Challenges in Instrumentation at the PANDA Experiment

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Instrumentation 2014

Helmholtz-Institut Mainz

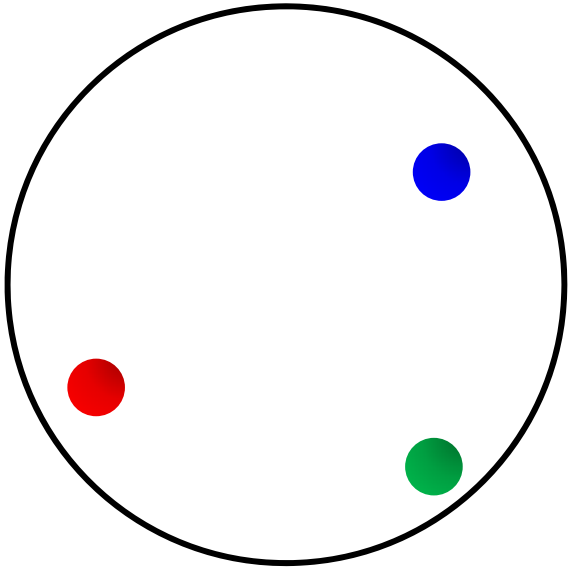
Millenium Question

How is the proton mass created ?

Proton consists of 3 quarks

But:

→ Only 2% of the proton mass from the quarks



Millenium Question

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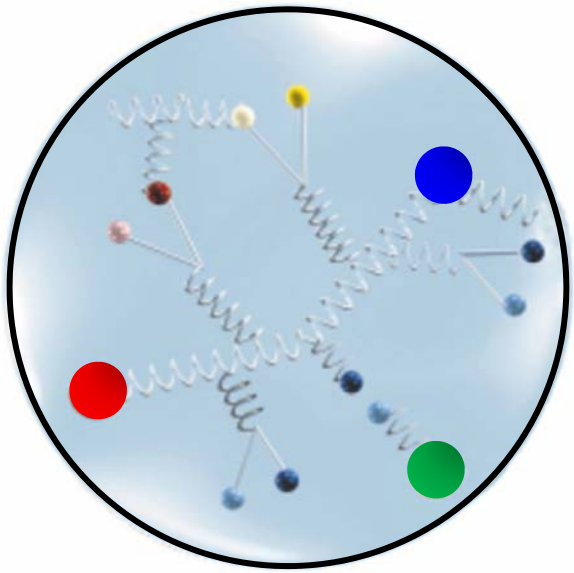


But:

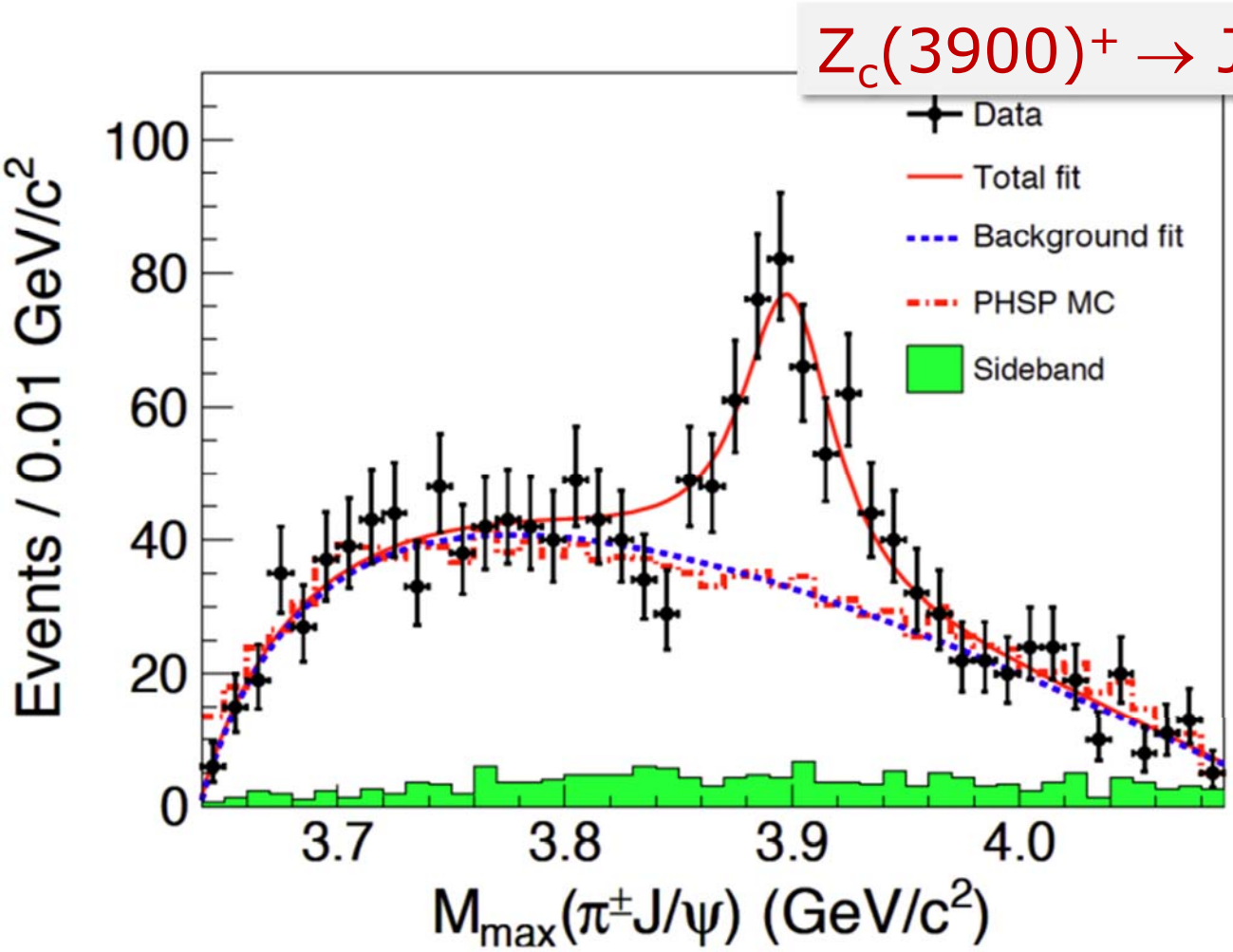
→ Only 2% of the proton mass from the quarks

→ 98% from complex binding not understood sufficiently

Binding force between the quarks ?

Internal structure ?

Charged Resonance by BESIII and Belle



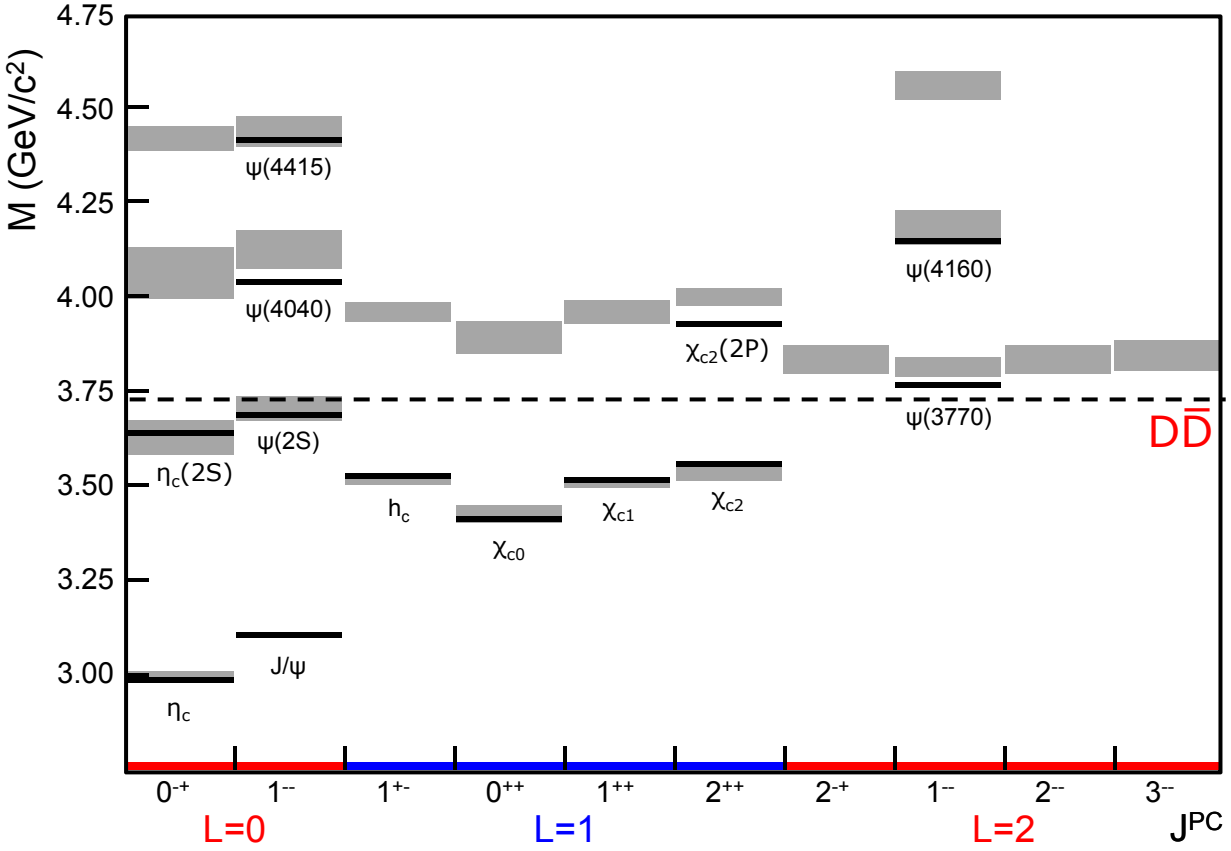
APS physics

Highlight of the year 2013

Necessarily exotic !

Charmonium Spectroscopy/Search for Exotics

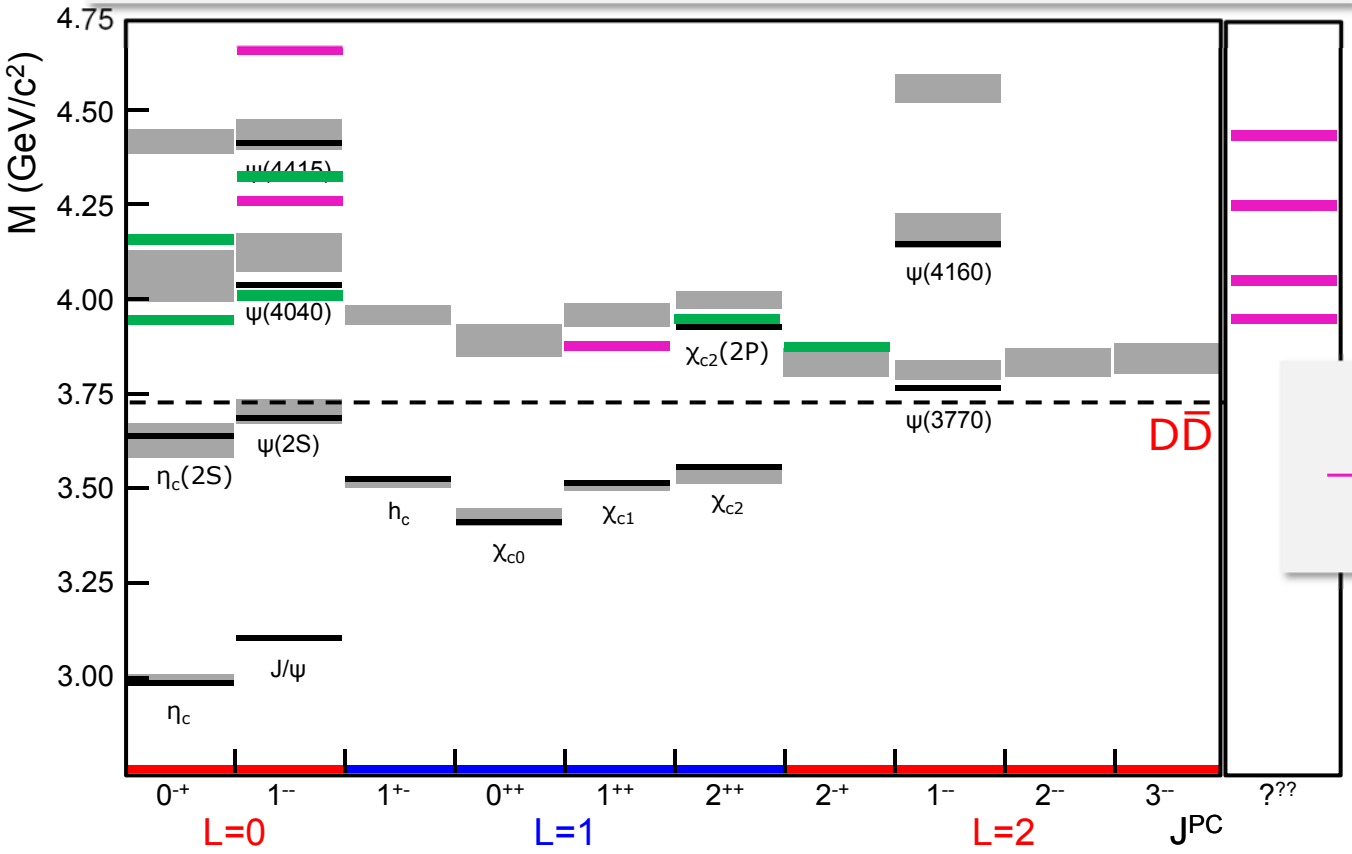
Charmonium Spectrum ($c\bar{c}$ mesons)



10 years ago

Charmonium Spectroscopy/Search for Exotics

Charmonium and
Exotic States with $c\bar{c}$ content

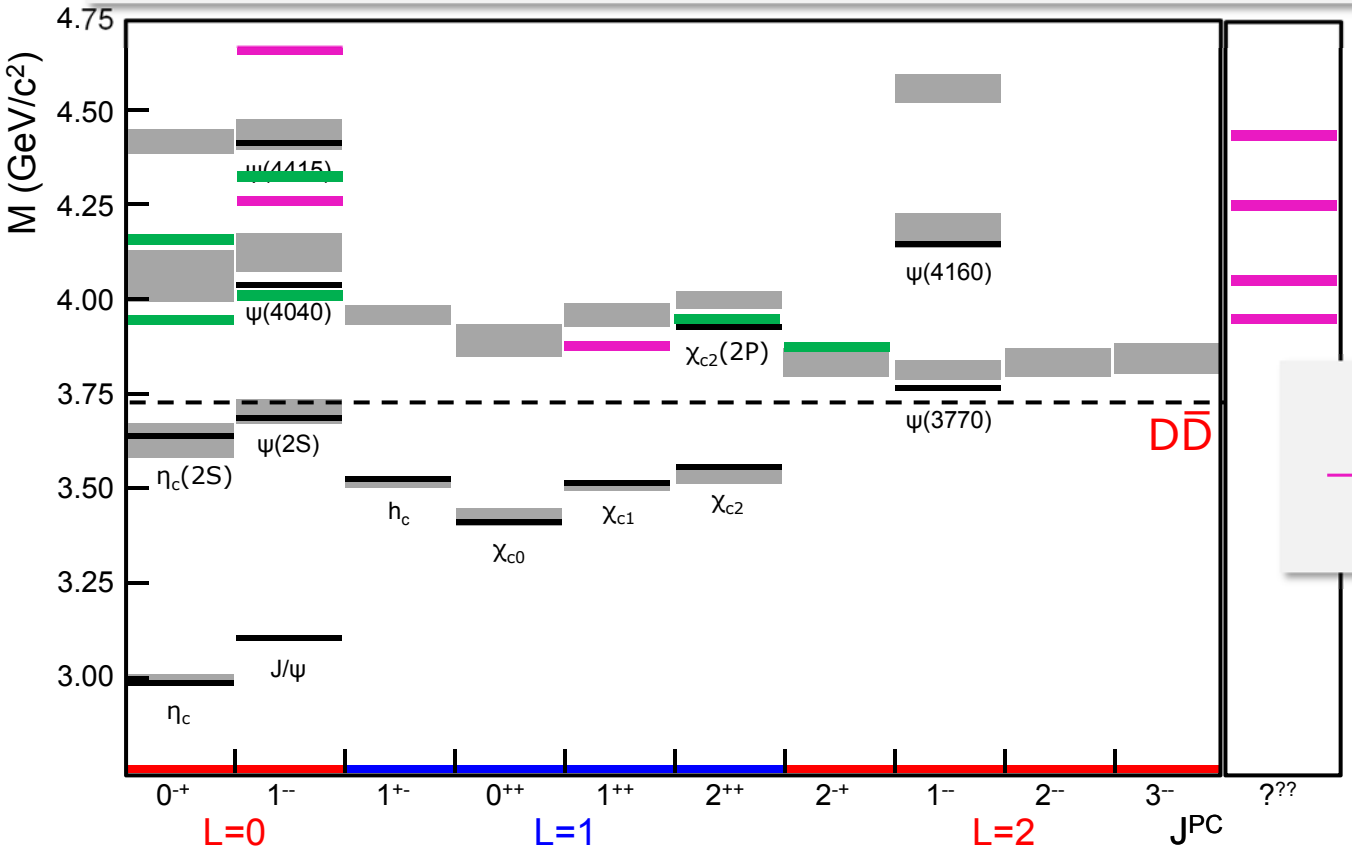


today

→ X,Y,Z states

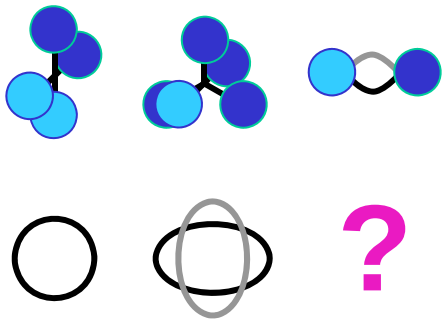
Charmonium Spectroscopy/Search for Exotics

