PANDA Overview

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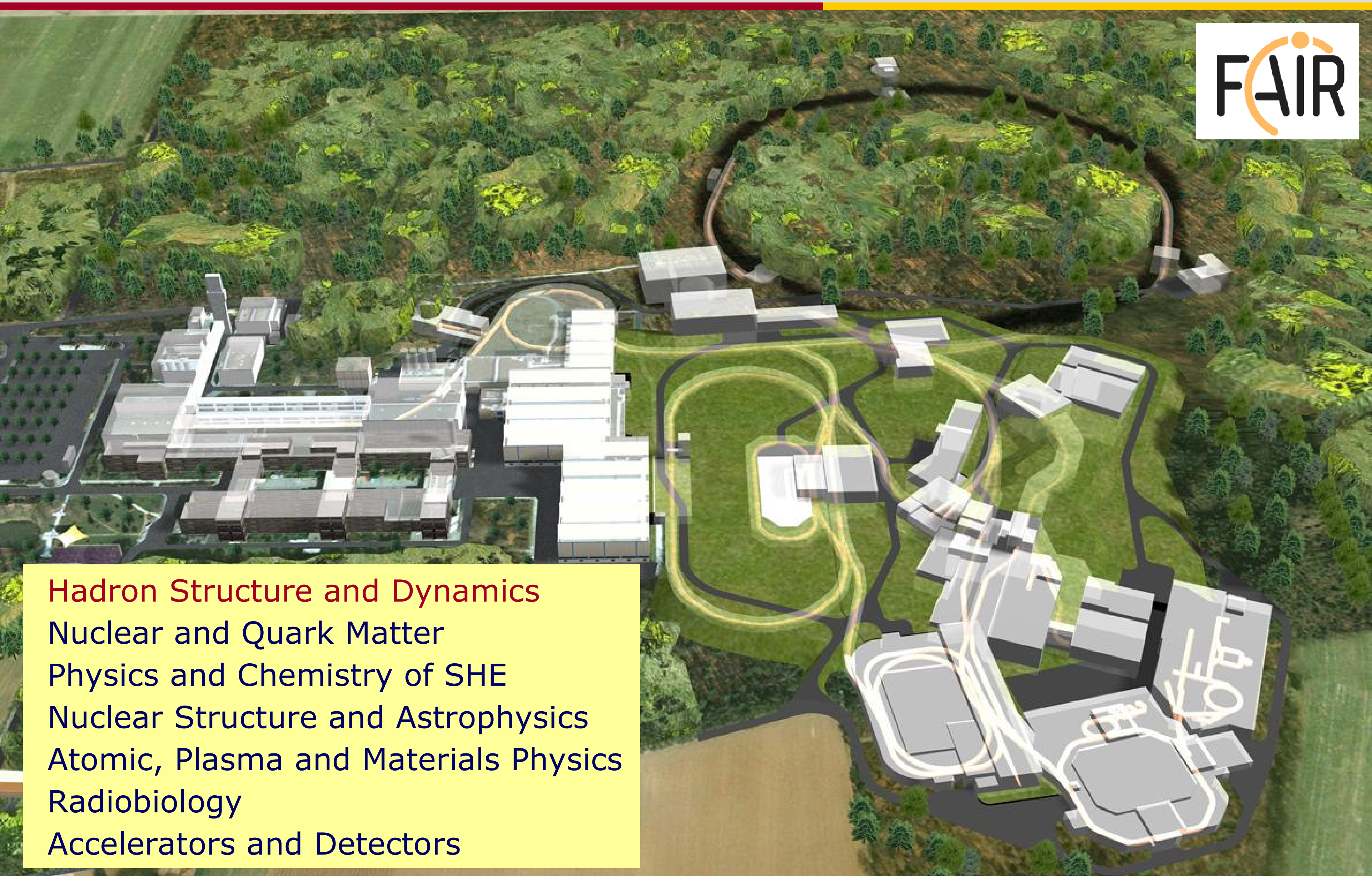
QWG 2010 - Fermilab

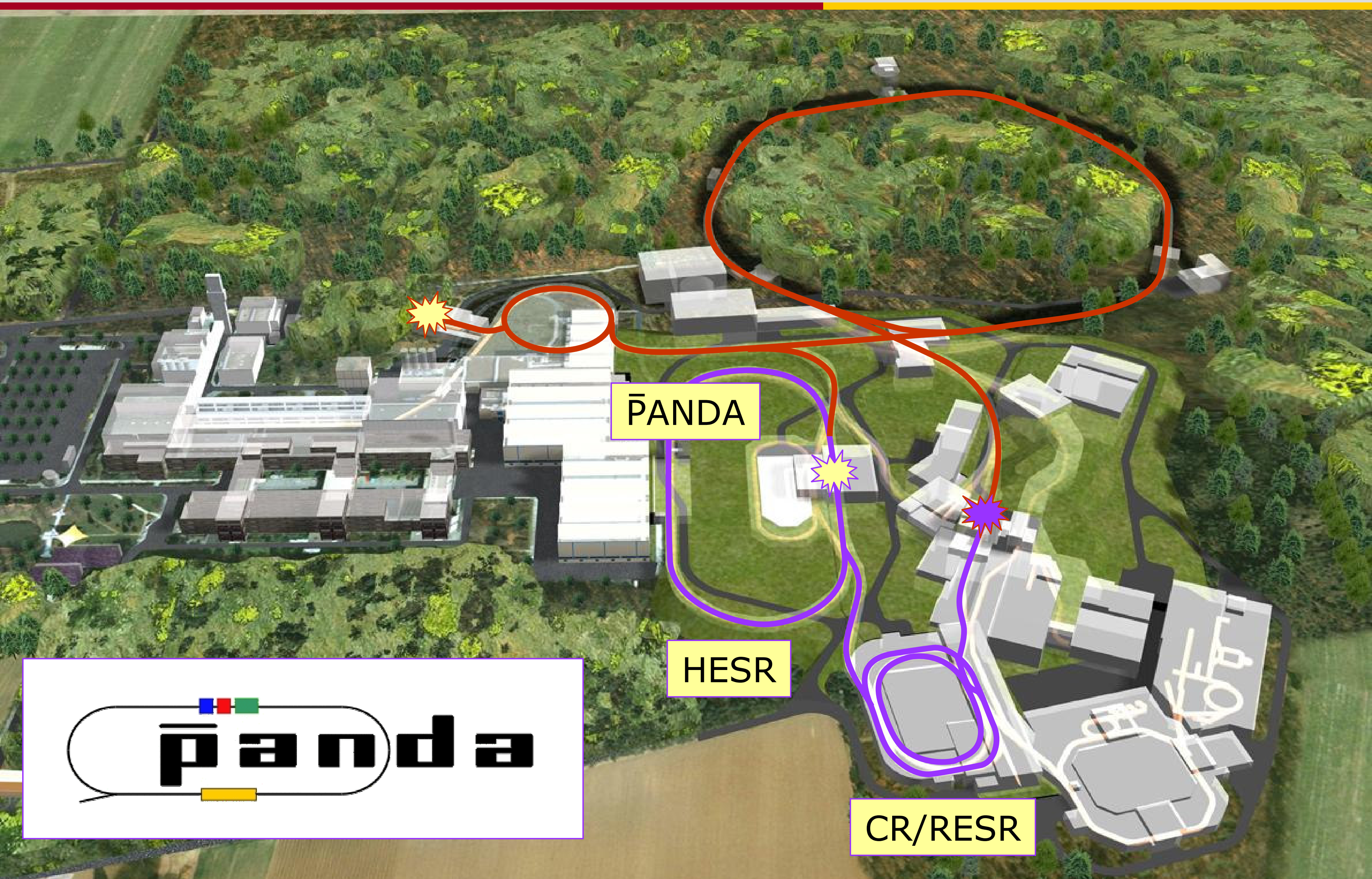
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

GSI Helmholtz Center and FAIR

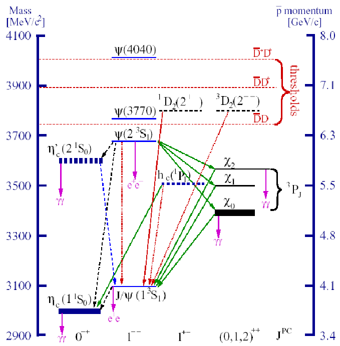


Hadron Structure and Dynamics
Nuclear and Quark Matter
Physics and Chemistry of SHE
Nuclear Structure and Astrophysics
Atomic, Plasma and Materials Physics
Radiobiology
Accelerators and Detectors

Antiproton Facility PANDA @ FAIR



Physics at PANDA



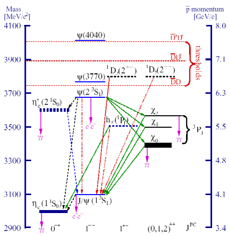
Charmonium Spectroscopy

Precision Spectroscopy

Study of Confinement Potential

Access to all these puzzling X,Y,and Z

Physics at PANDA



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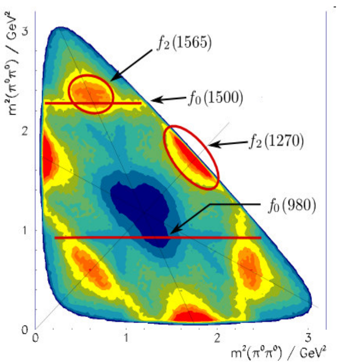
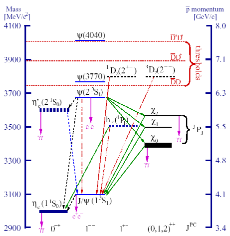


Search for Exotics

Look for Glueballs and Hybrids
Gluon rich environment $\rightarrow$ high discovery potential
Disentangle Mixing via PWA

Physics at PANDA



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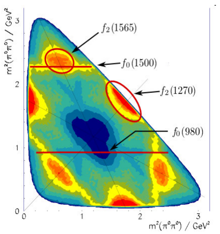

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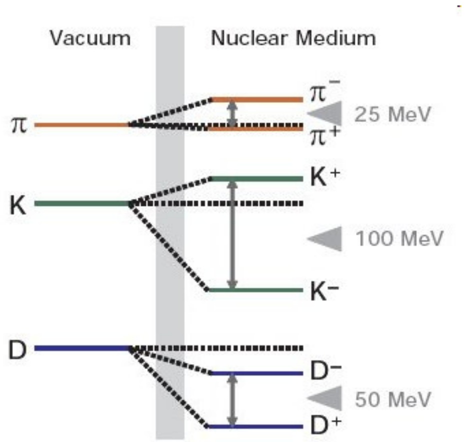
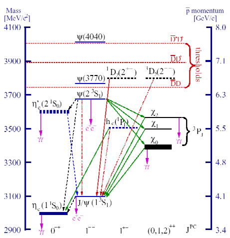


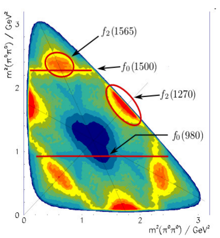
Charm in Medium

Study in-medium modification of Hadrons

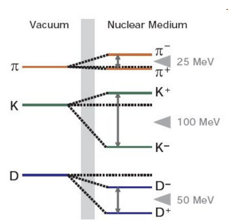
Physics at PANDA



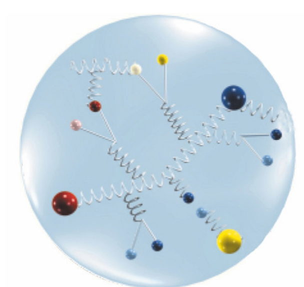
Charmonium Spectroscopy



Search for Exotics

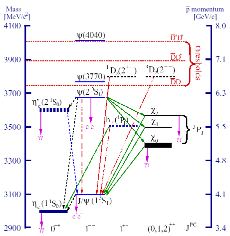


Charm in Medium

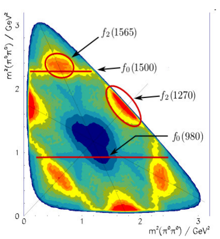


Nucleon Structure

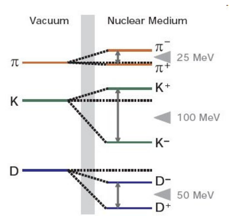
Generalized Parton Distribution
Timelike Form Factor of the Proton
Drell-Yan Process



