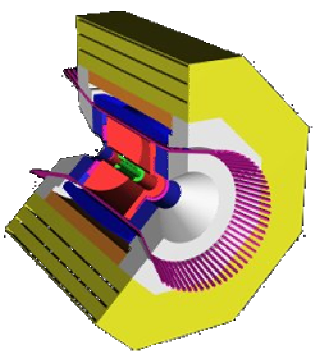
Charm – Production Between 3.97 and 4.26 GeV and R Measurements



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Joint Meeting of Pacific Region Particle Physics Communities (DPF2006)
October 29 - November 3, 2006
Honolulu, Hawaii

Outline

- Introduction
- Cross Sections between 3.97 and 4.26 GeV
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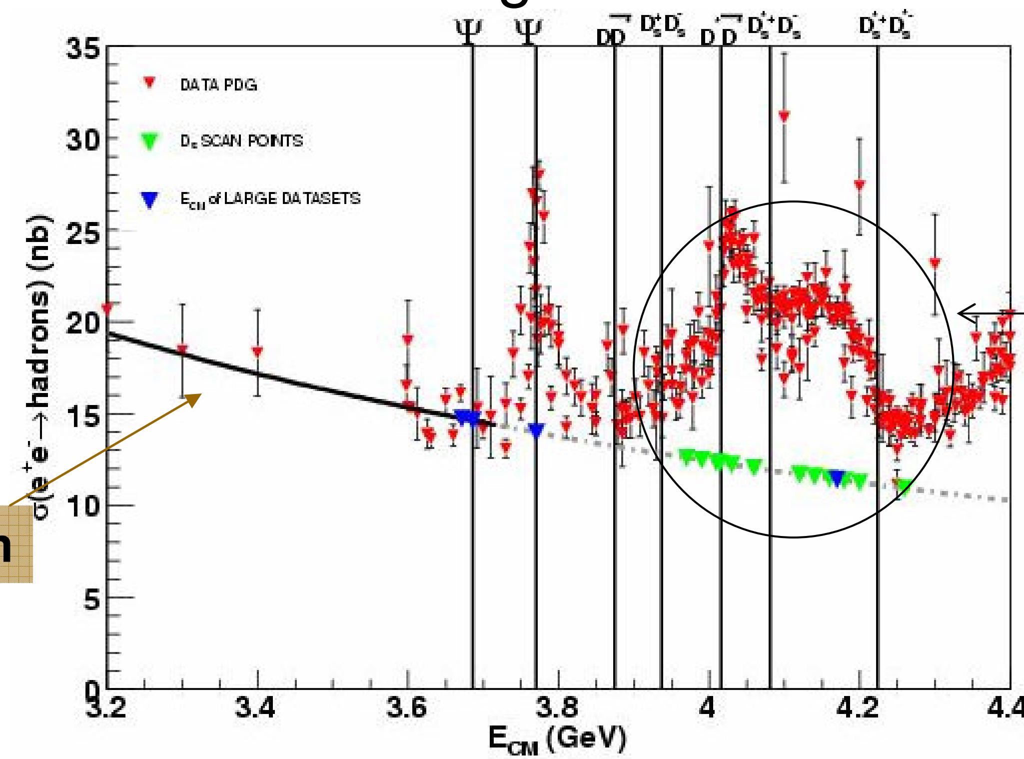
  - Exclusive $D_{(s)}^{(*)}D_{(s)}^{(*)}$ Cross Sections
  - Consistency Checks
  - Results and Radiative Corrections
- R between 6.9 and 10.6 GeV
- Conclusions

Introduction

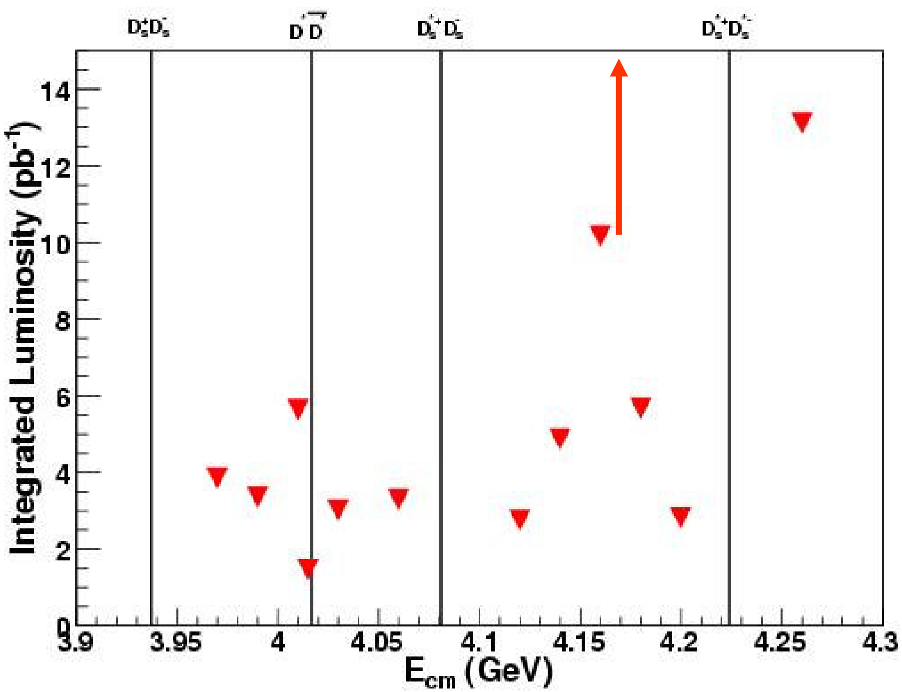
- Measure the production cross sections of $D\overline{D}$, $D^*\overline{D}$, $D^*\overline{D}^*$, $D_s\overline{D}_s$, $D_s\overline{D}_s^*$, $D_s^*\overline{D}_s^*$ and the total charm cross section at 13 center-of-mass energies between 3.97 and 4.26 GeV.



Cross section as a function of E_{cm} from the 2005 PDG

Data Sample

- Using the scan data which was collected between Aug. and Oct. of 2005.
- At each energy the data sample was sufficient to determine the cross sections for all expected charm states.

