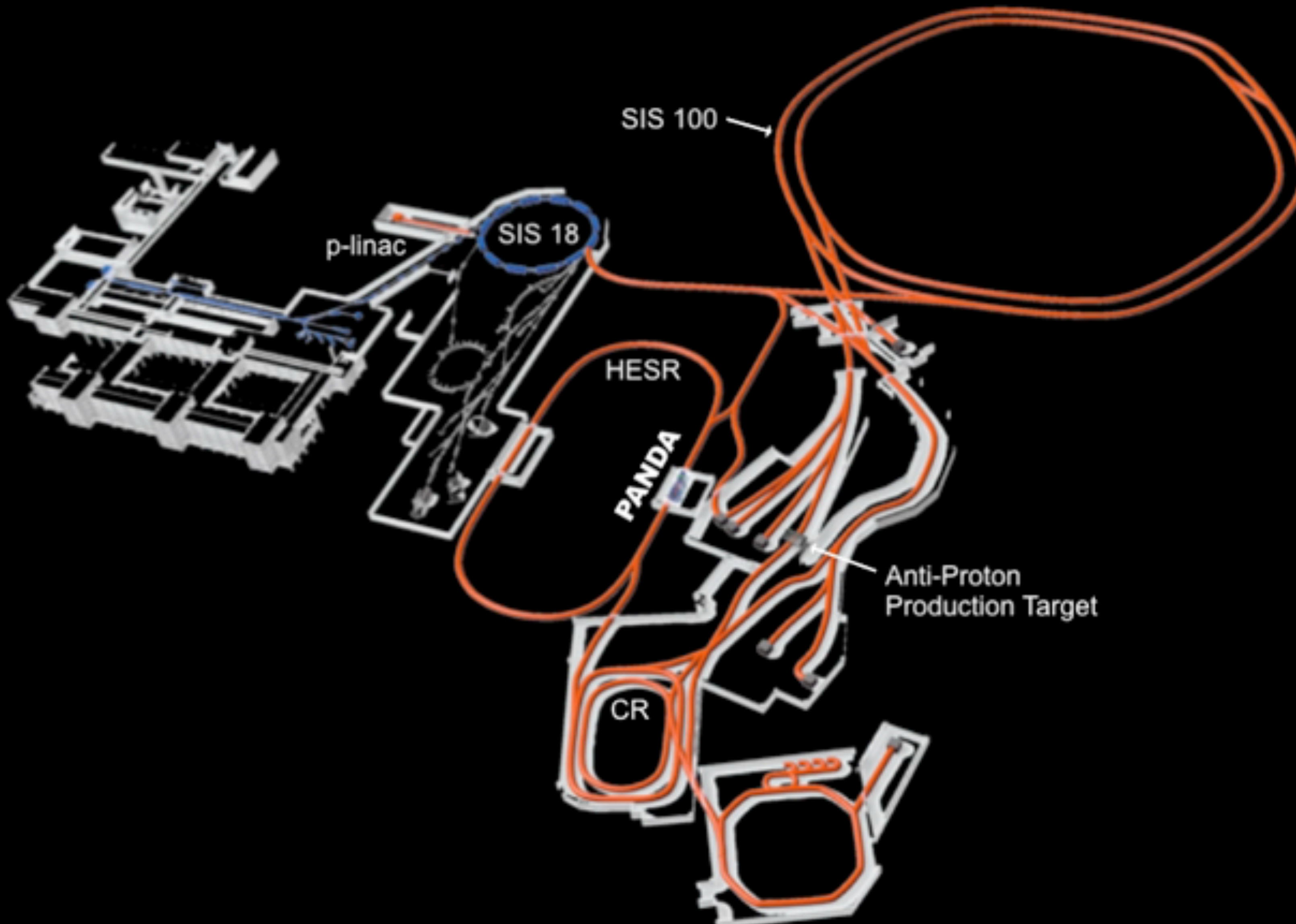
PANDA

Ulrich Wiedner
Ruhr-University Bochum

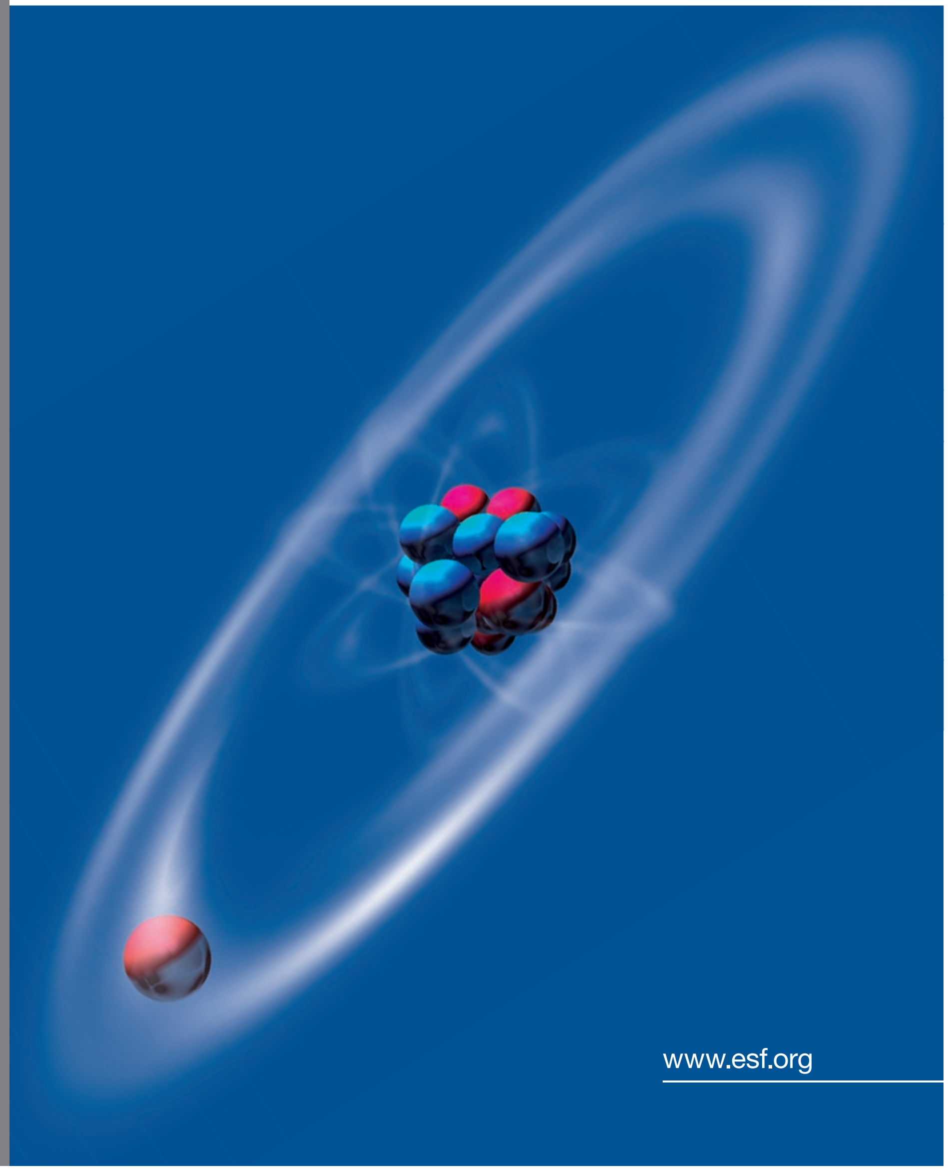
FAIR ECE meeting, 19.11.2011

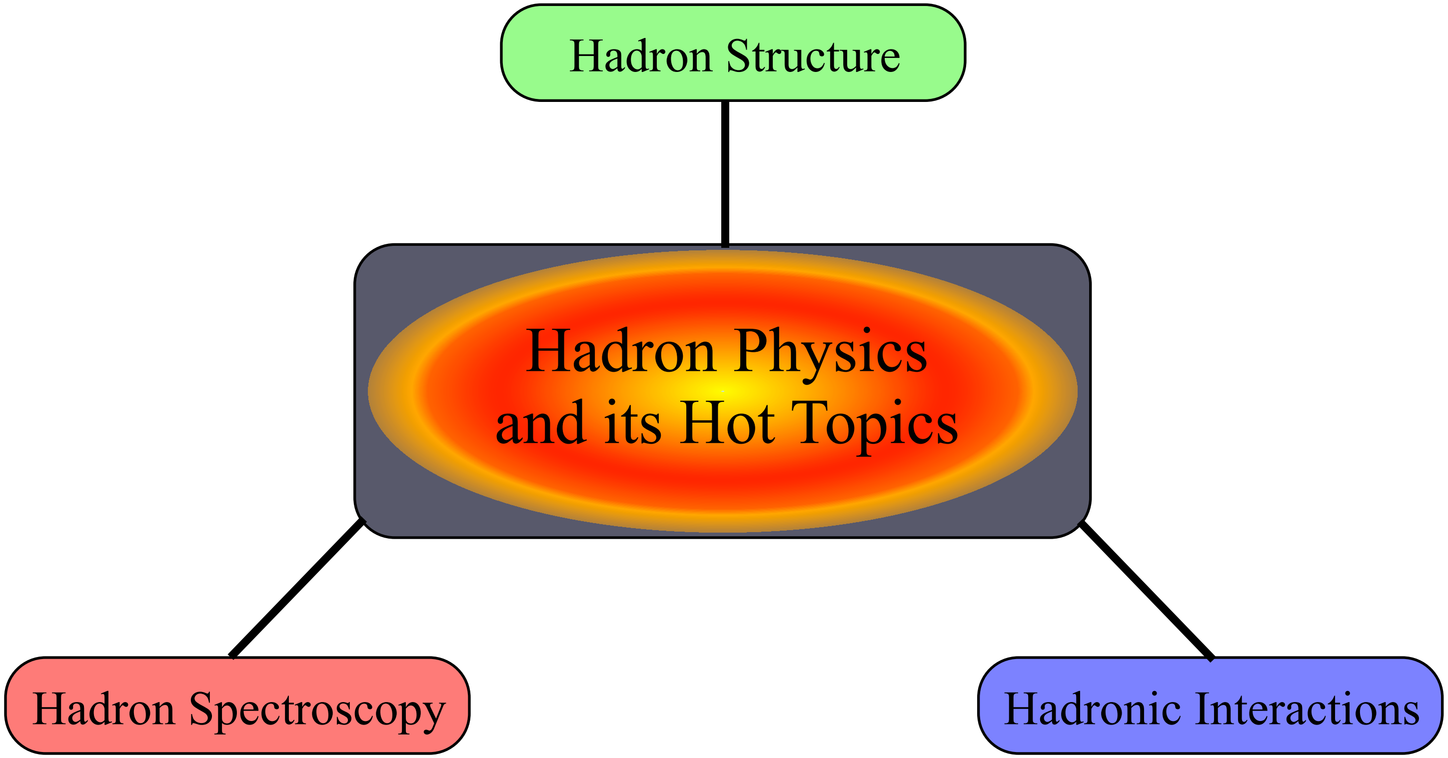

SIS 100
p-linac
SIS 18
HESR
PANDA
Anti-Proton
Production Target
CR

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

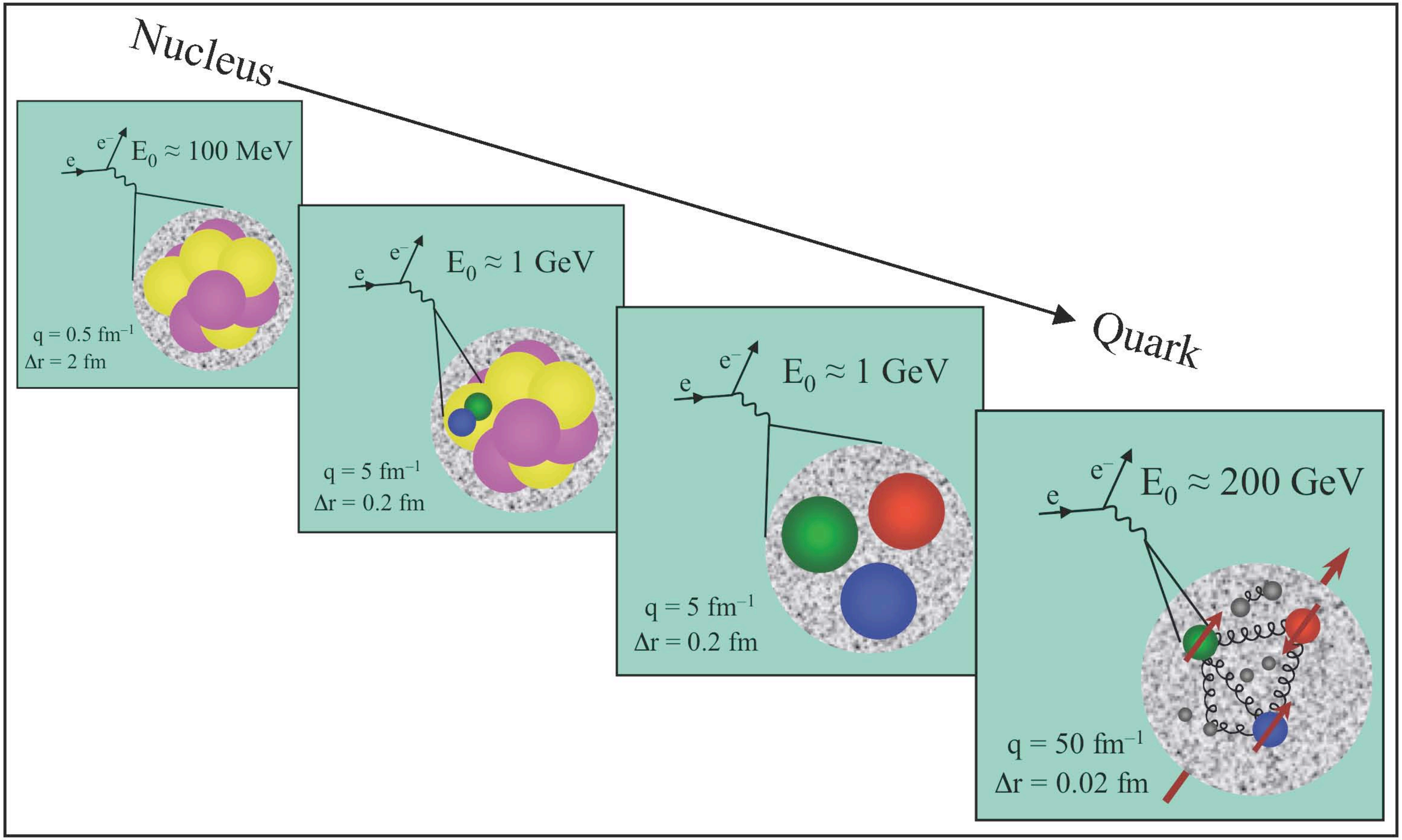
FORWARD LOOK

NuPECC Long Range Plan 2010

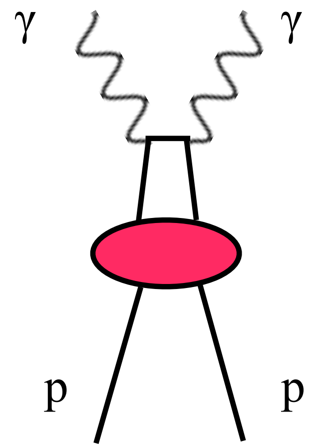



Hadron Structure
Hadron Physics
and its Hot Topics
Hadron Spectroscopy
Hadronic Interactions

