Status of the $\pi\pi\pi$ Dalitz analysis

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Talk outline

- The code for fitting the Dalitz has been generalized to any three body final state of D^+ and D^+_s
- This allowed us to check the $KK\pi$ final state with our previous E687 published results
- Tried to understand the more difficult $\pi\pi\pi$ final state
- Used several possible resonance in the full fit (will discuss results)
- Used a likelihood scan procedure to establish optimal resonances parameters: this method has been checked both on ϕ (in the $KK\pi$) sample and on miniMontecarlo samples
- A first look to $D^+ \rightarrow \pi\pi\pi$ has been given

$D \rightarrow KK\pi$ (preliminary study, a cross check)

Data from SUPERSTREAM 6 (Milano N-tuples)

Baseline physics analysis cuts

$L/\sigma > 8$
Mulprim > 1
Run > 9750
ISO1 < 0.01
ISO2 < 0.001
OoM > 0
Kcom < 3 .AND. Kaonicity > 0.5 (both K)
Picom < 3 (for pion)

D^+

Resonances included in the fit

$\overline{K}^{*0}$ (892)
$\overline{K}^{*}_{0}$ (1430)
ϕ (1020)

Data from SUPERSTREAM 6 (Milano N-tuples)

Baseline physics analysis cuts

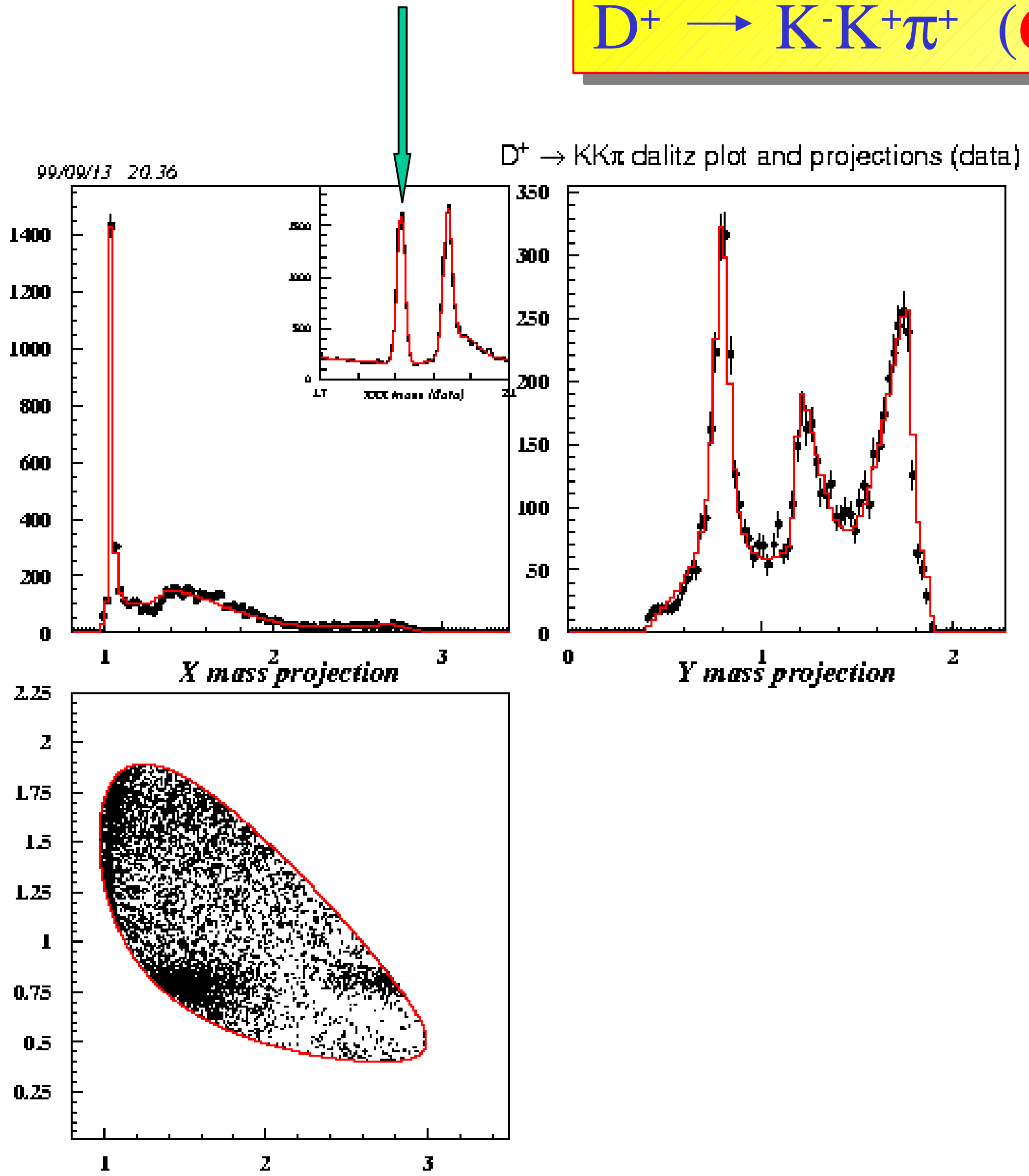
$L/\sigma > 5$
Mulprim > 1
Run > 9750
ISO1 < 0.01
ISO2 < 0.001
OoM > 0
Kcom< 3 .AND. Kaonicity > 6 (same sign K)
Kaonicity > 0.5 (opposite sign K)

D_s^+

Resonances included in the fit

$\overline{K}^{*0}$ (892)
$\overline{K}^{*}_{0}$ (1430)
ϕ (1020)
f_0 (980)
f_J (1710)

$D^+ \longrightarrow K^-K^+\pi^+$ (60% of the full sample)



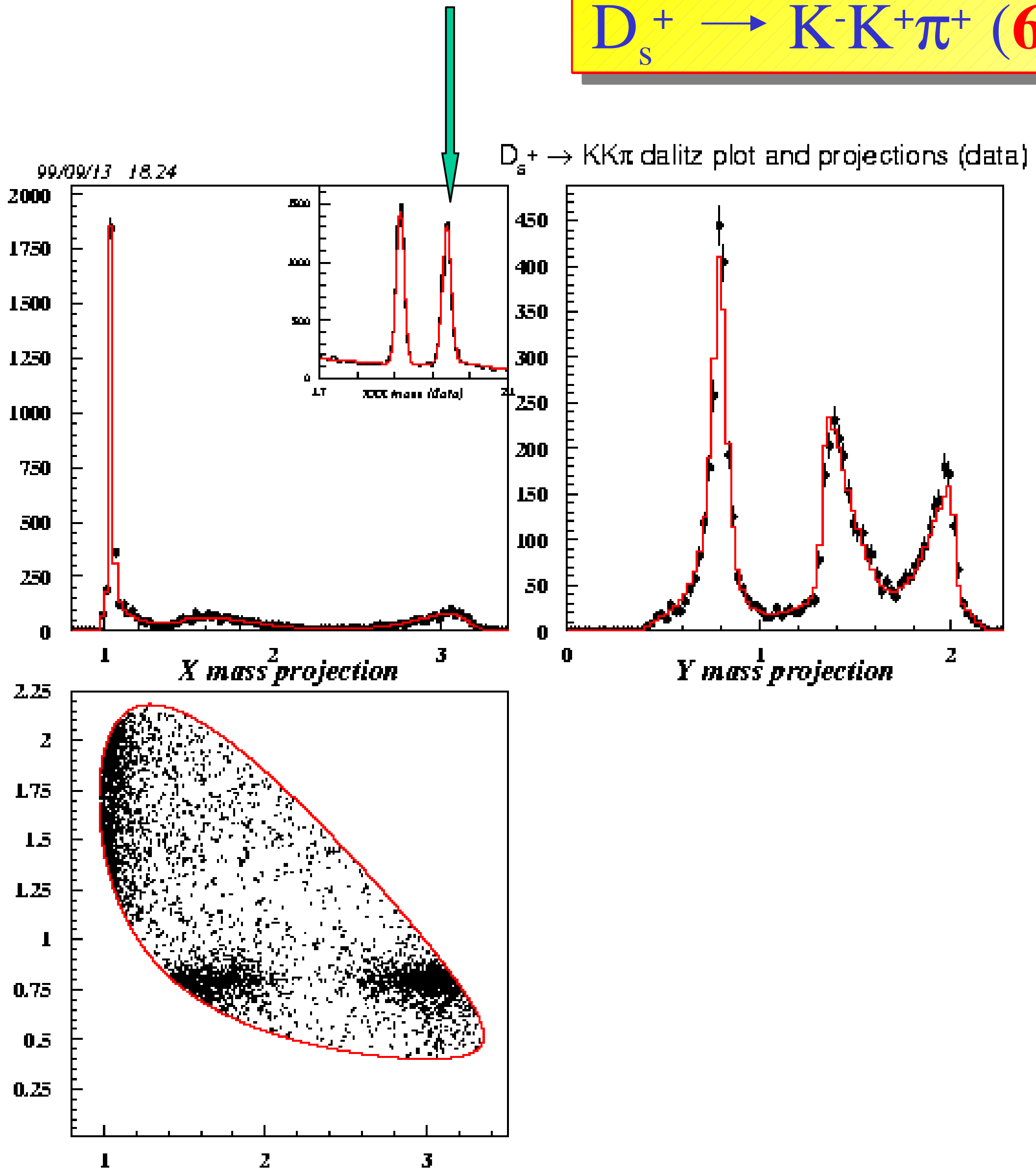
Fit results

	Fit frac.	Phase
K^{*0} (892)	0.31 ± 0.01	0.0 (fixed)
K^*_0 (1430)	0.37 ± 0.01	1.15 ± 0.04
ϕ (1020)	0.28 ± 0.01	-2.97 ± 0.05

