LEPP REU 2008

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  - Subject: J/ψ meson decays

J/ψ Decay

$e^+e^- \rightarrow \psi(2S)$

$\rightarrow \pi^+\pi^- J/\psi$

$\rightarrow \gamma\, \pi^+\pi^-\pi^+\pi^-$

- I have measured the branching ratio for:
- Used data from CLEO from over 25 million ψ(2S) decays
  - This particular decay occurs on the order of .1% of the time, so a large number of events is necessary to detect enough events for good statistics
- Also considered Monte Carlo
  - Signal MC contains desired or signal events (20,000)
    - Used to measure efficiency
  - Generic MC uses previous measurements to generate events that model the real events that occur
    - Nearly 120 million ψ(2S) decays

Motivation

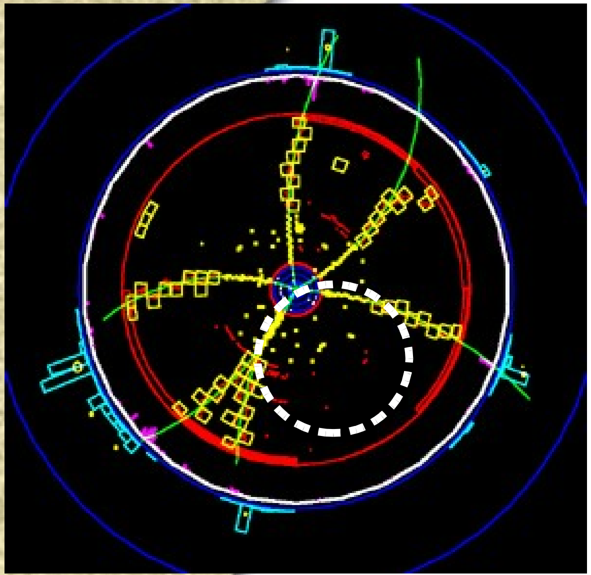
- One reason this decay is interesting involves some of its intermediate states
- c, cbar -> gluon, gluon, γ
  - J/ψ is made of a charm and an anticharm quark
  - Gluon is carrier of strong force
- Photons don't respond to the strong force
- This is a possible way to study gluons

Motivation

- Plotting frequency (of this particular decay occurring) versus the 4-pion mass
- If there is a peak at the mass of the 'glueball' (particle made of 2 gluons), that would be interesting
- Such a peak could be a starting point for further study
- Looking for other structure in 4-pion histogram, as well as in 3- and 2-pion plots

Extra tracks

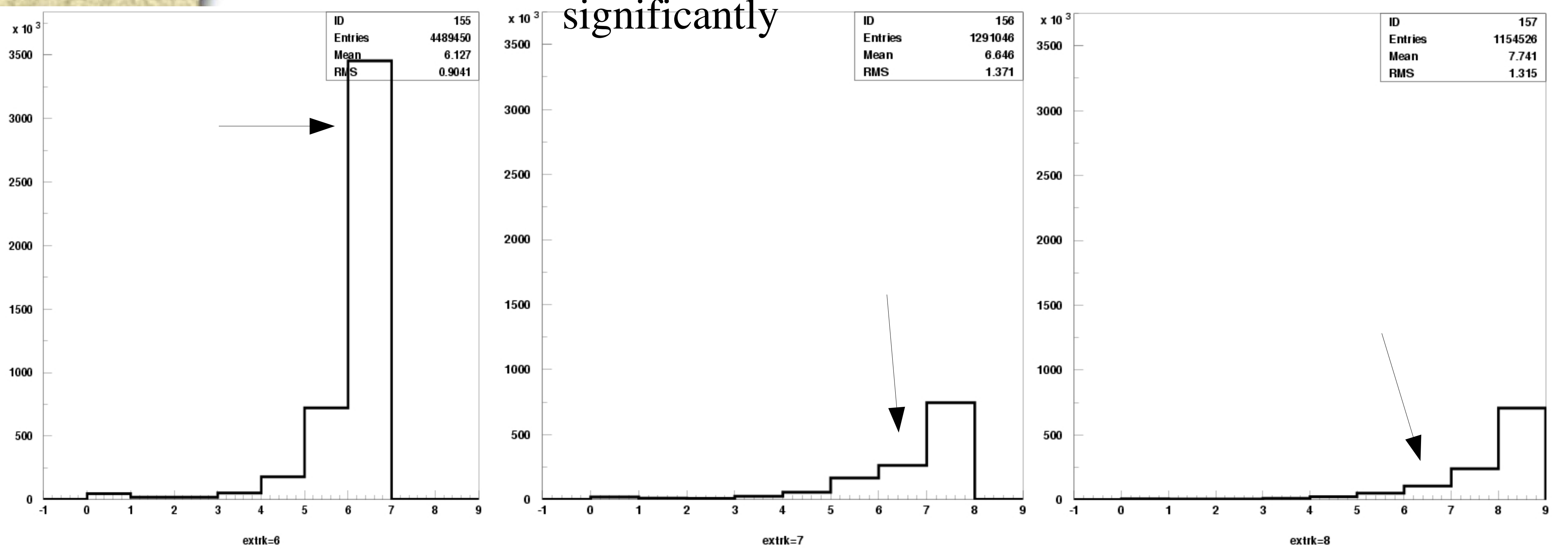
- There should be 6 tracks (4 pions from the J/psi decay, plus 2 transition pions)
- I initially allow up to 8, and then after Trkman demand six tracks
  - Trkman weeds out 'curlers,' low-energy tracks, and other types of unsatisfactory tracks



- Questions:
  - How much of an effect does this change have?
  - Is allowing eight initial tracks sufficient?
- Note: using MC decay tree printouts, I saw that there were a lot of 'curlers.'

