Proposal for precise measurement of $\eta_c(1s)$ and $\eta_c(2s)$ at BES

possible search for $h_c(1P)$ $(^1P_1)$

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Motivation

- Test of QCD models on charmonium states
  - . discrepancy in $\eta_c(1s)$ width
  - . discrepancy in $\eta_c(2s)$ mass between observation and prediction
  - . confirmation of $\eta_c(2s)$
- Good energy resolution from $\gamma \to e^+e^-$ at BES
  - . precise measurements of mass and width for $\eta_c(1s)$ and $\eta_c(2s)$
- search for $h_c(1P)$ $(^1P_1)$ state

Existing observations

- $\eta_c(1s)$

group	mass MeV	width MeV	year	comment
BES	$2976.3^{+2.3}_{-1.2}$	$11.0^{+8.1}_{-4.1}$	**2000**	$J/\psi, \psi(2s) \to \gamma\eta_c$
CLE2	$2980.4^{+2.3}_{-0.6}$	$27.0^{5.8+}_{-1.4}$	**2000**	$\gamma\gamma \to \eta_c$
DLPH	2999 ± 8		**1998**	e^+e^-
E760	$2988.3^{+3.3}_{-3.1}$	$23.9^{+12.6}_{-7.1}$	**1995**	$\bar{p}p$
DM2	2974.4 ± 1.9		**1991**	e^+e^-
MRK3	$2969.9 \pm 4 \pm 4$	$10.1^{33.0}_{8.2}$	**1990/1986**	e^+e^-
CBAL	$2984 \pm 2.3 \pm 4.0$	11.5 ± 4.5	**1986**	e^+e^-
BES		$17.0^{+3.8}_{-5.0}$	**2002**	$J/\psi \to \gamma\eta_c$

Existing observations

- $\eta_c(2s)$

group	mass MeV	width MeV	year	comment
Belle	$3654 \pm 6 \pm 8$	15^{+24}_{-15}	**2002**	e^+e^-
CBAL	3594 ± 5	< 8	**1982**	e^+e^-
BSW	**3560 to 3591**		**1997**	**QCD**
EFG	**3583**		**2000**	**QCD**

- $h_c(1P)$

group	mass MeV	width MeV	year	comment
E705	3527 ± 8		**1994**	$\bar{p}p$
E760	$3526.20 \pm 0.15 \pm 0.20$	1.1	**1992**	$\bar{p}p$
SPEC	$3525.4 \pm .8 \pm 0.4$		**1986**	$\pi^{\pm}, pL_i$
BSW	**3468 to 3486**		**1997**	**QCD**

Recent predictions

- **BSW : G.S.Bali, K.Schilling and A.Wachter**
  - **see: PRD56,(1997)2566)**

State $(n^{(2s+1)}L_J)$	**particle**	**Theory MeV**	**PDG MeV**
1^1S_0	η_c	**2966 to 3010**	2979.8 ± 1.8
1^3S_1	J/ψ	**3134 to 3175**	3096.87 ± 0.04
1^3P_0	χ_{c0}	**3442 to 3452**	3415.0 ± 0.8
1^3P_1	χ_{c1}	**3479 to 3490**	3510.51 ± 0.12
1^3P_2	χ_{c2}	**3465 to 3491**	3556.18 ± 0.13
2^1S_0	$\eta_c(2s)$	**3560 to 3591**	
2^3S_1	$\psi(2s)$	**3685 to 3705**	3685.96 ± 0.09
1^1P_1	h_c	**3468 to 3486**	

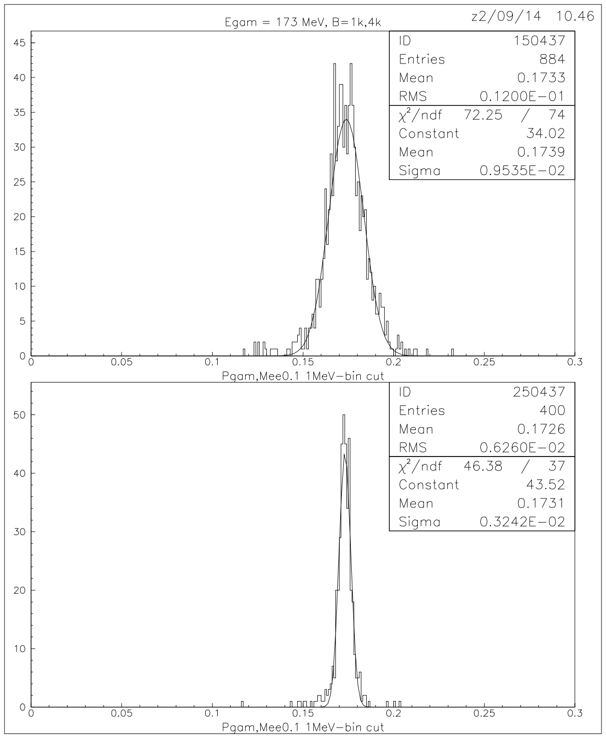
Recent predictions

- **EFG : D.Ebert, R.N.Faustov and V.O.Galkin**
  - . **see: PRD62,(2000)034014**
  - . **more precise**