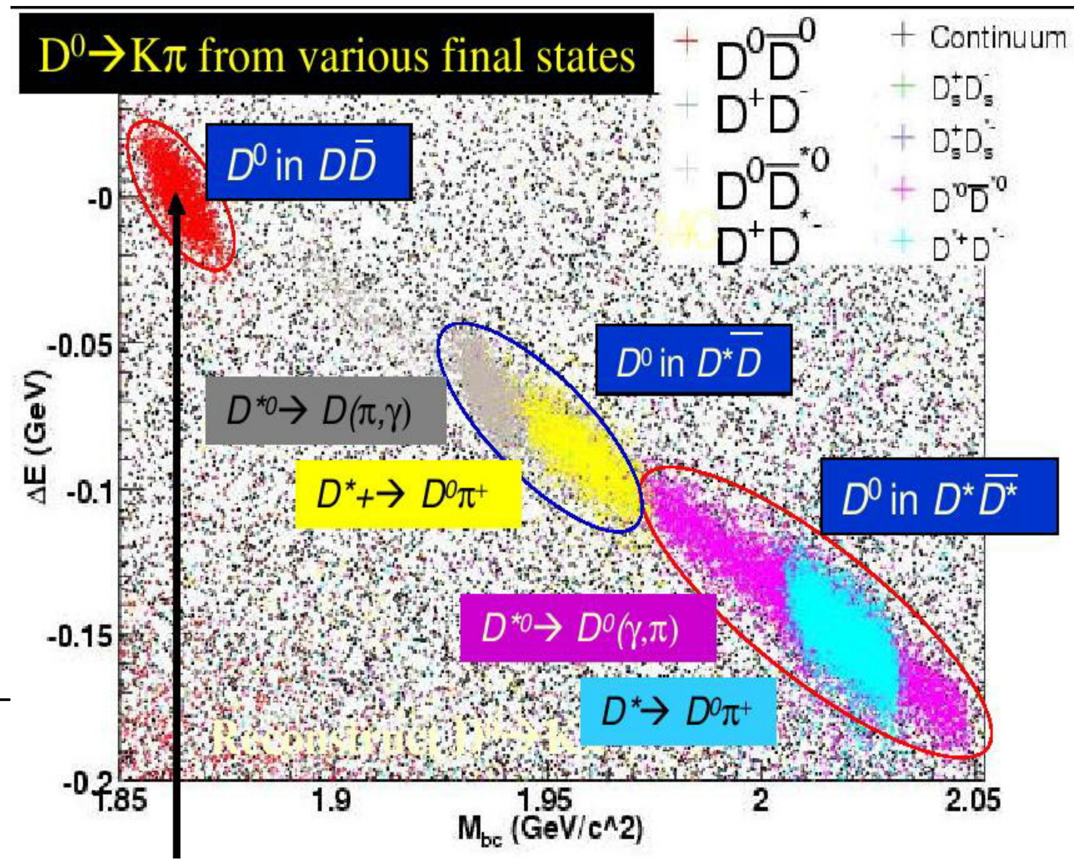


- **Total integrated Luminosity**
  - **Scan (12 energy points) ~ 60 pb^{-1}**
  - **4170 MeV ~ 180 pb^{-1}**

Cross Sections

MC Simulation E_{CM}=4160 MeV

- Do not reconstruct D^* since the momentum, in terms of M_{bc}, indicates event type



$$M_{bc} = \sqrt{E_{beam}^2 - |p_D|^2}$$

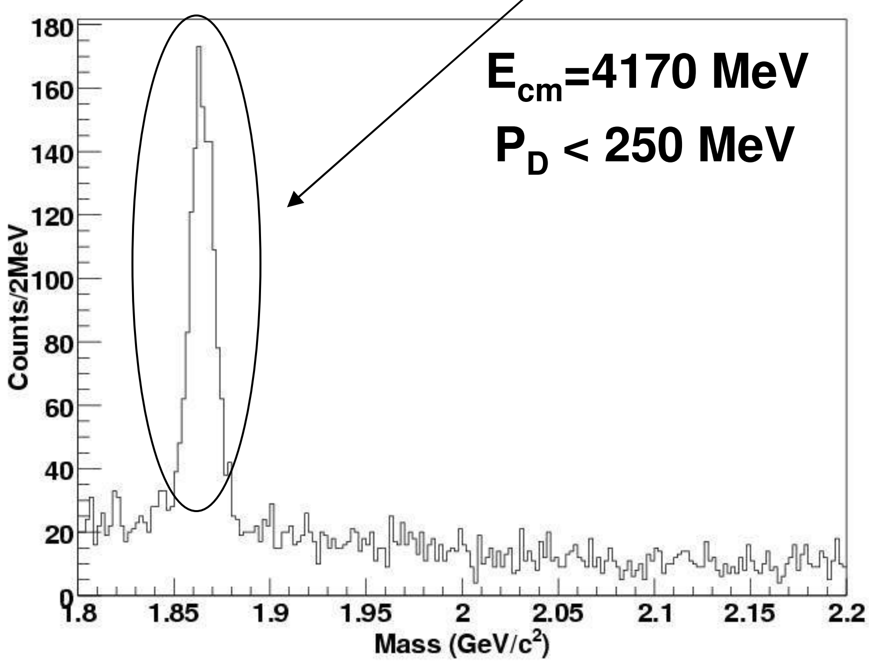
$$\Delta E = E_D - E_{beam}$$

$M_{bc} \approx M_D$ and $\Delta E \approx 0$ for $D\bar{D}$

Multi-Body Production

PRELIMINARY

- There is no reason why, for example, there can not exist multi-body events like $e^+e^- \rightarrow DD^*\pi$ or any other allowed combination of D-mesons and pions.
- First, are there events outside our two-body $D_{(s)}^{(*)}\overline{D}_{(s)}^{(*)}$ exclusive event categories. Yes!



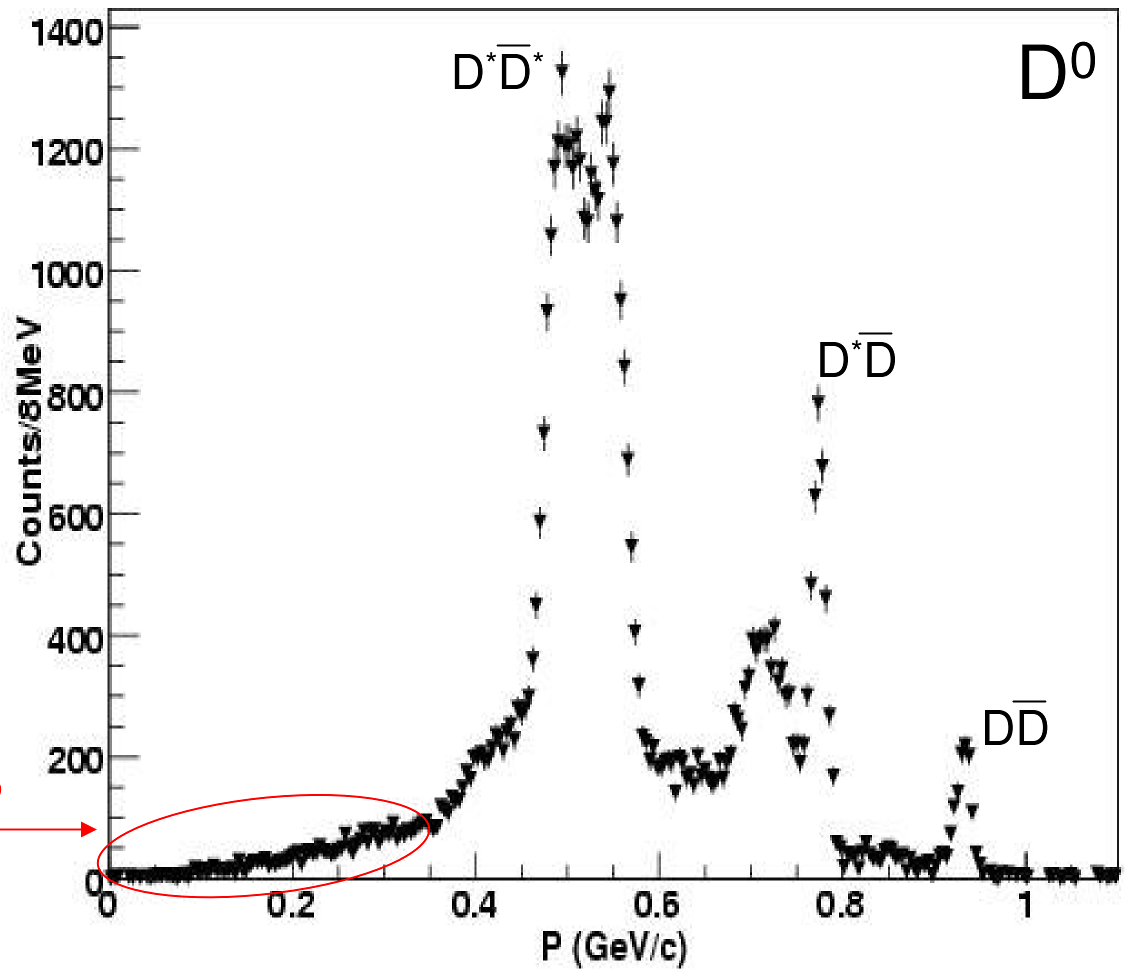
- Assuming only two bodies are produced, we should have no D^0 mesons with a momenta below ~350 MeV.
- Data shows a clear D^0 peak in the mass distribution for $K^-\pi^+$ candidates with momenta below 250 MeV.

