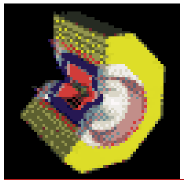


Cornell University
Laboratory for
Elementary-Particle Physics

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

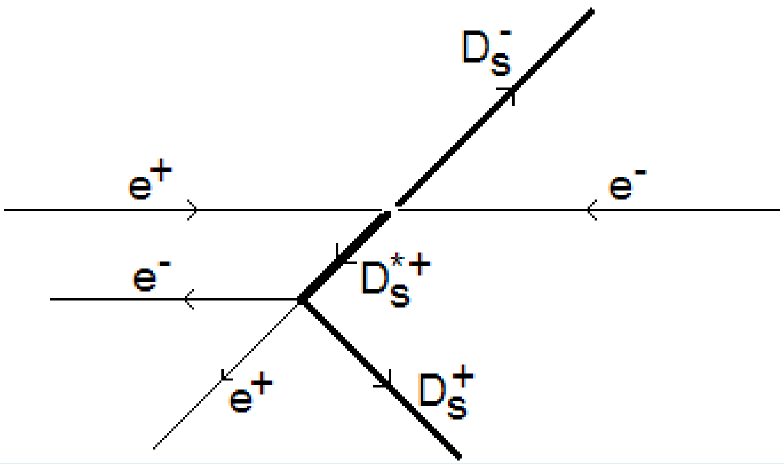
Souvik Das

Cornell University
For the CLEO Collaboration

Contents

13 February 2010

What Are We Looking For?



- Searching for $D_s^{*+} \rightarrow D_s^+ e^+ e^-$

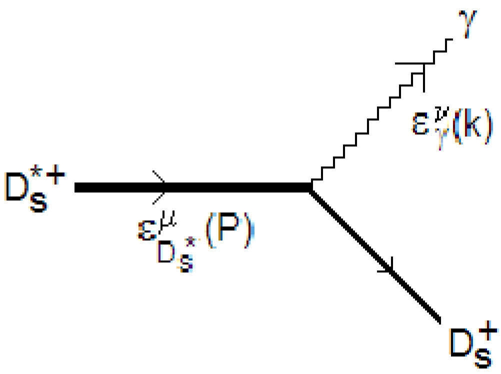
- Known decay channels are:
  - $D_s^{*+} \rightarrow D_s^+ \gamma$; Branching Fraction = 94.2%
  - $D_s^{*+} \rightarrow D_s^+ \pi^0$; Branching Fraction = 5.8% [Phys.Rev.D72:091101,2005]

- We are using e^+e^- collision data collected by the CLEO-c detector at the Cornell Electron Storage Ring (CESR) operating at $\sqrt{s}$ = 4170 MeV

- We have 586 pb^{-1} of data at this energy. This will give us ~ 600,000 $D_s^{*\pm} D_s^{\mp}$ events.

- This is a **blind analysis**

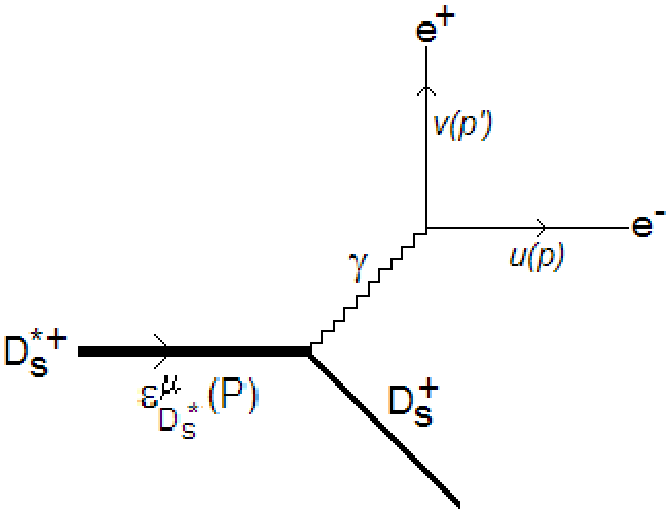
Predicted $D_s^{*\pm} \rightarrow D_s^{\pm} e^+ e^-$ Rate



If we write the matrix element of the D_s^* decay to a real photon in the form:

$$M = \varepsilon_{D_S^{*+}}^{\mu} \varepsilon_{\gamma}^{*\nu} T_{\mu\nu}(P,k)$$

Where $T_{\mu\nu}(P,k)$ is a generic form factor coupling the D_s^* with a photon.



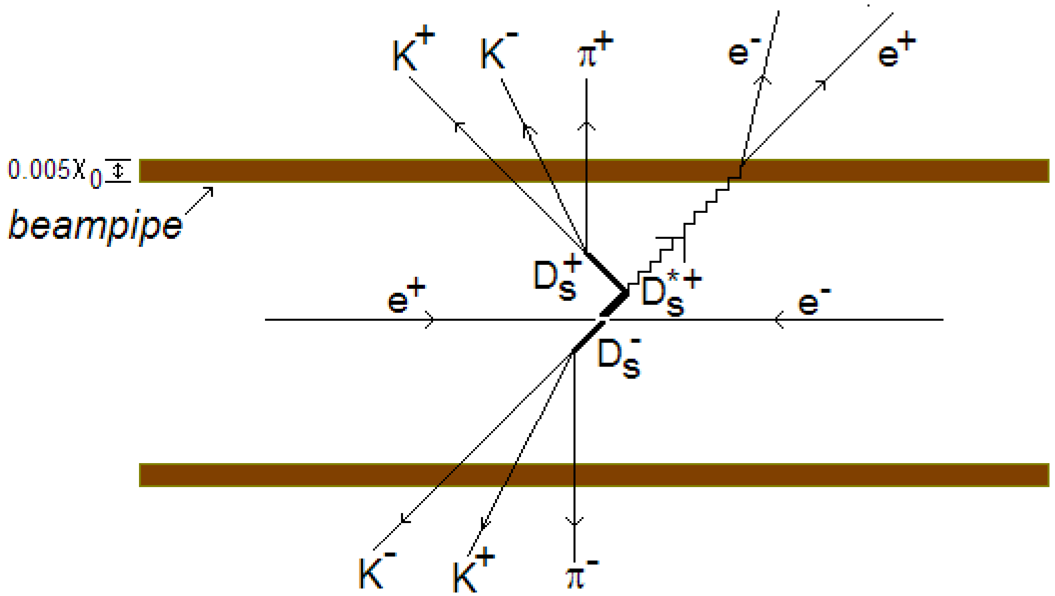
Then we can write the matrix element of the decay to e^+e^- in the form:

$$M = \varepsilon_{D_S^{*+}}^{\mu} T_{\mu\nu}(P,k)\left(\frac{-ig^{\upsilon\sigma}}{k^2}\right)\overline{u}(p)ie\gamma_{\sigma}v(p')$$

Evaluating the spin-average over the initial states and spin-sum over the final states of the invariant amplitudes and integrating over the phase space of daughters, we predict the ratio of decay rates:

$$\frac{\Gamma\left(D_s^{*+} \rightarrow D_s^+ e^+ e^-\right)}{\Gamma\left(D_s^{*+} \rightarrow D_s^+ \gamma\right)} = 0.65\% = 0.90\alpha$$

