Hadronic Charm Decays at FOCUS

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for the

FOCUS Collaboration

Heavy Quarks at Fixed Target
Fermi National Accelerator Laboratory
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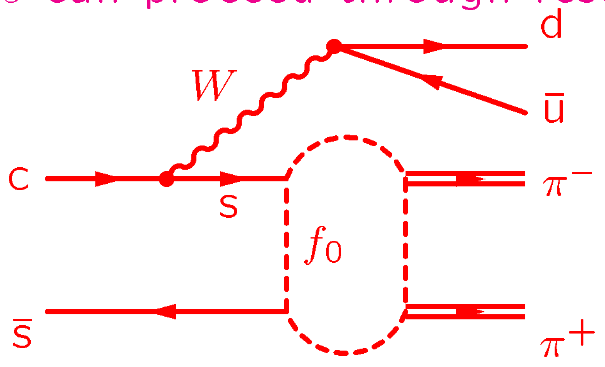
Overview

- Dalitz Analyses of Hadronic Meson Decays
  - E687 results
  - FOCUS prospects
- Charmed Baryon states
  - Spectroscopy
  - Searches
  - Lifetimes
- Rare and Forbidden Meson Decays
  - FCNC, LFNV, LNV
  - E687 results
  - FOCUS prospects
- Reconstruction Progress and Expectations for Results

D^+ and D_s^+ Dalitz analyses

- Dalitz is the most complete analysis that can be performed to understand decay mechanisms
  - Factorization theories only predict amplitudes for two-body modes
  - Interesting to see $D_s^+ \to \rho\pi^+$
    - $D_s^+ \to \pi^+\pi^-\pi^+$ cannot occur via simple spectator
    - $s\bar{s}$ can proceed through resonanace to $u\bar{u}/d\bar{d}$

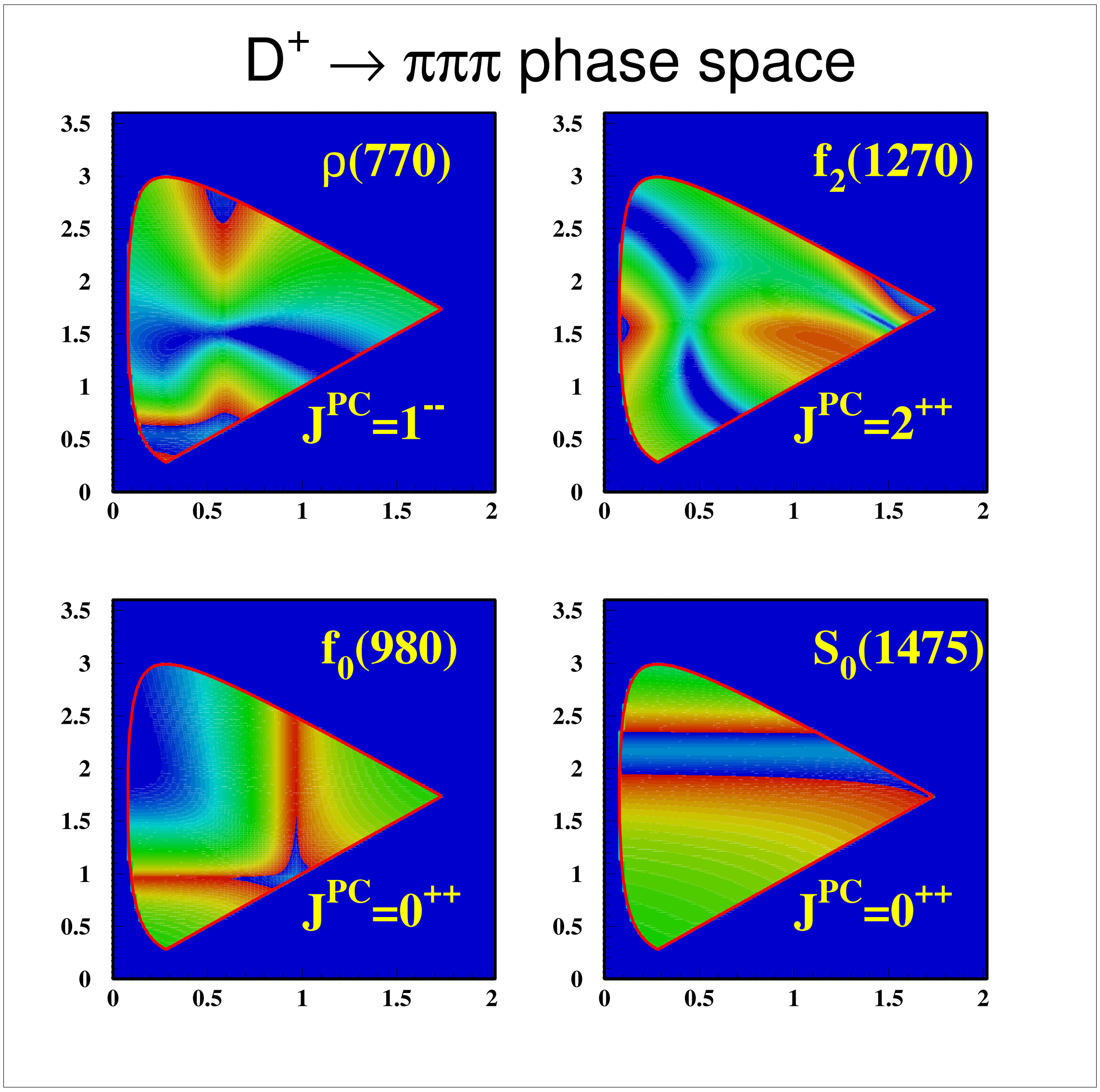


    - ρ has no $s\bar{s}$ component

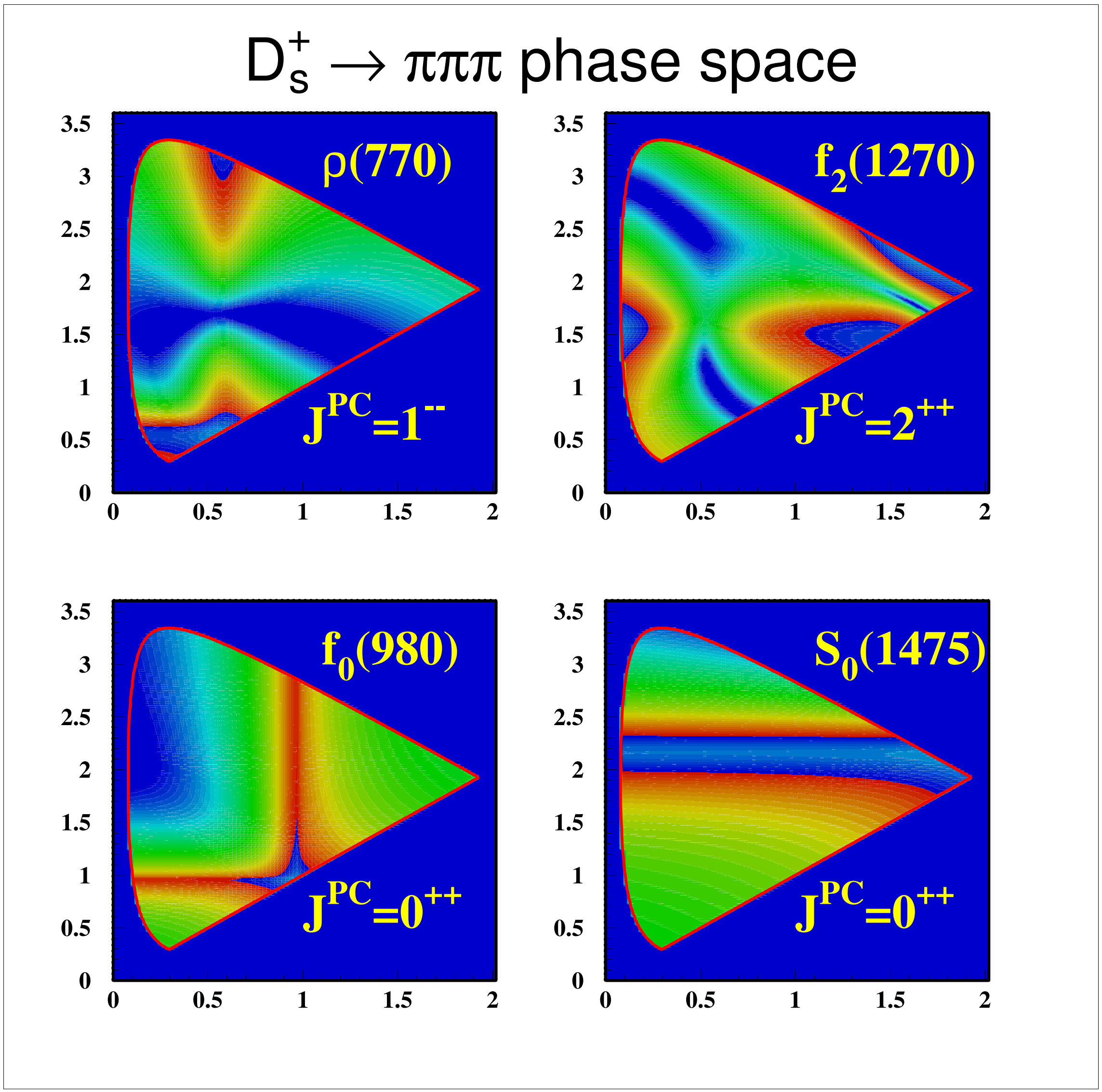
- Accurate measurements of resonant production to know efficiencies for B decay BRs

