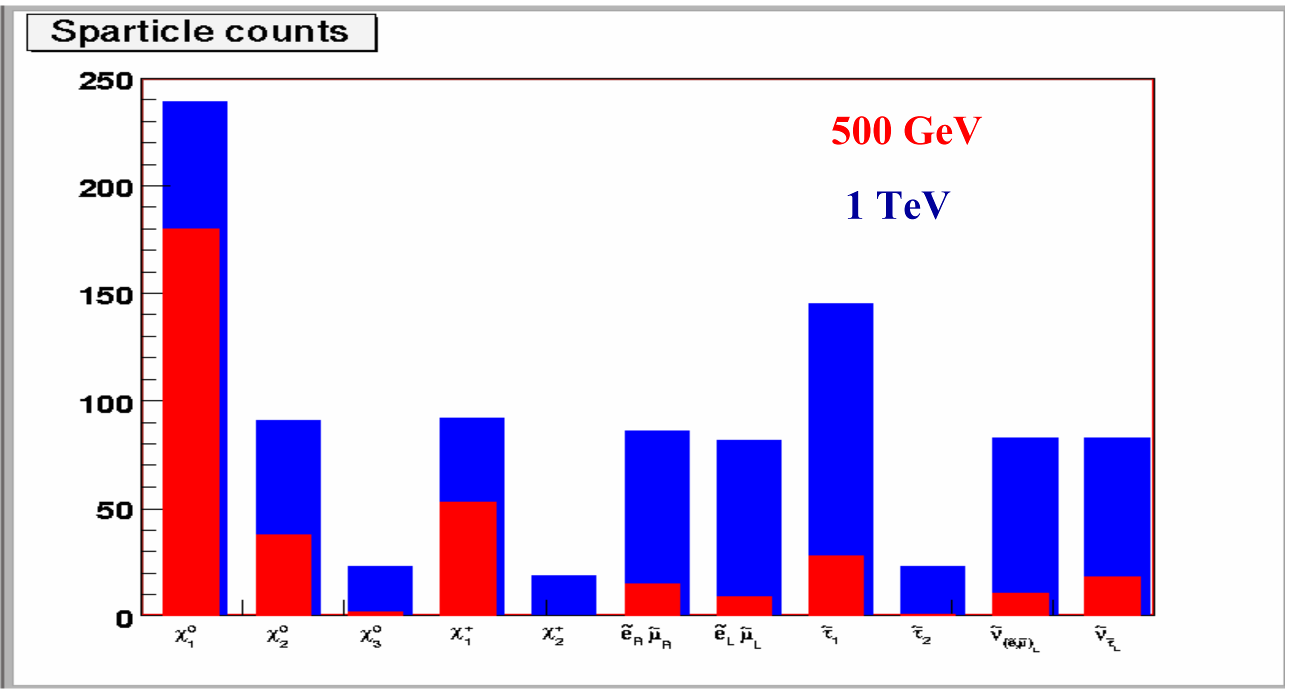
ILC = LHC^{-1} ? : Part II

- Chargino and Neutralino Analyses: ***Preliminary Results***



Recall: @ 500 GeV

•**242** models total

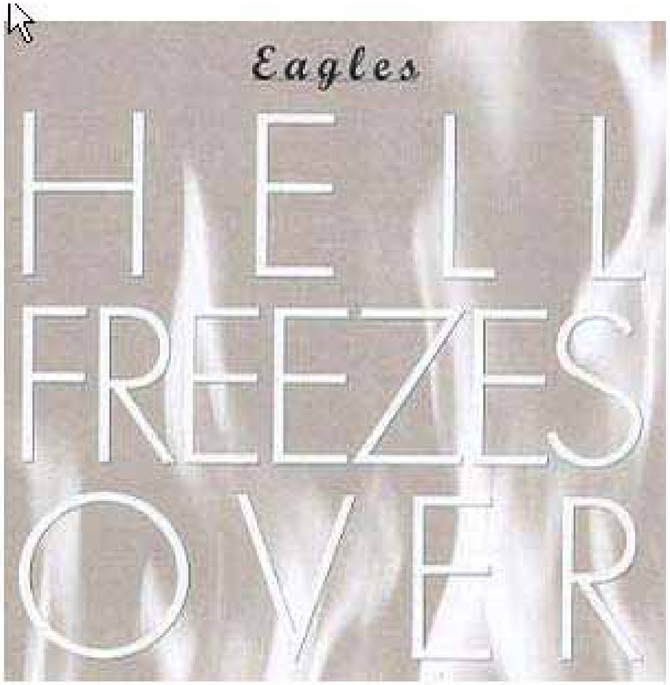
•**53** models have χ_1^+, 2 of which have sleptons and 8 of which have staus

•**99** models have ***only*** χ_1^0

•Chargino & neutralino final states are ***more*** common than sleptons in the set of models we examine

•-ino signatures are more ***sensitive*** to the MSSM parameters than sleptons


Hell


Eagles
HELL
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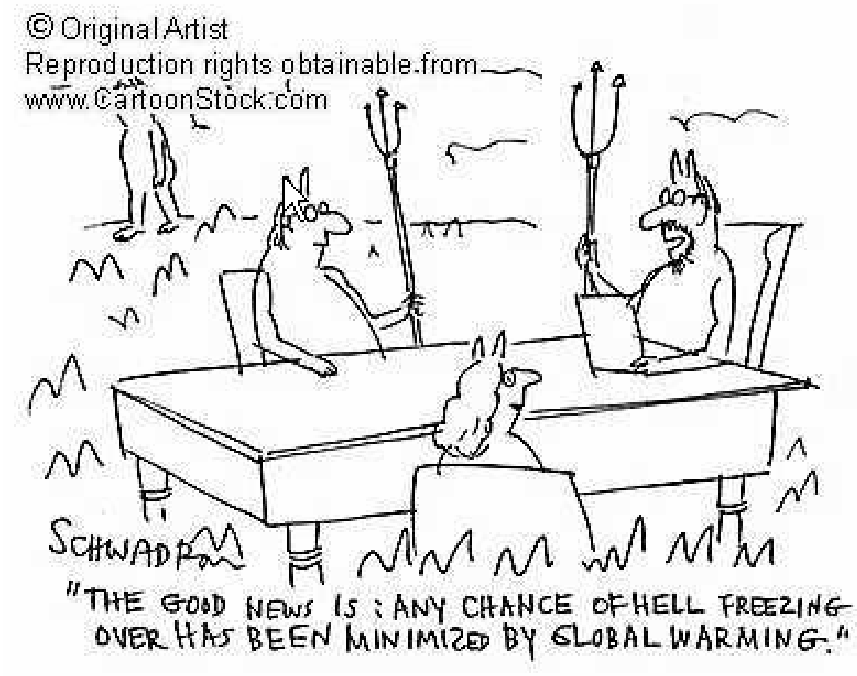
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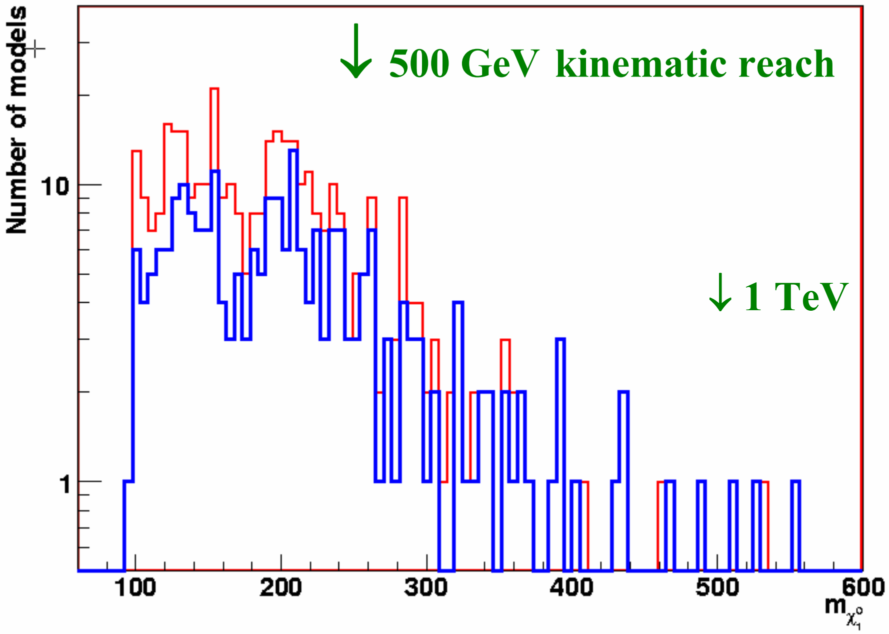
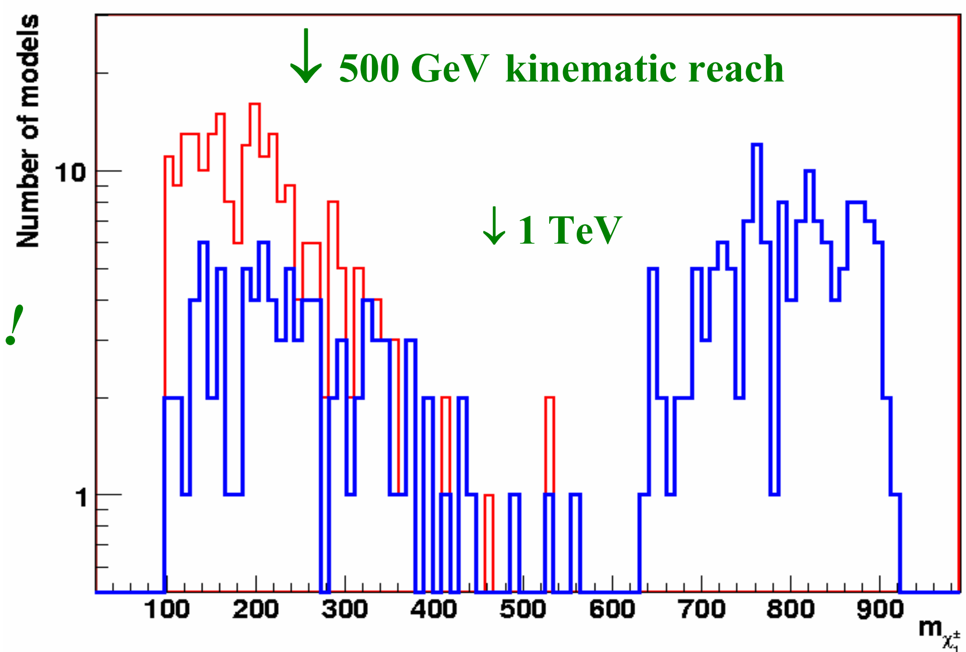
SCHWADRON
"THE GOOD NEWS IS: ANY CHANCE OF HELL FREEZING OVER HAS BEEN MINIMIZED BY GLOBAL WARMING."



Chargino and neutralino masses are widely distributed in our models… and the reach of the 500 GeV ILC is somewhat restricted. A 1 TeV machine is significantly better at covering this part of the spectrum.

