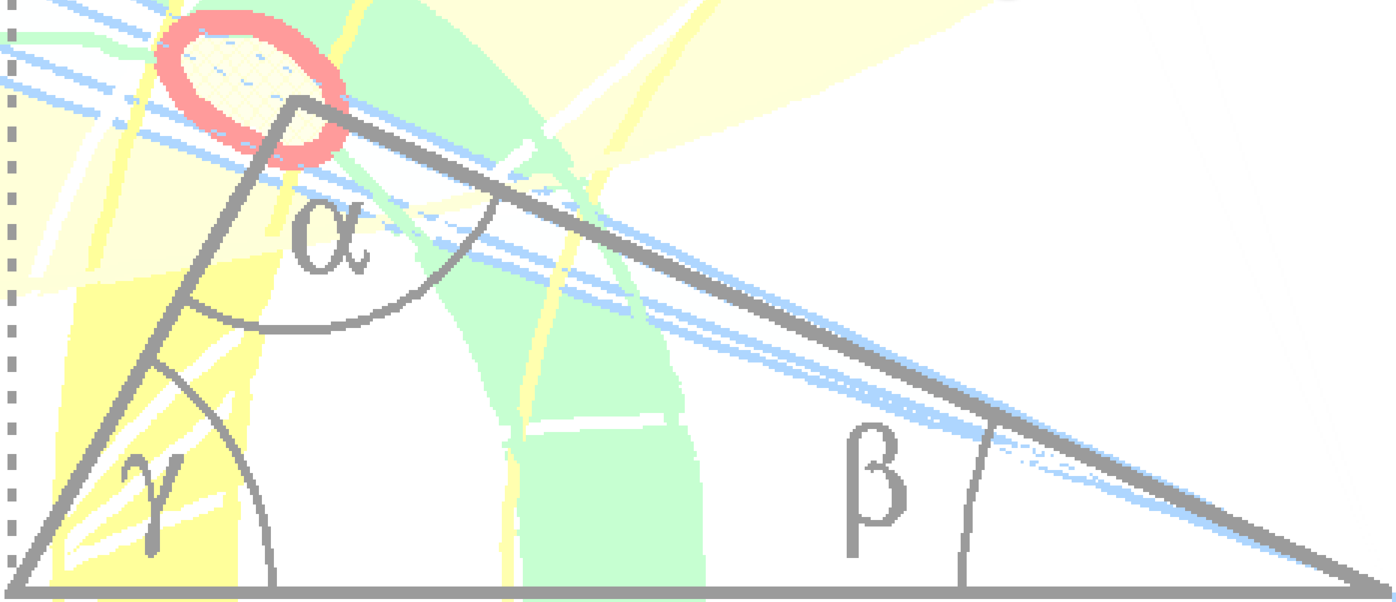
Flavor Physics and CP Violation 2011
May 23-27, Maale Hachamisha, Israel

CP Violation in b→s Penguins



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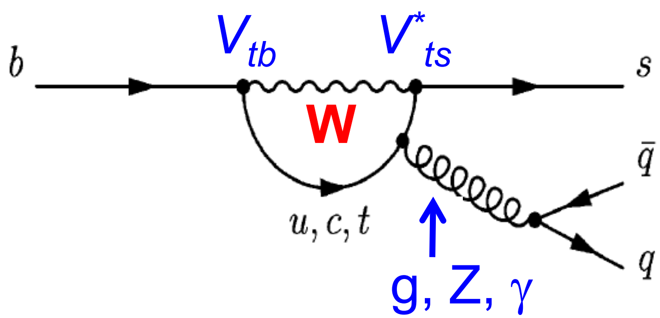
On behalf of the **Belle** and ***BABAR*** collaborations

Introduction

- Standard Model (SM): the leading decay amplitude of $b \rightarrow s$ transitions is



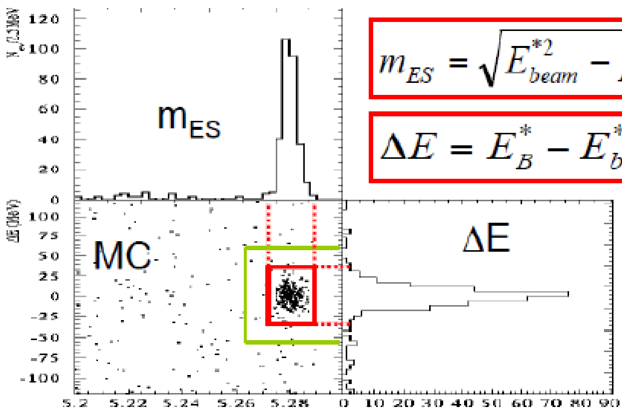
⇒ **CP violation (CPV) by CKM phase (only)**

- New physics (NP): another virtual particle in the loop.
- This can result in:
  - **New CP violating phases**
    ⇒ observable through CP asymmetries (?)
  - Enhanced branching fractions wrt SM expectations
  - Altered polarizations in final state (e.g. in $B \rightarrow VV$ decays)
  - …

All these observables: probes for new physics!

Common analysis techniques

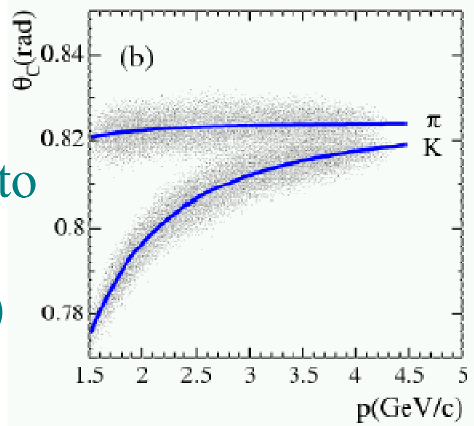
Kinematics of fully reconstructed B



$$m_{ES} = \sqrt{E^{*2}_{beam} - p^{*2}_{B}}$$

$$\Delta E = E^{*}_{B} - E^{*}_{beam}$$

Good charged particle ID up to few GeV/c (in particular K/π)



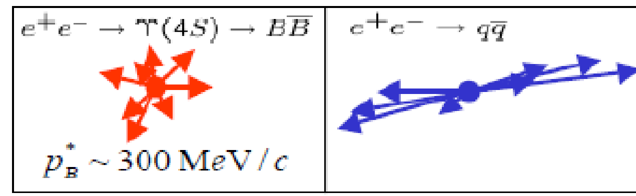
Background characterization:

→ Mainly continuum: $e^+e^- \to q\bar{q}$ (q = u,d,s,c).

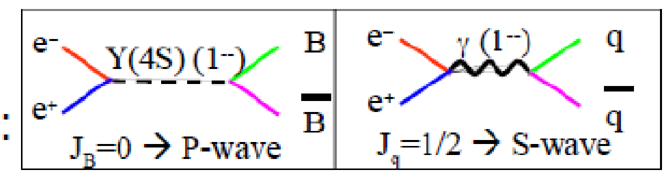
Suppression by multi-variable classifiers based on event-shape variables:

Fisher discriminant, Neural Networks (NN)…

Topology:



Angular distribution:



→ Background from B decays: classified by kinematic and topological properties

Variables are often combined to a likelihood function, used in a maximum likelihood fit for signal/background separation and to measure parameters of interest

Analyses and Results

- sin2β from b→s penguins

- Branching fractions, polarizations and direct CPV in $B^+ \to \rho^0 K^{*+}$ and $B^+ \to f_0(980) K^{*+}$
  BaBar arXiv:1012.4044 [hep-ex], Phys.Rev.D83:051101(R), 2011.

- Branching fractions, CP asymmetries and angular distributions for $B \to \phi \phi K$
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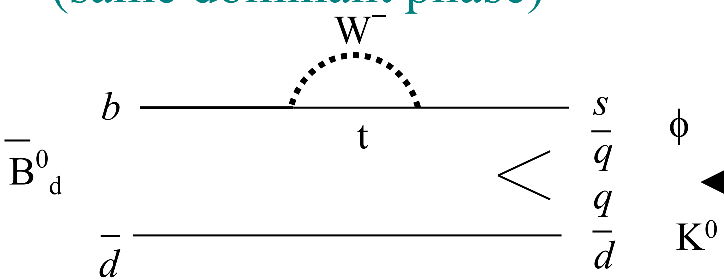
sin2β From b→s Penguins (I)

- Within the Standard Model (SM):

$$C_{c\bar{c}s} \approx C_{q\bar{q}s} = 0$$

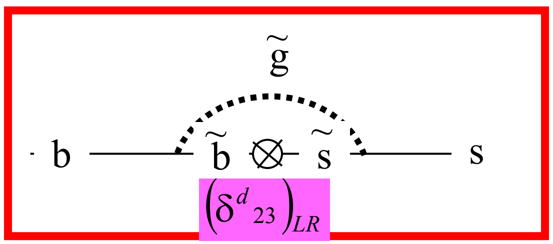
$$S_{c\bar{c}s} = S_{q\bar{q}s} + \Delta S_{SM} = -\eta_{CP} \sin 2\beta$$

(same dominant phase)



Standard Model contribution

- New physics in the loop may cause deviation in the values of S and C.



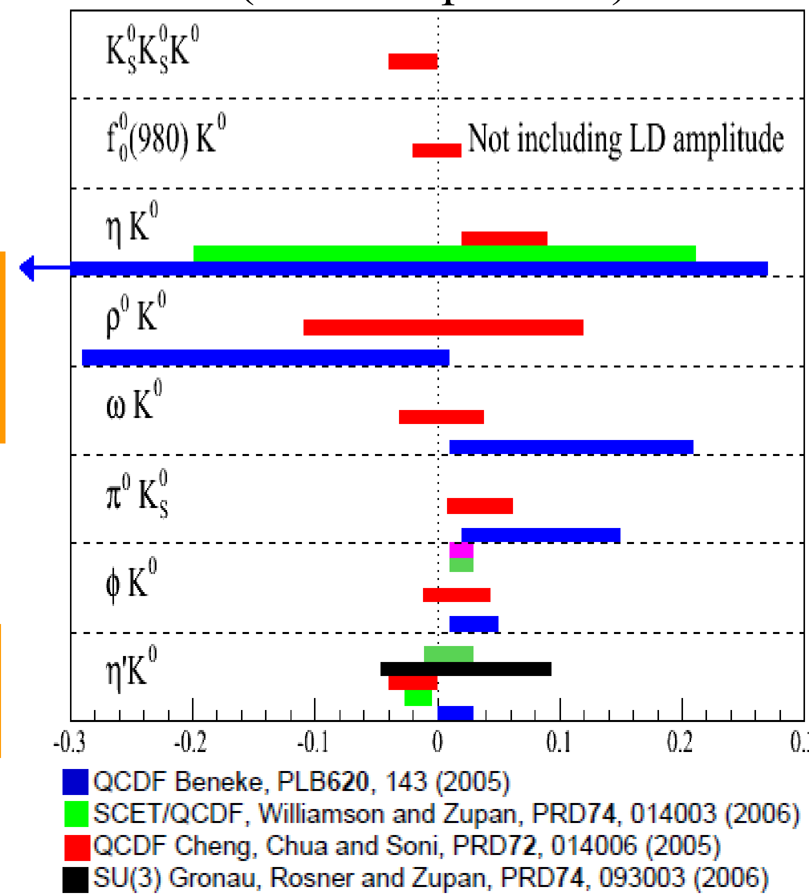
New Physics contribution

- Definitions:

$$\Delta S = S_{c\bar{c}s} - S_{q\bar{q}s}$$

$$\sin 2\beta^{eff} = -\eta_{CP} S_{q\bar{q}s}$$

Theoretical prediction for ΔS_{SM} (Mode dependent)



For most of the modes, theory predicts $\Delta S_{SM} > 0$

sin2β From b→s Penguins (I)

- Within the Standard Model (SM):

$$C_{c\bar{c}s} \approx C_{q\bar{q}s} = 0$$

$$S_{c\bar{c}s} = S_{q\bar{q}s} + \Delta S_{SM} = -\eta_{CP} \sin 2\beta$$

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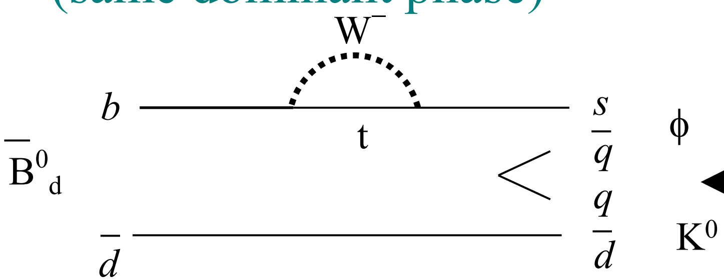

