Measurements of Charmless B Decays at Belle

Outline

- Introduction
- $B \to X_s \eta$
- Summary

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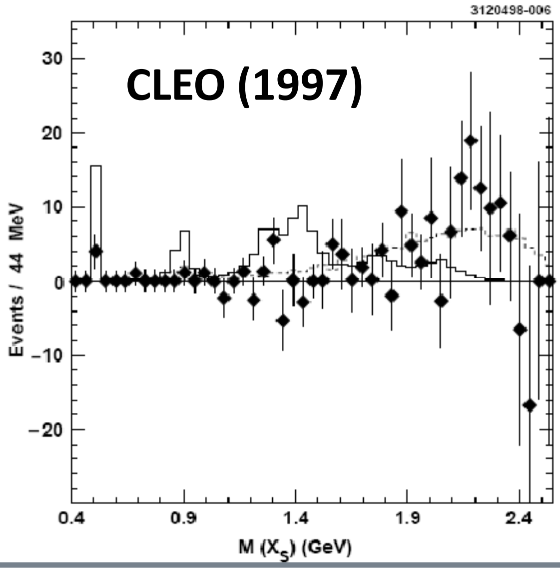
Motivations for $B \to X_s\eta$

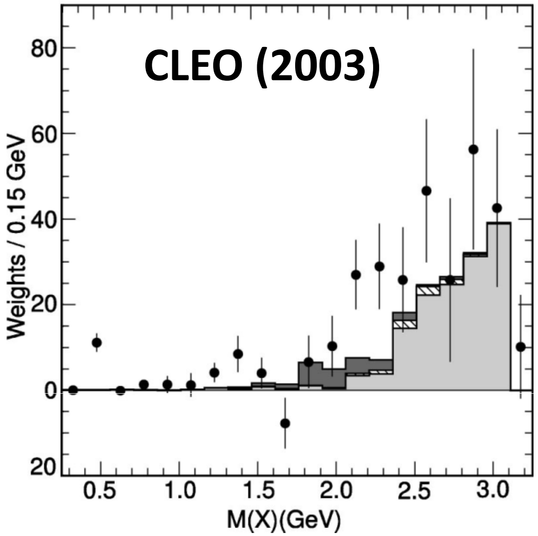
- Due to the uncertainty of hadronization effect, it is theoretically more accurate to estimate the inclusive B decay processes
- Direct CP violations are expected in final state with η/η' in two-body B decays

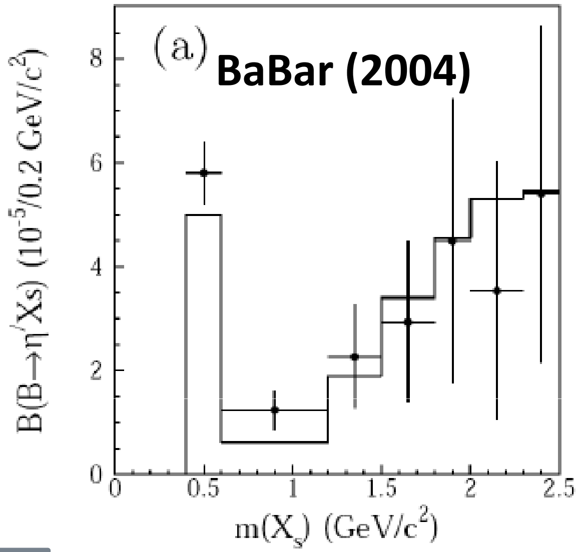
penguin – tree interference

$B \to X_s\eta'$

Observed by CLEO and later confirmed by BaBar



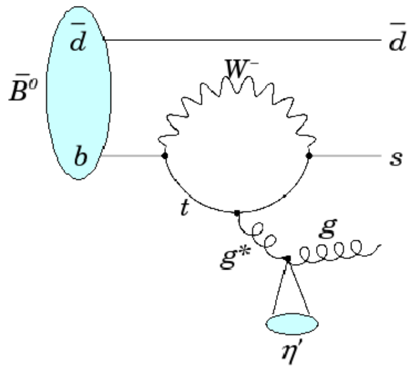




PDG average branching fraction: $(4.2 \pm 0.9) \times 10^{-4}$

Proposals for large branching fraction and high mass signal:

- QCD U(1) anomaly coupling of η' to two gluons
- Intrinsic charm content of η'
- New physics?



QCD anomaly?

