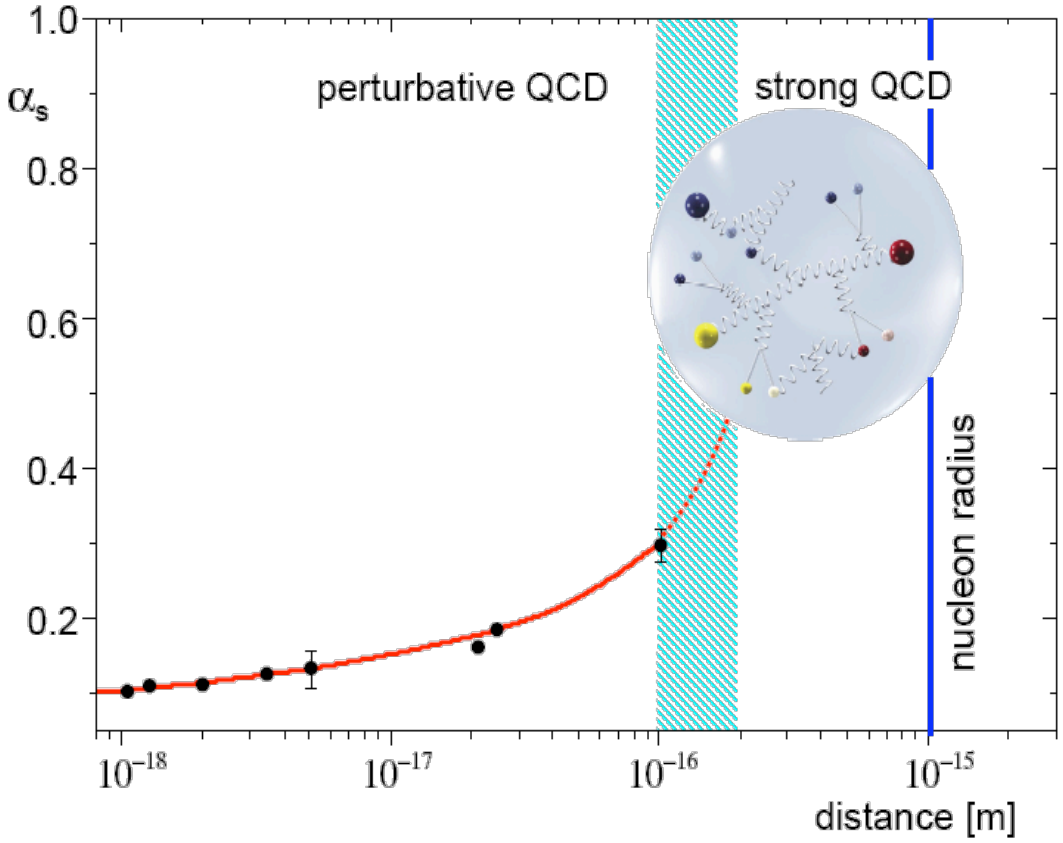
A systematic study of the strong interaction with PANDA

J.G. Messchendorp (KVI) for the PANDA collaboration

Hadron Physics - QCD at its best!



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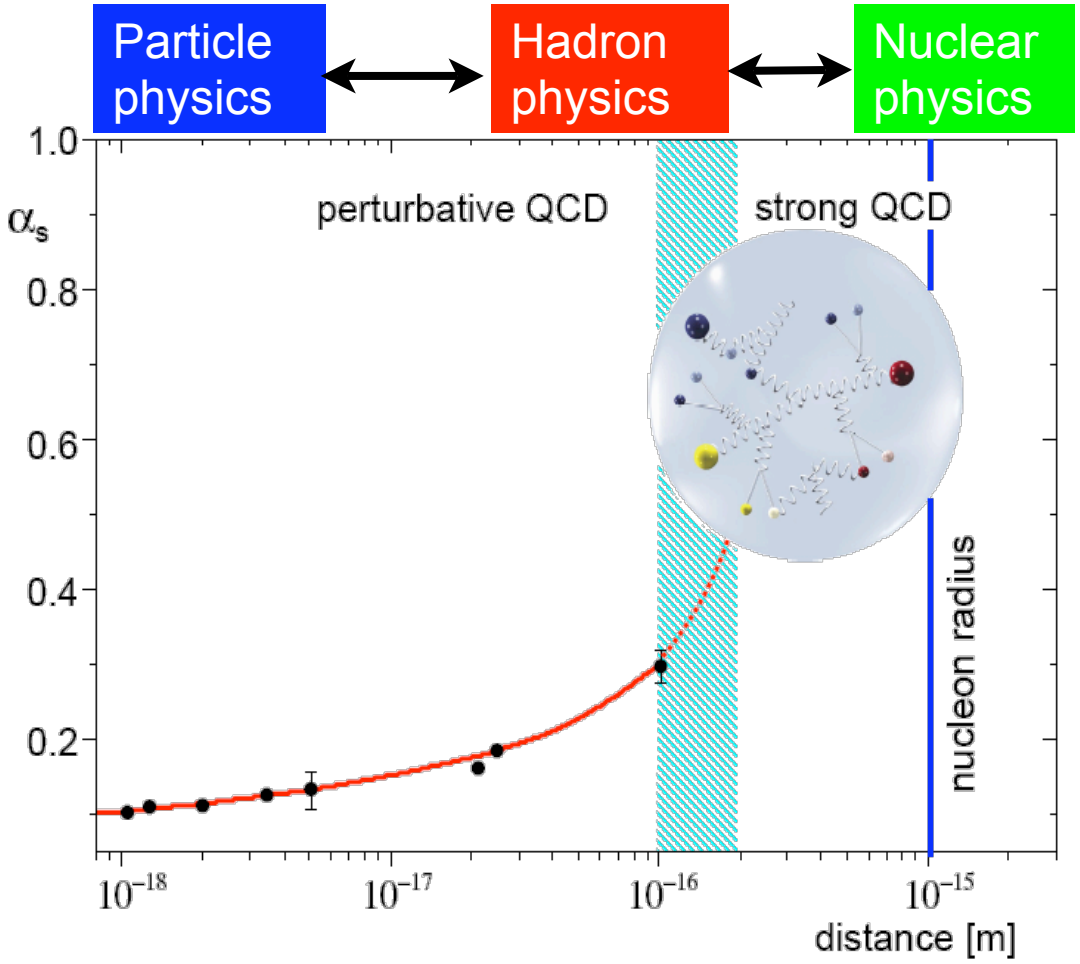

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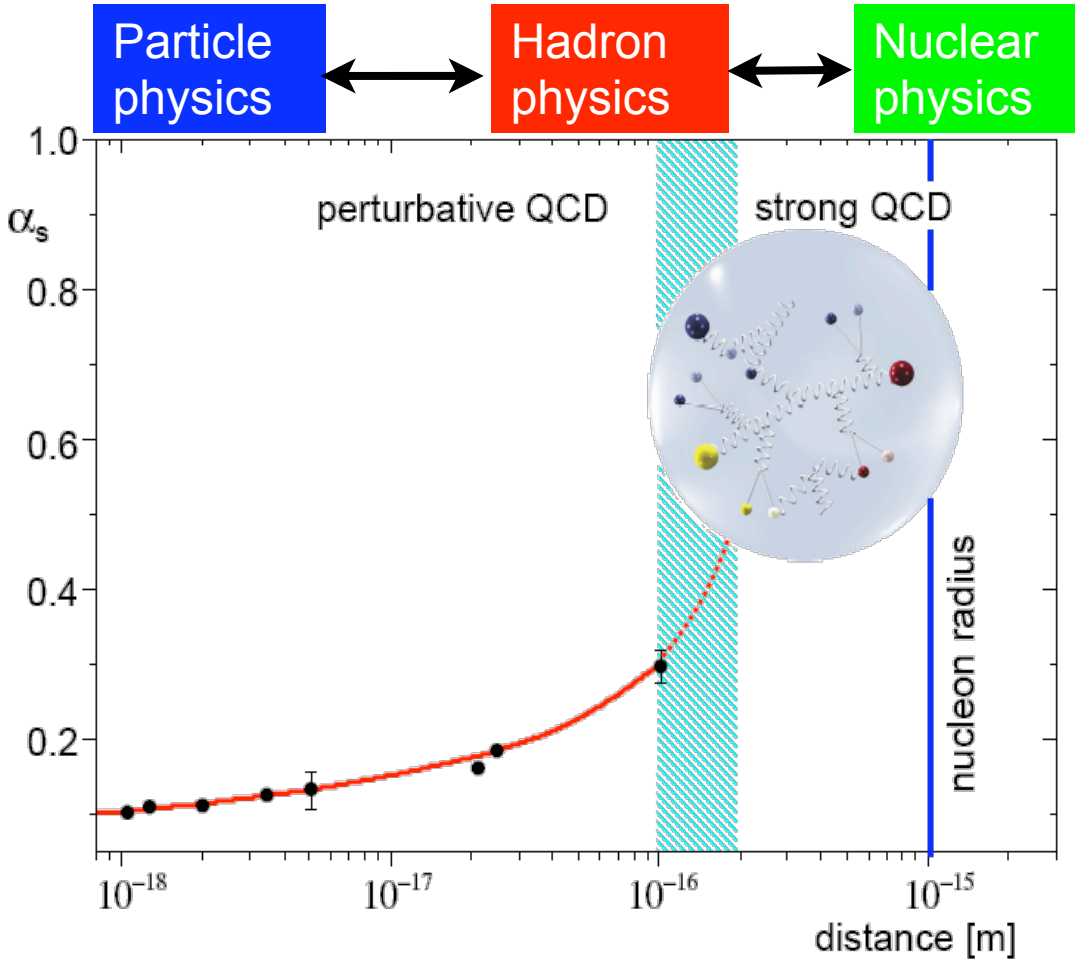

P̄ANDA

antiProton ANnihilation at Darmstadt

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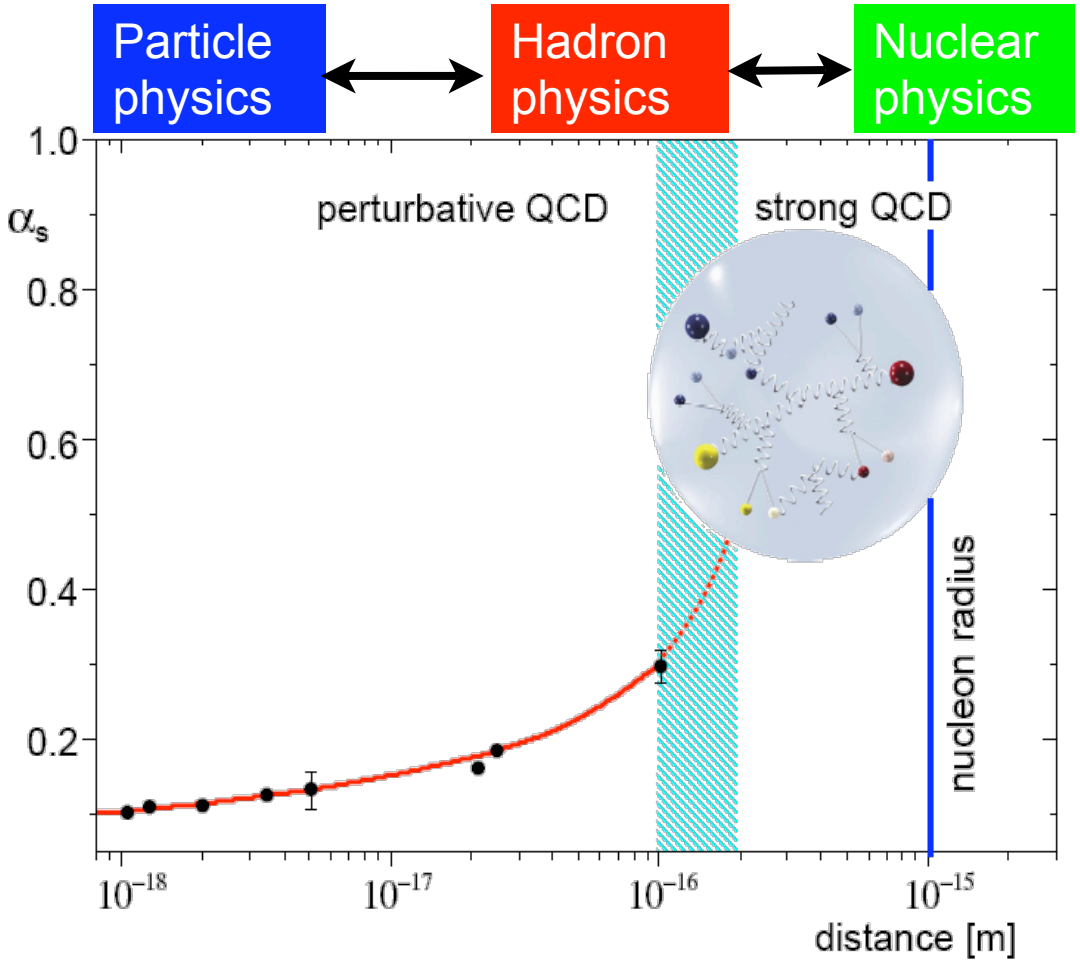

$\bar{P}$ANDA

antiProton ANnihilation at Darmstadt

PANDA Physics Program

Study of the strong force using anti-protons

PANDA Physics Program

Study of the strong force using anti-protons

Charmonium spectroscopy
- precision spectroscopy
- rigorous study of confinement potential
- extending measurements at e^+e^- colliders

