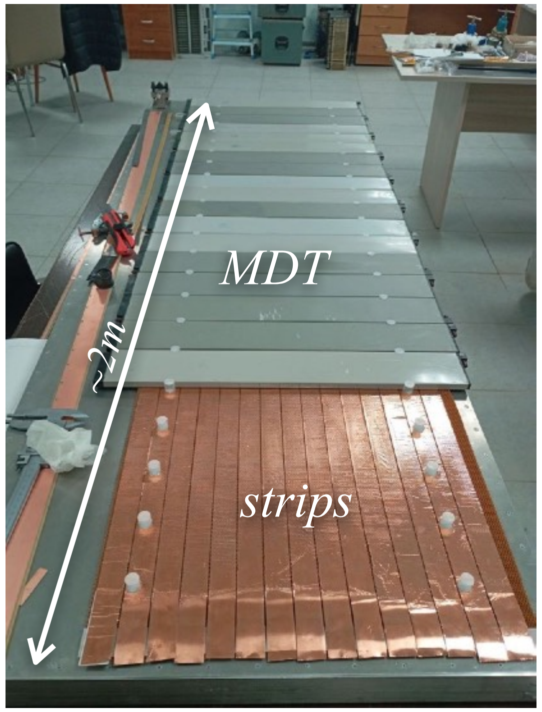
- 1.2 Tesla field in center
- Solenoid consists of 3 coils with 750 turns in total (two layer edge-wise winding)
  - central coil with 2×75=150 turns
  - 2 side coils with 2×150=300 turns
- The use of the *thermosyphon method* for cooling the superconducting coils (natural convection of two-phase helium at 4.5K)
- It is designed and will be constructed in BINP Novosibirsk

Rutherford-type cable made of 8-strands NbTi/Cu superconductor. The cable will be encased in an aluminum stabilizer using a co-extrusion process that provides a good bond between aluminum and superconductor in order to ensure quench protection during operation.

Range System (RS)

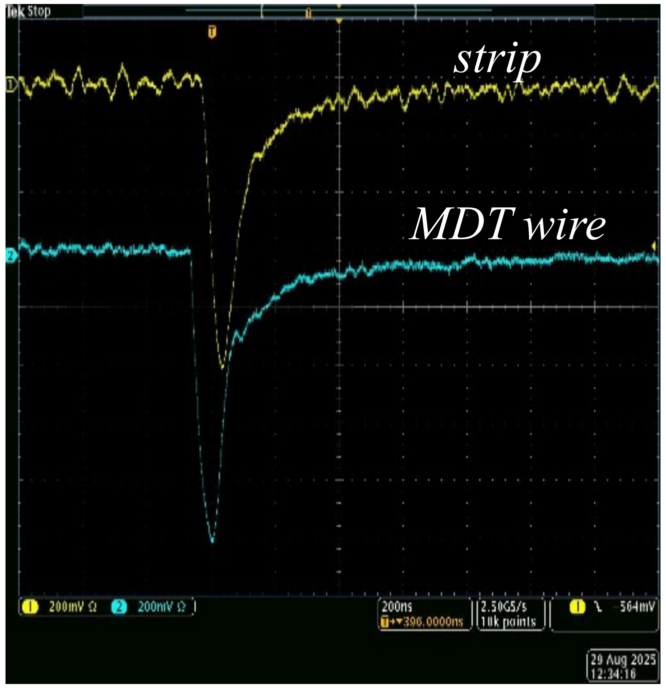
for μ identification and rough hadron calorimetry

MDT prototype

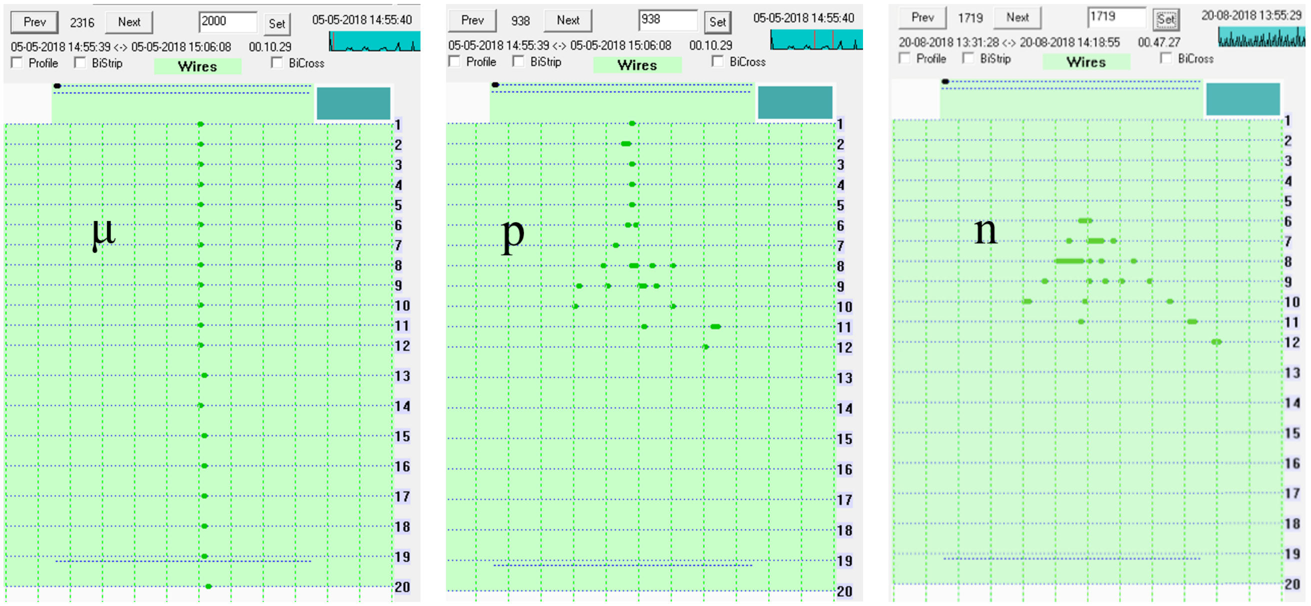


- 20 layers of Mini Drift Tubes (MDT) + external electrodes (strips) perpendicular to the tubes
- For the first time in 2025, the long strip (~2m) signals were observed with Detector Layer Prototype in practically final design of the layer
- The picture taken with cosmic corresponds to strip/yellow signal induced by wire/blue signal on the strip (3 cm × 2 m)

correlated signals



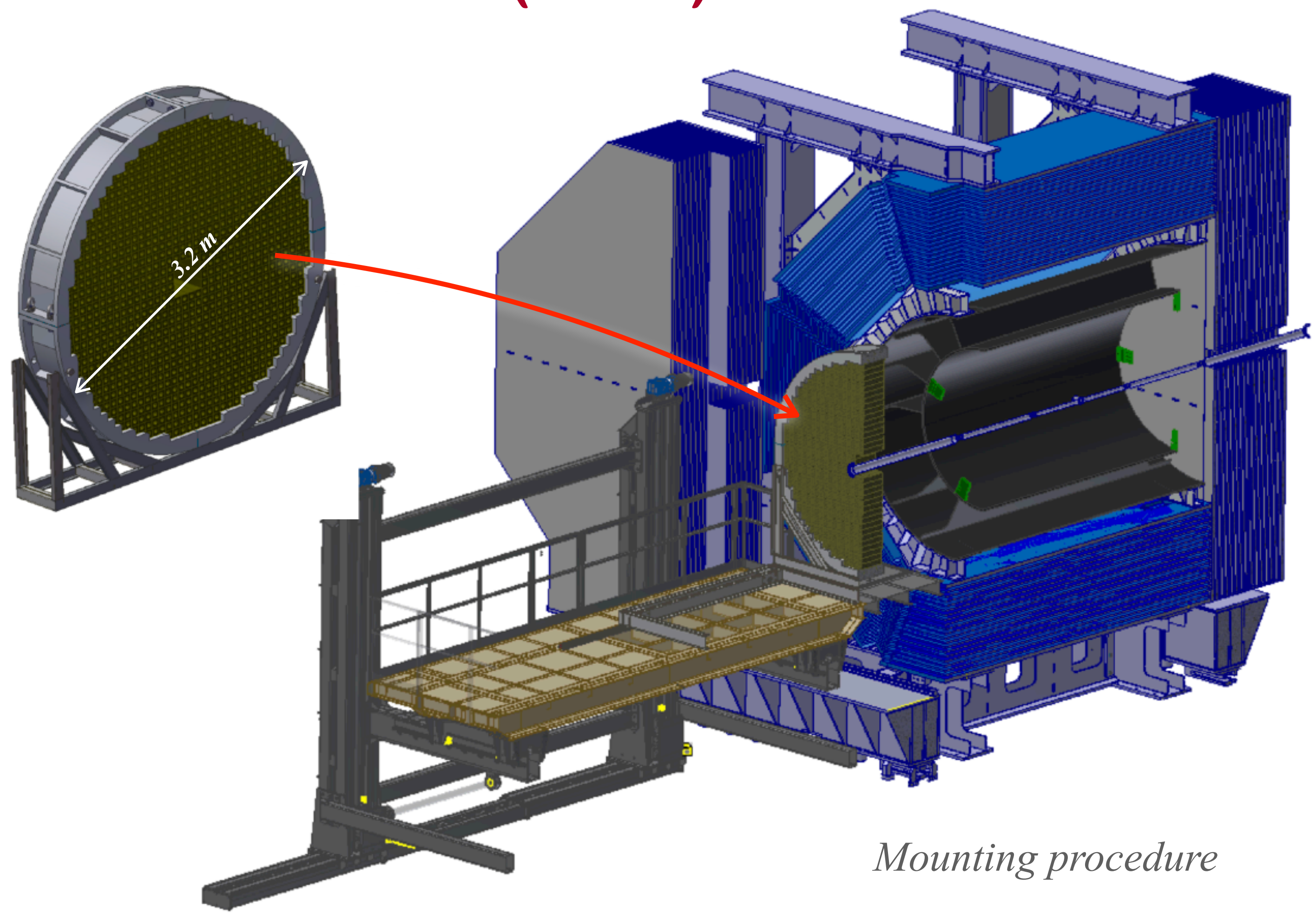
Results of beam tests of RS prototype (10 ton, 4k ch)



prototype

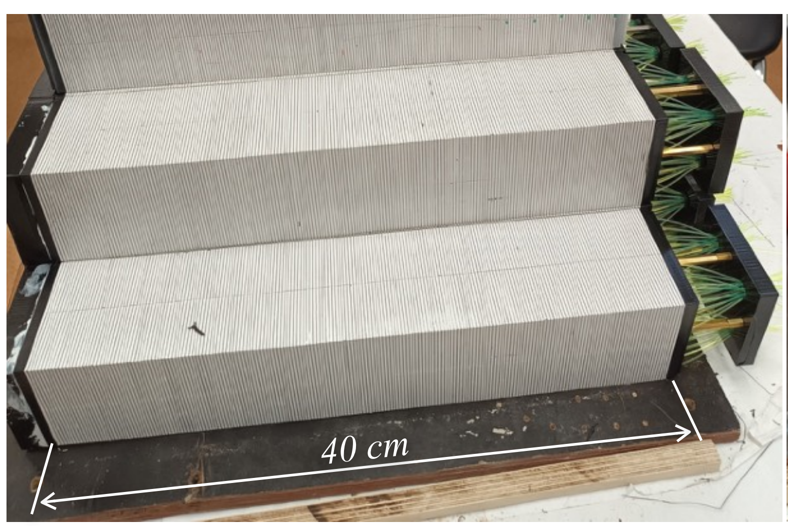
Electromagnetic calorimeter (ECal)