➔ **$B \to X_s\eta$ measurement can favor or rule out η' specific mechanisms.**

$B \rightarrow X_s\eta$ Analysis

657M $B\bar{B}$
To be submitted to PRL

- Sum of exclusive modes: $B \rightarrow X_s \eta \; (p_\eta^{cm} > 2.0 \text{ GeV/c})$
  - $\eta \rightarrow \gamma\gamma$
  - $X_s \rightarrow K n\pi \; (n \leq 4,\ n_{\pi^0} \leq 1)$
- Best candidate is that with

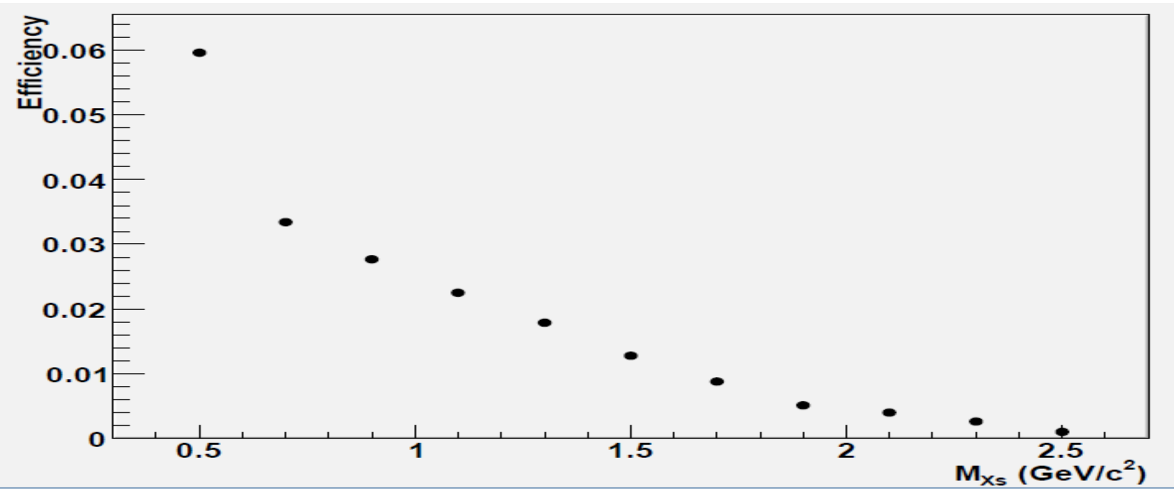
  $\chi^2 = \chi^2_{\Delta E} + \chi^2_{\text{vertex}}$; where $\chi^2_{\Delta E} = (\Delta E/\sigma_{\Delta E})^2$

  $$\Delta E = E_B^* - E_{\text{beam}}^*$$

- Signal yield is extracted using beam-constrained mass

  $$M_{\text{bc}} = \sqrt{(E_{\text{beam}}^*)^2/c^4) - (|\mathbf{p}_\mathbf{B}^*|)^2/c^2}$$

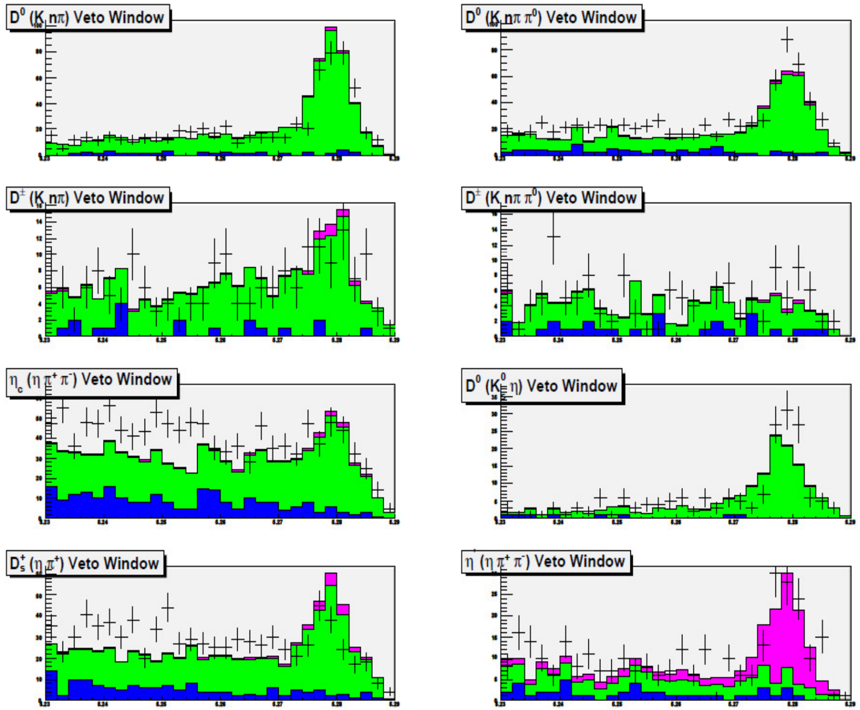
- Efficiency determined from MC



- Efficiency shown not including $\eta \rightarrow \gamma\gamma$ (39.30%).
- Fits are performed in 11 bins of M_{X_s}

