# Status Report onTwo Photon Veto with the BeamCal

Jack Gill
Gleb Oleinik
Uriel Nauenberg

University of Colorado

# Objectives

- Ultimate objective: measure the $\tilde{\tau}_1^{\pm}$ mass to an accuracy of ±1 GeV (Benchmark 6 in [1])
- Current objective: veto two photon background using BeamCal.

# Motivation

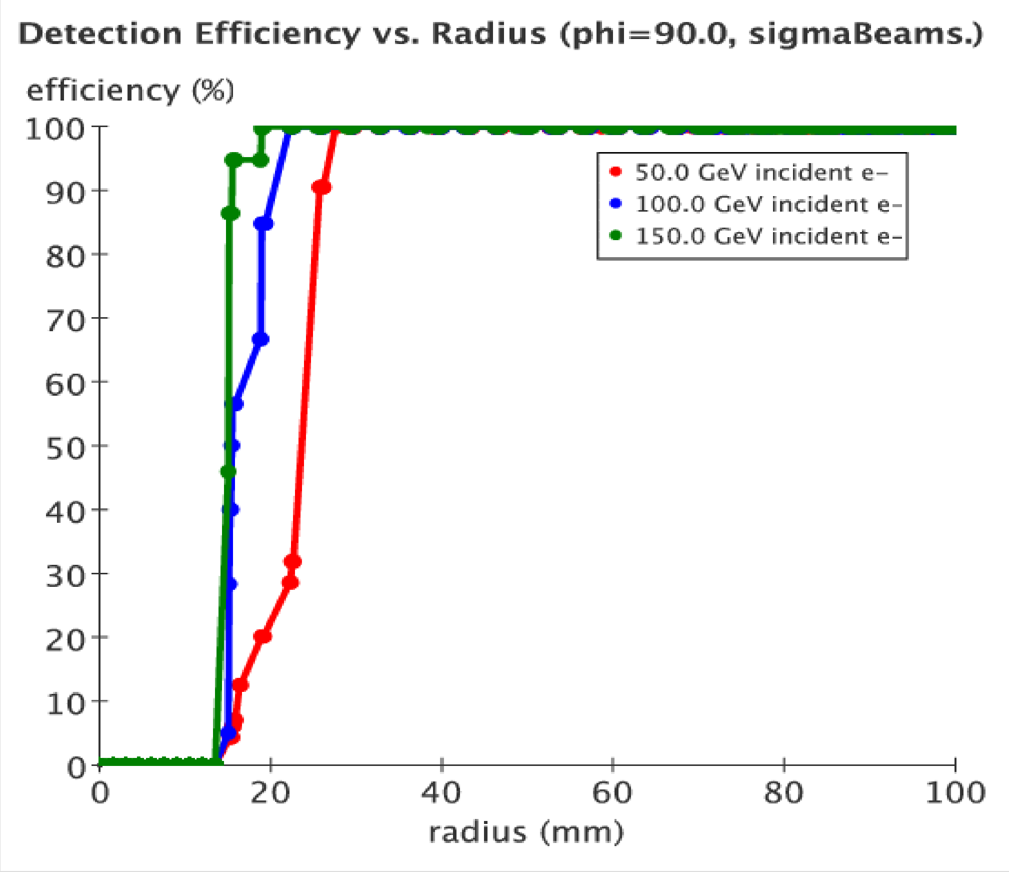
- The Cold Dark Matter relic density has been measured by WMAP, will be measured more accurately by Planck
- Density is determined by stau-neutralino co-annihilation rate, which is in turn determined by the stau-neutralino mass difference
- Neutralino mass measured via selectron or smuon signal [2]
- Accurate measurement of this mass difference will allow a comparison between ILC and Planck results. [3]

# Outline

- So far we have focused on signal final states with two leptons
- Largest background: two photon process, which leads to four lepton final states with two (beam) electrons in the far forward region
- Suppress two photon background by finding all leptons, using BeamCal in forward region

# BeamCal

- Covers 7 – 44 mrad
- New efficiency study by Gleb Oleinik:



# Signal

- Point D': $M_0 = 110, M_{1/2} = 525, A_0 = 0, tan(\beta) = 10, \mu = -658.26$ [4]
- (e- polarization, e+ polarization) = (80% L, 30% R)
- Ecm = 500 GeV

Cross section for $e^+e^- \to \widetilde{\tau}_1^+\widetilde{\tau}_1^-$ is 3.7 fb

Branching ratio for $\widetilde{\tau}_1^\pm \to \tau^\pm\widetilde{\chi}_1^0$ is ~100%

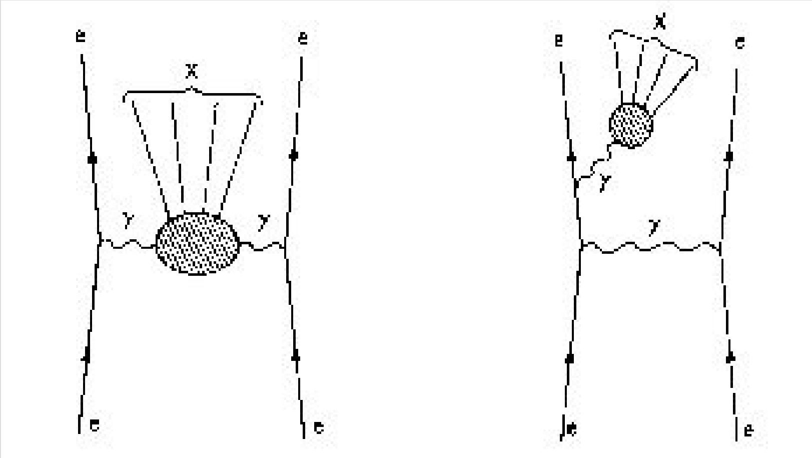
τ branching ratios: $\tau^\pm \to e^\pm\overline{\nu_e}\nu_\tau = 17.84\%$

$\tau^\pm \to \mu^\pm\overline{\nu_\mu}\nu_\tau = 17.36\%$

Final state cross sections: $\sigma_{e^+e^-} \approx \sigma_{\mu^+\mu^-} \approx \sigma_{e^\pm\mu^\mp} \approx 0.4fb$

# Two Photon Background

Main background is two photon process:




Phys Rev D **4**, 1532.

Cross section is high: $\sigma_{e^+e^-} \approx 3 * 10^8 fb$

$\sigma_{\mu^+\mu^-} \approx 1 * 10^7 fb$

$\sigma_{\tau^+\tau^-} \approx 2 * 10^5 fb$

Note: cross sections calculated using WHIZARD, depend on EPA parameters

# Other Backgrounds

- SUSY
  - Selectrons: 3.2 fb
  - Smuons: 3 fb
  - Higgs-Z: 96 fb
- SM
  - Two photon → quark antiquark
  - Bhabba scattering
  - W+W-

# Event generation

- Integrated Luminosity: 100 $fb^{-1}$
- Used WHIZARD 1.92
- For SUSY signal generation used benchmark point D' ($\Delta m \sim 6$ GeV)
- Account for effect of beamstrahlung on center of mass energy
- For two photon process, used EPA
  - EPA_mX = 4 GeV (minimum invariant mass of produced system)
  - EPA_Q_max = 4 GeV (maximum virtuality of photon)
- Need better understanding of how two photon cross sections are calculated

