Report of the technical coordinator

(focusing on the detector design)

Alexander Korzenev, JINR LHEP

SPD Collaboration Meeting
Apr 24, 2023

- In December last year, Agreement № 9 was signed with STRABAG on the conditions for the continuation of work in 2023. The completion of the contract is scheduled for July 31 (*PAC, N.Agapov, Jan 23*).

- The SPD hall is currently used for storing concrete blocks of biological protection and collider elements.
- Arrival of the rail system is planned for the end of May.

Important events since the previous meeting in October

- **First version of TRD has been released and presented by Alexey at PAC**
  - Updates are still coming…
- **Issue with two SC magnet variants was finally concluded**
  - Internally organized review committee (DAC is not available)
  - The BINP project is considered to be more realistic in terms of the SPD time schedule, manufacturing and commissioning, as well as guarantees of reliability in operation
- **Verification calculation of the distribution of loads on the floor of the SPD hall by "KOMETA" is completed**
  - The maximum permissible weight of the detector has been increased to 1500 tons (platform with electronics is not included)
  - The detector size has been increased (+10 cm radially, +30 cm for length)
  - New Cherenkov detectors for PID of particles with p>1.5 GeV (not yet approved by TB)

Comparative examination of two SPD magnet projects

- ***BINP project:*** The use of a *Rutherford-type cable* made of 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. *Indirect cooling of the superconductor will be provided by two-phase helium*, which will circulate in pipes welded to the outside of the coil former.

- ***LHEP JINR project:*** The technology of superconducting coils manufacturing is based on a *hollow high-current cable* similar to the one used for the Nuclotron magnets or the one used in the ITER systems. The manufacturing technology of the hollow cable made of NbTi/Cu composite wires is well developed at LHEP JINR. *The cooling system is supposed to use a single-phase cooling scheme with supercritical helium*.

Documents that were reviewed by the Committee

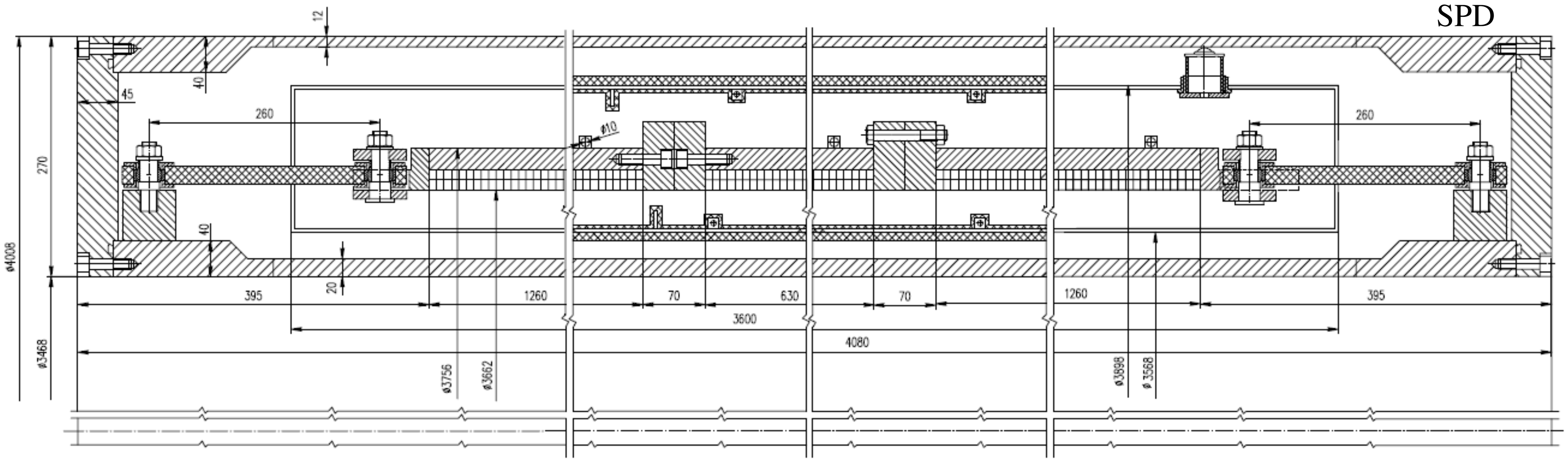
- Reviewer's report: "Comparative analysis of two projects of superconducting magnets of the SPD NICA experiment" prepared by E.Koshurnikov (founder of the company "Neva-Magnet", St. Petersburg).
- Responses to the Reviewer's comments on the review by the leader of the BINP project E.Pyata.
- Responses to the Reviewer's comments on the review by the leader of the LHEP JINR project H.Khojibagiyan.

Recommendation of the Committee (unanimously supported by the Technical Board)

The Committee appreciates the work done by the JINR and BINP groups on the preparation of the conceptual design of the SPD magnet. Based on the criteria for the reliability of the operation of the magnetic system, the possibility of implementing the proposed projects in the current conditions, as well as availability of human resources and their experience gained in the implementation of similar projects, the Committee makes the following recommendation. **The BINP project is considered to be more realistic in terms of the SPD time schedule, manufacturing and commissioning, as well as guarantees of reliability in operation.** The Committee recommends the SPD Technical Board to support this project for further development. The Committee would also like to point out that since the magnet will eventually operate in JINR, close cooperation between the two groups that submitted the projects is important to achieve the final result.

E.Pyata et al.

Design is based on the PANDA magnet



Length ≈ 4.1 m
$\varnothing_{inner}$ ≈ 3.5 m
ΔR = 27 cm

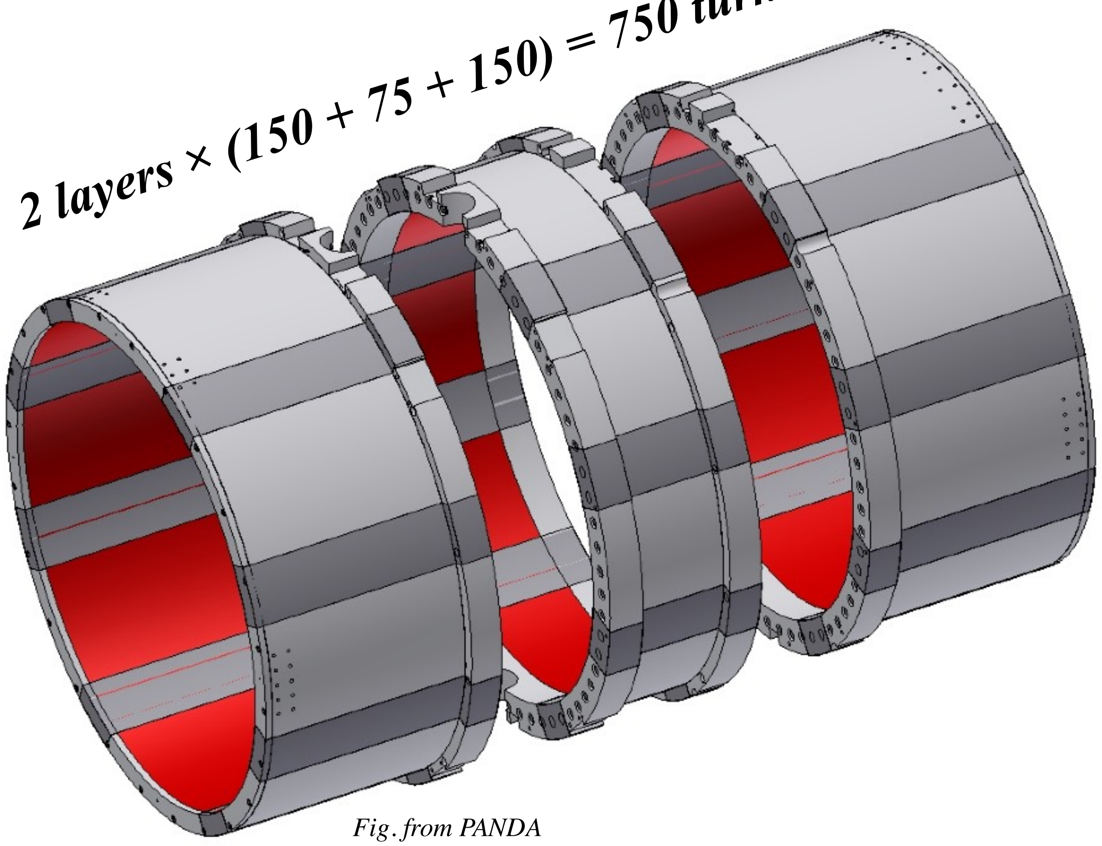
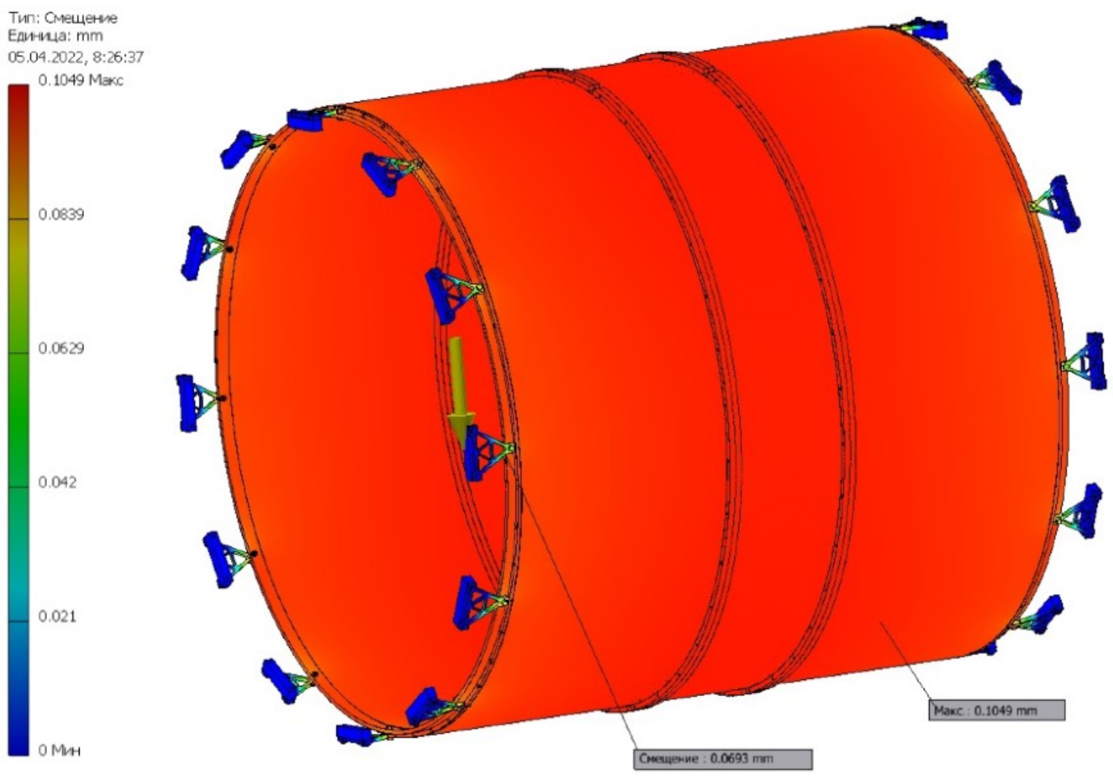


Fig. from PANDA (to be updated)

Results of deformation calculations for the SPD magnet (without magnetic forces) m=5 tons



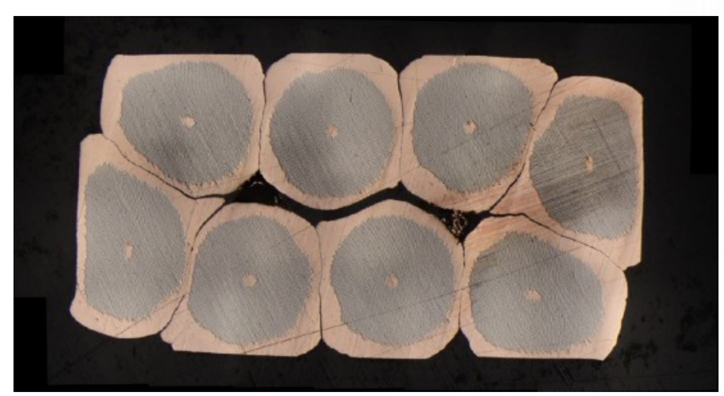
The superconducting cable

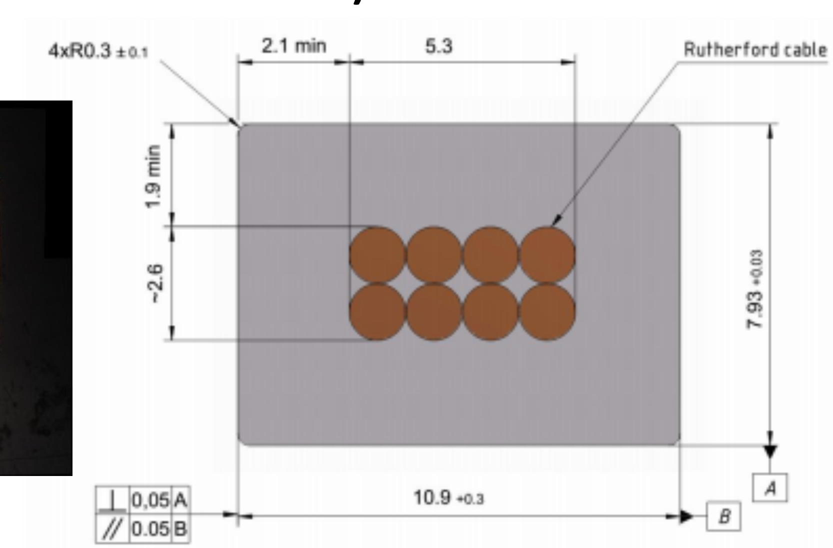
~4 years of R&D for the PANDA magnet

Conductor mechanical and electrical parameters

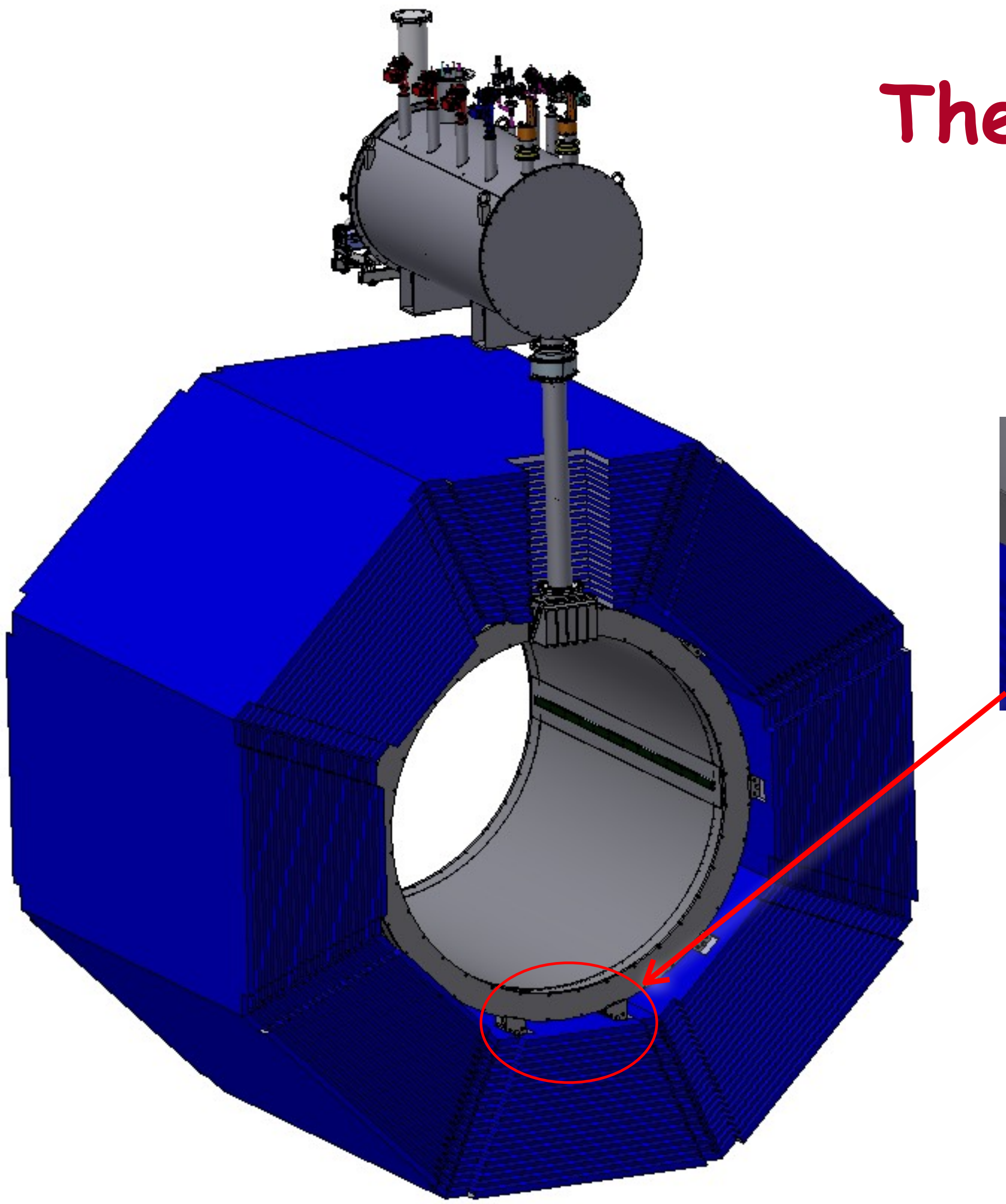
Thickness (after cold work) at 300 K	mm	7.93	± 0.03
Width (after cold work) at 300 K	mm	10.95	± 0.03
Critical current (at 4.2 K, 5 T)	A	> 14690	
Critical current (at 4.5 K, 3 T)	A	> 16750	
Overall Al/Cu/sc ratio		10.5/1.0/1.0	
Aluminum RRR (at 4.2 K, 0 T)		> 600	
Al 0.2% yield strength at 300 K	MPa	> 30	

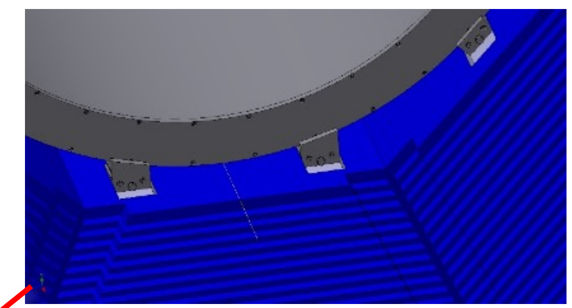
Cross-section of the conductor
(8 strands, extruded in Al matrix)