$B \to X_s\eta$ Charm Backgrounds

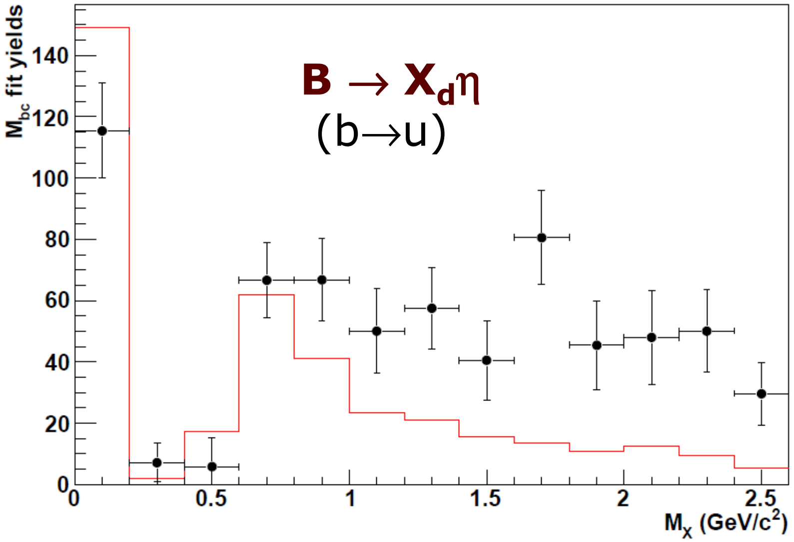
- Many modes (mostly $b \to c$ decays) have identical final states to $X_s\eta$
  - Most suppressed by p_η > 2.0 GeV/c
  - Vetoes on $D^{(*)}$ mass windows are applied for what remains .
- Remaining $b \to c$ backgrounds divided into 5 PDFs:
  - $B \to D\eta$
  - $B \to D^*\eta$
  - $B \to D\pi\eta$
  - $B \to D^*\pi\eta$
  - All other $b \to c$ modes
  - PDF shapes come from MC.
  - Normalizations from:
    - $D^{(*)}\eta$: Belle measurement
    - $D^{(*)}\pi\eta$: best fit to veto windows (shown at right).
    - Other $b \to c$: MC expectation.
  - Best fit to veto is tested on $D^{(*)}\eta$, gives consistent results with previous Belle measurement.



green : $b \to c$
blue : continuum
magenta : rare

$b \to s$ Backgrounds

- A small background is identified from $b \to s$ decays. The expected contamination is subtracted from fitted yields.
  - $B \to X_s\gamma$ (**< 1** event over all bins)
  - $B \to X_s\ \eta'$ (**< 2** events over all bins)
  - $B \to \pi\eta$ (**~ 5** events in lowest bin)
  - $B \to X_d\eta$ (**19.1 ±2.3** events over all bins)
    - Since this is not well measured, estimated from data by changing $X_s \to X_d$ and performing fit procedure in bins of M_{Xd}:

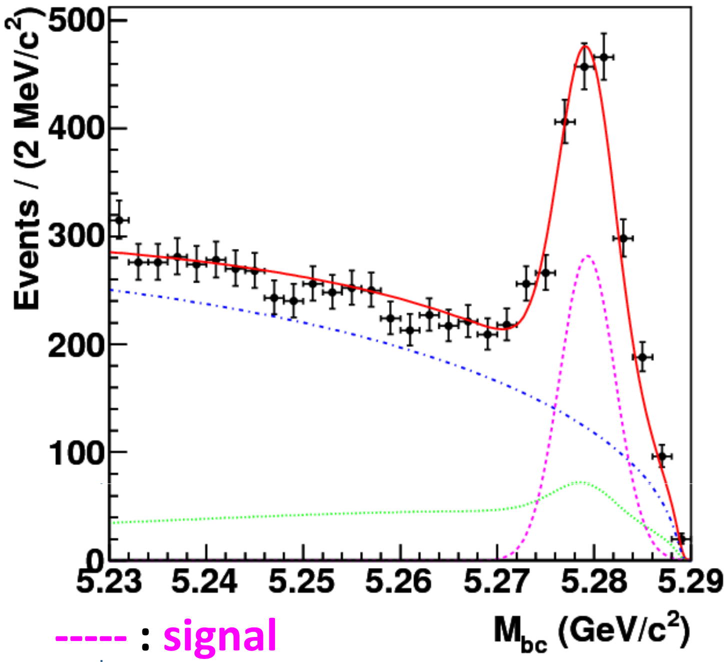


- Mis-ID of M_{Xd} as M_{Xs} estimated from MC

→ **Estimated $X_d\ \eta$ events in the $X_s\eta$ data: 19.1 ±2.3 events**

Red – MC expectation
Black – Data yields

Observed signal yield for $B \to X_s\eta$



----- : signal

----- : $B\bar{B}$ background

----- : combinatorial background

Signal yield ($0.4 < M_{X_s} < 2.6$ GeV/c^2) :

$$1053 \pm 54^{+16}_{-18} \quad (23\sigma)$$

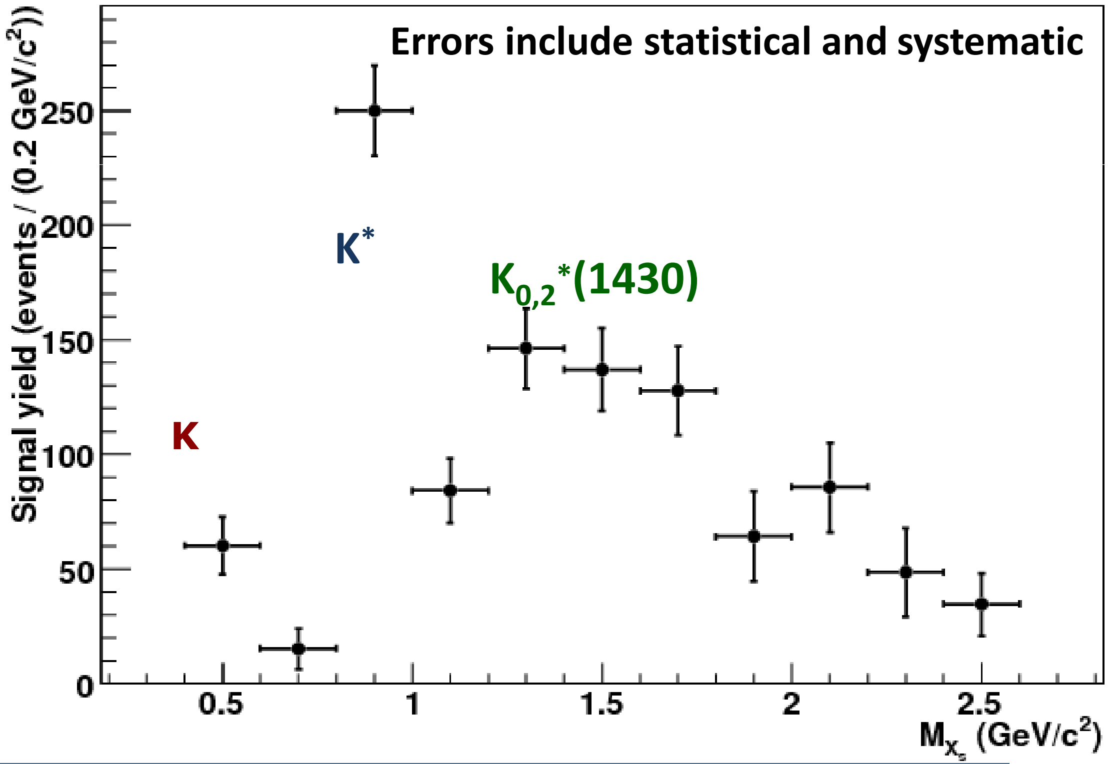
Signal yield ($1.8 < M_{X_s} < 2.6$ GeV/c^2) :