E687 published result

	Fit frac.	Phase
K^{*0} (892)	0.30 ± 0.02	0.0 (fixed)
K^*_0 (1430)	0.37 ± 0.04	1.22 ±0.12
ϕ (1020)	0.29 ± 0.03	-2.77 ±0.13

$D_s^+ \longrightarrow K^-K^+\pi^+$ (**60%** of the full sample)



Fit results

	Fit frac.	Phase
K^{*0} (892)	0.46 ± 0.01	0.0 (fixed)
K^*_0 (1430)	0.06 ± 0.01	2.63 ± 0.17
ϕ (1020)	0.42 ± 0.01	2.91 ± 0.09
f_0 (980)	0.15 ± 0.01	2.62 ± 0.09
f_j (1710)	0.03 ± 0.01	1.89 ± 0.11

E687 published result

	Fit frac.	Phase
K^{*0} (892)	0.48 ± 0.05	0.0 (fixed)
K^*_0 (1430)	0.09 ± 0.03	2.65 ± 0.69
ϕ (1020)	0.40 ± 0.03	3.10 ± 0.34
f_0 (980)	0.11 ± 0.04	2.77 ± 0.38
f_j (1710)	0.03 ± 0.02	1.92 ± 0.34

$D \longrightarrow \pi\pi\pi$

Data from SUPERSTREAM 6 (Milano N-tuples)

Baseline physics analysis cuts

$L/\sigma > 10$
Mulprim > 1
Run > 9750
ISO1 < 0.01
ISO2 < 0.001
OoM > 3
Picom < 3 .AND. Pionicity > 0.5 (same sign π)
Picom < 3 .AND. Pionicity > 4 (opposite sign π)
D momentum > 25 GeV .AND. $P_{z\ min}$ > 6 GeV

D^+

Resonances included in the fit

ρ (770)
f_0 (980)
f_2 (1270)
S_0 (1475)
ρ (1450)

Data from SUPERSTREAM 6 (Milano N-tuples)

Baseline physics analysis cuts

$L/\sigma > 10$
Mulprim > 1
All Runs
ISO1 < 0.01
ISO2 < 0.001
OoM > 3
Picom < 3 .AND. Pionicity > 0.5 (same sign π)
Picom < 3 .AND. Pionicity > 1 (opposite sign π)

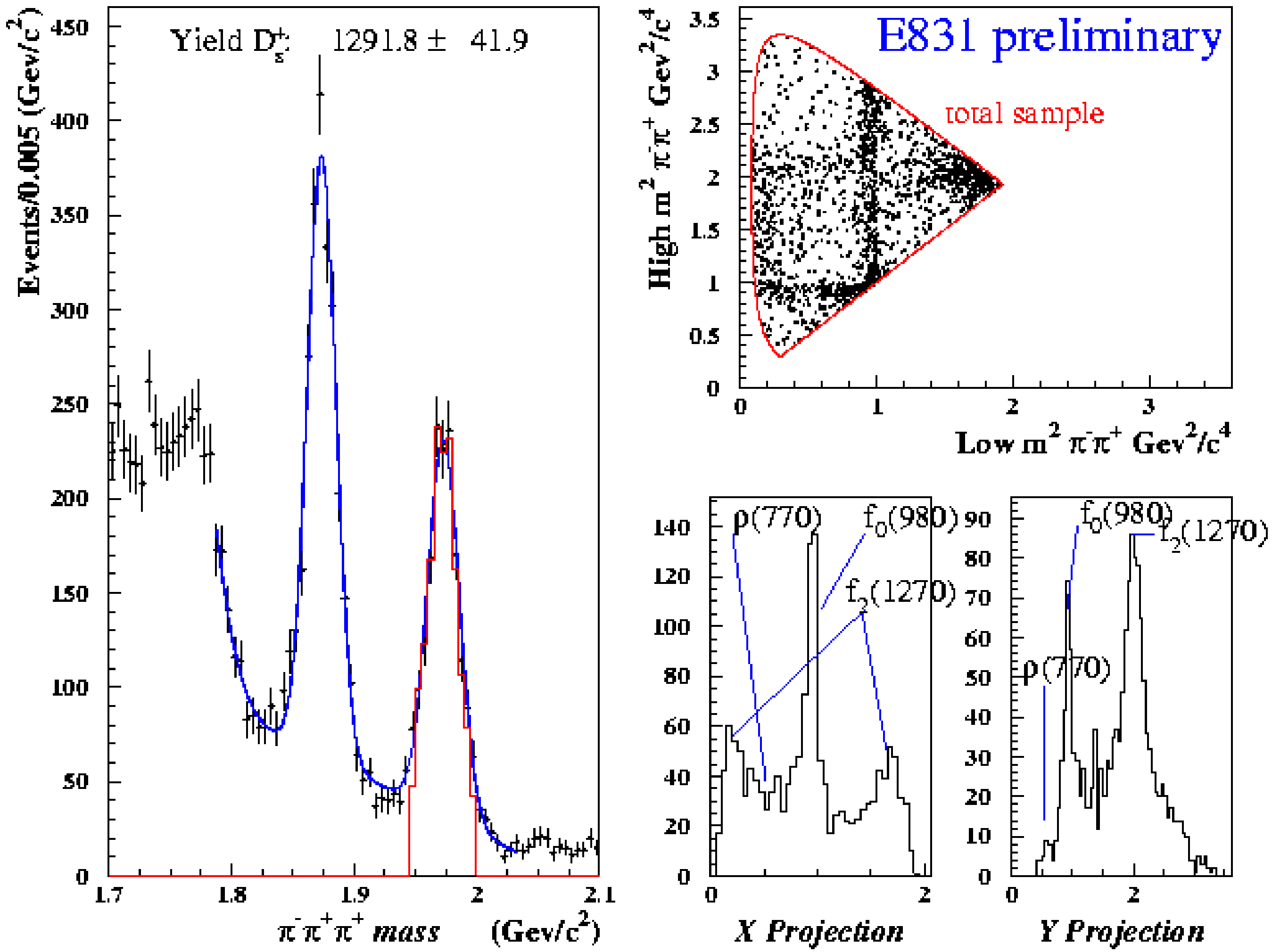
D_s^+

Resonances included in the fit

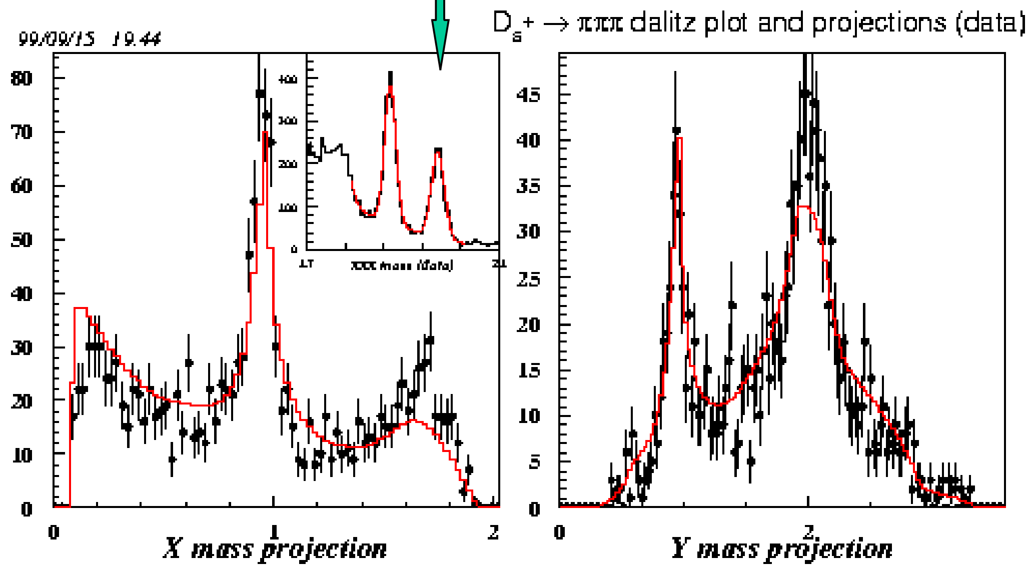
ρ (770)
f_0 (980)
f_2 (1270)
S_0 (1475)
ρ (1450)

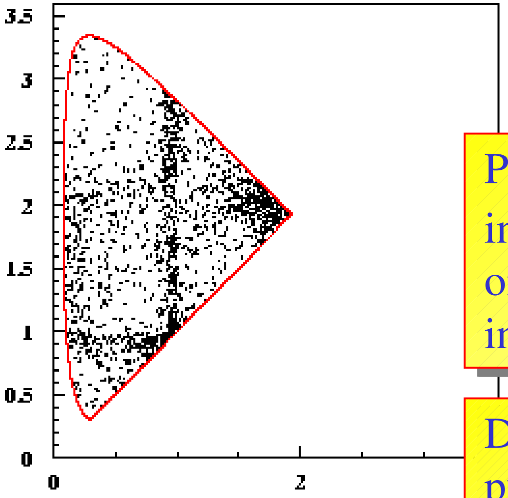
$D_s^+ \longrightarrow \pi^-\pi^+\pi^+$ (**100%** statistics)

$D_s^+ \rightarrow \pi^-\pi^+\pi^+$ dalitz plot and projections



$D_s^+ \longrightarrow \pi^- \pi^+ \pi^+$





Excellent agreement!!

