Hadronic decays of the D/D_s

David H. Miller
Purdue University
(CLEO collaboration)

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$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

This talk

This Talk

CLEO-c results

- **$818 pb^{-1}$ at the $\Psi(3770)$ taken just above $D\bar{D}$ threshold**
- **$586\ pb^{-1}$ taken at 4170 MeV to maximize D_s production**

Inclusive hadron yields from D_s decays — arXiv:0904.2417v1 [hep.ex]

D^0, D^+, D_s exclusive decays to two pseudoscalars — arXiv:0906.3198v1 [hep-ex]

D_s exclusive decays involving the ω — arXiv:0906.2138v1 [hep-ex]

Dalitz plot analysis of $D_s \to K^+K^-\pi^+$ — arXiv:0903.1301 [hep-ex] PRD 79, 072008 (2009)

Data and detector

818pb^{-1}

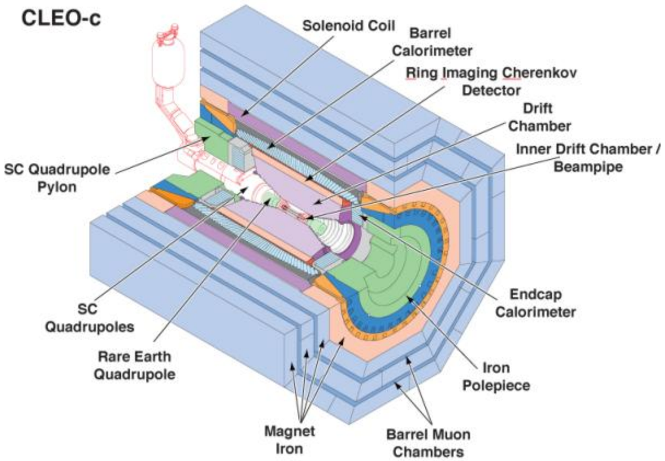
- $e^+e^- \rightarrow \Psi(3770) \rightarrow D\overline{D}$ produced at threshold, no extra particles.

  10-20% of all D^0 and D^+ are fully reconstructed in clean modes.

586pb^{-1}

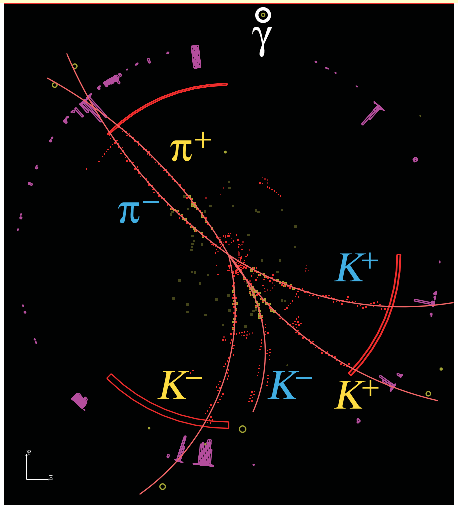
$e^+e^- \rightarrow D_s^{*+} D_s^-$ at 4170 MeV includes a photon or π^0 from D_s^* decay.

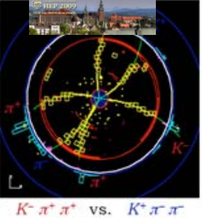
6% of all D_s^+ are fully reconstructed in clean modes.



Events are very clean.
The detector covers 93% of 4π and excellent photon detection

$e^+e^- \rightarrow D_s^- D_s^{*+} \rightarrow D_s^- D_s^+ \gamma$





Inclusive hadron yields from D_s decays

$e^+e^- \to D_s^- D_s^{*+} \to D_s^- D_s^+ \gamma$ or $D_s^+ D_s^{*-} \to D_s^+ D_s^- \gamma$

Reconstruct D_s^-

Compute the recoil mass

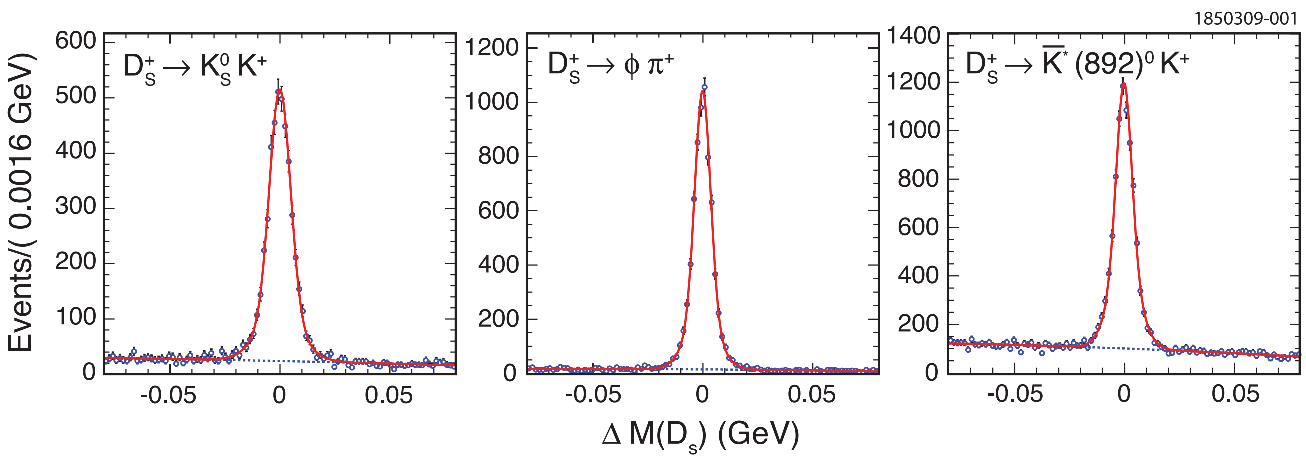
select ± 55 MeV of PDG mass

Compute M_{recoil} from $D_s^- \gamma$

select ± 30 MeV from PDG mass

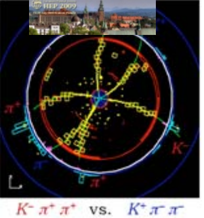
$$M_{recoil}(D_s) = \sqrt{(E_0 - E_{Ds})^2 - (p_0 - p_{Ds})^2}$$

$$M_{recoil}(D_s \gamma) = \sqrt{(E_0 - E_{Ds} - E_\gamma)^2 - (p_0 - p_{Ds} - p_\gamma)^2}$$

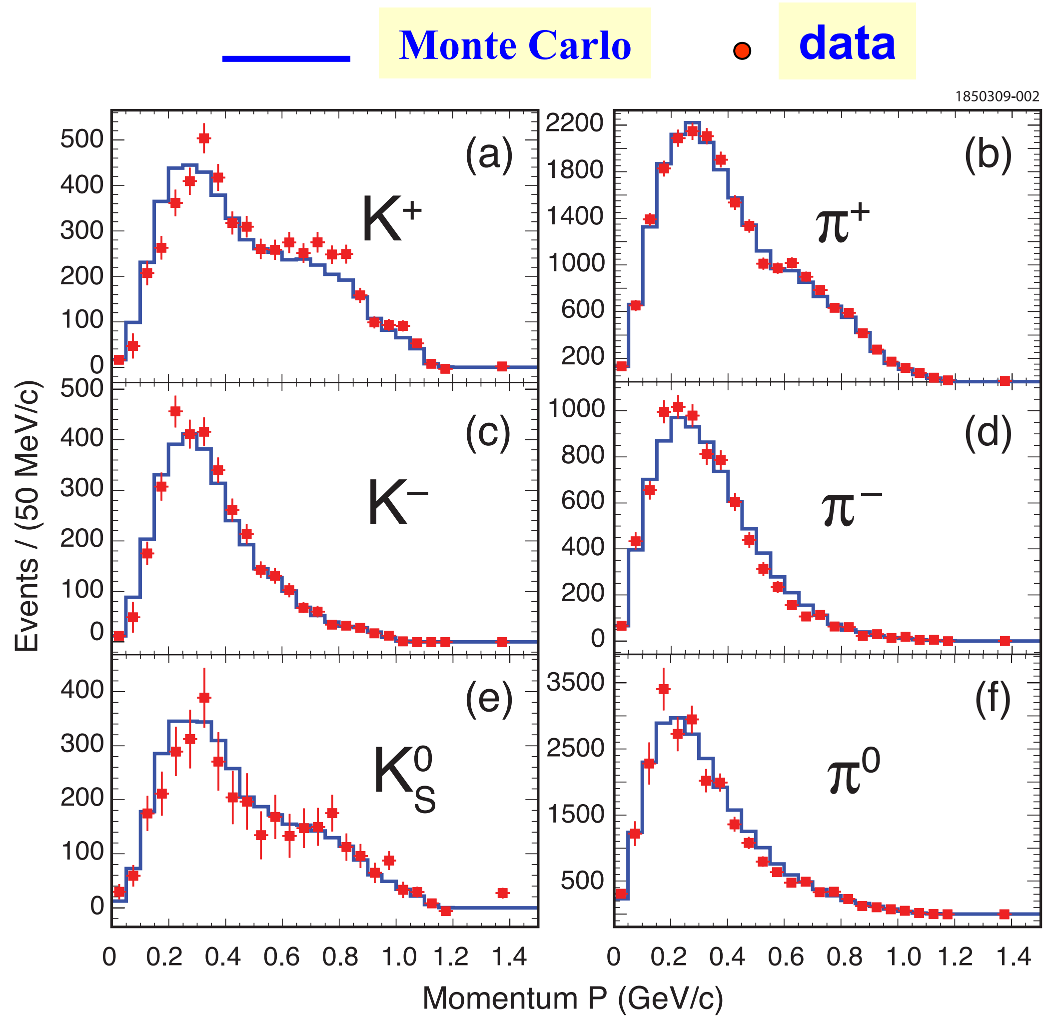


Total of 18586 ± 163 tags full data set 586pb^{-1}

Inclusive hadron yields from D_s decays [arXiv:0904.2417]