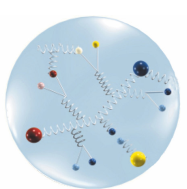
Charmonium Spectroscopy



Search for Exotics



Charm in Medium



Nucleon Structure

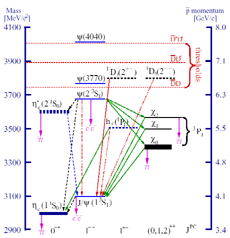
S=2 Hypernuclei

Nuclear structure

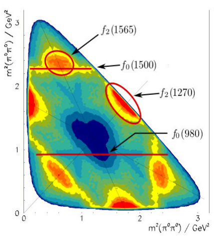
Baryon-Baryon interaction in $SU(3)_f$

H-dibaryon

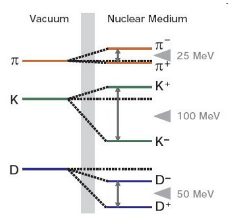
Physics at PANDA



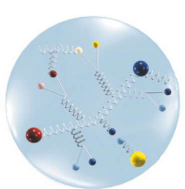
Charmonium Spectroscopy



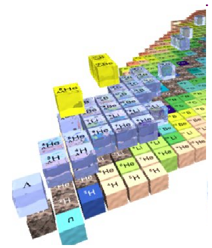
Search for Exotics



Charm in Medium



Nucleon Structure



S=2 Hypernuclei

FAIR/PANDA/Physics Book i

Physics Performance Report for:

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

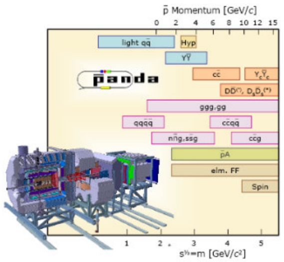
(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

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

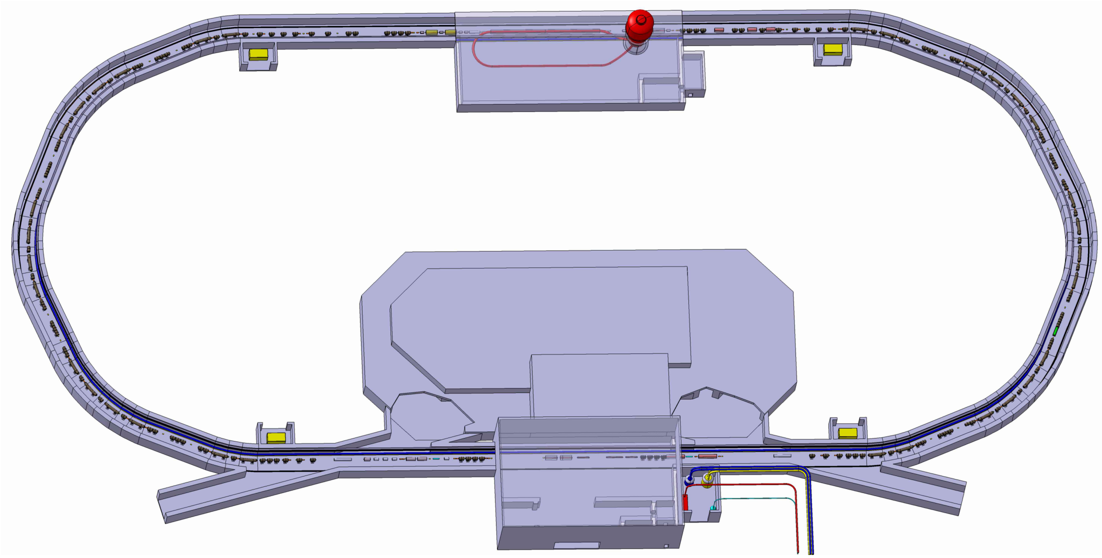
February 13, 2009 - Revision: 810

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.



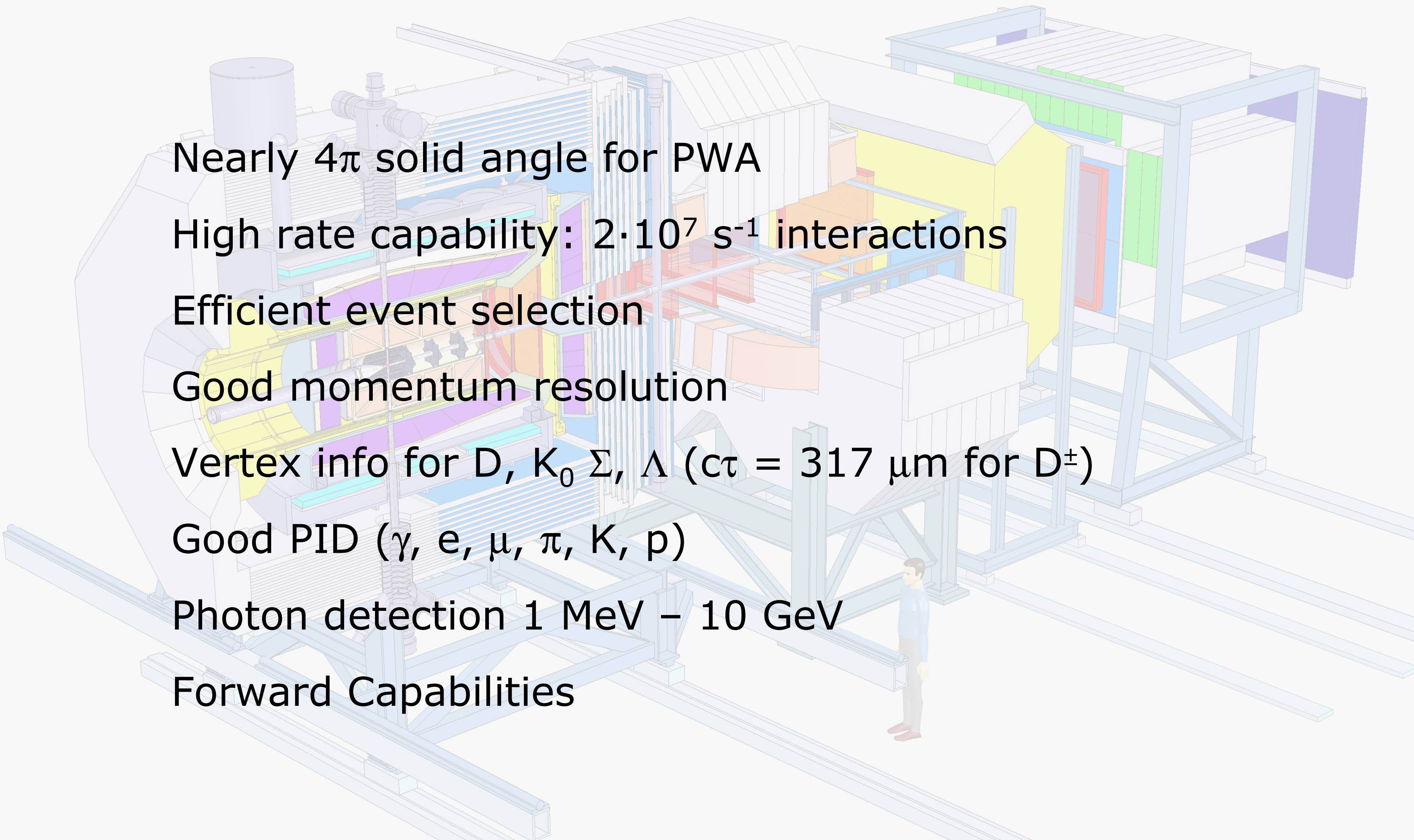
arXiv:0903.3905v1

HESR - High Energy Storage Ring



Mode	High Resolution	High Luminosity
Momentum range **Stored antiprotons** **Luminosity** **Mom. Resol. (rms)** **Beam cooling**	**1.5 - 8.9 GeV/c** 10^{10} $2 \cdot 10^{31}$ $cm^{-2}s^{-1}$ $\Delta p/p \leq 4 \cdot 10^{-5}$ **Electron (≤ 8.9 GeV/c)**	**1.5 – 15 GeV/c** 10^{11} $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$ $\Delta p/p = 1 \cdot 10^{-4}$ **Stochastic (≥ 3.8 GeV/c)**

Detector requirements



Nearly 4π solid angle for PWA

High rate capability: $2 \cdot 10^7\ s^{-1}$ interactions

Efficient event selection

Good momentum resolution

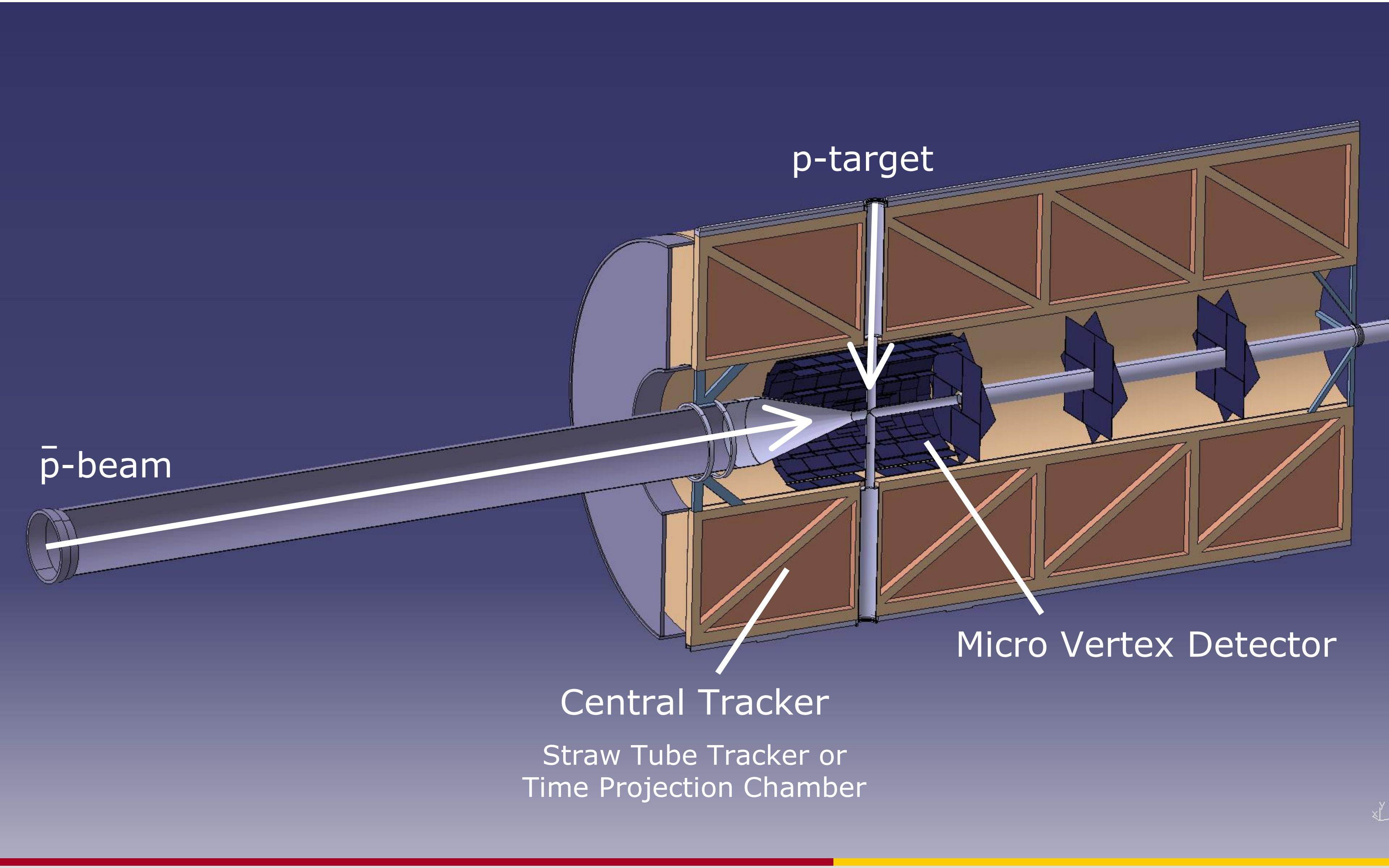
Vertex info for D, K_0 Σ, Λ ($c\tau$ = 317 μm for $D^{\pm}$)

