**BEACH 2010 - IX International Conference on Hyperons, Charm and Beauty Hadrons,
21-26 June 2010, Perugia, Italy**

Thomas Würschig

Contribution of the MVD to the charm spectroscopy at $\bar{P}$ANDA

* supported by BMBF and EU FP6 DIRAC Secondary Beams

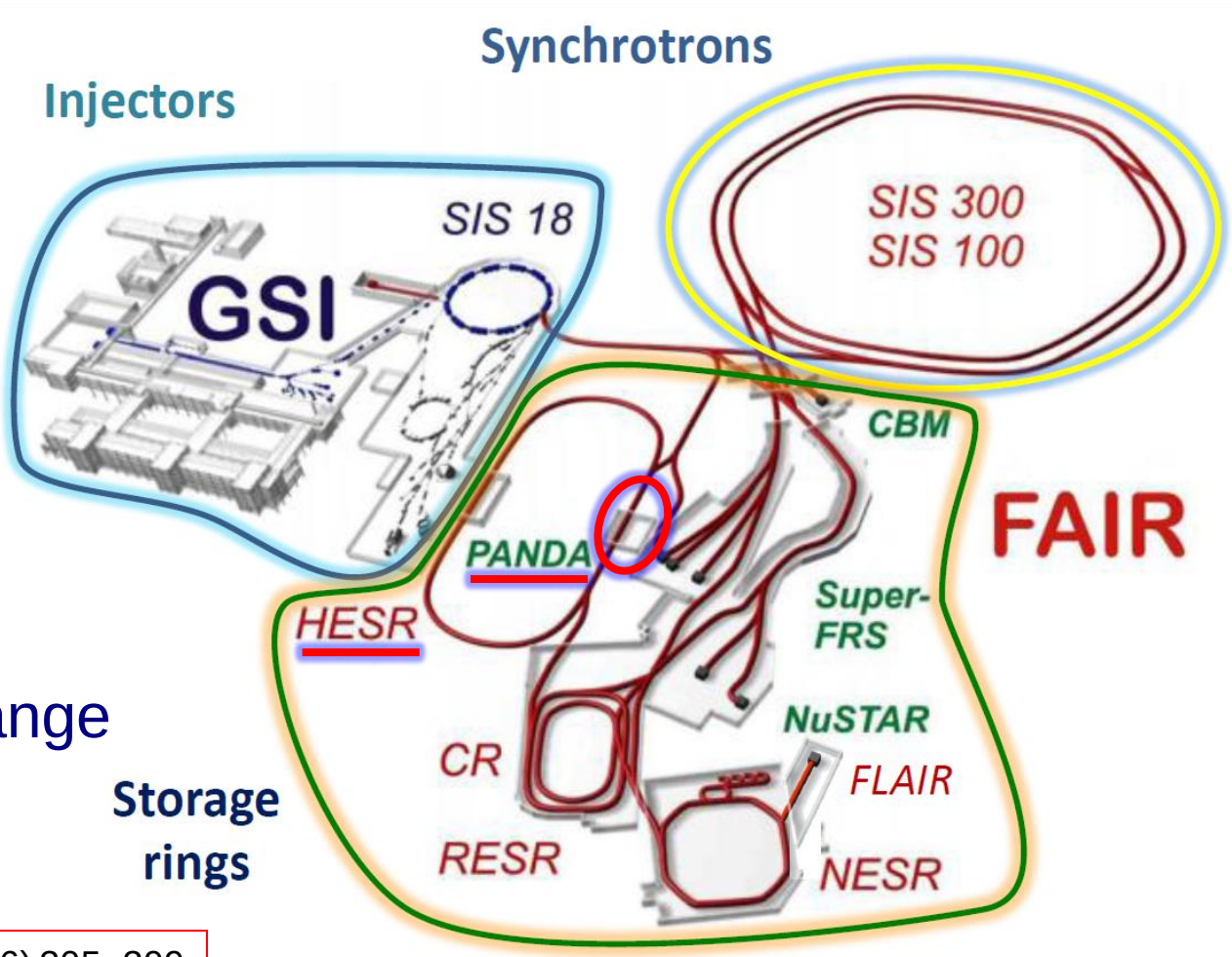
HISKP universitätbonn

Outline

- Introduction
- Charm spectroscopy at PANDA
- MVD detector layout
- Simulation
  - Basic features of MVD
  - Selected examples of MVD impact on physics performance
- Summary

Introduction

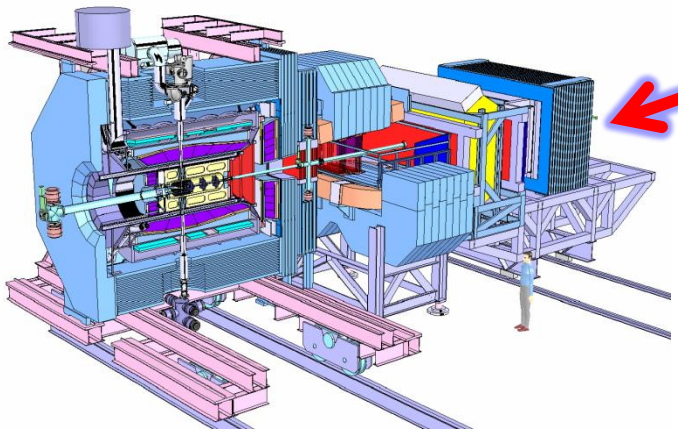
- FAIR facility
  - Very intense beams of protons, antiprotons and ions
  - High resolution
  - Wide energy range



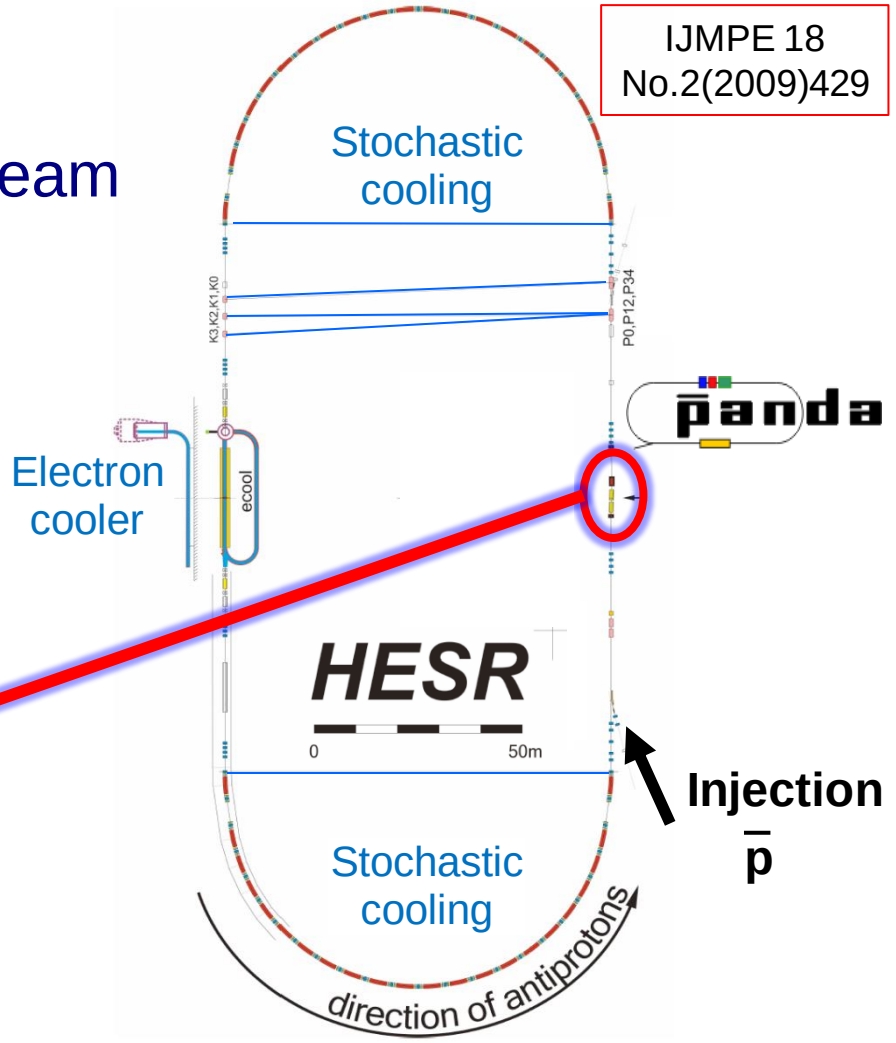
Nucl. Instr. Meth. A 561 (2006) 305–309

Introduction

- **H**igh **E**nergy **S**torage **R**ing
  - High luminosity antiproton beam
  - Phase space cooling
- **P̄ANDA** experiment
  - Anti**P**roton **An**nihilations at **Da**rmstadt



IJMPE 18
No.2(2009)429



Introduction

- PANDA - Experiment
  - Fixed target experiment
  - Frozen hydrogen and heavier nuclear targets (Ar...N, *Cu...Ag*)
    → Pellet target / Cluster-jet target / *Wire or foil targets*
  - Operation modes

    a) High luminosity: $L = 2 \cdot 10^{32}\ cm^{-2}\ s^{-1} \Leftrightarrow \Delta p/p \approx 10^{-4}$

    b) High resolution: $L = 10^{31}\ cm^{-2}\ s^{-1} \Leftrightarrow \Delta p/p \approx 4 \cdot 10^{-5}$

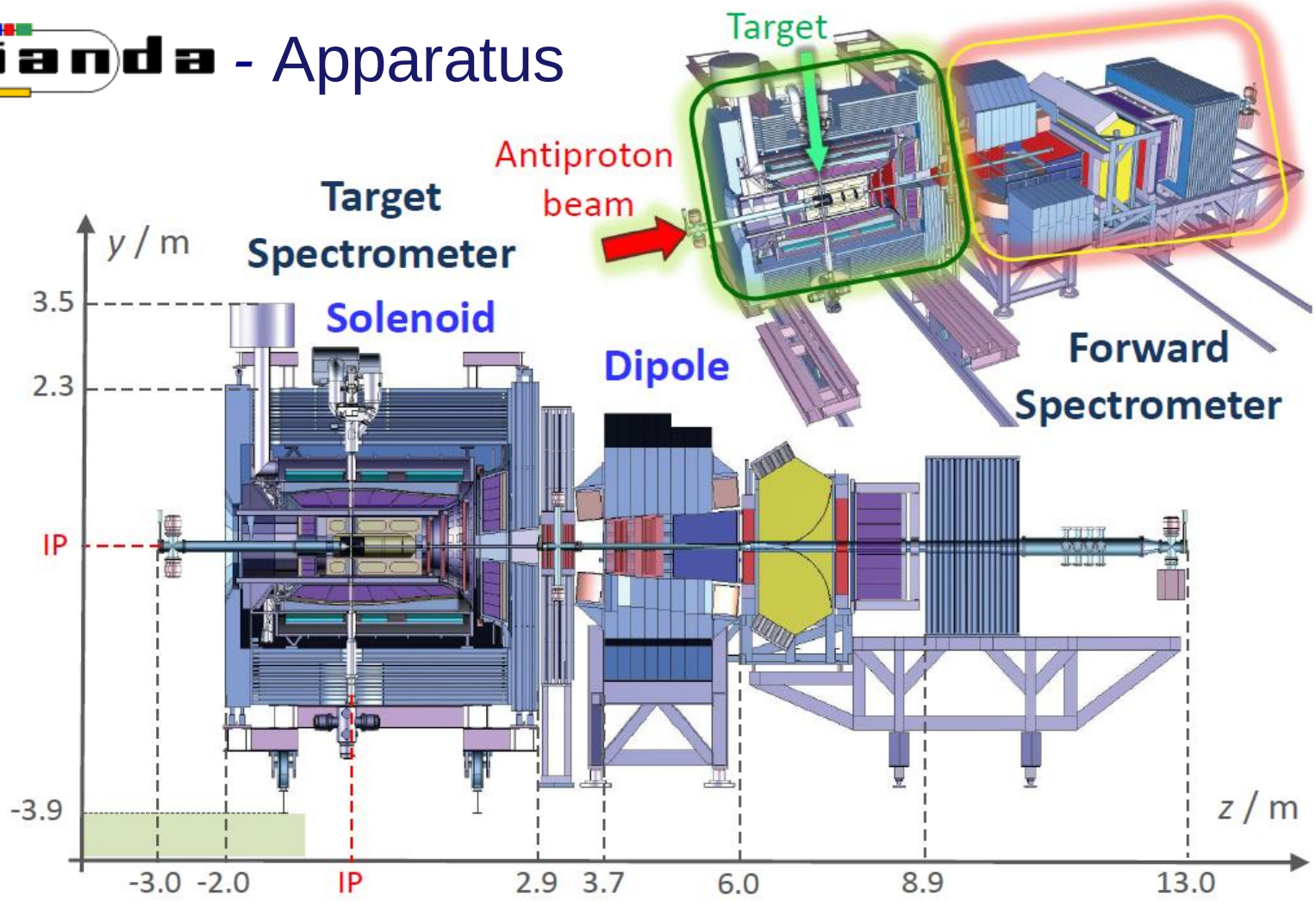
    Beam momentum: (1.5 ... 15) GeV/c
  - Beam-target interaction
    → $2 \cdot 10^7$ annihilations/s; No time structure

arXiv:0710.5664v1 [hep-ex]

arXiv:0711.1598v1 [nucl-ex]

Introduction

- PANDA - Apparatus



Introduction

- PANDA - Detection concept
  - Hermetic detector with modular sub-systems
  - Measurement of charged and neutral particles
  - Good particle identification and momentum resolution

Tracking

→ Central trackers
→ Forward trackers

Particle identification

→ Muon system
→ Electromagnetic calorimeter (EMC)
→ Čerenkov detectors (DIRC, RICH)
→ TOF systems

