Physics Requirements for Muon Detection at ILC

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Introduction

✧ SUSY decay processes put significant challenges on lepton response;

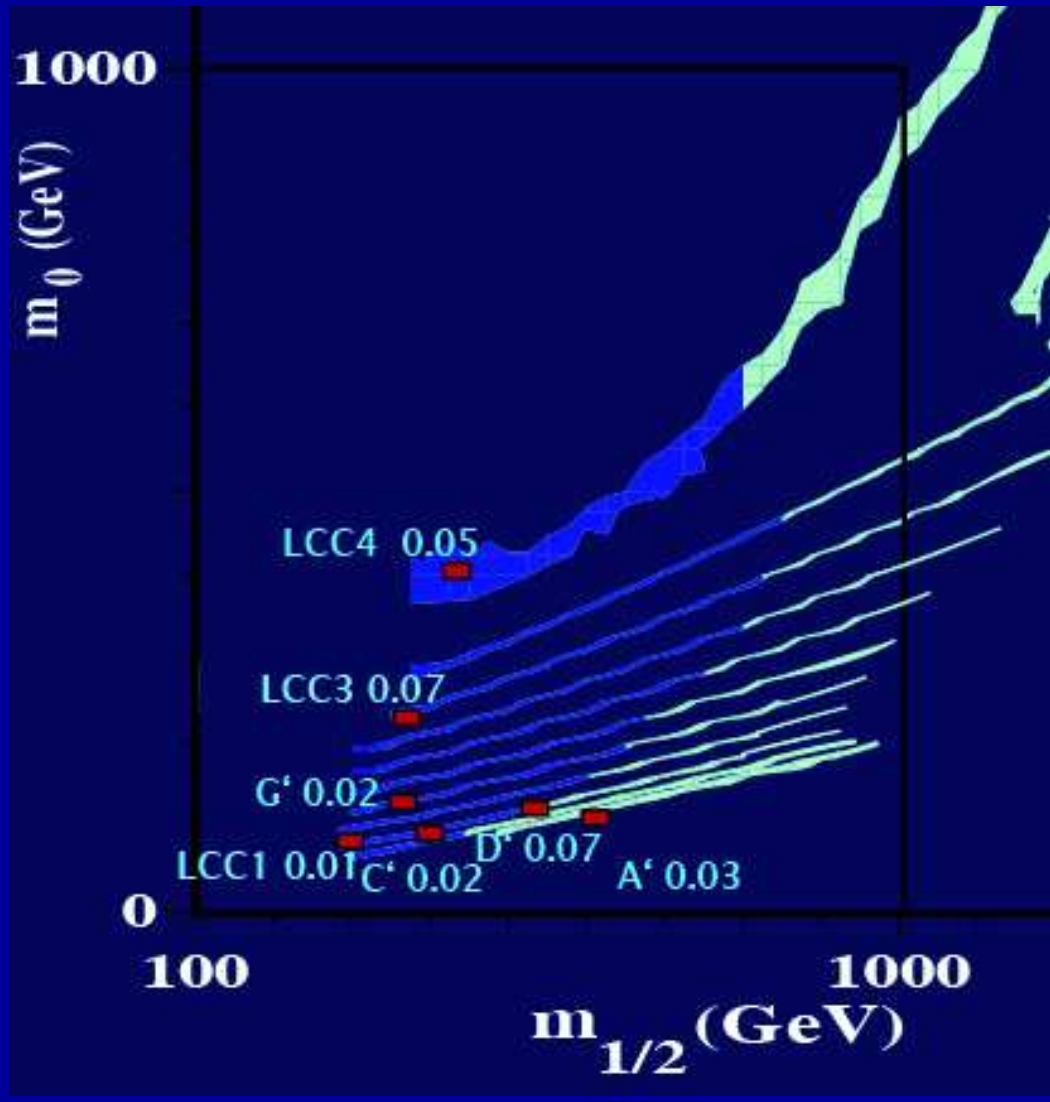
✧ Topologies vary from two low-momentum leptons in $e^+e^- \to \tilde{\ell}\tilde{\ell}$ to eight jets $e^+e^- \to H^+H^- \to tbtb$;

✧ Cosmology-motivated portions of (c)MSSM parameter space point to regions with characteristics mass relations (M_A/M_χ, $M_{\tilde{\tau}} - M_\chi$, ...) which need to be studied in great details and high accuracy;

✧ Review here some of these signatures in relation to muon-id response:

1. Low-Momentum Leptons
2. Lepton Id.
3. Lepton Momentum Resolution
4. Leptons in Jets

✧ based on results by Barklow, Dutta, Kamon, Bambade, M.B. *et al.*

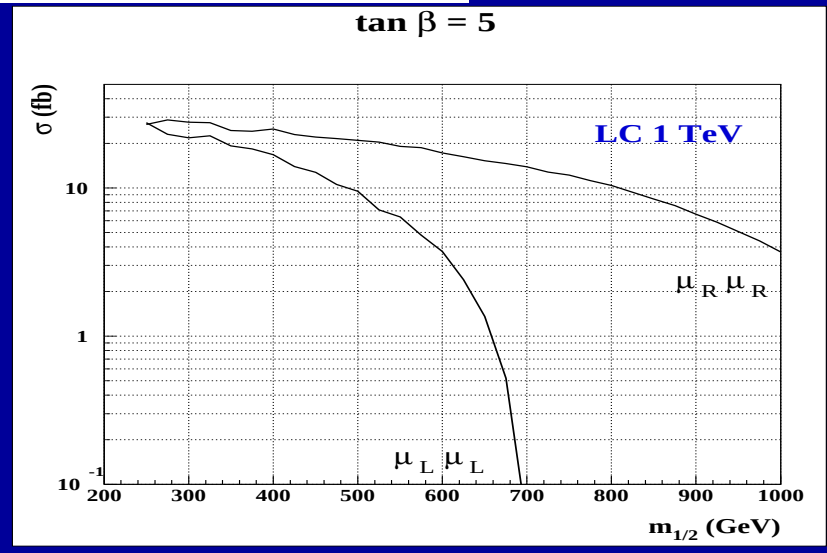

1000
m_0 (GeV)
LCC4 0.05
LCC3 0.07
G' 0.02
LCC1 0.01
C' 0.02
D' 0.07
A' 0.03
0
100
1000
$m_{1/2}$ (GeV)

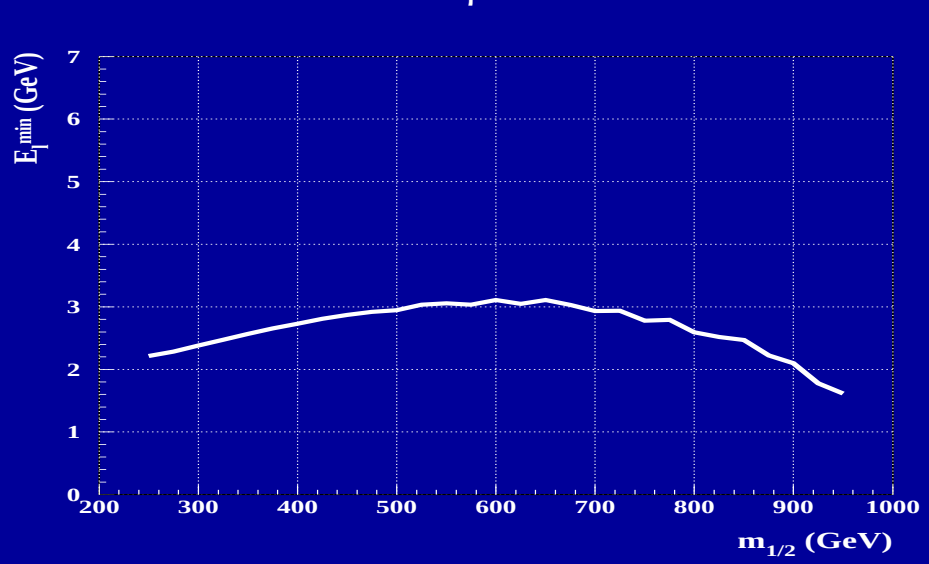
Slepton Signatures at low p_{lepton}

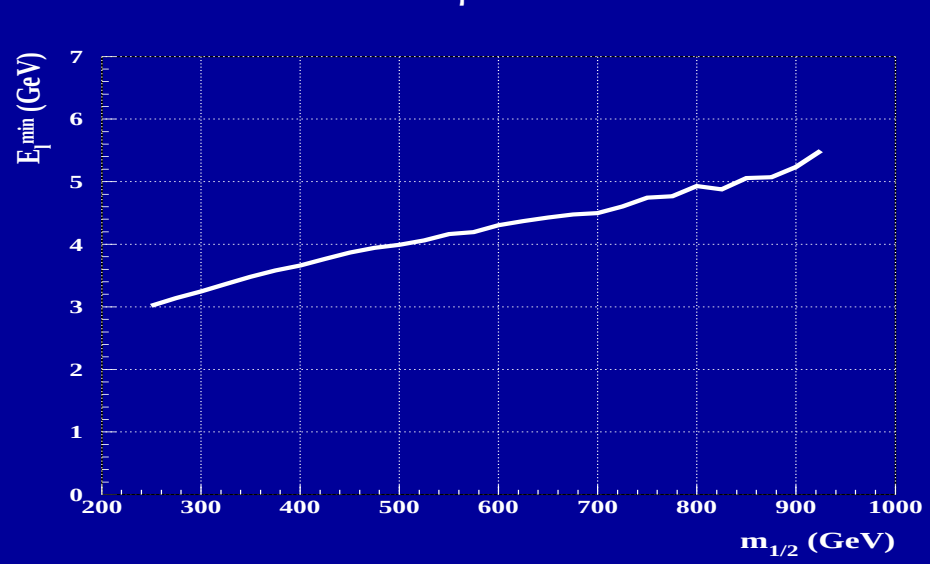
✧ Highest reach in $m_{1/2}$ from $e^+e^- \to \tilde{\ell}_R^+\tilde{\ell}_R^-$: LC at $\sqrt{s}$=1 TeV covers upper limit in $m_{1/2}$ for $\tan\beta =$ 5 - 10 with $\sigma(e^+e^- \to \tilde{\ell}^+\tilde{\ell}^-) = \mathcal{O}$(1-10 fb);

