# Neutrino Energy Spectrum From Semileptonic D Decays

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CLEO-c

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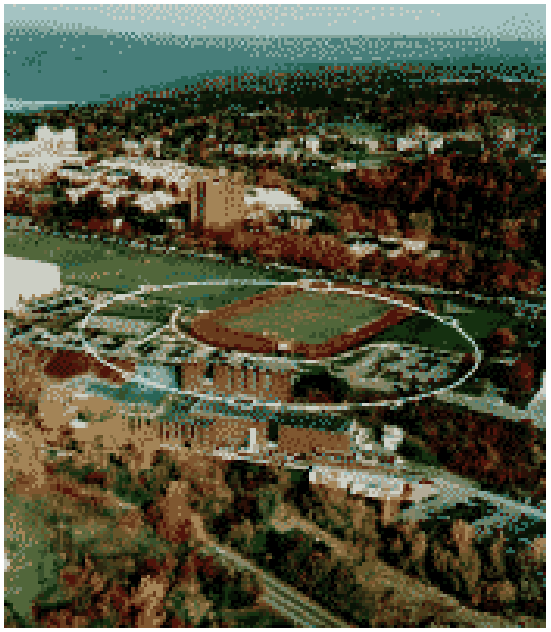
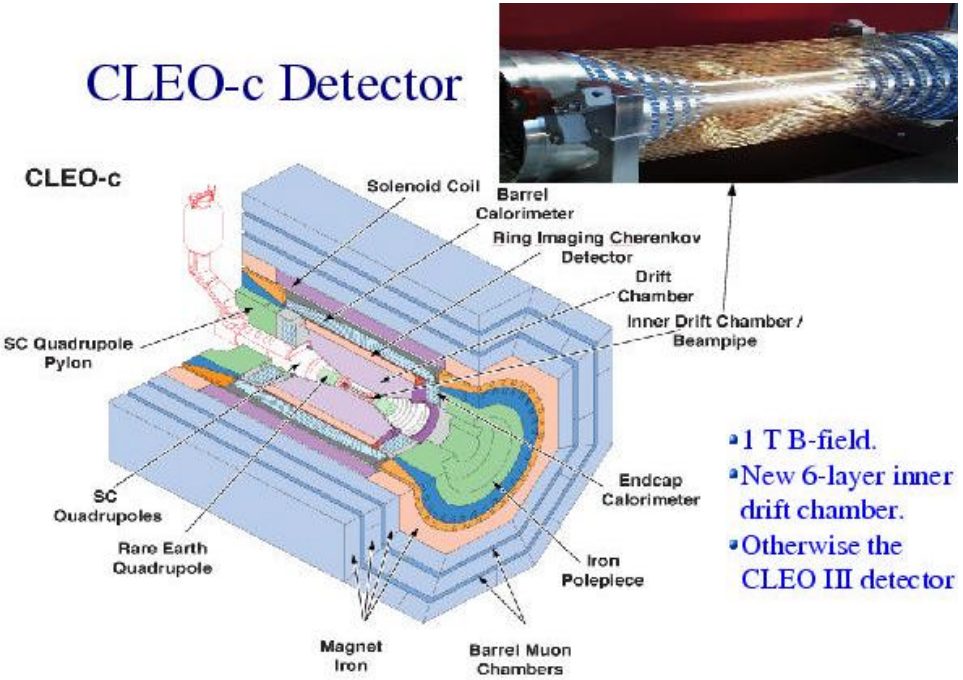
CORNELL UNIVERSITY LEPP

LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

# CLEOc



- CESR: symmetric $e^+e^-$ accelerator
- Running on Psi(3770)
  - Charm production threshold
- 57.2 /pb data taken
  - More to be taken starting in fall with higher running luminosity
- CLEOc: CLEOIII detector with silicon vertex replaced by drift chamber



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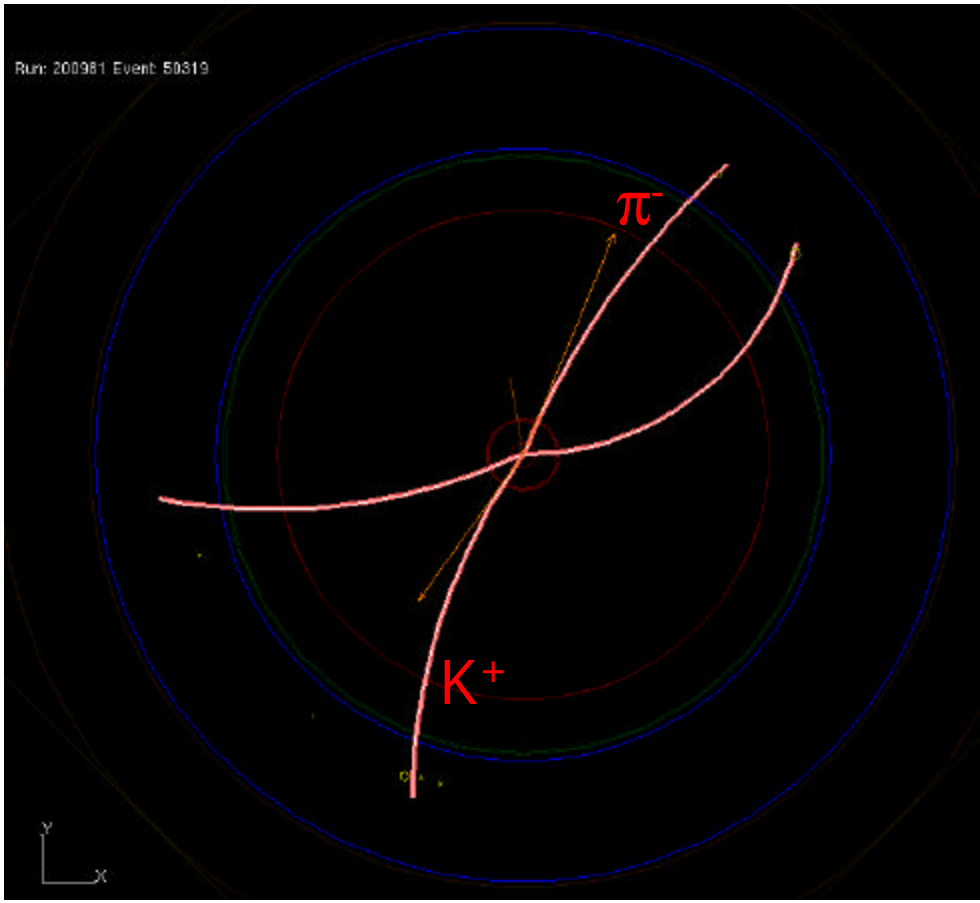
# Motivation

