Parametrization of the S-wave component of the Dalitz amplitude $D^0 \rightarrow K_S \pi^- \pi^+$ using K matrix formalism

Luigi Li Gioi

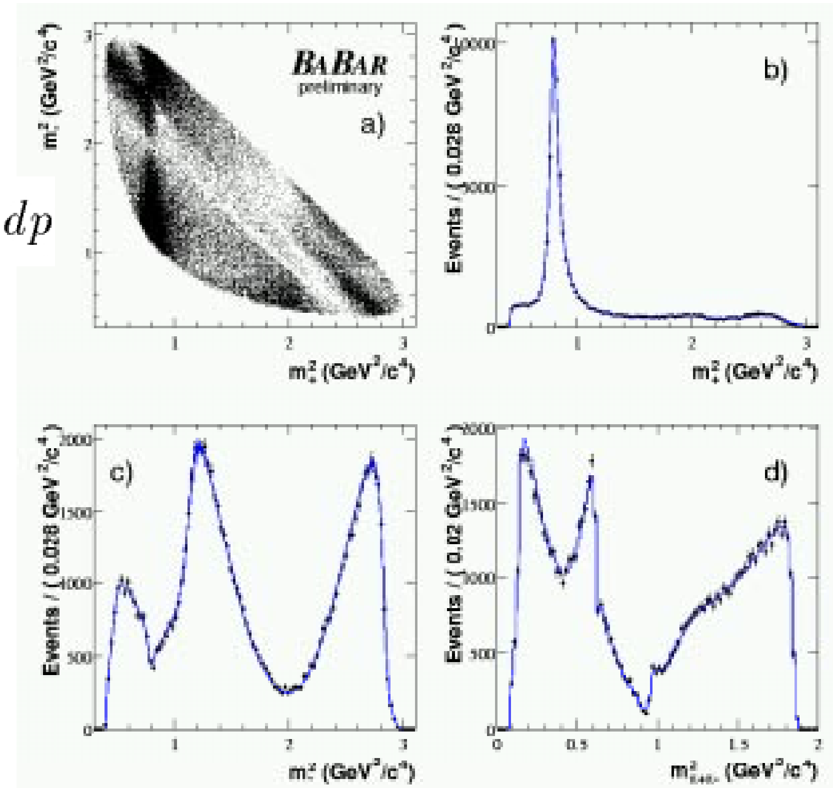
Università di Roma “La Sapienza” & INFN Roma

BaBar Collaboration Meeting

2005 February 23

Starting point

$$d\hat{\Gamma}(B^- \to (K_S\pi^-\pi^+)_D K^-) = \Big(A^2_{12,13} + r_B^2\, A^2_{13,12} + 2r_B \mathcal{R}e\left[A_D(s_{12},s_{13})\, A_D^*(s_{13},s_{12})\, e^{-i(\delta_B-\gamma)}\right]\Big)\,dp$$



$$A_D = a_{nr} e^{i\phi_{nr}} + \Sigma\, a_r e^{i\phi_r} A(K_S\pi^-\pi^+ | r)$$

A=Breit-Wigner × spin factor

A_D is a complex function:

- Very good amplitude parametrization
- How can we know phase parametrization is good ?
- Understand better phase parametrization can help to reduce systematic from Dalitz model

Breit-Wigner fit

Resonance	Amplitude	Phase (degrees)	Fraction (%)	Mass MeV/c^2	Width MeV/c^2	Functional form
$K^*(892)$	1.777 ± 0.018	131.0 ± 0.81	58.51	891.66	50.8	BW
$\rho^0(770)$	1 (fixed)	0(fixed)	22.33	775.8	146.4	GS
$K^*(892)$ DCS	0.1789 ± 0.0080	-44.0 ± 2.4	0.59	891.66	50.8	BW
$\omega(782)$	0.0391 ± 0.0016	114.8 ± 2.5	0.56	782.6	8.5	BW
$f_0(980)$	0.469 ± 0.011	213.4 ± 2.2	5.81	975	44	BW
$f_0(1370)$	2.32 ± 0.31	114.1 ± 4.4	3.39	1434	173	BW
$f_2(1270)$	0.915 ± 0.041	-22.0 ± 2.9	2.95	1275.4	185.1	BW
$K_0^*(1430)$	2.454 ± 0.074	-7.9 ± 2.0	8.37	1412	294	BW
$K_0^*(1430)$ DCS	0.350 ± 0.069	$-344. \pm 10.$	0.60	1412	294	BW
$K_2^*(1430)$	1.045 ± 0.045	-53.1 ± 2.6	2.70	1425.6	98.5	BW
$K_2^*(1430)$ DCS	0.074 ± 0.038	-98 ± 30	0.01	1425.6	98.5	BW
$K^*(1410)$	0.524 ± 0.073	-157 ± 10	0.39	1414	232	BW
$K^*(1680)$	0.99 ± 0.31	-144 ± 18	0.35	1717	322	BW
$\rho(1450)$	0.554 ± 0.097	$35 \pm 12.$	0.28	1406	455	GS
σ_1	1.346 ± 0.044	-177.5 ± 2.5	9.11	484 ± 9	383 ± 14	BW
σ_2	0.292 ± 0.025	-206.8 ± 4.3	0.98	1014 ± 7	88 ± 13	BW
Non resonant	3.41 ± 0.48	-233.9 ± 5.0	6.82	-	-	-

