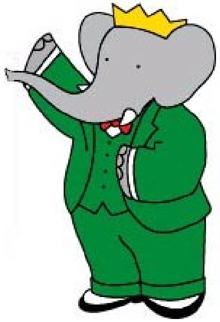
Charm of the charmless – Three-body Hadronic *B* decays at *B*a*B*ar

Gagan Mohanty



Warwick EPP Seminar

October 25, 2007

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Outline of the talk

- Theory and Motivation
- Dataset and Detector
- Analysis Strategy
  - Particle Identification
  - Continuum Suppression
  - Kinematical Variables
- Results
  - $B^+ \rightarrow K^+K^-\pi^+ / K^+\pi^+\pi^- / \pi^+\pi^-\pi^+$
  - $B^0 \rightarrow K_S\pi^+\pi^-$
- Summary and Outlook

Preliminary

History: Timeline (1993)

- 1st observation of charmless B decays by CLEO **PRL 71, 3922 (1993)**

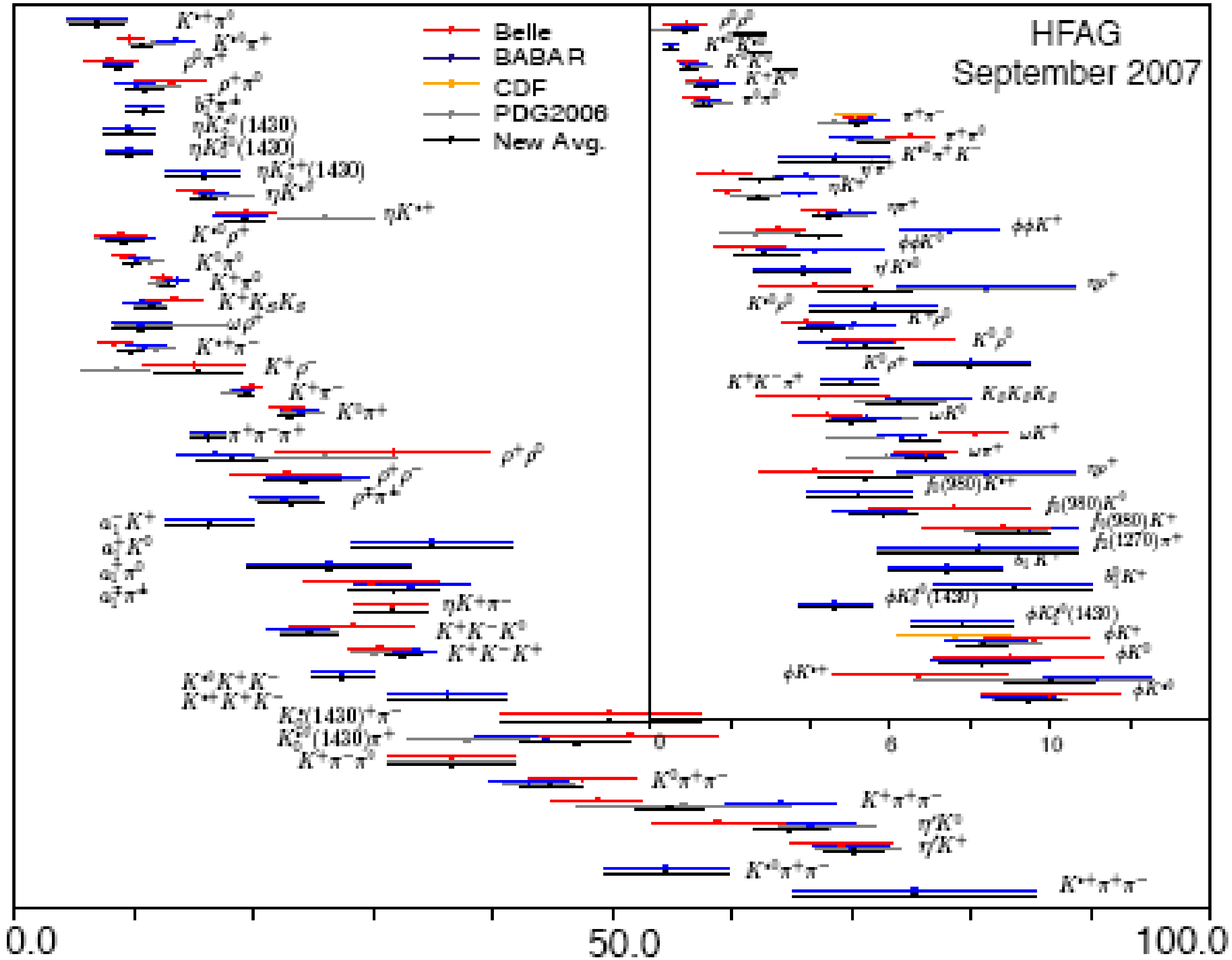
Abstract

We report results from a search for the decays $B^0 \to \pi^+\pi^-$, $B^0 \to K^+\pi^-$, and $B^0 \to K^+K^-$. We find 90% confidence level upper limits on the branching fractions, $B_{\pi\pi} < 2.9 \times 10^{-5}$, $B_{K\pi} < 2.6 \times 10^{-5}$, and $B_{KK} < 0.7 \times 10^{-5}$. While there is no statistically significant signal in the individual modes, the sum of $B_{\pi\pi}$ and $B_{K\pi}$ exceeds zero with a significance of more than four standard deviations, indicating that we have observed charmless hadronic B decays.

PACS numbers: 13.40.Hq, 14.40.Jz

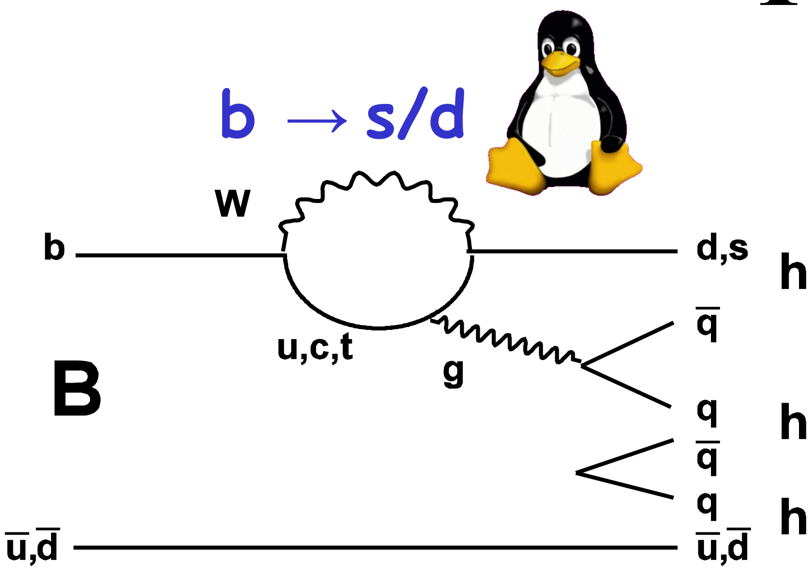
➢ Since then…

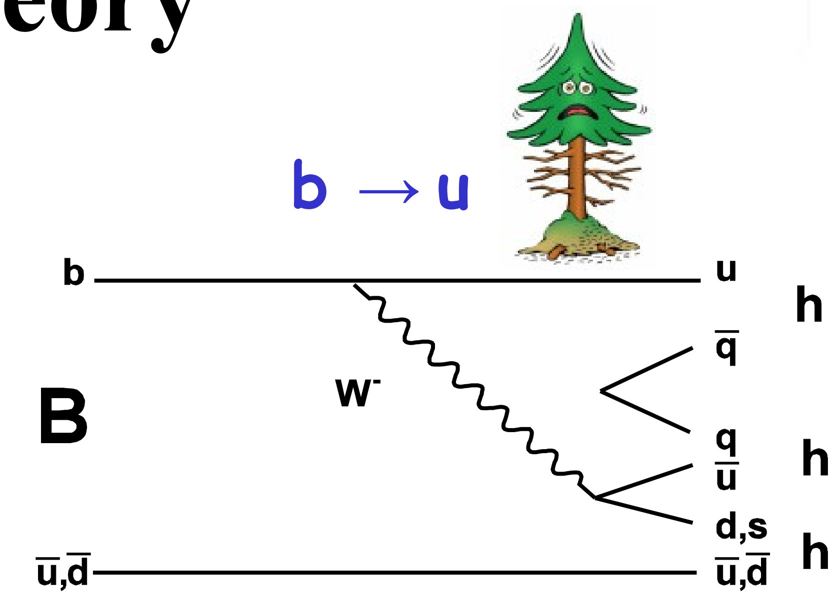
Today: LP2007



http://www.slac.stanford.edu/xorg/hfag/rare/index.html

Theory





- Typical diagrams for charmless three-body *B* decays (h denotes *K* or π)

b → s loop (penguin) transition contributes only to the final states with odd number of kaons due to presence s quark *e.g. Kππ, KKK*

Final states with even number of kaons, such as *KKπ* get contributions from b → u tree and b → d penguin diagrams. Odd number kaon states are further Cabibbo suppressed [~ $\sin\theta_c$]

Motivations

- Interfering tree and penguin amplitudes ➡ good place to search for direct *CP* violation

- New particles can appear in loop diagrams (signature of physics beyond SM)

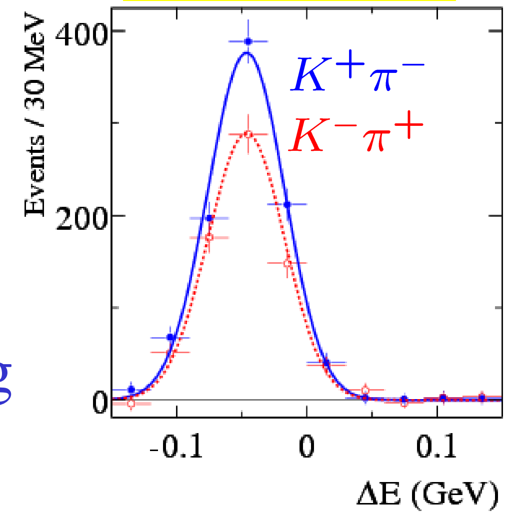
- Probes flavor sector, particularly by measuring
  - sin(2β) or just β in the $K_S h^+ h^-$ (K/π) Dalitz plot
  - α in the modes: ππ, ρπ and ρρ
  - γ using flavour symmetries (isospin, U-spin, *etc*.)

- Low energy spectroscopy

Klempt *et al.*, arXiv:0708.4016

- Testing ground for perturbative QCD, factorization, SU(3) flavor symmetry …

PRL 93, 131801



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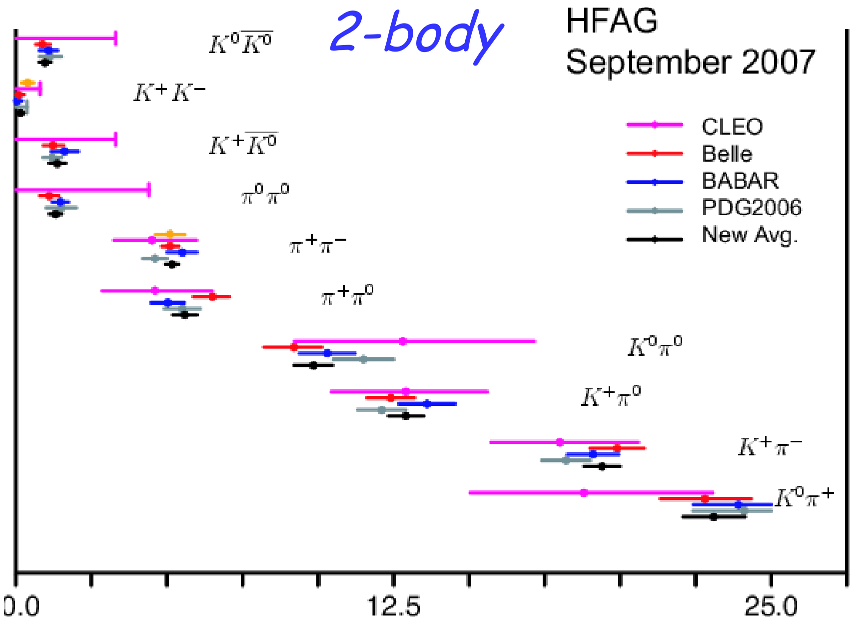
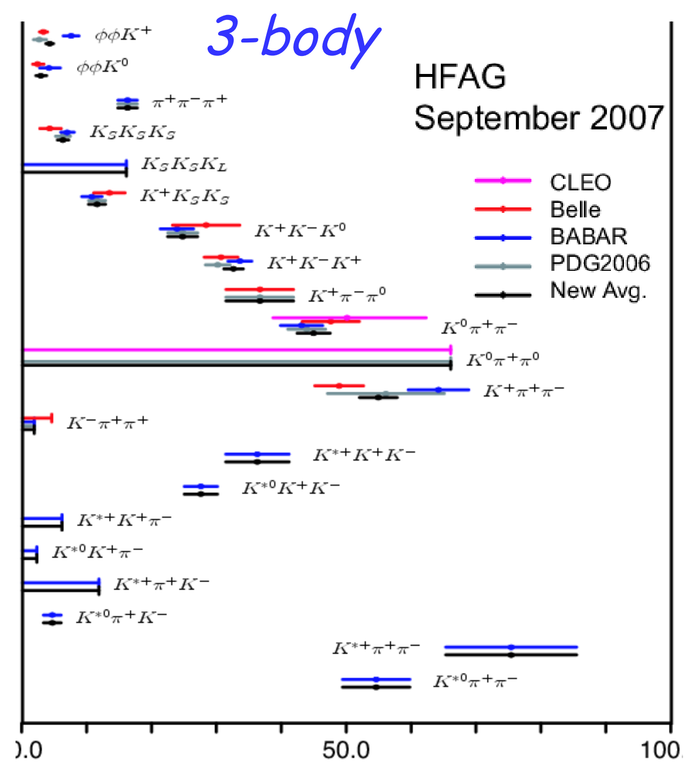
Why three-body?