Tagged $\overline{D}^0 \to K^+ p^-$

- Physics
  - Branching fractions and form factors by different method
- Spectrum not previously measured for neutrinos
  - Unique opportunity at CLEOc
    - Clean events
    - Tagged D fully reconstructed
- Lepton flavor blind
  - Electrons and muons on equal footing

Data event



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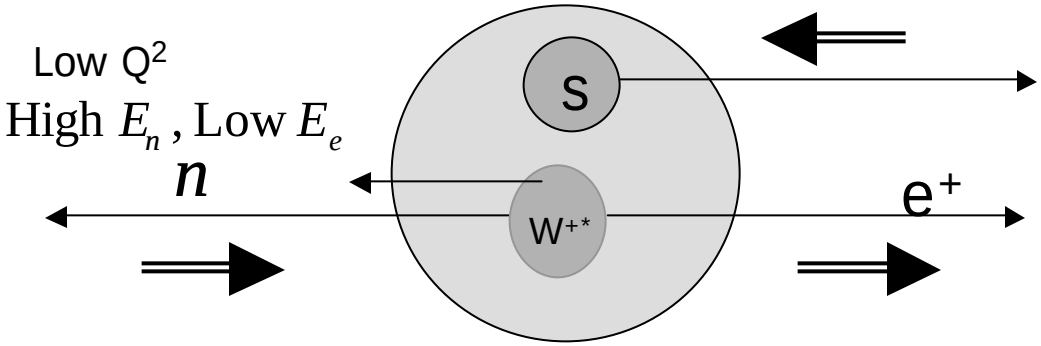
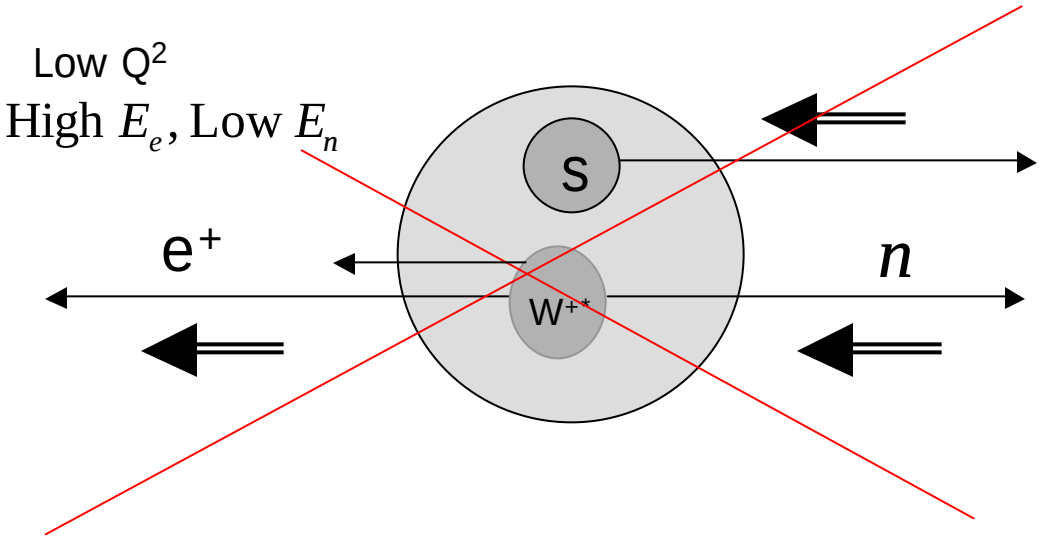
# Electron and Neutrino Spectra are Different

$$c \rightarrow s e^{+} n_e$$




In weak semileptonic decays of quarks, the lepton has the harder spectrum than the anti-lepton

Can look at spins to determine favorable and suppressed directions for neutrino

The top diagram is favored, the neutrino will get a boost from the $W^{+*}$ compared to the electron in the lab frame. The same effect will occur for the anti-c.

