Studies of Y decays at Belle

Mauro Verzetti, INFN, Univ. of Torino
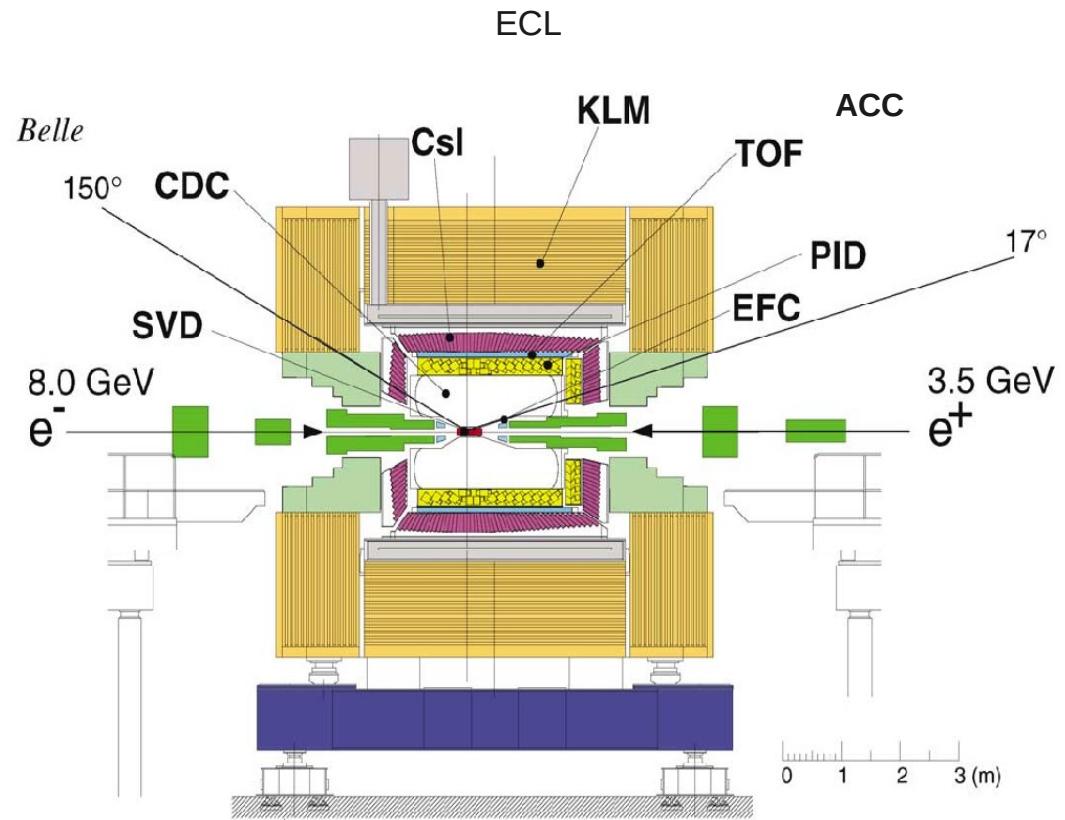
ICHEP, Paris, July 21-18 2010

Outline

- Y(5S) → Y(1,2,3S) $\pi^+\pi^-$

- Y(5S) → $B^{(*)}\overline{B}^{(*)}(\pi)$

- Y(2S) → $\gamma \chi_b$ → $\gamma \gamma$ Y(1S)
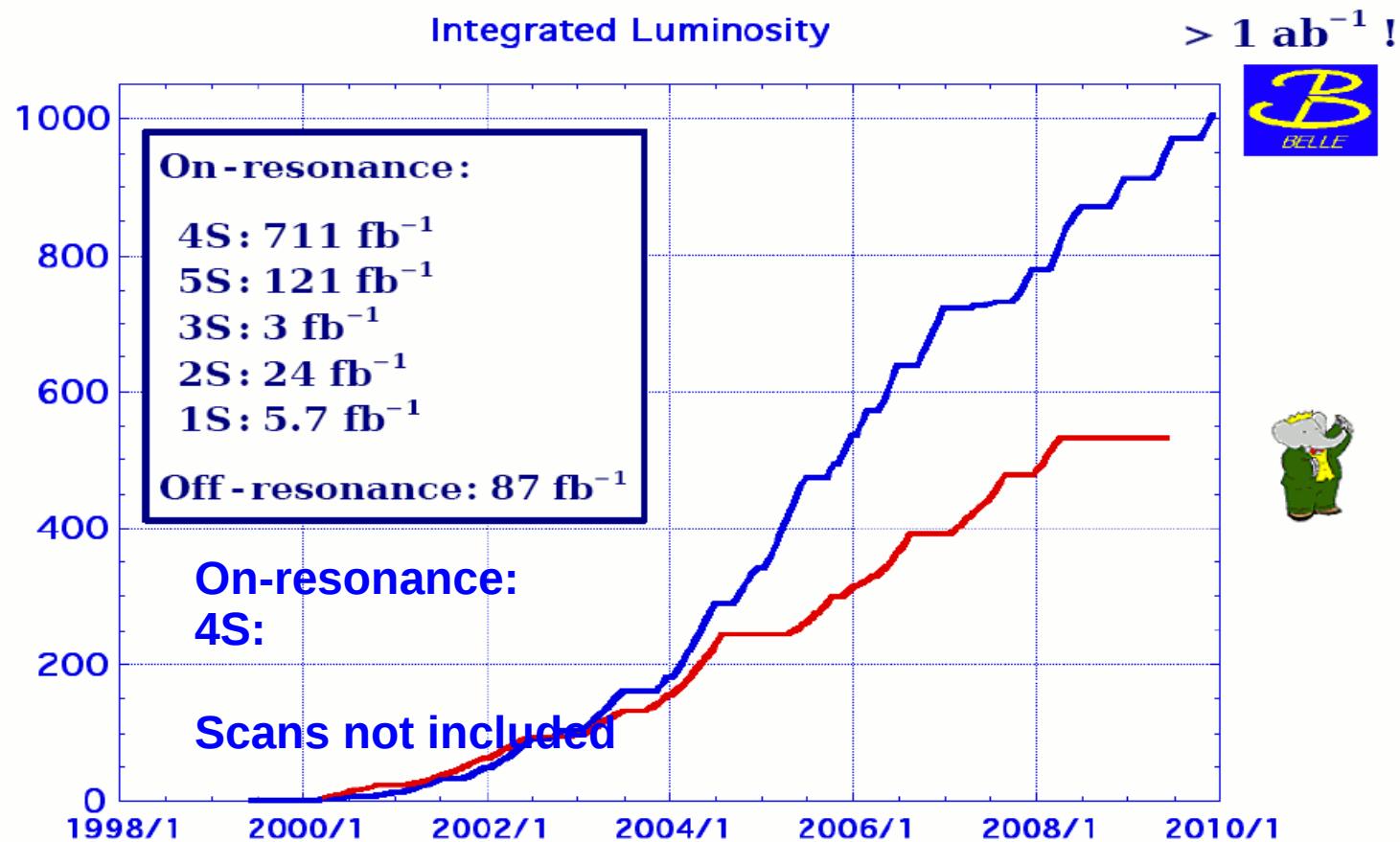
Belle Detector

- The Lorentz boost of the CM frame is kept constant varying the beam energies

- Run at Y(5S)

  - e^+:3.595 GeV
  - e^-:8.211 GeV

- Run at Y(2S)

  - e^+:3.316 GeV
  - e^-:7.575 GeV

Belle I ended data taking in June 2010

Belle data taking at Y(2,5S)

Integrated Luminosity

> 1 ab^{-1} !

