Inclusive B decays including Kaons at *BABAR*

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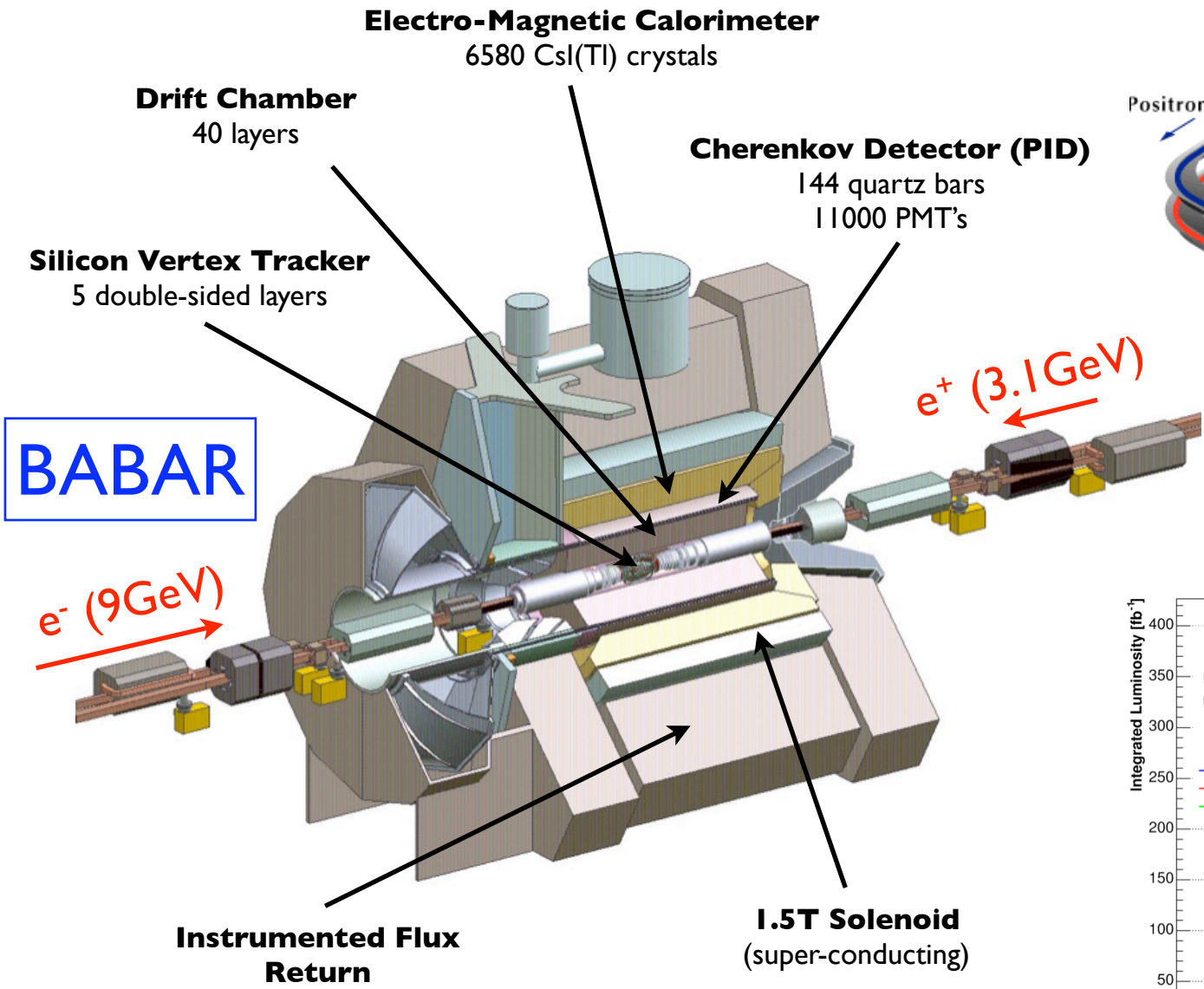
Introduction

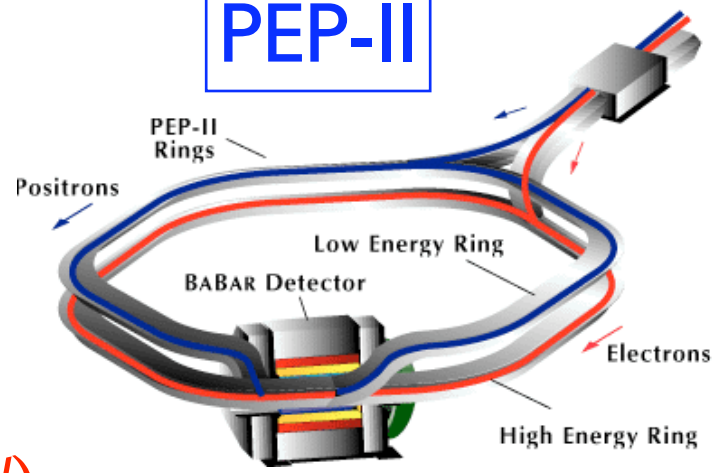
- Analysis of the (semi-)inclusive decays:
  1. $B^+ \rightarrow K^{*+} h^+ h^-$ (final results)
     - Measure charge asymmetries A_{ch} for significant signals
  2. $B \rightarrow K^+ X$ and $B \rightarrow K^0 X$ (preliminary results)
- Inclusive decays ⇒ simpler theoretical interpretation
- *most of* These decays are dominated by $b \rightarrow s$ penguin loops
- Sensitive to physics beyond the Standard Model (SM)

see e.g. Grossman and Worah, Phys. Lett. B395, 241 (1997)

