Overview of PANDA

H4F Workshop Accelerators & Experiments, July 29, 2014

Lars Schmitt, FAIR Darmstadt

- Antiprotons at FAIR
- PANDA Overview
- PANDA Systems
- TDR Schedule and Conclusions

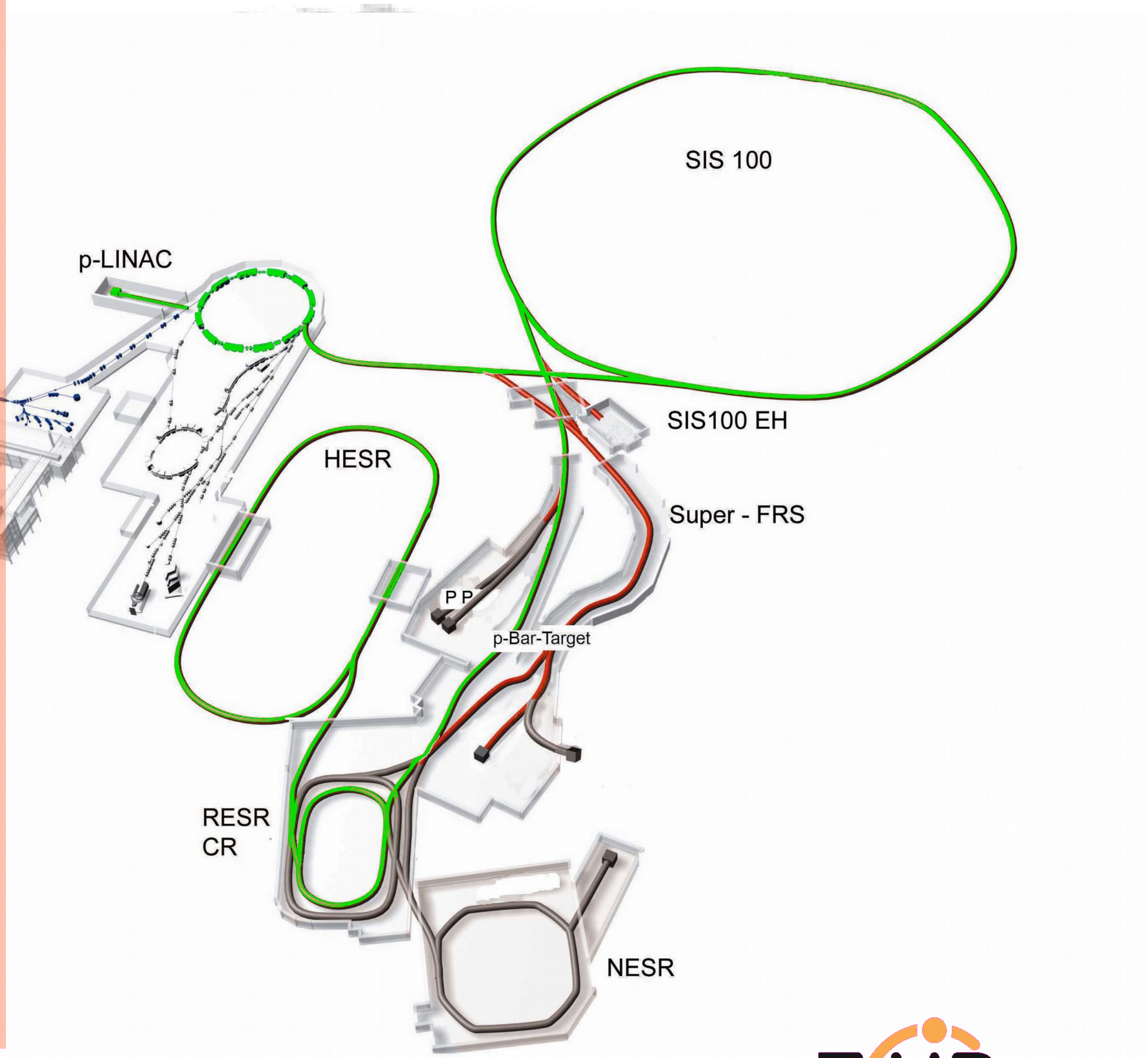
Antiprotons at FAIR

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} $cm^{-2}s^{-1}$



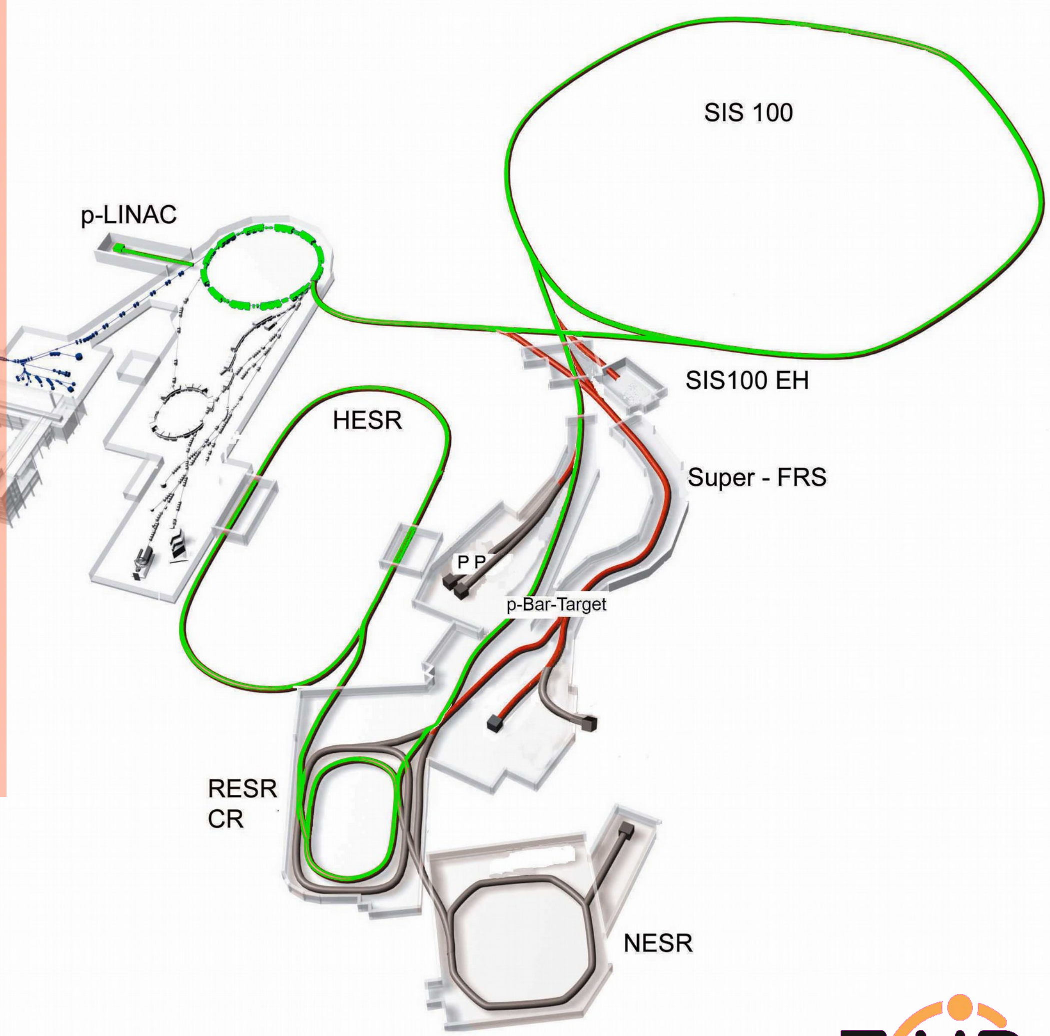
Antiprotons at FAIR

Antiprotons are unique:

- New dimension at FAIR wrt GSI
- Hadron physics bridges nuclear and HI physics to basic QCD
- No other $\bar{p}$ facility worldwide
- Successful predecessors have demonstrated the large potential

Unique precision at HESR:

- Beam cooling
  - ➔ $\Delta E \sim 50$ keV
  - ➔ Tune E_{CM} to scan
- Annihilation at threshold



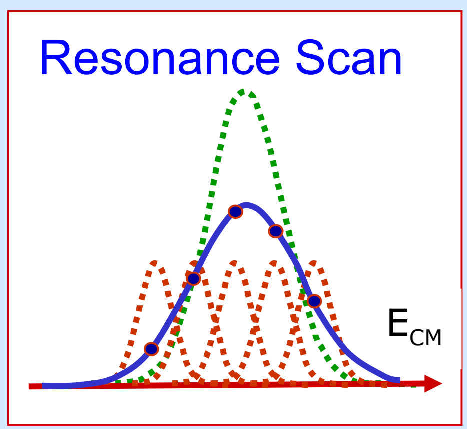
High Energy Storage Ring

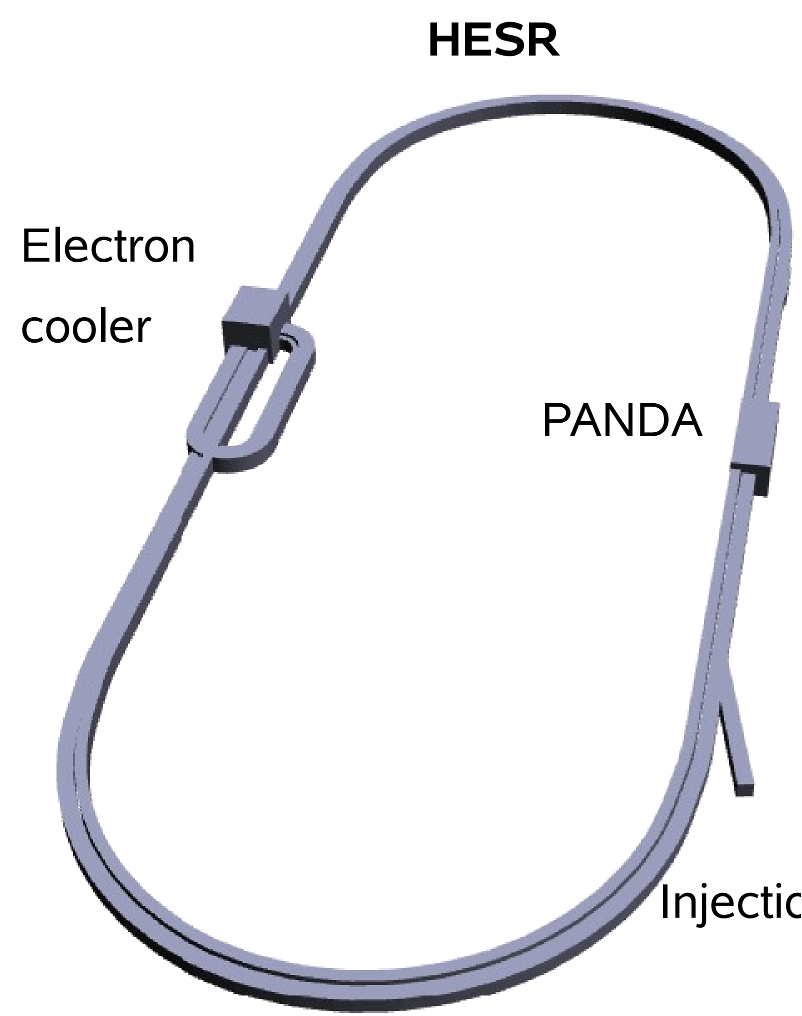
HESR Parameters

- 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~ 2×10^{32} $cm^{-2}s^{-1}$

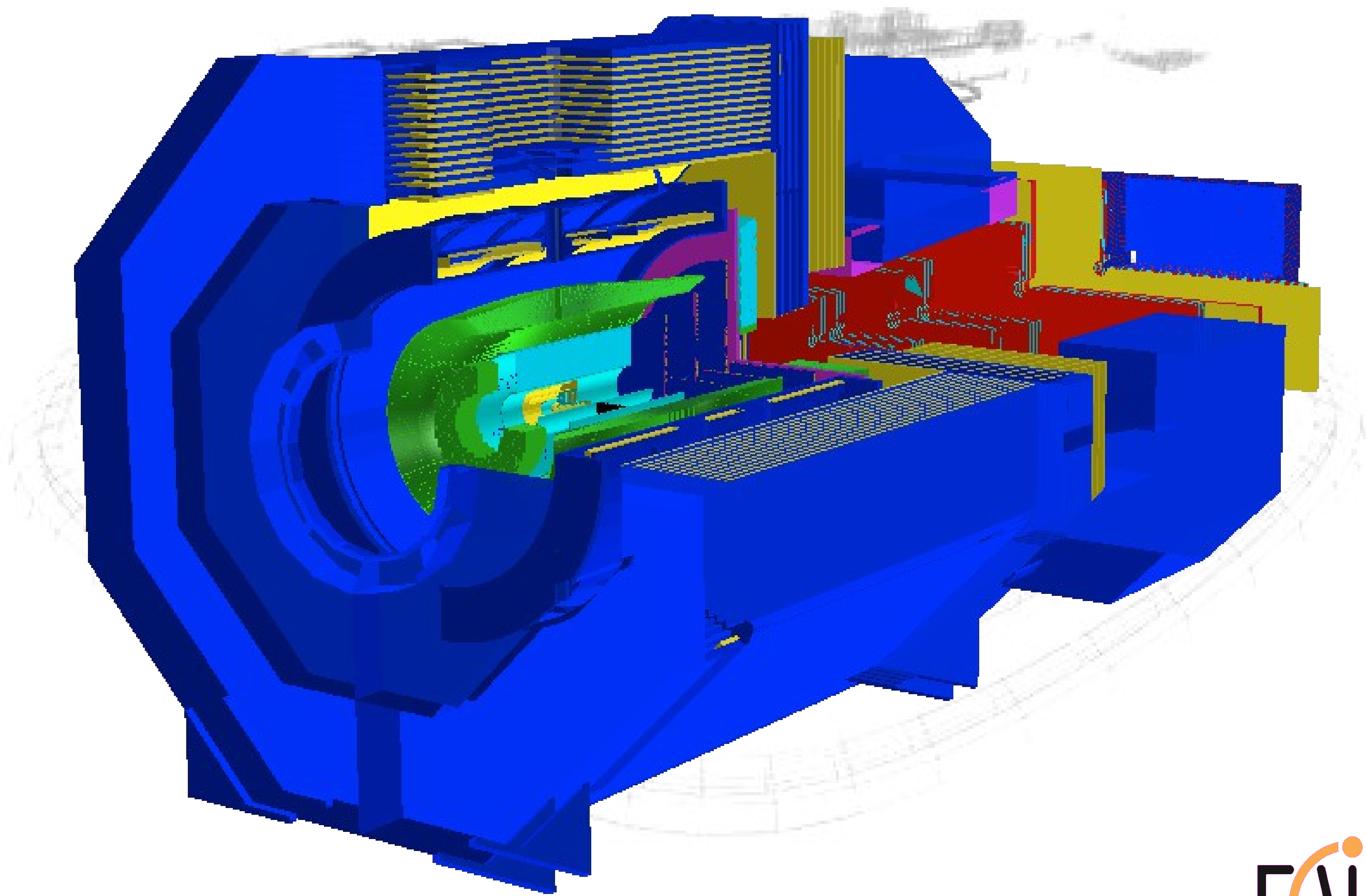
Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim10^{-4}$	$\sim4\times10^{-5}$
L ($cm^{-2}s^{-1}$)	2×10^{32}	2×10^{31}
Stored $\bar{p}$	10^{11}	10^{10}

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





PANDA Overview



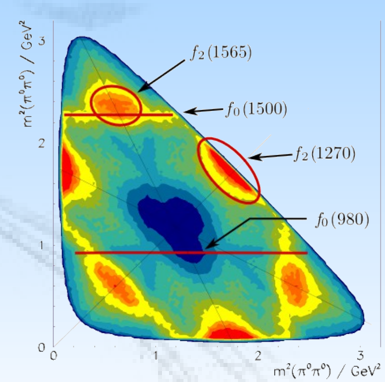
Physics Goals of $\overline{\text{P}}$ANDA

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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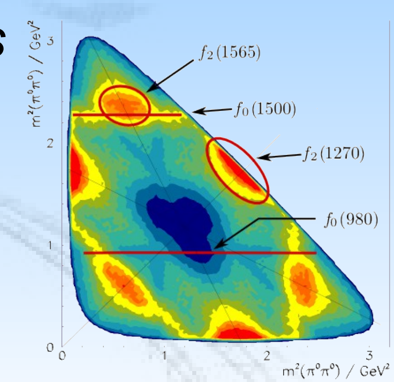


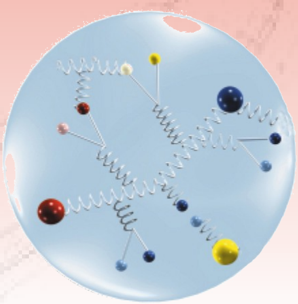
Hadron Structure

Time-like Nucleon Formfactors

➔ Measurable in annihilation, discrepancy with space-like

Generalized Parton Distributions

Drell-Yan Process



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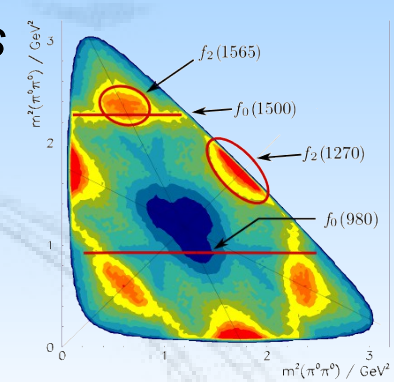

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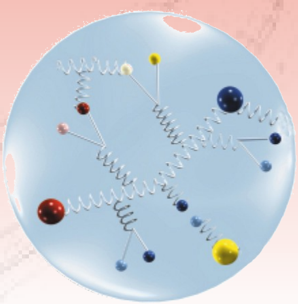
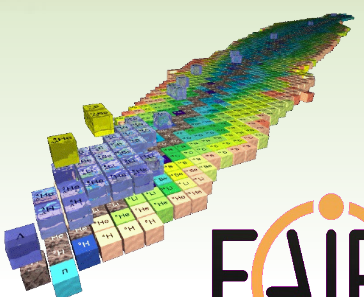


Nuclear Physics

Hypernuclei: Production of double Λ-hypernuclei

→ γ-spectroscopy of hypernuclei, YY interaction

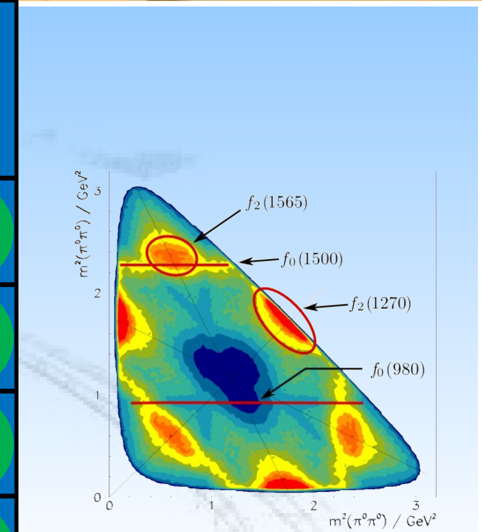
Hadrons in Nuclear Medium

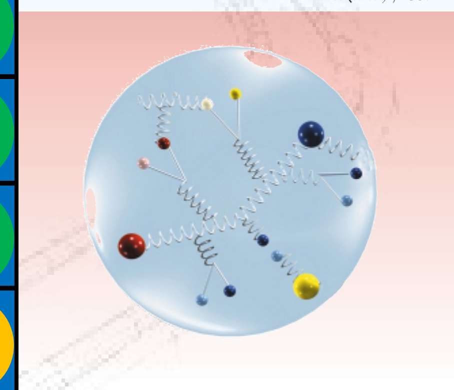


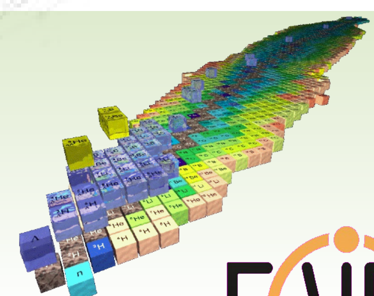
Physics Goals of $\overline{\mathrm{P}}$ANDA