Neutralino LSP mass spectrum

Chargino mass spectrum

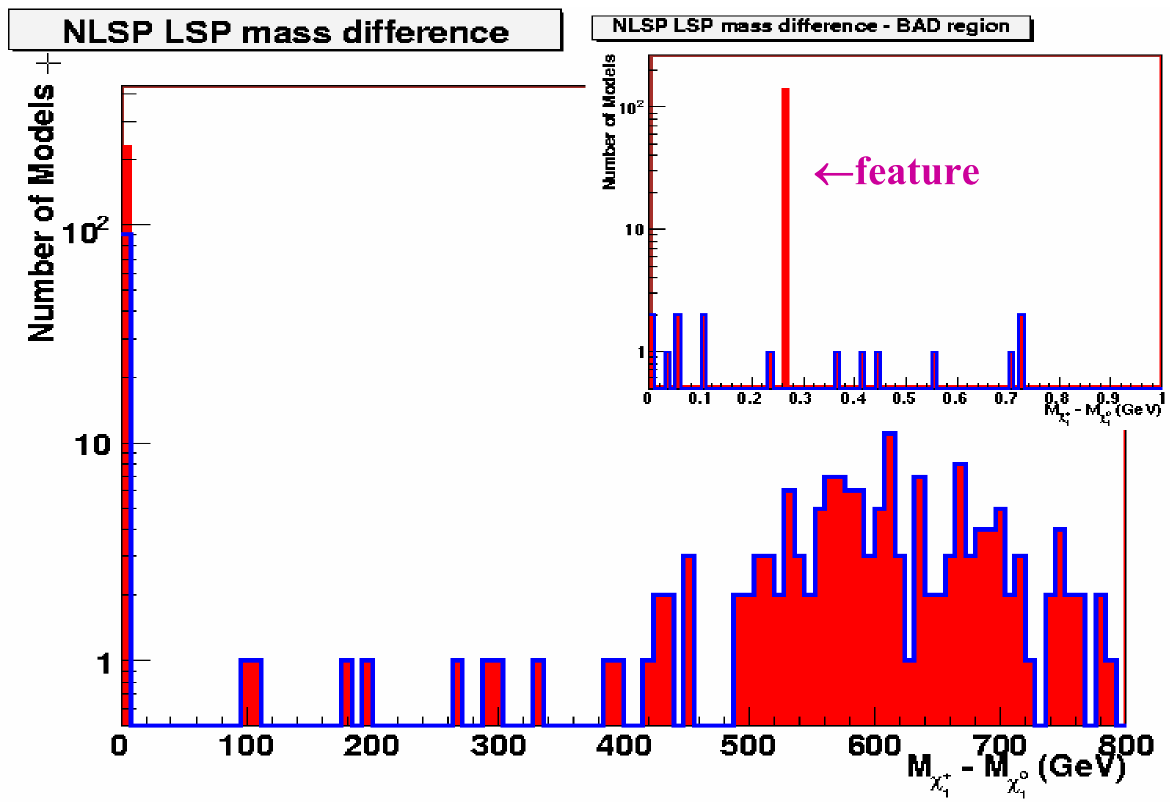


Our analyses need to be sufficiently general to cover all of the kinematically accessible models….with ***universal cuts !***

We consider charginos first...

Critical parameter for charginos: $\Delta m = m_{\chi_1^\pm} - m_{\chi_1^0}$

Models are randomly distributed in Δm so we need to worry about all possibilities…but first we encounter a ***feature*** which is a PYTHIA artifact…



If the chargino mass is less than that of the lightest neutralino then PYTHIA resets the chargino mass to be that of the neutralino $+2m_\pi$

without warning…

This is an issue which is now dealt with in later versions of PYTHIA…(thanks to Steve & Peter !)

Chargino Analyses: Non-Close Mass Case ($\Delta m > 1$GeV)

(i) **Muonic decay channel:** $\chi_1^\pm \rightarrow \tilde{\mu}^\pm \nu, \mu^\pm \tilde{\nu} \rightarrow \mu E^{miss}$

This is not a common mode in our models **

Look for $\chi_1^+ \chi_1^- \rightarrow \mu^+ \mu^- + E^{miss}$

and off

(ii) **Four-jet Final State: on^shell W's** $\chi_1^\pm \rightarrow jjE^{miss}$ ↑ **$W^{(*)}$**

Depending on the mass splitting the W can be virtual but in this case the W mass will not be reconstructed in dijets

Look for $\chi_1^+ \chi_1^- \rightarrow 4j + E^{miss}$

We perform **two distinct** analyses here to cover both the **real and virtual** W cases…

(iii) **2-jet + 1 muon Final State**

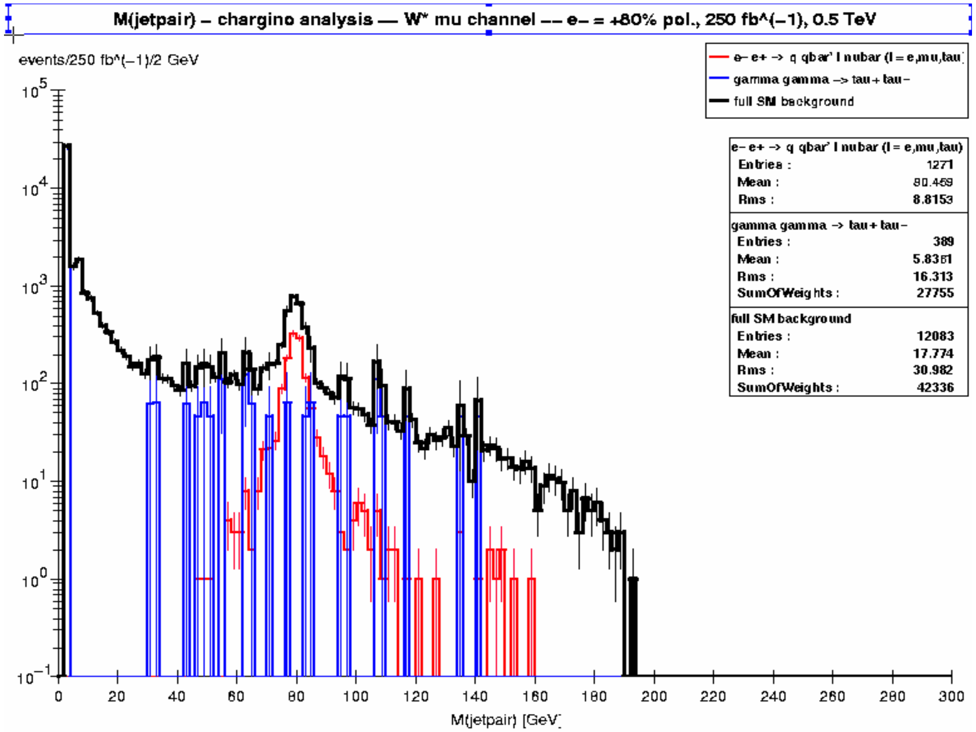
This is the mixed mode covering the case of one hadronic and one leptonic decay of the **real** or **virtual** W . There aren't many of these in our model sample…

Look for $\chi_1^+ \chi_1^- \rightarrow 2j + \mu^\pm + E^{miss}$

There are 4 extensive lists of cuts to cover all these possibilities….

** **Note that this mode also covers the case** $\chi^+_1 \rightarrow W^{(*)} \chi^0_1 \rightarrow \mu + \chi^0_1$

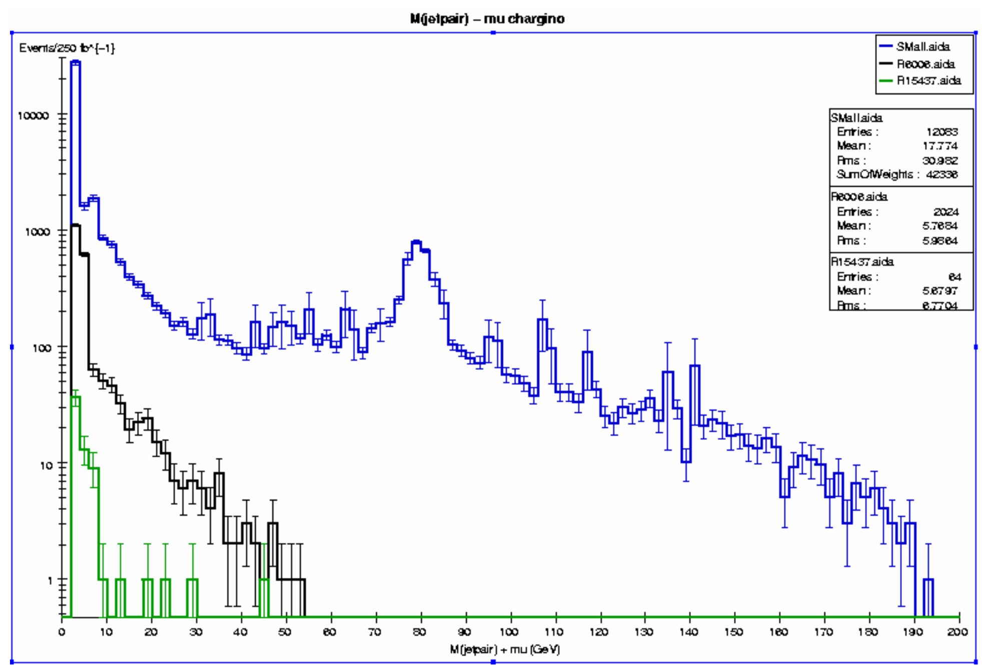
SM backgrounds for off-shell jj+μ analysis



The large SM backgrounds here are mainly due to the processes $e^+e^- \rightarrow W^+W^- \rightarrow jj\mu\nu$ and $\gamma\gamma \rightarrow \tau^+\tau^-$ with, e.g., $\tau \rightarrow \pi; \tau \rightarrow \pi\pi\nu, \pi \rightarrow \mu$