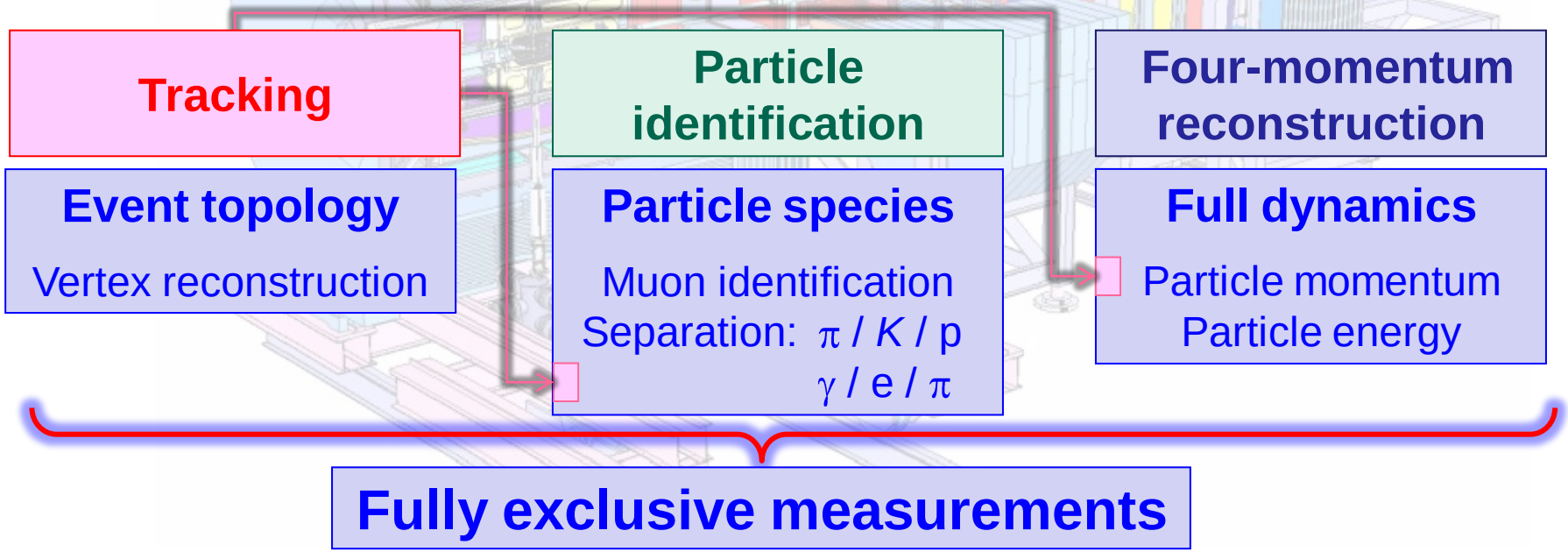
Four-momentum reconstruction

→ Tracking system: Particle momentum

→ Muon system+EMC: Particle energy

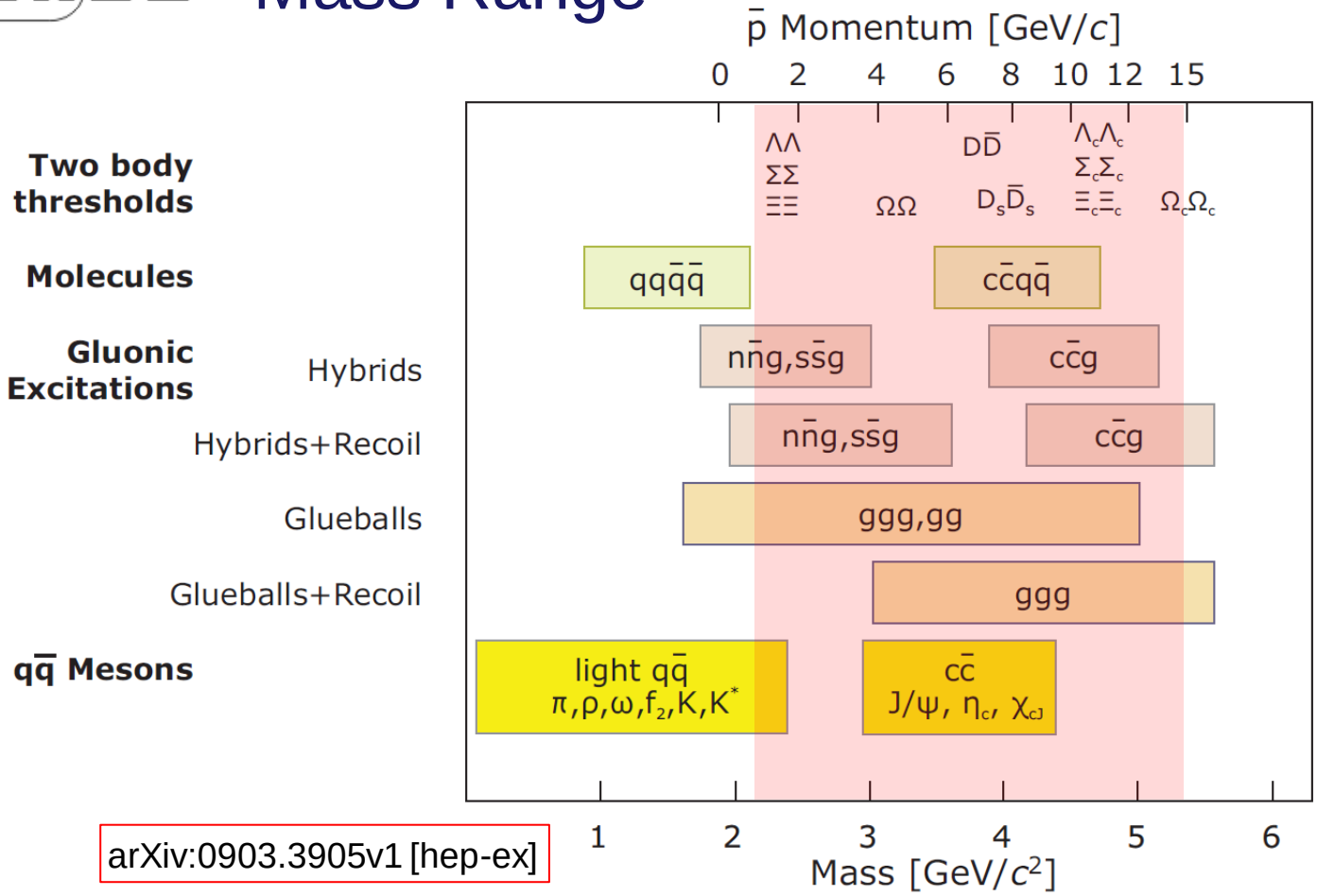
Introduction

- PANDA - Detection concept
  - Hermetic detector with modular sub-systems
  - Measurement of charged and neutral particles
  - Good particle identification and momentum resolution



Introduction

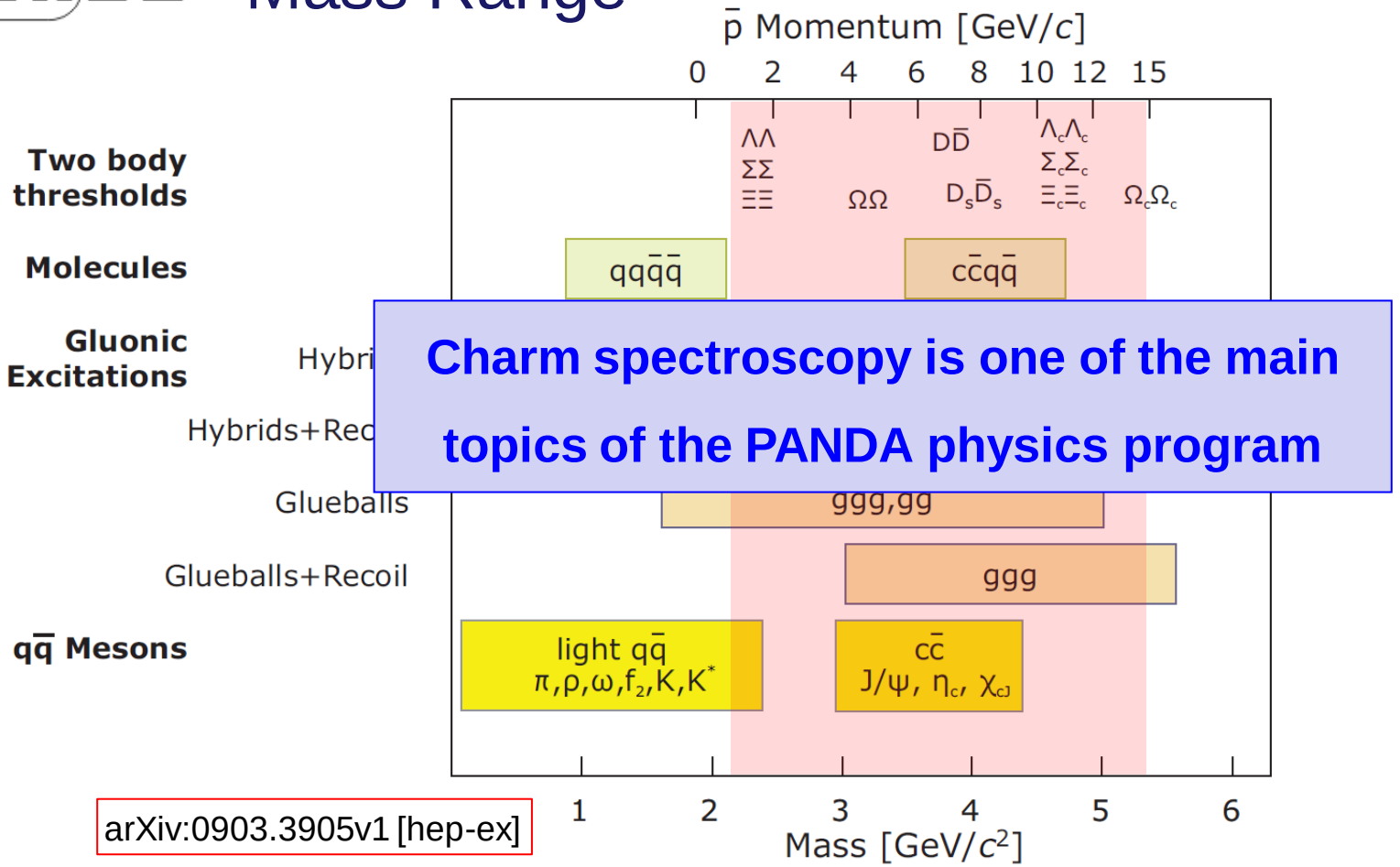
- p̄anda - Mass Range



arXiv:0903.3905v1 [hep-ex]

Introduction

- $\bar{\text{P}}$ANDA - Mass Range



Charm spectroscopy is one of the main topics of the PANDA physics program

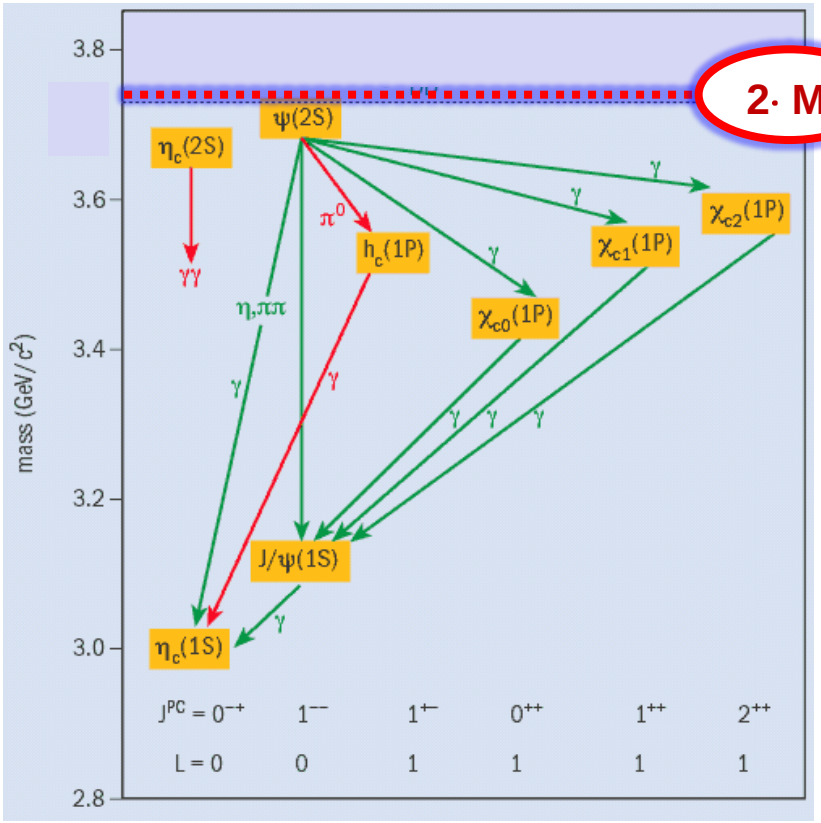
arXiv:0903.3905v1 [hep-ex]

Charm spectroscopy

- PANDA - Key aspects

Charmonium System

http://images.iop.org/objects/ccr/cern/46/5/31/CCEcle1_06-06.gif



2· M_D

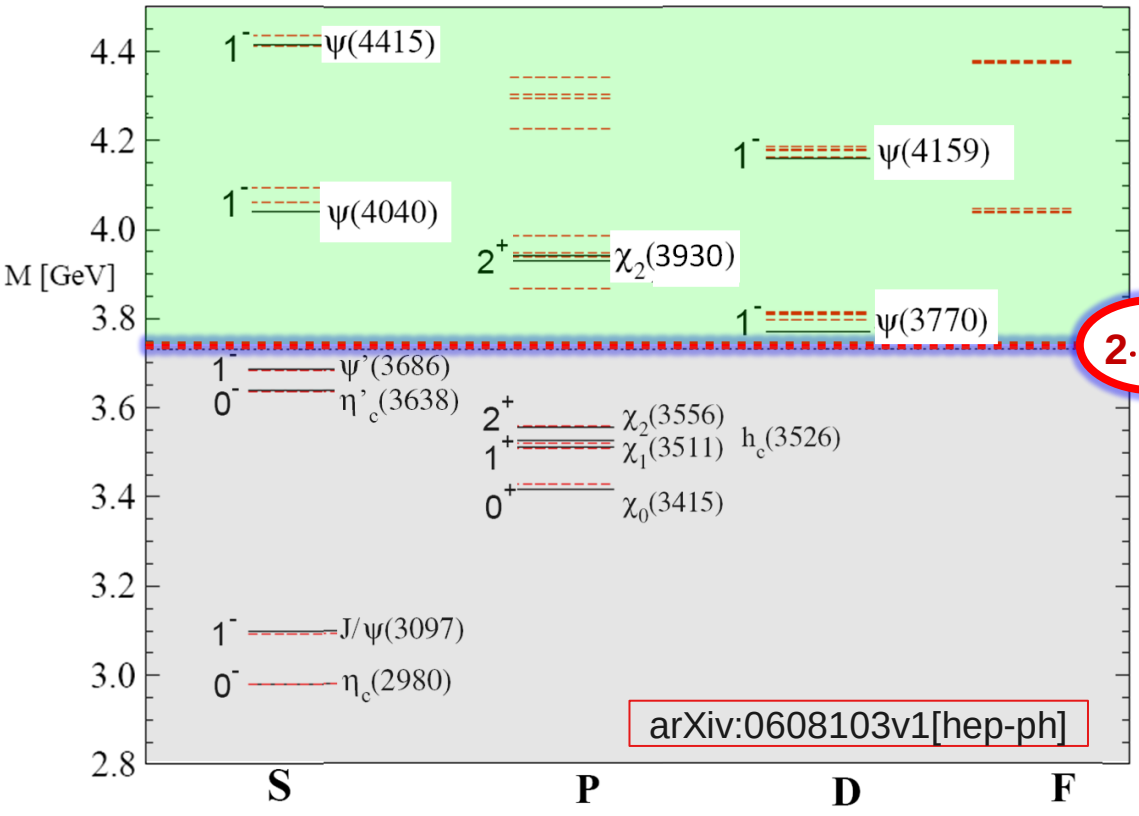
Below Open Charm Threshold

- High precision measurement of masses and widths
- Detailed analysis of decay branches

Charm spectroscopy

- $\bar{p}$anda - Key aspects

Charmonium System



Above Open Charm Threshold

- Exploring so far undiscovered states
- Confirmation of observed states as charmonium

