Update on Dalitz plot analysis of $D^0 \rightarrow K_S\pi^+\pi^-$

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(on behalf of Y.Lau and J.Olsen)

BaBar Collaboration Meeting Dec 2006

Charm AWG parallel sessions

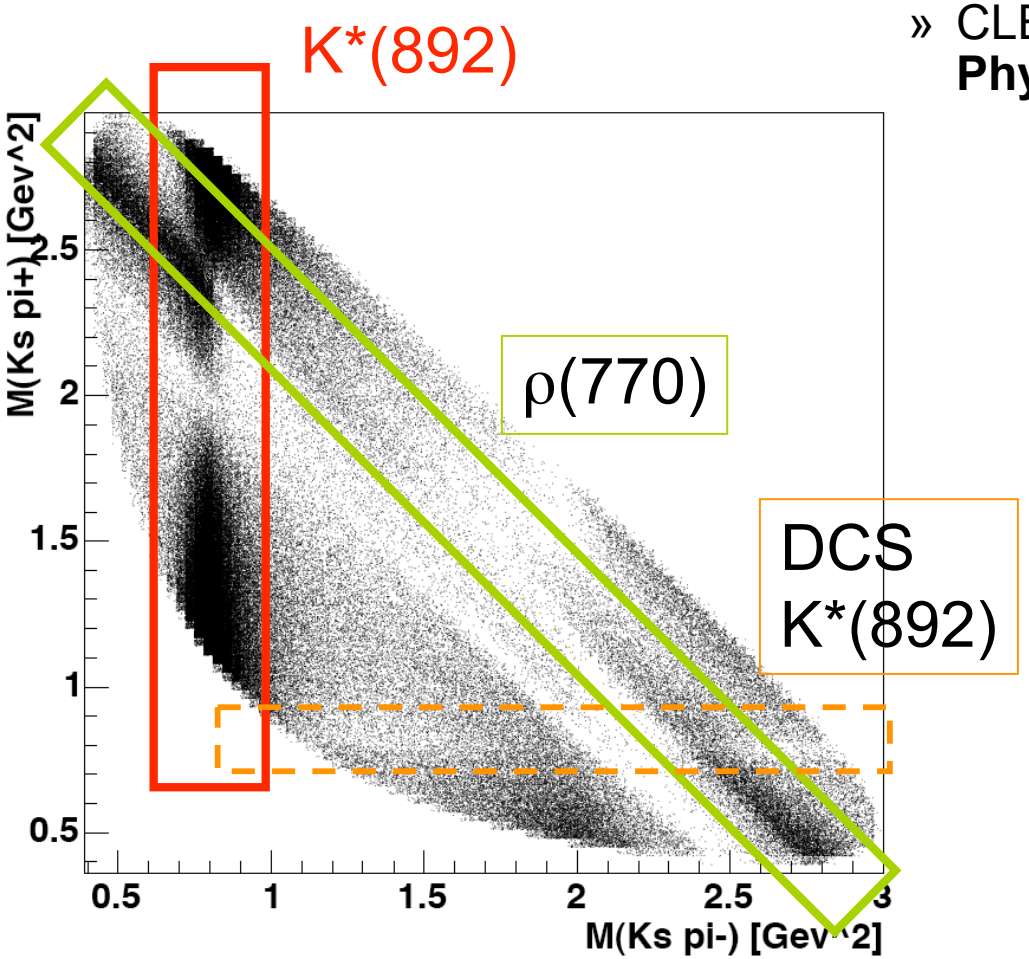
Introduction

- Dalitz plot fit results used in $B^+ \rightarrow D^0 K^+$ analysis for CKM γ extraction
  - presented several times in conference paper and in one publication.
- Never finalized as an indipendent publication
  - Big $\pi^+\pi^-$ S-wave component:
    K-matrix parametrization vs questioned BW broad "σ"
  - Reference for model systematic on γ extraction
  - Last publication was from CLEO
    Phys. Rev. Lett. 89, 251802 (2002)
    (5299 candidates - "σ"'s **treated as perturbation…)**
  - ***Punchline of paper would be showing S-wave***

- Here Run1-Run4 data
  - 215449 events selected with a purity of >98%
- Information in BAD 1237 (v3 to come)
- Writing a PRD

The Dalitz plot

BaBar Run1-4 data

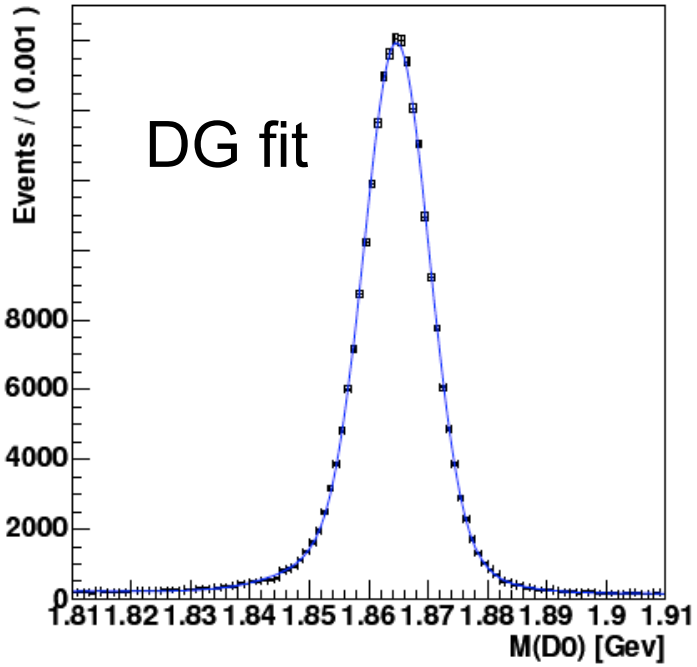


» CLEO model
Phys. Rev. Lett. 89, 251802 (2002)

$$K^*(892)^+\pi^- \times B[K^*(892)^+ \to K^0\pi^+]$$
$$\overline{K^0}\rho^0$$
$$\overline{K^0}\omega \times B(\omega \to \pi^+\pi^-)$$
$$K^*(892)^-\pi^+ \times B[K^*(892)^- \to \overline{K^0}\pi^-]$$
$$\overline{K^0}f_0(980) \times B[f_0(980) \to \pi^+\pi^-]$$
$$\overline{K^0}f_2(1270) \times B[f_2(1270) \to \pi^+\pi^-]$$
$$\overline{K^0}f_0(1370) \times B[f_0(1370) \to \pi^+\pi^-]$$
$$K_0^*(1430)^-\pi^+ \times B[K_0^*(1430)^- \to \overline{K^0}\pi^-]$$
$$K_2^*(1430)^-\pi^+ \times B[K_2^*(1430)^- \to \overline{K^0}\pi^-]$$
$$K^*(1680)^-\pi^+ \times B[K^*(1680)^- \to \overline{K^0}\pi^-]$$
$$\overline{K^0}\pi^+\pi^- \text{ nonresonant}$$

Very rich structure!