✧ along WMAP line $\tilde{\ell}_R$ becomes nearly degenerate with χ_1^0: tuning E_{beam} for sizeable σ softens E_ℓ^{min}:

$$E_\ell^{min} = \frac{1}{2} M_{\tilde{\ell}} \left(1 - \frac{M_{\tilde{\chi}_1^0}^2}{M_{\tilde{\ell}}^2}\right) \gamma \left(1 - \sqrt{1 - \frac{M_\ell^2}{E_{beam}^2}}\right);$$







Slepton Signatures in the post-WMAP cMSSM Parameter Space

✧ Lepton id. critical at lower endpoint due to:

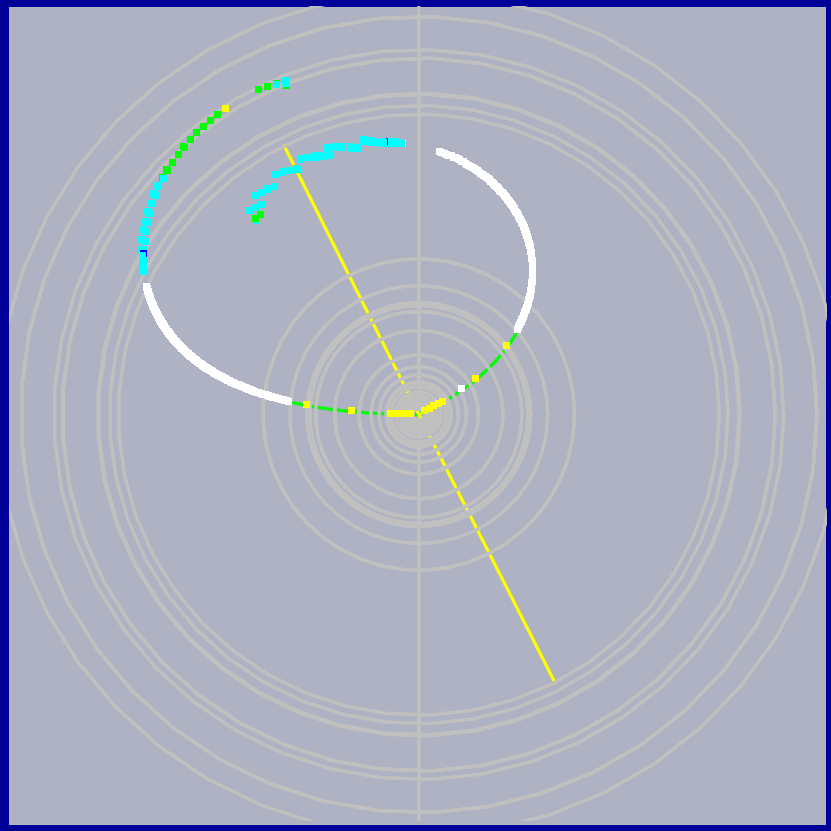
1. Intrinsic Momentum Cut-off
2. $\gamma\gamma \to \text{hadrons}$ Background

✧ Momentum cut-off p_t^{min} defined by radius R_{det} of ECal, HCal and Muon Chambers and solenoidal field B:

$$p_t^{min}[\text{GeV}] = \frac{R_{det}[\text{m}]}{0.3B[\text{Tesla}]}$$

✧ $\gamma\gamma \to \text{hadrons}$ bkg becomes relevant if only one lepton can be tagged

Wired Display of $e^+e^- \to \tilde{\mu}_R^+\tilde{\mu}_R^-$ at 1 TeV at lower endpoint
$\tan\beta = 5,\ m_{1/2} = 600,\ m_0 = 118$