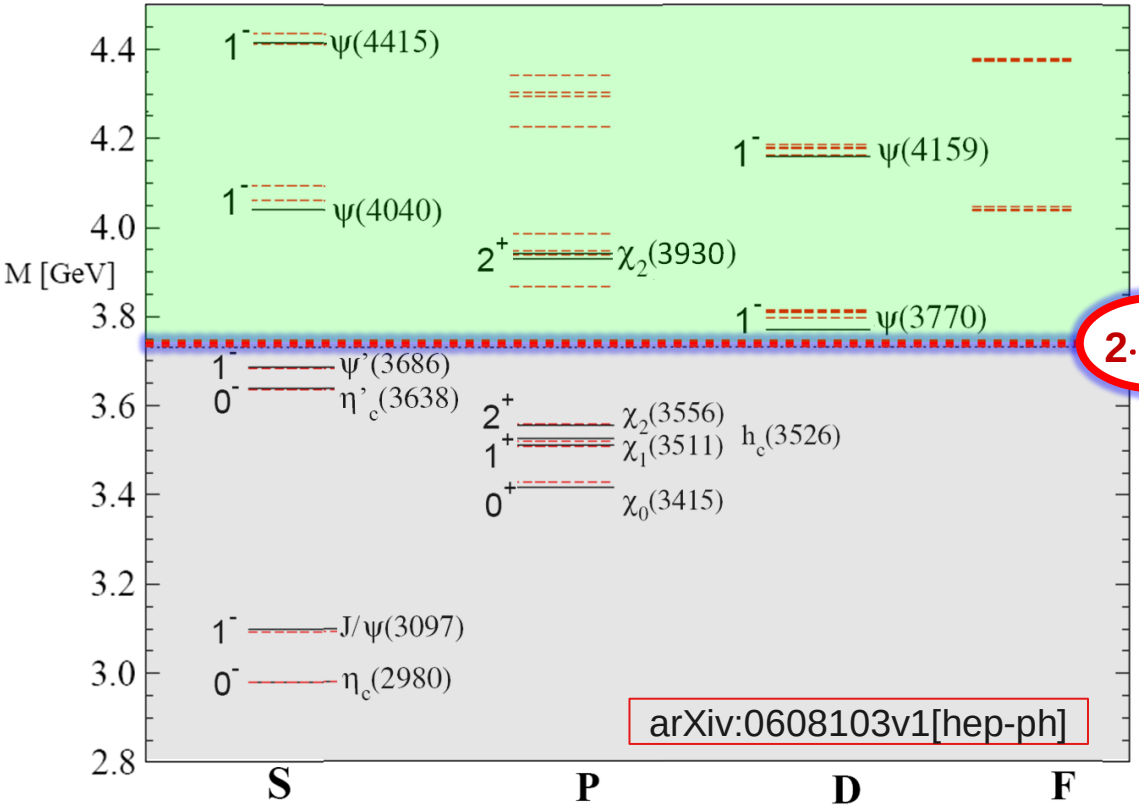
→ Complete analysis on quantum numbers

→ Measurement of masses and widths with high precision

Charm spectroscopy

- panda - Key aspects

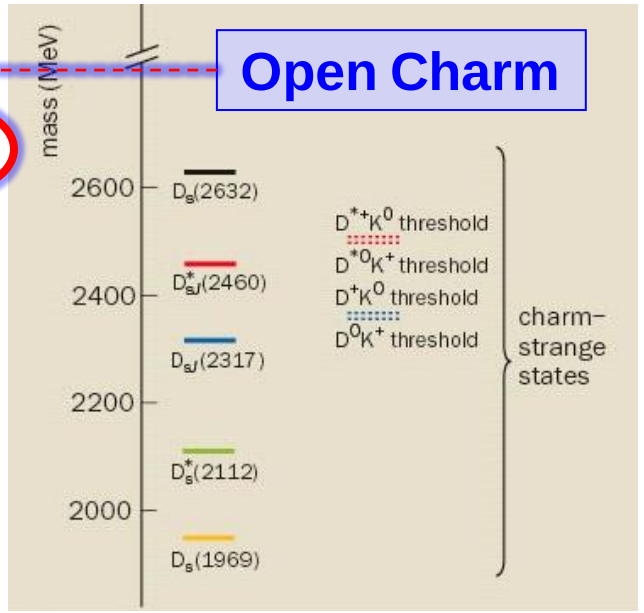
Charmonium System



2· M_D

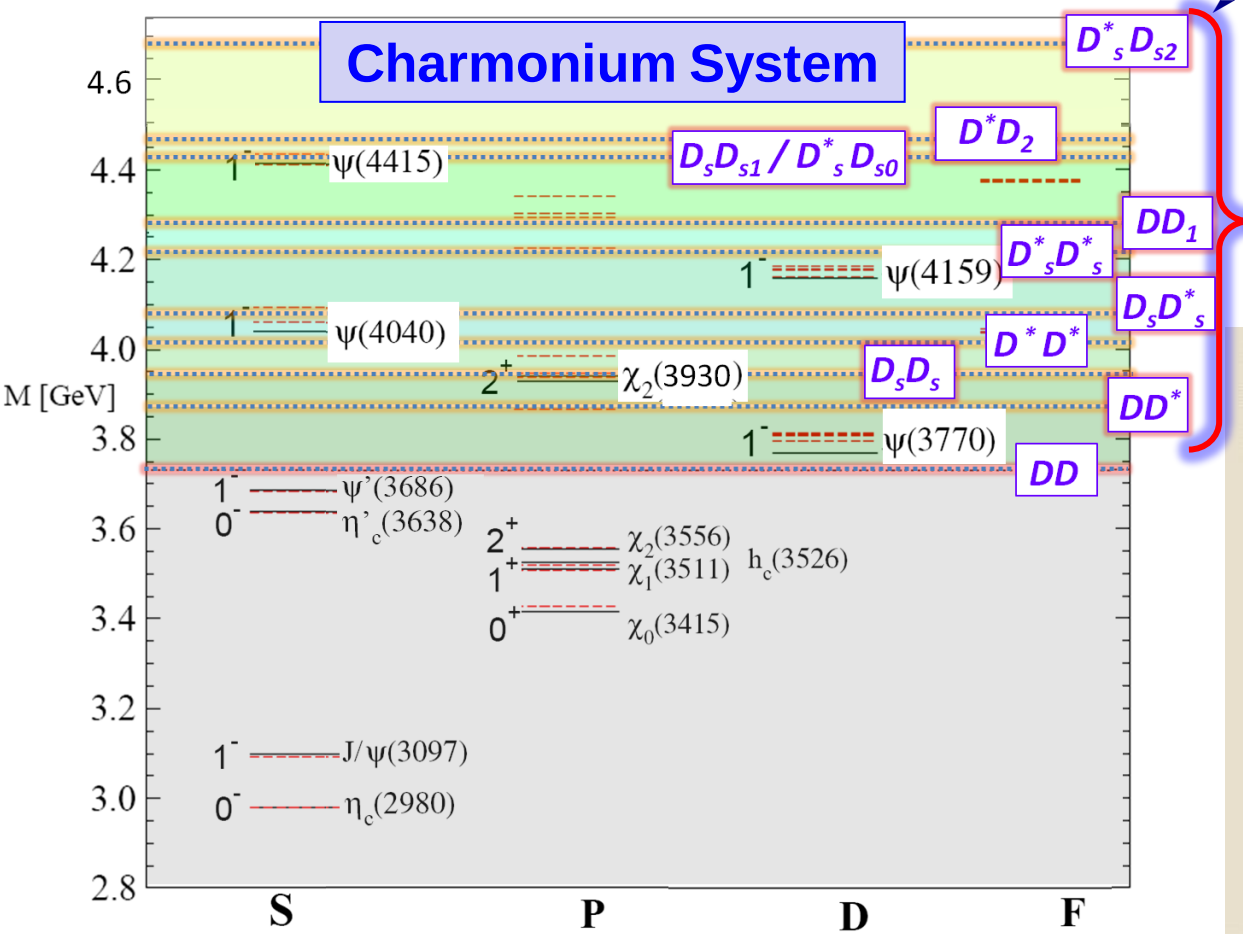
- *D* – meson spectrum
  - → Masses and widths
  - → Decay branches
  - → New states

