$D^0 \to K_S K^+ K^-$ Dalitz model study

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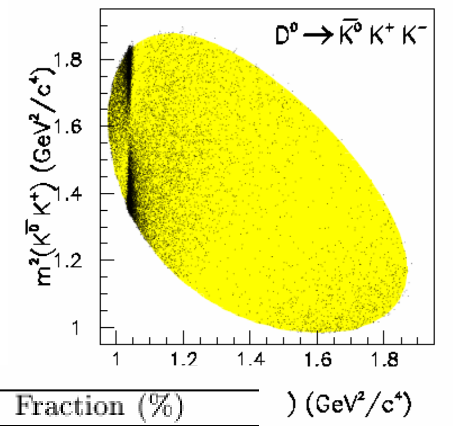
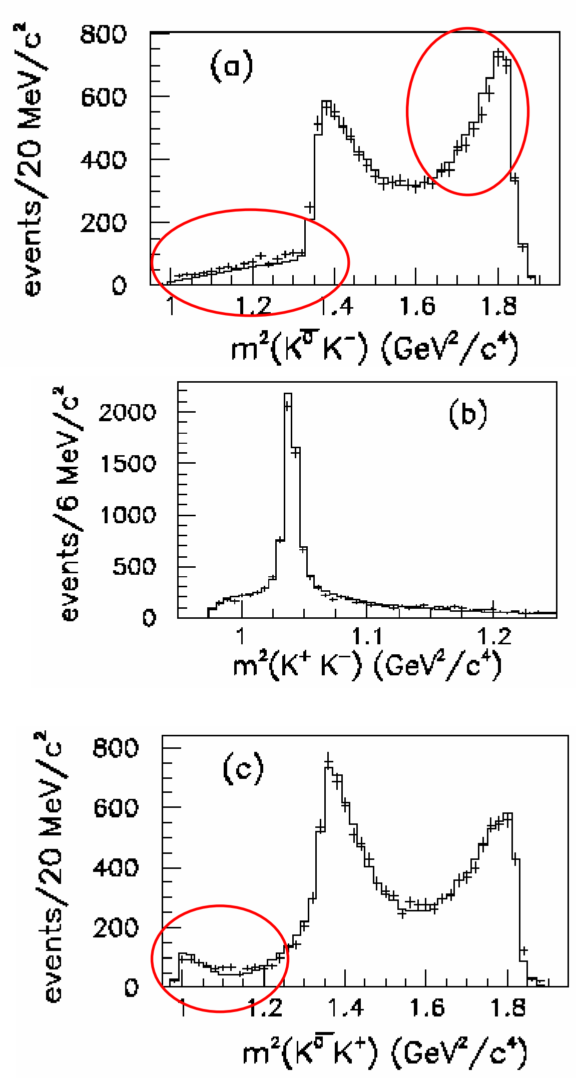
Antecedents and motivation

- **Phys.Rev.D72, 052008 (2005)**
  - Based on 91.5 fb^{-1}
  - 12540 signal events
  - 97.3% purity



Final state	Amplitude	Phase (radians)	Fraction (%)
$\overline{K}^0 a_0(980)^0$	1.	0.	66.4 ± 1.6 ± 7.0
$\overline{K}^0 \phi(1020)$	0.437 ± 0.006 ± 0.060	1.91 ± 0.02 ± 0.10	45.9 ± 0.7 ± 0.7
$K^- a_0(980)^+$	0.460 ± 0.017 ± 0.056	3.59 ± 0.05 ± 0.20	13.4 ± 1.1 ± 3.7
$\overline{K}^0 f_0(1400)$	0.435 ± 0.033 ± 0.162	-2.63 ± 0.10 ± 0 .71	3.8 ± 0.7 ± 2.3
$\overline{K}^0 f_0(980)$			0.4 ± 0.2 ± 0.8
$K^+ a_0(980)^-$			0.8 ± 0.3 ± 0.8
Sum			130.7 ± 2.2 ± 8.4



- Now, many more data (Run1-Run5 ~x4)
  - Is this model yet a good model?
- Want to use for γ from $B^\pm \to D^0[K_S h^+ h^-]K^\pm$
  - So far, h = π only
- Other analyses (e.g. D^0 mixing) can take profit

$D^0 \to K_S KK$ selection

Tagged D^0 data, obtained from $D^{*+} \to D^0 \pi^+$ decays from continuum

$p^*_{D^0} < 2.2$ GeV} From preselection

stDalitzD0 = 0.
mTotDalitzD0 = 1.8645 GeV
chi2DalitzD0 > 0.
} D^0 mass constraint