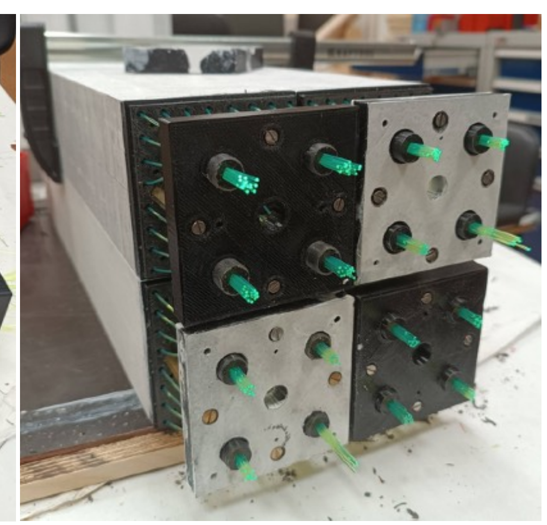
- Purpose: detection of prompt photons and photons from π^0, η and χ_c decays
- Identification of electrons and positrons
- Number of radiation lengths is $18.6X_0$
- Total number of channels is ~23k
- Total weight is 40t (barrel) + 28t (endcaps) = 68t
- Energy resolution is ~5% / √E
- Low energy threshold is ~50 MeV
- Time resolution is ~0.5 ns



Mounting procedure

Assembly of modules in LHEP JINR

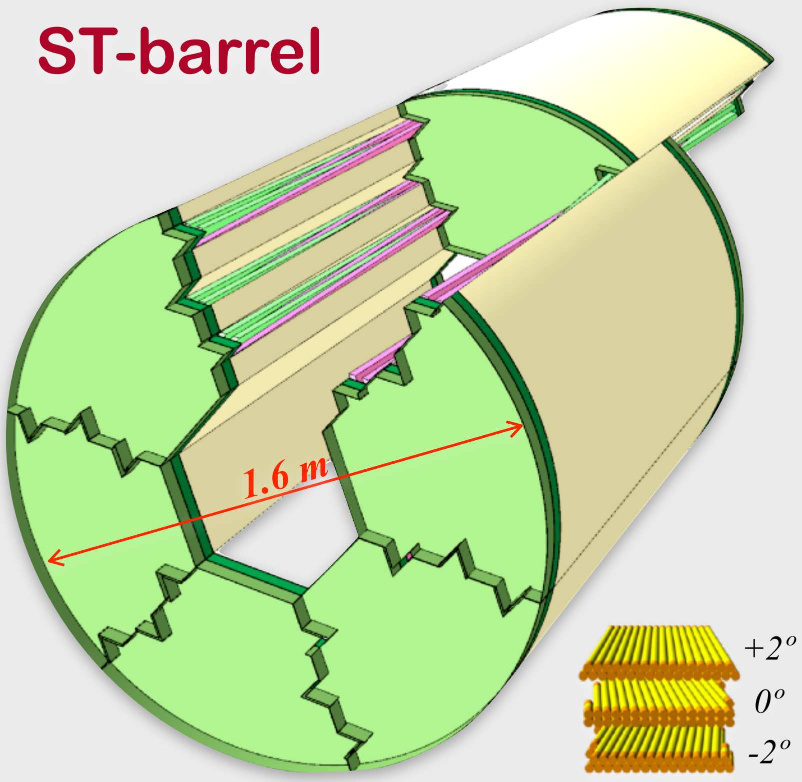




- 200 layers of lead (0.5 mm) and scintillator (1.5mm)
- 16 fibers of one cell transmit light to 6×6 mm^2 SiPM
- Moliere radius is ~2.4 cm
- One endcap will be assembled for the 1-st stage of SPD (2030)

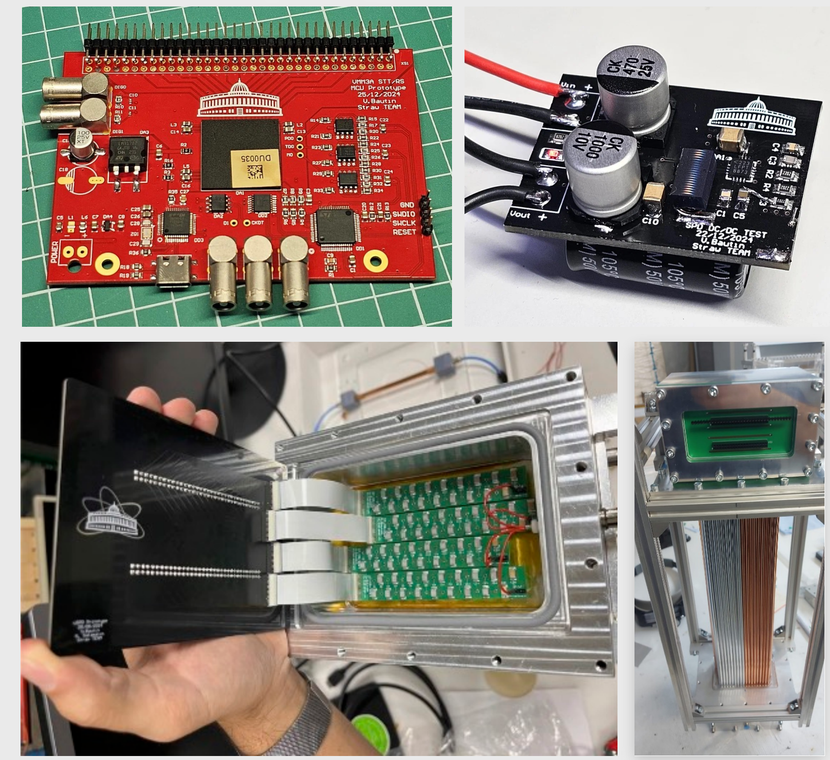
Straw tracker

ST-barrel



- ST-barrel consists of 6 sections with tube orientations 0°, +2°, -2° (20 kch in total)
- Straws are made of a PET film, which is ultrasonic welded to form a tube ∅ = 10 mm
- VMM3-based prototype card has been developed and tested in beam tests in CERN. New ASIC AST-SPD is being developed
- Spatial resolution is ~150 μm
- A gas system suitable for operating a 5 m³ detector with Ar:CO_2 to be developed

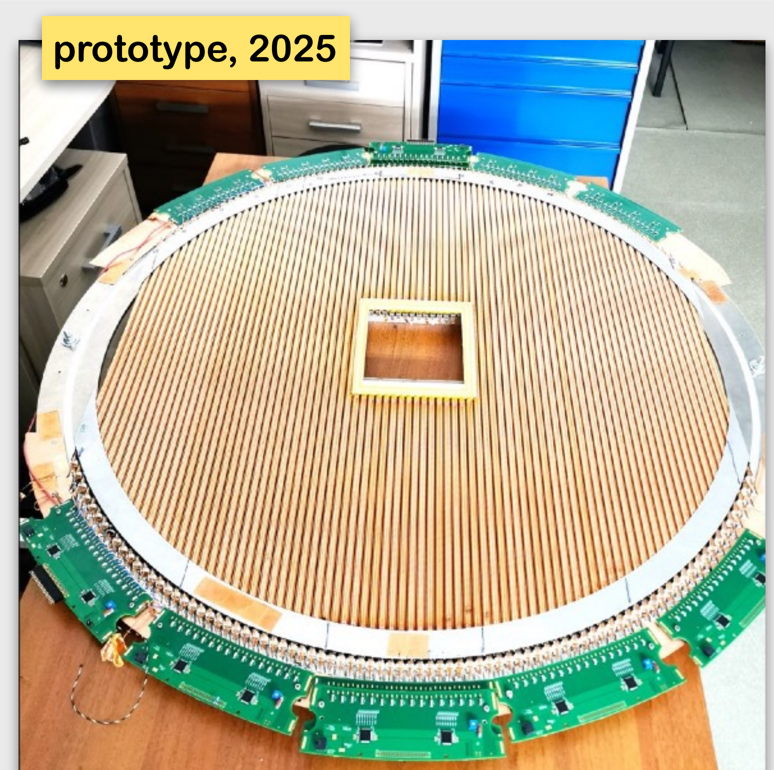
prototype electronics

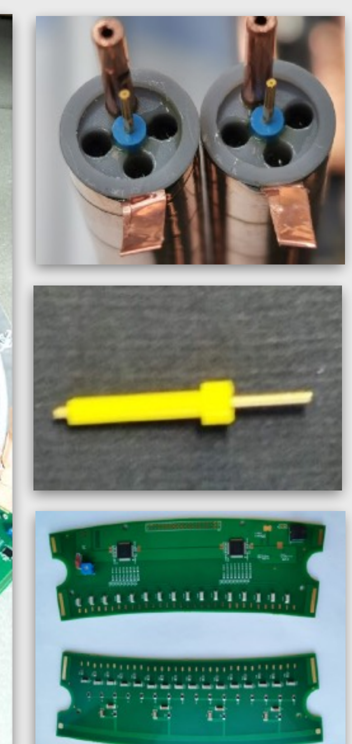


ST-endcaps

- One ST endcap contains 8 modules: *X, +45°, -45°, Y*
- One module contains 320 tubes in total, which are arranged in two layers shifted by half a tube
- Total number of tubes in two endcaps is