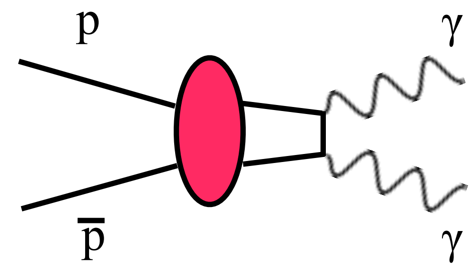
Hadronic Structure

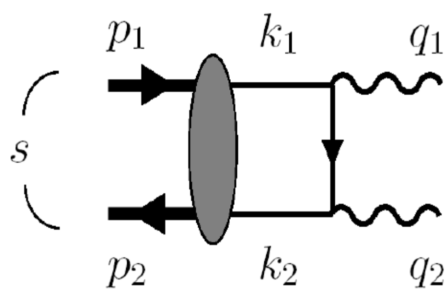


Electromagnetic Processes: $\bar{p}p \to \gamma\gamma$



crossed-channel
Compton scattering





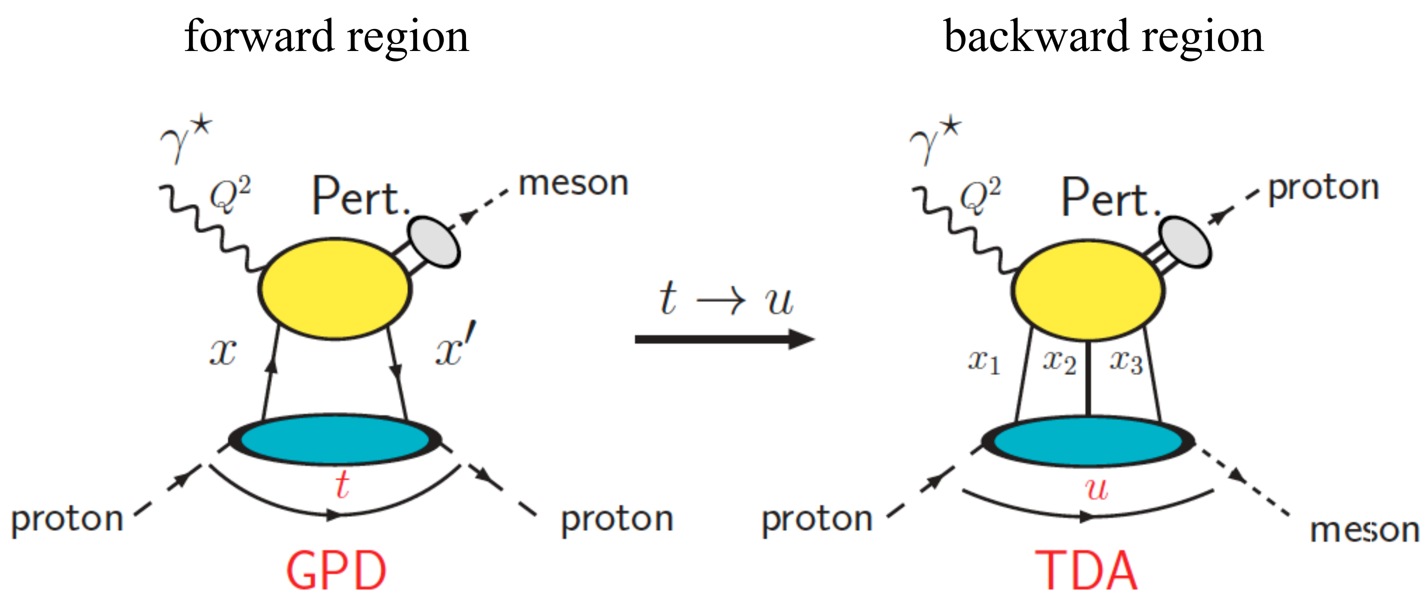
Handbag diagram separates a soft part described by GPDs from a hard $\bar{q}q$ annihilation process

Predicted rates*: several thousand / month or above

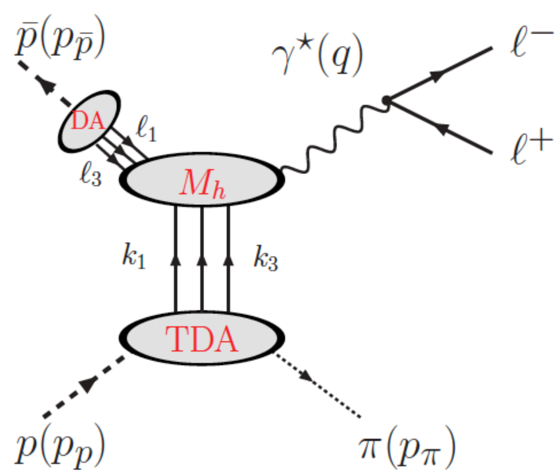
Exp. problem: Background channels like $\pi^0\gamma$ or $\pi^0\pi^0$ 5× - 100× stronger.

*A. Freund, A. Radyushkin, A. Schäfer, and C. Weiss, Phys. Rev. Lett. 90, 092001 (2003).

From GPDs to TDAs



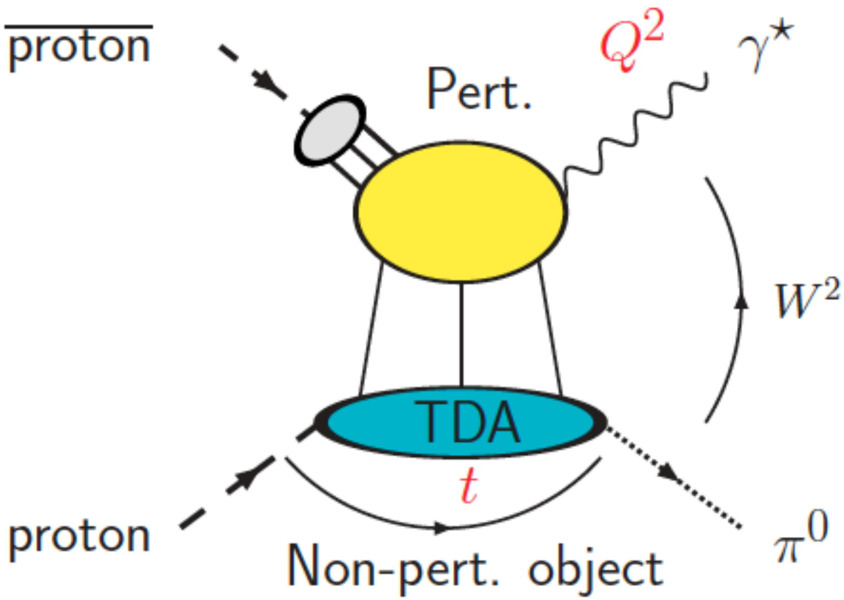
PANDA:

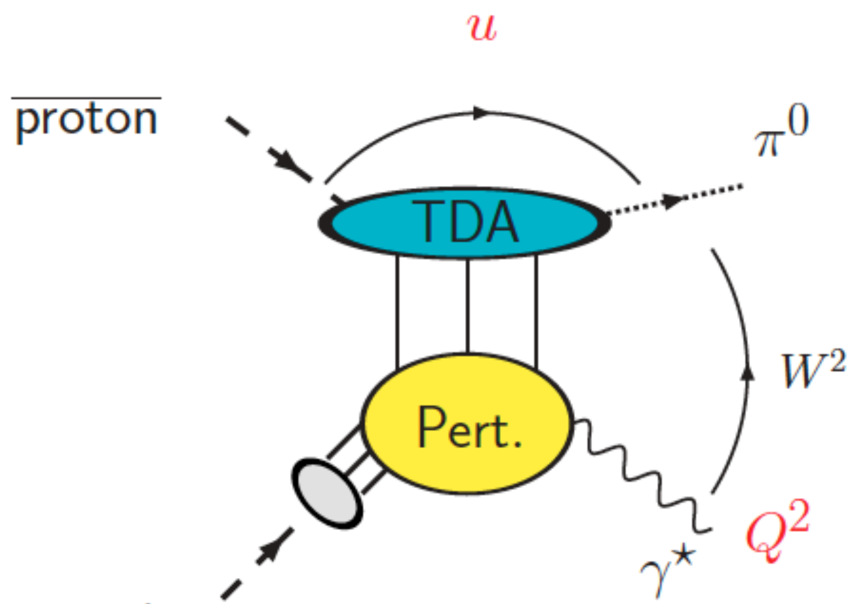


J.P. Lansberg, B. Pire, L. Szymanowski, Phys. Rev. D 76 (2007) 111502(R).

J.P. Lansberg, Workshop PANDA Orsay, France 2011

The π^0 could come from the p or the $\bar{p}$





J.P. Lansberg, B. Pire, L. Szymanowski, Phys. Rev. D 76 (2007) 111502(R).

J.P. Lansberg, Workshop PANDA Orsay, France 2011

Electromagnetic form factors of the proton

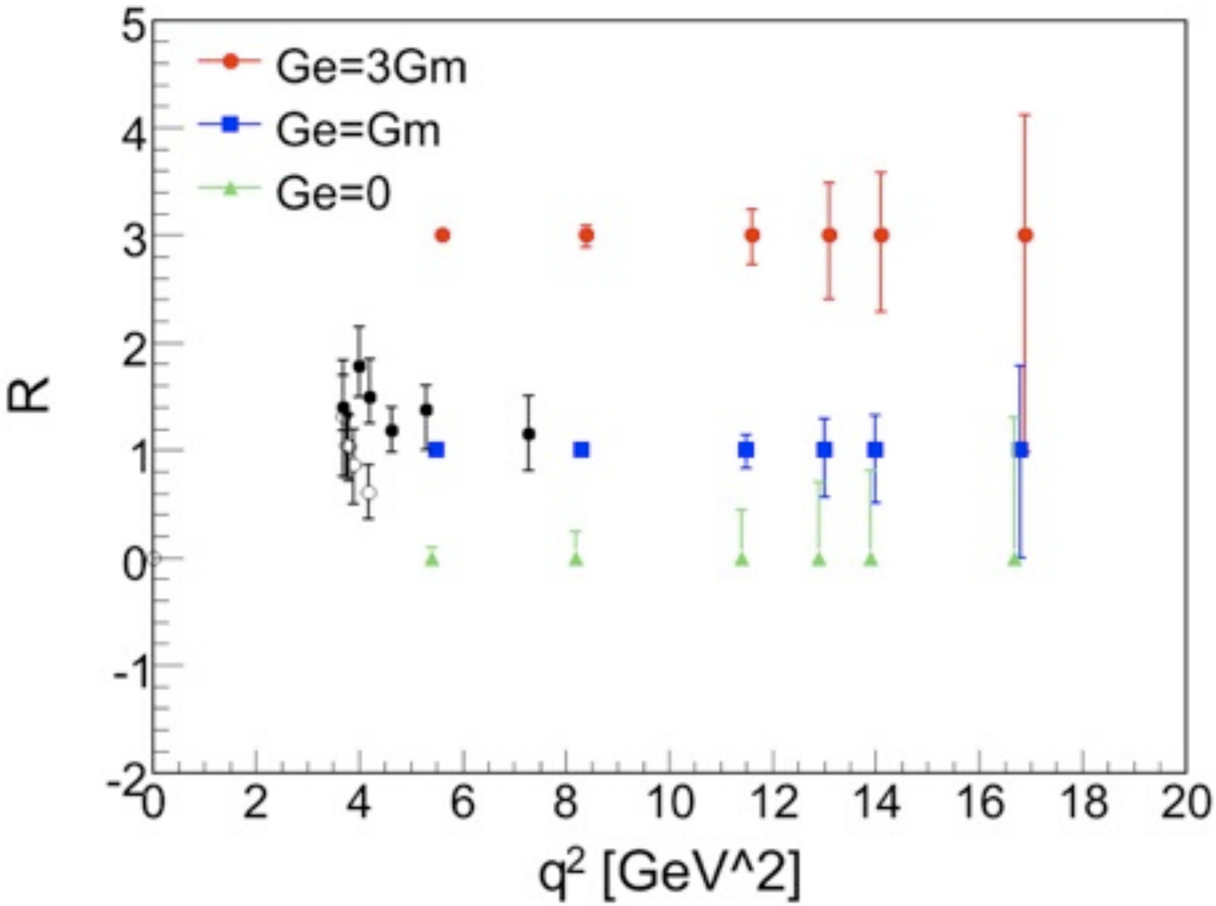
... can be extracted from the cross section: $\overline{\mathrm{p}} + \mathrm{p} \rightarrow \mathrm{e}^+ + \mathrm{e}^-$

$$\frac{d\sigma}{d(\cos\theta^*)} = \frac{\pi\alpha^2\hbar^2c^2}{2xs}\left[|G_M|^2(1+\cos^2\theta^*) + \frac{4m_p^2}{s}|G_E|^2(1-\cos^2\theta^*)\right]$$

(first order QED prediction)

