Glueball Searches in BaBar.

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Summary:

- Introduction.
- Experimental techniques.
- The BaBar experiment.
- Three body Dalitz plot analysis.
- First experimental results.
- Conclusions.

Introduction: Physics Motivations

• New generation experiments, fixed target and B-factories, are accumulating high quality, large data samples on Beauty and Charm Physics.

• Important information related to glueball searches can come from:

• The Dalitz plot analysis of 3-body Charm and B decays.

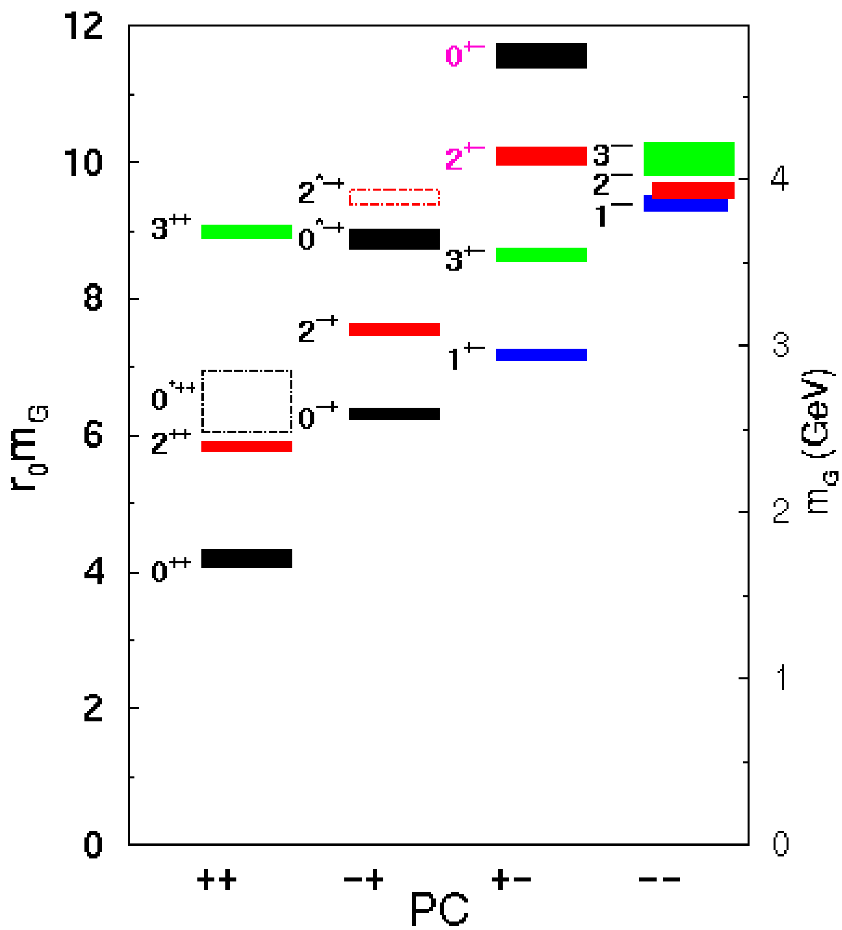
• The study of the process: $b \to sg$

• The Dalitz Plot Analysis of three-body decays is a relatively new powerful technique for studying Beauty and Charm Physics.

- It is the most complete way of analyzing the data.
- It allows to measure decay amplitudes and phases.
- The final state is the result of the interference of all the intermediate states.

Introduction

• One of the most important Motivations for continuing working on Light Meson Spectroscopy is the search for Glueballs and Exotic mesons.



• From Lattice QCD, the lightest glueball, with $J^{PC} = 0^{++}$ i s expected around 1.7 GeV.

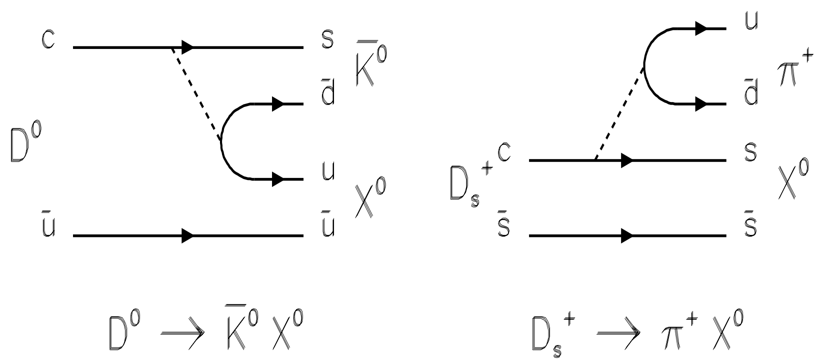
• A variety of exotics is also expected below 2.5 GeV. Hybrids ($\bar{q}qg$ mesons) or 4-quark states. Some of them could be narrow enough to be detected. Some of them have quantum numbers forbidden for $\bar{q}q$ mesons, such as: $J^{PC} = 1^{-+}, 0^{--}, 0^{+-}$, etc.

• The structure of the lowest $\bar{q}q$ multiplets is mostly still undefined and this prevents unique "exotic assignments" of gluonic candidates.

• *Strategy to find these states: they do not fit in the standard $\bar{q}q$ nonet. They are extra states.*

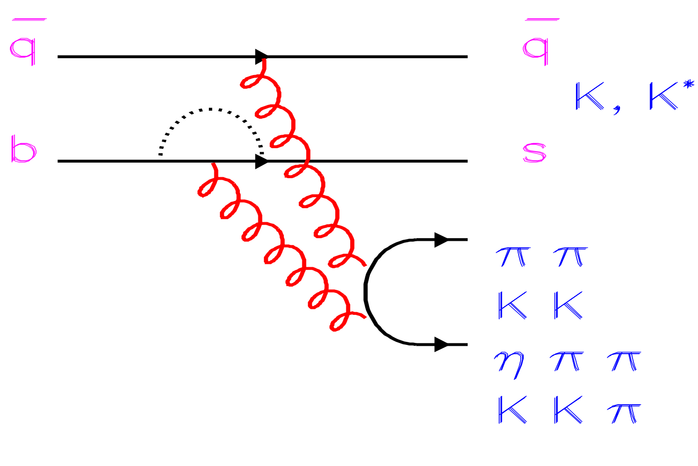
• New inputs from heavy mesons decays could solve old and new puzzles in light meson spectroscopy.

• In the charm sector, D are coupled to $\bar{u}u + \bar{d}d$ while D_S are coupled to $\bar{s}s$.



• Glueballs could be produced in B decays through the process:

$$b \longrightarrow sg$$



Recent experiments (fixed target).

- E791. Data taken during 1990-1991 using 500 GeV/c π^- beam at Fermilab. 2.5 $\times 10^5$ reconstructed charm.
- FOCUS. Successor to E687 which took data in 1990-1991. Data taken during 1996-1997. 170 GeV γ beam. 10^6 reconstructed charm.
- The technique employed here is to have good vertexing and good particle identification.
- Use of the Lorentz boost to separate the charm vertex.

Recent experiments (e^+e^- colliders).

e^+e^- colliders at the $\Upsilon(4S)$:

- Experiment CLEO: 9 fb^{-1}

- BaBar: 57.0 fb^{-1} at the end of 2001. Much more is coming.

- Belle.

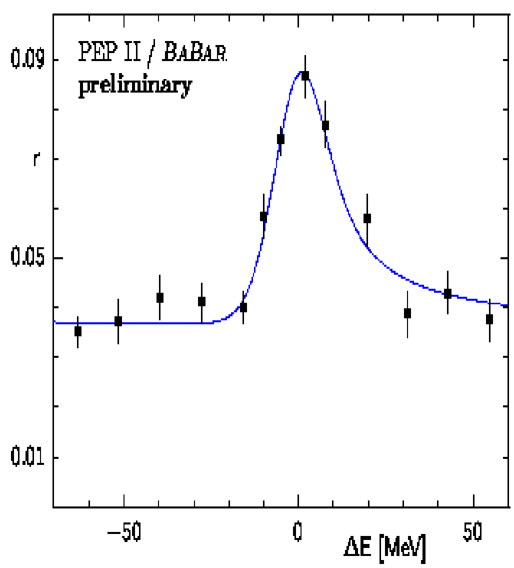
The BaBar Experiment

• The PEPII Collider is an Asymmetric storage ring which collides 9 GeV electrons with 3.1 GeV positrons.

• Peak Luminosity: $3.1 \times 10^{33}\ cm^{-2}s^{-1}$

• Produces $\Upsilon(4S)$ resonance with $\beta\gamma = 0.56$ in the lab frame at zero crossing angle.

• $\Upsilon(4S)$ Energy Scan from BaBar.



• The $\Upsilon(4S)$ Resonance sits on a large continuum background.

Technique

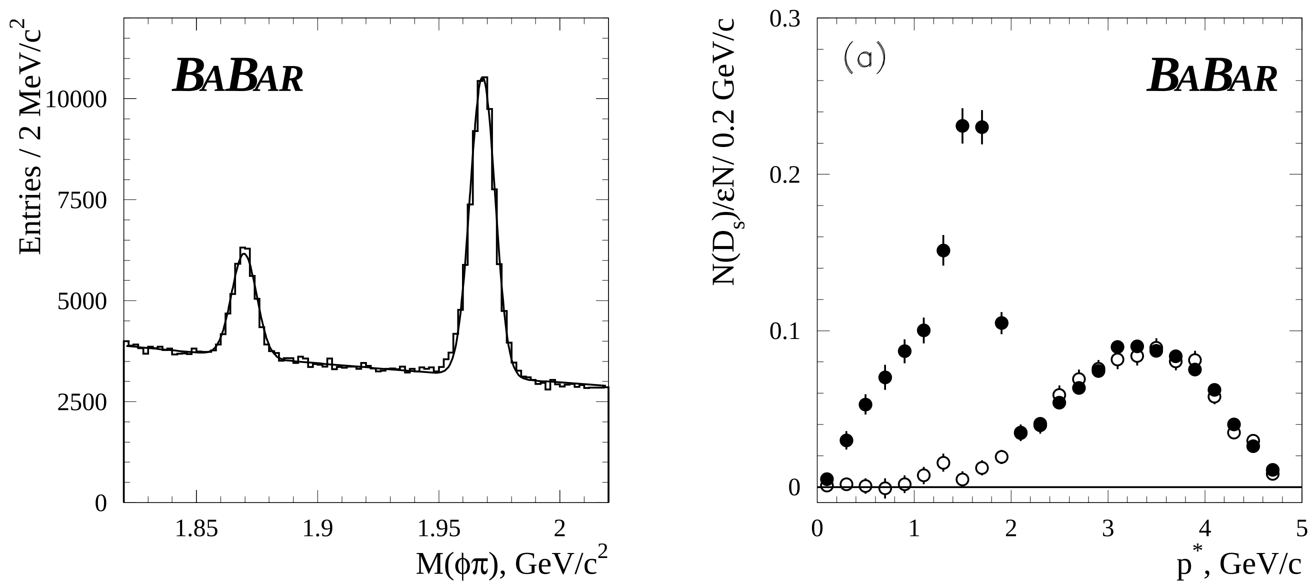
• Charmed mesons are obtained from e^+e^- continuum using cuts on the center of mass momentum p^* and/or the request that are coming from a D^* decay.