On-resonance:

4S: 711 fb^{-1}
5S: 121 fb^{-1}
3S: 3 fb^{-1}
2S: 24 fb^{-1}
1S: 5.7 fb^{-1}

Off-resonance: 87 fb^{-1}

On-resonance:
4S:

Scans not included
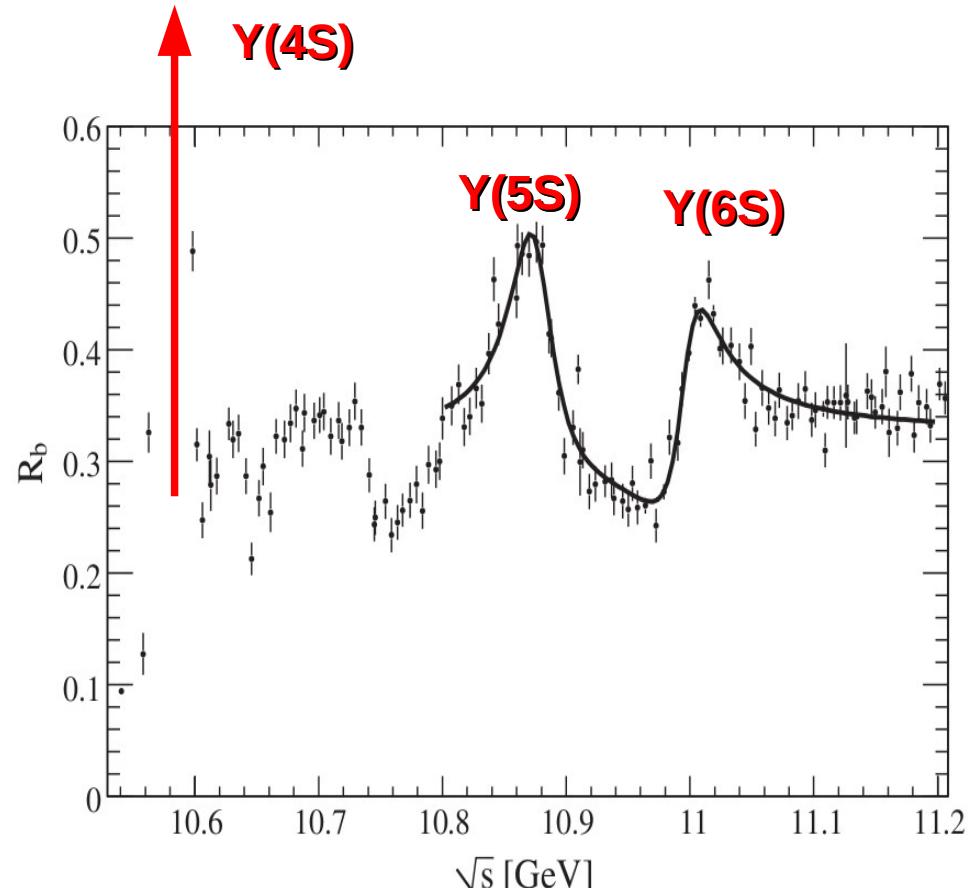
2010 Belle scan @ Y(5-6S) region: 16 points 5MeV apart with ~50pb^{-1} each

Hadronic cross section at Y(5S)

- Y(5S) and above:
  - Continuum:
    $e^+e^- \rightarrow q\bar{q}$ (q = u,d,s,c,**b**)
    - Production of open bottom
    - Resonant ISR
  - Resonance production:
    mainly decay in $B\bar{B}$ (OZI rule)
   - Increase of hadronic cross-section, mainly $B\bar{B}$ channel
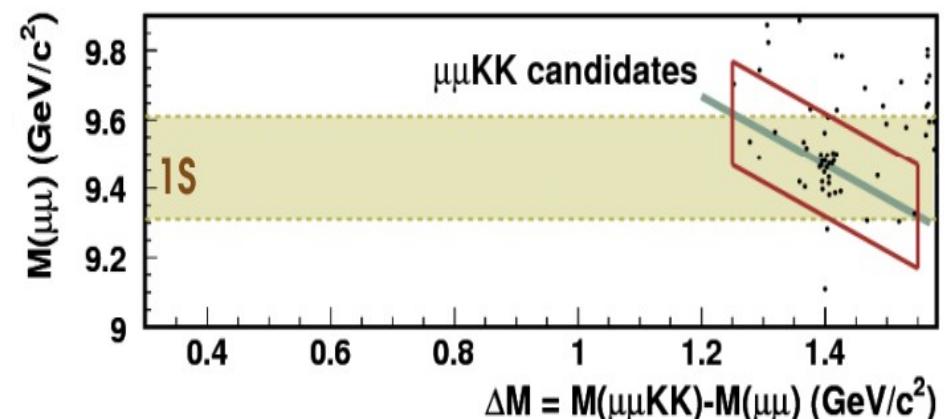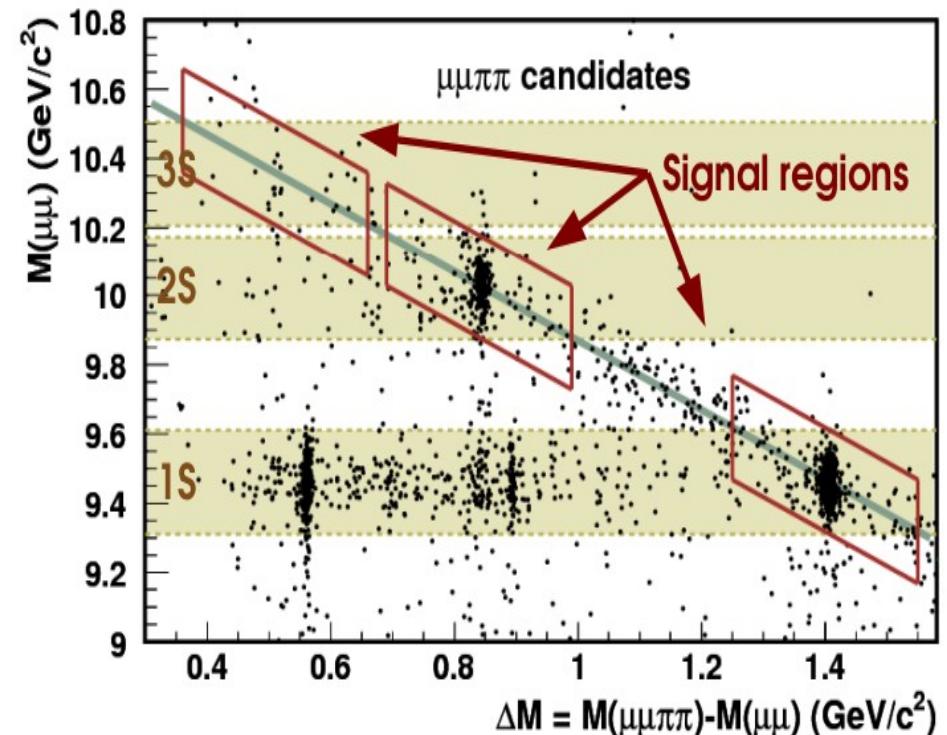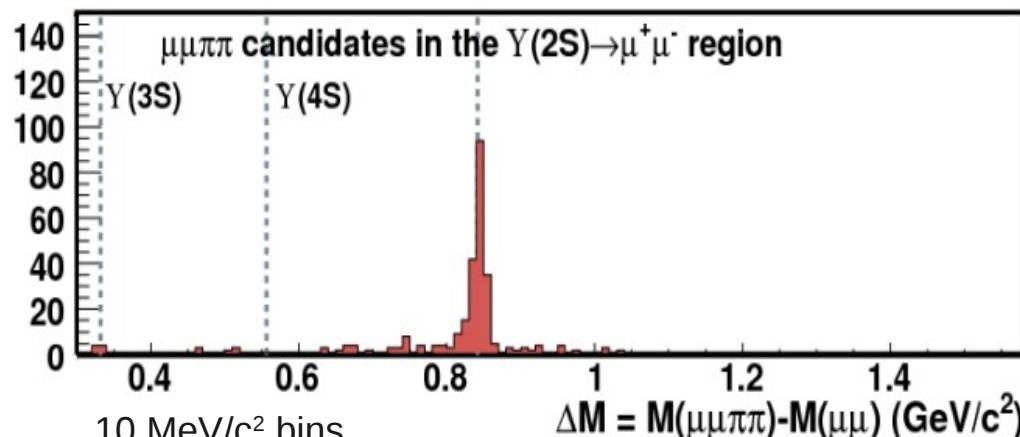
BaBar: PRL 102, 012001 (2009)
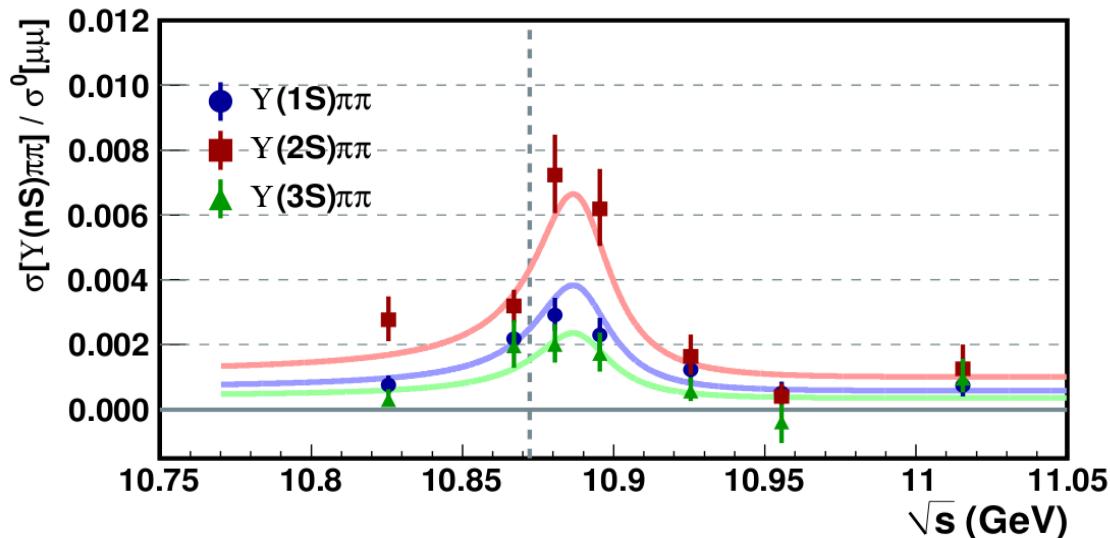
Observation of Y(5S) → $\pi^+\pi^-$Y(1,2S)