In B decays electron has harder spectrum than neutrinos, electron is now particle

$$b \rightarrow c e^{-} \bar{n}$$



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$$\psi(3770) \rightarrow D\bar{D}$$

$$Xln$$

## Simple Hadronic Modes

- Add up all signal side tracks and showers
  - Use RICH and dE/dx for particle ID
- Get missing 4-momentum
- Cut to eliminate non neutrino events

$$Mass^2_{miss} = E^2_{miss} - P^2_{miss} = 0$$

- $K_L$ suppression
- Clean reconstruction cuts

$$D^0 \begin{cases} Kp \\ Kp\pi^0 \\ Kppp \end{cases}$$

$$D^{\pm} \begin{cases} Kpp \\ K_S p \end{cases}$$

Fully reconstructed tags

Use tag to eliminate half of event for neutrino reconstruction



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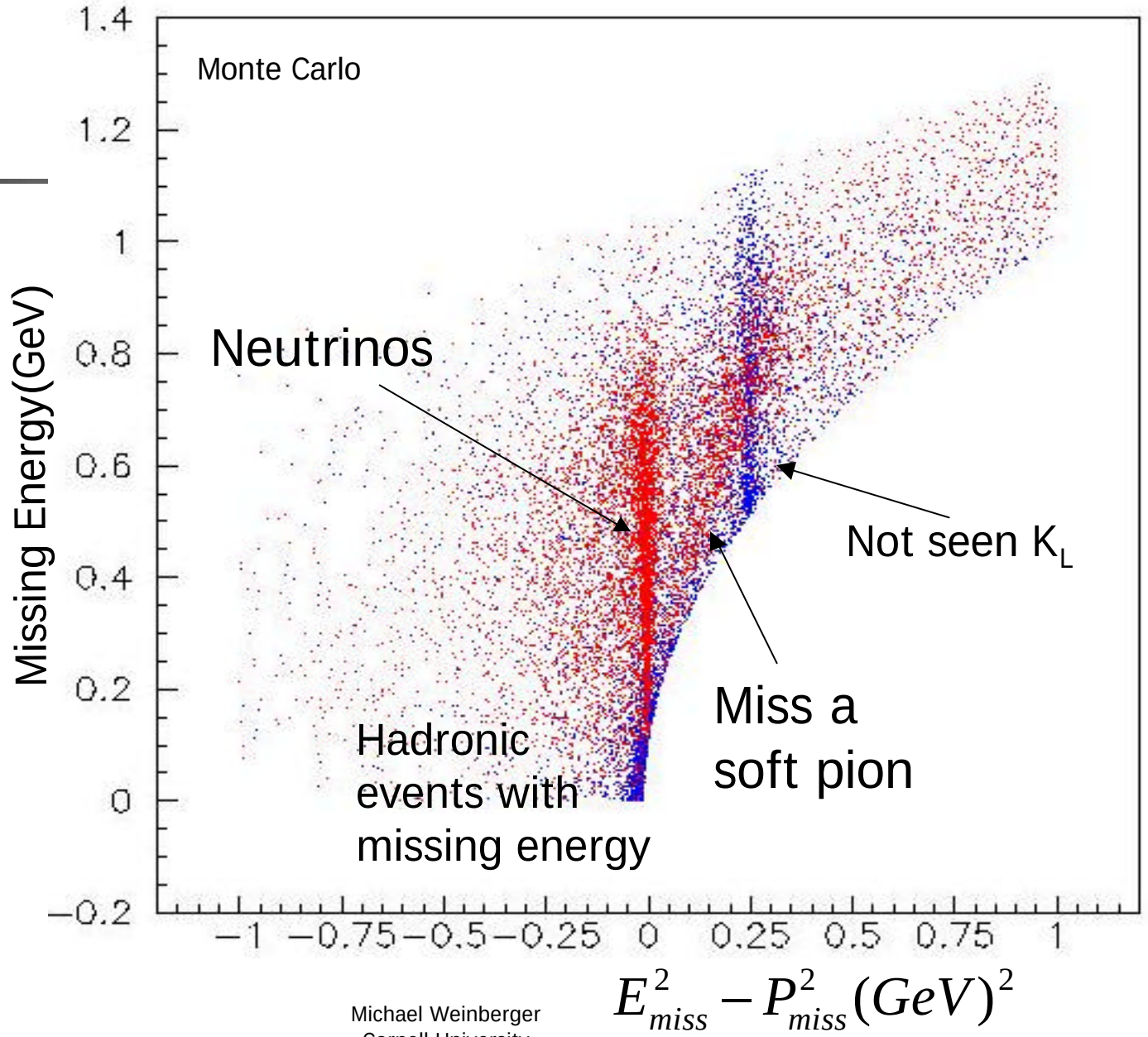
# $E_{miss}$ vs. $E^2 - P^2$

Red = event with neutrino

Blue = no neutrino in event



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# Cuts

- Good Tag Cuts
  - Only 1 tag per mode per event
  - Good Tag
    - Delta E cut
    - Beam constrained mass cut
- Clean Reconstruction Cuts
  - No tracks lost to quality cuts
  - Showers are not matched to track
  - Charge of event is = 0
  - Costheta of missing momentum is inside detector
  - At least one track in event – no ID performed
- $K_L$ suppression cuts


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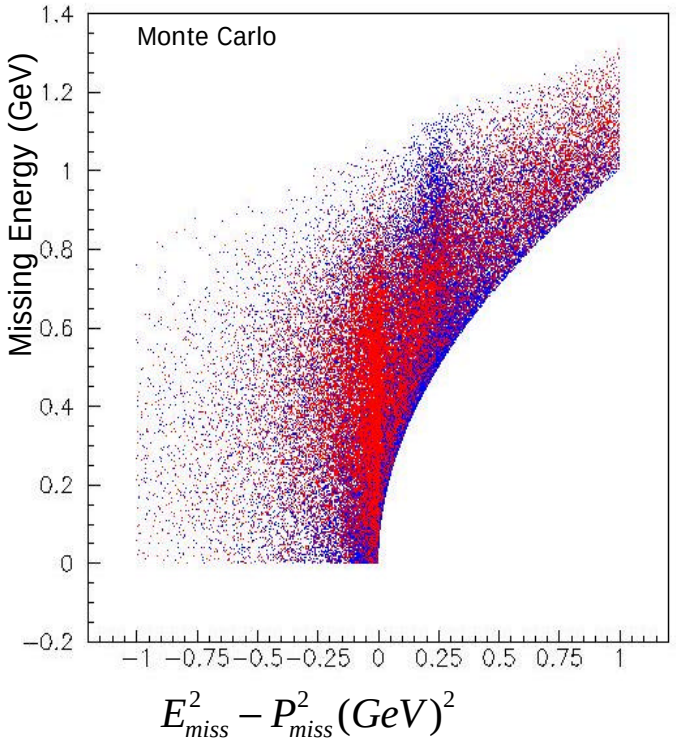
Red = neutrino event

