LPNHE, December 20th 2006

Ongoing efforts and some issues in $B \rightarrow K\pi\pi$ Dalitz analyses

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LPNHE-BaBar

Motivations

- Relate ***B→PV*** amplitudes via isospin and/or SU3 symmetries to constrain CKM parameters
  - Similar in spirit to previous work on ***B→PP*** modes (e.g. Julie's PhD thesis)
  - Can use ***B→K*π***, ***B→ρK*** modes and/or some combinations
  - Expect higher impact due to larger number of observables (interferences)
    - e.g 9 observables in ***B→Kπ*** versus 13 unknowns (4 CKM, 9 QCD)
    - Up to 4 extra phases available in ***B→K*π*** modes

- ***Charmless B→Kππ*** decays are dominated by ***b→qqs*** penguins
  - We have f_0K_S and ρ^0K_S contributing to our signal
  - Measurement of TDCPV parameters are promising probes for BSM
  - Deviation from results in ***b→ccs*** modes would indicate NP

- Main ongoing activities :
  - Time-dependent, full-Dalitz amplitude $K_S\pi^+\pi^-$ (ongoing)
  - Time-integrated, full-Dalitz amplitude $K_S\pi^+\pi0$ (ongoing)
  - Time-integrated, full-Dalitz amplitude K+π-π0 (preliminary result run1-4)

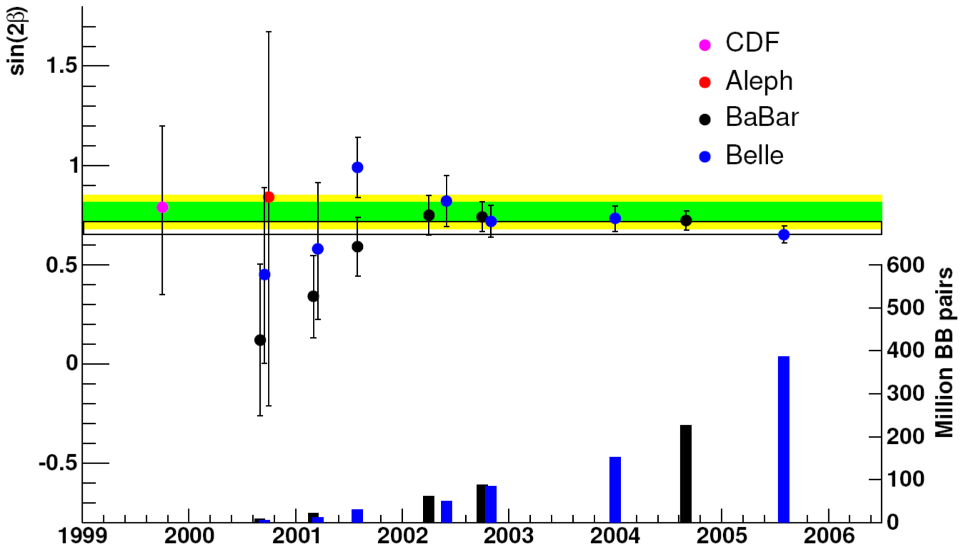
Constraints from β/ϕ_1 (charmonium modes)

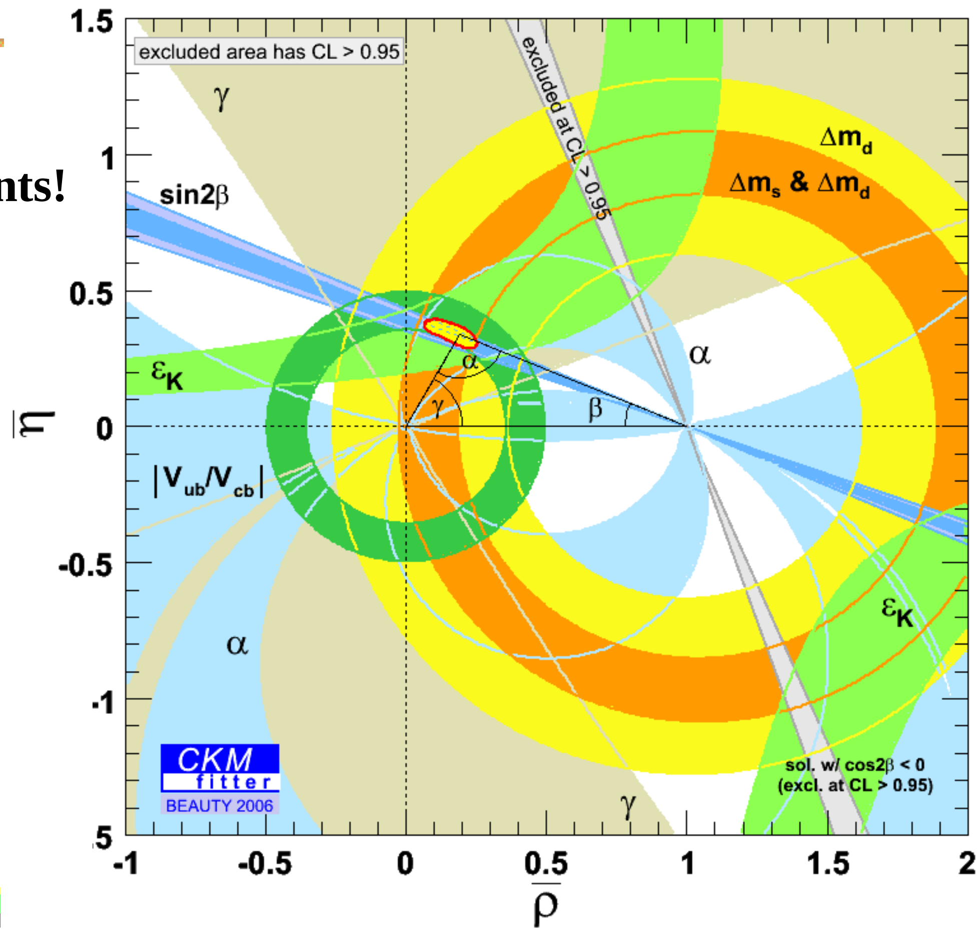
- **World average $sin2\beta_{WA}$ = 0.675 ± 0.026**

- **Now more precise than indirect constraints!**

- **A great success for the SM !**
…there is some "tension" in the fit

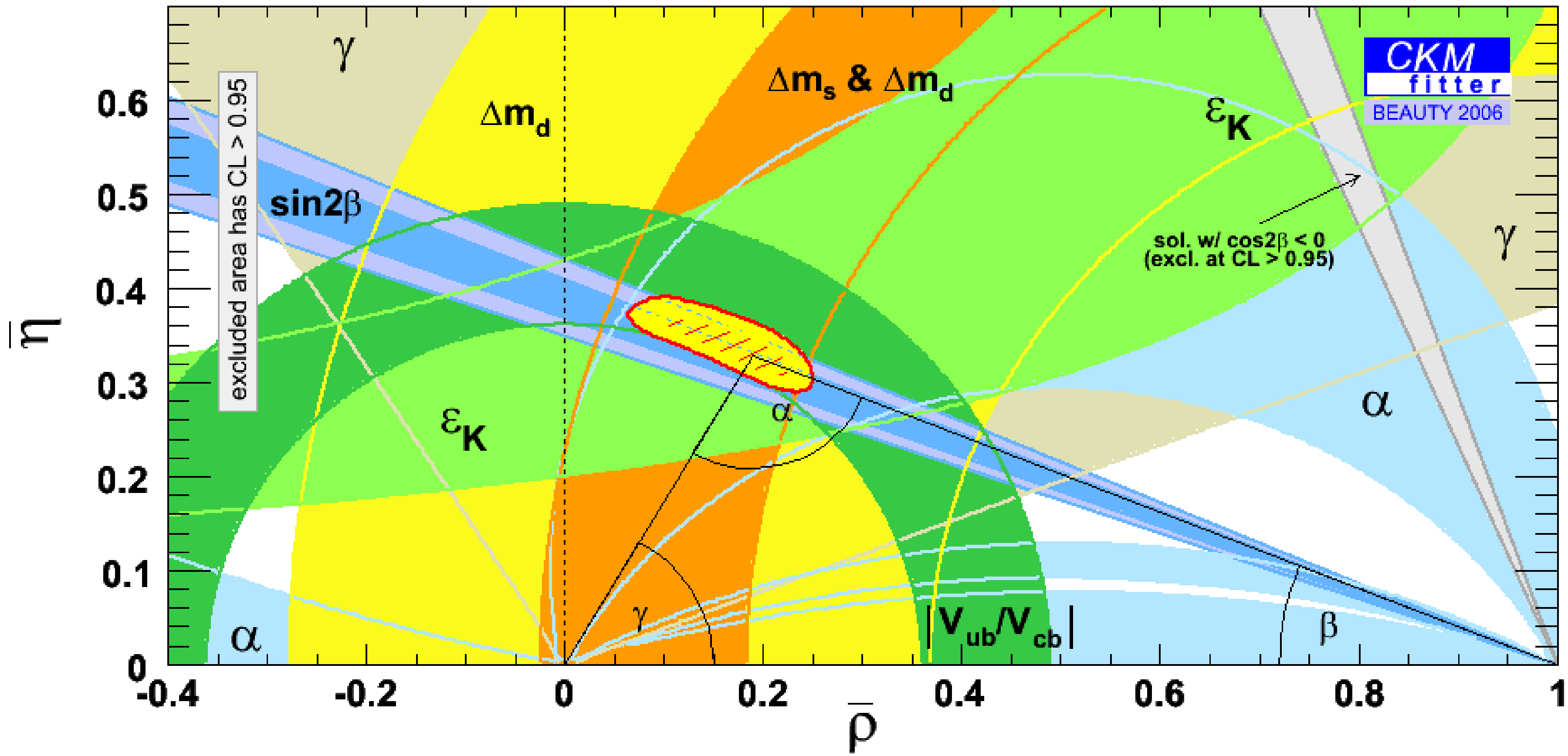
- **Entering the precision measurement era**