Inclusive K and π yields from D_s decays

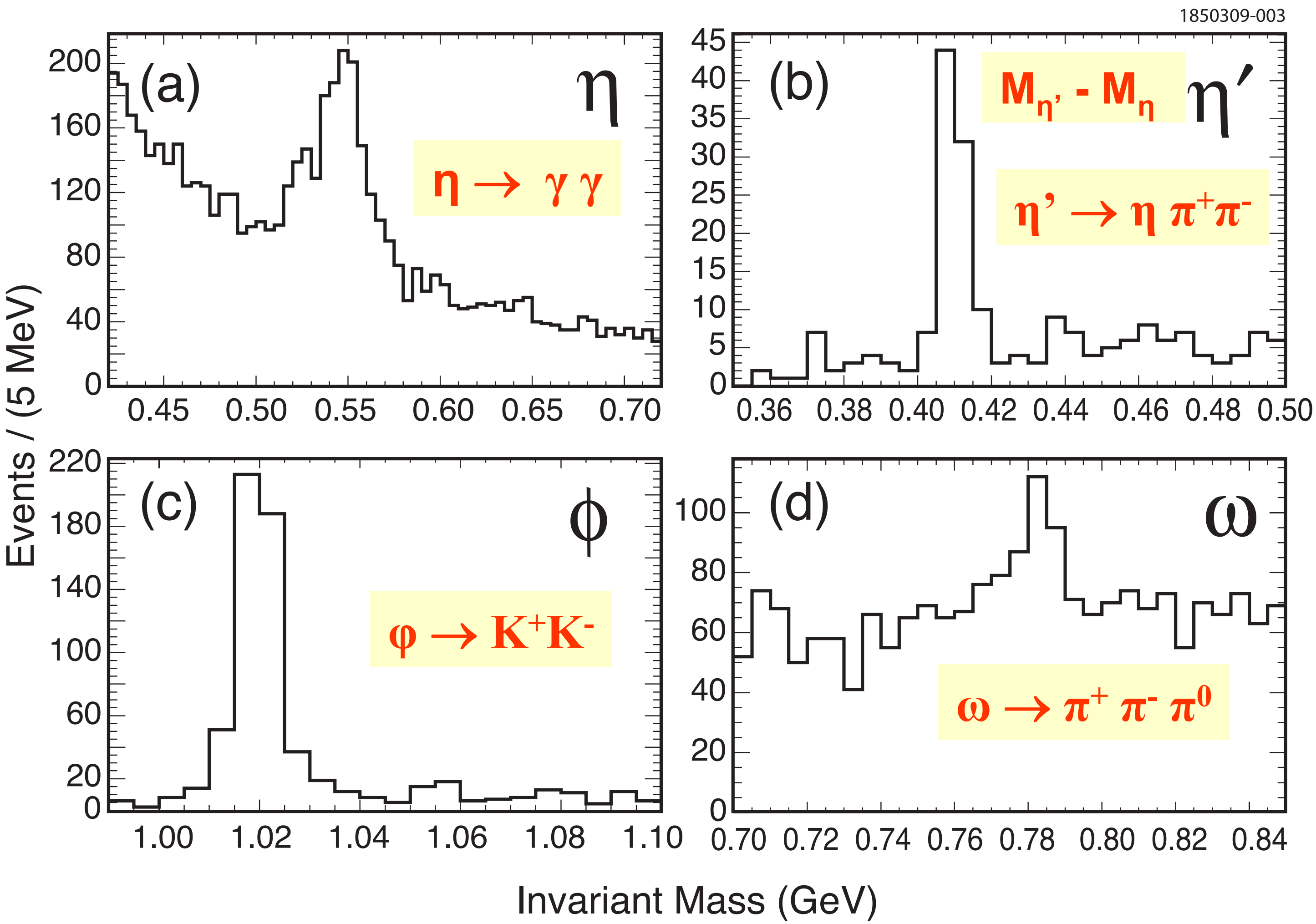


Subtract a variety of backgrounds
e.g. π^{+-0} from K_s^0,
Misidentification
$\pi \to K$ and $K \to \pi$

Use particle ID
both dE/dx and RICH
E/p for electron ID

Use D_s sideband subtraction

Inclusive η $\eta'\varphi$ ω yields from D_s decays




$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

Inclusive hadron yields from D_s decays

D_s inclusive yield results.

Mode	Yield(%)	K_L^0 Mode	Yield(%)	$\mathcal{B}$(PDG)(%)
$D_s^+ \to \pi^+ X$	$119.3 \pm 1.2 \pm 0.7$			
$D_s^+ \to \pi^- X$	$43.2 \pm 0.9 \pm 0.3$			
$D_s^+ \to \pi^0 X$	$123.4 \pm 3.8 \pm 5.3$			
$D_s^+ \to K^+ X$	$28.9 \pm 0.6 \pm 0.3$			$20\,^{+\,18}_{-\,14}$
$D_s^+ \to K^- X$	$18.7 \pm 0.5 \pm 0.2$			$13\,^{+\,14}_{-\,12}$
$D_s^+ \to \eta X$	$29.9 \pm 2.2 \pm 1.7$			
$D_s^+ \to \eta' X$	$11.7 \pm 1.7 \pm 0.7$			
$D_s^+ \to \phi X$	$15.7 \pm 0.8 \pm 0.6$			
$D_s^+ \to \omega X$	$6.1 \pm 1.4 \pm 0.3$			
$D_s^+ \to f_0(980)X,\ f_0(980) \to \pi^+\pi^-$	$< 1.3\%$ (90% CL)			
$D_s^+ \to K_S^0 X$	$19.0 \pm 1.0 \pm 0.4$	$D_s^+ \to K_L^0 X$	15.6 ± 2.0	20 ± 14
$D_s^+ \to K_S^0 K_S^0 X$	$1.7 \pm 0.3 \pm 0.1$	$D_s^+ \to K_L^0 K_S^0 X$	5.0 ± 1.0	
$D_s^+ \to K_S^0 K^+ X$	$5.8 \pm 0.5 \pm 0.1$	$D_s^+ \to K_L^0 K^+ X$	5.2 ± 0.7	
$D_s^+ \to K_S^0 K^- X$	$1.9 \pm 0.4 \pm 0.1$	$D_s^+ \to K_L^0 K^- X$	1.9 ± 0.3	
$D_s^+ \to K^+ K^- X$	$15.8 \pm 0.6 \pm 0.3$			
$D_s^+ \to K^+ K^+ X$	$< 0.26\%$ (90% CL)			
$D_s^+ \to K^- K^- X$	$< 0.06\%$ (90% CL)			

K^0_L modes are those with a single K^0_L found by missing mass

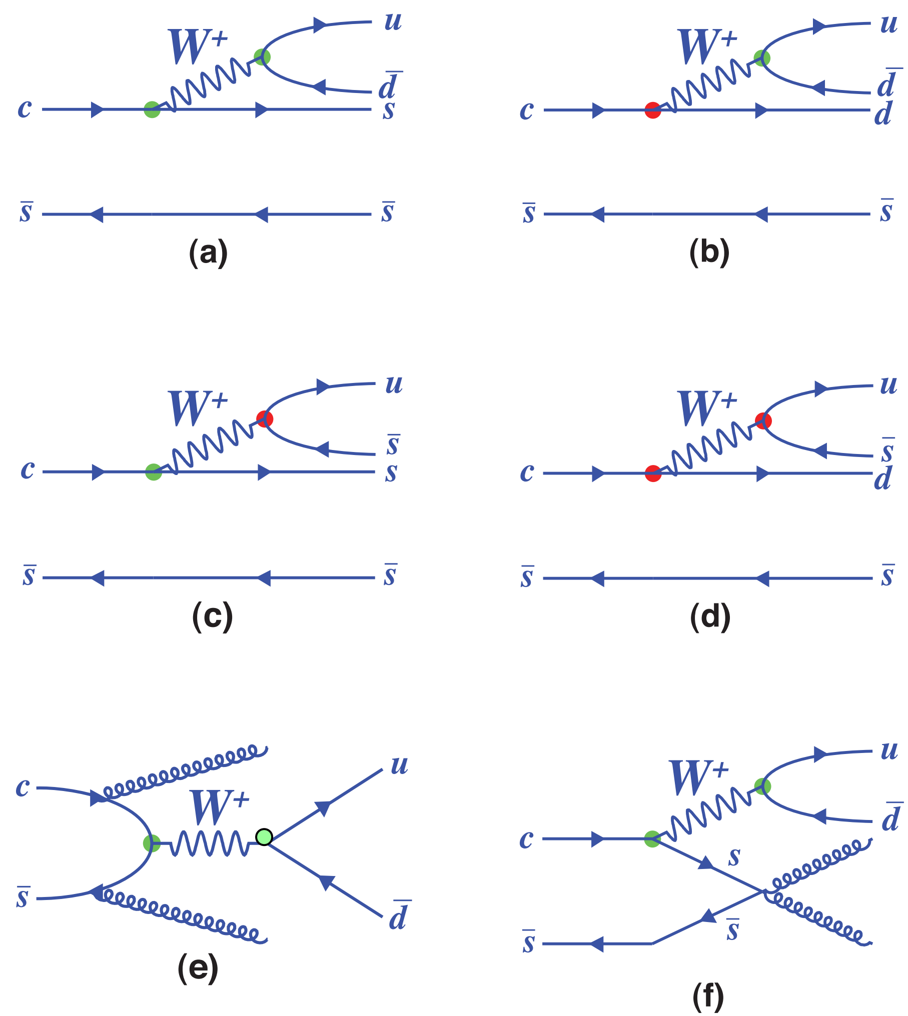
Gronau and Rosner arXiv:0903.2287 use measured branching ratios and an isospin statistical model to determine the exclusive channel contributions to inclusive π, K, η, η', φ, ω