State ($n^{(2s+1)}L_J$)	**particle**	**Theory MeV**	**PDG MeV**
1^1S_0	η_c	**2979**	2979.8 ± 1.8
1^3S_1	J/ψ	**3096**	3096.87 ± 0.04
1^1P_1	h_c	**no prediction**	
1^3P_0	χ_{c0}	**3424**	3415.0 ± 0.8
1^3P_1	χ_{c1}	**3510**	3510.51 ± 0.12
1^3P_2	χ_{c2}	**3556**	3556.18 ± 0.13
2^1S_0	$\eta_c(2s)$	**3583**	
2^3S_1	$\psi(2s)$	**3686**	3685.96 ± 0.09

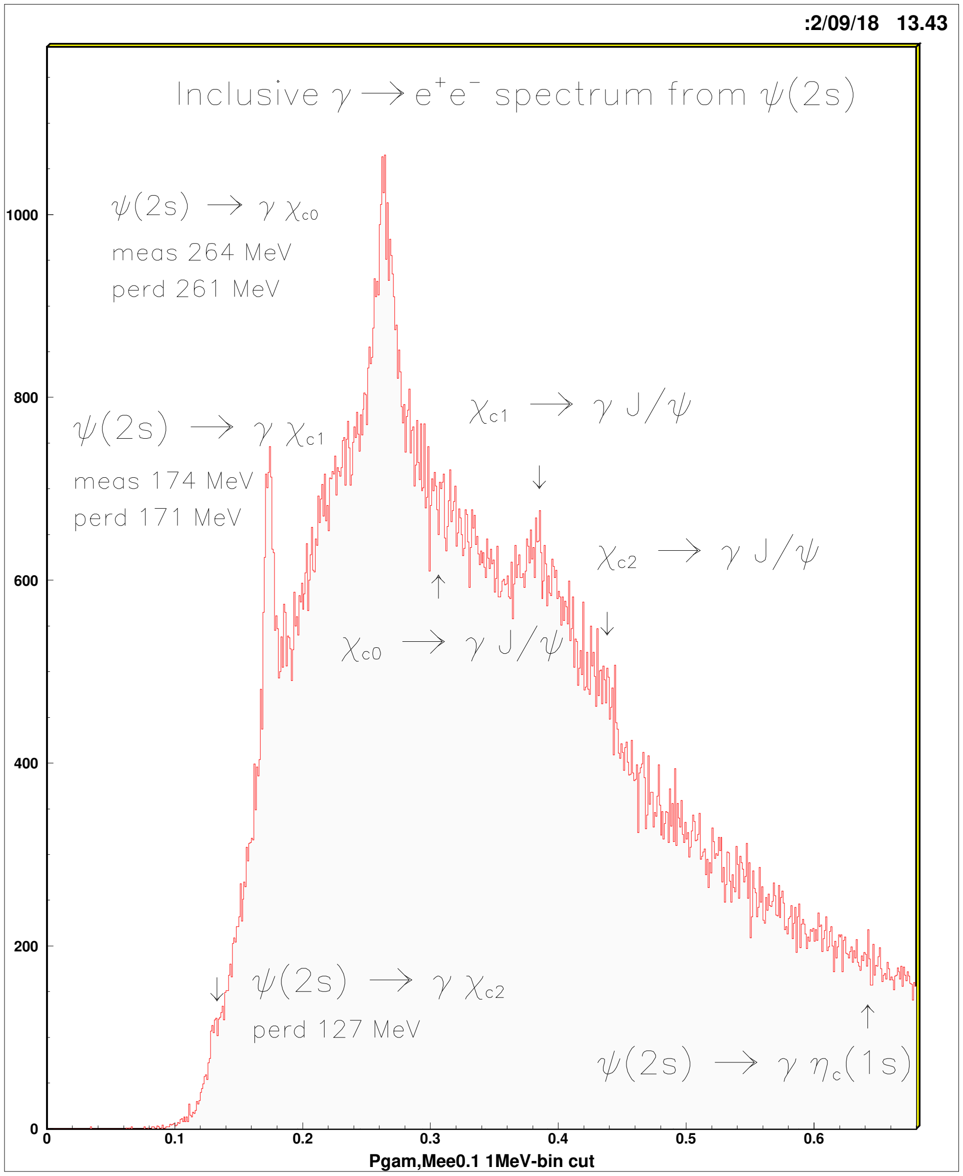
$E_{\gamma \to e^+e^-}$ *resolution in low energy region at BES*