Momentum Spectrum of D^0 at 4170 MeV

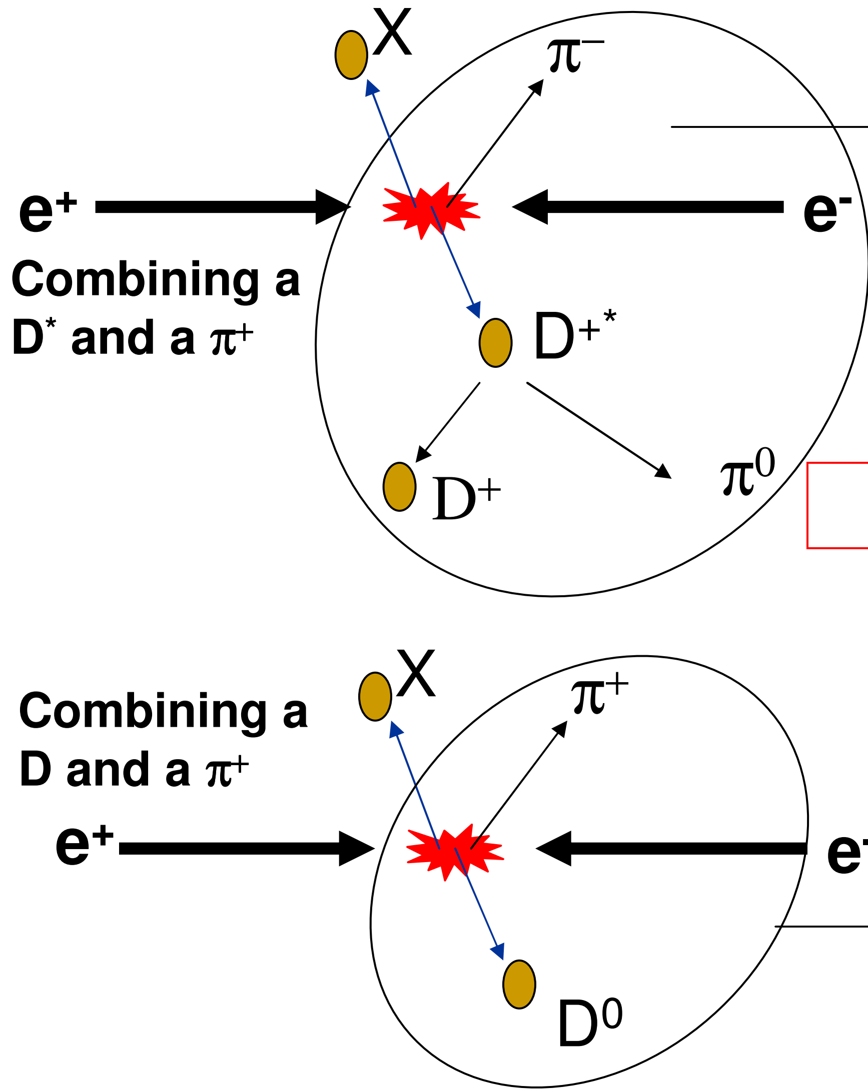
- $D^0 \rightarrow K^- \pi^+$ momentum spectrum after sideband subtraction