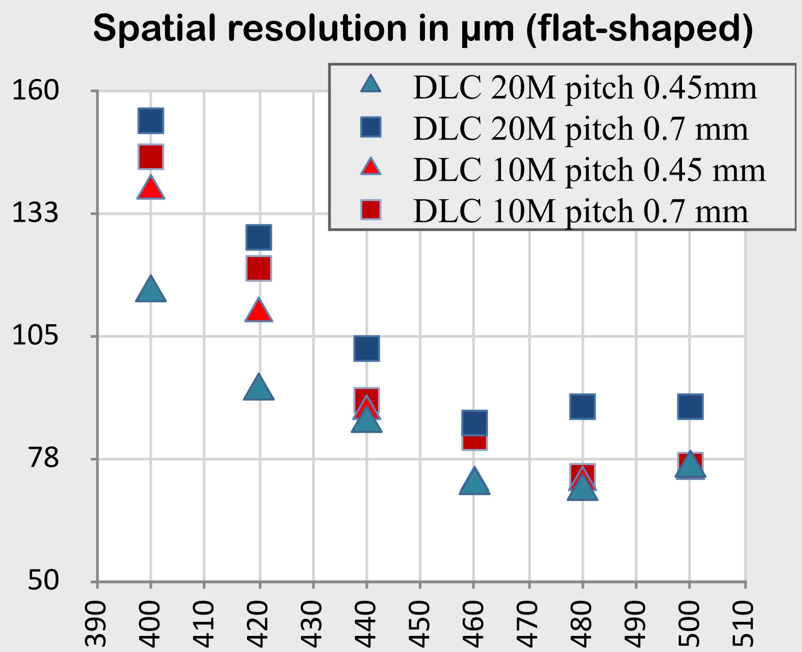
  160 tubes × 16 layers × 2 endcaps = 5120 tubes
- The thickness of one module is 30 mm
- Eight modules will be mounted together on a rigid flat table to form a 240 mm thick rigid block
- One straw is made by winding two Kapton tapes forming a tube with ∅ = 9.56 mm

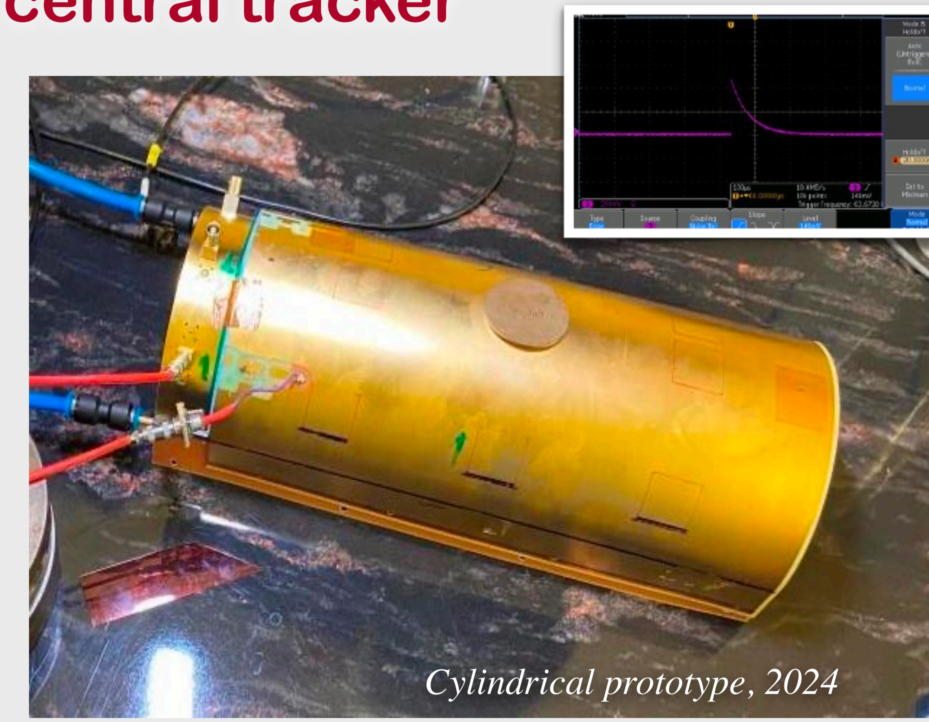




Stage I: Cylindrical Micromegas central tracker

- Flat-shaped MM prototypes - intrinsic efficiency and resolution of JINR MM chambers are excellent
- Cylindrical MM prototype with large read-out electrodes in 2024
- Stable operation was achieved with the gas gain above 10^4
- Good gain and breaking voltage uniformity
- Long-term test of DLC (Diamond Like Carbon) degradation due to discharge is completed, no degradation is observed

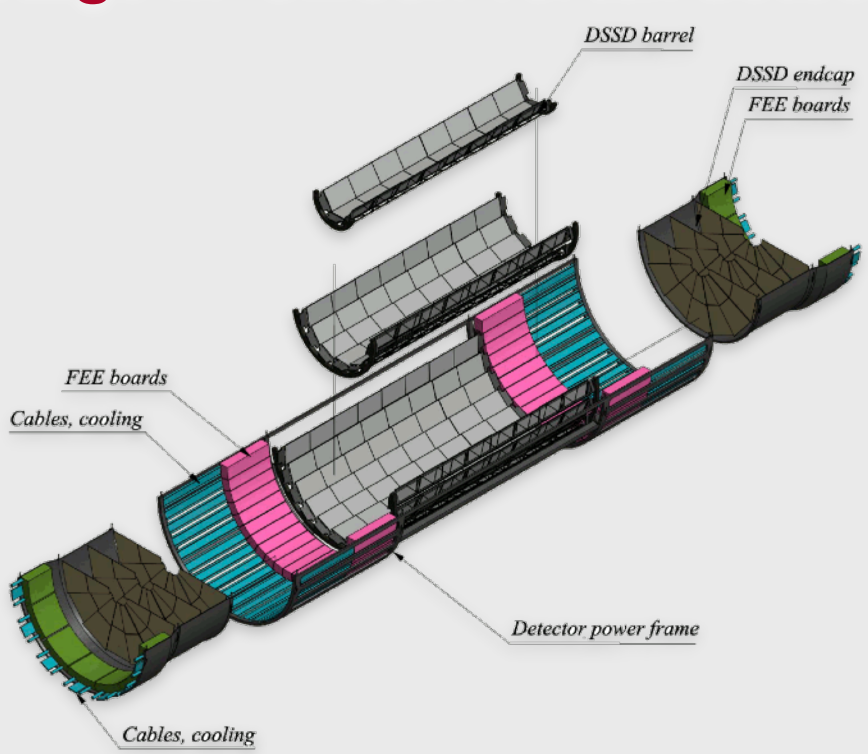


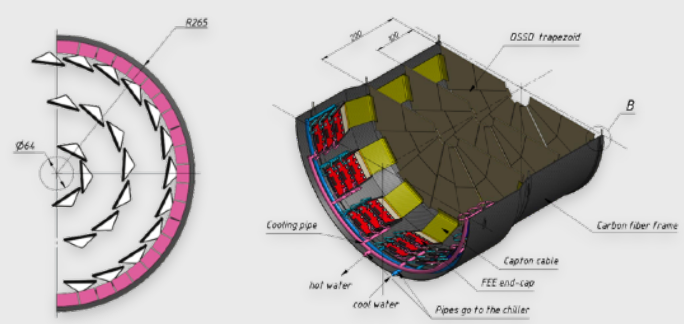


Cylindrical prototype, 2024

Stage II: Silicon vertex detector

- Main purpose of the DSSD detector is to reconstruct the position of D-meson decay vertices (σ_z=76 μm)
- Silicon wafer size 63×93 mm², thickness 300 µm, orthogonal strips on p^+ and n^+ sides, p^+ pitch 95 µm, n^+ pitch 282 µm, produced by ZNTC Russia, ***spatial resolution 27 (81) µm*** for p^+ (n^+) side
- DSSD modules are assembled in ladders with carbon fiber support, 3 layers (R=5, 13, 21 cm) in barrel 74 cm long, 3 layers in each endcap, ~108k channels



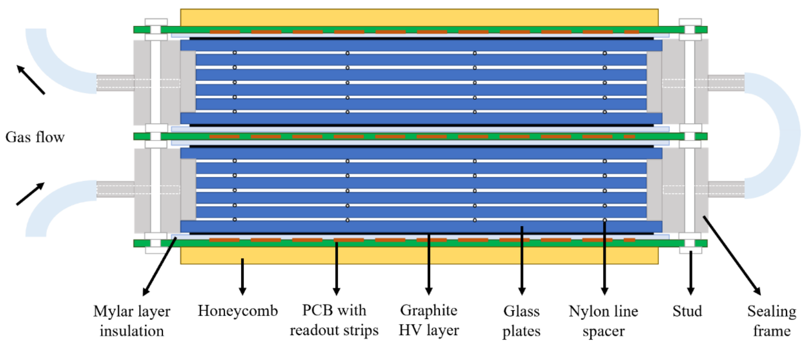


Example of DSSD module in JINR (for BM@N)

