Charmless B decays

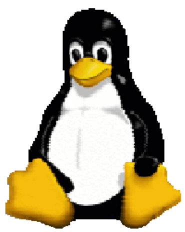
at BaBar and Belle

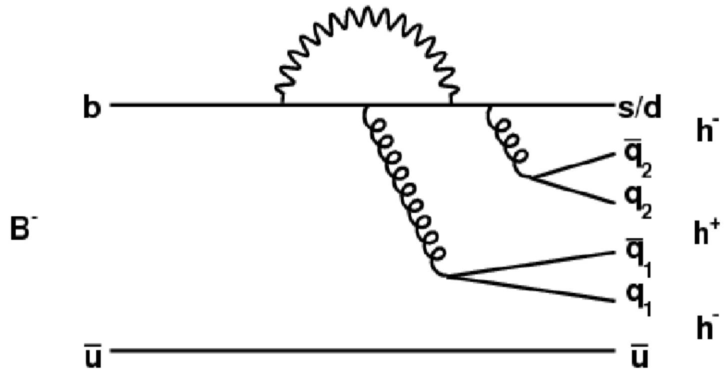
Simon Sitt (LPNHE Paris)
on behalf of the BaBar collaboration

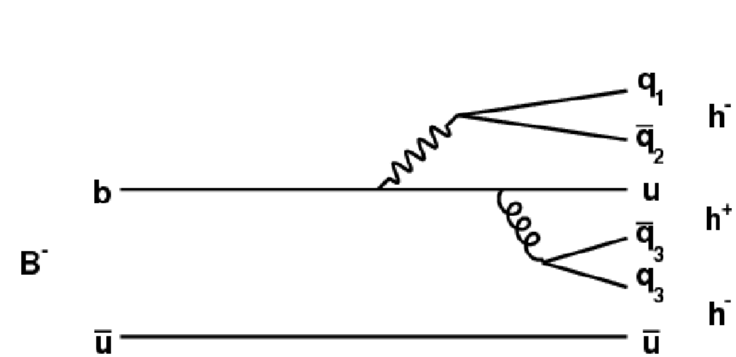
Overview

- Introduction
- Charmless hadronic 2-body and quasi-2-body decays
  - $B^0 \to K^+\pi^- \; K^{-/+}\pi^{+/-}$ and $B^0 \to \pi^+\pi^- \; K^+\pi^-$
  - Inclusive $B \to X_s \eta$ and $B \to \eta'\rho, \eta' f_0, \eta' K^*$
- Charmless hadronic 3-body decays
  - $B^0 \to K_s^0 K^{+/-}\pi^{+/-}$, $B^+ \to K^+\pi^0\pi^0$ and $B^0 \to 3K_s^0$
- Summary and conclusions

Why charmless B decays?







- Contributions from tree and penguin diagrams that could have contributions from new physics particles in the loop (heavy=enhanced)
- Can search for signs of new physics such as enhanced branching fractions, anomalous CP asymmetries or polarizations.
- Time-dependent measurements and interferences between intermediate states can allow measurements of all three CKM angles
- Informations on the nature of light hadron intermediate resonances

Recent results in hadronic charmless (quasi-) 2-body B decays

$B \to h^+\pi^- K^{-/+}\pi^{+/-}$ decays

657M $B\bar{B}$

$B^0 \to K^+\pi^- K^{-/+}\pi^{+/-}$

PRD 81 071101(R) (2010)

$B^0 \to \pi^+\pi^- K^+\pi^-$

PRD 80 051103(R) (2009)

Motivation:

- Contribution of electroweak and gluonic penguins.
- Provide information to help explain the unexpected low longitudinal polarization measured in the **B→VV** decay **B→ΦK*** (measured f_L**~0.5**, expected f_L**~1)**.

Angular analysis: is **form factor** at the origin of the unexpected low longitudinal polarization?

Non resonant $\pi^+\pi^-K^+\pi^-$ is a background to **resonant VV production**, with possibly different properties.

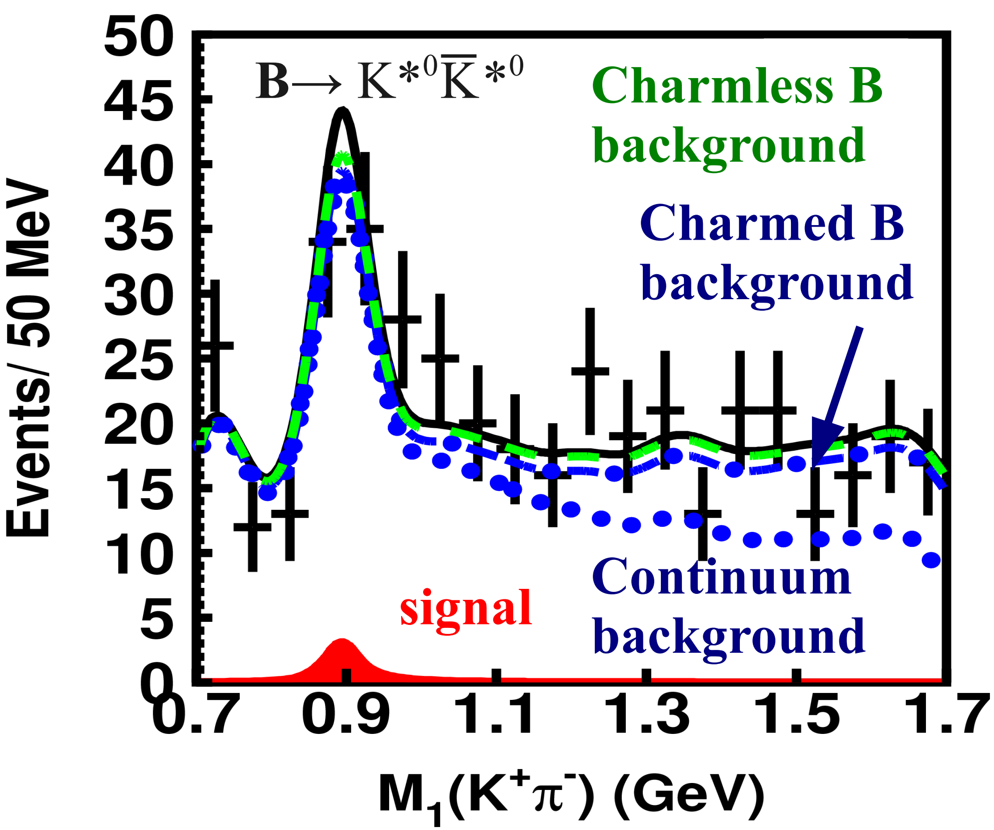
- **B→ $K^{*0}\bar{K}^{*0}$** : constraints on **α** and γ through BF measurement.
- **B→ $K^{*0}K^{*0}$** : BF could be enhanced via intermediate heavy bosons.

- **B→ $K^+\pi^-$** and **B→$K^+\pi^0$** : direct CPV inconsistent with naïve SM expectations.
- Insight could come from VV final states with same quark content (as **B→ρK***), differences would be mainly hadronic.

$B^0 \to K^+\pi^- K^{-/+}\pi^{+/-}$

Reconstruction and selection:
Vetos for **$B \to D^{*+/-}X$, $B^0 \to D_s^{+/-}X$, $B^0 \to D^0X$ and $B^0 \to \Phi X$.** Likelihood separation between **K** and **π**. Continuum suppression.

Likelihood: **M_{bc}, ΔE, $M_1(K^+\pi^-)$** vs **$M_2(K^-\pi^+)$**
or **$M_1(K^+\pi^-)$** vs **$M_2(K^+\pi^-)$**



Result (other modes see backup)

Mode	$B^0 \to K^{*0}\overline{K}^{*0}$	$B^0 \to K^{*0}K^{*0}$
Yield	$7.7^{+9.7+2.8}_{-8.5-2.2}$	$-3.7 \pm 3.3^{+2.5}_{-2.7}$
ϵ [%]	4.43 ($f_L = 1.0$)	5.74 ($f_L = 1.0$)
S[σ]	0.9	-
B[10^{-6}]	$0.26^{+0.33+0.20}_{-0.29-0.08}$	-
UL B[10^{-6}]	< 0.8	< 0.2

No significant signal

Comparison with BaBar (PRL 100, 081801 (2008), ~380 M BBbar):

2.2 σ discrepancy: $BF(B^0 \to K^{*0}\overline{K^{*0}}) = 1.28^{+0.35}_{-0.30} \pm 0.11$

Compatible upper limits: $BF(B^0 \to K^{*0}K^{*0}) < 0.41$

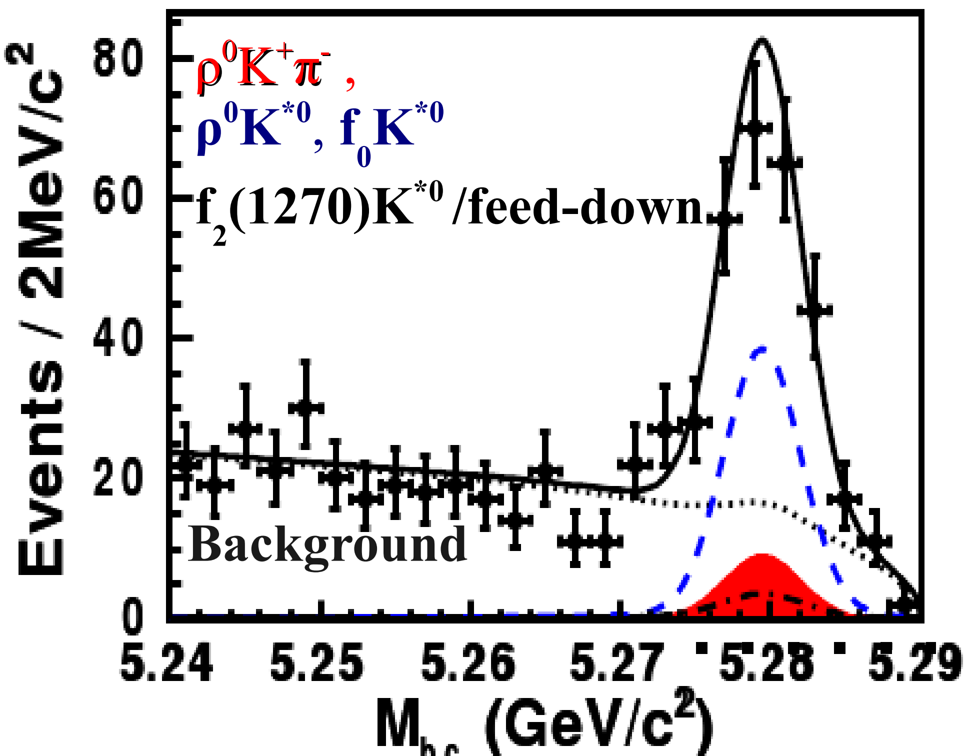
Both experiments are compatible with theoretical prediction:

Mode	$B^0 \to K^{*0}\overline{K}^{*0}$	$B^0 \to K^{*0}K^{*0}$
B	$0.17 - 0.92 \times 10^{-6}$	$2.9 \pm 0.2 \times 10^{-9}$
f_L	$0.69 \pm 0.01^{+0.16}_{-0.20}$	-

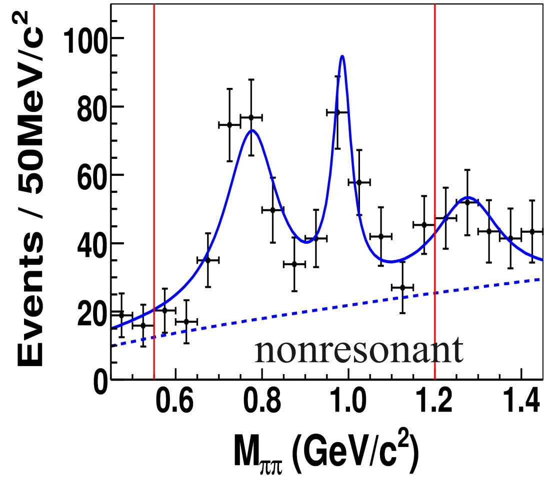
$B^0 \to \pi^+\pi^- K^+\pi^-$

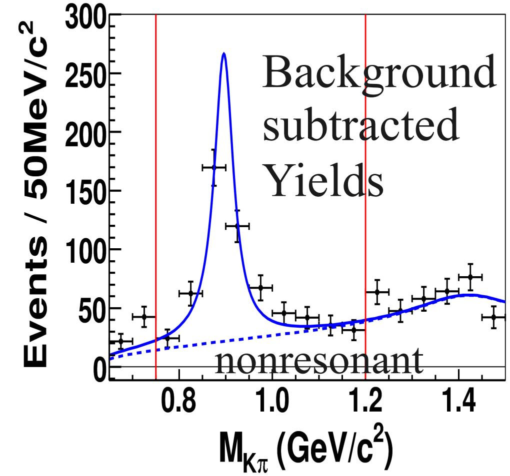
Reconstruction:
Veto for $\mathbf{D^{*+} \to K^-\pi^+\pi^-}$, $\mathbf{D^0 \to K^-\pi^+}$, $\mathbf{D^0 \to \pi^+\pi^-}$.
Likelihood separation between **K** and **π**.
Continuum suppression.

Likelihood: M_{bc}, ΔE, $M_{\pi\pi}$, and $M_{K\pi}$:



Background:**Continuum,charmed B, charmless B**





Mode	Y (events)	ε (%)	$\mathcal{S}$ (σ)	$\mathcal{B}$ (10^{-6})	$\mathcal{B}_{UL}$ (10^{-6})
$\rho^0 K^{*0}$	$77.6^{+28.6}_{-27.9}$	5.73	2.7	$2.1^{+0.8+0.9}_{-0.7-0.5}$	< 3.4
$f_0(980)K^{*0}$	$51.2^{+20.4}_{-19.3}$	5.56	2.5	$1.4^{+0.6+0.6}_{-0.5-0.4}$	< 2.2
$\rho^0 K^+\pi^-$	$207.8^{+39.8}_{-39.2}$	11.15	5.0	$2.8 \pm 0.5 \pm 0.5$	-
$f_0(980)K^+\pi^-$	$106.9^{+31.6}_{-29.9}$	11.43	3.5	$1.4 \pm 0.4^{+0.3}_{-0.4}$	< 2.1
$\pi^+\pi^- K^{*0}$	$200.7^{+46.7}_{-44.9}$	6.74	4.5	$4.5^{+1.1+0.9}_{-1.0-1.6}$	-
$\pi^+\pi^- K^+\pi^-$	$-5.4^{+54.9}_{-44.9}$	6.84	0.0	$-0.1^{+1.2+1.4}_{-1.1-0.8}$	< 2.1

First observation ($\rho^0 K^+\pi^-$)

Evidence ($f_0(980)K^+\pi^-$, $\pi^+\pi^- K^{*0}$)

First measurements of non resonant, may help understanding polarization puzzle in VV decays.

Babar : BF ($B^0 \to \rho^0 K^{*0}$) =(5.6 +/- 0.9 +/- 1.3)x10^{-6}

657M $B\bar{B}$

$B \to \eta^{(\prime)} X$ decays

467M $B\bar{B}$

Inclusive $B \to X_s \eta$

arXiv:0910.4751

$B \to \eta'\rho, \eta' f_0, \eta' K^*$

arXiv:1004.0240

Motivation:
Charmless B decays that involve η and η' exhibit unique properties due to mixing between underlying pseudoscalar octet and singlet components.

- Mixing effects are relatively well undertstood in exclusive **$B \to K^{(*)}\eta^{(\prime)}$**, the picture is less clear in **$B \to X_s \eta$** (X_s=inclusive state of unit strangeness).

- CLEO and Babar have found larger than expected BF with a **rise at high X_s mass** in **$X_s\eta'$** . Explanation: charming penguins?

- **$B \to X_s \eta$** could clarify the situation, as couplings with the singlet η_0 should be small in the mode with η, contrarily to η'.

- Belle and Babar have searched for these modes using 232 M and 535 M $B\bar{B}$. While **Babar** measured a **significant $B \to \eta' K^*$** and found **evidence for $B \to \eta' \rho^+$**, **Belle** reported upper limits that are in **poor agreement** with the **Babar** measurement.

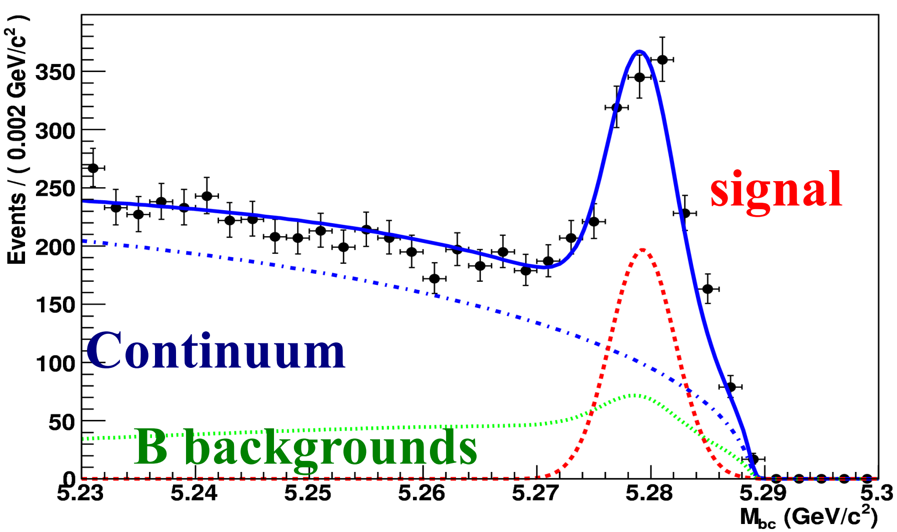
- Theoretical BF predictions:

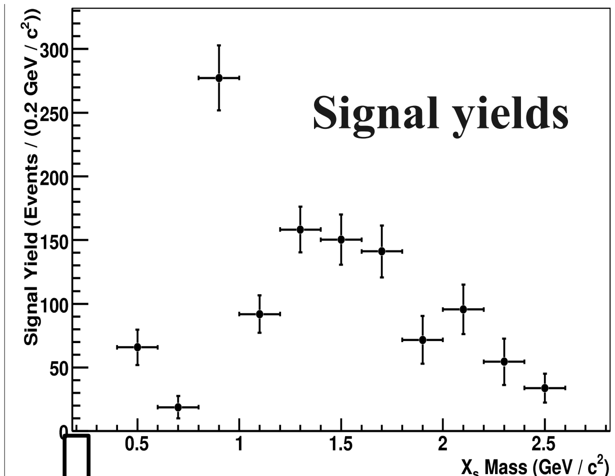
Mode	Model	BF
$B \to \eta' K^*$	various	few 10^{-6}
$B \to \eta' \rho^0$	various	$10^{-7} - 10^{-8}$
$B \to \eta' \rho^+$	pQCD/QCDF	$(6-9) \times 10^{-6}$
	SCET	0.4×10^{-6}

Inclusive $B \rightarrow X_s \eta$

Pseudo-inclusive method using 18 channels (+ charge conjugates, full list see backup) where $\mathbf{X_s}$ includes a charged or neutral kaon and $\boldsymbol{\eta}$ is reconstructed from pairs of photons with $\mathbf{E_\gamma > 200}$ **MeV**. Continuum supression using Fisher discriminant. Vetoes are applied to suppress decays involving charmed mesons and $\eta' \rightarrow \eta\pi^+\pi^-$.

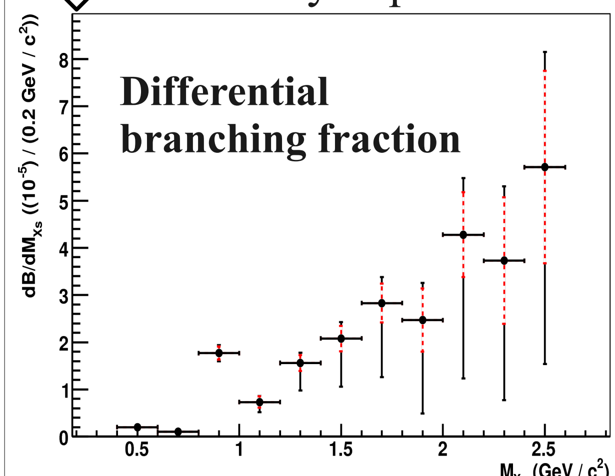
Likelihood: M_{bc}, 0.4<M(Xs)<2.6 GeV/c^2





Signal yields:
Fits to
200 MeV/c^2 bins of the X_s mass.