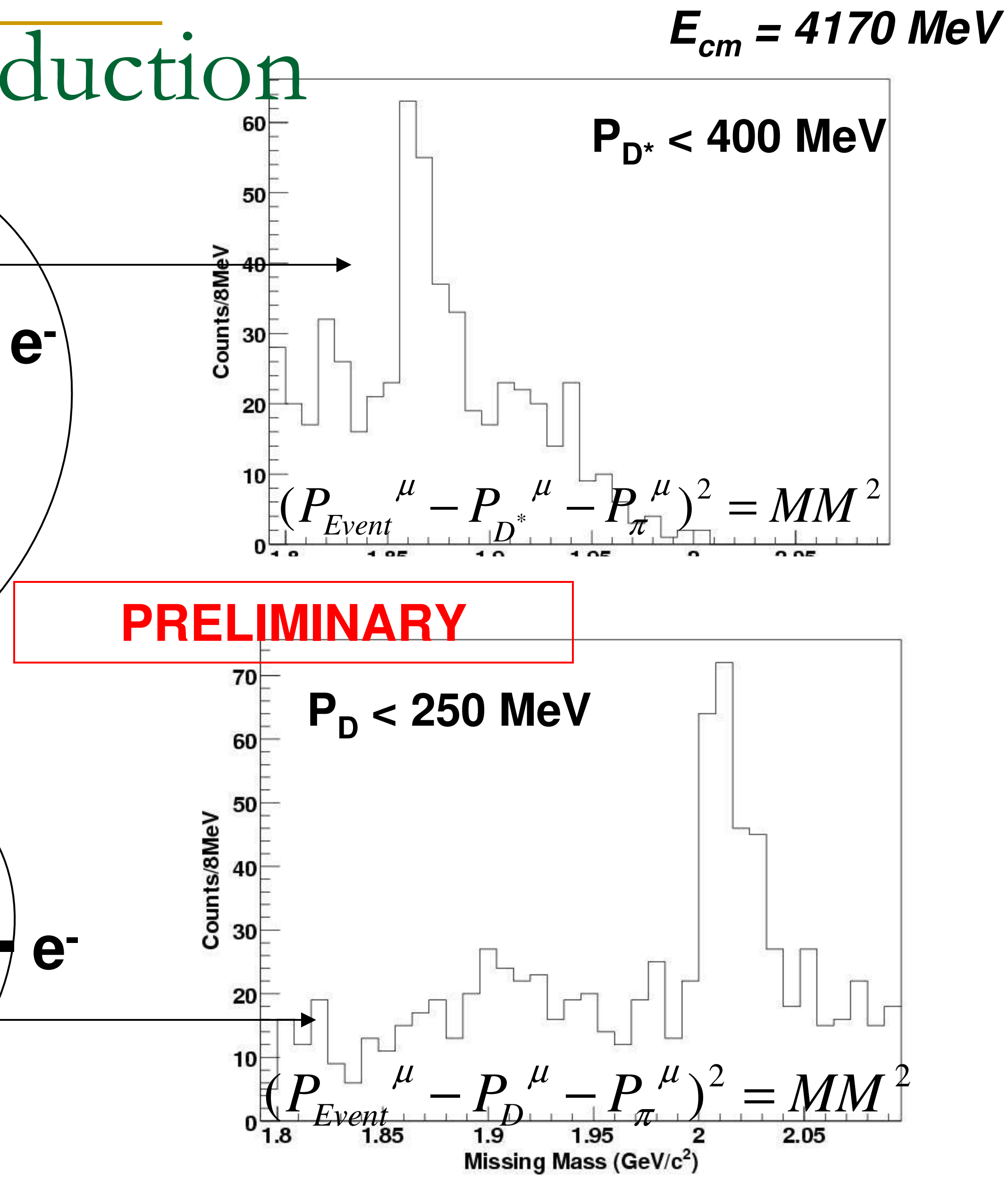
PRELIMINARY

What populates this region?



Multi-Body Production

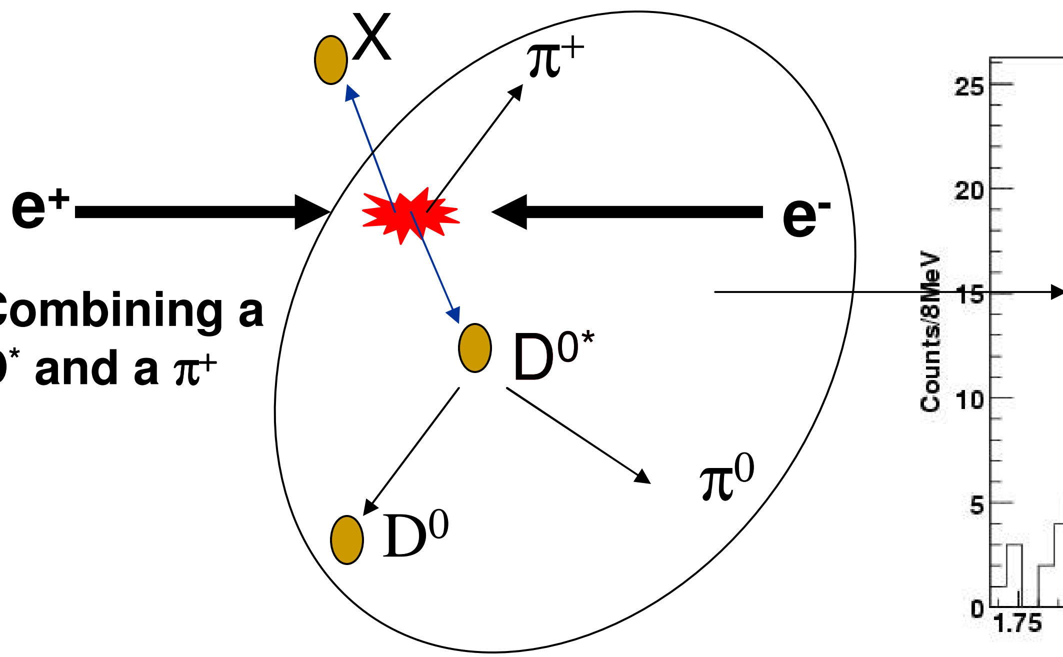




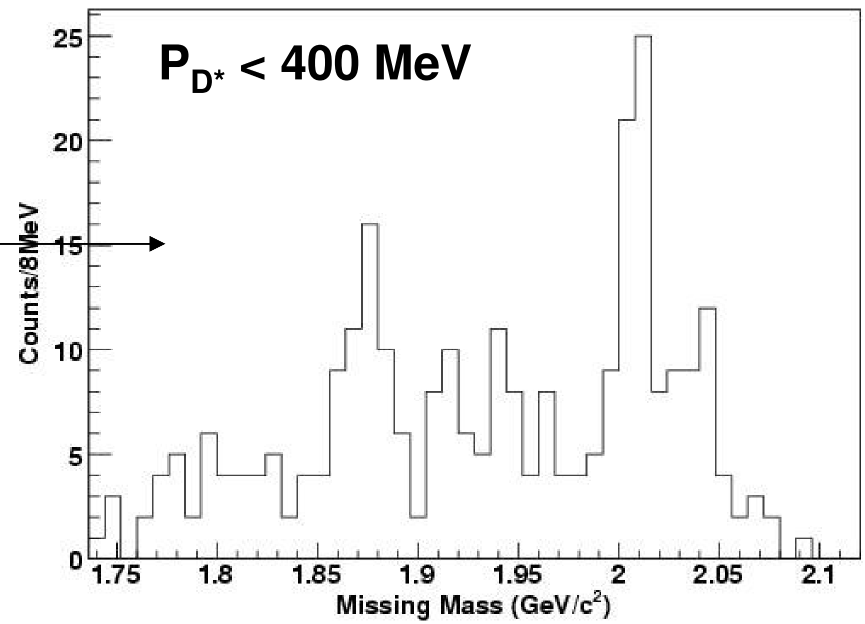
Multi-Body Production

E_{cm} = 4260 MeV

PRELIMINARY



Combining a D^* and a π^+



$$(P_{Event}{}^{\mu} - P_{D^*}{}^{\mu} - P_{\pi}{}^{\mu})^2 = MM^2$$

Momentum Fits using MC

- How do we get a handle on the multi-body contribution?
- It is possible to estimate the contribution of multibody events by fitting the observed *D* momentum spectrum with MC predictions for the two-body processes and some representation of multi-body.