Backgrounds



Photon Conversion Background

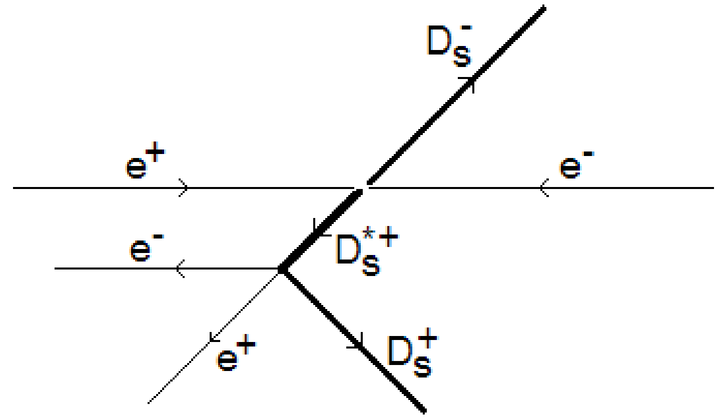
- A background that resembles the signal is expected from D_s^{*+} decaying to $D_s^+\ \gamma$ and the γ converting to e^+e^- in the beam-pipe and other material.
- Given that the beam-pipe is ~ 0.5% of a radiation length, we can estimate this conversion background to occur at roughly the same rate as the signal

Combinatorial Backgrounds

- Dalitz decay of any $\pi^0 \rightarrow \gamma\ e^+\ e^-$ also give equally soft electrons that appear to come from interaction point
- Fake D_s tags

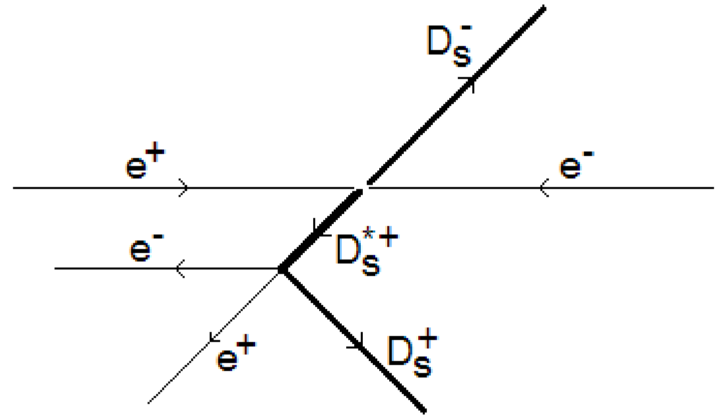
Analysis Strategy

•We will fully reconstruct the D_s^*



Analysis Strategy

- We will fully reconstruct the D_s^*
- The D_s *on the side of the* D_s^* is reconstructed through several tagged decay channels:



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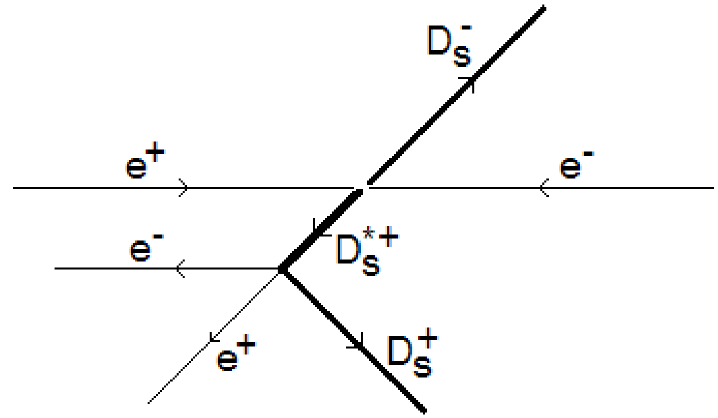
•We will fully reconstruct the D_s^*

•The D_s *on the side of the* D_s^* is reconstructed through several tagged decay channels:

•The e^+e^- share ~ 144 MeV

- •By default CLEO-c does not use electron mass hypothesis in its Kalman Fit
- •Pion-mass hypothesis results in significant deviation in momentum < 70 MeV
- •Motivated a massive re-reconstruction campaign to include electron hypothesis fit



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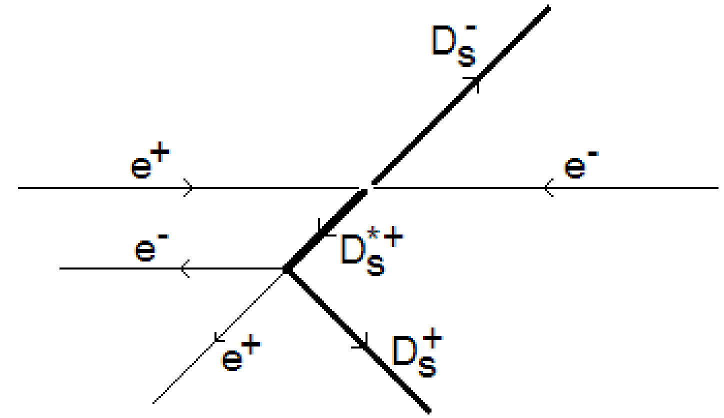

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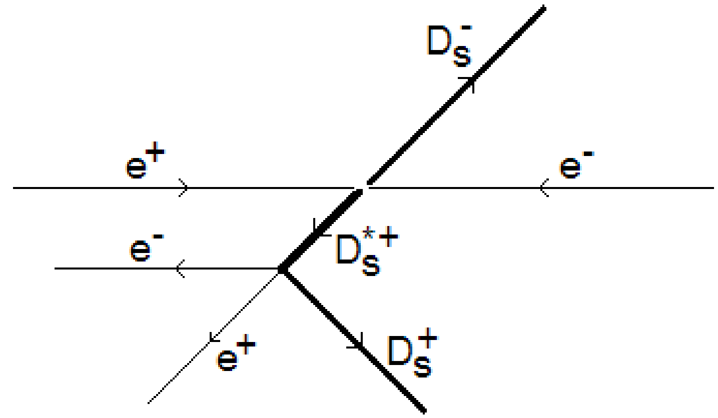

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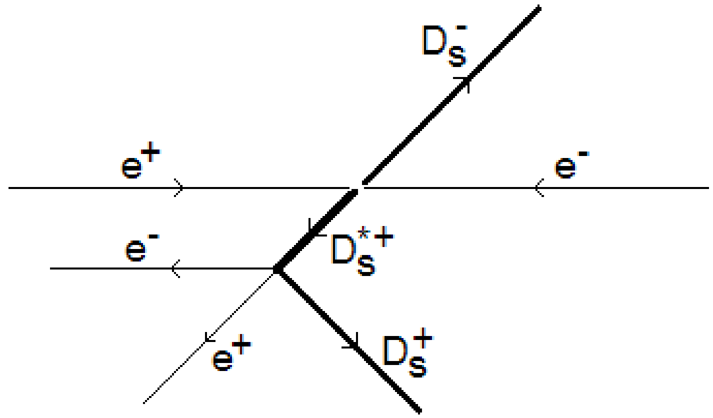
- We're trying to measure the ratio: $\dfrac{\Gamma\left(D_s^{*+} \to D_s^+ e^+ e^-\right)}{\Gamma\left(D_s^{*+} \to D_s^+ \gamma\right)}$