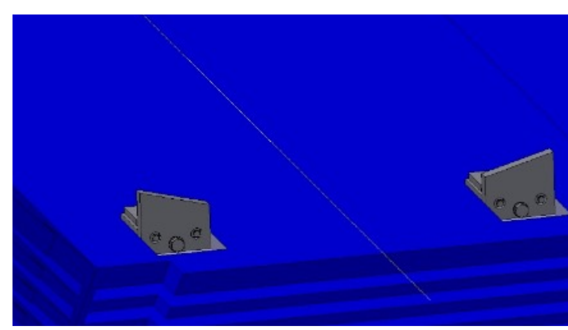


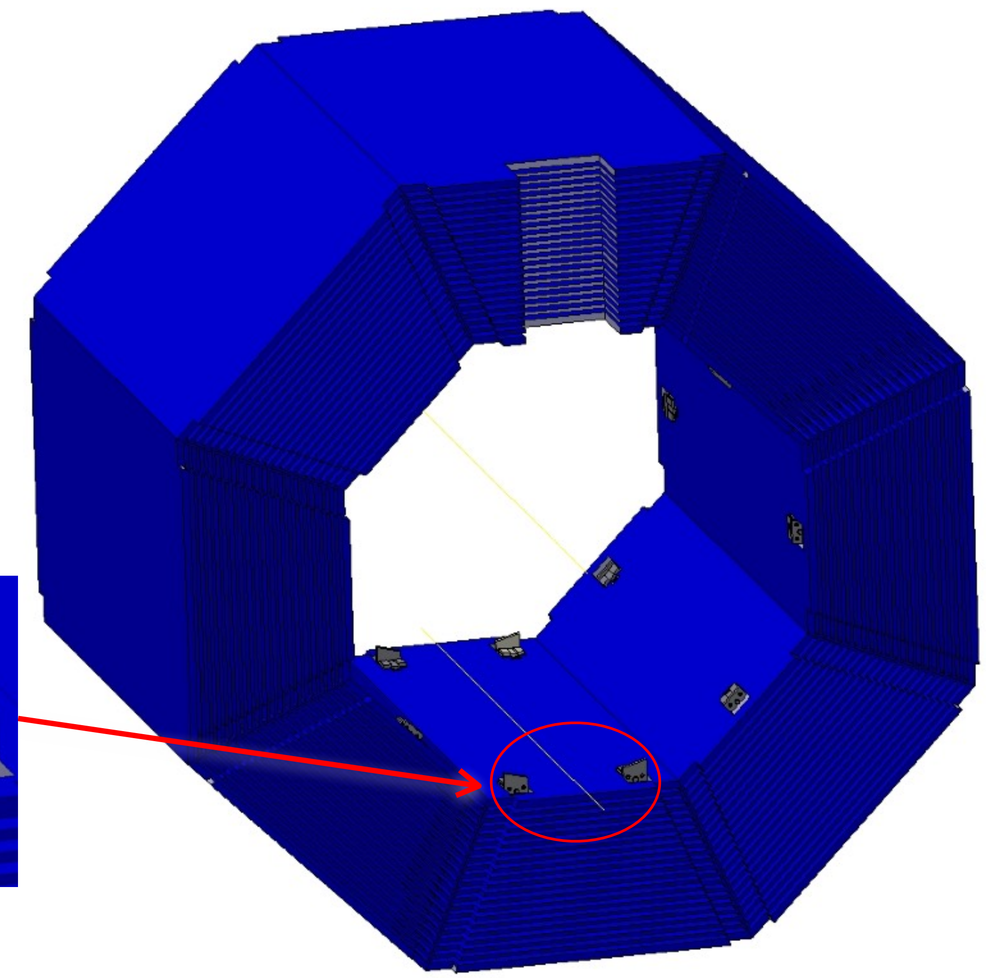


The magnet fixing scheme







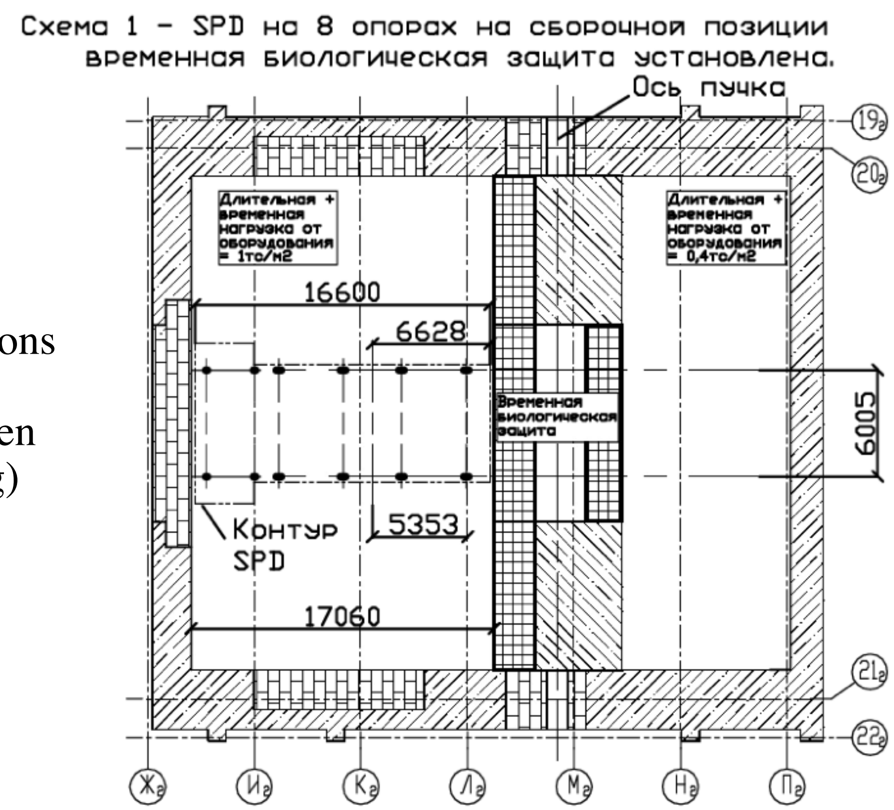


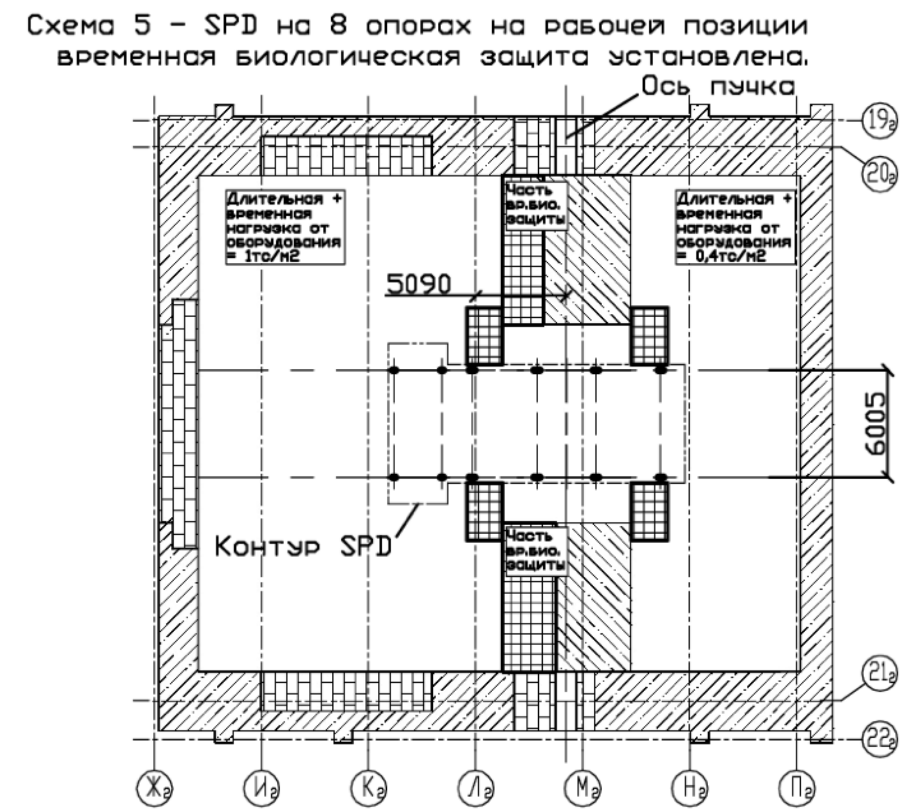
- The cryostat is positioned by means of special adjustable supports fixed on inner layer of RS octants. The minimum gap between the cryostat and RS is 20 mm.
- The magnet will be inserted into the RS barrel from the side (not from top as in MPD).
- The same stand that was used to assemble the magnet can also be used to insert the magnet into the RS.

Verification calculation of the distribution of loads on the floor of the SPD hall by “KOMETA”

5 schemes for detector in “assembling” and “beam” positions

Detector is supported by 8 (when parked) or by 6 (when moving) points





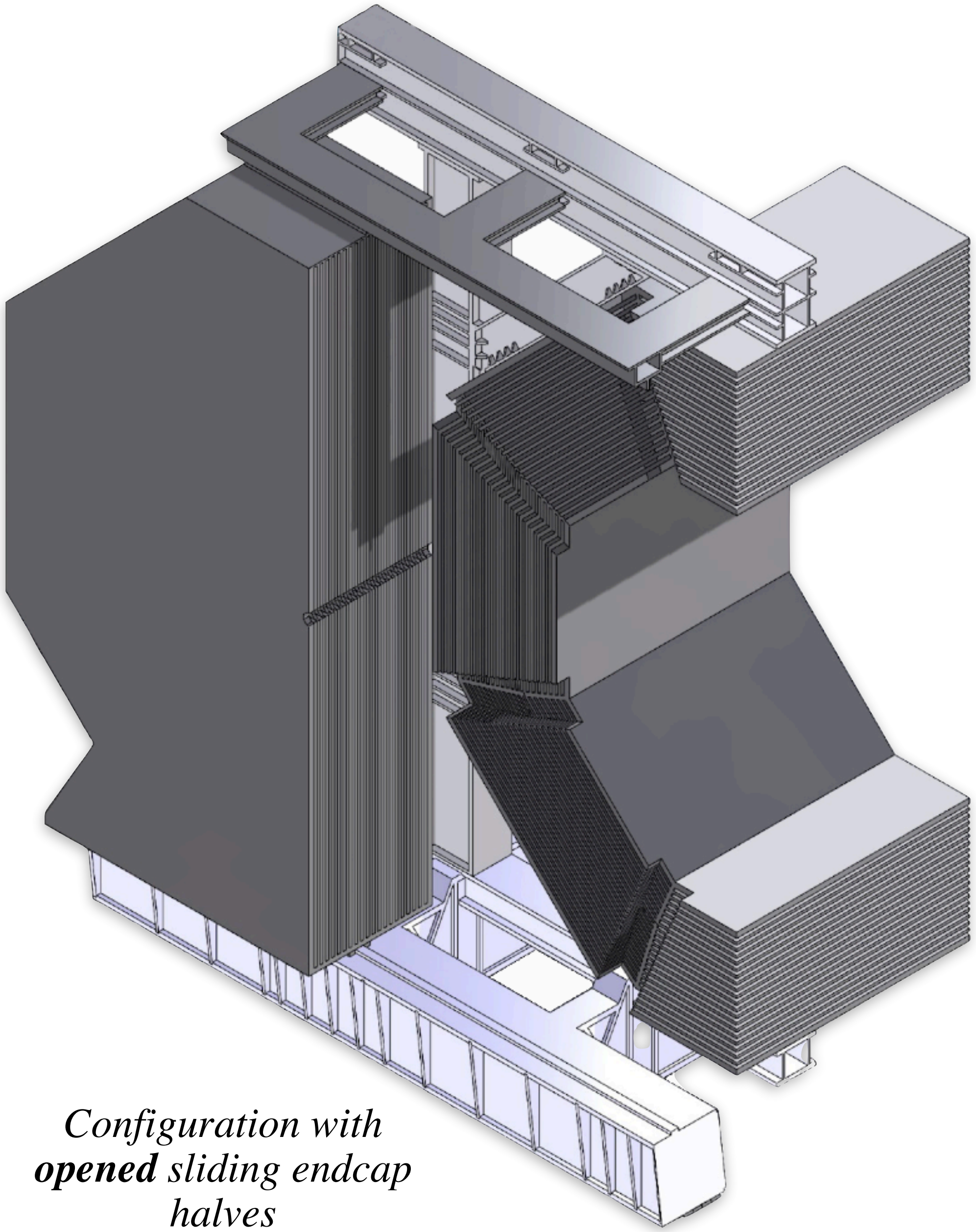
General Conclusion Based On The Results Of All Calculations Performed (report received on Jan 25,2023. page 96)

Based on the calculations performed, it can be concluded that with a given *detector weight of 1200 tons* and the weight of a platform with electrical equipment of 100 tons, the reinforcement of the foundation plate is sufficient, the *deformations of the plate and the pile field do not exceed critical values*. The bearing capacity of the plate and the pile field is provided. In this case, the weight of the detector is distributed on 8 support points when parked and on 6 support points when moving, the weight of the detector is distributed evenly on the supports.

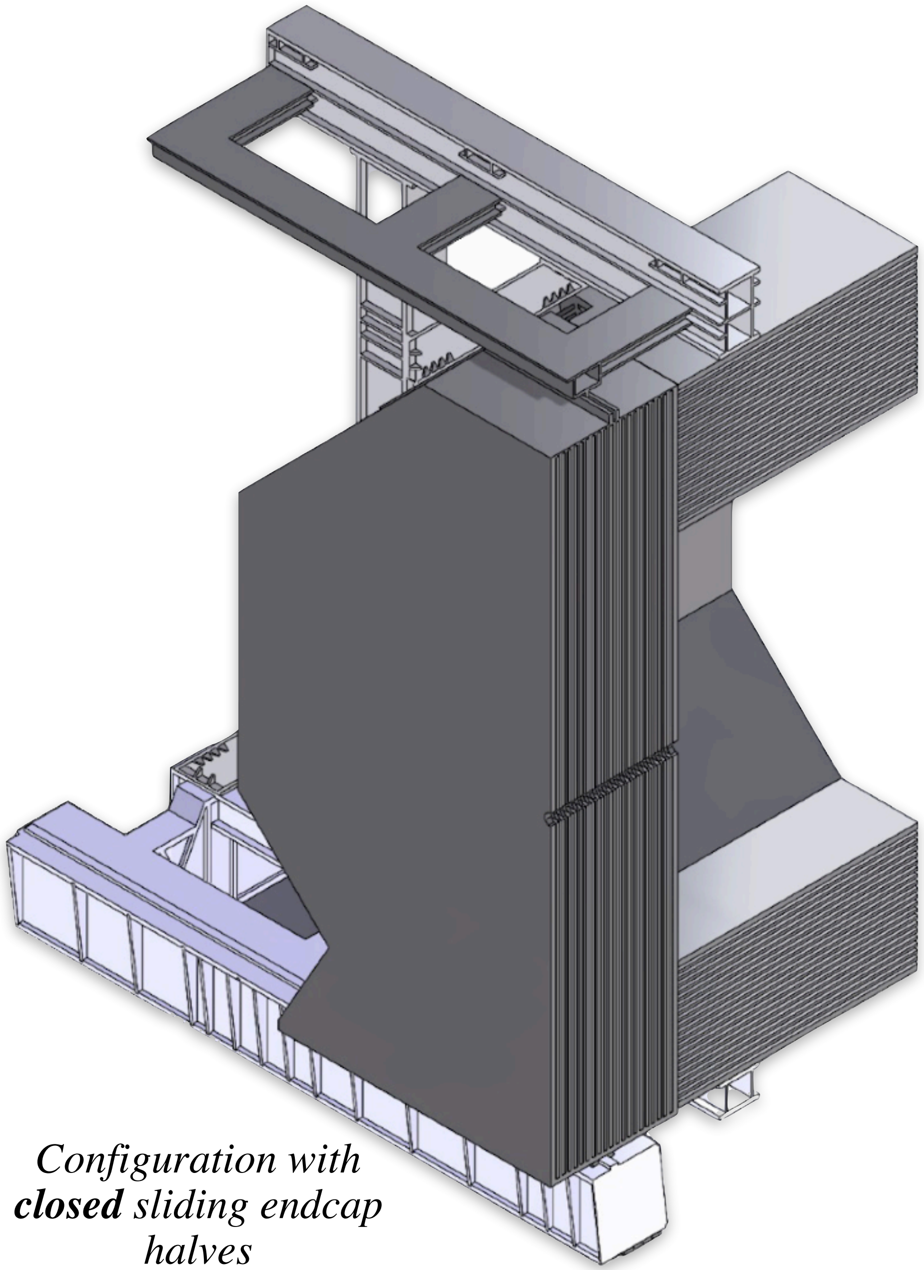
It is allowed to increase the weight of the detector to 1500 tons with the platform of a platform with electrical equipment of 100 tons, provided that the weight of the detector is distributed by 8 support points when parked and by 6 support points when moving, the weight of the detector is distributed evenly on the supports.

FEA calculations for stress and deflections (1/4 of RS)

- The detector weight can be increased by ~400 tons as compared to TDR.
- The RS barrel radius has been **increased by 10 cm** and the length **by 30 cm** as compared to the TDR values.
- All FEA calculations have been redone. Magnetic field was **not** yet taken into account.



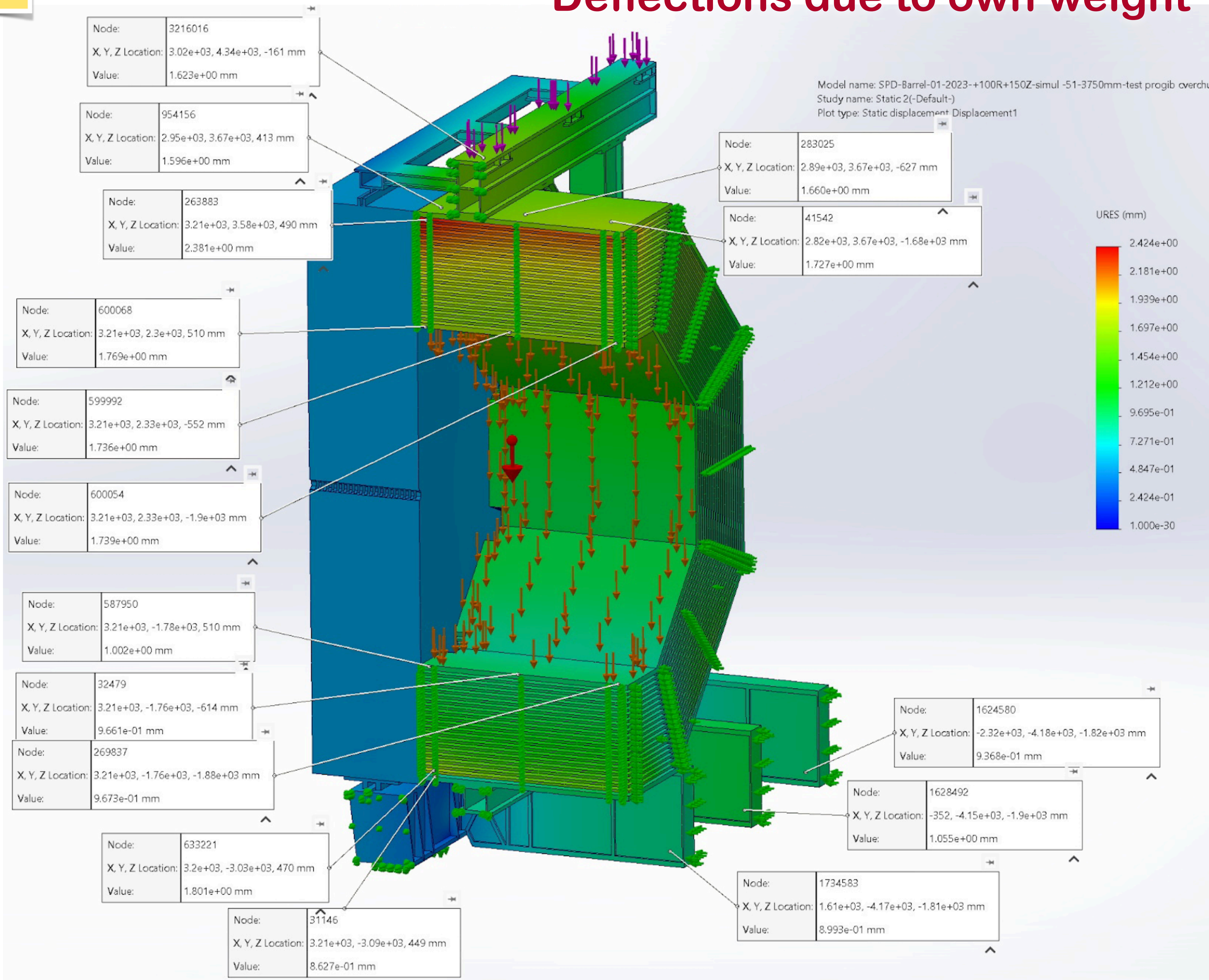
Configuration with ***opened*** *sliding endcap halves*



