Overview of PANDA

FAIR ECE Review of PANDA Target TDR, June 11th 2013

Lars Schmitt, GSI Darmstadt

- Antiprotons at FAIR
- PANDA Overview
- PANDA Systems
- Timeline and Conclusions

FAIR

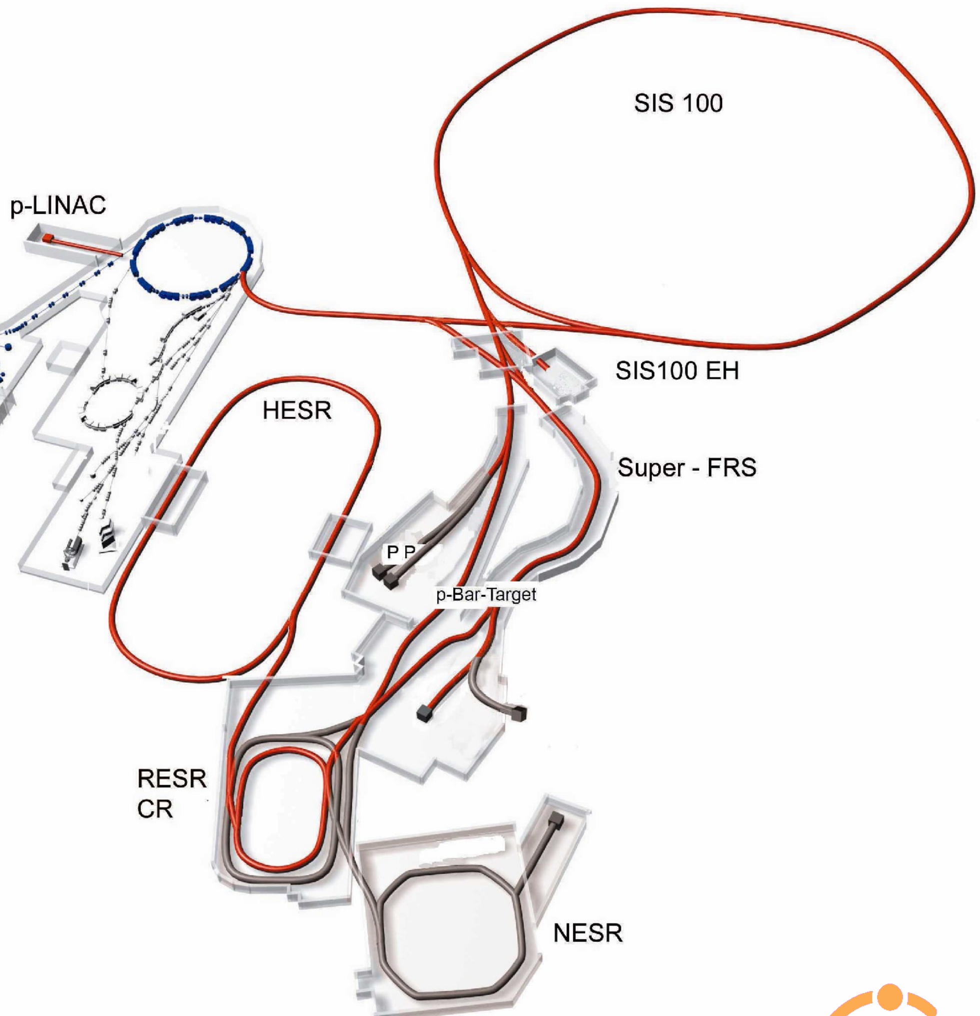
Antiprotons at FAIR

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

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



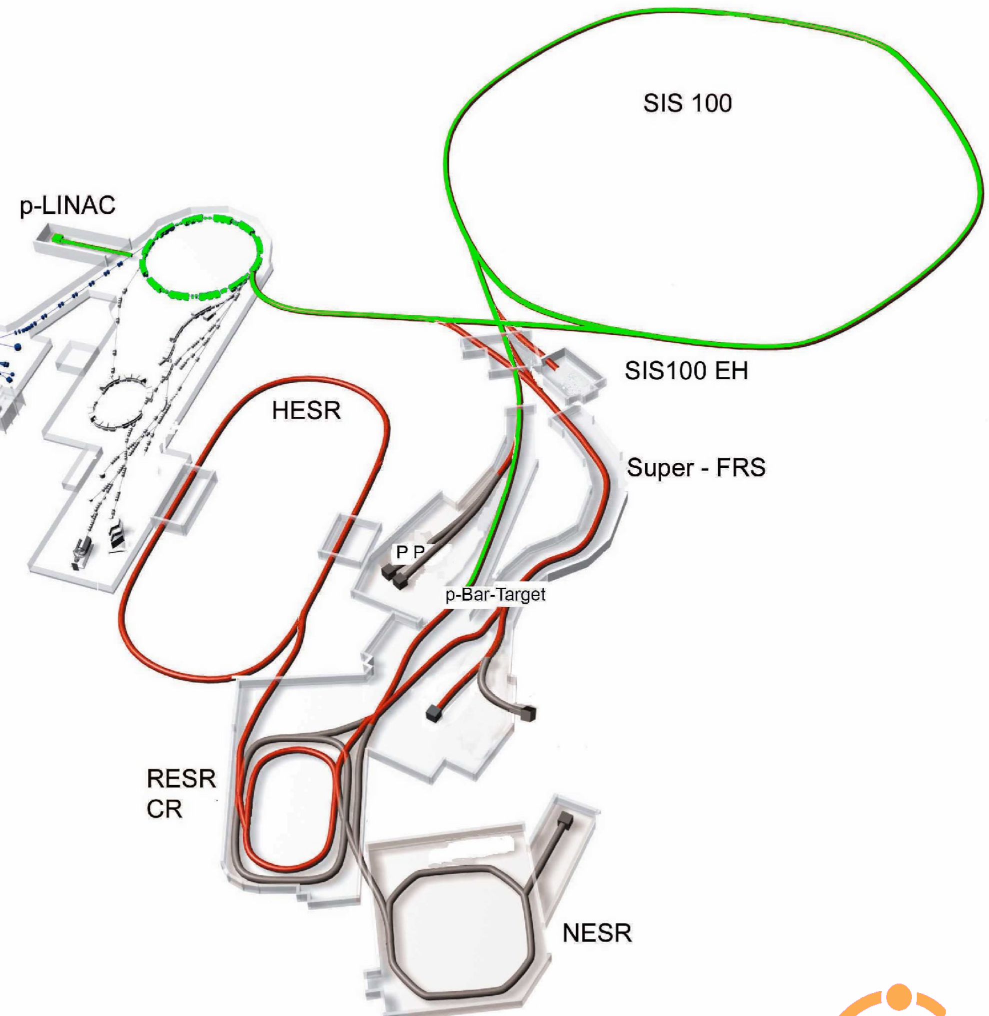
Antiprotons at FAIR

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

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



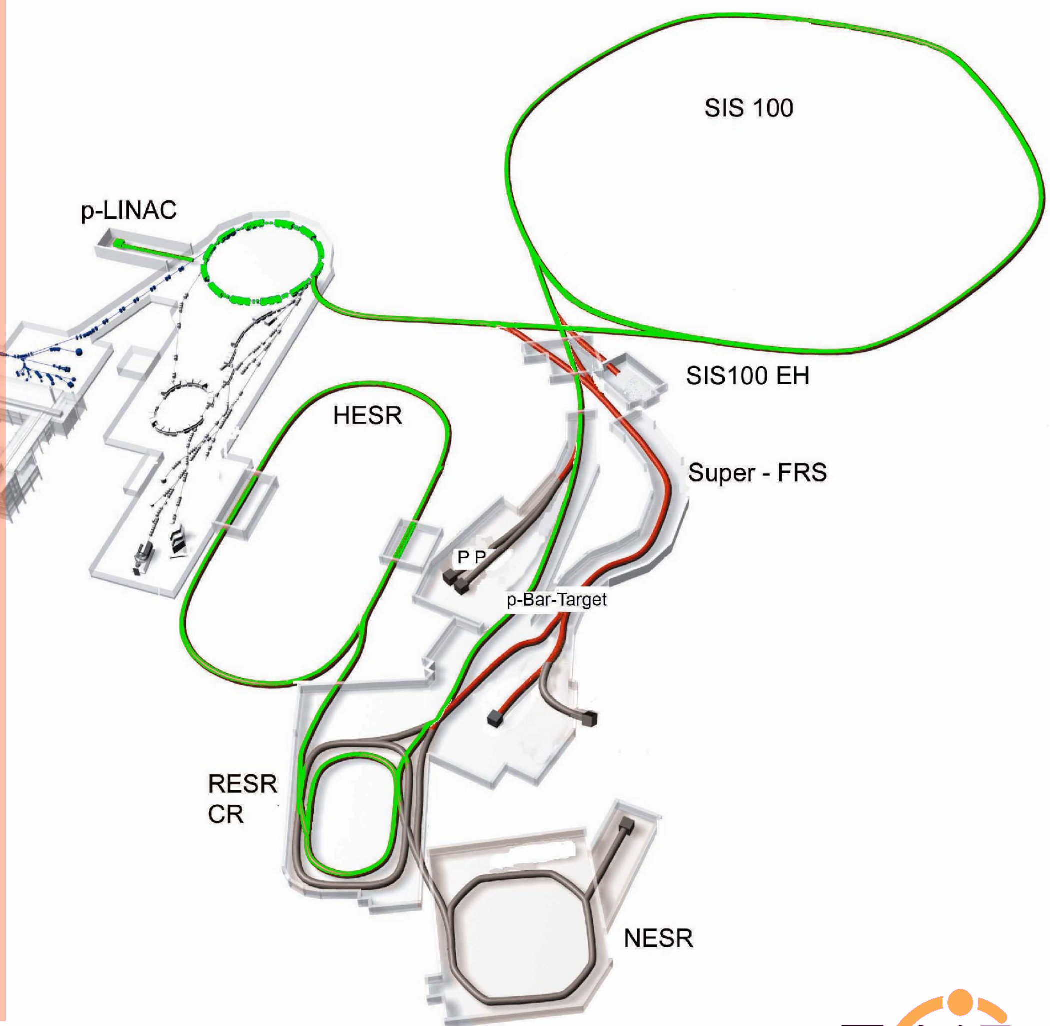
Antiprotons at FAIR

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

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



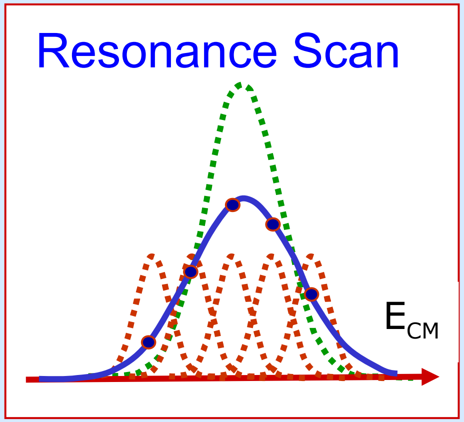
High Energy Storage Ring

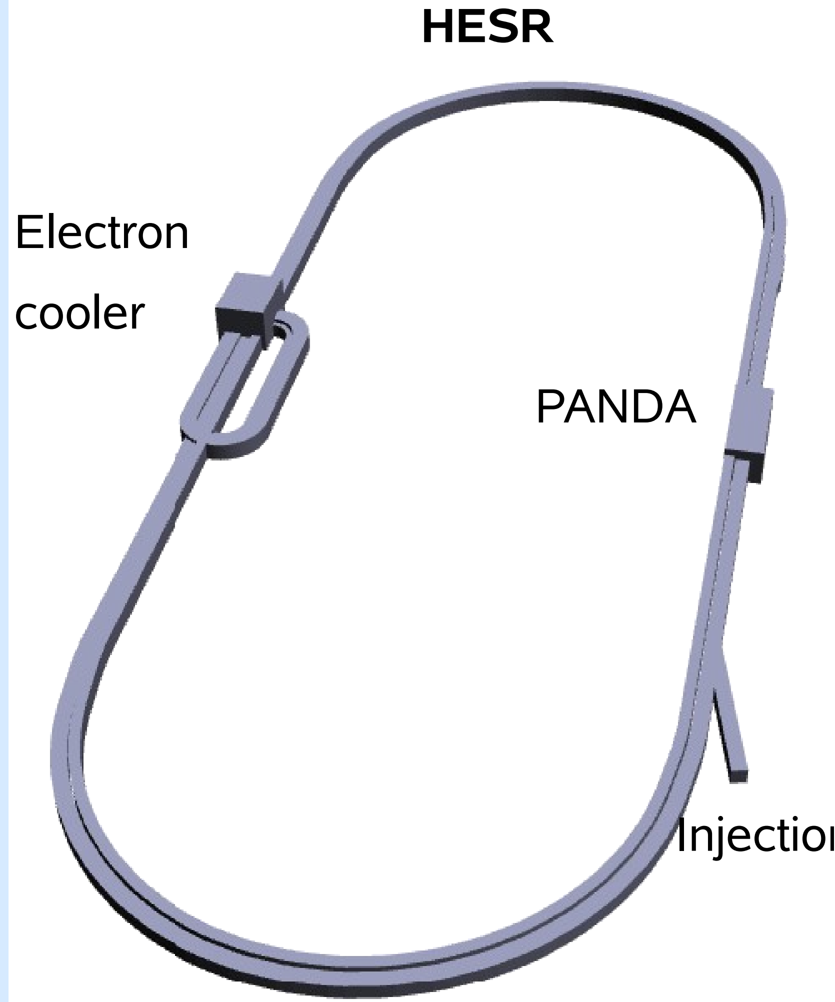
HESR Parameters

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

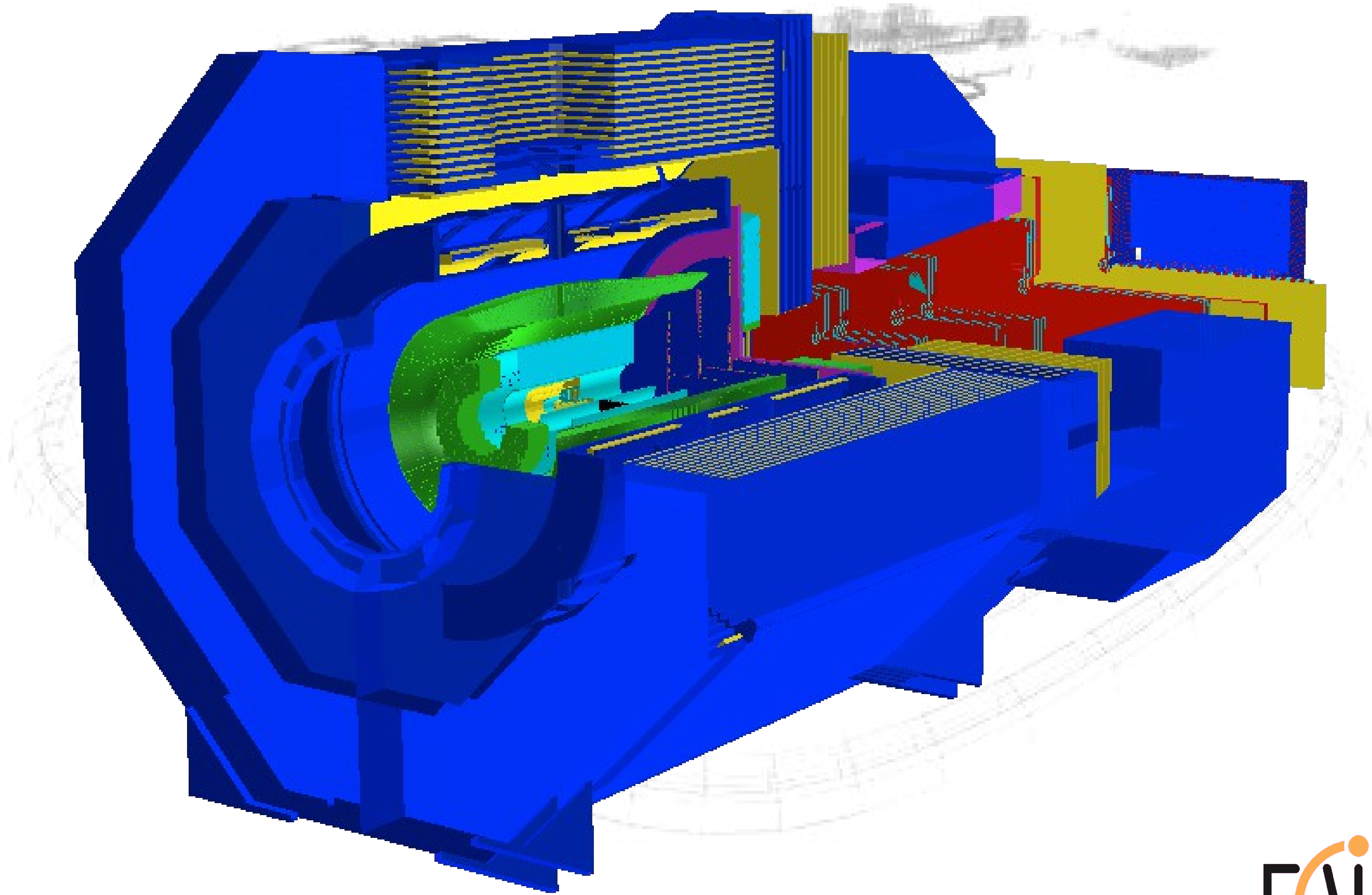
Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim10^{-4}$	$\sim4\times10^{-5}$
L ($cm^{-2}s^{-1}$)	2×10^{-32}	2×10^{-31}
Stored $\bar{p}$	10^{11}	10^{10}

- 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*

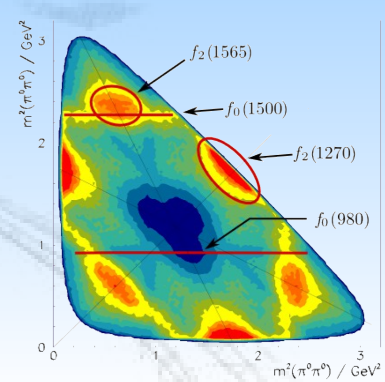