Good PID (γ, e, μ, π, K, p)

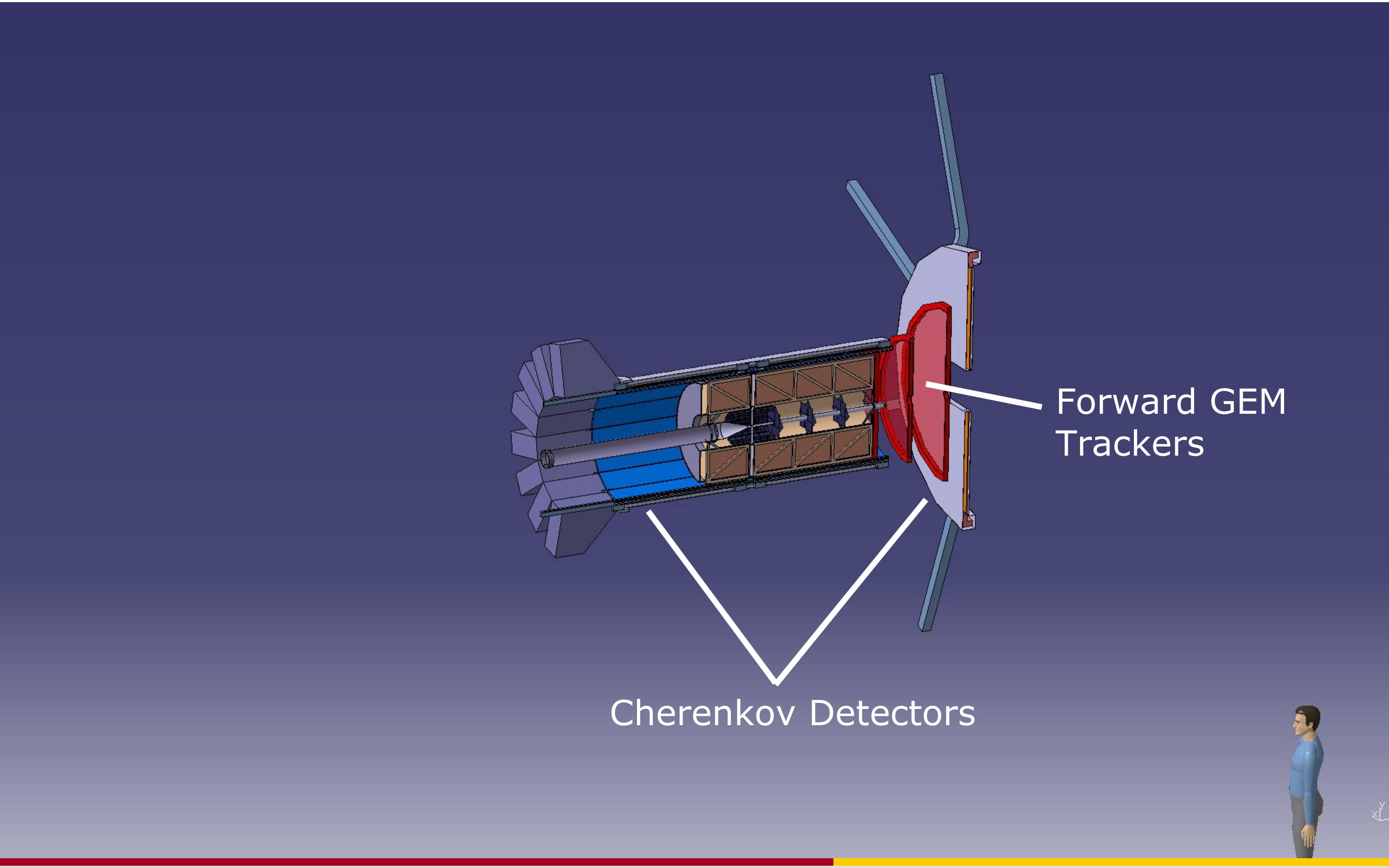
Photon detection 1 MeV – 10 GeV

Forward Capabilities

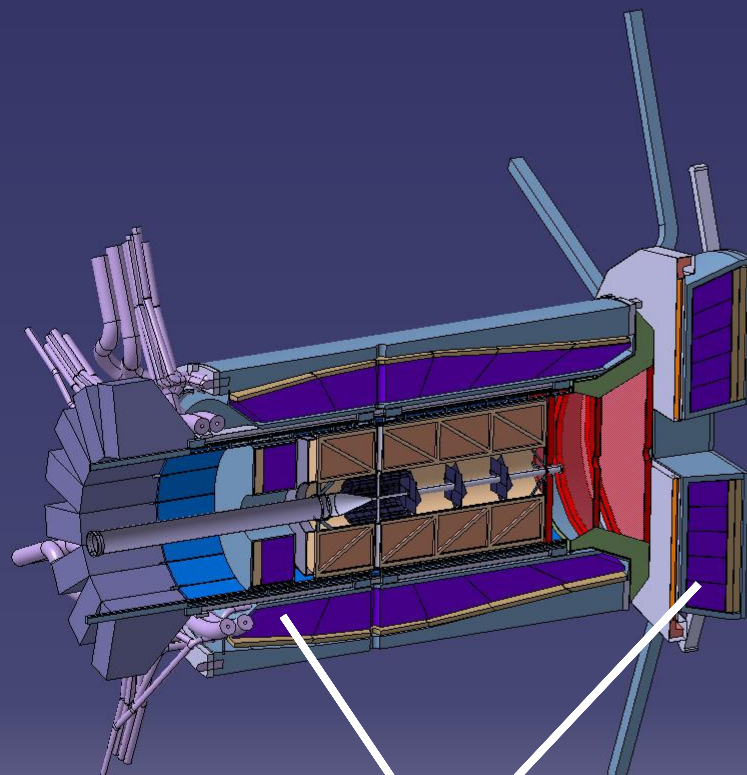
PANDA Detector



PANDA Detector

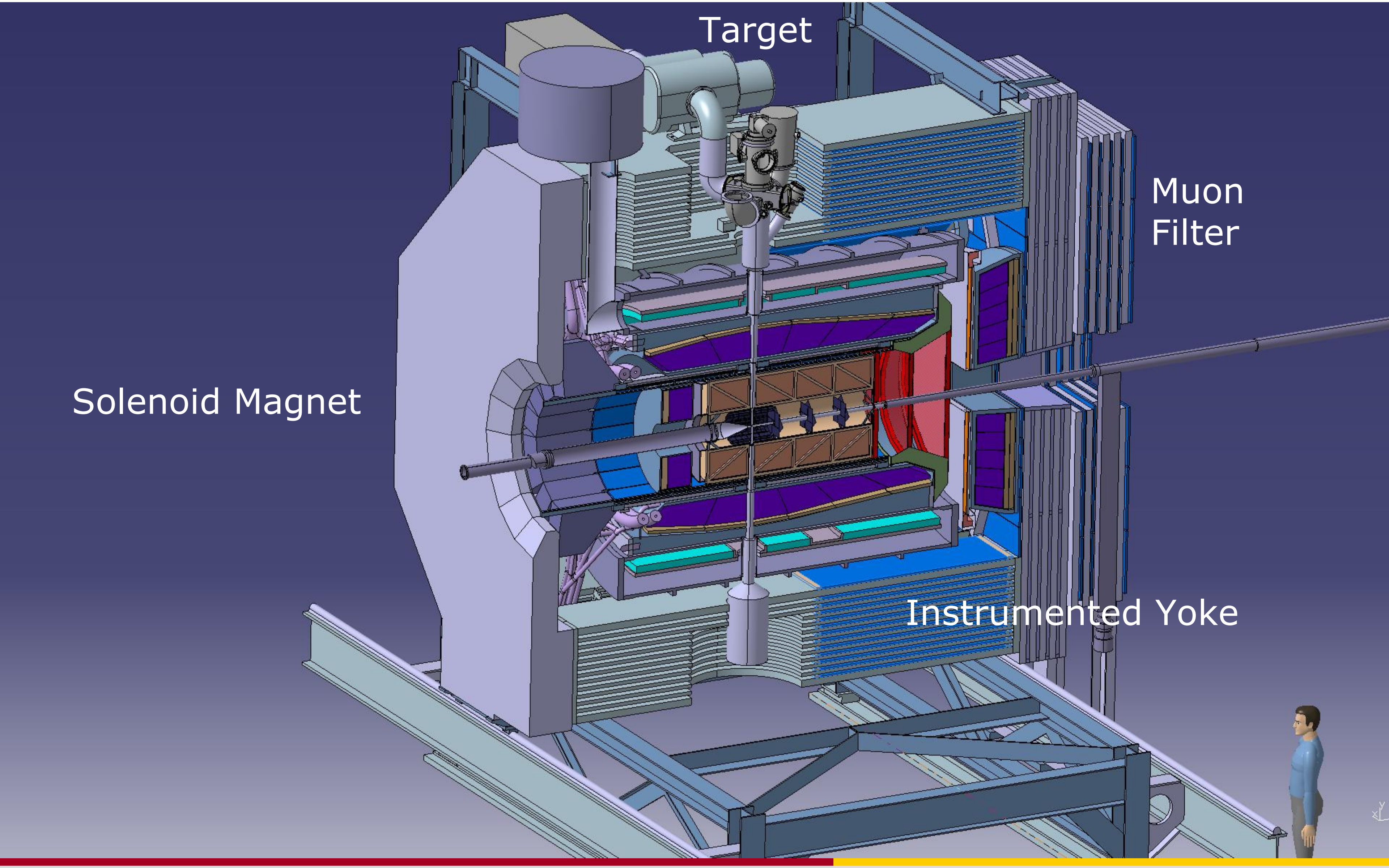


PANDA Detector

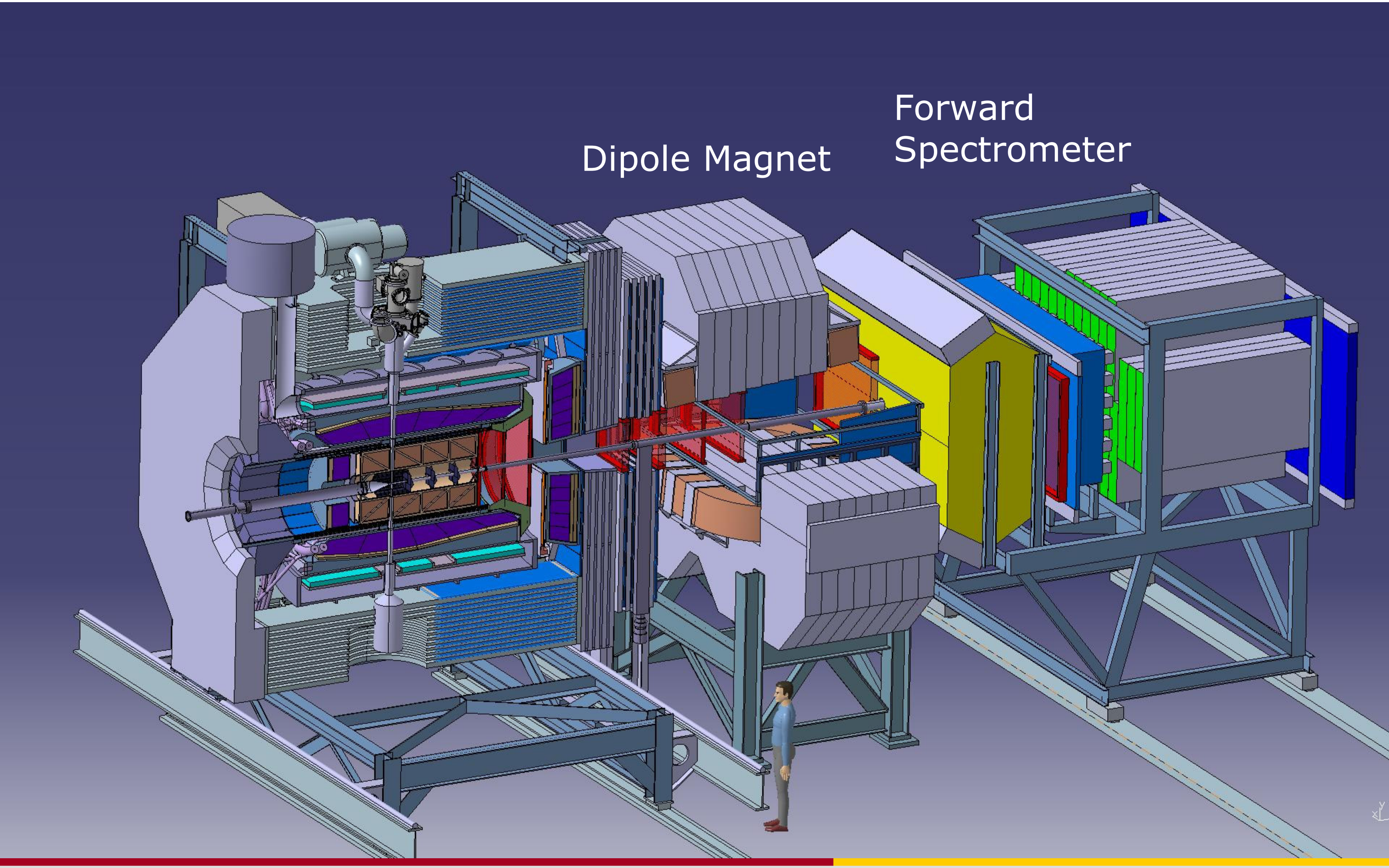


Electromagnetic Crystal
Calorimeters

