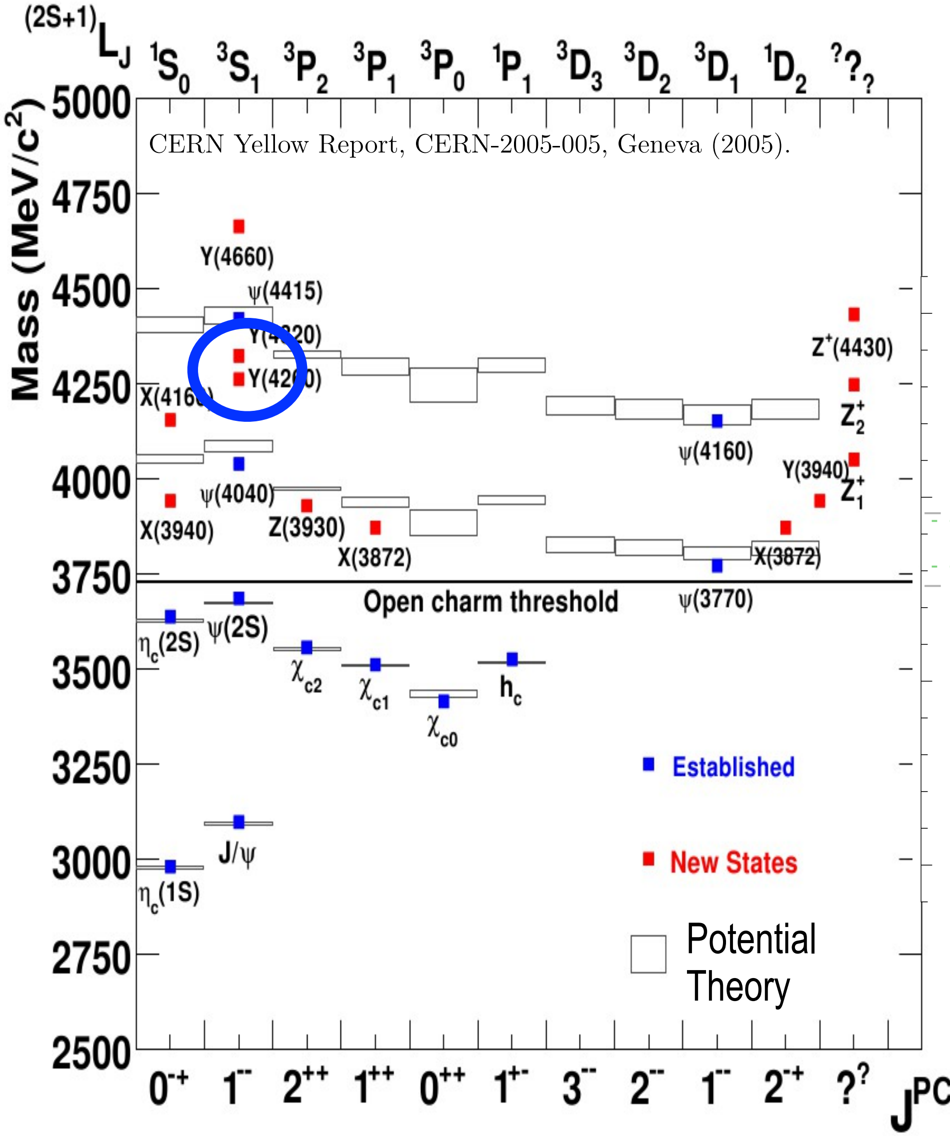
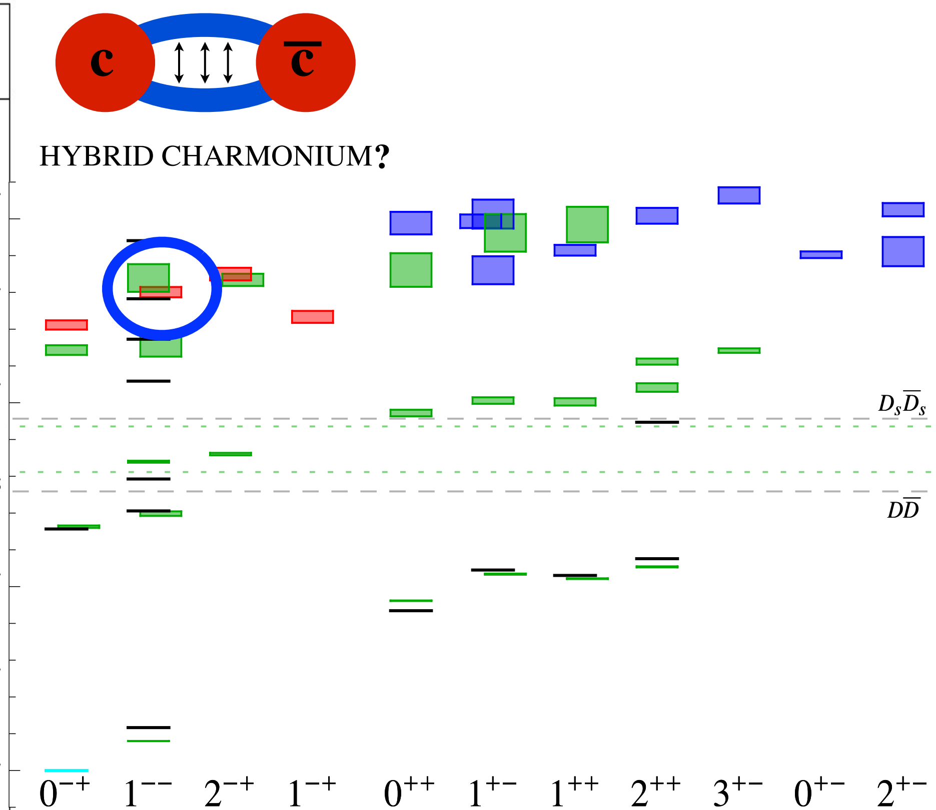
terra incognita: QCD exotics?