Efficiency depends on $M(X_s)$



stat error

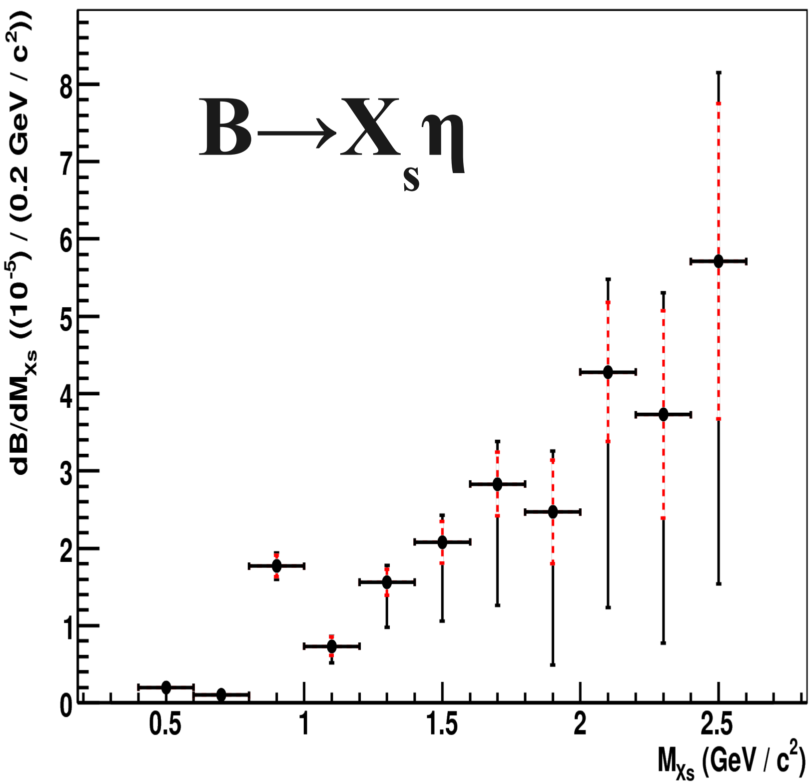
Systematic dominated by PYTHIA fragmentation.

$$BF = \left[25.5 \pm 2.7(stat) \pm 1.6(sys)^{+3.8}_{-14.1}(model)\right] \times 10^{-5}$$

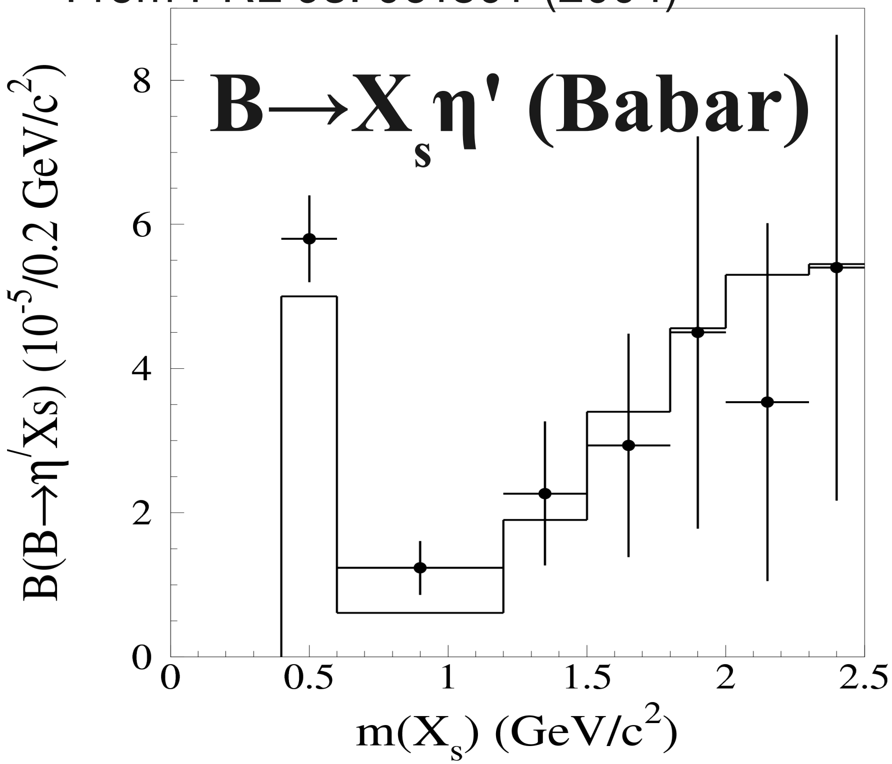
No theoretical prediction

Inclusive $B \to X_s \eta$

Spectral shape at high mass similar to $X_s \eta'$



From PRL 93. 061801 (2004)



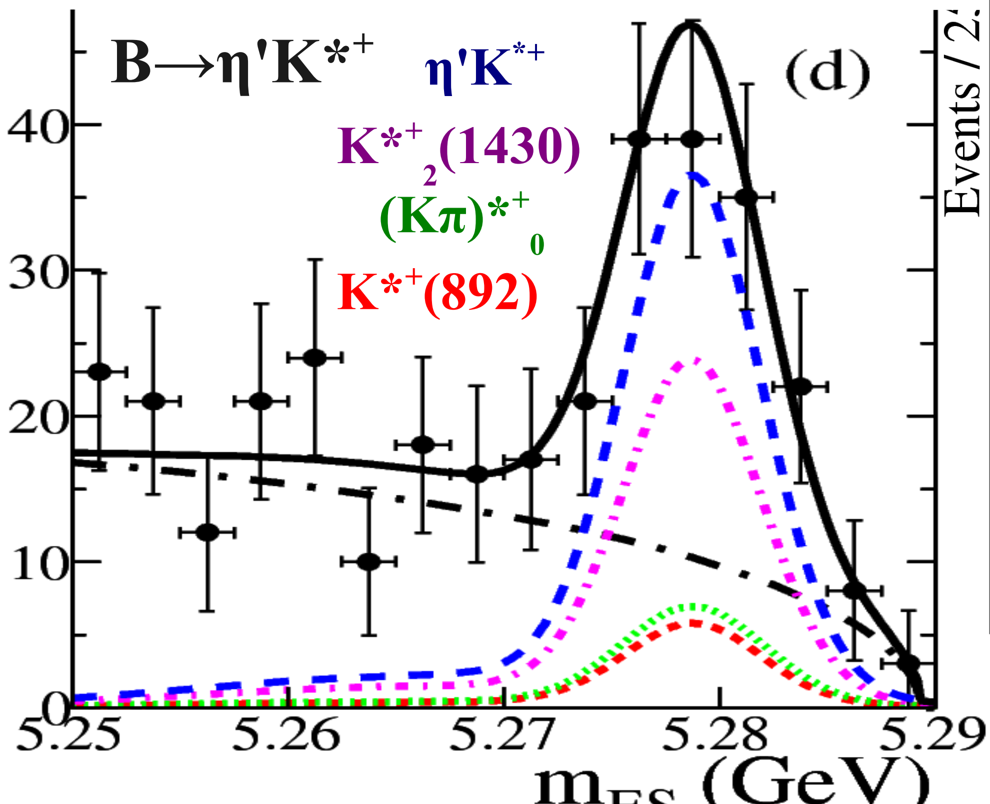
$$BF = [25.5 \pm 2.7(stat) \pm 1.6(sys)^{+3.8}_{-14.1}(model)] \times 10^{-5}$$

$$BF = [3.9 \pm 0.8(stat) \pm 0.5(sys) \pm 0.8(model)] \times 10^{-4}$$

No strong suppression wrt $\mathbf{B} \to X_s \eta'$.

