Physics with Charmonium

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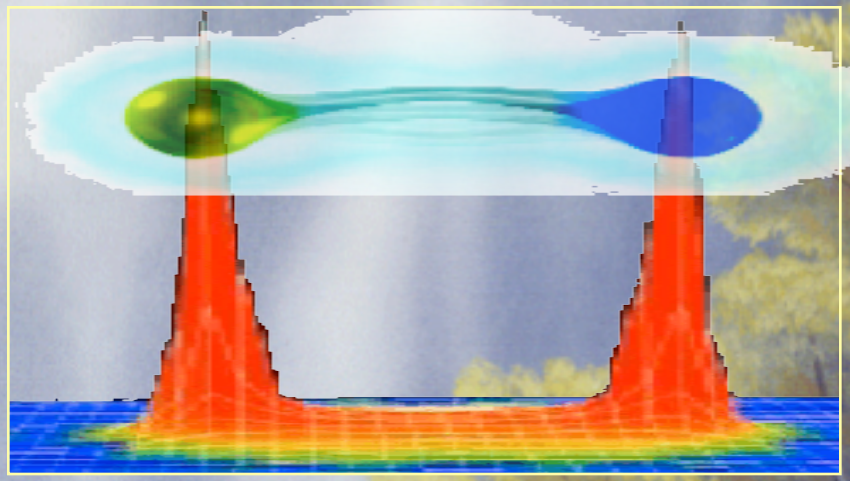
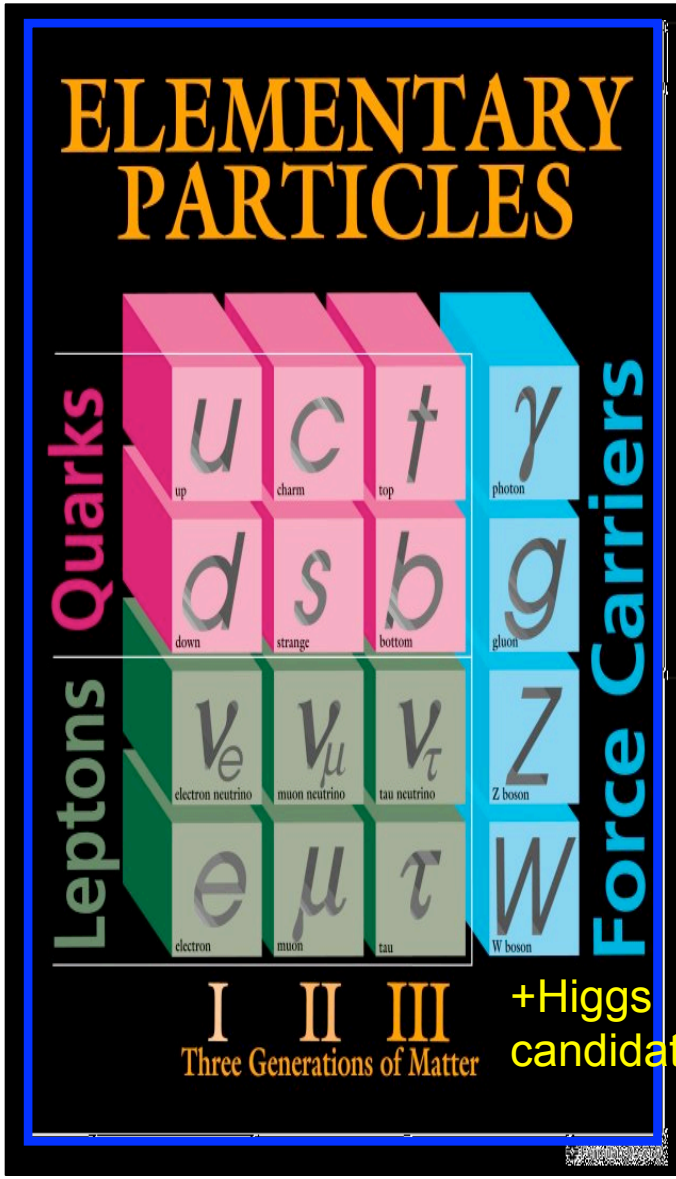
A few recent highlights of BESIII



Johan Messchendorp, KVI, Bormio Winter Meeting, January 2013

Fundamental building blocks and force carriers

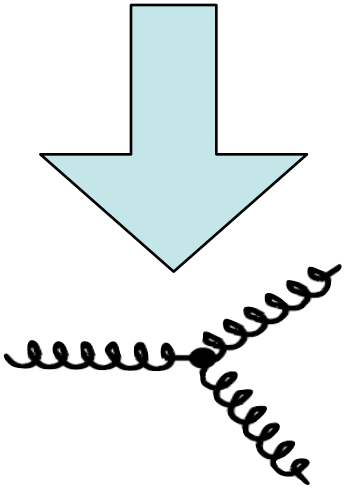


+Higgs candidate

$$\mathcal{L}_{QCD} = \sum_{q=u,d,s,c,b} \bar{q}\,(i\gamma_\mu D^\mu - m_q)\,q \; - \frac{1}{4} G^{\mu\nu} G_{\mu\nu}$$

QCD –
Quantum Chromo Dynamics

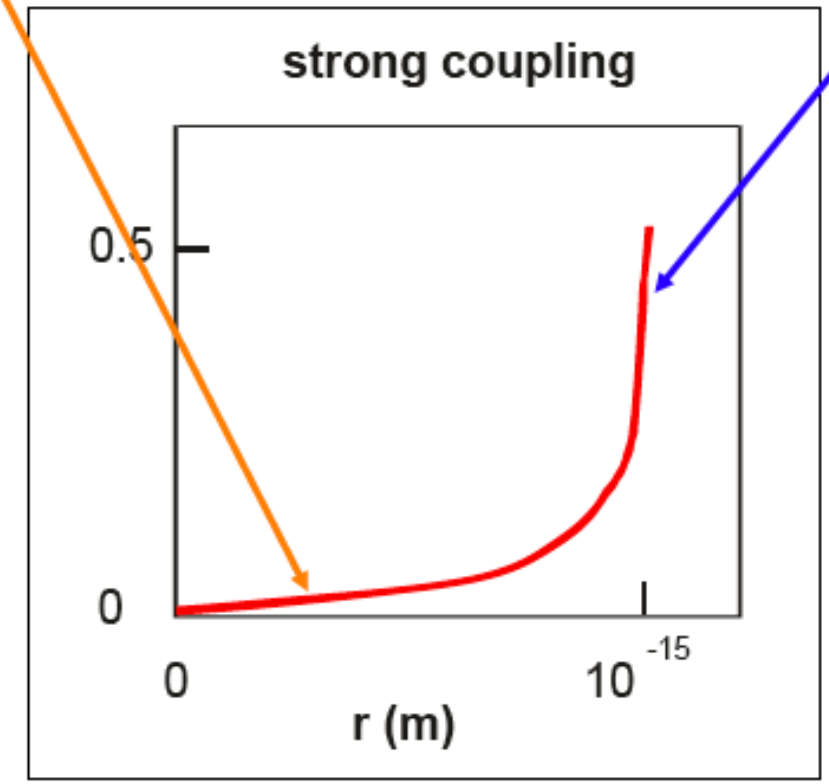
Quarks and gluons carry **color** charge



QCD, its consequences

asymptotic freedom

confinement



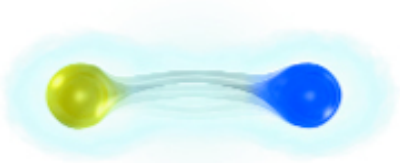
QCD and "exotic" hadronic matter....

The color charge of GLUONS allows ....