Selection

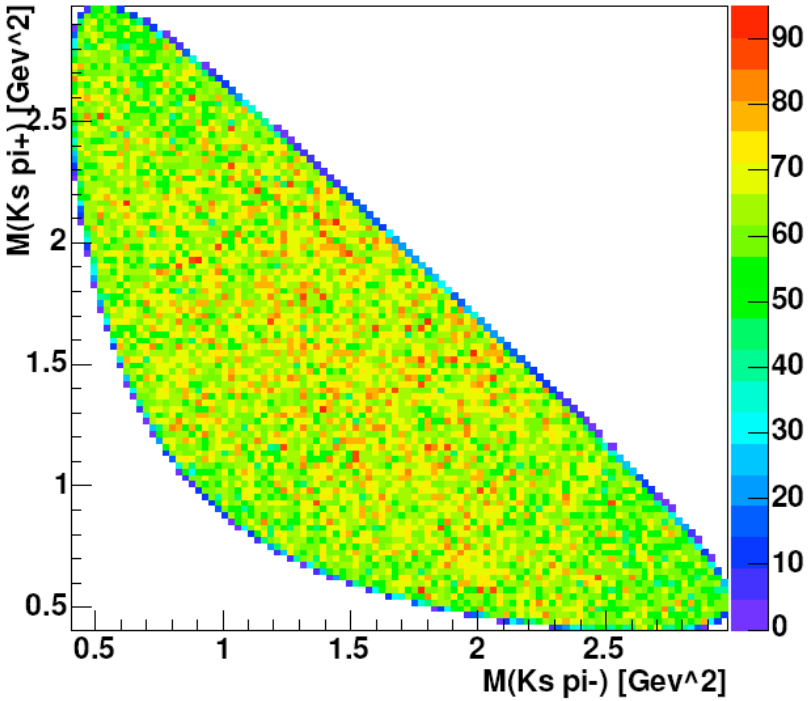


  - Very straightforward
- D^0 from D* decay (ccbar)
  - $pD^0 > 2.2$ GeV
  - $|\Delta m - \Delta m_{mean}| < 0.5$ MeV
- Cut on Ks mass (0.488-0.508 GeV) + vertex and flight direction requirements
- D^0 daughter mass constrained (TreeFitter)
- $P(\chi^2)$ (D*vertex) >0.001
- $|mD^0 - mD^0_{mean}| < 11$ MeV

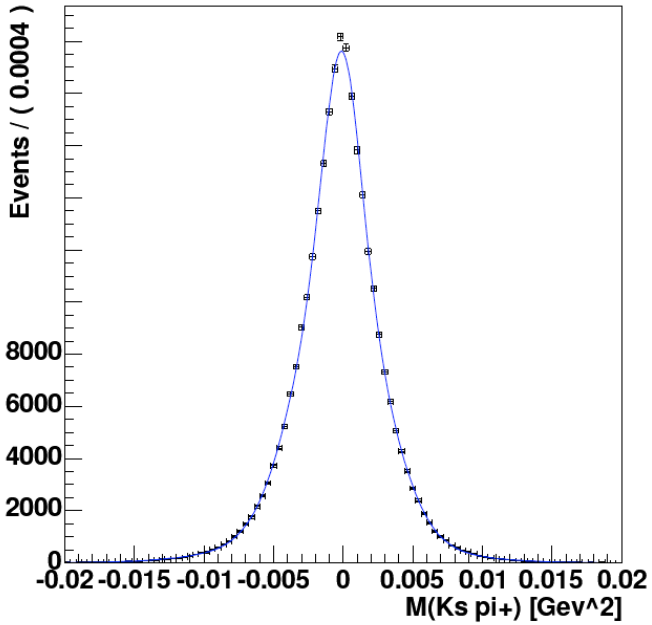
– Very little background left

Binned χ^2 fit (250x250 uniform binning)

Efficiency and resolution



Almost flat, parametrized with polynomial

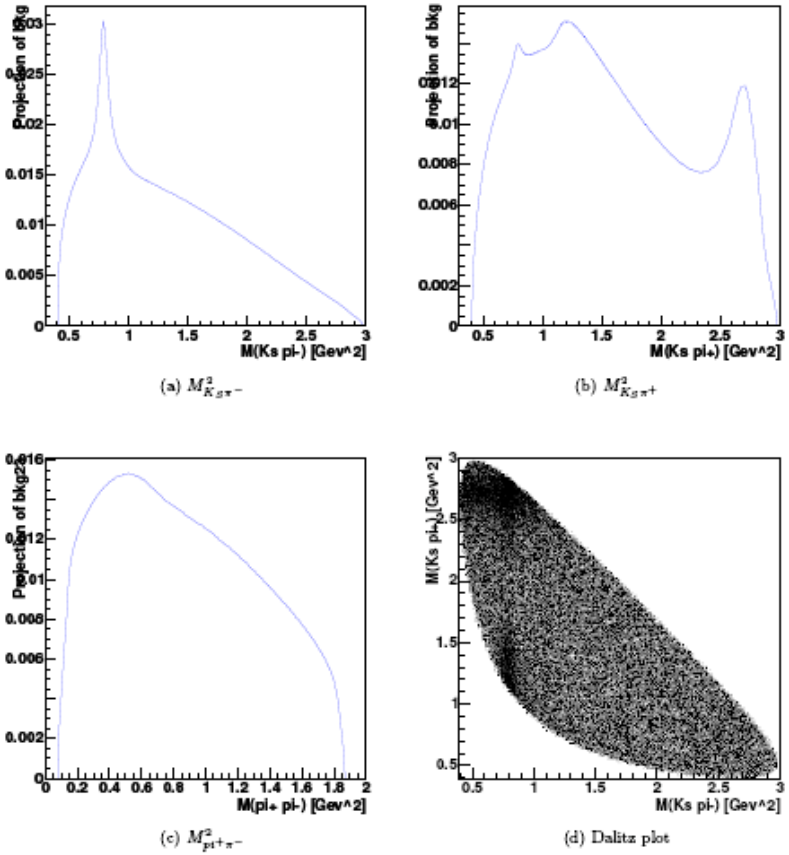


Negligible compared to natural width of resonance

Only $\omega(782)$ slightly affected

Model for background

Toy MC simulation



(a) $M^2_{K_S\pi^-}$ (b) $M^2_{K_S\pi^+}$

(c) $M^2_{\pi^+\pi^-}$ (d) Dalitz plot

Only 1.5% of the total sample

Look at Upper and lower mD^0 sideband

- » Parametrize separately resonances and combinatorics
- » Fraction of resonance averaged between upper and lower sideband
- » Rescale momenta to signal region

BaBar Dalitz model

- S-wave
  - $\pi\pi$: K-matrix parametrization (Anisovich et al.)
  - $K\pi$: LASS parametrization [$K^*_0(1430)$]
- P-wave
  - $\pi\pi$: Gounaris-Sakurai rel BW $\rho(770)$
    + $\omega(782)$
    [+ $\rho(1450)$ allowed for syst. check]
  - $K\pi$: rel BW $K^*(892)$
    [m and Γ from BaBar B J/psiK* crosscheck on signal data]
    + $K^*(1680)$
- D-wave
  - $K^*_2(1430)$
  - $f_2(1270)$
    - Using Zemach tensor formalism
    - Using PDG if not otherwise noted

