Requirements on Parton and Missing Energy Resolution

Outline

- Introduction
- Processes and measurement methods
- Basic requirements.
- CLIC bunch structure and background at 3 Tev
- 3 TeV detector layout
- Additional requirements
- Current performances
- Summary and prospects

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Introduction

Supersymmetry provides a symmetry breaking mechanism, predicts unification of the gauge couplings, and provides a candidate for CDM.

To test the SSB mechanism and determine m0 and m1/2 at GUT scale requires to measure the sparticle/Higss masses, couplings and mixing angles with good precision over a large fraction of the parameter space.

Final states with missing energy is the main signature for SUSY model, but also for UED, Z' (G.Servant) and split-SUSY (A.Djouadi).

CLIC at 3 TeV will cover almost the full SUSY parameter space, but to reach adequate luminosity at 3 TeV requests a bunch structure and final focus system creating severe background conditions which impose modifications to the ILC-like detectors to reach the required challenging performances.

SUSY: Charginos/Neutralinos

At 3 TeV, there is rich $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}$ spectrum:

The K' benchmark point was used to establish the requirements on the following processes:

$e^+ + e^- \rightarrow \tilde{\chi}_1^+ + \tilde{\chi}_1^-$: $\tilde{\chi}_1^{\pm} \rightarrow \tilde{\tau}^{\pm} + \nu$ (60%)

: $\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 + W^{\pm}$ (40%)

$e^+ + e^- \rightarrow \tilde{\chi}_2^+ + \tilde{\chi}_2^-$: $\tilde{\chi}_2^{\pm} \rightarrow \tilde{\chi}_1^{\pm} + Z^0$ or h^0

: $\tilde{\chi}_2^{\pm} \rightarrow \tilde{\chi}_2^0$ (or $\tilde{\chi}_1^{\circ}$) $+ W^{\pm}$

: $\tilde{\chi}_1^{\pm} \rightarrow \tilde{\tau}^{\pm} + \nu$

$e^+ + e^- \rightarrow \tilde{\chi}_3^0 + \tilde{\chi}_4^0$: $\tilde{\chi}_{3,4}^0 \rightarrow \tilde{\chi}_1^{\pm} + W^{\pm}$

: $\tilde{\chi}_{3,4}^0 \rightarrow \tilde{\tau}^{\pm} + \tau^{\pm}$

$m\chi^{\pm}$= 1064, $m\chi^0$ = 554 GeV ;$m\tilde{\chi}_2^{\pm}$ = 1435 GeV, m $\tilde{\chi}_2^0$=615 GeV.

For $\tilde{\chi}_1^{\pm}$ the main backgrounds are WW, ZZ and $\tilde{\chi}_2^{\pm}$

The following final states topologies have been studied up to now:

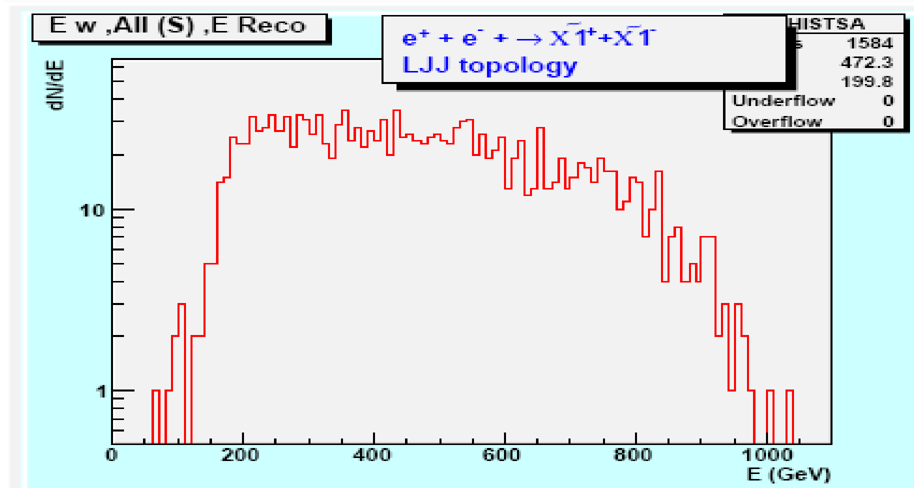
- LL (2 isolated lepton)
- LJJ (1 isolated lepton and 2 jets)
- 4J (4 jets)

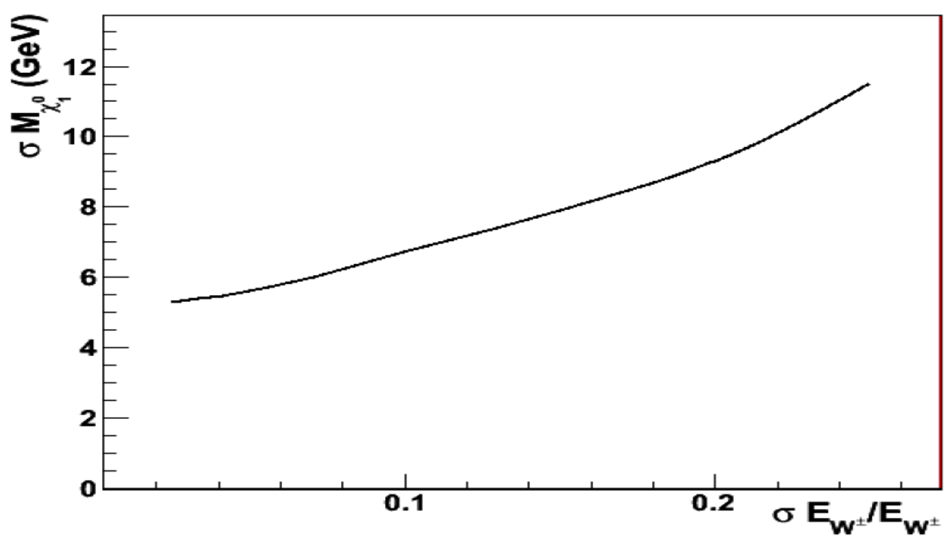
SUSY: Charginos/Neutralinos

The $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}^0$ masses are first determined from the W energy spectrum end points fit for the LJJ topology.
$\sigma(m\,\tilde{\chi}_1^{\pm})$ and $\sigma(m\,\tilde{\chi}^0)$ ~ 20 GeV.