$|ggg>$

GLUEBALLS

$|q\bar{q}g>$

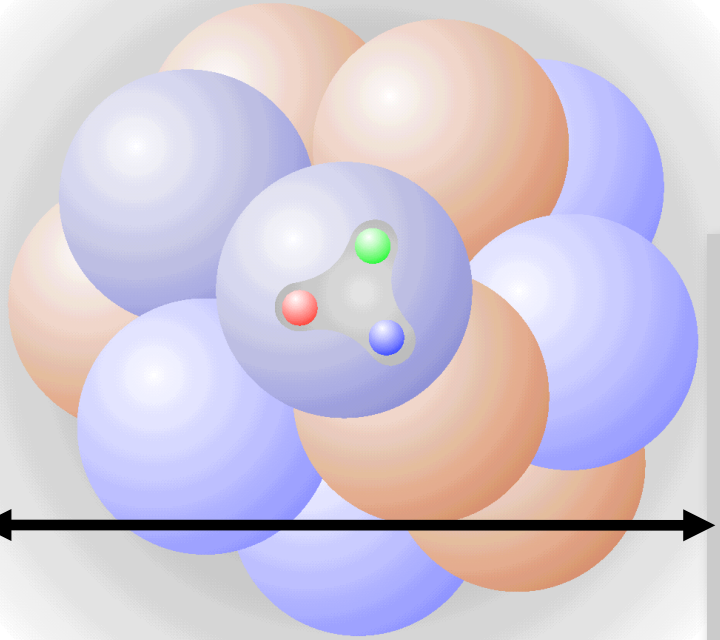


HYBRIDS

Approaches to study the strong interaction

Fundamental questions

- quark confinement
- origin of mass
- validity of QCD
- degrees of freedom?



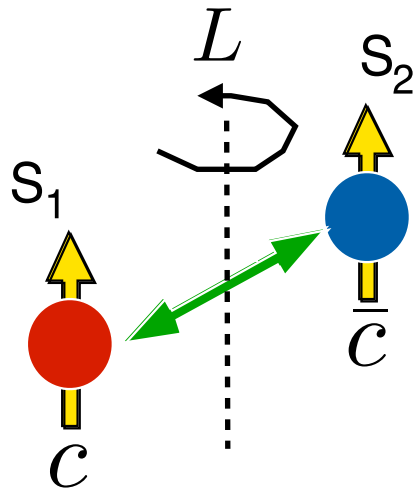
Theoretical challenges

- non-perturb. QCD
- lattice QCD
- EFT & χPT
- …

Experimental techniques

- nuclear physics
- hadron spectroscopy
- hadron scattering
- electron/photon scattering
- …