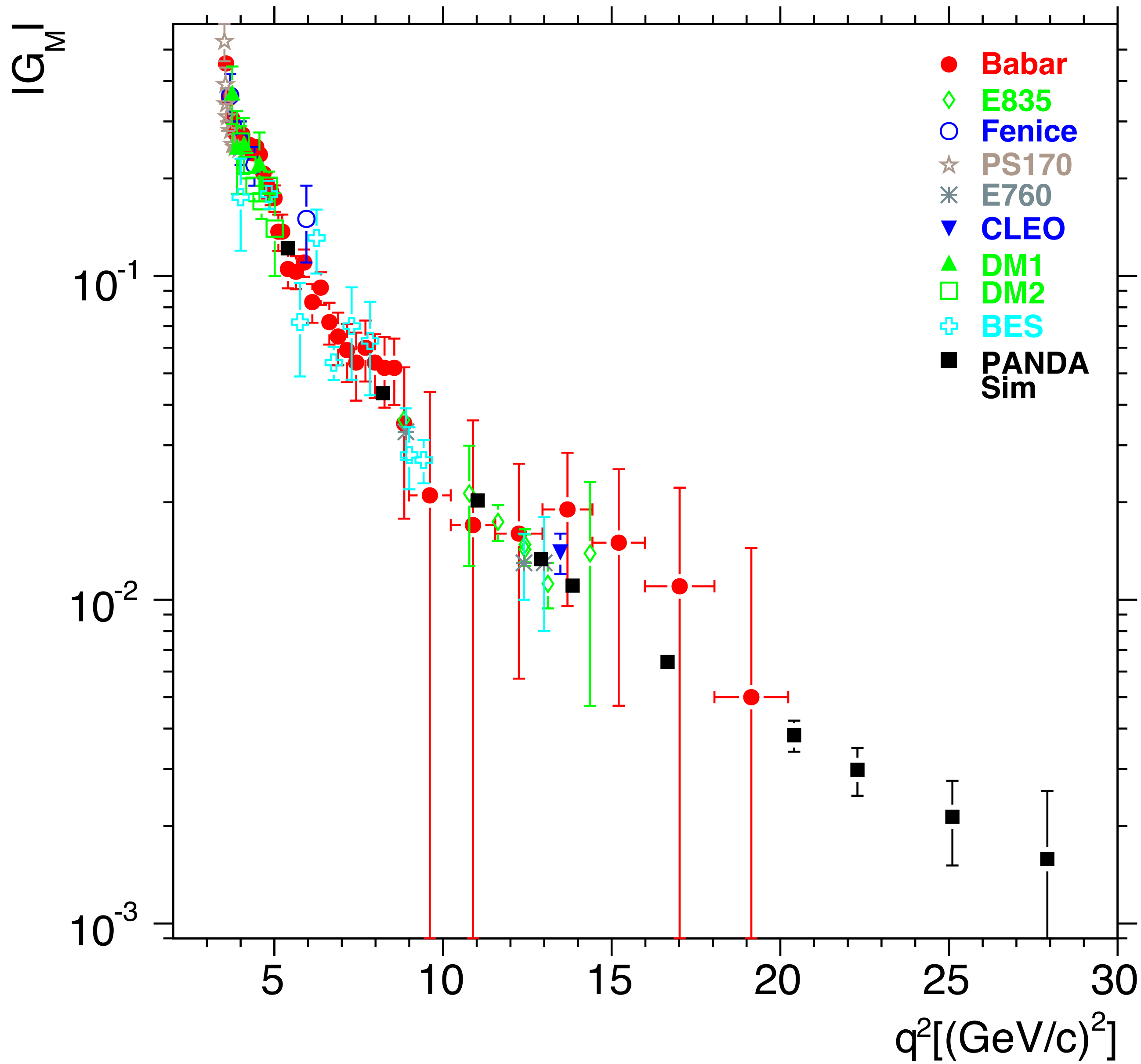
Data at high Q^2 test QCD predictions for the asymptotic behavior of the form factors and spacelike-timelike equality at corresponding Q^2.

MC studies



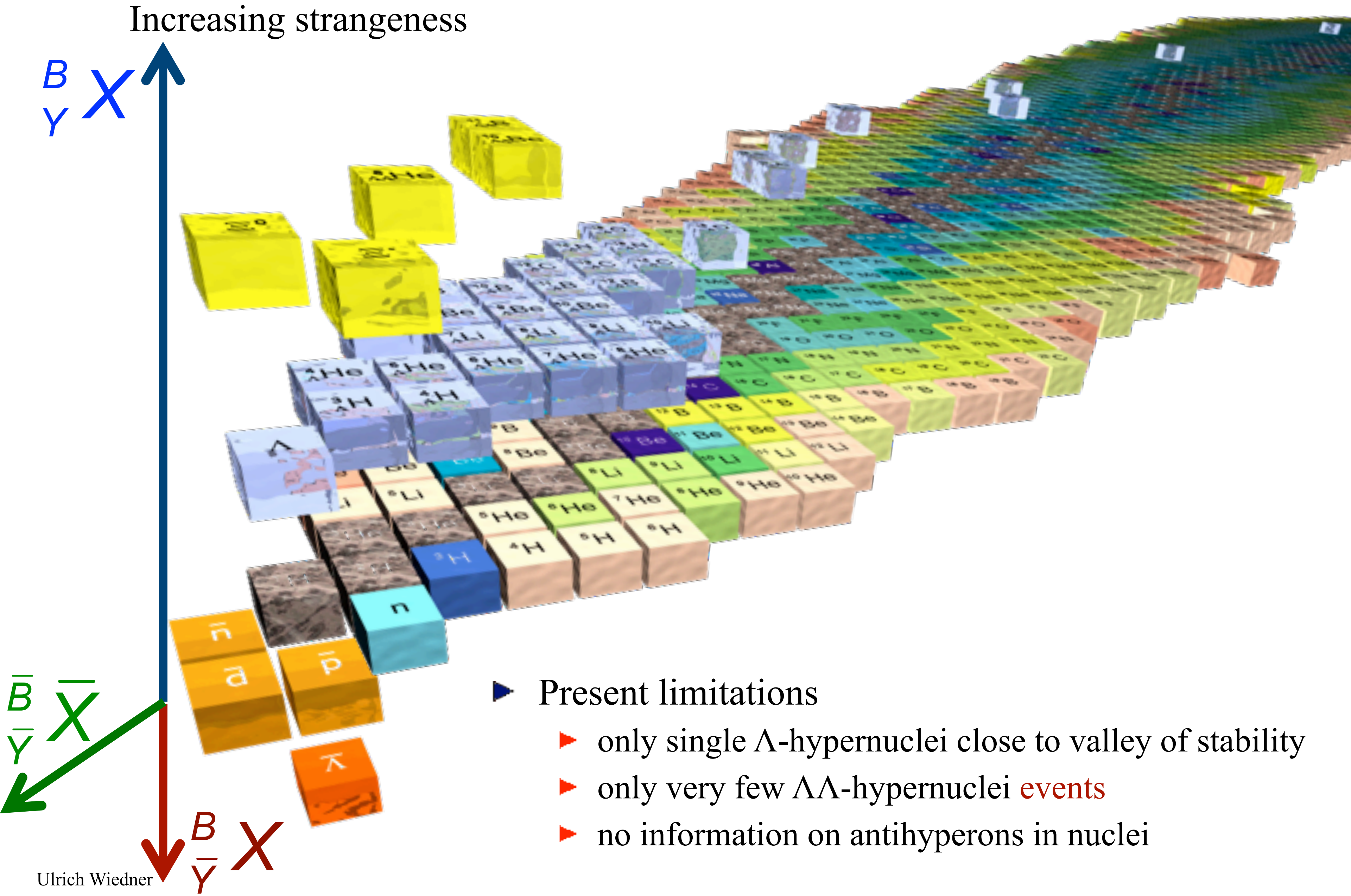
$$R = \frac{G_E}{G_M}$$

PANDA will measure the form factors in the biggest Q^2 range for a single experiment up to values of ~20 GeV^2/c^4 (beam time dependent).


|G_M|
10^-1
10^-2
10^-3
5
10
15
20
25
30
q^2[(GeV/c)^2]
Babar
E835
Fenice
PS170
E760
CLEO
DM1
DM2
BES
PANDA Sim

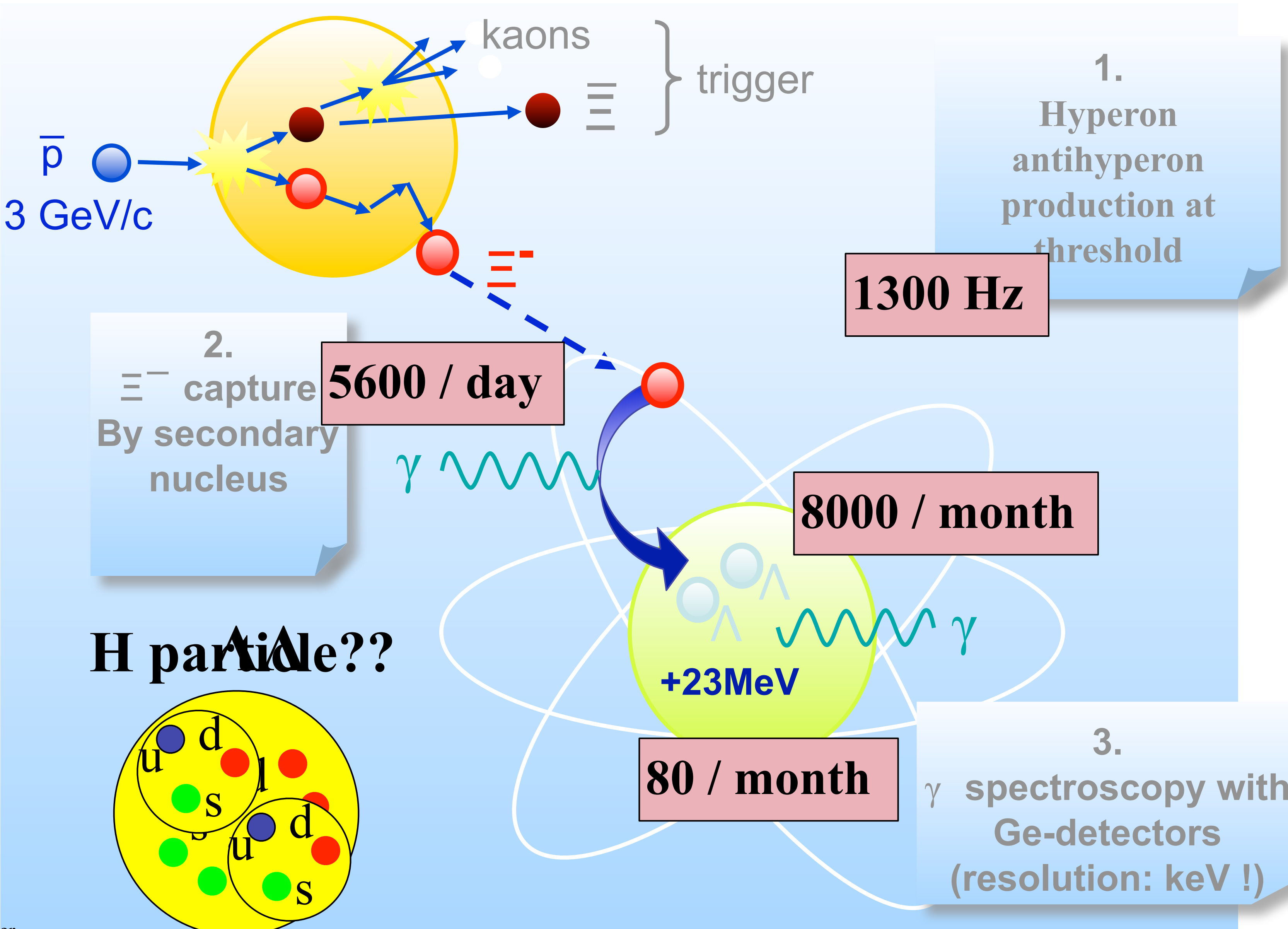
Hadronic Interactions

Adding the third dimension to the nuclear chart



- Present limitations
  - only single Λ-hypernuclei close to valley of stability
  - only very few ΛΛ-hypernuclei events
  - no information on antihyperons in nuclei

Production of double hypernuclei



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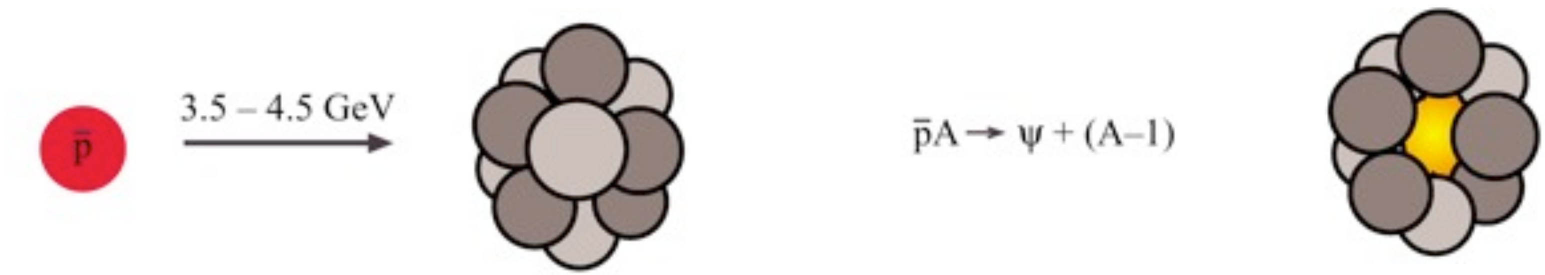
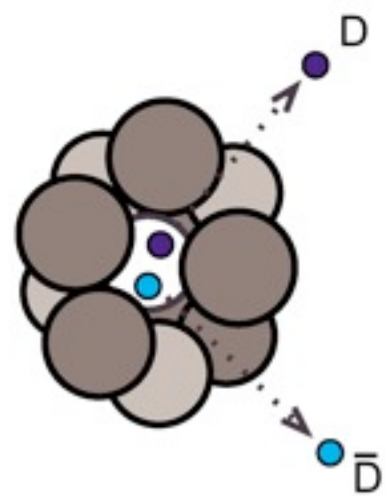
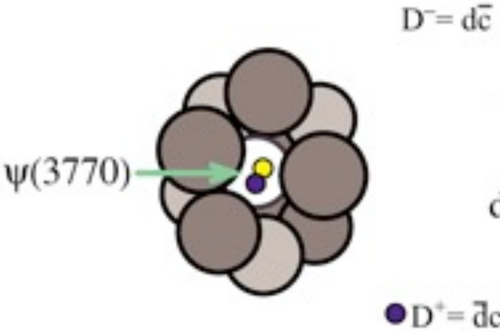
Implant charm in nuclei