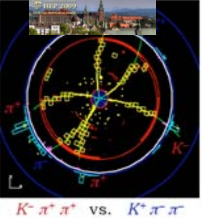
Quark Level Production Mechanisms

Inclusive hadronic decays can be produced by a variety of mechanisms.
Including:

(a) CF → ηX, η'X, φX and $K\bar{K}X$
(b) CS → KX
(c) CS → KηX, Kη'X, KφX
(d) DCS → K$\bar{\text{K}}$X
(e,f) Annihilation → no strange

Use the data to find the contribution of the annihilation processes





Fit to the Quark Level Production

In order to determine the contributions of specific diagrams the four branching ratios resulting in ss production are used as free parameters in a global fit

$$\mathcal{B}(s\bar{s}) = \mathcal{B}(\eta) + \mathcal{B}(\eta') + \mathcal{B}(\varphi) + \mathcal{B}(KK).$$

The s quark-level final state B(s) is not adjusted in the fit, but is included as

$$\mathcal{B}(\bar{s}) = C_1 \times |V_{cd}/V_{cs}|^2 \times \mathcal{B}(s\bar{s}),$$

where C_1 is a correction factor which is taken to be 1.25±0.25.

The $s\overline{ss}$ final state has 4 separate pieces and these are not adjusted but included in the fit with C_2 taken to be 0.75 ± 0.25.

$$\mathcal{B}(\eta\bar{s}) = C_2 \times |V_{us}/V_{ud}|^2 \times \mathcal{B}(\eta)$$
$$\mathcal{B}(\eta'\bar{s}) = C_2 \times |V_{us}/V_{ud}|^2 \times \mathcal{B}(\eta')$$
$$\mathcal{B}(\varphi\bar{s}) = C_2 \times |V_{us}/V_{ud}|^2 \times \mathcal{B}(\varphi)$$
$$\mathcal{B}(KK\bar{s}) = C_2 \times |V_{us}/V_{ud}|^2 \times \mathcal{B}(KK)$$

Finally, there are the annihilation diagrams.

$\mathcal{B}$(Annihilation) = $\mathcal{B}(D^+_s \to \mu^+ v) + \mathcal{B}(D^+_s \to \tau^+ v) + \mathcal{B}(D^+_s \to$ Other Annihilation).

where the measured values of the leptonic decays $\mathcal{B}(D^+_s \to \tau^+ v) = (5.62 \pm 0.41 \pm 0.16)\%$, and $\mathcal{B}(D^+_s \to \mu^+ v) = (0.565 \pm 0.045 \pm 0.017)\%$ are used.

Results

$B(s\bar{s}) + B(s\overline{ss}) + B(\bar{s}) + B(\text{Annihilation}) = 100\%$

Parameter	Value(%)	Error(%) δ_1	δ_2	δ_3	δ_4	δ_5
$\mathcal{B}(D_s \to s\bar{s} \to \eta X)$	14.7	2.9	0.2	0.2	1.0	3.7
$\mathcal{B}(D_s \to s\bar{s} \to \eta' X)$	10.3	1.7	0.2	0.1	1.0	0.1
$\mathcal{B}(D_s \to s\bar{s} \to \phi X)$	15.1	1.0	0.0	0.2	0.0	0.0
$\mathcal{B}(D_s \to s\bar{s} \to K\bar{K}X)$	25.4	1.2	0.3	0.6	0.1	0.1
$\mathcal{B}(D_s \to s\bar{s})$	65.6	2.7	0.7	1.0	1.8	3.5
$\mathcal{B}(\text{Other Annihilation})$	21.5	2.8	0.1	0.3	2.0	3.9

Errors

1. statistical
2. C_1 phase space
3. C_2 phase space
4. η, η from $u\bar{u}$, $d\bar{d}$
5. ηη, ηφ pair production

The *B*(other annihilation) is substantial particularly considering that part of the annihilation process $D_s \to$ gluons will be in the $s\bar{s}$ channel

$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

D_s, D^0, $D^+ \rightarrow$ two pseudoscalars

arXiv:0906.3198v1 [hep-ex]

Use the full 3770 and 4170 data sets

For the D^0 and D^+ use the beam constrained mass and cut on ΔE and extract yields from M_{bc}

$$M_{BC} = \sqrt{E_{\text{beam}}^2 - \left|p(D)\right|^2}$$

$$\Delta E = E(D) - E_{\text{beam}}$$

For the D_s Use M_{recoil} (D_s) and M_{recoil} ($D_s + \gamma$)

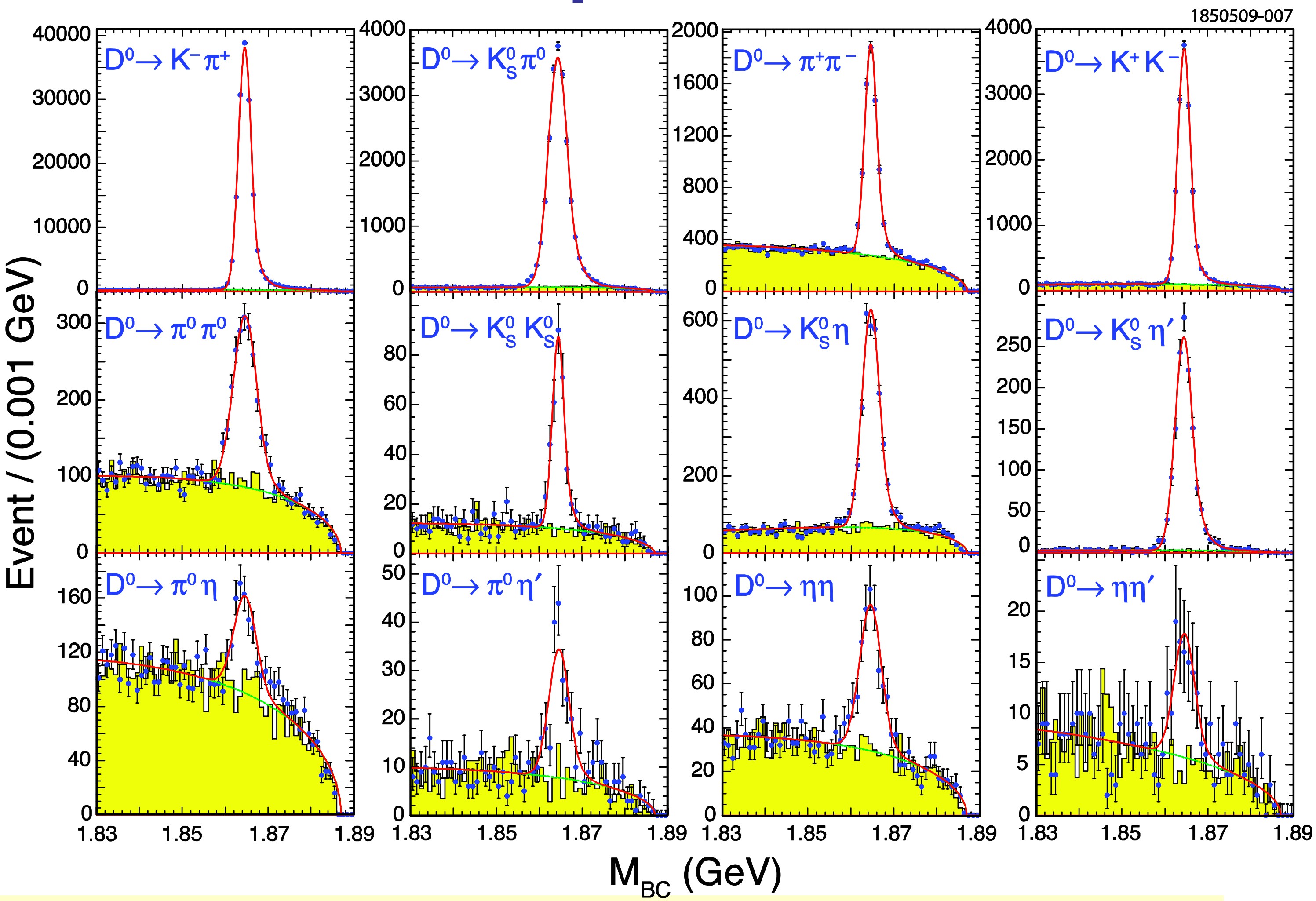
Use

$D^0 \rightarrow K^- \pi^+$ $D^+ \rightarrow K^- \pi^+ \pi^+$ $D_s^+ \rightarrow K_s^0 K^+$