A precise measurement of $m\chi_1^{\pm}$ is then obtained from the cross section threshold scan using all topologies.
=> $\sigma(m\,\tilde{\chi}_1^{\pm})$ ~ 6 GeV. Assuming the run plan presented by Marco.

The end points fit is repeated with larger statistics and with the $\tilde{\chi}_1^{\pm}$ mass constraint.
=> $\sigma(m\,\tilde{\chi}^0)$ ~ 8 GeV





SUSY: Charginos/Neutralinos

For the topologies with jets in the final state the jet energy resolution is crucial to:

- measure the energy of the W which comes from $\tilde{\chi}_1^{\pm}$ or from $\tilde{\chi}_{3,4}^{0}$ decay or the energy of the W±, Z° or h° which comes from the $\tilde{\chi}_2^{\pm}$ or $\tilde{\chi}_{3,4}^{0}$.
- reconstruct the di-jet mass and distinguish W± from Z° and h° in order to identify the final state and to reject the background.

SUSY: Sleptons

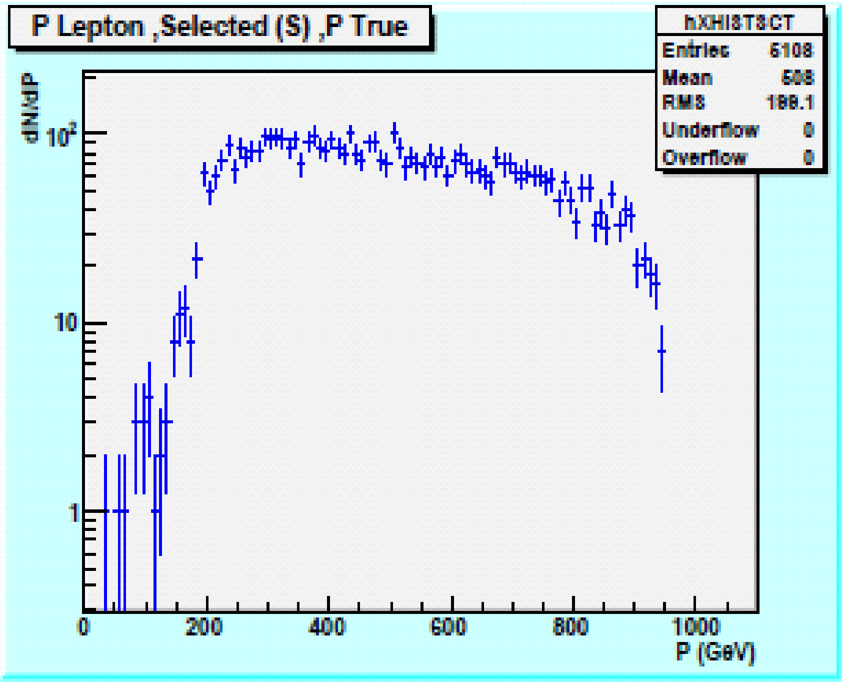
Mass determinations: $e^+e^- \to \tilde{\mu}_L^+ \tilde{\mu}_L^- \to \mu^+ \chi_1^0 \mu^- \chi_1^0$

- If $\sqrt{s} >> 2\tilde{m}_\mu$, μ spectrum end points

$$E_{\min,\max} = \frac{\sqrt{s}}{4}\left(1 - \tilde{m}_\chi^2 / \tilde{m}_\mu^2\right)\left(1 \pm \sqrt{1 - 4\tilde{m}_\mu^2 / s}\right)$$

The Slepton masses are measured from the lepton momentum spectrum end points fit and from the threshold scan .

The accuracy on the slepton mass depends on the lepton momentum resolution and the background rejection. (Andre's talk)

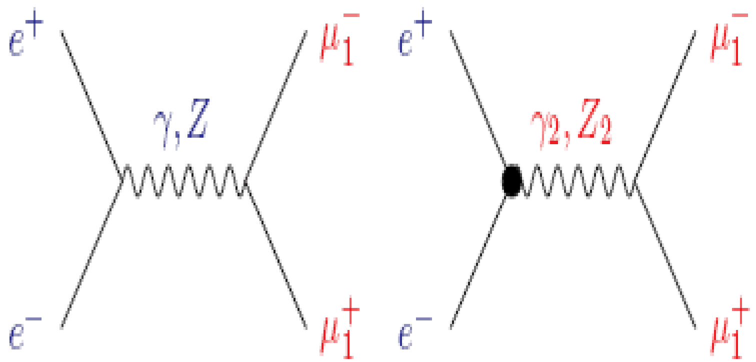


UED

Other models leads to similar experimental signatures as SUSY. Kaluza-Klein muon pair production in UED

$e^+ + e^- \rightarrow \mu_1^+ + \mu_1^- \rightarrow \mu^+ + \mu^- + \gamma_1 + \gamma_1$

has similar signature as smuons.



Marco Battaglia

- $m\mu_1$ and $m\gamma_1$ are determined from the muon momentum spectrum and from the pair production cross section threshold scan.