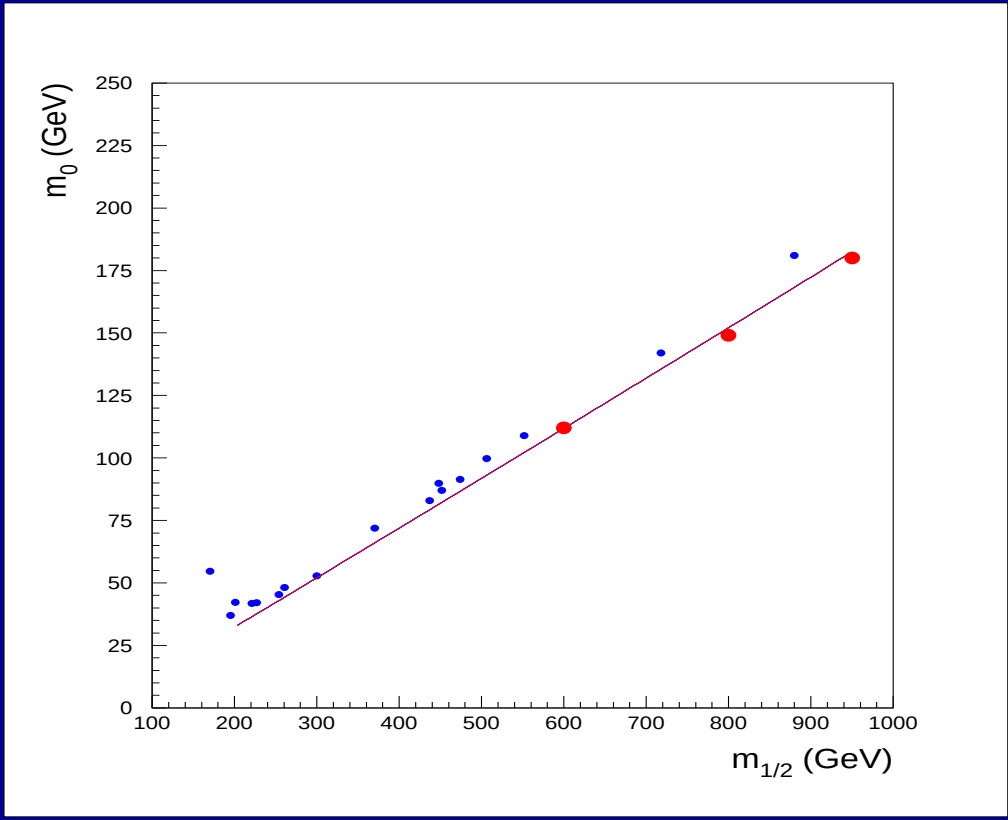


Benchmarking the co-Annihilation Tail

- Study co-annihilation tail with Micromegas and SSARD;
- define 3 study points at $\tan\beta = 5$ to track the slepton phenomenology at 1 TeV LC;

MASSES AT STUDY POINTS

$m_{1/2} = 600$	$m_0 = 114$
$M_{\tilde{\ell}_L} =$	428 GeV
$M_{\tilde{\ell}_R} =$	255 GeV
$M_{\chi_1^0} =$	243 GeV
$m_{1/2} = 800$	$m_0 = 149$
$M_{\tilde{\ell}_L} =$	564 GeV
$M_{\tilde{\ell}_R} =$	335 GeV
$M_{\chi_1^0} =$	329 GeV
$m_{1/2} = 950$	$m_0 = 182$
$M_{\tilde{\ell}_L} =$	668 GeV
$M_{\tilde{\ell}_R} =$	397 GeV
$M_{\chi_1^0} =$	394 GeV