Search for glueballs and hybrids
- test of QCD: mass & confinement
- inheritance of LEAR and FNAL
- high discovery potential

Charm in-medium
- origin of mass
- (partial) restoration of χ-symmetry
- new frontier

Baryon spectroscopy, Hypernuclei, EM studies, rare decays, ...

e^+e^- versus $p\bar{p}$ annihilations

e^+e^- reactions:	only 1^{--} states formed directly
$\bar{p}p$ reactions:	all states directly formed

e^+e^- versus $p\bar{p}$ annihilations

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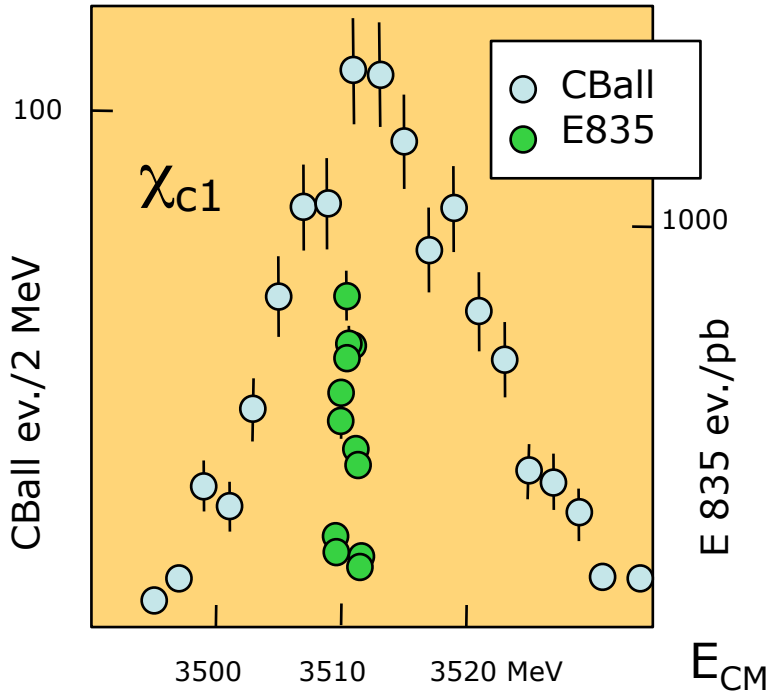
Example:

$$e^+e^- \to \Psi' \to \gamma\chi_1 \to \gamma\gamma J/\Psi$$

$$\bar{p}p \to \chi_1 \to \gamma J/\Psi$$

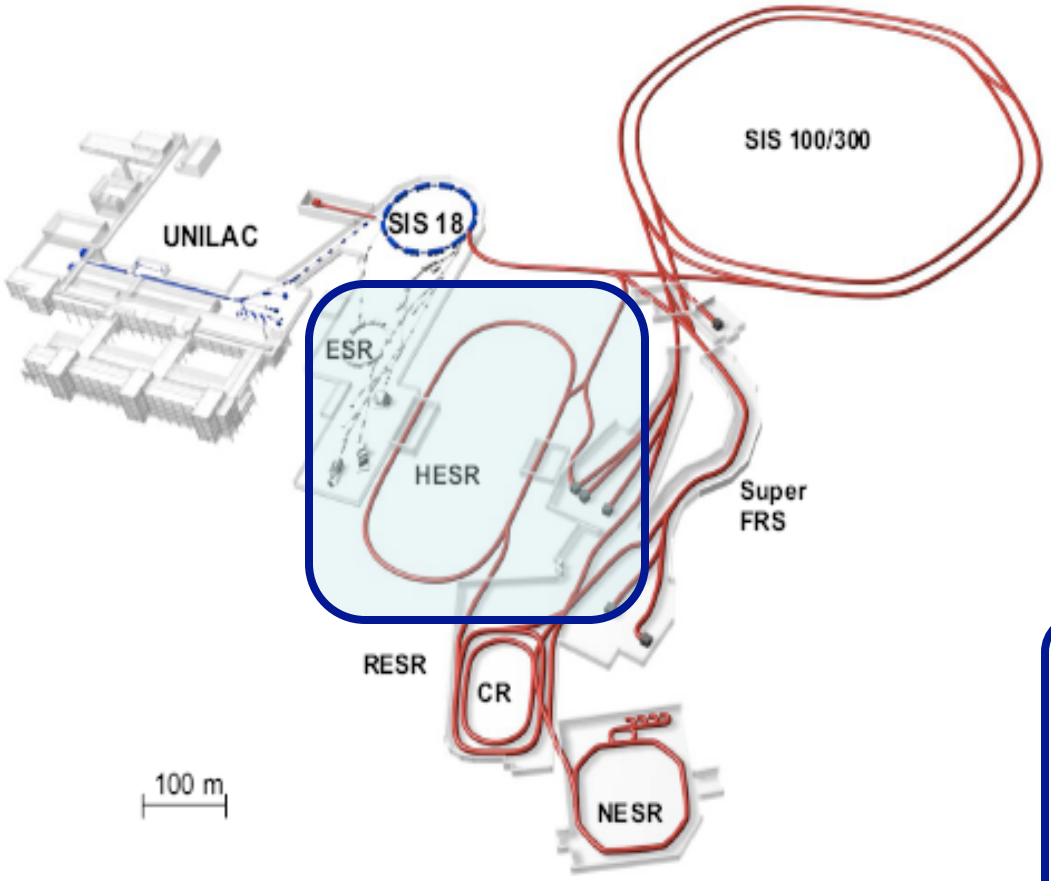
CBALL ~10 MeV
E835 ~240 keV



$M = 3510.66 \pm 0.07\,\mathrm{MeV}$
$\Gamma = 0.89 \pm 0.05\,\mathrm{MeV}$

FAIR : the GSI future facility

Facility for Antiproton and Ion Research



Key Technical Features

- Cooled beams
- Rapidly cycling superconducting magnets

Storage and Cooler Rings

- 5×10^{10} 1.5 -15 GeV/c antiprotons
- HESR+pellet target:

  $L = 2 \times 10^{32}$ cm^{-2}s^{-1} with $\Delta p/p = 10^{-4}$

  $L = 10^{31}$ cm^{-2}s^{-1} with $\Delta p/p = 10^{-5}$

High luminosity mode:

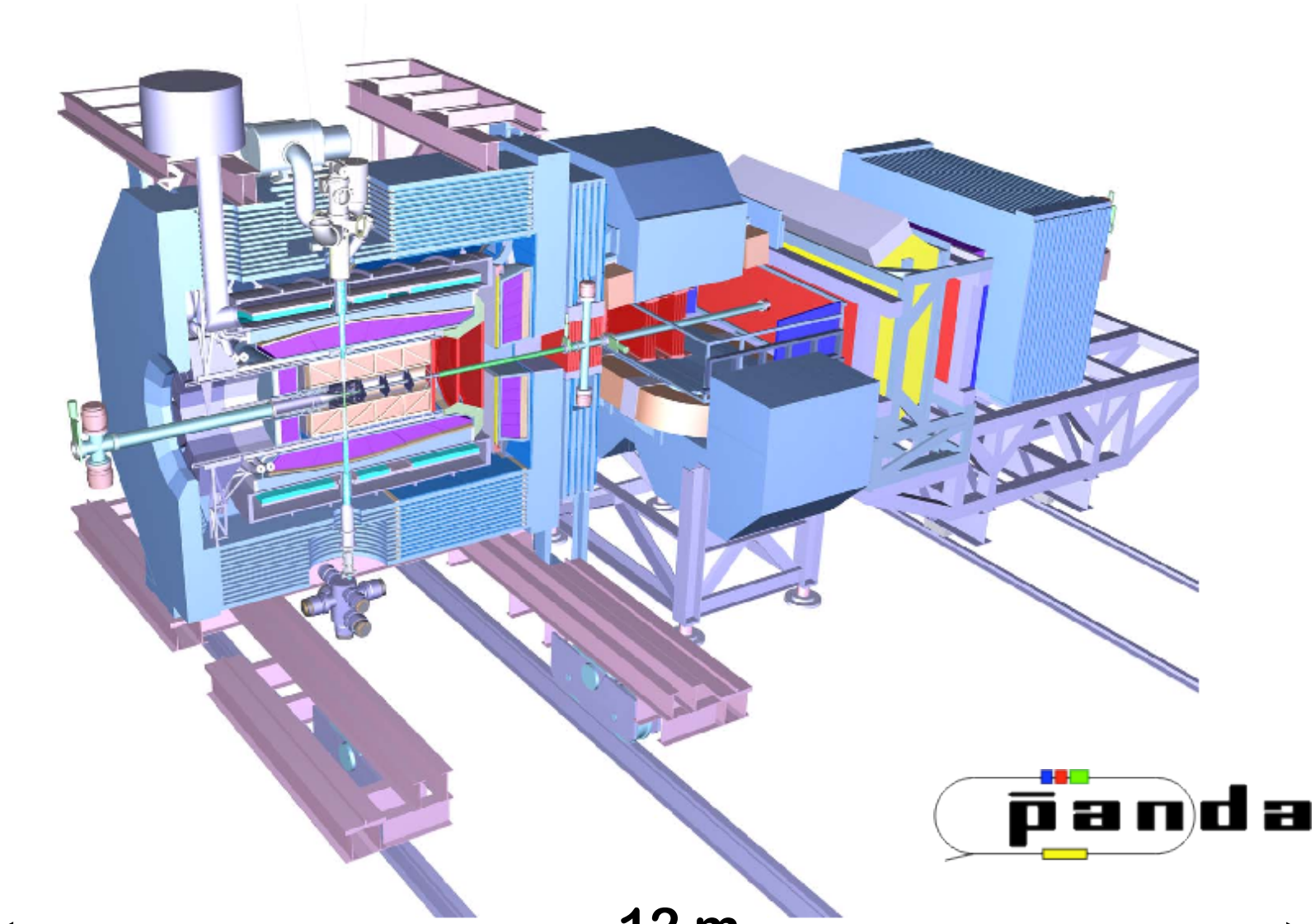
~8 pb^{-1}/day -> ~1.5 fb^{-1}/yr

High resolution mode

mass precision ~100 keV

widths ~10%

The PANDA Detector



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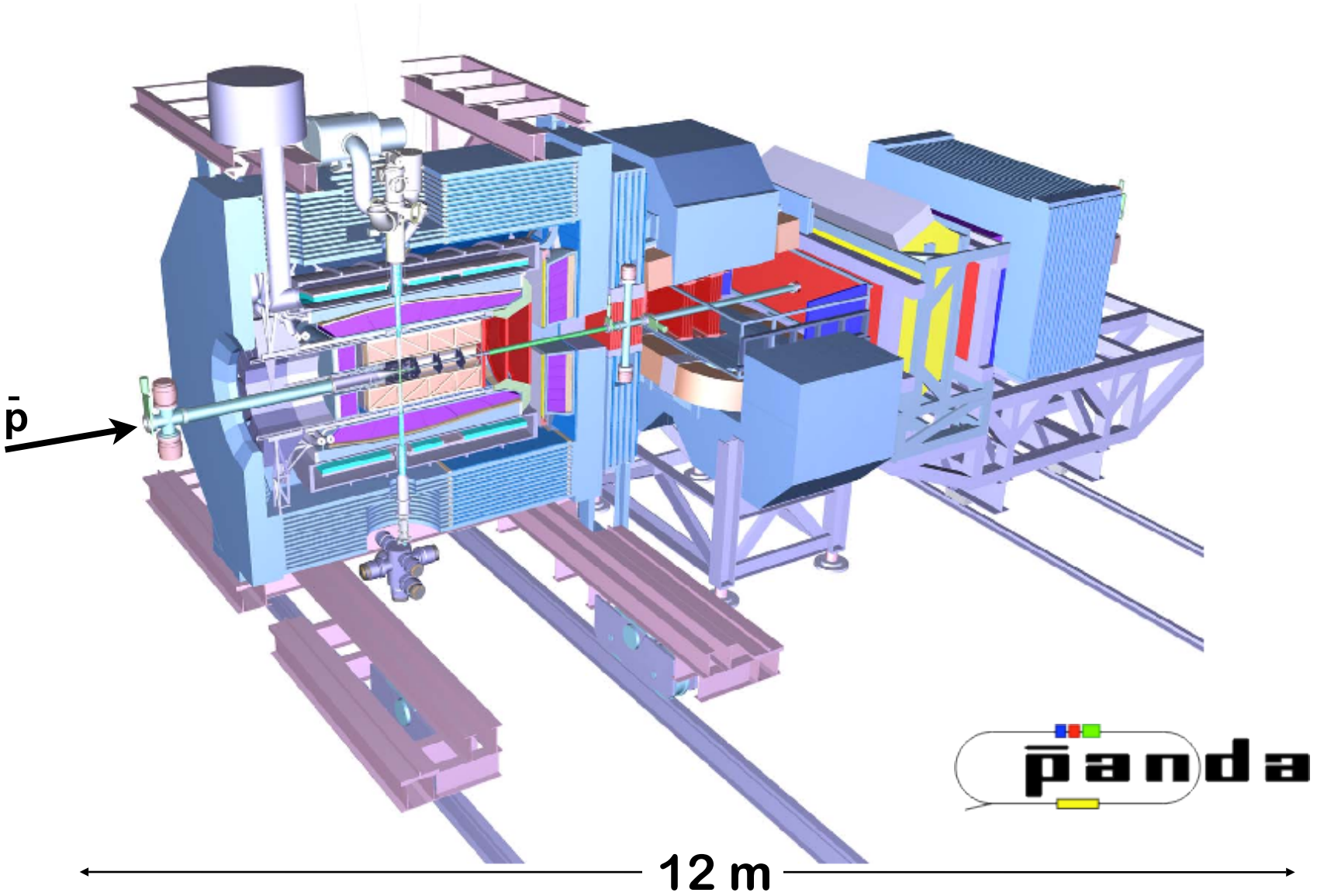