Extra tracks

- The number of six-track events recovered from events with 7 initial tracks is about 8.5% of the number of regular six-track events; the corresponding percent for the events with 8 initial tracks is about 3%
- Events with 7 initial tracks form 0% of the signal; events with 8 initial tracks constitute 0.13% of the signal.
- Allowing more than 8 initial tracks is not likely to change the signal significantly



Multiple showers; best photon

- Calculate the missing 4-momentum vector from the six pion tracks and the known 4-momentum of the $\psi(2S)$
- If multiple showers, the photon whose 4-momentum varies least from this calculated vector is chosen as the 'best' photon
- To check how well this method works, I modified the program to select the second-best photon instead
- No satisfactory fits resulted, using very loose chisquare cuts
- This shows that the method of selecting the photon is satisfactory; no good events are excluded by this cut

π^0 contamination

$e^+e^- \to \psi(2S)$

$\to \pi^+\pi^- J/\psi$

$\to \pi^0\pi^+\pi^-\pi^+\pi^-$

$\to \gamma\,\gamma\,\pi^+\pi^-\pi^+\pi^-$

- π^0 events are difficult to eliminate from the signal, and the rate of this decay is four times that of signal events
- One of the photons is often very low energy, and may not be picked up by the detector, or may be indistinguishable from noise

Cutting π^0 events

- Chi4Mfit
  - Requires the total momentum and energy of the event to be conserved (as measured in the six pions and the photon)
  - This is the most effective cut
  - This chisquared value is surprisingly low in many pi0 events, considering the loss of energy carried away by the second photon

$$e^+e^- \rightarrow \psi(2S) \quad \rightarrow \pi^+\pi^- J/\psi$$
$$\rightarrow \gamma\, \pi^+\pi^-\pi^+\pi^-$$

- ChiFit
  - Calculates the missing mass of the photon using the six pion tracks, assuming the above reaction
  - For the desired events this missing mass will be zero; a missing mass equal to the π^0 mass indicates a pi0 event