$m\mu_1$ = 1300 GeV.

$m\gamma_1$ = 1250 GeV.

Angular distributions and energy spectrum allow to distinguish SUSY from UED

UED requirements are the same as for SUSY

Z’

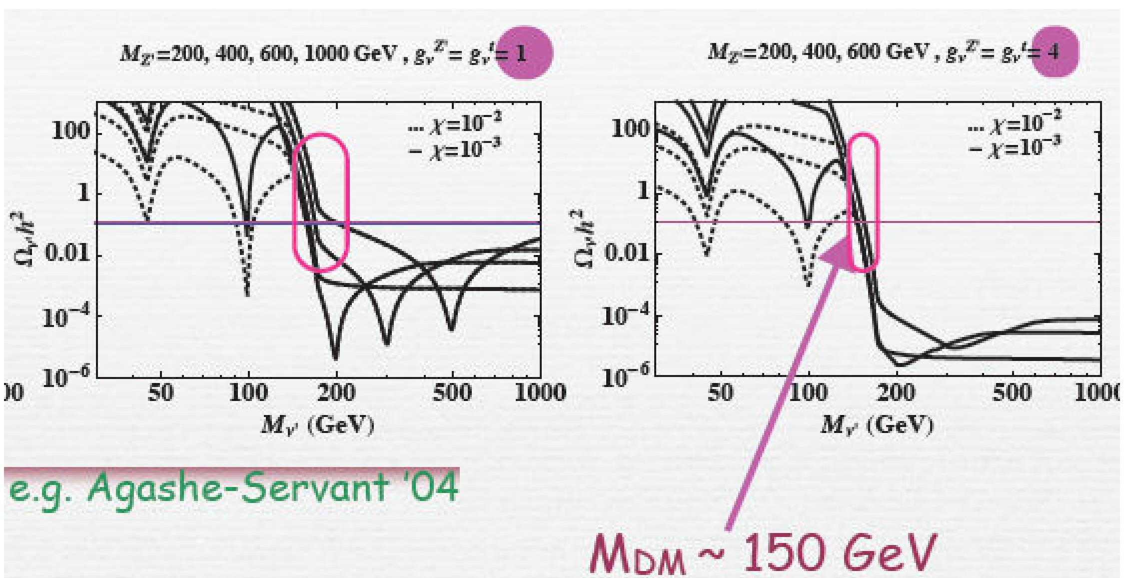
The Z’ DM motivated model, where the WIMP is a Dirac fermion ν, leads to final state with missing energy:

$e^+ + e^- \rightarrow t + \bar{t} \rightarrow t + \bar{t} + Z' \text{ and } Z' \rightarrow \nu\,\bar{\nu}$ (the t or $\bar{t}$ radiates a Z’)

mν is ~ to g νZ’ coupling, (Geraldine’s talk).

The t $\bar{t}$ final state has a low energy t and another at high energy.

The t with full energy is seen as monojet of ~1.4 TeV



Detailed equirements not yet studied; excellent jet energy resolution up to 1.4 TeV is probably needed.

Measurements

For processes with missing energy, the determination of the S/UED/particle masses is achieved by measuring:

- The momentum spectrum of the final state leptons or the energy spectrum of the the W$\pm$, Z$^\circ$ or h$^\circ$ which are decay products from of $\tilde{\chi}_1 \pm$ or $\tilde{\chi}_2 \pm$ or $\tilde{\chi}_{3,4}^{0}$, ...
- The pair production cross sections around the threshold

For the final states with W$\pm$, Z$^\circ$ or h$^\circ$, the boson mass is obtained from the di-jet invariant mass reconstruction.

These measurements drive the basic requirements.

Basic requirements

- Good hermiticity and minimum leakage
- Very forward calorimeter to tag electrons
- Good Lepton ID, (τ-> h); at 3 Tev more SUSY final states with $\tilde{\tau}$
- Good Jet/lepton energy/momentum resolution
- Good Di-jet invariant mass resolution, also in F/B regions
- Good missing energy sensitivity

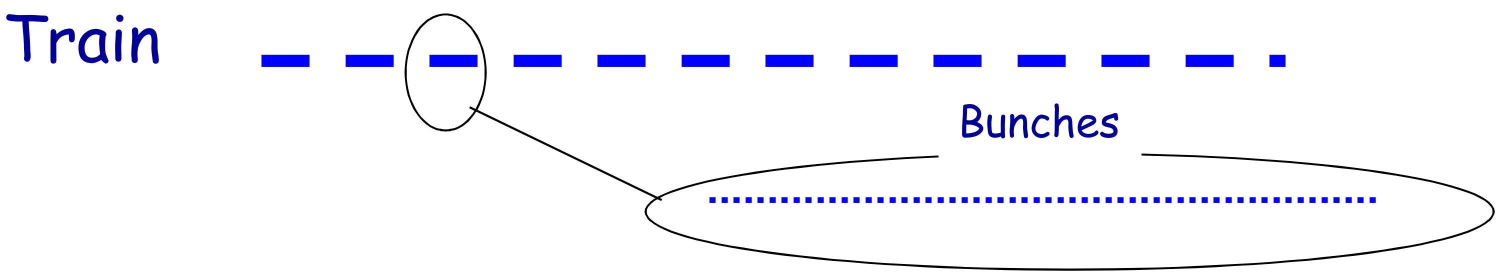
To reach a good S/B ratio, at 500 GeV ILC requirement is $\sigma E/E < 3.8\%$ over the range 45 to 400 GeV.

~ Comparable requirements are necessary at 3 TeV but for the energy range, from 50 Gev to 1.4 Tev including the forward/backward regions.

