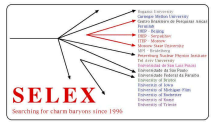


First Observation of a New Narrow D_s^+ Meson at 2632 MeV/c^2

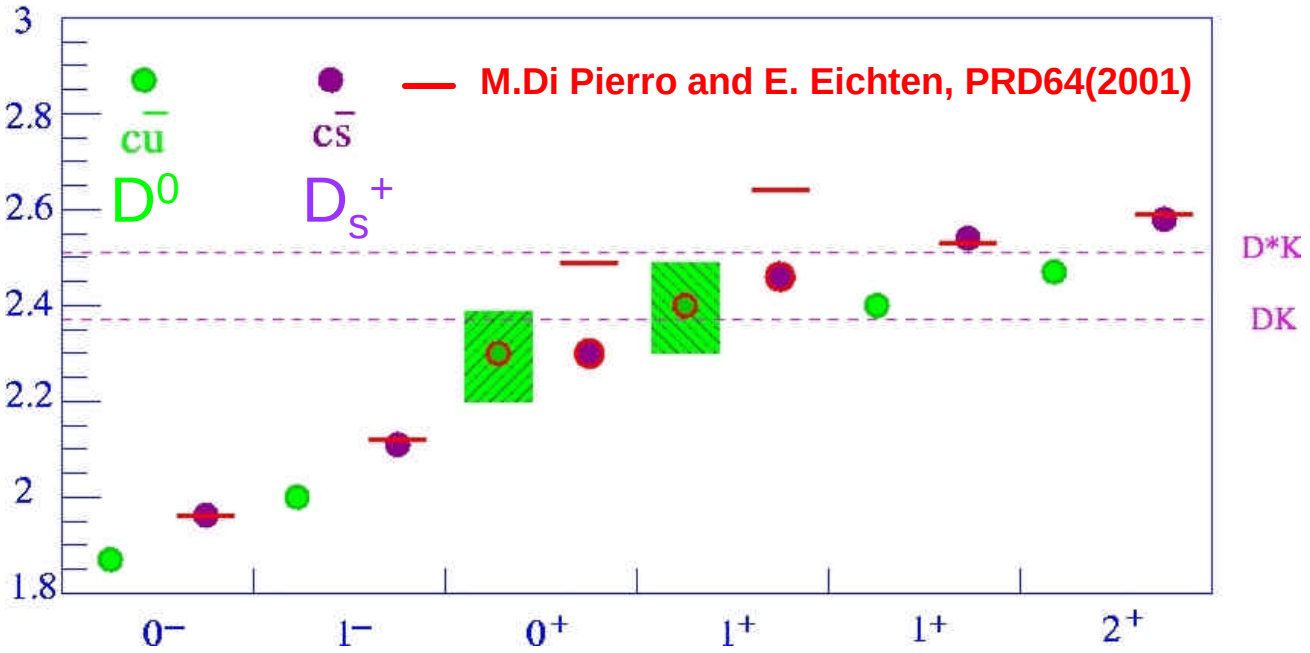
Peter S. Cooper

Fermi National Accelerator Laboratory

Batavia, IL

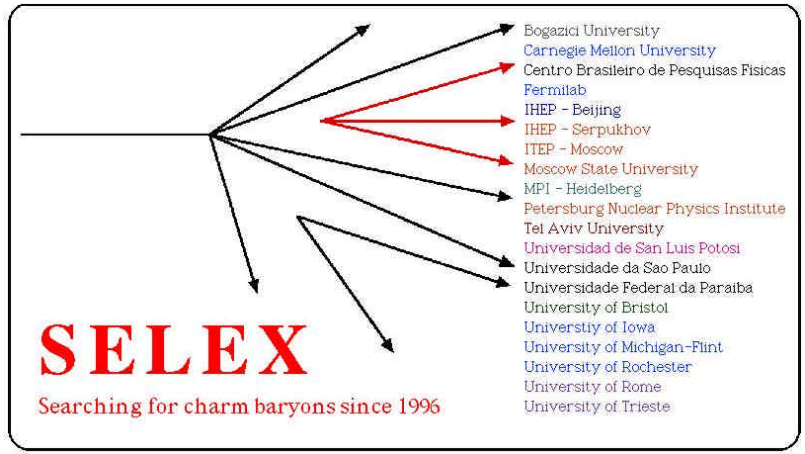
(*for the SELEX collaboration*)

Heavy-light spectroscopy



- Model predicts mass and widths – works well for D($c\bar{d}$), but not for all D_s($c\bar{s}$)
- 2003 – e^+e^- found Ds(2317), Ds(2463) – below DK threshold, inconsistent with model
- Higher states – expected above $D^{(*)}K$ threshold – therefore broad and hard to observe

SELEX(E781) Experiment

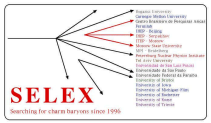


***SE**gmented **L**argE **X**$_F$ ($x_F > 0.1$) Experiment*

- SELEX(E781) is a multi-stage charged particle spectrometer with high acceptance for forward production and decays
- 1996-1997 Fixed Target Run at Fermilab Hyperon Beam with 600 GeV/c Σ^-, π^-

