Amplitude analysis of the $D^+ \to K^0_S \pi^+ \pi^0$ Dalitz plot

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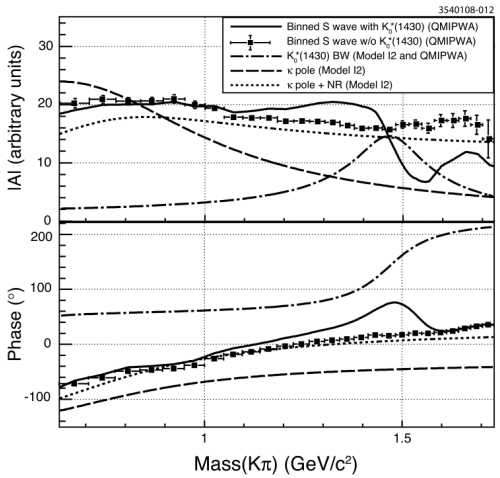
Motivation

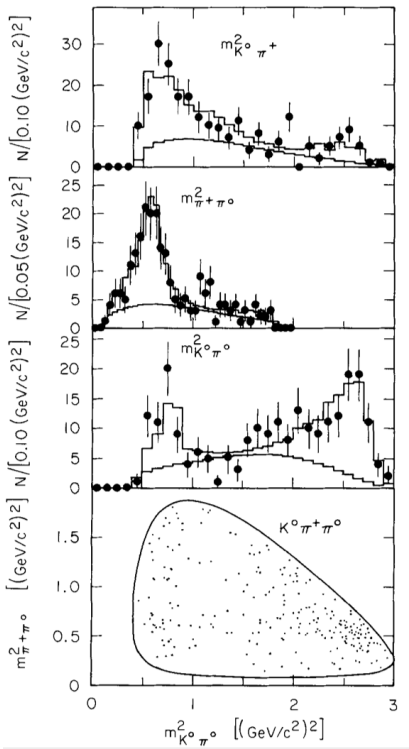
- Study final state interaction in 3-body decays
- Theory input for prediction of decay rates and phase shifts of decay amplitudes
- Refine partial branching-fraction
- Golden channel to study $K\pi$ S-wave
- Evidence for $\bar{\kappa}\pi$ contribution to S-wave from complementary channels (CLEO-c and E791 in $D^+ \to K^-\pi^+\pi^+$)



[Phys.Rev. D78 (2008)]

Previous measurement

- MARKIII analysis statistically limited

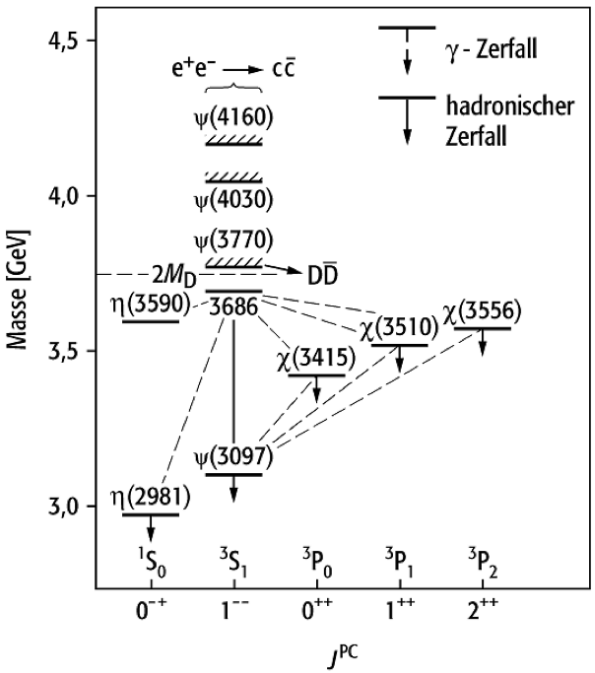


[Phys.Lett. B196 (1987)]