VERY CHALLENGING

CLIC train/bunch structure

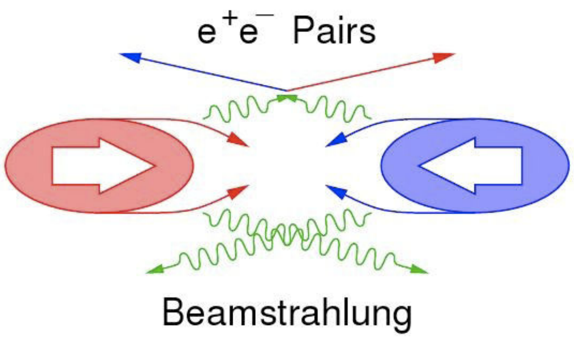
The CLIC train repetition rate is 50 Hz, (ILC, 5 Hz)



	Number of bunches per train	Time interval between bunches
CLIC:	312	0.5 ns
ILC:	2820	308 ns

Trains made of 312 very close bunches, ~16 cm distance.

CLIC Beamstrahlung



Close bunches and strong final focus fields lead to :

- high-beamstrahlung with large backgrounds
  - **Coherent pairs** (3.8×10^8 per B crossing)
  - **Incoherent pairs** (3.0×10^5 /Bx)

  They affect
  Vertexing/tracking (Marco)
  Very F/B regions (Andre)
  and F/B regions (Marcel)
  - **γγ interactions** (3.3 hadron events/Bx)
  (affect calorimeters)
  - Muon, neutron background from upstream

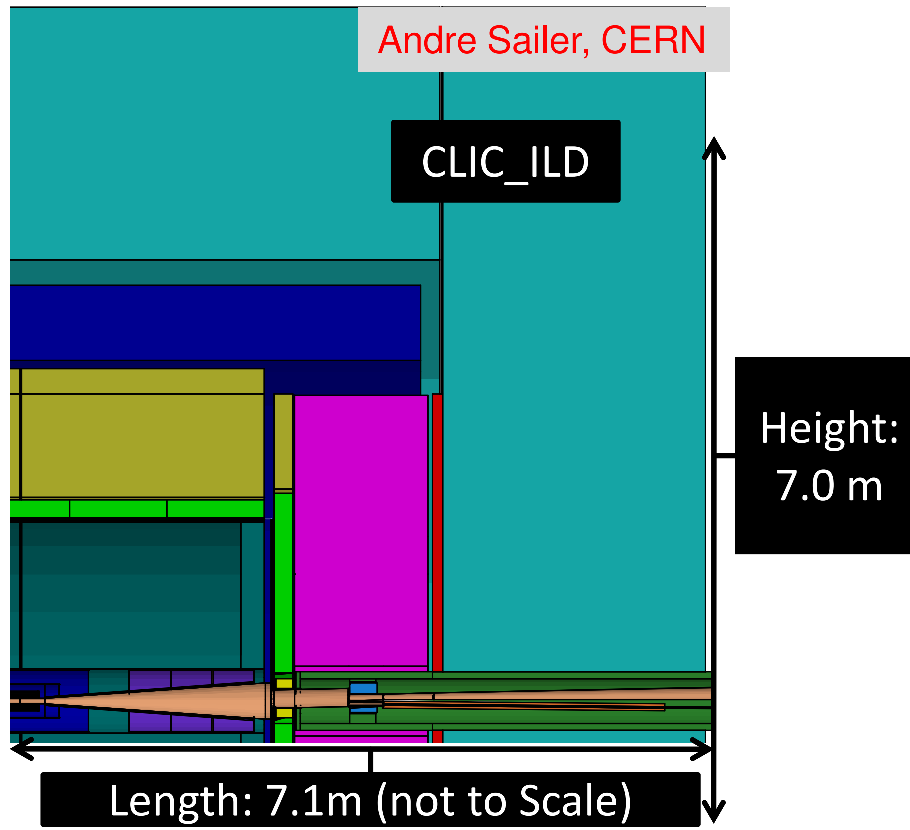
The train/bunch time structure and the **γγ** background generates significant events pile up.

3 TeV Detector layout

Detectors for CLIC (3 TeV) are based on the ILC Detectors for 500GeV.

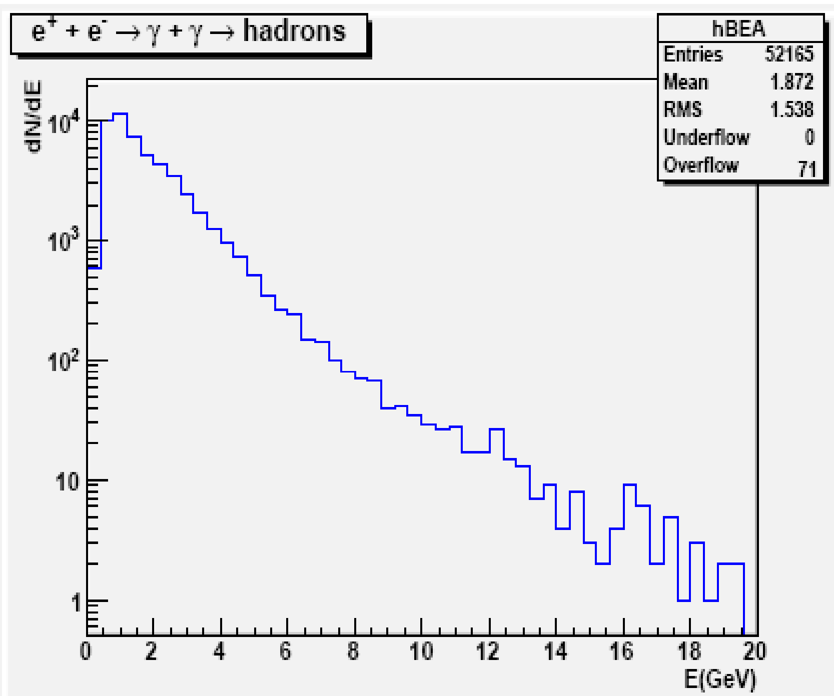
High energy and background conditions => main modifications :