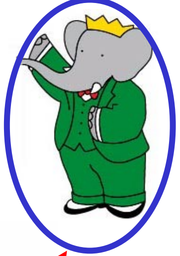
PRO :
- Larger BF than two-body decays
- Correct way to study interference
- Some modes in well-defined CP eigenstate

Gershon, Hazumi PLB 596, 163

CON :
- large phase space with low event density; hard to identify all phase-space structures
- mixture of CP-even, CP-odd final states
- more complicated analysis needed

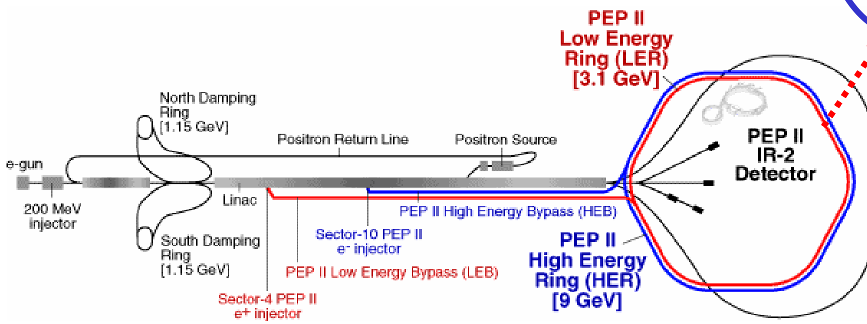


Dataset

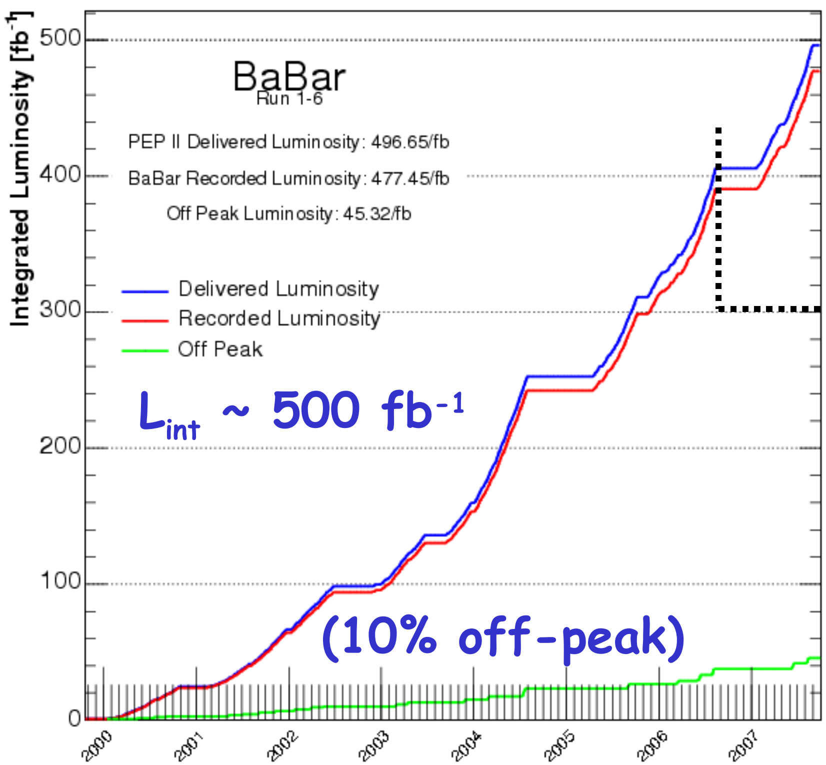


$9\ \text{GeV}\ e^- \rightarrow \Upsilon(4S) \leftarrow 3.1\ \text{GeV}\ e^+$

$\gamma\beta = 0.56 \qquad \langle\Delta z\rangle \sim 260\ \mu m$



- Peak luminosity > 3 X Design



- ✓ Run 6 just ended last month
- New results based on run 1-5 data (other on smaller set)
- ✓ Final run 7 scheduled to start on December 2007

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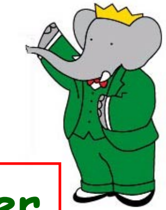
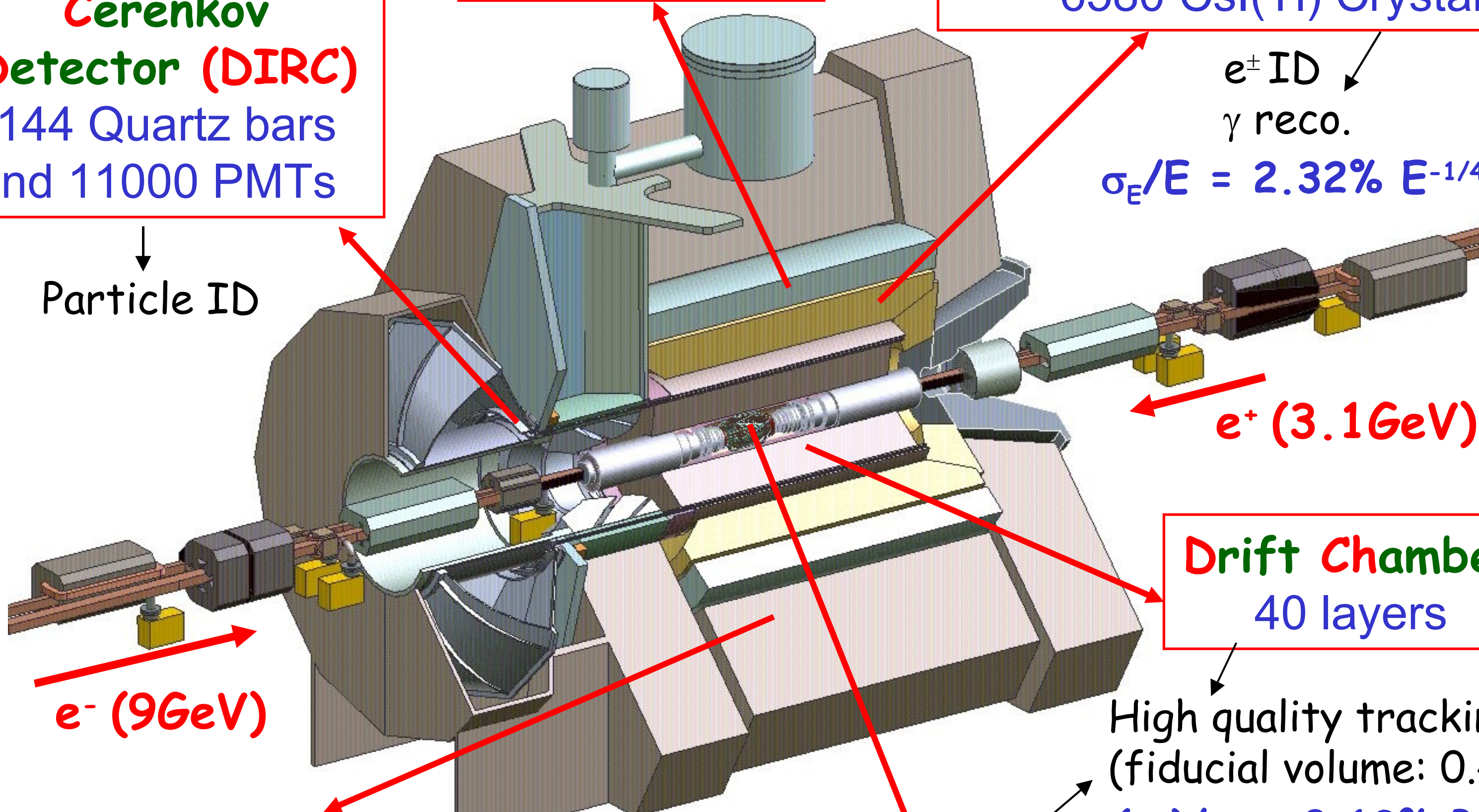


*Ba**B**ar* Detector



1.5T solenoid

Electromagnetic Calorimeter
6580 CsI(Tl) Crystals

$e^{\pm}$ ID
γ reco.
$\sigma_E/E = 2.32\% \, E^{-1/4} \oplus 1.85\%$

Cerenkov Detector (DIRC)
144 Quartz bars
and 11000 PMTs

Particle ID

e^{+} (3.1GeV)

e^{-} (9GeV)

Drift Chamber
40 layers

High quality tracking
(fiducial volume: $0.41 < \theta < 2.54$)
$\sigma(p_T)/p_T = 0.13\% \, P_T \oplus 0.45\%$

Instrumented Flux Return
Resistive Plate Chamber
& Limited Streamer Tube

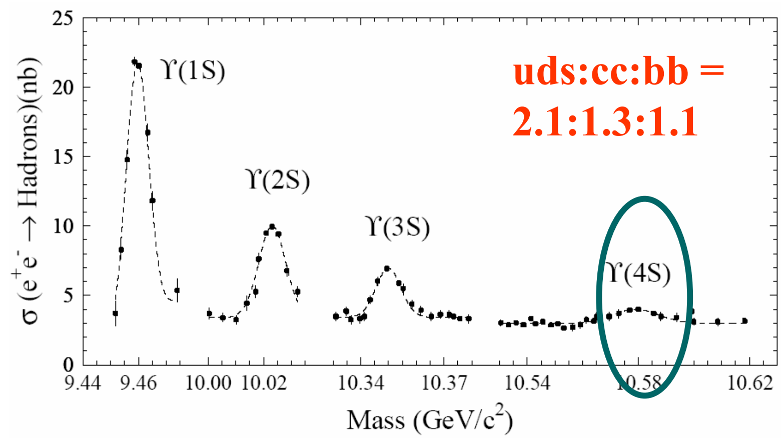
$\mu^{\pm}$ & K_L ID

Silicon Vertex Tracker
five layers, double strip

Analysis Strategy

Inclusive

- Background fighting:
  - ✓ Continuum (event topology)
  - ✓ Other types of *B* decays (PID, charm and charmonia veto)
- Signal extraction (kinematics)



Full (3body)/partial (*Q2B*)

- Dalitz plot technique (three-body decays having reasonable signal size)

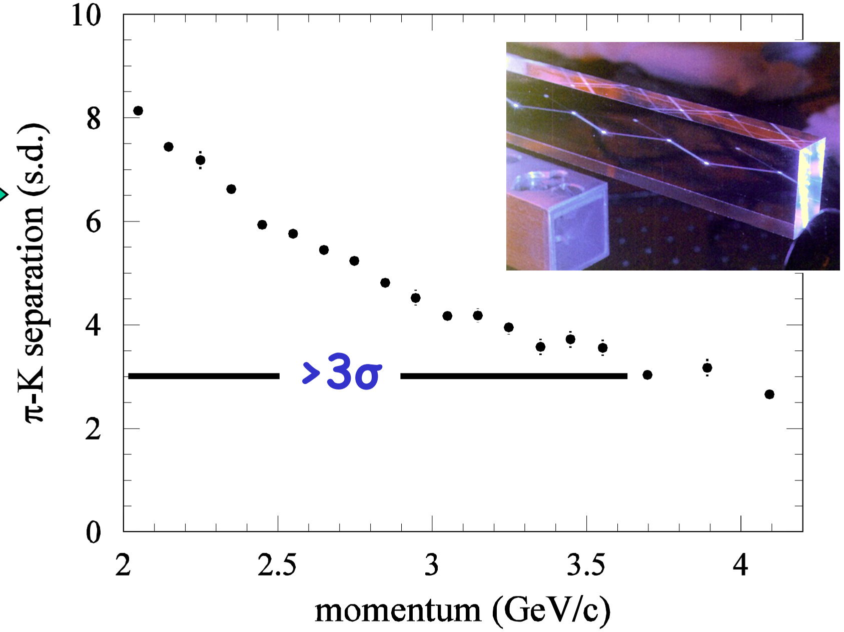
Time-dependent DP (3body)