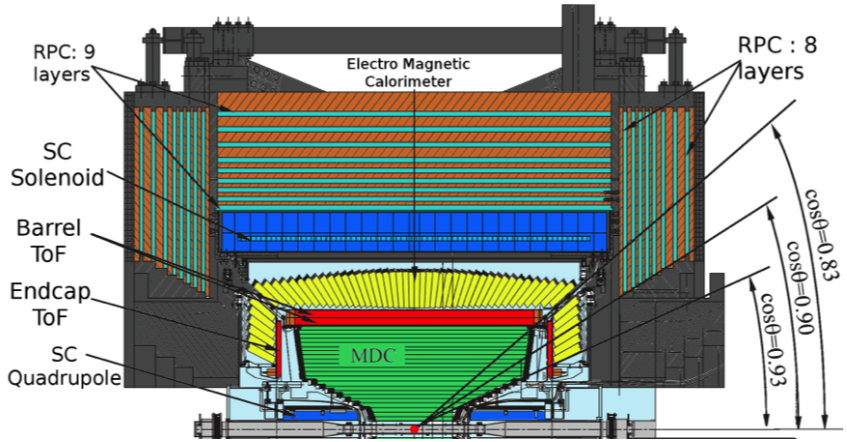
BEPCII and BESIII

Accelerator & Physics program

- Beijing Electron Positron Collider
- symmetric e^+e^- collisions
- Energy range 2.4-4.6 GeV
- max $\mathcal{L} = 0.6 \times 10^{33} cm^{-2} s^{-1}$