chi2DstarBS > 0.
dofDstarBS > 0.
probChi2DstarBS > 0.
} Beam spot convergence

$|m(K_S) - 0.4976| < 0.009$ GeV
$\cos\theta(K_S) > 0.99$
} K_S constraints

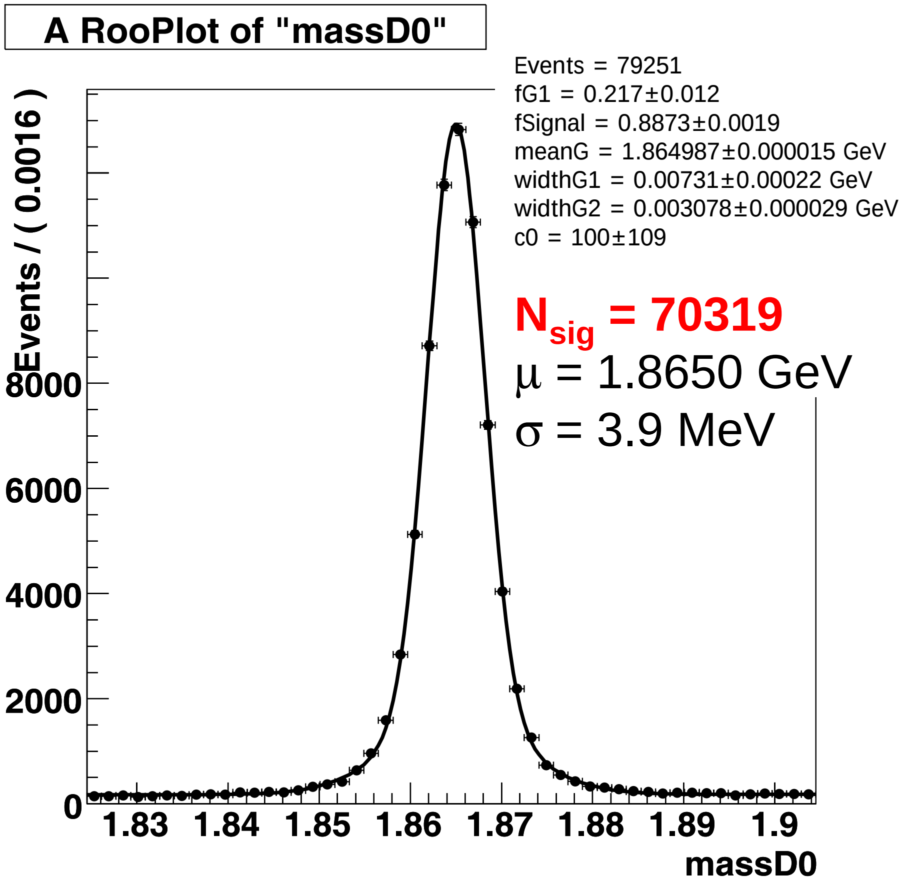
chi2D0 > 0.
chi2Ks > 0.
} Convergence of vertices

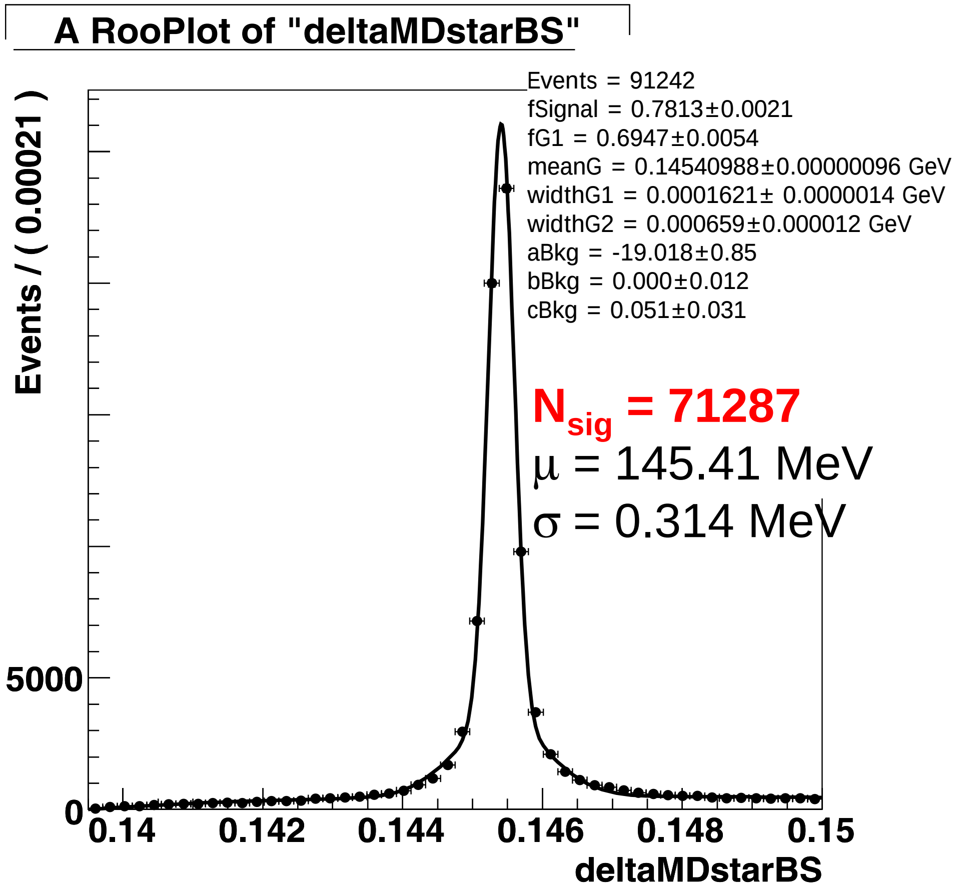
NotPionLHKaonMicroSelection for one of the two kaon tracks

$|m(D^0) - 1.8645| < 0.0078$ GeV
$|\Delta M - 0.1454| < 0.0006$ GeV
} (2σ cuts)

- DstD0ToKsHpHm skim
- TreeFitter
- K_S from ChargedTracks, vertex and mass constrained
- Soft pions from GoodTracksVeryLoose
- D^0 vertex and mass constrained
- D* beam spot vertex fit