- 125 participants from 20 institution in 11 countries

SELEX Collaboration



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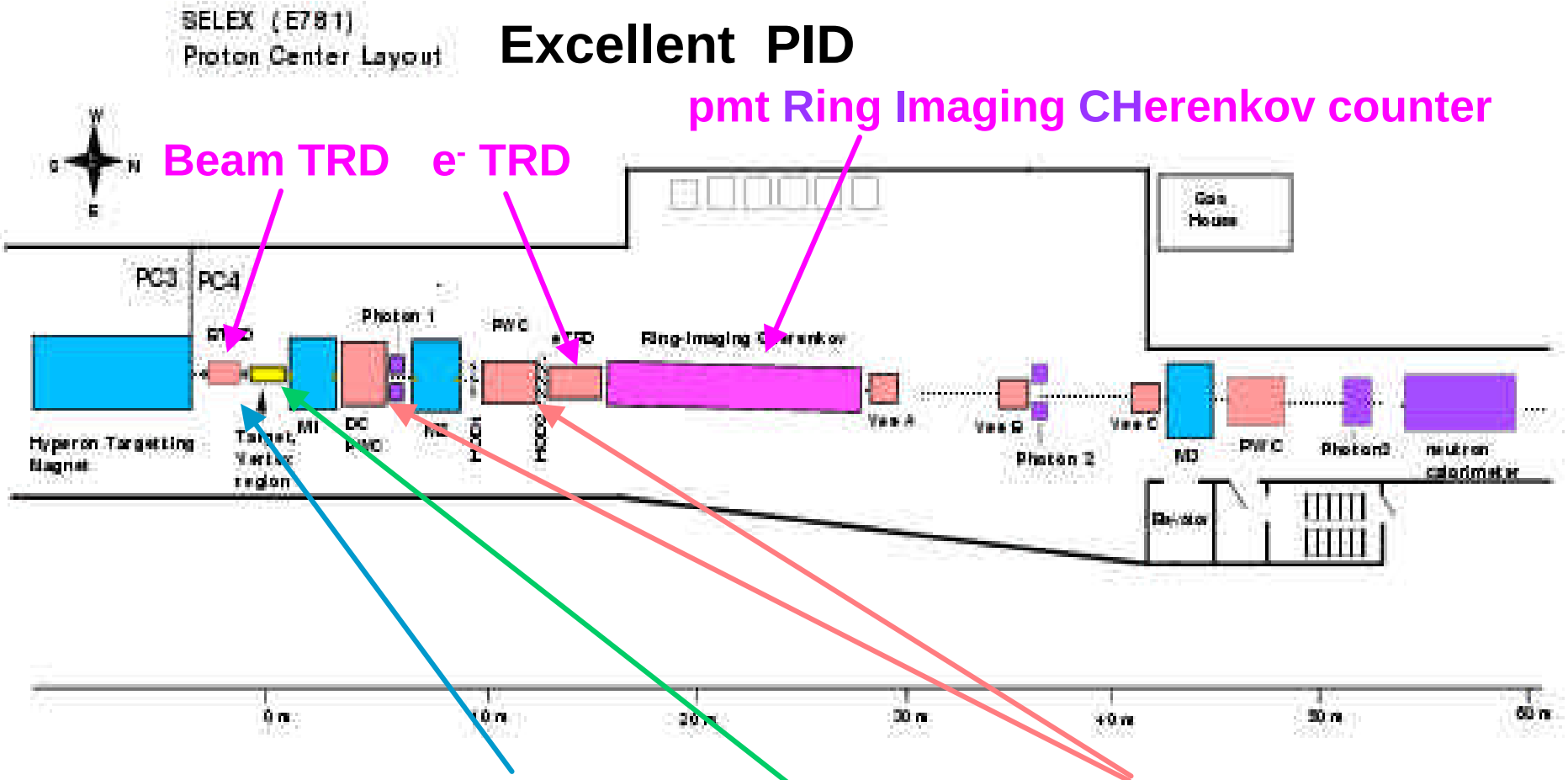
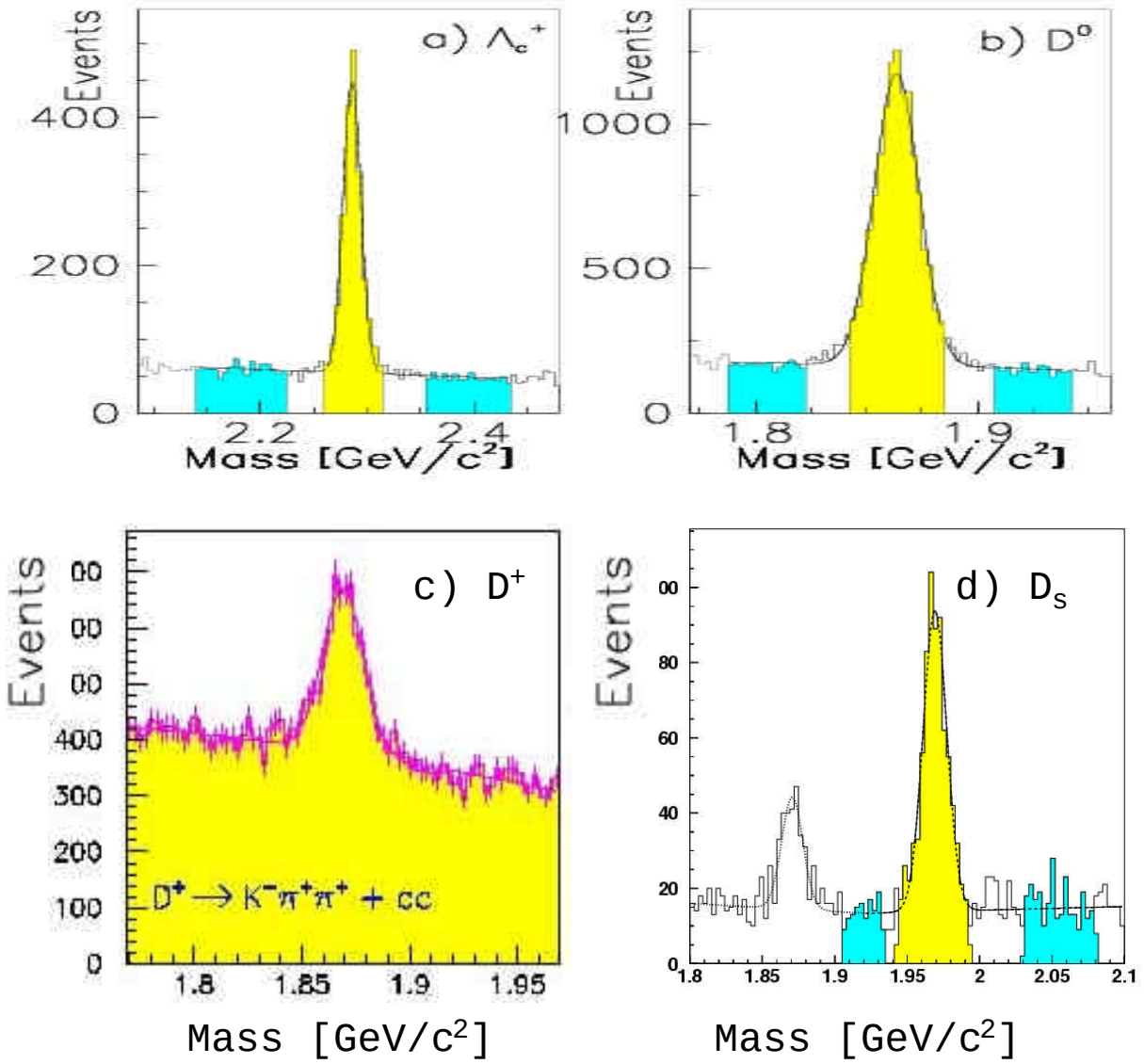
SELEX(E781) Tracking

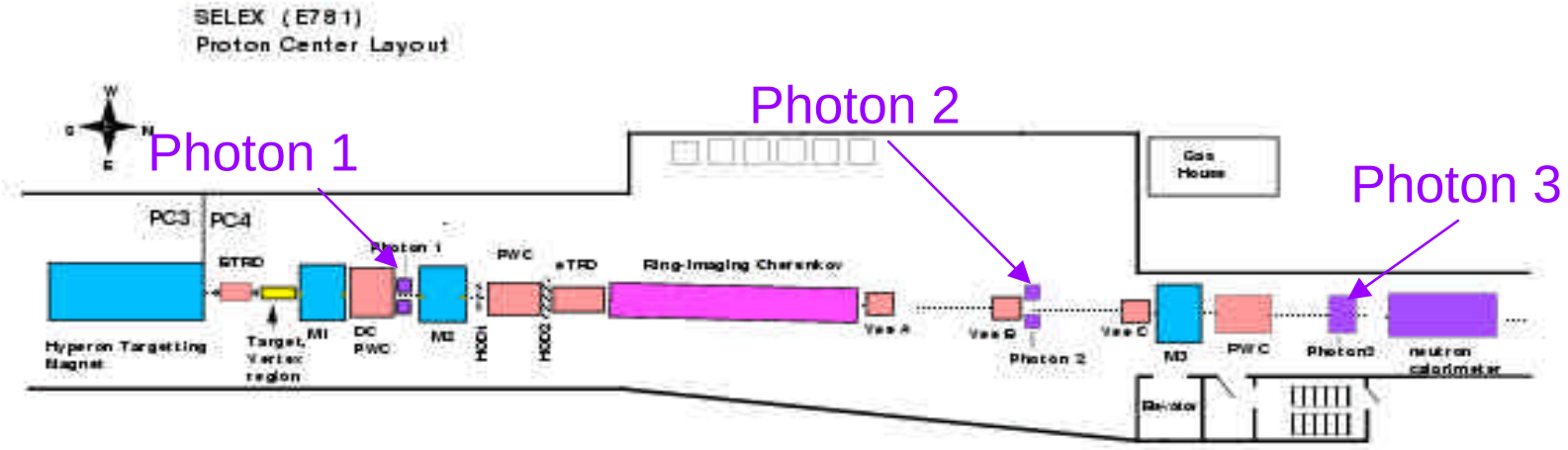


SELEX single charm states



This analysis uses D^0 and D_s data

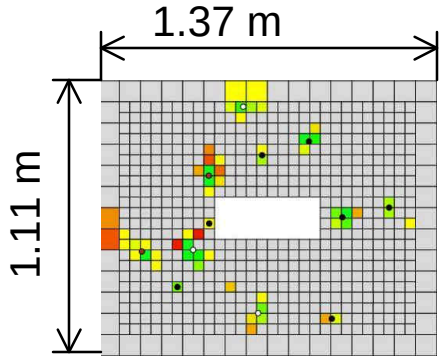
SELEX(E781) Photon Detectors



Each Spectrometer includes Lead-Glass Photon Calorimeter

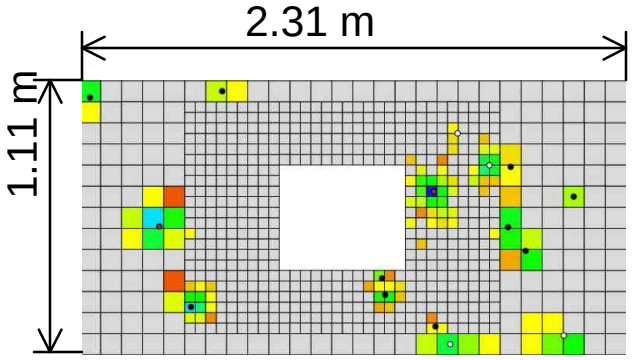
2 p coverage in c.m. of primary interaction