Allowing DCS Amplitude

S-wave $\pi^+\pi^-$

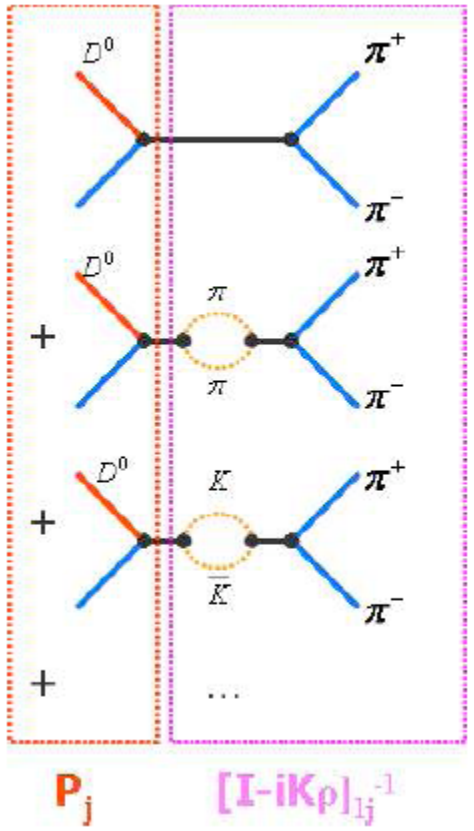
- K-matrix parametrization

Production vector

$$P_j(s) = \left\{ \sum_\alpha \frac{\beta_\alpha g_j^{(\alpha)}}{m_\alpha^2 - s} + f_{1j}^{prod} \frac{1.0 - s_0^{prod}}{s - s_0^{prod}} \right\}.$$

Transition amplitude

$$F_l = \sum_j (I - iK\rho)^{-1}_{lj} P_j$$



Pole masses ***couplings***

m_α	$g_{\pi\pi}$	$g_{K\bar{K}}$	$g_{4\pi}$	$g_{\eta\eta}$	$g_{\eta\eta'}$
0.65100	0.22889	-0.55377	0.00000	-0.39899	-0.34639
1.20360	0.94128	0.55095	0.00000	0.39065	0.31503
1.55817	0.36856	0.23888	0.55639	0.18340	0.18681
1.21000	0.33650	0.40907	0.85679	0.19906	-0.00984
1.82206	0.18171	-0.17558	-0.79658	-0.00355	0.22358
s_0^{scatt}	f_{11}^{scatt}	f_{12}^{scatt}	f_{13}^{scatt}	f_{14}^{scatt}	f_{15}^{scatt}
-3.92637	0.23399	0.15044	-0.20545	0.32825	0.35412
$s_{A0} = -0.15$	$s_A = 1$				

Full matrix from private comm.
Other two other "solutions" used for syst.

Kπ S-wave

- LASS parametrization

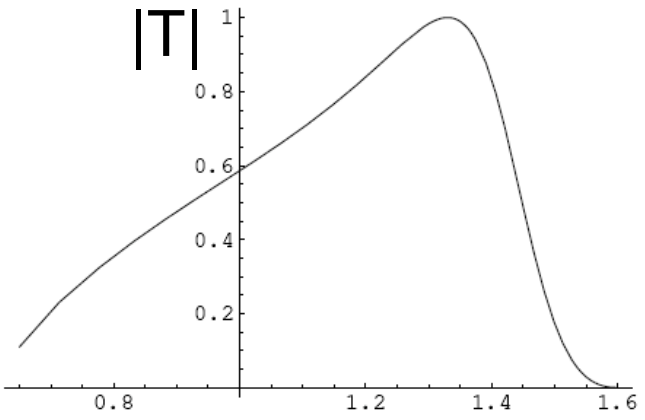
$$\mathcal{A}_0 = B \sin\delta_B e^{i\delta_B} + R \sin\delta_R e^{i\delta_R} e^{i2\delta_B}$$

$$\delta_B = \phi_B + ctg^{-1}(1/(ap) + (rp)/2) \quad \text{Non-resonant}$$

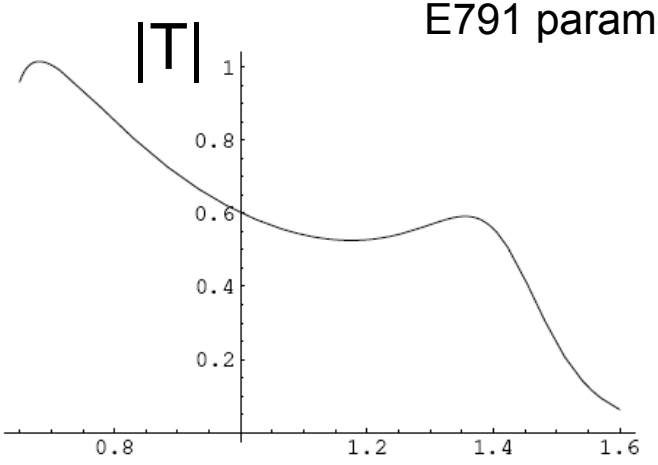
$$\delta_R = \phi_R + tg^{-1}\left(\frac{M \cdot \Gamma}{M^2 - m_{K\pi}^2}\right) \quad \text{resonant}$$