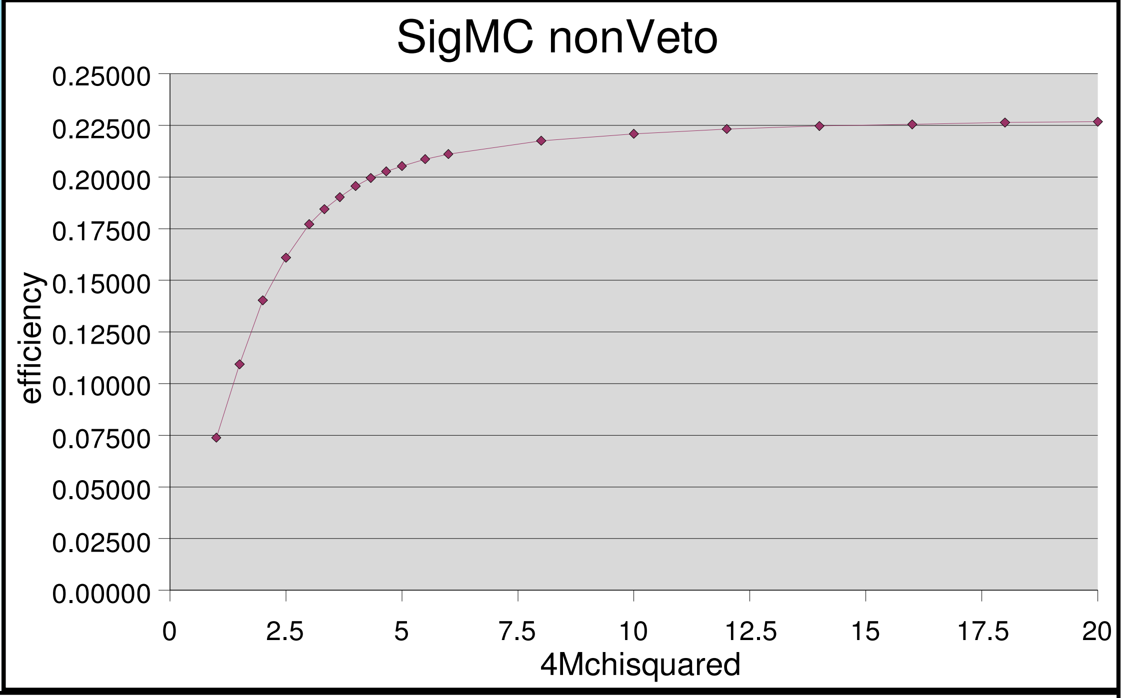
Cutting π^0 events

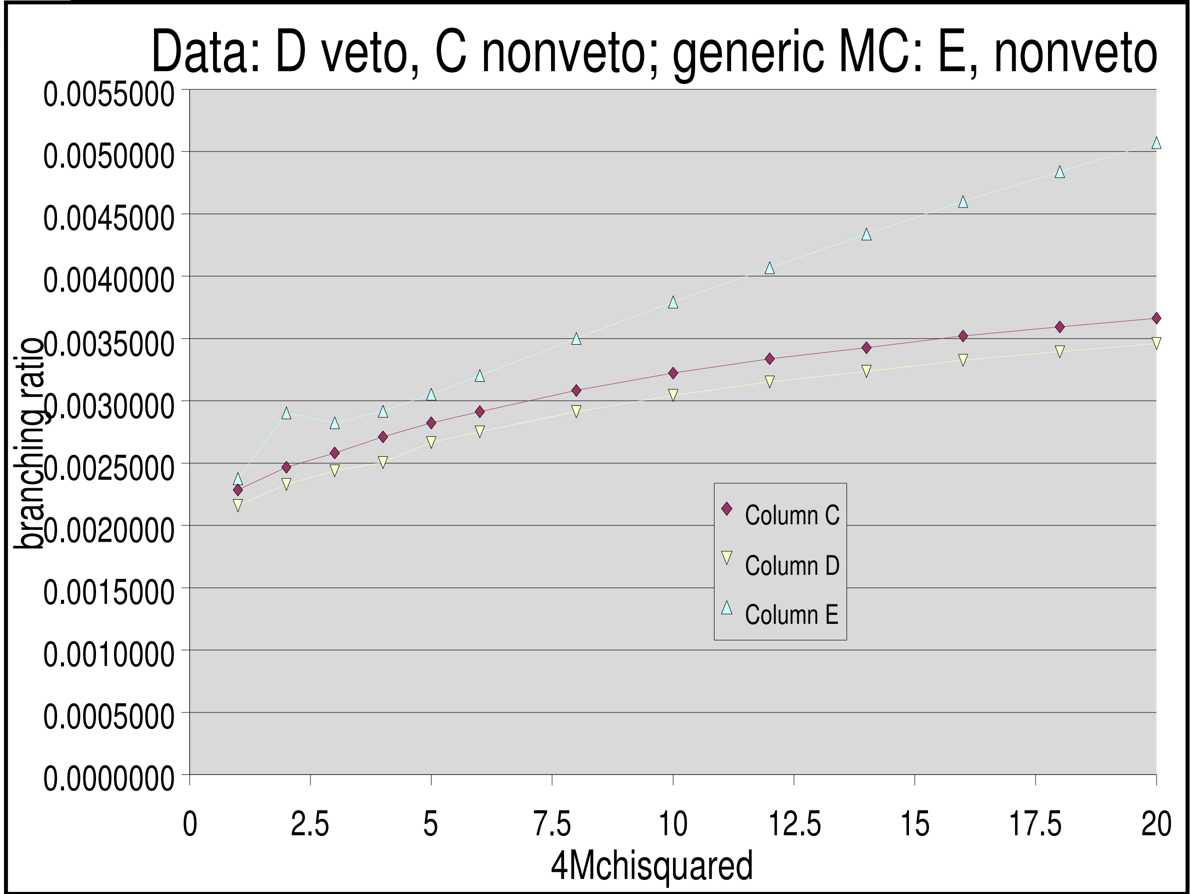
- π^0 veto
  - Explicit exclusion of photons from π^0 decays in the code
  - Not very effective
    - When cutting at Chi4MFit < 5, veto makes <5% difference in data, and <6% in MC, in terms of the number of events that pass the cut.
  - Signal MC indicates that the veto reduces efficiency by 3% or more depending on chisquare value
