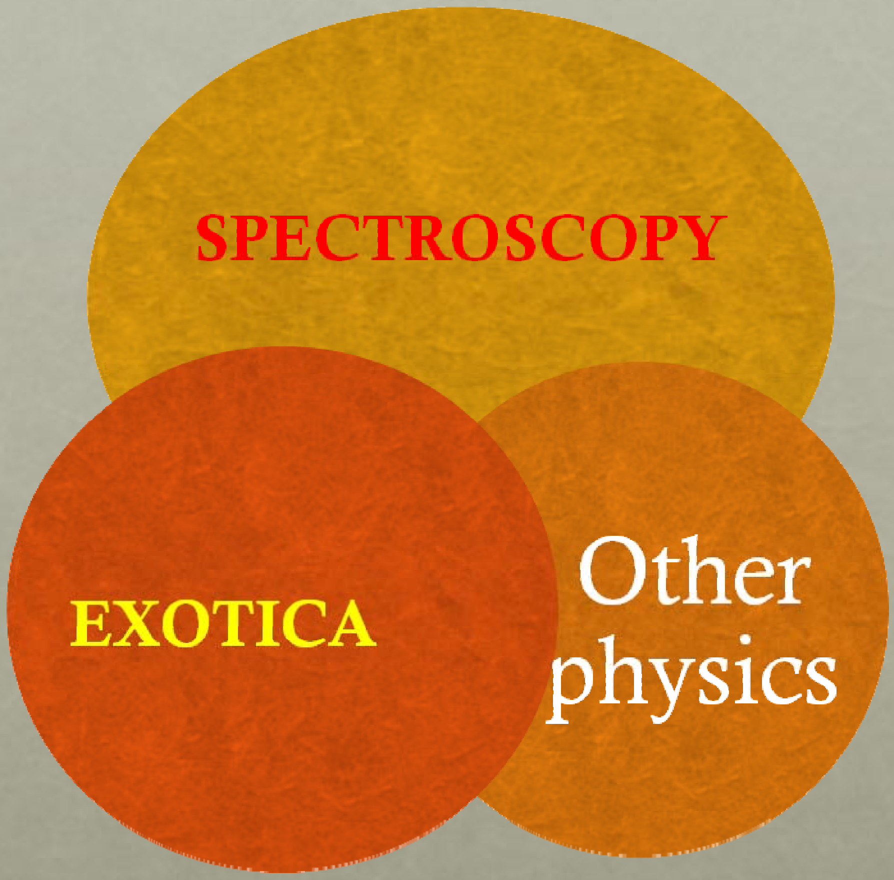
WG6 ACTIVITIES

Conveners:

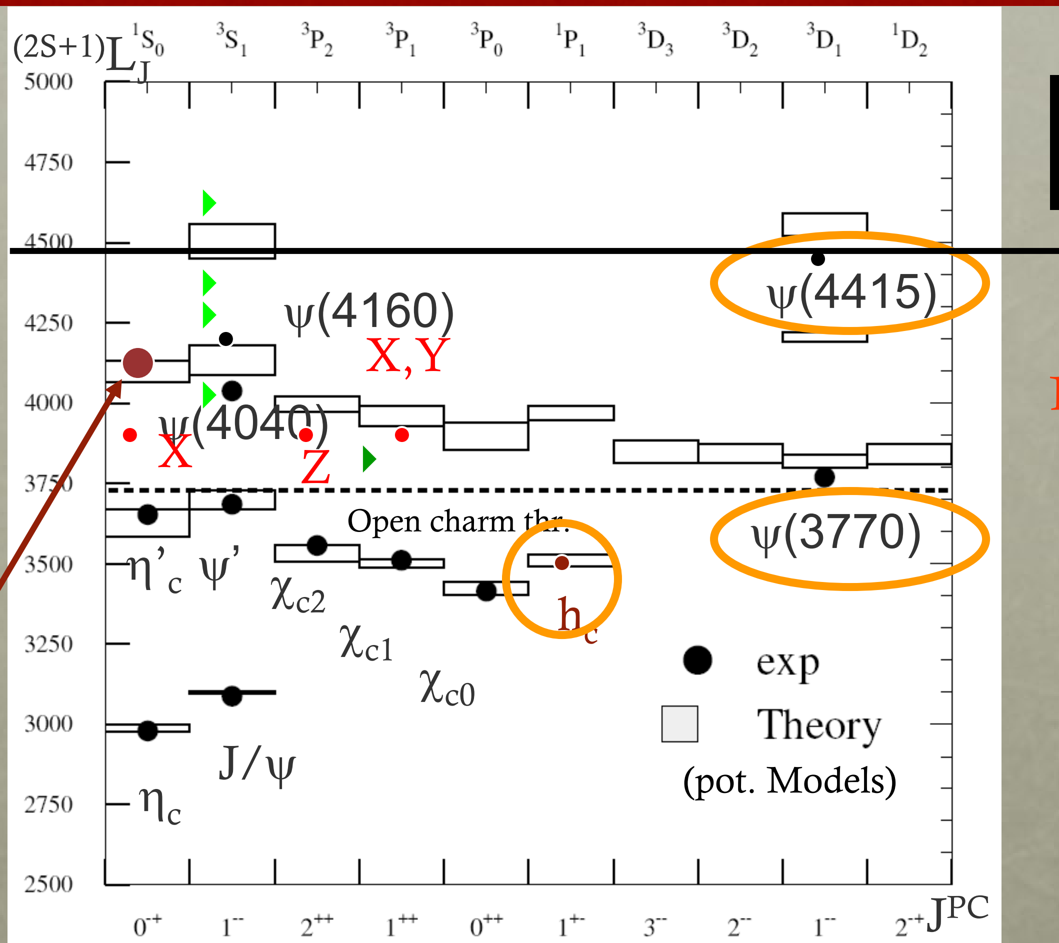
Riccardo Faccini, Antonio Polosa



VALENCIA SUMMARY

Updated properties

The 1⁻⁻ family: Charmonia, tetraquarks, molecules, hybrids?!?



Z(4430): the first charged state

News on the 3940 family

X(3872) the best tetraquark candidate

Yet another particle: X(4160) [$\eta_c(3S)$?]

+ updates on Y(nS)→Y(mS) transitions

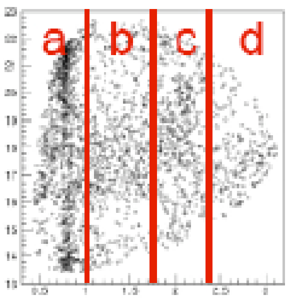
The Observation Matrix

	$J/\psi\pi^+\pi^-$	$D^{(*)}D^{(*)}$	$J/\psi\omega$	$J/\psi\pi^+\pi^0$	$\psi(2S)\pi$	$J/\psi K,\pi$	$\Psi(2S)\pi\pi$	$J/\psi\phi,\eta$	$J/\psi\gamma$
Notes	Mass range for B	Low stat	Only B dec	Mass range! No ISR	No ISR No π^0	No Search	No B-dec	Only B dec	Mass window
X(3872)	Seen	Seen	Not seen	Not seen	Not seen	No search	N/A	Not seen	Seen
Y(3940)	No search	X(3940)?	Seen	No search	Not seen	No search	No search	No Fit	No fit
Y(4260)	Seen	No fit	No fit	No search	No search	No search	Not seen	No fit	N/A
Y(4350)	Not seen	No fit	No fit	No search	No search	No search	Seen	No fit	N/A
Z(4430)	No search	No search	No fit	No search	Seen	No search	No search	No Fit	No search
Y(4660)	Not seen	No fit	No fit	No search	No search	No search	Seen	No Fit	N/A