- May be best places to study some resonances (f_0)
  - Direct production is swamped with π BG
  - Can use charm with lifetime cut to purify

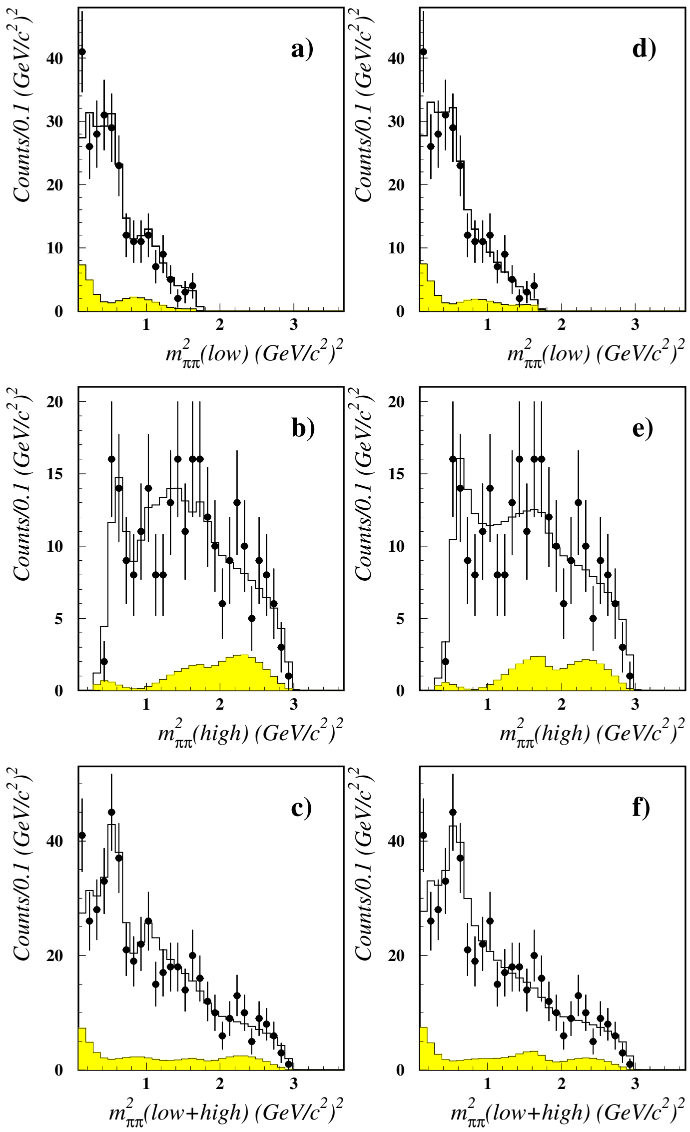
$D^+ \to \pi^-\pi^+\pi^+$ resonance models