Blue = no neutrino in event

# Effect of Cuts on Background

Events with good tag

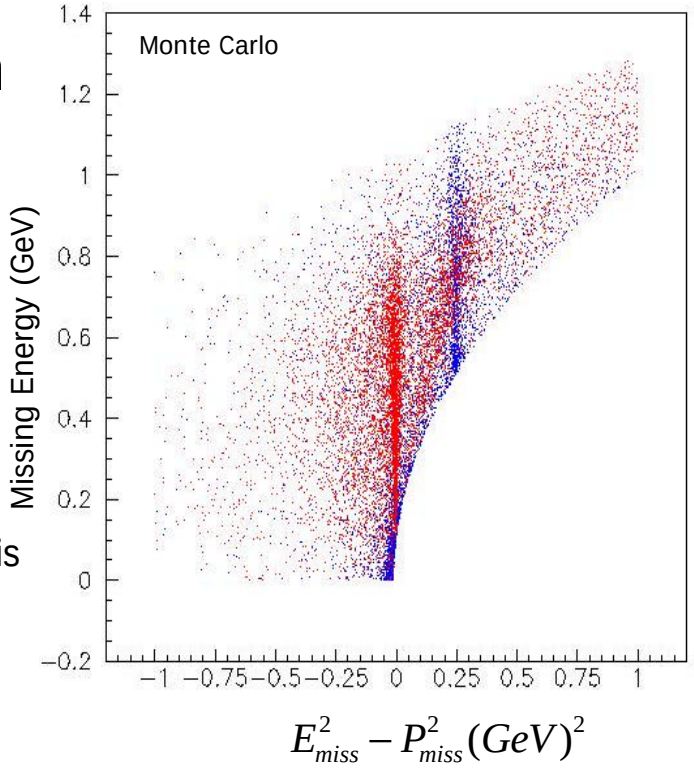



$K_L$ suppression

&

Clean reconstruction cuts

To make sure that event is fully reconstructed and that missing vector is in detector

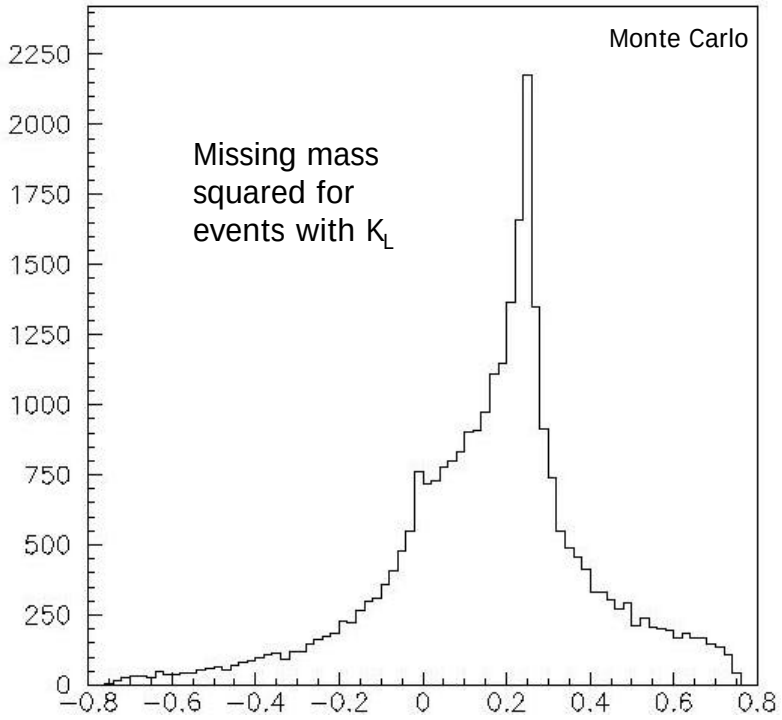


# $K_L$ Suppression Cuts

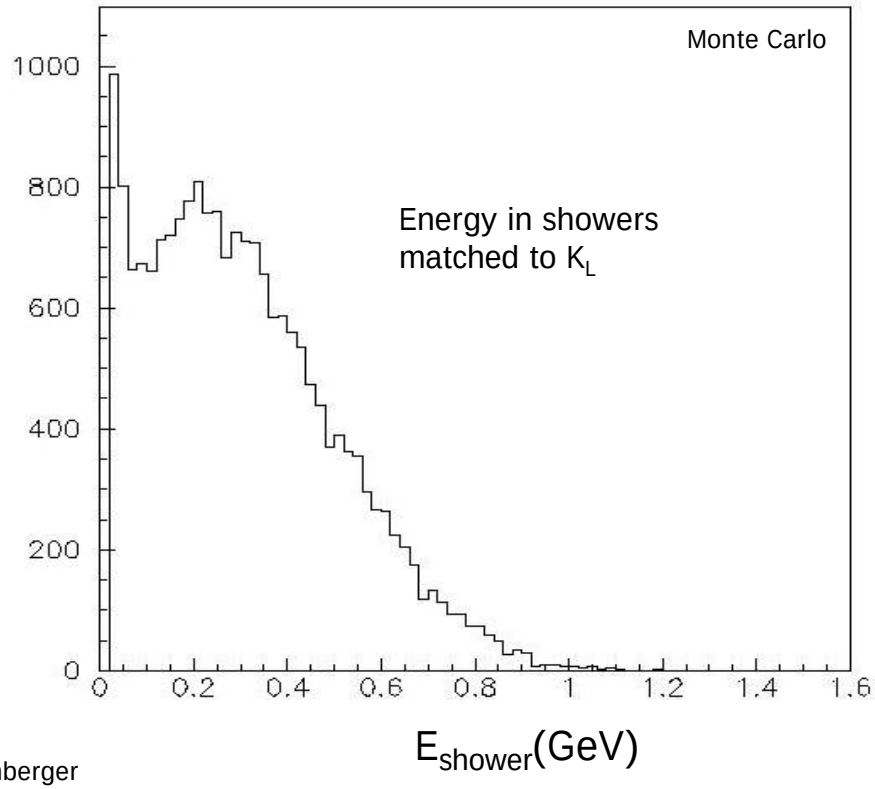
No Hadronic calorimeter for $K_L$ reconstruction