- **SIMBES MC study :** $E_\gamma = 173 MeV$
  - σ_p = **3.2(9.5) MeV for B = 4(1) KG**
  - **eff(1k) / eff(4k) = 2.2 / 1**



Inclusive $\gamma \to e^+e^-$ *from* $\psi(2s)$

- . **Selection criteria for hadronic events is imposed**
  - . **radiative Bhabha and di-muon events rejected**
  - . $\gamma \to e^+e^-$ **reconstructed and selected**
  - . **eID is applied for electrons from** γ **conversion**
- **Observed** σ_{E_γ} **from** $\psi(2s) \to \gamma\chi_{c1}$ **is about 3 MeV**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Inclusive $\gamma \to e^+e^-$ spectrum from $\psi(2s)$
$\psi(2s) \to \gamma\, \chi_{c0}$
meas 264 MeV
perd 261 MeV
$\psi(2s) \to \gamma\, \chi_{c1}$
meas 174 MeV
perd 171 MeV
$\chi_{c1} \to \gamma\, J/\psi$
$\chi_{c2} \to \gamma\, J/\psi$
$\chi_{c0} \to \gamma\, J/\psi$
$\psi(2s) \to \gamma\, \chi_{c2}$
perd 127 MeV
$\psi(2s) \to \gamma\, \eta_c(1s)$
1000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Pgam,Mee0.1 1MeV-bin cut

Suggestion to observe $\eta_c(1s)$ and $\eta_c(2s)$

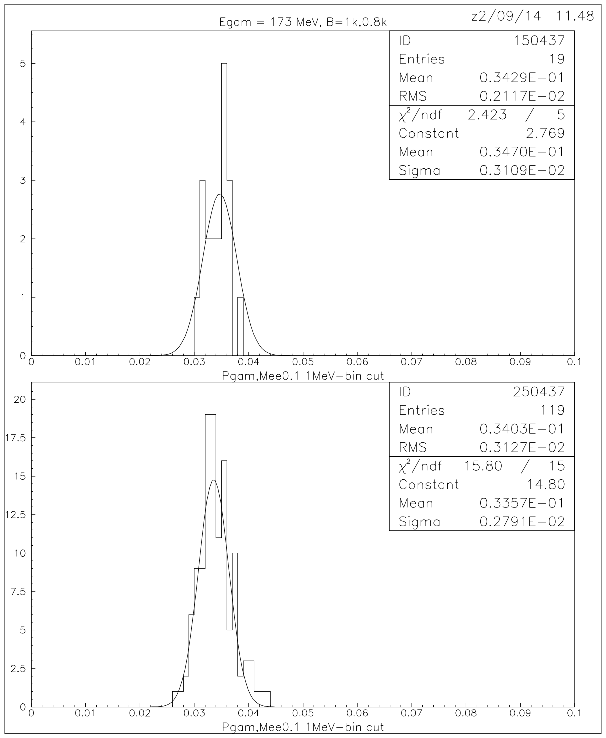
- E_γ **from** $J/\psi \to \gamma\eta_c(1s)$ **= 117.08 MeV (PDG)**
- E_γ **from** $\psi(2s) \to \gamma\eta_c(2s)$ **= 32 MeV (Belle)**
- **BES did not see such low energy** $\gamma \to e^+e^-$ **because of margin effect in momentum caused by magnetic field**

  . **lower limit of momentum at BES is about 60 MeV**

  . **They can be observed if to lower magnetic field**

Suggestion to observe $\eta_c(1s)$ and $\eta_c(2s)$

- **SIMBES MC study :** $E_\gamma = 31 MeV$
  - σ_p = **2.8(3.1) MeV for B = 1(0.8) KG**
  - **margin effect : eff(0.8k) / eff(1k) = 6.3 / 1**
  - **B field should be carefully chosen**



