Challenges in Instrumentation at the PANDA Experiment

Hadron 2013 Conference, Nara, November 8th 2013

Lars Schmitt, FAIR Darmstadt

- Antiprotons at FAIR
- PANDA Overview
- Selected Highlights
- Timeline and Conclusions

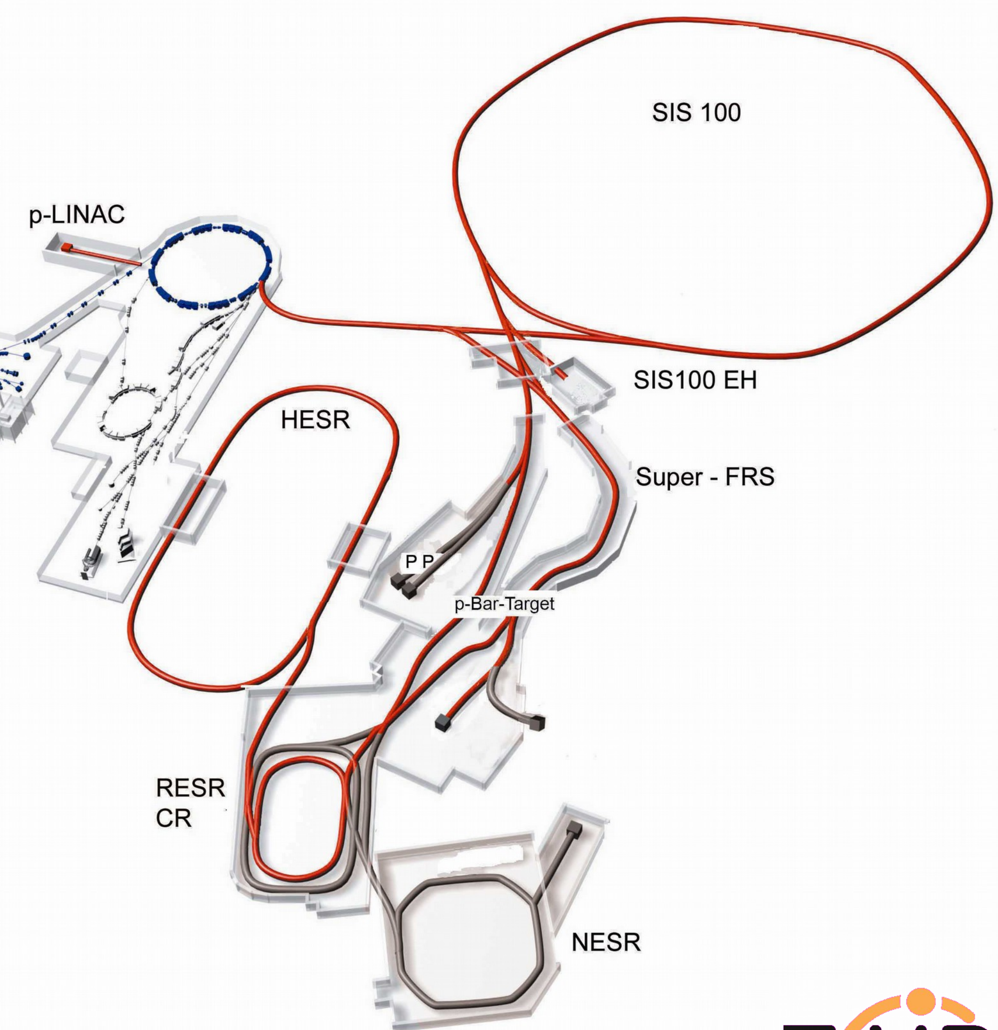
Facility for Antiproton and Ion Research

Four pillars of research at FAIR

- Applied, plasma and atomic physics, biophysics (APPA)
- Nuclear structure with RIB from Super-FRS (NUSTAR)
- Heavy ion physics at high baryon density (CBM)
- Hadron and nuclear physics with antiprotons (PANDA)

Antiprotons in FAIR

- Proton Linac 70 MeV
- Accelerate p in SIS100 to 30 GeV/c
- Produce $\bar{p}$ on Cu target
- Collect in CR, fast cooling
- Accumulate in RESR, slow cooling
- Start version: accumulate in HESR → 10x lower luminosity
- Store in HESR and use in PANDA



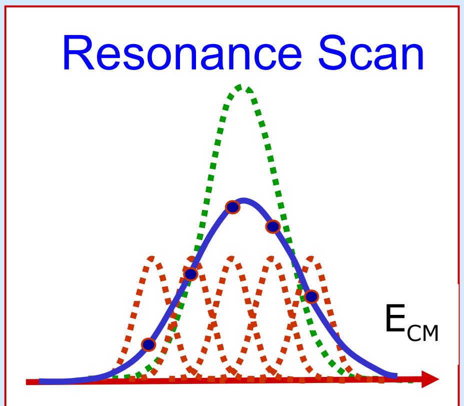
High Energy Storage Ring

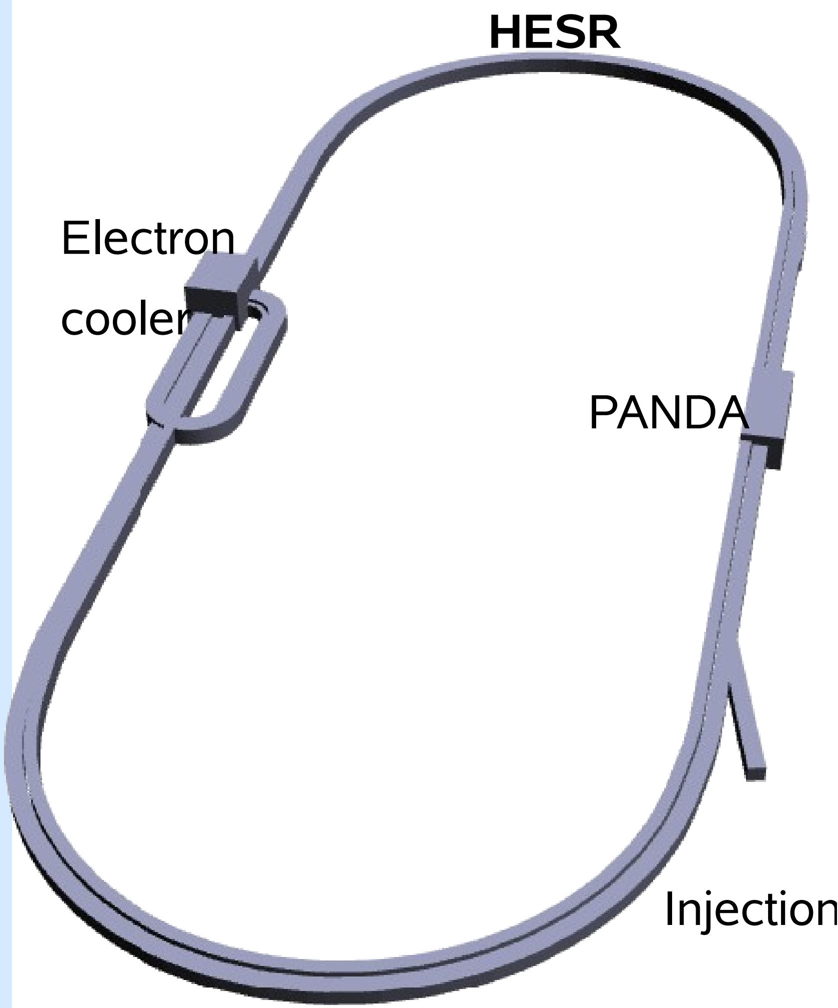
HESR Parameters

- Storage ring for internal target
- Luminosity up to L~ $2x10^{32}$ $cm^{-2}s^{-1}$
- Initially also accumulation (L 10x lower)
- Injection of $\bar{p}$ at 3.7 GeV/c
- Slow synchrotron (1.5-15 GeV/c)

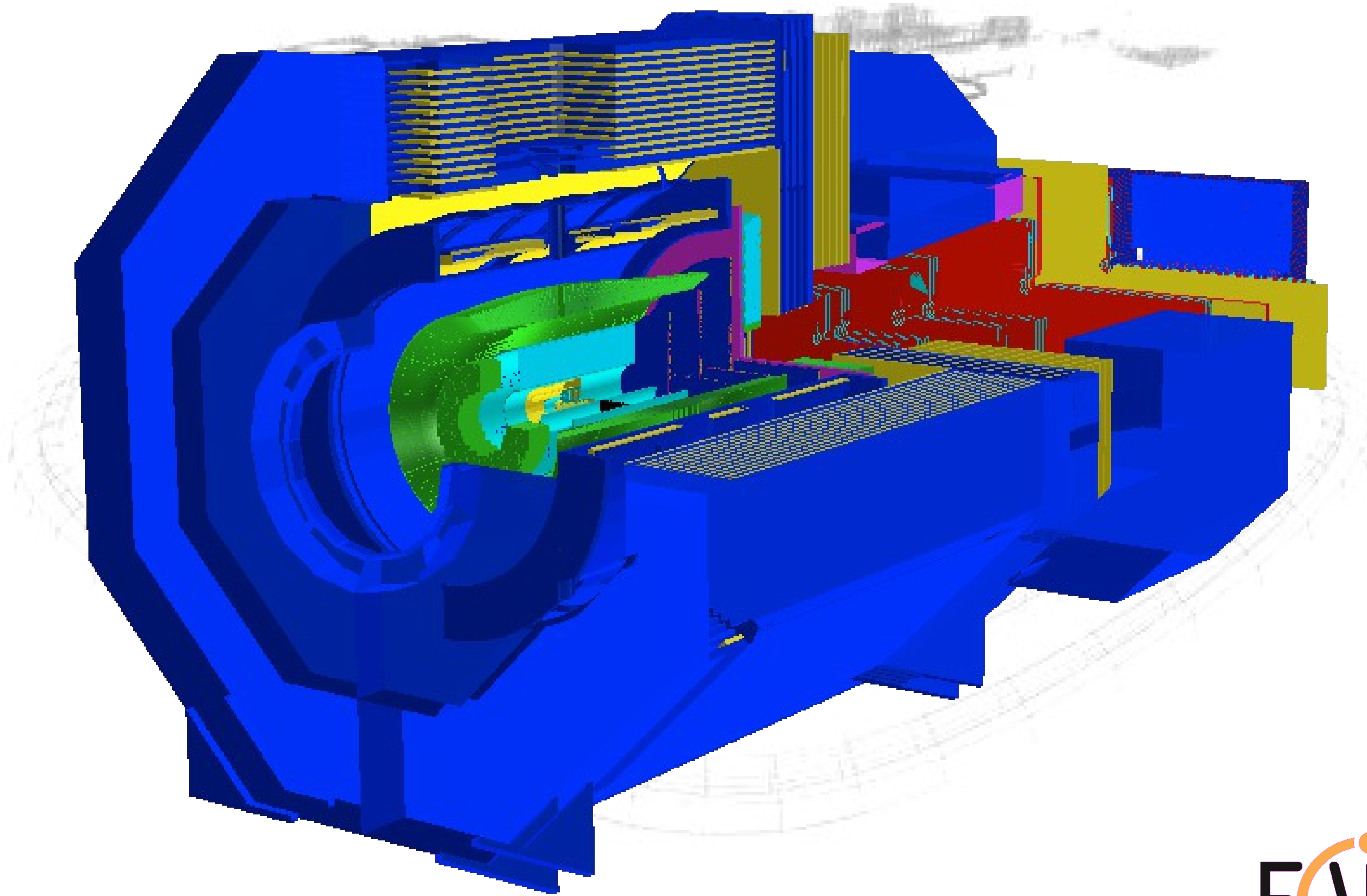
Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim 10^{-4}$	$\sim 4x10^{-5}$
L ($cm^{-2}s^{-1}$)	$2x10^{32}$	$2x10^{31}$
Stored $\bar{p}$	10^{11}	10^{10}