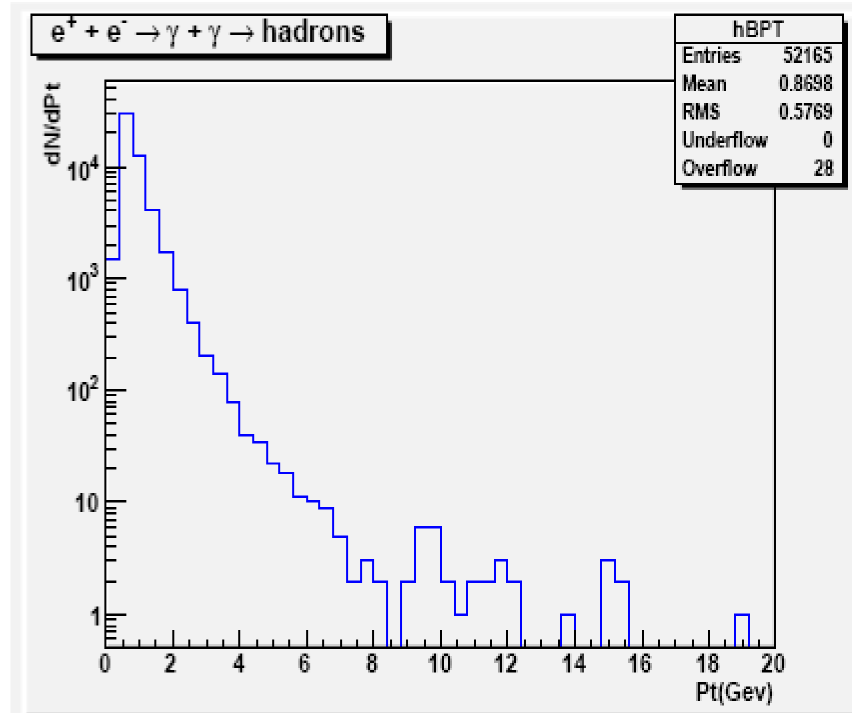
- 20 mrad crossing angle (instead of 14 mrad)
- Beam pipe with larger radius.
- Location and size of the vertex detector (inner radius ~ 30mm); matched to the beam pipe.
- Modified F/Backward regions, LumiCal, BeamCal.
- W, HCAL (barrel and endcap) with a depth of 7.5 λ
- 4 T field



$e^+ + e^- \to \gamma\gamma \to$ hadrons

At 3 TeV ~ 3.3 $e^+ + e^- \to \gamma\gamma \to$ hadrons events / Bx → ~ 13 particles/Bx



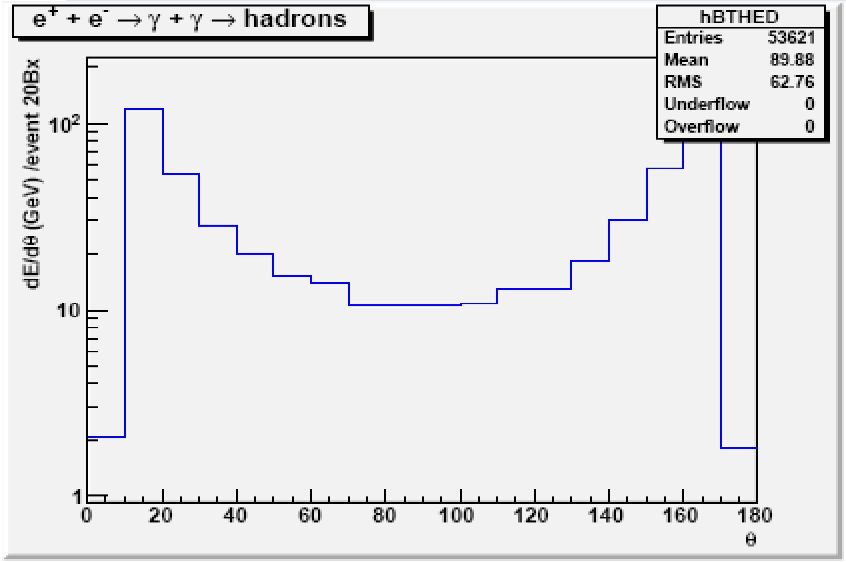


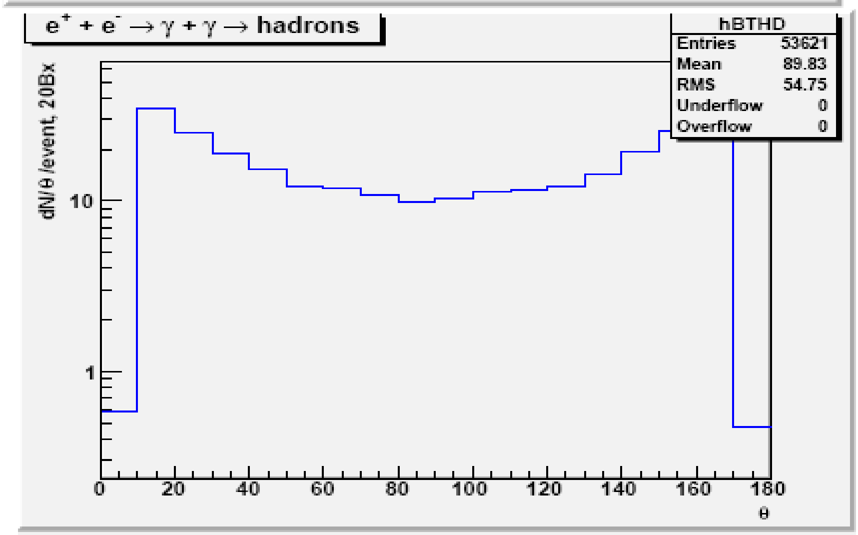
<Eh> ~ 1.9 GeV

<Pt> ~ 0.9 GeV.