$$233 \pm 34^{+13}_{-15} \quad (7\sigma)$$

$$B \to X_s\eta \; (p_\eta^{cm} > 2.0 \text{ GeV/c})$$

$\eta \to \gamma\gamma$

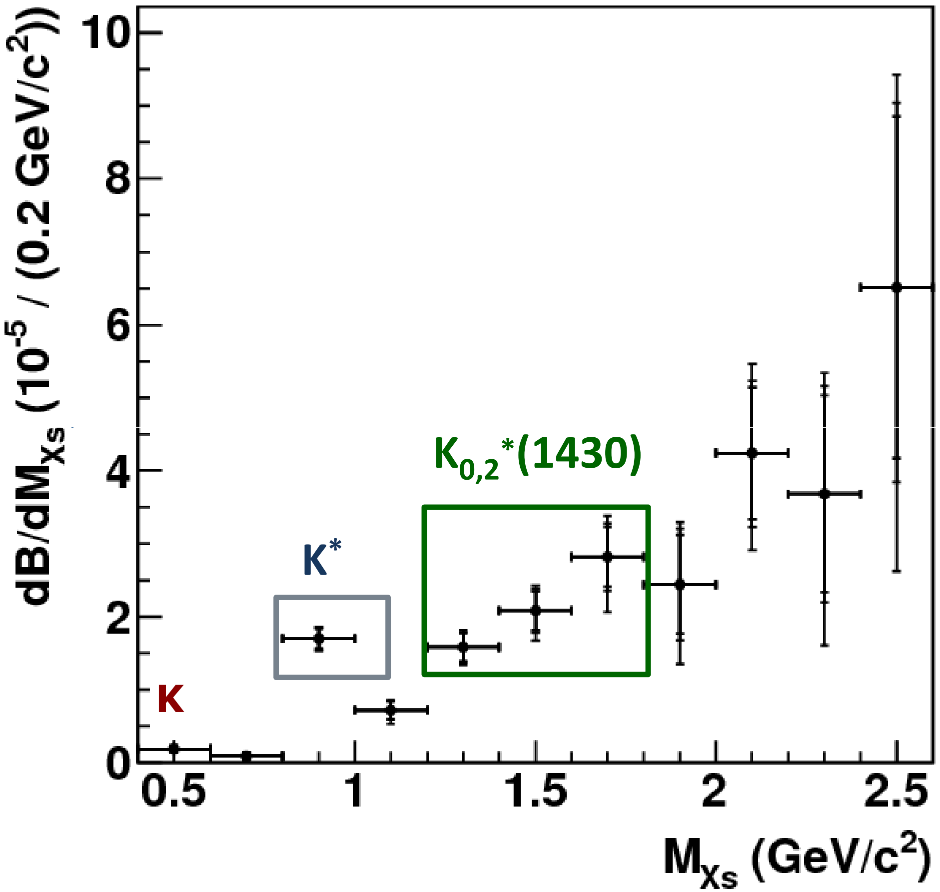
$X_s \to Kn\pi \; (n \leq 4,\, n_{\pi^0} \leq 1)$

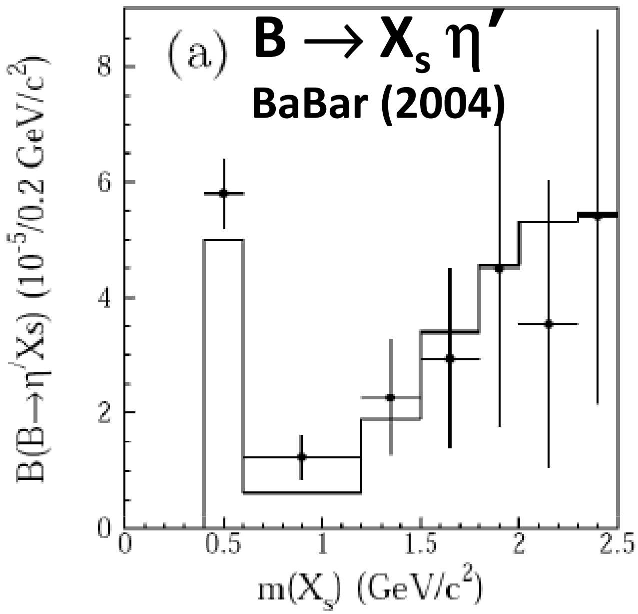


M_{bc} is fitted in bins of X_s mass.

$B \to X_s\eta$ Branching Fraction

Errors are statistical, systematic, and modeling.





- Lower mass range yields are consistent with previous measurements.
- No strong suppression relative to $X_s\eta'$, similar spectral shape.

➔ η' -specific explanations unlikely for $B \to X_s\eta'$ signal

- Prev. unobserved signal at high M_{Xs}

For X_s mass range 0.4 – 2.6 GeV/c^2 :

$$\mathcal{B}(B \to X_s\eta)^* = (26.1 \pm 3.0(\mathrm{stat})^{+1.9}_{-2.1}(\mathrm{syst})^{+4.0}_{-7.1}(\mathrm{model})) \times 10^{-5}$$

*assuming JETSET hadronization.