σ_1, σ_2 introduced to obtain an acceptable fit to the data

$f_0(980)$, $f_0(1370)$, σ_1,σ_2 scalar $\pi\,\pi$ resonances

K matrix formalism

Parametrize the S-wave component using K matrix formalism

$$F_l = (I - i\,K\rho)^{-1}_{lj}\; P_j$$

j,l = 1....N   N= number of modes considered

modes(i,j): ππ, KK, 4π, ηη, ηη'

F = amplitude vector

ρ = phase space matrix (diagonal matrix)

P = “initial” production vector

Following the parametrization of:

V.V. Anisovich, A.V. Sarantsev (Eur.Phys.J.A16:229-258,2003)

used also by Focus for their $D(s)^+ \to \pi^+\pi^-\pi^+$ analysis(Phys.Lett.B585:200-212,2004)

$$K^{00}_{ij}(s) = \left\{ \sum_\alpha \frac{g_i^{(\alpha)} g_j^{(\alpha)}}{m_\alpha^2 - s} + f_{ij}^{\rm scatt} \frac{1\,{\rm GeV}^2 - s_0^{\rm scatt}}{s - s_0^{\rm scatt}} \right\} \frac{(s - s_A m_\pi^2/2)}{(s - s_{A0})(1 - s_{A0})}$$

Pole term   Smooth part   Alder zero term

K matrix poles(α): $f_0(980)$, $f_0(1300)$, $f_0(1200-1600)$, $f_0(1500)$, $f_0(1750)$

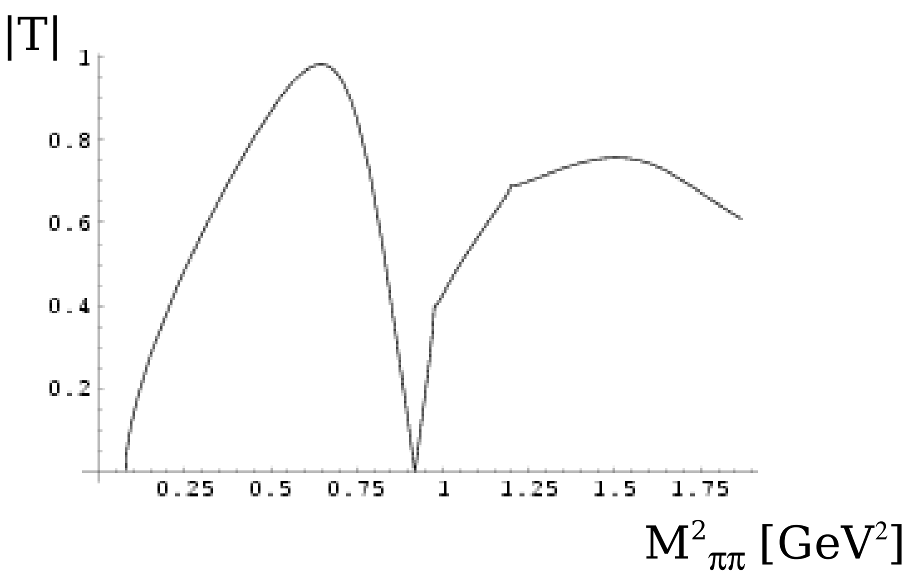
F-vector

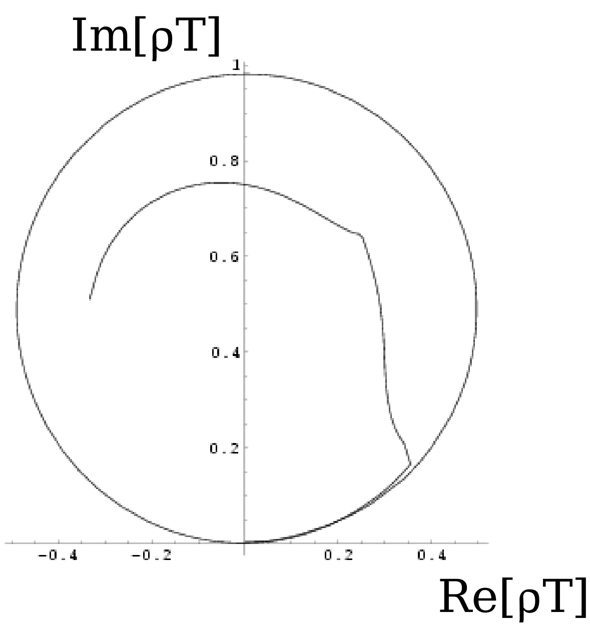
The ππ component of the F vector:

$$F_1 = (I - iK\rho)^{-1}_{1j} \left\{ \sum_\alpha \frac{\beta_\alpha g_j^{(\alpha)}}{m_\alpha^2 - s} + f_{1j}^{\rm prod} \frac{1\ {\rm GeV}^2 - s_0^{\rm prod}}{s - s_0^{\rm prod}} \right\} \times \frac{(s - s_A m_\pi^2/2)}{(s - s_{A0})(1 - s_{A0})}$$