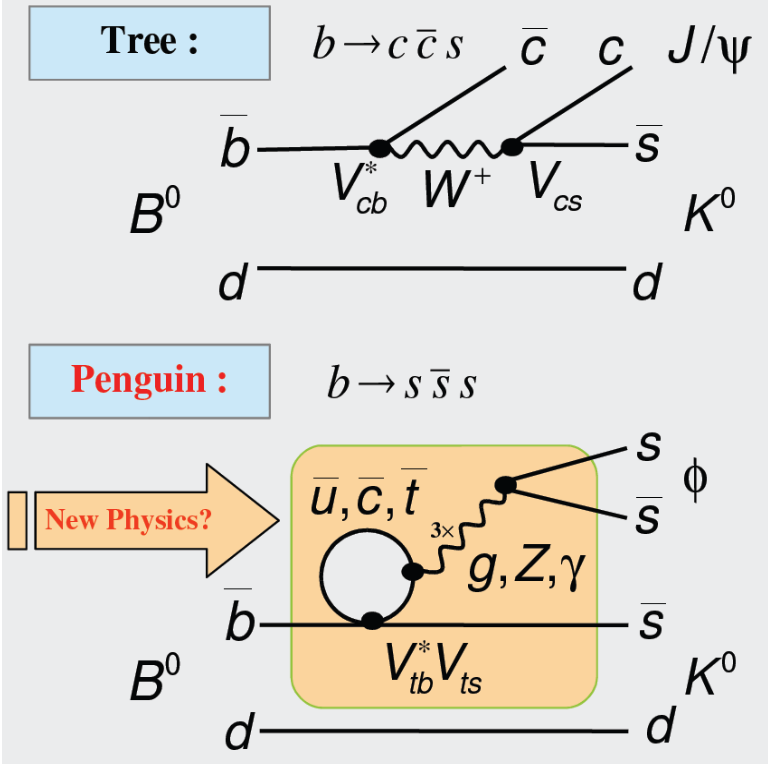
http://ckmfitter.in2p3.fr

Constraints from β/ϕ_1 (charmonium modes)



http://ckmfitter.in2p3.fr

b→s penguins : loop-dominance



• b→ccs :

- **tree-dominated decays**
- **penguins carry same weak phase**

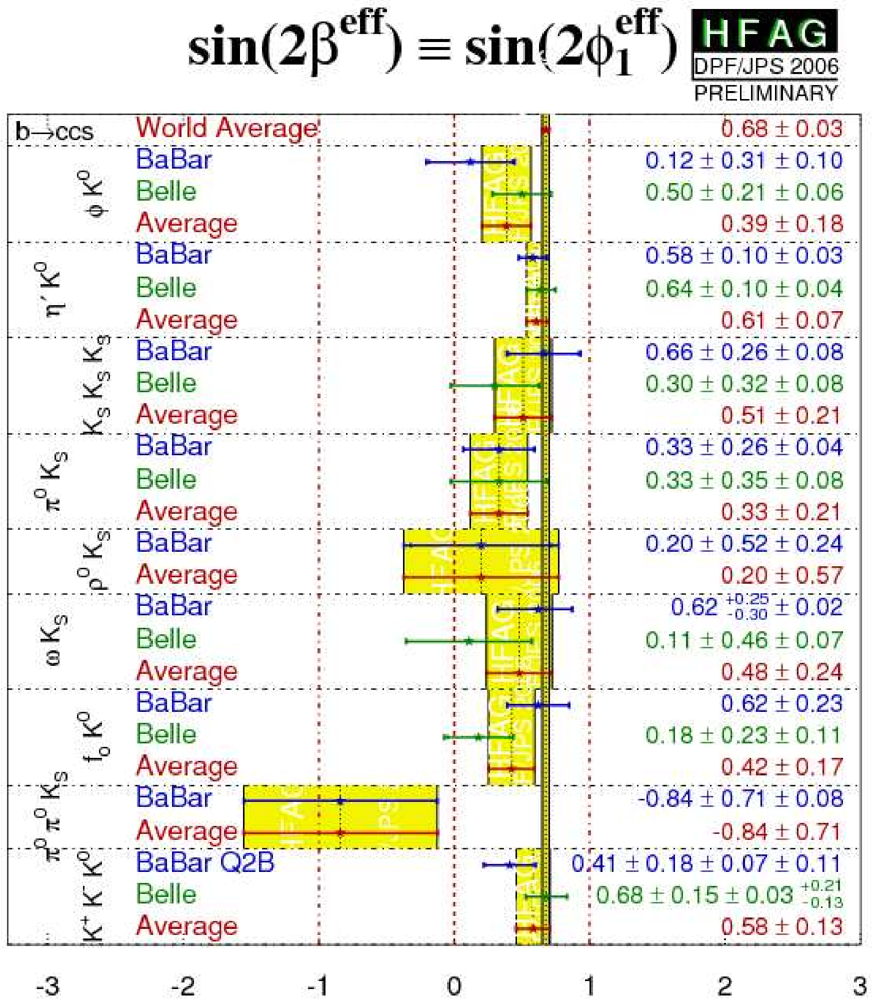
• b→qqs :

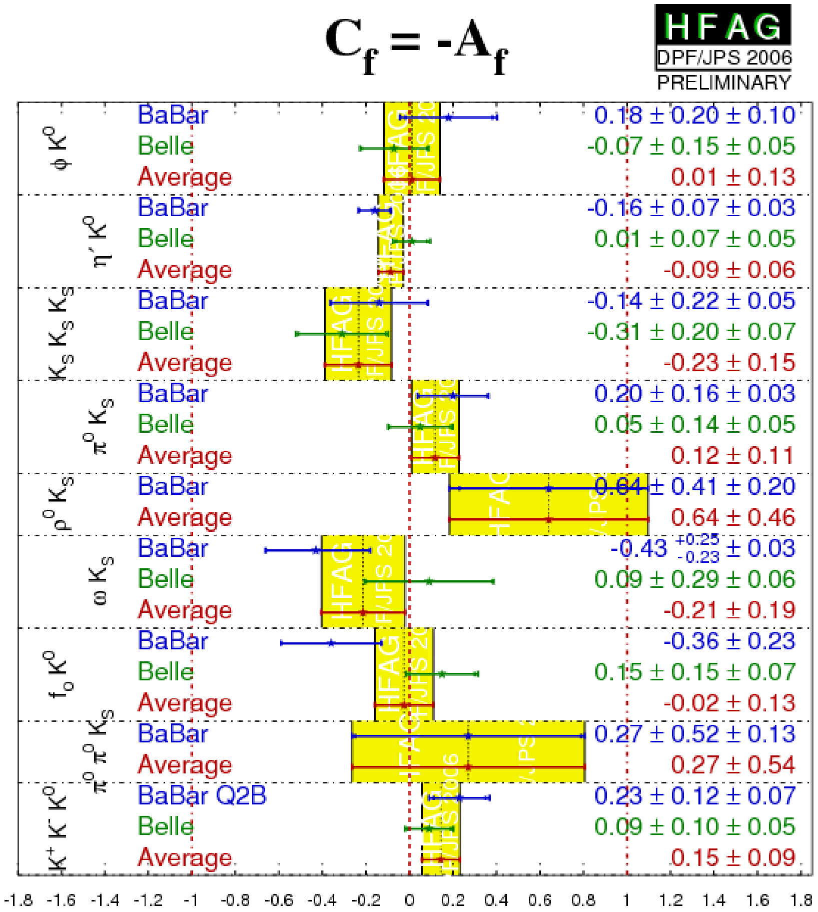
- **pure "internal" or "flavour-singlet" penguins**
- **dominant phase, same CKM factors as** b→ccs
- **usually more than one phase involved**
- **high mass scales involved in loops**
- **non-SM contributions could contribute**
- **a window to New Physics !**

Standard Model	New Physics
$S_{ccs} = S_{sss} + \Delta S_{SM} = \sin 2\beta$	$S_{ccs} + \Delta S_{SM} \neq S_{sss}$
$C_{ccs} \sim C_{sss} \sim 0$	$C_{ccs} \neq C_{sss}$