→ Understand new XYZ states, $D_s(2317)$ and others

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

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution



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

Hadron Spectroscopy

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

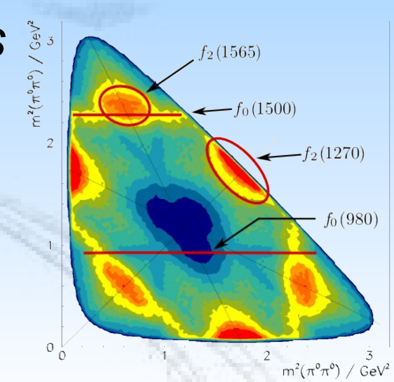
Charm Hadrons: *charmonia, D-mesons, charm baryons*

➔ 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



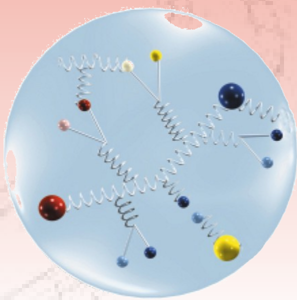
Hadron Structure

Generalized Parton Distributions

➔ Formfactors and structure functions, L_q

Timelike Nucleon Formfactors

Drell-Yan Process



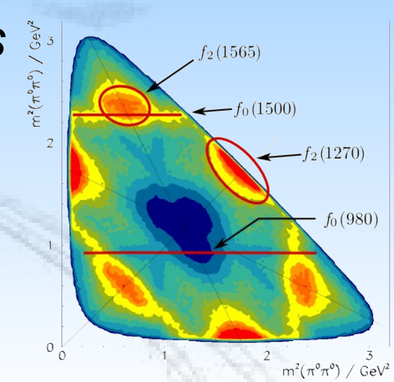
Physics Goals of $\overline{\text{P}}$ANDA

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:

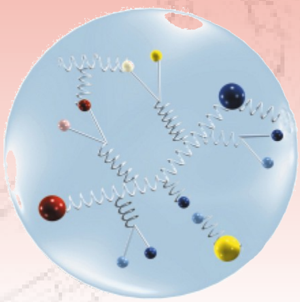
Production of states of all quantum numbers

Resonance scanning with high resolution

Hadron Structure

Generalized Parton Distributions

➔ Formfactors and structure functions, L_q



Timelike Nucleon Formfactors

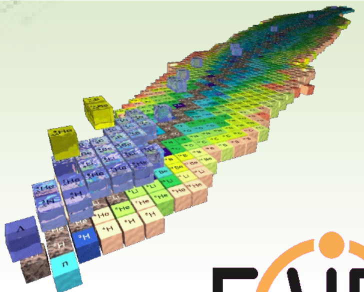
Drell-Yan Process

Nuclear Physics

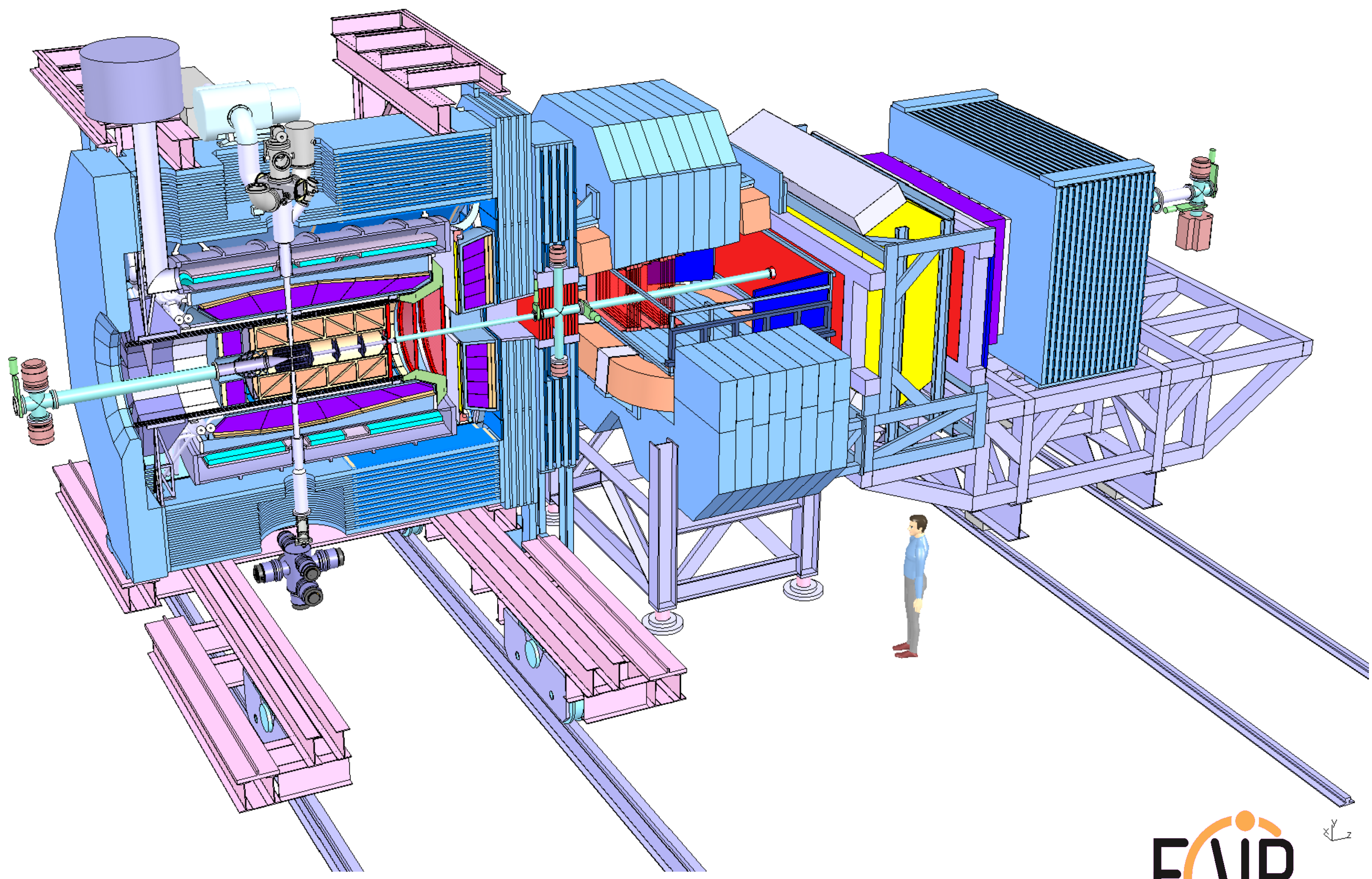
Hypernuclei*:* Production of double Λ-hypernuclei

