Coherent study of QCD exotics

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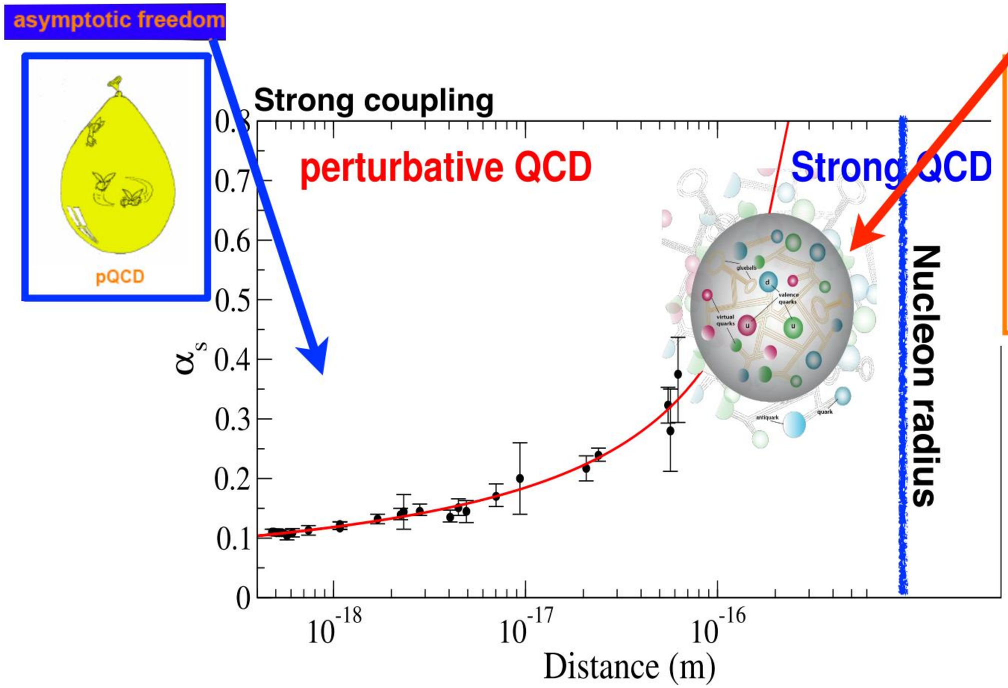
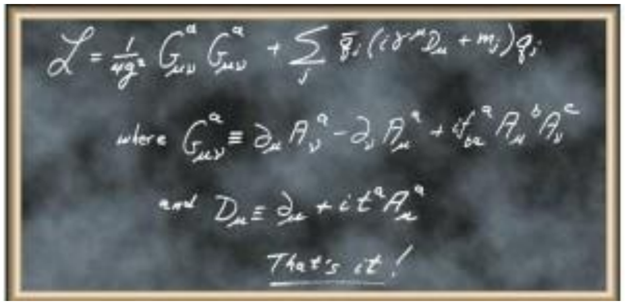
Hadron spectroscopy