1GeV < E g< 10GeV



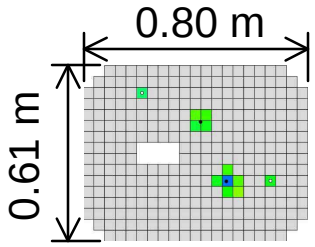
630 Channels

2GeV < E g< 40GeV



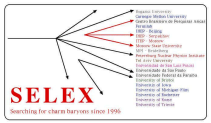
726 Channels

4GeV < E g< 80GeV

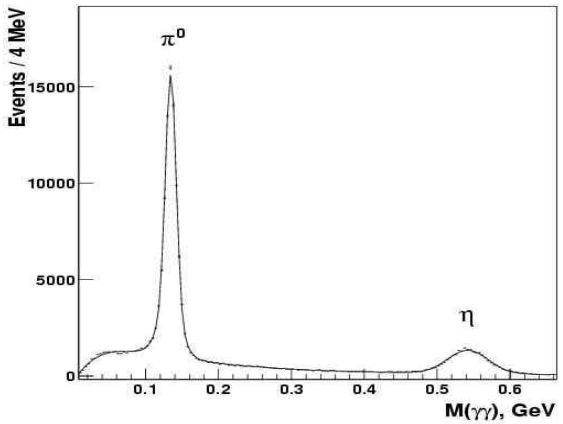


316 Channels

Mass distributions - Exclusive trigger (N_{ch} 3-5)