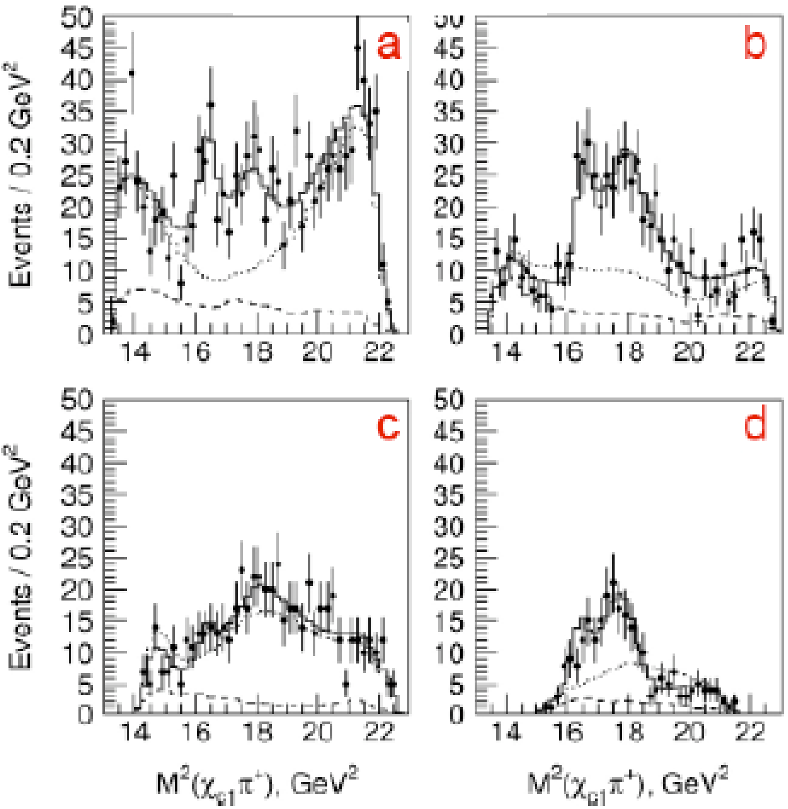
Comments & Perspectives @Valencia

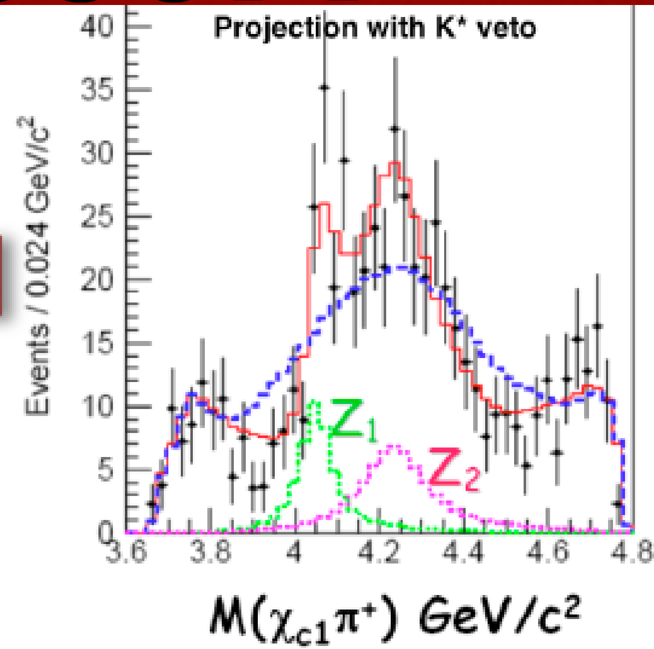
- A branch of physics where there is evidence that something 'new' is going on
  - Deserves full investigation!
  - Need to observe as many modes as possible in a large range of masses
    - Most of the non bserved modes have low εBF. Assuming one wants to reach at least those modes with a BF~0.1 max(BF) andεBF~0.1max(εBF), one needs at least 1000 times more stat.
  - Could exploit the possibility to scan in energy
- A long way before the panorama is clarified.
  - The BF picture still needs to be clarified
  - SuperB might be needed to say the final word
- Work to be done, starting from this workshop
  - Systematic definition of theory predictions in the most credited models
  - Collection of material on current results in order to sharpen the case for 'new' phenomena
  - Study of the impact of a SuperBF on this picture, in the context of its competitors

NEWS ON SPECTROSCOPY



Two more charged particles





$$M_1 = (4051 \pm 14^{+20}_{-41})\ \mathrm{MeV}/c^2,$$

$$\Gamma_1 = (82^{+21+47}_{-17-22})\ \mathrm{MeV},$$

$$M_2 = (4248^{+44+180}_{-29-35})\ \mathrm{MeV}/c^2,$$

$$\Gamma_2 = (177^{+54+316}_{-39-61})\ \mathrm{MeV},$$

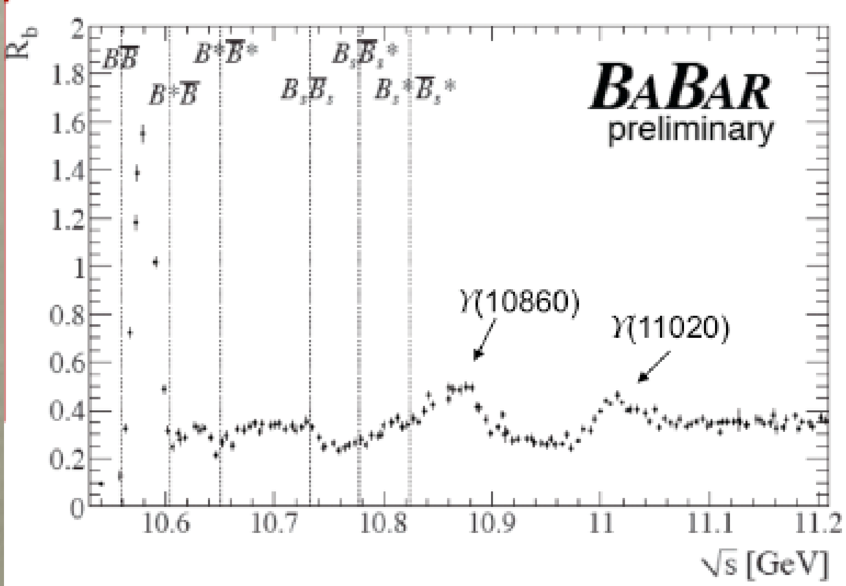
with the product branching fractions of

$$\mathcal{B}(\bar{B}^0 \to K^- Z_1^+) \times \mathcal{B}(Z_1^+ \to \pi^+ \chi_{c1}) = (3.0^{+1.5+3.7}_{-0.8-1.6}) \times 10^{-5},$$

$$\mathcal{B}(\bar{B}^0 \to K^- Z_2^+) \times \mathcal{B}(Z_2^+ \to \pi^+ \chi_{c1}) = (4.0^{+2.3+19.7}) \times 10^{-5}$$

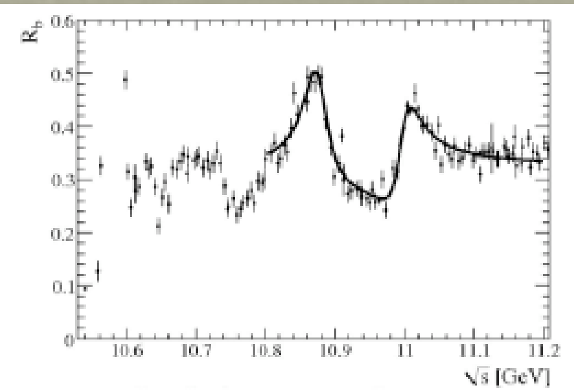
NEWS FROM SPECTROSCOPY

- Energy scan perfomed by PEP-II
  - Test of techniques for eventual SuperB scan in the cc~ area (or above 11.2 GeV?)