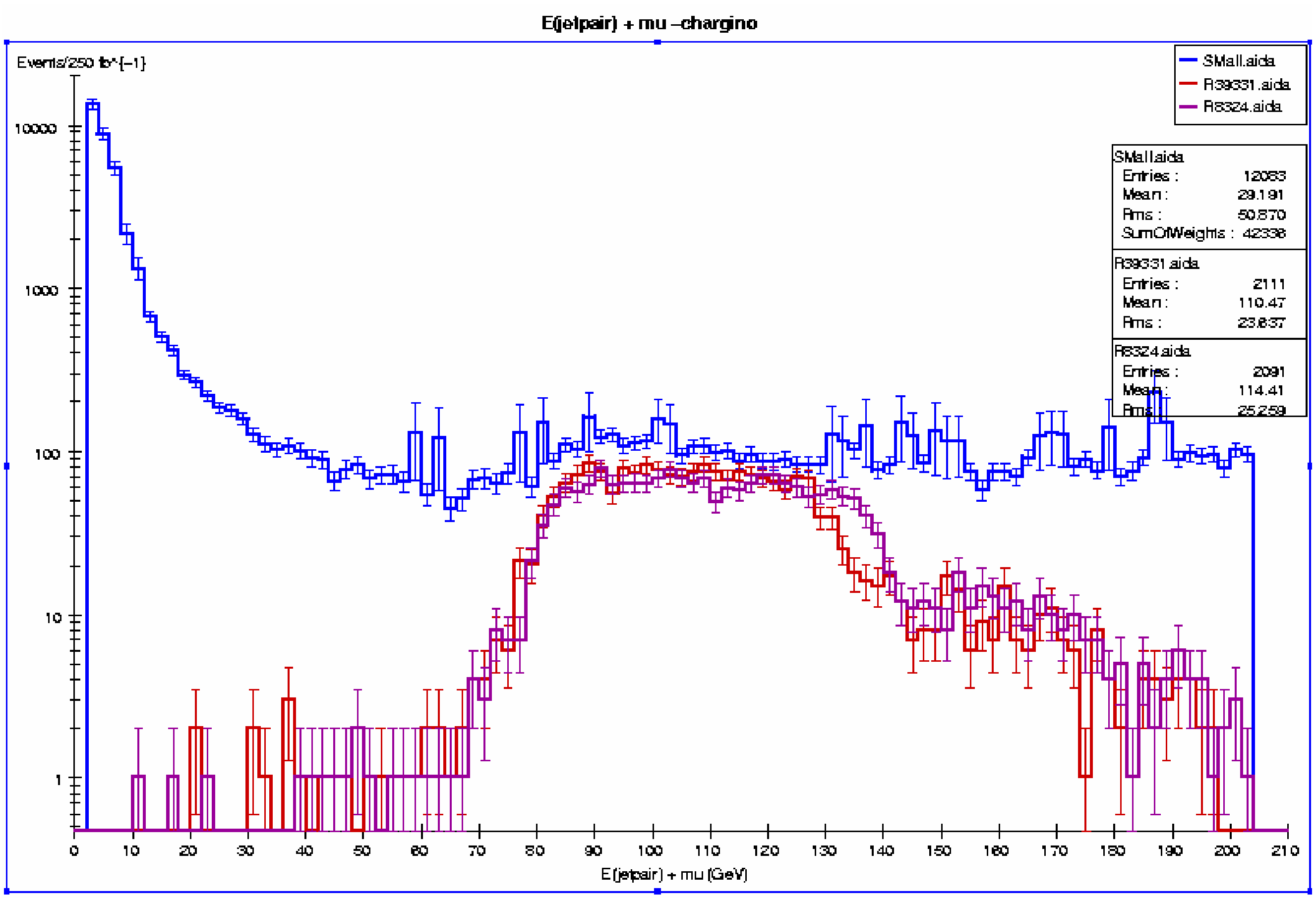
The large spikes are due to γγ background rescaling

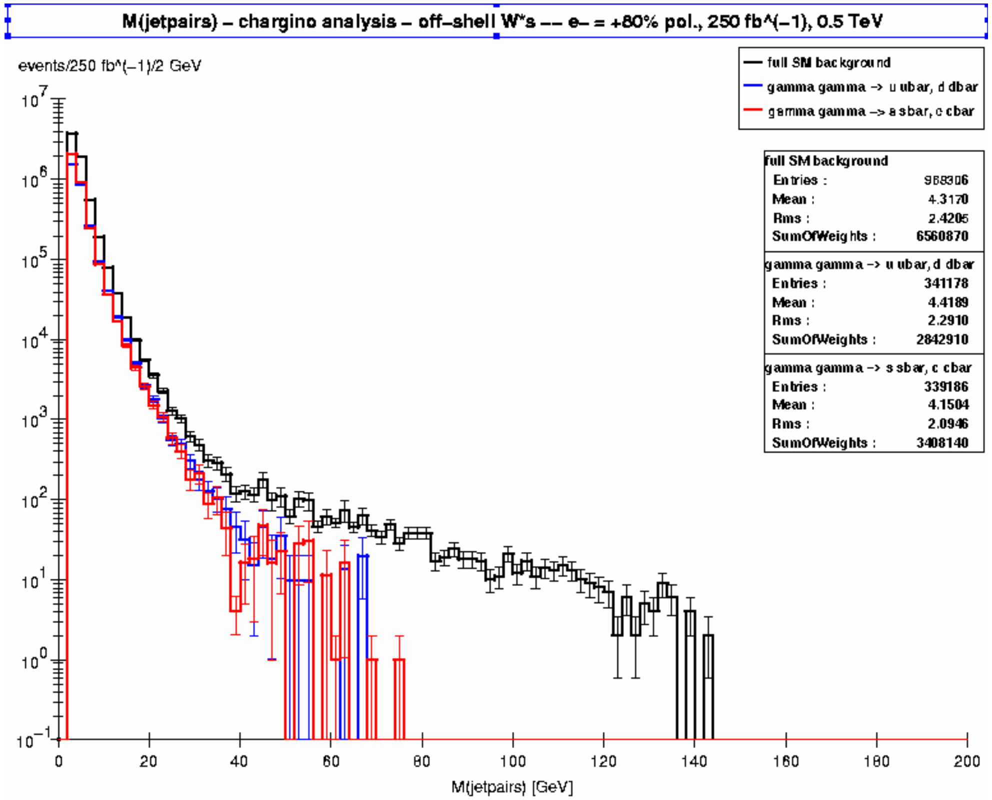
Here we see an off-shell **jj+μ** analysis example where the signals are quite small for both models. Clearly these two models are **not** distinguishable by this analysis if we use this observable. →



Charginos → jj+μ analysis producing **off-shell** W's :

Here is a case where S/B is large (~1) but the two models produce somewhat similar signal profiles we'll need to differentiate...





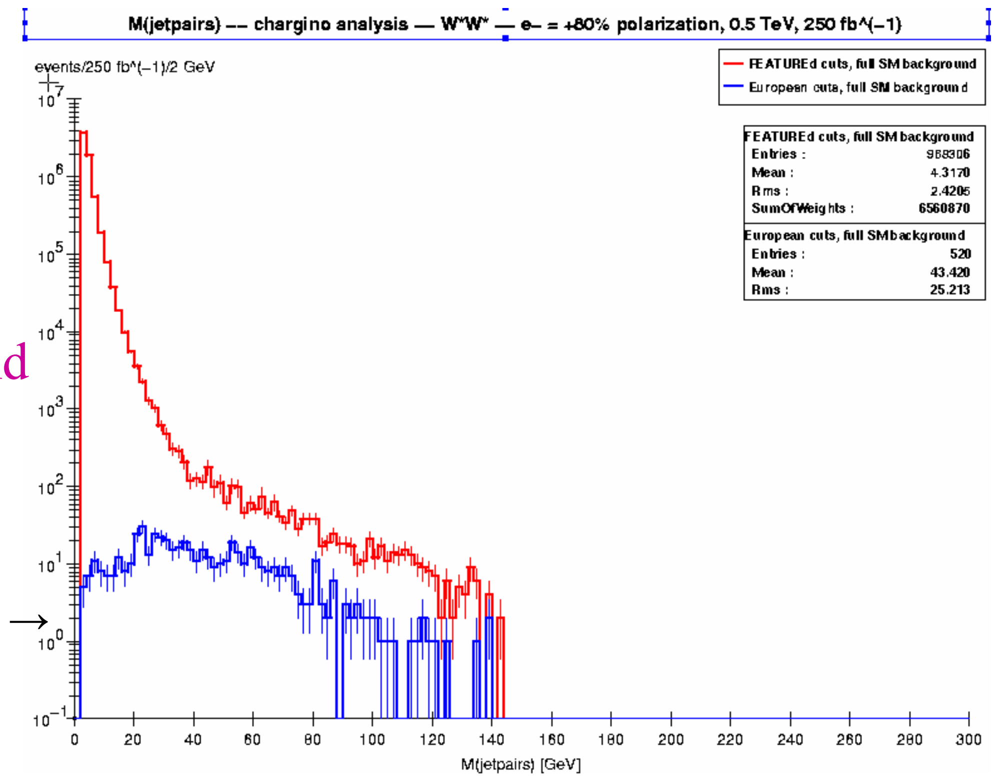
Charginos →4j Analysis

It is important to include all 1000+ background processes in many analyses. While some sources clearly dominate lots of other small contributions can add up.

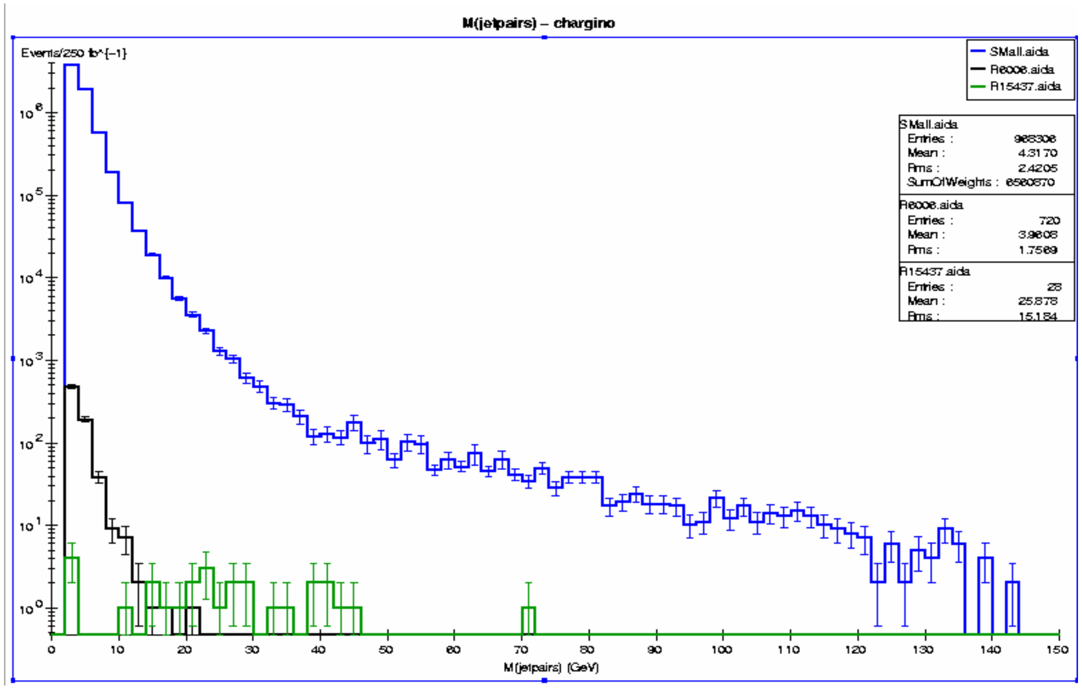
One has to be careful in adopting cuts used to analyze **SPS1a**, to the case of an arbitrary MSSM model point. For example, while this cut drastically reduces the low mass background it ***completely*** kills the signal too in most cases.

