Blind Analysis in MINOS

Week in the Woods
13 June 2005

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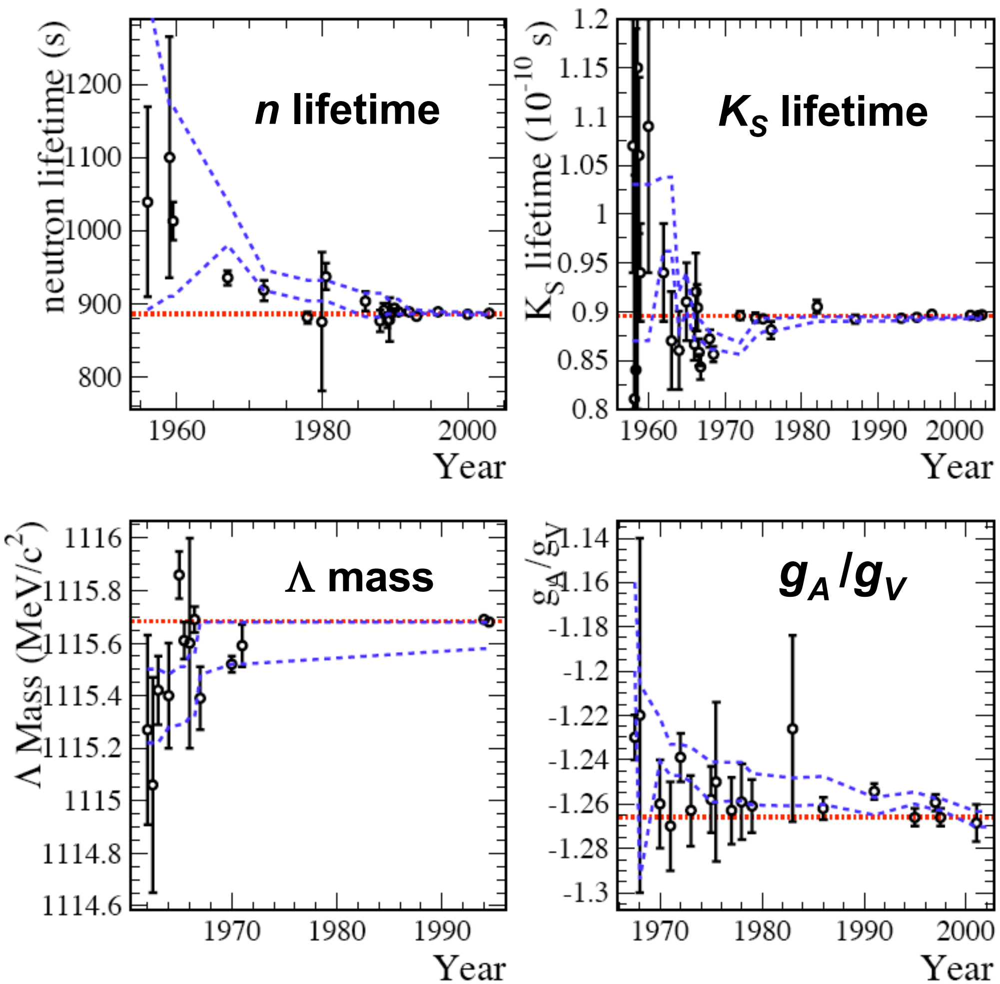
Introduction

- *First 7 slides will be a review of a draft of a paper by Josh Klein and Aaron Roodman*
- **Story of Hans von Osten, "Clever Hans"**
- **Medical practice**
  - **Double blind**
  - **Public registry**
- **Strong recent trend in particle physics toward blind analyses**

Klein-Roodman Analysis of 4 Particle Physics Results



Blue lines: Average before measurement

Red line: Current value

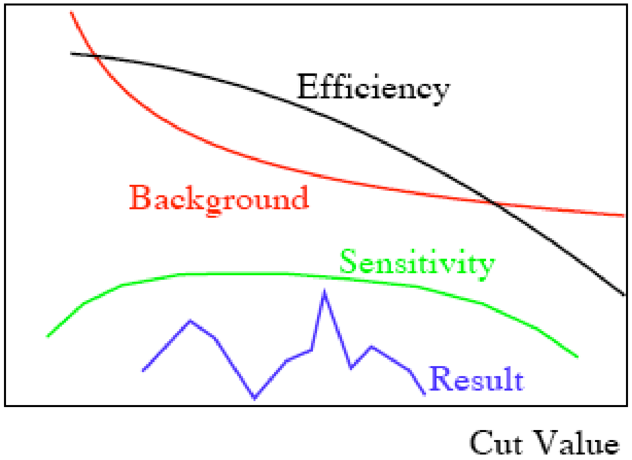
Hypothesis of normal distribution about prior or current value:

χ^2_{prior} = 131/83 DoF

$\chi^2_{current}$ = 250/83 DoF

Sources of Experimental Bias:
Order of Increasing Subtlety

- **Tuning on the data**
  - **If you are not tuning on the data, why do you need to see the data, and what aspects do you need to see?**
- **Making choices within the sensitivity plateau with a view of the data**
  - **Asymptotically unbiased**
  - **K&R: 2500 events, 10 cuts at 90% with a 1% bias ⇒ a 3 σ effect**



- **Stopping when the data "looks right"**
  - **Galison: "…there is no strictly logical termination point inherent in the experimental process"**

General Considerations

- The are several methods of blinding. The method chosen should allow the greatest exploration of the data consistent with the elimination of bias.
- Blinding can aid a collaboration's internal review process.
- Analysis does not necessarily have to stop with unblinding.
- What to do if the blind process breaks down:
  - "There is no reason to publish a result known to be wrong, just because the analysis was done blindly."
  - Just publish an account of what you did.