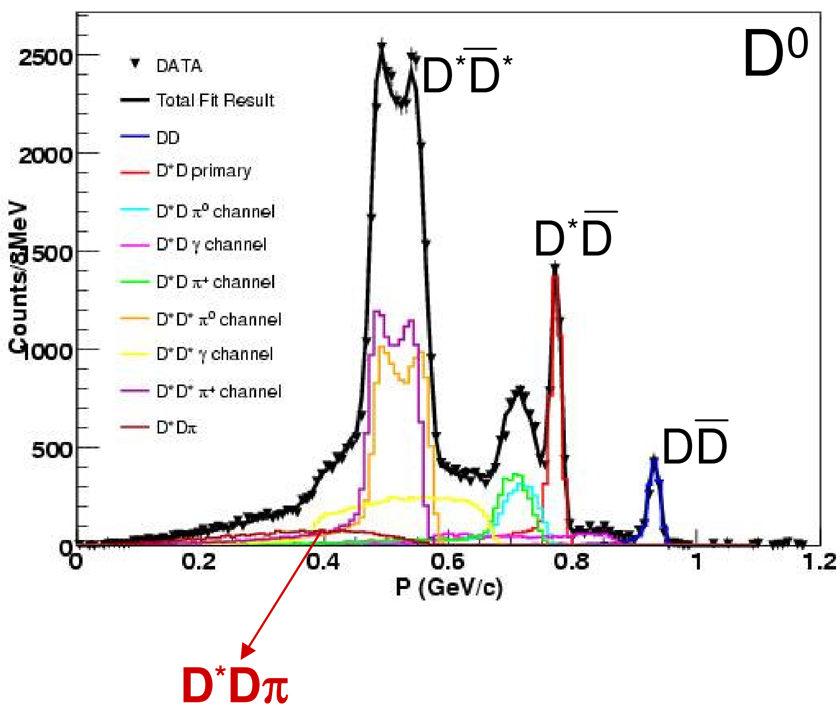
Momentum Fits using MC

E_{cm} = 4170 MeV
~ 180 pb^{-1}

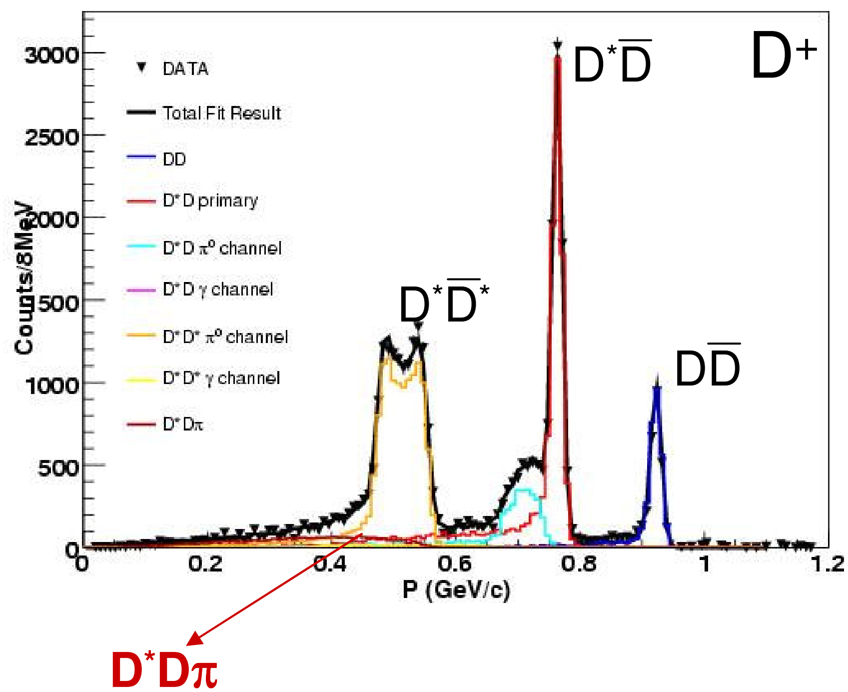
PRELIMINARY

Only assuming $D^*D\pi$ multi-body is present.

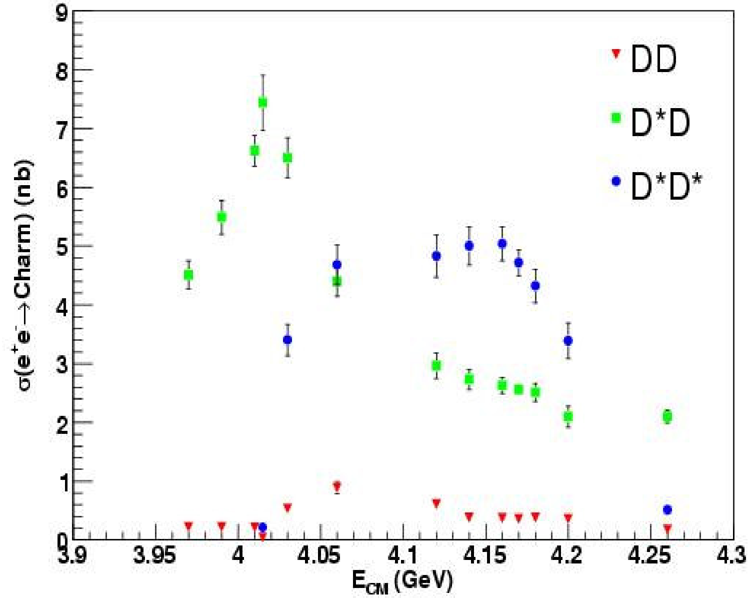
$D^0 \rightarrow K^-\pi^+$ Momentum Spectrum after sideband subtraction