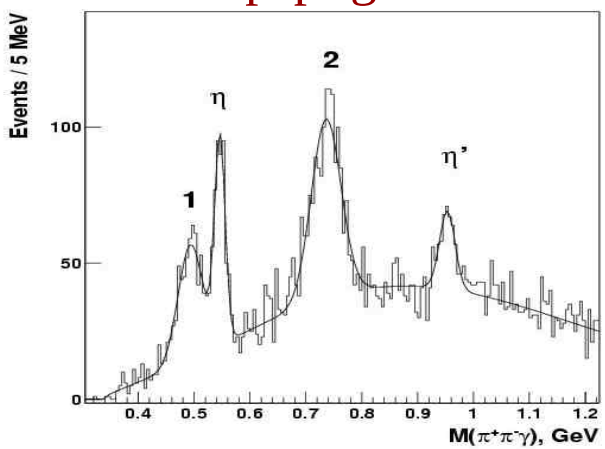


gg



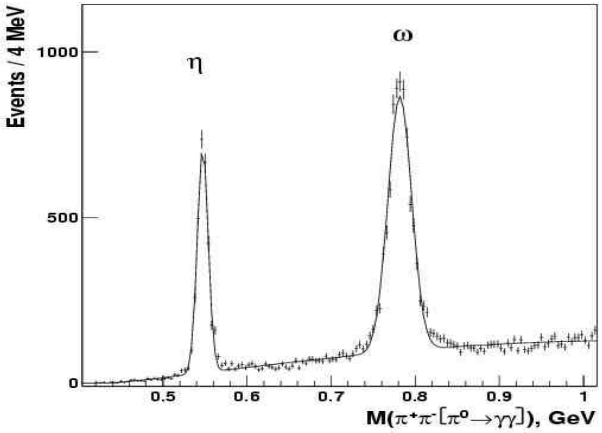
E g 2 GeV, N g= 2, E gg>10GeV

$p^- p^+ g$



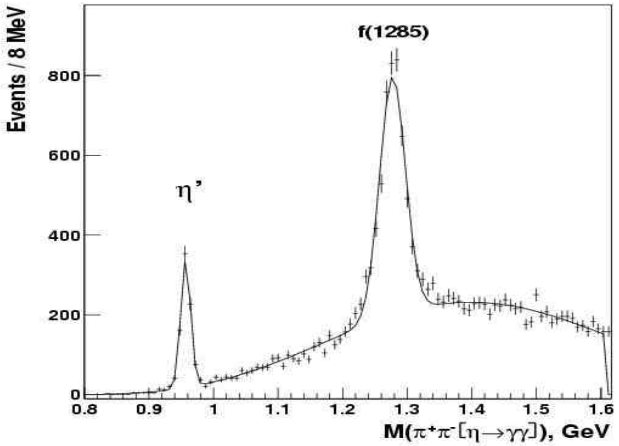
E g 2 GeV N g= 2 E gg>10GeV

$p^- p^+ (p^0 \rightarrow gg)$



E g 2 GeV N g= 2 E gg>10GeV

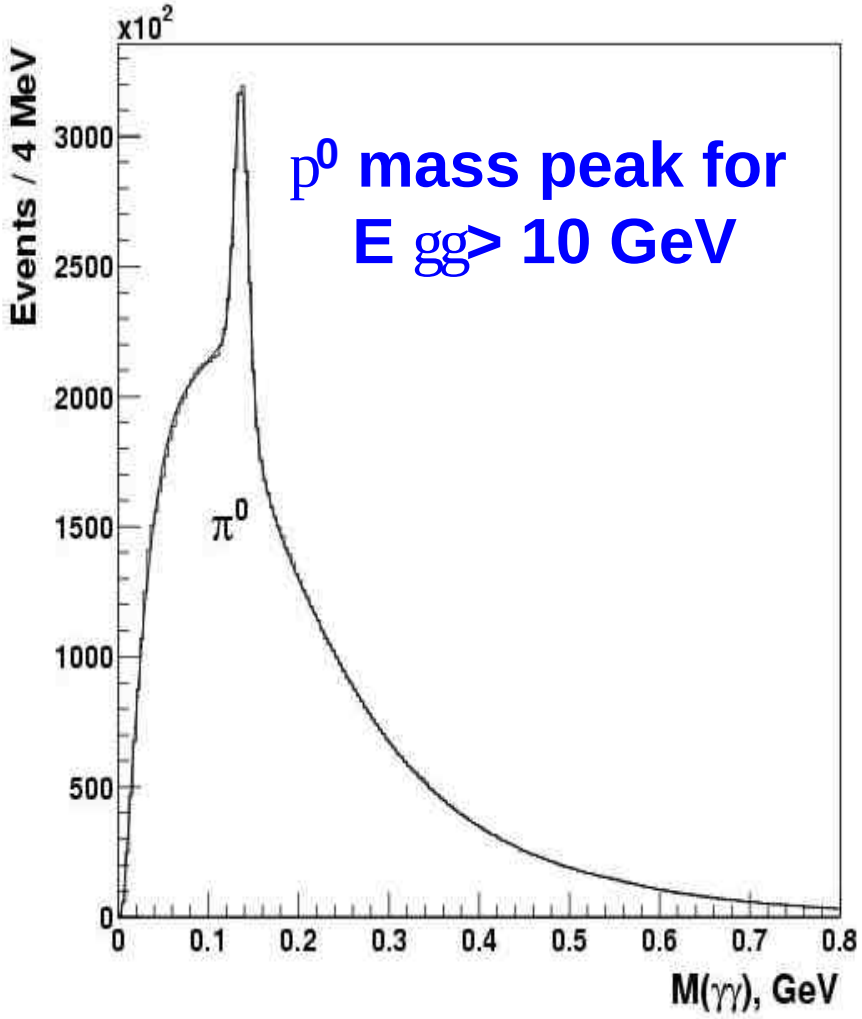
$p^- p^+ (h \rightarrow gg)$



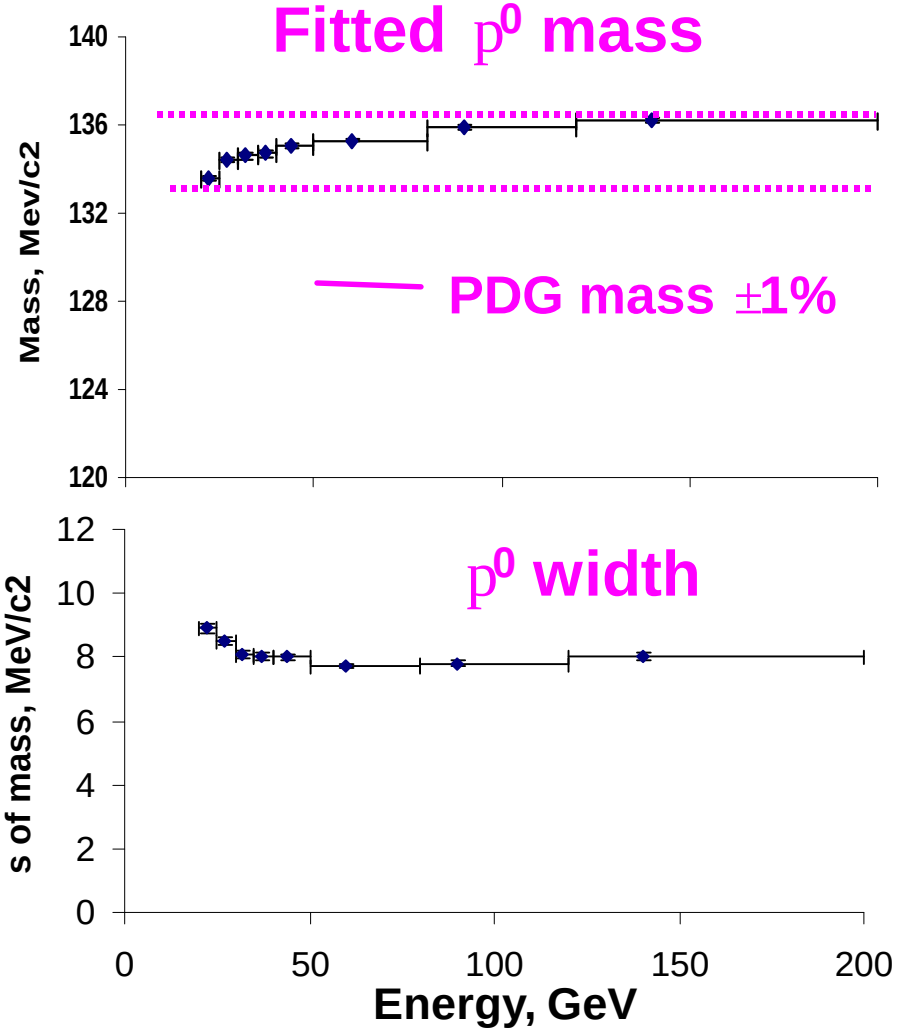
E g 2 GeV N g= 2 E gg>10GeV

CHARM trigger $\langle n_{ch} \rangle = 10$, $\langle n_{\gamma} \rangle = 8$

Photon cuts: E g>2 GeV, N g£10

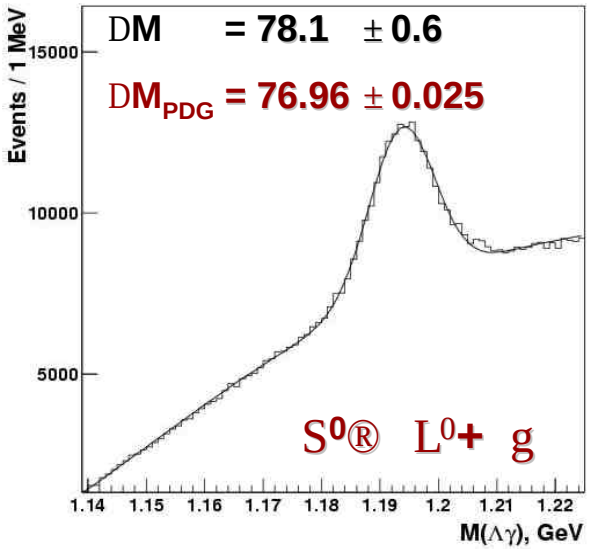


p^0 mass peak for
E gg> 10 GeV



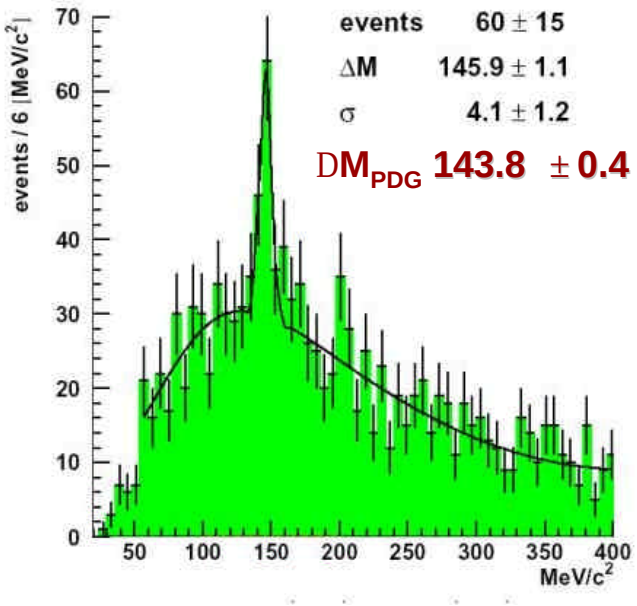
Single Photon States

Use $\Sigma^0 \to \Lambda^0 + \gamma$ to test energy scale



- ✓ Photon energy scale agrees better than 2% for this decay

Study Ds (2112) $\to$ Ds+ γ

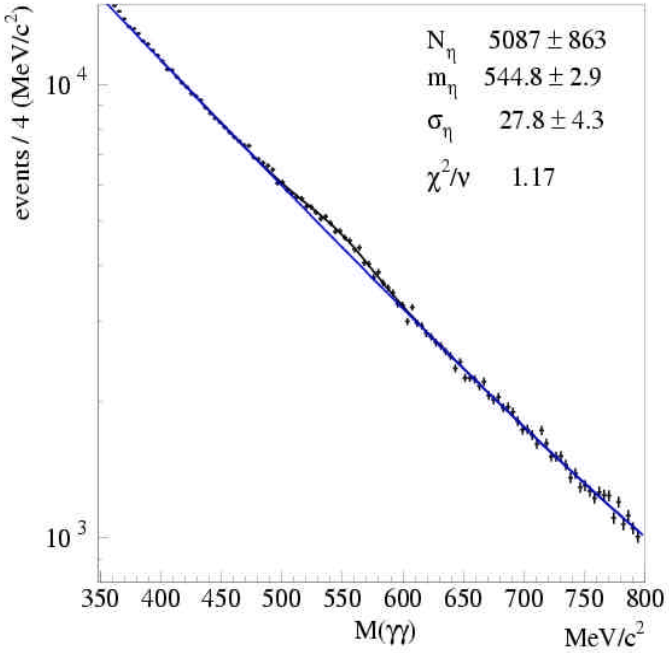


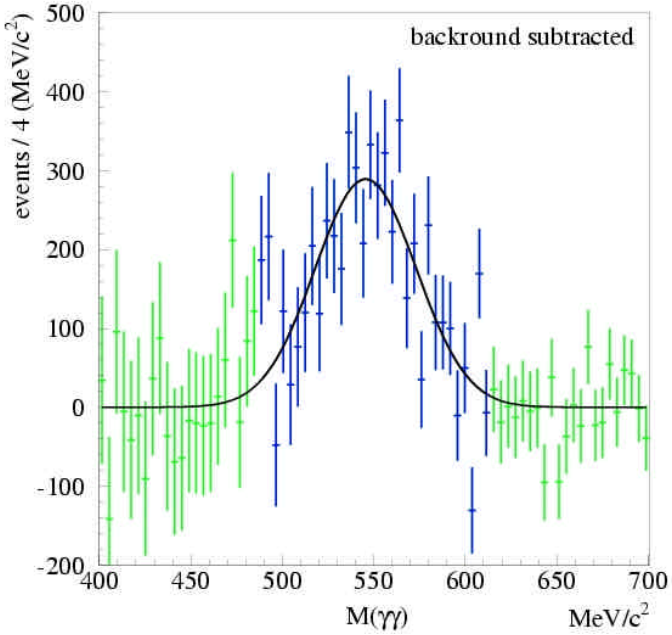
- ✓ Fitted with Gaussian width taken from Monte-Carlo
- ✓ Good argeement

✓ We understand detector response

✓ will use Monte-Carlo resolution in fits

h^0 signal in CHARM trigger





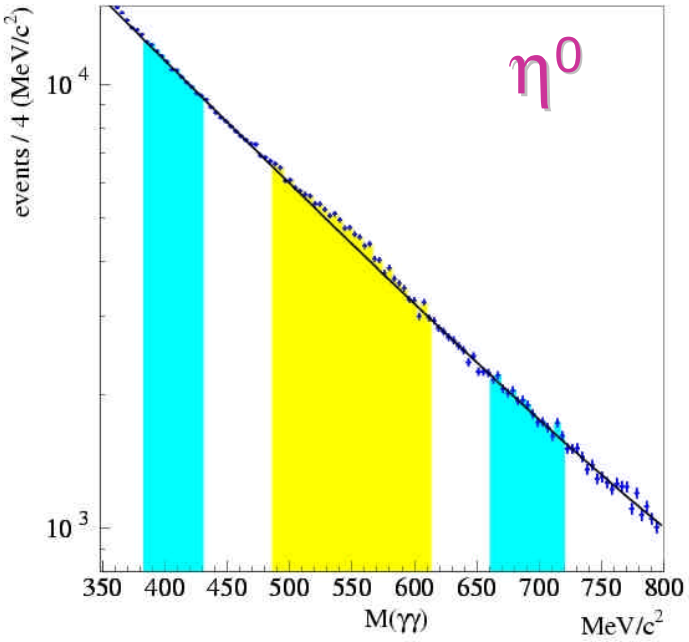
- ✓ Eγ >2 GeV,
- ✓ Eγγ > 10GeV,
- ✓ Nγ < 10
- ✓ Fit to: exp + Gaussian + constant
- ✓ good fit