➔ γ-spectroscopy of hypernuclei, YY interaction

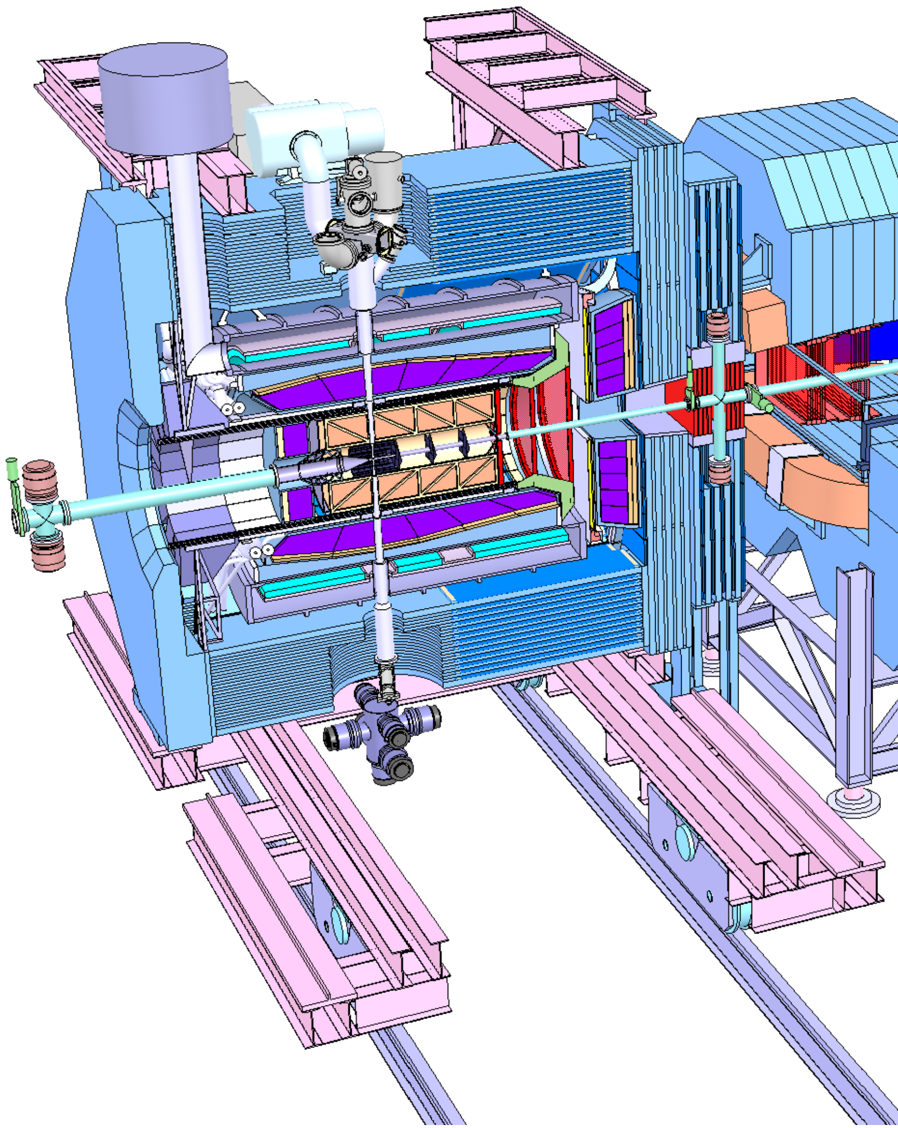
Hadrons in Nuclear Medium



PANDA Spectrometer



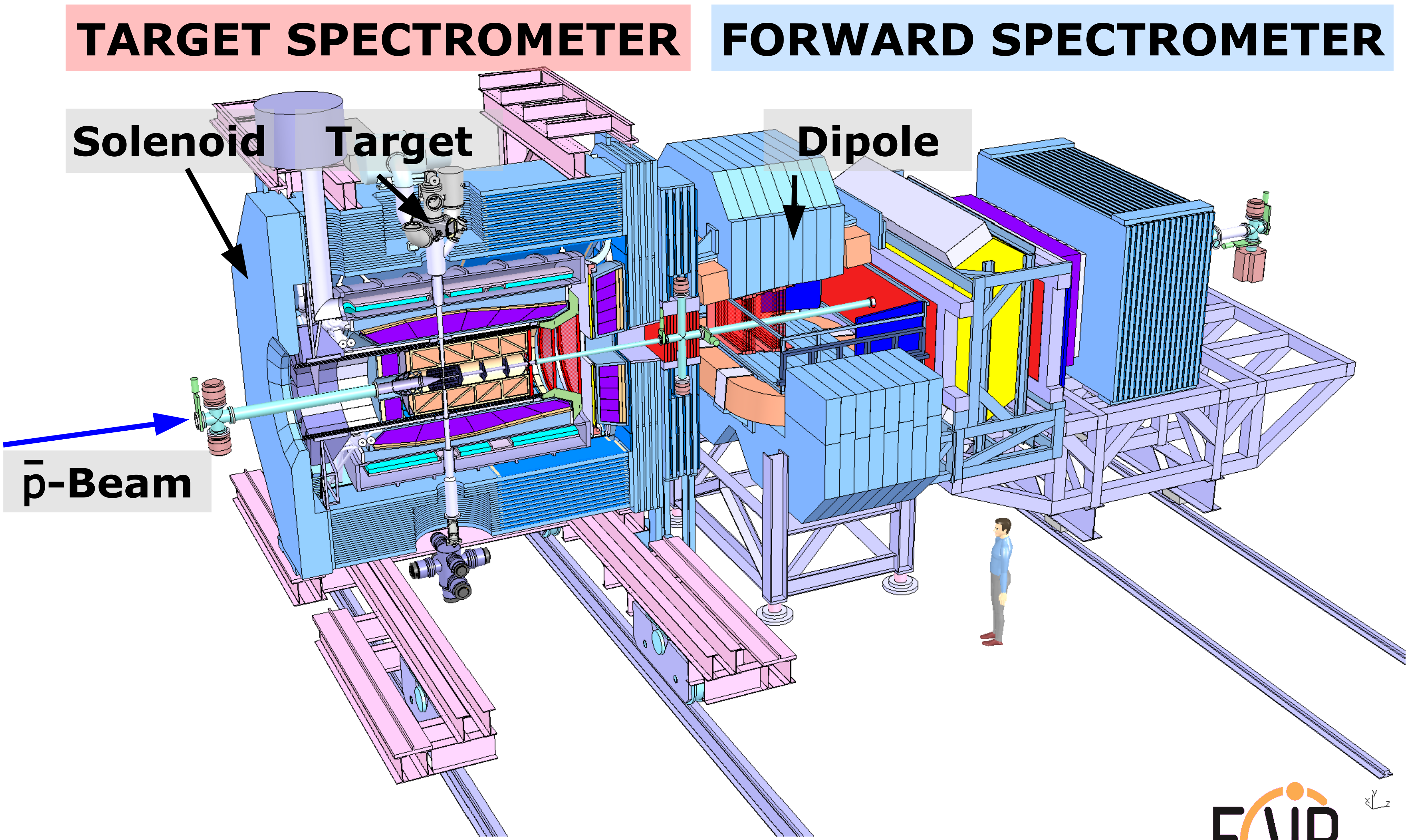
PANDA Spectrometer



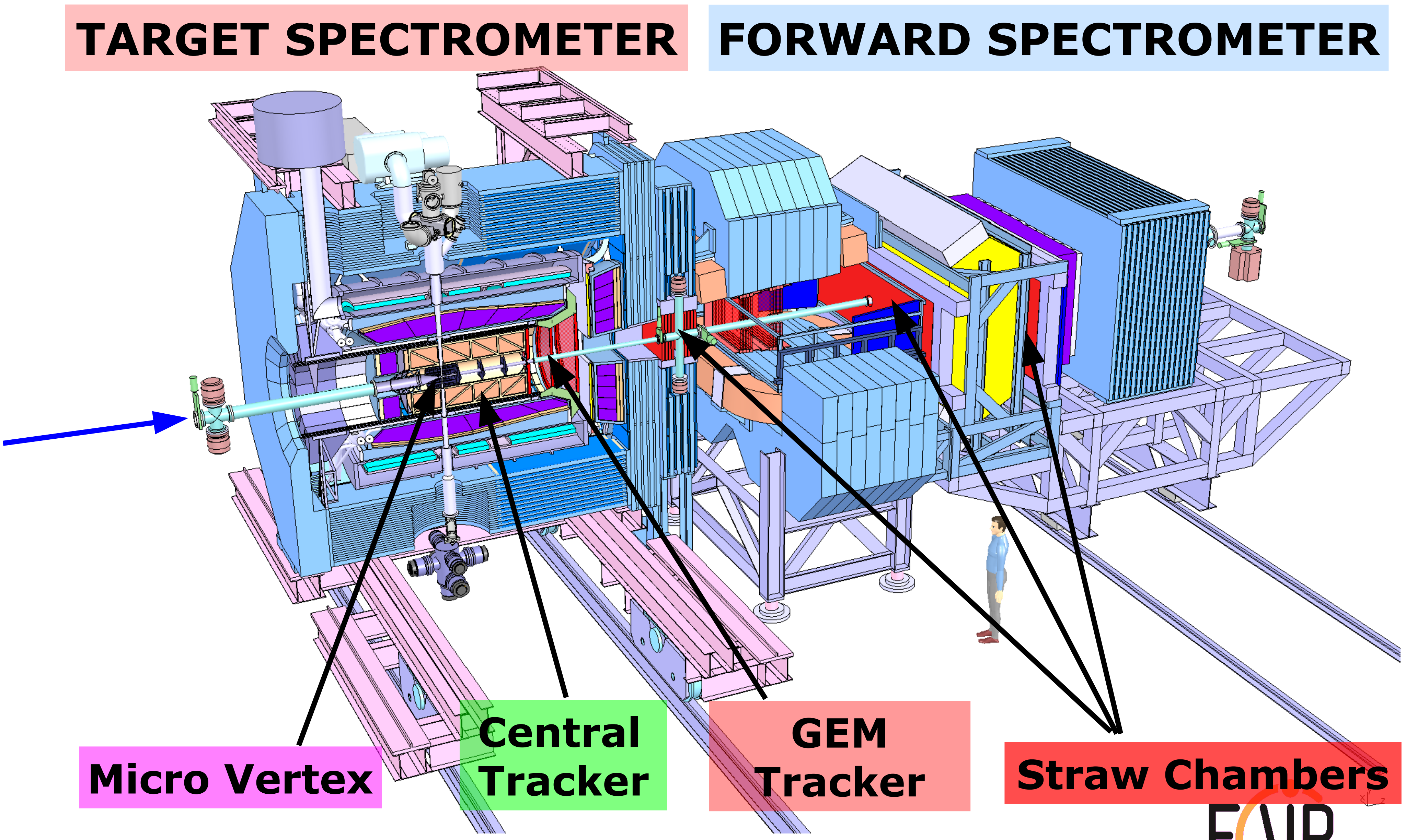
Detector requirements:

- 4π acceptance
- High rate capability: 2×10^{7} s^{-1} interactions
- Efficient event selection
  - ➔ *Continuous acquisition*
- Momentum resolution ~1%
- Vertex info for D, K^0_S, Υ ($c\tau$ = 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*

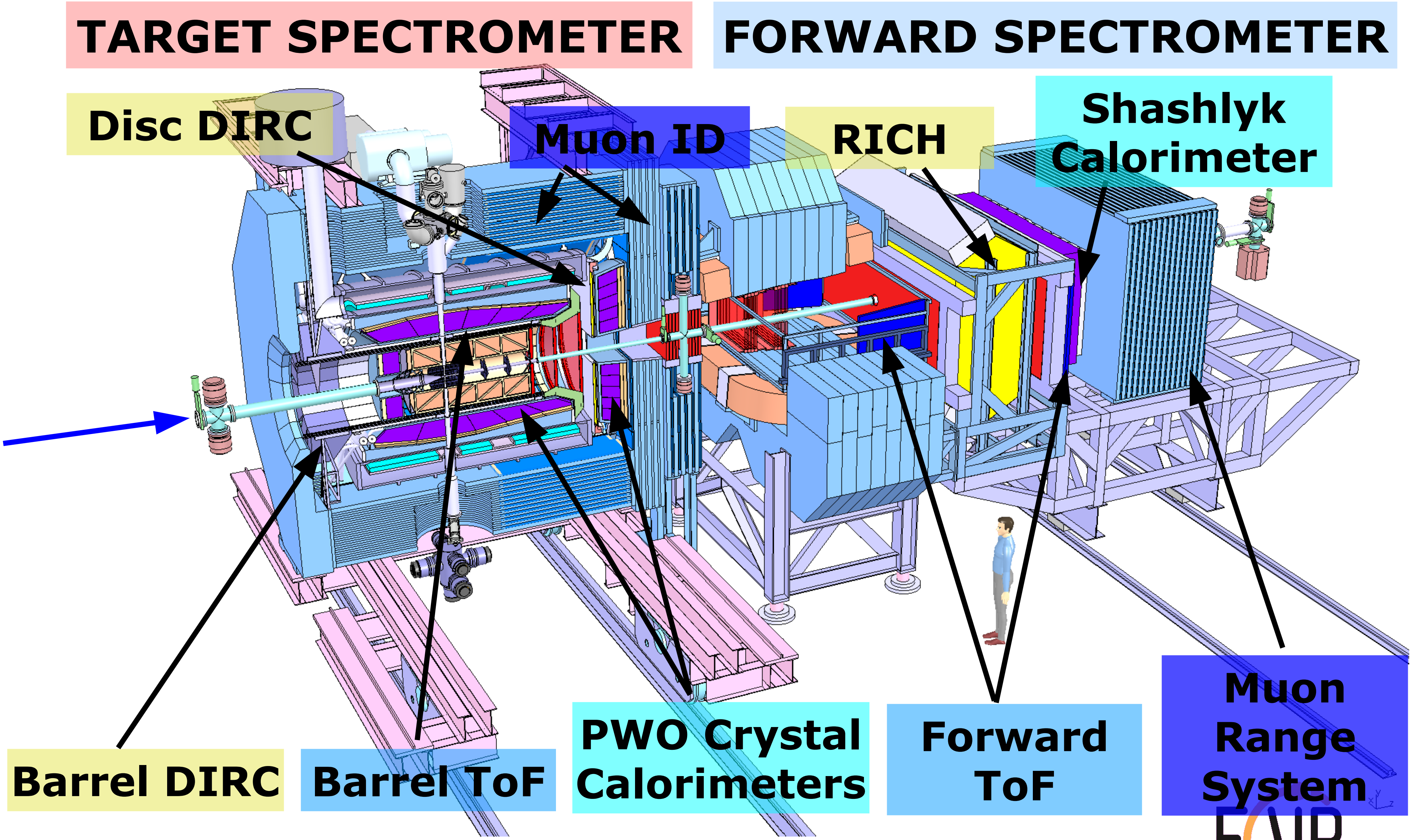
PANDA Spectrometer



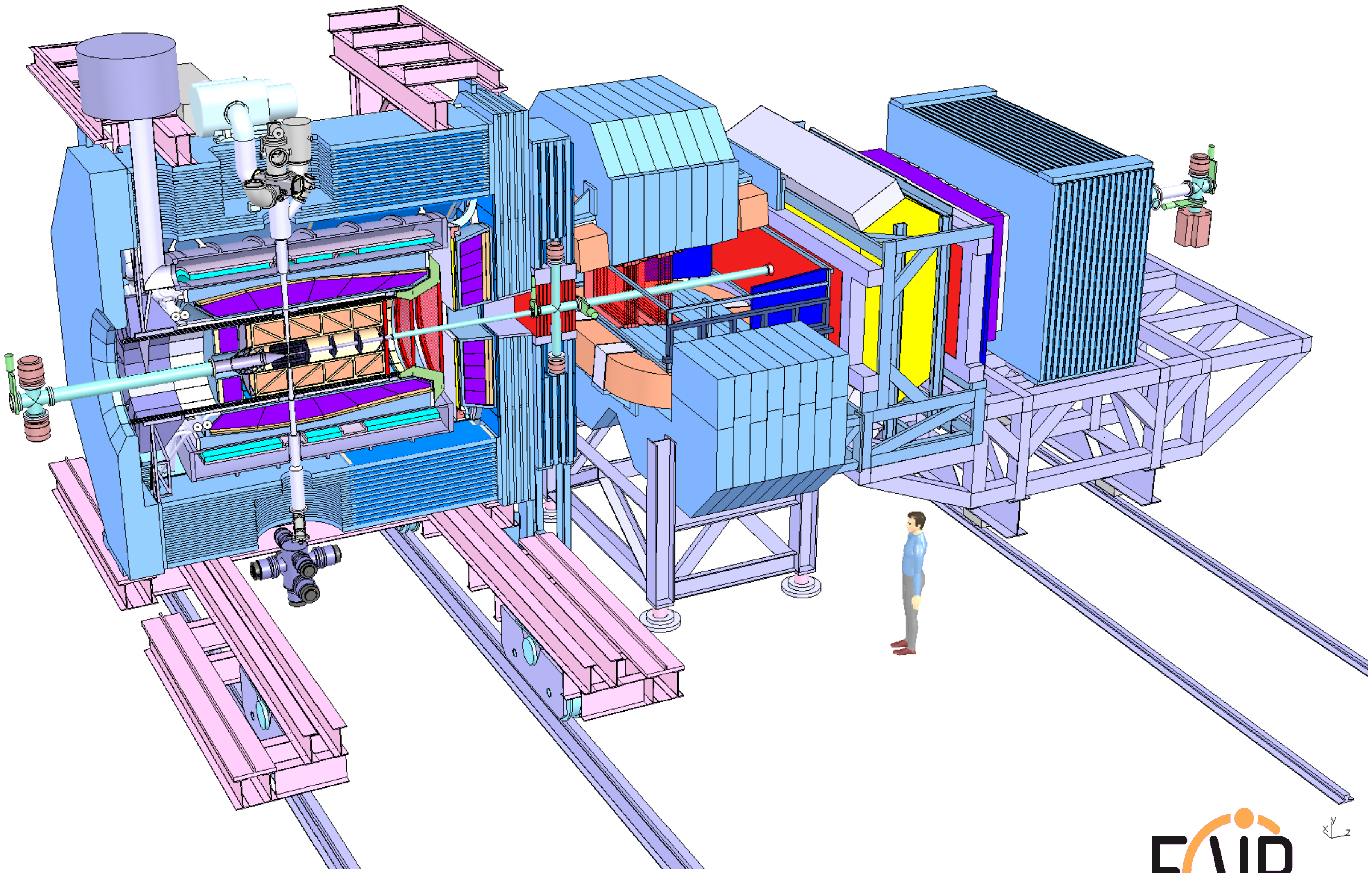
PANDA Spectrometer



PANDA Spectrometer



PANDA Systems



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

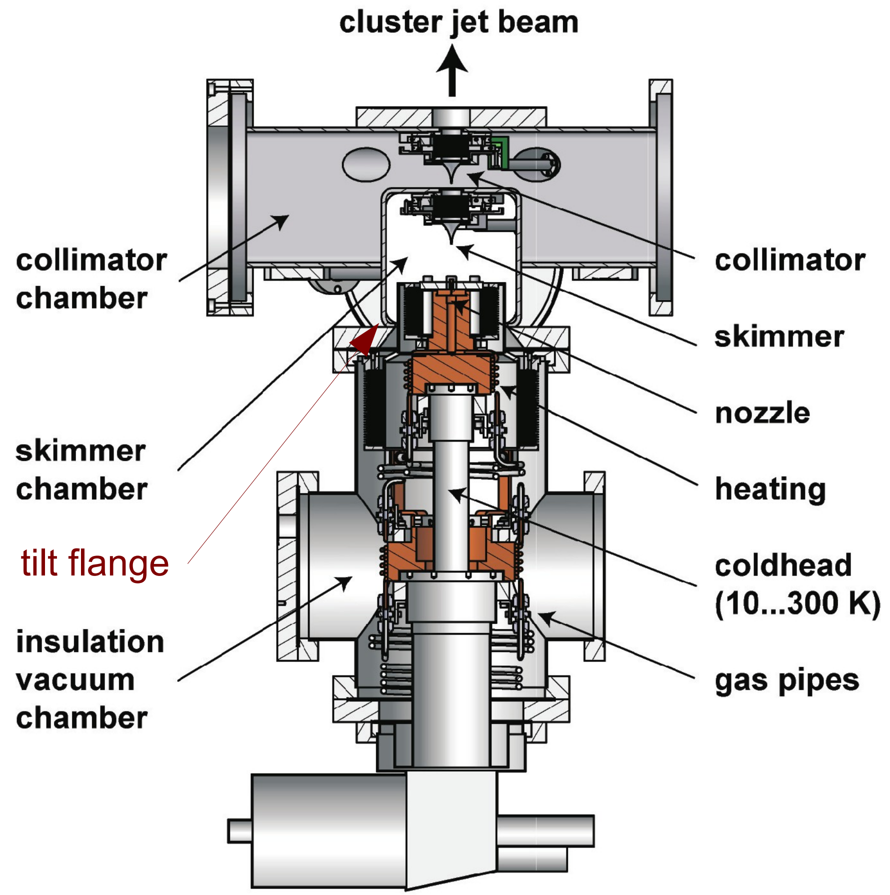
Cluster Jet Target

- Continuous development
  - Nozzle improvement
  - Better alignment by tilt
  - $\sim 2x10^{15}$ cm^{-2} reached
- TDR completed

