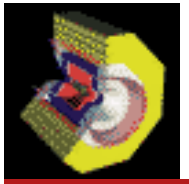

Cornell University
Laboratory for
Elementary-Particle Physics

$D_S^{*+} \to D_S^+ e^+ e^-$

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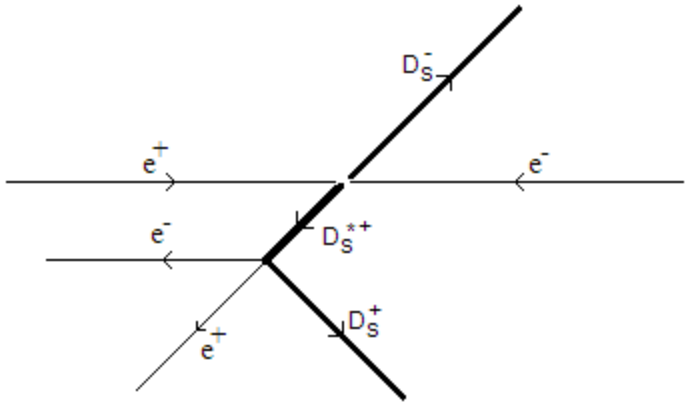
Cornell University

Contents

9 July 2009

What Are We Looking For?

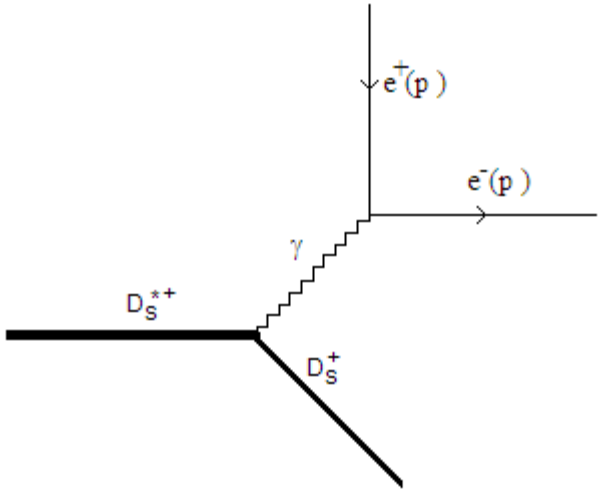


- We are looking for $D_S^{*+} \rightarrow D_S^+ e^+ e^-$ (+ c.c.) processes.

- We fully reconstruct the D_S^{*+}
  - The D_S^+ is reconstructed through several decay channels using DTag's default criteria. See CBX 06-11.
  - The $e+$ $e-$ share ~ 144 MeV. Pion fitted tracks for electrons (default in CLEO) at such low energies may not be reliable. Need fitting to electron hypothesis.
  - Events are selected using m_{DS+} , ΔE, m_{BC}, δm
  - Selection criteria on the e^+e^- tracks to reject conversion background $D_S^{*+} \rightarrow D_S^+ \gamma$

- Alternative analysis that reconstructs the D_S^- can give us more statistics.

Predicted $D_S^{*+} \rightarrow D_S^{+}\, e^{+}\, e^{-}$ Rate



If we write the decay of the D_S^{*+} to a real photon in the form:

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

Then we can write the decay to $e^{+}e^{-}$ in the form:

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

Evaluating the spin-average of the invariant amplitudes and integrating over phase space, we roughly predict the ratio of decay rates:

$$\frac{\Gamma\left(D_S^{*+} \rightarrow D_S^{+}e^{+}e^{-}\right)}{\Gamma\left(D_S^{*+} \rightarrow D_S^{+}\gamma\right)} \approx 1.4\alpha = 0.01$$

Decay Modes of D_S^+ Used

We reconstruct the D_s^+ through the following decay modes:

$$D_S^+ \to K^+K^-\pi^+$$

$$D_S^+ \to K_S K^+$$

$$D_S^+ \to \eta\pi^+; \eta \to \gamma\gamma$$

$$D_S^+ \to \eta'\pi^+; \eta' \to \pi^+\pi^-\eta; \eta \to \gamma\gamma$$

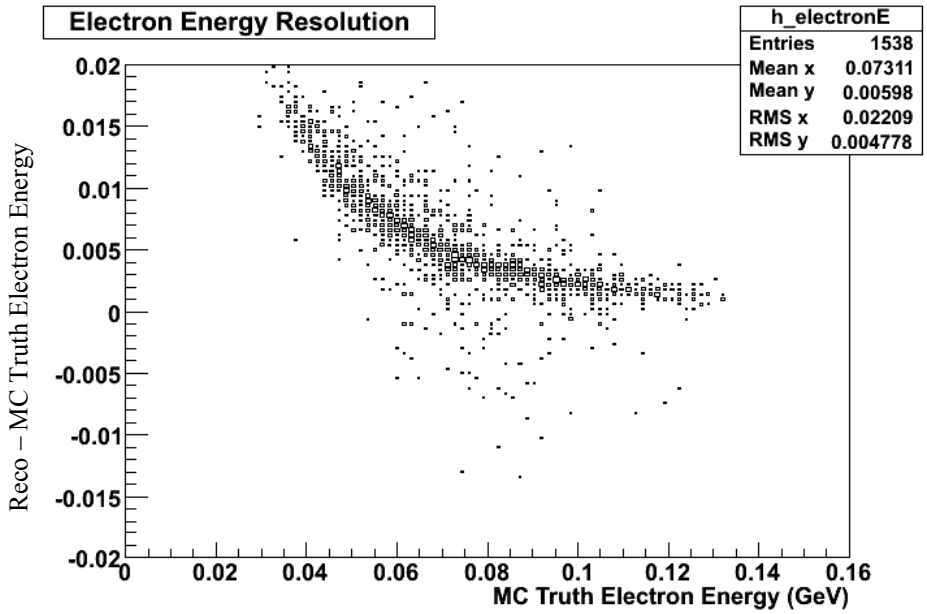
$$D_S^+ \to \pi^+\pi^+\pi^-$$

$$D_S^+ \to K^{*+}K^{*0}; K^{*+} \to K_S^0\pi^+; K^{*0} \to K^-\pi^+$$

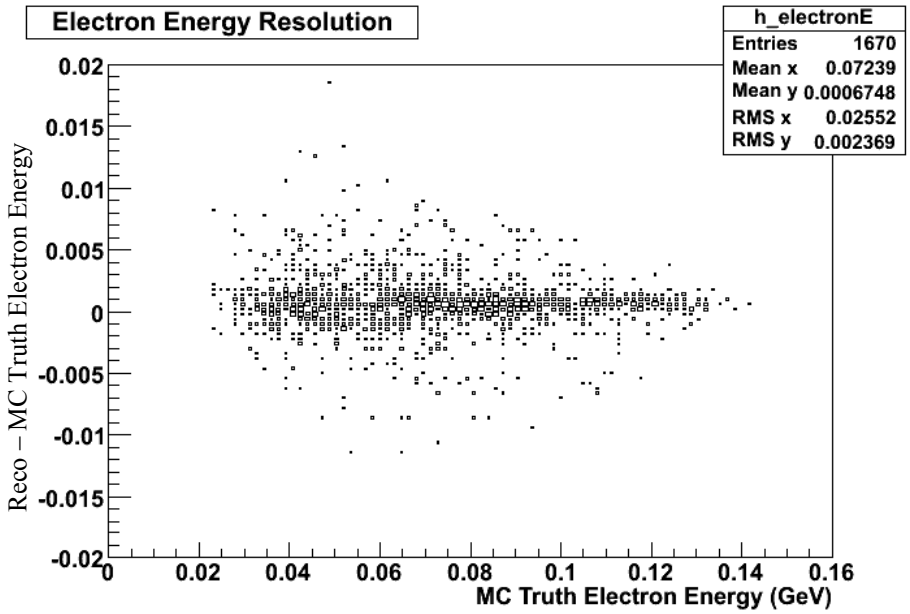
$$D_S^+ \to \eta\rho^+; \eta \to \gamma\gamma; \rho^+ \to \pi^+\pi^0$$

$$D_S^+ \to \eta'\pi^+; \eta' \to \rho^0\gamma$$

Fitting Soft Electrons to the Electron Hypothesis



Pion fit



Electron fit

We expect soft electron tracks with $p_T < 70$ MeV. Fitting electrons to the pion hypothesis is not reliable in this domain. Fitting to the electron hypothesis gives better energy resolution.

Signal and conversion background samples we generate have electrons fitted to the electron hypothesis.

CLEO data does not have tracks fitted to the electron hypothesis.

Signal Samples

- For signal Monte Carlo, we force the e^+e^- collision to produce a $\Psi(4160)$, and that to decay into D_s^{*+} , D_s^-
- We added an EVTGEN plug-in to generate vector (D_s^{*+}) to scalar (D_s^+), lepton (e^-), lepton (e^+) distributions with the invariant amplitude in consideration, apart from the invariant phase space factor.
- The D_s^+ was forced to decay through each of the previously mentioned channels. The D_s^- was allowed to decay generically.
- We fitted electrons to the electron hypothesis instead of the pion hypothesis.
- We generated 10,000 signal MC events for each decay mode of the D_s^+.

Conversion Background Samples

- A background that resembles the signal is expected from D_s^{*+} decaying to D_s^+, γ and the γ converting to e^+e^- in the beam-pipe 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 frequency as the signal.

- For this conversion background Monte Carlo, we force the e^+e^- collision to produce a $\Psi(4160)$, and then that to decay into the D_s^{*+}, D_s^-. The D_s^{*+} now decays via D_s^+, γ . The conversion of the photon to e^+e^- is taken care of in the detector simulation.
- We fitted electrons to the electron hypothesis instead of the pion hypothesis.
- We generated 100,000 events for each decay mode of the D_s^+.

Dataset Looked At

- We have looked at 110 pb^{-1} of data to determine the feasibility of this analysis.
- We used data collected at E_{CM} = 4170 MeV (dataset 47)
- CLEO-c has 602 pb^{-1} of data at this energy.
  $D_S^{*+}D_S^- + D_S^{*-}D_S^+$ cross section is ~ 1 nb at this energy.

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.