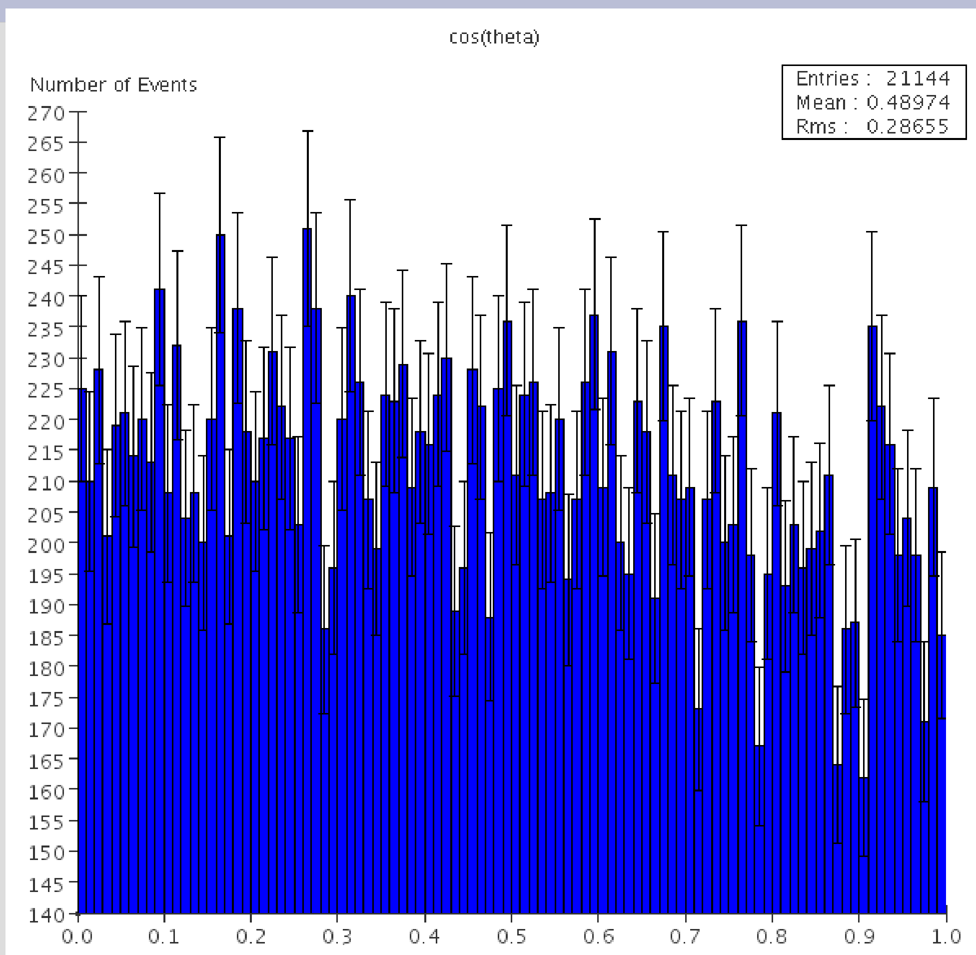
# Detector Simulation

- Define barrel as $\theta > 0.044$ rad, BeamCal as $\theta < 0.044$ rad
- Barrel is assumed to have 100% efficiency for electrons and muons
- BeamCal electron efficiency given by Gleb's lookup table. BeamCal is assumed to have no MIP sensitivity.