Region explored with unprecedented detail.

Interpretation of structures made difficult by threshold effects.



	Υ(10860)	Υ(11020)
mass (GeV)	10.876 ± 0.002	10.996 ± 0.002
width (MeV)	43 ± 4	37 ± 3
ϕ (rad)	2.11 ± 0.12	0.12 ± 0.07
PDG mass (GeV)	10.865 ± 0.008	11.019 ± 0.008
PDG width (MeV)	110 ± 13	79 ± 16

Overview of Developments

Three directions

1. Interplay and complementarity with other experiments
   - TODAY: Panda

   Talks from D. Bettoni, D. Bugg, and G. Cibinetto

2. Experimental effects → full simulation

3. Other physics
   - TODAY:
     - Higgs searches
     - Decoherence and CPT

   Talks from M. A. Sanchis-Lozano and A. Di Domenico

PANDA AT FAIR

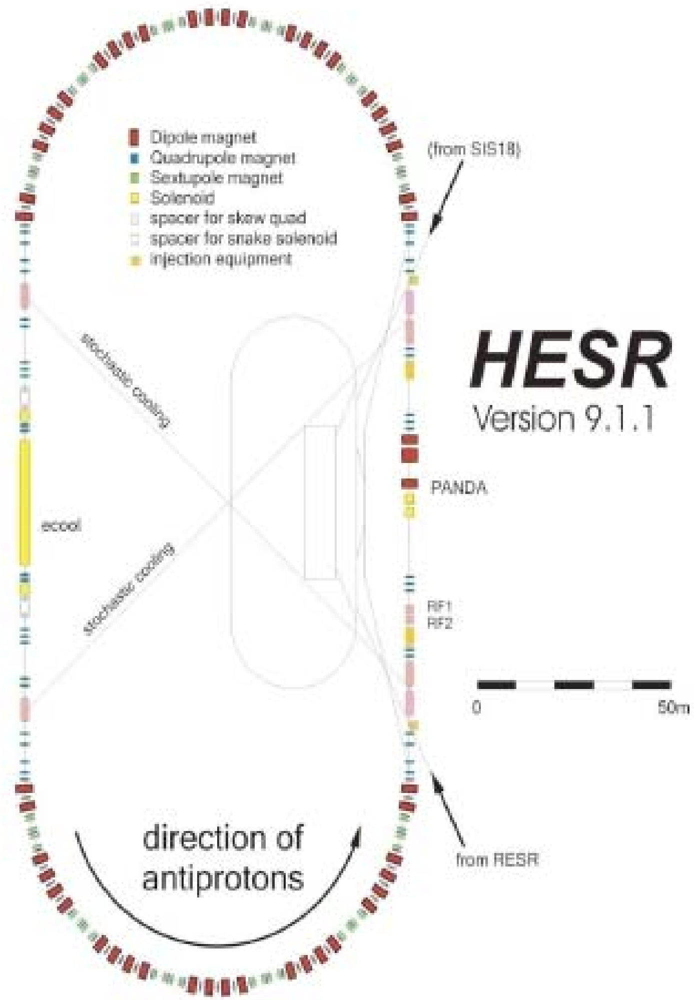
- $p\bar{p}$ annihilations
- P_{beam} = 1 - 15 GeV/c
- N_{stored} = 5×10^{10} $\bar{p}$
- Internal Target

