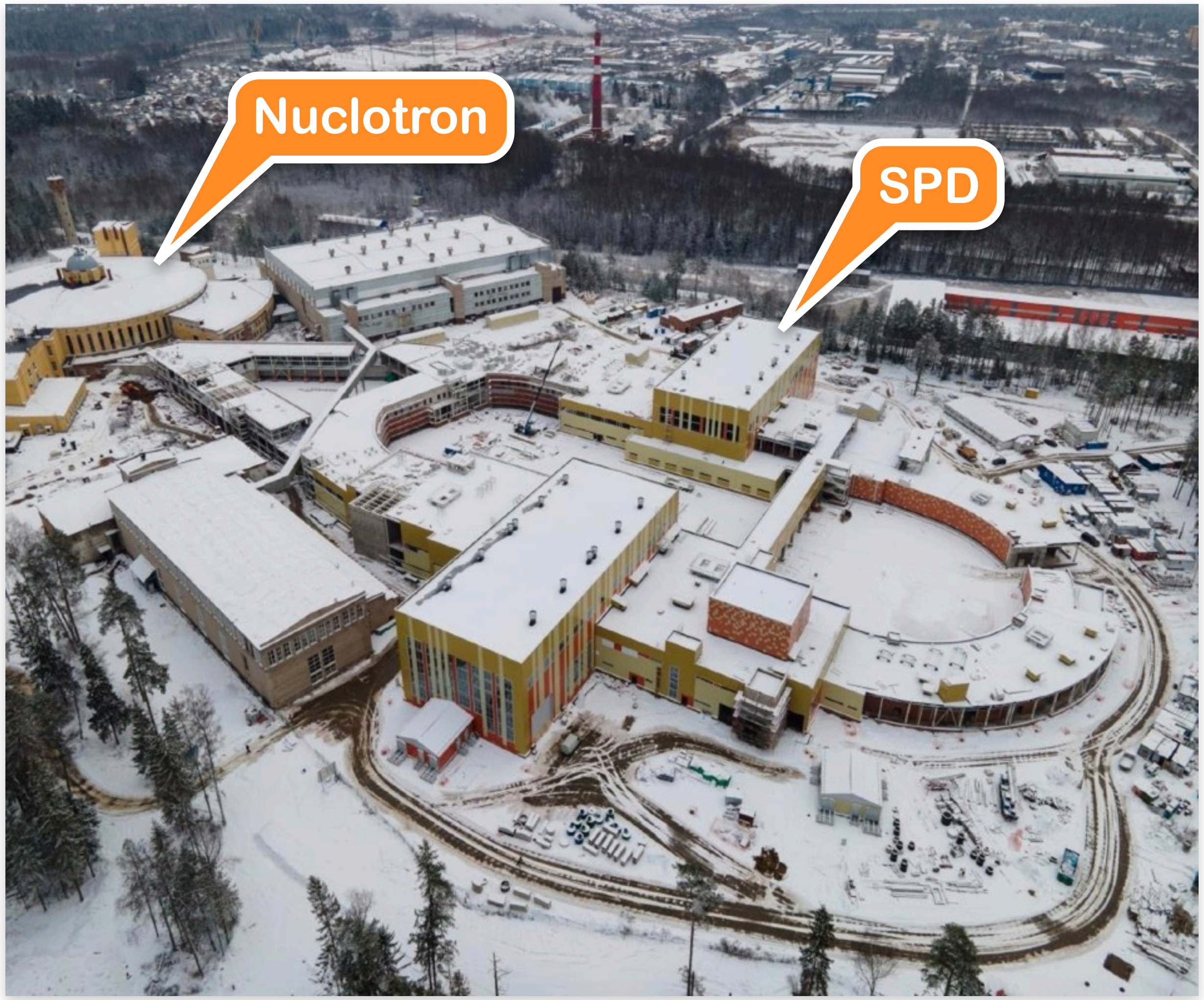
SPD experimental setup

Alexander Korzenev, JINR/LHEP

Meeting with Detector Advisory Committee
May 26, 2021

Outline

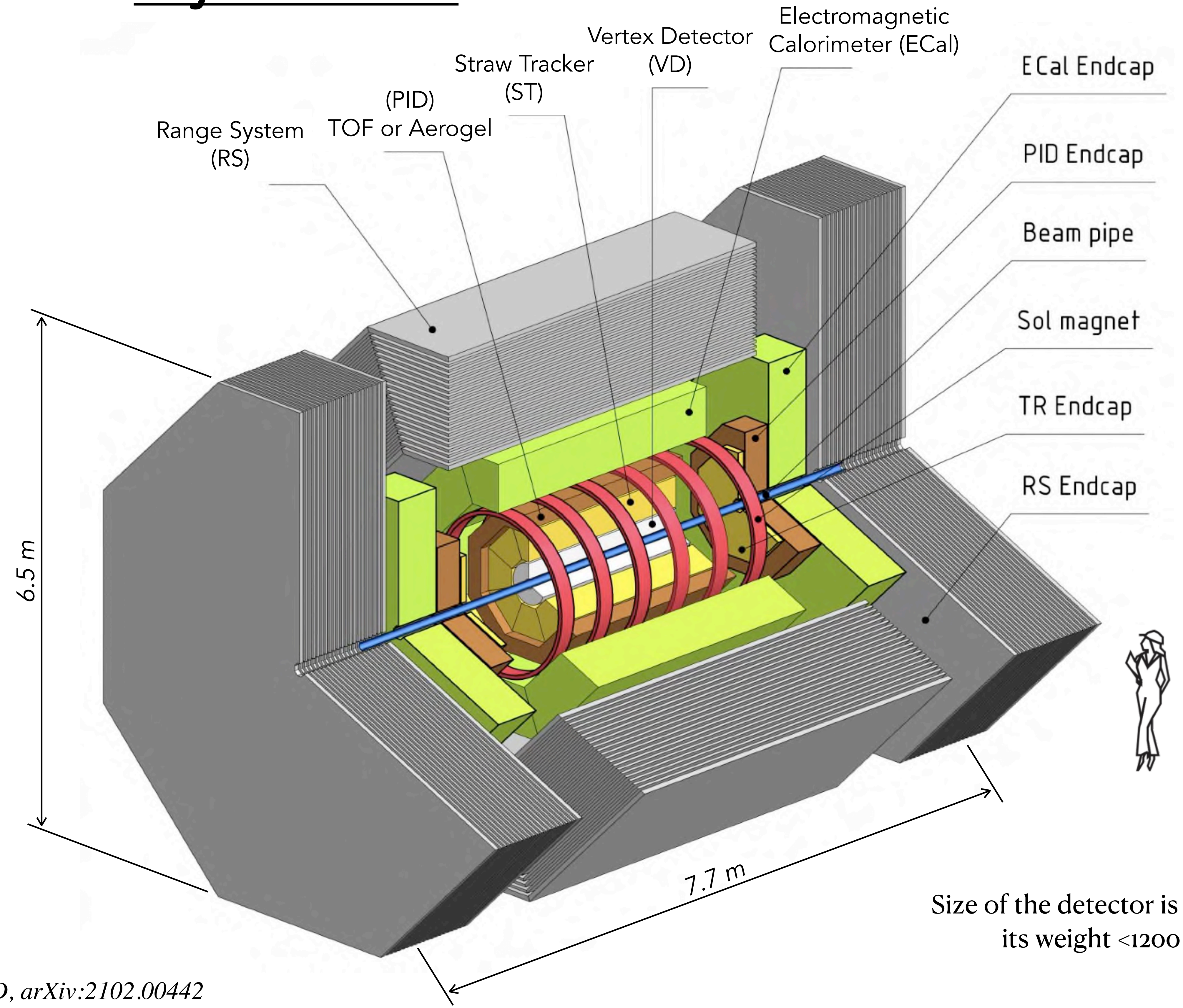
Aerial view to NICA



SPD experimental hall

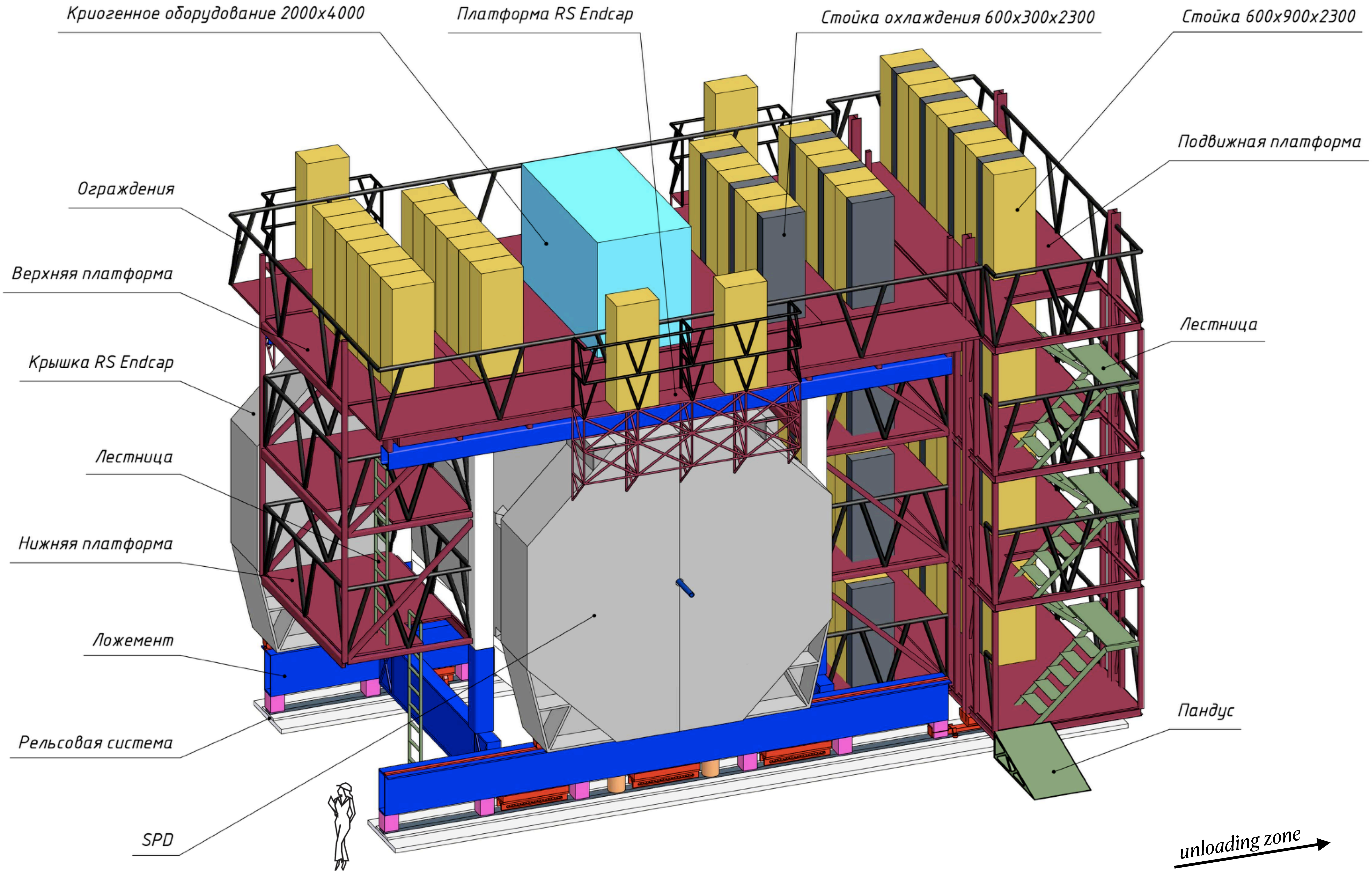
- Infrastructure development is ongoing: modernization of power supply system, upgrade of plants for liquid helium and nitrogen production, construction of new buildings
- Plans for the SPD hall for this year: complete work on the interior, make crane in operation

Layout of SPD

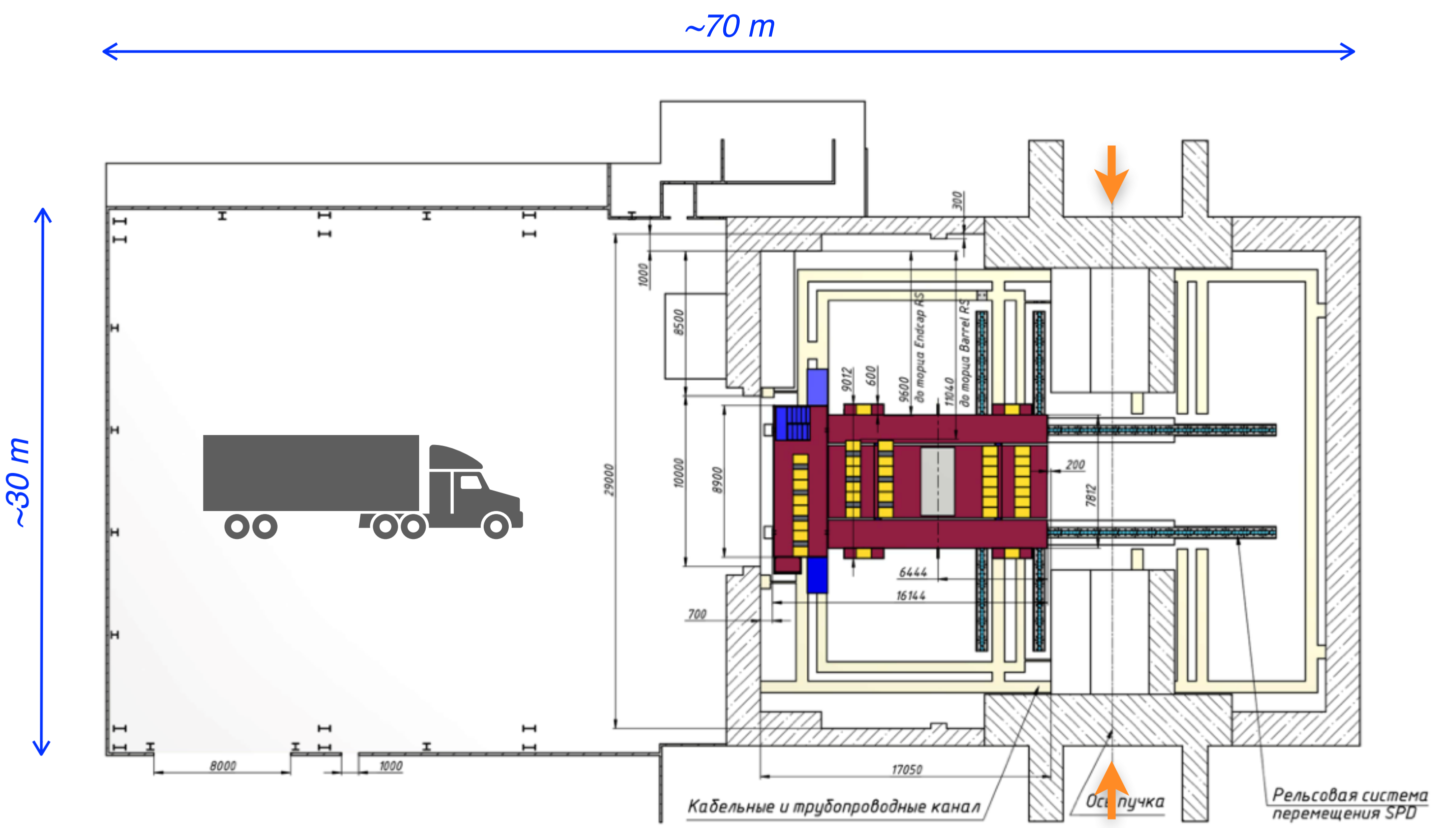


Size of the detector is limited by its weight <1200 ton

CDR of SPD, arXiv:2102.00442



Криогенное оборудование 2000x4000
Платформа RS Endcap
Стойка охлаждения 600x300x2300
Стойка 600x900x2300
Ограждения
Подвижная платформа
Верхняя платформа
Крышка RS Endcap
Лестница
Лестница
Нижняя платформа
Ложемент
Пандус
Рельсовая система
SPD
unloading zone

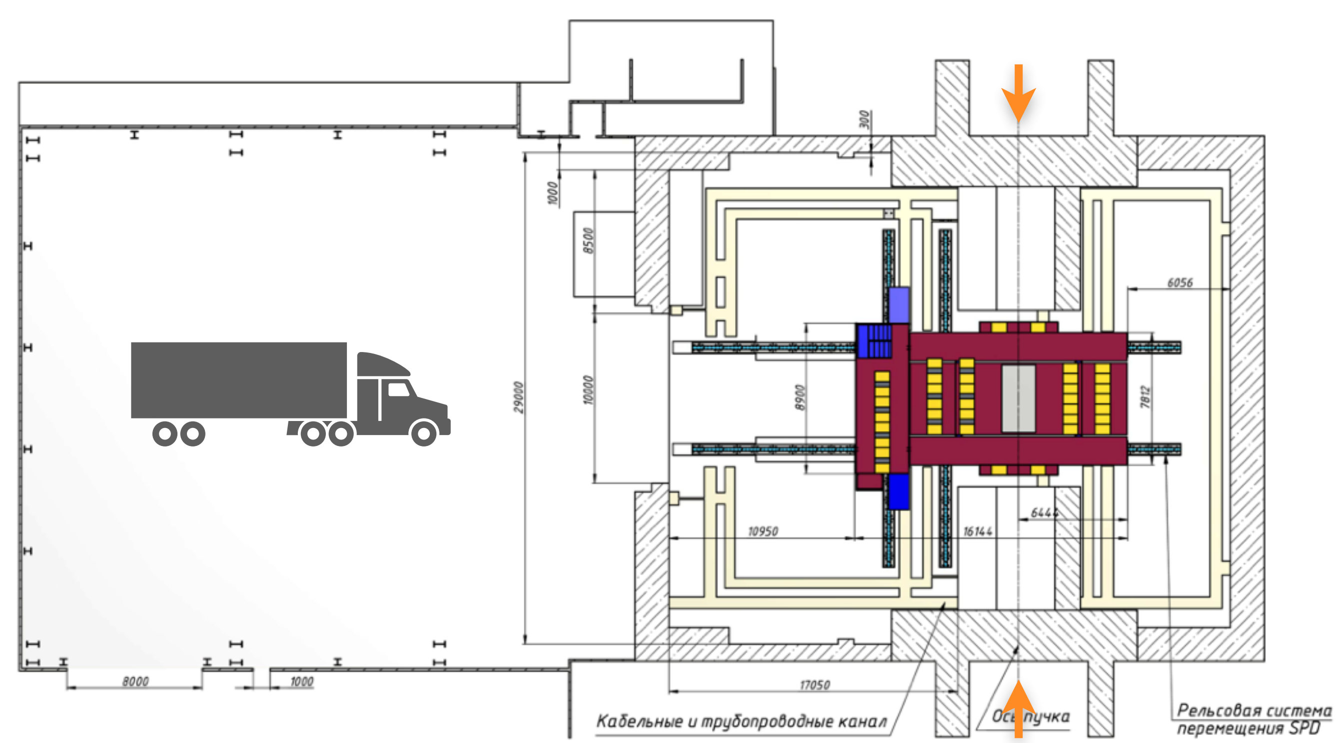


Assembling position

- Primary assembling of detectors can be done in the unloading zone
- Overhead traveling crane with a maximum lifting capacity of 80 ton
- Assembling can proceed while MPD takes data
- Beam-line will be isolated from the assembling by concrete blocks (thickness 2.3 m)

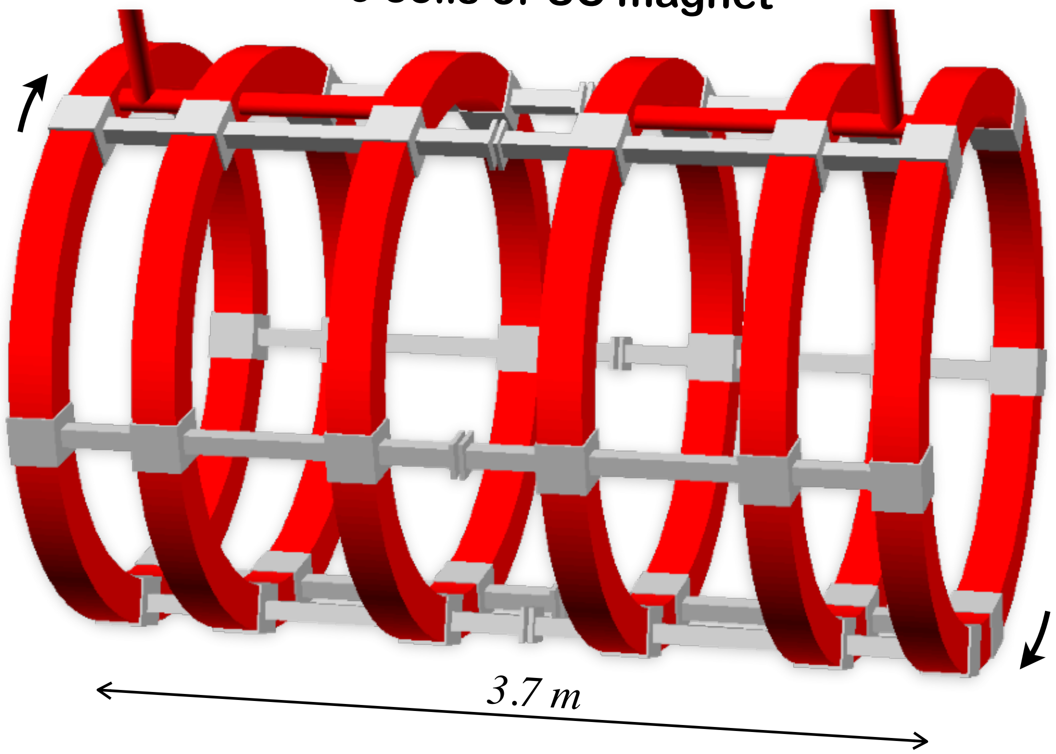
Beam position

- Rail system to transport the setup to the working position
- During data-taking the experimental site will be isolated from the unloading zone
- Unloading zone can be used for electronic barracks, counting house and so on

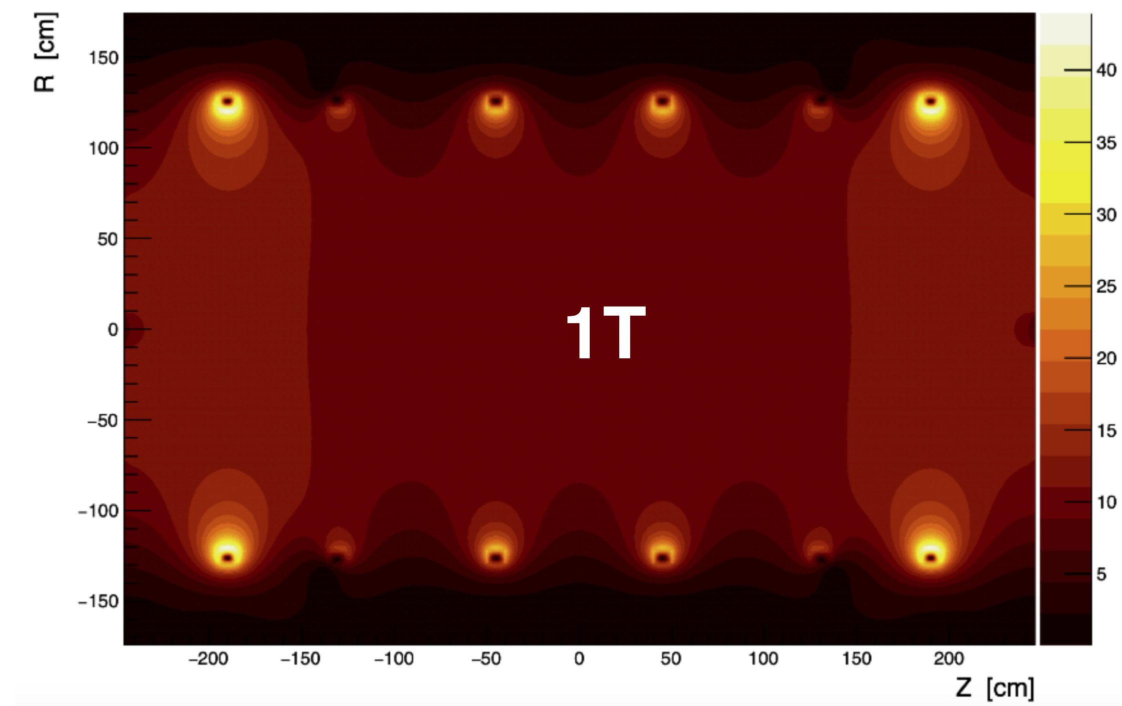


Superconductive magnetic system of SPD

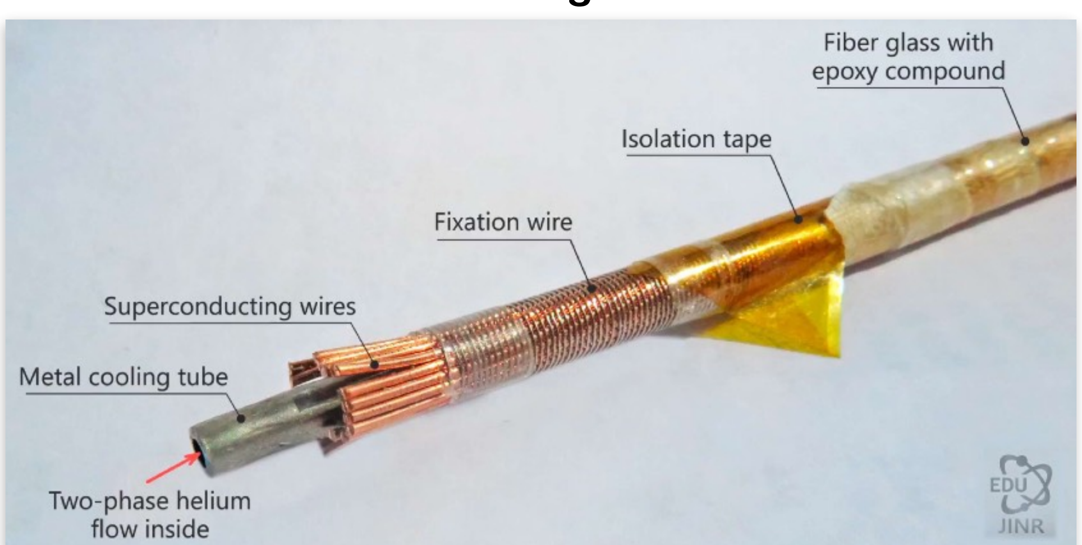
6 coils of SC magnet



Magnetic field [kG]