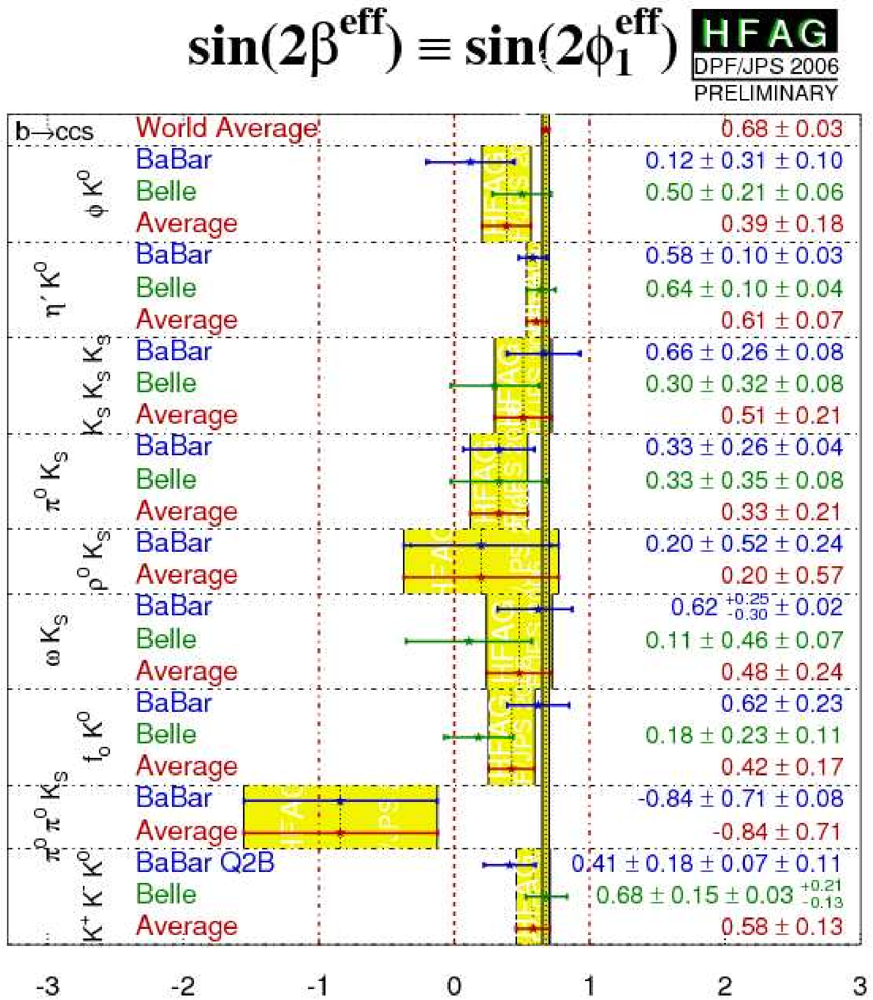
Theory issue : evaluate ΔS_{SM} for each mode
identify clean modes (expect small ΔS_{SM})

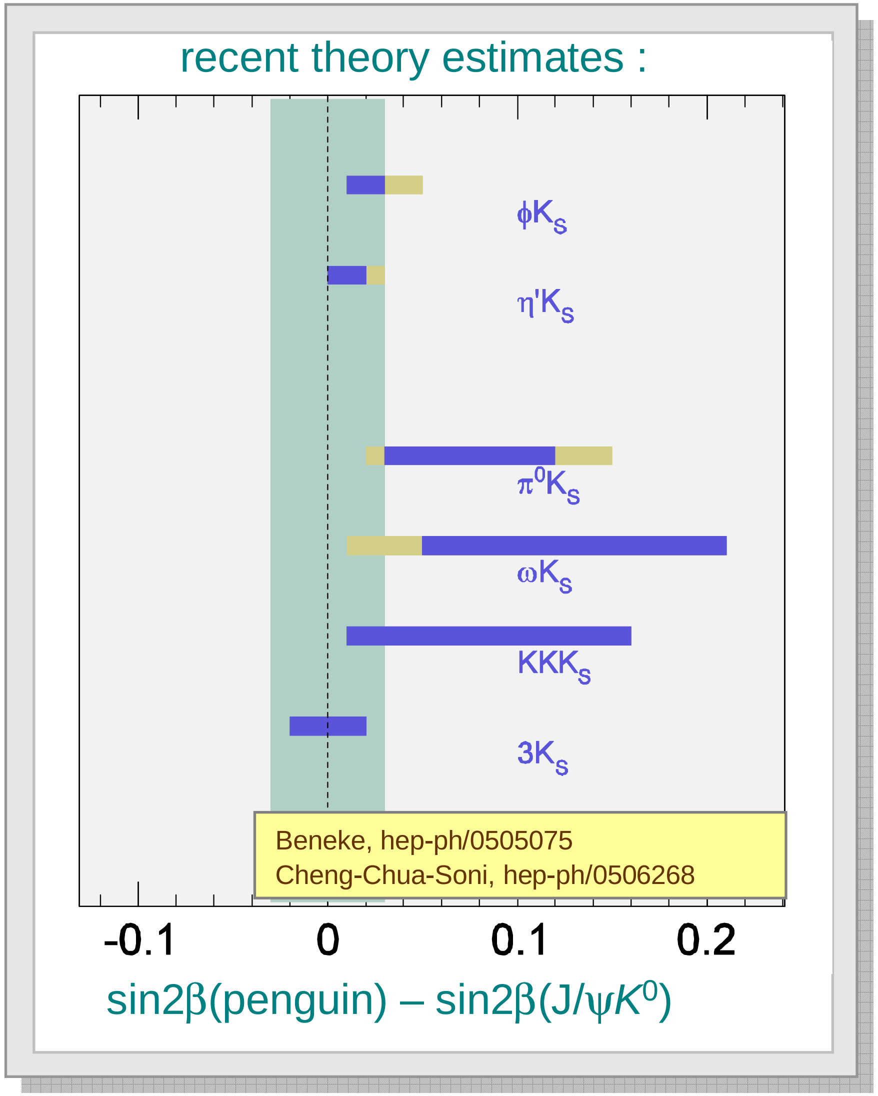
Motivations



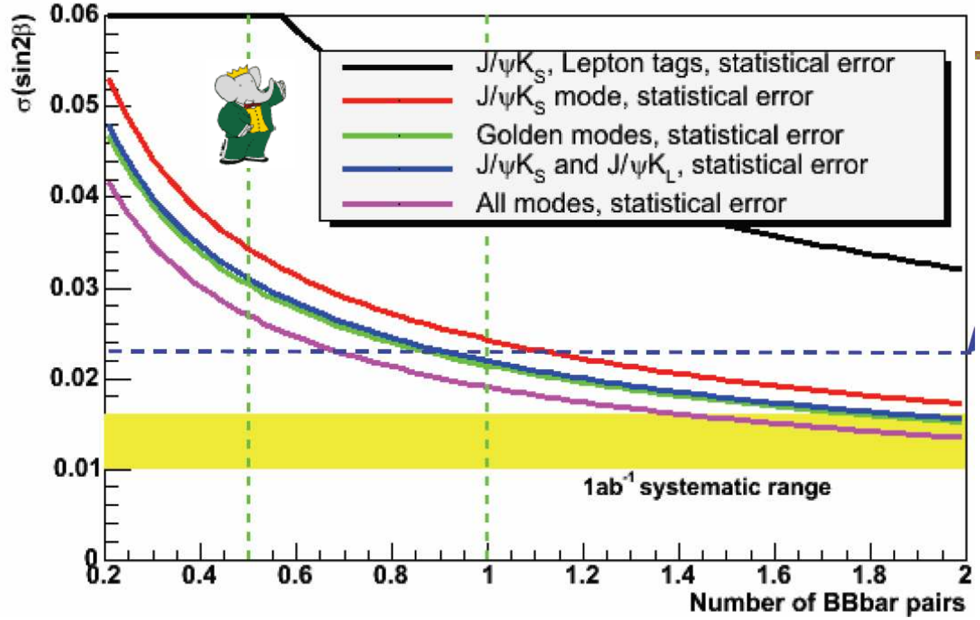


Motivations



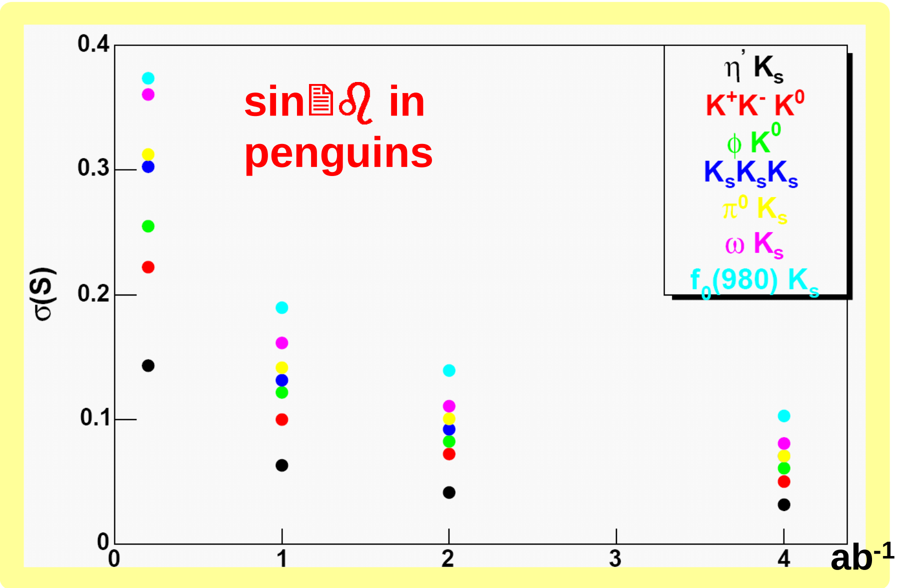


*Expected evolution of uncertainties (e.g. **BABAR**)*



With 1ab-1 :