Parameters determined in our fit

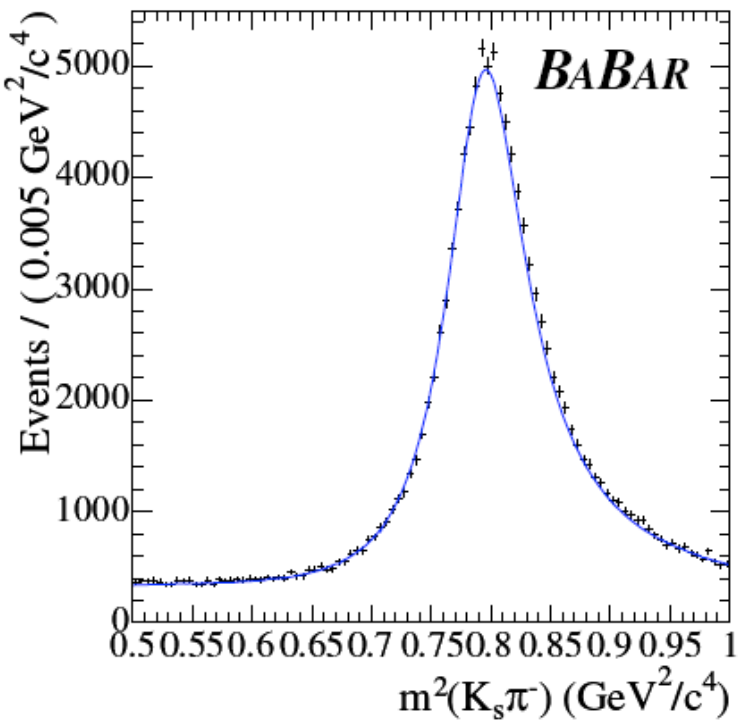
LASS parameters



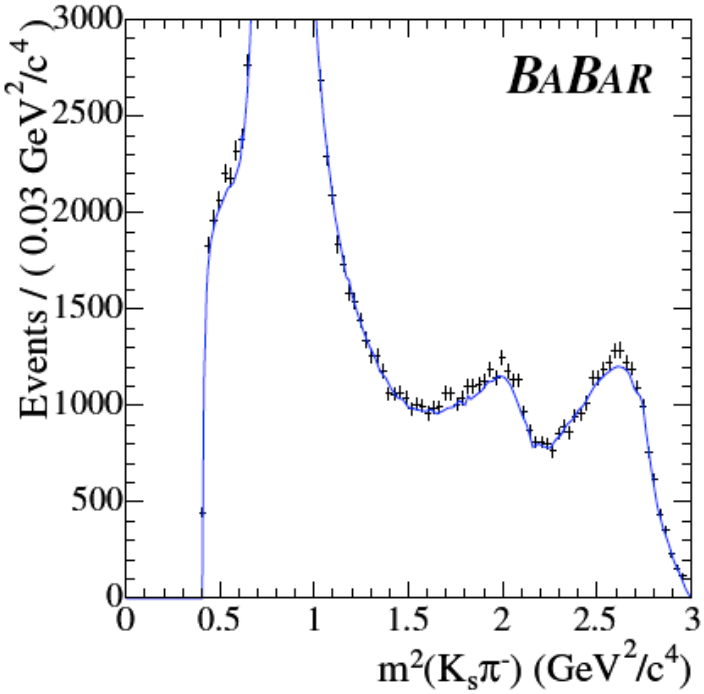
E791 parameters



Cabibbo Allowed $m^2_{K\pi}$

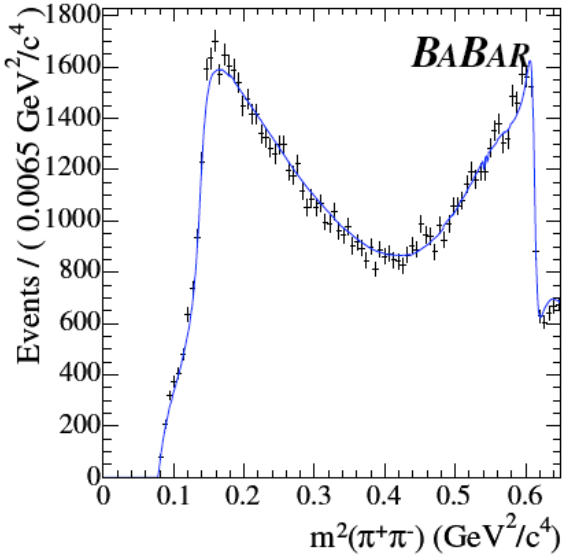


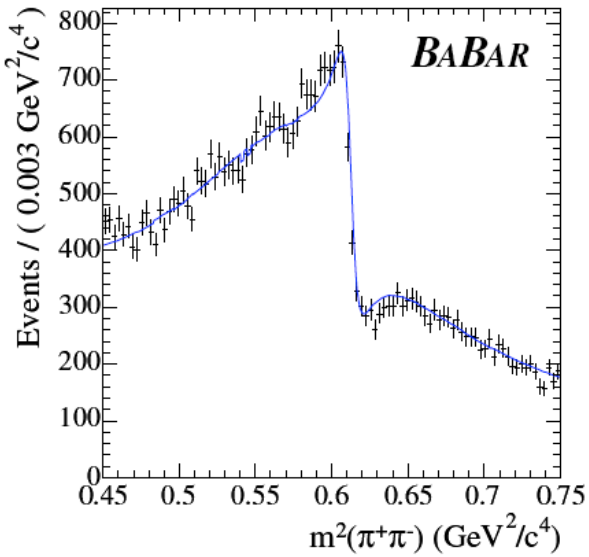
K*(892) improved using m and Γ determined in our data