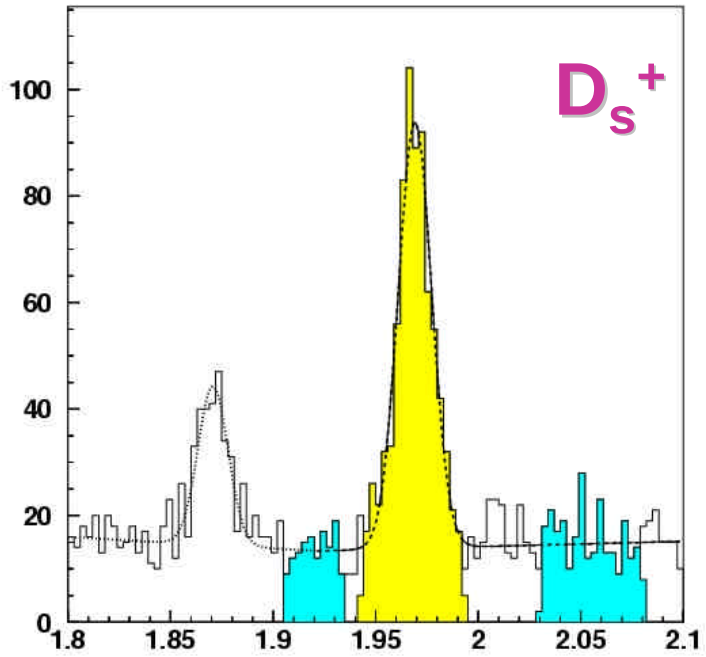
Fit M(η^0)	544.8 ± 2.9
PDG M(η^0)	547.3 ± 0.12
Fit resolution	27.8 ± 4.3
MC resolution	30.2 ± 1.2

✓ h^0 mass agrees with PDG value.

✓ MC represents resolution well.

η and D_s selection

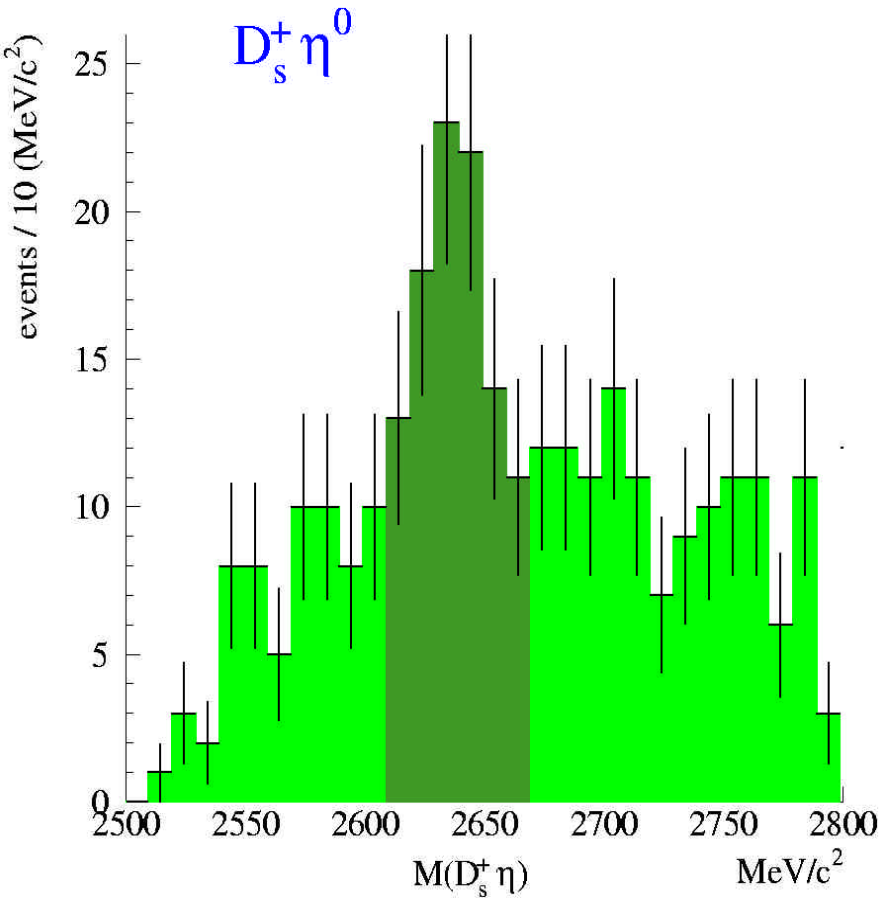




- ✓ Eγ >2 GeV, Eγγ > 15GeV
- ✓ η^0 mass region: $M_{PDG}(\eta^0) \pm 60$ MeV
- ✓ 5M η^0 in 150M candidates
  S/N ~ 1/30
- ✓ 0.15 η^0 candidates /event

- ✓ L/σ > 8, pvtx <8
- ✓ |M(KKπ) – 1968.5|< 25 MeV
- ✓ ~0.7 η^0 candidate/ D_s candidate

New charm-strange meson



✓We combined our clean sample of Ds with η^0 candidates

h® **mass constrained** p_h® **=[** M_{PDG}**(h), p]**

✓Reject events with Nη > 5 candidates (small loss)

✓ 384 η^0 cand in 554 D_s cand

- 52 ± 33 η^0 signal events
- 317 on plot, 67 overflows

✓Clear peak near 2635 MeV/c²

DM^+ **=** $M_{PDG}(D_s)$ **= M(KK ph)-M(KK p) +** $M_{PDG}(D_s)$

Sideband studies

Sidebands:

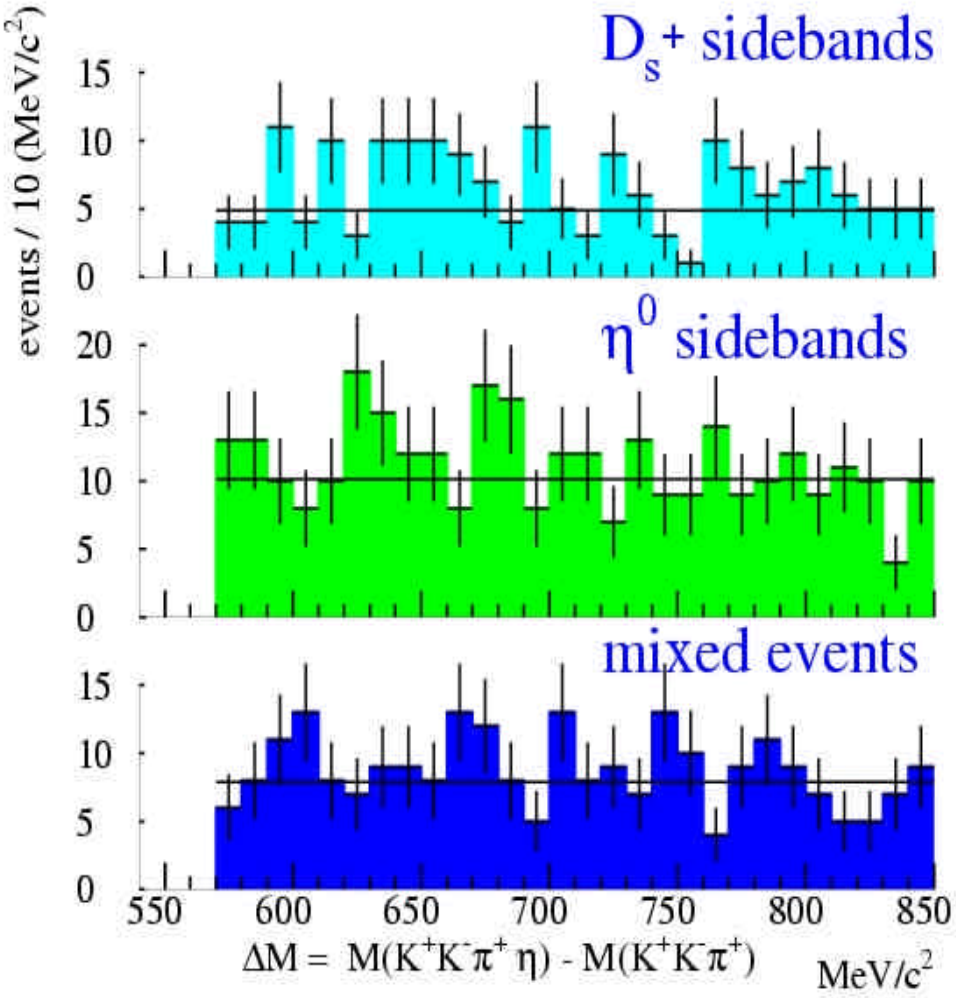
- ✓Ds sidebands + real η
- ✓η sidebands + real D_s

