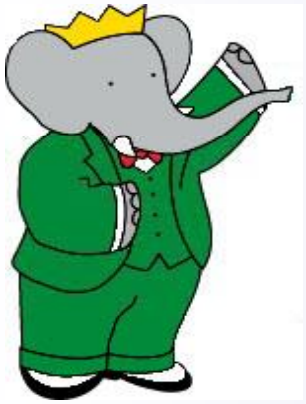


Time-Dependent Dalitz-plot Analysis of the $B^0 \to K_S \pi^+\pi^-$ decay at BABAR

Jelena Ilic

University of Warwick

Outline

- 3 body decays - Dalitz plot
- Motivation
- Backgrounds
- Results
- Conclusion

$B \to K\pi\pi$ decays

Charmless B decays – no c quark involved:

- Rare decays Bf ~ 10^{-6}

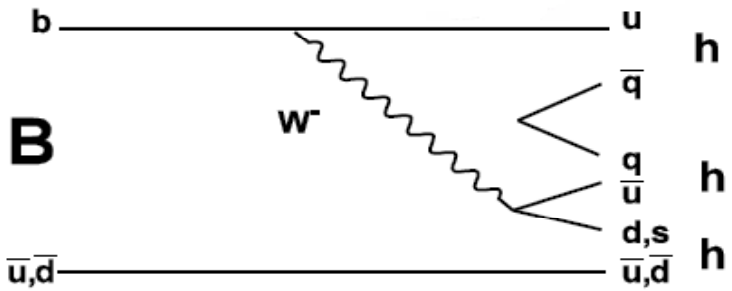
Rich Dalitz plot structure

- $(\pi\pi)$ and $(K\pi)$ intermediate resonant states
- $\sin(2\beta_{eff})$ in B^0 decays to CP eigenstates ($\rho^0 K_S$ and $f_0 K_S$)

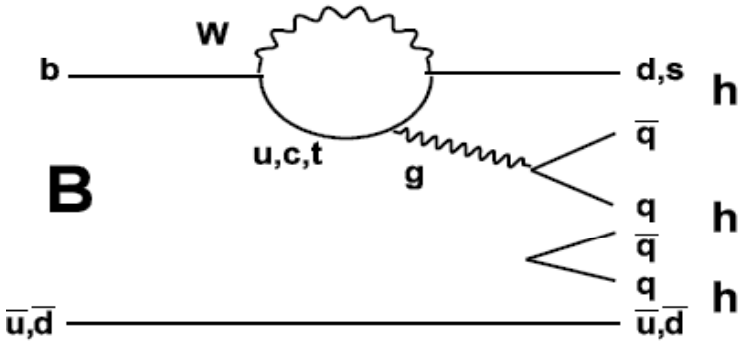
$b \to u$ (tree) and $b \to s$ (penguin) processes

- Possible direct CP violation
- tree & penguin relative phase $\Rightarrow \gamma$

