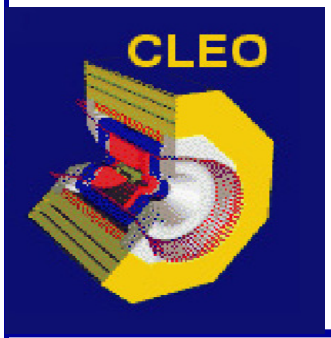
Y(5S) Results from CLEO

- Exclusive B_s Reconstruction (hep-ex/0510034)
- Inclusive D_s Measurement (hep-ex/0508047)



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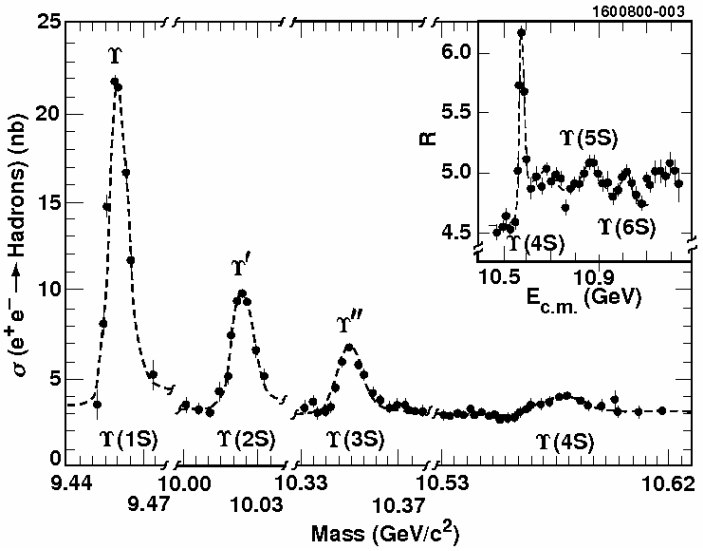
PANIC-2005

Introduction (1)

- The Y(5S) resonance was discovered by CLEO and CUSB collaborations operating at CESR in 1985.
- The Y(5S) resonance is massive enough to decay into the following channels:

$$B\bar{B},\ B\bar{B}^*,\ B^*\bar{B}^*,\ B\bar{B}\pi,\ B\bar{B}^*\pi, B^*\bar{B}^*\pi, B\bar{B}\pi\pi$$
$$B_s\bar{B}_s,\ B_s\bar{B}_s^*,\ B_s^*\bar{B}_s^*$$

- *No* evidence for B_s production at the Y(5S) was found using 116 pb^{-1} of data collected in 1985.
- The three channels with B_s mesons are in the focus of two CLEO III analyses using 0.42 fb^{-1} of data collected recently at the Y(5S).
- Knowledge of B_s production at the Y(5S) is essential for assessing the potential of B_s physics at a high luminosity e^+e^- collider.

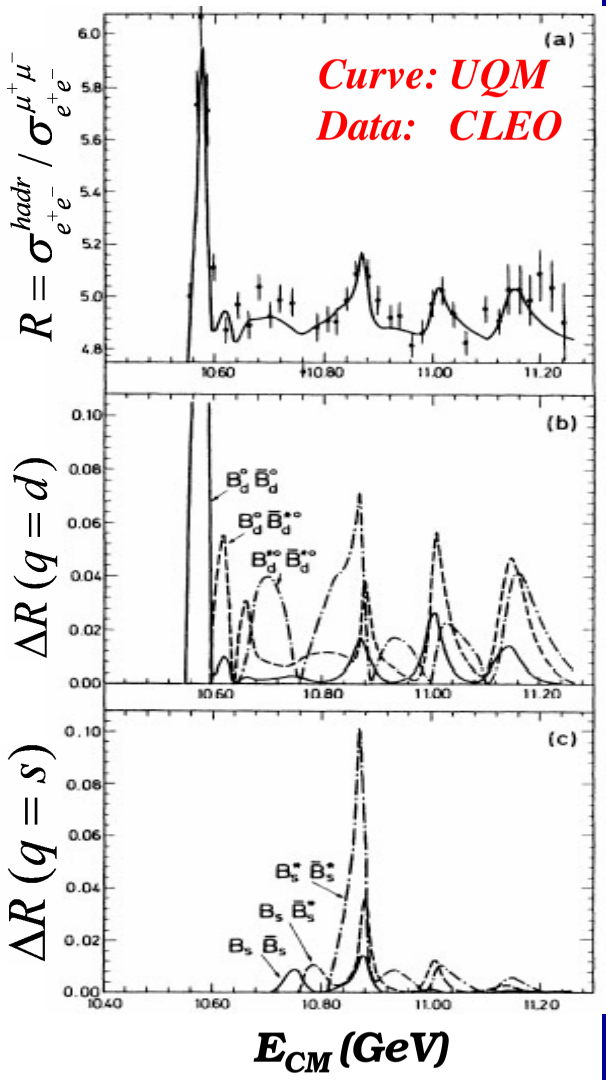


$PDG-2004:$
$M_{\Upsilon(5S)} = (10.865 \pm 0.008)\ GeV$
$\Gamma = (110 \pm 13)\ MeV$
$M_{Bs} = (5.370 \pm 0.002)\ GeV$
$M_{Bs^*} - M_{Bs} = (47.0 \pm 2.6)\ MeV$