Configuration with ***closed*** *sliding endcap halves*

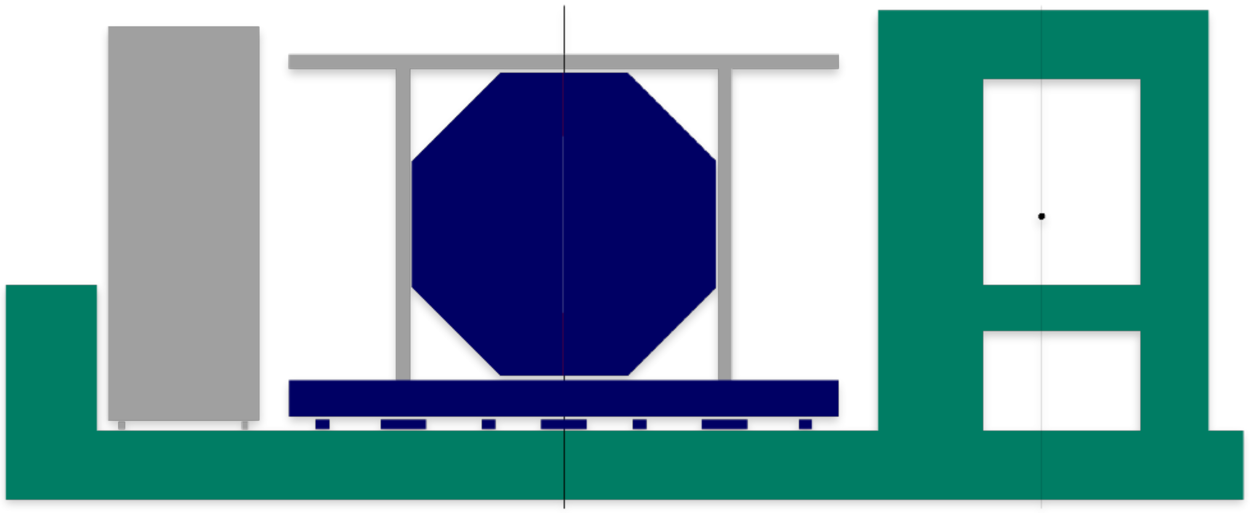
A.Samartsev

Deflections due to own weight

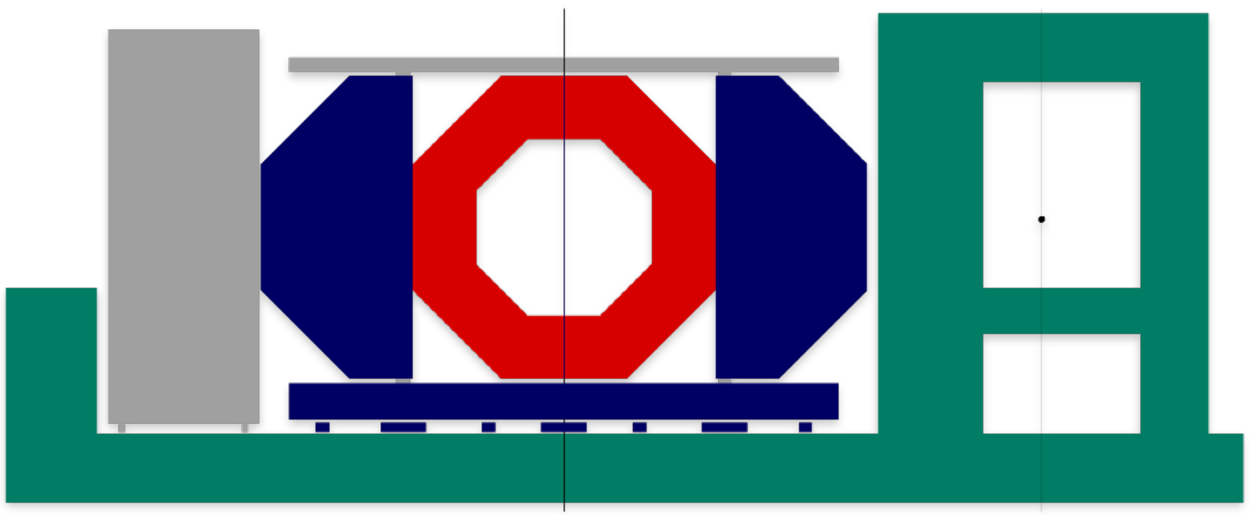


Weight estimate

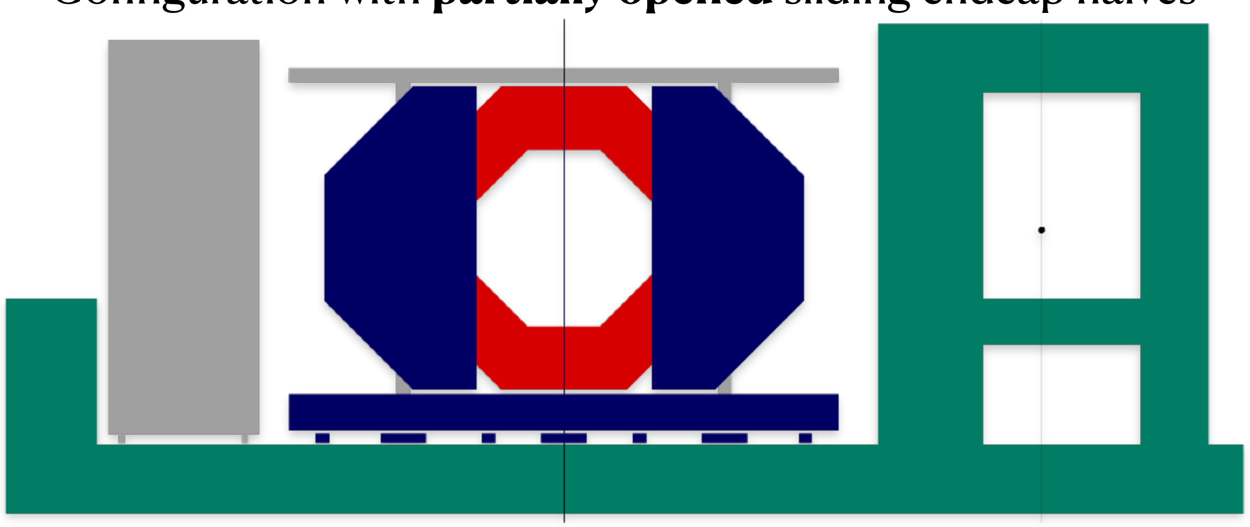
Configuration with **closed** sliding endcap halves



Configuration with **opened** sliding endcap halves



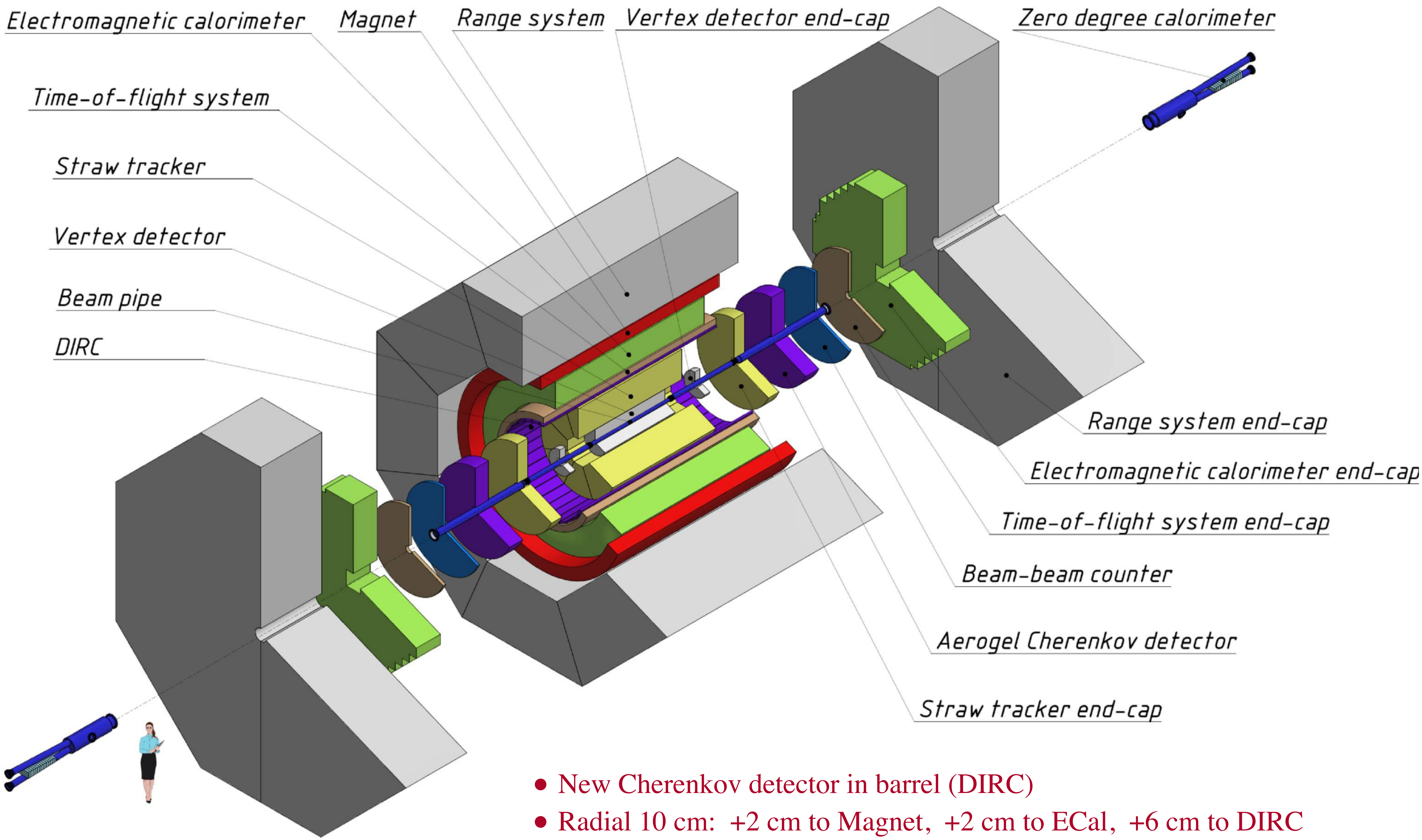
Configuration with **partially opened** sliding endcap halves



- Permitted weight is 1500 tons for the entire detector (without side platform)
- Uniform distribution on supports
  - 1500 t / 6 skate = 250 t
  - 1500 t / 8 jack = 188 t

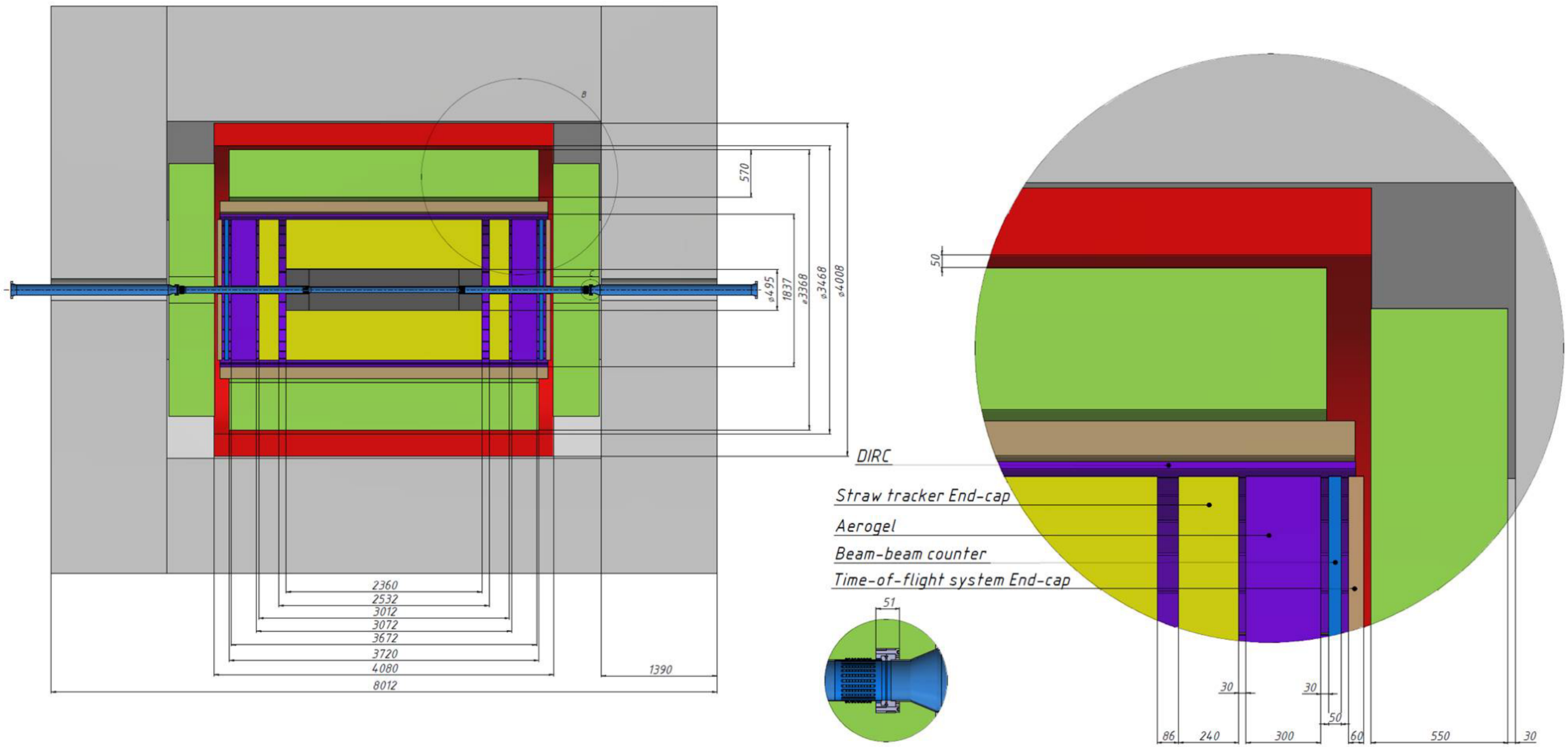
- Estimation of the total weight of the SPD detector
  - RS_{barrel} = 67 t × 8 = 536 t
  - RS_{endcap} = 118 t × 4 = 472 t
  - RS = 536 t + 472 t = 1008 t
  - STS = 119 t
  - Top platform = 40 t
  - Other detectors = 100 t
- Total = 1008 t + 119 t + 40 t + 100 t = 1267 t

Schematic view of the SPD setup (Apr 2023)



- New Cherenkov detector in barrel (DIRC)
- Radial 10 cm: +2 cm to Magnet, +2 cm to ECal, +6 cm to DIRC
- Longitudinal 30 cm: Width of Aerogel detector increased 16 cm → 30 cm

Schematic view of the SPD setup (Apr 2023)



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- Longitudinal 30 cm: Width of Aerogel detector increased 16 cm → 30 cm

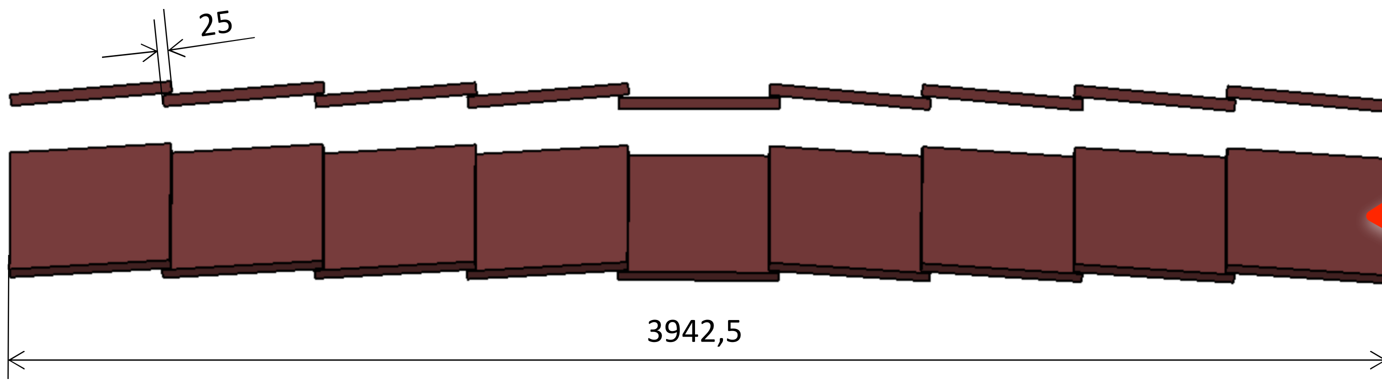
Detectors inside the magnet

- ECal will be suspended on the magnet. No changes in design as compered to the previous meeting.
  - +2 cm makes the ECal active length equal to 40 cm (quoted in CDR).
- PID detectors (TOF and DIRC) will be mounted to a single frame. No active development for the power frame ongoing so far.
  - The MRPC size has been optimized for the current dimensions.
- The ST volume stays unchanged. Contract with CRISM for conceptual design.
- No active development for VD so far.