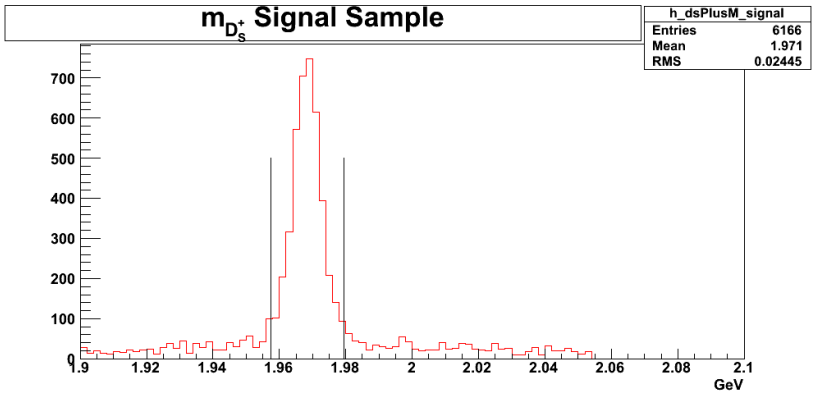
- These cuts, and the reconstruction of a D_S^{*+} were required for filling our n-tuples on which we applied subsequent cuts.

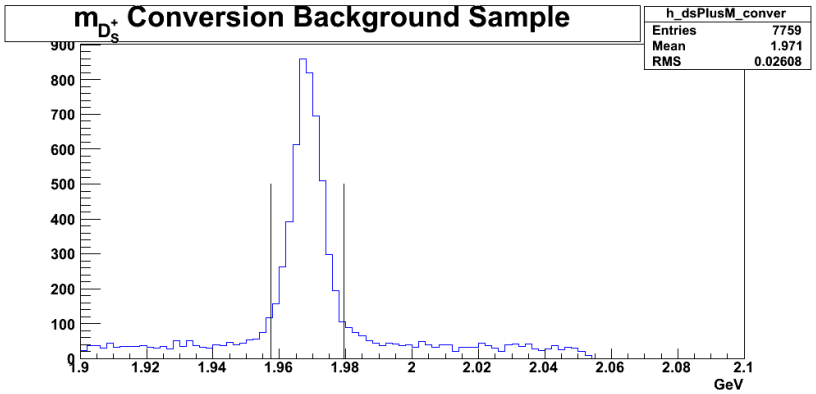
The $K^+K^-\pi^+$ Decay Mode

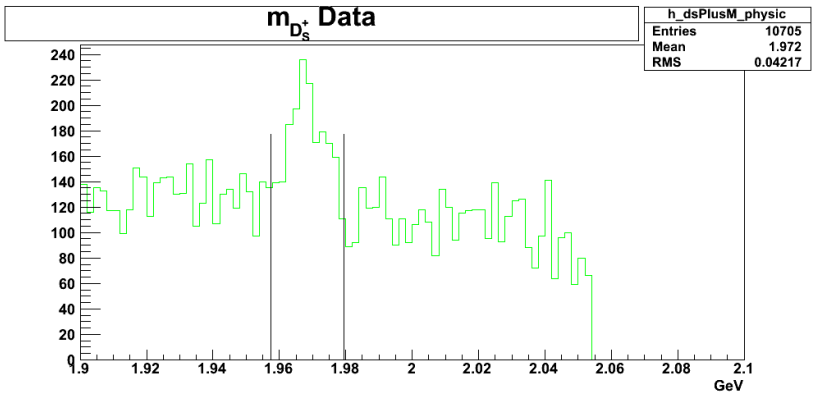
The following slides illustrate the selection criteria used to distinguish the signal from the conversion background by focusing on the $D_s^+ \rightarrow K^+K^-\pi^+$ channel.

- The top plot in red is the signal.
- The middle plot in blue is the conversion background.
- The bottom plot in green is the data.

$K^+K^-\pi^+$ Mode $D_S^+{}_{Mass}$ Cut



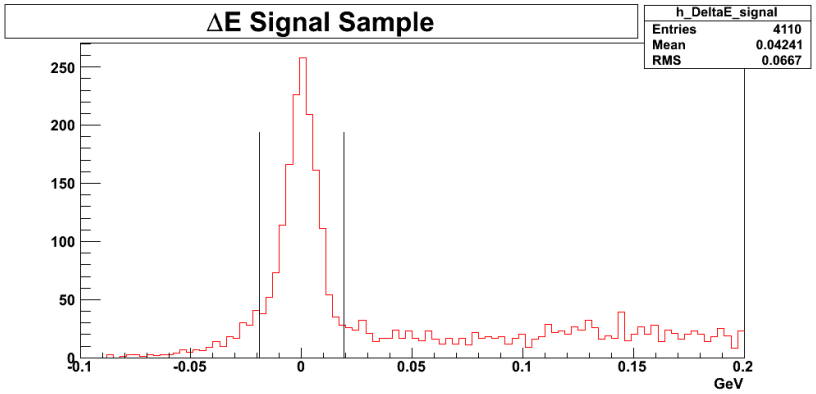


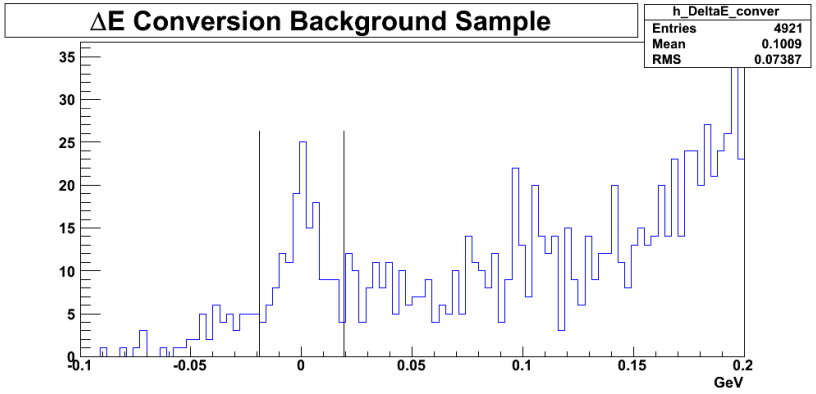


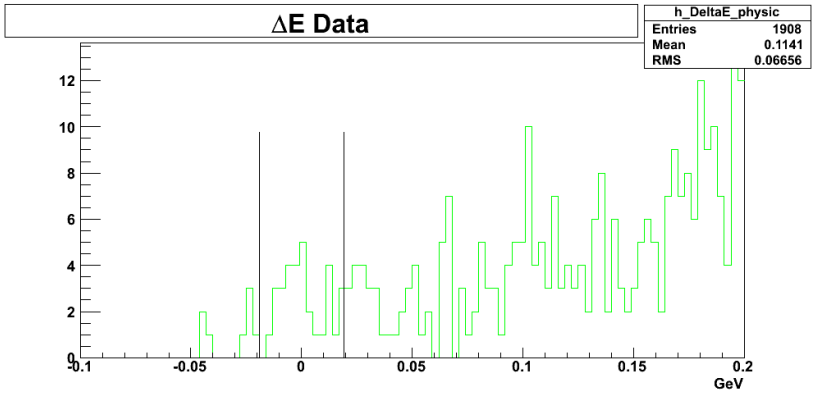
- Reconstructed $D_S^+{}_{Mass}$
- We cut on

$$| D_S^+{}_{Mass} - 1.969 \text{ GeV} | < 0.011 \text{ GeV}$$

$K^+K^-\pi^+$ Mode ΔE Cut



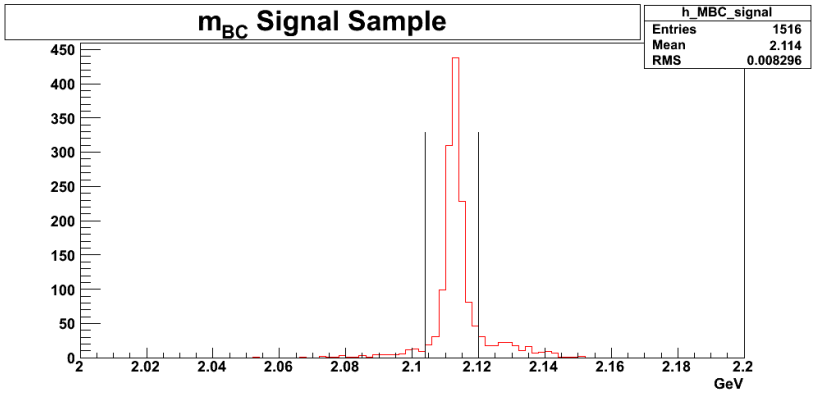


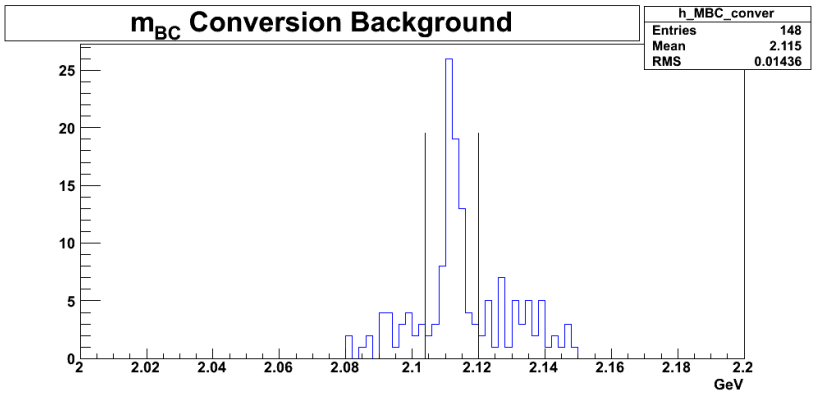


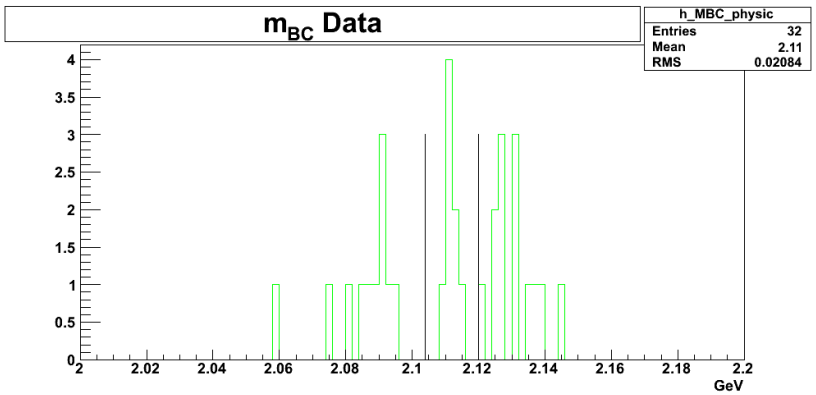
$$\Delta E = E(K^+K^-\pi^+e^+e^-) - E(D_S^{*+}beam)$$