Fit results

	Fit frac.	Phase
NR	0.17 ± 0.04	4.19 ± 0.08
ρ (770)	0.03 ± 0.01	1.00 ± 0.24
f_2 (1270)	0.15 ± 0.02	2.05 ± 0.10
f_0 (980)	1.07 ± 0.04	0.0 (fixed)
S_0 (1475)	0.18 ± 0.03	3.89 ± 0.09

Parametrization of f_0 (980) in this fit is the canonical one by WA76 and used in the E687 analysis also.

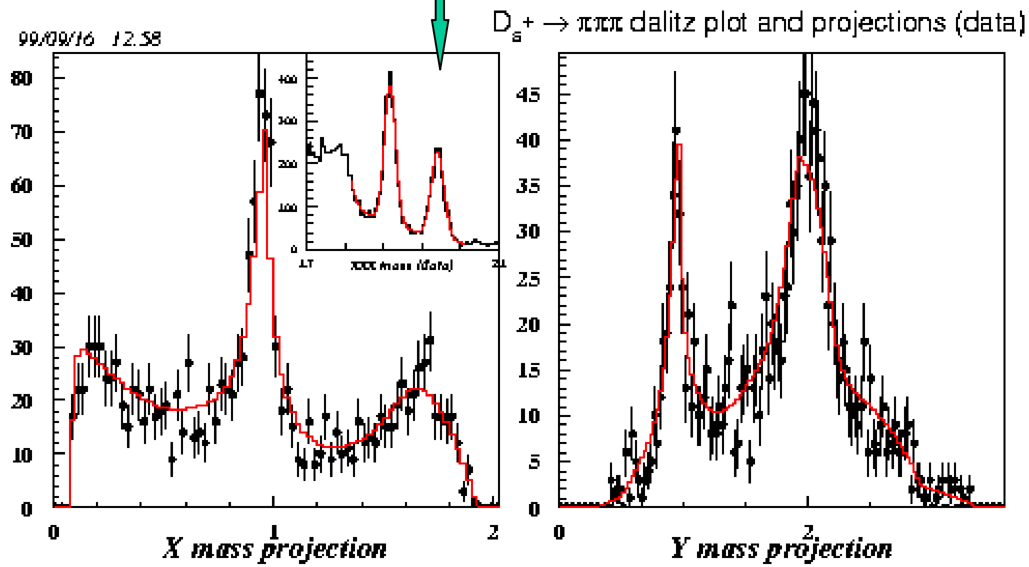
Direct comparison with E687 published results is possible

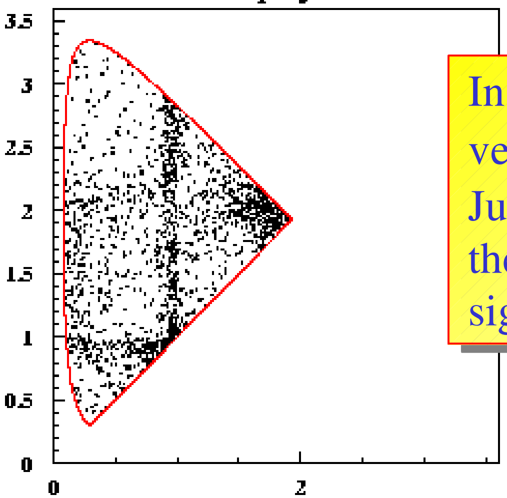
E687 published result

	Fit frac.	Phase
NR	0.12 ± 0.12	4.10 ± 0.38
ρ (770)	0.02 ± 0.03	0.93 ± 0.76
f_2 (1270)	0.12 ± 0.06	1.74 ± 0.31
f_0 (980)	1.07 ± 0.14	0.0 (fixed)
S_0 (1475)	0.27 ± 0.11	4.08 ± 0.26

$D_s^+ \longrightarrow \pi^-\pi^+\pi^+$

NR more than doubles!!





In this fit we have added a vector state, the **ρ(1450).** Judging from the projections the fit quality improves significantly

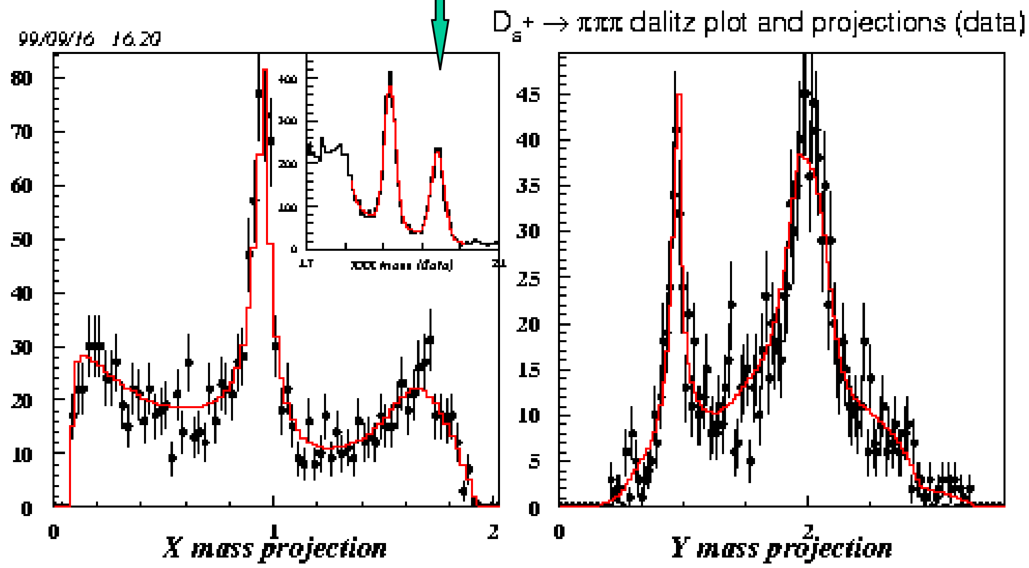
Fit results

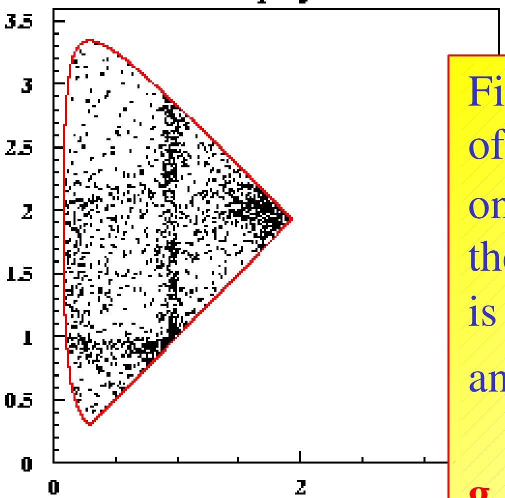
	Fit frac.	Phase
NR	0.27 ± 0.04	4.23 ± 0.07
ρ (770)	0.03 ± 0.02	-0.04 ± 0.28
f_2 (1270)	0.13 ± 0.02	2.35 ± 0.12
f_0 (980)	1.10 ± 0.05	0.0 (fixed)
S_0 (1475)	0.21 ± 0.03	4.31 ± 0.09
ρ (1450)	0.06 ± 0.02	3.84 ± 0.20

E687 published result

	Fit frac.	Phase
NR	0.12 ± 0.12	4.10 ± 0.38
ρ (770)	0.02 ± 0.03	0.93 ± 0.76
f_2 (1270)	0.12 ± 0.06	1.74 ± 0.31
f_0 (980)	1.07 ± 0.14	0.0 (fixed)
S_0 (1475)	0.27 ± 0.11	4.08 ± 0.26
ρ (1450)	Not considered !	