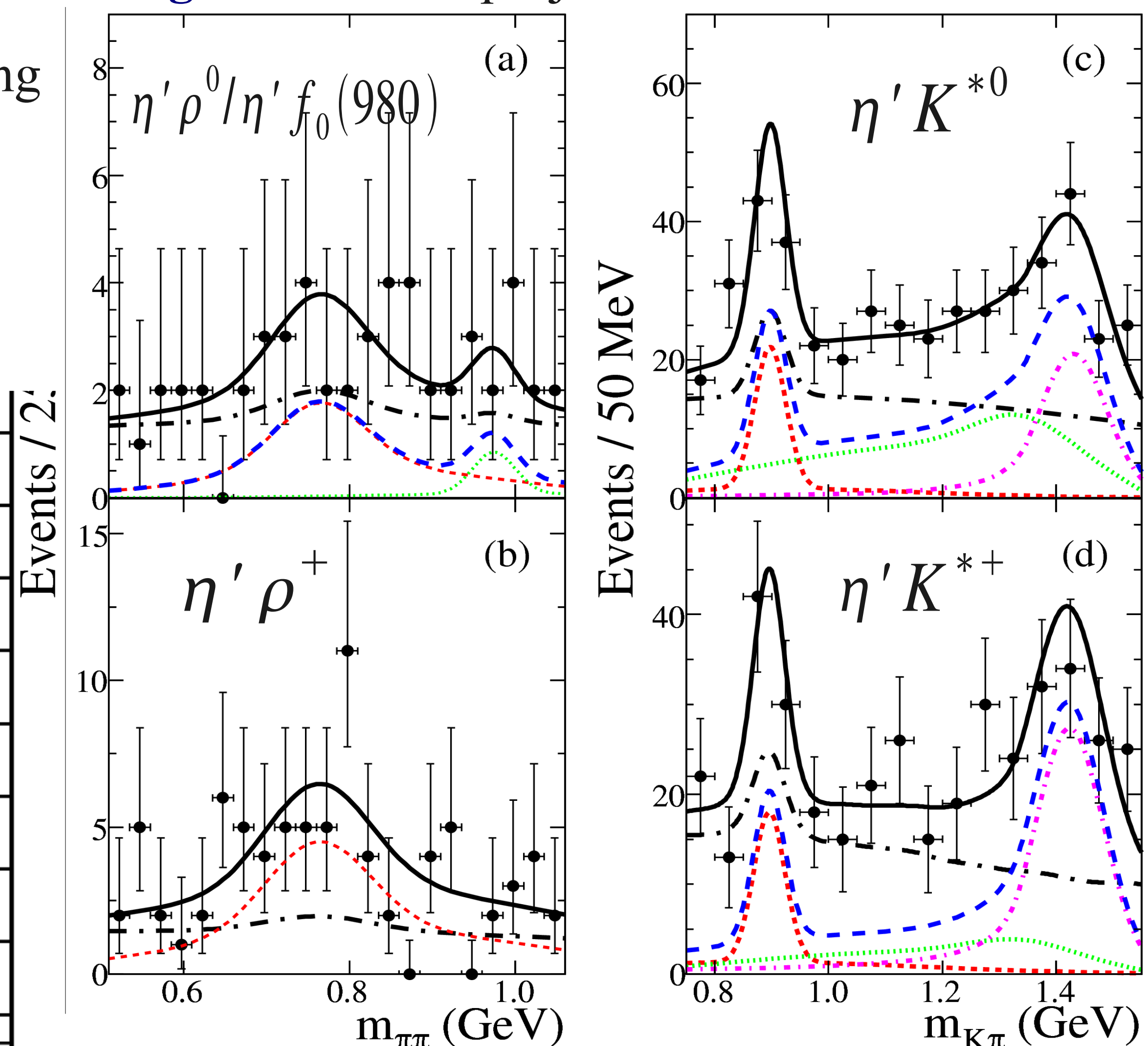
$B \to \eta'\rho, \eta' f_0, \eta' K^*$

Reconstruction from $\eta' \to \eta\pi^+\pi^-$ for all channels and from $\eta' \to \rho\gamma$ for $\eta' K^*$.
Continuum background suppression using angular distributions.
Likelihood: m_{ES}, ΔE, Fisher Discriminant, $M(\eta')$, $M(\rho/f_0/K^*)$ and helicity. Measure charge asymmetry.



Continuum and background from B decays

signal-enriched projections on invariant masses



BF measurements: four observations (next slide)

$B\to\eta'\rho, \eta' f_0, \eta' K^*$

BF measurements:

Mode	S	BF$[10^{-6}]$	UL$[10^{-6}]$	A_{ch}	BF Belle $[10^{-6}]$
$B\to\eta'\rho^0$	2.0	$1.5\pm0.8\pm0.3$	2.8	-	<3.1
$B\to\eta' f_0(980)$	0.5	$0.2^{+0.4}_{-0.3}\pm0.1$	0.9	-	-
$B\to\eta'\rho^+$	**5.8**	$9.7^{+1.9}_{-1.8}\pm1.1$	-	$0.26\pm0.17\pm0.02$	<5.8
$B\to\eta' K^{*0}$	4.0	$3.1^{+0.9}_{-0.8}\pm0.3$	4.4	$0.02\pm0.23\pm0.02$	<2.6
$B\to\eta' K^{*+}$	3.8	$4.8^{+1.6}_{-1.4}\pm0.8$	7.2	$-0.26\pm0.27\pm0.02$	<2.9
$B\to\eta'(K\pi)^{*0}_0$	**5.6**	$7.4^{+1.5}_{-1.4}\pm0.6$	-	$-0.19\pm0.17\pm0.02$	-
$B\to\eta'(K\pi)^{*+}_0$	2.9	$6.0^{+2.2}_{-2.0}\pm0.9$	9.3	$0.06\pm0.20\pm0.02$	-
$B\to\eta' K_2^*(1430)^0$	**5.3**	$13.7^{+3.0}_{-2.9}\pm1.2$	-	$0.14\pm0.18\pm0.02$	-
$B\to\eta' K_2^*(1430)^+$	**7.2**	$28.0^{+4.6}_{-4.3}\pm2.6$	-	$0.15\pm0.13\pm0.02$	-

Belle values:
arXiv:0701046

Unexpected **tensor enhancement.**

No significant direct CP asymmetry.

$B\to\eta'\rho^+$ favors pQCD and QCFD calculations

Remaining poor agreement with Belle.

Recent results in hadronic charmless 3-body B decays

$B \to Khh$ decays

467M $B\bar{B}$

$B^0 \to K_s^0 K^{+/-} \pi^{+/-}$

arXiv:1003.0640, submitted to PRD-RC

- Even number of Kaons. Contributions from **b→u trees** and **b→d penguins**.

- $B \to 2K_s^0$, $B \to K_s^0 K^+$ and the corresponding **B→VV** decays have been observed

- UL on the corresponding **B→PV** final state.

- A Dalitz plot (DP) analysis could help clarify the nature of the so-called **$f_X(1500)$** that was observed in $B^+ \to K^+ K^- \pi^+$ but not in $B^+ \to K_s^0 K_s^0 \pi^+$.

$B^+ \to K^+ \pi^0 \pi^0$

PRELIMINARY

arXiv:1005.3717

- The $B \to K^{*+} \pi^0$ has the largest experimental uncertainty in $B \to K^* \pi$ decays.

- **B→PV** decay to help understand decay rate and CPV measurements in related $B \to K\pi$.

- Information on the content of the **DP** could provide information on $B^+ \to K_s^0 \pi^0 \pi^0$ that shows deviation on the S parameter from SM prediction.

$B^0 \to 3K_s^0$

PRELIMINARY

- Golden channel for NP search in TDCPV (**pure penguin**)

- TD Measurement without DP analysis (CP definite). No reason why different Q2B parameters should be the same. Amplitude analysis to investigate resonant structure.

- Only **even-spin** resonances are permitted.

⇨ information on **$f_X(1500)$.**

Observation of the rare decay $B^0 \to K_s^0 K^{+/-} \pi^{+/-}$

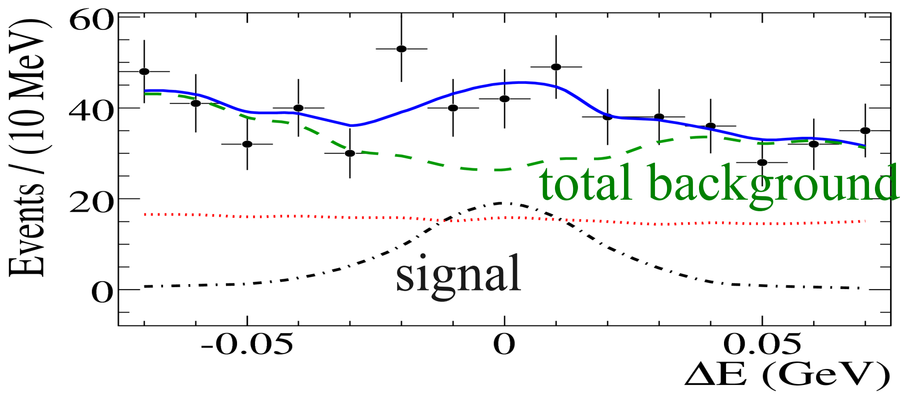
arXiv:1003.0640

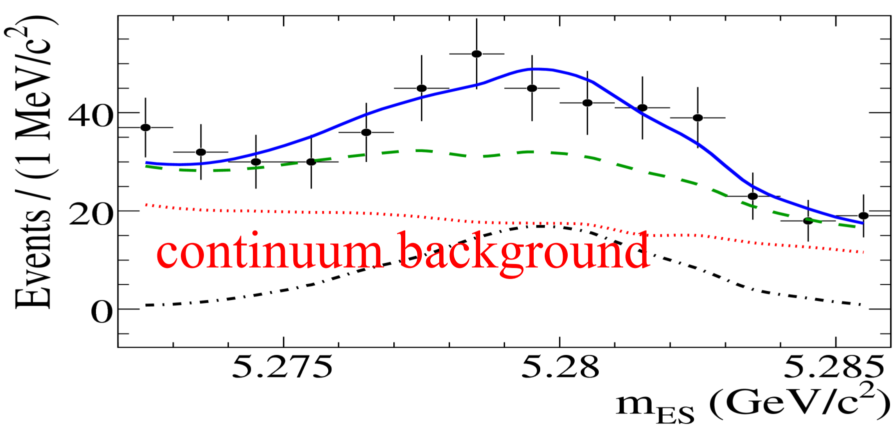
Reconstruction and selection

- K_s^0 from charged pions. Vetos for D^+, D_s^+, D^0, J/Ψ, $\Psi(2S)$ mesons.

Likelihood: m_{ES}, ΔE and Fisher discriminant

Projections:

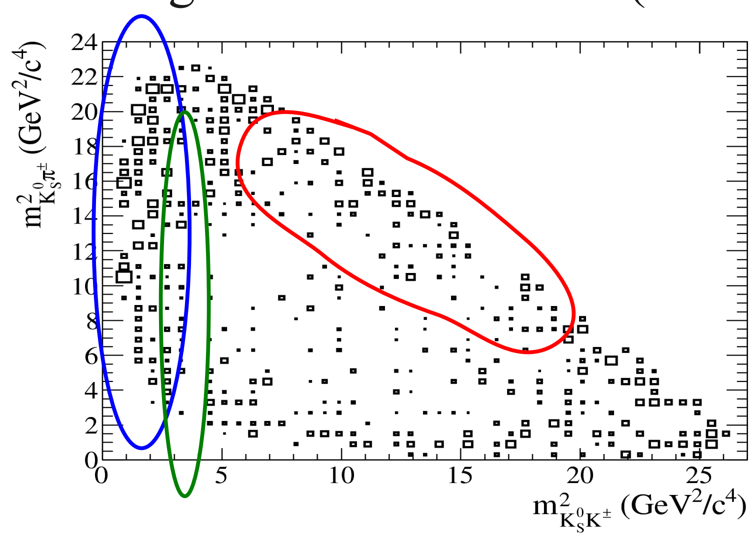




Results (5.2 σ observation)

$$BF(B^0 \to K_s^0 K^{\pm} \pi^{\mp}) = (3.2 \pm 0.5 \pm 0.3) \times 10^{-6}$$

Use $_s$*Plots* technique to obtain efficiency-corrected signal DP distribution (262+-47 evts)



Qualitative statements:

- Structure in K^{*0} region at low $K\pi$ mass
- Excess with asymmetric helicity angle distribution at low $K_s^0 K$ mass.
- No major contribution from isospin partner of $f_X(1500)$ decaying to $K_s^0 K$.