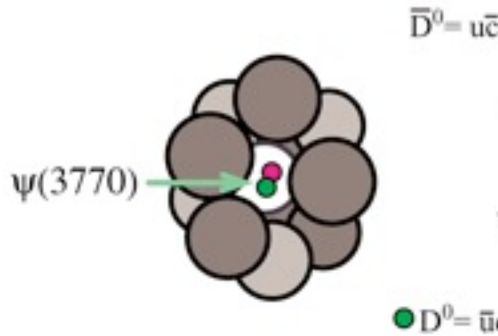
ψ (cc̄) decays into DD̄

D mesons interact
with rest nucleus

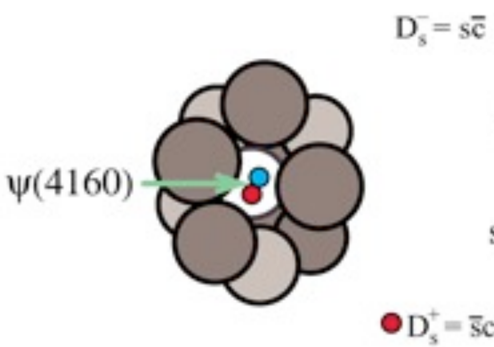




quark – nucleus interaction = d (or $\bar{d}$) – nucleus interaction*



quark – nucleus interaction = u (or $\bar{u}$) – nucleus interaction*



quark – nucleus interaction = s (or $\bar{s}$) – nucleus interaction*

* ignoring c (or $\bar{c}$) – nucleus interaction

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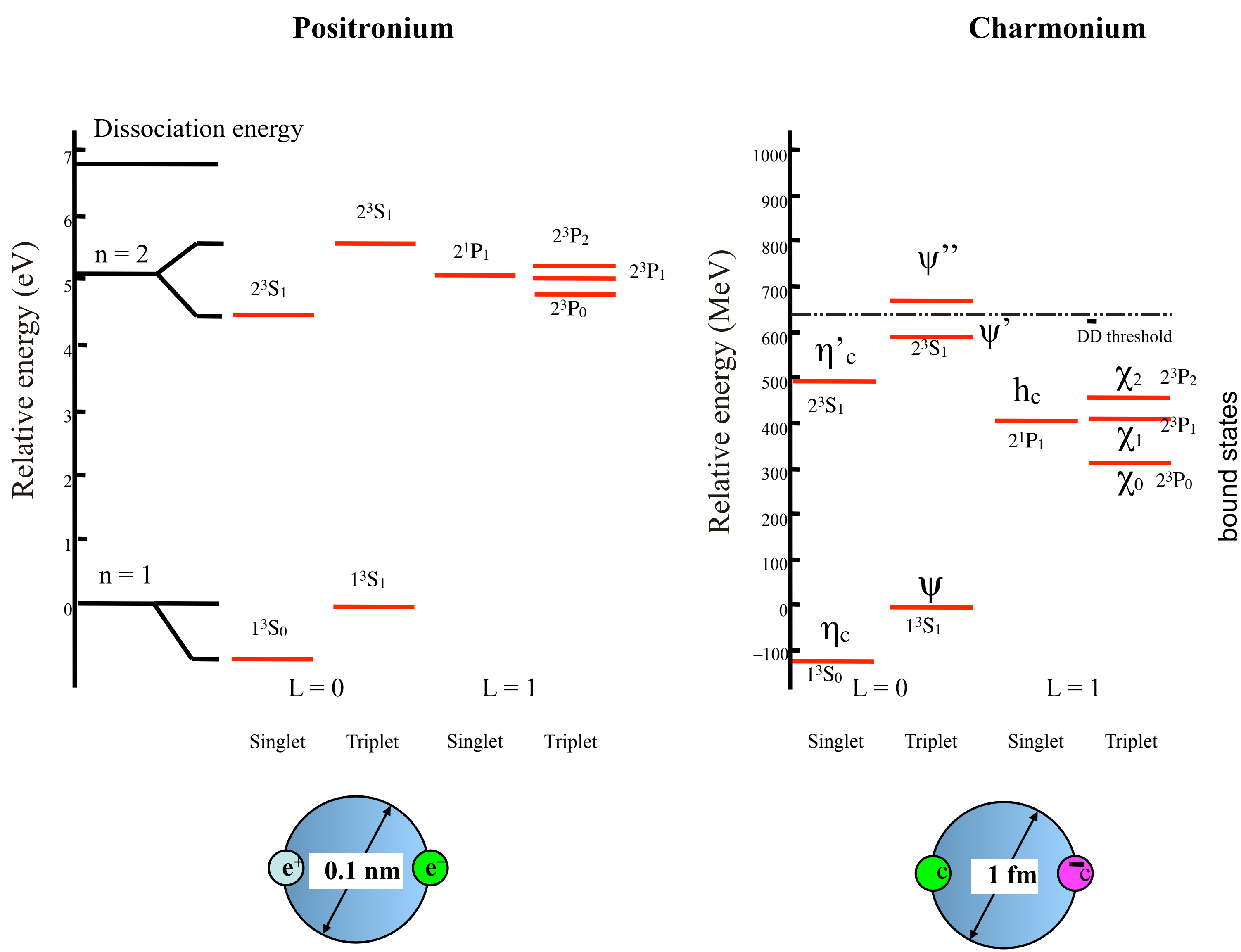
<u>Hadron Spectroscopy</u>



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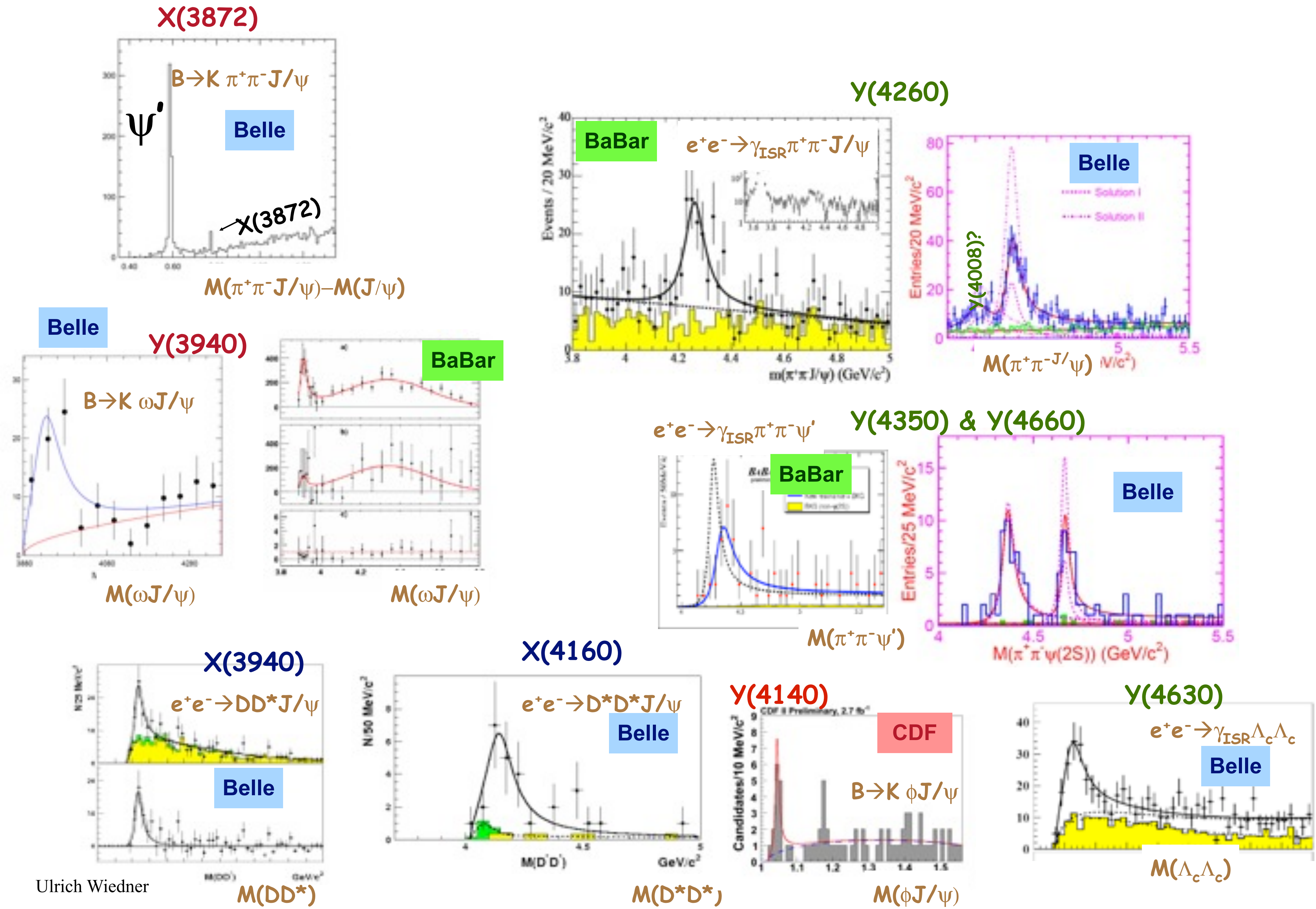
X and Y mesons



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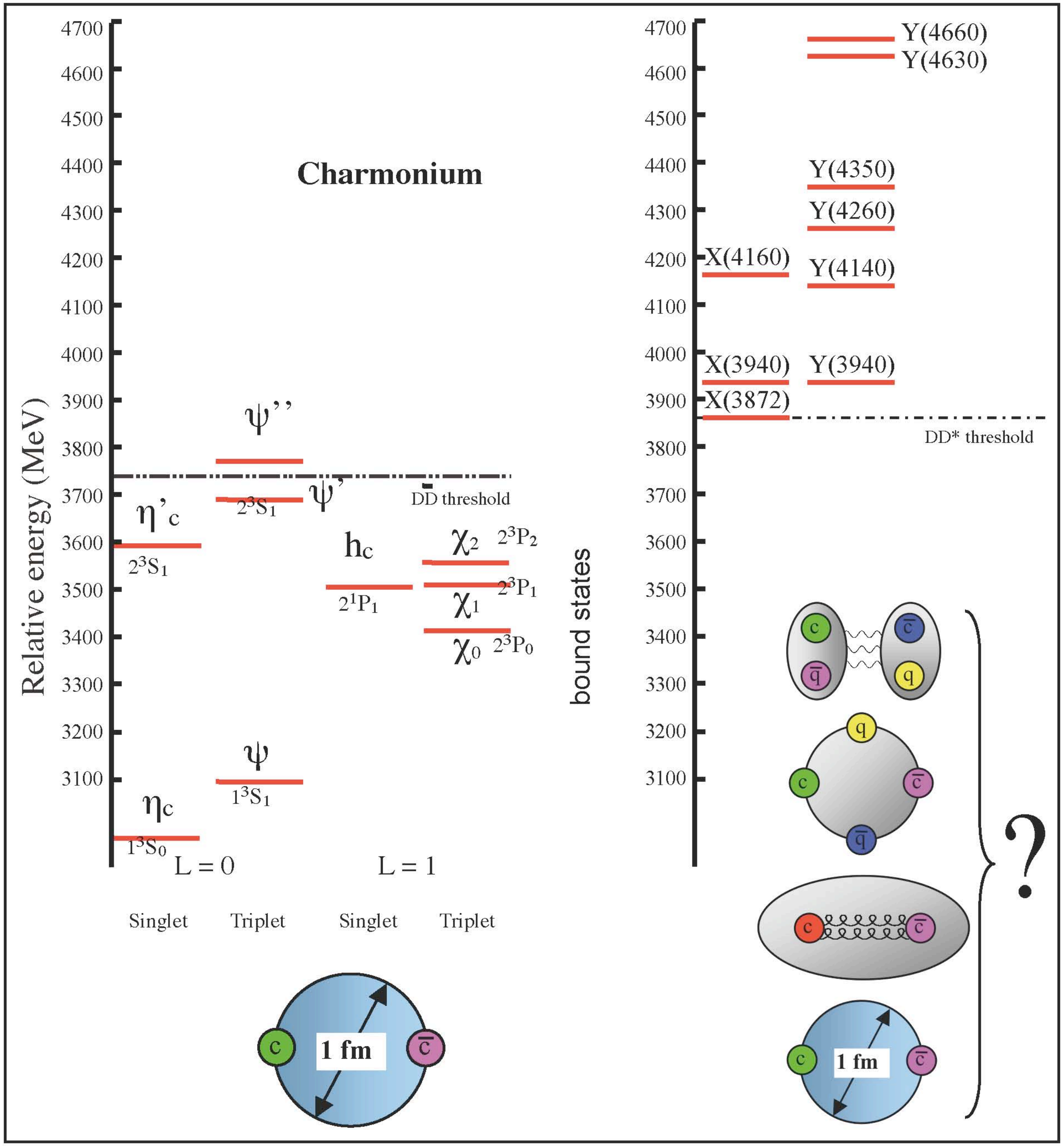

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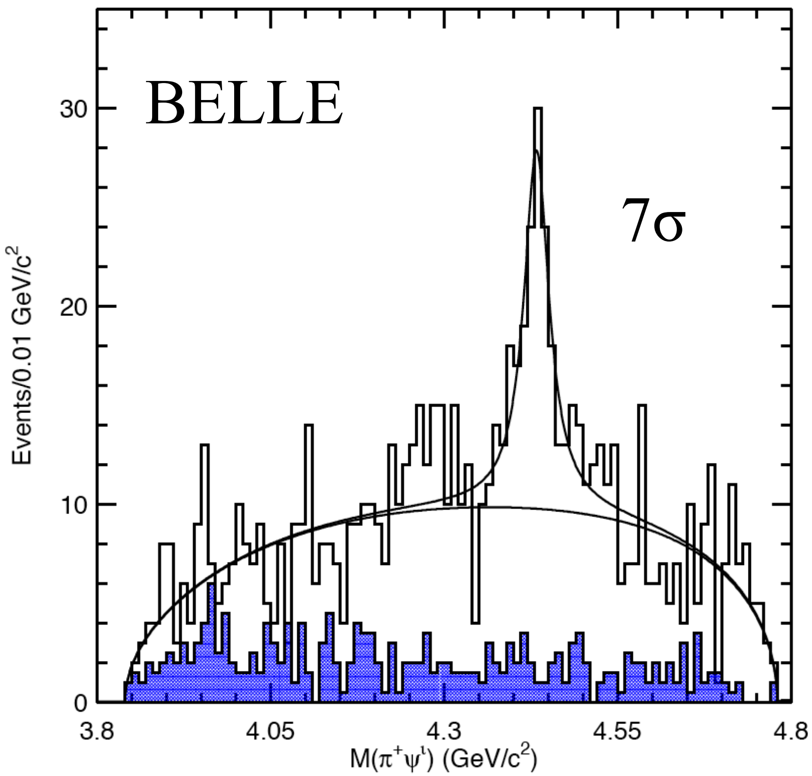
Z^+ (4430) - a new state of matter (tetraquark?) decaying into $\pi^+\psi'$