CC is ~1 nuclear interaction length => about half $K_L$ interact in detector

Half of $K_L$s leave no energy
Peak at Missing Mass$^2$ = (.497GeV)$^2$




Other half leaves some fraction of their energy in EM calorimeter



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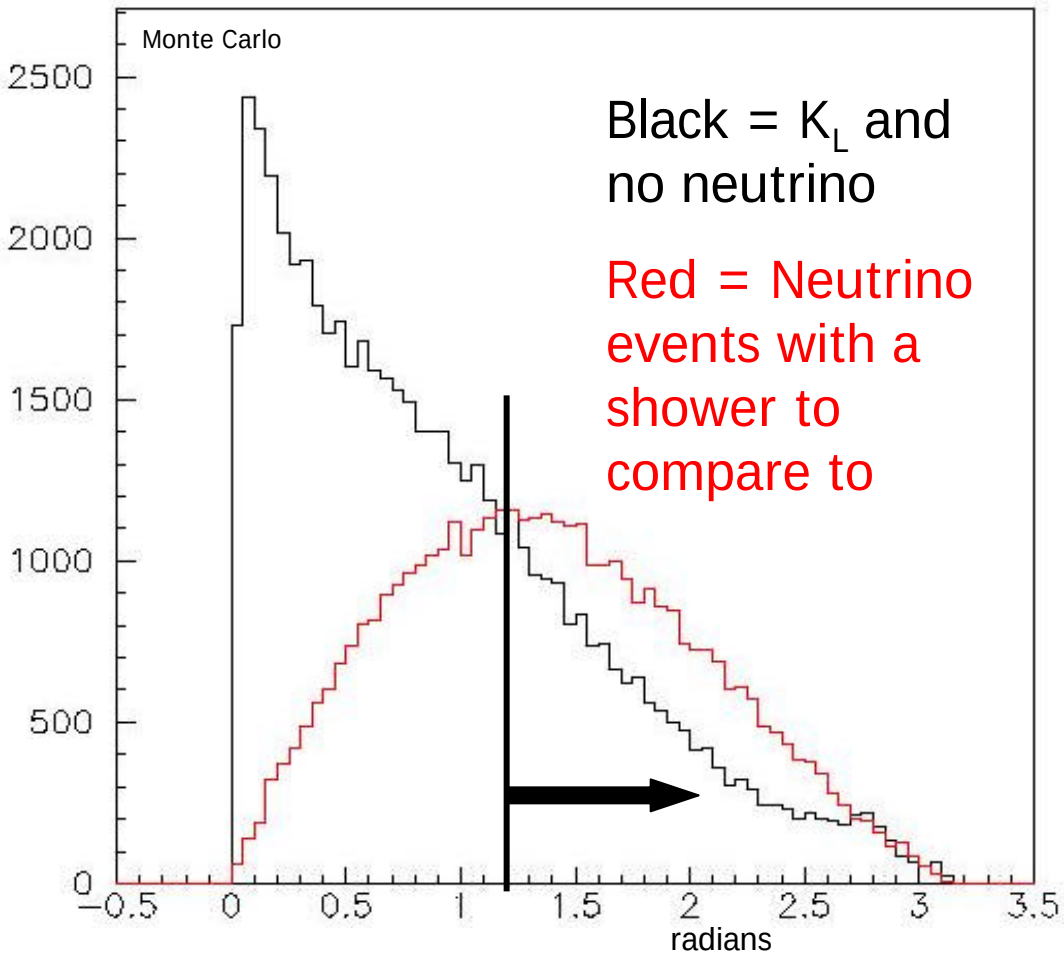
# $K_L$: Shower Distance Cut

- Angle of missing momentum vector to closest unmatched shower
  - 20% of events with neutrinos have no shower to measure angle to, this cut is then skipped