Observation of the rare decay $B^+ \rightarrow K^+\pi^0\pi^0$

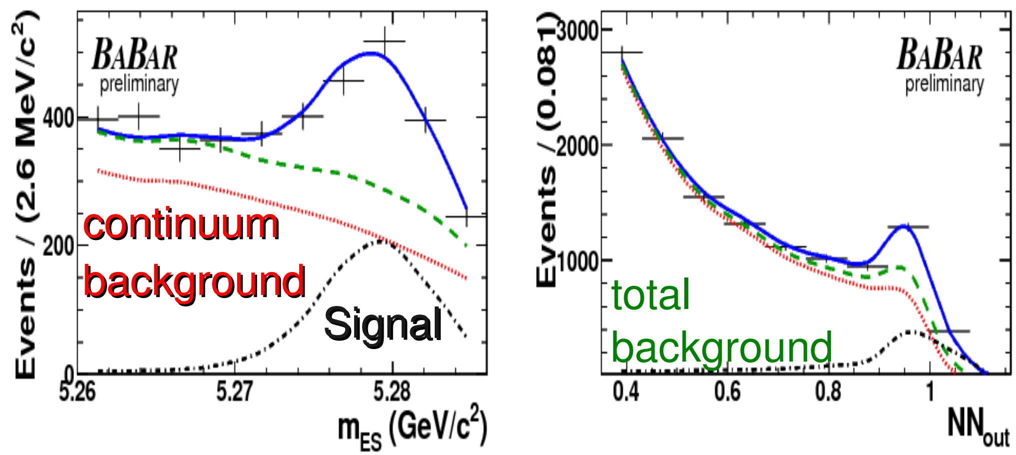
ArXiv:1005.3717, PRELIMINARY

Reconstruction:
π^0 from photons with E_γ > 50 MeV. Veto for $B^+ \rightarrow K_s^0(\pi^0\pi^0)K^+$.

Likelihood:
m_{ES} and a NN. No use of ΔE as is depends on the signal DP distribution that is unknown

The fraction of misreconstructed signal events (SCF) f_{SCF} **depends on the signal population** of the **DP**. An iterative approach is used: Starting from an initial value for f_{SCF} the sPlot technique is used to obtain the signal DP that is used to calculate a new average f_{SCF}. This procedure is repeated, until f_{SCF} converges.

Result: Convergence after 4 iterations with f_{SCF}=9.7%. Signal yield: 1220 +- 85



First 3-body measurement (>10 σ)

$$BF(B^+ \rightarrow K^+\pi^0\pi^0) = (15.5 \pm 1.1 \pm 1.6) \times 10^{-6}$$

Largest systematics from PDF uncertainties and π^0 reconstruction efficiency

First step towards understanding the DP structure

Amplitude analysis of $B^0 \rightarrow 3K_s^0$

PRELIMINARY

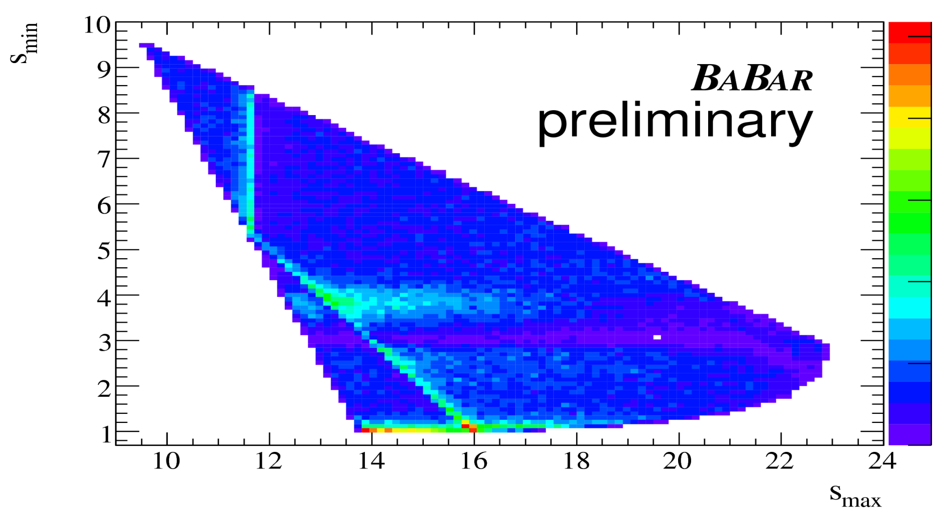
Reconstruction:

3 $K_s^0(\pi^+\pi^-)$, **S/B~2**, negligible background from B decays

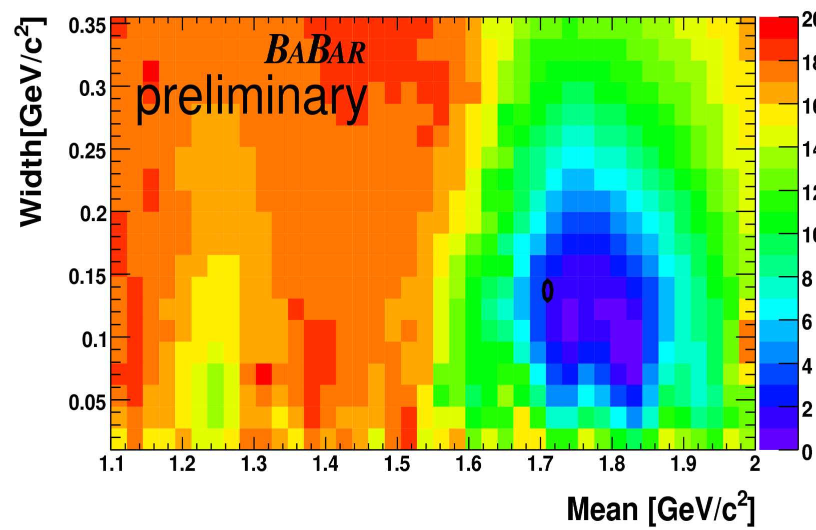
Likelihood: m_{ES}, ΔE, NN and describe decay amplitude

$$\begin{aligned} \mathcal{A}[B^0 \rightarrow K_s^0(p_1)K_s^0(p_2)K_s^0(p_3)] &= \frac{1}{2}^{3/2}\{\mathcal{A}_1[B^0 \rightarrow \overline{K}^0(p_1)K^0(p_2)K^0(p_3)] \\ &+ \mathcal{A}_2[B^0 \rightarrow \overline{K}^0(p_2)K^0(p_3)K^0(p_1)] \\ &+ \mathcal{A}_3[B^0 \rightarrow \overline{K}^0(p_3)K^0(p_1)K^0(p_2)]\}. \end{aligned}$$

using isobar model. Symmetrize amplitude of 3 identical particles by looking at the minimum and the maximum of the invariant masses. Population of one **sixth** of the DP:



First measurement: Find possible resonant contributions by the means of likelihood scans for additional resonances to baseline model (f_0, χ_{c0} ,non resonant).



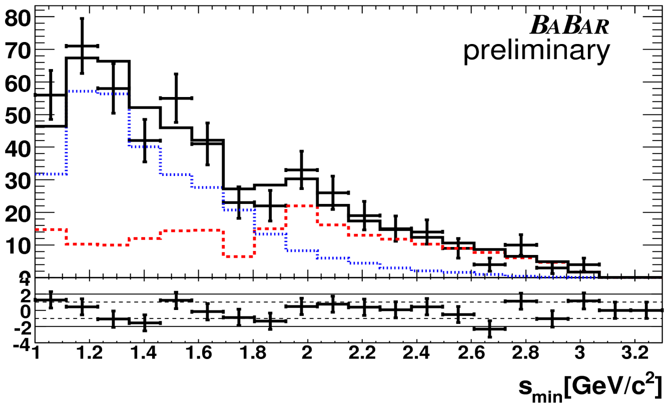
Scan for additonal scalar resonance shows contri-bution from $\mathbf{f_0(1710)}$

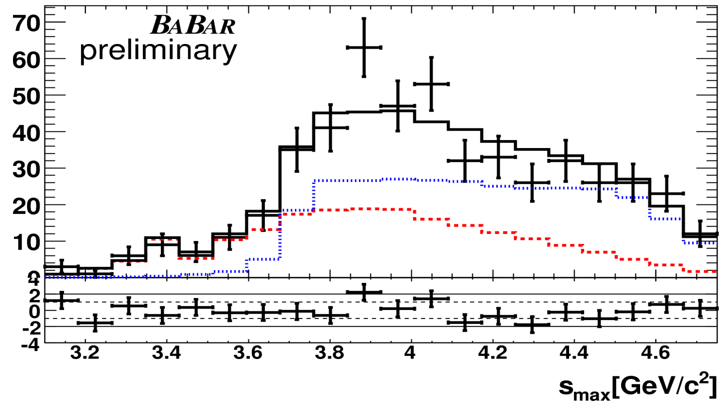
We find contributions from $\mathbf{f_0(980)}$, χ_{c0}, $\mathbf{f_0(1710)}$, $\mathbf{f_2(2010)}$ **and non resonant** (mass and width taken from PDG).