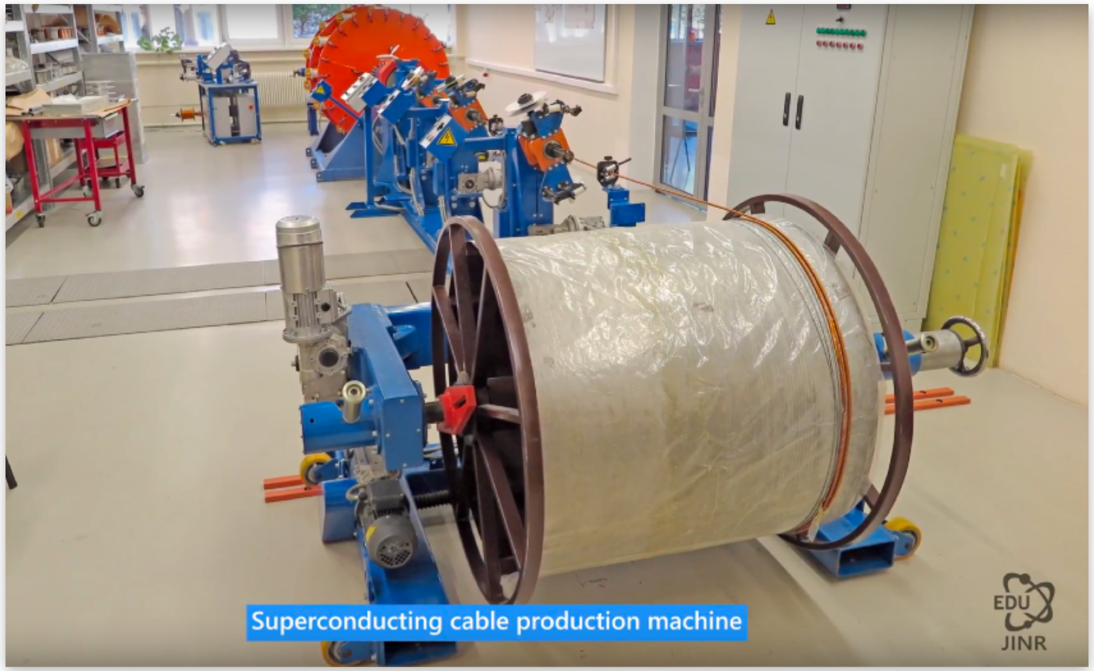


SC cable used for magnets of Nuclotron



- 6 isolated superconductive coils
    - Minimization of total amount of material
- Every coil consists of 60 turns of NbTi/CuNi cable with the 10 kA current
    - Total current: 60×10 kA = 600 kA · turn
- The same cable as used in Nuclotron magnets: hollow superconductor with the helium flows inside (~4 K)
- Similar cryogenic system as the one of Nuclotron

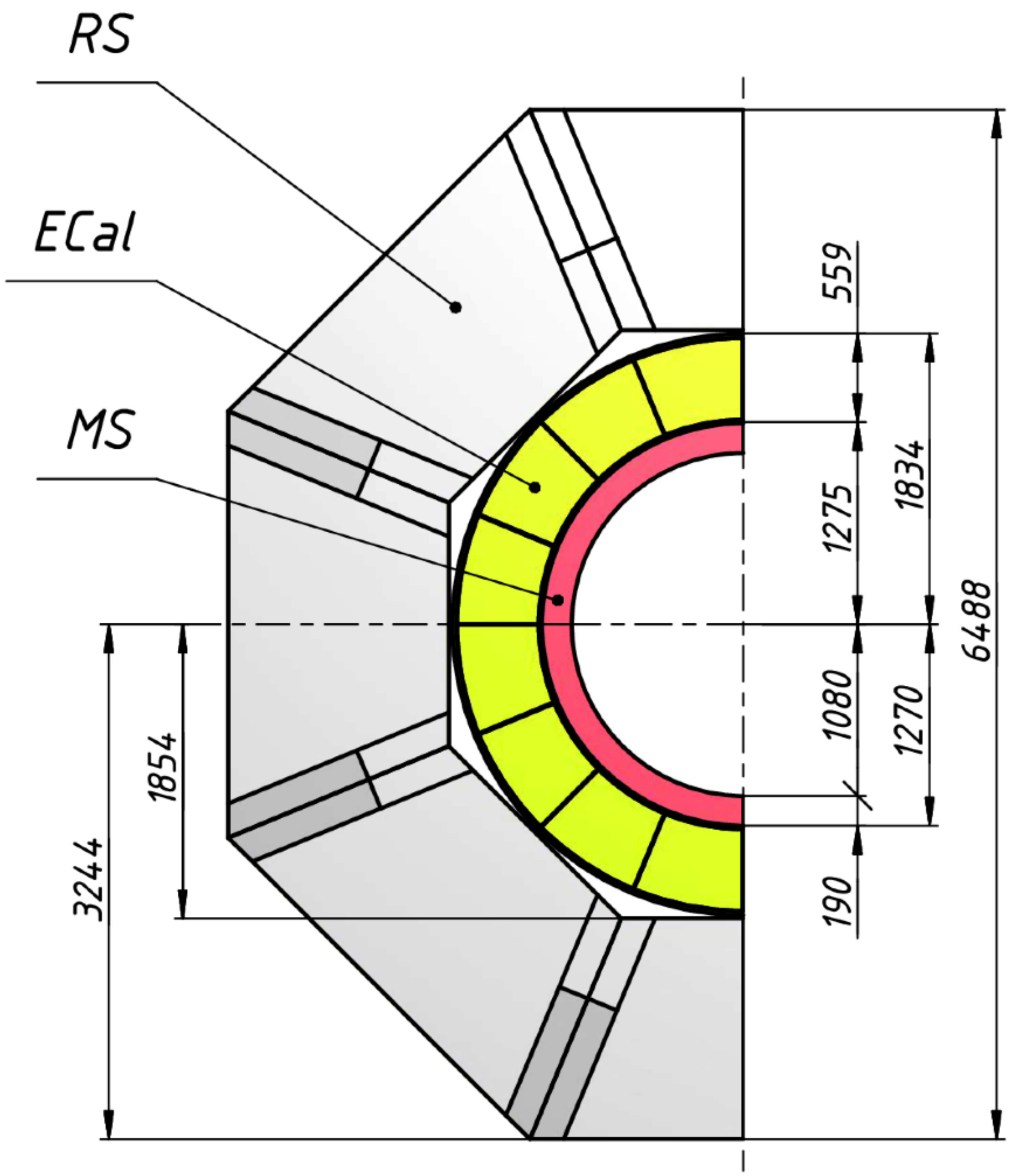
Production site for superconductive magnets of NICA



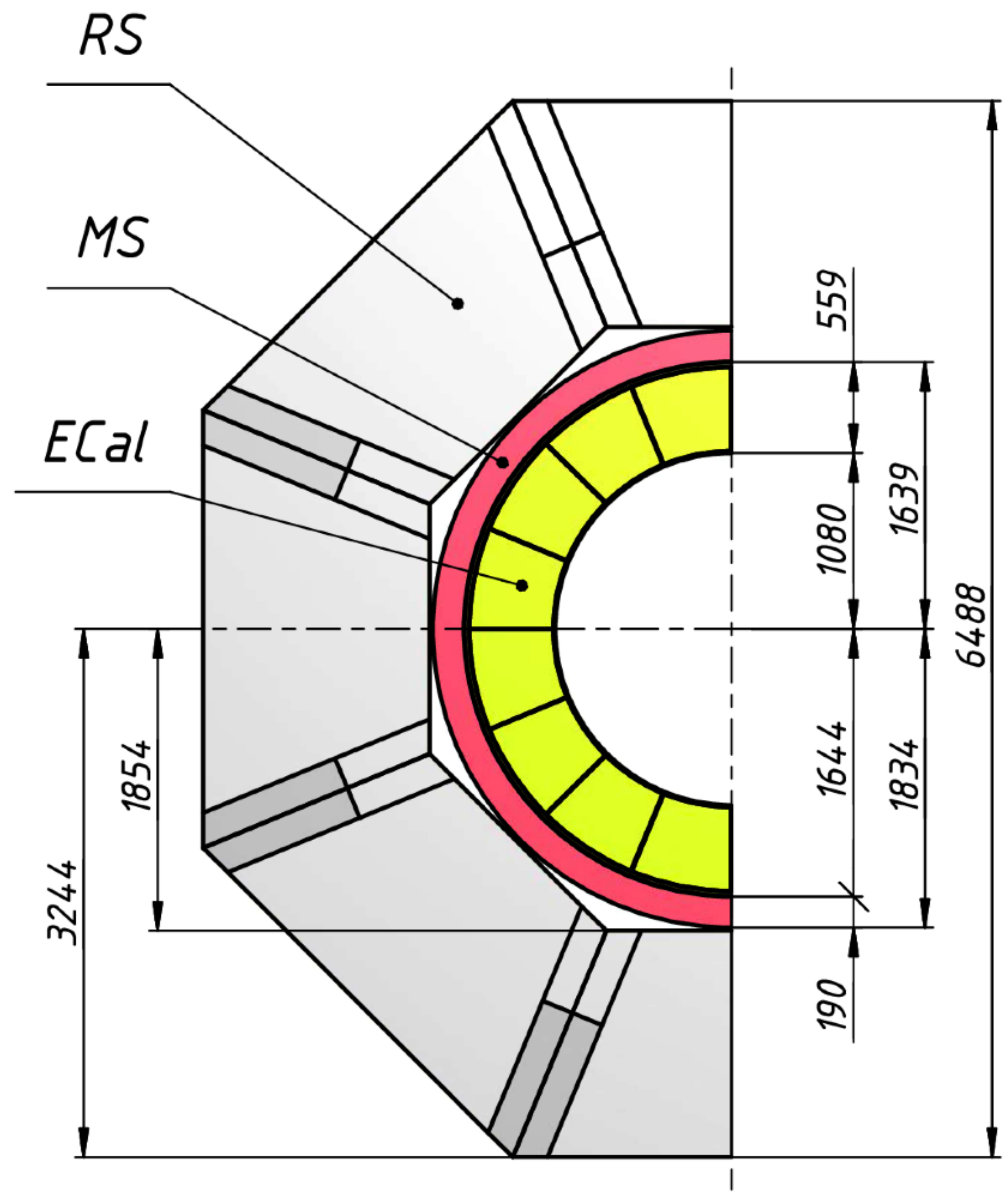
- Vast experience in production of SC magnets
  - 460 magnets to produce for NICA (buster + collider). ~75% has been completed.
  - Production of magnets for SIS100
  - Full chain of cryogenic tests
- Prototype production for SPD can start at the end of next year
  - Production for NICA will be finished next summer $\Rightarrow$ 1/2 of stand is unoccupied
- Option with external companies for magnet production is also considered

SC coil location with respect to ECal

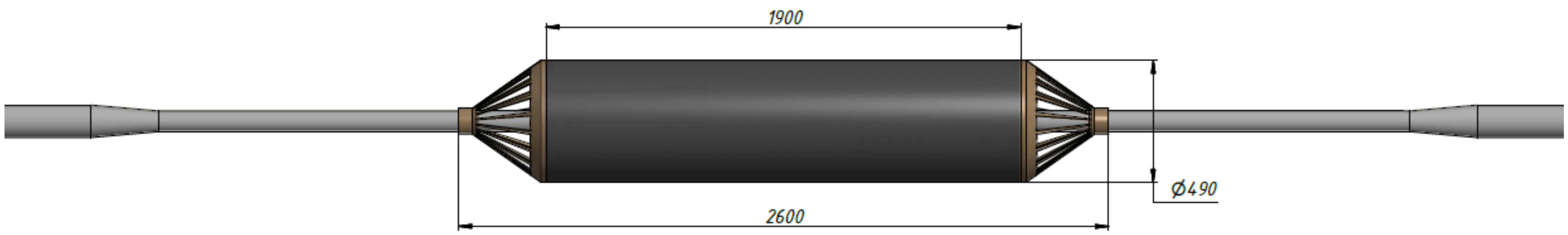
CDR version / A.Kovalenko
Coil cross-section is <u>20 cm x 20 cm</u>



Option for discussion / D.Nikiforov
Coil cross-section is <u>40 cm x 20 cm</u>

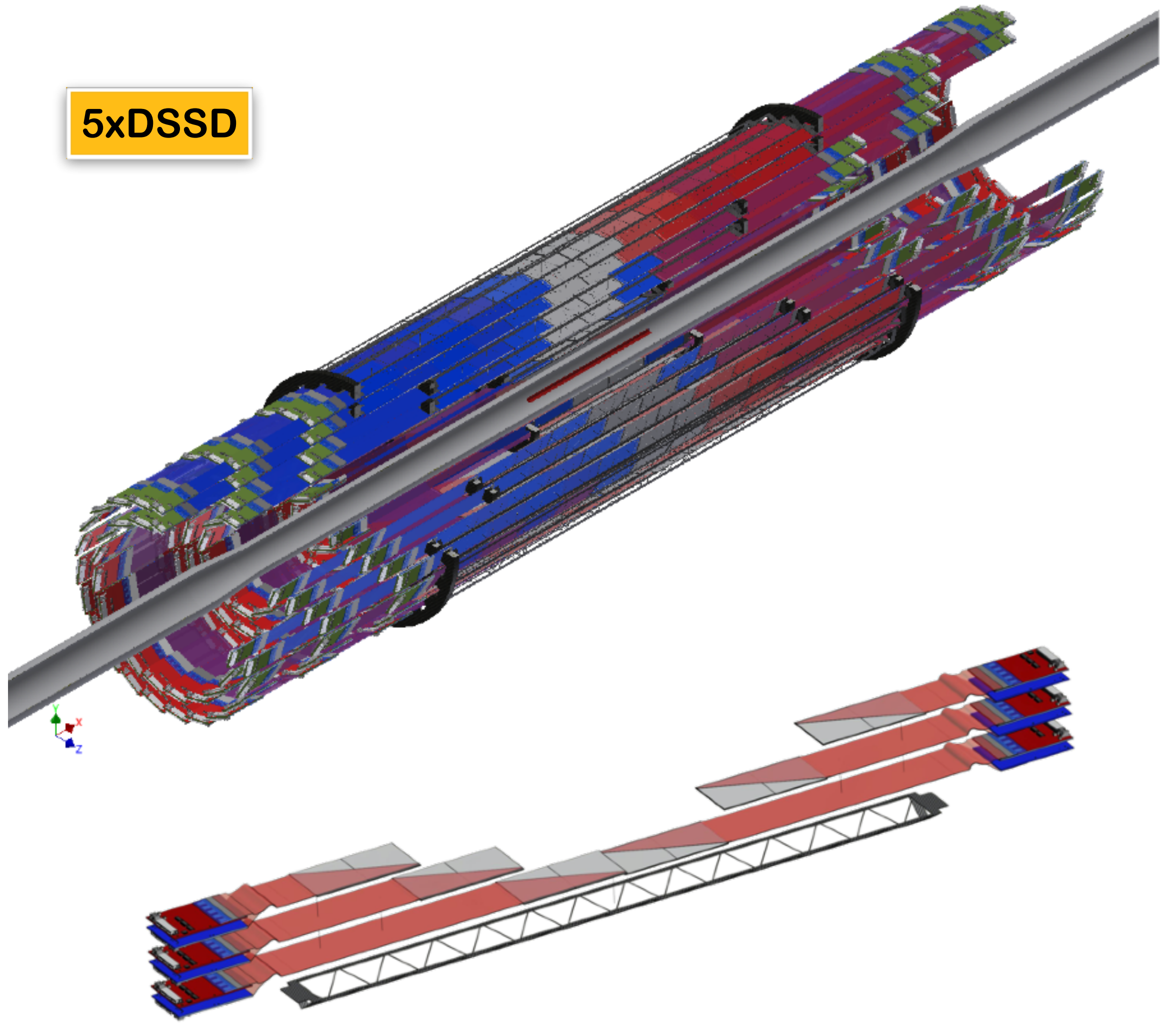


Vertex Detector (VD)



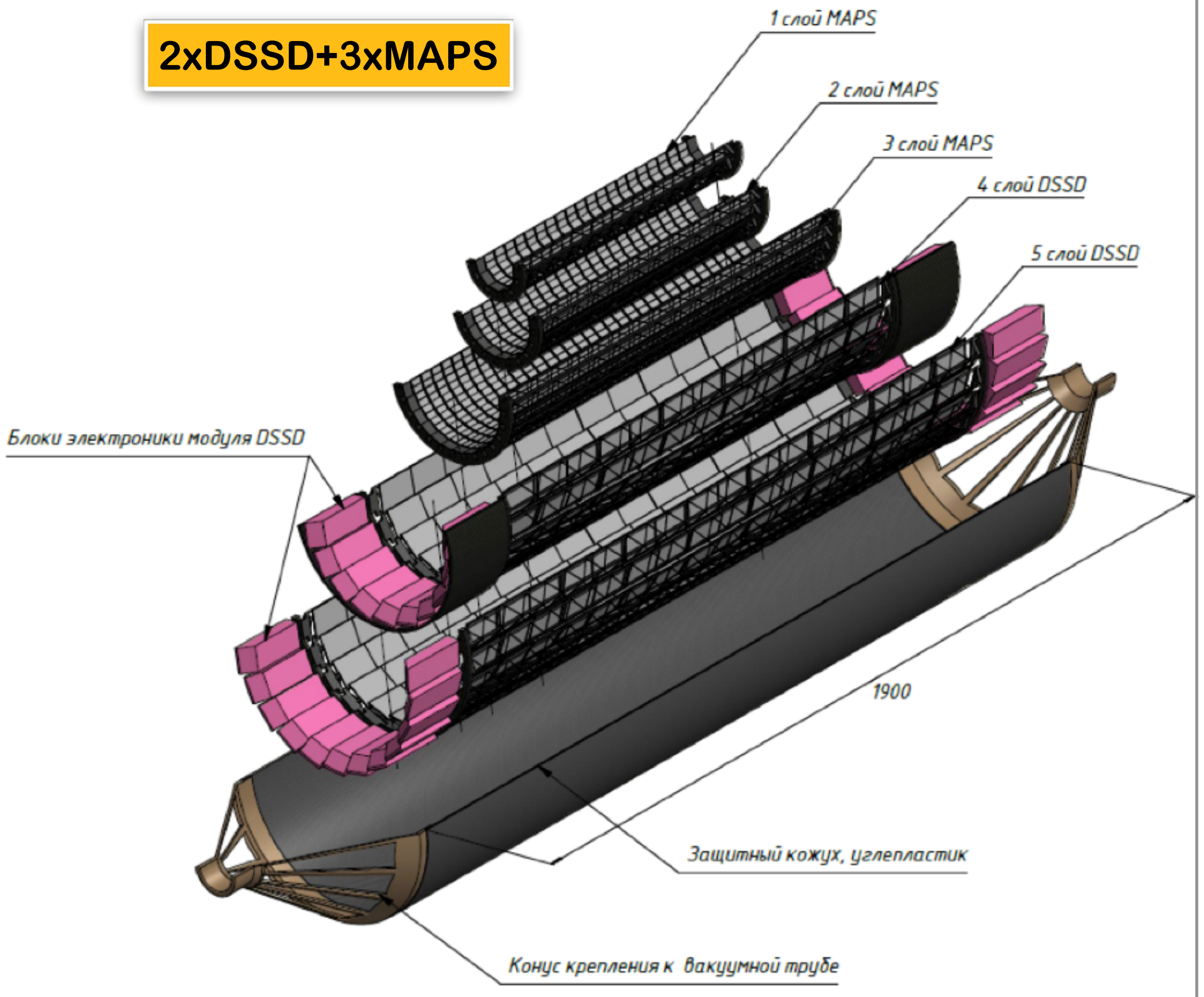
CDR version (end of 2020)

5xDSSD

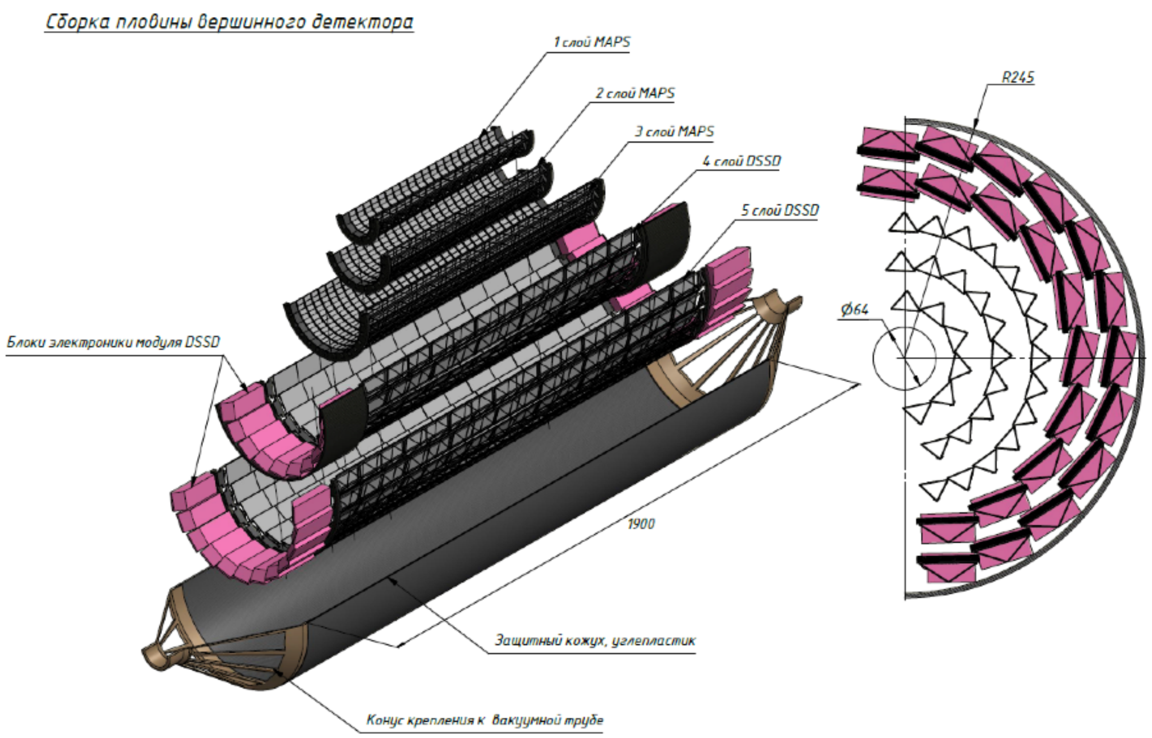


(May 2021)

2xDSSD+3xMAPS

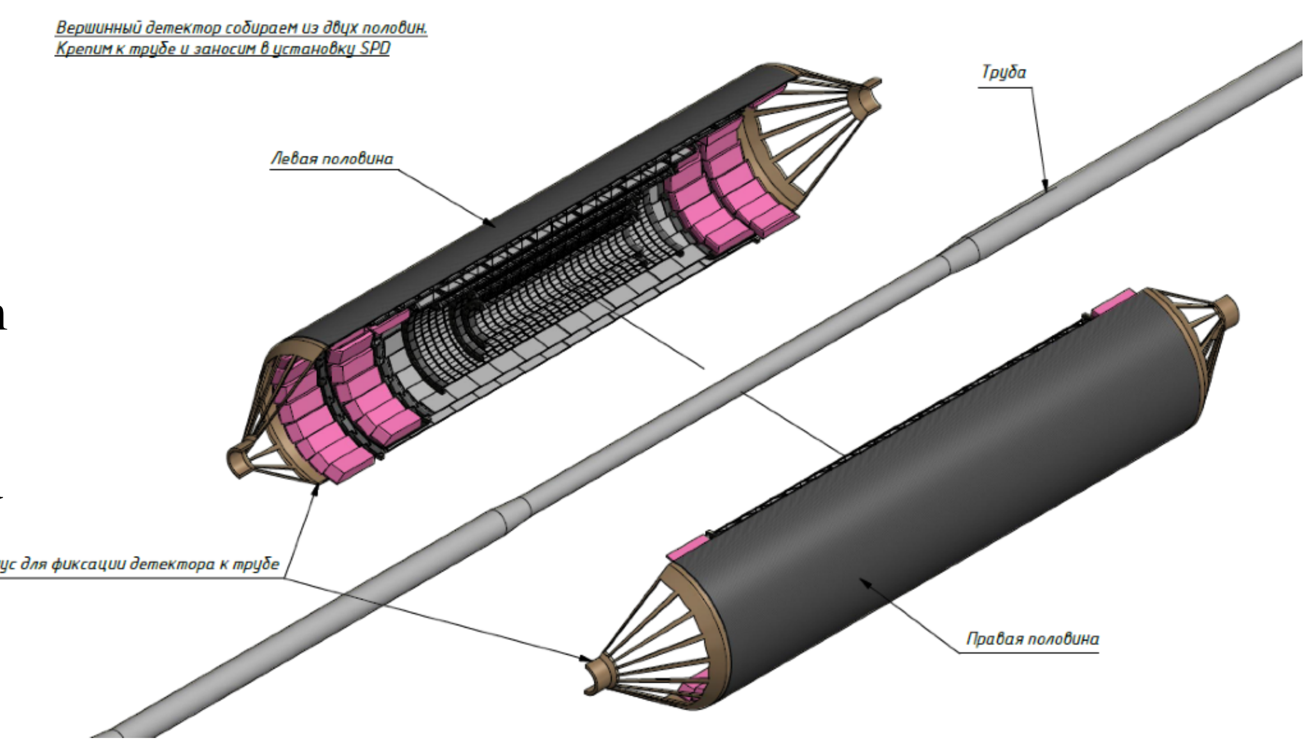


Vertex Detector (VD)

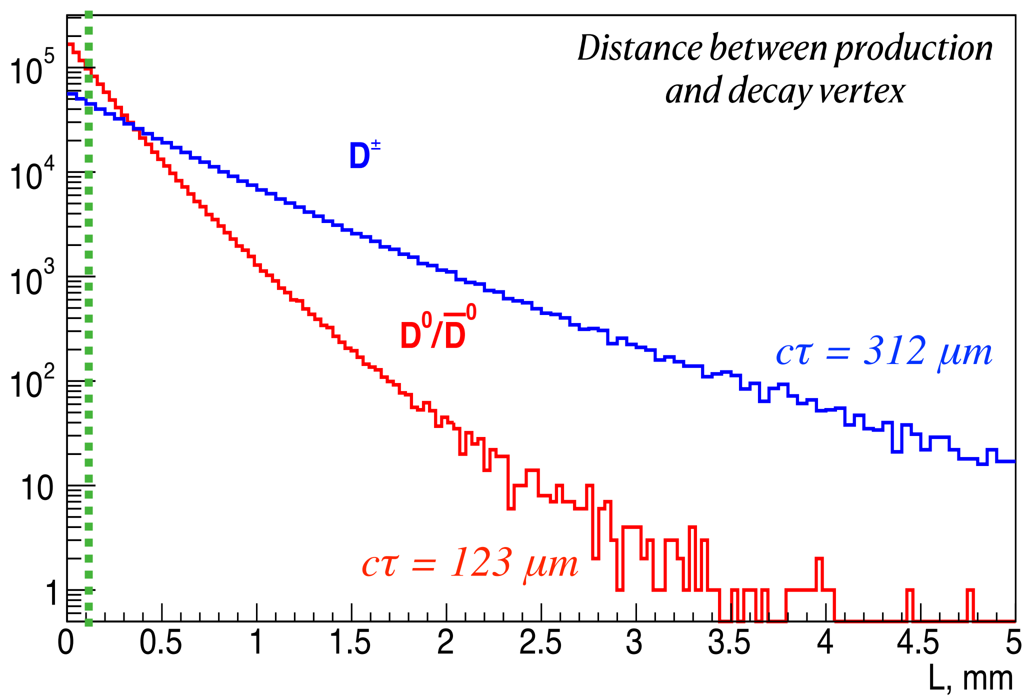


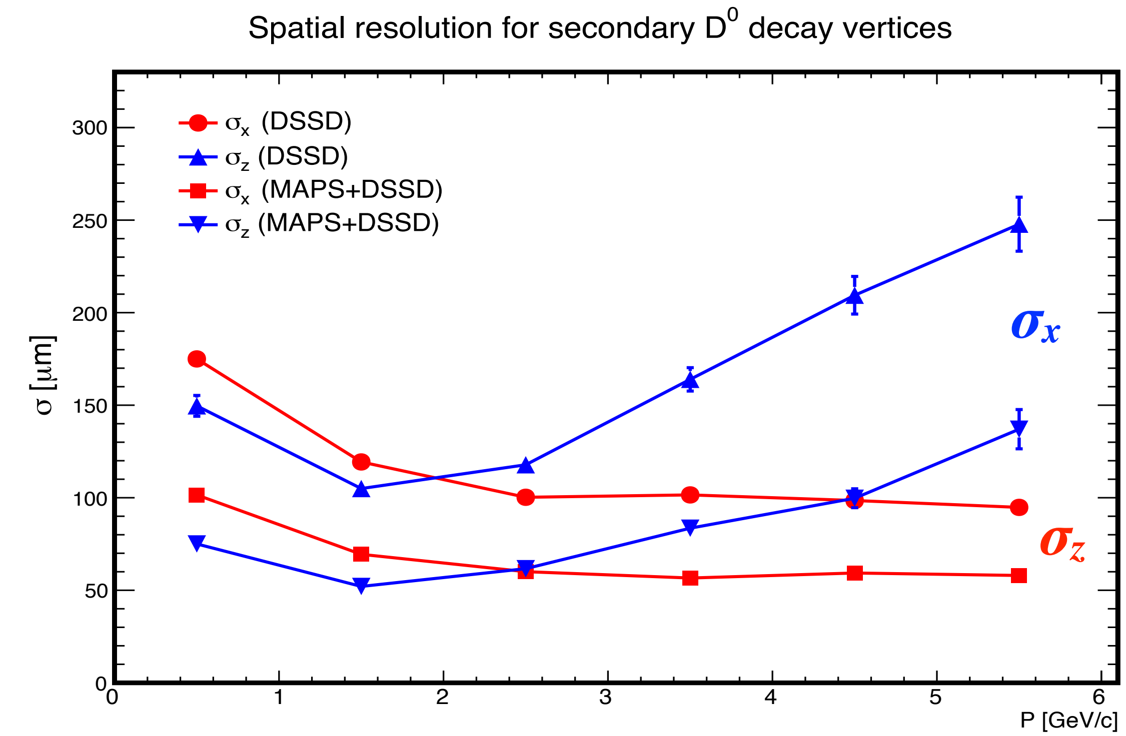
- Inner tracking system of SPD: barrel + endcaps
- Reconstruction of D meson decay vertices
- 5 layers = 2 DSSD + 3 MAPS
    - Double Side Silicone Strip (DSSD), 300 µm thickness, strip pitch 95 µm - 281 µm
    - Monolithic Active Pixel Sensors (MAPS) designed and produced for ALICE, pixel size 29 µm × 27 µm

