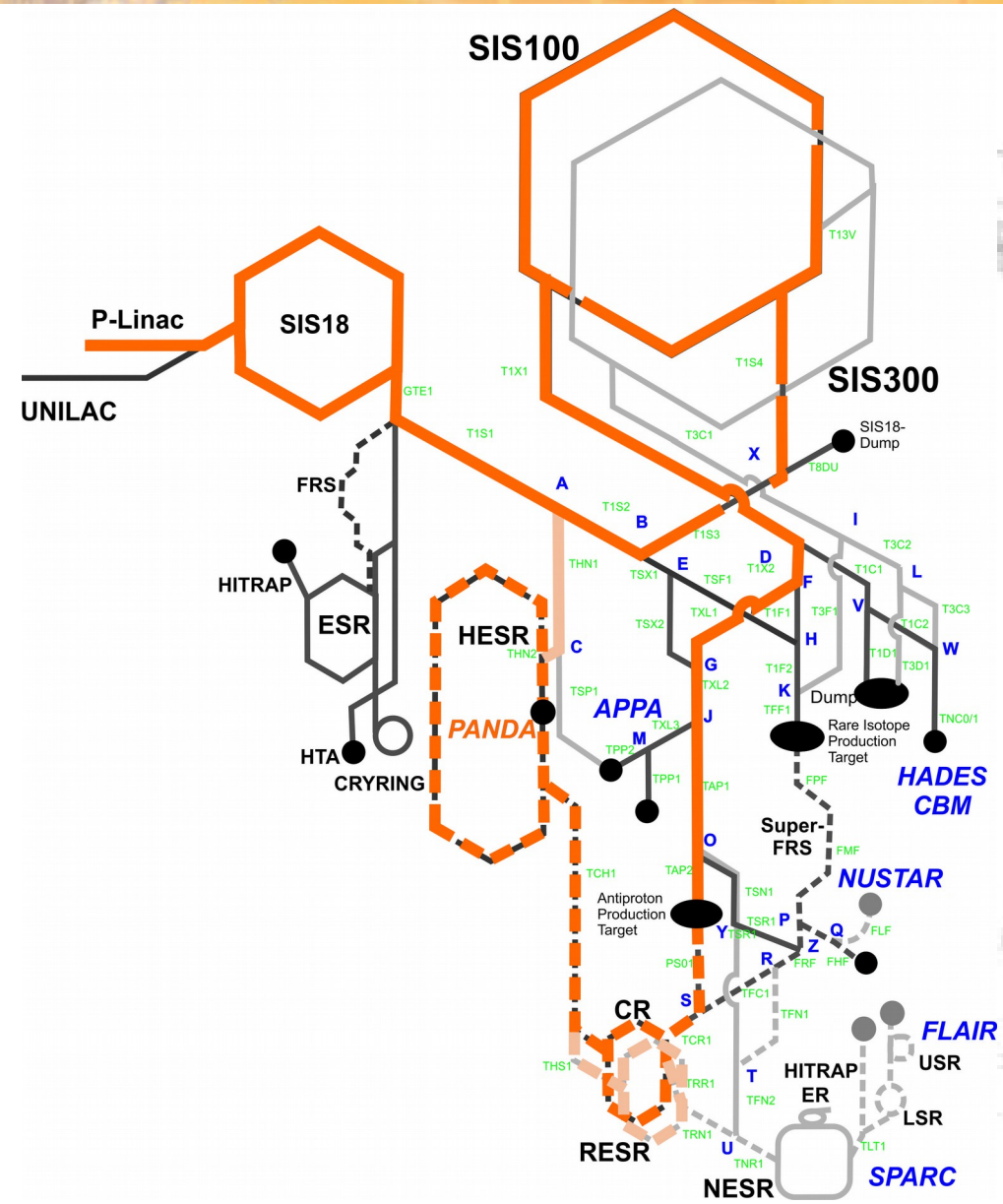
Requirements of

H4F Workshop Accelerators & Experiments, July 29, 2014

Lars Schmitt, FAIR Darmstadt

- Antiprotons at FAIR
- PANDA Physics
- System Requirements
- Summary

Antiprotons at FAIR



Antiproton production

- Proton Linac 70 MeV
- Accelerate p in SIS18 / 100
- Produce $\bar{p}$ on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA at < 2×10^{32} $cm^{-2}s^{-1}$

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity: 10^{31} $cm^{-2}s^{-1}$

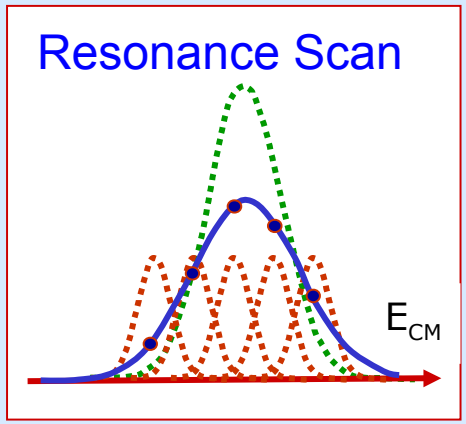
High Energy Storage Ring

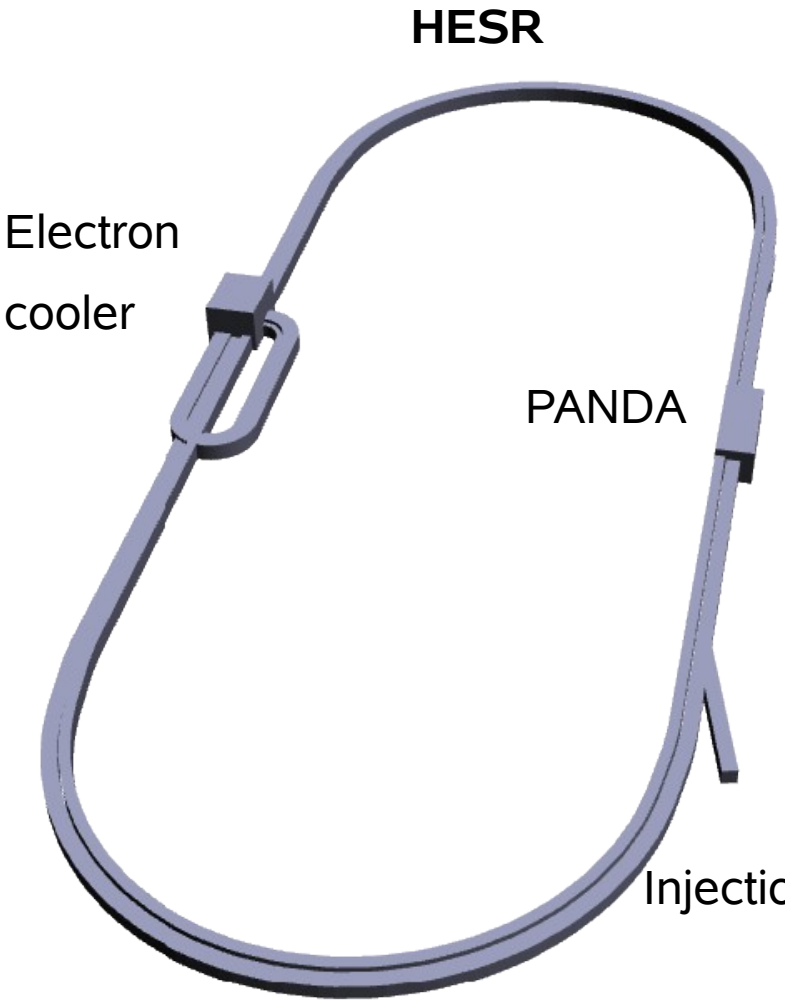
HESR Parameters

- Storage ring for internal target
- Initially also used for accumulation
- Injection of $\bar{p}$ at 3.7 GeV/c
- Slow synchrotron (1.5-15 GeV/c)
- Luminosity up to L~ $2x10^{32}$ $cm^{-2}s^{-1}$

Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim 10^{-4}$	$\sim 4x10^{-5}$
L ($cm^{-2}s^{-1}$)	$2x10^{32}$	$2x10^{31}$
Stored $\bar{p}$	10^{11}	10^{10}

- Stochastic & electron cooling
- Resolution ~50 keV
- Tune E_{CM} to probe resonance
- Get precise m and Γ





Requirements Commissioning and MSV

PANDA Experiment requirements				
Beam Parameters	High Luminosity Mode		High Resolution Mode	
	Commissioning	Operation in MSV	Commissioning	Operation in MSV
Time structure	Debunched, 20% gap			
Momentum range [GeV/c]	1.5-15		1.5-8.9	
Accumulation time Is necessary only for the MSV. [s]	1000			
Number of particles after accumulation	10^9	10^{10}	10^9	10^{10}
Reference energy [GeV]	14.1		8.0	
Energy range [GeV]	0.83-14.1		0.83-8.0	
Transverse emittance (rms) [mm rad]	1x1			
Peak Luminosity [$cm^{-2}s^{-1}$]	$2x10^{30}$	$2x10^{31}$	$2x10^{30}$	$2x10^{31}$
Momentum spread (rms)	10^{-4}		$\leq 4x10^{-5}$	
Beam spot radius (rms) [mm] at PANDA target	0.5(h) x 0.5(v)			