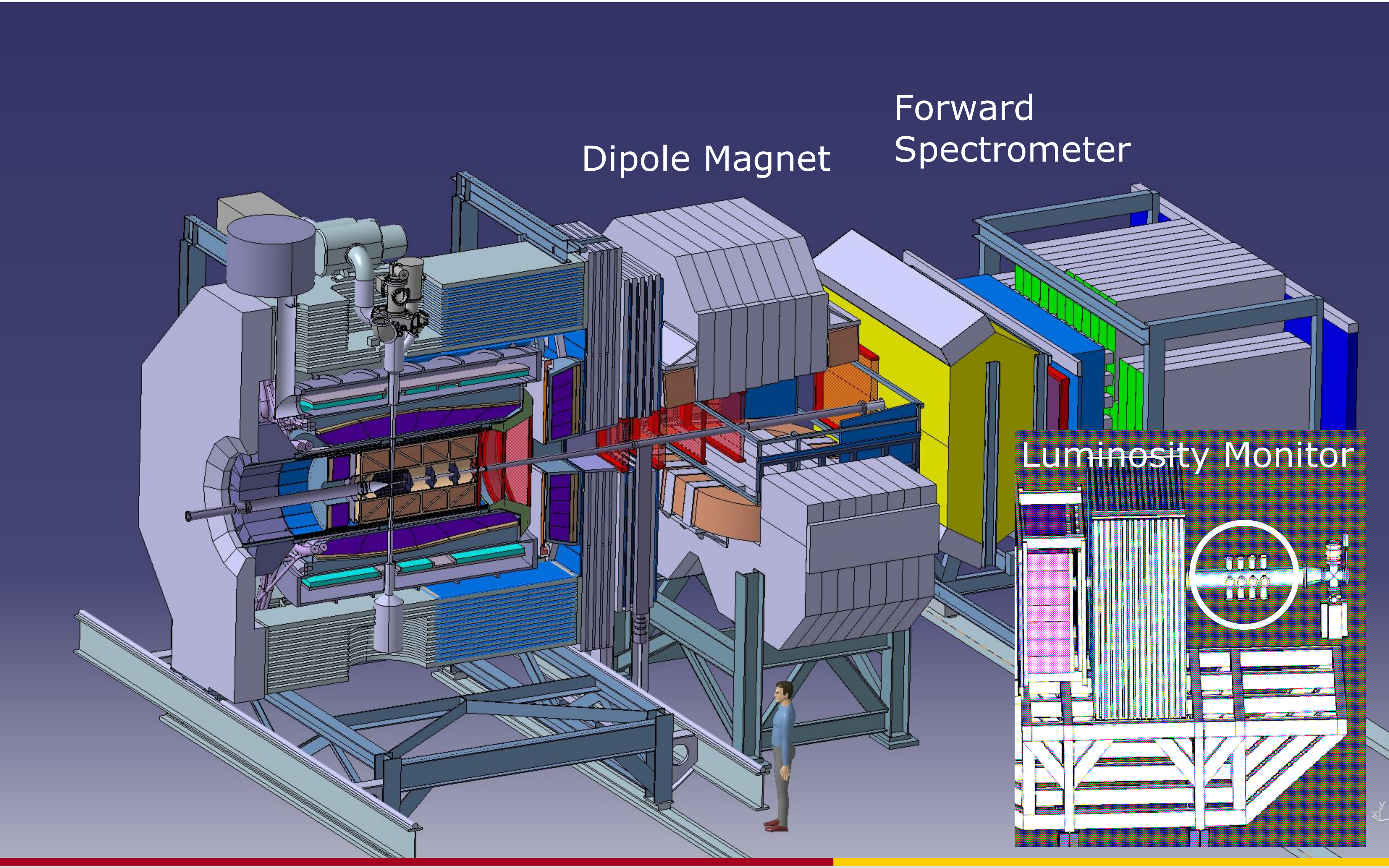
PANDA Detector



PANDA Detector

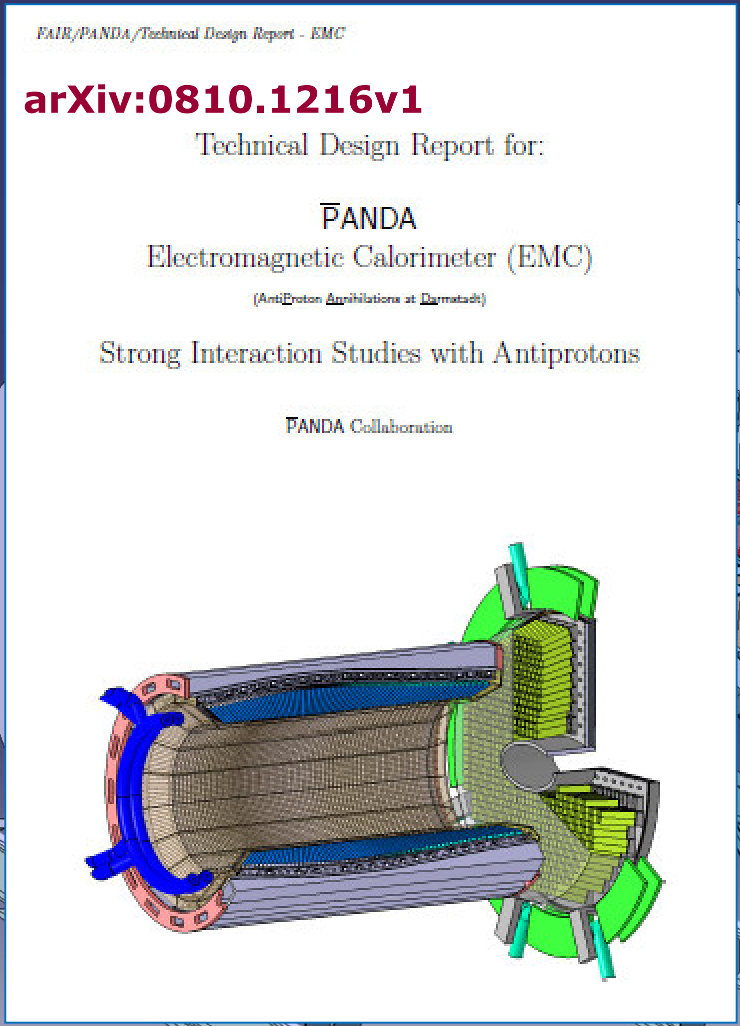


PANDA Detector



PANDA Detector

arXiv:0810.1216v1



FAIR/PANDA/Technical Design Report - EMC

Technical Design Report for:

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

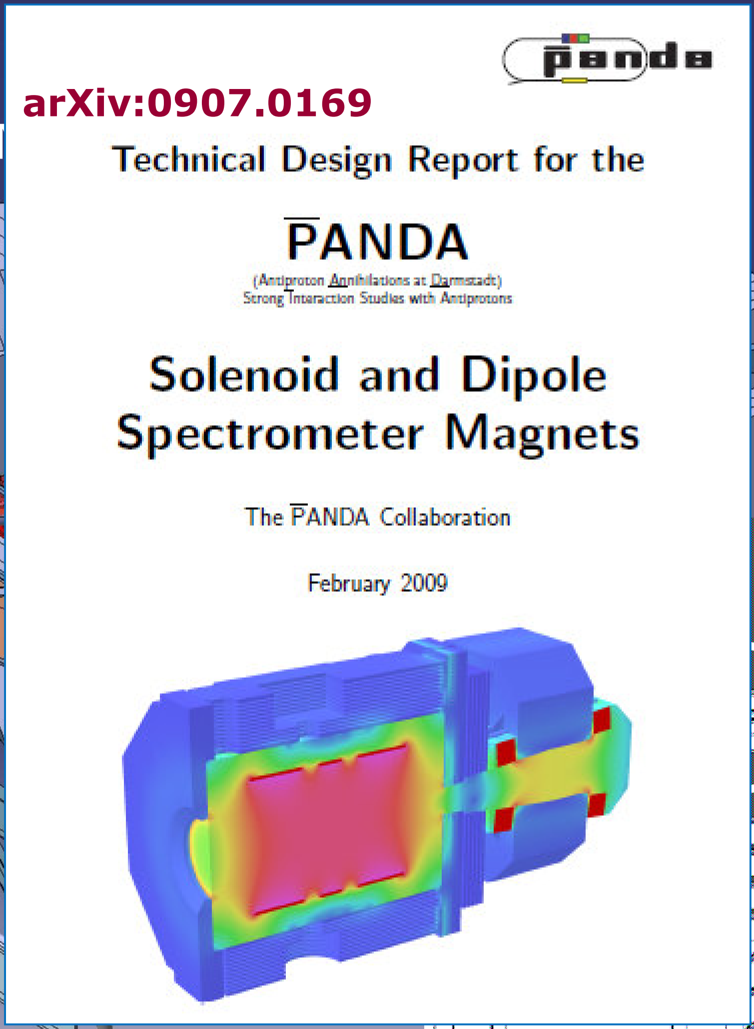
Electromagnetic Calorimeter (EMC)