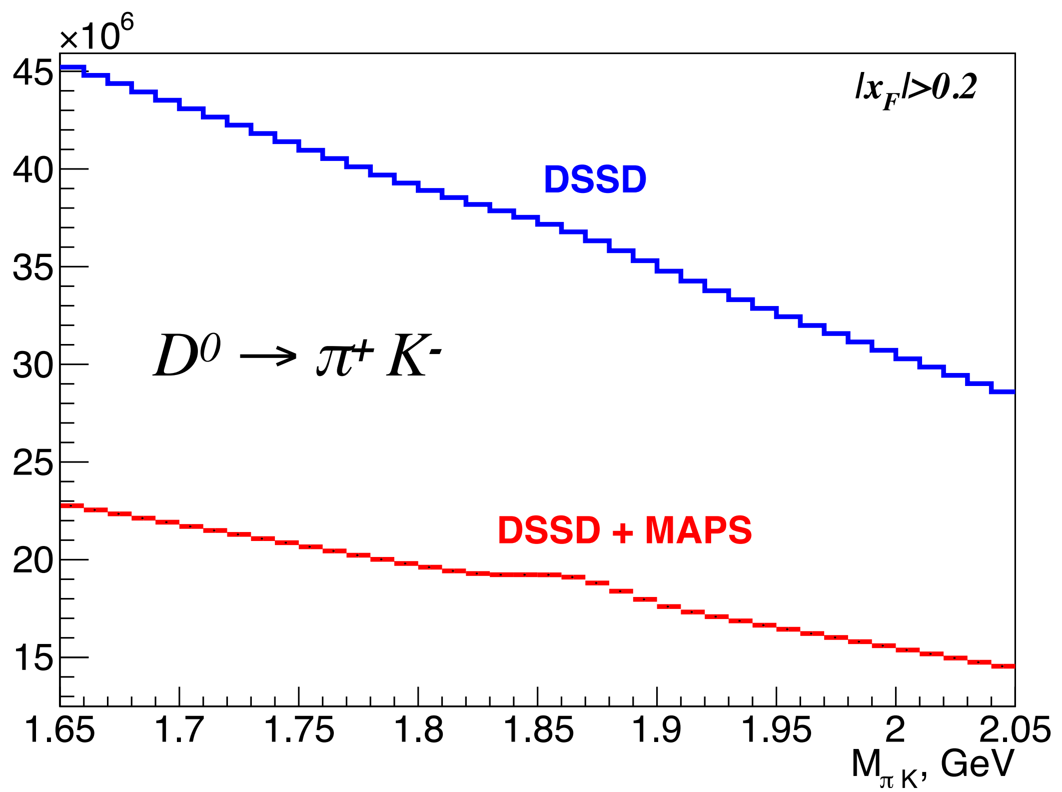
- Low material budget
- As close as possible to the beam pipe 5<R<25 cm
- Spatial resolution < 100 µm
- Use of MAPS improves the signal-to-background ratio of D meson peak by a factor of 3

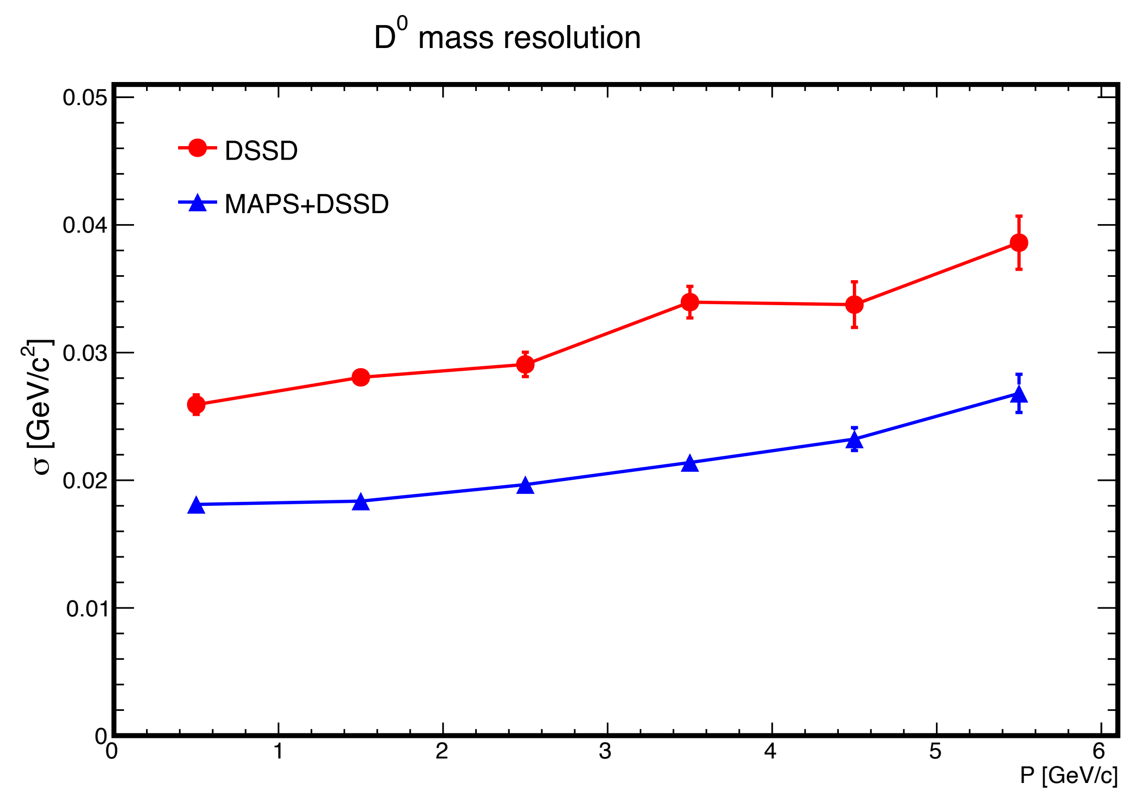


MC study: DSSD compared to MAPS+DSSD

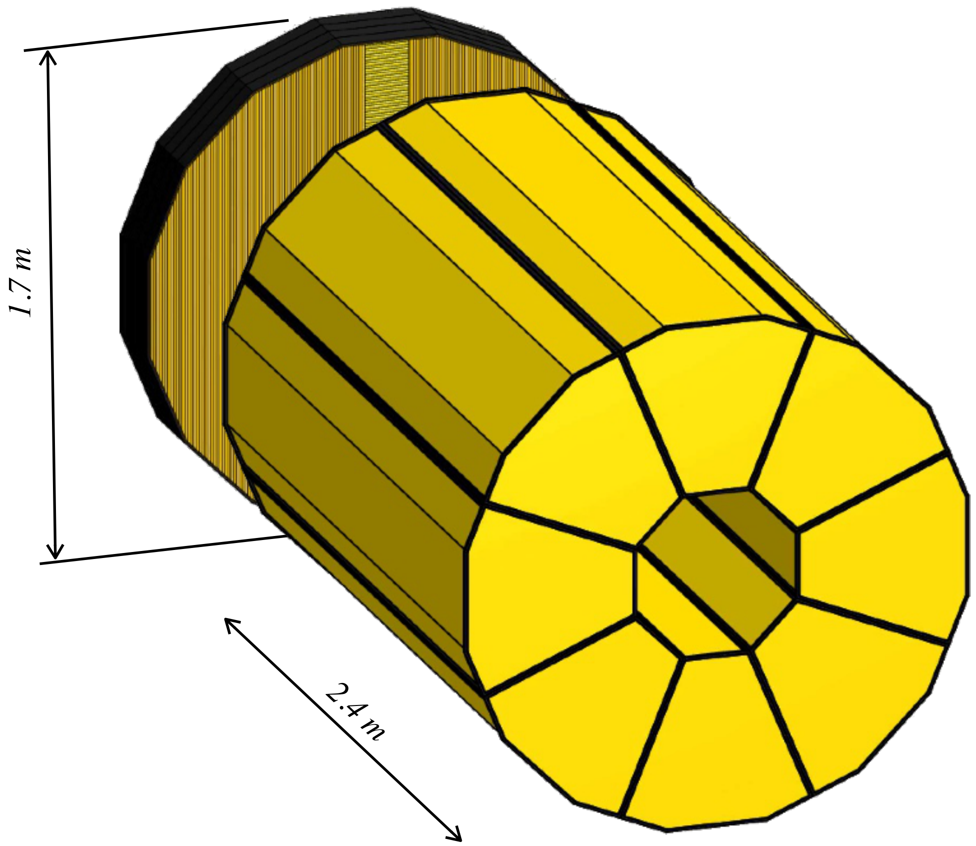








Straw Tracker (ST)

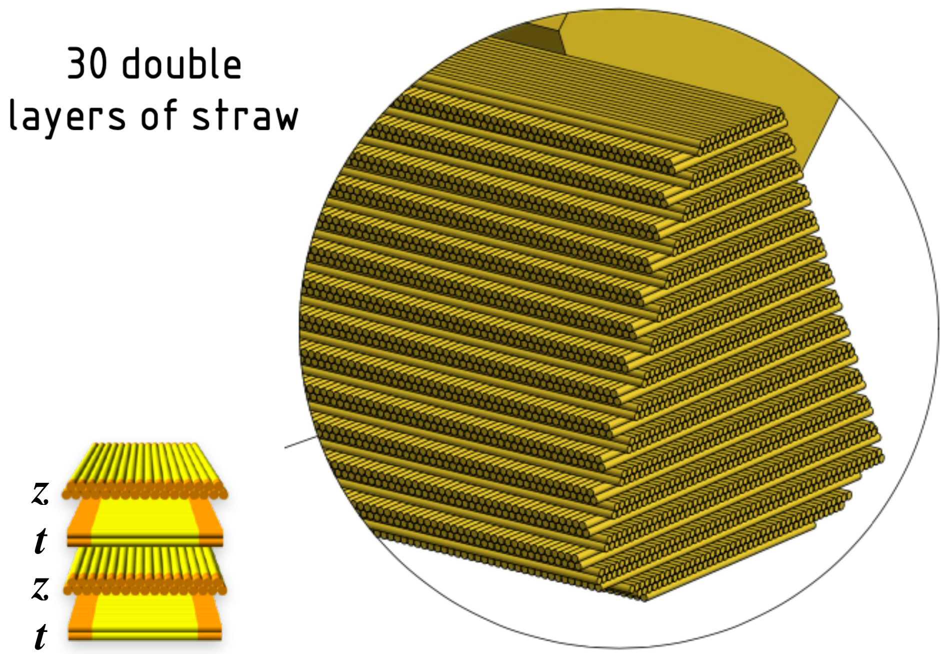


- Main tracker system of SPD
- Barrel is made of 8 modules with up to 30 double-layers, with the *ZUV* orientation
- Endcaps are made of 12 double-layers with the *XYUV* orientation
- Vast experience in straw production in JINR for several experiments: NA58, NA62, NA64; prototypes for: COZY-TOF, CREAM, SHiP, COMET, DUNE.

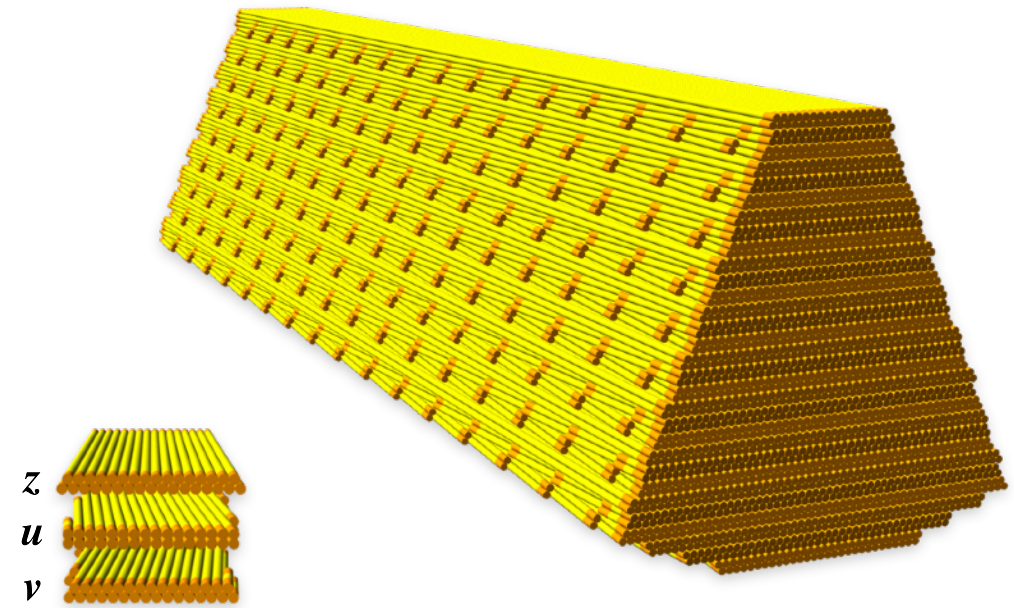
- Maximum drift time of 120 ns for ∅=10mm straw
- Spatial resolution of 150 µm
- Expected DAQ rate up to half MHz (electronics is limiting factor)
- Number of readout channels ~50k
- Can be used for PID if energy deposition if detected

Straw Tracker (ST)

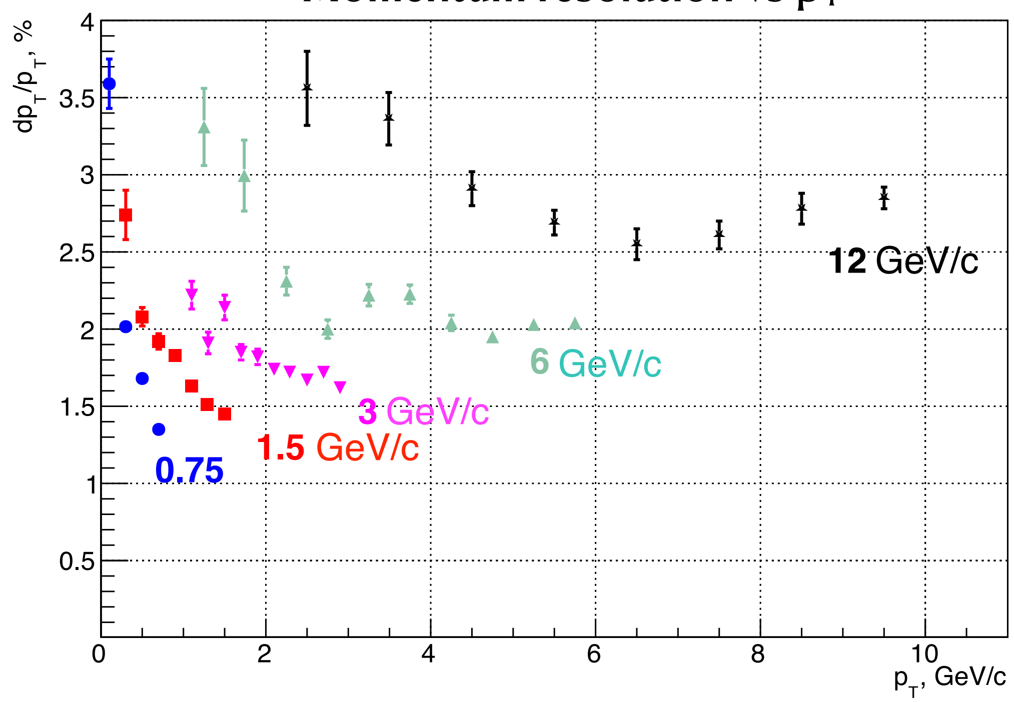
CDR version (end of 2020)



Layers 10x(ZUV)

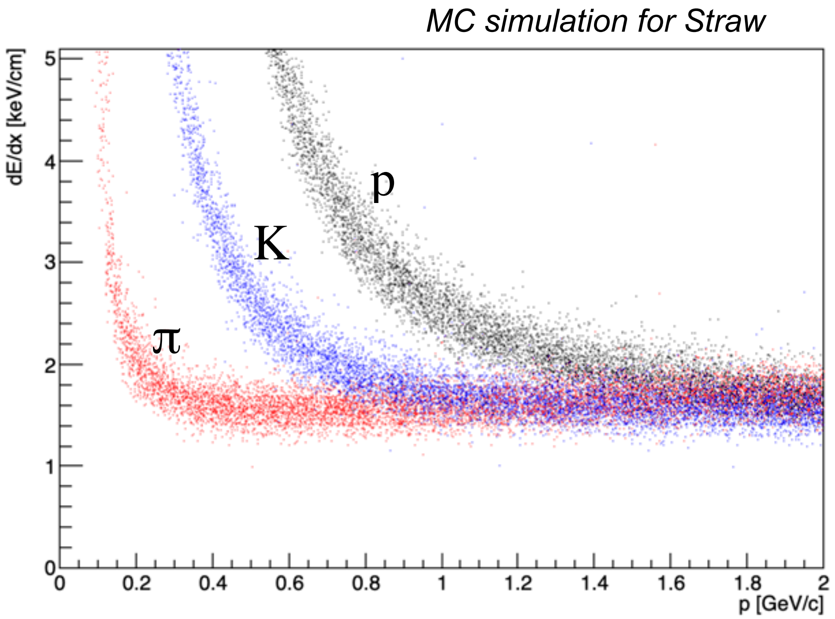


Momentum resolution vs p_T

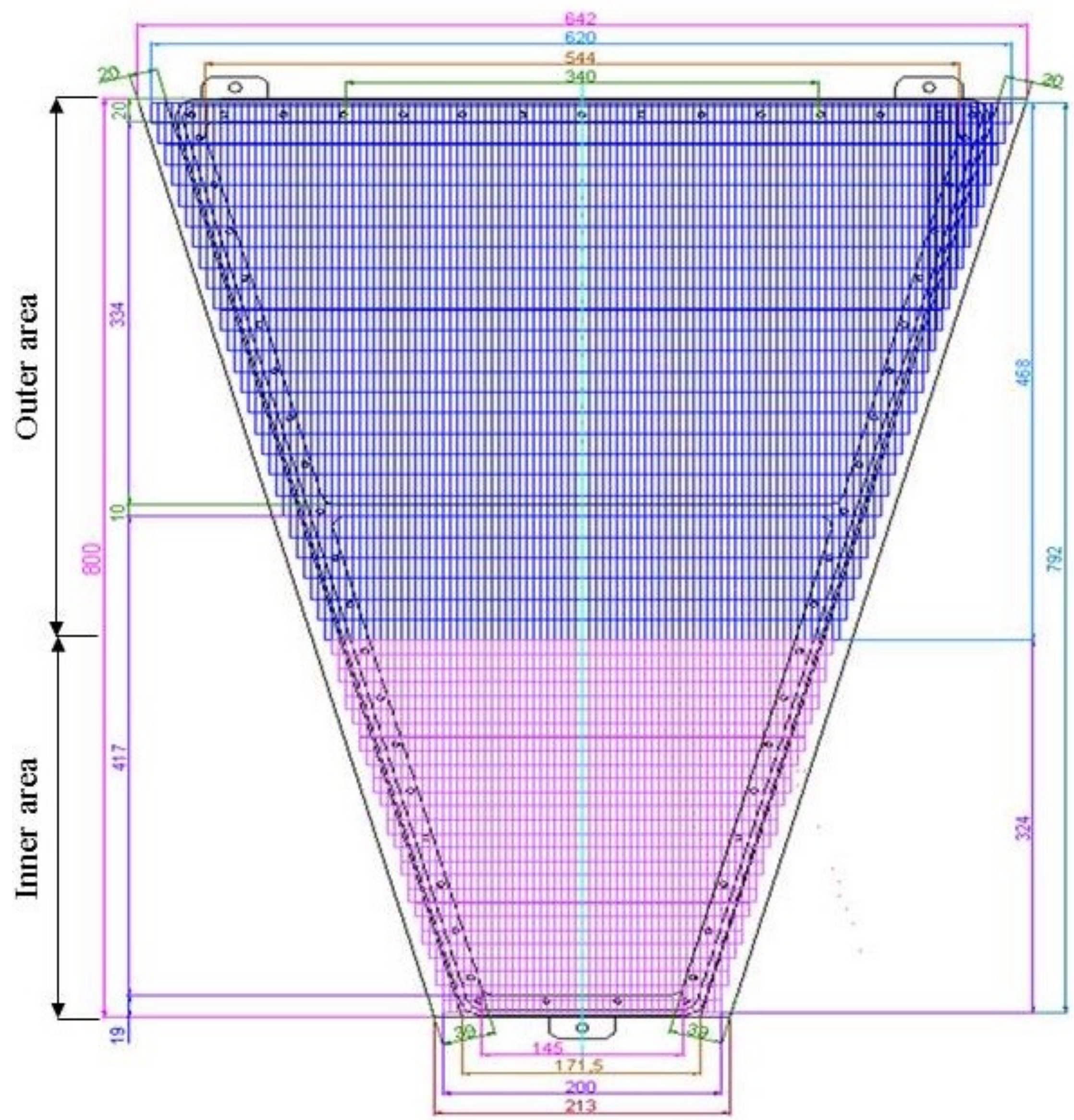


- Majority of tubes should be oriented ⊥ to the bending plane
- Number of channels can be reduced by a factor of 3
- Less dead space due to covers & electronics

PID: TPC compared to Straw in respect of the dE/dx analysis



TPC of MPD

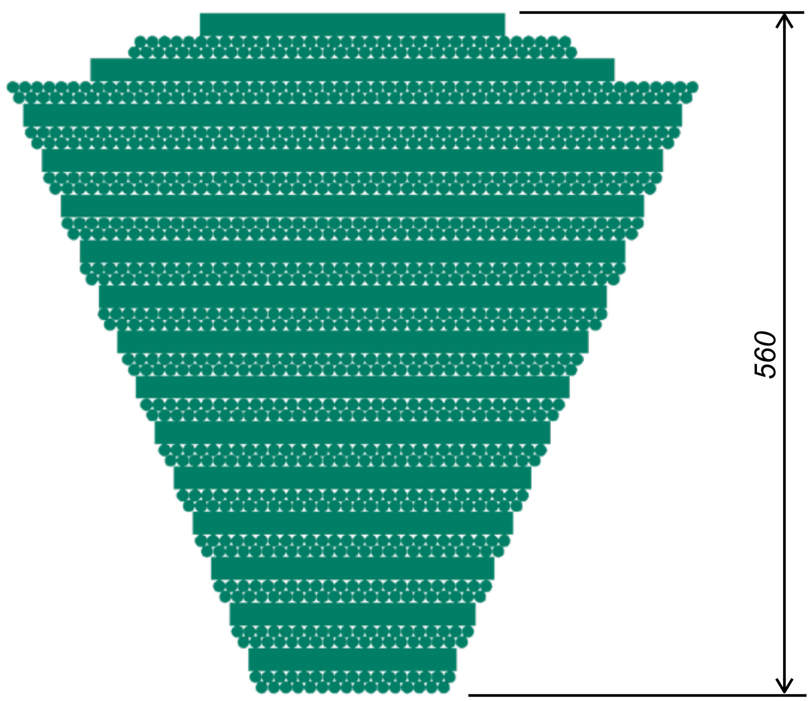


Inner pads: S = 5mm x 12mm = 60mm²

Outer pads: S = 5mm x 18mm = 90mm²

Maximum drift time 30 µs

Straw of SPD



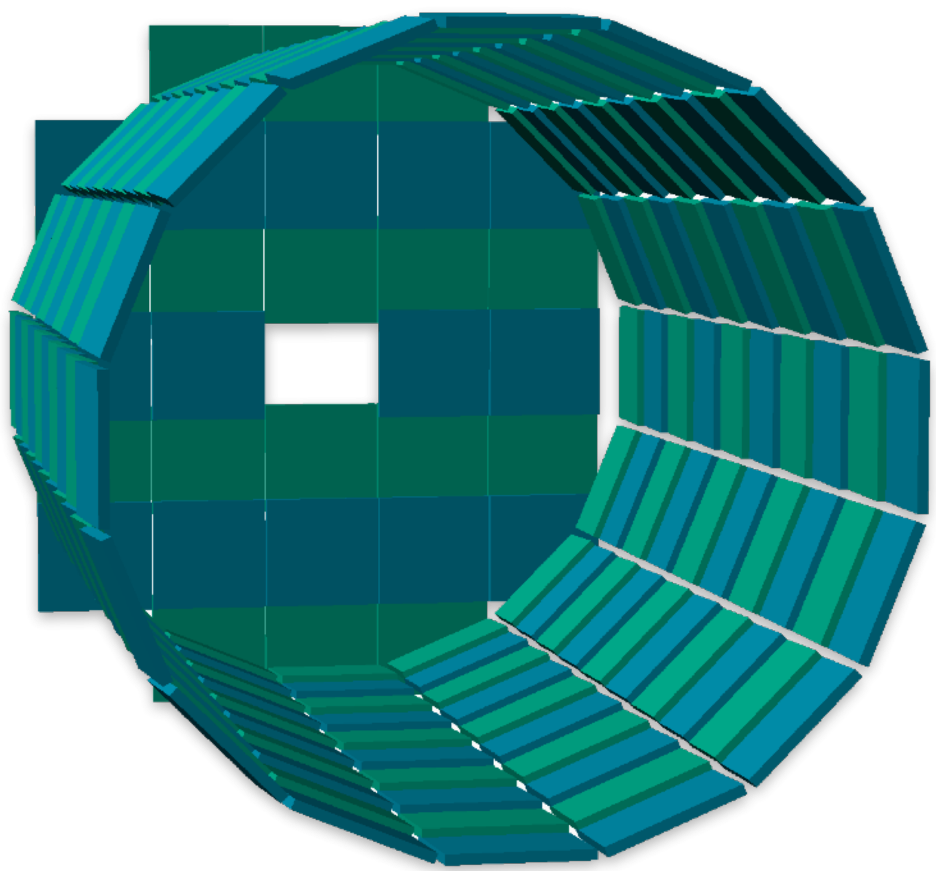
∅=10mm straw: S = 78mm²

∅=5mm straw: S = 20mm²

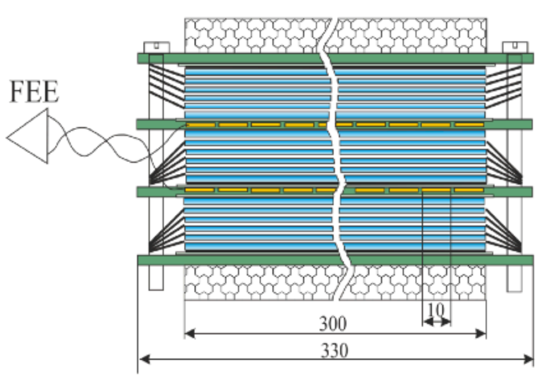
Maximum drift time 120 ns

PID: Time-of-Flight (TOF)