Lepton Identification

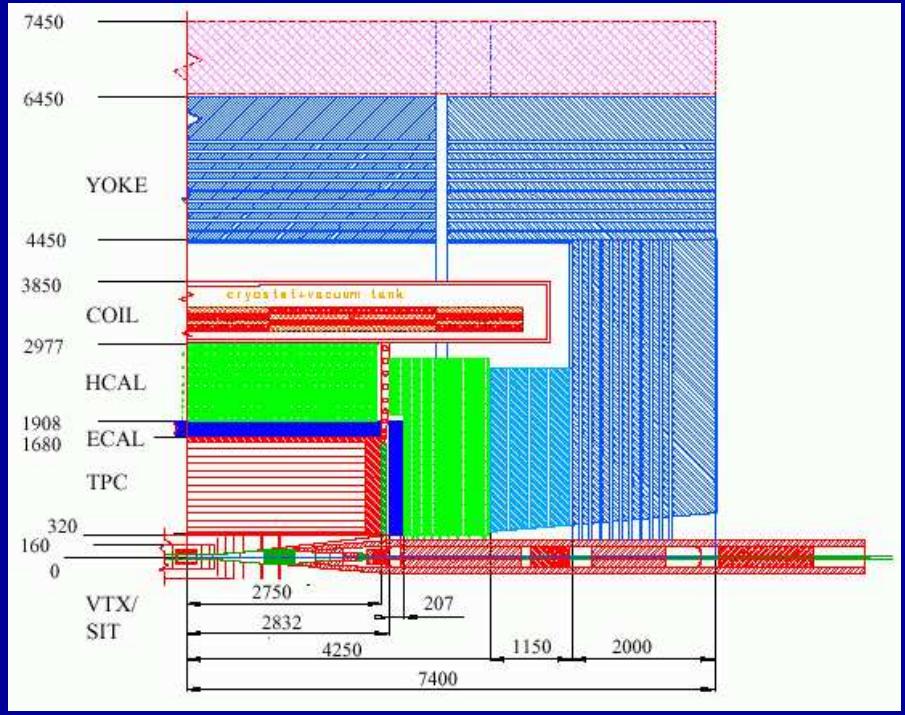
Muons

✧ Identify through hits in Muon Chambers and and Energy deposited in HCAL

Electrons

✧ Identify through shower in ECAL and dE/dx in Main Tracker

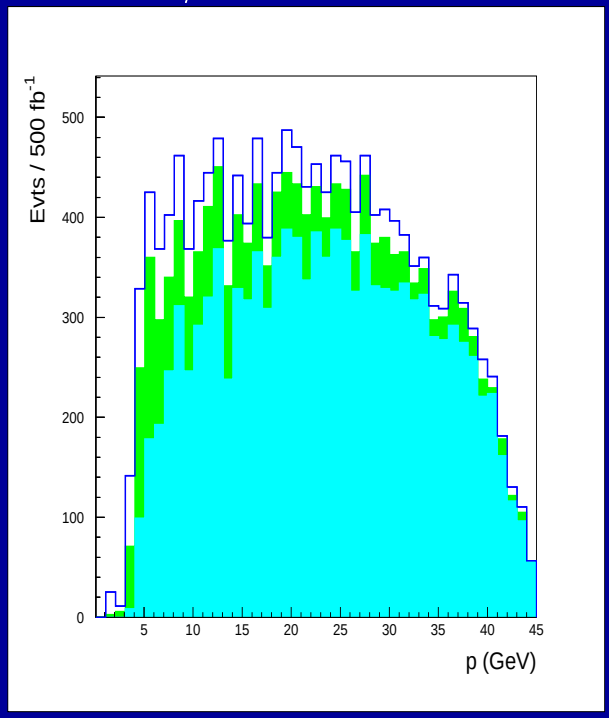
	Large Det
B [Tesla]	4
	p_t^{min} (GeV)
μ μCh	4.2
μ HCAL	2.0
e ECAL	1.5
e dE/dx	0.7



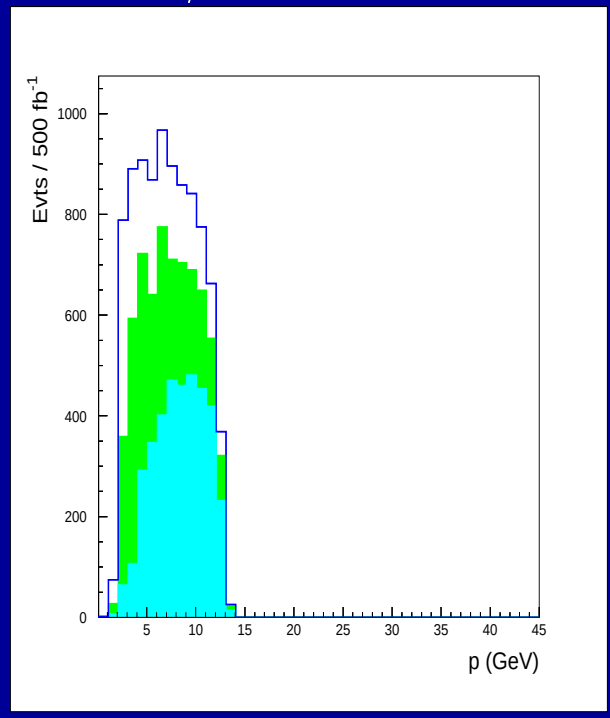
Lepton Momentum

Lepton Momentum Spectrum in $e^+e^- \to \tilde{\ell}_R^+\tilde{\ell}_R^- \to \ell^+\chi_1^0\ell^-\chi_1^0$ at 1 TeV for $\tan\beta = 5$ ($\ell = e, \mu$)

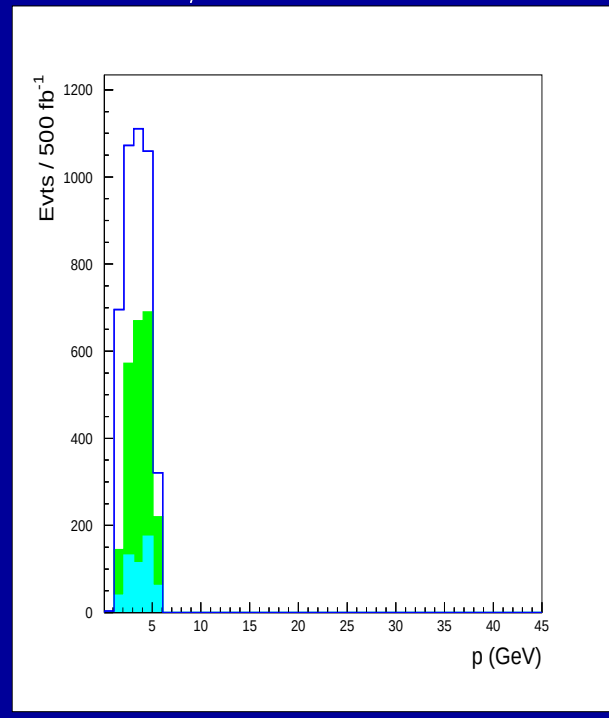
$m_{1/2} = 600$ GeV



$m_{1/2} = 800$ GeV



$m_{1/2} = 950$ GeV



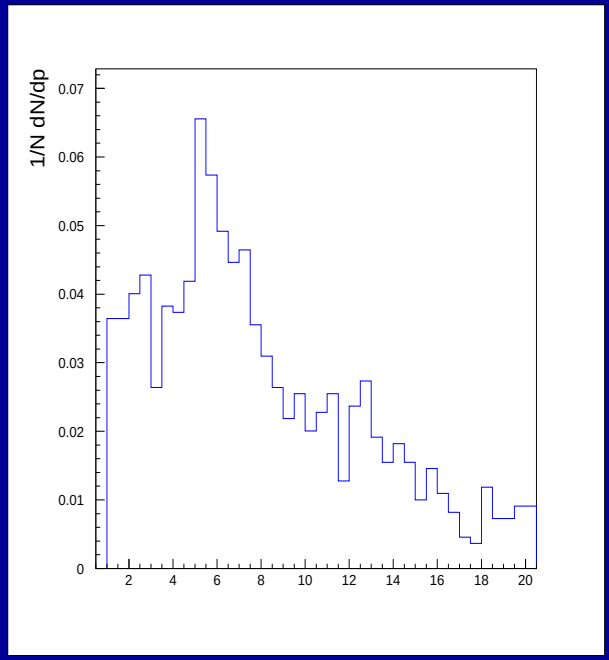
✧ Lepton Id momentum acceptance cuts into lower endpoint for $m_{1/2} > 500$ GeV.