↓

Includes an extra cut, $p_T^{vis} \geq 30$ GeV →



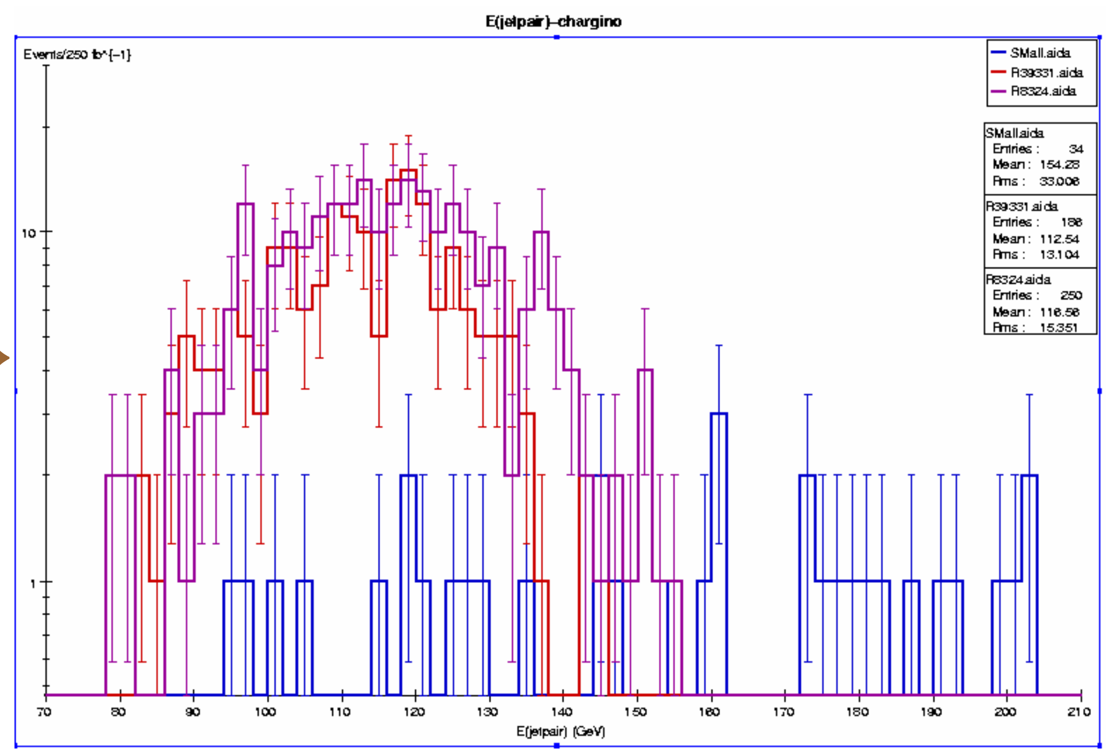
Charginos→4j Analysis



← Off-shell analysis

...very large backgrounds in this example…forget it !

On-shell W→jj case →



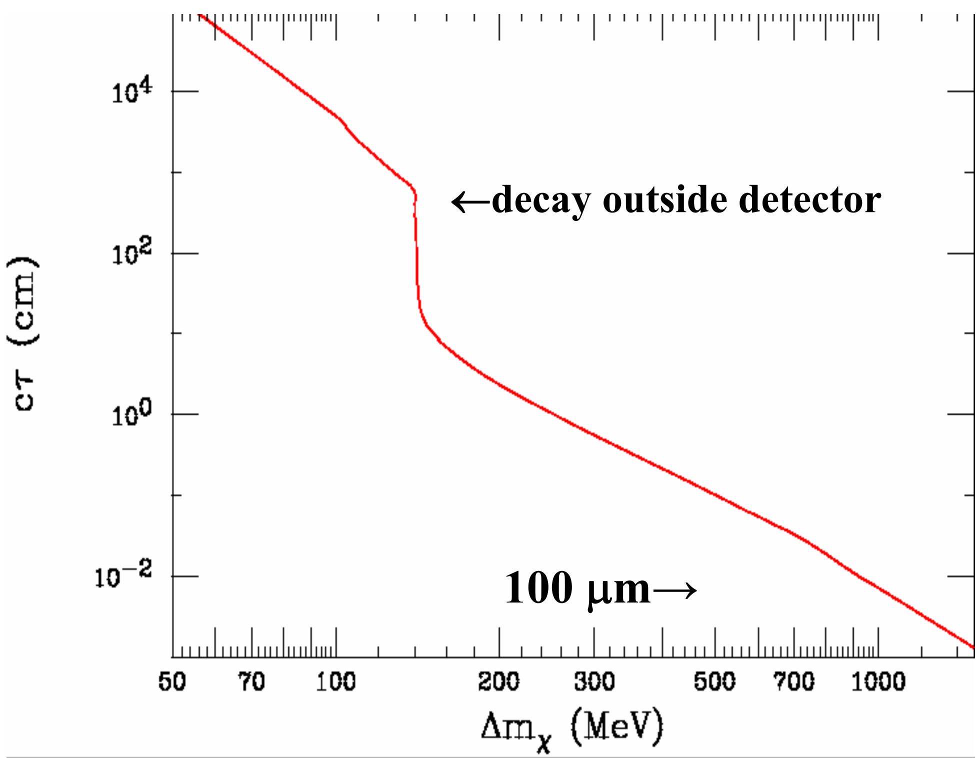
Reasonable model distinction

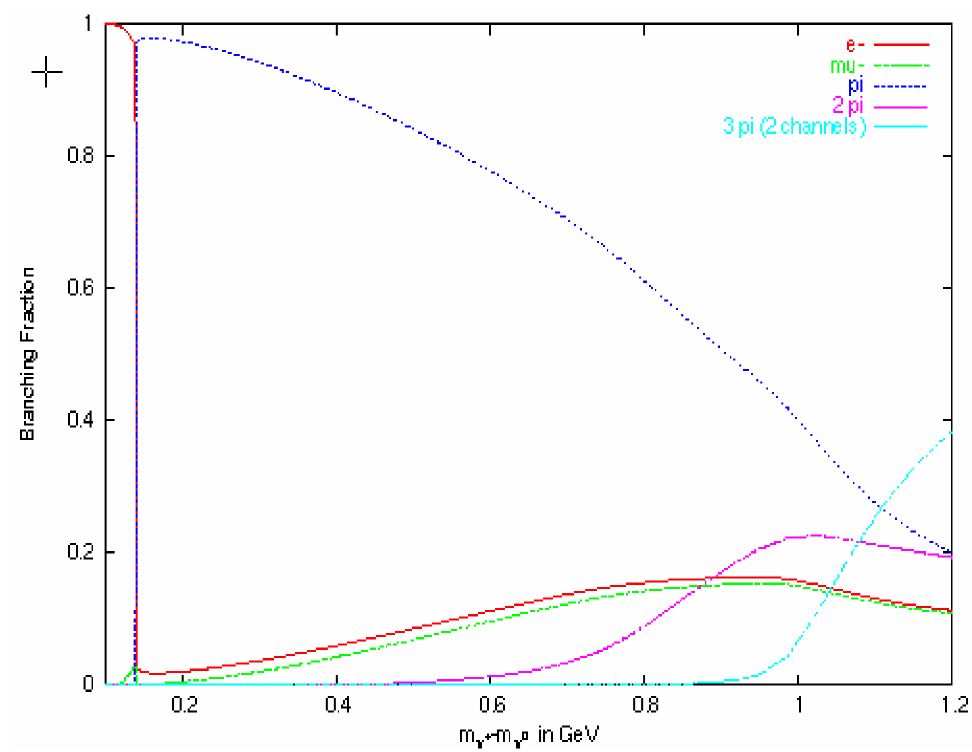
...good S/B !

Chargino Analyses: Close Mass Case ($\Delta m < 1$ GeV)

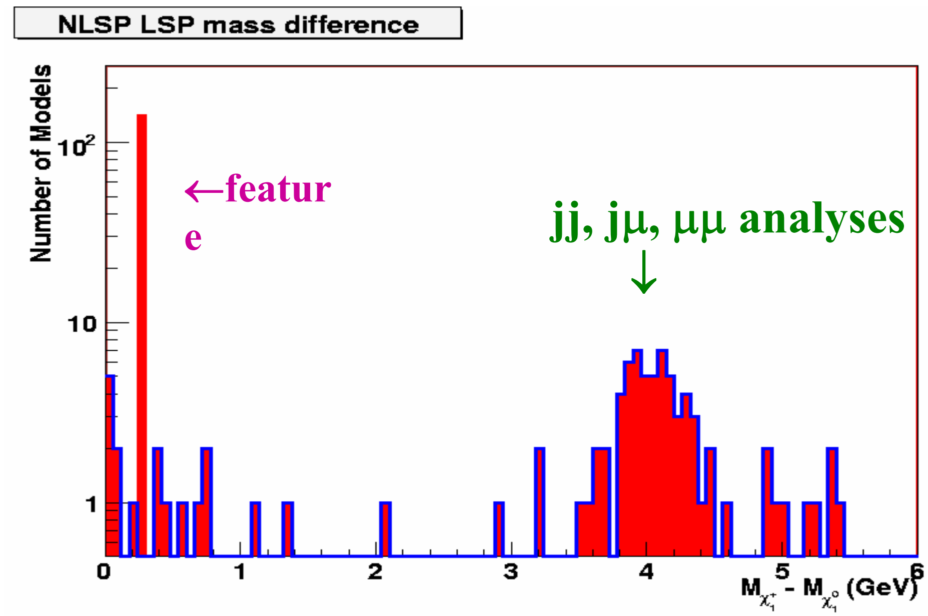
(1) $m_\pi < \Delta m < 1$ GeV : Then $\chi^+_1 \rightarrow \chi^0_1$ + soft hadron(s)...so we use a **γ tag…** we need the polarized $e^+e^- \rightarrow \chi^+_1 \chi^-_1 + \gamma$ matrix element & we use **CompHEP** for this.

(2) For this mass range one can also search for long-lived particles decaying, e.g., inside the vertex detector (but this is a separate analysis track we have not yet followed). Such an approach may also work to somewhat larger Δm values.





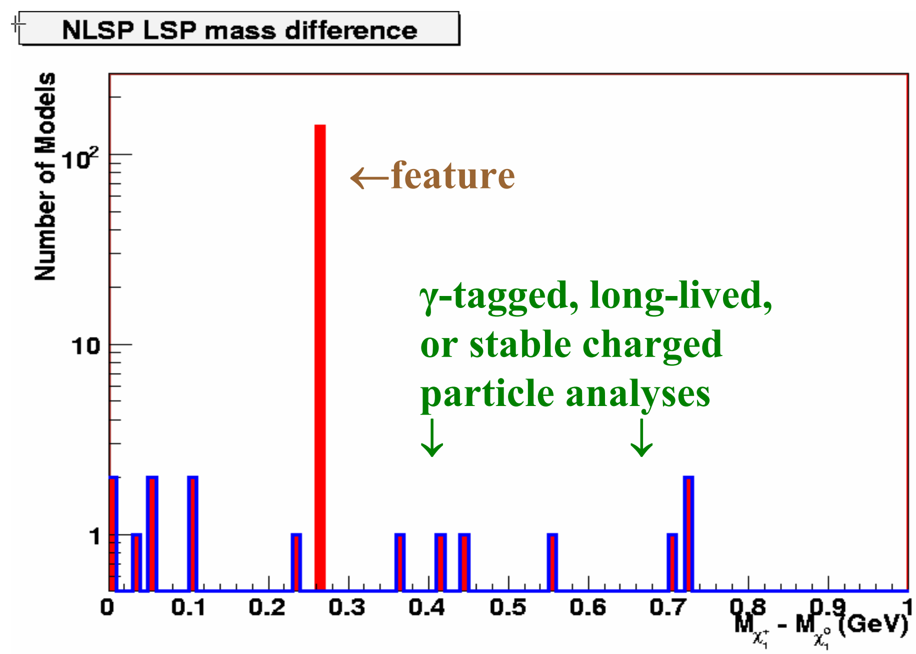
Chargino-LSP small Δm region



Many models produce off-shell W’s with masses of a few GeV leading to large backgrounds from $\gamma\gamma \rightarrow \tau^+\tau^-$.