$D_s^+ \to \pi^-\pi^+\pi^+$ resonance models

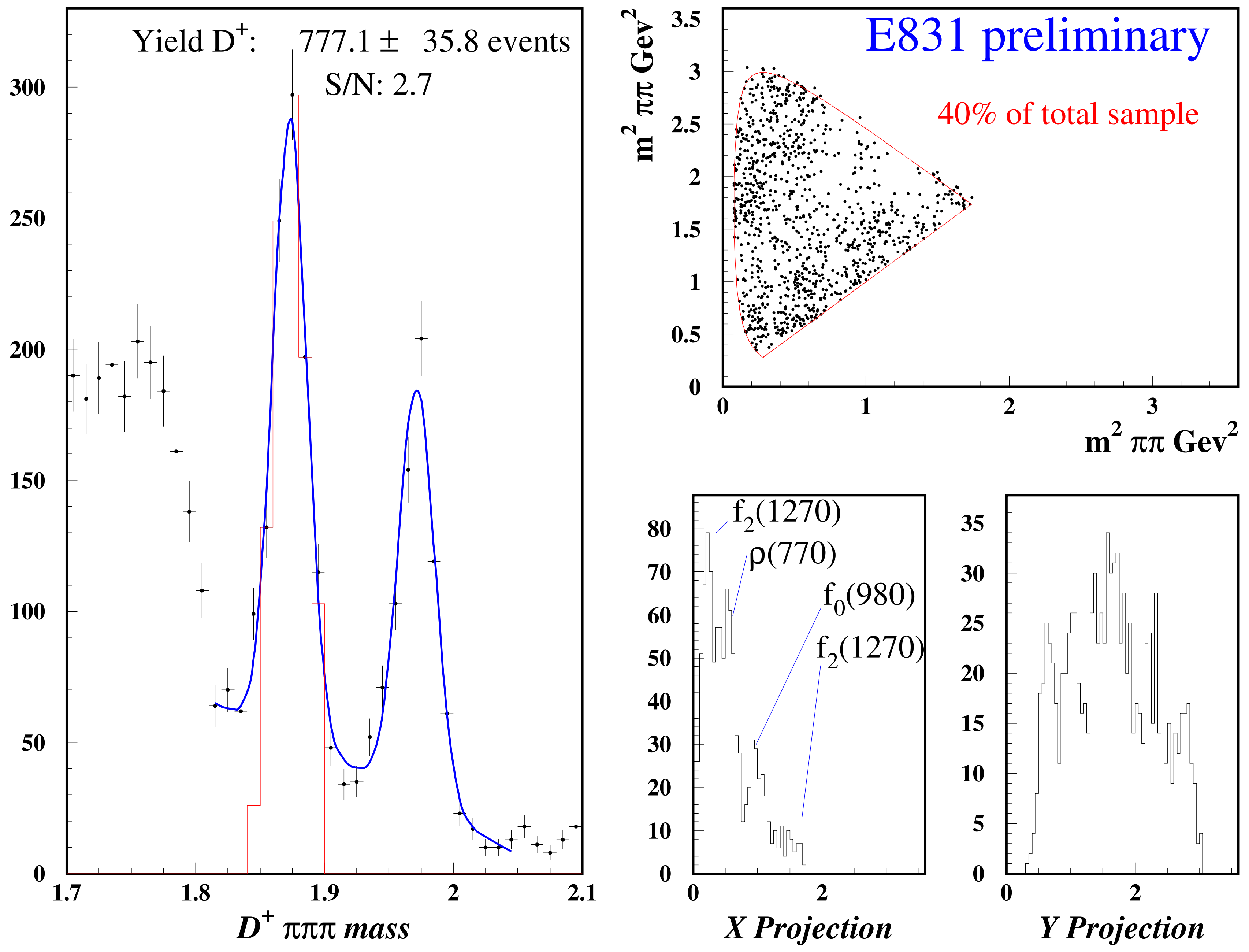


E687 $D^+ \to \pi^-\pi^+\pi^+$ Dalitz analysis

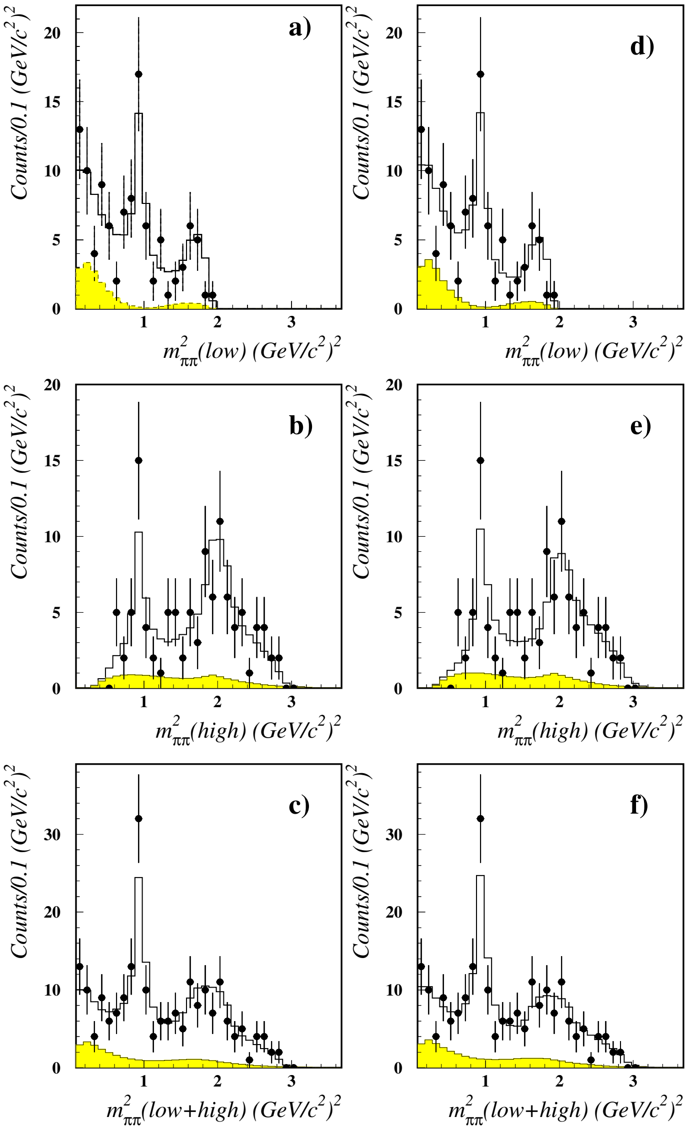


$D^+ \to \pi^-\pi^+\pi^+$ Dalitz fit results			
Decay Mode	Decay Fraction	Phase Degrees	Amp. Coeff
NR	0.768 ± 0.046	0 (*fixed*)	1.0 (*fixed*)
$\rho(770)\pi$	0.232 ± 0.046	36 ± 9	0.55 ± 0.07