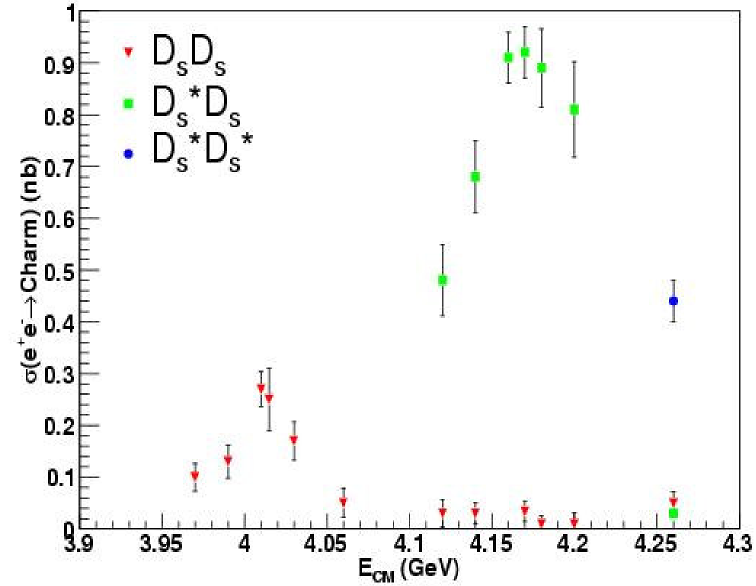


$D^+ \rightarrow K^-\pi^+\pi^+$ Momentum Spectrum after sideband subtraction



Exclusive Cross Sections Results





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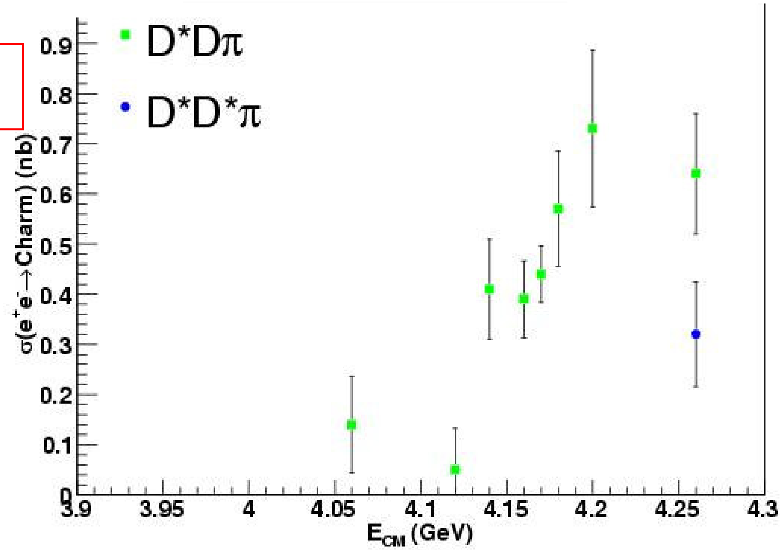
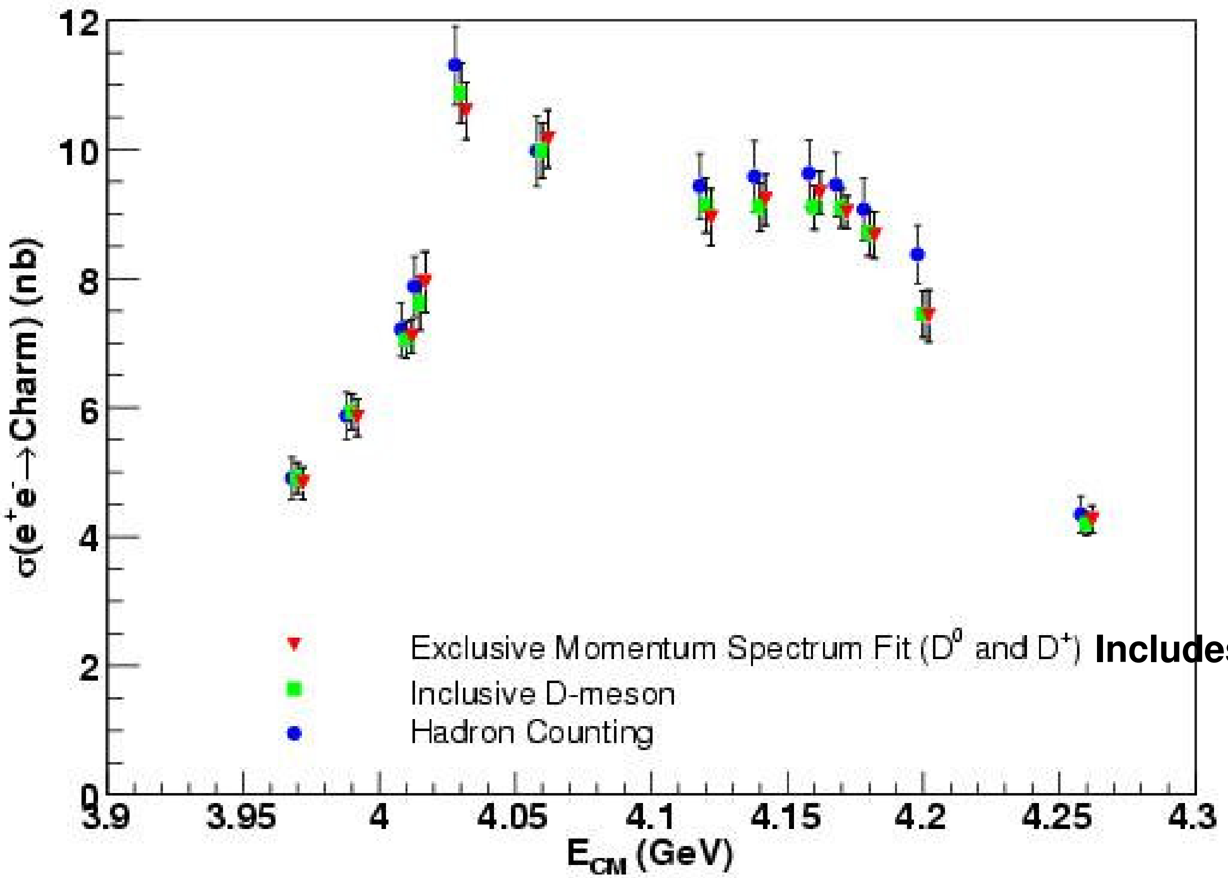


Check of the Total Charm Cross Section

- One can perform an inclusive measurement as a cross check on the total charm cross section.
  - The invariant mass used to extract the yields.
  - Only using $D^0 \rightarrow K^-\pi^+$, $D^+ \rightarrow K^-\pi^+\pi^+$ and the high yield mode of $D_s^+ \rightarrow K^+K^-\pi^+$.
- Also, one can count the number of hadronic events above the *uds* continuum background as an additional check to the total charm cross section.

Comparison: Exclusive from Momentum Fits vs. Inclusive

PRELIMINARY



Includes multi-body

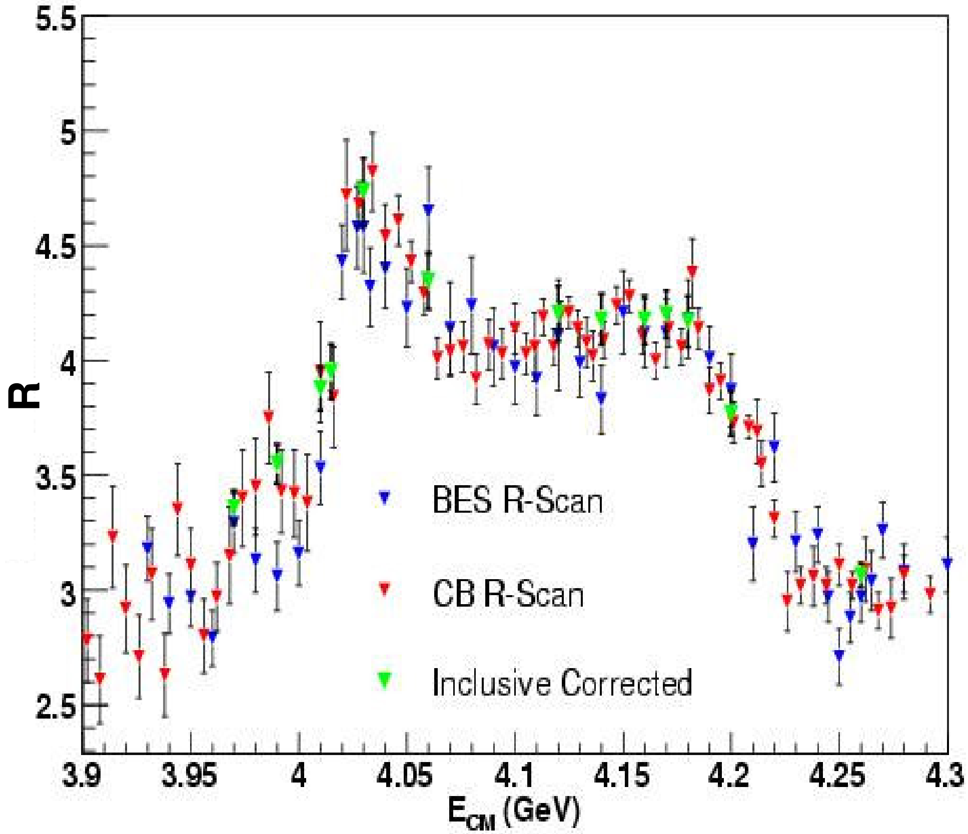
▼ Exclusive:
Sum of the two-body charmed mesons and multi-body

