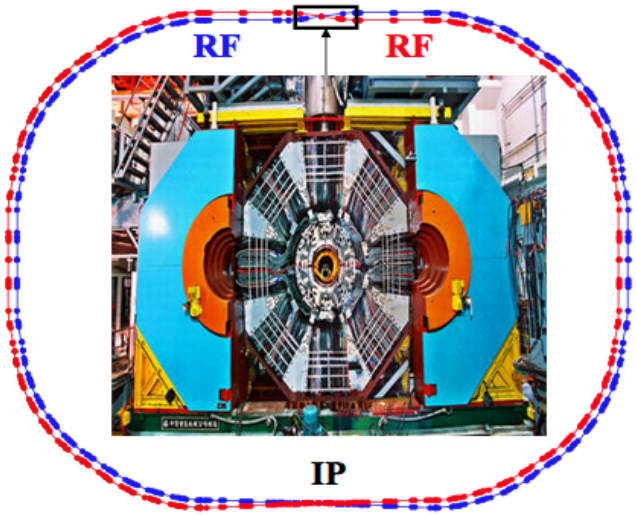
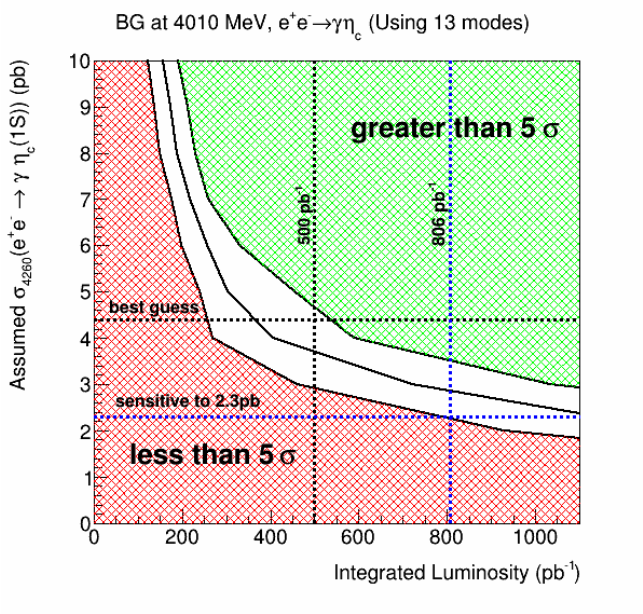
Radiative Transitions of the Y(4260) at BES III