Per train ~ 7.5 Tev are dumped in the detector. Low E/Pt hadrons, but requires time stamping to preserve the energy resolution and the missing energy measurements necessary to discriminate Signal and background

$e^+ + e^- \rightarrow \gamma\,\gamma \rightarrow$ hadrons





Background peaked in F/B region.

Fig1: dE/dθ **for 20 Bx**

Energy deposit in a ±10 ° cone:

- ~ 2 Gev in barrel region
- ~ 20 Gev in F/B regions

10 nsec time stamping ~ ok in barrel, EC?

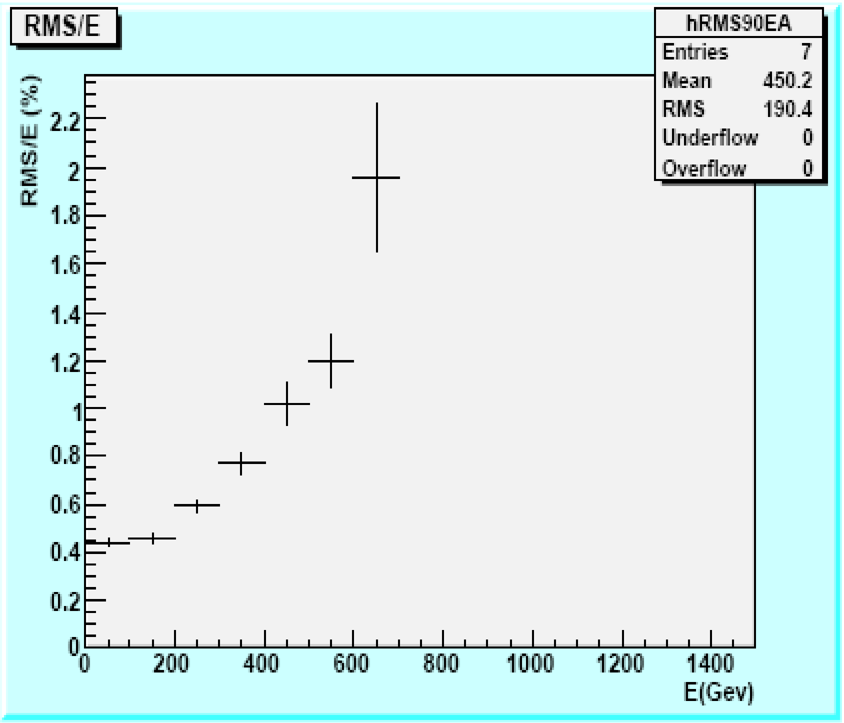
Fig2: dN/dθ **for 20 Bx**

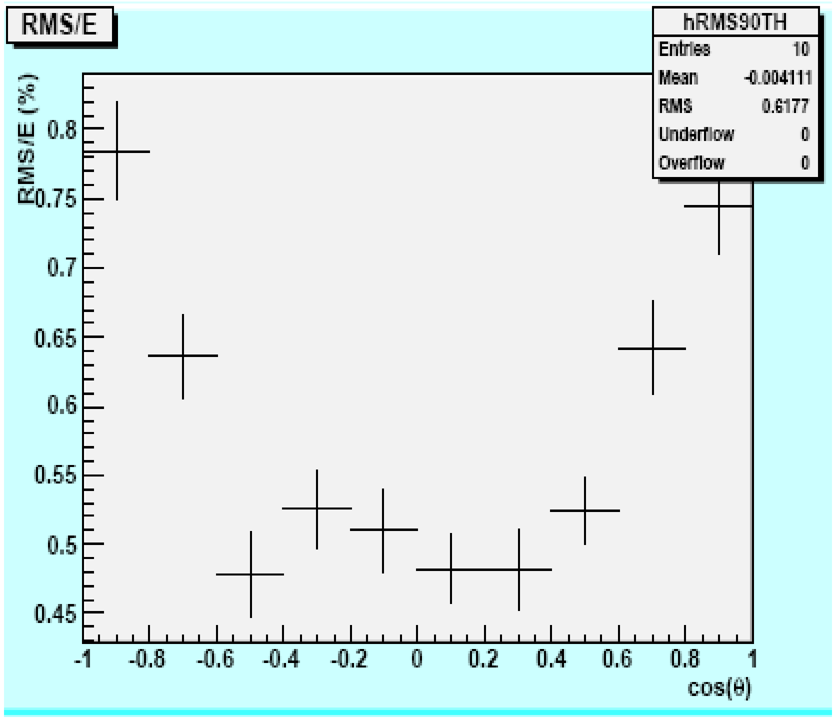