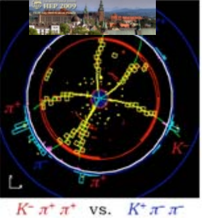
as reference modes to get absolute branching ratios

$K^-\pi^+\pi^+$ vs. $K^+\pi^-\pi^-$

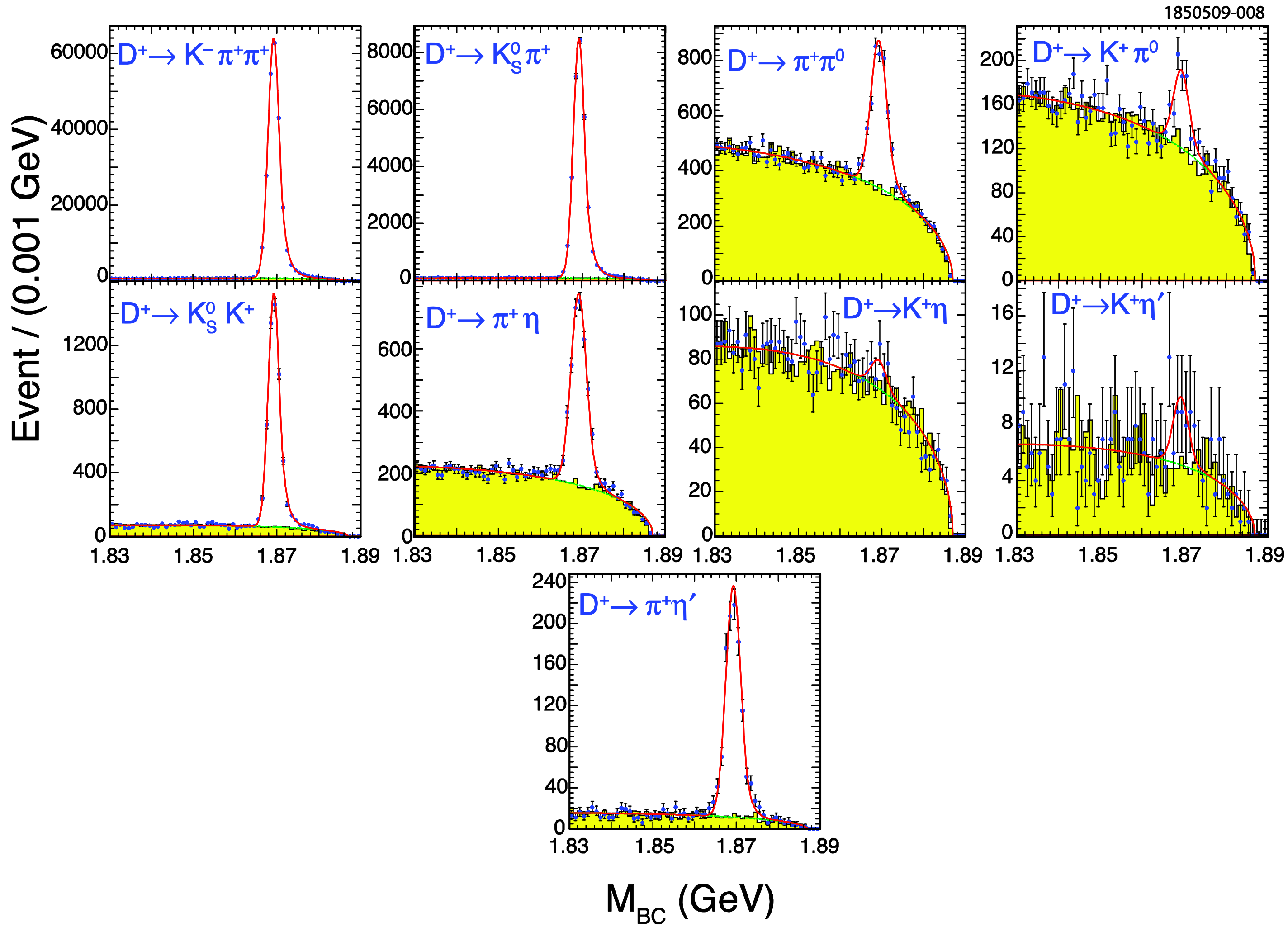
$D^0 \rightarrow$ two pseudoscalars



***M_{bc}* distributions The points are the ΔE signal region, the shaded histogram is from the ΔE sidebands, and the lines are the fit.**

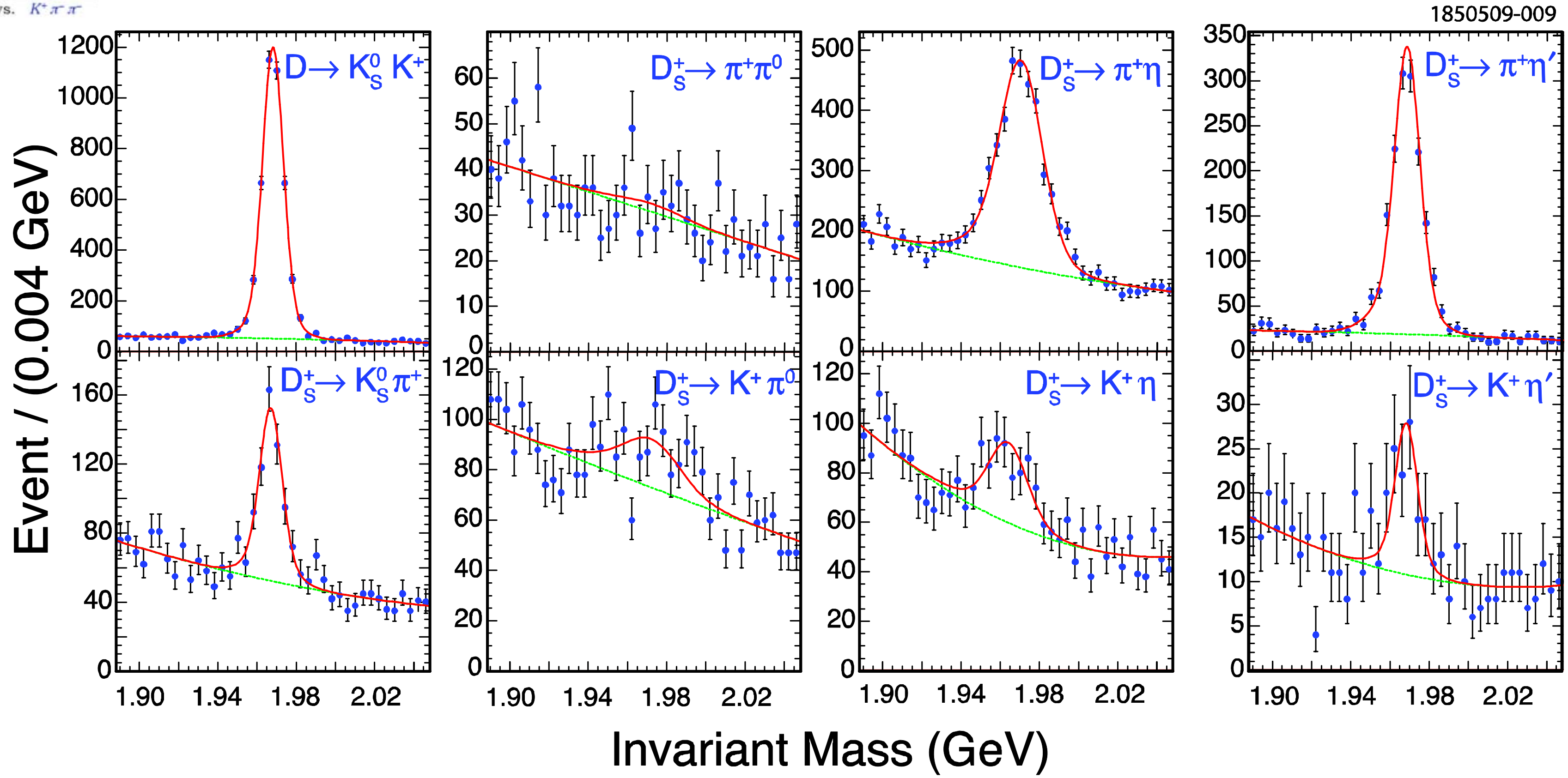


$D^+ \rightarrow$ two pseudoscalars



M_{bc} distributions The points are the ΔE signal region, the shaded histogram is from the ΔE sidebands, and the lines are the fit.