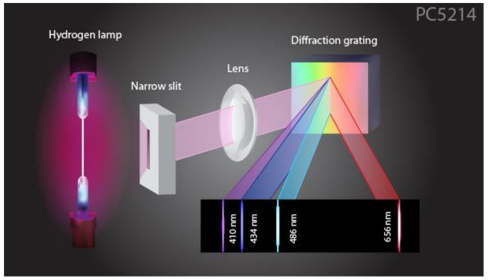




F. Wilczek, Physics Today

Hadron Spectrum

Atomic Spectrum

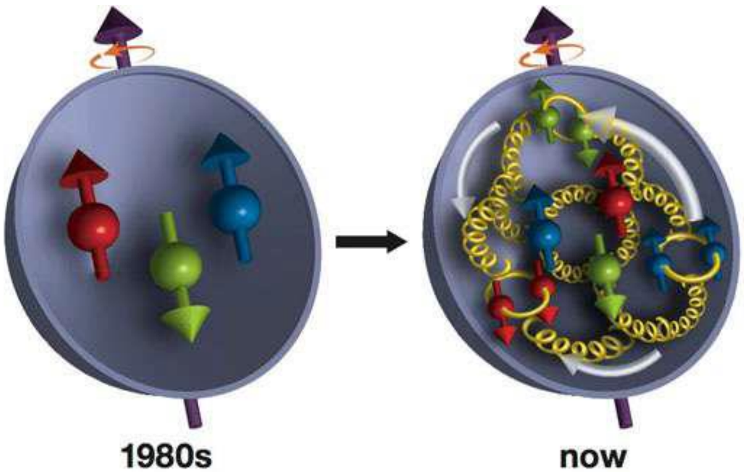


Bohr model → QED

Quark model → strong QCD

Non-Perturbative QCD

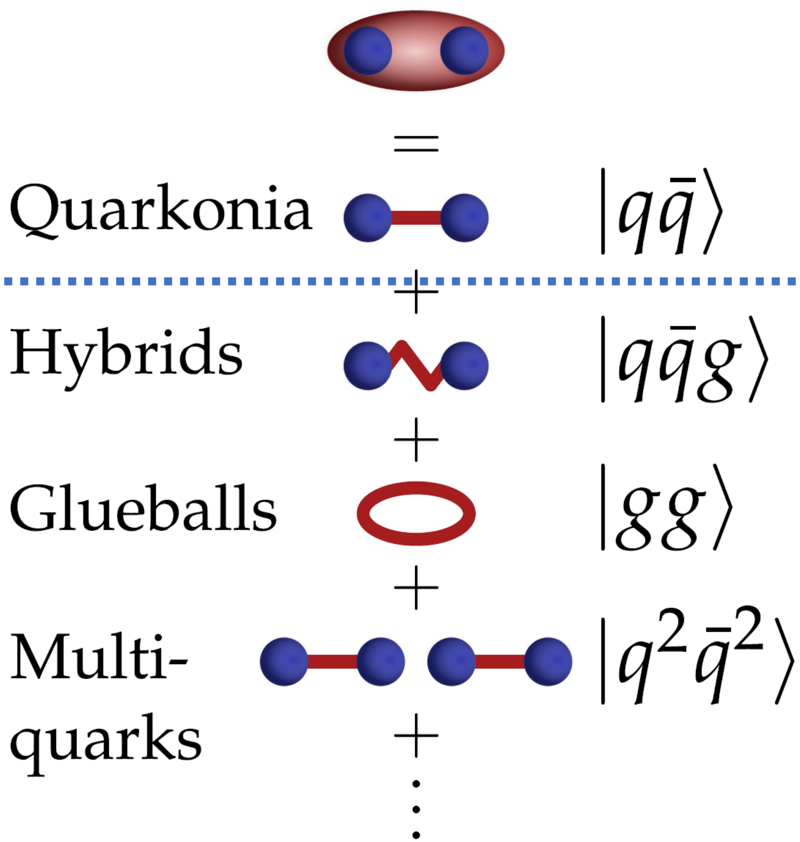
--how did the complex building blocks of our world come into being



Quark model seems to work really well. But, how does QCD give rise to hadrons?

- What is the origin of confinement?
- How is the mass generated in QCD? How are confinement and chiral symmetry breaking connected?
- What role do gluonic excitations play in the spectroscopy of light mesons, and can they help explain quark confinement?

QCD exotics



[Courtesy B. Grube]

QCD permits additional color-singlet configurations

Two general approaches:

- Manifested exotics (~~$|q\bar{q}>$~~), e.g.
  - quantum numbers incompatible with QM states
  - flavor: Charged-charmonium
- With internal exotic structure, no model free signature
  - Outnumbering of conventional QM states
  - Abnormal masses & decay properties…