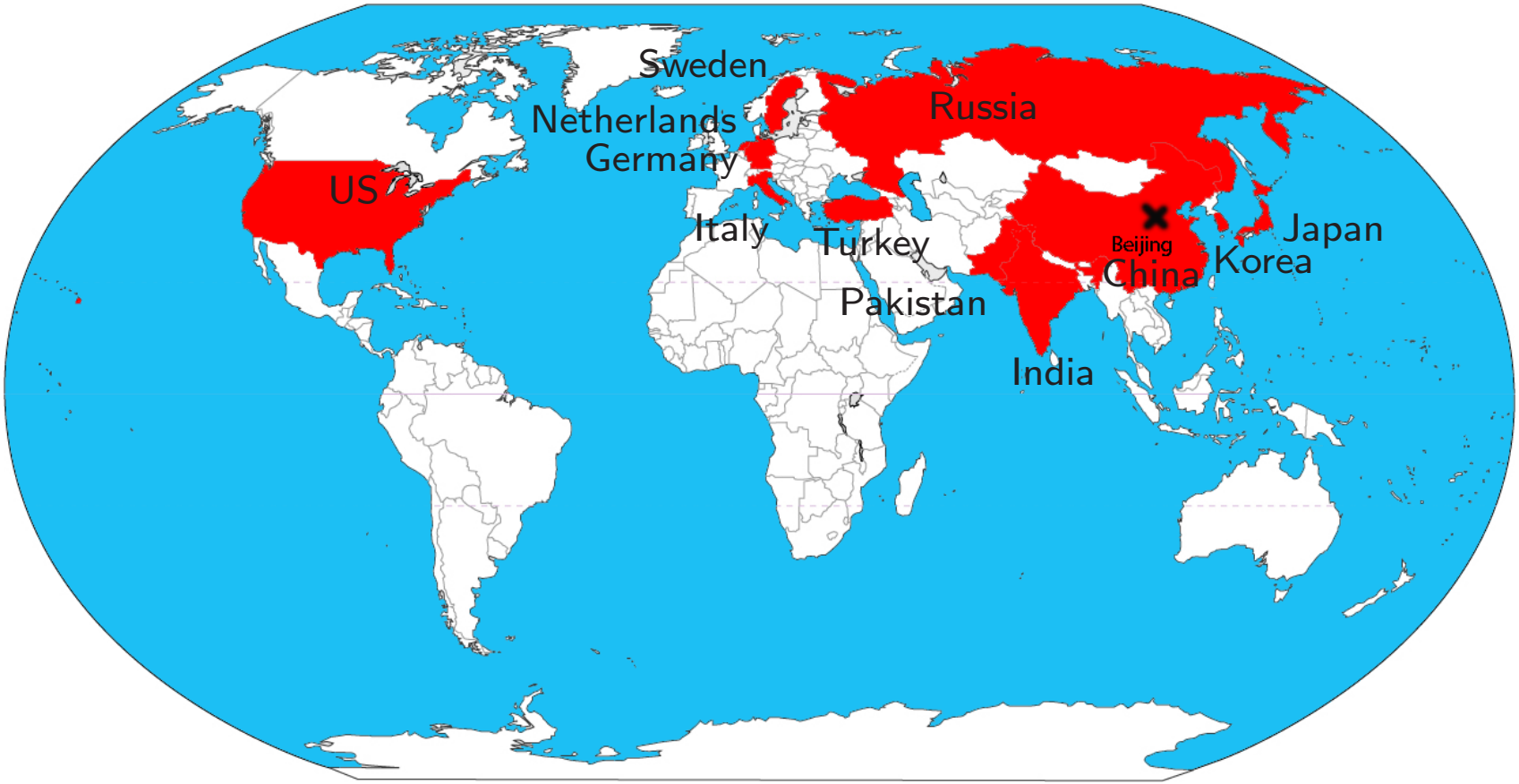


Experiment



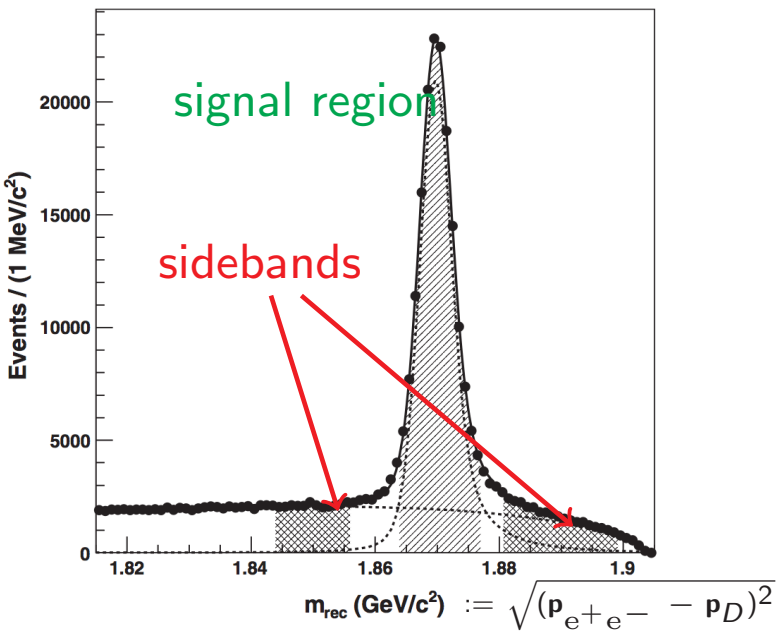
- 4π detector with 93% acceptance
- Multi-wire drift chamber
  σ_{pT} =0.5% @ 1 GeV/c, dE/dx
- plastic scintillator time-of-flight
  σ_t=80 ps$\rightarrow$ $2\sigma K/\pi$ sep @0.9 GeV/c
- CsI(Tl) crystal calorimeter
  $\sigma_E/E = 2.5\%\sqrt{E}$, $\sigma_x = 0.6\,\mathrm{cm}/\sqrt{\mathrm{E}}$
- RPC muon system

BESIII collaboration



- Currently 393 authors, 52 Institutions
- Growing foreign contribution
- Largest non-chinese group from Mainz