$$e^+e^- \to D^* \to \; X$$
$$\to D\pi$$

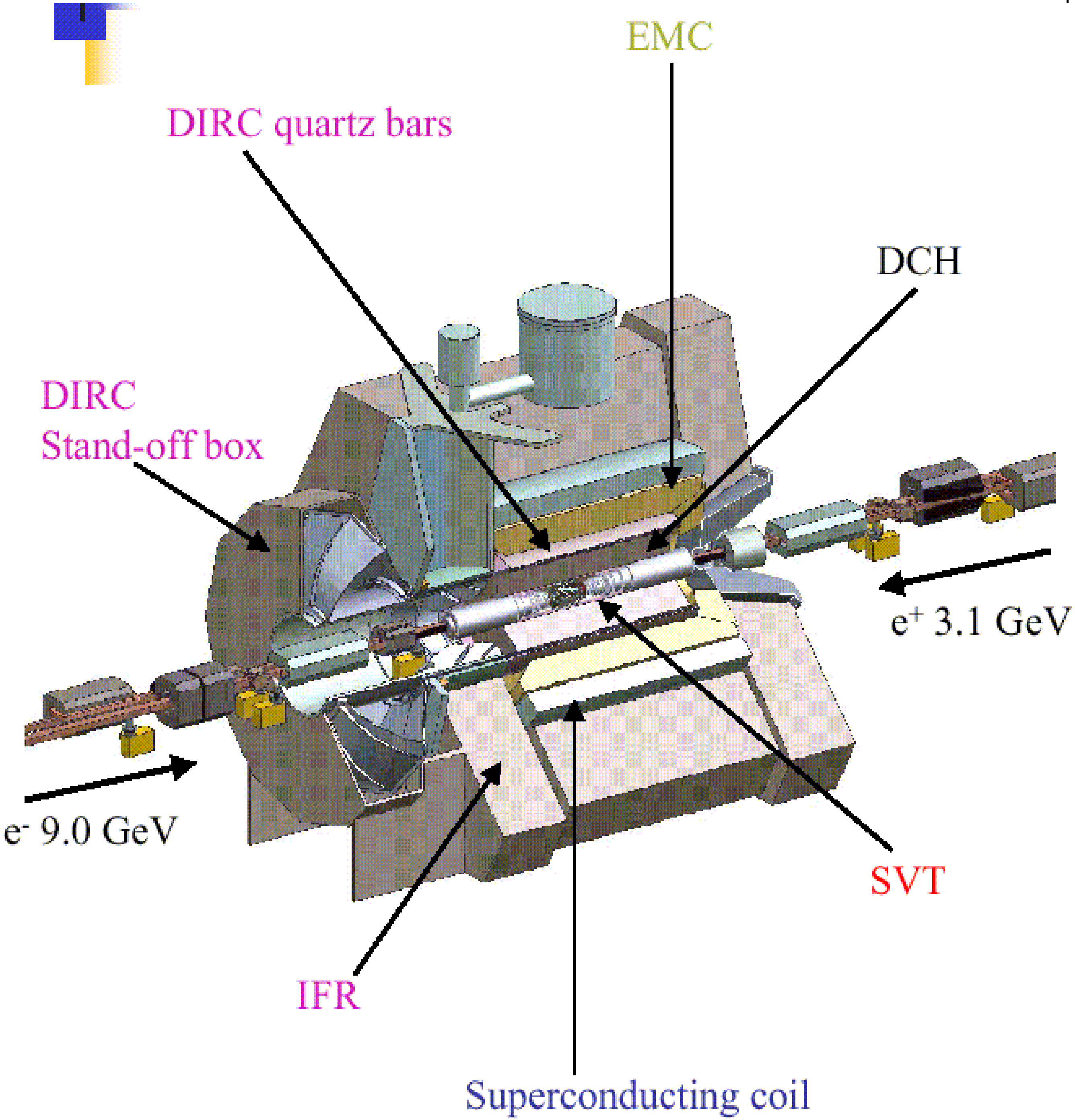
where $\pi = \pi^\pm, \pi^0$.

$$e^+e^- \to D_S^* \to \; X$$
$$\to D_S\gamma$$

• Example: mass distribution and p^* momentum spectrum of $D_S^+ \to \phi\pi^+$ from BaBar.

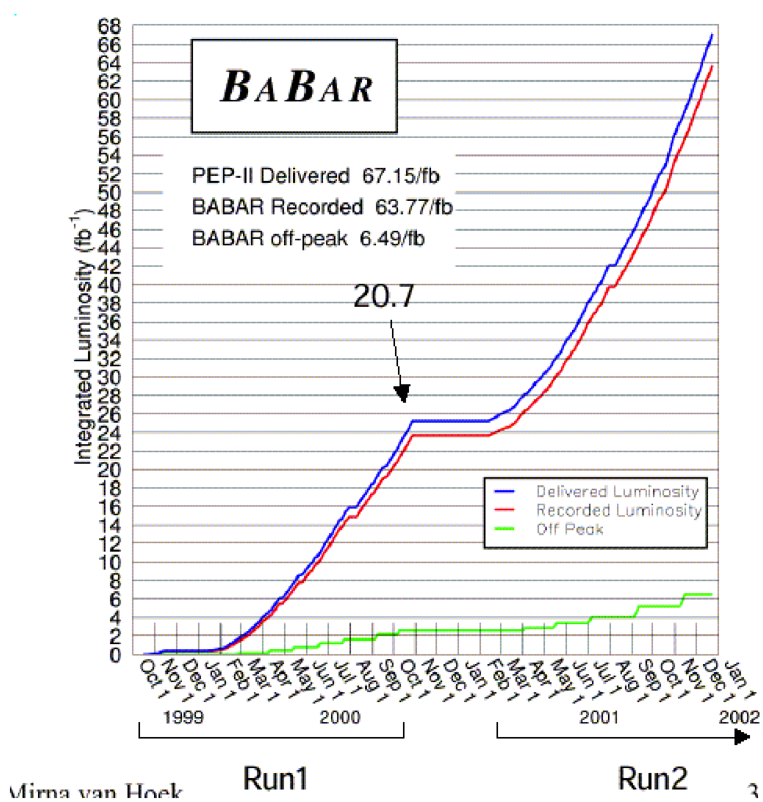


The BaBar Detector



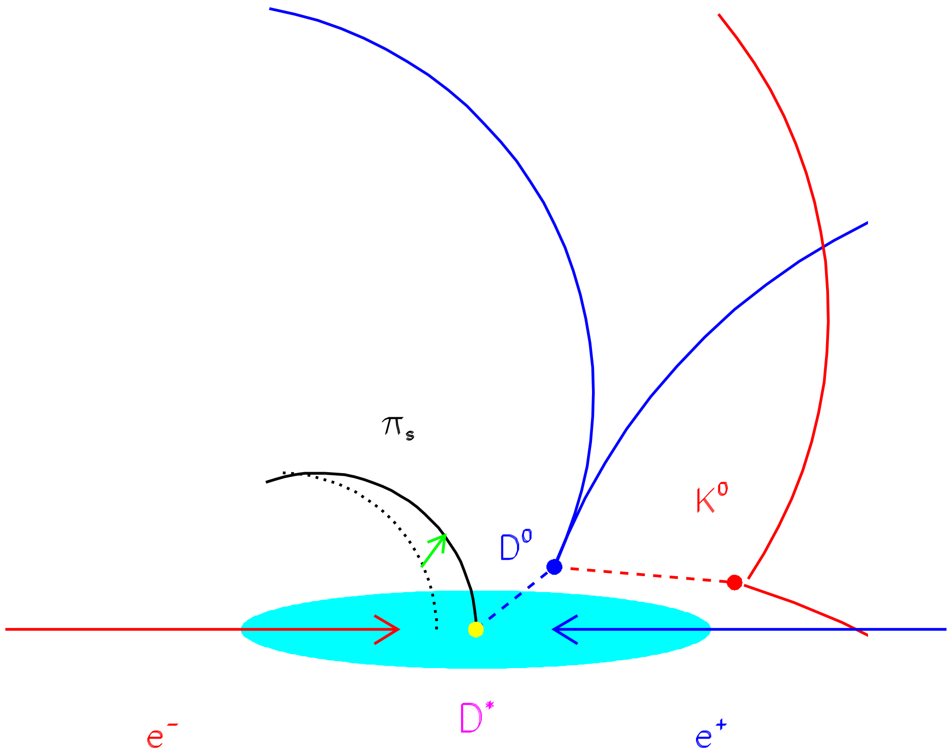
Data Sample

- The power of BaBar for Charm Physics is based on:
  - Relatively small combinatorial in e^+e^- interactions.
  - Good vertexing.
  - Good Particle Identification.
  - Detection of all possible final states, with charged tracks and γ's.
  - Very high statistics.
- Accumulated luminosity from BaBar.



Selection of $D^0 \to K_S^0 h^+ h^-$

- Sketch of one event (not in scale):



- Beam spot size:

$$\sigma_x = 0.15mm, \sigma_y = 0.05mm, \sigma_z = 8mm$$

- Reconstruction of K_S^0 and D^0 vertexes.

- Slow π refitted using the beam spot constraint to improve the resolution.

- Center of mass momentum of the D^0 (p^*) required to be:

$$p^* \geq 2.2 \quad GeV/c$$

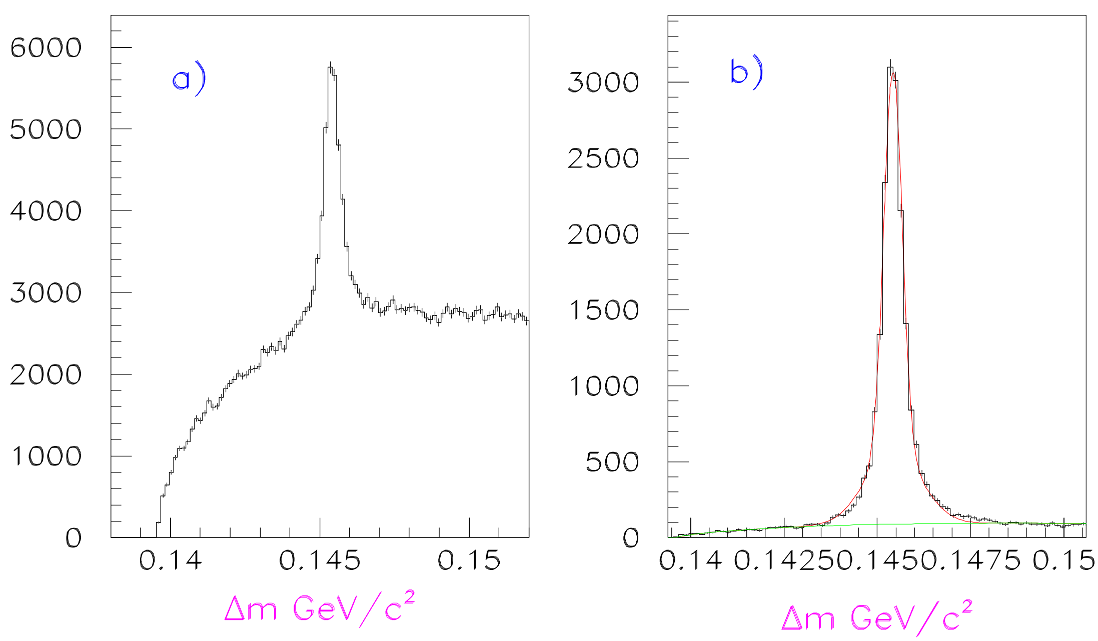
Mass difference

- Definition of the mass difference:

$$\Delta m = m(K^0\pi^+\pi^-\pi_s) - m(K^0\pi^+\pi^-)$$

where the slow pion π_s has a momentum below 0.6 GeV/c.