"Discovery experiment" with high precision

-- Need a well understood conventional hadron picture

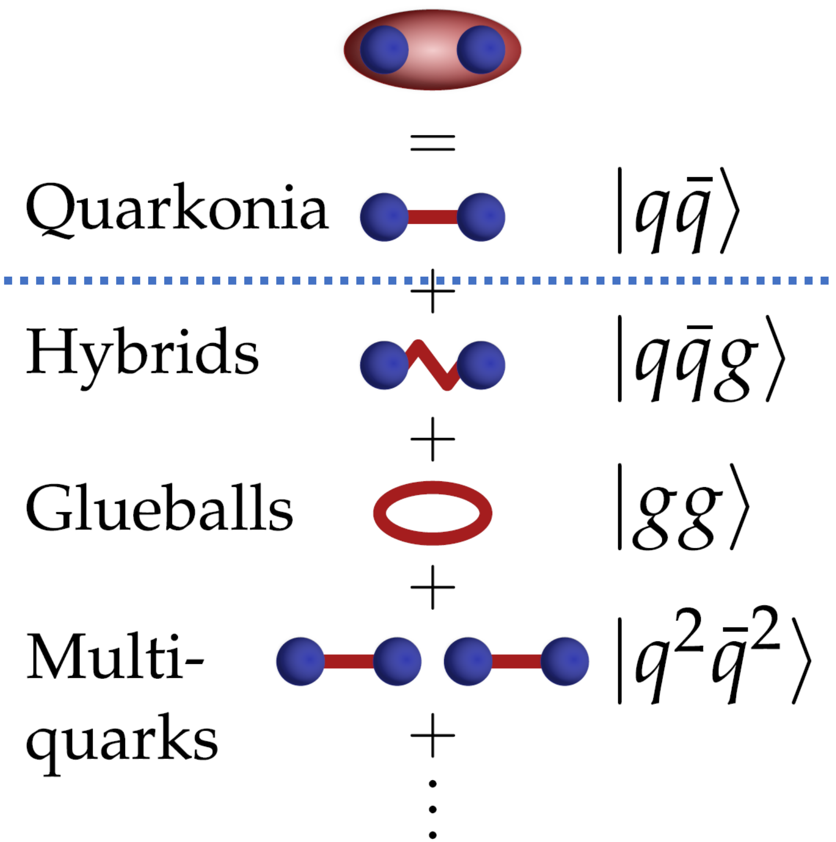
Coherent study

Multi probes：

- Production mechanism
- Decay modes

Observables:

- Mass/width/partial width
- Partners



边界条件

竞争：

BESIII, BelleII, LHCb

PANDA的特色

研究基础：

实验； 理论； 硬/软件贡献

产出：

预研阶段； 运行阶段

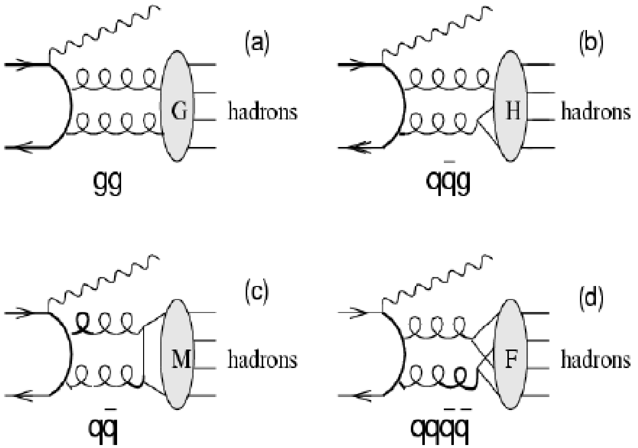
人力：

如何与研究基础结合

周期：

Phase1； Long term

Charmonium decays provide an ideal lab for light QCD exotics



$\Gamma(J/\psi \to \gamma G) \sim O(\alpha\alpha_s^2), \Gamma(J/\psi \to \gamma H) \sim O(\alpha\alpha_s^3),$

$\Gamma(J/\psi \to \gamma M) \sim O(\alpha\alpha_s^4), \Gamma(J/\psi \to \gamma F) \sim O(\alpha\alpha_s^4)$

- Clean high statistics data samples
- Well defined initial and final states
  - Kinematic constraints
  - $I(J^{PC})$ filter
- "Gluon-rich" process

Gluonic Excitations are expected to be largely produced, which provide a measurement of the excited QCD potential

BESIII研究内容：（1）轻奇特强子态

胶球

- 较轻的胶球具有常规量子数，与普通介子可能发生混合，无法直接区分

BESIII的系统研究显著改善了胶球的研究现状

	BESIII之前的研究现状	BESIII成果
0^{++}	实验: $f_0(1370)/f_0(1500)/f_0(1710)$?	$f_0(1710)/f_0(2100)$ 在 $J/\psi \to \gamma\,\eta\eta/KK/\pi\pi$ 大量产生，分支比接近LQCD预期
	LQCD: 1.7 GeV, 2.1 GeV *	
2^{++}	实验: 大量不确定性	$f_2(2340)$ 在 $J/\psi \to \gamma\eta\eta/KK/\pi\pi/\phi\phi$ 大量产生
	LQCD: 2.3-2.4 GeV	
0^{-+}	实验: 2GeV以上数据匮乏；η(1405 /1475) 疑难	η(1405/1475) 可能是同一个粒子由于动力学导致的劈裂；X(2370) 赝标量胶球候选者?
	LQCD: 2.3-2.6 GeV	