  - Therefore, the π^0 veto was not used in the final analysis

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

Choosing χ^2 - *Chi4MFit*

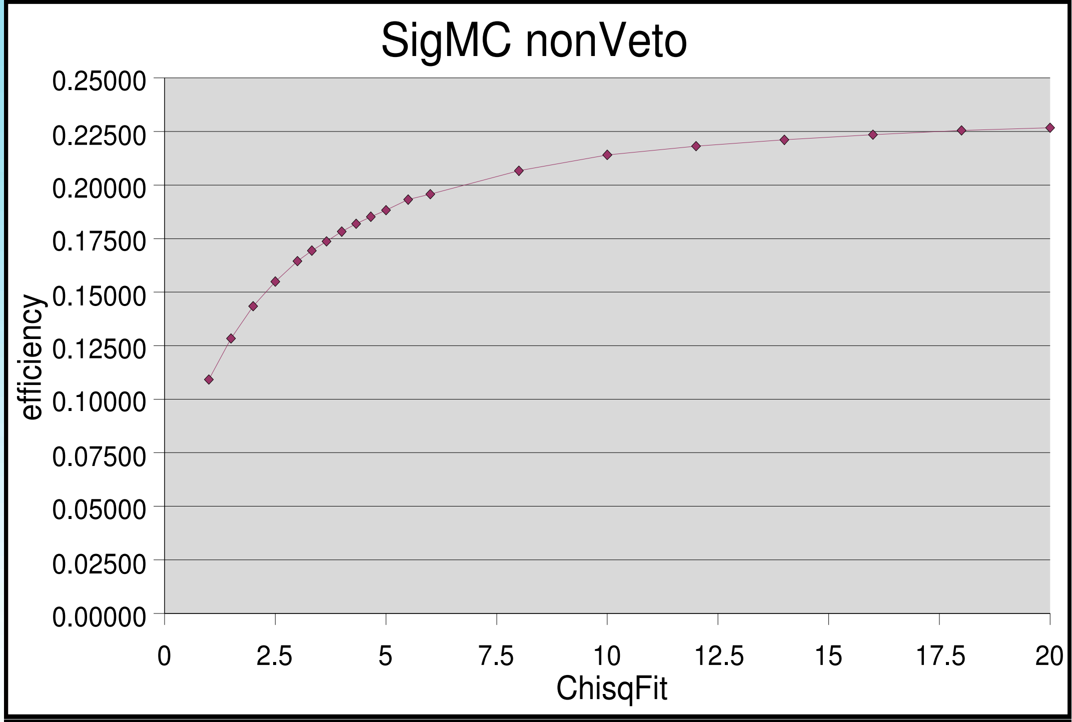
- Conservation of energy and momentum
- The signal MC plot shows what χ^2 cut begins to cut significantly into the signal
- The data and generic MC plots give an idea of where to cut to obtain the best branching ratio