Amplitude analysis of $B^0 \rightarrow 3K_s^0$

PRELIMINARY

Projections on invariant masses





signal

Continuum background

Measure (product) BF of 1st solution (2nd solution is separated by almost 2σ, see backup)

Mode	$\mathcal{B}(B^0 \rightarrow Mode)[10^{-6}]$
Inclusive $B^0 \rightarrow K_S^0 K_S^0 K_S^0$	$6.18 \pm 0.47 \pm 0.14 \pm 0.06$
$f_0(980) K_S^0$, $f_0(980) \rightarrow K_S^0 K_S^0$	$2.69^{+1.24}_{-1.18} \pm 0.36 \pm 1.87$
$f_0(1710) K_S^0$, $f_0(1710) \rightarrow K_S^0 K_S^0$	$0.50^{+0.46}_{-0.23} \pm 0.04 \pm 0.13$
$f_2(2010) K_S^0$, $f_2(2010) \rightarrow K_S^0 K_S^0$	$0.54^{+0.21}_{-0.20} \pm 0.03 \pm 0.44$
NR	$13.31^{+2.23}_{-2.30} \pm 0.55 \pm 2.77$
$\chi_{c0} K_S^0$, $\chi_{c0} \rightarrow K_S^0 K_S^0$	$0.46^{+0.25}_{-0.16} \pm 0.01 \pm 0.19$

Model uncertainty is dominated by poorly measured $f_2(2010)$.

Reminder TD measurement (preliminary):

$$S = -0.90^{+0.20}_{-0.18}(stat)^{+0.04}_{-0.03}(sys)$$

$$C = -0.16 \pm 0.17(stat) \pm 0.03(sys)$$

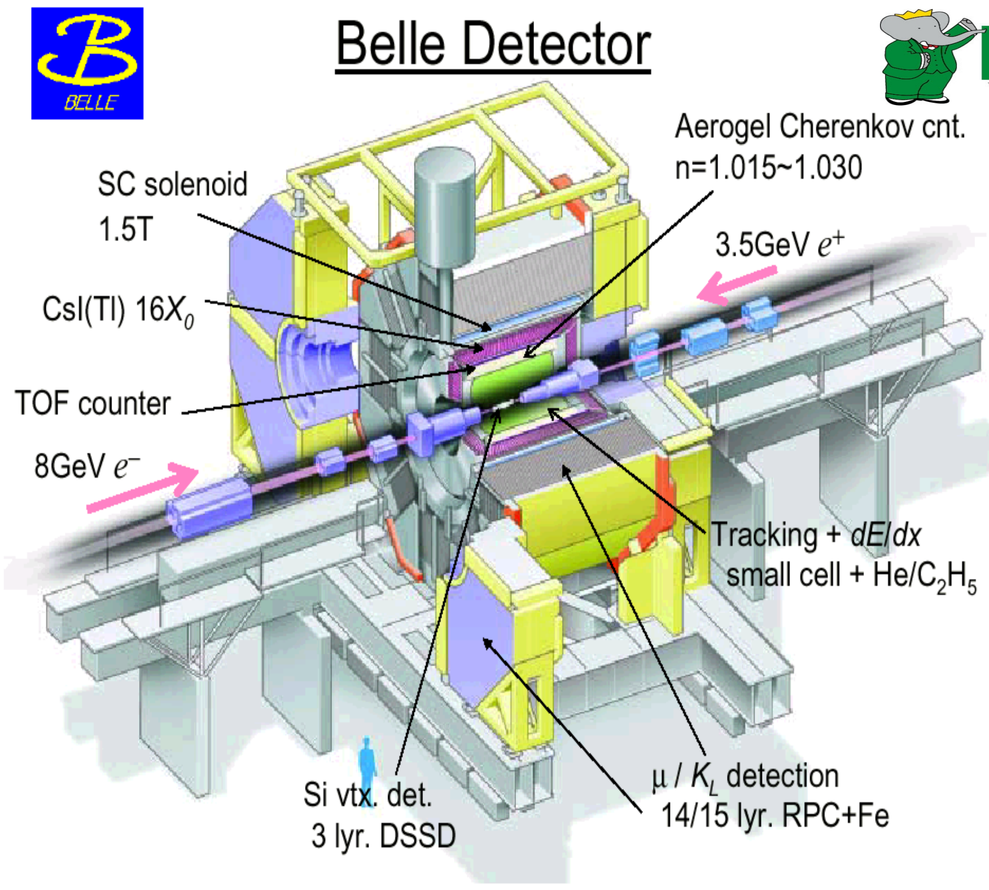
First measurement. No sign of scalar $\mathbf{f_X(1500)}$.

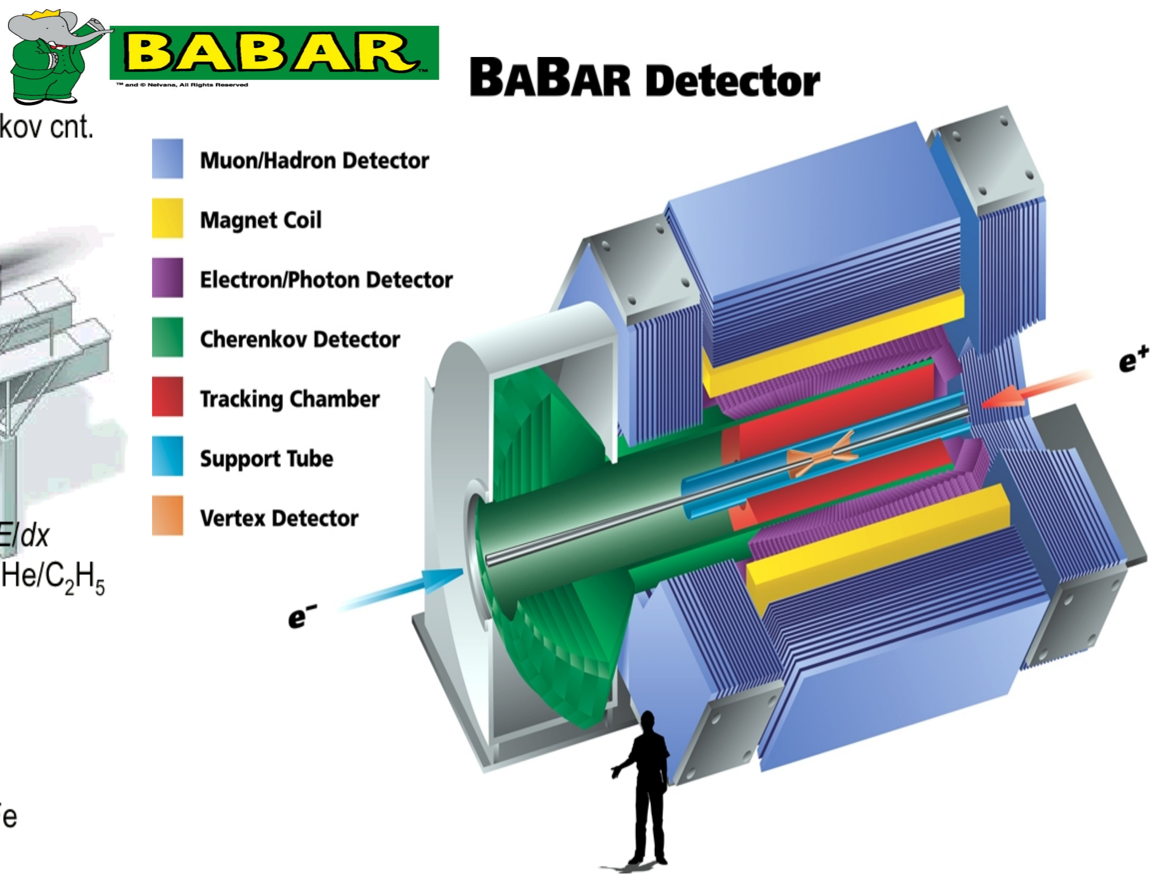
Summary and conclusions

- $B \to h^+\pi^- K^{-/+}\pi^{+/-}$ add information to polarization puzzle
- Some discrepancy between Babar and Belle in $B \to \eta^{(\prime)}X$
- 3-body decays help understand $f_X(1500)$
- Many rare decay are now accessible with data accumulated in B factories
- Many measurements are statistically limited and would benefit from next generation B factories

BACKUP

The BaBar and Belle experiments





$$\sim 770\times 10^6\, B\overline{B}$$

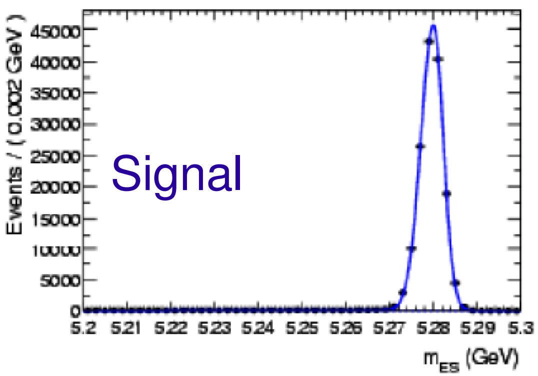
$$\sim 470\times 10^6\, B\overline{B}$$

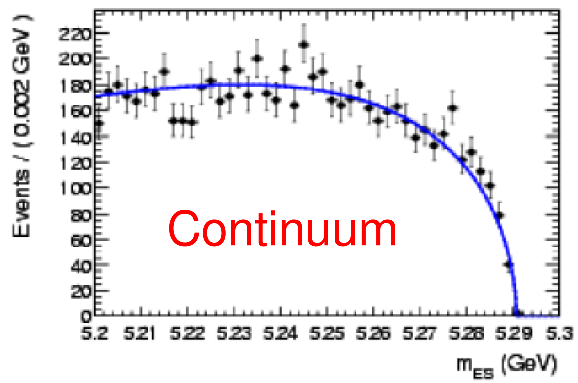
Analysis techniques

Discrimination between **signal** and **background** and/or fitting of **parameters of interest** using multi-dimensional extended maximum likelihood fits. Recurrent discriminating variable are