Methods of Blinding

(Methods are sometimes combined)

1) **Hidden signal box method**
   - Best suited to rare event searches.
   - Backgrounds must be estimated from sidebands, simulations, and/or subsidiary experiments.
2) **Hidden answer method**
   - Can be used when a single number is desired that does not depend on the number of events, e.g., an asymmetry.
   - Fits are done with a random sign and offset.
   - Additional tricks may be needed to examine some distributions without unblinding
3) **Divided analysis**
   - Used in g-2: one group measured the muon precession and another group measured the magnetic field.

Methods of Blinding

4) Adding an unknown number of signal events
   - Can use Monte Carlo events if the simulation is very realistic
   - Can use data events that closely resemble signal (SNO used "muon-follower" neutron capture events)

5) Prescaling the data
   - The prescaling factor is known; most or all of the data is hidden.
   - Most often used in conjunction with another method, e.g. a hidden signal box with 10% of all data open.
   - LIGO discards the 10% open data.

Methods of Blinding

6) **Removing an unknown number (and distribution) of events**

- **The number of removed events should be the minimum that will disguise the result.**

End of Klein-Roodman Paper

Some History

- At the March 2004 meeting, I made a proposal for blinding (updated slightly in April 2004)
- Discussion before and at the June 2004 meeting -- no decisions were made
- At the January 2005 meeting, Nathanial Tagg proposed a concrete implementation and wrote the code for it
- At the April 2005 meeting, more discussion, but decisions were put off to this meeting

Universal Blind Proposal

April 2004

- **Desired Properties:**
  - Same blind for all oscillation analyses — allows groups to work together and work across group boundaries
  - Safe harbor — collaboration only needs to approve blind procedure once
  - Administratively simple and secure
  - Easy to reblind
  - Near detector completely open — allows comparison of both shape and magnitude predictions
  - Significant fraction of far detector open for all event classes and energies— allows study of special far detector problems, e.g., multiplexing, coil holes, etc.

Proposal Design

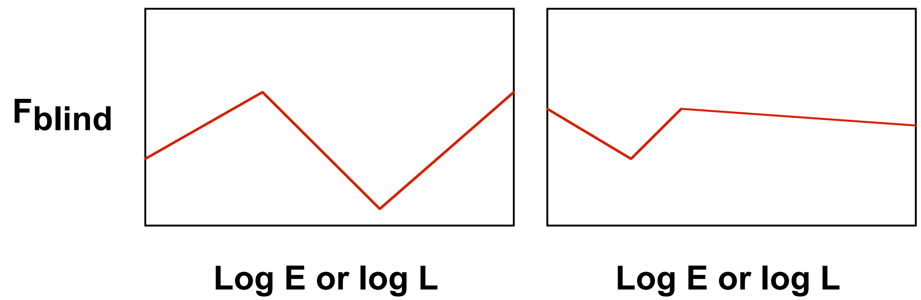
April 2004

- It is only necessary to blind enough that one is not biased.
- Need to blind with respect to three variables:
  - Overall rate
  - Energy spectrum
  - CC/NC (event length)
  - Electron/NC (probably will not be universal)