Pellet Target

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

Latest version of the cluster jet target



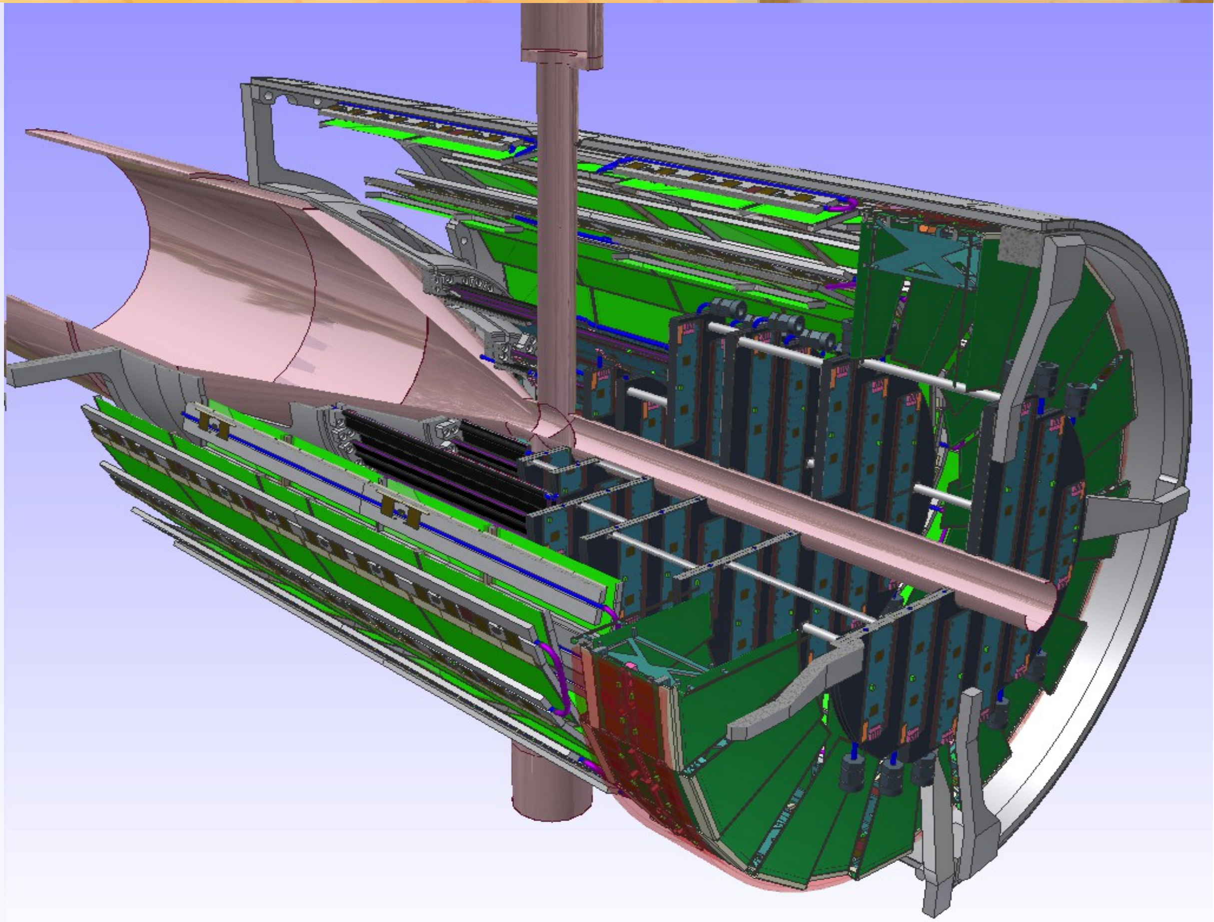
Micro Vertex Detector

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
  - 128 channel readout ASIC
- Mixed forward disks (pixel/strips)

Challenges

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



The Straw Tube Tracker

Detector Layout

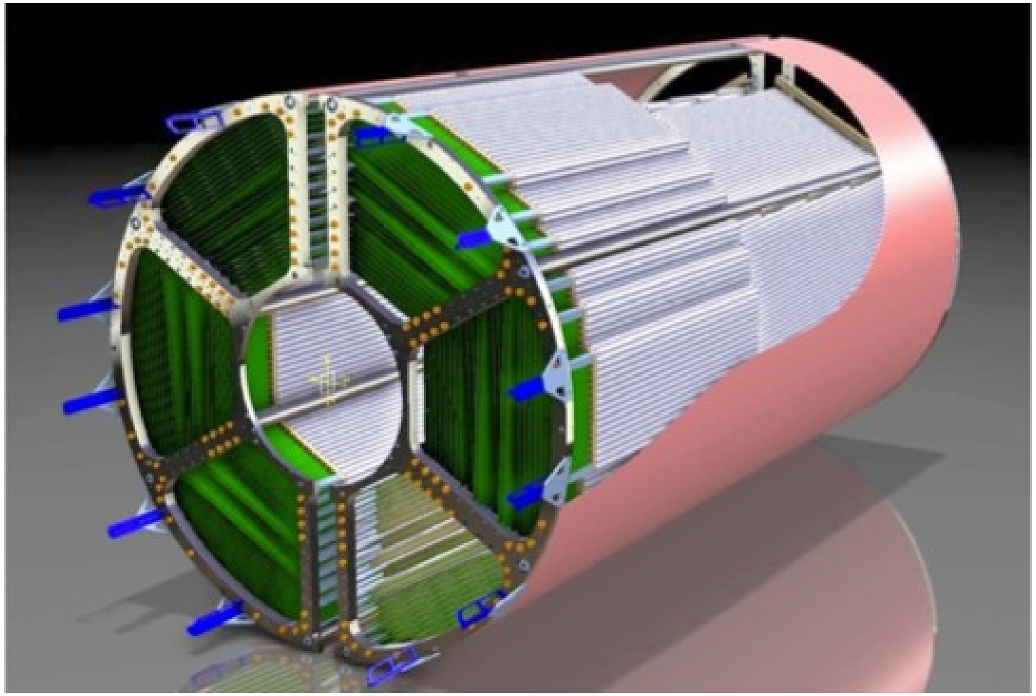
- 4600 straws in 21-27 layers, of which 8 layers skewed at ~3°
- Tube made of 27 μm thin Al-mylar, Ø=1cm
- R_{in}= 150 mm, R_{out}= 420 mm, l=1500 mm
- Self-supporting straw double layers at ~ 1 bar overpressure (Ar/CO_2)
- Readout with ASIC, TDC, FADC

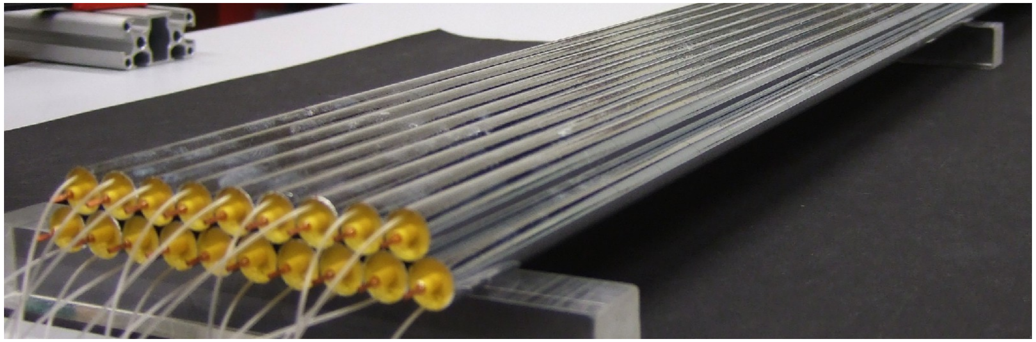
Material Budget

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

Detector Studies

- Prototype construction & tests
- Aging tests: up to 1.2 C/cm^2
- Cosmic tests for dE/dx
- Simulations of field and detector