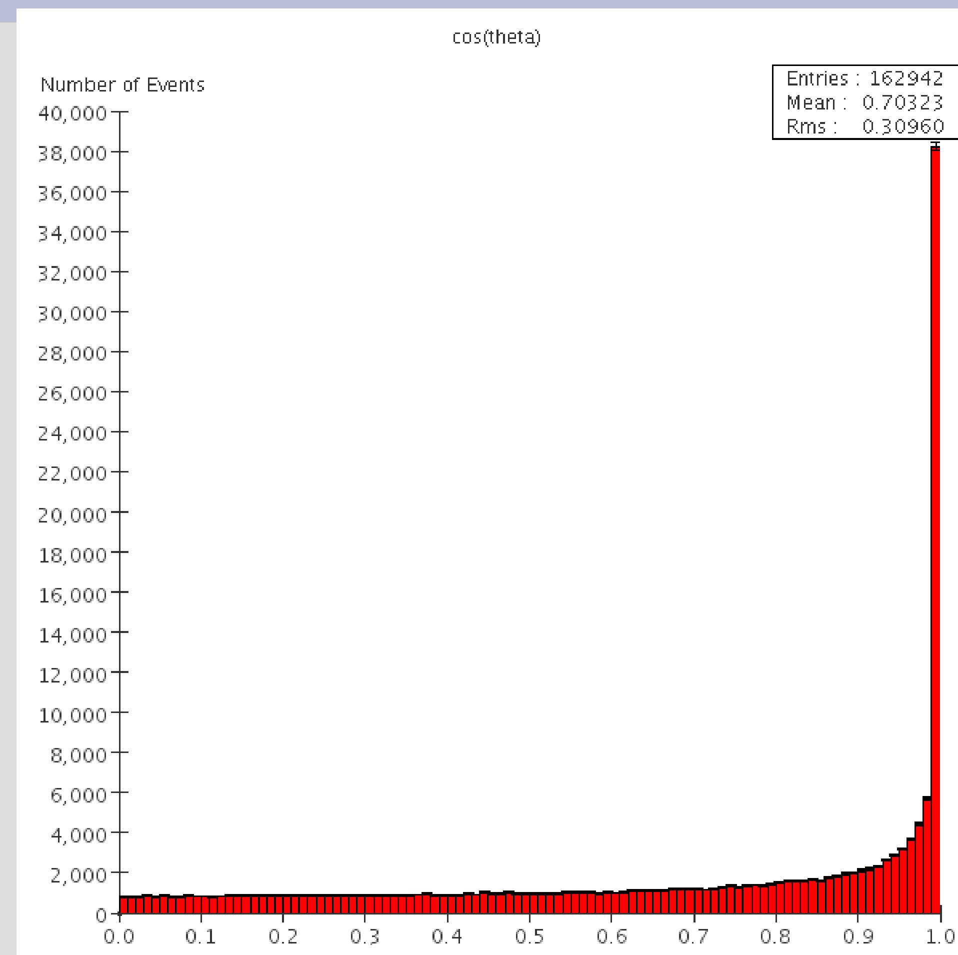
# Analysis

- Select events with two visible leptons in the final state (efficiency cut)
- Cuts on kinematic variables necessary to reduce background
- Possible variables: acoplanarity, invariant mass, etc
- At present, consider only two variables: $\cos(\theta)$ and combined Pt