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

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

arXiv:0907.0169



Technical Design Report for the

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

(Antiproton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

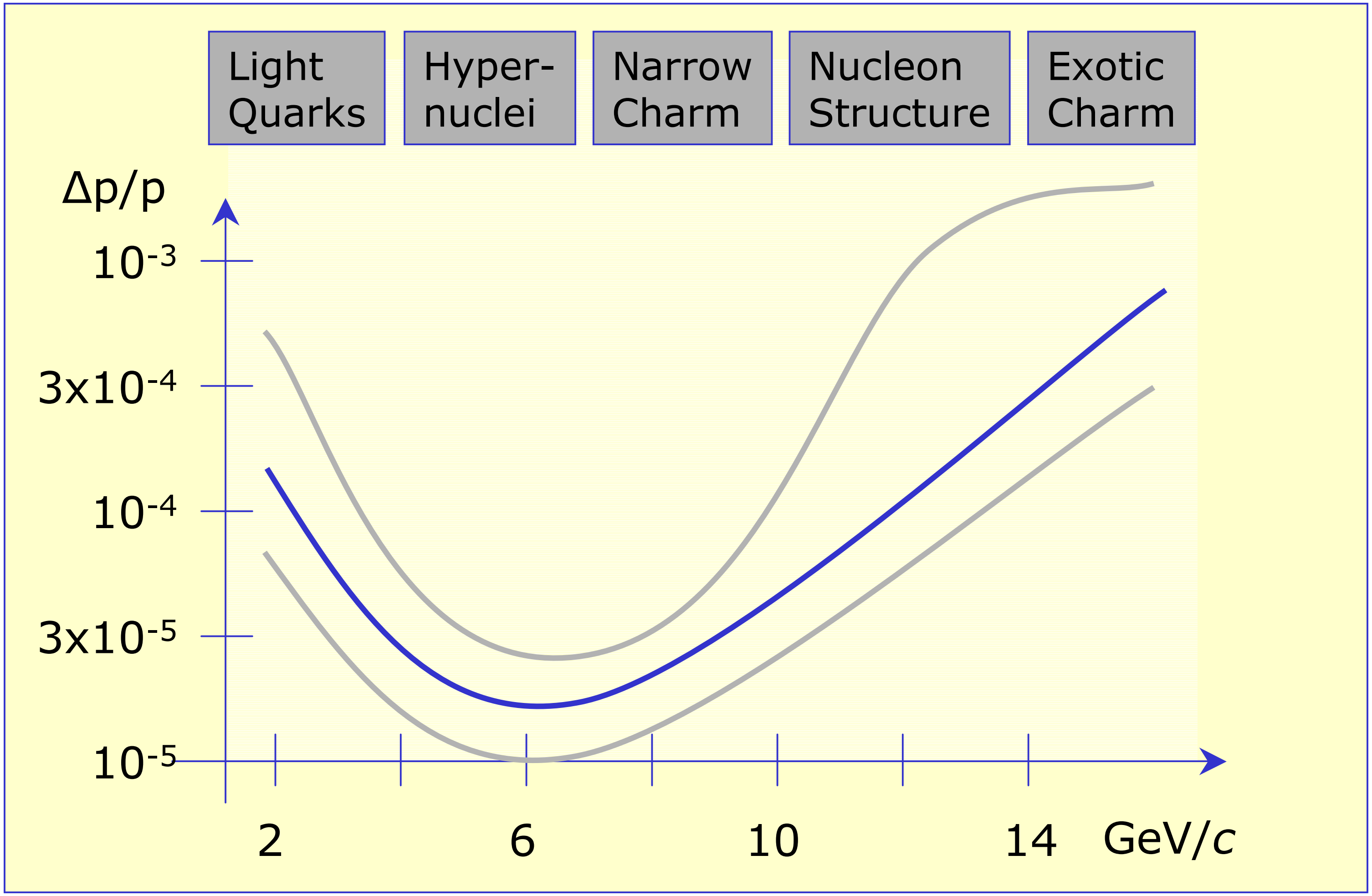
Solenoid and Dipole Spectrometer Magnets

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

February 2009

Resolution for various Δp/p @ various $p_{\bar{p}}$

Lowest Δp/p required for charm-state scans
Relaxed for detector resolution dominated cases



Benchmarks

Luminosity $2 \cdot 10^{32}$ cm^{-2} s^{-1} (High Luminosity Mode)

$\rightarrow$ 8 pb^{-1}/day or 1.5 fb^{-1}/year

$\rightarrow$ 10^4 - 10^7 $\bar{c}c$ states/day.

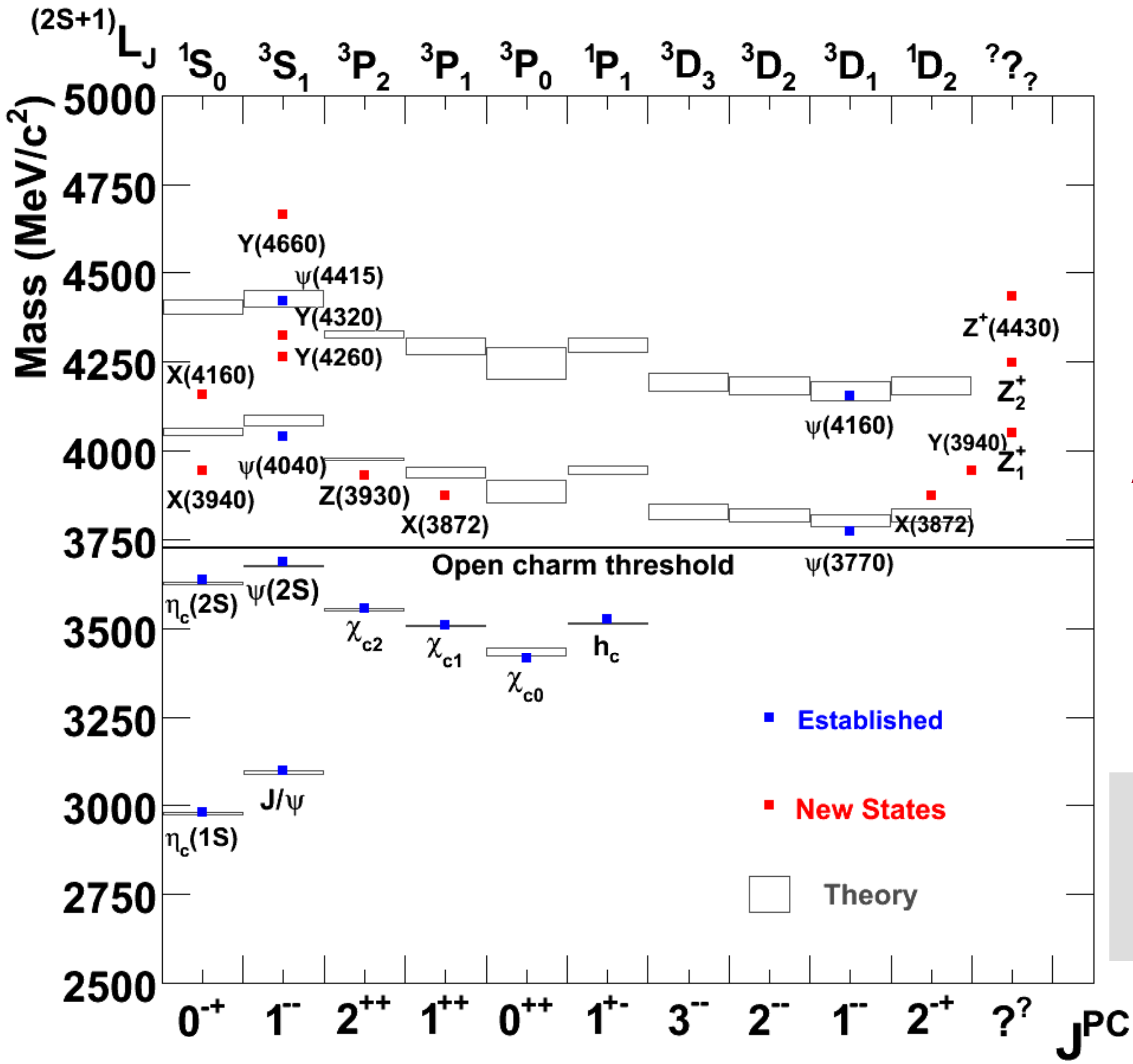
Improvements with respect to Fermilab E760/E835

- 10x higher instantaneous luminosity
- $\Delta p/p = 10^{-5}$ ($2 \cdot 10^{-4}$ FNAL)
- Better detector (higher angular coverage, magnetic field, ability to detect hadronic decay modes).

Fine scans to measure masses to ≈ 100 keV, widths to ≈ 10 %.