K.-F. Chen et al.
PRL 100, 112001 (2008)

- Huge excess of events
  Y(5S) → $\pi^+\pi^-$Y(1,2S):
  O(10^2)xY(4S)

- Similar process found in
  charmonium at an energy close to
  a dip of D$\overline{\text{D}}$ cross-section
  Y(4260) → J/$\Psi\pi\pi$

10 MeV/c² bins

Scan of the Y(5S) region

- In Dec 2007 Belle performed a scan of the Y(5S) region searching for the signature of a possible hybrid states

- 6 point scan with 1-2fb^{-1} each + data taken at Y(5S)

- Slight difference in mass compared to the nominal mass of the Y(5S)

Scan of the Υ(5S) region

Fit with common μ and Γ

Process	Peak σ (pb)	μ (MeV)	Γ (MeV)
$\Upsilon(1S)\pi\pi$	$2.46^{+0.27}_{-0.25} \pm 0.18$		
$\Upsilon(2S)\pi\pi$	$4.18^{+0.49}_{-0.46} \pm 0.55$	$10889.6 \pm 1.8 \pm 1.5$	$54.7^{+8.5}_{-7.2} \pm 2.5$
$\Upsilon(3S)\pi\pi$	$1.61^{+0.31}_{-0.28} \pm 0.21$		

Fit with separate μ's and Γ's

Process	Peak σ (pb)	μ (MeV)	Γ (MeV)
$\Upsilon(1S)\pi\pi$	$2.03^{+0.27}_{-0.22} \pm 0.15$	$10887.4^{+4.1}_{-4.5} \pm 1.6$	$74^{+19}_{-14} \pm 3$
$\Upsilon(2S)\pi\pi$	$5.77^{+0.90}_{-0.80} \pm 0.67$	$10890.3^{+2.3}_{-1.9} \pm 1.4$	$37.0^{+7.9}_{-6.2} \pm 3.1$
$\Upsilon(3S)\pi\pi$	$1.65^{+0.36}_{-0.32} \pm 0.21$	$10882.3^{+7.2}_{-7.3} \pm 1.5$	$52^{+20}_{-14} \pm 1$
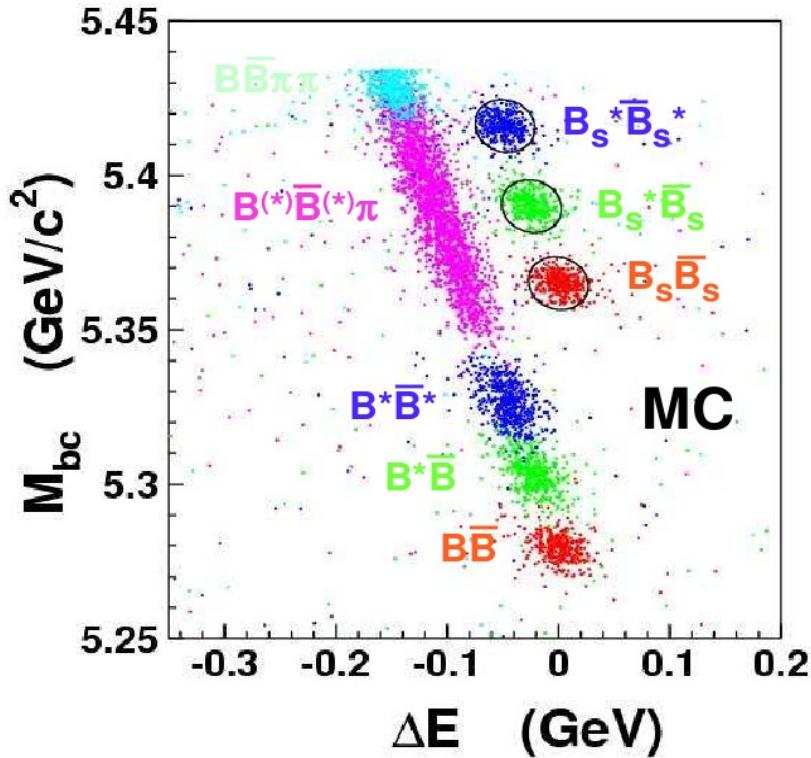
PDG Y(5S) Mass: 10865±0.008 (CLEO + CUSB 1985) plain Breit Wigner:

5.1σ discrepancy

BaBar Y(5S) Mass: 10869±0.002 (2009) interfering Breit Wigner + threshold effects:

3.4σ discrepancy
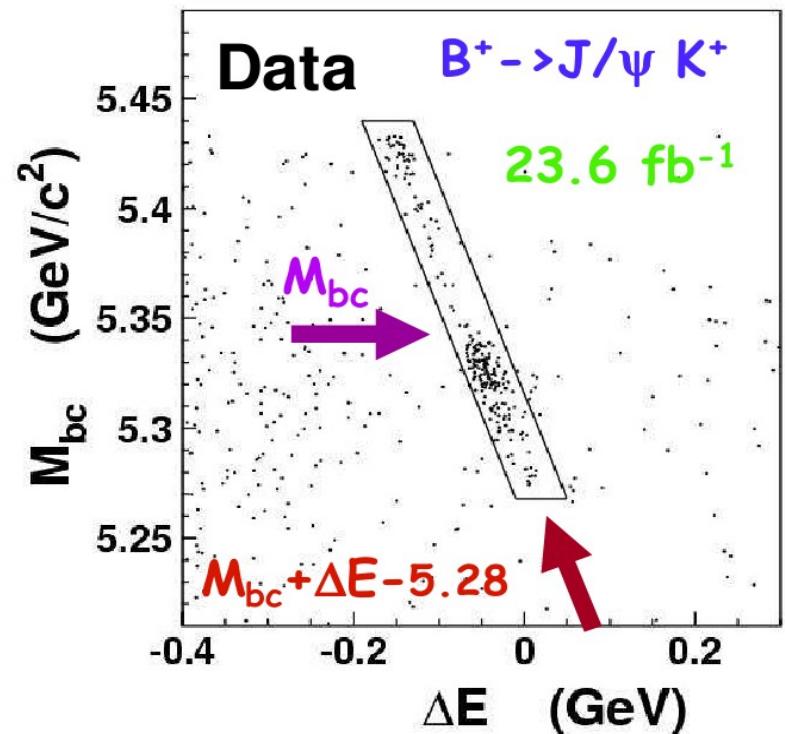
Outline

- $Y(5S) \rightarrow Y(1,2,3S) \, \pi^+\pi^-$

- **$Y(5S) \rightarrow B^{(*)}\overline{B}^{(*)}(\pi)$**

- $Y(2S) \rightarrow \gamma\chi_b \rightarrow \gamma\gamma Y(1S)$

$Y(5S) \rightarrow B^{(*)}\overline{B}^{(*)}(\pi)$


With

$B^* \rightarrow B\gamma$

Two kinematical variable used to tag the events:
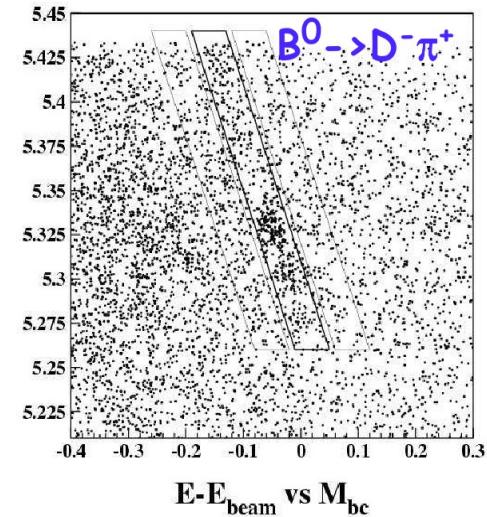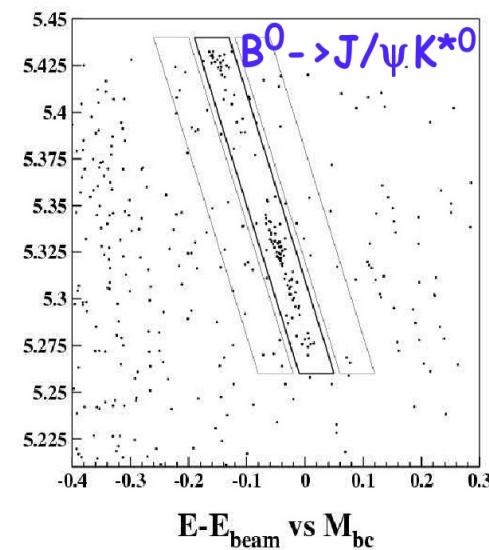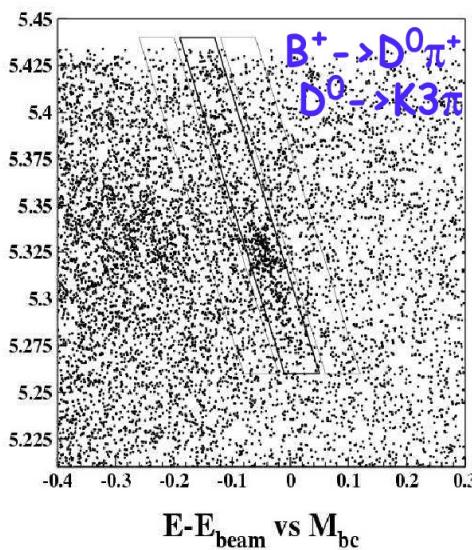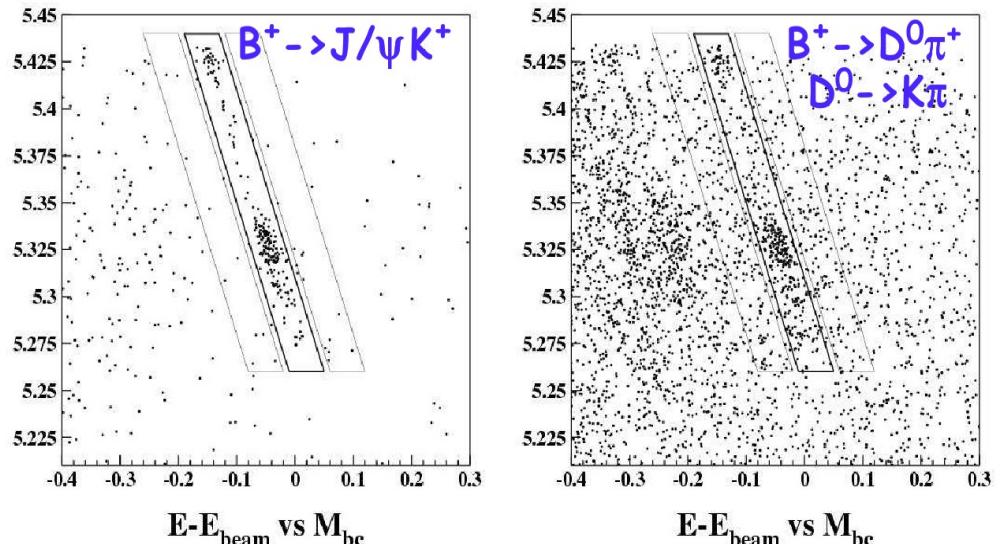
- $\Delta E = E^*_B - \sqrt{s}/2$
- $M_{bc} = \sqrt{(E^*_{beam}{}^2 - p^*_B{}^2)}$

Drutskoy A. et al. PRD81, 112003 (2010)
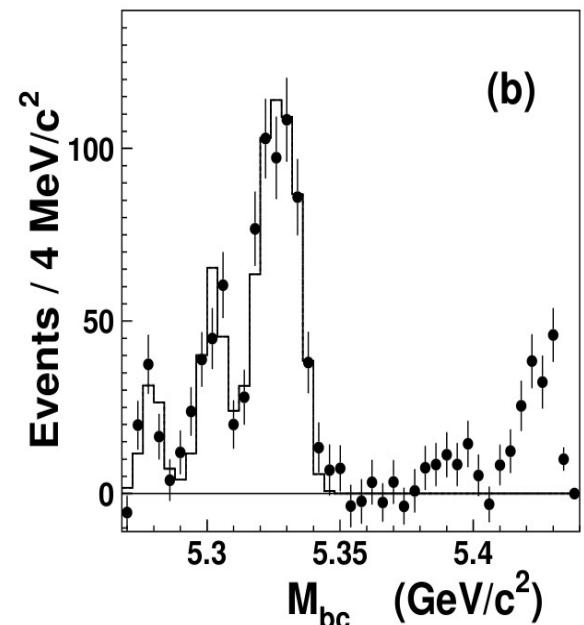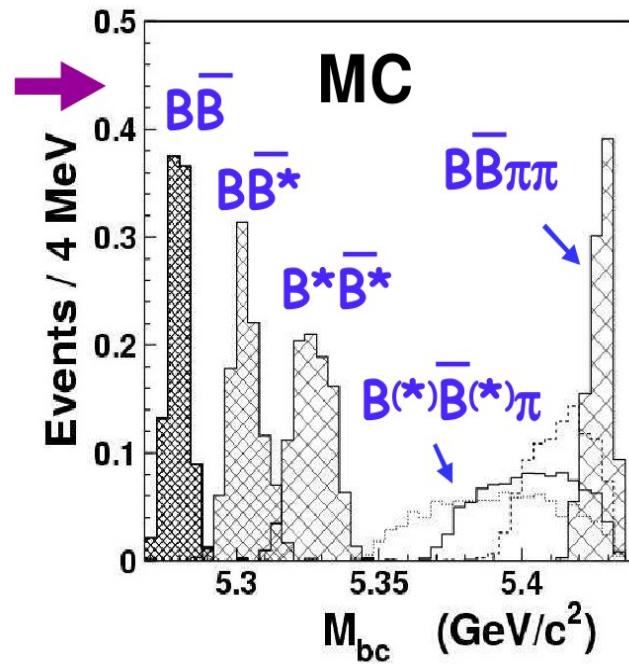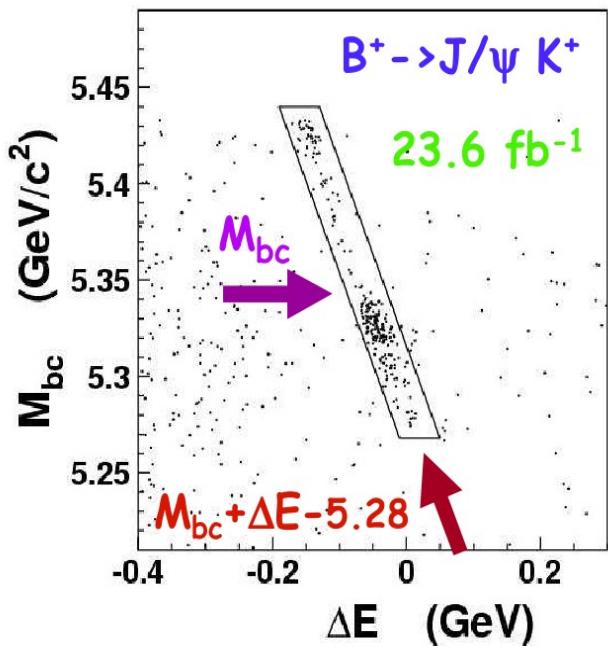
# Reconstruction B meson at Y(5S)