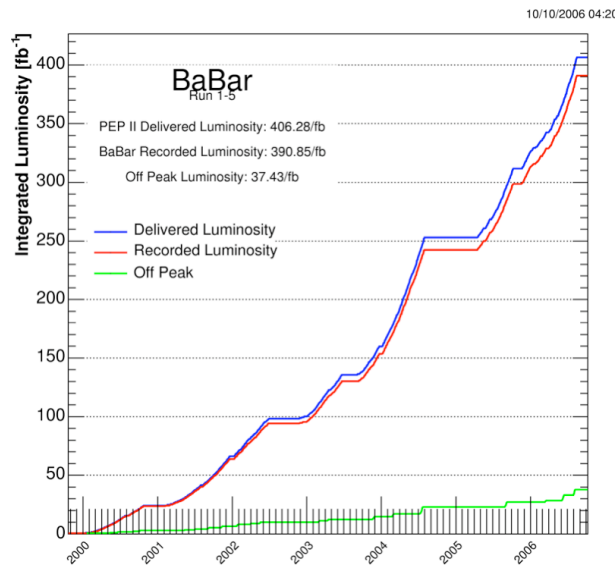
PEP-II & BABAR detector



PEP-II



L_{peak} = 12x10^{33} cm^{-2}s^{-1}
L_{int} = 406 fb^{-1}
210 fb^{-1} used for $B^+ \to K^{*+}h^+h^-$
288.5 fb^{-1} used for $B \to KX$