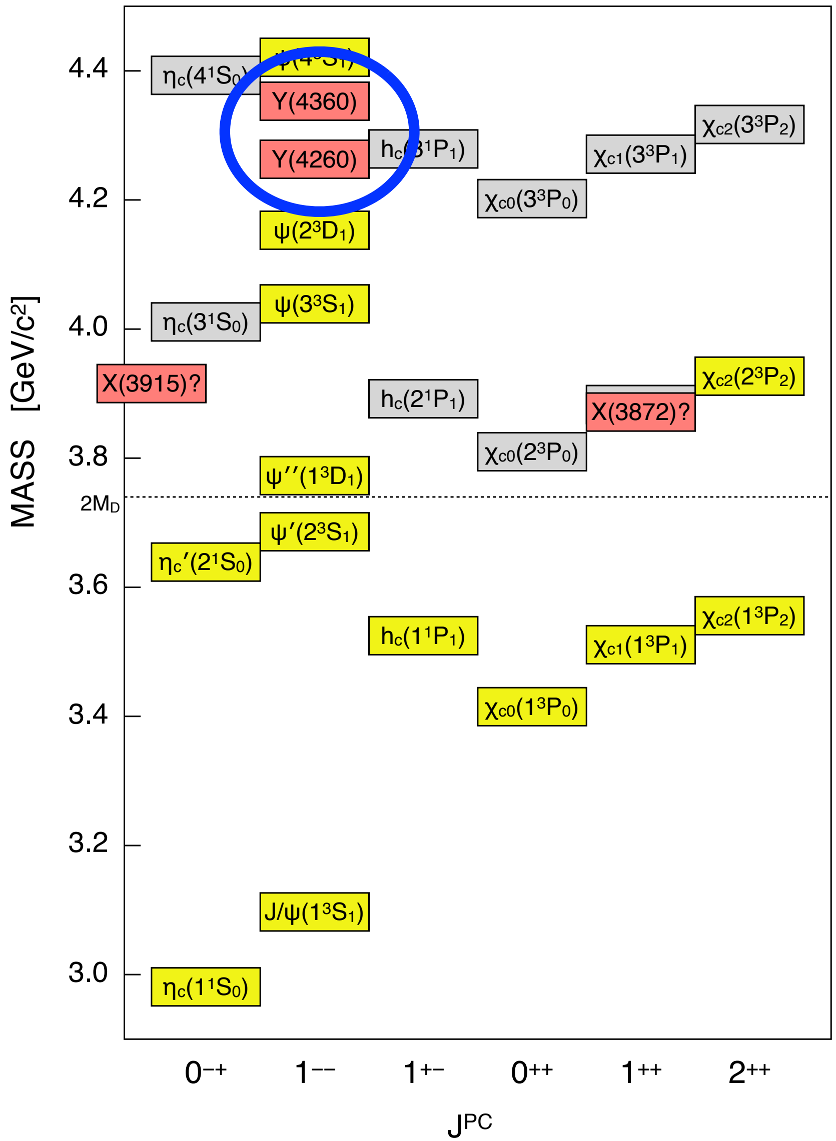


Lattice calculations



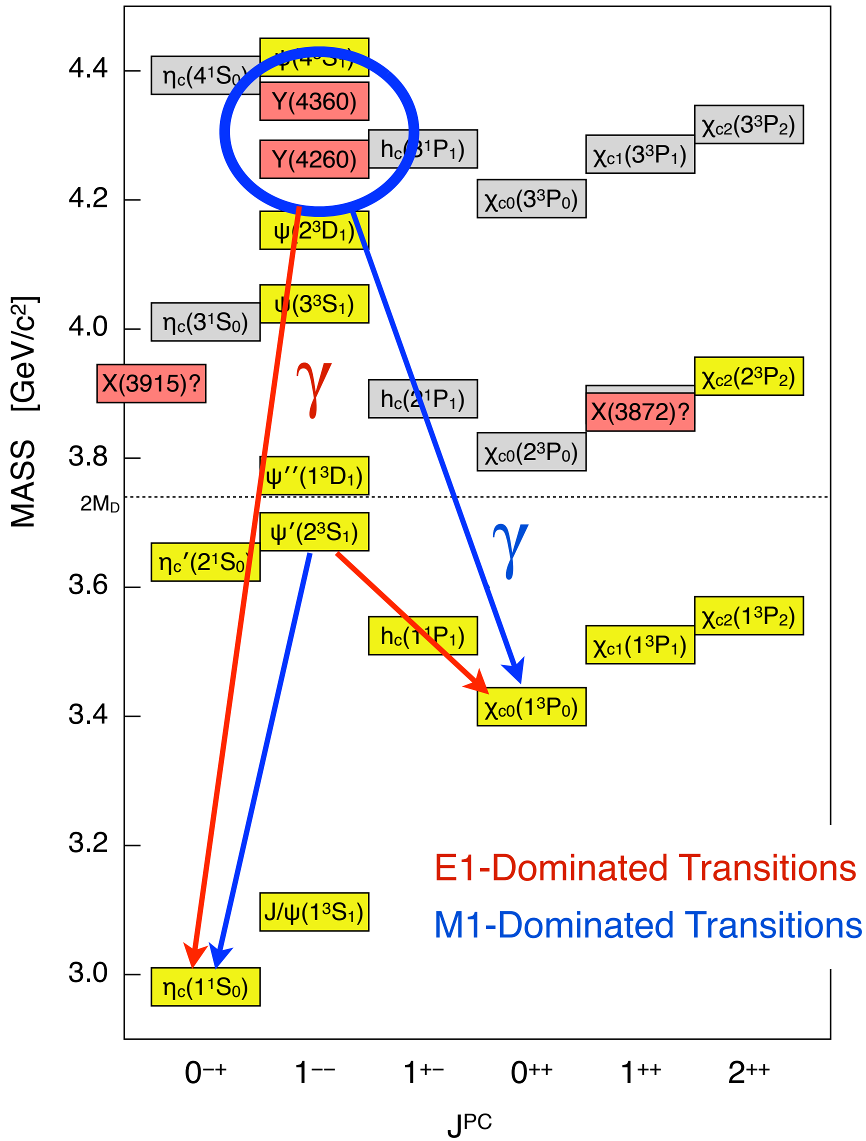
Hadron Spectrum Collaboration
JHEP 1207, 126 (2012)

terra incognita: QCD exotics?



ONGOING: 2x500 pb^{-1} data being taken at 4260 & 4360 MeV

terra incognita: QCD exotics?



BESШ

ONGOING: 2x500 pb^{-1} data being taken at 4260 & 4360 MeV

PLAN: measure hadronic & e.m. transition rates of Y states to study orbital-spin structure (e.g. S=0?)

A quark model state with $\mathbf{J^{PC} = 1^{--}}$ has:

even L (since $P = (-1)^{L+1}$) and

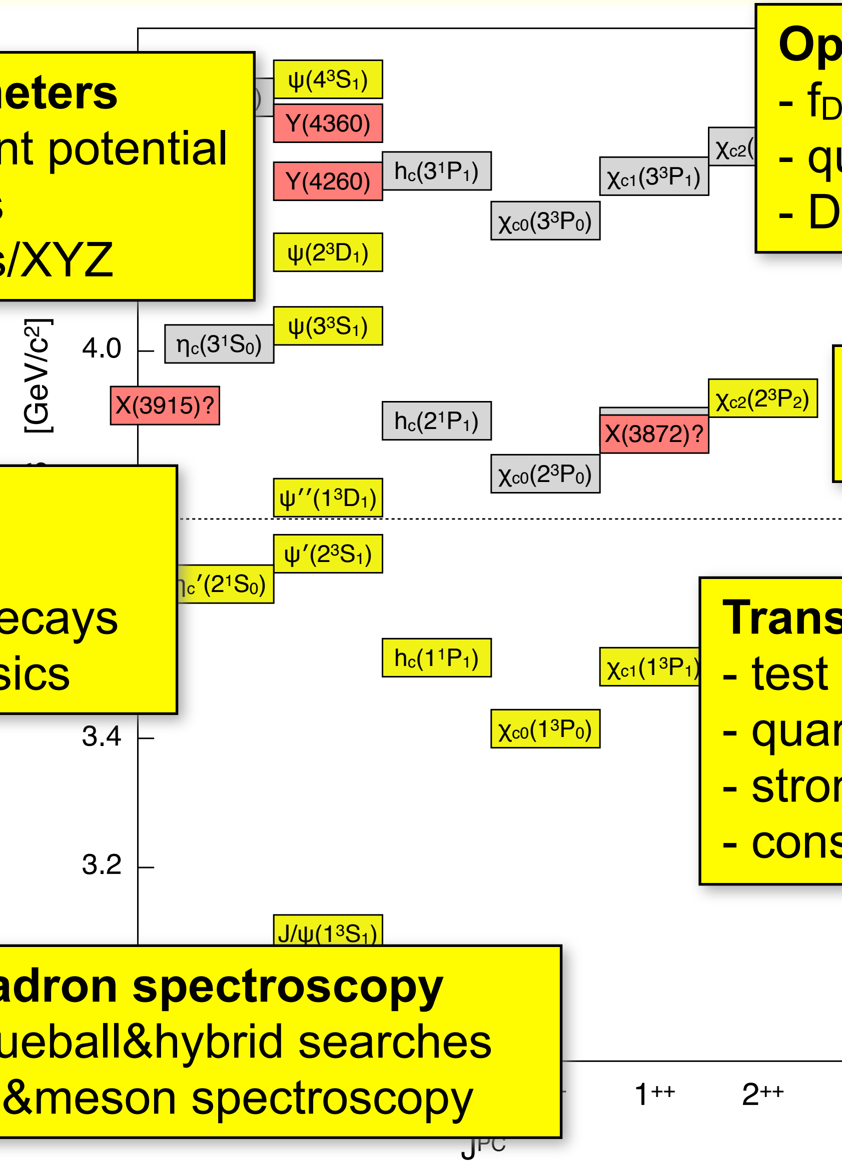
odd S (since $C = (-1)^{L+S}$).