- Plot of Δm: a) before and b) after having required a 2.5 σ cut around the D^0 signal.

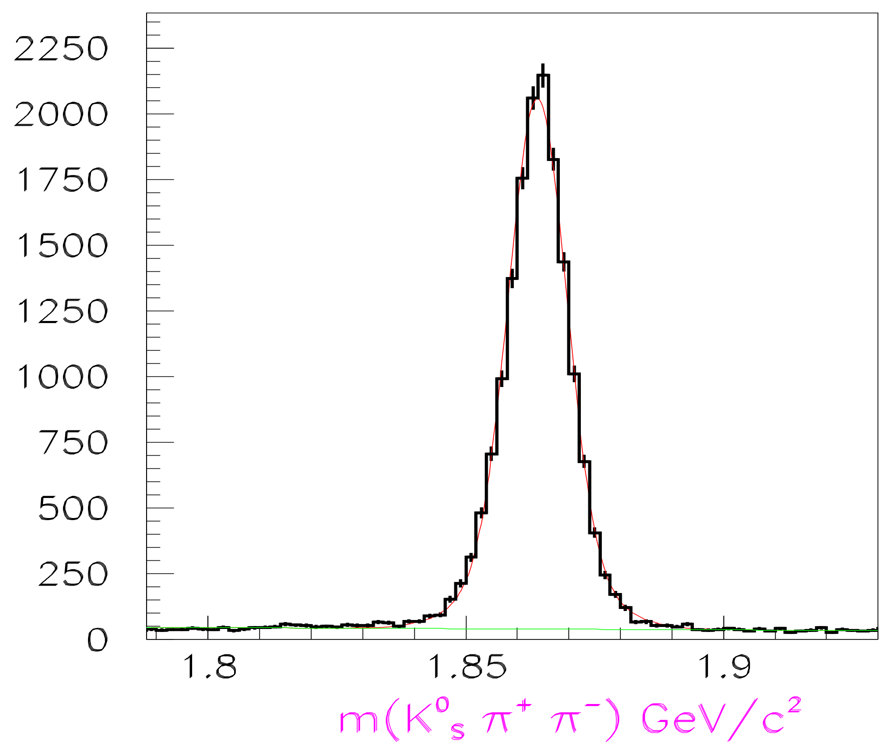


- Δm width using a sigle Gaussian:

$$\sigma = 326 \pm 10 \quad KeV/c^2$$

The $D^0 \to K_S^0 \pi^+ \pi^-$ signal

- $m(K_s^0 \pi^+ \pi^-)$ performing a 2.0 σ cut on Δm.

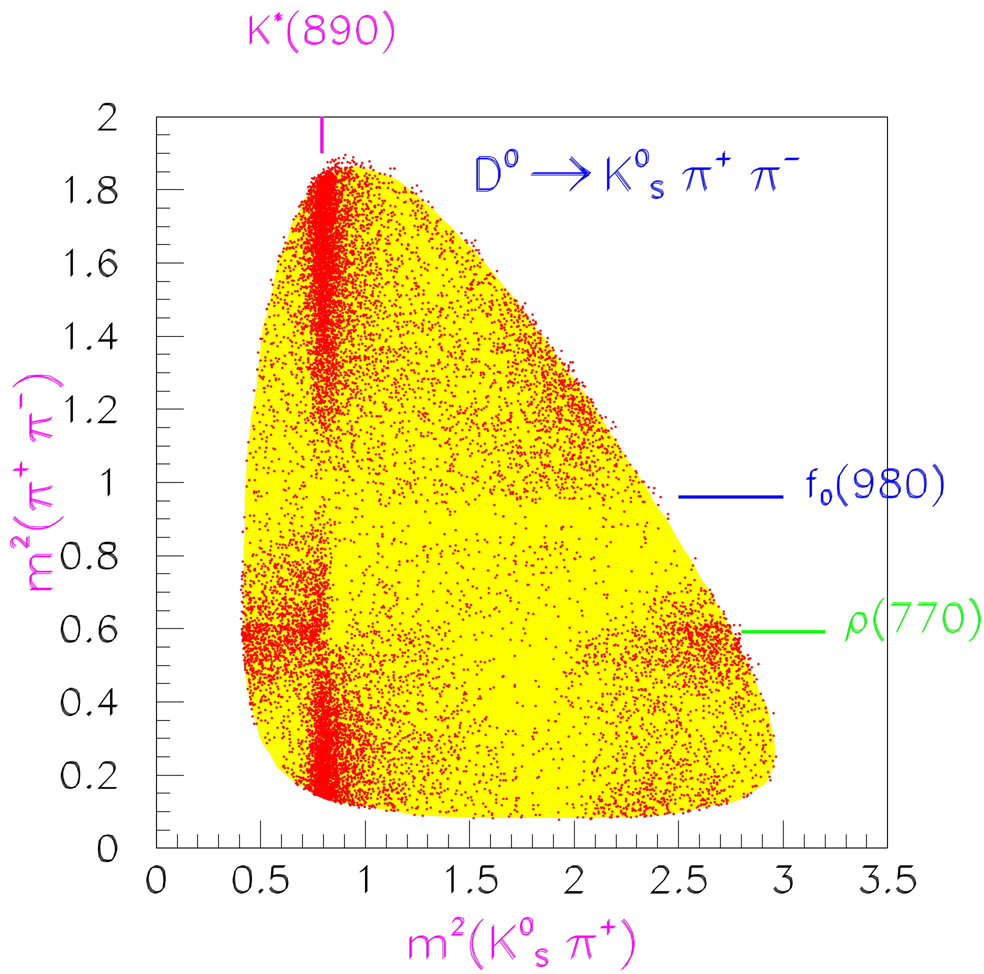


D^0 width with one Gaussian:

$$\sigma = 6.3 \pm 0.1 \quad MeV/c^2$$

Dalitz plot of $D^0 \to K^0_S \pi^+ \pi^-$

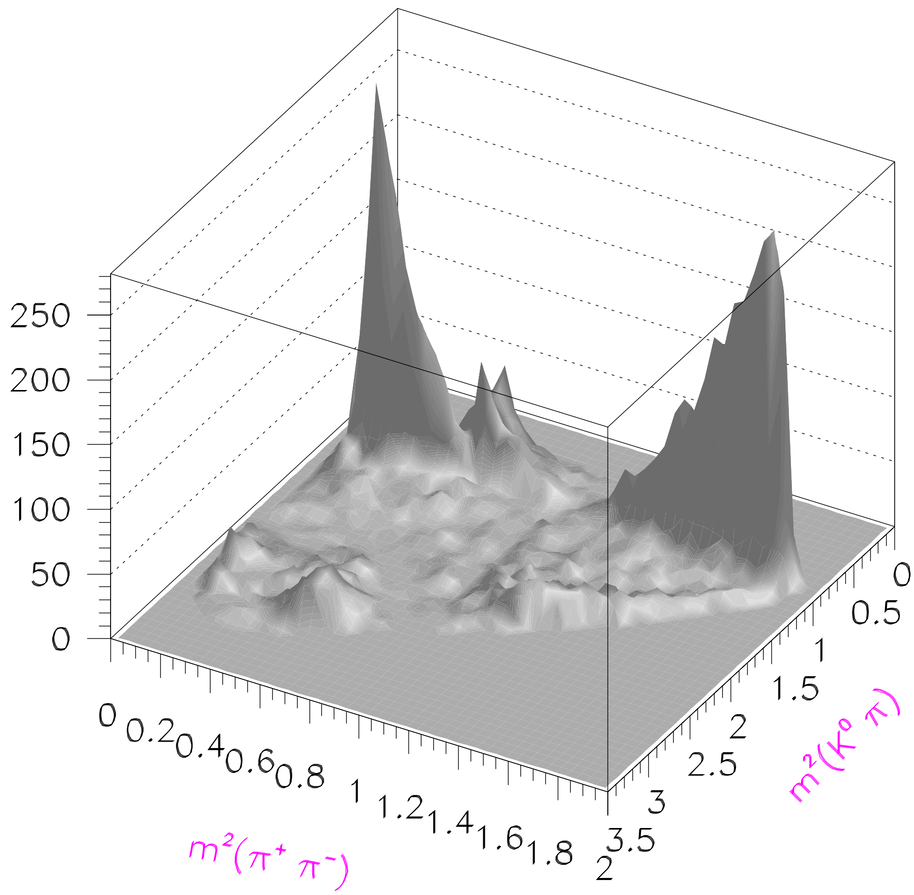
- Selecting events within 2.5 σ of the D^0 mass (15753 events):



- Background fraction: 4.1 % (not subtracted).