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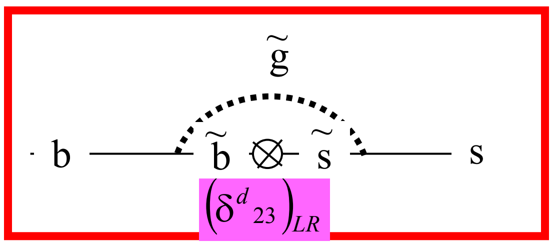
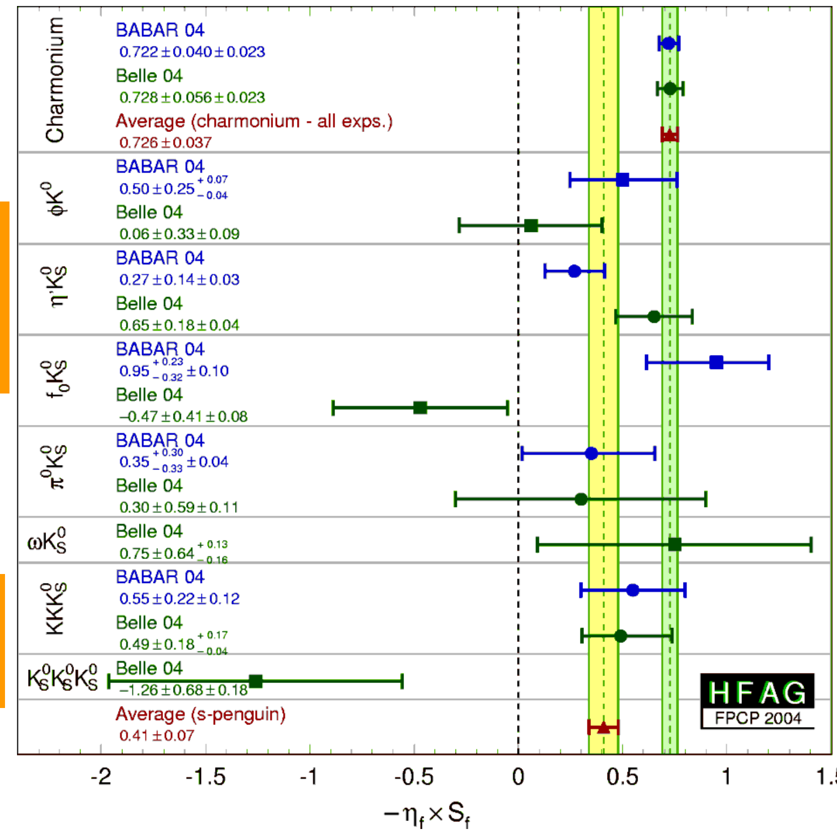


New Physics contribution

In 2004:



Tensions (~3σ) between sin2β from b→cc̄s and b→qq̄s (**ΔS < 0**)

- Definitions:

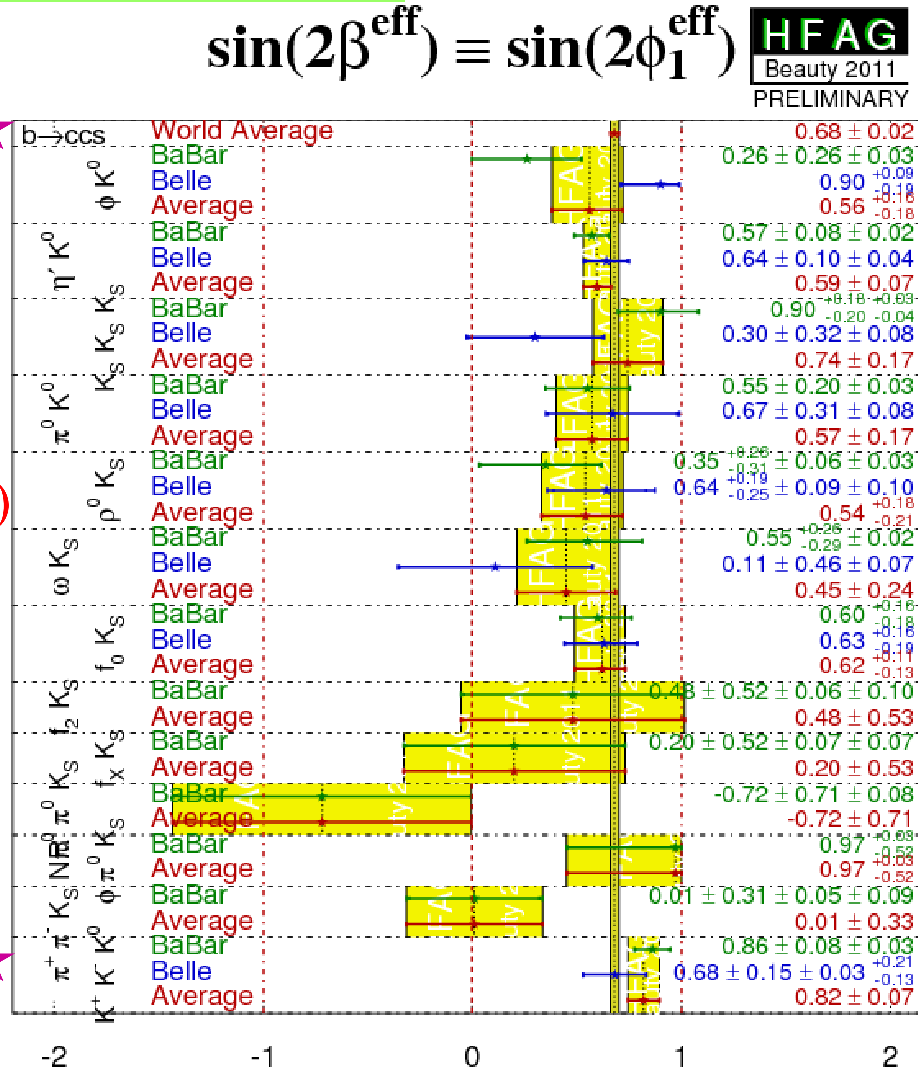
$$\mathbf{\Delta S} = S_{c\bar{c}s} - S_{q\bar{q}s}$$

$$\mathbf{\sin 2\beta^{eff}} = -\eta_{CP} S_{q\bar{q}s}$$

sin2β From b→s Penguins (II)

The situation today is quite different

- **Fresh sin*2β* world averages (HFAG):**
  - **b→c$\bar{c}$s: 0.678 ± 0.020**
  - **b→q$\bar{q}$s: 0.64 ± 0.04** (naïve!)
- Improvements:
  - hints of trends/deviations in previous measurements clarified by B factories
  - several results from (Time Dependent) Dalitz Plot analyses
- **Still… some tension persists because of the theoretical prediction $\Delta S_{SM} > 0$**



Results marked with ★ were presented yesterday by Himansu Sahoo

Analyses and Results

- sin2β from b→s penguins
- Branching fractions, polarizations and direct CPV in
  $B^+ \to \rho^0 K^{*+}$ and $B^+ \to f_0(980) K^{*+}$
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Introduction

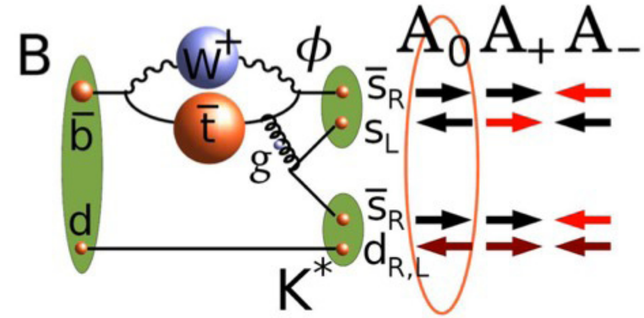
$B^+ \to \rho^0 K^{*+}$ and $B^+ \to f_0(980) K^{*+}$

- Polarization puzzle for $B \to VV$ modes

  Naïve expectation from helicity arguments: longitudinal polarization fraction (f_L) ~ 1

  $B \to \rho\rho$ has $f_L > 0.9$

  but other $b \to s$ penguin VV states have $f_L \sim 0.5$



$$|A_{00}|^2 \gg |A_{++}|^2 \gg |A_{--}|^2$$

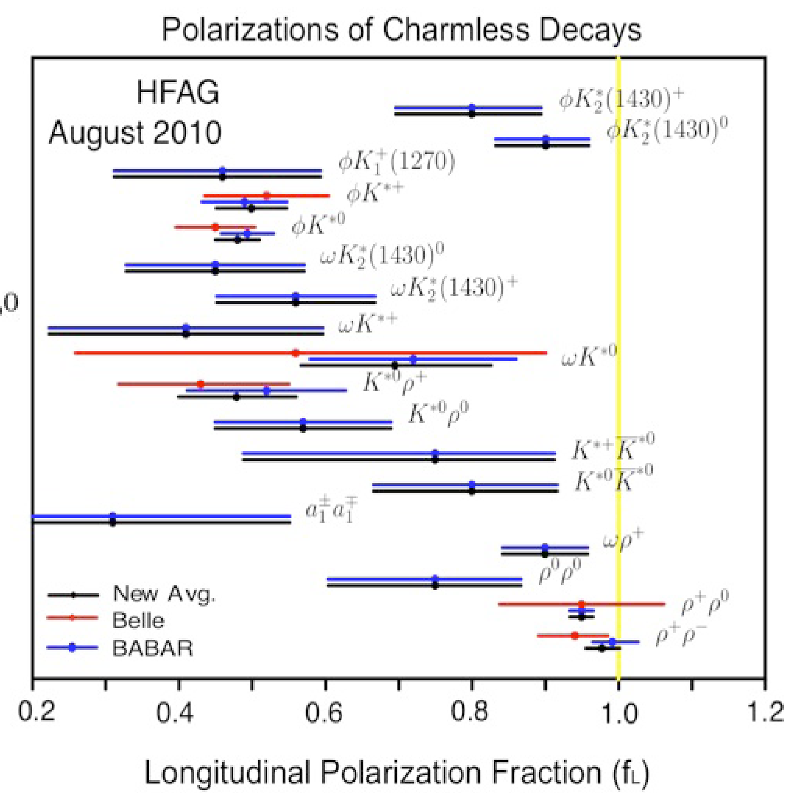
- $B^+ \to \rho^0 K^{*+}$ not observed before this analysis

  Predicted BF ~ $5\pm1 \times 10^{-6}$

- $B^+ \to \rho^0 K^{*+}$ (partially integrated) decay rate$\propto$

$$\frac{1-f_L}{4}\sin^2\theta_{K^{*+}}\sin^2\theta_{\rho^0} + f_L\cos^2\theta_{K^{*+}}\cos^2\theta_{\rho^0}$$