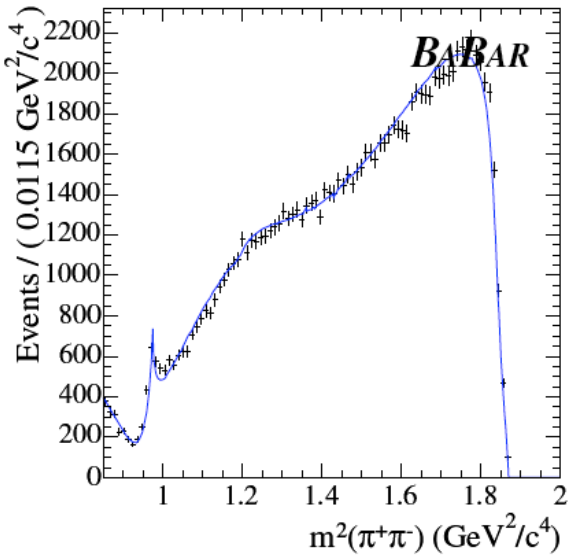


Improved a lot with LASS parametrization

$m^2_{\pi\pi}$ projections



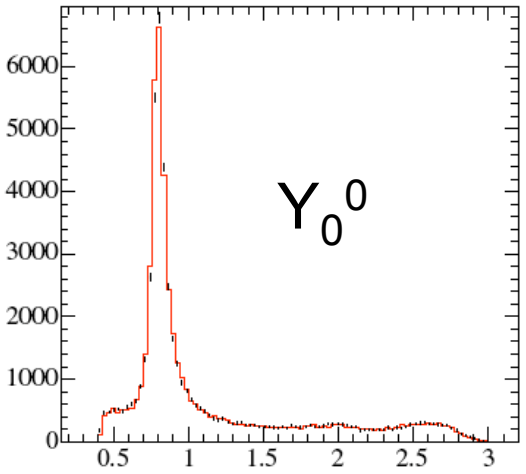




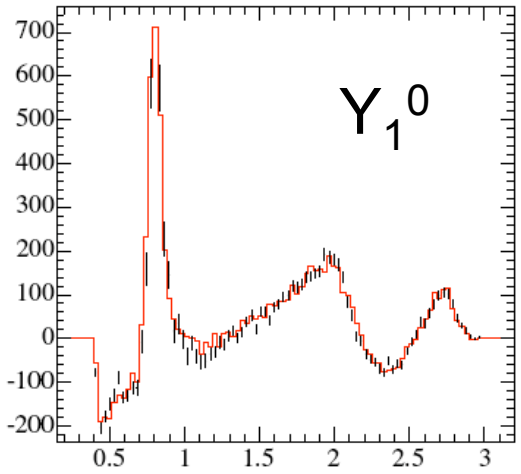
$\rho-\omega$ interference region

Angular moments

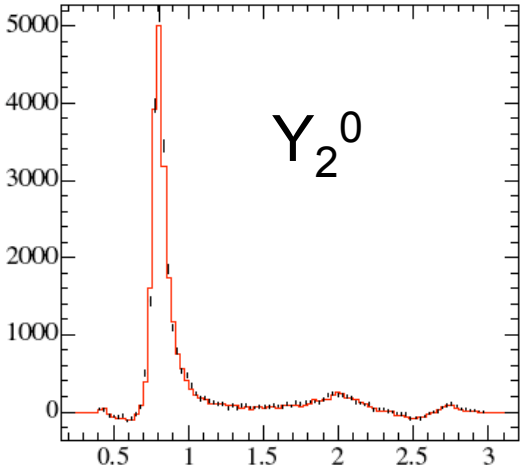
CA
$m^2K\pi$

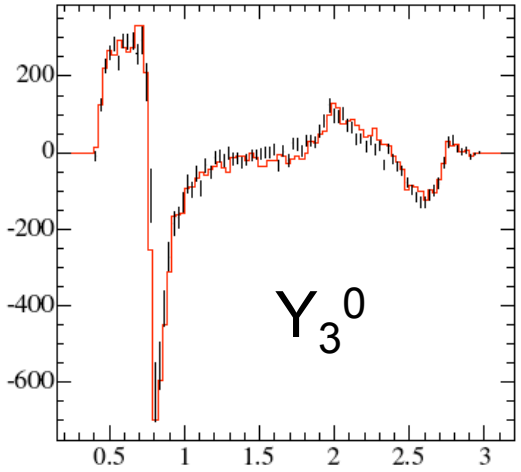


(a) $m^2_{K^0_S\pi^-}$ Y_0^0 projection

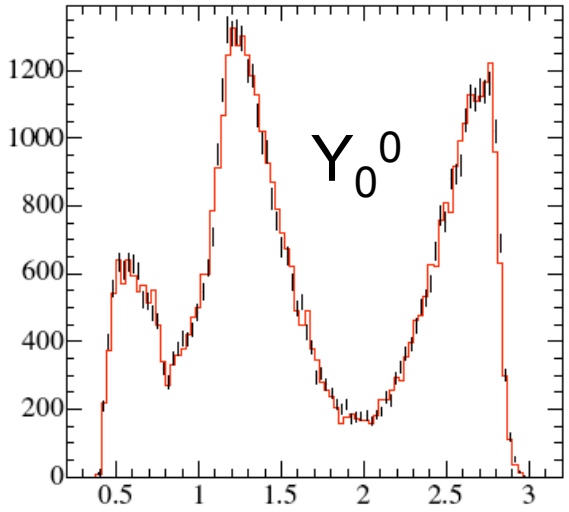


(b) Y_1^0 projection

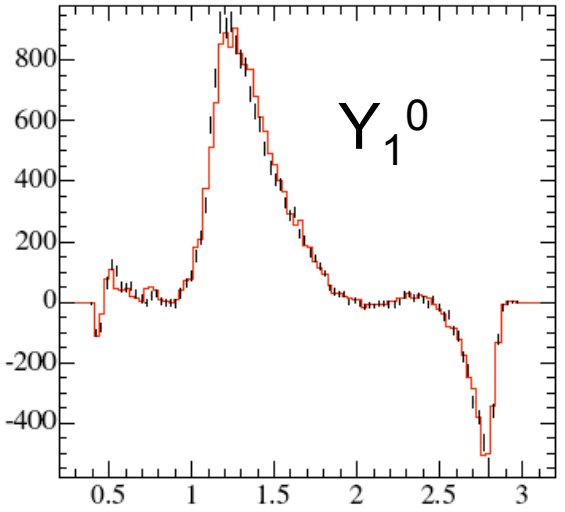




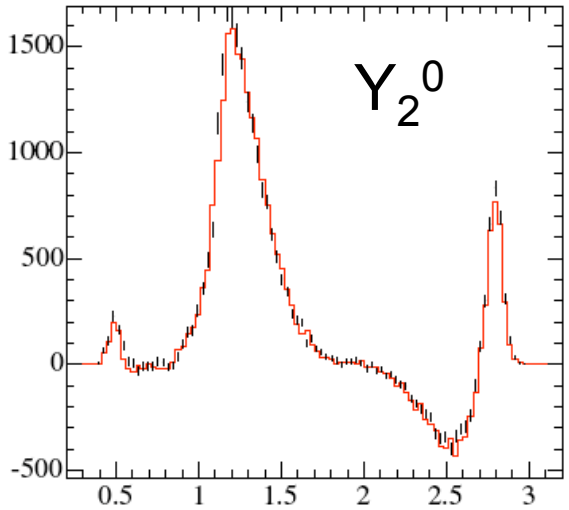
DCS Angular moments

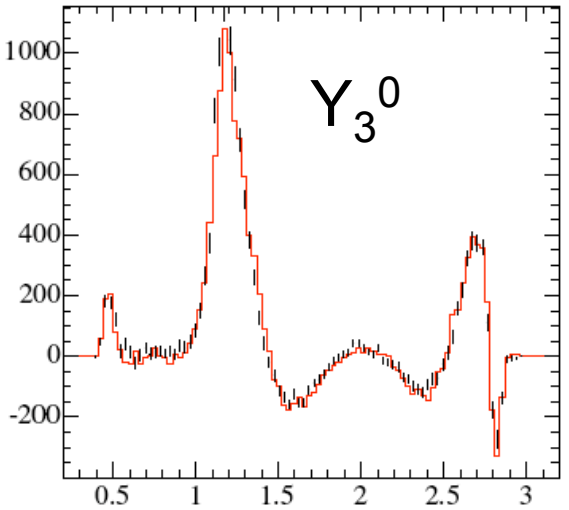


(a) $m^2_{K^0_S\pi^+}$ Y_0^0 projection

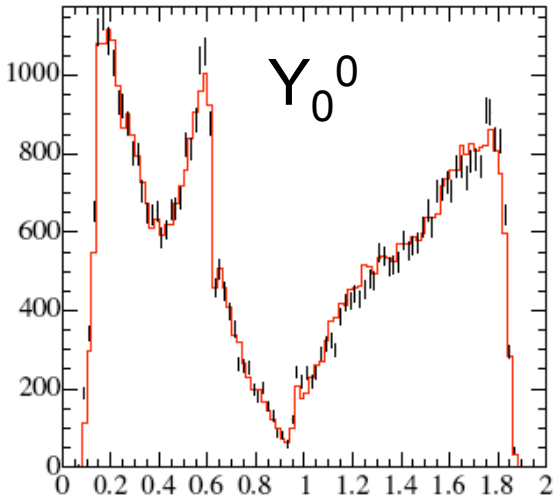


(b)