Explore entire region below and above open charm threshold

Charmonium Spectrum



Below threshold

Precision measurements of h_c, $\eta_c(1S)$, $\eta_c(2S)$

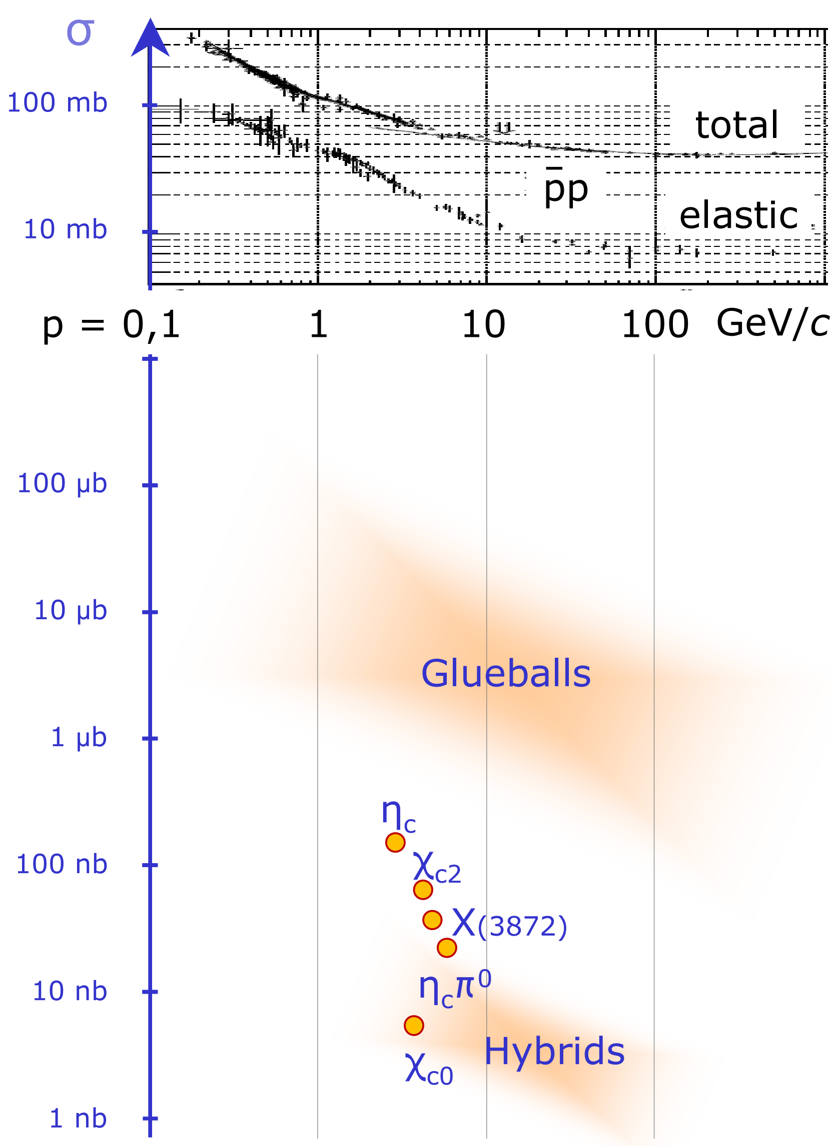
Above threshold

Missing D states

New states

Complete picture of the dynamics of $c\bar{c}$ system

$\bar{p}p$ cross sections – exclusive final states



Hybrid candidates

$\pi_1(1400)$ and $\pi_1(1600)$ with $J^{PC}=1^{-+}$

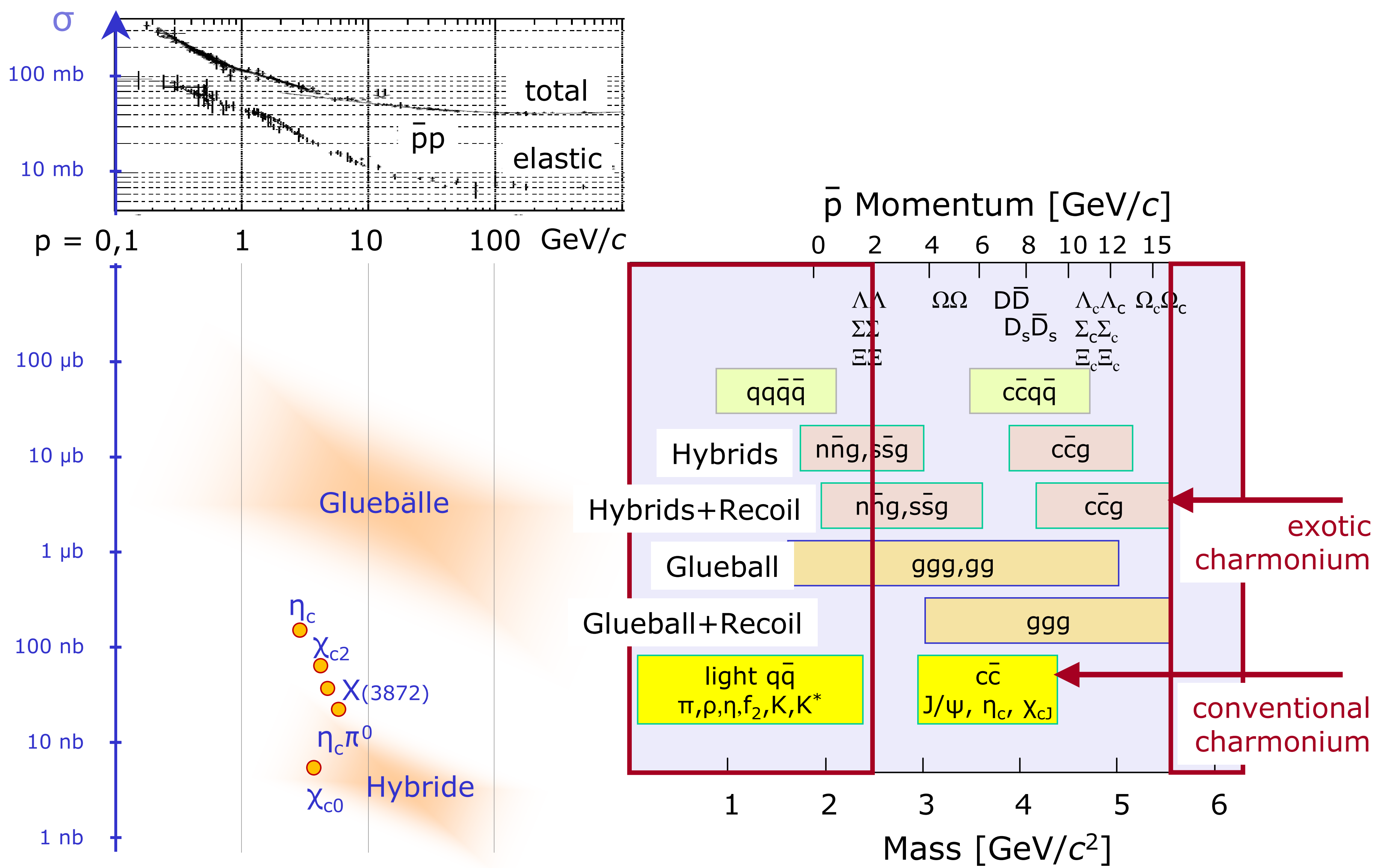
Important:
states with exotic quantum numbers

Glueball candidate

$f_0(1500)$ with $J^{PC}=0^{++}$

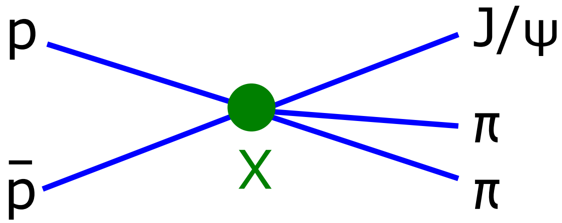
Overlap with conventional states
→ Charm sector

$\bar{p}p$ cross sections – exclusive final states

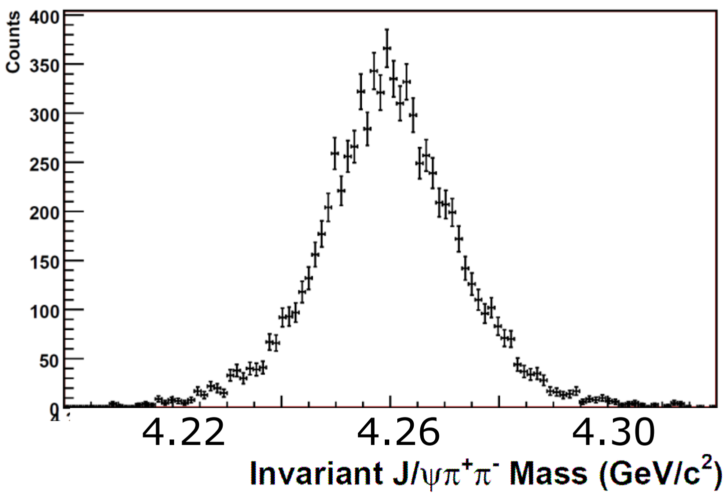


Y(4260) - $c\bar{c}$ hybrid with $J^{PC} = 1^{--}$

Formation reaction



Simulation at $\sqrt{s}$ = 4260 MeV/c^2



$J/\psi\pi^+\pi^-$

Efficiency: 33%

S/B: 2

$J/\psi\pi^0\pi^0$

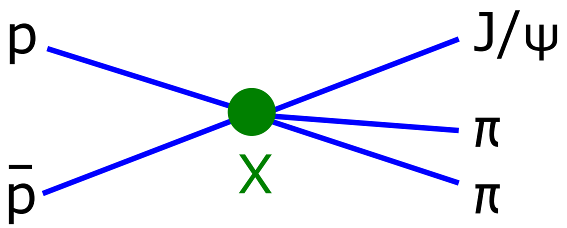
Efficiency: 17%

S/B: 25

RMS: 13.4 MeV/c^2

Y(4260) - $c\bar{c}$ hybrid with $J^{PC} = 1^{--}$

Formation reaction



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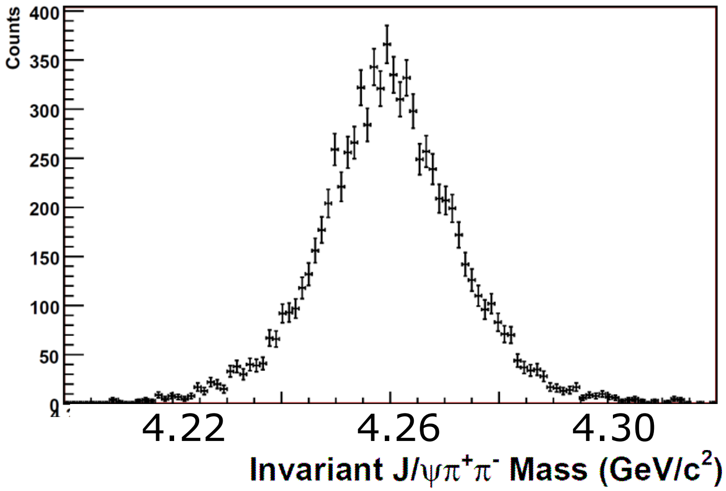
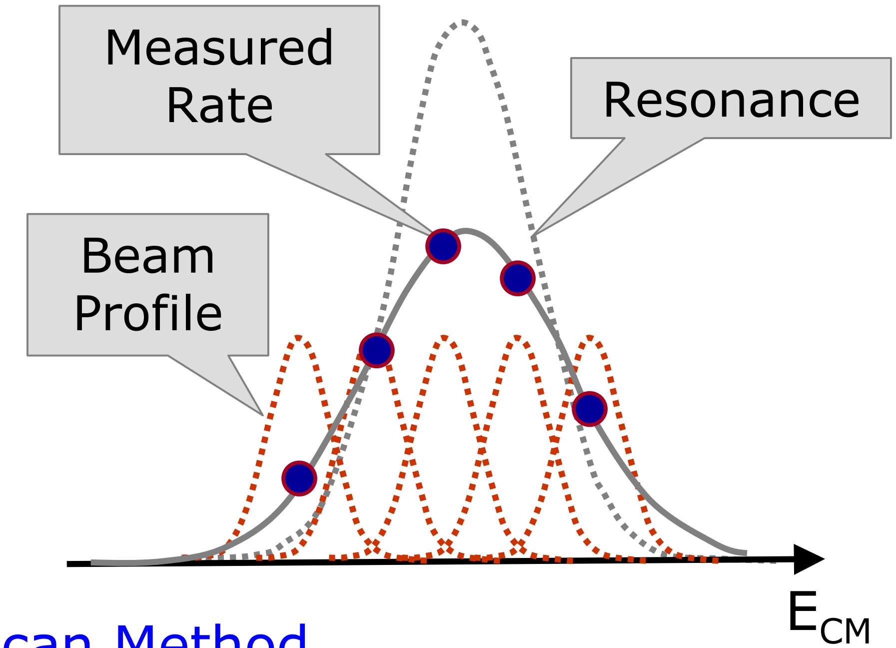


Line shape measurement



Scan Method

→ Energy resolution ≥50 keV

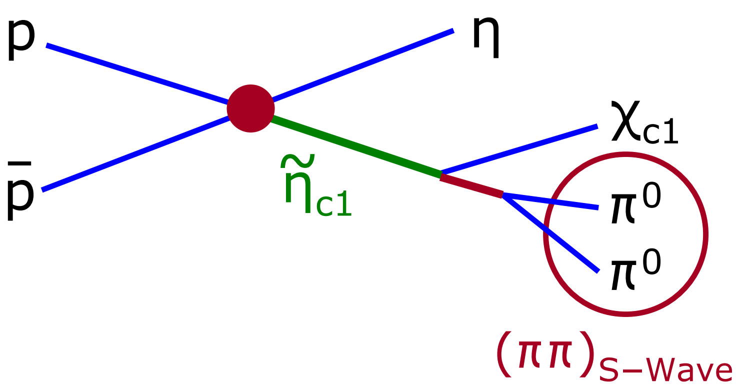
$\bar{p}p \rightarrow Y(4260)$

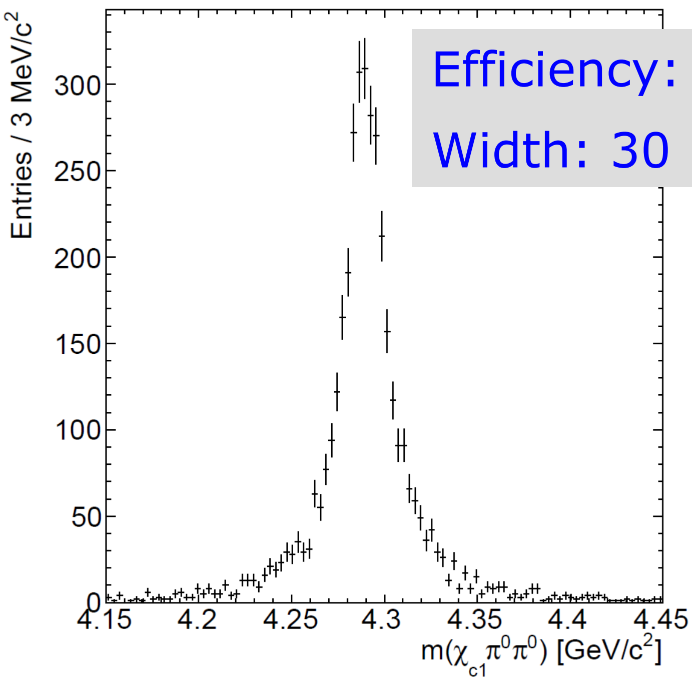
$\rightarrow J/\psi\pi^+\pi^- \approx$ 100 ev/day