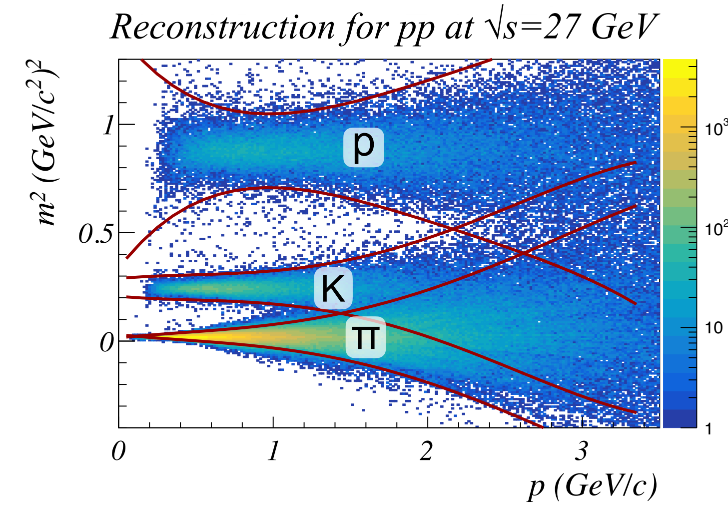
Time-of-flight (TOF) system

Schematic view of sealed MRPC

(B.Wang et al, JINST 15 (2020) 08, C08022)



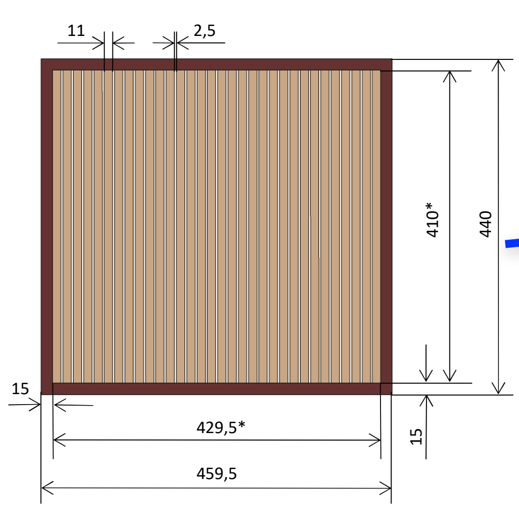
- Purpose: π/K/p discrimination for momenta ≲2 GeV, determination of t_0.
- Time resolution requirement <60 ps.
- Sealed Multigap Resistive Plate Chambers (MRPC) are the base option.
- DAQ electronics is under discussion. Analog of NINO chip is being designed.
- Number of readout channels is ~12k

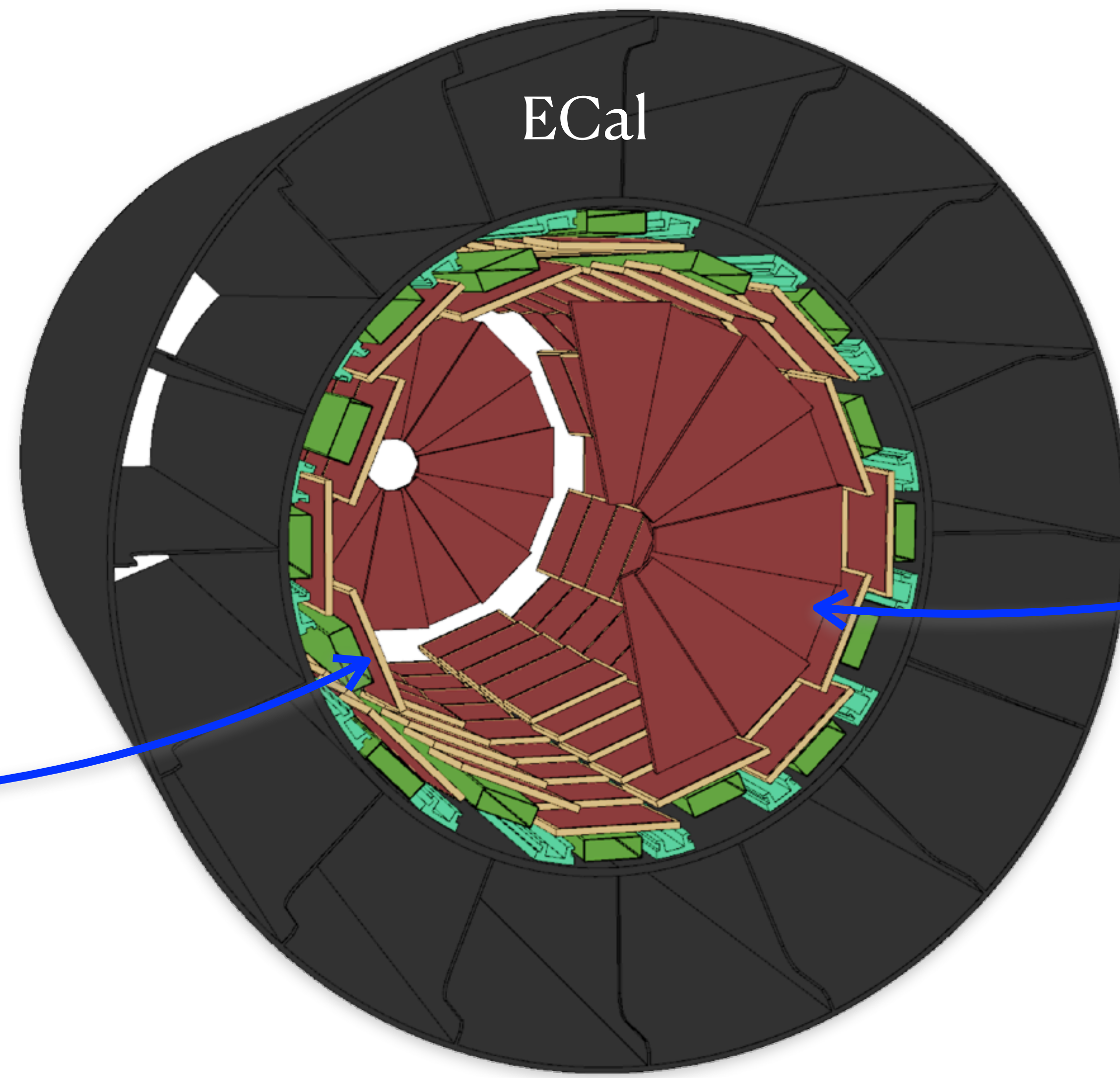


TOF Chambers for Barrel
(overlap in 2 dimensions)

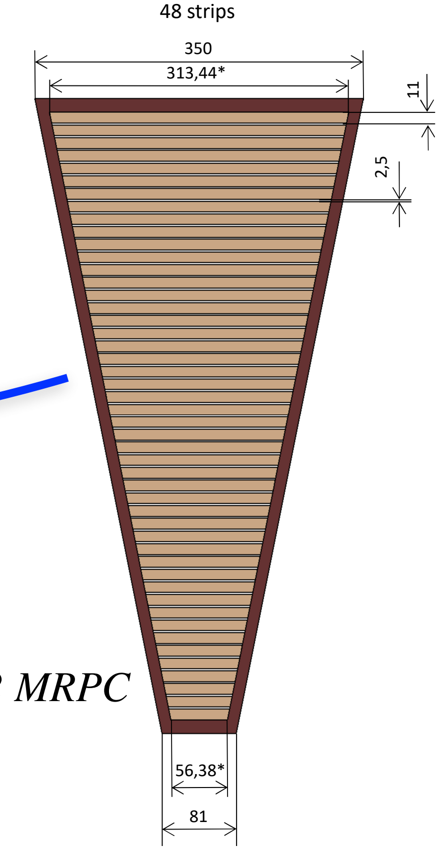
16×9=144 MRPC

TOF Chamder
32 strips





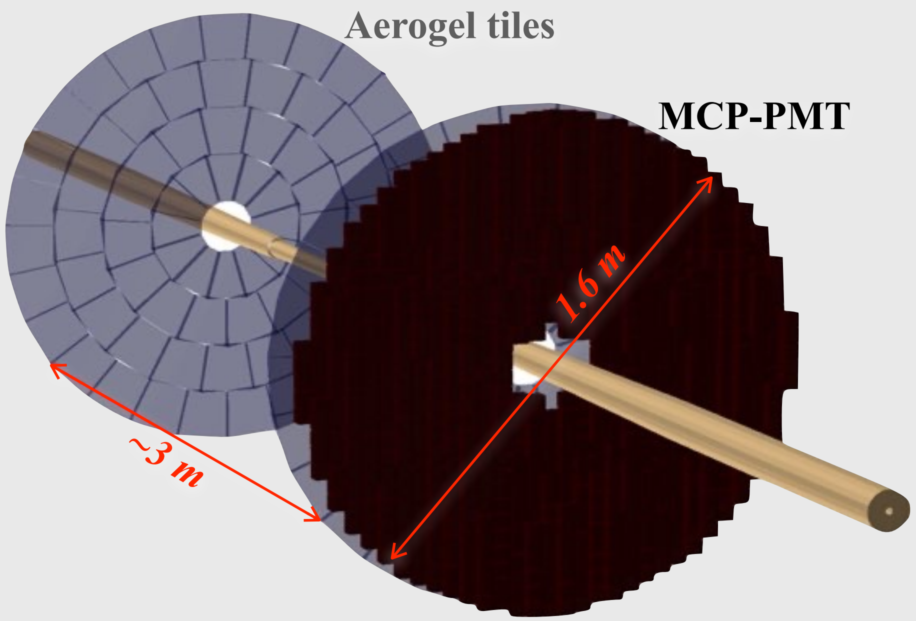
TOF Chambers for Endcap
48 strips



2×16=32 MRPC

Cherenkov detector (FARICH)

One of options for the Cherenkov detector



See talk of A.Barnyakov on Thursday

SPD – FARICH system concept

Aerogel:

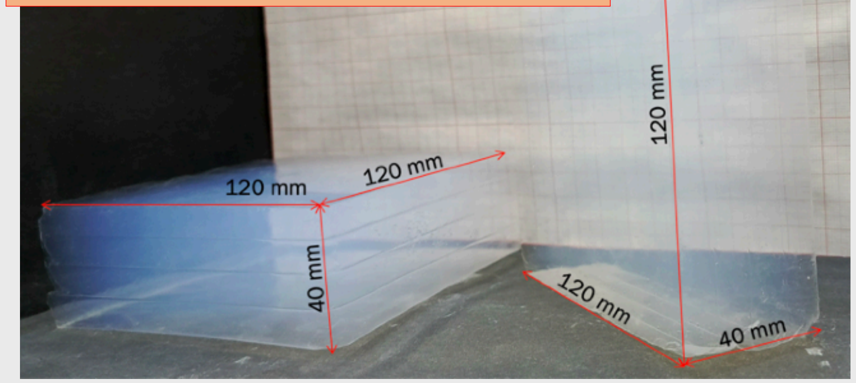
- 2 end-caps × 74 tiles (4 form-factors)
- 4-layer focusing aerogel:
  - n_{max}≤1.05 (to be optimized soon)
  - Total thickness 35÷40 mm (to be optimized)
  - Focus distance ~20 cm