Proposal

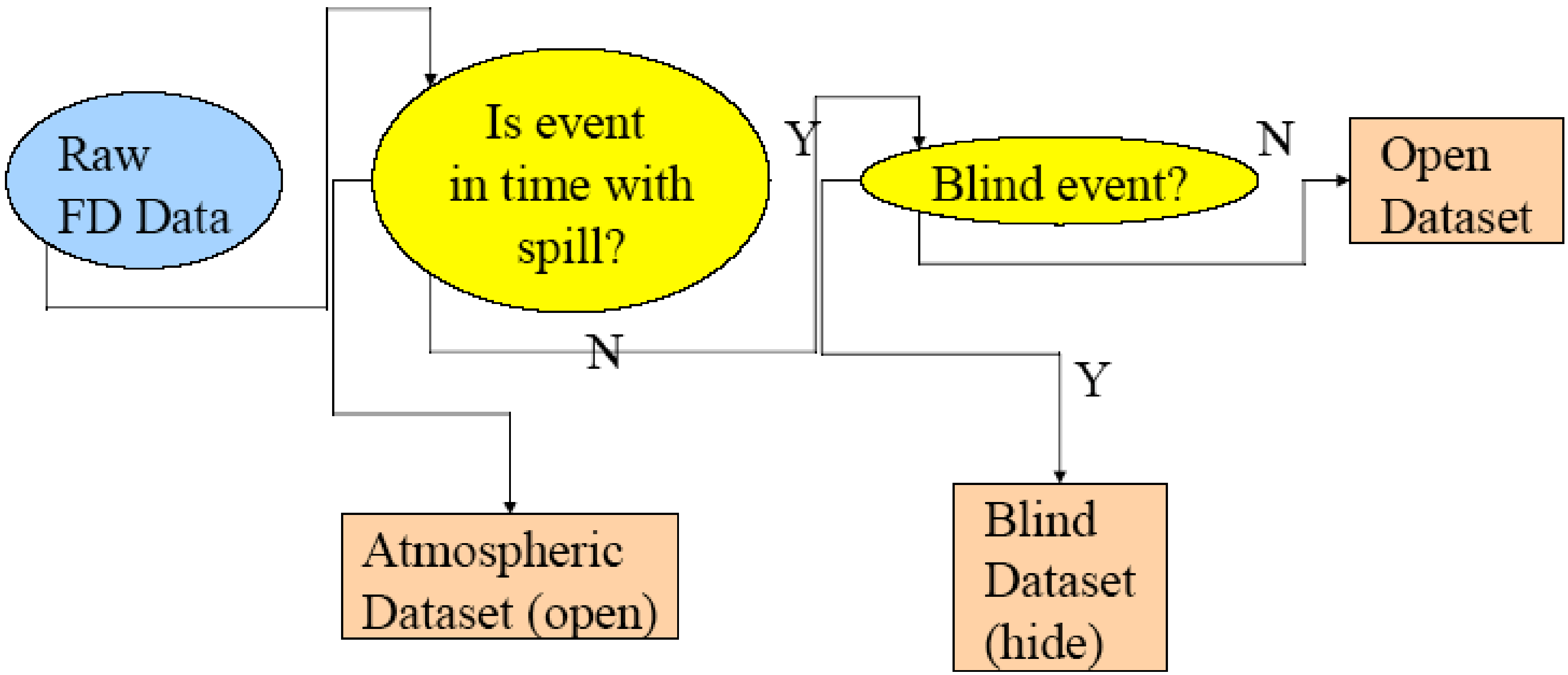
April 2004

- Randomly divide the far detector data into an open and blind set:
  - Overall blind set between 30 and 60% of events
  - Blinding function contains an unknown function of total pulse height and event length. Examples:



  - Could also use sin functions (Kopp suggestion)
- To reblind, just run a new blind on old data and start adding new data.

Throw away some (~half) of the FD beam data. Put it in a box until the final analysis.



Where to do it

Nathaniel Tagg
Oxford University

How to do it

Throw away data using a (hidden) function of total ADC and total event length. In this case:

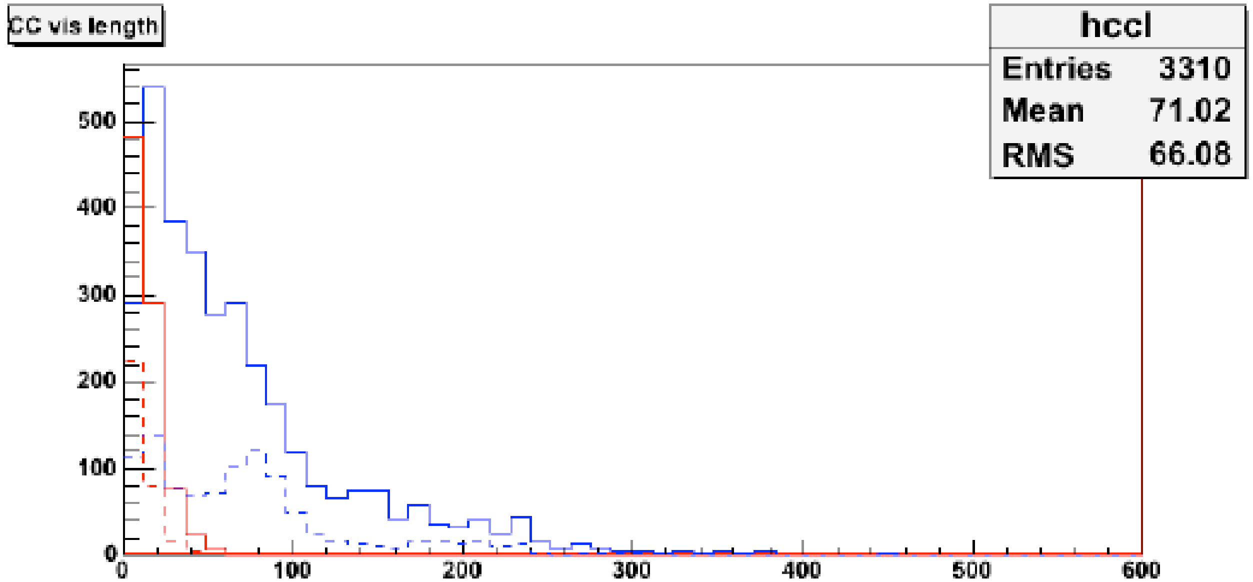
$$P(\text{keep}) = 0.2 + \left(0.4 \times \left(1 + \sin(\text{length}/fl + pl) \right) \times 0.4 \times \left(1 + \sin(\text{ADC}/fa + pa) \right) \right)$$

where pa = 360deg – pl

choose fl from 15 to 500 planes
choose fa from 0.8 to 2.0 GeV (i.e. 10 000 ADC/GeV)
choose fp 0 to 360 degrees