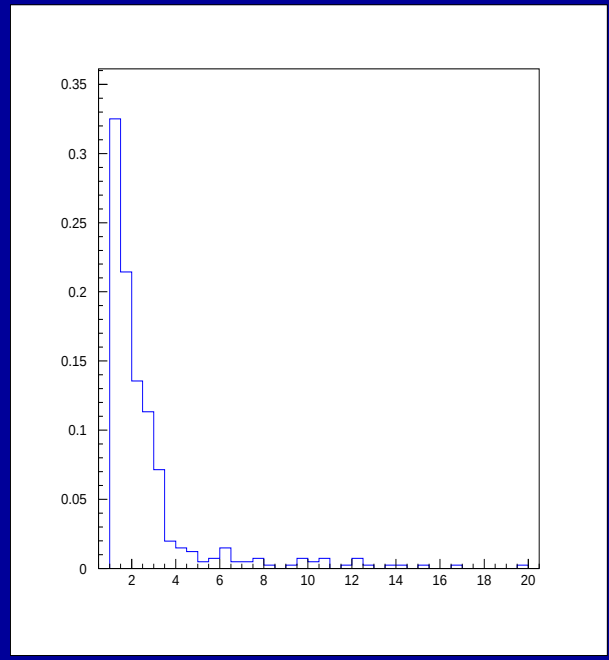
$e^+e^- \to \tilde{\tau}\tilde{\tau}$

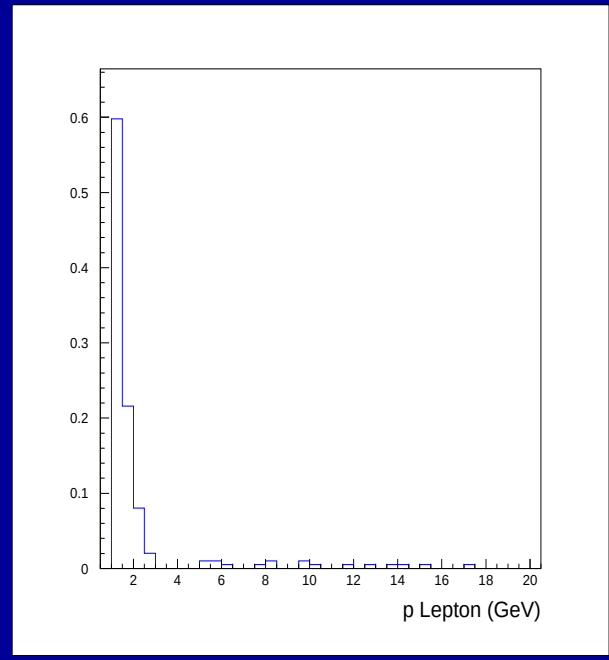
✧ Soft lepton spectrum also affects reconstruction of stau decays;

LEPTON MOMENTUM SPECTRUM IN
$e^+e^- \to \tilde{\tau}^+\tilde{\tau}^- \to \ell^+ X \chi_1^0 \ell^- X \chi_1^0$ AT 1 TeV FOR $\tan\beta = 5$

$m_{1/2} = 600$ GeV	$m_{1/2} = 800$ GeV	$m_{1/2} = 950$ GeV
$M_{\tilde{\tau}_1} = 253.6$ GeV	$M_{\tilde{\tau}_1} = 332.3$ GeV	$M_{\tilde{\tau}_1} = 396.8$ GeV
$M_{\tilde{\tau}_2} = 428.0$ GeV	$M_{\tilde{\tau}_2} = 563.7$ GeV	$M_{\tilde{\tau}_2} = 668.4$ GeV