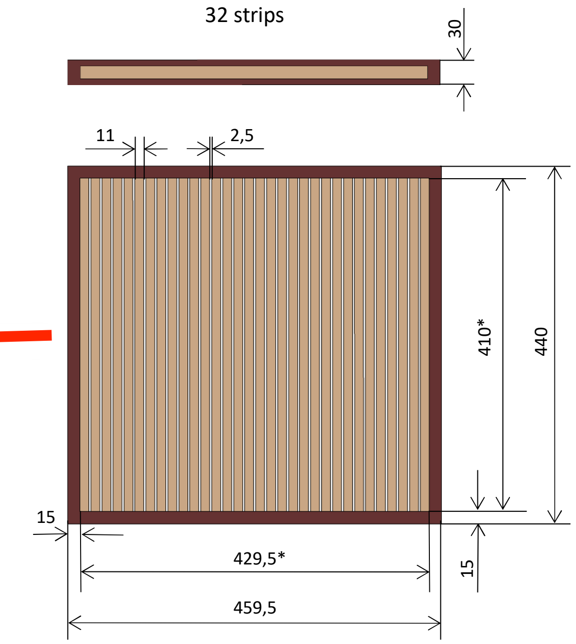
A.Shunko

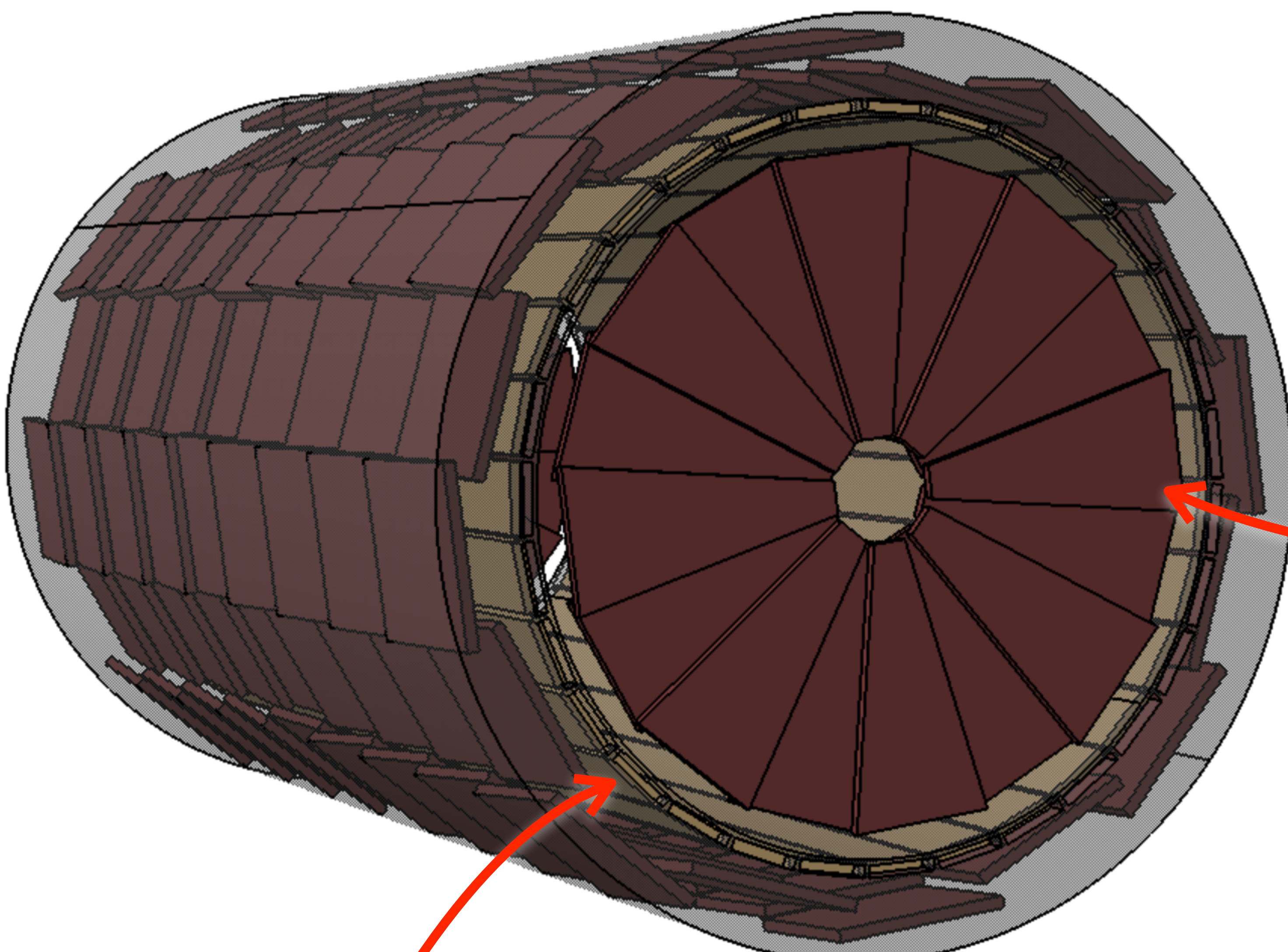
TOF detector (MRPC option)

16×9=144 MRPC



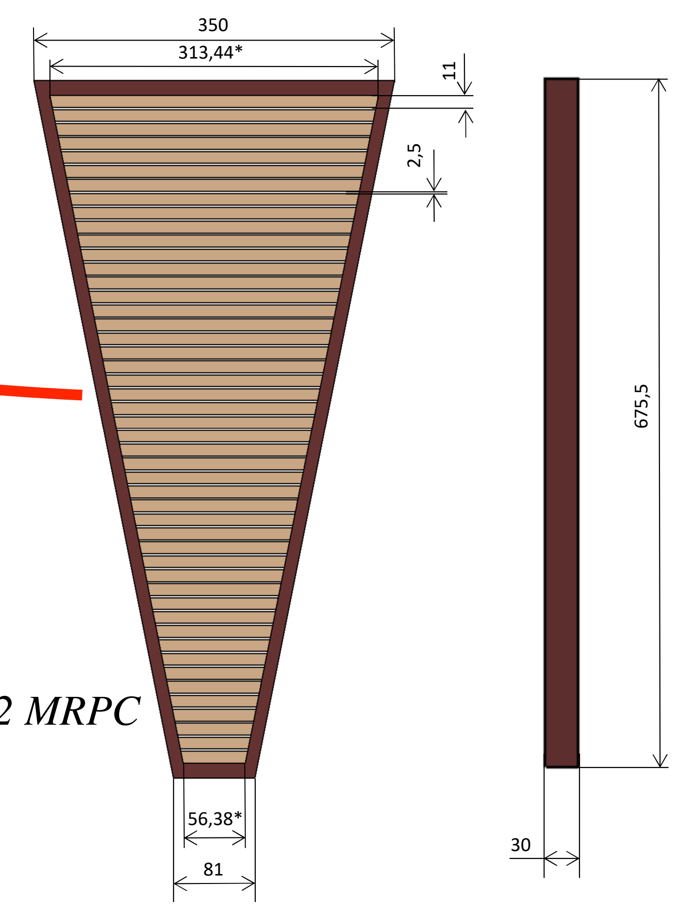
TOF Chamder
32 strips





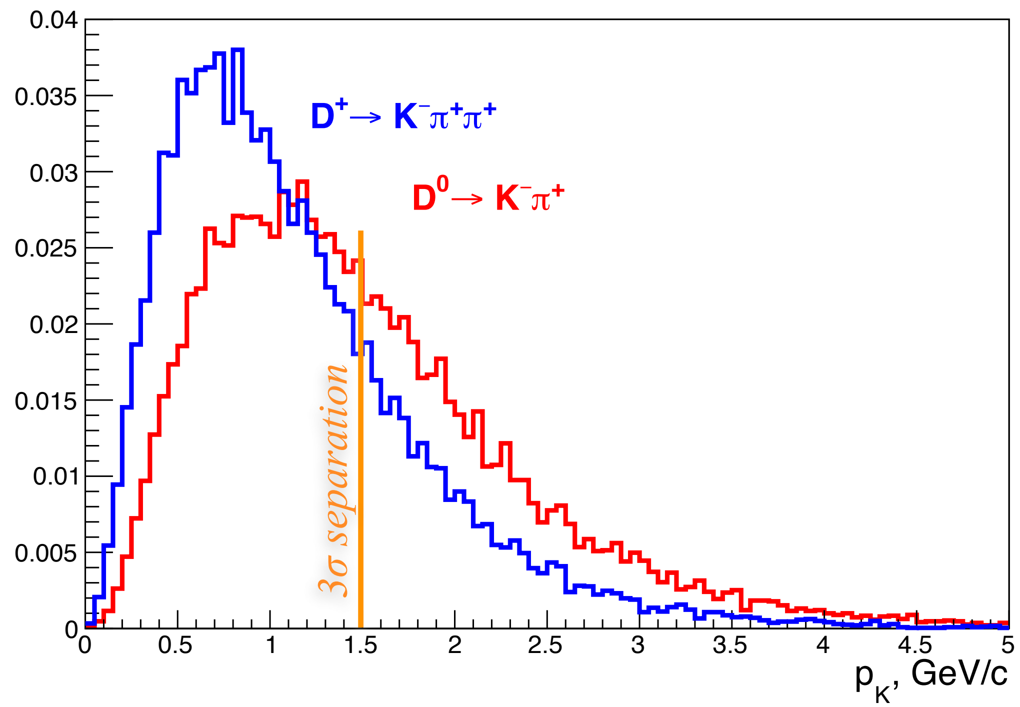
DIRC detector

TOF Chamder Endcap
48 strips



2×16=32 MRPC

Identification with TOF alone

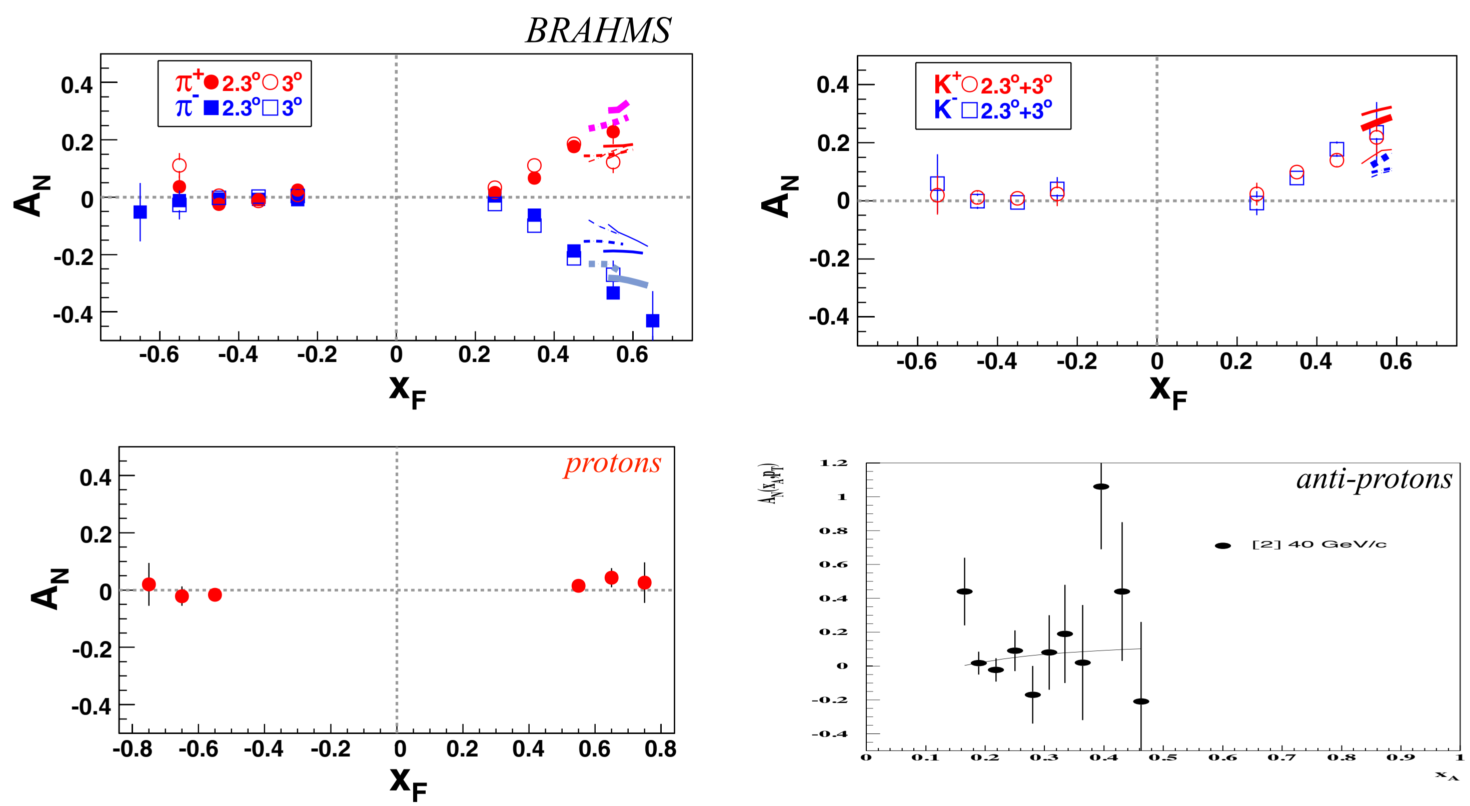


Production of D mesons in SPD

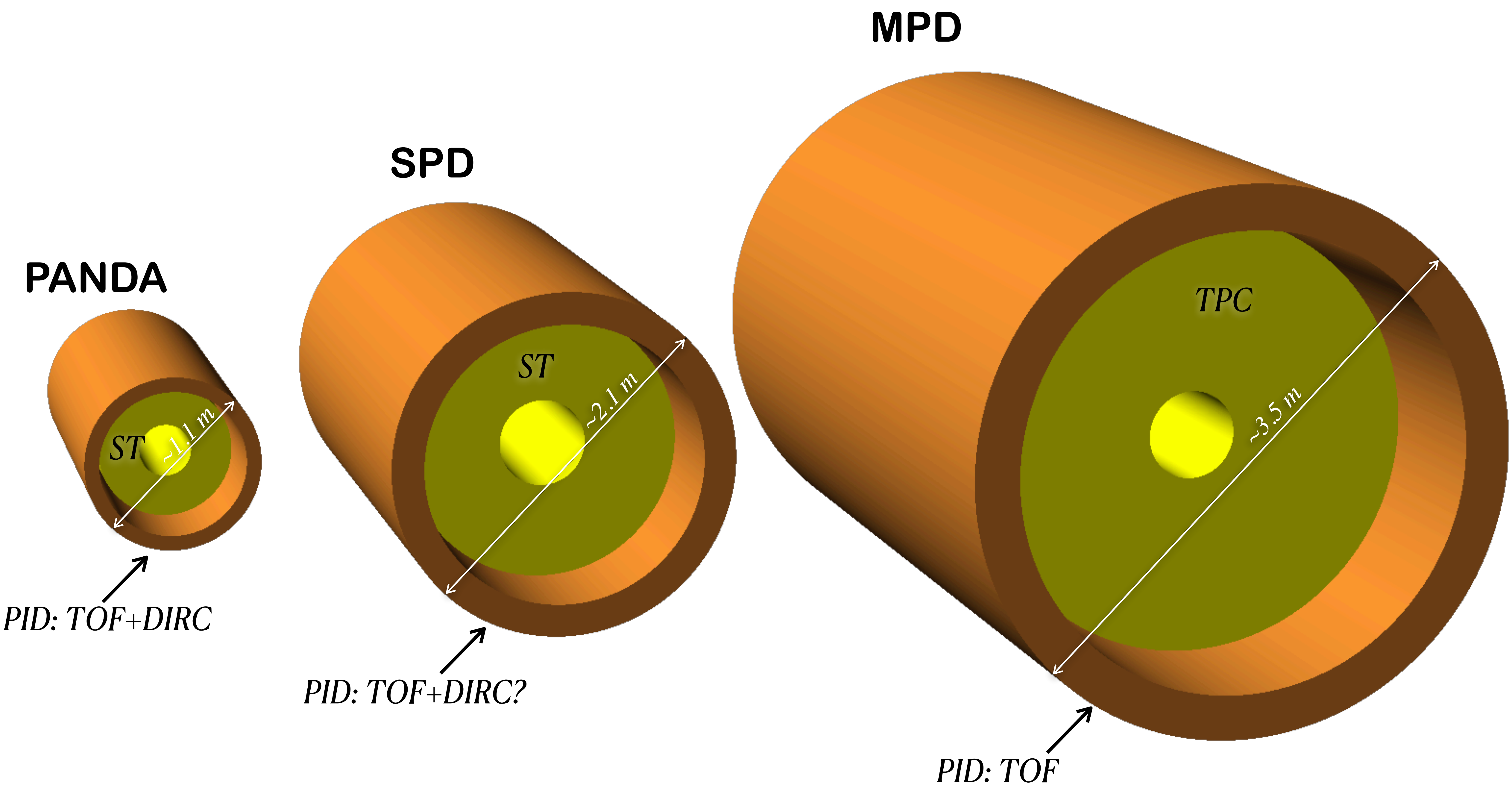
- The region of p<1.5 GeV (3σ separation) covers only half of kaons produced in D decays.
- The largest effect for A_N is expected for x_F=0.4, i.e. high momentum D mesons => higher momentum decay products.

SSA measurements for light hadrons (π,K,p)

- Physics related to TMDs of quarks
- For E_{CM} = 27GeV:
  - p=1.5GeV → x_F=0.11
  - p=4GeV → x_F=0.3
  - p=6GeV → x_F=0.45

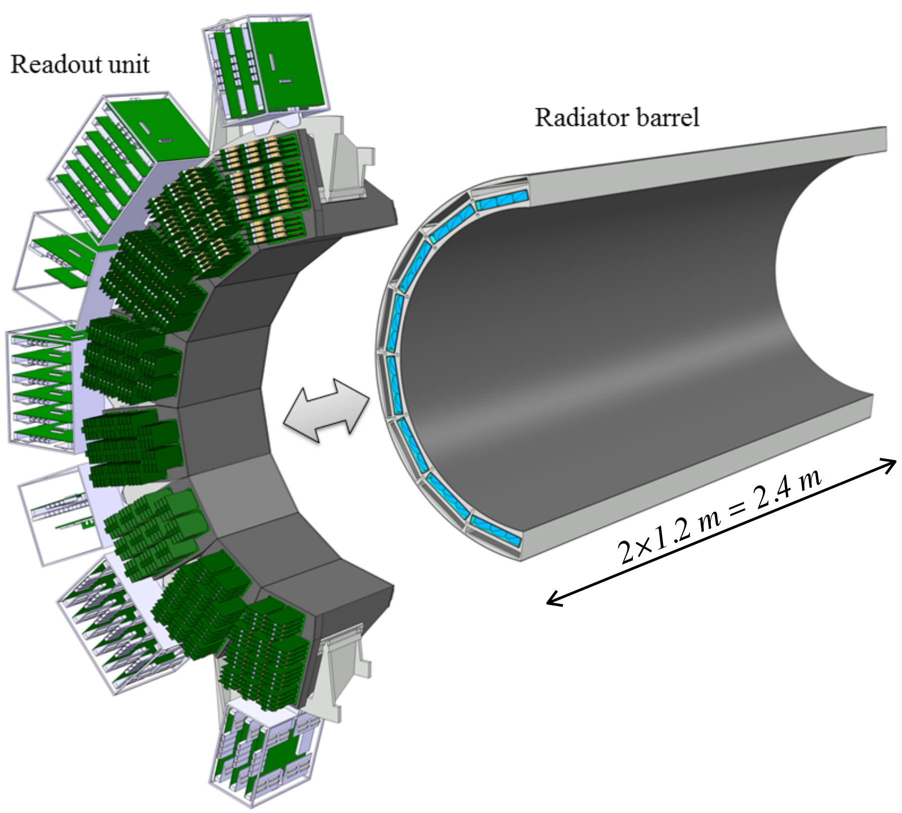


PID detector for higher momentum particles



- Shorter flight distance requires better time resolution for TOF
- Possible solution: Cherenkov detector (DIRC) for PID

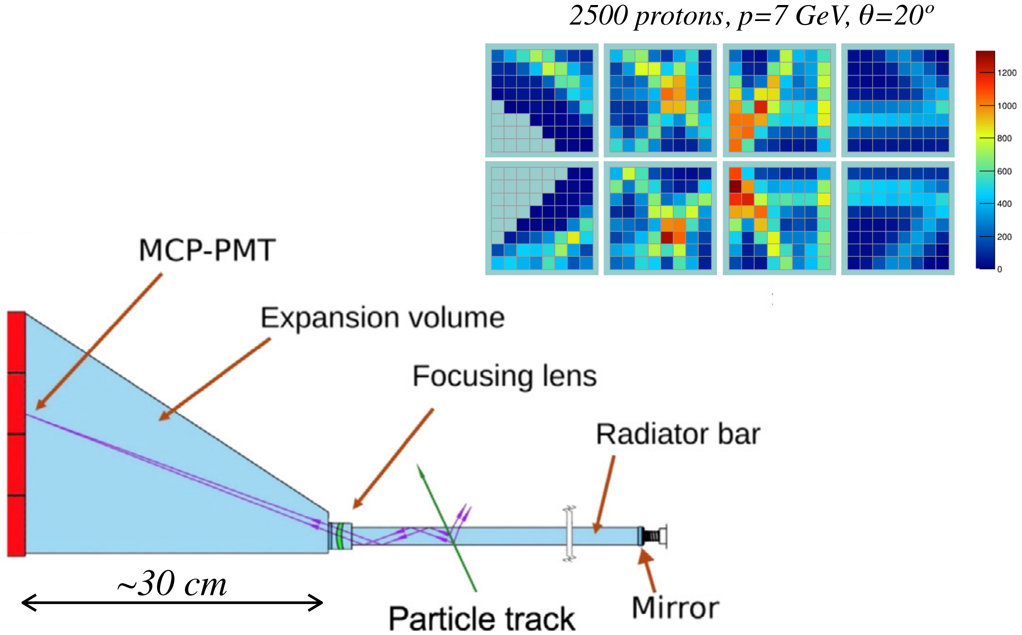
DIRC in PANDA



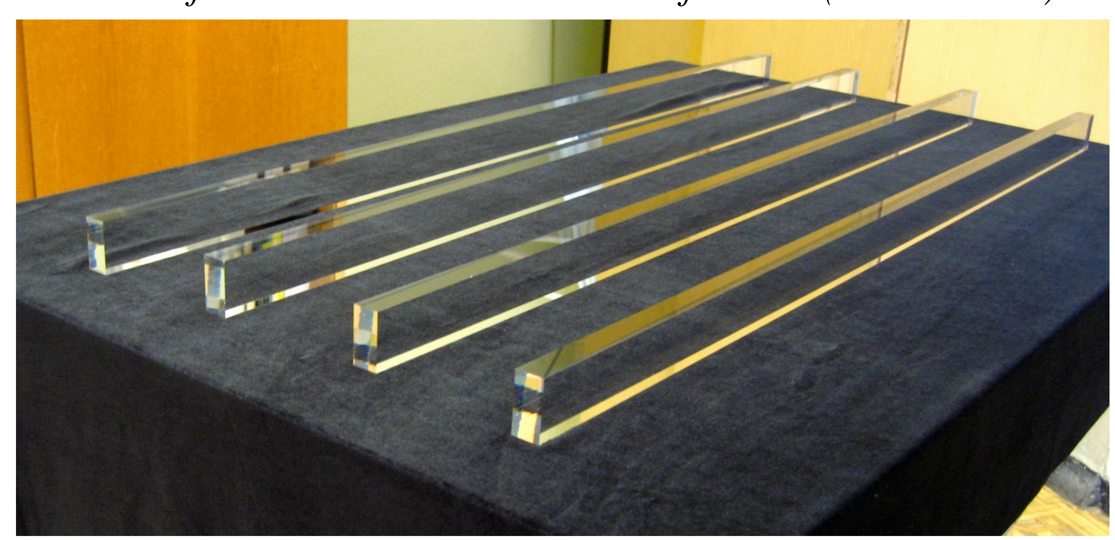
- Bars which are made of Fused Silica (“Quartz”) and serve as a radiator and a light guide
- DIRC is intrinsically a 3-D device, measuring: x, y, and time of Cherenkov photons, defining θ_C, ϕ_C, t_{prop}
- 16 containers with 3 bar each
- MaMCP for light detection: 8×8 pixels, 6×6 mm² pixel
- Goal: π/K separation better than 3σ for 0.5<p<3.5 GeV (5σ in MC)