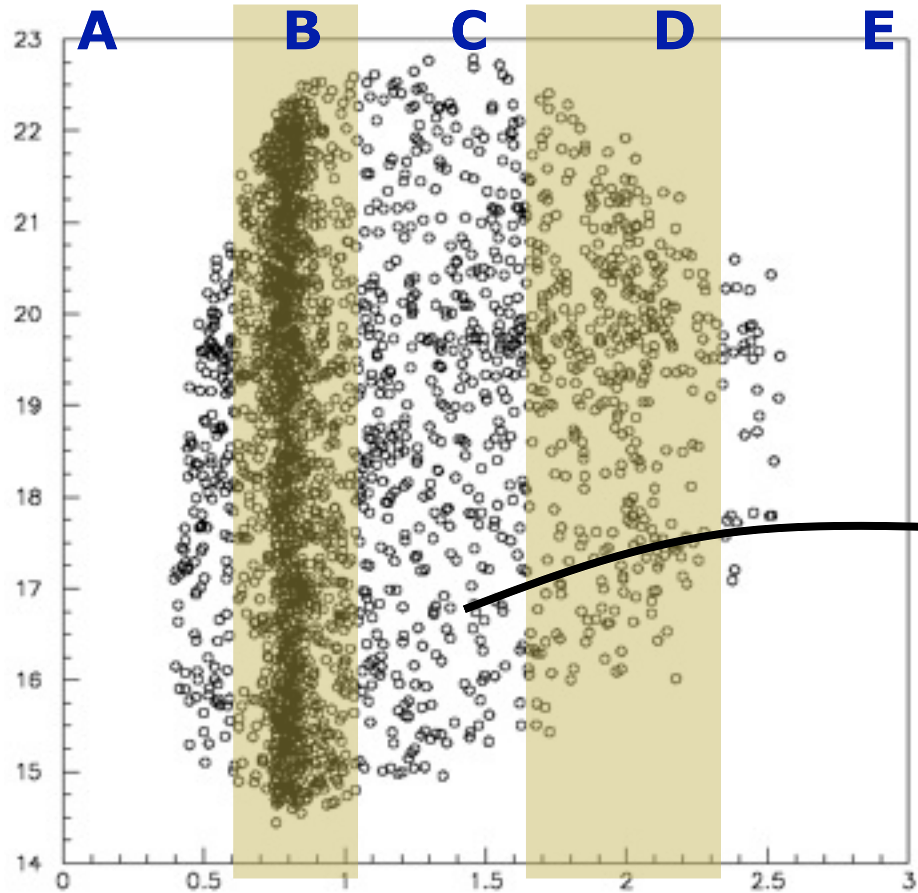
$$M = (4.433 \pm 0.004\ (\text{stat}) \pm 0.001\ (\text{syst}))\ \text{GeV}$$

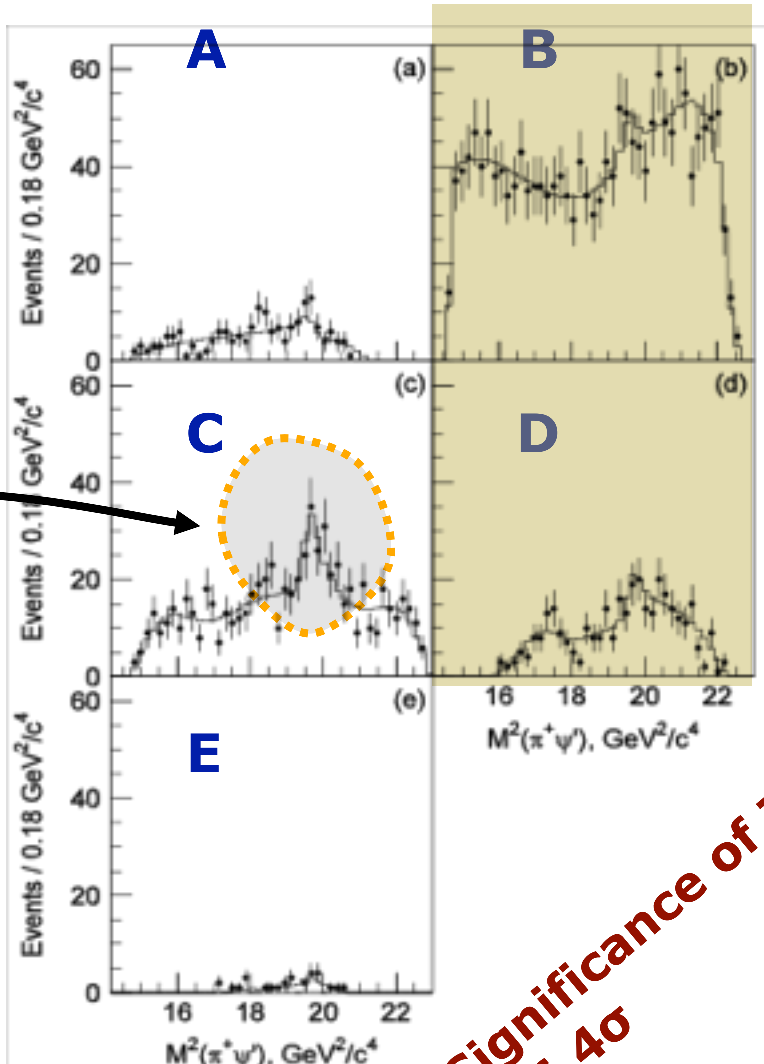
$$\Gamma = (0.044^{+0.017}_{-0.011}\ (\text{stat})^{+0.030}_{-0.011}\ (\text{syst}))\ \text{GeV}$$

$$\mathcal{B}(B \to KZ(4430)) \times \mathcal{B}(Z \to \pi^+\psi') = (4.1 \pm 1.0\ (stat) \pm 1.3\ (syst)) \times 10^{-5}$$

PRL 100, 142001 (2008)
arXiv:0708.1790 [hep-ex]

NEW results on Z(4430)⁺ from Dalitz plot fit





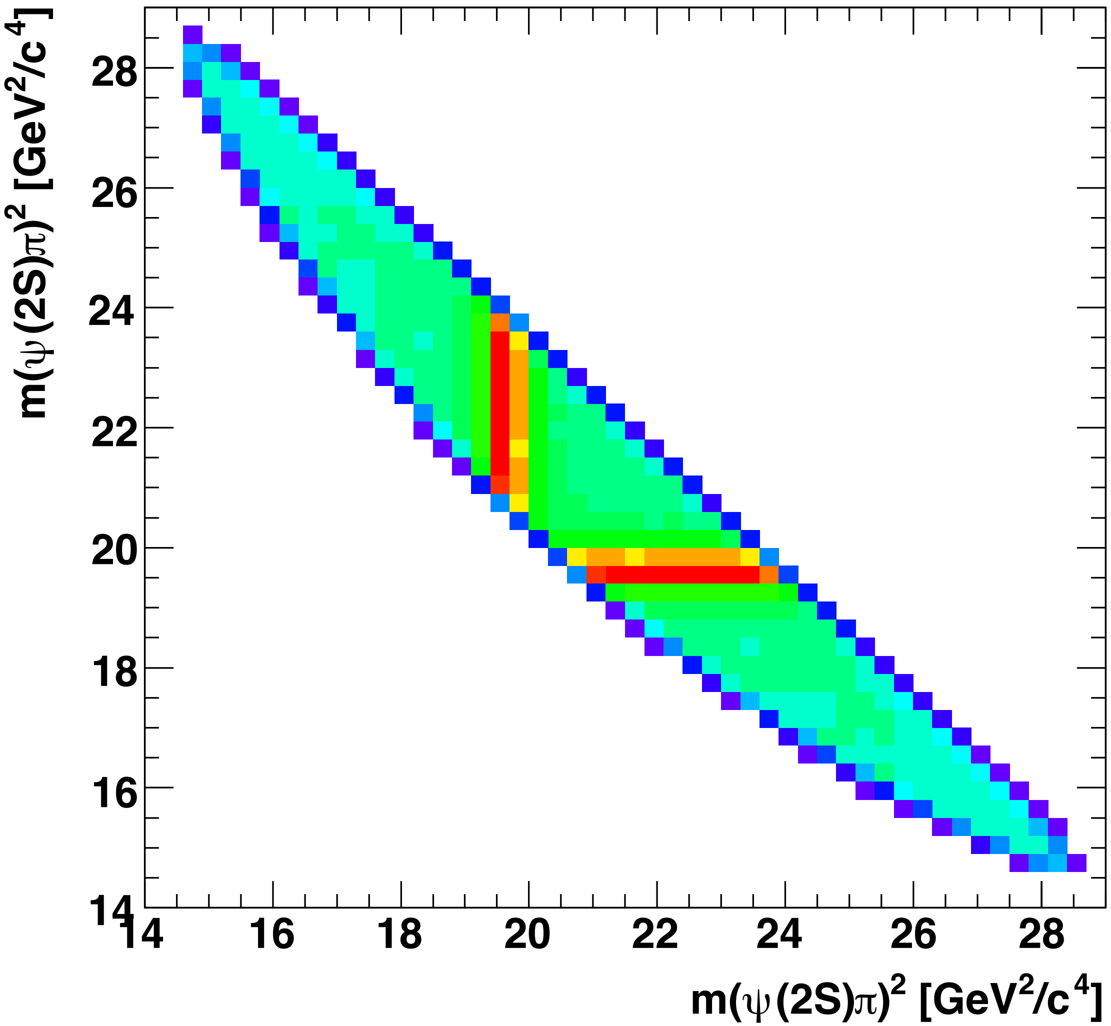
The results of the DP fit in its slices with Z:

Confidence Level of the fit WITH Z(4430)⁺ is 36%

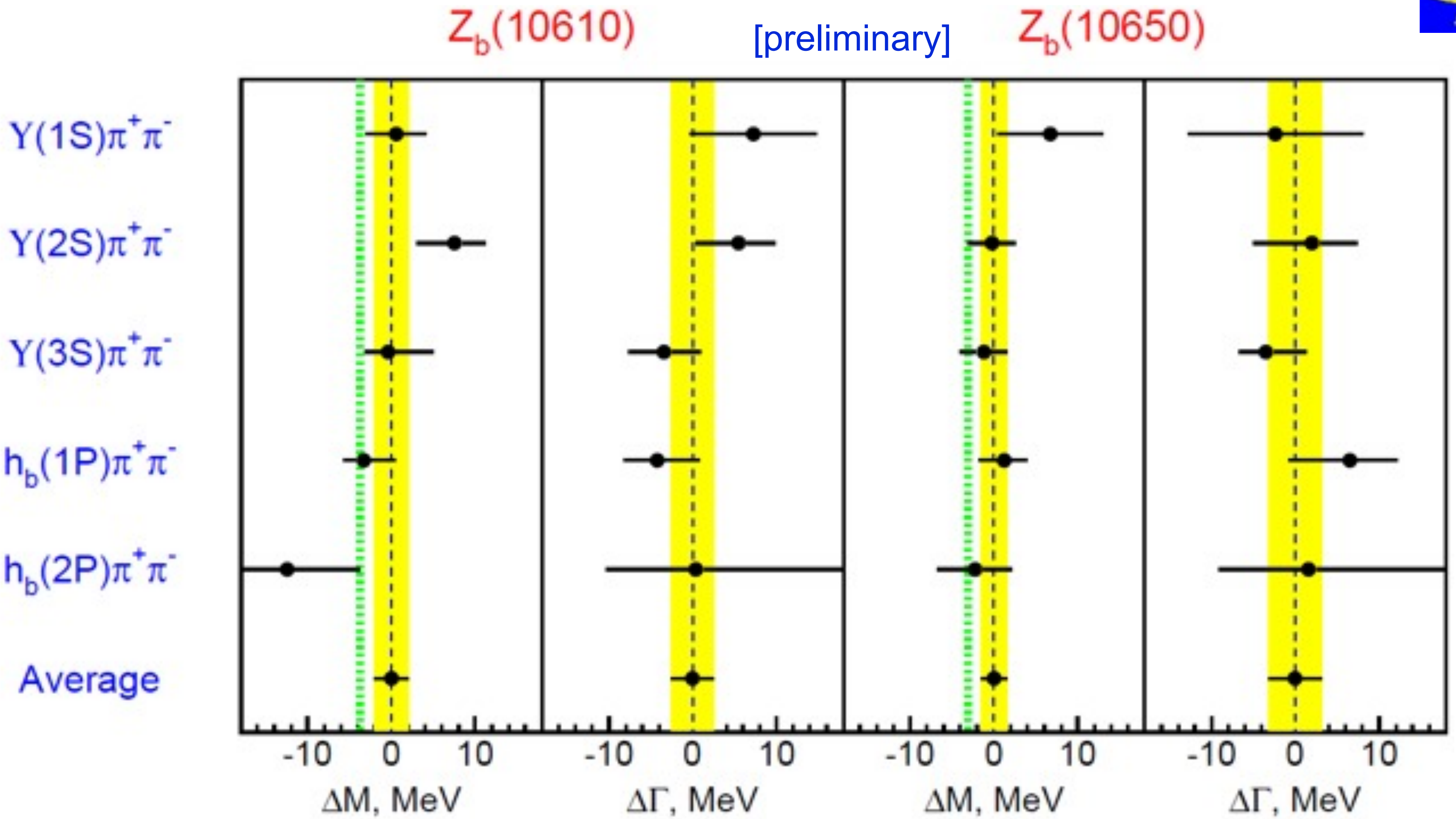
Significance of Z is 6.4σ

PANDA: $\bar{p}p \to Z^+(4430) + \pi^-$

panda MC studies



Summary of parameters of charged Z_b states



$Z_b(10610)$

M=10608.4±2.0 MeV

Γ=15.6±2.5 MeV

$Z_b(10650)$

M=10653.2±1.5 MeV

Γ=14.4±3.2 MeV

Alex Bondar, FPCP 2011, 23.5.2011

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x(3872) molecule

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[The **X(3872)** particle - The DZero Experiment - Fermilab]
www-d0.fnal.gov/Run2Physics/WWW/results/final/B/.../B04A.htm
Apr 15, 2004 – The **X(3872)** particle -- What is it? April 15 ... Some theories have predicted that the **X(3872)** is a new type of particle called a meson-**molecule**.

[PDF] D (2700), D (2860) and the open-charm system **X(3872)**: **molecu**...
web.na.infn.it/fileadmin/b-physics-workshop-2/.../colangelo.pdf
File Format: PDF/Adobe Acrobat - Quick View
sJ. (2860) and the open-charm system. **X(3872)**: **molecule** vs charmonium with Fulvia De Fazio, Rossella Ferrandes, Floriana Giannuzzi and Stefano Nicotri ...

X (3872) as a DD* **molecule** bound by quark exchange forces
arxiv.org › hep-ph
by C Pena - 2011 - Related articles
Dec 31, 2011 – Abstract: The Bethe-Salpeter equation for the T-Matrix of D-D* scattering is solved with a meson-meson potential that results from 2nd order ...

The **X (3872)** boson: **Molecule** or charmonium
arxiv.org › hep-ph
by M Suzuki - 2005 - Cited by 103 - Related articles
Aug 24, 2005 – Abstract: It has been argued that the mystery boson **X(3872)** is a **molecule** state consisting of primarily D0-D0*bar + D0bar-D*0. In contrast ...

Spin-parity analysis of the **X(3872)** « A Quantum Diaries Survivor
dorigo.wordpress.com/2006/06/.../spin-parity-analysis-of-the-**x3872**/
Jun 9, 2006 – Two possible spin-parity assignments of the **X(3872)** are equally probable: in particular, the X may be indeed a **molecular** bound state of two ...