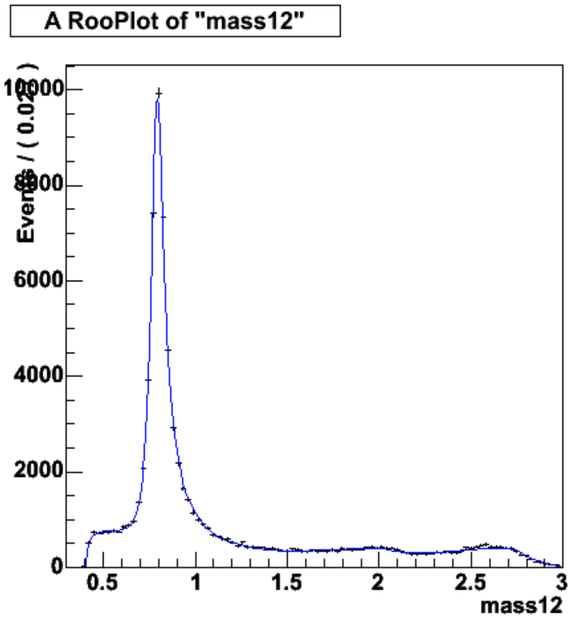
β_α and $f_{1j}^{\rm prod}$ are free parameters in our fit

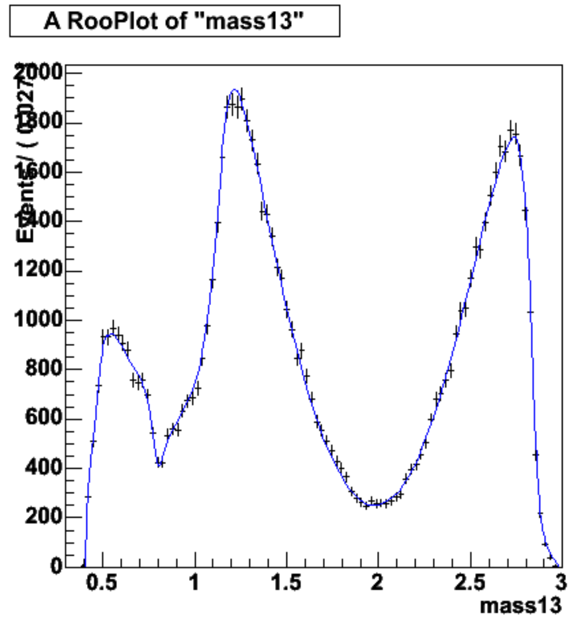
The transition matrix: $T = (I - i\,K\rho)^{-1} K$

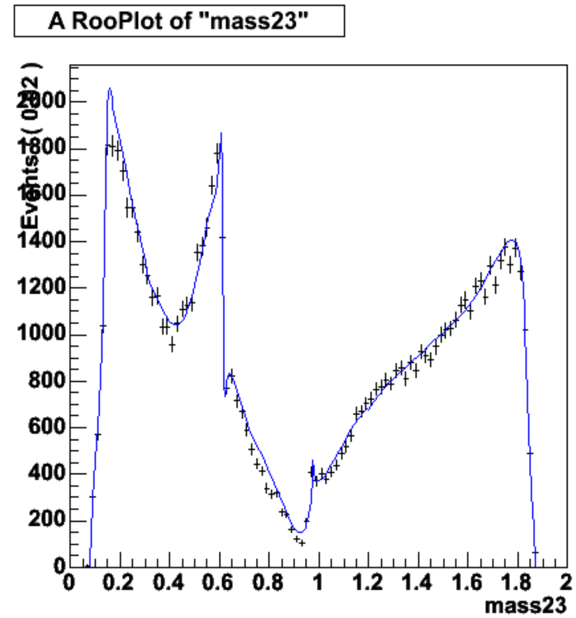




Fit result





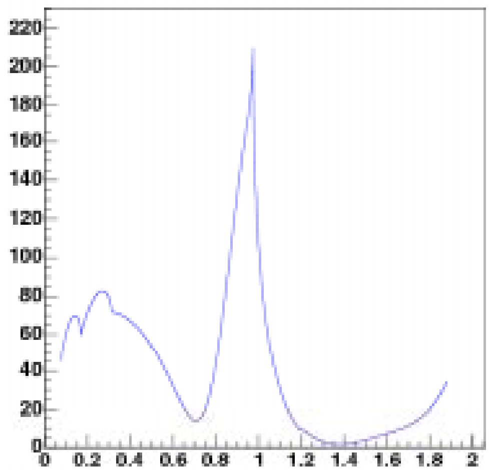


- Values of mass and wight of B.-W. terms fixed to the P.D.G. 2004 values.
- Amplitudes and phases of B.-W. terms floated.
- Parameter of the Production vector floated
- Parameter on the K-matrix fixed.