Occupancy/10ns/cm2 at 2m

- ~ 3.10-4 in barrel region
- ~ 3.10-3 in F/B regions

~ ok if calorimeter cells not >> 1cm2

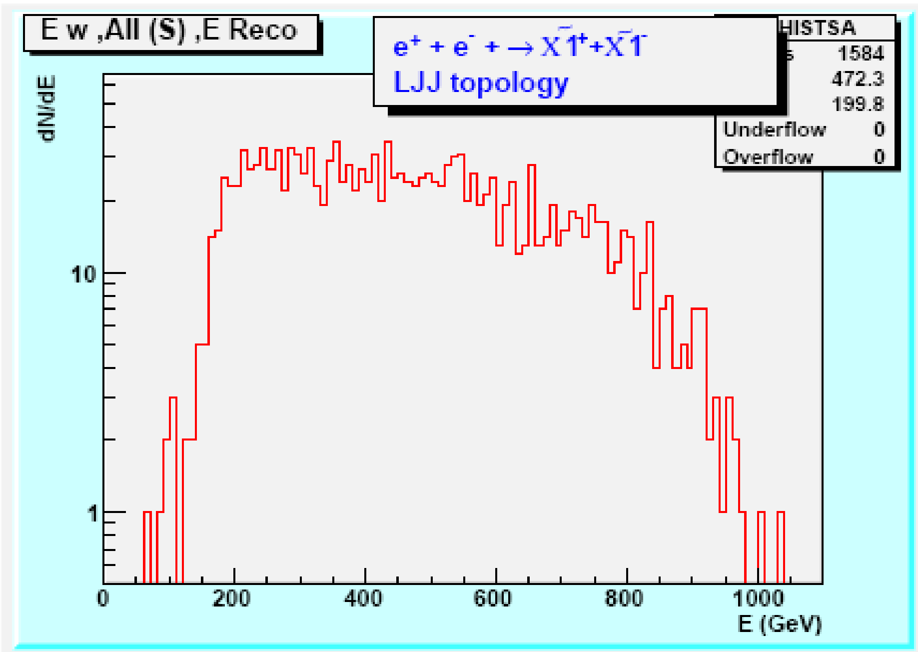
Current performance: μ, e

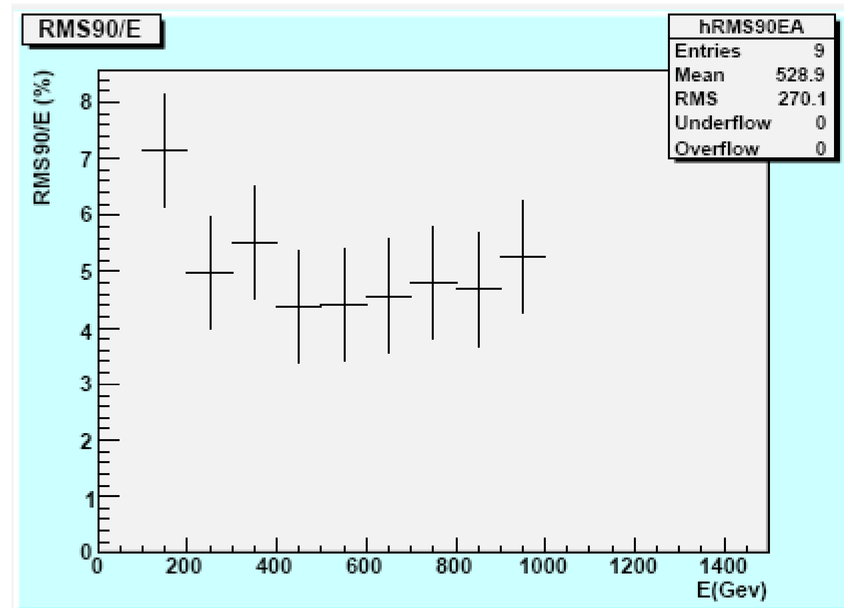




For the LL topology and without γγ background: σPμ/Pμ ~ 0.5% and : σEe/Ee ~ 0.5% in barrel region. With γγ background and 10ns time stamping the resolution is the same. Such resolution is adequate for $\tilde{\chi}_1^{\pm}$ (LL topology) and Slepton measurements.

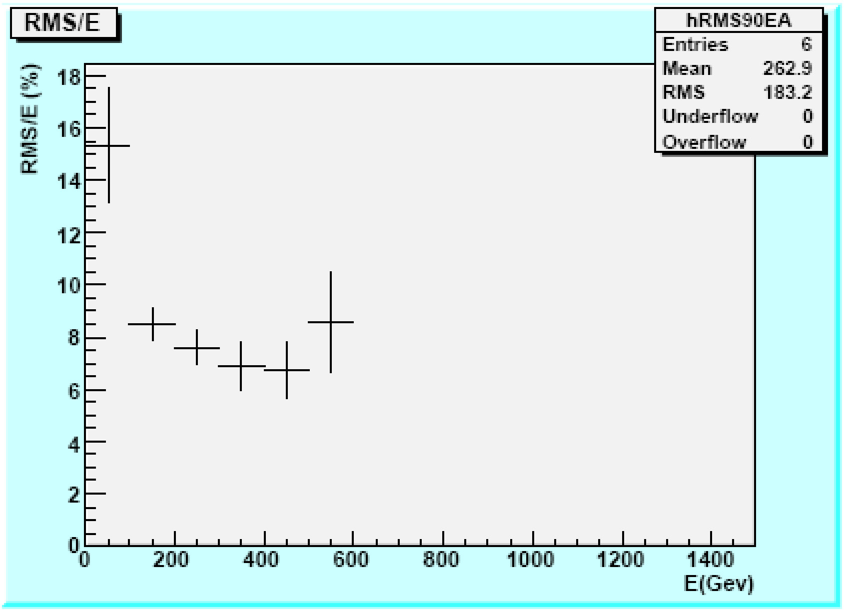
Current performance: $\tilde{\chi}^0$ (LJJ)