Requirements FAIR Phase A

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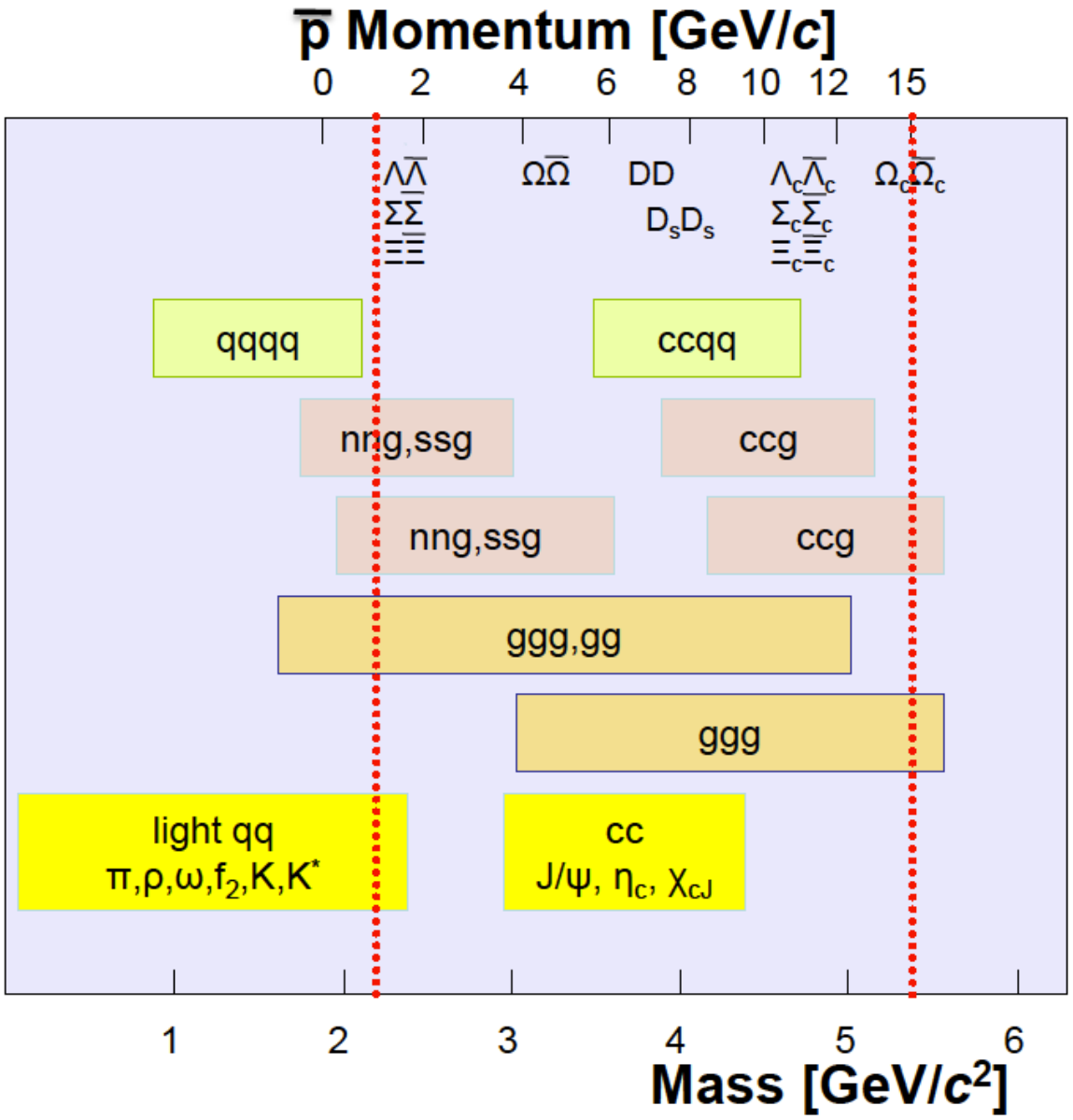
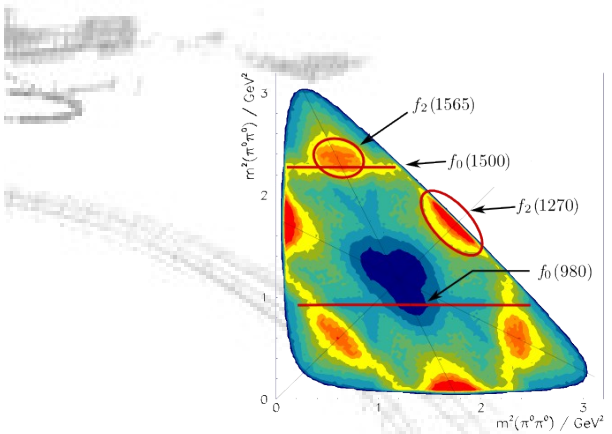
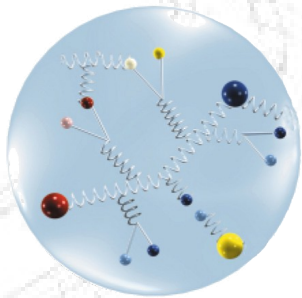
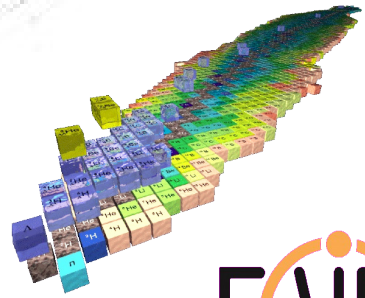
PANDA Physics Planning









Physics Goals of $\overline{\text{P}}$ANDA

Hadron Spectroscopy

Experimental Goals: *mass, width & quantum numbers J^{PC} of resonances*

Charm Hadrons: *charmonia, D-mesons, charm baryons*

➔ Understand new XYZ states, $D_s(2317)$ and others

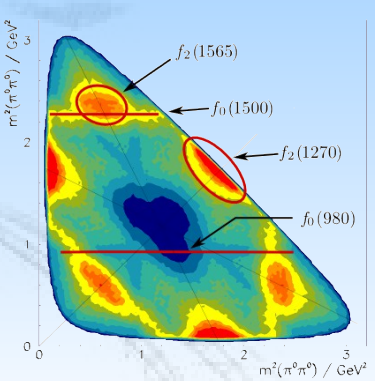
Strange hadrons: hyperon polarisation, spectroscopy

Exotic QCD States: *glueballs, hybrids, multi-quarks*

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution



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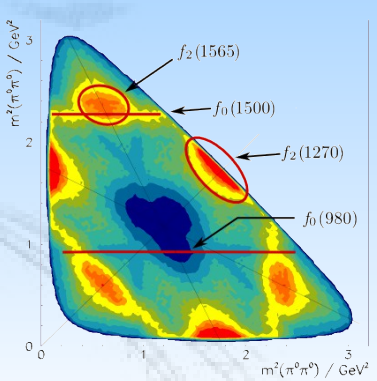


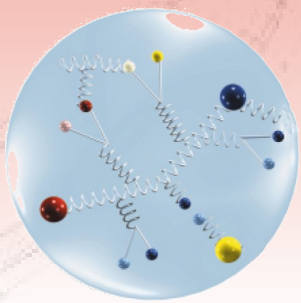
Hadron Structure

Time-like Nucleon Formfactors

➔ Measurable in annihilation, discrepancy with space-like

Generalized Parton Distributions

Drell-Yan Process



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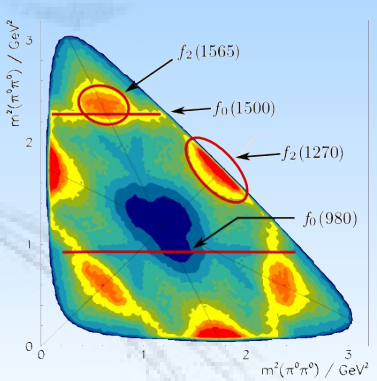

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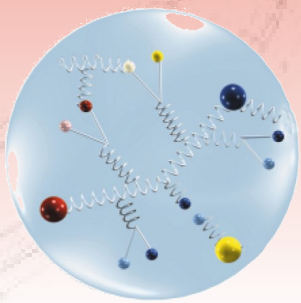
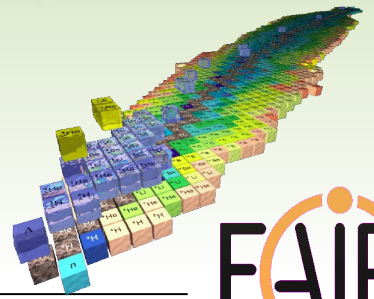


Nuclear Physics

Hypernuclei: Production of double Λ-hypernuclei

➔ γ-spectroscopy of hypernuclei, YY interaction

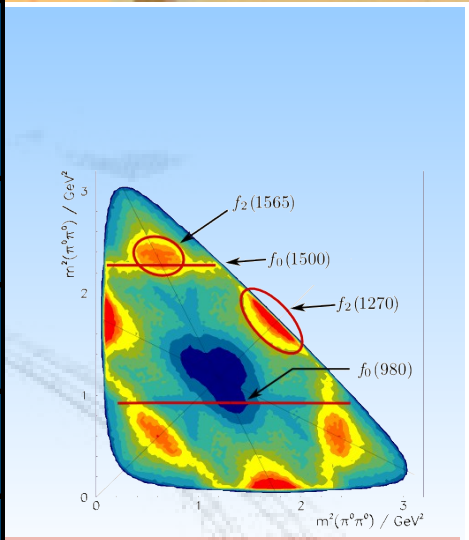
Hadrons in Nuclear Medium

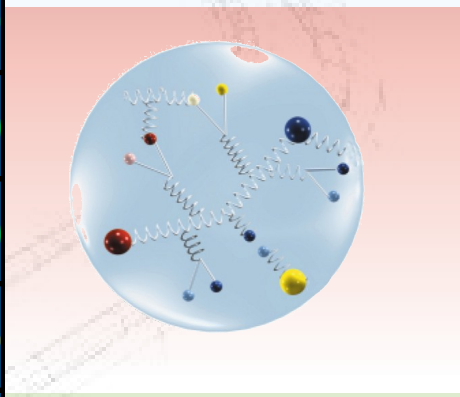


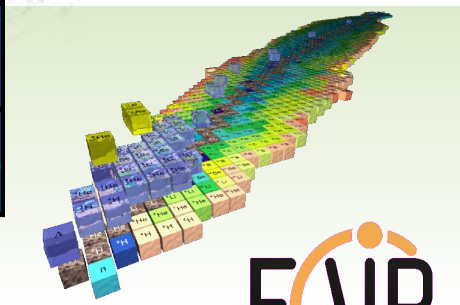
Physics Goals of $\overline{\text{P}}$ANDA

PANDA	LHCb	Belle2	BES III	JLab	J-PARC	RHIC	Compass	FAIR (MSV)
Light exotics	limited	limited	limited/excellent	excellent	limited	impossible	limited/excellent	excellent
Charm exotics	limited/excellent	limited/excellent	limited/excellent	impossible	impossible	impossible	impossible	excellent
Open charm	excellent	excellent	excellent	impossible	limited	limited	impossible	excellent
Multistrange-Baryons	limited	limited	limited	limited	limited	limited	limited	excellent
Hyperon spin physics	impossible	impossible	impossible	limited	impossible	limited	limited	excellent
Time-like form factors	impossible	limited	limited	impossible	impossible	impossible	impossible	excellent
TMDs, GPDs, TDAs	impossible	impossible	impossible	limited	impossible	limited	limited	limited
Charm in nuclei	impossible	impossible	impossible	impossible	impossible	limited	impossible	excellent
Hypernuclei	impossible	impossible	impossible	limited	excellent	limited	impossible	excellent

impossible limited excellent







Potential PANDA Run-Plan: Year 1

Part of machine development approx. 7 days @ J/ψ & ψ(2S) peaks
- calibration/commissioning