$D^+ \rightarrow \pi\pi\pi$ dalitz plot and projections

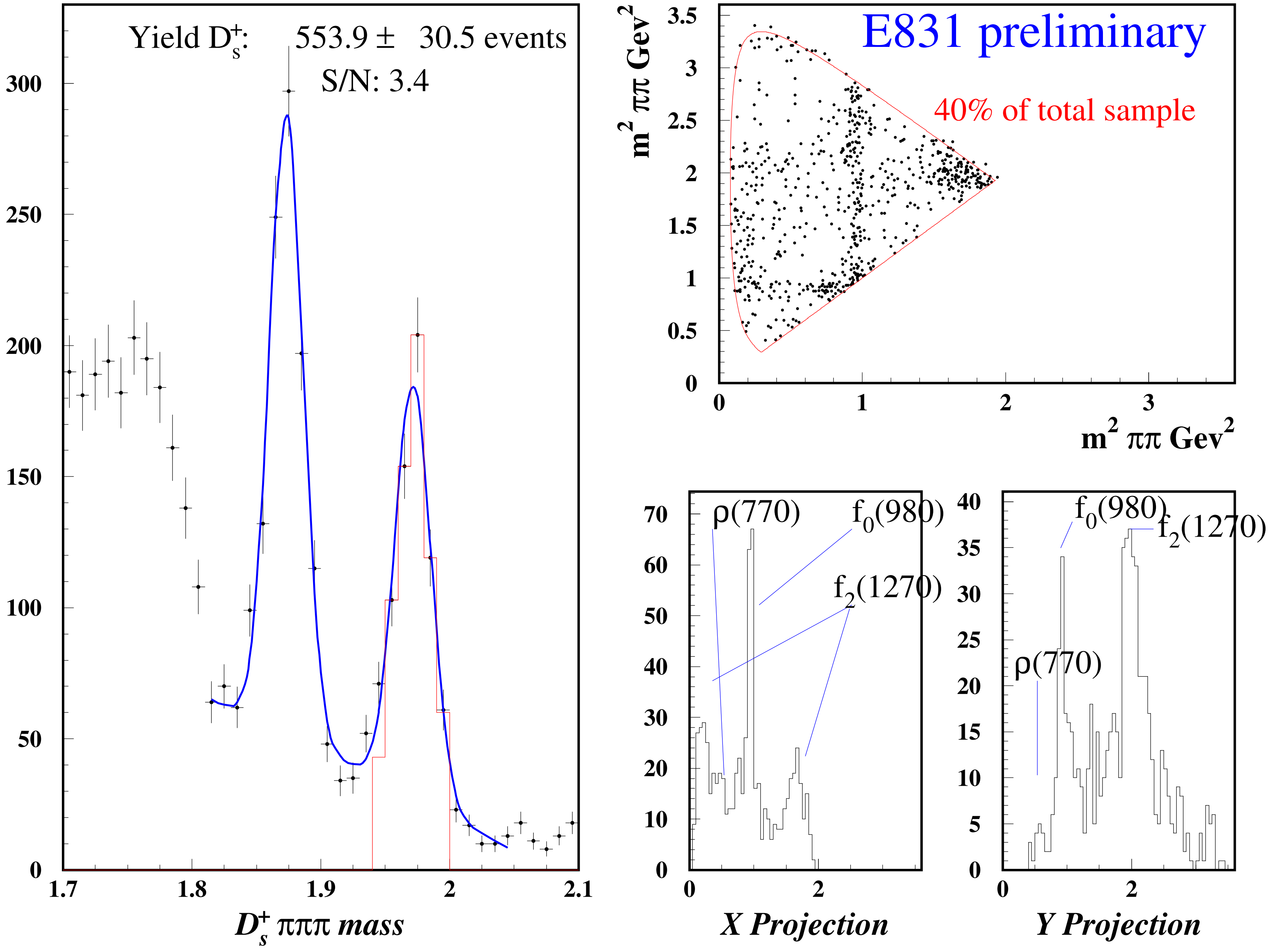


E687 $D_s^+ \to \pi^-\pi^+\pi^+$ Dalitz analysis

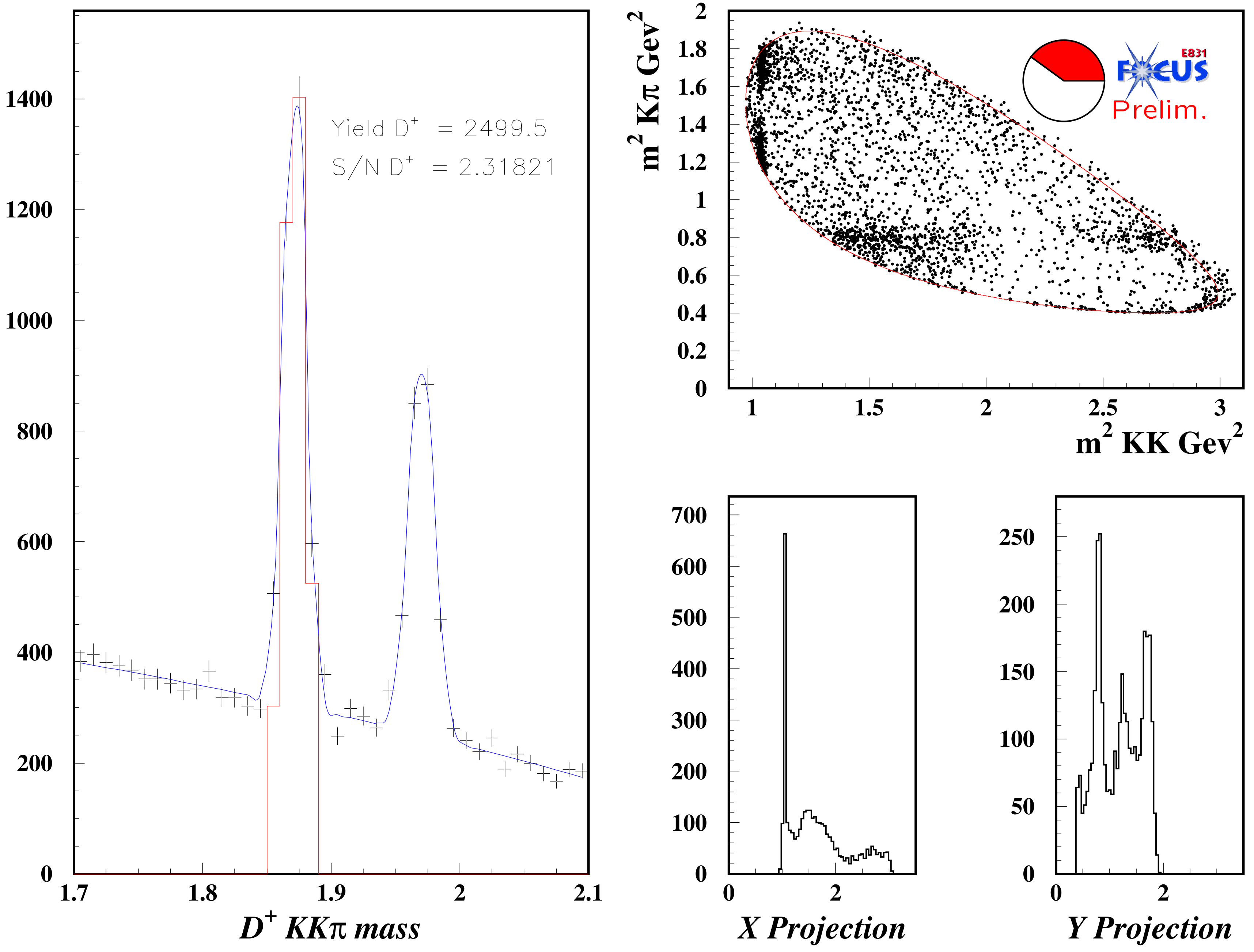


$D_s^+ \to \pi^-\pi^+\pi^+$ Dalitz fit results			
Decay Mode	Decay Fraction	Phase Degrees	Amp. Coeff
$f_2(1270)\pi$	0.147 ± 0.053	83 ± 16	0.42 ± 0.08
$f_0(980)\pi$	0.848 ± 0.067	0 (*fixed*)	1.0 (*fixed*)
$S(1475)\pi$	0.341 ± 0.078	210 ± 10	0.63 ± 0.09

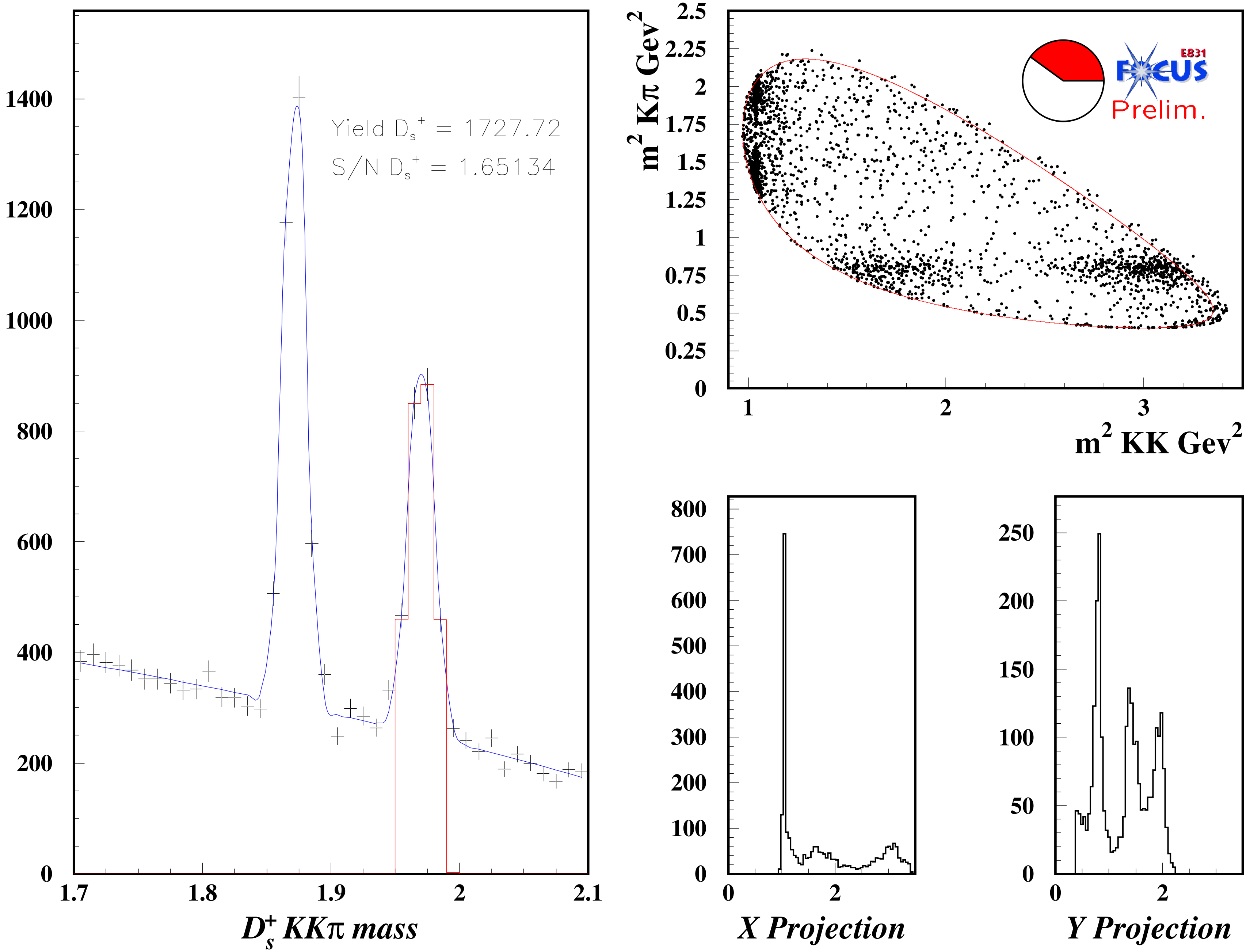
$D_s^+ \to \pi\pi\pi$ dalitz plot and projections



