CLIC CDR detector benchmarks

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Introduction

CDR Vol3 deals with Physics&Detectors. While the main emphasis of the CDR is clearly on Vol2, i.e. the feasibility of the CLIC accelerator, we have to show in Vol3 that some basic detector performances will provide the interesting physics we want to extract from CLIC.

The idea is to select few benchmark processes and do the analysis including full simulation, backgrounds, beamstrahlung, etc… The assumption is that both proposals, CLIC_ILD and CLIC_SiD, should perform similarly, so to some approximation it does not matter which detector is used for each benchmark → No detailed comparison of detector performance is foreseen in the CDR.

The benchmark processes have been selected to test complementary requirements on the detectors performance. They have not been selected as the most interesting physics case for CLIC (i.e. they have not been optimized to show the best possible CLIC results), but rather the scenarios chosen are required to be compatible with existing measurements, and having a high probability to provide signatures at the LHC.

Introduction

LHC "almost" guaranteed to find SUSY if it has any relevance to the Naturalness problem

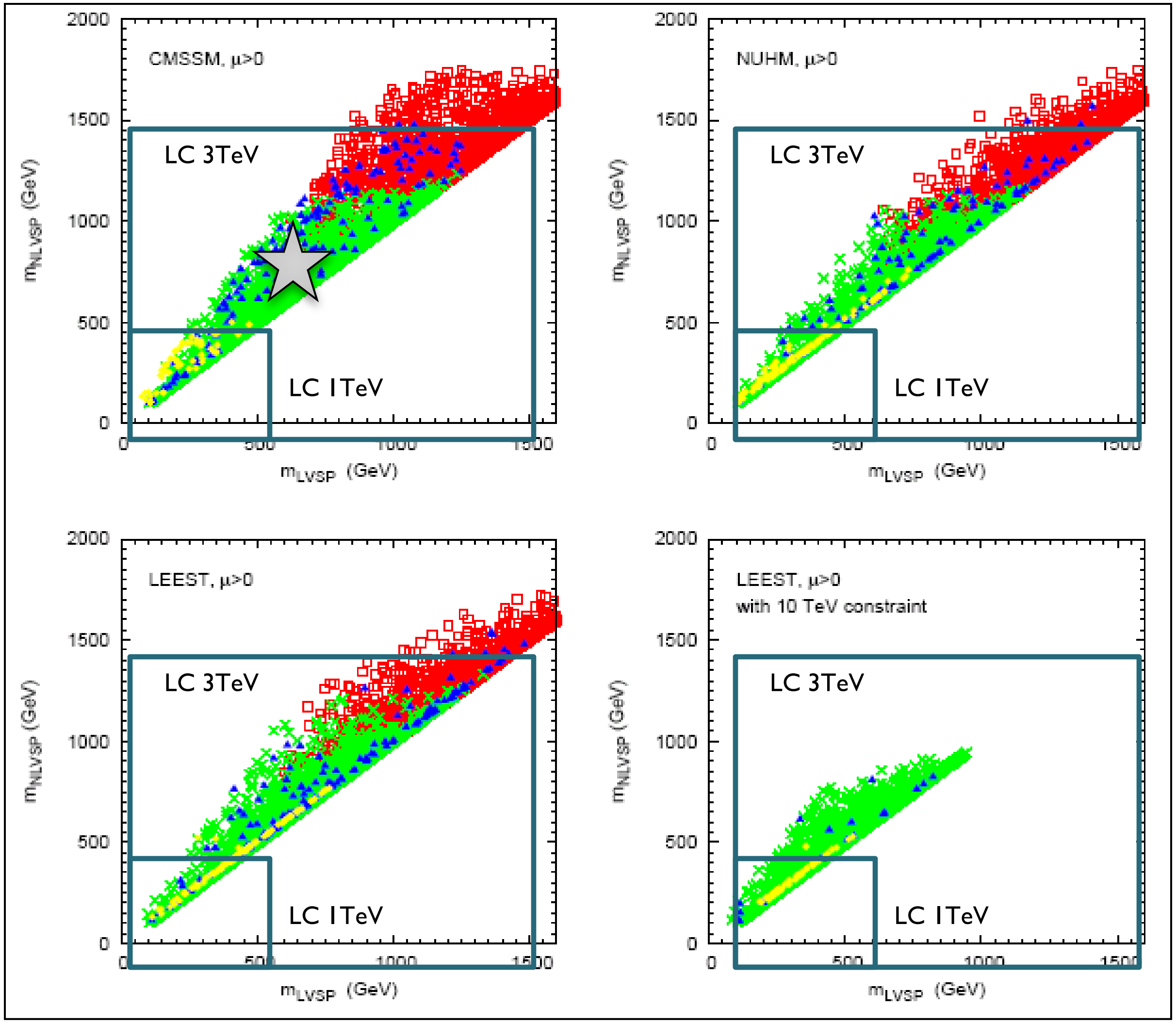
From J.Ellis

all samples

Detectable @ LHC

Provide Dark Matter

Dark Matter Detectable Directly



Lightest visible sparticle →

← Second lightest visible sparticle

List of benchmark processes:

- 5+1 benchmark channels for the CDR
- At 3 TeV
  - $e^+e^- \to H\nu_e\nu_e$ $H \to bb$, $\mu\mu$ (m_H=120 GeV)

$M_1 = 780\ \mathrm{GeV},\ M_2 = 940\ \mathrm{GeV},\ M_3 = 540\ \mathrm{GeV},$

$A_0 = -750\ \mathrm{GeV},\ m_0 = 303\ \mathrm{GeV},\ \tan\beta = 24,\ \mu > 0$

- $e^+e^- \to H^+H^- \to tbtb$ $e^+e^- \to HA \to bbbb$ ($m_{H,H+,A}$=900 GeV)
- $e^+e^- \to \tilde{q}_R\tilde{q}_R$ $m_{\tilde{q}R}$= 1.1 TeV

$m_{1/2} = 800\ \mathrm{GeV},\quad A_0 = 0,\quad m_0 = 966\ \mathrm{GeV}$

$\tan\beta = 51,\quad \mu > 0$

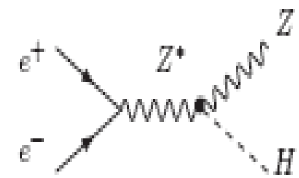
- $e^+e^- \to \tilde{l}^+\tilde{l}^-$ $m_{\tilde{e}_R} = m_{\tilde{\mu}_R} =$ 1.0 TeV, $m_{\tilde{e}_L} = m_{\tilde{\mu}_L} =$ 1.1 TeV
- $e^+e^- \to \chi^+\chi^-, \chi^0\chi^0$ $m\chi^0$=340 GeV

- At 500 GeV
  - $e^+e^- \to tt$ (same as ILC Benchmark)

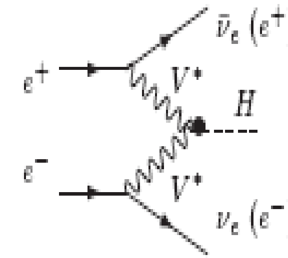
Higgs Physics

Light SM-like Higgs

Assume the Higgs has been found at LHC/Tevatron with Mh~120 GeV. The SM cross-section at ~3TeV is enormous → access to very rare decays (BR~10^{-4}).

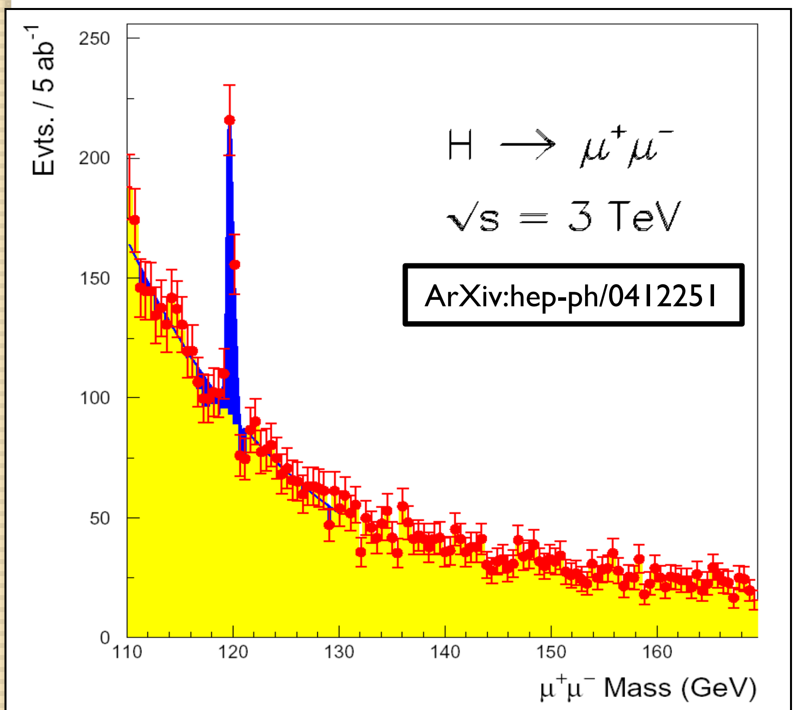


$\sigma \propto 1/s$



$\sigma \propto \log(s)$

Measure Higgs couplings to leptons, for instance with 0.5 ab^{-1}, we expect ~20 $H \to \mu^+\mu^-$ candidates in $\pm 2\sigma$ (B/S~1) for M_h=120 GeV/c^2, hence measure the couplings with ~10% precision, and compare with other (bb,cc,tt…) couplings → test Higgs coupling



