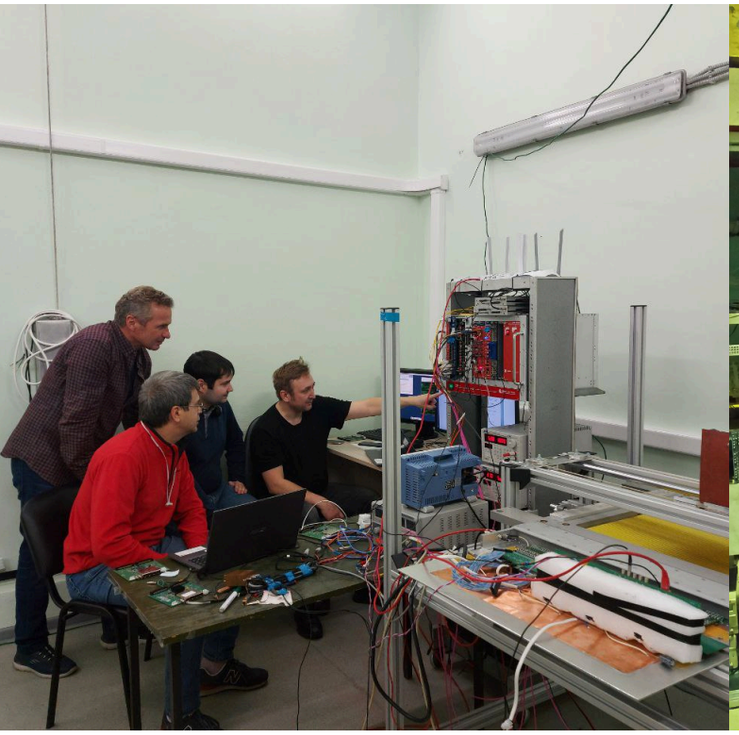
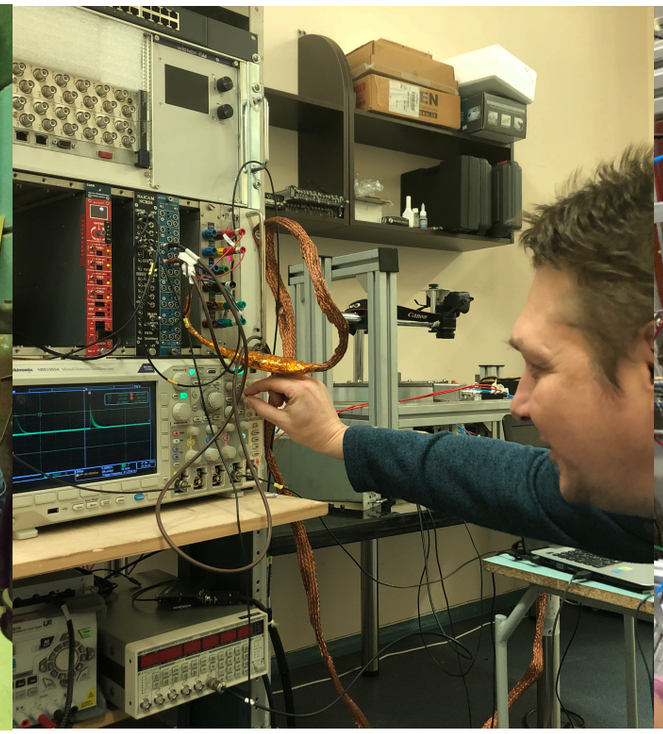
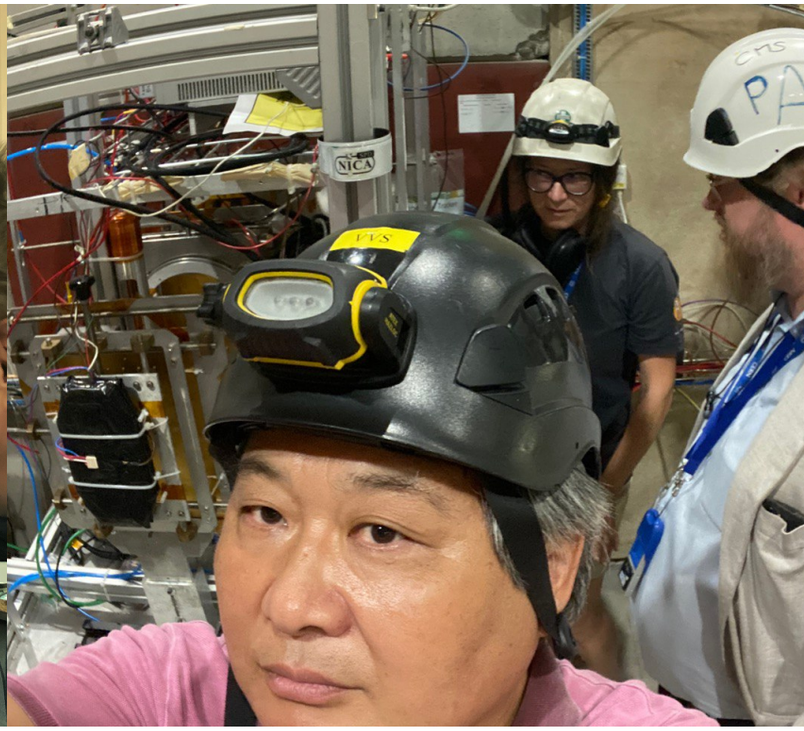
SPD Technical Design Report



A. Guskov, avg@jinr.int

23.1.2023

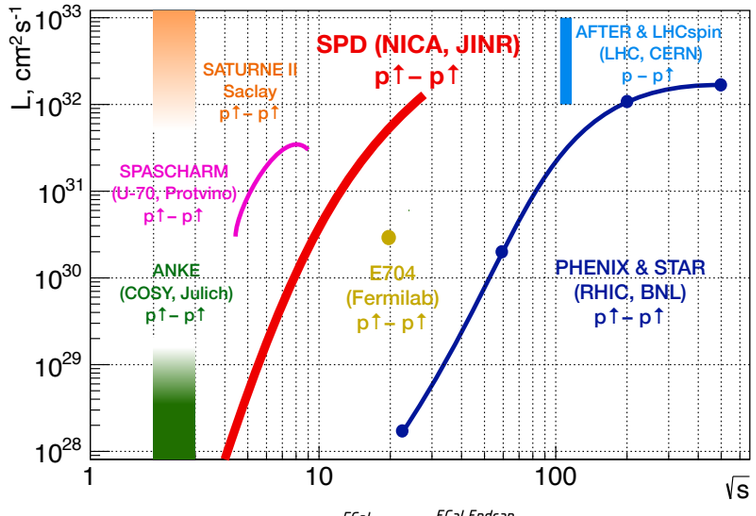
SPD international collaboration

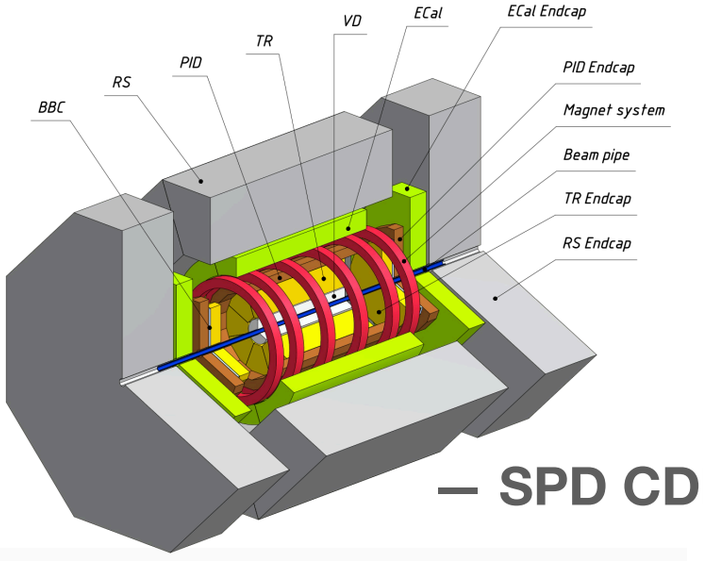
32 institutes from 14 countries, ~300 members

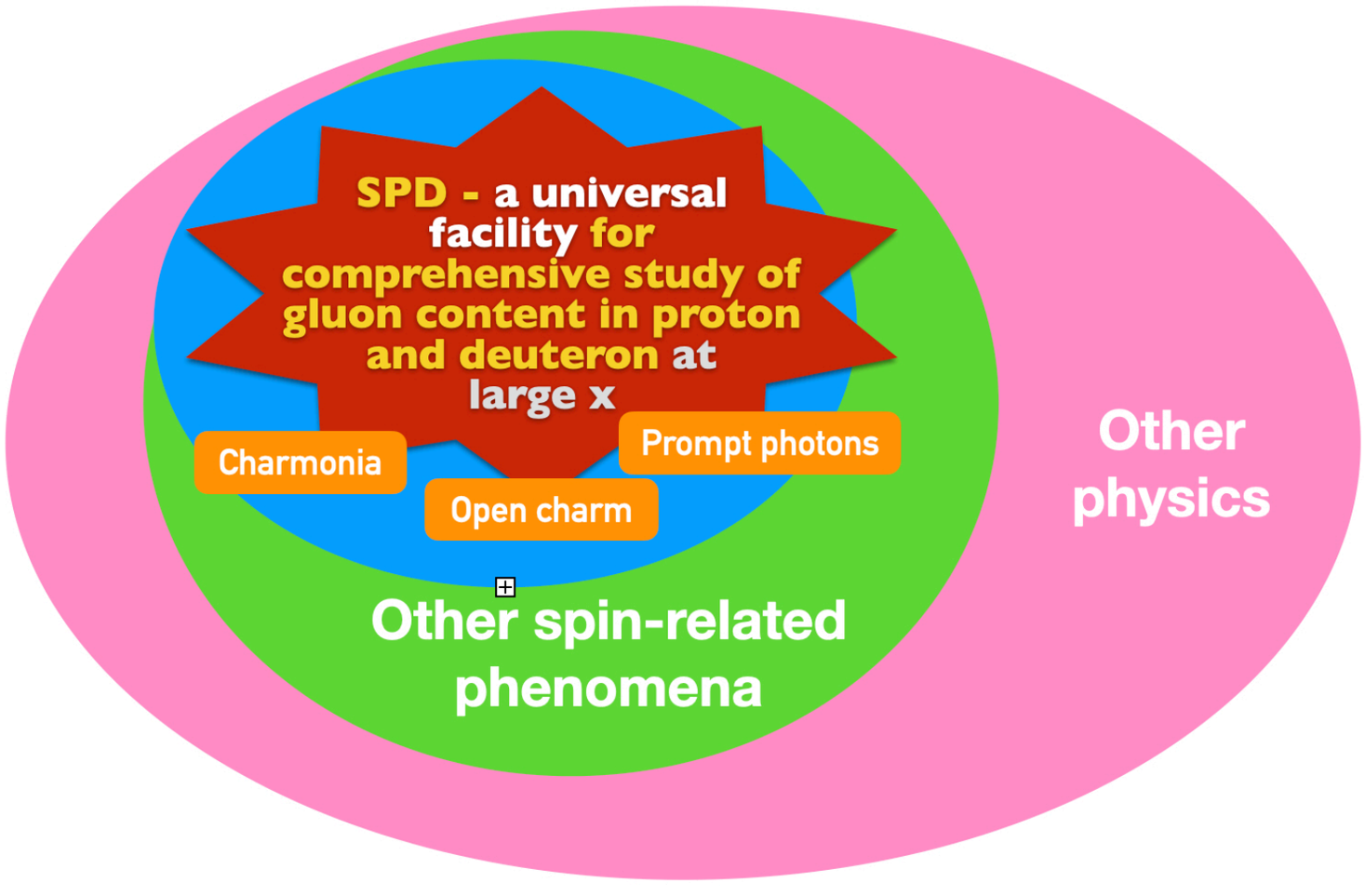
MoU:

- signed 6
- signing in in progress 2
- agreed 1

spd.jinr.ru







Prog.Part.Nucl.Phys. 119 (2021) 103858 arXiv:2011.15005

Phys.Part.Nucl. 52 (2021) 6, 1044-1119 arXiv:2102.08477

— SPD CDR was presented at PAC in Jan 2021 and approved by PAC in Jan, 2022

Important remarks:

Cost estimate is based on the cost of materials and equipment as well as the currency exchange rates at the beginning of Feb. 2022.

The technical solutions used in the Project are based on the availability of materials and equipment at the beginning of Feb. 2022.

The detectors of the Phase-II are developed on the level of well-advanced concept and we still keep some different options for them.

SPD Technical Design Report

Creating of polarized infrastructure

Upgrade of polarized infrastructure

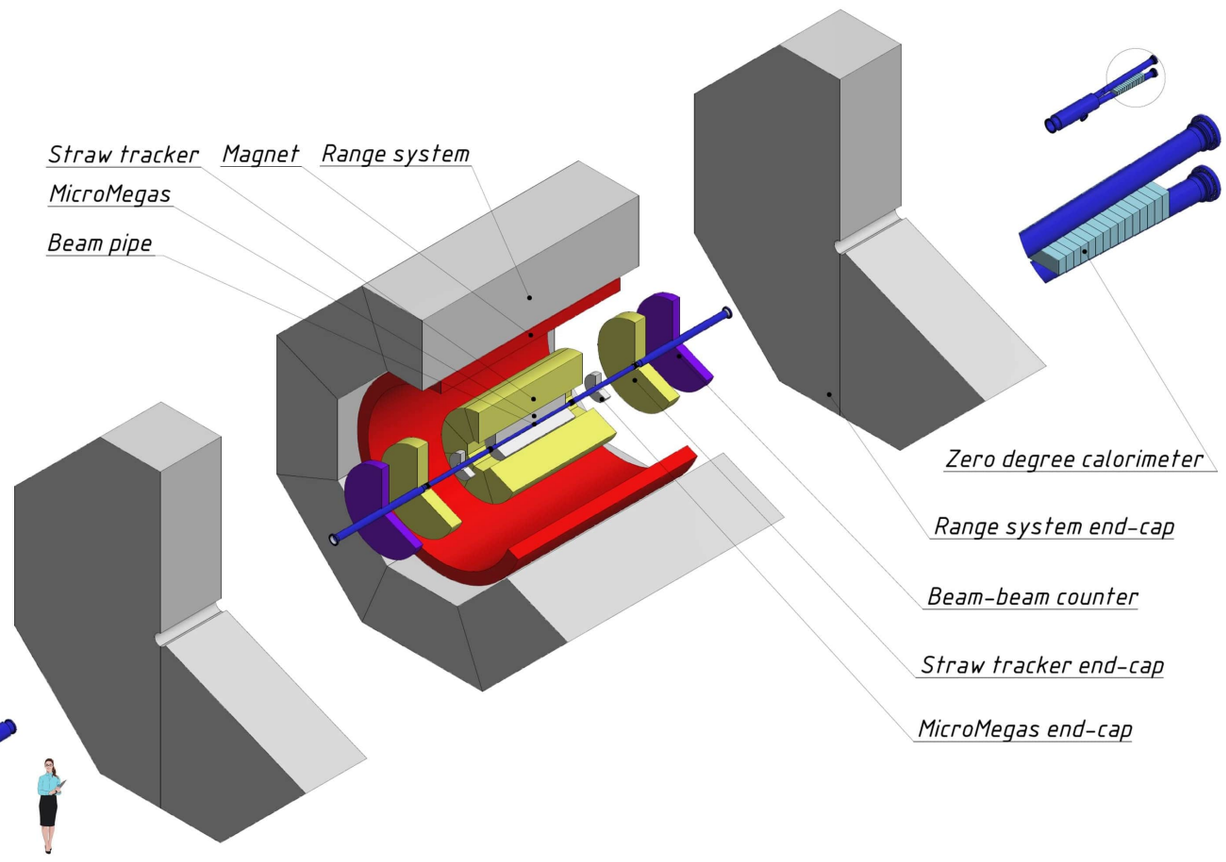
2023 **2026** **2028** **2030** **2032**