$CDF-2005\ (hep-ex/0508022):$
$M_{Bs} = (5.3660 \pm 0.0008(stat+sys))\ GeV$

Introduction (2)

- Two papers exist that describe the hadronic cross section above the Y(4S) resonance:
  - ✓ CLEO: PRL **54,** 381 (1985)
  - ✓ CUSB: PRL **54**, 377 (1985)
- The cross section above the Y(4S) resonance is described well by the Unitarized Quark Model (S.Ono *et al.*, Phys.Rev.D **34**, 186 (1986)).
- The model predicts:
  - ✓ Y(5S) $\rightarrow$ B^* B^* or B_s^* B_s^*,
  - ✓ The B_s cross section is about 1/3 of the total cross section.
  - ✓ $\sigma(e^+ e^- \rightarrow \Upsilon(5S)) \sim 0.35$ nb
- Using these predictions, we expect about 100K of B_s mesons in the 0.42 fb^{-1} data sample.



EXCLUSIVE B_s RECONSTRUCTION

(hep-ex/0510034; submitted to PRL)

Overview of the Exclusive Method

- An extension of B meson reconstruction technique used at the Y(4S) is employed to reconstruct B_s mesons at the Y(5S):
  - ✓ $M_{bc} = \sqrt{E_{beam}^2 - P_{candidate}^2}$
  - ✓ $\Delta E = E_{candidate} - E_{beam}$
  - ✓ Continuum background suppression variables
- Three decay channels of the Y(5S) to B_s mesons are possible:
  - ✓ Decay channel 1: $\Upsilon(5S) \to B_s \overline{B_s}$: $E_{B_s} = E_{beam}$
  - ✓ Decay channel 2: $\Upsilon(5S) \to B_s^* \overline{B_s}^*$: $E_{B_s^*} = E_{beam}$
  - ✓ Decay channel 3: $\Upsilon(5S) \to B_s \overline{B_s}^*$: $E_{B_s^*} > E_{beam}, E_{B_s} < E_{beam}$

PDG–2004:

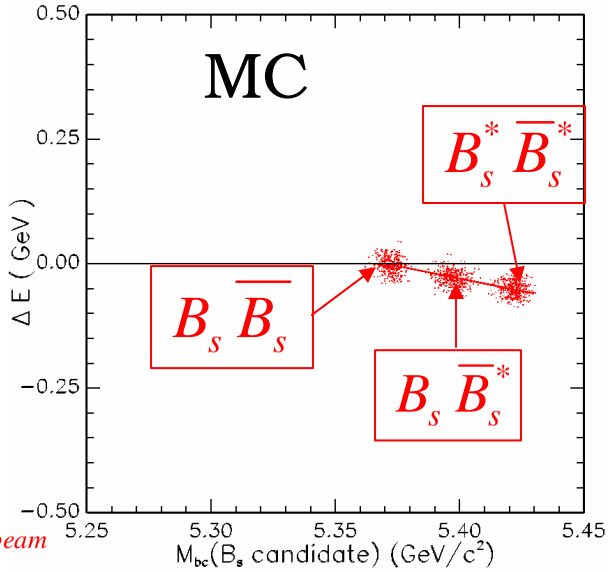
$M_{Bs} = (5.370 \pm 0.002)\, GeV$

$M_{Bs^*} - M_{Bs} = (47.0 \pm 2.6)\, MeV$

Assumption: $B(B_s^* \to B_s \gamma) = 100\%$

CDF–2005 (hep–ex/0508022):