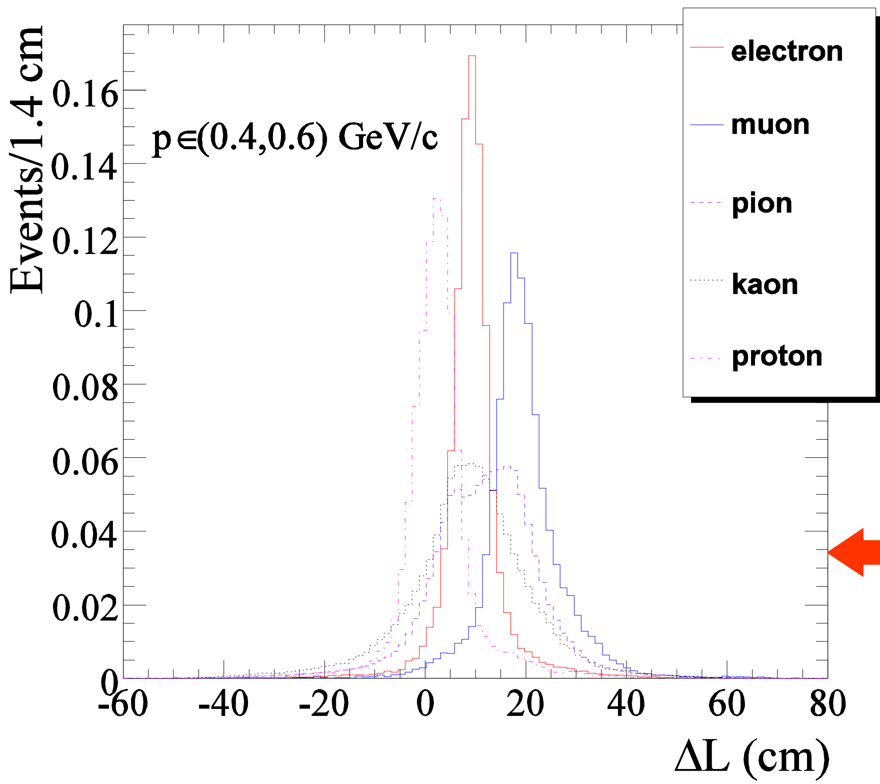
- Time-dependent analysis in neutral *B* meson decays to determine *CP* violation parameters at each point of the phase space

Complexity

Particle Identification

- PID is crucial for these analyses
  - distinguish K *vs.* π
  - veto the leptons



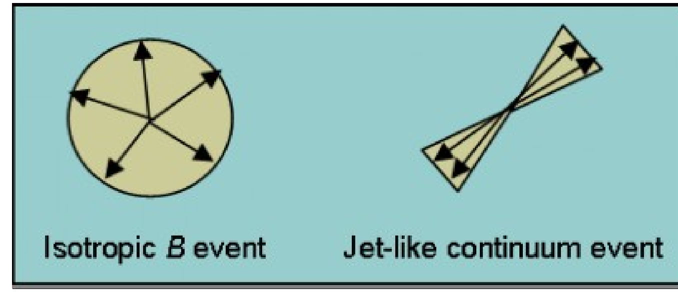


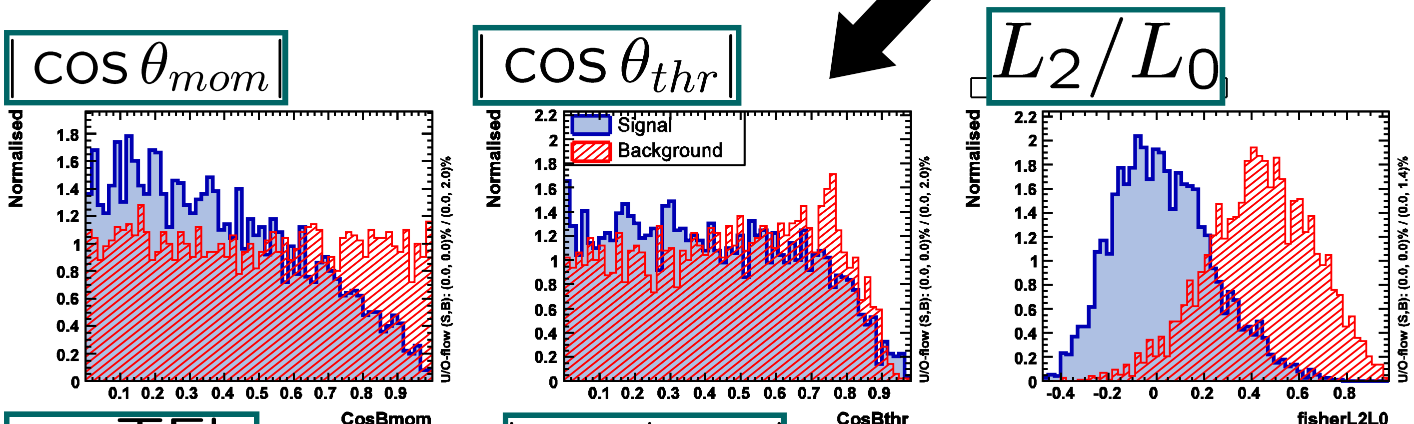
- Always room to improve (NIM article in preparation)

Longitudinal shower depth from an unsegmented EMC

Continuum Suppression

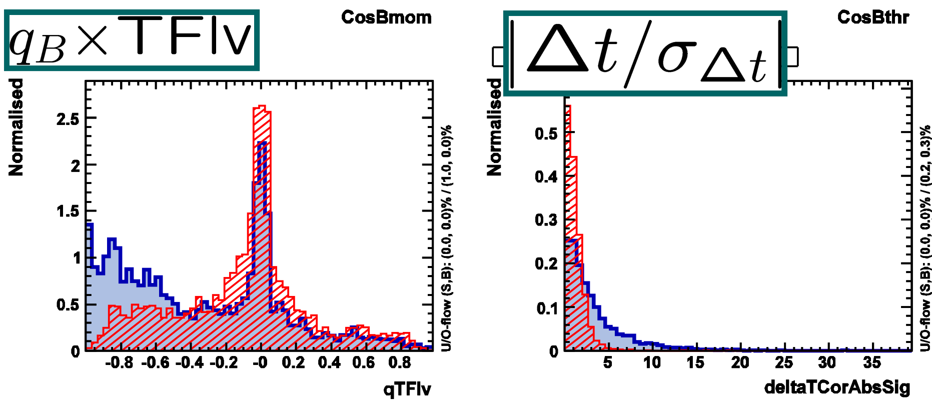
- Event topology
  - B produced at rest (spherical)
  - Jet-like udsc events





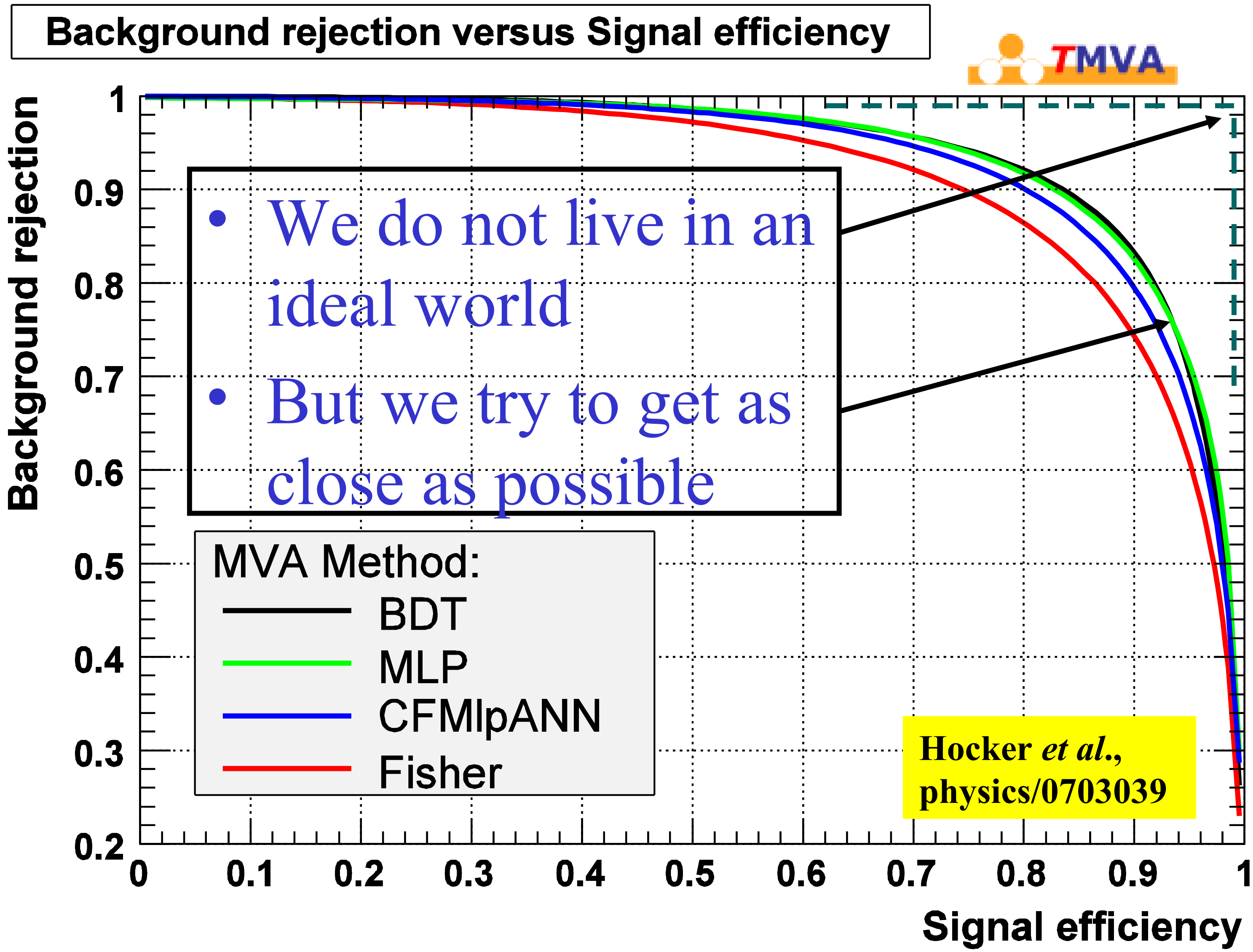
Signal

Background

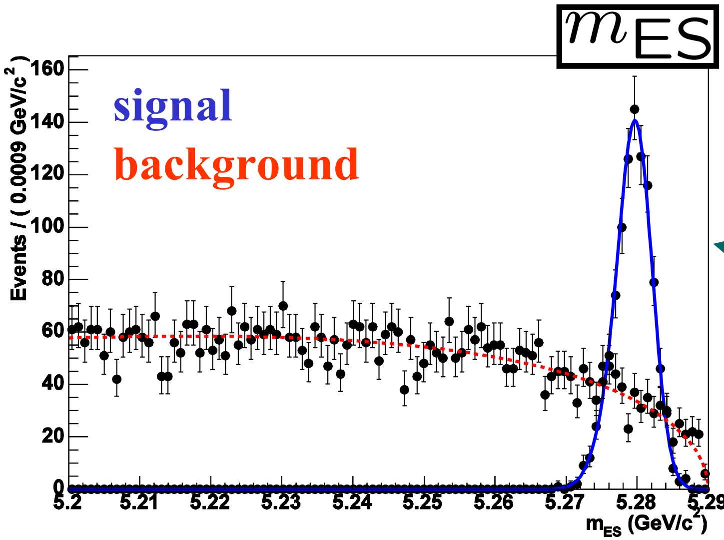


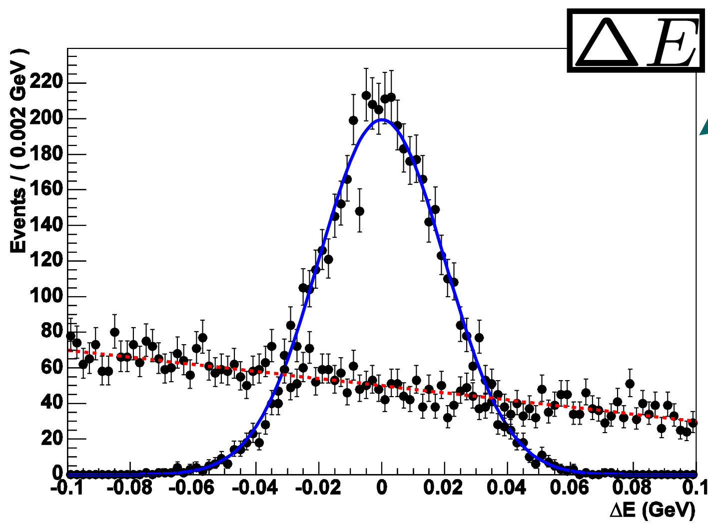
- Flavour and decay-time of the B meson candidate (not used in TD analysis)

Typical Performance



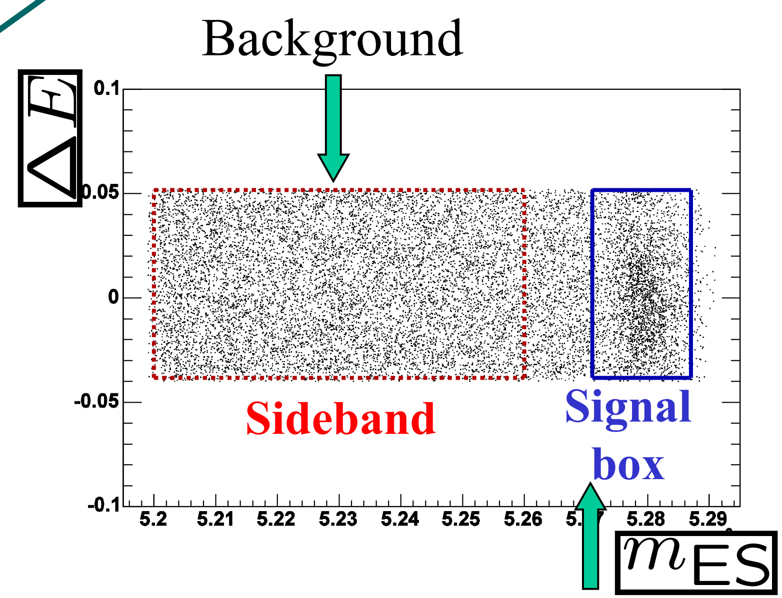
Kinematical Variables





- Utilize precise beam energy information and (E,**p**) conservation

- $m_{\text{ES}} = \sqrt{E^{\star 2}_{\text{beam}} - \mathbf{p}^{\star 2}_{B}}$
- $\Delta E = (E^{\star}_{B} - E^{\star}_{\text{beam}})$