  $\Rightarrow$ angles give access to f_L



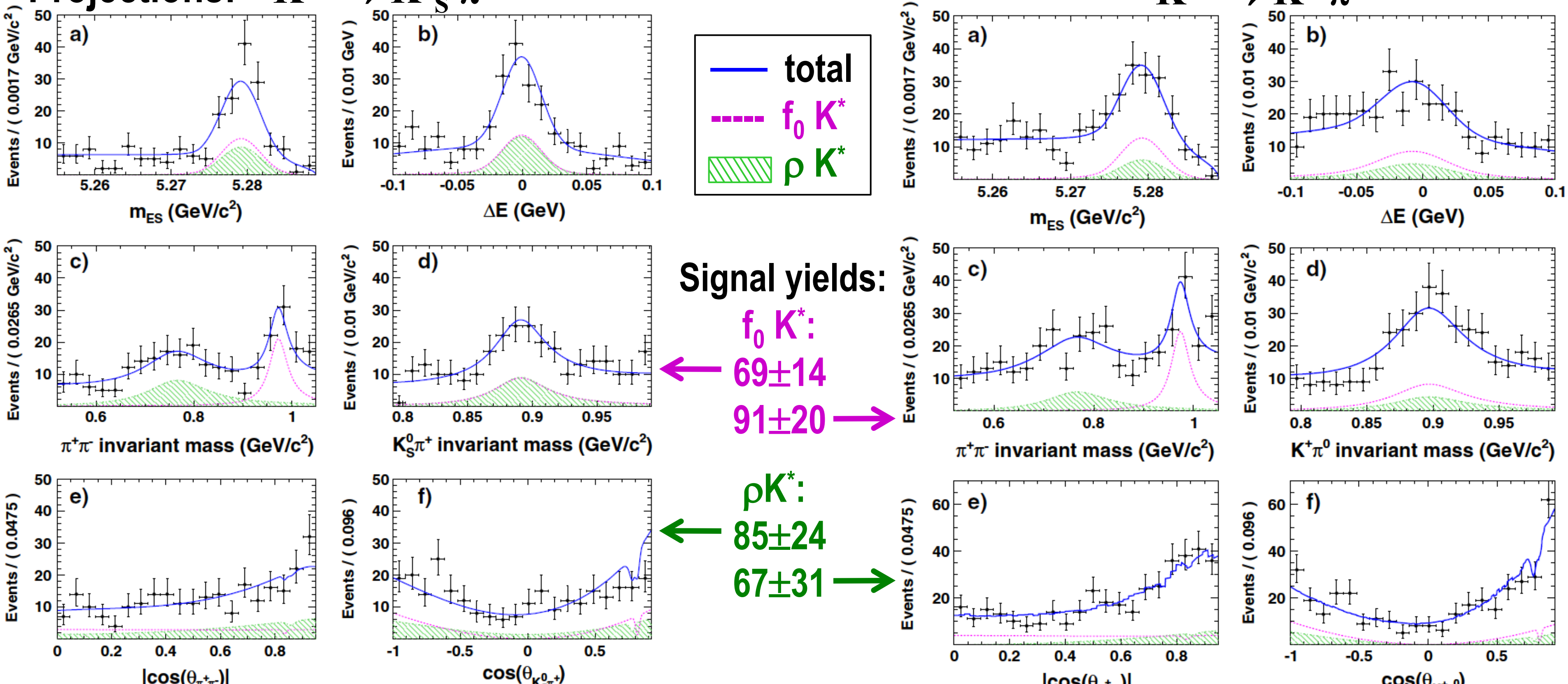
- The present analysis uses full BaBar dataset (467M $B\overline{B}$ pairs) → twice the previous analysis

Analysis

$B^+ \to \rho^0 K^{*+}$ and $B^+ \to f_0(980) K^{*+}$

- Reconstruction: ρ^0 and $f_0(980) \to \pi^+ \pi^-$; $K^{*+} \to K^0_S \pi^+$ and $K^+ \pi^0$
- Maximum likelihood fit with :
  - 7 variables: m_{ES}, ΔE, NN, $m_{\pi\pi}$, $m_{K\pi}$, $|\cos\theta_{\pi\pi}|$, $\cos\theta_{K\pi}$
  - 12 event categories: 2 signals, continuum, 9 classes of background from B

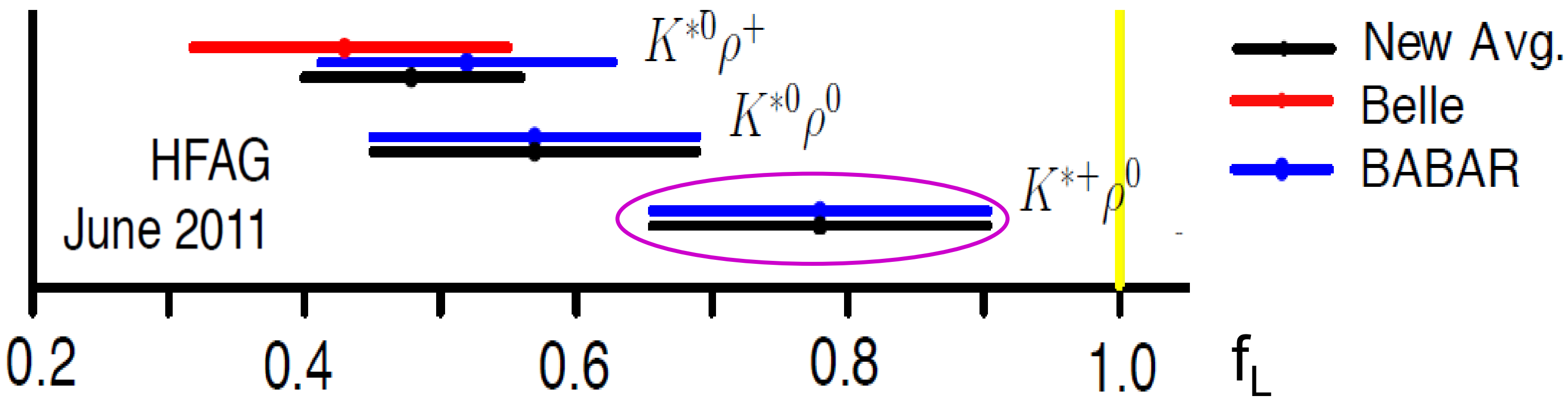
Projections: $K^{*+} \to K^0_S \pi^+$ $K^{*+} \to K^+ \pi^0$



Results

$B^+ \to \rho^0 K^{*+}$ and $B^+ \to f_0(980) K^{*+}$

- **Observation** of the $B^+ \to \rho^0 K^{*+}$ decay
  - BF = $(4.6 \pm 1.0 \pm 0.4)\ 10^{-6}$ $\Rightarrow$ Significance = 5.3σ (including syst.)
  - $f_L = 0.78 \pm 0.12 \pm 0.03 \Rightarrow$ Consistent with large f_L prediction and other $K^*\rho$ modes
  - $A_{CP} = 0.31 \pm 0.13 \pm 0.03$



$K^{*0}\rho^+$: pure penguin

$K^{*0}\rho^0$: penguin + color-suppressed $\bar{b} \to \bar{u}u\bar{s}$ tree

$K^{*+}\rho^0$: penguin + color-allowed $\bar{b} \to \bar{u}u\bar{s}$ tree

- **Improved** $B^+ \to f_0(980) K^{*+}$ results
  - BF$[f_0(\to \pi^+\pi^-) K^{*+}] = (4.2 \pm 0.6 \pm 0.3)\ 10^{-6}$
  - $A_{CP} = -0.15 \pm 0.12 \pm 0.03$

Previous results based on 232M $B\bar{B}$
BF($B^+ \to \rho^0 K^{*+}$) < 6.1×10^{-6} @ 90% CL
BF($B^+ \to f_0(980) K^{*+}$) = $(5.2 \pm 1.2 \pm 0.5)\ 10^{-6}$
PRL 97, 201801 (2006)

Analyses and Results

- $\sin 2\beta$ from b→s penguins

- Branching fractions, polarizations and direct CPV in
  $B^+ \to \rho^0 K^{*+}$ and $B^+ \to f_0(980) K^{*+}$
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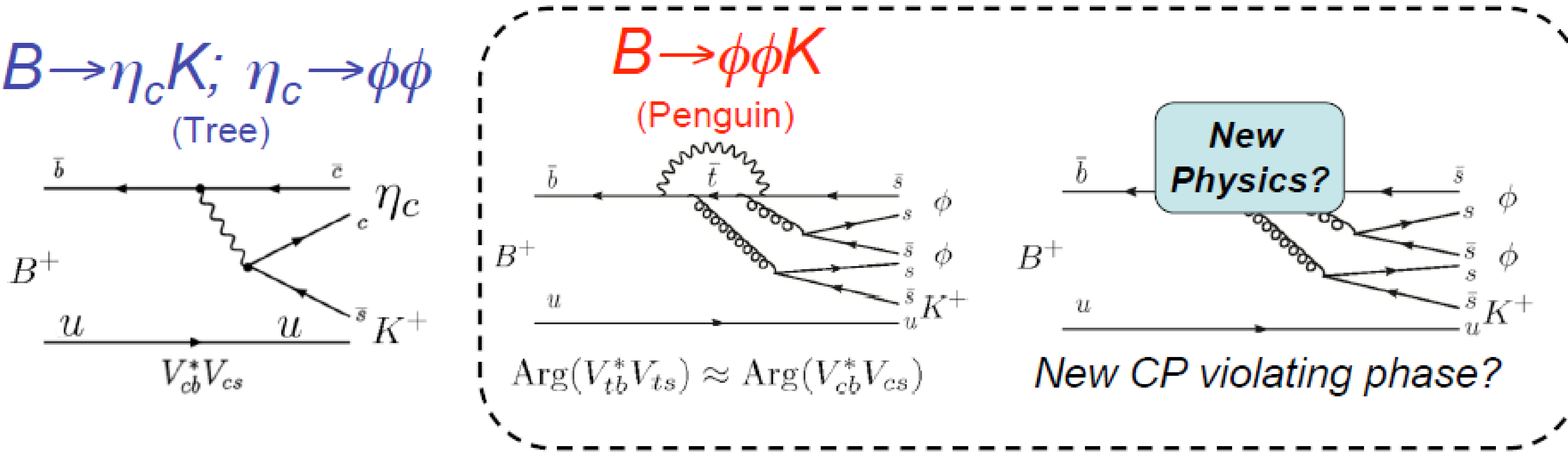
Introduction

B → ϕ ϕ K

- Interference between tree and penguin amplitudes under the η_C peak



- Standard Model: tree and penguin have ~ the same weak phase

  ⇒ no direct CP-Violation expected

- **Non-zero NP relative CP violating phase ⇒ significant direct CP asymmetry**

  could be at the ~40% level (Hazumi, Phys. Lett B 583, 285 (2004))

- Only the $J^P=0^-$ component of $(\phi\phi)K$ interferes with $(\eta_C)K$

  ⇒ angular analysis needed to study the spin structure of the $\phi\phi$ system

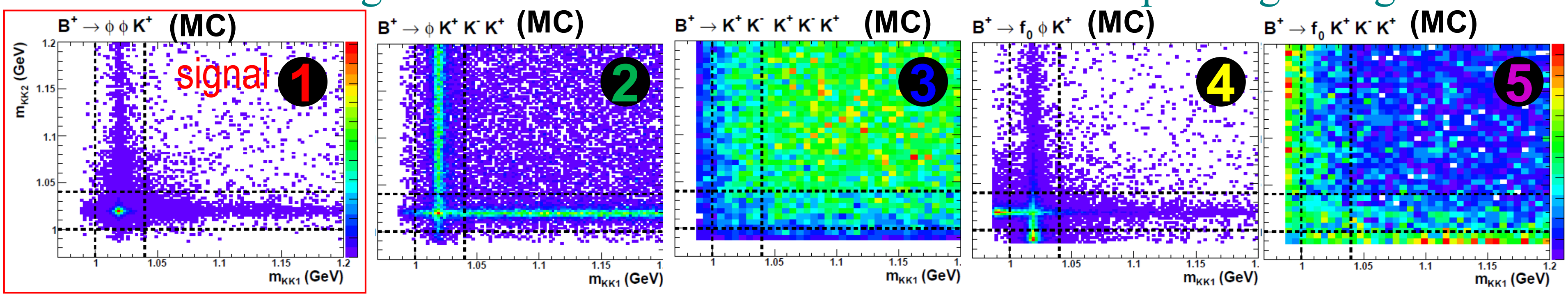
  } not discussed in this talk

- **BaBar: Full dataset (464M $B\bar{B}$) ~ Belle: 449M $B\bar{B}$ (update coming soon…)**

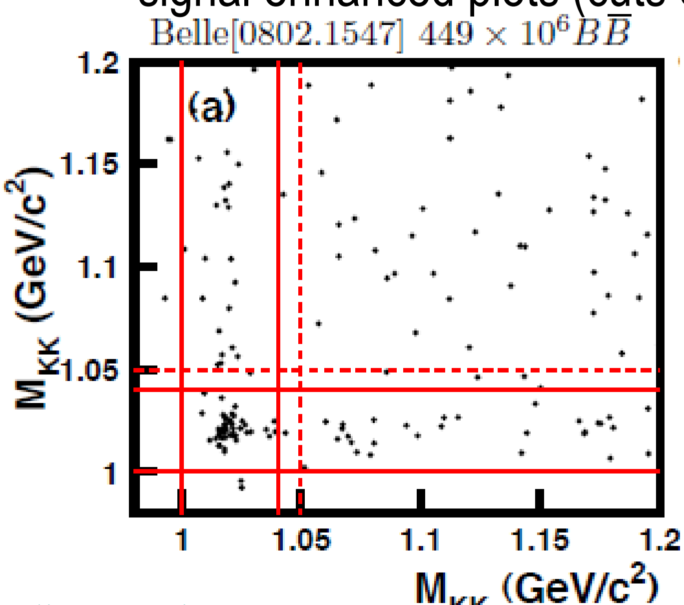
Analysis: peaking background

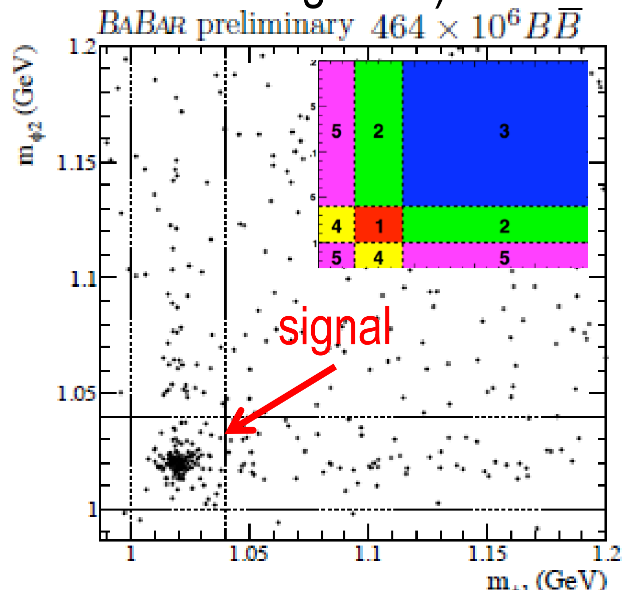
$B \to \phi \phi K$

- Use 5 regions in the $m_{\phi 2}$ - $m_{\phi 1}$ plane to distinguish final states with 5 kaons
  - $B \to 5K$ fits in the different regions
  - Use cross-region fractions from Monte Carlo to estimate peaking background



signal enhanced plots (cuts on discriminating vars.)