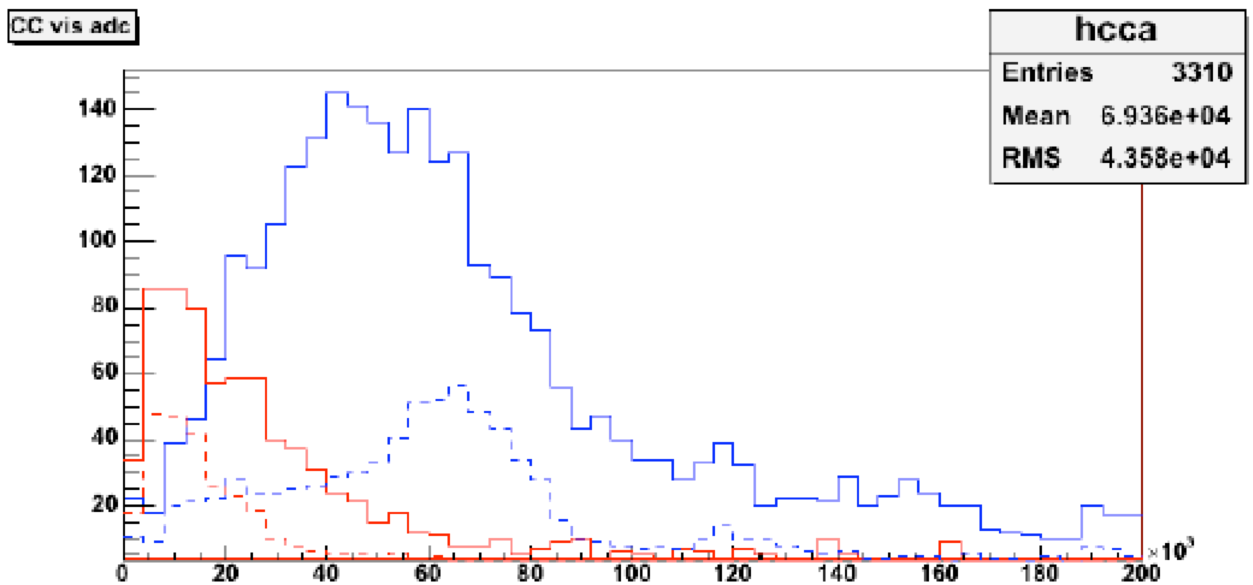
Then, roll pseudo-random number R(snarl,run). Keep open if R<P.

Event length



- CC
- NC
- CC blind
- NC blind

Event ADC



A Trial Experiment

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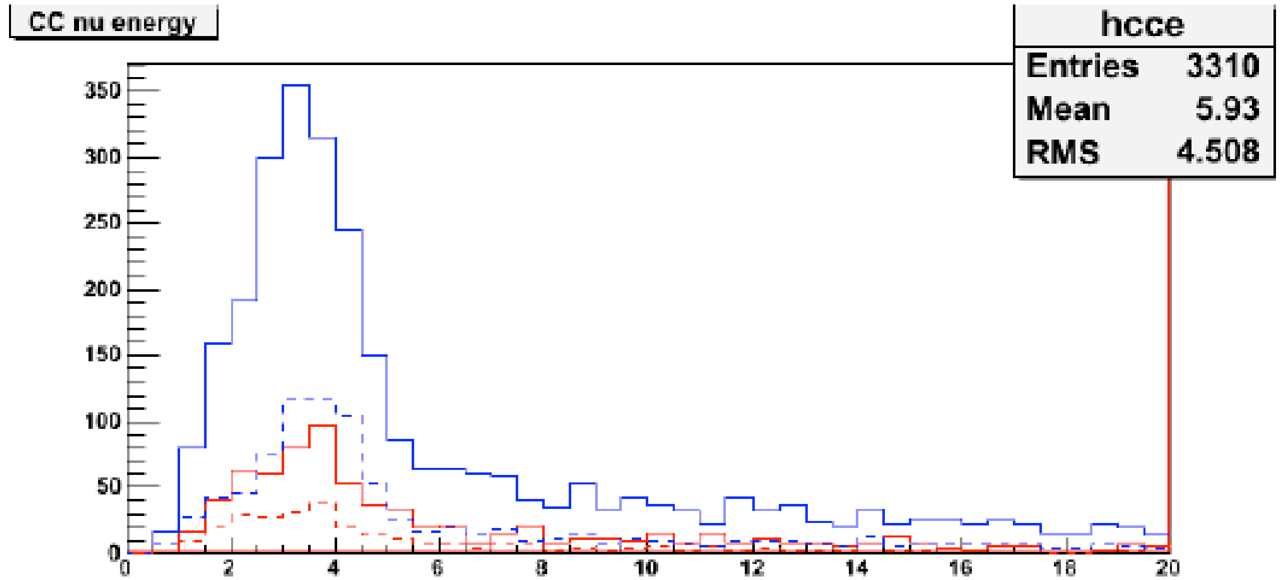
Oxford University