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





PANDA Overview



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

Hadron Spectroscopy

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

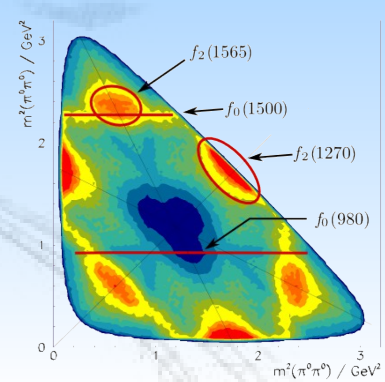
Charm Hadrons: *charmonia, D-mesons, charm baryons*

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

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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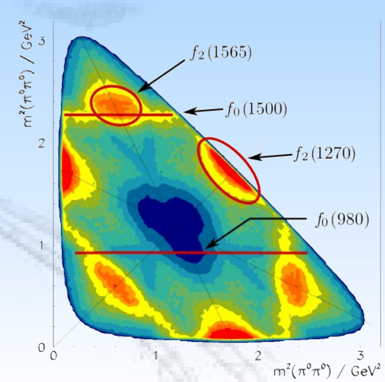


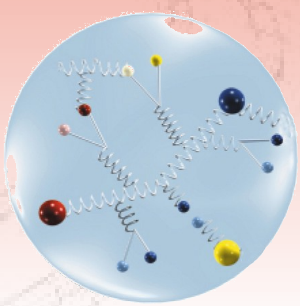
Hadron Structure

Generalized Parton Distributions

➔ Formfactors and structure functions, L_q

Timelike Nucleon Formfactors

Drell-Yan Process



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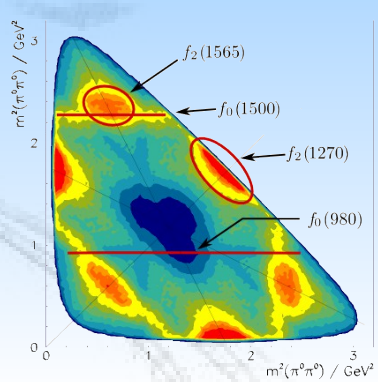

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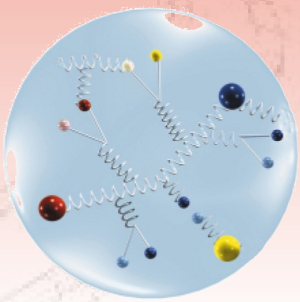
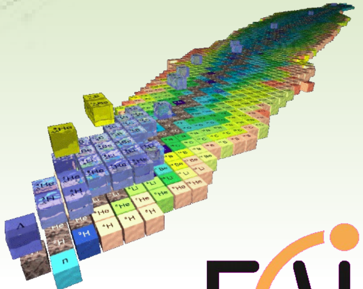


Nuclear Physics

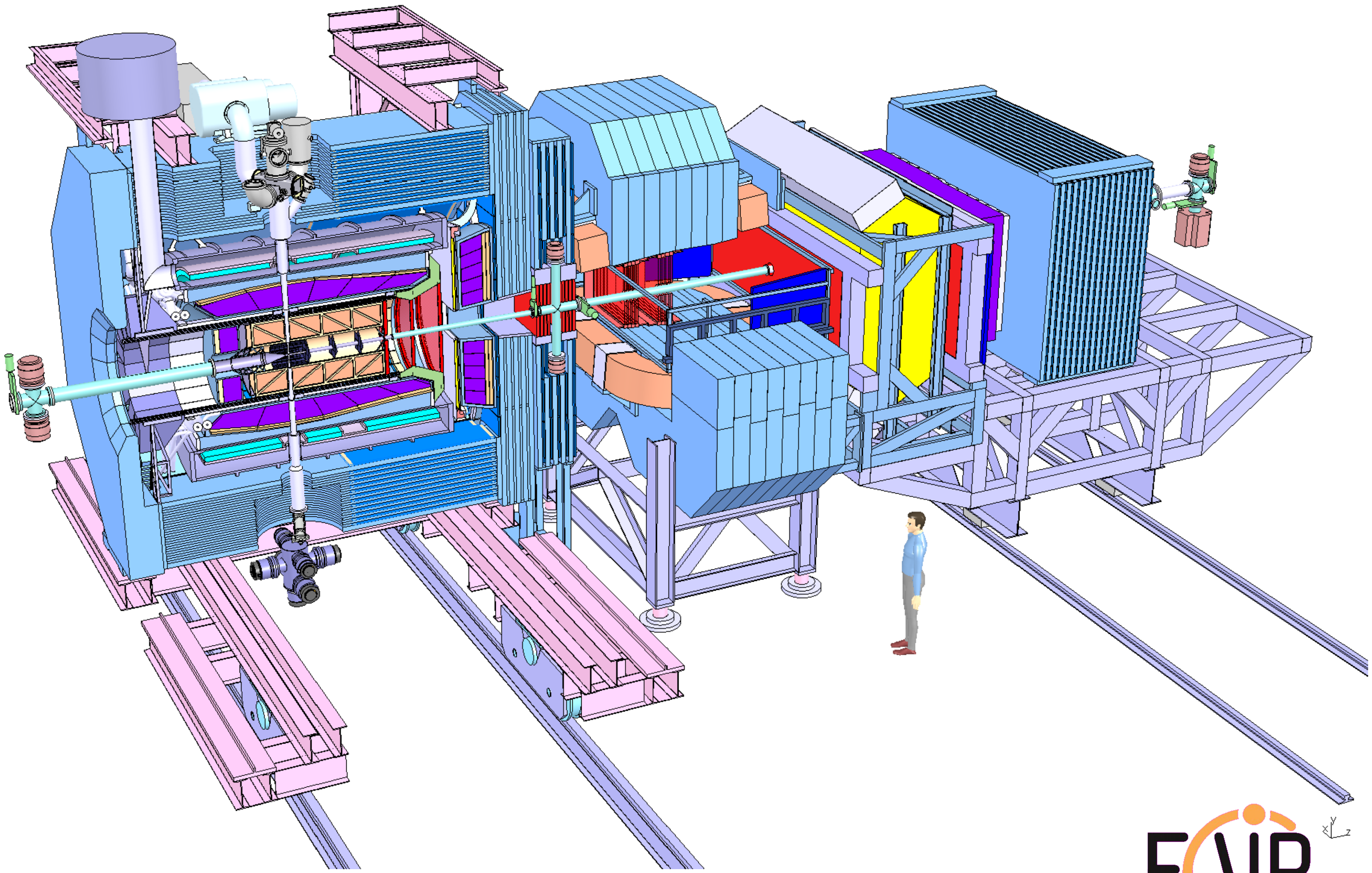
Hypernuclei*: Production of double Λ-hypernuclei*

➔ γ-spectroscopy of hypernuclei, YY interaction

Hadrons in Nuclear Medium



PANDA Spectrometer



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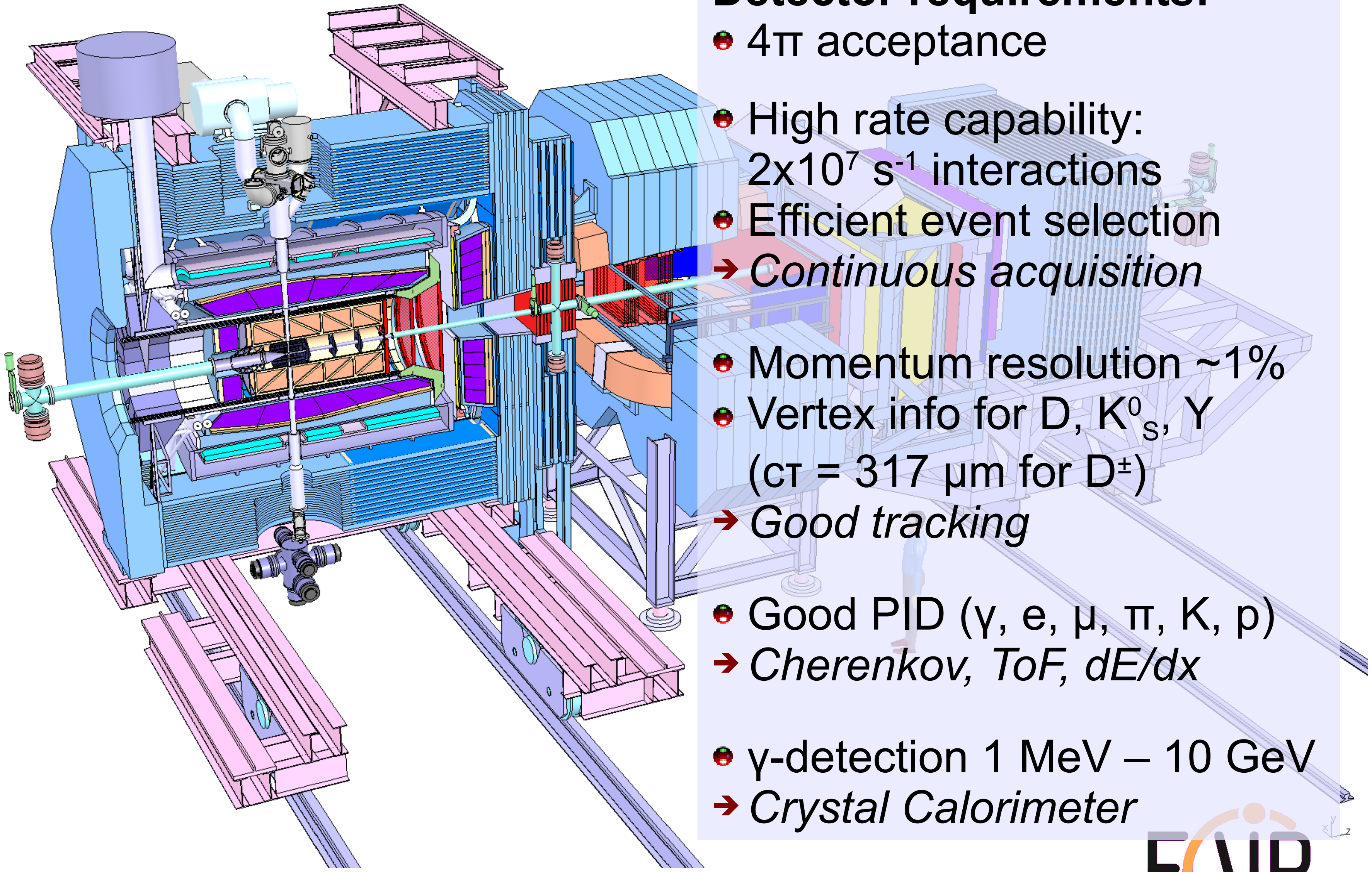

Detector requirements:

- 4π acceptance
- High rate capability: $2 \times 10^7\ s^{-1}$ 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 1 MeV – 10 GeV
  - ➔ *Crystal Calorimeter*