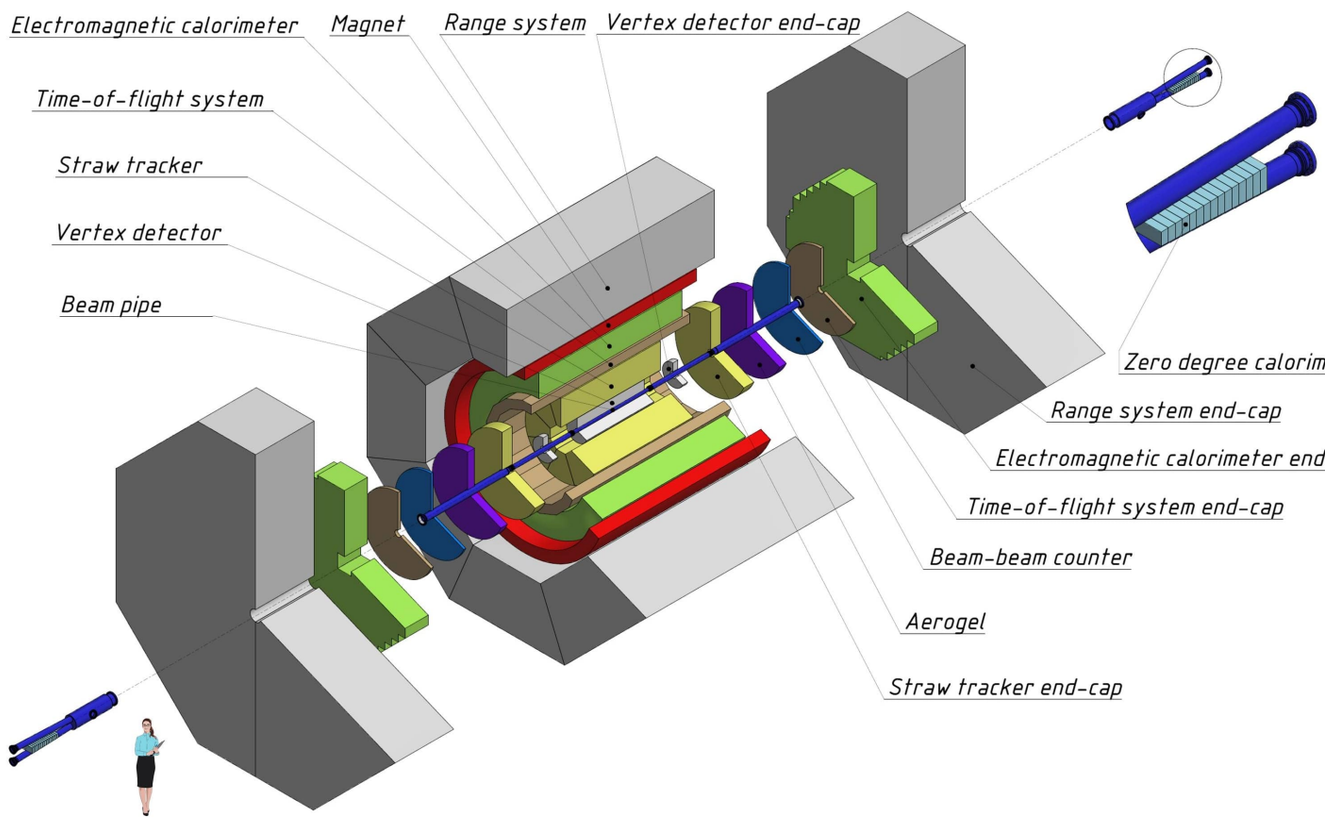
SPD construction

1st stage of operation

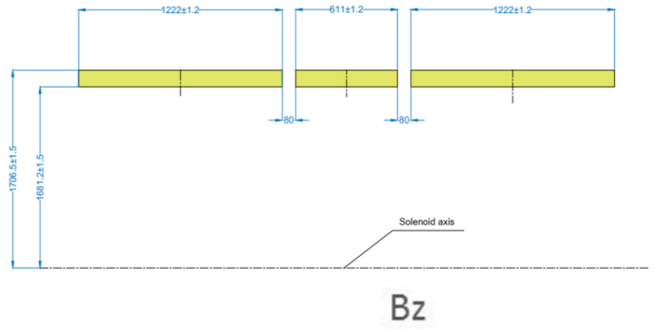
SPD upgrade

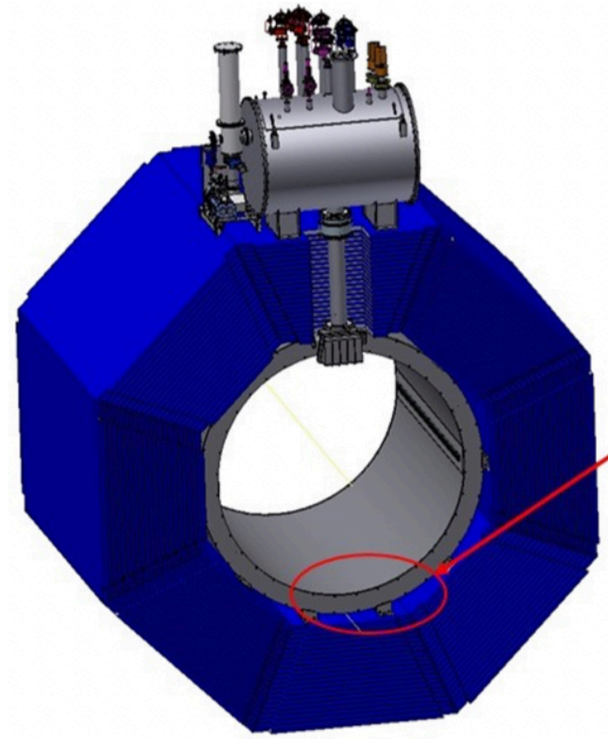
2nd stage of operation





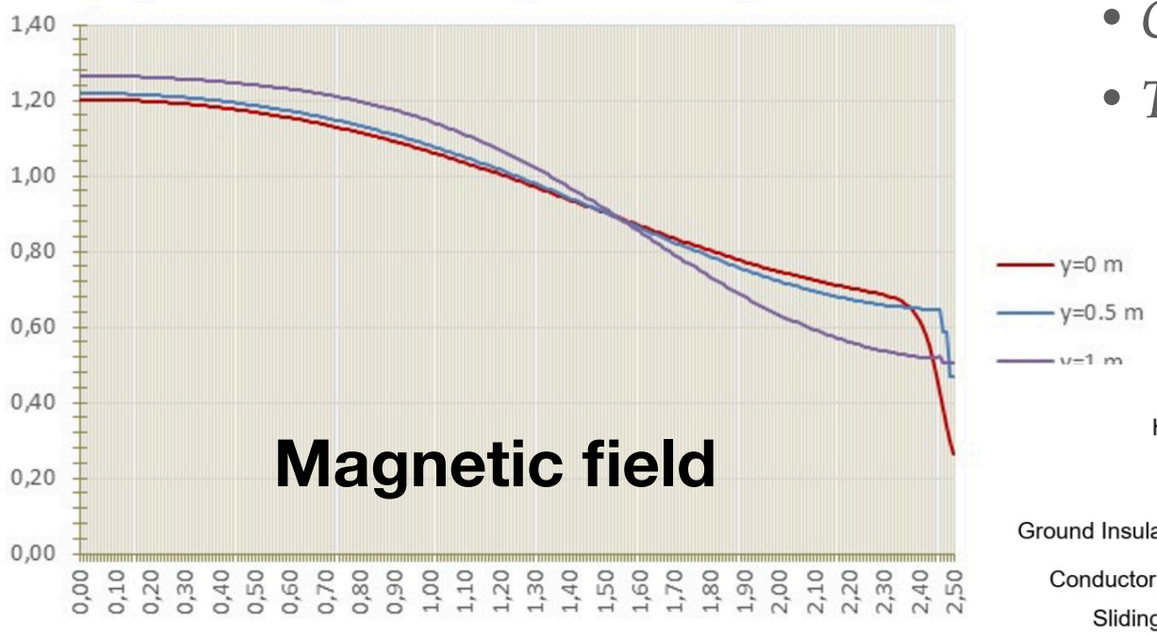
Superconducting magnet





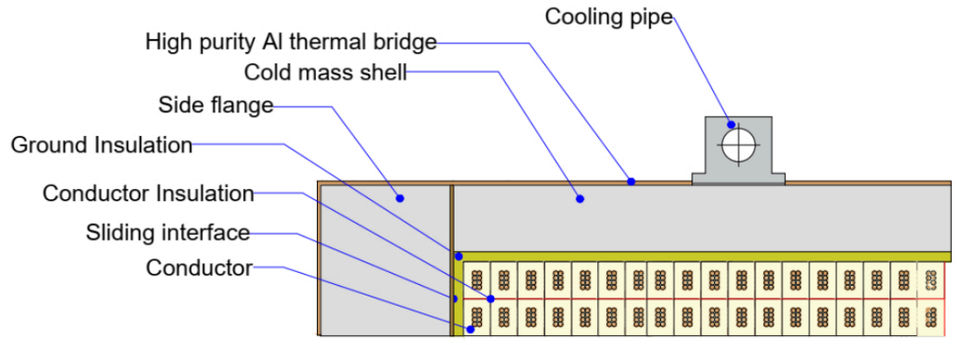
- *PANDA technology*
- *Field at axis: 1.0 T*
- *Operating current: 4.4 kA*
- *Total stored energy: 19.3 MJ*

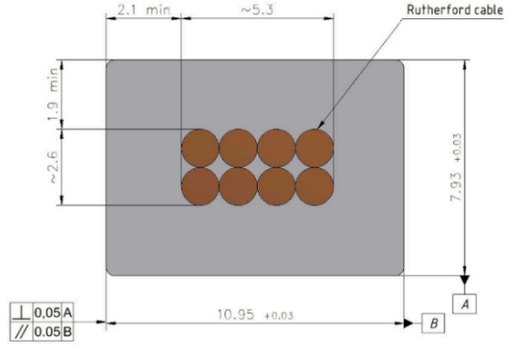
Bz



Magnetic field

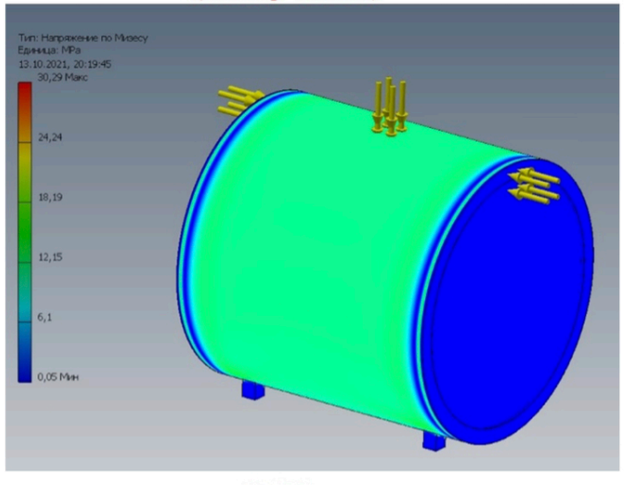
Cross section of the cold mass and cable



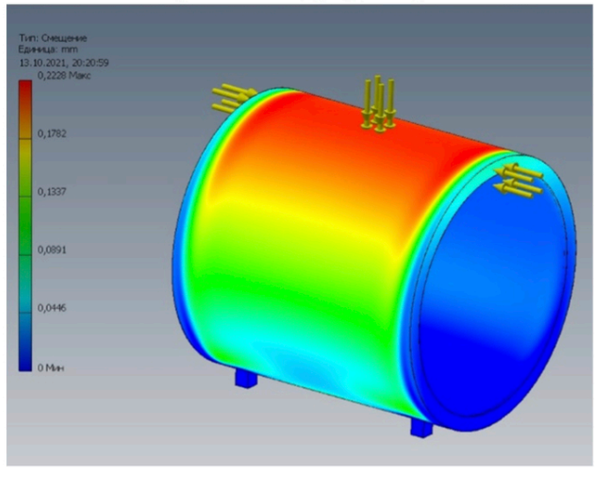


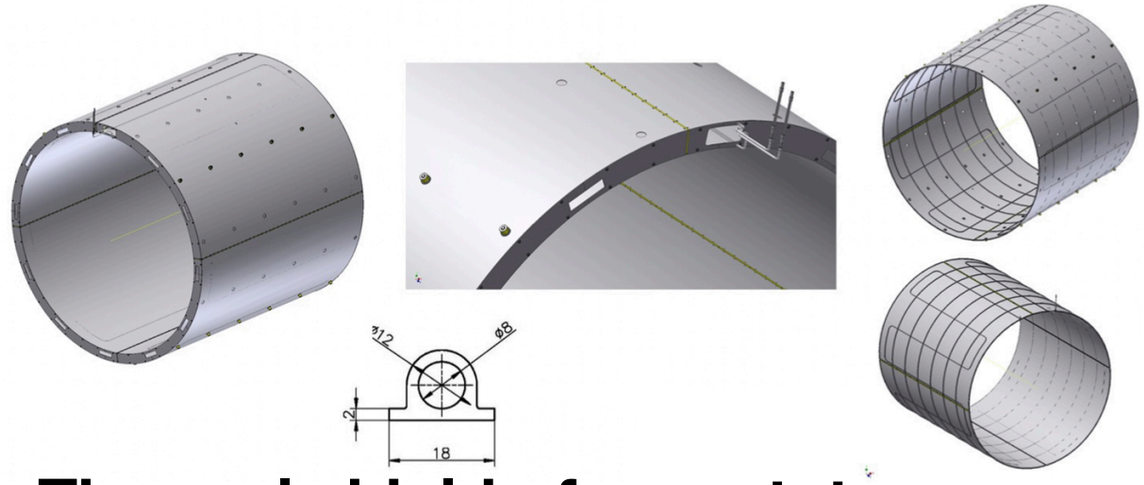
Mechanical properties

SPD Magnet
(Stress, p=0,1MPa)



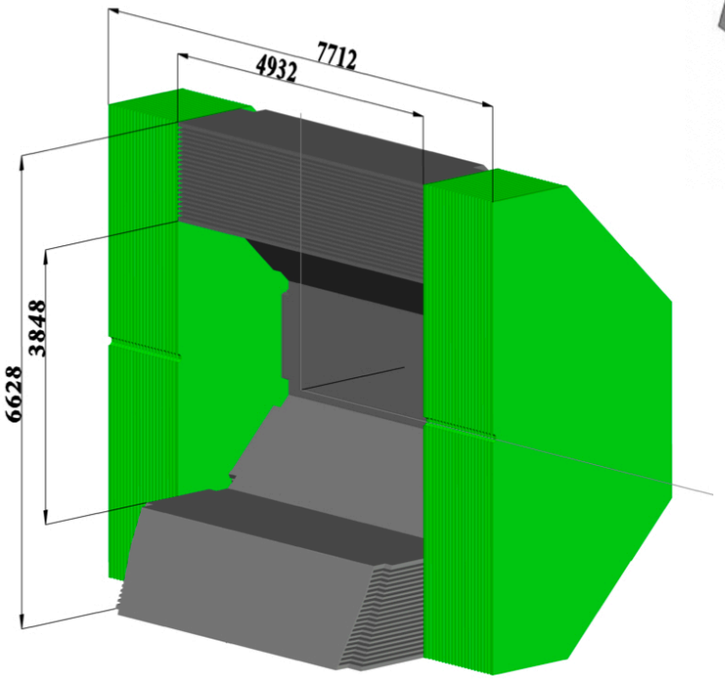
SPD Magnet
(Deformation, p=0,1MPa)

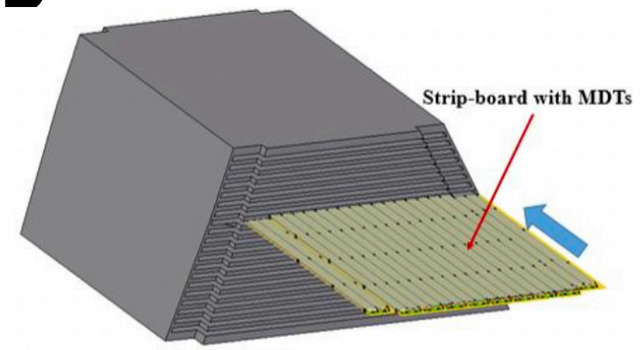




Thermal shield of cryostat

Range system



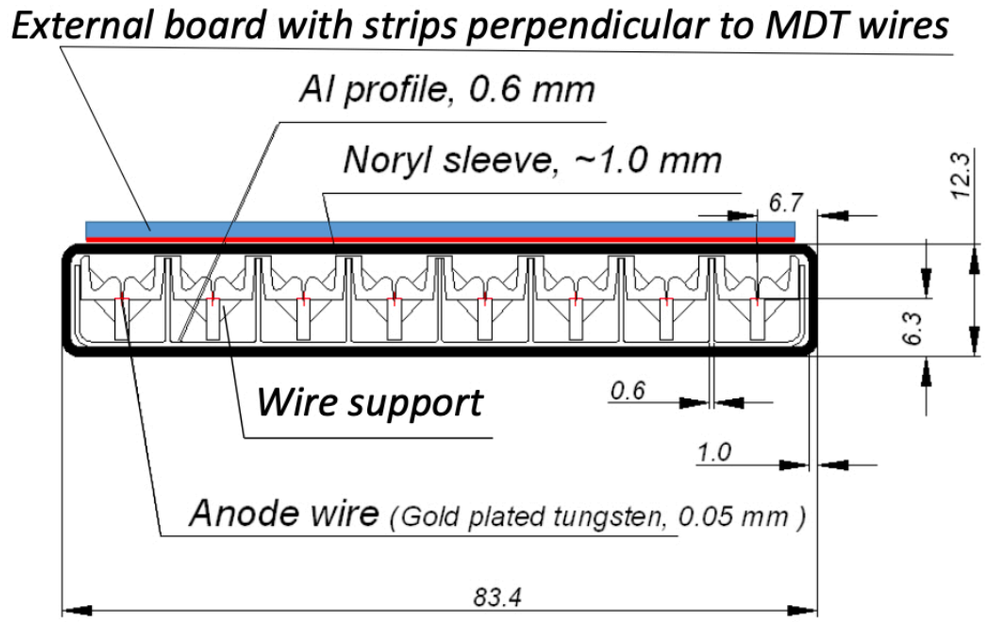


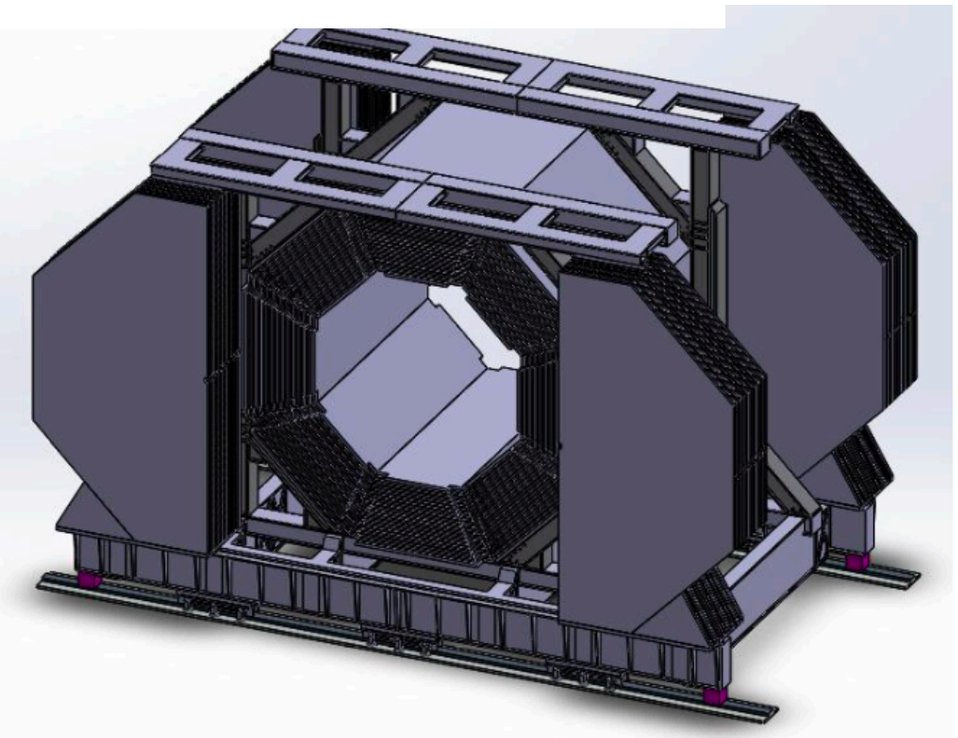
Goals:

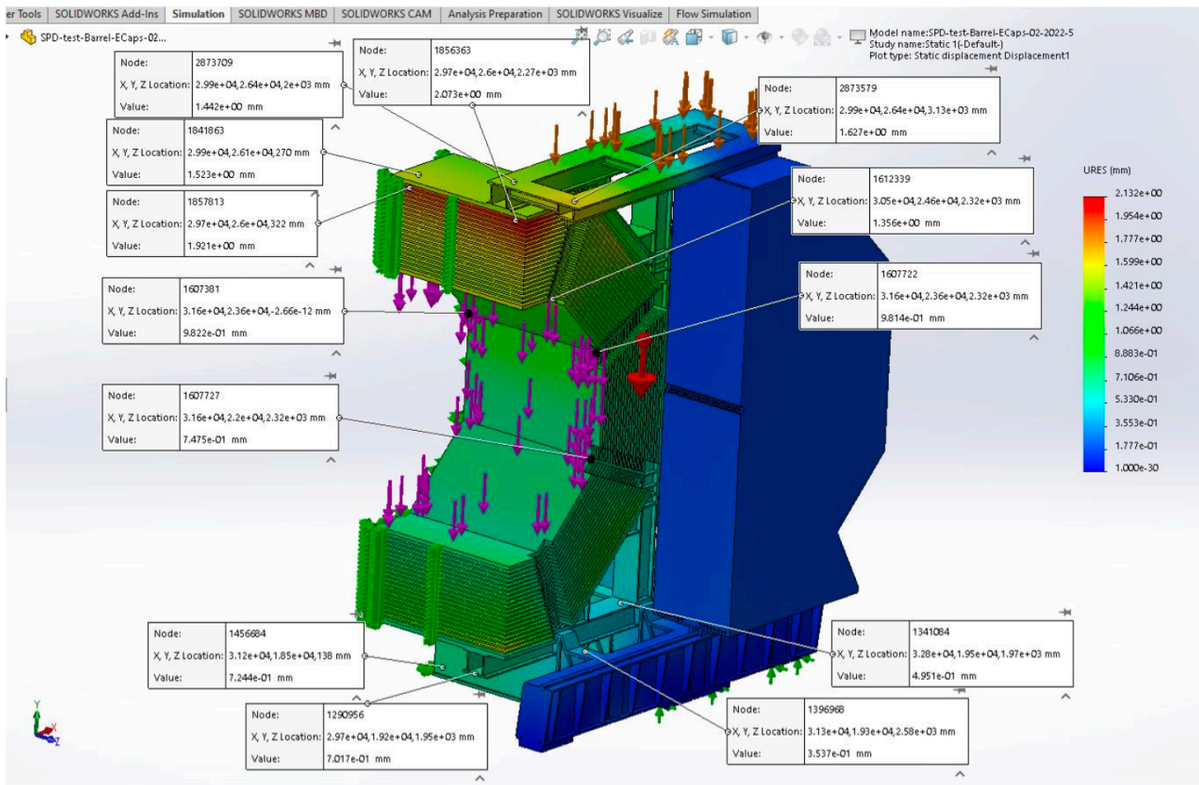
- *Muon identification*
- *Rough hadron calorimetry*
- *Yoke of the magnetic system*

Requirements:

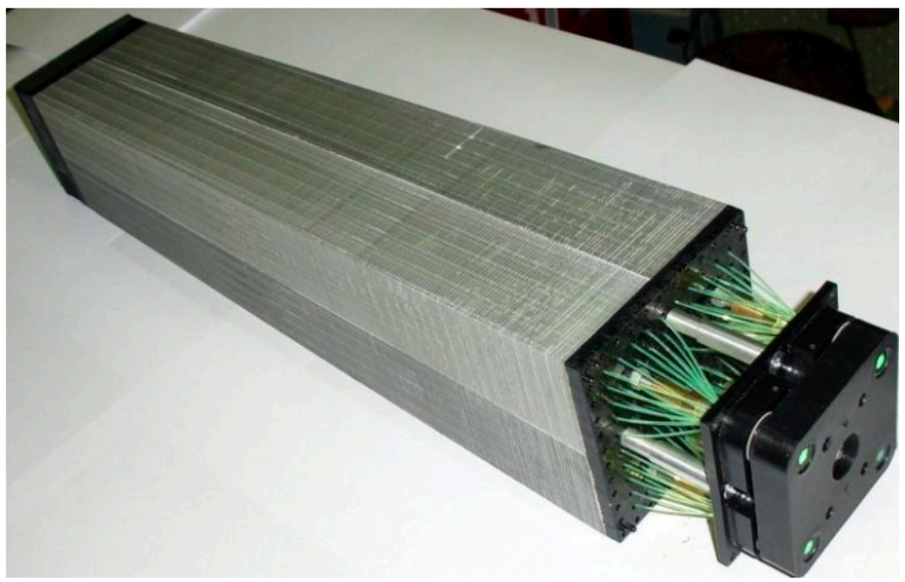
- *should have at least $4\lambda_I$*

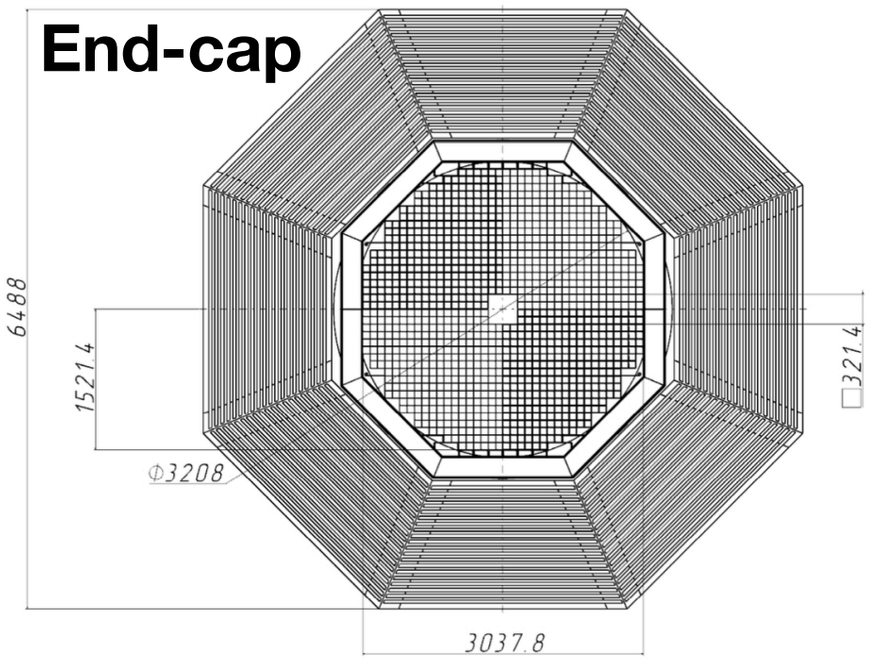


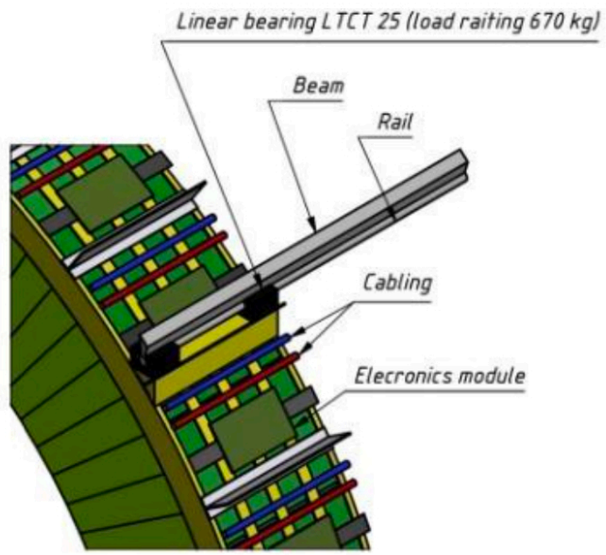




Electromagnetic calorimeter







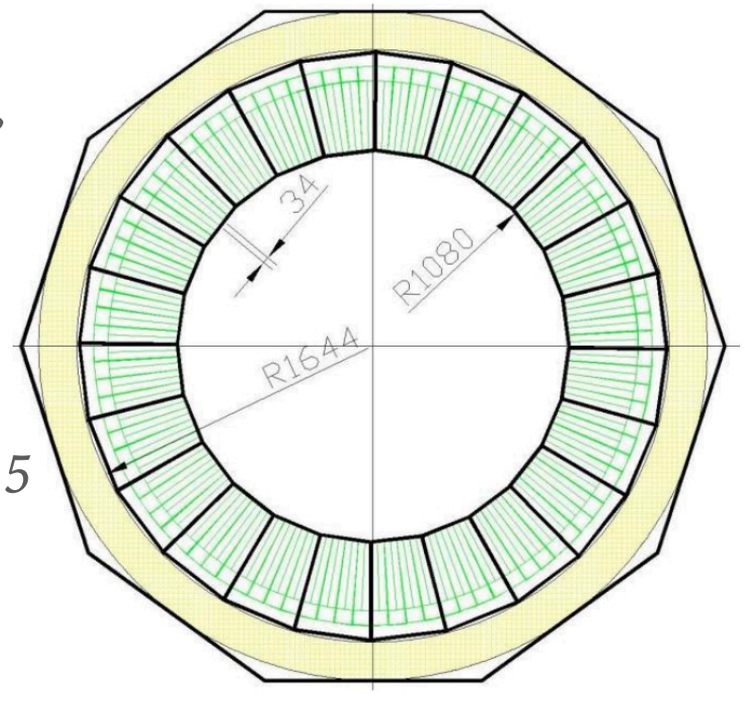
Goals:

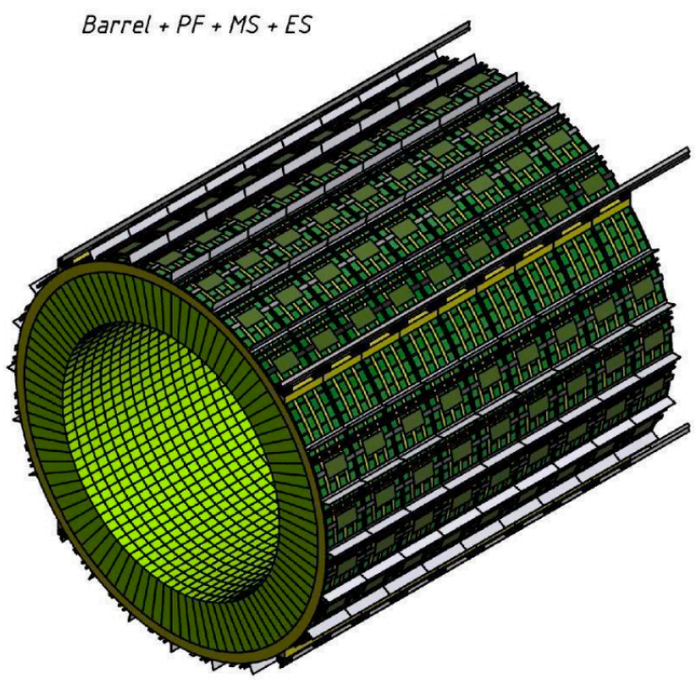
- *Detection of prompt photons, photons from π^0, η and χ_c decays*
- *Identification of electrons and positrons, participation in muon identification*
- *Local polarimetry with π^0*

Requirements:

- *Granularity ~4 cm*
- *Sampling: 190 layers (1.5 mm Sc. + 0.5 mm Pb), $X/X_0 = 17.6$*
- *Low energy threshold (~50 MeV)*
- *Energy resolution* $\sim 5\,\%/\sqrt{E}$

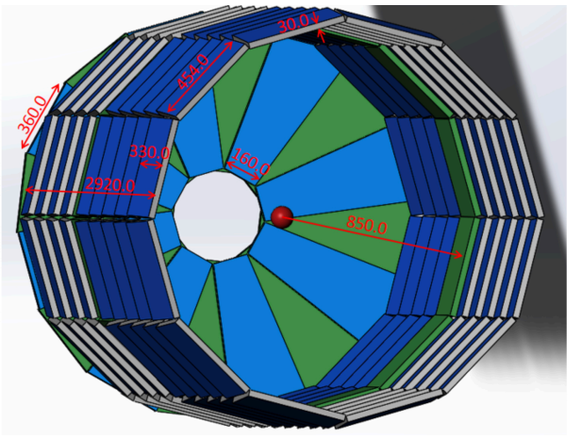
Barrel





Time-of-Flight system and Aerogel counters

MRPC-based TOF

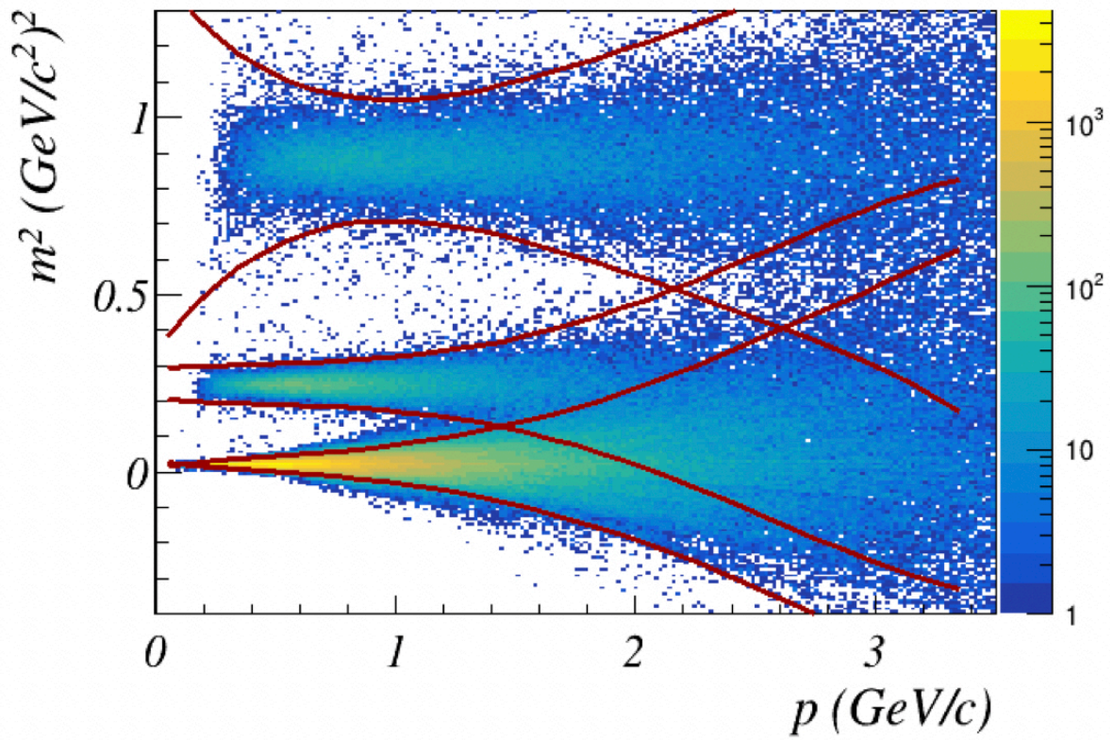


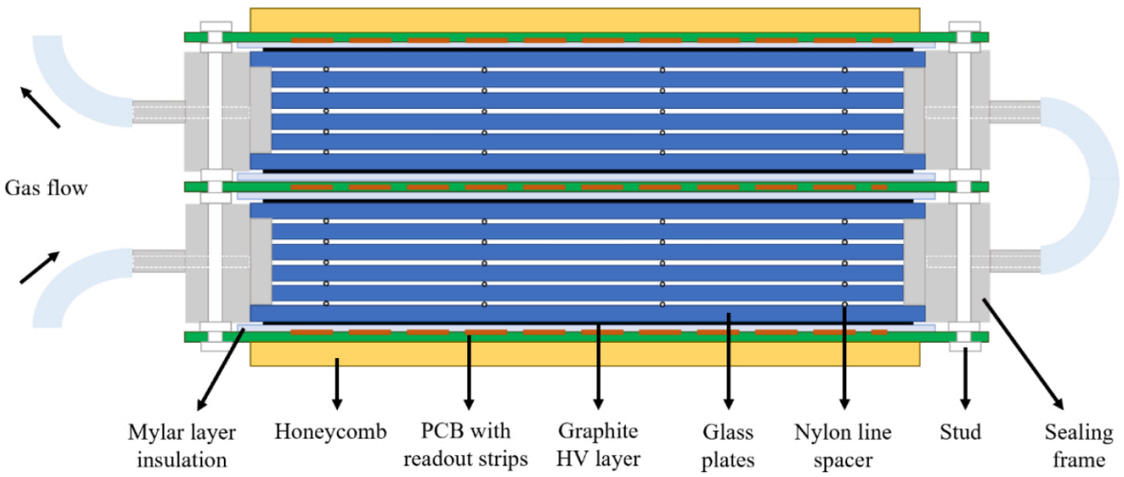
Goals:

- *π/K separation up to ~1.5 GeV*
- *K/p separation*
- *t_0 determination*

Requirements:

- *Time resolution <60 ps*





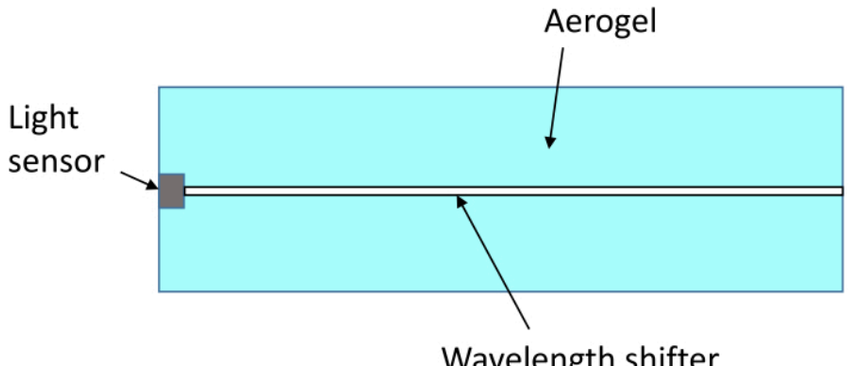
Aerogel counter in End-Caps

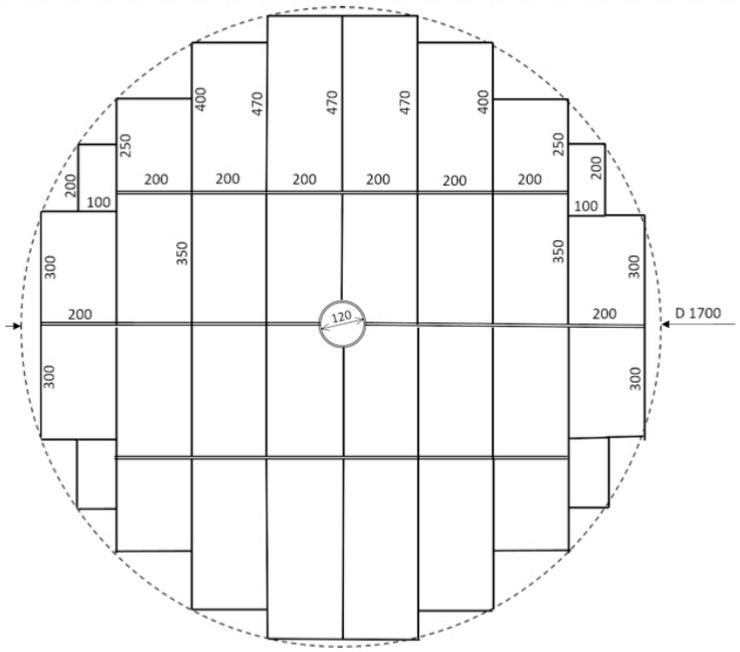
Goals:

- *π/K separation up to 2.5 GeV range*

Requirements:

- *We should have enough light!*





Straw Tracker

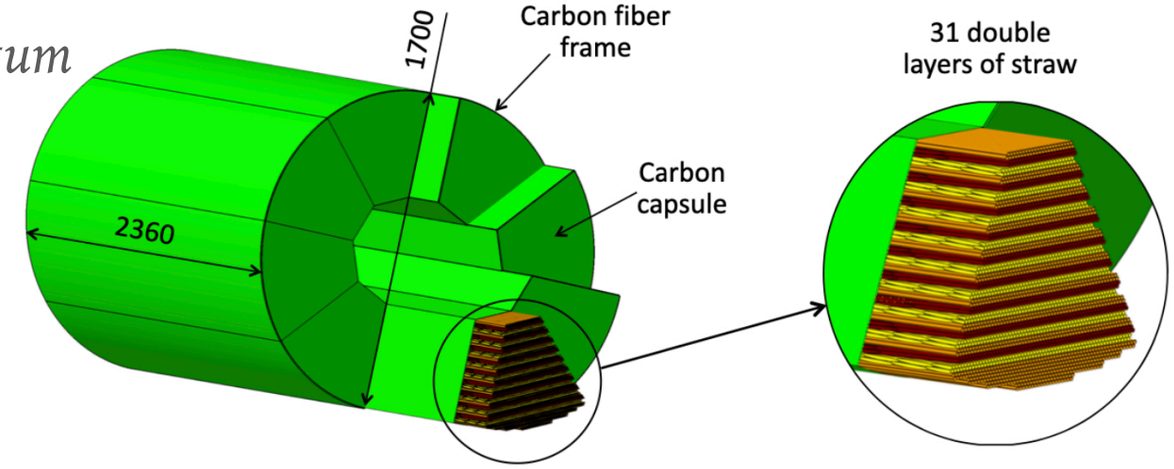
Goals:

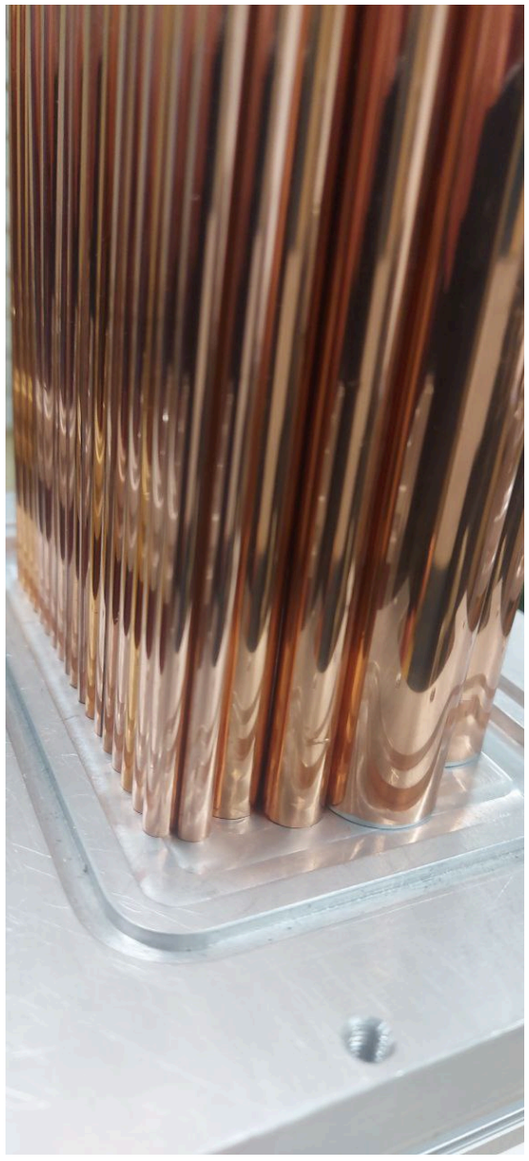
- *Track reconstruction and momentum measurement*
- *Participation in PID via dE/dx measurement*