1: $B \to \phi\phi K$
2: $B \to \phi KKK$
3: $B \to KKKKK$
4: $B \to f_0\phi K$
5: $B \to f_0 KKK$

$B \to \phi \phi K$

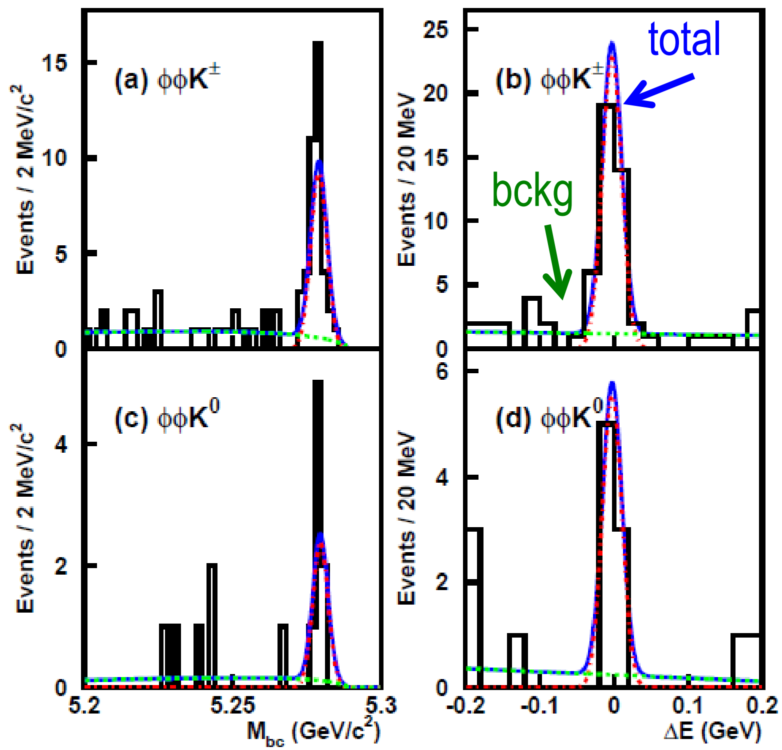
Analysis: fit to data, yields

- BaBar: Maximum likelihood fit to m_{ES}, ΔE, Fisher, $m_{\phi 1}$, $m_{\phi 2}$
- Belle: Cut on a likelihood of Fisher, $\cos\theta_B$, Δz, and flavor tagging on recoiled B, then fit m_{bc} (m_{ES}), ΔE

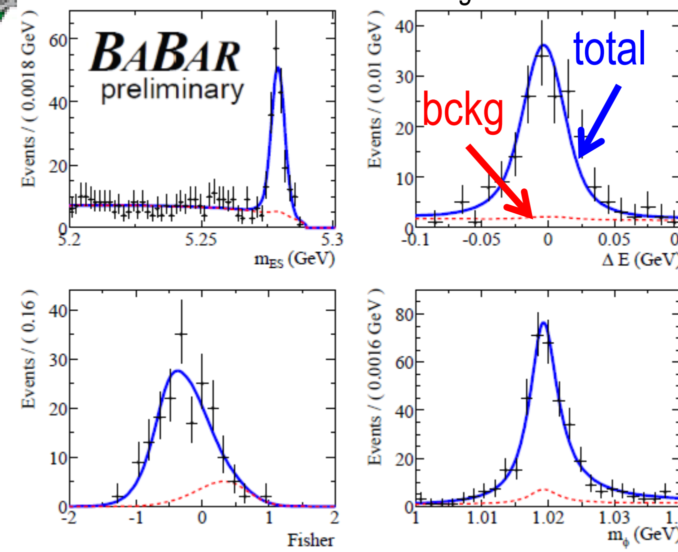
Projections with $m_{\phi\phi} < 2.85$ GeV

$N_{sig}=34\pm6$

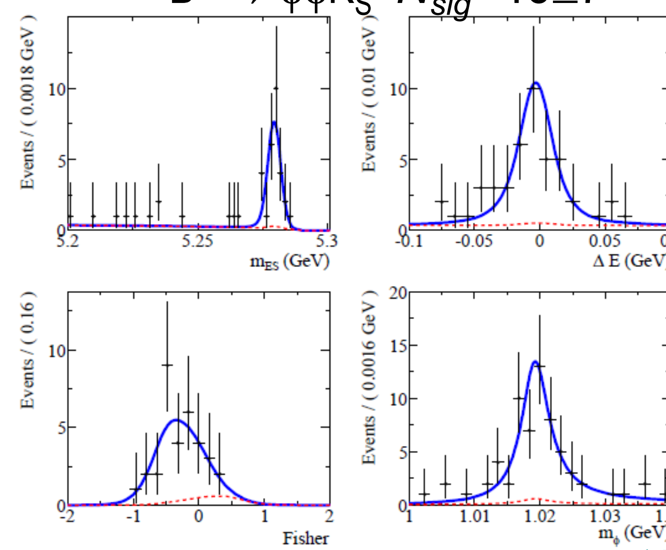
$N_{sig}=7.3\pm^{3.0}_{2.4}$



$B^+ \to \phi\phi K^+$ $N_{sig}=178\pm15$



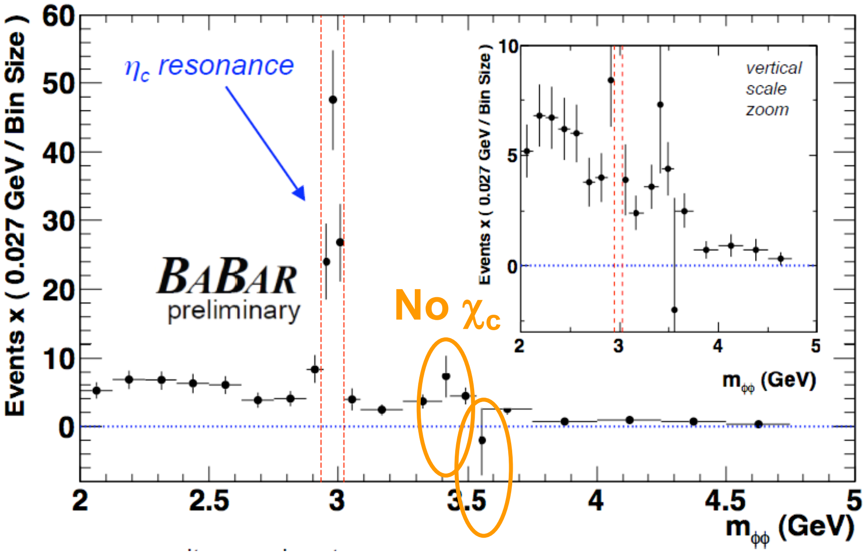
$B^0 \to \phi\phi K_S$ $N_{sig}=40\pm7$

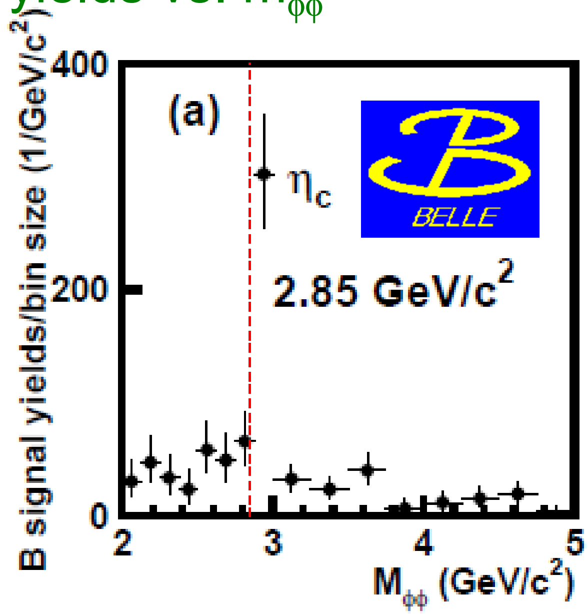


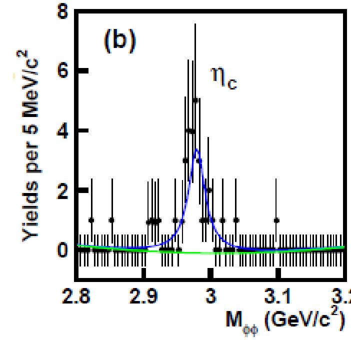
Results: branching fraction and A_{CP}

$B \to \phi \phi K$

$B^+ \to \phi\phi K^+$ yields vs. $m_{\phi\phi}$







Partial BF ($m_{\phi\phi}$ < 2.85 GeV)

(10^{-6})	$\mathcal{B}(B^+ \to \phi\phi K^+)$	$\mathcal{B}(B^0 \to \phi\phi K^0)$
BABAR	$5.6 \pm 0.5 \pm 0.3$	$4.5 \pm 0.8 \pm 0.3$
Belle	$3.2^{+0.6}_{-0.5} \pm 0.3$	$2.3^{+1.0}_{-0.7} \pm 0.2$

} ! ...