Study performed with
23.6fb-1 (N_{bb}=7.13M):

**1/5 of the total
available sample**

M$_{bc}$ Projections

Five decay modes fitted simultaneously

At high values of M$_{bc}$ there is a large amount of data, out of 2-body boundary.

40% of the four body is due to Initial State Radiation to Y(4S).

Results
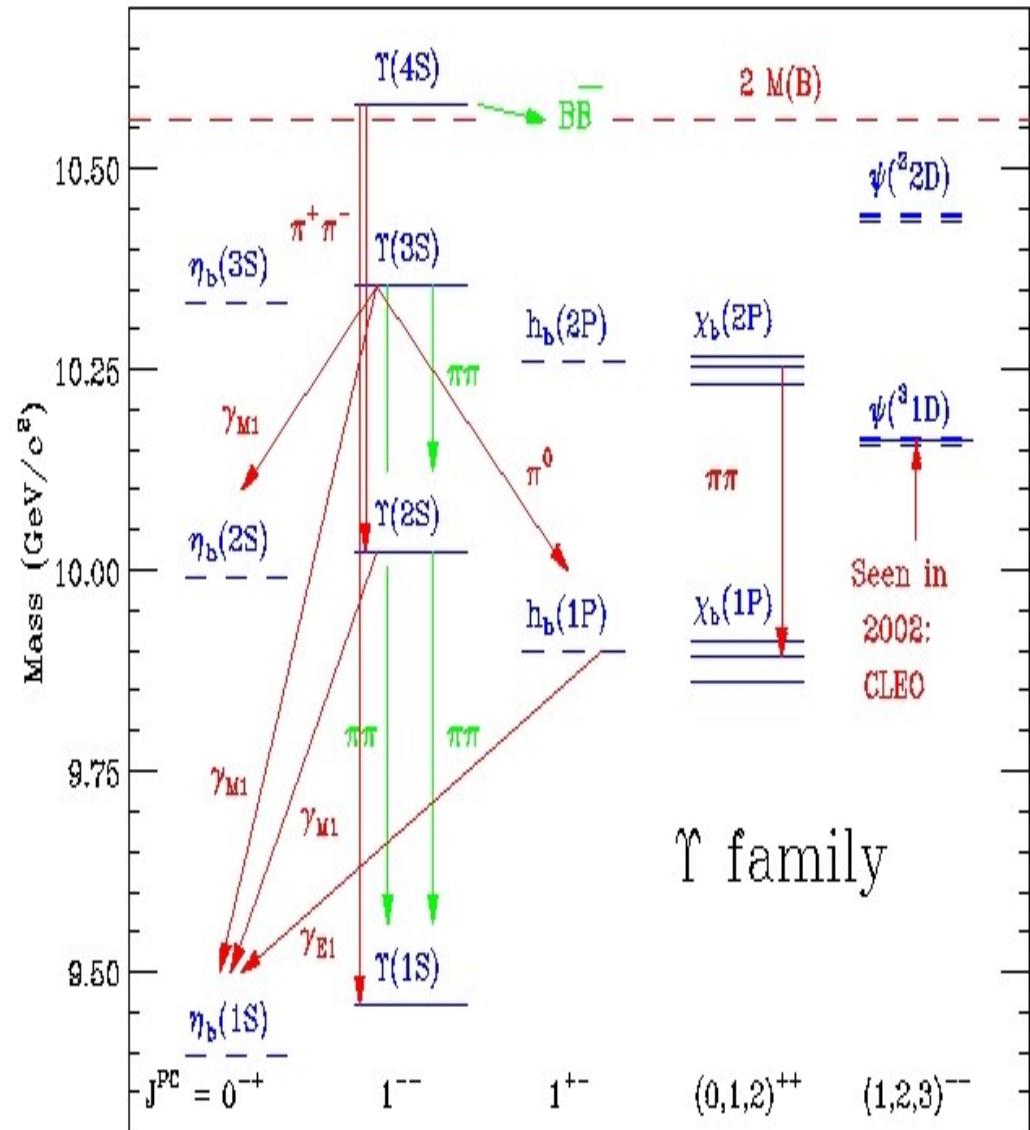
Channel	Yield (π^+), events	Fraction over large M_{bc} %	Fraction per $b\bar{b}$ event %
$B\bar{B}\pi$	$0.2\,^{+7.2}_{-6.9}$	$0.2\,^{+6.8}_{-6.5}$	$0.0 \pm 1.2 \pm 0.3$
$B\bar{B}^*\pi + B^*\bar{B}\pi$	$38.3\,^{+10.5}_{-\ 9.8}$	$41.6\,^{+12.1}_{-11.4}$	$7.3\,^{+2.3}_{-2.1} \pm 0.8$
$B^*\bar{B}^*\,\pi$	$4.8\,^{+6.4}_{-5.9}$	$5.9\,^{+7.8}_{-7.2}$	$1.0\,^{+1.4}_{-1.3} \pm 0.4$
Residual		$52.3\,^{+15.9}_{-15.0}$	$9.2\,^{+3.0}_{-2.8} \pm 1.0$
Large M_{bc}		$100.$	$17.5\,^{+1.8}_{-1.6} \pm 1.3$