Requirements:

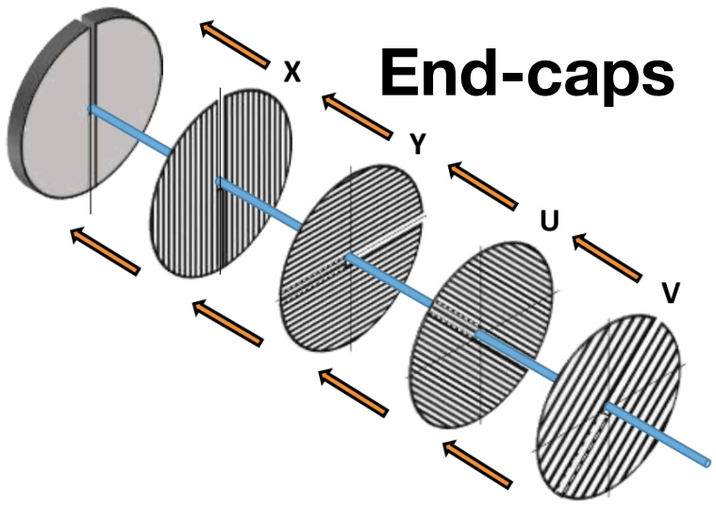
- *Spatial resolution ~150 μm*
- *Low material budget*
- *Operation in magnetic field of about 1 T*

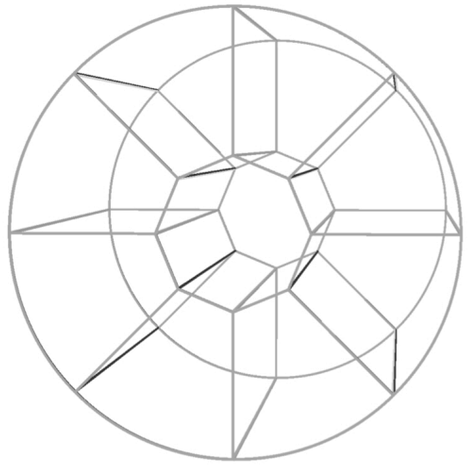
Barrel

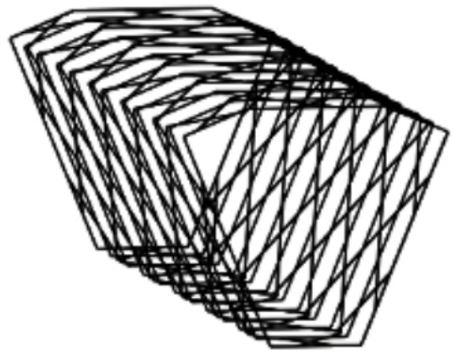


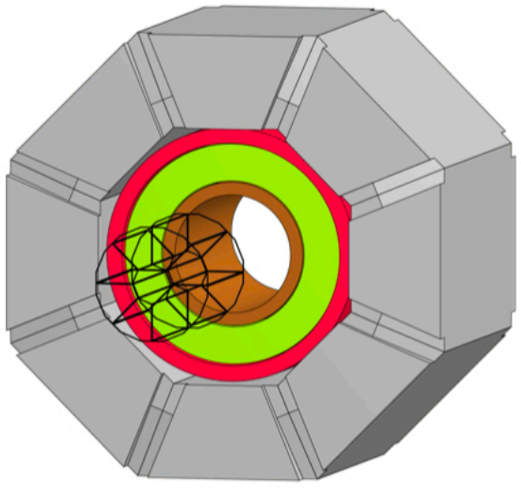


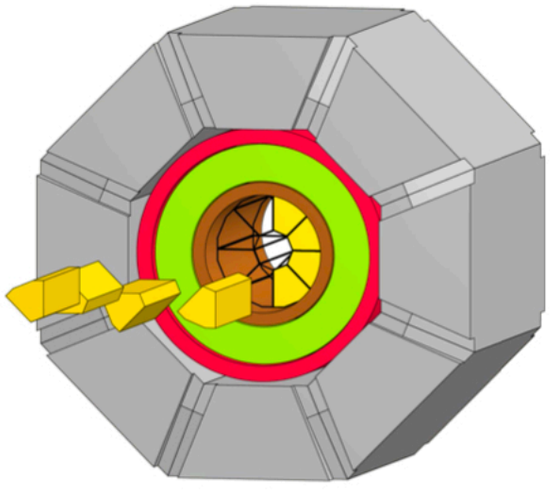
End-caps

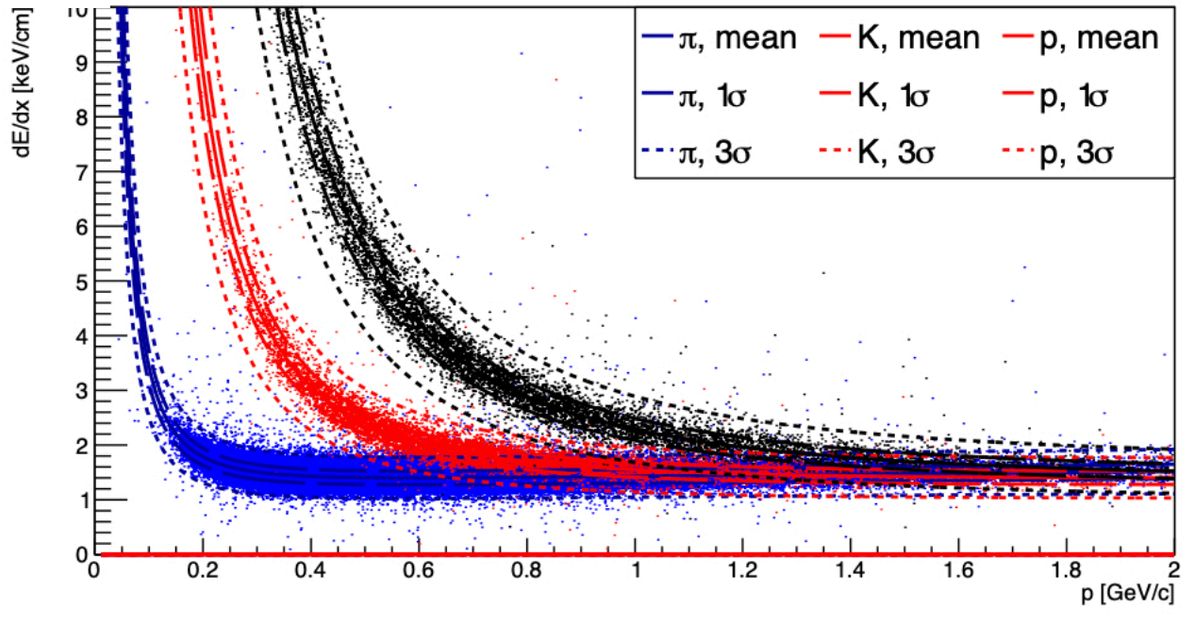












Silicon Vertex Detector

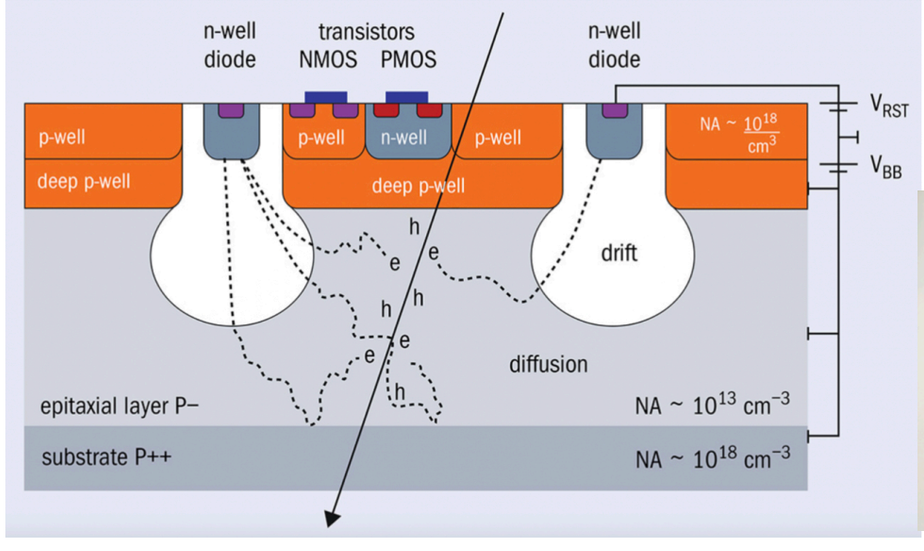
Goals:

- *Reconstruction of secondary vertices for D-mesons decay*
- *Participation in track reconstruction and momentum measurement*

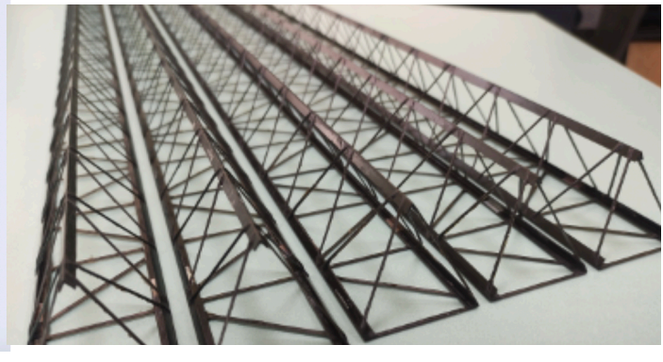
Requirements:

- *Spatial resolution <100 μm*
- *Low material budget*
- *Has to be installed as close as possible to the IP*

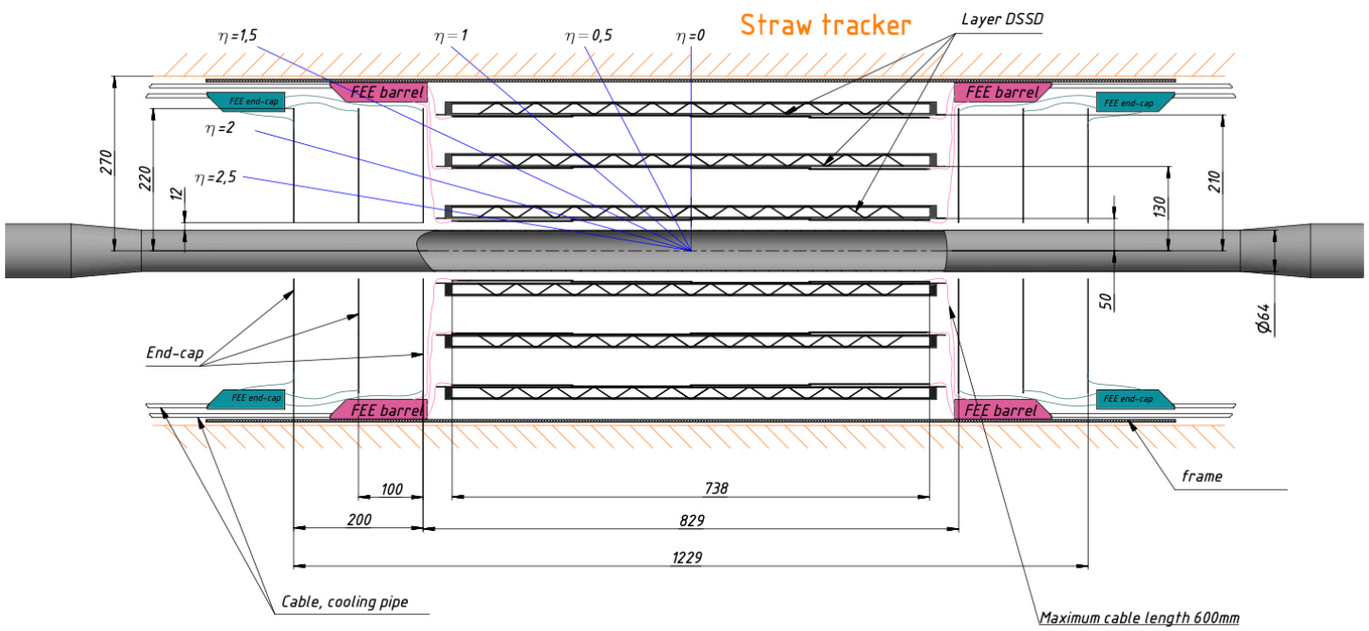
MAPS option: 4 layers

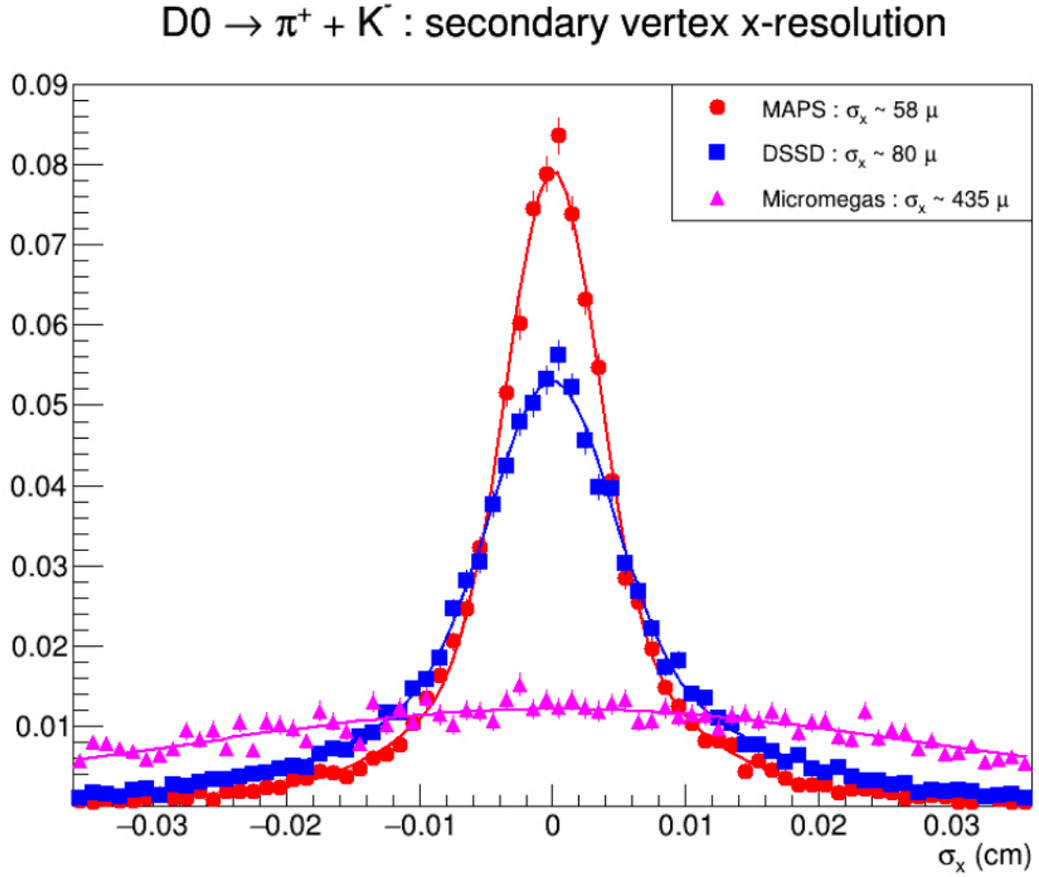


Carbon supports



DSSD option: 3 layers





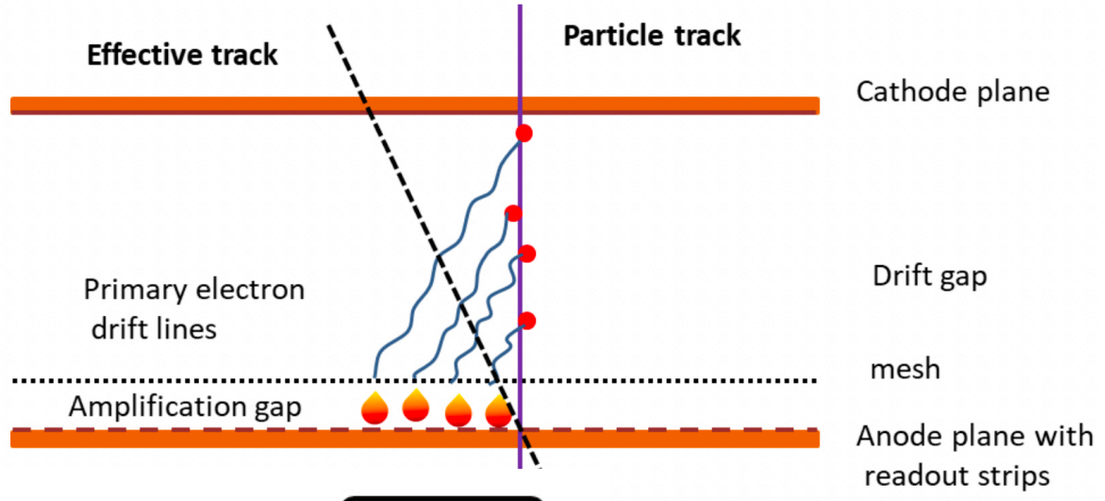
Micromegas-based Central Tracker

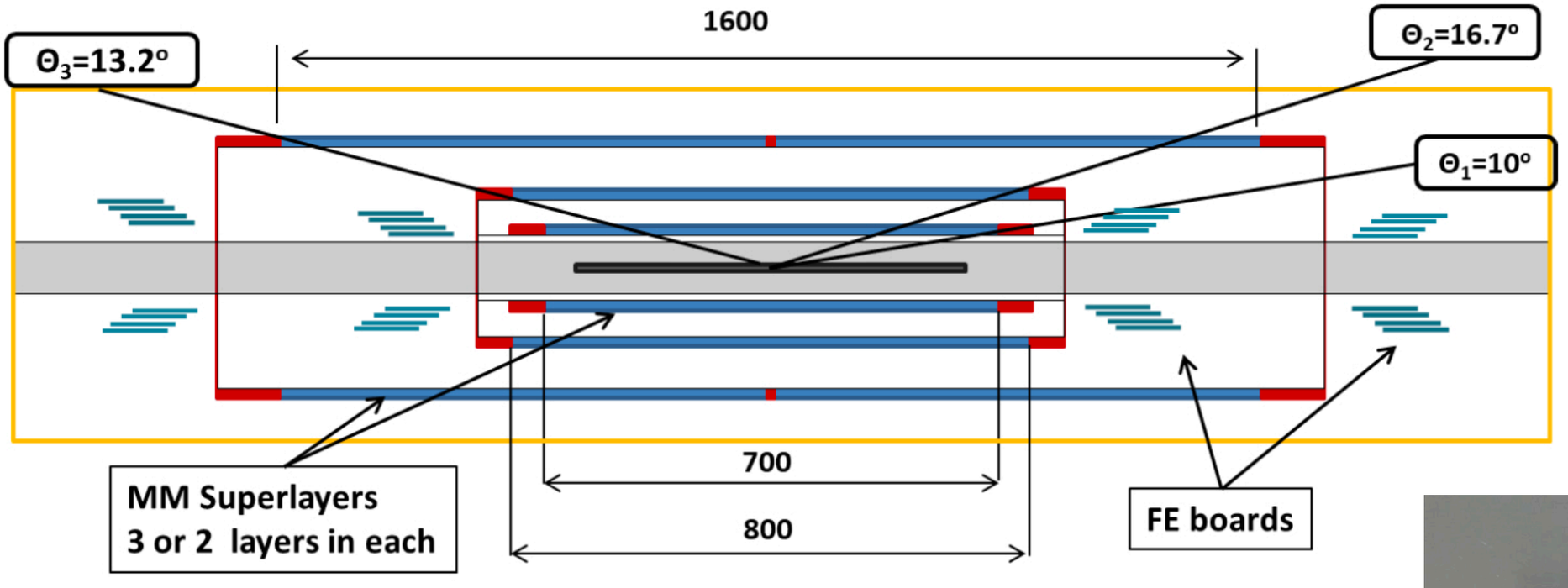
Goals:

- *Improvement of the momentum resolution*

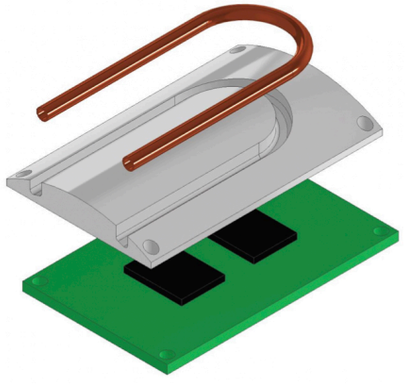
Requirements:

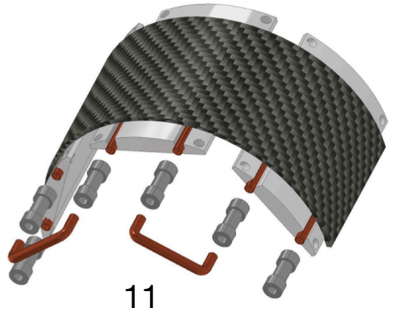
- *should operate in 1 T magnetic field*

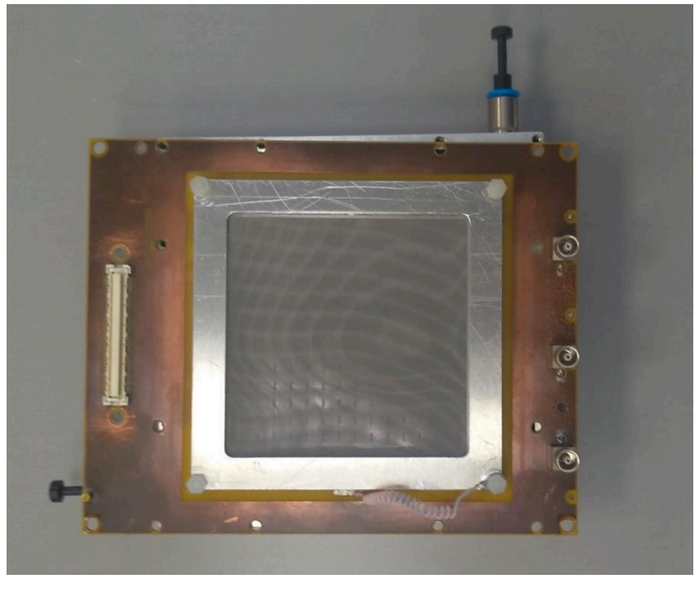




Water cooling

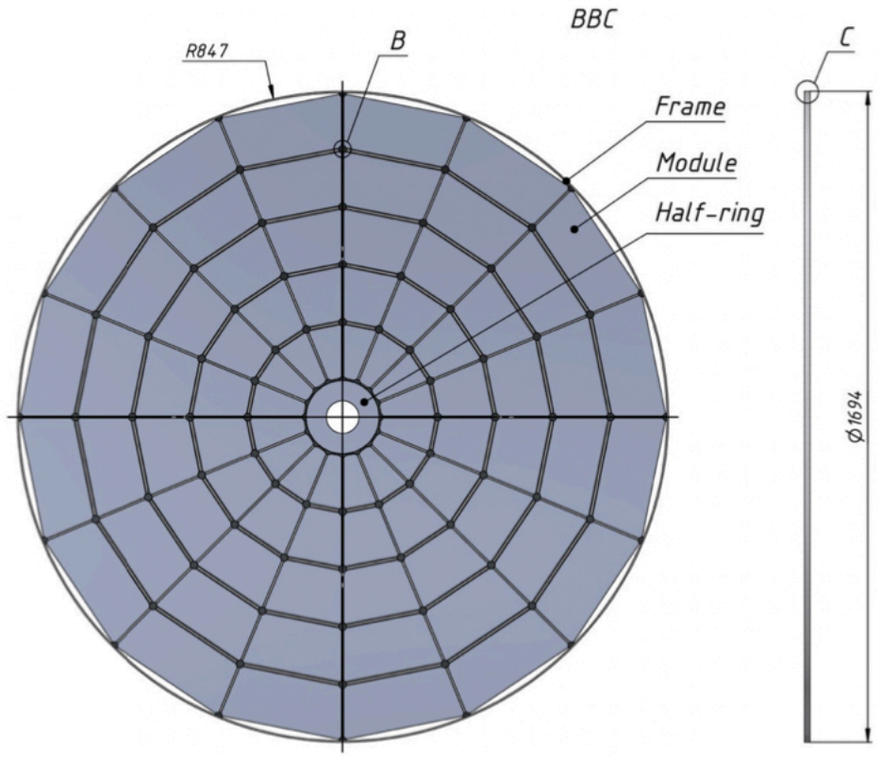


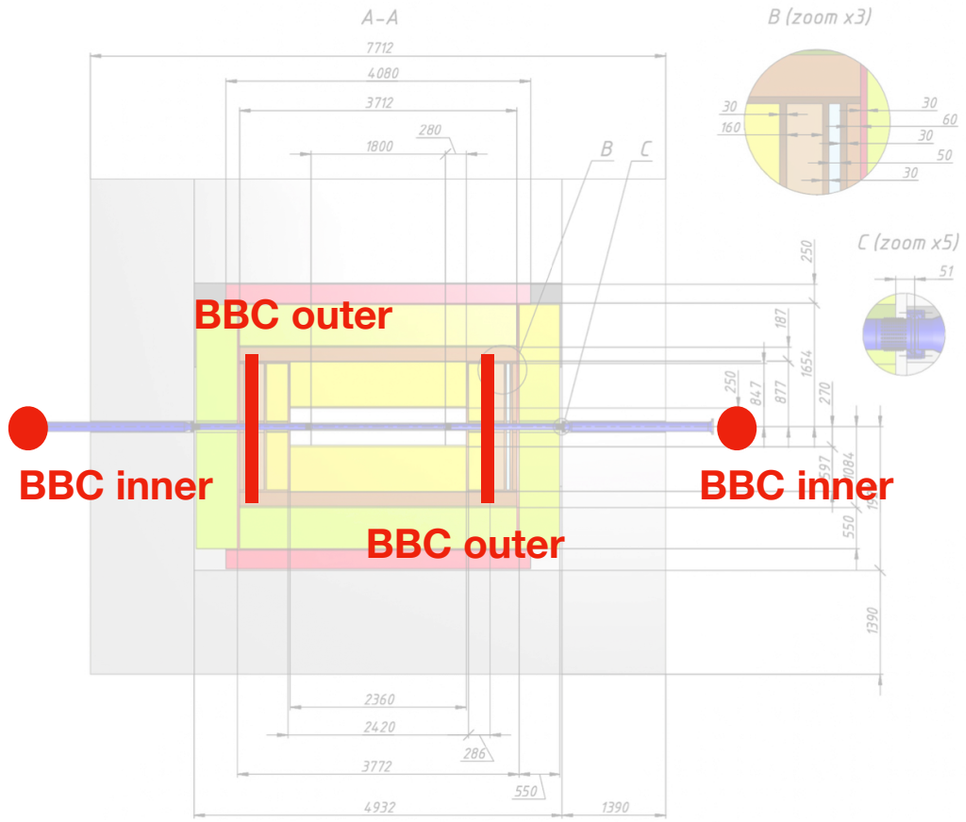




Beam-Beam Counters

Plastic scintillator-based outer part





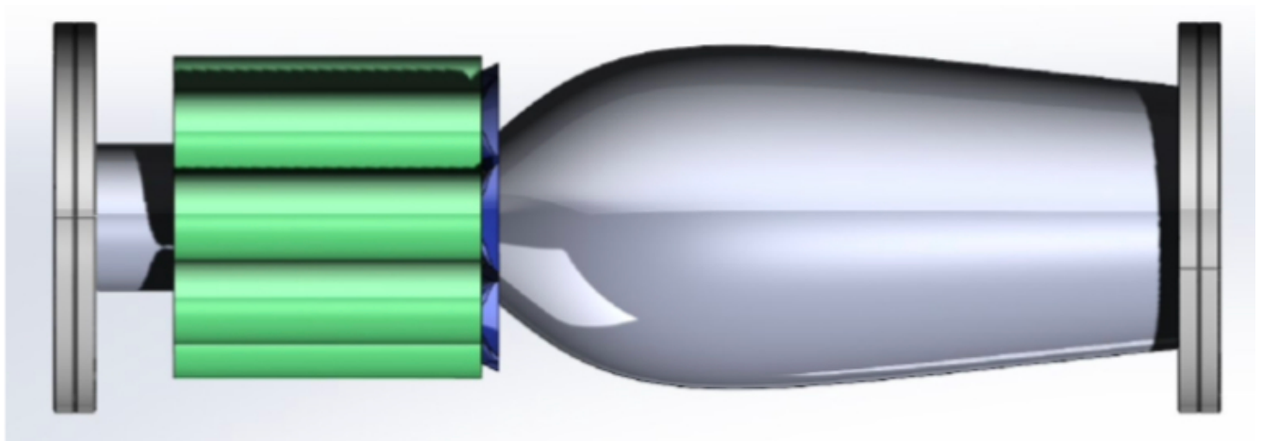
Goals:

- *Local polarimetry*
- *Luminosity control*
- *Timing*

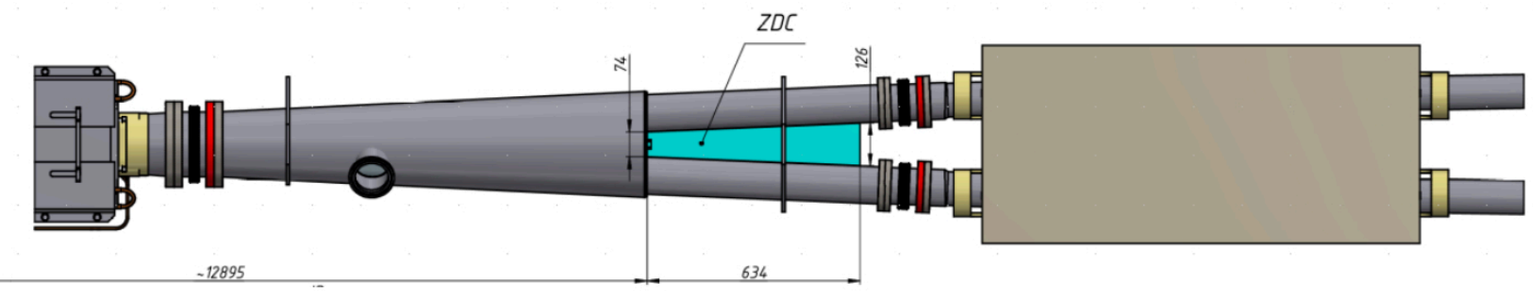
Requirements:

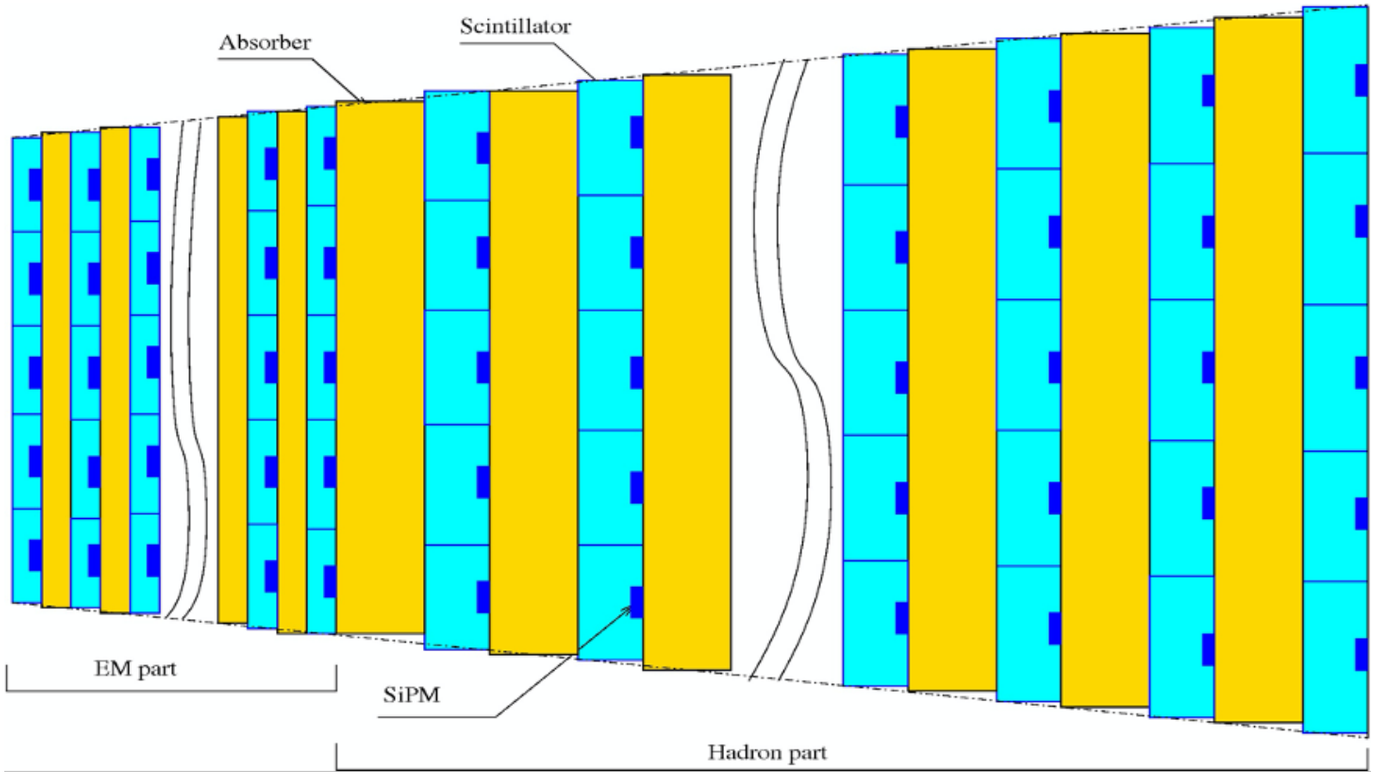
- *Operation close to the beam pipe (inner part)*
- *Time resolution ~1 ns (inner) and ~400 ps (outer part)*

MCP-based inner part



Zero Degree Calorimeters



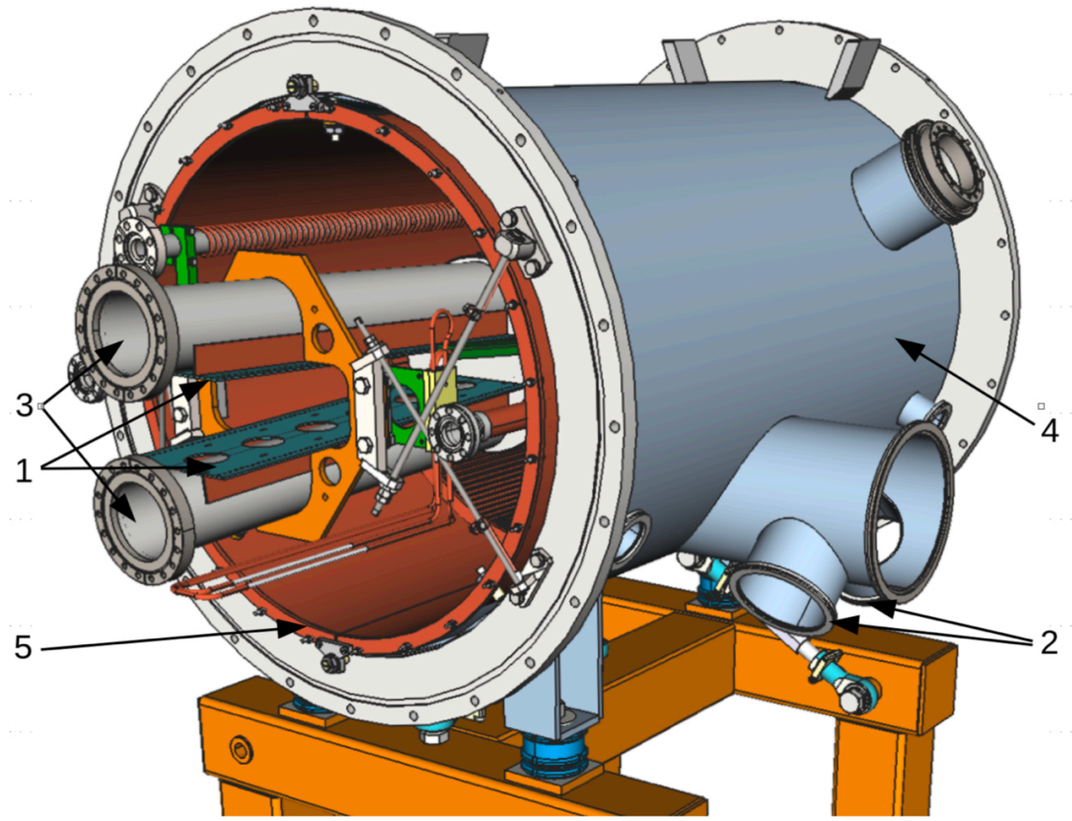


Goals:

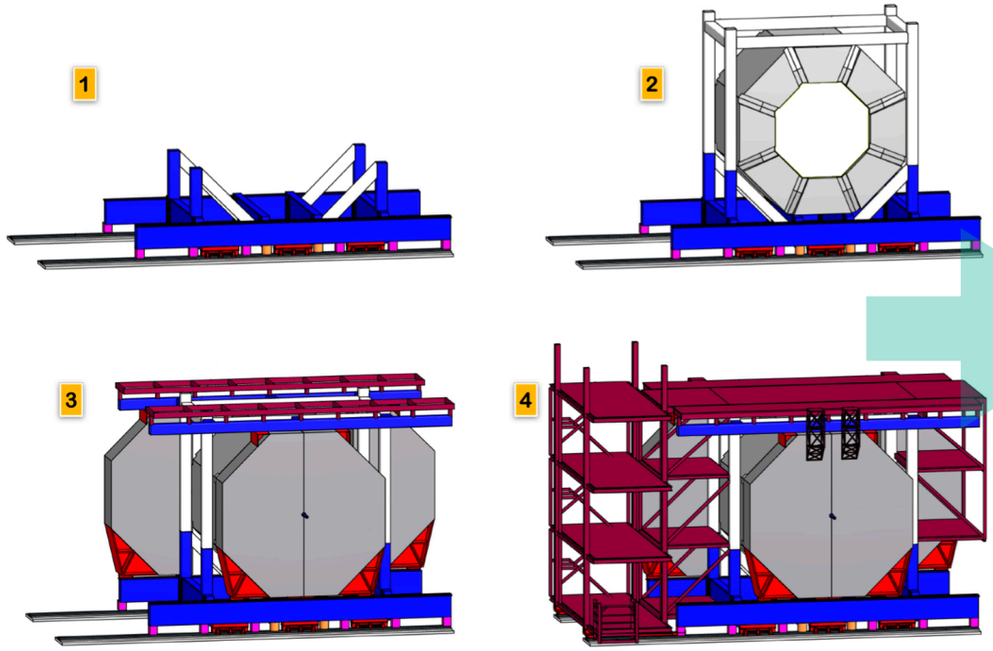
- *Luminosity monitor*
- *n/γ detection*