$\rightarrow J/\psi\pi^0\pi^0 \approx$ 40 ev/day

$c\bar{c}$ hybrid $J^{PC} = 1^{-+}$ ($\tilde{\eta}_{c1}$) in $\chi_{c1}\pi^0\pi^0$

Production reaction





Efficiency: 6.83%

Width: 30 MeV/c²

Beam momentum: 15 GeV/c

Mass = 4.29 GeV/c²

Width = 20 MeV/c²

Final state:

7 photons and e^+e^- from J/ψ

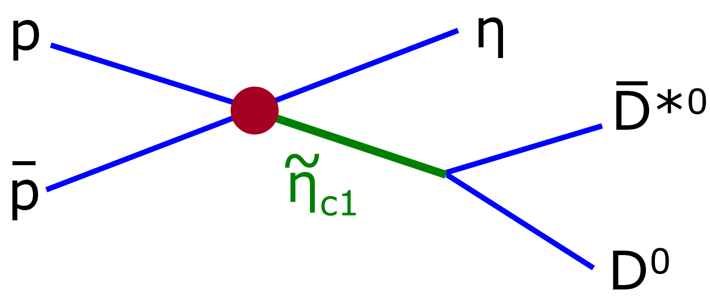
$$\mathcal{R} = \frac{\sigma_S \mathcal{B}(\tilde{\eta}_{c1} \to \chi_{c1}\pi^0\pi^0)}{\sigma_B}$$

Reaction $\bar{p}p \to$	η $[10^3]$	S/B $[10^3]$
$\chi_{c0}\pi^0\pi^0\eta$	5.33	$10.1\,\mathcal{R}$
$\chi_{c1}\pi^0\eta\eta$	26.6	$4.57\,\mathcal{R}$
$\chi_{c1}\pi^0\pi^0\pi^0\eta$	> 80	$> 5.53\,\mathcal{R}$
$J/\psi\pi^0\pi^0\pi^0\eta$	9.98	$0.25\,\mathcal{R}$

S/B ≈ 250-10^4 · R

$c\bar{c}$ hybrid $J^{PC} = 1^{-+}$ ($\tilde{\eta}_{c1}$) in $D^0\bar{D}^{*0}$

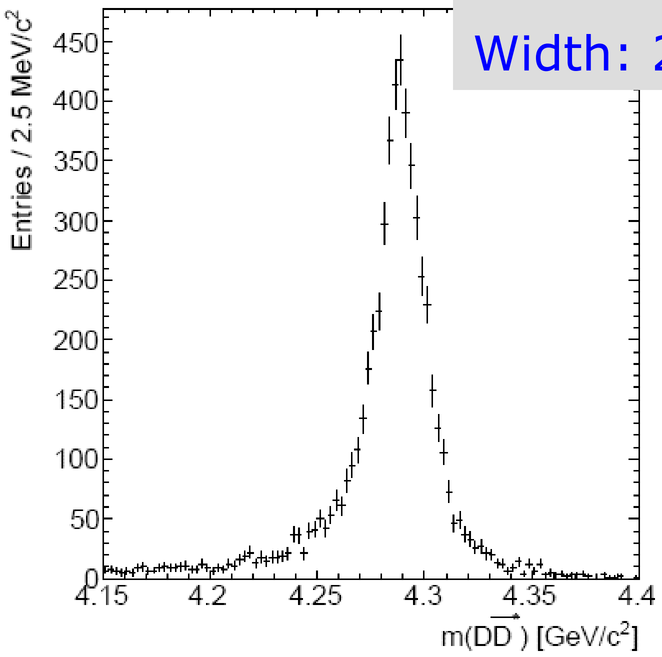
Production reaction



Reaction $\bar{p}p \to$	$\mathcal{B}$
$\tilde{\eta}_{c1}\eta$	$0.47\% \times \mathcal{B}(\tilde{\eta}_{c1} \to D^0\overline{D}^{*0})$
$D^0\overline{D}^{*0}\eta$	$3.2\% \times \mathcal{B}(D^0 \to K^-\pi^+\pi^0\pi^0) = 0.16\%^*$
$D^0\overline{D}^{*0}\pi^0$	1.17%

Efficiency: 5.17%

Width: 23 MeV/c^2



$S/B > B(\tilde{\eta}_{c1} \to D^0\bar{D}^{*0}) \cdot 2900$

Expected events per day:

$N = B(\tilde{\eta}_{c1} \to D^0\bar{D}^{*0}) \cdot 0.077$

$N = B(\tilde{\eta}_{c1} \to \chi_{c1}\pi^0\pi^0) \cdot 0.16$

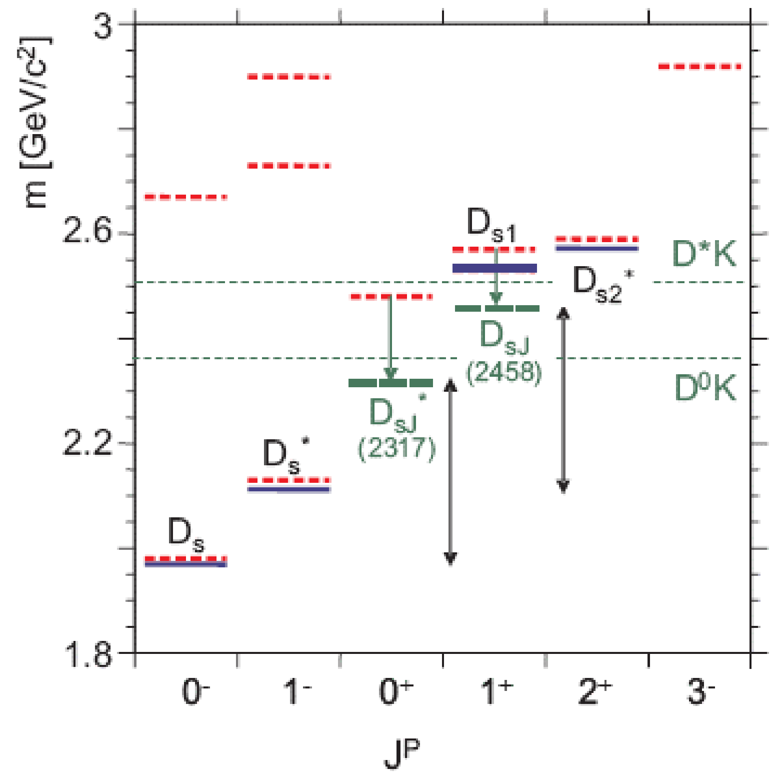
Open Charm

Charm spectroscopy

Charmonium states above $\bar{D}D$ threshold

Search for hybrids decaying to $\bar{D}D$

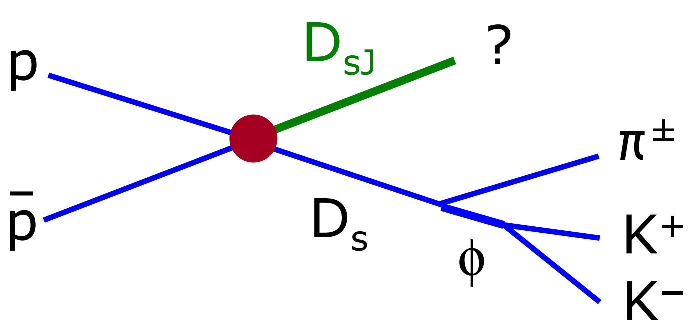
Rare D decays (and CP violation)
→ Separation from large hadronic background
→ Total $\bar{D}D$ cross section unknown



D_{sJ} discovered at B-factories

$D_{sJ}(2317)^+$

Production reaction



Mass resolution at B-Factories limited to 2.3 MeV/c² !

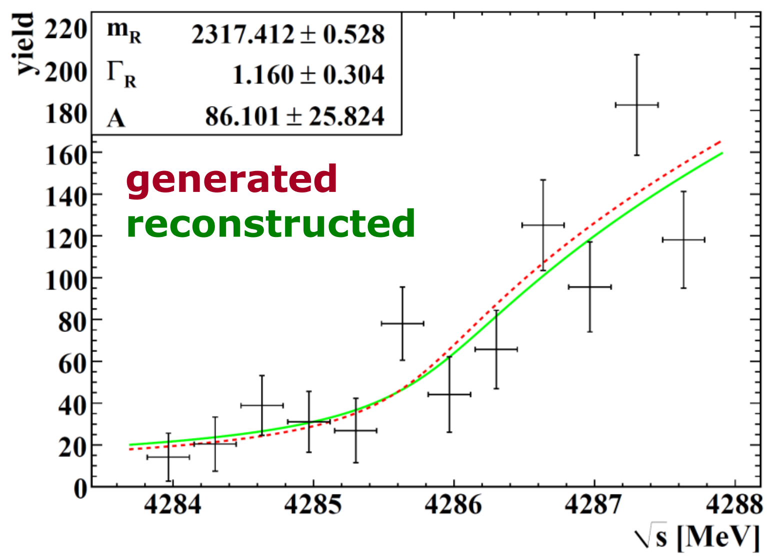
Prediction $\Gamma < 1$ MeV/c²

Inclusive Reconstruction !