PANDA	LHCb	Belle2	BES III	JLab	J-PARC	RHIC	Compass	FAIR (MSV)
Light exotics	limited	limited	excellent (hatched)	excellent	limited	impossible	excellent (hatched)	excellent
Charm exotics	excellent (hatched)	excellent (hatched)	excellent (hatched)	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

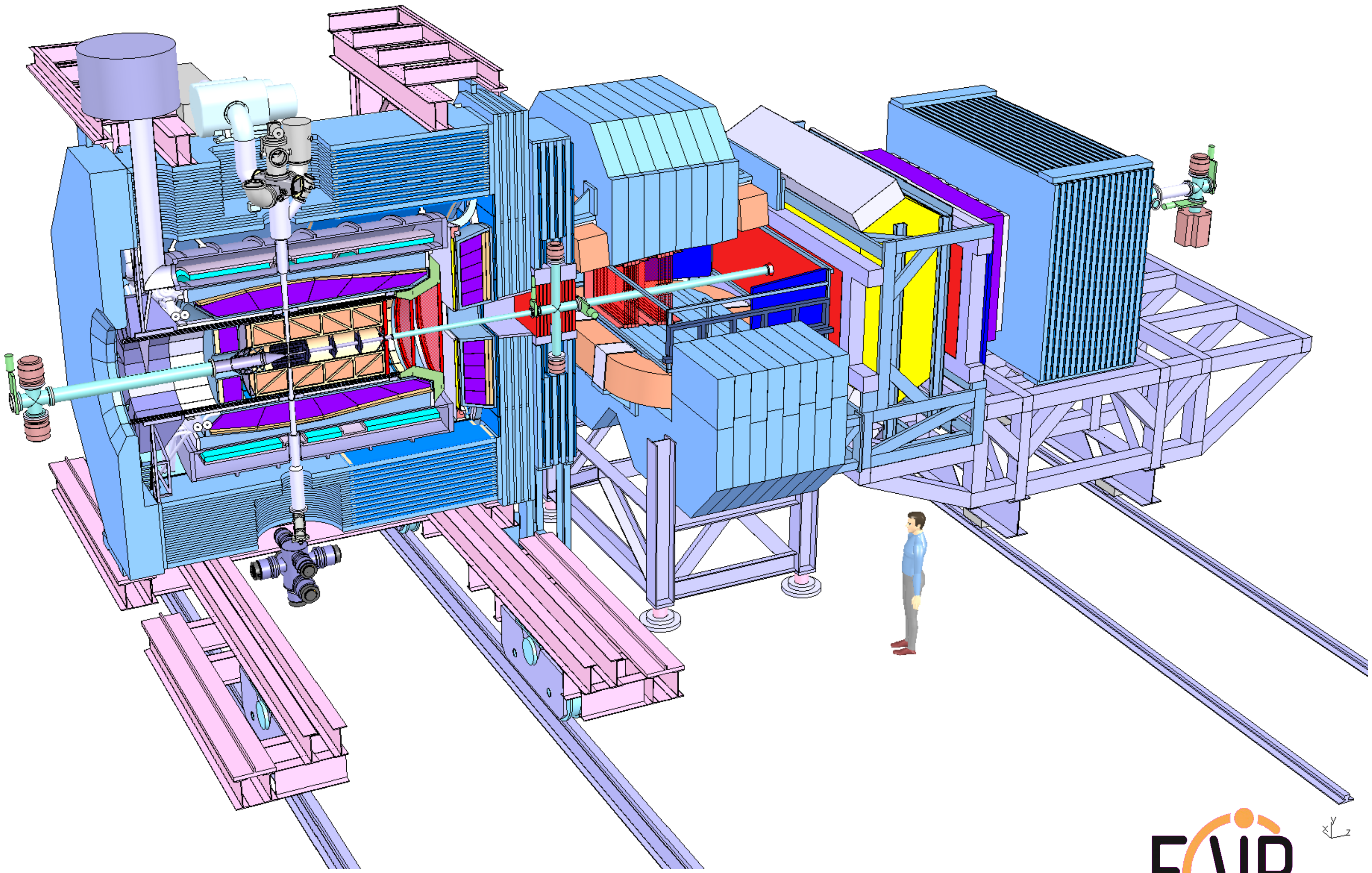
impossible limited excellent







PANDA Spectrometer



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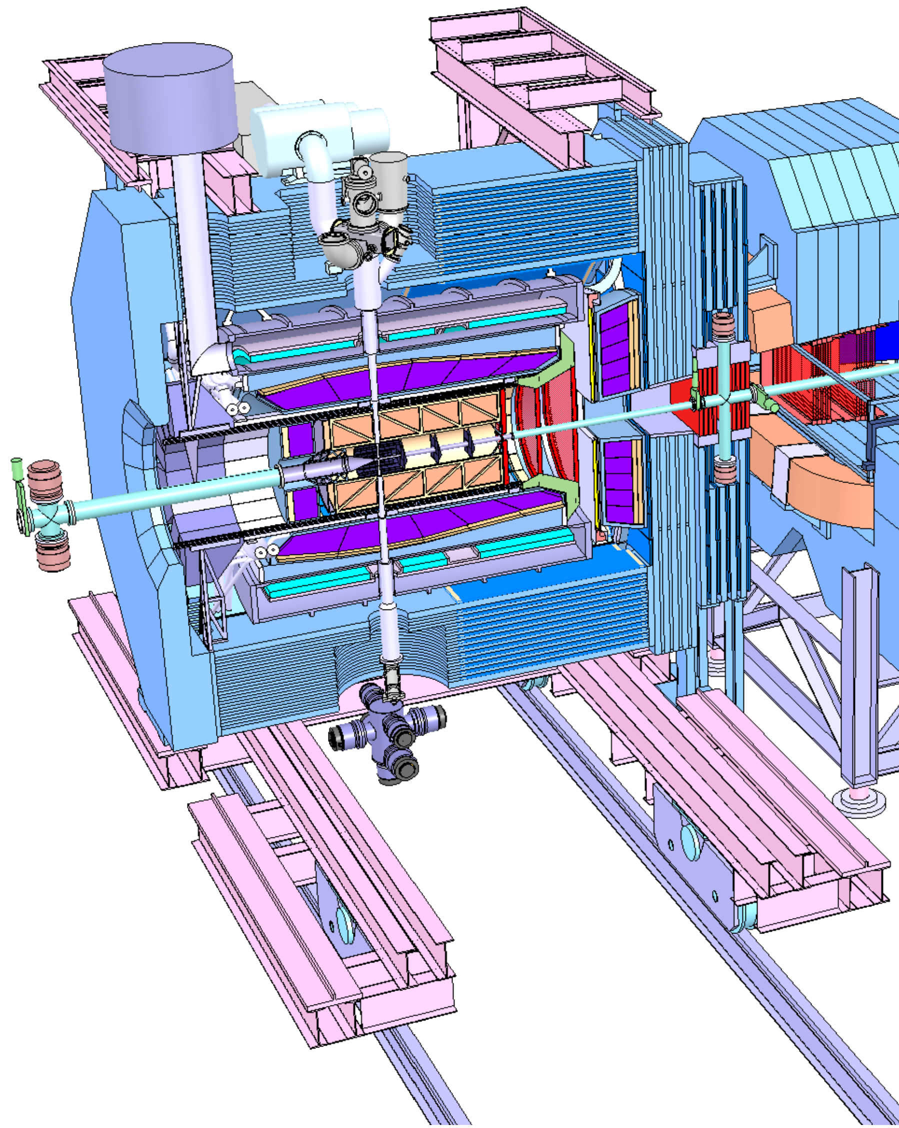


Detector requirements:

- 4π acceptance
- High rate capability: $2\mathrm{x}10^{7}$ s^{-1} interactions
- Efficient event selection

➔ *Continuous acquisition*

- Momentum resolution ~1%
- Vertex info for D, K^0_S, Y ($c\tau$ = 317 μm for $D^{\pm}$)

➔ *Good tracking*

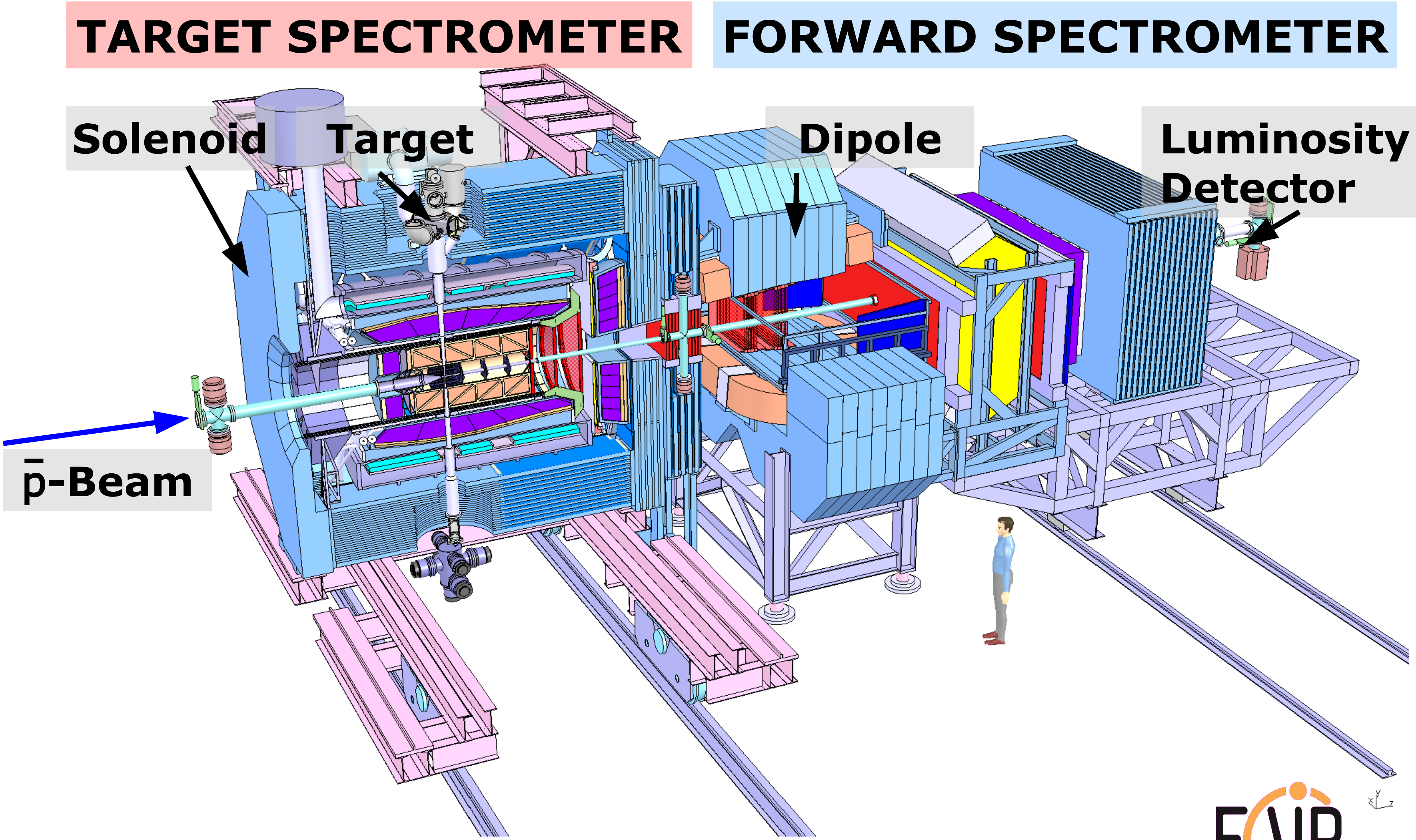
- Good PID (γ, e, μ, π, K, p)

➔ *Cherenkov, ToF, dE/dx*

- γ-detection MeV – 15 GeV

➔ *Crystal Calorimeter*

PANDA Spectrometer



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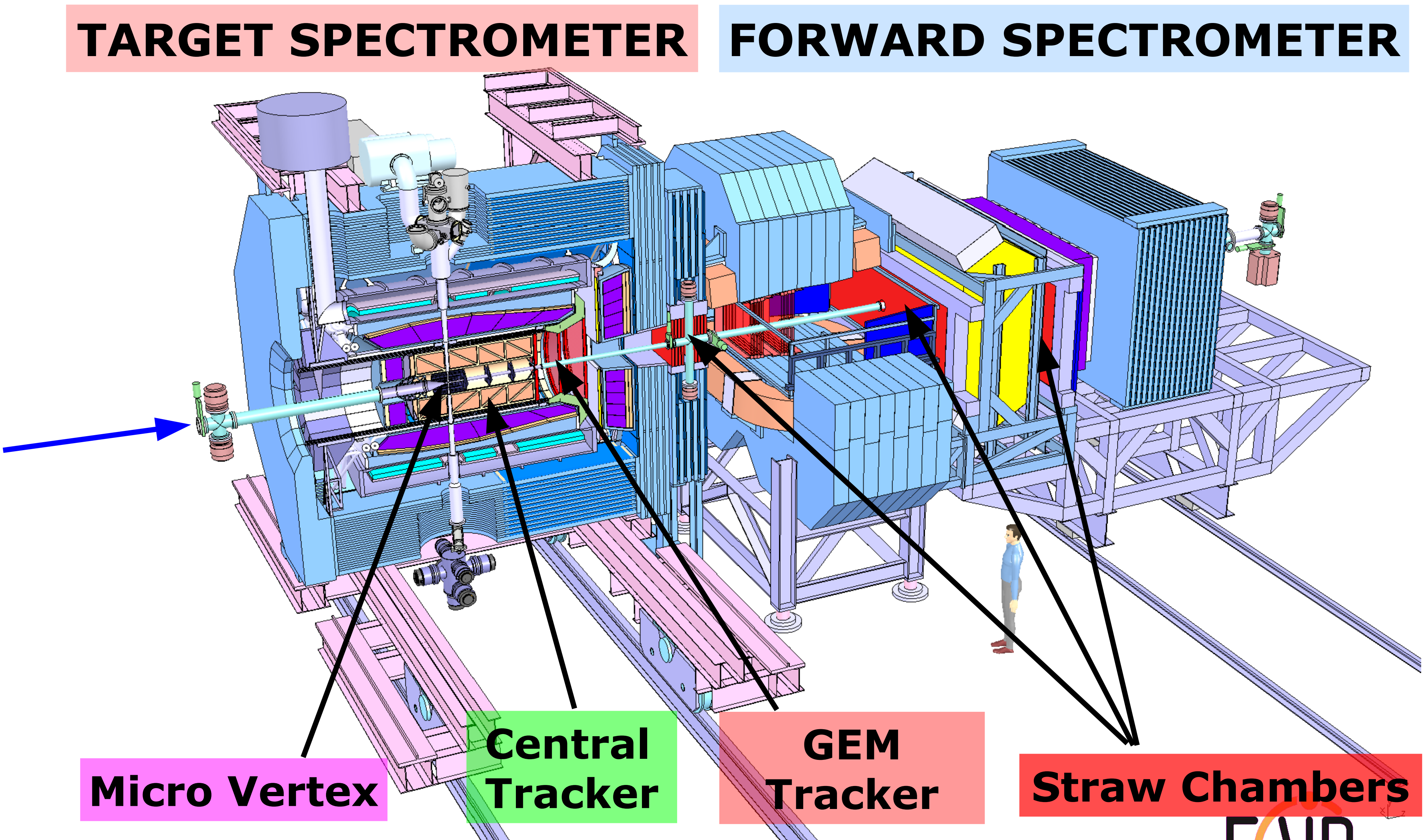