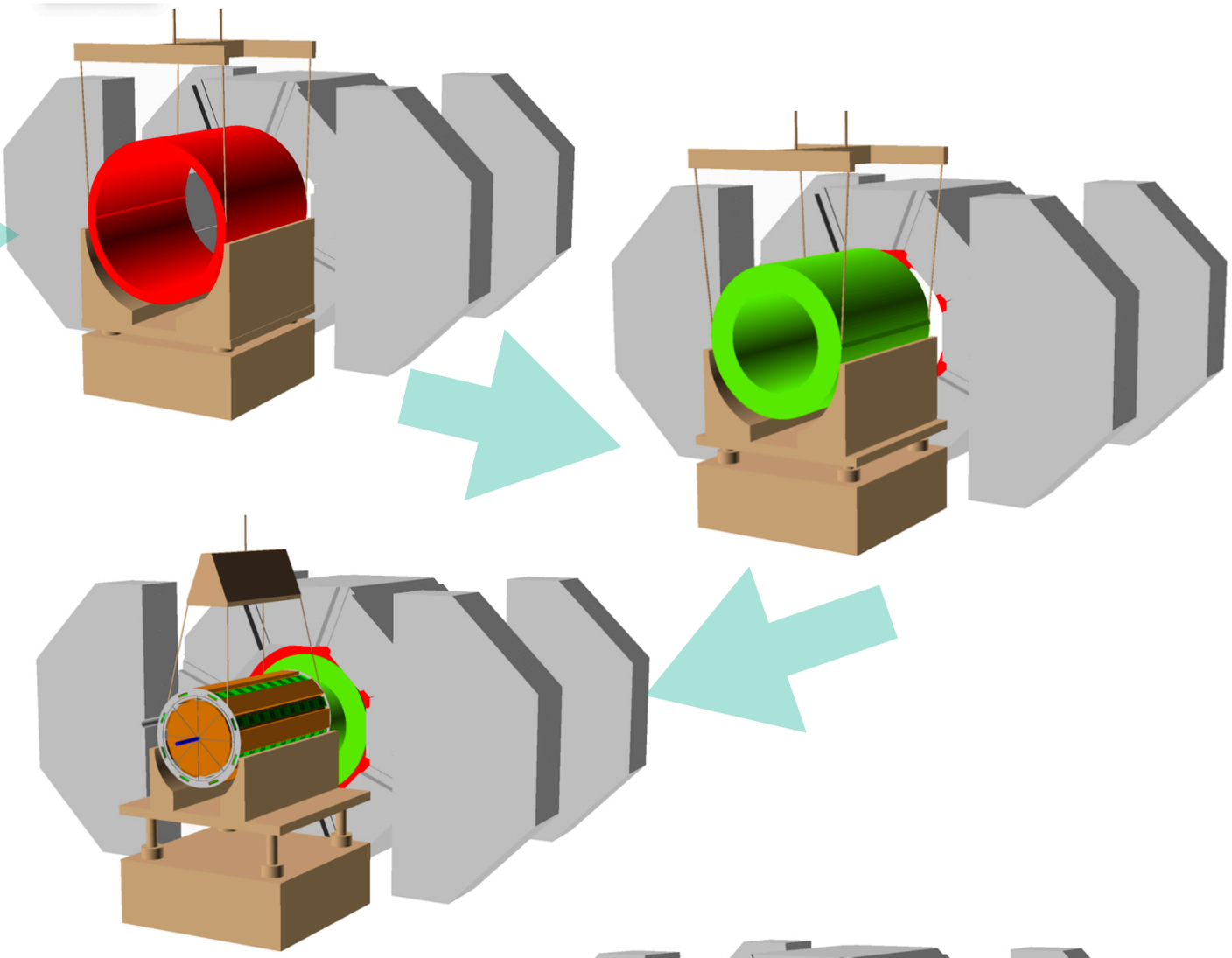
Requirements:

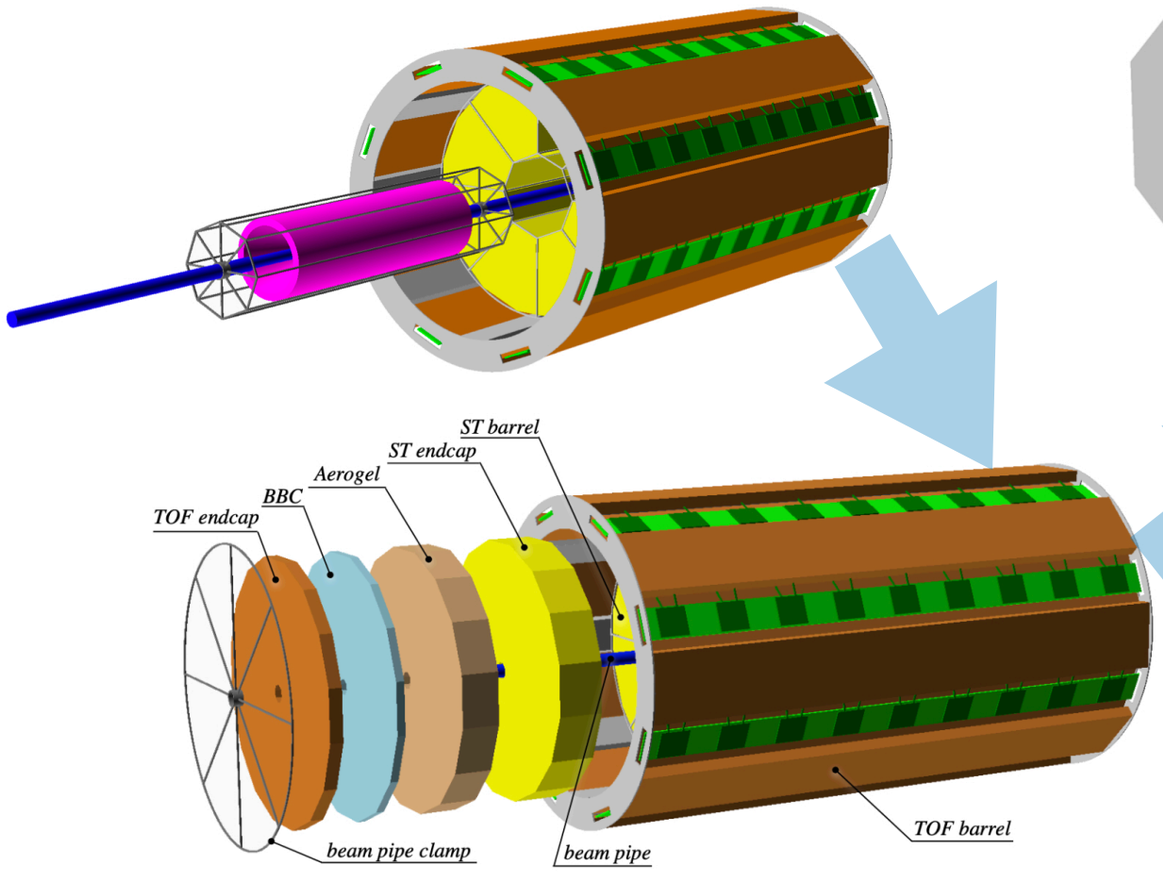
- *$13X_0$ for EM-part and $2.9\lambda_I$ for hadron part*
- *Energy resolution $50\,\%/\sqrt{E} \oplus 30\,\%$ for hadrons and $20\,\%/\sqrt{E} \oplus 9\,\%$ for γ*
- *Time resolution ~150 ps*



Detector assembly





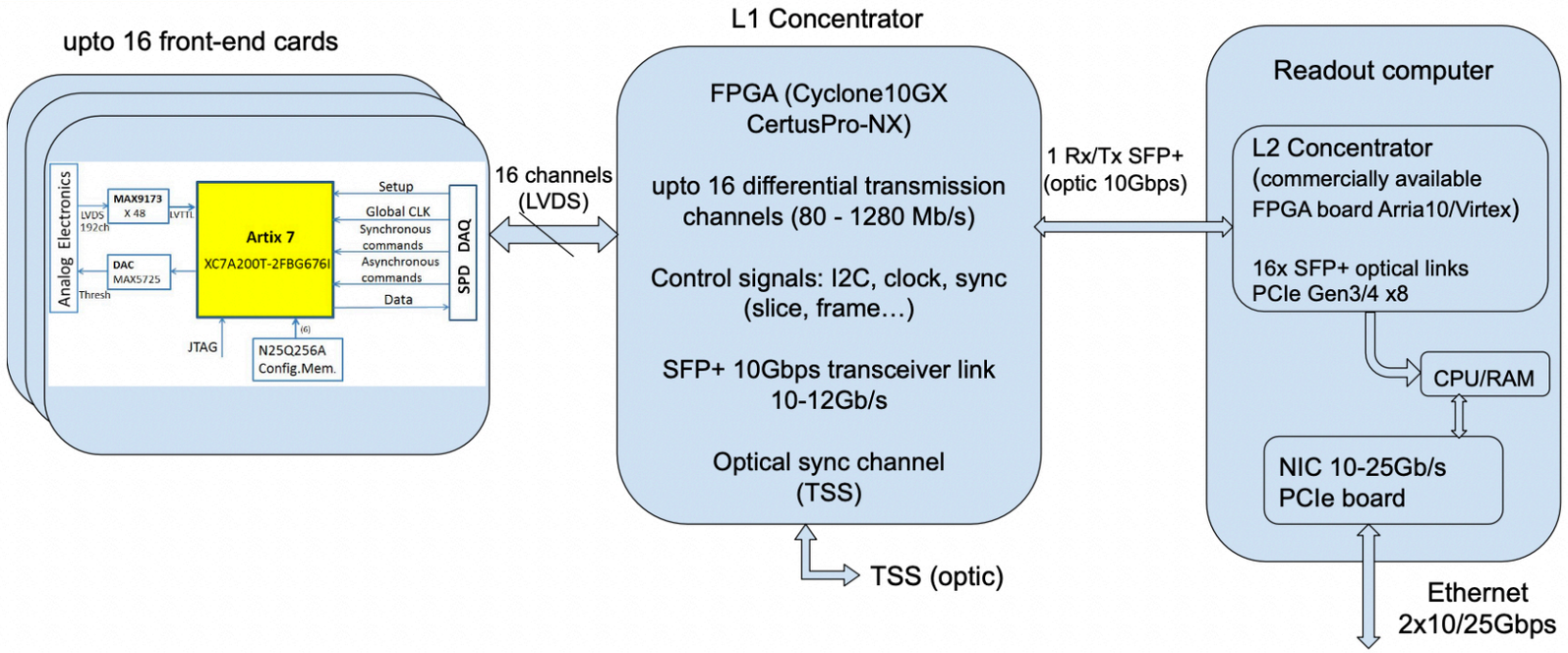


DAQ

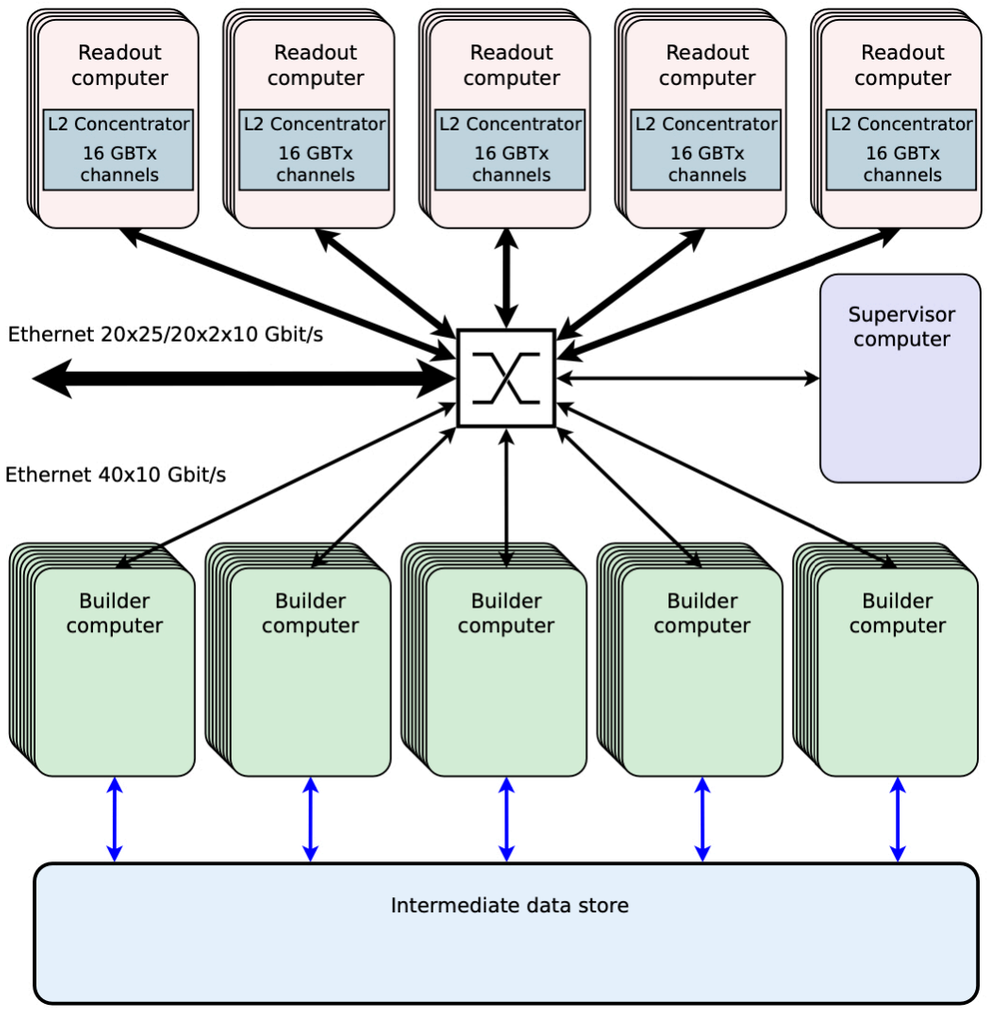
No hardware trigger!

Sub-detector	Information type	Number of channels	Channels per FE card	Number of outputs
Vertex detector 3 DSSD	A	107520	640	168
Vertex detector 4 MAPS	A	12000		2204
Straw tracker	T + A	25904 + 4608	128	239
Calorimeter	T + A	22986	64	360
TOF	T	8832	16	552
Aerogel	T + A	128×2	16	16
BBC (inner+outer)	T + (T + A)	(32 + 112)×2	32	2 + 8
Range system	T	130200	192	679
ZDC	T + A	1050×2	64	34
Total (vertex DSSD)		302694		2058
Total (vertex MAPS)		207174		4094