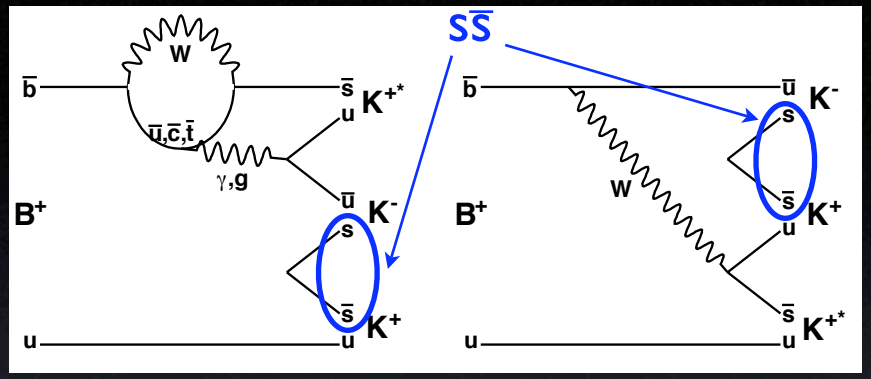


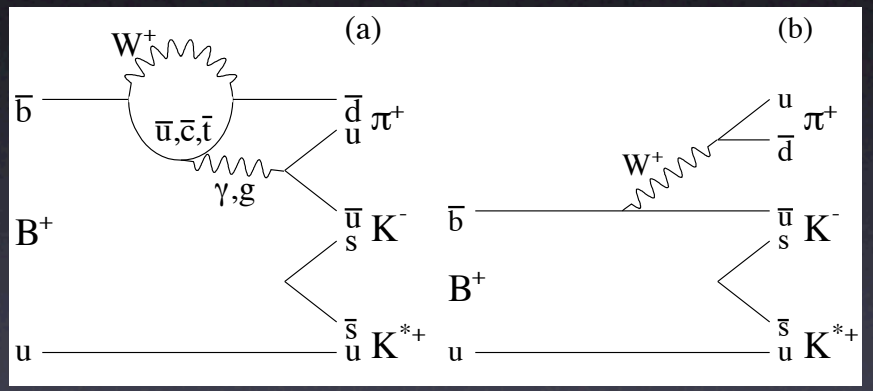
Common analysis technique

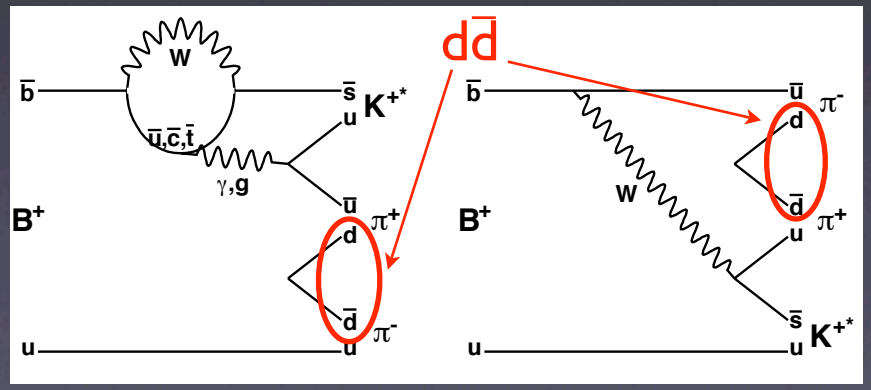
- Event selection with loose cuts ⇒ high efficiency
- Unbinned extended Maximum Likelihood (ML) Fit to extract signal yields, A_{ch} (+some PDF parameters)
- Background-rejection variables used in ML Fit:
  - kinematic:
    - $m_{ES} = \sqrt{s/4 - |p_B|^2}$ ($\sigma(m_{ES}) \approx 2.5$–$3.0 MeV/c^2$)
    - $\Delta E = E^*_B - \sqrt{s}/2$ ($\sigma(\Delta E) \approx 10$–$50 MeV$)
    - $m(K^*)$ = K^{*+} reconstructed mass (for $K^{*+}h^+h^-$ analysis)
  - Event topology:
    - BB events are isotropic, qq-continuum events are jet-like ⇒ multiple variables combined into a Fisher discriminant

$B^+ \to K^{*+} h^+ h^-$ (h=K,π)

- Consider 3-body decays:
  - $B^+ \to K^{*+} K^+ K^-$ — $b \to s$ & $b \to u$
  - $B^+ \to K^{*+} \pi^+ K^-$ — $b \to d$ & $b \to u$
  - $B^+ \to K^{*+} K^+ \pi^-$
    - SM suppressed ($\Delta S=2$)
      $\Rightarrow$ sensitive to physics beyond SM
  - $B^+ \to K^{*+} \pi^+ \pi^-$ — $b \to s$ & $b \to u$
- SM expectations:
  $\mathcal{B}(B^+ \to K^{*+} \pi^+ \pi^-) > \mathcal{B}(B^+ \to K^{*+} K^+ K^-)$
  $> \mathcal{B}(B^+ \to K^{*+} \pi^+ K^-) > \mathcal{B}(B^+ \to K^{*+} K^+ \pi^-)$