So $\mathbf{J^{PC} = 1^{--}}$ and $\mathbf{S = 0}$

⇒ a non-quark model state

STAY TUNED!

Charmonium physics potentials



Resonance parameters
- details confinement potential
- line shape studies
- exotic resonances/XYZ

Open charm ($D_{(s)}$)
- f_D decay constant
- quark mixing matrix
- D_s spectroscopy

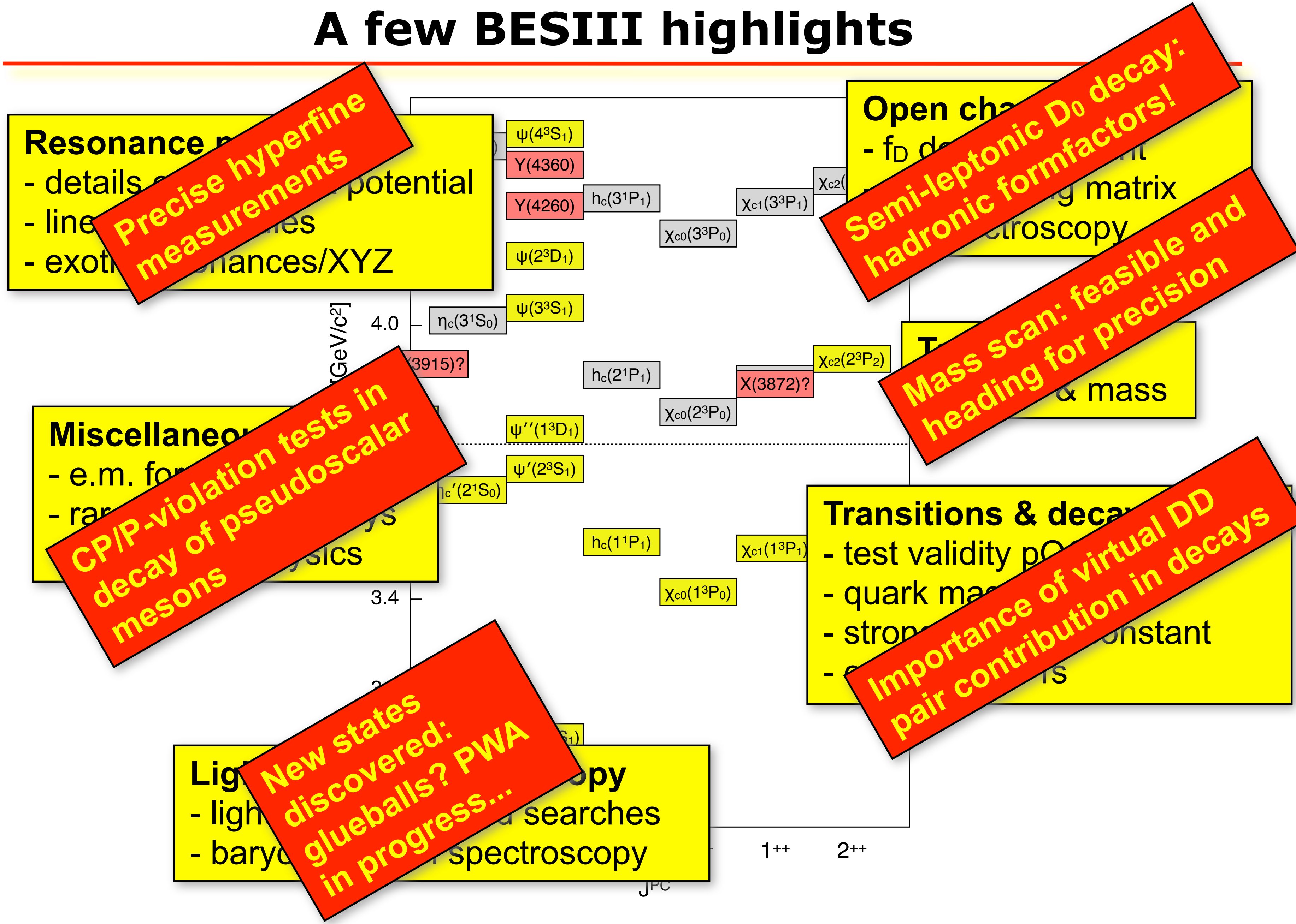
Tau physics
- decays & mass

Miscellaneous
- e.m. formfactors
- rare/forbidden decays
- beyond SM physics

Transitions & decays
- test validity pQCD
- quark masses
- strong coupling constant
- constrain EFTs

Light hadron spectroscopy
- light glueball&hybrid searches
- baryon&meson spectroscopy