New result from Belle expected this summer

A_{CP} ($\phi\phi K^+$) below and within the η_C region (consistent with 0 and SM)

$m_{\phi\phi}$	$< 2.85\,\mathrm{GeV}$	2.94–$2.98\,\mathrm{GeV}$	2.98–$3.02\,\mathrm{GeV}$
BABAR	$-0.10 \pm 0.08 \pm 0.02$	$-0.10 \pm 0.15 \pm 0.02$	$-0.08 \pm 0.14 \pm 0.02$
Belle	$0.01^{+0.19}_{-0.16} \pm 0.02$	$0.15^{+0.16}_{-0.17} \pm 0.02$	

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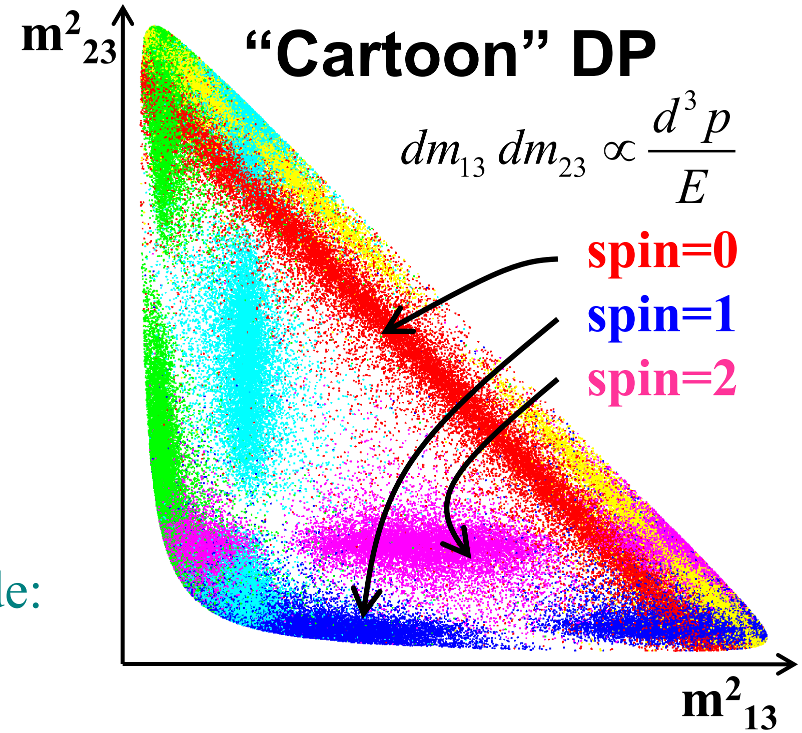
Introduction: Dalitz-plot (DP)

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

- Each intermediate resonance in P → 1 2 3 appears as a structure in the DP according to its mass, width and spin



- Resonance parameterization (isobar model):

  $A = \Sigma A_i = \Sigma\, \mathbf{C_i}\, \mathbf{F}(m^2_{13}, m^2_{23})$

  complex ↙ ↘ e.g. Breit-Wigner

  + similar relation for the CP conjugate amplitude:

  $\bar{A} = \Sigma \bar{A}_i = \Sigma\, \mathbf{\bar{C}_i}\, \mathbf{F}(m^2_{13}, m^2_{23})$

- Superimposed resonant contributions → interference → **access to phases**

Directly extracted parameters: isobar amplitudes $\mathbf{C_i}$
Other parameters (A_{CP}, relative phases, Branching Fractions) are computed from them

The present analysis is done with the full BaBar dataset: 454M $B\bar{B}$ pairs

The Dalitz-plot model

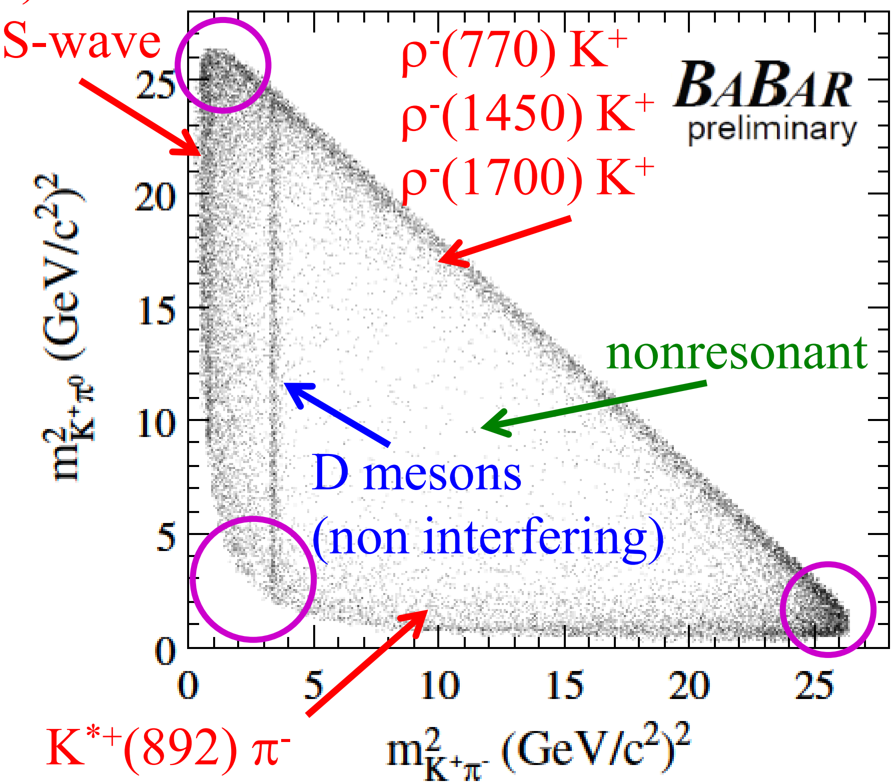
$B^0 \to K^+ \pi^- \pi^0$

- Resonances populate the **borders of the DP**
- **Corners** (where one particle is soft) are "strategic" for interference measurement
- This is a **flavor specific mode**: no interference between specific components of the B^0 / $\overline{B}^0$ DP (e.g. $K^{*+} \pi^-$ and $K^{*-} \pi^+$)

  $\Rightarrow$ A_{CP} is measurable here

  $\Rightarrow$ relative phase measurable only in **$B^0 \to K_S \pi^+ \pi^-$ (self-conjugate)**
- Model also contains :
  - Continuum background
  - 19 backgrounds from B decays

$B^0 \to K^+ \pi^- \pi^0$ Dalitz plot
(selected dataset: ~24 kEvents)



Motivations

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

- In general: rich resonance structure ⇒ access to many observables:
  - A_{CP} } For each component
  - Branching Fraction }
  - relative phases between components

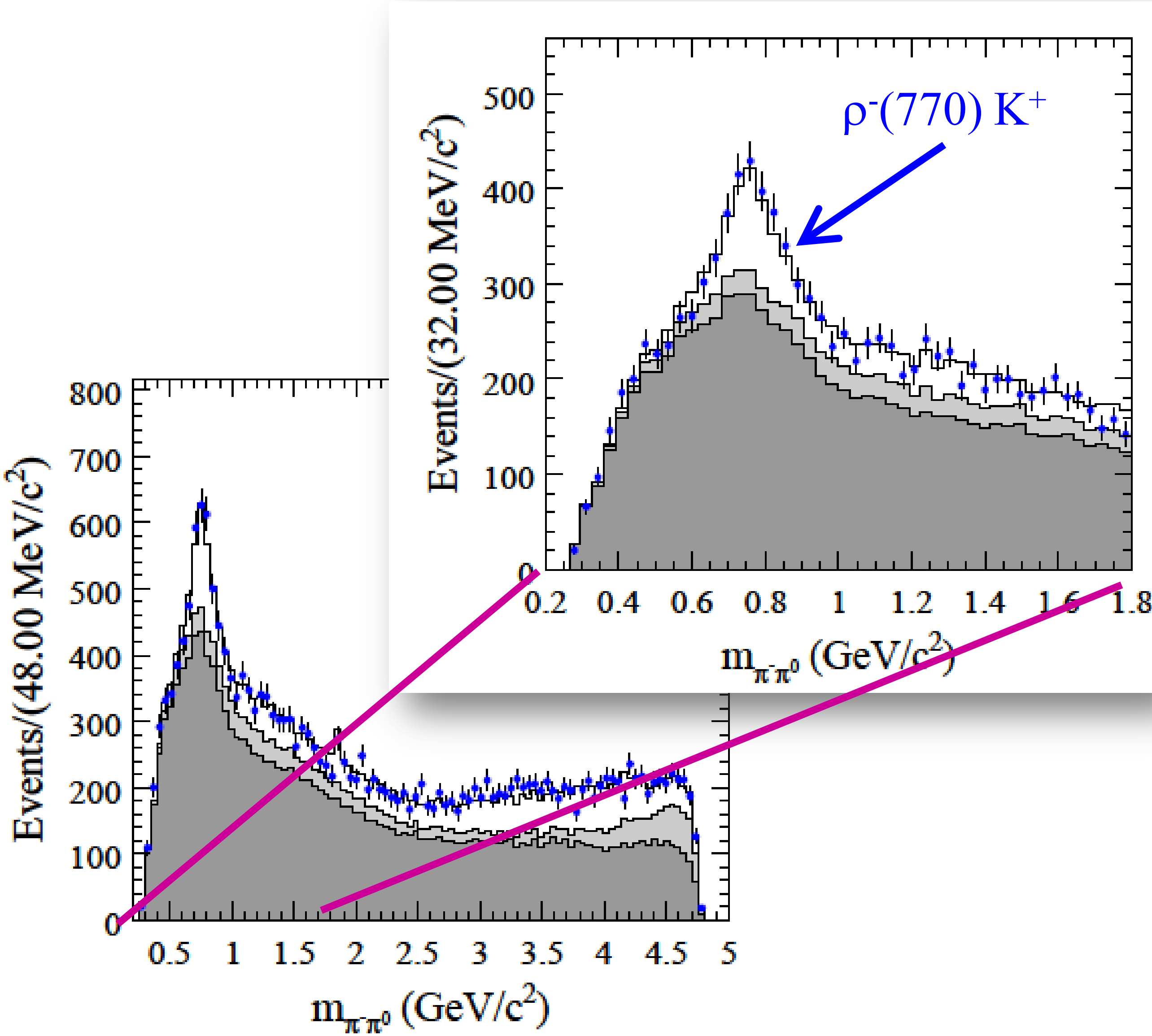
  which can be used to set non-trivial constraints on the CKM parameters $(\bar{\rho}, \bar{\eta})$

- In particular: measurement of the direct CP violation in $B^0 \to K^{*+} \pi^-$ decays
  (Gaining sensitivity by combination with $B^0 \to K_S \pi^+ \pi^-$ [PRD 80, 112001 (2009), BABAR])
  ⇒ $K\pi$ puzzle in the $K^*\pi$ system? (See talks from Gagan Mohanty and Harry Lipkin)

(But also… (not the main subject of this talk…)
Access CKM angle γ from phases related to the $K^*\pi$ intermediate states in $B^0 \to K^+\pi^-\pi^0$ and $B^0 \to K_S\pi^+\pi^-$
γ **measurement: tree amplitudes of** $B \to K^* \pi$ (Cabibbo supressed wrt $b \to s$ penguins)
⇒ need to **eliminate** $b \to s$ **penguin amplitudes**)

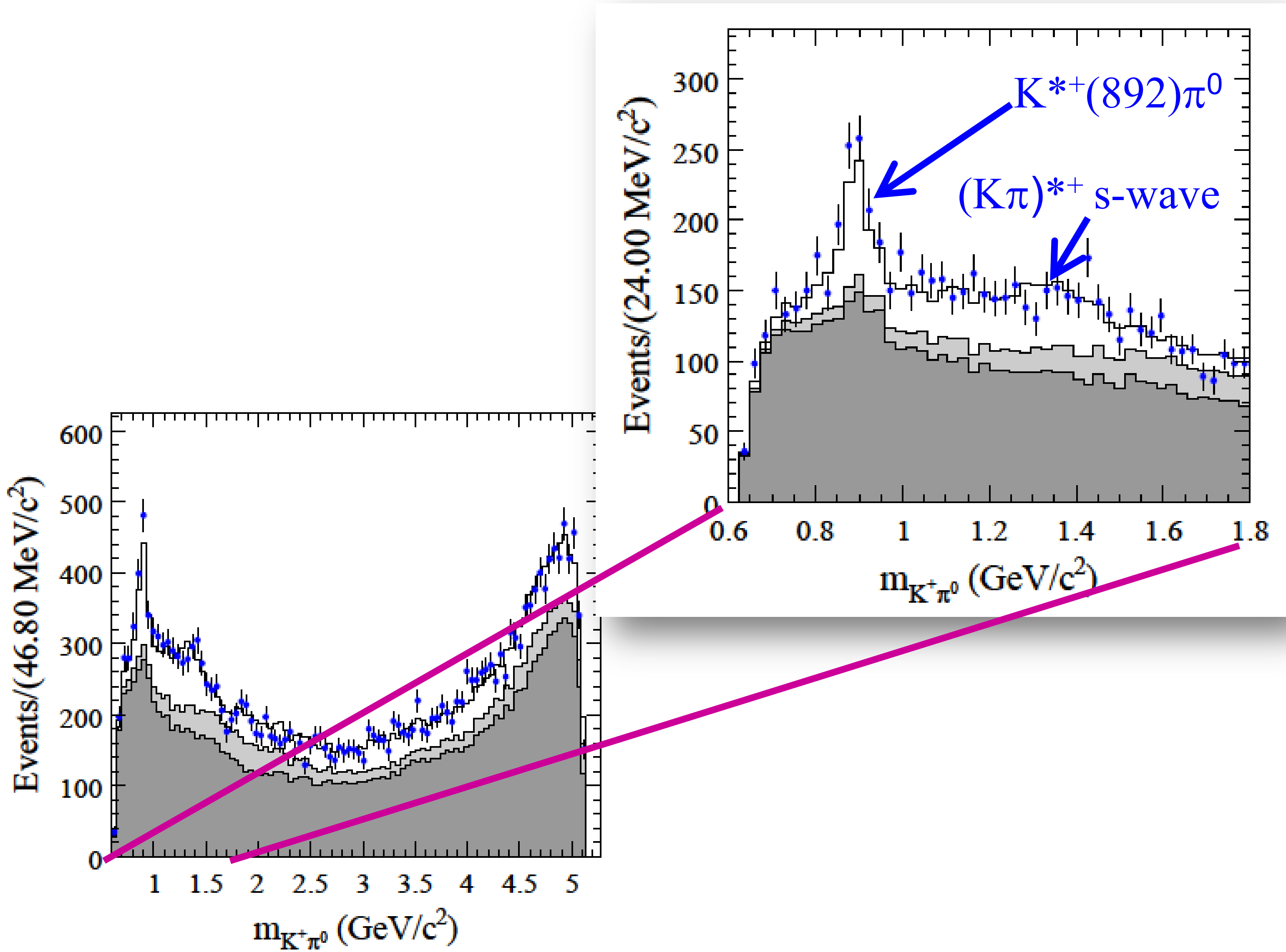
Goodness of fit – distributions of $m(\pi^-\pi^0)$