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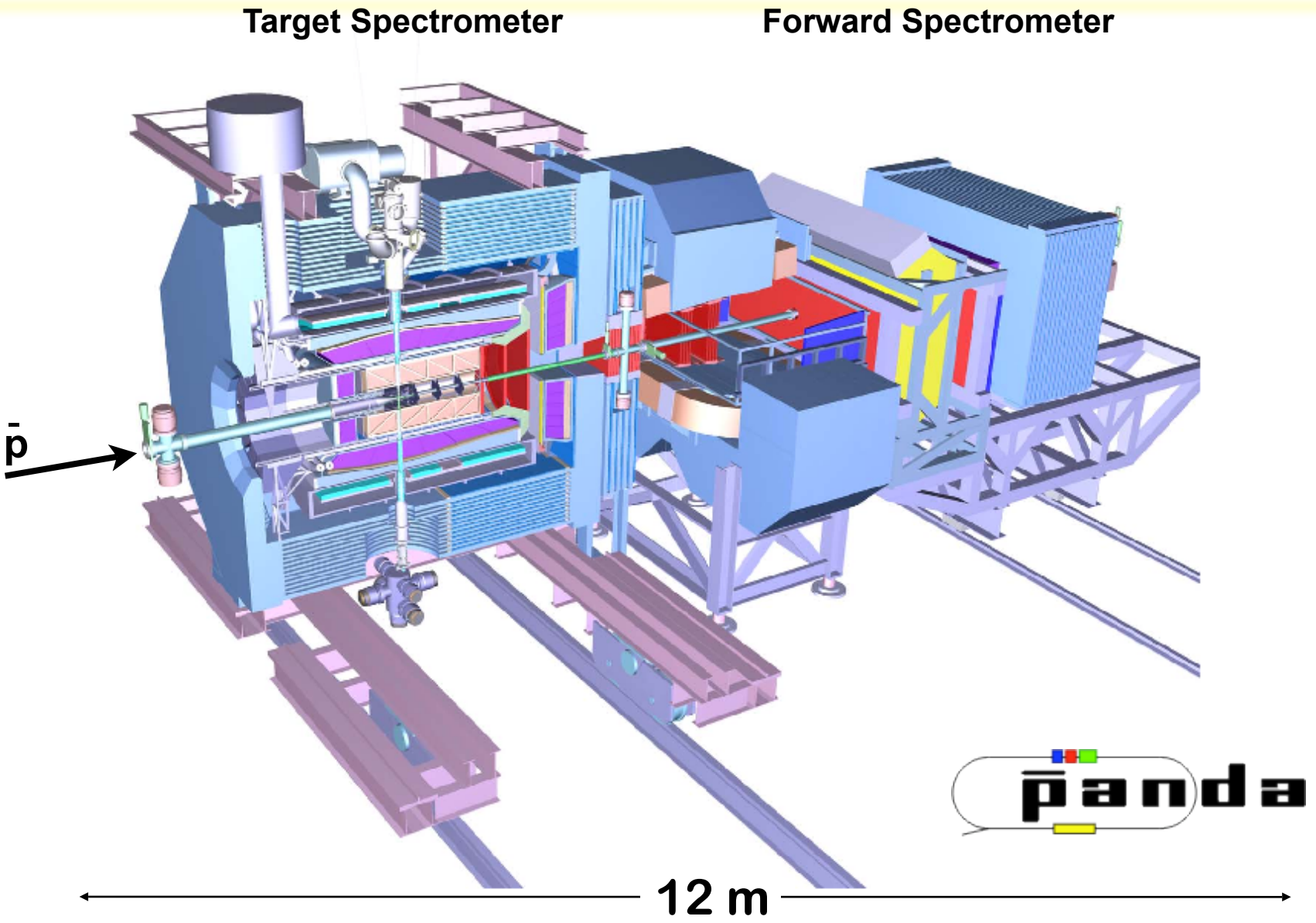

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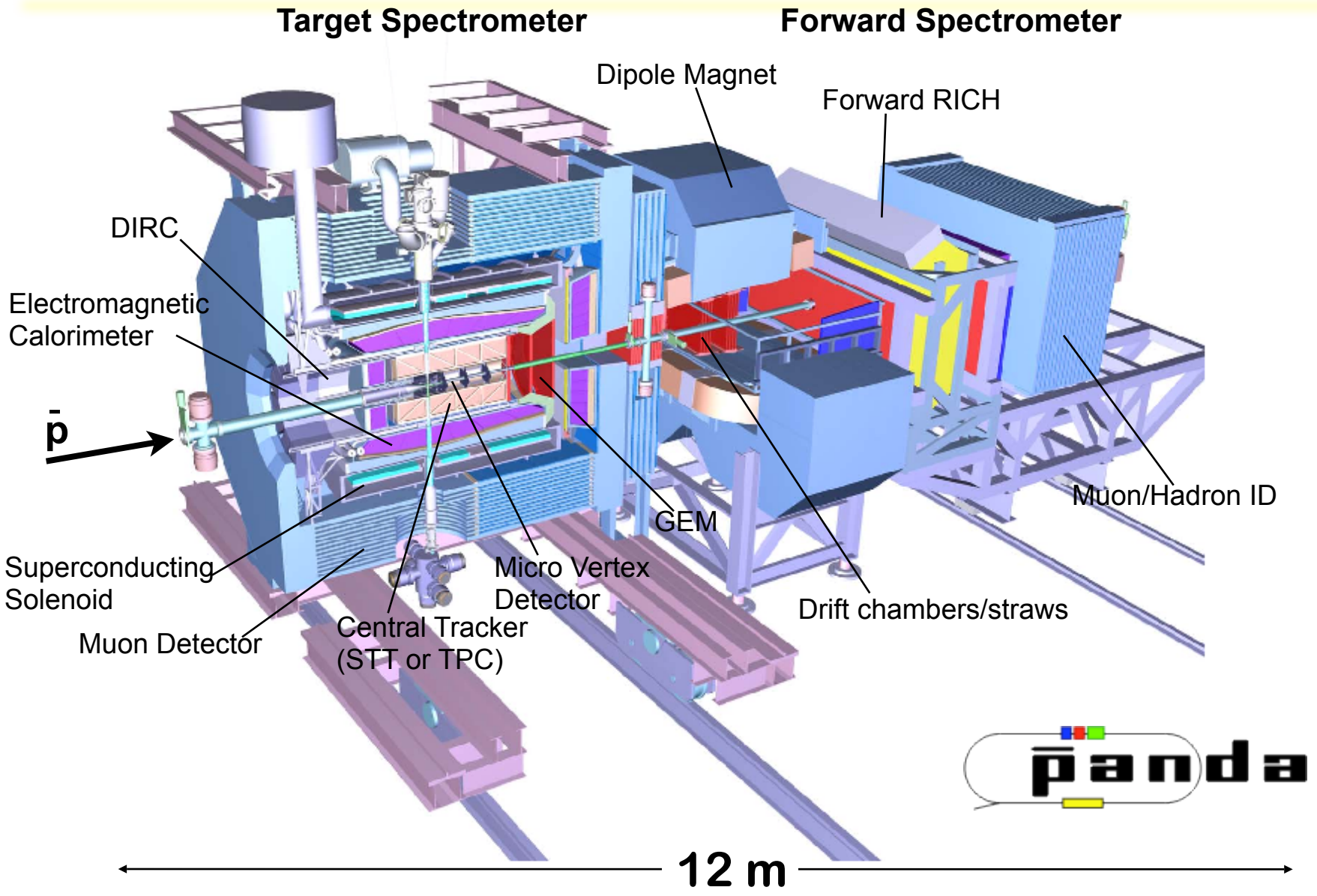
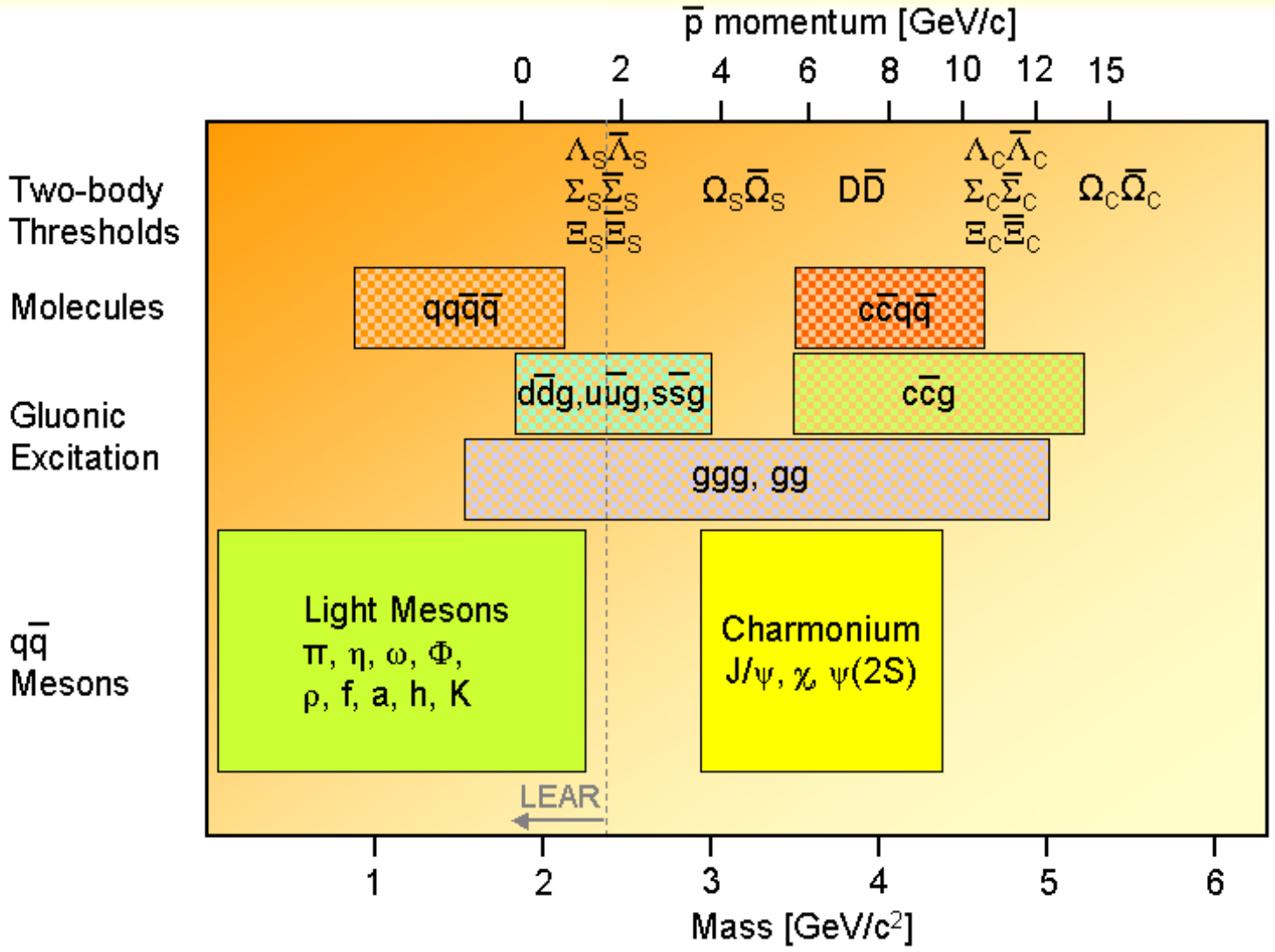


The PANDA Detector

PANDA is a modular multi-purpose device:

- nearly 4π solid angle (partial wave analysis)
- high rate capability ($2 \cdot 10^7$ annihilations/s)
- good PID (γ, e, μ, π, K, p)
- momentum resolution (~1%)
- vertex info for D, K^0_S, Λ (c_τ = 317 μm for $D^\pm$)
- e.m. calorimeter (sensitive to low energies)
- efficient trigger (e,μ,K,D,Λ,real-time feature extr.)
- modular design (Hypernuclei experiments)