$M_{Bs} = (5.3660 \pm 0.0008\,(stat+sys))\, GeV$

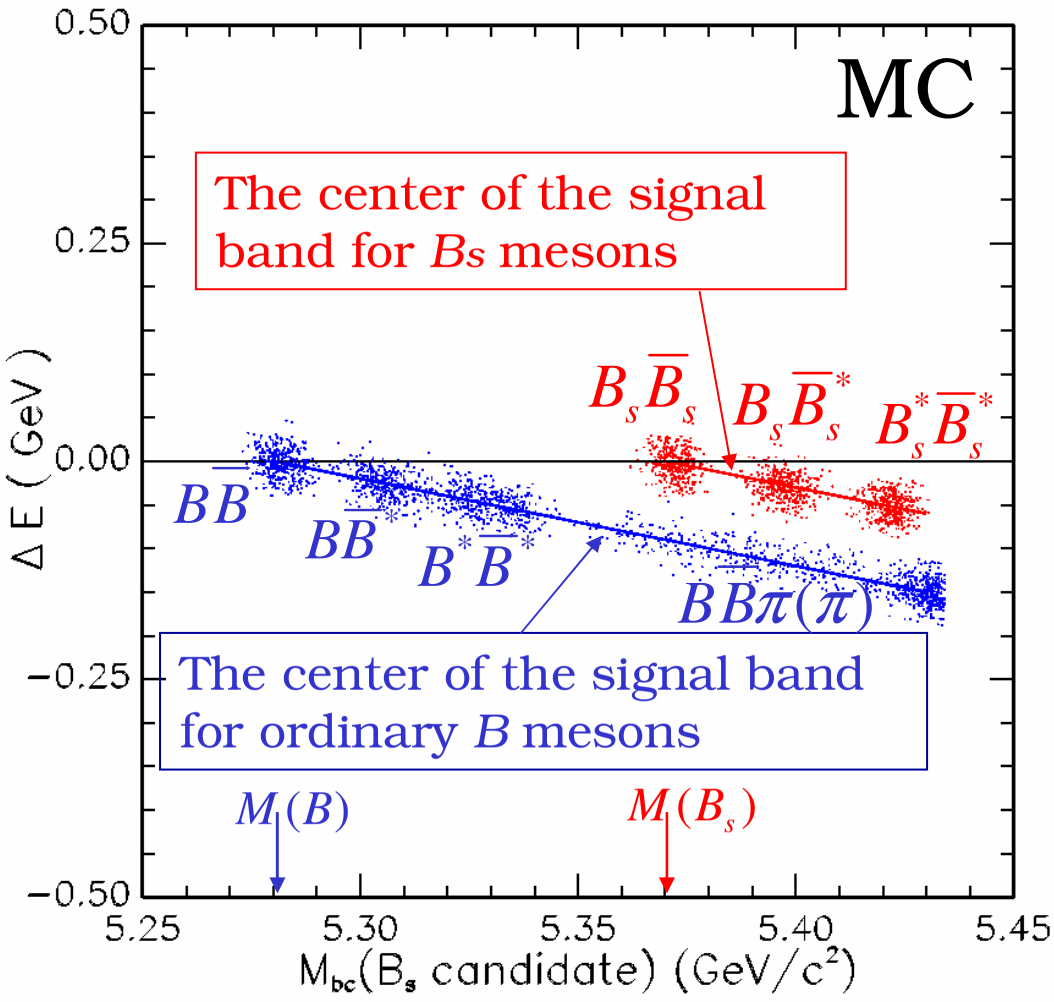


Backgrounds

- The Y(5S) resonance can decay into a variety of states with ordinary B mesons:

$$B\bar{B},\ B\bar{B}^*,\ B^*\bar{B}^*,\ B\bar{B}\pi,\ B\bar{B}^*\pi, B^*\bar{B}^*\pi, B\bar{B}\pi\pi$$

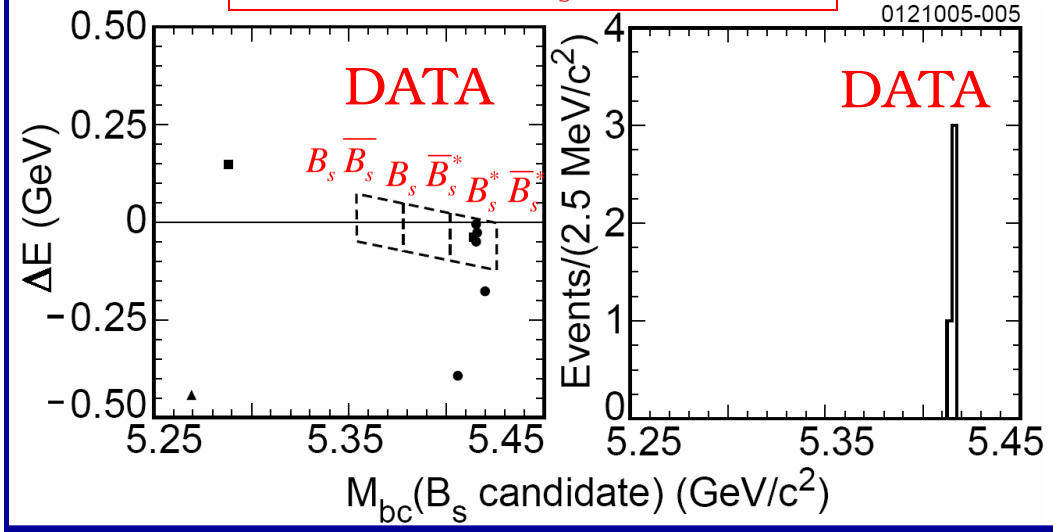
- The continuum ($e^+e^- \to qq$) background is large:
  - ✓ $\Upsilon(4S)$: $\dfrac{\sigma(B\bar{B})}{\sigma(e^+e^- \to q\bar{q})} \sim 0.3$
  - ✓ $\Upsilon(5S)$: $\dfrac{\sigma(B_s^{(*)}\bar{B}_s^{(*)})}{\sigma(e^+e^- \to q\bar{q})} \sim 0.03$
- B_s decay modes are poorly known.