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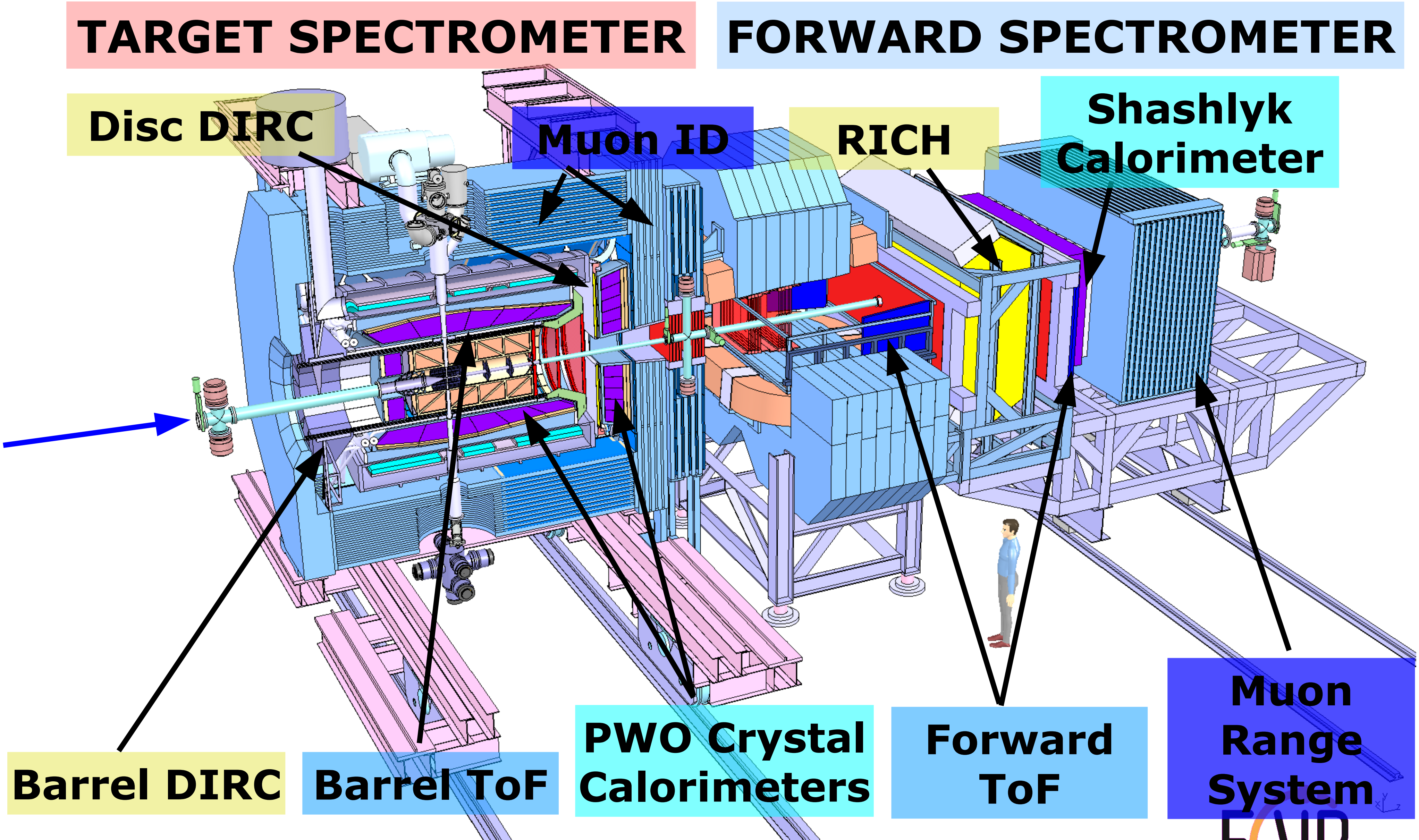
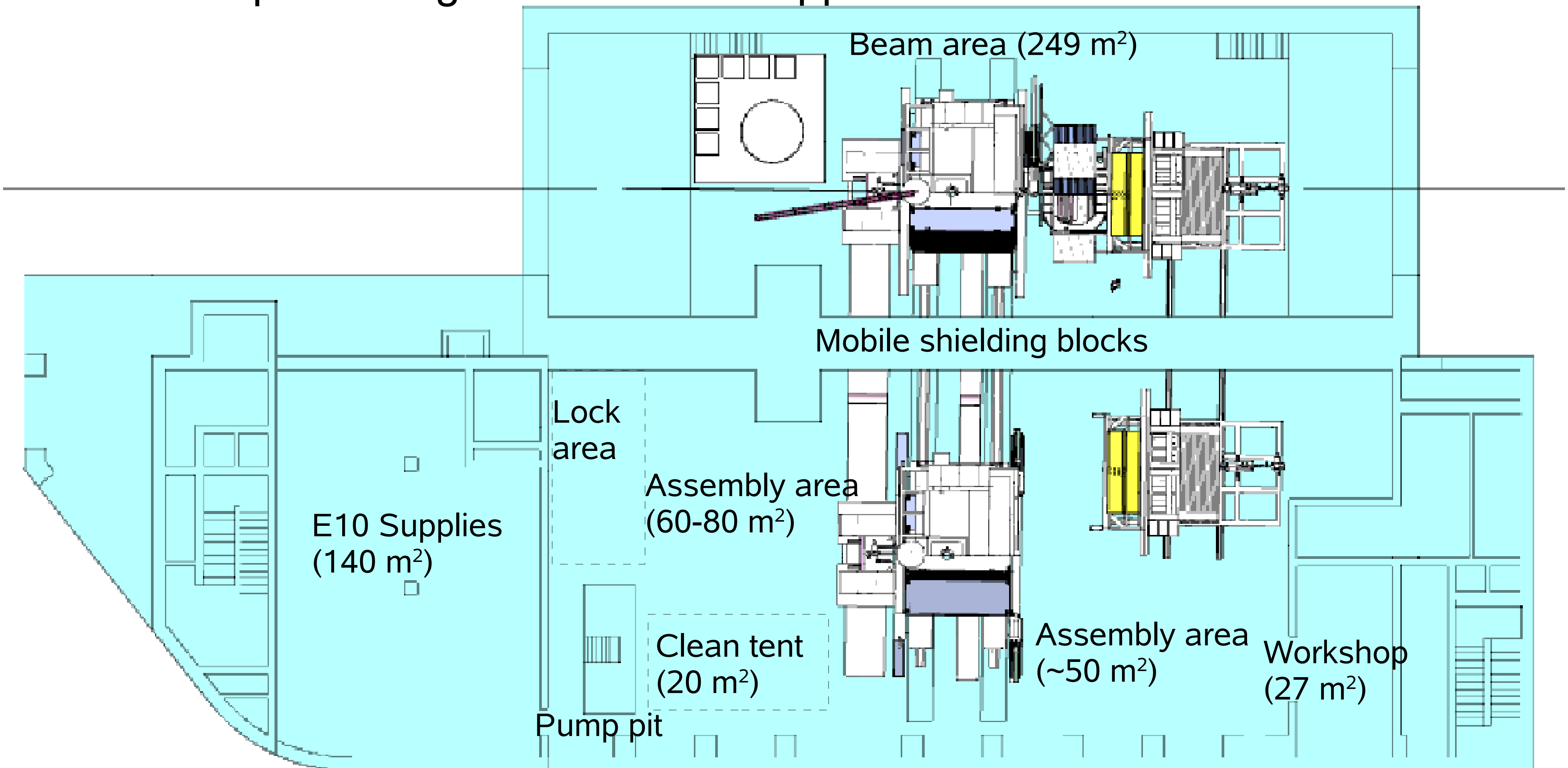
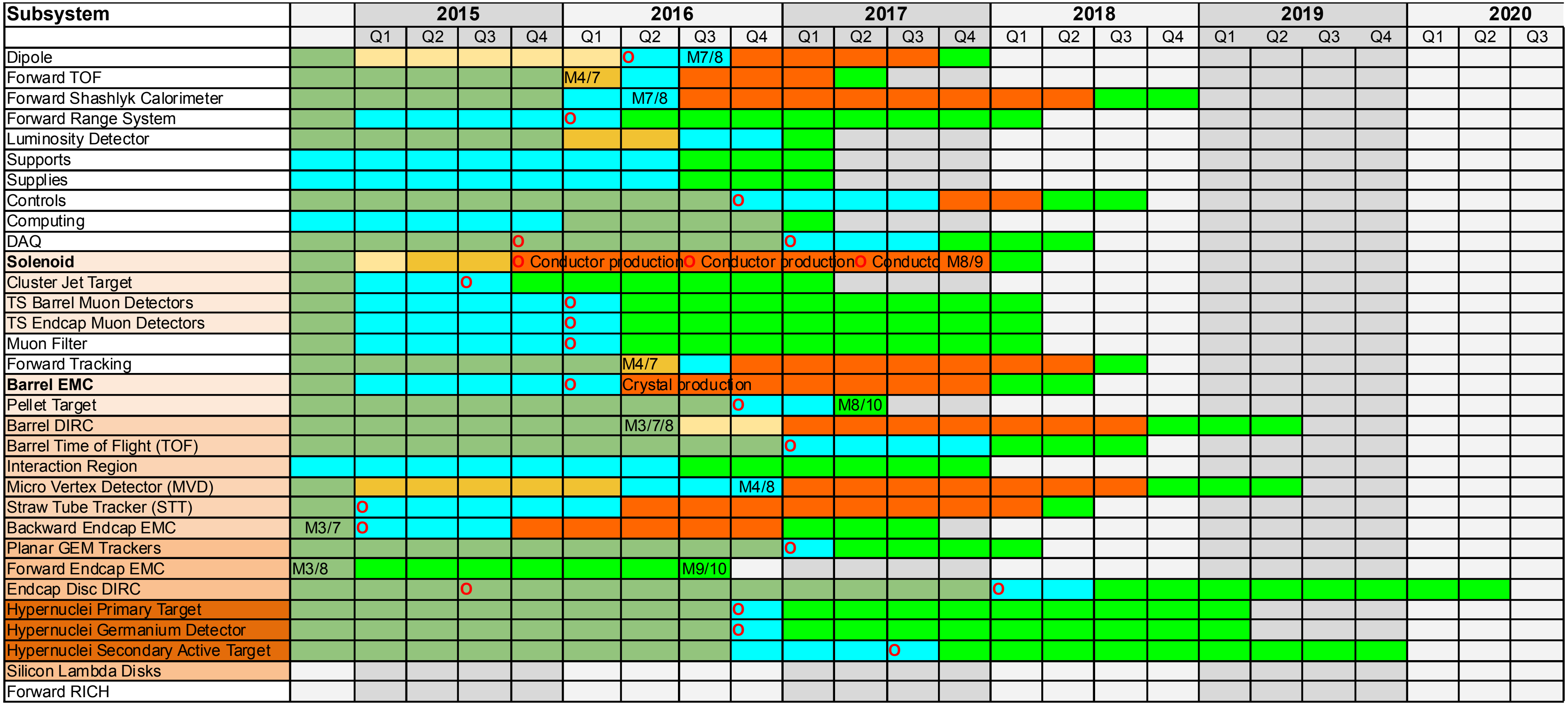


The PANDA Hall

- Architects approaching execution planning
- Detailed layout of infrastructure, shielding, services
- Next steps: routing of cables and supplies



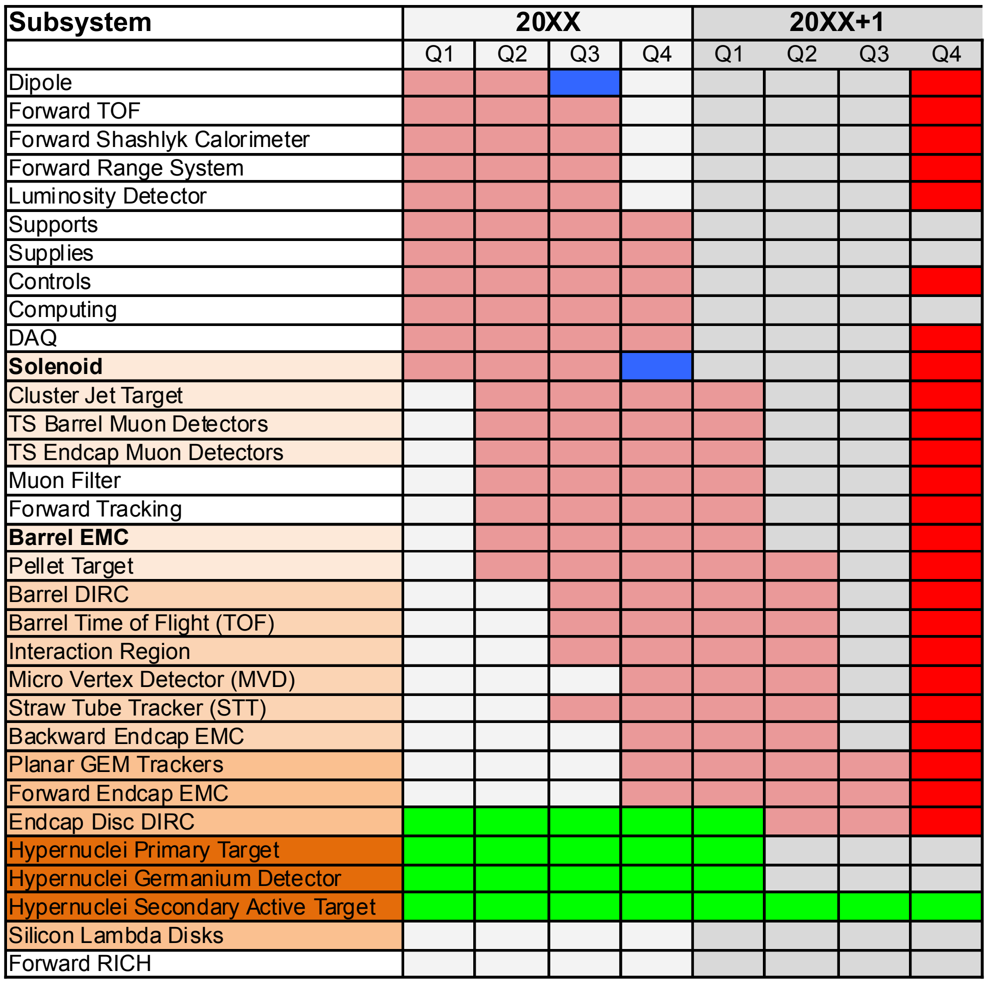
PANDA Construction Schedule



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



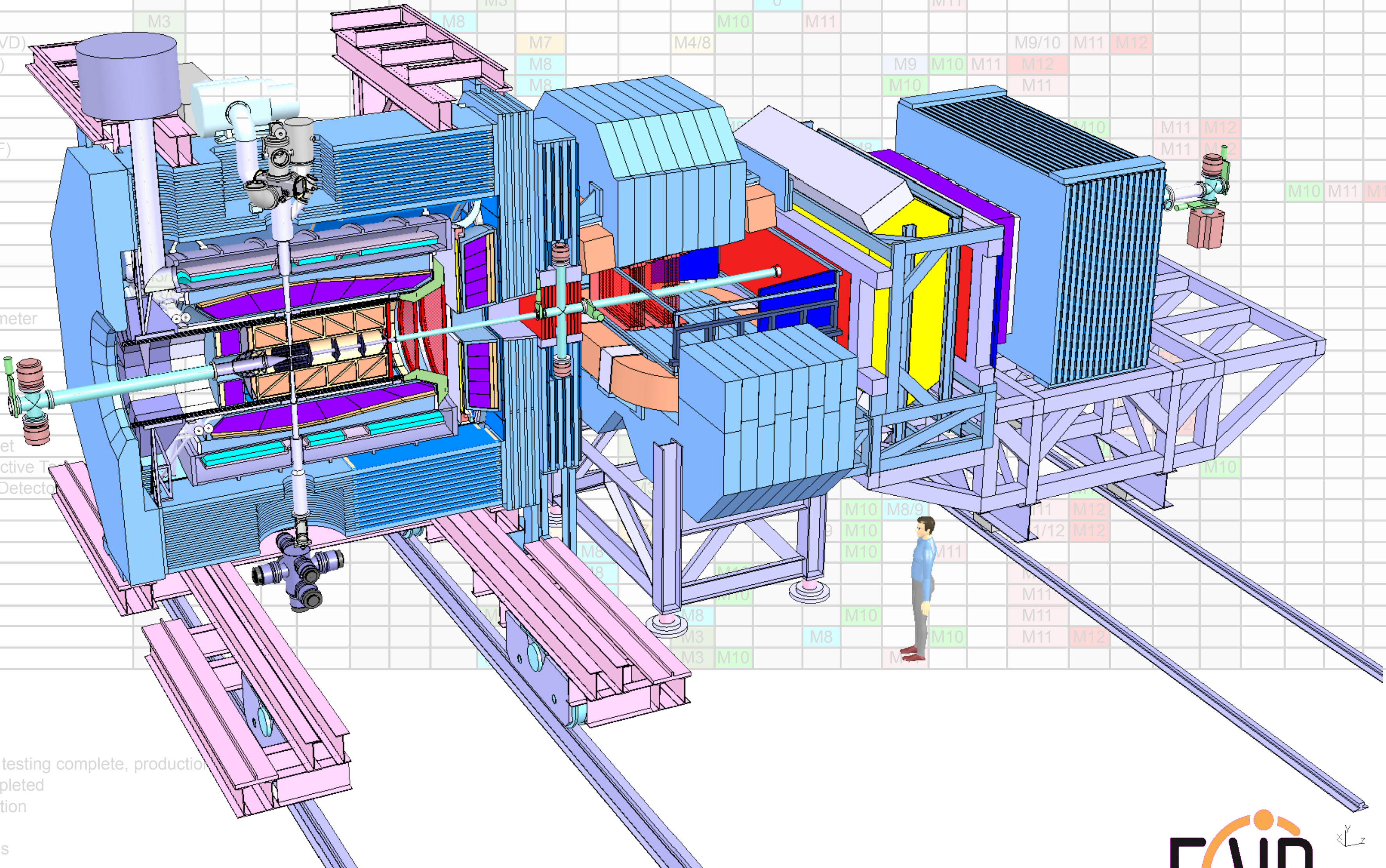
Pre-assembly, off-site testing, Transport to FAIR, site-acceptance tests, **M10:** Approval for installation
Installation at FAIR, commissioning without beam, **M11:** Ready for beam
Commissioning with beam, **M12:** Ready for operations
Magnet field mapping

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

PANDA Systems

Subsystem		2014				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	Q4	Q1	Q2	Q3	Q4
Pellet Target									M3						0				M11										
Cluster Jet Target	M3							M8						M10		M11													
Micro Vertex Detector (MVD)										M7			M4/8								M9/10	M11	M12						
Straw Tube Tracker (STT)										M8								M9	M10	M11	M12								
Planar GEM Trackers										M8								M10			M11								
Silicon Lambda Disks																													
Barrel DIRC																						M10		M11	M12				
Barrel Time of Flight (TOF)																								M11					
Forward Tracking																													
Endcap Disc DIRC																											M10	M11	M12
Forward RICH																													
Forward TOF																													
Barrel EMC																													
Backward Endcap EMC																													
Forward Endcap EMC																													
Forward Shashlyk Calorimeter																													
Luminosity Detector																													
Detectors																													
Detectors																													
Muon Filter																													
Forward Range System																													
Hypernuclei Primary Target																													
Hypernuclei Secondary Active T																									M10				
Hypernuclei Germanium Detecto																													
Solenoid																	M10	M8/9				M12							
Dipole																	M10					M12							
Interaction Region																	M10												
Supports																													
Supplies																					M11								
Controls													M8				M10				M11								
DAQ													M3			M8			M10		M11	M12							
Computing													M3	M10															



M3: TDR approved
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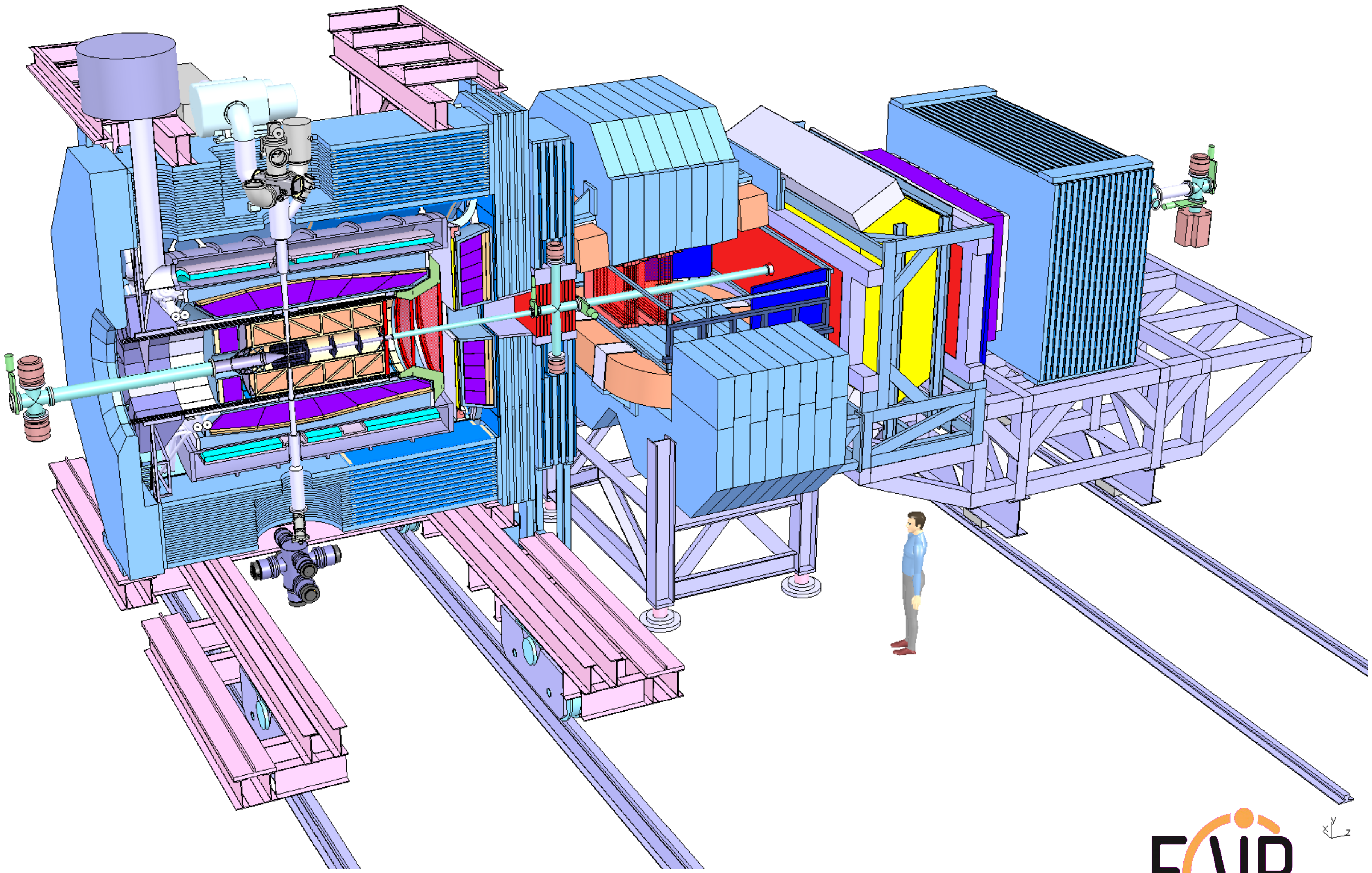
M8: Prototype/Pre-series testing complete, productio
M9: Acceptance test completed
M10: Approval for installation
M11: Ready for beam
M12: Ready for operations