Phys. Rev. D 72, 114013 (2005): **X(3872)** boson: **Molecule** or ...
link.aps.org › Journals › Phys. Rev. D › Volume 72 › Issue 11
by M Suzuki - 2005 - Cited by 103 - Related articles
Dec 19, 2005 – It has been argued that the mystery boson **X(3872)** is a **molecule** state consisting of primarily D0D̄ *0+D̄ 0D*0. In contrast, apparent puzzles ...

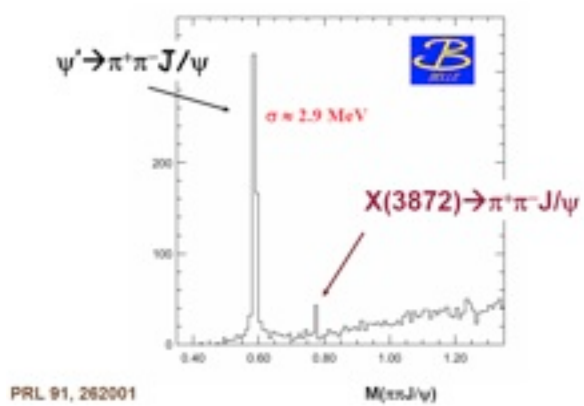
Charm meson **molecules** and the **X(3872)**
drc.ohiolink.edu/.../7166?...X(**3872**)...1...
Title: Charm meson **molecules** and the **X(3872)**. Author: Kusunoki, Masaoki.
Description: The recently discovered resonance **X(3872)** is interpreted as a ...

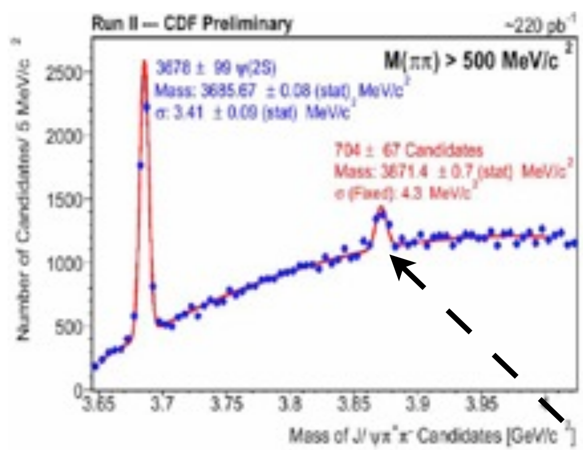
PROPERTIES OF **X(3872)** AS A HADRONIC **MOLECULE** WITH A ...
www.worldscinet.com/ijmpcs/02/0201/.../S2010194511000857.pdf
by M HARADA - Related articles

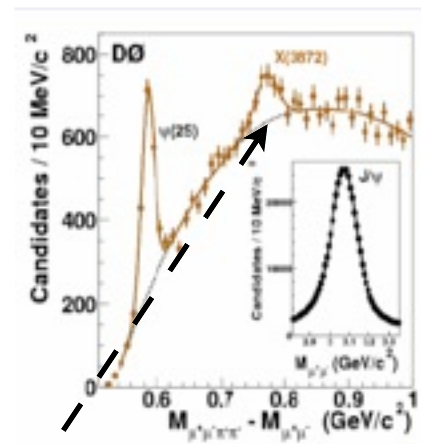
X(3872)

$\mathrm{B} \rightarrow KX;\ p\bar{p}$
$\mathrm{X} \rightarrow \pi^+\pi^- J/\psi$
$\mathrm{X} \rightarrow \pi^+\pi^-\pi^0 J/\psi$
$\mathrm{X} \rightarrow \gamma J/\psi;\ X \rightarrow \gamma\psi(2S)$
$\mathrm{X}(3875) \rightarrow D^0\bar{D}^0\pi^0$

$J^{PC} = 1^{++}$ (or 2^{-+})
$M = 3871.68 \pm 0.17$ MeV
$\Gamma < 1.2$ MeV
$> 10\ \sigma$





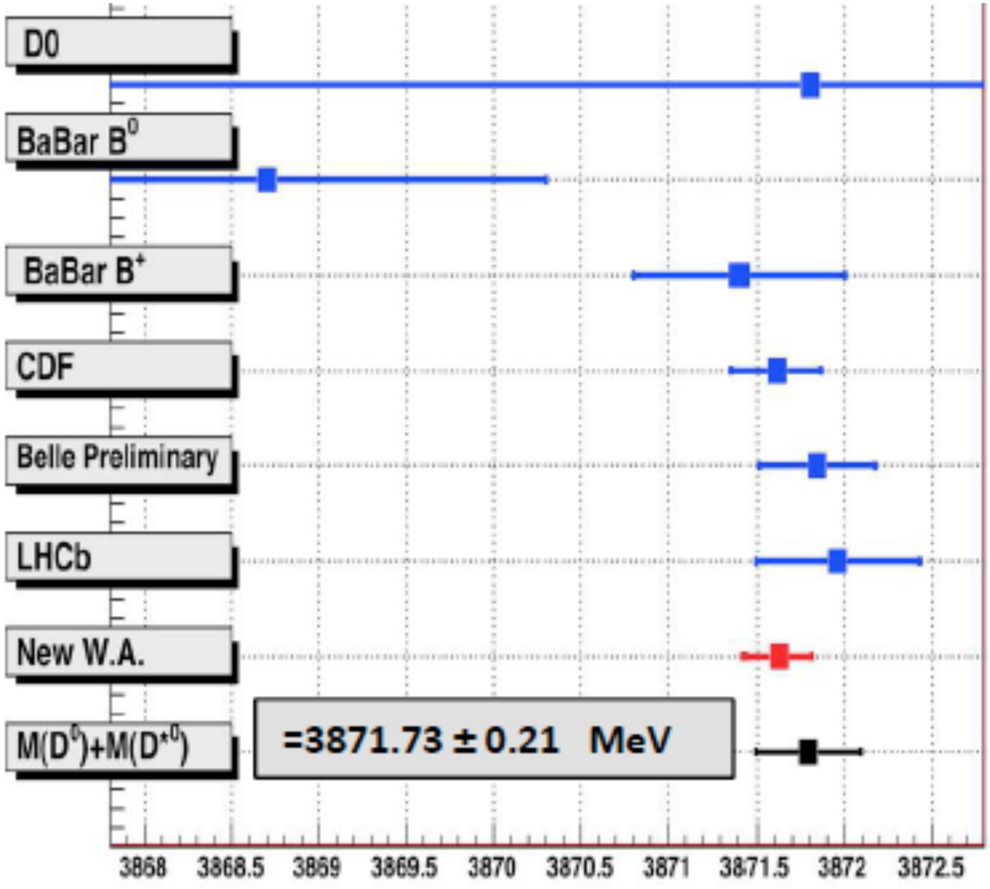


X(3872)

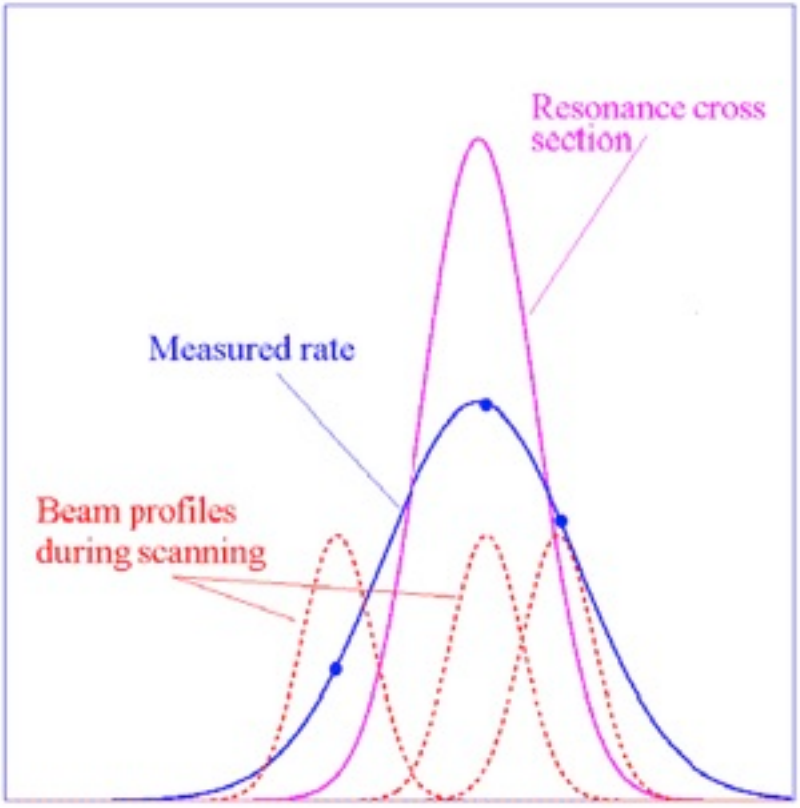
?

DD* molecule
threshold effect
<u>tetraquark</u>

X(3872 mass)


D0
BaBar B^0
BaBar B^+
CDF
Belle Preliminary
LHCb
New W.A.
$M(D^0)+M(D^{*0})$
=3871.73 ± 0.21 MeV
3868
3868.5
3869
3869.5
3870
3870.5
3871
3871.5
3872
3872.5

Resonance scan

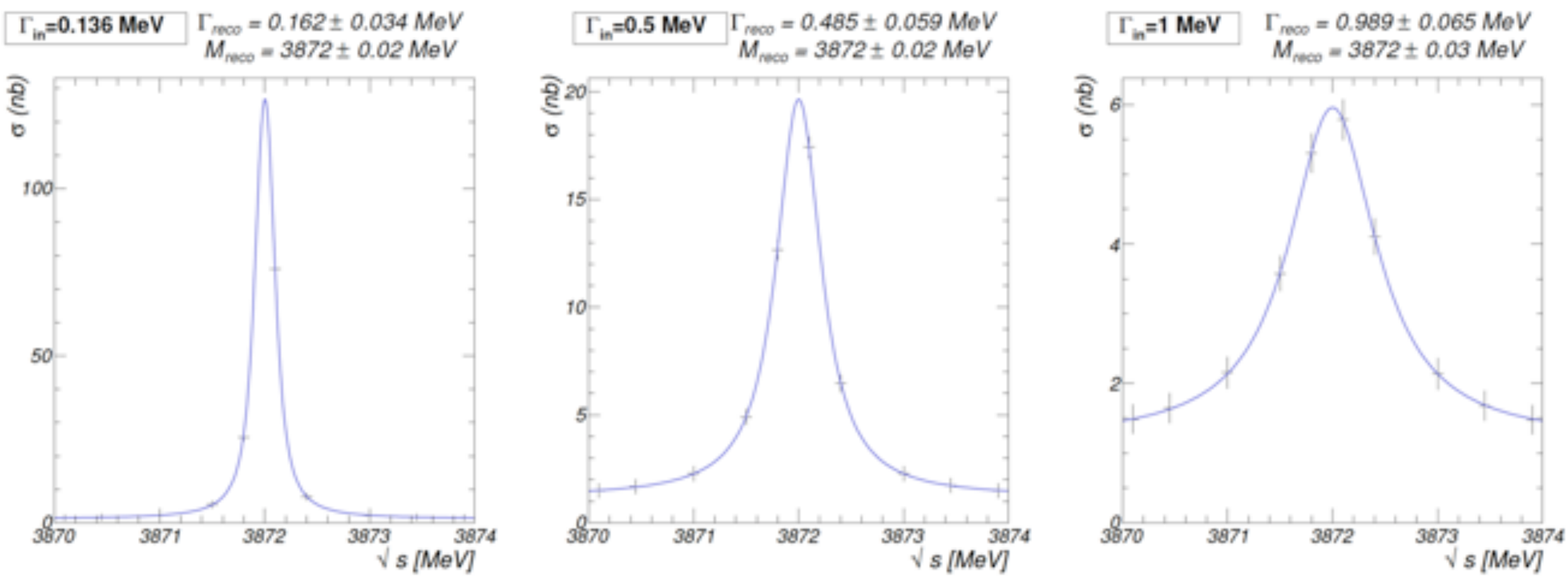


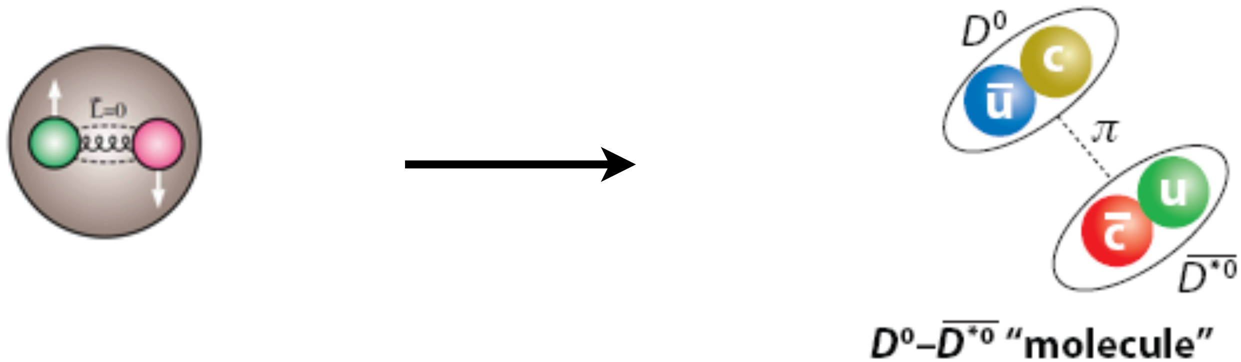
Measure rate of final state under study:

$$R_i = L_0 \bullet \sigma(p_i) \bullet K\,(\Delta p/p,\ |p_i - p_R|)$$

(K takes overlap between beam and resonance into account)

PANDA reconstruction of X(3872) mass and width

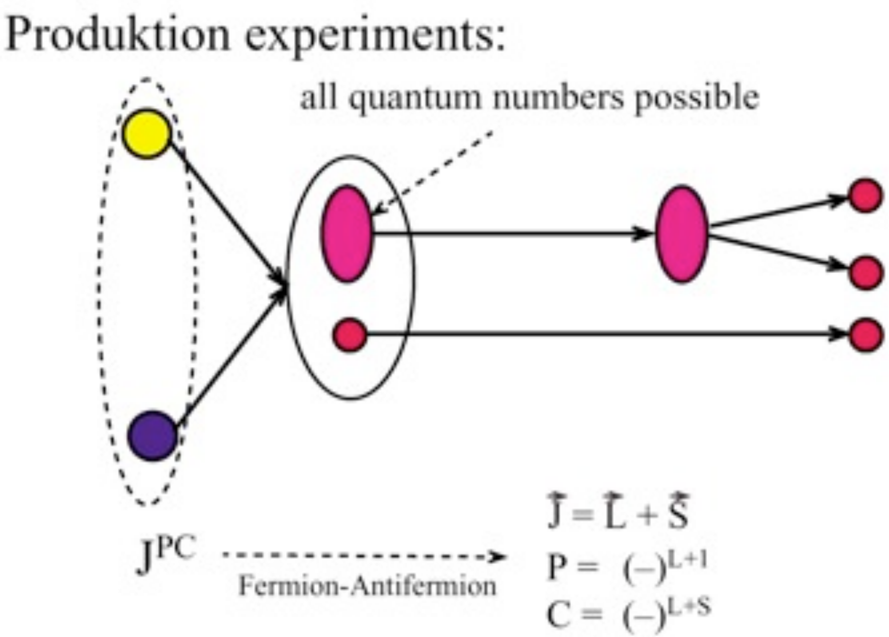


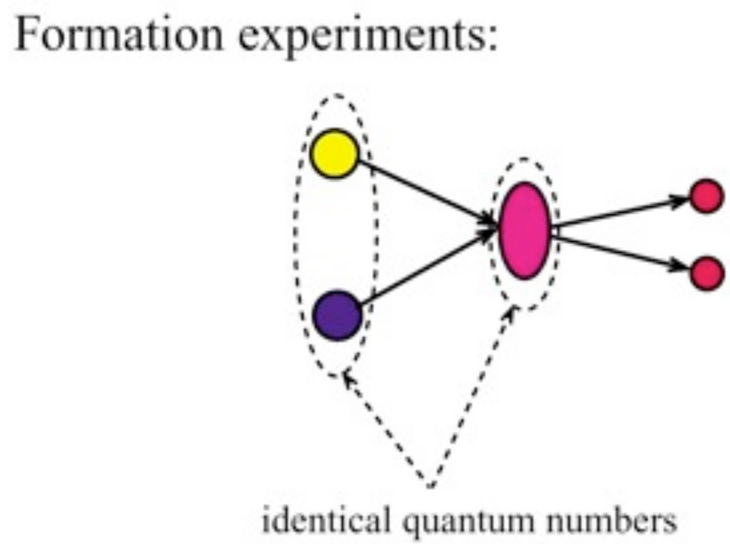


Transition from color forces to colorless nuclear forces ?