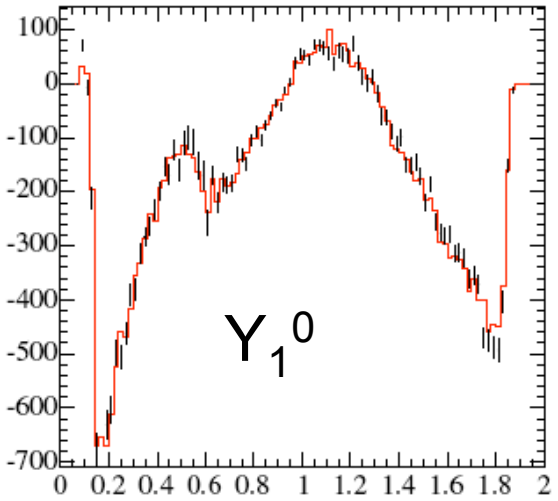




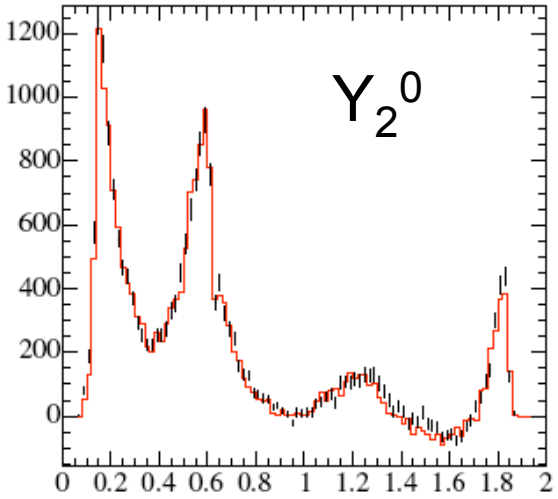
ππ ang.moments

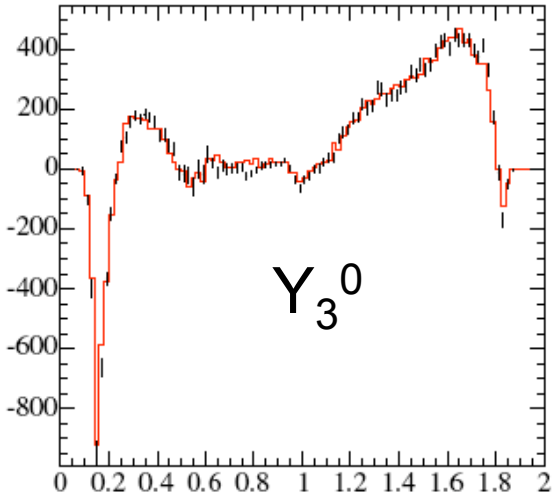


(a) $m^2_{\pi^+\pi^-}$ Y_0^0 projection

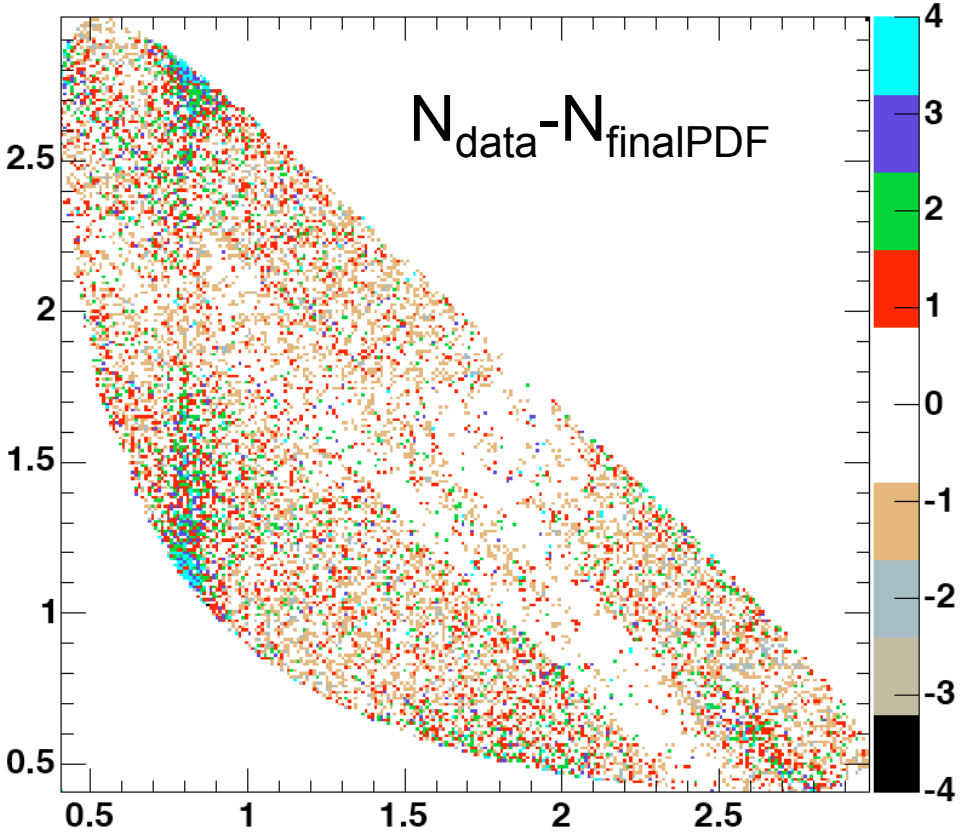


(b)





Residual distribution



- *Total χ2 not good…*

Amplitude:fit results

K*892_im	1.22 ± 0.01
K*892_re	-1.193 ± 0.01
K0*1430_im	4.3 ± 0.2
K0*1430_re	2.5 ± 0.3
K0*1430_mass	1.431 ± 0.003
K0*1430_width	0.28 ± 0.01
a	0.356 ± 0.008
phiB	109 ± 2
phiR	-172.2 ± 5
r	-10.49 ± 0.2
B	0.00 ± 0.07
K2*1430_im	0.97 ± 0.03
K2*1430_re	-0.829 ± 0.03
K*1680_im	-0.266 ± 0.09
K*1680_re	-0.252 ± 0.10
K*892_DCS_im	-0.1133 ± 0.004
K*892_DCS_re	0.103 ± 0.005
K0*1430_DCS_im	0.25 ± 0.06
K0*1430_DCS_re	-0.054 ± 0.06
K2*1430_DCS_im	0.01 ± 0.03
K2*1430_DCS_re	0.04 ± 0.03

Kπ LASS parameters

DCS amplitudes

omega782_im	0.036 ± 0.001
omega782_re	-0.0133 ± 0.001
f2_1270_im	0.10 ± 0.03
f2_1270_re	-0.529 ± 0.02
beta1_im	-9.11 ± 0.2
beta1_re	-0.23 ± 0.2
beta2_im	-7.68 ± 0.2
beta2_re	-15.26 ± 0.2
beta3_im	-13.3 ± 2
beta3_re	-66.0 ± 2
beta4_im	2.2 ± 0.6
beta4_re	-1.26 ± 0.7
fprod1_im	13.3 ± 0.2
fprod1_re	9.9 ± 0.2
fprod2_im	21.5 ± 0.8
fprod2_re	29.5 ± 0.8
fprod3_im	54 ± 2
fprod3_re	18 ± 2
fprod4_im	32.7 ± 0.5
fprod4_re	10.7 ± 0.5
s_prod	-0.533 ± 0.02

ππ K-matrix Production vector

- Amplitude ρ(770) fixed to 1 (phase to zero)
- Use cartesian parametrization
  - To be converted into module and phase for the Pub

Fit fraction results

Errors using

full covariance matrix

[500 extraction,

Fit fraction is
mean
of distribution

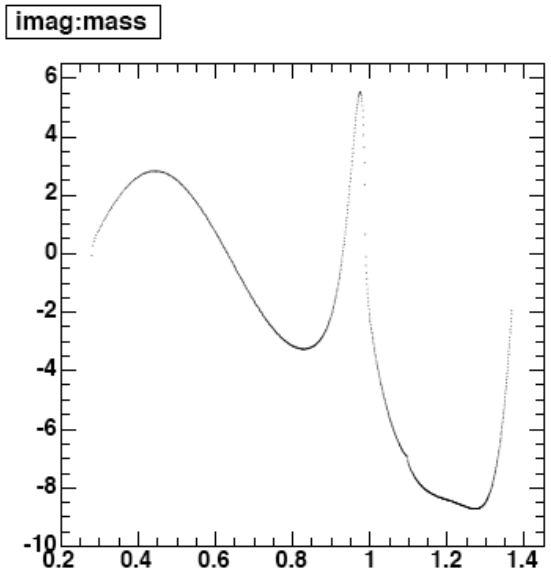
Error is RMS]

Component		Fit fraction (%)
$K^*(892)^-$	CA	54.23 ± 0.25
$K_0^*(1430)^-$		4.79 ± 0.19
$K_2^*(1430)^-$		1.888 ± 0.079
$K^*(1680)^-$		0.055 ± 0.023
$K^*(892)^+$	DCS	0.443 ± 0.029
$K_0^*(1430)^+$		0.0143 ± 0.0056
$K_2^*(1430)^+$		0.0037 ± 0.0029
$\rho(770)$		20.88 ± 0.17
$\omega(782)$		0.507 ± 0.035
$f_2(1270)$		0.449 ± 0.040
sum of $\pi^+\pi^-$ S-wave		16.64 ± 0.37

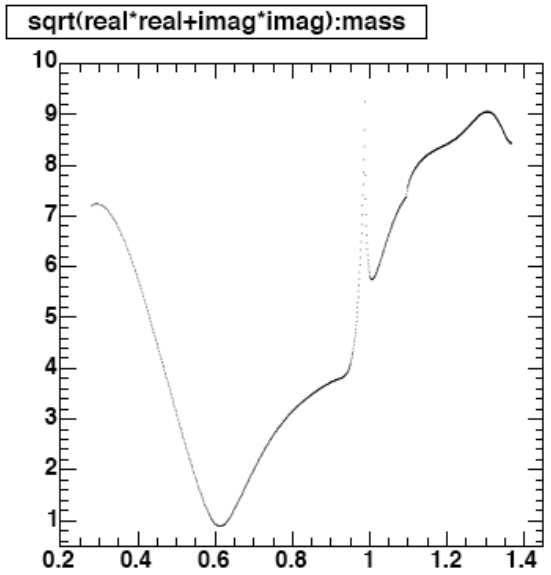
Total fit fraction 99.9%
No Non-resonant term needed!