B_s modes with a J/ψ

- Search for very clean modes having very large S/B ratio. The best mode to start with is $B_s \to J/\psi\,\varphi$. The search is also made for $B_s \to J/\psi\,\eta$ and $B_s \to J/\psi\,\eta'$.
- The J/ψ is reconstructed in the $\mu\mu$ and ee channels. The following channels are used for other particles: $\varphi \to KK$, $\eta \to \gamma\gamma$, $\eta' \to \eta(\gamma\gamma)\pi^+\pi^-$.
- Expect to find only 2-3 signal events, assuming branching fractions similar to those for B mesons. In the Y(5S) data, we find:

4 events in the signal box for $\Upsilon(5S) \to B_s^* B_s^*$:
3 events in $B_s \to J/\psi\varphi$
1 event in $B_s \to J/\psi\eta'$

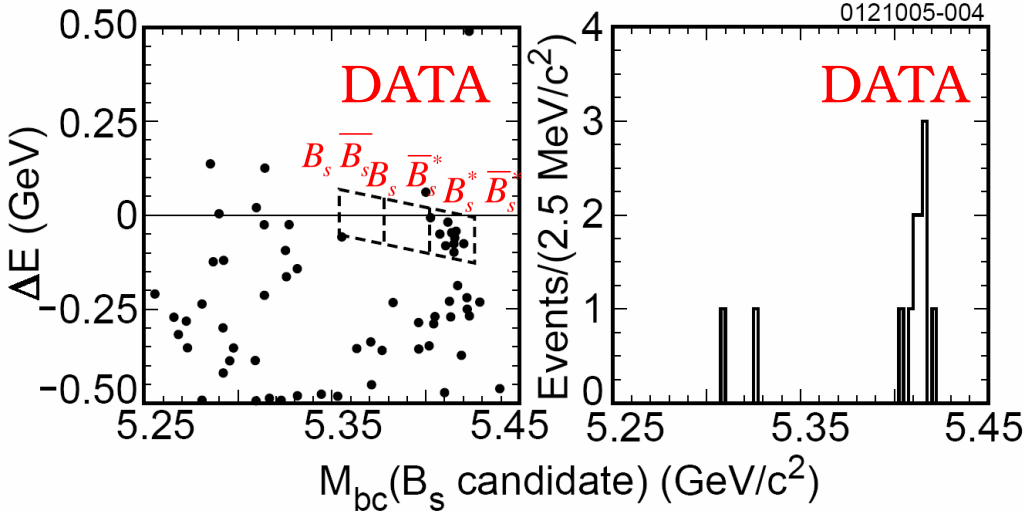


- Using data taken at other energies, the level of non-B_s background is found to be < 0.08 events at 68% CL in the $B_s^* B_s^*$ signal region.
- The Poisson probability for 0.08 events to fluctuate to 4 events or more is $P_I < 1.6 \times 10^{-6}$
- $M(B_s^*) = 5.4150 \pm 0.0018(\text{stat})$ (GeV)

B_s modes with a $D_s^{(*)-}$

- The choice of $B_s \to D_s^{(*)}\,\pi/\rho$ and the four D_s modes listed above is motivated by the difficulty of background modeling
- MC predicts that a total of 10-14 events can be reconstructed in these channels
- In the Y(5S) data we find 10 signal events (including background):

	$D_s^+ \to$	$K^+K_S^0$	$K^+\bar{K}^{0*}$	$\phi\pi^+$	$\phi\rho^+$
$\bar{B}_s \to D_s^+\pi^-/\rho^-$		0/0	1/1	1/3	1/1
$\bar{B}_s \to D_s^{*+}\pi^-/\rho^-$		0/1	1/0	0/0	0/0



B^0 branching fractions:

Decay Mode	$\mathcal{B} \times 10^{-3}$
$\bar{B}_s \to D_s\pi^-$	(2.8 ± 0.3)
$\bar{B}_s \to D_s\rho^-$	(7.7 ± 1.3)
$\bar{B}_s \to D_s^*\pi^-$	(2.8 ± 0.2)
$\bar{B}_s \to D_s^*\rho^-$	(6.8 ± 0.9)

Decay Mode	$\mathcal{B}$ (%)
$D_s \to K^+\bar{K}^0$	(3.6 ± 1.1)
$D_s \to K^+K^{*0}(892)$	(3.3 ± 0.9)
$D_s \to \phi\pi^+$	(3.6 ± 0.9)
$D_s \to \phi\rho^+$	(6.7 ± 2.3)
$D_s^* \to D_s\gamma$	(94.2 ± 2.5)

- Using the events in the sidebands on the search plane, the level of background is found to be < 1.8 events at 68% CL in the $B_s^*B_s^*$ signal region.
- The Poisson probability for 1.8 events to fluctuate to 10 events or more is $P_{II} < 1.9 \times 10^{-5}$
- $M(B_s^*) = 5.4129 \pm 0.0012(\text{stat})$ (GeV)