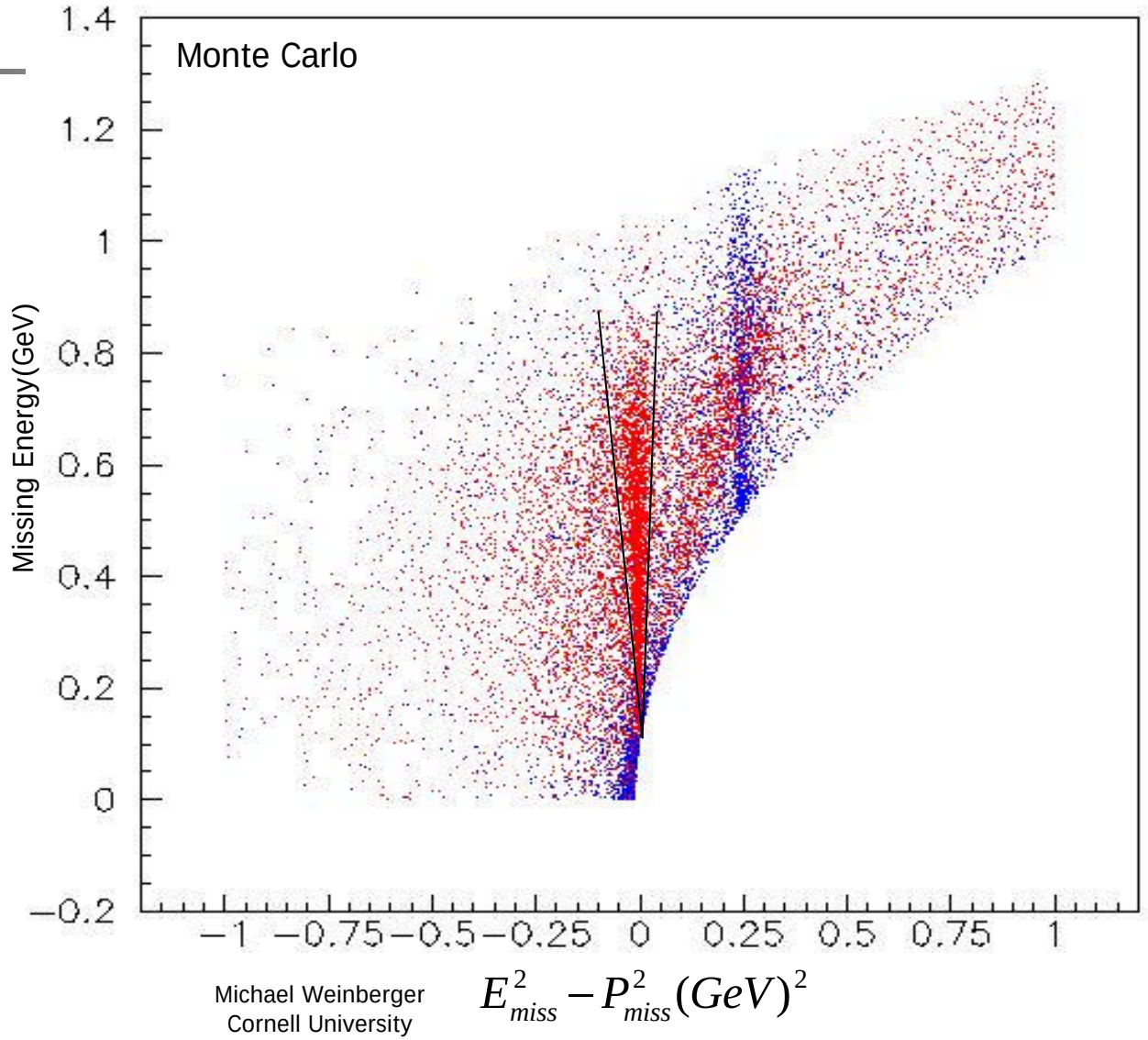


# V Cut on $E_{miss}$ vs. $E^2 - P^2$

"V" cut on $E^2 - P^2$

Error on $Mass^2_{miss}$ is dominated by error on energy. The "V" cut is then a constant cut on the fractional error of the $Mass^2_{miss}$

Shower distance cut will not eliminate non-interacting $K_L$



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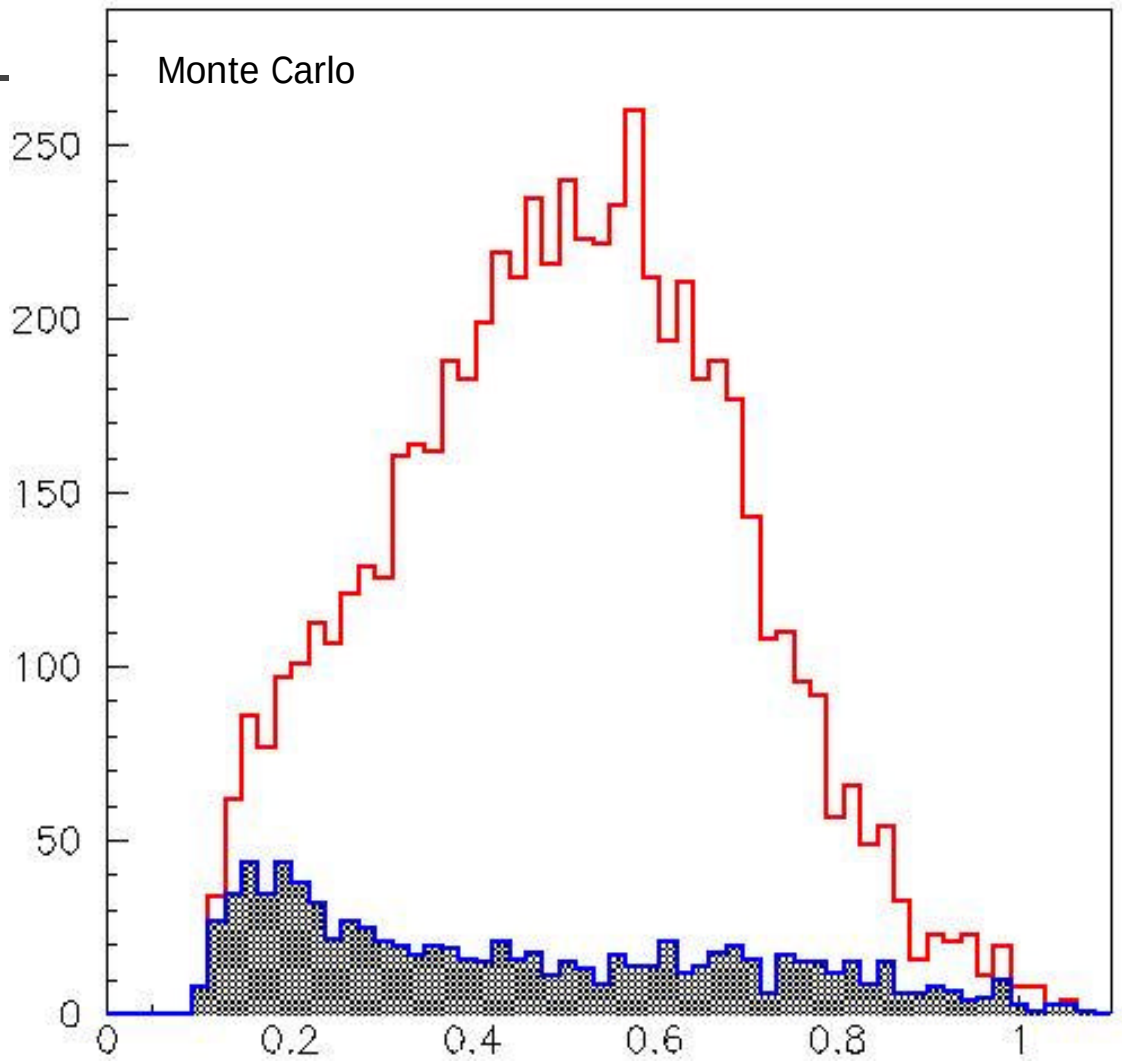
# Missing Energy Spectrum