Hadron Spectroscopy



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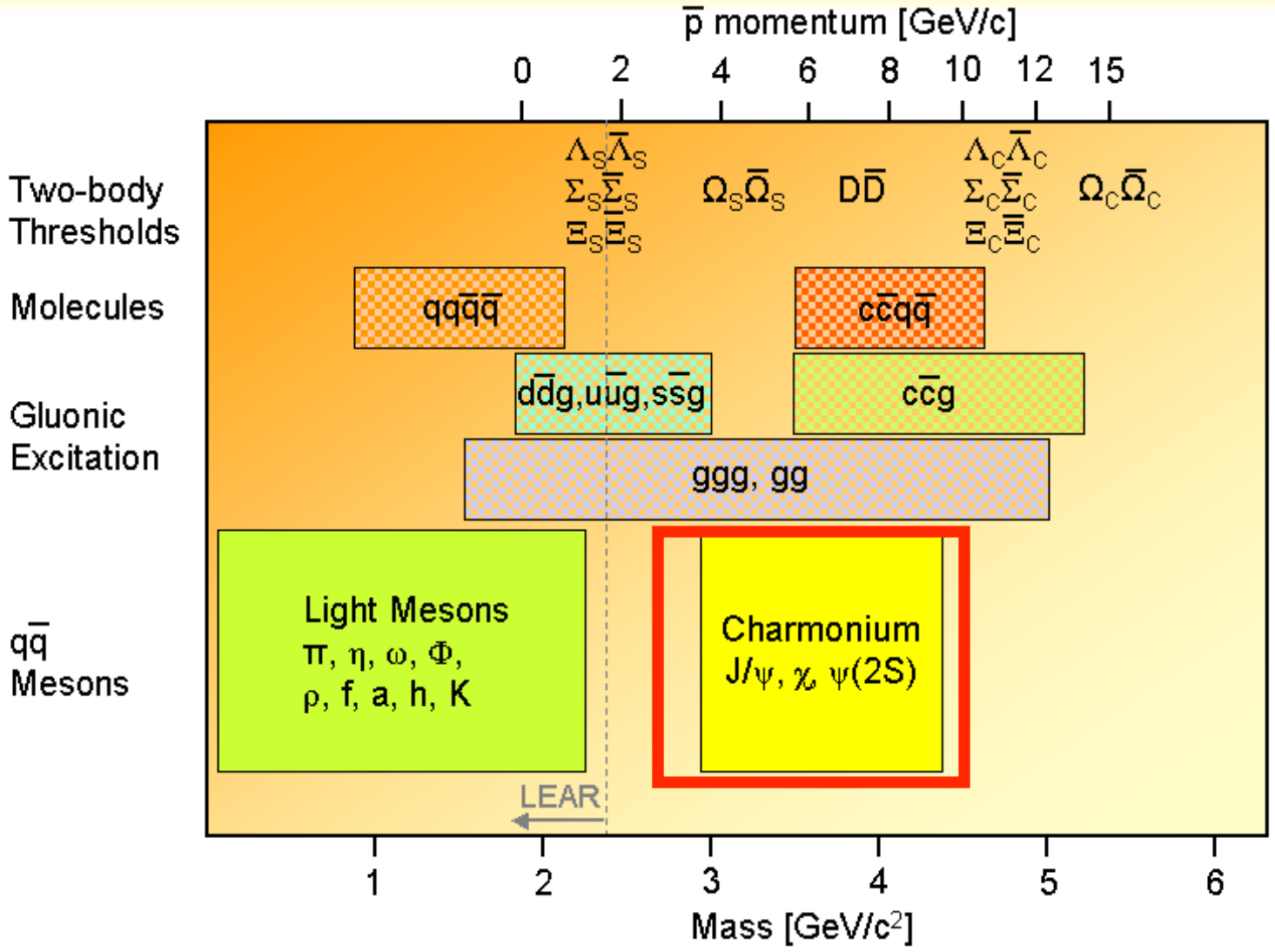
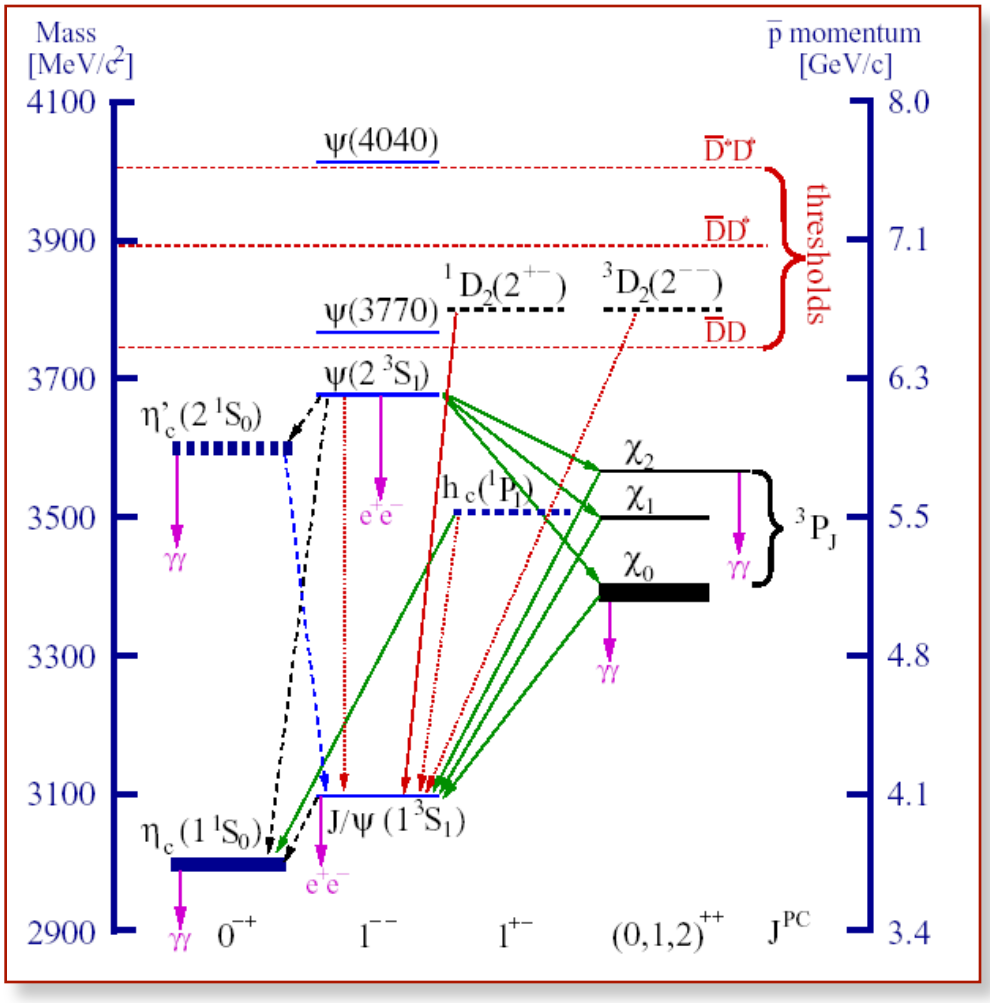


Charmonium - positronium of QCD

- confinement potential
- narrow states (e.m. decay)
- lots known…
- many open problems left!



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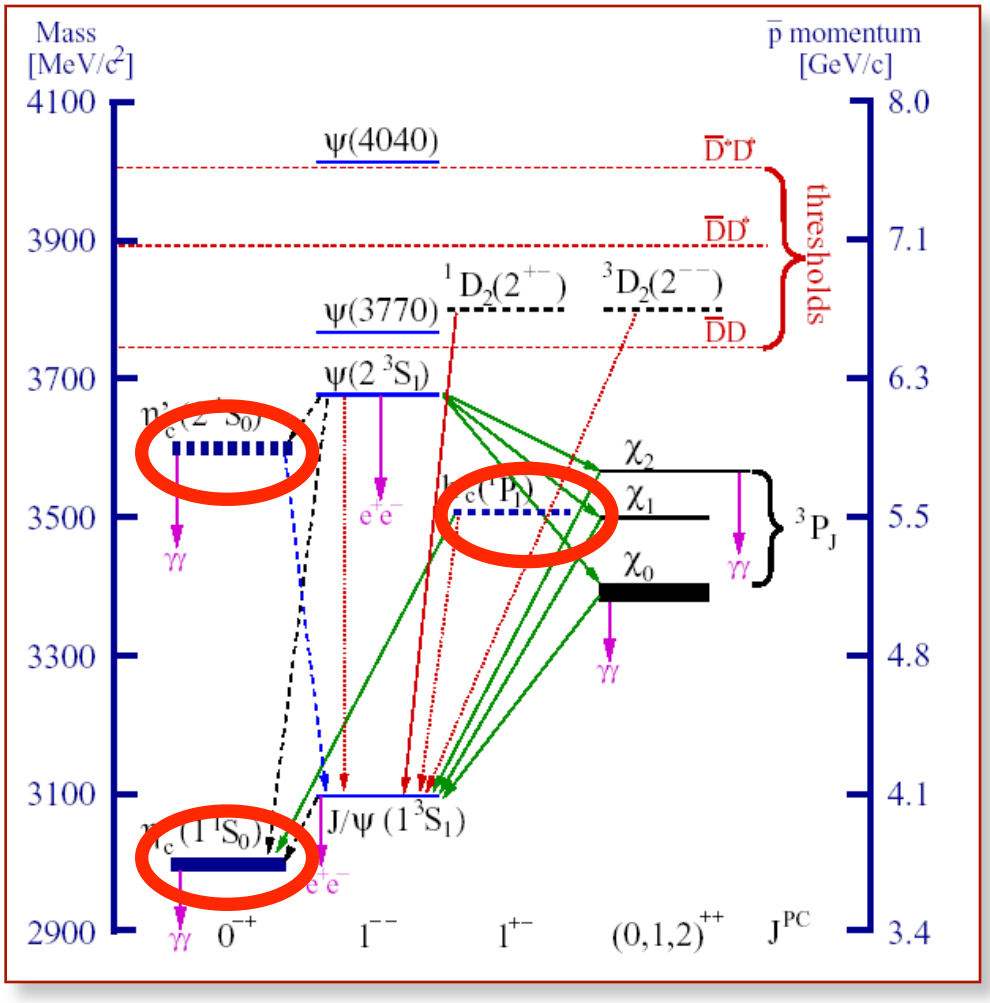
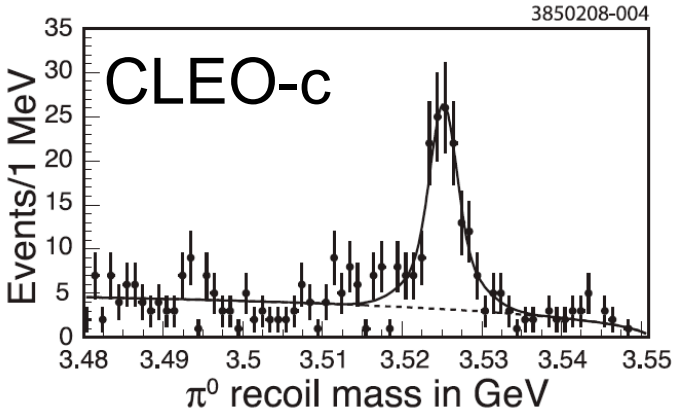


Charmonium - $h_c(1^1P_1)$

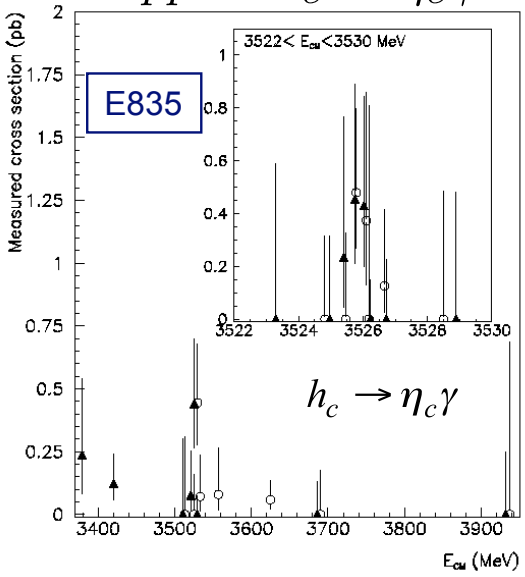
$e^+e^- \to \Psi' \to \pi^\circ h_c \to \pi^\circ \eta_c \gamma$



M(E835) = 3525.8 ±0.2 ±0.2 MeV/c^2
M(CLEOc) = 3525.28±0.19±0.12 MeV/c^2

Width unknown!