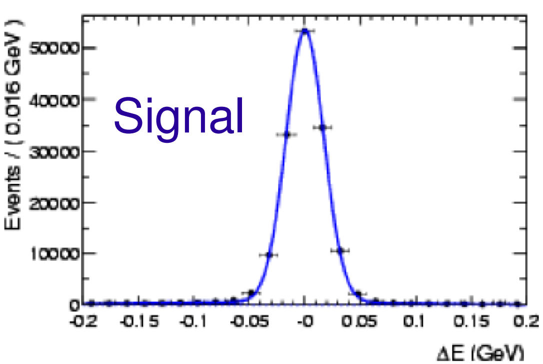
Kinematic variables

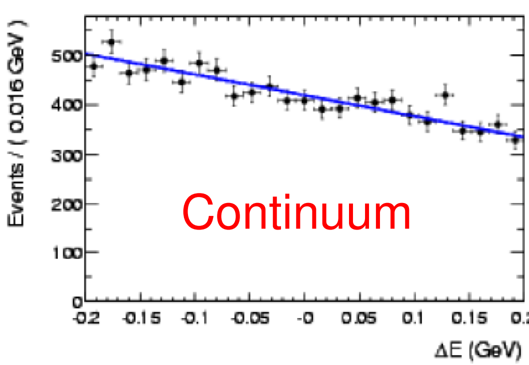
$$M_{bc} = m_{ES} = \sqrt{E_{beam}^2 - p_B^2}$$





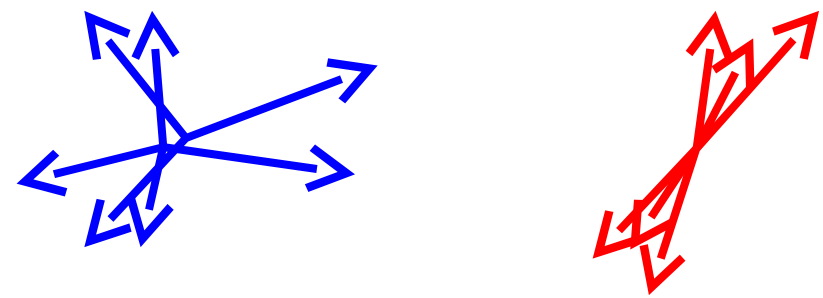
$$\Delta E = E_B - E_{beam}$$



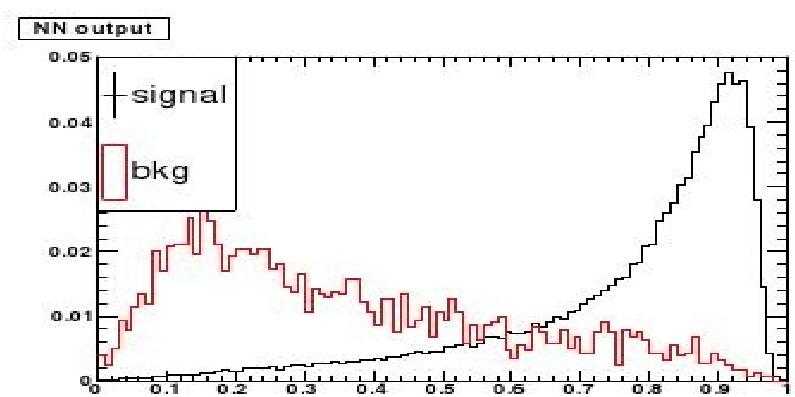


Events shape and other variables

Signal spherical Continuum jet-like



Combined to a Neural Network (NN) or Fisher Discriminant or used directly.



Search for $B^0 \to K^{*0}\ \overline{K}^{*0}$, $B^0 \to K^{*0}\ K^{*0}$ and $B^0 \to K^+\ \pi^-\ K^\mp\ \pi^\pm$

Mode	Fit bias	Yield	ε (%)	$\mathcal{S}$	$\mathcal{B} \times 10^6$	UL $\times 10^6$
$B^0 \to K^{*0}\overline{K}^{*0}$	1.5 ± 0.7	$7.7^{+9.7+2.8}_{-8.5-2.2}$	4.43 ($f_{\rm L} = 1.0$)	0.9	$0.26^{+0.33+0.10}_{-0.29-0.08}$	< 0.8
$B^0 \to K^{*0}K^-\pi^+$	-5.4 ± 2.9	$18.2^{+48.4+41.7}_{-45.3-40.9}$	1.31	0.3	$2.11^{+5.63+4.85}_{-5.26-4.75}$	< 13.9
$B^0 \to K_0^*(1430)\overline{K}_0^*(1430)$	2.1 ± 5.1	$78.5^{+70.6+56.4}_{-69.6-56.8}$	3.72	0.8	$3.21^{+2.89+2.31}_{-2.85-2.32}$	< 8.4
$B^0 \to K_0^*(1430)\overline{K}^{*0}$	13.3 ± 2.3	$19.6^{+31.1+40.0}_{-31.0-43.0}$	4.38	0.4	$0.68 \pm 1.08^{+1.39}_{-1.49}$	< 3.3
$B^0 \to K_0^*(1430)K^-\pi^+$	14.6 ± 9.8	$-222.8^{+171.5+159.8}_{-170.8-168.6}$	1.34	—	—	< 31.8
Nonresonant $B^0 \to K^+\pi^-K^-\pi^+$	-10.8 ± 7.3	$158.4^{+120.6+104.1}_{-117.8-105.0}$	0.82	1.0	$29.41^{+22.39+19.32}_{-21.87-19.49}$	< 71.7
$B^0 \to K^{*0}K^{*0}$	1.0 ± 0.5	$-3.7 \pm 3.3^{+2.5}_{-2.7}$	5.74 ($f_{\rm L} = 1.0$)	—	—	< 0.2
$B^0 \to K^{*0}K^+\pi^-$	-2.5 ± 2.7	$0.5 \pm 32.3^{+43.5}_{-40.1}$	1.93	0.0	$0.04 \pm 2.55^{+3.43}_{-3.16}$	< 7.6
$B^0 \to K_0^*(1430)K_0^*(1430)$	3.4 ± 1.3	$-28.4 \pm 16.1^{+87.7}_{-21.1}$	4.28	—	—	< 4.7
$B^0 \to K_0^*(1430)K^{*0}$	8.2 ± 1.6	$8.0 \pm 18.7^{+23.9}_{-30.3}$	5.14	0.3	$0.24 \pm 0.55^{+0.71}_{-0.90}$	< 1.7
Nonresonant $B^0 \to K^+\pi^-K^+\pi^-$	7.7 ± 2.2	$10.8 \pm 28.3^{+31.4}_{-101.5}$	1.98	0.3	$0.83 \pm 2.17^{+2.42}_{-7.80}$	< 6.0

Inclusive $B \to X_s \eta$

Reconstructed modes

$$B^+ \to K^+(\pi^0)\eta$$
$$B^+ \to K^0_S\pi^+(\pi^0)\eta$$
$$B^+ \to K^+\pi^+\pi^-(\pi^0)\eta$$
$$B^+ \to K^0_S\pi^+\pi^-\pi^+(\pi^0)\eta$$
$$B^+ \to K^+\pi^+\pi^-\pi^+\pi^-\eta$$

$$B^0 \to K^0_S(\pi^0)\eta$$
$$B^0 \to K^+\pi^-(\pi^0)\eta$$
$$B^0 \to K^0_S\pi^+\pi^-(\pi^0)\eta$$
$$B^0 \to K^+\pi^-\pi^+\pi^-(\pi^0)\eta$$
$$B^0 \to K^0_S\pi^+\pi^-\pi^+\pi^-\eta$$