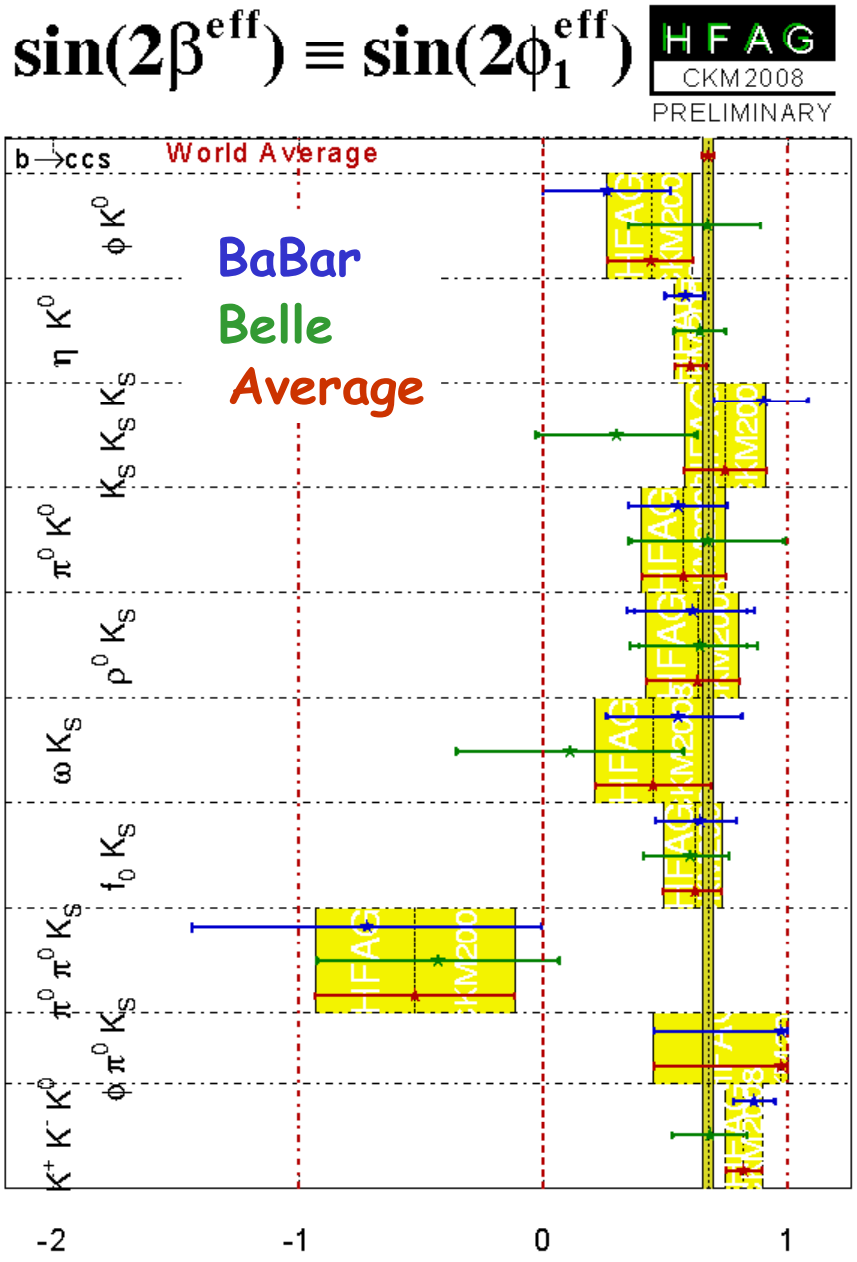
TREE



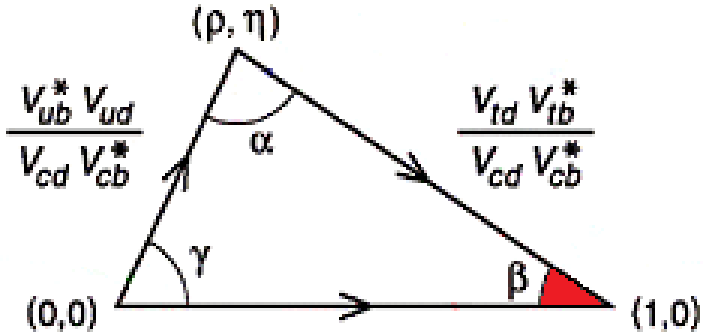
PENGUIN



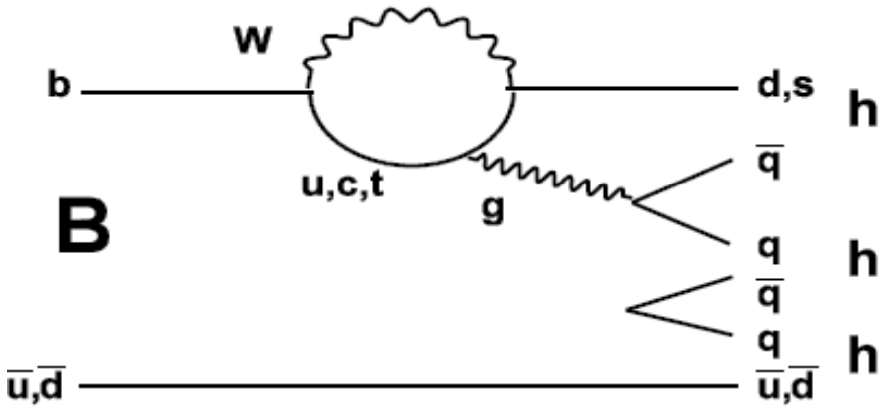
B → Kππ decays



- Possibility to measure the UT angle β



Sensitivity to possible new physics effects



Possibility to measure the UT angle γ in charmless decays

Use χ_{c0} resonance

•Interference between the χ_{c0} and the nonresonant or other resonant states in $B^+ \to \pi^+\pi^+\pi^-$ or $K^+\pi^+\pi^-$ could, in principle, allow a determination of γ

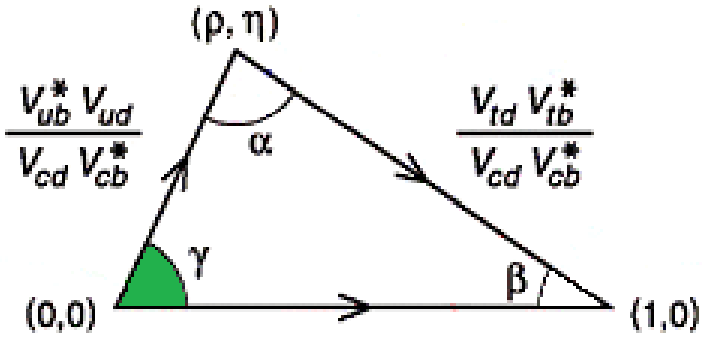
Eilam et al., Phys. Rev. Lett. 74, 4984 (1995)

Bediaga et al., Phys. Rev. Lett. 81, 4067 (1998)

Blanco et al., Phys. Rev. Lett. 86, 2720 (2001)

• **Small BF of $B \to \chi_{c0}K$ and $B \to \chi_{c0}\pi$!!!**

  • **Limits the sensitivity**



Use $K^*\pi$ resonance

•Main method involves $K^+\pi^-\pi^0$ and $K_S\,\pi^+\pi^-$ DPs

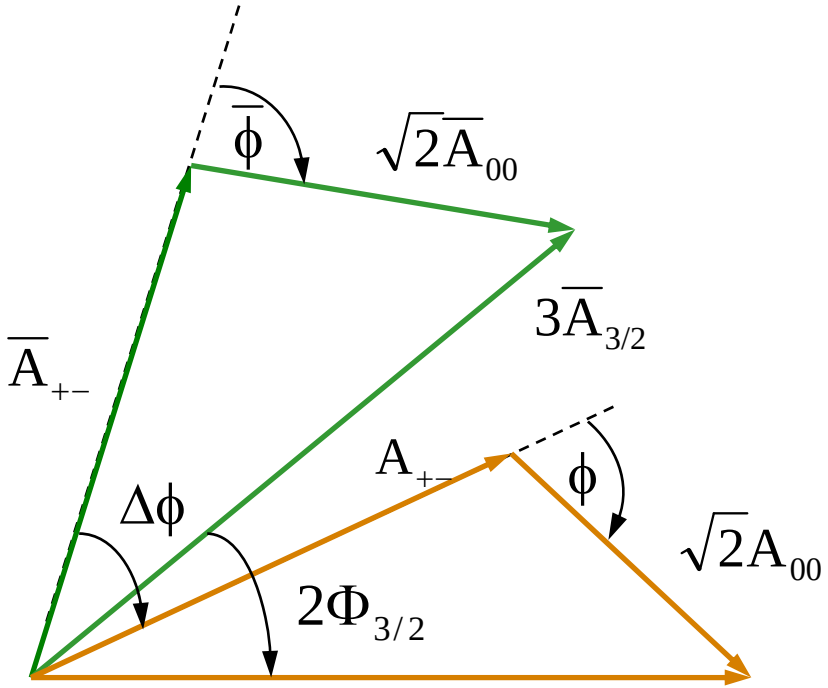
Ciuchini et al., Phys. Rev. D74, 051301 (2006)
Gronau et al., Phys. Rev. D75, 014002 (2007)
Gronau et al., Phys. Rev. D77, 057504 (2008) and D78, 017505 (2008)

$B \to K\pi\pi$ decays and the UT angle γ

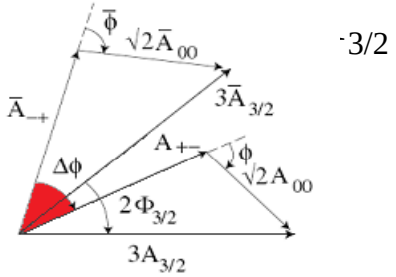
$$A_{ij} = A(B^0 \to K^{*i}\pi^j)$$

- Write the amplitudes for $B^0 \to K^*\pi$ modes using the isospin symmetry
- Use them to cancel penguin contribution
- Form isospin triangles ($B^0 \to K^{*+}\pi-$ and $B^0 \to K^{*0}\pi^0$)
- $\Phi_{3/2} = \gamma$ (up to correction from EW penguins)

$$\gamma = \Phi_{3/2} \equiv -\frac{1}{2}\arg\left(\frac{\overline{A}_{3/2}}{A_{3/2}}\right)$$