S-wave component

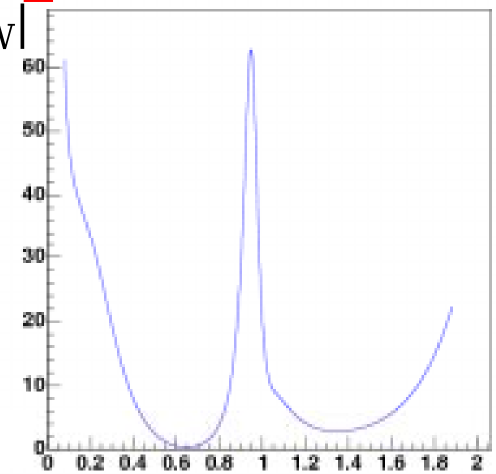
F-vector

$|F_1|$



$M^2_{\pi\pi}$ [GeV^2]

$|\Sigma_{BW}|$

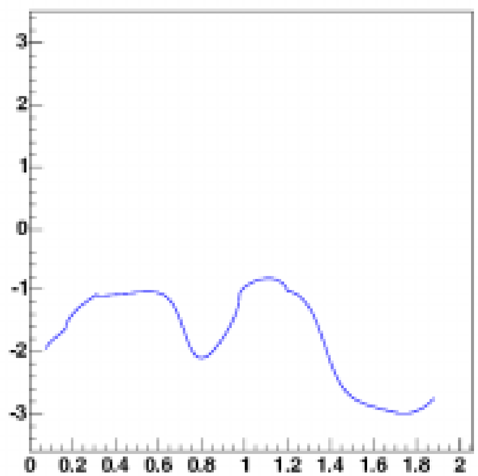


$M^2_{\pi\pi}$ [GeV^2]

B.–W.

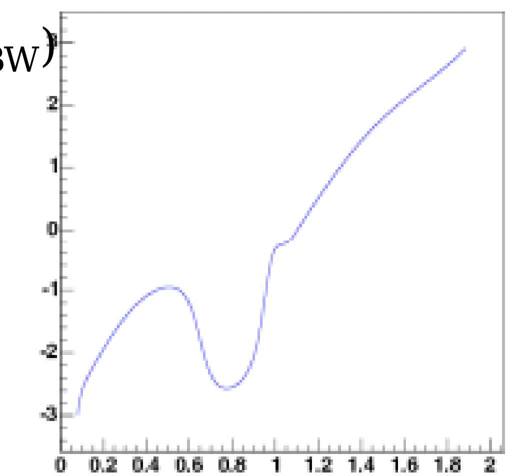
F-vector

$Arg(F_1)$



$M^2_{\pi\pi}$ [GeV^2]

$Arg(\Sigma_{BW})$



$M^2_{\pi\pi}$ [GeV^2]

B.–W.

The shape of the amplitude is similar in the two fits (K-matrix and Breit-Wigner). The shape of the phase instead is quite different.

Other components

	K-fit val.	K-fit err	BW-fit val	BW-fit err	Pull
Kst1410_amp	0.33	0.05	0.524	0.071	-2.194
Kst1410_phase	208.4	8.73	156.560	9.982	3.909
K2*1430_DCS_amp	0.13	0.03	0.075	0.037	1.236
K2*1430_DCS_phase	-180.54	14.72	-97.774	0.045	-5.624
K2*1430_amp	1.19	0.03	1.045	0.045	2.605
K2*1430_phase	-55.68	1.67	-53.057	2.508	-0.872
Kst1430_DCS_amp	0.55	0.05	0.350	0.067	2.381
Kst1430_DCS_phase	-357.33	5.2	-343.712	10.305	-1.180
Kst1430_amp	2.62	0.05	2.454	0.073	1.817
Kst1430_phase	-10.52	1.23	-7.955	1.973	-1.103
Kst1680_amp	4.66	0.17	0.997	0.287	11.051
Kst1680_phase	-184.19	2.12	-143.985	17.266	-2.311
Kstminus_amp	1.72	0.01	1.778	0.018	-2.594
Kstminus_phase	127.68	0.69	130.980	0.795	-3.126
Kstplus_amp	0.17	0.01	0.179	0.008	-0.635
Kstplus_phase	-51.5	2.15	-43.967	2.405	-2.336
NonReson_amp	6.06	0.15	3.410	0.443	5.652
NonReson_phase	-251.27	1.43	-232.866	4.901	-3.604
f2_1270_amp	0.91	0.03	0.915	0.041	-0.187
f2_1270_phase	-27.83	2.26	-21.985	2.857	-1.605
omega782_amp	0.04	0	0.039	0.002	-1.489
omega782_phase	113.64	2.5	114.760	2.469	-0.319
rho1450_amp	1.33	0.06	0.554	0.090	7.199
rho1450_phas	0.63	3.81	34.709	12.271	-2.652