- **SPD**: 32 containers of the same cross section. Bars are longer ~3m. Cost of project ~10 M$ ⇒ 2-nd stage of SPD

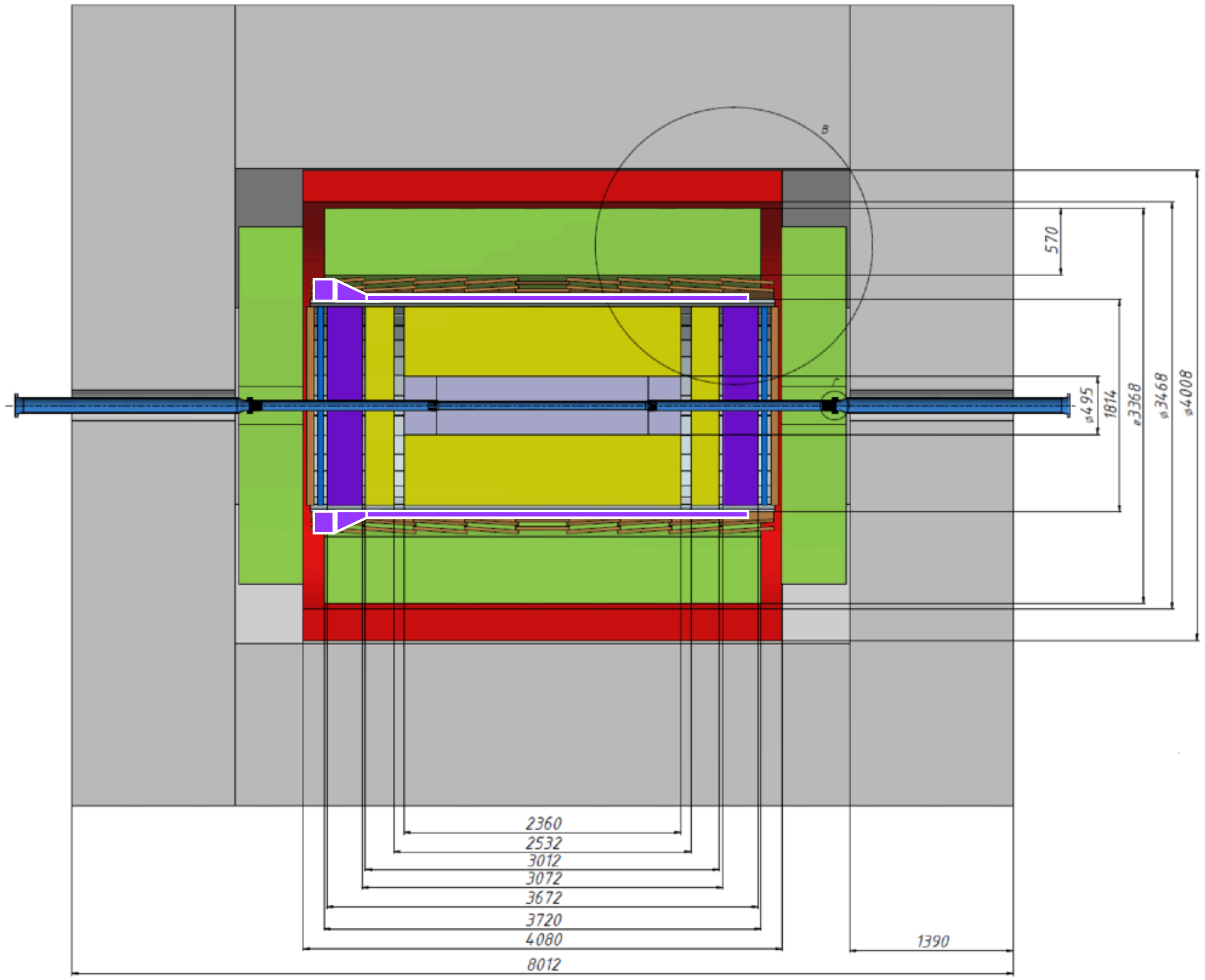
2500 protons, p=7 GeV, θ=20°

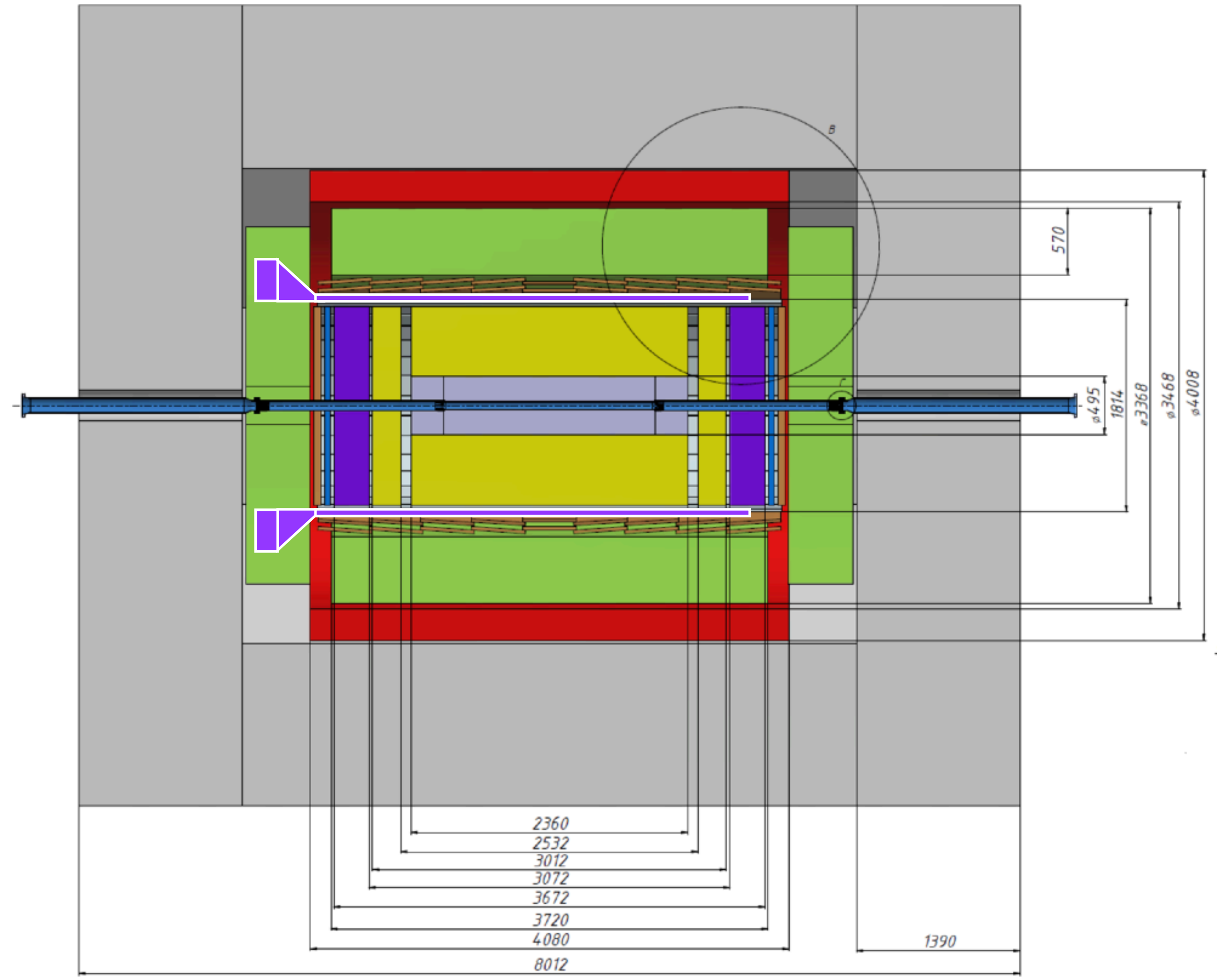


Silica radiators produced for the PANDA R&D ~10 years ago
Some of them are stored in bl. 201 of LHEP (V.Dodokhov)



Where we can place DIRC in SPD?

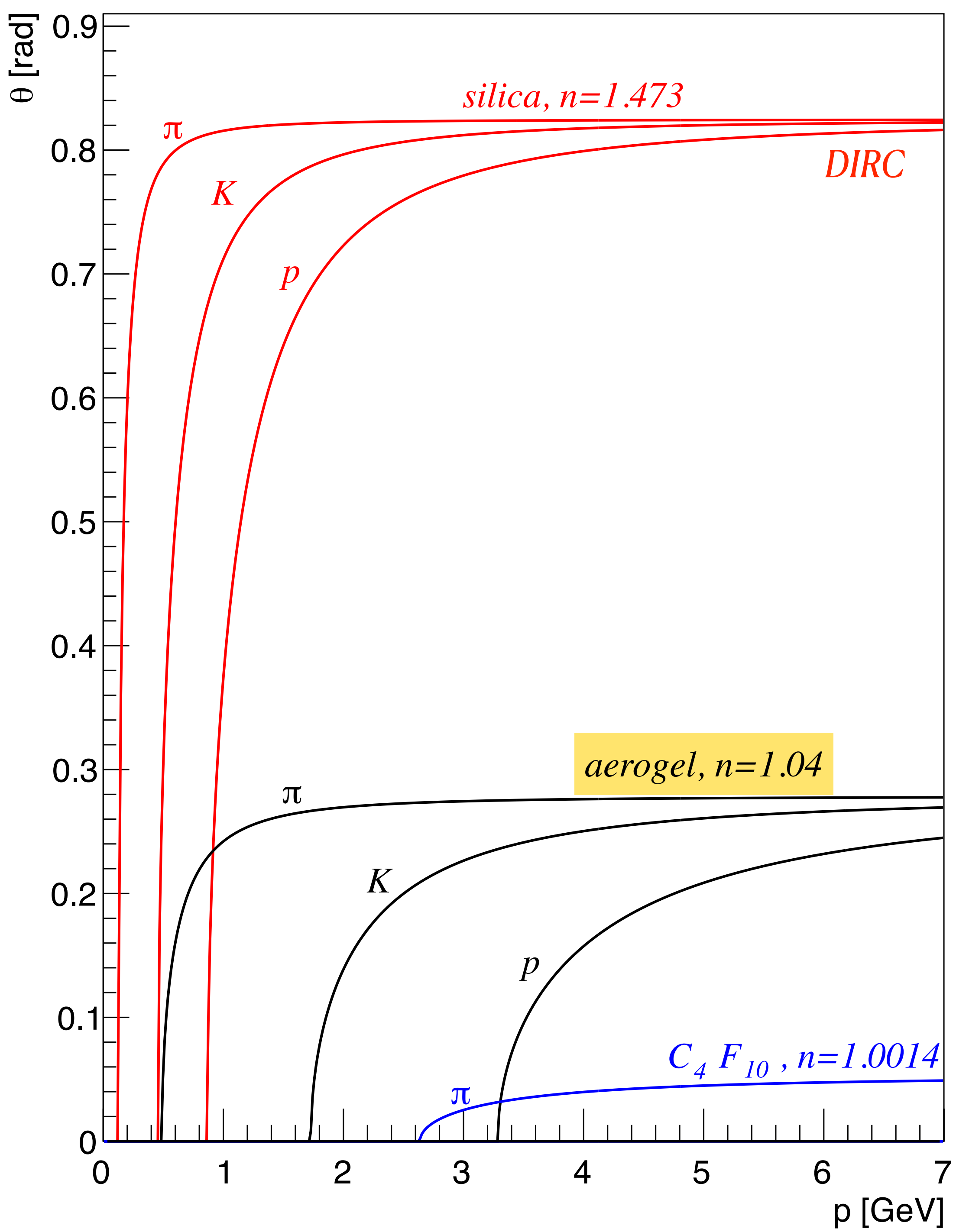




- The region available to PID detectors (TOF+DIRC) is about ~22 cm in the radial direction. DIRC can be placed between TOF and Straw Tracker
    - If one ring of MRPC is remove, we can place the imaging part of DIRC instead of it
    - If size of one ECal-endcap is decreased radially, we can place the imaging part of DIRC outside of it
- No need to discuss now whether we can afford DIRC (phase 2 or 3 of SPD) but **the volume must be reserved** before the beginning of the 1-st phase construction.

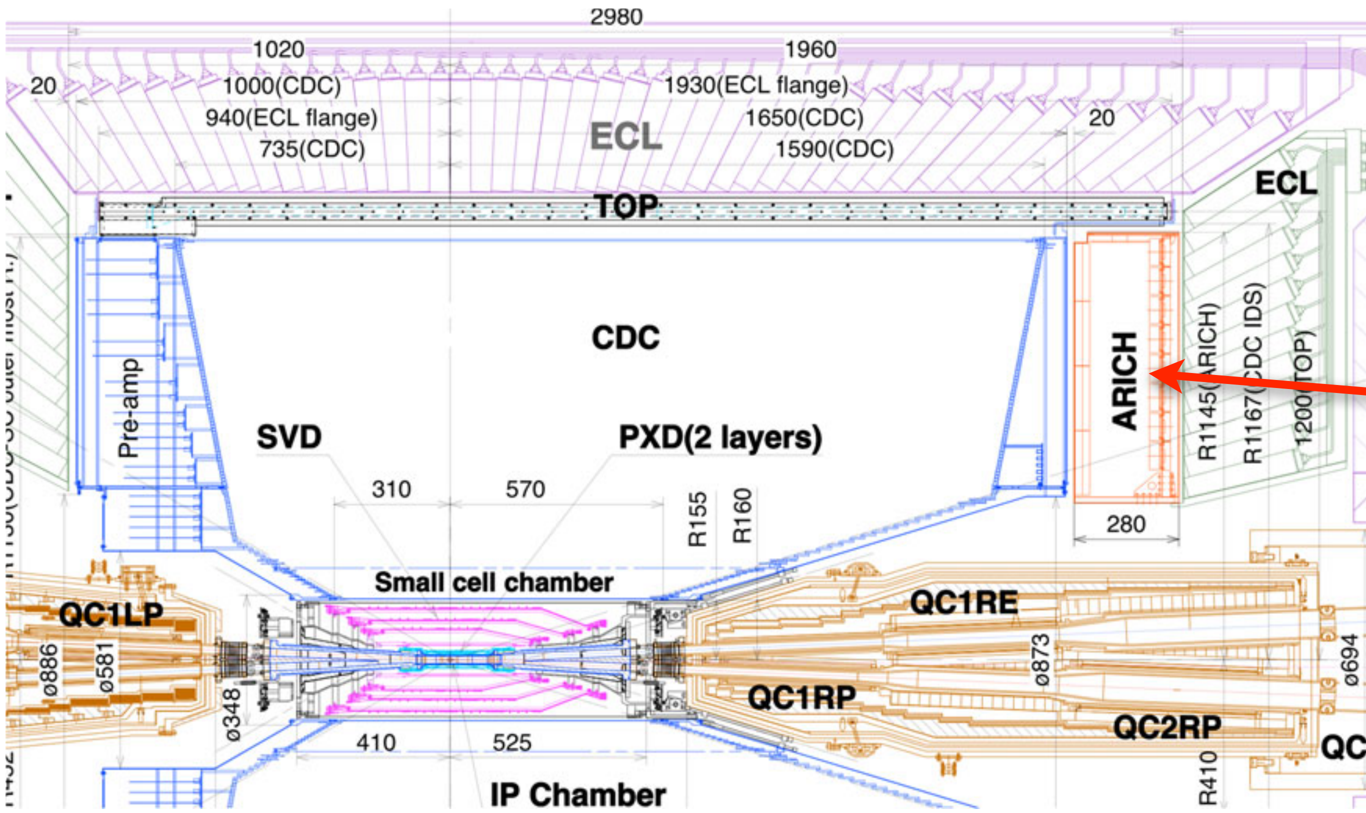
A.Kulikov

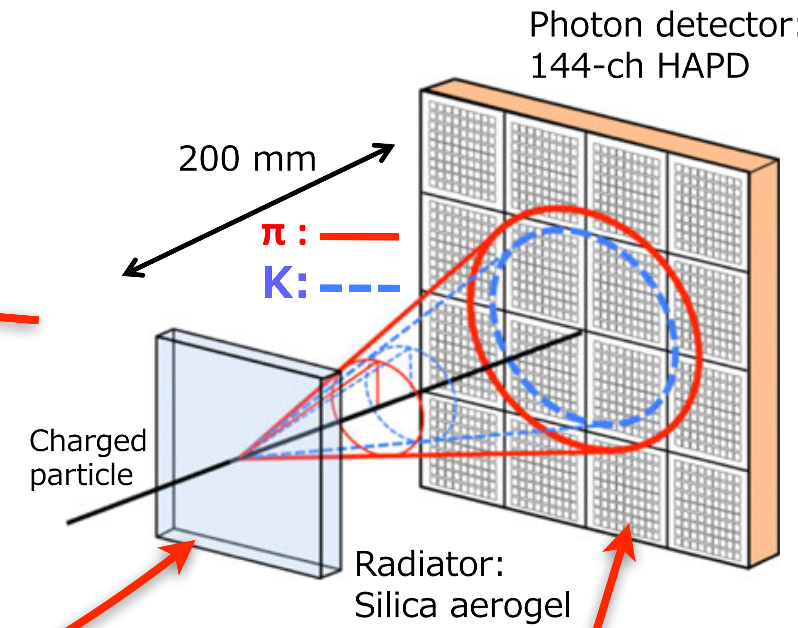
Cherenkov detector for the endcaps



- **Threshold detector in TDR SPD**
  - Proposal was based on ASHIPH (Aerogel SHifer PHotomultplier) presently used in KEDR
- **RICH (Ring Imaging CHerenkov) detectors**
  - Mirror focused light detection
    - RICH1 of LHCb (Aerogel+gas)
    - RICH of HERMES (Aerogel+gas)
  - Direct light detection
    - ARICH (Aerogel RICH) endcap detector in Belle II in KEK/Japan