Dalitz $D^+ \rightarrow KK\pi$



Dalitz $D_s^+ \rightarrow KK\pi$



Future Dalitz Analysis

- Will check $K^-\pi^+\pi^+$ Dalitz.
  Some discrepancies in earlier studies

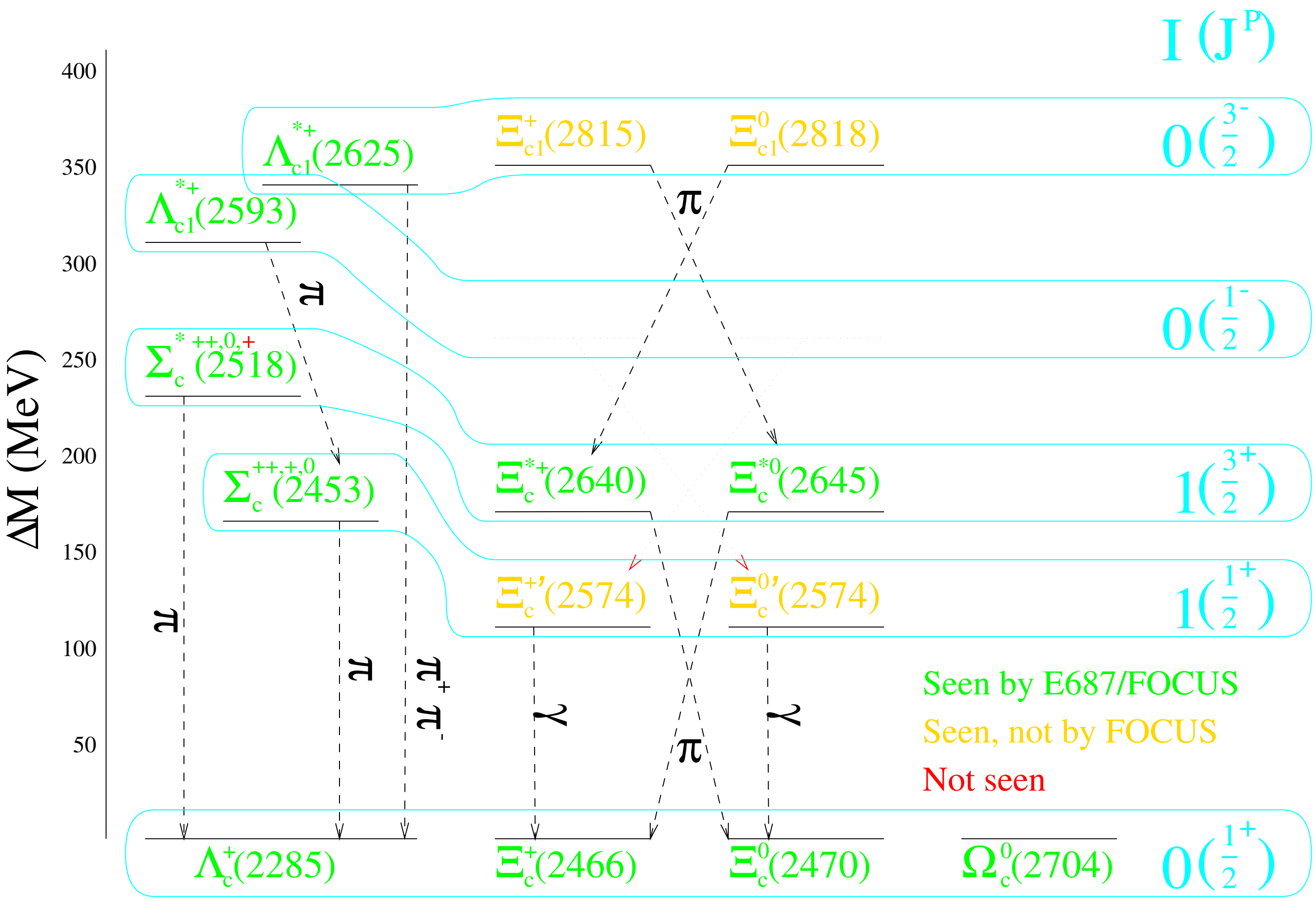
- $K^+K^-\pi^+$ and $\pi^+\pi^-\pi^+$
  - No evidence for $D_s^+ \to \rho^0\pi^+$
  - Will improve greatly on E687 results
  - Working towards full fits

- Doubly Cabibbo suppressed D^+ and
  Singly Cabibbo suppressed D_s^+
  - Recall talk by Jonathan Link
  - $K^+\pi^-\pi^+$: Our analysis underway
  - Will also study $K^+K^+K^-$ channels