- We cut on $|\Delta E|<0.019$ GeV

$K^+K^-\pi^+$ Mode m_{BC} Cut



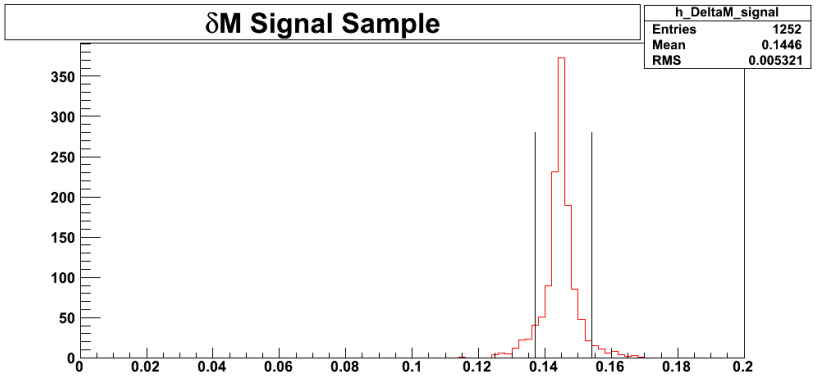


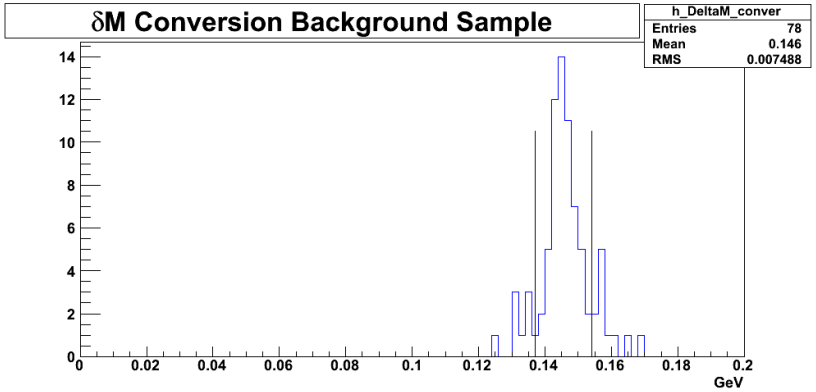


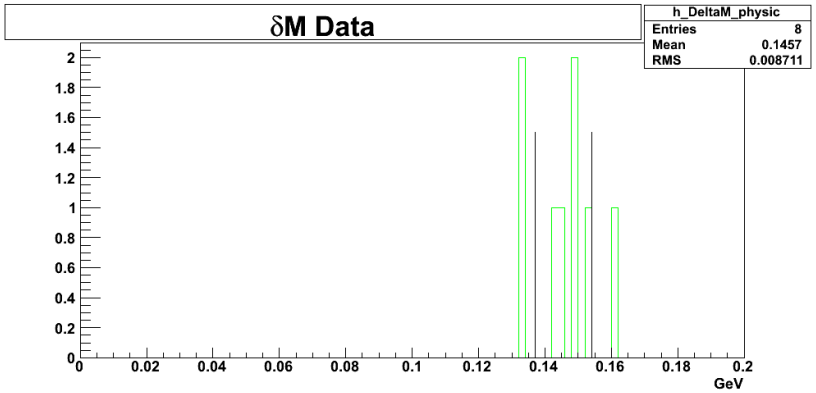
$$m_{BC} = \sqrt{E^2(D_S^{*+}beam) - P^2(K^+K^-\pi^+e^+e^-)}$$

- Will cut on $|\ m_{BC} - 2.112\ \text{GeV}\ | < 0.008\ \text{GeV}$

$K^+K^-\pi^+$ Mode δm Cut



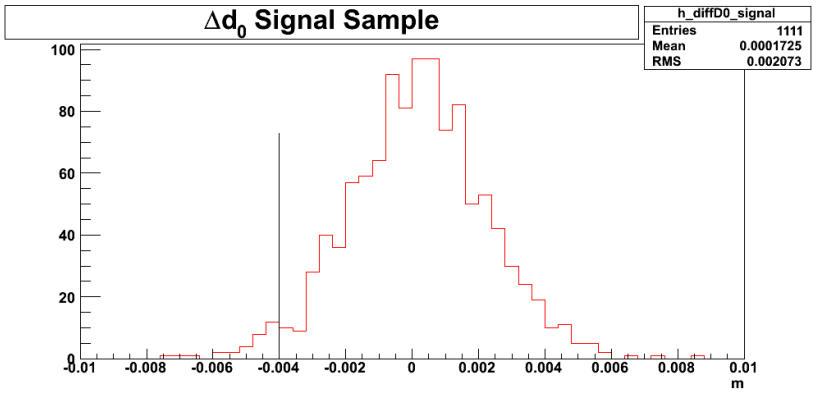


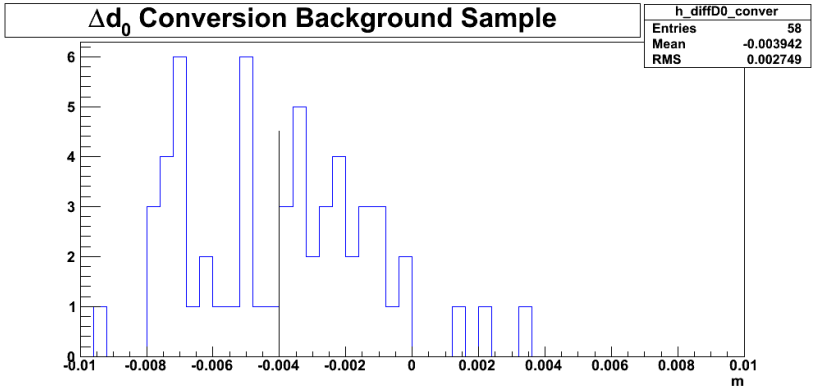


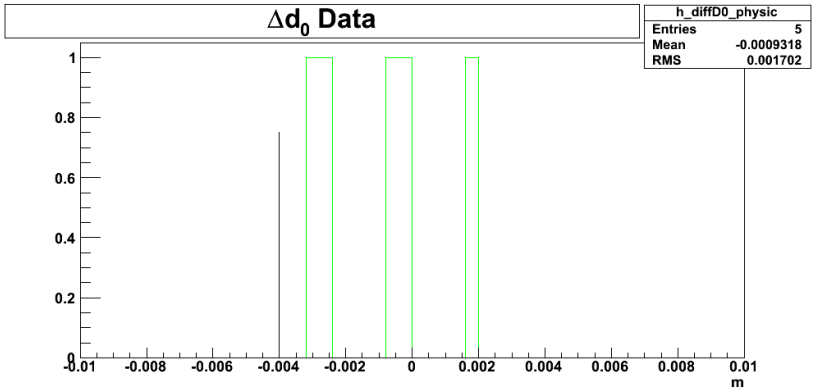
$$\delta m = M(K^+K^-\pi^+e^+e^-) - M(K^+K^-\pi^+)$$

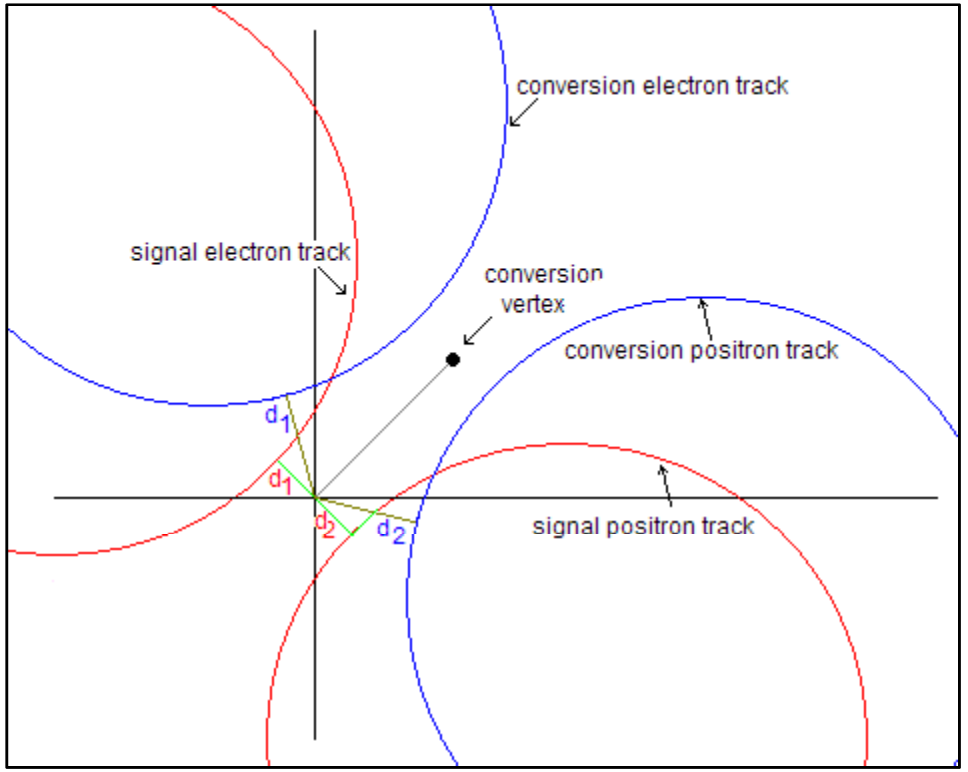
- We cut on $|\delta m - 0.1455\ \text{GeV}| < 0.0085\ \text{GeV}$