Detector requirements:

1. Muon ID and flavour tagging
2. Momentum resolution
3. Forward track acceptance
4. Forward jet reconstruction

If there is NP the Higgs may not be light or alone…

The presence of New Physics may partially cancel the virtual effects of a heavy Higgs and still be in agreement with precision measurements.

Indeed LHC should have discovered a heavy Higgs, and roughly measure its properties.

However a precise determination of its mass, width and couplings will require a LC.

$e^+ e^- \rightarrow H^+ H^- \rightarrow tb\ tb$

$e^+ e^- \rightarrow H^0 A^0 \rightarrow bb\ bb$

$$m_{A^0} = 902.6 \text{ GeV}$$
$$m_{H^0} = 902.4 \text{ GeV}$$
$$m_{H^\pm} = 906.3 \text{ GeV}$$

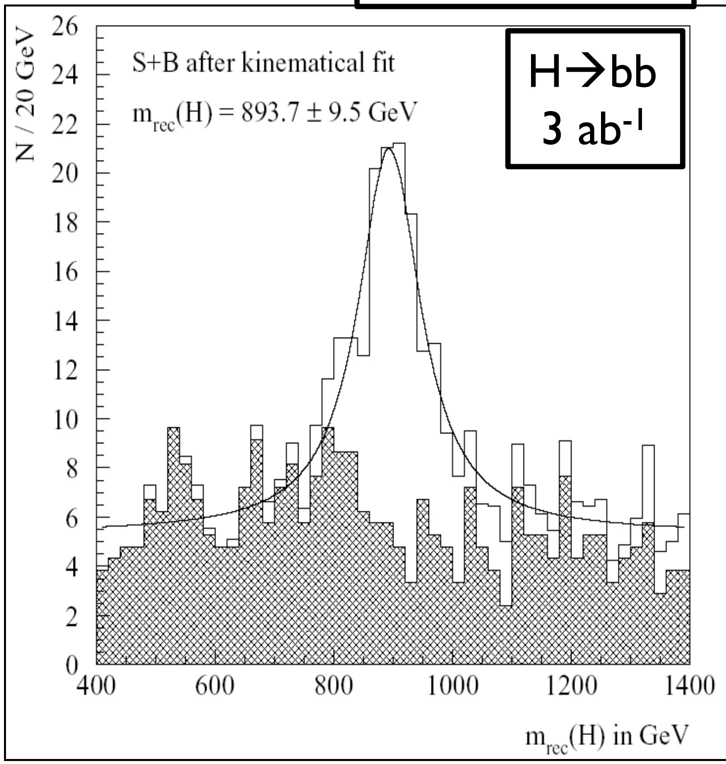
At $\sqrt{s} = 3$ TeV:
$$e^+e^- \rightarrow H^+H^- \quad 1.67 \text{ fb}$$
$$e^+e^- \rightarrow H^0A^0 \quad 0.692 \text{ fb}$$

Many jets topology in busy events.

Detector requirements:

1. Flavour tagging in busy events
2. Dijet mass resolution in high multiplicity events

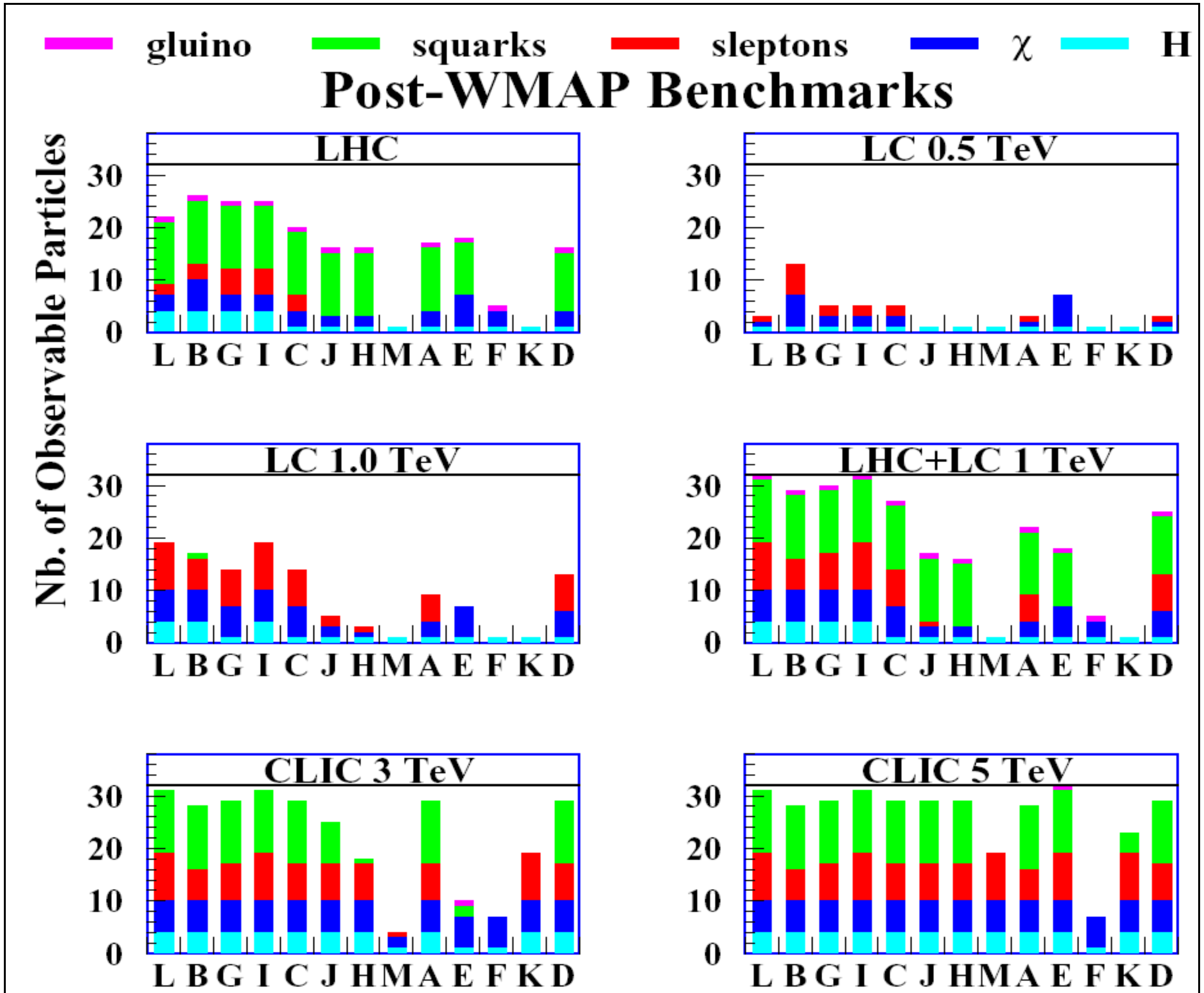
ArXiv:hep-ph/0412251



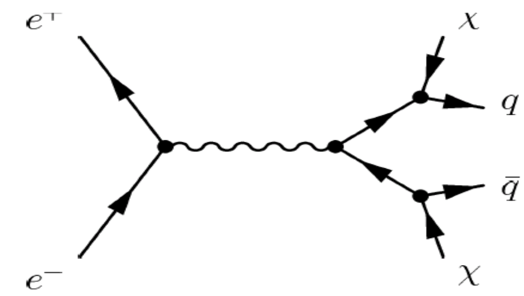
Supersymmetry

LHC vs LC

LHC is good with sparticles that mainly interact strongly, (gluino, squarks, …), while a LC could complement the spectra with sparticles that mainly interact weakly (sleptons, neutralinos,…)



Looking for heavy squarks



$$e^+e^- \to \tilde{q}_R\bar{\tilde{q}}_R \to q\bar{q}\tilde{\chi}_1^0\tilde{\chi}_1^0$$

$$\tilde{q}_R \to q\tilde{\chi}_1^0 \ (99.7\%)$$

$$m_{\tilde{u}_R} = m_{\tilde{c}_R} = 1126 \text{ GeV}$$
$$m_{\tilde{d}_R} = m_{\tilde{s}_R} = 1116 \text{ GeV}$$