Charmonium and Exotic States with $c\bar{c}$ content



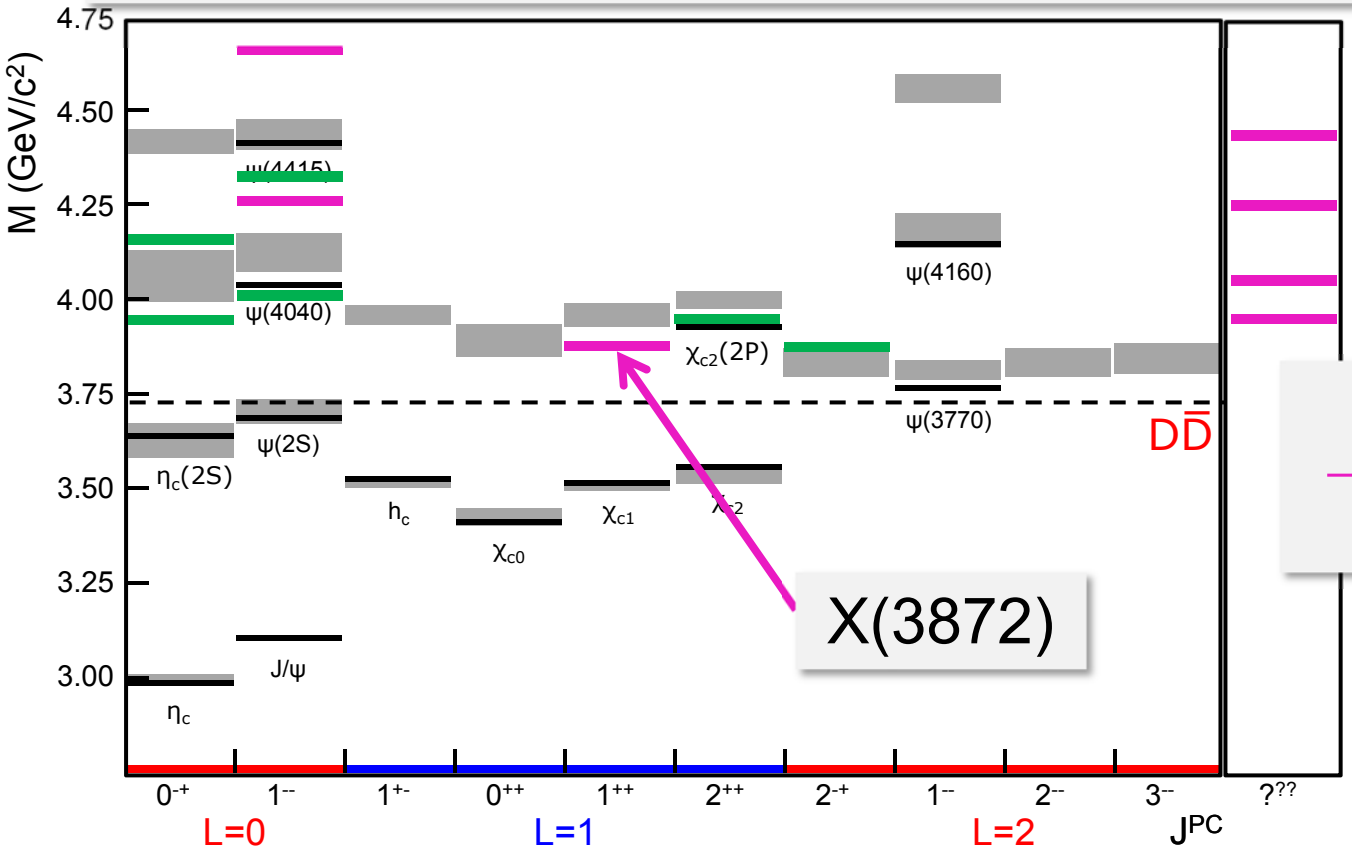
today

→ X,Y,Z states



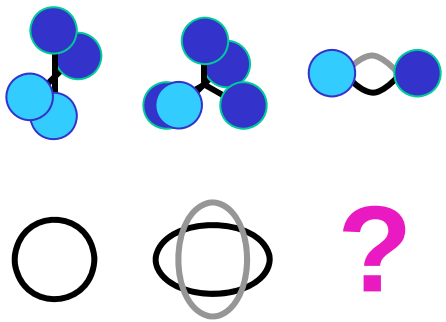
Charmonium Spectroscopy/Search for Exotics

Charmonium and Exotic States with $c\bar{c}$ content

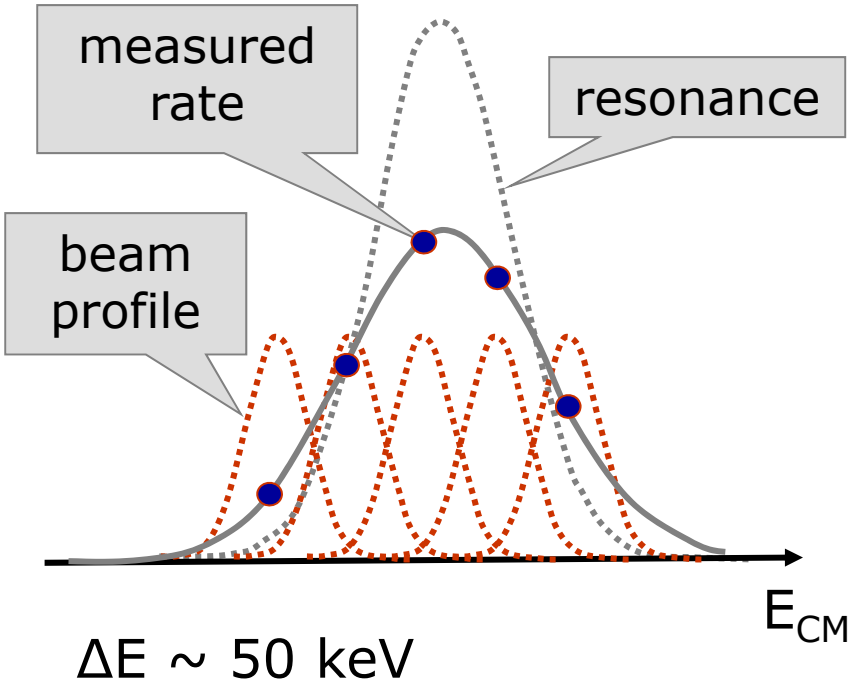


Second Charm Revolution

→ X,Y,Z states



Line shape measurement: X(3872)



Energy scan method

X(3872) with

Γ = 136 keV

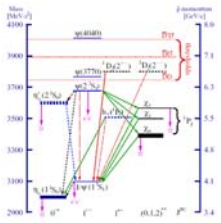
σ = 100 nb

16 Scan points, 40 days

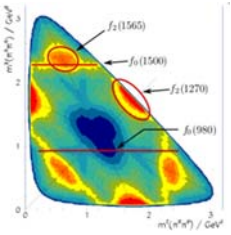
Width measurement < 10%

All conventional Quantum Numbers accessible

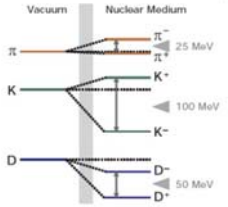
PANDA Physics Program



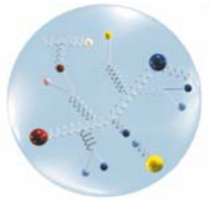
Charmonium Spectroscopy



Search for Exotic States

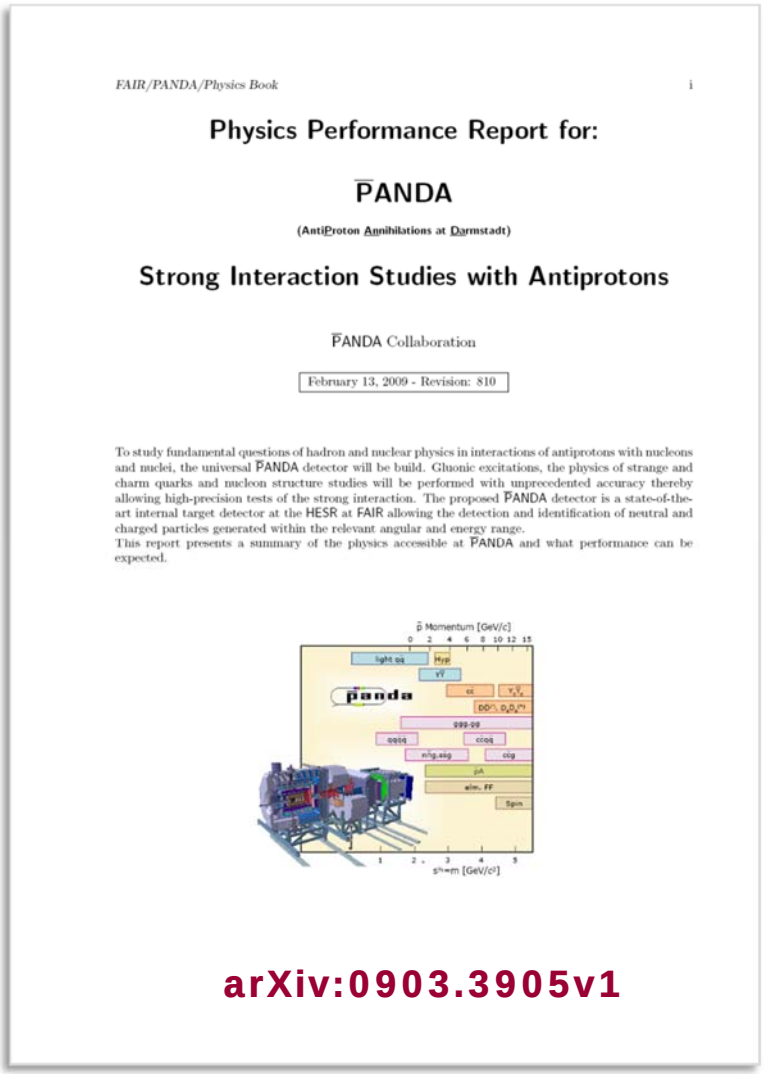


Charm in Medium



Nucleon Structure

S=2 Hypernuclei



FAIR/PANDA/Physics Book i

Physics Performance Report for:

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

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

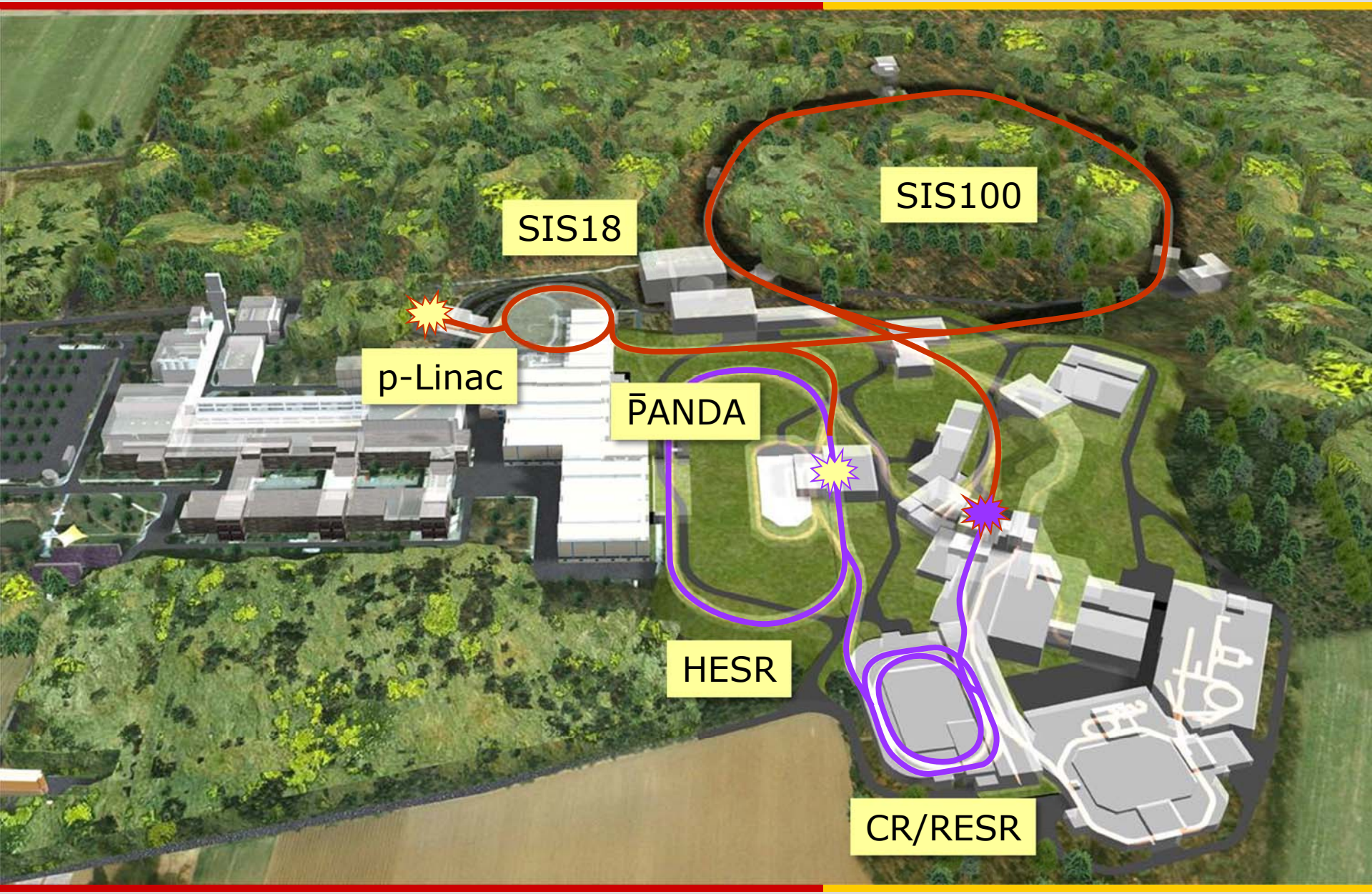
$\overline{\text{P}}$ANDA Collaboration

February 13, 2009 - Revision: 810

To study fundamental questions of hadron and nuclear physics in interactions of antiprotons with nucleons and nuclei, the universal $\overline{\text{P}}$ANDA detector will be build. Gluonic excitations, the physics of strange and charm quarks and nucleon structure studies will be performed with unprecedented accuracy thereby allowing high-precision tests of the strong interaction. The proposed $\overline{\text{P}}$ANDA detector is a state-of-the-art internal target detector at the HESR at FAIR allowing the detection and identification of neutral and charged particles generated within the relevant angular and energy range.
This report presents a summary of the physics accessible at $\overline{\text{P}}$ANDA and what performance can be expected.