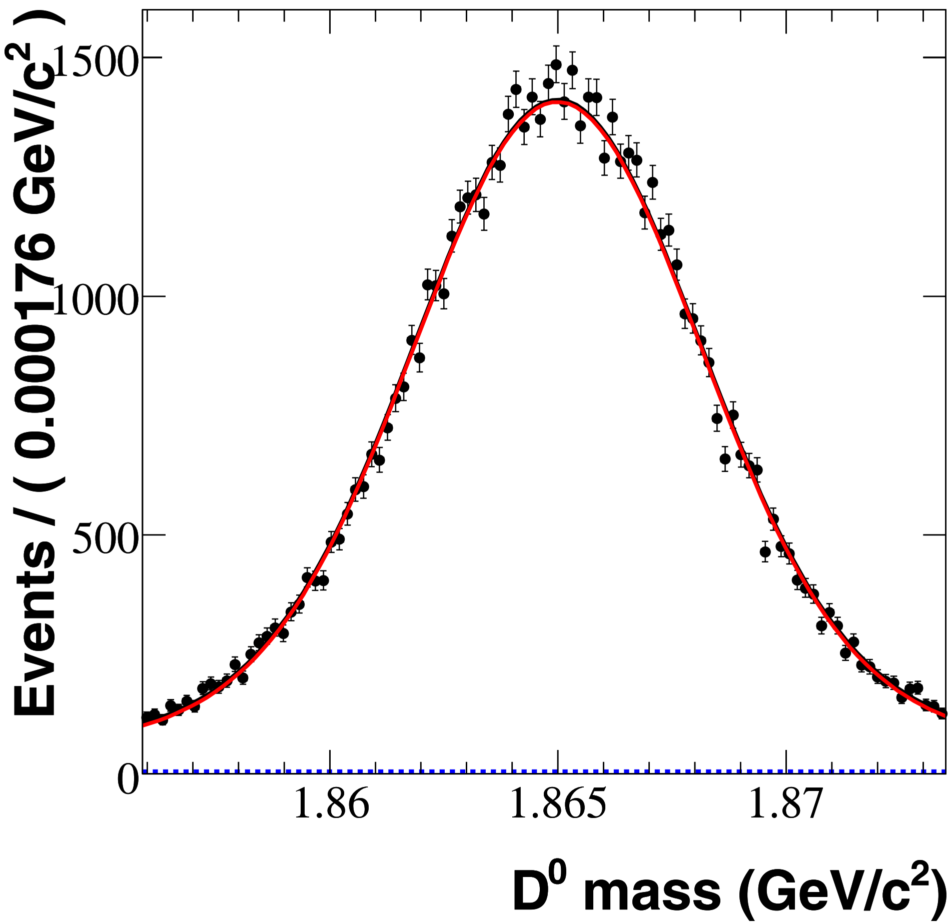
m(D^0) and Δm





All cuts applied except in the plotted variable

m(D^0) (Signal box)



RANGE: 1.8645±2.2σ

f_{Sig} = (99.3±0.4)%

Dalitz isobar model and likelihood fit I

- Isobar model with coherent sum of Breit-Wigner amplitudes

$$A_D(m_0^2, m_+^2) = a_{NR}e^{i\phi} + \sum_r a_r e^{i\phi_r} A_r(m_0^2, m_+^2)$$

$$A_r(m_0^2, m_+^2) = F_D \times F_r \times M_r^J \times BW_r$$

↑ Zemach tensors

$$m_0^2 \equiv s_0 \equiv m_{AB}^2 \equiv m^2(K^+K^-)$$
$$m_+^2 \equiv s_+ \equiv m_{AC}^2 \equiv m^2(K_S K^+)$$
$$m_-^2 \equiv s_- \equiv m_{BC}^2 \equiv m^2(K_S K^-)$$

Angular dependence of the amplitude depends on the spin ***J*** of the resonance ***r***. Includes $\boldsymbol{F_D}$ and $\boldsymbol{F_r}$ form factors (≈Blatt-Weisskopf penetration factors)

- Single relativistic BW with mass dependent width Γ_r

$$BW_r(s) = \frac{1}{M_r^2 - s - iM_r\Gamma_r(\sqrt{s})}$$

$$s = \{m_0^2, m_+^2, m_-^2\}$$

Resonance	***M* (MeV)**	***Γ* (MeV)**	**From**
φ(1020)	1019.63±0.07	4.28±0.13	BaBar Phys.Rev.D72, 052008 (2005)
f_0(1370)	1350±50 1434±18	265±40 173±32	BES PLB607, 243 (2005) E791 PRL89, 121801 (2002)

Dalitz isobar model and likelihood fit II

- Coupled BW (Flatté)

$$BW_{chan}(s) = \frac{g_{KK}}{M^2 - s - i[g_{KK}^2 \rho_{KK}(s) + g_{chan}^2 \rho_{chan}(s)]}$$