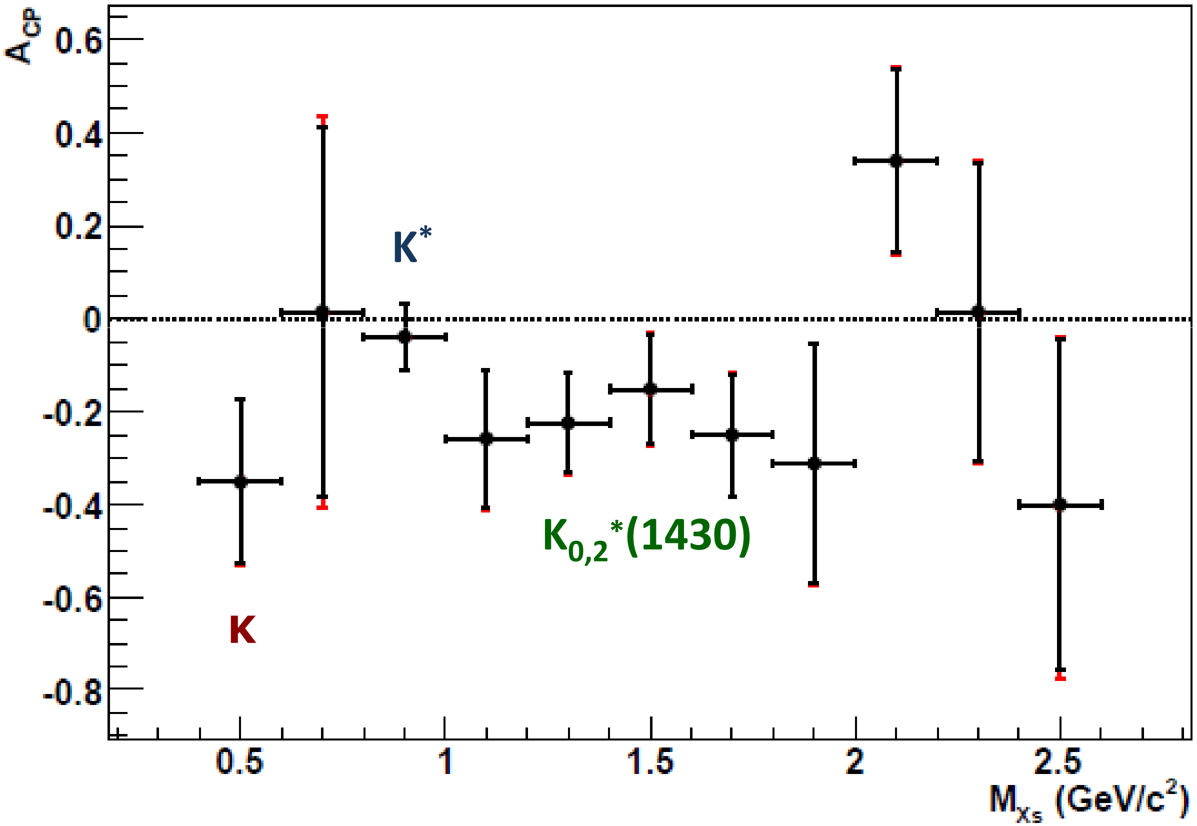
$\mathcal{B}(B \to X_s\eta') = (42 \pm 9) \times 10^{-5}$

Direct CP Asymmetry, A_{CP}

- Measured over self-tagged modes only:

$$A_{CP} = \frac{N_b - N_{\bar{b}}}{N_b + N_{\bar{b}}}$$

$M_{X_s}(\mathrm{GeV}/c^2)$	$\mathcal{A}_{CP}(10^{-2})$
0.4–0.6	$-35 \pm 18 \pm 2$
0.6–0.8	$2 \pm 40 \pm 13$
0.8–1.0	$-4 \pm 7 \pm 2$
1.0–1.2	$-26 \pm 15^{+3}_{-4}$
1.2–1.4	$-22 \pm 11^{+2}_{-3}$
1.4–1.6	$-15 \pm 12^{+2}_{-3}$
1.6–1.8	$-25 \pm 13^{+2}_{-3}$
1.8–2.0	$-31 \pm 26 \pm 6$
2.0–2.2	$34 \pm 20^{+4}_{-3}$
2.2–2.4	$2 \pm 32 \pm 5$
2.4–2.6	$-40 \pm 36^{+7}_{-12}$
0.4–2.6	$-13 \pm 4^{+2}_{-3}$
1.0–2.6	$-15 \pm 6 \pm 3$
1.8–2.6	$0 \pm 14 \pm 5$



For X_s mass range 0.4 – 2.6 GeV/c^2 :

$$\mathcal{A}_{CP} = -0.13 \pm 0.04(\mathrm{stat})^{+0.02}_{-0.03}(\mathrm{syst})$$