Open Charm



Charm spectroscopy

- **panda** - Key aspects

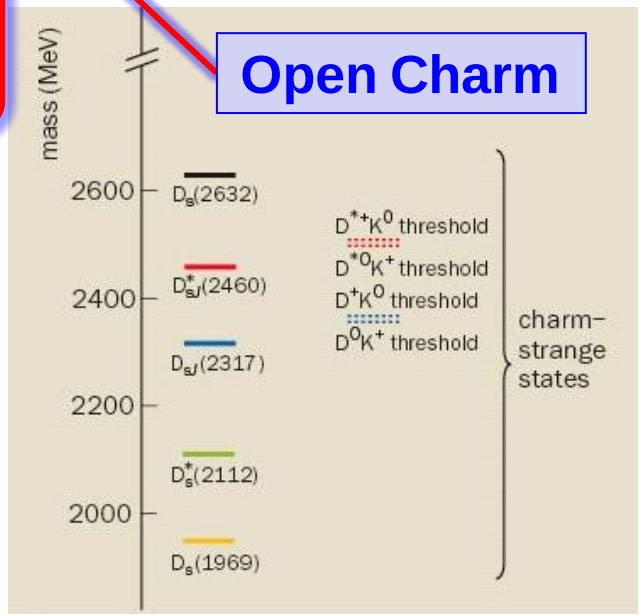


D – meson spectrum

→ Masses and widths

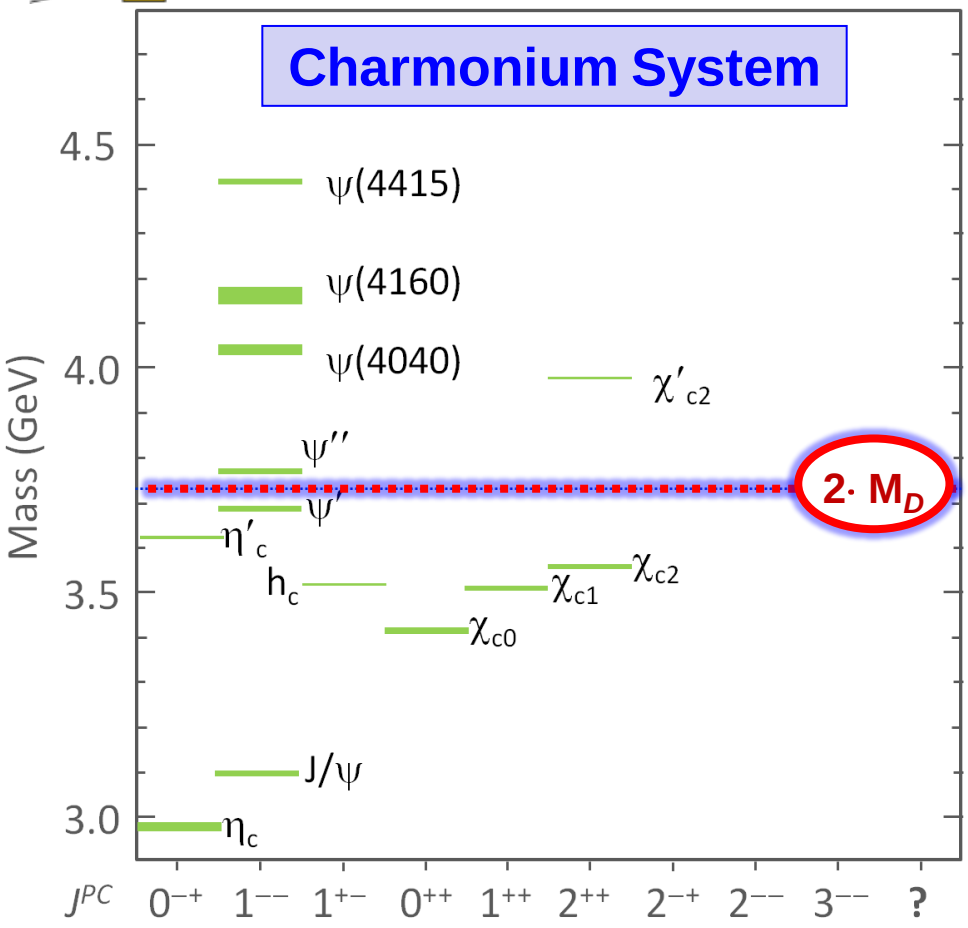
→ Decay branches

→ New states

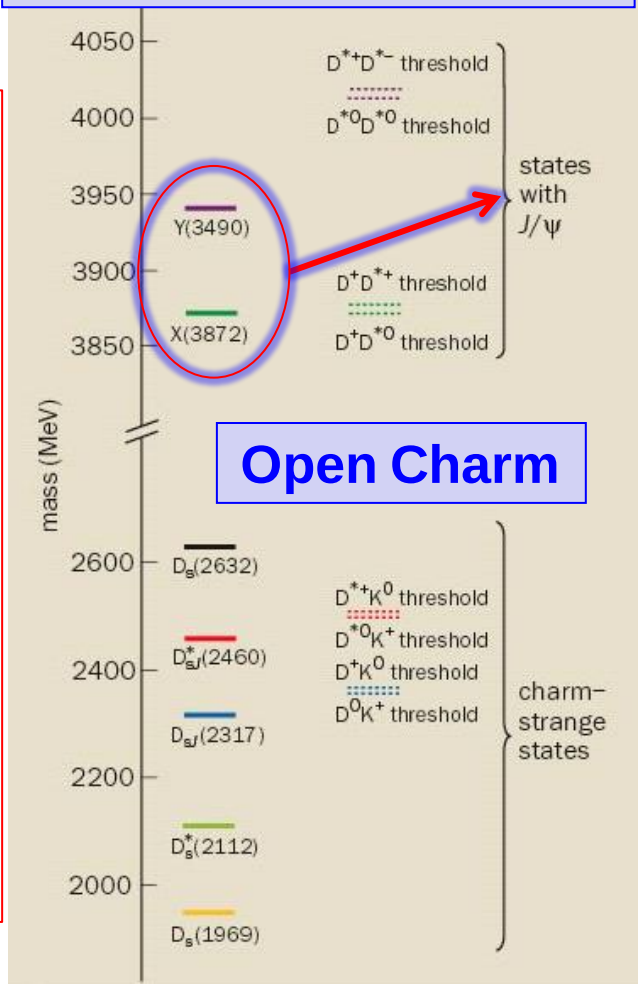


Charm spectroscopy

- panda - Key aspects



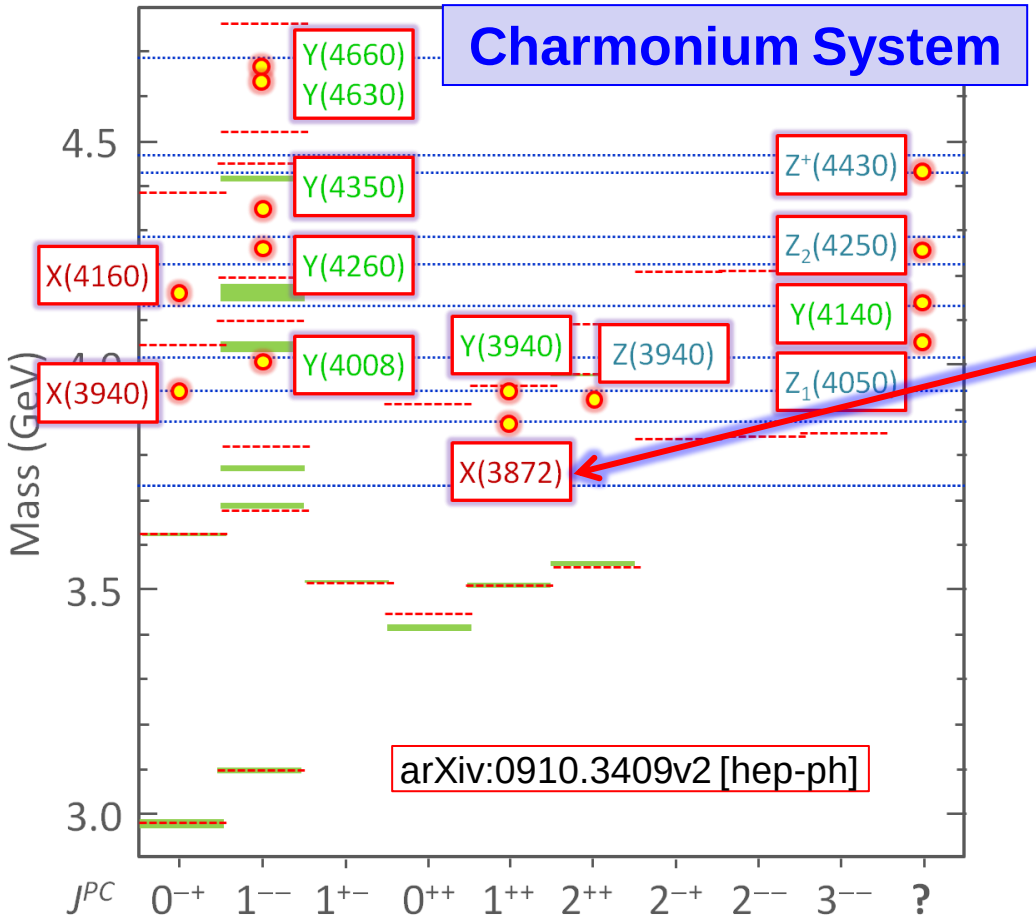
Non conventional QCD

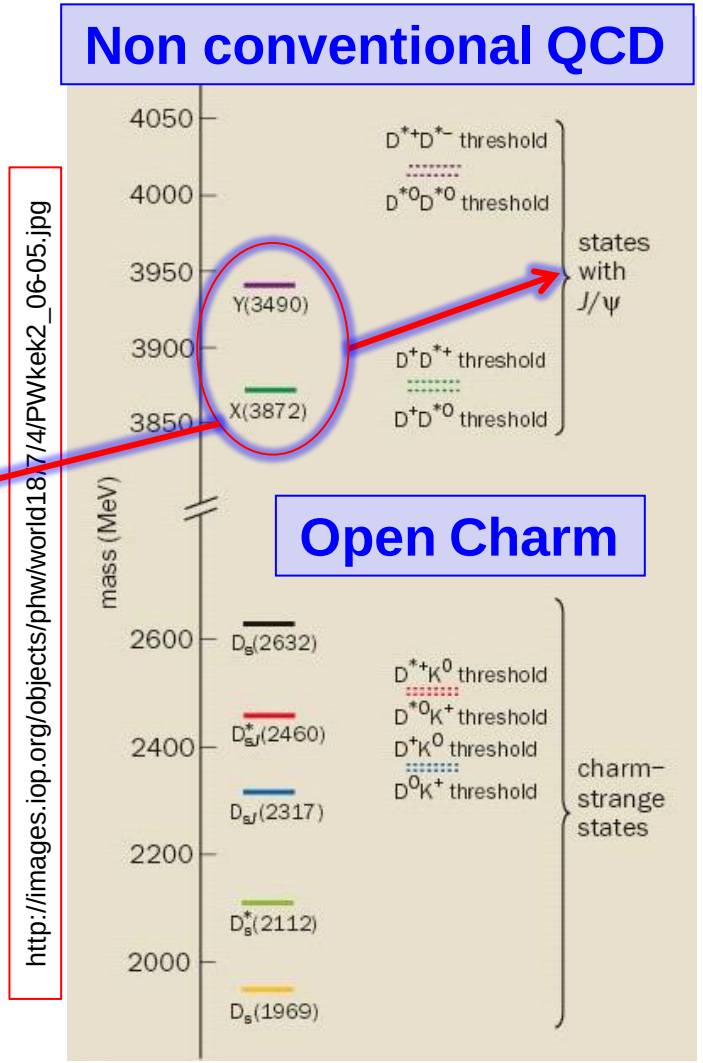


http://images.iop.org/objects/phw/world18/7/4/PWkek2_06-05.jpg

Charm spectroscopy

- panda - Key aspects





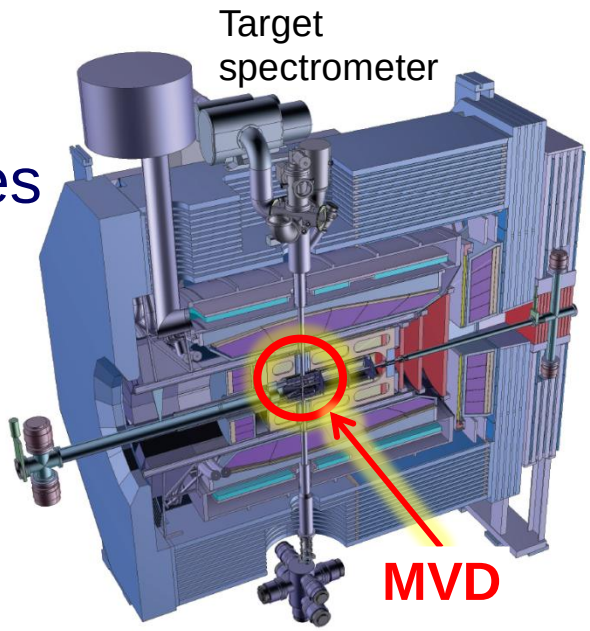
PANDA MVD detector

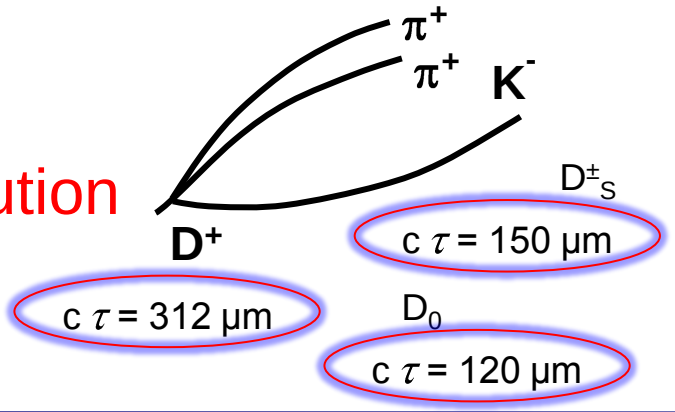
- Micro-Vertex-Detector (MVD)
  - **Tracking detector** for charged particles
  - **Innermost** detector in PANDA
  - **Main tasks:**

(1) High vertex resolution for primary interaction vertex and secondary vertices of short lived particles and delayed decays

(2) Improvement of momentum resolution

(3) Additional input for particle-ID





PANDA MVD detector

- Micro-Vertex-Detector (MVD)
  - **Tracking detector** for charged particles
  - **Innermost** detector

Low material budget
Radiation tolerance

  - **Main tasks:**

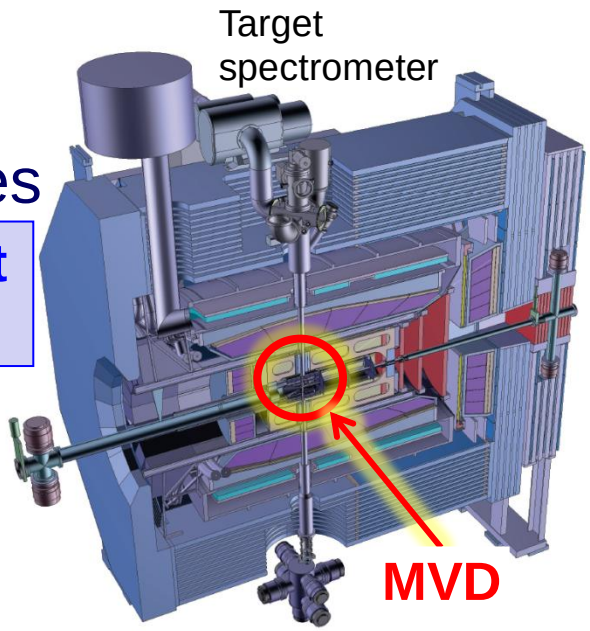
(1) High vertex resolution

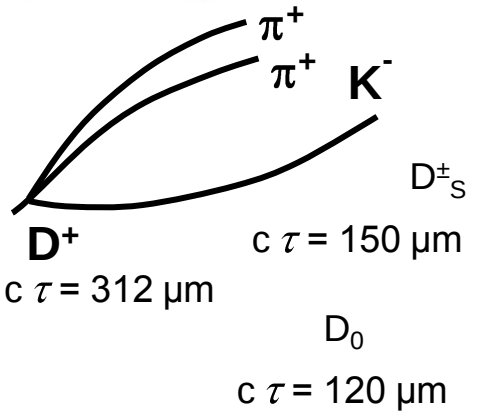
High granularity
Optimized spatial coverage
Detection close to interaction point

(2) Improvement of momentum resolution

(3) Additional input

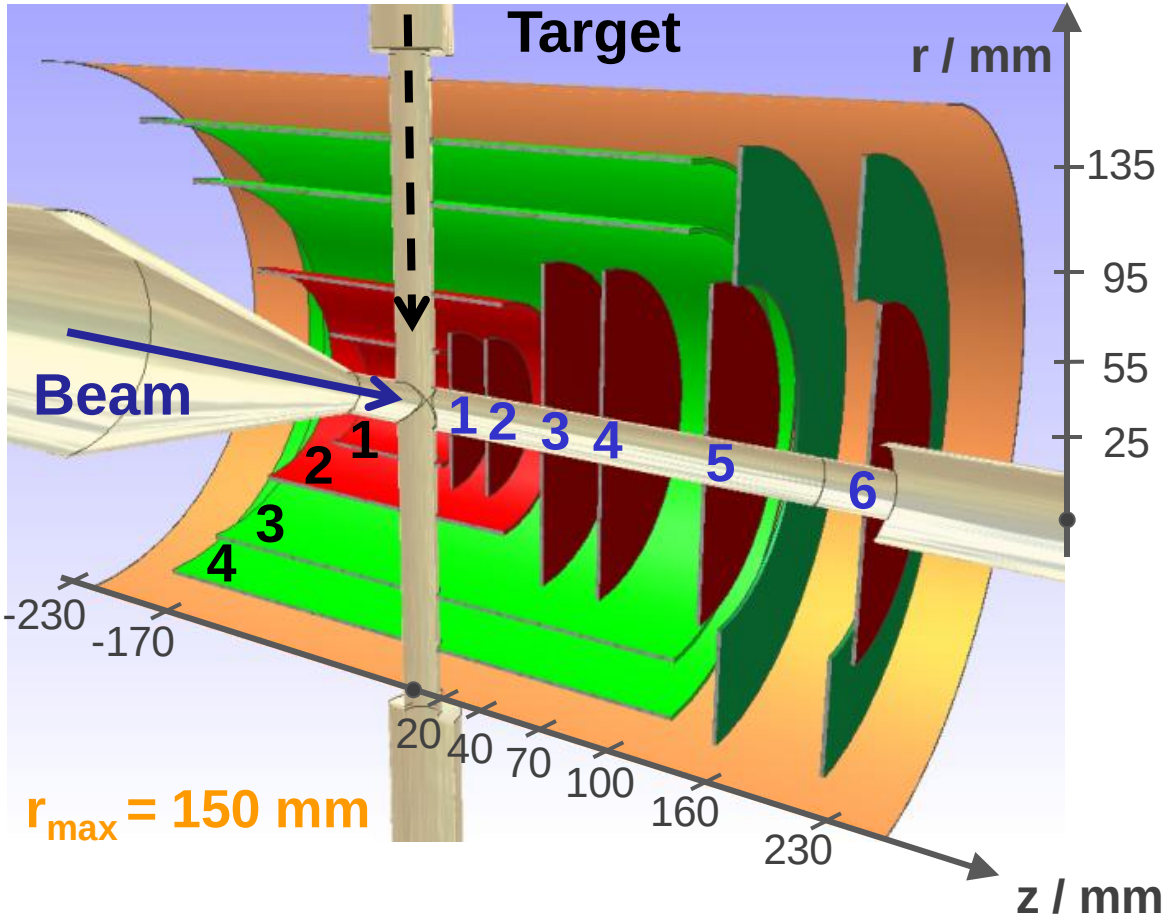
Good time resolution
Energy loss information





MVD layout

- Micro-Vertex-Detector (MVD)
  - Central part:
    Four barrel layers
  - Forward part:
    Six disk layers
  - Detector types:
    - ✓ Pixel sensors
    - ✓ Double-sided microstrip sensors



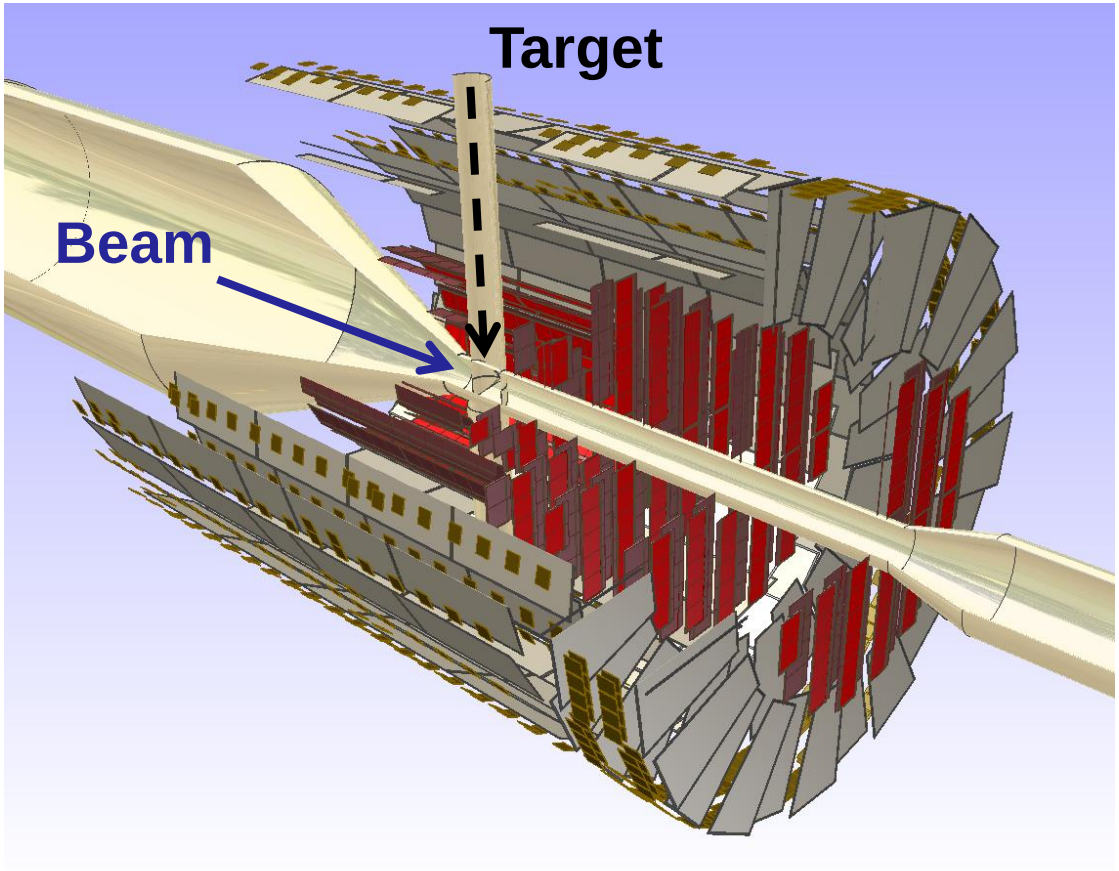
Implementation

- Micro-Vertex-Detector (MVD)
  - Central part:
    Four barrel layers
  - Forward part:
    Six disk layers
  - Detector types:
    - ✓ Pixel sensors
    - ✓ Double sided microstrip sensors

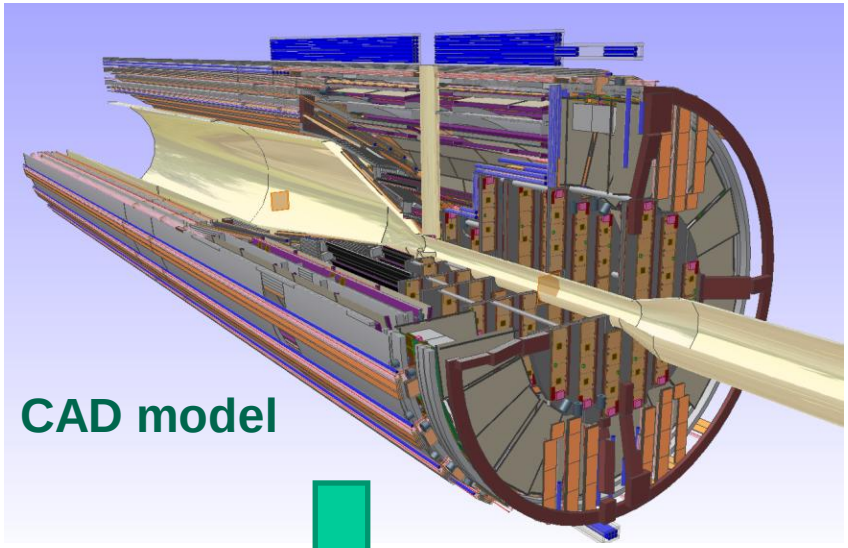
Readout channels:

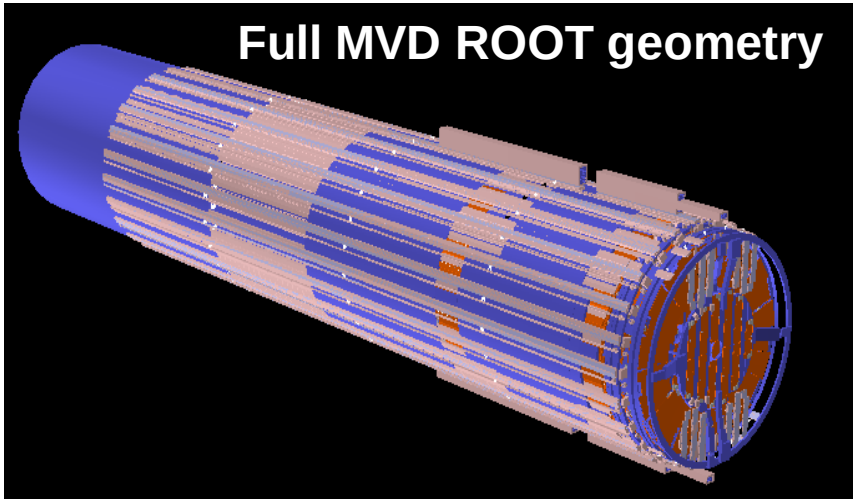
~ 11 million (pixel)

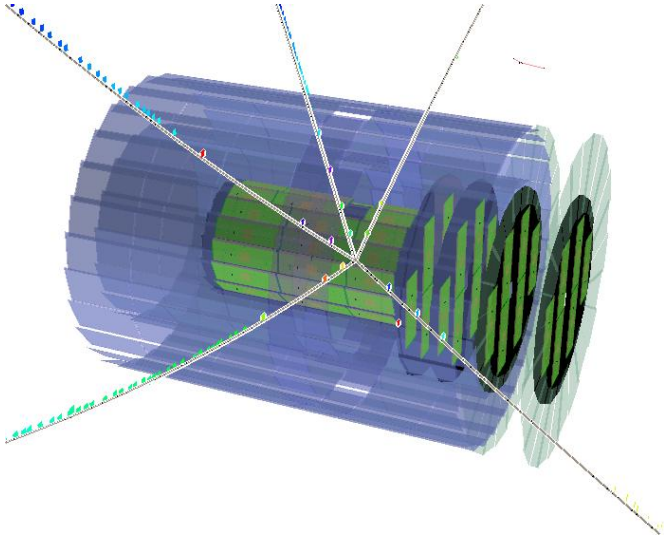
~ 200.000 (strip)



Simulation



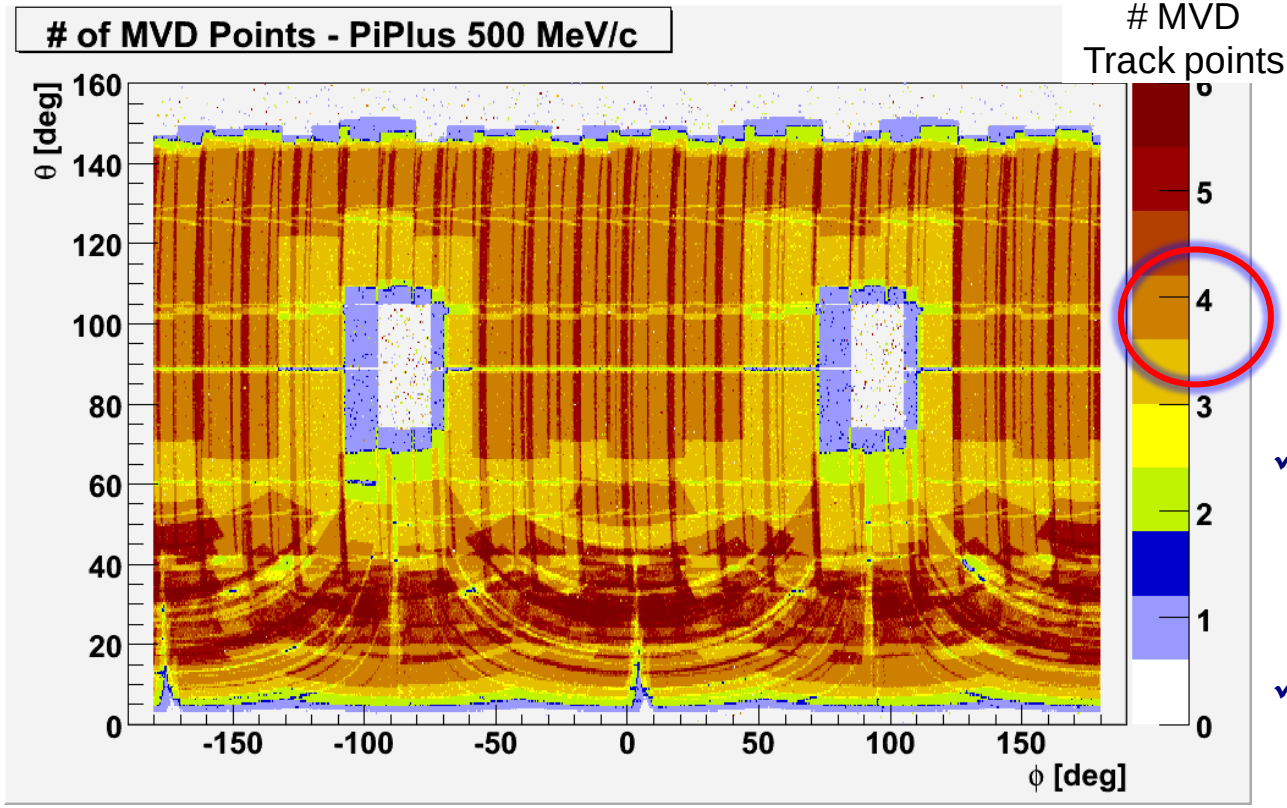


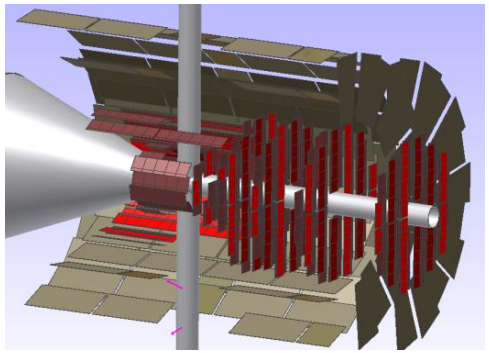


- CAD Converter
  - Translation of technical CAD drawings to ROOT geometry
  - Access to full detector simulation with realistic model

Simulation

- Spatial coverage
  - 2D mapping: Number of MVD points / track

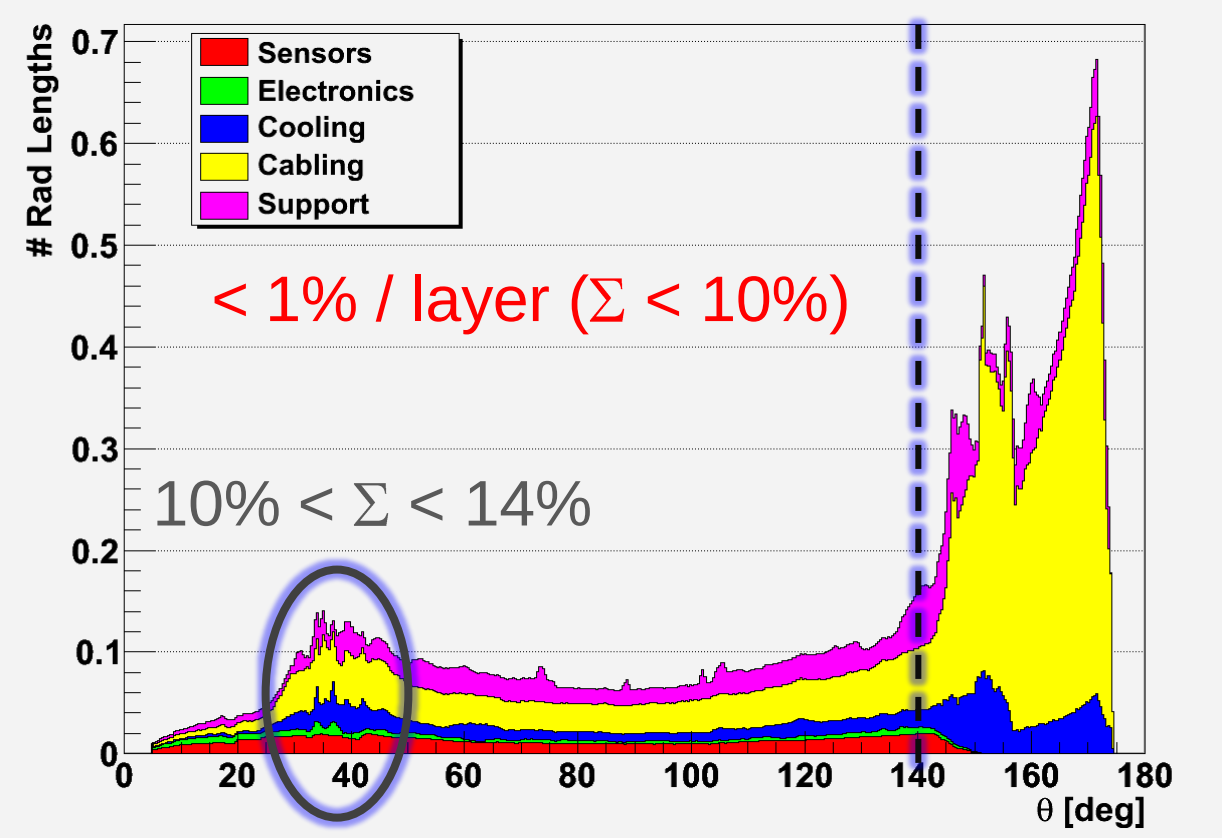


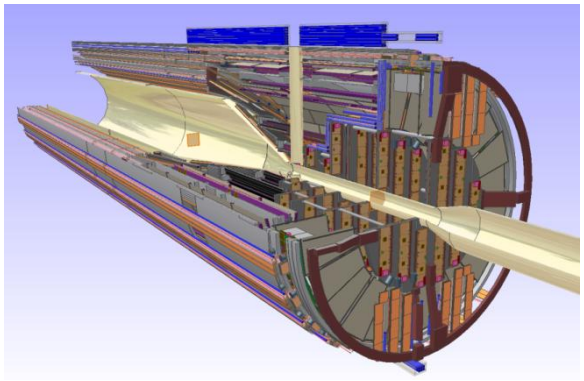


- ✓ Optimized design: **4 track points** $\theta = (10° \ldots 140°)$
- ✓ High coverage $\theta = (5° \ldots 145°)$

Simulation

- Radiation length studies (*Geantino*)
  - 1D profile scan for polar angle

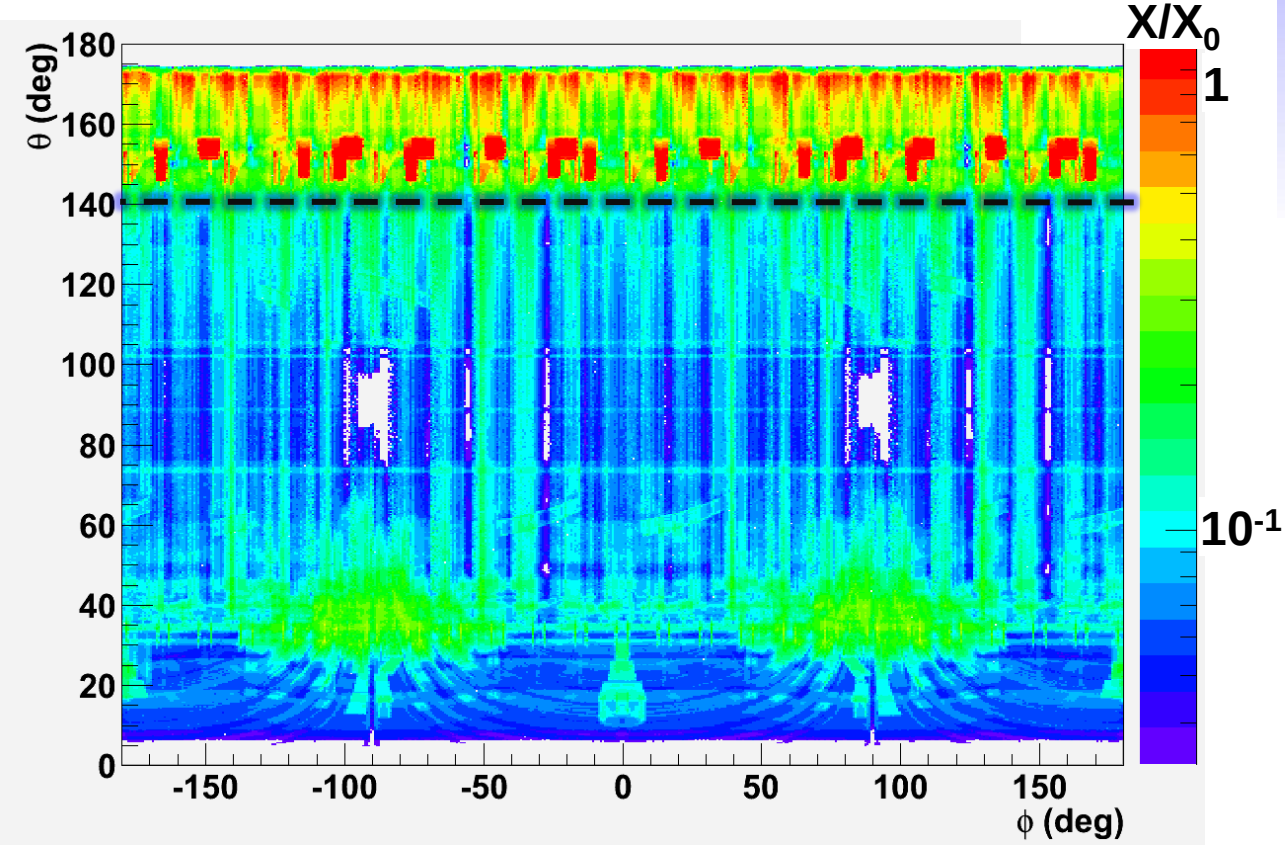


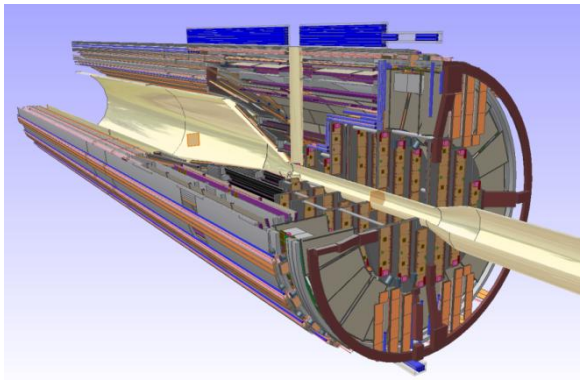


- ✓ Minimized material load below polar angle of 140°
- ✓ Hot spots in upstream region due to backward routing

Simulation

- Radiation length studies (*Geantino*)
  - 2D mapping of overall material budget