$$\rho_i(s) = 2q/\sqrt{s}$$

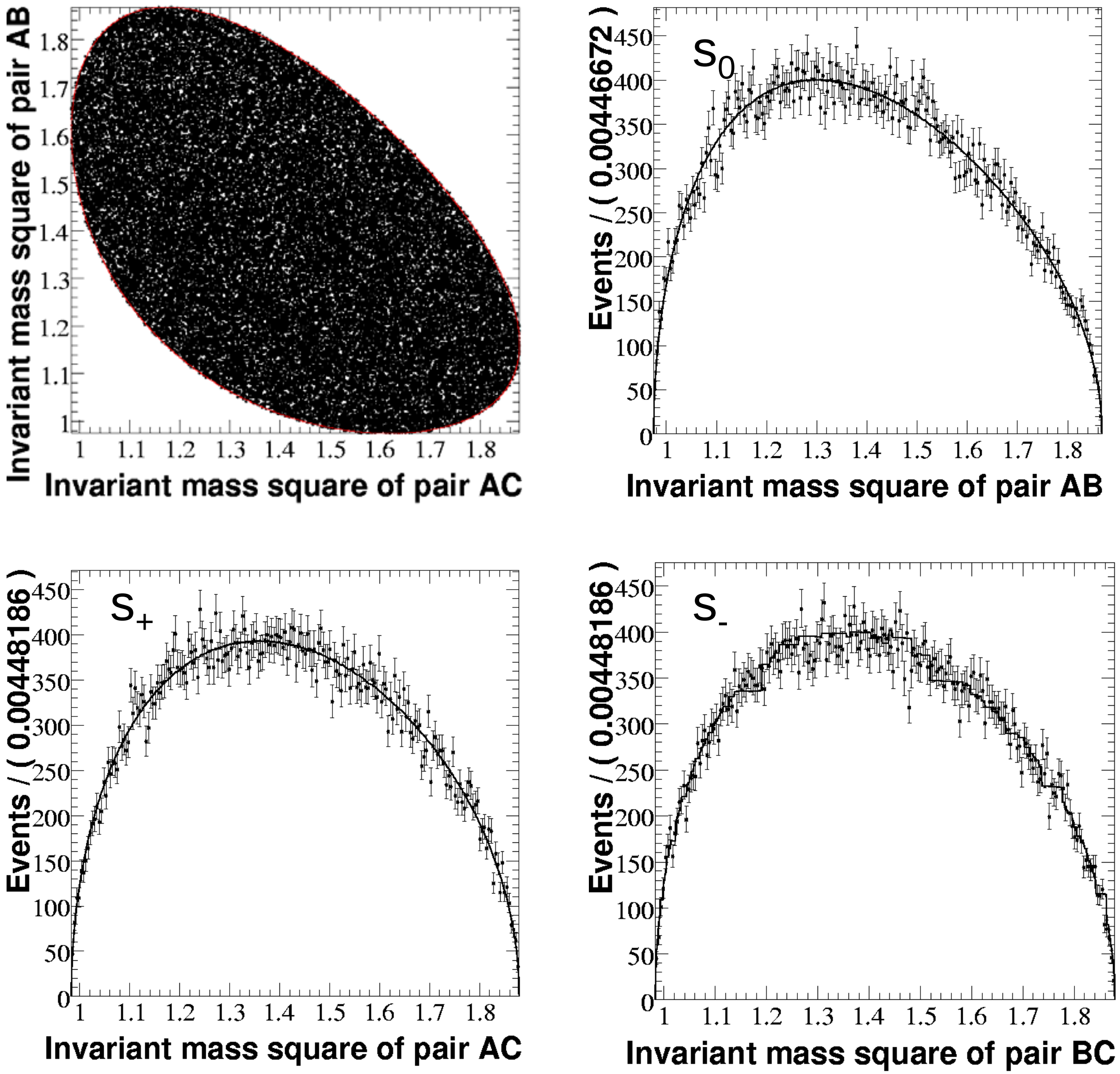
Phase space factor

Res.	g_{KK}	**From**	***chan***	g_{chan}	***M* (MeV)**	**From**
$a_0(980)$	464±49 $\text{MeV}^{1/2}$	BaBar, PRD72, 052008 (2005)	$\eta\pi$	324±15 $\text{MeV}^{1/2}$	999±2	Crystal Barrel PRD57, 3860 (1998)
$f_0(980)$	165±18 MeV	BES, PLB607, 243 (2005)	$\pi\pi$	695±94 MeV	965±10	BES PLB607, 243 (2005)

- Probability density function

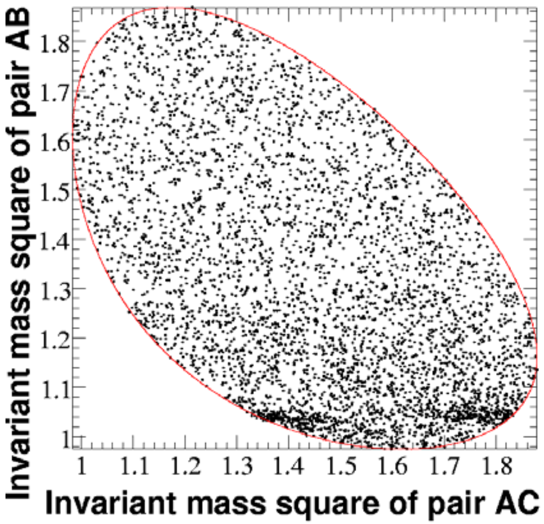
$$PDF = f_{Sig} \frac{\varepsilon(s_0,s_+)\sum_{i,j} c_i c_j^* A_i(s_0,s_+) A_j^*(s_0,s_+)}{\int \varepsilon(s_0,s_+)\sum_{i,j} c_i c_j^* A_i(s_0,s_+) A_j^*(s_0,s_+) ds_0 ds_+} + (1-f_{Sig}) \frac{|A_\phi(s_0,s_+) + P_2(s_0,s_+)|^2}{\int |A_\phi(s_0,s_+) + P_2(s_0,s_+)|^2 \, ds_0 ds_+}$$