- **Errors on β/ϕ_1 from b→ccs modes can be improved by nearly a factor of 2**
- **Sustained impact on CKM fits**
  - **uncertainties scaled faster than $1/\sqrt{\mathcal{L}}$ so far (adding new channels)**
- **Effort to be pursued : precision physics**



Uncertainties on b→s penguin modes will remain statistically dominated

Signals from New Physics ? Will require

- **Theoretical predictions of ΔS values**
- **A sustained experimental effort**
  - **add more channels**

Existing measurements (I)

- BAD 1065 (K.Ford et al.) time integrated, quasi two body, Runs 1-4 (210 fb^{-1})

$$\begin{aligned}
\mathcal{B}(B^0 \to K^0\pi^+\pi^- \text{ Inclusive}) &= (43.0 \pm 2.3 \pm 2.3) \times 10^{-6} \\
\mathcal{B}(B^0 \to K^0_S\pi^+\pi^- \text{ nonresonant}) &< 2.1 \times 10^{-6} \\
\mathcal{B}(B^0 \to K^{**\pm}\pi^{\mp}, K^{**\pm} \to K^0\pi^{\pm}) &= (24.4 \pm 2.6 \pm 0.9) \times 10^{-6} \\
\mathcal{B}(B^0 \to \rho^0 K^0_S) &= (4.0 \pm 1.0 \pm 0.5 \pm 0.2) \times 10^{-6} \\
\mathcal{B}(B^0 \to f_0 K^0_S) &= (5.5 \pm 0.7 \pm 0.5 \pm 0.3) \times 10^{-6} \\
\mathcal{B}(B^0 \to K^{*+}\pi^-) &= (11.0 \pm 1.5 \pm 0.5 \pm 0.5) \times 10^{-6}
\end{aligned}$$

  Acp ($B^0 \to K^{*+}\pi^-$) = -0.11 ± 0.14 ± 0.05

- BAD992, hep-ex/0408095, BaBar result (Run 1-4) for $B \to f_0Ks$ time dependent quasi two body analysis

  S = -0.95 + 0.32 - 0.23 ± 0.10

  C = -0.24 ± 0.31 ± 0.15

- hep-ex/0609006, Belle result for $B \to f_0Ks$ time dependent quasi two body analysis

  S = 0.18 ± 0.23 ± 0.11

  A = -0.15 ± 0.15 ± 0.07

- BAD791, hep-ex0608061, BaBar result (Run 1-4) for $B \to \rho^0Ks$ time dependent quasi two body analysis

  S=0.20 ± 0.52 ± 0.24

  C=0.64±0.41±0.20

Existing measurements (II)

- Belle (hep-ex/0610081) time integrated, tag independent, Dalitz plot analysis, 357 fb^{-1}

Mode	f_i %	δ_i °	$\mathcal{B}(B \to Rh) \times \mathcal{B}(R \to hh) \times 10^6$	$\mathcal{B}(B \to Rh) \times 10^6$
$K^0\pi^+\pi^-$ charmless	$99.3 \pm 0.4 \pm 0.1$	–	–	$47.5 \pm 2.4 \pm 3.7$
$K^*(892)^+\pi^-$	$11.8 \pm 1.4 \pm 0.5^{+0.9}_{-0.6}$	0 (fixed)	$5.6 \pm 0.7 \pm 0.5^{+0.4}_{-0.3}$	$8.4 \pm 1.1 \pm 0.8^{+0.6}_{-0.4}$
$K_0^*(1430)^+\pi^-$	$64.8 \pm 3.9 \pm 0.5^{+1.6}_{-6.3}$	$45 \pm 9 \pm 2^{+9}_{-13}$	$30.8 \pm 2.4 \pm 2.4^{+0.8}_{-3.0}$	$49.7 \pm 3.8 \pm 6.7^{+1.2}_{-4.8}$
$K^*(1410)^+\pi^-$	–	–	< 3.8	–
$K^*(1680)^+\pi^-$	–	–	< 2.6	–
$K_2^*(1430)^+\pi^-$	–	–	< 2.1	–
$\rho(770)^0K^0$	$12.9 \pm 1.9 \pm 0.3^{+2.1}_{-2.2}$	$-7 \pm 28 \pm 7^{+27}_{-13}$	$6.1 \pm 1.0 \pm 0.5^{+1.0}_{-1.1}$	$6.1 \pm 1.0 \pm 0.5^{+1.0}_{-1.1}$
$f_0(980)K^0$	$16.0 \pm 3.4 \pm 0.8^{+1.0}_{-1.4}$	$36 \pm 34 \pm 5^{+38}_{-21}$	$7.6 \pm 1.7 \pm 0.7^{+0.5}_{-0.7}$	–
$f_X(1300)K^0$	$3.7 \pm 2.2 \pm 0.3^{+0.5}_{-0.5}$	$-135 \pm 25 \pm 2^{+26}_{-31}$	–	–
$f_2(1270)K^0$	–	–	< 1.4	–
Non-resonant	$41.9 \pm 5.1 \pm 0.6^{+1.4}_{-2.5}$	$\delta_1^{\rm nr} = -22 \pm 8 \pm 1^{+6}_{-6}$ $\delta_2^{\rm nr} = 175 \pm 30 \pm 4^{+54}_{-30}$	–	$19.9 \pm 2.5 \pm 1.6^{+0.7}_{-1.2}$
$\chi_{c0}K^0$	–	–	< 0.56	< 113

- In general, compatible with Q2B result from BaBar
- Exception: non-resonant (They use a complicated, non flat component. See later on)
- Something happens around 1400 MeV…

Likelihood

$$L=\prod_{c=1}^{5} e^{-N'_c}\prod_{i=1}^{N_c}\left(N_s\varepsilon_c\left(1-f_{SCF,c}\right)P_{S,c}^{TM}+N_s\varepsilon_c f_{SCF,c}P_{S,c}^{SCF}+N_{q\bar{q}}P_{q\bar{q},c}+\sum_{j=1}^{N_{class}^B}N_{B,j}\varepsilon_{B,c}P_{B,c}\right)(\vec{x}_i)$$

$$f\left(\Delta t,Q_{tag}\right)\propto\left(|A|^2+|\bar{A}|^2\right)\frac{e^{-|\Delta t|/\tau}}{4\tau}$$

$$\left(1+2Q_{tag}\frac{\mathrm{Im}\left[\bar{A}A^*e^{-i\phi_{mix}}\right]}{|A|^2+|\bar{A}|^2}\sin(\Delta m_d\Delta t)-Q_{tag}\frac{|A|^2-|\bar{A}|^2}{|A|^2+|\bar{A}|^2}\cos(\Delta m_d\Delta t)\right)$$

A and A are described using isobar model.

$$\mathcal{A}=\mathcal{A}_{K^{*+}\pi^-}+\mathcal{A}_{\rho^-K^+}+\mathcal{A}_{\mathrm{n.r.}}+\ldots=\sum_j\mathcal{A}_j=\sum_j|\mathcal{A}_j|\,e^{i\varphi_j}f_j(DP)$$

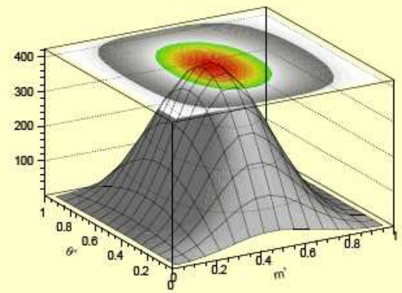
$f_i(\mathrm{DP})=$ Blatt-Weiskopf penetration factor $\times$ spin-dependent kinematic function $\times$ relativistic Breit-Wigner (or GS, LASS...)