139 days based on $10^{31}cm^2s^{-1}$

30 days @ 1.64 GeV/c
- time-like form-factors
- light meson spectroscopy and $\Lambda\bar{\Lambda}$ physics

40 days @ 15 GeV/c
- survey of light and heavy exotics at max momentum (hybrids, tetraquarks)
- generic open charm production >10σ (yields and angular distributions)

14 days @ 12 GeV/c
- $\Omega\bar{\Omega}$ and $\Lambda_c\bar{\Lambda}_c$ production and dynamics, excited Ωs
- generic open and hidden charm production

25 days $\bar{p}$A @ 2 GeV/c
- $\bar{p}$ and $\bar{\Lambda}$-potentials incl. calibration (N, Ne, Ar targets)

10 days $\bar{p}$d @ 8 GeV/c
- ΔΔ content of the deuteron and feasibility studies of $\bar{p}$d for spectroscopy (d-target)

13 days @ 5.55 GeV/c
- χ_{c1} angular distribution
- excited Ξs

7 days @ 3.75 GeV/c
- Investigate Y(2175) and ΦΦ resonances, T/PS-glueball search

Potential PANDA Run-Plan: Year 2

14 days @ 3 GeV/c
- Ξ-Atoms with hypernuclear setup and Ge-Counter

7 days @ 3 GeV/c
- excited Λs

7 days @ 4.4 GeV/c
- $\Xi\bar{\Xi}$ production and dynamics

36 days @ 5.73 GeV/c
- χ_{c2} angular distribution

80 days @ 6.99++ GeV/c
- X(3872) width scan

144 days based on $10^{31}cm^2s^{-1}$

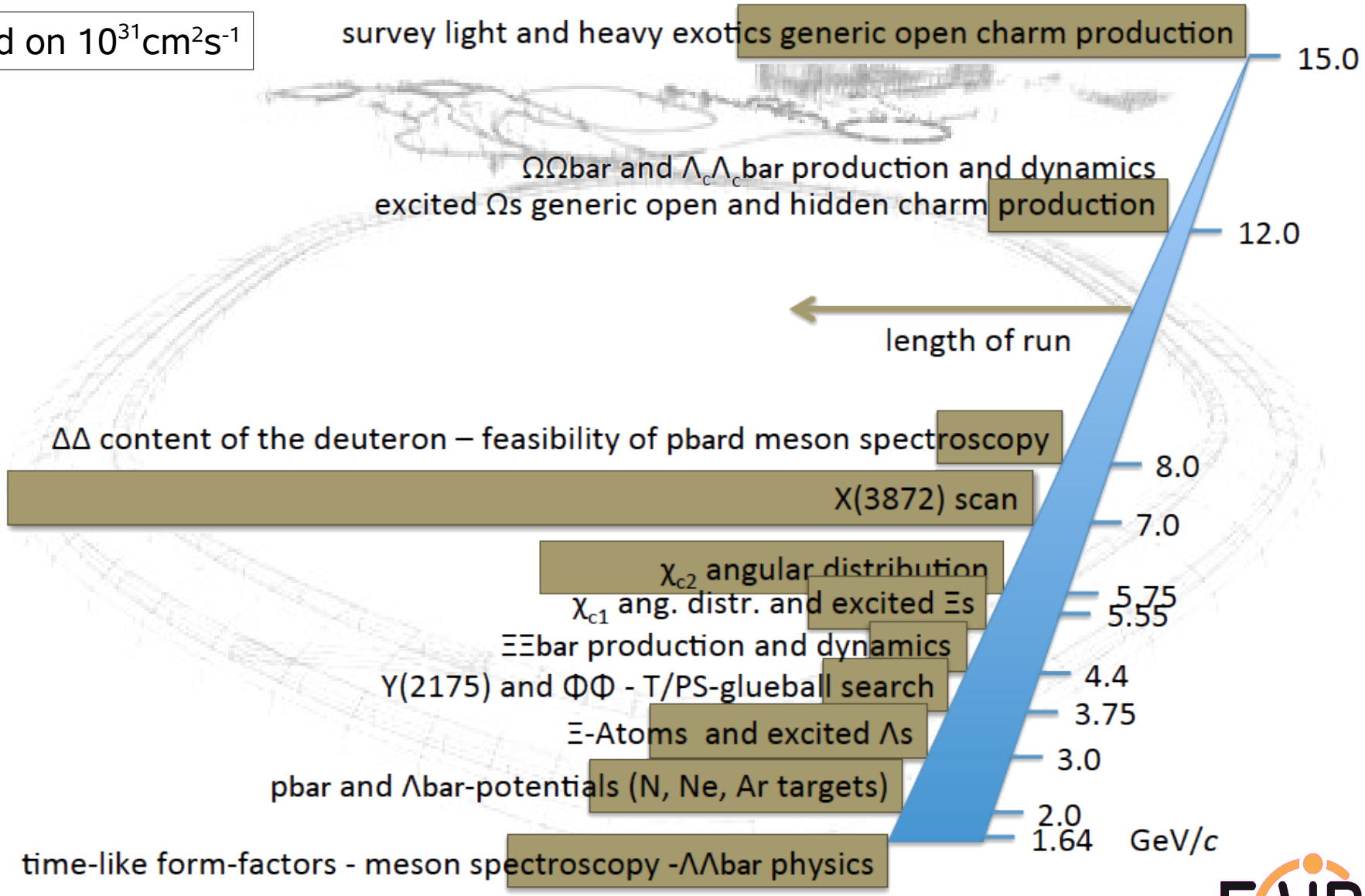
Other options depending on PANDA results and the development of the field until start of operation:

60 days – 5.61 GeV/c
- h_c width

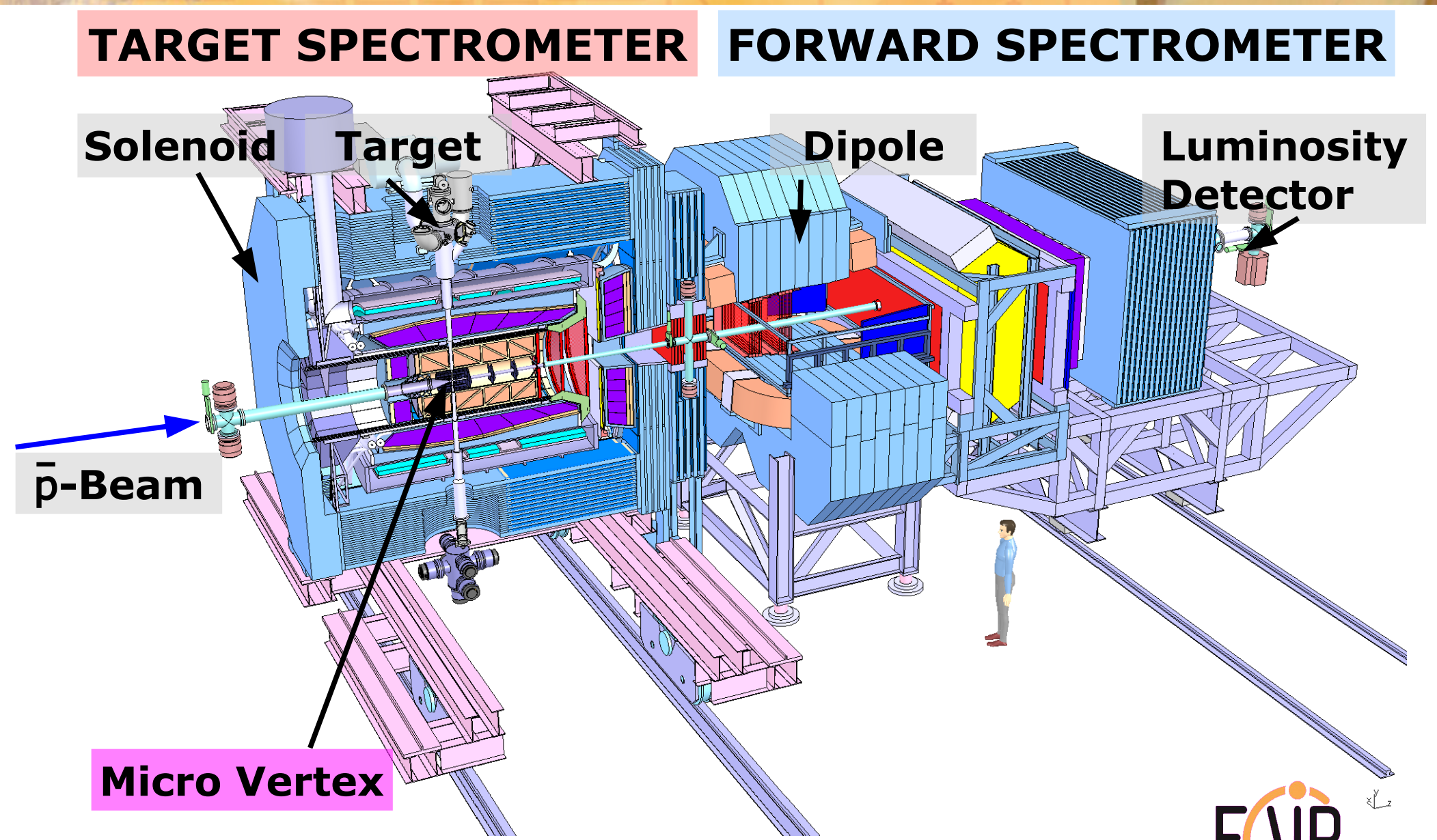
30-80 days on various momenta
- detailed scans of potentially interesting signals