$\bar{p}p \to h_c \to \eta_c \gamma$



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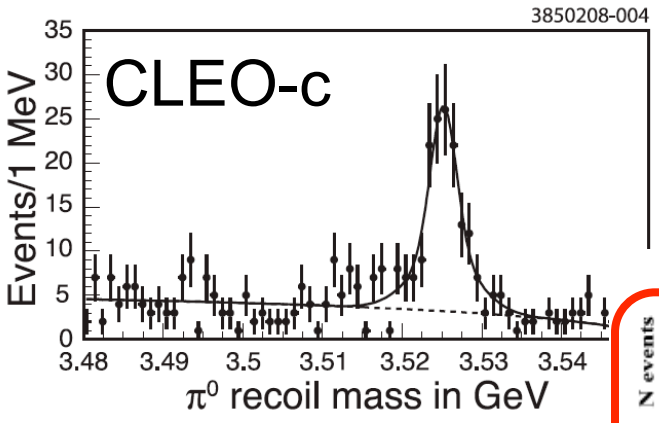

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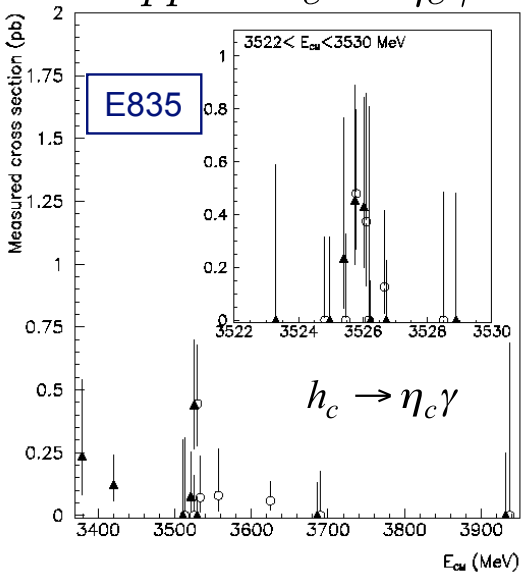
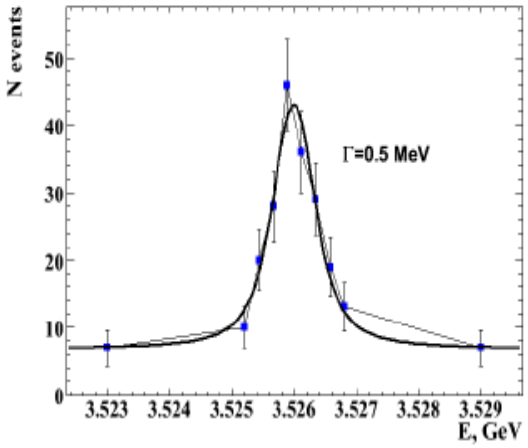
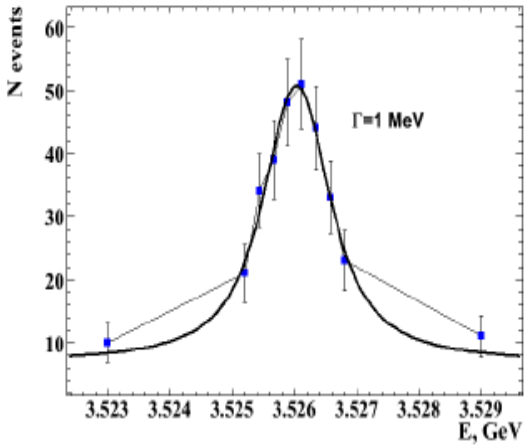






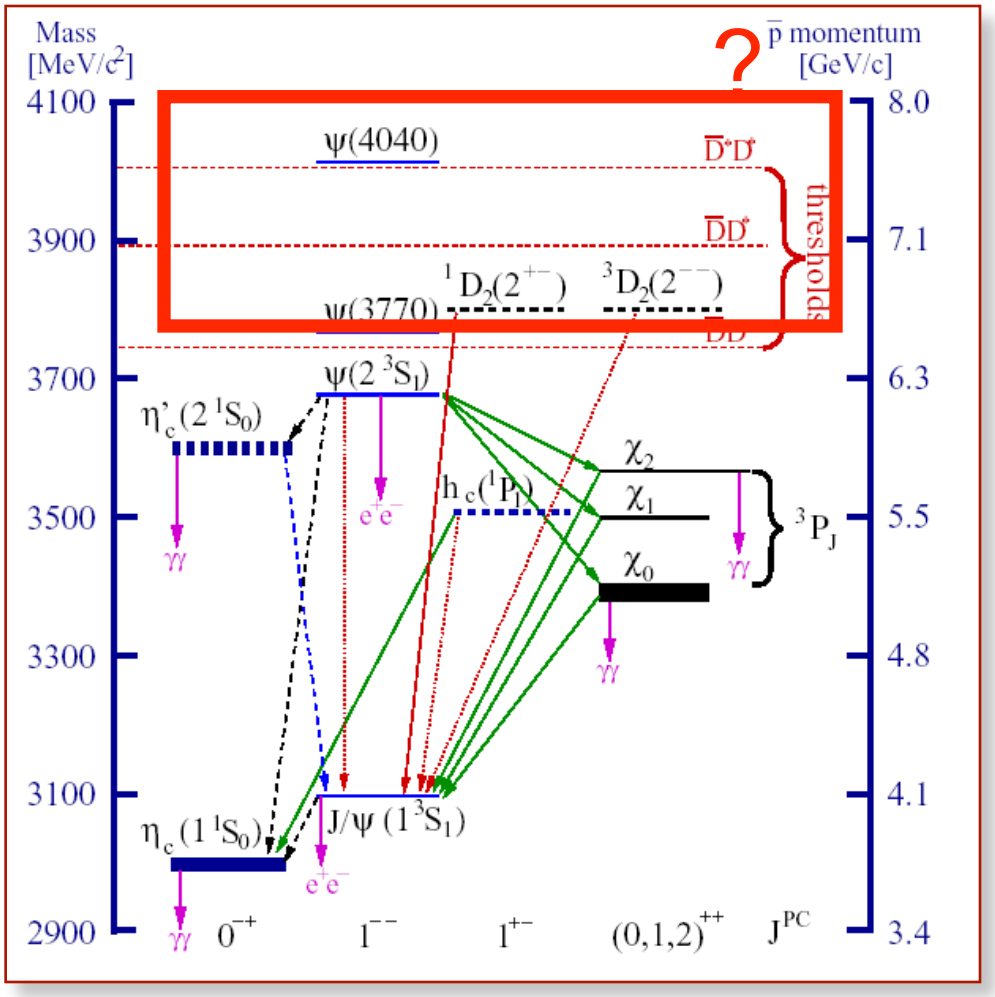
$\bar{p}p \to h_c \to \eta_c + \gamma$

5 days/scan

$\Gamma_{R,MC}$, MeV	$\Gamma_{R,reco}$, MeV	$\Delta\Gamma_R$, MeV
1	0.92	0.24
0.75	0.72	0.18
0.5	0.52	0.14

Charmonium - new frontiers

- data and interpretation above $\bar{D}D$ threshold not clear
- recent discovered narrow states
- alphabet “XYZ” states



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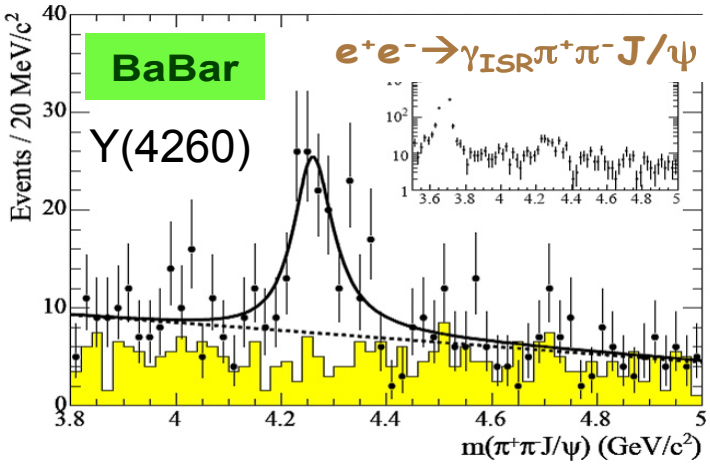

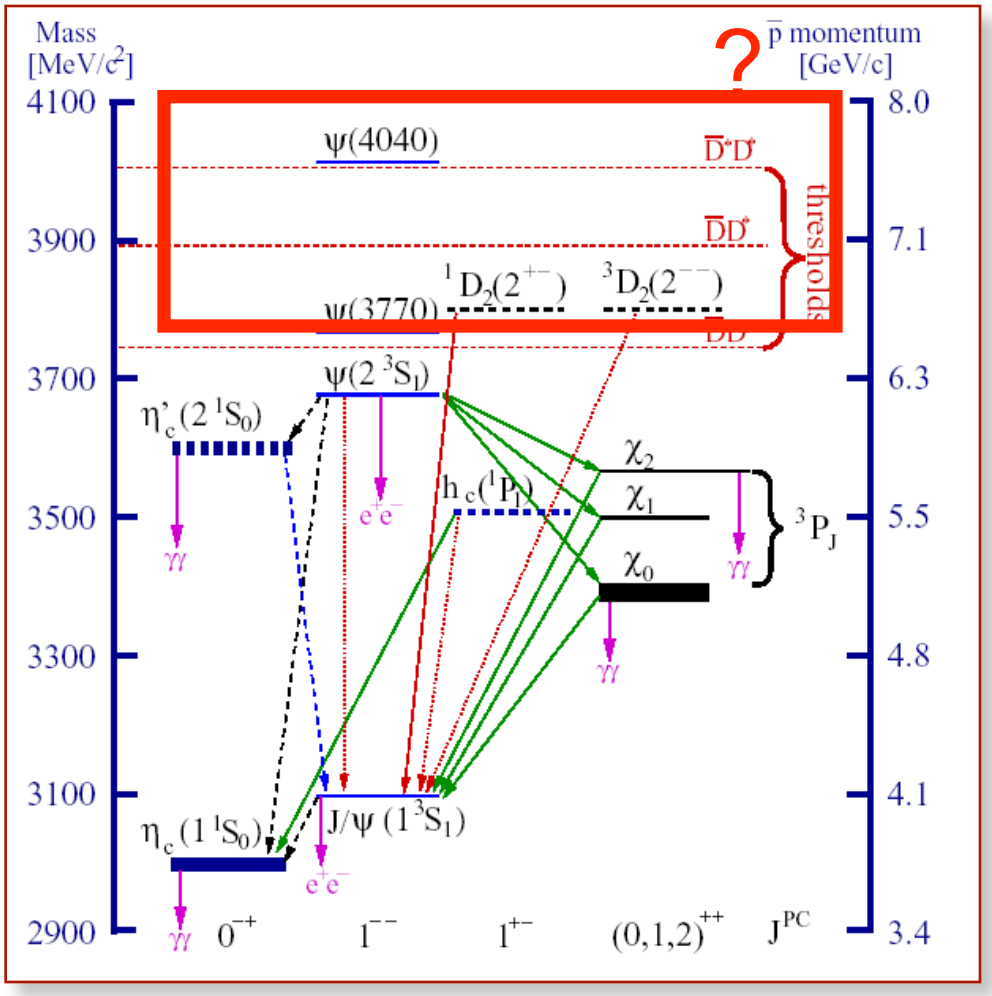

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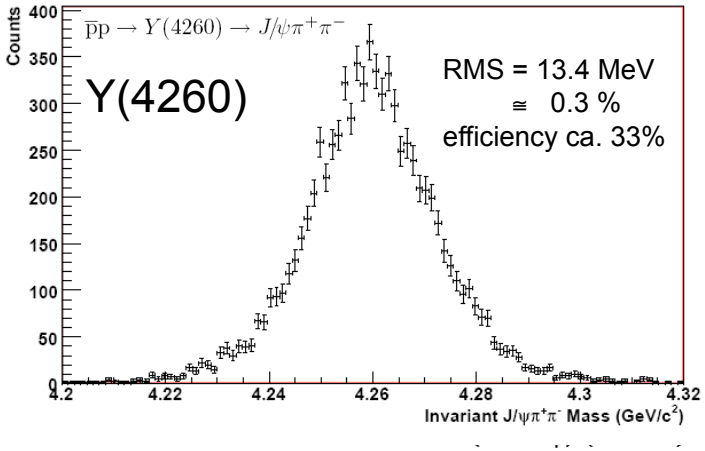
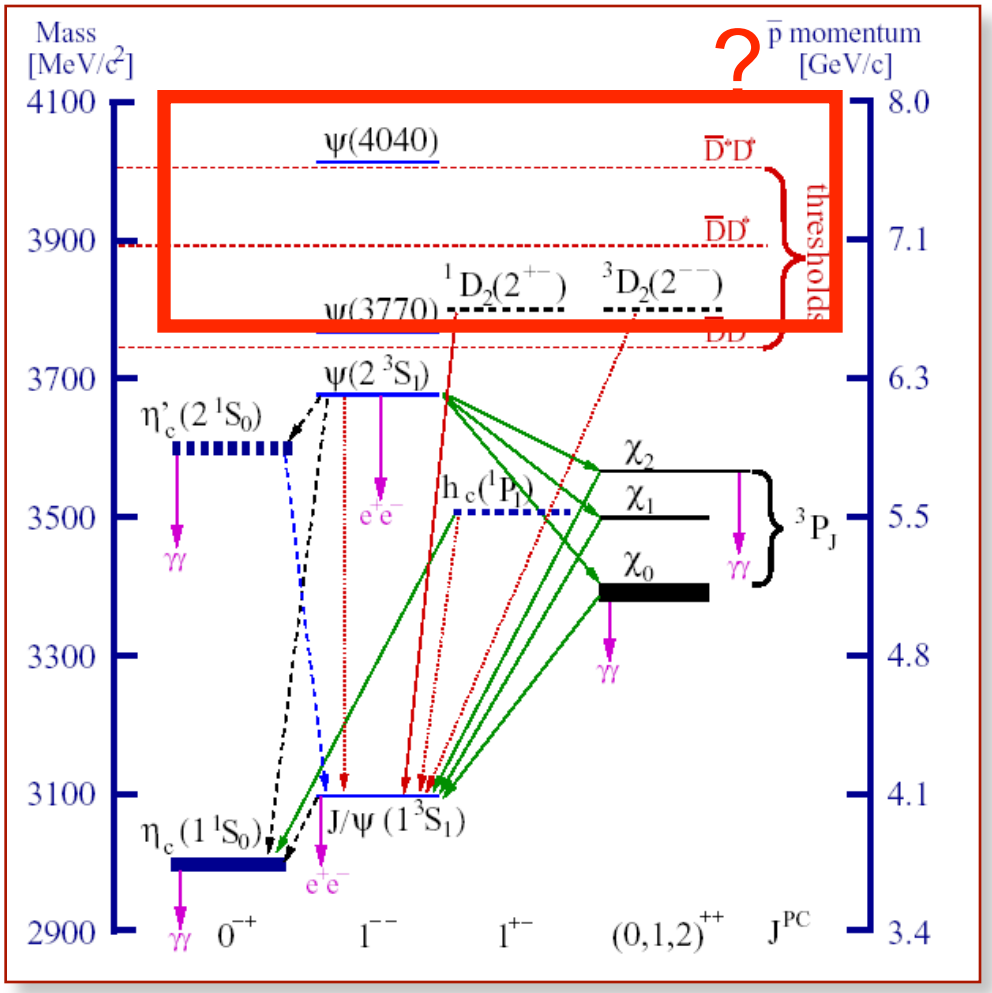
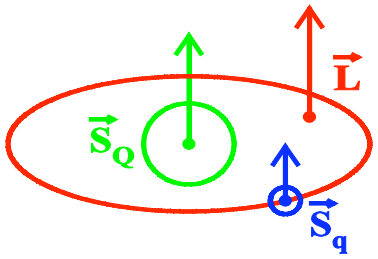