Manuel Lara

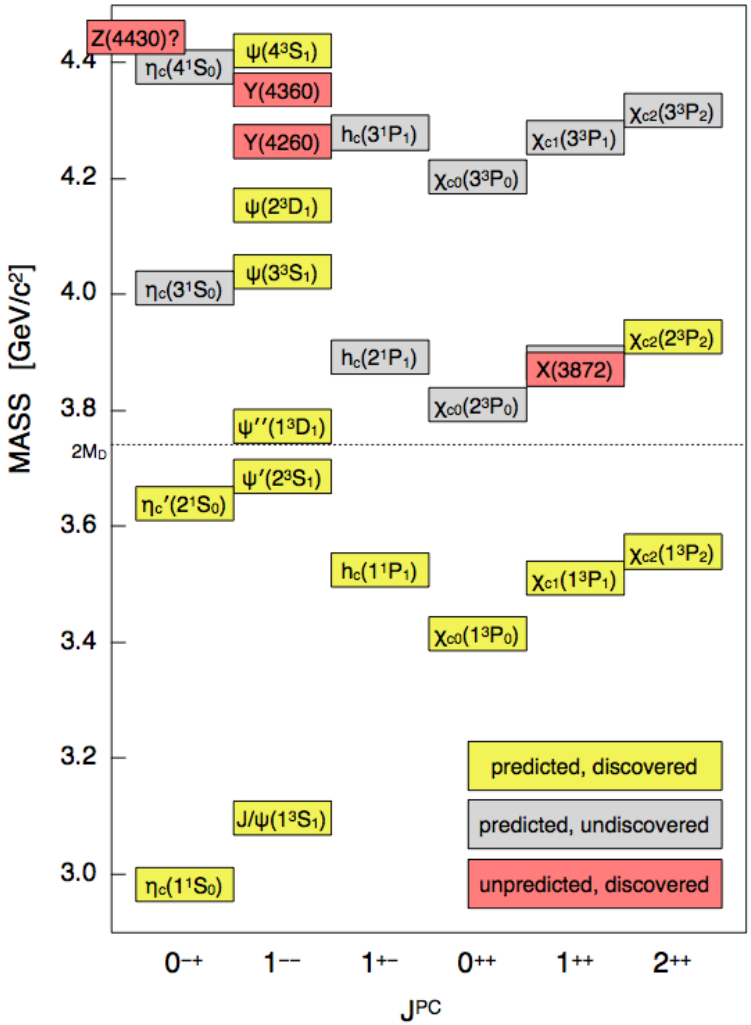
Indiana University

April 12, 2015



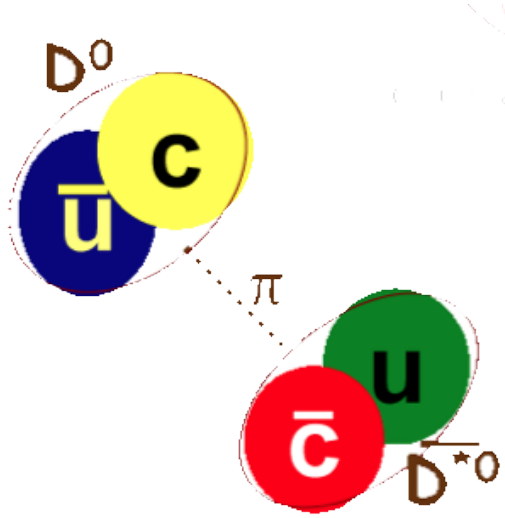


Charmonium Today

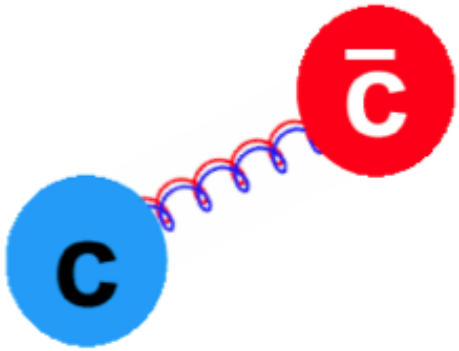


- Charmonium is a bound $c\bar{c}$ state
- Models have been extremely successful in predicting most of the states
- The discovery of the XYZ states shed new light on charmonium system
- What do these new states mean?

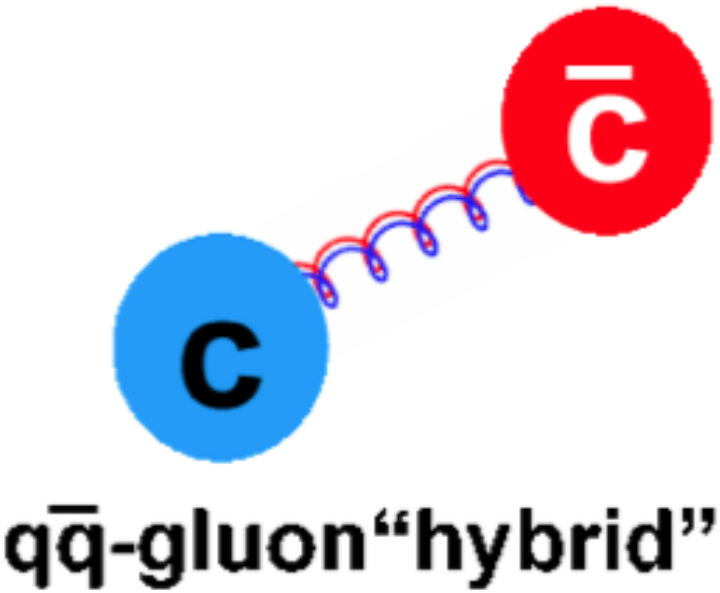
diquark-diantiquark



$D^0 - \bar{D}^{*0}$ "molecule"



$q\bar{q}$-gluon"hybrid"



- Excited gluonic field between the quarks acts as a constituent gluon
- Expected mass of charmonium hybrid: 4.2-4.5 GeV[a]
- Allows for an extra quantum number: I_{gluon}

[a] E. Kou and O. Pene, Phys. Lett. B 631, 164 (2005) [hep-ph/0507119]