Potential PANDA Run-Plan: first 2 years

Based on $10^{31}cm^2s^{-1}$



PANDA Spectrometer



PANDA Construction Schedule

Subsystem		2015				2016				2017				2018				2019				2020		
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Dipole							O	M7/8																
Forward TOF						M4/7																		
Forward Shashlyk Calorimeter							M7/8																	
Forward Range System						O																		
Luminosity Detector																								
Supports																								
Supplies																								
Controls									O															
Computing																								
DAQ					O					O														
Solenoid					O	Conductor production		O	Conductor production		O	Conductor	M8/9											
Cluster Jet Target				O																				
TS Barrel Muon Detectors						O																		
TS Endcap Muon Detectors						O																		
Muon Filter						O																		
Forward Tracking							M4/7																	
Barrel EMC						O	Crystal production																	
Pellet Target									O		M8/10													
Barrel DIRC							M3/7/8																	
Barrel Time of Flight (TOF)										O														
Interaction Region																								
Micro Vertex Detector (MVD)									M4/8															
Straw Tube Tracker (STT)		O																						
Backward Endcap EMC	M3/7	O																						
Planar GEM Trackers										O														
Forward Endcap EMC	M3/8							M9/10																
Endcap Disc DIRC				O										O										
Hypernuclei Primary Target									O															
Hypernuclei Germanium Detector									O															
Hypernuclei Secondary Active Target												O												
Silicon Lambda Disks																								
Forward RICH																								

R&D, **M3:** TDR approved
Tendering, Contract Preparation, **M4:** Contracts signed
Construction design, **M7:** Planning completed
Prototype/Pre-series construction, **M8:** Prototype/Pre-series testing complete, production readiness
Component construction & testing, Module assembly & testing, **M9:** Acceptance test completed
Pre-assembly, off-site testing, Transport to FAIR, site-acceptance tests, **M10:** Ready for installation
O Funding Milestone

Subject to change due to funding

PANDA Installation Schedule

Subsystem	20XX				20XX+1			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Dipole								
Forward TOF								
Forward Shashlyk Calorimeter								
Forward Range System								
Luminosity Detector								
Supports								
Supplies								
Controls								
Computing								
DAQ								
Solenoid								
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TS Barrel Muon Detectors								
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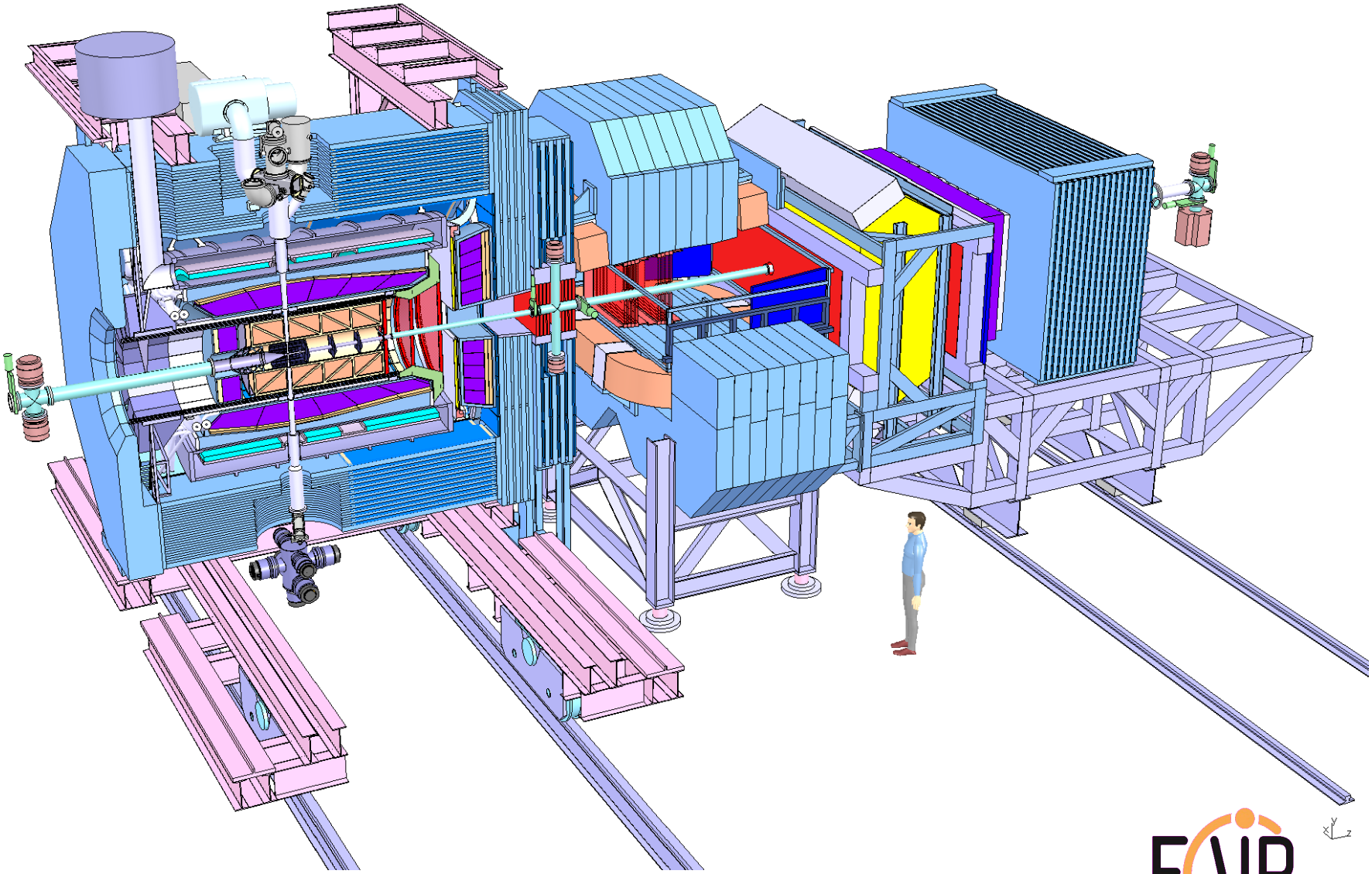
Hypernuclei Primary Target								
Hypernuclei Germanium Detector								
Hypernuclei Secondary Active Target								
Silicon Lambda Disks								
Forward RICH								

Pre-assembly, off-site testing, Transport to FAIR, site-acceptance tests, **M10:** Approval for installation
Installation at FAIR, commissioning without beam, **M11:** Ready for beam
Commissioning with beam, **M12:** Ready for operations
Magnet field mapping

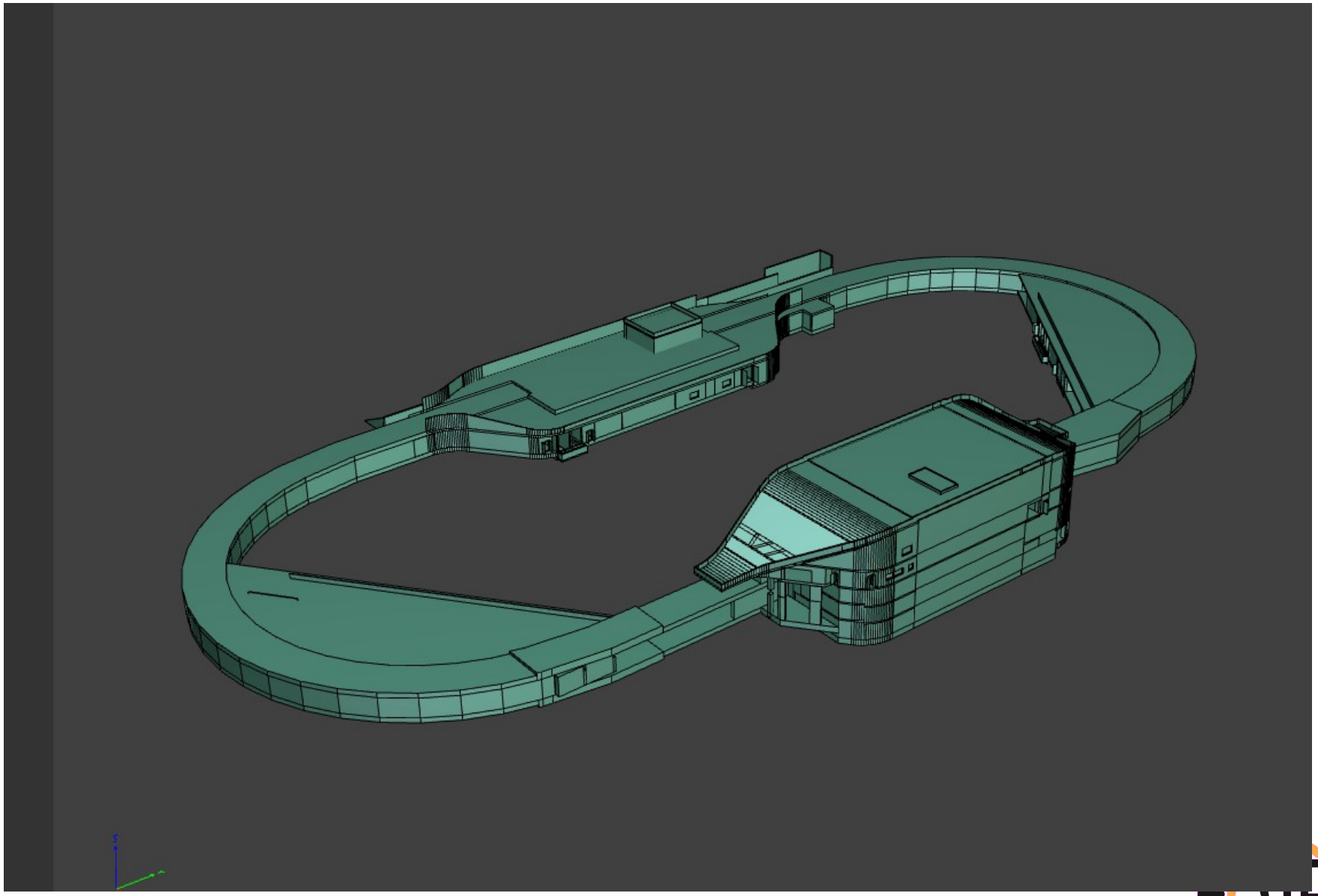
Assumptions:

- CC delayed
- Start of installation once hall available
- Dipole first: HESR
- TS and FS separate
- FS: from upstream towards downstream
- TS sequence:
  - Solenoid
  - Barrel EMC
  - Inner systems
  - Endcap