$K^+K^-\pi^+$ Mode Δd_0 Cut







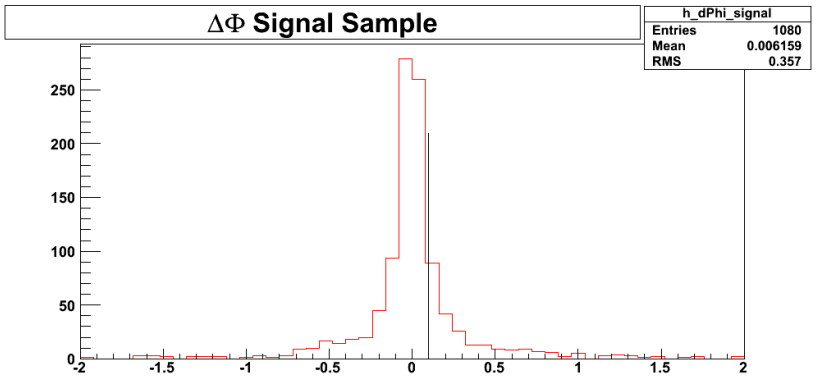


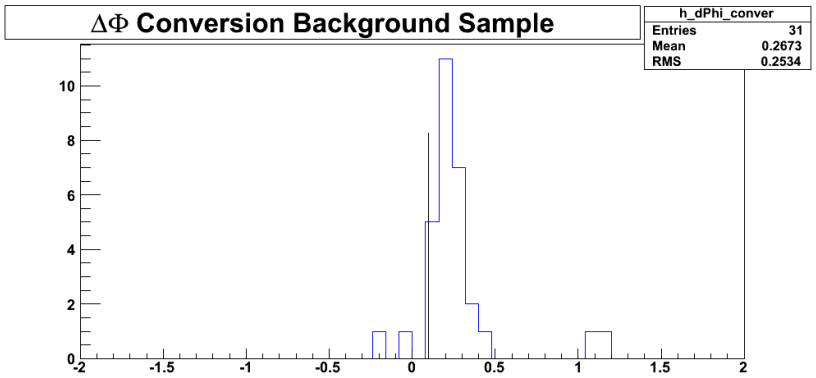
Δd_0 between the electron and positron in the signal (red) and conversion (blue)

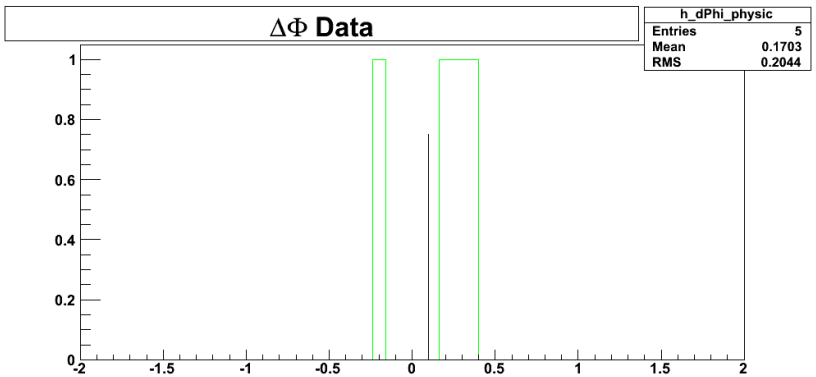
- The $\Delta d_0 = d_1 - d_2$ is centered around 0 for the signal and offset from 0 for conversion backgrounds

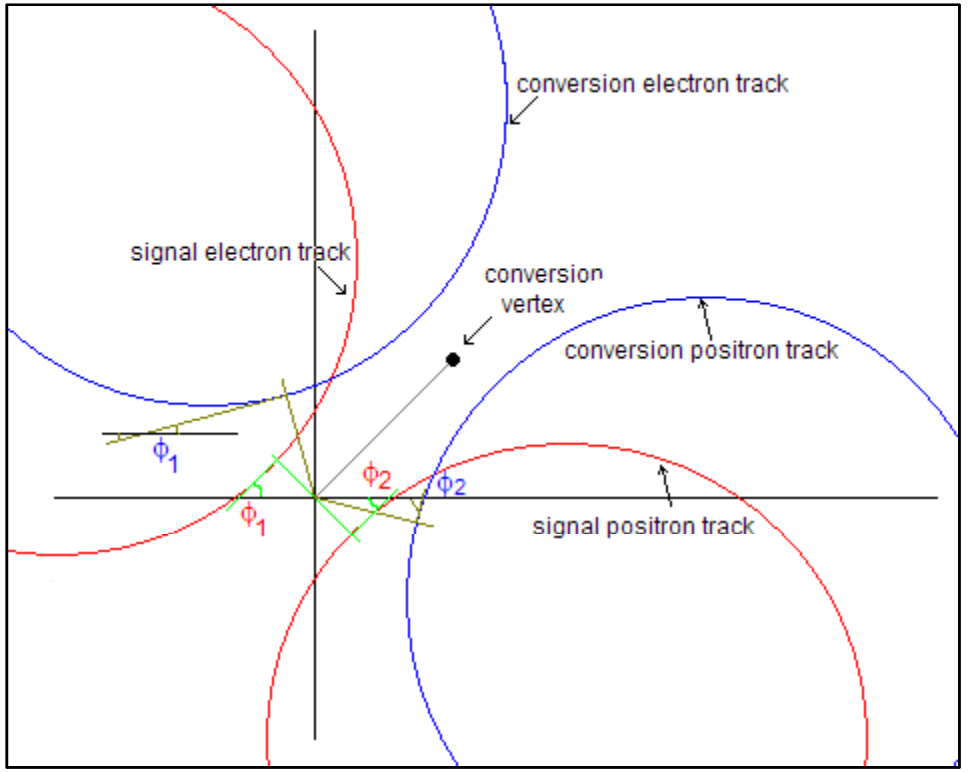
- We require $d_1 - d_2 > -0.004$ m

$K^+K^-\pi^+$ Mode $\Delta\Phi$ Cut







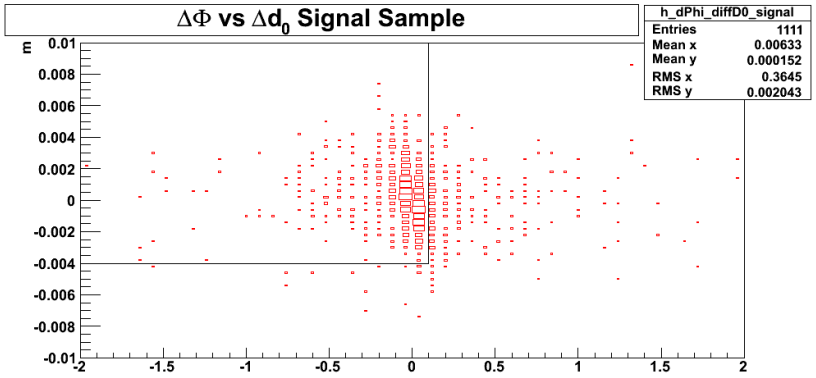


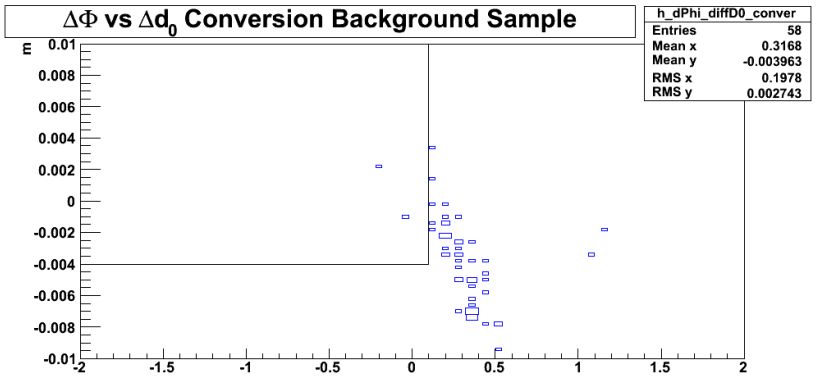
ΔΦ between the electron and positron in the signal (red) and conversion (blue)

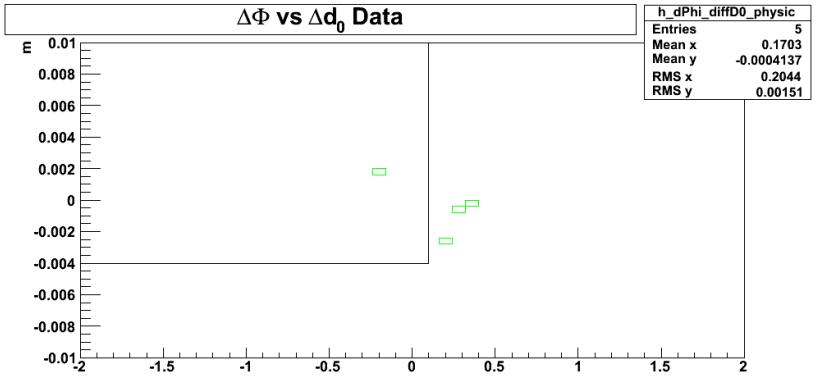
- $\Delta\Phi = \Phi_1 - \Phi_2$ is centered around 0 for the signal and offset for the conversion background.