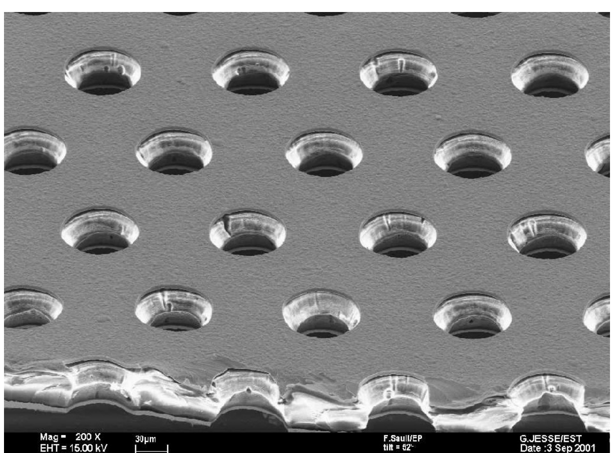


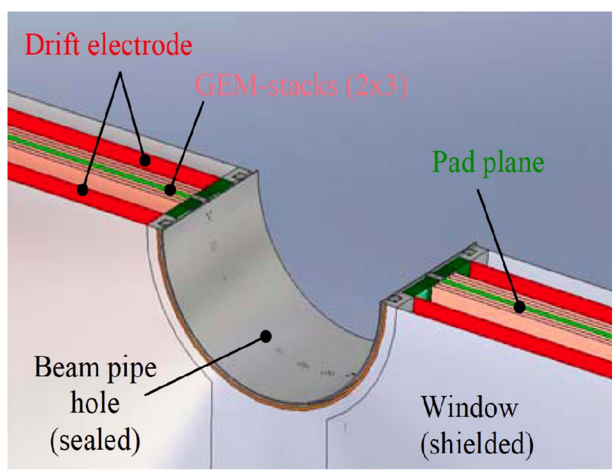


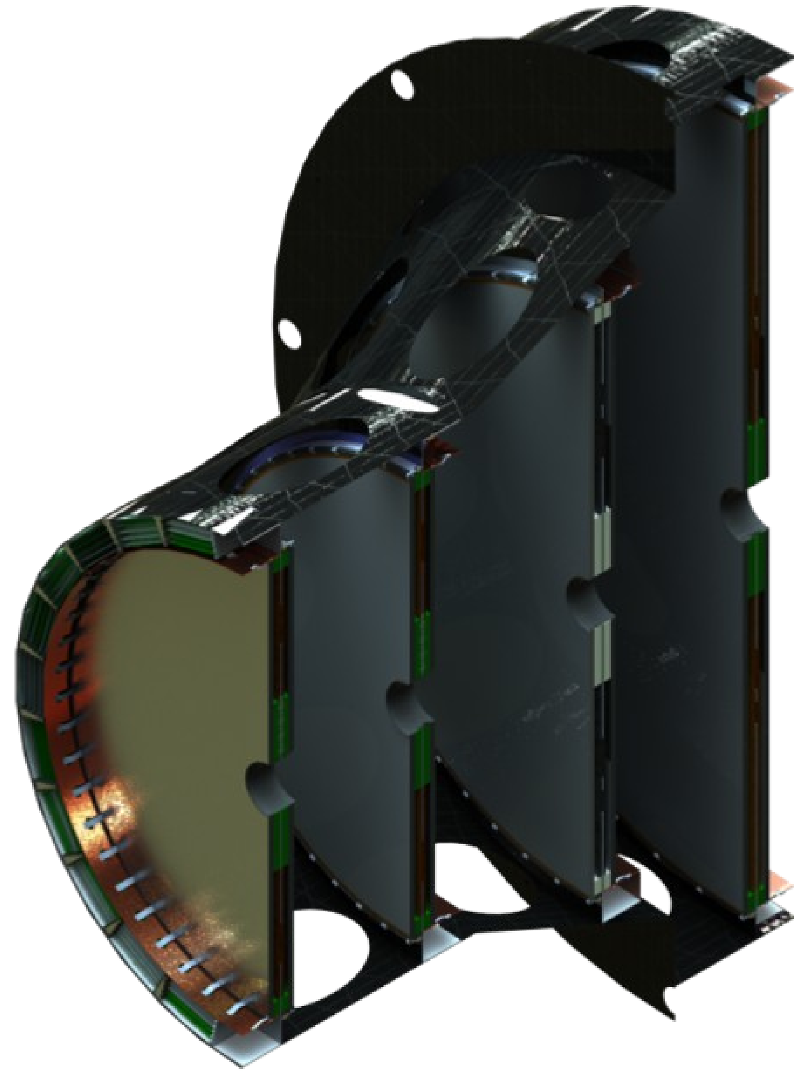
Forward GEM Tracker

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



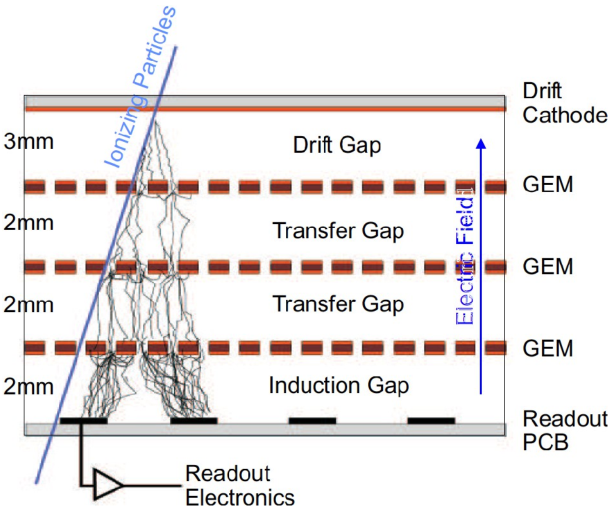


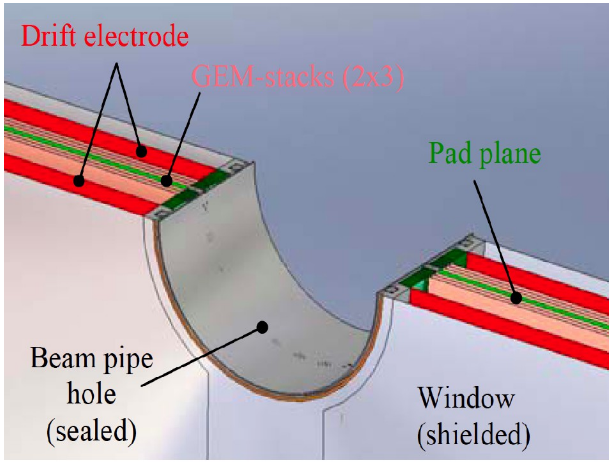


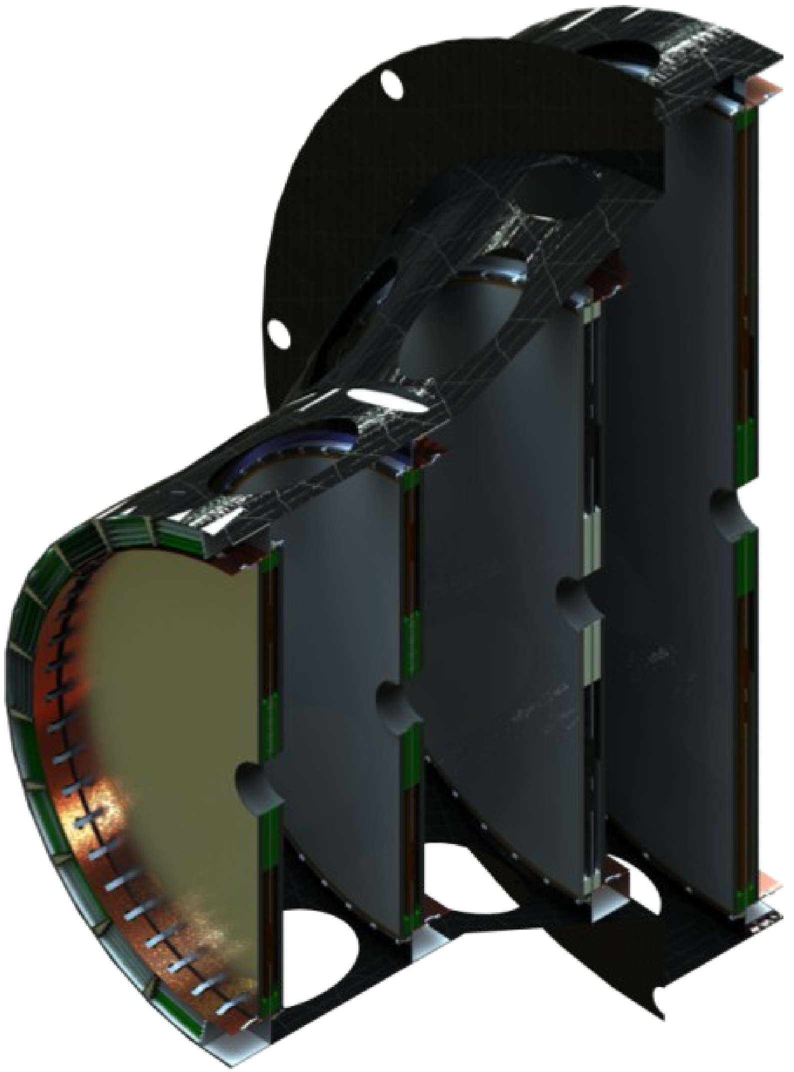
Forward GEM Tracker

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





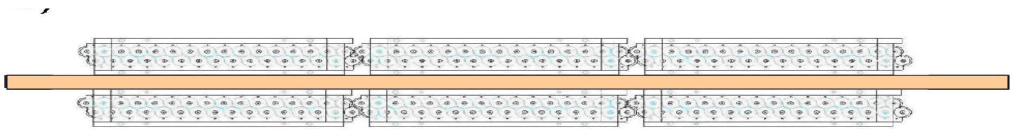


Forward Tracking

Tracking in Forward Spectrometer

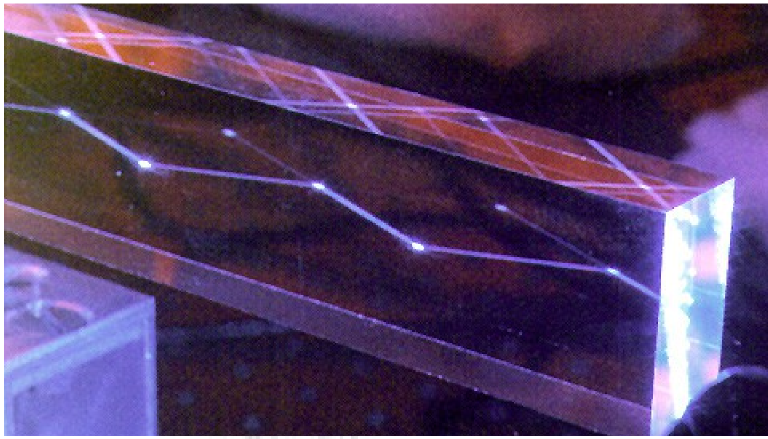
- 3 stations with 2 chambers each
  - FT1&2 : between solenoid and dipole
  - FT3&4 : in the dipole gap
  - FT5&6 : largest chambers behind dipole
- Straw tubes arranged in double layers
  - 27 µm thin mylar tubes, 1 cm Ø
  - Stability by 1 bar overpressure
- 3 projections per chamber (0°, ±5°)

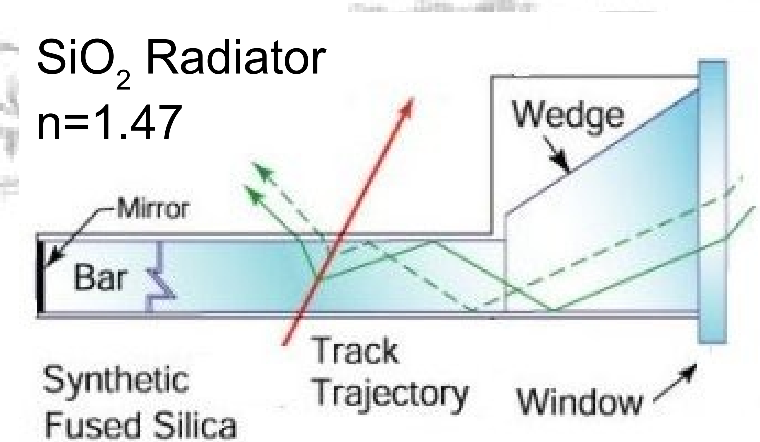
Modular layout of straws

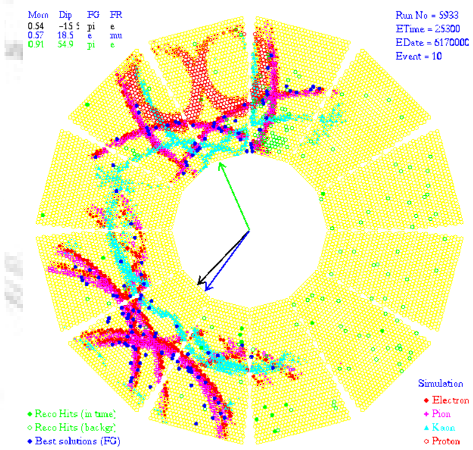


$\overline{\text{P}}$ANDA DIRC Detectors

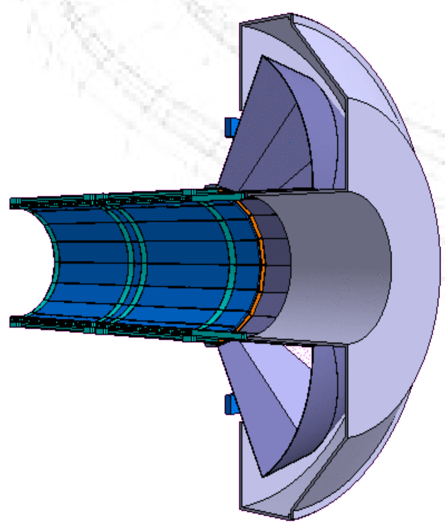
Detection of Internally Reflected Cherenkov light







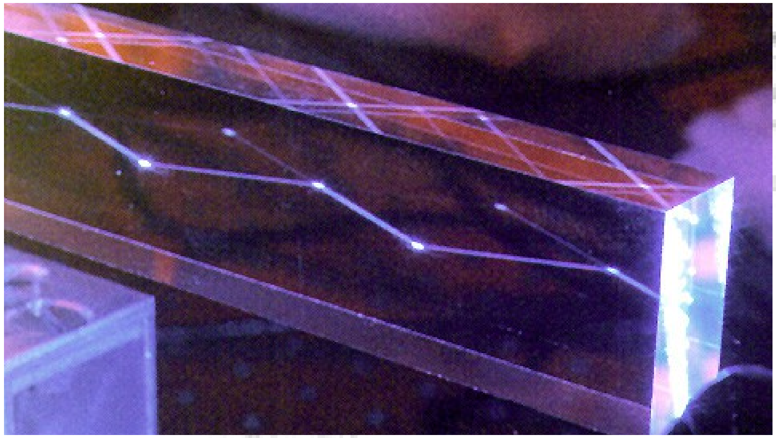
BaBar type Barrel DIRC

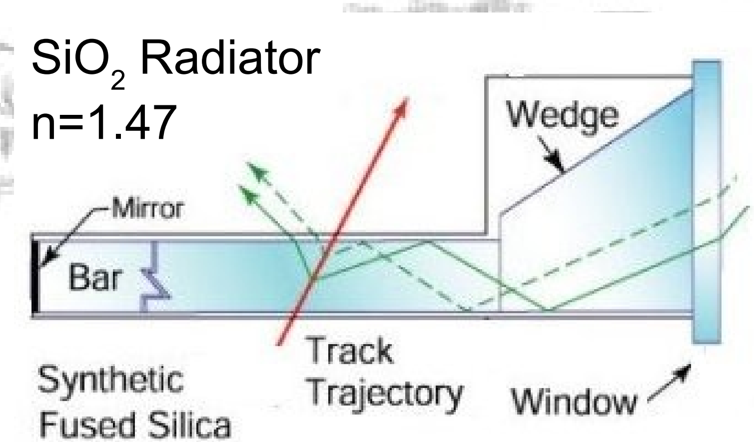


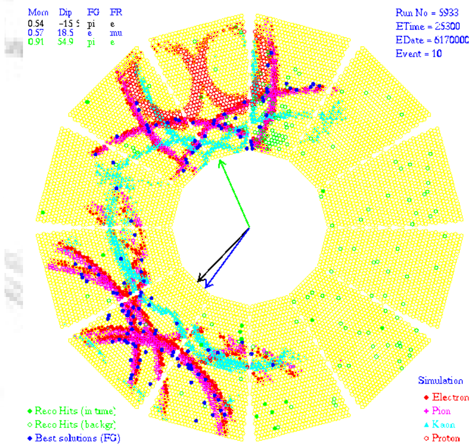
- Pin hole focusing
- Large water tank
- Readout with PMTs (BaBar 11000, $\overline{\text{P}}$ANDA 7000)