Approved Systems

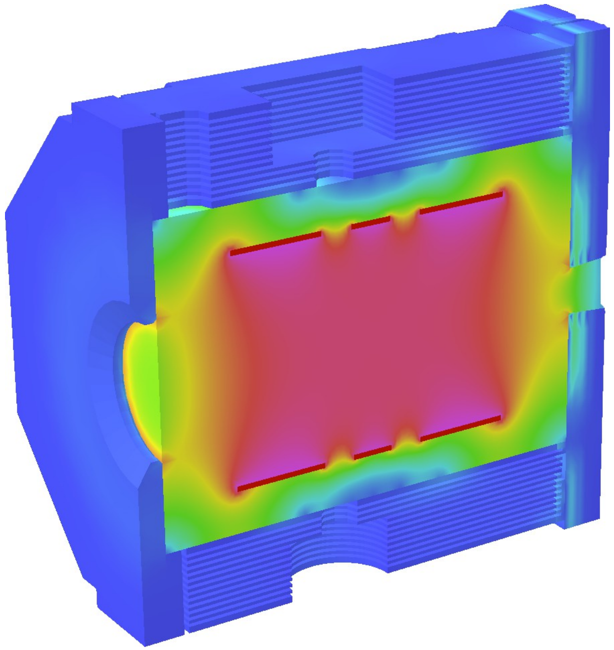


Magnets

Solenoid Magnet

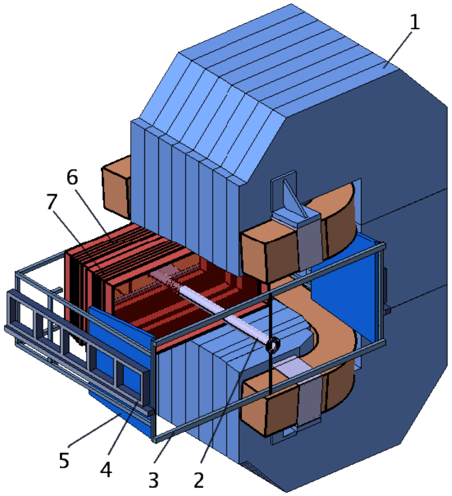
- Super conducting coil
- 2 T central field
- Segmented coil for target
- Instrumented iron yoke
- Doors for installation and maintenance
- ***Status:***

  - Cooperation with CERN for cold mass
  - Conductor optimized, close to tender
  - Yoke design complete
- Time critical !



Dipole Magnet

- Normal conducting racetrack design
- Dipole also bends the beam
- Segmented yoke for ramping



PANDA Target

Luminosity Considerations

- Goal: $2x10^{32}$ cm^{-2}s^{-1} (HL mode)
- With 10^{11} stored $\bar{p}$ and 50 mb: $4x10^{15}$ cm^{-2} target density

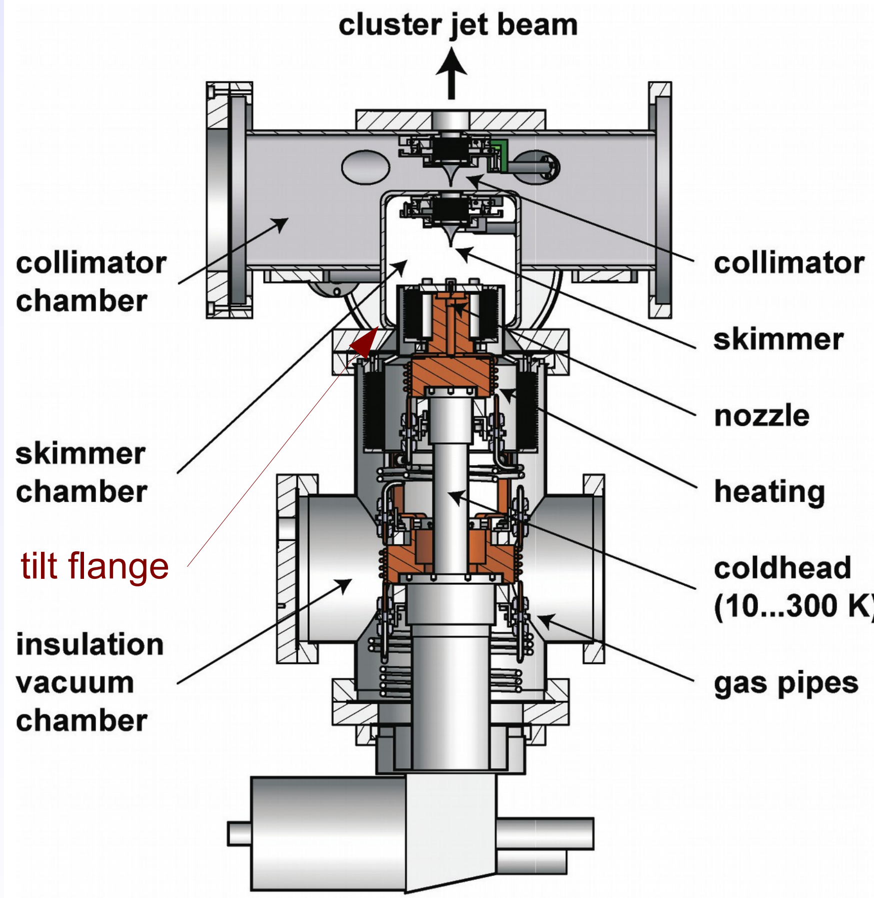
Cluster Jet Target

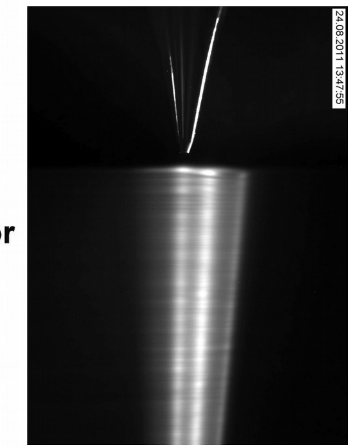
- Continuous development
  - Nozzle improvement
  - Better alignment by tilt device
  - Record $2x10^{15}$ cm^{-2} reached
- TDR approved

Pellet Target

- >$4x10^{15}$ cm^{-2} feasible
- Prototype under way
- Pellet tracking prototype
- Second TDR part 2015/16

Latest version of the cluster jet target

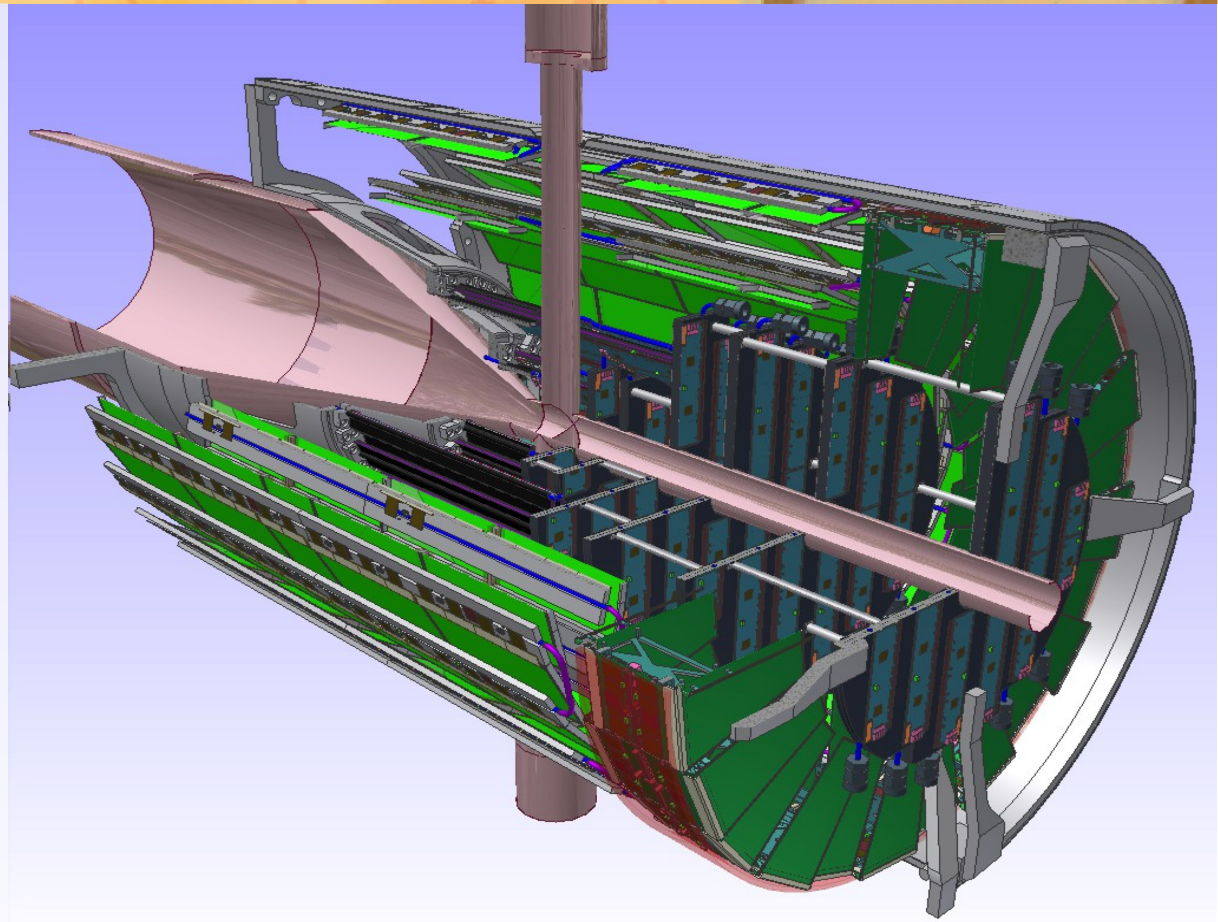




Micro Vertex Detector

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

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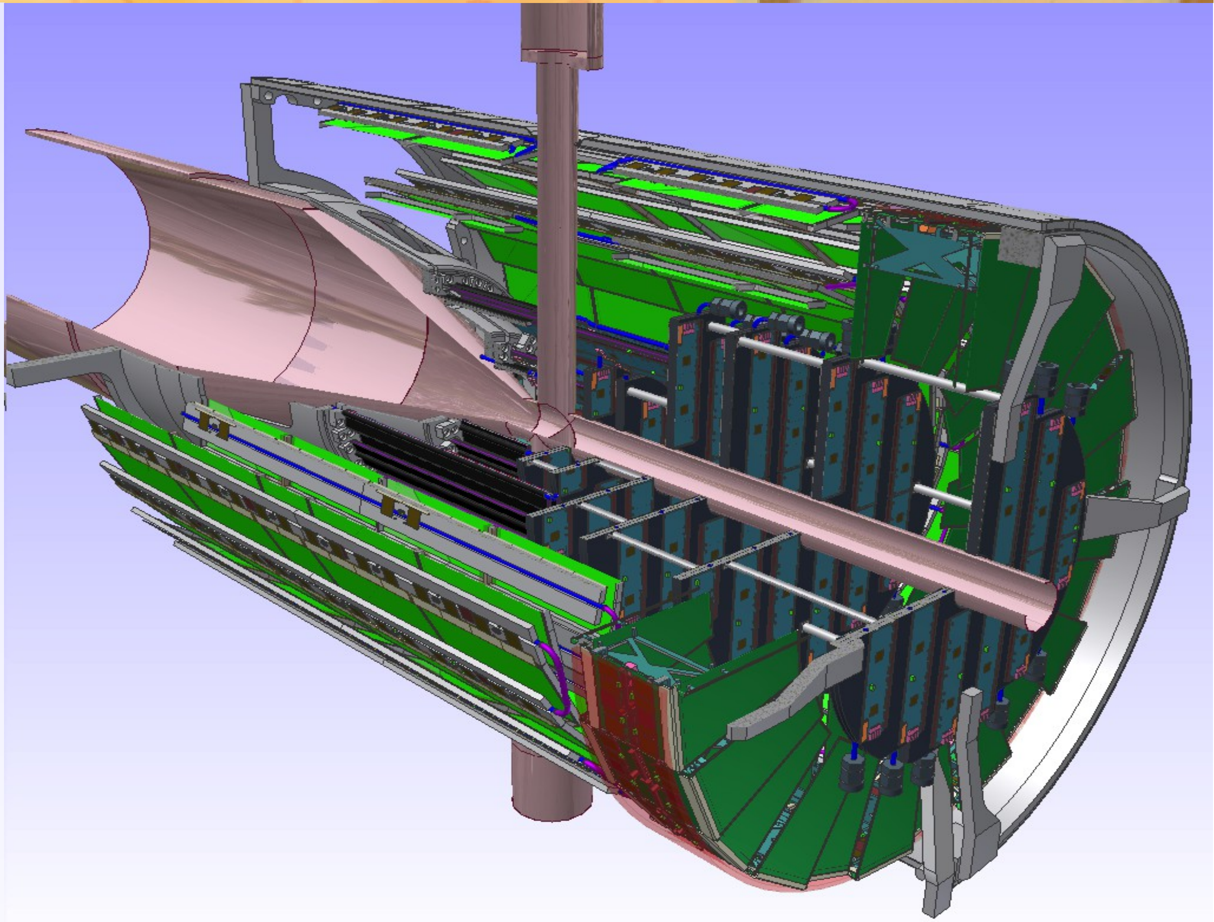


- ToPiX full version in 2015
- PASTA ASIC in 2015
- Detailed service planning

Straw Tube Tracker

Detector Layout

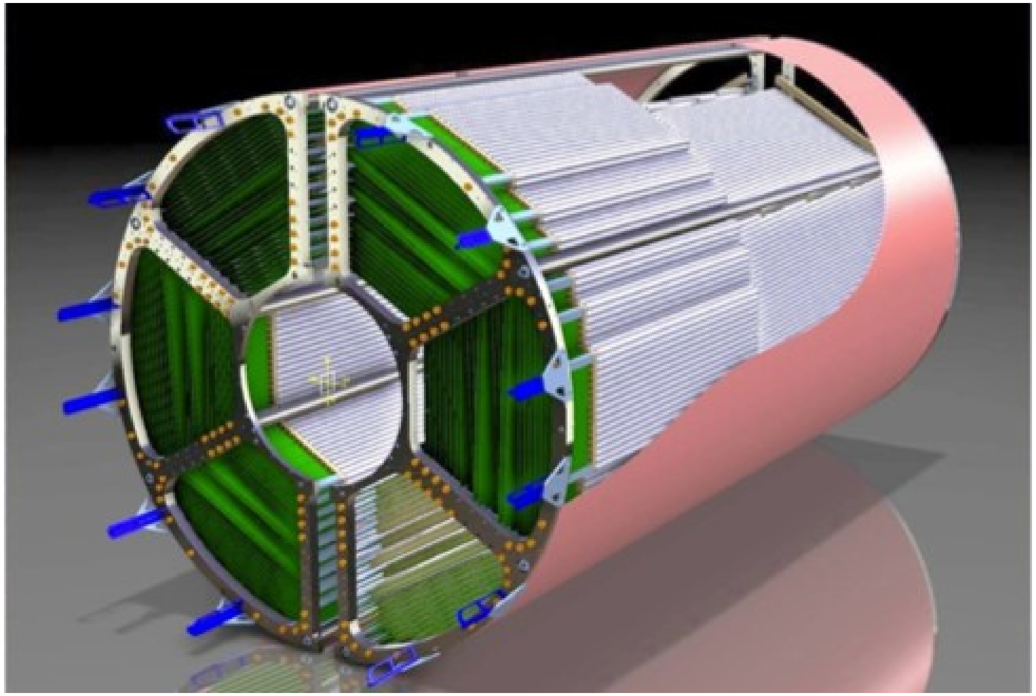
- 4600 straws in 21-27 layers, of which 8 layers skewed at ~3°
- Tube made of 27 µm thin Al-mylar, Ø=1cm
- R_{in}= 150 mm, R_{out}= 420 mm, l=1500 mm
- Self-supporting straw double layers at ~1 bar overpressure (Ar/CO_2)
- Readout with ASIC+TDC or FADC

Material Budget

- Max. 26 layers,
- 0.05 % X/X_0 per layer
- Total 1.3% X/X_0

Project Status

- Prototype construction & beam tests
- Aging tests: up to 1.2 C/cm^2
- Straw series production started



Straw Tube Tracker Developments

Mechanics status

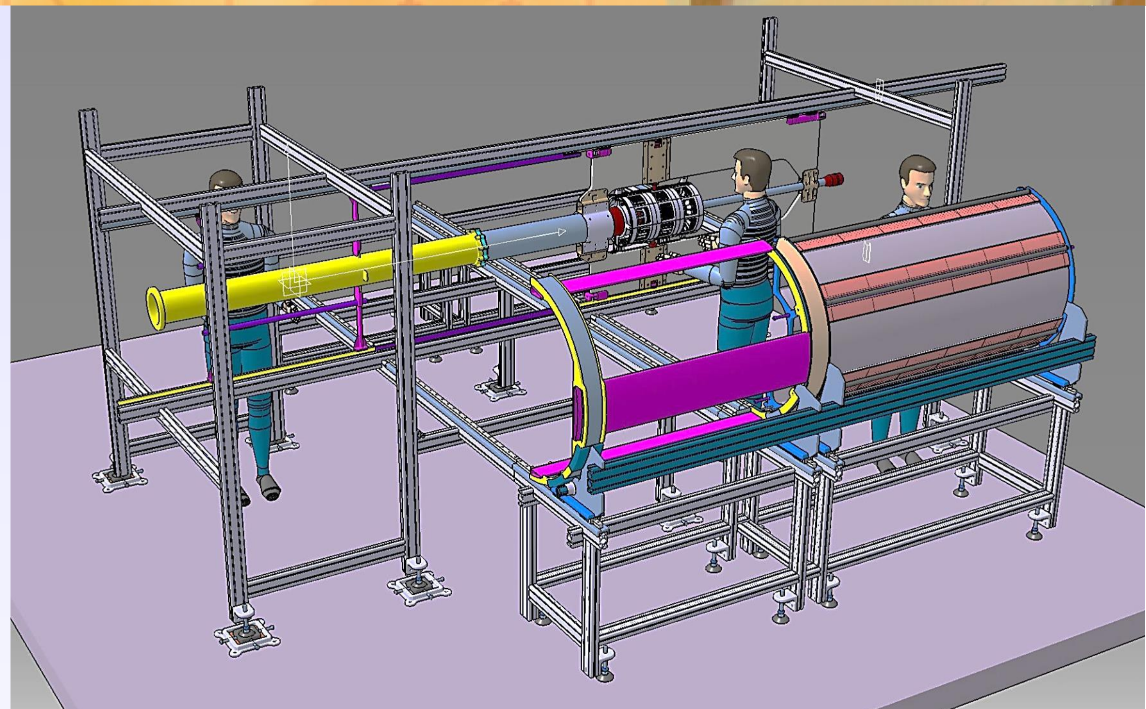
- Prototype frame installed
- Assembly scheme
- Frontend layout CAD