High resolution mode

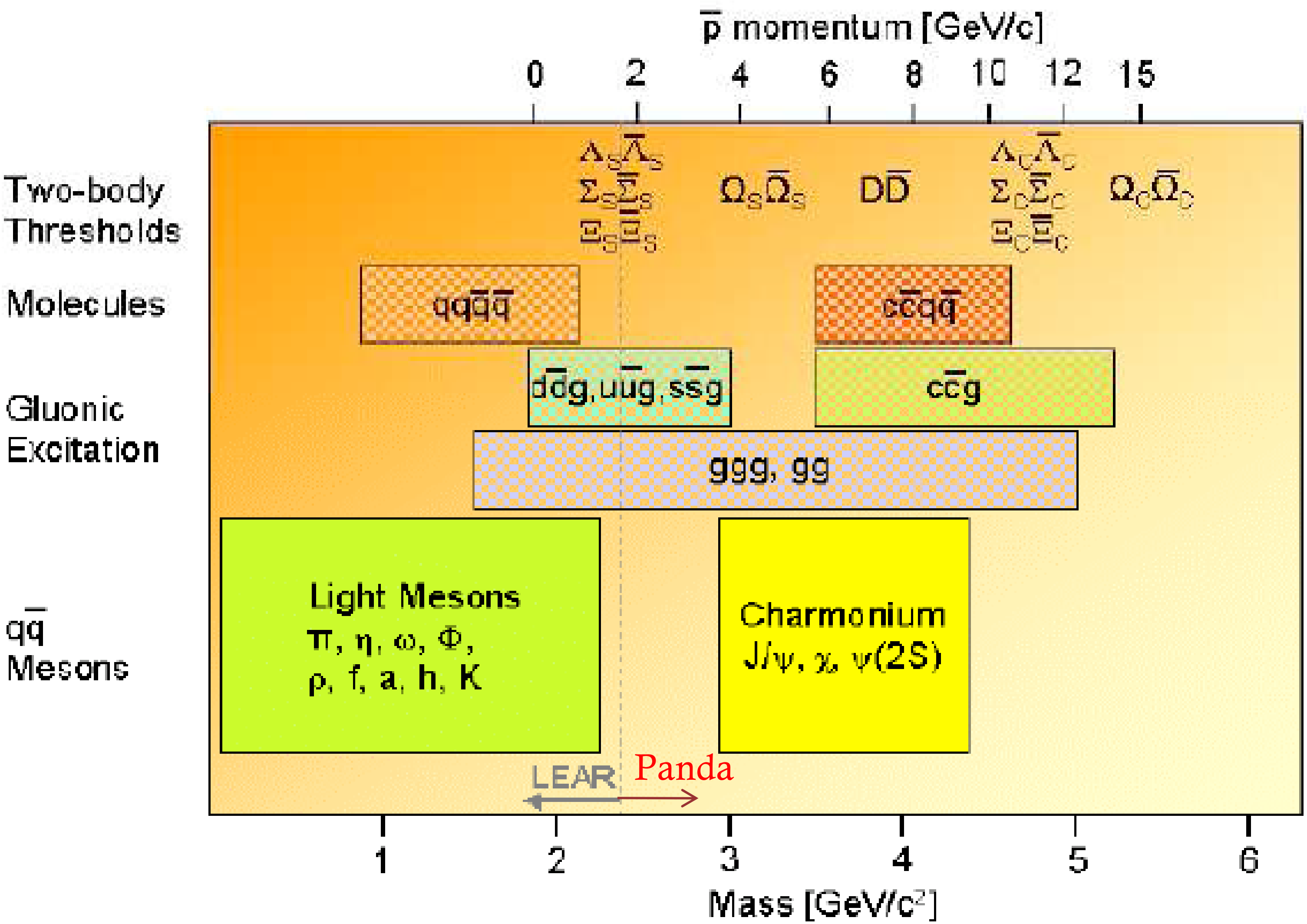
- $\delta p/p \sim 10^{-5}$ (electron cooling)
- Lumin. = 10^{31} cm^{-2} s^{-1}

High luminosity mode

- Lumin. = 2×10^{32} cm^{-2} s^{-1}
- $\delta p/p \sim 10^{-4}$ (stochastic cooling)



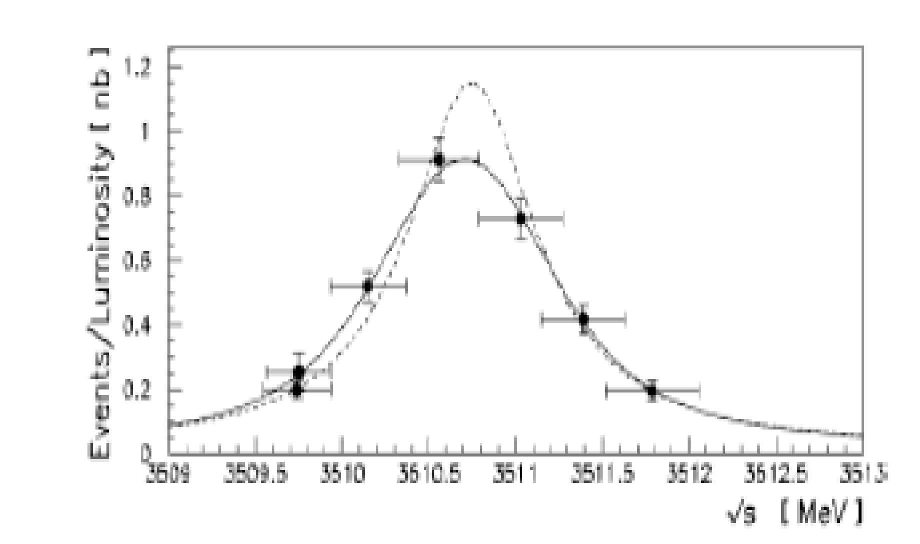
QCD Systems to be Studied in $\overline{\text{P}}$ANDA



Plan:
• Sit at high
• make a su
states
•Perform sc
most interes
points

PANDA VS SUPERB (I)