$D_s \to$ two pseudoscalars



***M*(D_s) distributions for D_s modes. The points are the data and the superimposed line is the fit**

$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

D^0 decays to two pseudoscalars

Mode	Efficiency (%)	Yield
$D^0 \to K^+K^-$	57.35 ± 0.16	13782 ± 136
$D^0 \to K^0_S K^0_S$	22.73 ± 0.13	215 ± 23
$D^0 \to \pi^+\pi^-$	72.68 ± 0.14	6210 ± 93
$D^0 \to \pi^0\pi^0$	32.95 ± 0.14	1567 ± 54
$D^0 \to K^-\pi^+$	65.11 ± 0.15	150259 ± 420
$D^0 \to K^0_S\pi^0$	28.57 ± 0.14	20045 ± 165
$D^0 \to K^0_S\eta$	10.08 ± 0.05	2864 ± 65
$D^0 \to \pi^0\eta$	11.97 ± 0.05	481 ± 40
$D^0 \to K^0_S\eta'$	2.35 ± 0.02	1321 ± 42
$D^0 \to \pi^0\eta'$	2.97 ± 0.02	159 ± 19
$D^0 \to \eta\eta$	4.35 ± 0.02	430 ± 29
$D^0 \to \eta\eta'$	1.06 ± 0.01	66 ± 15

Mode	$\mathcal{B}_{\rm mode}/\mathcal{B}_{\rm Normalization}$ (%)	This result $\mathcal{B}$ (%)	$\mathcal{A}_{CP}$ (%)
$D^0 \to K^+K^-$	$10.41 \pm 0.11 \pm 0.11$	$0.407 \pm 0.004 \pm 0.004 \pm 0.008$	
$D^0 \to K^0_S K^0_S$	$0.41 \pm 0.04 \pm 0.02$	$0.0160 \pm 0.0017 \pm 0.0008 \pm 0.0003$	
$D^0 \to \pi^+\pi^-$	$3.70 \pm 0.06 \pm 0.09$	$0.145 \pm 0.002 \pm 0.004 \pm 0.003$	
$D^0 \to \pi^0\pi^0$	$2.06 \pm 0.07 \pm 0.10$	$0.081 \pm 0.003 \pm 0.004 \pm 0.002$	
$D^0 \to K^-\pi^+$	100	3.9058 external input [2]	$0.5 \pm 0.4 \pm 0.9$
$D^0 \to K^0_S\pi^0$	$30.4 \pm 0.3 \pm 0.9$	$1.19 \pm 0.01 \pm 0.04 \pm 0.02$	
$D^0 \to K^0_S\eta$	$12.3 \pm 0.3 \pm 0.7$	$0.481 \pm 0.011 \pm 0.026 \pm 0.010$	
$D^0 \to \pi^0\eta$	$1.74 \pm 0.15 \pm 0.11$	$0.068 \pm 0.006 \pm 0.004 \pm 0.001$	
$D^0 \to K^0_S\eta'$	$24.3 \pm 0.8 \pm 1.1$	$0.95 \pm 0.03 \pm 0.04 \pm 0.02$	
$D^0 \to \pi^0\eta'$	$2.3 \pm 0.3 \pm 0.2$	$0.091 \pm 0.011 \pm 0.006 \pm 0.002$	
$D^0 \to \eta\eta$	$4.3 \pm 0.3 \pm 0.4$	$0.167 \pm 0.011 \pm 0.014 \pm 0.003$	
$D^0 \to \eta\eta'$	$2.7 \pm 0.6 \pm 0.3$	$0.105 \pm 0.024 \pm 0.010 \pm 0.002$	

Ratios of branching fractions to the normalization mode $D^0 \to K^- \pi^+$, branching fractions, and charge asymmetries A_{CP}. Uncertainties are statistical error, systematic error, and the error from the input branching fractions of normalization modes

$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

D^+ decays to two pseudoscalars

Mode	Efficiency (%)	Yield
$D^+ \to K^- \pi^+ \pi^+$	54.92 ± 0.16	231058 ± 515
$D^+ \to K^0_S K^+$	36.62 ± 0.15	5161 ± 86
$D^+ \to \pi^+ \pi^0$	48.69 ± 0.15	2649 ± 76
$D^+ \to K^0_S \pi^+$	42.54 ± 0.16	30095 ± 191
$D^+ \to K^+ \pi^0$	43.29 ± 0.15	343 ± 37
$D^+ \to K^+ \eta$	15.95 ± 0.06	60 ± 24
$D^+ \to \pi^+ \eta$	18.07 ± 0.06	2940 ± 68
$D^+ \to K^+ \eta'$	4.29 ± 0.02	23 ± 18
$D^+ \to \pi^+ \eta'$	4.81 ± 0.02	1037 ± 35

Mode	$\mathcal{B}_{\text{mode}}/\mathcal{B}_{\text{Normalization}}$ (%)	This result $\mathcal{B}$ (%)	$\mathcal{A}_{CP}$ (%)
$D^+ \to K^- \pi^+ \pi^+$	100	9.1400 external input [2]	$-0.1 \pm 0.4 \pm 0.9$
$D^+ \to K^0_S K^+$	$3.35 \pm 0.06 \pm 0.07$	$0.306 \pm 0.005 \pm 0.007 \pm 0.007$	$-0.2 \pm 1.5 \pm 0.9$
$D^+ \to \pi^+ \pi^0$	$1.29 \pm 0.04 \pm 0.05$	$0.118 \pm 0.003 \pm 0.005 \pm 0.003$	$2.9 \pm 2.9 \pm 0.3$
$D^+ \to K^0_S \pi^+$	$16.82 \pm 0.12 \pm 0.37$	$1.537 \pm 0.011 \pm 0.034 \pm 0.033$	$-1.3 \pm 0.7 \pm 0.3$
$D^+ \to K^+ \pi^0$	$0.19 \pm 0.02 \pm 0.01$	$0.0172 \pm 0.0018 \pm 0.0006 \pm 0.0004$	$-3.5 \pm 10.7 \pm 0.9$
$D^+ \to K^+ \eta$	< 0.14 (90% C.L.)	< 0.013 (90% C.L.)	
$D^+ \to \pi^+ \eta$	$3.87 \pm 0.09 \pm 0.19$	$0.354 \pm 0.008 \pm 0.018 \pm 0.008$	$-2.0 \pm 2.3 \pm 0.3$
$D^+ \to K^+ \eta'$	< 0.20 (90% C.L.)	< 0.018 (90% C.L.)	
$D^+ \to \pi^+ \eta'$	$5.12 \pm 0.17 \pm 0.25$	$0.468 \pm 0.016 \pm 0.023 \pm 0.010$	$-4.0 \pm 3.4 \pm 0.3$

Ratios of branching fractions to the normalization mode $D^+ \to K^- \pi^+ \pi^+$, branching fractions, and charge asymmetries A_{CP}. There is no evidence of charge asymmetries. The third error is the error from the normalization mode.

D_s decays to two pseudoscalars

Mode	Efficiency (%)	Yield
$D_s^+ \to K_S^0 K^+$	24.73 ± 0.14	4076 ± 71
$D_s^+ \to \pi^+ \pi^0$	16.60 ± 0.12	19 ± 28
$D_s^+ \to K_S^0 \pi^+$	28.15 ± 0.14	393 ± 33
$D_s^+ \to K^+ \pi^0$	29.57 ± 0.14	202 ± 70
$D_s^+ \to K^+ \eta$	11.40 ± 0.05	222 ± 41
$D_s^+ \to \pi^+ \eta$	12.70 ± 0.06	2587 ± 89
$D_s^+ \to K^+ \eta'$	2.87 ± 0.02	56 ± 17
$D_s^+ \to \pi^+ \eta'$	3.28 ± 0.02	1436 ± 47

Mode	$\mathcal{B}_{\text{mode}}/\mathcal{B}_{\text{Normalization}}$ (%)	This result $\mathcal{B}$ (%)	$\mathcal{A}_{CP}$ (%)
$D_s^+ \to K_S^0 K^+$	100	1.4900 external input [3]	$4.7 \pm 1.8 \pm 0.9$
$D_s^+ \to \pi^+ \pi^0$	< 2.3 (90% C.L.)	< 0.037 (90% C.L.)	
$D_s^+ \to K_S^0 \pi^+$	$8.5 \pm 0.7 \pm 0.2$	$0.126 \pm 0.011 \pm 0.003 \pm 0.007$	$16.3 \pm 7.3 \pm 0.3$
$D_s^+ \to K^+ \pi^0$	$4.2 \pm 1.4 \pm 0.2$	$0.062 \pm 0.022 \pm 0.004 \pm 0.004$	$-26.6 \pm 23.8 \pm 0.9$
$D_s^+ \to K^+ \eta$	$11.8 \pm 2.2 \pm 0.6$	$0.176 \pm 0.033 \pm 0.009 \pm 0.010$	$9.3 \pm 15.2 \pm 0.9$
$D_s^+ \to \pi^+ \eta$	$123.6 \pm 4.3 \pm 6.2$	$1.84 \pm 0.06 \pm 0.09 \pm 0.11$	$-4.6 \pm 2.9 \pm 0.3$
$D_s^+ \to K^+ \eta'$	$11.8 \pm 3.6 \pm 0.6$	$0.18 \pm 0.05 \pm 0.01 \pm 0.01$	$6.0 \pm 18.9 \pm 0.9$
$D_s^+ \to \pi^+ \eta'$	$265.4 \pm 8.8 \pm 13.9$	$3.95 \pm 0.13 \pm 0.21 \pm 0.23$	$-6.1 \pm 3.0 \pm 0.3$

Ratios of branching fractions to the normalization mode $D_s^+ \to K_s^0 K^+$, branching fractions, and charge asymmetries A_{CP}. There is no evidence of charge asymmetries. The third error is the error from the normalization mode.