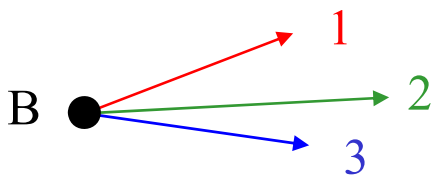


- The amplitude magnitudes as well as ϕ, $\overline{\phi}$ and $\Delta\phi$ can be measured from Dalitz-plot analyses of $K^+\pi^-\pi^0$ and $K_s\pi^+\pi^-$



Analysis Method – Dalitz Plot

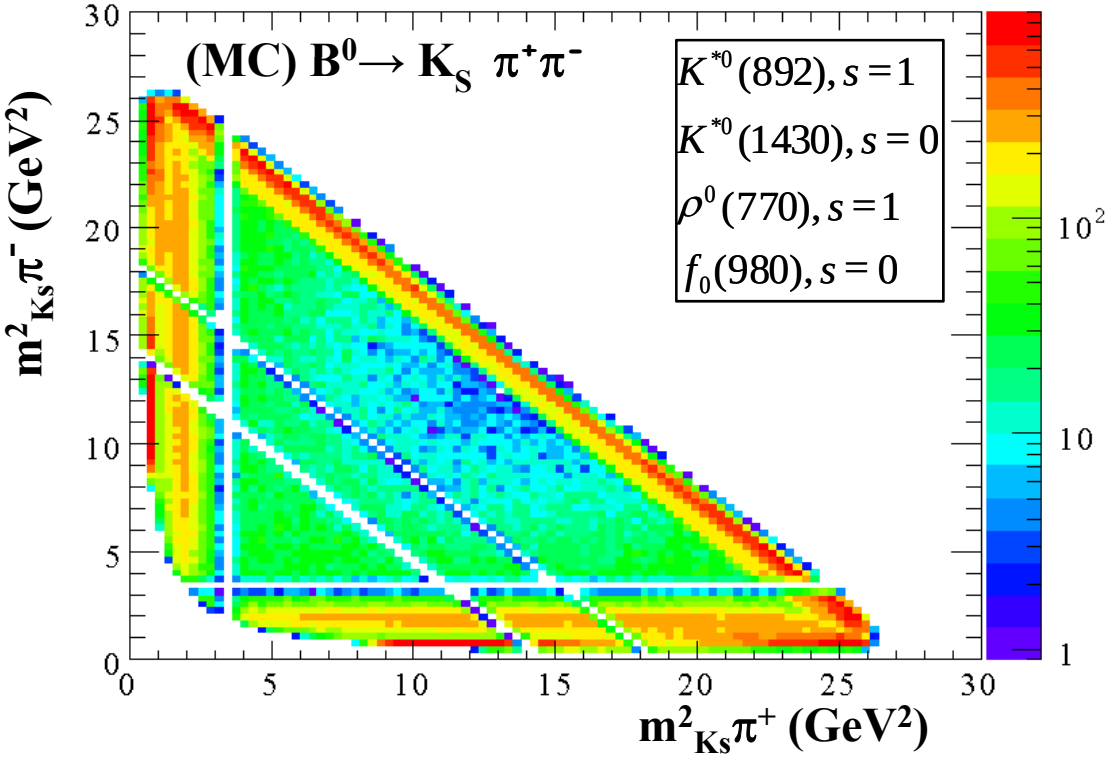
4 vectors	12
conservation laws	-4
meson masses	-3
free rotation	-3
total	**2**



- Invariant mass of combined ij particle
- Decay rate:

$$\Gamma \propto |M|^2 dm_{12}^2 dm_{23}^2$$ (M – invariant amplitude)

Dalitz plot - visualisation of the 3 body phase space



- **Interference between resonances**
- **DP analysis sensitive to phases**
- Measurements of $2\beta_{eff}$ (rather than just $\sin(2\beta_{eff})$)
- Penguin – tree relative phase:
  - **UT angle γ**

Signal

- Decay Rate

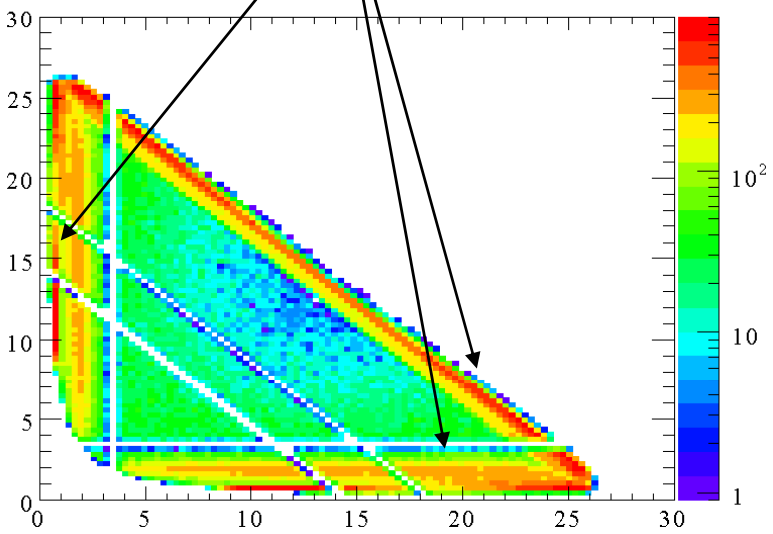
$$\frac{d\Gamma}{d\Delta t\, dm_+^2\, dm_-^2} \approx e^{-|\Delta t|/\tau_{B^0}} \times \left[(|\mathcal{A}|^2 + |\overline{\mathcal{A}}|^2) - q\,(|\mathcal{A}|^2 - |\overline{\mathcal{A}}|^2)\cos(\Delta m \Delta t) + 2q\,\mathrm{Im}\left[\overline{\mathcal{A}}\mathcal{A}^* e^{-2i\beta}\right]\sin(\Delta m \Delta t) \right]$$

- B^0/B^0bar DP Amplitudes

(isobar model)

$$\mathcal{A} = \sum_{j=1}^{N} c_j F_j$$

$$c_j = (x_j + \Delta x_j) + i(y_j + \Delta y_j)$$
$$\bar{c}_j = (x_j - \Delta x_j) + i(y_j - \Delta y_j)$$



Signal Model:

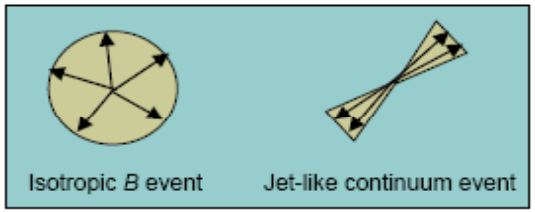
(1) $f_0(980)K_S^0$
(2) $\rho^0(770)K_S^0$
(3) $f_0(1300)K_S^0$
(4) NR
(5) $K^*(892)\pi$
(6) $K_0^*(1430)\pi$
(7) $f_2(1270)K_S^0$
(8) $\chi_{c0}K_S^0$