True event energy



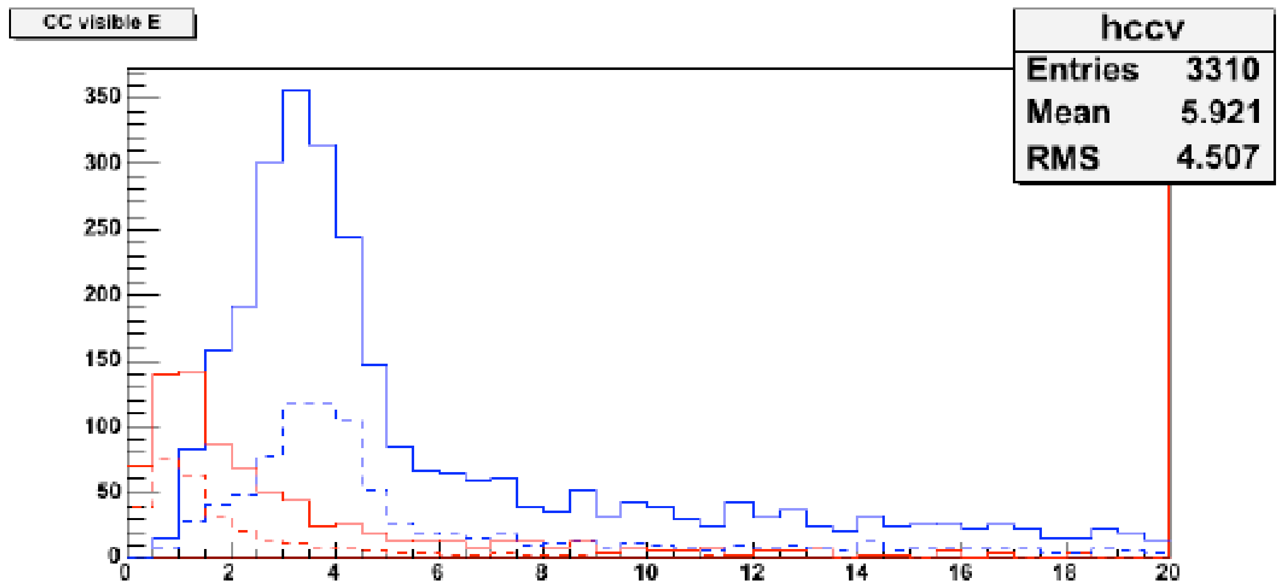
CC

NC

CC blind

NC blind

Visible event energ



A Trial Experiment

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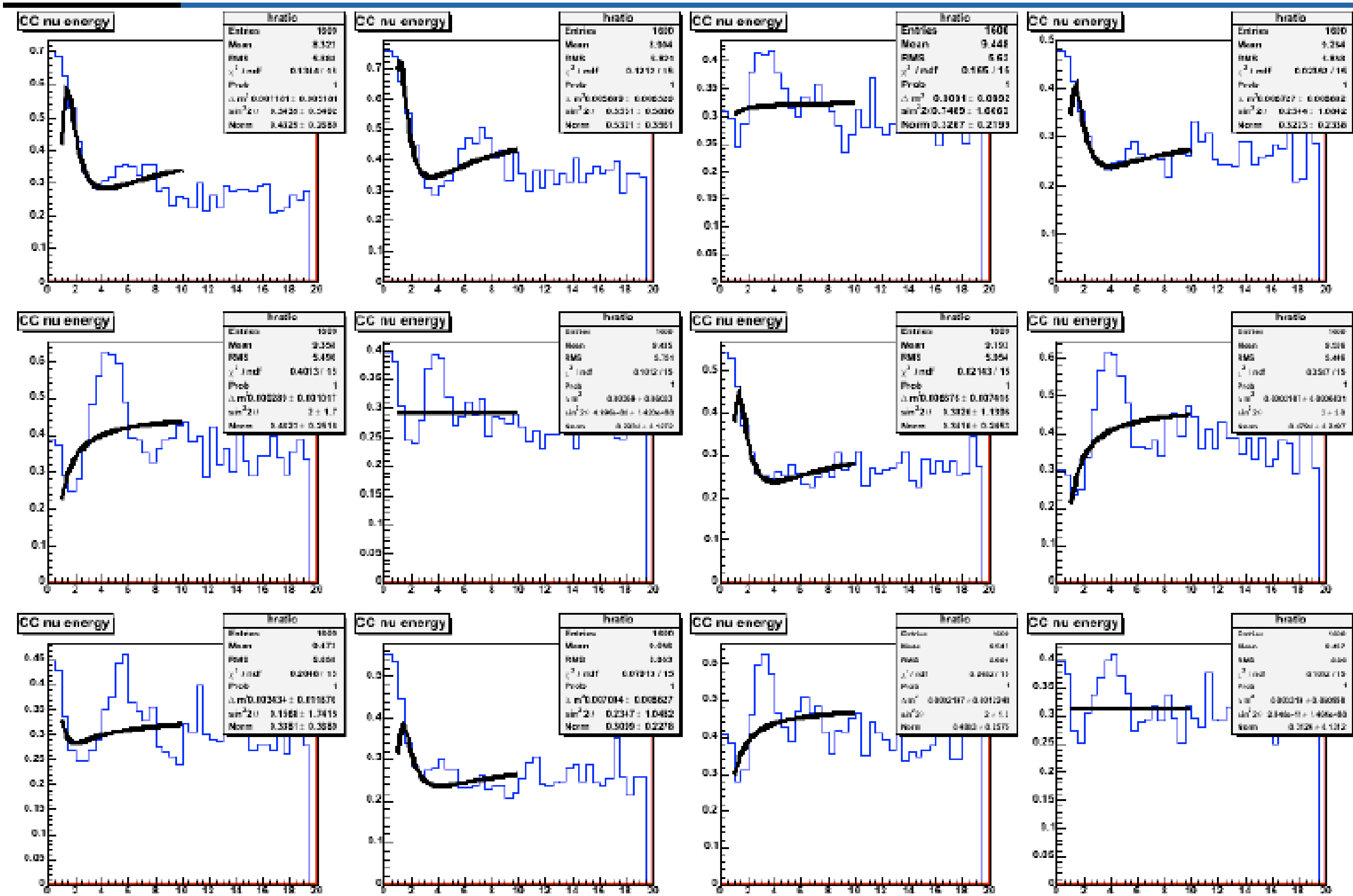