- 如何确定共振态的性质、如何确定其中的胶子成分是至关重要的问题
- 通过多种产生和衰变过程，研究中间共振态的性质
  - 0^+, 2^+ : 关键过程；多道联合分析
    - $J/\psi \to \gamma\eta\eta',\ \gamma\eta'\eta', \gamma4\pi, \gamma2K2\pi$
    - 味道过滤器：$J/\psi \to \omega X, \phi X$
  - 0^- : 在实验结果非常匮乏的高质量区建立赝标量介子谱, X(2370)
    - $J/\psi \to \gamma PPP$
    - 味道过滤器：$J/\psi \to \gamma X, X \to \gamma V\ (V = \omega/\phi)$

BESIII研究内容：（1）轻奇特强子态

混杂态

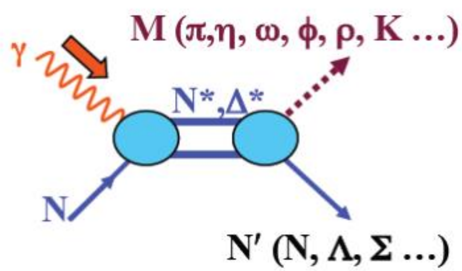
- 1^{-+}混杂态是格点QCD和唯象模型给出的最轻的具有奇特量子数的混杂态，奇特量子数是其区分于普通介子的明显判据
- 同位旋为0 的1^{-+}混杂态（η_1和η'_1）是建立混杂态九重态的关键环节，国际上相关实验研究尚属空白
- 丰胶子过程J/ψ辐射衰变为寻找同位旋为0的1^{-+}混杂态提供了新机遇
    - 对J/ψ辐射过程开展系统的分波分析研究，在确立常规量子数成分的基础上，在关键衰变道寻找1^{-+}奇特量子数成分 S波：$\eta f_1(1285)$和$K_1 K$；P波：$\eta\eta'$）