Threshold scan

$M = 2317.30$ MeV/c²

$\Gamma = 1$ MeV/c²



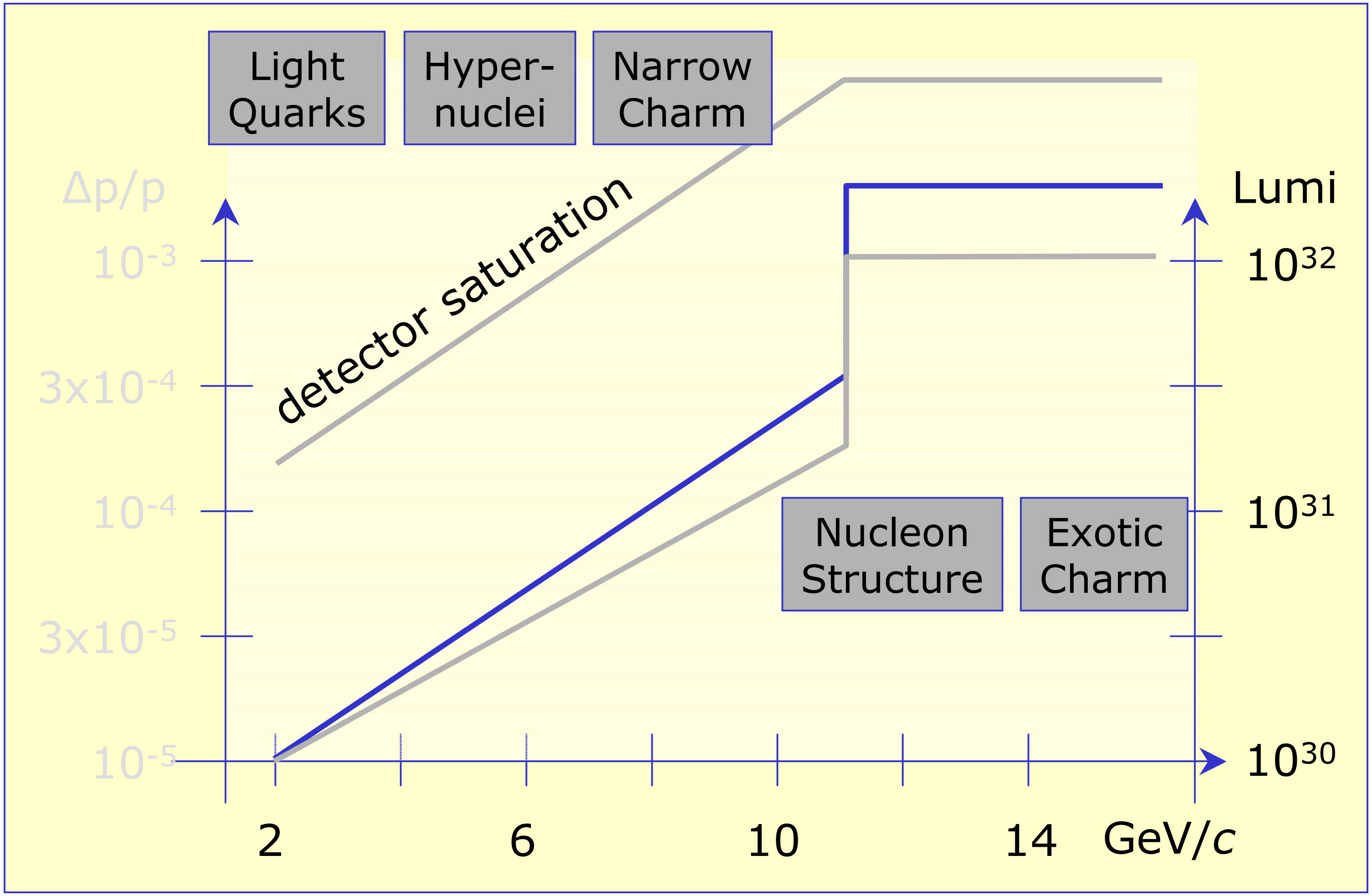
σ_Γ = 0.3 MeV/c²

σ_m = 0.5 MeV/c²

S/B = 1/3 14 days

Luminosities @ various $p_{\bar{p}}$

Highest luminosity required for exotic charm discoveries
and nucleon structure physics

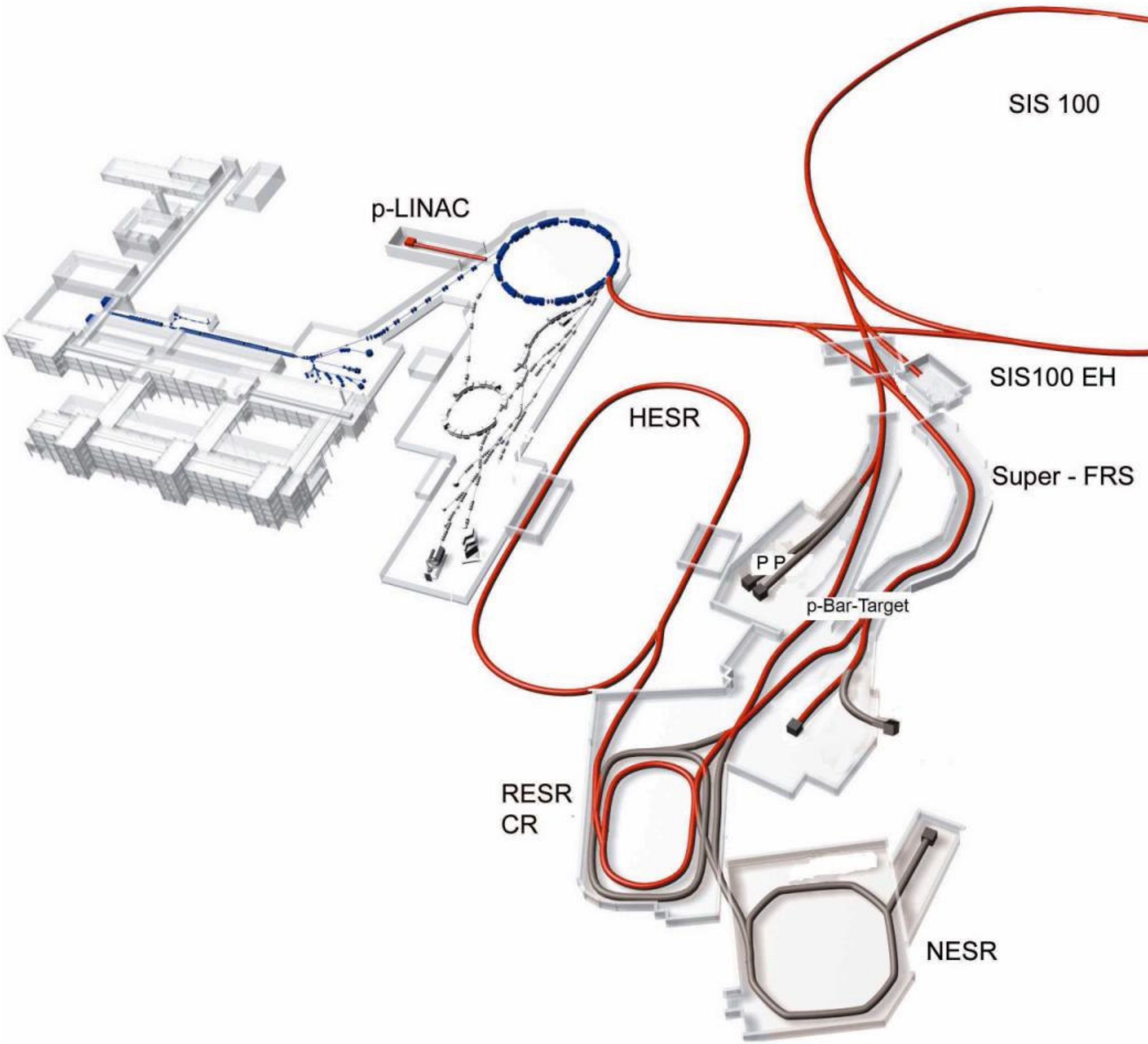


Development of Project Staging at FAIR

2003	**Recommendation by WissenschaftsRat** **FAIR Realisation in three stages**						
2005	**Entire Facility** **Baseline Technical Report**						
2007	**Phase A**						**Phase B** SIS300
2009	**Module 0** SIS100	**Module 1** expt areas CBM/HADES and APPA	**Module 2** Super-FRS fixed target area NuSTAR	**Module 3** $\bar{p}$-facility, incl. CR for PANDA, options for NuSTAR	**Module 4** LEB for NuSTAR, NESR for NuSTAR and APPA, FLAIR for APPA	**Module 5** RESR nominal intensity for PANDA & parallel operation with NuSTAR and APPA	**Module 6** SIS300

Modularized Start Version

Modularized Start Version



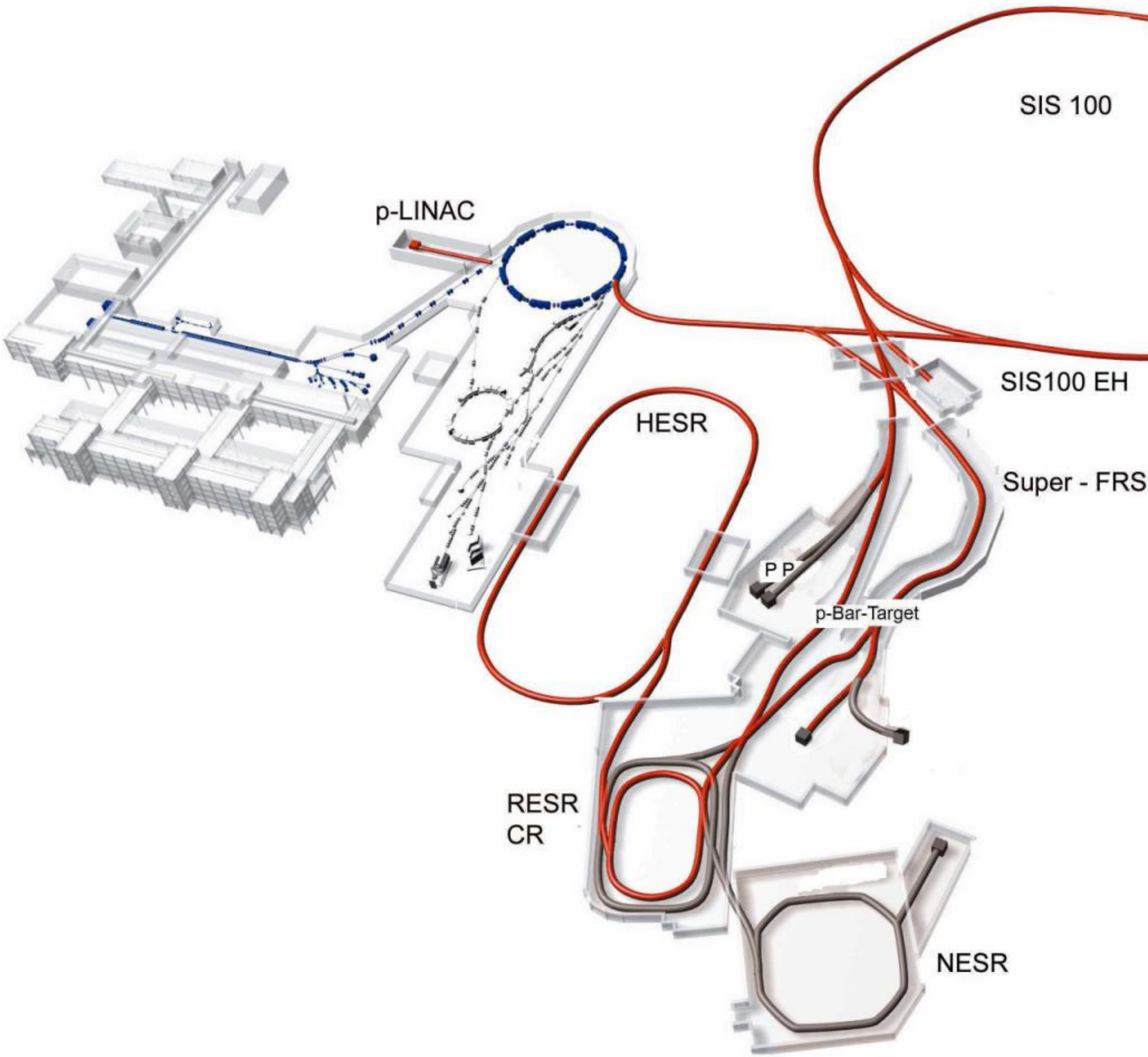
Module 0
SIS100 and connection to existing GSI accel.

Module 1
Experimental areas

Module 2
Super-FRS (NuSTAR)

Module 3
High-energy antiprotons (p-linac, pbar-target, CR, HESR)

Effect of Staging on PANDA



Module 5
RESR

Consequences
Accumulation in HESR
Smaller luminosity
(≤1/2 L_{max} maybe 1/3)
High precision running not affected
Longer running until RESR is added

But
No charmed hypernuclei
No open charm physics
(rare decays, mixing, CP)

Summary

PANDA will be a versatile QCD experiment

- Large acceptance and double spectrometer
- Tracking and vertexing capabilities
- Particle identification and calorimetry
- Flexible data acquisition & trigger

Novel techniques in detector and readout design

First components are being produced

Technical design finished 2010

PANDA Physics Performance Report completed

Modularized Start Version does not affect too much

PANDA Collaboration

> 430 Scientists
56 Institutions
16 Countries

U Basel
IHEP Beijing
U Bochum
U Bonn
U & INFN Brescia
IFIN Budapest
U & INFN Catania
U Cracow
GSI Darmstadt
TU Dresden
JINR Dubna
(LIT,LPP,VBLHE)
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 I + II
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