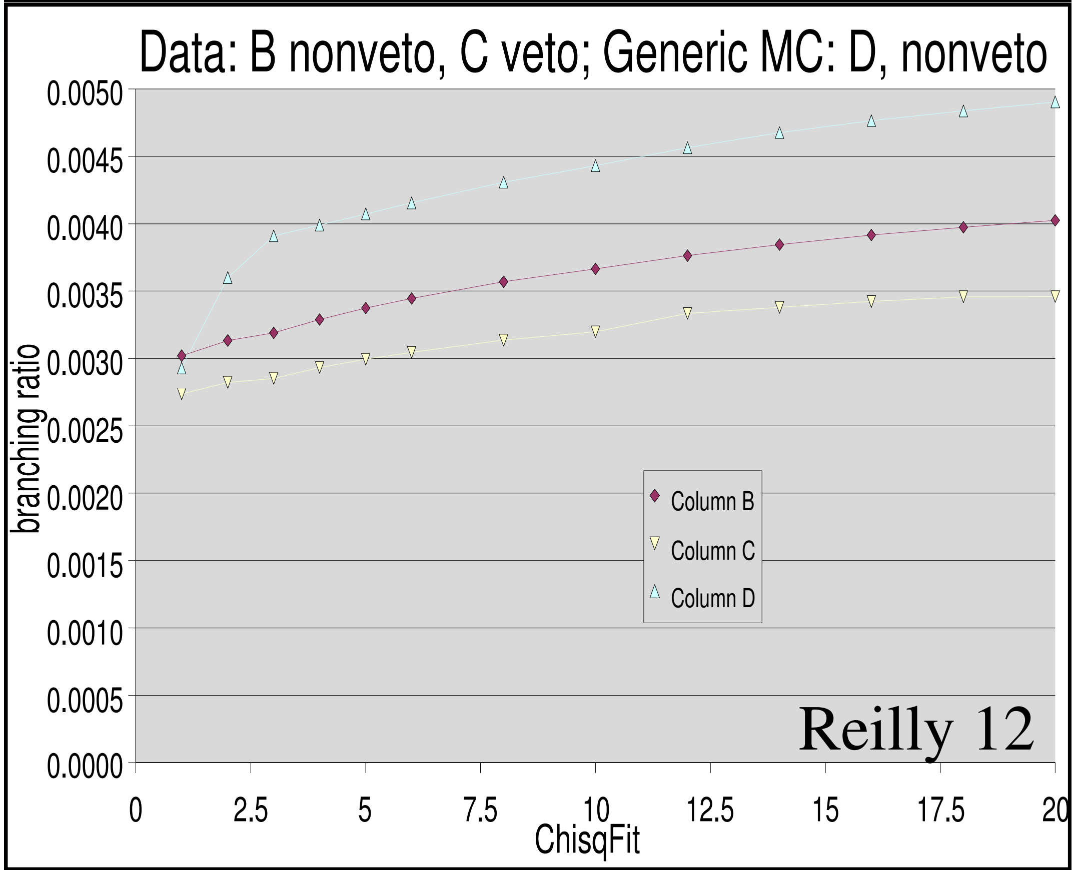




Choosing χ^2 - *ChisqFit*

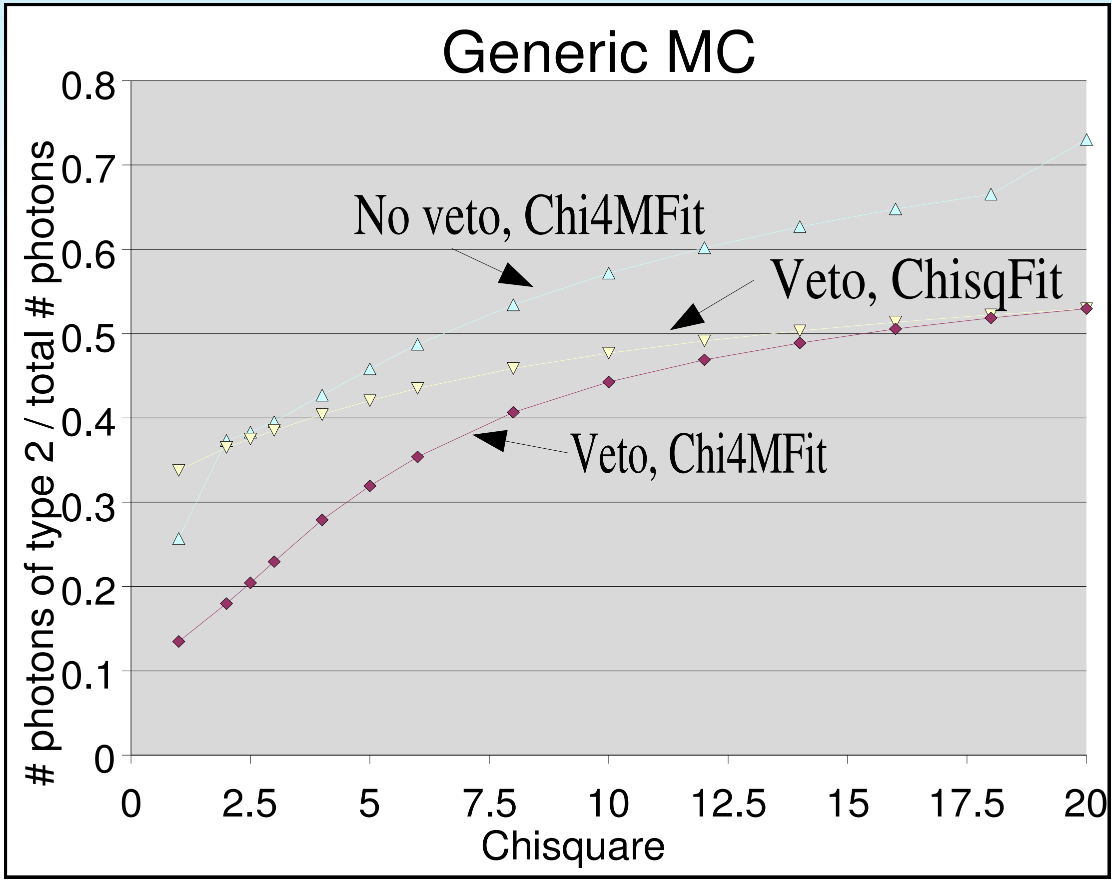
- ChisqFit refers to requiring that the mass missing from the six pions be zero (ie, no pi0)
- The signal MC plot shows what χ^2 cut begins to cut significantly into the signal
- The data and generic MC plots give an idea of where to cut to obtain the best branching ratio





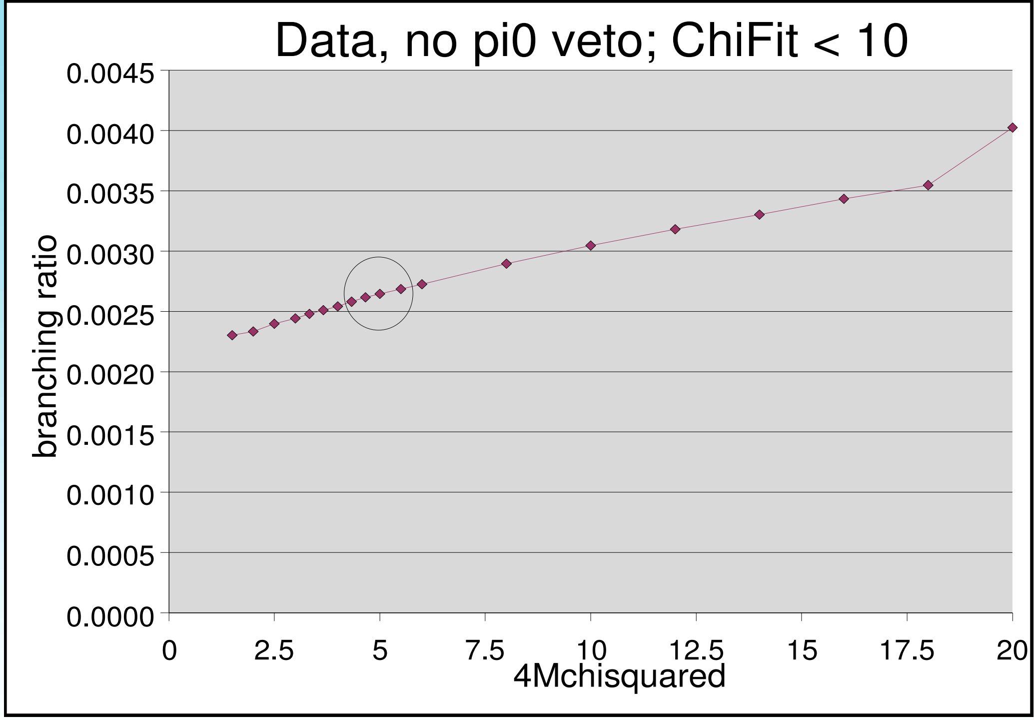
Determining effectiveness of χ^2 π^0 rejection