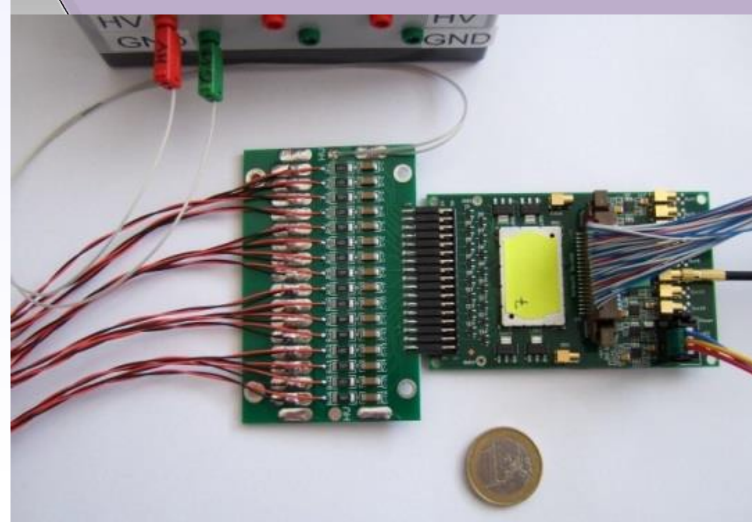
Electronics Status

- New PASSTREC ASIC available
- New 125 MSPS FADC, no FEE at detector side

Testbeam campaign

- December '14 and May '15:
  5 energies between 0.6 and 3.0 GeV
- Both types of electronics:
  - PASTTREC ASIC + TRB3 TDC
  - FADC (240 MHz & 125 MHz)
- Goal of further testbeams:
  Fully characterise readout
- Final selection: cost/performance



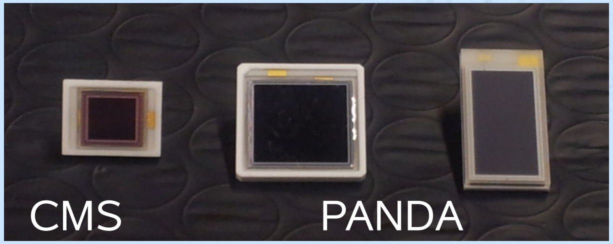


Electromagnetic Calorimeters

$\overline{\text{P}}$ANDA PWO Crystals

- PWO is dense and fast
- Low γ threshold is a challenge
- Increase light yield:
  - improved PWO II (2xCMS)
  - operation at -25°C (4xCMS)
- Challenges:
  - temperature stable to 0.1°C
  - control radiation damage
  - low noise electronics
- Delivery of crystals 54%

Large Area APDs



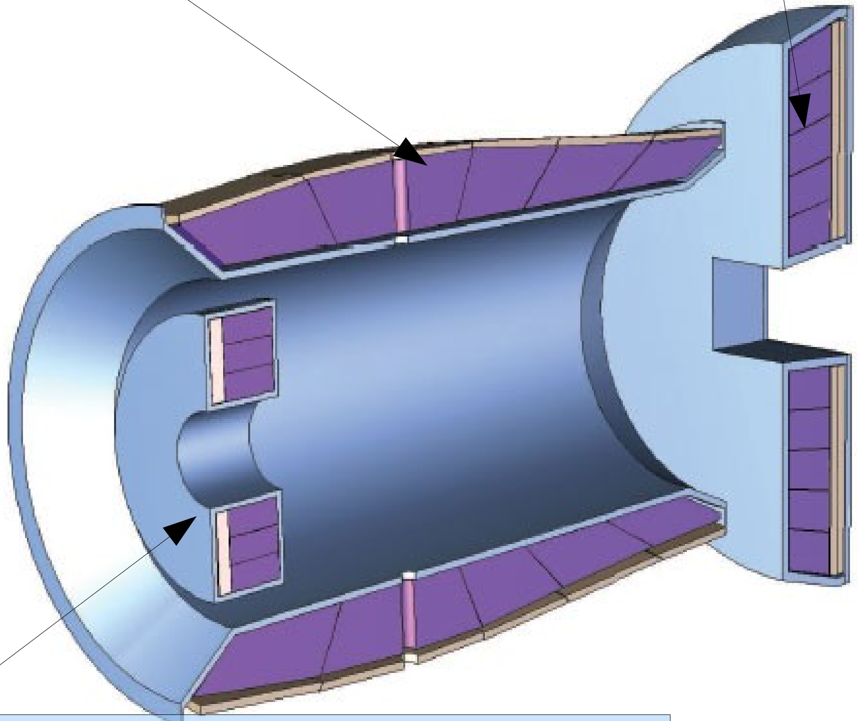
5x5 mm^2 10x10 mm^2 and 7x14 mm^2

Barrel Calorimeter

- 11000 PWO Crystals
- LAAPD readout, 2x1cm^2
- σ(E)/E~1.5%/√E + const.

Forward Endcap

- 4000 PWO crystals
- High occupancy in center
- LA APD and VPTT



Backward Endcap for hermeticity, 530 PWO crystals

Electromagnetic Calorimeters

PWO Crystal Production

- 2 new producers: SICCAS & Crytur
- ➔ *First good samples received*
- 54% of crystals produced
- EoI to fund remaining crystals

APD Screening

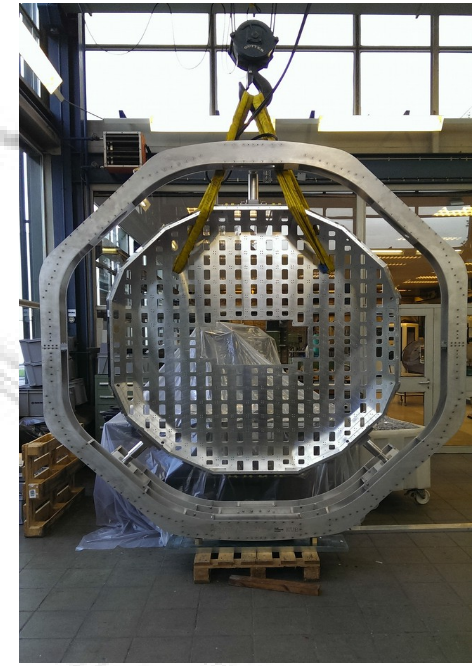
- Screening of 30000 APDs at GSI
- Facility started shift operation

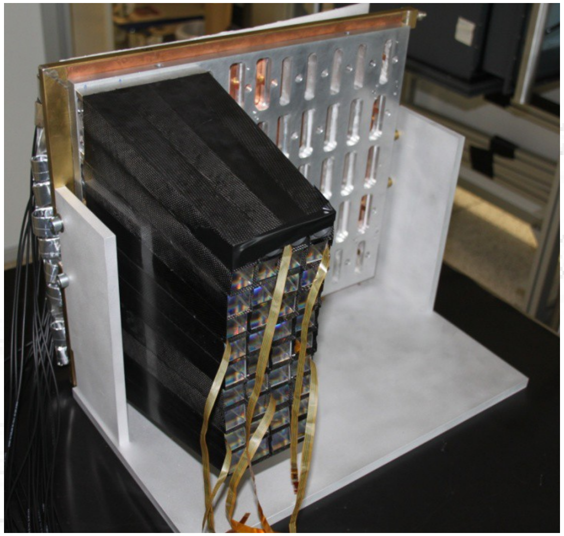
Backward Endcap

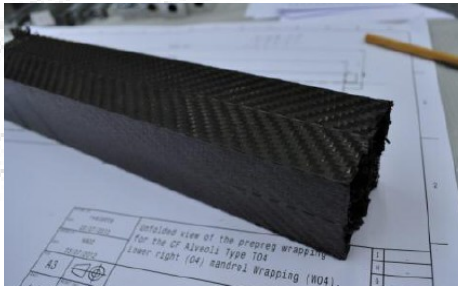
- Prototyping advanced
- Mech design being finalised

Forward Endcap

- Support frame done
- Module production commencing

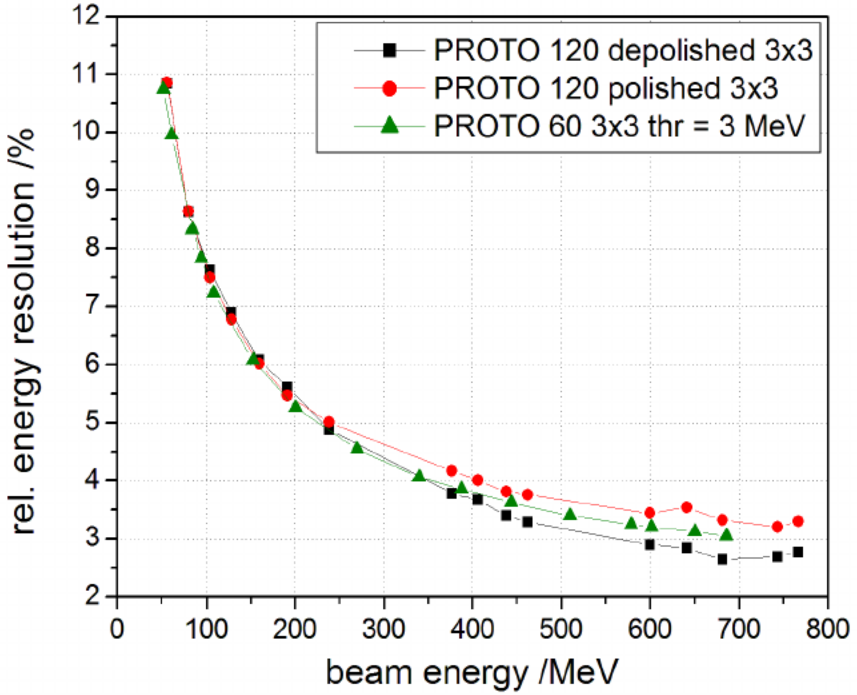


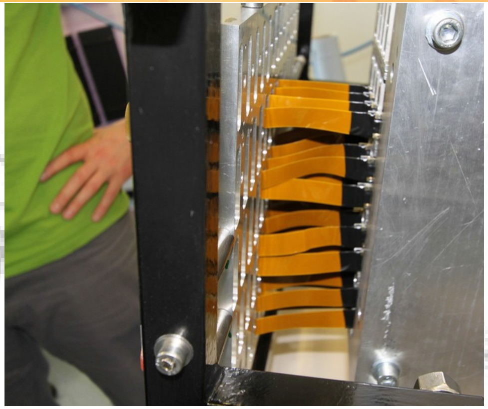


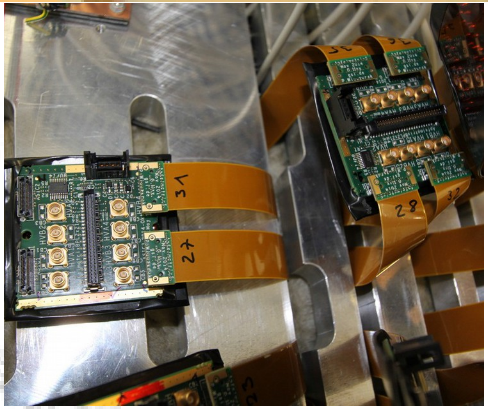


FAIR

Barrel EMC







Barrel prototype tests

- Mechanics design being finalised, 65% of alveoles produced
- APD readout ASIC characterisation at testbeam *successful*
- ➔ *ASICs being ordered*
- Final layout of auxiliary electronics: flex PCB, backplane, shielding
- Tests with depolished crystals to improve homogeneity

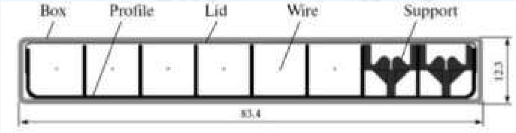
Muon Detector System

Muon system rationale:

- Low momenta, high BG of pions
- ➔ Multi-layer range system

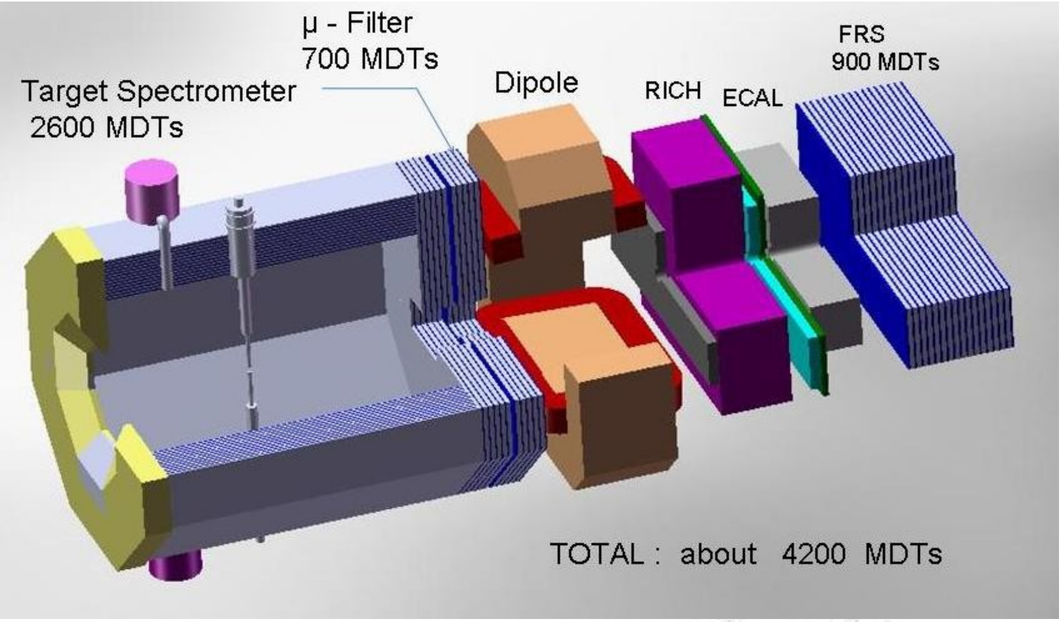
Muon system layout:

- *Barrel*: 12+2 layers in yoke
- *Endcap*: 5+2 layers
- *Muon Filter*: 4 layers
- *Fw Range System*: 16+2 layers
- *Detectors:* Drift tubes with wire & cathode strip readout

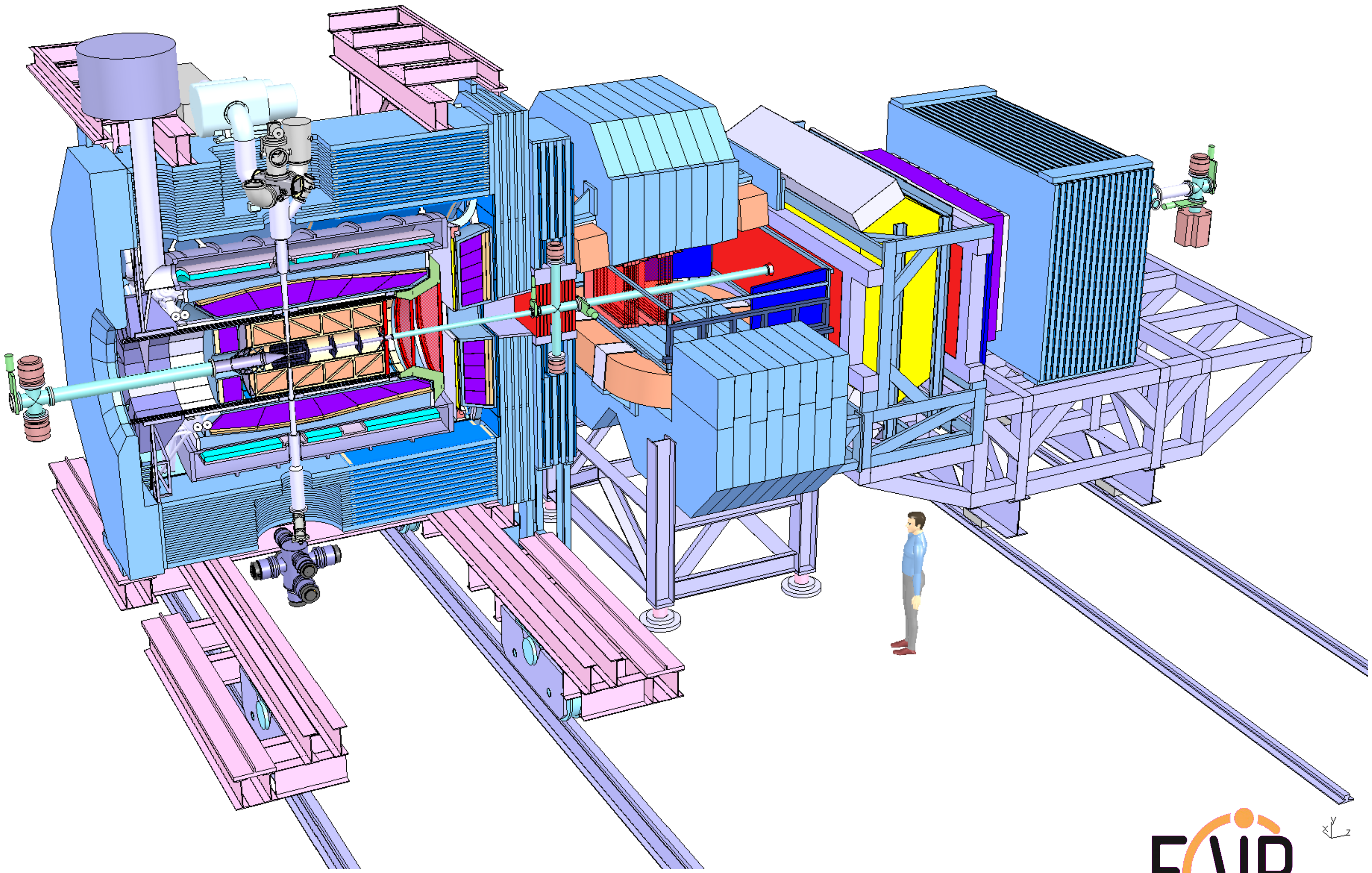


System status

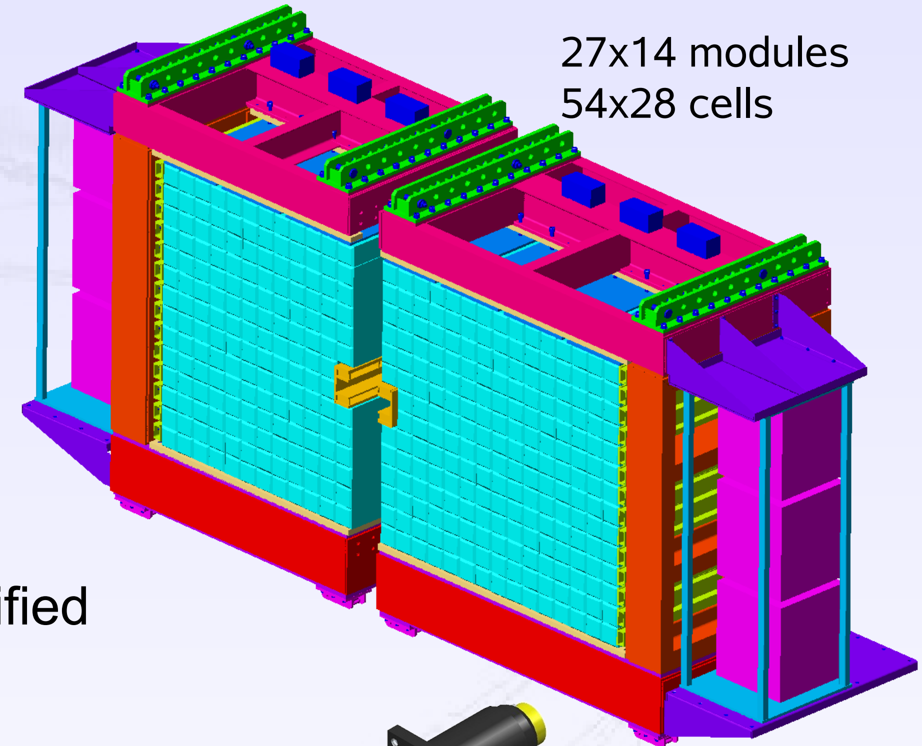
- TDR approved Sep 2014
- Range system tests at CERN