$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

D_s exclusive decays with an ω in the final state

arXiv:0906.2138v1 [hep-ex]

The inclusive branching fraction

$$D_s \to \omega X \text{ is } (6.1 \pm 1.4)\ \%$$

which is unexpectedly large

Only exclusive mode observed prior to this analysis is

$$D_s \to \pi^+\omega = (0.25 \pm 0.09)\%$$

Use the 18586 ± 163 tags D_s^- in $K^0_s K^-$, $\varphi\pi^-$, $K^*(892)^0 K^-$

Modes $D_s^+ \to \pi^+\pi^0\omega,\ \pi^+\omega,\ \pi^+\eta\omega,\ \pi^+\pi^+\pi^-\omega$

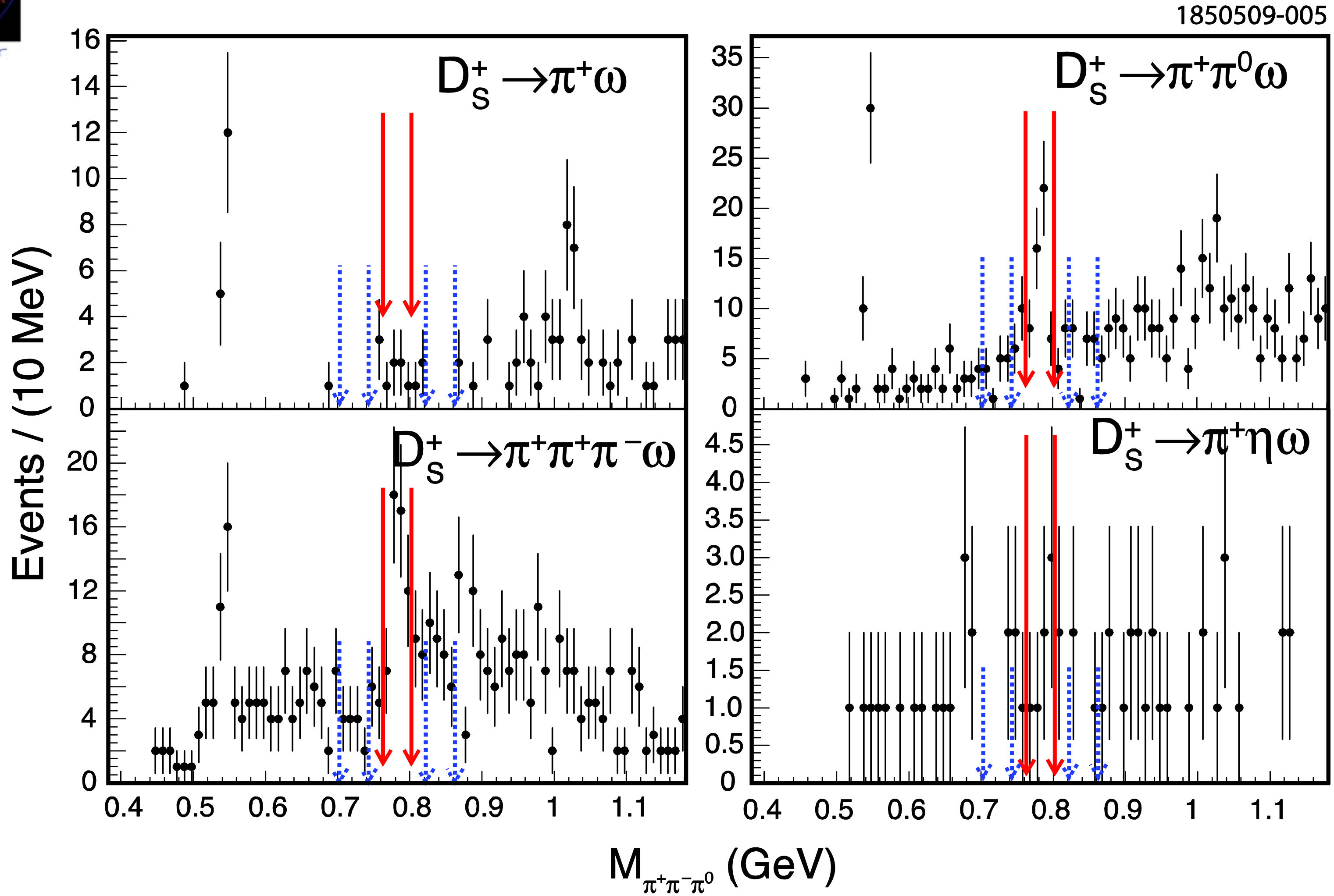
$D_s^+ \to K^+\pi^0\omega,\ K^+\omega,\ K^+\eta\omega,\ K^+\pi^+\pi^-\omega$

$$B_{mode} = N_{mode}/N_{tag} * \varepsilon_{tag}/\varepsilon_{mode}$$

Select events with three charged particles on the signal side

either $\pi^+ \pi^- \pi^-$ or $K^-\pi^+\pi^-$

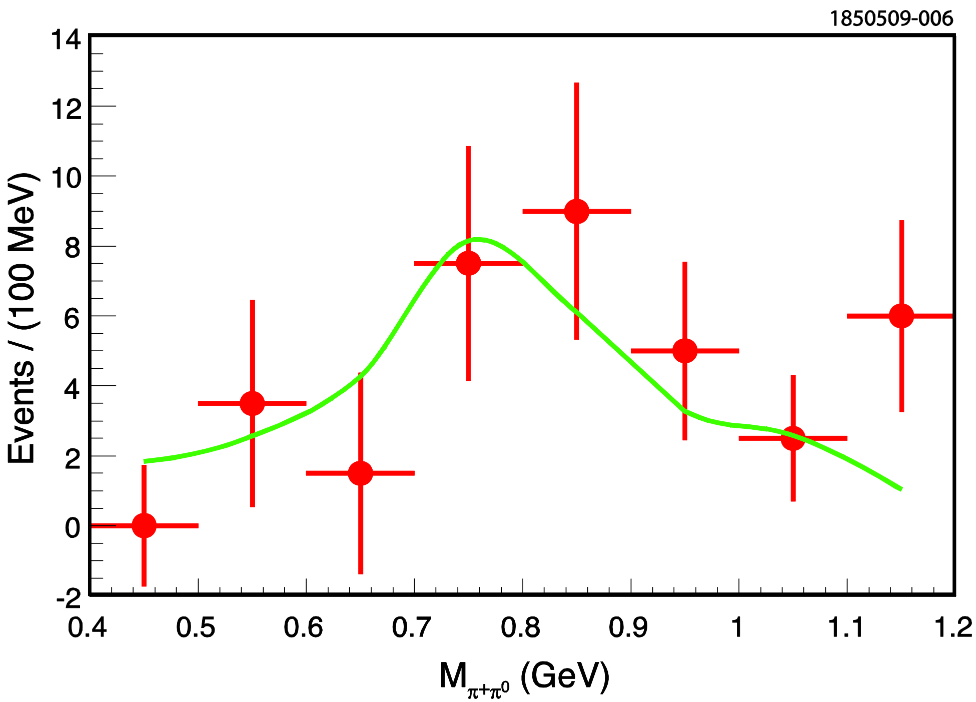
$D_s^+ \to \pi^+\pi^0\omega$, $\pi^+\omega$, $\pi^+\eta\omega$, $\pi^+\pi^+\pi^-\omega$



The red lines show the ω region and the blue lines indicate the sideband region Signals from η and φ are also present.