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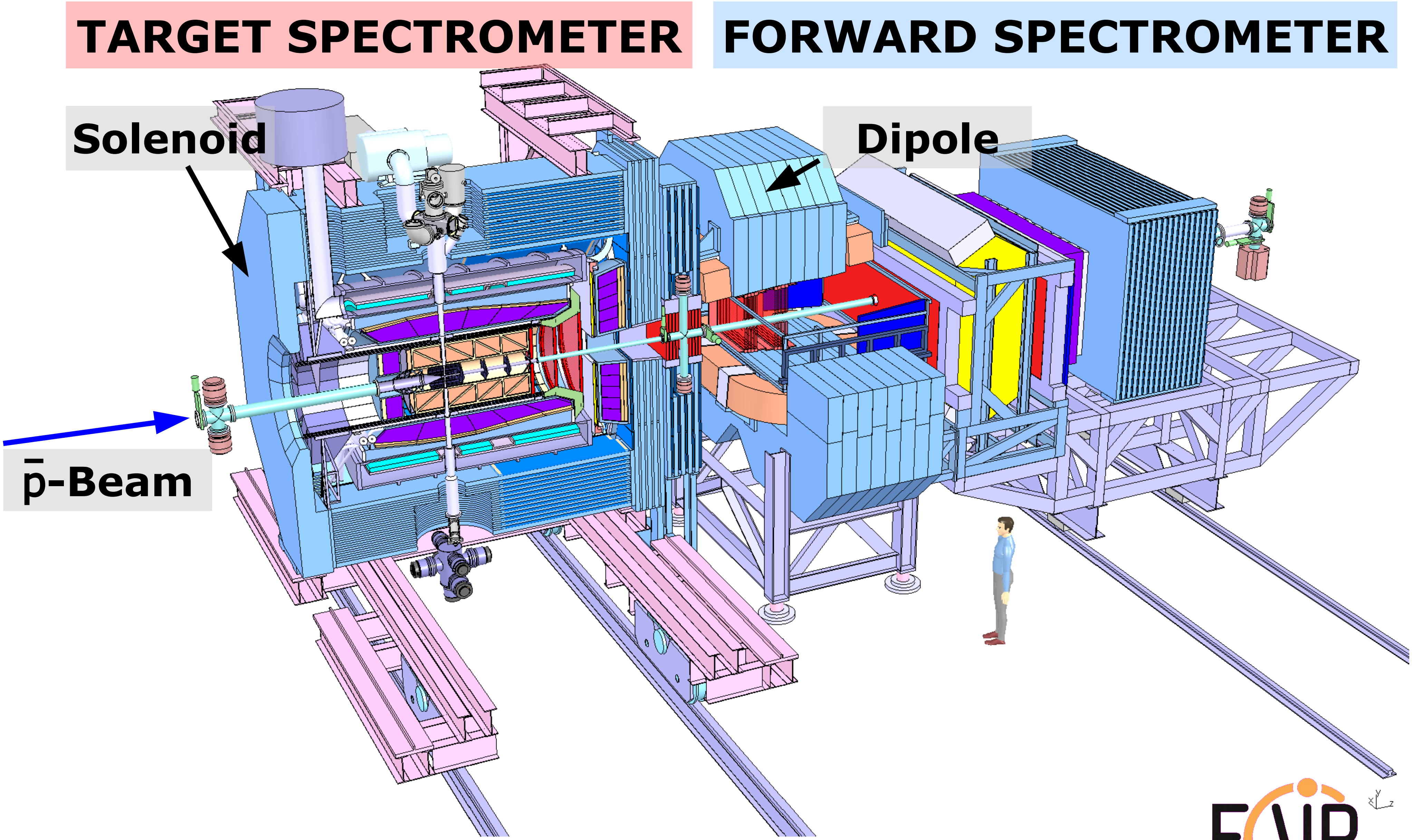
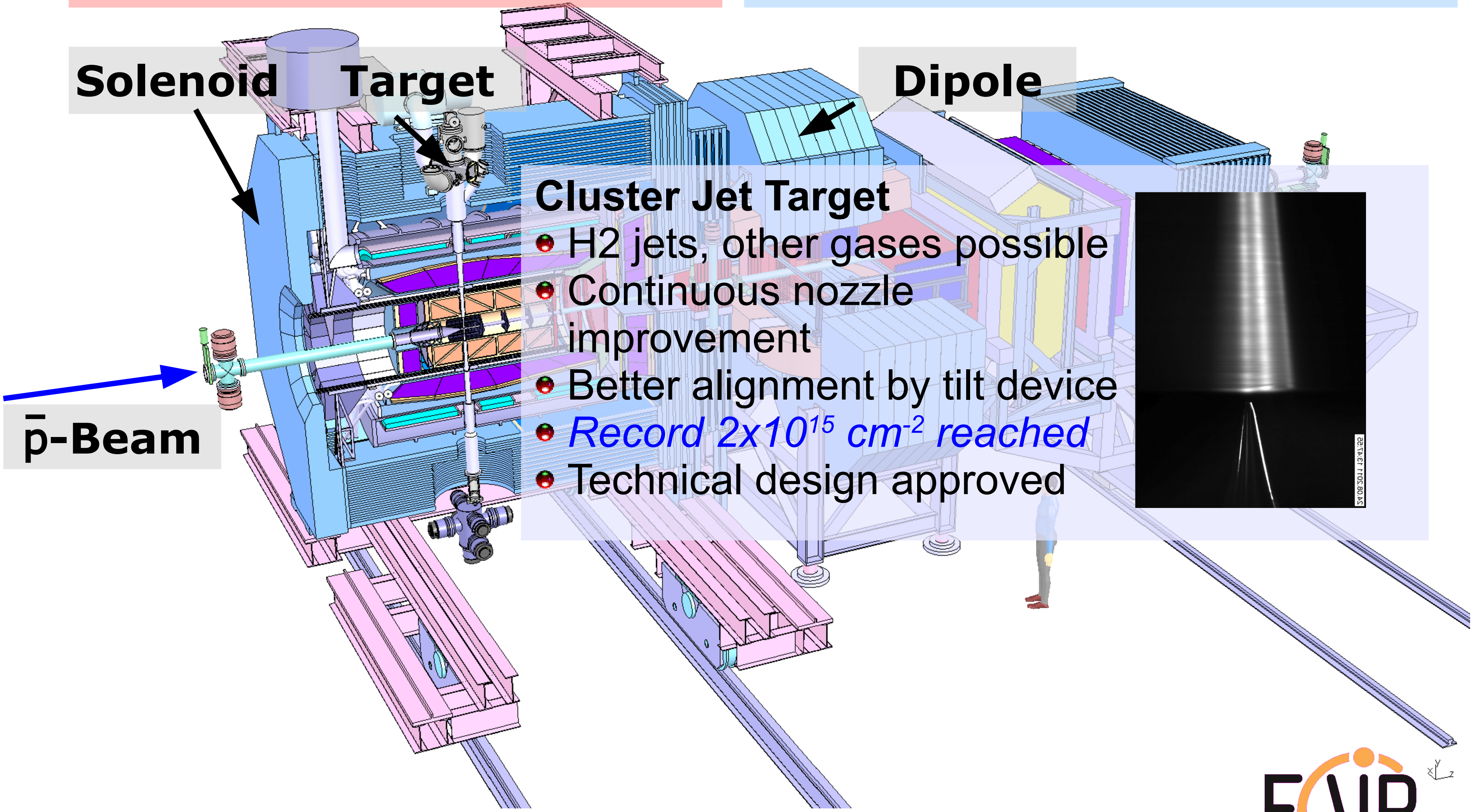


PANDA Spectrometer

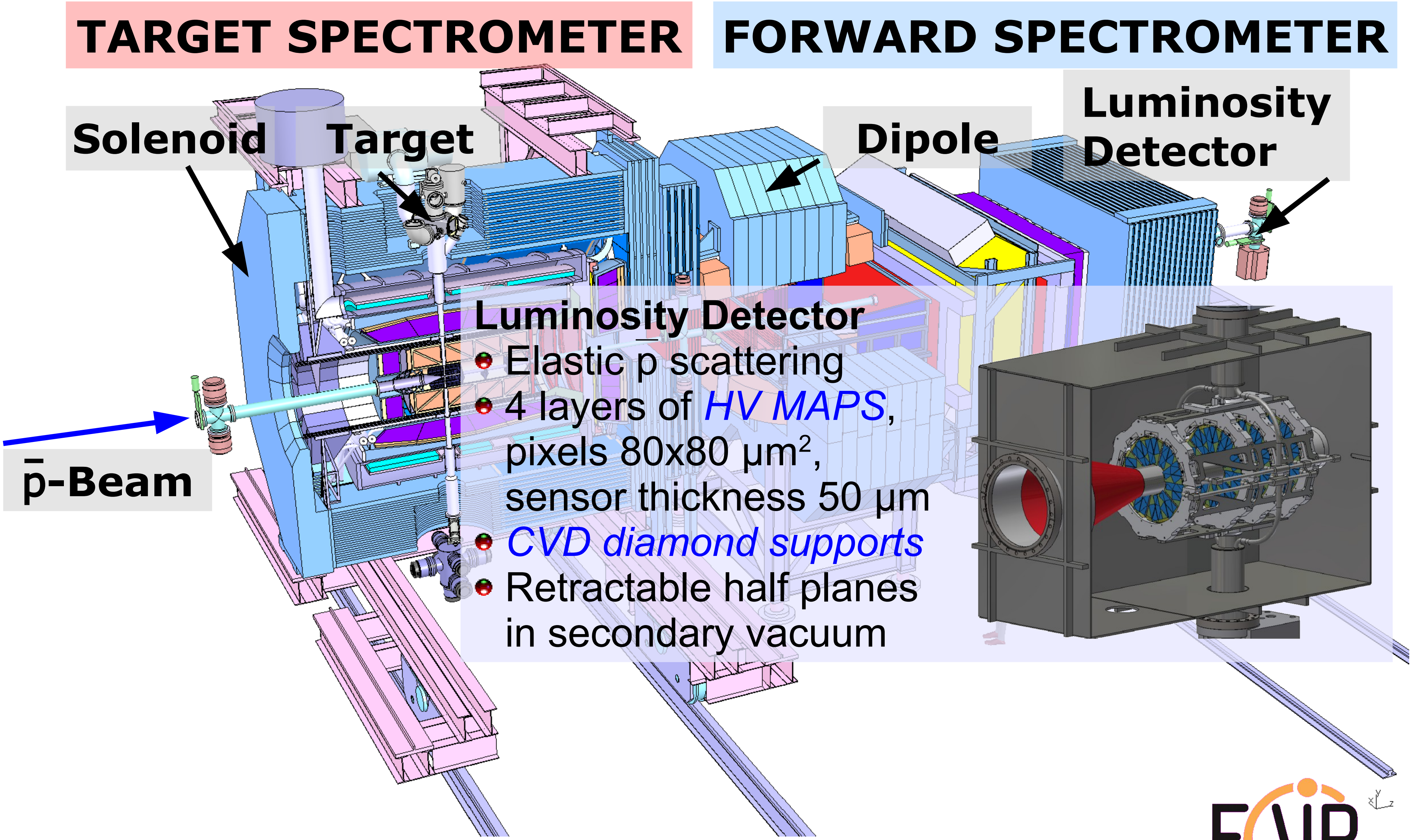
TARGET SPECTROMETER | FORWARD SPECTROMETER