A few BESIII highlights



The next generation charmonium spectroscopy

BESIII at IHEP, China

> electron+positron

> couples to $J^{PC}=1^{--}$ states

> clean environment

PANDA at FAIR, Germany

> **anti-proton**+proton or light nuclei

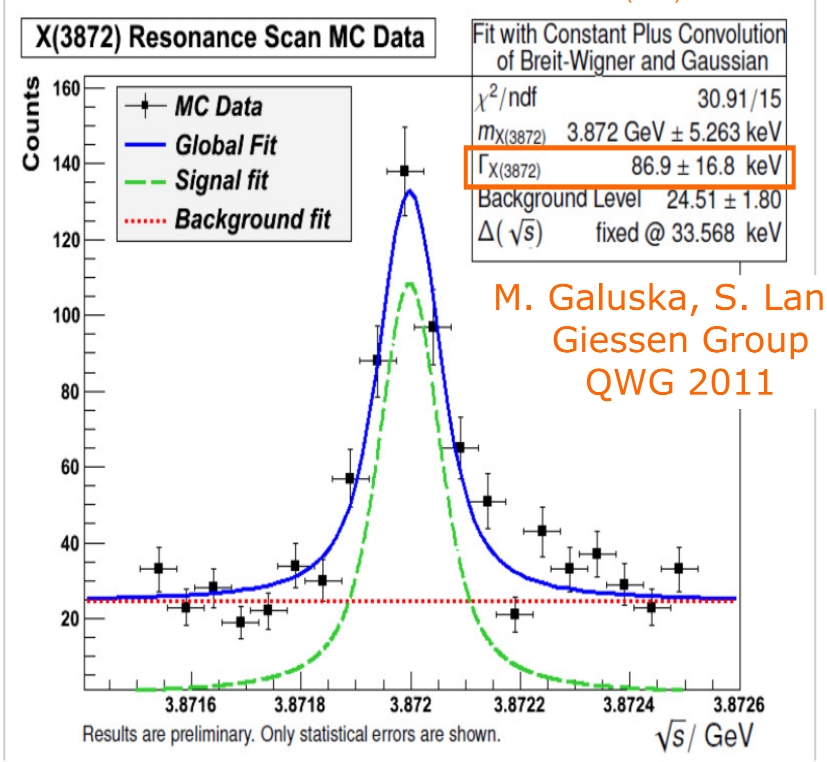
> couples to **all** J^{PC} states

> hadronic environment, background

The next generation charmonium spectroscopy

Scanning with cooled anti-protons: mass and width determination

$X(3872)$
MC simulations



M. Galuska, S. Lange
Giessen Group
QWG 2011

PANDA at FAIR, Germany

> **anti-proton**+proton or light nuclei

> couples to **all** J^{PC} states

> hadronic environment, background

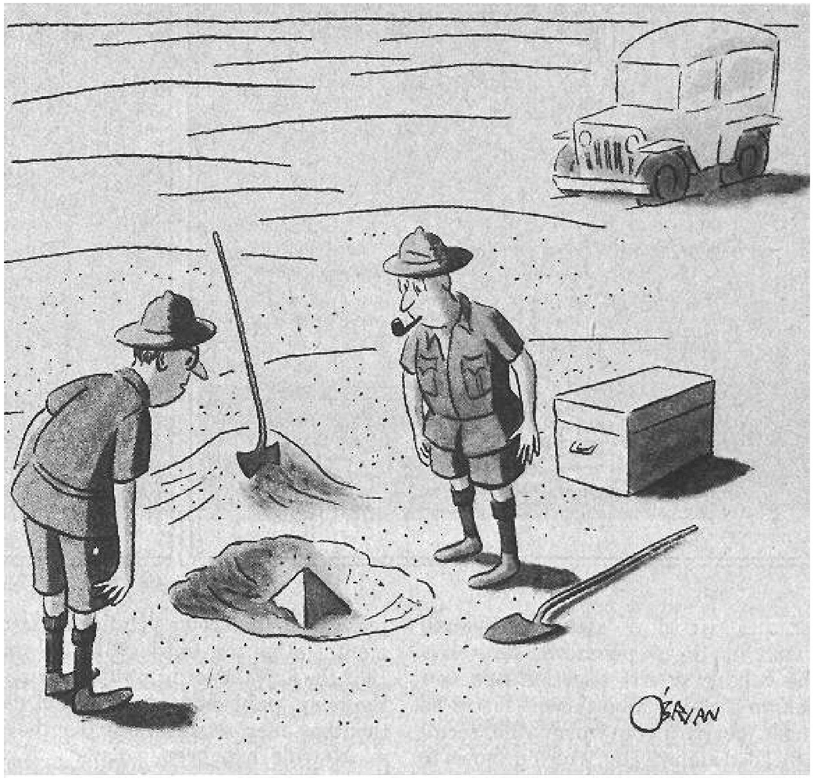
Charmonium Physics - probing the strong force & beyond

**The strong force fascinates:
confinement & generation of hadron mass**

**Charmonium provides a unique window
to study the dynamics of the strong force**

**Since its discovery in 1974, charmonium
spectroscopy has become a precision field**

**New discoveries are emerging with
todays BESIII, and near future experiments
such as PANDA, Belle2, ...**



"This could be the discovery of the century. Depending, of course, on how far down it goes."

BESIII collaboration: >300 physicists, 51 institutions from 10 countries

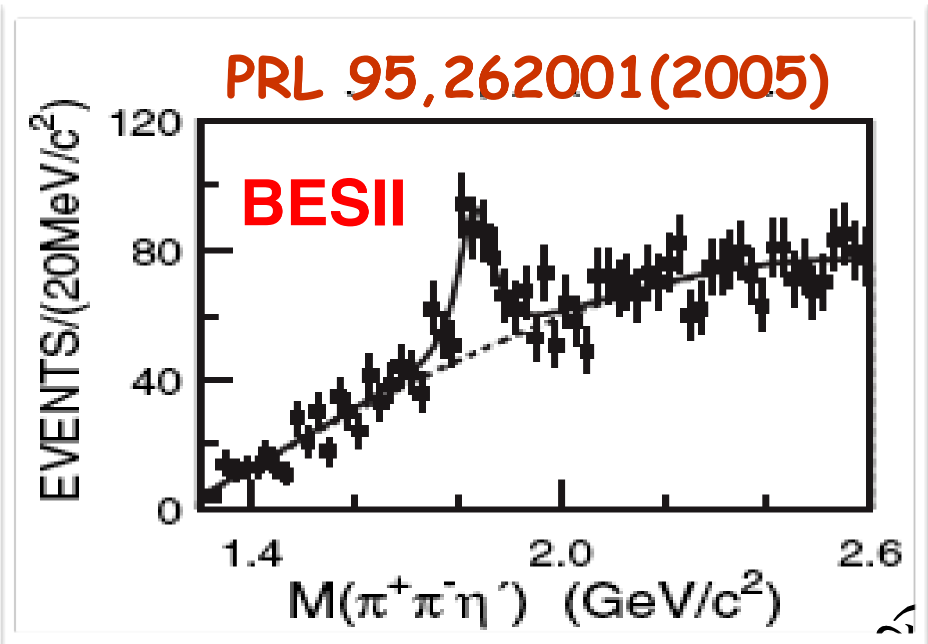
terra incognita: QCD exotics?

exploit radiative decay of "charmonium" to study light hadronic matter:

search for gluon-rich matter!

?