arXiv:0903.3905v1

Antiproton Facility PANDA @ FAIR



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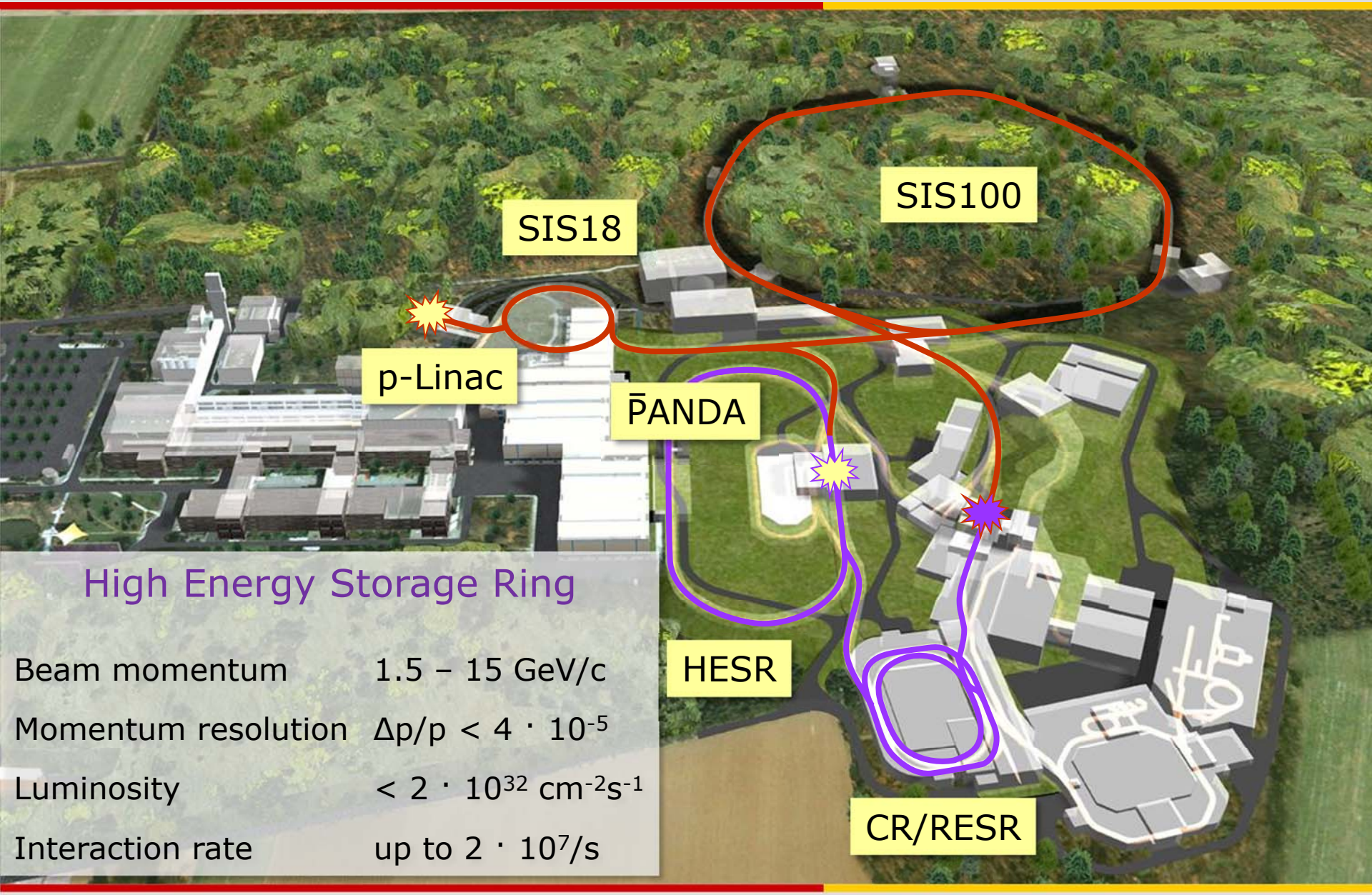
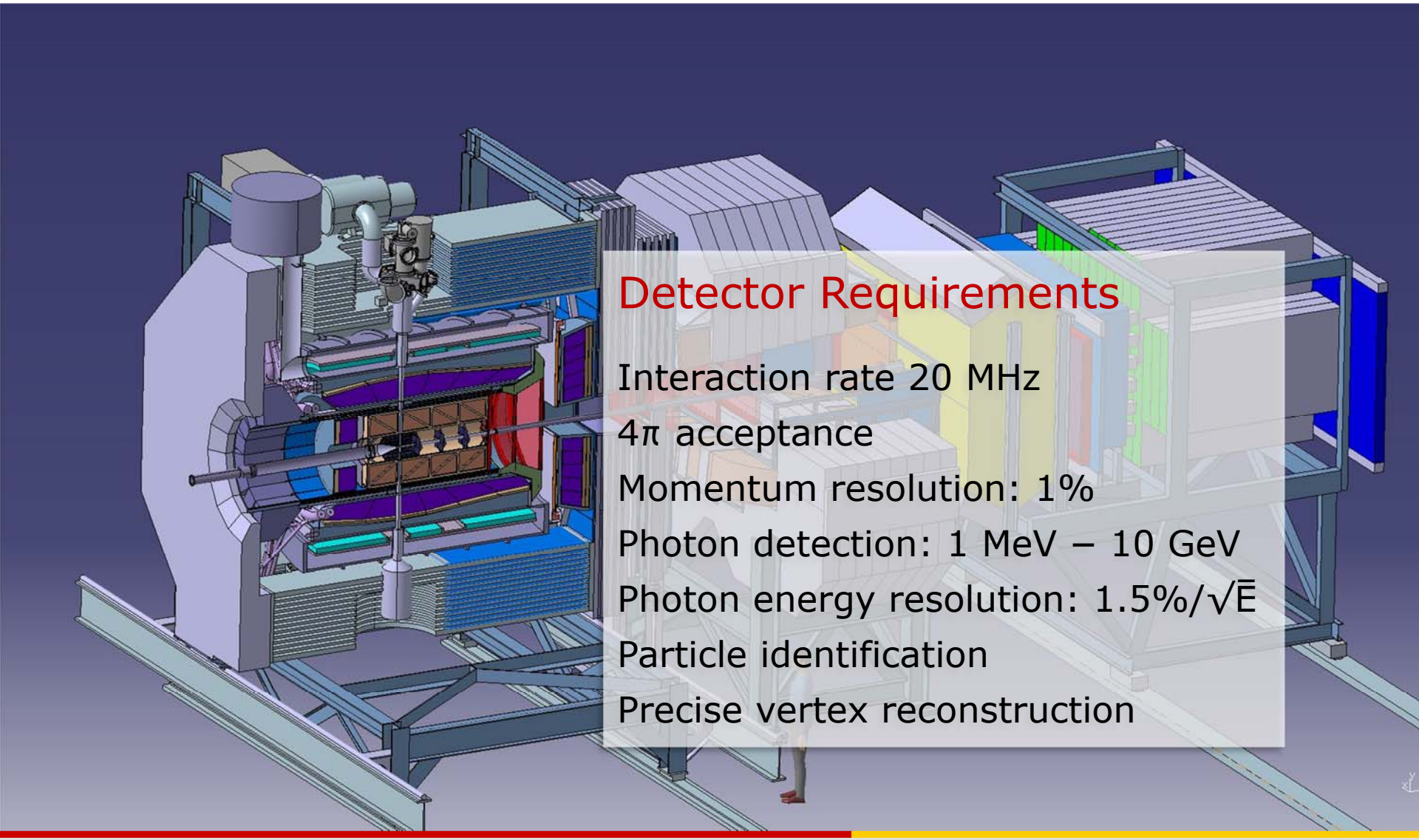


High Energy Storage Ring

Beam momentum	1.5 – 15 GeV/c
Momentum resolution	$\Delta p/p < 4 \cdot 10^{-5}$
Luminosity	$< 2 \cdot 10^{32}$ cm^{-2}s^{-1}
Interaction rate	up to $2 \cdot 10^{7}$/s