Summary and Outlook

- First inclusive measurement for $B \to X_s\eta$
- Large rate observed and similar M_{Xs} spectral shape as $B \to X_s\eta'$ (explanation needed for both $B \to X_s\eta'$ and $B \to X_s\eta$)
- A_{CP} determined in bins of M_{Xs}
- With the largest data set at hand and improved tracking efficiency, more results will be released very soon
- Continuously search/update for more charmless B decay modes, with the hope to find surprises

BACKUP

Summary Tables

Signal Yield, Branching Fraction, A_{CP}

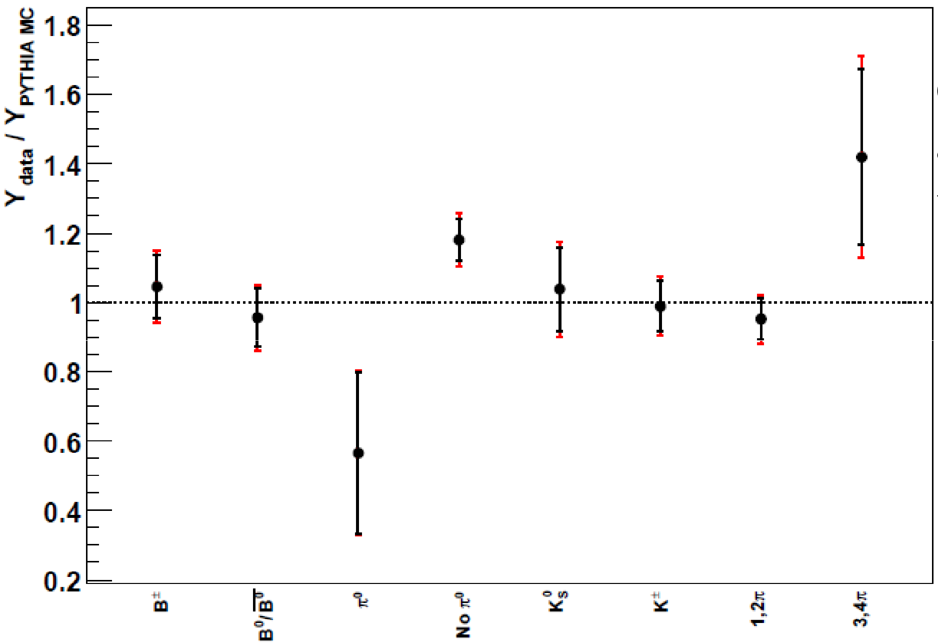
M_{X_s} (GeV/c^2)	N_S	$\mathcal{B}(10^{-6})$	$\mathcal{A}_{CP}(10^{-2})$
0.4–0.6	60 ± 12	$1.9 \pm 0.4 \pm 0.1 \pm 0.0$	$-35 \pm 18 \pm 2$
0.6–0.8	15 ± 9	$0.9 \pm 0.5 \pm 0.1^{+0.1}_{-0.0}$	$2 \pm 40 \pm 13$
0.8–1.0	250 ± 19	$17.0 \pm 1.3^{+0.9}_{-1.0} \pm 0.0$	$-4 \pm 7 \pm 2$
1.0–1.2	84 ± 14	$7.2 \pm 1.2^{+0.4+0.3}_{-0.5-1.4}$	$-26 \pm 15^{+3}_{-4}$
1.2–1.4	146 ± 17	$15.8 \pm 1.9 \pm 1.0^{+1.0}_{-1.1}$	$-22 \pm 11^{+2}_{-3}$
1.4–1.6	137 ± 18	$20.8 \pm 2.7^{+1.3+1.9}_{-1.4-2.8}$	$-15 \pm 12^{+2}_{-3}$
1.6–1.8	128 ± 18	$28.2 \pm 4.1 \pm 2.1^{+3.3}_{-6.1}$	$-25 \pm 13^{+2}_{-3}$
1.8–2.0	64 ± 18	$24.4 \pm 6.8^{+3.6+3.7}_{-3.4-7.8}$	$-31 \pm 26 \pm 6$
2.0–2.2	86 ± 18	$42.4 \pm 9.1^{+3.8+7.3}_{-4.3-8.7}$	$34 \pm 20^{+4}_{-3}$
2.2–2.4	49 ± 18	$36.8 \pm 13.5^{+5.9+7.6}_{-6.1-14.5}$	$2 \pm 32 \pm 5$
2.4–2.6	35 ± 13	$65.1 \pm 23.4^{+9.5+14.5}_{-12.8-28.3}$	$-40 \pm 36^{+7}_{-12}$
0.4–2.6	1053 ± 54	$261 \pm 30^{+19+40}_{-21-71}$	$-13 \pm 4^{+2}_{-3}$
1.0–2.6	728 ± 48	$241 \pm 30^{+18+40}_{-20-71}$	$-15 \pm 6 \pm 3$
1.8–2.6	233 ± 34	$169 \pm 29^{+15+33}_{-18-59}$	$0 \pm 14 \pm 5$