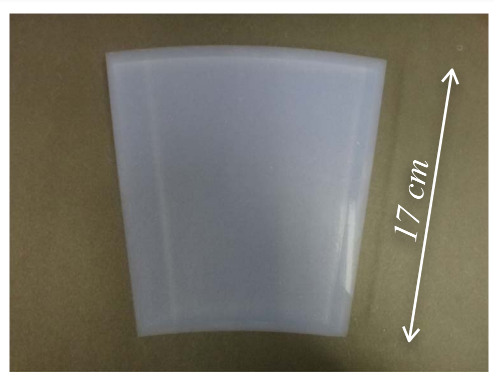
ARICH (in endcap) of the Belle II experiment

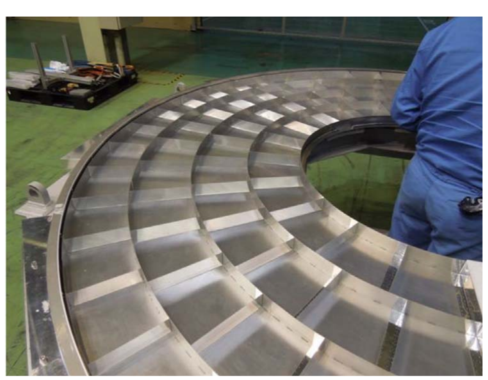


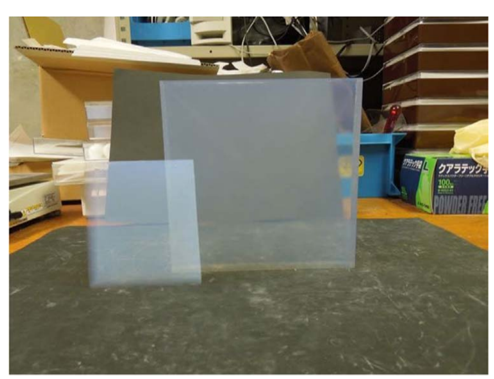


Dual-Aerogel radiator

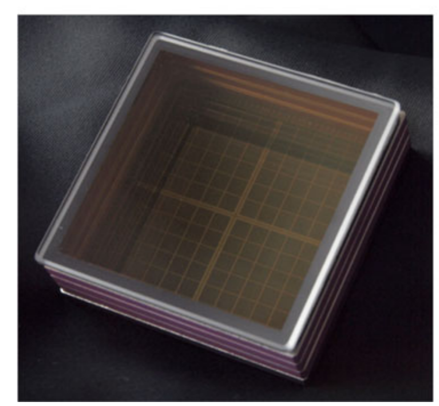
- Focusing effect using n_1=1.045 and n_2=1.055
- Mass production in 2014
- Ref: *NIMA 876 (2017) 129*

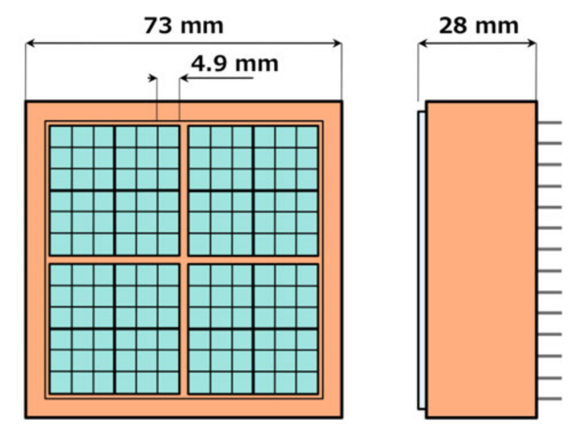






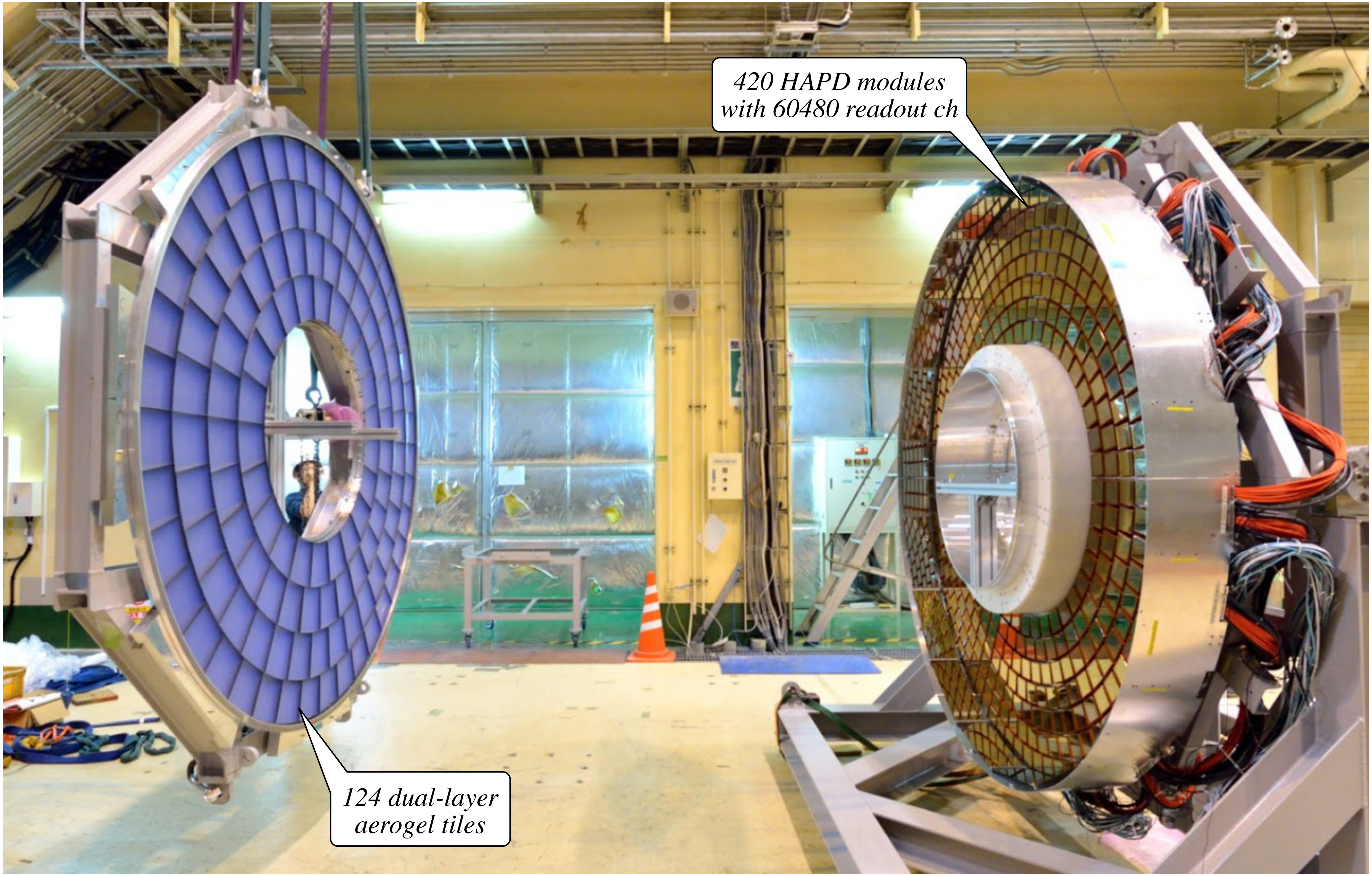
HAPD (Hybrid Avalanche Photo Detector)





- R_π -R_K = 5 mm for p = 4 GeV → pixel size is 5 mm
- Ref: *PTEP 2016 (2016) 3, 033H01 [1603.02503]*

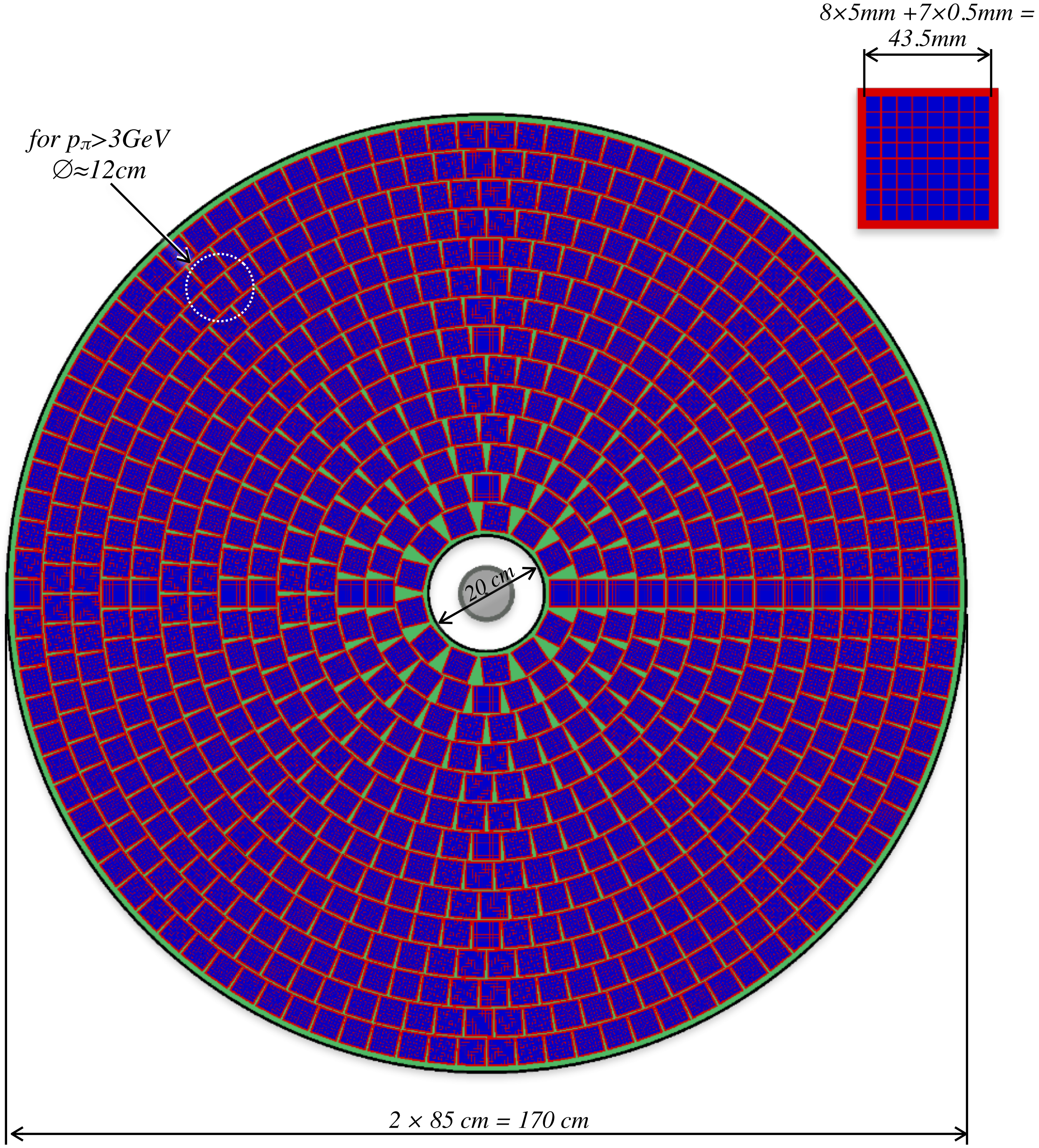
ARICH (in endcap) of the Belle II experiment



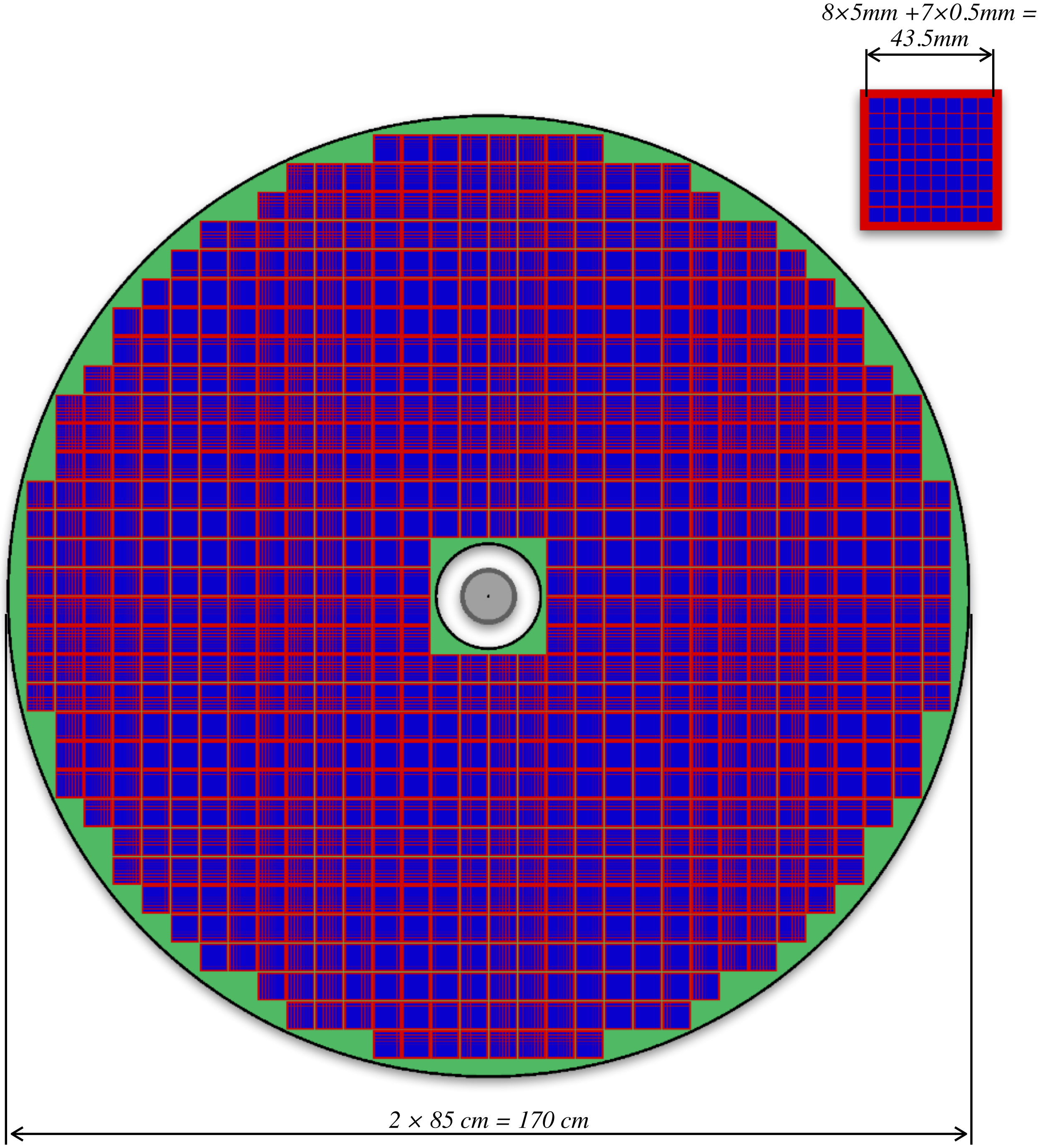
Installed in Oct 2017

Different PMT layouts

Multi-Anode MCP-PMT: $8 \times 8 = 64$ pads, $S_{pad} = 5 \times 5$ mm^2
S_{ARICH}=2.2 m^2, $N_{PMT} = 777$, filling=57%, $N_{ch} = 777 \times 64 \approx 50$k



Multi-Anode MCP-PMT: $8 \times 8 = 64$ pads, $S_{pad} = 5 \times 5$ mm^2
S_{ARICH}=2.2 m^2, $N_{PMT} = 804$, filling=59%, $N_{ch} = 804 \times 64 \approx 51$k



- Discussion with “Baspik” (Vladikovkaz) and “Ekran FEP” (Novosibirsk) on MaMCP production has started.
- Groups from JINR and YerPhI expressed their interest in participation.

T.Enik

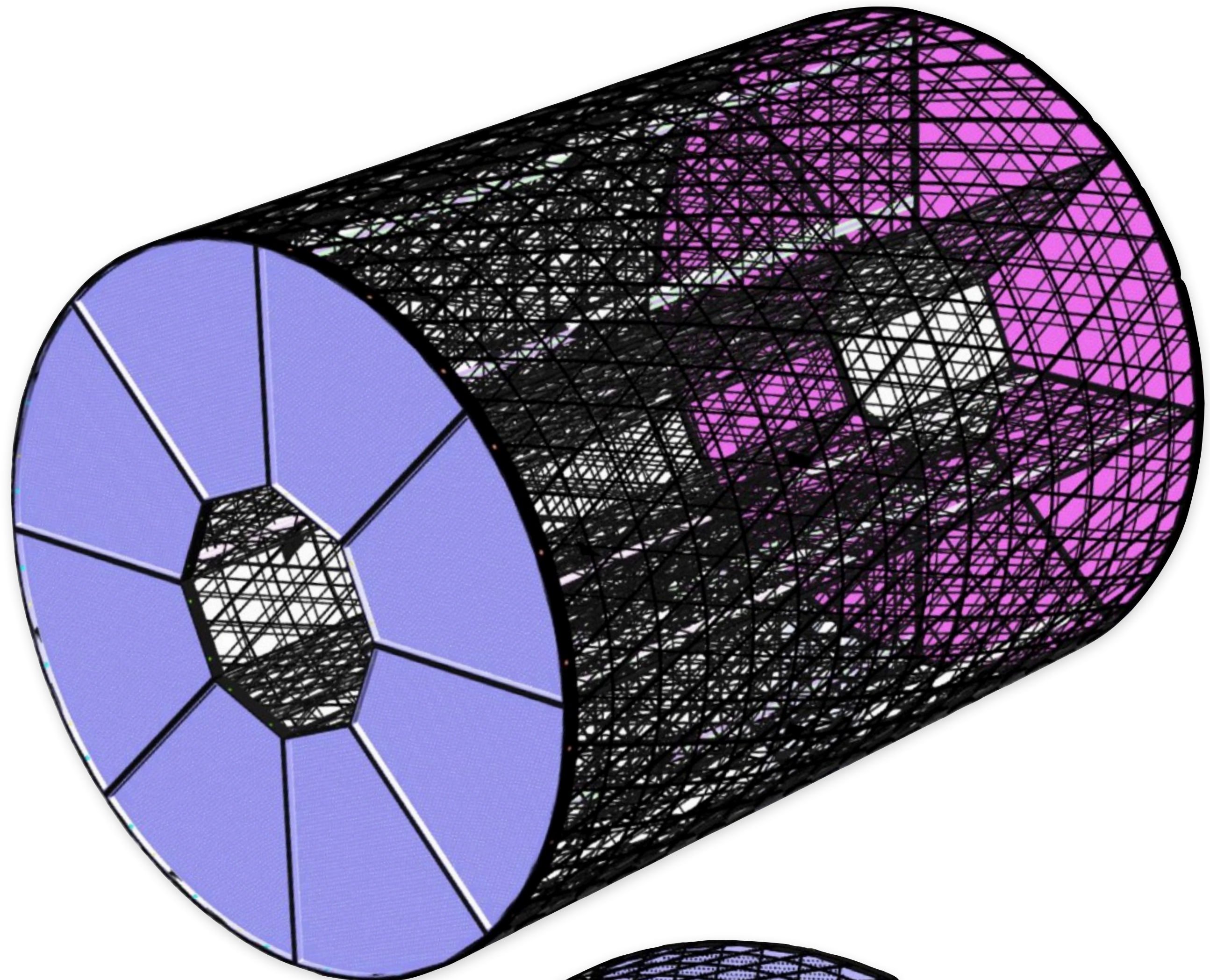
Power frame for the ST barrel

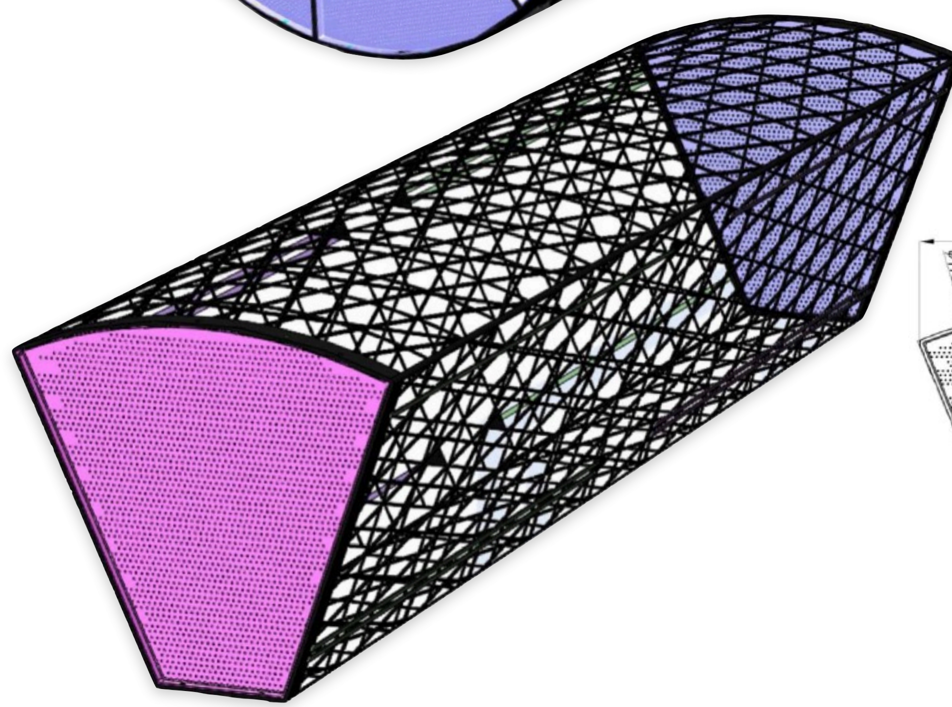
- One octant contains ~3.2k tubes in total, which are arranged in layers with orientation *Z, +3º, -3º*
- Total number of tubes is 3.2k tubes × 8 modules = 25.6k tubes
- The radial size of one octant is 28 cm < R < 59 cm