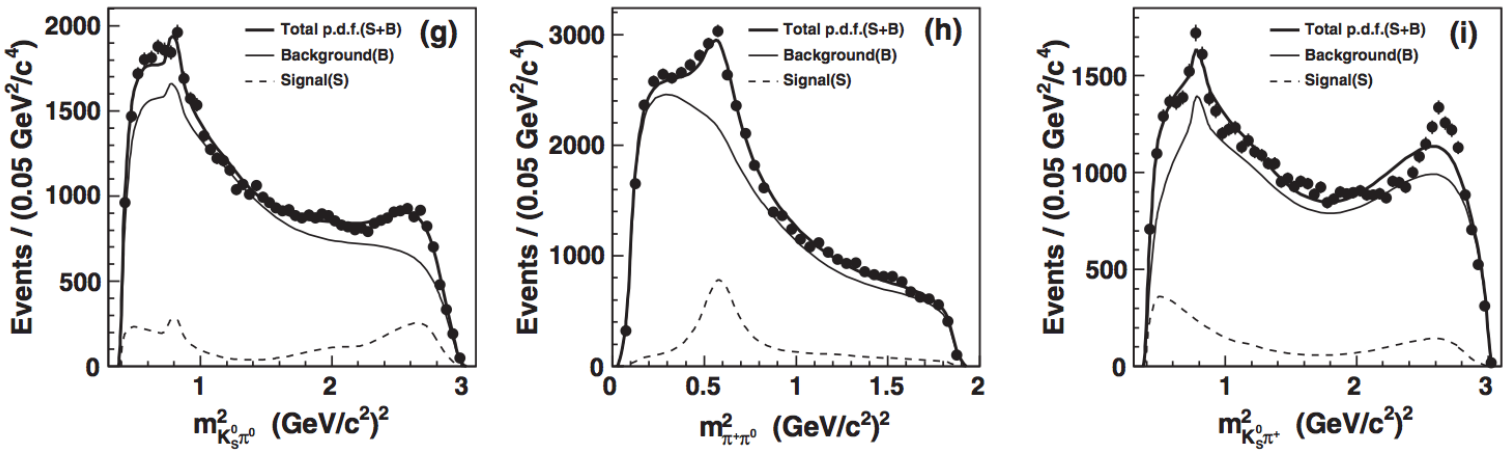
Signal selection



- $\mathbf{K^0_S \to \pi^+\pi^-}$ dE/dx, separated K^0_S vertex, $m_{K^0_S} \pm 20\,\mathrm{MeV}$
- $\boldsymbol{\pi^+}$ from PV, PID by TOF&dE/dx
- $\boldsymbol{\pi^0 \to \gamma\gamma}$ $E^{\gamma}_{min} = {}^{25\,\mathrm{MeV(barrel)}}_{50\,\mathrm{MeV(endcap)}}$, m_{π^0} ${}^{+15\,\mathrm{MeV}}_{-20\,\mathrm{MeV}}$
- $\mathbf{D^+}$ best cand $\Delta E = E_D - E_{e^+e^-}$, kinematic fit m_D

166694 signal events with 84.9% purity

Background



- Background determined on data sidebands
- Combinatorial $\to$ flat in PHSP
- Background sample is contaminated with signal events
- self-cross feed $\to$ non-PHSP shape