To remove these in the dijet case we require dijet masses ≥ 2 GeV.

In the case of the photon tag analysis, one needs to look for a peak in the hadronic mass recoiling against the isolated, high p_T photon



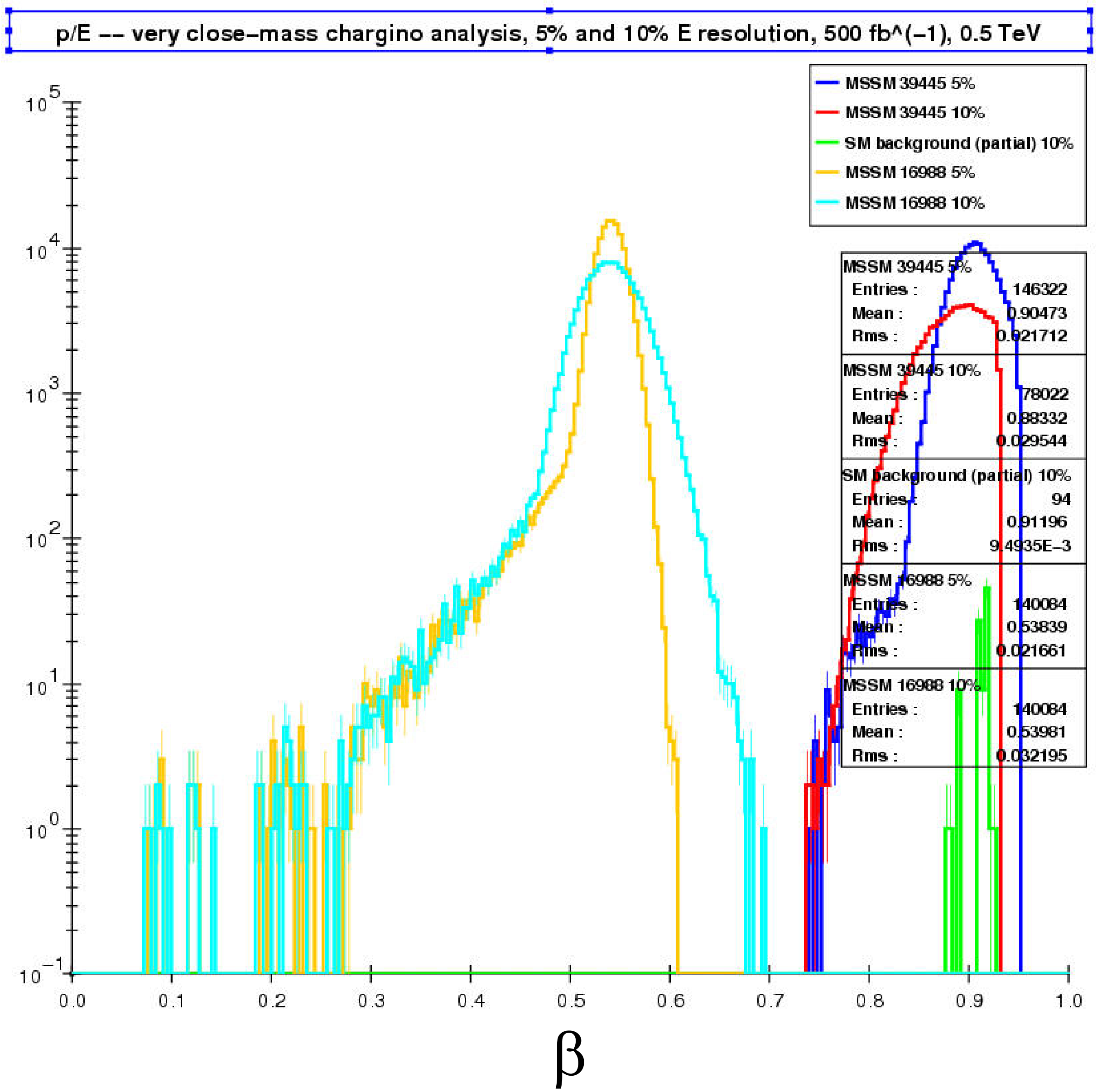
Chargino Analyses: Close Mass Case ($\Delta m < 100$ MeV)

In this case the chargino, while quite heavy, has a very long lifetime, going many meters (some **~1 AU!**) and then decaying only via the mode $\chi_1^+ \rightarrow \chi_1^0 e^+ \nu$. Thus we perform a **stable** charged particle search…

1. 2 massive, charged tracks only
2. no tracks within $<$ 100 mrad
3. $\frac{p}{E} < 0.93$ for both **(since they were not seen at LEPII)**
4. $\sum_{i=1}^{2} E_i > 0.75\sqrt{s}$
   These last two cuts kill any potential muon background. There should not be any background left (aside from detector fakes).

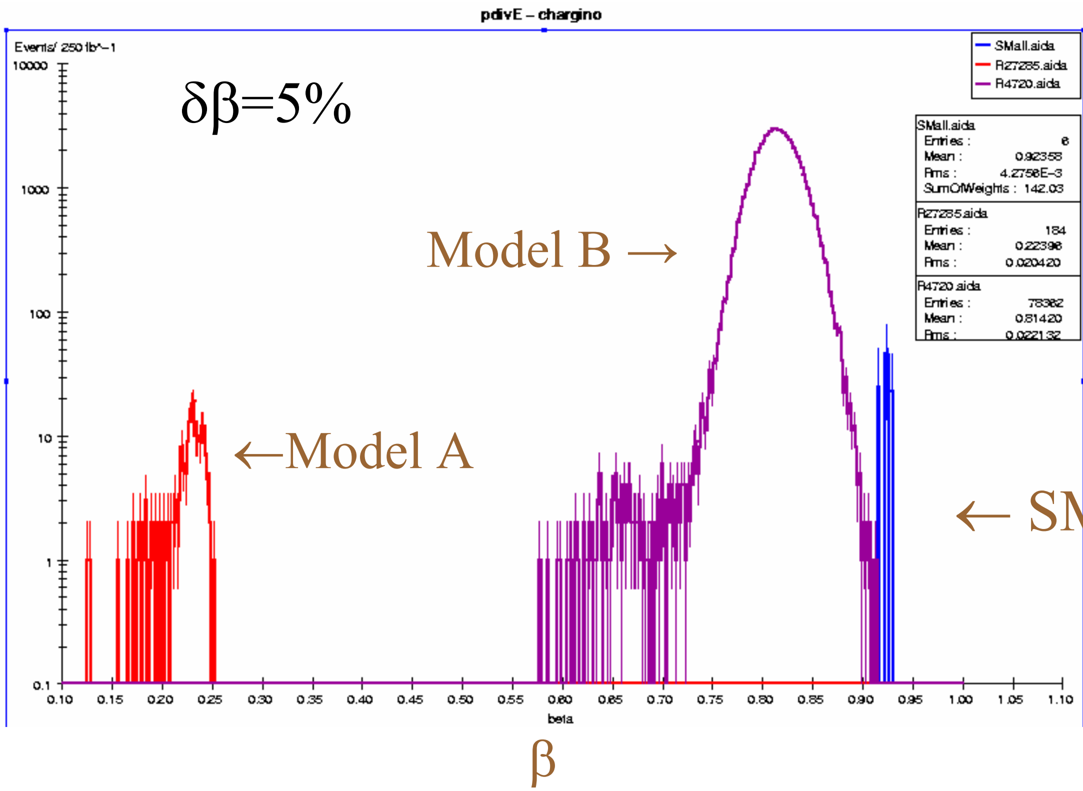
$\beta = p/E$: p is determined by track curvature in the B field while E is determined by dE/dx or TOF…we assume a resolution of $\delta\beta = 5(10)\%$ in our analysis consistent with ILC detector models

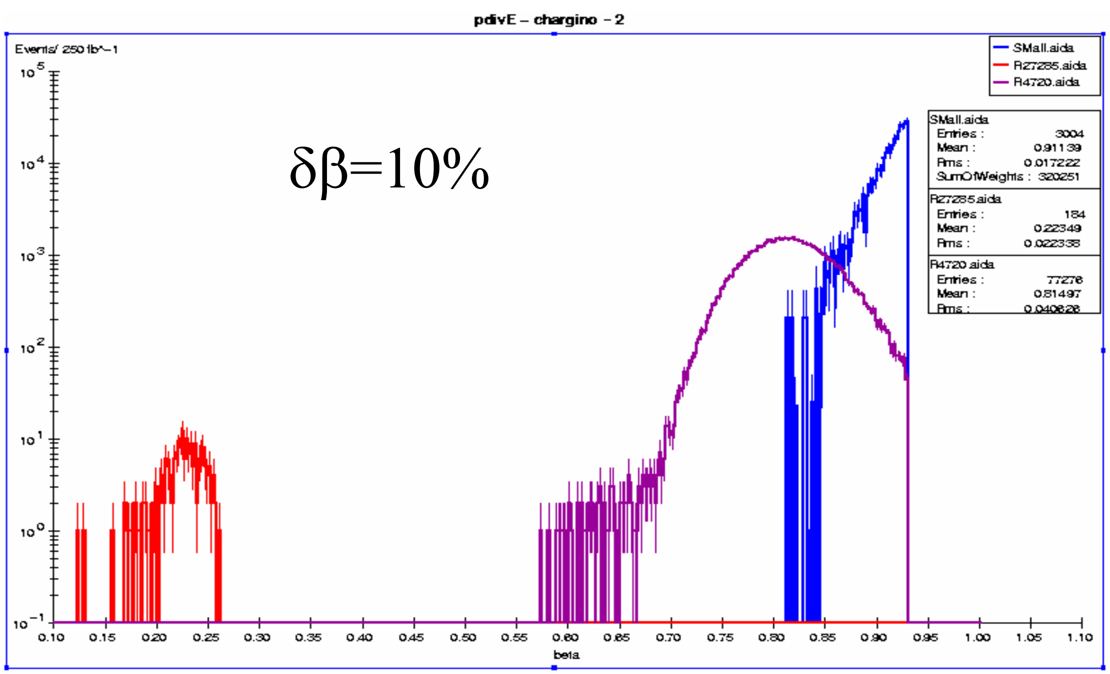
Background & Signal for Close Mass Case #2



Looks pretty good!