Monte-Carlo simulations
PANDA physics performance studies
(arxiv:0903.3905)



Open Charm Spectroscopy - D_{sJ}

D_{sJ} spectroscopy:
The analog of hydrogen atom



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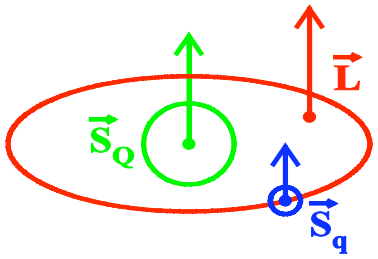
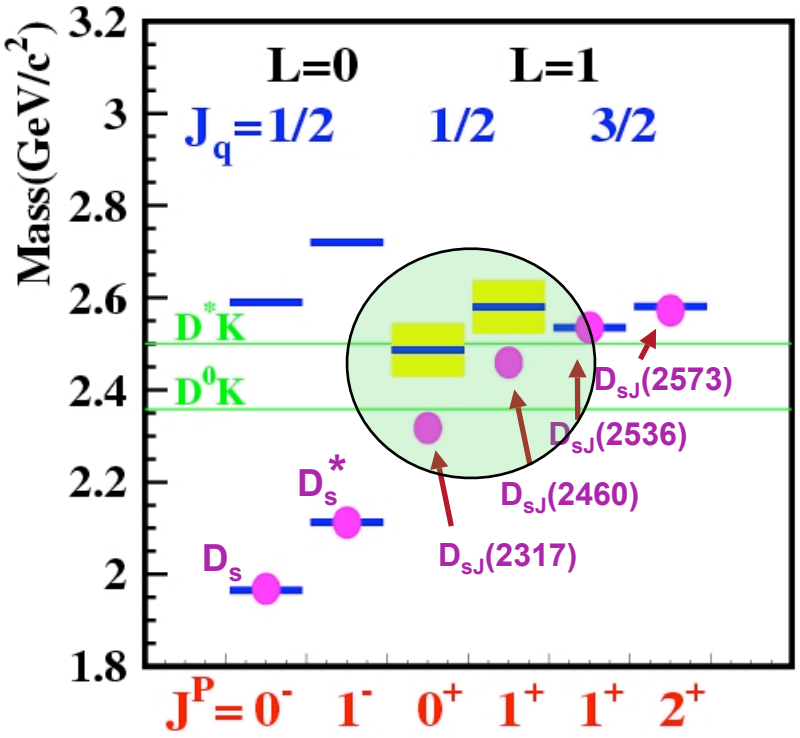


A. Drutskoy

Striking discrepancies
of recently discovered states
(B factories, CLEO&BaBar)
Chiral partners? DK threshold effects?
4-q state?



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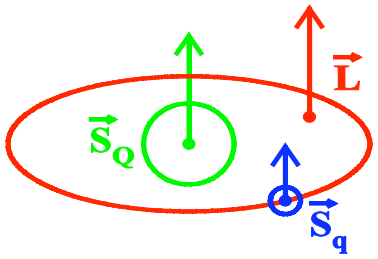

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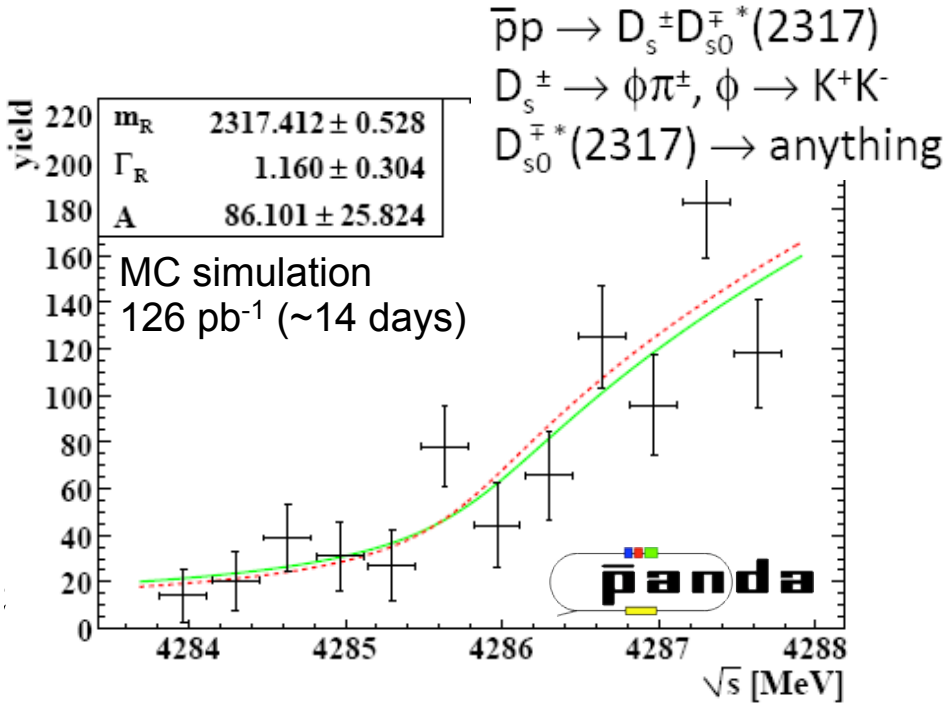

PANDA:
near-threshold scan -> M,Γ

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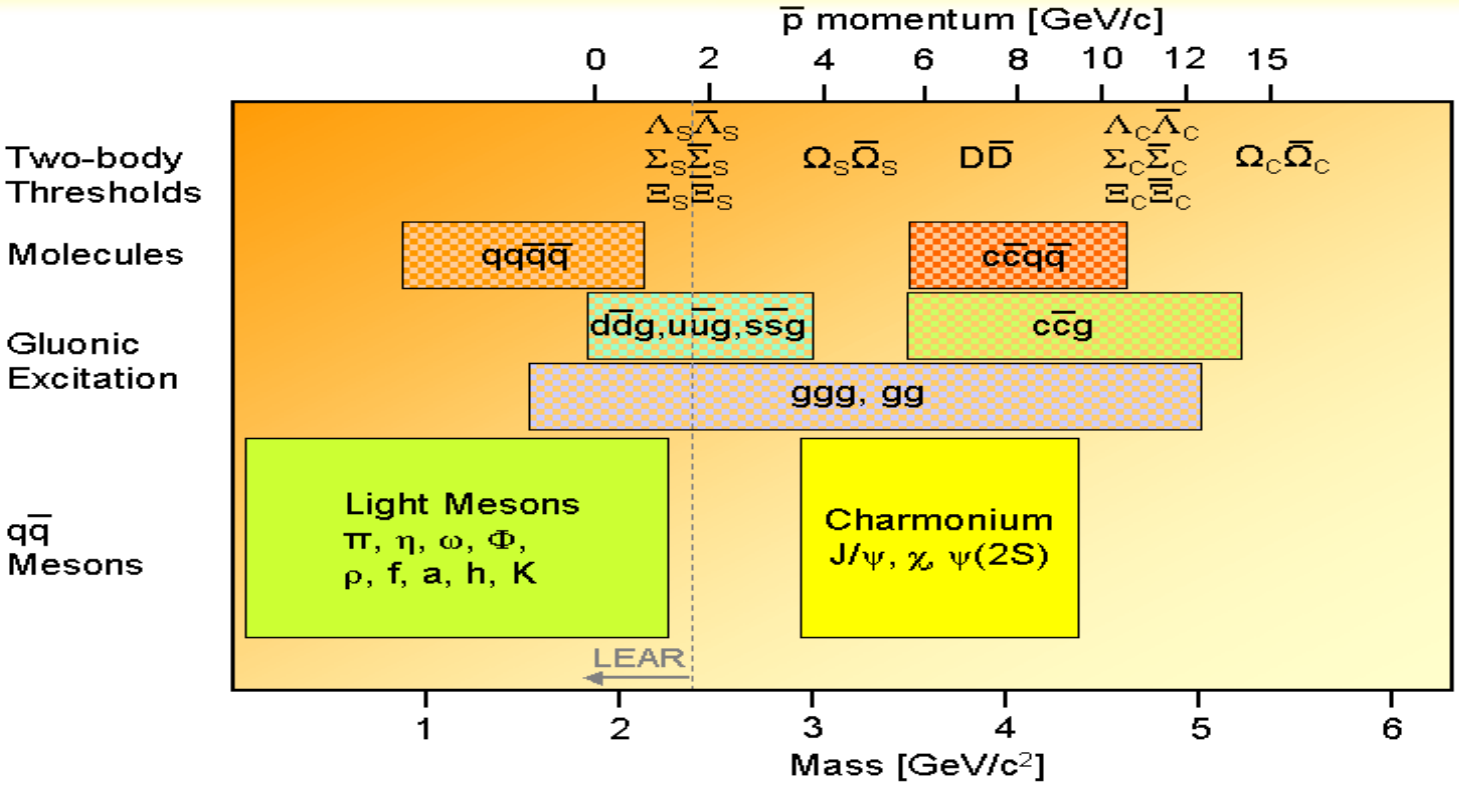

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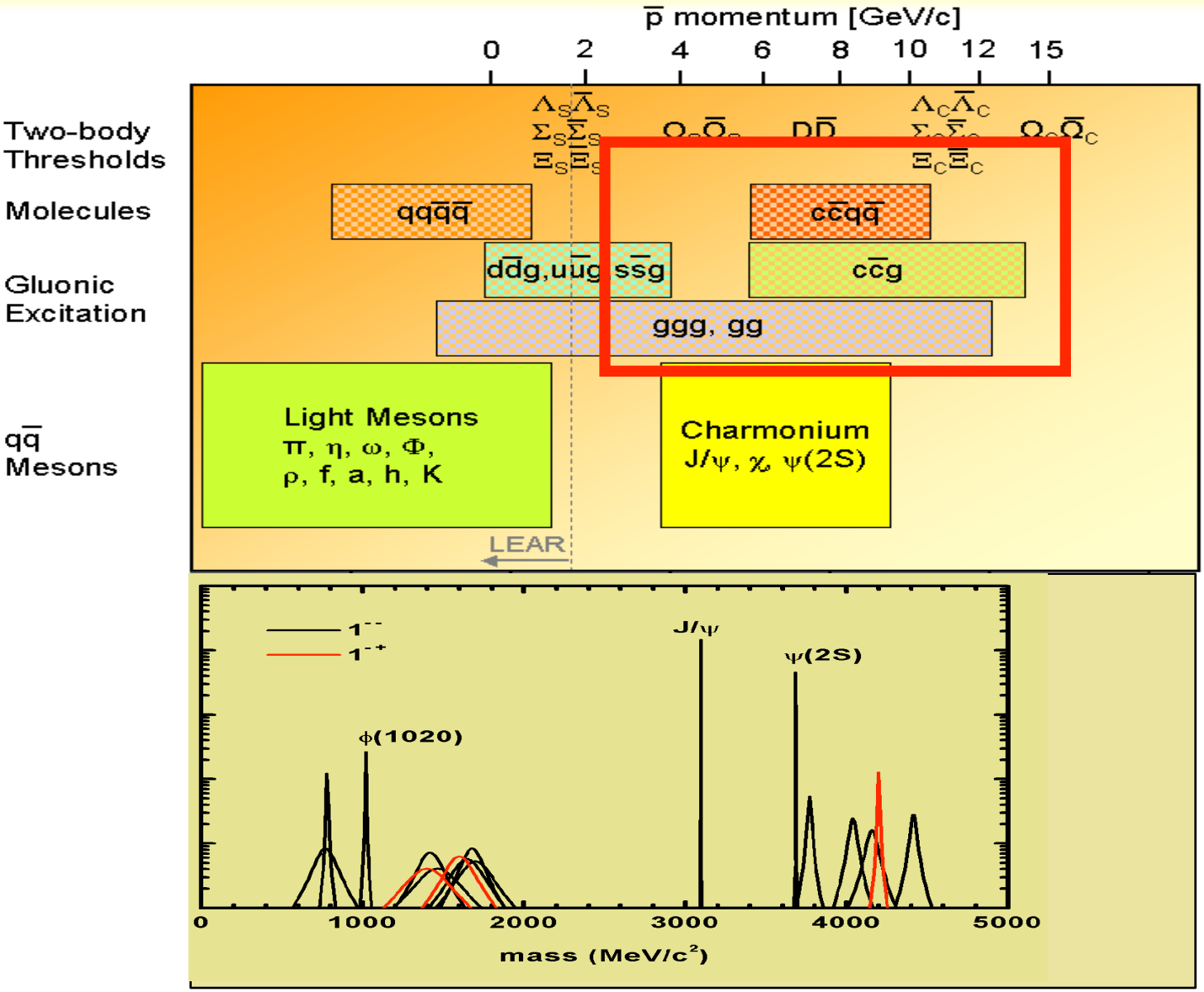
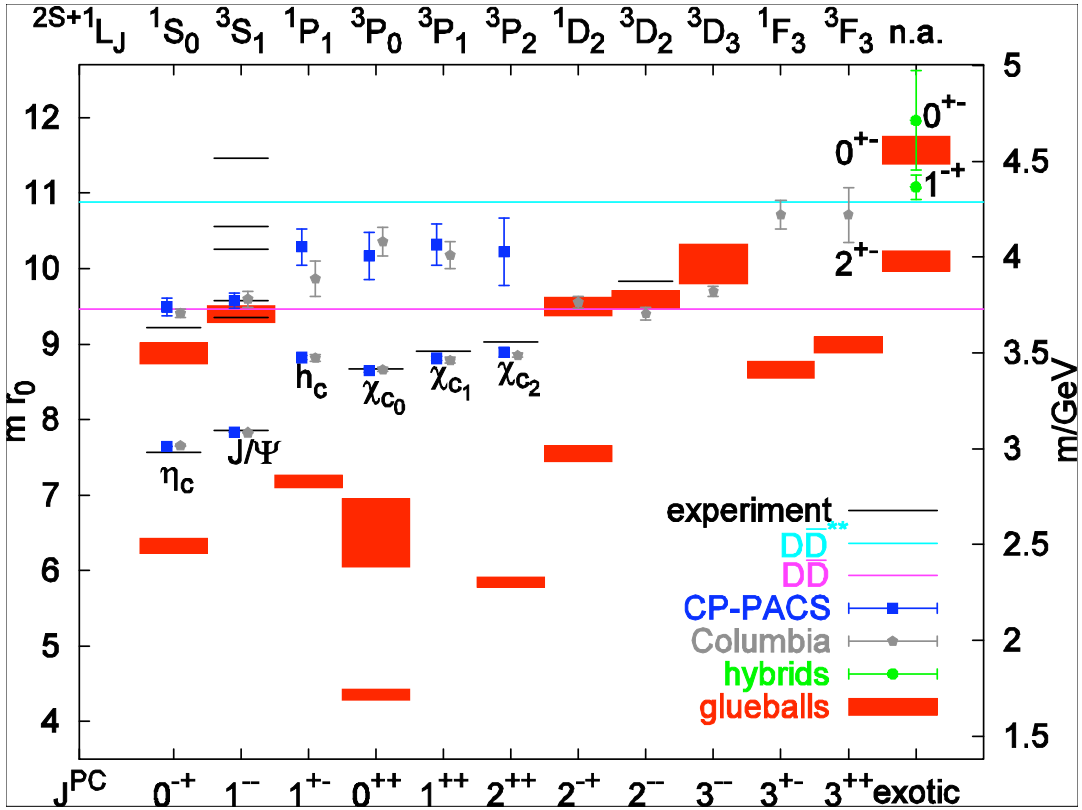