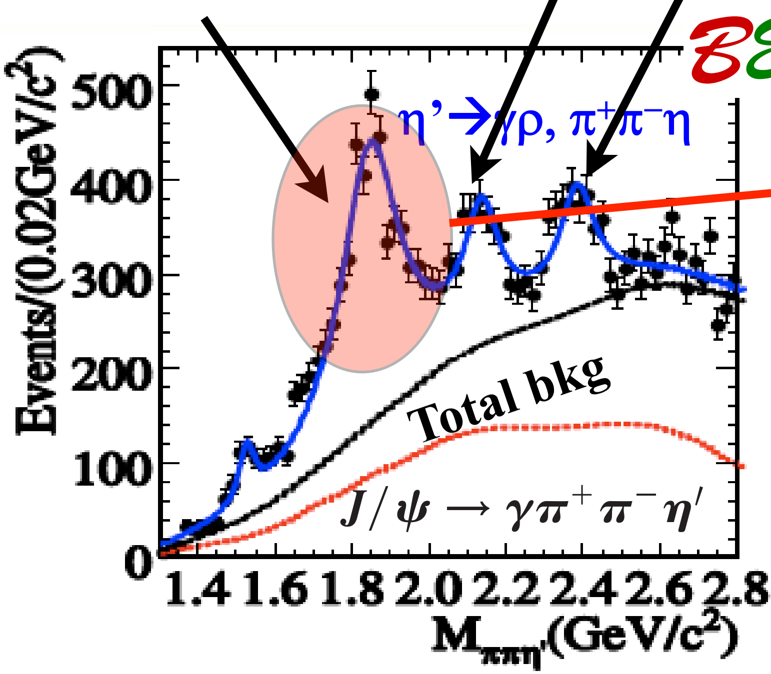
$$J/\Psi \rightarrow \gamma + X(1835)$$



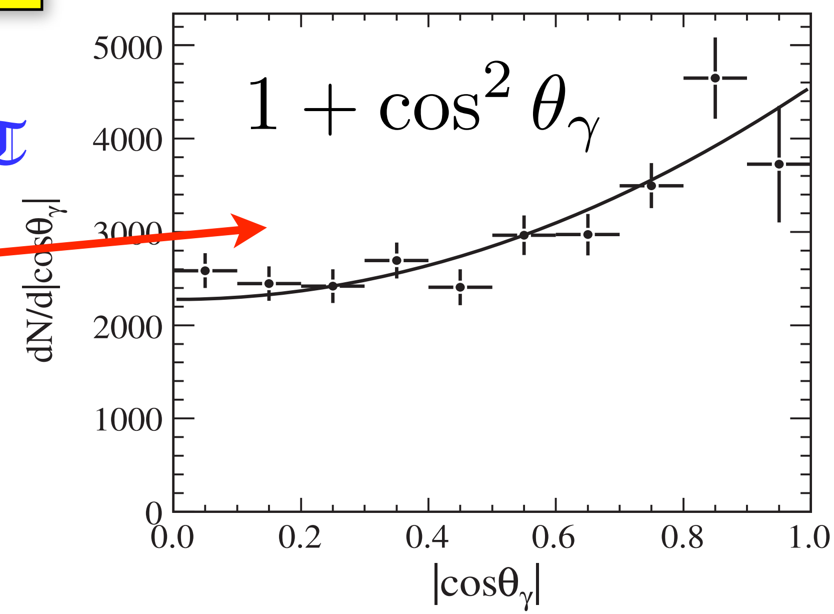
terra incognita: QCD exotics?

X(1835): 0^{-+}
glueball,excited η'?

X(2120), X(2370): ?



PRL106, 072002 (2011)



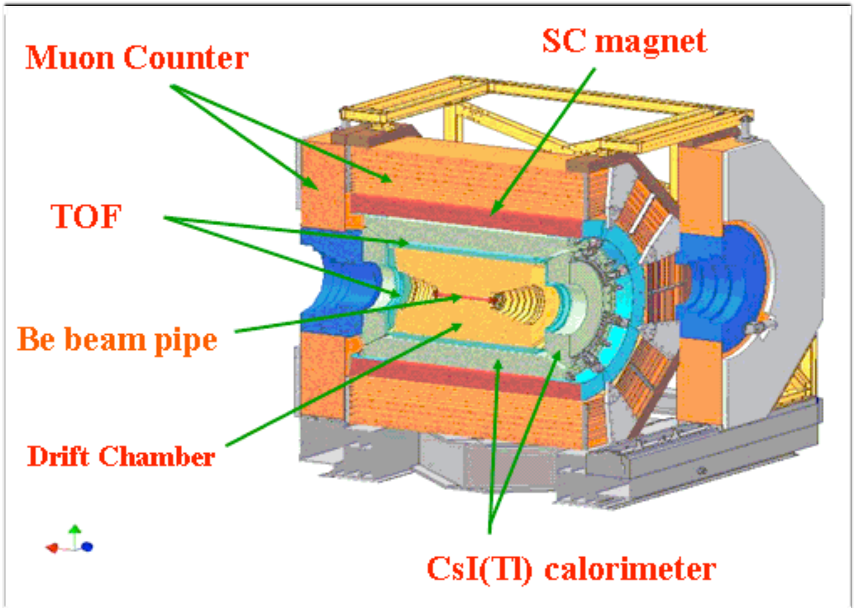
$$J/\Psi \to \gamma + X(1835)$$

Re-discovery of the X(1835)

What's the nature of this pseudoscalar?

Partial-wave analysis with more data in progress....

BESIII@BEPCII - the facility

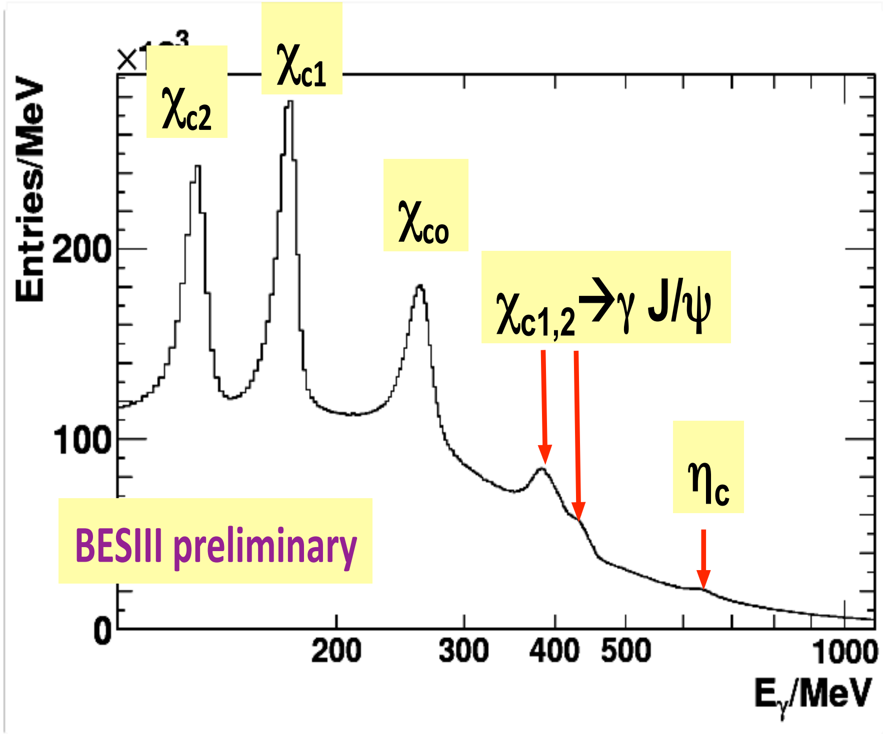


Excellent tracking and calorimetry with a uniform acceptance:

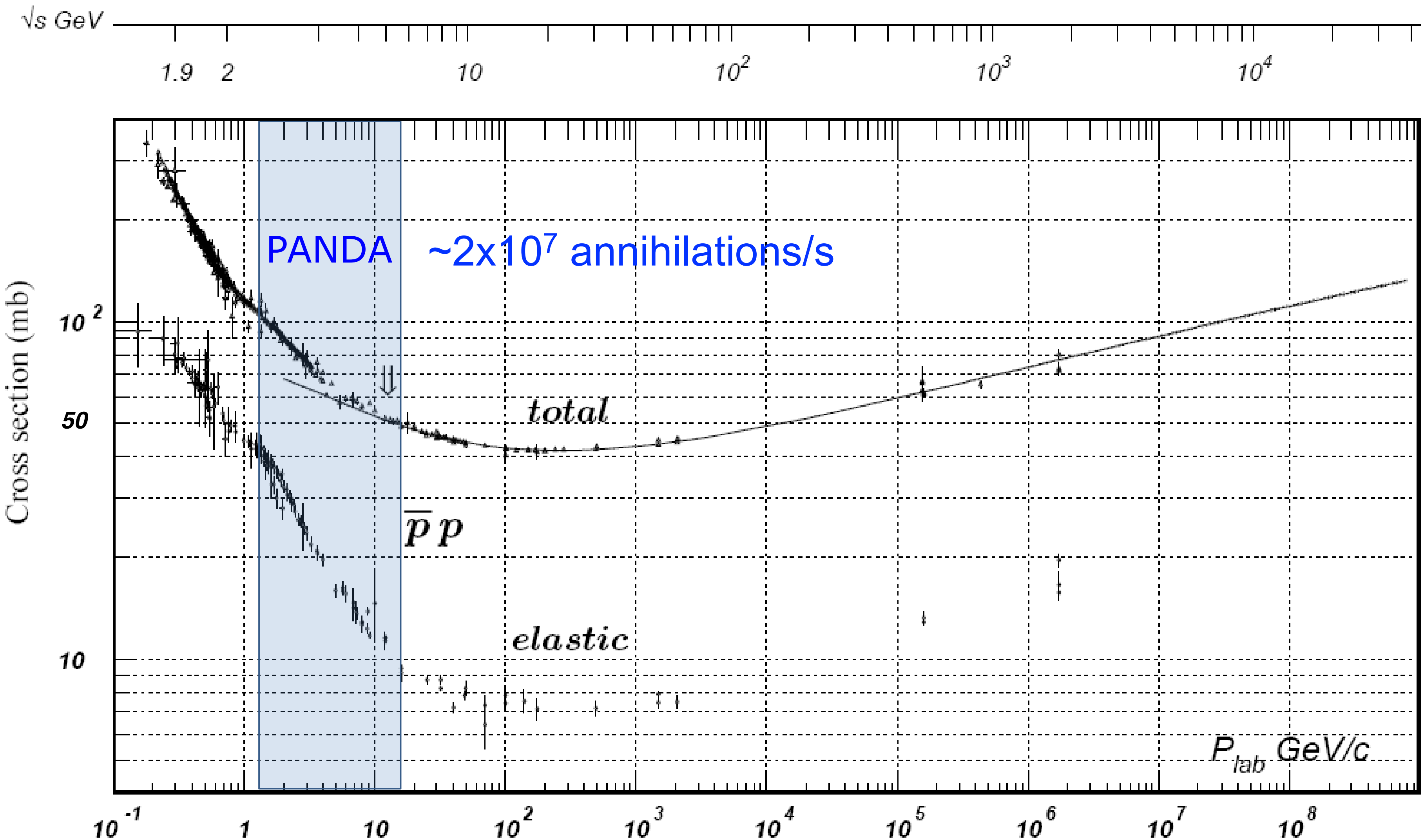
tracks: $\sigma_p/p = 0.5\%$ at 1 GeV/c

photons: $\sigma_E/E = 2.5\%$ at 1 GeV

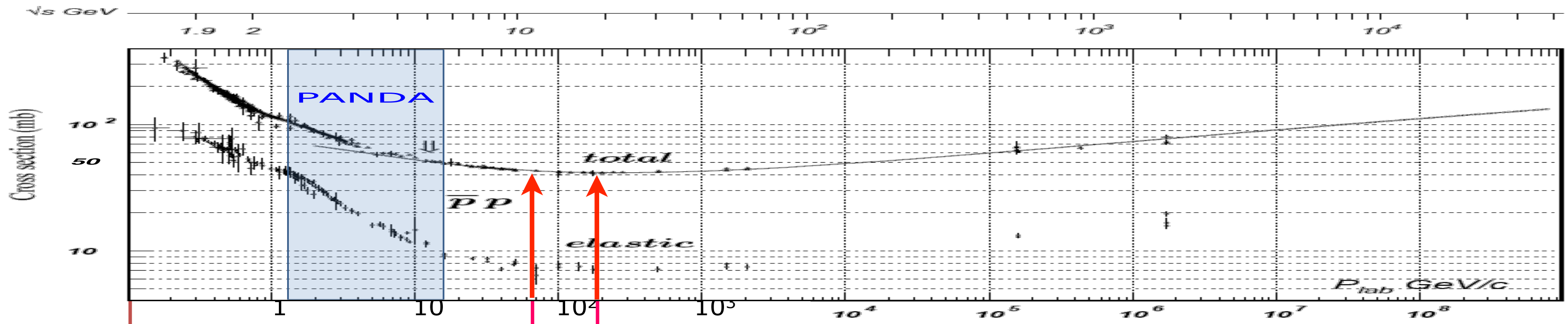
$$\Psi' \to \gamma X$$

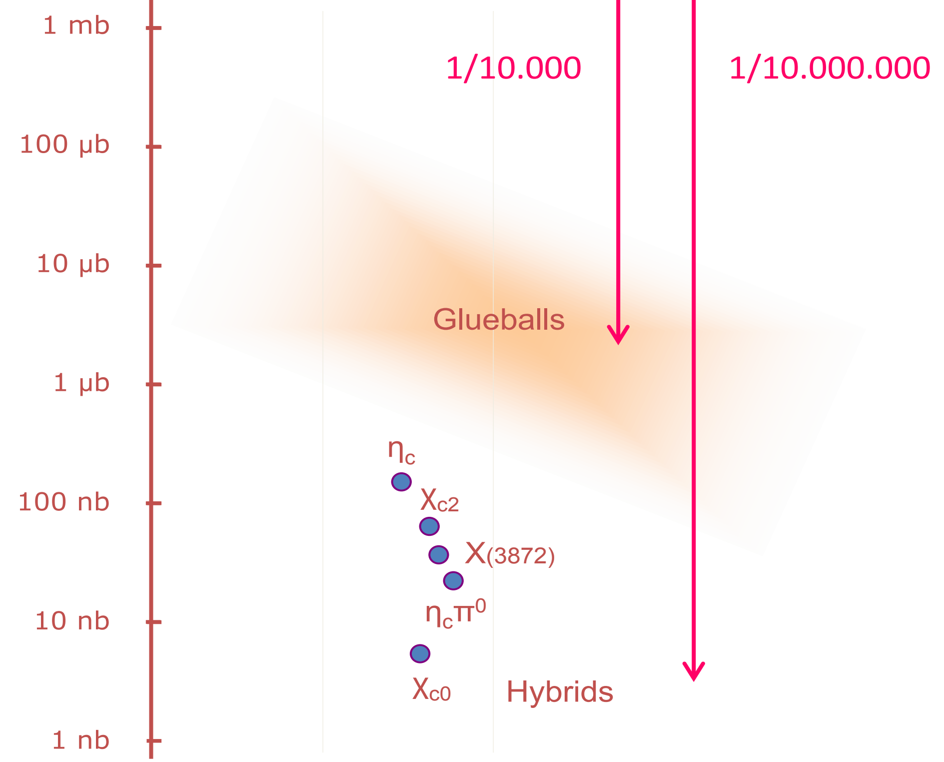


PANDA, the challenges



PANDA, the challenges

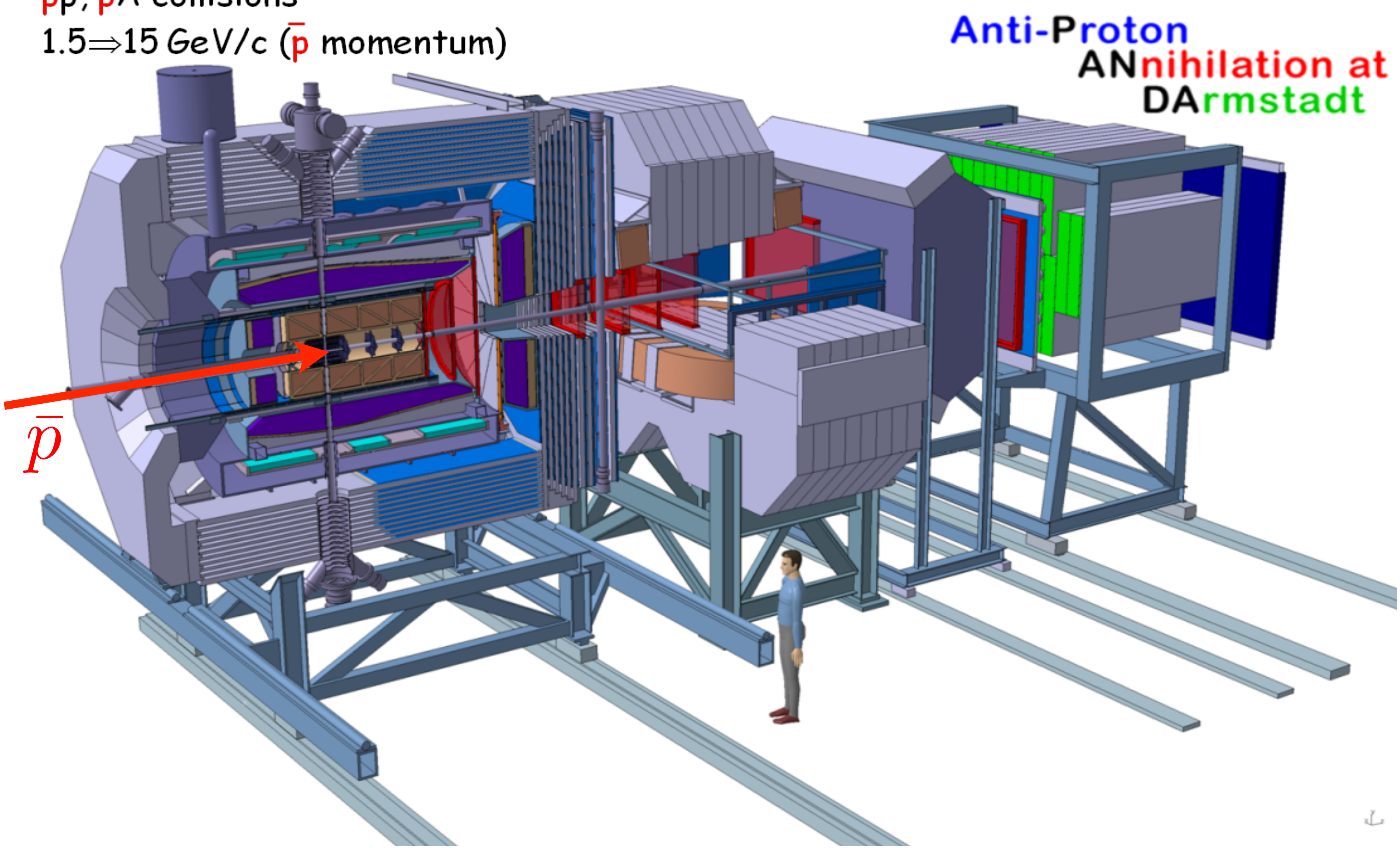




....finding needles in haystack!

The PANDA Detector

$\bar{p}p$, $\bar{p}A$ collisions