■ Inclusive charm:
$D^0 + D^+ + D_s$

● Inclusive Hadrons:
Excess over *uds*

Radiative Corrections

PRELIMINARY

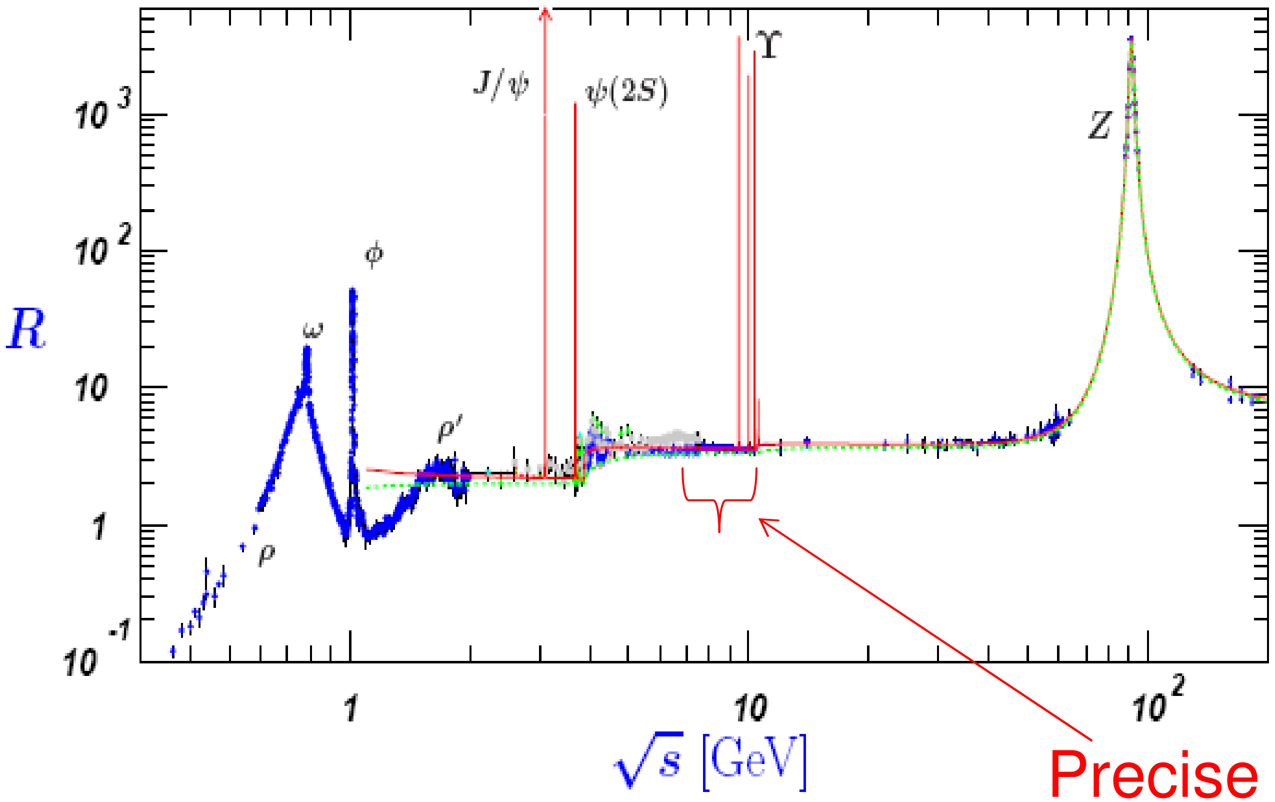


$$R = R_{uds} + R_{charm}$$

$$R_{uds} = 2.29 \pm 0.03$$

- In order to compare the observed cross sections to theory and previous experiments the cross sections need to be corrected for the effects of initial-state radiation.
- Using theoretical treatment of Kuraev and Fadin (Sov. J. Nucl. Phys. 41 466) and Crystal Ball R measurement

R measurements between 6.9 and 10.6 GeV

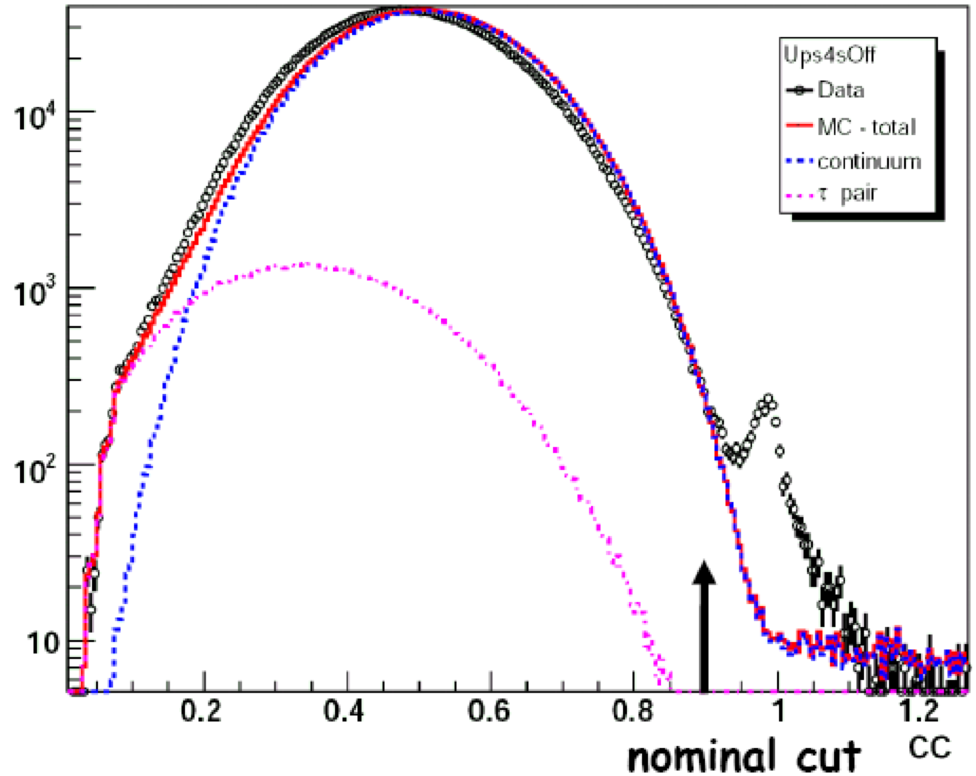


Precise measurement of R at 7 energy points between 6.9 and 10.6 GeV.