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



Goodness of fit – distributions of $m(K^+\pi^0)$

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

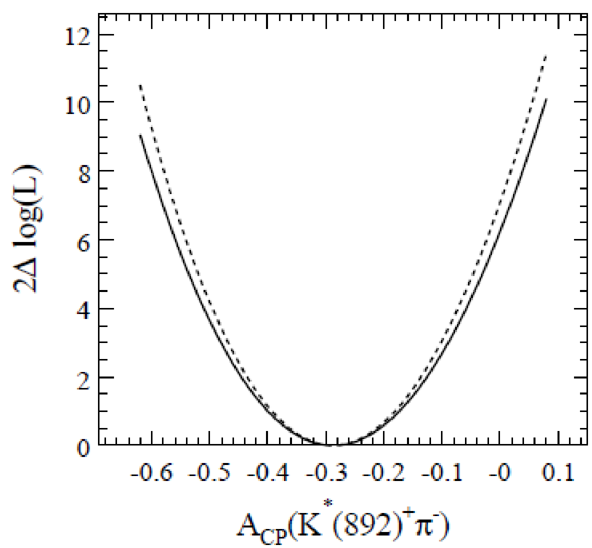


Results

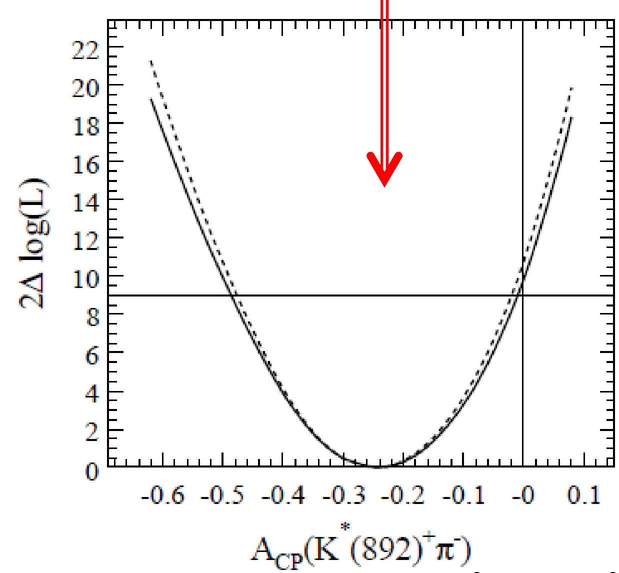
$B^0 \to K^+ \pi^- \pi^0$

- **Signal events**: 3670 ± 96 (stat.) ± 94 (syst.)
- **Four different minima found by the fit.** The lowest is separated from the others by 5.4 units of the log-likelihood (3.3 σ); signal yields are very close
- **BF($B^0 \to K^+\pi^-\pi^0$)** = 38.5 ± 1.0 (stat.) ± 3.9 (syst.) × 10^{-6}
- **Evidence of direct CP violation in $B^0 \to K^{*+}\pi^-$** (3.1 σ)

$A_{CP}(K^*(892)^+\pi^-) = -0.24 \pm 0.07$ (stat.) ± 0.02 (syst.)



Present analysis (mind the scales)



Combination with $B^0 \to K^0_S\pi^+\pi^-$

(

Other results

Information about γ from $K^*(892)\pi$

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

- The following linear combination is free from QCD penguins
  Ciuchini, Pierini & Silvestrini [PRD74:051301 2006]

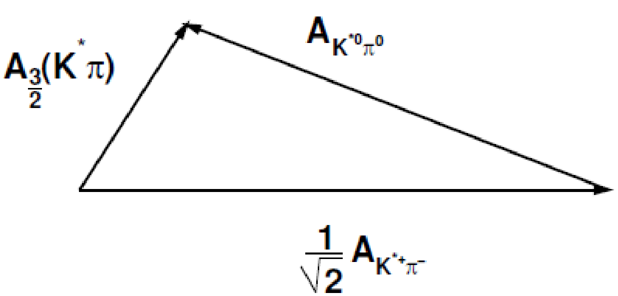
$$\mathcal{A}_{\frac{3}{2}}(K^*\pi) = \frac{1}{\sqrt{2}}\mathcal{A}(B^0 \to K^{*+}\pi^-) + \mathcal{A}(B^0 \to K^{*0}\pi^0)$$

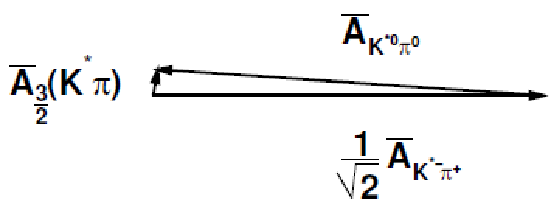
Populate the same $B^0 \to K^+ \pi^- \pi^0$ DP

Neglecting EW penguins, its weak phase $\Phi_{\frac{3}{2}} = -\frac{1}{2}\mathrm{Arg}\left(\overline{\mathcal{A}}_{\frac{3}{2}}/\mathcal{A}_{\frac{3}{2}}\right)$ is γ

Phase difference from $B^0 \to K_S \pi^+ \pi^-$ DP

- $K^*\pi$ amplitudes (drown to scale):





$\Rightarrow$ Destructive interference of the neutral and charged $K^*\pi$ amplitudes (expected…)

$\Rightarrow$ We cannot measure $\Phi_{3/2}$ using $K^*(892)\pi$ amplitudes

Other results

Information about γ from ρK

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

- Similar argument in the $B^0 \to \rho K$ system:

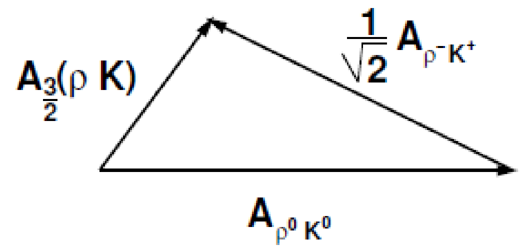
$$\mathcal{A}_{\frac{3}{2}}(\rho K) = \frac{1}{\sqrt{2}}\mathcal{A}(B^0 \to \rho^- K^+) + \mathcal{A}(B^0 \to \rho^0 K^0)$$

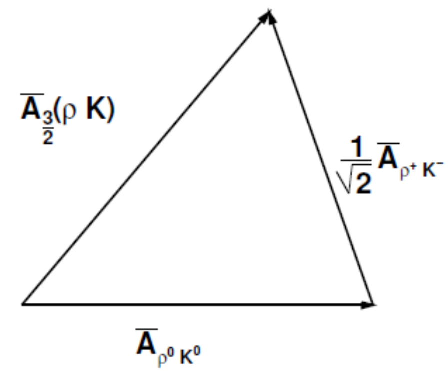
From $B^0 \to K^+ \pi^- \pi^0$ DP

From $B^0 \to K_S \pi^+ \pi^-$ DP

Interference with $K^{*+} \pi^-$

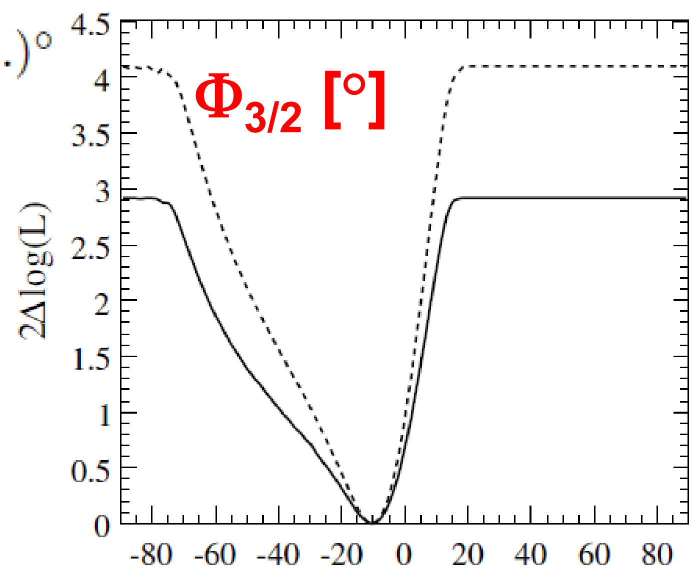
- ρK amplitudes (drown to scale):





- The resulting $\Phi_{3/2}$:

$$\Phi_{\frac{3}{2}} = -10^{+10}_{-20}\ (\text{stat.})^{+7}_{-22}\ (\text{syst.})^{\circ}$$



Other results
SU(3) sum rule

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

- Sum rule assuming SU(3) symmetry:

  Gronau, Pirjol & Zupan [PRD81:094011 2010]

$$|\overline{\mathcal{A}}_{\frac{3}{2}}(K^*\pi)|^2 - |\mathcal{A}_{\frac{3}{2}}(K^*\pi)|^2 = |\mathcal{A}_{\frac{3}{2}}(\rho K)|^2 - |\overline{\mathcal{A}}_{\frac{3}{2}}(\rho K)|^2.$$

- We measure the asymmetry parameter defined like:

$$\Sigma_{\frac{3}{2}} = \frac{|\overline{\mathcal{A}}_{\frac{3}{2}}(K^*\pi)|^2 - |\mathcal{A}_{\frac{3}{2}}(K^*\pi)|^2}{|\overline{\mathcal{A}}_{\frac{3}{2}}(\rho K)|^2 - |\mathcal{A}_{\frac{3}{2}}(\rho K)|^2} + 1.$$

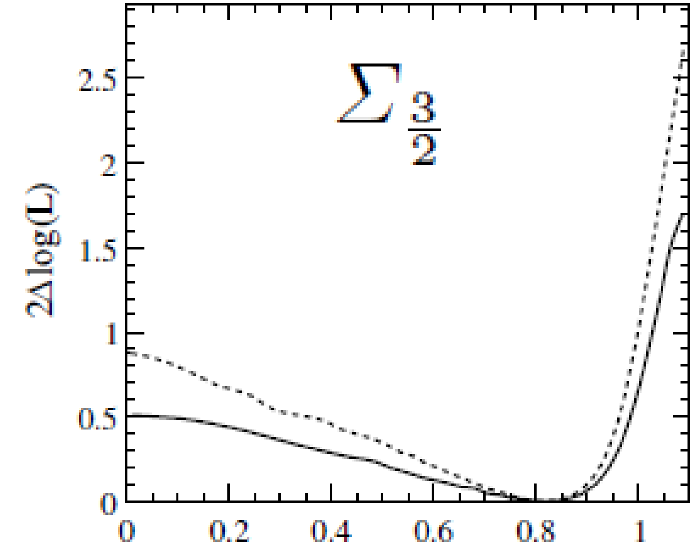
$\Sigma = 0 \Leftrightarrow$ exact SU(3)

$\Sigma \neq 0 \Rightarrow$ contribution from strangeness violating New Physics operators

- Result:

$$\Sigma_{\frac{3}{2}} = 0.82^{+0.18}_{-0.92}\ (\text{stat.})^{+0.11}_{-1.35}\ (\text{syst.})$$

$\Rightarrow$ Sum rule applies within uncertainties



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Summary and Conclusions

- BaBar and Belle continue to produce physics results, adding more information and using more sophisticated analysis techniques to improve the precision of measurement in $b \to s$ penguin modes

- All measurements agree with the standard model predictions, though a few tensions and puzzles still exist