1.5⇒15 GeV/c ($\bar{p}$ momentum)



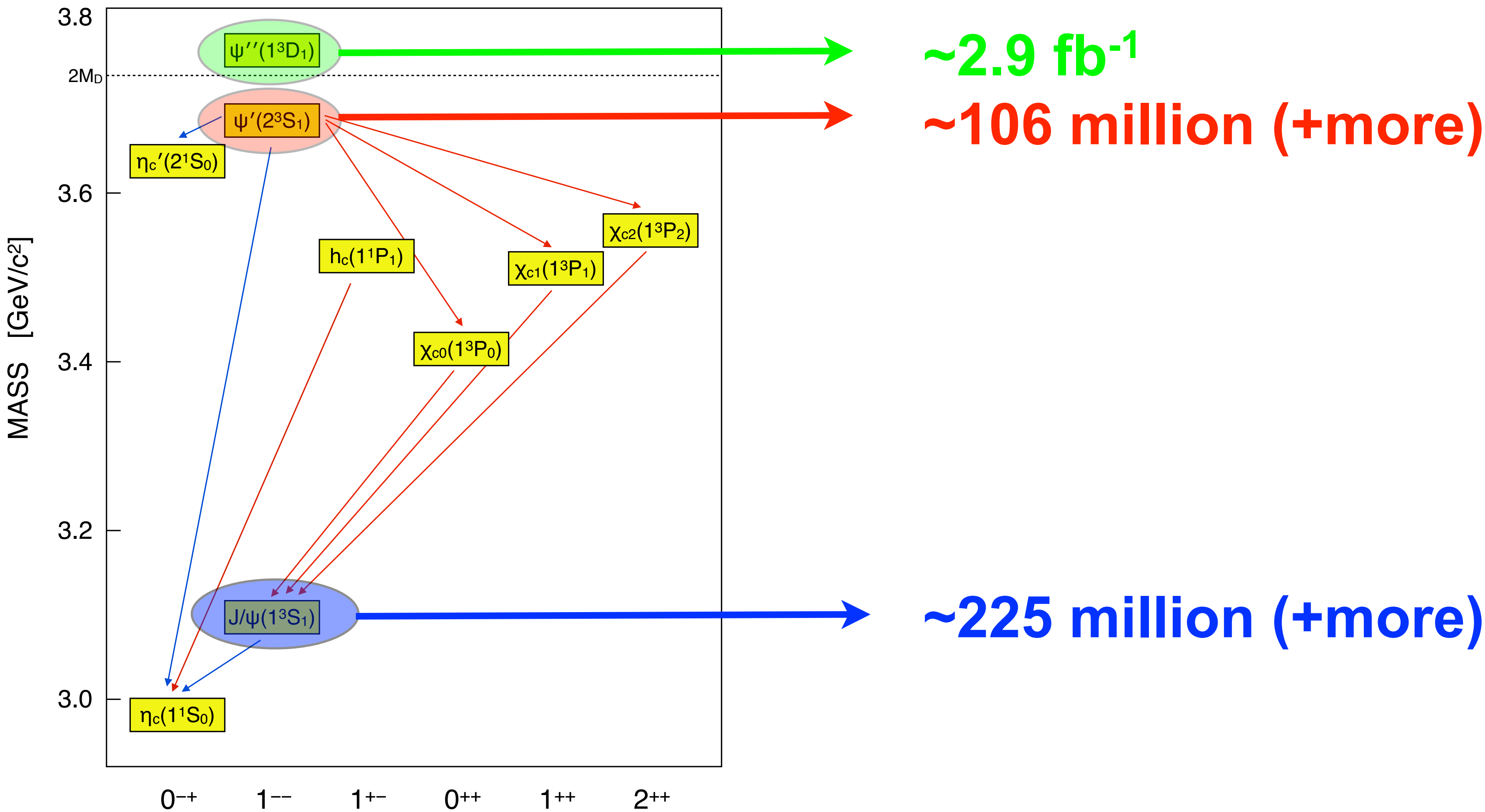
The PANDA Detector

PANDA is a modular multi-purpose device:

- nearly 4π solid angle (partial wave analysis)
- high reaction rate capability ($2\cdot10^7$ annihilations/s)
- high data rate capability (200 GB/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 $D^\pm$)
- efficient, software trigger (e, μ, K, D, Λ)
- modular design (Hypernuclei experiments)