Immitent TDRs: 2015



Forward Shashlyk Calorimeter



27x14 modules
54x28 cells

Forward electromagnetic calorimeter:

- Interleaved scintillator and absorber
- WLS fibres for light collection
- PMTs for photon readout
- FADCs for digitization
- Active area size 297x154 cm^2

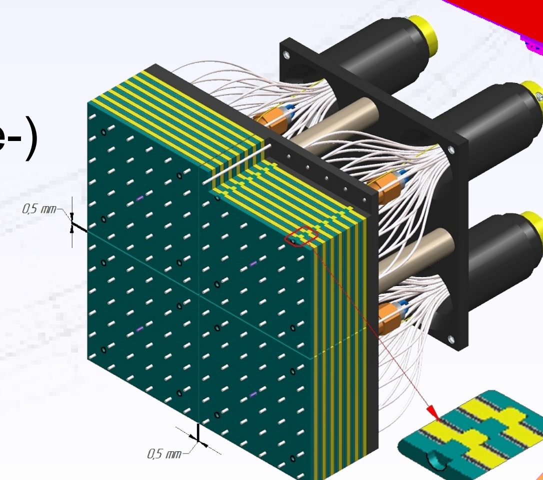
System status:

- Module design 2x2 cells of 5.5x5.5 cm^2 verified
- Tests with electrons and tagged photons:

➔ **Energy resolution:**

$\sigma_E /E = 5.6/E \oplus 2.4/\sqrt{E}$ [GeV] $\oplus$ 1.3 [%] (1-19 GeV e-)

$\sigma_E /E = 3.7/\sqrt{E}$ [GeV] $\oplus$ 4.3 [%] (50-400 MeV ph)

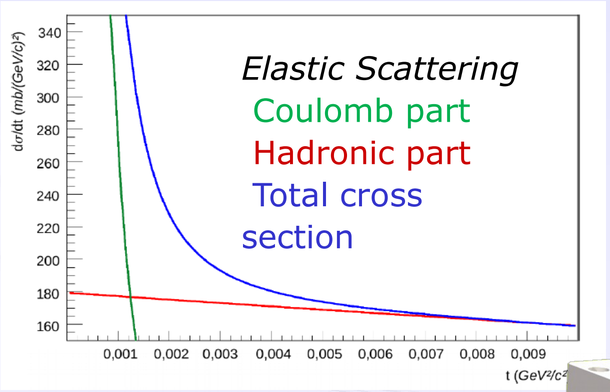


- **Time resolution:** 100 ps/$\sqrt{E}$ [GeV]
- **Internal review:** recommends production readiness prototype, now planned for 2016
- **TDR submitted to FAIR June 17, 2015**

Luminosity Detector

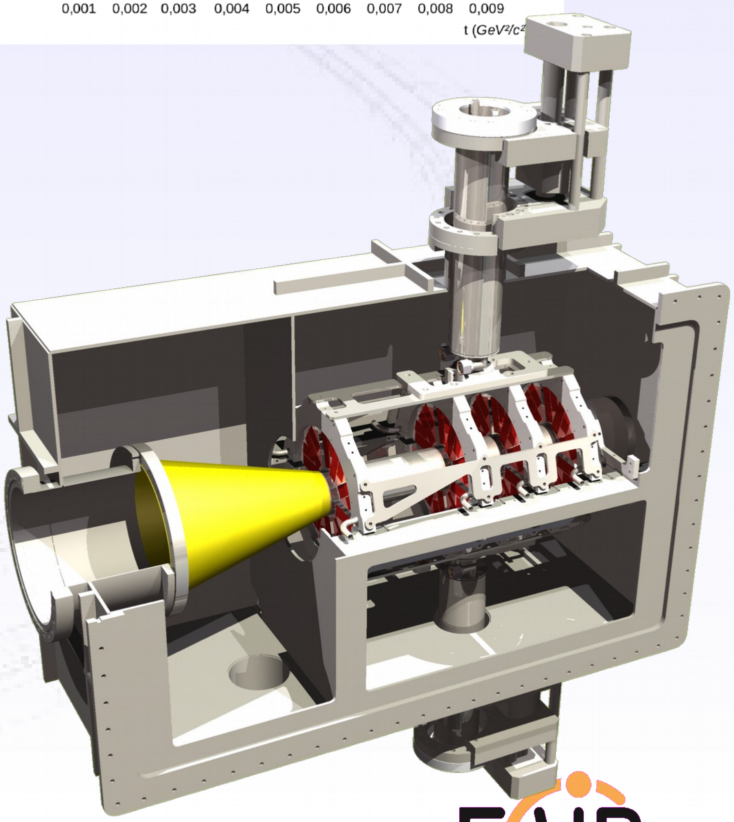
Elastic scattering:

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



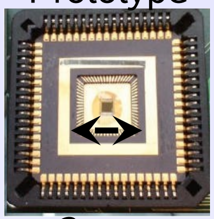
Detector layout:

- Roman pot system at z=11 m
- Silicon pixel detector:
  - 4 layers of HV MAPS (50 µm thick)
  - pixels 80x80 µm^2
- CVD diamond supports (200 µm)
- Retractable half planes in secondary vacuum

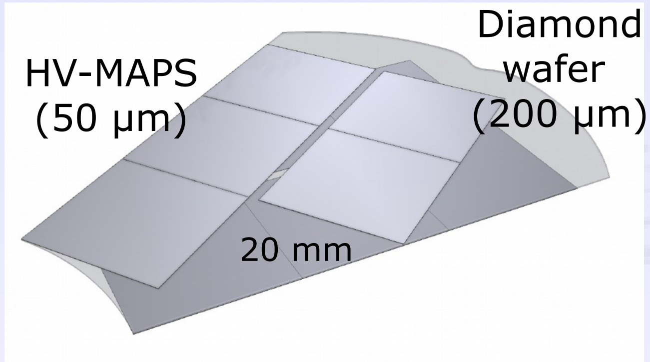


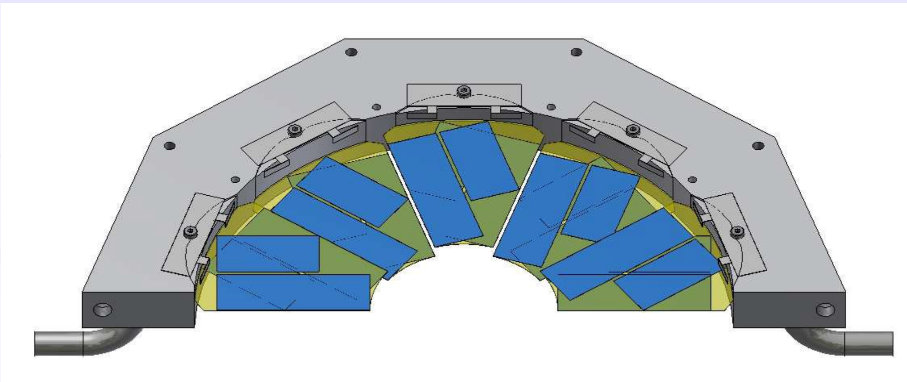
Luminosity Detector

Prototype



3 mm





HV MAPS:

- Development at U Heidelberg for Mu3e Experiment at PSI
- Active pixel sensor in HV CMOS: faster and more rad. hard
- Digital processing on chip
- Testbeam results: S/N ~ 20, Efficiency ~99.5%

Project status:

- Cooling system prototype tested
- Mechanical vessel and vacuum system prototype tested
- CVD diamond supports available
- TDR was reviewed internally with external experts
- ➔ Recommendations: implement more testbeam results, further simulations, material tests

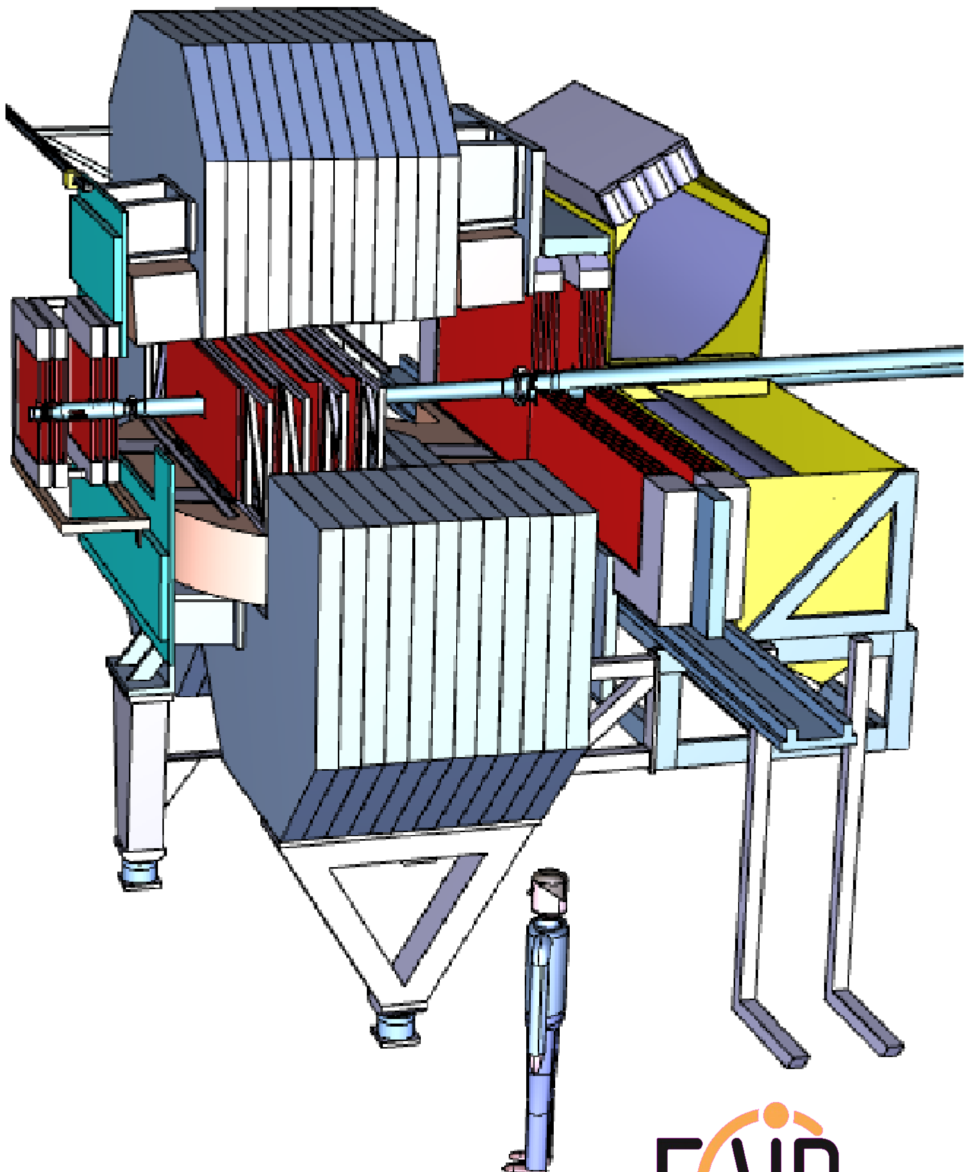
Forward Tracking

Tracking in Forward Spectrometer

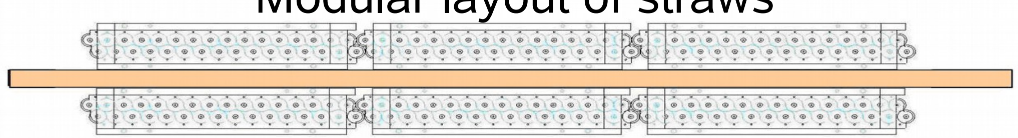
- 3 stations with 2 chambers each
  - FT1&2 : between solenoid and dipole
  - FT3&4 : in the dipole gap
  - FT5&6 : large chambers behind dipole
- Straw tubes arranged in double layers
  - 27 µm thin mylar tubes, 1 cm Ø
  - Stability by 1 bar overpressure
- 3 projections per chamber (0°, ±5°)

Present status

- Optimisation of setup: FT6 before RICH
- Final simulation ongoing
- Testbeam at COSY, PASTTREC readout



Modular layout of straws

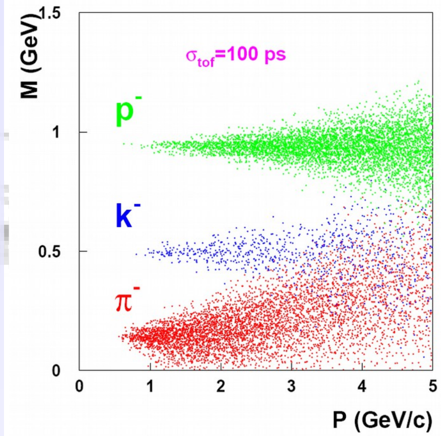


Forward Time of Flight

Forward Spectrometer PID

- Time-of-Flight essential
- No start detector
- Relative timing to Barrel

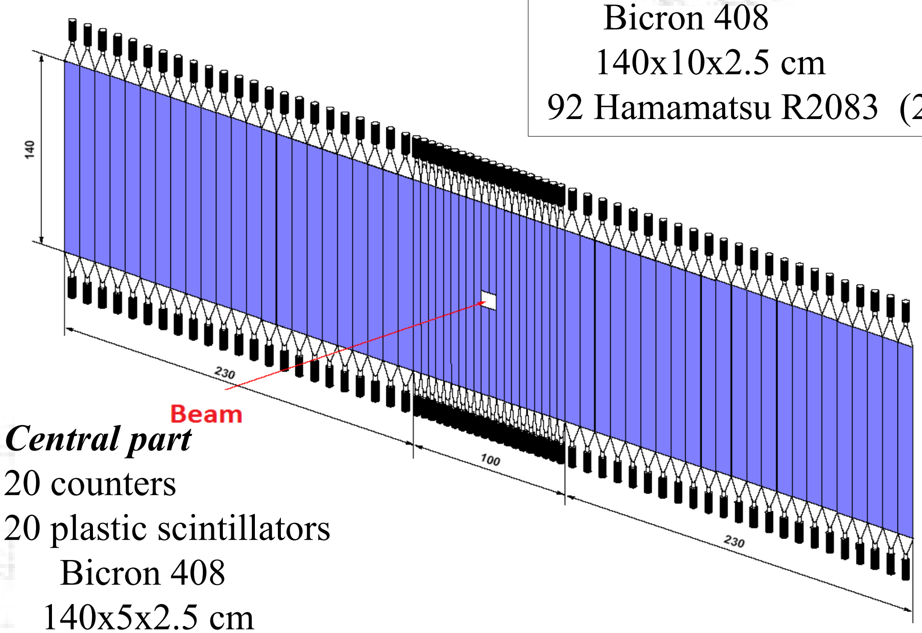
Goal: Time-of-flight with σ(t) better than 100 ps



Detector layout:

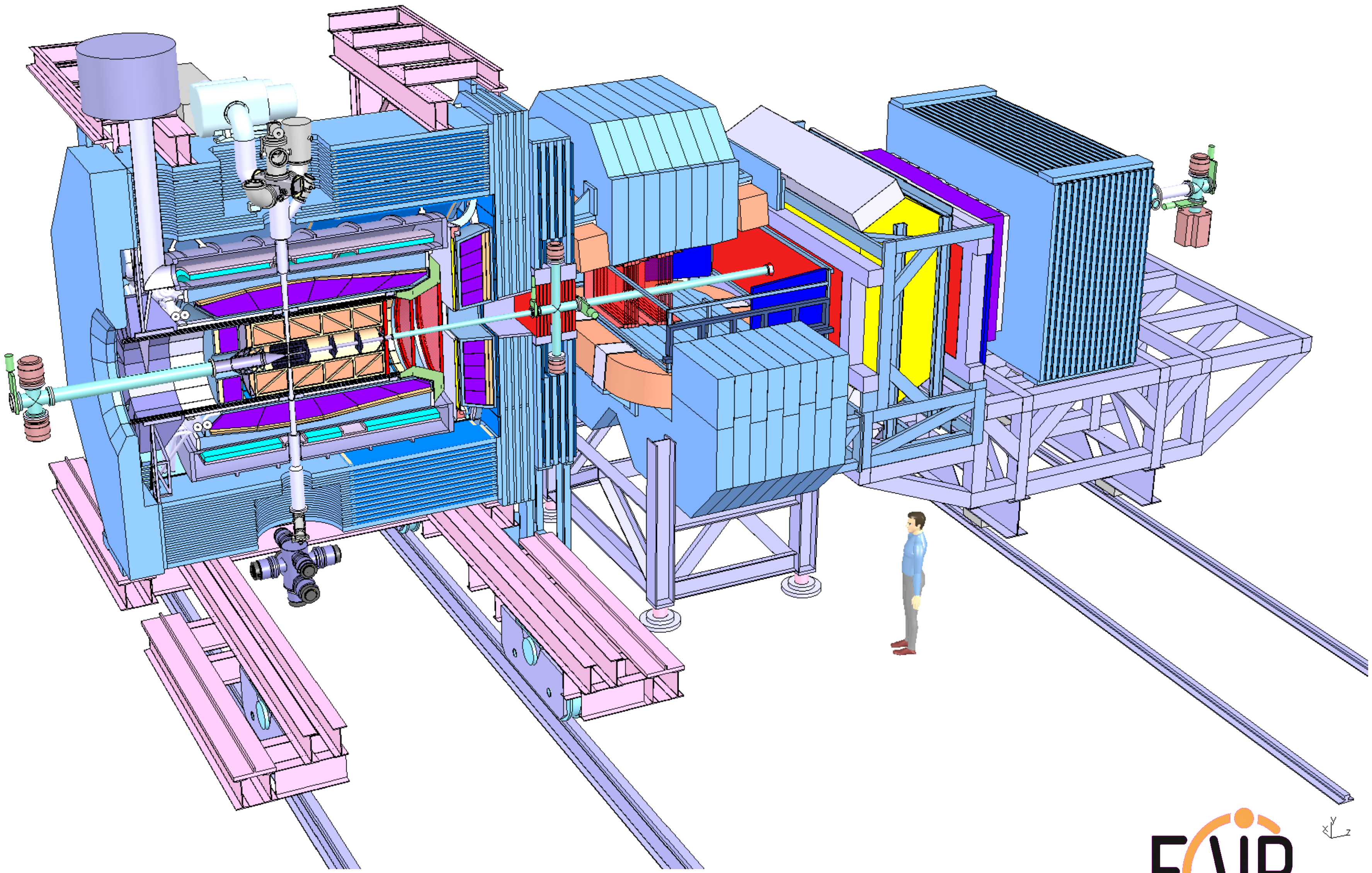
- Scintillator wall at z=7.5m made of 140 cm long slabs
- Bicron 408 scintillator
- PMT readout on both ends
- 10 cm slabs on the sides, 5 cm slabs in the center
- TDC readout
- **Additionally:** Side walls inside dipole for low momentum tracks