$$\left\langle f_i f_j^* \right\rangle$$

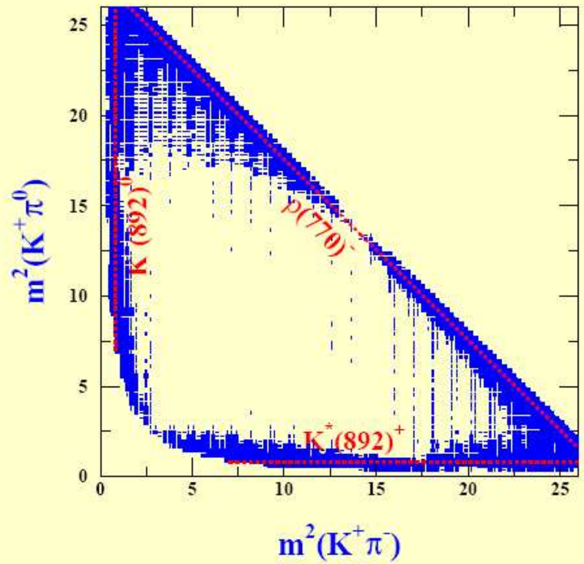
"bilinears" are evaluated by numerical MC integration
And fixed in the signal model
(i.e. we cannot fit resonance parameters)

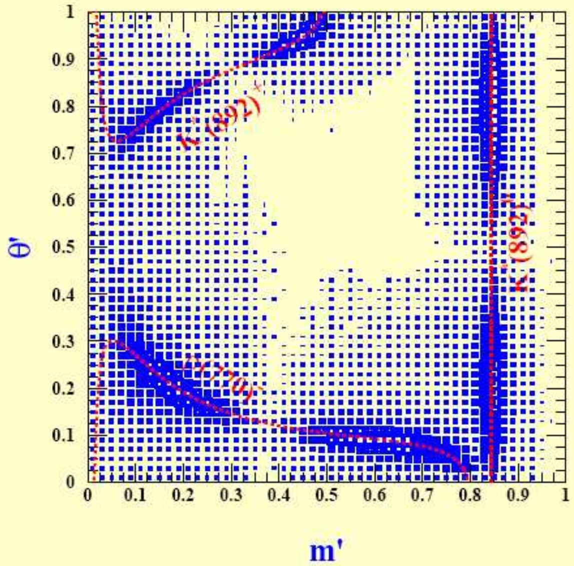
Analysis Overview (I)

- Use Square Dalitz Plot
- ✓ Easier efficiency parametrisation
- ✓ Phase space and bin boundaries coincide
- ✓ Zoom into interference corners
- Needs Jacobian... (CPU issue...)



$$m' = \frac{1}{\pi}\cos^{-1}\left(\frac{m_{+-} - m_{+-}^{\min}}{m_{+-}^{\max} - m_{+-}^{\min}}\right) \,,\ \theta' = \frac{1}{\pi}\theta_{+-}$$





$K^+\pi^-$ Q2B **dedicated study (III)**

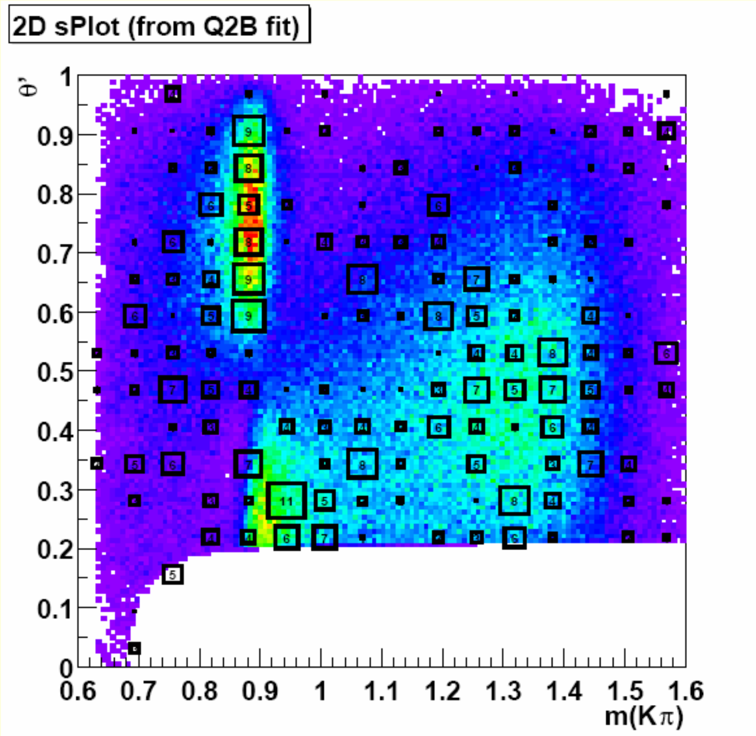
- Dalitz `sPlot` on Q2B region

➪ overlaid: S-wave plus $K_0^*(892)$ model

☞ model uses amplitudes and phases from full Dalitz fit

➪ qualitative agreement: interference pattern similar to toy

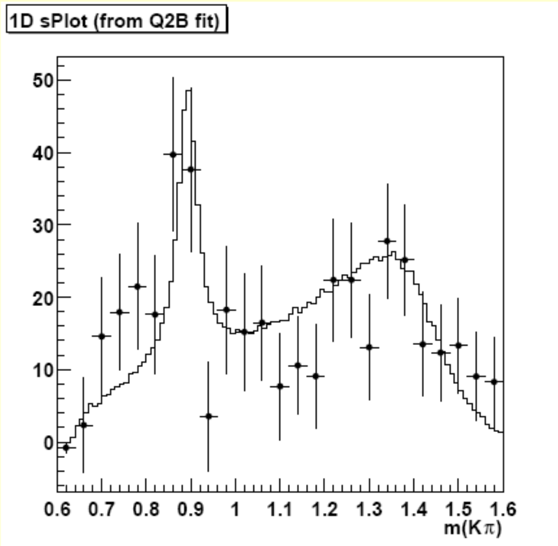
➪ some discrepancies too...

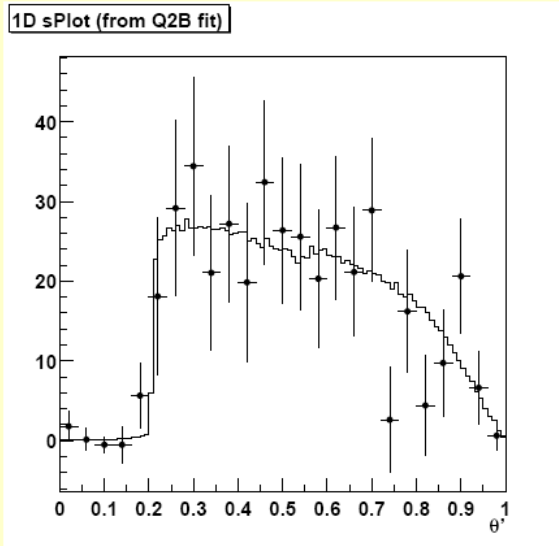


Mode	$\mathcal{A}$	φ	$\bar{\mathcal{A}}$	$\bar{\varphi}$
$K_0^*(892)$	0.92	11.3	1.03	-36.7
$K_0^*(1430)^0$	49.1	-187.2	50.2	125.3

$K^+\pi^-$ Q2B **dedicated study (IV)**

One-dimensional projections:





- signal excess at low $m(K\pi)$?

☞ S-wave propagates up to low masses? SCF from other modes?

➪ warning: overlaid distributions from S-wave plus $K_0^*(892)$ model ...

➪ warning: `sPlot` substraction relies on B background MC...

➪ ... more studies needed...

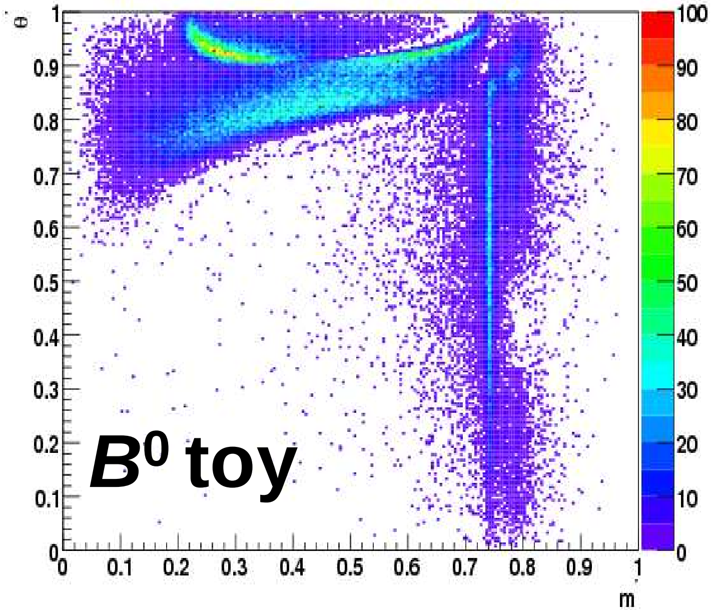
Nominal Signal Model

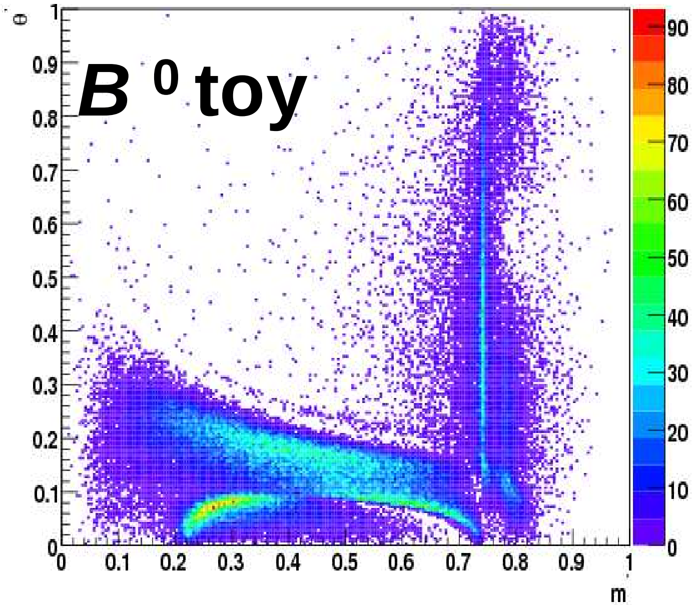
- $B^0 \rightarrow \rho^0 K^0_S$ (GS)
- $B^0 \rightarrow f_0 K^0_S$ (Flatte)
- $B^0 \rightarrow K^*(980)\,\pi$ (RBW)
- $B^0 \rightarrow K^*(1430)\,\pi$ (LASS)

- Non resonant (flat)
- $B^0 \rightarrow f_x(1300) K^0_S$ (RBW)

Introduced very recently. See discussion later on.