$D_s^+ \longrightarrow \pi^-\pi^+\pi^+$





NR still higher than E687, but f_0 a little lower

Fit results

	Fit frac.	Phase
NR	0.20 ± 0.04	4.28 ± 0.08
ρ (770)	0.03 ± 0.02	0.20 ± 0.34
f_2 (1270)	0.12 ± 0.02	2.46 ± 0.13
f_0 (980)	0.92 ± 0.04	0.0 (fixed)
S_0 (1475)	0.22 ± 0.03	4.32 ± 0.10
ρ (1450)	0.06 ± 0.02	3.87 ± 0.20

Finally, the parametrization of f_0(980) in this fit is the one adopted by WA 102: the difference with WA 76 is the values taken by g_K and g_π

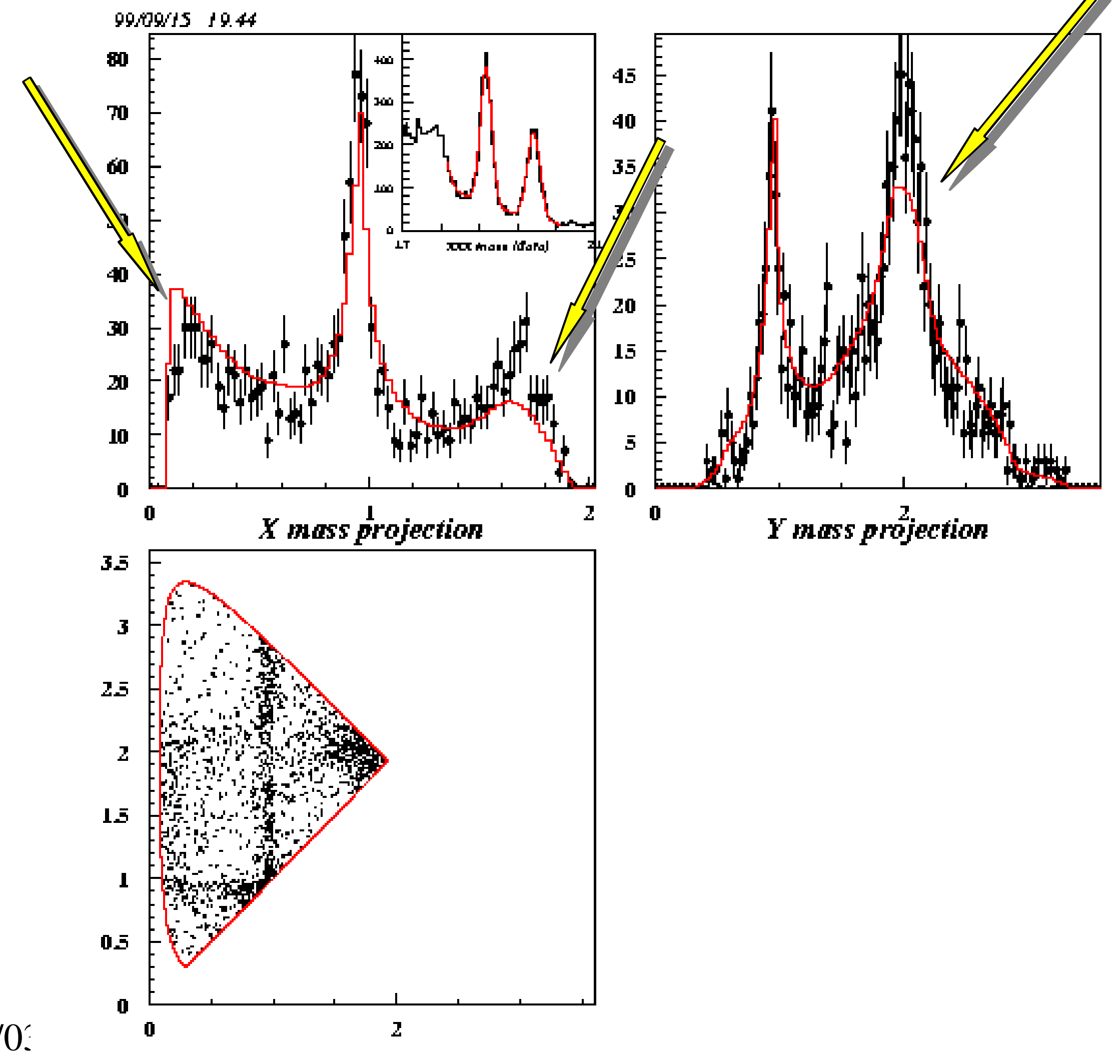
g_K = 0.40 (was 0.56 ± 0.18)
g_π = 0.19 (was 0.28 ± 0.04)

E687 published result

	Fit frac.	Phase
NR	0.12 ± 0.12	4.10 ± 0.38
ρ (770)	0.02 ± 0.03	0.93 ± 0.76
f_2 (1270)	0.12 ± 0.06	1.74 ± 0.31
f_0 (980)	1.07 ± 0.14	0.0 (fixed)
S_0 (1475)	0.27 ± 0.11	4.08 ± 0.26
ρ (1450)	Not considered !	