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

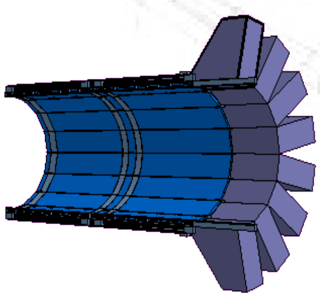
Detection of Internally Reflected Cherenkov light

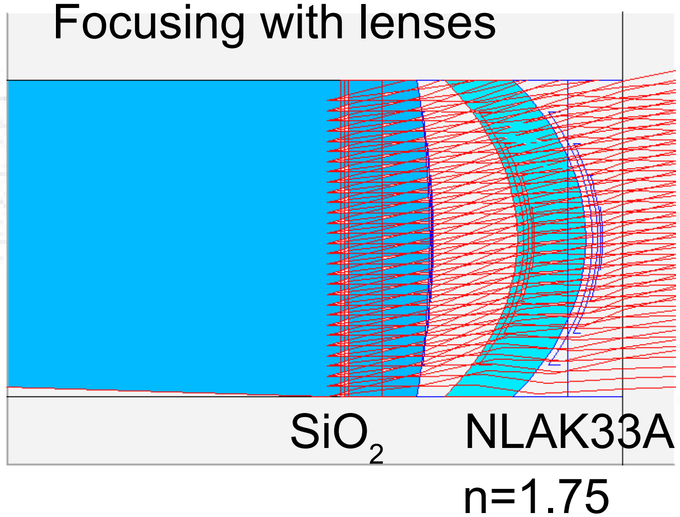






$\overline{\text{P}}$ANDA Barrel DIRC

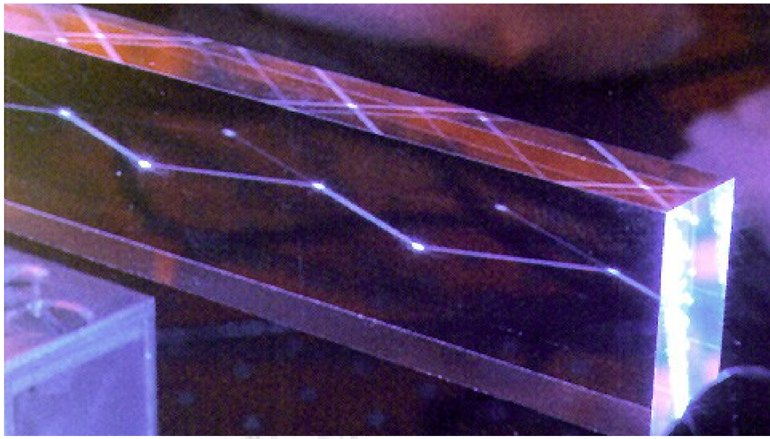


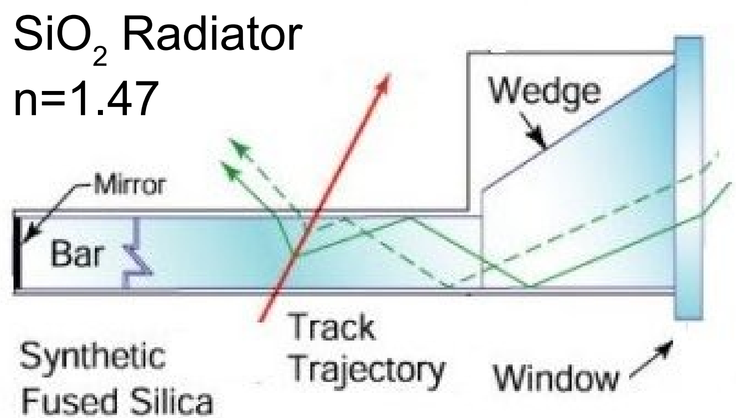


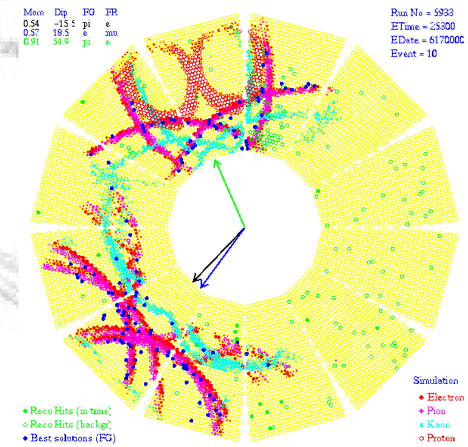
- Shorter radiator
- No large tank

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

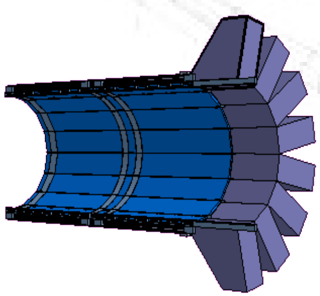
Detection of Internally Reflected Cherenkov light