$B \to \eta'\rho, \eta' f_0, \eta' K$

Babar detailed

*

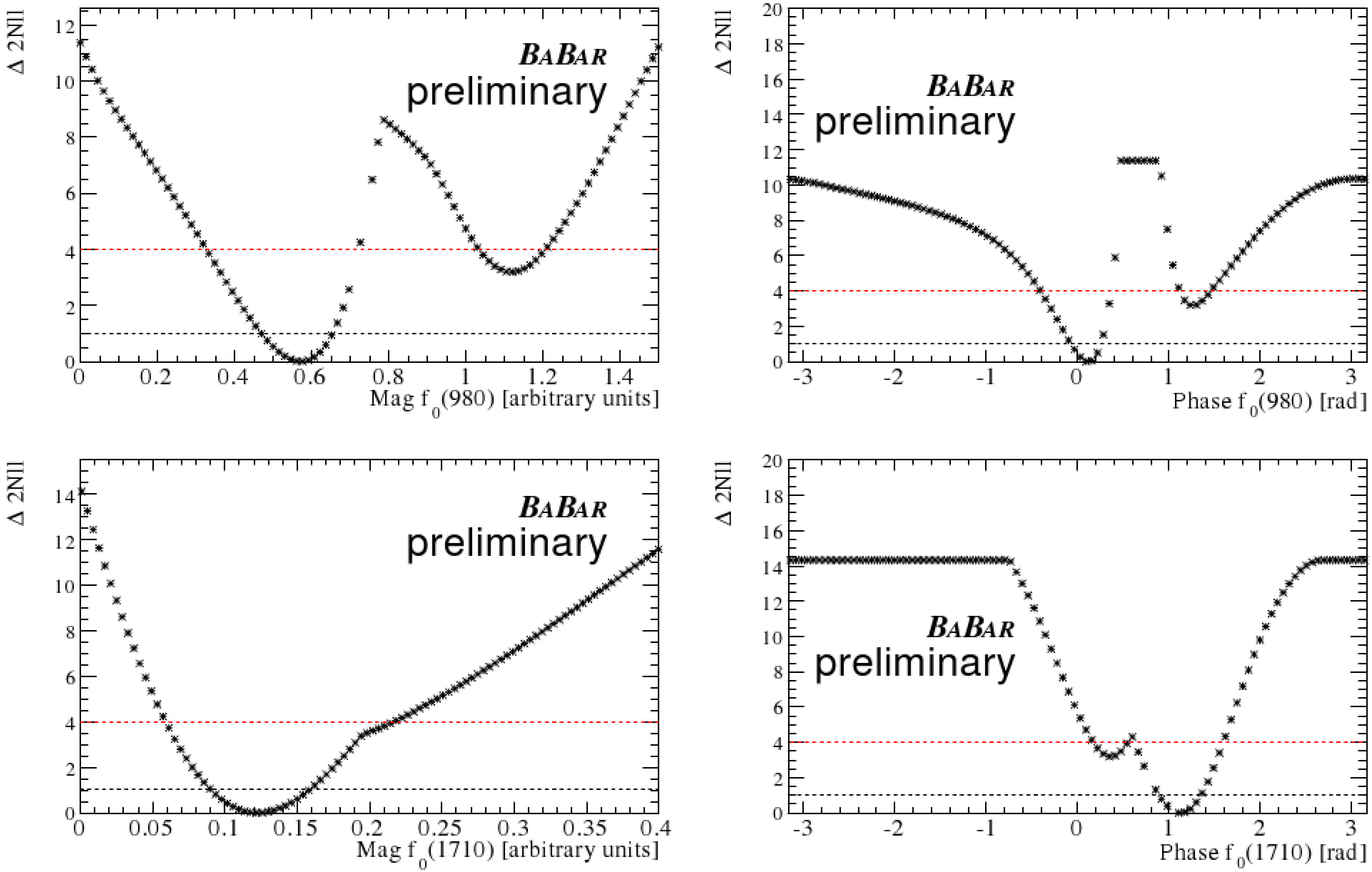
Mode	Y (events)	Y_0 (events)	ϵ (%)	$\prod \mathcal{B}_i$ (%)	S (σ)	$\mathcal{B}$ (10^{-6})	$\mathcal{B}$ U.L. (10^{-6})	$\mathcal{A}_{ch}$
$\eta'\rho^0$	37±15	9±5	23.4	17.5	2.0	$1.5 \pm 0.8 \pm 0.3$	2.8	—
$\eta' f_0$	8±8	4±2	25.9	17.5	0.5	$0.2^{+0.4}_{-0.3} \pm 0.1$	0.9	—
$\eta'\rho^+$	128±22	15±8	14.3	17.5	5.8	$9.7^{+1.9}_{-1.8} \pm 1.1$	—	$0.26 \pm 0.17 \pm 0.02$
$\eta' K^{*0}$					4.0	$3.1^{+0.9}_{-0.8} \pm 0.3$	4.4	$0.02 \pm 0.23 \pm 0.02$
$\eta'_{\eta\pi\pi} K^{*0}$	28±10	4±2	18.9	11.7	2.7	$2.4^{+1.1}_{-0.9} \pm 0.3$		-0.04 ± 0.35
$\eta'_{\rho\gamma} K^{*0}$	61±18	9±5	13.3	19.6	3.1	$4.3^{+1.6}_{-1.5} \pm 0.5$		0.06 ± 0.29
$\eta' K^{*+}$					3.8	$4.8^{+1.6}_{-1.4} \pm 0.8$	7.2	$-0.26 \pm 0.27 \pm 0.02$
$\eta'_{\eta\pi\pi} K^{*+}_{K^+\pi^0}$	14±8	2±1	11.5	5.8	2.0	$3.9^{+3.1}_{-2.1} \pm 0.5$		-1.00 ± 0.78
$\eta'_{\rho\gamma} K^{*+}_{K^+\pi^0}$	26±19	6±3	9.7	9.8	1.1	$4.7^{+4.5}_{-4.1} \pm 1.3$		0.05 ± 0.66
$\eta'_{\eta\pi\pi} K^{*+}_{K^0_S\pi^+}$	23±10	3±2	19.1	4.0	2.6	$5.5^{+2.9}_{-2.4} \pm 0.7$		-0.47 ± 0.37
$\eta'_{\rho\gamma} K^{*+}_{K^0_S\pi^+}$	34±15	10±5	16.2	6.8	1.6	$4.8^{+3.2}_{-2.8} \pm 1.2$		0.24 ± 0.44
$\eta'(K\pi)^{*0}_0$					5.6	$7.4^{+1.5}_{-1.4} \pm 0.6$	—	$-0.19 \pm 0.17 \pm 0.02$
$\eta'_{\eta\pi\pi}(K\pi)^{*0}_0$	106±21	12±6	20.2	11.7	4.9	$8.5^{+2.0}_{-1.9} \pm 1.0$		-0.39 ± 0.20
$\eta'_{\rho\gamma}(K\pi)^{*0}_0$	115±36	21±11	17.6	19.6	2.7	$5.8^{+2.3}_{-2.2} \pm 1.0$		0.32 ± 0.31
$\eta'(K\pi)^{*+}_0$					2.9	$6.0^{+2.2}_{-2.0} \pm 0.9$	9.3	$0.06 \pm 0.20 \pm 0.02$
$\eta'_{\eta\pi\pi}(K^+\pi^0)^{*+}_0$	36±15	2±1	13.9	5.8	2.4	$8.8^{+4.2}_{-3.8} \pm 1.3$		0.00 ± 0.41
$\eta'_{\rho\gamma}(K^+\pi^0)^{*+}_0$	185±51	31±15	12.8	9.8	2.8	$26.4^{+9.0}_{-8.5} \pm 5.9$		0.23 ± 0.27
$\eta'_{\eta\pi\pi}(K^0_S\pi^+)^{*+}_0$	18±12	1±1	18.6	4.0	1.6	$5.1^{+3.5}_{-3.2} \pm 0.9$		0.13 ± 0.59
$\eta'_{\rho\gamma}(K^0_S\pi^+)^{*+}_0$	-29±22	-8±4	17.4	6.8	—	$-3.8^{+4.0}_{-3.9} \pm 1.5$		-0.40 ± 1.48
$\eta' K^*_2(1430)^0$					5.3	$13.7^{+3.0}_{-2.9} \pm 1.2$	—	$0.14 \pm 0.18 \pm 0.02$
$\eta'_{\eta\pi\pi} K^*_2(1430)^0$	42±13	2±1	15.1	5.8	3.7	$9.8^{+3.4}_{-3.2} \pm 0.9$		0.58 ± 0.32
$\eta'_{\rho\gamma} K^*_2(1430)^0$	125±26	20±10	10.6	9.8	4.1	$21.7^{+5.4}_{-5.3} \pm 3.0$		-0.05 ± 0.20
$\eta' K^*_2(1430)^+$					7.2	$28.0^{+4.6}_{-4.3} \pm 2.6$	—	$0.15 \pm 0.13 \pm 0.02$
$\eta'_{\eta\pi\pi} K^*_2(1430)^+_{K^+\pi^0}$	42±11	5±3	9.9	2.9	3.5	$27.1^{+8.8}_{-8.1} \pm 4.5$		0.29 ± 0.25
$\eta'_{\rho\gamma} K^*_2(1430)^+_{K^+\pi^0}$	115±28	20±10	8.5	4.9	2.9	$46.2^{+14.4}_{-13.8} \pm 12.2$		-0.33 ± 0.24
$\eta'_{\eta\pi\pi} K^*_2(1430)^+_{K^0_S\pi^+}$	42±10	5±2	15.3	2.0	4.5	$25.9^{+7.8}_{-7.1} \pm 2.7$		0.44 ± 0.23
$\eta'_{\rho\gamma} K^*_2(1430)^+_{K^0_S\pi^+}$	62±16	14±7	12.4	3.4	3.0	$24.1^{+8.7}_{-8.0} \pm 4.1$		0.22 ± 0.25

Belle

	$B^0 \to \eta'\rho^0$	$B^+ \to \eta'\rho^+$	$B^0 \to \eta' K^{*0}$	$B^+ \to \eta' K^{*+}$	$B^0 \to \eta'\phi$
$\epsilon(\eta\pi\pi)$ [%]	7.0 ± 0.1	5.9 ± 0.1	8.5 ± 0.1	4.5 ± 0.1	12.9 ± 0.1
$\epsilon(\rho\gamma)$ [%]	5.4 ± 0.1	3.9 ± 0.1	5.9 ± 0.1	2.2 ± 0.1	7.4 ± 0.1
$\epsilon_t(\eta\pi\pi)$ [%]	1.13 ± 0.02	0.93 ± 0.02	0.92 ± 0.01	0.35 ± 0.01	1.08 ± 0.01
$\epsilon_t(\rho\gamma)$ [%]	1.51 ± 0.03	1.07 ± 0.02	1.09 ± 0.02	0.30 ± 0.01	1.08 ± 0.02
N_S	$0.1^{+8.2}_{-7.0}$	$18.5^{+23.3}_{-21.7}$	$14.2^{+9.1}_{-8.0}$	$-6.4^{+10.9}_{-7.9}$	$-2.4^{+2.5}_{-3.5}$
UL [10^{-6}]	< 1.3	< 5.8	< 2.6	< 2.9	< 0.5
BABAR[10^{-6}]	< 3.7	< 14	$3.8 \pm 1.1 \pm 0.5$	$4.9^{+1.9}_{-1.7} \pm 0.8$	< 4.5

Amplitude Analysis of $B^0 \to K_s^0 K_s^0 K_s^0$

Mode	Solution 1	Solution 2
FF $f_0(980)K_S^0$	$0.44^{+0.20}_{-0.19}$	$1.03^{+0.22}_{-0.17}$
Phase [rad]$f_0(980)K_S^0$	0.09 ± 0.16	1.26 ± 0.17
Significance $[\sigma]f_0(980)K_S^0$	3.3	-
FF $f_0(1710)K_S^0$	$0.07^{+0.07}_{-0.03}$	$0.09^{+0.05}_{-0.02}$
Phase [rad] $f_0(1710)K_S^0$	1.11 ± 0.23	0.36 ± 0.20
Significance $[\sigma]f_0(1710)K_S^0$	3.7	-
FF $f_2(2010)K_S^0$	$0.09^{+0.03}_{-0.03}$	0.10 ± 0.02
Phase [rad] $f_2(2010)K_S^0$	2.50 ± 0.20	1.58 ± 0.22
Significance $[\sigma]f_2(2010)K_S^0$	3.3	-
FF$\chi_{c0}K_S^0$	$0.07^{+0.04}_{-0.02}$	0.07 ± 0.02
Phase [rad]$\chi_{c0}K_S^0$	0.63 ± 0.47	-0.24 ± 0.52
Significance $[\sigma]\chi_{c0}K_S^0$	4.2	-
FF NR	$2.15^{+0.36}_{-0.37}$	$1.37^{+0.26}_{-0.21}$
Phase [rad] NR	0.0	0.0
Significance $[\sigma]$NR	8.2	-
Total FF	$2.84^{+0.71}_{-0.66}$	$2.66^{+0.35}_{-0.27}$


Δ 2Nll
BABAR
preliminary
Mag f0(980) [arbitrary units]
Phase f0(980) [rad]
Mag f0(1710) [arbitrary units]
Phase f0(1710) [rad]