Glueballs & Hybrids

Lattice calculations



G.S. Bali, Eur. Phys. J. A19 1 (2004)

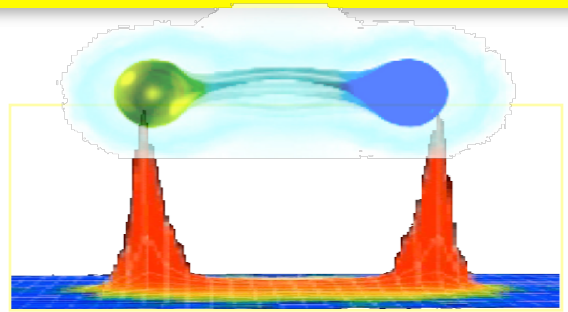
Glueballs:

rich glueball spectrum
odd-balls ~4-5 GeV

the *ultimate* evidence
for confinement…
we *better* find them!

Hybrids:

exotic charm-hybrid
$J^{PC} = 1^{-+}$: 4.2-4.5 GeV
Flux-tube prediction:
$\Gamma < 50$ MeV, σ~100-150 pb



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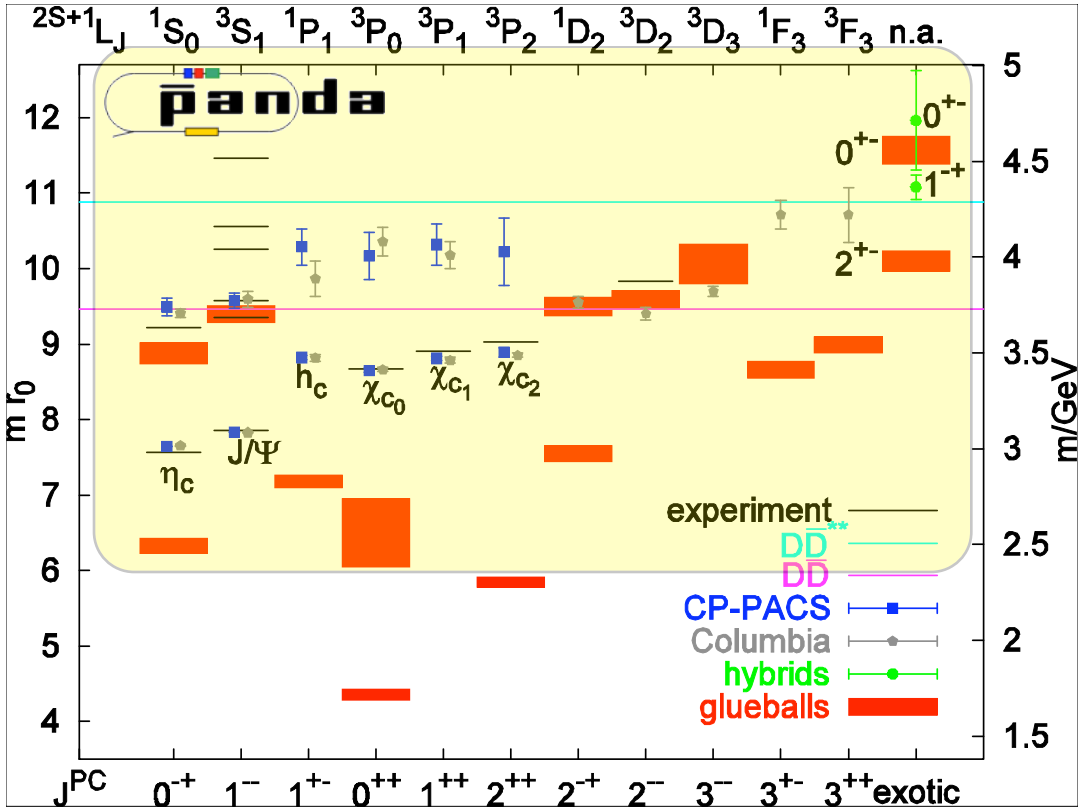

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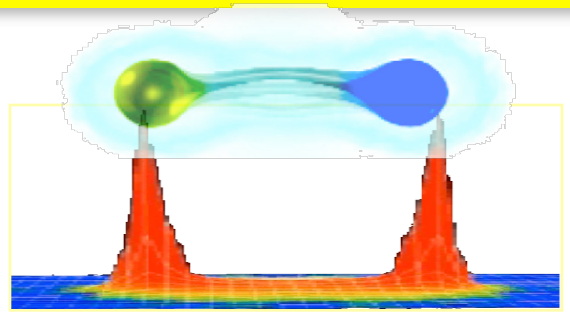

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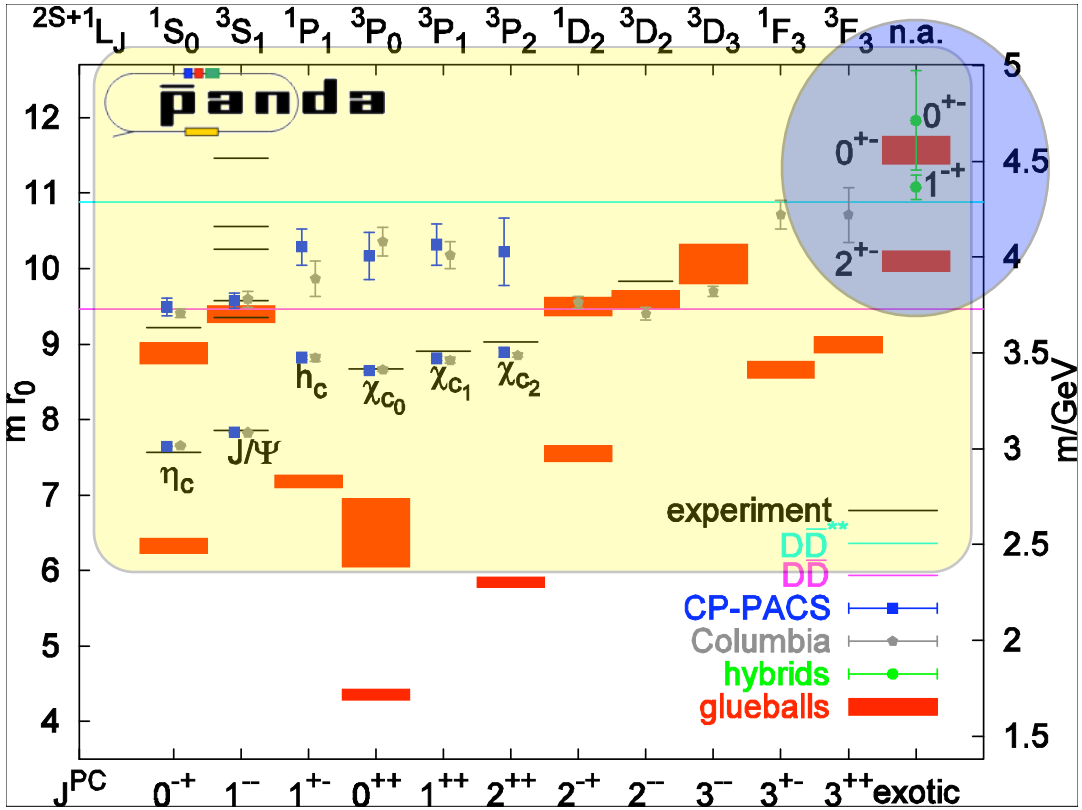

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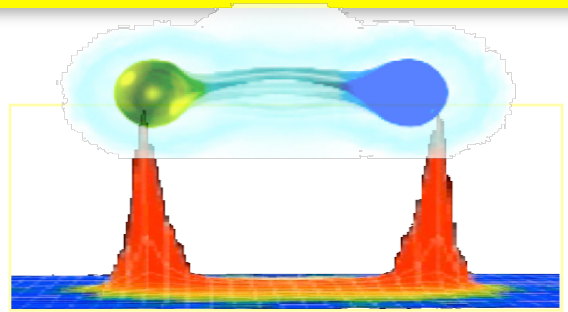


Anti-protons as tool to study…

QCD with Nuclei

Hyperon interactions in $\Lambda\,\Lambda$ hypernuclei

Mass modification of mesons - direct and indirect in-medium mass measurements of charmed mesons

Structure of the Proton

GPDs via reversed Deeply Virtual Compton Scattering & Drell-Yan

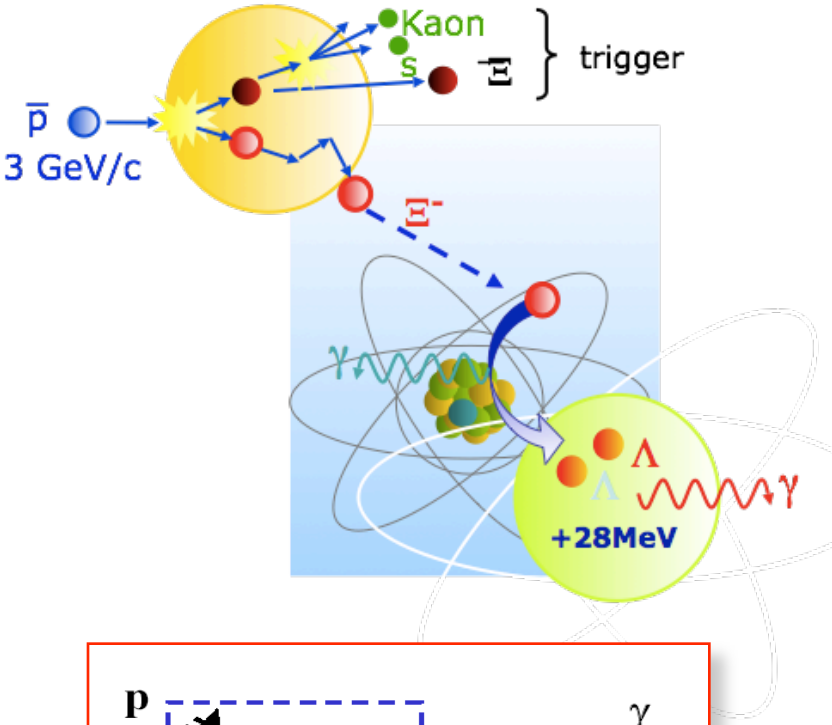
"Spin" Structure using polarized anti-protons (PAX)