Results for the Exclusive B_s Reconstruction

- P_I and P_{II} are combined to obtain an overall probability for a background fluctuation: $P < 8 \times 10^{-10}$ (~6.1σ)
- All signal events correspond to $B_s^* B_s^*$ production. We set the following limits:

$$\frac{\sigma(e^+e^- \to B_s\overline{B}_s)}{\sigma(e^+e^- \to B_s^*\overline{B}_s^*)} < 0.16 \quad \text{and} \quad \frac{\sigma(e^+e^- \to B_s\overline{B}_s^*) + \sigma(e^+e^- \to B_s^*\overline{B}_s)}{\sigma(e^+e^- \to B_s^*\overline{B}_s^*)} < 0.16$$

- Relating B_s branching fractions to B branching fractions with contributions from the same quark-level diagrams and assuming SU(3) symmetry, we find:

$$\sigma(e^+e^- \to B_s^*\overline{B}_s^*) = [0.11^{+0.04}_{-0.03}(stat) \pm 0.02(syst)]\ nb$$

which is consistent with the theory (UQM): 1/3 of 0.35 nb.

- The mass of the B_s^* meson is measured to be

$$M(B_s^*) = [5.414 \pm 0.001(stat) \pm 0.003(syst)]\ GeV$$

INCLUSIVE D_s MEASUREMENT

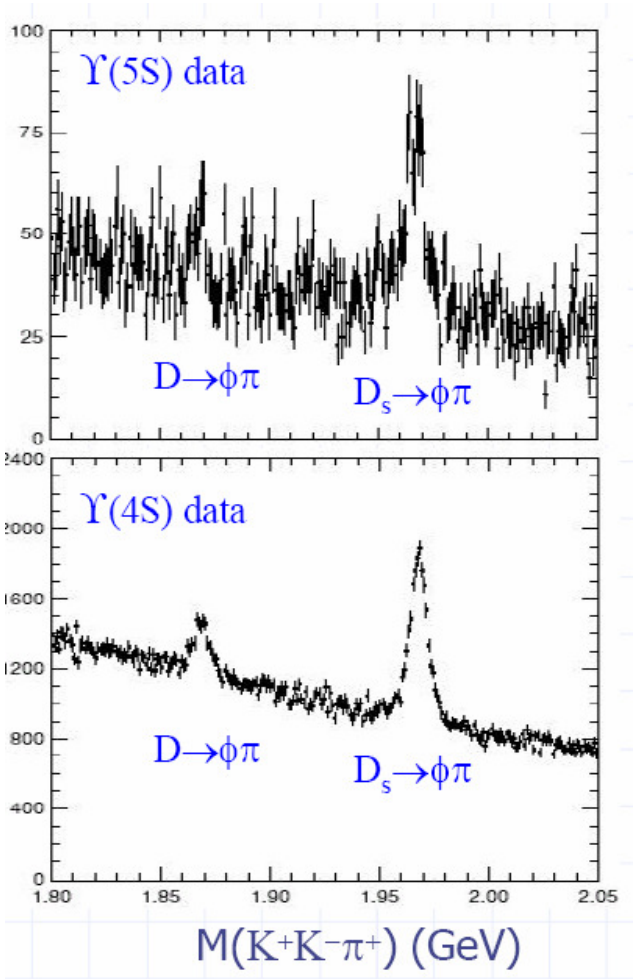
(hep-ex/050847; submitted to PRL)

Overview of the Inclusive Method

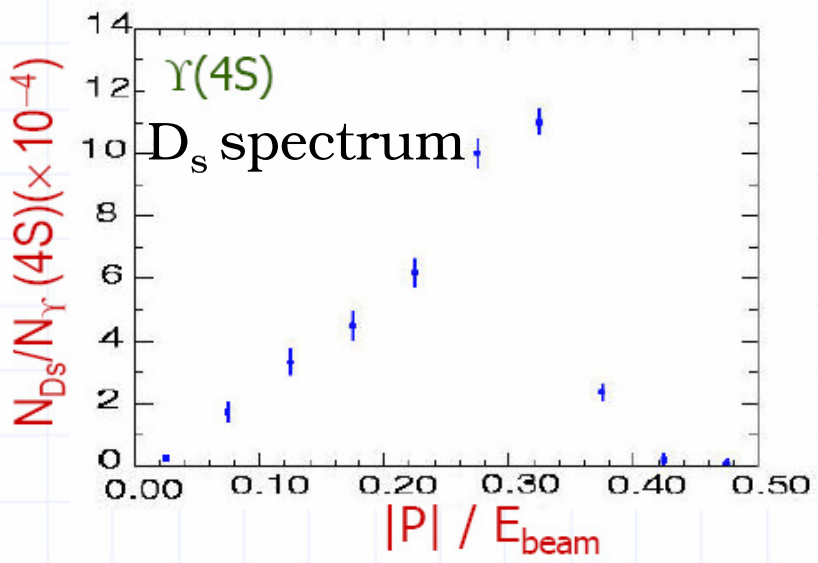
- D_s mesons are expected to be produced in B_s decays more copiously than in B decays (PDG):
  - ✓ $\mathcal{B}(B_s \to D_s X) = (94 \pm 30)\%$
  - ✓ $\mathcal{B}(B \to D_s X) = (10.5 \pm 2.6)\%$