- This talk will focus only on $\Gamma\left(D_s^{*+} \to D_s^+ e^+ e^-\right)$



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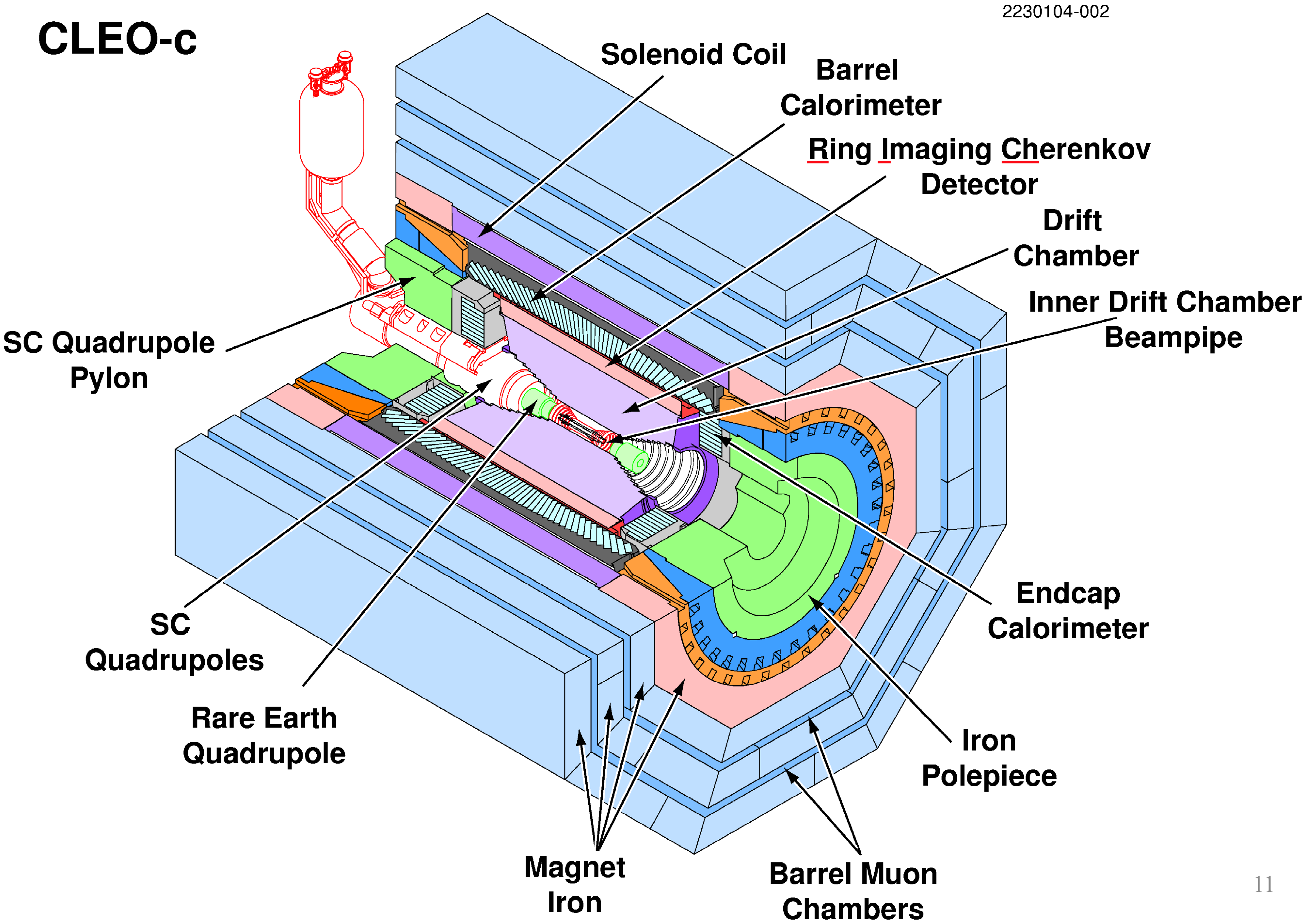
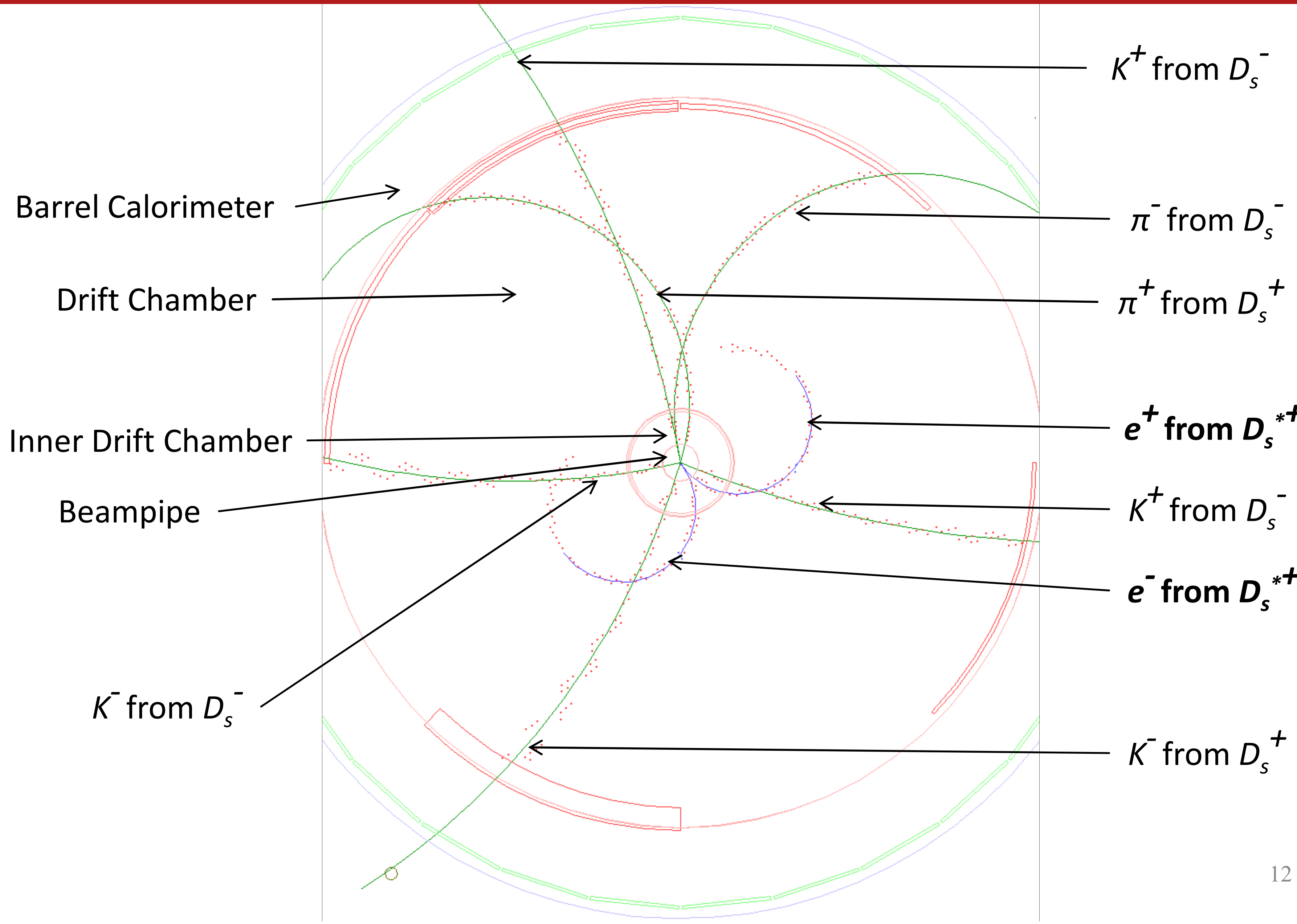
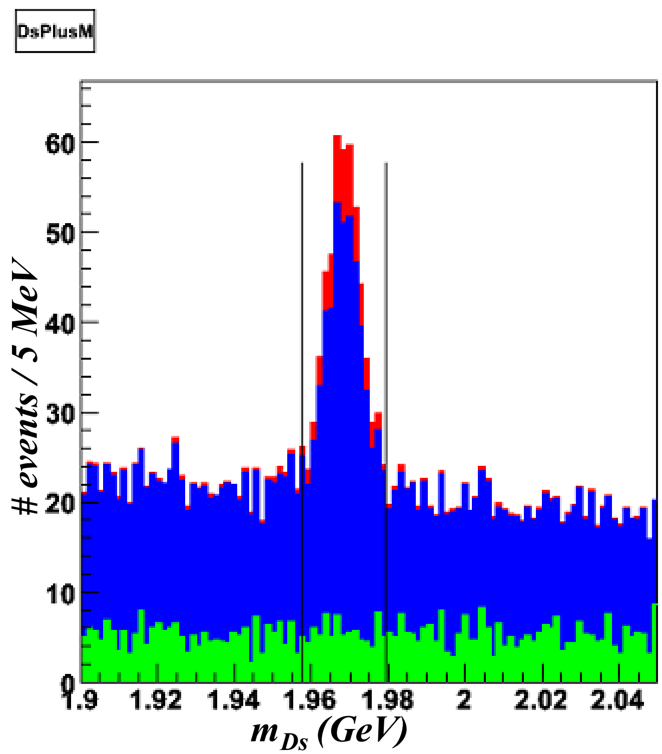
The CLEO-c Detector