PANDA Detector



Detector Requirements

Interaction rate 20 MHz

4π acceptance

Momentum resolution: 1%

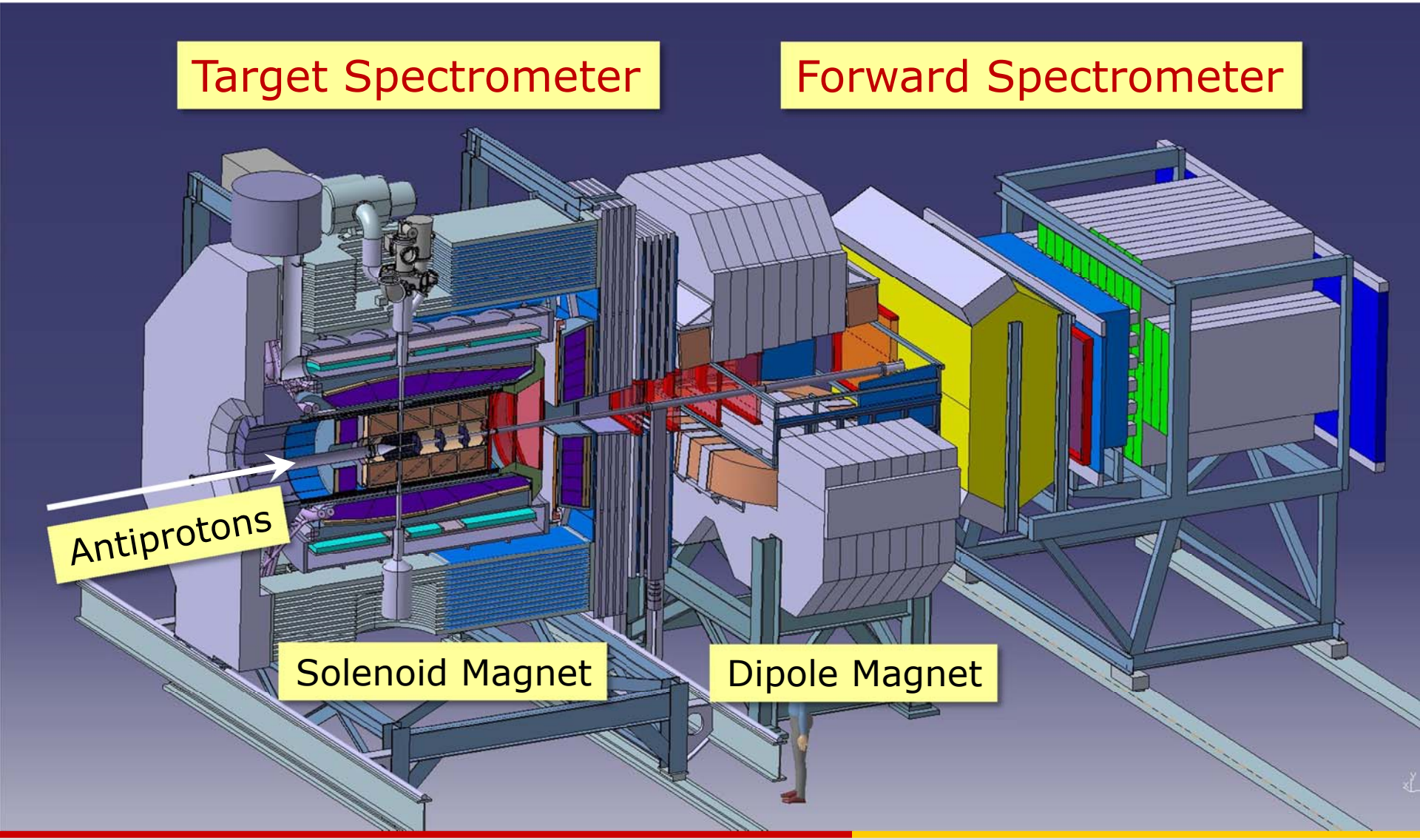
Photon detection: 1 MeV – 10 GeV

Photon energy resolution: $1.5\%/\sqrt{E}$

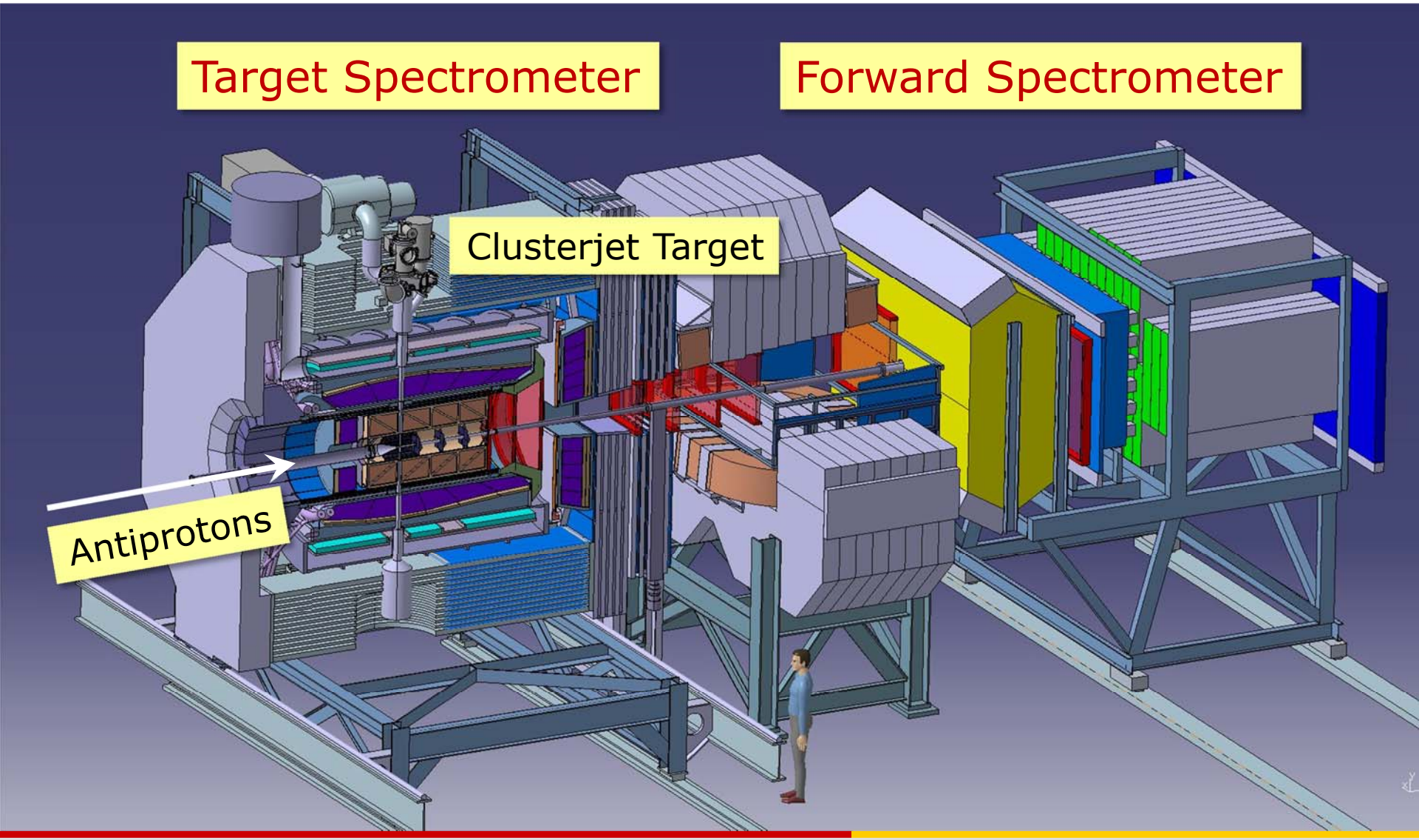
Particle identification

Precise vertex reconstruction

PANDA Detector



PANDA Detector



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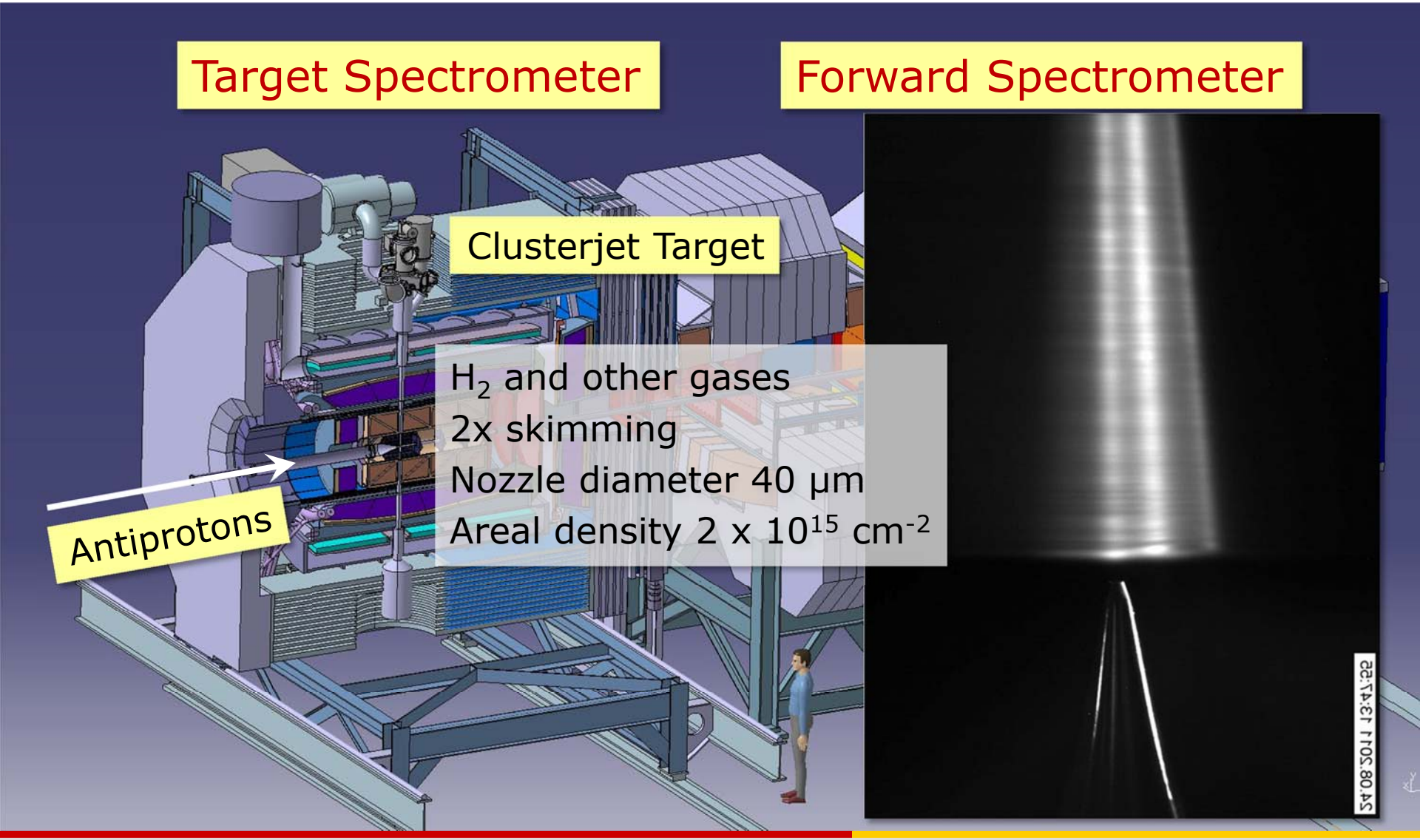
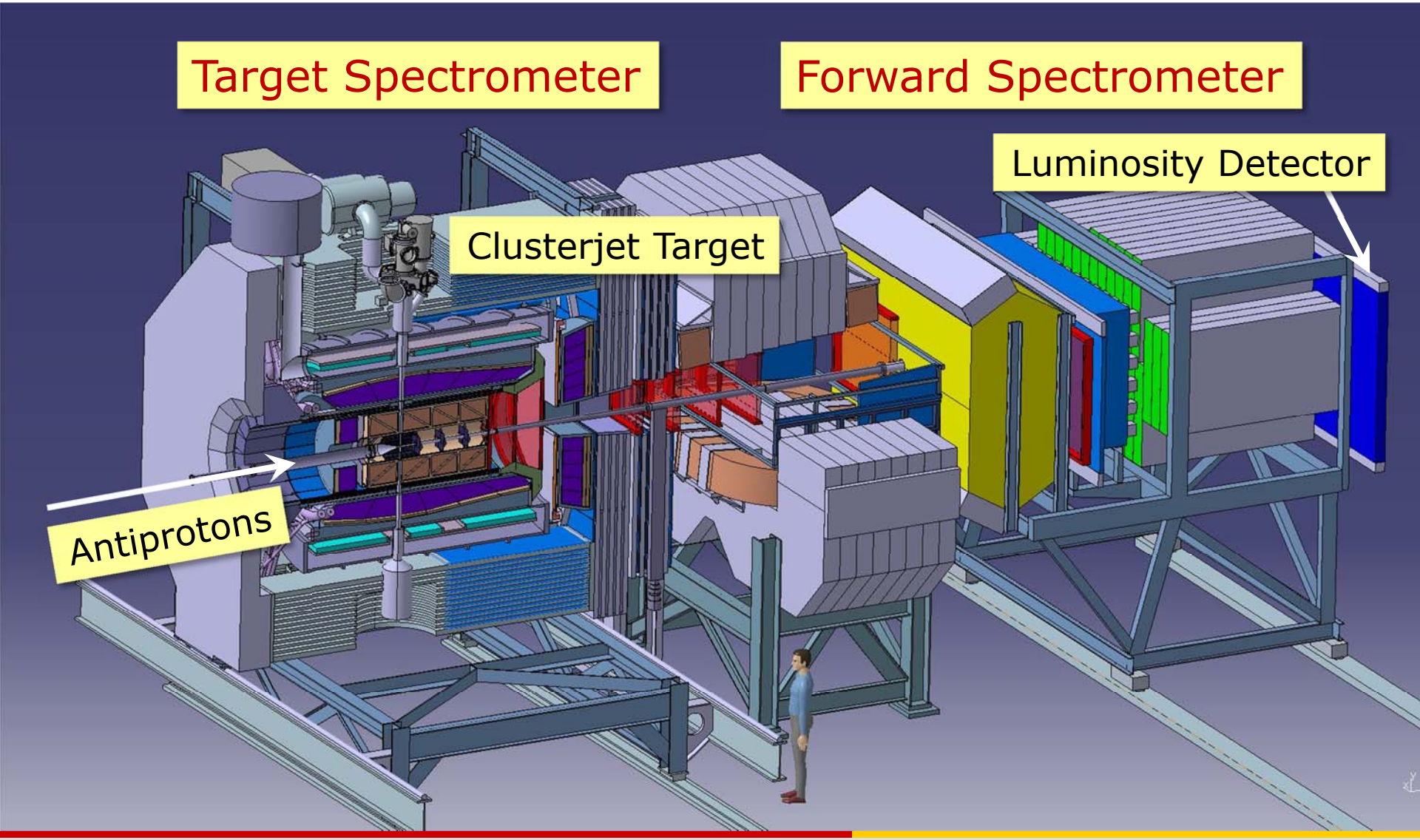


PANDA Detector



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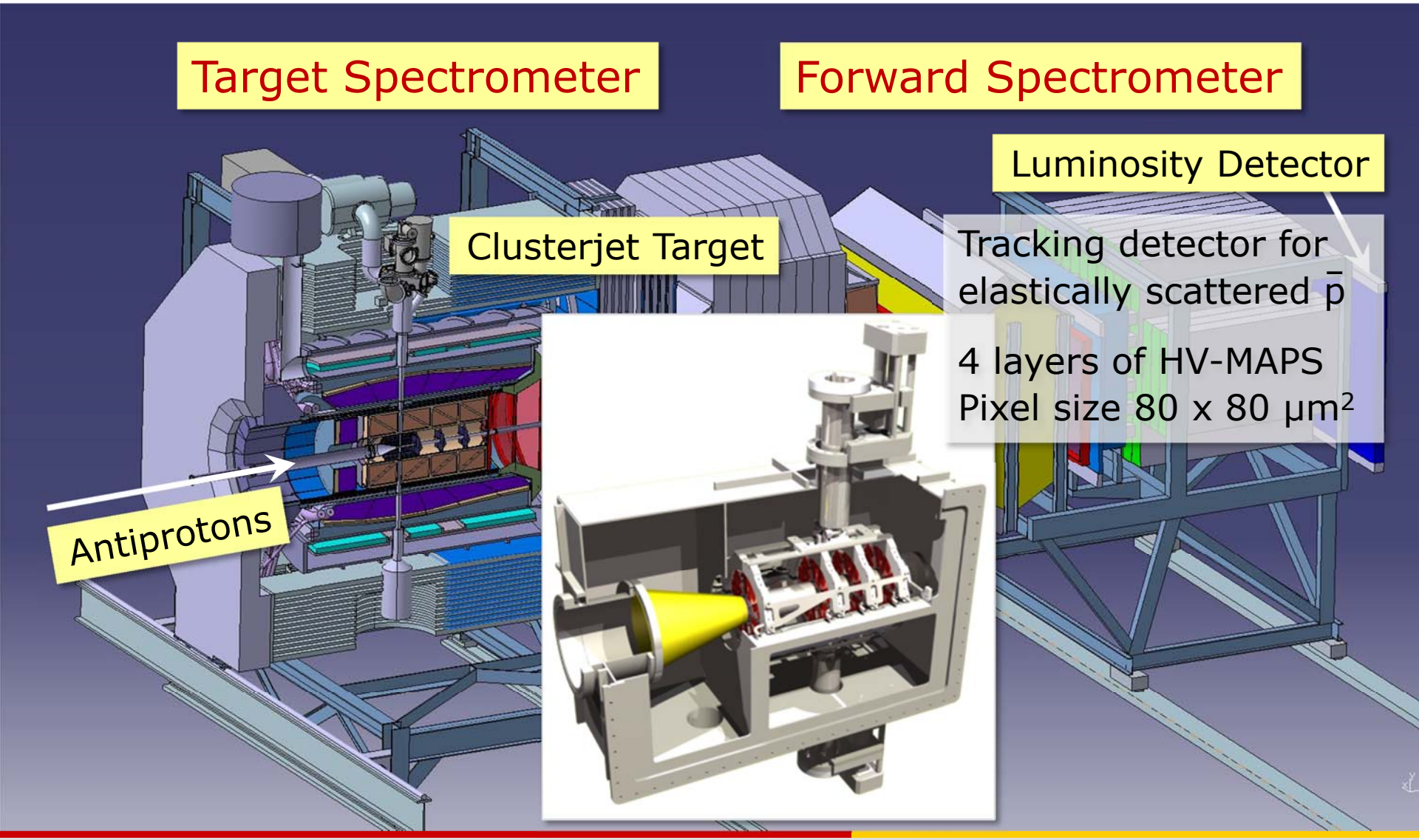
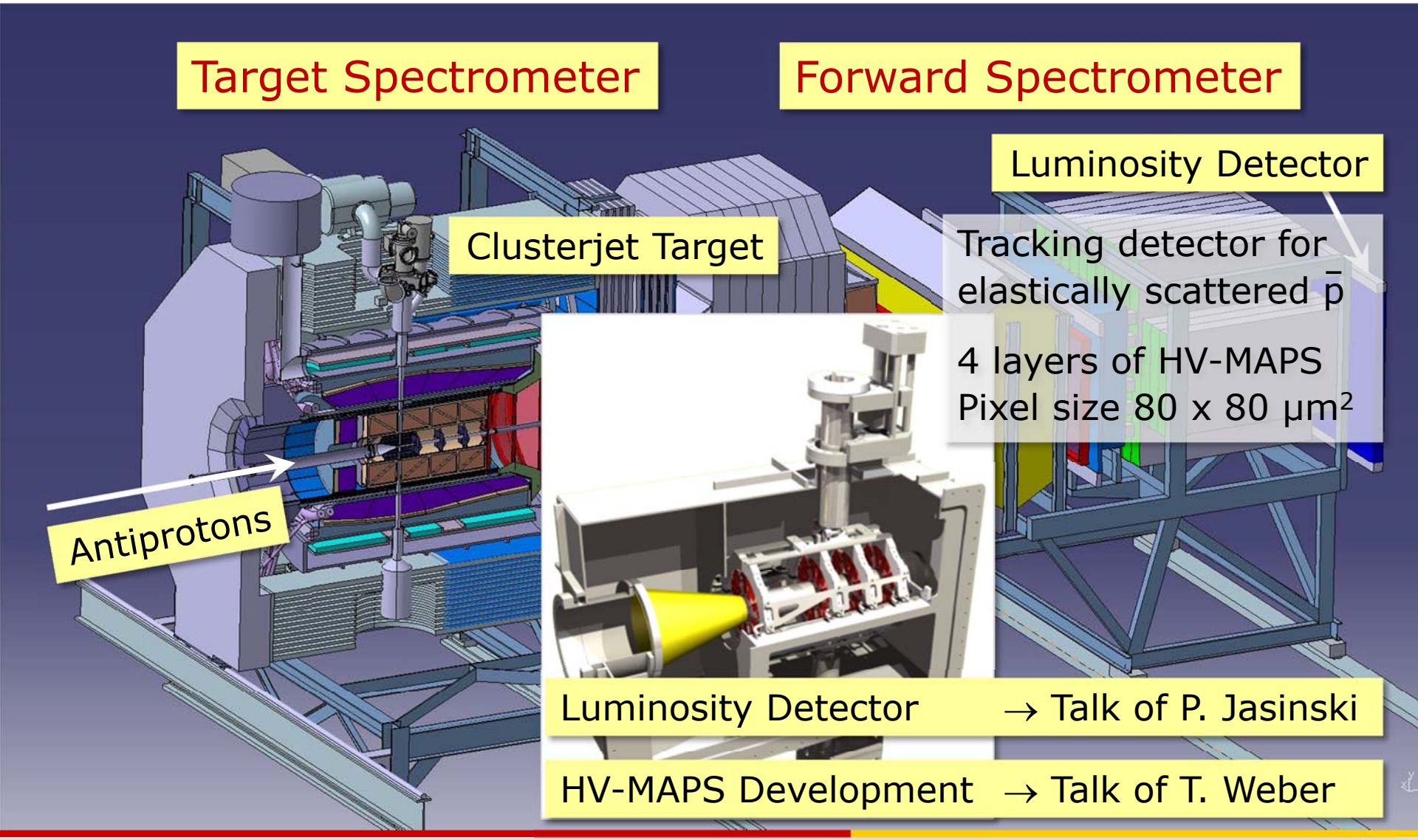
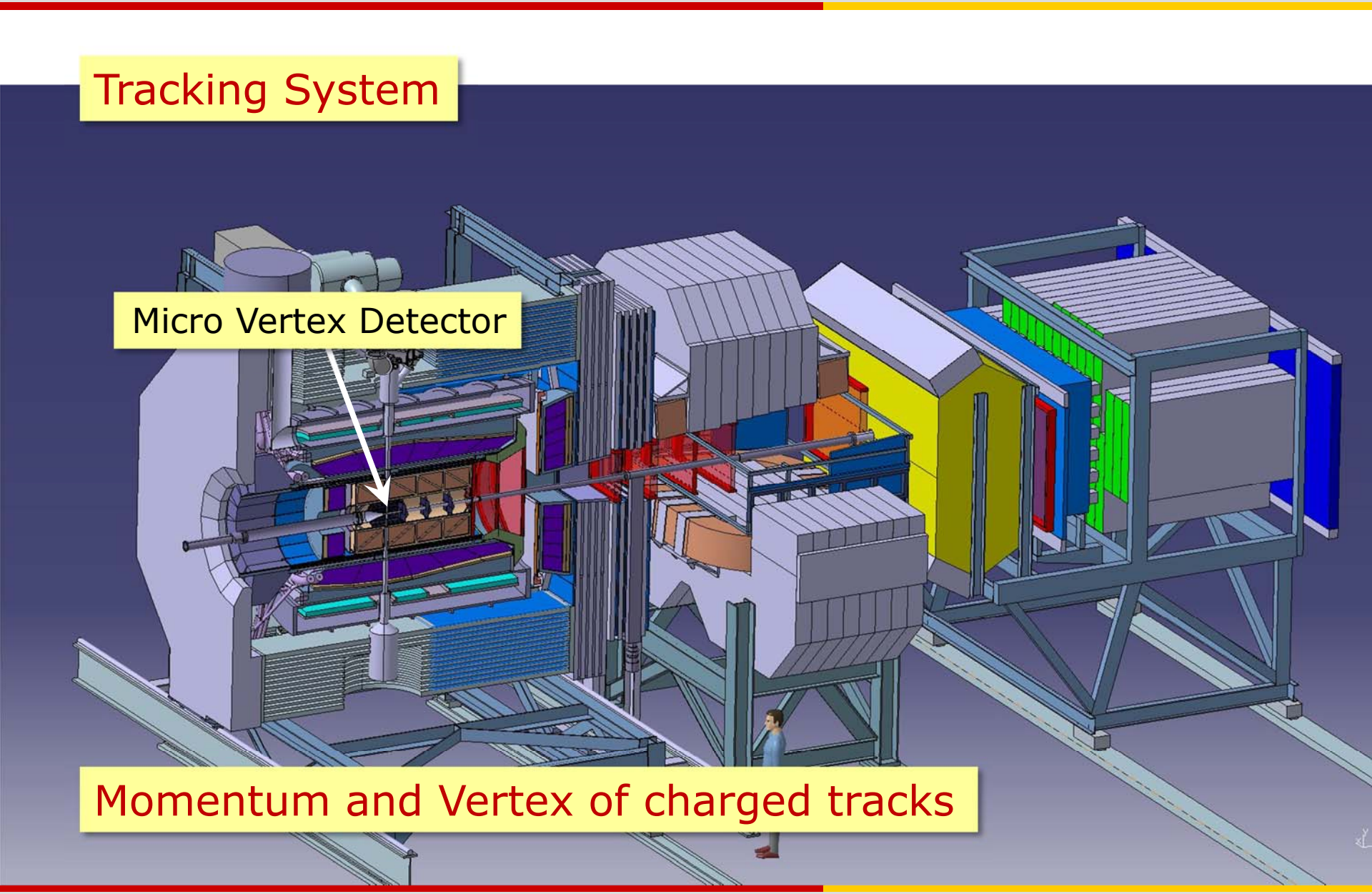