Systems with Requirements



PANDA at HESR



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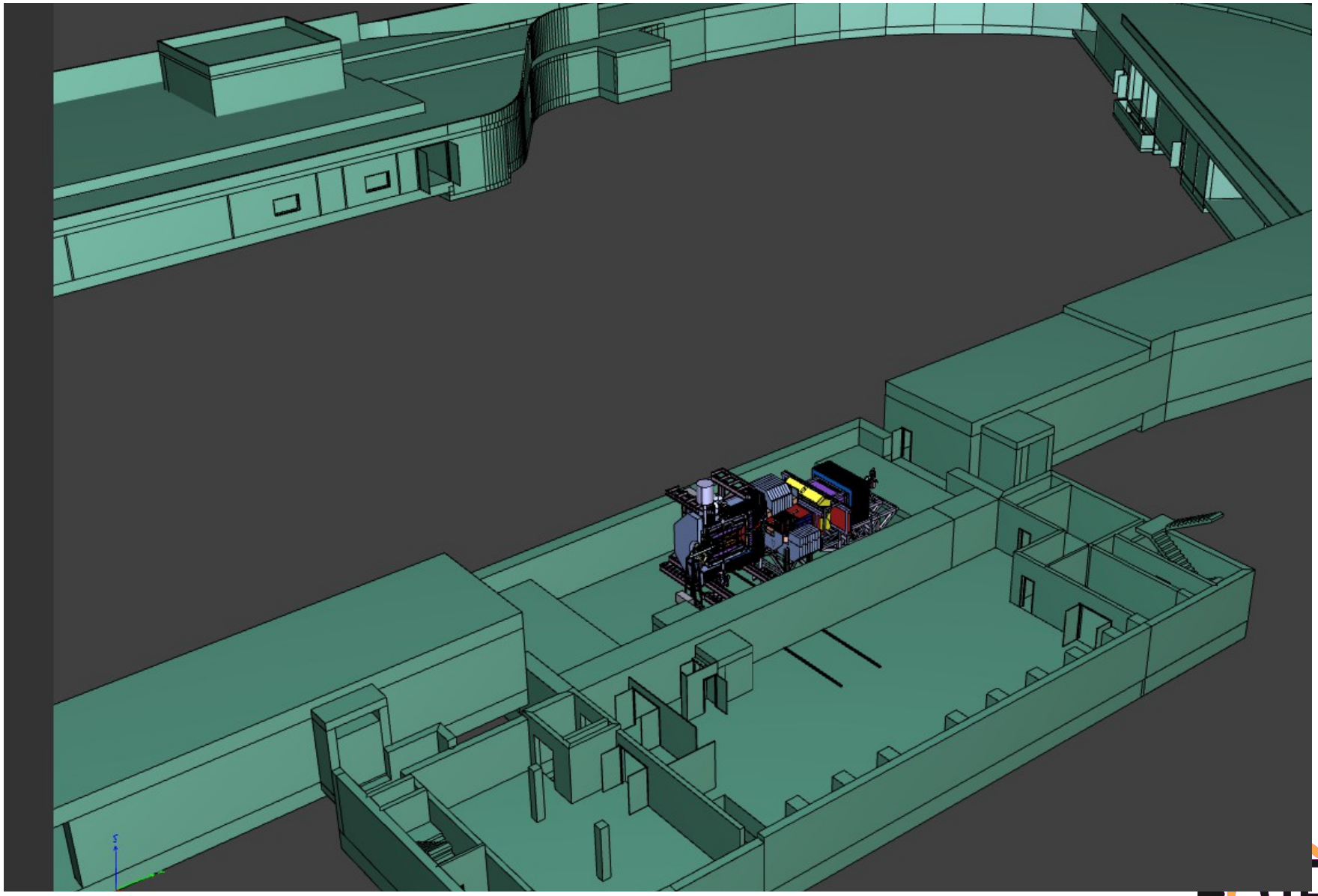
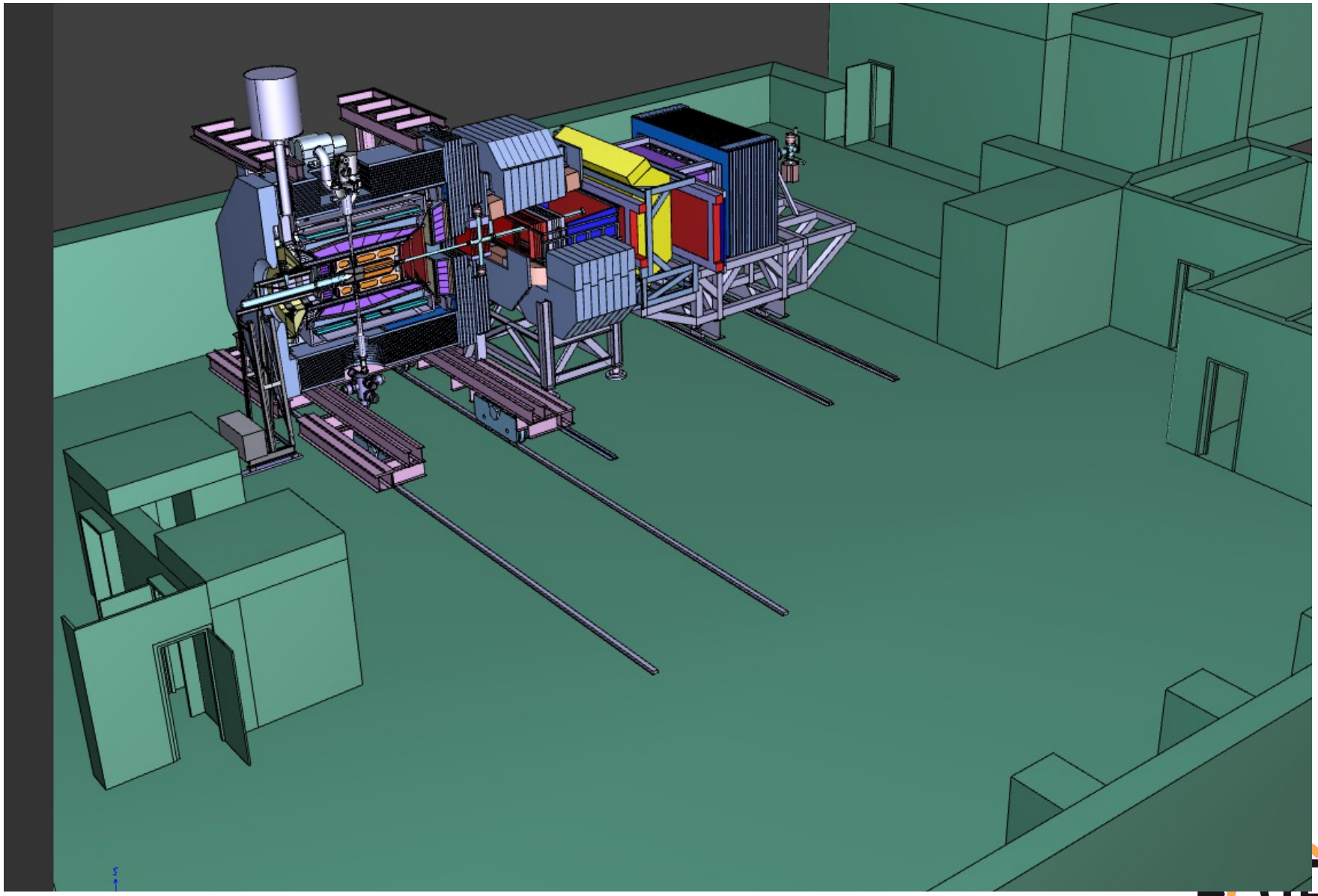


PANDA at HESR



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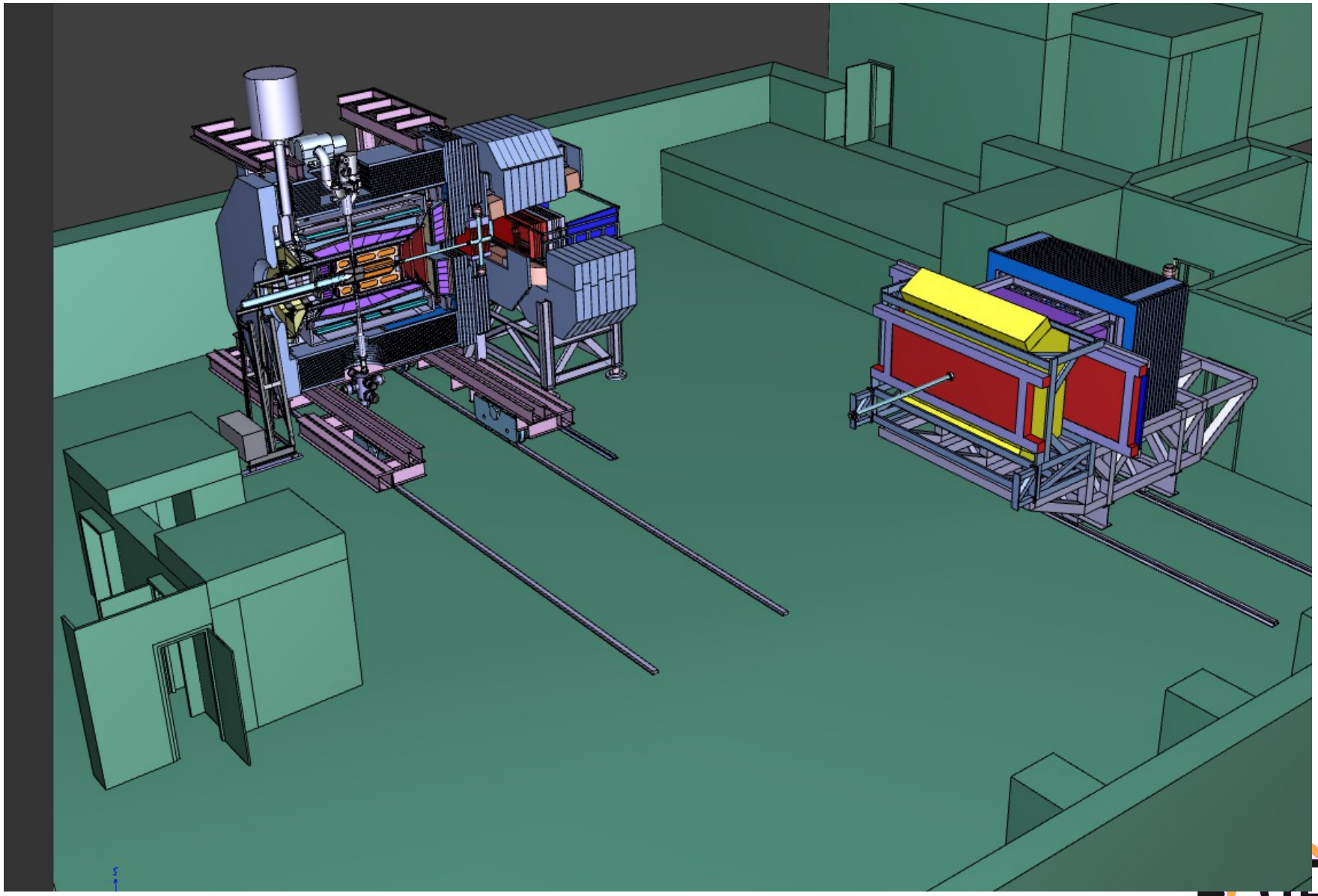