$K^-\pi^+\pi^+$ vs. $K^+\pi^-\pi^-$

ρ production in $\pi^+\pi^0\omega$

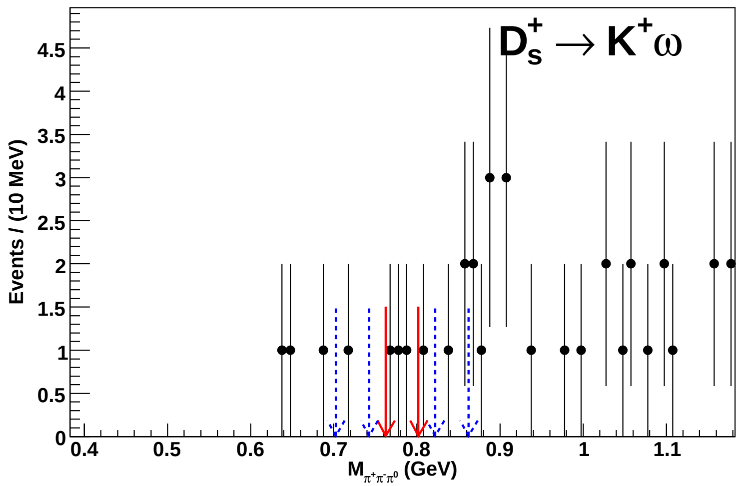


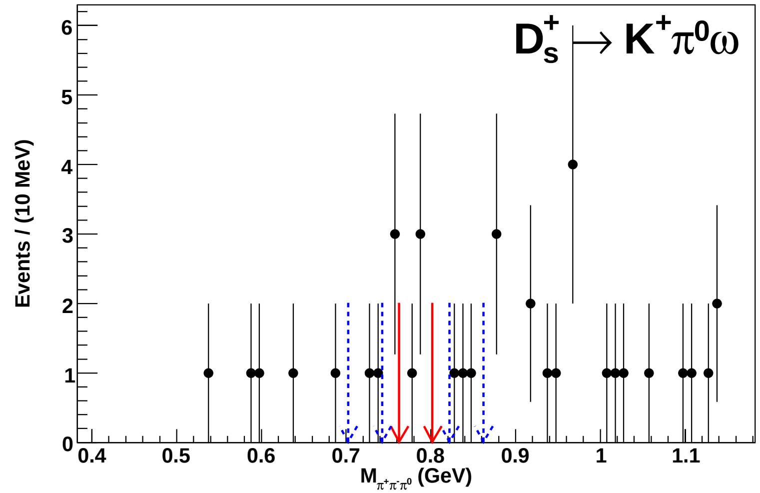
$\pi^+\pi^0$ invariant mass distribution fit to the sum of phase space $\pi^+\pi^0$ and $\rho \to \pi^+\pi^0$. The fit results in The fraction of ρω is 0.52 ± 0.30

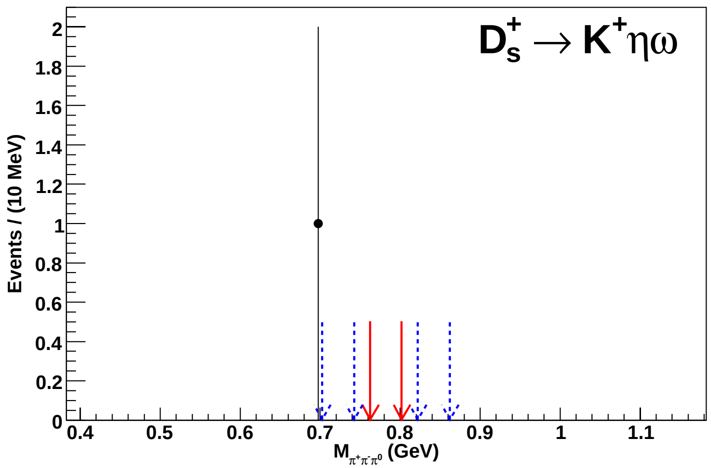
$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

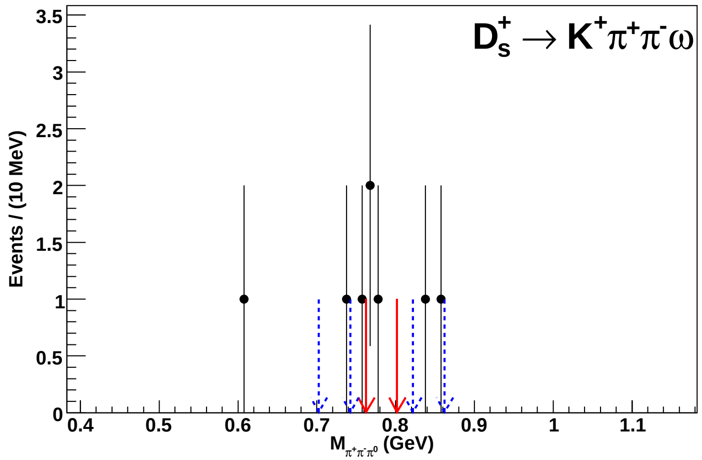
$D_s^+ \to K^+\pi^0\omega$, $K^+\omega$, $K^+\eta\omega$, $K^+\pi^+\pi^-\omega$

No signals are seen so upper limits set










$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

D_s exclusive decays with an ω

Mode	N_{Sg}	N_{Sd}	N_{Ss}	$\epsilon_{DT}(\%)$
$D_s^+ \to \pi^+\omega$	6.0	0.0	6.0 $\pm$2.4	4.07$\pm$0.08
$D_s^+ \to \pi^+\pi^0\omega$	53.0	19.0	34.0$\pm$7.9	1.75$\pm$0.04
$D_s^+ \to \pi^+\pi^+\pi^-\omega$	54.0	24.8	29.2$\pm$8.2	2.64$\pm$0.07
$D_s^+ \to \pi^+\eta\omega$	7.0	2.5	4.5 $\pm$2.9	0.76$\pm$0.04
$D_s^+ \to K^+\omega$	3.0	2.0	1.0 $\pm$2.0	3.66$\pm$0.08
$D_s^+ \to K^+\pi^0\omega$	4.0	2.5	1.5 $\pm$2.3	1.32$\pm$0.05
$D_s^+ \to K^+\pi^+\pi^-\omega$	3.0	1.5	1.5 $\pm$1.9	1.72$\pm$0.05
$D_s^+ \to K^+\eta\omega$	0.0	0.0	0.0 $\pm$0.0	0.45$\pm$0.03

Mode	$\mathcal{B}_{\rm mode}(\%)$
$D_s^+ \to \pi^+\omega$	$0.21 \pm 0.09 \pm 0.01$
$D_s^+ \to \pi^+\pi^0\omega$	$2.78 \pm 0.65 \pm 0.25$
$D_s^+ \to \pi^+\pi^+\pi^-\omega$	$1.58 \pm 0.45 \pm 0.09$
$D_s^+ \to \pi^+\eta\omega$	$0.85 \pm 0.54 \pm 0.06$
	< 2.13 (90% CL)
$D_s^+ \to K^+\omega$	< 0.24 (90% CL)
$D_s^+ \to K^+\pi^0\omega$	< 0.82 (90% CL)
$D_s^+ \to K^+\pi^+\pi^-\omega$	< 0.54 (90% CL)
$D_s^+ \to K^+\eta\omega$	< 0.79 (90% CL)

Total exclusive

= (5.4 ± 1.0)%

Which accounts for most of the inclusive

(6.1 ± 1.4)%

Branching fractions and upper limits.

$K^-\pi^+\pi^+$ vs. $K^+\pi^-\pi^-$

Dalitz plot analysis of $D_s \to K^+K^- \pi^+$

arXiv:0903.1301 PRD 79, 072008 (2009)

Isobar analysis of $D_s \to K^+K^- \pi^+$

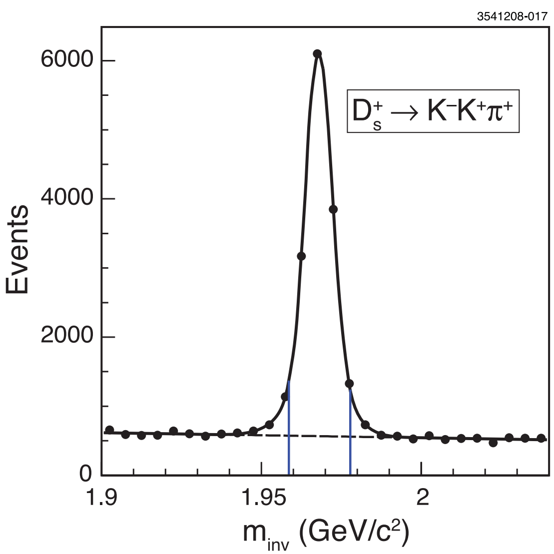
586 pb^{-1} at 4.17 GeV 14400 events (background of 15%)
E687 701 signal events PLB 351, 591 (1995)

- K^{*0} (892) K^+
- K^{*0} (1430) K^+
- φ (1020) π^+
- f_0 (980) π^+
- f_0 (1710) π^+
- f_0 (1370) π^+