Cluster Jet Target

- H2 jets, other gases possible
- Continuous nozzle improvement
- Better alignment by tilt device
- *Record $2x10^{15}$ cm^{-2} reached*
- Technical design approved

PANDA Spectrometer



Luminosity Detector

- Elastic $\bar{p}$ scattering
- 4 layers of *HV MAPS*, pixels 80x80 μm^2, sensor thickness 50 μm
- *CVD diamond supports*
- Retractable half planes in secondary vacuum

PANDA Spectrometer

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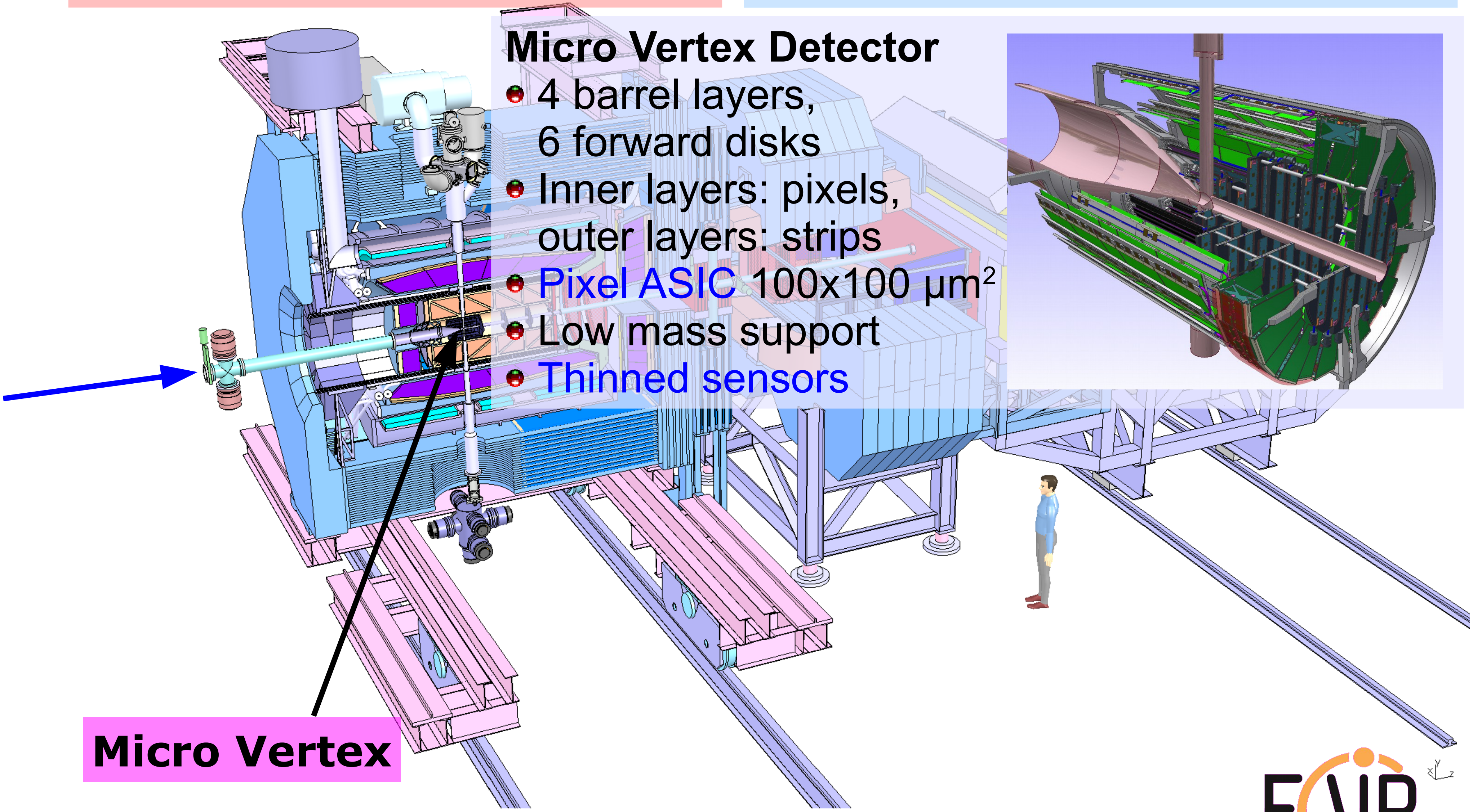
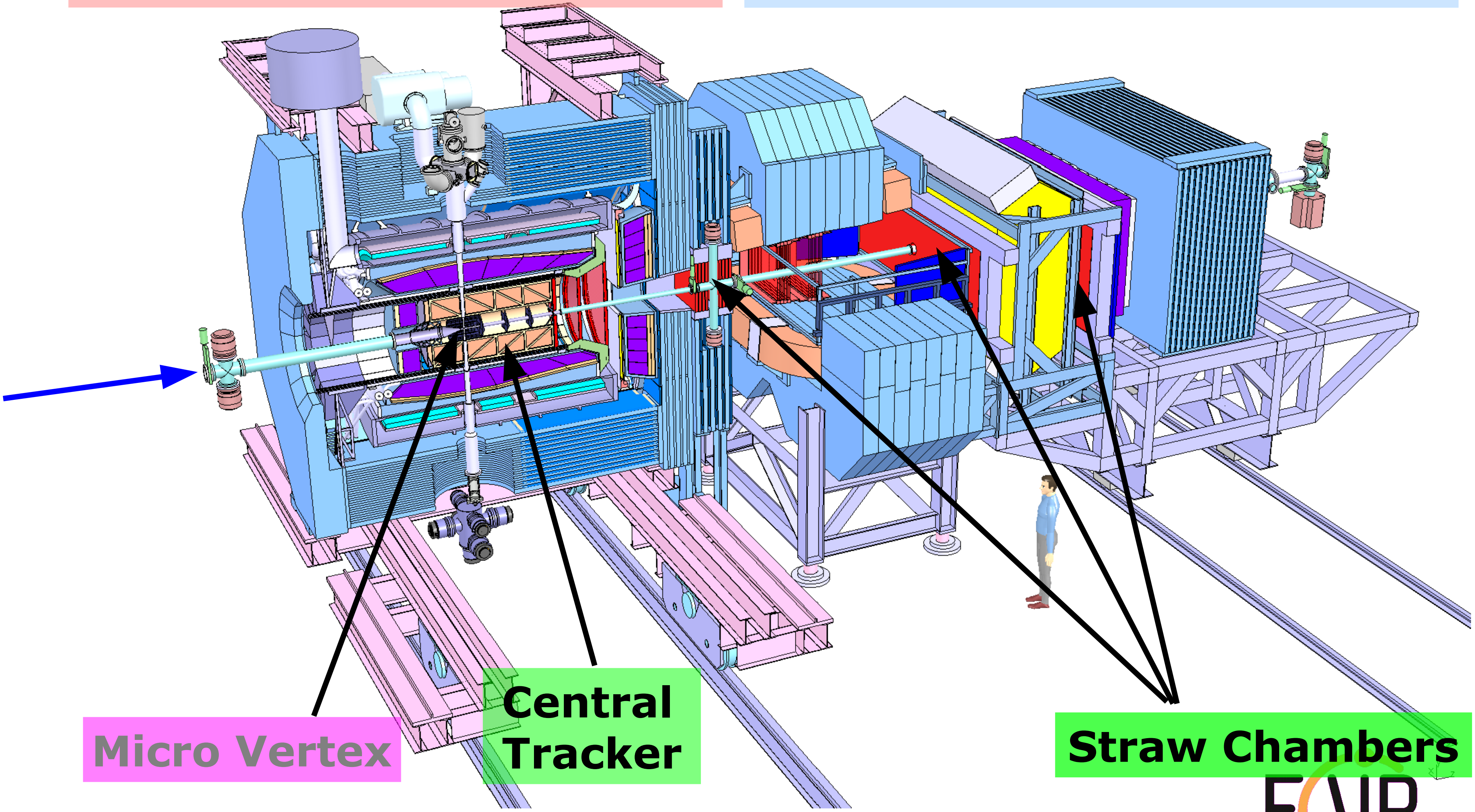


Micro Vertex Detector

- 4 barrel layers, 6 forward disks
- Inner layers: pixels, outer layers: strips
- Pixel ASIC 100x100 μm^2
- Low mass support
- Thinned sensors