Amplitude description

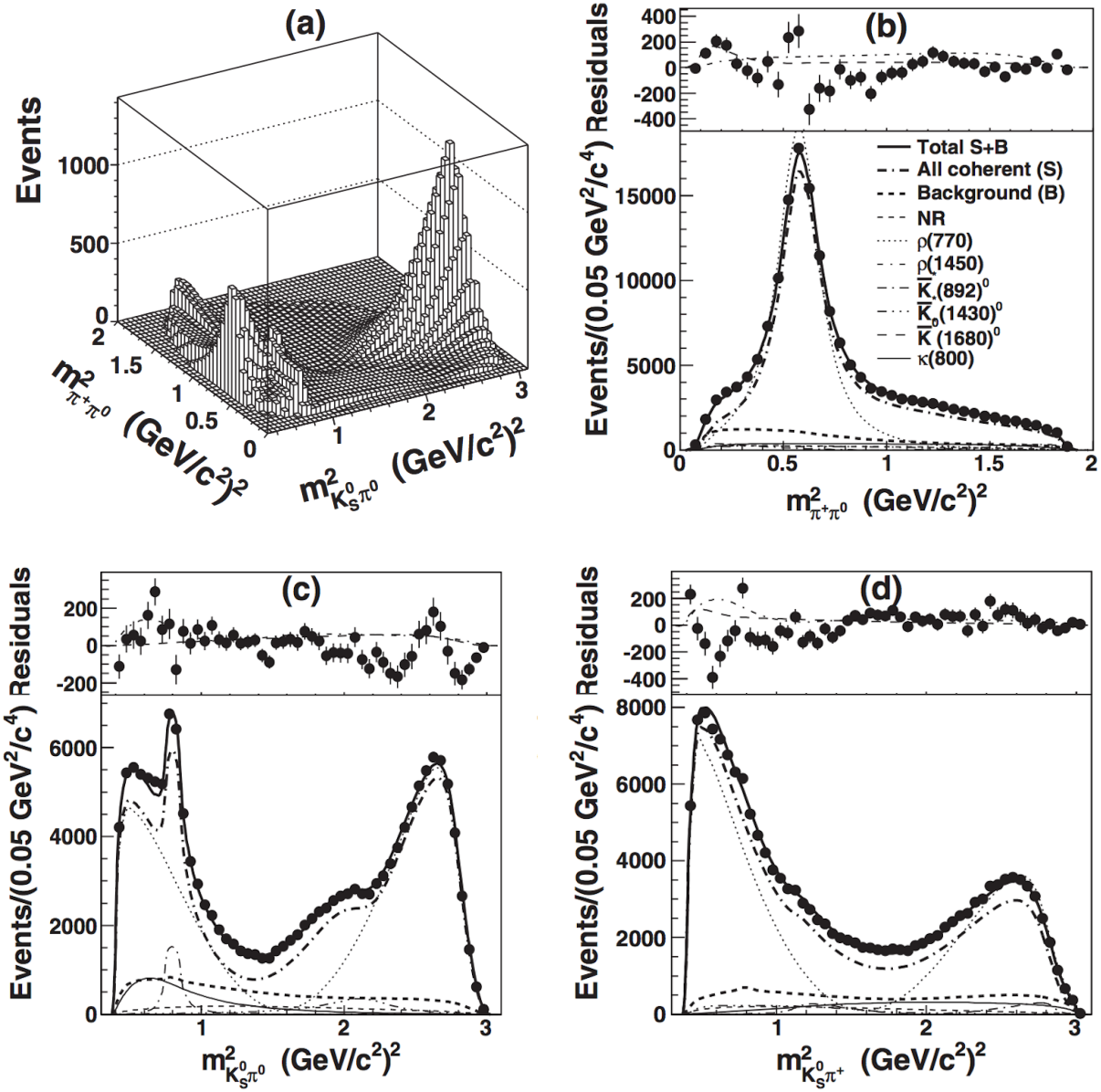
- Isobar model

$$\frac{d\sigma}{d\Omega} \sim |\mathcal{M}|^2 = \Big| \sum_L \underbrace{\mathcal{Z}_L}_{\text{angular term}} \; \underbrace{F_D^L}_{\text{barrier factors}} \Big\{ \sum_R c_R \; \underbrace{\mathcal{W}_R(m_{ab}^2)}_{\text{dynamic term}} \; F_R \Big\} \Big|^2$$

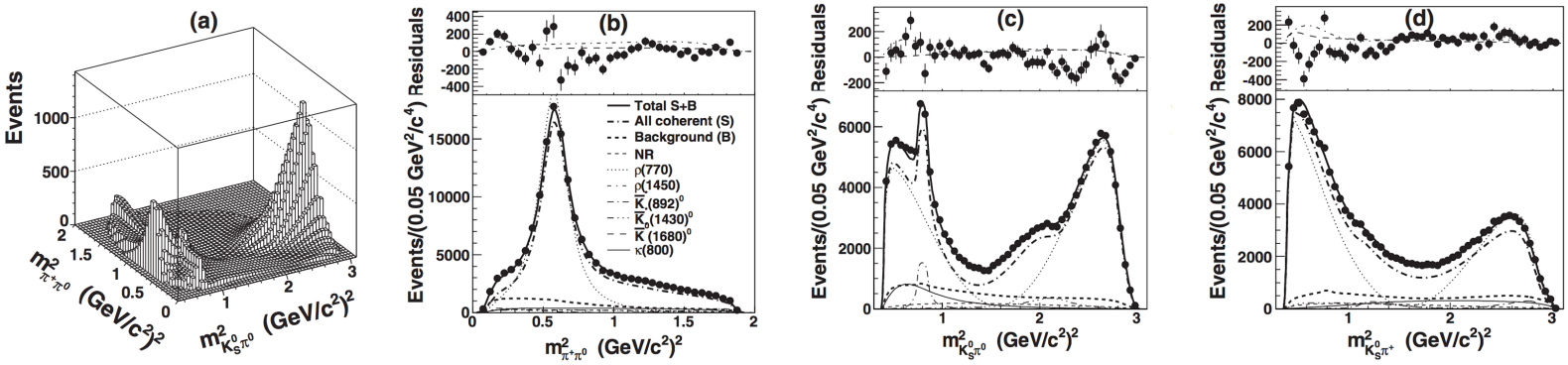
- $\mathcal{W}_R(m_{ab}^2)$ Breit-Wigner with mass depended width
- Non resonant contribution: $c_{NR} = a_{NR} e^{i\phi_{NR}}$
- κ descibed by single pole (BW with constant width):