Outline

- $Y(5S) \rightarrow Y(1,2,3S)\, \pi^+\pi^-$

- $Y(5S) \rightarrow B^{(*)}\overline{B}^{(*)}(\pi)$

- **$Y(2S) \rightarrow \gamma\, \chi_b \rightarrow \gamma\, \gamma\, Y(1S)$**
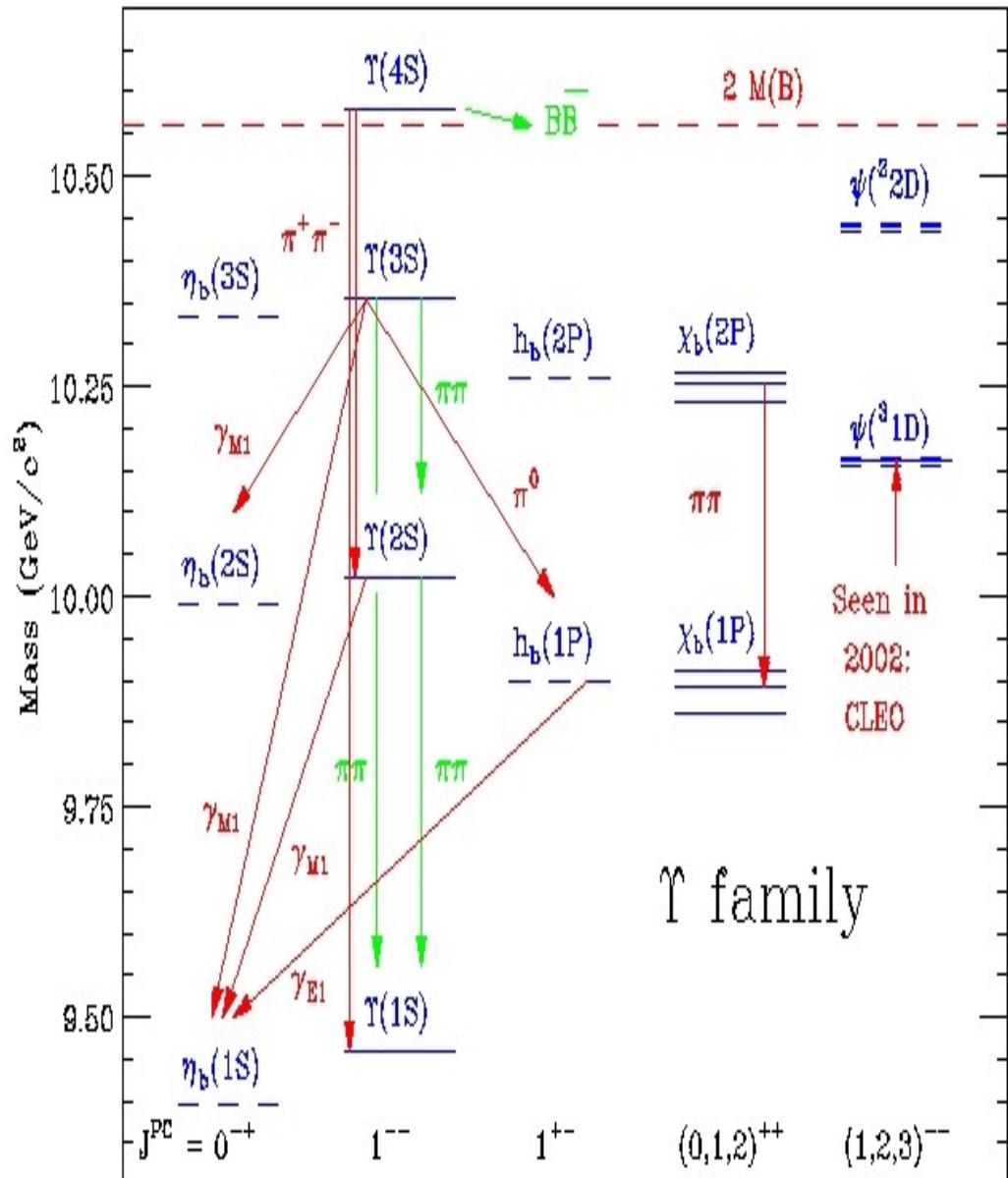
Data taking at Y(2S)

- Two main samples:

  - Dec 2008: 6.5fb^{-1}, 46.4M Y(2S)

  - Nov 2009: 17.6fb^{-1}, 124.6M Y(2S) + 1.7fb^{-1} off-resonance

Contribution to photon spectrum

- Photons from Y(2S)→Y(1S) transitions

  - Y(2S)→$\gamma\chi_{bx}$→$\gamma\gamma$Y(1S): (110-160)MeV, (391-442)MeV

  - Y(2S)→$\pi^0\pi^0$Y(1S) : <400 MeV

- Searches under way:

  - Y(2S)→ $\gamma\eta_b$: ~607MeV

  - Y(2S)→$\gamma\chi_{b0}$→$\gamma\gamma$Y(1S): 160MeV, 391MeV

- Backgrounds:

  - Continuum events: $e^+e^- \to q\bar{q}$ (γ)

  - ISR: $e^+e^- \to \gamma$ Y(1S) : 547MeV

  - Photons from light hadrons in decays

    – Y(1,2S) → LH

    – χ_b (1P$_{0,1,2}$)→LH (Unknown)

  - Prompt photons from Y(1,2S)→γgg

  - Beam background

Contribution to photon spectrum

- Photons from Y(2S)→Y(1S) transitions
  - Y(2S)→$\gamma\chi_{bx}$→$\gamma\gamma$Y(1S): (110-160)MeV, (391-442)MeV
  - Y(2S)→$\pi^0\pi^0$Y(1S) : <400 MeV

- Searches under way:
  - Y(2S) → $\gamma\eta_b$: ~607MeV
  - Y(2S)→$\gamma\chi_{b0}$→$\gamma\gamma$Y(1S): 160MeV, 391MeV

- Backgrounds:
  - Continuum events: $e^+e^- \rightarrow q\bar{q}$ (γ)
  - ISR: $e^+e^- \rightarrow \gamma$ Y(1S) : 547MeV
  - Photons from light hadrons in decays
    – Y(1,2S) → LH
    – χ_b (1P$_{0,1,2}$)→LH (Unknown)
  - Prompt photons from Y(1,2S)→γgg
  - Beam background

$Y(2S) \to \gamma\gamma Y(1S) \to \gamma\gamma\mu^+\mu^-$ sample

- Cleanest sample to study χ_b peak

- Cuts applied:
  - $|M_{\mu\mu} - M_{Y(1S)}| < 70 \text{MeV}$
  - $p_{\mu\mu} > 250 \text{ MeV}$
  - $N_\gamma < 4$

- Plotted E* of the most energetic photon vs. the energy of the second one

- Two different selections:
  - Barrel only (to match inclusive sample acceptance)
  - All ECL to maximize χ_{b0} signal in $\mu\mu\gamma\gamma$ sample

Fit of the χ_{b1} region

- Asymmetric collider → asymmetric resolution in CM frame

  - Sample divided in 3 bands in Cosθ*

  - Each band fitted separately

- Background: Gaussian + constant

- Peak: Crystall Ball Function + Doppler Shift (PDG value)

χ_{b0} in $Y(2S) \rightarrow \gamma\gamma\mu^+\mu^-$ sample (PRELIMINARY)