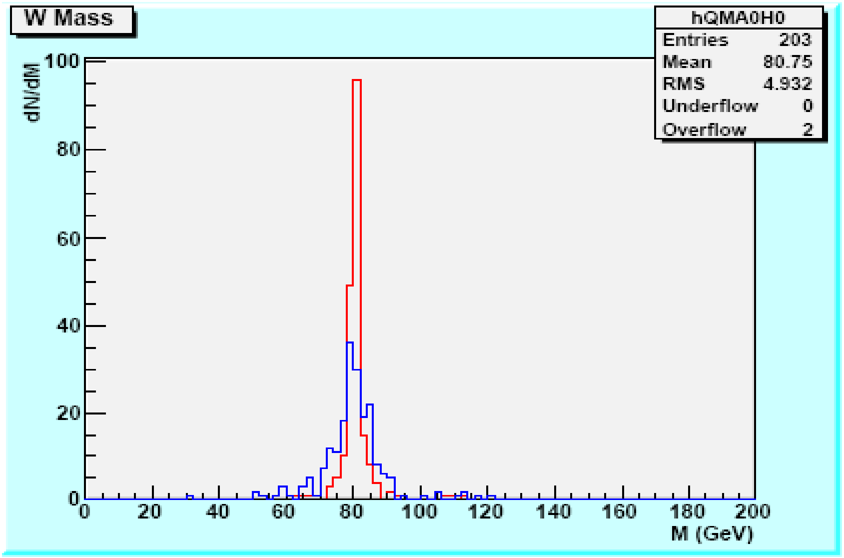




For $\tilde{\chi}_1 \pm$ and $\tilde{\chi}^0$ searches, currently σEw/Ew ~ 5% for the LJJ topology, without γγ background. With γγ background and 10ns time stamping σEw/Ew ~ 7.5% it leads to σM $\tilde{\chi}^0$ /M $\tilde{\chi}^0$ ~ 8%; ok. . The mass resolution is ~ 15%, this resolution is not good enough to have a good W±, Z^0 and h^0 separation

Current performance: 4J





For the 4J topology and without γγ background: σEj/Ej ~ 9% . The mass resolution is ~ 13%, this resolution (not good enough).

With γγ background and 10ns time stamping σEj/Ej ~ 9% increases to ~12%

Summary

New physics expected at the TeV scale. To reach adequate luminosity at 3 TeV, requires a bunch structure and beam conditions which create new and challenging detector issues.

To measure the sparticle/Higss masses, couplings and mixing angles with good precision requires ILC-like performances for the energy range, from 50 Gev to 1.4 TeV including the forward/backward regions.

For $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}^0$ searches, the performances reached with the current detector layout are adequate for final states with leptons, but not for topologies with multi-jets final states. Next steps:

- Asses the performance for $\tilde{\chi}_2^{\pm}$ or $\tilde{\chi}_{3,4}^0$ and other missing energy processes.
- Understand the components of the jet energy resolution (calorimeter resolution, track reconstruction efficiency, confusion, leakage) and study the calorimeter granularity and time stamping accuracy necessary to improve the performances.

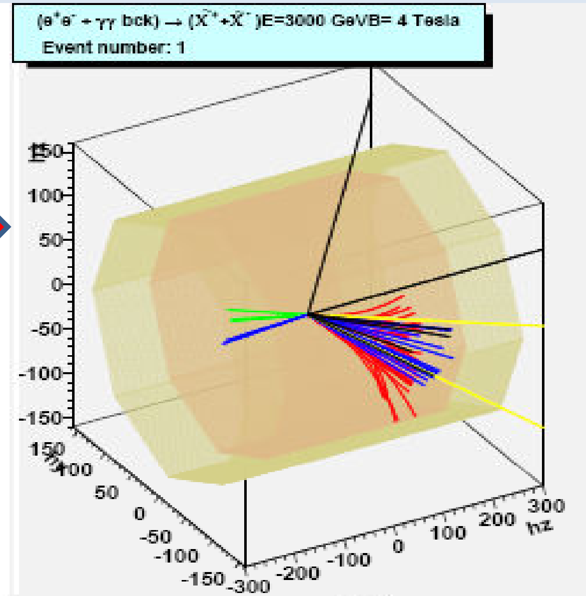
Spare slides

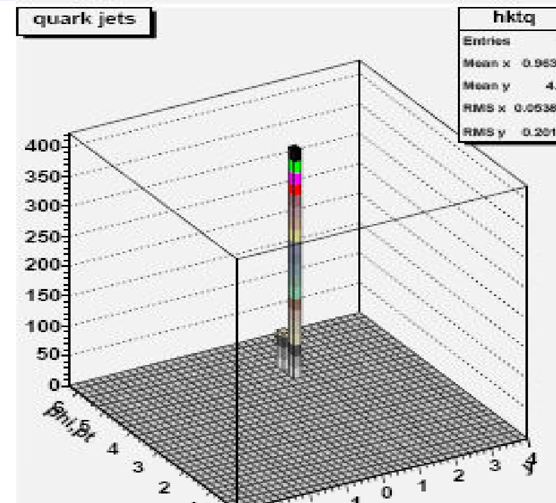
γγ Background

$e^+ + e^- \rightarrow \tilde{\chi}^\pm + \tilde{\chi}^\pm \rightarrow \tilde{\chi}^0 + \tilde{\chi}^0 + W^+ W^-$

Without γ γ

- Two jets, close each other,





Reconstructed Υ, ϕ, Pt values of jets

with 20 Bx γ γ → hadrons pile up.

The backg affects the jet energy resolution and the discrimination variables e.g missing energy, Θ missing E, ..

But low E, Pt particles.