Systematic Errors (in %)

M_{X_s} (GeV/c^2)	Efficiency	Fitting	Bkg. Subtr.	Fragmentation	Other Model
0.4–0.6	±4.9	$^{+1.6}_{-1.8}$	±2.6	±0.0	±0.7
0.6–0.8	±5.1	$^{+5.1}_{-5.5}$	$^{+1.6}_{-12.5}$	$^{+9.6}_{-0.0}$	±2.2
0.8–1.0	±5.2	$^{+1.4}_{-1.6}$	$^{+0.1}_{-0.8}$	±0.0	±2.9
1.0–1.2	±5.3	$^{+2.7}_{-2.9}$	$^{+0.9}_{-2.3}$	$^{+0.0}_{-18.3}$	±4.8
1.2–1.4	±5.4	$^{+2.3}_{-2.7}$	$^{+0.3}_{-1.3}$	$^{+0.0}_{-2.6}$	±6.4
1.4–1.6	±5.6	$^{+2.8}_{-3.1}$	$^{+0.2}_{-1.4}$	$^{+0.0}_{-9.6}$	±9.2
1.6–1.8	±5.7	±4.2	$^{+0.7}_{-1.5}$	$^{+0.0}_{-18.4}$	±11.5
1.8–2.0	±5.9	$^{+13.3}_{-12.2}$	$^{+0.5}_{-3.0}$	$^{+0.0}_{-28.0}$	±15.0
2.0–2.2	±5.9	$^{+6.7}_{-7.8}$	$^{+0.4}_{-2.2}$	$^{+0.0}_{-10.9}$	±17.3
2.2–2.4	±6.0	$^{+14.6}_{-14.8}$	$^{+1.2}_{-4.1}$	$^{+0.0}_{-33.4}$	±20.7
2.4–2.6	±6.0	$^{+13.1}_{-17.9}$	$^{+0.8}_{-5.5}$	$^{+0.0}_{-37.4}$	22.3

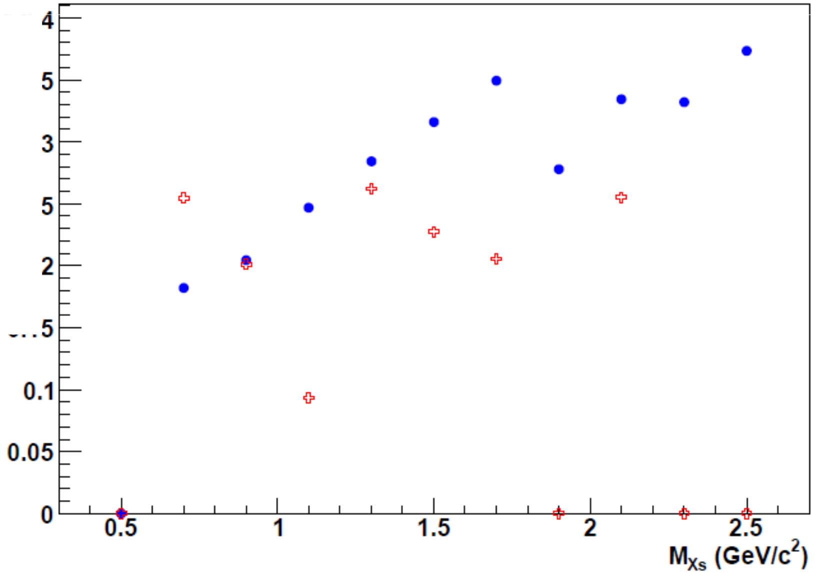
PYTHIA Uncertainties

- We check the distribution of mode categories between PYTHIA MC and data:



• All categories consistent within errors, except for modes with/without a π^0, where we see excess of modes without π^0 over those with π^0.

• The difference is studied bin-by-bin:



Blue – fraction of signal yield with a π^0 in MC

Red – same fraction in data.

➔We recalculate the efficiency using the measured fractions of π^0, use this difference in efficiency to estimate a systematic error.

<u>This error dominates the model uncertainty.</u>