NB: fit fractions contain BF of intermediate resonance

Total fitted S-wave

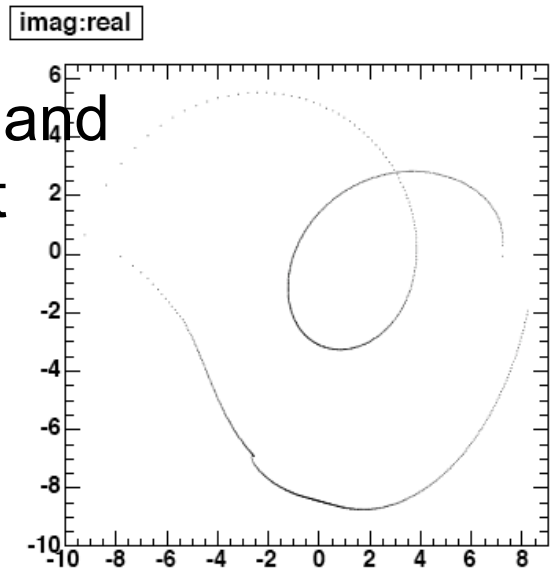


mππ

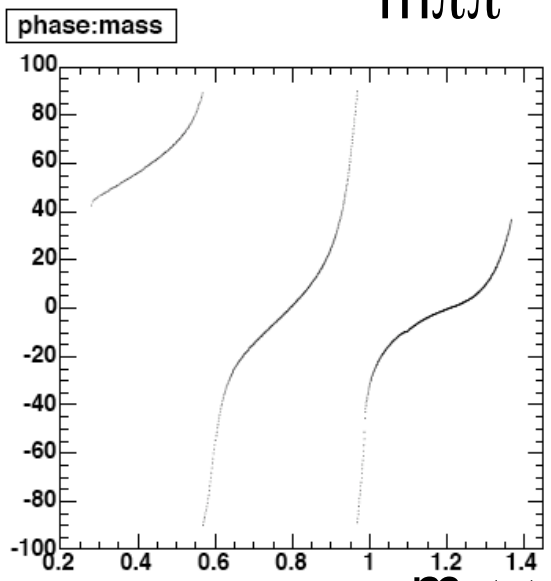


mππ

|T|



Argand plot



mππ

δ phase shift

Alternative fit

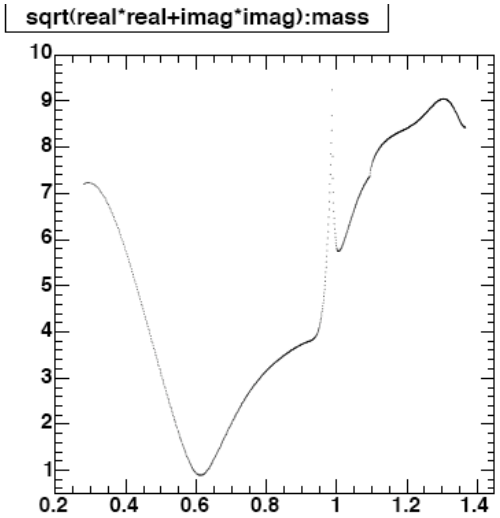
K*892_im	1.32 ± 0.02
K*892_re	-1.348 ± 0.02
K0*1430_im	5.2 ± 0.2
K0*1430_re	-6.30 ± 0.2
K0*1430_mass	1.465 ± 0.002
K0*1430_width	0.180 ± 0.004
K*1410_im	-0.118 ± 0.05
K*1410_re	-0.150 ± 0.05
K*1680_im	-1.24 ± 0.2
K*1680_re	-1.07 ± 0.1
K2*1430_im	0.89 ± 0.04
K2*1430_re	-0.801 ± 0.03
K*892_DCS_im	-0.1110 ± 0.005
K*892_DCS_re	0.117 ± 0.006
K0*1430_DCS_im	-0.533 ± 0.10
K0*1430_DCS_re	-0.741 ± 0.09
K2*1430_DCS_im	-0.040 ± 0.03
K2*1430_DCS_re	0.10 ± 0.03
omega782_im	0.039 ± 0.001
omega782_re	-0.0139 ± 0.001
rho1450_im	1.05 ± 0.08
rho1450_re	0.58 ± 0.04

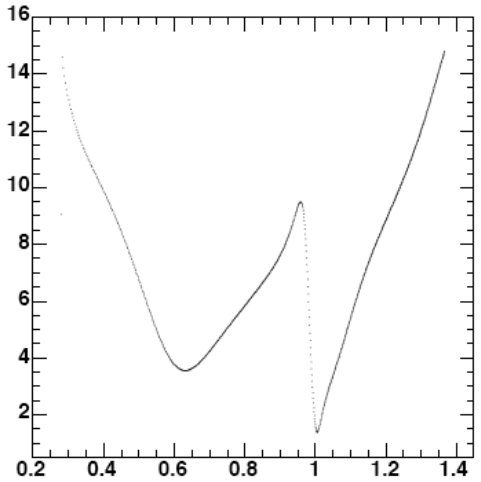
S-wave BW

sigma1_im	0.24 ± 0.07
sigma1_re	1.42 ± 0.07
sigma1_mass	0.500 ± 0.006
sigma1_width	0.39 ± 0.01
sigma2_im	0.51 ± 0.06
sigma2_re	0.45 ± 0.07
sigma2_mass	1.059 ± 0.005
sigma2_width	0.20 ± 0.01
f0_980_im	0.16 ± 0.01
f0_980_re	0.433 ± 0.008
f0_1370_im	-2.58 ± 0.2
f0_1370_re	3.0 ± 0.2
f2_1270_im	0.16 ± 0.04
f2_1270_re	-0.944 ± 0.03
NonReson_im	-3.71 ± 0.3
NonReson_re	4.4 ± 0.3