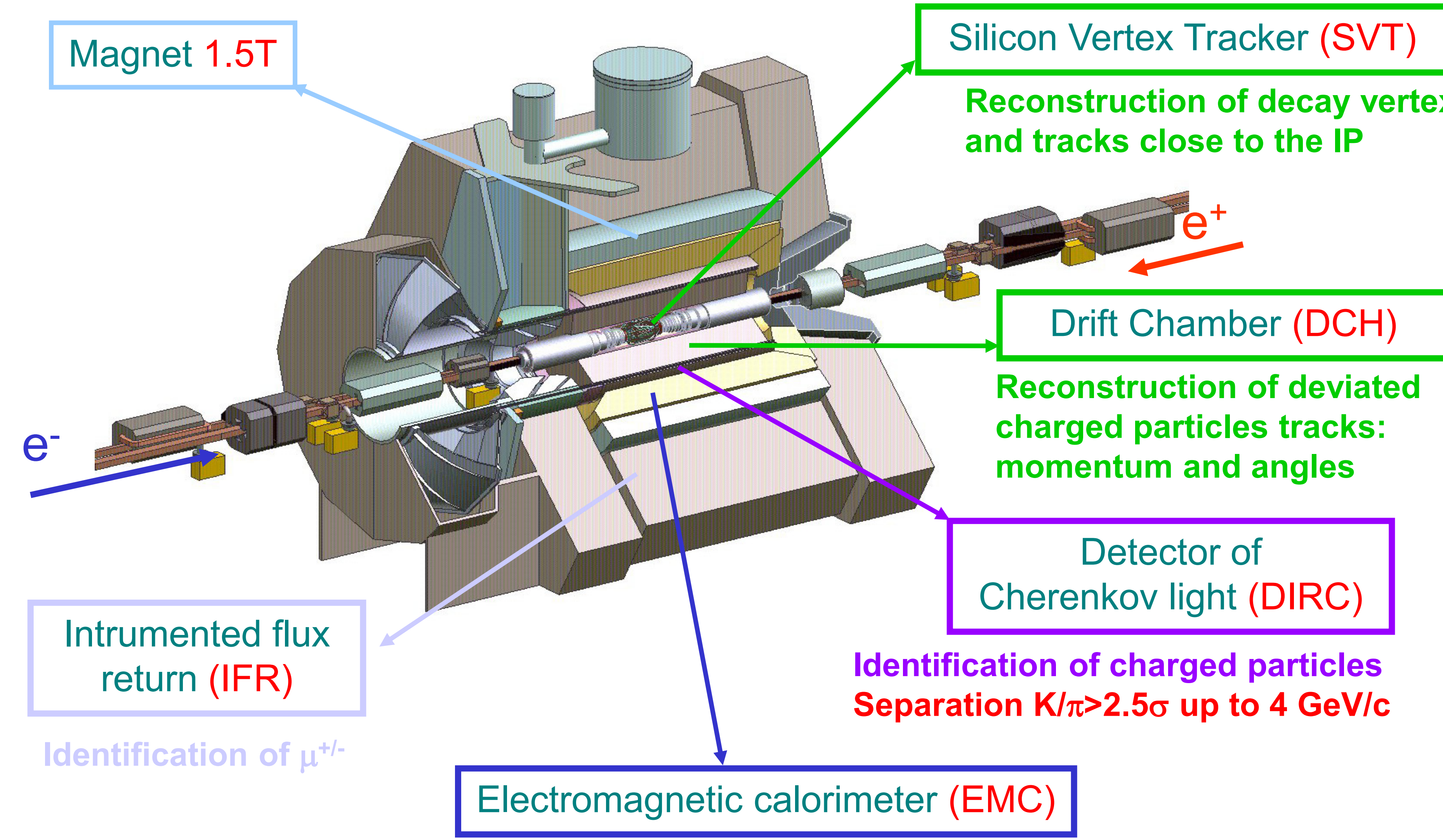
- The actual statistics is not sufficient to tell whether or not these could be indications for new physics.

To find new physics in $b \to s$ penguins we need

LHCb SuperB Belle II

Backup

The BaBar Detector



Reconstruction of decay vertex and tracks close to the IP

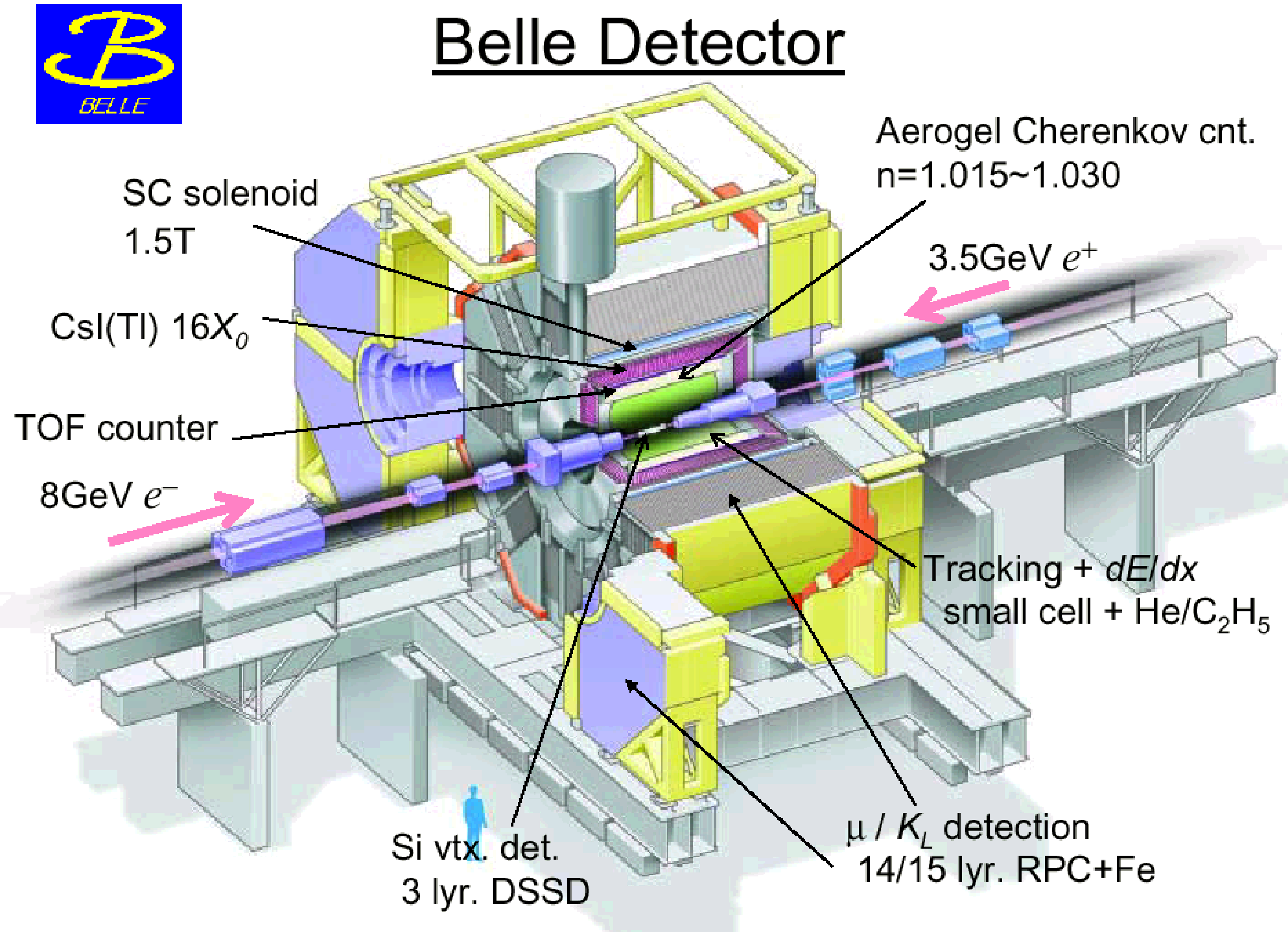
Reconstruction of deviated charged particles tracks: momentum and angles

Identification of charged particles
Separation $K/\pi > 2.5\sigma$ up to 4 GeV/c

Identification of $\mu^{+/-}$

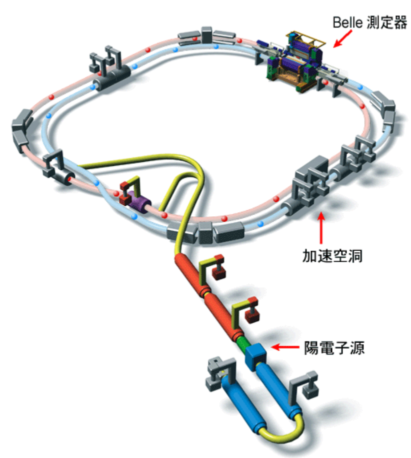
Detection of γ, e^- identification
Reconstruction of $\pi^0 \rightarrow \gamma\gamma$, Energy measurement

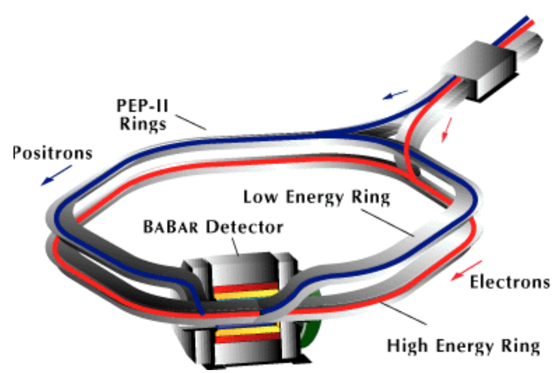
The Belle Detector

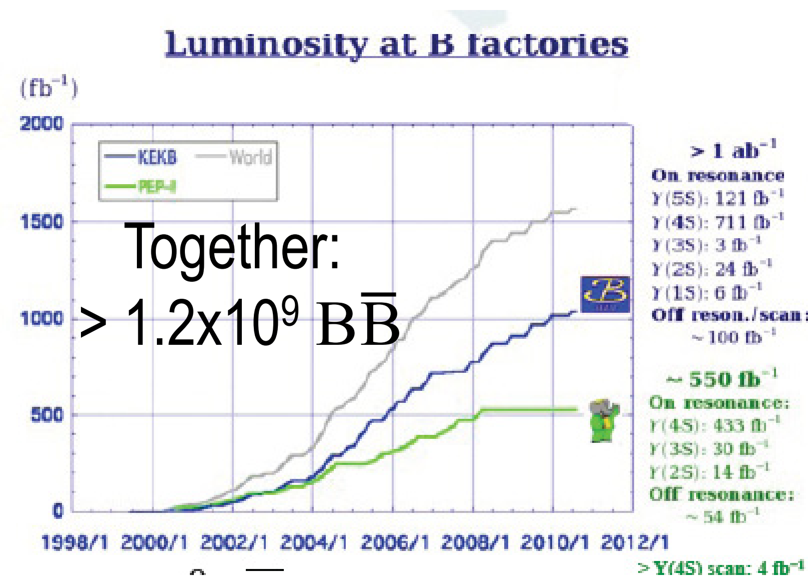


More on BaBar and Belle

- Data taking periods over for the B-Factories
  - In April 2008 for BABAR
  - In June 2010 for Belle
- Outstanding luminosity records
  - BABAR: 433 fb^{-1} @ $\Upsilon(4S)$ + ~54 fb^{-1} 40 MeV below
  - Belle: 711 fb^{-1} ~100 fb^{-1}
- Hundred of journal articles published
  - Sustained publication rates for both experiments – Physics of the B-Factories
  - Plans for data preservation and long-term analysis (e.g. BABAR LTDA project)







Quick Reminder of Basics

CKM matrix — Wolfenstein parameterization:

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \simeq \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

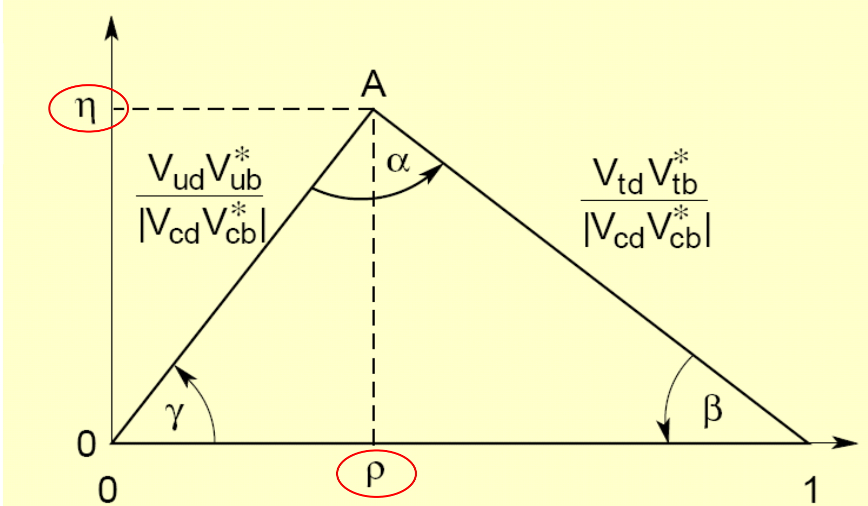
V_{CKM} Unitarity ⇒

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$\propto\lambda^3$ $\propto\lambda^3$ $\propto\lambda^3$

In other unitarity conditions (triangles) sides are very different.