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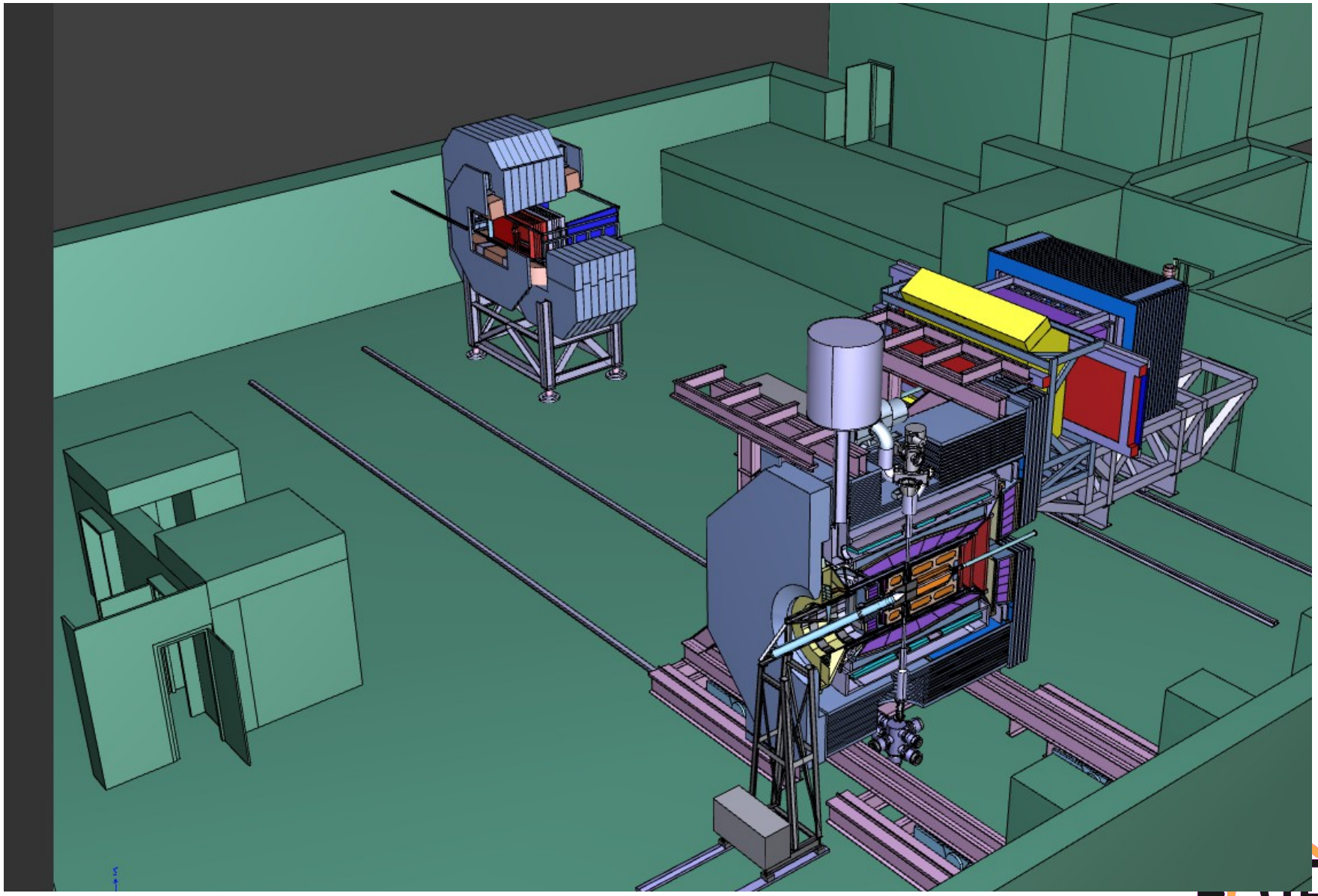


PANDA Target

Luminosity Considerations

- Goal: 2×10^{32} cm^{-2}s^{-1} (HL mode)
- With 10^{11} stored $\bar{p}$ and 50 mb: 4×10^{15} cm^{-2} target density

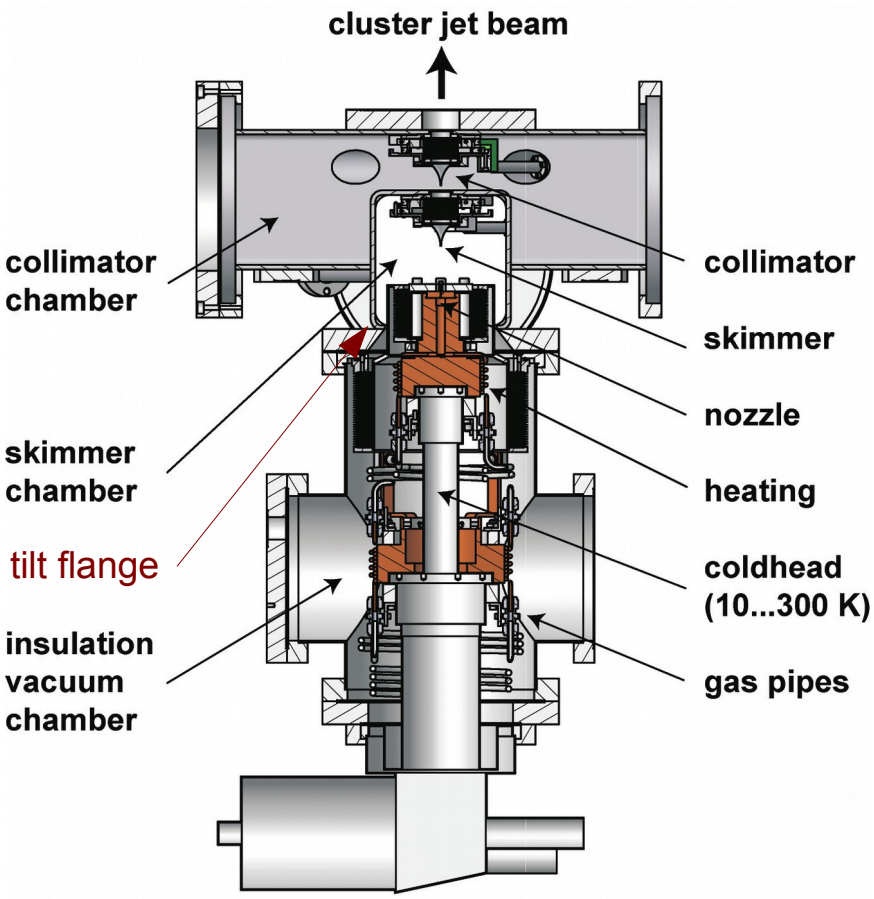
Cluster Jet Target

- Continuous development
  - Nozzle improvement
  - Better alignment by tilt device
  - Record 2×10^{15} cm^{-2} reached
- TDR approved

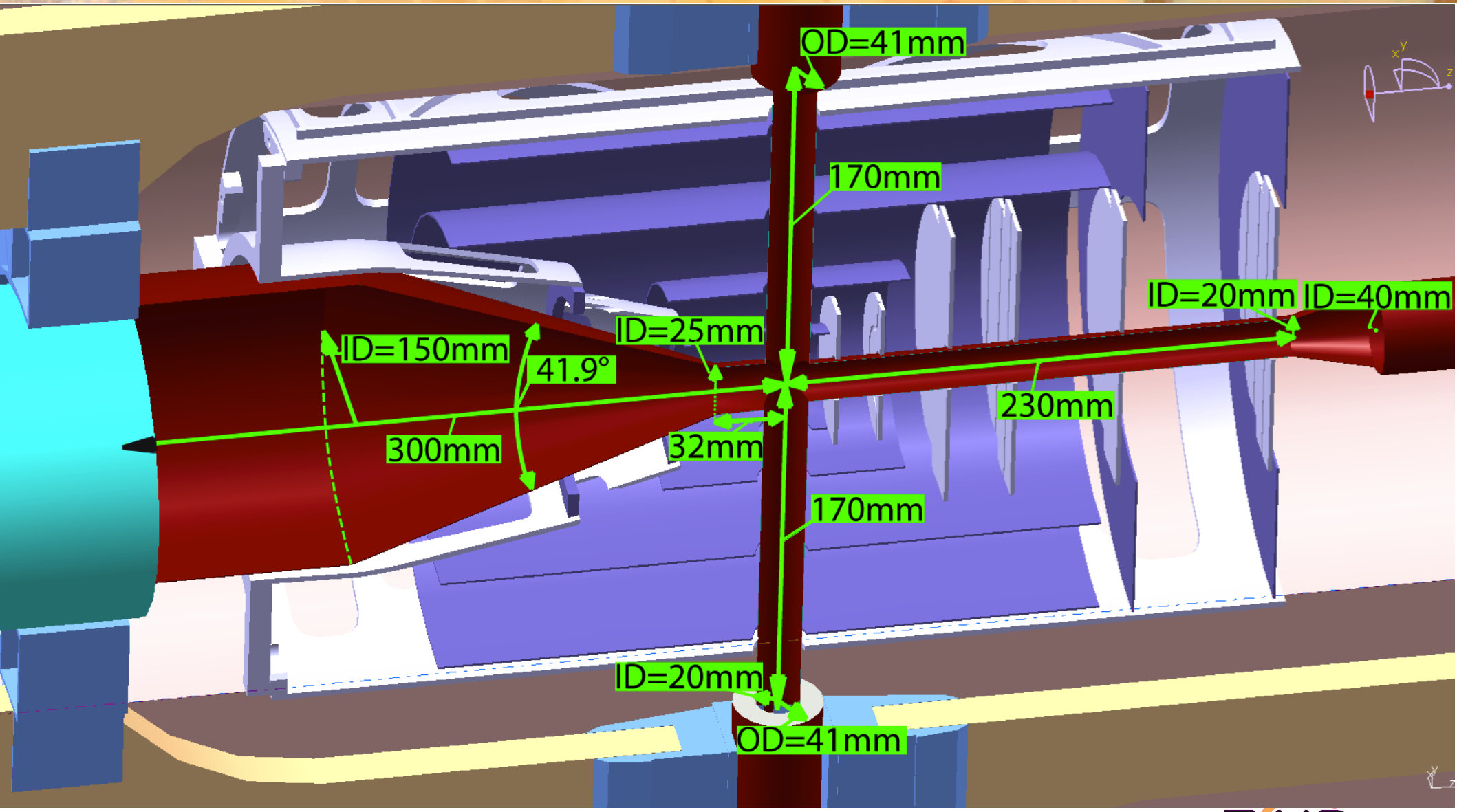
Pellet Target

- $>4 \times 10^{15}$ cm^{-2} feasible
- Prototype under way
- Pellet tracking prototype
- Second TDR part 2015/16