Transitions to χ_{c0}	Γ_{lat}/keV	Γ_{exp}/keV	Transitions to η_c	Γ_{lat}/keV	Γ_{exp}/keV
$\chi_{c0} \to J/\psi\gamma$	199(6)	131(14)	$J/\psi \to \eta_c\gamma$	2.51(8)	1.85(29)
$\psi' \to \chi_{c0}\gamma$	26(11)	30(2)	$\psi' \to \eta_c\gamma$	0.4(8)	0.95(16)
$\psi'' \to \chi_{c0}\gamma$	265(66)	199(26)	$\psi'' \to \eta_c\gamma$	10(11)	-
$\Upsilon_{\text{hyb}} \to \chi_{c0}\gamma$	$\leq$20	-	$\Upsilon_{\text{hyb}} \to \eta_c\gamma$	42(18)	-

Table: J. J. Dudek, R. Edwards, and C. E. Thomas, Phys.Rev. D79, 094504 (2009)

Recall: radiative transitions that involve a spin flip in the final state are suppressed by $1/m_q^2$.

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If the Y(4260) is a conventional meson then: spin triplet resonance with $c\bar{c}$ constituent quarks, similar to $\psi(2S)$

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Implies:
$Y(4260) \to \gamma\chi_{c0}$ does NOT involve a spin flip
$Y(4260) \to \gamma\eta_c$ does involve a spin flip

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Recall: radiative transitions that involve a spin flip in the final state are suppressed by $1/m_q^2$.
Example:
$\Gamma(\psi' \to \gamma\chi_{c0}) = 26$ keV
$\Gamma(\psi' \to \gamma\eta_c) = 0.4$ keV
$\frac{\Gamma(\psi' \to \gamma\chi_{c0})}{\Gamma(\psi' \to \gamma\eta_c)} = 65$

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Example:
$\Gamma(\Upsilon_{\text{hyb}} \to \gamma\chi_{c0}) \leq 20$ keV
$\Gamma(\Upsilon_{\text{hyb}} \to \gamma\eta_c) = 42$ keV
$\frac{\Gamma(\Upsilon_{\text{hyb}} \to \gamma\chi_{c0})}{\Gamma(\Upsilon_{\text{hyb}} \to \gamma\eta_c)} \leq 0.5$

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Recall: radiative transitions that involve a spin flip in the final state are suppressed by $1/m_q^2$.

$\text{BF}(\Upsilon_{\text{hyb}} \to \gamma\eta_c) = \frac{42keV}{95MeV} = 4.4 \times 10^{-4}$