Charmonium - the positronium of QCD



$S = S_1 + S_2$

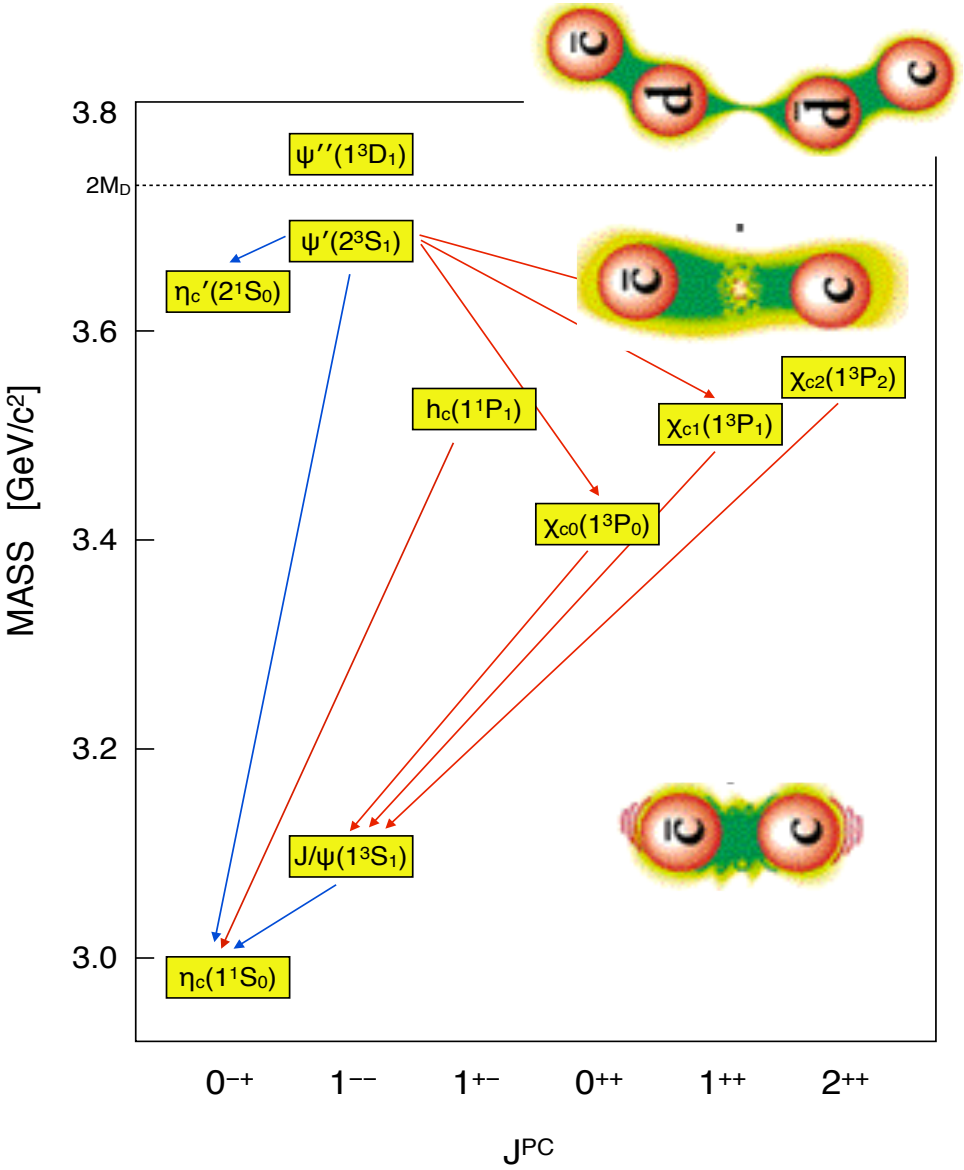
$J = L + S$

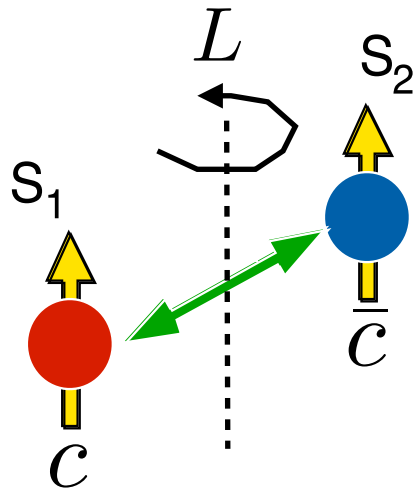
$P = (-1)^{L+1}$

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

+radial excitations

Charmonium - the positronium of QCD





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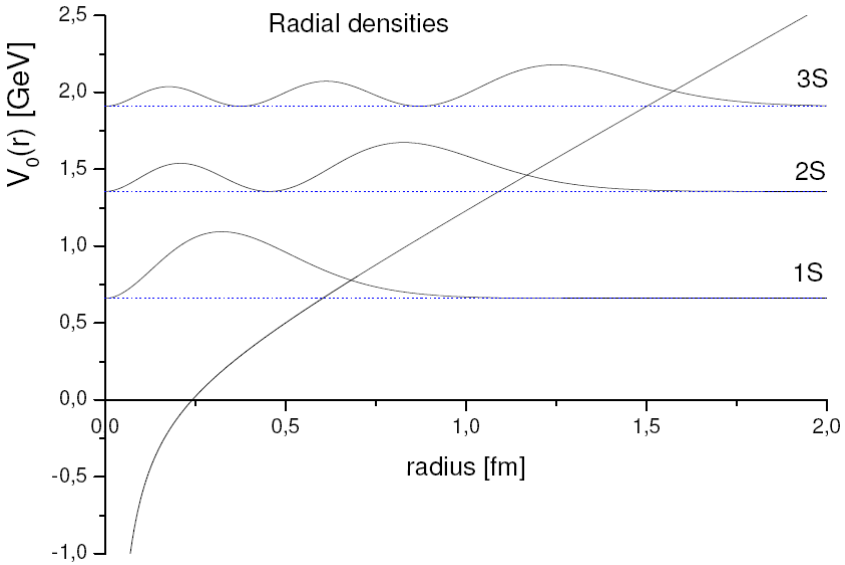
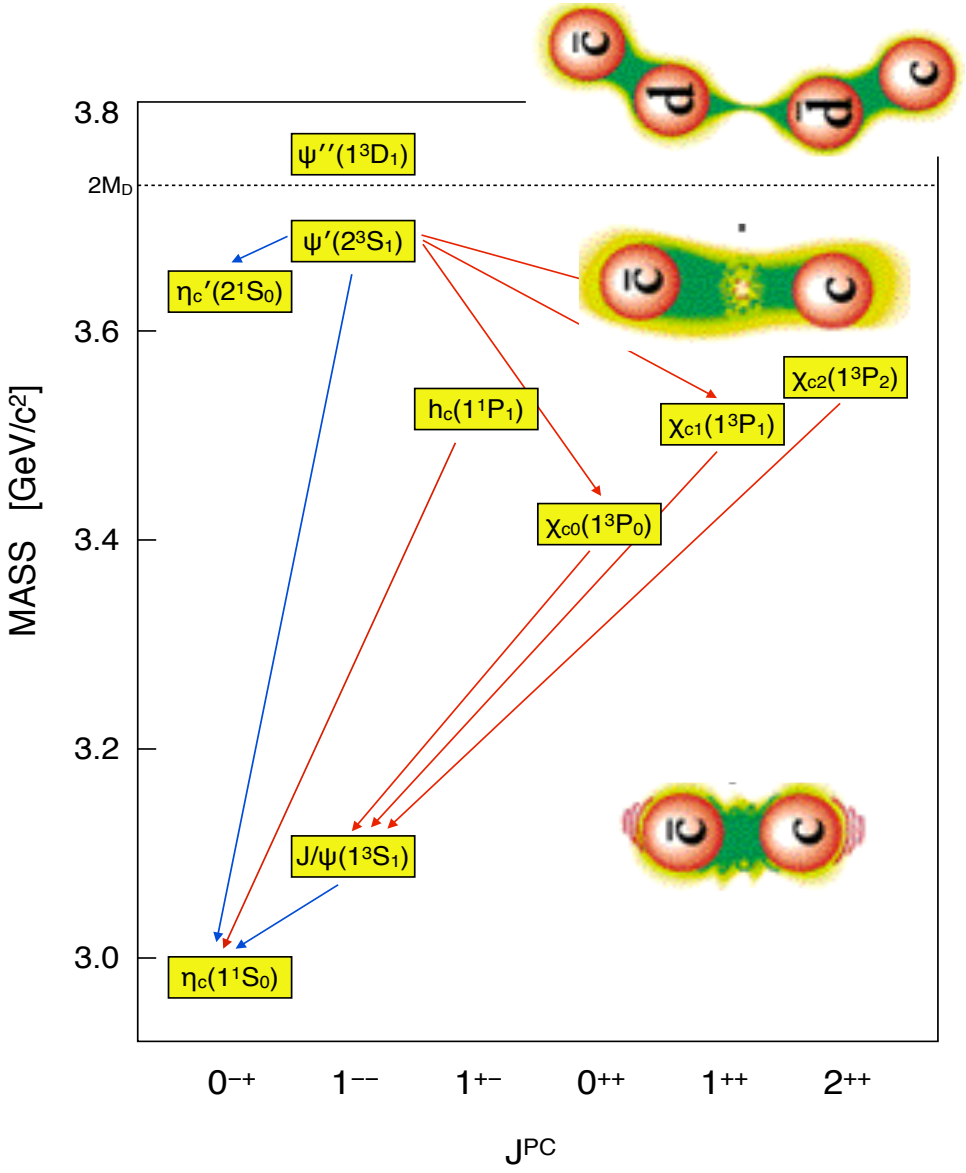


Charmonium - the positronium of QCD



Narrow quantum states
- beacons of QCD
- hardly overlapping
- background suppressed
- ideal experimental probes

Heavy charm quarks
- dominant non-relativistic
- probes regime between perturbative and strong QCD

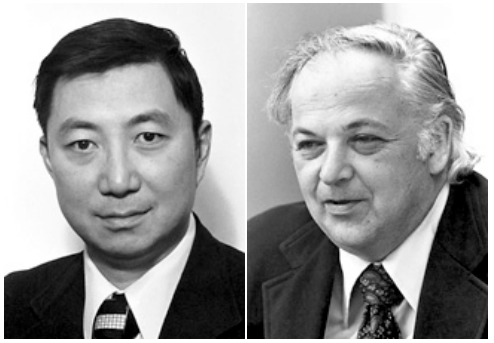
Physics!
- confinement potential
- search for exotic hadrons
- QCD dynamics
- beyond standard model

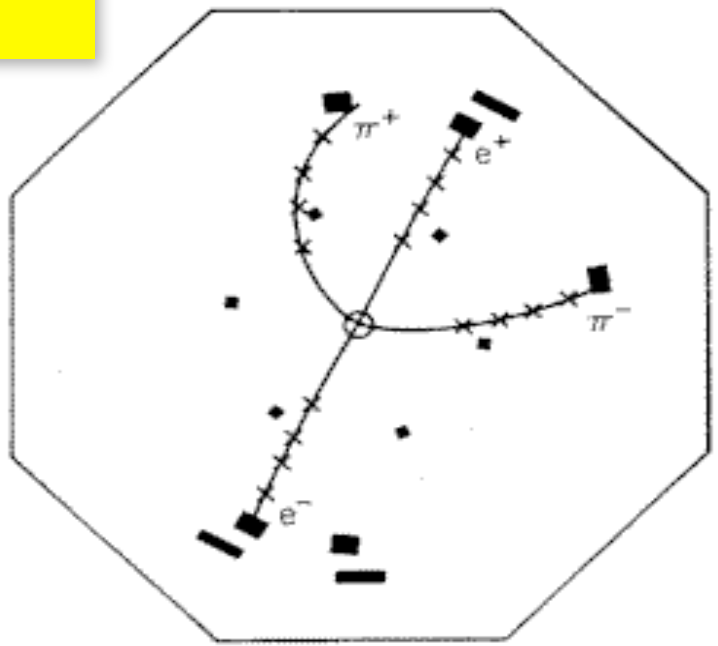
Charmonium - the discovery

1974: discovery of narrow state ~3.1 GeV
BNL (J) & SLAC (PSI)!!

"**November Revolution**"
in theory and experiment

1976: Nobel Prize to Ting&Richter





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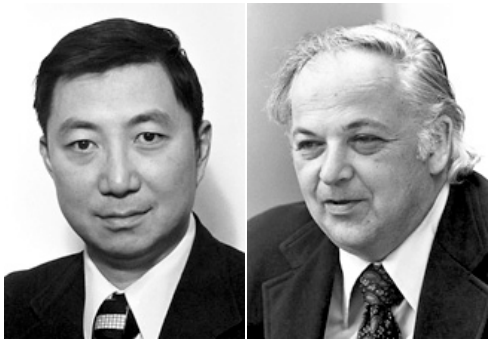
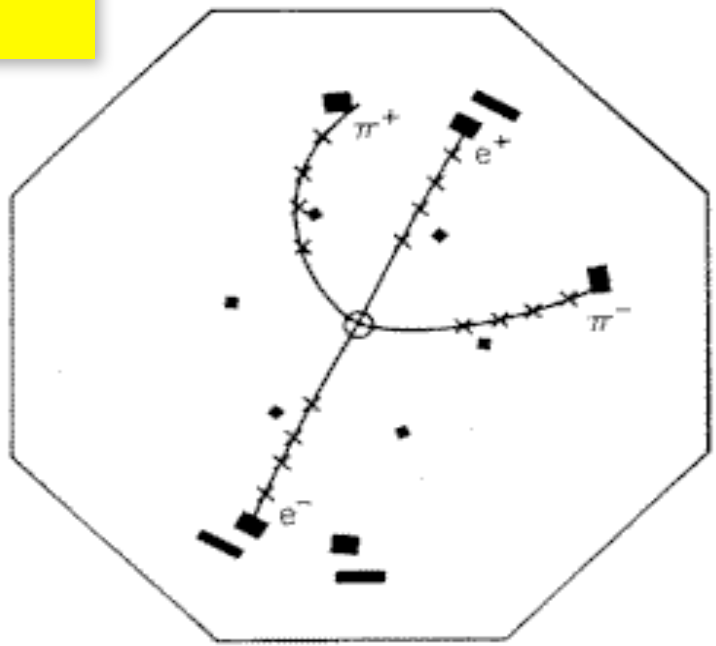


next available Greek letter was
"iota" ι = "insignificance"

Be happy they skipped that one!



From discovery to precision...

- B (looks like DD for D or charm physics)
- E (looks like cc for charmonium physics)
- S (for light hadron Spectroscopy)
- T (for tau physics, looks like a Roman number “III”)

From 1974 till today: charmonium factories...