32 parameters to fit

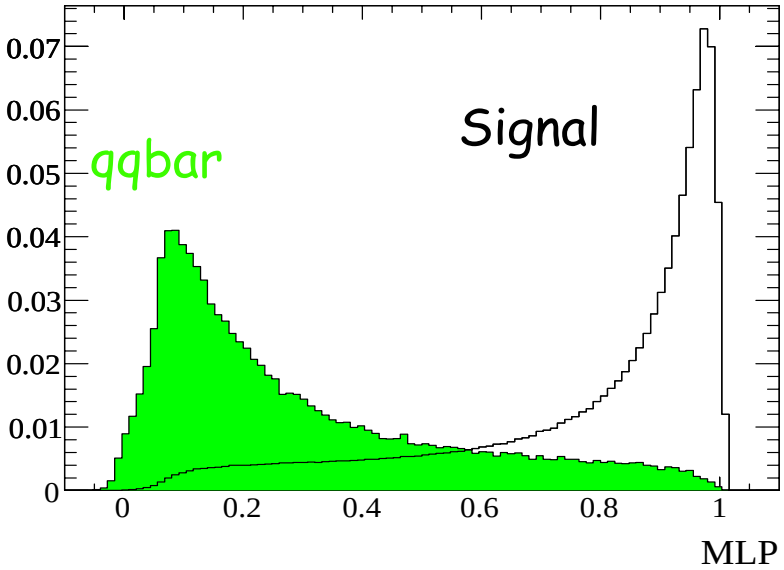
Background

$e^+e^- \to q\bar{q}$ (q=light quark)

- Dominant background
- Use events topology



Combine topological variables to form a NN

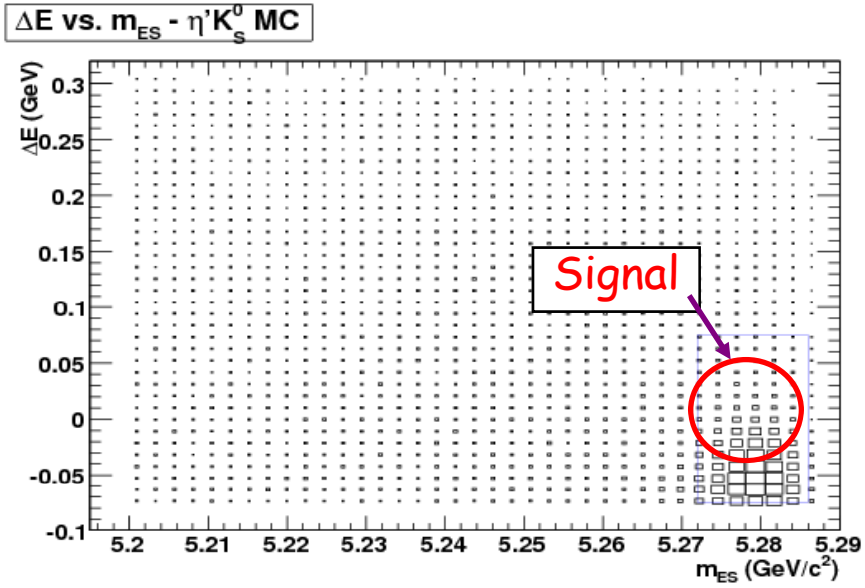


$B\bar{B}$ background

- B decay events
- Final state is not a product of charmless B meson decay to $K_S\pi^+\pi^-$
- Study using both generic and exclusive MC samples
- Find dominant decay modes
- Use DP and kinematical variables (m_{ES}, ΔE)

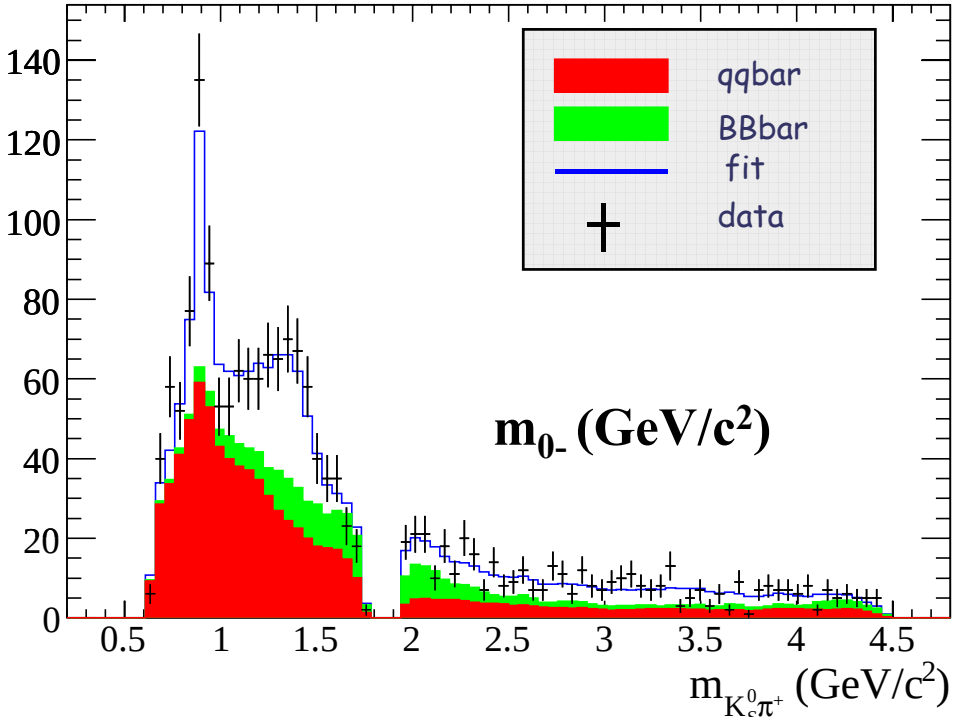
$$m_{ES} = \sqrt{E_x^2 - \vec{p}_B^2} \qquad \Delta E = E_B - E_x \qquad E_x = \frac{1}{2}\sqrt{s}$$