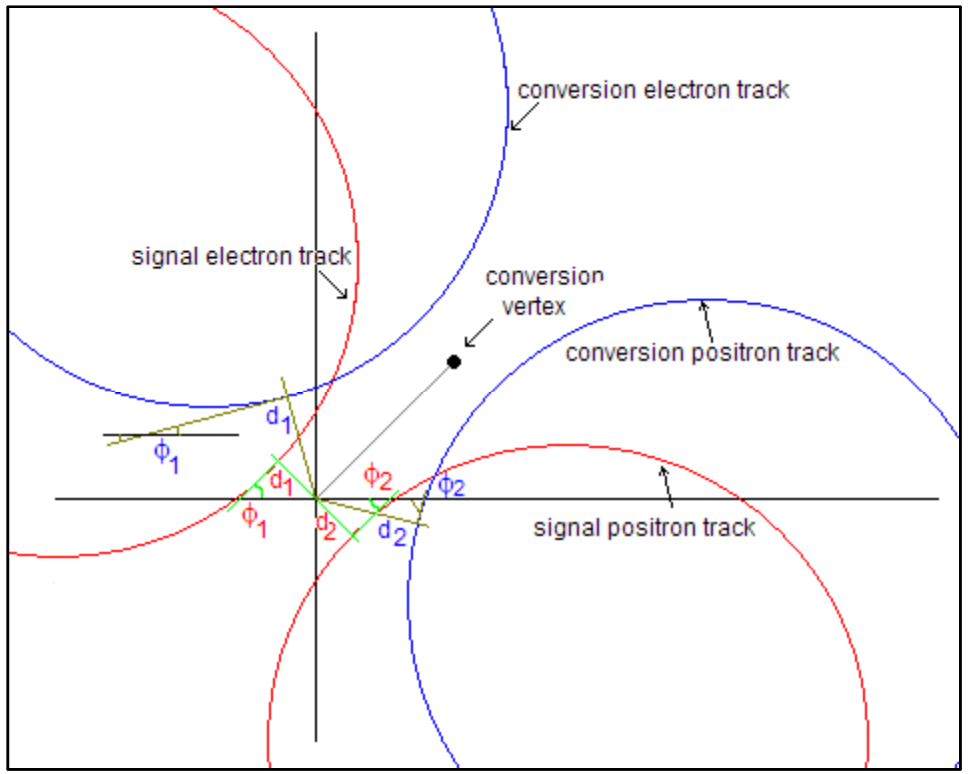
- We require $\Delta\Phi < 0.1$

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









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

Prediction for Data

Decay Mode of the D_S^+	Remaining in Signal Sample starting from 10,000 events	Remaining in Background Sample starting from 100,000 events	Signal Events Expected in 110 pb^{-1}	Background Events Expected in 110 pb^{-1}	Events in 110 pb^{-1} (electrons still fitted to pion hypothesis)
$K^+K^-pi^+$	815	2	4.743	0.114	2
K_sK^+	712	3	1.123	0.046	0
$\pi^+\eta$; $\eta\to\gamma\gamma$	839	2	0.551	0.129	0
$\pi^+\acute{\eta}$; $\acute{\eta}\to\pi^+\pi^-\eta$; $\eta\to\gamma\gamma$	504	1	0.356	0.007	1
$\pi^+\pi^-\pi^+$	1200	2	1.415	0.023	2
$K^{*+}K^{*0}$; $K^{*+}\to K^0{}_S\pi^+$; $K^{*0}\to K^-\pi^+$	453	2	0.789	0.034	2
$\eta\rho^+$; $\eta\to\gamma\gamma$; $\rho^+\to\pi^+\pi^0$	641	8	3.492	0.427	6
$\acute{\eta}\pi^+$; $\acute{\eta}\to\rho^0\gamma$	875	8	1.032	0.092	0
Total			13.74	0.757	13

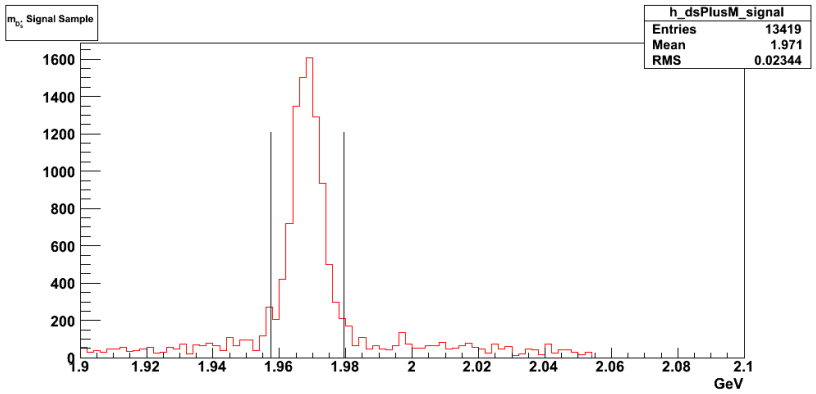
Total number of signal events expected in 602 inv-pb ~ **74**
Total number of conversion background events expected in 602 inv-pb ~ **4**

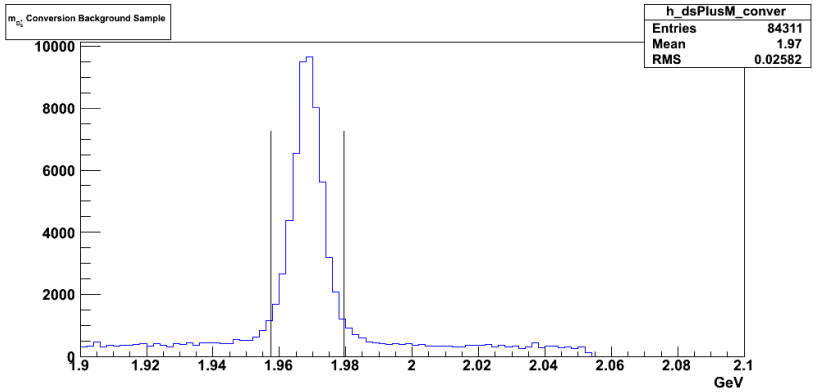
Summary and Plans

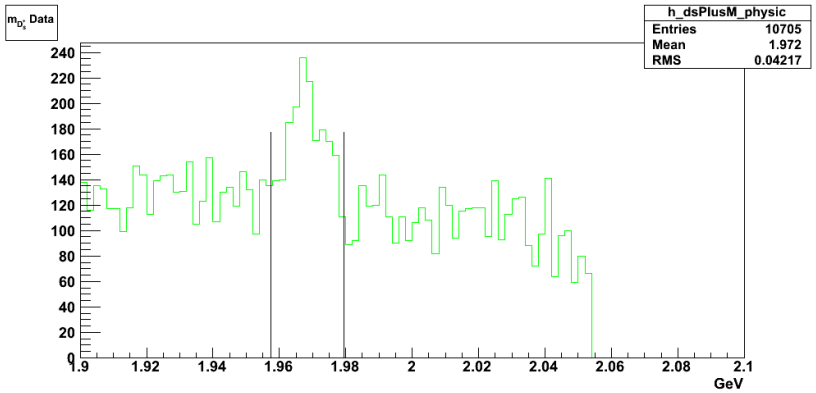
- This analysis is feasible with the data available at CLEO.
- The theoretically predicted ratio of the rate of $D_S^{*+} \rightarrow D_S^+ e^+ e^-$ to the rate of $D_S^{*+} \rightarrow D_S^+ \gamma$ can be refined.
- Selection criteria for all the decay modes need to be optimized systematically.
- Still studying how best to separate signal from conversion background.
- We can reconstruct the other D_S^- in the event and increase statistics.
- We need to measure the tracking efficiency for low momentum electrons.
- Events in data that pass some loose selection criteria will need to have tracks fitted to the electron hypothesis.

Backup Slides

$K^+K^-\pi^+$ Mode $D_S^+{}_{Mass}$ Cut





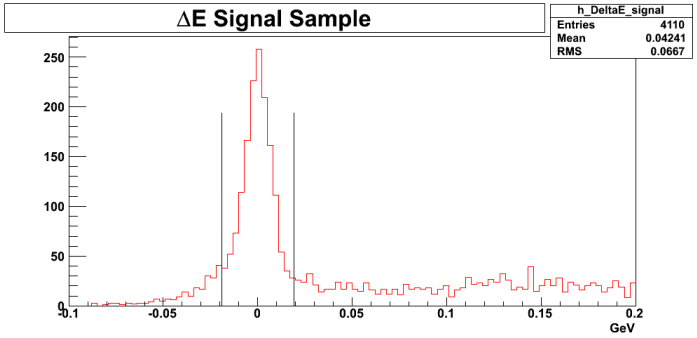


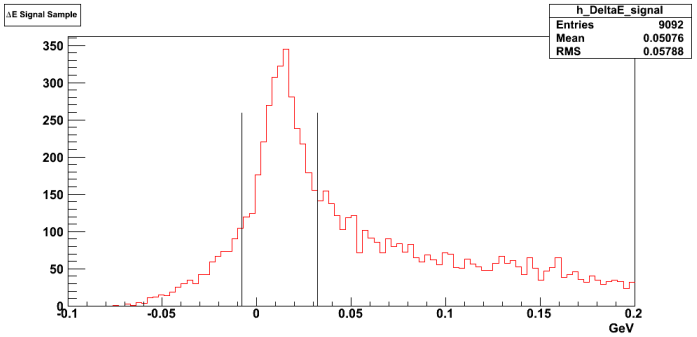
- Reconstructed $D_S^+{}_{Mass}$
- We cut on

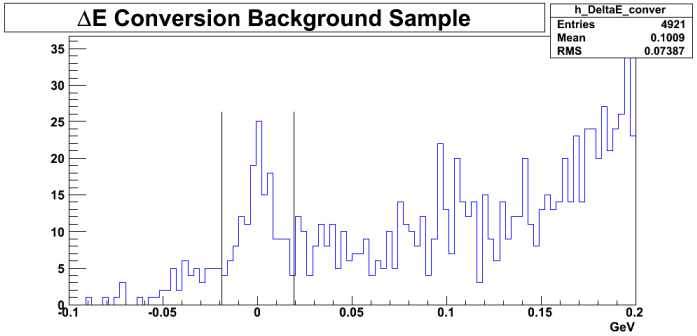
$$| D_S^+{}_{Mass} - 1.969 \text{ GeV} | < 0.011 \text{ GeV}$$

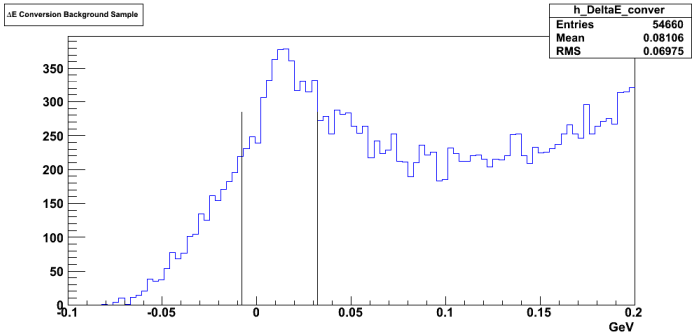
$K^+K^-\pi^+$ Mode ΔE Cut

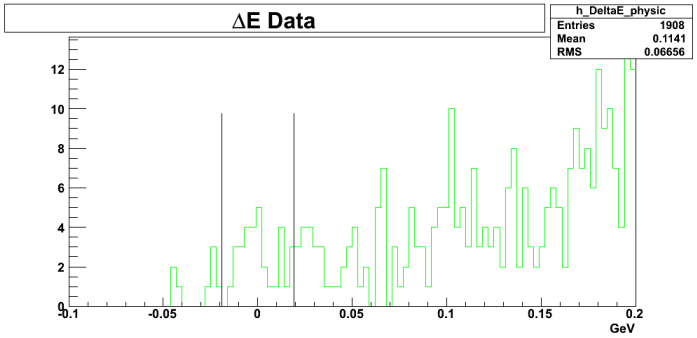
Electron Fit $\Delta E = E(K^+K^-\pi^+e^+e^-) - E(D_S^{*+}beam)$ **Pion Fit**