Inclusive/Dalitz plot

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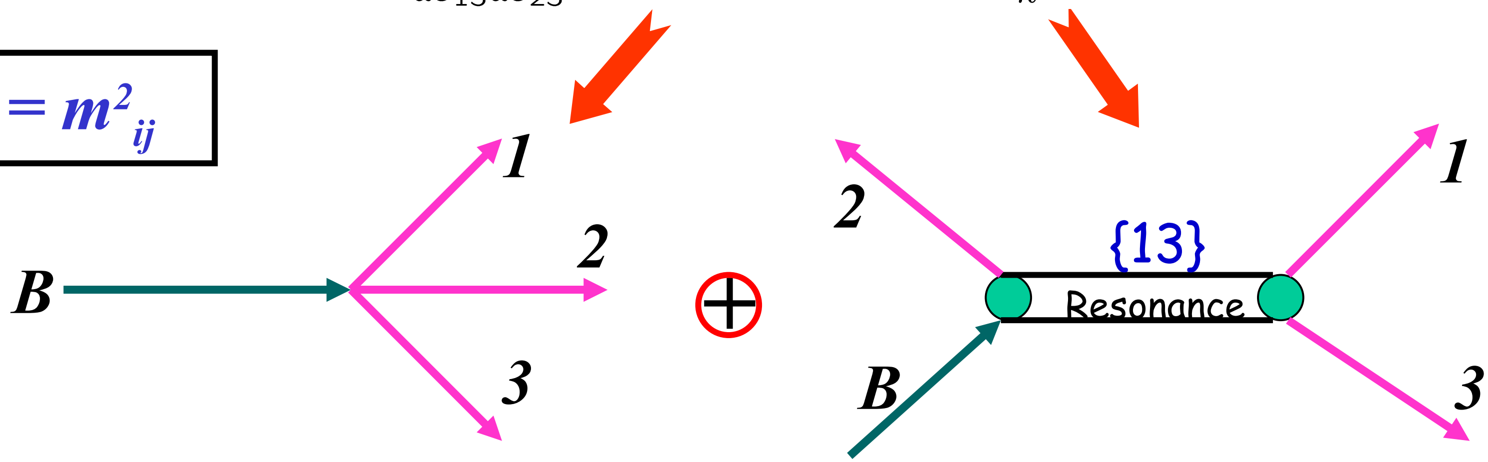
Dalitz-plot Analysis

- Powerful technique relying on Lorentz invariant phase-space variables in a three-body decay

Decay rate, $|\mathcal{A}|^2 = \frac{d\Gamma}{ds_{13}ds_{23}} \propto |c_{NR}e^{i\theta_{NR}} + \sum_k c_k e^{i\theta_k}\mathcal{D}_k(s_{13}, s_{23})|^2$

$$s_{ij} = m^2_{ij}$$



$\mathcal{D}_k = R_k(s_{13}) \times T_k(s_{13}, s_{23})$

$R_k(s_{13}) = \frac{1}{m_0^2 - s_{13} - im_0\Gamma(s_{13})}$ and T_k is the angular term

Zemach, PL133 B1021 (1964)

For single channel BW
$\Gamma = \Gamma_0\left(\frac{q}{q_0}\right)^{2J+1} \frac{m_0}{\sqrt{s_{13}}} \frac{X_J^2(q)}{X_J^2(q_0)}$

For coupled channel BW
$\Gamma = \Gamma_\pi(s_{13}) + \Gamma_K(s_{13})$,
where $\Gamma_h = g_h\sqrt{s_{13} - 4m_h^2}$

Flatte, PLB63, 224 (1973)

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Dalitz-plot Analysis [2]

- Extract $c_{k,NR}$ and $\theta_{k,NR}$ by performing a maximum likelihood fit

$$\mathcal{L}(s_{13}, s_{23}) = f_{sig} \cdot \mathcal{L}_{sig}(\text{Model}, \epsilon_{sig}) + f_{bkg} \cdot \mathcal{L}_{bkg}$$

- Fit fraction is the ratio of the integral of a single decay amplitude squared to the coherent sum of all

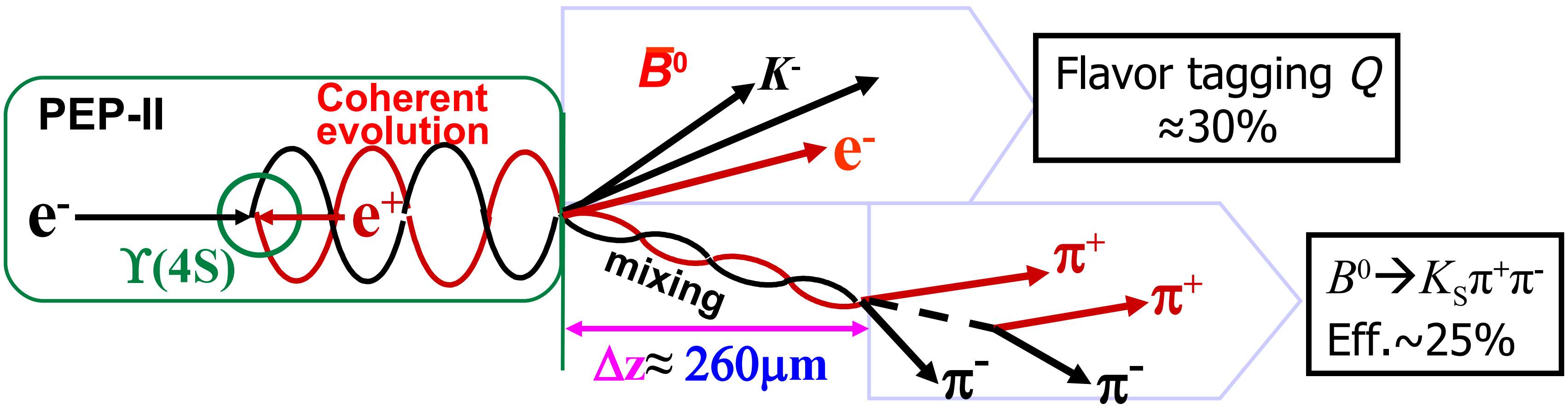
$$\sum_k F_k \neq 1$$

$$\mathcal{B}_k \Leftarrow \left(\frac{N_{sig}}{\bar{\epsilon} N_{B\bar{B}}}\right) \times$$

$$F_k = \frac{\int |c_k e^{i\theta_k} \mathcal{D}_k(s_{13}, s_{23})|^2 ds_{13} ds_{23}}{\int |\sum_j c_j e^{i\theta_j} \mathcal{D}_j(s_{13}, s_{23}) ds_{13} ds_{23}|^2}$$

- Measure *CP* violation asymmetries by comparing *B* and $\bar{B}$ amplitudes

Time-dependent DP



- Time-dependent decay rate of $B^0(\overline{B^0}) \rightarrow$ three-body

$$\Gamma^{\pm}(\Delta t, Q) \propto \left(|\mathcal{A}|^2 + |\bar{\mathcal{A}}|^2\right) \frac{e^{-|\Delta t|/\tau}}{4\tau} \times \left(1 \pm 2Q\,\mathcal{I}m\frac{(\bar{A}A^{\star}e^{-i\phi_{mix}})}{|A|^2+|\bar{A}|^2}\sin(\Delta m \Delta t) \mp Q\frac{|A|^2-|\bar{A}|^2}{|A|^2+|\bar{A}|^2}\cos(\Delta m \Delta t)\right)$$

  - Include detector effects (mistagging and resolution)
- Determine mixing-induced ~~*CP*~~ [sine coefficient] and direct ~~*CP*~~ [cosine coefficient] at each point in the DP
  - $\mathcal{A}(B \rightarrow f) \neq \overline{\mathcal{A}}(\overline{B} \rightarrow \overline{f}))$ ➡ direct ~~*CP*~~

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

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Motivations

- Potentially rich Dalitz structure
- Good place to look for direct ~~*CP*~~ (interference between b→u tree and b→d penguin amplitudes)
- Little experimental information exists ➡ new physics effects not excluded
- Rate and asymmetry in $B^+ \to \bar{K}^{*0}(892)K^+$ are inputs to a method to extract γ

Soni and Suprun, PRD 75, 054006

- Same *Q2B* state helps on understanding observed discrepancy of $\sin(2\beta^{eff})$ in the $B \to \varphi K_S$ mode

Grossman *et al.*, PRD 68, 015004

And... • Surprises do happen

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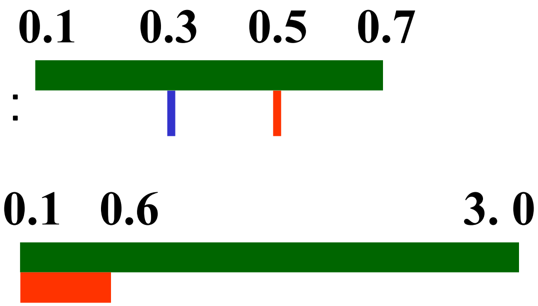
Current Status

Theory

$\mathcal{B}(\overline{K}^{*0}(892)K^{+})[10^{-6}]$:

$\mathcal{B}(\phi(1020)\pi^{+})\ [10^{-8}]$:



Factorization

pQCD

SU(3)

Interesting Lower Limit:

$$\mathcal{B}(B^{+} \to \overline{K}^{*0}(892)K^{+}) > \Xi_{\pi}^{K} \times (0.68^{+0.11}_{-0.13}) \times 10^{-6},$$

Fleischer and Recksiegel

PRD 71, 051501 (2005)

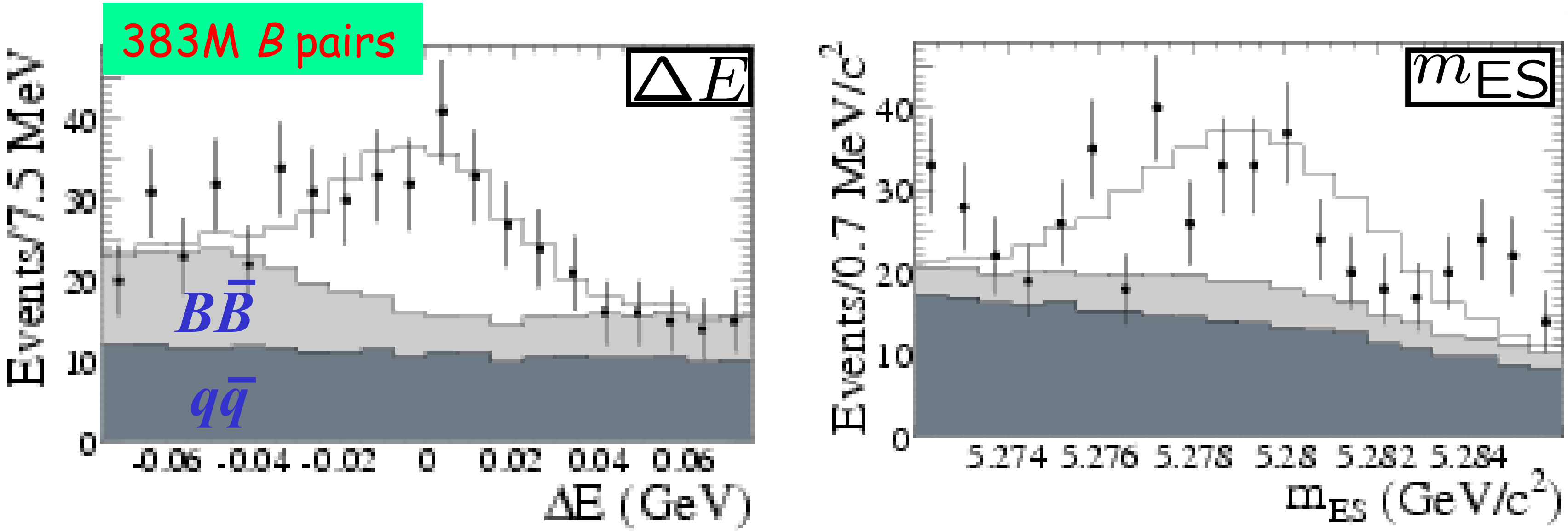
$$\text{with } \Xi_{\pi}^{K} = \left[\frac{f_0^K}{0.331}\frac{0.258}{f_0^{\pi}}\right]^2 \sim 1$$