Event mixed technique:

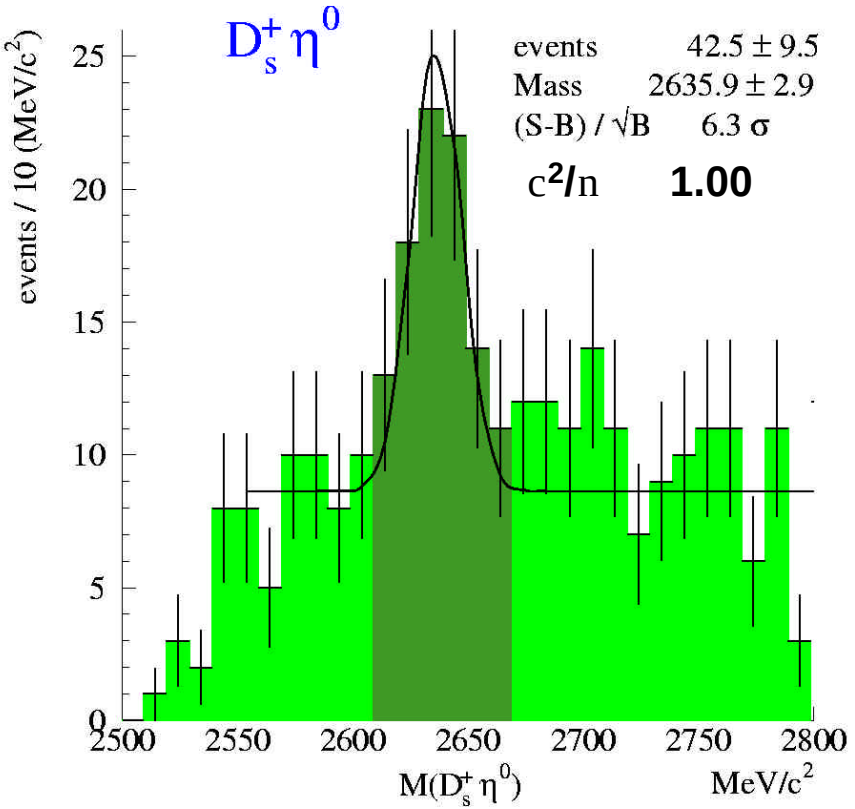
- ✓η^0 from previous event + D_s candidate

✓ No structure seen anywhere

✓ All distributions fit constant backgrounds.



Fit to D_{sJ} mass



Probability of 6 bins region with >100 events anywhere on this plot with background of 54.4±**2.5**:

3 x 10^{-6}

- ✓M-C simulation gives resolution of 10.7 MeV
- ✓Sideband studies show that background is flat
- ✓Fit with fixed width Gaussian and constant background to data + mixed events background
- ✓c^2 for fit is good

Count S = 101, B = 54.4 ± 2.5

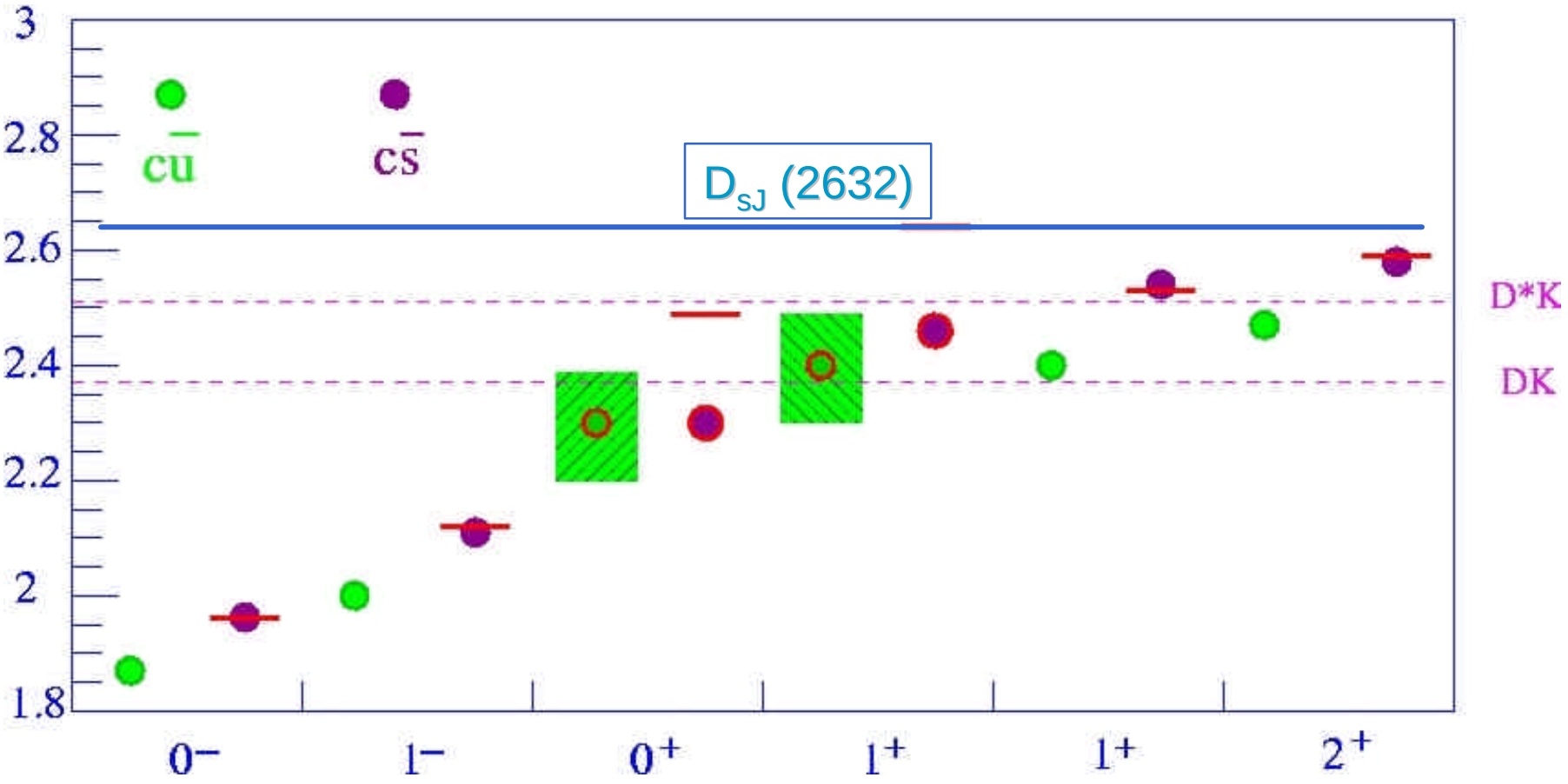
(S-B)/√B = 6.3 σ

Fit events: 42.5 ± 9.5

Mass 2635.9 ± 2.9 MeV/c^2

σ (fixed MC) 10.7 MeV/c^2

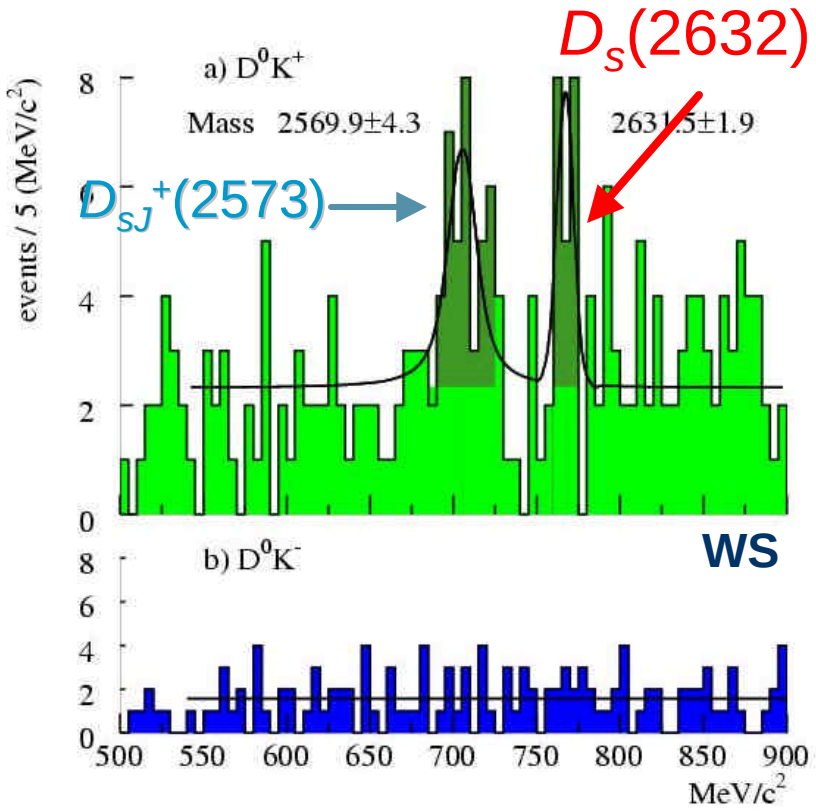
Heavy-light spectroscopy now



New state lies above $D^{(0)}$ K threshold

We looked for Ds(2632) $\overset{?}{\Rightarrow} D^0K^+$

Fitting D_s (2632) → D^0 K^+



DsJ(2573) PDG	**2573.5 ± 1.7 MeV/c²**	**15^{+5}_{-4} MeV/c²**
DsJ(2573) SELEX	**2569.9 ± 4.3 MeV/c²**	**14^{+9}_{-6} MeV/c²**