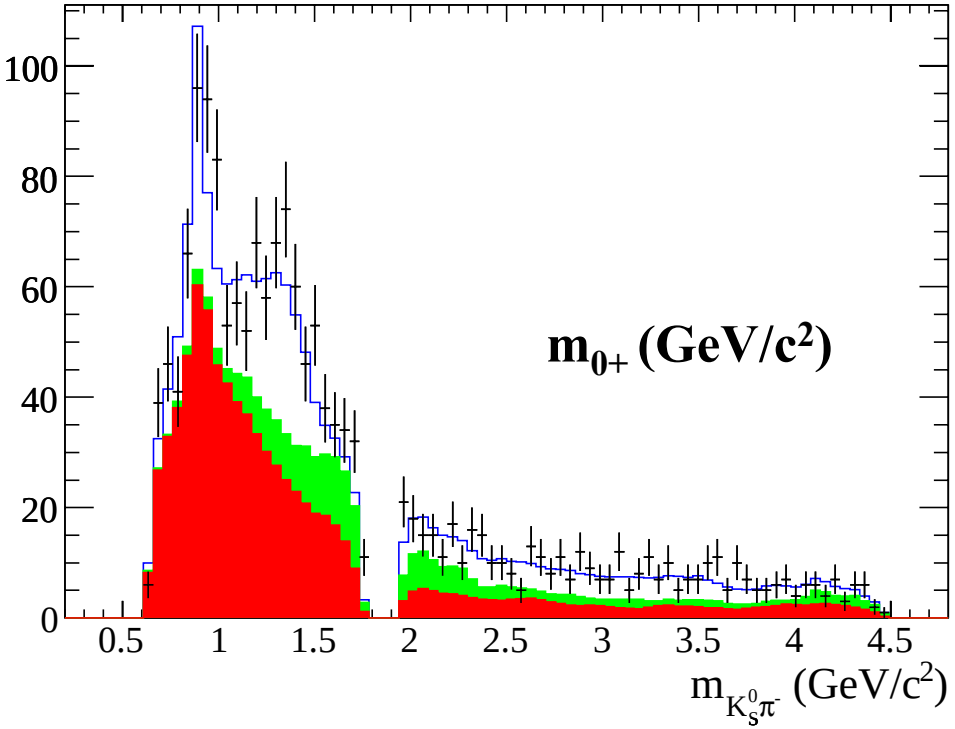
Sqrt(s) - Invariant mass of e^+e^- system

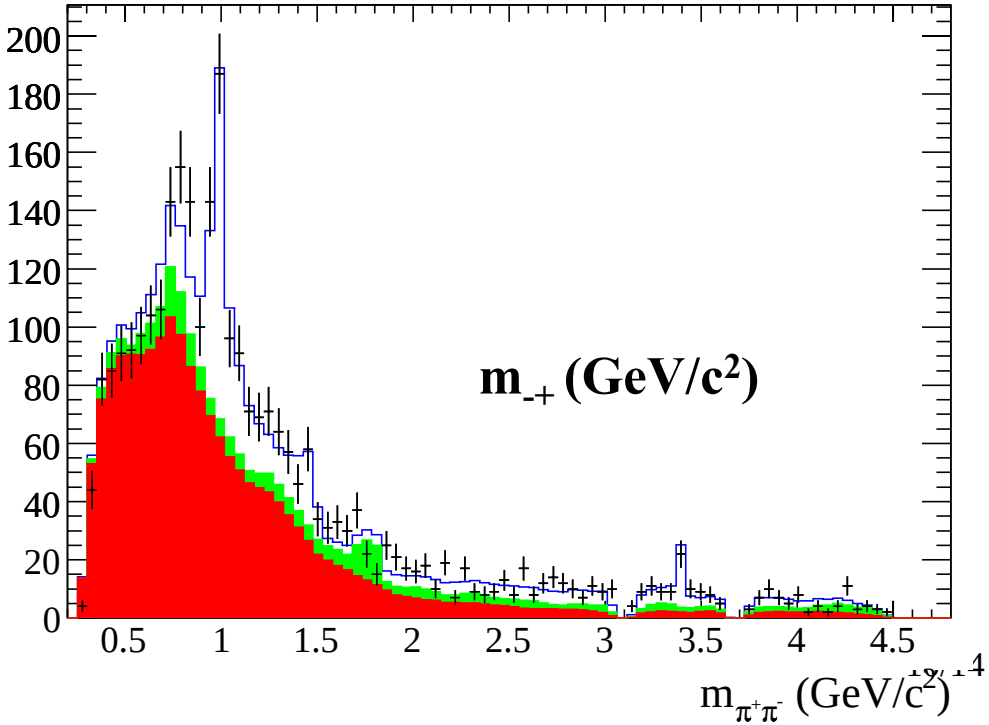


Results

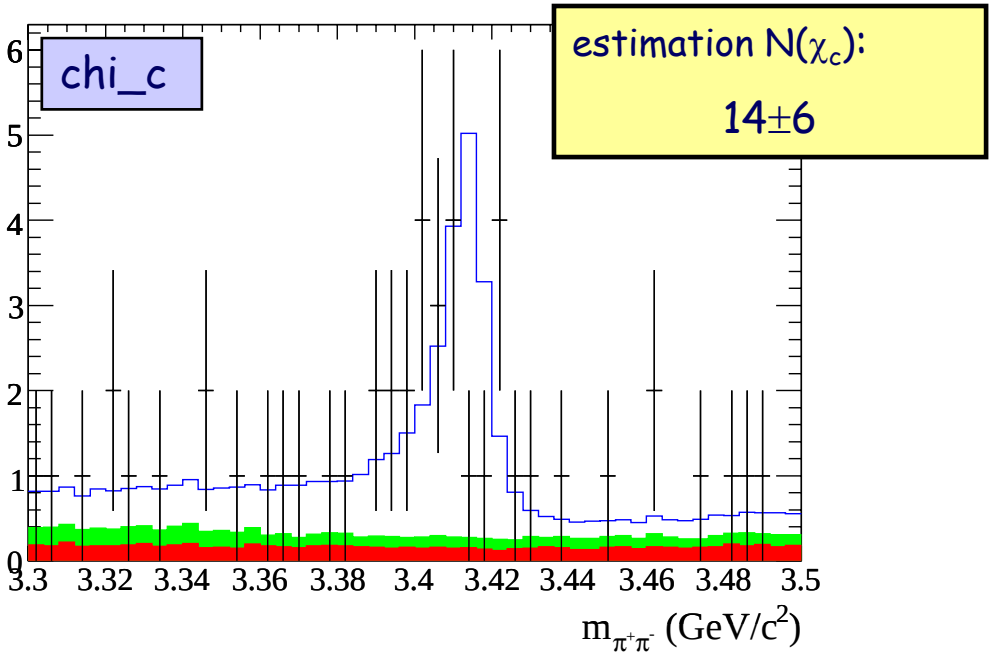
- (465 ± 5)10^6 BBbar decays
  - 16949 candidates
  - $B \to K_S \pi^+ \pi^-$ signal yield. 2240±58
  - qqbar yield: 13762 ±117