150MeV < $E_{\gamma low}$ < 170MeV
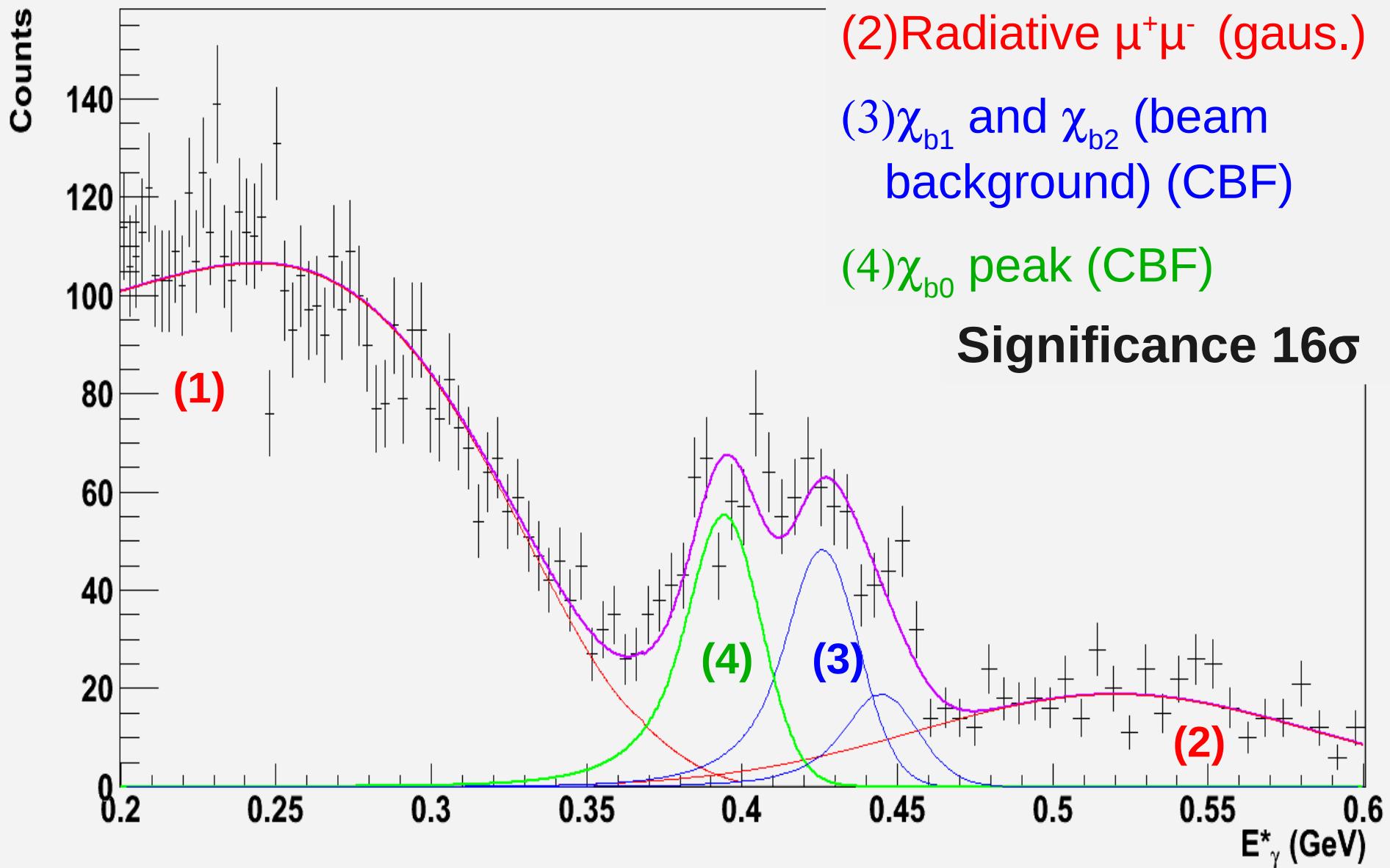
(1) $Y(2S) \rightarrow \pi^0\pi^0\ Y(1S)$ (MC)

(2) Radiative $\mu^+\mu^-$ (gaus.)
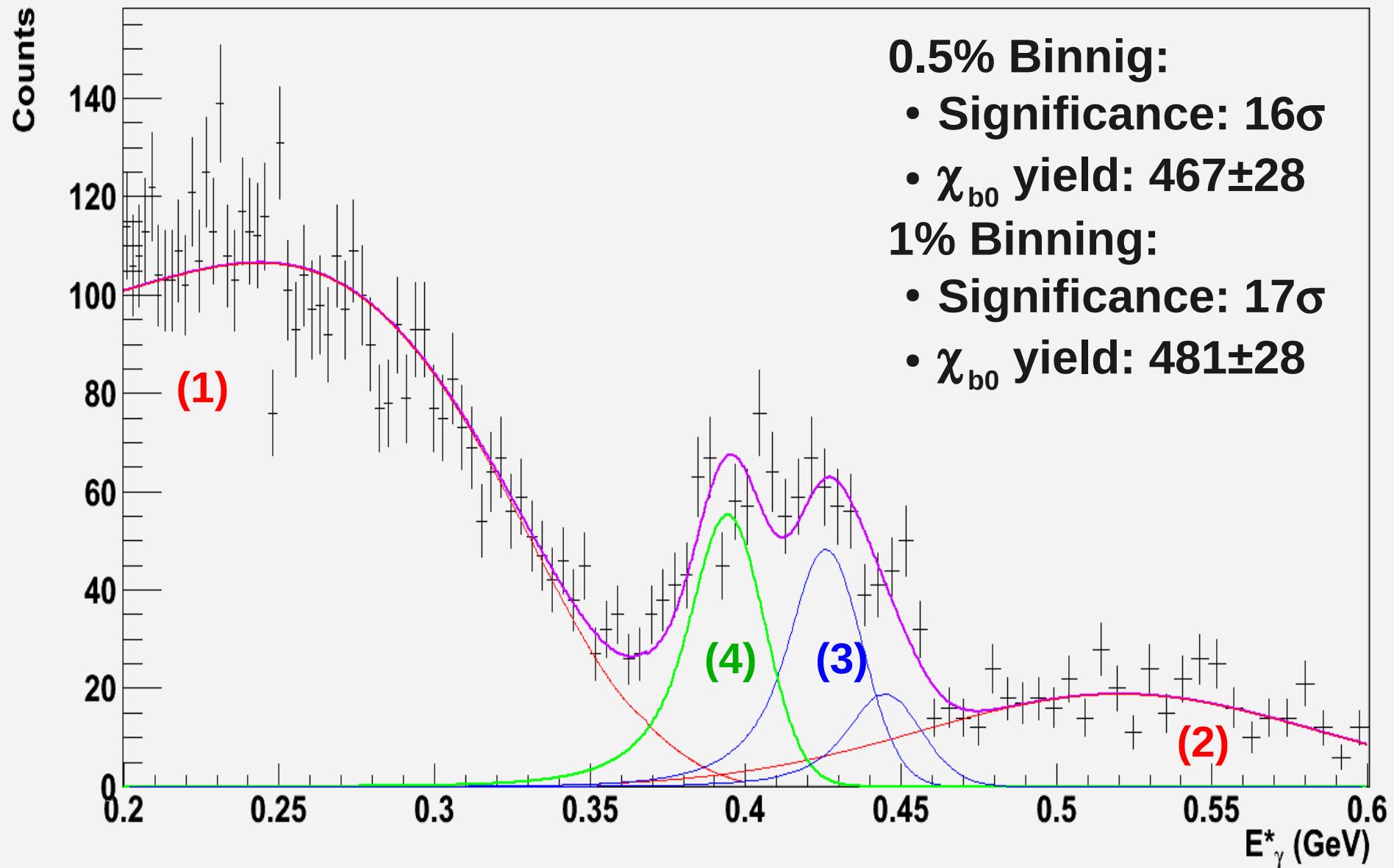
(3) χ_{b1} and χ_{b2} (beam background) (CBF)