Latest version of the cluster jet target

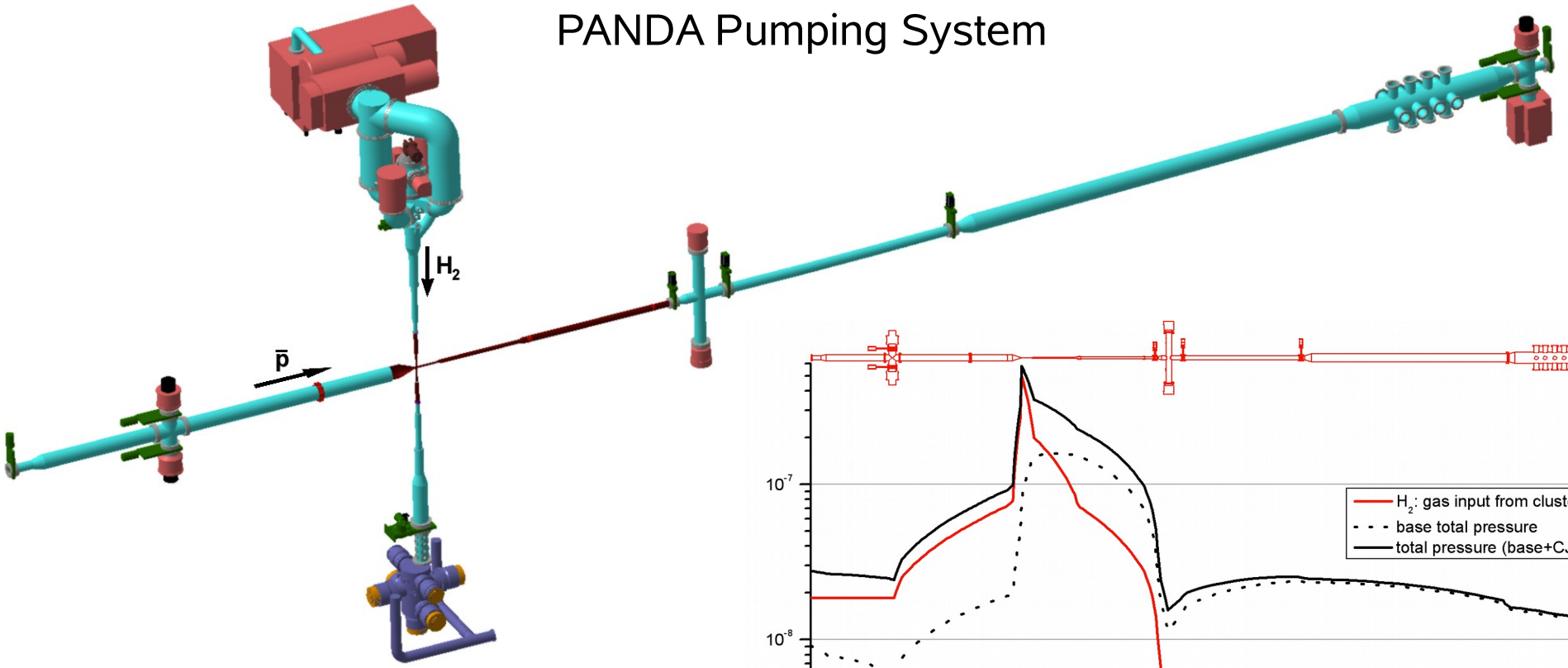


PANDA IP


OD=41mm
170mm
ID=20mm
ID=40mm
ID=25mm
ID=150mm
41.9°
230mm
300mm
32mm
170mm
ID=20mm
OD=41mm

PANDA Vacuum

PANDA Pumping System



Pressure profile with cluster target

Main issue: ion trapping of $\bar{p}$

Need cryo pump or getter electrode

More material

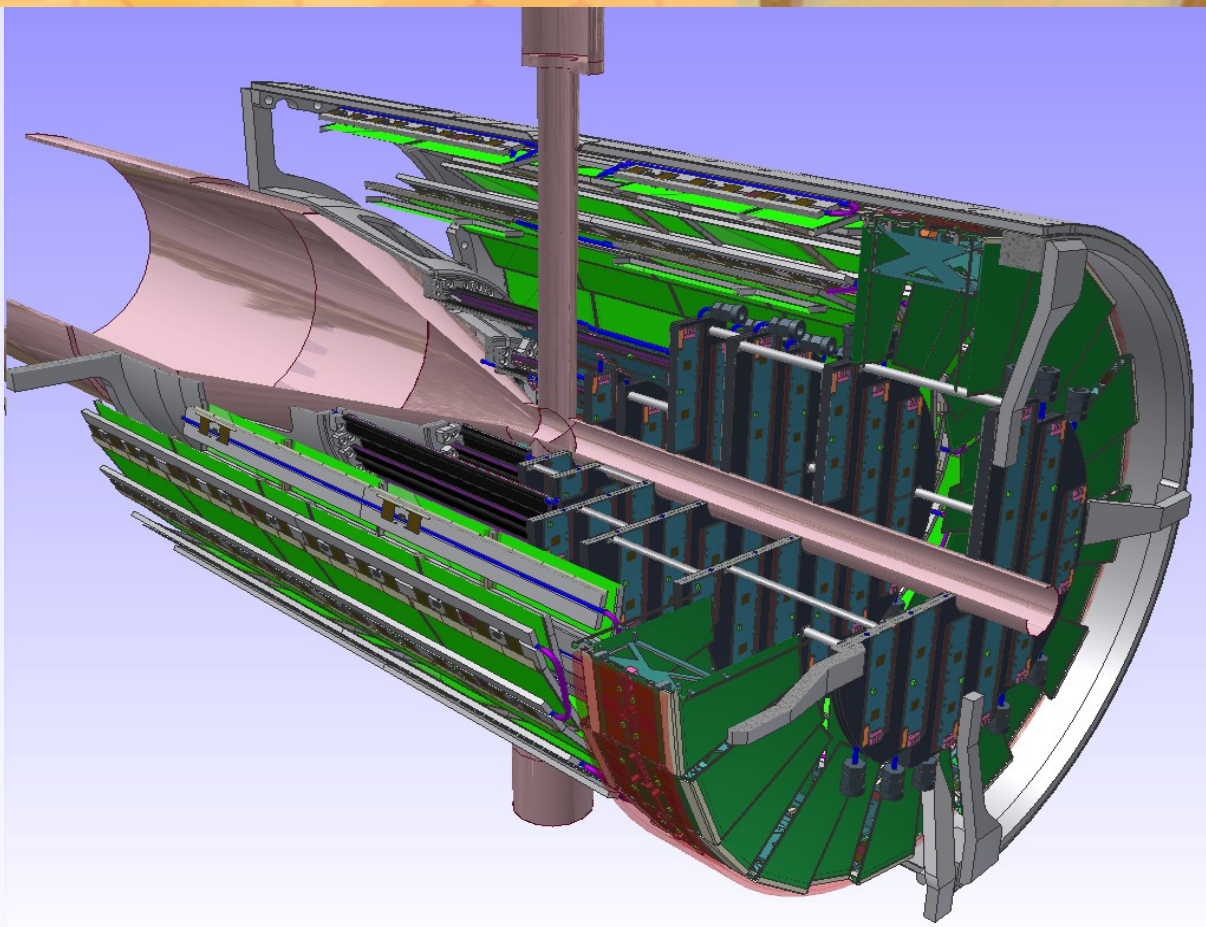
Micro Vertex Detector

Design of the MVD

- 4 barrels and 6 disks
- Continuous readout
- *Inner layers*: hybrid pixels (100x100 μm^2)
  - *ToPiX* chip, 0.13µm CMOS
  - Thinned sensor wafers
- *Outer layers*: double sided strips
  - Rectangles & trapezoids
  - 64 ch ASIC *PASTA*
- Mixed forward disks (pixel/strips)

Challenges

- Low mass supports
- Cooling in a small volume
- Radiation tolerance

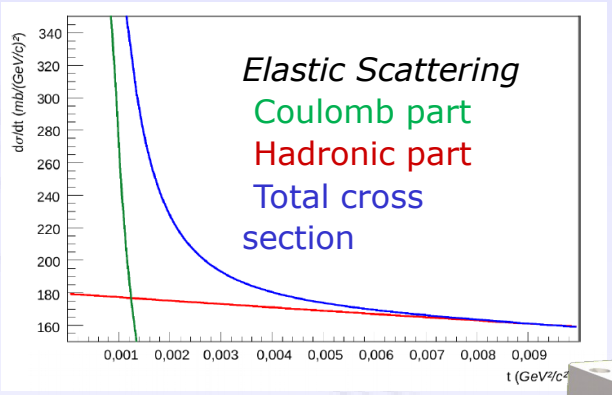


- Detector closest to IP
- HESR commisioning without MVD
- HESR ion operation without MVD