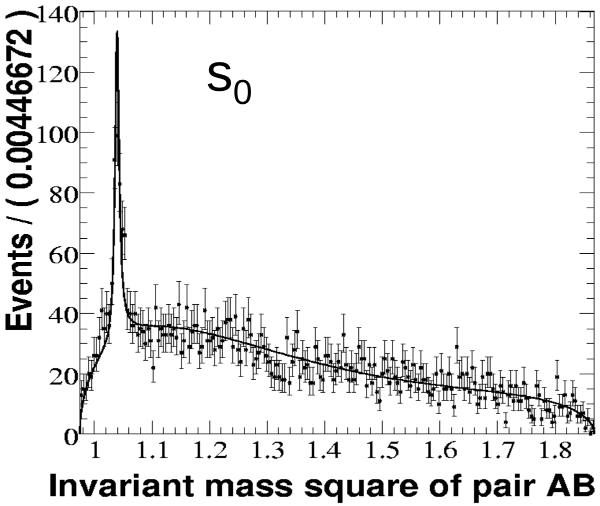
Efficiency mapping

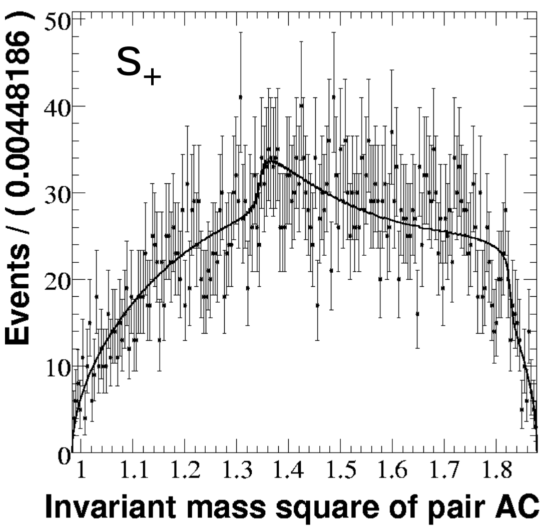


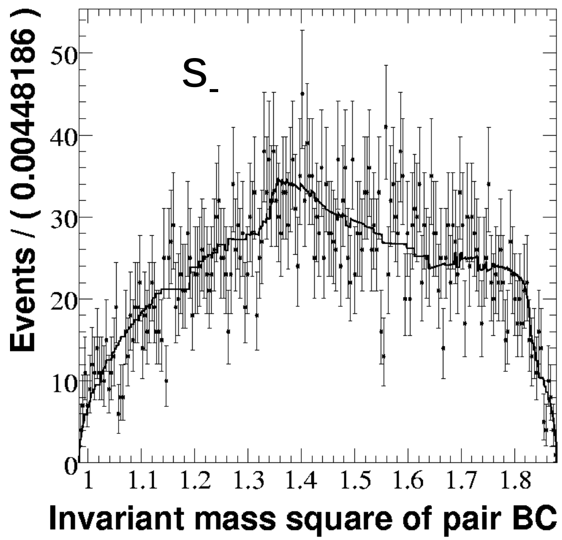
- Efficiency map $\varepsilon(s_0,s+)$ described by 2nd order asymmetric polynomial
- Very flat efficiency

Dalitz - background







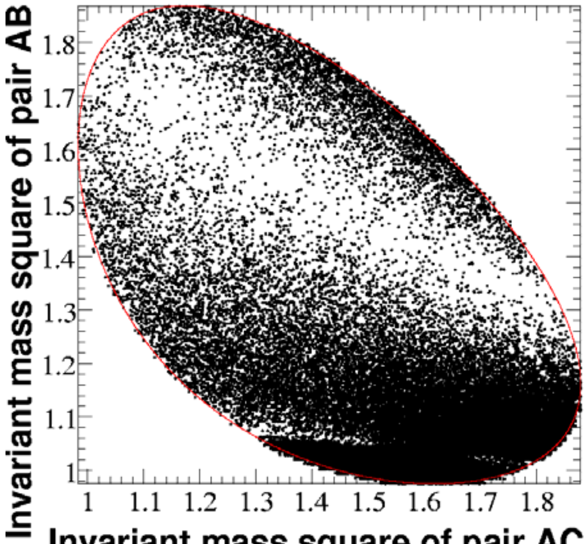


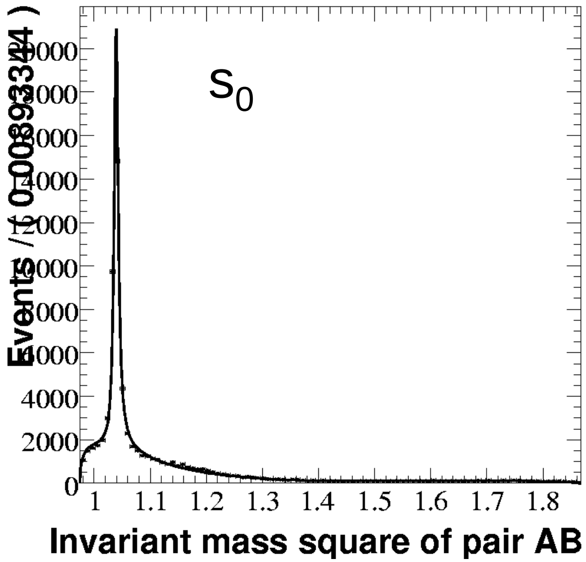
- Dalitz shape for small background characterized using the upper and lower D^0 mass sidebands

  $(m_{D0}-40\ \text{MeV}, m_{D0}-5\sigma)$
  $(m_{D0}+5\sigma,\ m_{D0}+40\ \text{MeV})$