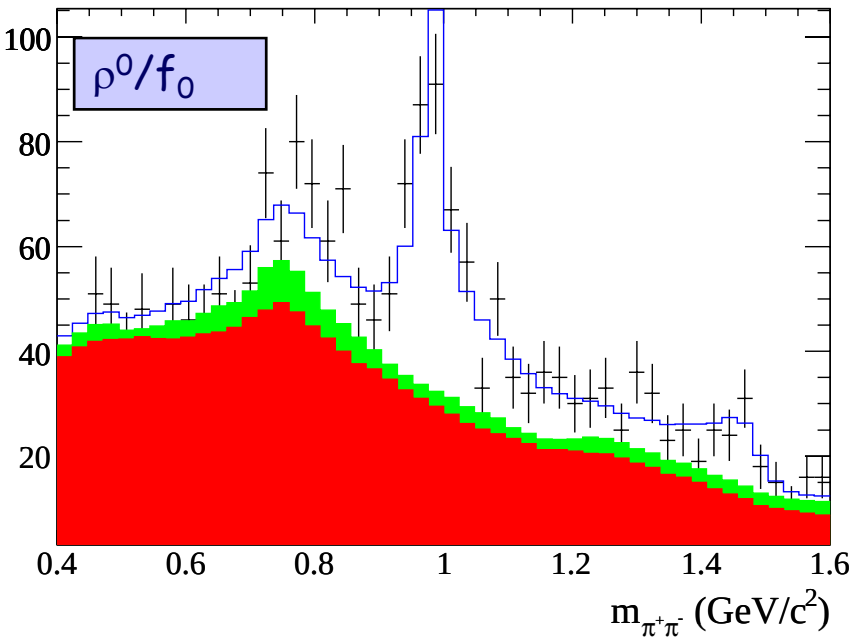


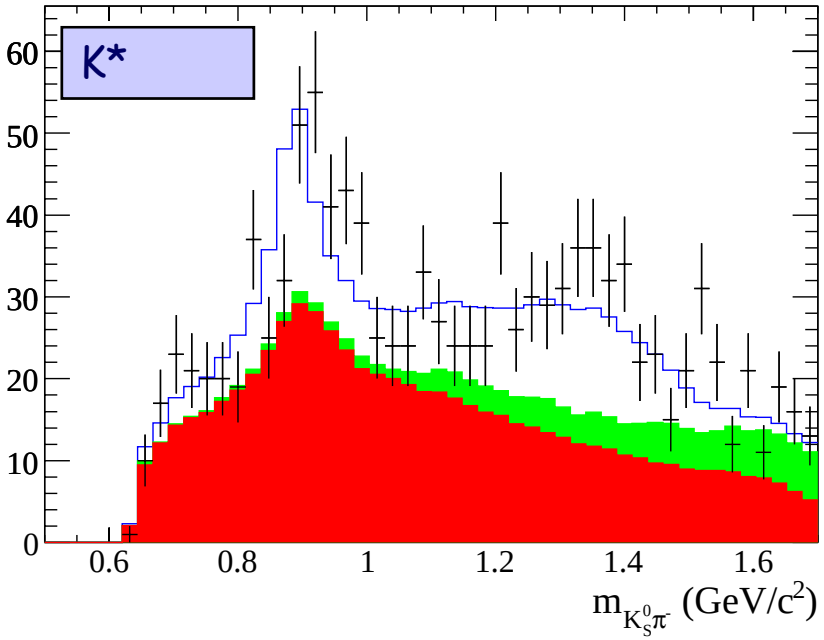


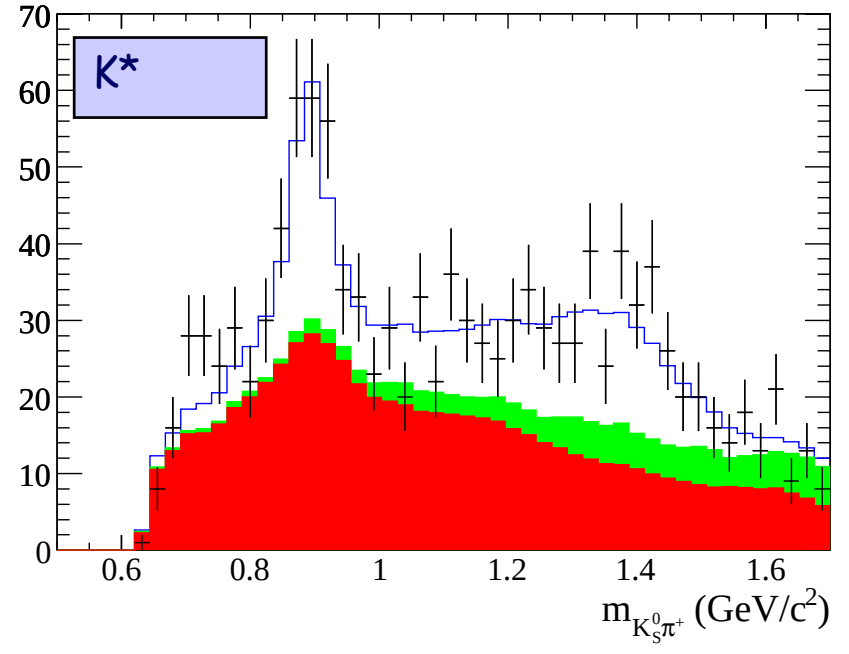


Results


chi_c
estimation N(χc):
14±6
$m_{\pi^+\pi^-}$ (GeV/c^2)


ρ0/f0
$m_{\pi^+\pi^-}$ (GeV/c^2)


K*
$m_{K^0_S\pi^-}$ (GeV/c^2)