Second and third columns: flat triangle for B_S



CP Violation is possible in the Standard Model only if
V_{CKM} is complex ⇔ $\eta \neq 0$ ⇔ Unitarity Triangle is not flat

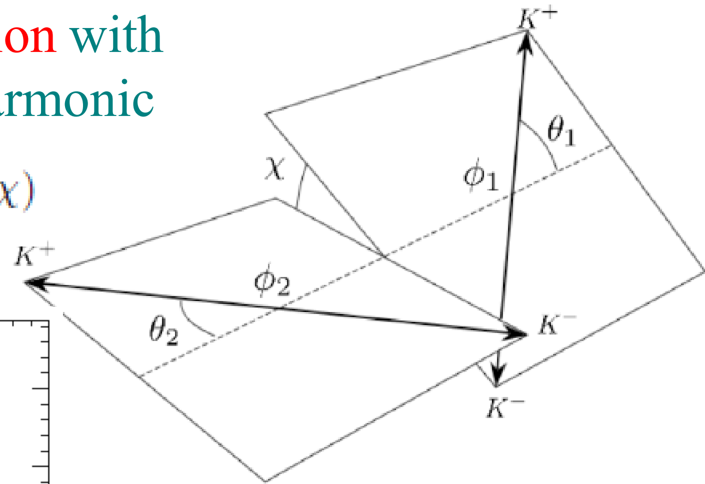
We want to determine ρ and η experimentally

Results: angular study

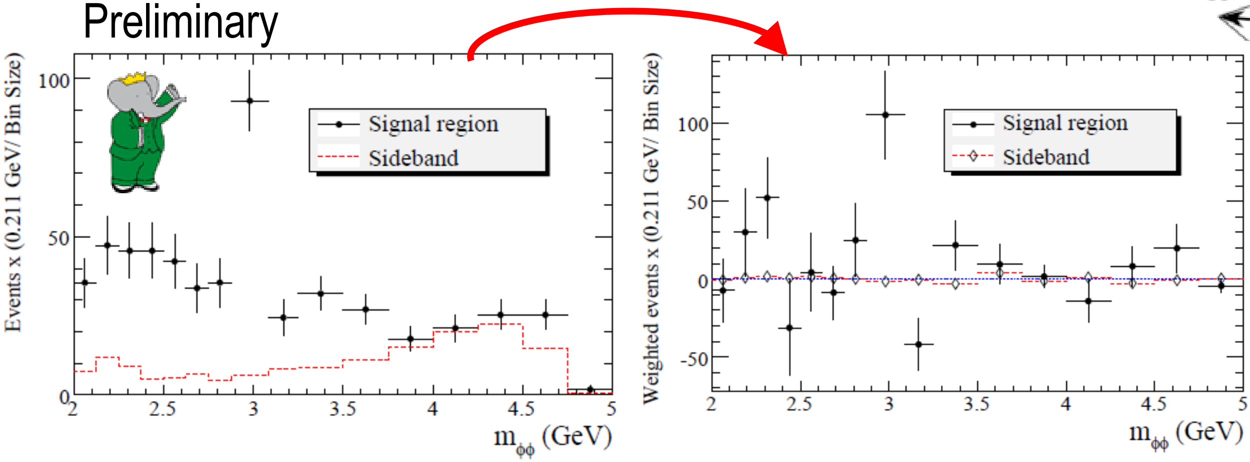
$B \to \phi \phi K$

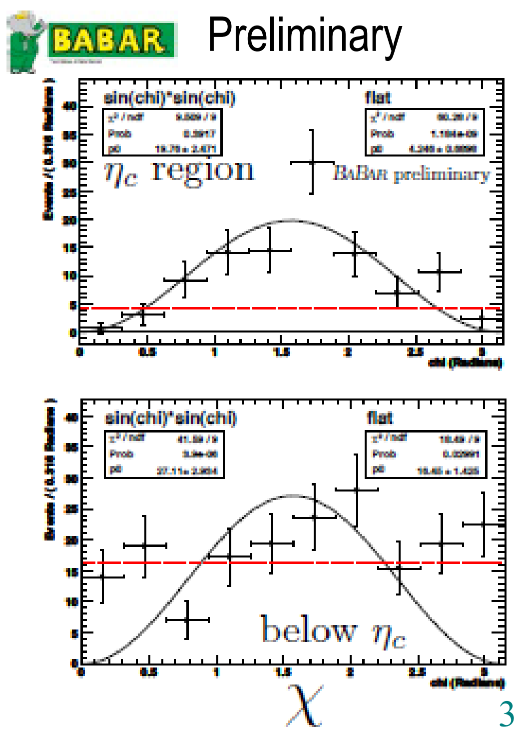
- Project $J^P=0^-$ component by weighting $m_{\phi\phi}$ distribution with the product of Legendre polynomial and spherical harmonic

$$P_2(\cos\theta_1)\ \mathrm{Re}\ [Y_2^2(\theta_2,\chi)] = \frac{25}{4}\{3\cos^2(\theta_1)-1\}\ \sin^2(\theta_2)\ \cos(2\chi)$$



Preliminary





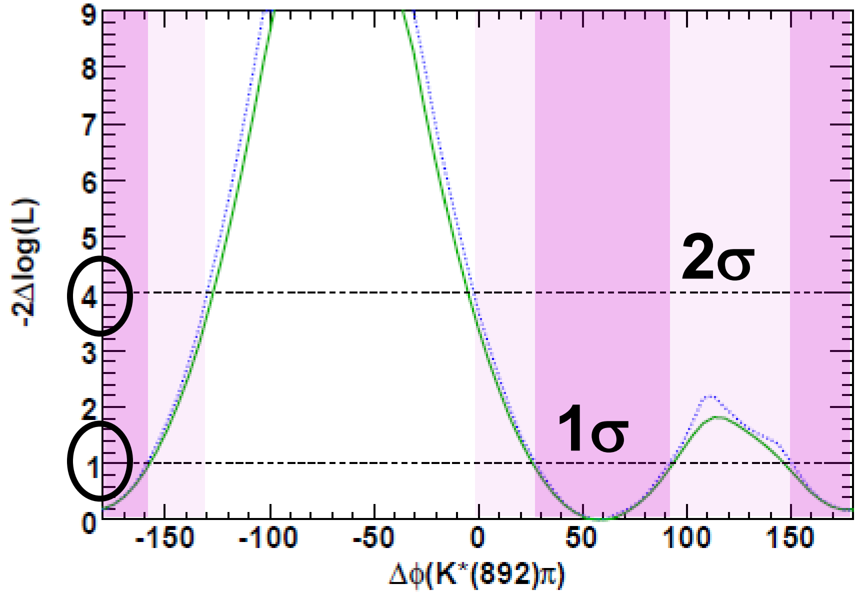
- η_C region: consistent with $J^P=0^-$
- Below η_C region: not consistent with $J^P=0^-$ (but with $J^P=0^+$).

Information from $B^0 \to \pi^+ \pi^- K^0_S$

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

- The likelihood projection (including systematic uncertainties) of the parameters

$$\Delta\Phi(K^*(892)\pi) \equiv \arg(C_{K^{*+}(892)\pi^-}) - \arg(C_{K^{*-}(892)\pi^+})$$



- The constraint (statistically limited):

$-137° < \Delta\phi$ [K*(892) π] $< -5°$ excluded at 95% CL

Extraction of CKM Angle γ

$K^*\pi$ Isospin relations:

$$A(B^0\to K^{*+}\pi^-) = V_{us}V^*_{ub}T^{+-} + V_{ts}V^*_{tb}P^{+-}$$

$$A(B^+\to K^{*0}\pi^+) = V_{us}V^*_{ub}N^{0+} + V_{ts}V^*_{tb}(-P^{+-}+P^C_{EW})$$

$$A(B^+\to K^{*+}\pi^0) = V_{us}V^*_{ub}(T^{+-}+T^{00}-N^{0+}) + V_{ts}V^*_{tb}(P^{+-}-P^C_{EW}+P_{EW})$$

$$\sqrt{2}A(B^0\to K^{*0}\pi^0) = V_{us}V^*_{ub}T^{00} + V_{ts}V^*_{tb}(-P^{+-}+P_{EW})$$

No other hypothesis than Isospin is used

Taking the $B^0\to K^{*+}\pi^-$ and $B^0\to K^{*0}\pi^0$ subsystem

Neglecting P_{EW}, the amplitude combinations:

$$3A_{3/2} = A(B^0\to K^{*+}\pi^-) + \sqrt{2}.A(B^0\to K^{*0}\pi^0) = V_{us}V^*_{ub}(T^{+-}+T^{00})$$

$$3\overline{A}_{3/2} = \overline{A}(\overline{B^0}\to K^{*-}\pi^+) + \sqrt{2}.\overline{A}(\overline{B^0}\to \overline{K}^{*0}\pi^0) = V^*_{us}V_{ub}(T^{+-}+T^{00})$$

Gives: $R_{3/2} = (3A_{3/2})/(3\overline{A}_{3/2}) = e^{-2i\gamma}$

CPS PRD74:051301
GPSZ PRD75:014002

Direct access to γ CKM angle

Extraction of CKM Angle γ

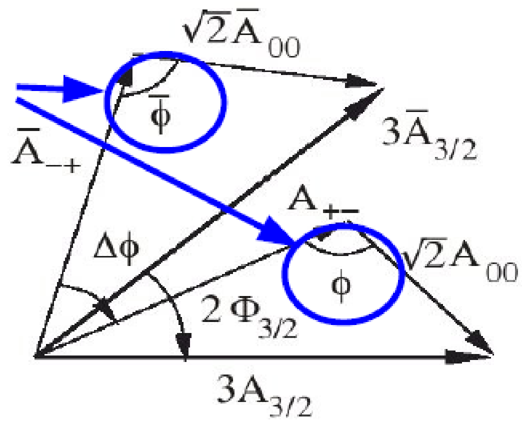
From experiment:

Measurable from $K^+\pi^-\pi^0$ and $K^0_S\pi^+\pi^-$

- $|A(B^0\to K^{*+}\pi^-)|$ and $|A(B^0\to K^{*0}\pi^0)|$
- $|\bar{A}(B^0\to \bar{K}^{*-}\pi^+)|$ and $|\bar{A}(\bar{B}^0\to \bar{K}^{*0}\pi^0)|$

Through BRs and A_{CP}

Measurable from $K^+\pi^-\pi^0$

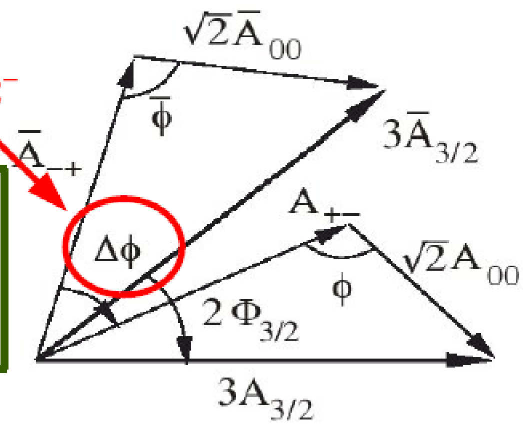


$\phi = \arg(A(B^0\to K^{*+}\pi^-)A^*(B^0\to K^{*0}\pi^0))$

$\bar{\phi} = \arg(\bar{A}(\bar{B}^0\to K^{*-}\pi^+)\bar{A}^*(\bar{B}^0\to \bar{K}^{*0}\pi^0))$

Through interference in the same DP B^0(B^0-bar) plane

Measurable from $K^0_S\pi^+\pi^-$



$\Delta\phi = \arg(\bar{A}(\bar{B}^0\to K^{*-}\pi^+)A^*(B^0\to K^{*+}\pi^-))$

Through interference with other components