Some resonances show significant changes

$K^{*+}(892)$, that gives the greater sensibility in γ,shows a very little change

Fit fractions

	K-M fit [%]	B-W fit [%]
Rho770	22.99	22.33
Kst1410	0.14	0.39
K2*1430_DCS	0.05	0.01
K2*1430	3.22	2.70
Kst1430_DCS	0.43	0.60
Kst1430	9.52	8.37
Kst1680	5.21	0.35
Kstminus	59.21	58.51
Kstplus	0.59	0.59
NonReson	21.94	6.82
F2_1270	2.59	2.95
Omega782	0.49	0.56
Rho1450	1.20	0.28
S-wave	29.49	19.29
SUM	157.06	123.75

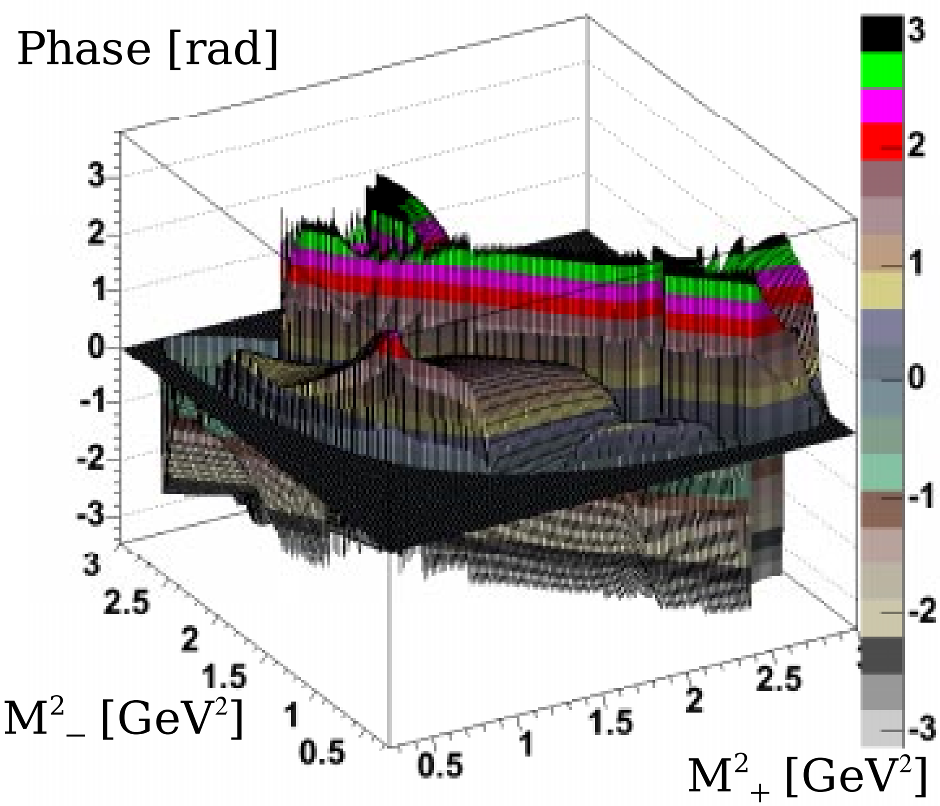
The sum of the fit fraction is larger in the K-matrix fit