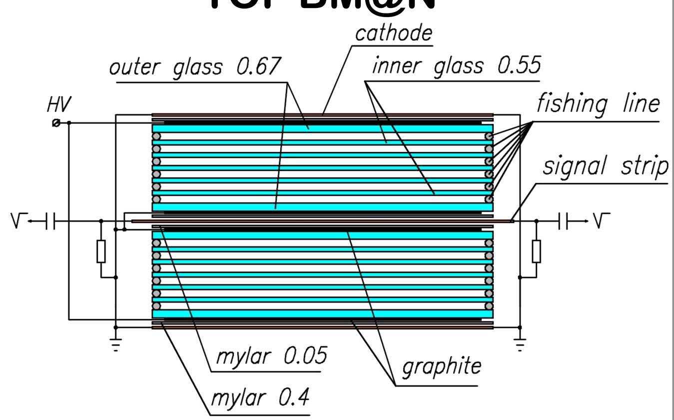
mRPC option



TOF MPD

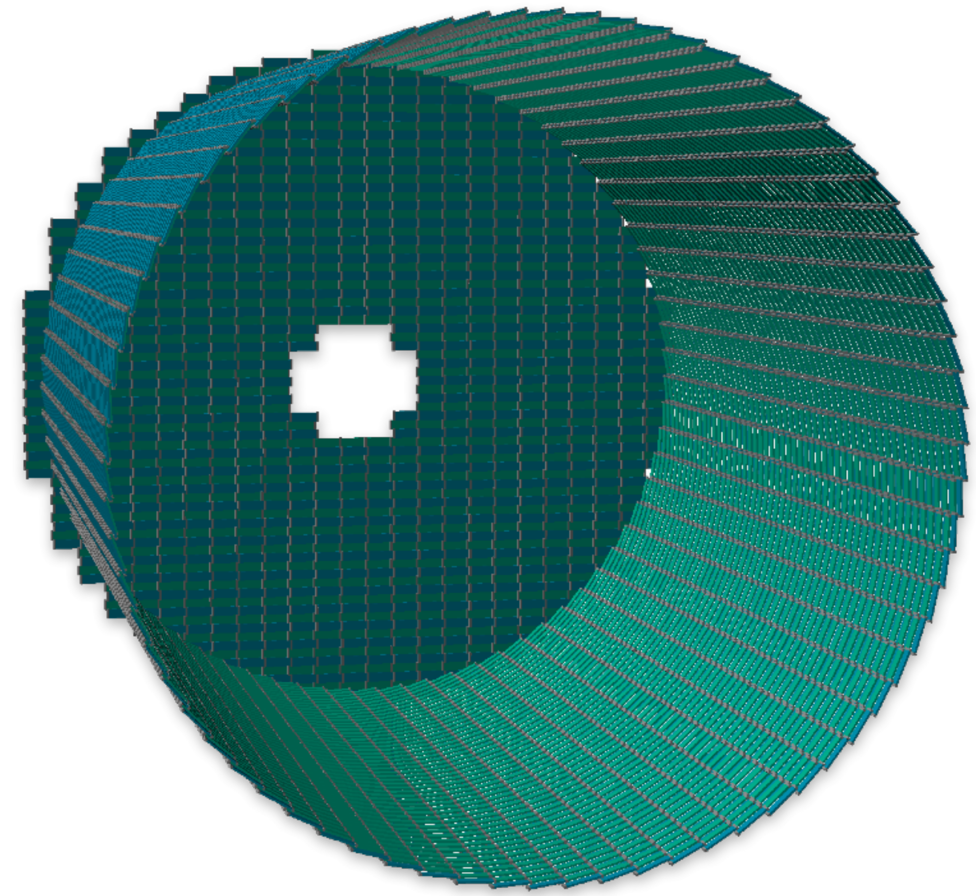


TOF BM@N

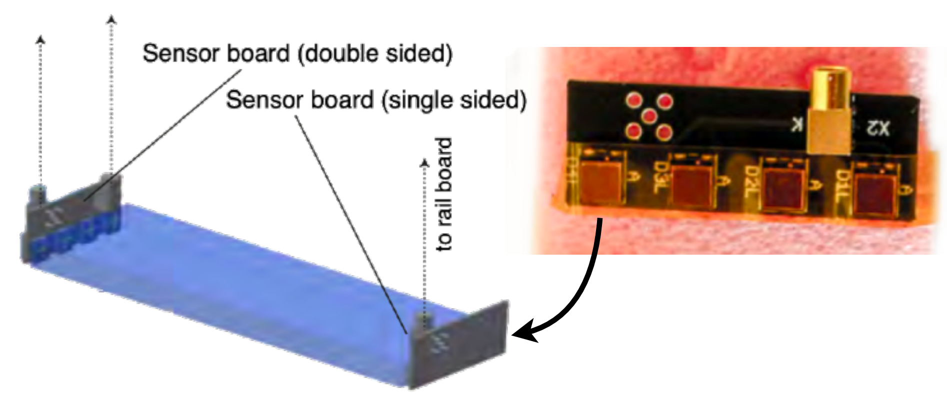


MPD NICA TDR TOF, Nov 2018, Rev 3.0

Plastic scintillator option

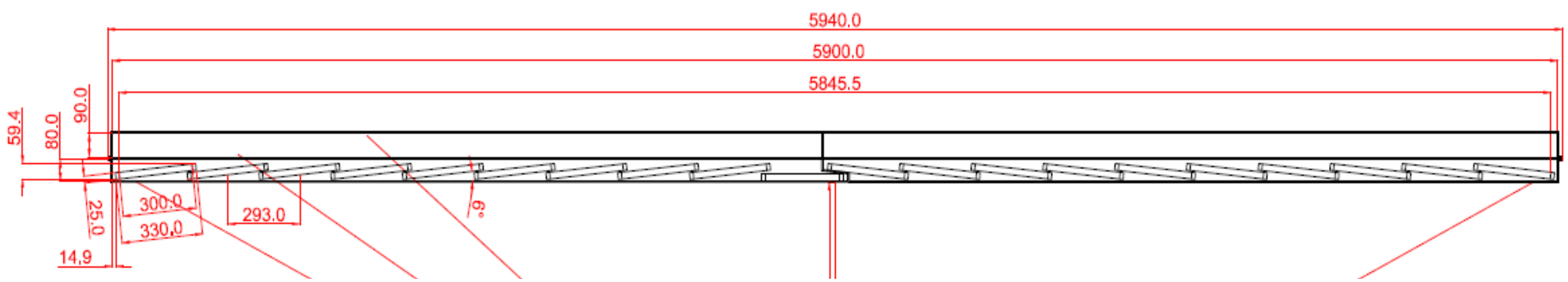


Inspired by the TOF of PANDA

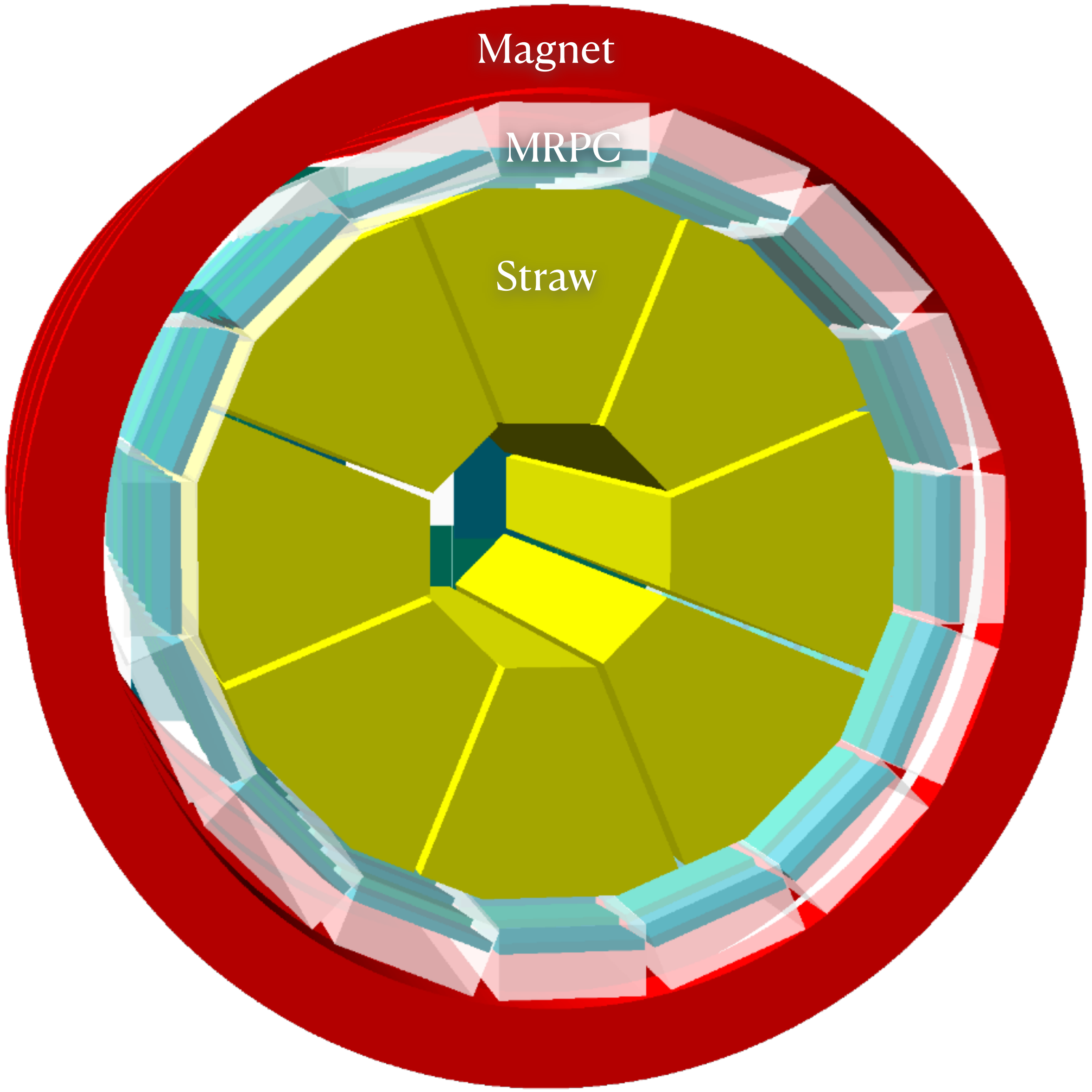


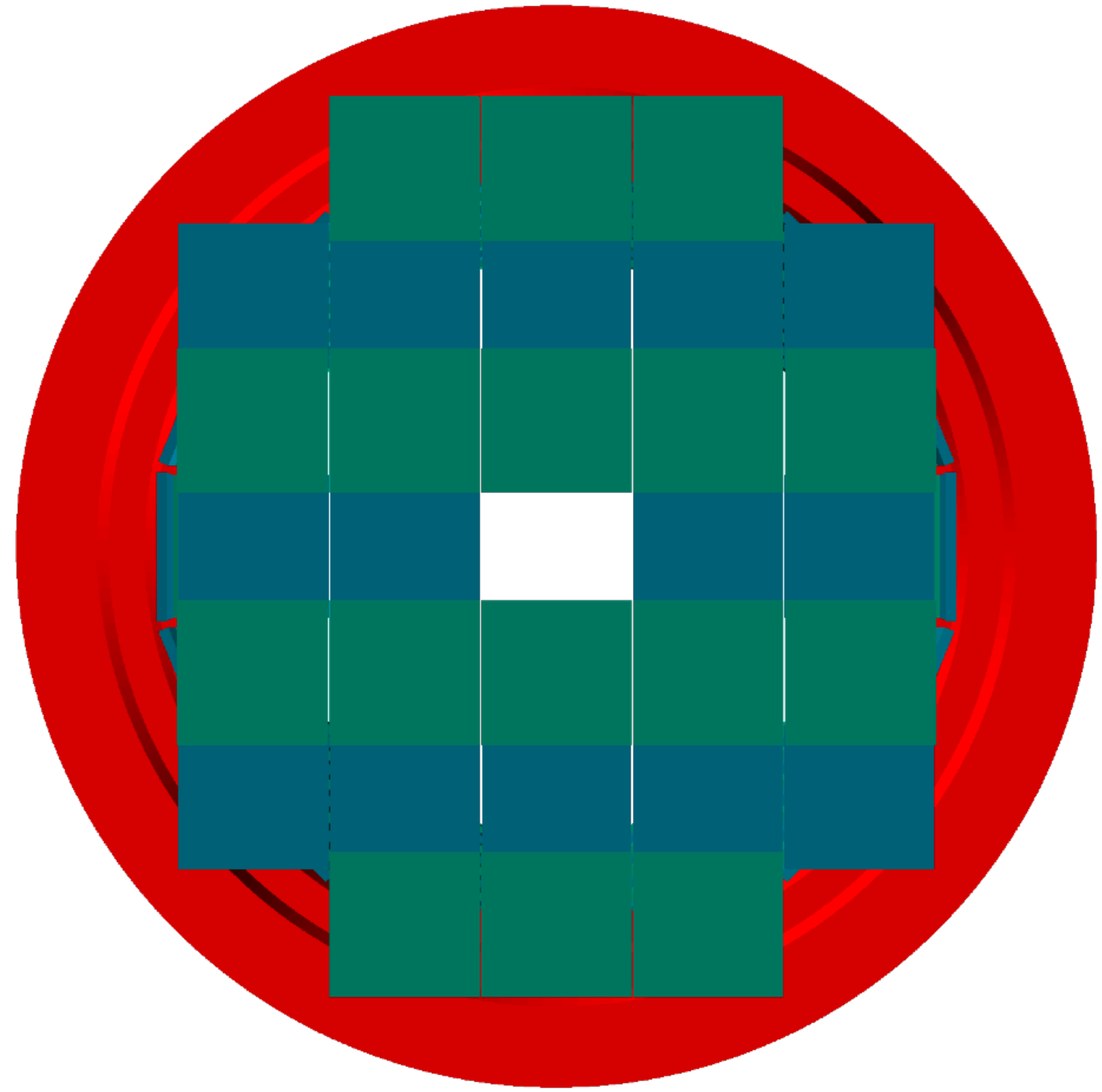
TDR for the PANDA Barrel TOF, July 4, 2018

Assembling room for the MRPC barrel of MPD in JINR/LHEP



Mechanics issues of the MRPC option for TOF/SPD

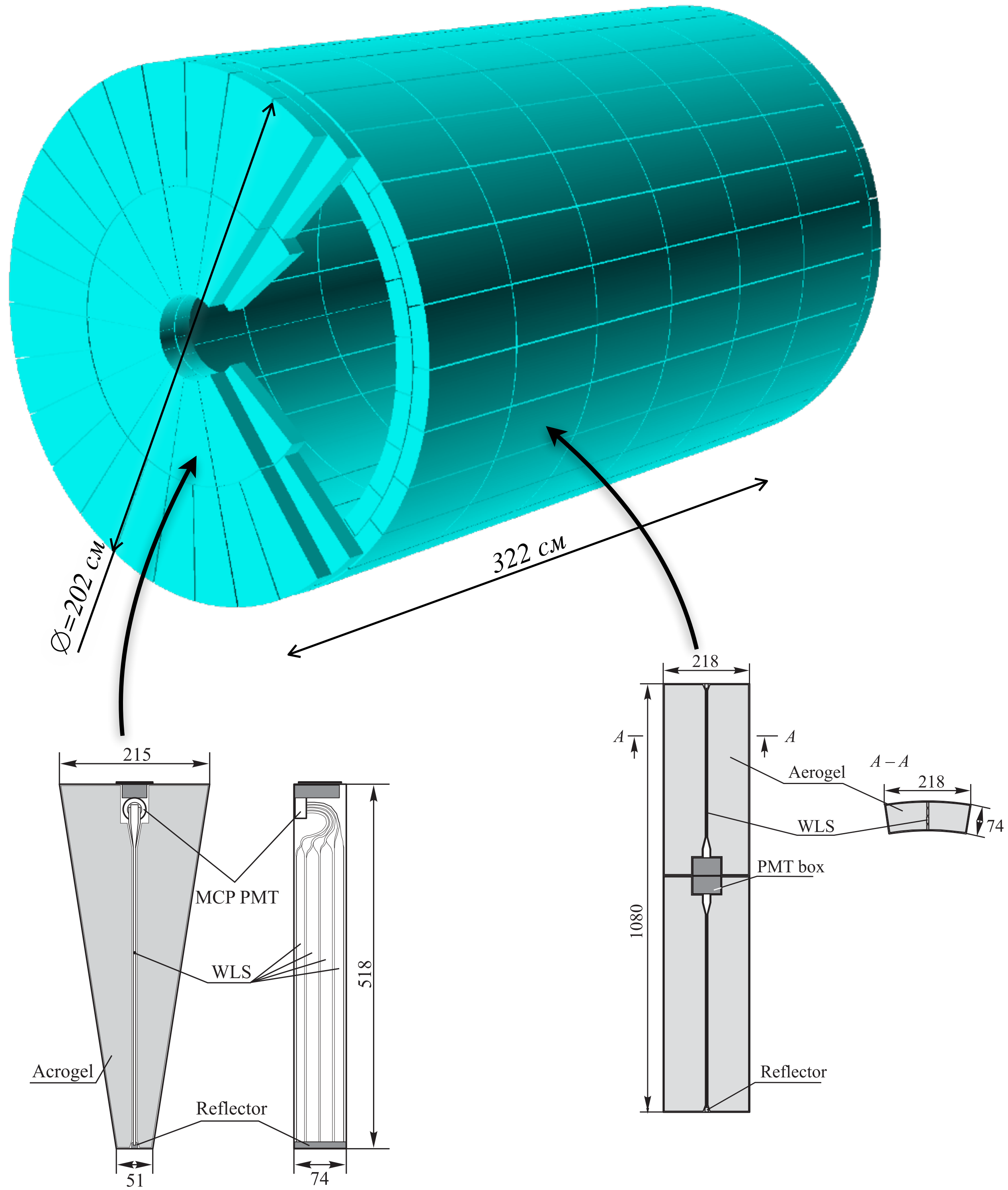


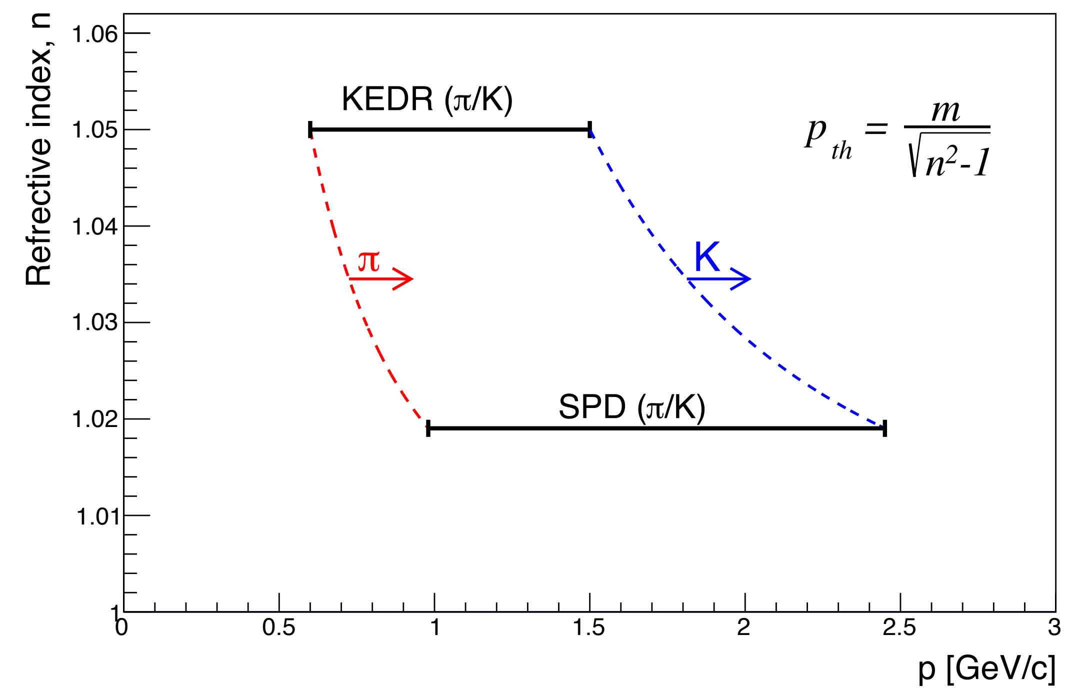


- MPD module has 17cm thickness radially → no space for another PID detector

- To be removable, the diameter of the TOF end-cap must be smaller than the one of the magnet coil
- Either large dead regions or conflict with coils

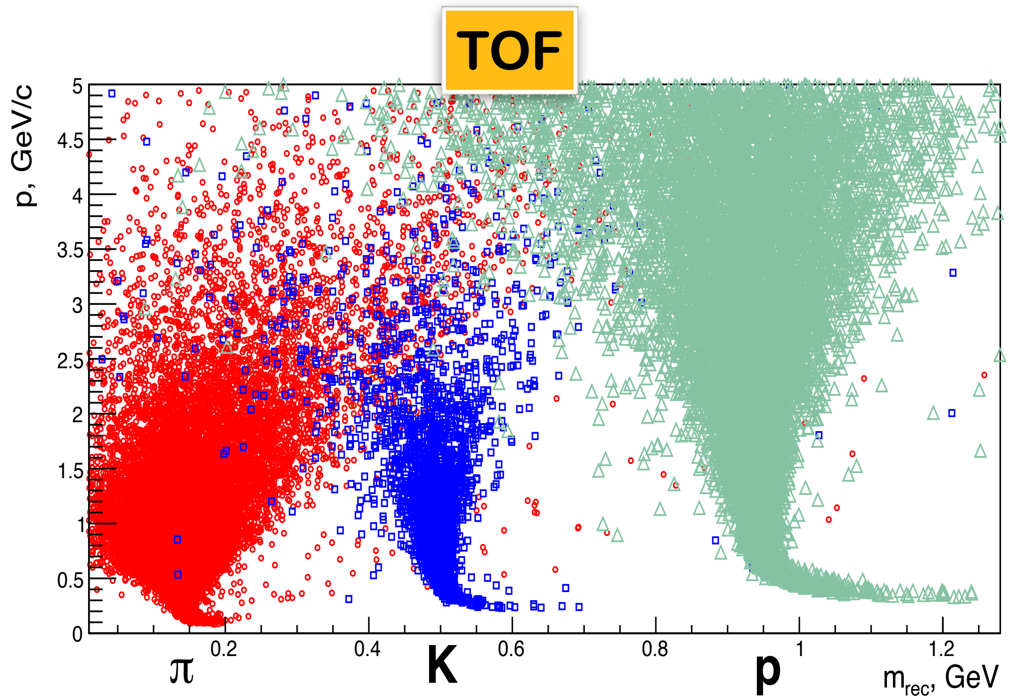
Aerogel counters for PID

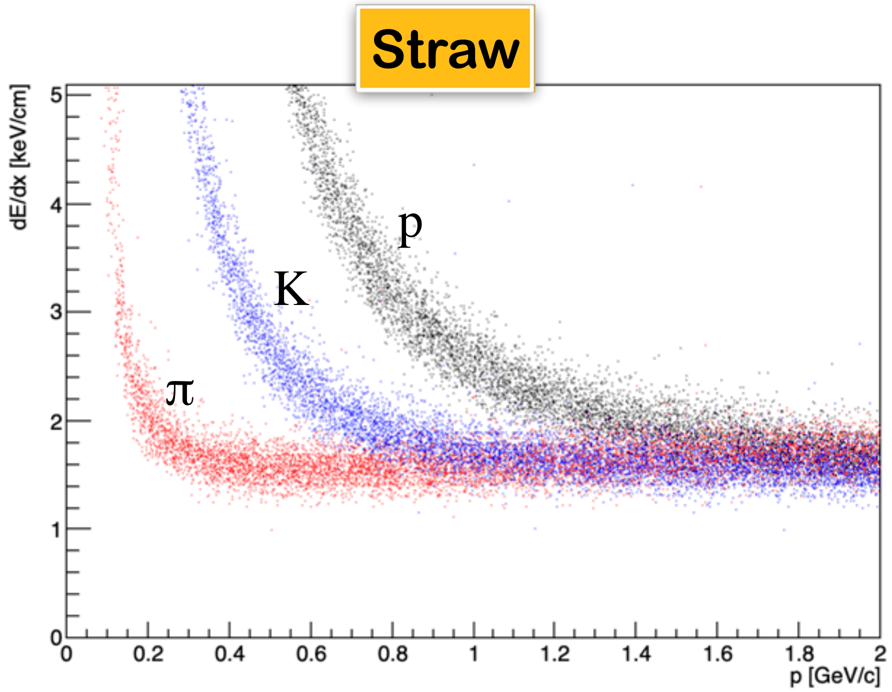


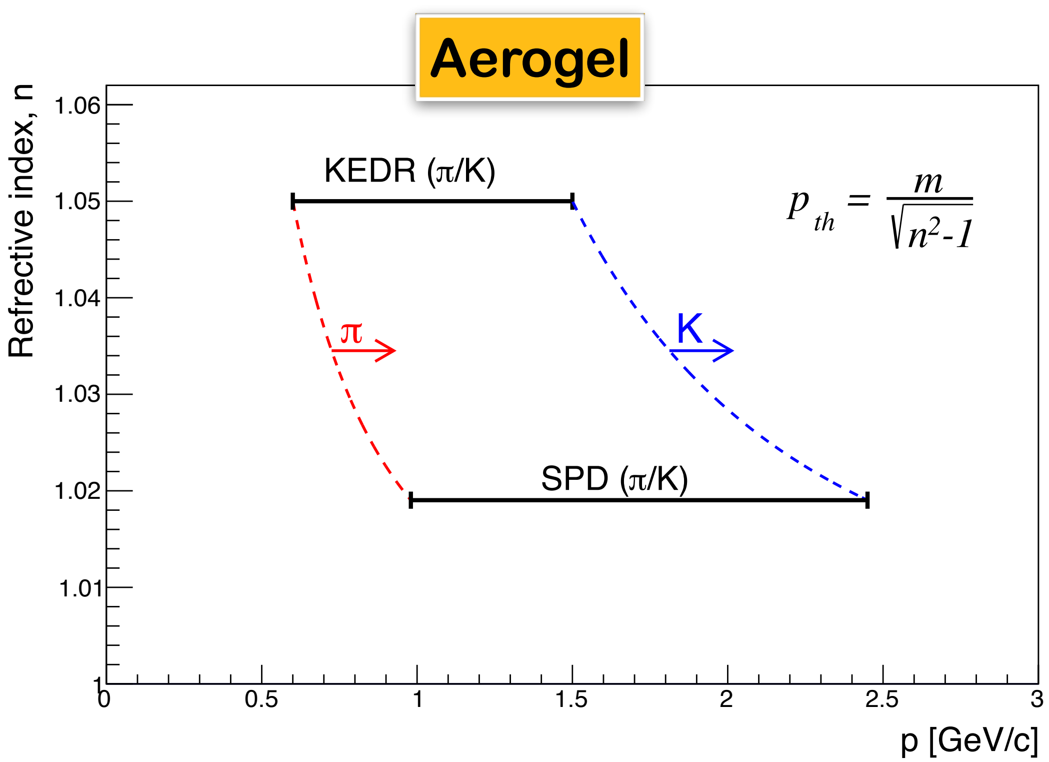


- Identification based on Cherenkov light radiation
- Range of π/K separation is a function of refractive index *n*
- The design follow closely the one of KEDR (Novosibirsk)
- Low light yield ~6 p.e.
- Can be used only in endcaps since there is more space and it is a region of higher momentum particles