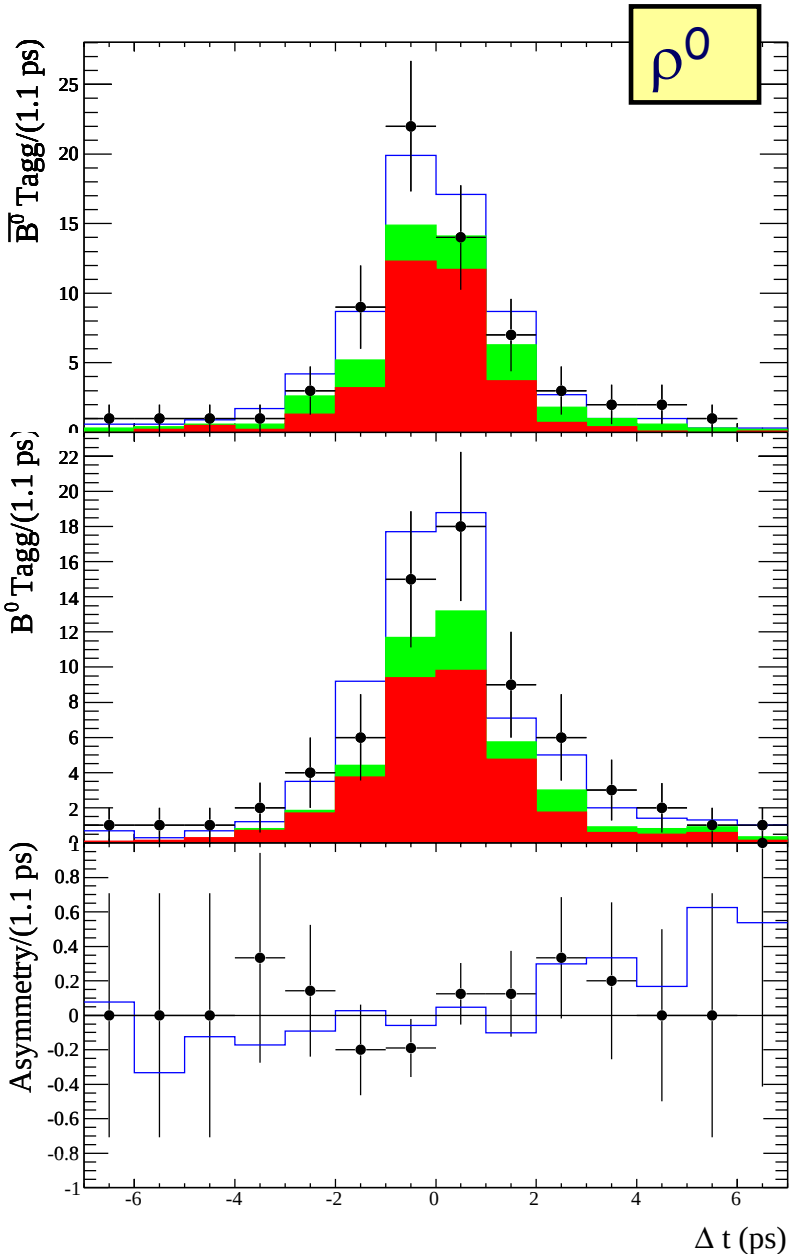

K*
$m_{K^0_S\pi^+}$ (GeV/c^2)

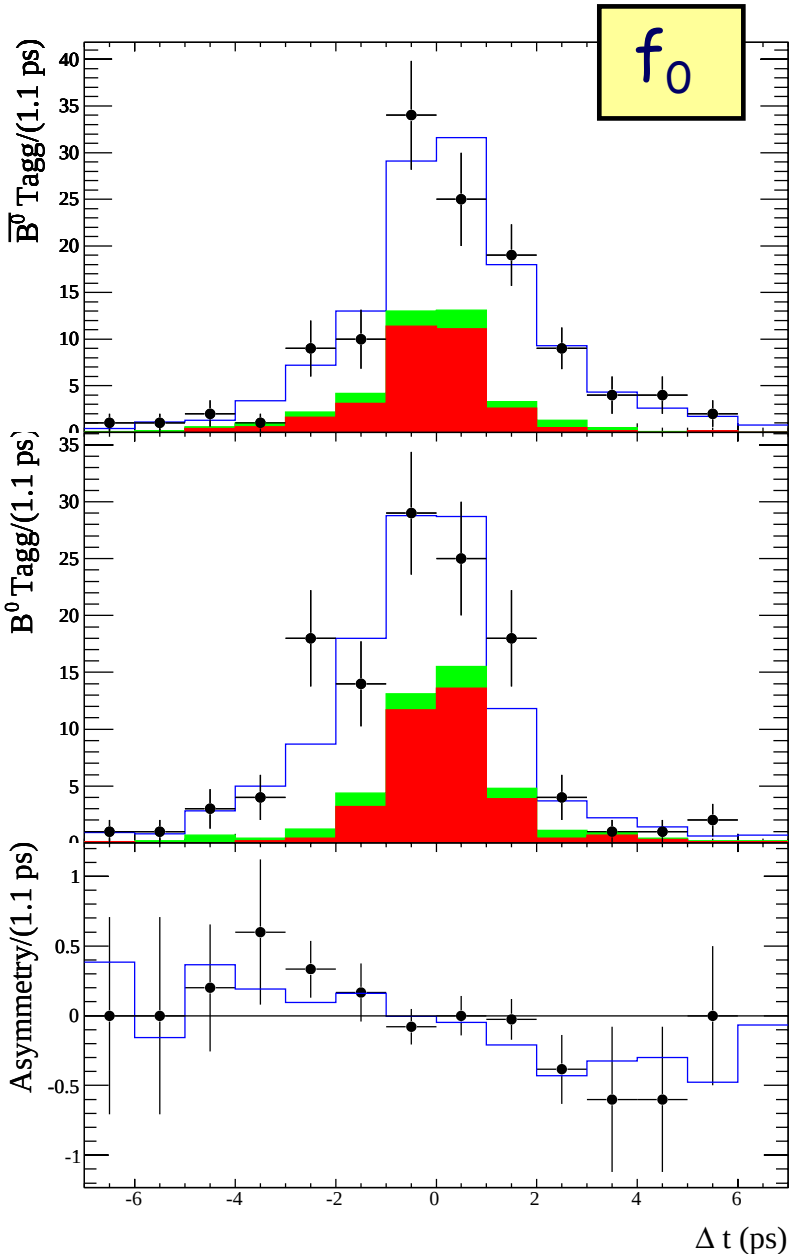
Results

$f_0(980)K_S^0$	C	$0.02 \pm 0.4 \pm 0.08 \pm 0.02$
	S	$-0.97 \pm 0.09 \pm 0.01 \pm 0.01$
	2β	$77.0 \pm 18.5 \pm 4.0 \pm 2.6$
	$f\bar{f}$	$15.2 \pm 2.4 \pm 1.5 \pm 0.6$
	$f\bar{f}$	$16.1 \pm 3.0 \pm 0.3 \pm 0.6$
$\rho_0(770)K_S^0$	C	$-0.14 \pm 0.27 \pm 0.04 \pm 0.02$
	S	$0.67 \pm 0.20 \pm 0.06 \pm 0.04$
	2β	$42.8 \pm 16.6 \pm 5.9 \pm 3.4$
	$f\bar{f}$	$5.2 \pm 1.9 \pm 0.7 \pm 0.4$
	$f\bar{f}$	$7.6 \pm 1.3 \pm 0.6 \pm 0.2$
$K^*(892)\pi$	A_{cp}	$-0.18 \pm 0.10 \pm 0.04 \pm 0.00$
	$\Delta\phi$	$34.9 \pm 23.1 \pm 7.5 \pm 4.7$
	$f\bar{f}$	$12.6 \pm 1.6 \pm 0.9 \pm 0.1$
	$f\bar{f}$	$9.8 \pm 1.4 \pm 1.0 \pm 0.1$
$K^*(1430)\pi$	A_{cp}	$-0.03 \pm 0.06 \pm 0.02 \pm 0.00$
	$\Delta\phi$	$67.2 \pm 15.5 \pm 6.4 \pm 5.5$
	$f\bar{f}$	$46.7 \pm 2.9 \pm 1.9 \pm 0.6$
	$f\bar{f}$	$51.8 \pm 2.6 \pm 0.5 \pm 0.5$
$f_2(127)K_S^0$	C	$0.57 \pm 0.80 \pm 0.09 \pm 0.06$
	$\Delta\phi$	$58.2 \pm 48.3 \pm 8.4 \pm 2.4$
	$f\bar{f}$	$1.6 \pm 1.0 \pm 0.6 \pm 0.1$
	$f\bar{f}$	$1.4 \pm 0.7 \pm 0.3 \pm 0.1$
$f_X(1300)K_S^0$	C	$0.01 \pm 0.42 \pm 0.09 \pm 0.04$
	$\Delta\phi$	$3.4 \pm 29.8 \pm 5.2 \pm 5.0$
	$f\bar{f}$	$2.0 \pm 1.1 \pm 0.3 \pm 0.2$
	$f\bar{f}$	$2.1 \pm 1.3 \pm 0.7 \pm 0.2$
NR	C	$0.14 \pm 0.23 \pm 0.08 \pm 0.06$
	$\Delta\phi$	$23.8 \pm 19.2 \pm 4.1 \pm 1.6$
	$f\bar{f}$	$10.7 \pm 2.7 \pm 1.0 \pm 0.9$
	$f\bar{f}$	$8.9 \pm 2.7 \pm 0.6 \pm 0.6$
$\chi_{c0}K_S^0$	C	$-0.20 \pm 0.40 \pm 0.10 \pm 0.02$
	$\Delta\phi$	$19.5 \pm 36.2 \pm 5.35 \pm 2.5$
	$f\bar{f}$	$1.4 \pm 0.7 \pm 0.4 \pm 0.1$
	$f\bar{f}$	$1.0 \pm 0.7 \pm 0.1 \pm 0.1$