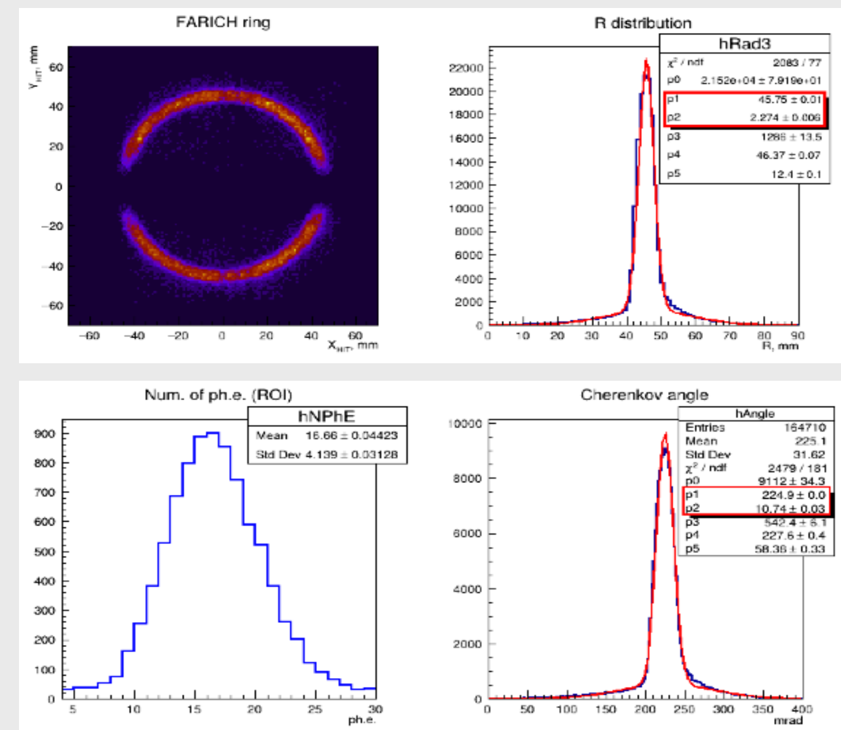
Position-sensitive MCP-PMT:

- 2 × 550 PMTs ~51×51 mm² (pixel 6×6 mm²), i.e. N6021 (NNVT)
- 2 × 2200 PMTs ~31×31 mm² (pixel 3×3 mm²) from Ekran FEP in Novosibirsk

Aerogel optimisation (4 vs 3 layers, data 2025)

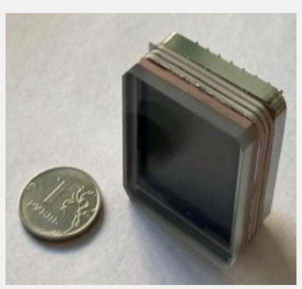
- 4-layer aerogel optimized for 6x6 mm² pixel size
- $L_{sc} \geq 60\ mm$ for all aerogel tiles

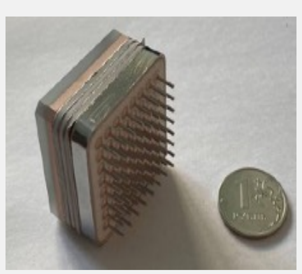




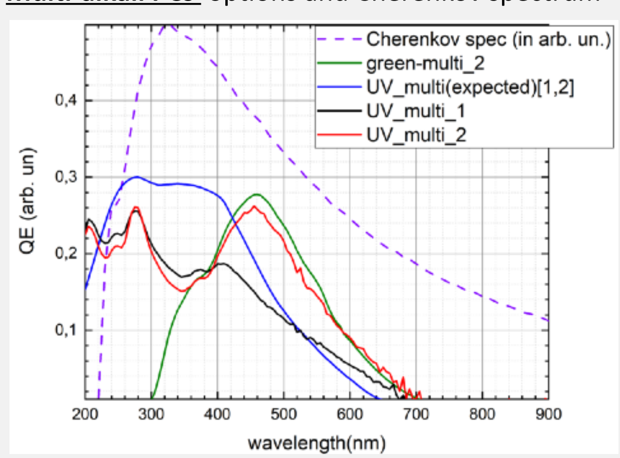
$\sigma_{1pe}^{4\,layer} = 10.7\,mrad$ $\sigma_{1pe}^{3\,layer} = 11.6\,mrad$