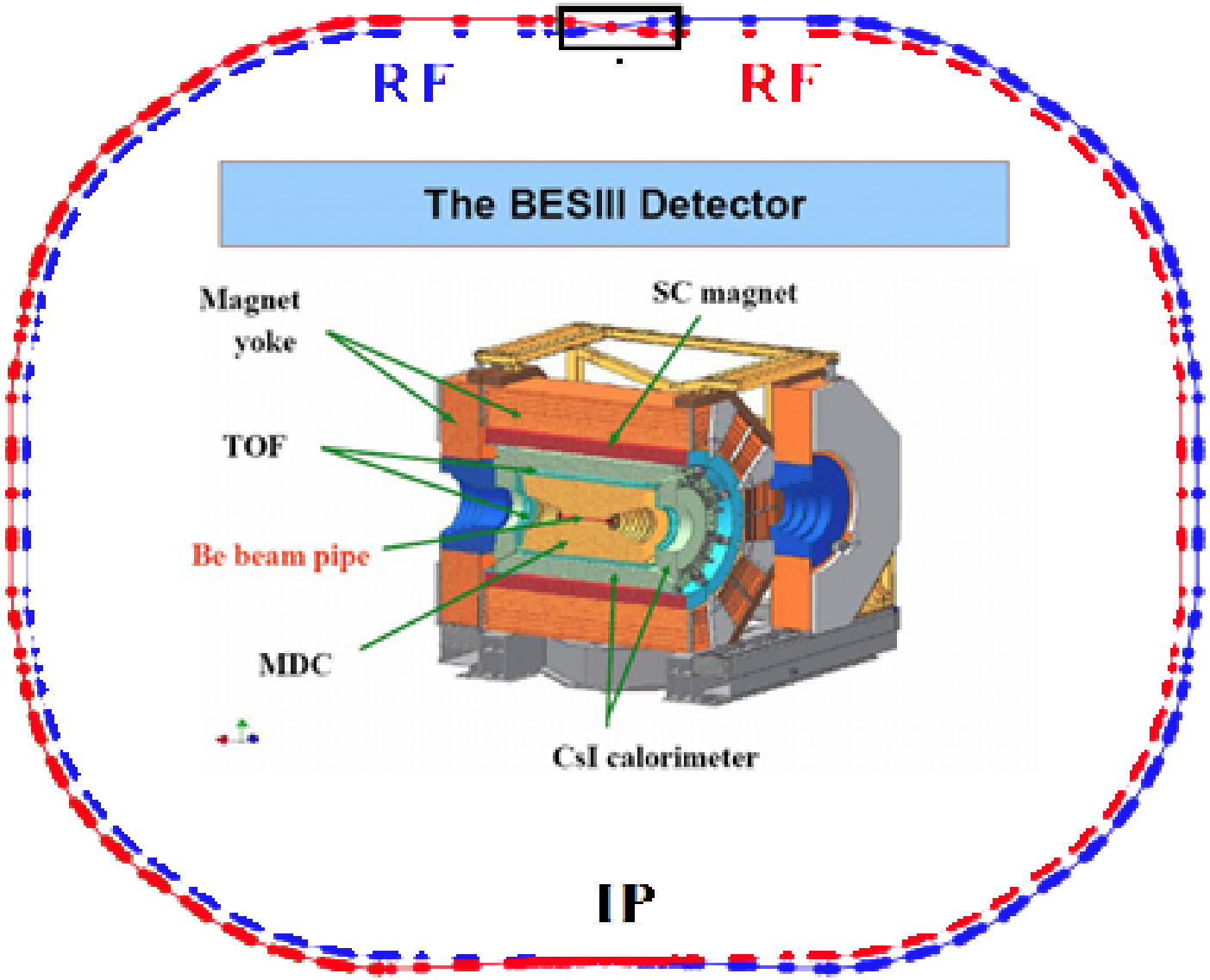
$\text{BF}(\Upsilon_{\text{hyb}} \to \gamma\chi_{c0}) \leq 2.1 \times 10^{-4}$

$\sigma_{\text{upper limit}}(e^+e^- \to Y(4260)) = 1 \times 10^4 pb$[1]

$\sigma_{\text{upper limit}}(e^+e^- \to Y(4260) \to \gamma\eta_c) = 4.4pb$

$\sigma_{\text{upper limit}}(e^+e^- \to Y(4260) \to \gamma\chi_{c0}) = 2.1pb$

[1] T. E. Coan et al. (CLEO Collaboration), Phys. Rev. Lett.96, 162003 (2006)


RF
RF
The BESIII Detector
Magnet yoke
SC magnet
TOF
Be beam pipe
MDC
CsI calorimeter
IP

η_c and χ_{c0} decays

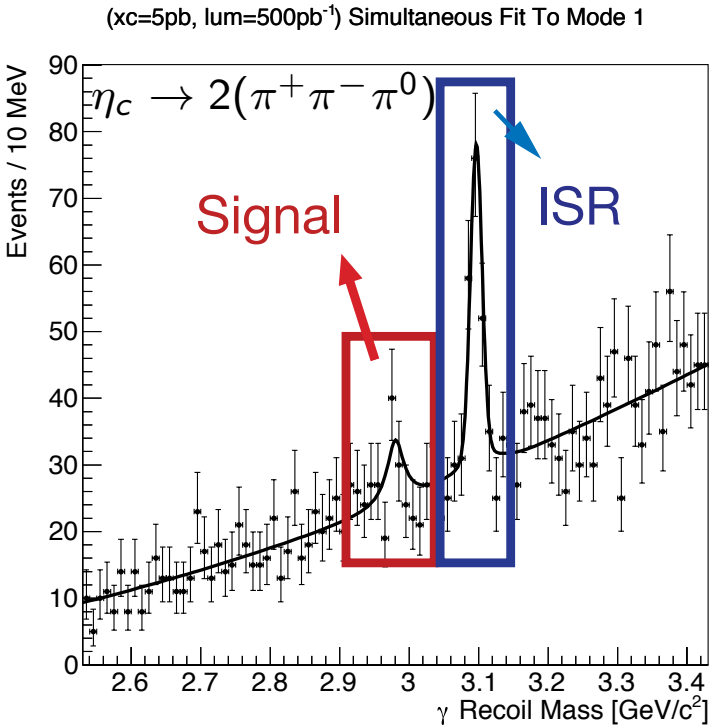
η_c Decay Mode	Branching Fraction (%)
$\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0$	17.23
$\pi^+\pi^-\pi^0\pi^0$	4.66
$\eta\pi^+\pi^-\pi^+\pi^-$	4.40
$K^\pm K_s\pi^\mp\pi^+\pi^-$	2.75
$K^\pm K_s\pi^\mp$	2.6
$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$	2.02
$\pi^+\pi^-\pi^+\pi^-$	1.72
$\eta\pi^+\pi^-$	1.66
$K^+K^-\pi^0$	1.04
$K^+K^-\pi^+\pi^-$	0.95
$K^+K^-\pi^+\pi^-\pi^+\pi^-$	0.83