PID analysis in SPD (π, K, p)



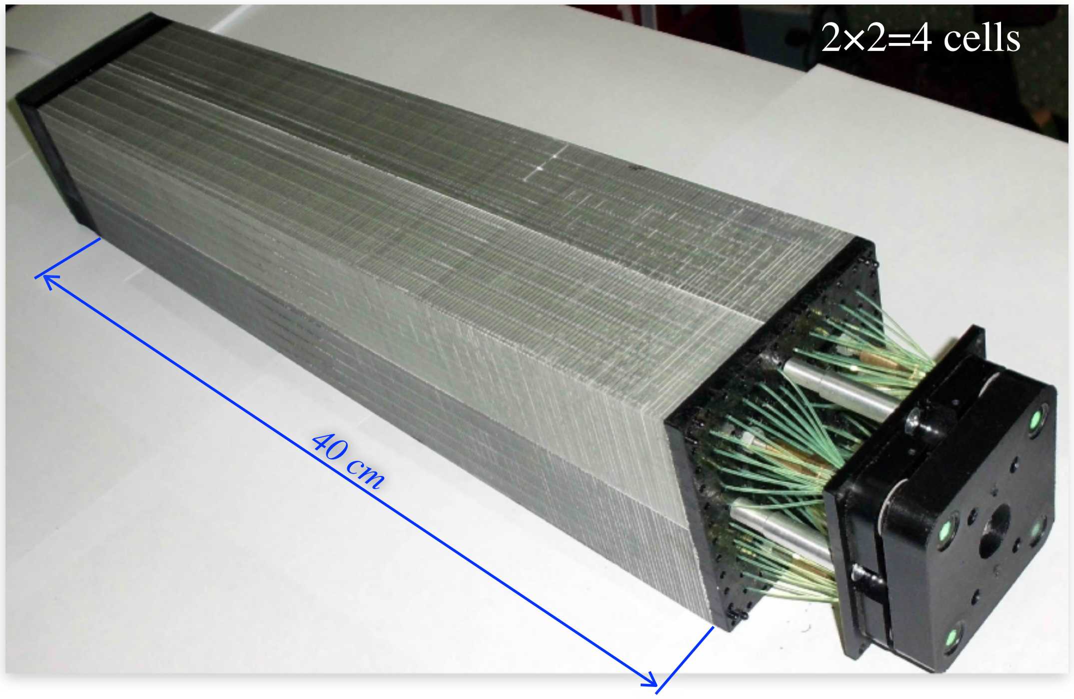




π/K separation

- Short tracks (R<1m) to be identified by straw up to 0.7 GeV/c
- Long tracks (R>1m) to be identified by straw+TOF up to 1.5 GeV/c
- tracks with p>1.5 GeV/c to be identified by aerogel

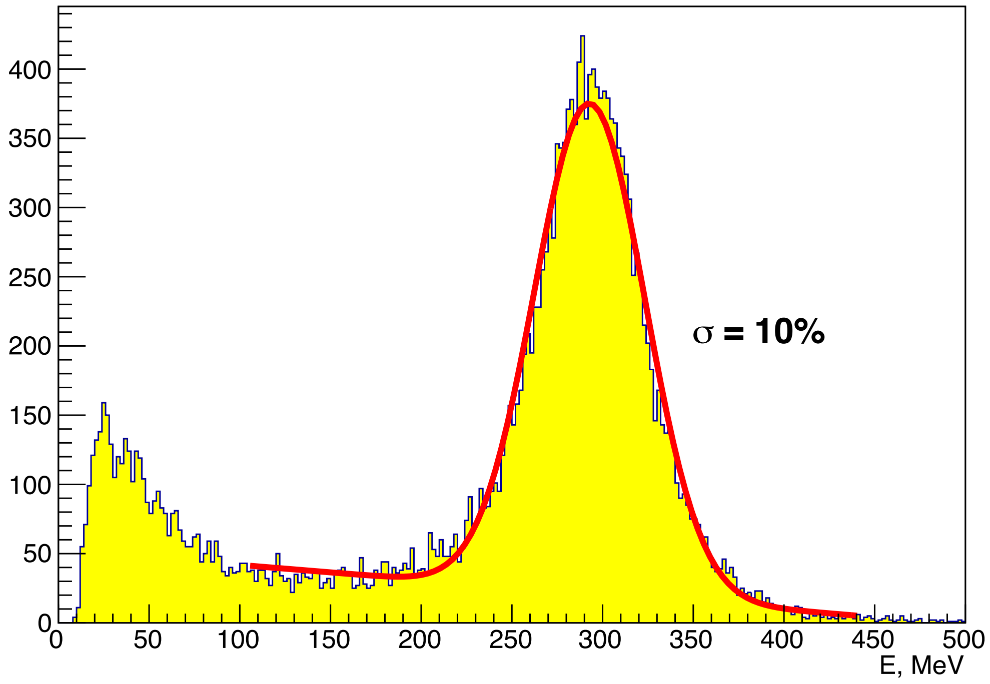
Electromagnetic Calorimeter (ECal)



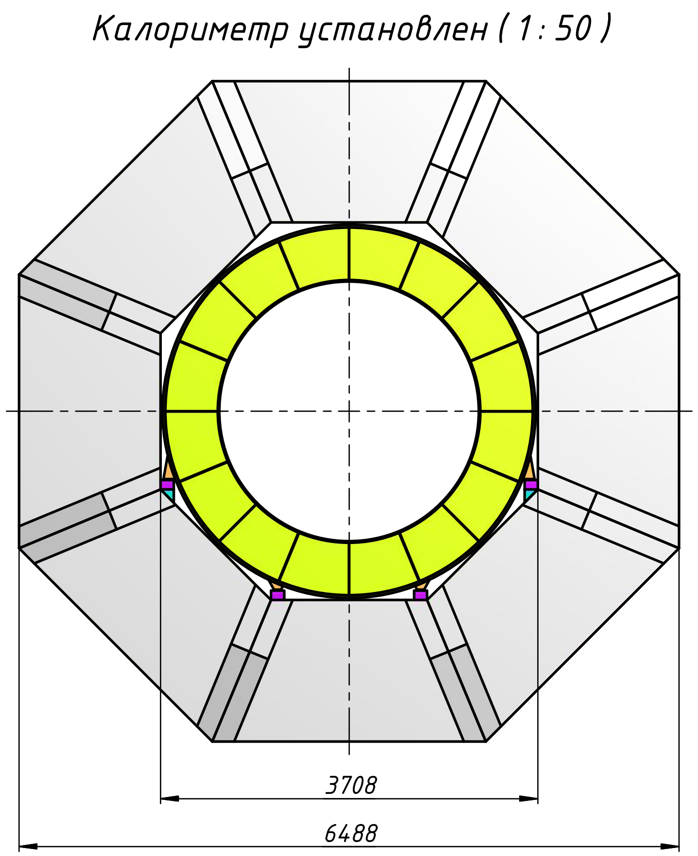
- Purpose: detection of prompt photons and photons from π^0, η and χ_c decays
- Identification of electrons and positrons
- Number of radiation lengths $18.6X_0$
- Total weight is 40t (barrel)+2×14t (endcap) = 68t
- Support structure will be made of carbon composite materials
- Total number of channels is ~30k

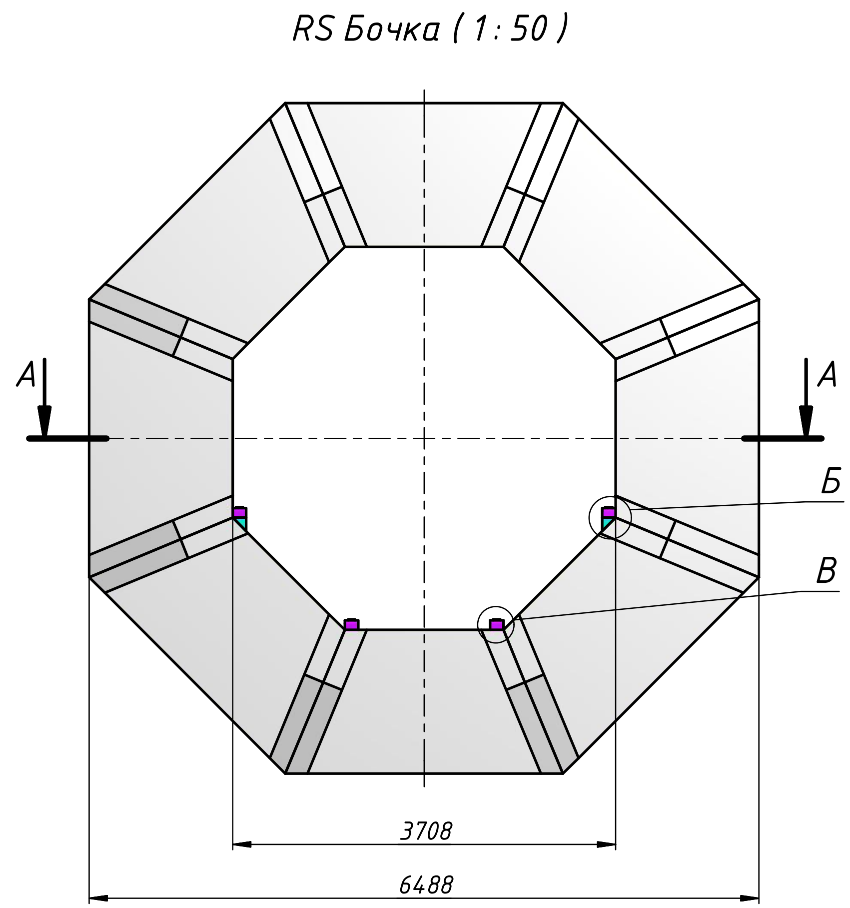
- 200 layers of lead (0.5 mm) and scintillator (1.5mm)
  - Size of one sandwich: $4 \times 4 \times 40$ cm^3
- Moliere radius is ~2.4 cm
- 36 fibers of one cell transmit light to 6×6 mm^2 SiPM
- Energy resolution is ~5% / $\sqrt{E}$
- Low energy threshold is ~50 MeV
- Time resolution is ~0.5 ns

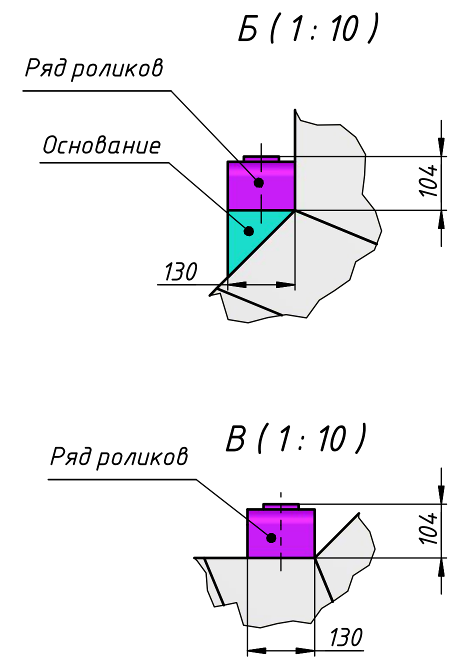
Energy deposition of one cell for MIP

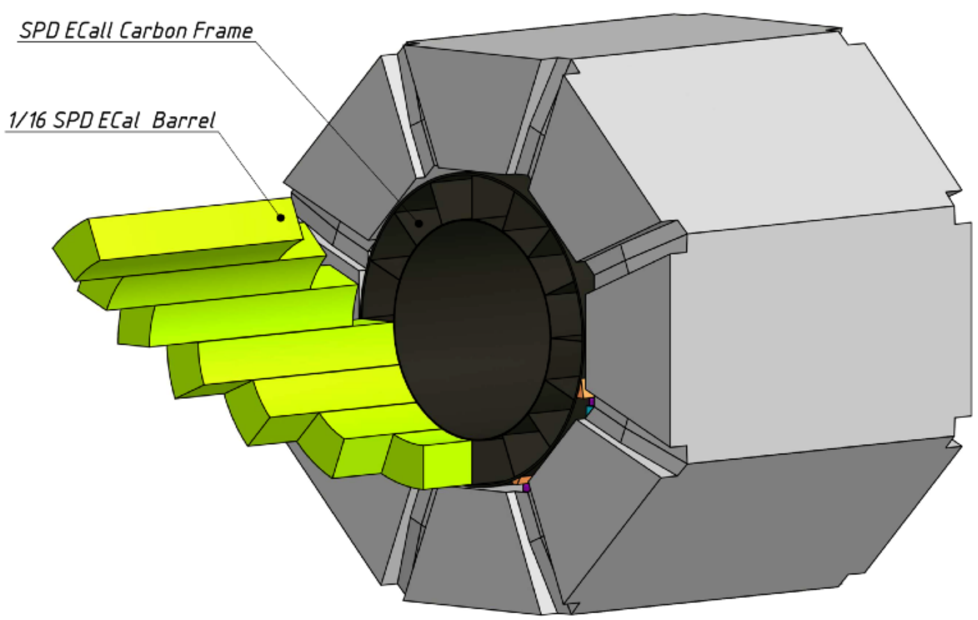


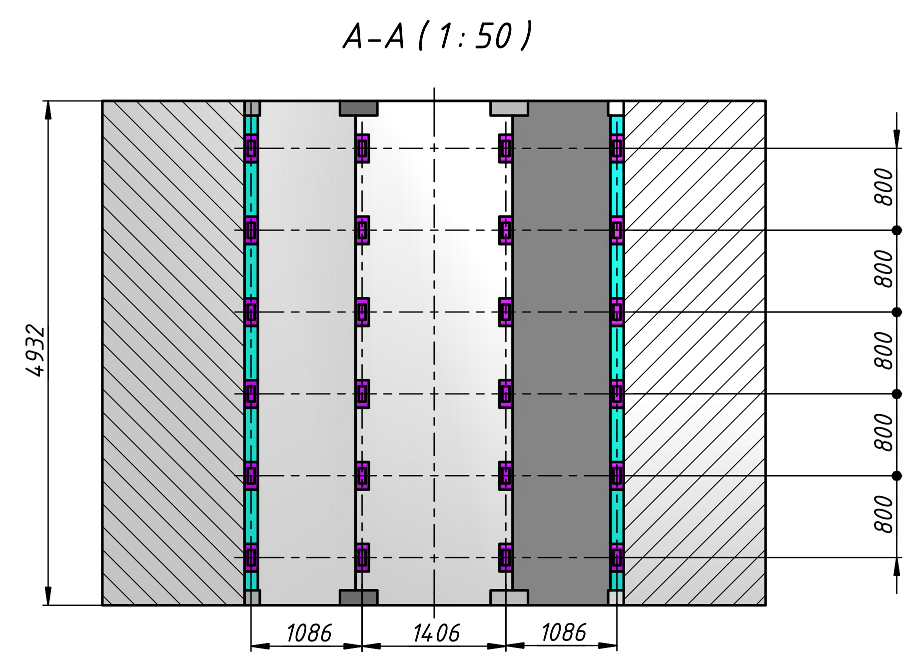
Electromagnetic Calorimeter (ECal)





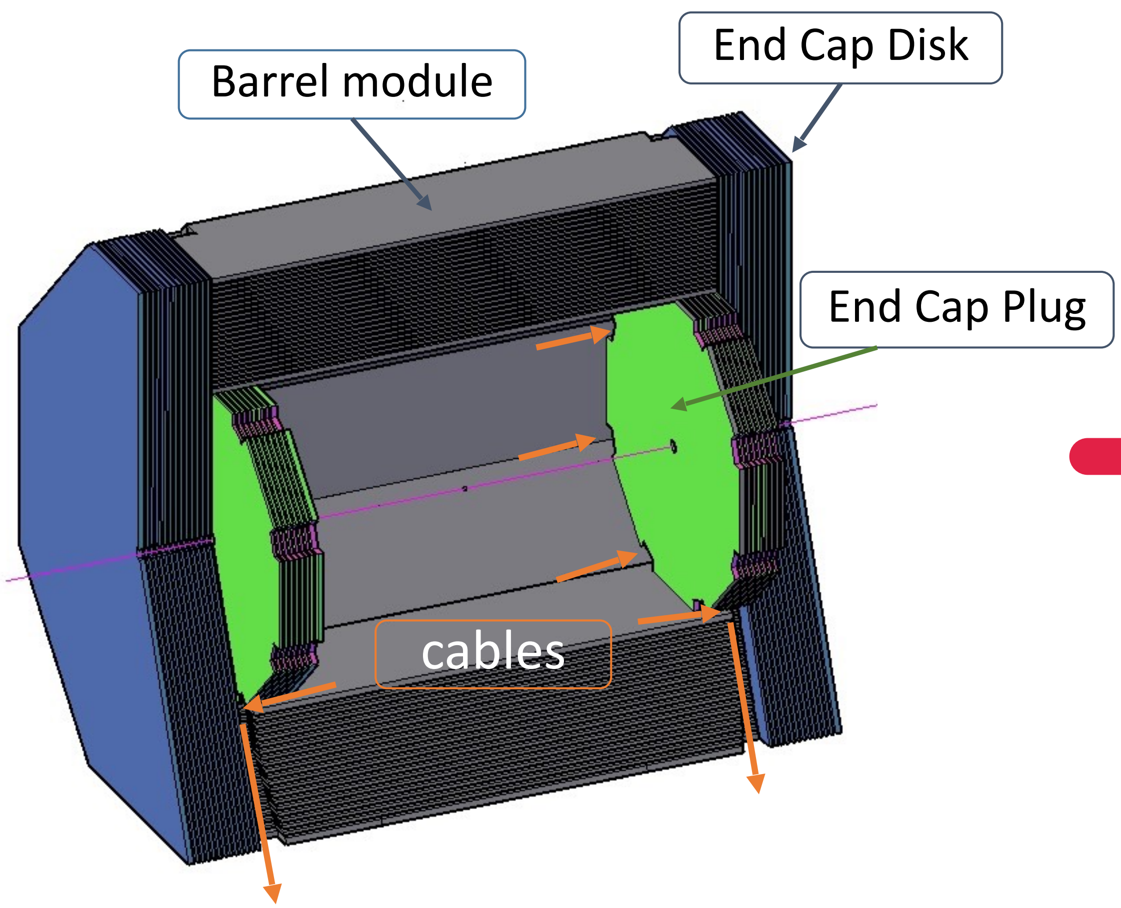




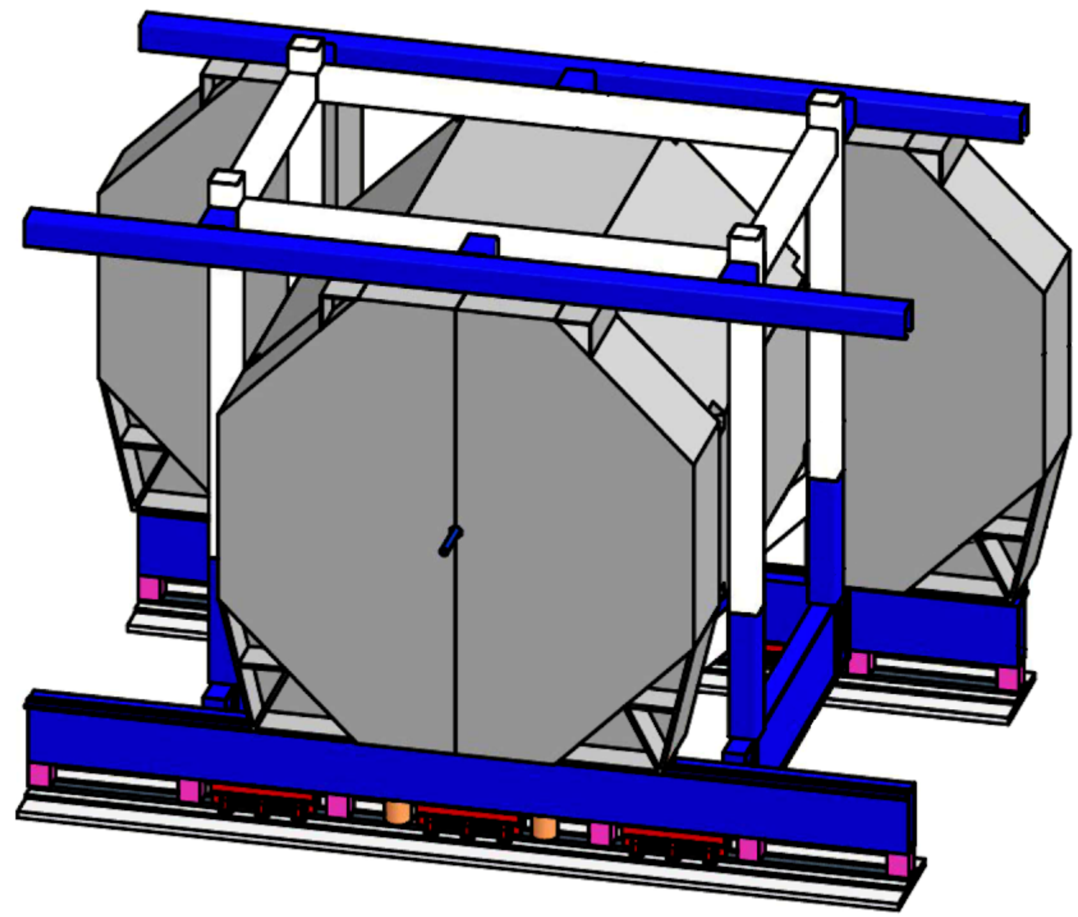


Range System (RS)

CDR version (end of 2020)



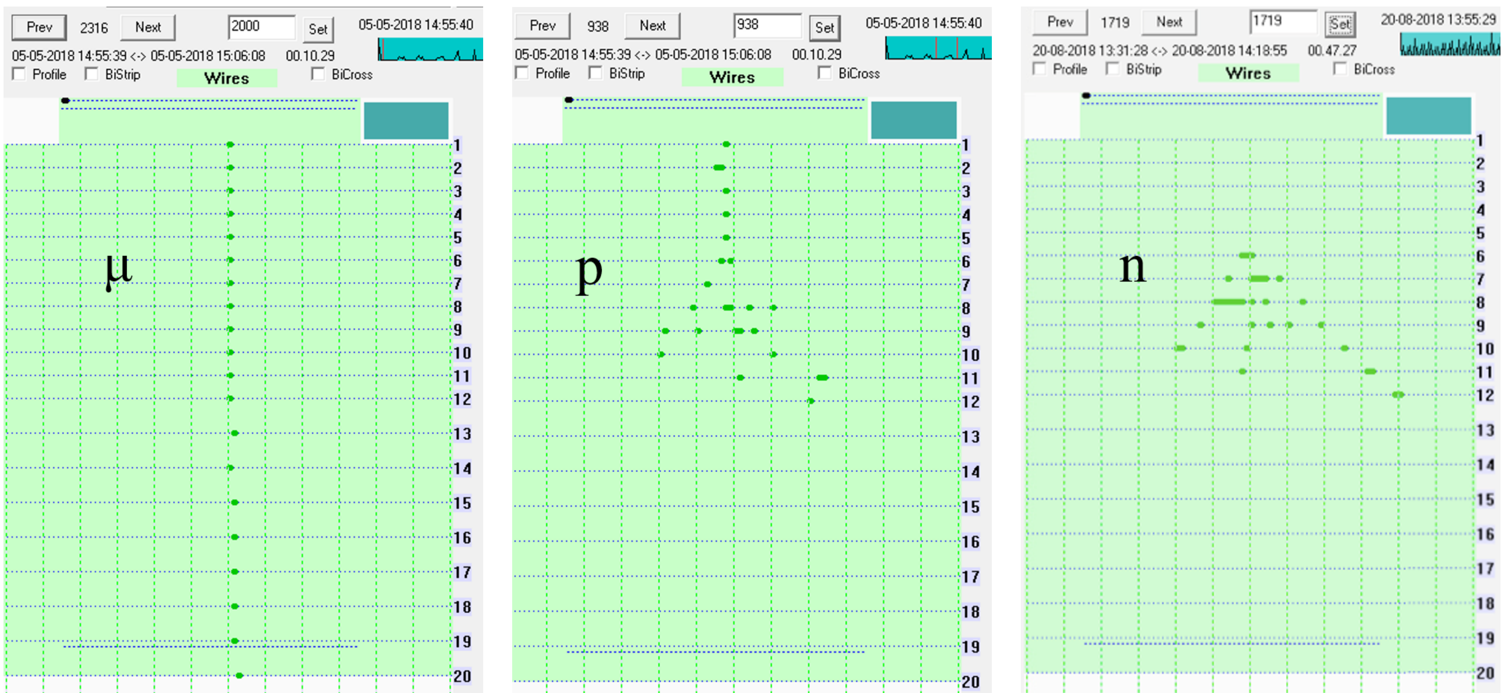
Update (May 2021)