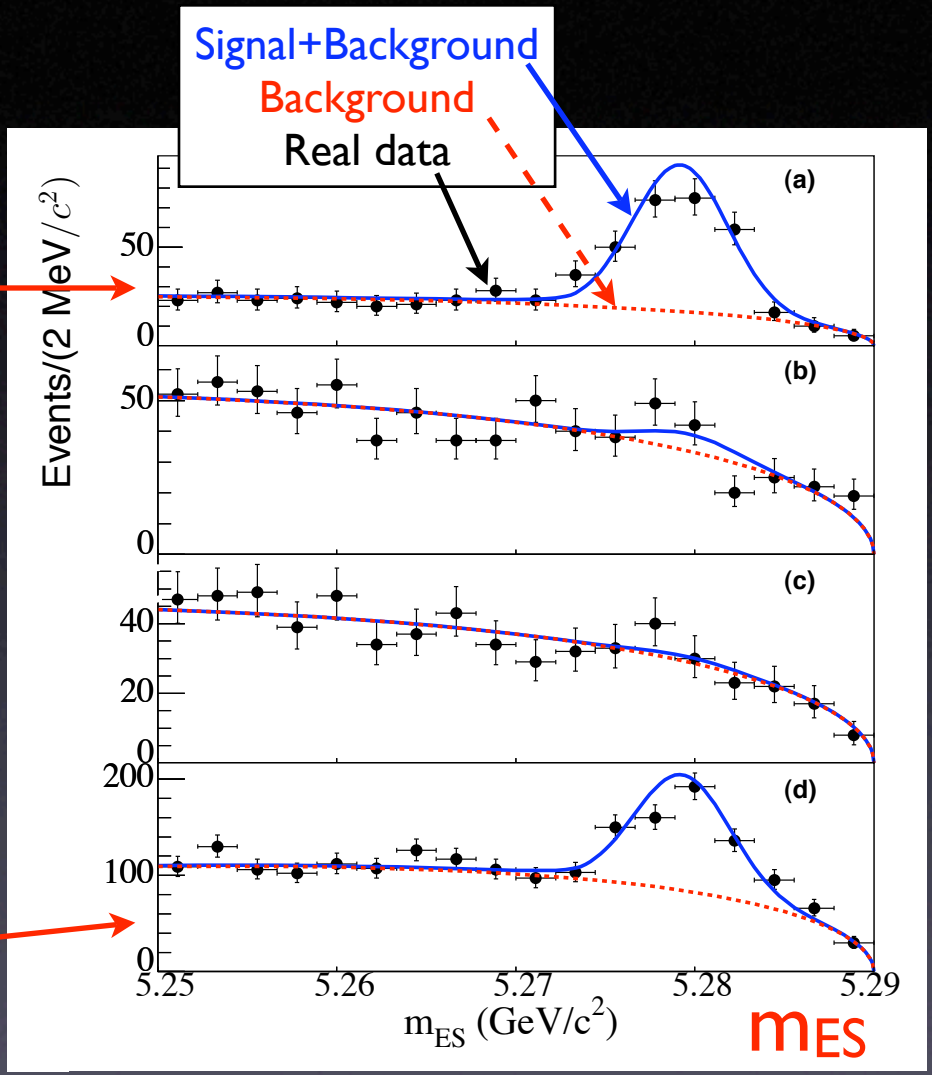


$B^+ \to K^{*+} h^+ h^-$ event selection

- Reconstruct K^{*+} as $K^{*+} \to K^0_S \pi^+$ ($K^0_S \to \pi^+\pi^-$)
- $B^+ \to K^{*+} h^+ h^-$ includes ($K^{*+} h^-$) and ($h^+ h^-$) resonances: e.g. $\phi(\to K^+K^-)$, $\rho^0(\to \pi^+\pi^-)$, $K^*(K^+\pi^-)$
  => semi-inclusive measurement
- $B \to$ charm decays rejected with J/Ψ, D veto
- 29% of events have multiple candidates
  - select candidate with smallest B vertex χ^2
    - correct in 70% of cases
- Signal efficiency weighted as function of position of $K^{*+} h^+ h^-$ event in Dalitz plane

$B^+ \to K^{*+} h^+ h^-$: fit results

1. $B^+ \to K^{*+} K^+ K^-$
   - ✳ 288±26 signals
2. $B^+ \to K^{*+} \pi^+ K^-$
   - no signal
3. $B^+ \to K^{*+} K^+ \pi^-$
   - no signal
     ($\Delta S=2$ => SM-suppressed)
4. $B^+ \to K^{*+} \pi^+ \pi^-$
   - ✳ 583±46 signals



m_{ES} projection plots

$B^+ \to K^{*+} h^+ h^-$: crosschecks

- Generate and fit simulated data samples with expected signal and background contributions:
  - bias = N_{signal}(fitted) - N_{signal}(generated) used as correction to measured signal yield
    - mode-dependent bias = ~1-38 events
    - assign 1/2 of bias as systematic uncertainty
- A_{ch} for background compatible with zero

$B^+ \to K^{*+} h^+ h^-$: systematics

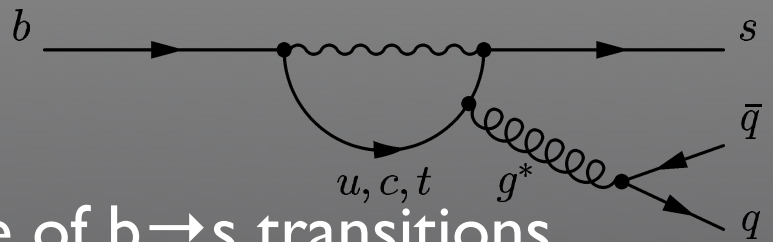
Source	σ_{syst}
Reconstruction efficiency (MC) Tracking K^0 reconstruction Nb BB pairs	5.3-9.4% 2.4% 1.2% 1.1%
Total multiplicative errors	6.0-9.8%
Background to $K^{*+}(892)$ from higher resonances B background Fit bias Signal mis-ID (from K/π mis−ID) PDF parametrization	4.5-25.6 events 1.3-37.9 events 0.3-18.7 events 0.0-15.5 events 3.0-19.4 events
Total additive errors	16.5 - 51.4 events
Total systematic error on Branching Fraction	$(2.0\text{-}8.1)\times10^{-6}$

$B^+ \to K^{*+} h^+ h^-$ results

Mode	Signal yield	Efficiency	Branching Fraction [10^{-6}]	Charge asym.
$B^+ \to K^{*+} K^+ K^-$	288±26	3.4%	36.2 ±3.3 ±3.6	+0.11±0.08±0.03
$B^+ \to K^{*+} \pi^+ K^-$	20.1±24.7	3.5%	2.5±3.1±5.3 <11.8 @90% C.L.	N/A
$B^+ \to K^{*+} K^+ \pi^-$ (SM-suppressed)	9.7±17.1	3.5%	1.2±2.1±2.0 <6.1 @90% C.L.	N/A
$B^+ \to K^{*+} \pi^+ \pi^-$	583±46	3.3%	75.3 ±6.0 ±8.1	+0.07±0.07±0.04

- First observation of $B^+ \to K^{*+} K^+ K^-$ and $B^+ \to K^{*+} \pi^+ \pi^-$
- Hierarchy of result compatible with SM expectations
- A_{ch} not significant for observed decays

Inclusive B→KX decays



- Motivation:
  - search for B→KX as signature of b→s transitions
  - sensitive to physics beyond SM:
    BF(b→s) = 1-2% (SM) → up to 10% is certain models