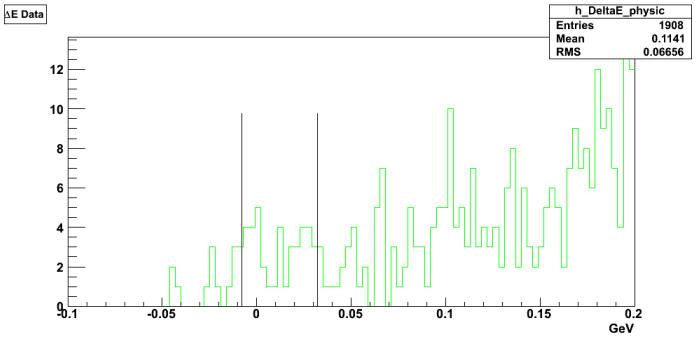








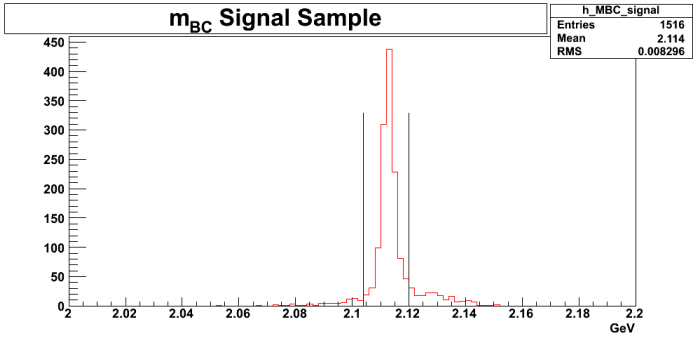


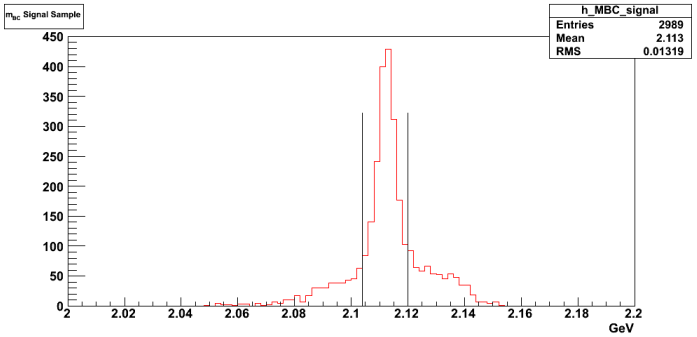


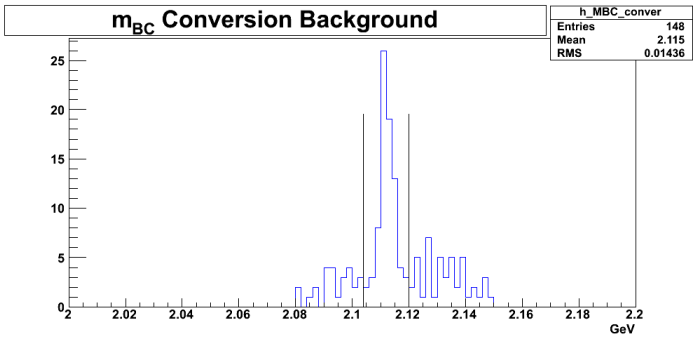
- We cut on $|\Delta E|<0.019$ GeV
- We cut on $|\Delta E - 0.12 \text{ GeV}|<0.02$ GeV

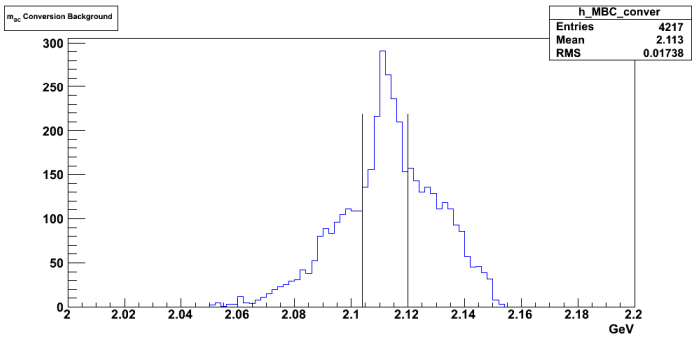
$K^+K^-\pi^+$ Mode m_{BC} Cut

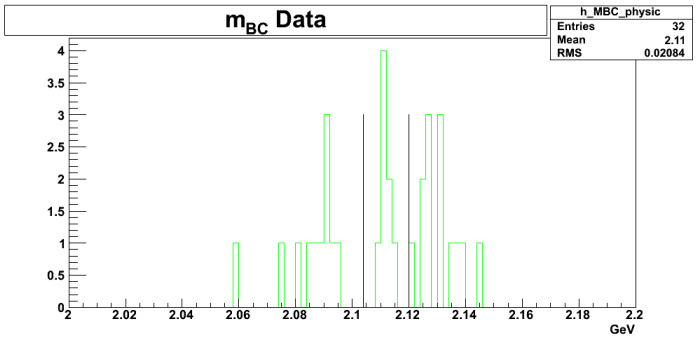
Electron Fit $m_{BC} = \sqrt{E^2(D_S^{*+}beam) - P^2(K^+K^-\pi^+e^+e^-)}$ **Pion Fit**

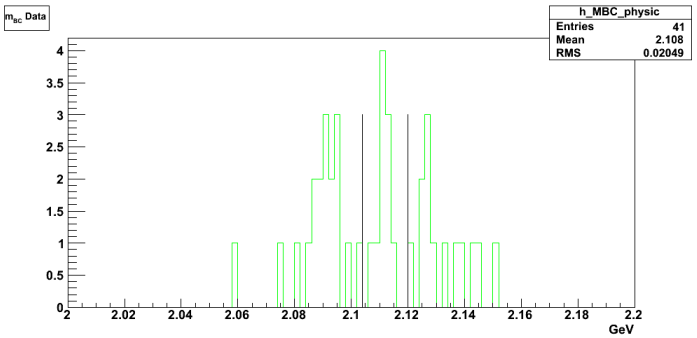








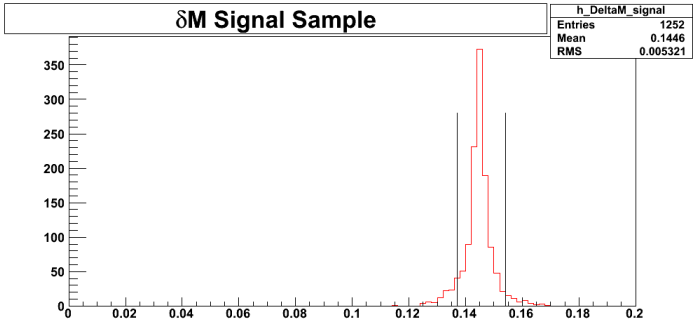


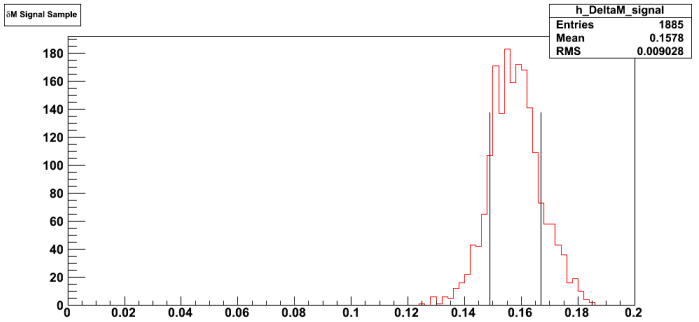


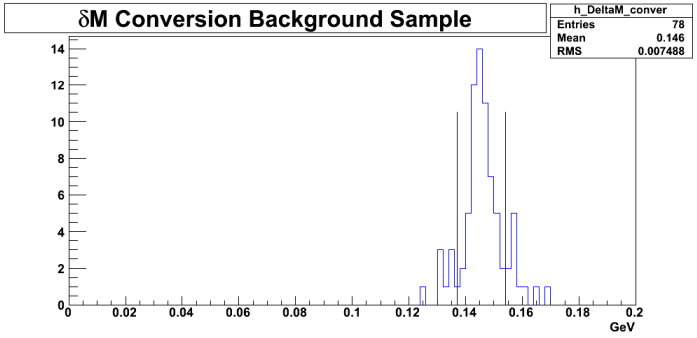
- Will cut on | m_{BC} – 2.112 GeV | < 0.008 GeV
- Will cut on | m_{BC} – 2.112 GeV | < 0.008 GeV

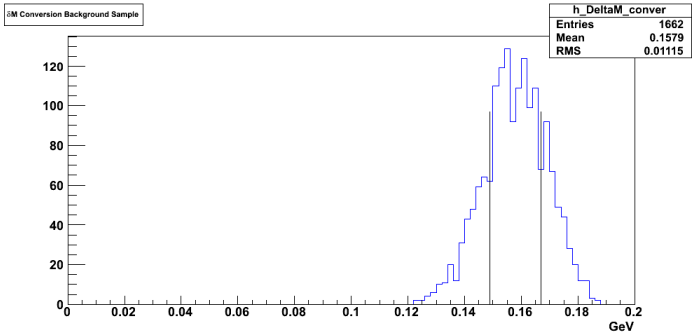
$K^+K^-\pi^+$ Mode δm Cut

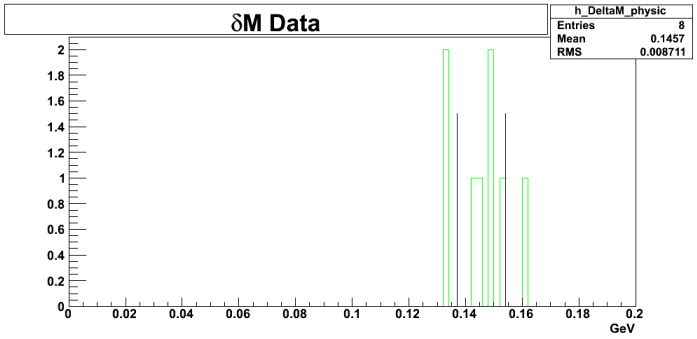
Electron Fit $\delta m = M(K^+K^-\pi^+e^+e^-) - M(K^+K^-\pi^+)$ **Pion Fit**