Dalitz plot of $D^0 \to K_S^0 \pi^+ \pi^-$

- The same in 3D view:



Dalitz plot of $D^0 \to K_S^0 \pi^+ \pi^-$

- Complex structure. Presence of several intermediate states.

$$D^0 \to \bar{K}^{*+} \pi^-$$

$$D^0 \to \bar{K}_0^{*+}(1430) \pi^-$$

$$D^0 \to \bar{K}^0 \rho^0$$

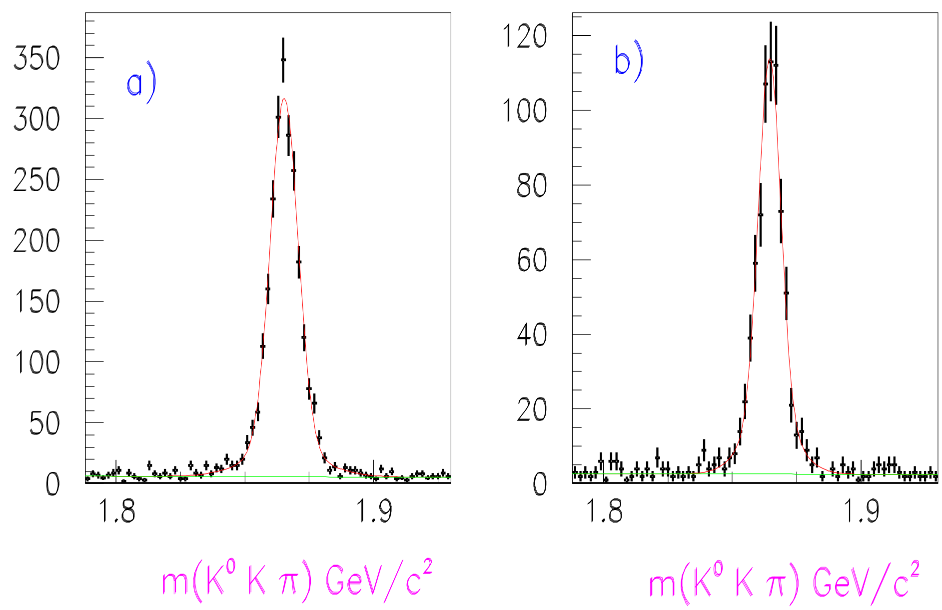
$$D^0 \to \bar{K}^0 f_0(980)$$

$$D^0 \to \bar{K}^0 f_0(1400)$$

- Partial Wave Analysis in progress: possibility of extracting amplitudes and phases.

$D^0 \to K^0_S K^+ \pi^-$

- One of the two charged tracks identified as a kaon.
- $K^0_S K \pi$ mass distributions for the two decay modes.



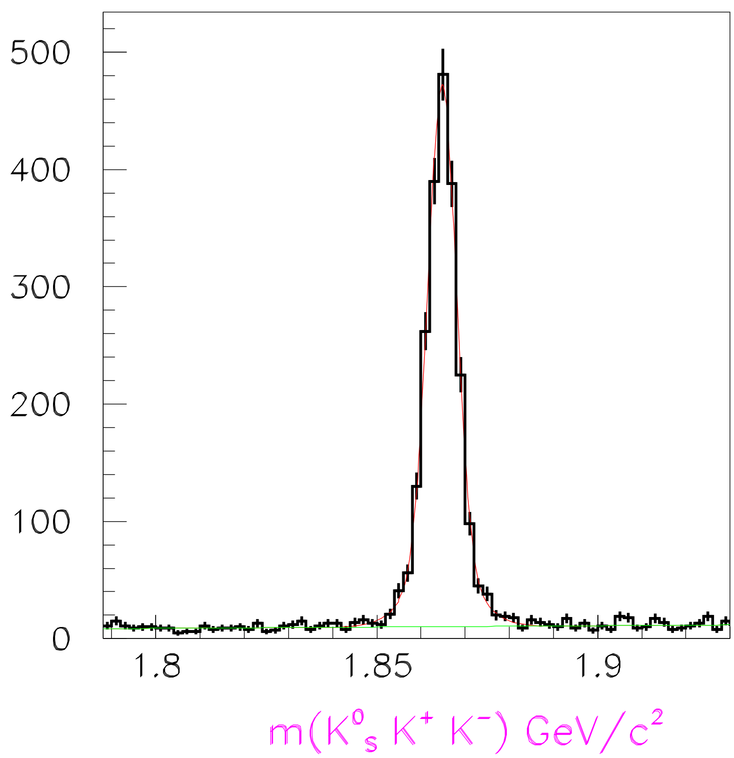
- Yields:

$$D^0 \to K^0 K^- \pi^+ \quad (a): \quad 2335 \quad events$$

$$D^0 \to \bar{K}^0 K^+ \pi^- \quad (b): \quad 731 \quad events$$

Selection of $D^0 \to K^0_S K^+ K^-$

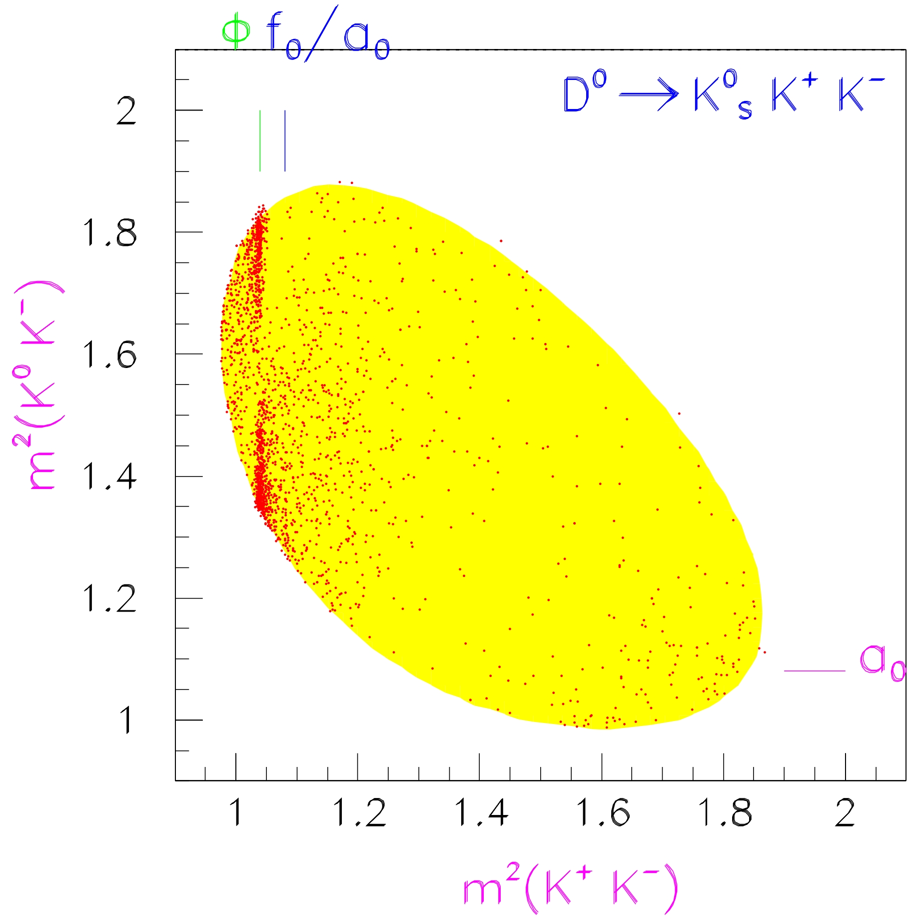
- Similar Δm cut. One of the two charged tracks identified as a kaon.
- Mass spectrum:



$$D^0 \to \bar{K}^0 K^+ K^- : \quad 2089 \quad events$$

Dalitz plot of $D^0 \to K^0_S K^+ K^-$

- Background fraction: 3 %



- Presence of intermediate states:

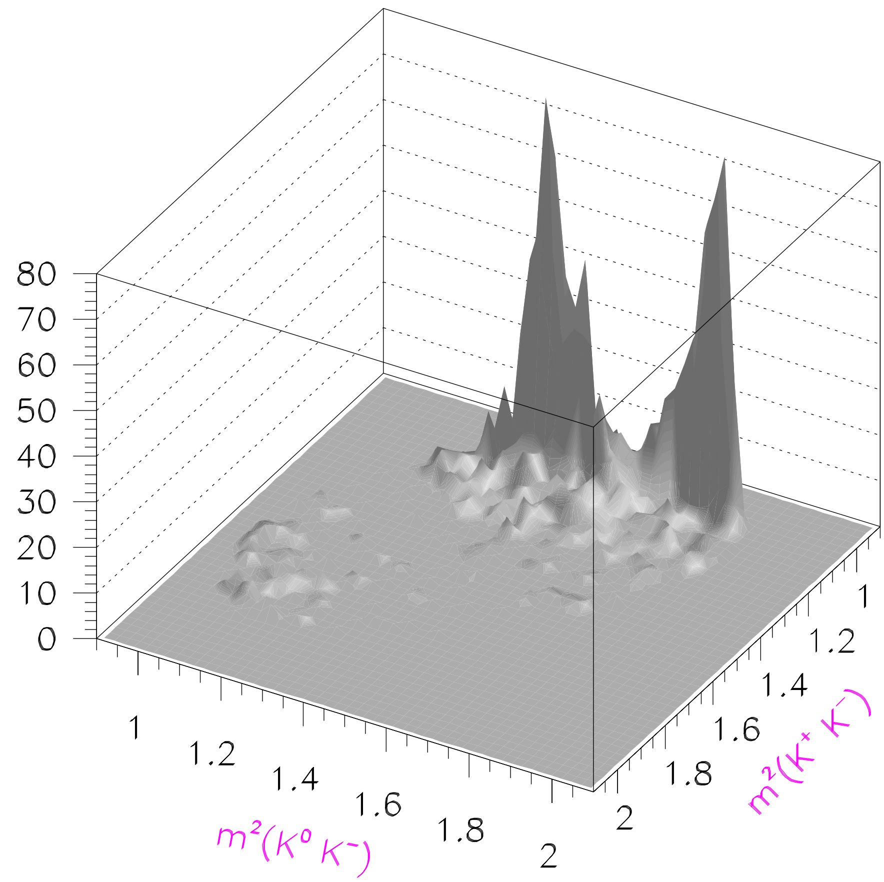
$$\bar{K}^0 \phi$$

$$\bar{K}^0 f_0(980)/a_0(980)$$

$$a_0^{\pm} K^{\mp}$$

Dalitz plot of $D^0 \to K_S^0 K^+ K^-$

- The same in 3D view:



Dalitz Plot Analysis

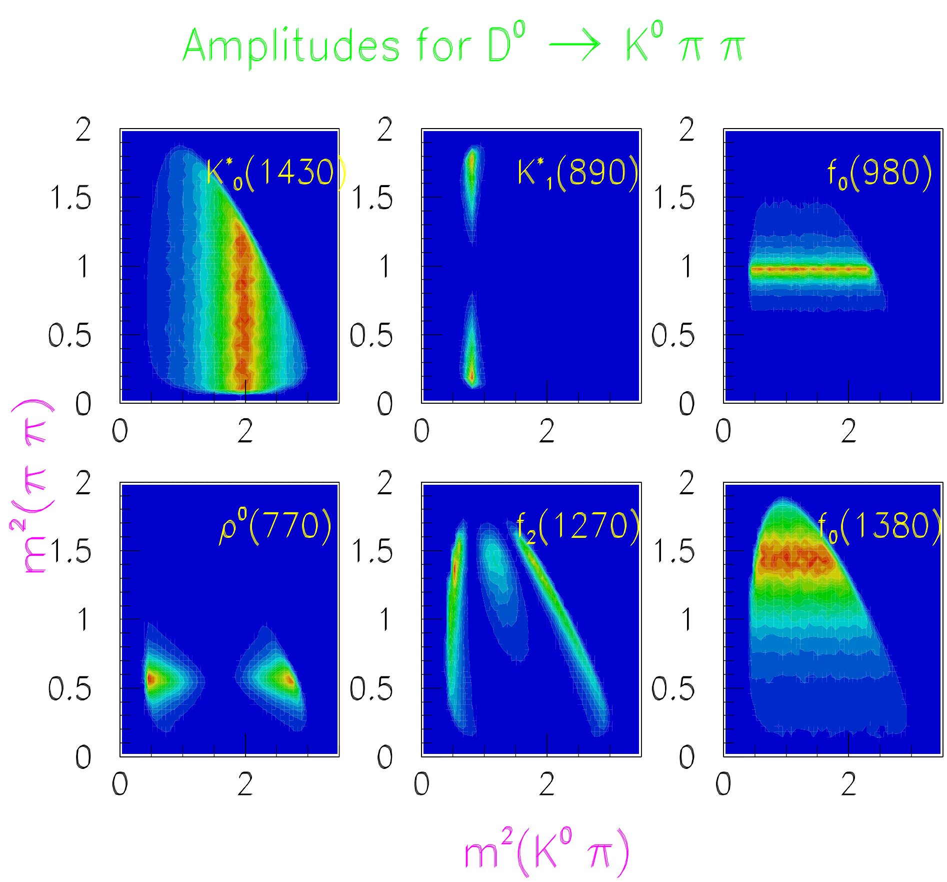
• Dalitz plots fitted using the sum of interfering amplitudes:

$$|\sum c_i A_i e^{i\phi_i}|^2$$

• Each amplitude is described by the product of a Breit-Wigner and a term describing the angular distributions (for example Zemach Tensors):

$$A_i = BW(m)Z(\Omega)$$

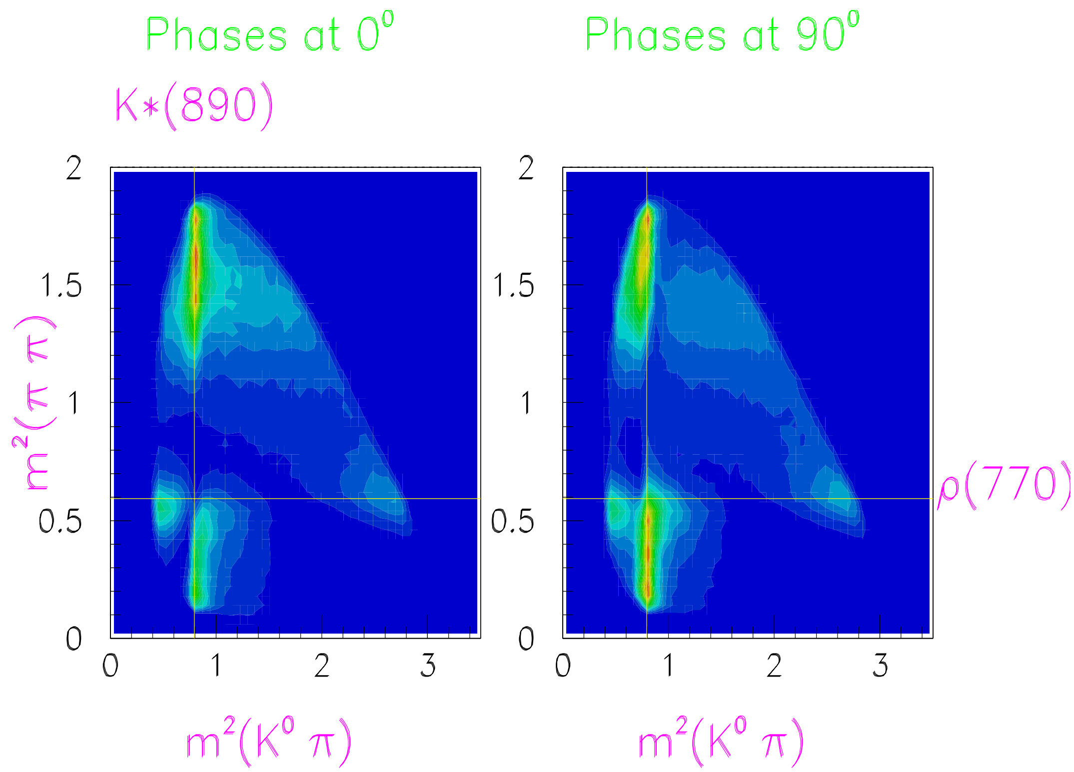
• Example: Some amplitudes for $D^0 \to \bar{K}^0\pi^+\pi^-$.



Dalitz Plot Analysis

- The Dalitz plot distributions are strongly modified by interferences.

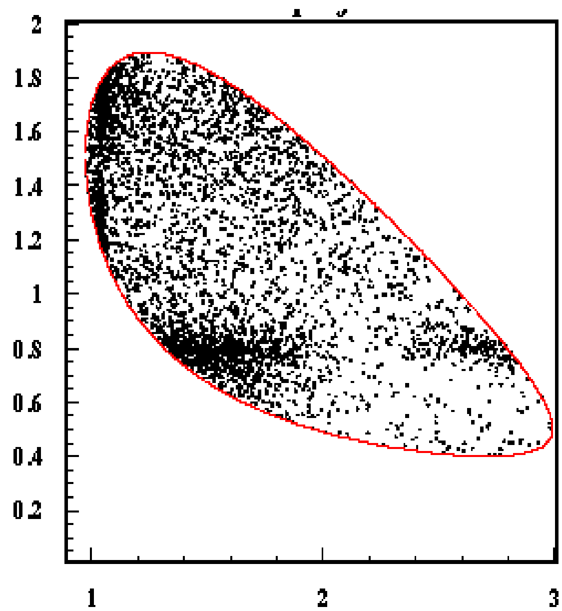
- Example of a Monte-Carlo simulation for $D^0 \to \bar{K}^0 \pi^+ \pi^-$ with $\rho^0(770)$, $K^*(890)$ and $f_0(1370)$.



Dalitz analysis.

• Bare amplitudes are real ($\phi = 0$ or 180^0).
Asymmetry can only be generated by FSI.

• Example from $D^+ \to K^+K^-\pi^+$ from FOCUS:
strong asymmetry between the two K^* lobes.



The puzzle of the scalar mesons.

- The scalar mesons are still a puzzle in Light Meson Spectroscopy.
- We expect 9 states, in PDG we find 15 candidates:

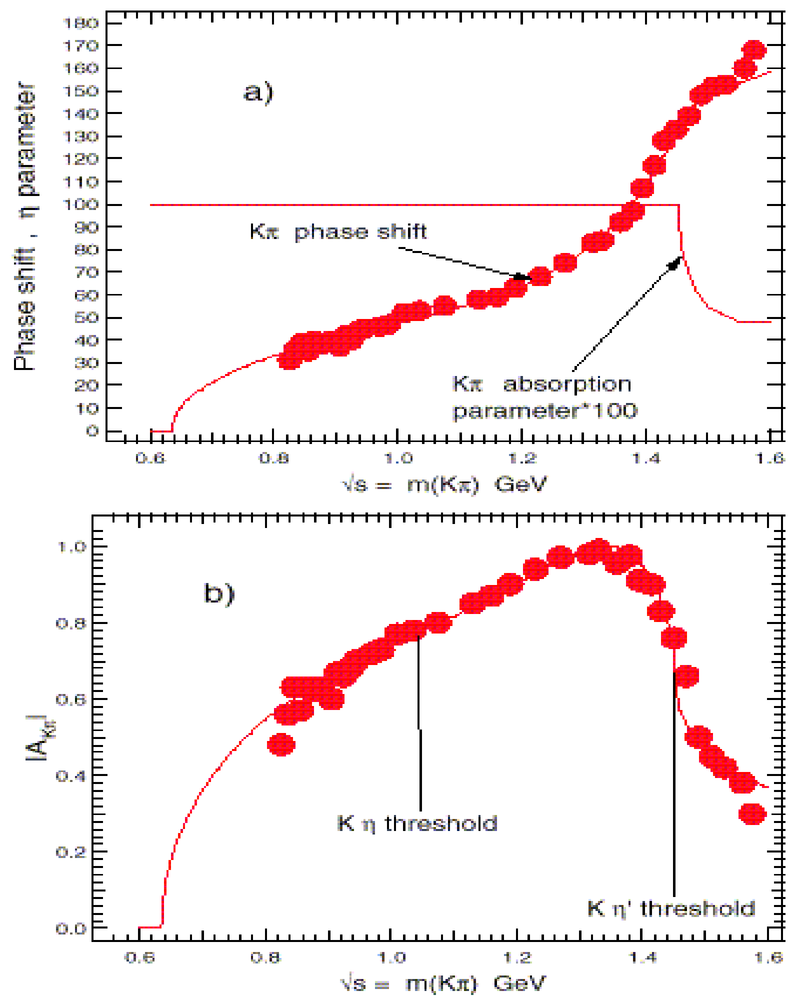
I = 1/2	I = 1	I = 0
		$f_0(400-1200)$
	$a_0(980)$	$f_0(980)$
$K_0^*(1430)$	$a_0(1490)$	$f_0(1370)$ $f_0(1500)$ $f_0(1710)$

- Among these, $f_0(1710)/f_2(1710)$ appears with different spins in different experiments.
- What new information is coming from the analysis of charm decays?

The resonance $K_0^*(1430)$

• The actual parameters in PDG are from LASS experiment at SLAC using 11 GeV/c incident K.

$$K^- p \to K^- \pi^+ n$$

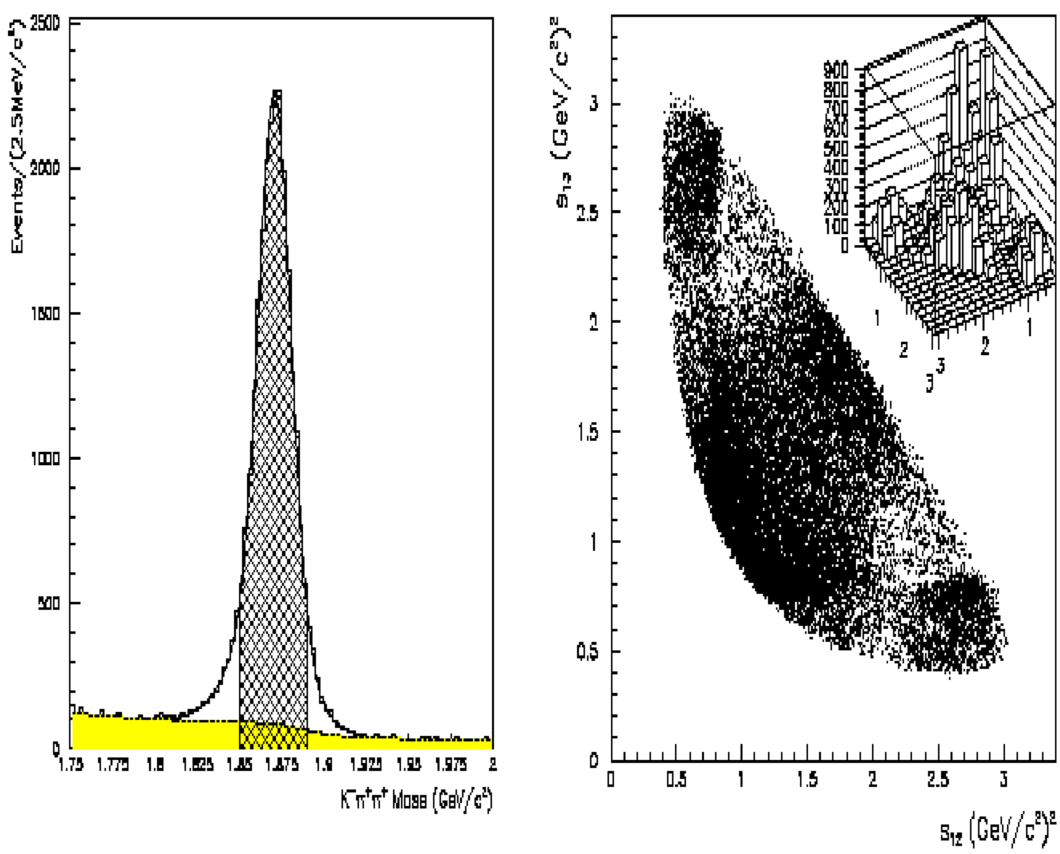


• Wide resonance, therefore parameters difficult to extract. Presence of an S-wave elastic background.