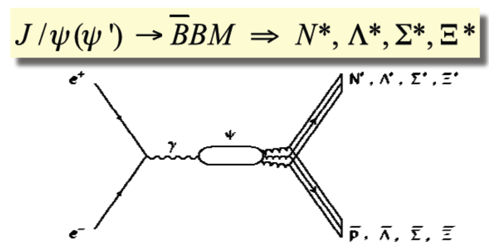
与胶球的研究互相结合

轻多夸克态

- X(1835)在$p\bar{p}$质量阈值的反常结构为我们研究多夸克态带来了重要契机。将关注更多的质量阈值附近的增长结构

BESIII内容：（2）重子谱



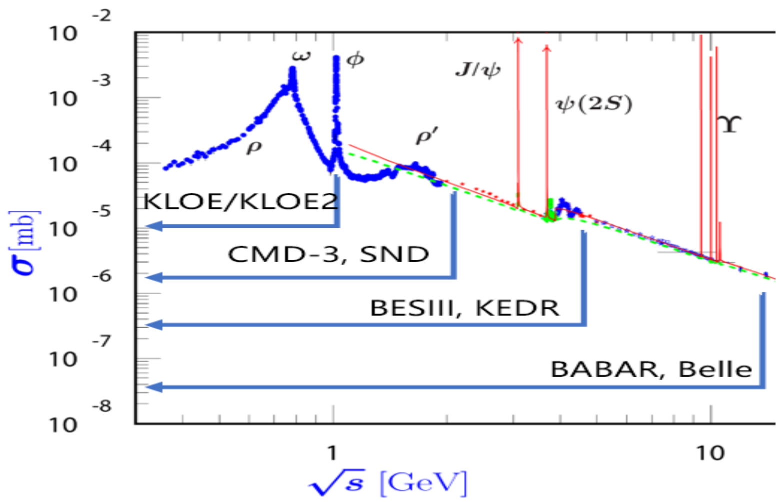


- 重子谱是研究重子内部结构和夸克、胶子相互作用的主要手段，理论预言的很多重子激发态至今未被发现
- 与其他光生和电生反应实验相比，阈值处产生的大统计量粲偶素数据研究重子激发态提供了一个极佳的场所
- 采用分波分析方法研究粲偶素衰变$\mathrm{J}/\psi, \psi(3686) \rightarrow \mathrm{B\bar{B}M}, \mathrm{B\bar{B}MM}$（$B$为重子，M为介子）。对实验已经发现的重子，测量其更多的衰变模式；寻找“失踪”的核子激发态和超子激发态

BESIII研究内容：（3）轻介子性质

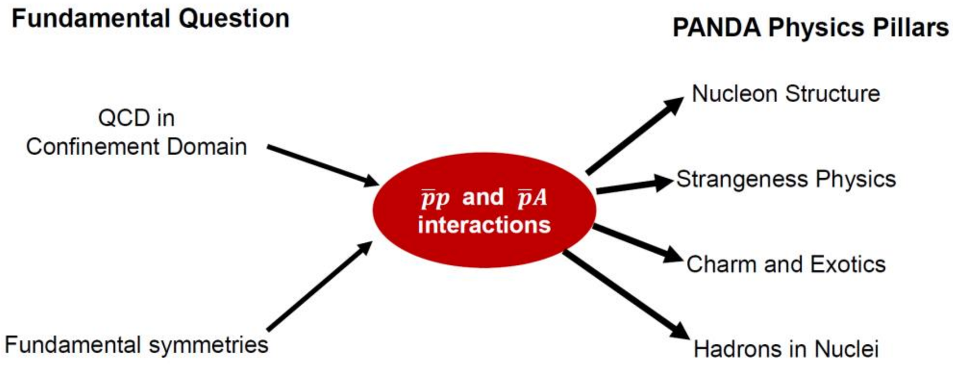
- 通过精确研究轻介子的衰变机制，可以检验粒子物理的基本对称性和低能强相互理论
  - **10^{10} J/ψ→ O(10^7) η，η′, ω**

- 系统研究轻介子激发态，介子谱的丰富和完善可以为研究QCD在非微扰能区的有效自由度提供重要信息，也是寻找超出夸克模型的奇特强子态的重要基础



From PANDA's phase one paper

PANDA will study antiproton-proton interactions in the centre of mass energy range between 2.0 and 5.5 GeV and will be unique in the world in terms of beam momentum resolution and luminosity($10^{31} cm^{-2} s^{-1}$ in phase1, $\int L = 0.5\ fb^{-1}$)

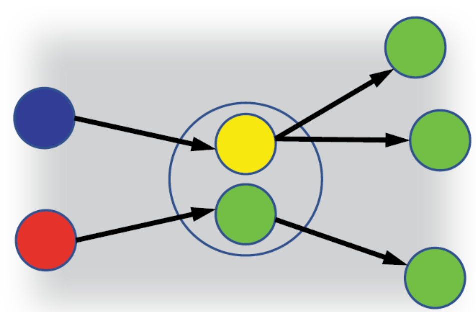


FSI

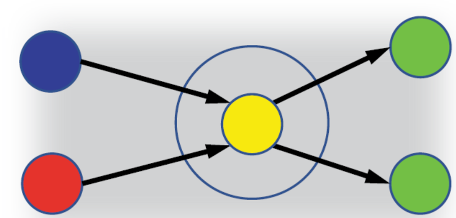
Hyperon production and hyperon spectroscopy

Lineshape of X(3872), $D_{S0}^{*}(2370)$

Light glueballs, $\phi(2170)$, π_1



all quantum numbers possible



quantum numbers like $\bar{p}p$

重子激发态

- P_c (~ $\Sigma_c D^*, \Sigma_c^* D$)→ P_s (i.e. N* ~ $\Sigma K^*, \Sigma^* K$)
- Hyperon excitations
  - Near threshold structures