Experiment

$B^{+} \to$ Mode	Best existing limit	References
$K^{+}K^{-}\pi^{+}$	$< 6.3 \times 10^{-6}$	PRL 91 (2003) 051801 (*)
$f_0(980)\pi^{+}$	$< 3.0 \times 10^{-6}/\mathcal{B}(f_0(980) \to \pi^{+}\pi^{-})$	PRD 72 (2005) 052002
$\phi(1020)\pi^{+}$	$< 2.4 \times 10^{-7}$	PRD 74 (2006) 012001 (*)
$K^{+}\overline{K}^{*0}(892)$	$< 1.1 \times 10^{-6}$	arXiv:0706.1059[hep-ex] (*)
$K^{+}\overline{K}_0^{*0}(1430)$	$< 2.2 \times 10^{-6}$	arXiv:0706.1059[hep-ex]

- Numbers are from *B*a*B*ar, competitive limits also available from Belle and CLEO for the modes indicated by (*)

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



- An unbinned maximum likelihood fit of [m_{ES}, ΔE, NN] to 16143 candidate events finds a signal yield of 429±43
  - 12.6σ (statistical only) and 9.6σ including systematic uncertainty

arXiv:0708.0376, accepted by PRL

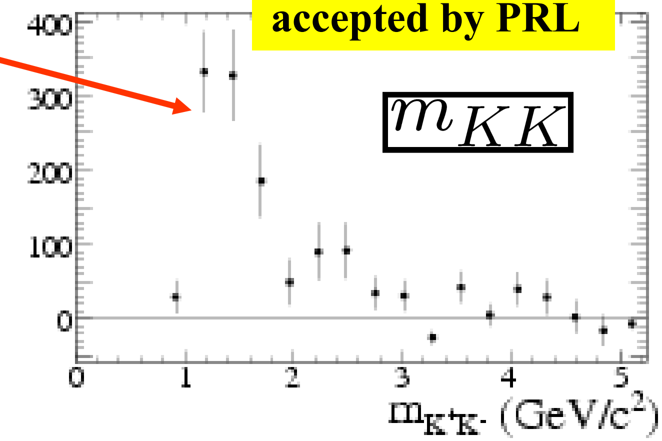
$$\mathcal{B}(B^+ \to K^+K^-\pi^+) : (5.0 \pm 0.5 \pm 0.5) \times 10^{-6}$$

$$A_{CP} = 0.00 \pm 0.10 \pm 0.03$$

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

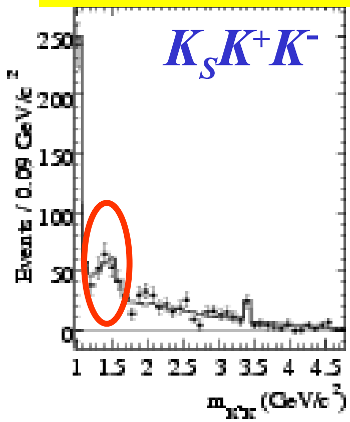
- ✓ Half of the events originates from
- ✓ Reminiscent of similar structures in $K_sK^+K^-$ and $K^+K^+K^-$

arXiv:0708.0376, accepted by PRL

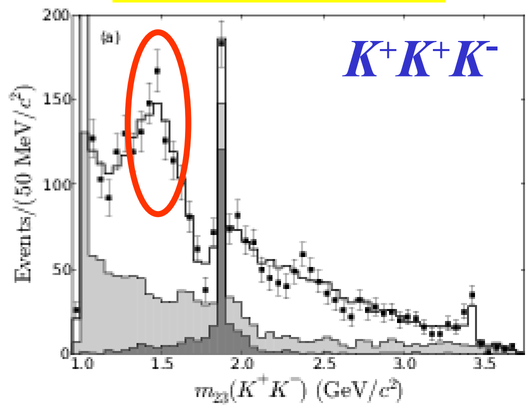


Efficiency-corrected distribution

arXiv:0706.3885, accepted by PRL



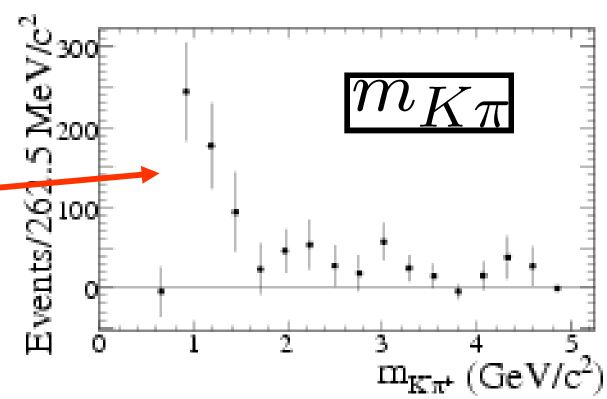
PRD 74, 032003



➢ Nature of this state around 1.5GeV/c² is not very clear

- ✓ Rate reasonably consistent with the Q2B results on $K^{*0}K$

arXiv:0708.2248, accepted by PRD(R)



Efficiency-corrected distribution

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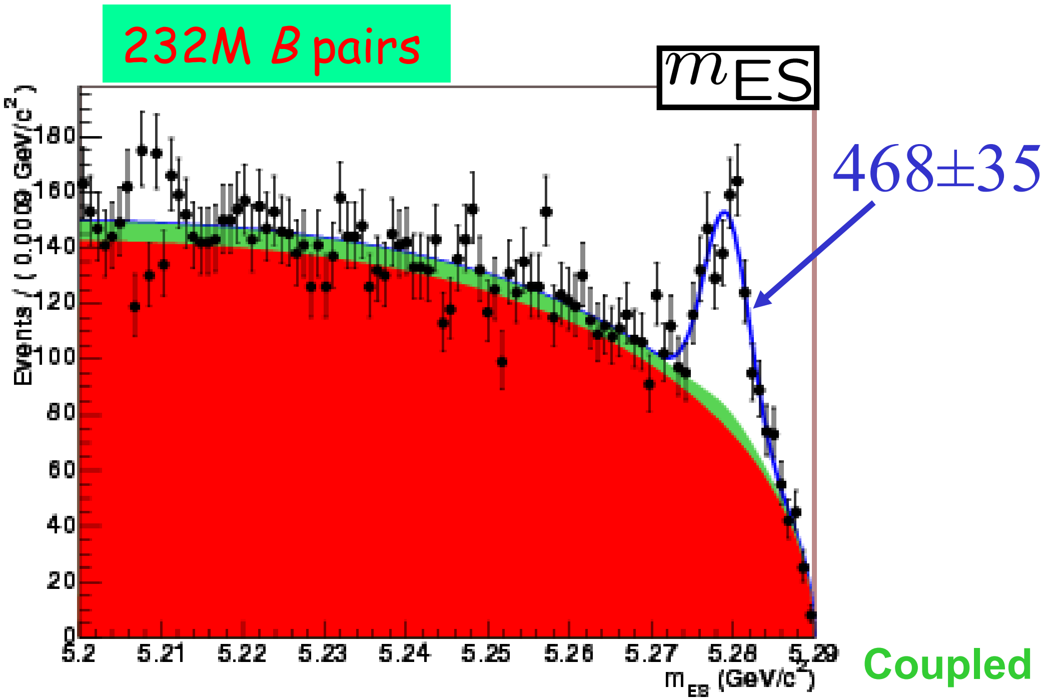
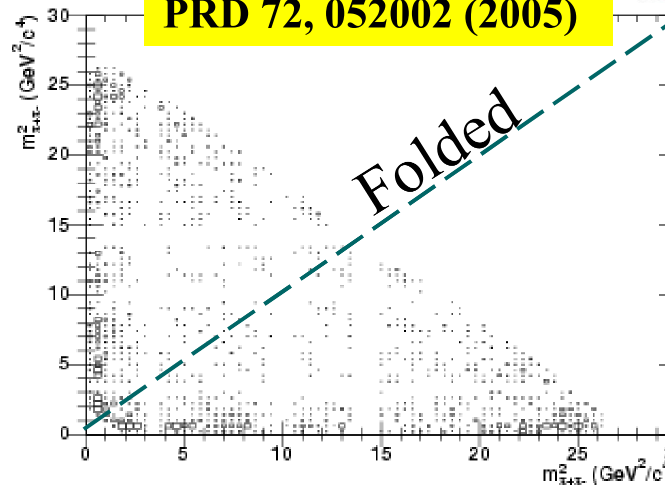
Dalitz plot analyses of $B^+ \rightarrow K^+\pi^+\pi^-$ and $\pi^+\pi^-\pi^+$

$B^+ \to \pi^+\pi^+\pi^-$ Dalitz plot



PRD 72, 052002 (2005)

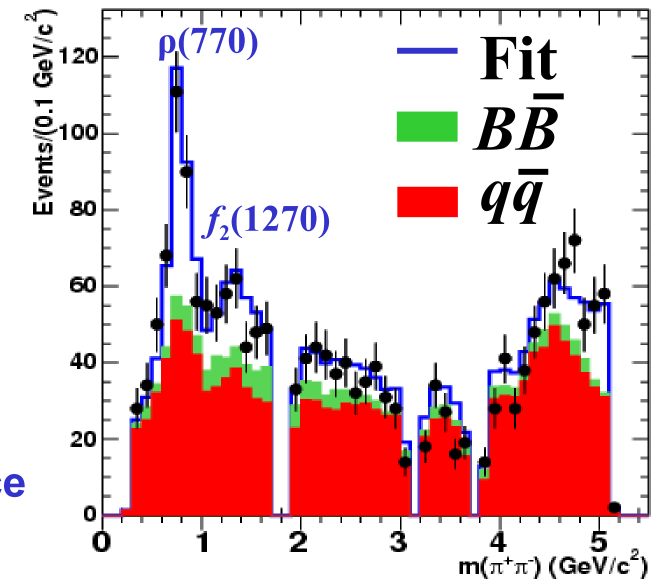


Coupled BW

$$\text{Signal} \equiv \rho^0(770) + f_0(980) + f_2(1270) + \rho^0(1450) + NR$$

Single BW

Phase-space



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$B^+ \to \pi^+\pi^+\pi^-$: Summary

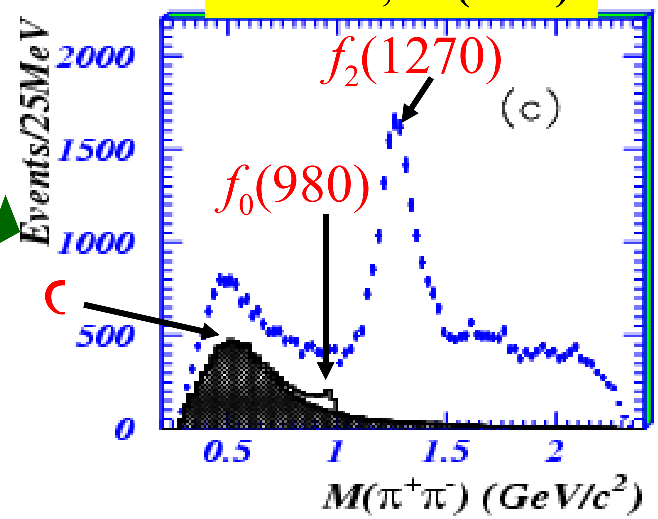
PRD 72, 052002 (2005)

Mode	$\mathcal{B}(B^\pm \to$ Mode (10^{-6})	90% CL UL $\mathcal{B}$ (10^{-6})	A_{CP} (%)
$B^\pm \to \pi^\pm\pi^\pm\pi^\mp$ total	$16.2 \pm 1.2 \pm 0.9$	–	$-0.7 \pm 7.7 \pm 2.5$
$\rho^0(770)\pi^\pm, \rho^0(770) \to \pi^+\pi^-$	$8.8 \pm 1.0 \pm 0.6^{+0.1}_{-0.7}$	–	$-7.4 \pm 12.0 \pm 3.4^{+0.6}_{-4.4}$
$f_2(1270)\pi^\pm, f_2(1270) \to \pi^+\pi^-$	$2.3 \pm 0.6 \pm 0.2 \pm 0.3$	< 3.5	$-0.4 \pm 24.7 \pm 2.8^{+0.4}_{-1.6}$
$B^\pm \to \pi^\pm\pi^\pm\pi^\mp$ Nonresonant	$2.3 \pm 0.9 \pm 0.3 \pm 0.4$	< 4.6	$+8.0 \pm 41.2 \pm 6.5 \pm 2.4$
$\rho^0(1450)\pi^\pm, \rho^0(1450) \to \pi^+\pi^-$	$1.0 \pm 0.6 \pm 0.2 \pm 0.2$	< 2.3	$+15.5 \pm 62.1 \pm 7.9^{+0.4}_{-1.0}$
$f_0(980)\pi^\pm, f_0(980) \to \pi^+\pi^-$	$1.2 \pm 0.6 \pm 0.1 \pm 0.4$	< 3.0	$-49.5 \pm 53.7 \pm 4.9^{+3.7}_{-2.9}$
$\chi_{c0}\pi^\pm, \chi_{c0} \to \pi^+\pi^-$	–	< 0.3	–
$f_0(1370)\pi^\pm, f_0(1370) \to \pi^+\pi^-$	–	< 3.0	–
$\sigma\pi^\pm, \sigma \to \pi^+\pi^-$	–	< 4.1	–