- Other modes are included when evaluating model uncertainty.





$K^- \pi^+$ Elastic Scattering : I = ½ S-wave Amplitude

Subtract I = 3/2 Amplitude from Total S-wave {Total = | I = 1/2 > + 0.5 | I = 3/2 >}

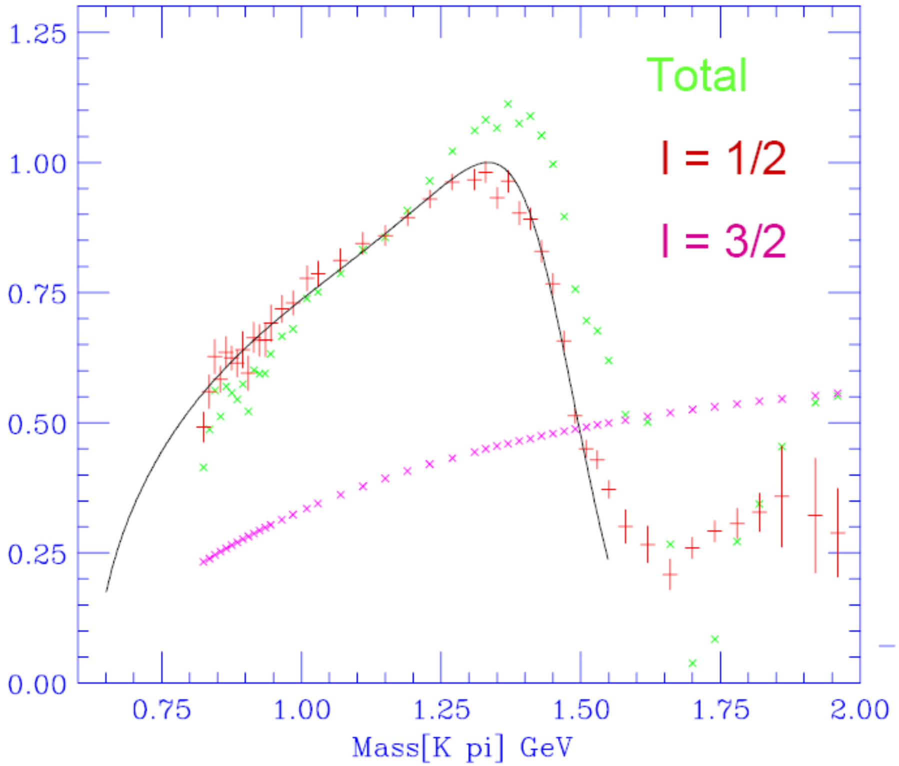
Result consistent with elastic unitarity up to ~1.5 GeV/c^2

Fit with coherent superposition of Effective Range and Resonant amplitudes

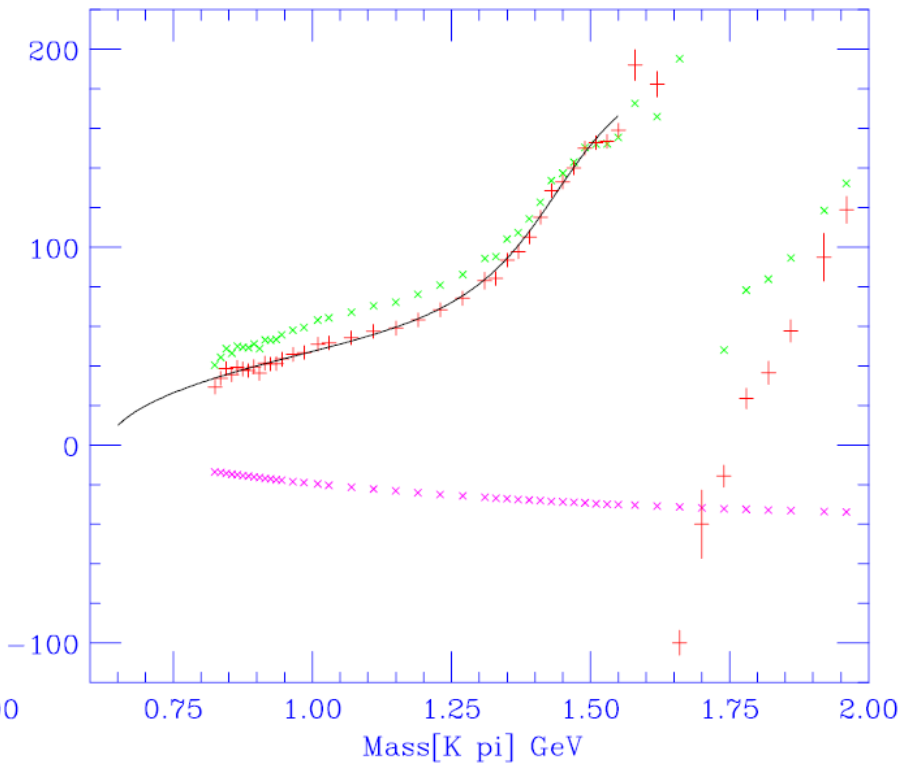
(Resonance parameters : M ~ 1.435 GeV/c^2, Γ ~ 0.279 GeV)

Possible radial excitation in 1.9 - 2.0 GeV region, elasticity ~ 0.35

Amplitude

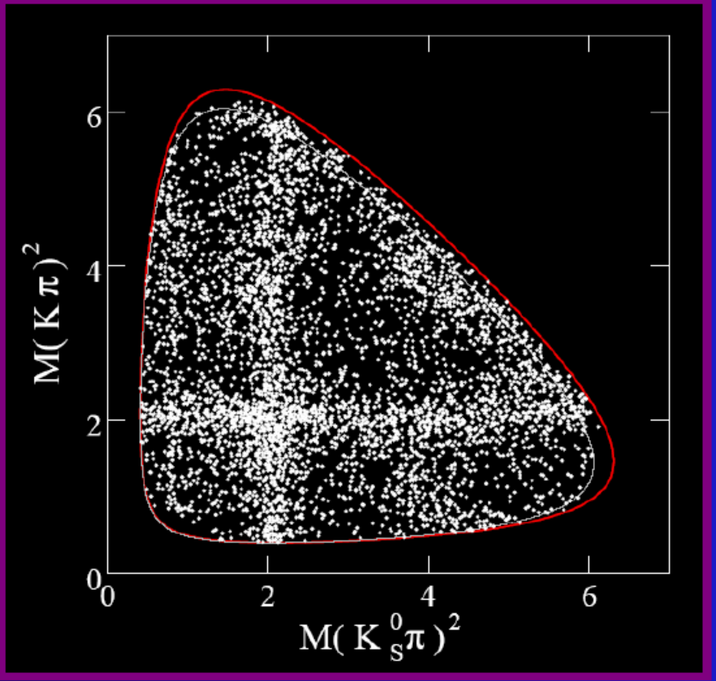


Phase (deg.)