$$\mathcal{W}_\kappa(m_{ab}^2) = \frac{1}{\Re + i\Im - m_{ab}^2}$$

Dalitz anlaysis results



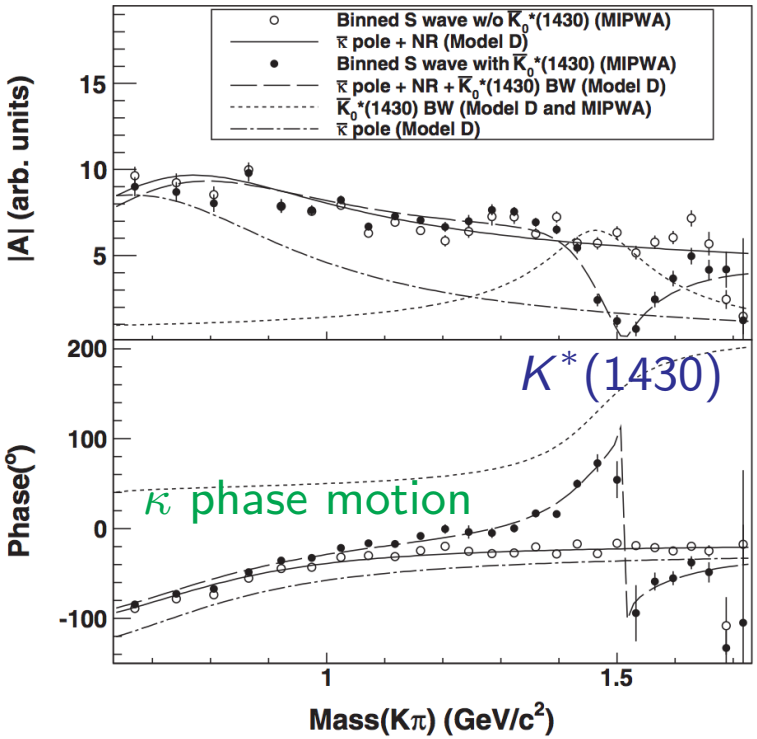
Dalitz anlaysis results



decay mode	fit fraction [%]		
NR	4.6	± 0.7	$^{+5.3}_{-5.0}$
$K^0_S\rho(770)^+$	83.4	± 2.2	$^{+7}_{-3.5}$
$K^0_S\rho(1450)^+$	2.1	± 0.3	$^{+1.5}_{-1.9}$
$\bar{K}^*(892)^0\pi^+$	3.58	± 0.17	$^{+0.39}_{-0.38}$
$\bar{K}^*_0(1430)^0\pi^+$	3.7	± 0.6	± 1.2
$\bar{K}^*(1680)^0\pi^+$	1.3	± 0.2	$^{+0.92}_{-1.3}$
$\bar{\kappa}^0\pi^+$	7.7	± 1.2	$^{+6.4}_{-4.8}$

- $K^0_S\rho(770)^+$ dominant
- visible NR contribution
- $K^0_S\pi^0$ S-wave $=$ $(17.3 \pm 1.4)\%$
- significant S-wave contribution from κ
- NR+$\bar{\kappa}^0\pi^+ = (18.6 \pm 1.7)\%$
- Systematical limitation

(Quasi-) Model independet analysis



- Model dependence critical
- cross-check for $K\pi$ S-wave model (κ)
- substitute S-wave model by $W_S = a_S e^{i\phi_S}$ measure a_S, ϕ_S binned
- K*(1430) and phase motion at low masses $\rightarrow \kappa$ pole
- Result from model depended analysis confirmed