A Simulated Signal Event



m_{Ds} Selection Criterion for the $K^+K^-\pi^+$ Mode



Red: Signal Monte Carlo
Blue: Generic Monte Carlo (c$\underline{c}$ production)
Green: Continuum Monte Carlo (light quarks)

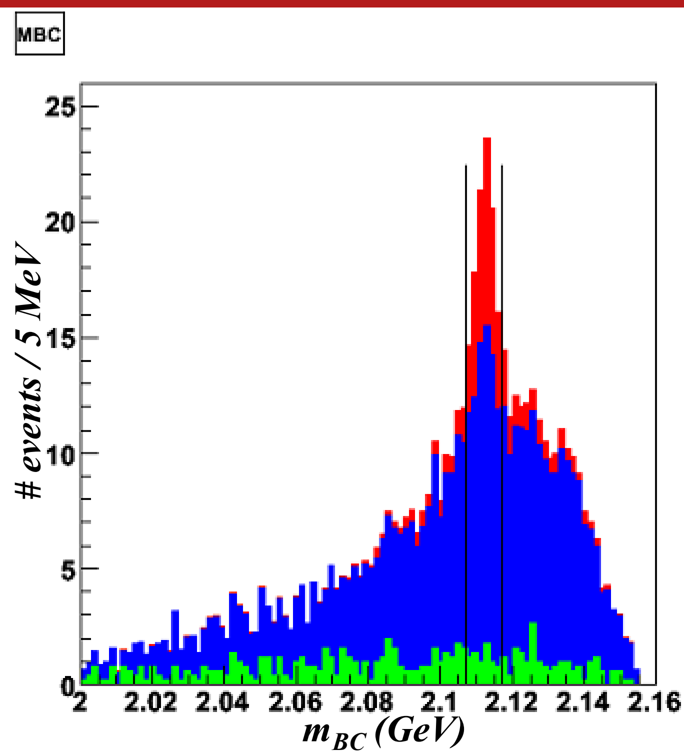
Histograms normalized to 586 pb^{-1}

- We reconstruct the invariant mass m_{D_s} of a D_s from its decay products.

- Selection Criterion for this mode:

$$\left| m_{D_s} - 1.969 GeV \right| < 0.011 GeV$$

m_{BC} Selection Criterion for the $K^+K^-\pi^+$ Mode



Red: Signal Monte Carlo
Blue: Generic Monte Carlo ($c\underline{c}$ production)
Green: Continuum Monte Carlo (light quarks)

Histograms normalized to 586 pb^{-1}

•We know the energy of the CESR beam to high precision. Given the masses of the D_s^* and D_s, we can calculate the energy carried away by the D_s^*

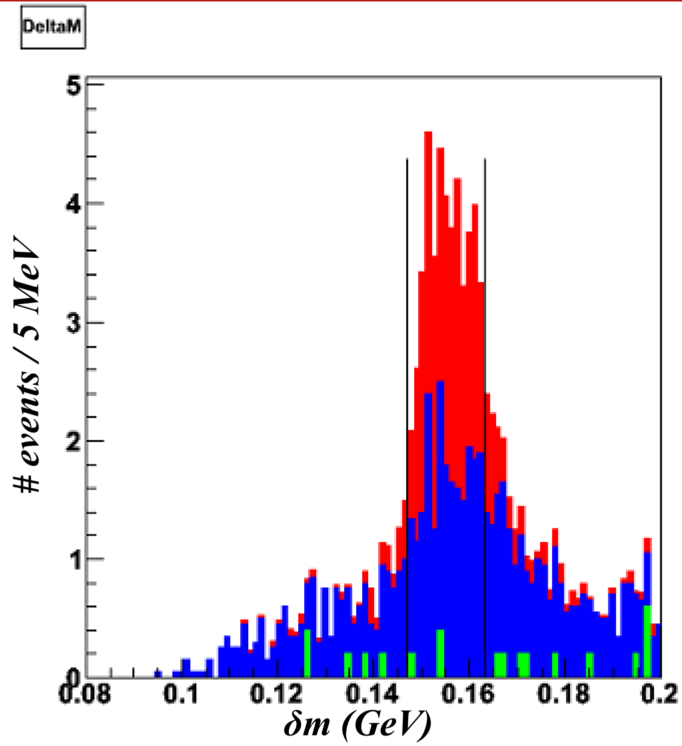
•We define the beam-constrained mass of the D_s^* as:

$$m_{BC} = \sqrt{E^2(D_S^{*+} beam) - P^2(K^+K^-\pi^+e^+e^-)}$$

•Selection Criterion for this mode:

$$|m_{BC} - 2.112 GeV| < 0.005 GeV$$

δm Selection Criterion for the $K^+K^-\pi^+$ Mode



Red: Signal Monte Carlo
Blue: Generic Monte Carlo (cc production)
Green: Continuum Monte Carlo (light quarks)