- Also $K^0\pi^+\pi^-$ and $K^0K^\pm\pi^\mp$

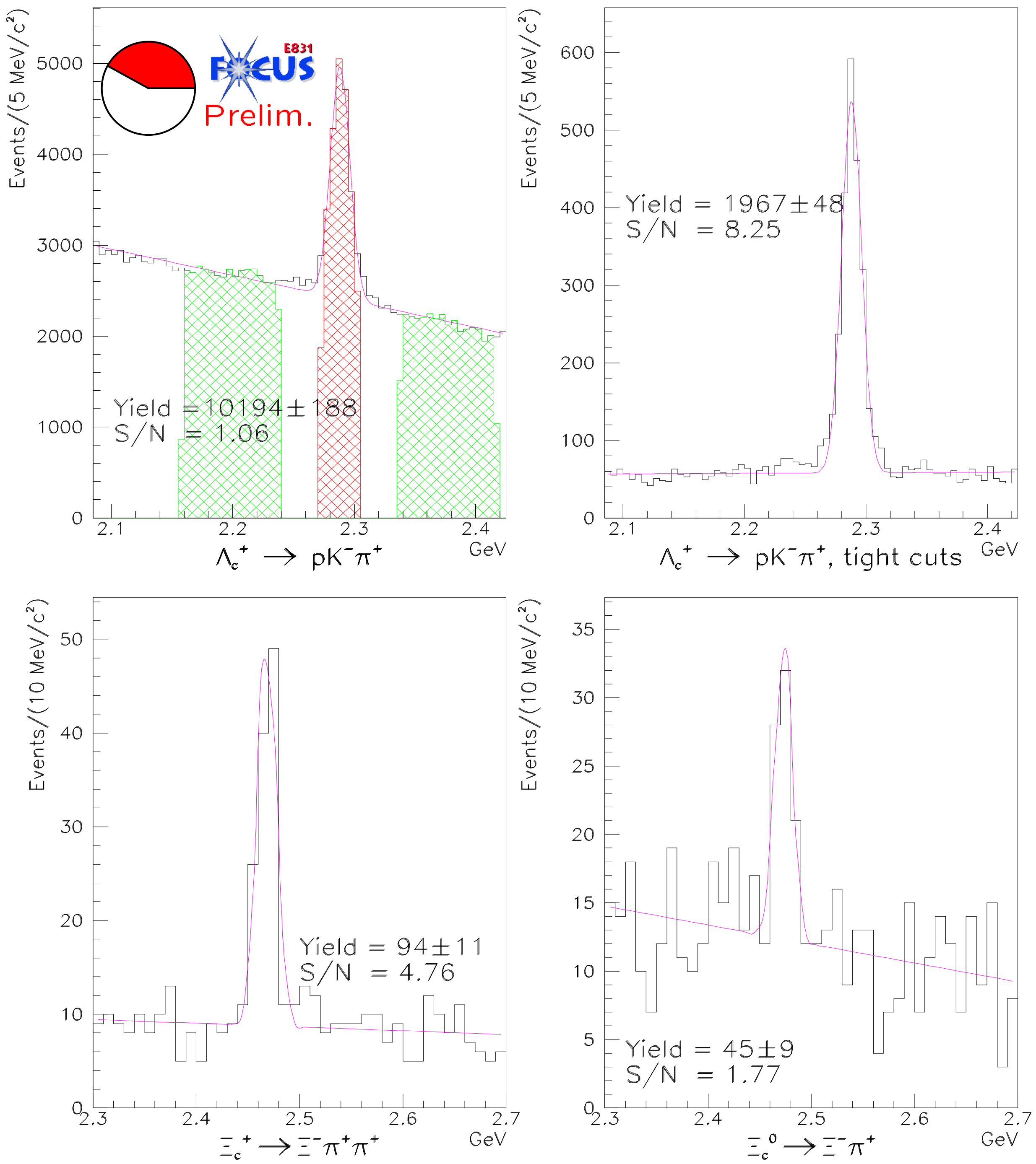
Charmed Baryon Spectroscopy

- 17 charmed baryon states have been observed

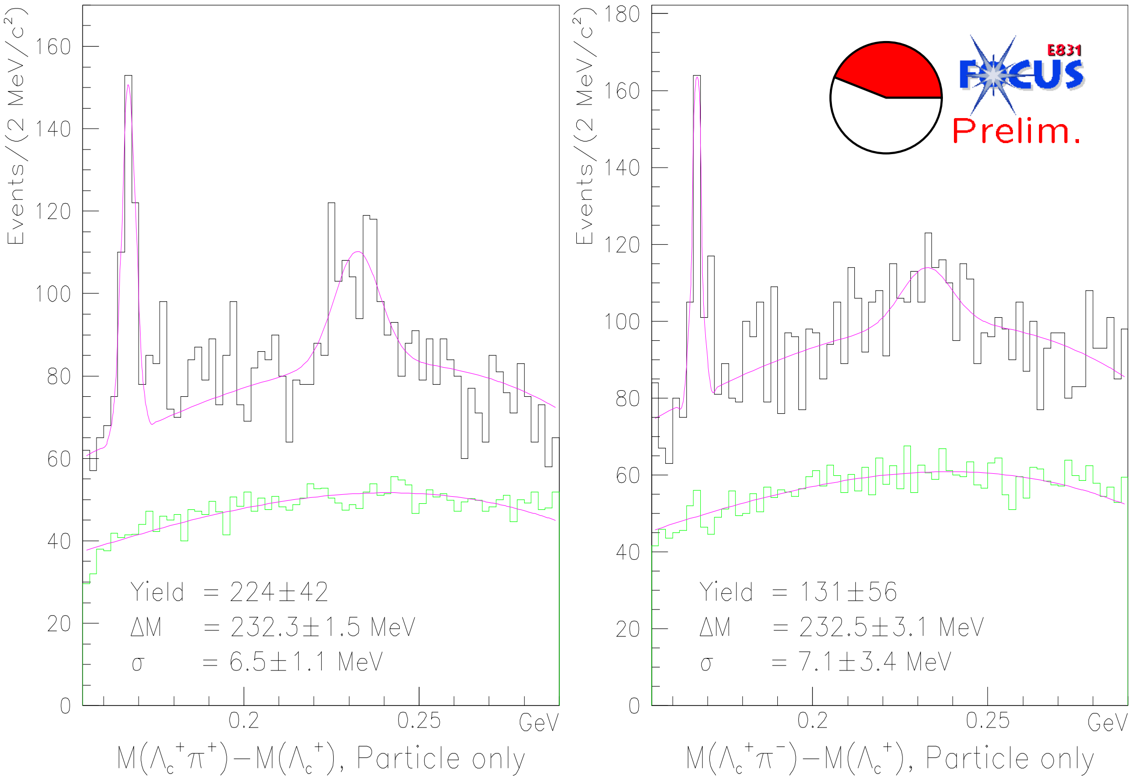


- Unobserved states in this scheme
  - $\Sigma_c^{*+}(2518)$
  - Ξ_{c1} states, expected to decay to $\Xi'_c\pi$
  - Excited Ω_c states, lowest likely decay $\Omega_c\gamma$
- Need to understand widths of states

- FOCUS will have large, clean samples of charm baryons

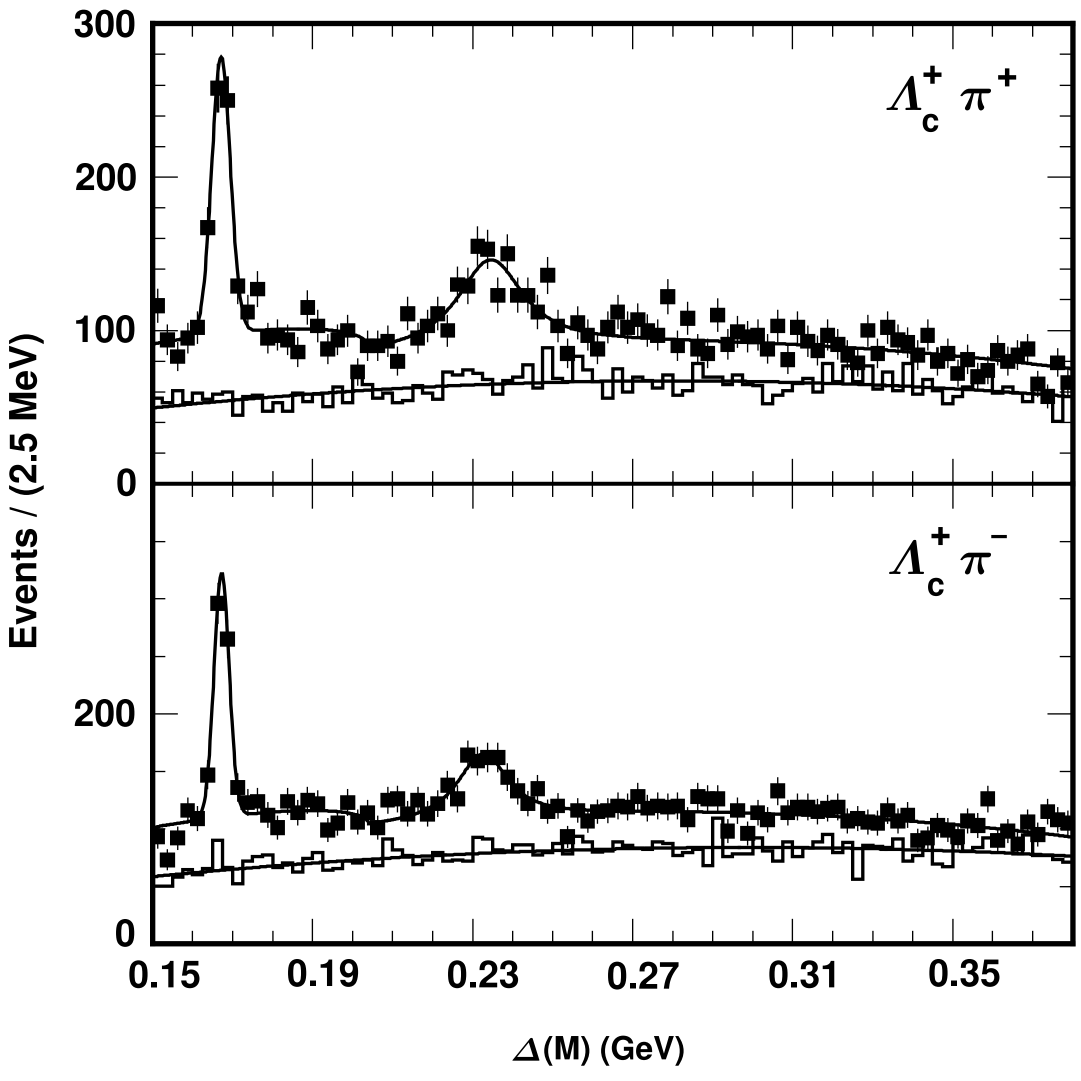


- $\Sigma_c^*(2518)$ seen by CLEO in 1996, FOCUS can confirm
  - Σ_c^{*++}: $\Delta M = 234.5 \pm 1.4$ MeV, $\Gamma = 18 \pm 5$ MeV
  - Σ_c^{*0}: $\Delta M = 232.6 \pm 1.3$ MeV, $\Gamma = 13 \pm 5$ MeV