Suggestion to observe $\eta_c(1s)$ and $\eta_c(2s)$

- **Magnetic field required to be dropped down for**
  - . **precise measurement of $\eta_c(2s)$ mass and width from $\psi(2s) \to \gamma\eta_c(2s)$**
  - . **precise measurement of $\eta_c(1s)$ width from $J/\psi \to \gamma\eta_c(1s)$**
- **Test run at $\psi(2s)$ at B = 3 KG down to 0.48 KG is suggested (1 day)**
  - . **check trigger rate**
  - . **see if background level can be suffered**
- **Study of hadronic events with lower B field**
  - . **No problem to reject Bhabha and di-muon events**
  - . **How to select hadronic events**

- **Study of reconstruction and calibration of MDC tracks**
  - **lorenz angle correction needs to be tunned**

Suggestion to observe $\eta_c(1s)$ and $\eta_c(2s)$

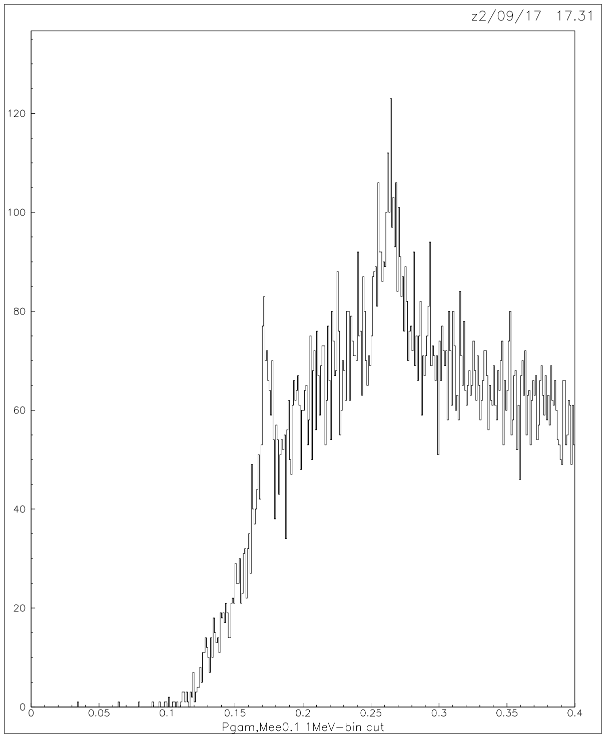
- **B field required to see inclusive $\gamma \to e^+e^-$ signals and make precise measurement**

Decay	$N_{obs} = 200$	$N_{obs} = 390$	**Data**
$J/\psi \to \gamma\eta_c(1s)$	**2.7 KG**	**1.8 KG**	**8.4M** J/ψ
$J/\psi \to \gamma\chi_{c2}$	**2.9 KG**	**1.9 KG**	**1.4M** $\psi(2s)$
$\psi(2s) \to \gamma\eta_c(2s)$	**720 G**	**480 G**	**7M** $\psi(2s)$

- **Here assuming that** $B_r(\psi(2s) \to \gamma\eta_c(2s)) = B_r(\psi(2s) \to \gamma\eta_c(1s)) = (2.8 \pm 0.6) \times 10^{-3}$
- **Fred and Changzhen commented that** $B_r(\psi(2s) \to \gamma\eta_c(2s))$ **might be very low, if** $M_{\psi(2s)}$ **-** $M_{\eta_c(2s)}$ **is as low as Belle observed (32 MeV)**
- **But Belle's observation needs to be confirmed**

Suggestion to observe $\eta_c(1s)$ and $\eta_c(2s)$

- **χ_{c1} and χ_{c0} signals found from $\psi(2s)$ sample of 1.4M events**
  - $N_{signal}(\chi_{c1}) \simeq$ **200**
  - $N_{signal}(\chi_{c0}) \simeq$ **390**



- **Similar signals of $\eta_c(1s)$ and $\eta_c(2s)$ is expected to be found from J/ψ and $\psi(2s)$**

  . **depends on widths of $\eta_c(1s)$ and $\eta_c(2s)$**

Summery

- **Perfect resolution of $E_\gamma \to e^+e^-$,3 MeV, is obtained in region below 300 MeV at BES**

  . **CLEO-II :** $\sigma_{E_\gamma} \geq 9MeV$ **at** $E_\gamma \leq 300MeV$

- **Precise measurement of $\eta_c(1s)$ and $\eta_c(2s)$ can be made by using γ conversion technique**

- **First 7M $\psi(2s)$ events for a search of $\eta_c(2s)$, then 8.4M J/ψ events for $\eta_c(1s)$**

- **Possible search for $h_c(1P)$ can also be explored by using this method**

- **Hadron events selection, trigger rate and calibration in case of lower B field should be studied**