S-wave K-matrix vs BW

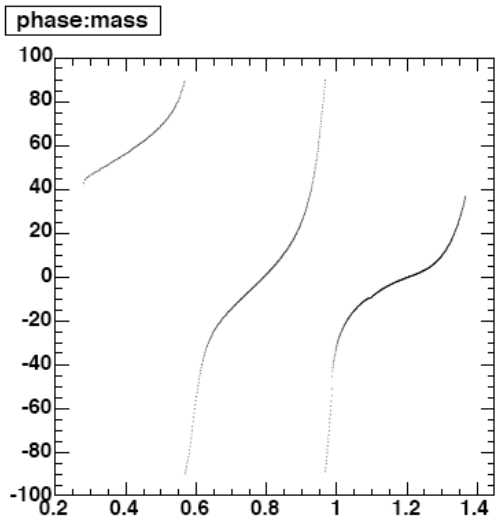
K-matrix

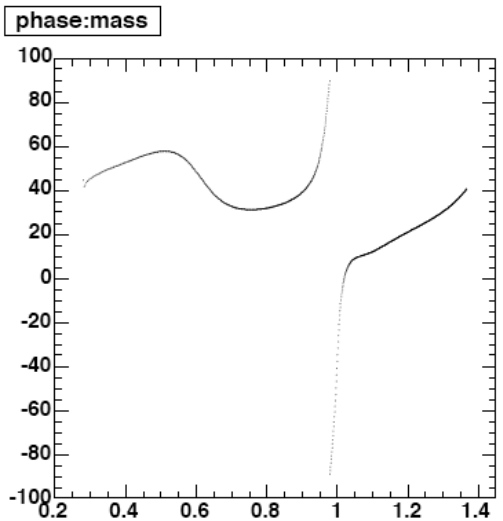




|T|

BW





δ phase shift

Systematics

- Efficiency correction
  - » Almost flat, fit with no correction
- Background parametrization
  - » 1.5%, fit with flat background
- Resolution and binning
  - » Fit with different binning (100x100)
- Resolution
  - » Fit with ω width increased of resolution (8.7 MeV)
- Include flavour mistag probability
  - » Fit with mistag fraction (from MC: 0.1%)

Model systematics

- S-wave
  - K-matrix, fit with A&S alternative solutions (2)
  - Kp : rel BW fit (with parameters from E791)
- P-wave
  - Vary m and Γ within exp. Uncertainty
  - Float m and Γ of K*(892)
- D-wave
  - Vary m and Γ within exp. Uncertainty
- Helicity formalism
  - Fit with helicity formalism
- Change Blatt-Weisskopf penetration factor
  - Deafult is 1.5, fit with 0.0 and 3.0
- Inclusion of more resonances
  - r(1450), K_1(1410),K*(1680)

Total systematics

Component	Fit fraction (%)	syst error (%)
$K^*(892)^-$	54.23 ± 0.25	0.70
$K_0^*(1430)^-$	4.8 ± 0.2	2.2
$K_2^*(1430)^-$	1.89 ± 0.08	0.53
$K^*(1680)^-$	0.06 ± 0.02	0.94
$K^*(892)^+$	0.443 ± 0.029	0.005
$K_0^*(1430)^+$	0.0143 ± 0.0056	0.023
$K_2^*(1430)^+$	0.0037 ± 0.0029	0.009
$\rho(770)$	20.88 ± 0.17	0.93
$\omega(782)$	0.507 ± 0.035	0.043
$f_2(1270)$	0.45 ± 0.04	0.36
sum of $\pi^+\pi^-$ S-wave	16.6 ± 0.4	2.6

- » RMS of variation for all the various alternative fits
- » Still incomplete and preliminary
- » But comparable or smaller than CLEO's

Plans

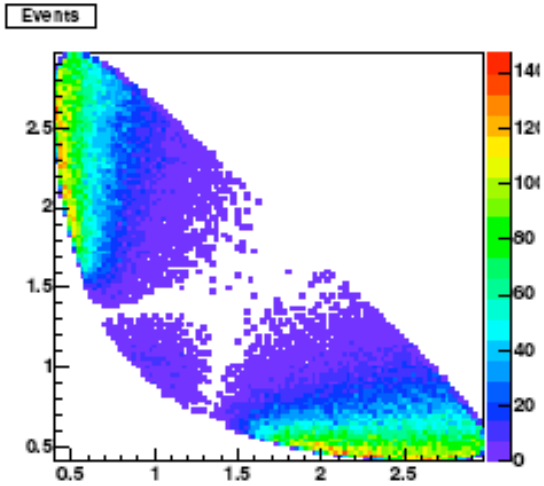
- Run more fits to compute systematics
- Propagate stat and syst error on phase and amplitude.

- Write a draft of a paper
  - Document nominal Dalitz model
  - Add results for alternative fit with BW "σ"
  - *Would like to converge by Moriond*

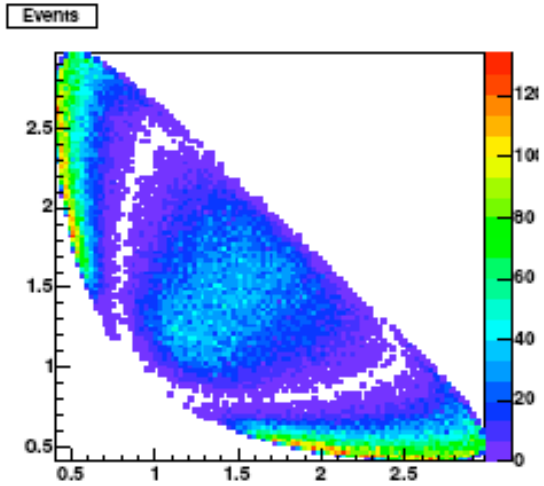
- *Move on to time dependent fit for D-mixing*
  - *Reuse technology developed for* $D^0 \to K^+\pi^-\pi^0$ $[K^-\pi^+\pi^0]$

Back up

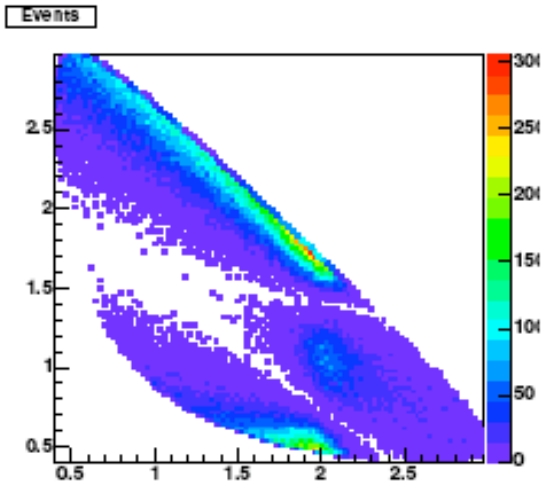
Zemach vs helicity



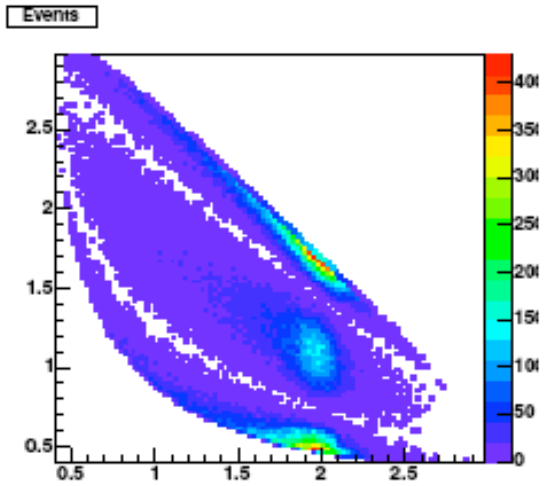
(c) $f_2(1270)$ Helicity Model



(d) $f_2(1270)$ Zemach tensor



(e) $K_2^*(1430)$ Helicity Model



(f) $K_2^*(1430)$ Zemach tensor

Total $K\pi$ Swave