- Higher energy states exist
  - Σ_{c1} (wide) and Σ_{c2} (narrow)
  - Higher excitations of Ξ_c states

CLEO $\Sigma_c^* \to \Lambda_c^+ \pi$ Signals



Σ_c^{*++}: 677 ± 97 events, $\Delta M = 234.5 \pm 1.4$ MeV, $\Gamma = 18 \pm 5$ MeV

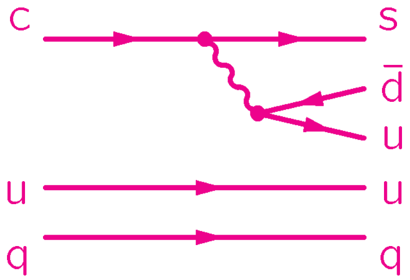
Σ_c^{*0}: 504 ± 88 events, $\Delta M = 232.6 \pm 1.3$ MeV, $\Gamma = 13 \pm 5$ MeV

Charmed Baryon Lifetimes

- Several contributions to hadronic partial widths

External Spectator
Γ_{ext}

W Exchange
Γ_{exc}



Internal Spectator (Destruct.)
Γ^{-}_{int}

Internal Spectator (Construct.)
Γ^{+}_{int}

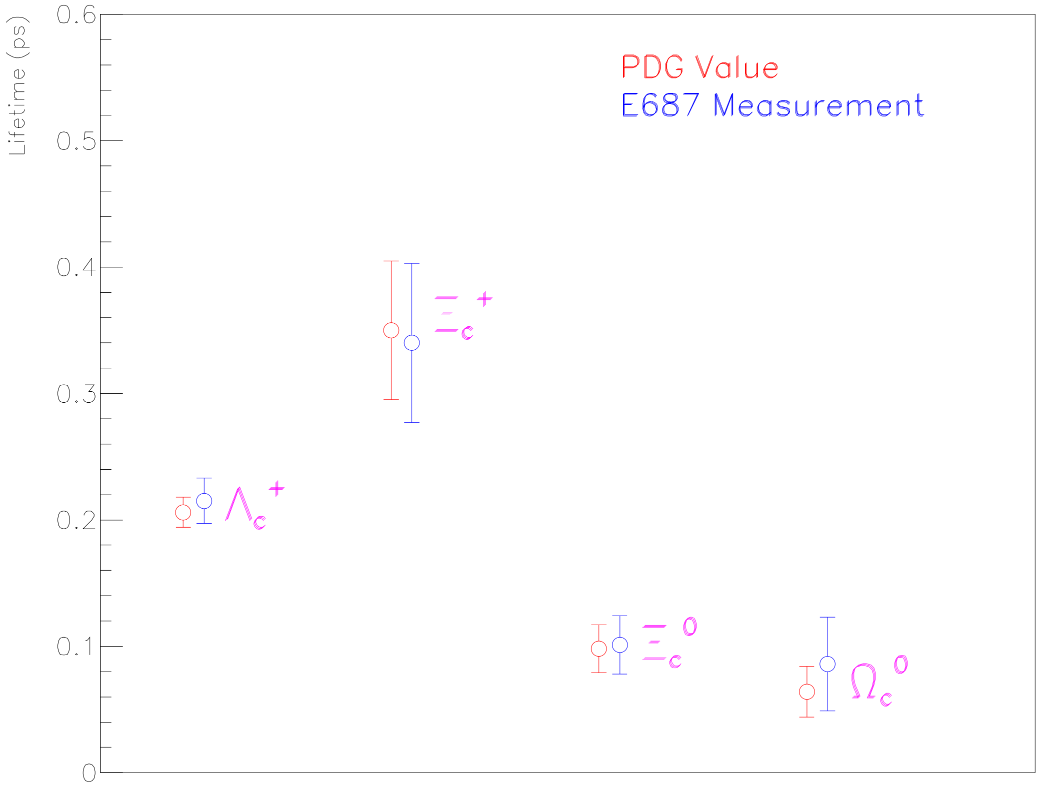
- Have ignored Cabibbo suppressed W exchange
  - May be important if CF W exchange dominates

- Each baryon has different contributions
  - Λ_c^+(cud): $\Gamma_{ext} + \Gamma_{exc} + \Gamma^{-}_{int}$
  - Ξ_c^+(csu): $\Gamma_{ext} + \Gamma^{-}_{int} + \Gamma^{+}_{int}$
  - Ξ_c^0(csd): $\Gamma_{ext} + \Gamma_{exc} + \Gamma^{+}_{int}$
  - Ω_c^0(css): $\Gamma_{ext} + \frac{10}{3} \times \Gamma^{+}_{int}$

- Measuring lifetimes critical to understanding magnitude of these contributions

- E687 is only experiment to measure all charmed baryon lifetimes

- FOCUS has better statistics and lifetime resolution



- Guberina, et al.: $\tau(\Omega_c^0) \approx \tau(\Xi_c^0) < \tau(\Lambda_c^+) < \tau(\Xi_c^+)$

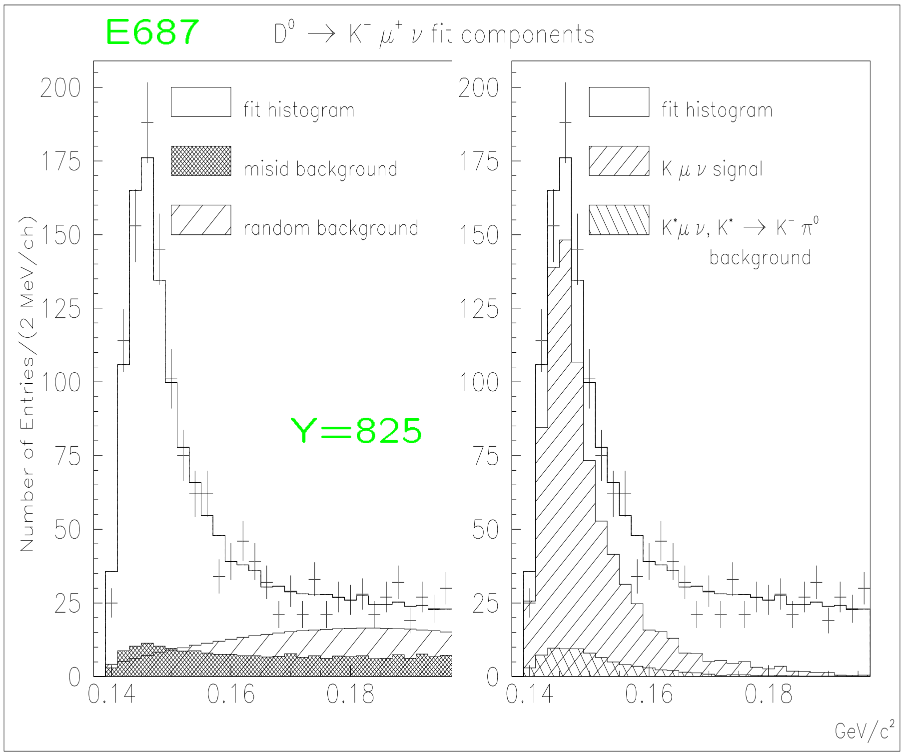
- Data is inconclusive w.r.t. $\tau(\Omega_c^0), \tau(\Xi_c^0)$