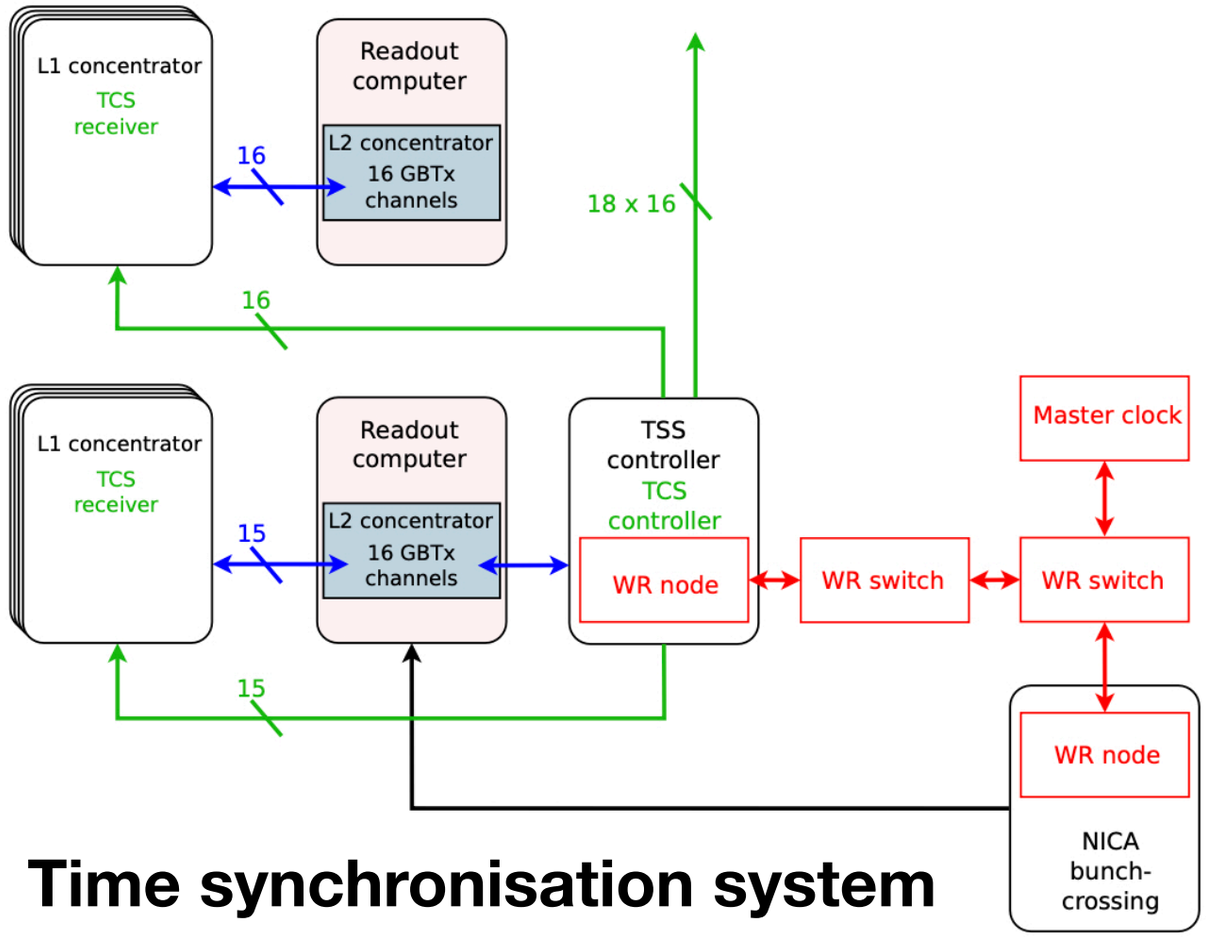
Readout chain

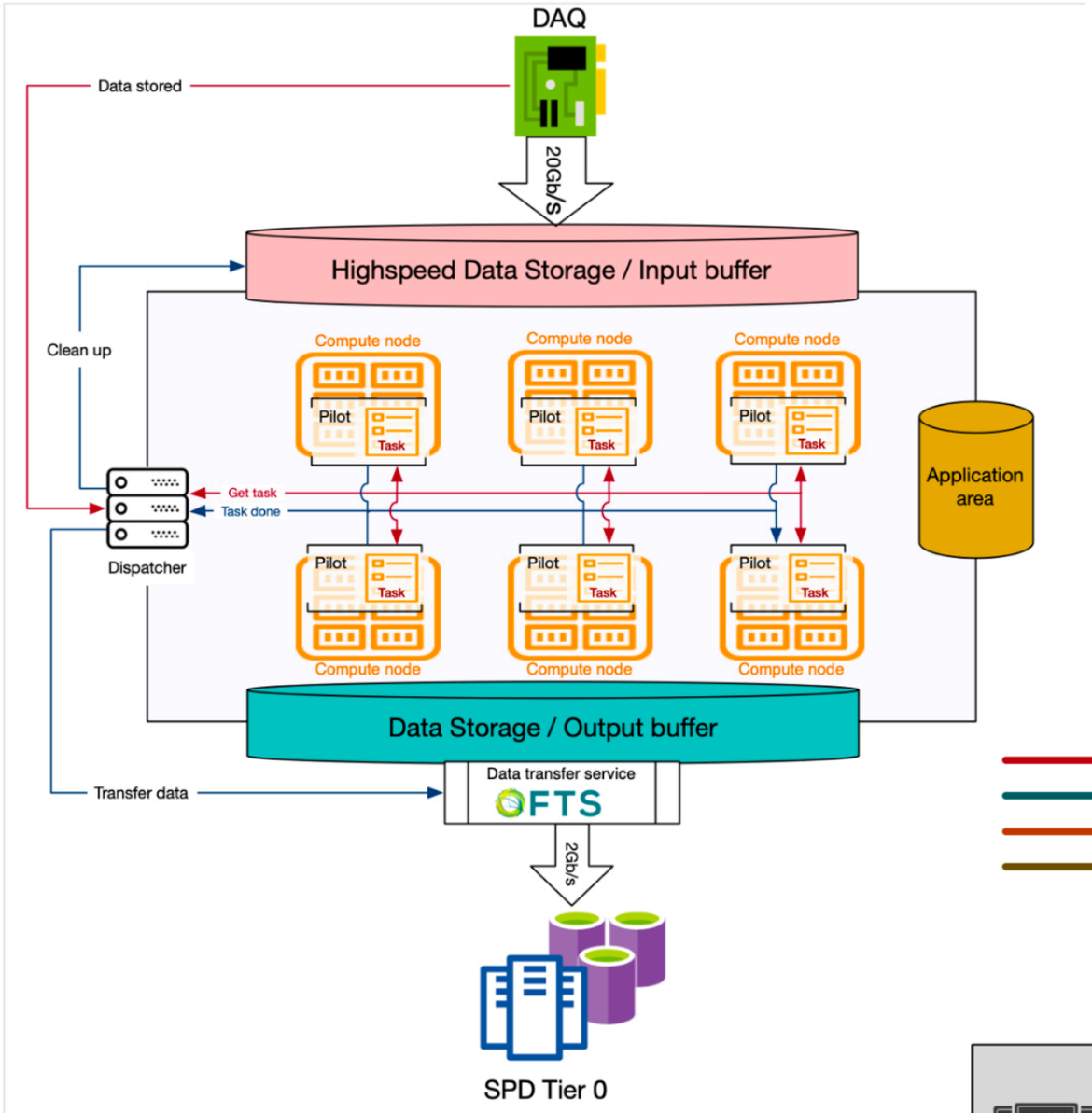


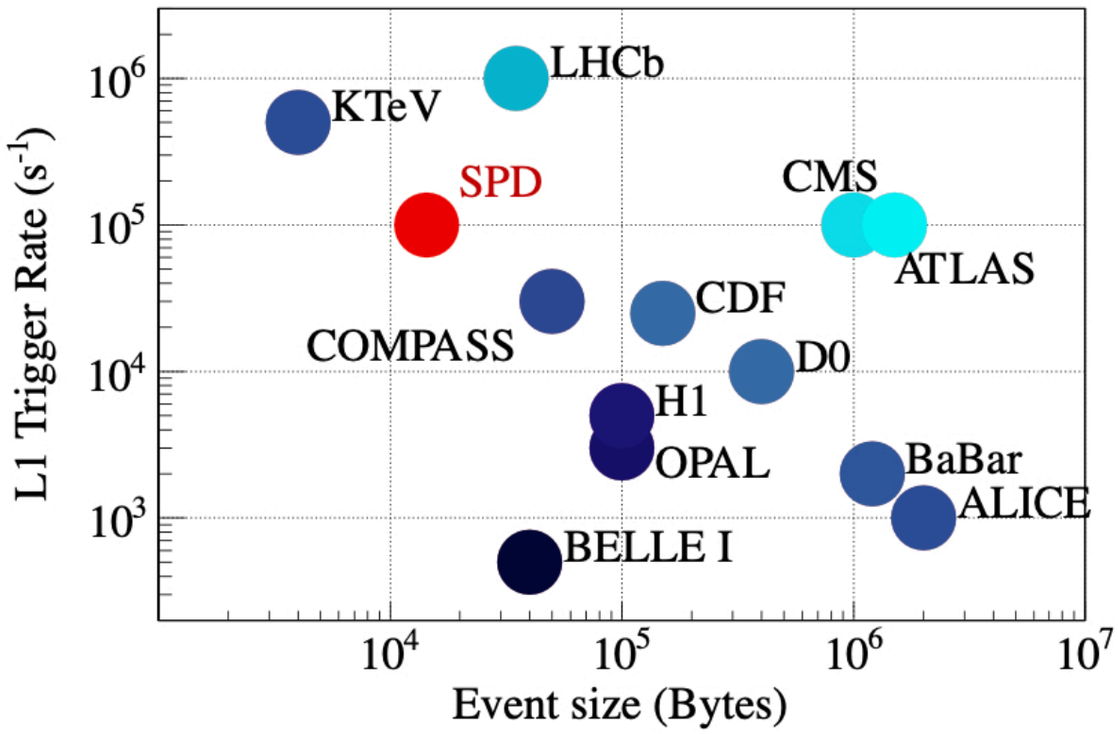
Slice building chain

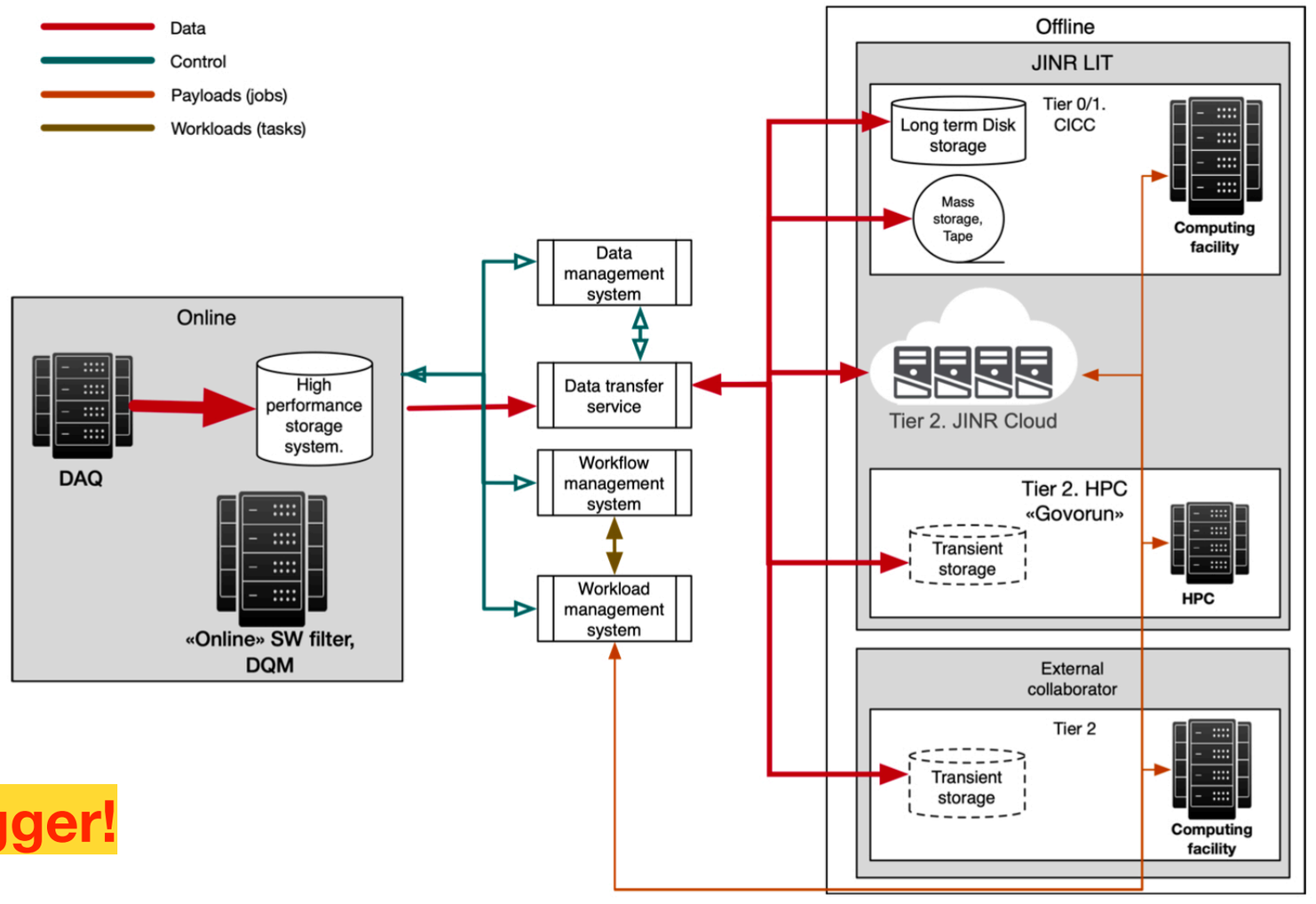


Time synchronisation system







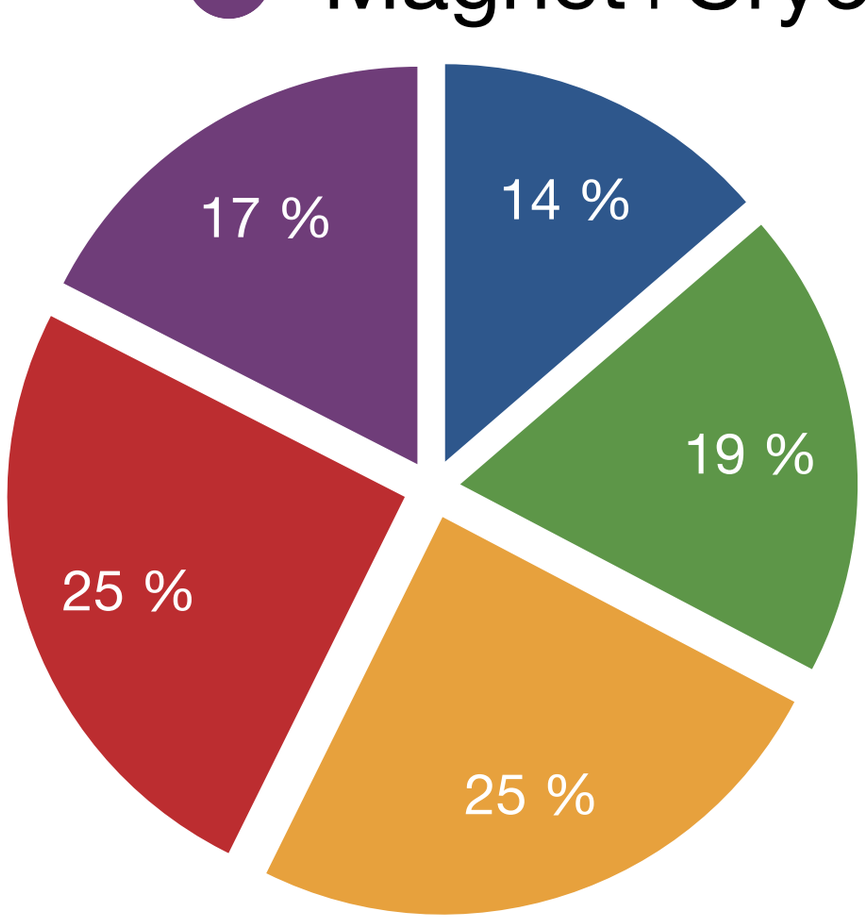


Computing

No hardware trigger!

Cost estimate

- Infrastructure
- Computing
- Electronics
- Detectors
- Magnet+Cryo



Subsystem	Option	Stage	Cost, M$
SPD setup	Vertex detector:		
	– DSSD	II	7.3
	– MAPS	II	13.5
	Micromegas Central Tracker	I	0.9
	Straw tracker	I+II	3.0
	PID system:		
	– TOF	II	2.0
	– Aerogel PID system	II	2.4
	ECal		
	– mock-up	I	0.4
		I+II	9.4
	Range system	I+II	16.1
	ZDC	I+II	0.6
	BBC (inner+outer)	I+II	0.6
	Magnetic system		
	Novosibirsk option	I+II	8.3
	JINR option	I+II	7.3
	& cryogenic infrastructure		
	Novosibirsk option	I+II	6.4
	JINR option	I+II	6.1
	Beam pipe		
	– Al	I	0.1
	– Be	II	0.4
General infrastructure		I	1.2
		I+II	1.7
Detector Control System		I	1.0
		I+II	1.8
Data Acquisition System		I	0.8
		I+II	1.3
Computing		I	5
		I+II	15*
TOTAL COST	stage I		44.4
	stage I+II		83.4

* + 4.5 M$ per year for tapes

Possible working plan

	2022	2023	2024	2025	2026	2027	2028
	SPD Technical Design Report						
	Magnet						
Technical project							
Production							
Commissioning at JINR							
	1-stage detectors*						
R&D							
Production							
Commissioning							
Installation							
	2-stage detectors**						
R&D							
Production							
	Data taking						
	Development of NICA polarized infrastructure						

Operation

* - Micromegas, Straw, Range System, BBC, ZDC ** - ECAL, ToF(?), Silicon Vertex, Aerogel

SUMMARY

- We have presented the first version of the Technical Design of the Spin Physics Detector at NICA, a sophisticated experimental apparatus for the study of the spin structure of the proton and deuteron, as well as fundamental properties of the strong interaction.
- We propose to implement the project in two stages. **The first stage** of the SPD experiment will be devoted to the study of polarized and non-polarized phenomena at low energies and reduced luminosity. It implies construction of a minimum setup configuration. The main part of the SPD physics program of the experiment, the study of the polarized gluon content in proton and deuteron, is planned to be implemented during **the second stage** with the full setup.
- We estimated the cost of the fist stage and the full setup as 44.4 and 83.4 M$, respectively. Cost estimate is based on the cost of materials and equipment as well as the currency exchange rates at the beginning of Feb. 2022.