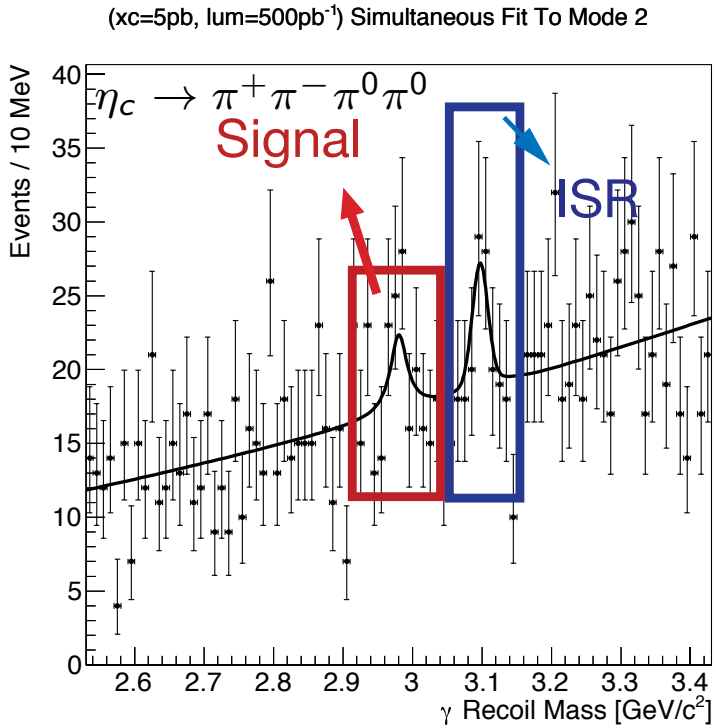
Table: η_c branching fractions taken from BESIII measurements

χ_{c0} Decay Mode	Branching Fraction (%)
$\pi^+\pi^-\pi^0\pi^0$	3.3
$2(\pi^+\pi^-)$	2.25
$3(\pi^+\pi^-)$	1.77
$K^+K^-\pi^+\pi^-$	1.20
K^+K^-	0.598
$\pi^+\pi^-K_SK_S$	0.57
K_SK_S	0.31
$\eta\eta$	0.3
$2(K^+K^-)$	0.277
$\pi^+\pi^-p\bar{p}$	0.21
$\gamma J/\psi(e^+e^-/\mu^+\mu^-)$	0.154