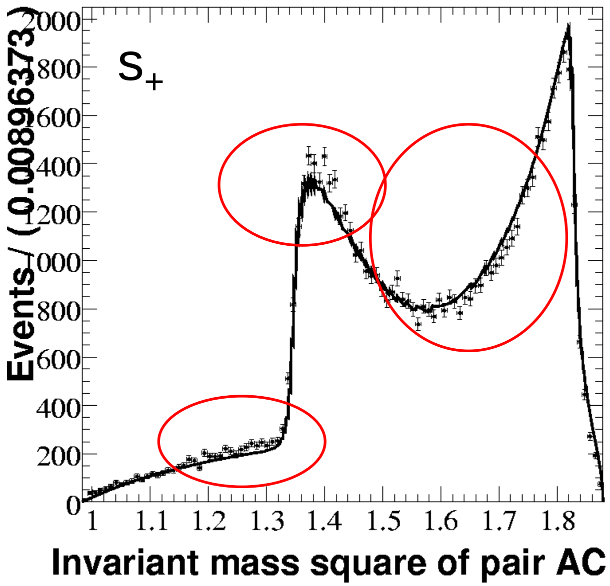
- Well described by a $\phi(1020)$ component and a 2nd order asymmetric polynomial

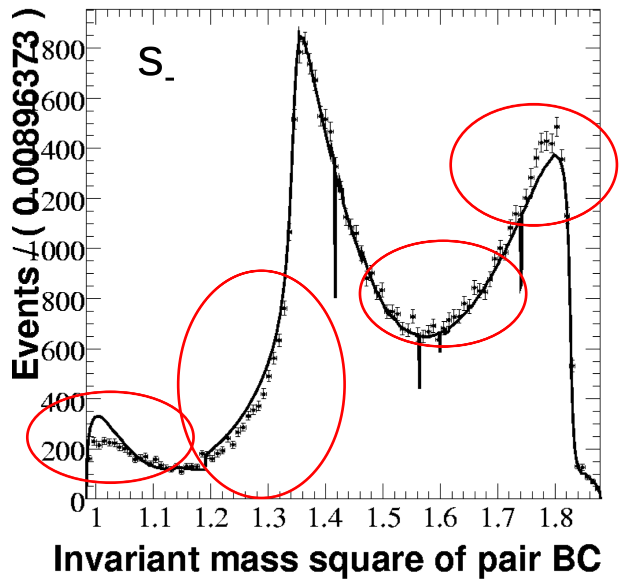
Base line (BL) model with new data





Res.	Fit fraction
$a_0(980)^0$	70.61
ϕ	43.12
$a_0(980)^+$	12.59
$f_0(1370)$	9.31
$a_0(980)^-$	0.89
Total	136.5
χ^2/dof	9130/6856=1.33