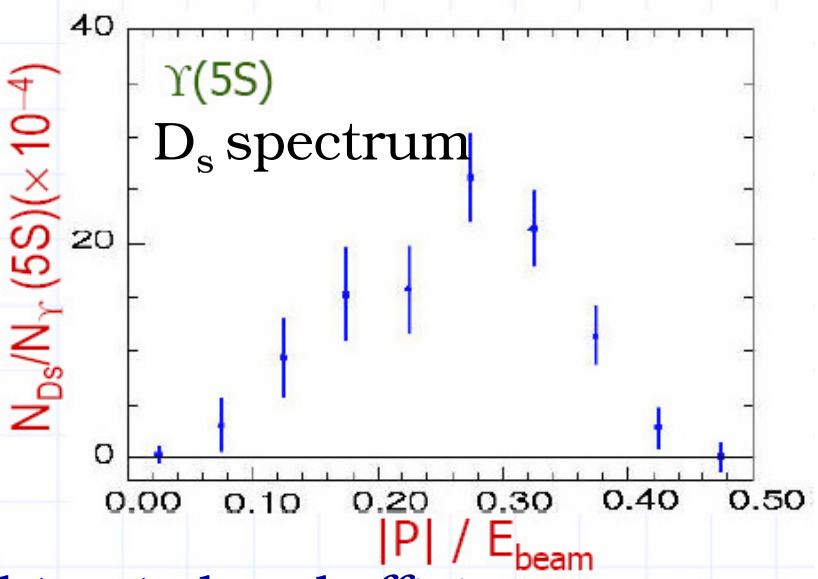
Main Analysis Steps:

- Measure D_s yields ($D_s \to \varphi \pi^+$, $\varphi \to K^+K^-$) in bins of $x = |P_{Ds}|/E_{beam}$ in the continuum, Y(4S) and Y(5S) data.
- Measure $\mathcal{B}(\Upsilon(4S) \to D_s X)$ and $\mathcal{B}(\Upsilon(5S) \to D_s X)$ by subtracting properly scaled and normalized continuum yields from the Y(4S) and Y(5S) yields.
- Extract $\mathcal{B}(\Upsilon(5S) \to B_s^{(*)} B_s^{(*)})$ from the measured $\mathcal{B}(\Upsilon(4S) \to D_s X)$ and $\mathcal{B}(\Upsilon(5S) \to D_s X)$.



D_s spectra at the Y(4S) and the Y(5S)





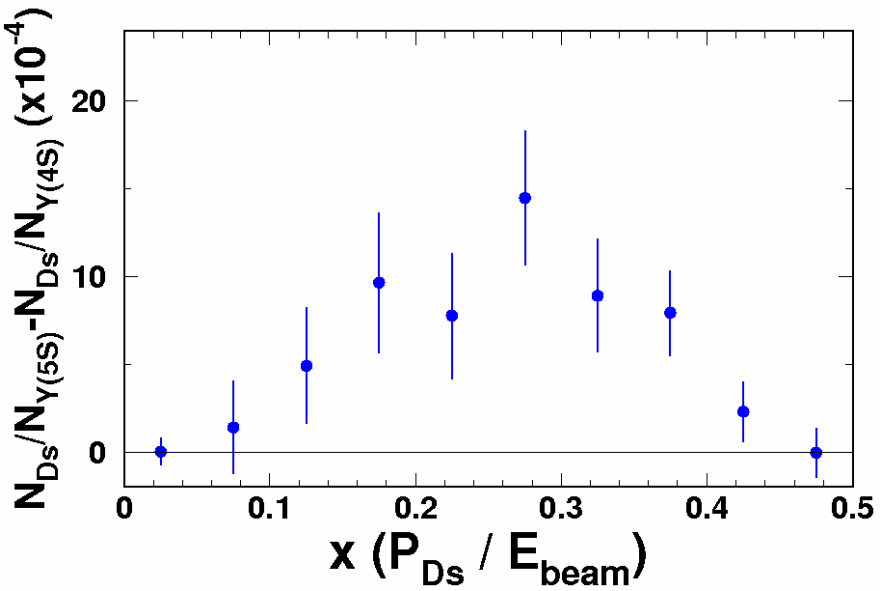
- The plots show the continuum subtracted and efficiency corrected D_s yields at the Y(4S) and Y(5S). (*No* D_s branching fraction correction was applied to be above plots.)
- Using $B(D_s \to \varphi\pi)$ = (4.4±0.5)% [PDG+BABAR], CLEO finds:

$$B(Y(4S) \to D_s X) = (18.1 \pm 0.5 \pm 2.8)\%$$
$$B(Y(5S) \to D_s X) = (44.7 \pm 4.2 \pm 9.9)\%$$

$$B(Y(5S) \to D_s X) / B(Y(4S) \to D_s X) = 2.4 \pm 0.3^{+0.6}_{-0.3}$$

Results for the Inclusive D_s Method

- The plot shows an excess in the D_s production at the Y(5S) over that at the Y(4S). The excess is interpreted as evidence for the B_s at the Y(5S).