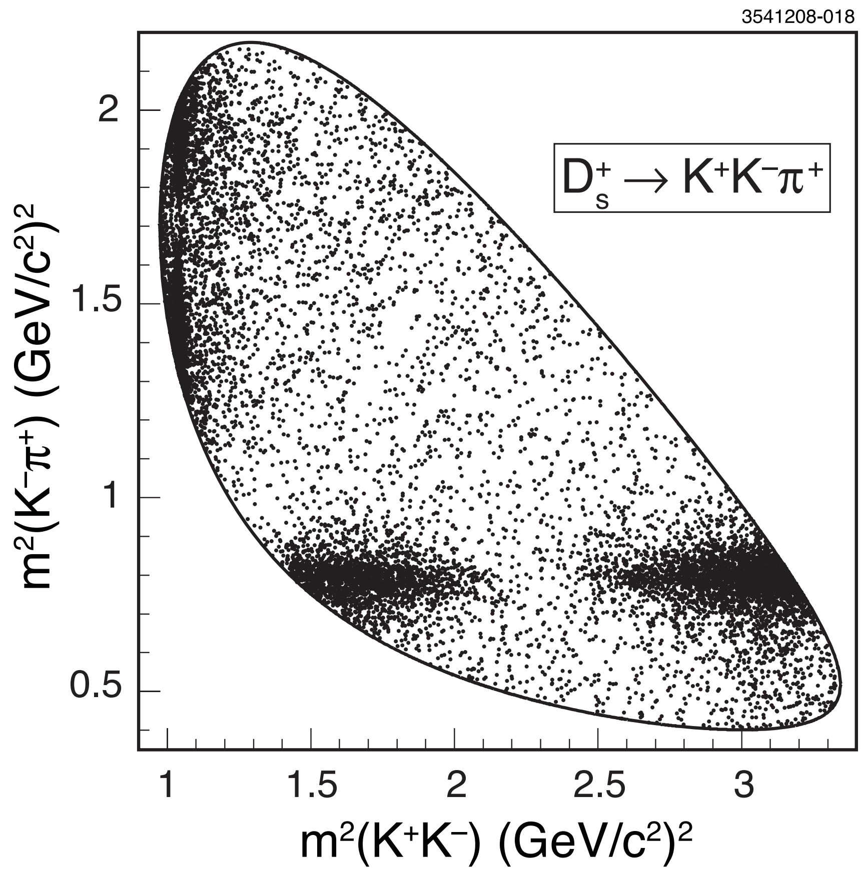
❖Breit Wigner parameterization for most resonances
❖ Flatte parameterization for the f_0(980)
❖a complex pole description of the kappa
❖ add f_0 (1370) π^+ (not used in E687 but required for the fit)

Measure the magnitude, phase, and fraction of the resonant contributions and limit the possible contributions of other KK and Kπ resonances that could appear in this decay.

Dalitz plot analysis of $D_s \rightarrow K^+K^- \pi^+$



D_s mass spectrum



D_s Dalitz plot

$K^-\pi^+\pi^+$ vs. $K^+\pi^-\pi^-$

Final fit contributions

Mode	Param	E687	CLEO-c
$\overline{K}^{*0}(892)K^+$	FF (%)	$47.8 \pm 4.6 \pm 4.0$	$47.4 \pm 1.5 \pm 0.4$
	Phase (°)	0 (fixed)	0 (fixed)
$\overline{K}_0^{*0}(1430)K^+$	FF (%)	$9.3 \pm 3.2 \pm 3.2$	$3.9 \pm 0.5 \pm 0.5$
	Phase (°)	$152 \pm 40 \pm 39$	$146 \pm 8 \pm 8$
$\phi(1020)\pi^+$	FF (%)	$39.6 \pm 3.3 \pm 4.7$	$42.2 \pm 1.6 \pm 0.3$
	Phase (°)	$178 \pm 20 \pm 24$	$-8 \pm 4 \pm 4$
$f_0(980)\pi^+$	FF (%)	$11.0 \pm 3.5 \pm 2.6$	$28.2 \pm 1.9 \pm 1.8$
	Phase (°)	$159 \pm 22 \pm 16$	$157 \pm 3 \pm 4$
$f_0(1710)\pi^+$	FF (%)	$3.4 \pm 2.3 \pm 3.5$	$3.4 \pm 0.5 \pm 0.3$
	Phase (°)	$110 \pm 20 \pm 17$	$89 \pm 5 \pm 5$
$f_0(1370)\pi^+$	FF (%)	—	$4.3 \pm 0.6 \pm 0.5$
	Phase (°)	—	$53 \pm 5 \pm 6$

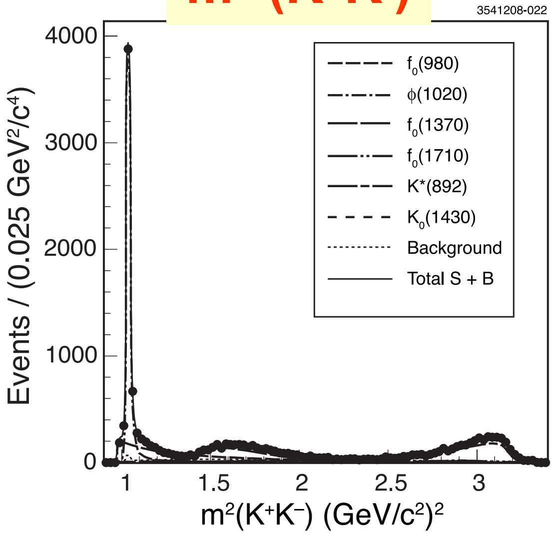
Major differences from E687 is the need for the $f_0(1370)$ and the $f_0(980)$ fit fraction and much smaller errors

Fit was redone adding 5 $K^-\pi^+$ and 7 K^-K^+ resonances one by one but no significant change in the fit

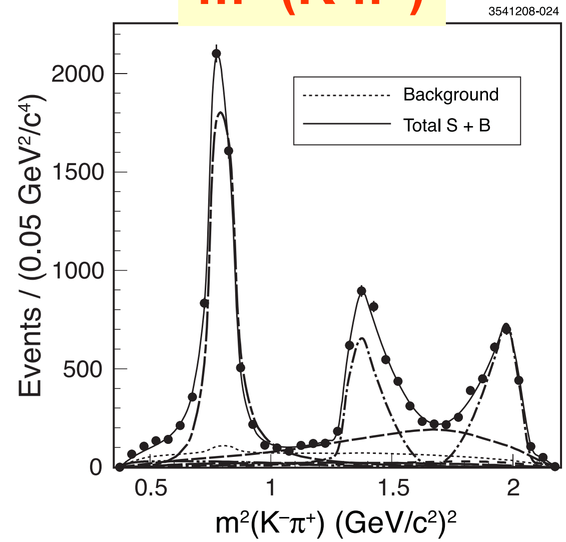
$K^- \pi^+ \pi^+$ vs. $K^+ \pi^- \pi^-$

Mass Projections for the final fit

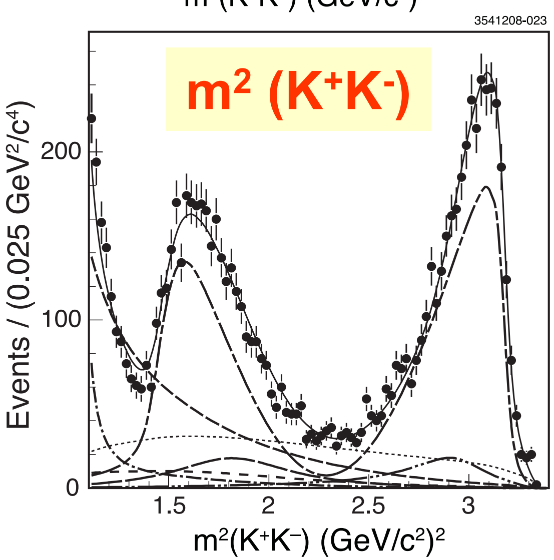
m² (K⁺K⁻)



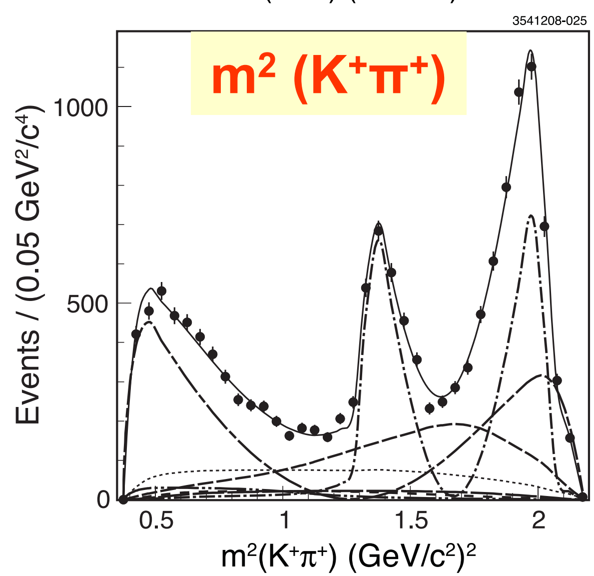
m² (K⁻π⁺)



m² (K⁺K⁻)



m² (K⁺π⁺)



$K^-\pi^+\pi^+$ vs. $K^+\pi^-\pi^-$

Summary

The detailed analysis of D and D_s decays continues at CLEO-c as well as at BaBar and Belle.
(CLEO-c talks at this conference by Skwarnicki and Ricciardi, and other recent talks at CIPANP and Charm 2009)

Analysis of the full D_s data set continues including updating the hadronic decays of the D_s (published from $300 pb^{-1}$)

Phys.Rev.Lett.100:161804,2008

I'd like to thank my colleagues at CLEO particularly Ed Thorndike, Fan Yang and Mikhail Dubrovin