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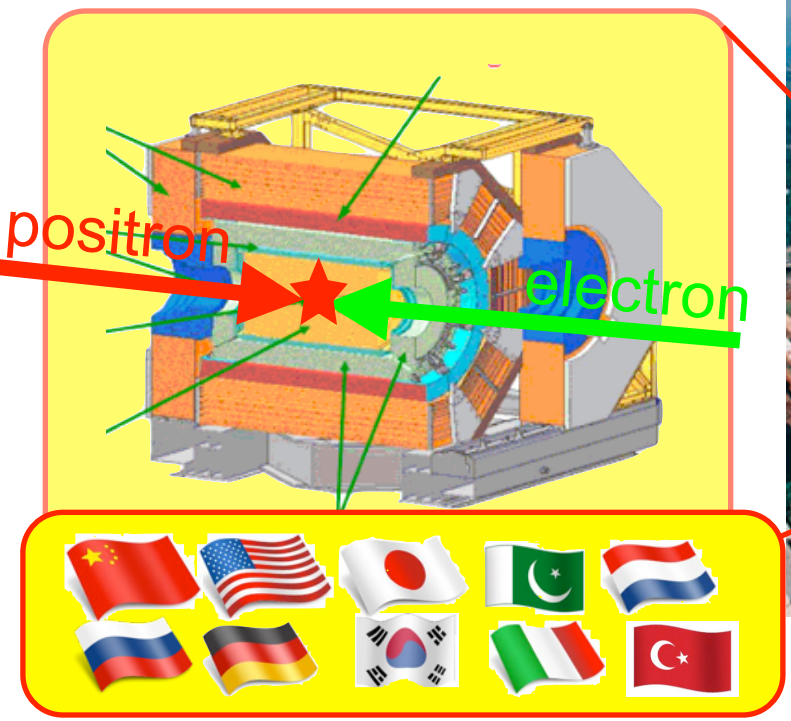
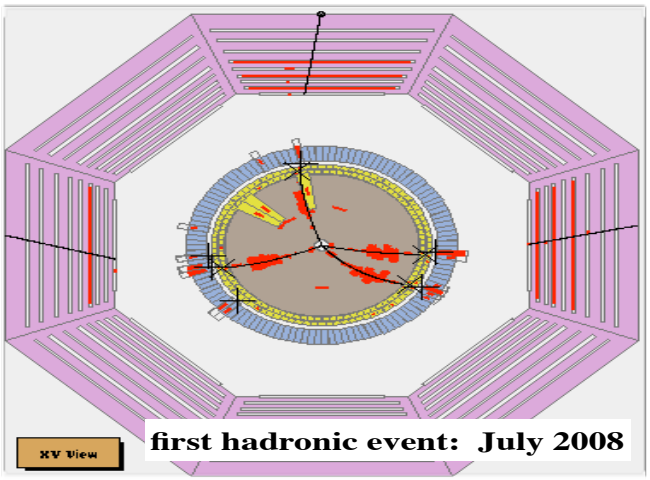
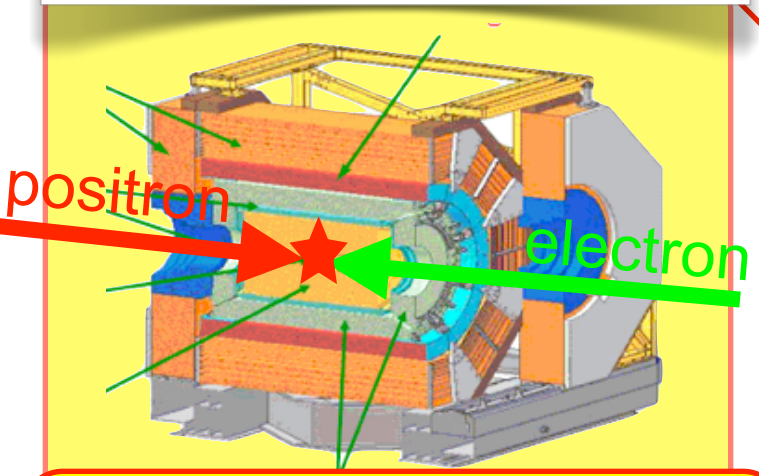


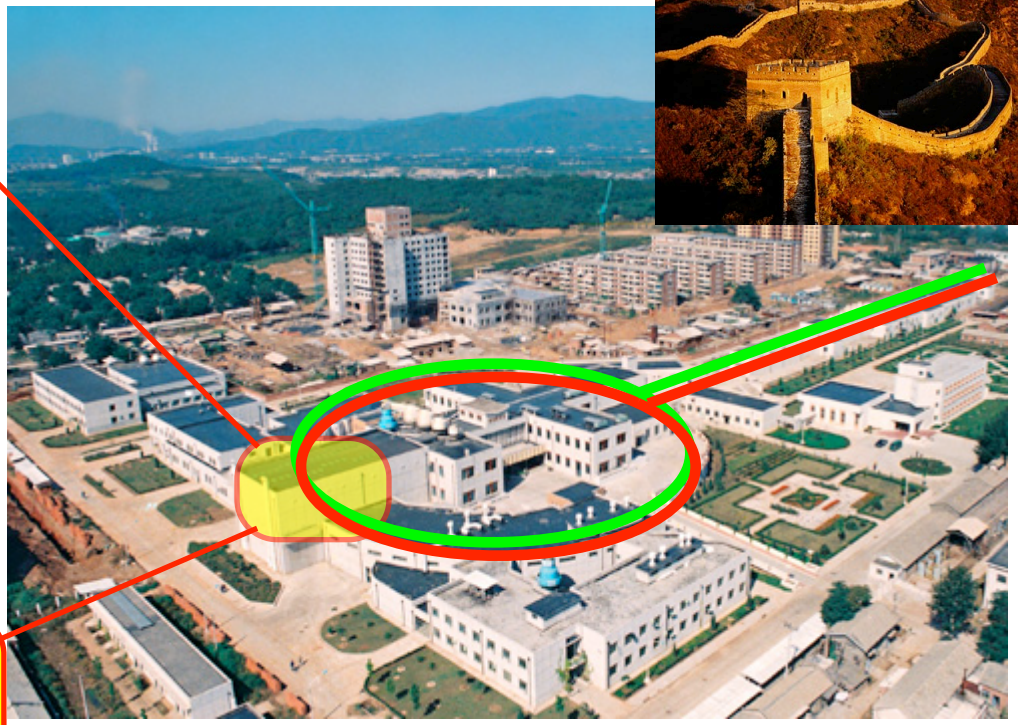
BEijing **S**pectrometer - **III**

From 1974 till today: charmonium factories...



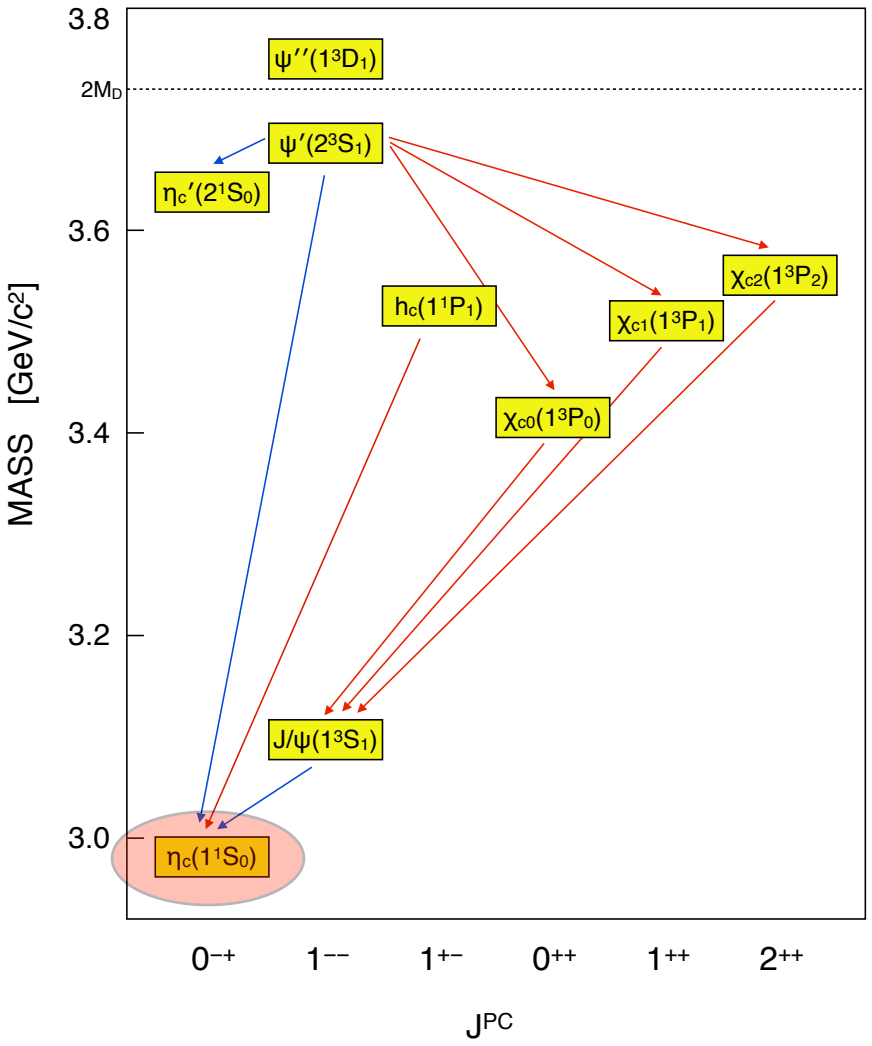
July 2008: first hadronic event
March 2009: physics data taking
Now: 10-20x previous c-factories