- From $\mathcal{B}(Y(4S)\to D_sX)$ and $\mathcal{B}(Y(5S)\to D_sX)$, we obtain a model dependent estimate:

$$B(Y(5S)\to B_s^{(*)}\overline{B_s^{(*)}}) = (16\pm 3(stat)\pm 6(syst))\%$$

The largest sources of the systematic uncertainty are

- ✓ the uncertainty associated with the luminosity measurements
- ✓ the error from the uncertainty in $\mathcal{B}(D_s\to\varphi\pi)$.

Summary

- Using full reconstruction, we have observed the B_s meson at the Y(5S) energy.
- Relating B_s branching fractions to B branching fractions with contributions from the same quark-level diagrams and assuming SU(3) symmetry, we find:

$$\sigma(e^+e^- \to B_s^* \overline{B}_s^*) = [0.11^{+0.04}_{-0.03}(stat) \pm 0.02(syst)]\, nb$$

- We have established that B_s production proceeds predominantly through the creation of $B_s^* \overline{B}_s^*$ pairs:

$$\frac{\sigma(e^+e^- \to B_s \overline{B}_s)}{\sigma(e^+e^- \to B_s^* \overline{B}_s^*)} < 0.16 \quad \text{and} \quad \frac{\sigma(e^+e^- \to B_s \overline{B}_s^*) + \sigma(e^+e^- \to B_s^* \overline{B}_s)}{\sigma(e^+e^- \to B_s^* \overline{B}_s^*)} < 0.16$$

- The mass of the B_s^* meson is measured to be

$$M(B_s^*) = [5.414 \pm 0.001(stat) \pm 0.003(syst)]\, GeV$$

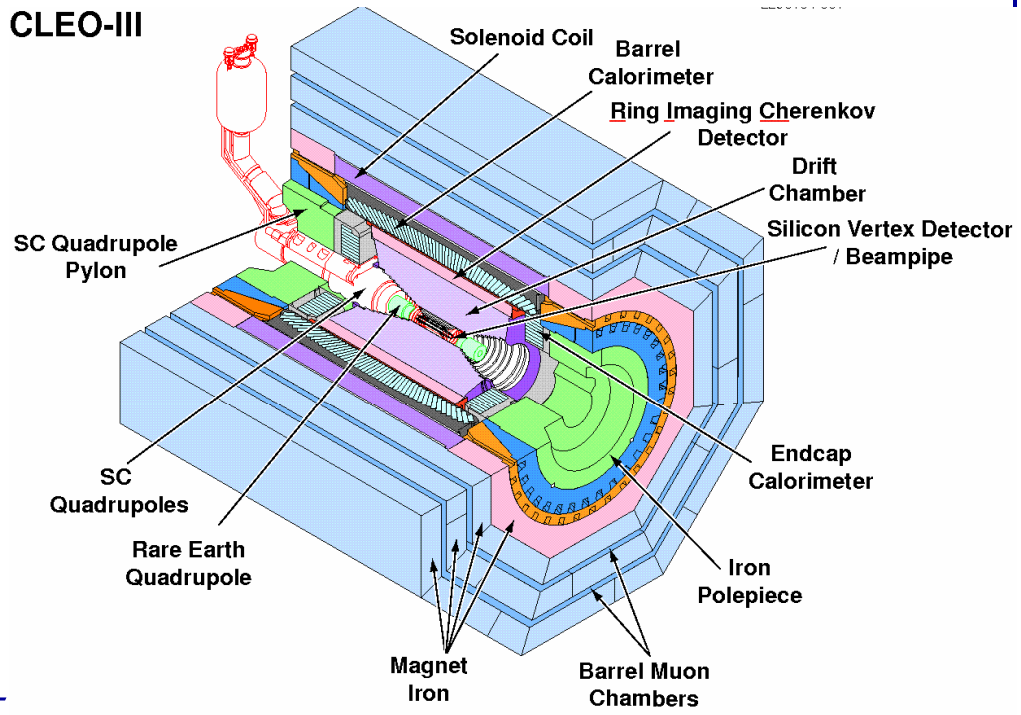
- In a separate analysis, using inclusive D_s measurements at the Y(4S) and Y(5S), we find:

$$B(Y(5S) \to B_s^{(*)} \overline{B_s^{(*)}}) = (16 \pm 3(stat) \pm 6(syst))\%$$

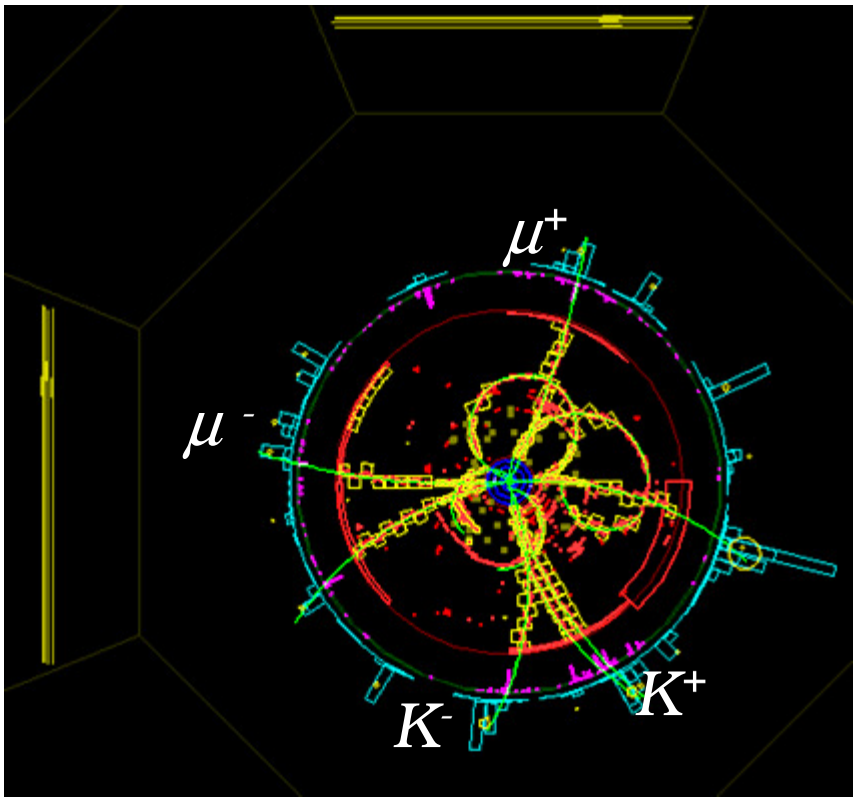
Additional Slides

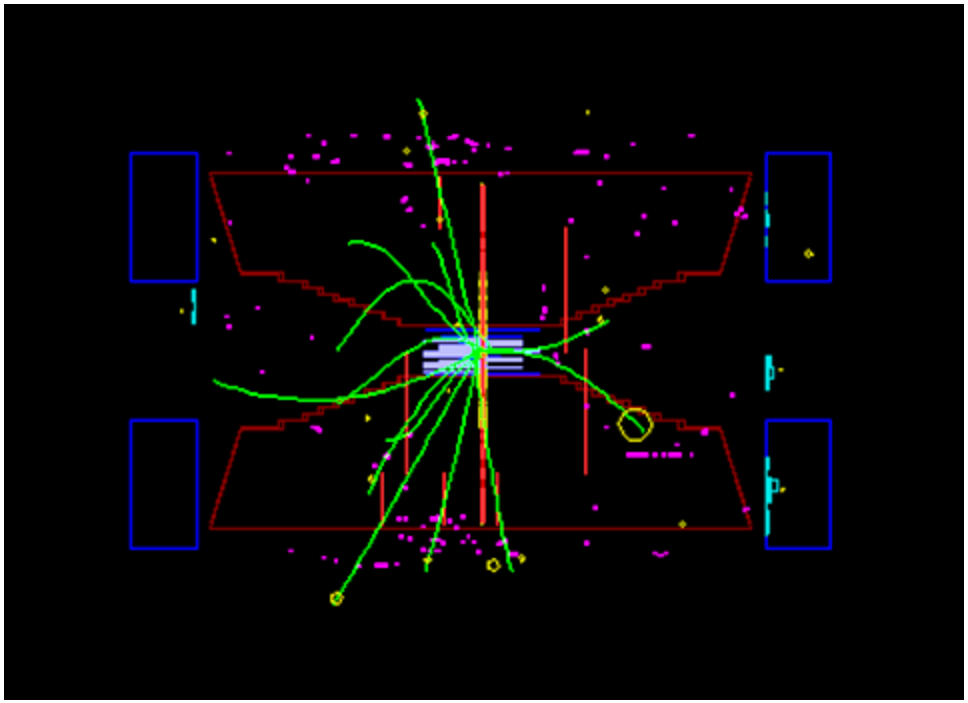
The Data Sample and CLEOIII Detector

- The Y(5S) data sample: 0.42fb^{-1} collected with the CLEO III detector in 2003:
  - ✓ if $\sigma(e^+e^- \to B_s^{(*)}B_s^{(*)}) \sim 0.1$ nb, expect ~ 90K of B_s mesons in 0.42 fb^{-1}
- Background from B mesons is studied using the ON Y(4S) CLEO III data
- The continuum ($e^+ e^- \to qq$) background is studied using the OFF Y(4S) CLEO III data and data from a Λ_b scan (11.2 – 11.4GeV)



A Signal Event





$$Y(5S) \to B_s^* \overline{B}_s^*, \quad B_s^* \to B_s \gamma \quad and$$
$$B_s \to J/\psi\phi, J/\psi \to \mu^+\mu^-, \phi \to K^+K^-$$