Histograms normalized to 586 pb^{-1}

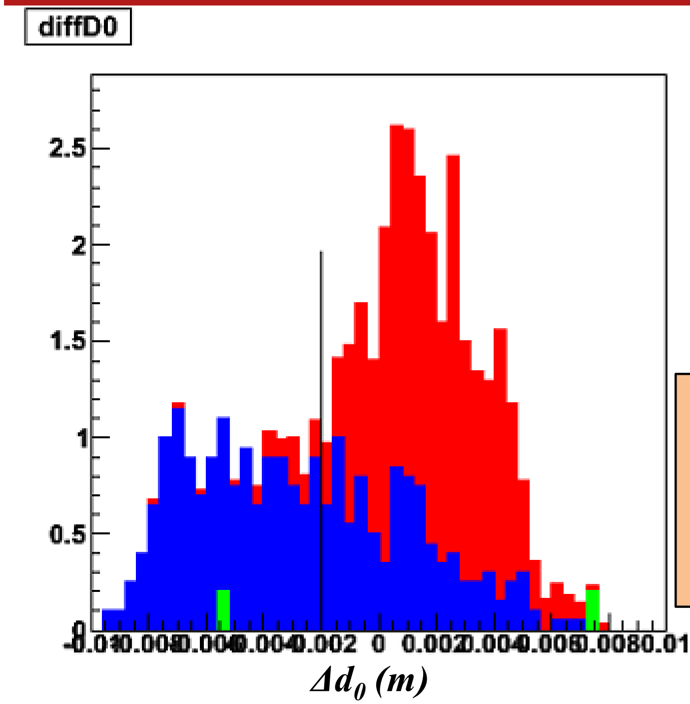
- We define δm as the mass difference the D_s^* and the D_s where both are reconstructed from their daughters:

$$\delta m = M(K^+K^-\pi^+e^+e^-) - M(K^+K^-\pi^+)$$

- Selection Criterion for this mode:

$$\left|\delta m - 0.1438 GeV\right| < 0.008 GeV$$

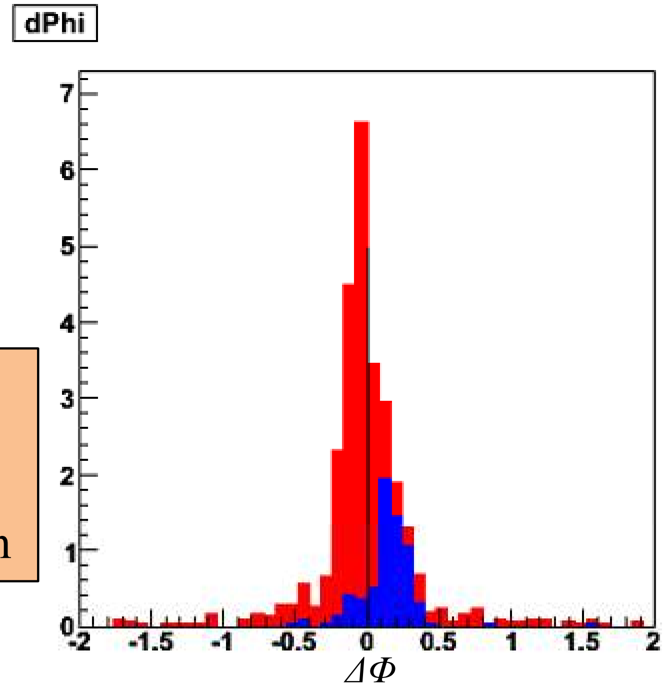
Δd_0 & $\Delta \Phi$ Selection Criteria for the $K^+K^-\pi^+$ Mode



Red: Signal Monte Carlo
Blue: Generic Monte
Green: Continuum Monte Carlo
Histograms normalized to 586 pb^{-1}

d_0: Track's closest distance of approach to the beamline

Φ: Azimuth of track at origin



•The $\Delta d_0 = d_{0\_e-} - d_{0\_e+}$ is centered around 0 for the signal and offset from 0 for conversion backgrounds

•We require $d_1 - d_2 > -0.002$ m

•$\Delta\Phi = \Phi_{e-} - \Phi_{e+}$ is centered around 0 for the signal and offset for the conversion background.

•We require $\Delta\Phi < 0.01$

These variables are **powerful against the photon conversion background** as there the tracks don't come from the interaction point

Prediction for Data for Sample Set of Cuts

Decay Mode of the D_S^+	Expected Signal Events in 586 pb^{-1}	Expected Background Events in 586 pb^{-1}
$K^+K^-\pi^+$	18.2	2.1
K_sK^+	2.6	0.6
$\pi^+\eta;\ \eta\to\gamma\gamma$	4.0	0.2
$\pi^+\eta';\ \eta'\to\pi^+\pi^-\eta;\ \eta\to\gamma\gamma$	0.8	0.0
$K^+K^-\pi^+\pi^0$	3.7	0.9
$\pi^+\pi^-\pi^+$	3.9	2.9
$K^{*+}K^{*0};\ K^{*+}\to K^0_S\pi^+;\ K^{*0}\to K^-\pi^+$	2.2	1.0
$\eta\rho^+;\ \eta\to\gamma\gamma;\ \rho^+\to\pi^+\pi^0$	6.1	2.7
$\eta'\pi^+;\ \eta'\to\rho^0\gamma$	2.5	2.1
Total	**44**	**13**

If $D_s^{*+} \to D_s^+e^+e^-$ exists, and our QED based estimation of its rate is correct, **we should see a clear signal over the background for it** in our data on unblinding.

Conclusion

•In our search for the $D_s^{*+} \rightarrow D_s^{+} e^{+} e^{-}$ we have converged on a set of selection criteria that should allow us to extract signal at the estimated level.

•Cuts are being optimized.

•Background levels are being studied by looking at data in the sideband regions.