12 Trial Experiments

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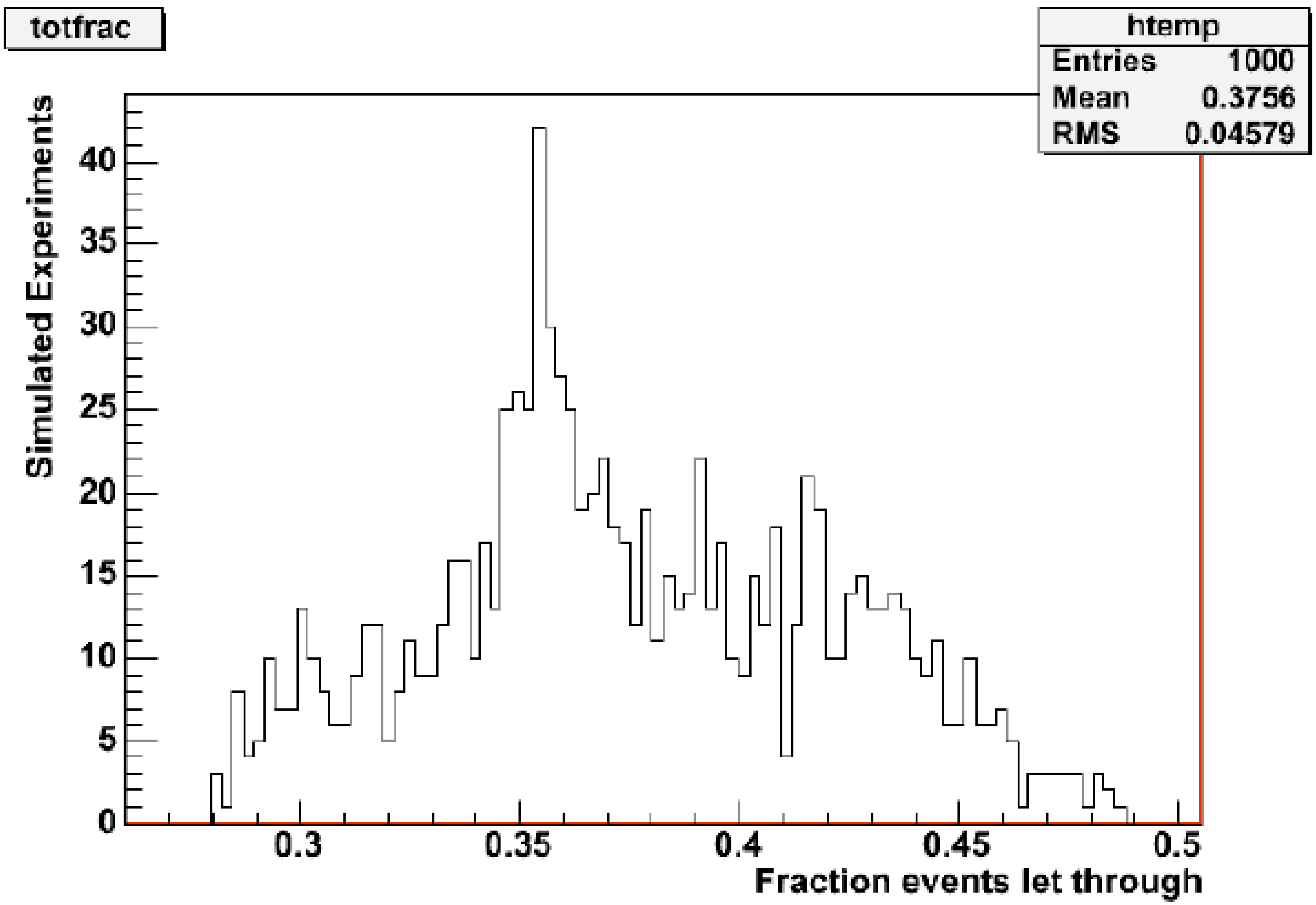

Tend to get 1/3 of the data in the 'open' sample.