Luminosity Detector

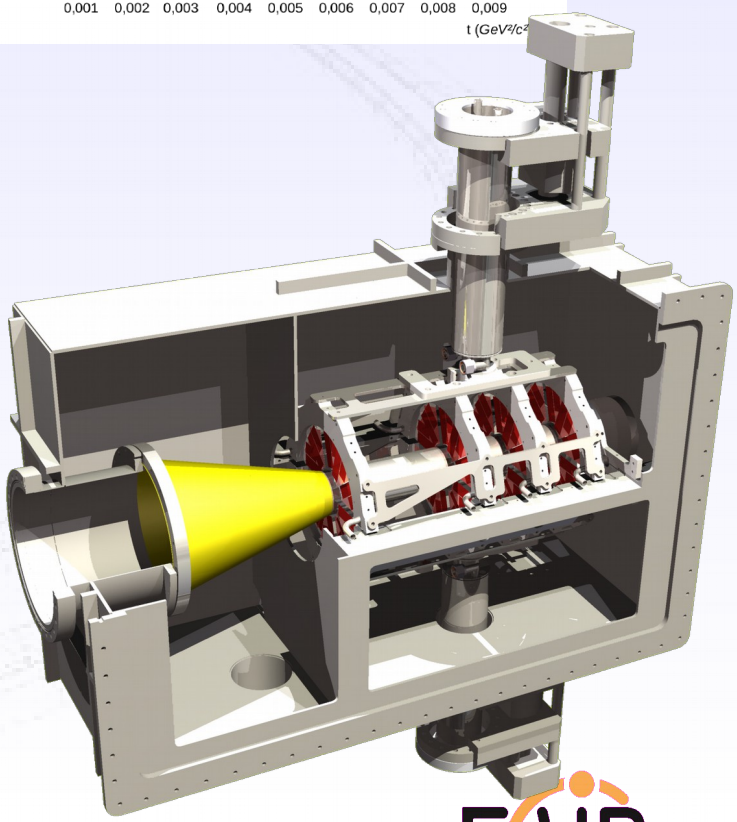
Elastic scattering:

- Coulomb part calculable
- Scattering of $\bar{p}$ at low t
- Precision tracking of scattered $\bar{p}$
- Acceptance 3-8 mrad



Detector layout:

- Roman pot system at z=11 m
- Silicon pixel detector:
  - 4 layers of HV MAPS (50 µm thick)
  - pixels 80x80 µm²
- CVD diamond supports (200 µm)
- Retractable half planes in secondary vacuum



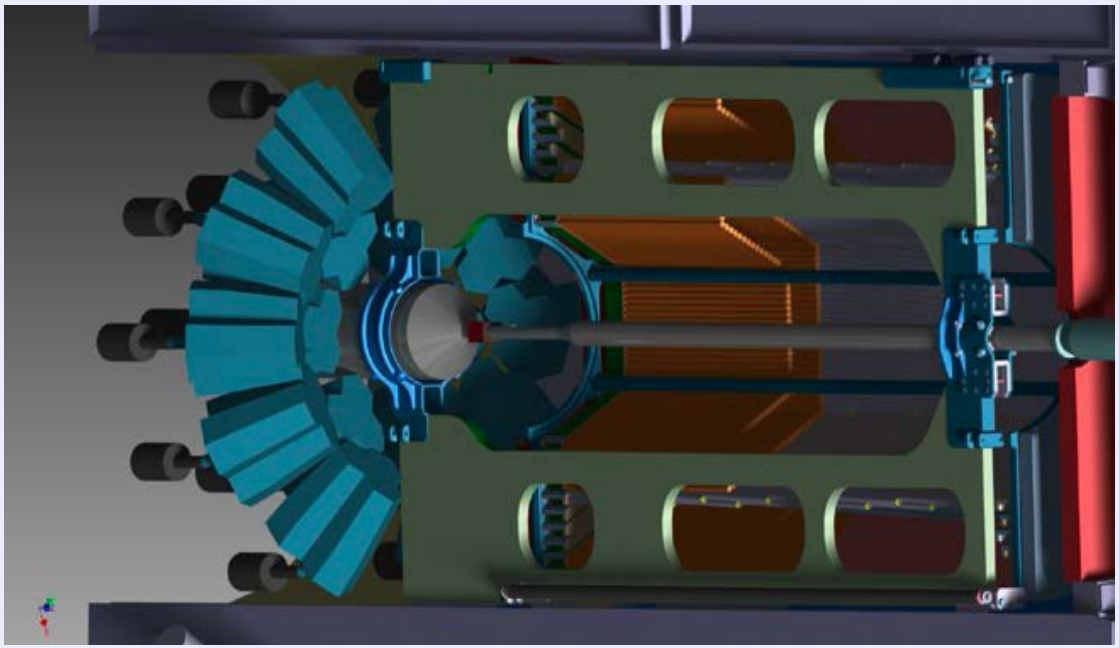
Hypernuclear Setup

Principle:

- Produce hypernuclei from captured Ξ

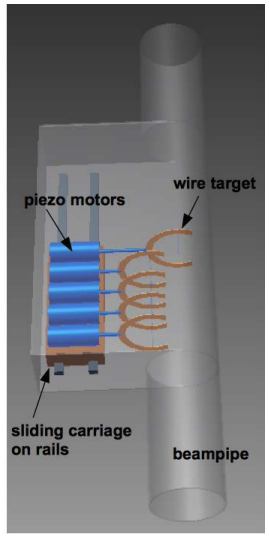
Modified Setup:

- Primary retractable wire/foil target
- Secondary active target to capture Ξ and track products with Si strips
- HP Ge detector for γ-spectroscopy



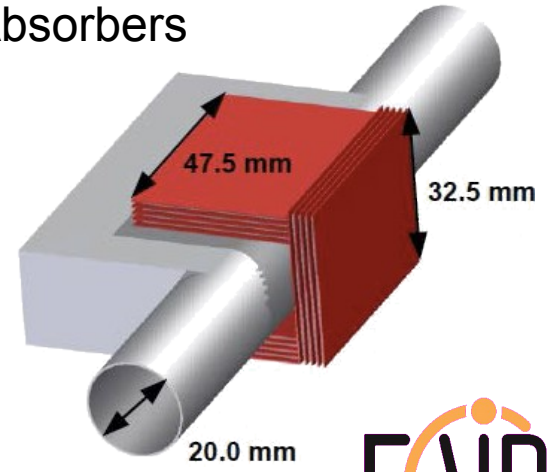
Primary Target:

- Diamond wire
- Piezo motored wire holder



Active Secondary Target:

- Silicon microstrips
- Absorbers

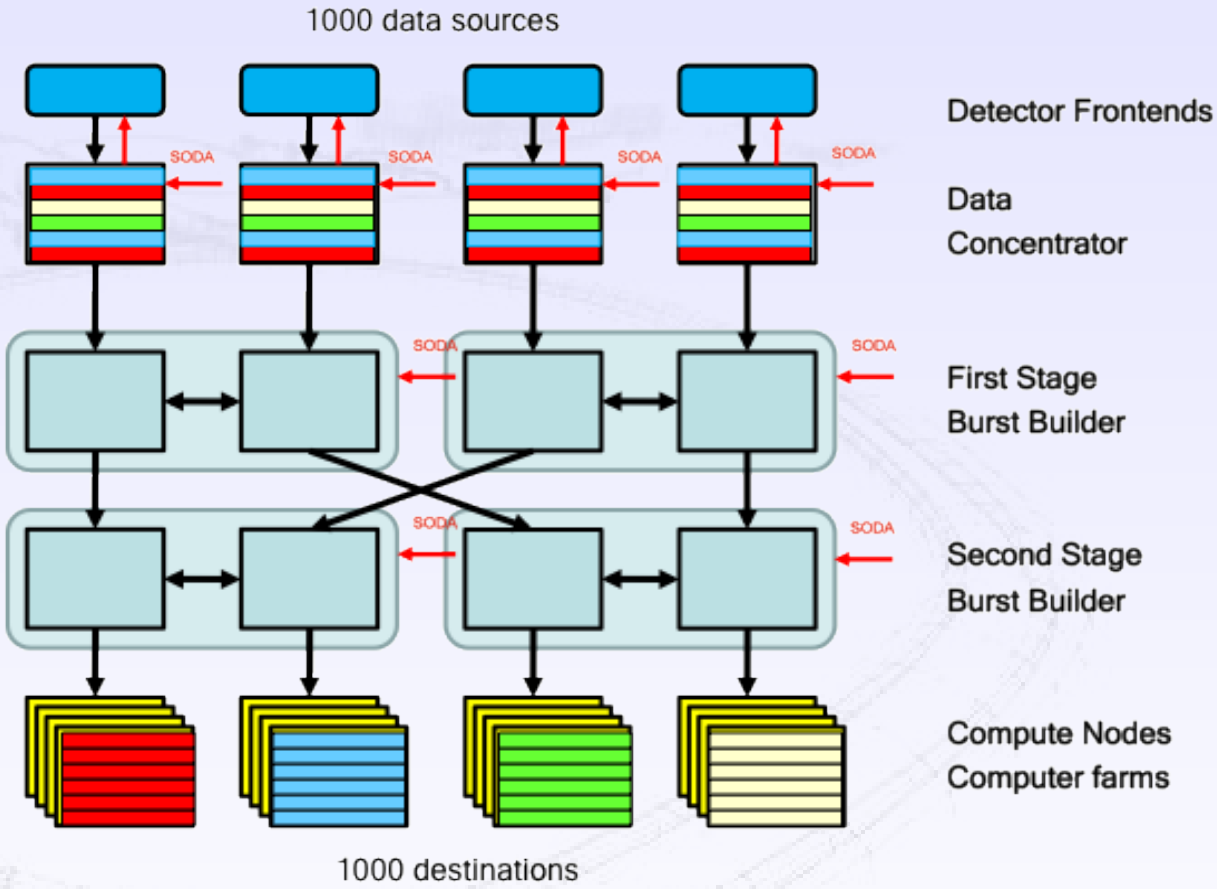


PANDA Data Acquisition

Self triggered readout

- Components:
  - Time distribution system
  - Intelligent frontends
  - Powerful compute nodes
  - High speed network
- Data Flow:
  - Data reduction
  - Local feature extraction
  - Data burst building
  - Event selection
  - Data logging after online reconstruction

➔ **Programmable Physics Machine**



- HESR bucket barrier: 20% gap in beam
  ➔ burst structure of 2 µs + 400 ns break
- Super bursts: 16 bursts forming data chunks

Summary

Luminosity requirements

- 10^{30} $cm^{-2}s^{-1}$ for commissioning
- 10^{9} stored $\bar{p}$
- 10^{31} $cm^{-2}s^{-1}$ for physics in MSV
- 10^{10} stored $\bar{p}$
- 10^{32} $cm^{-2}s^{-1}$ for physics in full Phase A
- 10^{11} stored $\bar{p}$

Setup constraints

- Cluster jet target with high impact on vacuum
- Other targets: hypernuclear wire target, pellet target
- MVD closest to IP: damage by badly tuned beam or beam loss
- PANDA detectors roll out for maintenance and ion operation
- Luminosity detector in roman pot, 3-8 mrad acceptance
- 20% gap for barrier bucket used for data bunching