•**On the verge of unblinding data.**

Backup Slides

Miscellany

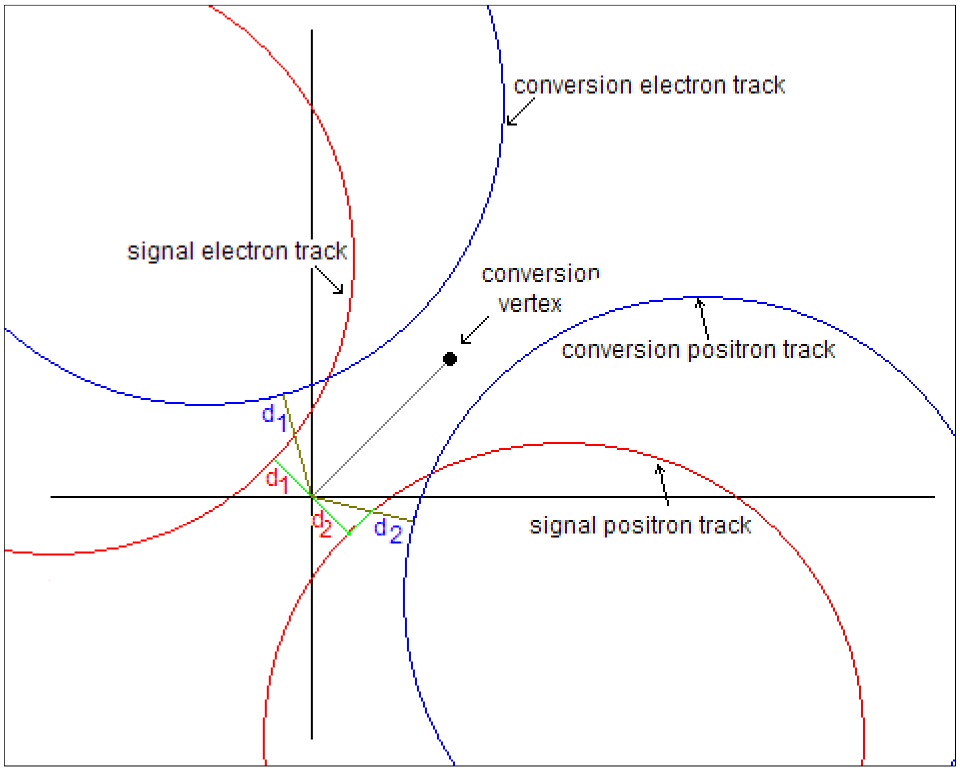
•Backgrounds are being estimated through investigation of sidebands of the kinematic variables around the signal region.

•The tracking efficiency for such soft electrons in CLEO is unknown. This is being estimated by studying the electrons from:

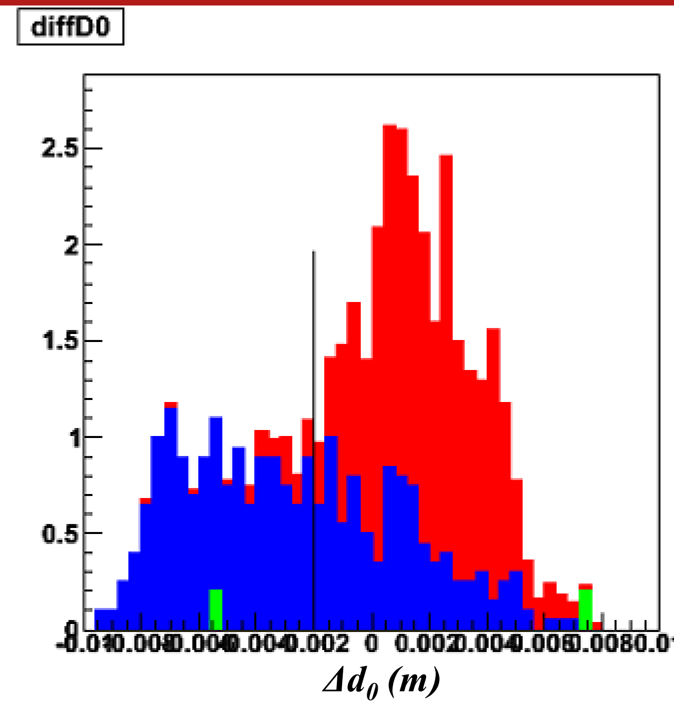
$$\psi(2S) \rightarrow J/\psi\ \pi^0\ \pi^0$$
$$J/\psi \rightarrow e^+\ e^-;\ \mu^+\ \mu^-$$
$$\pi^0 \rightarrow \gamma\ \gamma$$
$$\pi^0 \rightarrow \gamma\ e^+\ e^-$$

•Beginning to un-blind data.

Δd_0 Selection Criterion for the $K^+K^-\pi^+$ Mode



Δd_0 between the electron and positron in the signal (red) and conversion (blue)

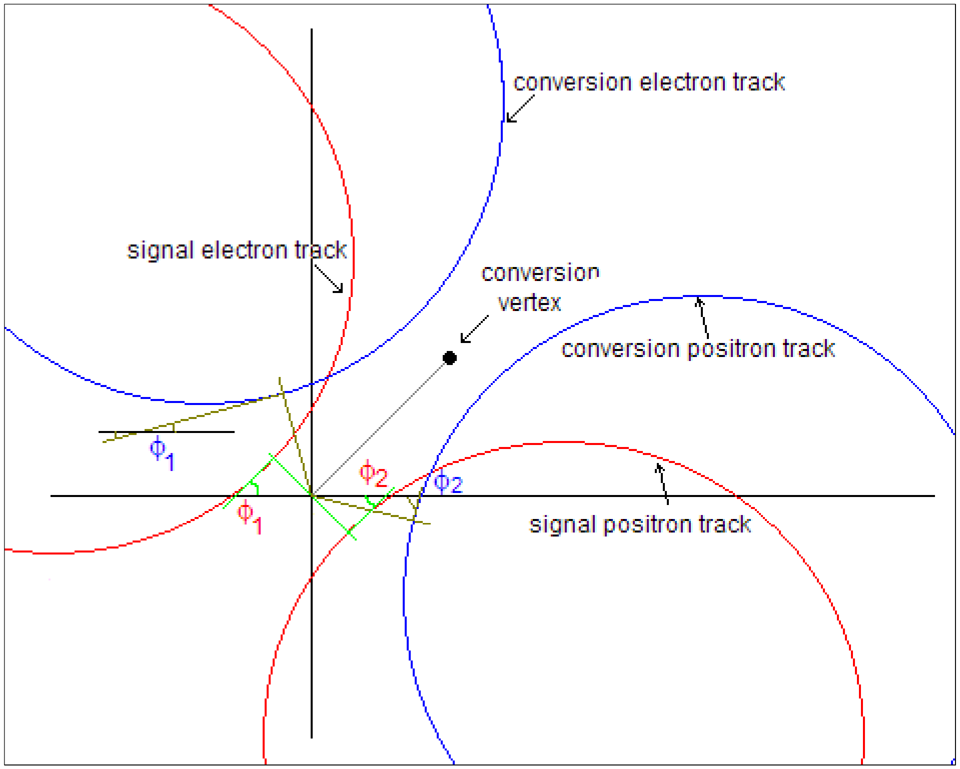


Red: Signal Monte Carlo
Blue: Generic Monte Carlo (heavy quarks)
Green: Continuum Monte Carlo (light quarks)
Histograms normalized to 586 pb^{-1}

•The $\Delta d_0 = d_1 - d_2$ is centered around 0 for the signal and offset from 0 for conversion backgrounds