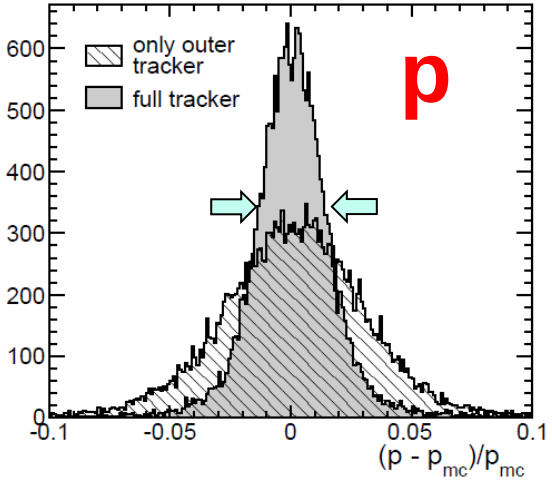


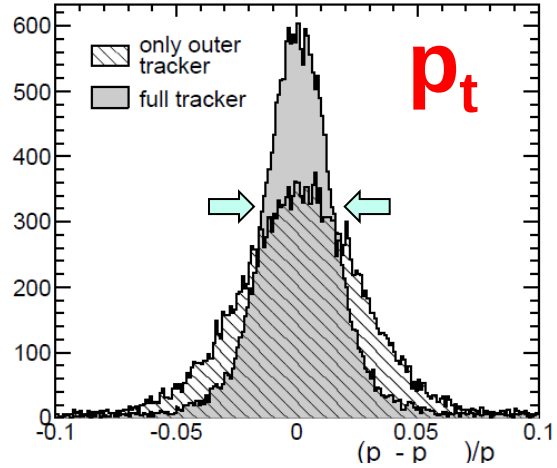
- ✓ Minimized material load below polar angle of 140°
- ✓ Hot spots in upstream region due to backward routing

Performance

- Momentum resolution

1 GeV/c pions (0;0;0)





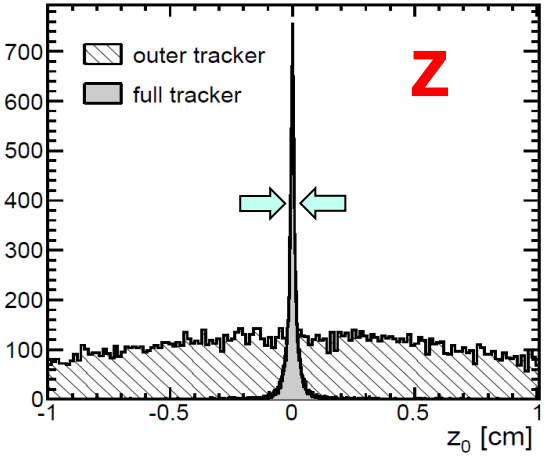
$\sigma(p)$ without MVD = 2.6 %
$\sigma(p)$ with MVD = 1.4 %

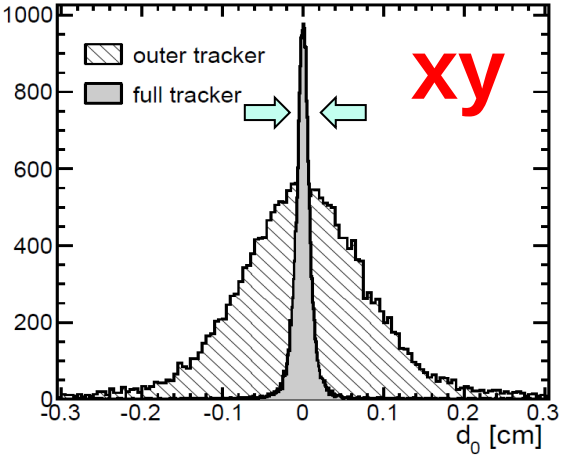
$\sigma(p_t)$ without MVD = 2.9 %
$\sigma(p_t)$ with MVD = 1.4 %

→ Improvement by 50%

- Single track resolution

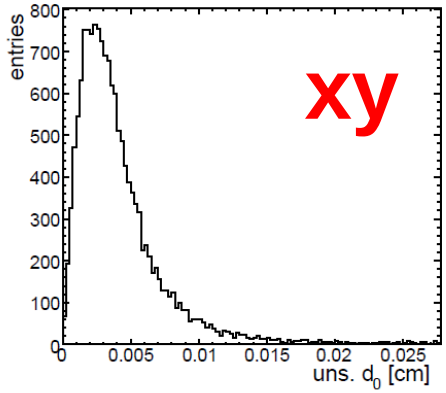
→ No resolution along beam axis without MVD

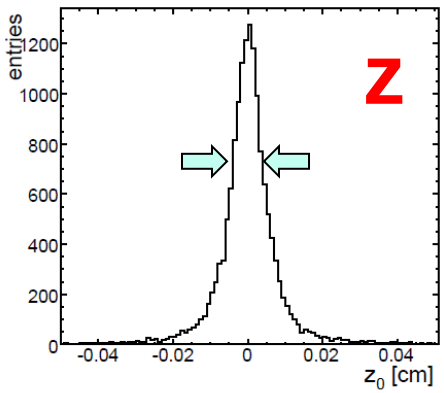


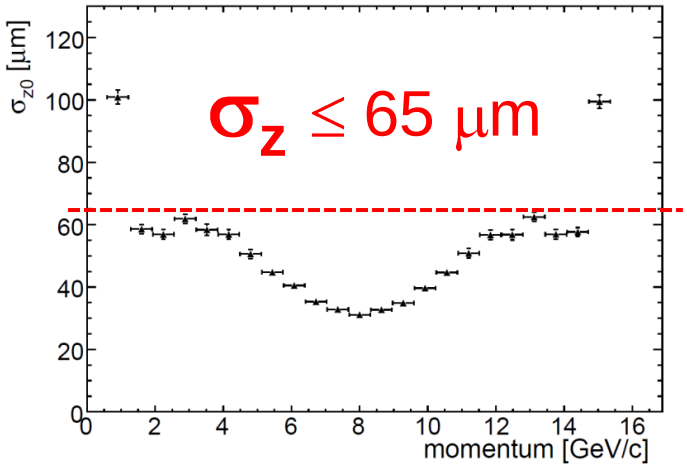


Performance

- Primary vertex resolution $\bar{p}p \rightarrow \pi^+\pi^-$ **15 GeV/c**







- Vertex resolution $\bar{p}p \rightarrow D^+D^-$ **(6.57 / 7.50 / 8.50) GeV/c**

momentum	vertex resolution [μm]					
	primary			secondary		
GeV/c	$\sigma_{prim,x}$	$\sigma_{prim,y}$	$\sigma_{prim,z}$	$\sigma_{sec,x}$	$\sigma_{sec,y}$	$\sigma_{sec,z}$
6.57	30.7	30.7	493.6	35.4	35.2	77.1
7.50	30.4	30.3	208.5	37.1	36.4	84.0
8.50	30.0	29.0	157.4	36.7	36.2	92.4

→ Primary and secondary vertex resolution:

$\sigma_{x,y} \leq 35$ μm

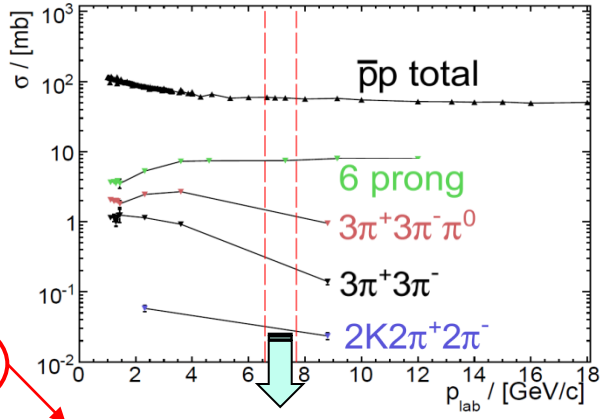
$\sigma_z \leq 100$ μm

D – mesons: $D^{\pm}$

- Physics analysis $\bar{p}p \rightarrow D^+D^-$
  - Reconstruction: $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$

Conservative estimate

$$R = \frac{\sigma(\bar{p}p \rightarrow D^+D^-)}{\sigma(\bar{p}p \rightarrow X)} = \frac{2.83nb \cdot (0.092)^2}{60mb} = 4.0 \cdot 10^{-10}$$



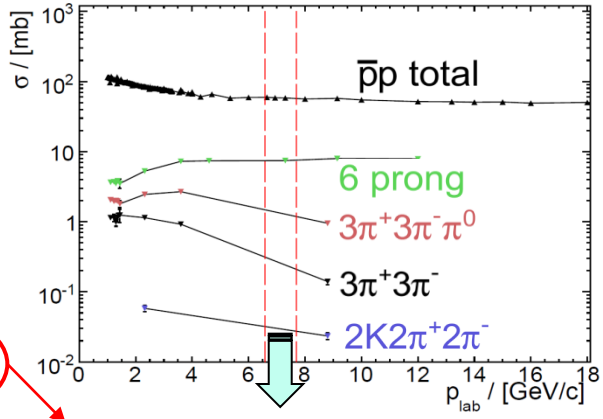
6 orders of magnitude lower

D – mesons: $D^{\pm}$

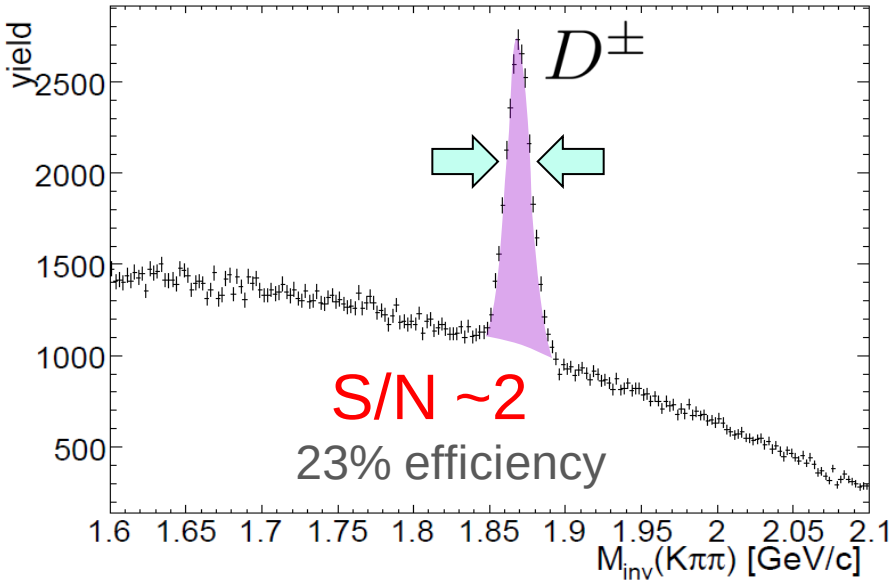
- Physics analysis $\bar{p}p \rightarrow D^+D^-$
  - Reconstruction: $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$

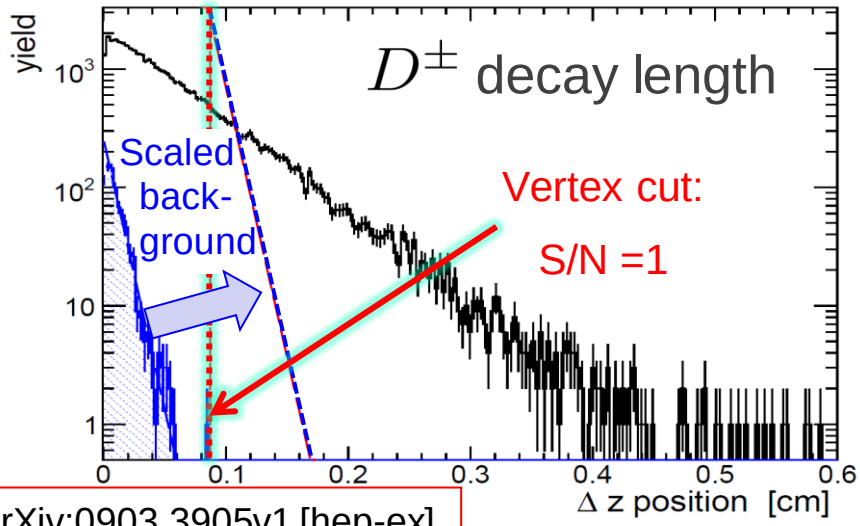
Conservative estimate

$$R = \frac{\sigma(\bar{p}p \rightarrow D^+D^-)}{\sigma(\bar{p}p \rightarrow X)} = \frac{2.83nb \cdot (0.092)^2}{60mb} = 4.0 \cdot 10^{-10}$$



6 orders of magnitude lower





arXiv:0903.3905v1 [hep-ex]

D – mesons: $D^{*\pm}$

- Physics analysis $\bar{p}p \longrightarrow D^{*+}D^{*-}$
  - Reconstruction: $D^{*+} \longrightarrow D^0\pi^+, D^0 \longrightarrow K^-\pi^+$

$$R = \frac{\sigma(\bar{p}p \longrightarrow D^{*+}D^{*-})}{\sigma(\bar{p}p \longrightarrow X)} = \frac{0.90nb \cdot (0.677)^2 \cdot (0.038)^2}{60mb} = 1.0 \cdot 10^{-11}$$

7 orders of magnitude below main background channels

Conservative estimate

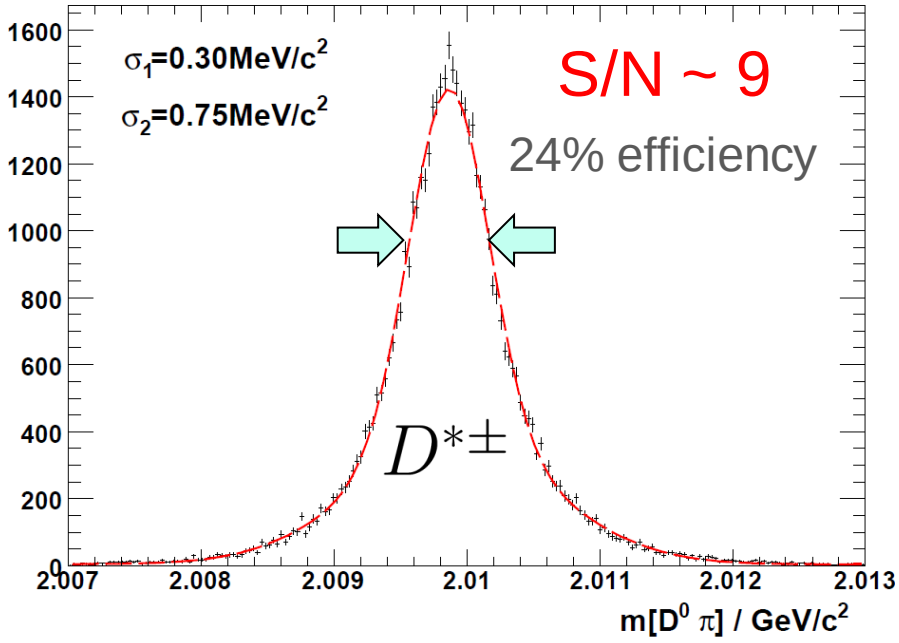
D – mesons: $D^{*\pm}$

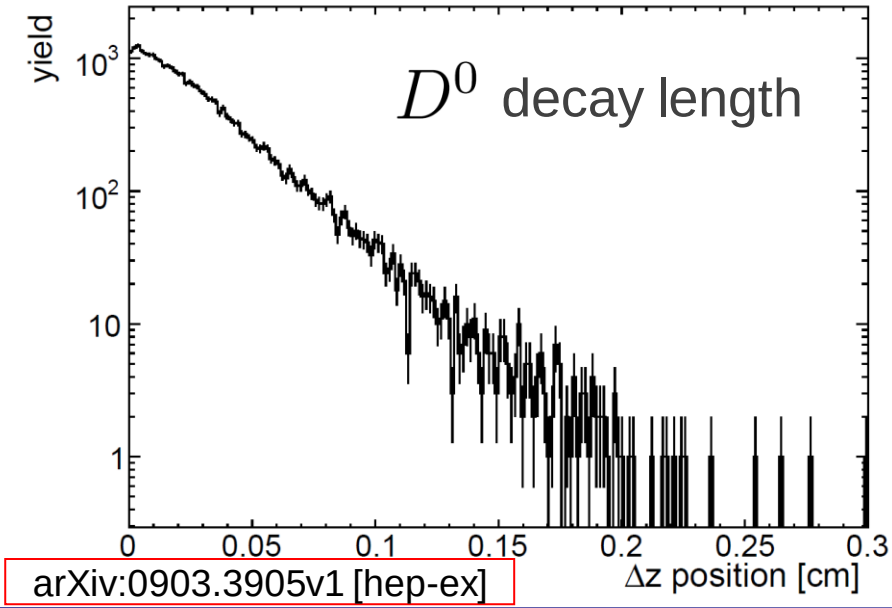
- Physics analysis $\bar{p}p \rightarrow D^{*+}D^{*-}$
  - Reconstruction: $D^{*+} \rightarrow D^0\pi^+, D^0 \rightarrow K^-\pi^+$

$$R = \frac{\sigma(\bar{p}p \rightarrow D^{*+}D^{*-})}{\sigma(\bar{p}p \rightarrow X)} = \frac{0.90nb \cdot (0.677)^2 \cdot (0.038)^2}{60mb} = 1.0 \cdot 10^{-11}$$