(4) χ_{b0} peak (CBF)
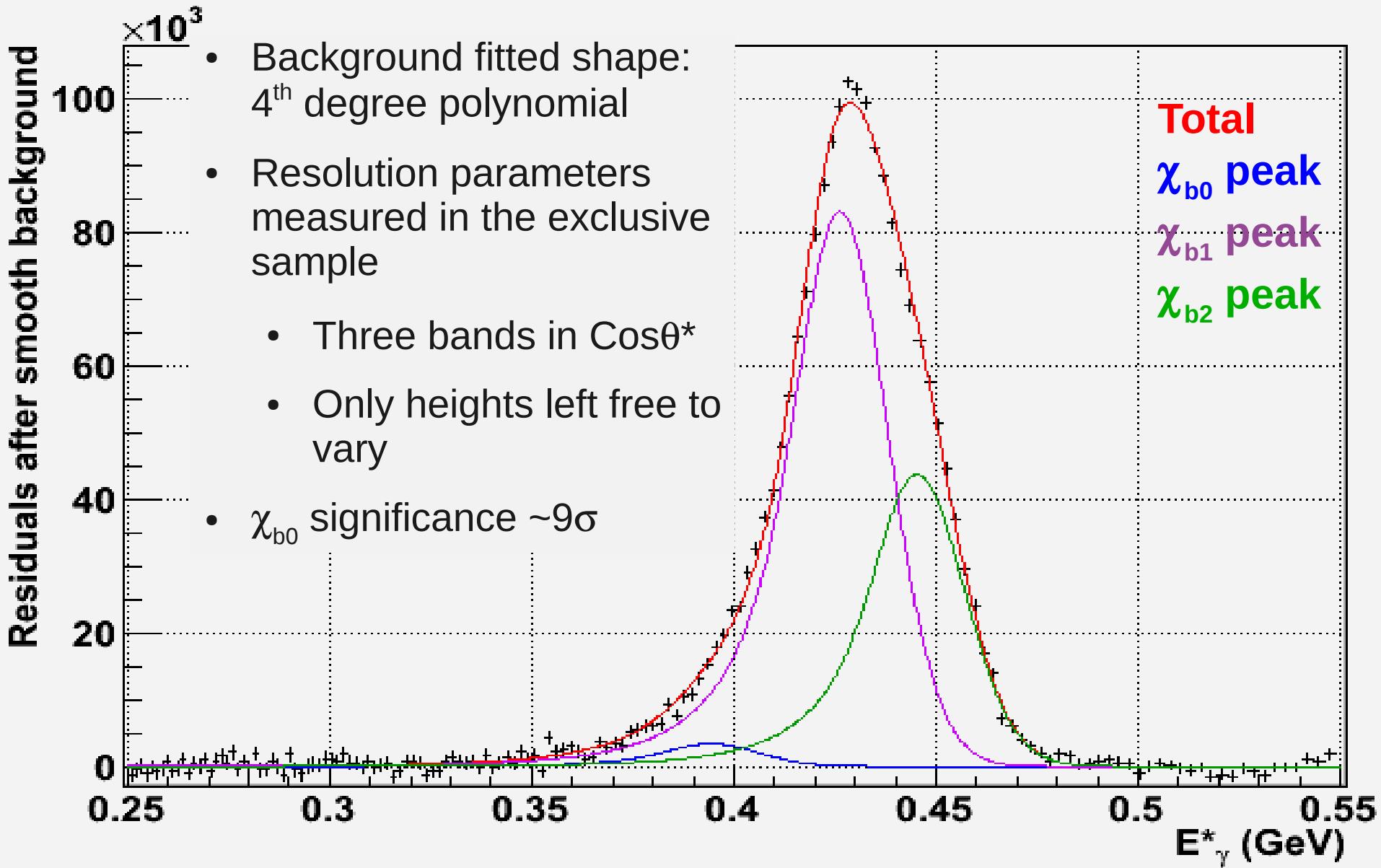
Significance 16σ
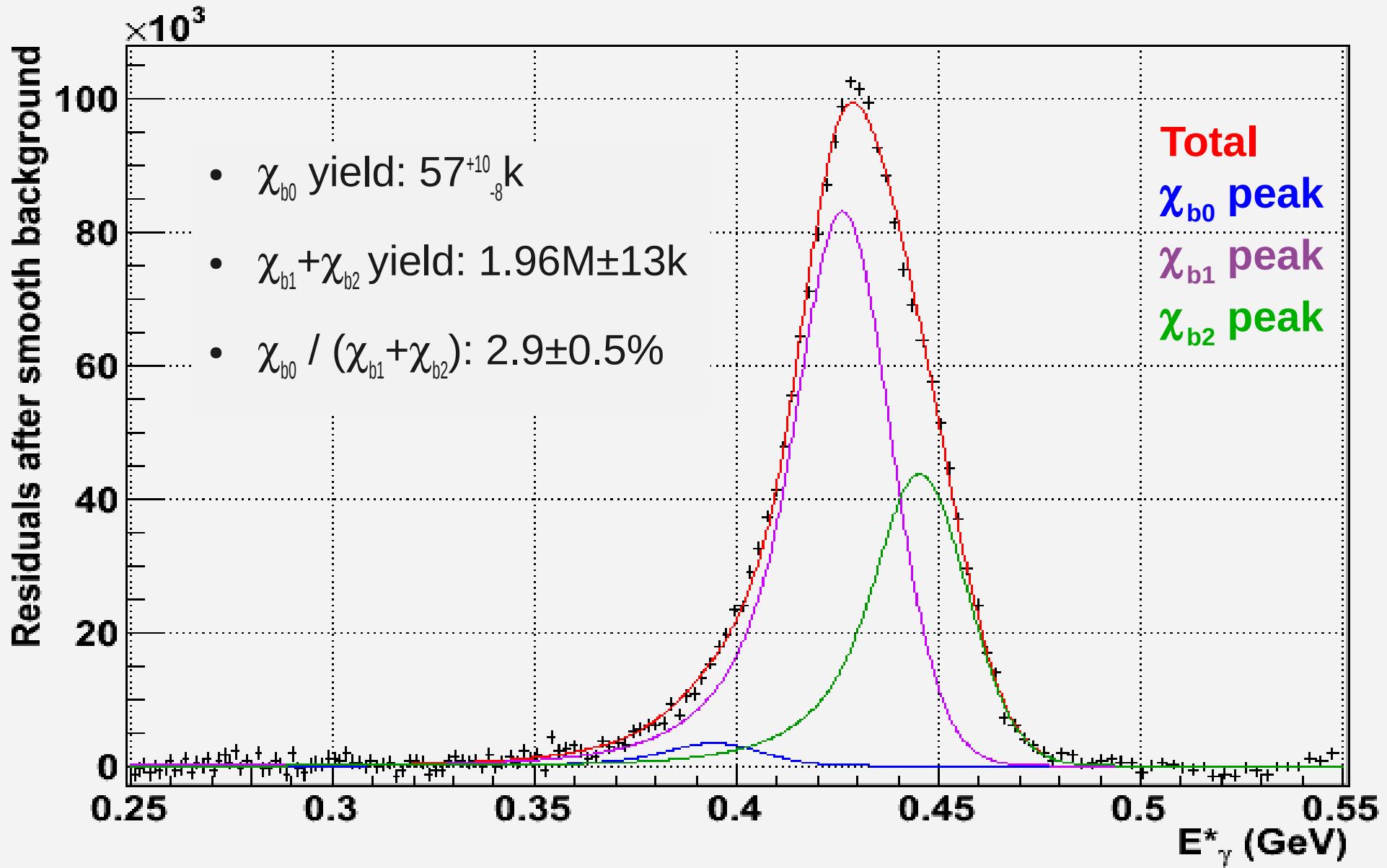
χ_{b0} in $Y(1S) \rightarrow \mu+\mu-$ sample (PRELIMINARY)

χ_b peak in the inclusive sample (PRELIMINARY)

- Background fitted shape: 4th degree polynomial

- Resolution parameters measured in the exclusive sample

  - Three bands in $\cos\theta^*$

  - Only heights left free to vary

- χ_{b0} significance ~9σ

χ_b peak in the inclusive sample (PRELIMINARY)

- χ_{b0} yield: 57^{+10}_{-8}k
- $\chi_{b1}+\chi_{b2}$ yield: 1.96M±13k
- χ_{b0} / ($\chi_{b1}+\chi_{b2}$): 2.9±0.5%

Total
χ_{b0} peak
χ_{b1} peak
χ_{b2} peak

Residuals after smooth background

$\times 10^3$

E^*_γ (GeV)

Conclusions

- Belle measured two body decay fraction in $\mathrm{B\overline{B}}$ with high precision.

    - Three-body fractions are measured. Larger than predicted

- Unexpectedly large production of $\pi\pi Y(1,2,3S)$ from $Y(5S)$

    - The scan suggeste the hypothesis of a "Y_b" analof in charmonium

- Observed the expected transition $\chi_{b0} \to \gamma Y(1S)$ both in exclusive and inclusive channels (PRELIMINARY)

Stay tuned for future results

Backup

M. Verzetti: Studies of Y decay at Belle

Crystal Ball function

- Derives its name from the experiment that introduced it

- Gaussian part describes the finite resolution of the detector

- Power law tail takes into account lateral leakage of the shower and pre-shower effects

$$f_{CB} = \begin{cases} \dfrac{N_0}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} & \text{with } t = \dfrac{x-\mu}{\sigma} > |\alpha| \\[2em] N_0 \cdot e^{-\frac{\alpha^2}{2}} \cdot \left(1 - \dfrac{\alpha^2}{n} - \dfrac{\alpha}{n}\dfrac{x-\mu}{\sigma}\right)^{-n} & \text{with } t < |\alpha| \end{cases}$$