Side parts
2x23 counters
46 plastic scintillators
Bicron 408
140x10x2.5 cm
92 Hamamatsu R2083 (2")



Central part
20 counters
20 plastic scintillators
Bicron 408
140x5x2.5 cm
40 Hamamatsu R4998 (1")

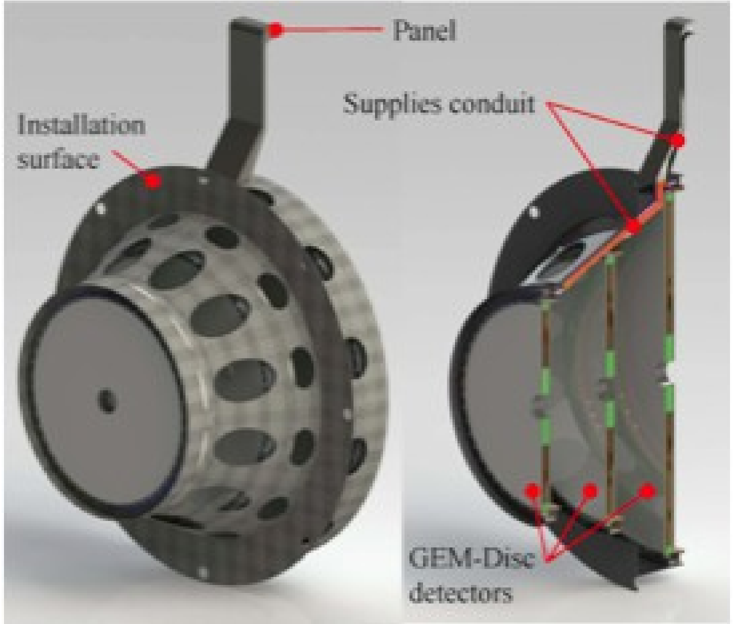
Further Systems: 2016+

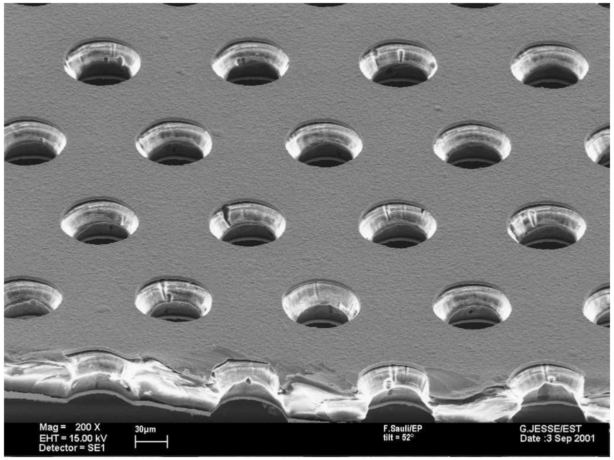


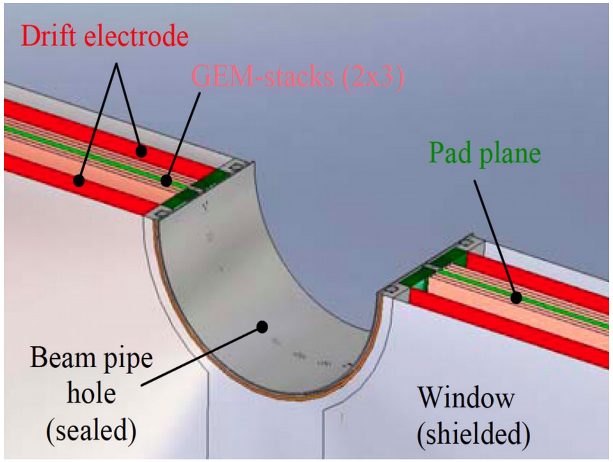
Forward GEM Tracker

Forward Tracking inside Solenoid

- 3-4 stations with 4 projections each
  - ➔ Radial, concentric, x, y
- Central readout plane for 2 GEM stacks
- Large area GEM foils from CERN (50µm Kapton, 2-5µm copper coating)
- ADC readout for cluster centroids
  - ➔ Approx. 35000 channels total
- Challenge to minimize material







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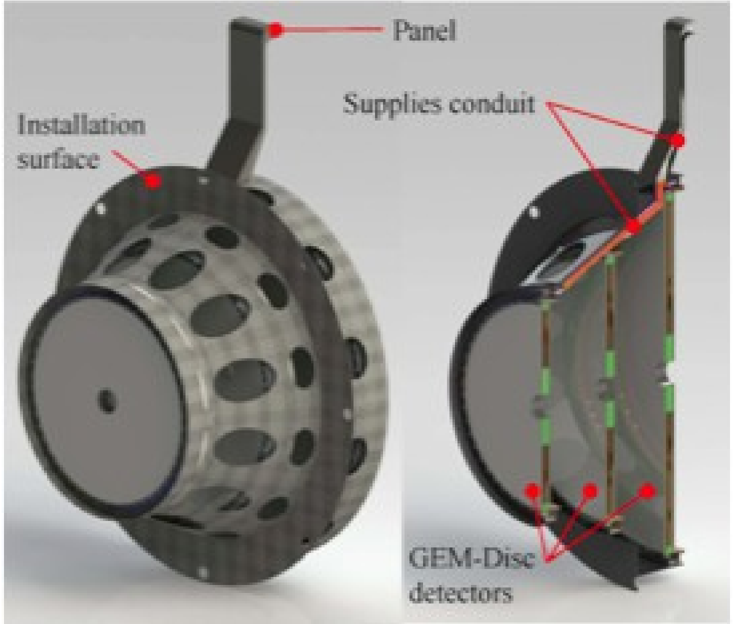
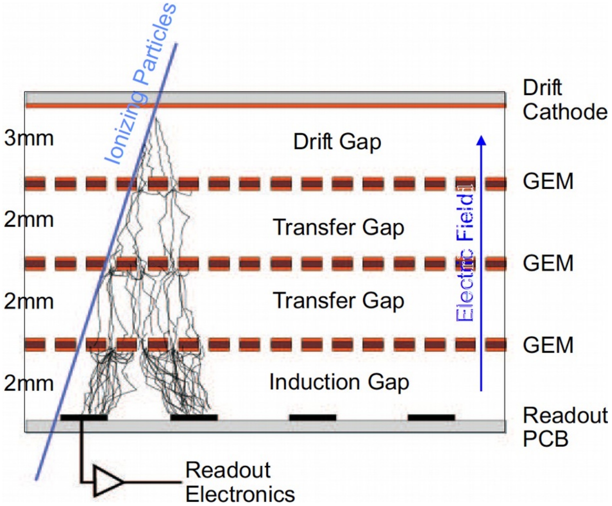
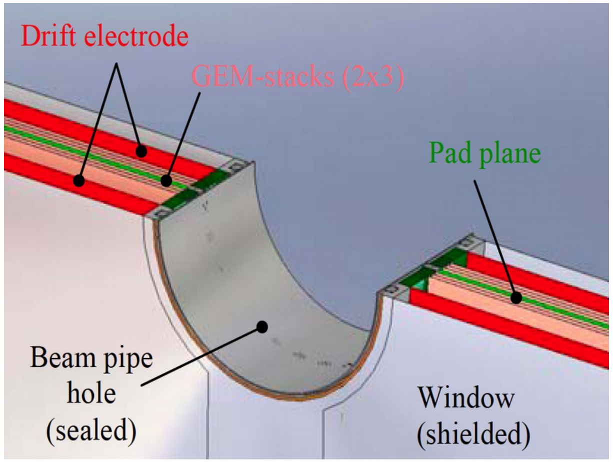


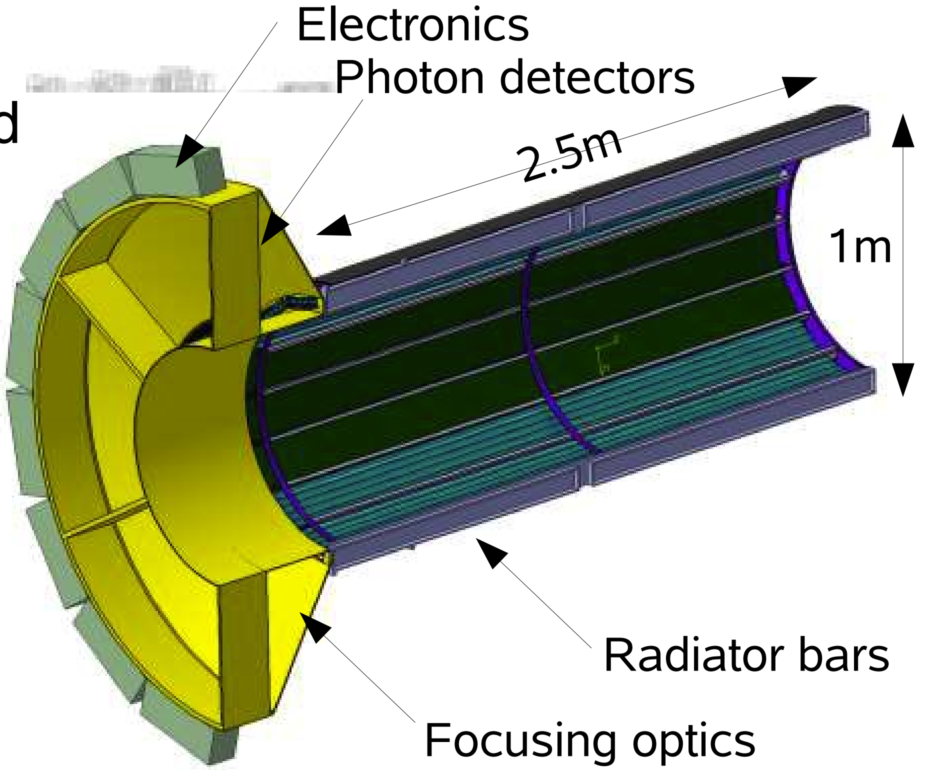




$\overline{\text{P}}$ANDA Barrel DIRC

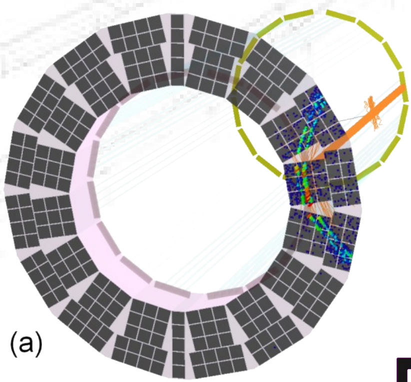
Baseline design

- DIRC: Detection of Internally Reflected Cherenkov light pioneered by BaBar
- Cherenkov detector with SiO_2 radiator
- Detected patterns give β of particles



Optimization and challenges

- Focusing by lenses/mirrors
- More compact design
- Magnetic field → MCP PMT
- Fast readout to suppress BG
- Plates as more economic radiator



Project status

- Baseline design verified
- Qualification of final design in 2015

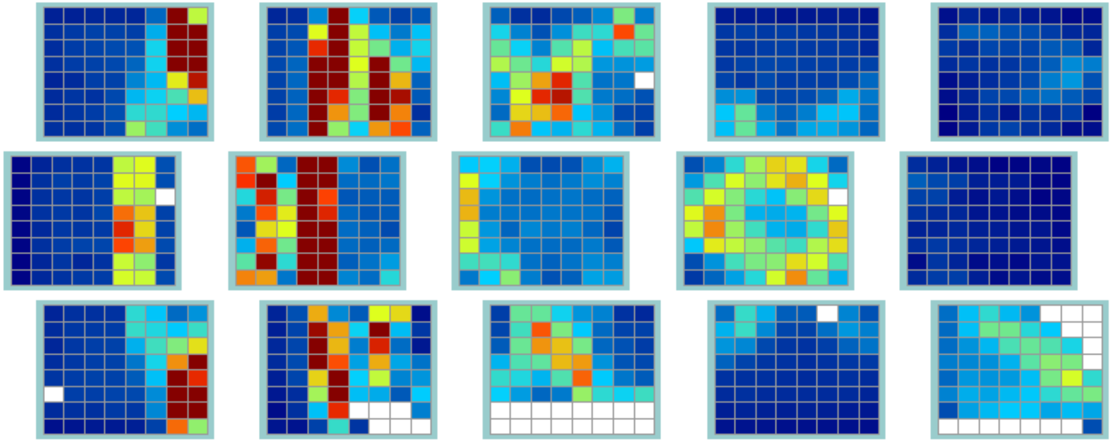
$\overline{\text{P}}$ANDA Barrel DIRC: Recent Results

Testbeam campaign at CERN T9

- 2 periods: 3+2 weeks May-July
- ToF reference at multi-hadron beam
- Readout with TRB3/PADIWA

Measurement program

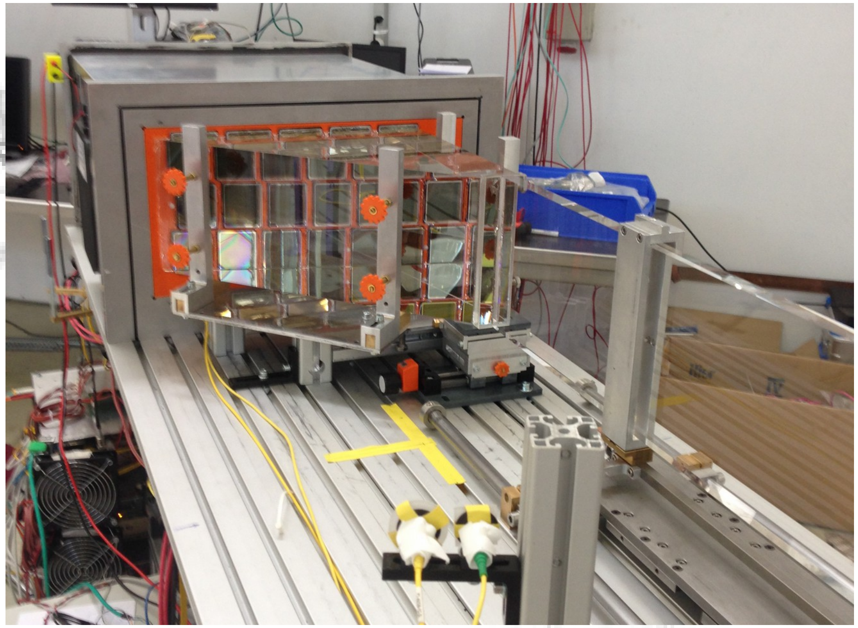
- Focusing by various lenses
- Prism as expansion volume
- Bars as baseline radiator
- Plate radiator as alternative



Outlook

- Data analysis ongoing
- Results for design choice until end 2015
- TDR draft end 2015

$\overline{\text{P}}$ANDA Barrel DIRC: Recent Results



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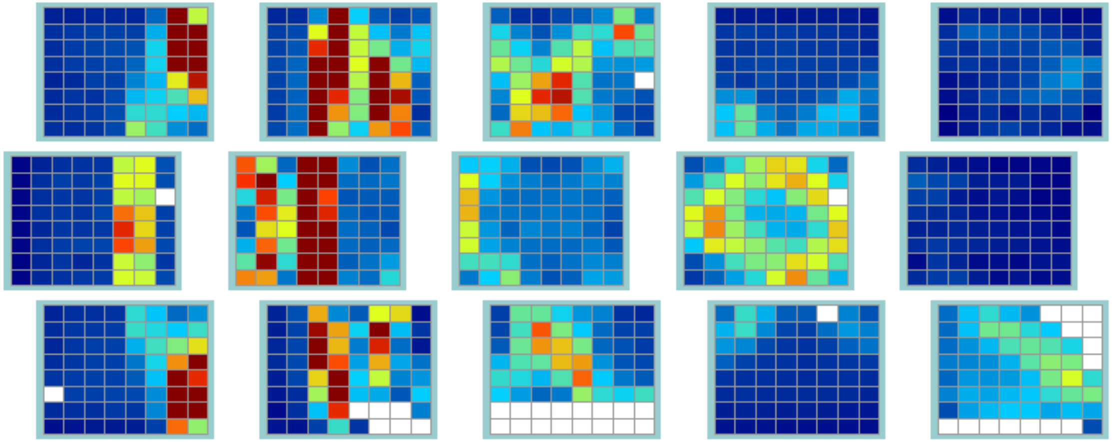

Outlook

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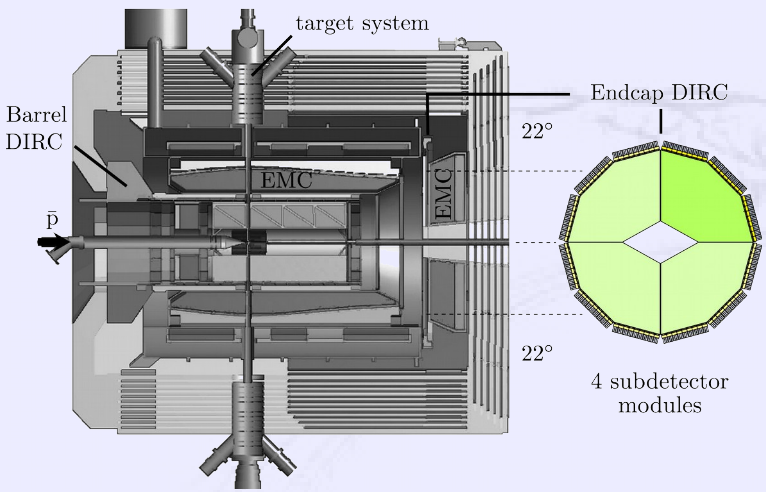
- Results for design choice until end 2015
- TDR draft end 2015