PANDA antiproton physics has advantages:

Production vs. Formation





Discovery potential

Precision physics

Ulrich Wiedner

Exotics

What we know:

$\pi_1(1400)$

Mass: 1400 ± 30 MeV
Width: 310 ± 70 MeV
Decay: $(\eta\pi)_{L=1}$
$J^{PC} = 1^{-+}$

A. Abele et al., Phys. Lett. B 423 (1998) 175.

light quarks: BROAD (~300 MeV) (likely unmixed)

$\pi_1(1660)$

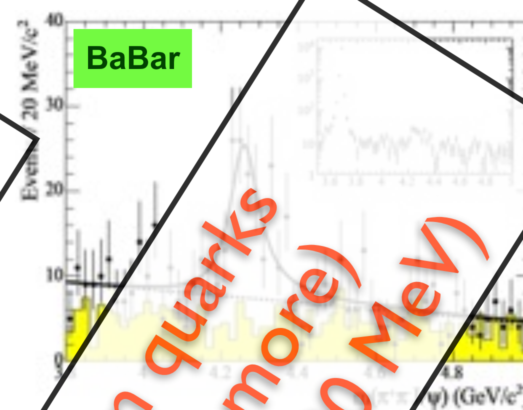
Mass: $1660 \pm 10^{+0}_{-64}$ MeV/c^2
Width: $269 \pm 21^{+42}_{-64}$ MeV/c^2
Decay: $(\rho\pi)$
$J^{PC} = 1^{-+}$

M.G. Alekseev et al., PRL 104 (2010) 241803

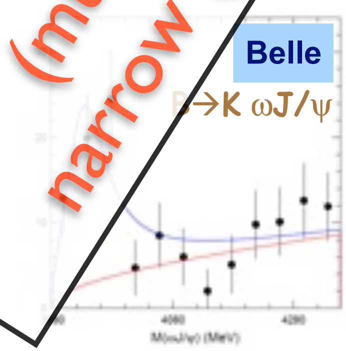
$s\bar{s}$ hybrids

??????

Y(4260)



Y(3940)



charm quarks (much more) narrow (~80 MeV)

JLAB@12 GeV

PANDA

PANDA Collaboration

- At present a group of **500 physicists** from 62 institutions and 16 countries

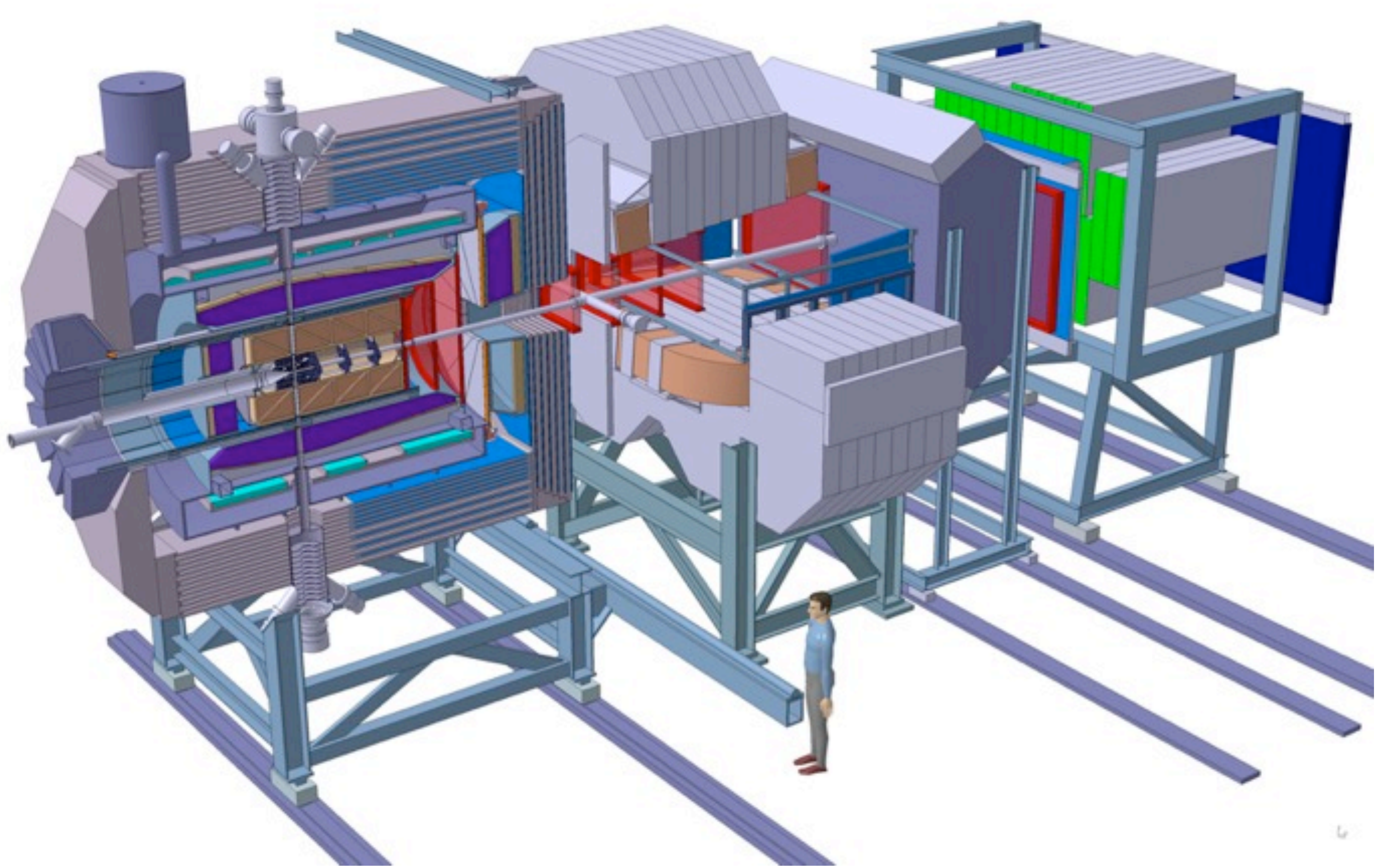
Austria – Belaruz – China – France – Germany – India – Italy – The Netherlands – Poland – Romania – Russia – Spain – Sweden – Switzerland – U.K. – U.S.A.

AMU Aligarh, Basel, Beijing, BITS Pillani, Bochum, IIT Bombay, Bonn, Brescia, IFIN Bucharest, IIT Chicago, AGH-UST Cracow, JGU Cracow, IFJ PAN Cracow, Cracow UT, Edinburgh, Erlangen, Ferrara, Frankfurt, Gauhati, Genova, Giessen, Glasgow, GSI, FZ Jülich, JINR Dubna, Katowice, KVI Groningen, Lanzhou, Legnaro, LNF, Lund, Mainz, Minsk, ITEP Moscow, MPEI Moscow, TU München, Münster, BARC Mumbai, Northwestern, BINP Novosibirsk, IPN Orsay, Pavia, IHEP Protvino, PNPI St.Petersburg, South Gujarat University, SVNIT Surat, Sadar Patel University, KTH Stockholm, Stockholm, FH Südwestfalen, Suranaree University of Technology, Dep. A. Avogadro Torino, Dep. Fis. Sperimentale Torino, Torino Politecnico, Trieste, TSL Uppsala, Tübingen, Uppsala, Valencia, NCBJ Warsaw, TU Warsaw, AAS Wien

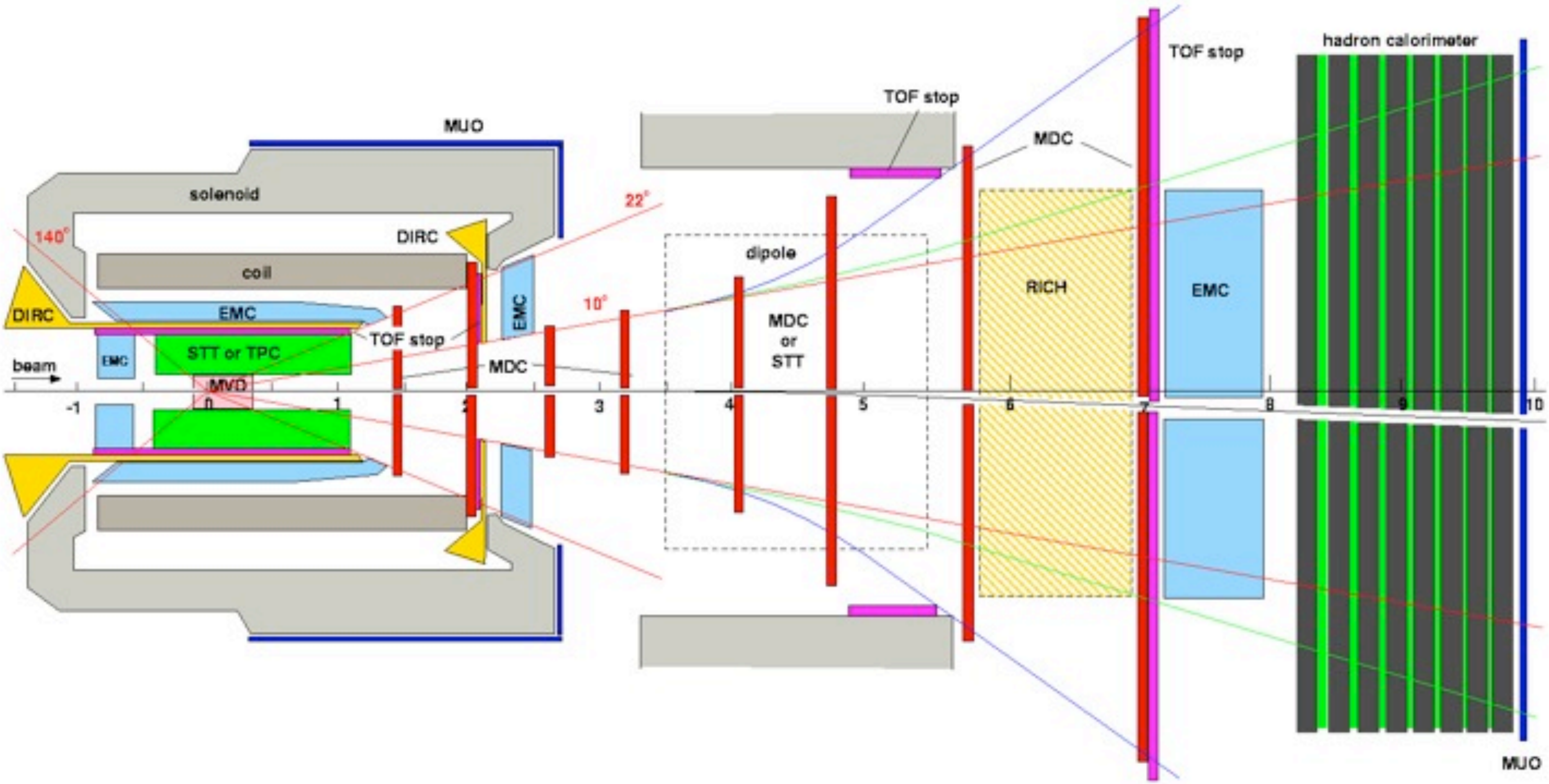
Spokesperson: Ulrich Wiedner (Bochum)