$$\sigma \sim \mu b$$

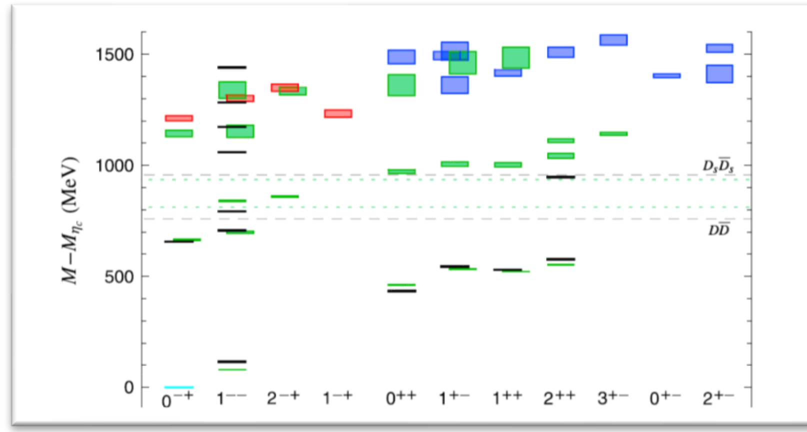
In addition, rare processes & new physics

- Searching for NP in hyperon decays
- Weak radiative hyperon decays

类粲偶素

- X(3872) 束缚能？

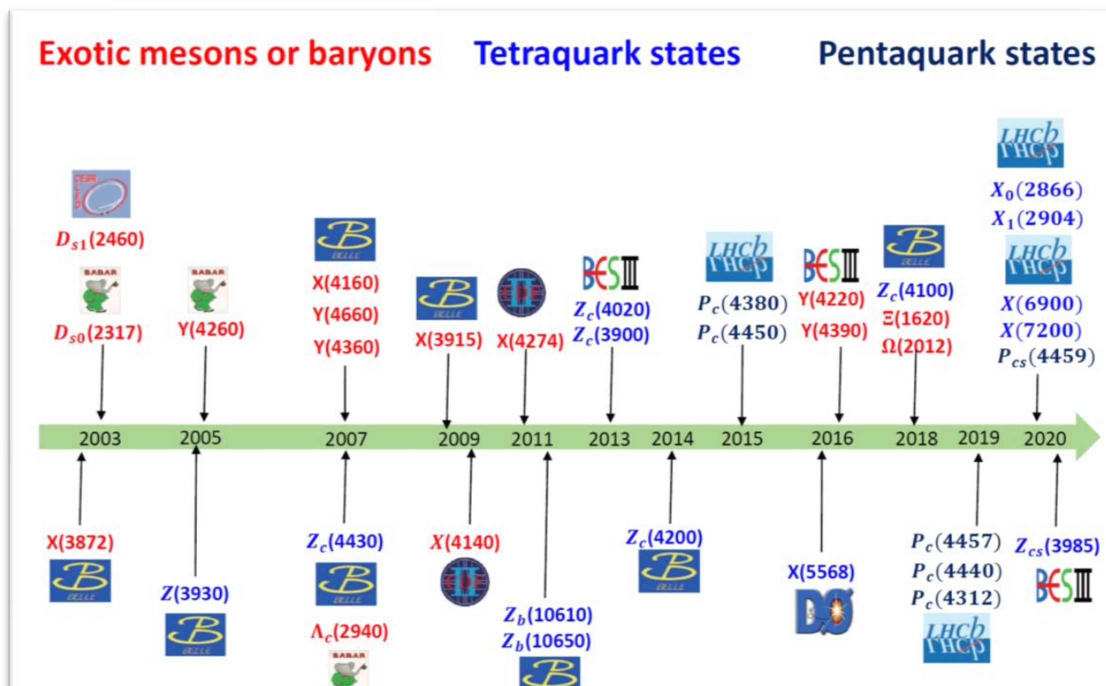
  Scan of X(3872) is planned in phase1



L. Liu, et al., [Hadron Spectrum Collaboration], J. High Energy Phys. 07 (2012) 126.

- Hybrid multiplets of Y(4xxx)

- Partners of Zc ?