Data fraction

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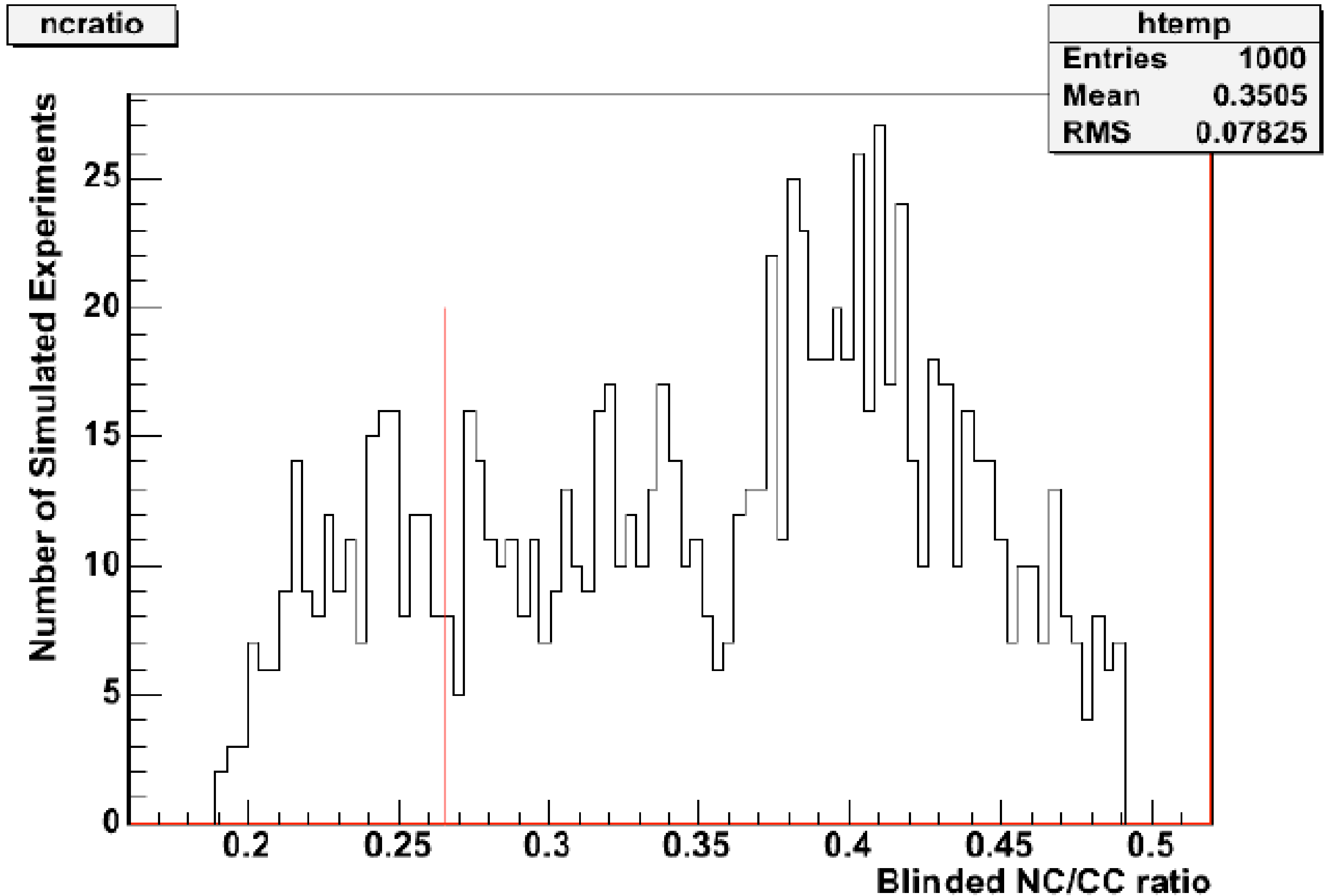

CC events are usually more supressed than NC events.

NC/CC Ratio

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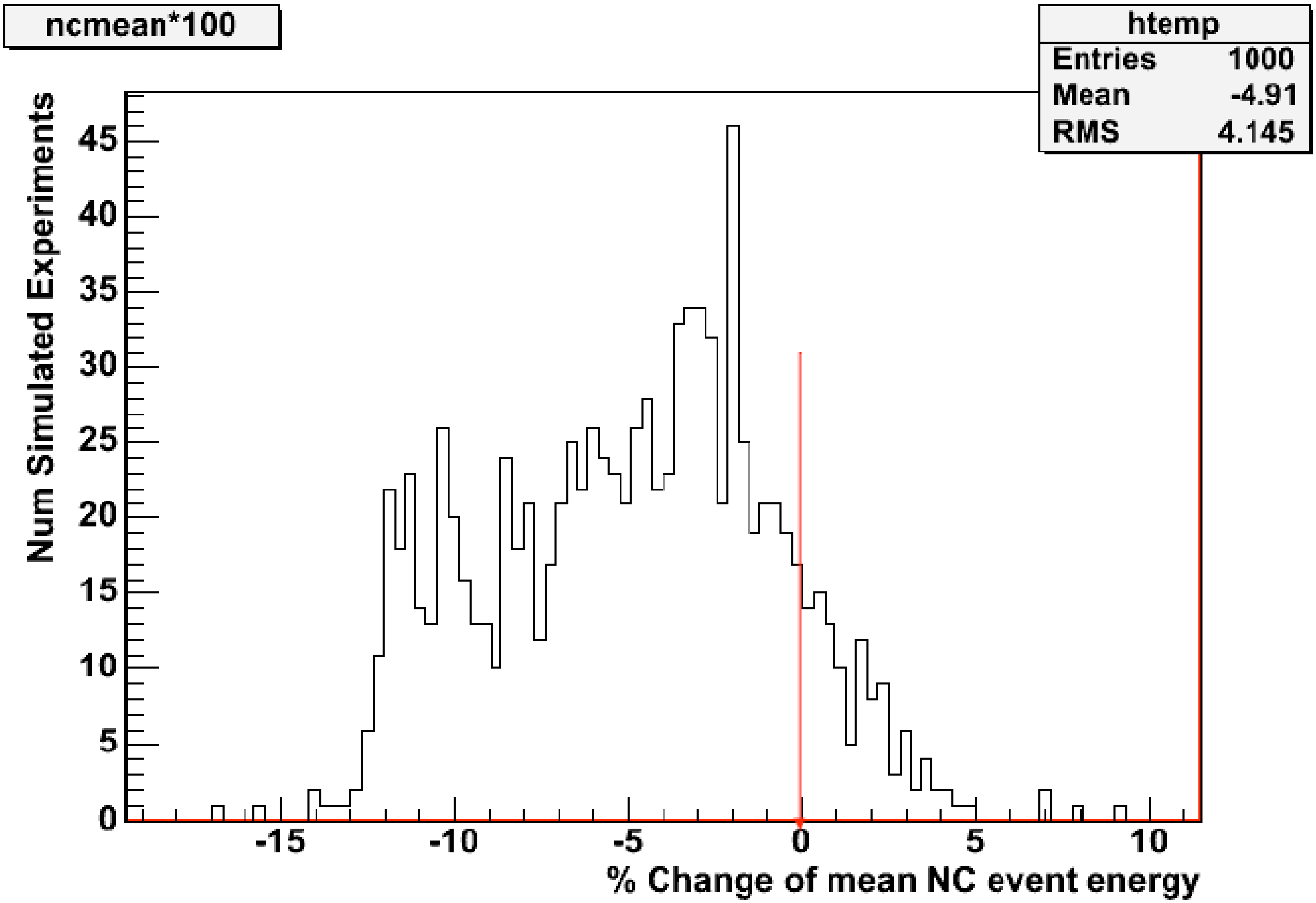