Red = event with neutrino Blue = event without neutrino - Stacked



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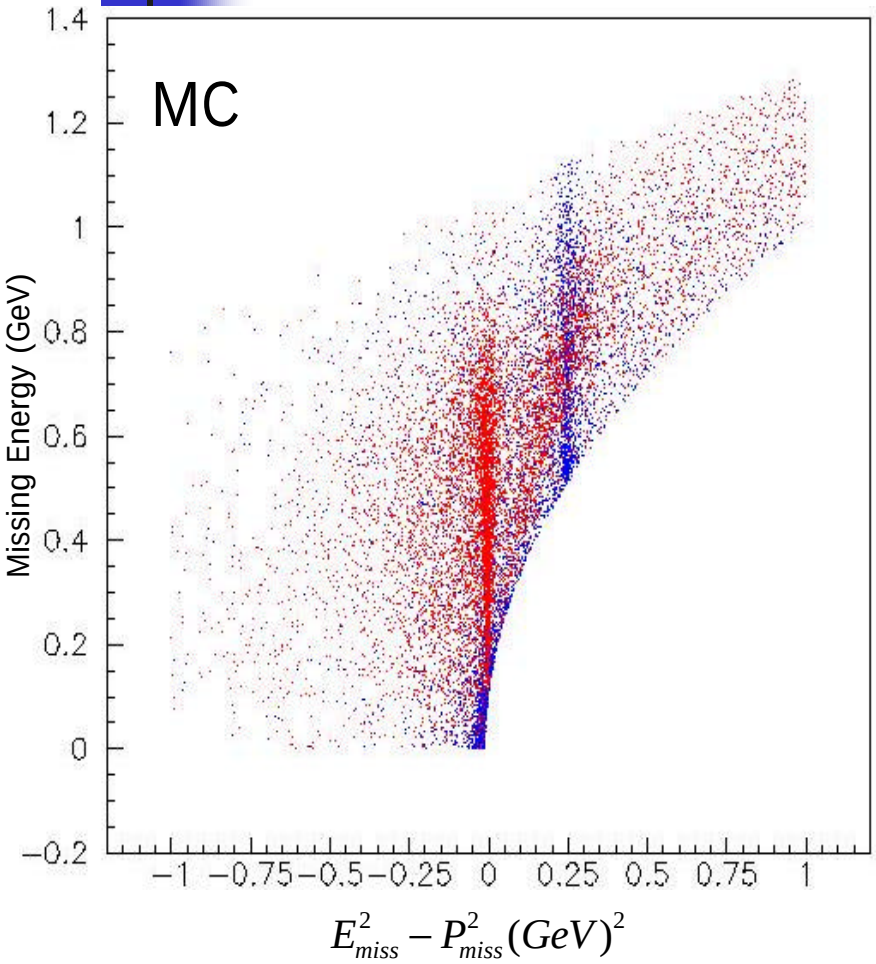
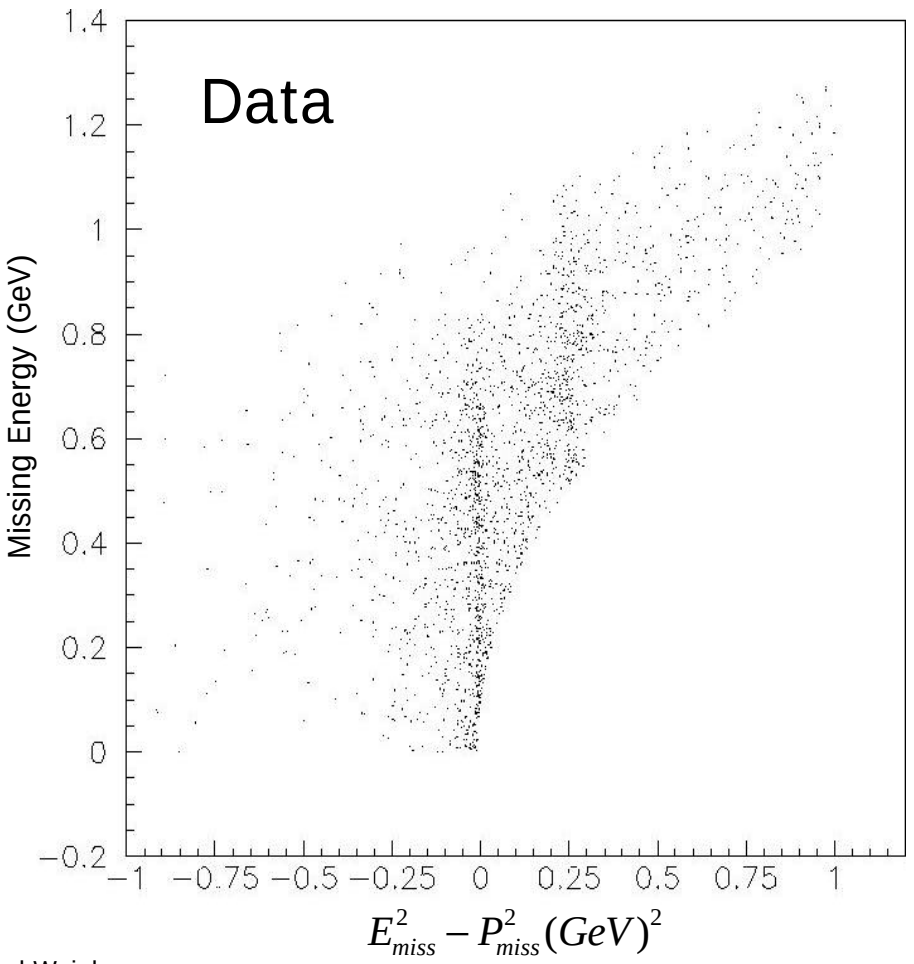
# Data vs. MC comparisons
# $E_{miss}$ vs $E^2 - P^2$