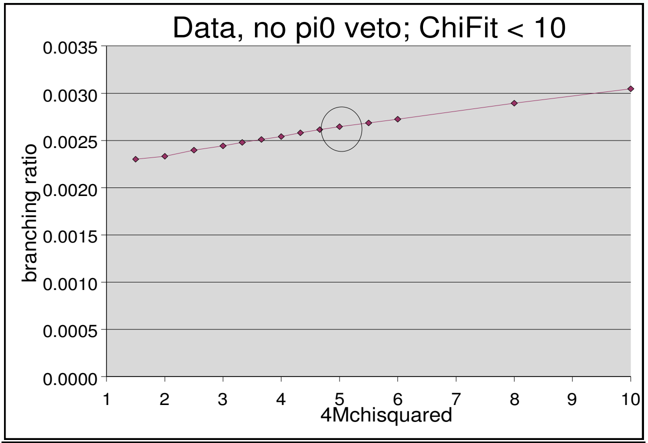
- Using MC to identify and measure secondary photons; MC decay tree
- Showing effectiveness of each χ^2 value in minimizing π^0 contamination
- Keep in mind that at low χ^2, signal events are lost

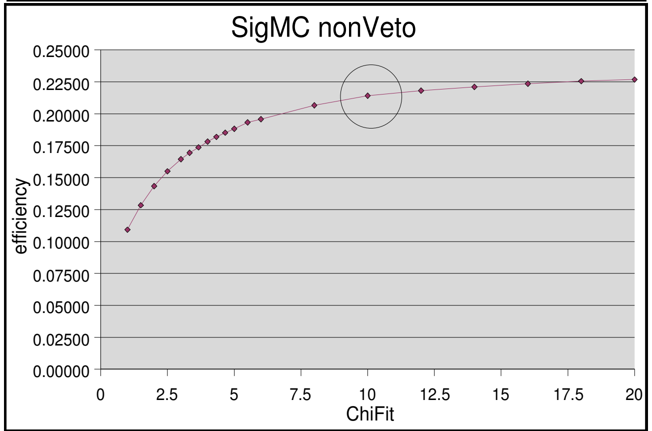


Choosing chisquared values

- Have to pick a set of chisquared values in order to calculate a final branching ratio
- Error will be larger since there is not a very clear point at which it would be obvious to cut
- This will be a major source of systematic error in the calculation of the branching ratio







Estimating Error

- Cut at ChisqFit < 10; 4MChiFit < 5
- +/- 1 unit of Chi4MFit gives 3.5% systematic error
- The same method for ChisqFit gives 0.5% error
- Note that this is a rough calculation and will need to be refined (π^0 analysis)
- Statistical error is calculated to be less than 1%
  - Small uncertainty due to the large number of signal events found (13471)
  - Large amount of data which is available (over 25 million $\psi(2S)$ decays)

Systematic Error

Source of Systematic Error	% error
Fitting procedure	3.5
Track finding: 0.3% per track	1.8
Photon finding	2
# psi(2S)	2
Branching ratio for psi(2S)->pi+pi-J/psi	1.9
Demanding one set of transition pions	?
Added in quadrature:	**5.21**

Branching Ratio: $(2.64 +/- 0.02 +/- 0.14)*10^{-3}$

Comparing my histograms to similar from paper

- I made a few histograms that show the same results as some that were published in 2004
- Obvious similarities
- I have less J/ψ data events than they did, but a lot more MC
- CLEO is a better detector