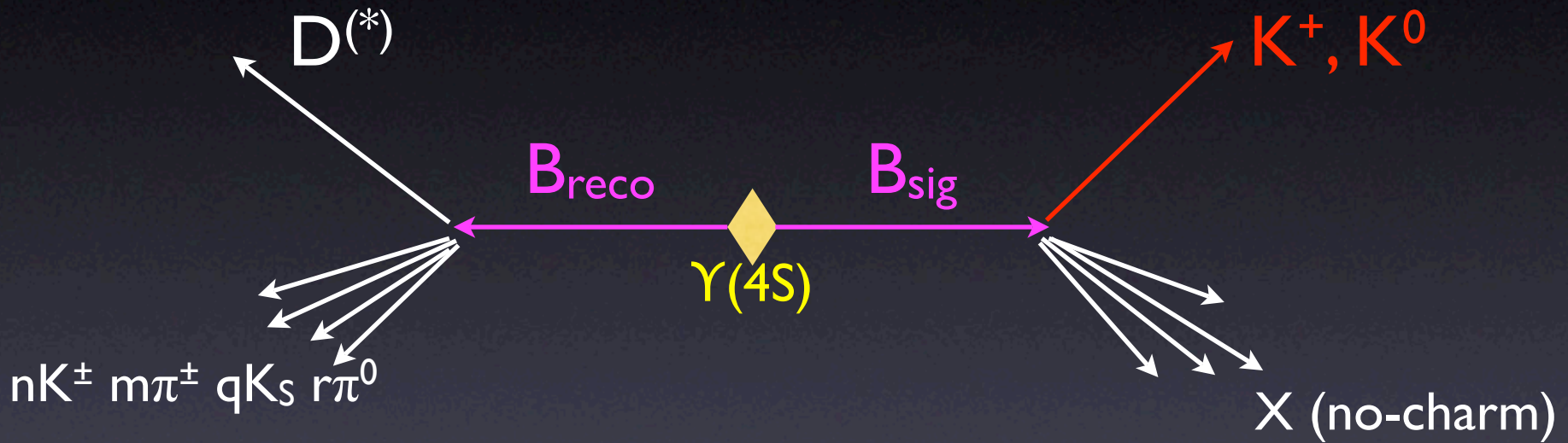
    Bigi et al. Phys. Lett. B323, 408 (1994)
    Gosky et al. Phys. Rev. D 64, 054006 (2001)
  - provide input to understanding of b→s decays

    Buchalla et al., JHEP 0509, 074 (2005)
    Hiller and Krüger, Phys. Rev. D 69, 074020 (2004)
- Analysis overview:

  [first suggested by Browder et al., Phys. Rev. D 57, 6829 (1998)]
  - reject qq-continuum by selecting events containing fully reconstructed B (B_{reco}) recoiling against a signal B (B_{sig})
  - Separate b→c charm background with p*(K) in B_{sig} rest frame

$B \to KX$ analysis method

- Select event with a fully reconstructed B_{reco}
  - $B_{reco} \to D^{(*)}\, nK^{\pm}\, m\pi^{\pm}\, qK_S\, r\pi^0$ $(n+m=1,3,5;\ q,r<3)$