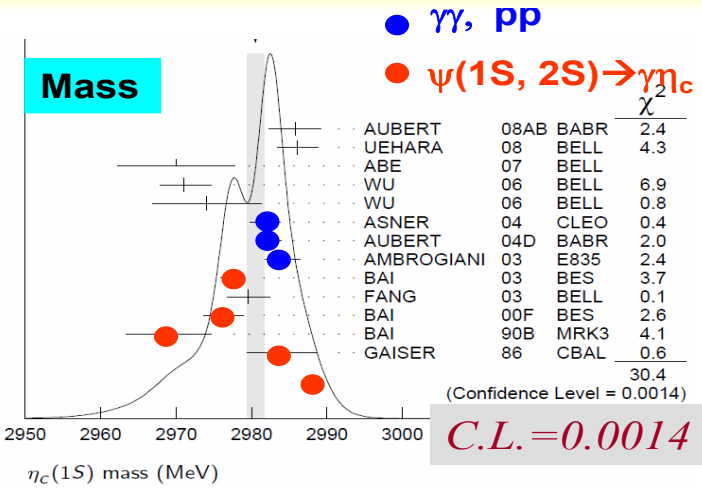


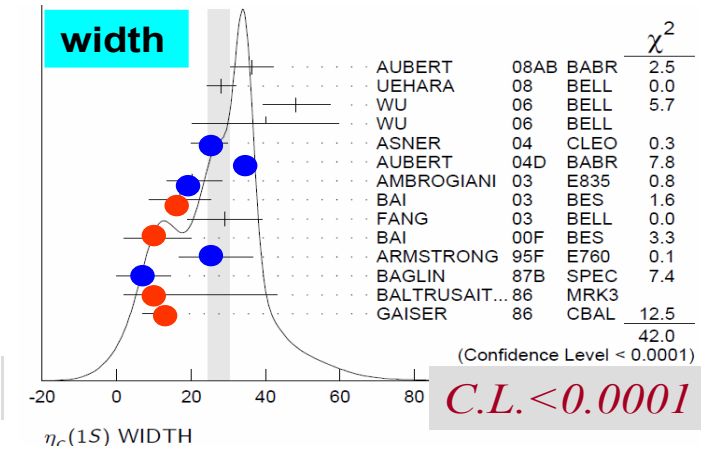


BEijing **S**pectrometer - **III**

"charmonium ground state"