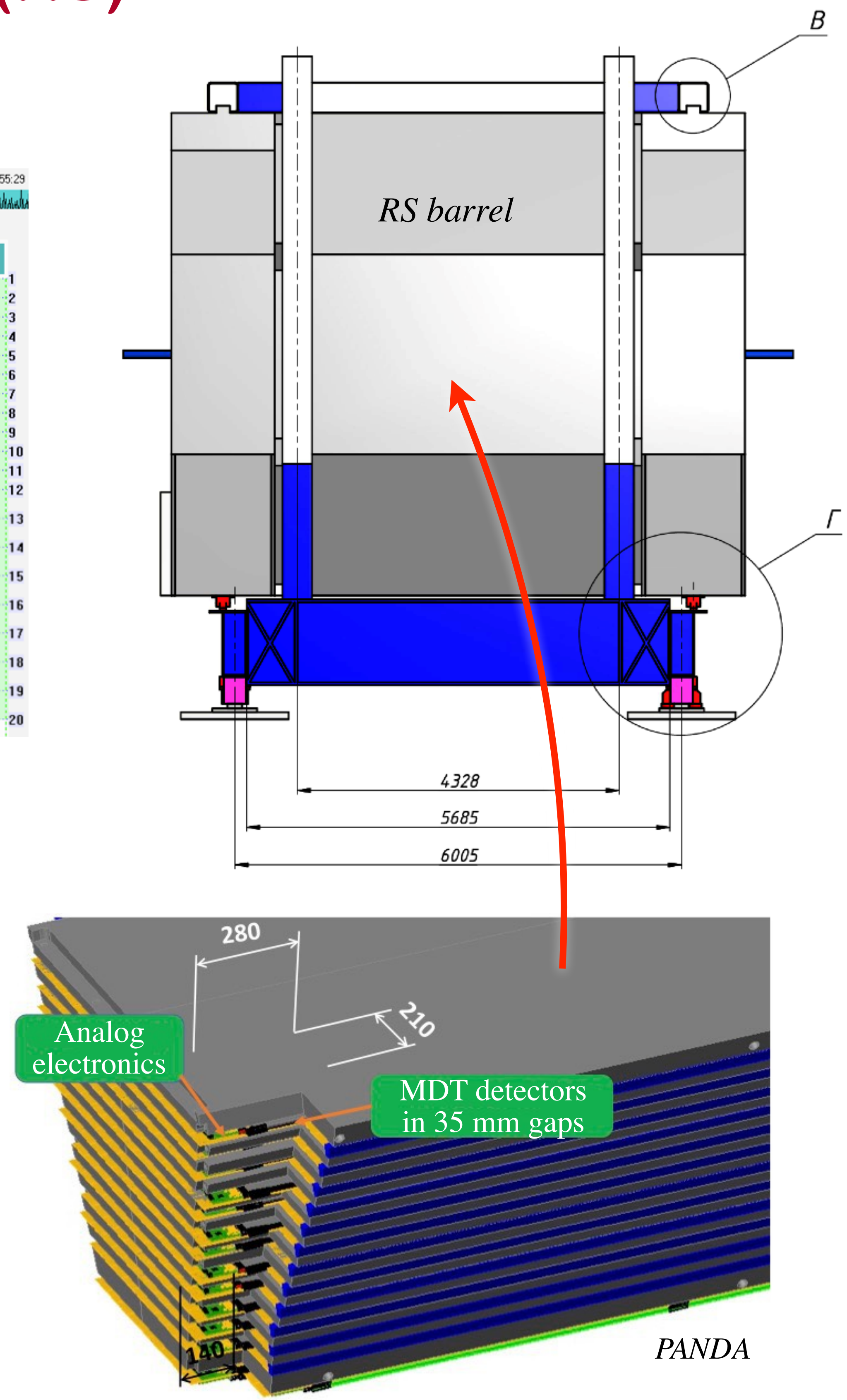


- End-cap disk&plug is replaced with sliding halves
- Radial size increased by 10 cm

Range System (RS)

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

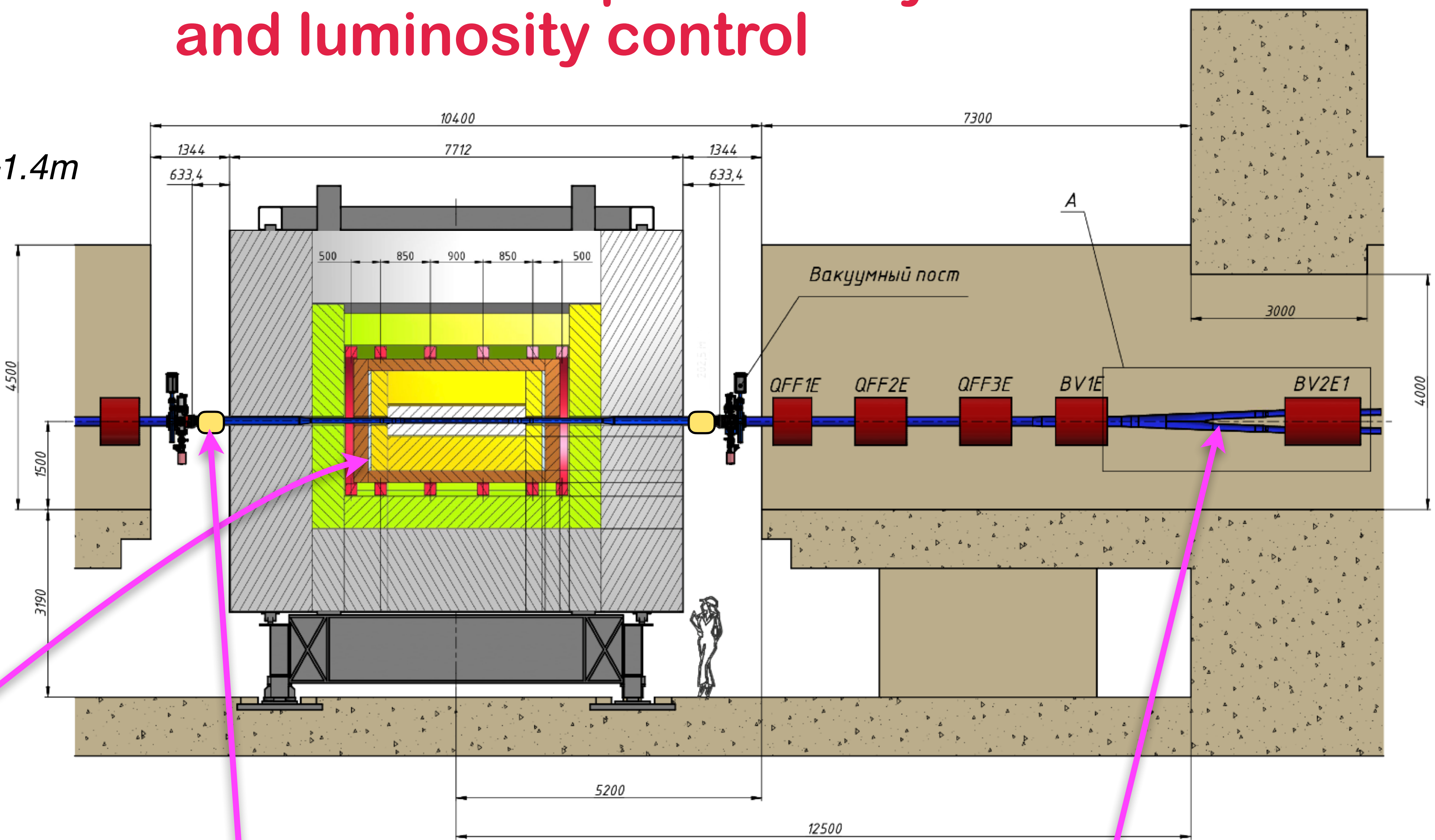




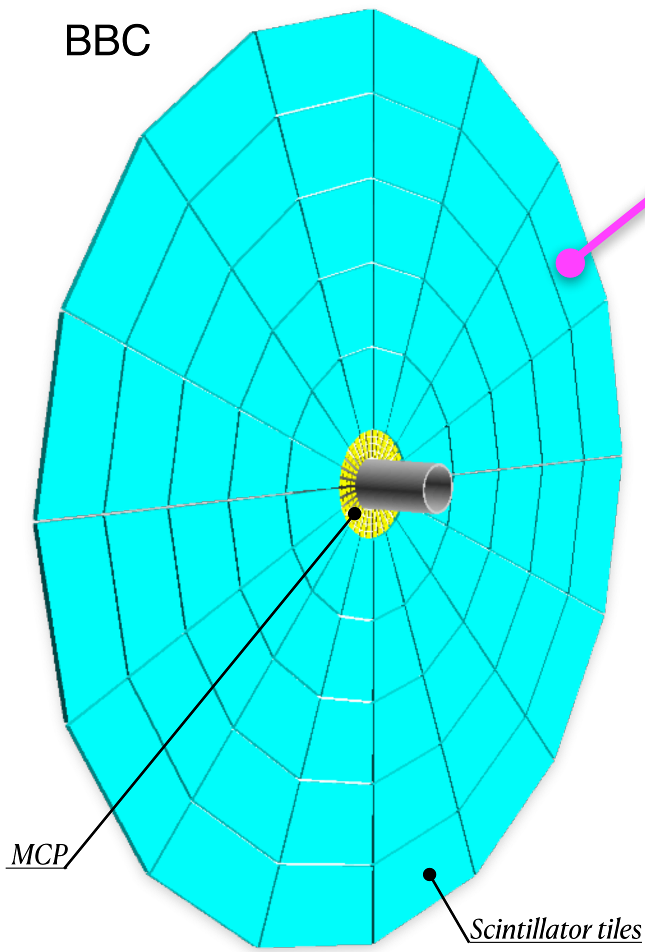
- Purposes: μ identification, rough hadron calorimetry
- 17 layers of Fe (3-6 cm) interleaved with gaps for Mini Drift Tube (MDT) detectors
- Total mass ~800 t, at least $4\lambda_I$
- The design will follow closely the one of PANDA
- MDT provide 2 coordinate readout (~100 kch)
    - Al extruded comb-like 8-cell profile with anode wires + external electrodes (strips) perpendicular to the wires

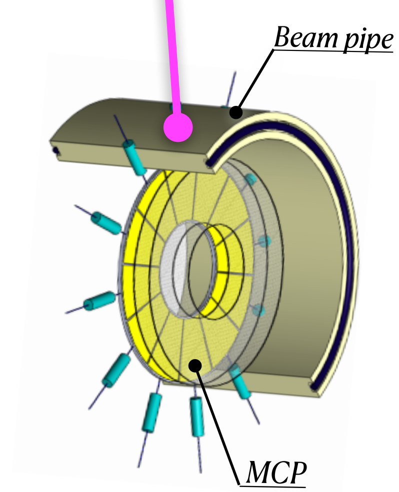
Detectors for local polarimetry and luminosity control

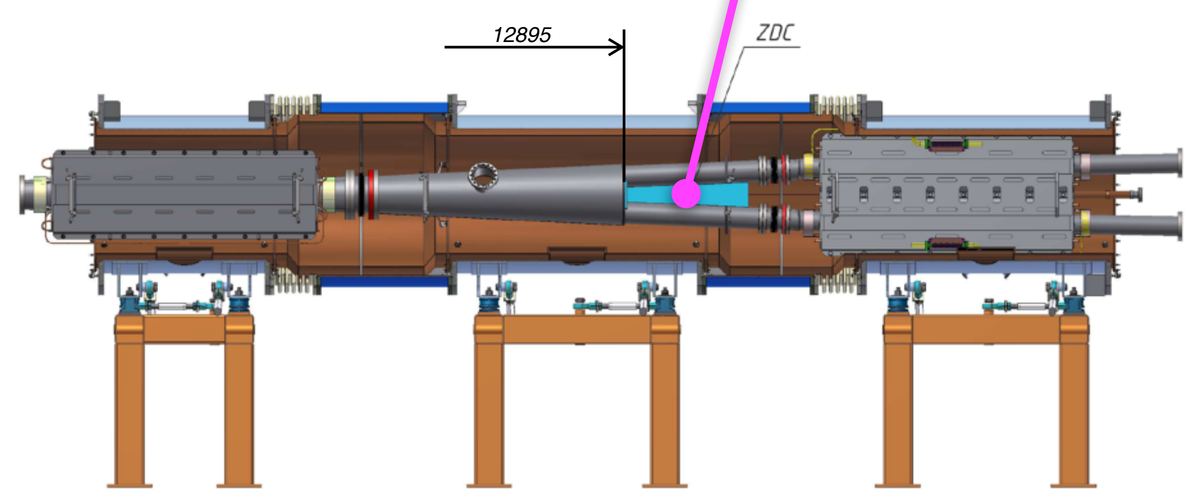
- BBC (MCP+SciTil) at *z=±1.4m*
- MCP at *z=±3.9m*
- ZDC at *z=±12.9m*



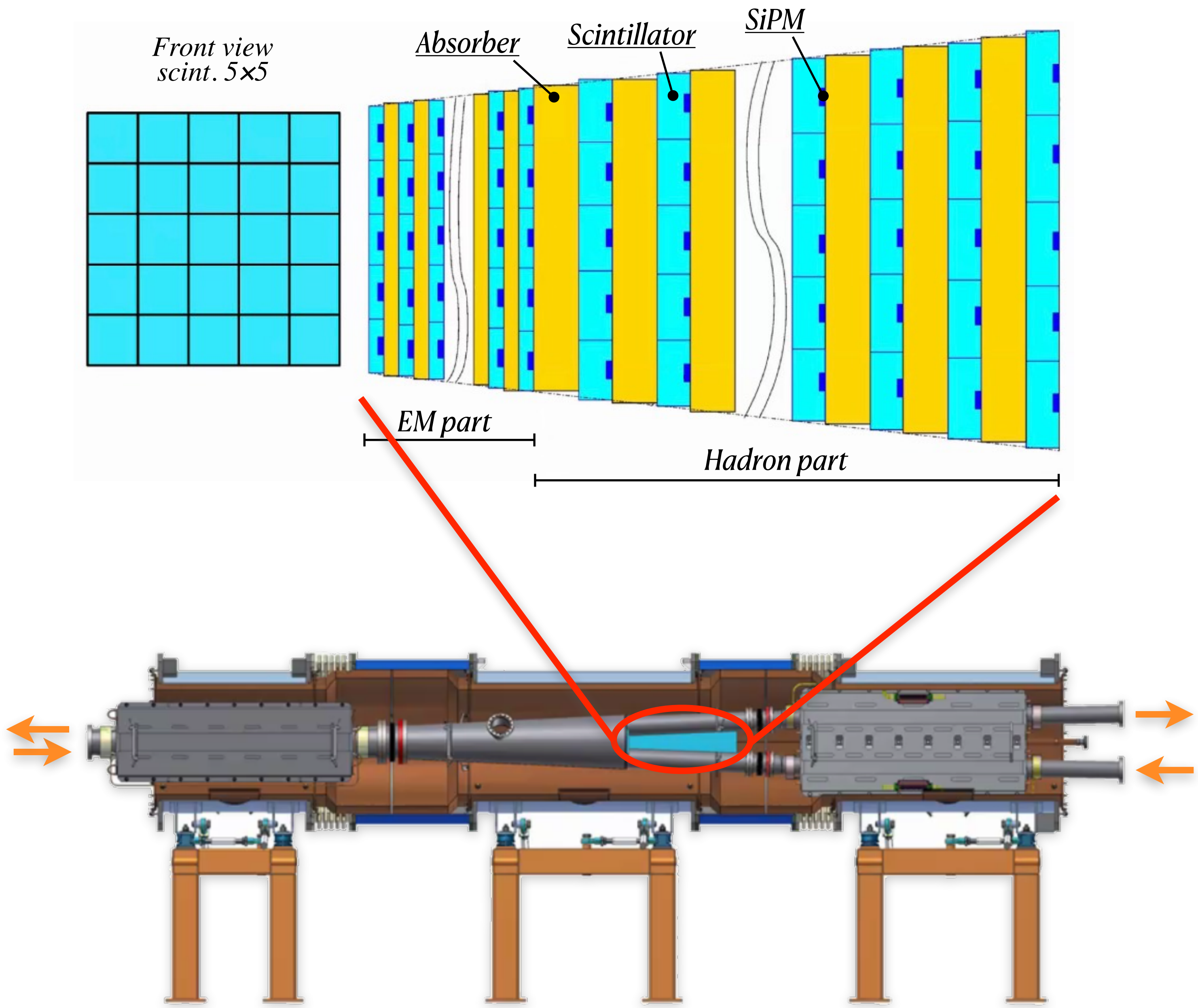
BBC





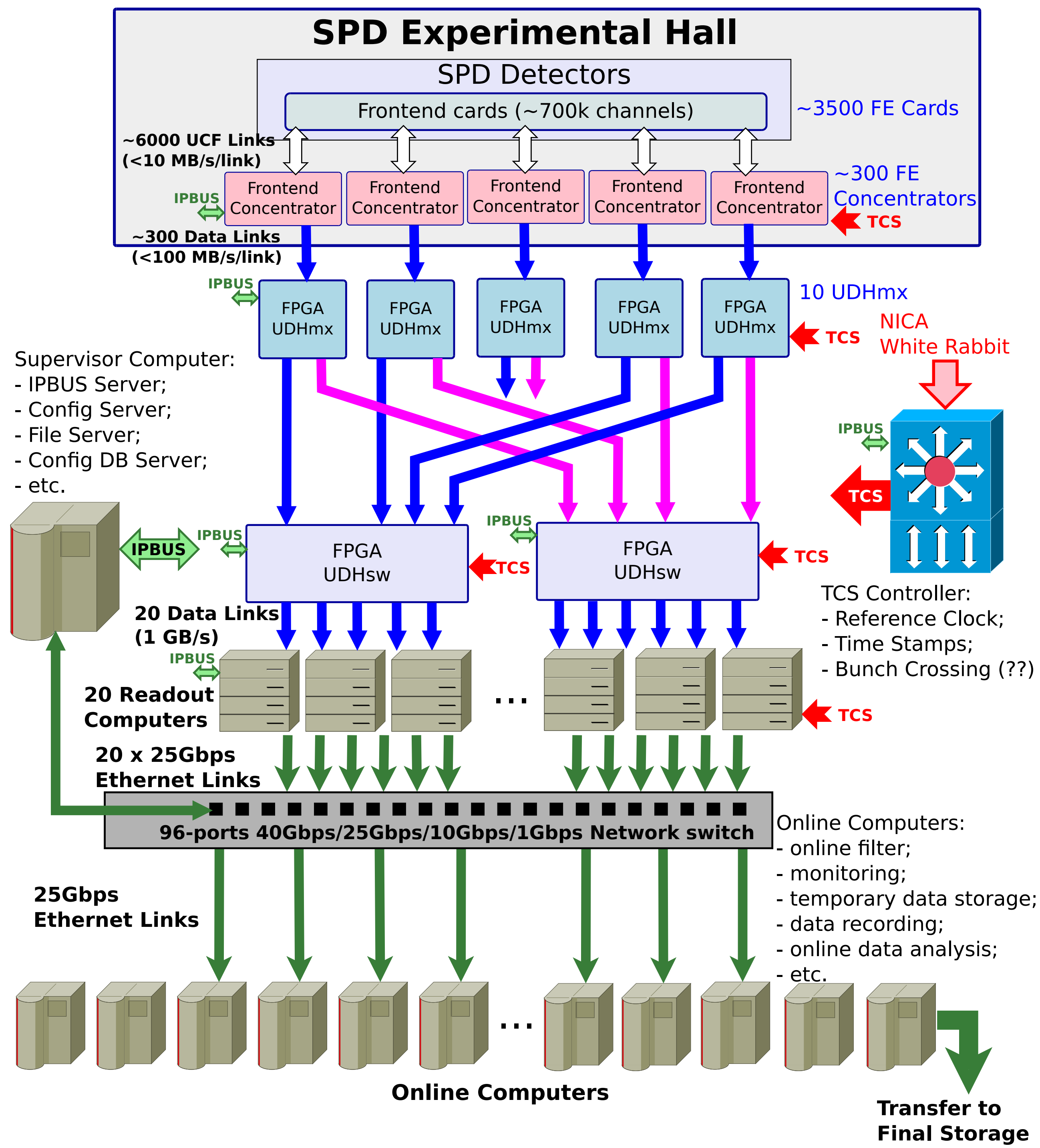


Zero Degree Calorimeter (ZDC)

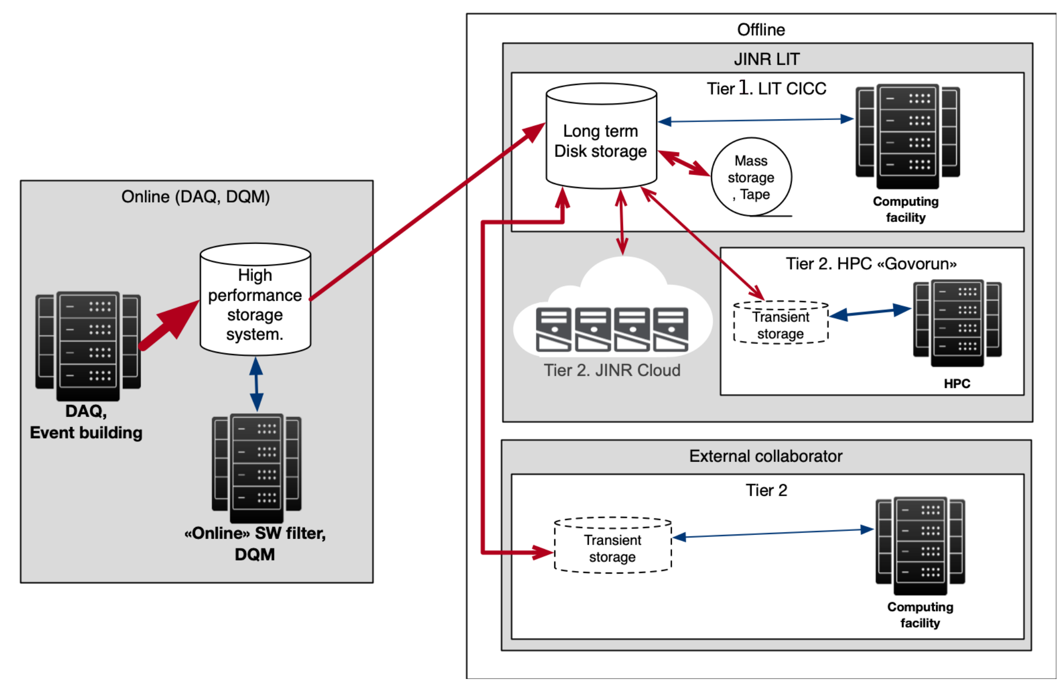


- ZDC will be integrated in the cryostat placed between two vertically deflecting magnets, 13 m from IP
- Sampling calorimeter with fine segmentation, 5x5 matrix
- SiPM light readout, about 1000 channels
- Readout based on electronics designed for the DANSS neutrino experiment at Kaliniskaya NPP
- Time resolution ~150 ps
- Energy resolution for neutrons
  - $50\div60\% / \sqrt{E} \oplus 8\div10\%$
- Neutron entry point spatial resolution 10 mm
- The main issue to solve: how to place the detector in vacuum cryostat of accelerator

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 oder of magnitude ~10 PB/year

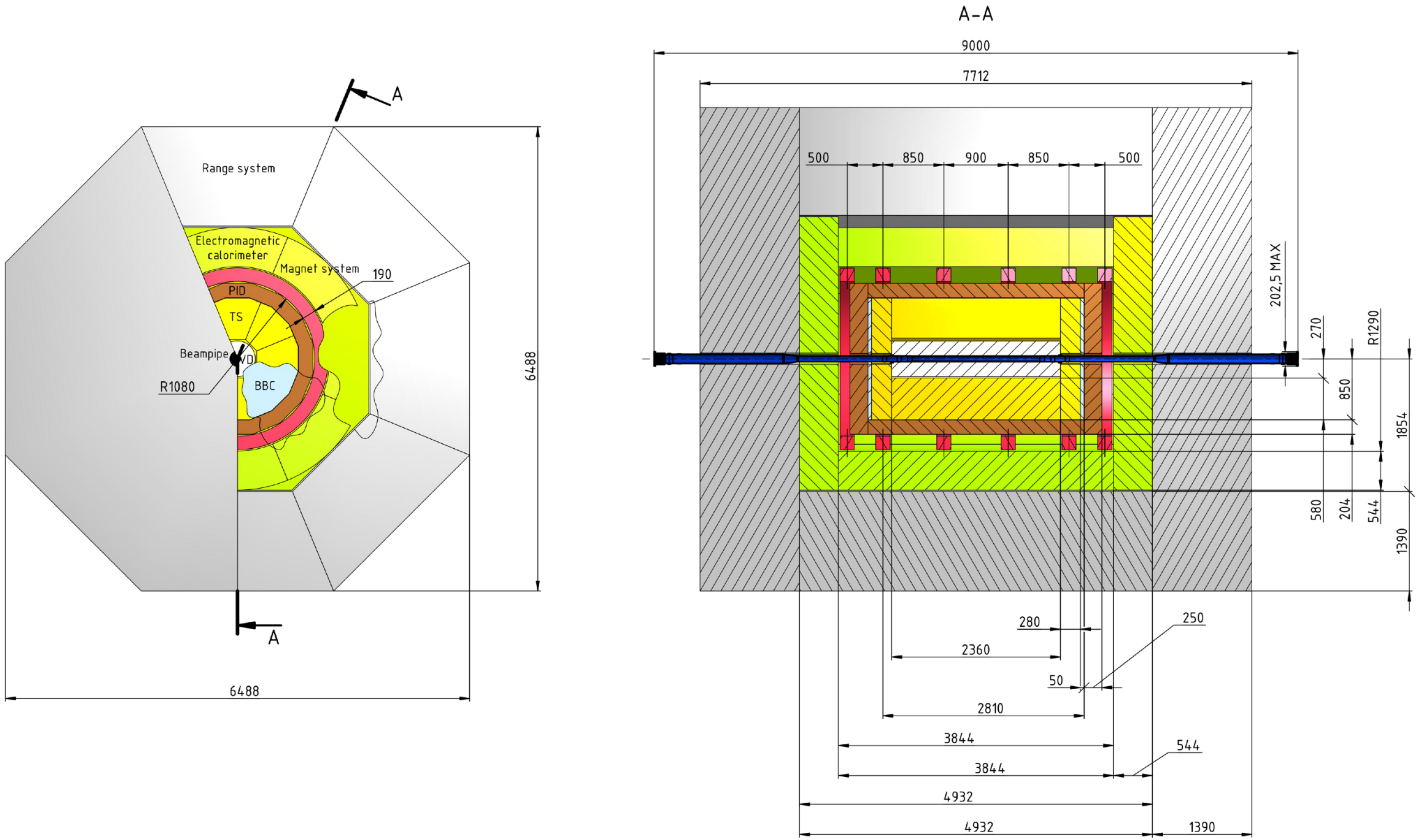


	CPU [cores]	Disk [PB]	Tape [PB]
Online filter	6000	2	none
Offline computing	30000	5	9 per year

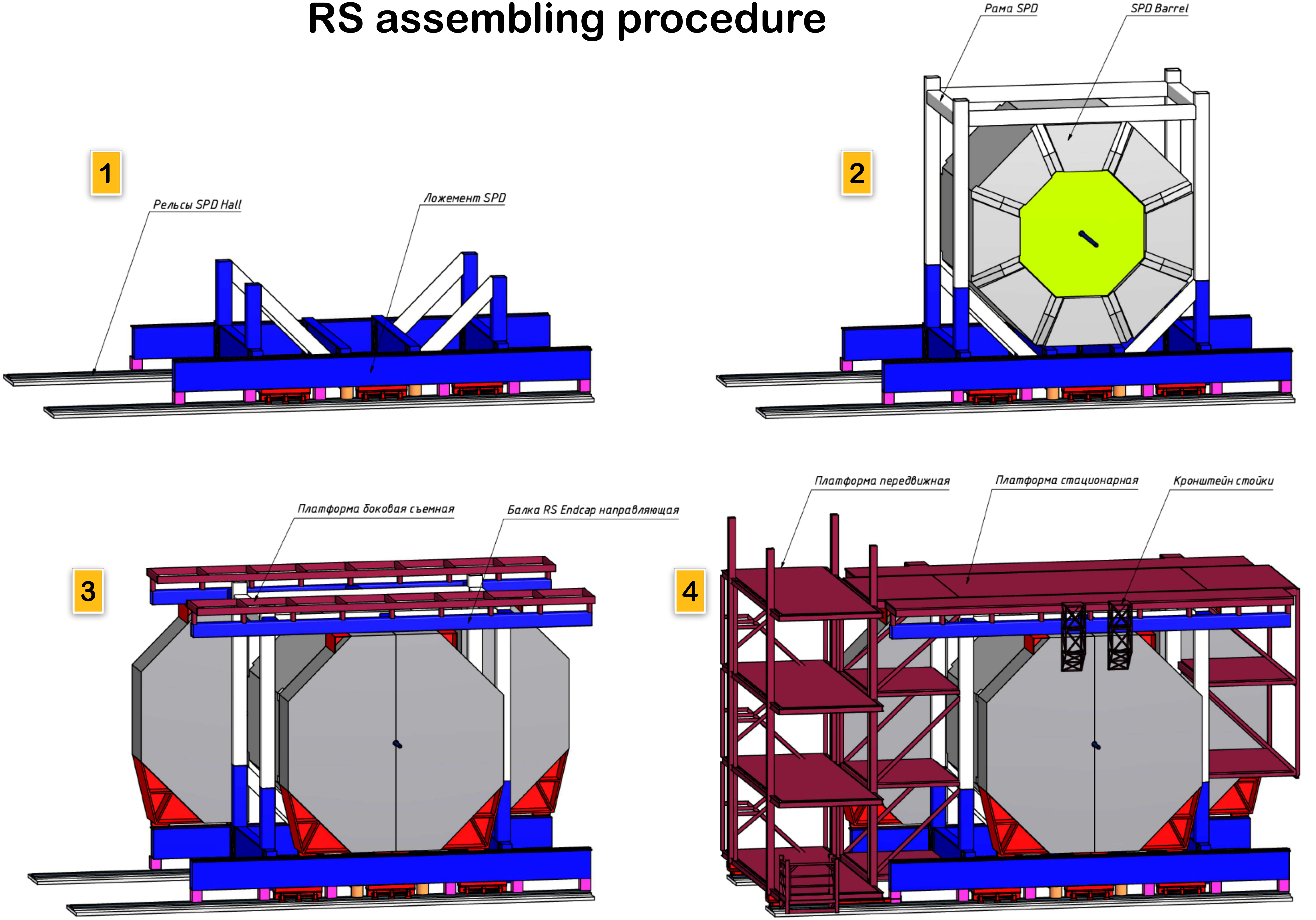
Conclusions

- SPD (Spin Physics Detector) is a universal facility with the primary goal to study unpolarized and polarized gluon content of *p* and *d*
  - Almost 4π coverage of acceptance
  - Tracking by silicon vertex detector (VD) and straw tracker (ST)
  - PID by TOF, Aerogel counters and dE/dx in ST
  - EM calorimeter for $e^{\pm}$ and γ identification
  - Range system for the muon identification and rough hadron calorimetry
  - Local polarimetry and luminosity control
- Magnetic system is an open issue for today
  - Superconductive magnet: either solenoid or isolated coils
  - If built in JINR, it has to be the isolated coils
  - Inside or outside ECal