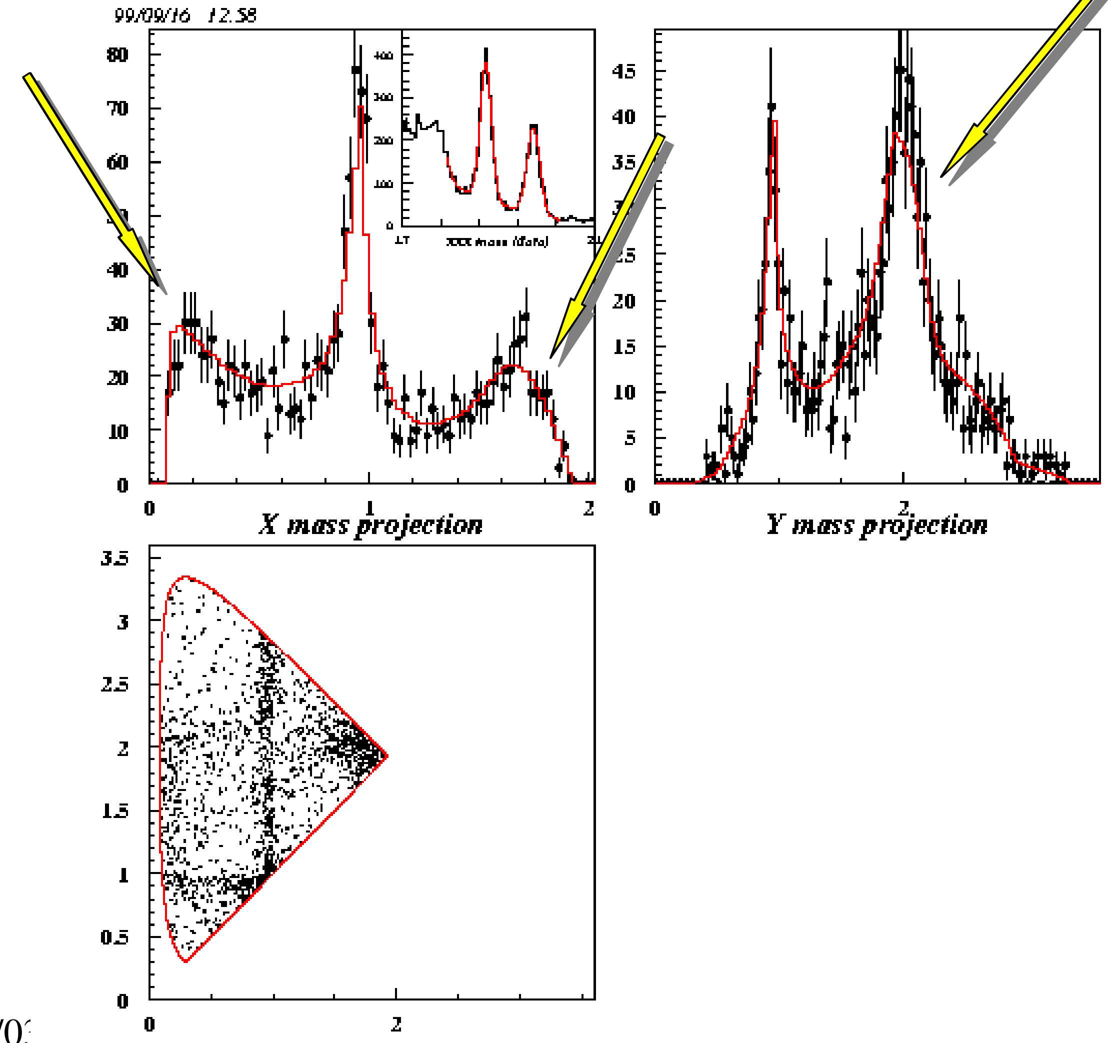
E687 parametrization

Bad fit if ρ (1450) is NOT included



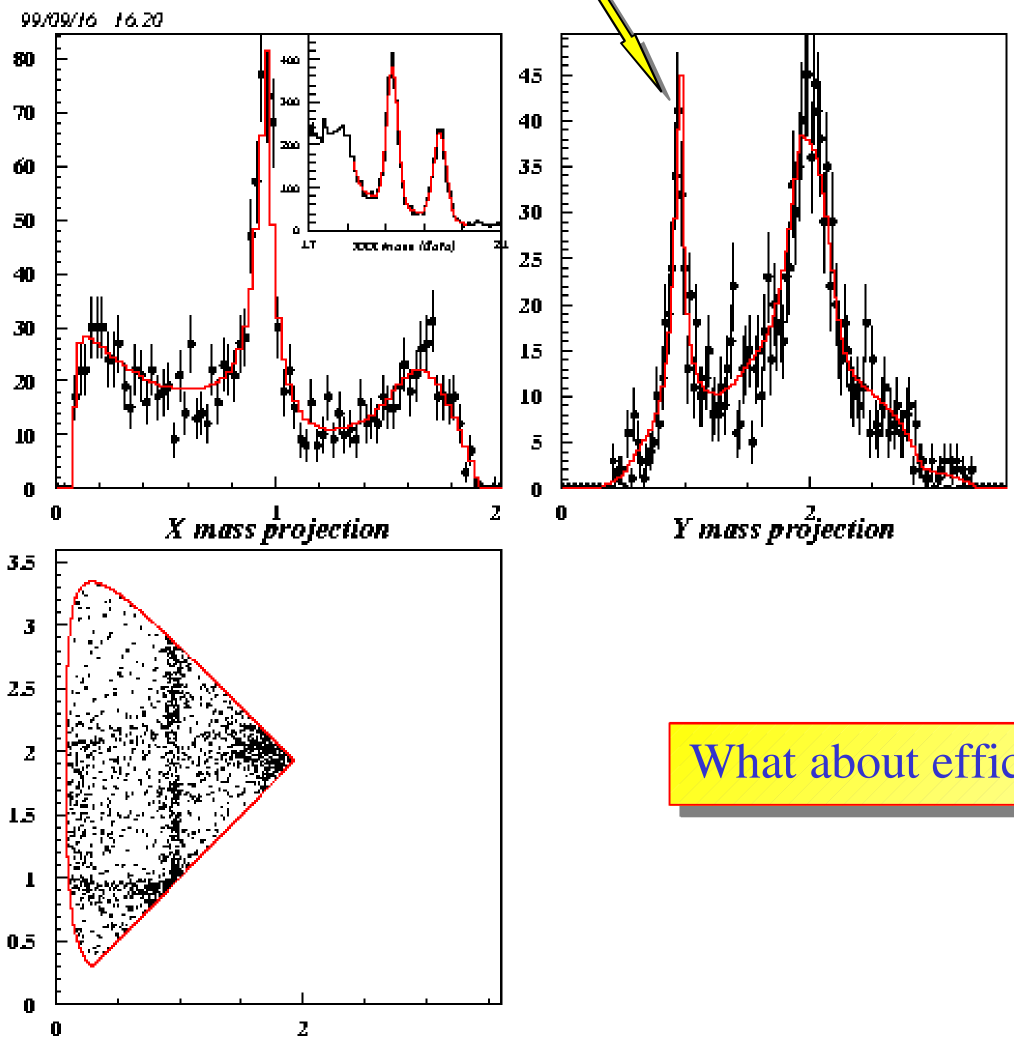
New Focus parametrization

Better fit if ρ (1450) IS included

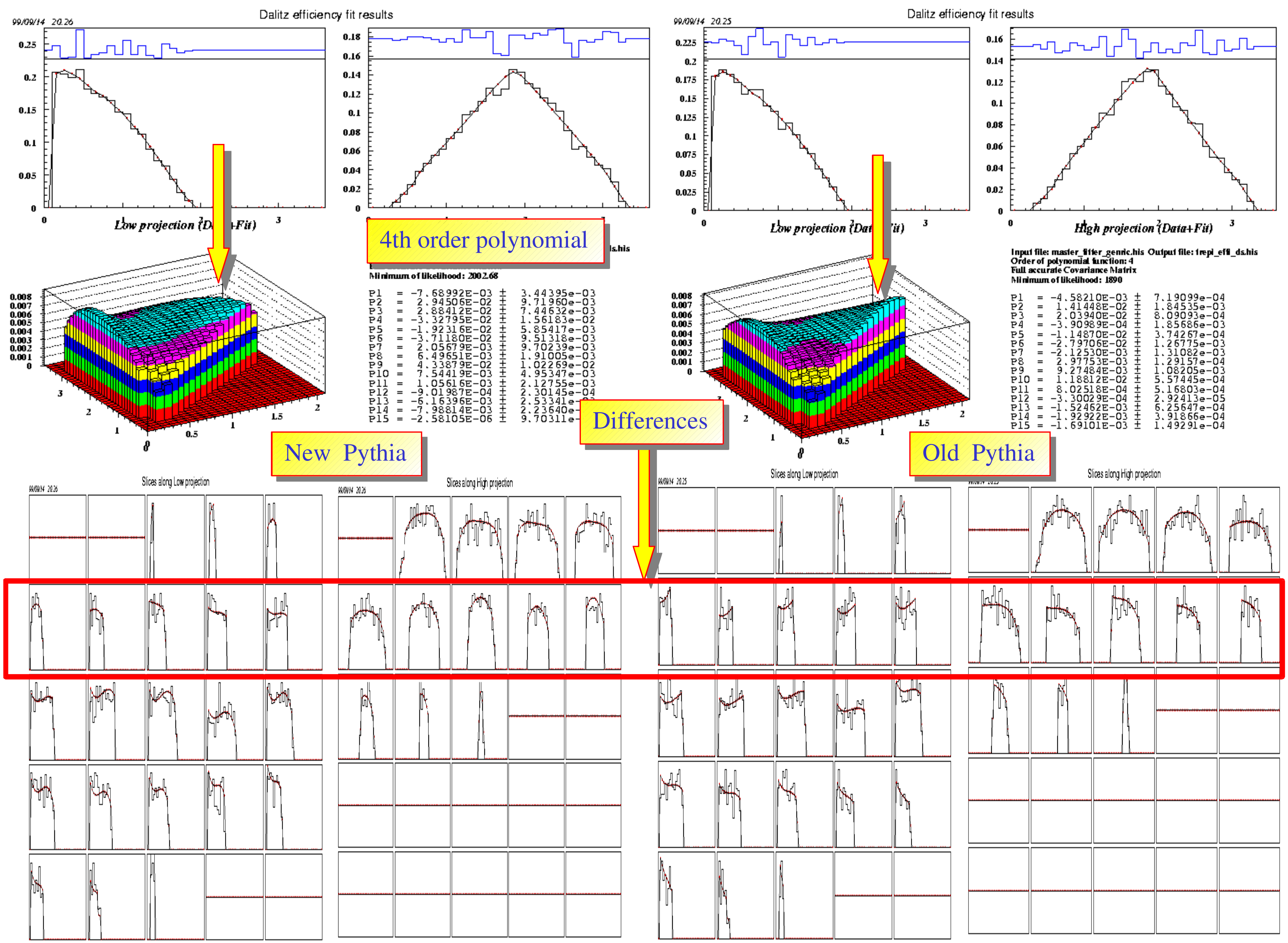


New values of g_K and g_π by WA102

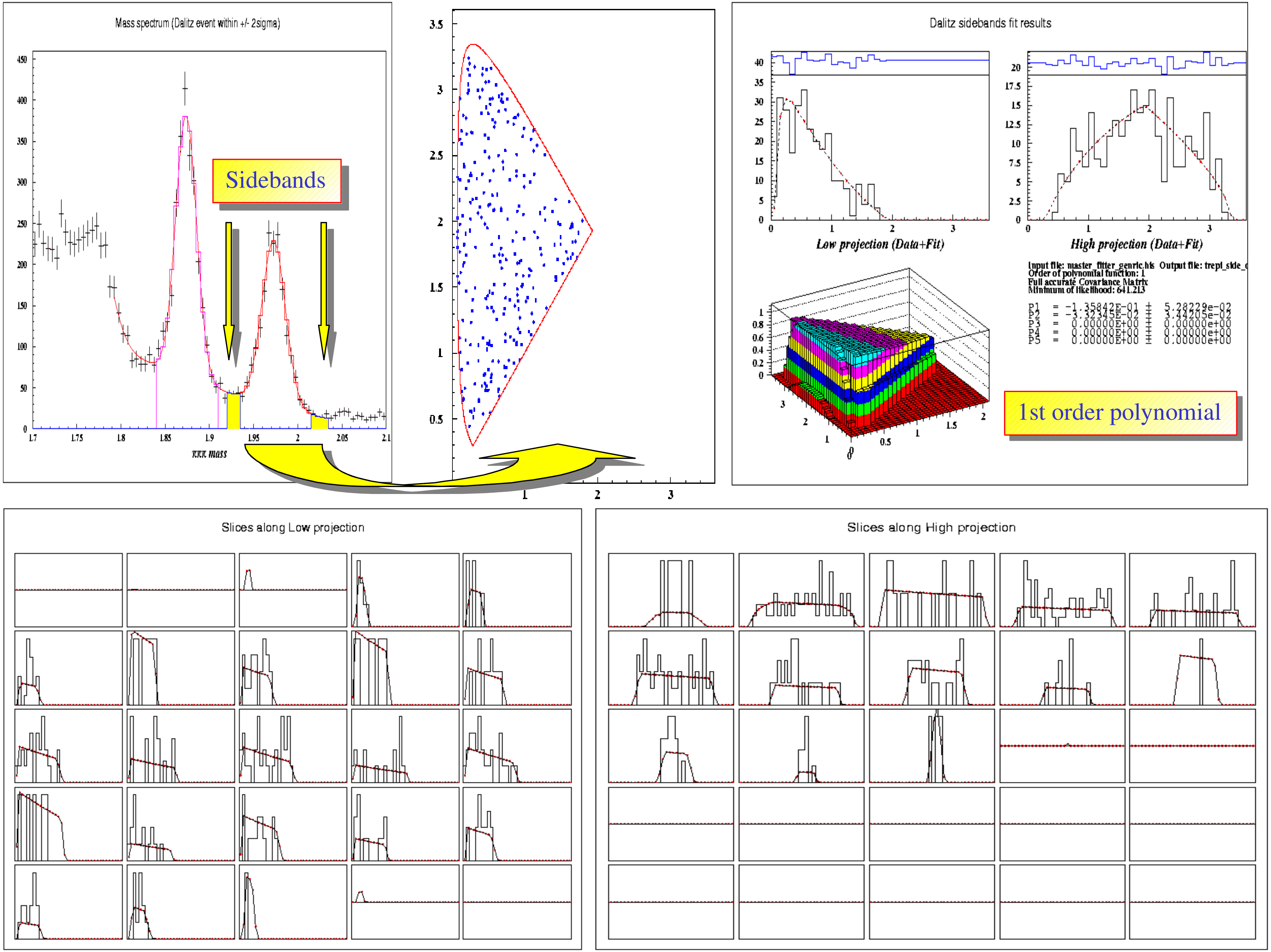
Better agreement in this region?