PANDA Detector



PANDA Detector



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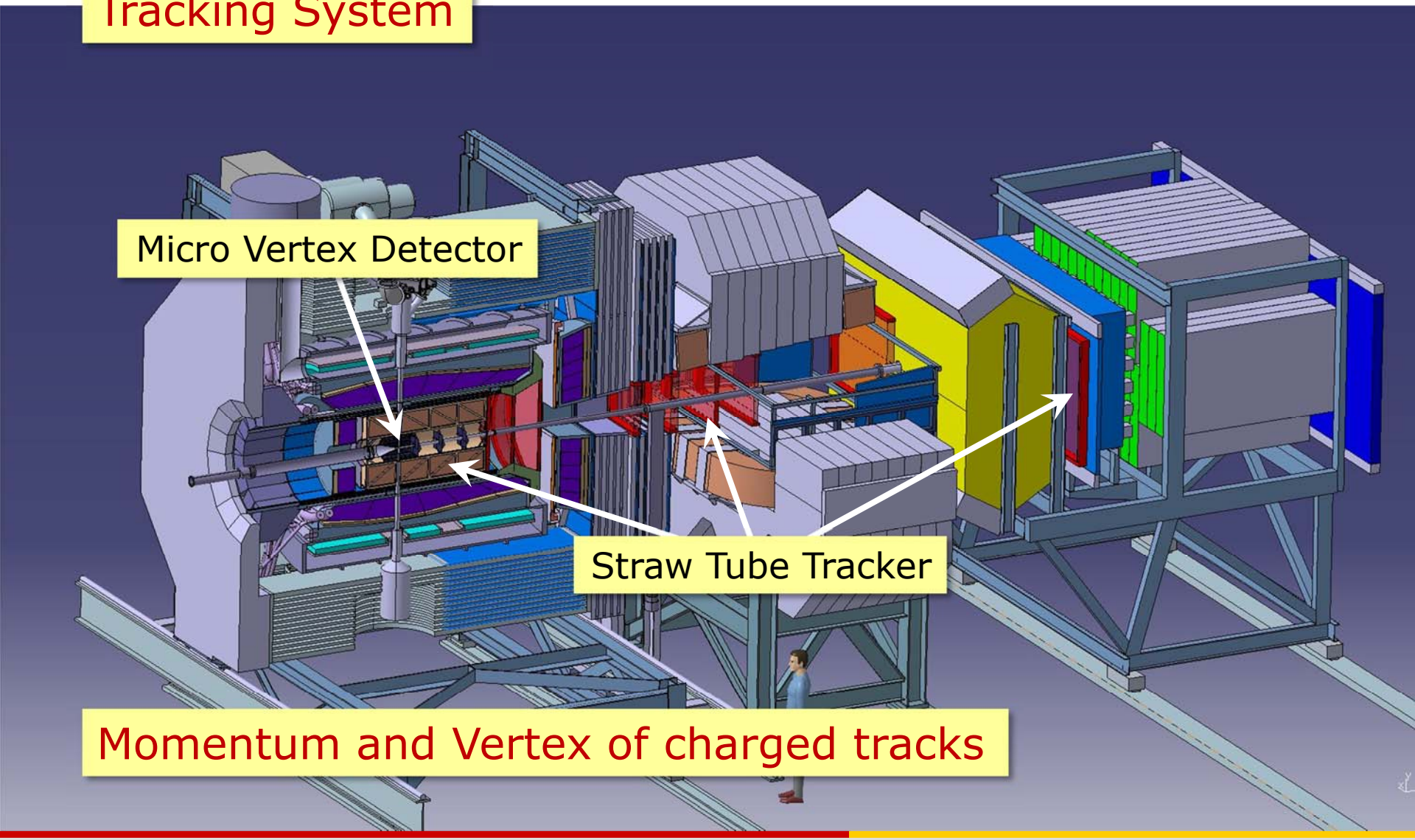

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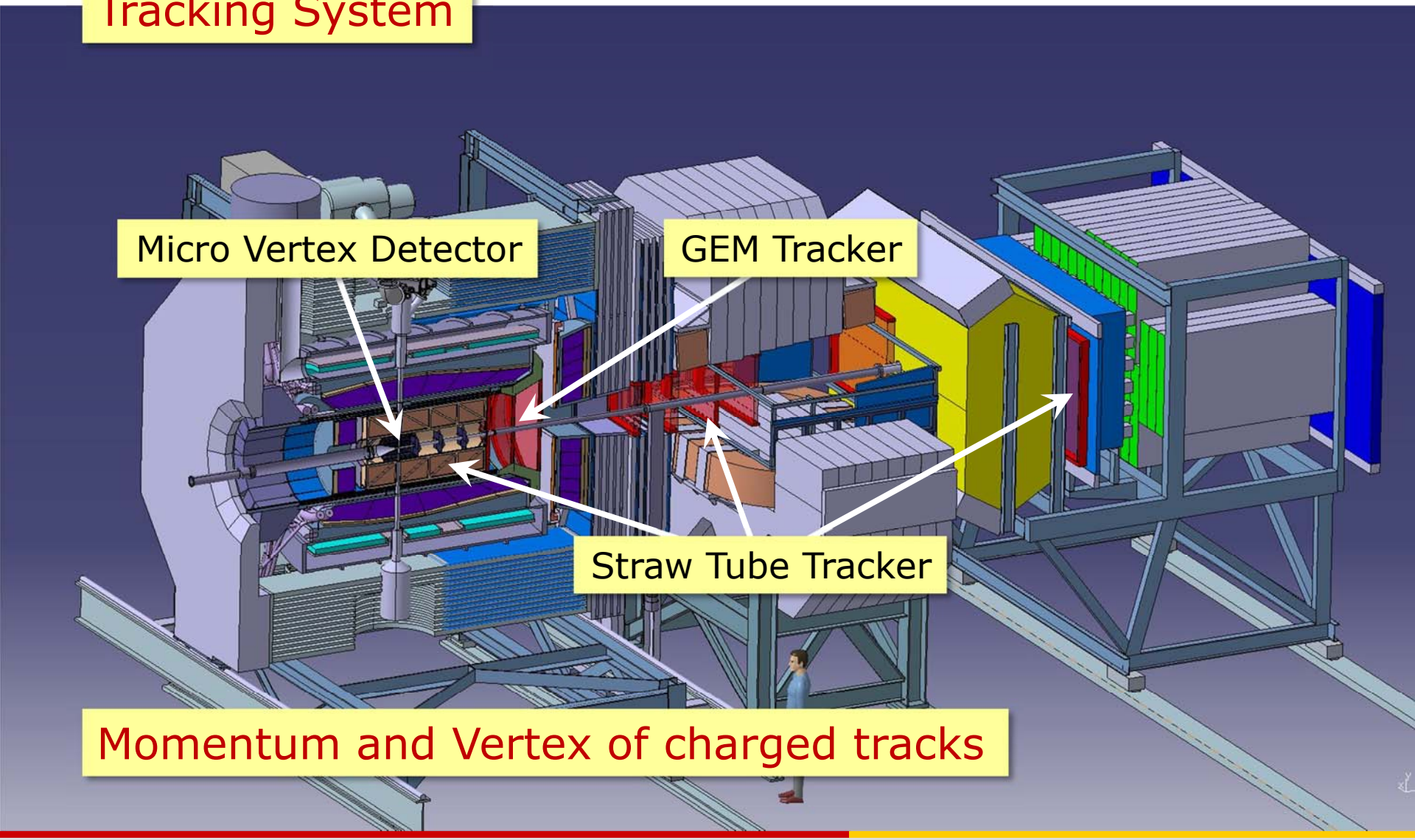


Micro Vertex Detector

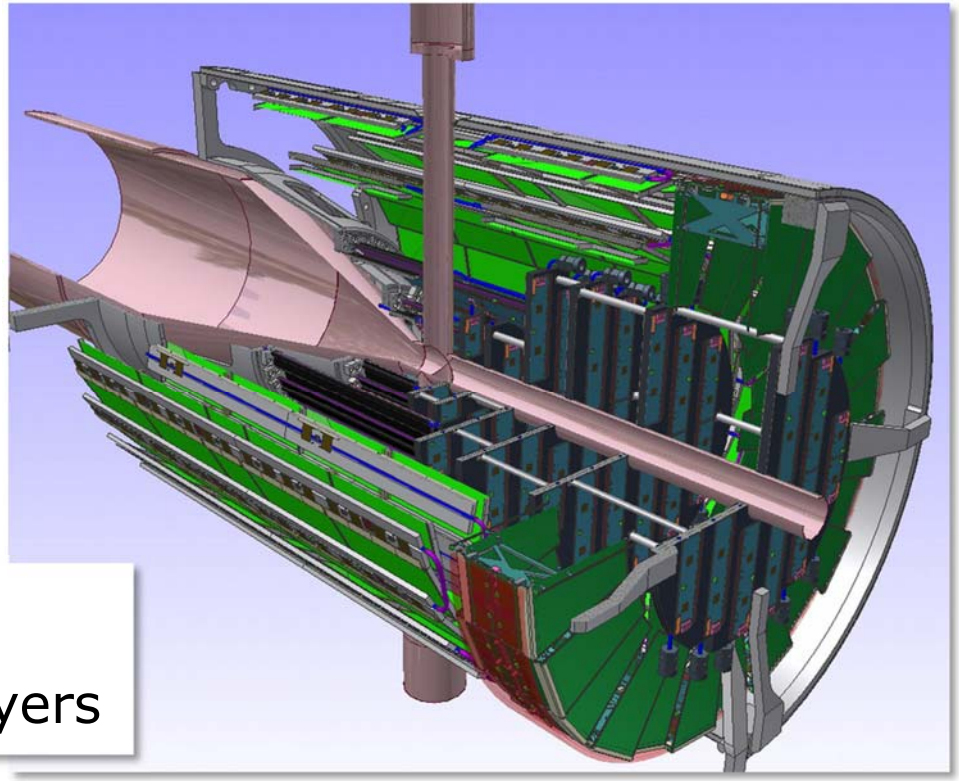
Sensors

Hybrid pixels sensors
(inner layers)

Double-sided micro strips detectors
(outer layers)

Cooling of front-ends

Low mass support structure



4 barrel layers

6 forward disks layers

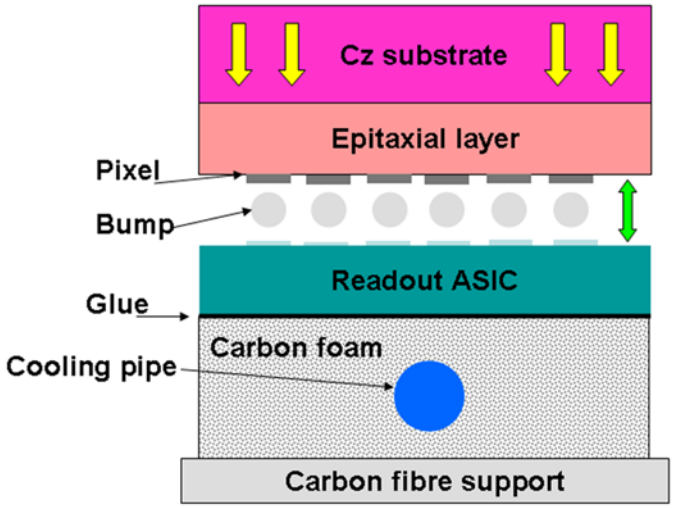
Sensors and Readout

Silicon pixel sensors (10^7 channels)

Pixel size 100 x 100 μm^2

Specialized custom hybrid $\rightarrow$ ToPix

- ToT for dE/dx
- Fast data handling
- Untriggered readout
- Radiation hard
- Minimum material load



Silicon strip sensors (200.000 channels)

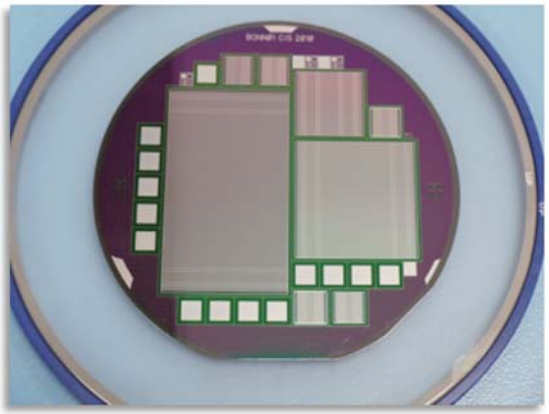
Double-sided sensors

Pitch of 50 or 65 µm

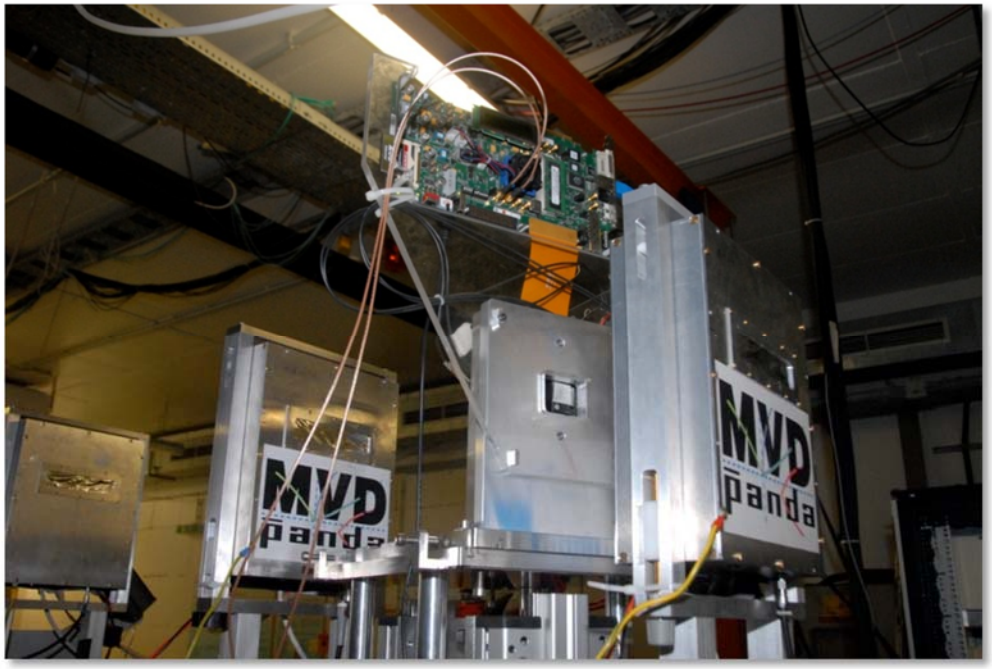
285 µm thick

Customized free-running front-end

$\rightarrow$ Under development (ToPix-like)