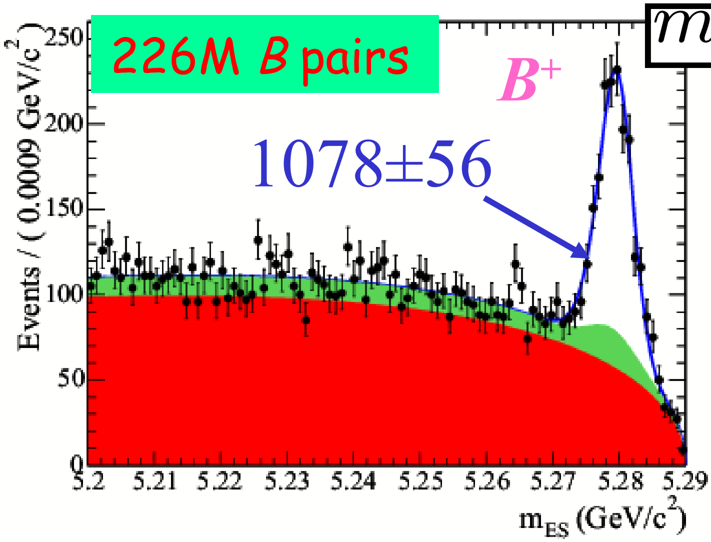
- ✓ $\rho^0(770)$ is the dominant component
- ❑ 3σ indication for $f_2(1270)$ and *NR*
- ❖ Little evidence for σ (seen by BES in the decay $J/\psi \to \omega\pi^+\pi^-$)
- ➢ No contribution from χ_{c0} ➡ not feasible to measure γ with analysed dataset

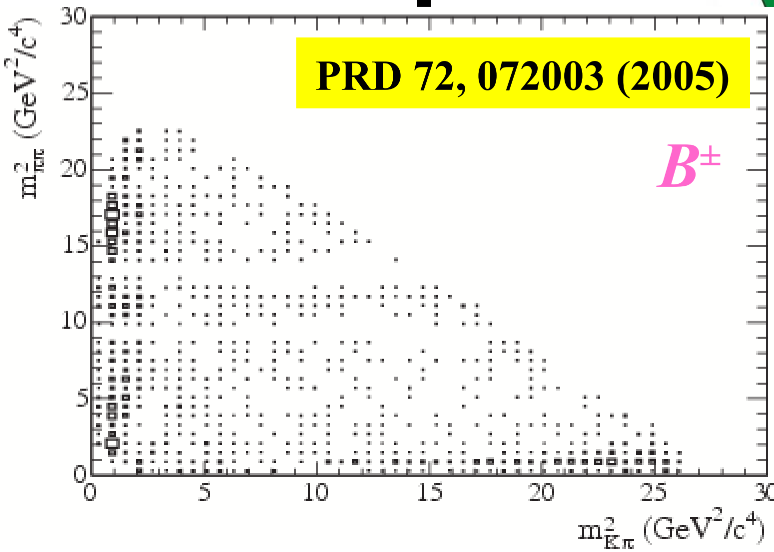
Bediaga *et al.*, PRL 81, 4067 (1998)

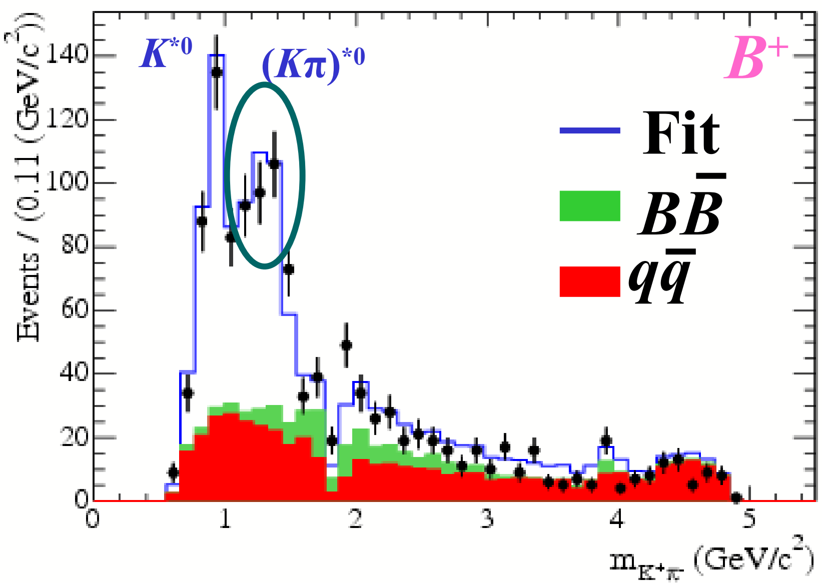
PLB 597, 39 (2004)

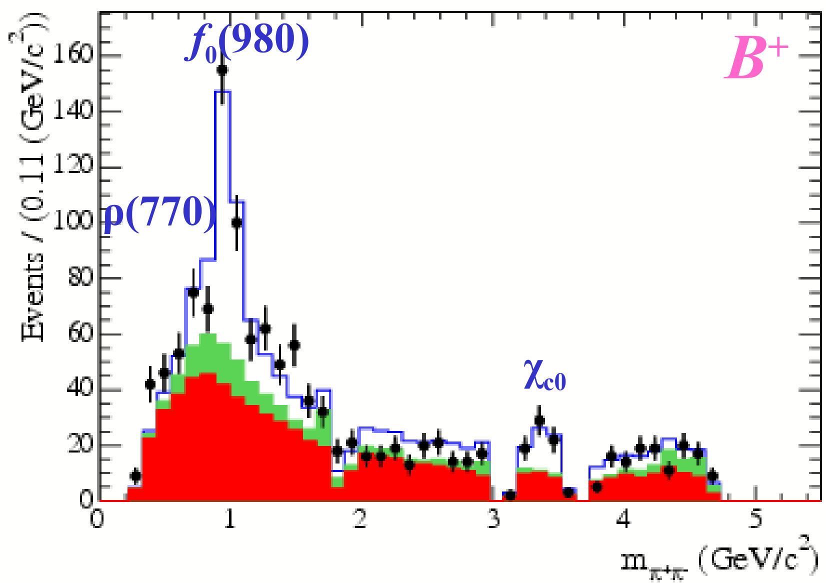


$B^+ \to K^+\pi^+\pi^-$: Dalitz plot









Signal $\equiv K^{\star 0}(892) + (K\pi)^{\star 0}_0 + f_0(980) + \rho^0(770) + \chi_{c0} + NR$

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$B^+ \rightarrow K^+\pi^+\pi^-$: Summary

PRD 72, 072003 (2005)

Mode	$\mathcal{B}(B^\pm \to \text{Mode})$ (10^{-6})	90% CL UL $\mathcal{B}$ (10^{-6})	A_{CP} (%)
$B^\pm \to K^\pm\pi^\pm\pi^\mp$ total	$64.1 \pm 2.4 \pm 4.0$	–	$-1.3 \pm 3.7 \pm 1.1$
$K^{\star 0}(892)\pi^\pm$, $K^{\star 0}(892) \to K^+\pi^-$	$8.99 \pm 0.78 \pm 0.48^{+0.28}_{-0.39}$	–	$6.8 \pm 7.8 \pm 5.7^{+4.0}_{-3.5}$
$(K\pi)^{\star 0}_0\pi^\pm$, $(K\pi)^{\star 0}_0 \to K^+\pi^-$	$34.0 \pm 1.7 \pm 1.5^{+1.2}_{-1.6}$	–	$-6.4 \pm 3.2 \pm 2.0^{+1.1}_{-1.7}$
$f_0(980)K^\pm$, $f_0(980) \to \pi^+\pi^-$	$9.47 \pm 0.97 \pm 0.46^{+0.42}_{-0.75}$	–	$8.8 \pm 9.5 \pm 2.6^{+9.3}_{-5.0}$
$\rho^0(770)K^\pm$, $\rho^0(770) \to \pi^+\pi^-$	$5.07 \pm 0.75 \pm 0.35^{+0.42}_{-0.68}$	–	$32 \pm 13 \pm 6^{+8}_{-5}$
$\chi_{c0}K^\pm$, $\chi_{c0} \to \pi^+\pi^-$	$0.66 \pm 0.22 \pm 0.07 \pm 0.03$	< 1.1	–
$B^\pm \to K^\pm\pi^\pm\pi^\mp$ Nonresonant	$2.85 \pm 0.64 \pm 0.41^{+0.70}_{-0.34}$	< 6.5	–
$K^{\star 0}_2(1430)\pi^\pm$, $K^{\star 0}_2(1430) \to K^+\pi^-$	–	< 7.7	–
$K^{\star 0}(1680)\pi^\pm$, $K^{\star 0}(1680) \to K^+\pi^-$	–	< 3.8	–
$f_2(1270)K\pm$, $f_2(1270) \to \pi^+\pi^-$	–	< 8.9	–
$f_0(1370)K^\pm$, $f_0(1370) \to \pi^+\pi^-$	–	< 10.7	–
$\rho^0(1450)K^\pm$, $\rho^0(14570) \to \pi^+\pi^-$	–	< 11.7	–
$f_0(1500)K^\pm$, $f_0(1500) \to \pi^+\pi^-$	–	< 4.4	–
$f'_2(1525)K^\pm$, $f'_2(1525) \to \pi^+\pi^-$	–	< 3.4	–

- Total BF differs significantly from Belle $(48.8 \pm 1.1 \pm 3.6) \cdot 10^{-6}$

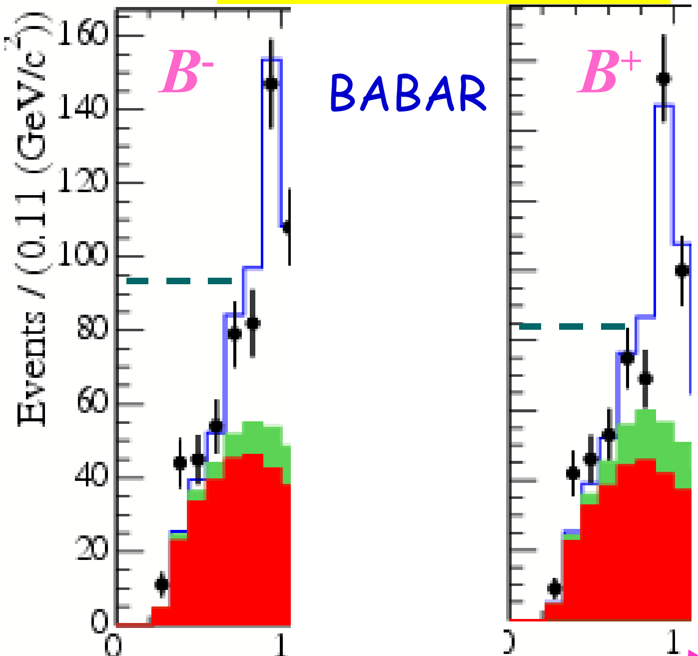
PRL 96, 251803 (2006)

- $(K\pi)^{*0}$ ➡ $K^{*0}(1430)$ resonance + Effective range nonresonant component (Belle uses $K^{*0}(1430)$ only)

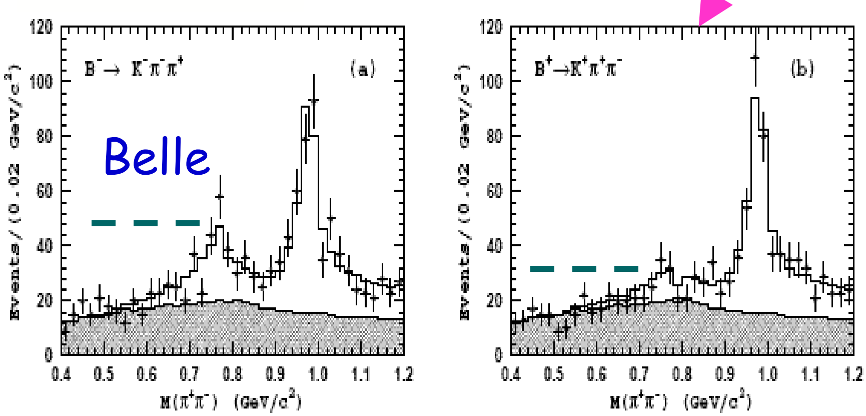
- Evidence for direct *CP* violation in the $\rho^0(770)K^\pm$ mode

~~CP~~ in charged *B* decays?