PANDA Spectrometer



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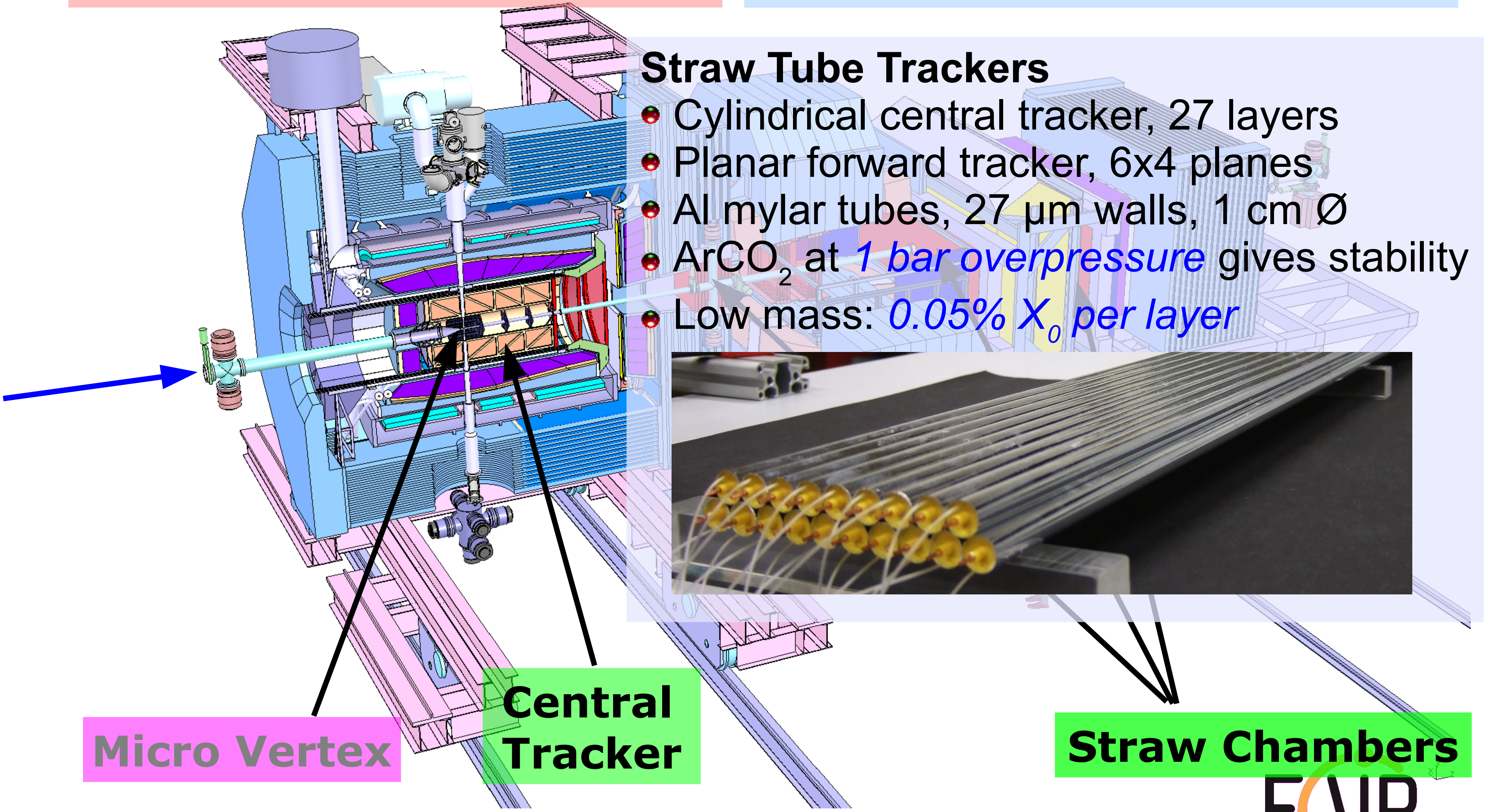
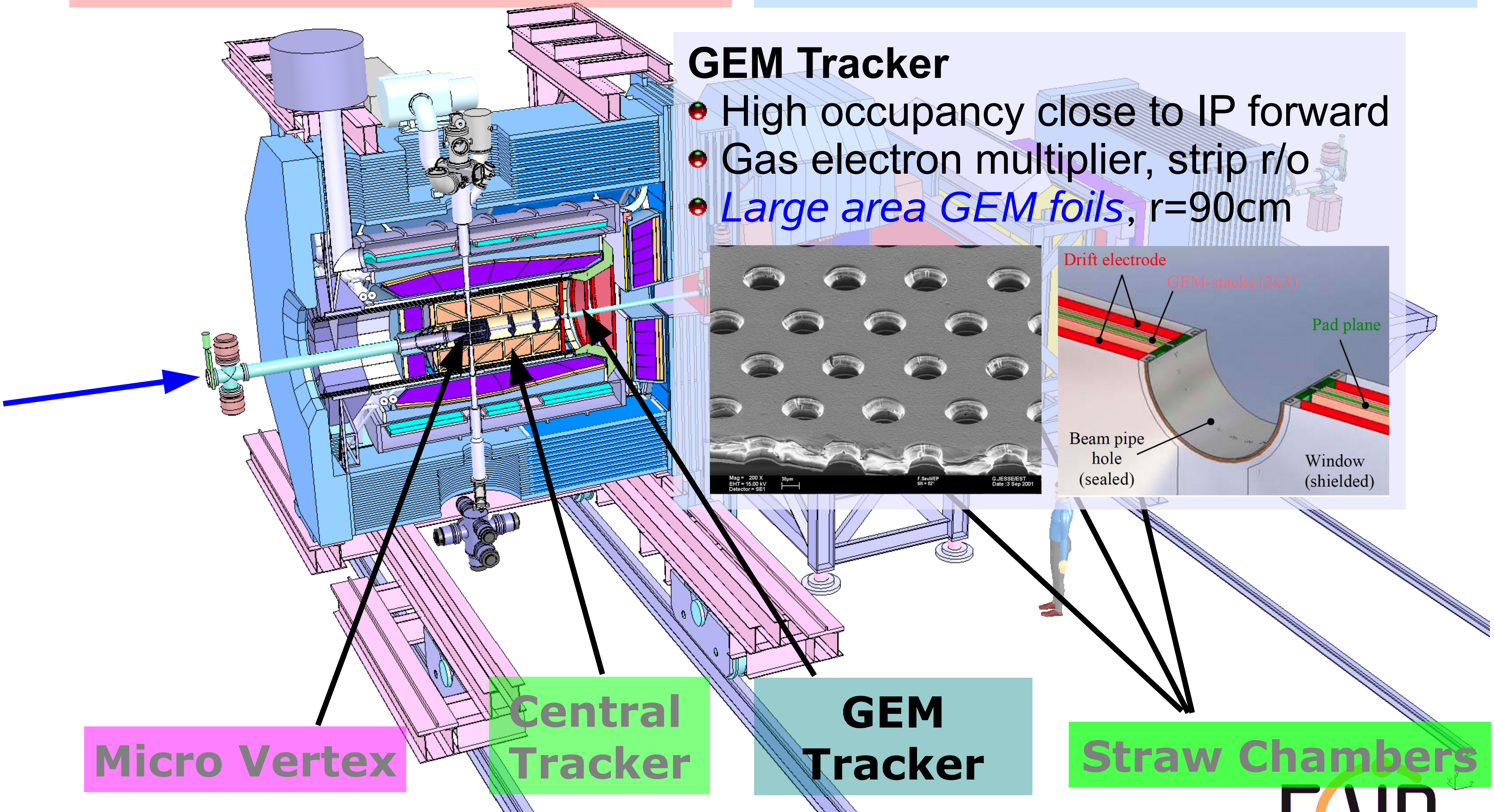


Straw Tube Trackers

- Cylindrical central tracker, 27 layers
- Planar forward tracker, 6x4 planes
- Al mylar tubes, 27 µm walls, 1 cm Ø
- $ArCO_2$ at *1 bar overpressure* gives stability
- Low mass: *0.05% X_0 per layer*

PANDA Spectrometer

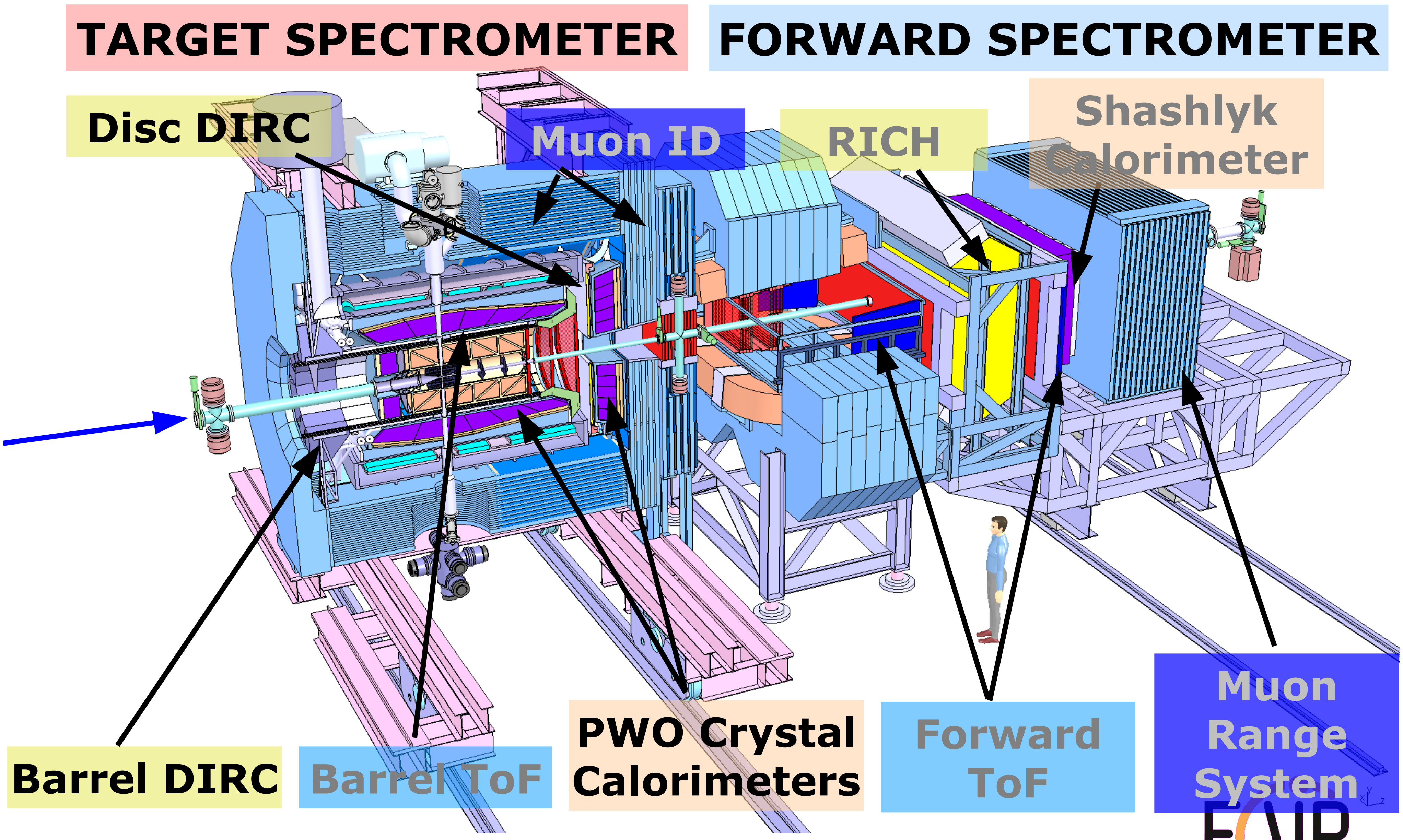
TARGET SPECTROMETER | **FORWARD SPECTROMETER**



GEM Tracker

- High occupancy close to IP forward
- Gas electron multiplier, strip r/o
- *Large area GEM foils*, r=90cm