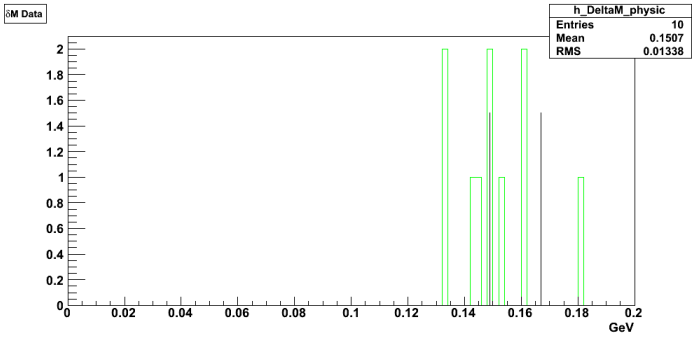








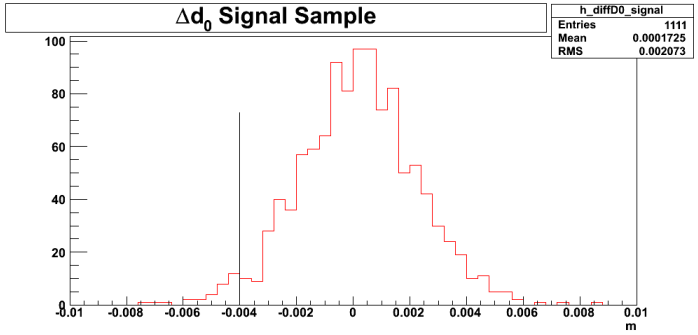


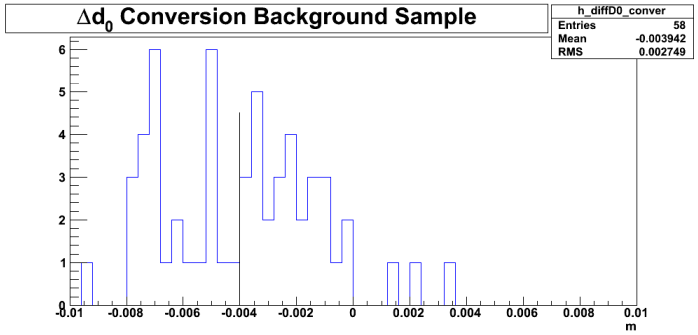


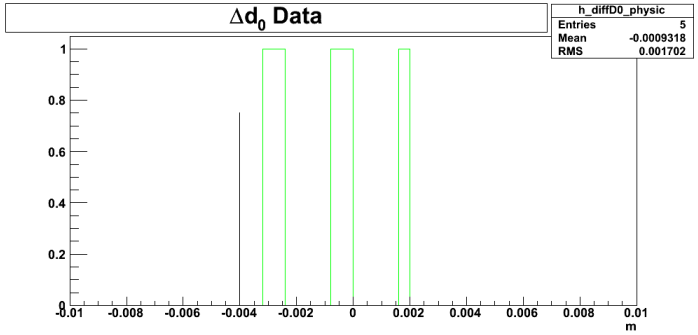
- We cut on |δm – 0.1455 GeV | < 0.0085 GeV
- We cut on |δm – 0.158 GeV | < 0.009 GeV