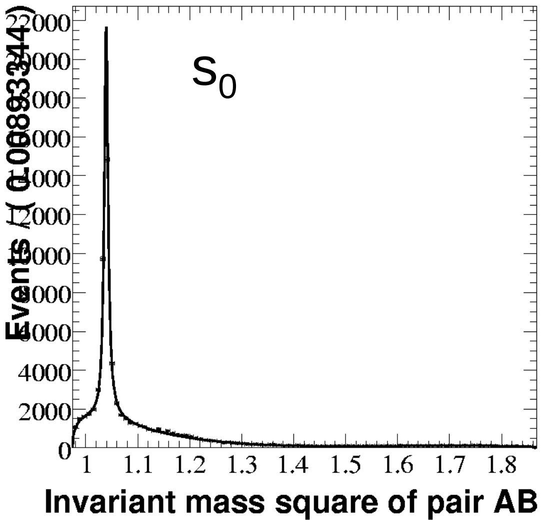


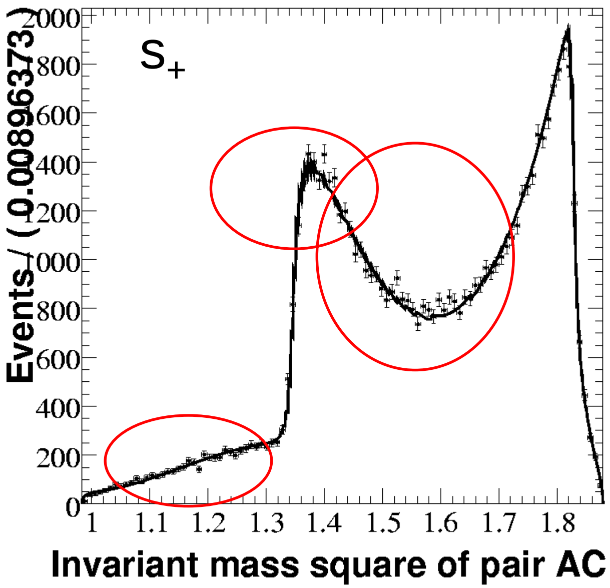
New Dalitz model I

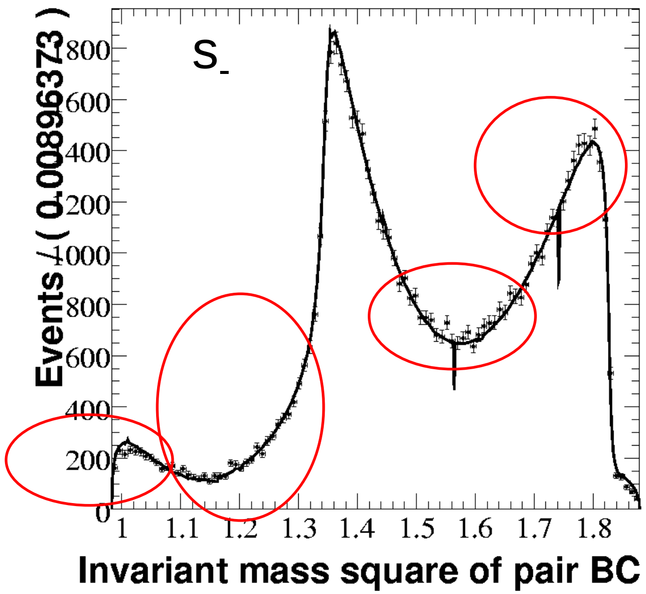
Resonances	Total fit fraction	χ^2/6856
$a_0(980)^0$, ϕ, $a_0(980)^+$, $a_0(980)^-$	133.8	9962
$a_0(980)^0$, ϕ, $a_0(980)^+$, $a_0(980)^-$, $f_0(1370)$ (BL)	136.5	9130
$a_0(980)^0$, ϕ, $a_0(980)^+$, $a_0(980)^-$, $a_2(1230)^0$, $a_2(1230)^+$	157.9	9030
$a_0(980)^0$, ϕ, $a_0(980)^+$, $a_0(980)^-$, $a_2(1230)^0$, $a_2(1230)^+$, $a_2(1230)^-$	156.6	9027
$a_0(980)^0$, ϕ, $a_0(980)^+$, $a_0(980)^-$, $f_2(1270)$	135.8	9946
(BL), $f_2(1270)$	148.4	8920
(BL), $a_0(1450)^0$, $a_0(1450)^+$	125.4	8446
(BL), $a_0(1450)^0$, $a_0(1450)^+$, $a_0(1450)^-$	159.0	8297
(BL), $a_2(1230)^0$, $a_2(1230)^+$	152.1	8751
(BL), $a_0(1230)^0$, $a_0(1230)^+$, $a_0(1230)^-$	149.0	8766
(BL), $a_0(1450)^0$, $a_0(1450)^+$, $f_2(1270)$	130.9	8210
(BL), $a_0(1450)^0$, $a_0(1450)^+$, $a_0(1450)^-$, $f_2(1270)$	141.8	8198

- $a_0(1450)$, $a_2(1230)$, $f_{2(}1270)$ parameters from PDG
- Fits including $f_0(980)$ give very large fit fractions (>160)
- Any missing resonance? $\rho(1450)$, $f_0(1500)$, $f_2'(1525)$,…?

New Dalitz model II

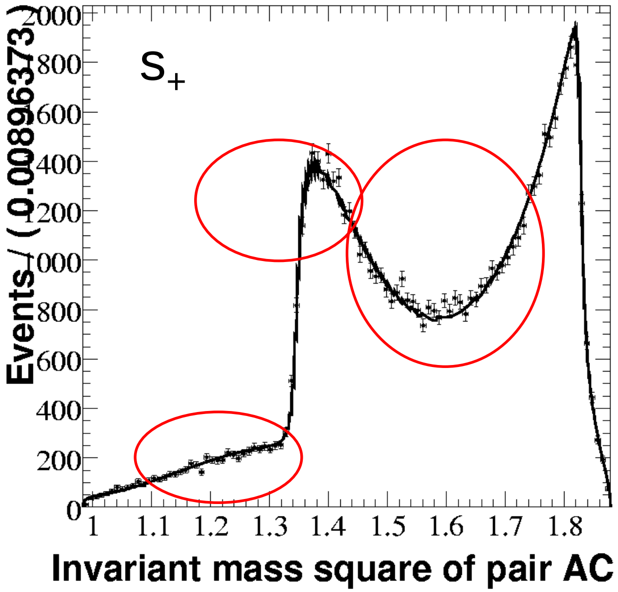


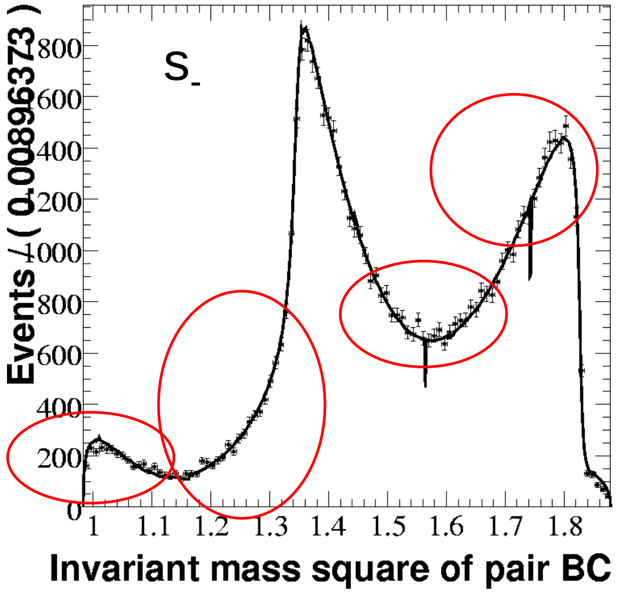




Res.	Fit fraction
$a_0(980)^0$	47.79
ϕ	44.82
$a_0(980)^+$	13.15
$f_0(1370)$	0.16
$a_0(980)^-$	0.70
$f_2(1270)$	0.39
$a_0(1450)^0$	14.61
$a_0(1450)^+$	19.77
$a_0(1450)^-$	0.42
Total	141.8
$\chi 2$/dof	8198/6856=1.196