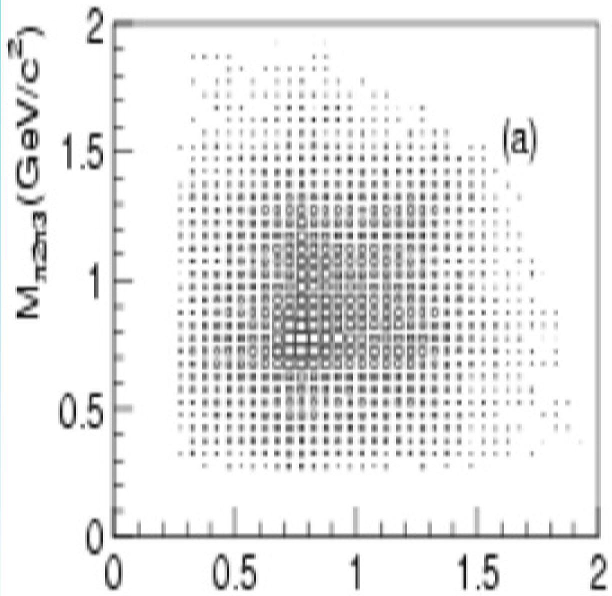


Fig. 1 [1] $M_{\pi 1\pi 4}(GeV/c^2)$

M_{4pi}>=2.0 GeV

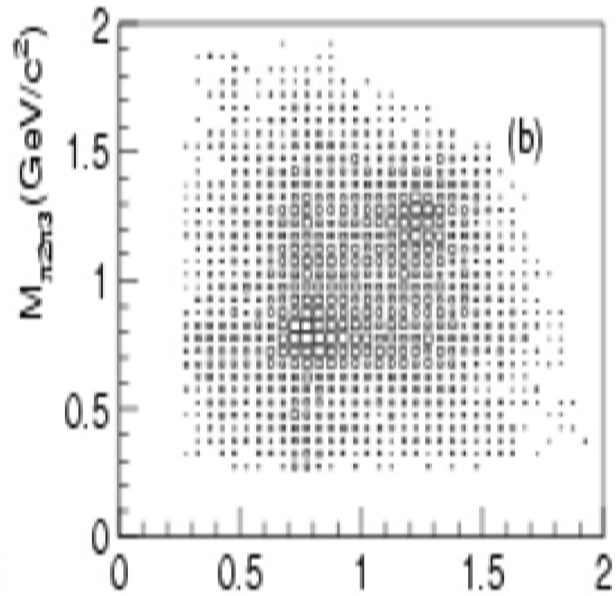
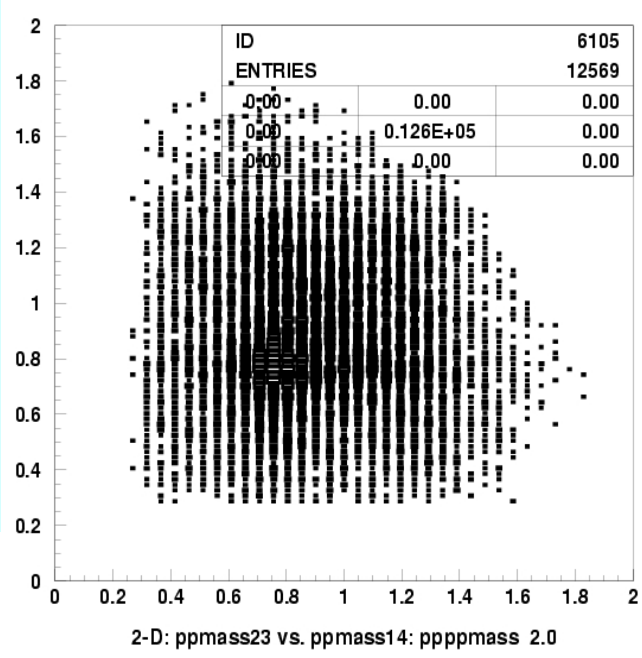
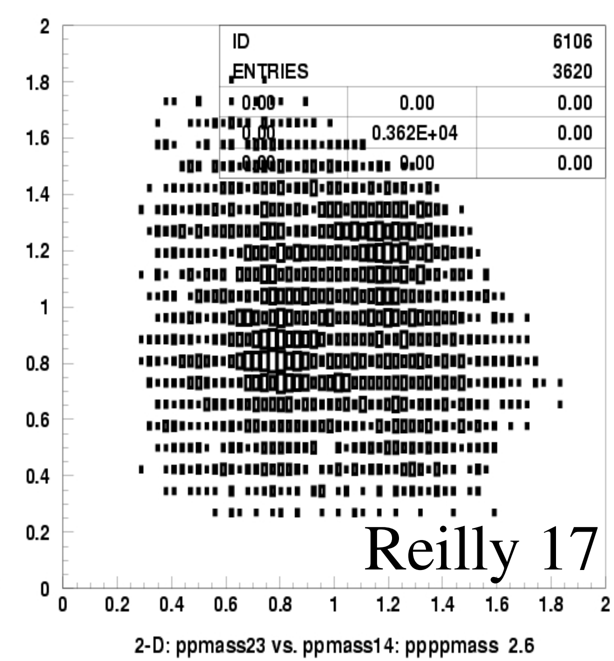


Fig. 2 [1] $M_{\pi 1\pi 4}(GeV/c^2)$

M_{4pi}>=2.6 GeV

[1] M. Ablikim *et al.* (BES Collaboration), Phys. Rev. **D70**, 112008 (2004)