•We require $d_1 - d_2 > -0.004\ m$

ΔΦ Selection Criterion for the $K^+K^-\pi^+$ Mode



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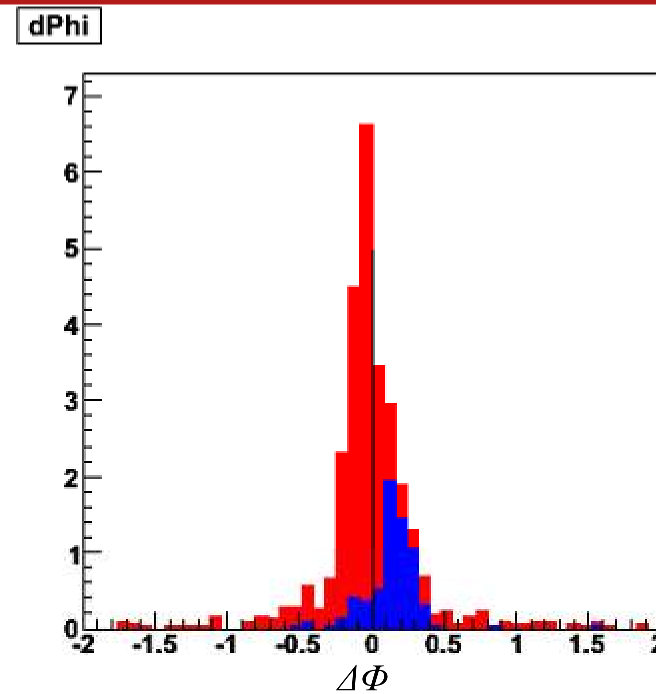

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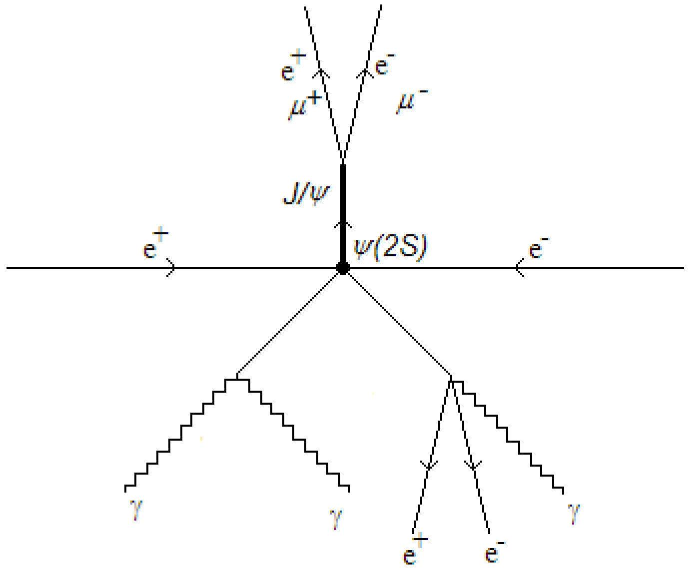
•$\Delta\Phi = \Phi_1 - \Phi_2$ is centered around 0 for the signal and offset for the conversion background.

•We require $\Delta\Phi < 0.1$

Low Energy Electron Reconstruction Efficiency



$$\psi(2S) \rightarrow J/\psi\ \pi^0\ \pi^0$$
$$J/\psi \rightarrow e^+\ e^-;\ \mu^+\ \mu^-$$
$$\pi^0 \rightarrow \gamma\ \gamma$$
$$\pi^0 \rightarrow \gamma\ e^+\ e^-$$

•We seek to exploit the electrons from Dalitz decay of the π^0 in this channel to measure the tracking efficiency for soft electrons at CLEO.

• Dataset 42 that has 53 /pb of data at psiprime resonance is used for this study.

•The J/ψ is reconstructed from e^+e^- or $\mu^+\mu^-$. One π^0 is reconstructed from two showers. The shower and an electron from the other π^0 are reconstructed and the expected 4-vector of the last electron is constructed from the above information.

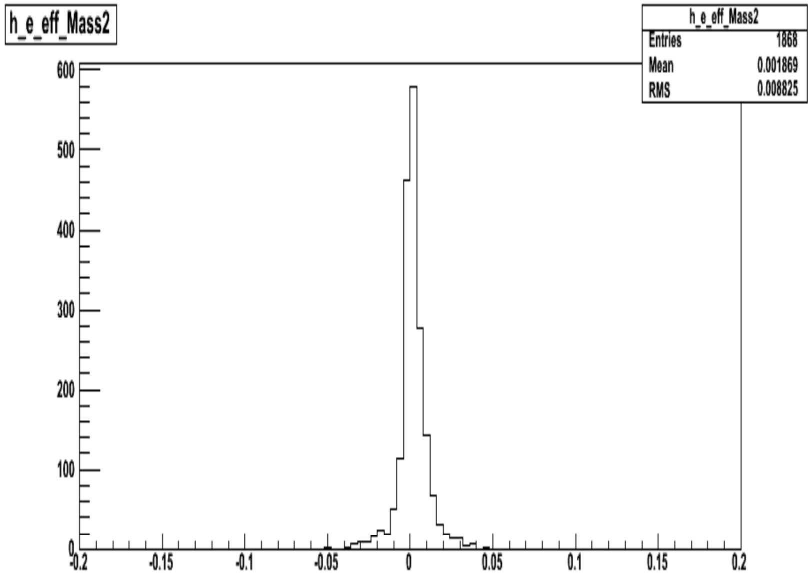
Low Energy Electron Reconstruction Efficiency

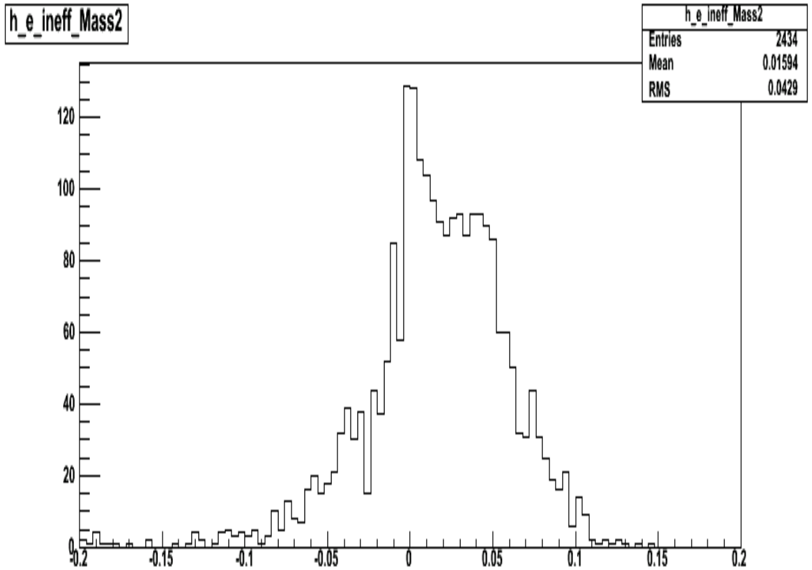
•The missing mass of this last electron is split into two plots:

- •the Efficient plot where the *ψ(2S)* is correctly reconstructed (top plot)
- •the Inefficient plot where the *ψ(2S)* is not correctly reconstructed (bottom plot)

•By cutting and counting, we can roughly estimate the efficiency of electron reconstruction to be ~ 90%

•We will generate Monte Carlo to fit these plots for a more precise measurement.