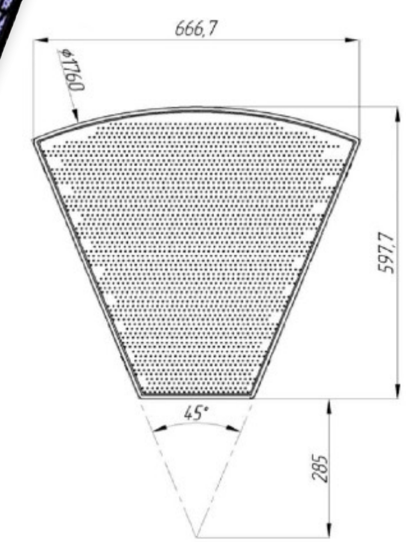
- Contract for the preparation of the conceptual design of the power frame was signed with CRISM earlier this year
- Engineers of CRISM were in charge for the development and production of the ECal power frame in MPD

- The frame will be made of carbon fiber composite material UMT49-12K-EP (Rosatom)
- A preliminary design, which takes into account all the tolerances imposed by the Technical Assignment, was presented in April

- After discussion, a request was submitted to expand the frame to allocate space for all end cap detectors.

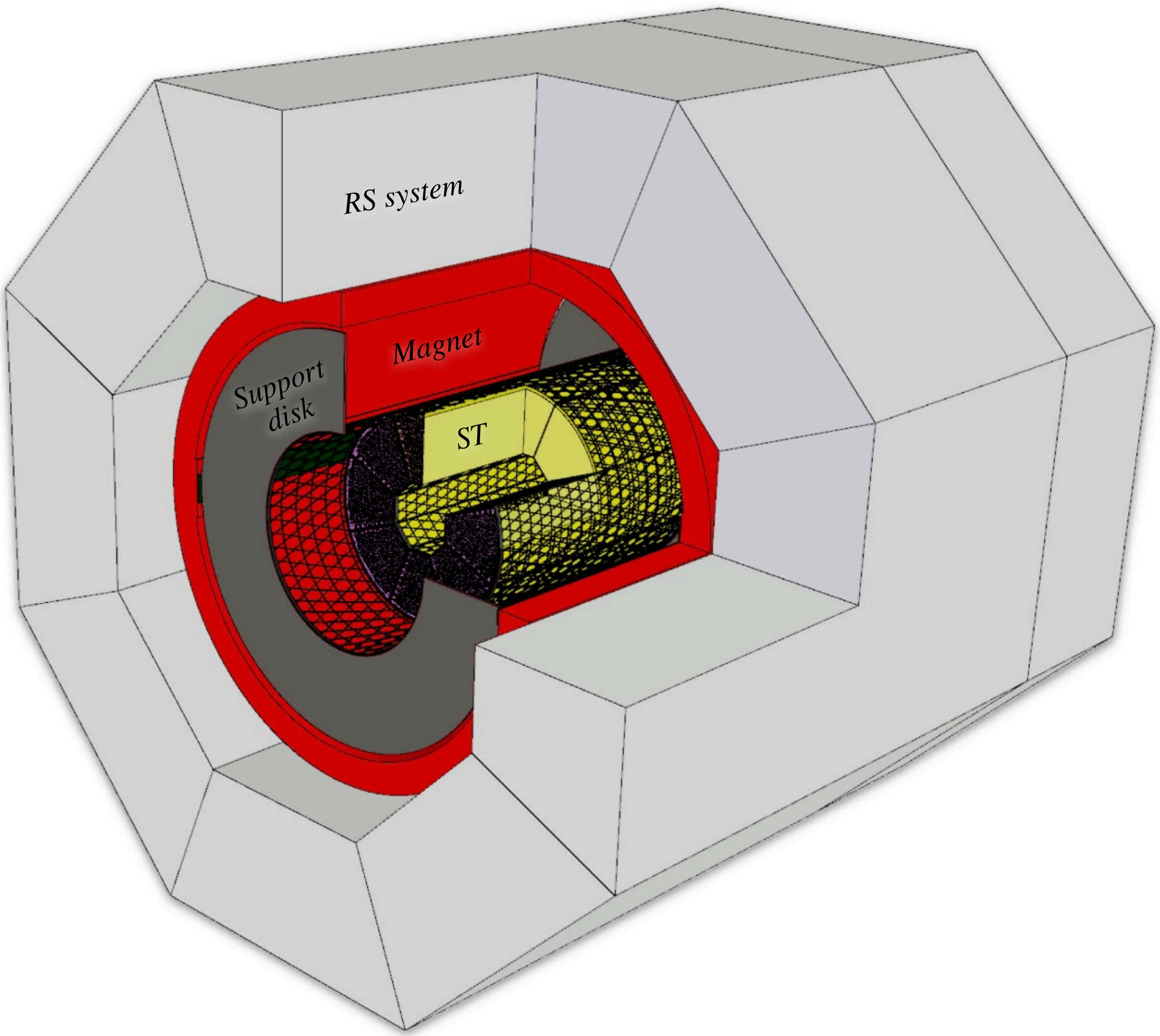




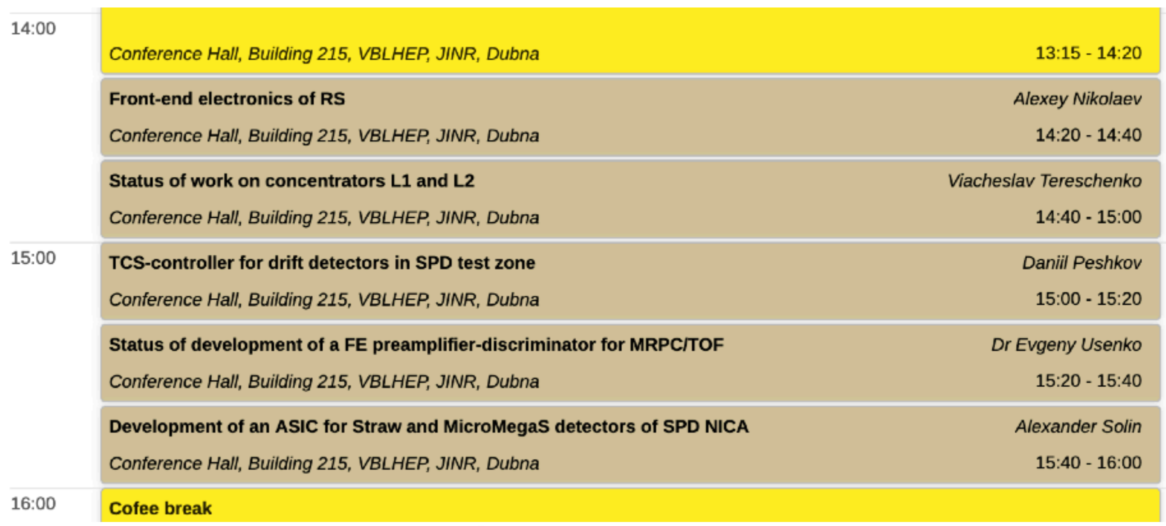


S.Sukhovarov

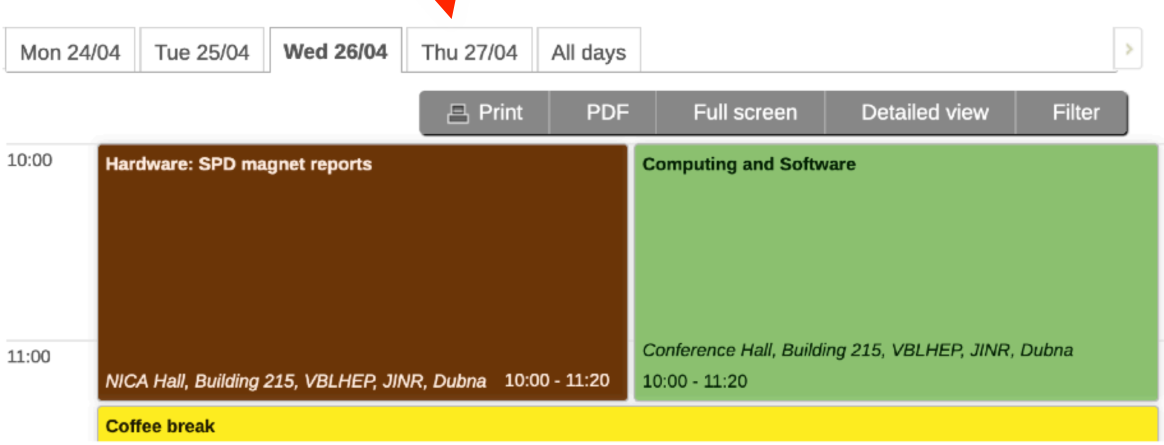
Detector mounting approach



- An approach in which an internal detector is attached to its external neighbor cannot be applied because of different delivery times of these detectors.
- The ST power frame (and later the TOF frame) can be hung directly on the magnet's cryostat. One can use the same rails as for the magnet.
- Two fiberglass support discs at the two ends of the frame will support the ST detector as well as other endcap detectors to be installed later.

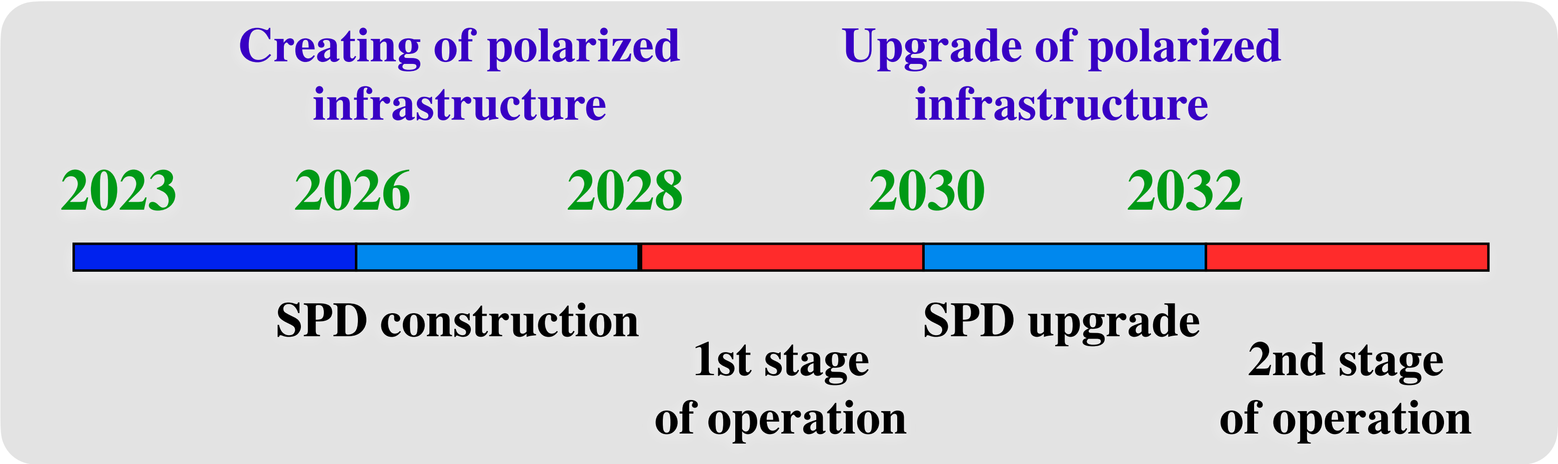


- FEE + DAQ today after lunch
- Hardware session tomorrow
- SC magnet (parallel session)



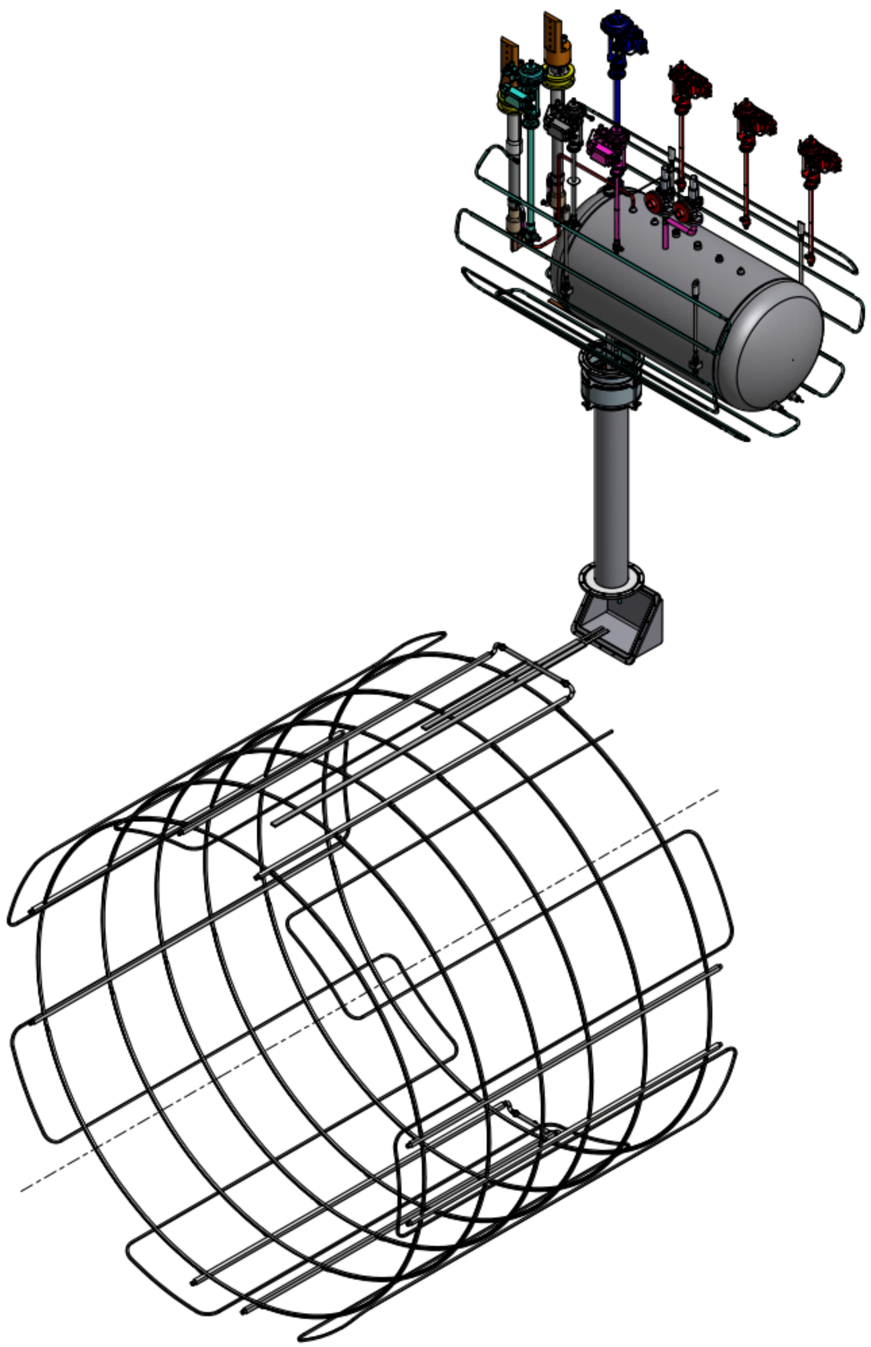
Conclusions

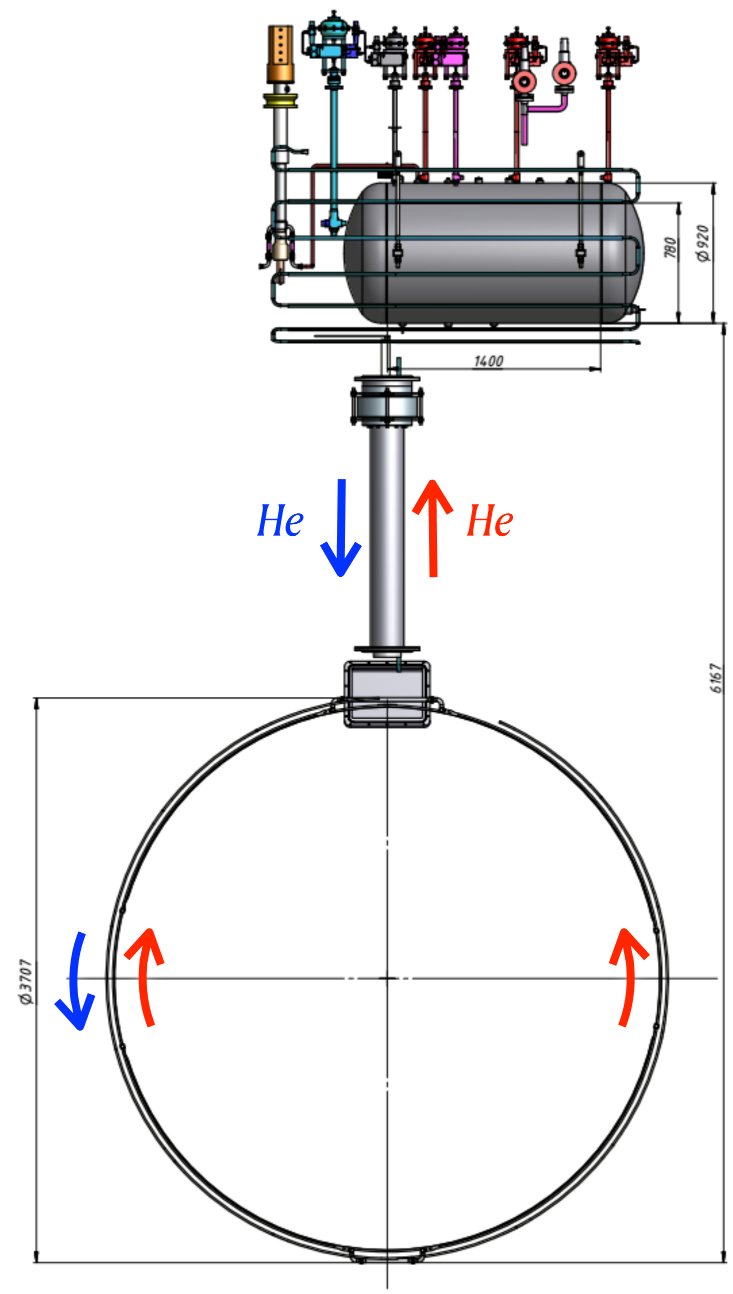
- First version of TDR was released in January and was presented at PAC.
- Main updates for the next version
  - The choice of the SPD magnet project was made. The magnet will be designed and built in Russia by the BINP group.
  - Due to the large upper limit of the detector's weight (1500 t), its dimensions are increased and presumably are finite. Drawings and 3D model to be updated.
- Due to lack of engineering personnel the power frames of many detectors will be outsourced. Our engineers will provide only basic calculations and Technical Specifications.
- New Cherenkov detectors are discussed: DIRC for barrel and ARICH for endcaps. Projects should be prepared, discussed at the Technical Board and inserted into the text of the TDR. Both detectors are intended for the 2-nd stage of the experiment.
- According to present plans, only 5 years left before the datataking starts. Clear planning required from corresponding groups. Financial support will certainly be matter.