$K^+K^-\pi^+$ Mode Δd_0 Cut

Electron Fit

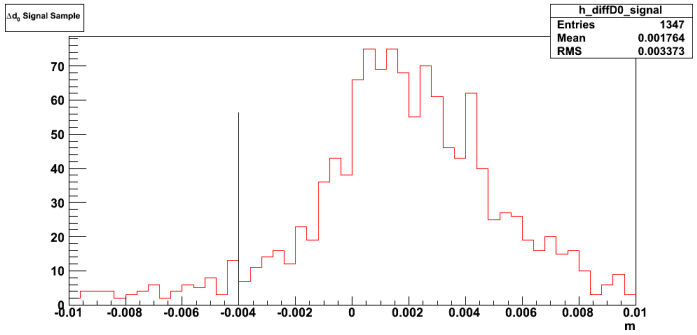


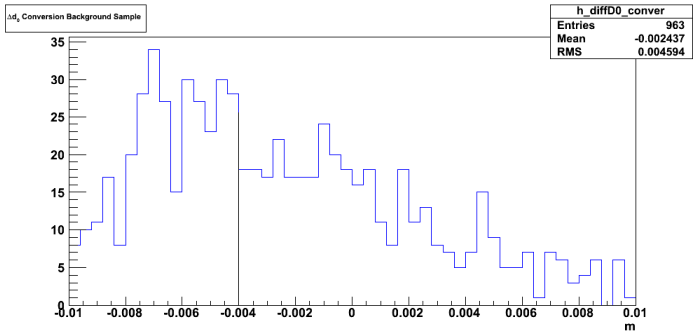


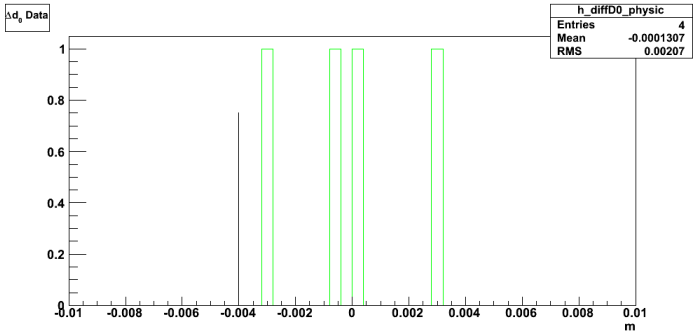


•We require $d_1 - d_2 > -0.004$ m

Pion Fit



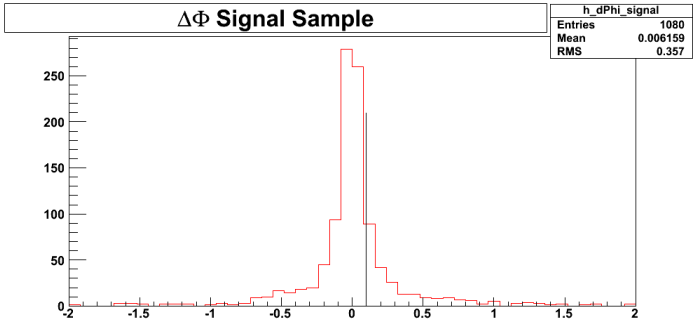


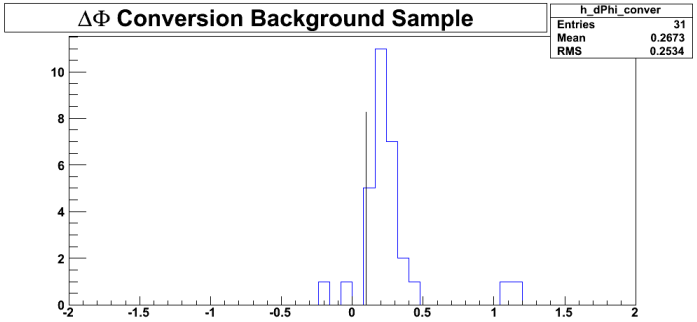


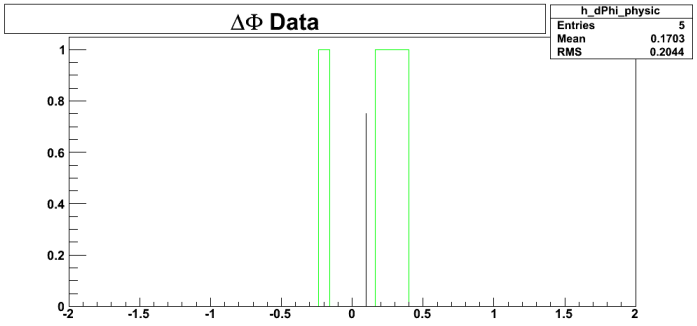
•We require $d_1 - d_2 > -0.004$ m

$K^+K^-\pi^+$ Mode ΔΦ Cut

Electron Fit

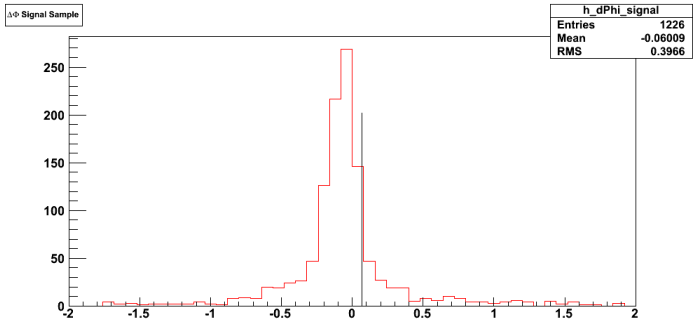


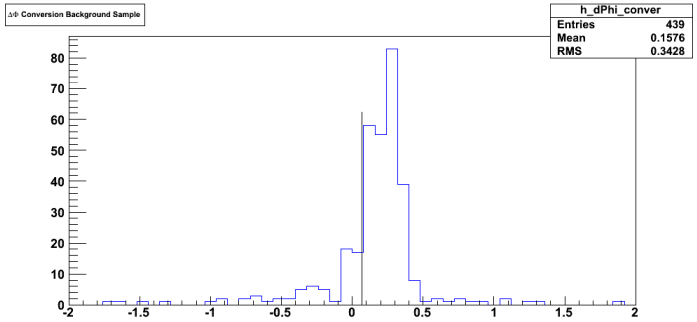


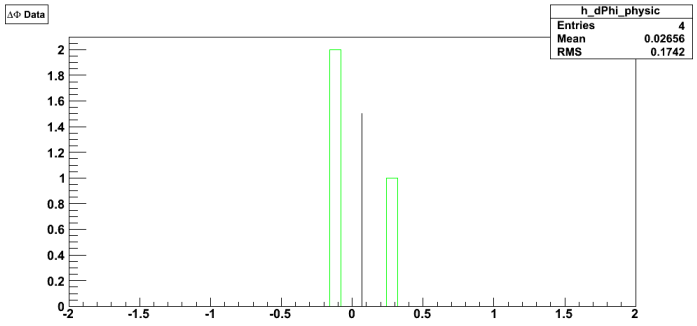


•We require ΔΦ < 0.1

Pion Fit





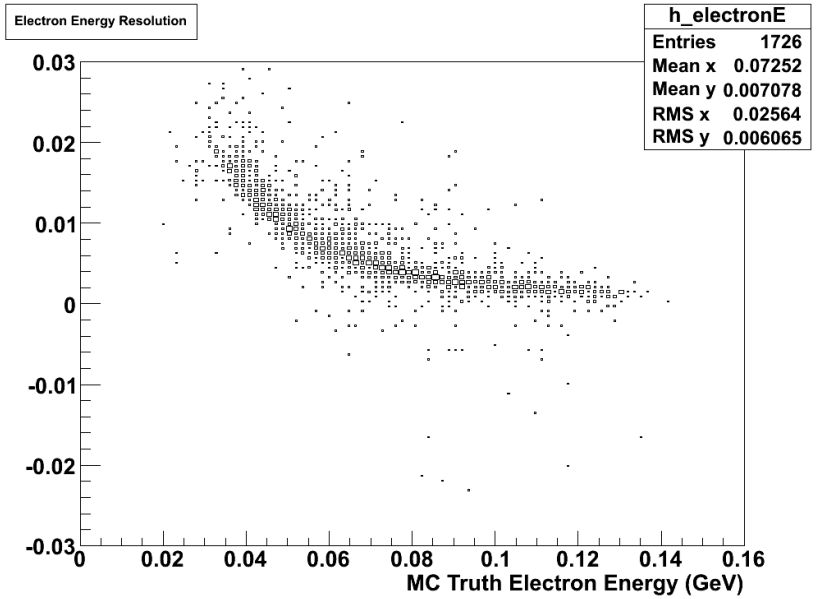


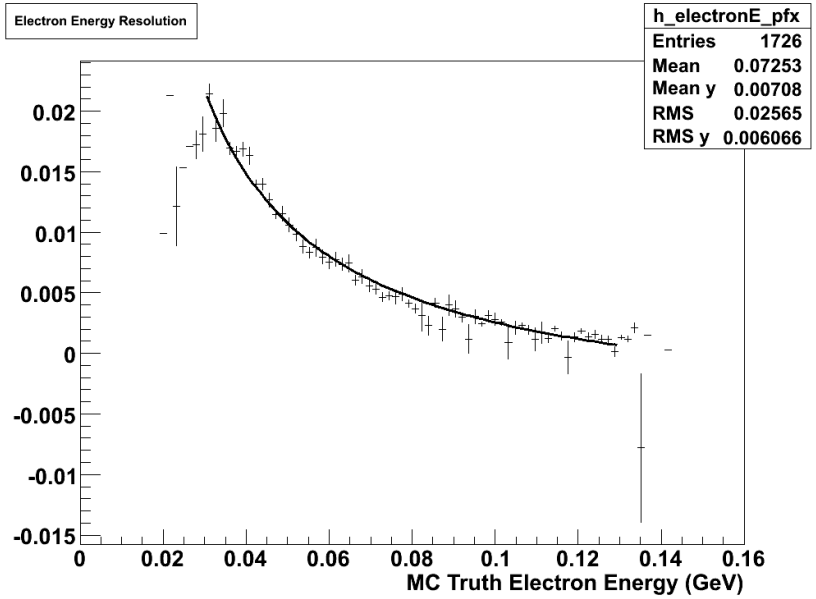
•We require ΔΦ < 0.07

Prediction for Data

Decay Mode of the D_S^+	Remaining in Signal Sample starting from 10,000 events	Remaining in Background Sample starting from 100,000 events	Signal Events Expected in 110 pb^{-1}	Background Events Expected in 110 pb^{-1}	Events in 110 pb^{-1} (electrons still fitted to pion hypothesis)
(Electron Fit) $K^+K^-pi^+$	815	2	4.7	0.11	2
(Pion Fit) $K^+K^-pi^+$	863	72	5.0	0.41	3

Parameterizing the Corrections due to Pion Fit



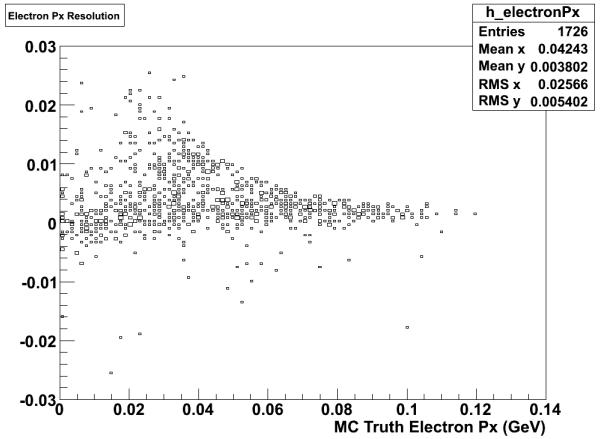


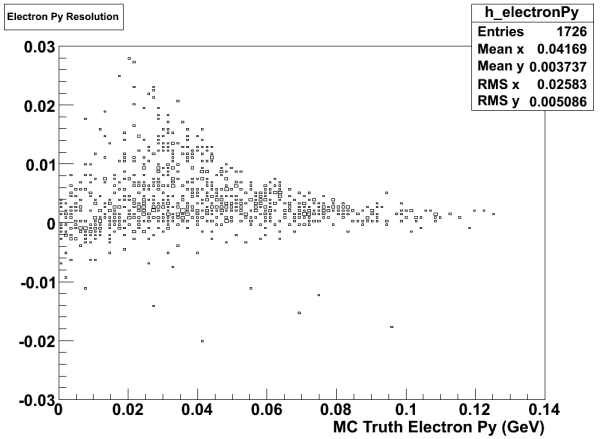
Fitted the E_reco – E_MC to:

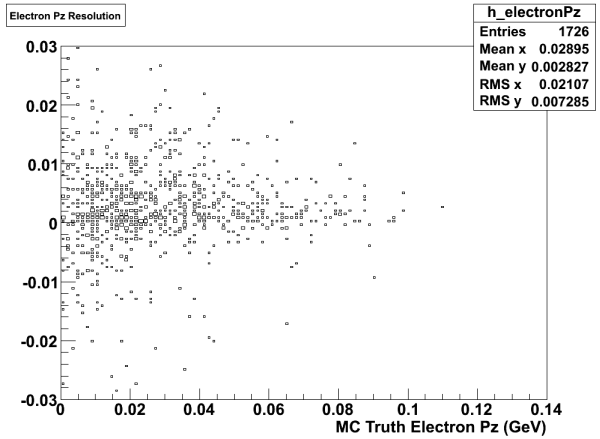
E_reco – E_MC = -5.6e-3 + 8.2e-4 / E_MC

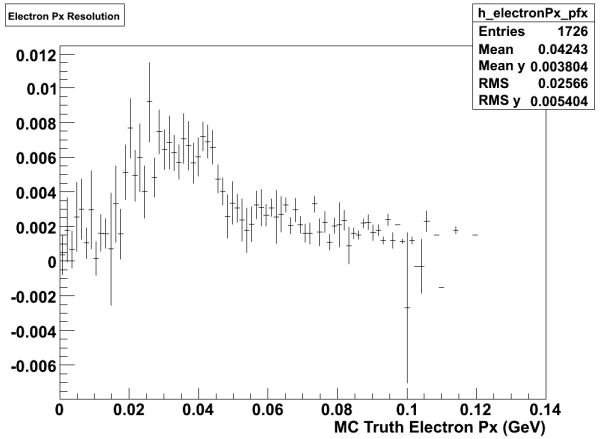
Between 30 MeV and 130 MeV.

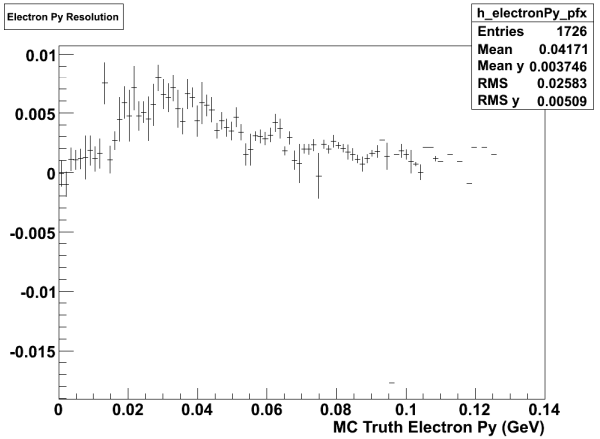
Parameterizing the Corrections due to Pion Fit

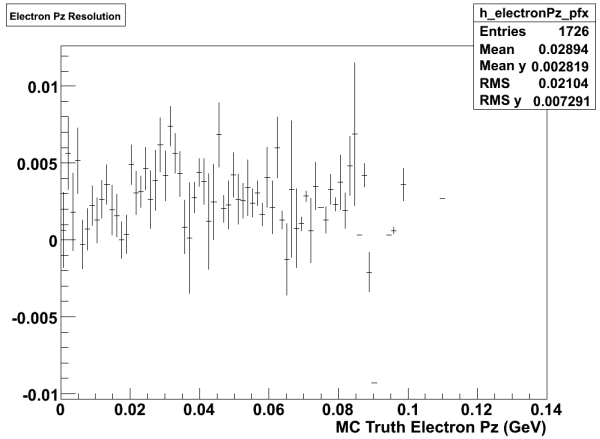












Near Few Days…

- Parameterize the deviations in d0 and \phi for a pion fitted track.
- Correct the pion fitted KKpi channel's parameters like dE, mBC, dPhi etc and see if yields and signal/background are closer to the electron fit.
- Looking at angle between z and Ds*+, and between Ds*+ and Ds+