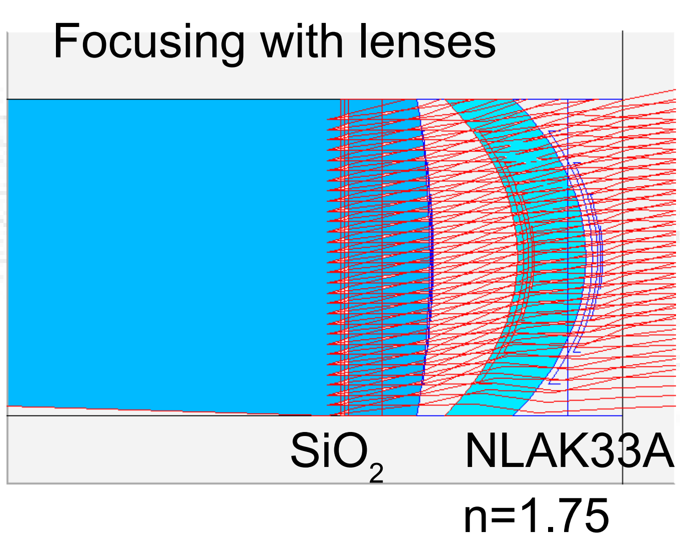






$\overline{\text{P}}$ANDA Barrel DIRC

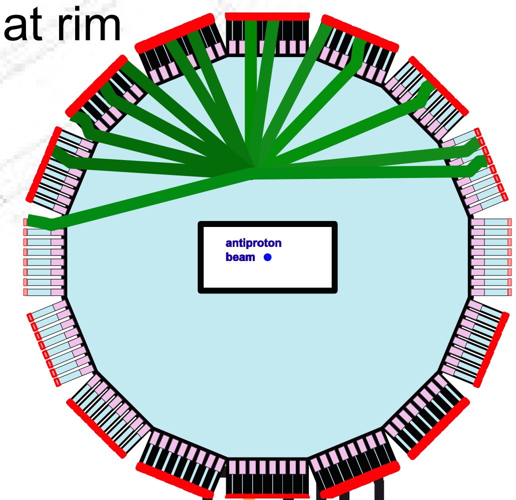




- Shorter radiator
- No large tank

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

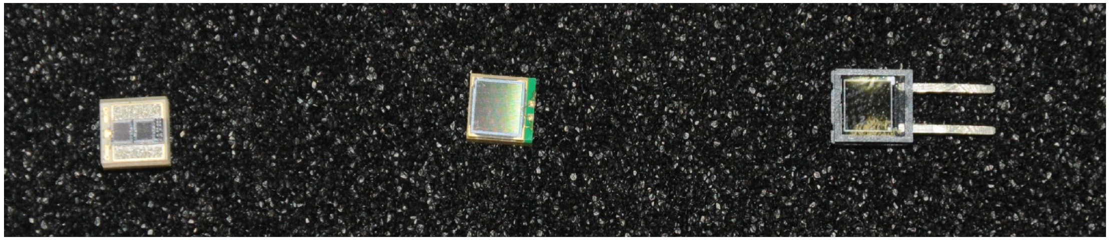
- Disc shaped radiator
- Readout at rim



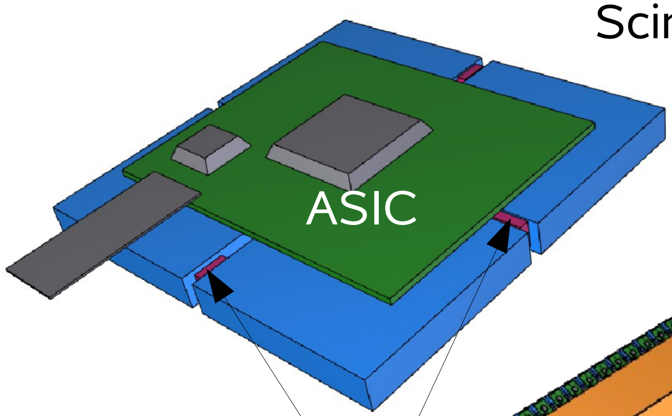
Scintillator Tile Hodoscope

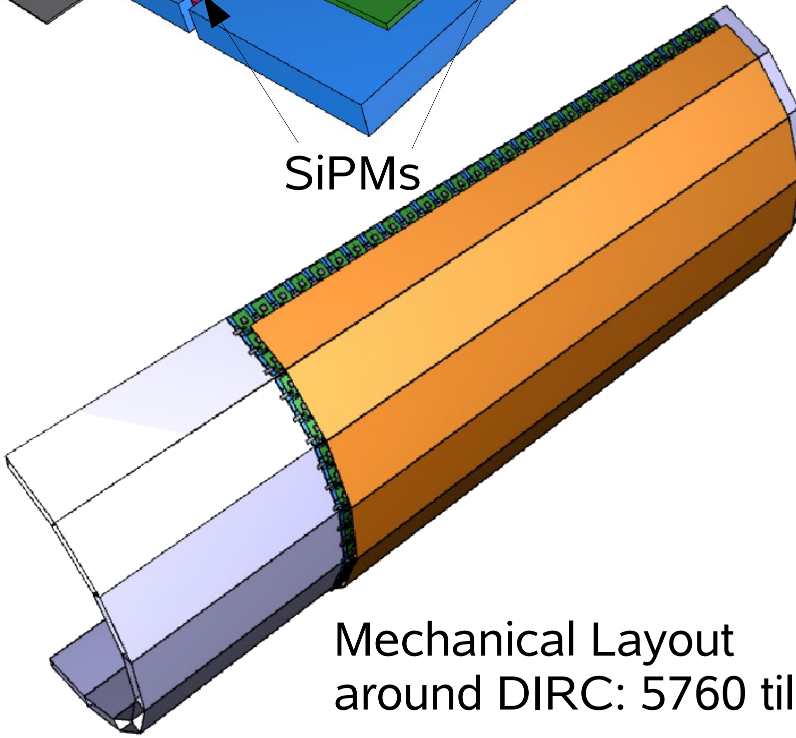
Detector for ToF and event timing

- 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



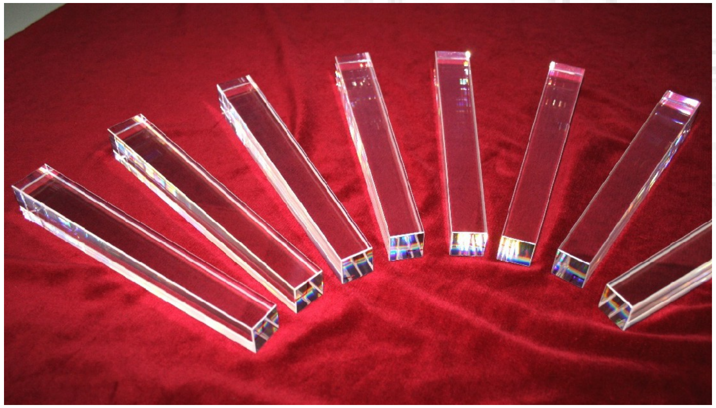


Mechanical Layout
around DIRC: 5760 tiles

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



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

Large Area APDs

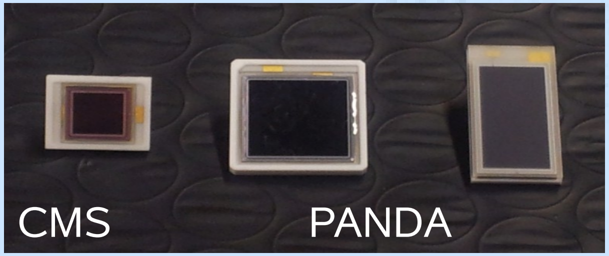
5x5 mm^2 10x10 mm^2 and 7x14 mm^2

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

Large Area APDs



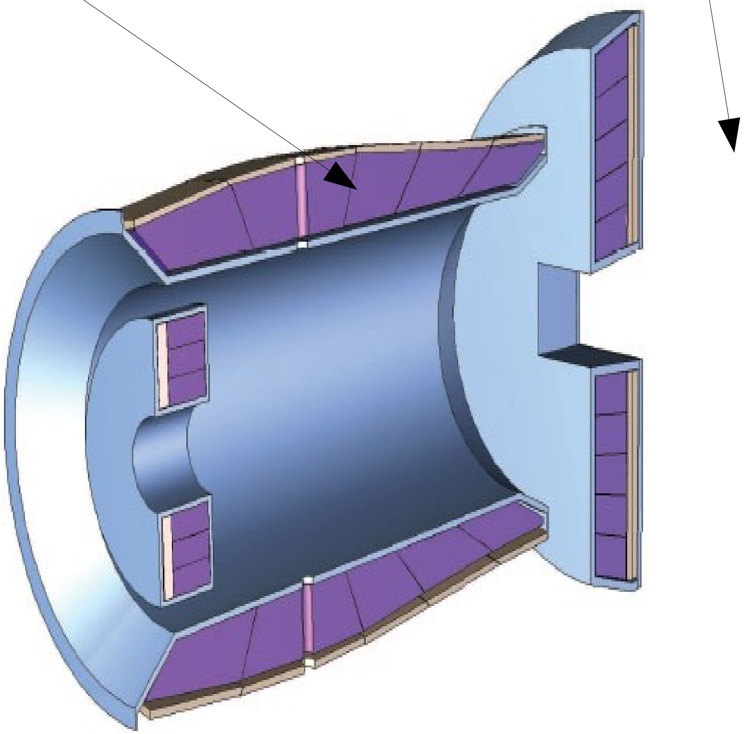
5x5 mm^2 10x10 mm^2 and 7x14 mm^2

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

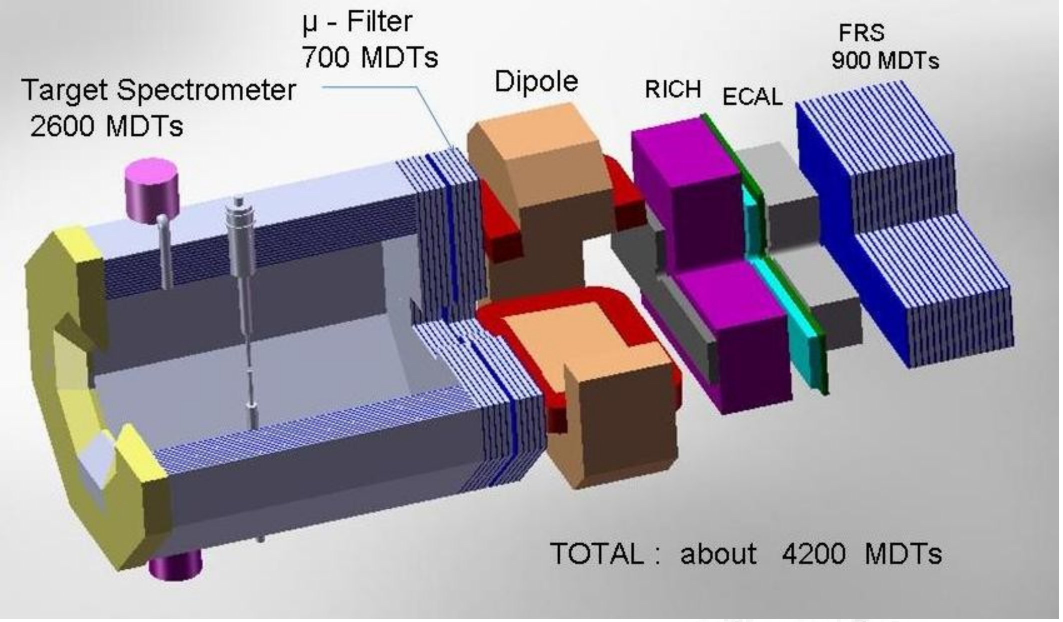
Muon Detector System

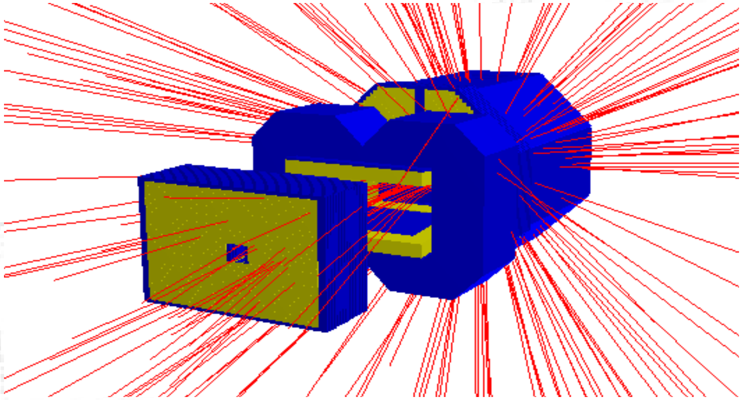
Muon system rationale:

- Low momentum particles
- High background of pions
- Multi-layer range system

Muon system layout:

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



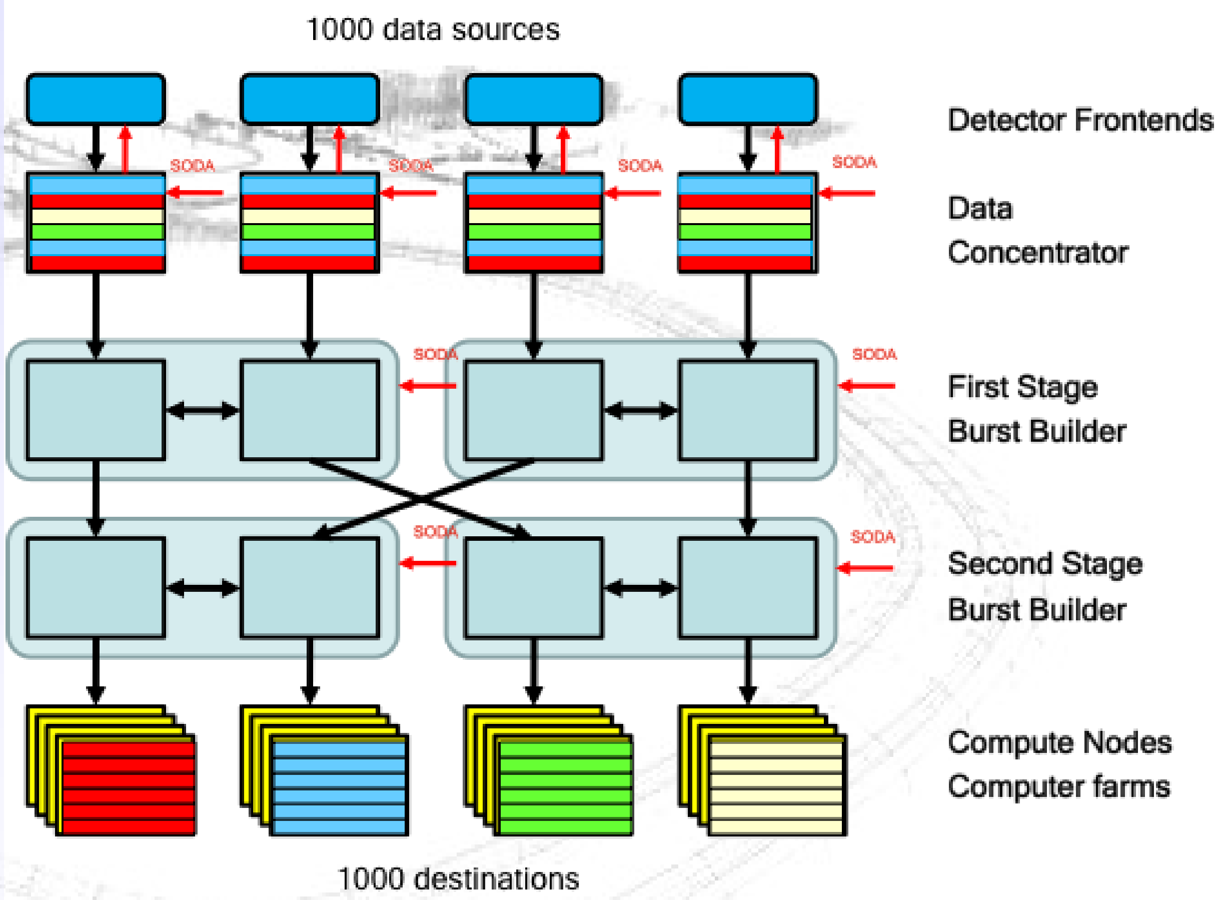


P̄ANDA Data Acquisition

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**



PANDA Timeline and TDR Status

- Completion of technical design
  - TDRs of MVD end 2011, of STT and Target in spring 2012
  - Further TDRs during 2012
  - Evaluation of most TDRs in 2012
  - Preparation of Construction MoU in 2012
- 2013: Start of construction
  - TDRs of DIRC and SciTil
  - Production of detector components starts
- End 2014: Production of components complete for most systems
- 2015/16: Preassembly in Jülich
  - Solenoid magnet: mounting and field mapping
  - Mechanics of MVD and STT
  - Cosmic tests with STT
  - EMC
- 2017: Installation at FAIR
- 2018: First beam for commissioning and physics

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 2012
- Start of construction in 2013
- Start of preassembly at Jülich in 2015/16
- Mounting at FAIR in 2017

PANDA & FAIR start in hadron physics from 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

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

More than 520 physicists from 66 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
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