Stable Particle Searches

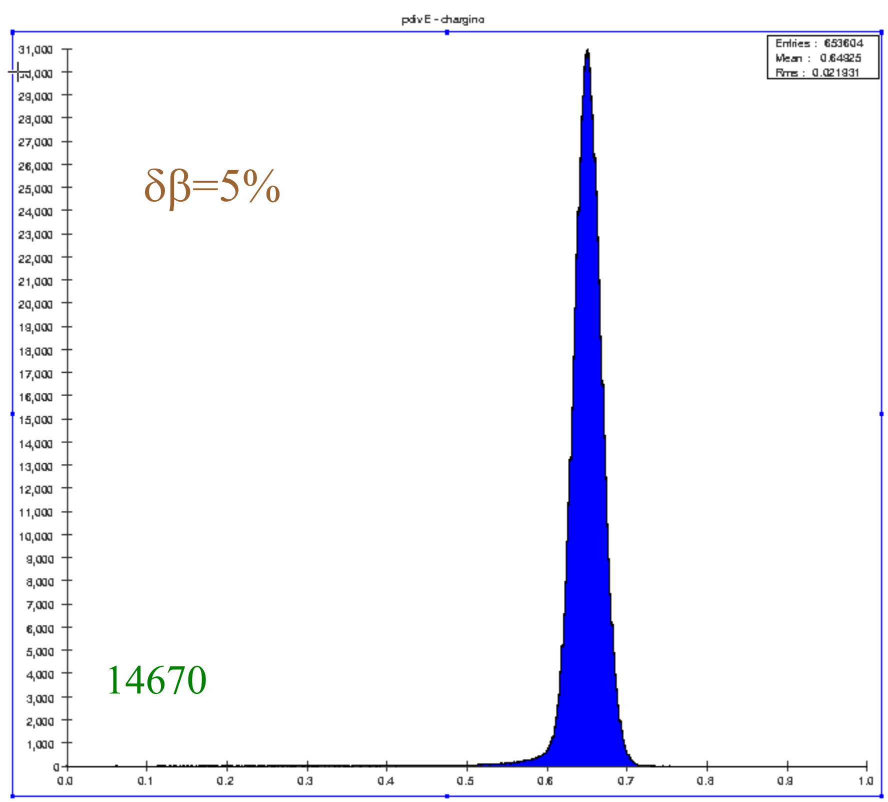


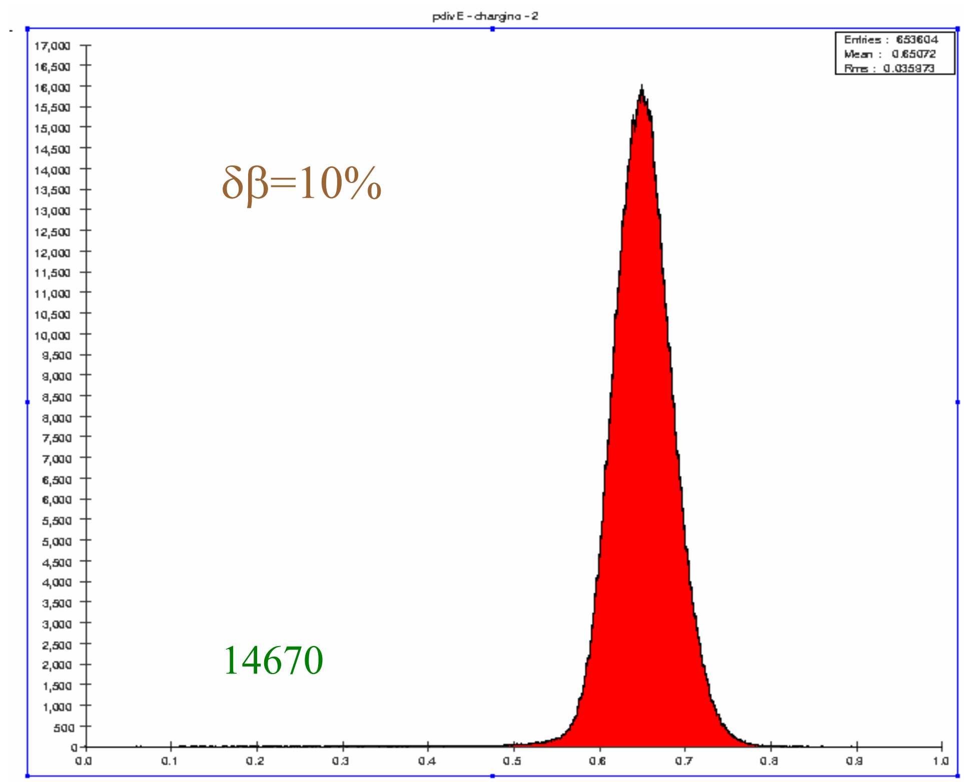


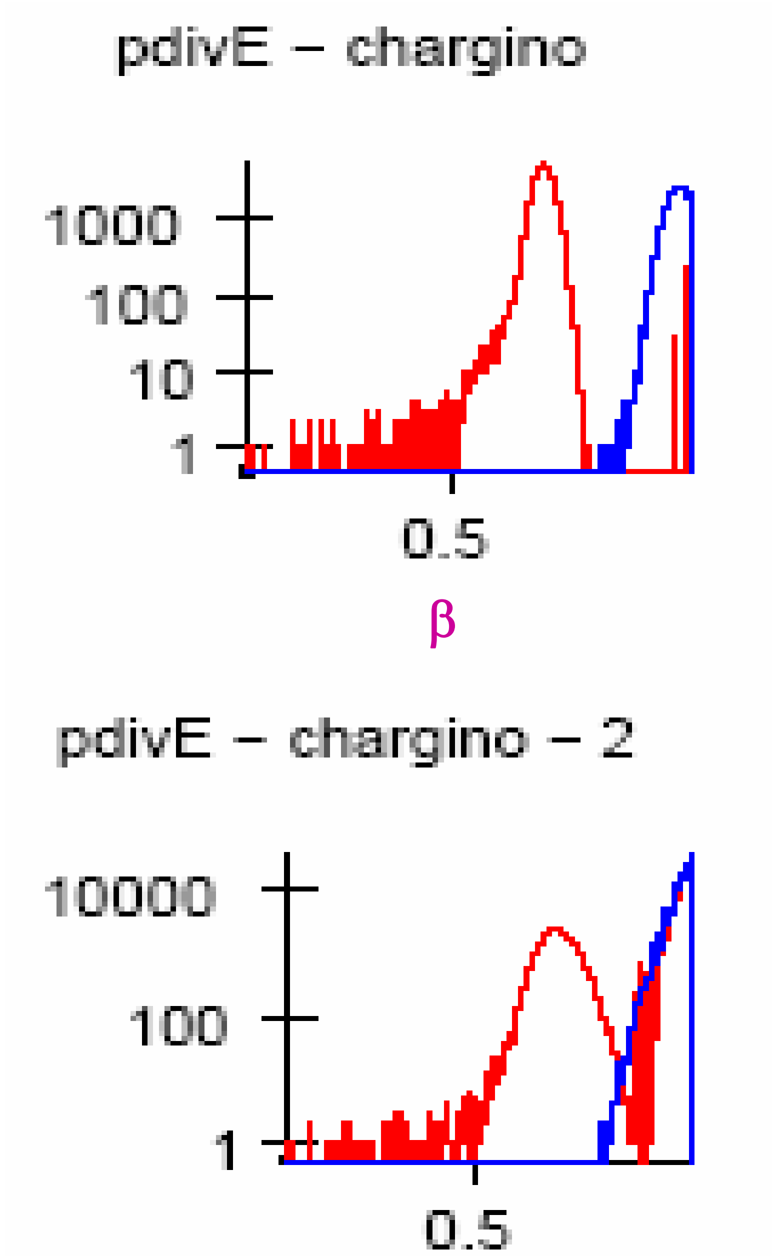
These two models are clearly different for either velocity resolution

Long-lived Chargino Analysis (cont.)

At least for all the cases we have examined, model distinction via the stable charged particle analysis appears to be mostly straightforward, even with the poorer resolution, except when the chargino masses are nearly identical.

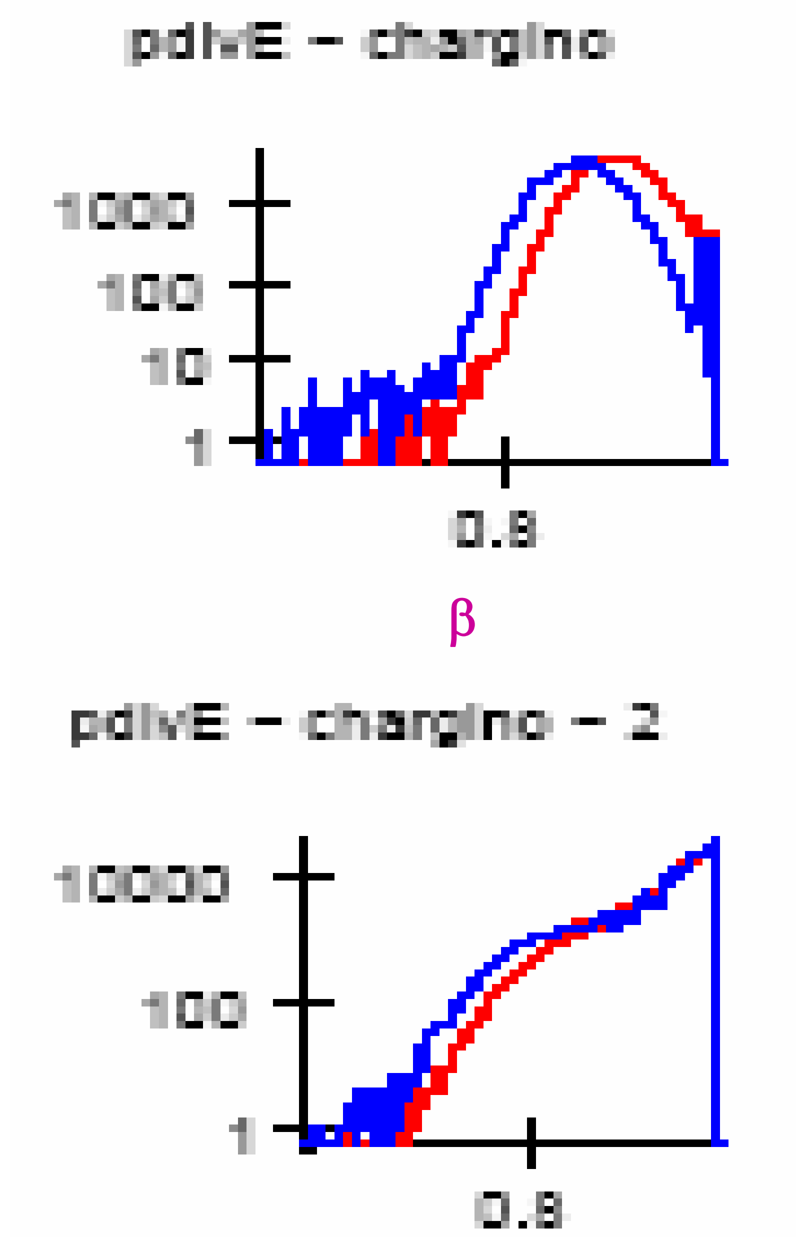






Right 39440 (red) 39445 (blue)

easy



5%

10%

Left 13348 (red) 17431 (blue)