$\overline{\mathrm{P}}$ANDA Disc DIRC

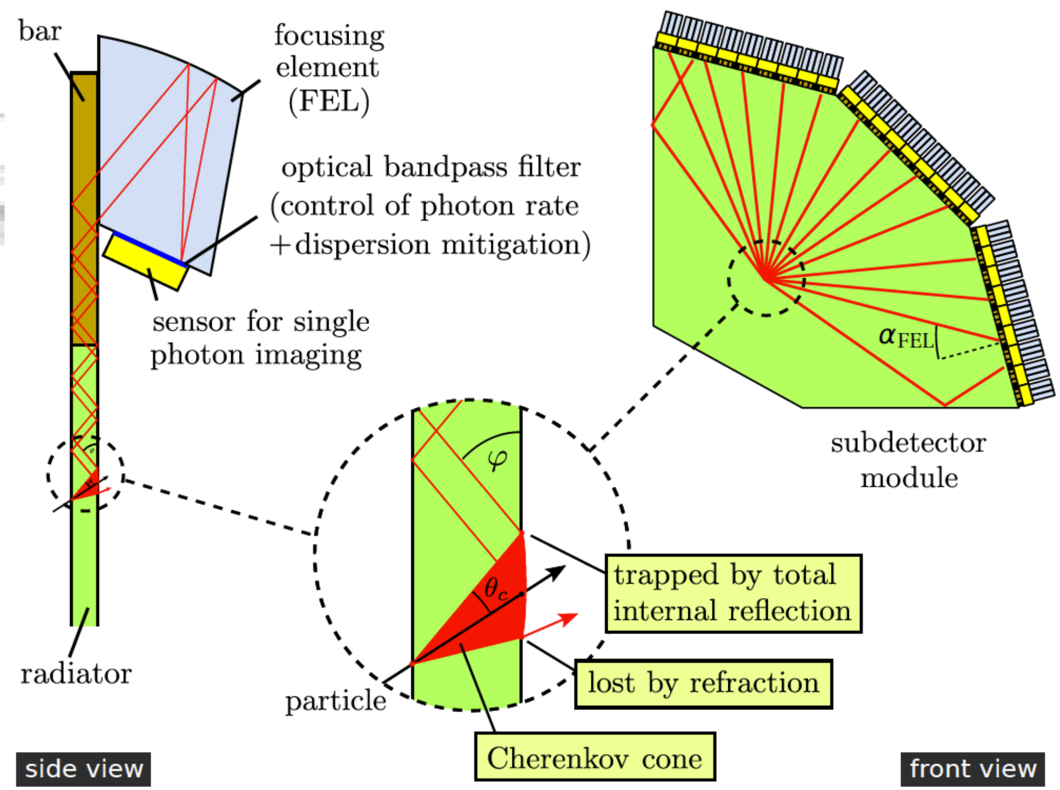


Novel concept for forward PID

- Based on DIRC principle
- Disc shaped radiator
- Readout at the disc rim

Project status:

- Advanced design, first tests
- Review with external experts
- Next: full quarter disc prototype



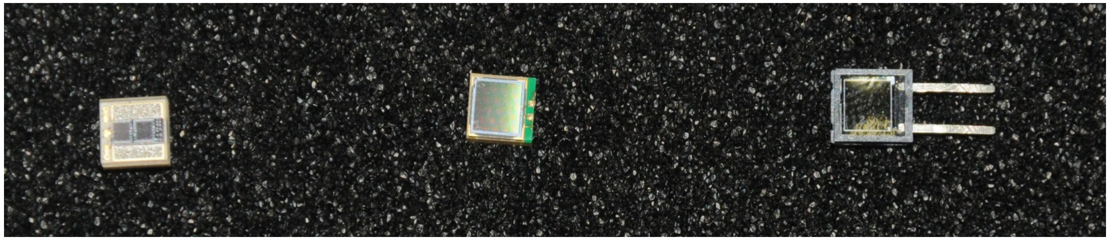
Basic components:

- SiO_2 radiator disc
- Focusing element
- Optical bandpass filter
- MCP PMT for photon readout in magnetic field
- ASIC for electronic readout

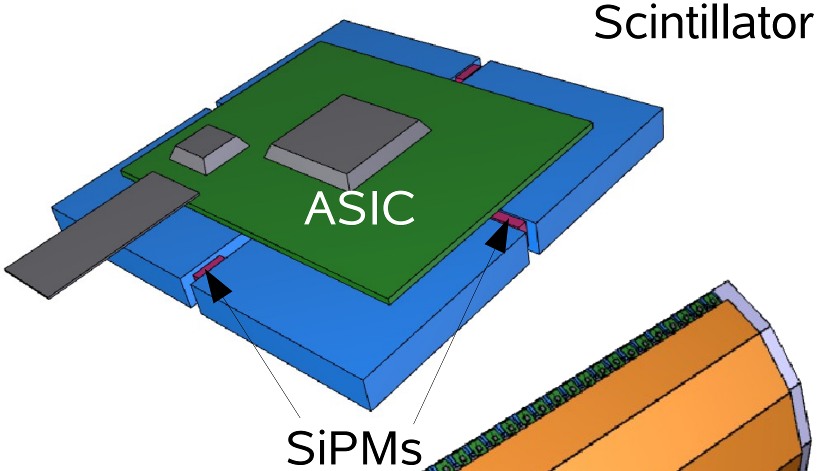
Scintillator Tile Hodoscope

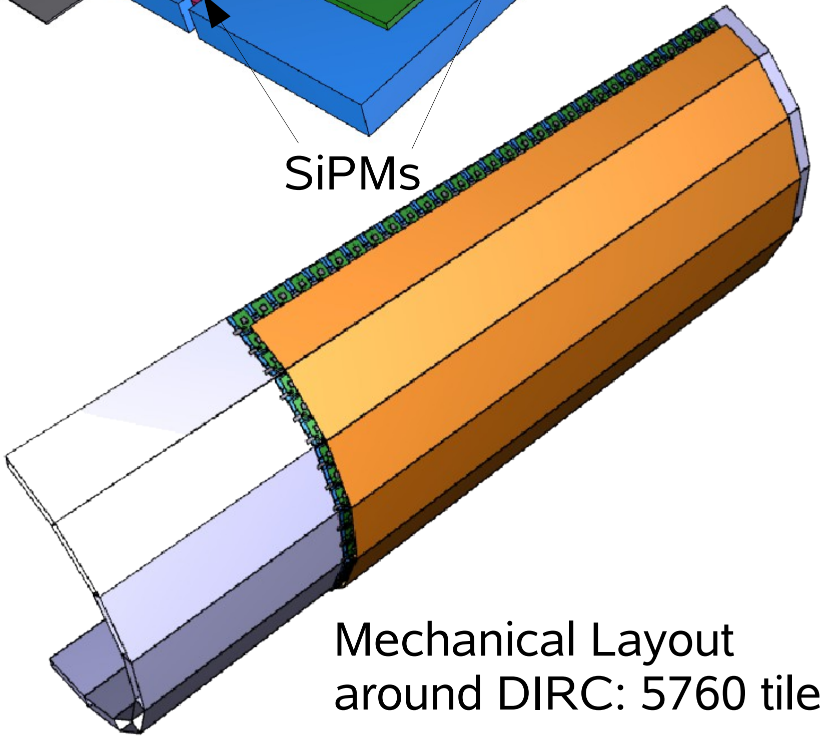
Detector for ToF and event timing

- Scintillator tiles 3x3x0.5 cm^3
  - BC404, BC408 or BC420
  - Space points with precision timing
  - Lowest possible material budget
- Photon readout with 2 SiPMs (3x3 mm^2)
  - High PDE, time resolution, rate capability
  - Work in B-fields, small, robust, low bias
  - *High intrinsic noise*
  - *Temperature dependence*
- Goal for time resolution: 100 ps
- ASIC for SiPM readout



Quad Module



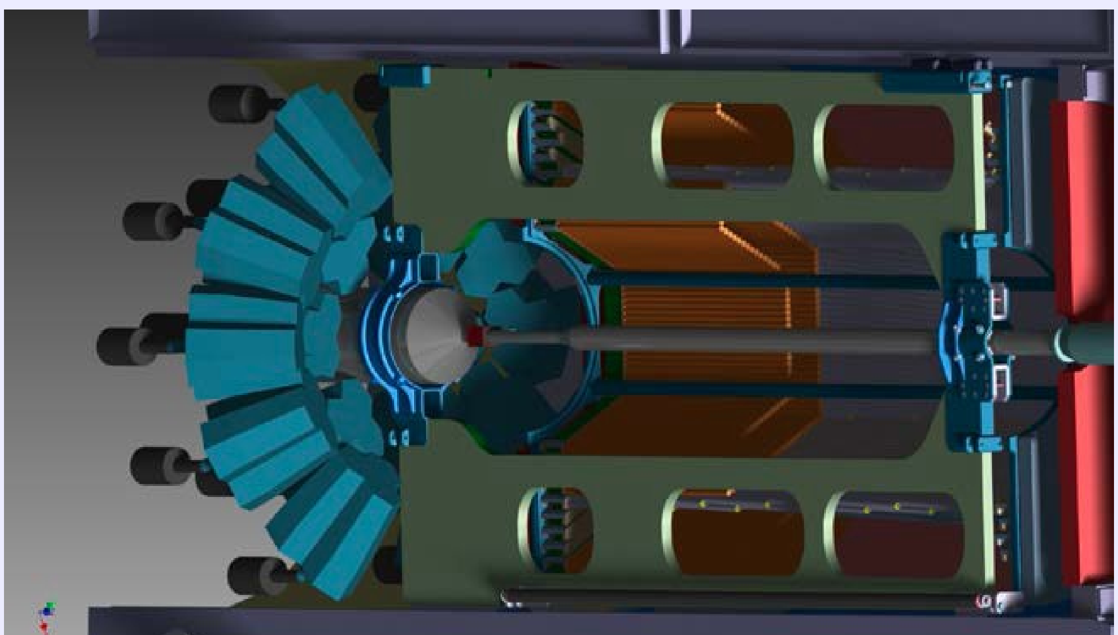


Mechanical Layout
around DIRC: 5760 tiles

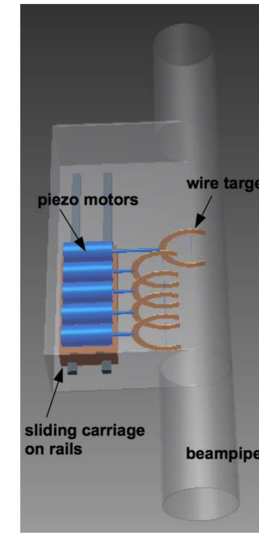
Hypernuclear Setup

Principle:
- Produce hypernuclei from captured Ξ

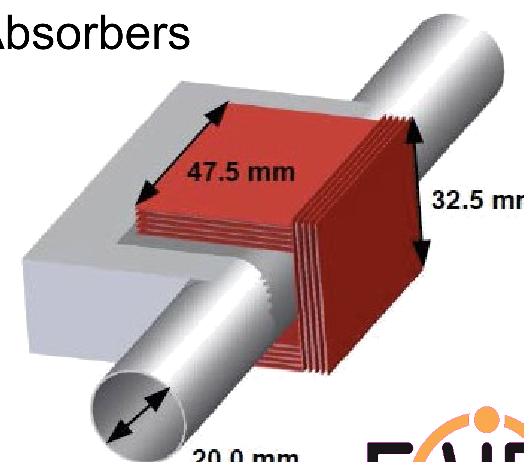
Modified Setup:
- Primary retractable wire/foil target
- Secondary active target to capture Ξ and track products with Si strips
- HP Ge detector for γ-spectroscopy



Primary Target:
- Diamond wire
- Piezo motored wire holder



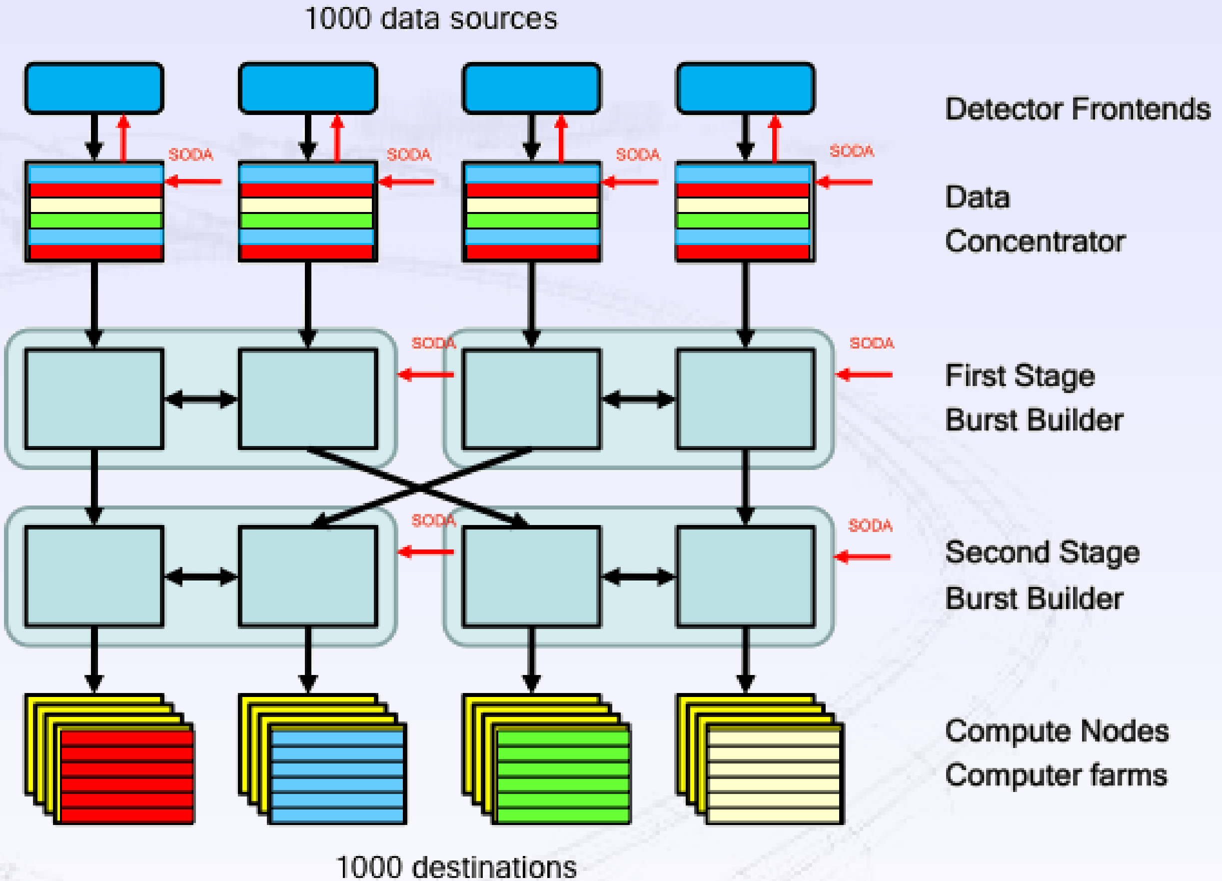
Active Secondary Target:
- Silicon microstrips
- Absorbers



$\overline{\text{P}}$ANDA 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**

DAQ chain tested with time distribution system, frontend and concentrator

PANDA TDR Schedule

Submission 2015:

- Forward Shashlyk: June 17
- Q4: Luminosity Detector
- Q4: Forward Time of Flight
- Q4: Forward Tracking
- Q4: Pellet Target Addendum

Submission early 2016:

- GEM Tracker
- Detector Controls

Submission 2016/17:

- Barrel DIRC
- Hypernuclear Setup
- SciTil / Barrel ToF
- DAQ and Computing
- Disc DIRC

System	Submission *Expected*	M3 (Approval) *Expected*
Target Spectrometer EMC		08/08/2008
Barrel EMC		08/08/2008
Backward Endcap EMC		08/08/2008
Forward Endcap EMC		08/08/2008
Solenoid		05/21/2009
Dipole		05/21/2009
Micro Vertex Detector (MVD)		02/26/2013
Straw Tube Tracker (STT)		01/29/2013
Cluster Jet Target		08/28/2013
Muon System		09/22/2014
Forward Shashlyk Calorimeter	17/6/2015	*12/2015*
Luminosity Detector	*10/2015*	*3/2016*
Forward TOF	*12/2015*	*6/2016*
Forward Tracking	*12/2015*	*6/2016*
Barrel DIRC	*6/2016*	*12/2016*
Hypernuclear Setup	*3/2016*	*09/2016*
Pellet Target	*6/2016*	*12/2016*
Controls	*6/2016*	*12/2016*
Planar GEM Trackers	*9/2016*	*3/2017*
Barrel Time of Flight (TOF)	*9/2016*	*3/2017*
DAQ	*9/2016*	*3/2017*
Computing	*9/2016*	*3/2017*
Endcap Disc DIRC	*6/2017*	*12/2017*
Silicon Lambda Disks	tba	tba
Forward RICH	tba	tba

tba: to be announced Status 11/7/2015

For the items “Interaction Region”, “Supports” and “Supplies” no TDRs are planned, only specification documents.

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Forward Shashlyk Calorimeter	17/6/2015	*[illegible]2015*
Luminosity Detector	*10/2015*	[illegible]
Forward TOF	*12/2015*	*6/2[illegible]*
Forward Tracking	*12/2015*	*6/201[illegible]*
Barrel DIRC	*6/2016*	*12/2016*
Hypernuclear Setup	*3/2016*	*09/2016*
Pellet Target	*6/2016*	*12/2016*
Controls	*6/2016*	*12/2016*
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Computing	*9/2016*	*3/2017*
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Silicon Lambda Disks	tba	tba
Forward RICH	tba	tba

tba: to be announced Status 11/7/2015

Approved TDRs cover 71 % of costs (*)

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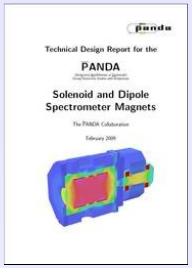
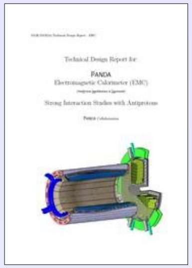
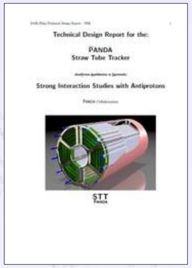
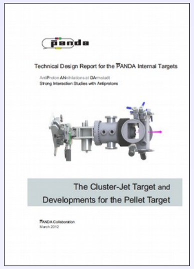
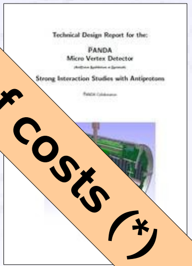
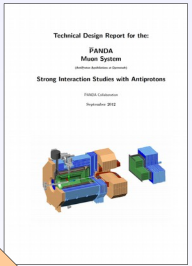


Summary

Present Status of PANDA

- Several systems head for TDR submission
- Preparation for Construction MoU
- Physics and detector topics

Timeline of PANDA

- Most TDRs to complete by end 2016
- Start of construction in 2014 for some systems
- Start of possible preassembly at Jülich in 2015
- Ready for mounting at FAIR by 2019

PANDA & FAIR start in hadron physics from 2022

- Versatile physics machine with full detection capabilities
- PANDA will shed light on many of today's QCD puzzles
- Beyond PANDA further plans for spin physics at FAIR exist

The $\overline{\text{P}}$ANDA Collaboration

More than 520 physicists from 67 institutions in 18 countries

Aligarh Muslim University
U Basel
IHEP Beijing
U Bochum
Magadh U, Bodh Gaya
BARC Mumbai
IIT Bombay
U Bonn
IFIN-HH Bucharest
U & INFN Brescia
U & INFN Catania
NIT, Chandigarh
AGH UST Cracow
JU Cracow
U Cracow
IFJ PAN Cracow
GSI Darmstadt

Karnatak U, Dharwad
TU Dresden
JINR Dubna
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara
FIAS Frankfurt
LNF-INFN Frascati
U & INFN Genova
U Glasgow
U Gießen
Birla IT&S, Goa
KVI Groningen
Sadar Patel U, Gujart
Gauhati U, Guwahati
IIT Guwahati

IIT Indore
Jülich CHP
Saha INP, Kolkata
U Katowice
IMP Lanzhou
INFN Legnaro
U Lund
U Mainz
U Minsk
ITEP Moscow
MPEI Moscow
U Münster
BINP Novosibirsk
IPN Orsay
U & INFN Pavia
IHEP Protvino
PNPI Gatchina

U of Sidney
U of Silesia
U Stockholm
KTH Stockholm
Suranree University
South Gujarat U, Surat
U & INFN Torino
Politechnico di Torino
U & INFN Trieste
U Tübingen
TSL Uppsala
U Uppsala
U Valencia
SMI Vienna
SINS Warsaw
TU Warsaw