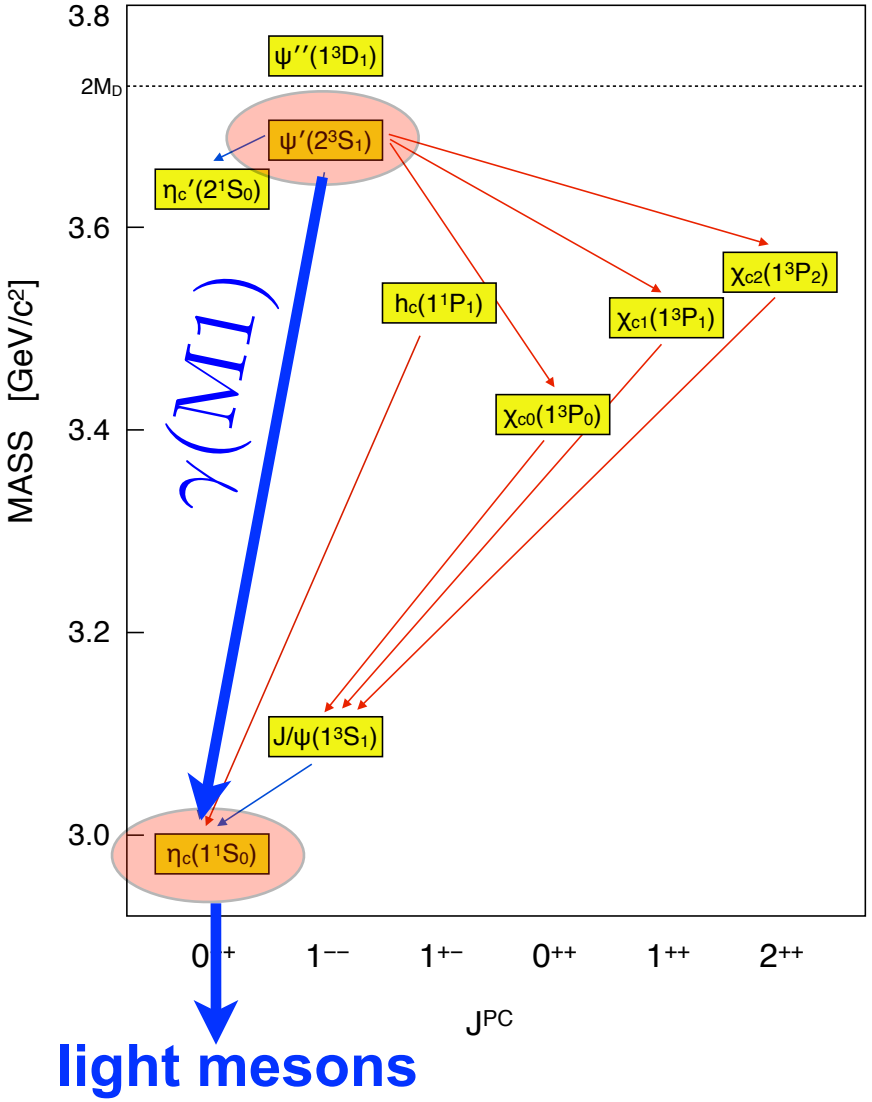






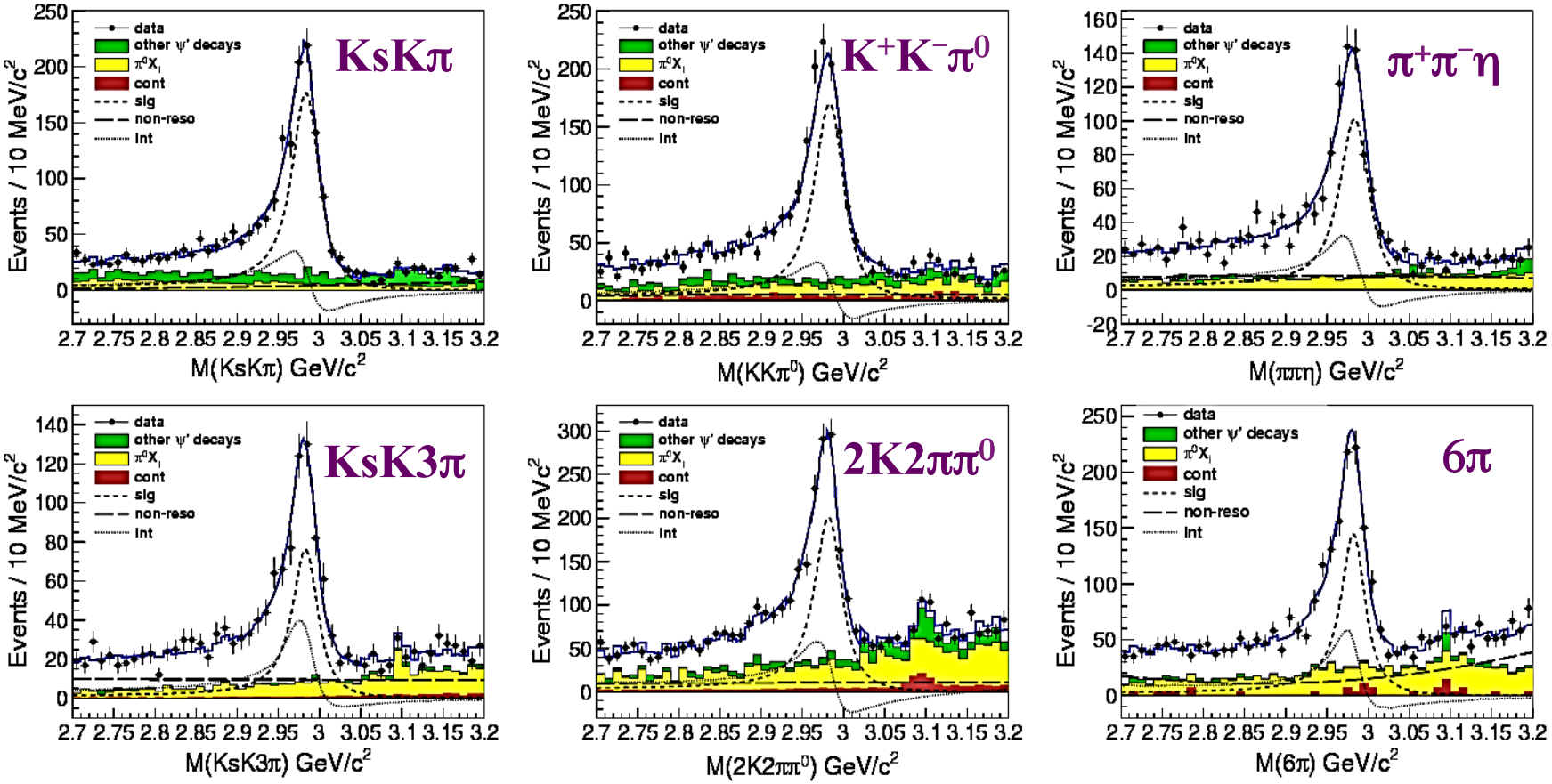
Even on simplest parameters of the ground state there are consistency problems!

"charmonium ground state"



"charmonium ground state"

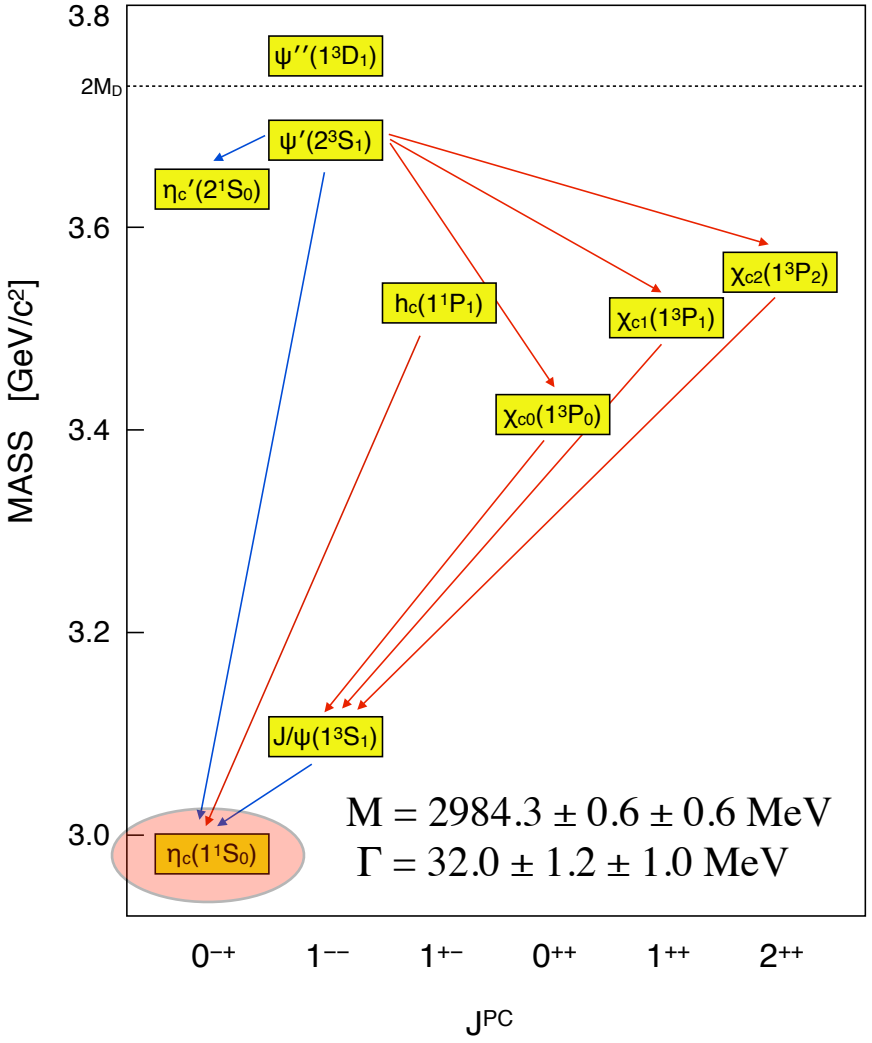
PRL108, 222002 (2012)

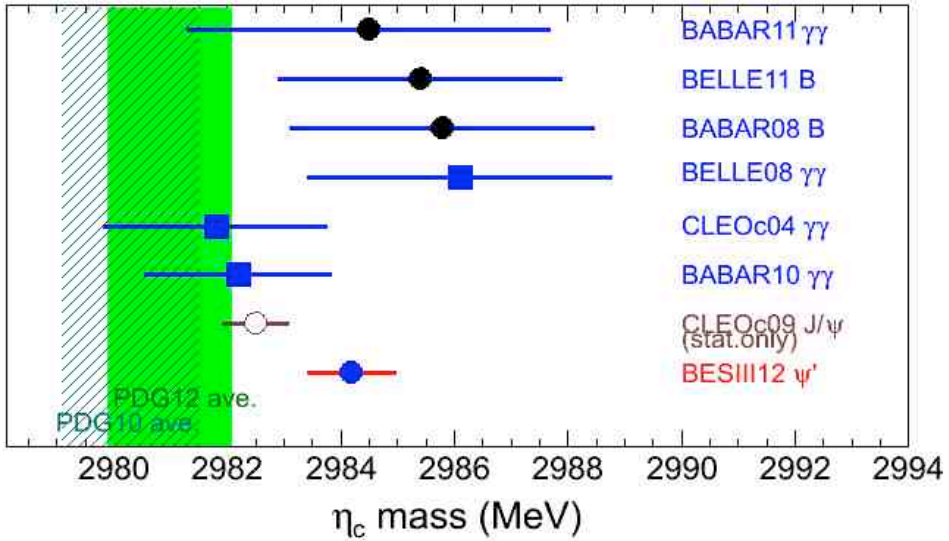


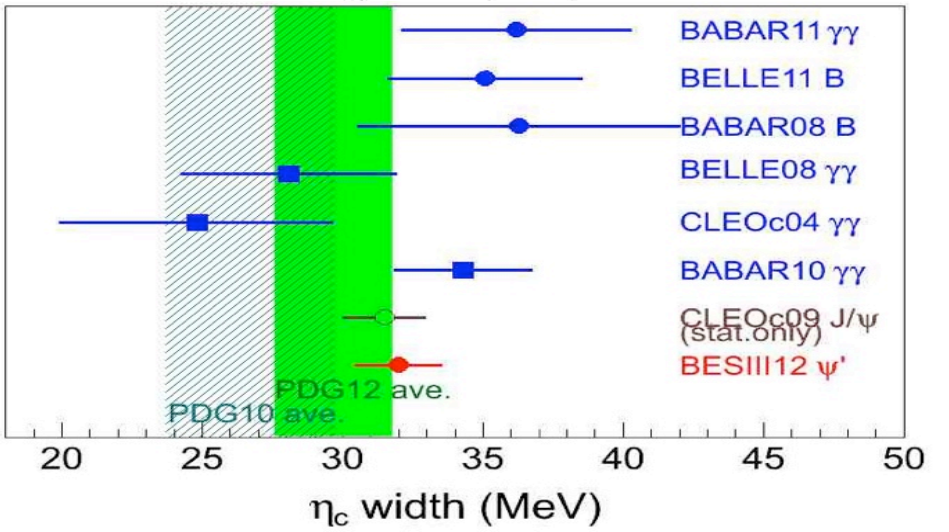
Bottom line: must take into account distorted line-shape and interferences with "non-resonant" decays