Rare and Forbidden Decays

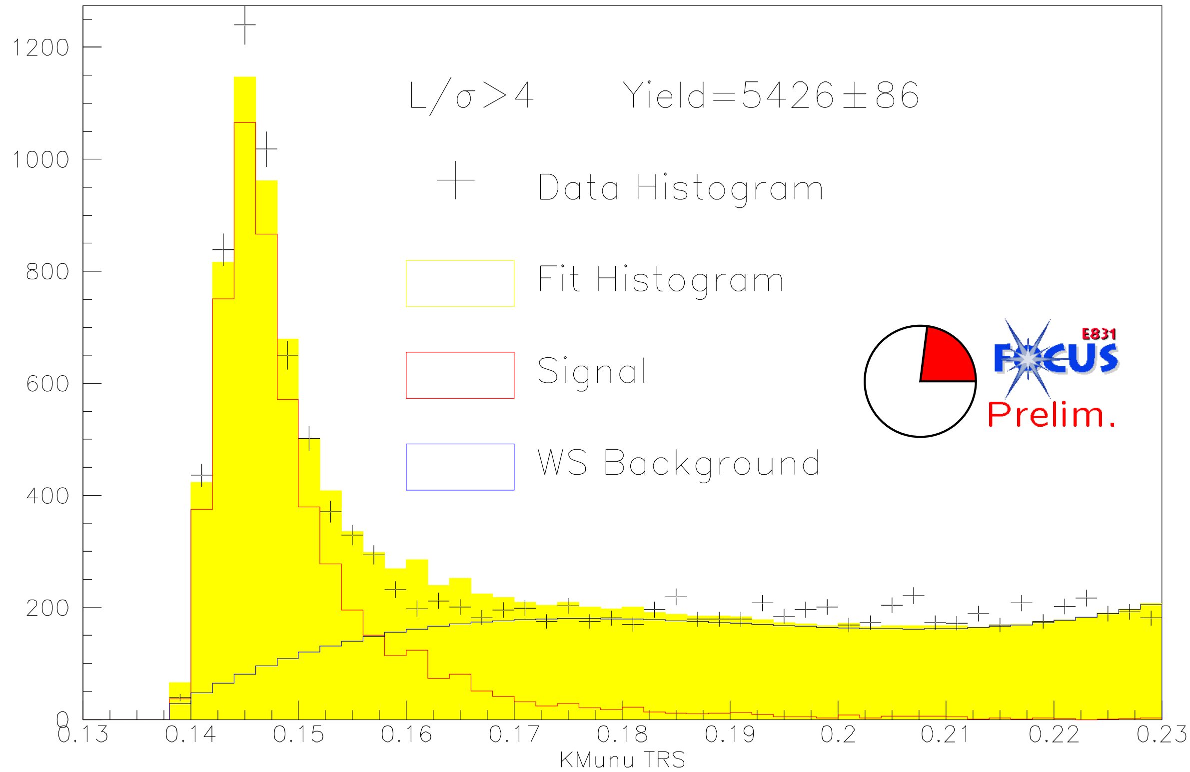
- Flavor Changing Neutral Current (FCNC)
  - SM predicts FCNC in charm sector $< 10^{-8}$
  - Larger rate would imply physics beyond the SM
  - Easiest place to look is $D^+ \to X l^+ l^-$
    - $*$ $D^0 \to l^+ l^-$ helicity suppressed $\times 10^{-3} - 10^{-7}$

D^+ Decay Mode	E687 Limit ($\times 10^{-5}$)	Previous Limit ($\times 10^{-5}$)
$\pi^+ e^+ e^-$	11	6.6
$K^+ e^+ e^-$	20	480
$\pi^+ \mu^+ \mu^-$	8.9	1.8
$K^+ \mu^+ \mu^-$	9.7	32
E791 limits lower than E687		

  - E687 signals are nearly background free
  - FOCUS could lower $\mu\mu$ limits by about 30$\times$, and ee limits by about 10$\times$



$$D^{*+} \to D^0 \pi^+,\ D^0 \to K^- \mu^+ \nu$$



See talk by Will Johns for FOCUS semileptonics

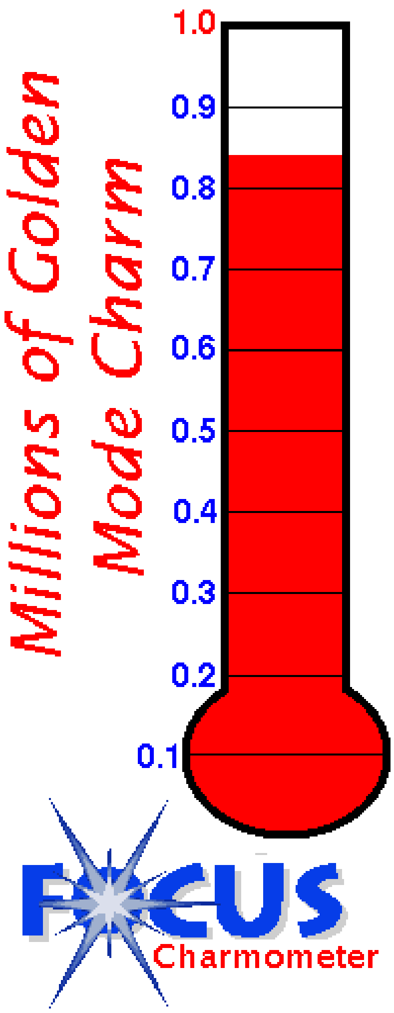
- Lepton Family Number Violating (LFNV) and Lepton Number Violating (LNV) decays
  - Forbidden by Standard Model
  - FCNC or LFNV decays may be induced by leptoquarks or new gauge bosons

D^+ Decay Mode	E687 Limit ($\times 10^{-5}$)	Previous Limit ($\times 10^{-5}$)
$\pi^+\mu^+e^-$	13	330
$K^+\mu^+e^-$	12	340
$\pi^+e^+\mu^-$	11	330
$K^+e^+\mu^-$	13	340
$\pi^-e^+e^+$	11	480
$K^-e^+e^+$	12	910
$\pi^-\mu^+\mu^+$	8.7	22
$K^-\mu^+\mu^+$	12	32
$\pi^-\mu^+e^+$	11	370
$K^-\mu^+e^+$	13	400

  - Best limits in all channels by E687
  - FOCUS will be substantially better

Reconstruction Timetable

- Data reconstruction done at FNAL
- Early look at lots of data
  - Many signals with 20-45% sample
  - Invaluable experience
- 1^{st} level event selection in progress
  - By Vanderbilt, Colorado
  - Will finish early 1999
- 2^{nd} level event selection gearing up
  - Many institutions
  - Also in early 1999



The graph on the right is a representation of the total number of $D^+ \to K\pi\pi$, $D^0 \to K3\pi$, and $D^0 \to K\pi$ decays collected by FOCUS. This estimate uses a non-optimized reconstruction method which substantially underestimates the total.

Conclusions

- FOCUS surpassed its quantitative data collection goals in monitoring channels
- FOCUS data quality is significantly better than E687
- We will make valuable contributions in many areas
  - Meson lifetimes, decay processes, branching ratios
  - Rare and forbidden meson decays
  - Baryon spectroscopy, lifetimes, decay processes
  - Semileptonics
    - See talk by Will Johns
- First results next year

Watch for results on the web

www-focus.fnal.gov