# Cos(θ) Cut

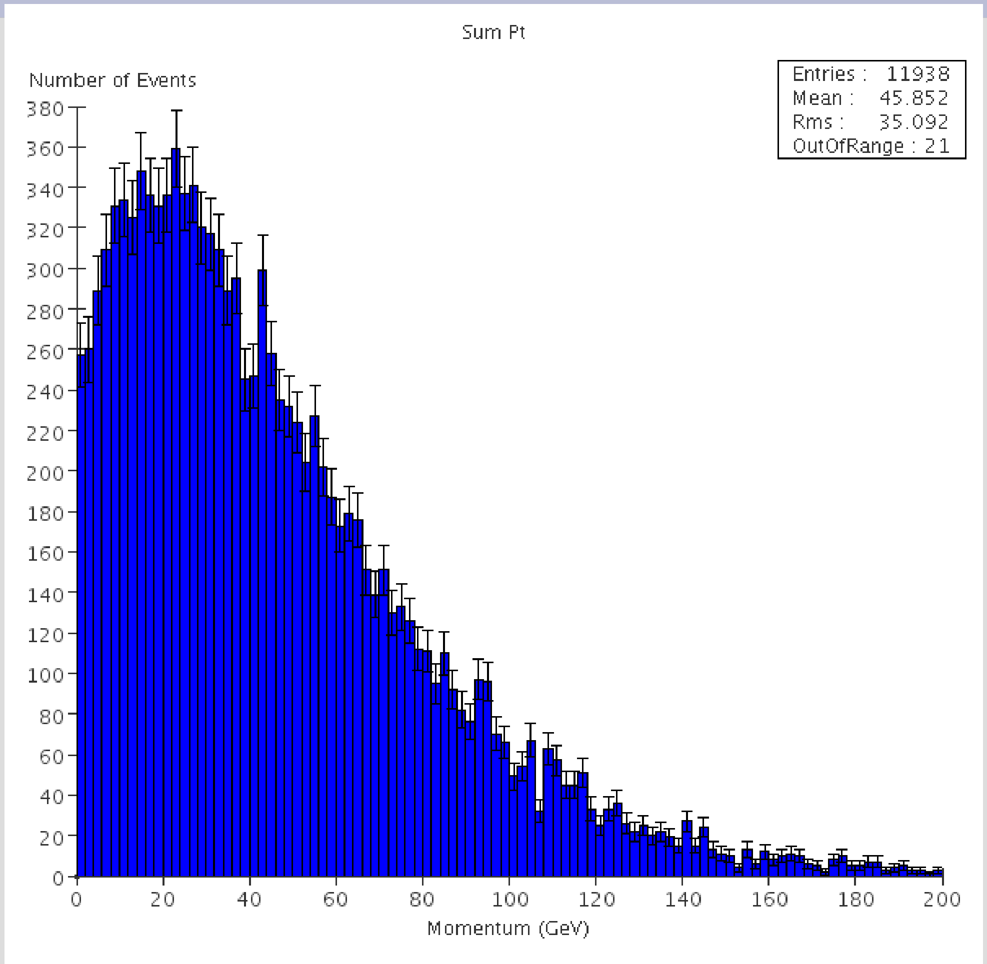



Stau (Not to scale)