PANDA Spectrometer



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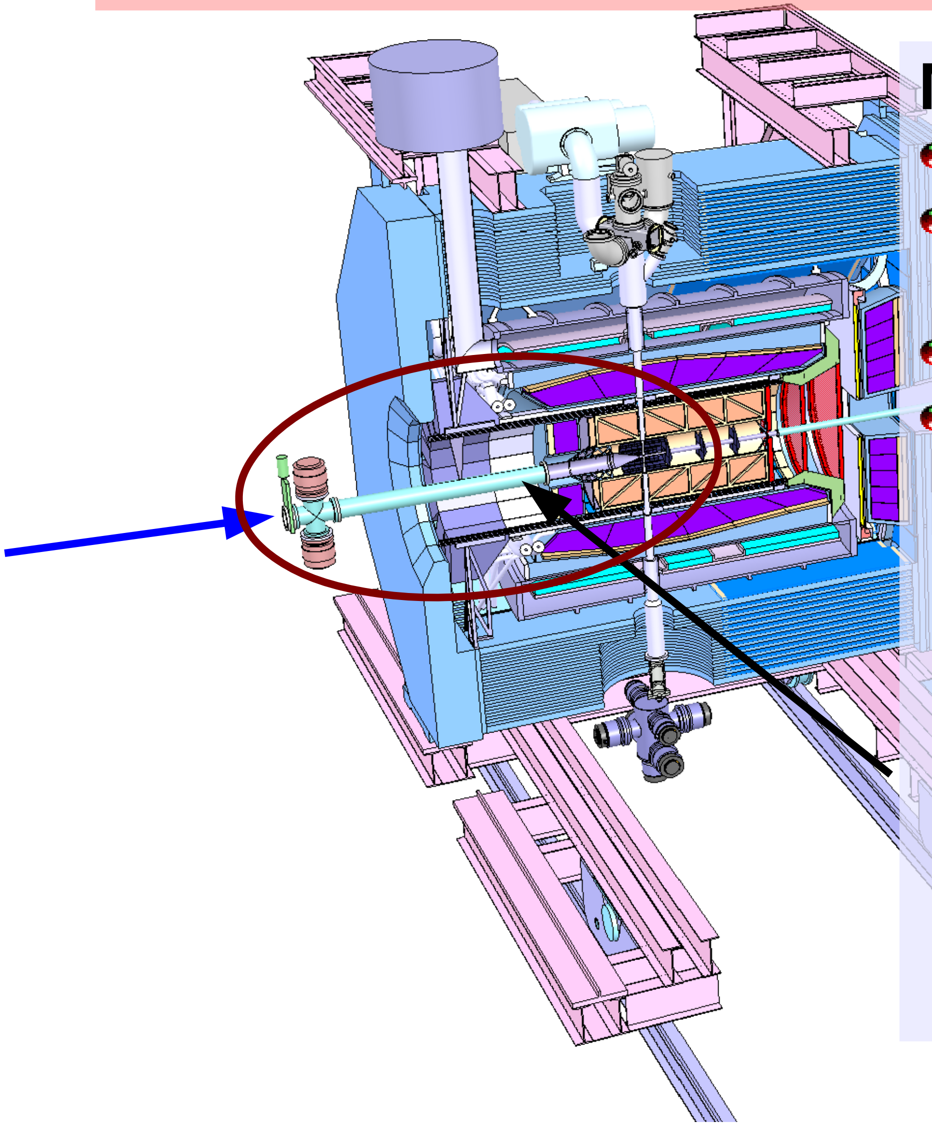
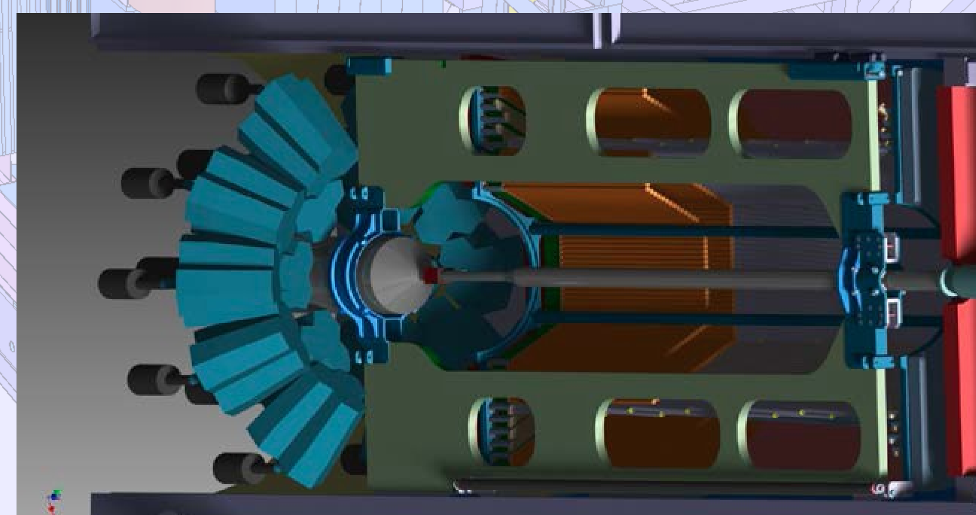
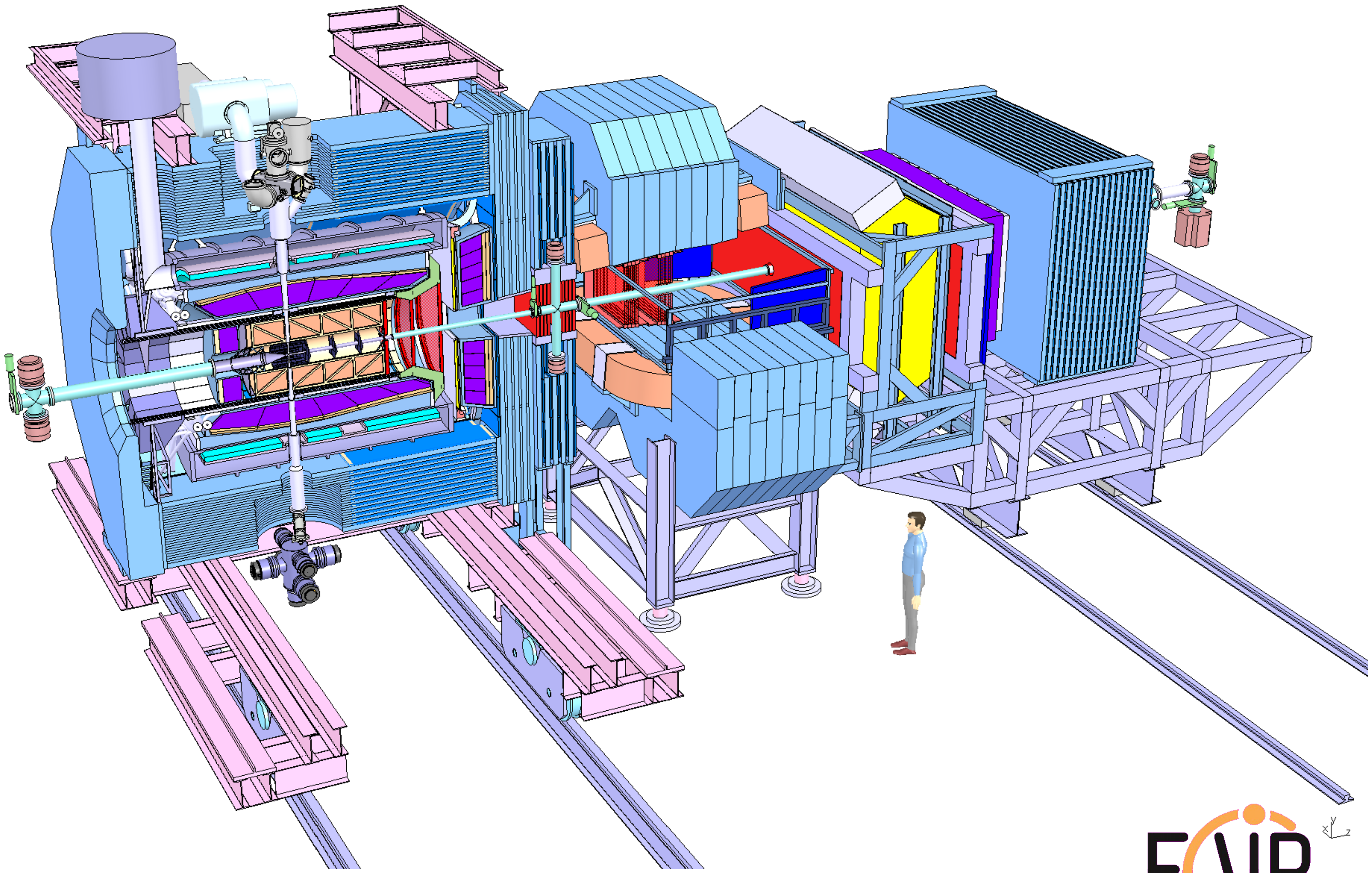


Modified Hypernuclear Setup

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

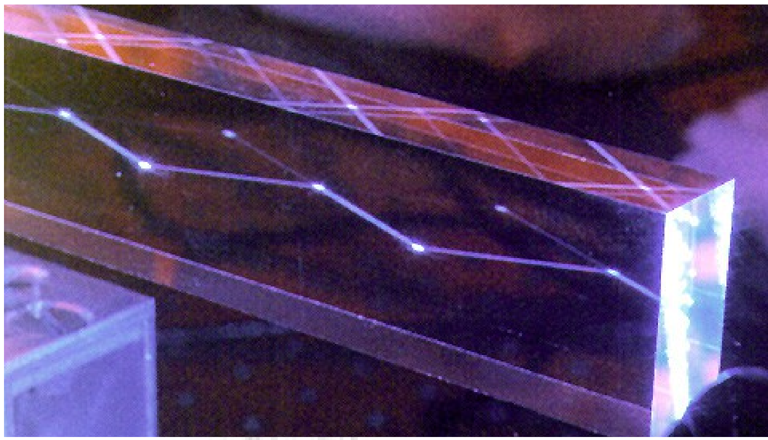


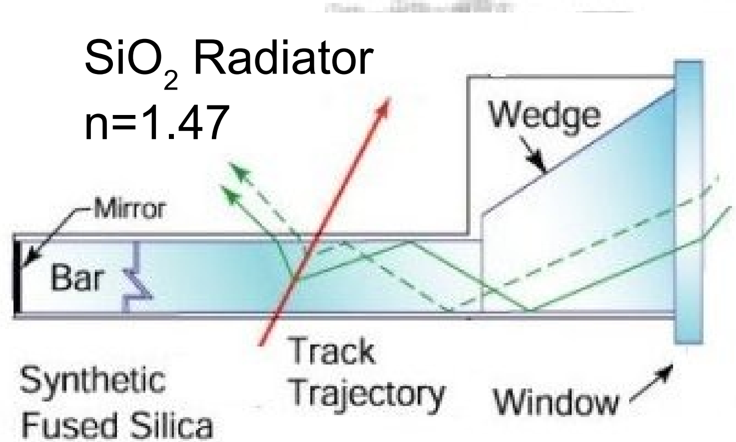
Selected Highlights

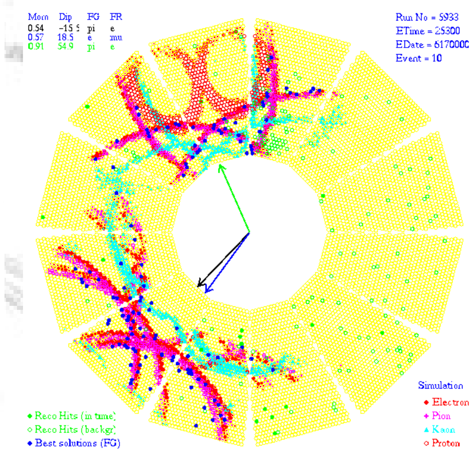


$\overline{\mathrm{P}}$ANDA DIRC Detectors

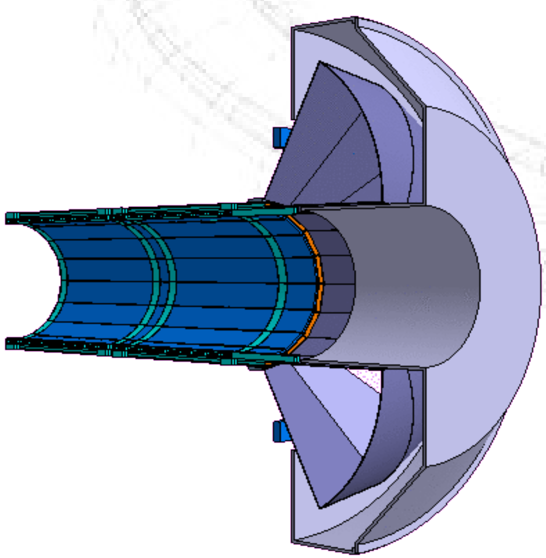
Detection of Internally Reflected Cherenkov light







BaBar type Barrel DIRC



- Pin hole focusing
- Large water tank
- Readout with PMTs (BaBar 11000, $\overline{\mathrm{P}}$ANDA 7000)