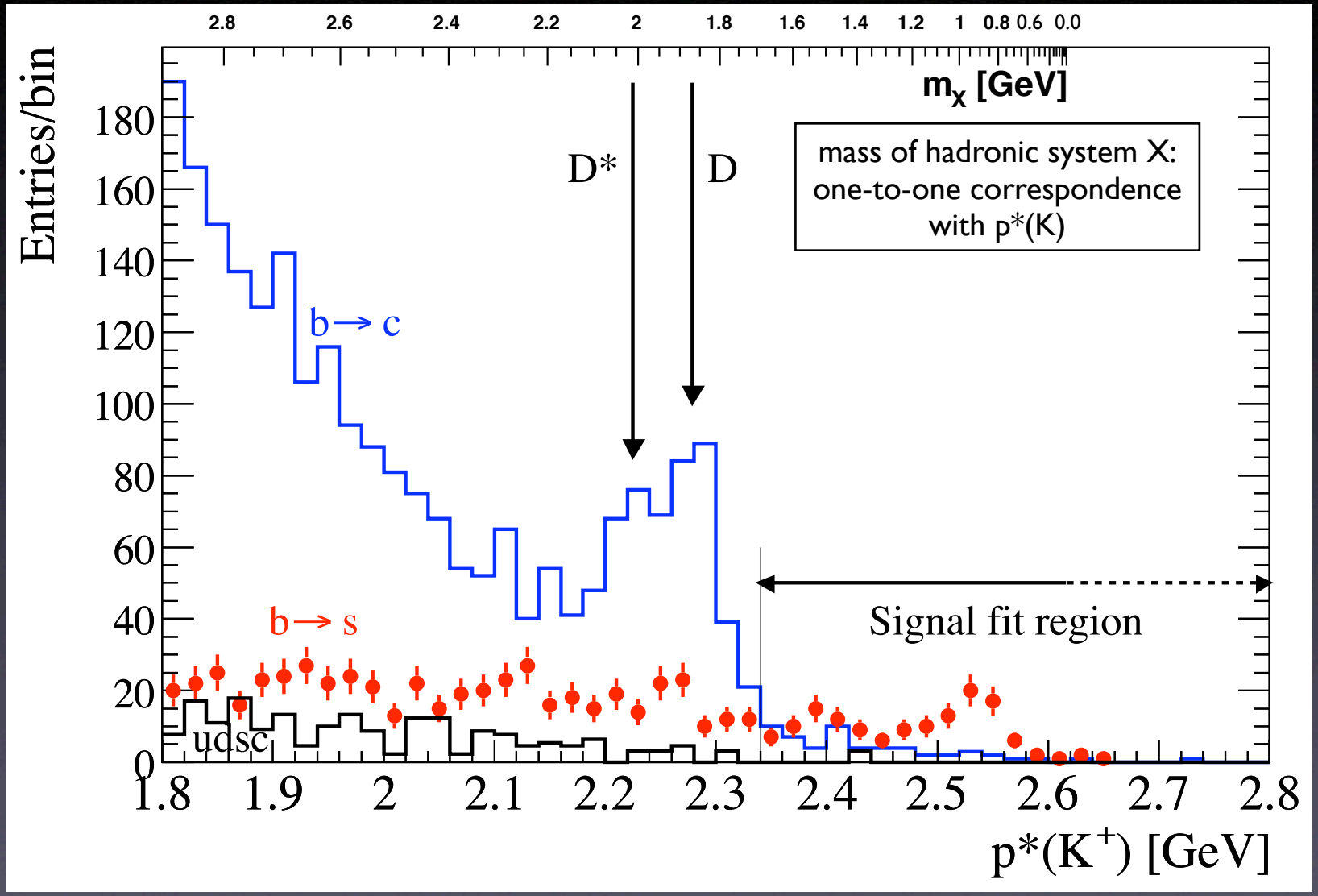
- ML fit to $m_{ES}(B_{reco})$, Fisher(B_{reco}), and $p^*(K)>2.34$GeV

  $\Upsilon(4S)$ and B_{reco} 4-mom. $\Rightarrow$ B_{sig} 4-mom. $\Rightarrow$ kaon 3-mom. $p^*(K)$ in B_{sig} CM

  - 3 components in ML fit: $B \to KX$, $b \to c$, qq
- Extract signal yield at $p^*(K)>2.34$GeV $\Rightarrow$ partial BF

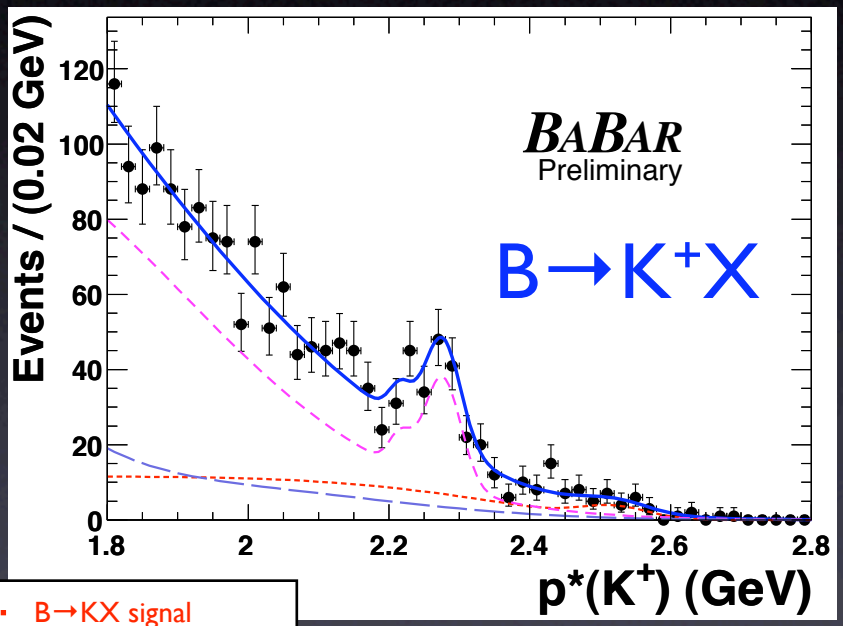
p*(K+) spectrum (MC data)