R measurements between 6.9 and 10.6 GeV

The following selection criteria has been used to suppress background.

|Zvertex|<0.06 m – beam-gas/wall.
(z-component of event vertex)
Evis/2Ebeam>0.5 – two-photon, beam-gas/wall
(Visible energy of event)
|PzMiss/Evis/2Ebeam|<0.3 – two-photon, QED.
(z-component of missing momentum)
CE/2Ebeam < 0.9 Bhabha events.
(Calorimeter energy of events)
Multiplicity > 3 – two-photon, QED.
(# of charge tracks)
Egamma/Ebeam < 0.8 – ISR events
(The most energetic photon energy)



Distribution of the calorimeter energy over 2Ebeam (CE) when all other cuts have been applied.

PRELIMINARY

Results

PRELIMINARY

$$R = \sigma_0(e^+e^- \to hadrons)/\sigma_0(e^+e^- \to \mu\mu)$$

Energy Point (GeV)	Luminosity (pb^{-1})	R
10.54	905.0	3.60 +/- 0.01 +/-0.08
10.33	150.0	3.49 +/- 0.01 +/-0.08
10.00	432.0	3.49 +/- 0.01 +/-0.07
9.43	181.0	3.49 +/- 0.01 +/-0.07
8.38	6.7	3.58 +/- 0.02 +/-0.06
7.38	8.5	3.55 +/- 0.02 +/-0.06
6.96	2.5	3.60 +/- 0.03 +/-0.06

- The R values are consistent from one energy point to the next
- The statistical errors are small, the largest is ~1% at 6.96 GeV
- The systematic errors are at the 2% level (main source is event selection).

Conclusions

- Determined the E_{cm} that maximized the D_s yield.
- Measured all kinematically allowed exclusive Charm production cross sections at 13 center-of-mass energies in addition to the total charm cross section between 3.97 and 4.26 GeV.
- Measured R at 7 center-of-mass energies between 6.9 and 10.6 GeV.

$$\sigma_0(s) = \frac{\sigma_{obs}(s) - \sigma_{res}(s)}{\epsilon(0)\delta_{sv} + I_{hard}}$$

The effective soft and virtual part of observed cross section can be determined as

$$\sigma_{sv}(s) = \epsilon(0)\sigma_0(s)\delta_{sv} \quad \textbf{with} \quad \delta_{sv} = \delta_{vp} + \delta_0$$

$$\delta_{vp} = \sum_l \frac{2\alpha}{\pi}\left(\frac{1}{3}ln\frac{s}{m_l^2} - \frac{5}{9}\right)(l = e, \mu, \tau, h, \ldots).$$

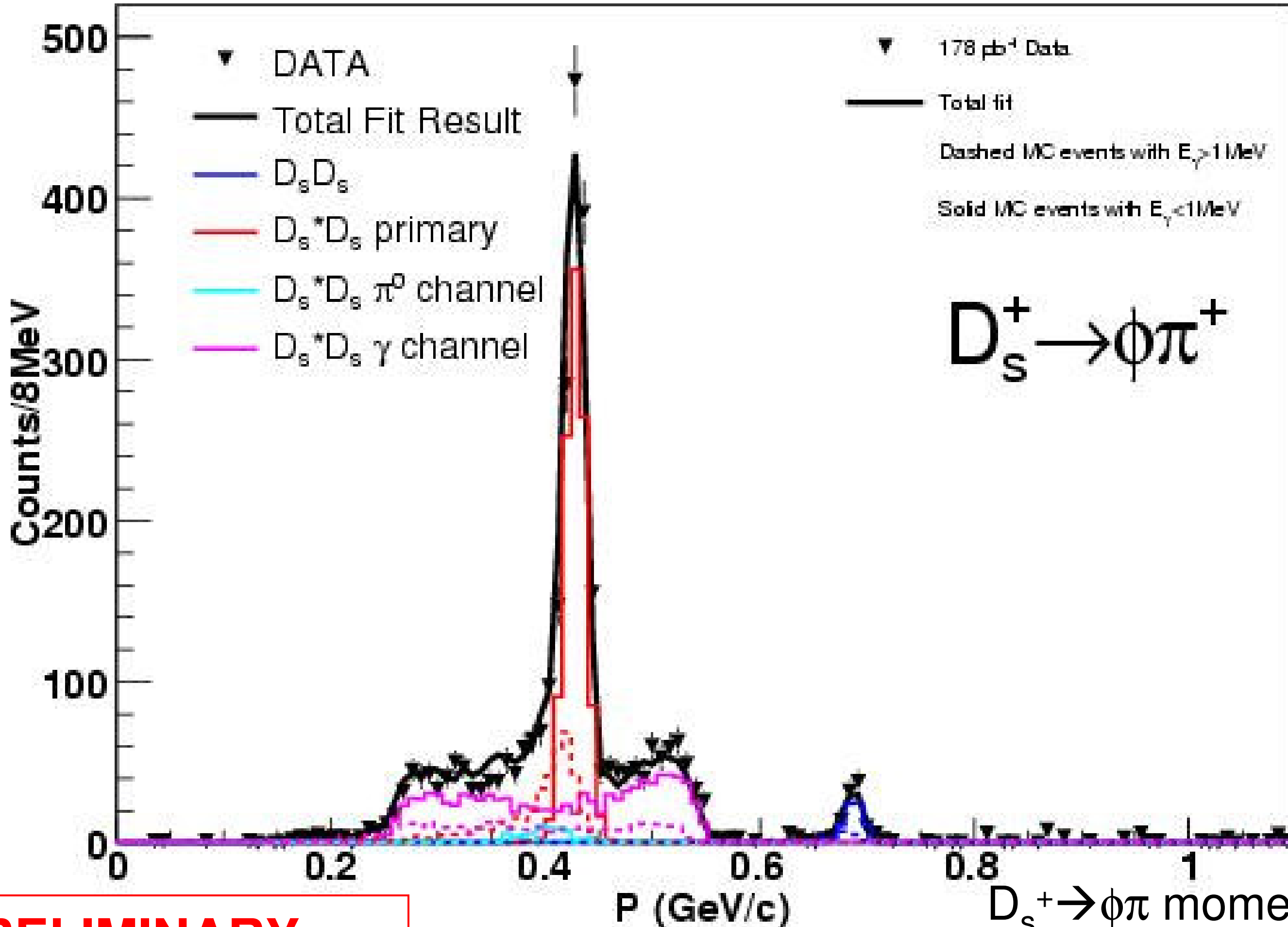
$$\delta_0 = \frac{2\alpha}{\pi}\left(\frac{3}{4}ln\frac{s}{m_e^2} + \frac{\pi^2}{6} - 1\right)$$

The hard photon contribution is actually an integral over all

$$I_{hard} = \int_0^{kmax} \epsilon(k)\left(\frac{\sigma_0^{cont}(s')}{\sigma_0(s)}\right) t\frac{1}{k^{1-t}}\left(1 - k + \frac{k^2}{2}\right) dk$$

Momentum Fits to Data

E_{cm} = 4170 MeV
~ 180 pb^{-1}



PRELIMINARY

$D_s^+ \to \phi\pi$ momentum spectrum after sideband subtraction