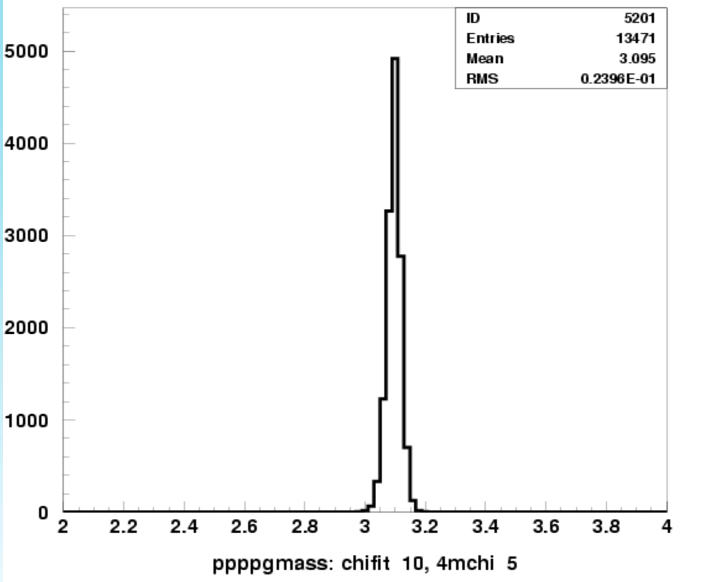


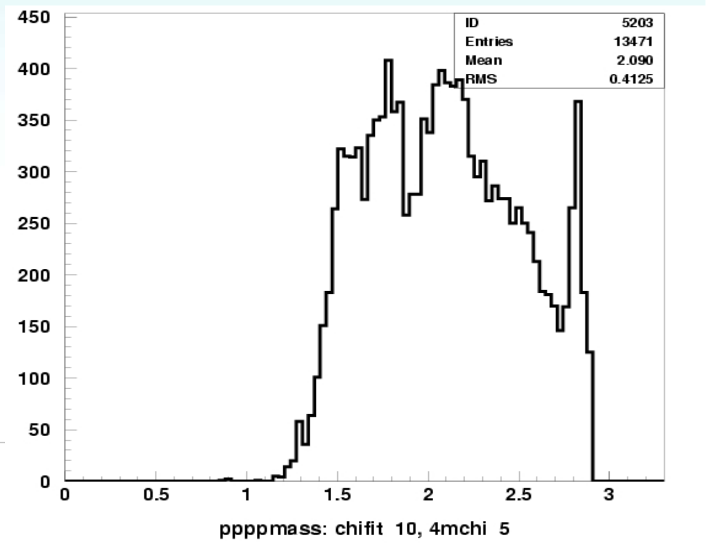
Results

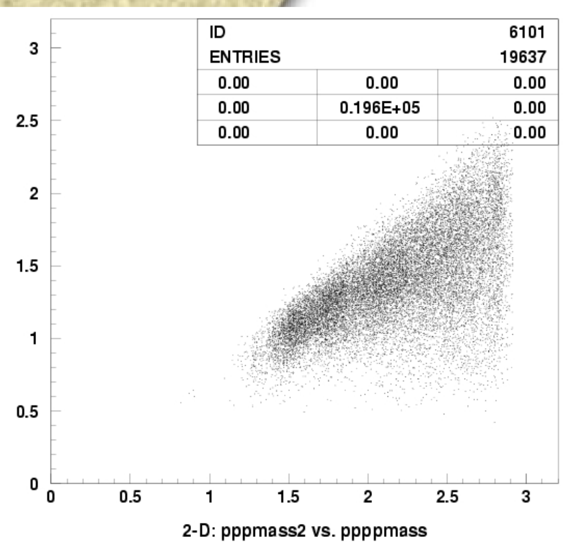
$$Branching\ Ratio = \frac{\#\ \text{events observed}}{(efficiency * \#\ psi(2S))}$$

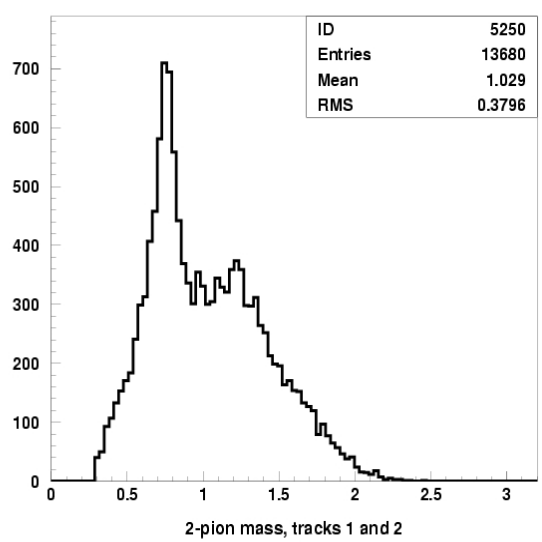
$$Statistical\ Error = \frac{\text{sqrt}(\#\ \text{events observed})}{(\#\ \text{events observed})}$$

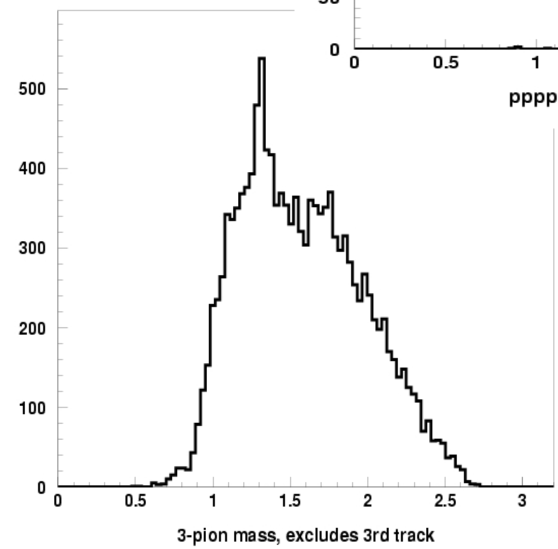
- Interesting structure in plots to investigate











Conclusions

- I have modified an existing program to measure the branching ratio
- I have determined how to deal with events with extra tracks and showers
- I have calculated a measurement of the branching ratio of: $(2.64 +/- 0.02 +/- 0.14)*10^{-3}$
- Future (π^0) analysis is needed to obtain a more precise measurement

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Acknowledgments

- Thanks go to:
  - David Kreinick
  - Rich Galik
  - LEPP
  - NSF
  - and everyone else who helped make this REU possible