Systematic studies

Background

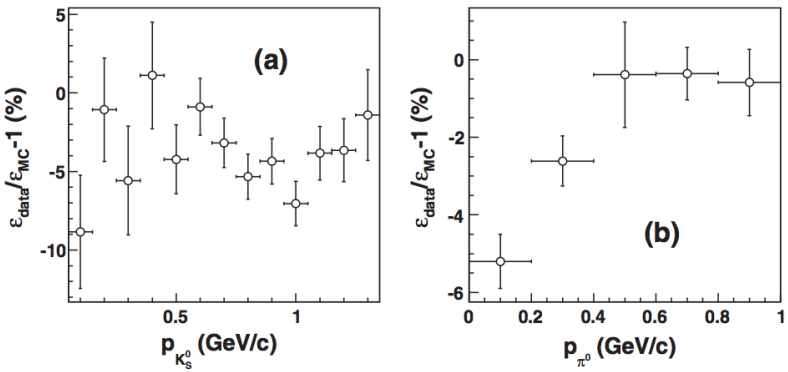
- Background level: changing signal fraction by 1σ
- Background shape: Differences using low and high sideband

Model

- Use different barrier factor parametrization
- Changing radial parameters
- Different resonance parametrizations
- Different sets of amplitudes

Efficiency

- Efficiency parameterization
  - binned efficiency
  - PHSP sample
- Difference Data$\Longleftrightarrow$Monte Carlo
  - Correction for tracking and PID
  - detector resolution of DP variables



- Correction applied to data
- RMS taken as systematic error

Summary

- Study $K^0_S \pi^0$ S-wave
- Dalitz analysis of $D^+ \to K^0_S \pi^+ \pi^0$
- 166694 signal candidates with a purity of 84.1%
- Amplitude well described by six quasi-two-body decay channels [$K^0_S \rho^+$, $K^0_S \phi(1450)$, $\bar{K}^{*0}$, $\bar{K}_0(1430)^0$, $\bar{K}(1680^0 \pi^+$, $\bar{\kappa}^0 \pi^+$]
- Significant contribution from κ+NR
- Results cross-checked by model independent analysis
- Analysis systematically limited
- Partial branching ratios were updated with higher precision

Mode	Partial branching fraction (%)
$D^+ \to K^0_S \pi^+ \pi^0$ nonresonant	$0.32 \pm 0.05 \pm 0.25^{+0.28}_{-0.25}$
$D^+ \to \rho^+ K^0_S$, $\rho^+ \to \pi^+ \pi^0$	$5.83 \pm 0.16 \pm 0.30^{+0.45}_{-0.15}$
$D^+ \to \rho(1450)^+ K^0_S$, $\rho(1450)^+ \to \pi^+ \pi^0$	$0.15 \pm 0.02 \pm 0.09^{+0.07}_{-0.11}$
$D^+ \to \bar{K}^*(892)^0 \pi^+$, $\bar{K}^*(892)^0 \to K^0_S \pi^0$	$0.250 \pm 0.012 \pm 0.015^{+0.025}_{-0.024}$
$D^+ \to \bar{K}^*_0(1430)^0 \pi^+$, $\bar{K}^*_0(1430)^0 \to K^0_S \pi^0$	$0.26 \pm 0.04 \pm 0.05 \pm 0.06$
$D^+ \to \bar{K}^*(1680)^0 \pi^+$, $\bar{K}^*(1680)^0 \to K^0_S \pi^0$	$0.09 \pm 0.01 \pm 0.05^{+0.04}_{-0.08}$
$D^+ \to \bar{\kappa}^0 \pi^+$, $\bar{\kappa}^0 \to K^0_S \pi^0$	$0.54 \pm 0.09 \pm 0.28^{+0.36}_{-0.19}$
$NR + \bar{\kappa}^0 \pi^+$	$1.30 \pm 0.12 \pm 0.12^{+0.12}_{-0.30}$
$K^0_S \pi^0$ S-wave	$1.21 \pm 0.10 \pm 0.16^{+0.19}_{-0.27}$