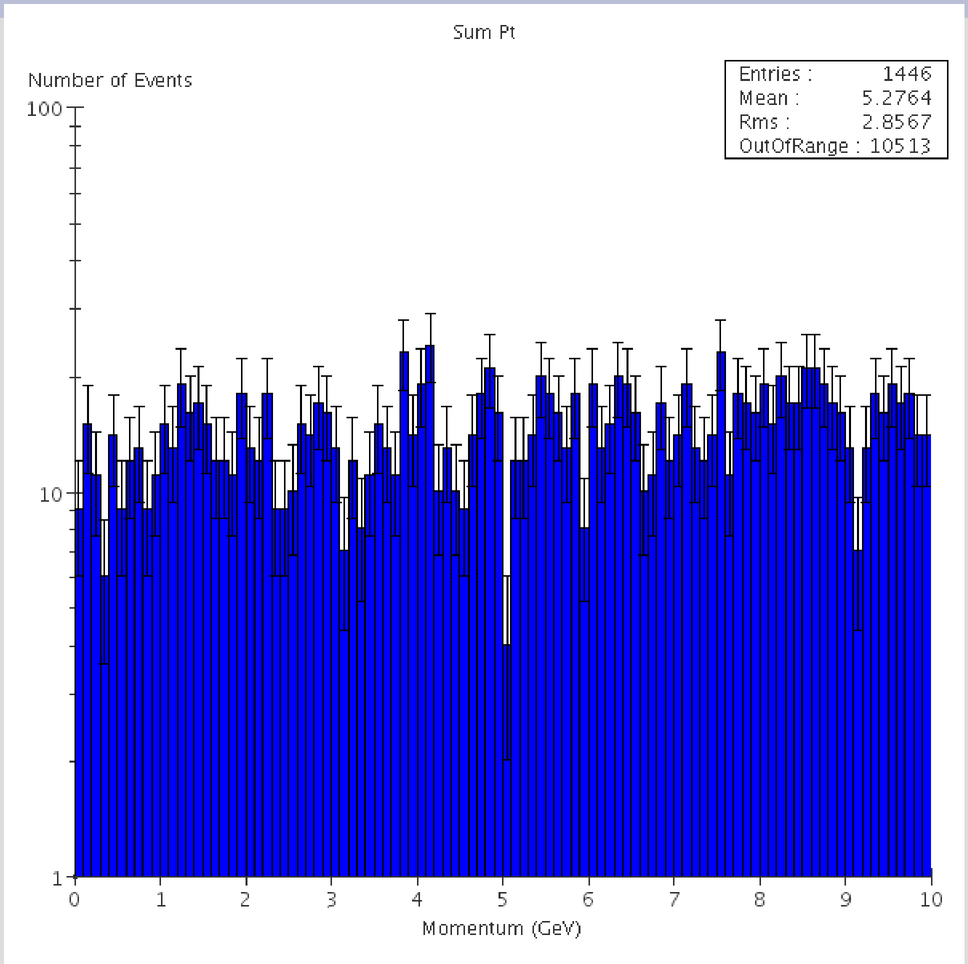



Two Photon

# Combined Pt - Signal




Stau Events

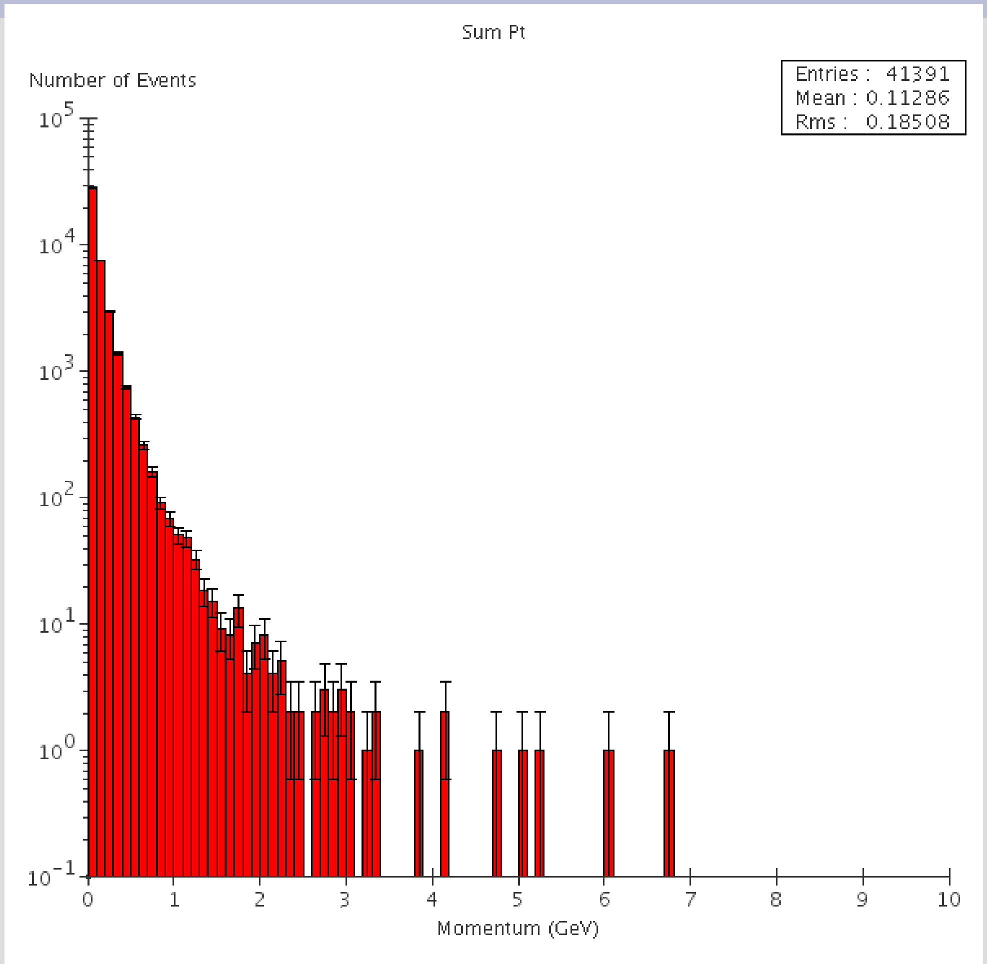


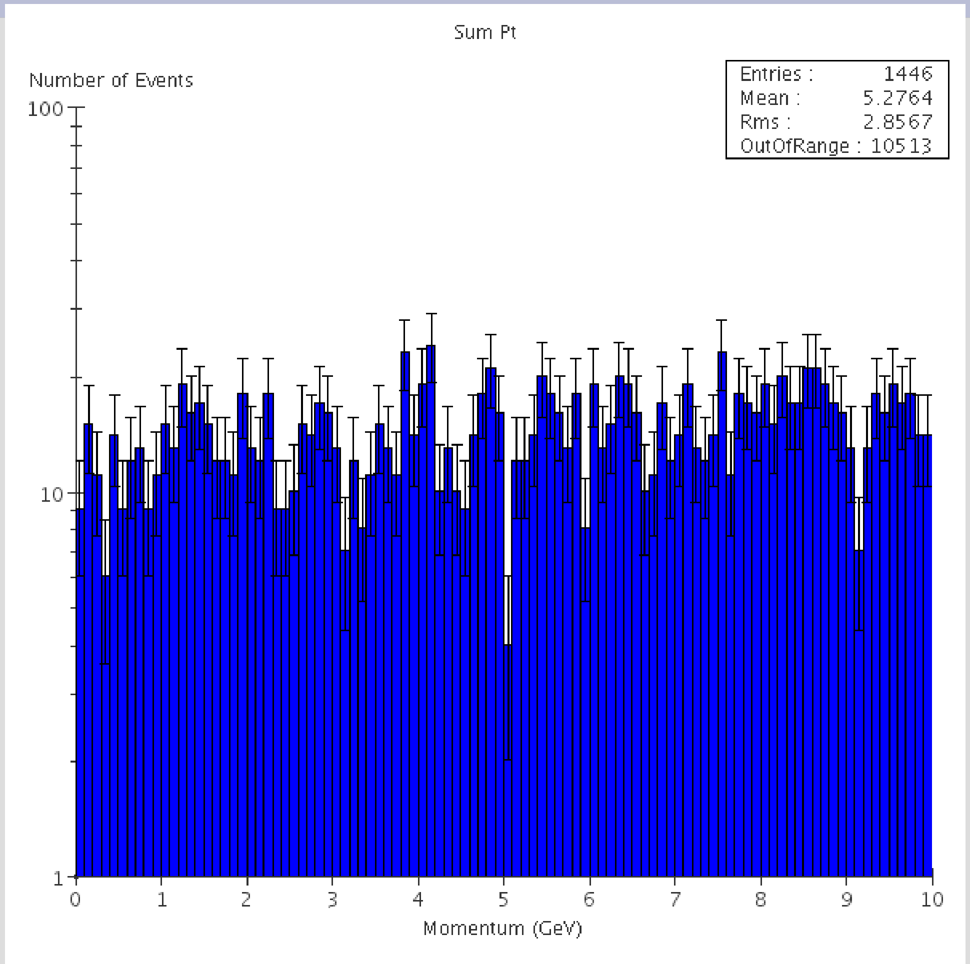

Stau Events (detail)

$$P_{t,combined} = \sqrt{(P_{x,1} + P_{x,2})^2 + (P_{y,1} + P_{y,2})^2}$$

(after Cos(θ) cut)

# Combined Pt – Signal and Background




Two Photon

Stau (Not to scale)

(after Cos(θ) cut)

# Cuts

- Cuts used:
  - Efficiency Cut (2 lepton final state)
  - $|\cos(\theta)| < .95$
  - Pt_combined > 8 GeV
- These cuts are fairly aggressive, necessary due to high cross section of background
- Cuts on other kinematic variables may be desirable to preserve more of signal

# Preliminary Results

| Type | # Events (all final states) | # Events (2 lepton final states) BEFORE cuts | # Events (2 lepton final states) AFTER cuts | % remaining after cuts |
|---|---|---|---|---|
| $\gamma^*\gamma^* \rightarrow$ leptons | $3.5*10^{10}$ | $7.1*10^{9}$ | 0 | 0 |
| Stau | 367 | 45 | 33 | 73 |

Note: two photon events weighted by a factor of 100,000 – statistical fluctuations have a large effect here.

Two photon background with leptonic final states is vetoed, while retaining 73% of signal

# Conclusions

- Preliminary results show two photon background with leptonic final states can be adequately suppressed by kinematic cuts.
- Future work:
  - Improve event generation:
    - Increase two photon statistics significantly
    - validity of EPA? [5]
    - Include other sources of background
  - Barrel detector simulation (MCFast to start, later full simulation/reconstruction)
  - Cuts on additional variables (acoplanarity, etc) to remove additional background while preserving as much of signal as possible

# References

[1] M. Battaglia et al, “Physics Benchmarks for the ILC Detectors.” hep-ex/0603010
[2] C.F Berger et al, “General Features of Supersymmetric Signals at the ILC: Solving the LHC Inverse Problem.” arxiv:0712.2965v2
[3] P. Bambade et al, “Experimental Implications for a Linear Collider of the SUSY Dark Matter Scenario.” hep-ph/0406010v1
[4] M. Battaglia et al, “Updated Post-WMAP Benchmarks for Supersymmetry.” hep-ph/0306219
[5] J. Kalinowski et al, “Pinning down the invisible sneutrino.” arxiv:0809.3997