MCP-PMT development in Novosibirsk

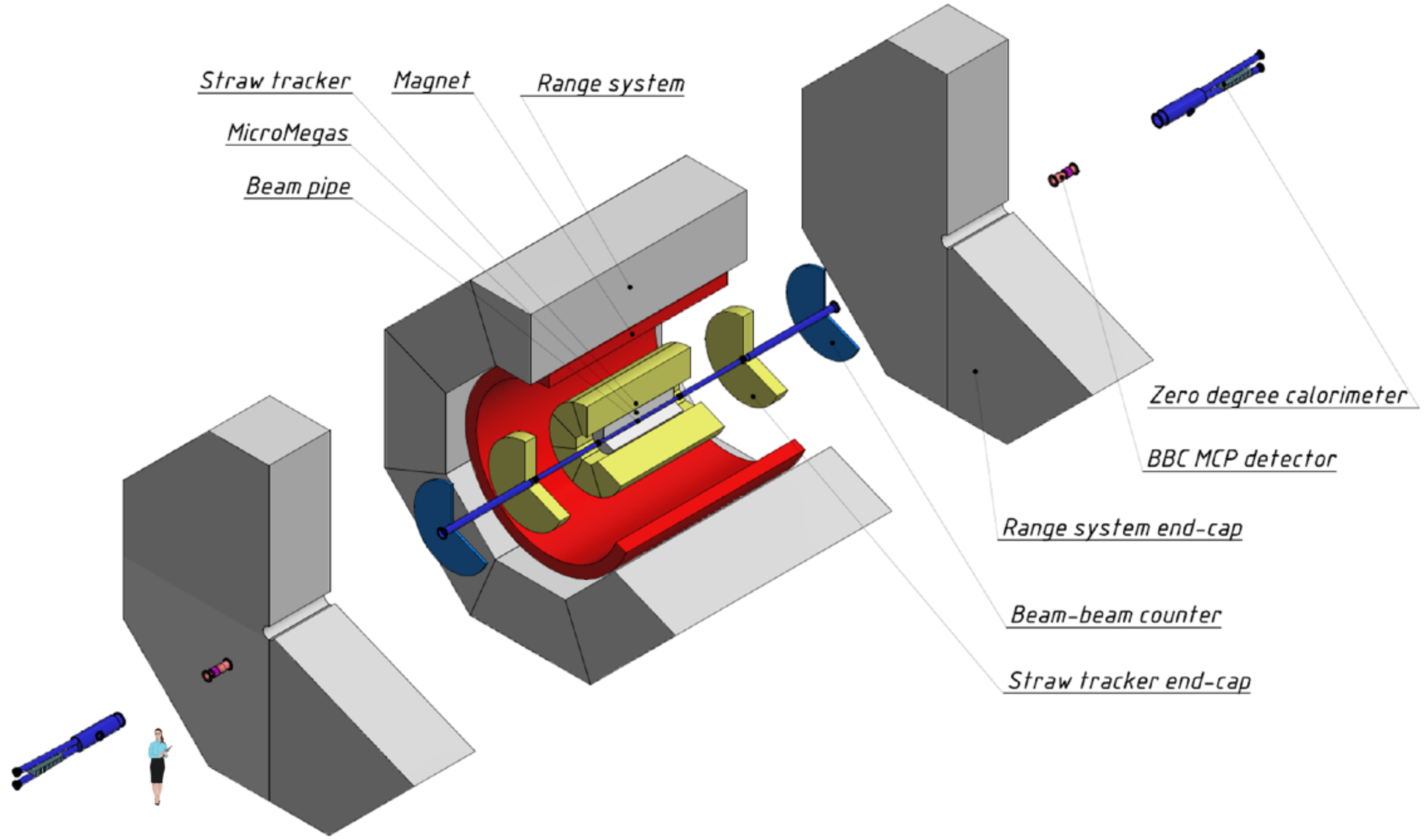




Multi-alkali PCs options and Cherenkov spectrum

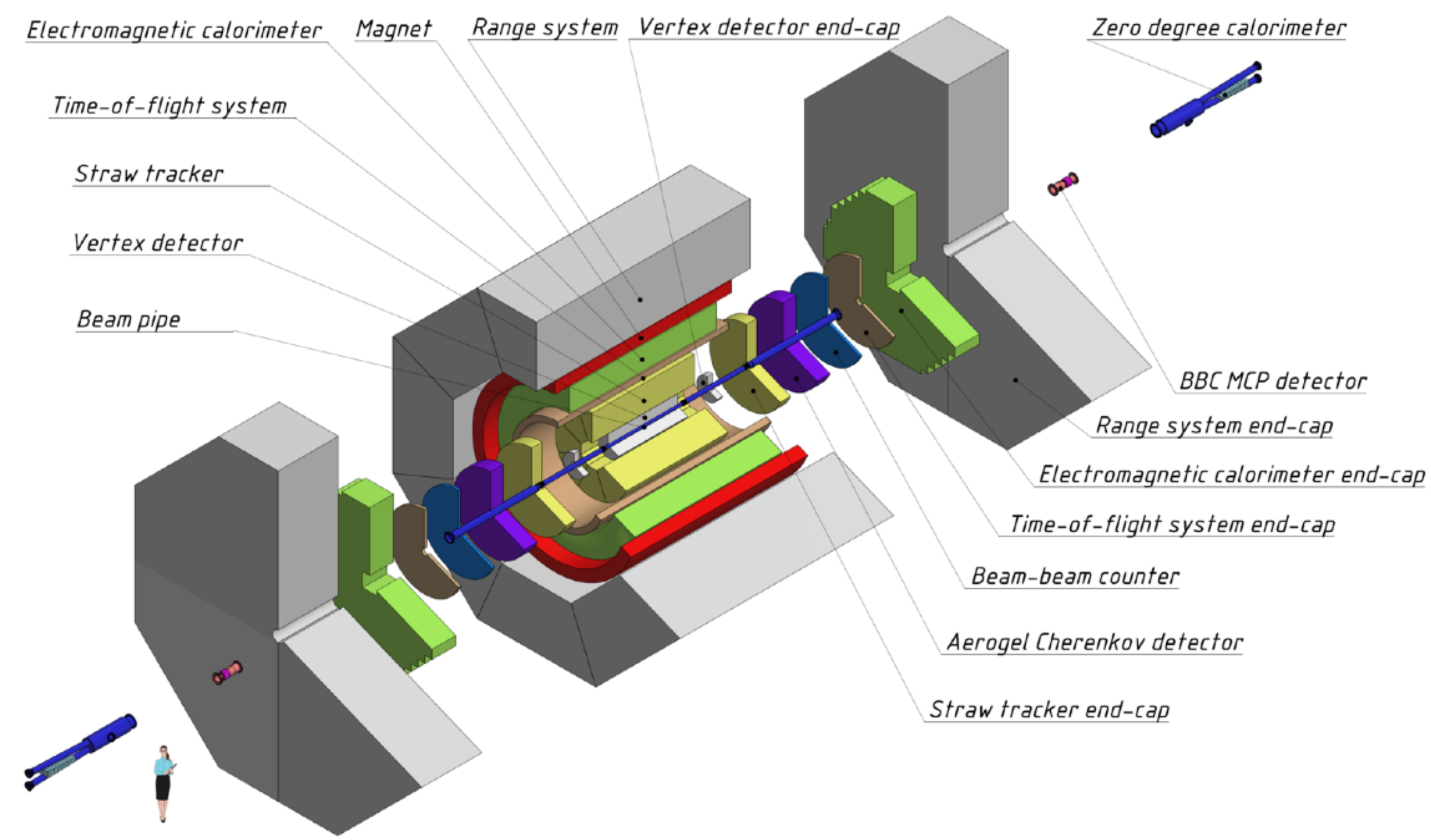


- By the end of 2025: fabricate and test the parameters of several bi-alkali and multi-alkali quartz photocathodes in a round MCP PMT design
- Develop the ALD technology on round MCP PMTs: gain, photocathode collection efficiency, time resolution



Stage I of experiment (~2031)

- Basic set of subsystems
  - Magnet, RS, Straw
  - MM, BBC, MCP, ZDC
- No PID detector (TOF, FARICH), no ECal, no SVD
- p-beam: $\sqrt{s} \lesssim 10$ GeV, $\mathcal{L} \lesssim 10^{30}$ $s^{-1}cm^{-2}$



Stage II: Fully assembled setup

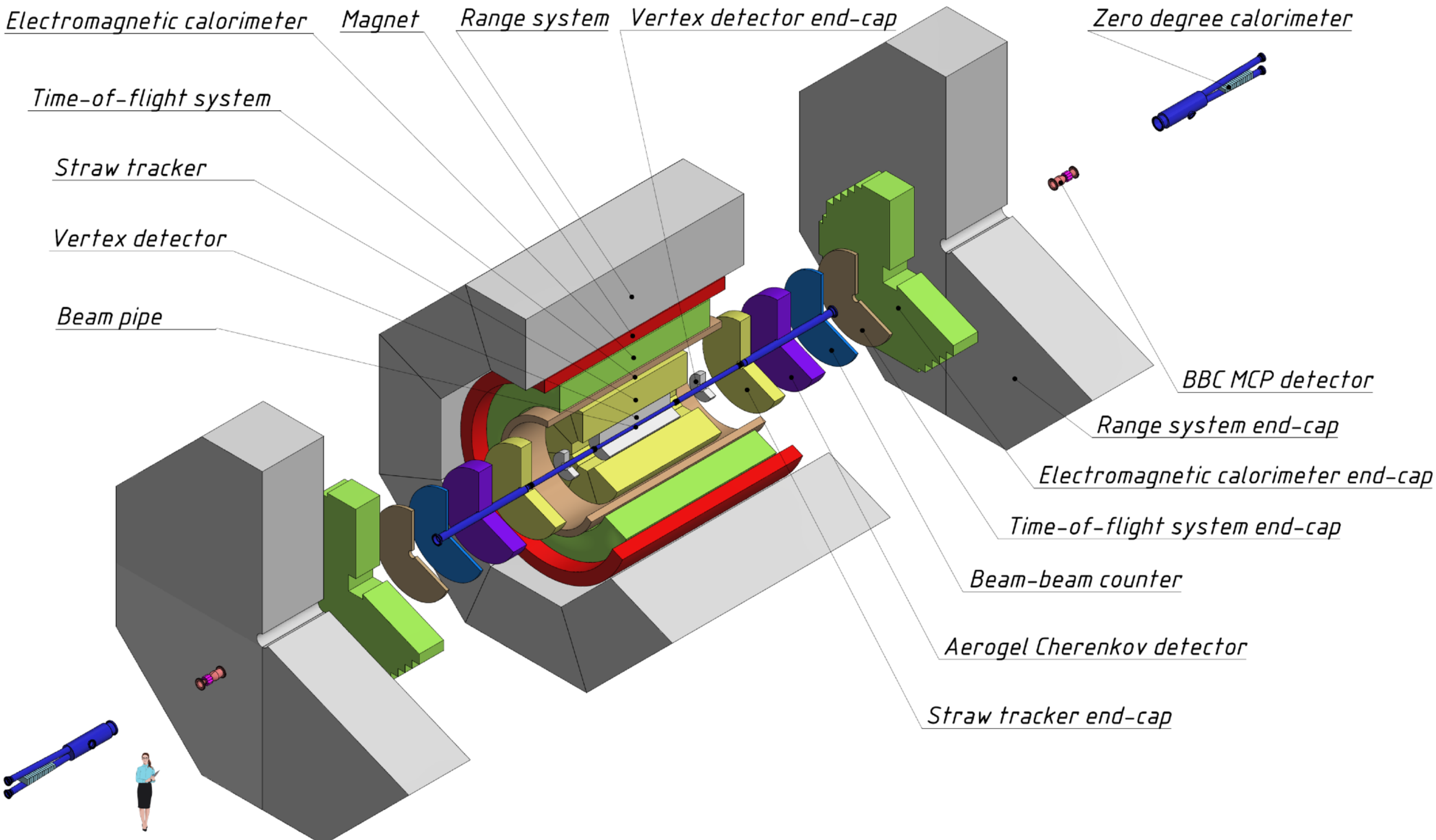
- p-beam: $\sqrt{s}=27$ GeV, $\mathcal{L}=10^{32}$ $s^{-1}cm^{-2}$ with interaction rate of ~4 MHz

Conclusions

- NICA collider successfully began operating using the Xe beam in Jan 2026
  - The first physics run in heavy ion mode is schedules for the end of 2026
- **SPD (Spin Physics Detector)** is a universal facility with the primary goal to study unpolarized and polarized gluon content of p and d
  - 4π detector will be equipped with silicon detector, straw tracker, TOF and FARICH for PID, calorimetry, muon system and monitoring detectors
  - Possibility of running (polarized) p and d beams in NICA has been studied
- SPD Technical Design Report was released in 2023
  - The first data using proton and deuteron beams (stage-I) are planned for 2032
- More information could be found at http://spd.jinr.ru

backup

Schematic view of the SPD setup



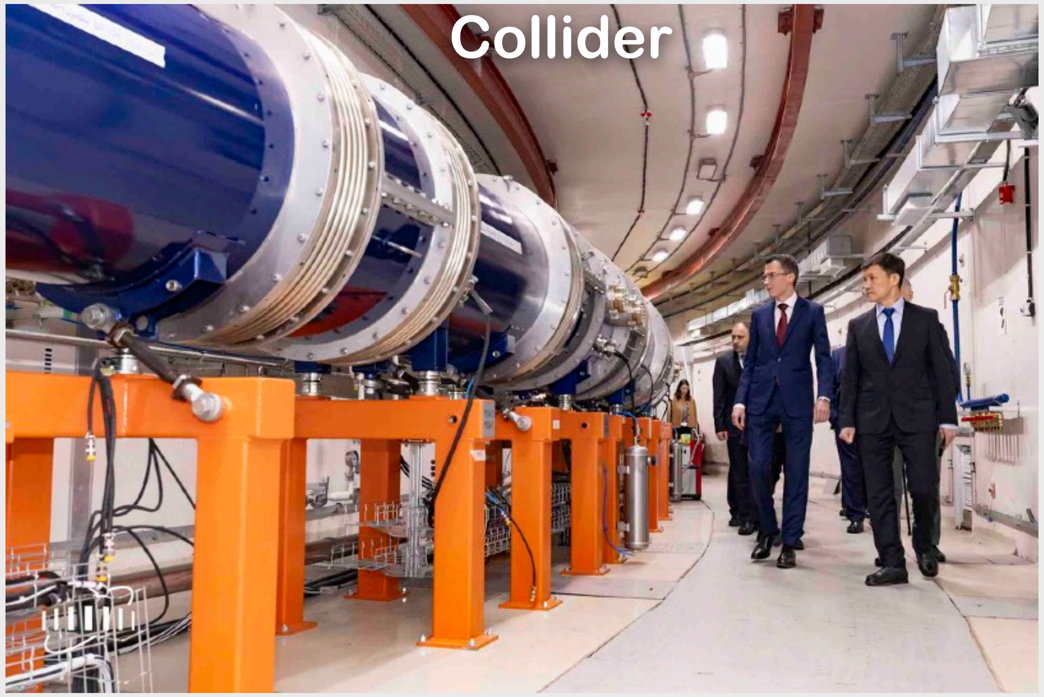
The total weight is ~1.3k tons

Nuclotron

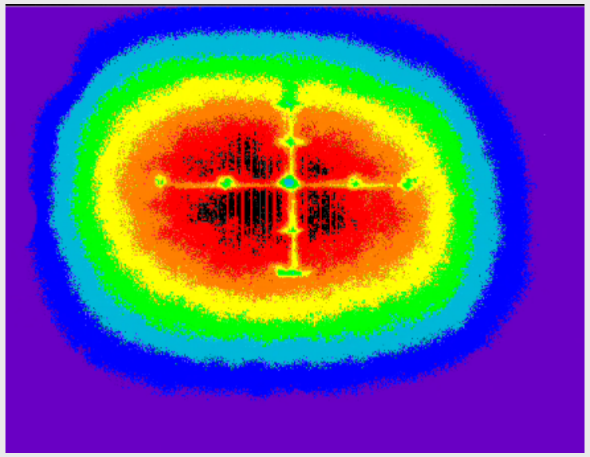
It began operating in 1993. First SC synchrotron in Europe using hollow SC cable, cooled by circulating 2-phase helium. It is scheduled for upgrade by 2030.