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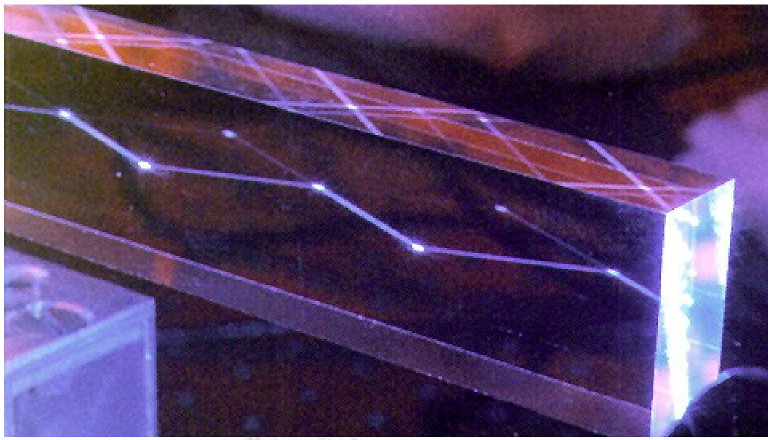
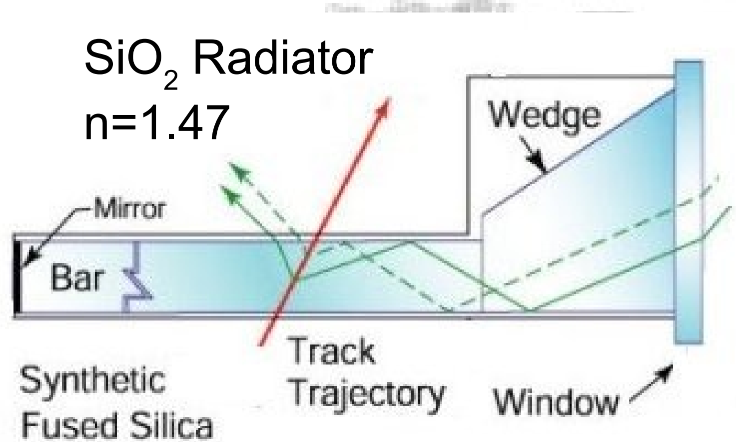
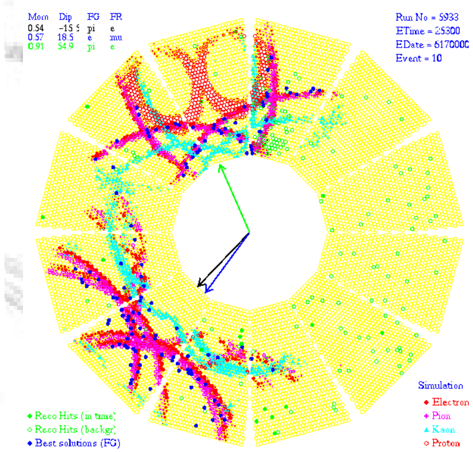
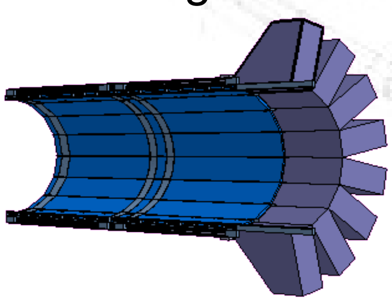






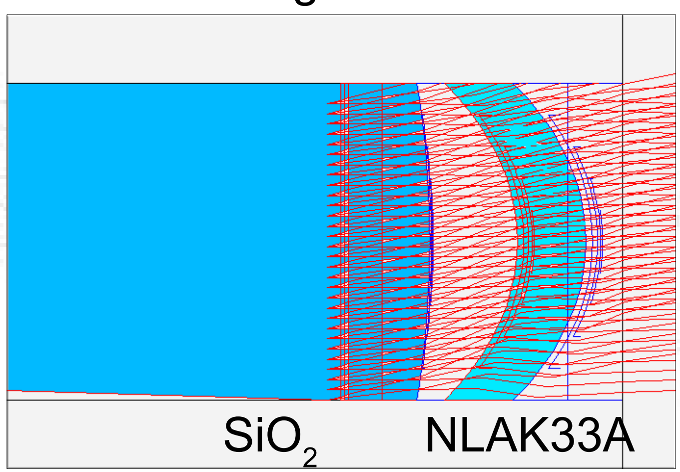
$\overline{\text{P}}$ANDA Barrel DIRC

- Shorter radiator
- No large tank



- Faster photo sensor

Focusing with lenses



n=1.75

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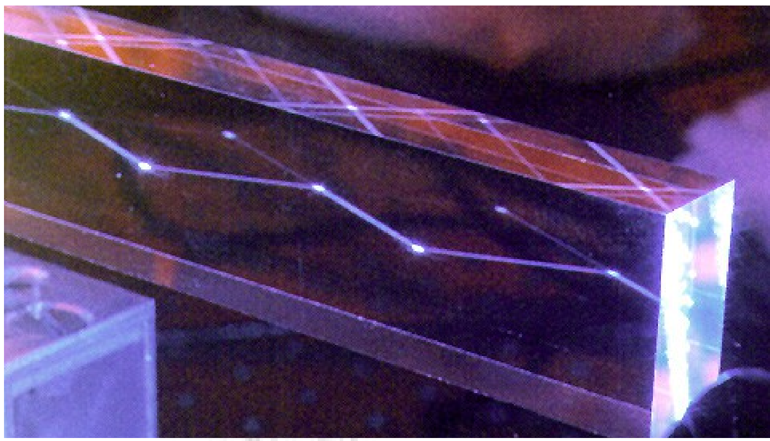

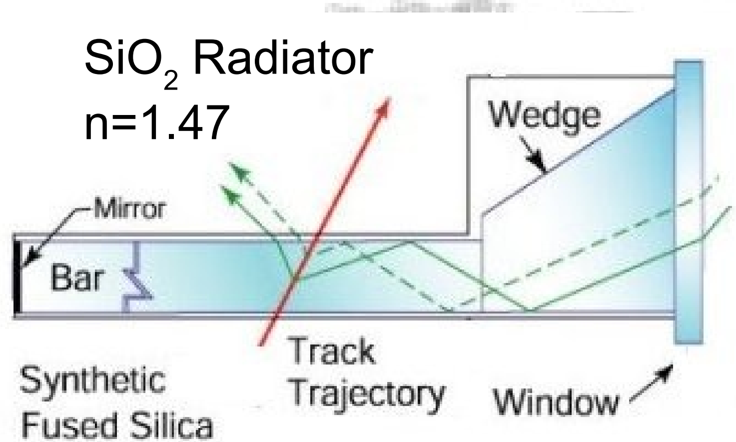

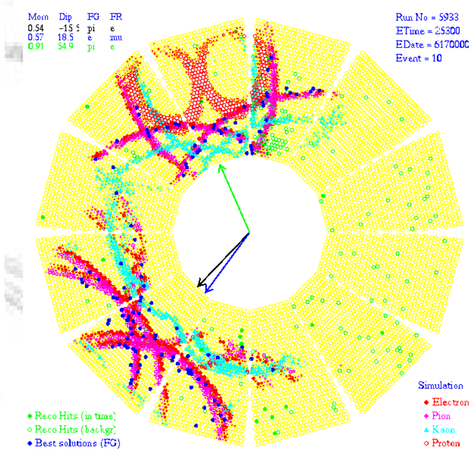

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- Shorter radiator
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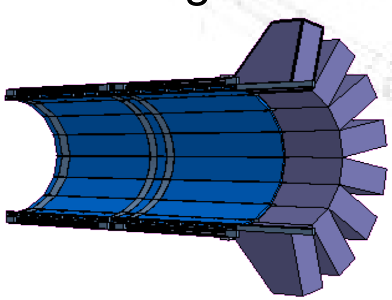

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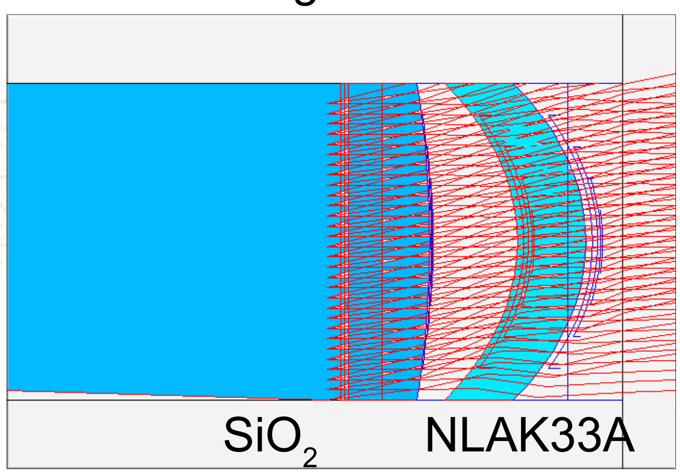

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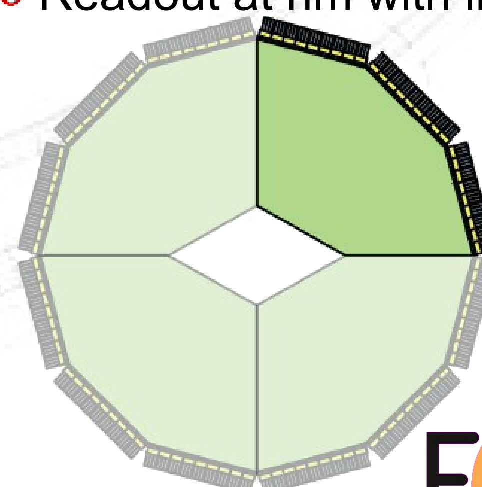
$\overline{\mathrm{P}}$ANDA Disc DIRC

- Disc shaped radiator
- Readout at rim with light guides

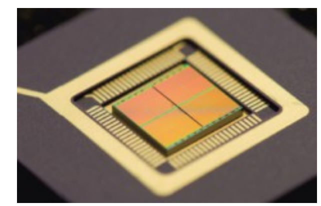


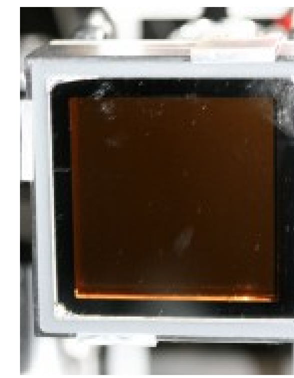
DIRC Challenges and Progress

Radiator production and QA

- BABAR-DIRC bars polished to 5 Å rms, PANDA needs ~15 Å rms
- Candidates for synthetic fused silica material (Heraeus, Corning)
- Laser test stand to measure transmission and reflectivity

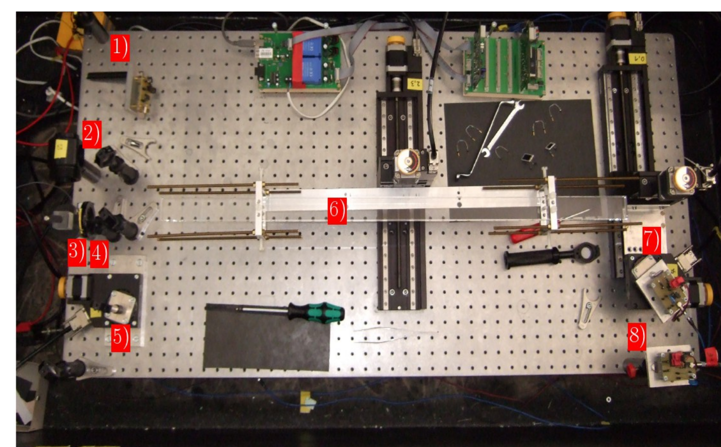
Photosensors for DIRCs





- Single photon sensitivity, low dark count rate, high PDE, fast timing: σ(TTS) ≈ 100 ps, operation in magnetic field, few mm position resolution, high rates up to 2 MHz/cm^2
- Long lifetime: 4-10 C/cm^2 per year at 10^6 gain (Barrel: 0.5 C/cm^2/yr)
- For long time no sensor matched all criteria, Most promising candidate: MCP PMTs with enhanced lifetime

DIRC Prototyping



- Testbeams at GSI, CERN and DESY
- Radiator characterisation
- Electronics developments