BESIII@BEPCII - breaking all records

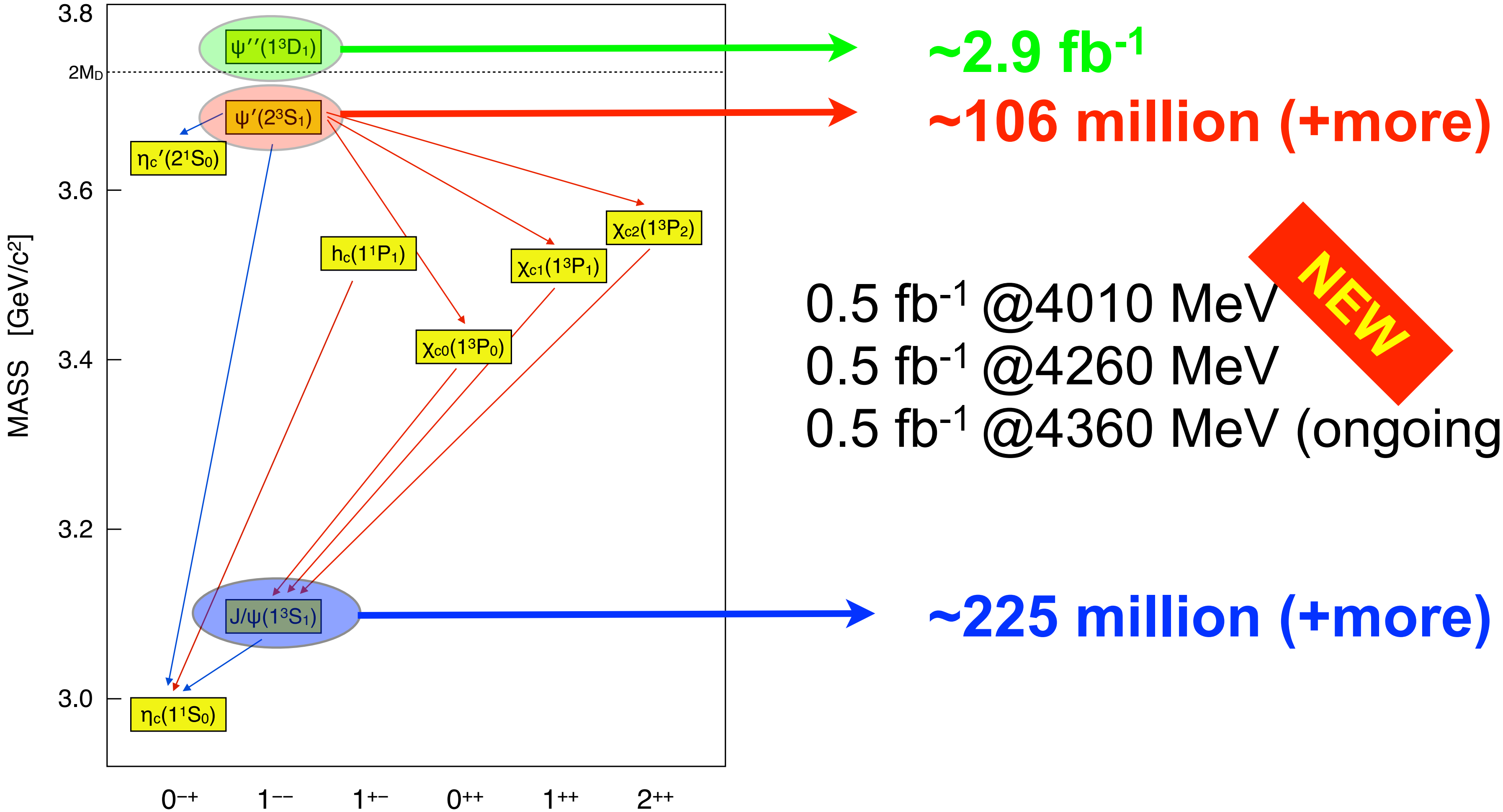
(+data taken at 3.65 GeV and resonance scans)



~10-20x previous generation charmonium factories

BESIII@BEPCII - breaking all records

(+data taken at 3.65 GeV and resonance scans)



NEW

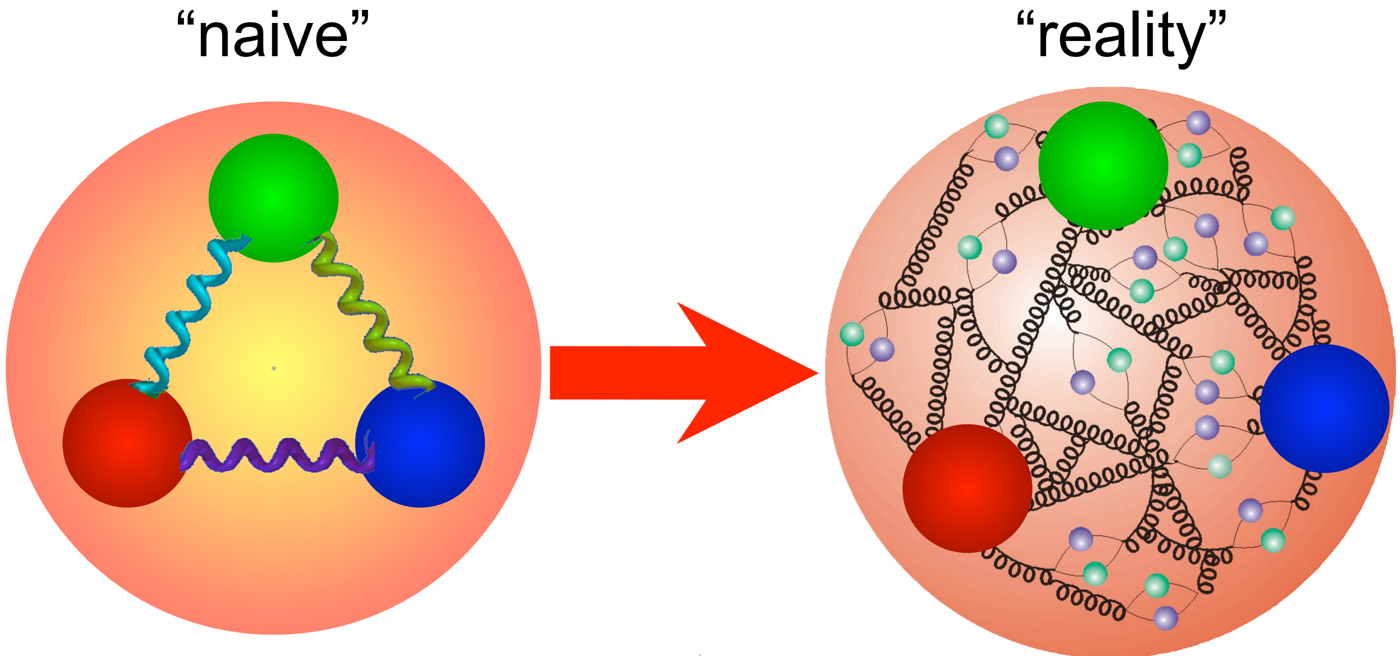
0.5 fb^{-1} @4010 MeV

0.5 fb^{-1} @4260 MeV

0.5 fb^{-1} @4360 MeV (ongoing!)

~10-20x previous generation charmonium factories

The proton revisited



$$M_{\text{proton}} \approx 3 \times M_{\text{quark}} \approx 10\,\text{MeV}/c^2$$

$$M_{\text{proton}} = 938\,\text{MeV}/c^2$$

Strong interaction = mass !