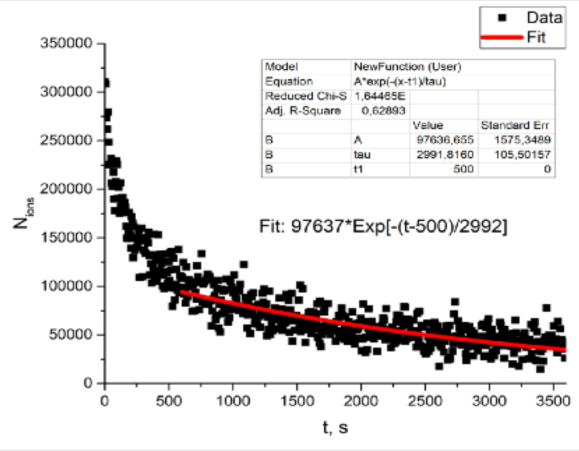
Booster

It was mainly introduced for the heavy ion mode (He, Xe, Fe, …, Au). The first run took place in December 2020. In pp mode, it is used only to reduce the beam emittance.



- The foundation stone for NICA was laid in March 2016.
- First run and stable $^{124}Xe^{54+}$ beam operation achieved for both rings in **January 2026**.





Detectors for local polarimetry and luminosity control

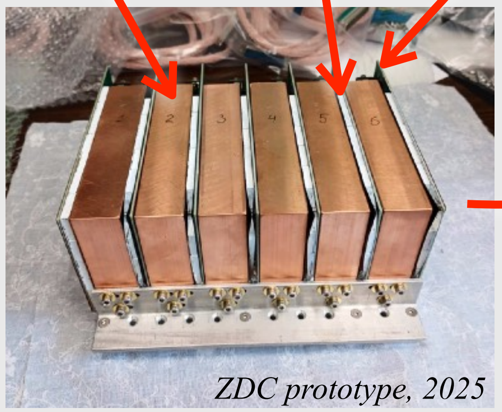
Zero Degree Calorimeter (ZDC)

- Purpose: detection of neutral particles n or γ
- Two ZDC are integrated in the cryostat placed between two accelerator dipole magnets, ±14 m from IP
- Sampling calorimeter (scintillator/led) with fine segmentation and SiPM light readout
- Prototype (is installed in 2025): 200 channels, readout based on CAEN FERS-5200.
- Detector (will be installed by 2030): 1000 channels, readout based on electronics designed for the DANSS neutrino experiment at Kaliniskaya NPP

Copper radiator

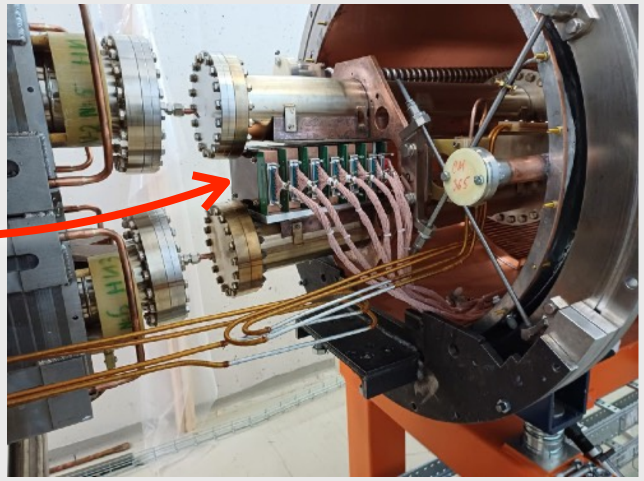
31 scintillator tiles in one layer

PCB with 31 SiPMs



ZDC prototype, 2025

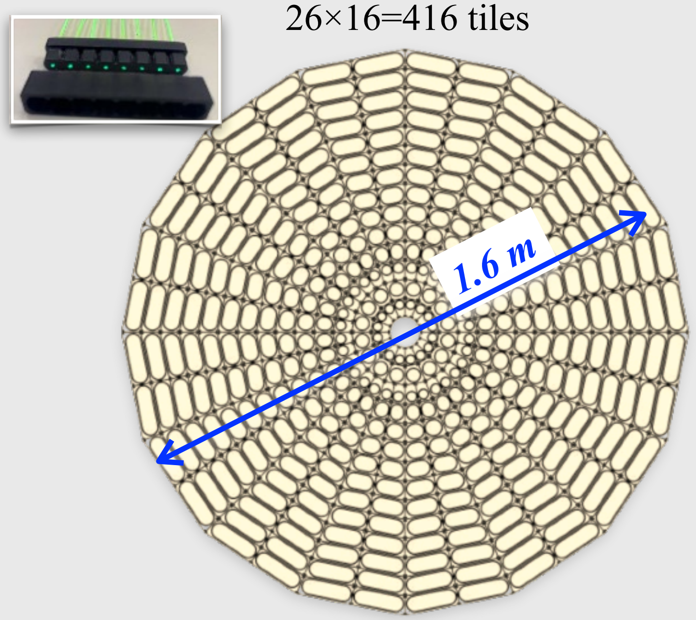
ZDC prototype installed in the accelerator cryostat



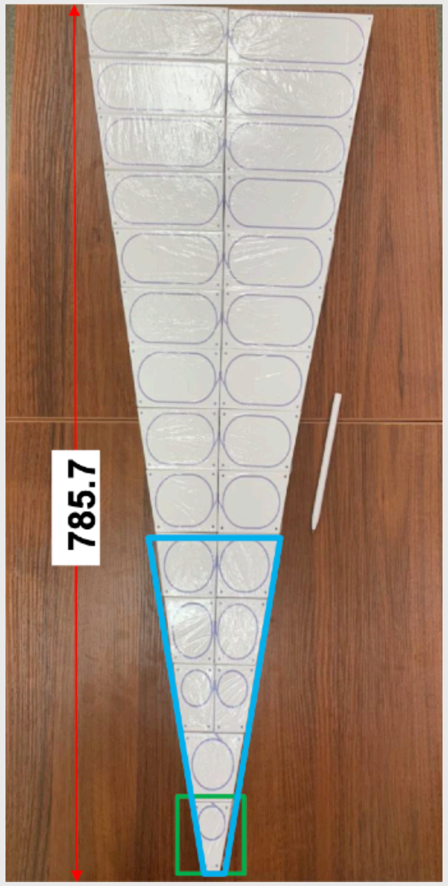
Beam-beam counter (BBC)

- Purpose: a quick response registration of charged particles
- BBC consists of inner and outer parts
  - Inner part: Micro-Channel Plates (MCP) located around the beam pipe, ±8 m from IP
  - Outer part: plastic scintillator tiles with WLS fiber coupled to SiPM for readout, ±1.4 m from IP