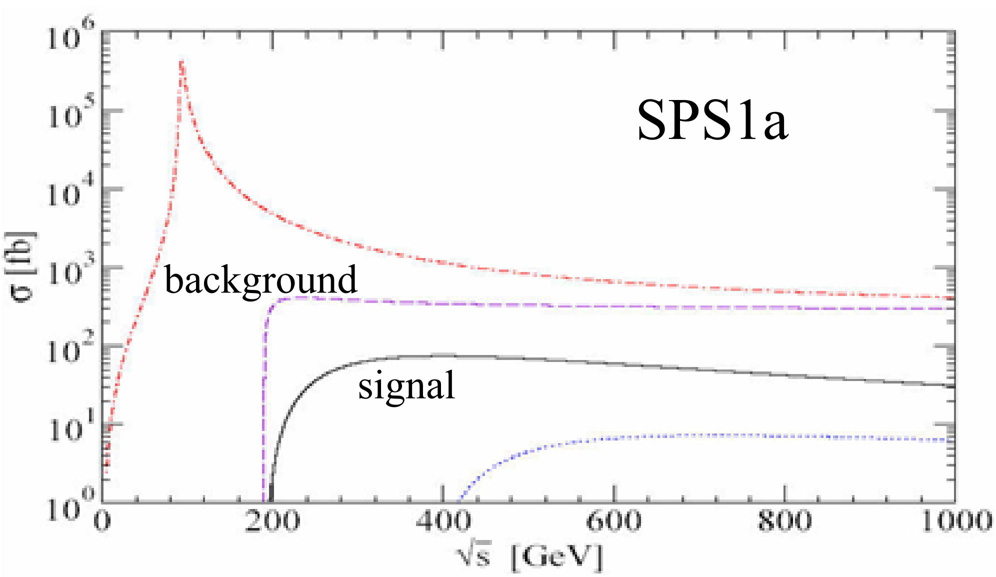
A bit harder…but doable

Radiative Neutralino Production

$e^+e^- \to \chi_1^0\chi_1^0$ is *invisible* so we employ the **γ-tag** again, i.e $e^+e^- \to \chi_1^0\chi_1^0 + \gamma$ which we calculate using **CompHEP**…..

ANALYSIS CUTS AT 500 GeV :

1. One γ and nothing else visible in the event
2. $E_T^\gamma = E^\gamma \sin\theta^\gamma > 0.03\sqrt{s}$, θ^γ is γ angle w/ beam axis
3. $\sin\theta^\gamma > 0.1$
4. $E^\gamma < 160.0$ GeV (removes radiative return to the Z)
5. Use CompHEP to generate hard matrix element



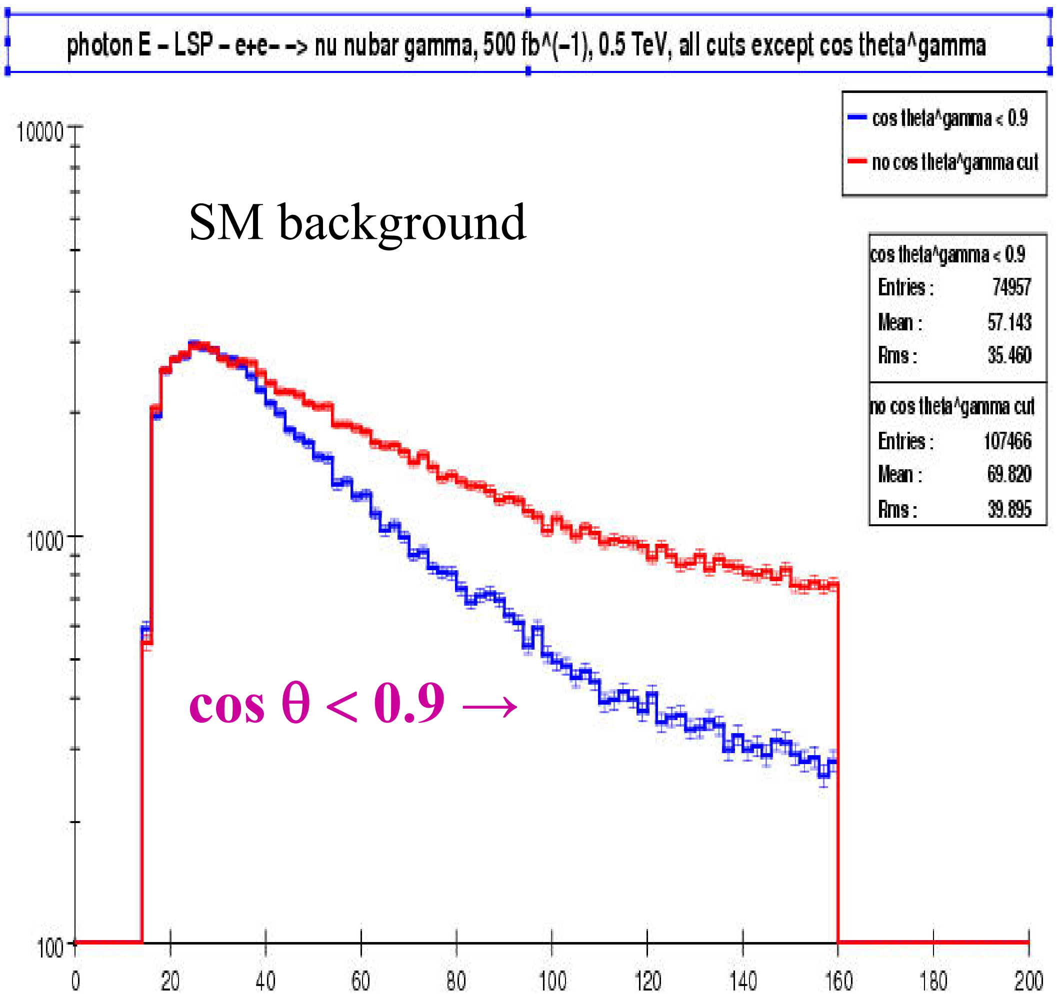
The signal is big for **SPS1a** but this is ***not so*** over the model space we explore…SM backgrounds from $e^+e^- \to \nu\nu\gamma(\gamma)$ are also very large and difficult to kill with standardized cuts