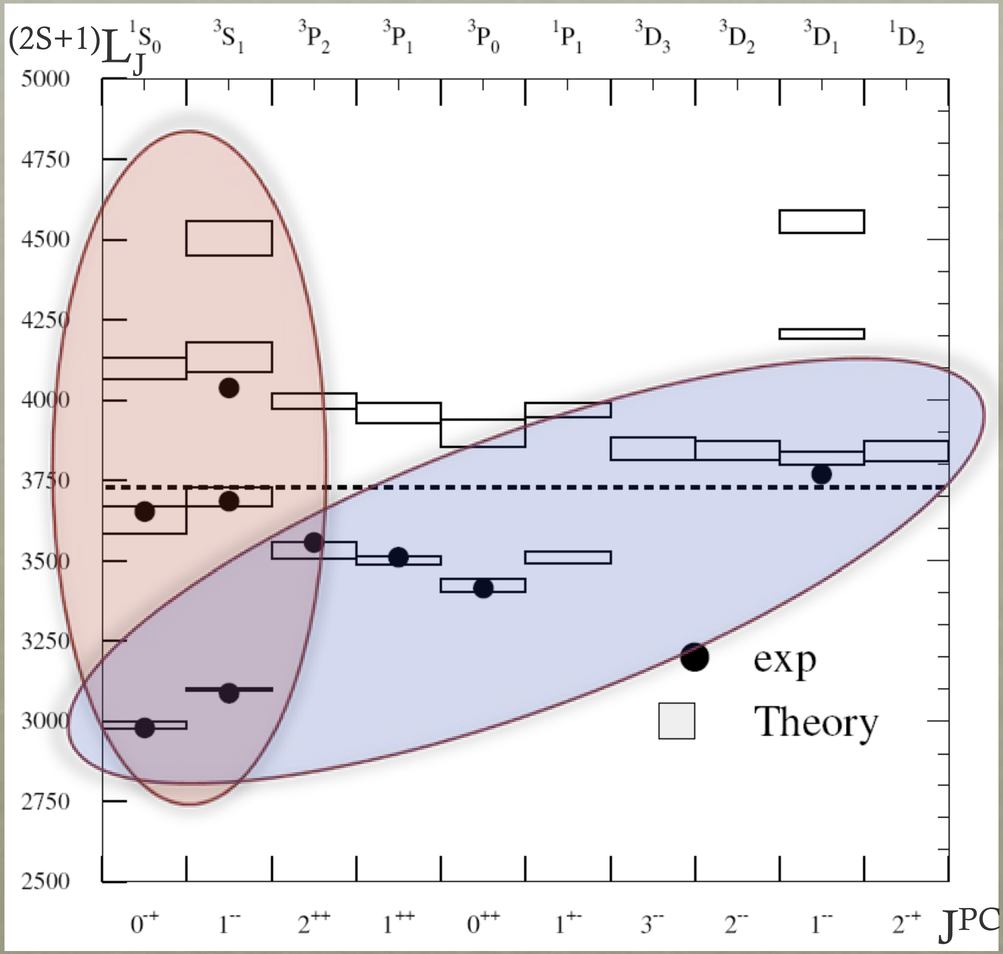
- Common coverage of all chamonium states (up to sqrt(s)~5GeV)
- Panda very suited for measurement of widths and form factors: eccellent center of mass resolution



χ_c width measurement at E835

PANDA VS SUPERB (II)

B-Factories better suited to low L and 1--



$p\bar{p}$ annihilations better suited to lower states (narrower)

Still need to compare yields on same footing!

Simulation Needs

- Valentina Santoro has agreed to run some simulations
- The goal is to have enough statistics to have unmistakable signals (full reco)
  - Relatively little dependence on detector performances
  - We just need to be sure nothing is worsened too much wrt BaBar
- Critical need: machine background
- Major worries: ISR reconstruction (missing mass) and neutrals
  - Choise of modes to simulate (~50K each):
    - e+e- → $Y\gamma_{ISR}$, Y→$D_s^{(*)}D_s^{(*)}$ [most interesting final state and testing ISR]
    - B0→X+K- , X+→ J/ψπ+π0 [testing PID and π0 reco]
- Time scale: end of year

Sensitivity to little Higgs Update since Valencia

We have incorporated in our study (arXiv:0810.4763 [hep-ph]):

- **All constraints from B-physics, LEP and g-2 using NMSSMtools [hep-ph/0406215], including the recent discovery of the $\eta_b(1S)$ state by BaBaR**

Method: search for Y(nS)→ Aγ , A-->ττ
- exclusive reco
- lepton universality in YnS) decays

- **More complete expressions on branching ratios taking into account the mixing of pseudoscalar Higgs A_1 with *all* $\eta_b(nS)$ states below open bottom threshold (n=1, 2, 3).**

- **2-sigma region of discovery in a X_d - M_{A1} plot is shown**

Conclusions

What if …

there exists a light CP-odd Higgs *of about* 10 GeV?

We have checked that current BLEP bounds can be evaded in the NMSSM

- A high luminosity B factory is the ideal place to discover/study such a light Higgs boson using ϒY(nS) (n=1,2,3) by looking at
  - decay into $\tau^+ \tau^-$ (γ): Lepton universality test
  - direct searches for monochromatic photons (1- or 2-peak scenario)
  - decay into hadrons via the $\eta\eta_{b0}$ component of the A_1

In progress

- Higher states like ϒY(4S) could be considered at a Super B factory
- Related topics: B_s decay, muon g-2 anomaly, light dark matter …
- Difficult but not impossible discovery scenario for a light A_1 at the LHC

  Moreover Higgses other than the light pseudoscalar would be at LHC reach!
- The seek of the A_1 boson can be seen as complementary/prior to other searches to be performed at the LHC/ILC

CPTV and Quantum Coherence

- **New topic** [Not so sure how much it belongs to this WG…]
- Talk from A. Di Domenico (KLOE) on applications to B-Physics of Kaon studies
- Possible CPT Violation:

  1) in eigenstate definition

$$B_L^0(t) = \left[p \cdot \sqrt{1-z} \cdot B^0 + q \cdot \sqrt{1+z} \cdot \overline{B}^0\right] \cdot e^{-\gamma_L t}$$

$$B_H^0(t) = \left[p \cdot \sqrt{1+z} \cdot B^0 - q \cdot \sqrt{1-z} \cdot \overline{B}^0\right] \cdot e^{-\gamma_H t}$$

Test of quantum coherence

2)

$$|i\rangle = \frac{1}{\sqrt{2}}\left[\left|B^0\right\rangle\left|\overline{B}^0\right\rangle - \left|\overline{B}^0\right\rangle\left|B^0\right\rangle\right]$$

$$I(f_1,f_2;\Delta t) = \frac{N}{2}\left[\left|\left\langle f_1,f_2\left|B^0\overline{B}^0(\Delta t)\right.\right\rangle\right|^2 + \left|\left\langle f_1,f_2\left|\overline{B}^0 B^0(\Delta t)\right.\right\rangle\right|^2\right.$$

$$\left. -\left(1-\zeta_{0\bar{0}}\right)\cdot 2\Re\left(\left\langle f_1,f_2\left|B^0\overline{B}^0(\Delta t)\right.\right\rangle\left\langle f_1,f_2\left|\overline{B}^0 B^0(\Delta t)\right.\right\rangle^*\right)\right]$$

Feynman described the phenomenon of interference as containing "the only mistery" of quantum mechanics

Decoherence parameter:

$\zeta_{0\bar{0}} = 0 \rightarrow$ QM

$\zeta_{0\bar{0}} = 1 \rightarrow$ total decoherence (also known as Furry's hypothesis or spontaneous factorization) [W.Furry, PR 49 (1936) 393]

Special case if ζ=0 (totally destructive QM interference):

$$I(f,f;\Delta t = 0) = 0$$

Decoherence and CPT violation

Modified Liouville – von Neumann equation for the density matrix of the kaon system:

3) $$\dot{\rho}(t) = \underbrace{-iH\rho + i\rho H^{+}}_{\text{QM}} + L(\rho)$$

extra term inducing decoherence:
pure state => mixed state

Possible decoherence due quantum gravity effects:

Black hole information loss paradox => Possible decoherence near a black hole.
Hawking [1] suggested that at a microscopic level, in a quantum gravity picture, non-trivial space-time fluctuations (generically space-time foam) could give rise to decoherence effects, which would necessarily entail a violation of CPT [2].
J. Ellis et al.[3-6] => model of decoherence for neutral kaons => 3 new CPTV param. α,β,γ:

$$L(\rho) = L(\rho; \alpha, \beta, \gamma)$$

$$\alpha, \gamma > 0 \quad , \quad \alpha\gamma > \beta^2$$

At most: $\alpha, \beta, \gamma = O\left(\frac{M_K^{\ 2}}{M_{PLANCK}}\right) \approx 2\times 10^{-20}$ GeV

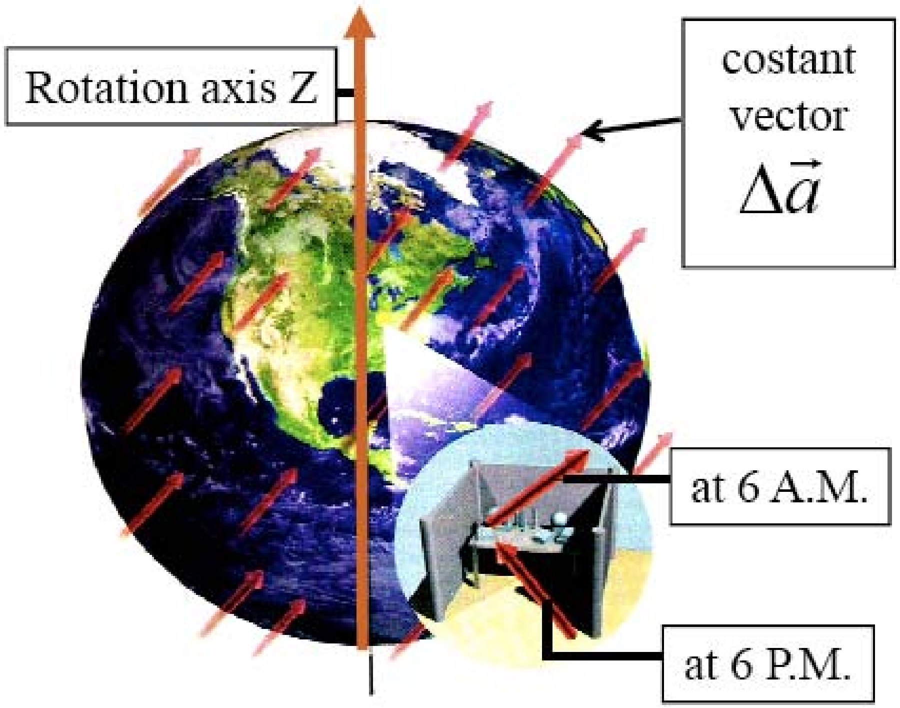
$$|i\rangle \propto \left(K^0\overline{K}^0 - K^0\overline{K}^0\right) + \omega\left(K^0\overline{K}^0 + K^0\overline{K}^0\right)$$
$$\propto \left(K_S K_L - K_L K_S\right) + \omega\left(K_S K_S - K_L K_L\right)$$

at most one expects: $|\omega|^2 = O\left(\frac{E^2/M_{PLANCK}}{\Delta\Gamma}\right) \approx 10^{-5} \Rightarrow |\omega| \sim 10^{-3}$