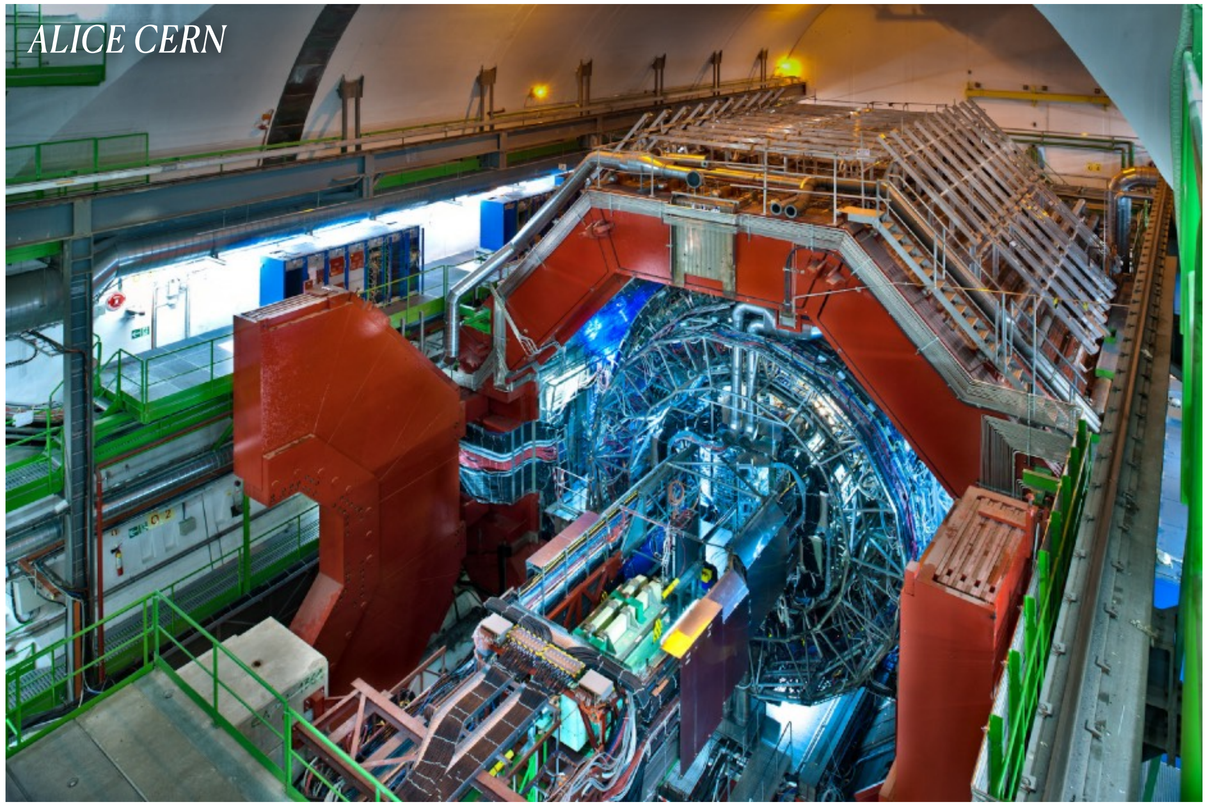
backup slides

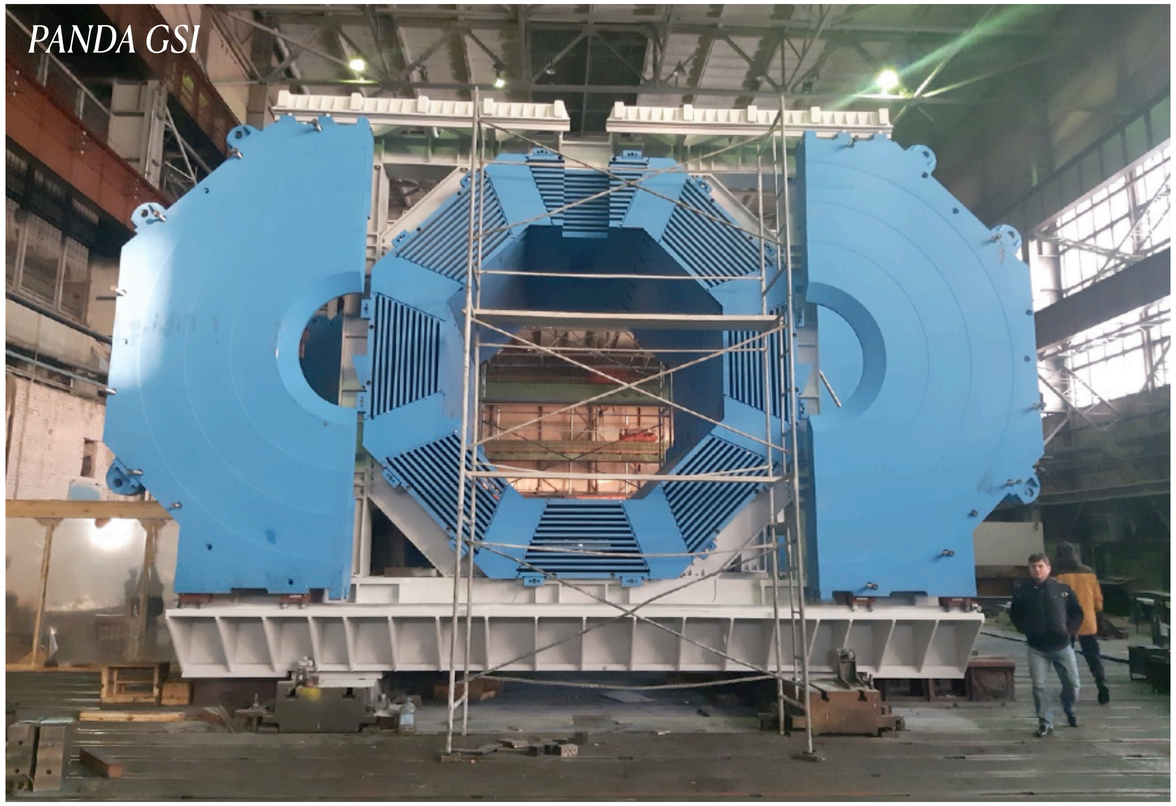

A
Range system
Electromagnetic calorimeter
Magnet system
190
PID
TS
Beampipe
VD
BBC
R1080
6488
A
6488
A-A
9000
7712
500
850
900
850
500
202,5 MAX
270
R1290
850
1854
580
204
544
1390
280
250
2360
50
2810
3844
3844
544
4932
4932
1390

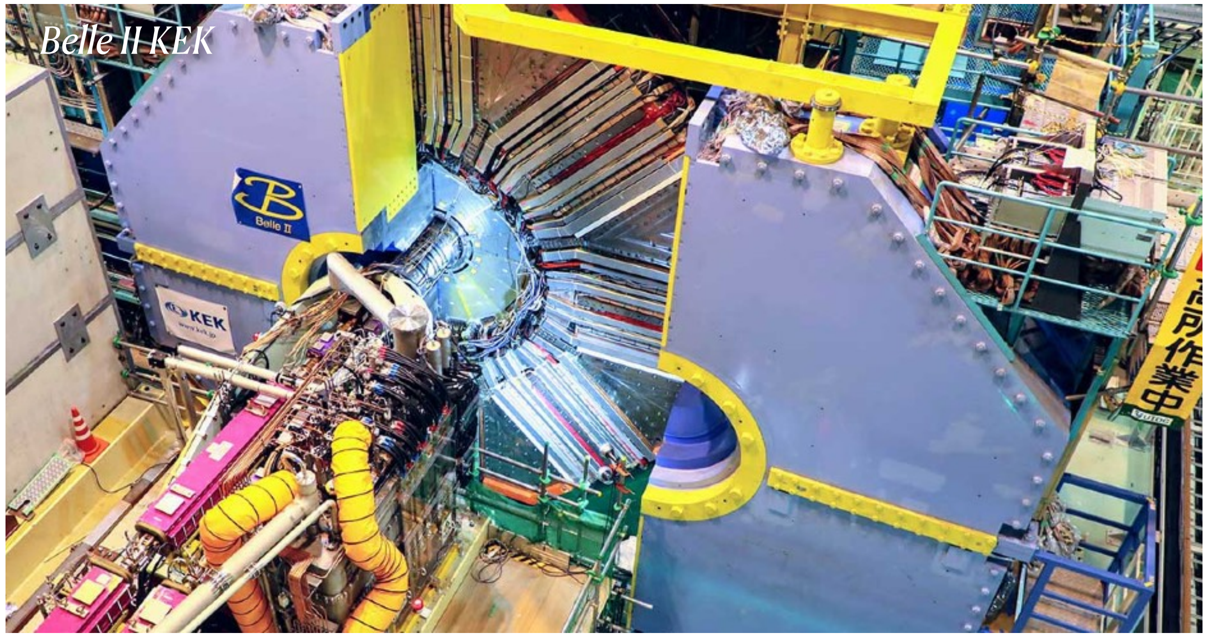
RS assembling procedure



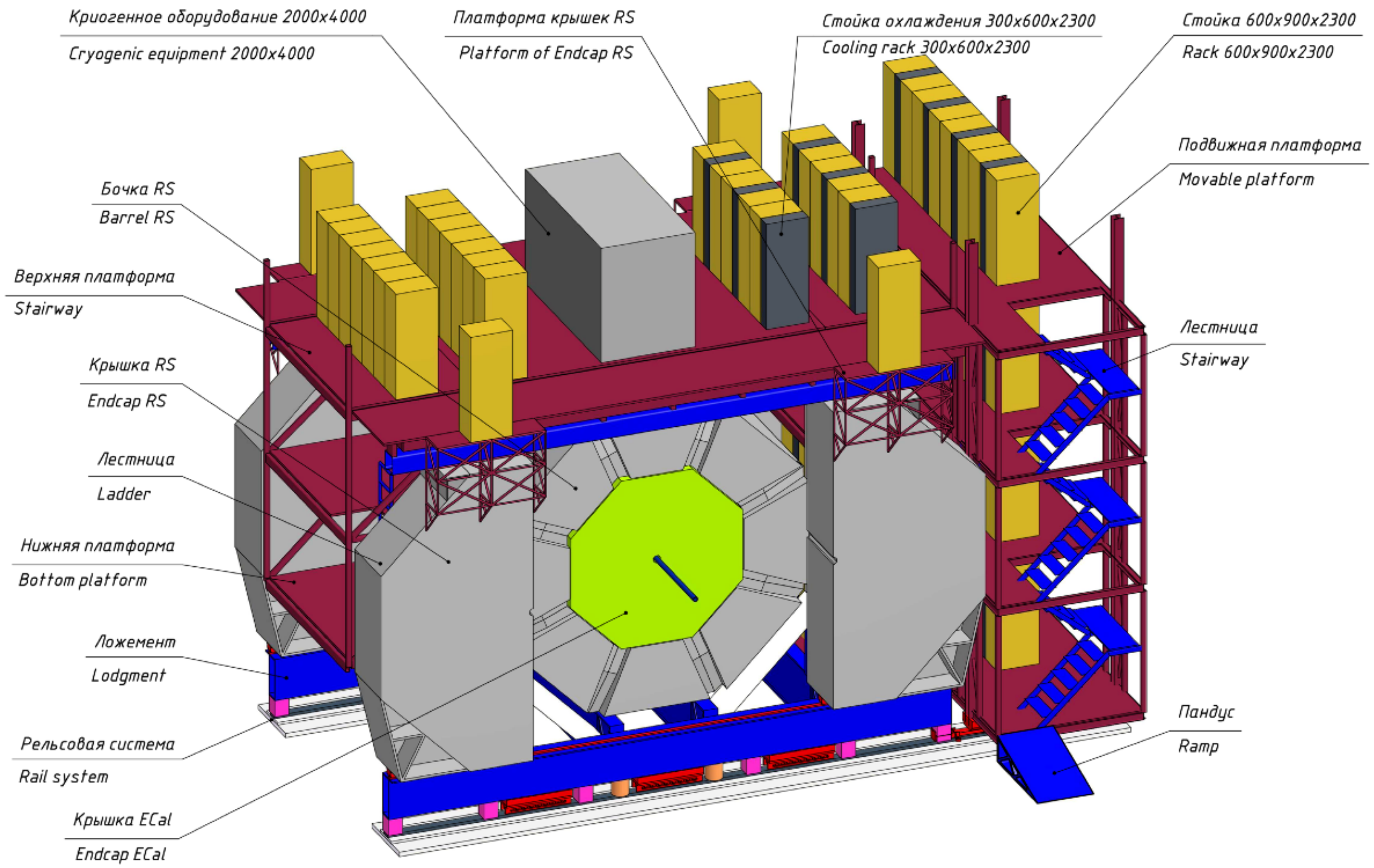
Motivation for the RS end-cap update



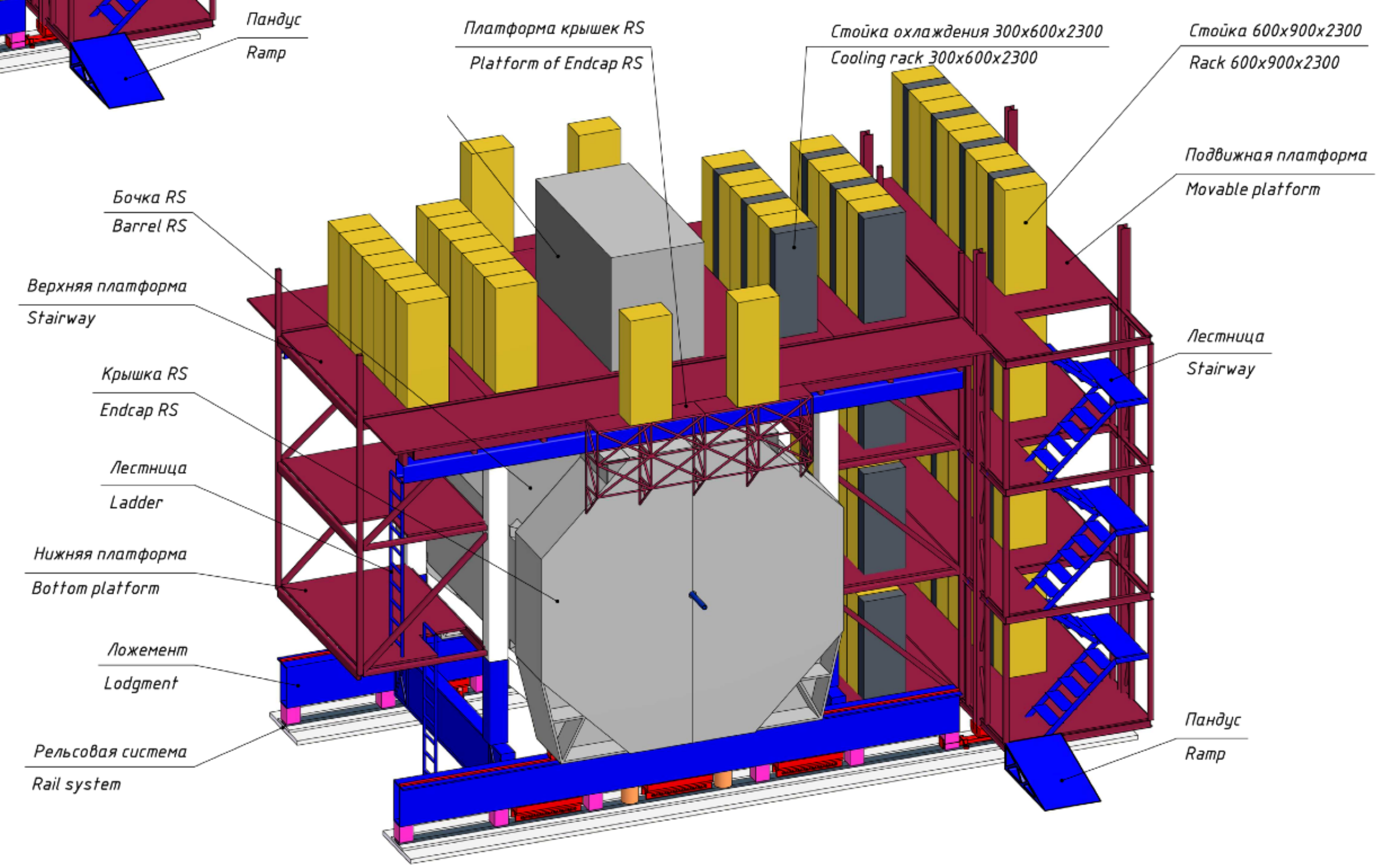




- Sliding end-cap halves are more convenient for long-term use
  - faster and safer to open
  - no need to disconnect cables



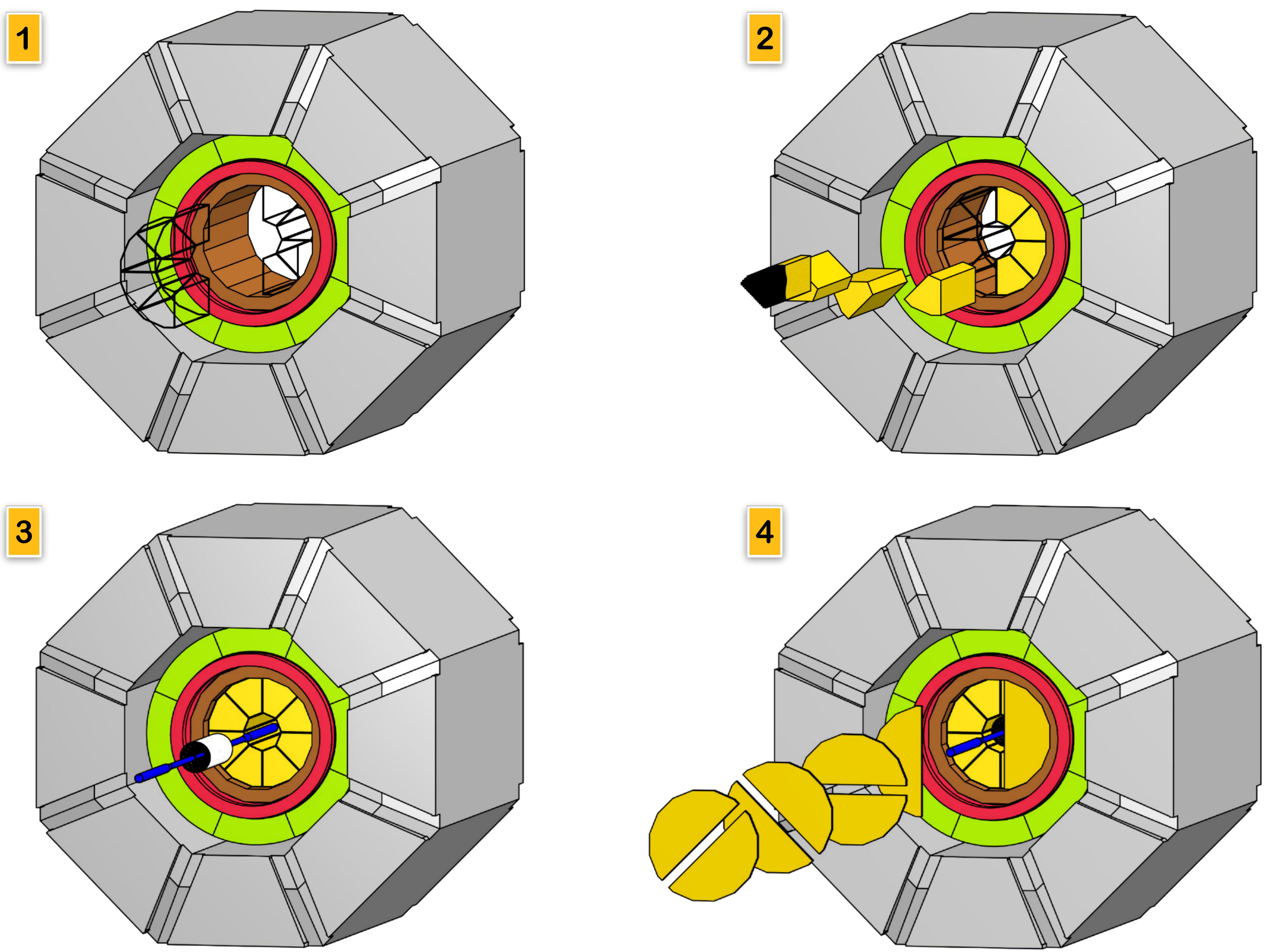
Assembling position with open end-caps of RS



Working "beam" position with closed end-caps of RS

ST assembling procedure

all will be done by hand



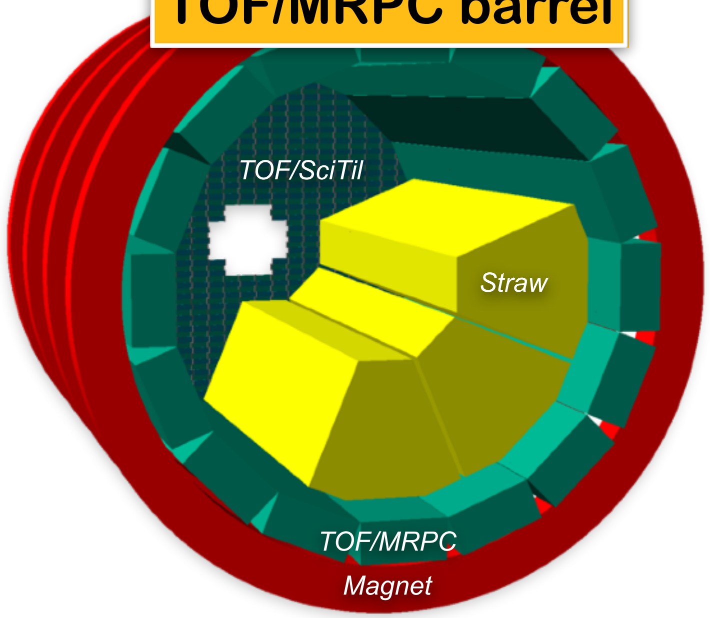
Two options for TOF (pros & cons)

	MRPC	SciTil	
	sophisticated production procedure	assembling is fast and easy	👍
	requires gas flow, HV (trips)	easier to maintain (no gas, only LV)	👍
	takes radially 17cm (MPD), no way for Aerogel	can be squeezed within ~6cm, space for Aerogel	👍
	rectangular shape, large size (inconvenient for round end-caps)	small tile ⇒ can fit cylindrical shape	👍
	rad. length ≈ $0.14X_0$ *(MPD)*	rad. length ≈ $0.02X_0$	👍
👍	σ_t is independent of l_{strip}	σ_t drops exponentially with l_{tile}	
👍	S = pitch x length = 1.25cm x 40cm = 50cm^2 $N_{channel}$ ≈ 10k	S = pitch x length = 2.9cm x 9cm = 26cm^2 $N_{channel}$ ≈ 20k	
👍	not sensitive to radiation	sensitive to radiation	
👍	well established technology (MPD, BM@N)	requires R&D	

- Both options are able to provide the resolution of ~60ps
- Applying different options for barrel and end-caps will double expenses/efforts for: DAQ, Power supply, Slow control, calibration & analysis

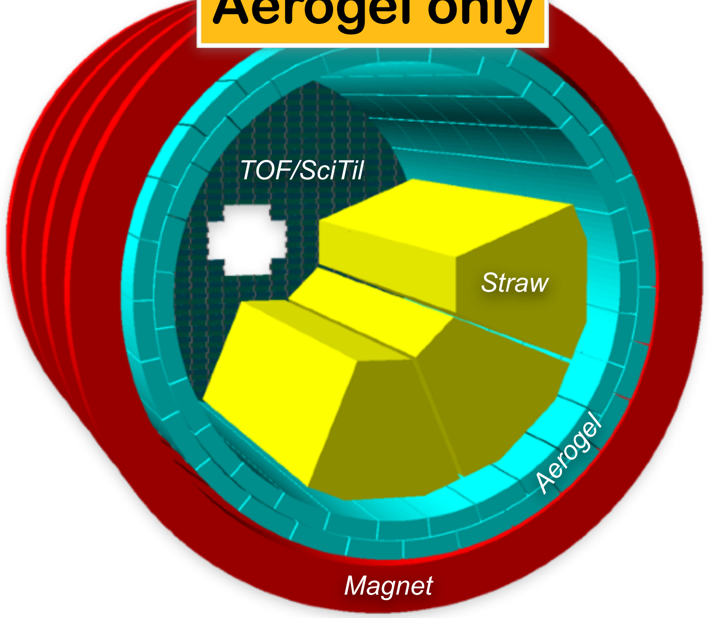
Summary: options for PID (TOF, Aerogel, Straw)

TOF/MRPC barrel



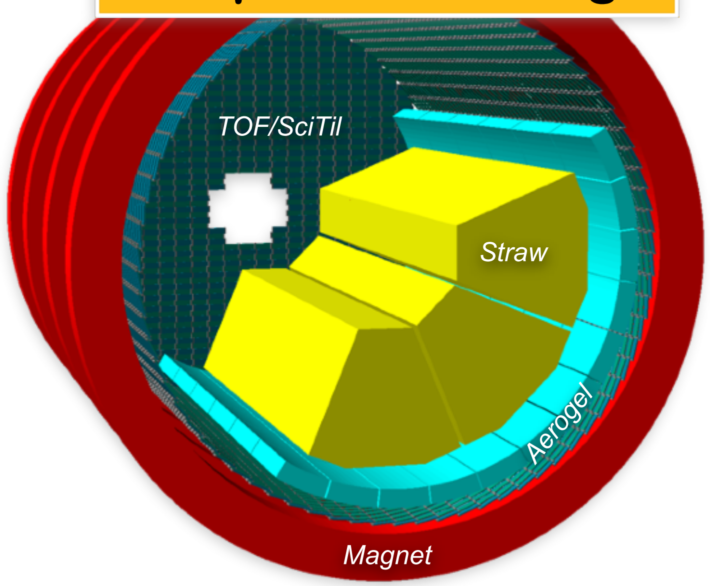
- Module takes 17cm radially (no place for other PID detector)
- Choice for TOF end-caps is still opens