PRD 72, 072003 (2005)



$N(B\overline{B})$ $\times 10^6$	Total yield [$\rho^0 K^\pm$ frac]	$A_{CP}(\rho^0 K^\pm)$ in %
226	2125 ± 79 [$\sim 8\%$]	$32 \pm 13 \pm 6^{+8}_{-5}$
386	4286 ± 110 [$\sim 8\%$]	$30 \pm 11 \pm 2^{+11}_{-4}$



PRL 96, 251803 (2006)

✓ Large A_{CP} in agreement with predictions based on flavour SU(3) symmetry (19-24)%

Chiang *et al.*, PRD 69, 034001 (2004)

➢ Interesting to see the results with higher statistics…

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Time-dependent Dalitz plot analysis of $B^0 \rightarrow K_S\pi^+\pi^-$

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Motivations

- Dominantly $b \to s$ penguin transition ➡ prone to NP effect
- Provides a test if mixing-induced ~~*CP*~~ asymmetry equals to that of tree-level transition $b \to c\bar{c}s$
- Measure β^{eff} in *Q2B* modes unambiguously ➡ interference term allows determination of cosine term (beauty of DP)
- We can determine the relative phase between $B^0 \to K^{*+}(892)\pi^-$ and $\bar{B}^0 \to K^{*-}(892)\pi^+$ ➡ access to CKM angle γ

Deshpande *et al.*, PRL 90, 061802 (2003)
Ciuchini *et al.*, PRD 74, 051301 (2006)
Gronau *et al.*, PRD 75, 014002 (2007)

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Existing Measurements

Time-dependent *Q2B*

CP parameters	BaBar hep-ex/0408095	Belle hep-ex/0507037
$S(f_0(980)K_S^0)$	$-0.95^{+0.32}_{-0.23} \pm 0.10$	$-0.47 \pm 0.36 \pm 0.08$
$C(f_0(980)K_S^0)$	$-0.24 \pm 0.31 \pm 0.15$	$-0.23 \pm 0.23 \pm 0.13$
$S(\rho^0(770)K_S^0)$	$0.20 \pm 0.52 \pm 0.24$	–
$C(\rho^0(770)K_S^0)$	$0.64 \pm 0.41 \pm 0.20$	–

	Time-integrated *Q2B*	**Time-integrated DP**
$\mathcal{B}(B^0 \to \text{Mode})[10^{-6}]$	BaBar PRD 73, 031101	Belle PRD 75, 012006
$K_S^0\pi^+\pi^-$	$43.0 \pm 2.3 \pm 2.3$	$47.5 \pm 2.4 \pm 3.7$
$f_0(980)(\to \pi^+\pi^-)K_S^0$	$5.5 \pm 0.7 \pm 0.5 \pm 0.3$	$7.6 \pm 1.7 \pm 0.7^{+0.5}_{-0.7}$
$\rho^0(770)K_S^0$	–	$6.1 \pm 1.0 \pm 0.5^{+0.6}_{-0.4}$
$K^{*+}(892)\pi^-$	$11.0 \pm 1.5 \pm 0.5 \pm 0.5$	$8.4 \pm 1.1 \pm 0.8^{+0.6}_{-0.4}$
$K_0^{*+}(1430)\pi^-$	–	$49.7 \pm 3.8 \pm 6.7^{+1.2}_{-4.8}$
nonresonant $K_S^0\pi^+\pi^-$	< 2.1 @ 90% CL	$19.9 \pm 2.5 \pm 1.6^{+0.7}_{-1.2}$
$\mathcal{A}_{CP}(K^{*+}\pi^-)$	$-0.11 \pm 0.14 \pm 0.05$	–

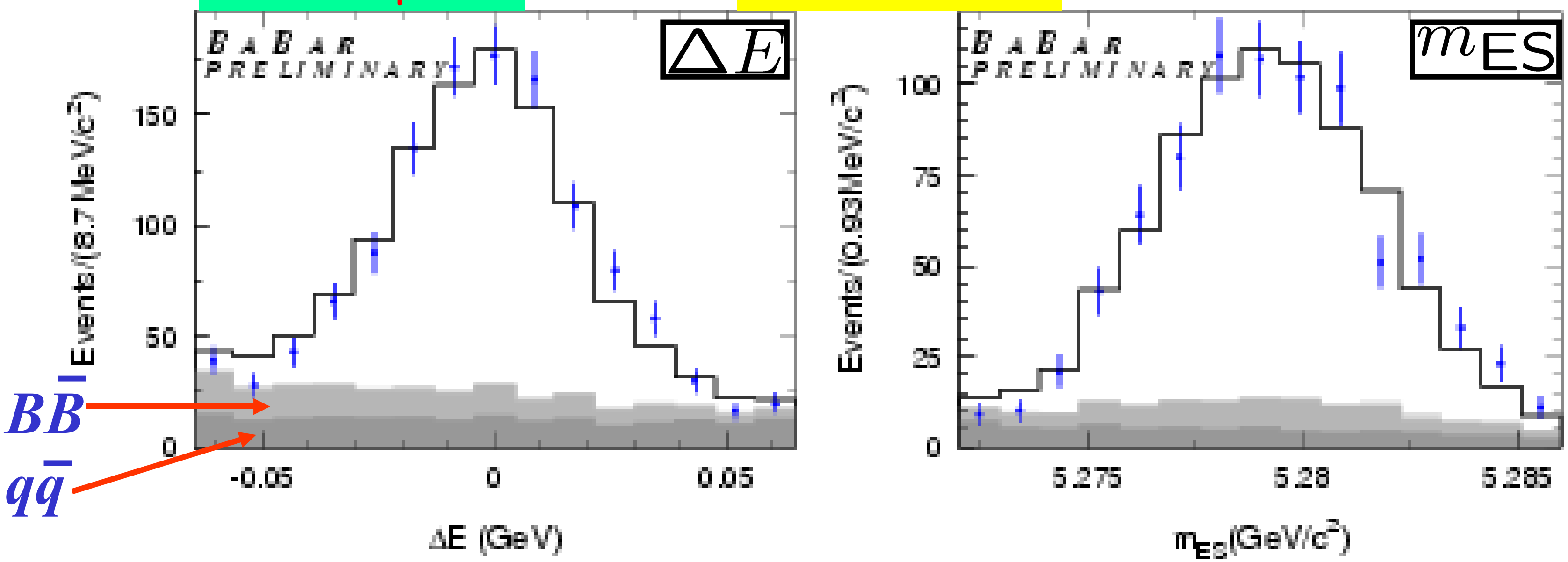
- Both agree reasonably well
  - Discrepancy in the nonresonant contribution
  - Belle also observes structure near 1.3 GeV/c² in the $\pi^+\pi^-$ spectrum

Signal Yield

- Simultaneous fit including
  - m_{ES}, ΔE, NN, Δt and tagged ($B^0/\overline{B^0}$) DP variables

arXiv:0708.2097
Contrib. LP2007

383M *B* pairs

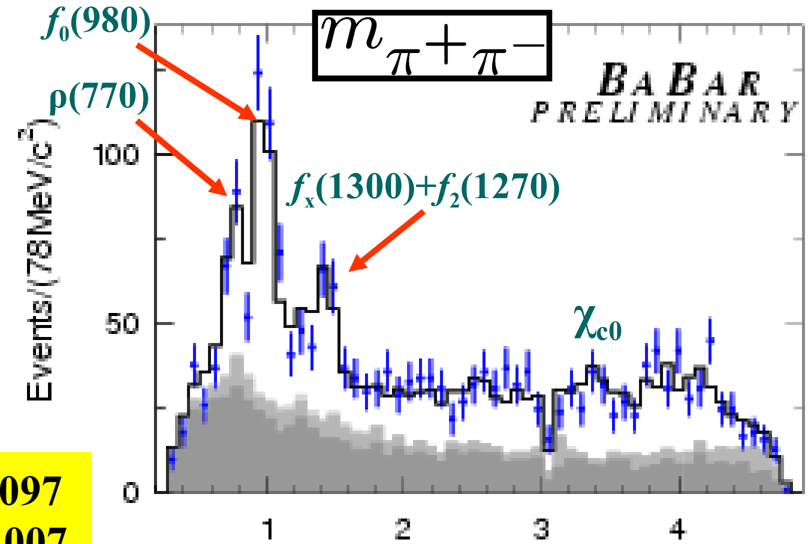


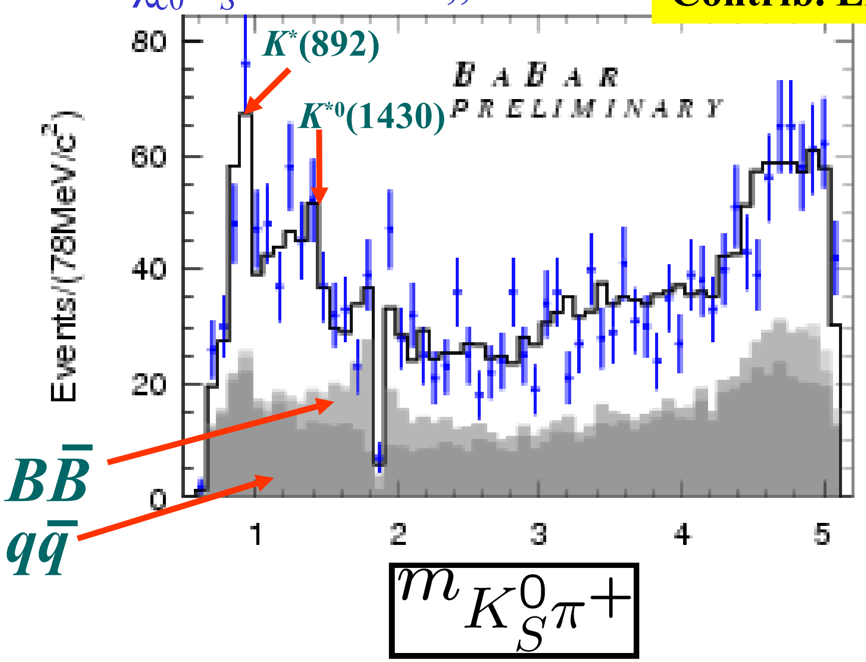
➢ Signal: (2172±70) in total candidate sample of 22525

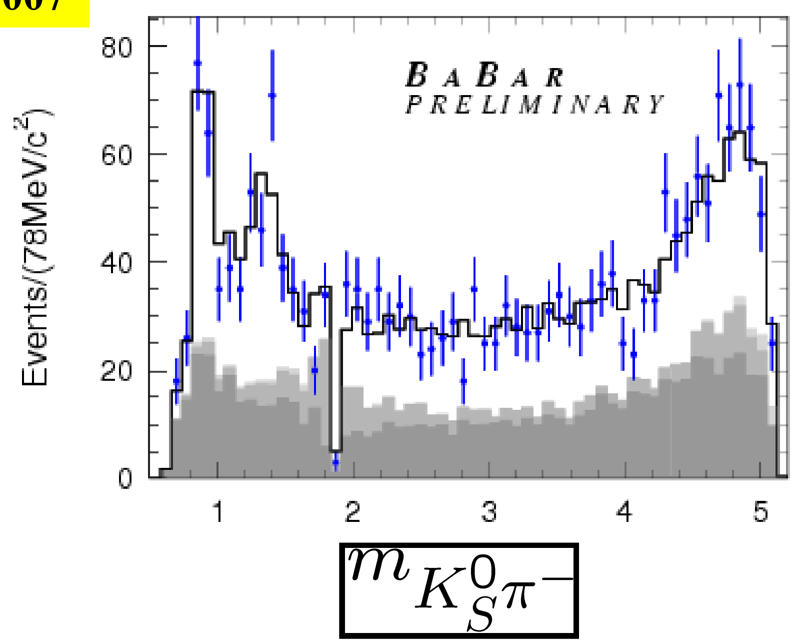
Dalitz plot Content

- $\rho^0(770)K_S$ Gounaris-Sakurai
- $f_0(980)K_S$ Coupled BW
- $K^*(892)\pi$ Single BW
- $K^{*0}(1430)\pi$ LASS shape
- $f_x(1300)K_S$ Single BW
- $f_2(1270)K_S$ „
- $\chi_{c0}K_S$ „

arXiv:0708.2097
Contrib. LP2007



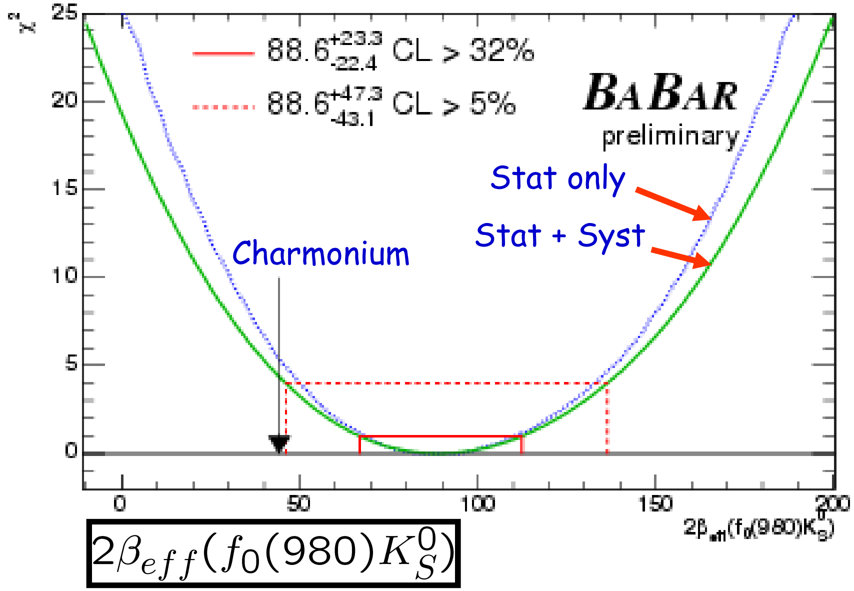


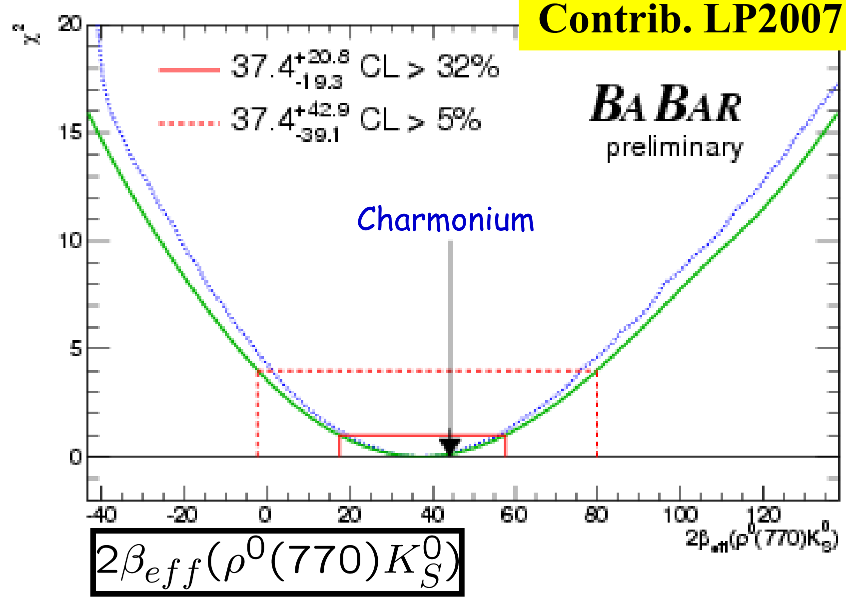


Time-dependent CP violation

- Time-dependent CP asymmetry measured at each point in the $K_S\pi^+\pi^-$ Dalitz plot for the first time