"charmonium ground state"

PRL108, 222002 (2012)

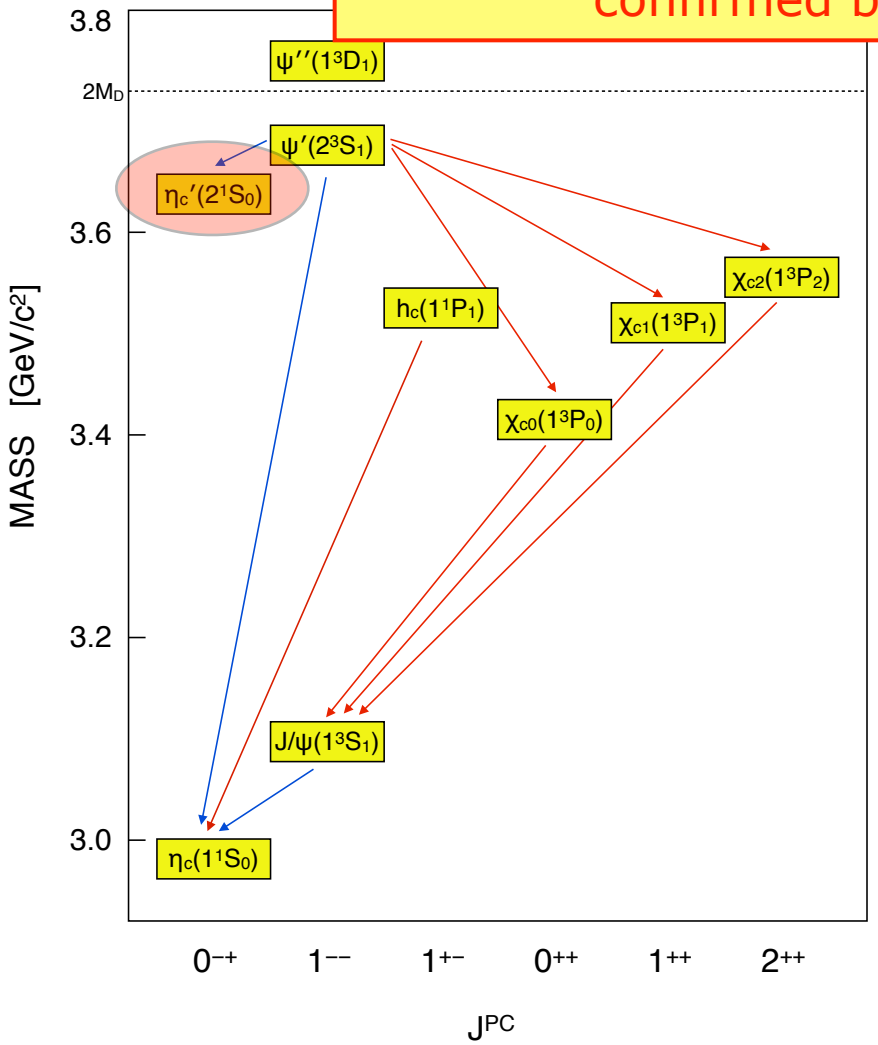


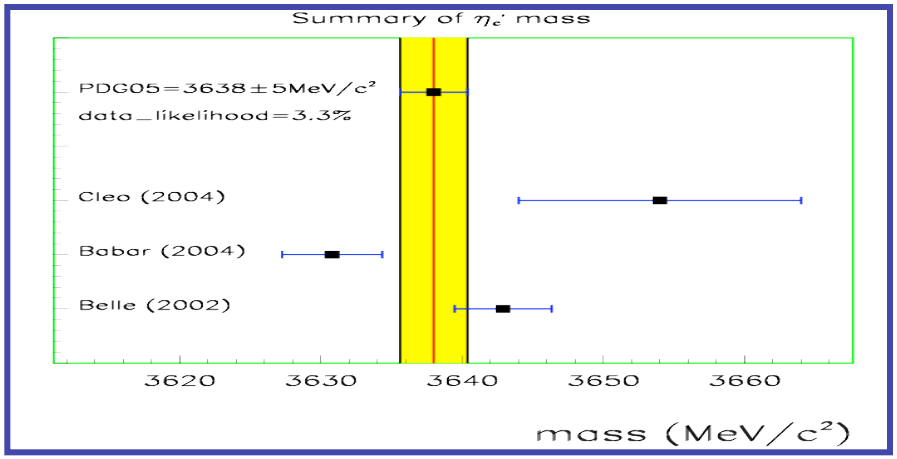


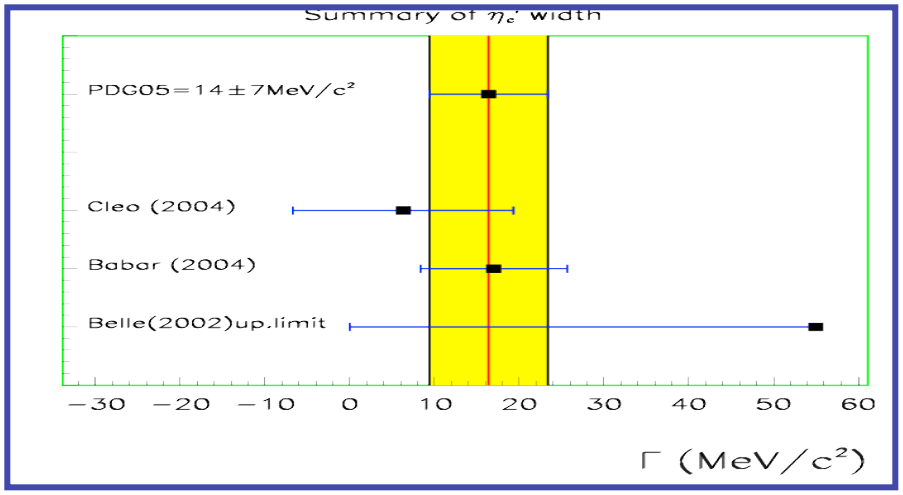


radial excitation of the g.s.

Discovery of η'_c by Belle in $B \to K\eta_c'(\to KK\pi)$ confirmed by BaBar, Cleo