CPT and Lorentz invariance violation (SME)

z depends on sidereal time t since laboratory frame rotates with Earth

$$\beta^{\mu}\Delta a_{\mu} = \gamma_K [\Delta a_0 + \beta_K \Delta a_Z \cos\chi + \beta_K \Delta a_Y \sin\chi \sin\Omega t + \beta_K \Delta a_X \sin\chi \cos\Omega t]$$



Ω: Earth's sidereal frequency
χ : angle between the z lab. axis and the Earth's rotation axis

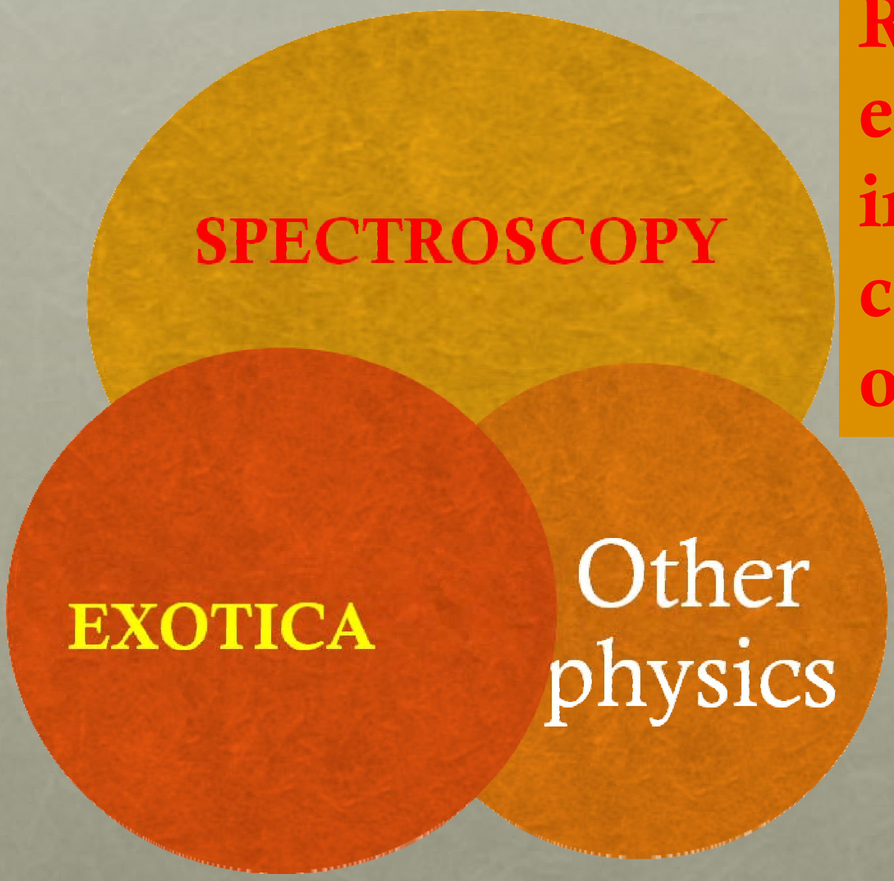
SuperB Sensitivity

@B-Factories: time dependence of doubly tagged events

Test of	Param.	Present best measurement	SuperB $L \sim 50\ ab^{-1}$
CPT	Re z	0.00 ± 0.12	$\pm 0.3 \times 10^{-3}$
CPT	Im z	$(-13.9 \pm 7.8) \times 10^{-3}$	$\pm 0.6 \times 10^{-3}$
QM	$\zeta_{\underline{00}}$	$(2.9 \pm 5.7) \times 10^{-2}$	$\pm 3.6 \times 10^{-3}$
QM	ζ_{SL}	$(0.4 \pm 1.7) \times 10^{-2}$	$\pm 1 \times 10^{-3}$
CPT & QM	α,β,γ		
CPT & EPR corr.	$Re(\omega)$	<0.01	$\pm 4 \times 10^{-4}$
CPT & EPR corr.	$Im(\omega)$		
CPT & Lorentz	$\Delta a_0 - 0.3 \Delta a_Z$	$(-3.0 \pm 2.4) \times \Delta m/\Delta\Gamma \times 10^{-15}$ GeV	$\pm 1.5 \times \Delta m/\Delta\Gamma \times 10^{-16}$ GeV
CPT & Lorentz	Δa_X	$(-22 \pm 7) \times \Delta m/\Delta\Gamma \times 10^{-15}$ GeV	$\pm 4.4 \times \Delta m/\Delta\Gamma \times 10^{-16}$ GeV
CPT & Lorentz	Δa_Y	$(-14 \pm 12) \times \Delta m/\Delta\Gamma \times 10^{-15}$ GeV	$\pm 7.6 \times \Delta m/\Delta\Gamma \times 10^{-16}$ GeV

PATH TO TDR

Refine the case adding efficiencies
include complementarity with other experiments



Are we missing anything? Ideas are welcome!

Only one open thread .. Anything more?