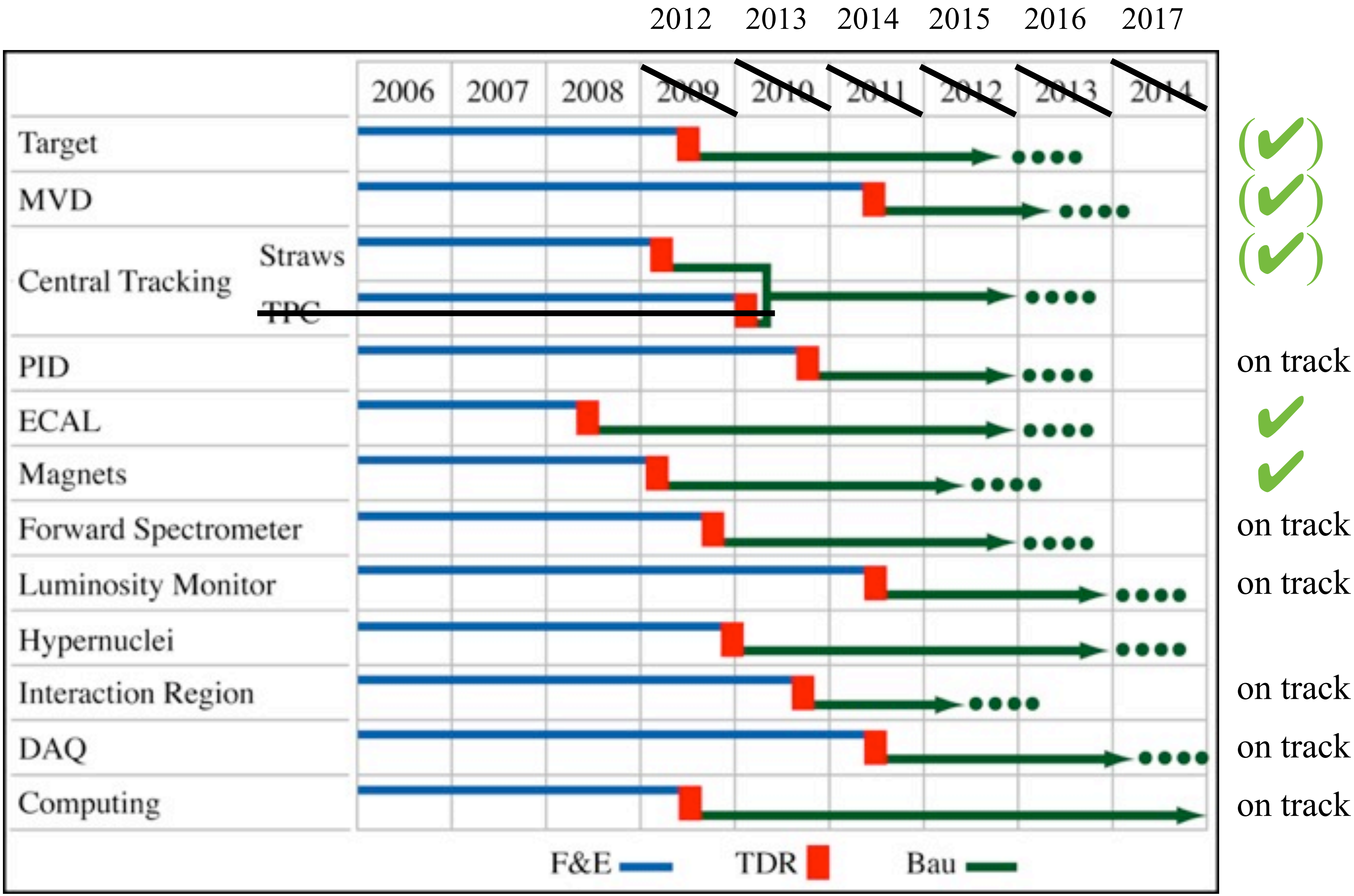
http://www.gsi.de/panda

The PANDA Detector



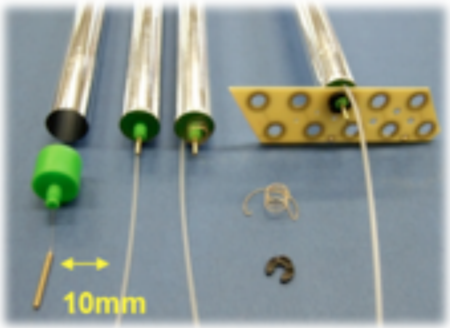
Layout of the detector (top view)

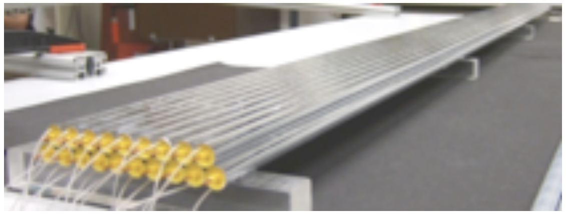


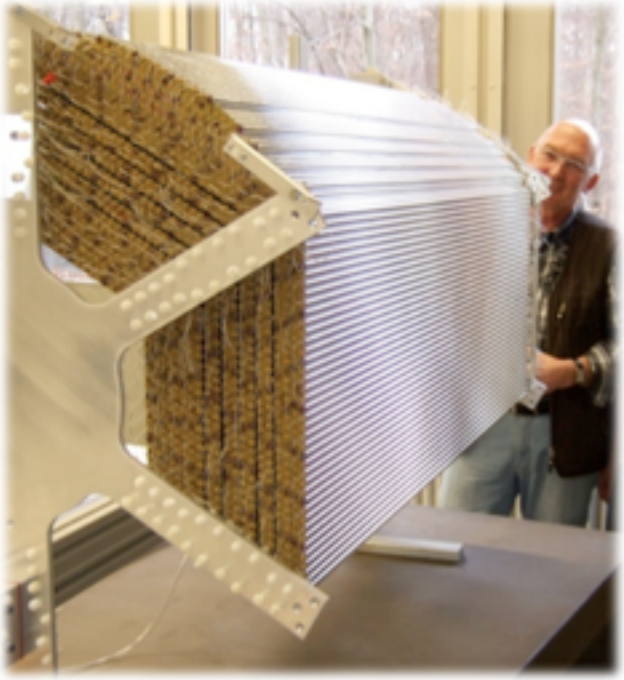


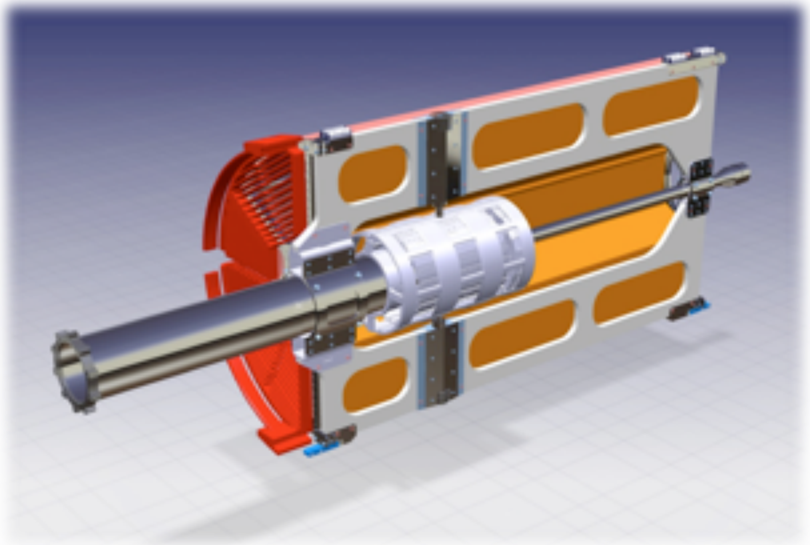
2012 2013 2014 2015 2016 2017
2006 2007 2008 2009 2010 2011 2012 2013 2014
Target
MVD
Central Tracking
Straws
TPC
PID
ECAL
Magnets
Forward Spectrometer
Luminosity Monitor
Hypernuclei
Interaction Region
DAQ
Computing
F&E
TDR
Bau
(✔)
(✔)
(✔)
on track
✔
✔
on track
on track
on track
on track
on track

The PANDA Central Tracker

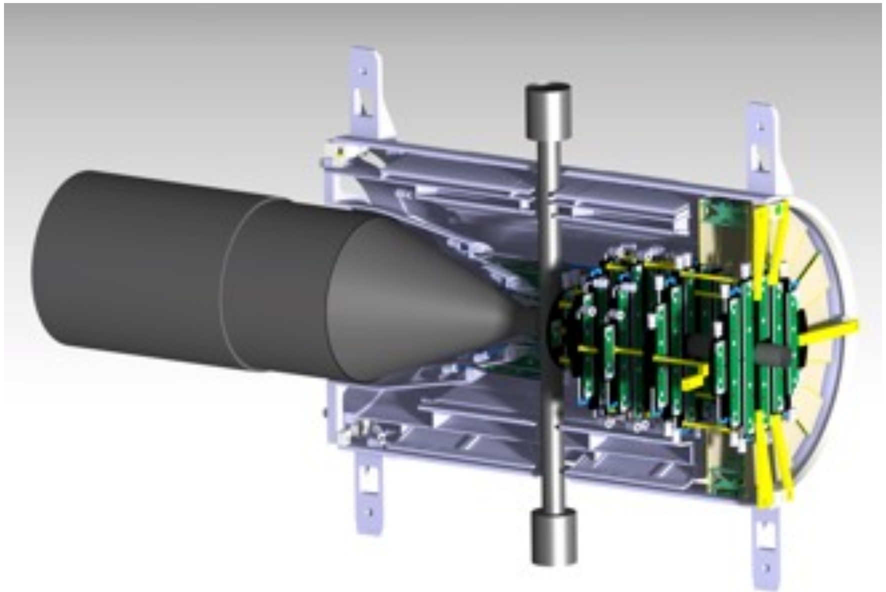




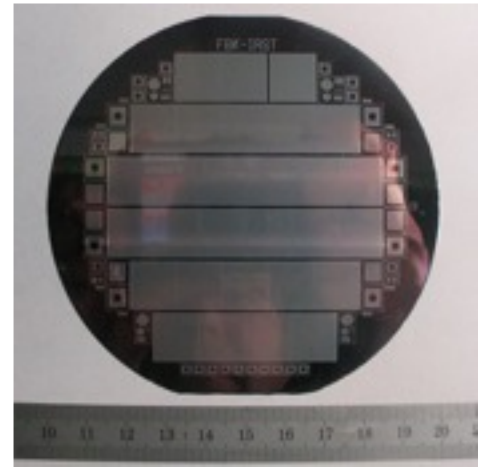




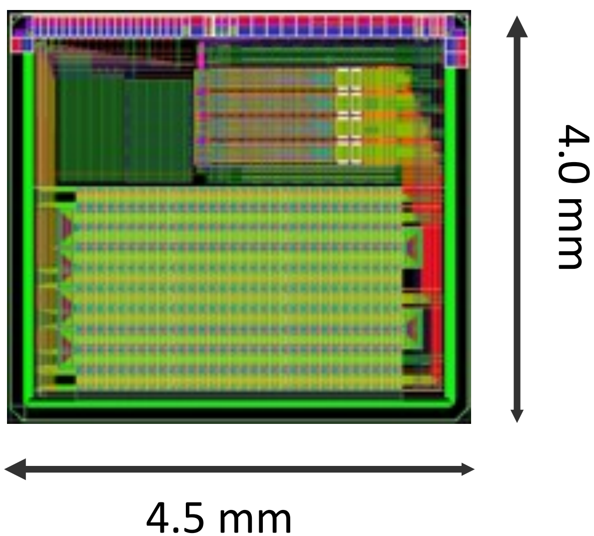
The PANDA MVD



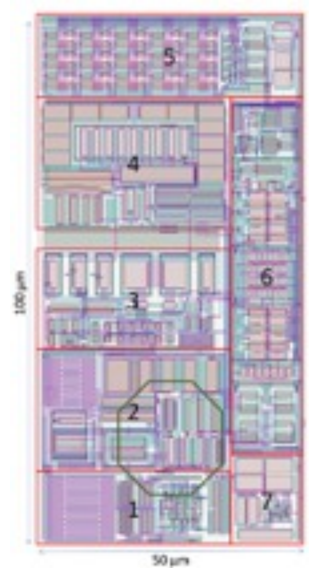
Full-Size Prototypes

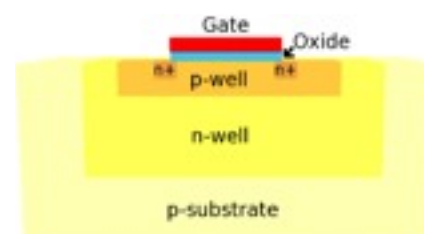


ASIC Prototypes

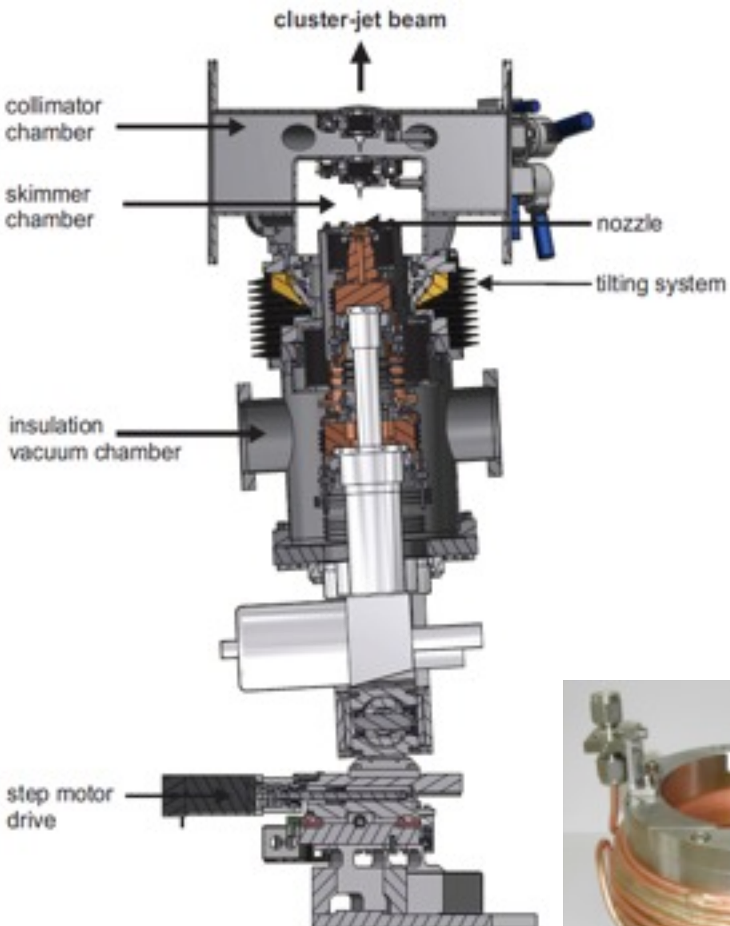


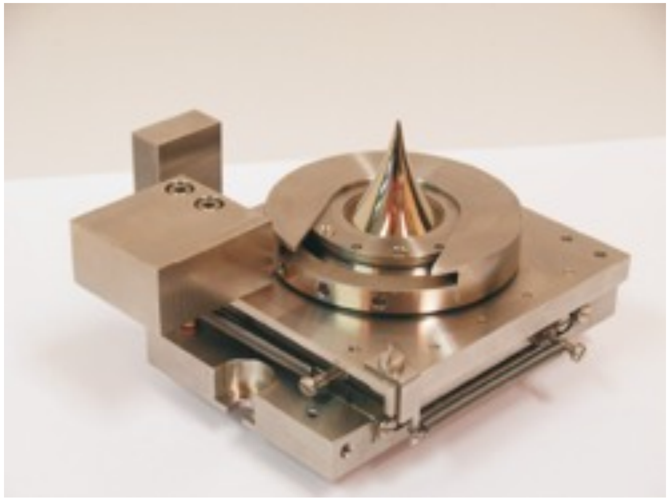
ToPix v3 Full-Feature Prototype





The PANDA Cluster Target





Topics not mentioned

- study of glueballs
- baryon-antibaryon pair production
- CP violation in the charm sector
- J/ψ nucleon scattering
- open charm physics
- anti-deuteron production
- …

Thank you!