7 orders of magnitude below main background channels

Conservative approach





arXiv:0903.3905v1 [hep-ex]

D – mesons: D_s

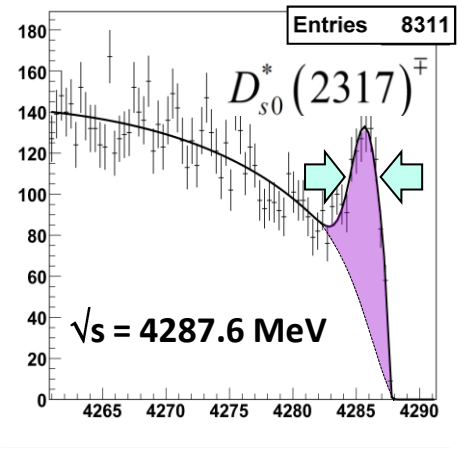
- Physics analysis $\bar{p}p \to D_s^{\pm} D_{s0}^{*} \left(2317\right)^{\mp}$
  - Reconstruction: $D_s^{\pm} \to \phi\pi^{\pm}, \quad \phi \to K^{+}K^{-}$

    → $D_{s0}^{*} \left(2317\right)^{\mp}$ identification via missing mass

    ≈ 40 events / day

D – mesons: D_s

- Physics analysis $\bar{p}p \to D_s^{\pm} D_{s0}^{*} \left(2317\right)^{\mp}$
  - Reconstruction: $D_s^{\pm} \to \phi\pi^{\pm}$, $\phi \to K^{+}K^{-}$
    → $D_{s0}^{*} \left(2317\right)^{\mp}$ identification via missing mass
    ≈ 40 events / day



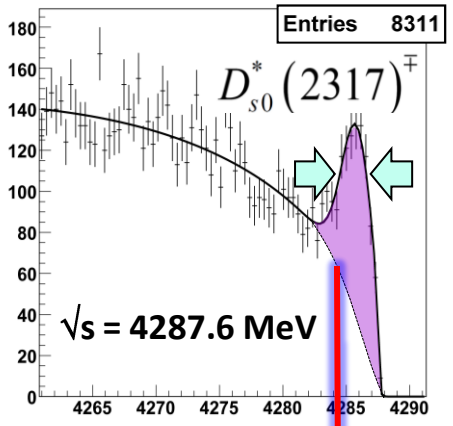
D – mesons: D_s

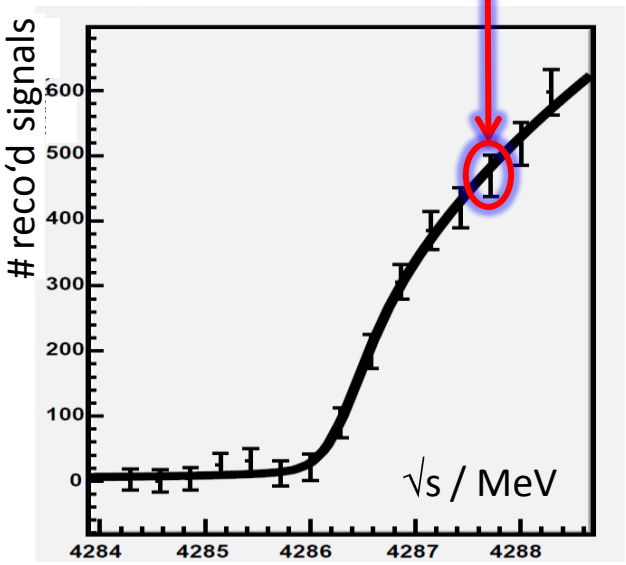
- Physics analysis $\bar{p}p \to D_s^{\pm} D_{s0}^{*} \left(2317\right)^{\mp}$
  - Reconstruction: $D_s^{\pm} \to \phi\pi^{\pm}, \quad \phi \to K^{+}K^{-}$

    → $D_{s0}^{*} \left(2317\right)^{\mp}$ identification via missing mass

    ≈ 40 events / day
  - Energy scan around threshold

    → Excitation function: Determination of $D_{s0}^{*} \left(2317\right)^{\mp}$ Width and Mass





$$\frac{\sigma(s)}{|M|^2} = \frac{\Gamma}{4\pi * \sqrt{s}} \cdot \int_{-\infty}^{\sqrt{s}-m_{D_s}} \frac{\sqrt{\left(s-\left(m+m_{D_s}\right)^2\right)\cdot\left(s-\left(m-m_{D_s}\right)^2\right)}}{\left(m-m_{D2317}\right)^2+\left(\frac{\Gamma}{2}\right)^2} dm$$

D – mesons: D_s

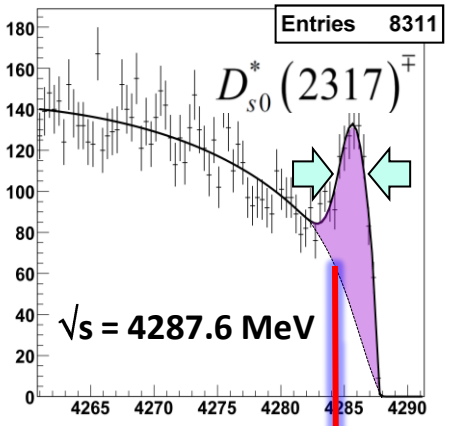
- Physics analysis $\bar{p}p \to D_s^{\pm} D_{s0}^{*} \left(2317\right)^{\mp}$
  - Reconstruction: $D_s^{\pm} \to \phi\pi^{\pm}, \quad \phi \to K^{+}K^{-}$

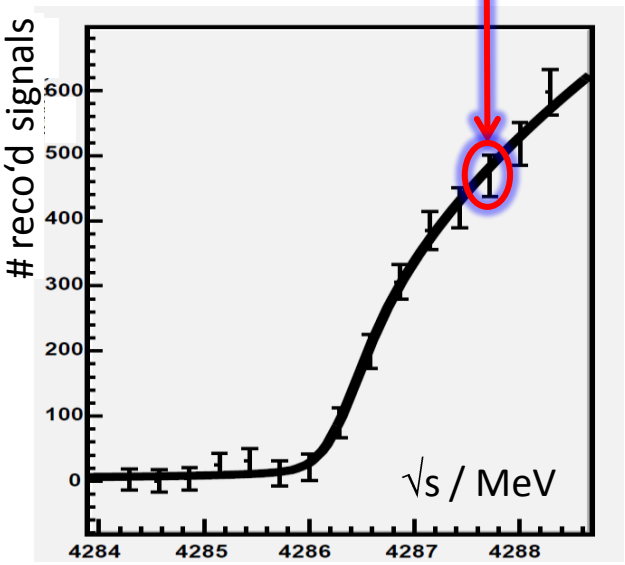
    → $D_{s0}^{*} \left(2317\right)^{\mp}$ identification via missing mass

    ≈ 40 events / day
  - Energy scan around threshold

    → $D_{s0}^{*}(2317)$ world average (PDG)
    - Mass: 2317.8 **± 0.6** MeV/c²
    - Width: **< 3.8** MeV/c²

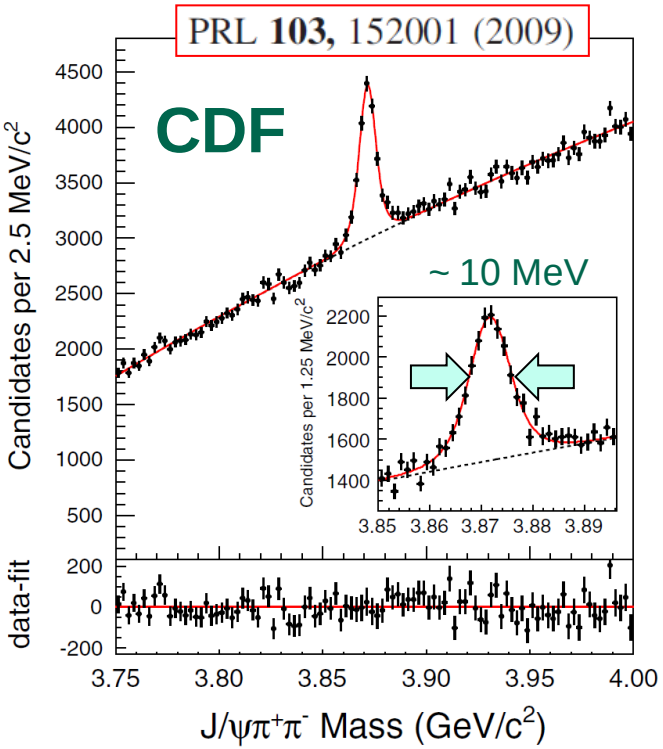
    Achievable PANDA performance
    - Mass resolution: **~100keV/c²**
    - Width resolution: **~ 0.1 MeV/c²**





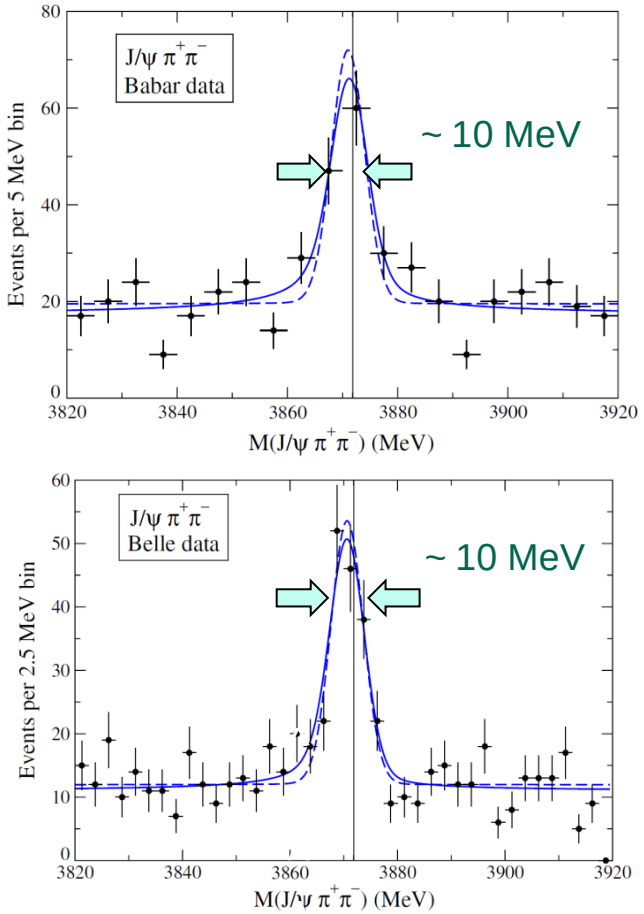
Outlook: X(3872)

- Physics analysis $X(3872) \rightarrow \pi^+\pi^- J/\psi$



High yield $\bar{p}p$-collisions

PANDA: ~ 250 events / day



PHYSICAL REVIEW D **81,** 014019 (2010)

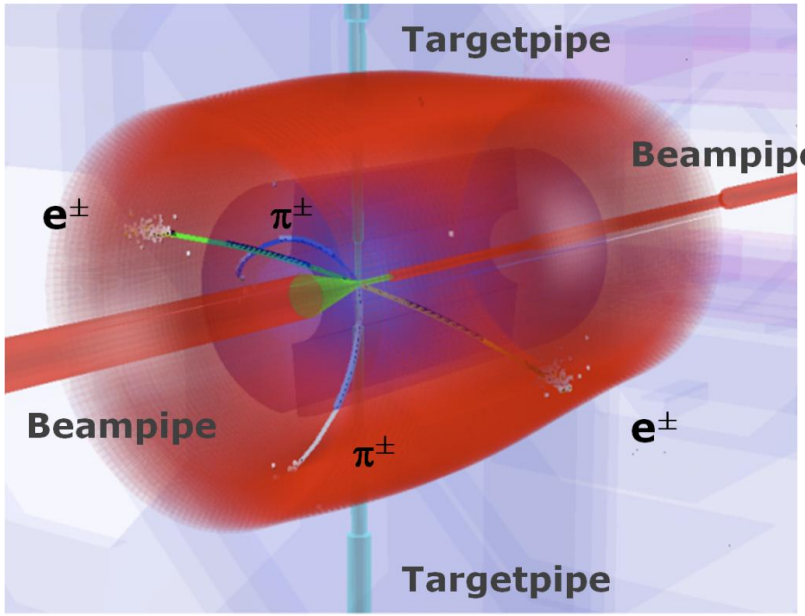
Outlook: X(3872)

- Physics analysis $X(3872) \rightarrow \pi^+\pi^- J/\psi$

$\rho \rightarrow \pi^+\pi^-$

$J/\psi \rightarrow \mu^+\mu^-$, e^+e^-

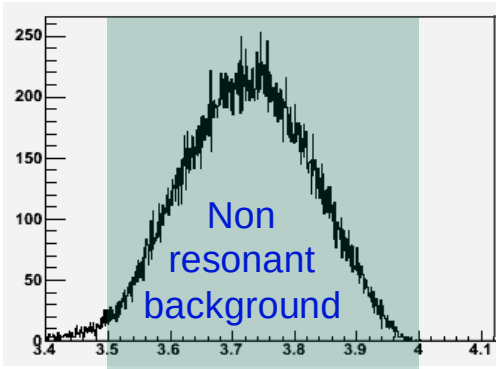
  - Two pion invariant mass spectrum
    - ✓ Angular distribution
  - J/ψ reconstruction
    - ✓ High precision
  - $X(3872)$ reconstruction
    - ✓ Mass and width (resonance scan)
    - ✓ Line shape
    - ✓ Quantum numbers

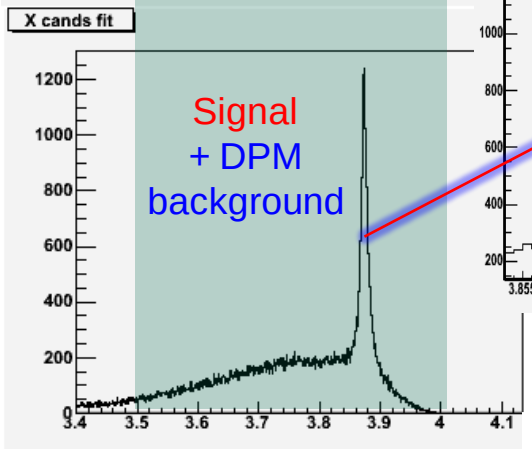


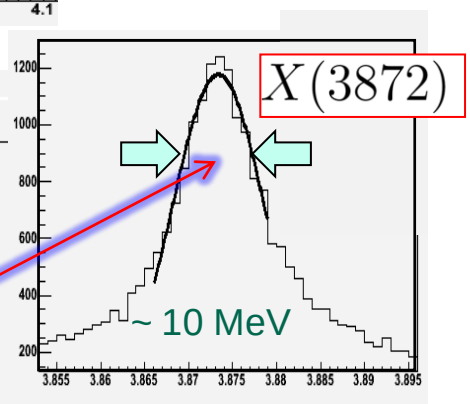
Outlook: X(3872)