What about efficiency and sidebands?

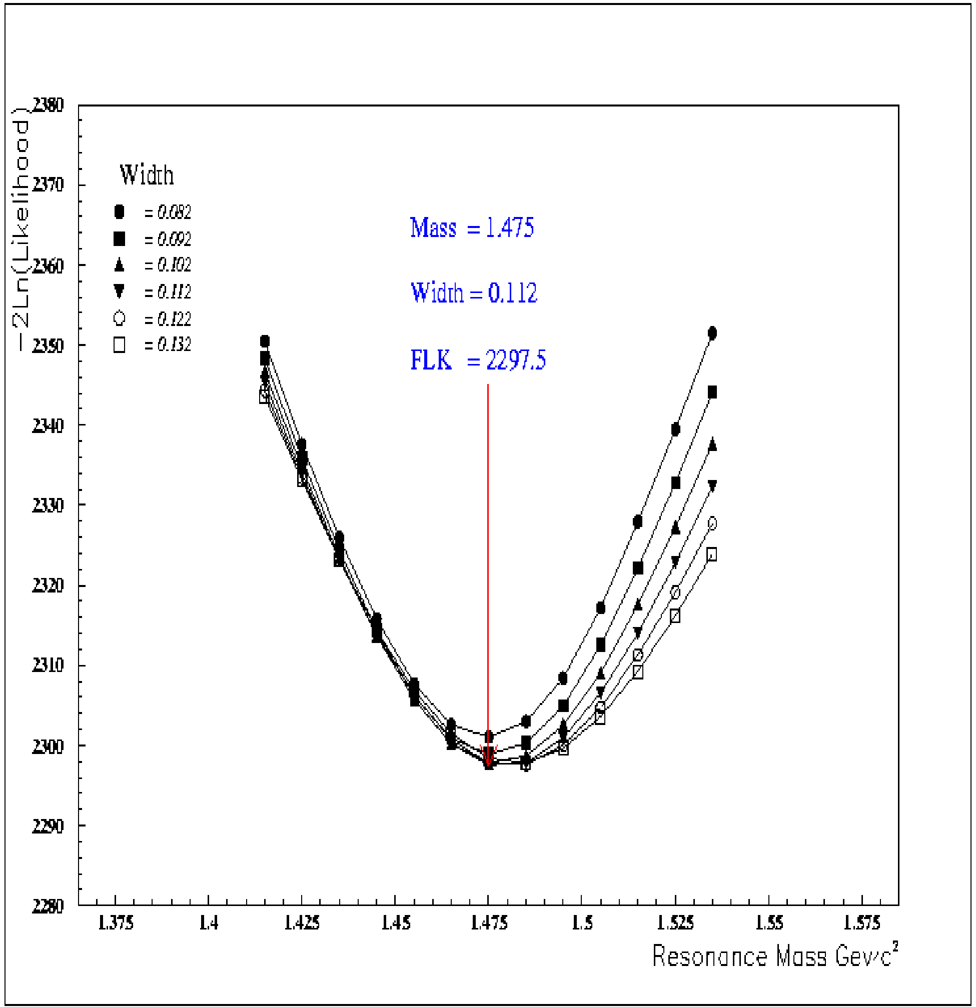


Dalitz efficiency fit results
99/09/14 20.26
Low projection (Data+Fit)
4th order polynomial
Minimum of likelihood: 2002.68
P1 = -7.68992E-03 ± 3.44395e-03
P2 = 2.94506E-02 ± 9.71960e-03
P3 = 2.88412E-02 ± 7.44632e-03
P4 = -3.32795E-02 ± 1.56183e-02
P5 = -1.92316E-02 ± 5.85417e-03
P6 = -3.71180E-02 ± 9.51318e-03
P7 = 2.05679E-03 ± 9.70239e-03
P8 = 6.49651E-03 ± 1.91005e-03
P9 = 4.33879E-02 ± 1.02269e-02
P10 = 7.54419E-03 ± 4.95347e-03
P11 = 1.05616E-03 ± 2.12755e-03
P12 = -9.01987E-04 ± 2.30145e-04
P13 = -6.16396E-03 ± 2.53341e-
P14 = -7.98814E-03 ± 2.23640e-
P15 = -2.58105E-06 ± 9.70311e-
New Pythia
Slices along Low projection
Slices along High projection
Differences
Dalitz efficiency fit results
99/09/14 20.25
Low projection (Data+Fit)
High projection (Data+Fit)
Input file: master_filter_genric.his Output file: 1repi_effi_ds.his
Order of polynomial function: 4
Full accurate Covariance Matrix
Minimum of likelihood: 1890
P1 = -4.58210E-03 ± 7.19099e-04
P2 = 1.41448E-02 ± 1.84535e-03
P3 = 2.03940E-02 ± 8.09093e-04
P4 = -3.90989E-04 ± 1.85686e-03
P5 = -1.14870E-02 ± 3.74267e-04
P6 = -2.79706E-02 ± 1.26775e-03
P7 = -2.12530E-03 ± 1.31082e-03
P8 = 2.97753E-03 ± 1.29157e-04
P9 = 9.27484E-03 ± 1.08205e-03
P10 = 1.18812E-02 ± 5.57445e-04
P11 = 8.02518E-04 ± 5.16803e-04
P12 = -3.30029E-04 ± 2.92413e-05
P13 = -1.52462E-03 ± 6.25647e-04
P14 = -1.92922E-03 ± 3.91866e-04
P15 = -1.69101E-03 ± 1.49291e-04
Old Pythia
Slices along Low projection
Slices along High projection



Mass spectrum (Dalitz event within +/- 2sigma)
Sidebands
πππ mass
Dalitz sidebands fit results
Low projection (Data+Fit)
High projection (Data+Fit)
Input file: master_fitter_genric.his Output file: trepl_side_
Order of polynomial function: 1
Full accurate Covariance Matrix
Minimum of likelihood: 641.213
P1 = -1.35842E-01 ± 5.28229e-02
P2 = -3.32345E-02 ± 3.44205e-02
P3 = 0.00000E+00 ± 0.00000e+00
P4 = 0.00000E+00 ± 0.00000e+00
P5 = 0.00000E+00 ± 0.00000e+00
1st order polynomial
Slices along Low projection
Slices along High projection

In order to establish the best parameters for the S0(1475), we performed a likelihood scan varying mass and width of this state.



Good news!

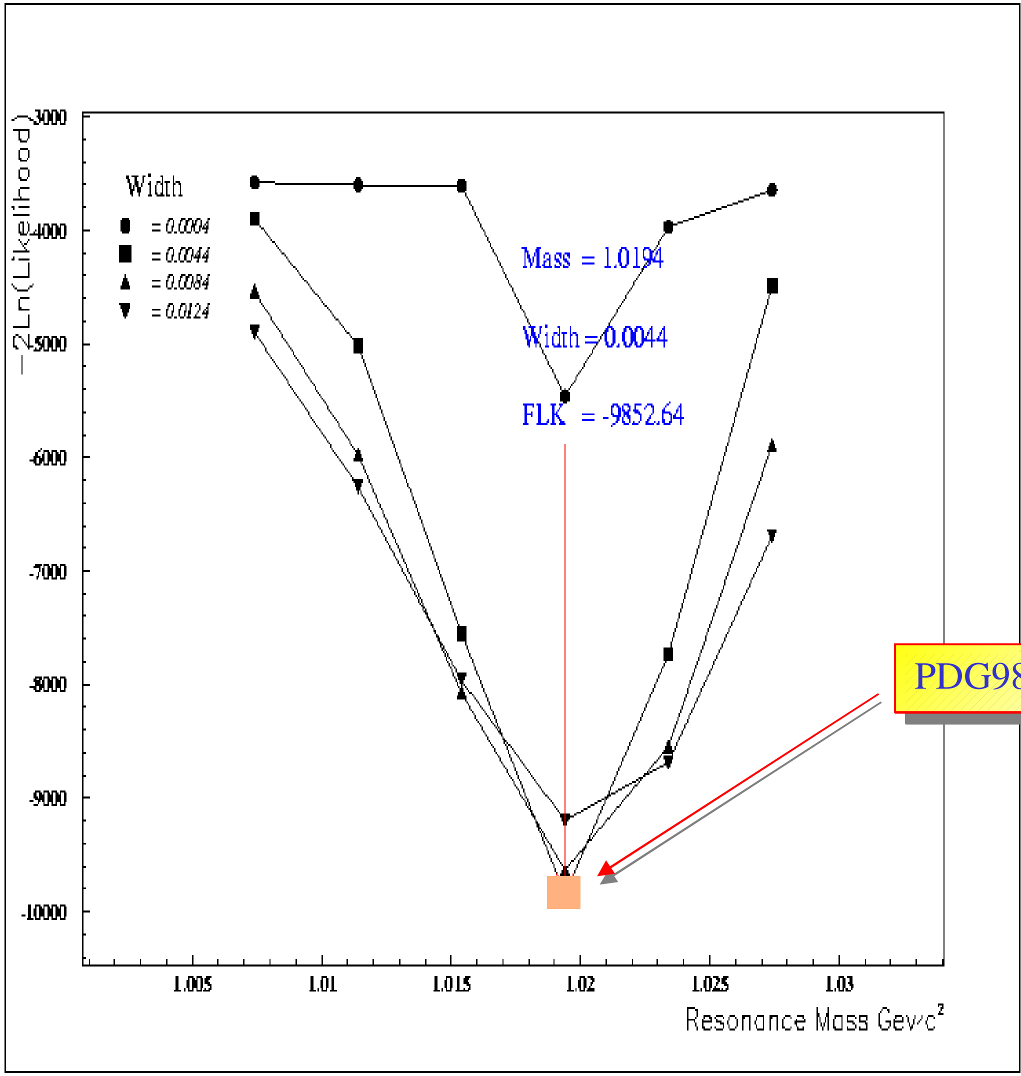
As we already observed in E687 data, the best likelihood is obtained for the following values of mass and width:

$M = 1.475\ \mathrm{GeV}/c^2$

$\Gamma = 0.1\ \mathrm{GeV}/c^2$

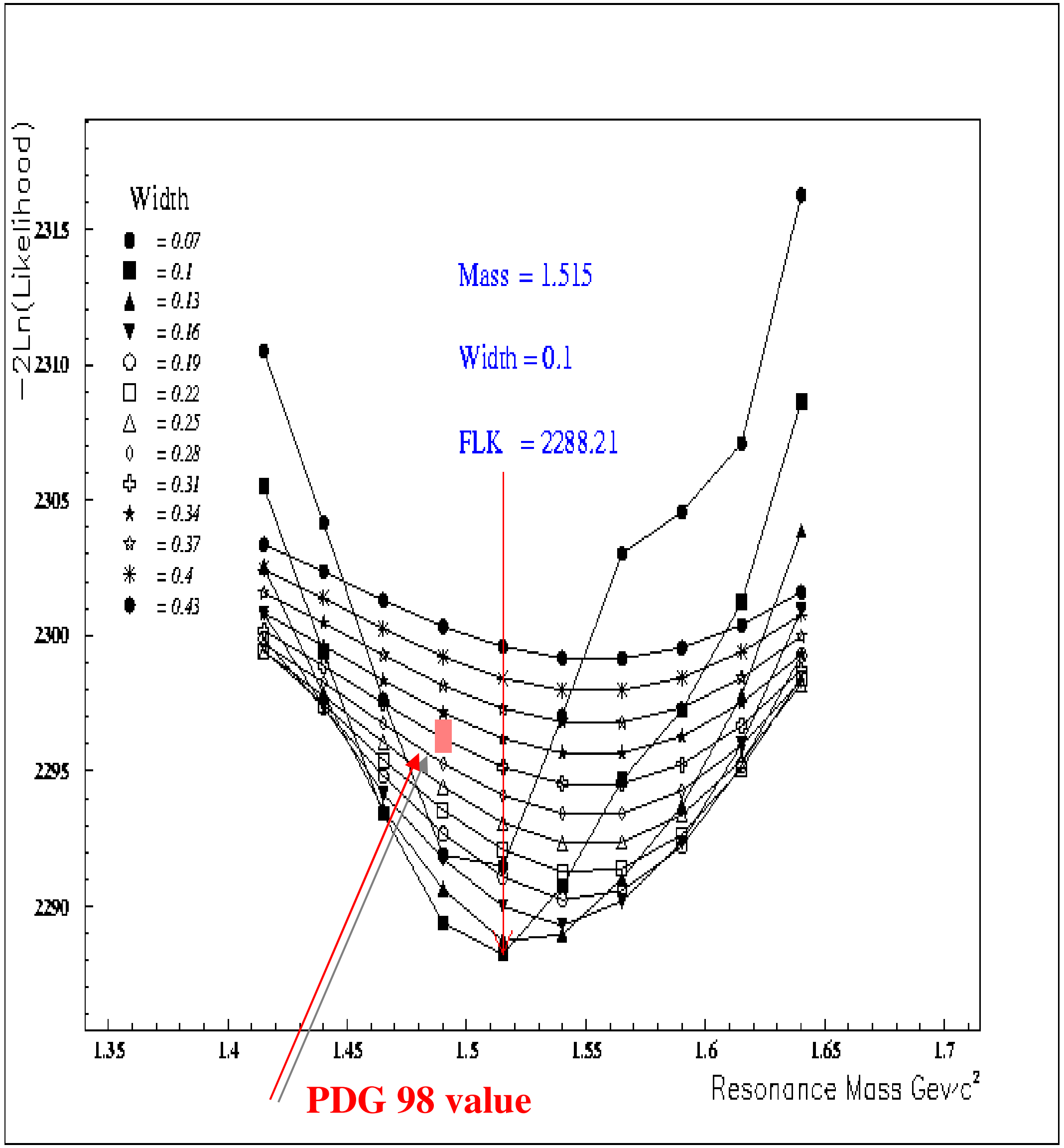
As a cross check for the validity of this likelihood scan method, we tried it for ϕ the $KK\pi$ sample

High statistics, clean evidence and well established PDG values



The result is satisfying: we find the expected PDG values

PDG98 value



At this point we did the same exercise for the ρ**(1450).**

Bad news!

The likelihood scan indicates an optimal mass which is higher than the PDG value and a width which is much narrower.

	We find	PDG98 says
M	1.515 GeV/c^2	1.465 ± 0.025 GeV/c^2
Γ	0.10 GeV/c^2	0.31 ± 0.06 GeV/c^2

Using PDG values

Fit results

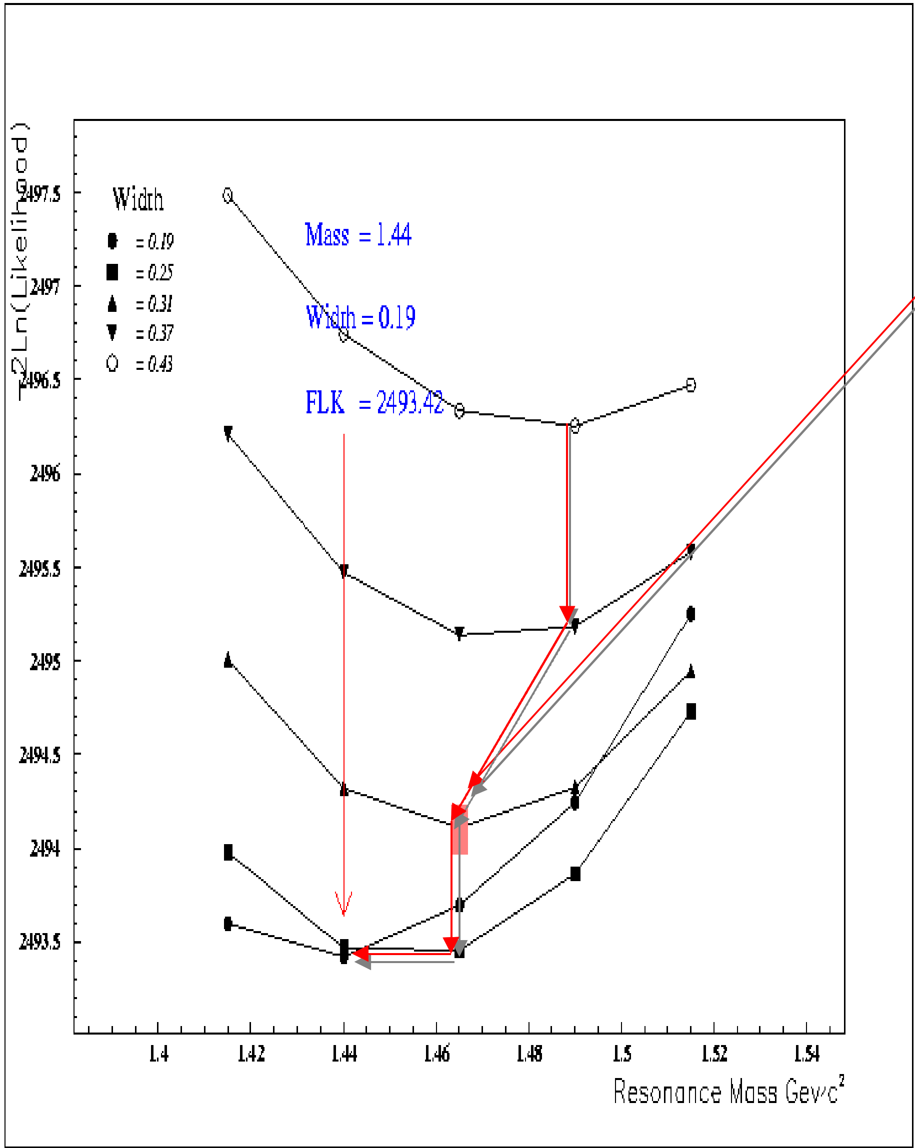
	Fit frac.	Phase
NR	0.27 ± 0.04	4.23 ± 0.07
ρ (770)	0.03 ± 0.02	-0.04 ± 0.28
f_2 (1270)	0.13 ± 0.02	2.35 ± 0.12
f_0 (980)	1.10 ± 0.05	0.0 (fixed)
S_0 (1475)	0.21 ± 0.03	4.31 ± 0.09
ρ (1450)	0.06 ± 0.02	3.84 ± 0.20