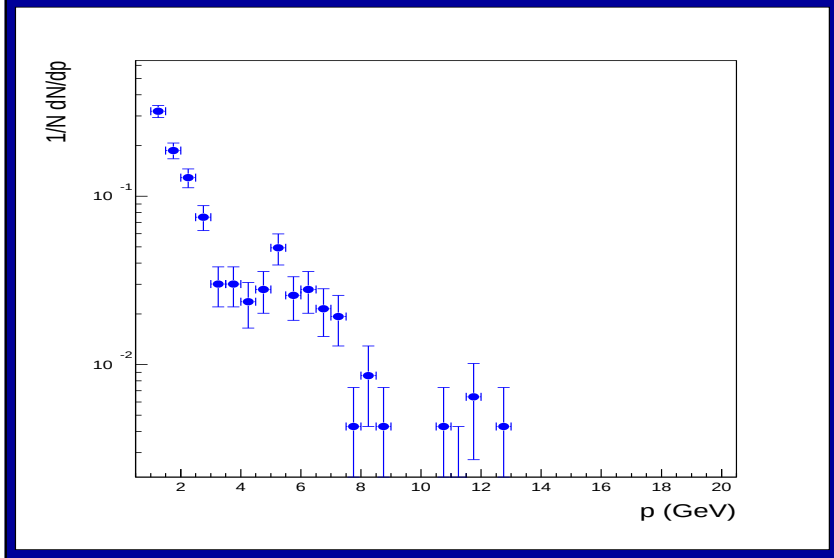


$\gamma\gamma \to$ hadrons **Background**

- Estimate rate from $\gamma\gamma \to$ hadrons background

	TESLA 0.8 TeV	NLC 1.0 TeV
$\mathcal{L}$ (fb BX^{-1})	2.7×10^{-9}	1.3×10^{-9}
$N_{\gamma\gamma}$ BX^{-1}	0.40	0.27
$N_{\gamma\gamma}$ 500 fb^{-1}	0.75×10^{11}	1.05×10^{11}

- Sample generated with `GuineaPig` + `Pythia` for TESLA at 800 GeV;
- Suppress $\gamma\gamma \to$ hadrons bkg using event shape and kinematical variables;
- Assume $\epsilon(\pi \to \ell) \simeq 0.10$ at low p (see M. Piccolo talk)



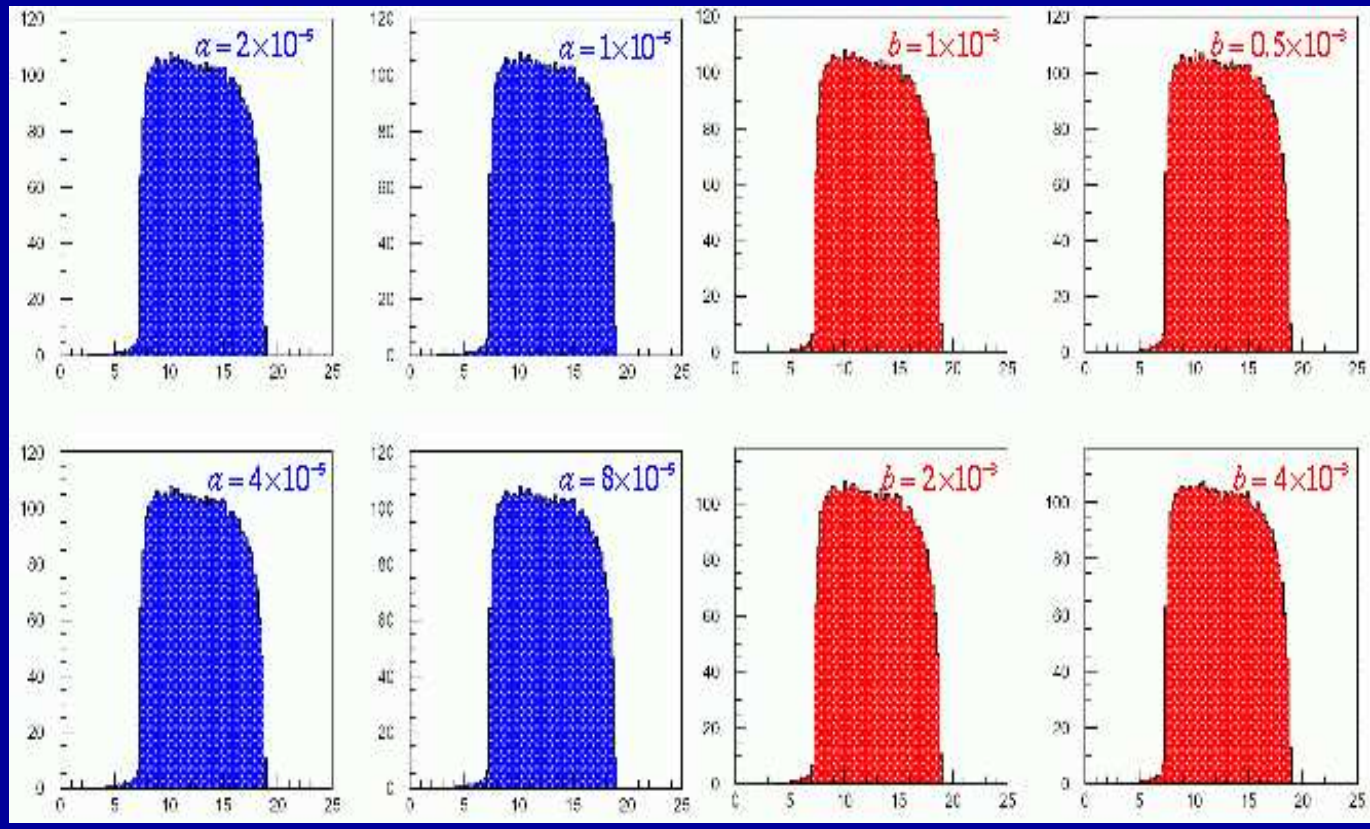
Evts/500 fb^{-1}	1.5 - 2.5 GeV	2.5 - 5 GeV
$2\ \ell\ +\ E_{miss}$	$\sim$ 22k	$\sim$ 7 k

- Important to tag fwd electrons down to small angles to suppress $\gamma\gamma \to$ hadrons.