- ✓ Strong selection criteria on D_s & K^+
  - ✓ $D^0 \rightarrow K^- \pi^+$ only (S/N 4/1)
  - ✓ L/σ>6, svtx χ^2<3, pointback χ^2<5
  - ✓ Prob(K^+) >10 Prob(any other)
- ✓ Wrong sign background constant
- ✓Fit with 2 [BW convolved with Gaussian] + constant background
- ✓Fix resolution from MC (4.9 MeV)

New state is narrow (resolution only)

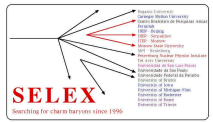
Count S = 21, B = 7.0 ± 0.6, (S-B)/√B = 5.3 σ

3 bin Poisson excess probability = 1×10^{-4}

Fit events: 14 ± 4.5, Mass 2631.5 ± 1.9 MeV/c²

✓A 90% CL upper limit Γ<17MeV/c²

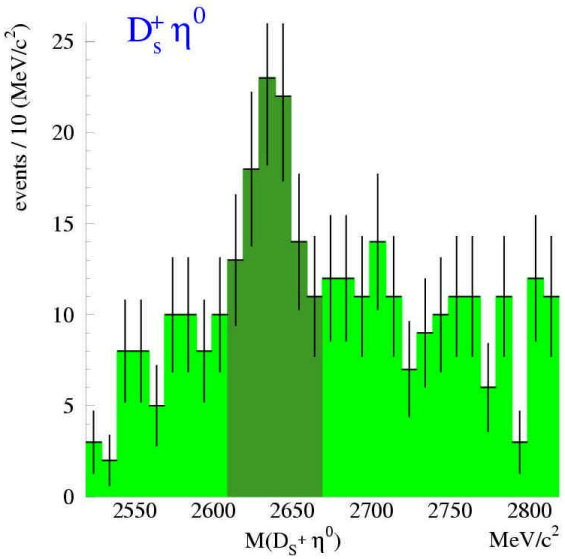
$D_{sJ}(2632)$ Branching Ratios

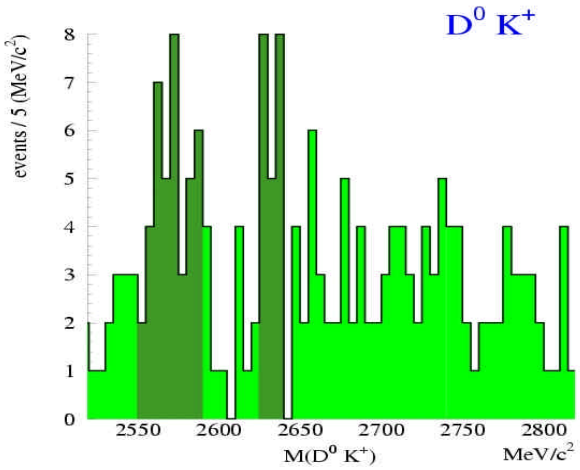


- Most models say that D^0K^+ coupling should be much bigger than $D_s^+ h^0$
- Phase space favors D^0K^+ mode by 2.3x
- Acceptances given a detected D(s) meson are comparable
- We see 3x as many $D_s^+ h^0$ decays as D^0K^+

SURPRISE: $\Gamma(D^0 K^+)/ \Gamma(D_s^+\eta^0) = 0.16 +/- 0.06$

Ds (2632) summary

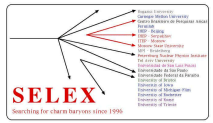




State	**Ds (2632) ® Dsh**	**Ds(2632) ® D^0K**
mass	2635.9 ± 2.9	2631.5 ± 1.9
Sign.	6.3 s	5.3 s
Events	42.5 ± 9.5	14 ± 4.5
c^2 / n_d	1.00	0.77

- ✓Average $D_{sJ}^+(2632)$ mass 2632.6 ± 1.6 MeV/c²
- ✓Γ<17 MeV/c² @ 90% CL(D^0K^+)
- ✓ $\Gamma(D^0K^+)/ \Gamma(D_s^+\eta^0)$ = 0.16 +/- 0.06

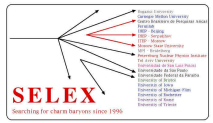
Conclusions



- ✓ We combined our clean sample of D_s^+ mesons with photon pairs made h^0 candidates
- ✓ We observed a clear peak of 42.5 ± 9.5 events with a significance of 6.3 s at a mass difference 667.4 ± 2.9 MeV/c^2 above ground state
- ✓ We combined our clean sample of D^0 mesons with pure K^+
- ✓ We observed a clear peak of 14 ± 4.5 events with a significance of 5.3 s at a mass difference 767.0 ± 1.9 MeV/c^2 above ground state
- ✓ Clear evidence for a new state D_{sJ}^+ (2632) !
- ✓ Combined of the mass is 2632.6 ± 1.6 MeV/c^2
- ✓ A 90% CL upper limit for the width of this state from D^0K^+ G< 17 MeV/c^2

We await news from our experimental colleagues !

Extra Slides - Recent Questions



? How does the 2632 asymmetry compare with the overall Σ^- D_s asymmetry

Consistent with overall (~ -0.4)

Beam particle	Interaction fraction	D_s Yield	Yield fraction	Raw asymmetry
Σ^-	67%	613±38	100%	-0.42±0.04
π^-	14%	60±16	10%	-0.06±0.13
p	19%	86±16	19%	-0.28±0.10

? What about the D_s's from pions

Only adds 10% with ½ S/N

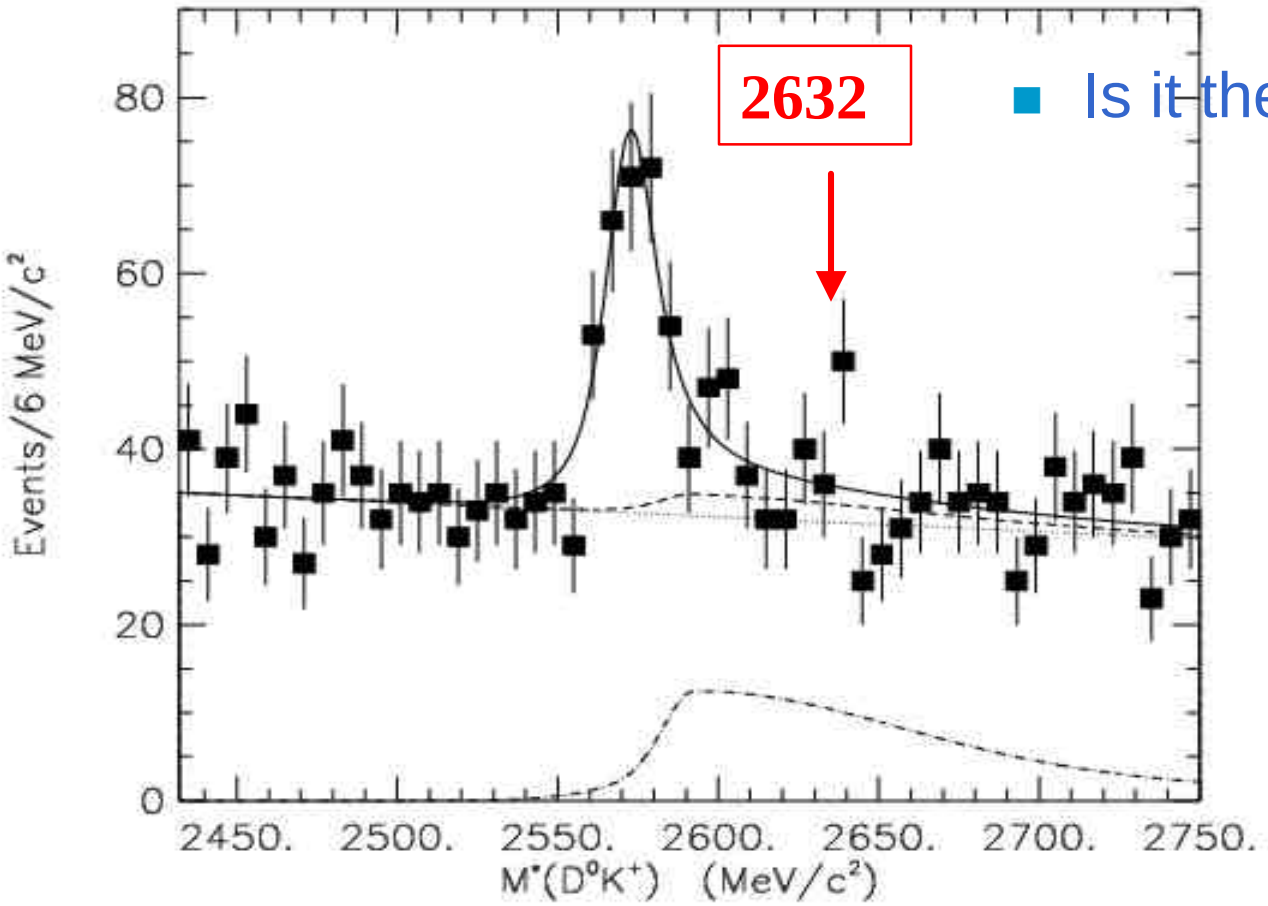
? Have we broken up the D_s's into $\phi\pi$ and K*K