$$m = 1.412 GeV \qquad \Gamma = 294 MeV$$

Study of $D^+ \to K^-\pi^+\pi^+$ (E791)

- This Dalitz plot analyzed by several other experiments (E691, E687).
- In contrast to all other charmed mesons decays, a large Non Resonant contribution.
- Data from E791, $\approx$ 23 000 events



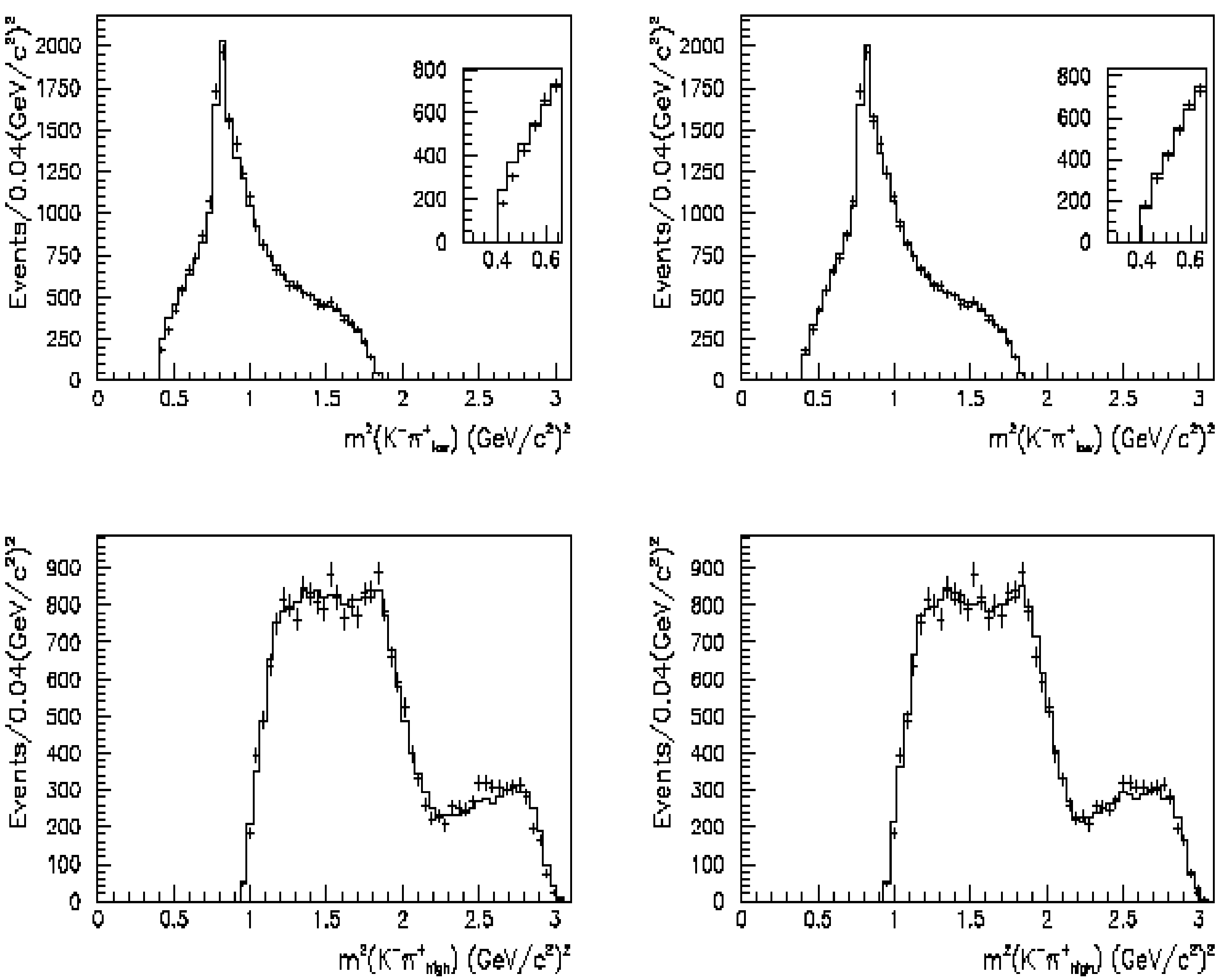
- Strong interferences. Channel dominated by $K^*(890)$ (13 %) and $K_0^*(1430)$ (34 %).
- Need a large Non Resonant contribution (104 %).

Study of $D^+ \to K^-\pi^+\pi^+$ (E791)

• Data not fitted well. Need to include a new scalar $\kappa(800)$:

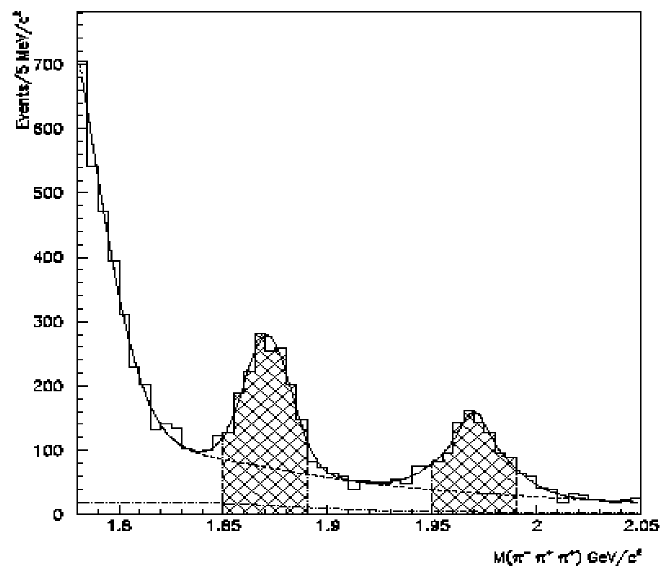
$$m = 815 \pm 30 MeV, \qquad \Gamma = 560 \pm 116 MeV$$

• In this scenario the Non Resonant contribution goes to (52 %) and that of κ to 21 % with 180^0 relative phase.

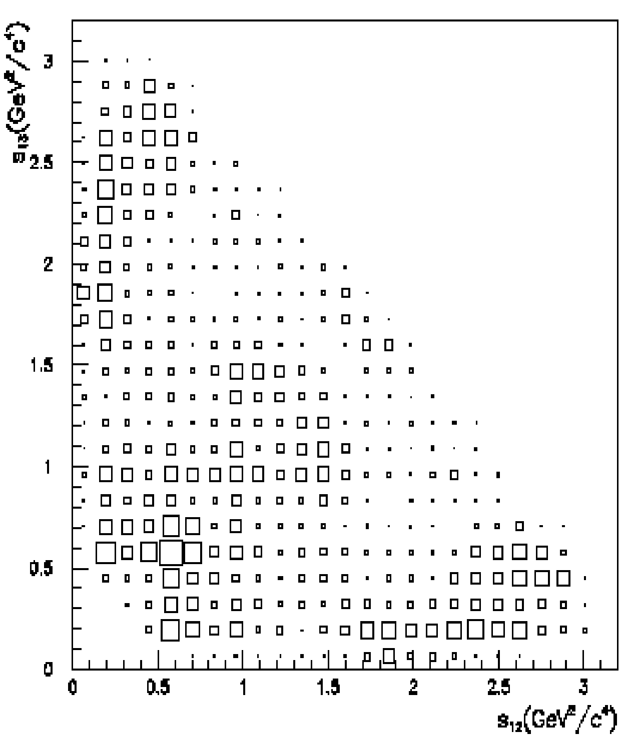


Study of $D^+ \to \pi^-\pi^+\pi^+$ (E791)

- $\pi^+\pi^+\pi^-$ mass spectrum from E791. (1686 events in D^+ and 937 in D_S^+.) Signal/Background 2/1.

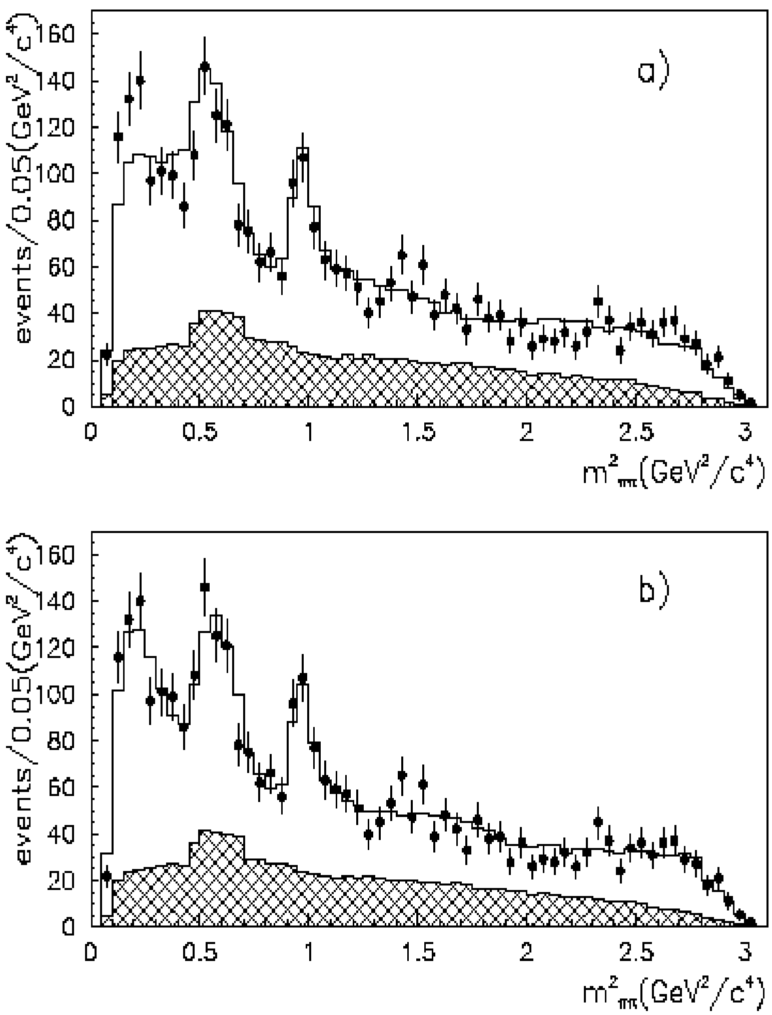


- D^+ Dalitz plot (symmetrized).