Using minimum of likelihood scan

Fit results

	Fit frac.	Phase
NR	0.24 ± 0.04	4.10 ± 0.09
ρ (770)	0.02 ± 0.02	0.02 ± 0.34
f_2 (1270)	0.12 ± 0.01	2.26 ± 0.12
f_0 (980)	1.13 ± 0.04	0.0 (fixed)
S_0 (1475)	0.20 ± 0.03	4.42 ± 0.11
ρ (1450)	0.06 ± 0.02	3.53 ± 0.14

Actual values of resonance parametrization have marginal effect on fit fraction, phases and overall fit quality (judging from the projections)



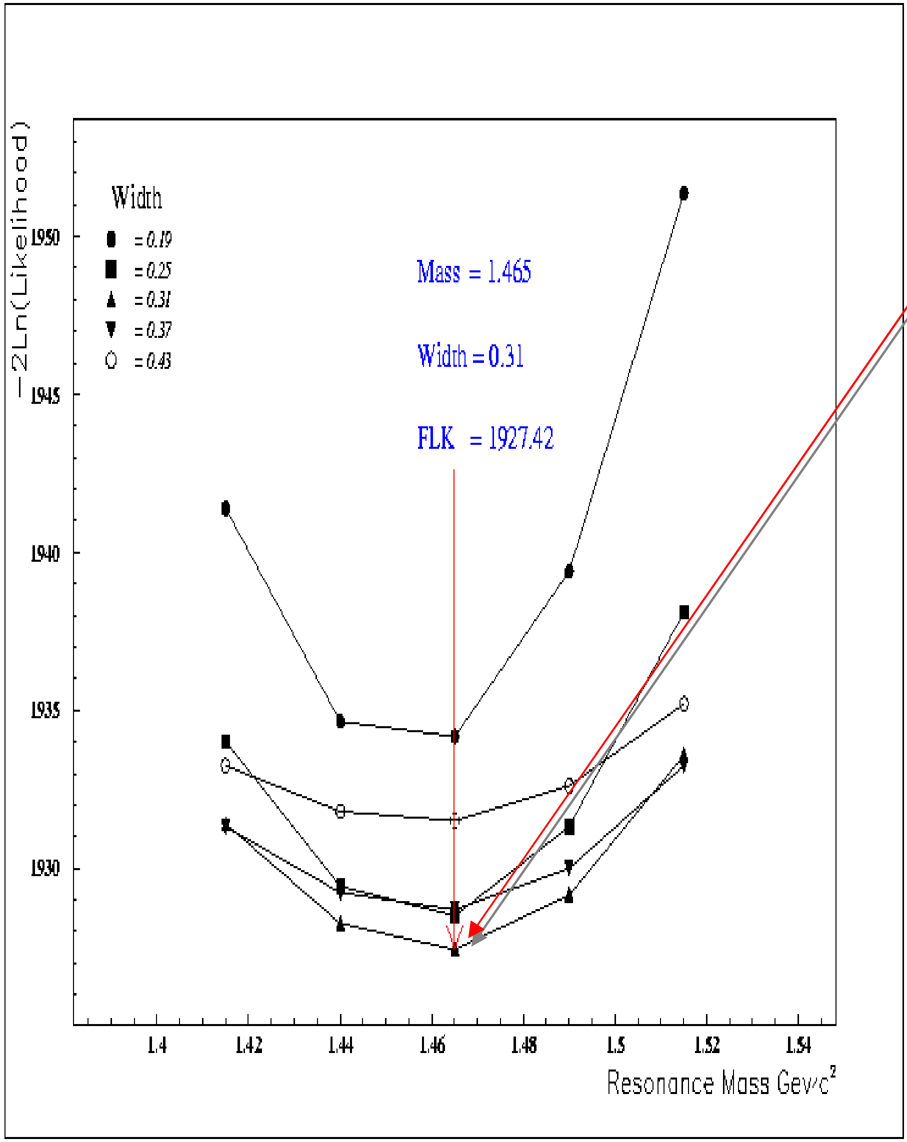
In order to understand the reason of this behaviour, we generated a miniMontecarlo sample with the parameters of the **ρ(1450),** set to the PDG98 values of:

M = 1.465 GeV/c^2 and G = 0.31 GeV/c^2

The fit fraction was set to **4%**

From this scan we would conclude that with just a **4%** evidence of a fit fraction, the scan method allows for a determination of the resonance parameters with very wide error bars.

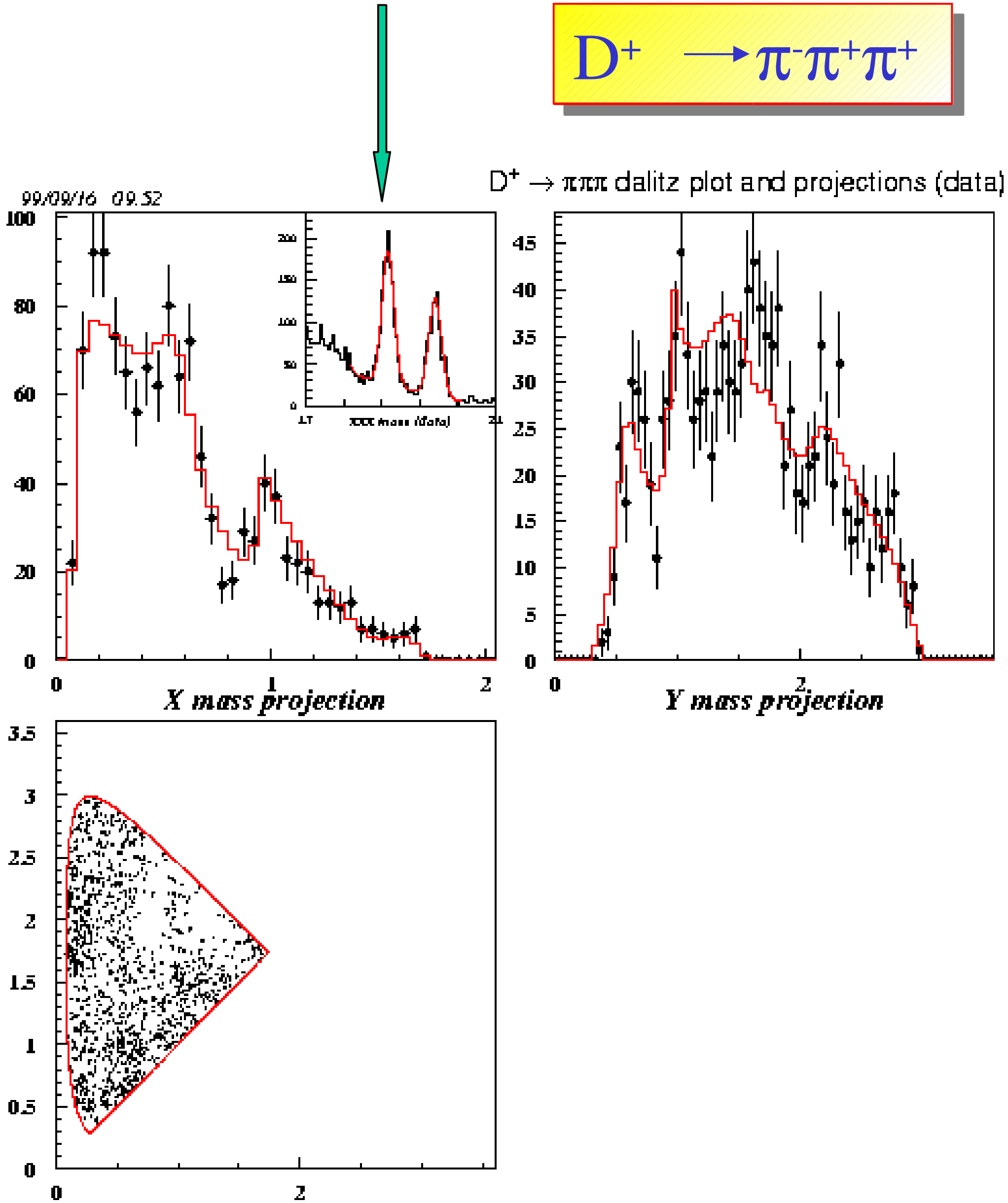
In order to check this hypotesis, we simulated a new miniMontecarlo sample with a higher fit fraction for the **ρ(1450),** set to **20%** instead of **4%**



In this case the scan procedure converges to the correct values of the generated model

We would then conclude that, given the small fit fraction featured by the ρ **(1450)** , the best thing we can do is just using the parametrization given by PDG98: the inclusion of this resonance in the overall fit is nevertheless not enough to make a perfect match between data and fit.

$D^+ \longrightarrow \pi^- \pi^+ \pi^+$



Using the same admixture of resonances as the D_s the fit quality doesn't look great.

Still much work to be done for this decay mode.

Conclusions

- We have now a manageable tool for Dalitz analysis (can study several decay modes)
- We are able to reproduce E687 results in the KKπ mode (for both D and D_s) with an improved statistical error (we only considered 60% of the sample for this study)
- We also reproduced E687 results for the πππ sample (Ds only): given the much higher statistics, there is room for improvements (consider more resonances? Try different parametrizations?)
- Several studies were undertaken to understand the likelihood scan methodology. These studies indicate that the inclusion of a new vector state, ρ(1450), is not enough to perfectly match data and fit along the Dalitz projections
- We have just begun to understand the D+: much work still to be done