Prototype Tests

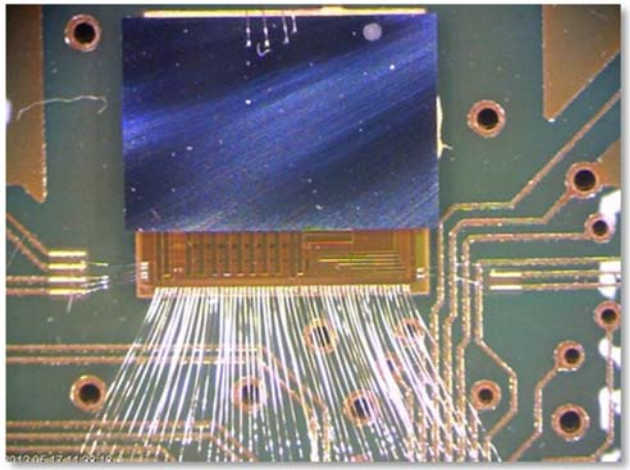


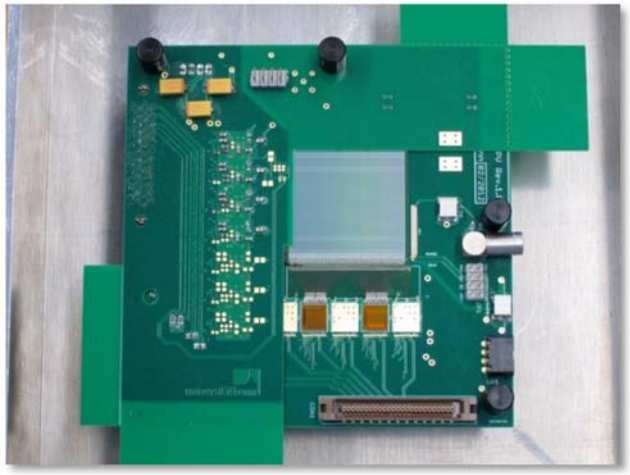
Successful hardware tests in-beam

Free-running data collection

Radiation hardness studies

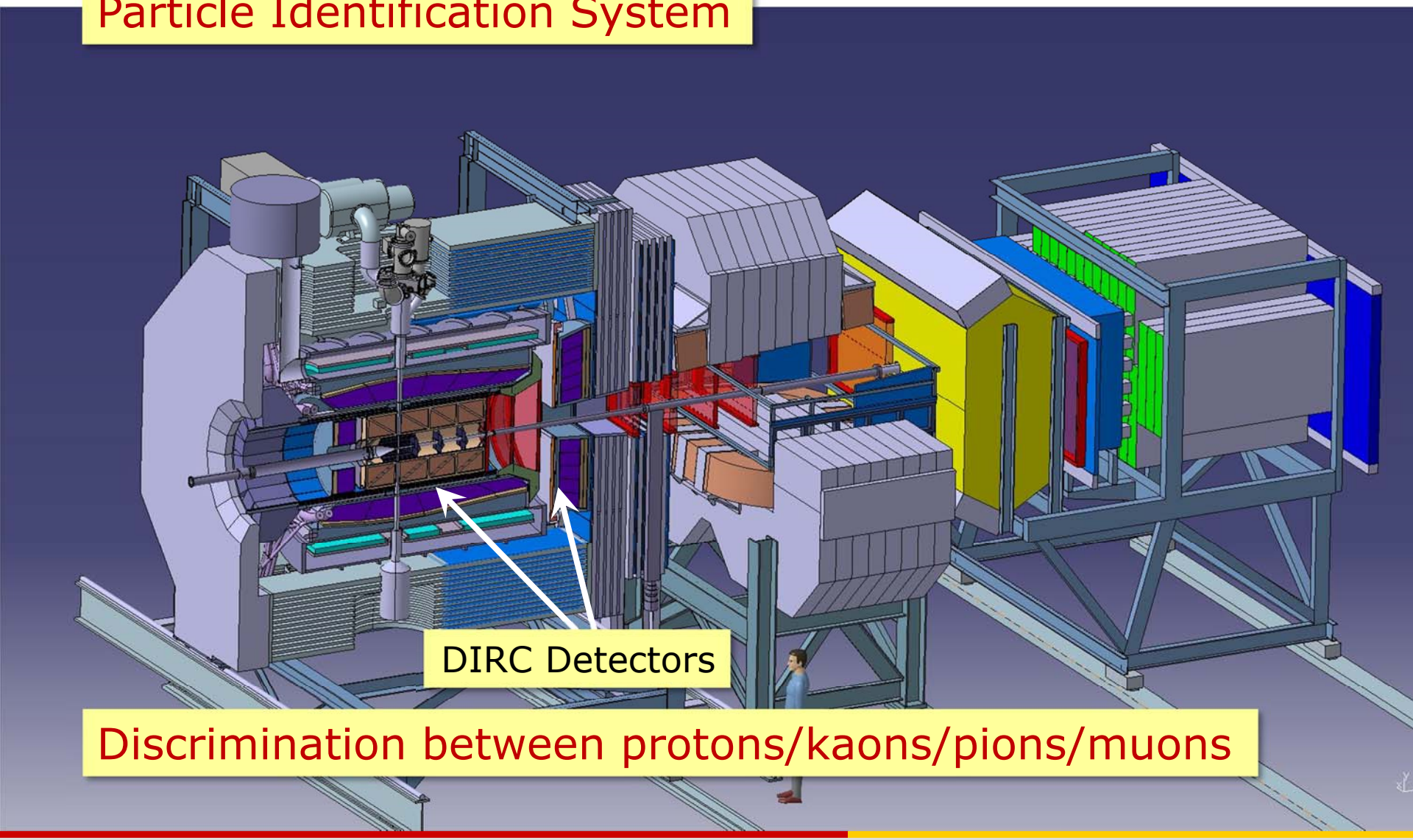
Mechanics





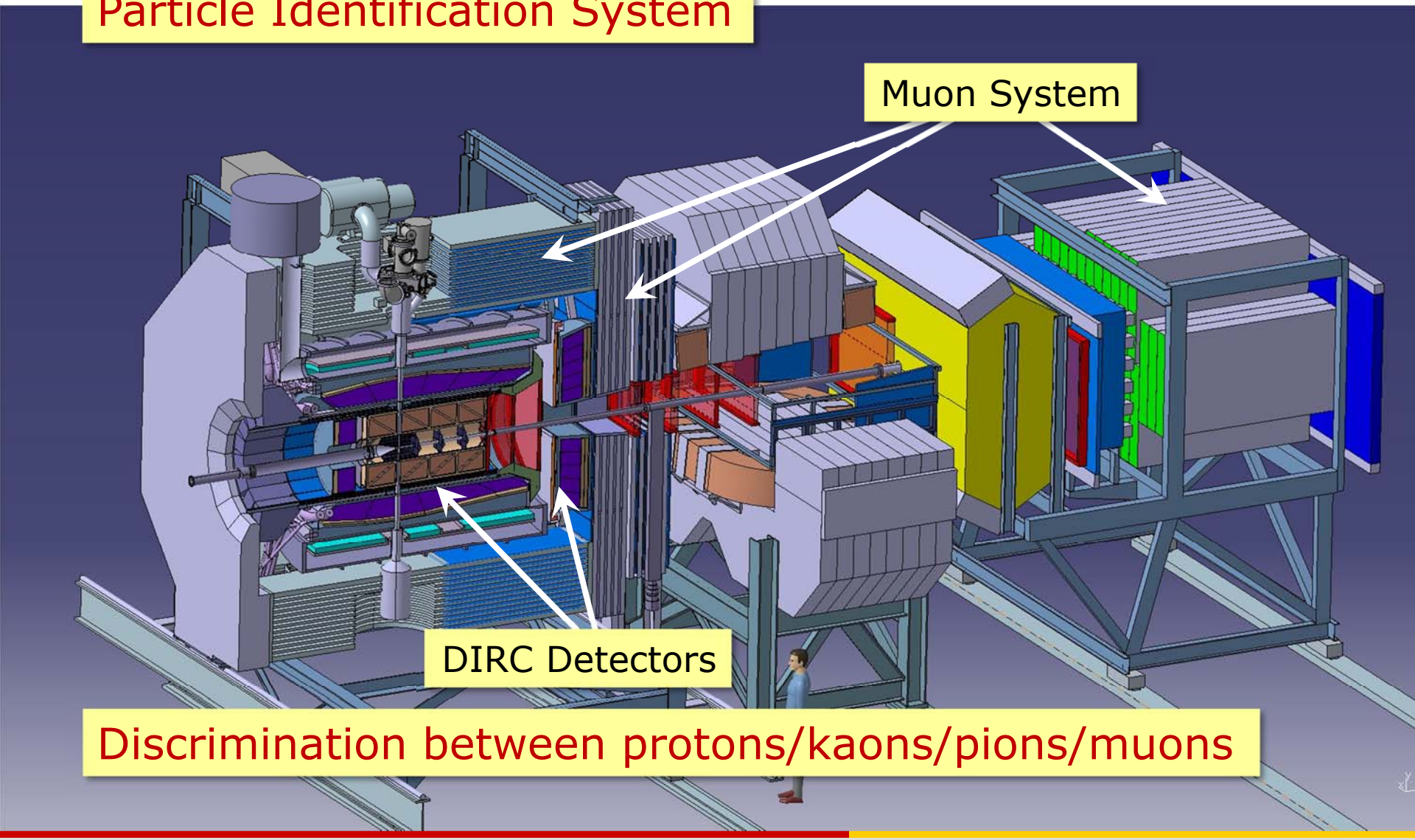
PANDA Detector

Particle Identification System

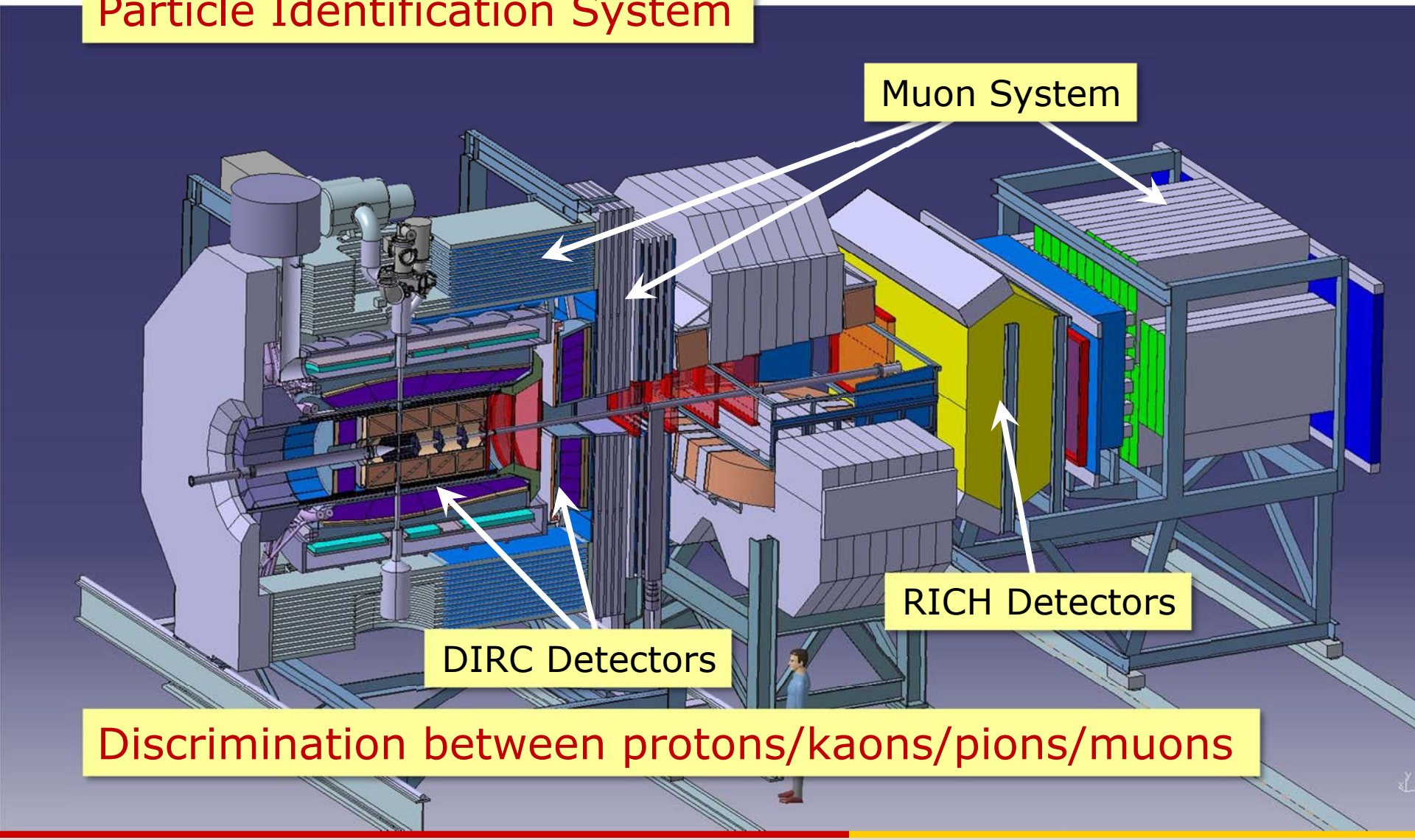


Discrimination between protons/kaons/pions/muons

PANDA Detector

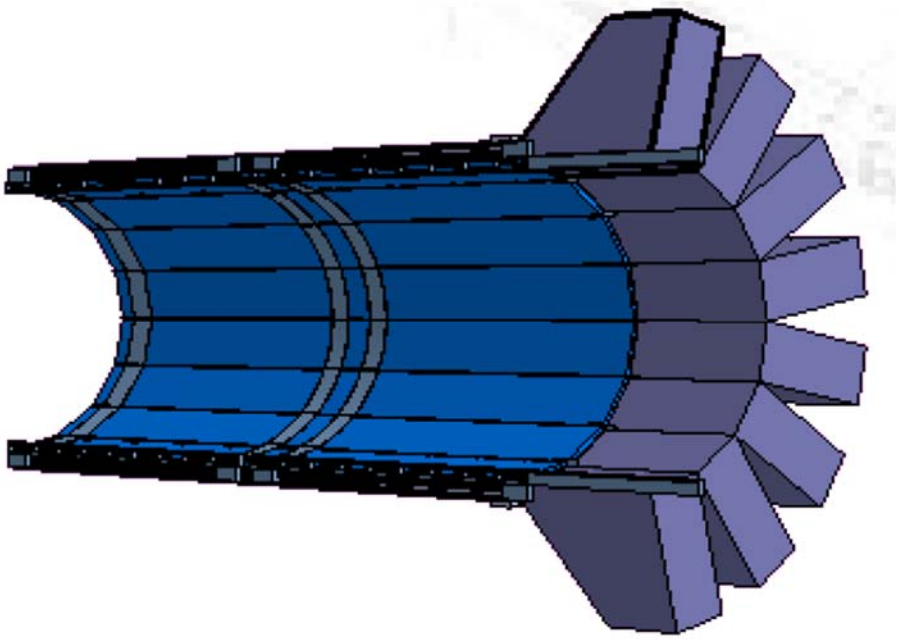


PANDA Detector



DIRC Detectors

Detection of Internally Reflected Cherenkov light



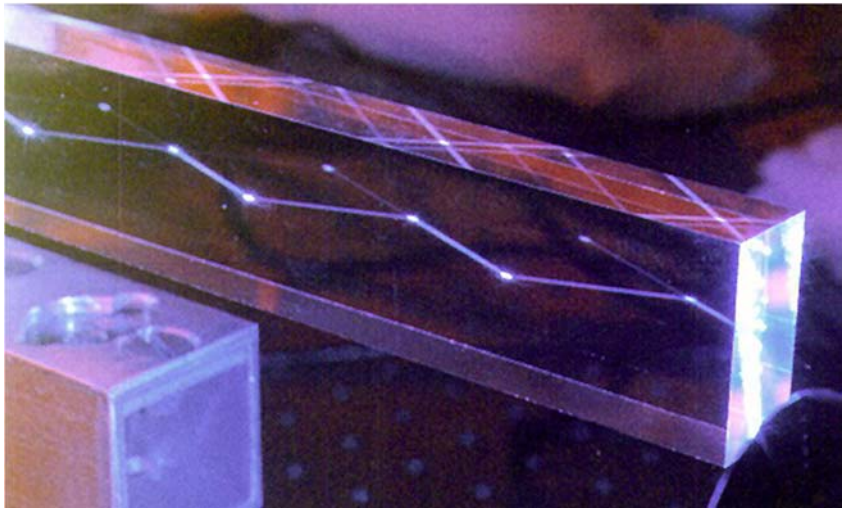
Radiator

80 radiator bars

Synthetic fused silica

1.7 x 3.3 x 250 cm^3

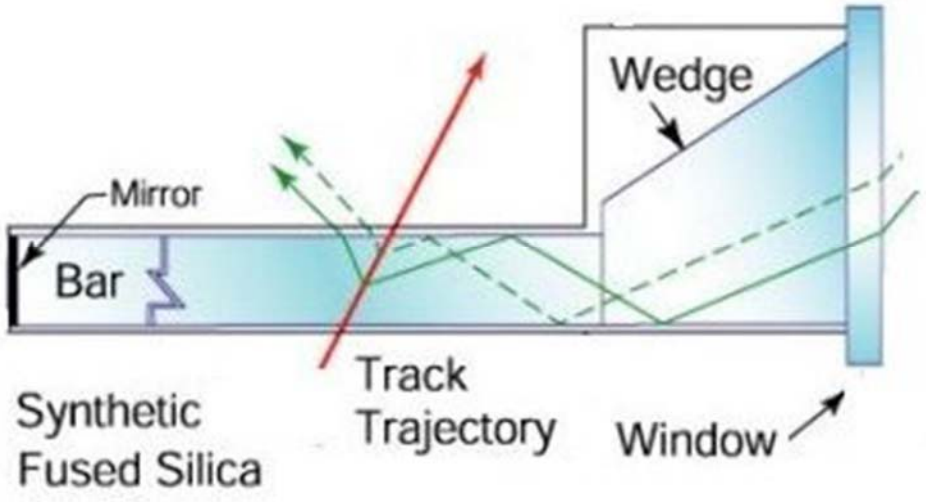
Polished to 150 nm rms



Laser tests

characterize transmission and reflectivity

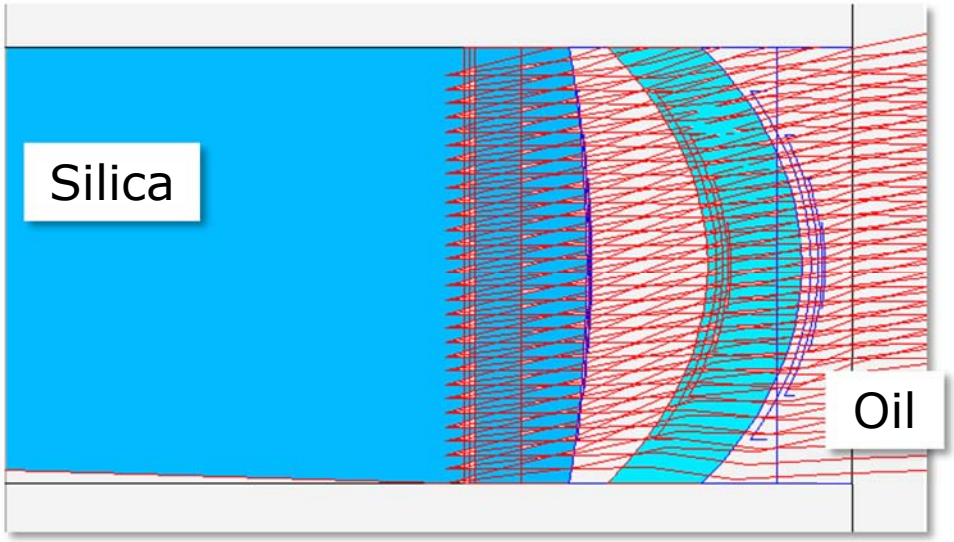
Barrel DIRC



Focussing system

Double lens system,

30 cm container oil-filled



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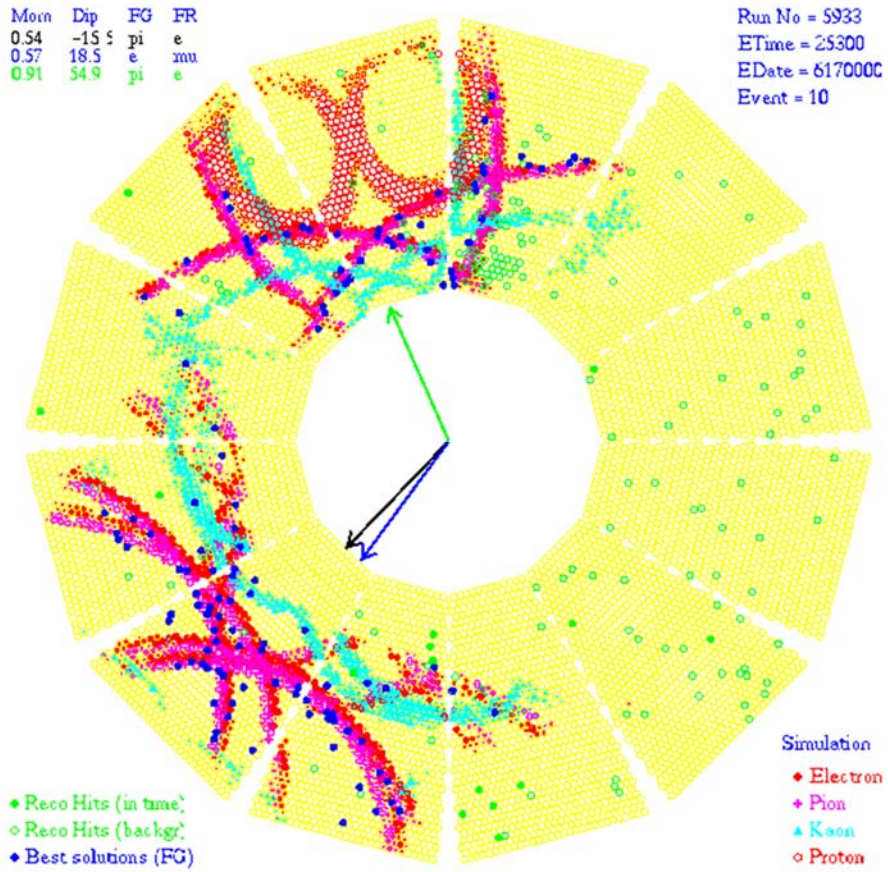