Lepton Momentum Resolution

✧ Study $e^+e^- \to \tilde{\mu}^+\tilde{\mu}^- \to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$, for $M_{\tilde{\mu}} = 224$ GeV, $\sqrt{s} = 0.5$ TeV;

✧ Parametrise $\delta p_t/p_t^2 = a \oplus \frac{b}{p_t sin\theta}$ with $1 \times 10^{-5} < a < 8 \times 10^{-5}$ and $0.5 \times 10^{-3} < b < 4 \times 10^{-3}$ and study the effect on the reconstructed smuon mass;



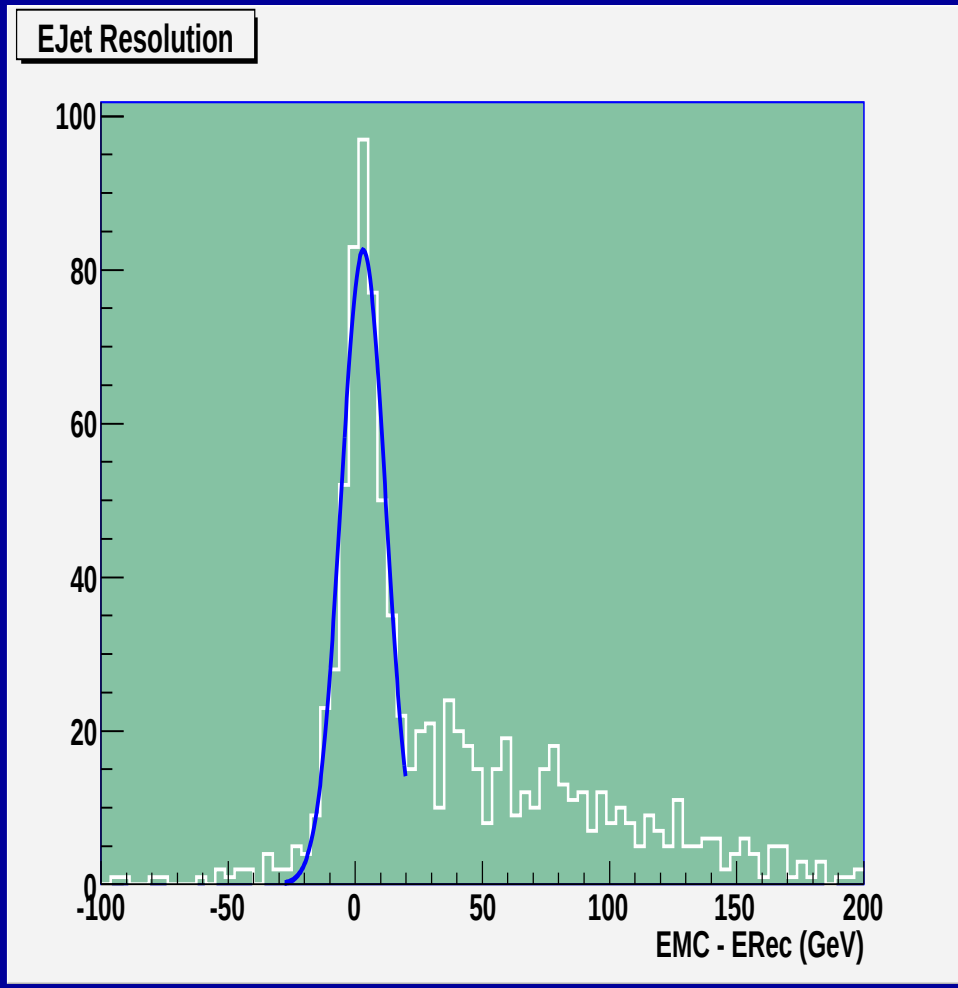
✧ No significant dependence of fit accuracy on a and b as the endpoint smearing is dominated by the ILC beamstrahlung spectrum;

Lepton Id. in Jets

$e^+e^- \to \chi_2^0\chi_3^0,\ \chi_3^0 \to \chi_1^0 Z^0,\ Z^0 \to b\bar{b},\ B \to X\ell\nu$ at $\sqrt{s} = 1.0$ TeV

$\chi_{3,4}^0 \to \chi_1^0 Z^0,\ Z^0 \to q\bar{q}$ **at 1.0 TeV**

- Significant decay branching fractions to real Z^0, requires reconstruction of E_{Z^0} to determine the χ_3 and χ_4 mass and the μ parameter, which is essential in the determination of $\Omega_\chi h^2$;
- Energy reconstruction distorted by $B \to X\ell\nu$ decays which need to be identified and corrected;
- Single secondary particle tagging in b jet.



Lepton Id. in Jets

$e^+e^- \to Z^0H^0,\ H^0 \to b\bar{b}$

✧ Detailed study of Higgs couplings to fermions and gauge bosons, requires use of inclusive 4-jet events where $H \to b\bar{b} \to \ell X$ will distort the M_{JJ} invariant mass distribution;

✧ Important to tag secondary leptons in jets to apply corrections and determine b direction from vertexing information in these cases;

✧ Single secondary particle tagging in b jet.

$e^+e^- \to H\nu\bar{\nu}$ **and** $e^+e^- \to ZZ\nu\bar{\nu}$
at 0.5 TeV