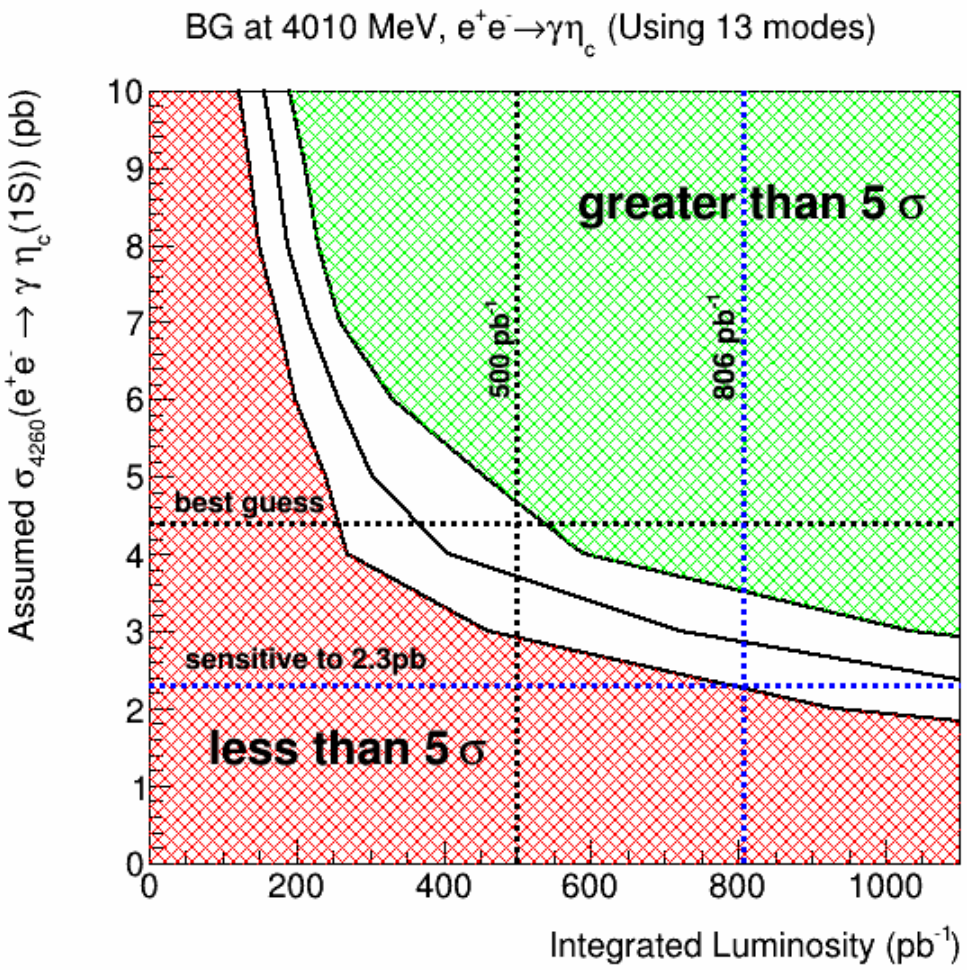
Table: χ_{c0} branching fractions taken from PDG

Toy Monte-Carlo Studies





- The BES Event Generator is used to generate background for each mode reconstructed.
  A Breit-Wigner function is used for the signal shape
- Background Components
  - Continuum: 2nd order Chebychev Polynomial
  - ISR: Double Gaussian



Energy (MeV)	Luminosity (pb^{-1})
4230	1054
4260	806

Table: Luminosity

13 η_c modes are simultaneously fit

1. Assume a cross section and luminosity
2. Simultaneously fit with and without a signal
3. Calculate significance
4. Repeat 50 times
5. Calculate mean and root mean square of significance
6. Repeat 1-5

Conclusion

This is an ongoing analysis, paper should be out in the coming months
These are exciting times at BESIII. 5 papers have been published using the 4260 data set with many more coming in the following months.

- XYZ Data collection period: December 2012 - June 2013 and 2014
- About 4.5 fb^{-1} of data was collected, mostly at 4.23, 4.26, 4.36, 4.42, and 4.6 GeV
- Y(4260) publications published thus far:
  1. Observation of a charged charmoniumlike structure in $e^+e^- \to \pi^+\pi^- J/\psi$ at $\sqrt{s}$=4.26 GeV, Phys. Rev. Lett(2013) 252001
  2. Observation of a charged charmoniumlike structure $Z_c(4020)$ and search for the $Z_c(3900)$ in $e^+e^- \to \pi^+\pi^- h_c$, Phys. Rev. Lett. 111, 242001 (2013)
  3. Observation of a charged $(D^*\bar{D}^*)^\pm$ mass peak in $e^+e^- \to \pi D^*\bar{D}^*$ at $\sqrt{s}$=4.26 GeV, Published in Phys. Rev. Lett 112, 022001 (2014)
  4. Observation of $e^+e^- \to \gamma X(3872)$ at BESIII, Published in Phys.Rev.Lett. 112 (2014) 092001
  5. Observation of $e^+e^- \to \pi^0\pi^0 h_c$ and a neutral charmoniumlike state $Z_c^0(4020)$, Published in Phys.Rev.Lett. 113 (2014) 21, 212002