Dalitz Analysis of the Decay $\eta_c \to K_S K \pi$ and Study of the $K\pi$ (I= 1/2) S-wave

documentation: BAD 1602, version 1

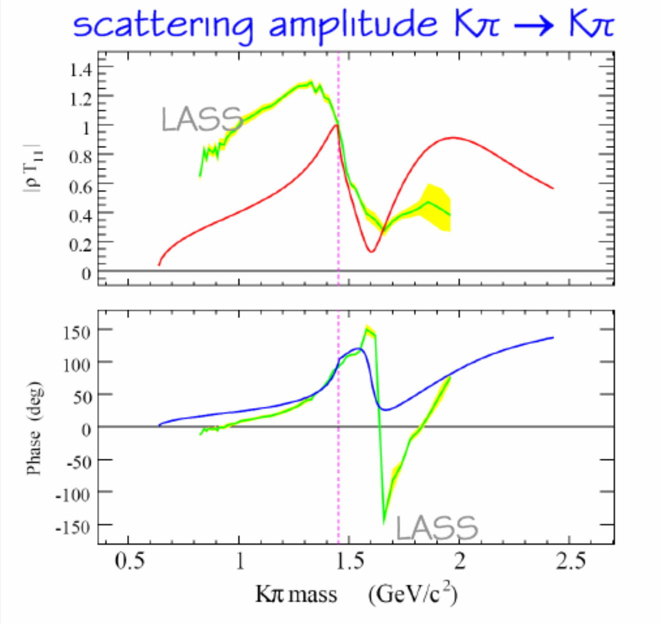


G. Hamel de Monchenault, Saclay

BABAR France – 20 November 2006

Summary

- A fit of the Dalitz Plot has been performed
  - chi-squared per d-o-f ~ 1.14
- The DP is dominated by the K S-wave
  - fit fraction ~85%
- $K\pi$ S-wave/D-wave interference described
- Higher $K\pi$ spectrum: imperfectly described
  - see in particular Y_4
- Structure at the crossing between the two $K\pi$ S-waves around 1.450 GeV
  - interference with high-mass KK resonance?
  - the high mass KK region is poorly known…
- No κ(800) seems necessary to fit the data
- Preliminary information on parameters of $K^*_0(1430)$ and $K^*_0(1950)$
- Fit in bins of $m(K\pi)$
  - phase: unstable results
  - missing a reference wave

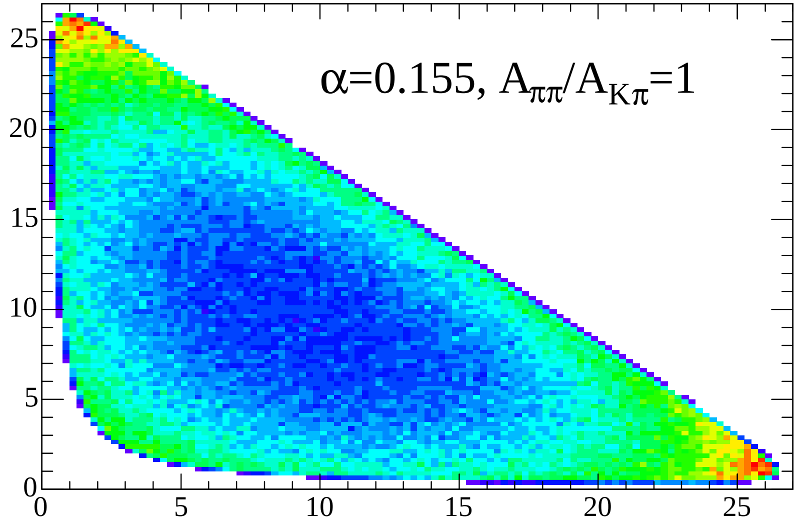


At this point, difficult to conciliate present results with scattering data at low energy. Tentative cooperation with theorists (incl. Pr. M. Pennington) to refine the parameterization of the S-wave.

Including NR Component In the Model (I)

- The two existing results are not in agreement:
  - BAD1065 sets a strong limit on the BF ($<2.1X10^{-6}$)
  - Belle uses a complex NR component, with big BF ($19.6\pm3.1X10^{-6}$)

$$A_{NR}[K_S^0\pi^+\pi^-] =$$
$$A_{\pi\pi}e^{-\alpha s_{13}}e^{i\phi(\pi\pi)} +$$
$$A_{K\pi}e^{-\alpha s_{13}}e^{i\phi(K\pi)} +$$
$$A_{K\pi}e^{-\alpha s_{23}}e^{i\phi(K\pi)}$$
$$s_{12} = m^2_{\pi\pi}; s_{13} = m^2_{K\pi^-}; s_{23} = m^2_{K\pi^+}$$



We do not plan to use this because:

Having a single alpha for Kpi and pipi looks arbitrary

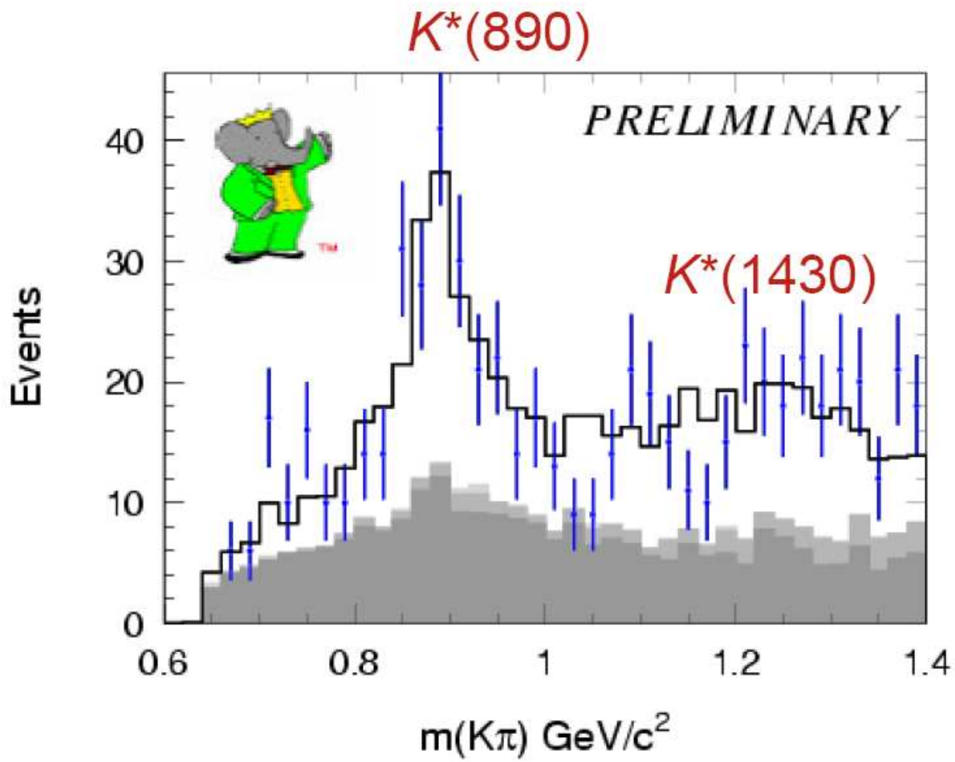
Kpi s-wave is taken into account with LASS parametrization

This line shape will not propagate to the center of the DP as in our data

Our NR component will be flat in phase space.

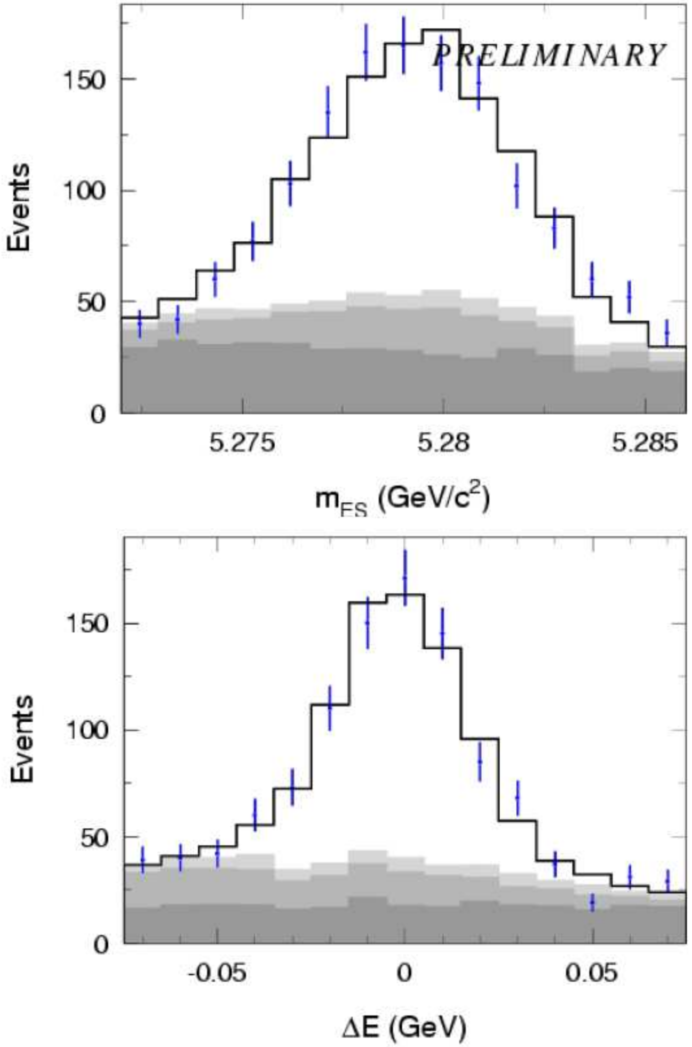
We *may* use the Belle pi pi parametrisation for systematics.