Readout

Number of photoelectrons per track > 20

→ Single photon sensitivity

→ Low dark count rate

Fast timing ~100 ps

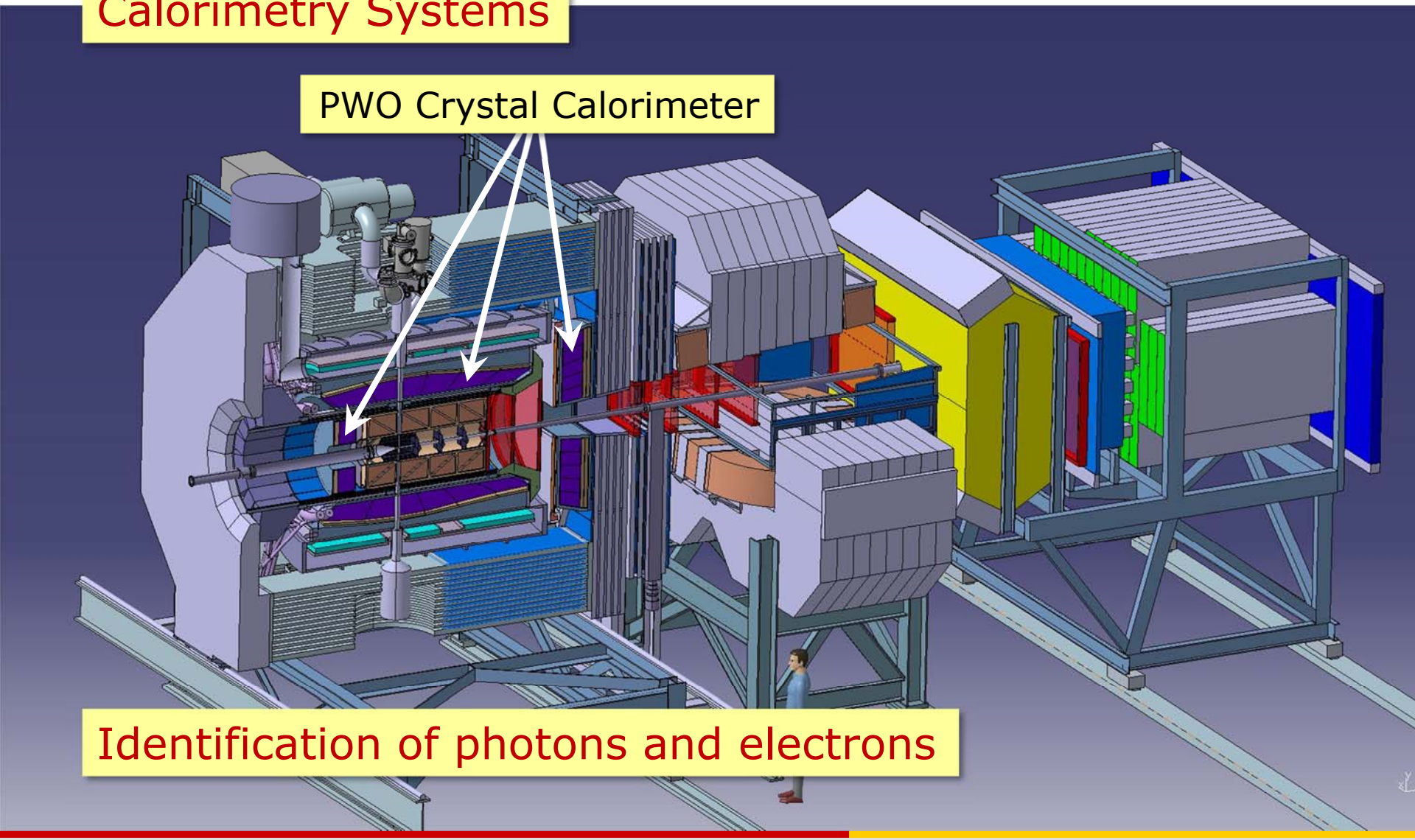
Operation in magnetic field

High rates up to 2 MHz/cm^2

→ MCP-PMTs (15 kchannels)

PANDA Detector

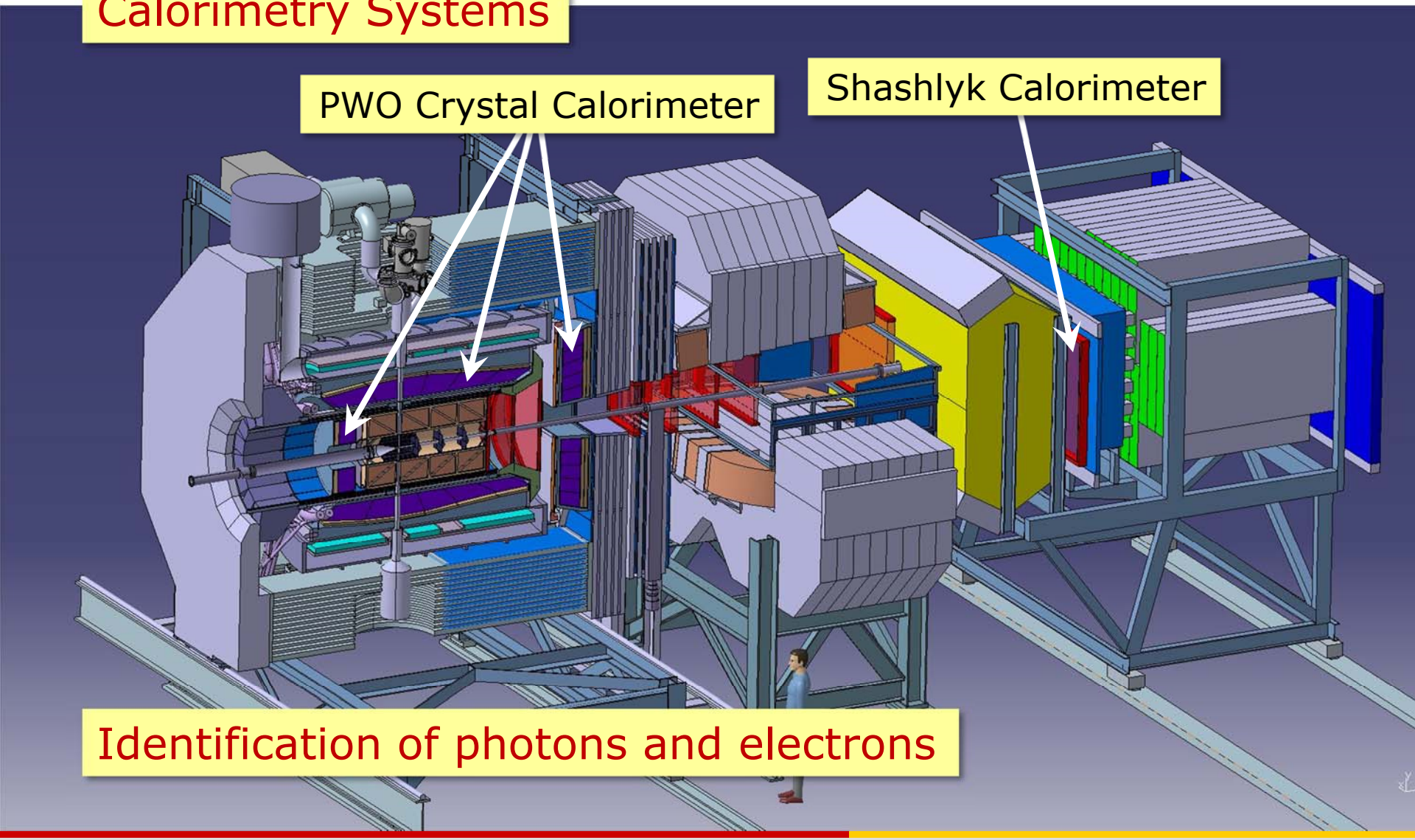
Calorimetry Systems



Identification of photons and electrons

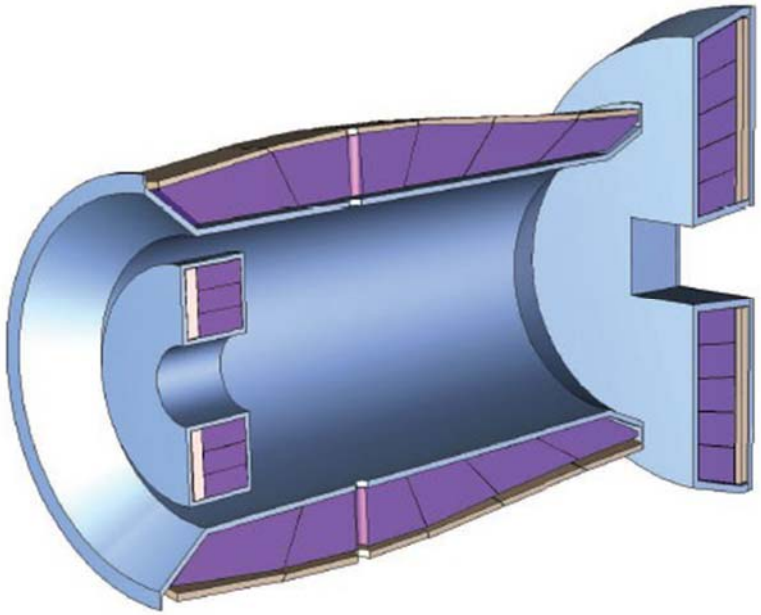
PANDA Detector

Calorimetry Systems



Identification of photons and electrons

PWO Crystal Calorimeter



~ 16000 PWO Crystals

Requirements

Low and high energetic photons

Resolution $\sigma(E)/E \sim 1.5\%/\sqrt{E} \oplus C$

Fast signals

PWO

Operation at -25°C

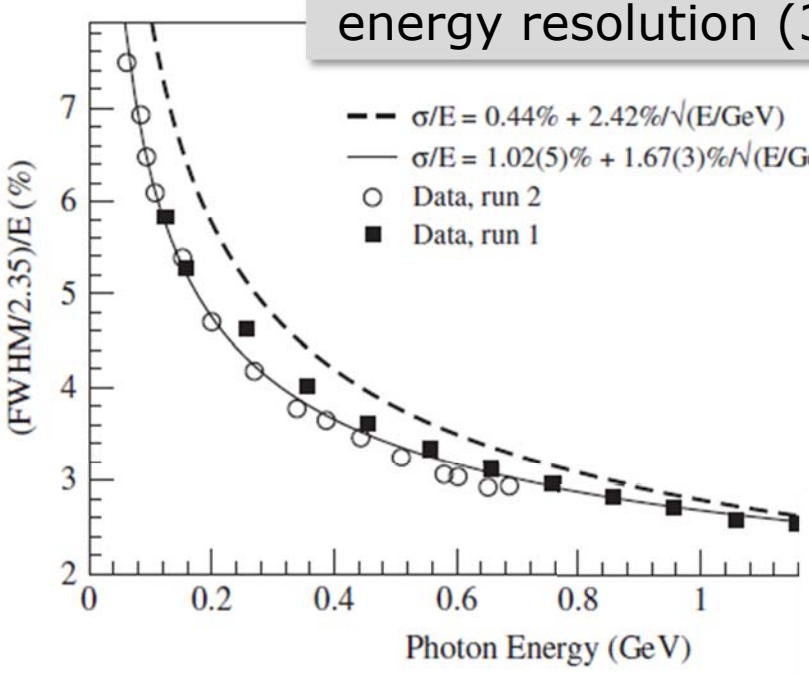
Temperature stability 0.1°C

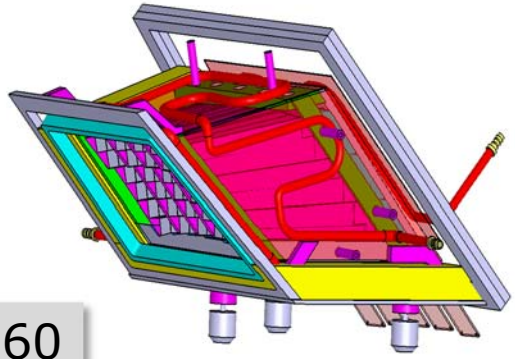
Large Photosensors LA APD

10x10 mm^2 7x14 mm^2

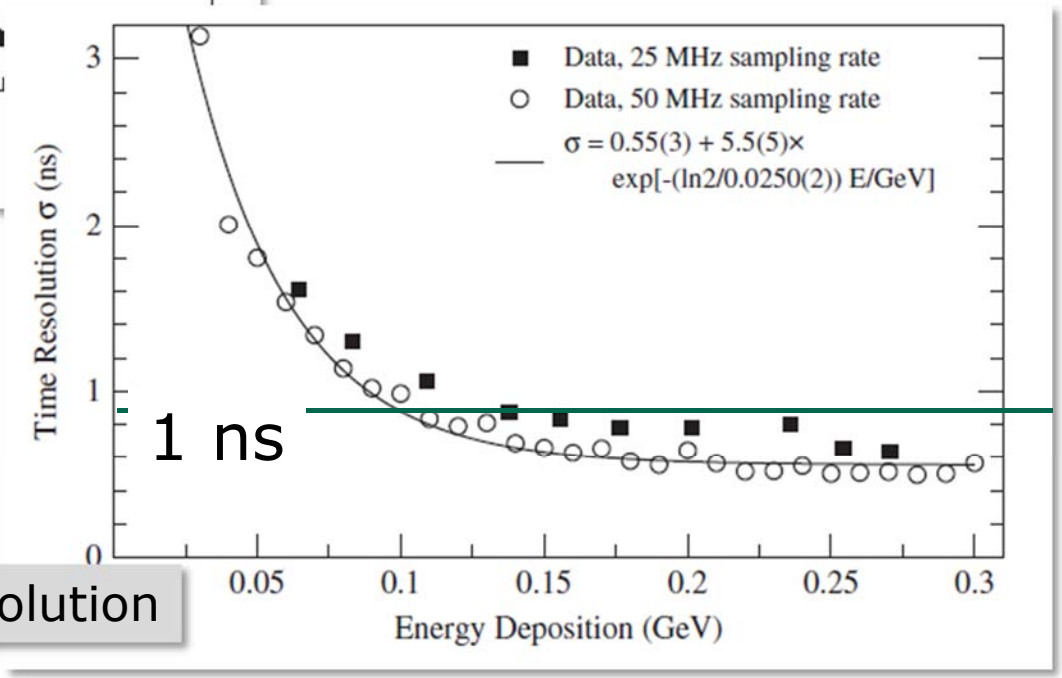
Prototype Tests

energy resolution (3x3 matrix)