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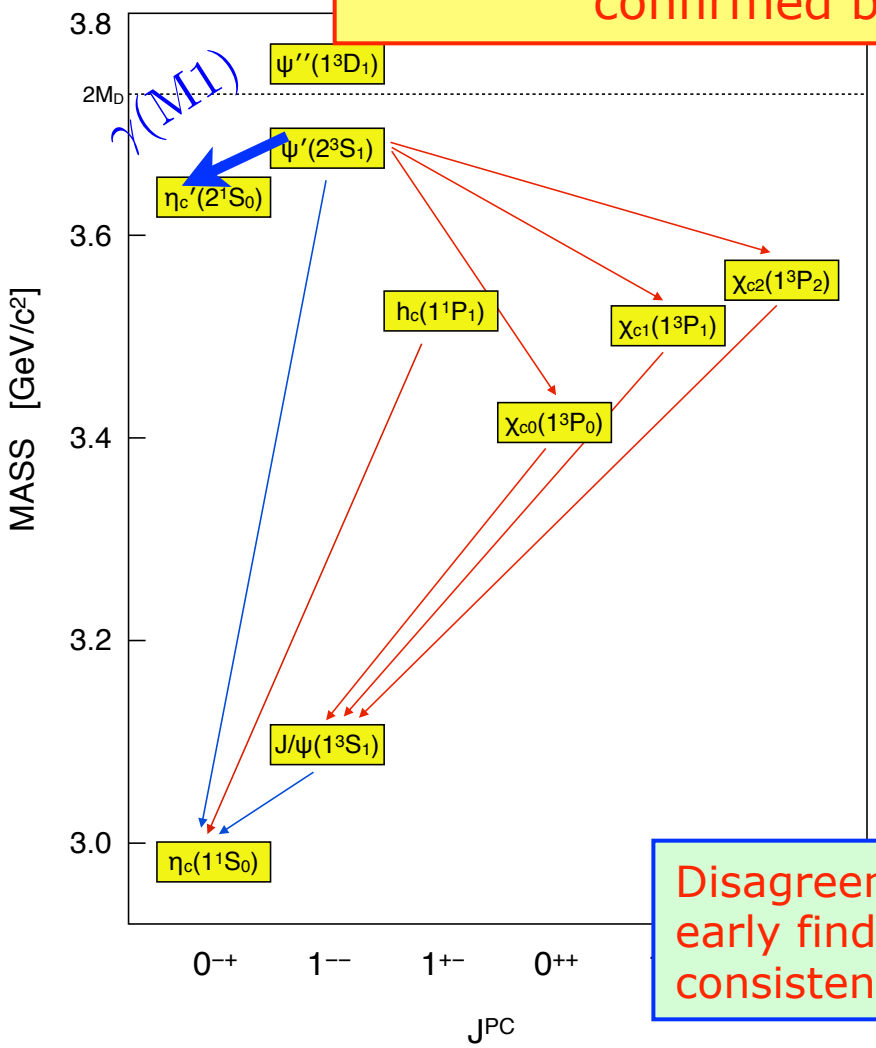
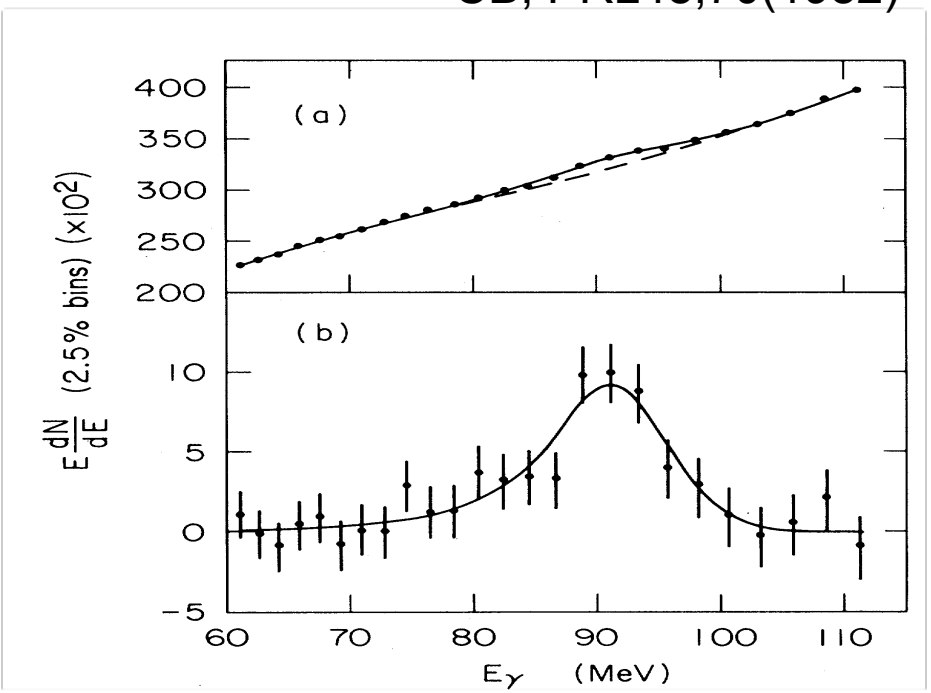


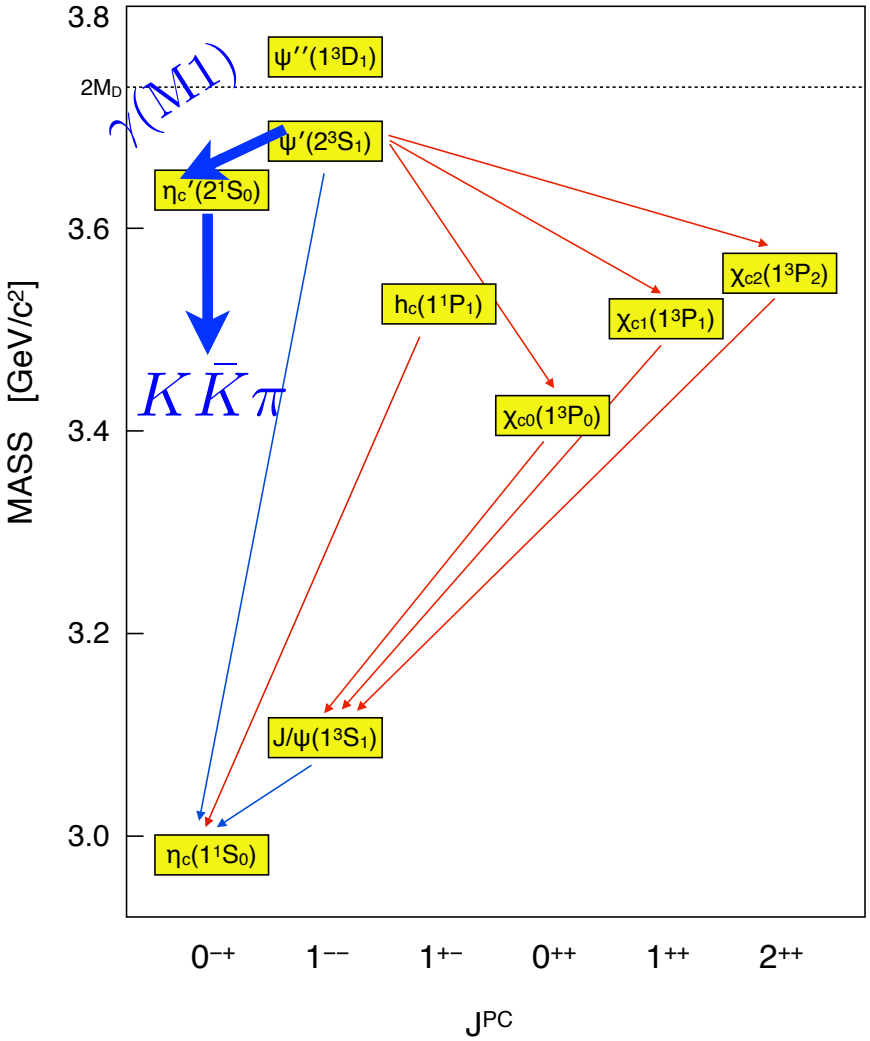
CB, PRL48,70(1982)

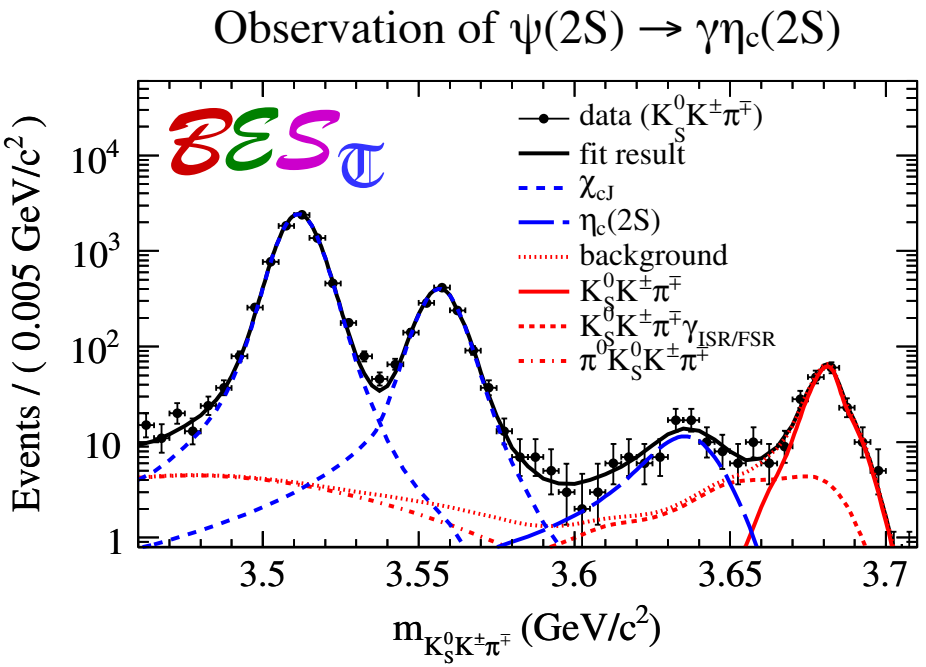


Disagreement of experiments on the mass and with early findings by Crystal Ball (3594). Only marginal consistency with most theoretical predictions.

radial excitation of the g.s.

PRL 109, 042003 (2012)





$M = 3637.6 \pm 2.9 \pm 1.6$ MeV

$\Gamma = 16.9 \pm 6.4 \pm 4.8$ MeV

$B(\psi(2S) \to \gamma\eta_c(2S)) = (6.8 \pm 1.1 \pm 4.5) \times 10^{-4}$