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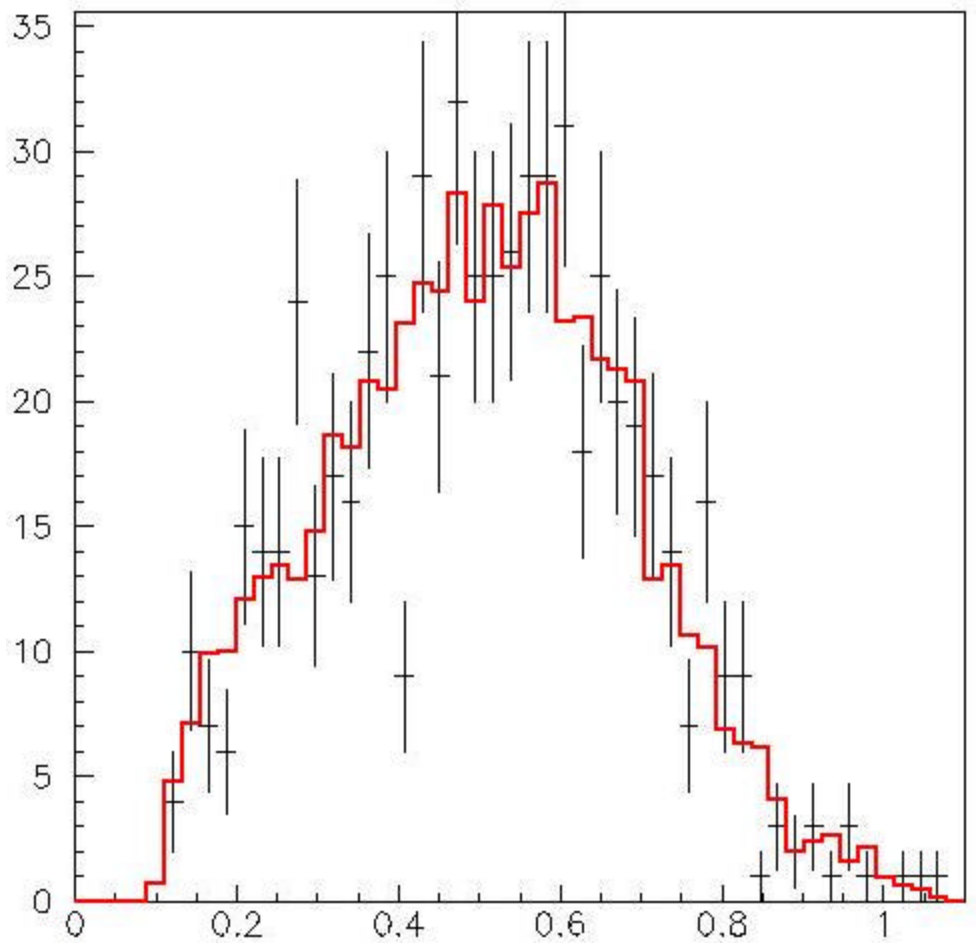
# Data vs. MC comparisons
# $E_{miss}$ Spectrum

- Combined $D^0$ and $D^+$
- No background subtraction
- No efficiency correction




Black points = data

Red = MC scaled down by luminosity

=> Not A Fit <=



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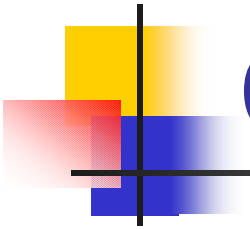

# Conclusion

- CLEOc allows first opportunity to make measurement of neutrino spectrum
- Fully inclusive as to:
  - Lepton flavor
  - Semileptonic decay mode
- Can make completely orthogonal measurement to existing measurements