arXiv:0708.2097
Contrib. LP2007





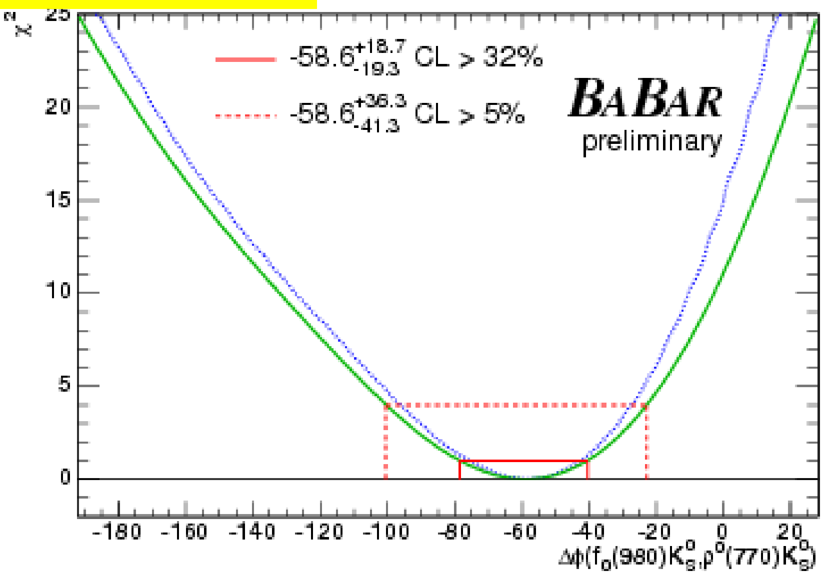
CP parameters	arXiv:0708.2097 [hep-ex]
$C(f_0(980)K_S^0)$	$0.35 \pm 0.27 \pm 0.07 \pm 0.04$
$S(f_0(980)K_S^0)$	$-0.94^{+0.07}_{-0.02}\,^{+0.05}_{-0.03} \pm 0.02$
$2\beta_{eff}(f_0(980)K_S^0)$	$(89^{+22}_{-20} \pm 5 \pm 8)^\circ$
$C(\rho^0(770)K_S^0)$	$0.02 \pm 0.27 \pm 0.08 \pm 0.06$
$S(\rho^0(770)K_S^0)$	$0.61^{+0.22}_{-0.24} \pm 0.09 \pm 0.08$
$2\beta_{eff}(\rho^0(770)K_S^0)$	$(37^{+19}_{-17} \pm 5 \pm 6)^\circ$

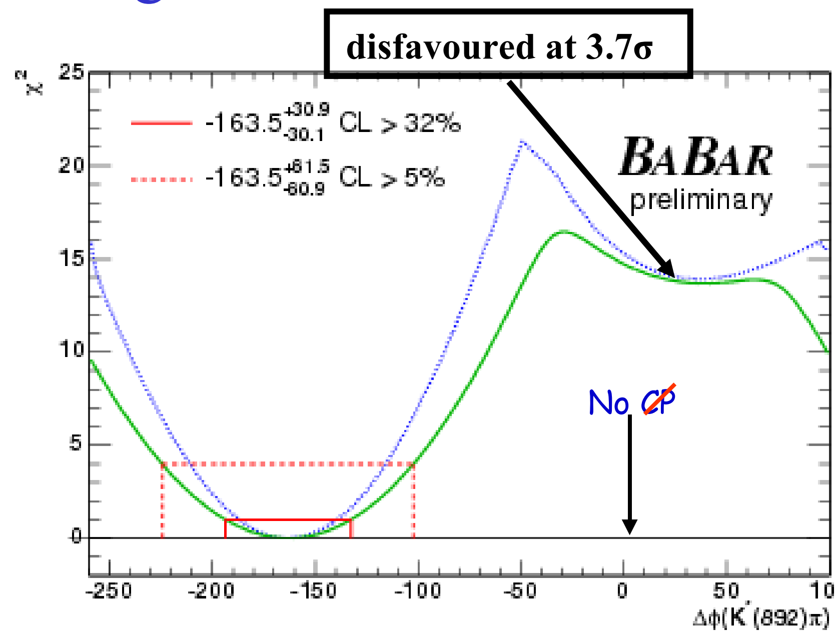
- ✖ $f_0(980)K_S$ value 2.1σ above charmonium
- ✓ ρ^0K_S consistent with the world-average

CP violation in DP amplitudes

- Advantage of time-dependent Dalitz plot ➡ probes *CP* violation from two orthogonal directions

arXiv:0708.2097
Contrib. LP2007



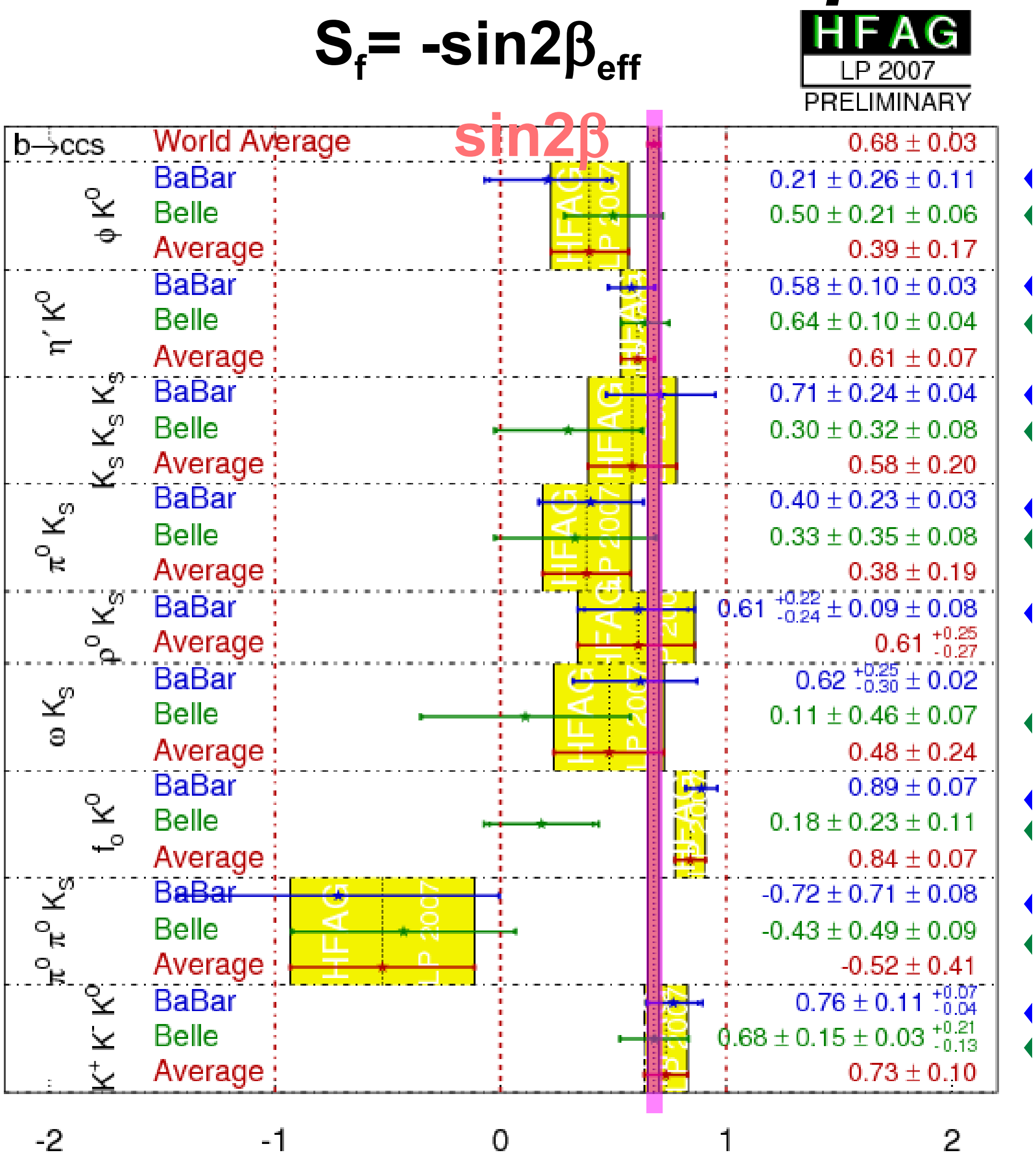


$\Delta\phi(f_0(980)K^0_S,\rho^0K^0_S)$	$(-59^{+16}_{-17}\pm6\pm6)^\circ$
$\mathrm{Frac}(f_0(980)K^0_S)$	$(14.3^{+2.8}_{-1.8}\pm1.5\pm0.6)\%$
$\mathrm{Frac}(\rho^0(770)K^0_S)$	$(9.4\pm1.4\pm1.1\pm1.1)\%$
$\Delta\phi(K^*(892)\pi)$	$(-164\pm24\pm12\pm15)^\circ$
$A_{CP}(K^{*+}(892)\pi^-)$	$-0.18\pm0.10\pm0.03\pm0.03$
$\mathrm{Frac}(K^*(892)\pi)$	$(11.7\pm1.3\pm1.3\pm0.6)\%$

- Phase diff in $K^*\pi$ mode is significantly different from zero

sin2β in Penguins

$S_f = -\sin 2\beta_{eff}$



♦≡ **New/Updated BaBar/Belle Result**

$$\langle \sin 2\beta_{eff} \rangle = 0.67 \pm 0.04$$

1% CL for the average

New naïve HFAG average <1σ from the charmonium mode sin2β value

Take with extreme caution

Slide from LP2007 (Dave Brown)

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Conclusions

- First measurement of the inclusive mode $B^+ \rightarrow K^+K^-\pi^+$
- DP measurements in the charged $K\pi\pi$ and $\pi\pi\pi$ modes
- Evidence of direct *CP* violation in the $\rho^0(770)K^\pm$ mode of charged $K\pi\pi$ final state
- β_{eff} measured without any sign ambiguity (thanks to the time-dependent DP technique)
- Measured *CP* violation parameters agree reasonably well with SM predictions
- Look forward to last run that along with run 6 would double the dataset ➡ crucial for many rare modes

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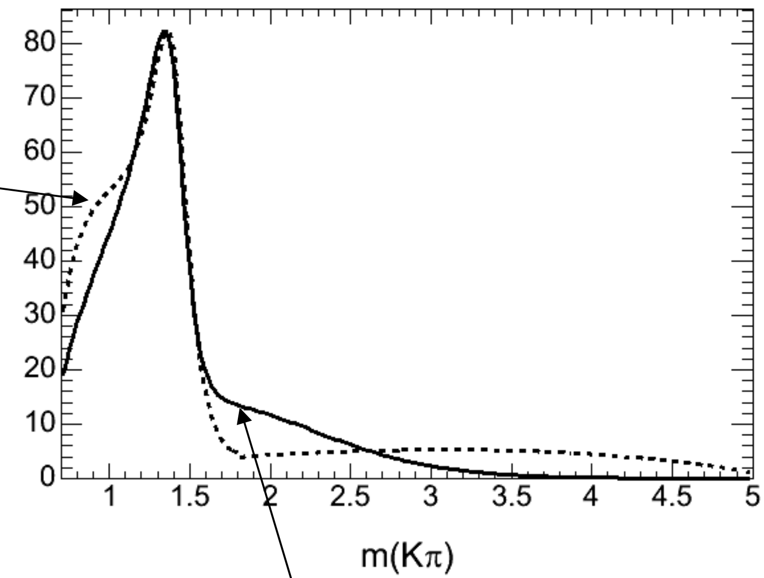
Bonus slides

Scalar $K\pi$ near 1.4 GeV/c²

- BaBar:
  - BW for K*(1430) plus an effective range NR component

$$\frac{m_{K\pi}}{q\cot\delta_B - iq} \quad \text{where } \cot\delta_B = \frac{1}{aq} + \frac{rq}{2}$$

  - Flat NR component



- parameters a,r taken from LASS experiment(*)
- valid up to 1.8GeV

(*) LASS, Kπ scattering at 11GeV at SLAC

- Belle:
  - BW for K*(1430)
  - exponential NR