statistical, systematic and model-dependent errors

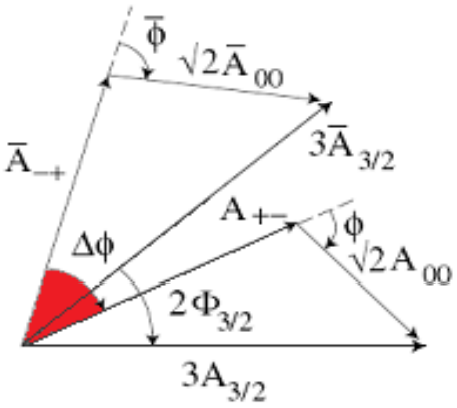
Results


ρ0
$\overline{B}^0$ Tagg/(1.1 ps)
B^0 Tagg/(1.1 ps)
Asymmetry/(1.1 ps)
Δ t (ps)


f0
$\overline{B}^0$ Tagg/(1.1 ps)
B^0 Tagg/(1.1 ps)
Asymmetry/(1.1 ps)
Δ t (ps)

Summary

- Good agreement with previous analysis
- Improved statistical accuracy
- Direct CP asymmetries measured for all the resonant submodes ~ consistent with 0
- $A_{CP}(K^*\pi) = -0.18 \pm 0.10$
- $2\beta_{eff}$ measured for f_0 and ρ^0 ($2\beta_{eff}(f_0 K_S^0) = 77.0 \pm 18.5$, $2\beta_{eff}(\rho^0 K_S^0) = 42.8 \pm 16.6$)
- Relative phase between $K^{*-}\pi^+$ and $K^{*+}\pi^-$ has been determined; Possibility to measure the UT angle γ!

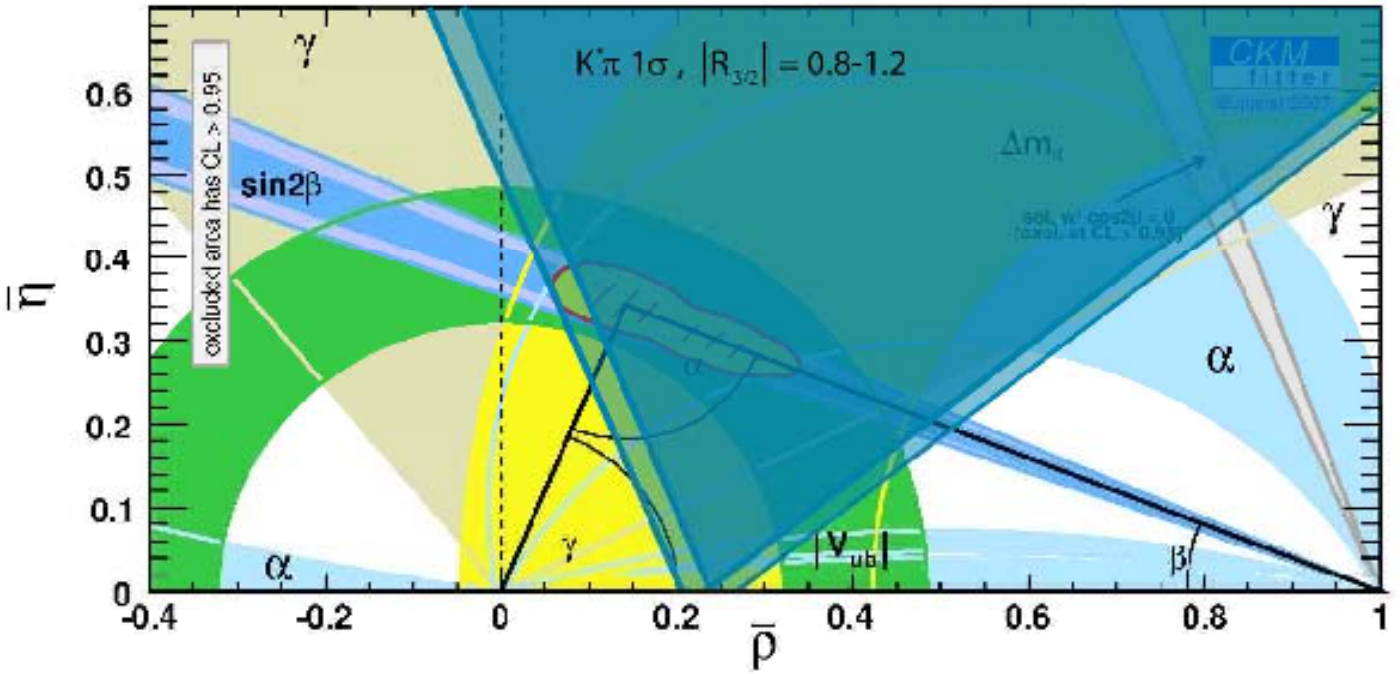


Backup slides

Combining results

- CKM constraint in presence of EW penguins:

$$\overline{\eta} = \tan\Phi_{3/2}\left[\overline{\rho} - 0.24 \pm 0.03\right]$$



Analysis Method - Self Cross Feed

- Misreconstructed signal events

(one or more particles originates from the other B in the event)

~1% SCF events