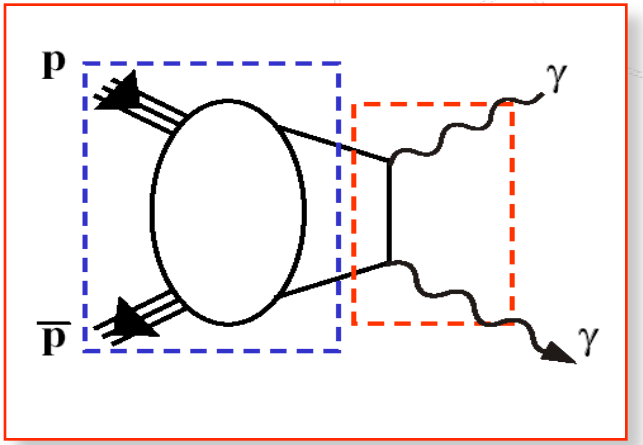
EM Form Factors of the Proton - time-like region up to Q^2=25 GeV^2

Beyond the Standard Model

CP-violation in D/Λ - sector - $D^0\overline{D}^0$ mixing and in $\Lambda\overline{\Lambda}$ decay asymmetries

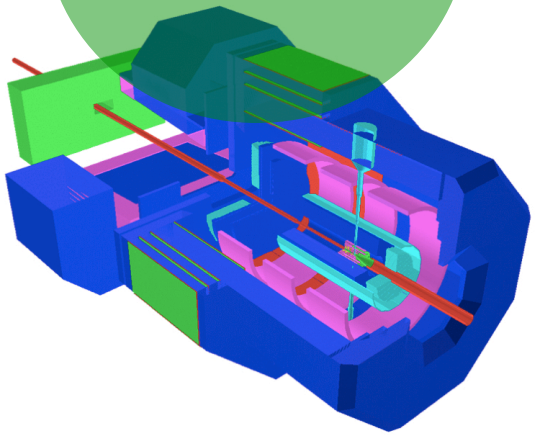
Rare decays : $D^+ \to \mu^+\nu$, $D^- \to \mu^+\mu^-$



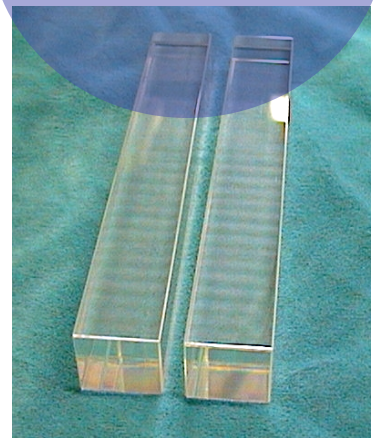


Physics analysis

Simulations



R&D



Collaboration with theory

Development of event generators

Partial Wave Analysis

achievements:

- **Physics benchmark report (arxiv:0903.3905)**

Simulation&analysis framework

Physics benchmark & detector design

Large-scale comp. (GRID)

achievements:

- **Computing model**
- **Detailed simulation framework**

Detector & target developments

Prototype testing

FEE, Trigger & DAQ

achievements:

- **TDRs: EMC, Magnets,...**
- **Funding: EMC, Dipole magnet, Cerenkov**

The PANDA Collaboration

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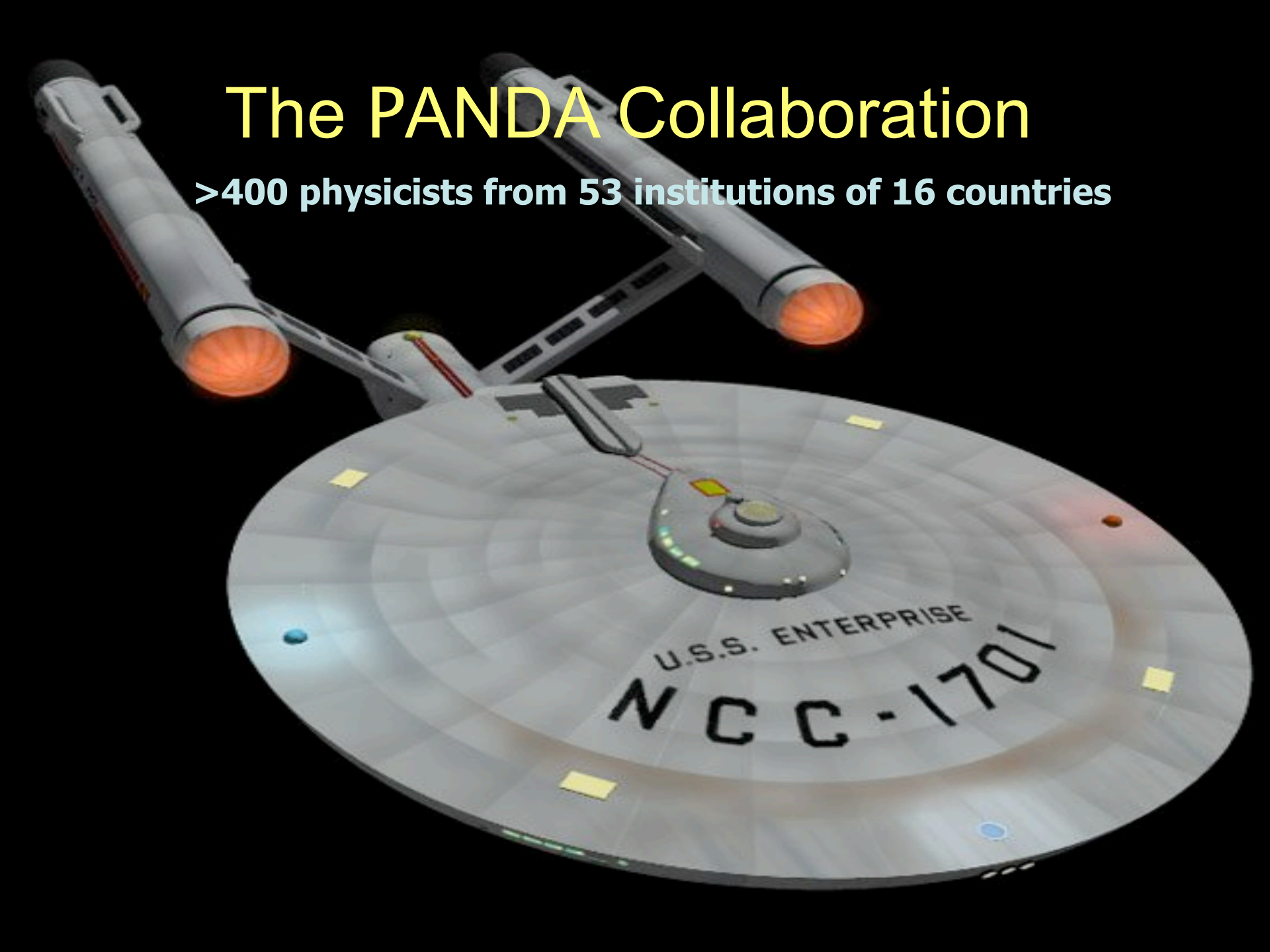
>400 physicists from 53 institutions of 16 countries



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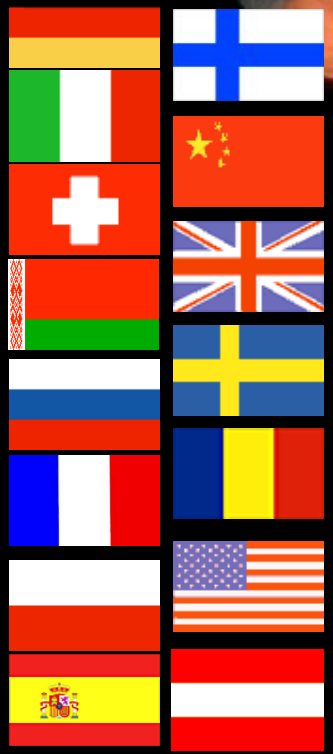
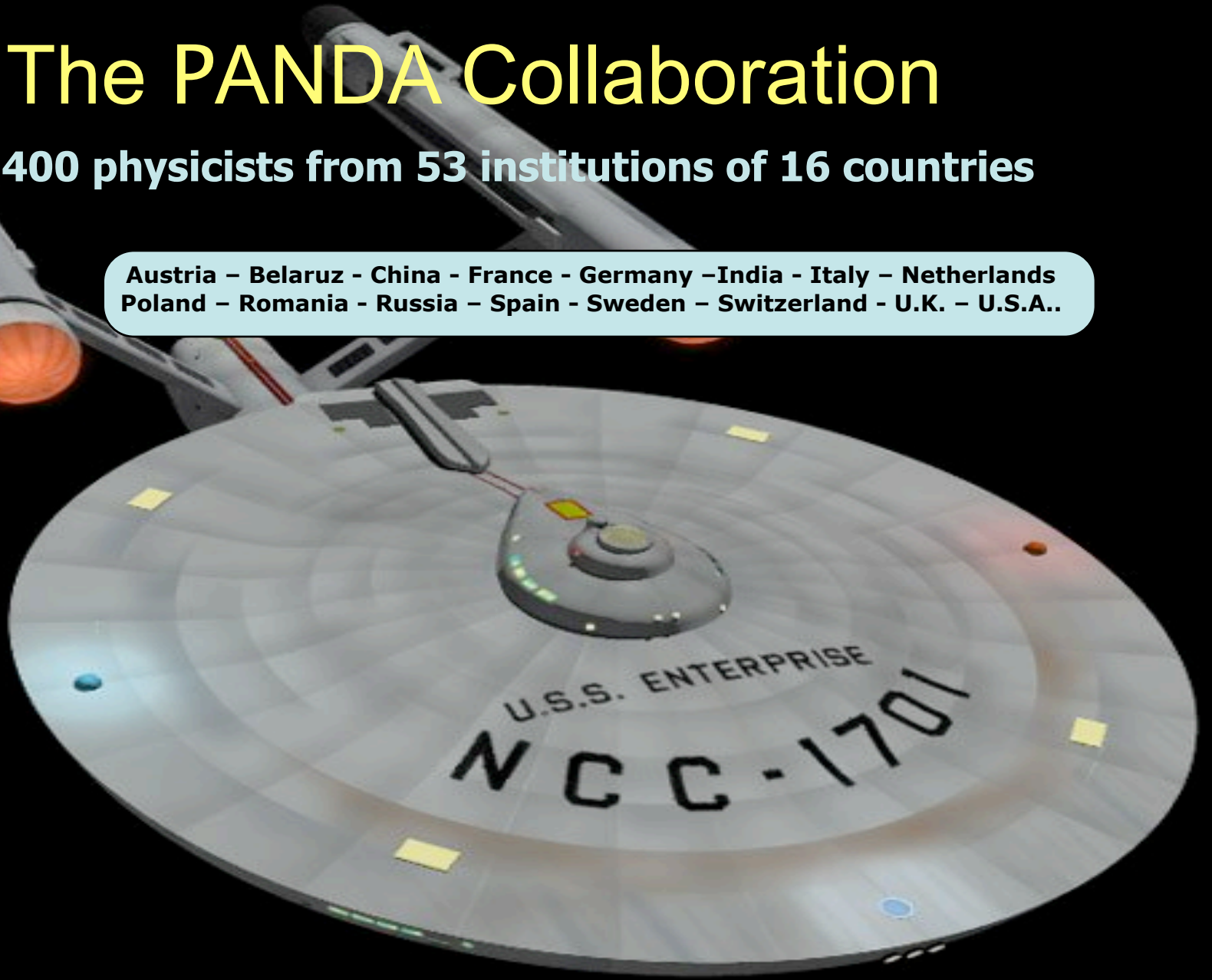
Austria – Belaruz - China - France - Germany –India - Italy – Netherlands Poland – Romania - Russia – Spain - Sweden – Switzerland - U.K. – U.S.A..





The PANDA Collaboration

>400 physicists from 53 institutions of 16 countries

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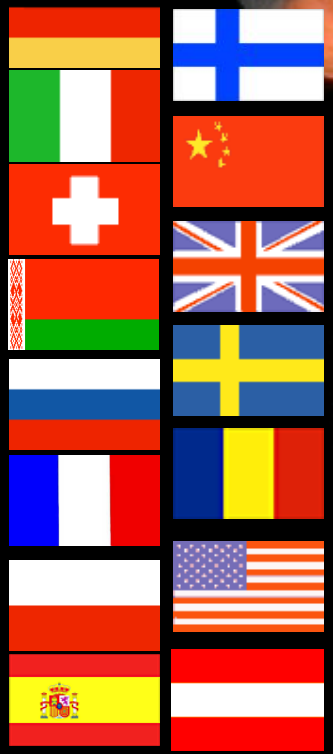

Basel, Beijing, Bochum, IIT Bombay, Bonn, Brescia,
IFIN Bucharest, Catania, Chicago, Cracow,
IFJ PAN Cracow, Cracow UT, Dresden, Edinburg, Erlangen,
Ferrara, Frankfurt, Genova, Giessen, Glasgow, GSI,
FZ Jülich, JINR Dubna, Katowice, KVI Groningen, Lanzhou,
LNF, Lund, Mainz, Minsk, ITEP Moscow, MPEI Moscow,
TU München, Münster, Northwestern, BINP Novosibirsk,
IPN Orsay, Pavia, Piemonte_Orientale, IHEP Protvino,
PNPI St. Petersburg, KTH Stockholm, Stockholm, U Torino,
INFN Torino, Torino Politecnico, Trieste, TSL Uppsala,
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New optimism for panda survival

The giant panda has a better chance of survival than previously thought, scientists have discovered.

The Wolong Giant Panda Research Centre helped with the fieldwork

The fear had been that their bamboo diet, slow reproduction rate and isolated habitat made them unable to adapt as a species in the modern world.

But research by Cardiff University and scientists in Beijing shows they are more capable of evolving than believed.