BACKUP

BRIEF HISTORY OF THE SPD PROJECT

2006: Idea of spin measurements at NICA

2014: SPD Letter of intent

Jan 2019: SPD project approved at JINR

June 2019: proto-collaboration meeting in Dubna

Jan 2021: SPD CDR presented at PAC

Jan 2022: SPD CDR approved by PAC

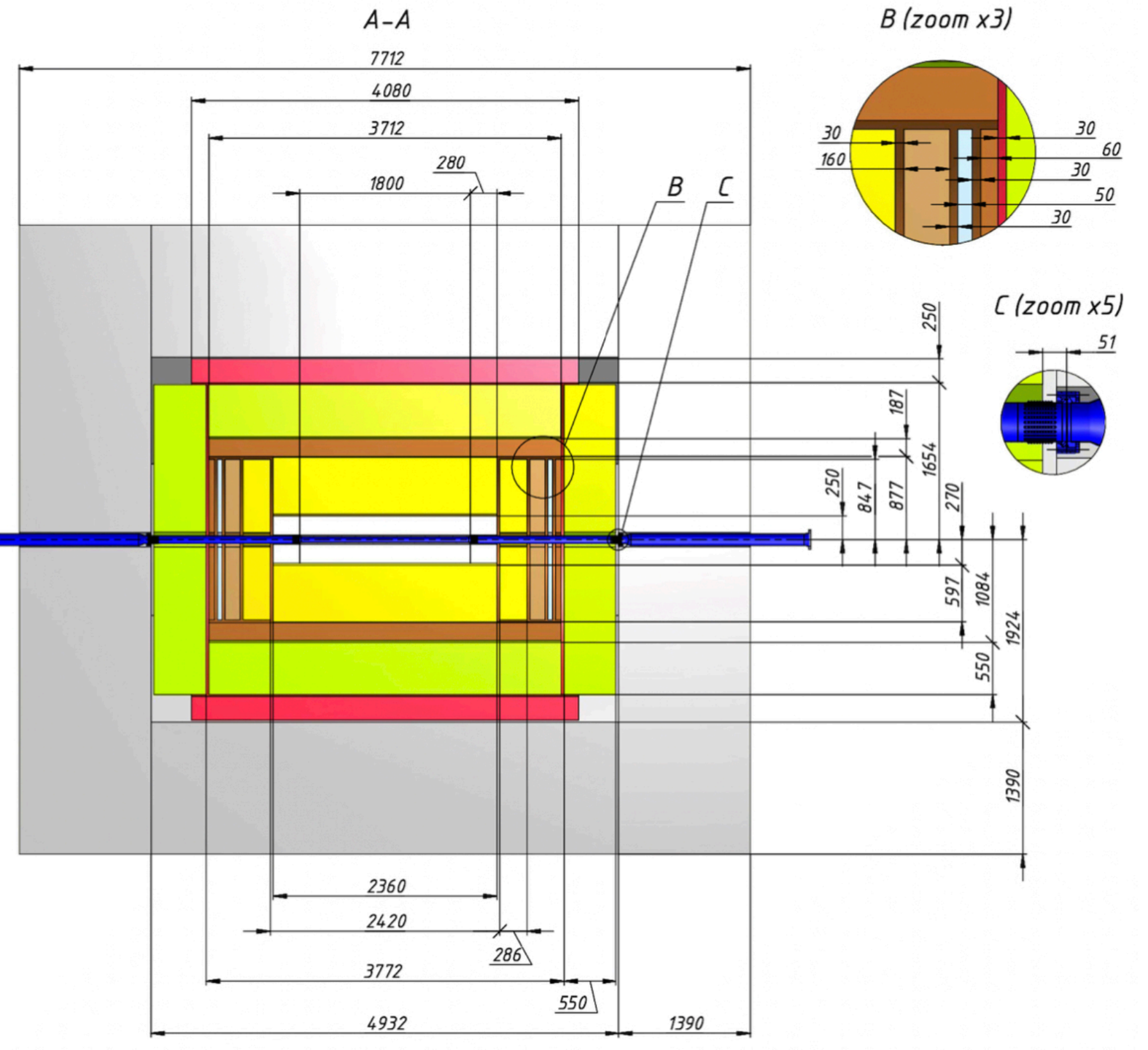
Jul 2018: SPD workshop in Prague

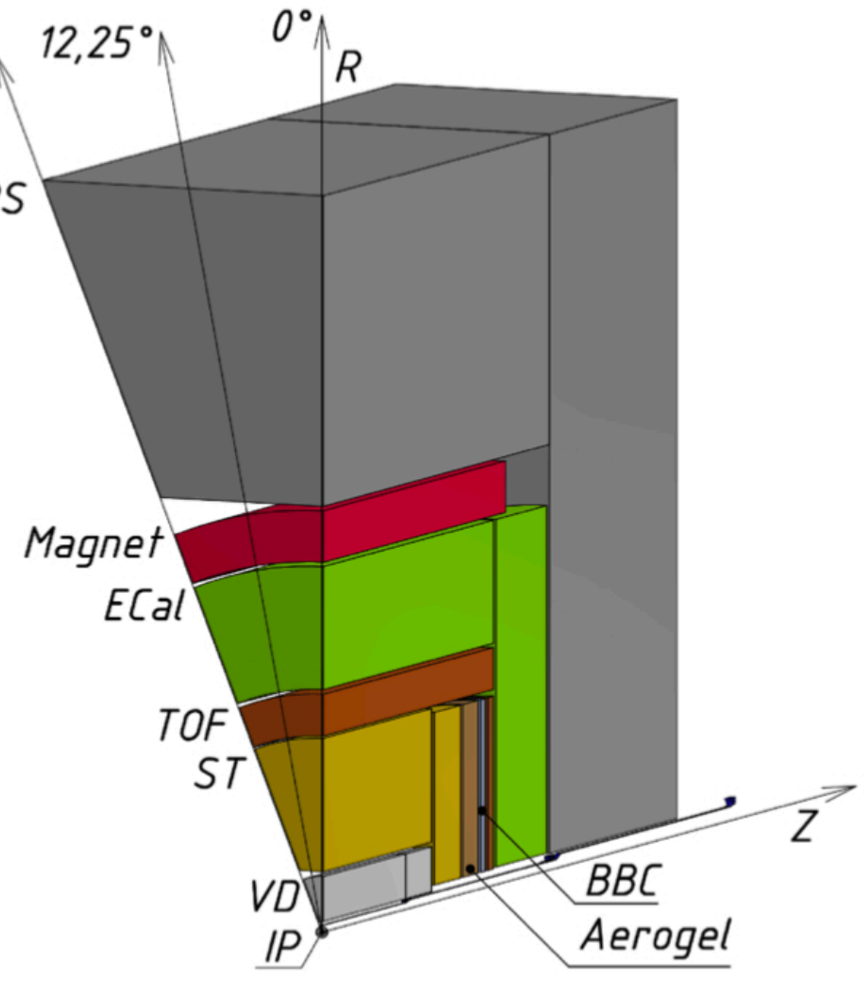
Sep 2020: two remote SPD workshops

June 4, 2021: birthday of the SPD collaboration

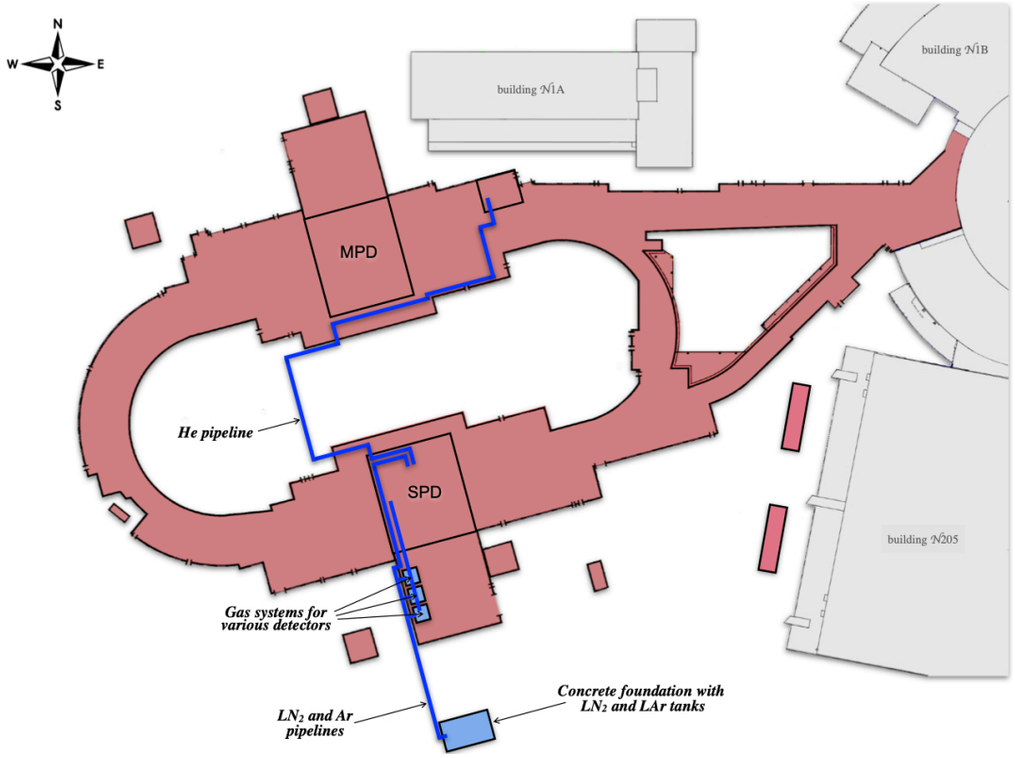
NOW SPD TDR is presenting at PAC

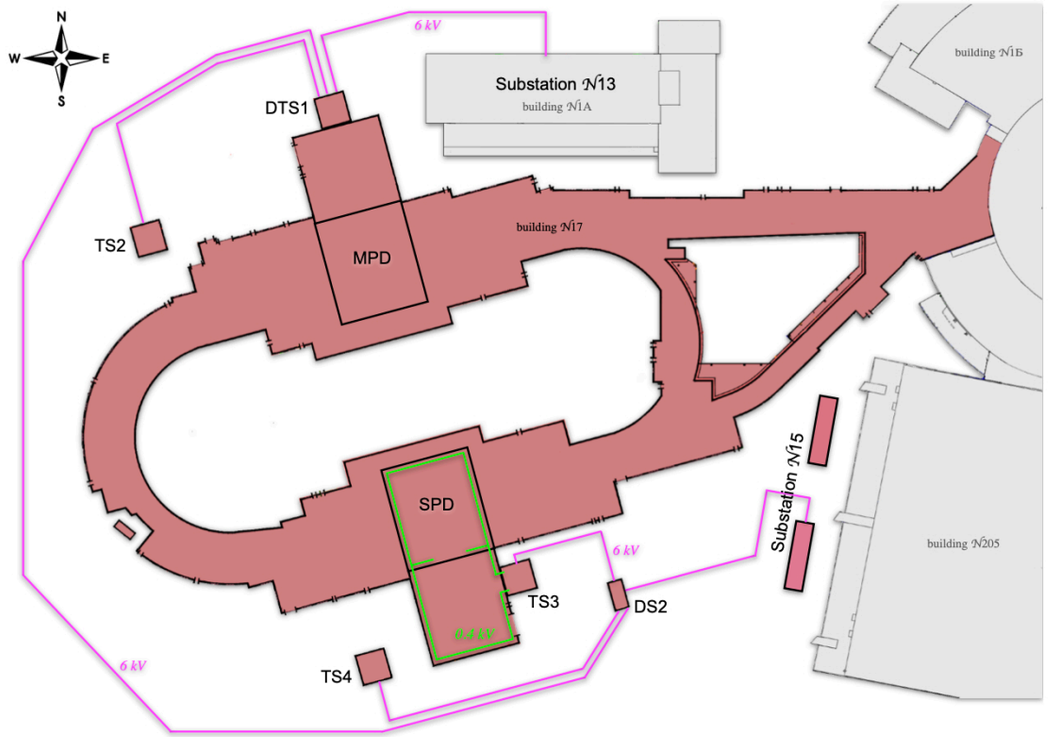
General sketch of the detector

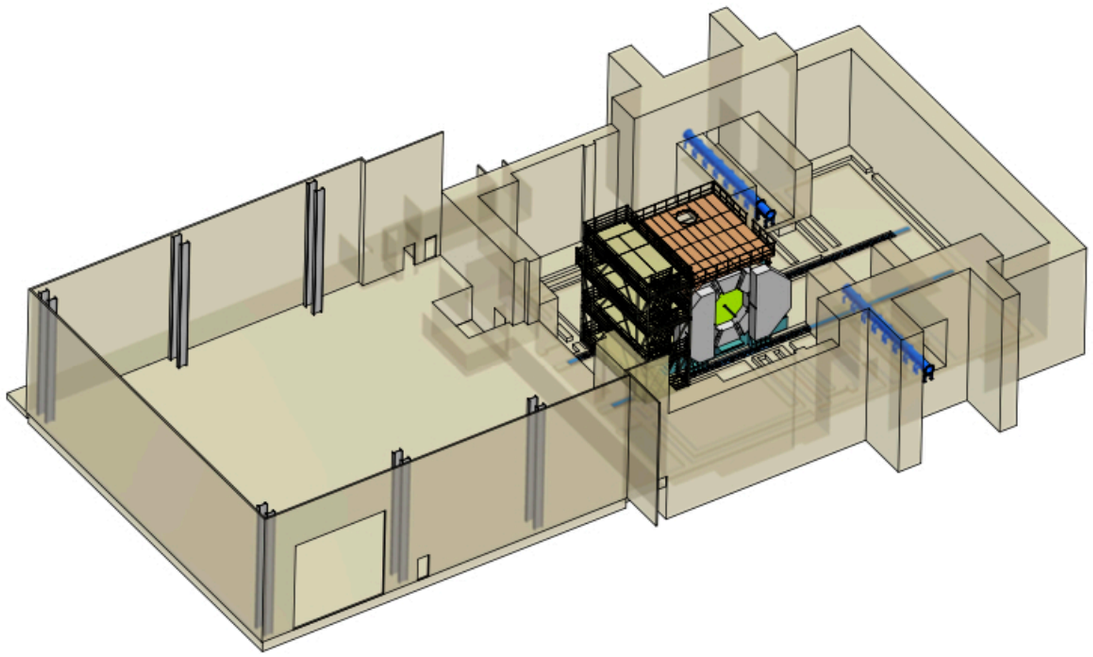


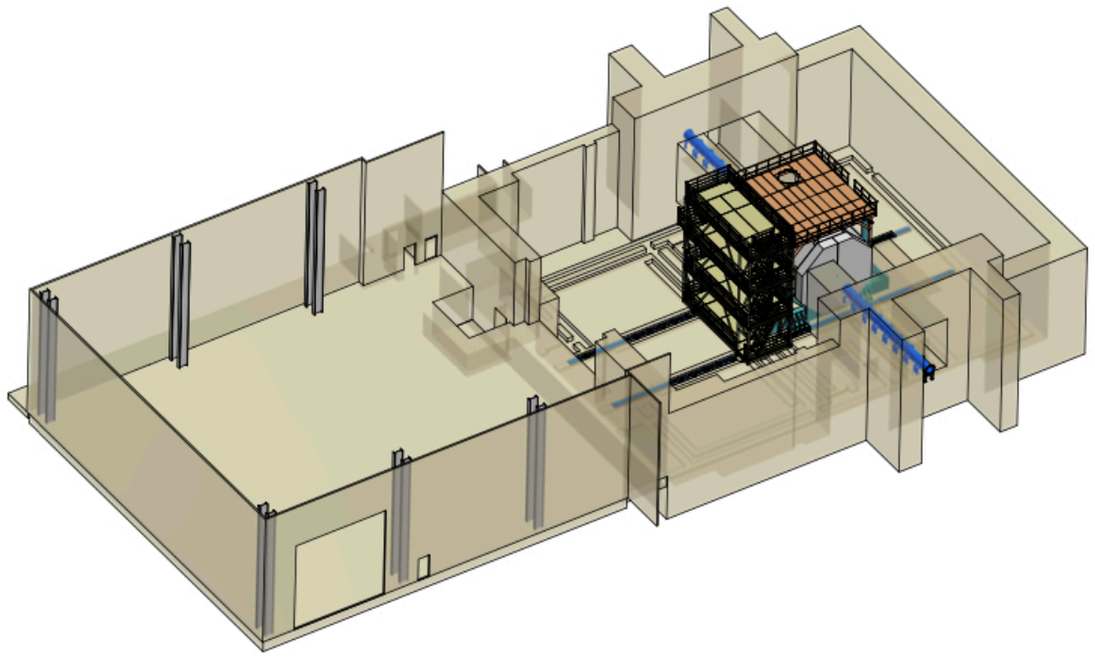


Infrastructure

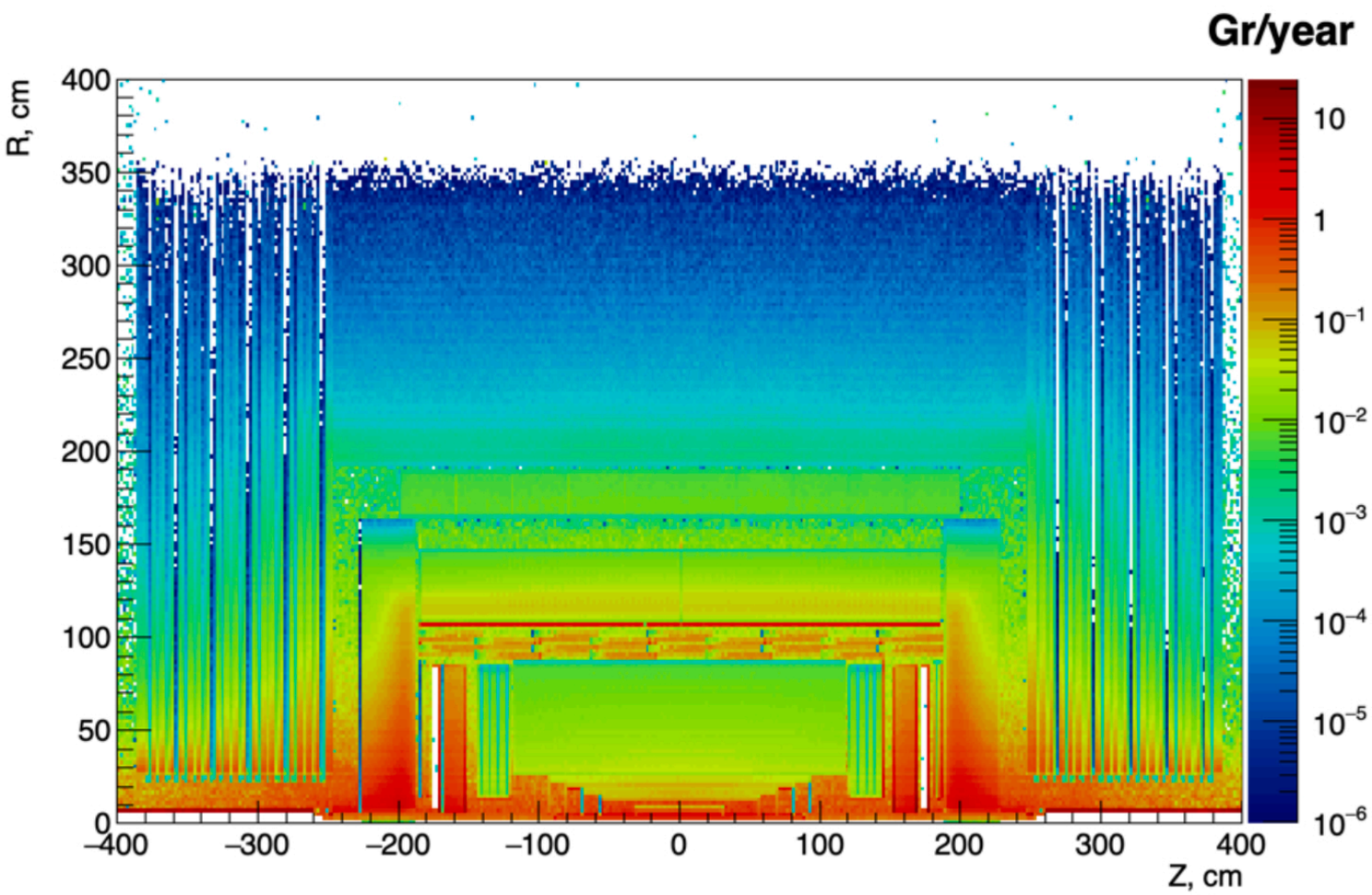


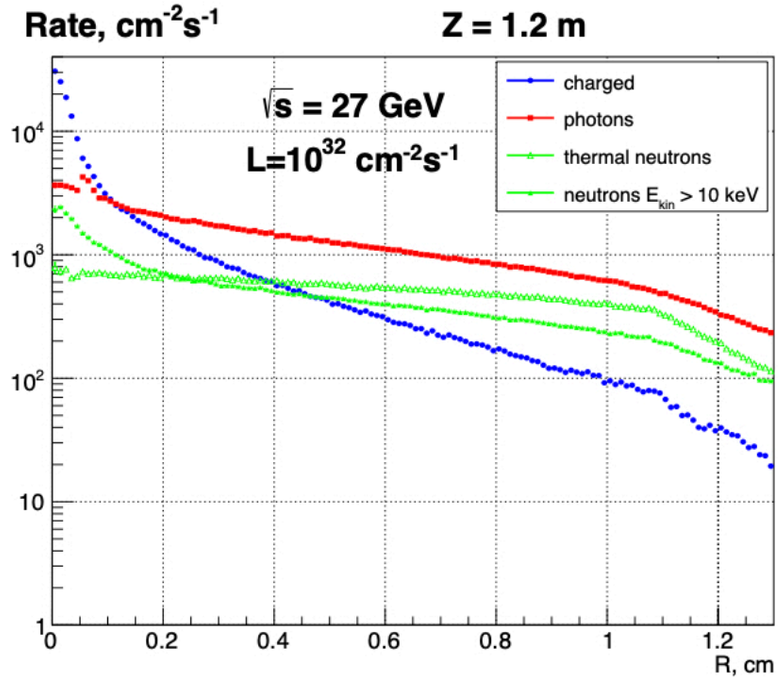


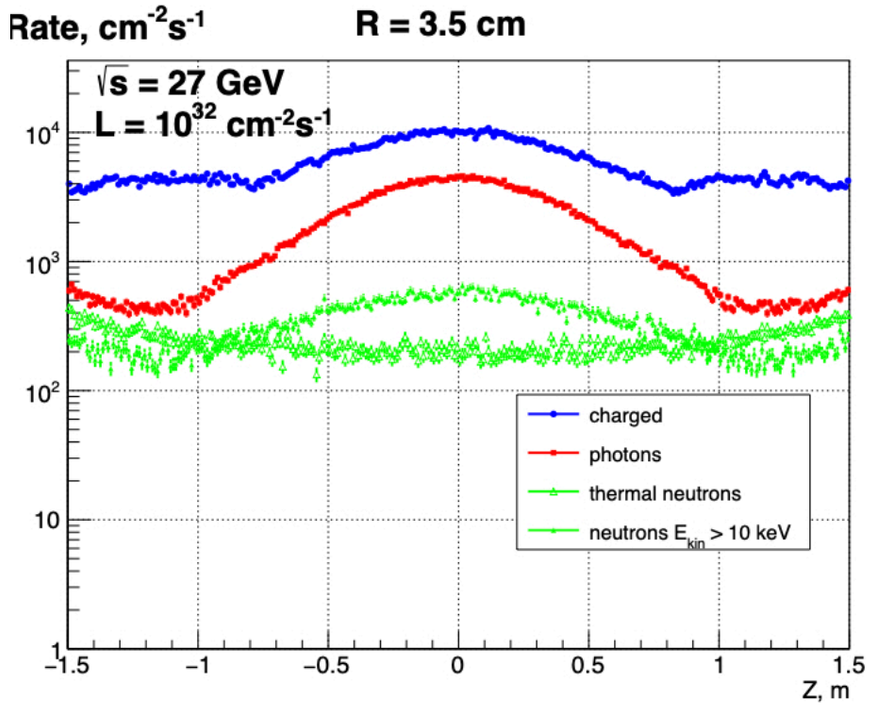




Radiation environment







Nota bene: radiation conditions on the SPD are not extreme and do not require radiation-hard electronics!

Main parameters of the SPD setup

	Stage I	Stage II
Maximum luminosity, 10^{32} cm^{-2} s^{-2}	up to 0.1	1
Interaction rate, MHz	up to 0.4	4
Magnetic field at IP, T	up to 1.0	1.0
Track momentum resolution $\frac{\delta p}{p}$ at 1 GeV/c, %	~1.7	~1.0
Photon energy resolution, %		$5/\sqrt{E} \oplus 1$
$D^0 \to K\pi$ vertex spatial resolution, μm	440	60 for MAPS 80 for DSSD
PID capabilities	dE/dx, RS	dE/dx, ECal, RS, TOF, Aerogel
Number of channels, 10^3	189 207	for MAPS) 303 for DSSD
Raw data flow, GB/s	up to 1	20
Total weight, t	1236*	1240
Power consumption, kW	77	113 for MAPS 90 for DSSD

*ECal mock-up of similar weight will be used for the first stage

Main parameters of the SPD subsystems

Subsystem	Stage	Main task	Active element	Weight, t	Power, kW	Channels, 10^3
Range System (RS)	I+II	μ-ID	mini drift tubes $Ar:CO_2$ 70 : 30	927	47	130.2
Electromagnetic Calorimeter (ECal)	II	γ detection	Pb/scint.-shashlyk	68	8	23
Time-of-Flight system (TOF)	II	PID	RPC chambers $C_2H_2F_4:C_4H_{10}:SF_6$ 90:5:5	4	4	8.8
Aerogel	II	PID	aerogel	0.1	0.5	0.3
Straw Tracker (ST)	I+II	tracking, PID	straw tubes $Ar:CO_2$ 70:30	0.2	4	30.5
Silicon Vertex Detector (SVD)						
– MAPS	II	vertex, tracking	Si pixels	< 0.1	22	12
– DSSD	II	vertex, tracking	Si strips	< 0.1	2	107.5
Micromegas-based Central Tracker (MCT)	I	tracking	gas chambers $Ar:C_4H_{10}$, 90:10	< 0.1	1	25.6
Beam-Beam Counter (BBC)						
– inner	I+II	polarimetry	MCP	$\ll 0.1$	$\ll 1$	0.1
– outer	I+II	polarimetry, timing	scint.	0.1	0.5	0.3
Zero Degree Calorimeter (ZDC)	I+II	n,γ detection	W/scint.	0.3	2	2
Magnet	I+II			20	23	
Support and transportation system	I+II			80.3		
Top platform (loaded)	I+II			40		
Side platform (loaded)	I+II			100		