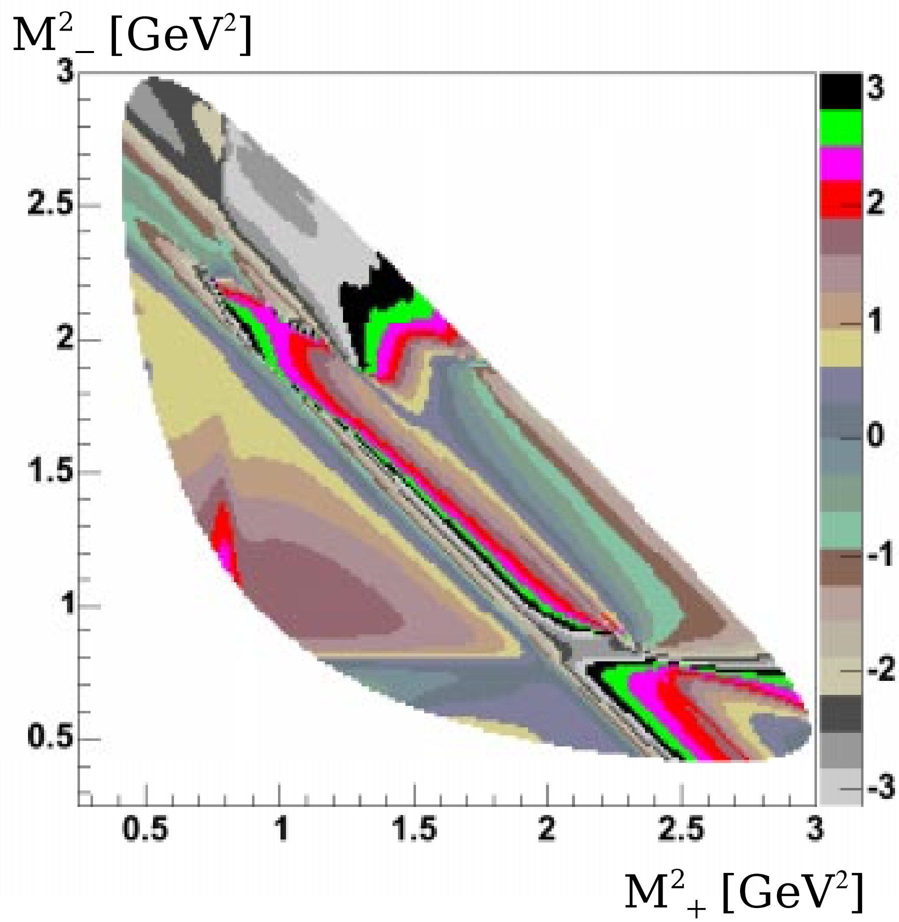
Larger fit fractions of both the S-wave component and the non-resonant in the K-matrix fit.

Large non resonant component. Possible interference between $K\pi$ (not included in the fit) and $\pi\pi$ S-wave.

Phase of the Dalitz amplitude (I)

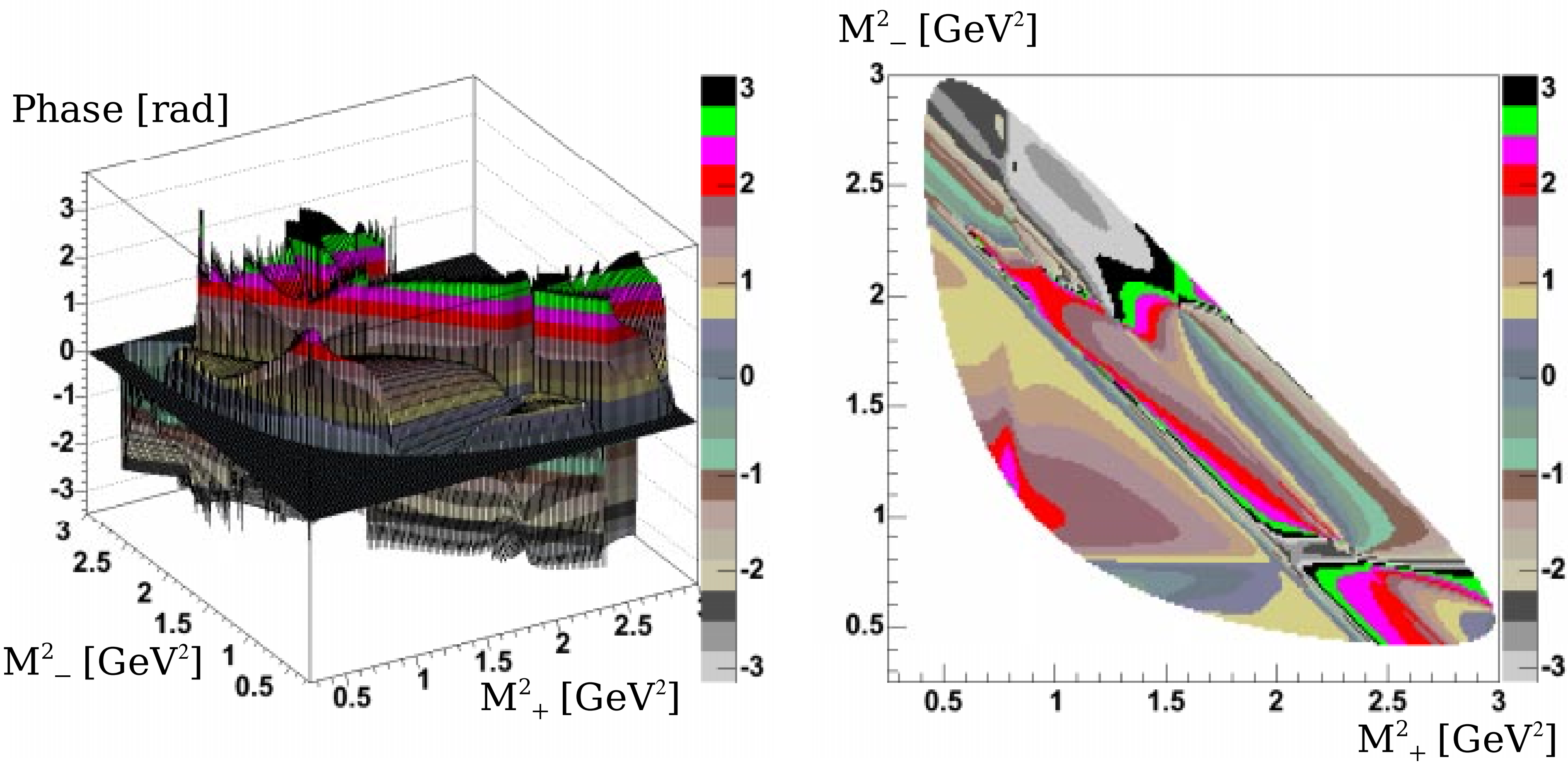
The phase of the $\overline{D}^0 \in K_S\pi^+\pi^-$ decay amplitude resulting from the K-matrix fit:





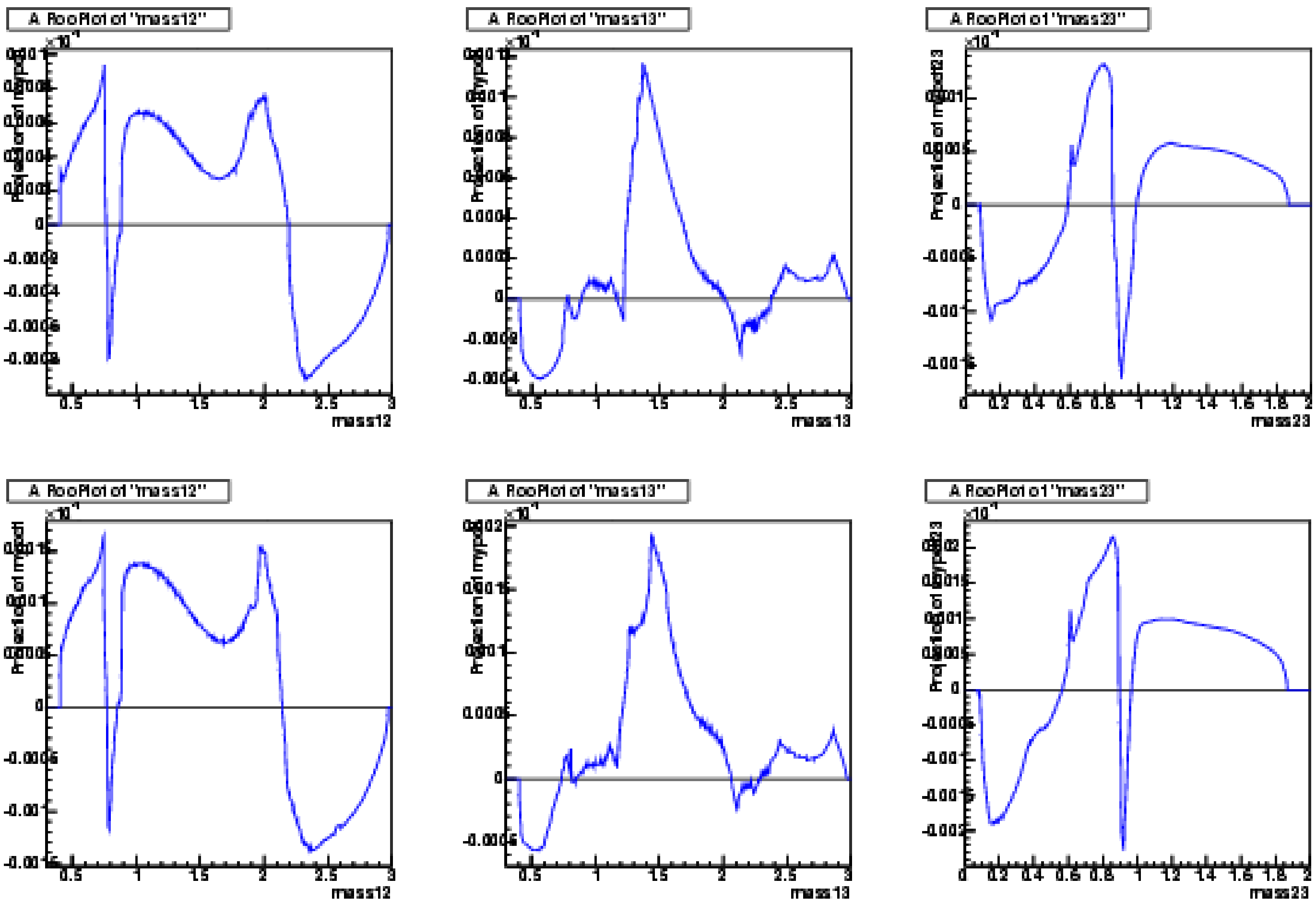
Phase of the Dalitz amplitude (II)

The phase of the $\overline{D}^0 \in K_S\pi^+\pi^-$ decay amplitude resulting from the Breit-Wigner fit:



Phase projections

Projections of the phase function can show the difference of the phase shape in the two cases

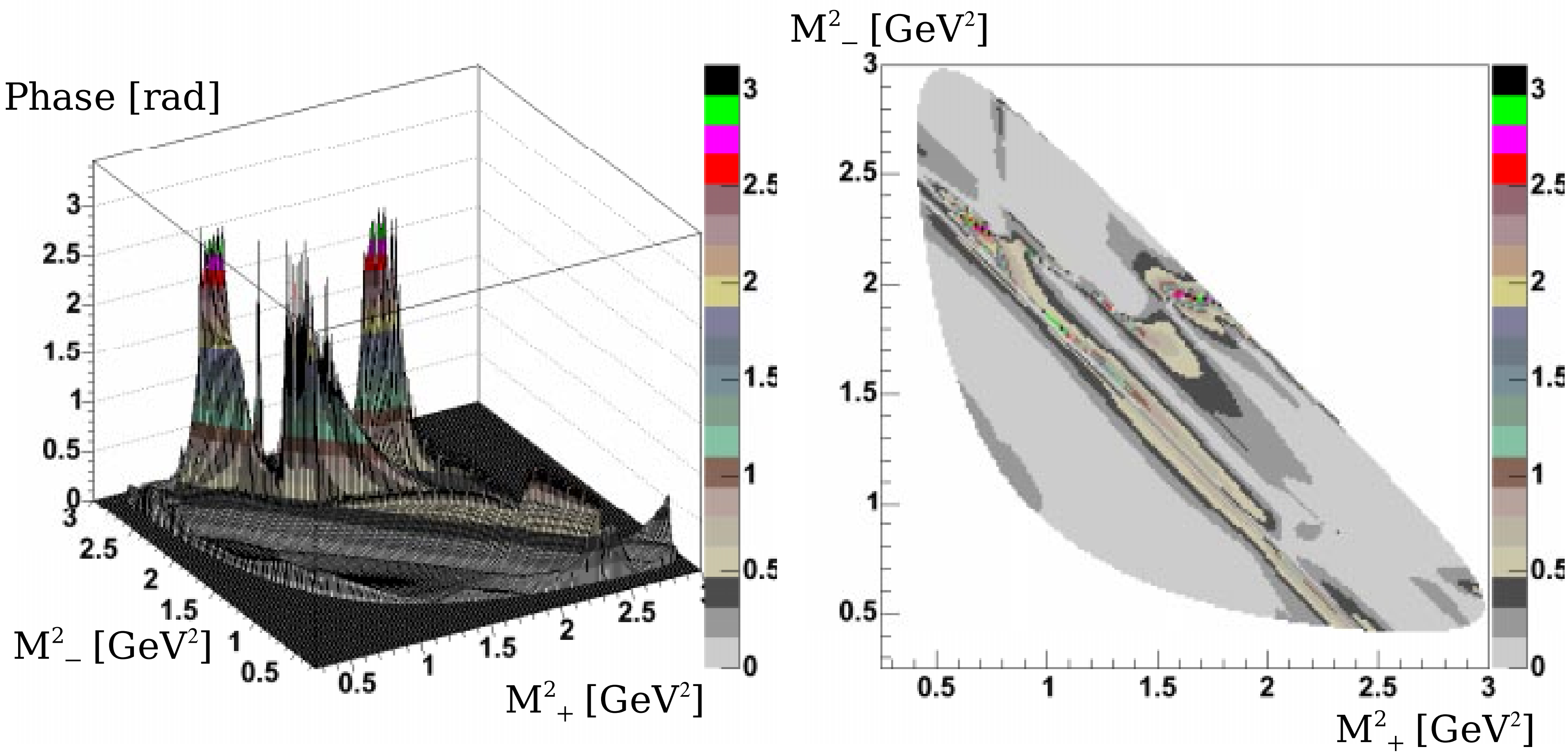


F-vector

B.–W.

Phase difference

The difference of the phase of Dalitz amplitudes in the two cases:



Significant difference only in limited regions of the Dalitz plot, in particular in the region of the $f_0(980)$ and σ_2

Summary and outlook

- K-matrix formalism is useful for the description of the ππ S-wave component.
- K-matrix parametrization from scattering data (V.V. Anisovich, A.V. Sarantsev) gives a good description of the ππ S-wave component of the D decays.
- S-wave fit fraction larger in the K-matrix fit respect to the B.-W. fit.
- Large non resonant fit fraction to be understood ; maybe due to the absence of the Kπ S-wave in the fit.

- Add the Kπ S-wave to the fit.
- Update to Run1-4 (waiting for the end of DstD0ToKsHpHm Run4 skim).
- Parametrization error in the Anisovich and Sarantsev work (M. Pennington), waiting for their new result.
- Floating the K-matrix parameters we are more sensitive (using the covariance matrix) in order to improve the knowledge of the K-matrix parametrization.