backup

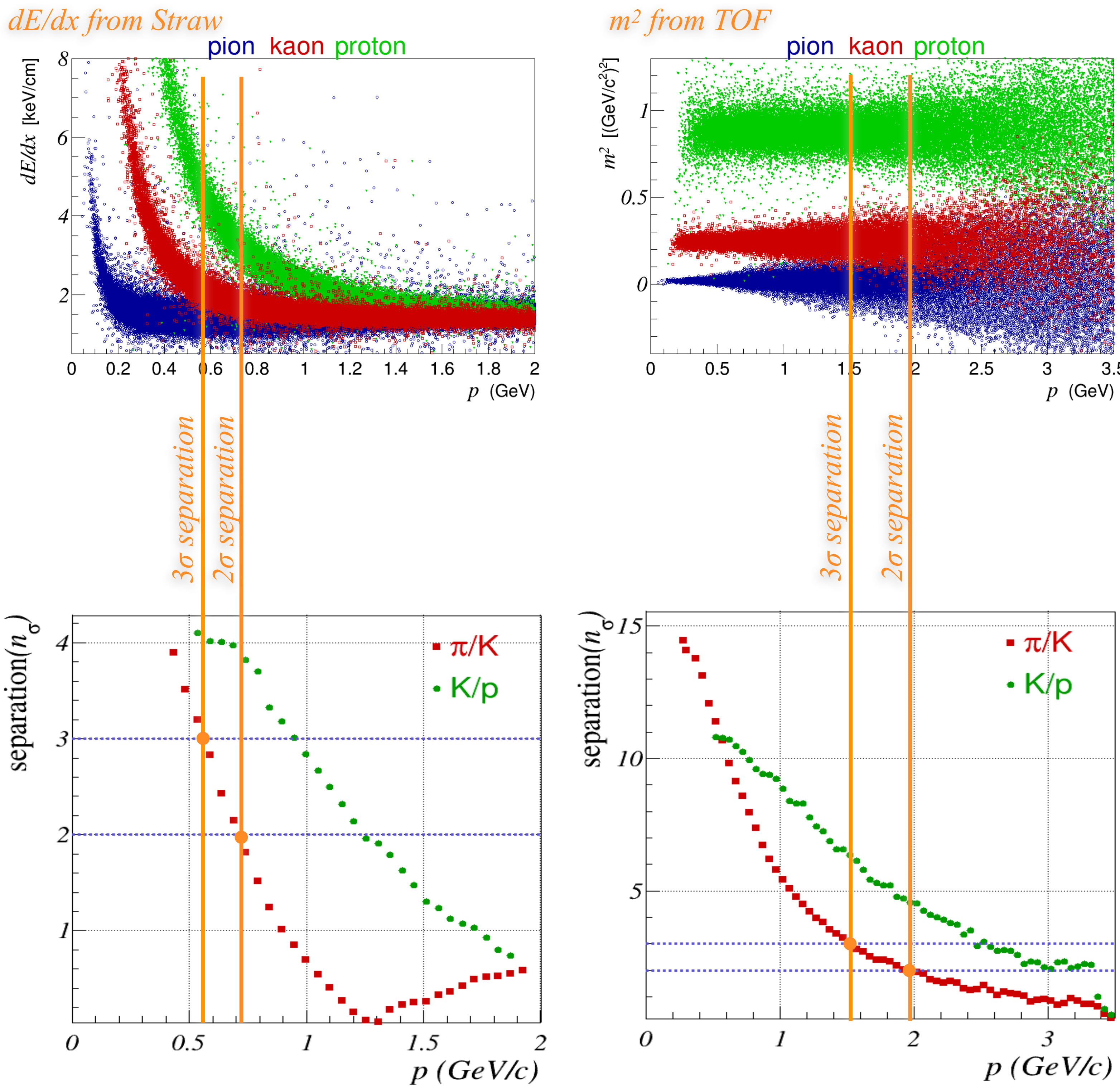
Cold mass cooling scheme





- It is planned to use the *thermosyphon method* of cooling the superconducting coils
- It uses the *natural convection of two-phase helium*, which will make it possible to avoid emergency withdrawal of stored energy from the superconducting winding in the event of a short-term power outage or problems with the helium refrigerator
- The volume of the Dewar is enough to operate in autonomy mode for about one day

TOF vs dE/dx for π/K separation in SPD

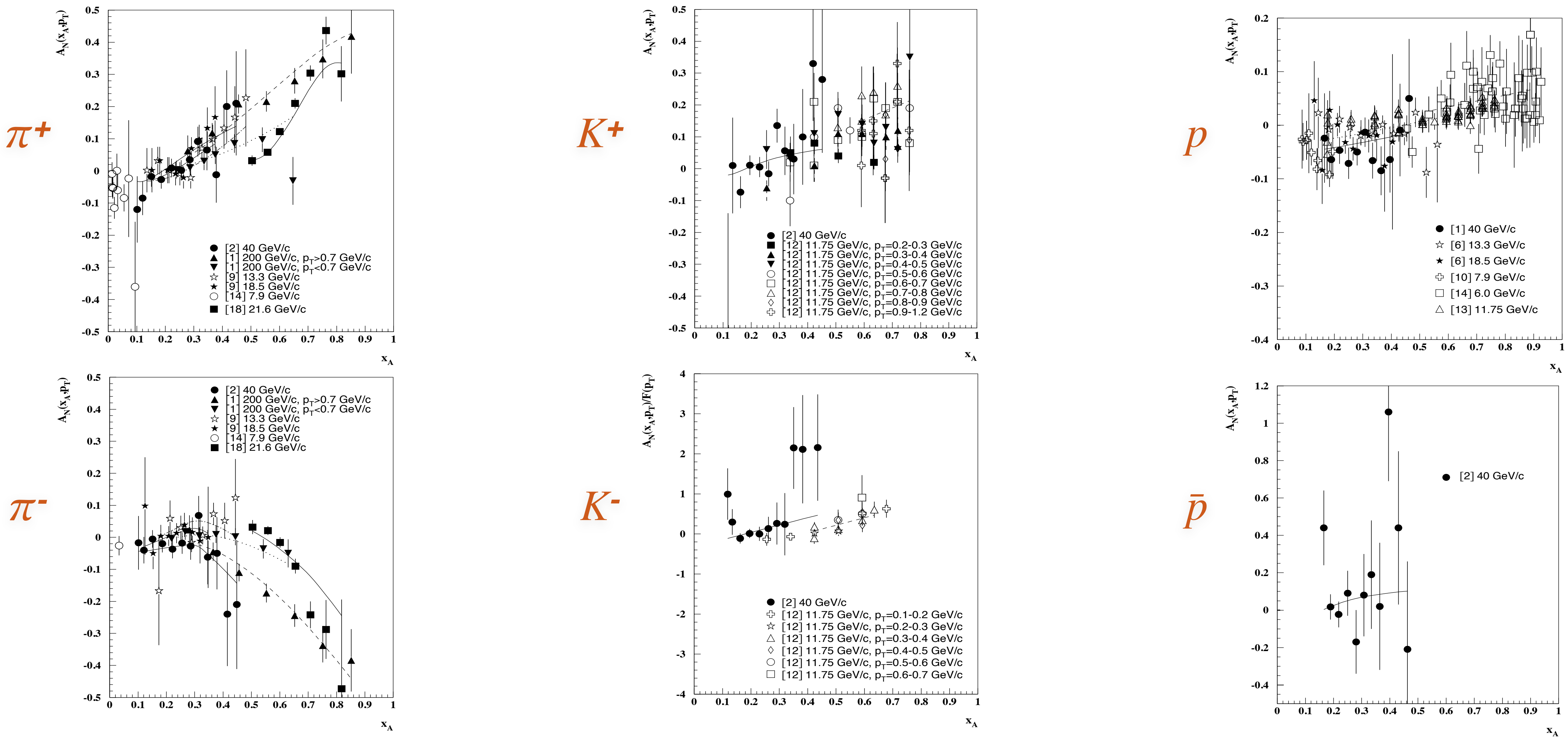


- According to present state of simulation, a 3σ separation of π and K can be achieved for momenta
  - p < 0.55 GeV (ST)
  - p < 1.5 GeV (TOF)
- ST is useful only for short tracks which do not cross TOF (or 1-st phase setup without TOF)
- Many physics applications will require a PID for momenta p > 1.5 GeV

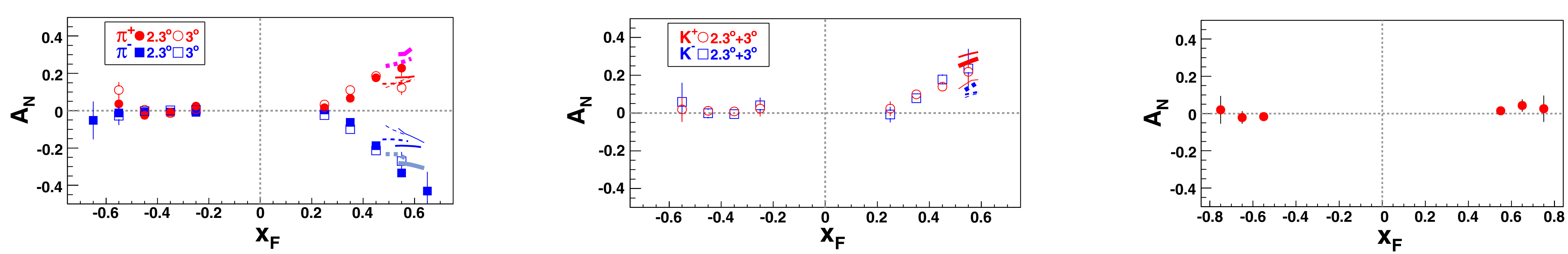
A.Ivanov, SPD CM in Oct 2022

Light hadron (π, K, p) asymmetries

Fixed target experiments (Eur.Phys.J.C14(2000)427)



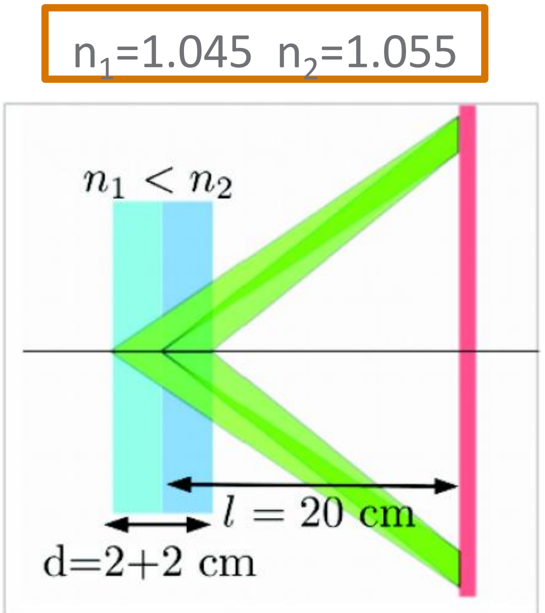
Collider experiment BRAHMS (Phys.Rev.Lett.101(2008)042001)

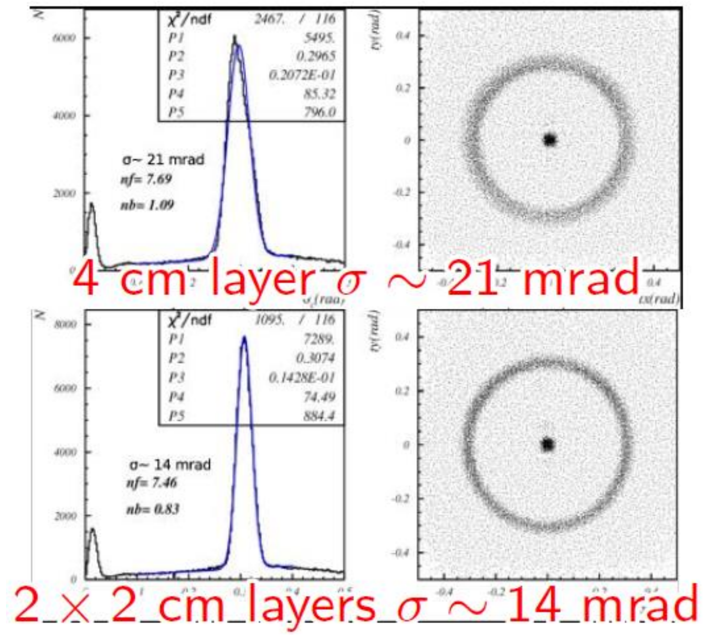


For E_{CM}*=27GeV: p=4GeV →* x_F*=0.3, p=6GeV →* x_F*=0.45*

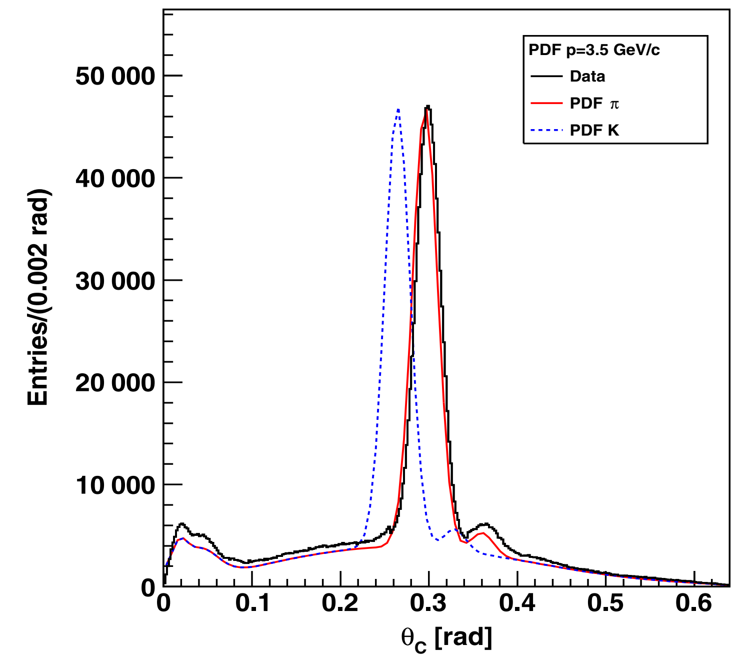
ARICH (in endcap) of the Belle II experiment

Focusing principle

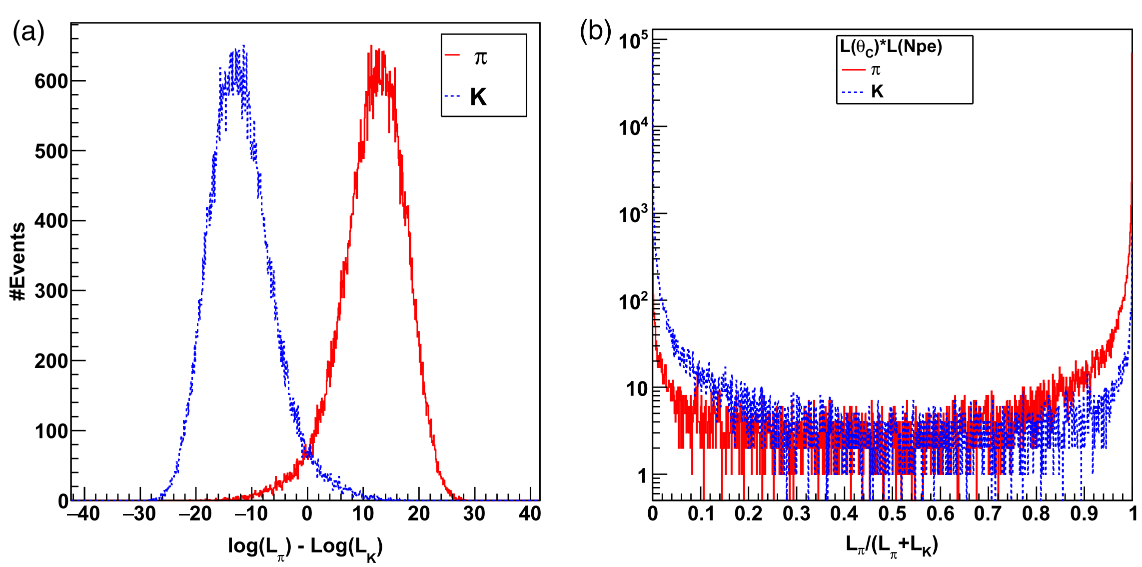




Cherenkov angle for π and K



π and K likelihoods



The difference between the likelihoods

Likelihood ratio distribution

Fig. 15. (a) Distribution of the likelihood difference between the pion (solid line) and kaon (dashed line) at 3.5 GeV/c. (b) Likelihood ratio distribution for pions and kaons at 3.5 GeV/c.

Efficiency of π and K identification

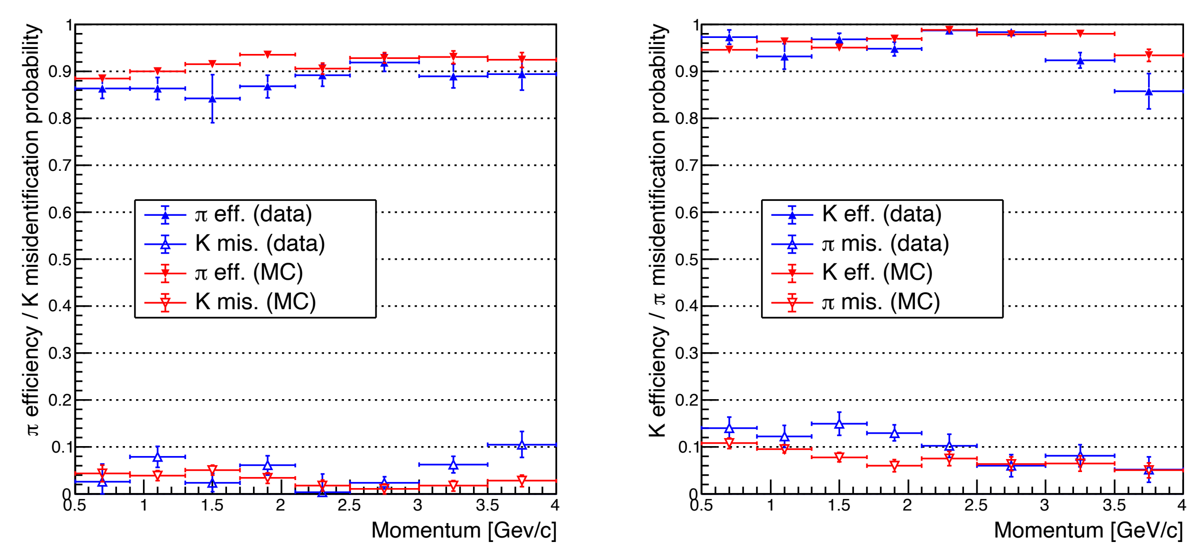


Figure 14: Efficiency and misidentification probability as a function of the momentum: π efficiency and K misidentification probability (left), and K efficiency and π misidentification probability (right).