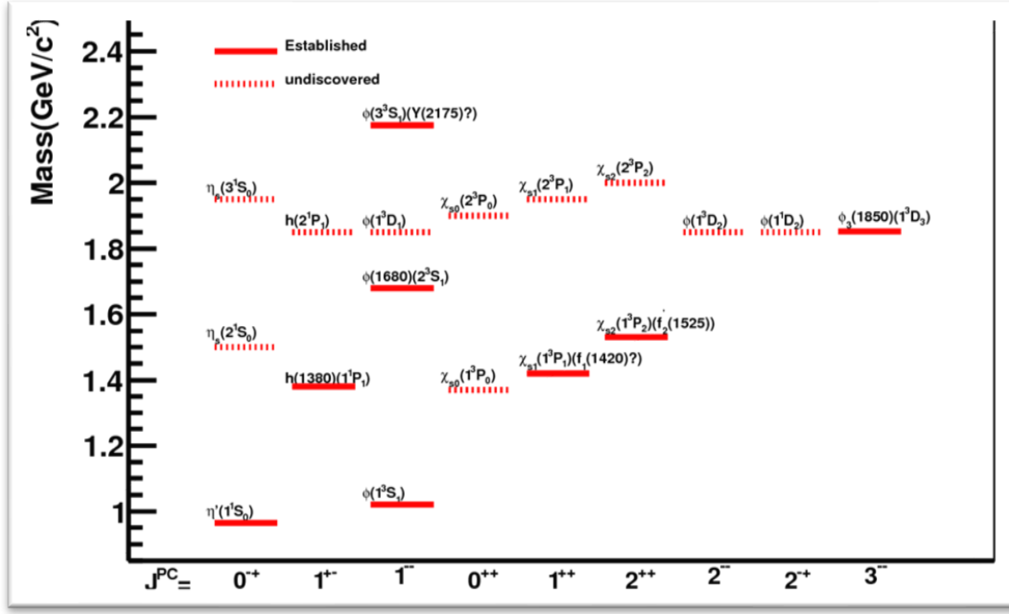


[Courtesy L.S. Geng]

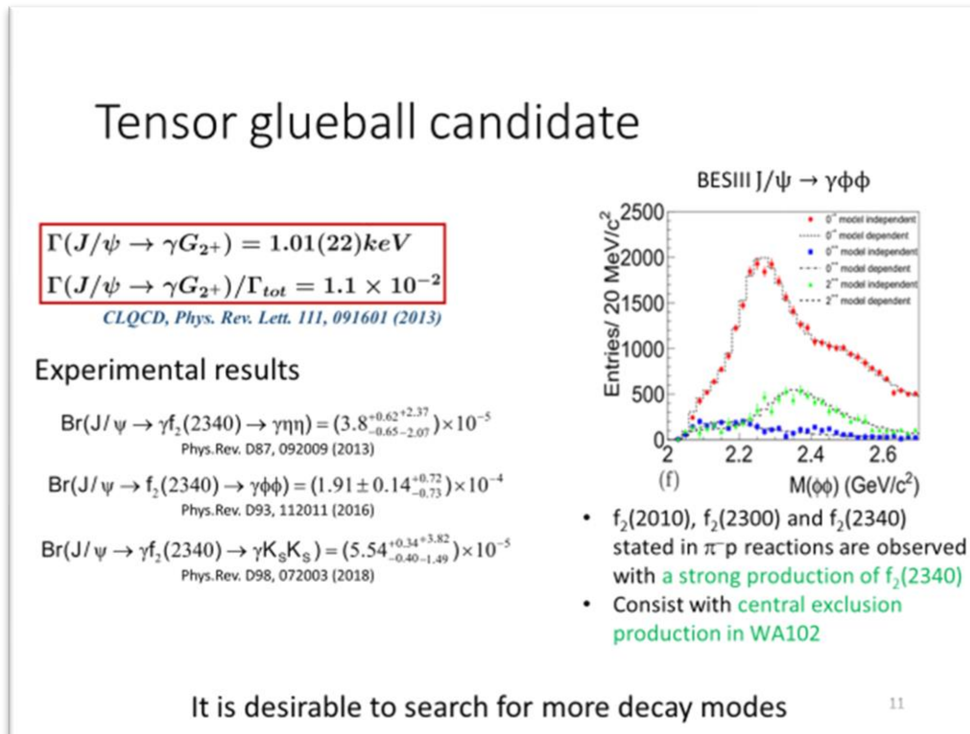
轻奇特强子

- Hybrid multiplets

- 类奇异夸克偶素



5×10^4 reconstructed $\bar{p}p \to \phi\phi$ per day



抛砖引玉

谢谢