Study of $D^+ \to \pi^-\pi^+\pi^+$ (E791)

- $\pi^+\pi^-$ projection. Evidence for $\rho(770)$ and $f_0(980)$.



- Need of an extra scalar resonance $\sigma(500)$ to fit the data.

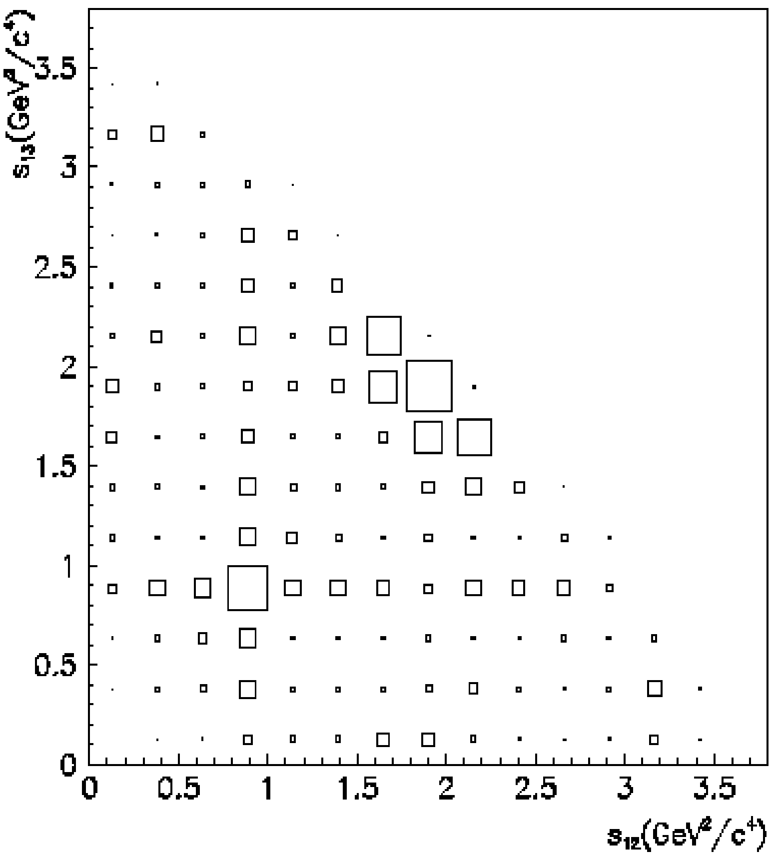
$$m = 478 \pm 24, \qquad \Gamma = 324 \pm 41 \qquad MeV$$

- In this hypothesis the dacay $\sigma\pi$ accounts for nearly half (46 %) of D^+ decay.

- In this scenario the $f_0(1370)$ contribution vanishes.

Study of $D_S^+ \to \pi^-\pi^+\pi^+$ (E791)

- 850 events



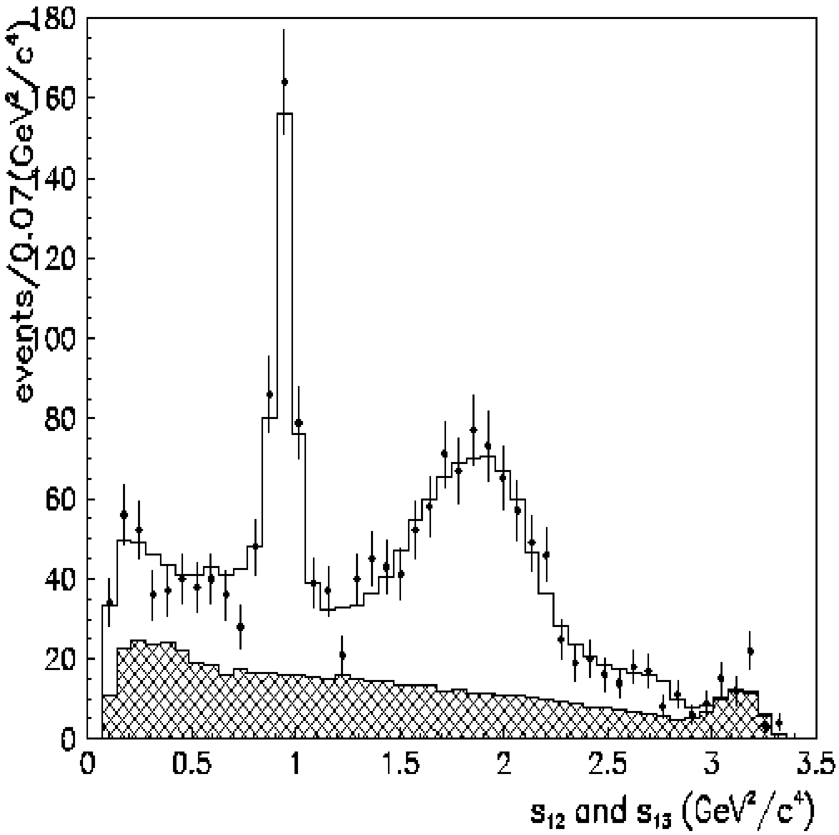
- $f_0(980)$ parameters insensitive to the $\bar{K}K$ coupling.

Study of $D_S^+ \to \pi^-\pi^+\pi^+$ (E791)

- Strong $f_0(980)$ appearing as a narrow peak.
- Fitting with a standard BW, they obtain:

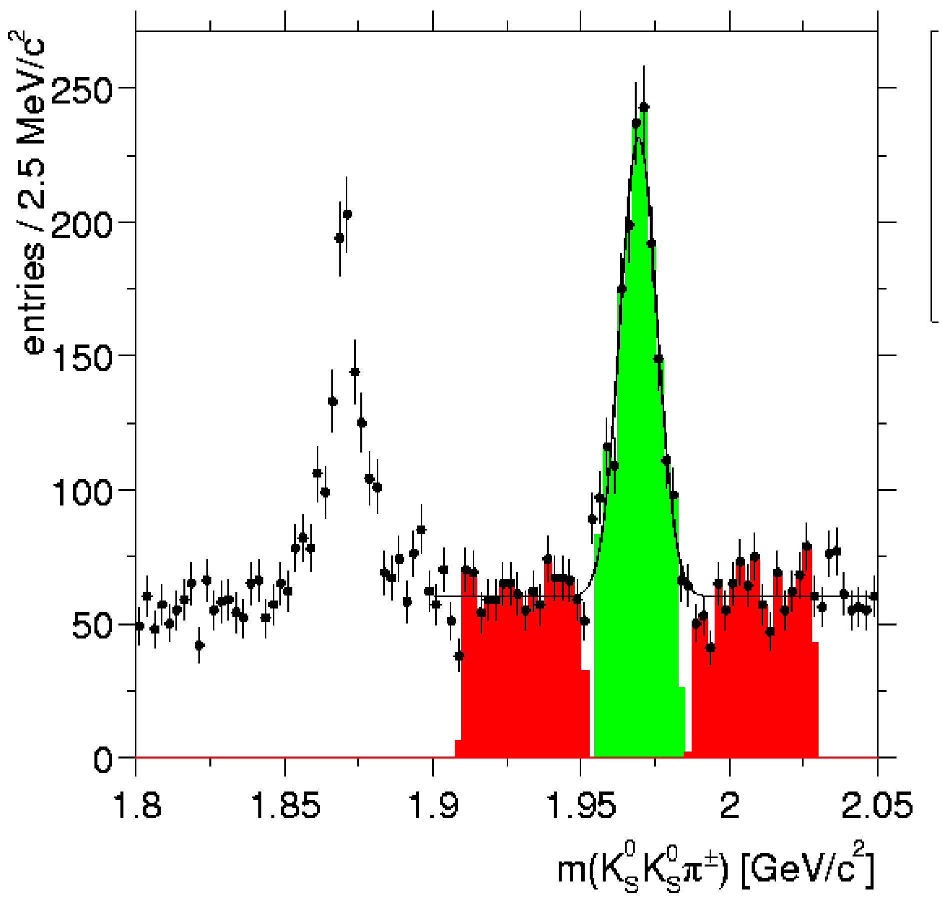
$$m = 975 \pm 3 \quad MeV \qquad \Gamma = 44 \pm 2 \quad MeV$$

- Large $f_0(980)$ contribution: 57 %. $\bar{s}s$ meson?.
- The fit requires the presence of an $f_0(1370)$ 32 %, a $\bar{u}u + \bar{d}d$ state. W-annihilation or rescattering?



Study of $D_S^+ \to K_S^0 K_S^0 \pi^+$ (BaBar)