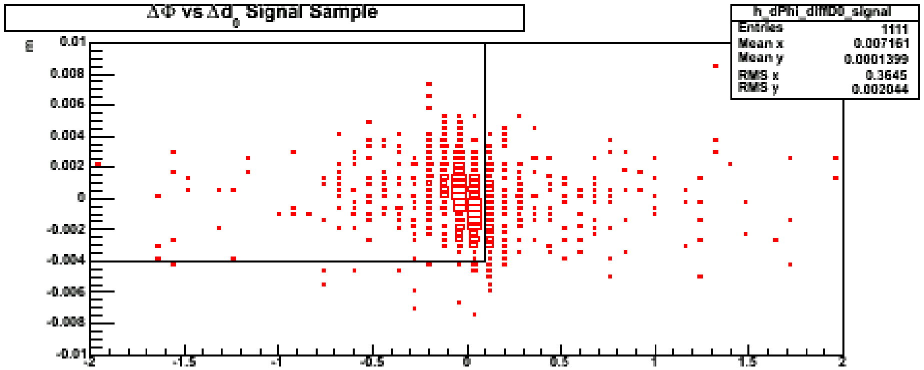
Selection Criteria Common to All D_S^+ Decay Modes

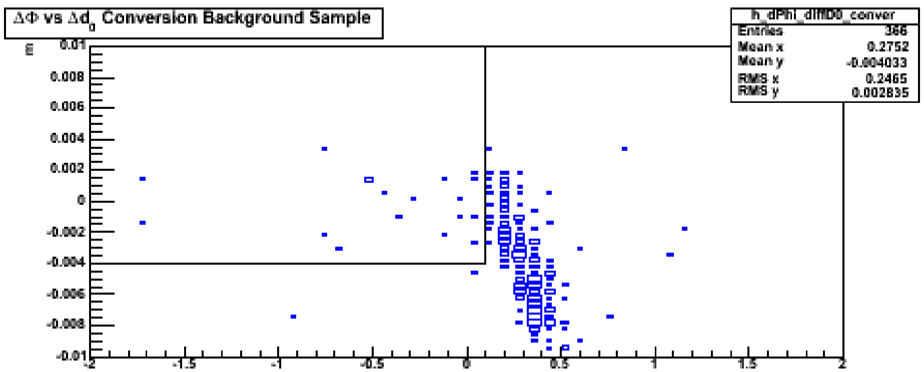
- Electron tracks must pass track quality cuts:
  - 10 MeV < Track Momentum < 2.0 GeV
  - $\chi^2 < 100{,}000$
  - $|d_0| < 5$ mm
  - $|z_0| < 5$ cm
- The track's *dE/dx* is required to be within 3.0 σ of that expected for an electron.

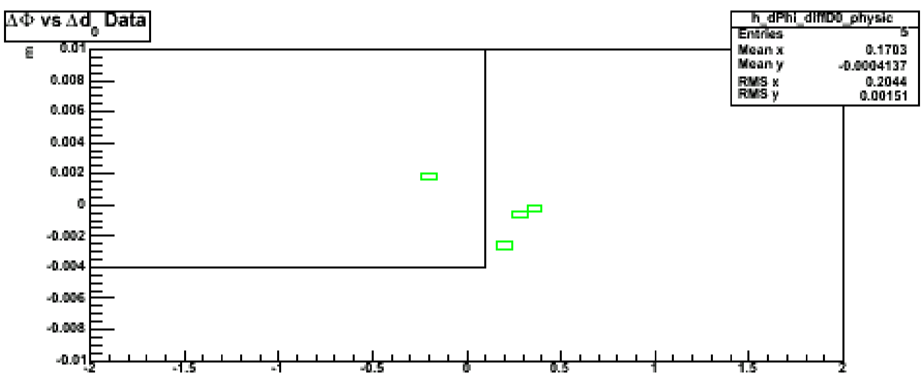
- The DTag tools applied their default criteria for the eight investigated modes.

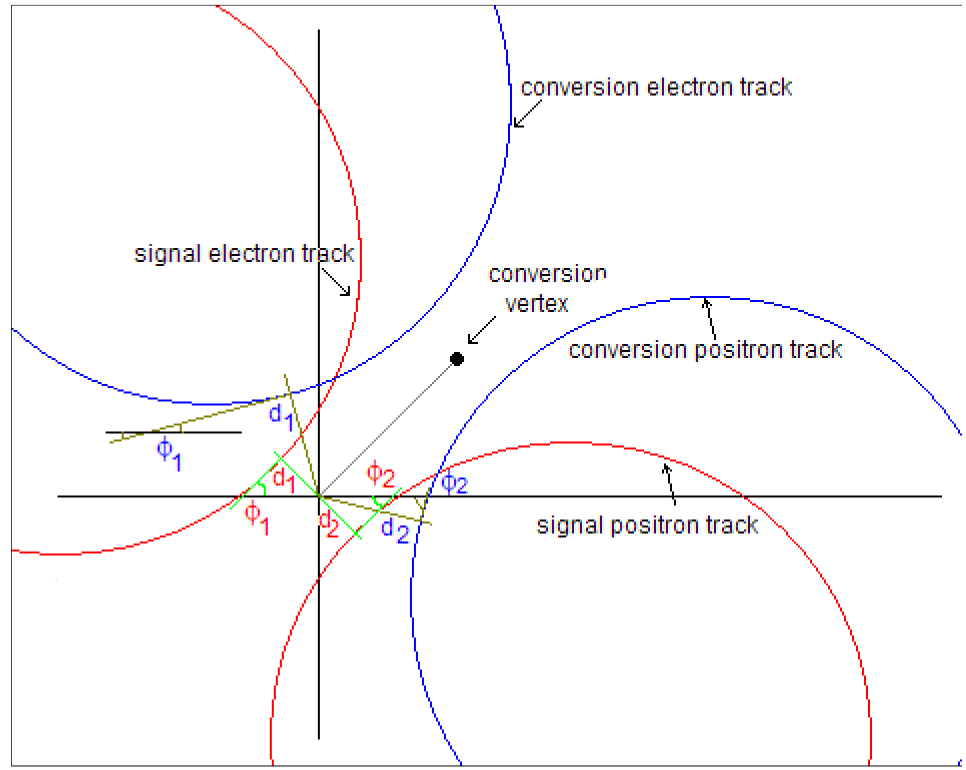
- These cuts, and the reconstruction of a D_S^{*+} were required for filling our n-tuples on which we applied subsequent cuts.

$K^{+}K^{-}\pi^{+}$ Mode $\Delta\Phi$ vs Δd_0









The $\Delta\Phi$ & Δd_0 between the electron and positron in the signal (red) and conversion (blue)