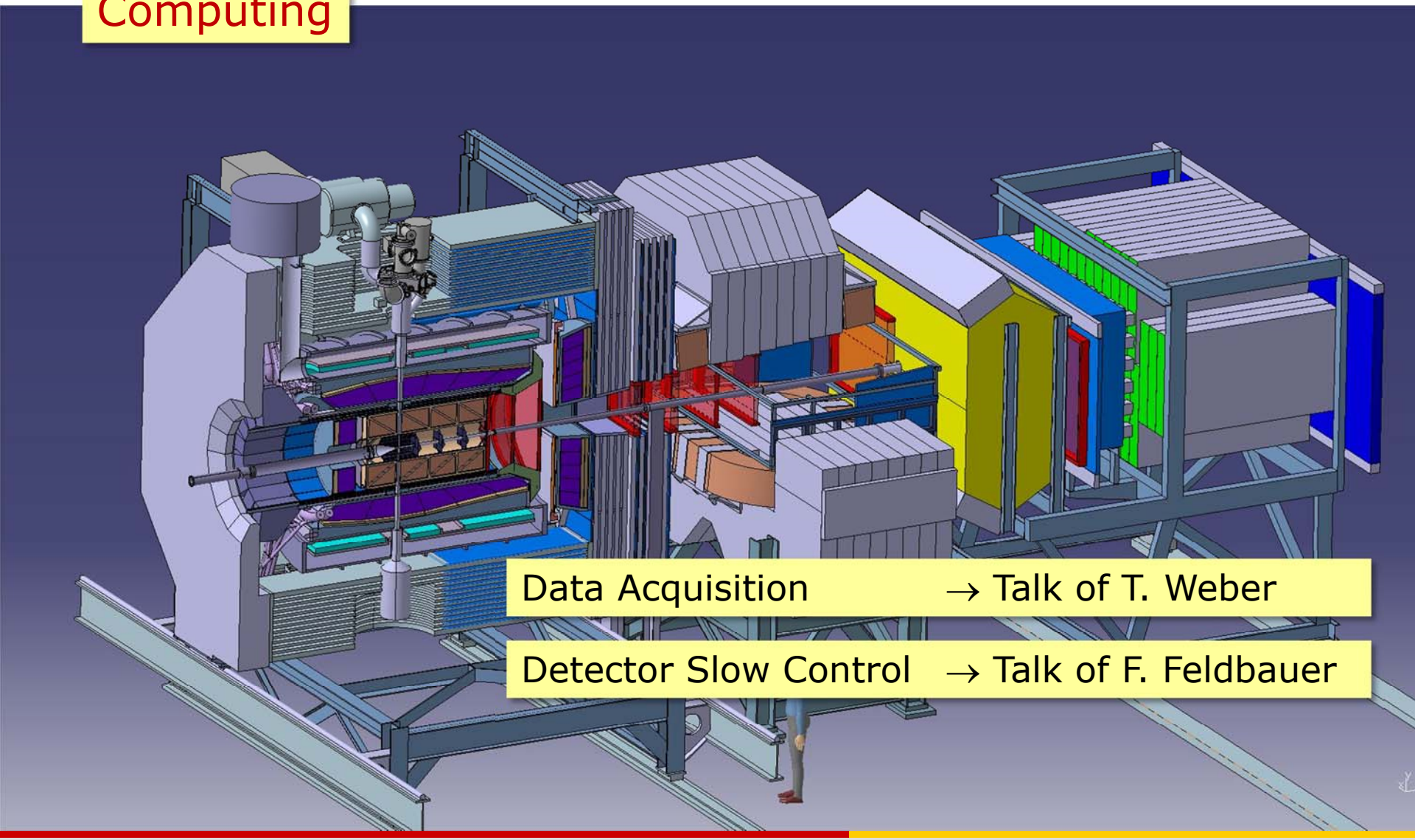
PROTO60



time resolution

PANDA Detector

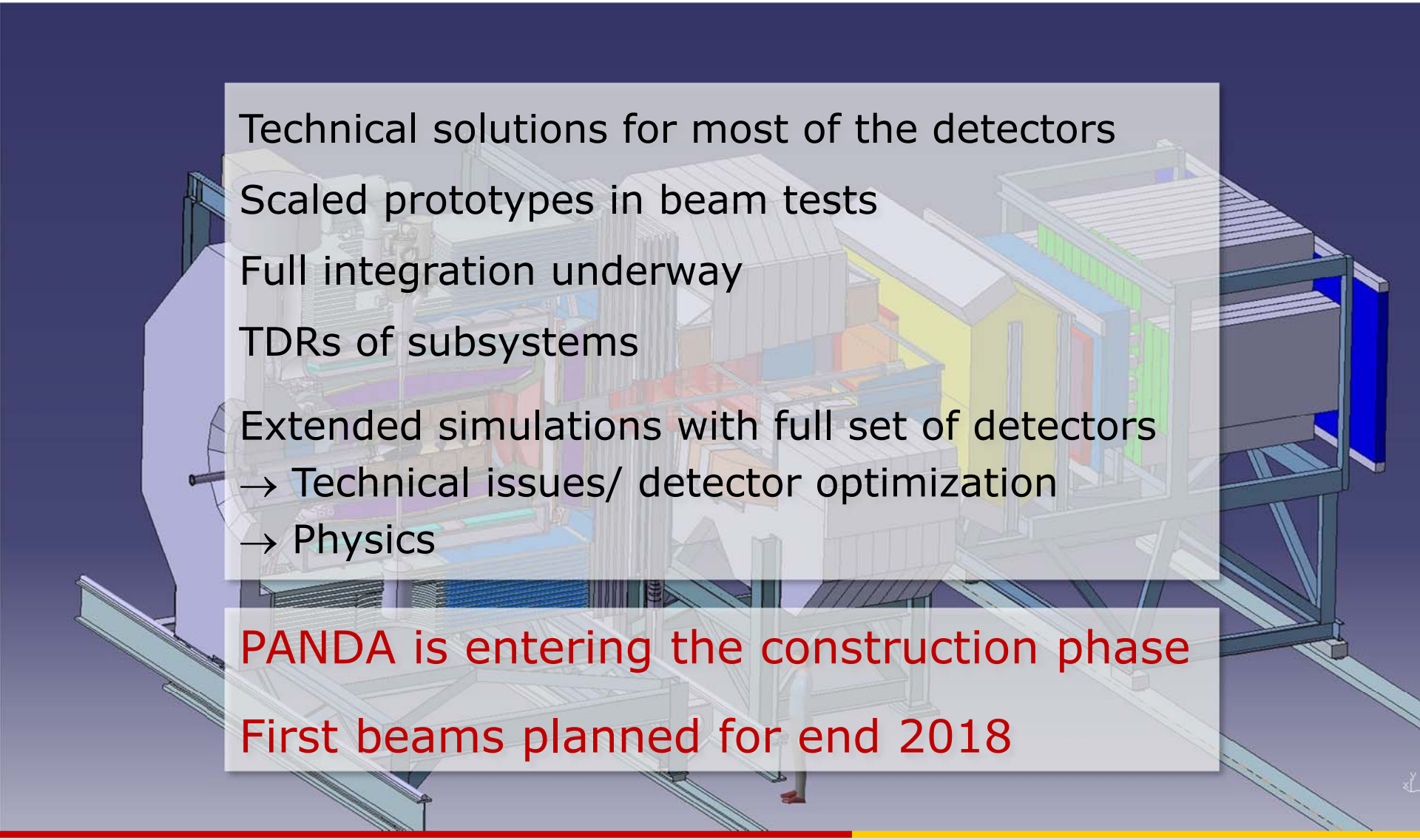
Computing



Data Acquisition → Talk of T. Weber

Detector Slow Control → Talk of F. Feldbauer

Summary and Outlook



Technical solutions for most of the detectors

Scaled prototypes in beam tests

Full integration underway

TDRs of subsystems

Extended simulations with full set of detectors
→ Technical issues/ detector optimization
→ Physics

PANDA is entering the construction phase

First beams planned for end 2018

PANDA Collaboration

> 520 Scientists

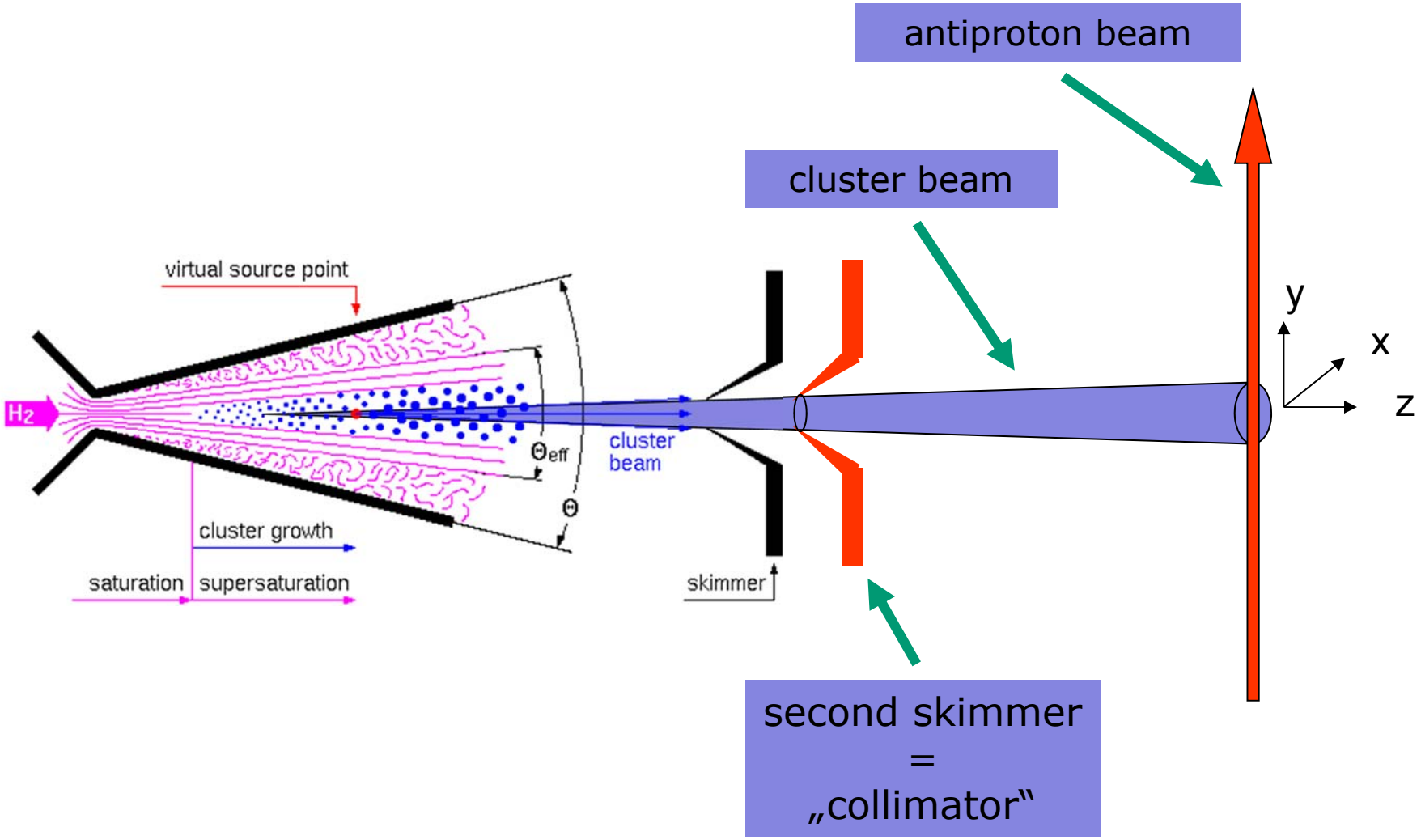
67 Institutions

17 Countries

U Basel
IHEP Beijing
U Bochum
U Bonn
U & INFN Brescia
IFIN Bukarest
U & INFN Catania
U Cracow
GSI Darmstadt
TU Dresden
JINR Dubna
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara
U Frankfurt
LNF-INFN Frascati
U & INFN Genoa
U Glasgow
U Gießen
KVI Groningen
IKP Jülich
U Katowice
IMP Lanzhou
U Mainz
U & INFN Milano
Politecnico di Milano
U Minsk
TU München
U Münster
BINP Novosibirsk
LAL Orsay
U & INFN Pavia
IHEP Protvino
PNPI Gatchina
U of Silesia, Katowice
U Stockholm
KTH Stockholm
U & INFN Torino
Politechnico di Torino
U Oriente, Torino
U & INFN Trieste
U Tübingen
U & TSL Uppsala
U Valencia
SMI Vienna
SINS Warsaw
U Warsaw

Backup

Clusterjet Target



PANDA Detector

Tracking System

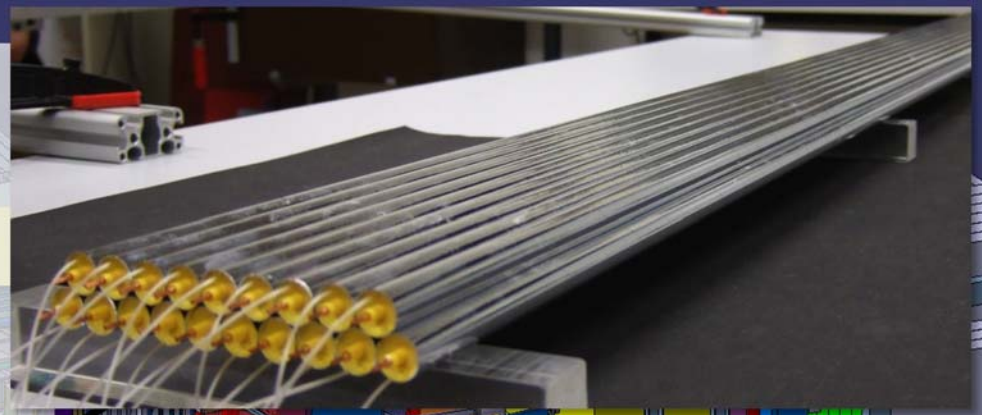
Cylindrical central tracker
27 layers

Planar forward tracker
6x4 planes

Aluminum mylar tubes
with 1 cm Ø and 27 µm walls

$ArCO_2$ at 1 bar overpressure

Low mass
0.05% X_0 per layer

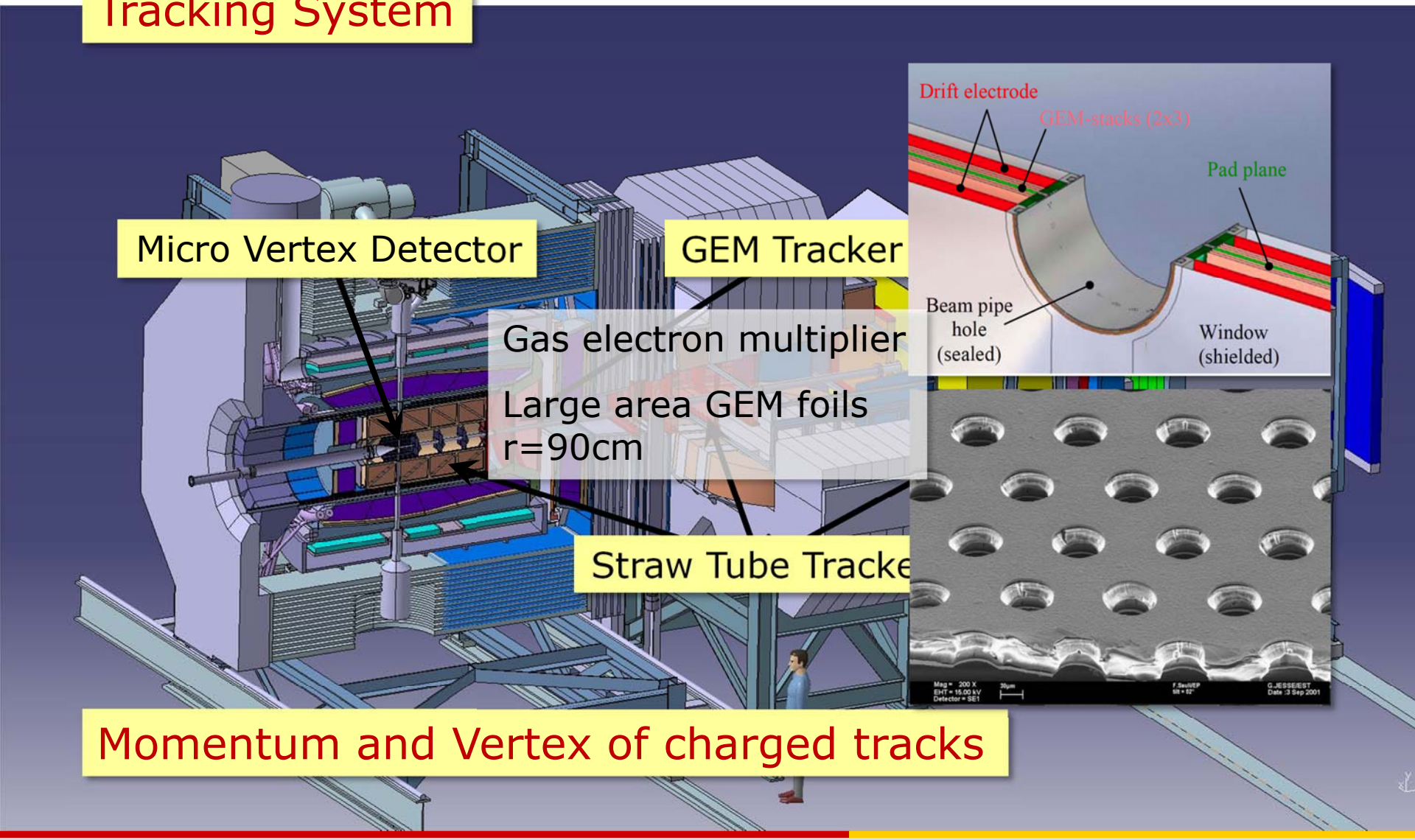


Straw Tube Tracker

Momentum and Vertex of charged tracks

PANDA Detector

Tracking System



Momentum and Vertex of charged tracks