Aerogel only



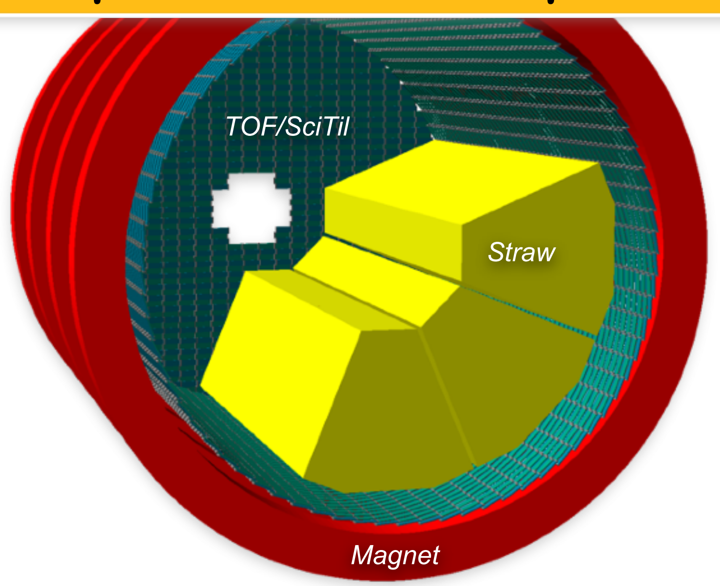
- Module takes 17cm radially (no place for other PID detector)
- Missing timing measurements in barrel

TOF/plastic + Aerogel



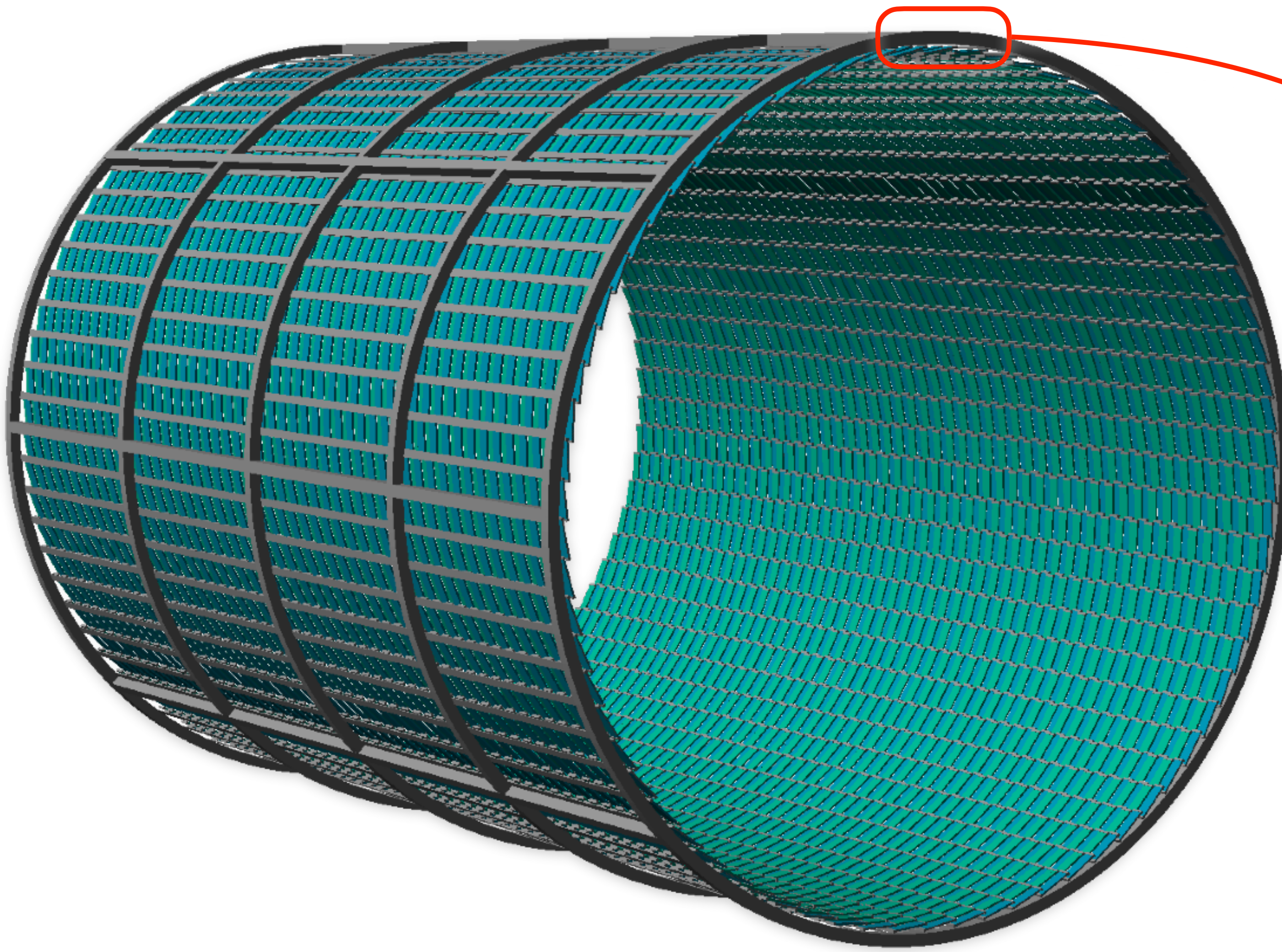
- The same choice of TOF for barrel and end-caps
- Lower thickness → lower efficiency for Aerogel

TOF/plastic + Straw expansion

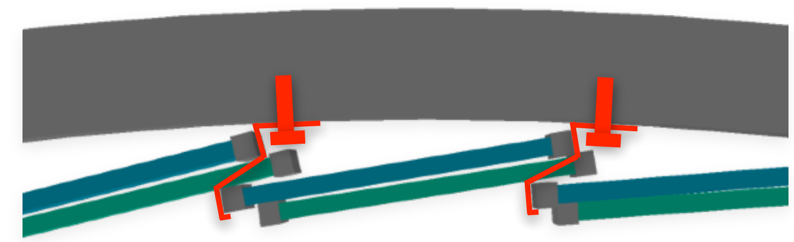


- The same choice of TOF for barrel and end-caps
- Improvement of dE/dx via increasing straw layers by 10

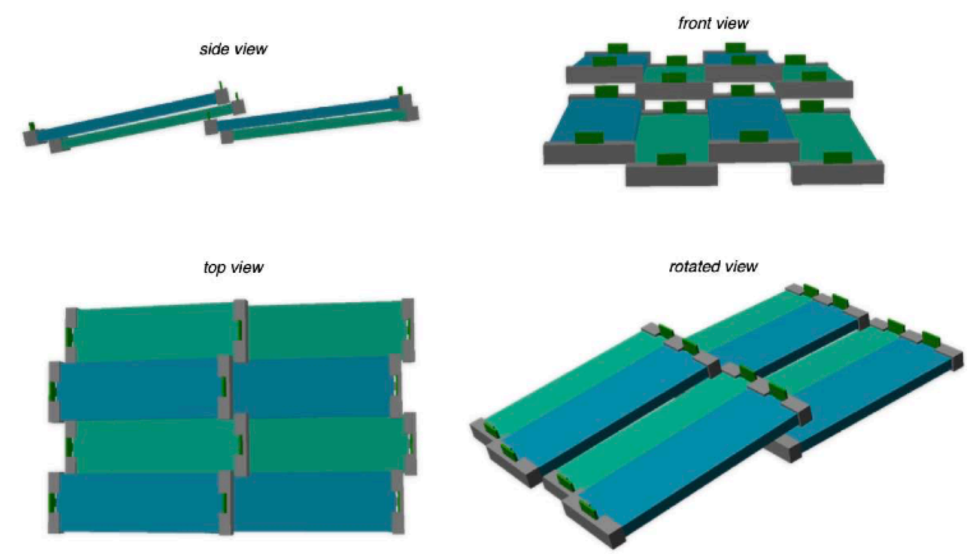
Plastic scintillator option for TOF/SPD



Brackets for fixation



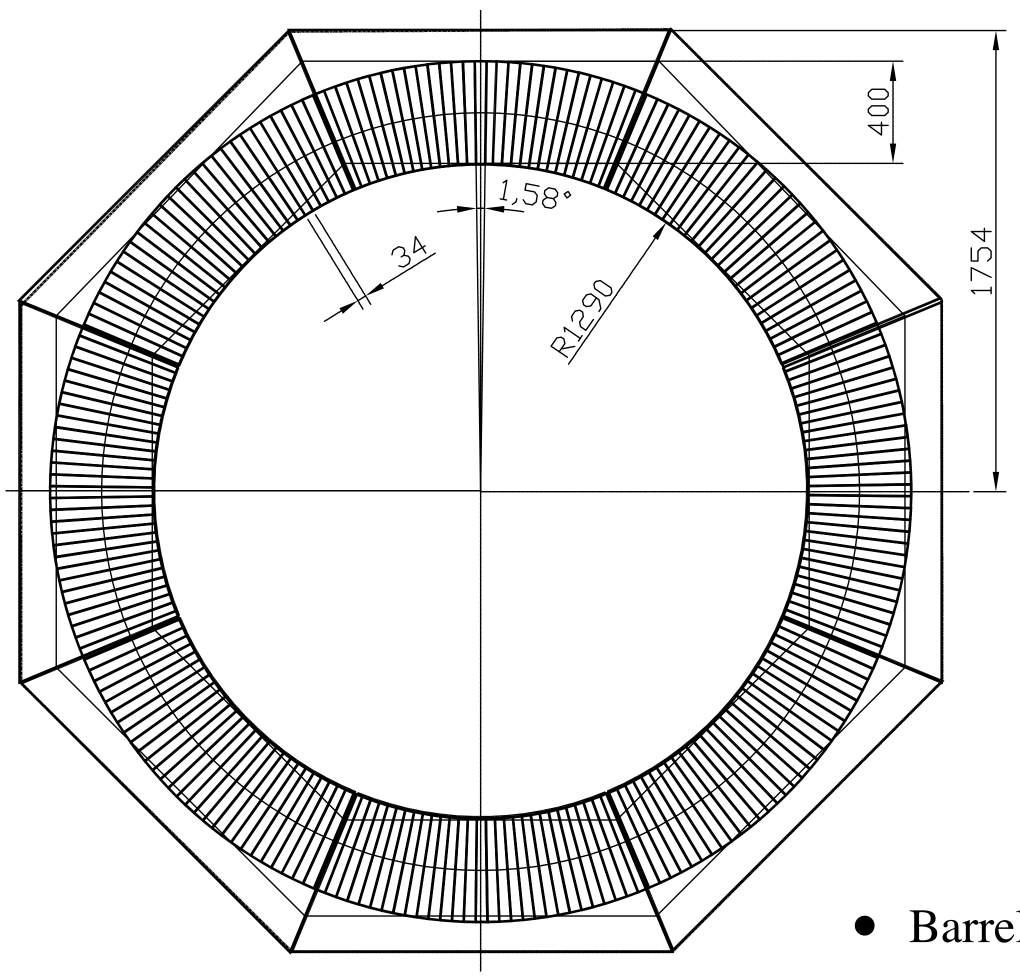
Alignment of tiles without dead zones



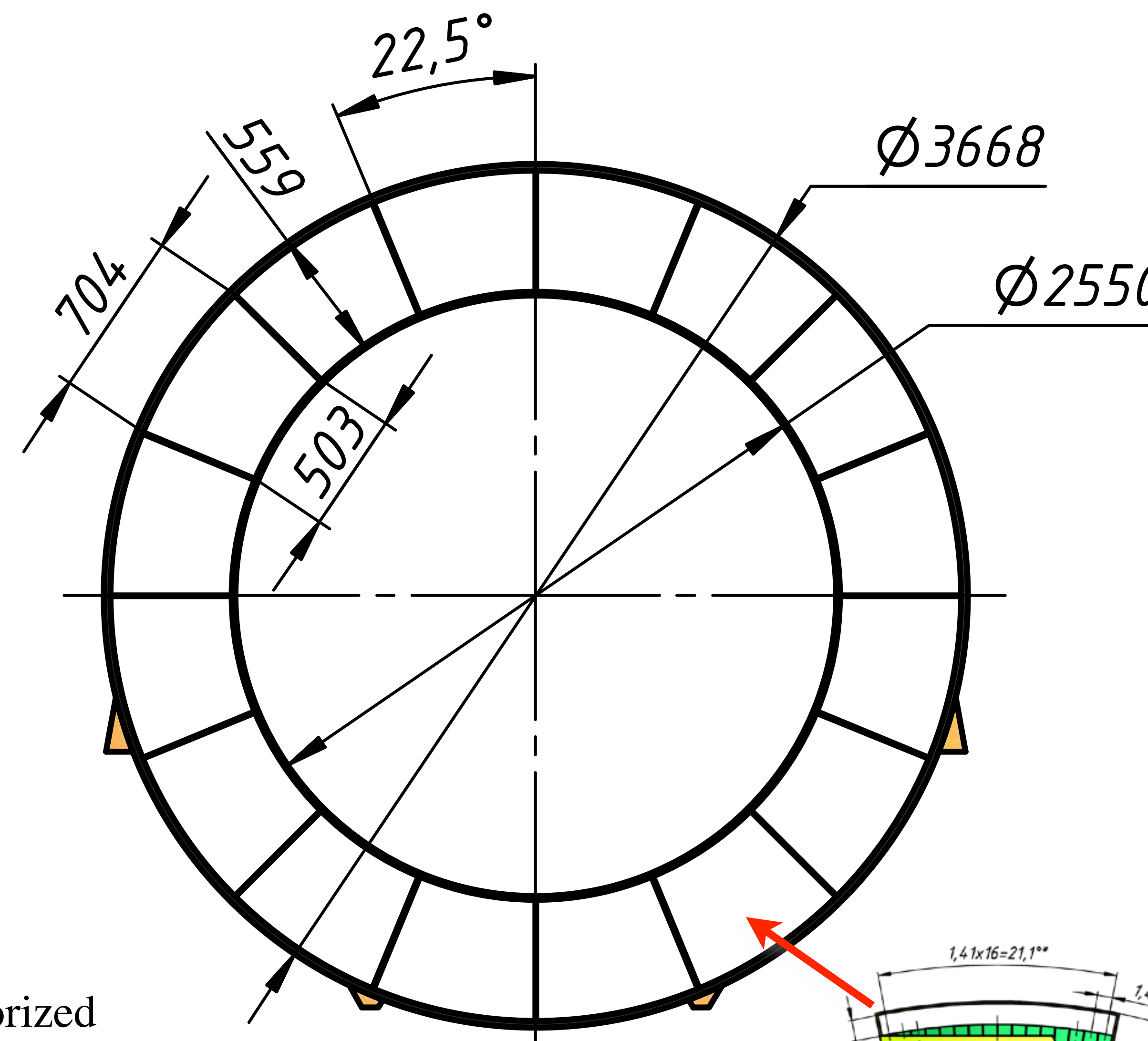
- V_{tile} = 9cm x 3cm x 0.5cm = 13.5 cm^3
- ρ_{tile} = 1.032 g/cm^3 → m_{tile} = 13.9g
- m_{barrel} = 7.3k x 13.9g = 101kg

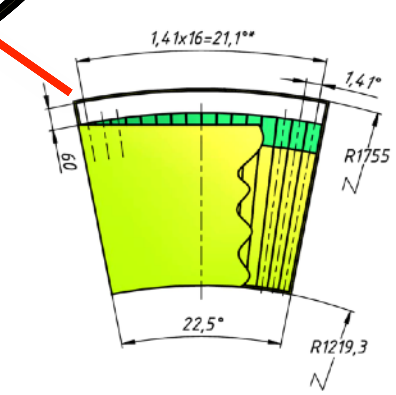
Electromagnetic Calorimeter (ECal)

CDR version (end of 2020)



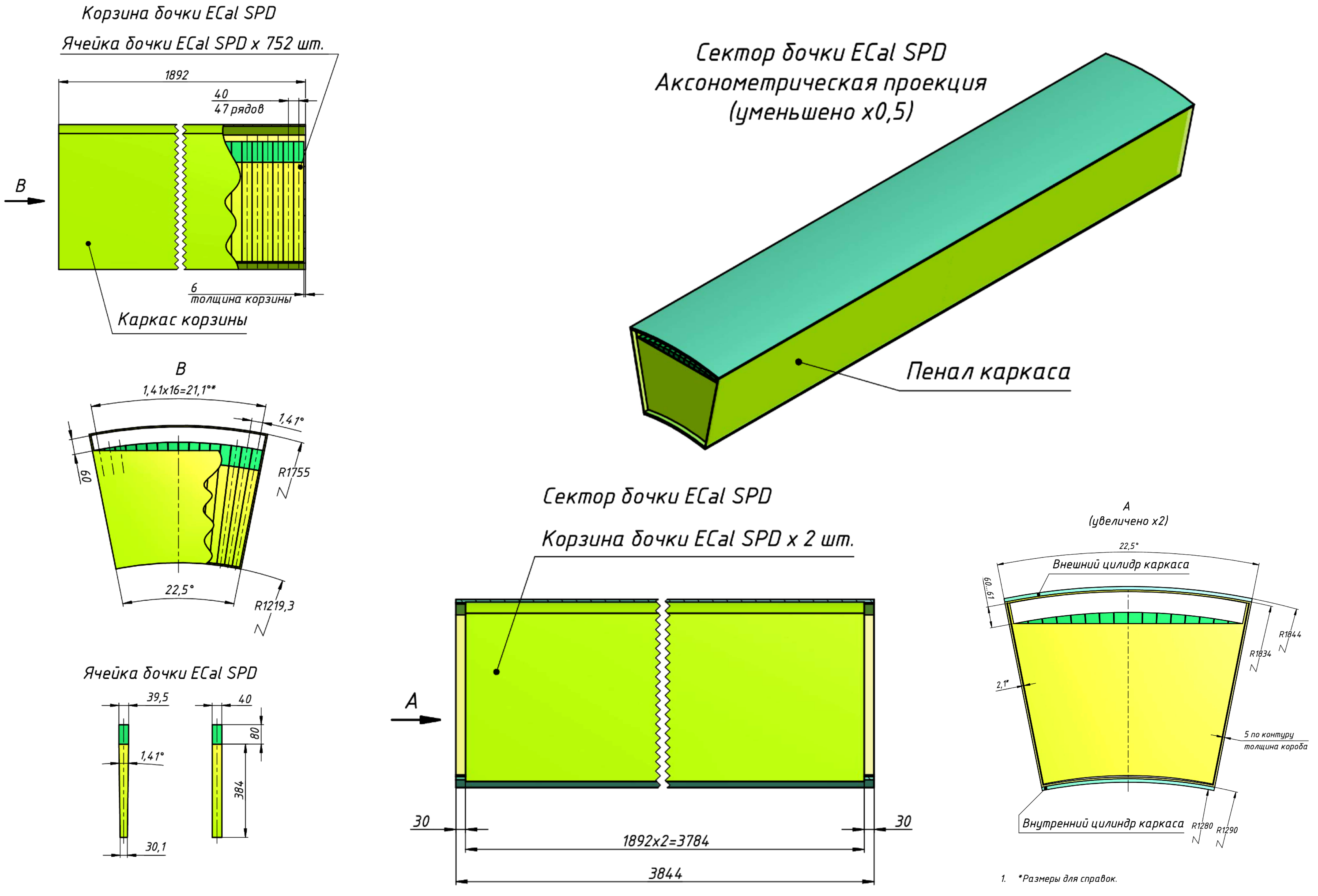
Update (May 2021)





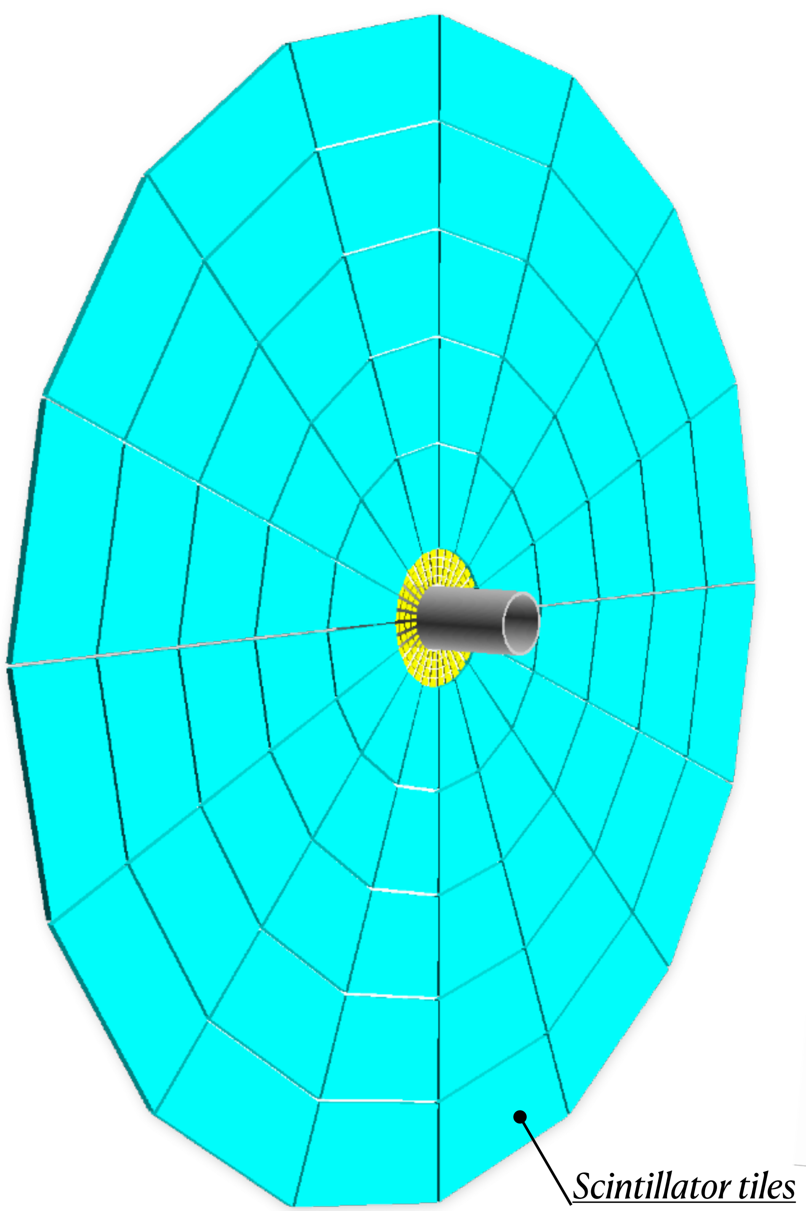
- Barrel layout is sectorized
- Follow the MPD procedure for the frame & installation
- Radial size increased by 10 cm

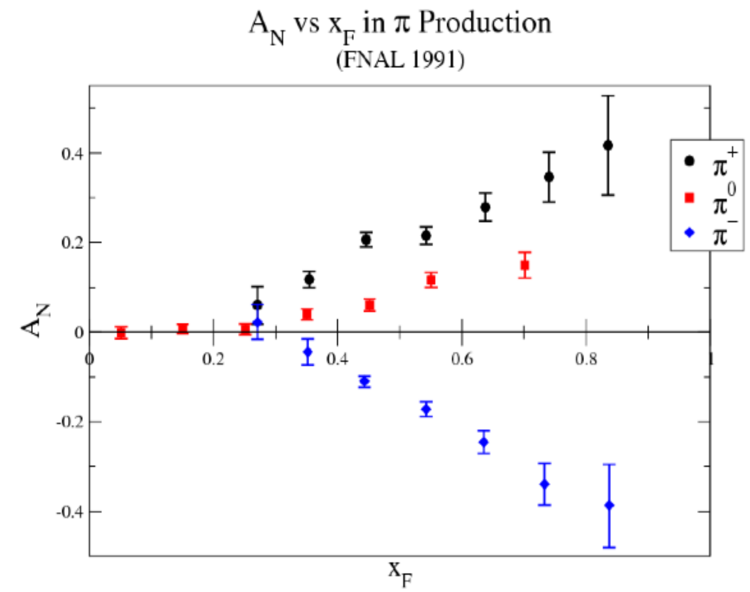
Electromagnetic Calorimeter (ECal)

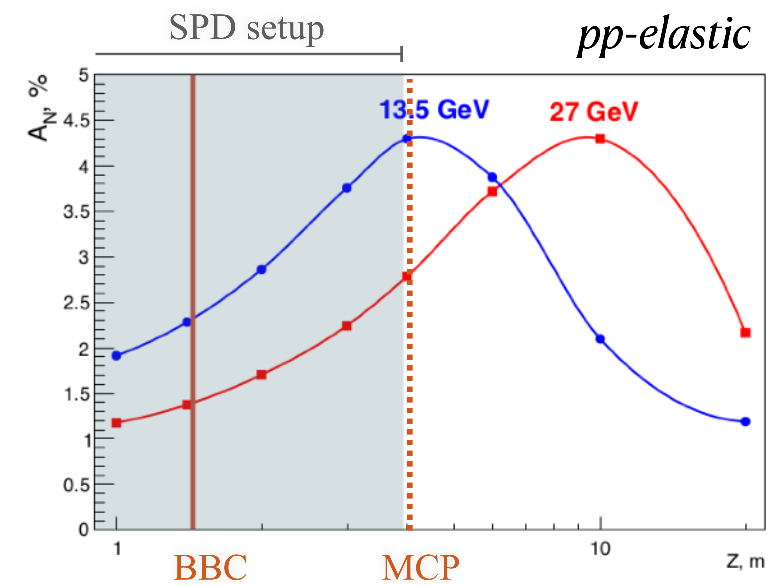


Beam Beam Counter (BBC)

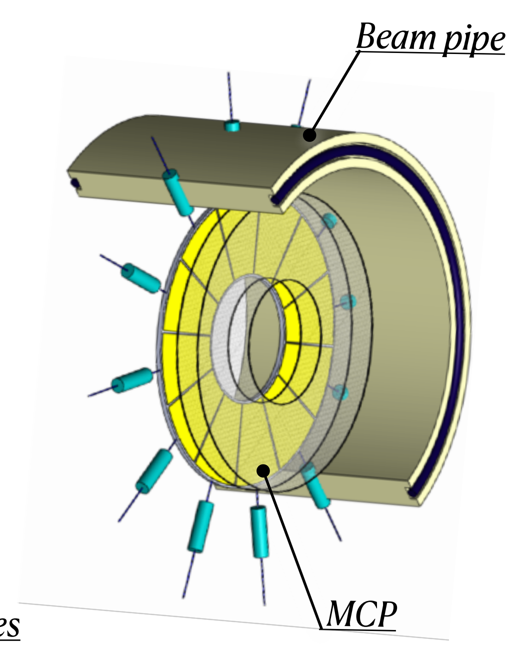
z = ±1.4 m







z = ±3.9 m



- BBC consists of inner and outer parts
  - *Inner part*: Micro-Channel Plates (MCP) located outside the beam pipe in its own vacuum volume. Excellent time resolution.
  - *Outer part*: plastic scintillator tiles with SiPM readout. Time resolution of 0.5 ns.

Unloading zone of MPD