NC Spectrum

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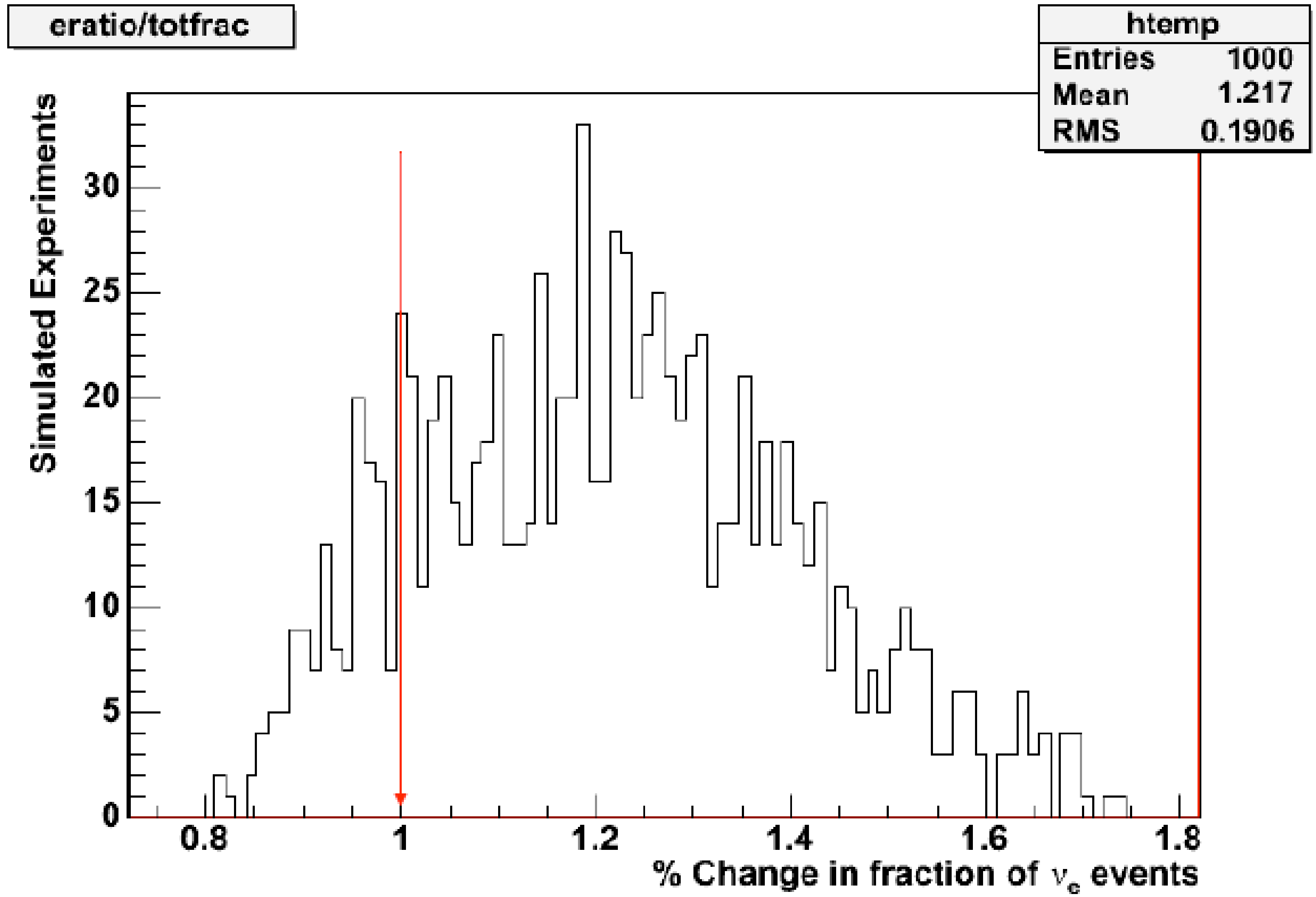

Electron events tend to be supressed less, too.

Nu_e events

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Oxford University

Response to Call for Comments

- Mary Bishai: Concern about being able to verify that far detector is functional within a year (Peter Litchfield previously expressed similar opinions.)
- Sanjib Mishra:
  - 10% open, 90% closed
  - Strip muons from CC events to make fake NC events
- Discussion?