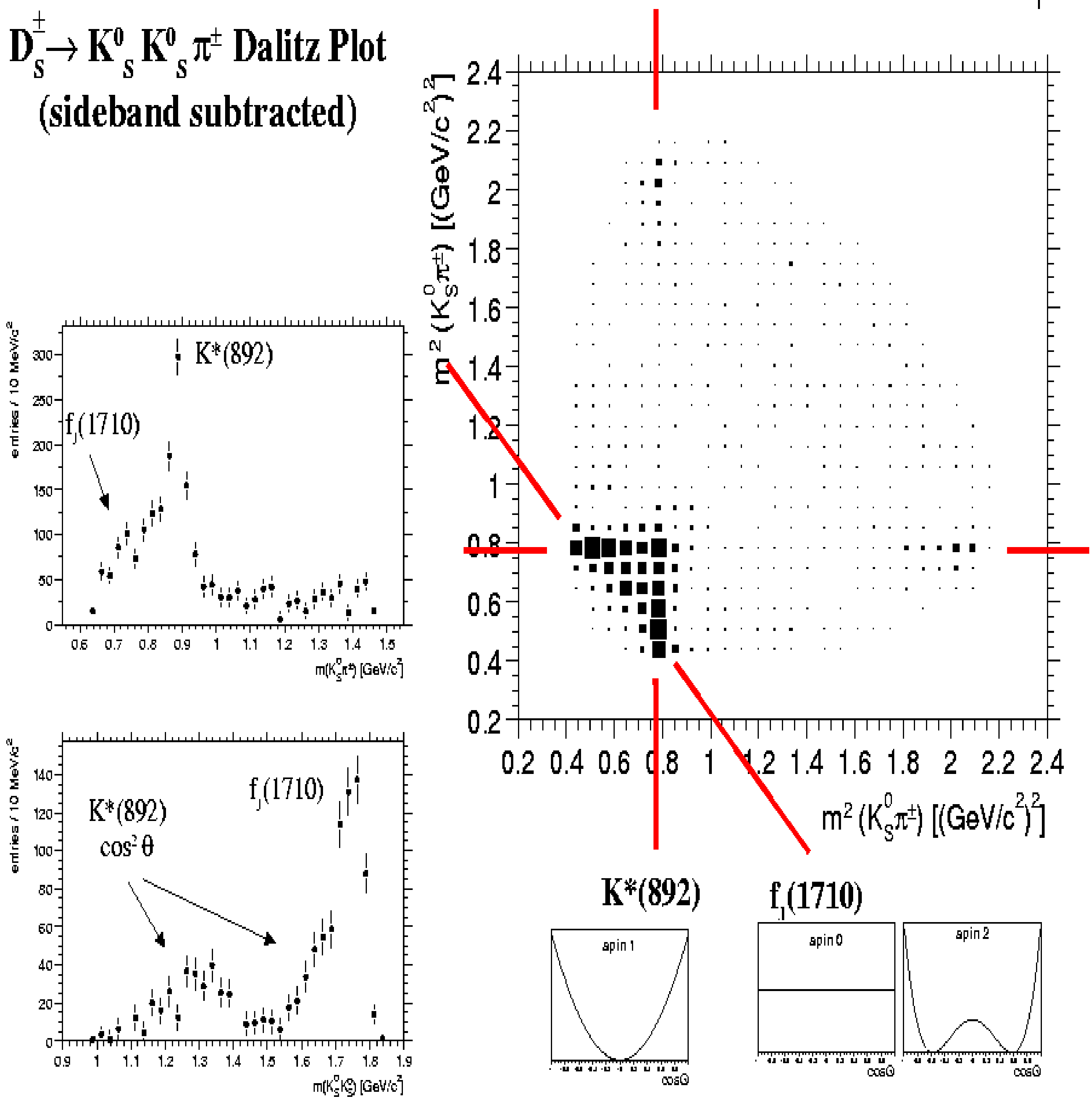
- The question of the spin of the $\theta/f_j(1710)$
- This state measured with spin 0 or 2 in different experiments.
- Candidate for being the tensor or scalar glueball.
- Channel isolated using $D_S^* \to D_S \gamma$ and p^* cuts.



- Evidence for the decay $D_S \to f_j(1700)\pi$

Study of $D_S^+ \to K_S^0 K_S^0 \pi^+$ (BaBar)

- Dalitz plot analysis in progress.



Charmless B decays.

• The evidence from CLEO for a large branching fraction for:

$$B \to \eta' X_S$$

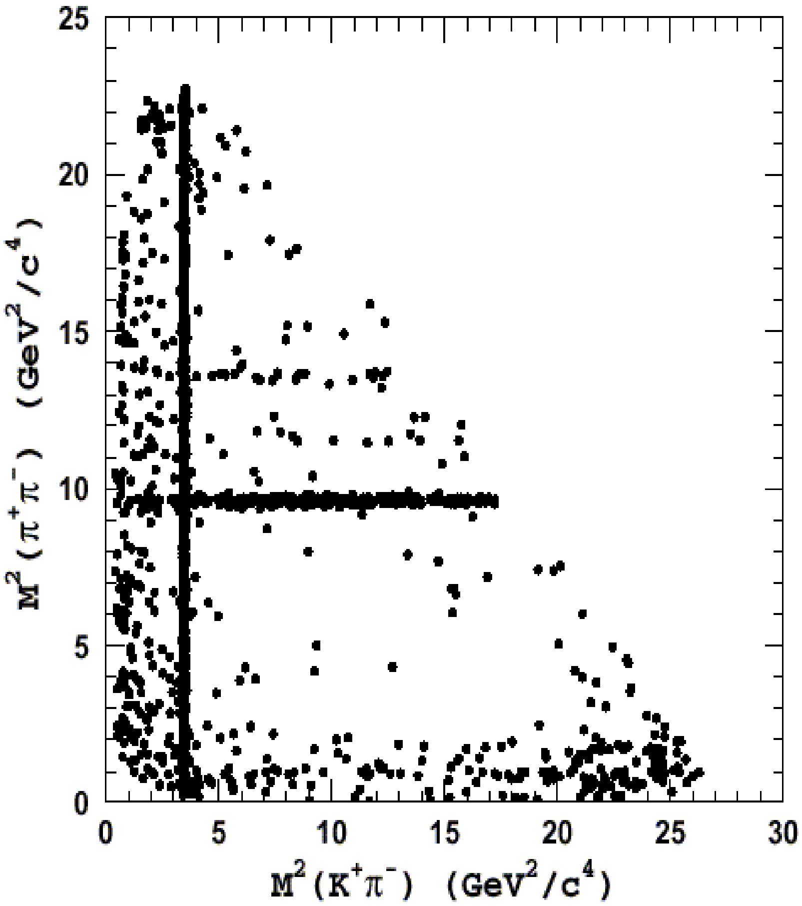
has been confirmed by Belle and BaBar.

$$B \to \eta' X_S = 6.8^{+0.7}_{-1.0} \times 10^{-4}$$

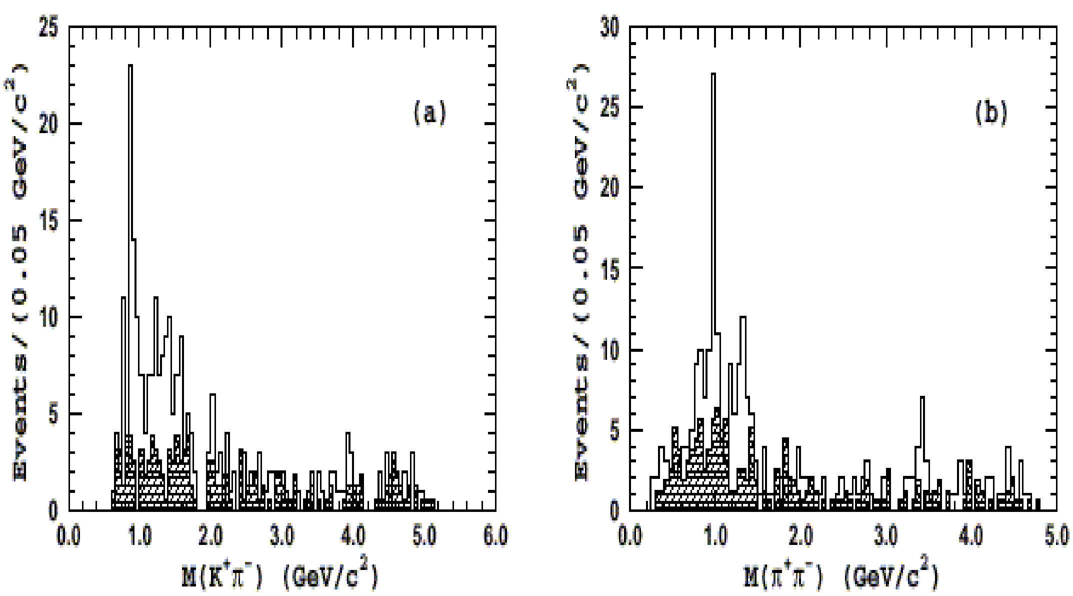
$$B^+ \to K^+ \eta' = 70 \pm 8 \pm 5 \times 10^{-6}$$

• Possible interpretations include a large gluon content in the η' and the evidence for $b \to s \quad gluon$

• Dalitz plot of $B^+ \to K^+\pi^+\pi^-$ (Belle):

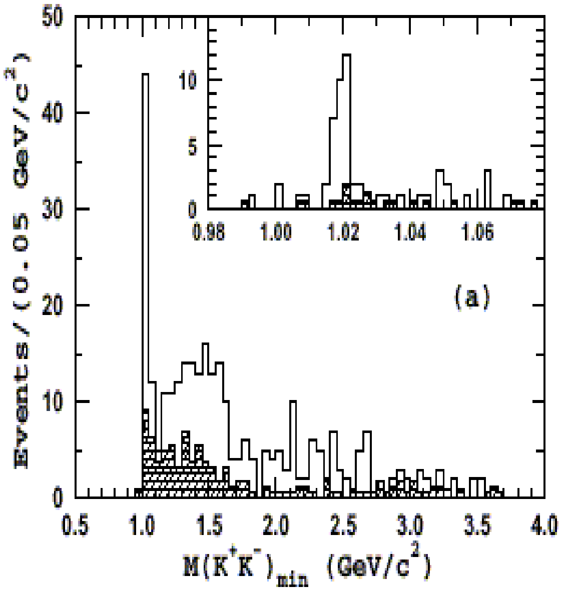


and projections:



• Presence of a strong $f_0(980)$.

- Dalitz plot projection of $B^+ \to K^+K^+K^-$ (Belle):



Conclusions.

• A new chapter in physics has been open: the hight statistics Dalitz analysis of charmed mesons decays.

These studies will give information on:

• The different diagrams which originate charm decays.

• Possible signs of CP violation in the charm sector.

• Possibly solve several questions left open in light meson spectroscopy.

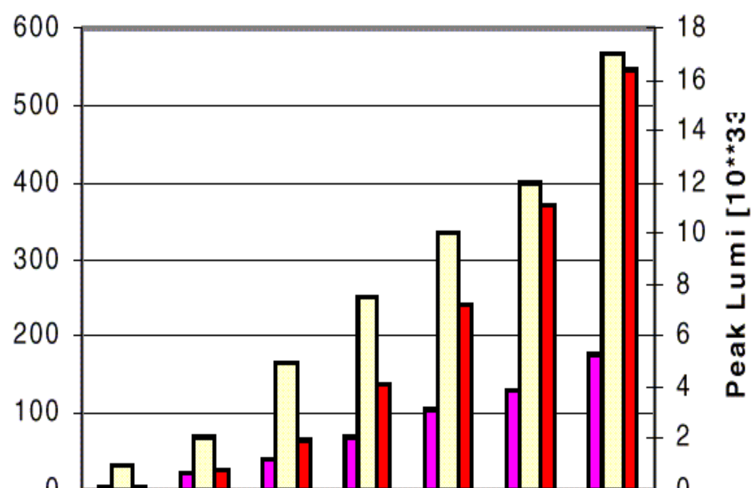
Conclusions.

Near Future will be dominated by B-factories and τ-charm factories.

Present available data on Dalitz decays from fixed target and B-factories:

- Cabibbo allowed 1-5 $\times 10^4$ events
- Cabibbo suppressed 1-10 $\times 10^3$ events.
- Doubly Cabibbo suppressed 50 - 300 events.

Expected integrated luminosity from BaBar.



	1999	2000	2001	2002	2003	2004	2005
Yearly Lumi	2	23	40	70	105	130	175
Cumulative Lumi	2	25	65	135	240	370	545
Peak Lumi	1	2	5	7.5	10	12	17

Year

- In the next few years we expect an increase of these yields by a factor 20.