$B^0 \to \pi\pi K_S$ Final State

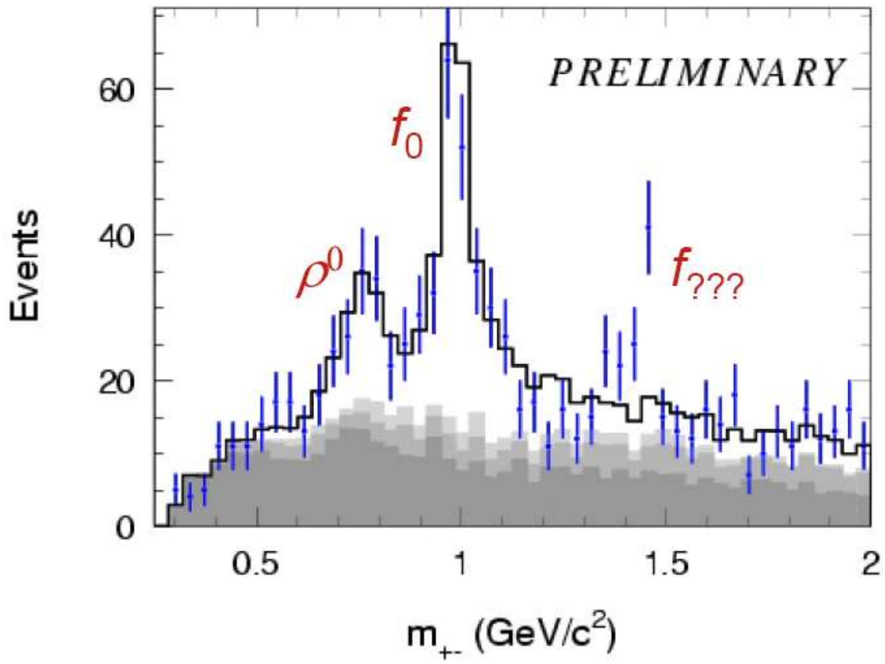


- A Dalitz plot with rich structures, apart from CP eigenstates, there are also flavor eigenstates.
- $K^*(890)\pi$, $K^*_0(1430)\pi$ are important for testing QCD factorization and other schemes.
- Can look for direct CP violation and test SU(3) symmetry in the $B \to$ PV decays
- Interference with flavor eigenstates can help lift the degeneracy in the $\sin 2\beta$ measurement

Analysis of $B^0 \to \pi\pi K_S$ Dalitz Plot



Similar analysis technique, need to handle additional flavor eigenstates



Strong signal with 347M BBbar 18

Model Systematics (II)

Moderato

(blind)

Probes for Belle's "fX(1300)": $f_2(1270)$, $f_0(1370)$, $\rho^0(1450)$, $f_0(1500)$, $\rho^0(1700)$

Component	Δ(NLL)	BF
$f_2(1270)$	19.5	~ 3.8 %
$f_0(1370)$	31.1	~ 4.2 %
$\rho^0(1450)$	35.2	~ 13.1 %
$f_0(1500)$	11.0	~ 1.6 %
$\rho^0(1700)$	7.6	~ 2.9 %
$\sigma(500)$	8.1	<1%
Non resonant	127 to 131	~ 23.6 %

- *f2(1270), f0(1370), ρ0(1450)* : in fact we're after the "f_x(1300)"
- We plan to use the fx(1300) from the signal model in the $K^+\pi^-\pi^+$ analysis
- … There is a big issue with the NR …

Model Systematics (III)

Moderato
(blind)

Significance of the non-resonant component calls for extra studies…

- Kelly's analysis (BAD1065) set a strong limit on it (BF<5%)
- Belle uses a complicated NR component, with big BF
- Larger variations in fit result (wrt nominal fit) concern :
  - *Signal yield : + 270 events*
  - *Generic charged (-50) and neutral (-90) B backgrounds*
  - *Continuum yield (-110)*
  - *Changes in the CP parameters:*

Parameter	Typical Error on Toys	Change(with-without)
Weak phase ($f_0K_S^0$)	$\sim 15^o$	-13.3^o
Weak phase ($\rho^0K_S^0$)	$\sim 18^o$	$+6.5^o$
Phase ($f_0K_S^0/\rho^0K_S^0$)	$\sim 17^o$	$+9.5^o$
Phase ($K^{*+}\pi^-/K^{*-}\pi^+$)	$\sim 37^o$	$+32.5^o$

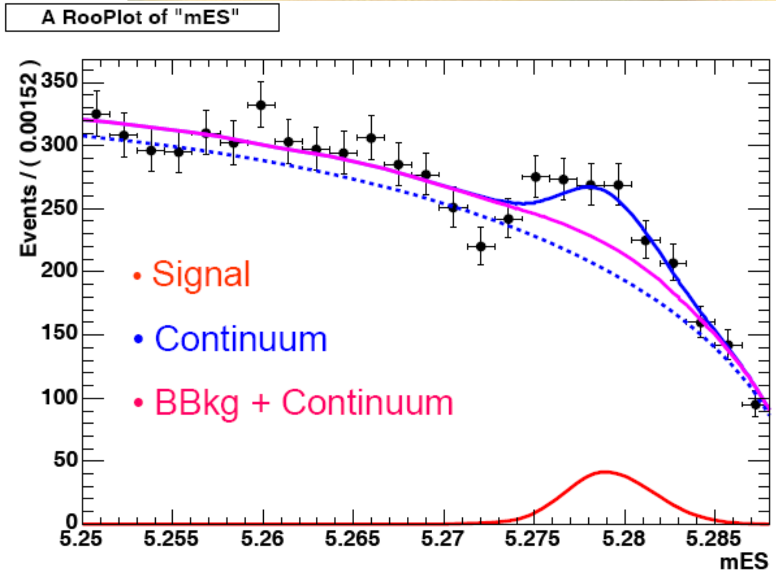
Looks bad…

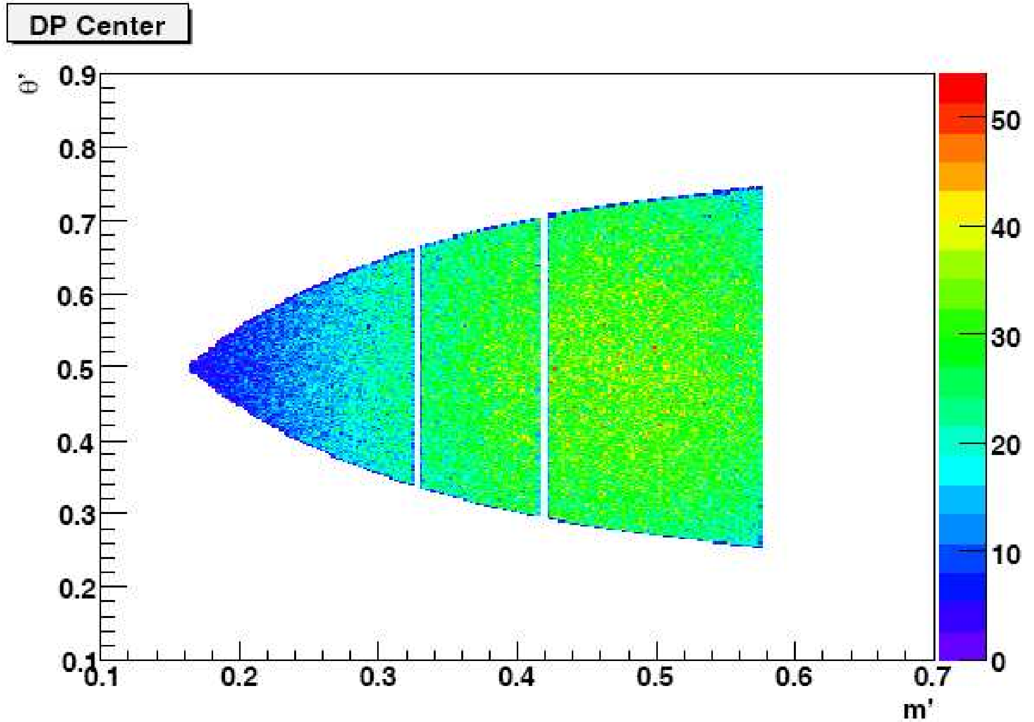
Summary

- Time dependent Dalitz plot analysis of $K\pi\pi$ final states will open new windows on $b \to s$ penguin amplitudes and CKM constraints

- Many analysis issues related to the signal model
  - Resonant structure *needs* to be hardcoded (CPU issue)
  - Signal model systematics will be estimated by impact of adding/removing extra isobar components
  - *Very large* $K\pi\pi$ S-wave component
    - Is is ok to use LASS ?
    - What about the m($K\pi$) >1.6 GeV regions?
    - Can something else be considered?
  - The $\pi\pi$ component has additional sharp terms
    - Same issues
  - What is this signal in the center of the DP ?
- Feedback is VERY welcome !

A Few sPlots in the DP Center (II)





- with nominal cuts:

  too few continuum …

  -99% correlation continuum/Bbkg

- Apply looser cuts on mES, dE, no cut on NN

Expect : ~200 Bbkg events (from Generic MC)

Yields	sFit Value
Signal	170 ± 29
Continuum	6036 ± 185
B Background	354 ± 175