- Physics analysis $X(3872) \rightarrow \pi^+\pi^- J/\psi$

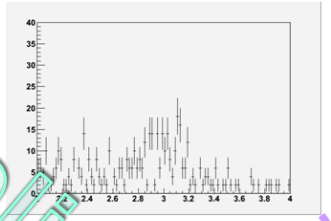
Feasibility studies for PANDA started; 1st preliminary results







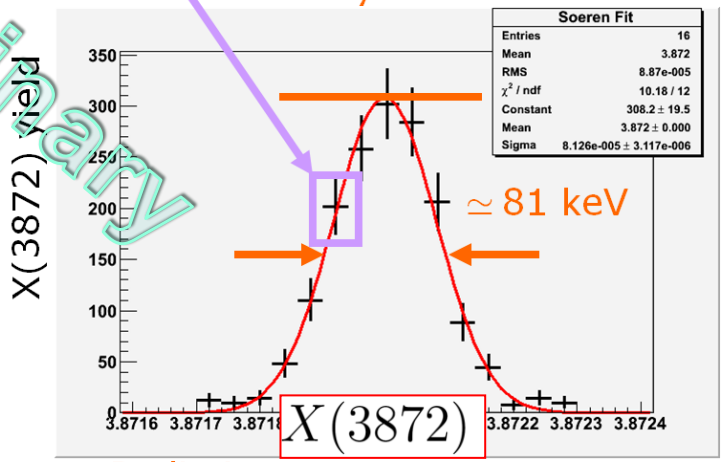
Production



Preliminary

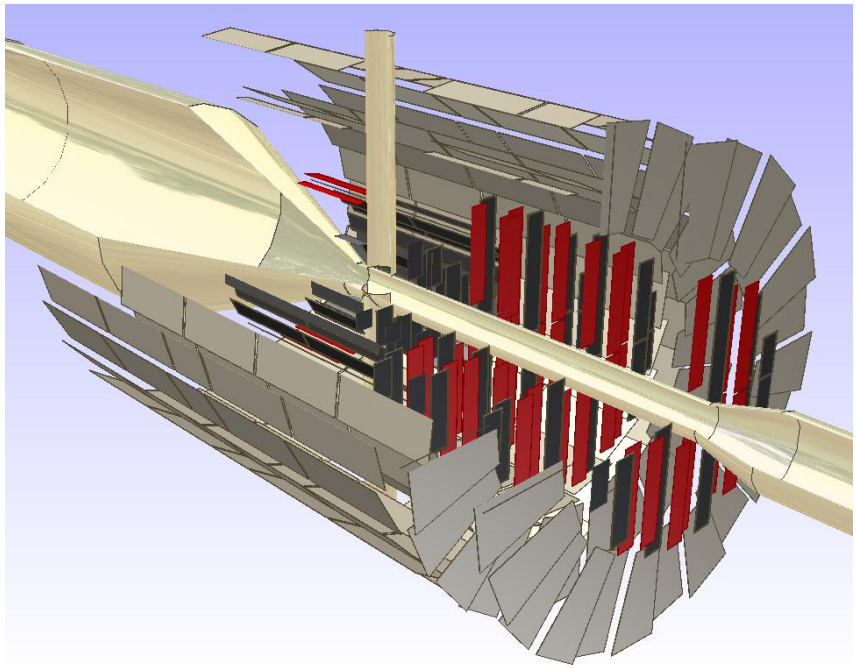
Resonance Scan

Reconstruction efficiency ≃72%



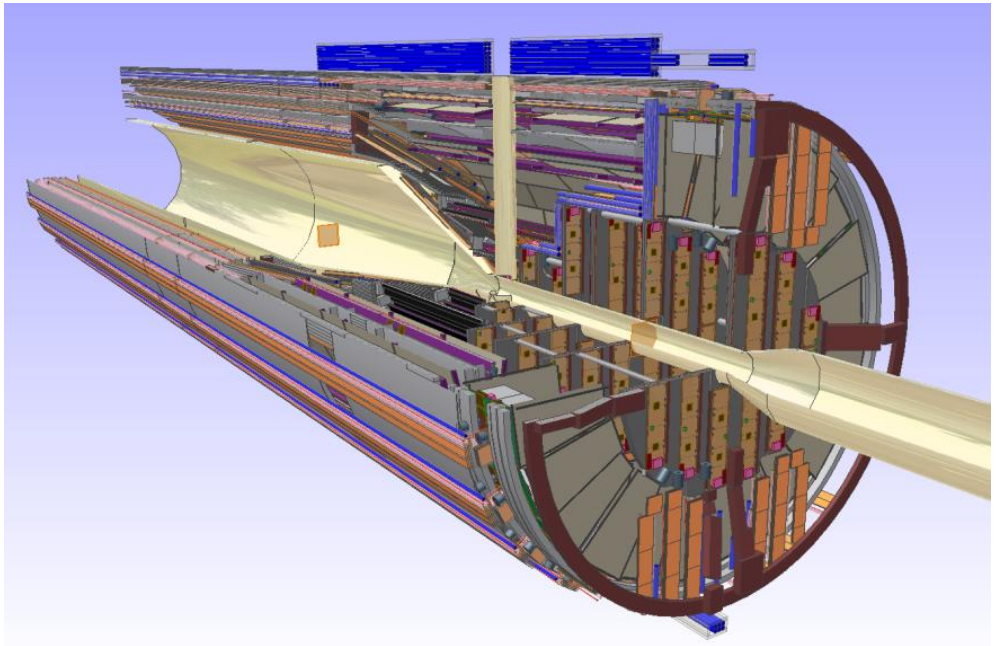
Summary

- MVD facilitates optimized measurement close to interaction point
  - Small radiation length
    → Low scattering, low impact on outer systems
  - High granularity
- Detailed detector model implemented in physics simulation
- MVD plays key role for charmonium spectroscopy at PANDA
  - Vertex reconstruction (Tagging of D-mesons)
  - Momentum resolution



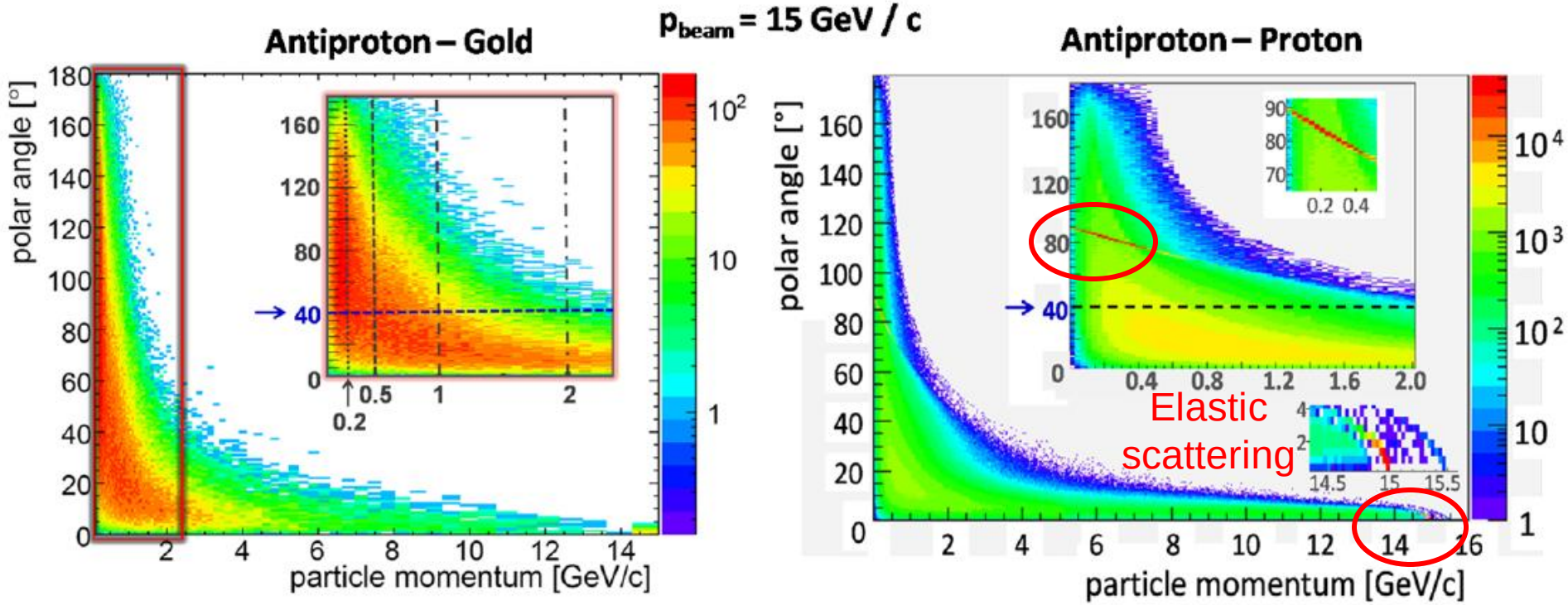
MVD: Active detector volumes only

MVD: Detailed CAD model

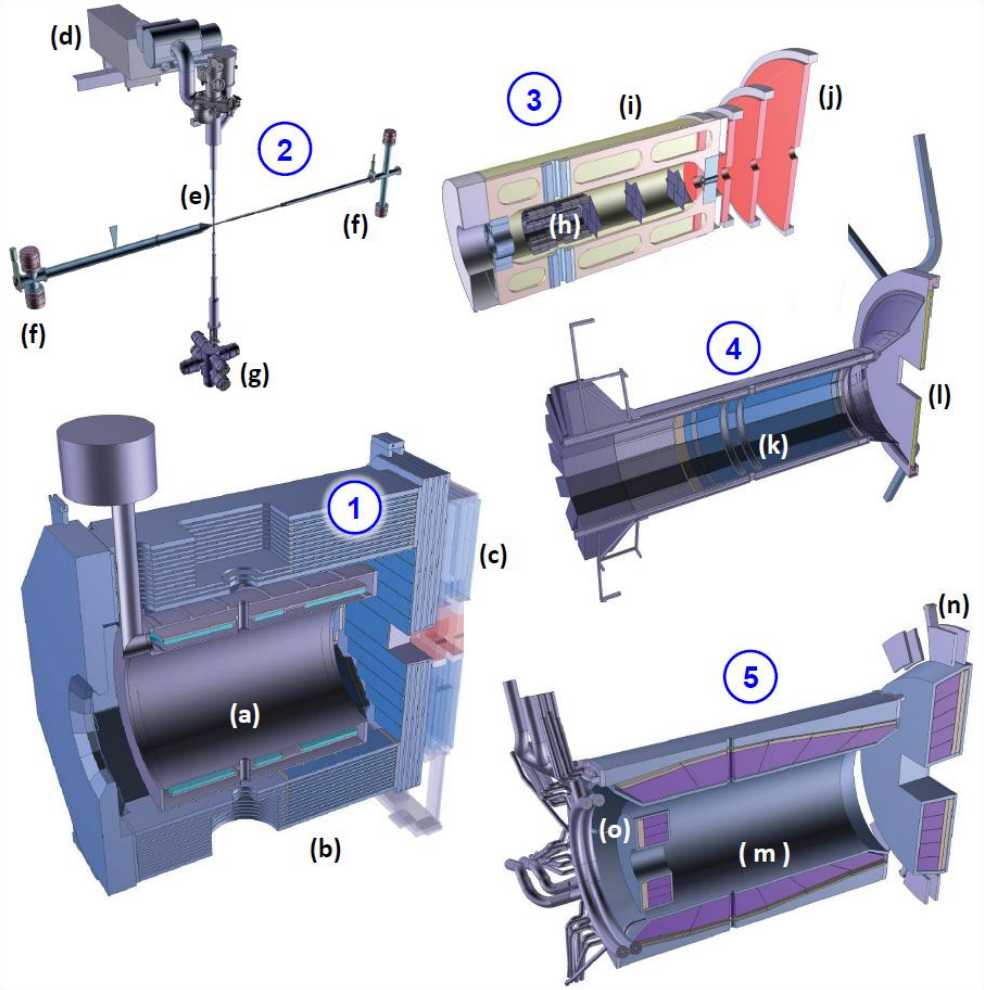


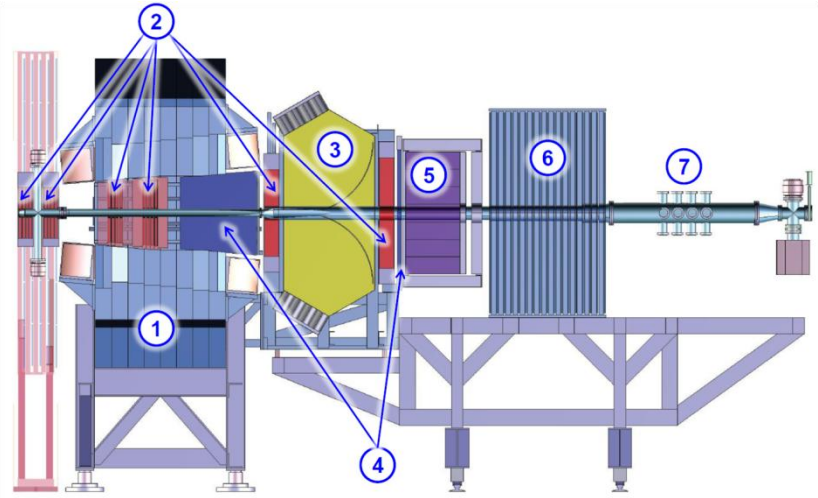
Introduction

- PANDA - Experiment: Particle distribution
  - Enhanced emission in forward direction
  - Low-momentum particles (< 1 GeV/c) in full polar angle



PANDA apparatus



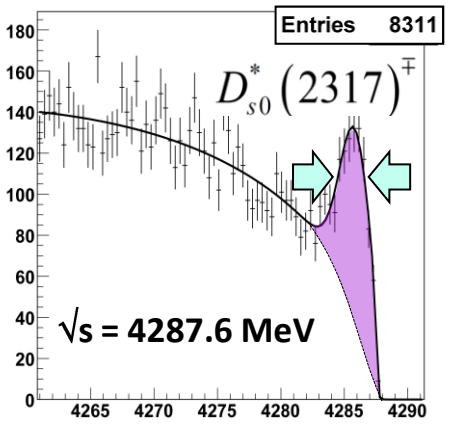


D – mesons: D_s

- Physics analysis $\bar{p}p \rightarrow D_s^{\pm} D_{s0}^{*} \left(2317\right)^{\mp}$
  - Reconstruction: $D_s^{\pm} \rightarrow \phi\pi^{\pm}, \quad \phi \rightarrow K^{+}K^{-}$

    → $D_{s0}^{*} \left(2317\right)^{\mp}$ identification via missing mass

    ≈ 40 Signals / day



  - Energy scan around threshold

    → Excitation function: Determination of $D_{s0}^{*} \left(2317\right)^{\mp}$ Width and Mass

$$\frac{\sigma(s)}{|M|^2} = \frac{\Gamma}{4\pi * \sqrt{s}} \cdot \int_{-\infty}^{\sqrt{s}-m_{D_s}} \frac{\sqrt{\left(s-\left(m+m_{D_s}\right)^2\right)\cdot\left(s-\left(m-m_{D_s}\right)^2\right)}}{\left(m-m_{D2317}\right)^2+\left(\frac{\Gamma}{2}\right)^2} dm$$