New Dalitz model III





Res.	Fit fraction
$a_0(980)^0$	44.98
ϕ	44.69
$a_0(980)^+$	13.46
$f_0(1370)$	2.13
$a_0(980)^-$	0.69
$f_2(1270)$	0.34
$a_0(1450)^0$	4.43
$a_0(1450)^+$	20.17
Total	130.9
$\chi 2$/dof	8210/6856=1.197

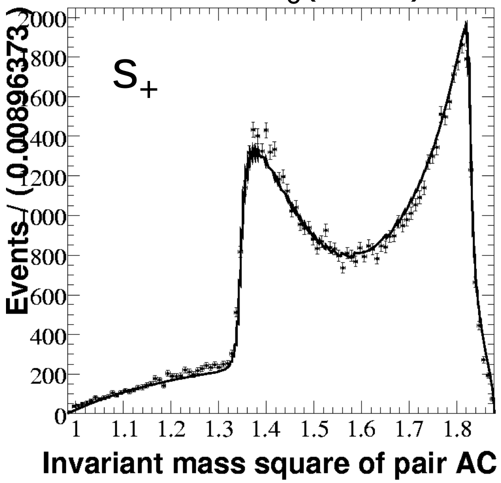
Re(phi) = -1.26316e-01 +/- 2.995e-03 L(-1 - 1)
Re(a0p_980) = -5.68843e-01 +/- 1.362e-02 L(-1 - 1)
Re(f0_1370) = -1.76074e-01 +/- 6.336e-02 L(-1 - 1)
Re(a0m_980) = -6.37925e-02 +/- 1.512e-02 L(-1 - 1)
Re(f2_1270) = 2.66634e-01 +/- 2.131e-02 L(-1 - 1)
Re(a00_1450) = 6.07274e-02 +/- 1.138e-01 L(-1 - 1)
Re(a0p_1450) = 2.12624e-01 +/- 6.945e-02 L(-1 - 1)

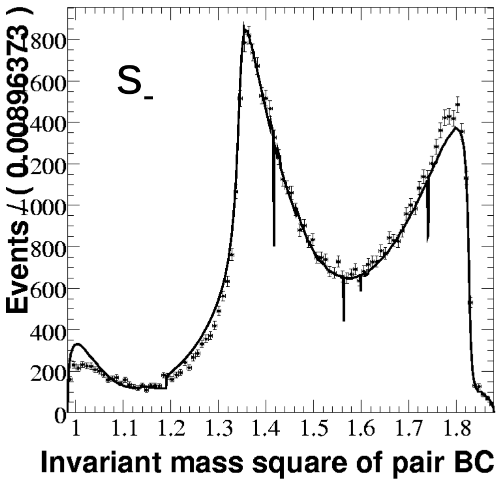
Im(phi) = 1.89055e-01 +/- 5.314e-03 L(-1 - 1)
Im(a0p_980) = 9.52304e-02 +/- 3.119e-02 L(-1 - 1)
Im(f0_1370) = 2.55317e-02 +/- 4.912e-02 L(-1 - 1)
Im(a0m_980) = 1.13638e-01 +/- 1.552e-02 L(-1 - 1)
Im(f2_1270) = -4.70966e-02 +/- 2.619e-02 L(-1 - 1)
Im(a00_1450) = -3.99625e-01 +/- 9.838e-02 L(-1 - 1)
Im(a0p_1450) = 8.13207e-01 +/- 2.974e-02 L(-1 - 1)

Summary

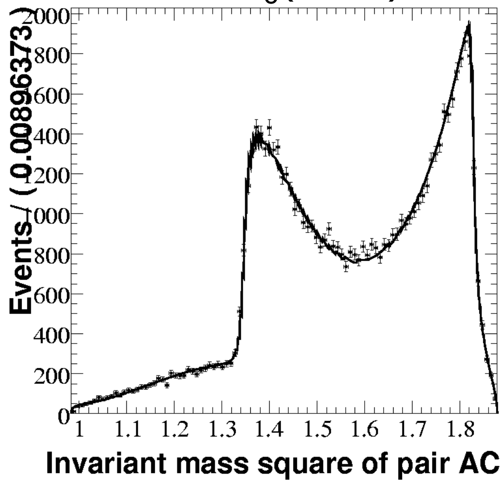
- The analysis of all Run1-Run5 data reveals the need of the higher I=1 scalar $a_0(1450)$ to describe the $D^0 \to K_S K^+ K^-$ decay

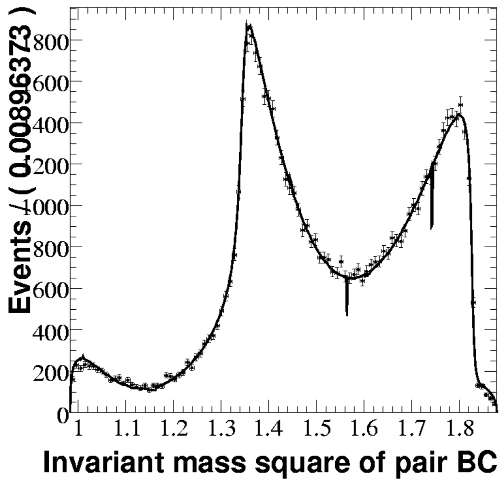
Without $a_0(1450)$





With $a_0(1450)$





Proposed new reference model

Res.	**Fit fraction**
$a_0(980)^0$	44.98
ϕ	44.69
$a_0(980)^+$	13.46
$f_0(1370)$	2.13
$a_0(980)^-$	0.69
$f_2(1270)$	0.34
$a_0(1450)^0$	4.43
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Total	130.9
χ^2/dof	8210/6856=1.197