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 started

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Large Area APDs

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

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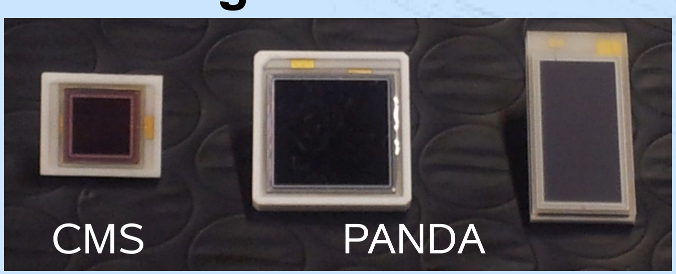


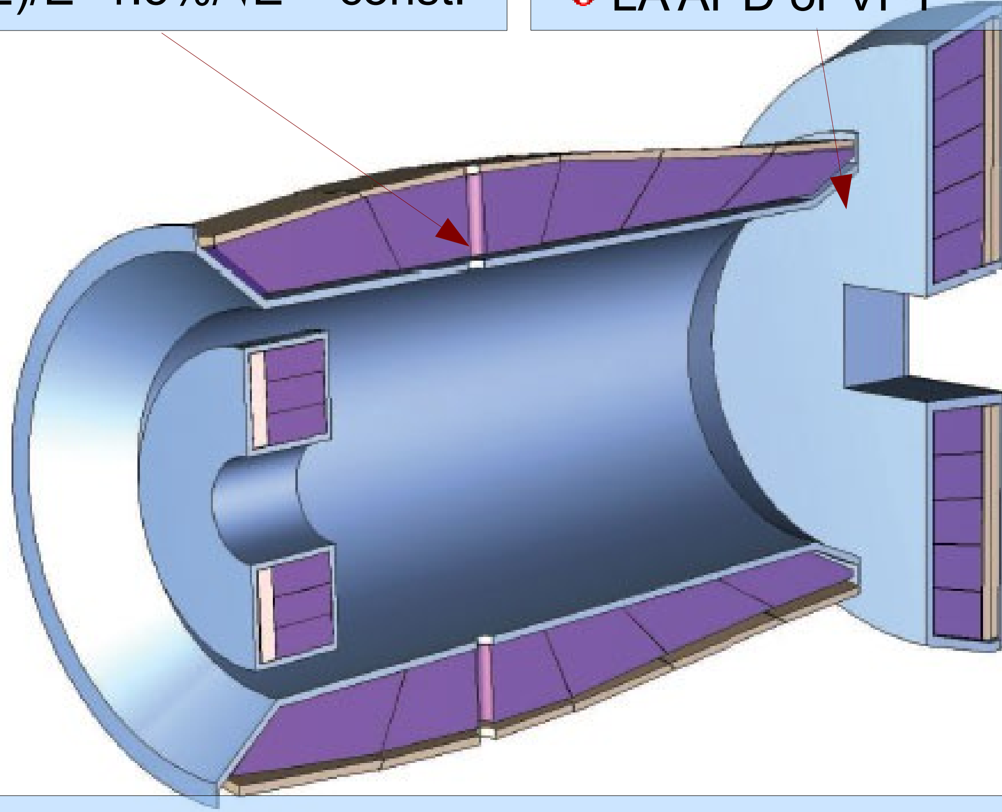
5x5 mm^2 10x10 mm^2 and 7x14 mm^2

Barrel Calorimeter

- 11000 PWO Crystals
- LAAPD readout, 2x1cm^2
- $\sigma(E)/E \sim 1.5\%/\sqrt{E}$ + const.

Forward Endcap

- 4000 PWO crystals
- High occupancy in center
- LA APD or VPT

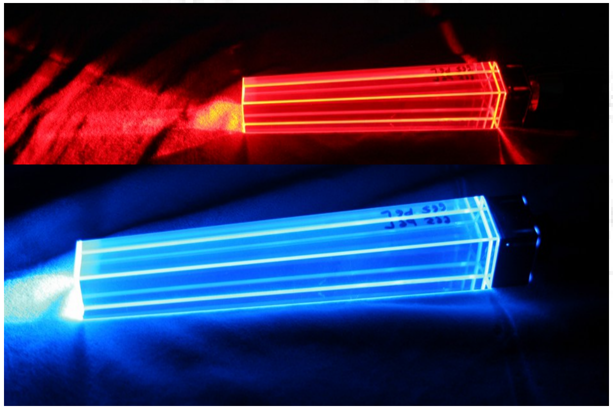


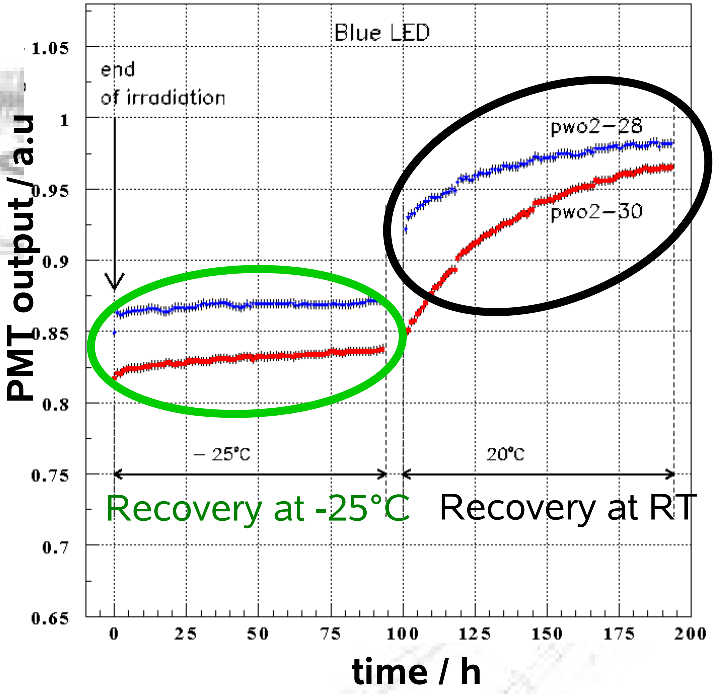
Backward Endcap for hermeticity, 560 PWO crystals
Forward EMC shashlyk behind dipole

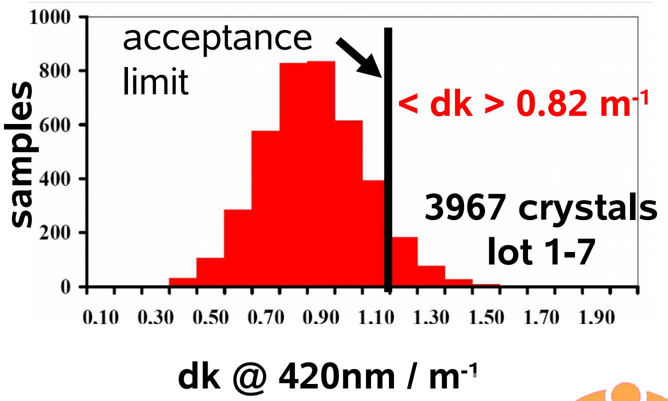
Radiation Damage in PWO

- Radiation induced absorption
  → reduces light yield
- At RT recovery by annealing
- At -25°C annealing is slower
- PANDA crystals: control radiation induced absorption loss dk

- Recovery can be stimulated with light
  - Fast recovery with blue light
  - Slow recovery with IR light (online)







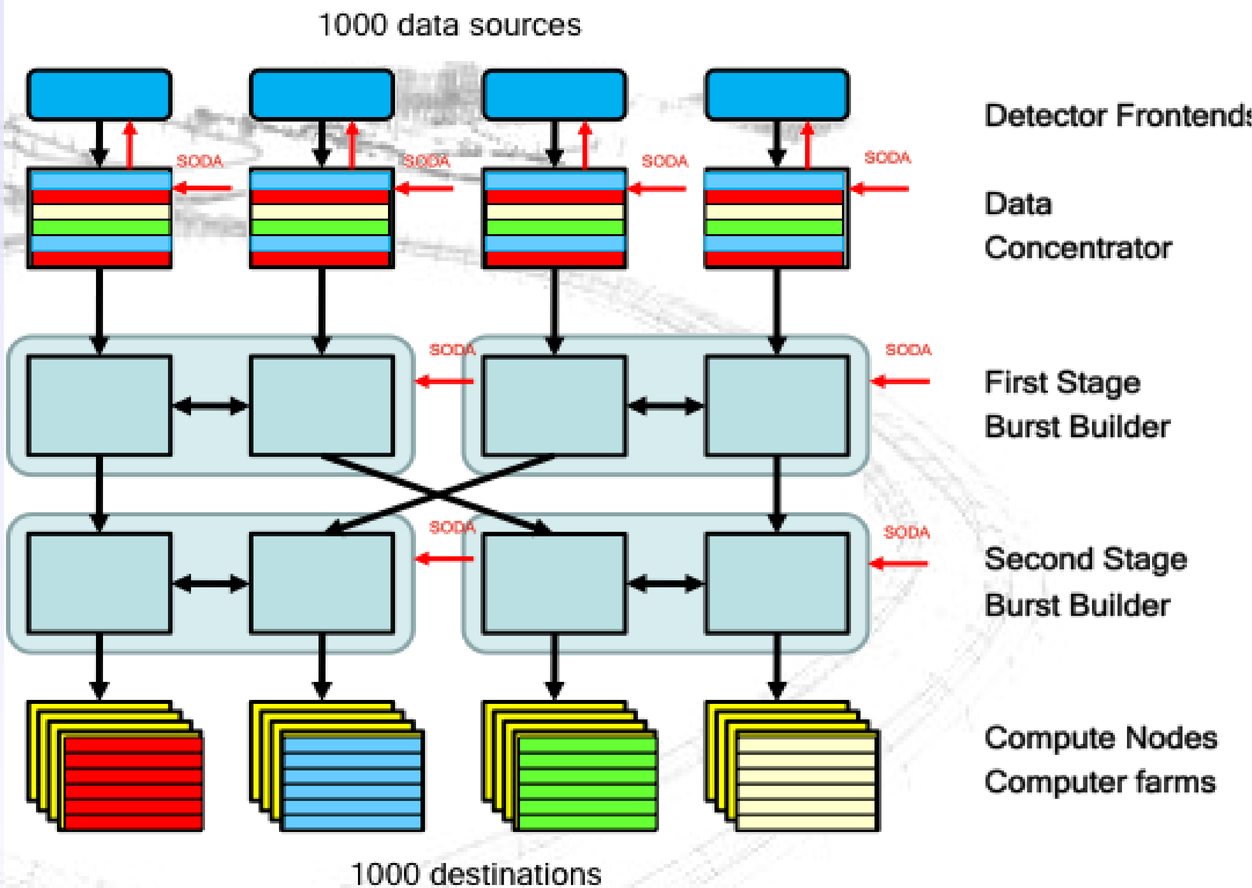
Courtesy R. Novotny

P̄ANDA 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**



Summary

Present Status of PANDA

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

Timeline of PANDA

- Many TDRs to complete by end 2013
- Start of construction in 2014
- Start of preassembly at Jülich in 2016/17
- Mounting at FAIR in 2017/18

PANDA & FAIR start in hadron physics from end 2018

- 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

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See plenary Fr 8/11, 15:30

by James Ritman

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

More than 520 physicists from 67 institutions in 17 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
TU München
U Münster
BINP Novosibirsk
IPN Orsay
U & INFN Pavia
IHEP Protvino

PNPI Gatchina
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