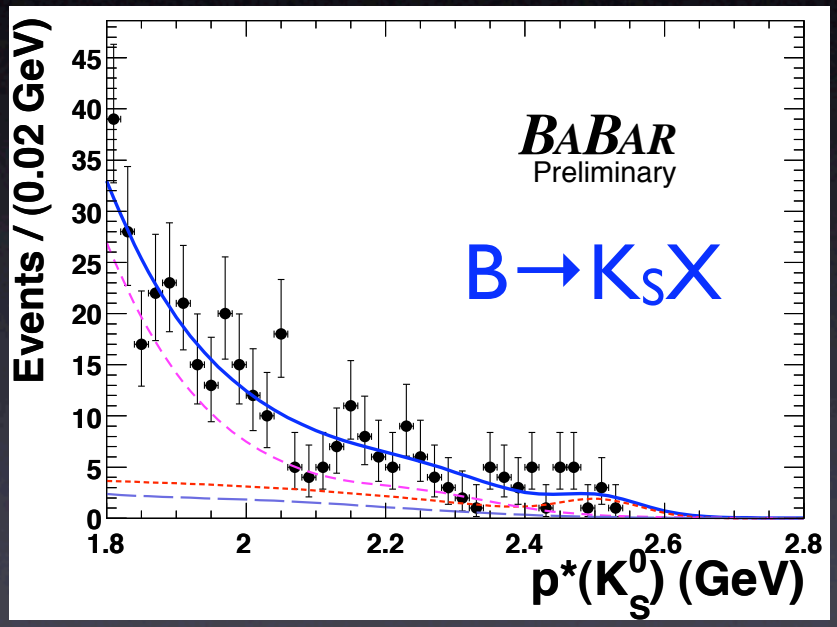
- MC data
- Equivalent luminosity: ~1.1ab^{-1}
- qq continuum rejected with cut on m_{ES} and Fisher discriminant
- Main experimental difficulty: understand b→c $p^*(K)$ spectrum