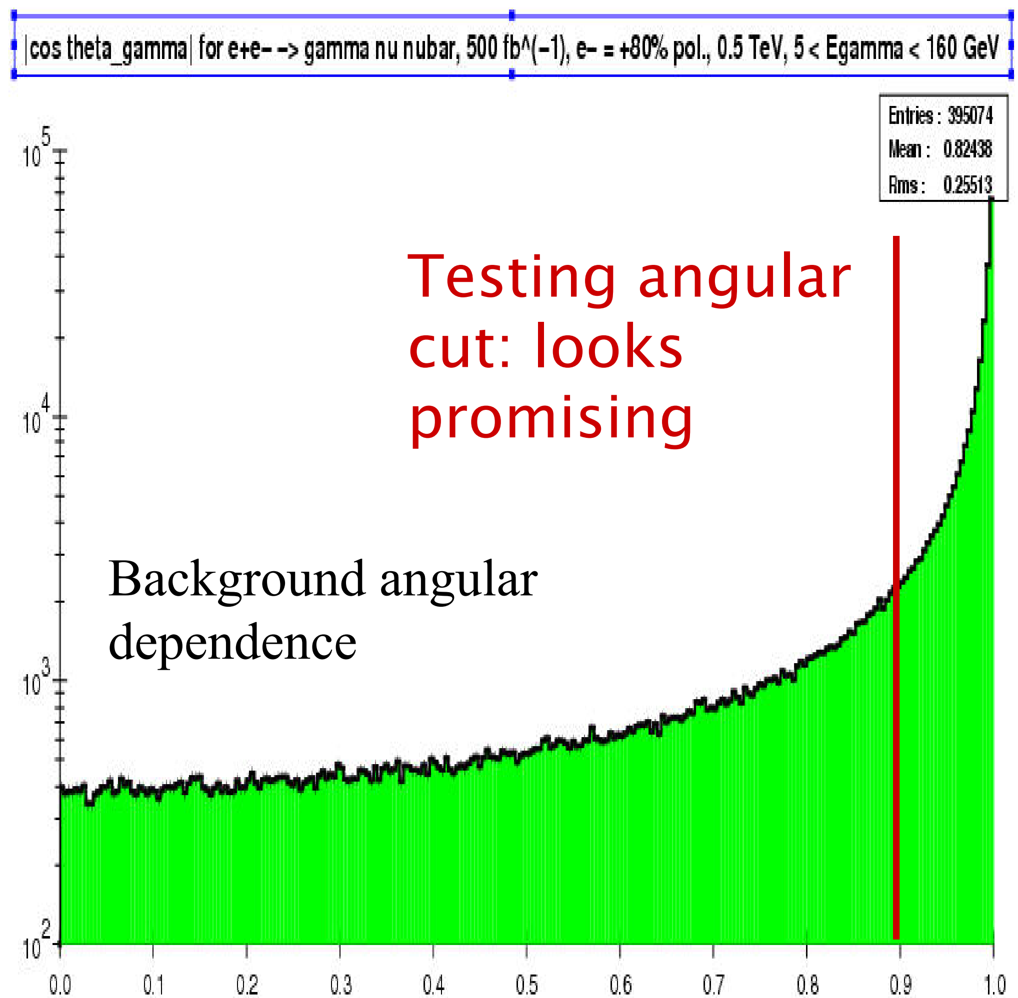
Dreiner et al., hep-ph/0610020

Background is looking difficult…

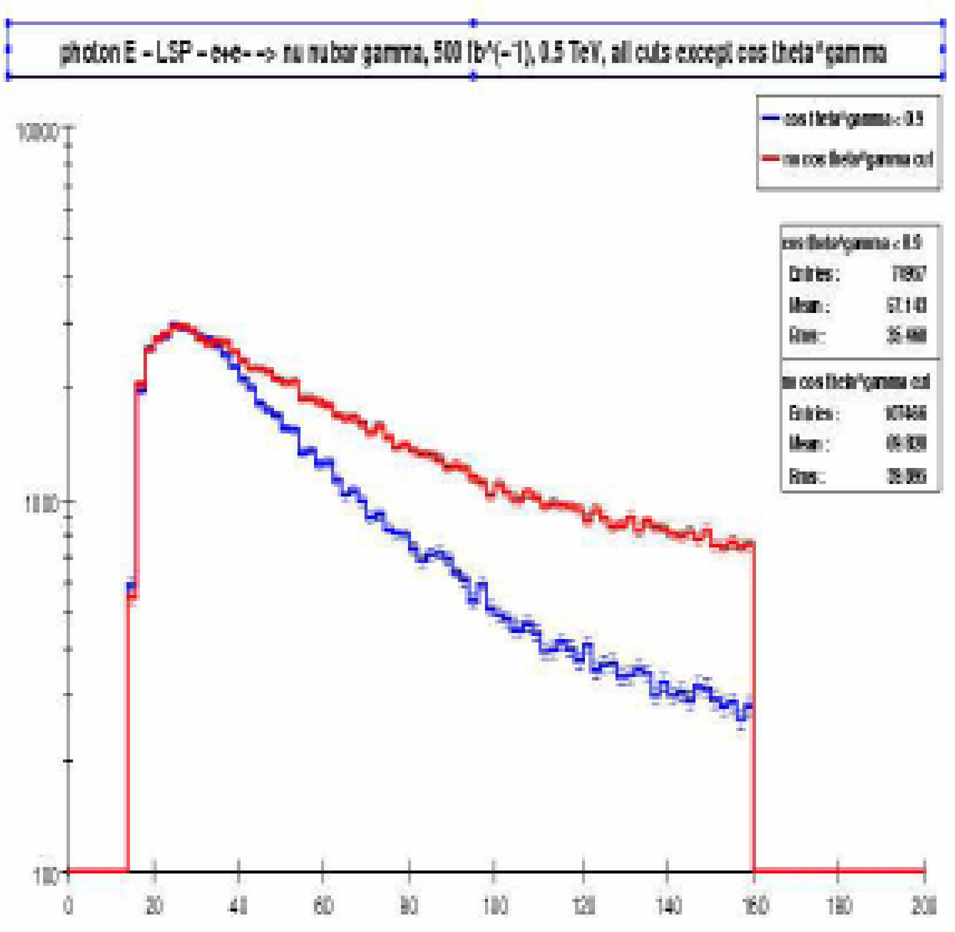
$e^+e^- \rightarrow \nu\bar{\nu}\gamma$

The γ is strongly peaked forward in the SM background but this is also true in many of the signal models depending on the MSSM spectrum details.

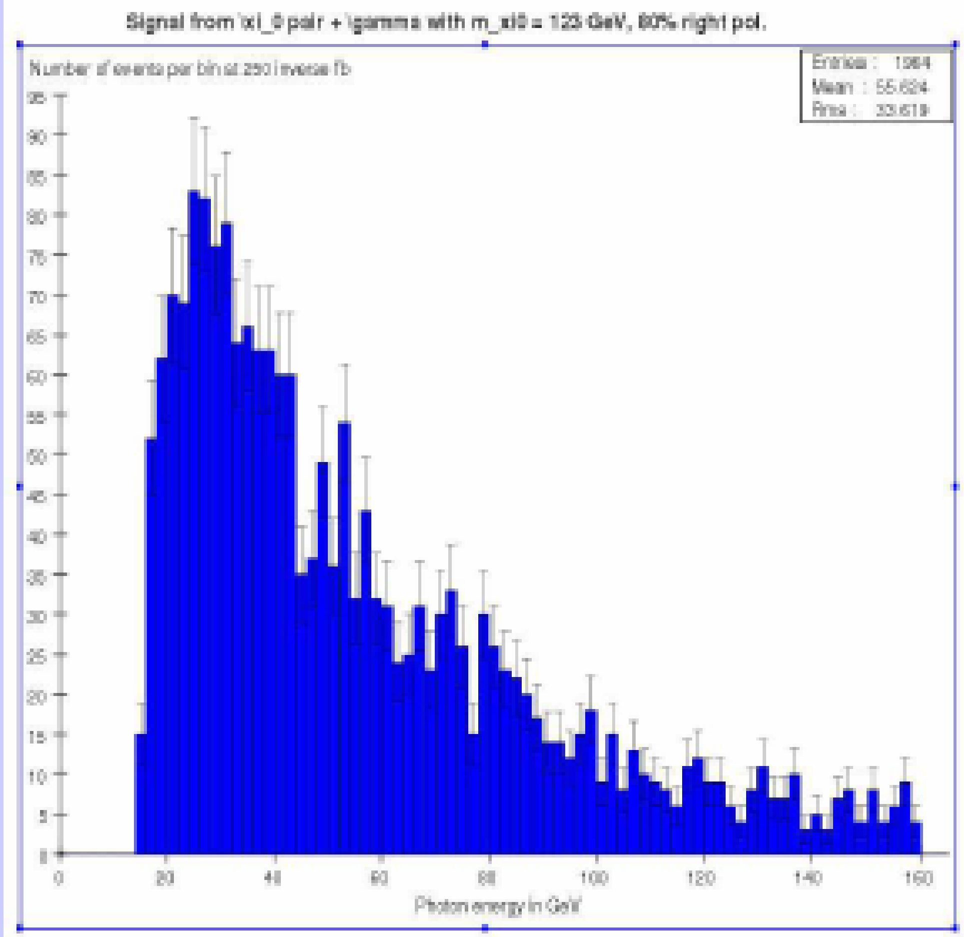




Background



Model 8365



In this sample case, S/B ≈1/20 even after tight angle cuts..many models produce rather small cross sections … life is very difficult in this channel. It will be difficult even to observe this signal for most models.

The largest contribution to the $e^+e^- \rightarrow \nu\nu\gamma$ background is from graphs with a W-exchange coupling to a LH e^- , but this shows a strong polarization dependence, $\sigma^B(e^-_L)$ ~50 $\sigma^B(e^-_R)$….

The best way to remove this background is with RH beam polarization and having both beams polarized is even ***better*** . For the signal, the models mostly cluster with either ***(i)*** **$\sigma^S_L \sim \sigma^S_R$** or *(ii)* **$\sigma^S_R >> \sigma^S_L$** This provides **another** good reason to have positron polarization . (hep-ph/0507011)

What does beam polarization give us compared to unpolarized beams?

	increase in signal (i)	increase in signal (ii)	decrease in background	R=S/B gain (i)	R=S/B gain (ii)
$P^- = 0.80$, $P^+ = 0.00$	1.0	1.8	0.2	5.0	8.0
$P^- = 0.80$, $P^+ = -0.30$	1.24	2.34	0.14	8.86	16.71
$P^- = 0.80$, $P^+ = -0.45$	1.36	2.61	0.11	12.36	23.73
$P^- = 0.80$, $P^+ = -0.60$	1.48	2.88	0.08	18.5	36.0

So what do we do when we have all the `data' ?

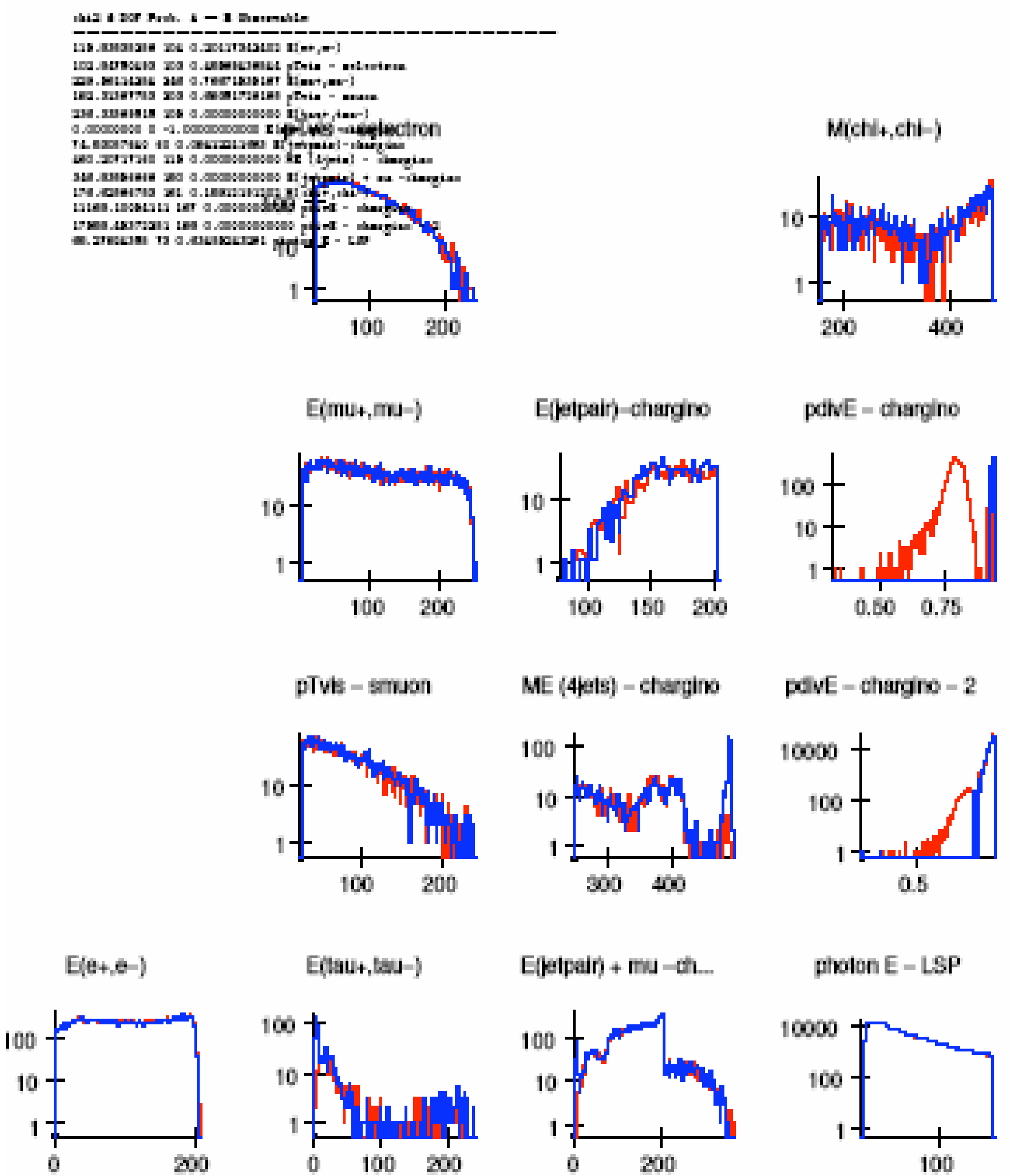


Figure 1: Left 207 (red) 3848 (blue)

(i) We combine the results for each analysis of Model X and Model Y with those obtained from two different full background samples, B1 & B2

(ii) For each e^- polarization we perform a statistical comparison of the various distributions for (X+B1) vs (Y+B2)

(iii) We then ask if the 2 models are distinguishable at a given level of significance , e.g, 5σ

We're just starting these comparisons…

Outlook and Summary

- First large scale `scan' of MSSM parameter space at ILC `not SPS1a'…***Results presented here are preliminary!***
- Full SM backgrounds, ISR, beamstrahlung w/ beam energy spread by GuineaPig, plus lcsim fast detector simulation of SiD
- Finish model comparisons, tune analyses, optimize cuts, etc
- ***Expect*** ILC will be able to remove most degeneracies, in principle, for visible kinematically accessible states..but there are difficult parameter space regions we need to study in more detail
- → do the 1 TeV case, study positron polarization, detector variations, low angle tracking, …..
- Limitations: CPU time, data storage and retrieval issues