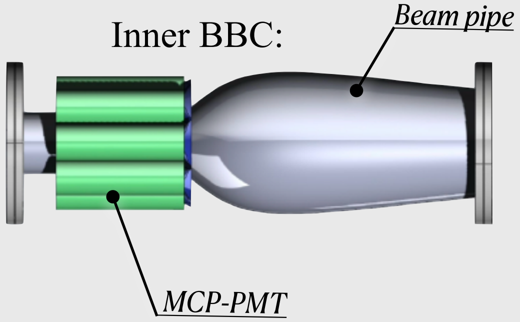
Outer BBC design: 26×16=416 tiles

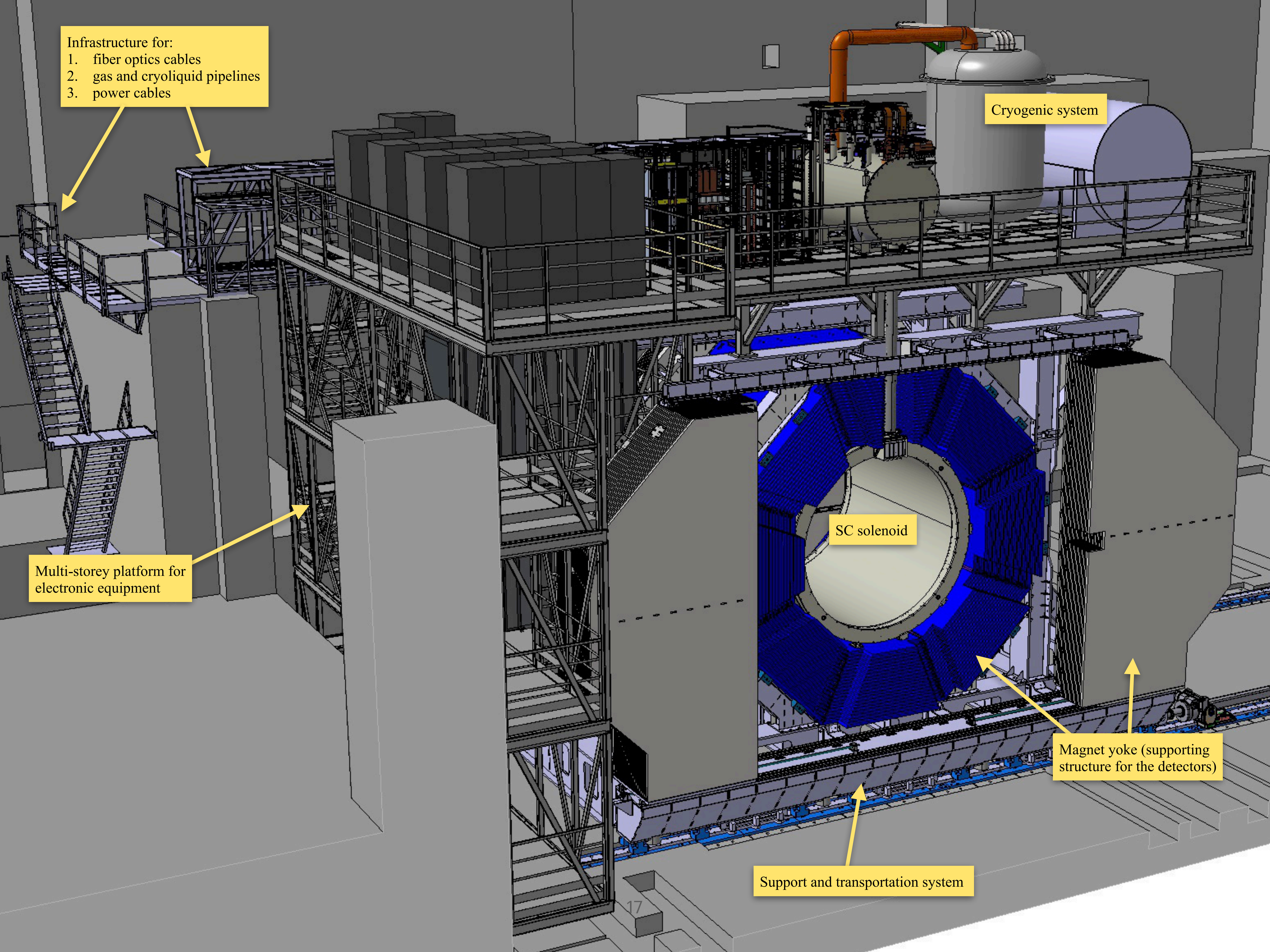


Outer BBC sector: (1/16 of wheel) 26 tiles



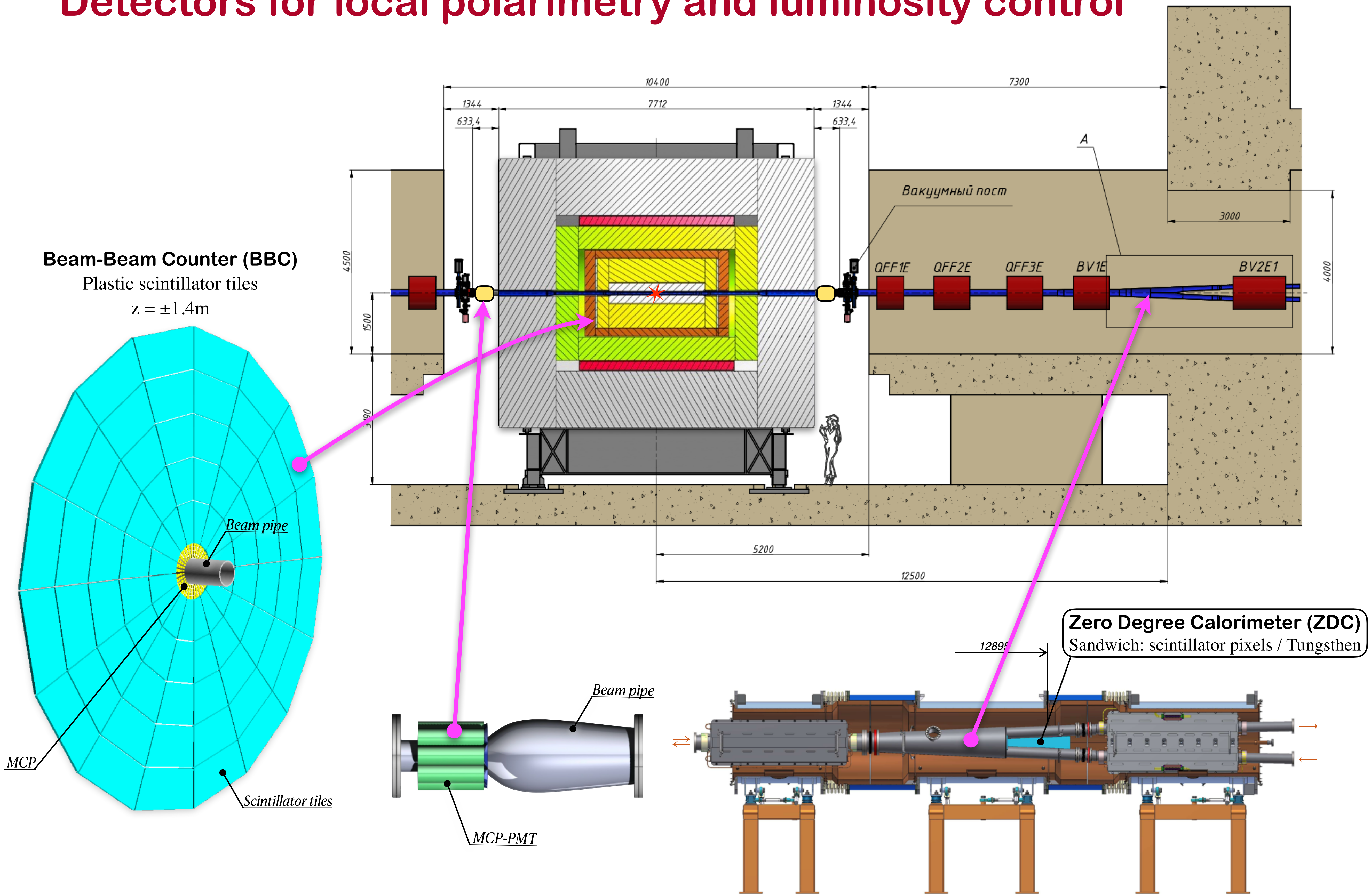
Inner BBC:





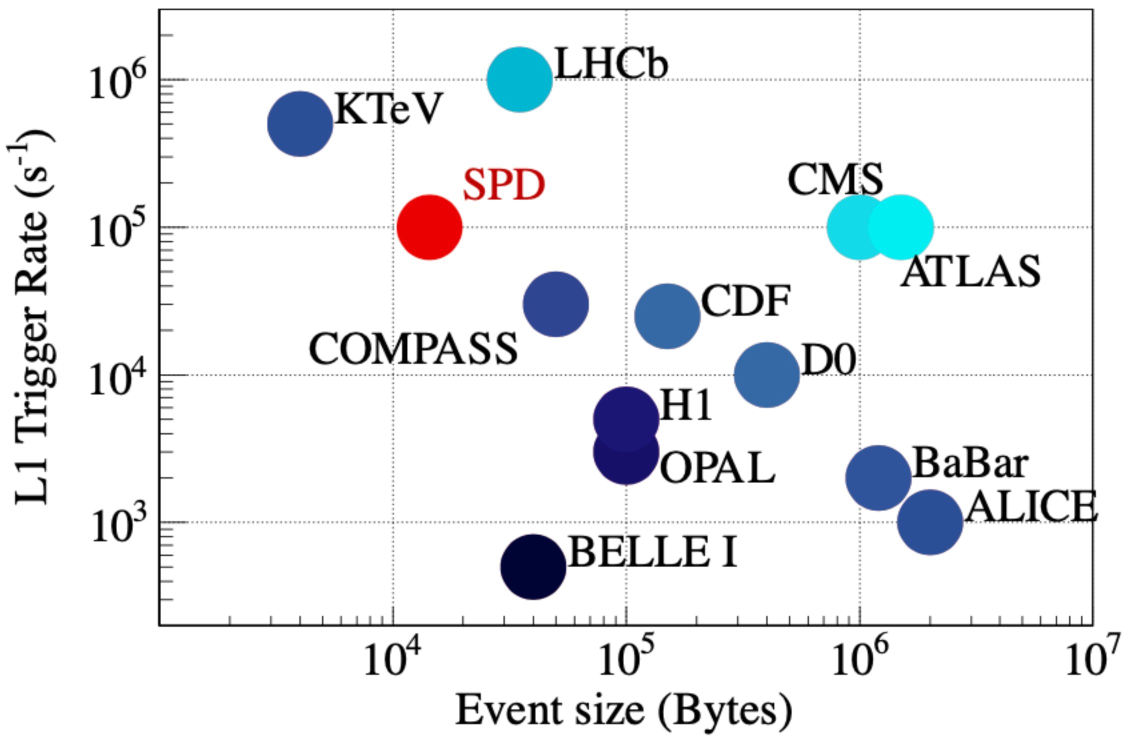
Infrastructure for:
1. fiber optics cables
2. gas and cryoliquid pipelines
3. power cables
Cryogenic system
SC solenoid
Multi-storey platform for electronic equipment
Magnet yoke (supporting structure for the detectors)
Support and transportation system

Detectors for local polarimetry and luminosity control



Data Acquisition System (DAQ)

- Bunch crossing every 76 ns → crossing rate 12.5 MHz
- At maximum luminosity of 10^{32} cm^{-2}s^{-1} the interaction rate is 4 MHz
- No hardware trigger to avoid possible biases
- Raw data stream 20 GB/s or 200 PB/year
- Online filter to reduce data by order of magnitude to ~10 PB/year



Data volume vs time

- ***Preparation for the experiment.*** Monte Carlo simulation from 2024 to 2028 will provide 2 PB per year. Total per stage: ***10 PB***.
- ***Stage I:*** running at low luminosity of the NICA collider. Monte Carlo simulation and real data taking from 2028 to 2030 will provide 4 PB per year. Reprocessing: 2 PB per year. Total per stage: ***18 PB***.
- ***Upgrade of the setup*** for operation at high luminosity. Monte Carlo simulation from 2031 to 2032 will provide 2 PB per year. Reprocessing: 2 PB per year. Total per stage: ***8 PB***.
- ***Stage II:*** running at maximum design luminosity of the NICA collider. Monte Carlo simulation and real data taking from 2033 to 2036 will provide 20 PB per year. Reprocessing: 10 PB per year. Total per stage: ***120 PB***.