B→KX: 2-step ML Fit

1. ML Fit 1: fit p*(K)>1.8GeV to determine p*(K) spectrum for b→c background

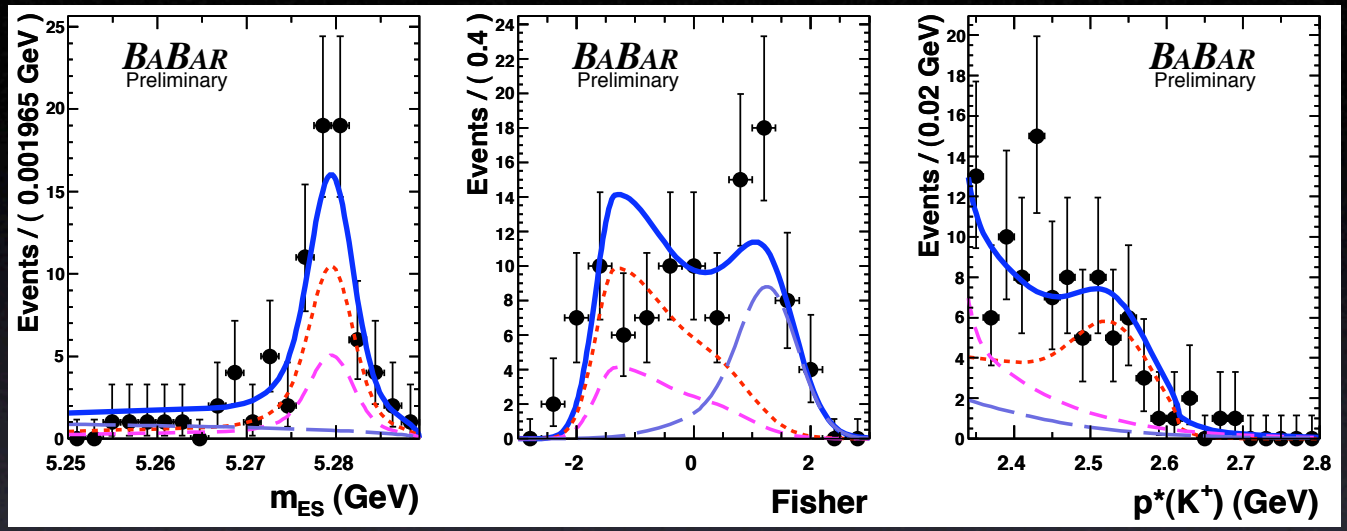




2. ML Fit 2: fit signal range 2.34<p*(K)<2.8GeV
   - Fix b→c yield and shape to results of Fit 1

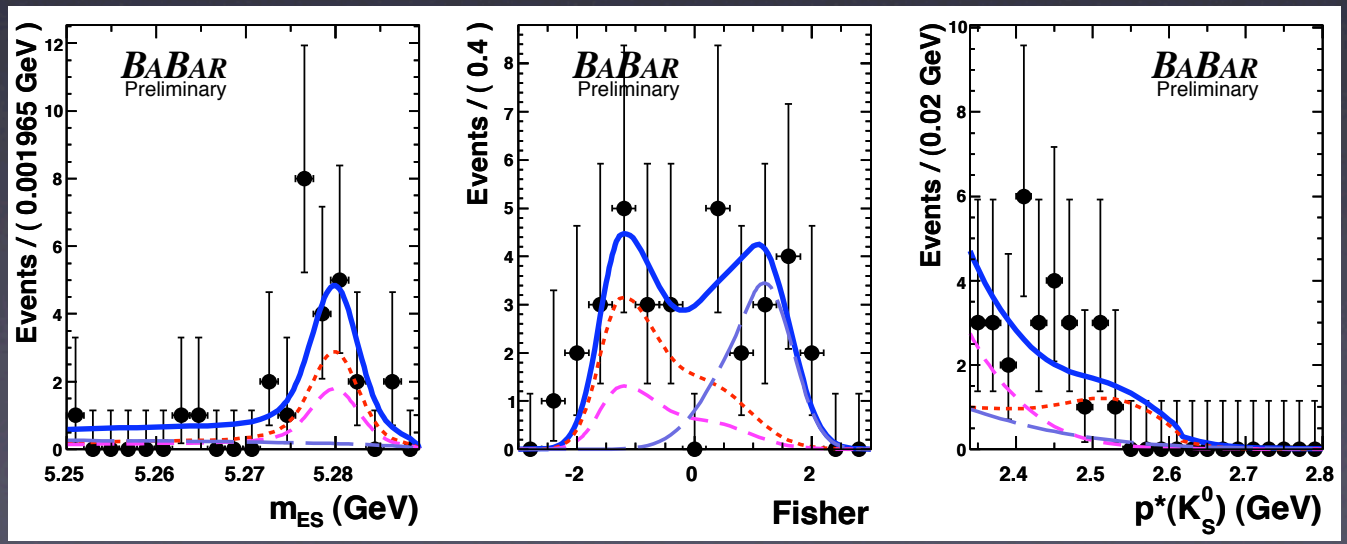
B→KX: Fit Results

- B→K^+X
  - 58±10 signals



Projection plots made with cut on signal likelihood, retaining ~85% (75%) of the B→K^+X (B→K_SX) signal

- B→K^0_SX
  - 21±6 signals



B→KX signal
b→c background
udsc continuum
signal + backgrounds

$B \to KX$: Crosschecks and Systematic uncertainties

- Crosschecks:
  - Bias due to fit procedure tested on simulated data. Fit bias used as correction to fit result.
  - Data/MC agreement checked with inclusive $B \to \pi X$ control sample
- Systematics:

Source	$B \to K^+X$	$B \to K^0X$
Reconstruction efficiency (MC) Tracking efficiency $K_S \to \pi^+\pi^-$ reconstruction efficiency K^+ particle identification B_{reco} counting	9.4% 0.5% -- 2.4% 5.0%	16.1% 1.0% 2.1% -- 5.0%
Total multiplicative errors	10.9%	17.0%
Fixed $b \to c$ yield PDF parametrization Fit bias correction	$^{+6.0}_{-5.6}$ events $^{+2.6}_{-2.4}$ events 1.2 events	$^{+4.1}_{-3.5}$ events $^{+3.9}_{-0.8}$ events 1.4 events
Total additive errors	$^{+6.6}_{-6.2}$ events	$^{+5.8}_{-3.9}$ events
Total systematic error on Branching Fraction	$(^{+31}_{-30}) \times 10^{-6}$	$(^{+55}_{-41}) \times 10^{-6}$

$B \to KX$: Partial BF ($p^*(K)>2.34$GeV)

Mode	Signal yield	Efficiency	Partial BF [10^{-6}]	significance
$B \to K^+X$	$58.4^{+10.5}_{-9.7}$	16.1%	$196^{+37\ +31}_{-34\ -30}$	6.0σ
$B \to K^0X$	$21.1^{+6.5}_{-5.7}$	6.7%	$154^{+55\ +55}_{-48\ -41}$ (<266)	3.1σ

BABAR PRELIMINARY

Remarks:

- yield normalized to number of B_{reco} determined from a fit to m_{ES} and Fisher: $N(B_{reco}) = (1.78\pm0.09)\times10^6$
- "B-recoil" method is efficient for $B \to K^+X$ (and $B \to K^0X$)
  - Larger integrated luminosity will be needed to apply this method to inclusive B decays to resonances

$B \to KX$: Interpretation

- Known charmless 2-body decays account for ~60% of partial branching fractions ($p^* > 2.34$GeV)
  - dominated by $B^+ \to \eta' K^+$ and $B^0 \to \eta' K^0$
- Extrapolation to full p^* range:
  - Theoretically uncertain:
    - spectrum at high p^* expected similar to that of $b \to s\gamma$
    - ...but non-perturbative QCD effects at low energy are uncertain
  - May have to rely on JETSET to make statement on $\mathcal{B}(b \to sg^*)$
- Sensitive to charming penguins [Soni and Zupan, hep-ph/0510325]

Conclusion

Presented (semi-)inclusive measurements of B decays including kaons:

1. First observation of $B^+ \to K^{*+}K^+K^-$ and $B^+ \to K^{*+}\pi^+\pi^-$
   - $K^*h^+h^-$ results published in Phys.Rev. D74, 051104 (2006)
2. $B \to KX$ branching fractions are compatible with SM expectations
   - preliminary result: hep-ex/0607053