No; background is small (slide 12)

? η^0 economics

? Fitting

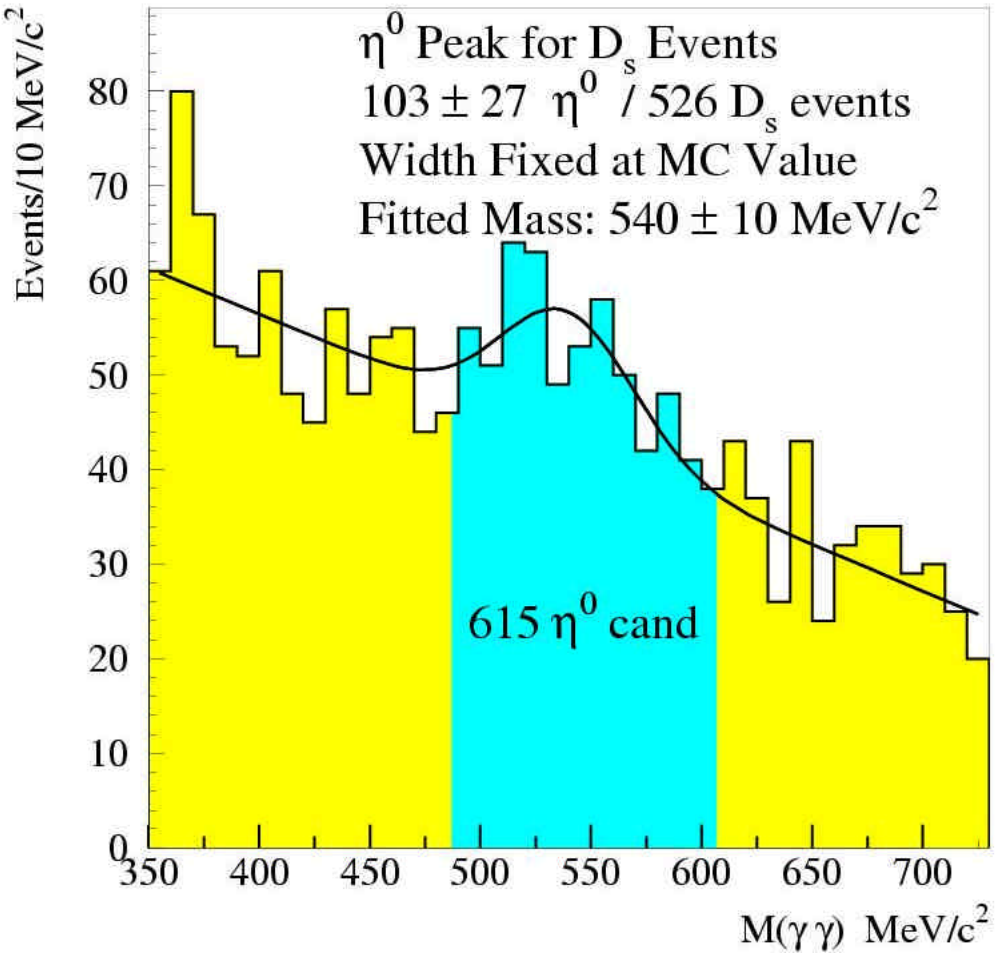
Something interesting: CLEO results on $D_s(2573)$



- Is it the same signal ?

Y.Kubota et al. (CLEO) PRL 72(1994)

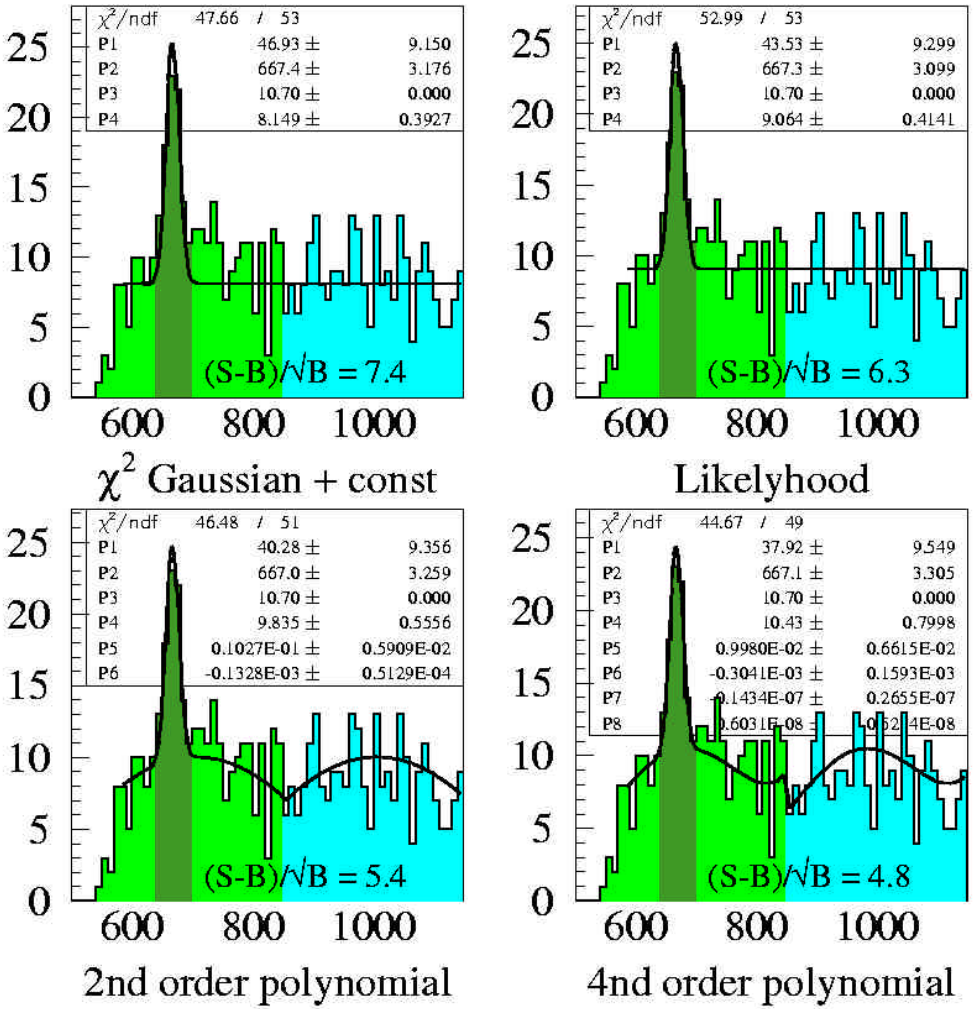
η^0 in events with D_s^+ candidates



η candidates / event	N(η) candidates	N(D_s) events
0	0	205
1	158	158
2	174	87
3	117	39
4	76	19
5	90	18
6	30	5
7	7	1
8	48	6
9	0	0
10	40	4
11	22	2

sum	762	544
	615	526
<N(η)> / D_s		1.17

$D_s^+\eta^0$ Fitting Variations



- ✓ Fit signal and mixed event background simultaneously.
- ✓Adopt Likelihood fit

Seems χ^2 underestimates background.

- ✓Running more mixed event background now
- ✓Fitting aside

If that thing were sitting on my chair I wouldn't sit down!