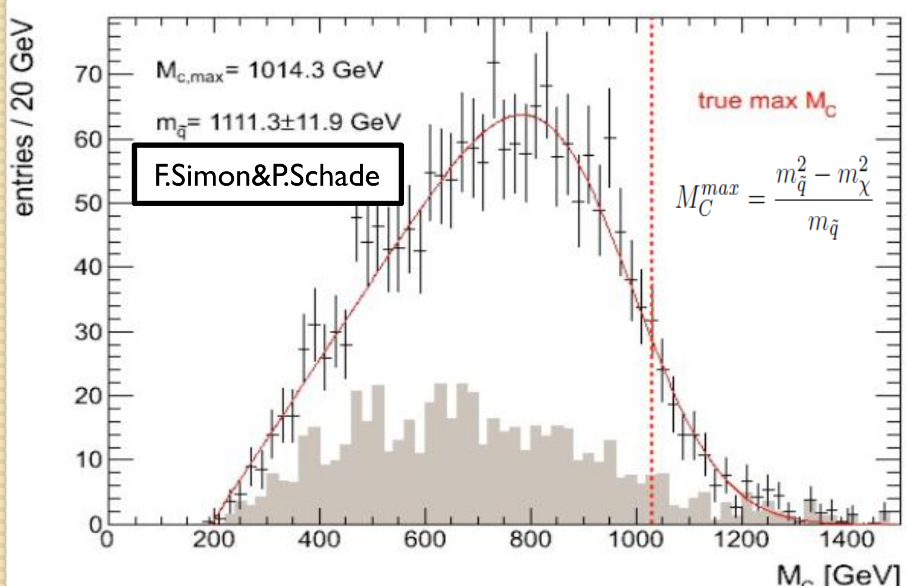
At $\sqrt{s} = 3$ TeV:

e^+e^-	$\to$	$\tilde{u}_R\bar{\tilde{u}}_R$	1.14 fb	($\times$ 2 for $\tilde{c}_R$)
e^+e^-	$\to$	$\tilde{d}_R\bar{\tilde{d}}_R$	0.291 fb	($\times$ 2 for $\tilde{s}_R$)

Relatively simple to extract the mass of the squarks (one can assume the neutralino mass is known from other processes), from the 2-jets and missing energy distribution in a clean event.

The classic approach is to look at Emin,max which suffers from beamstrahlung and backgrounds. Alternative approaches using modified definition of invariant mass, reduces these dependences, see:

D.R. Tovey, JHEP 04, 34 (2008)



Detector requirements:
1. High energy jet reconstruction
2. Missing energy

Looking for heavy sleptons

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

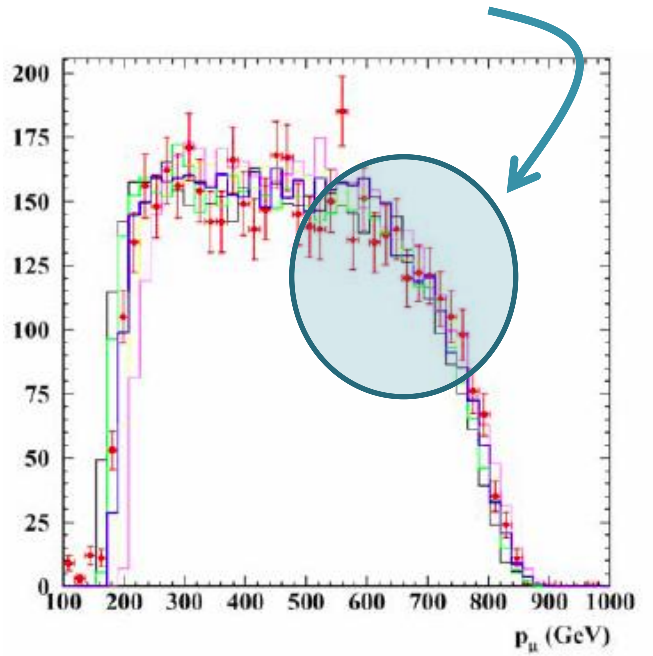
- If $\sqrt{s} >> 2\tilde{m}_\mu$, μ spectrum end points

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

$\sigma(e^+e^- \to \quad ^-) = 3.2$ fb.

$\sigma(e^+e^- \to \quad ^+ e^-) = 25.2$ fb.

Here beamstrahlung is again an important issue! Maybe alternative techniques are also useful here… in any case the beamstrahlung probability will be determined with other techniques.



Detector requirements:

1. High energy electron and muon reconstruction
2. Missing energy
3. Beam polarization

1 ab^{-1} $\tilde{m}_\mu = (1145 \pm 25)\,\text{GeV}$ 2% $\tilde{m}_\chi = (652 \pm 22)\,\text{GeV}$ 3%

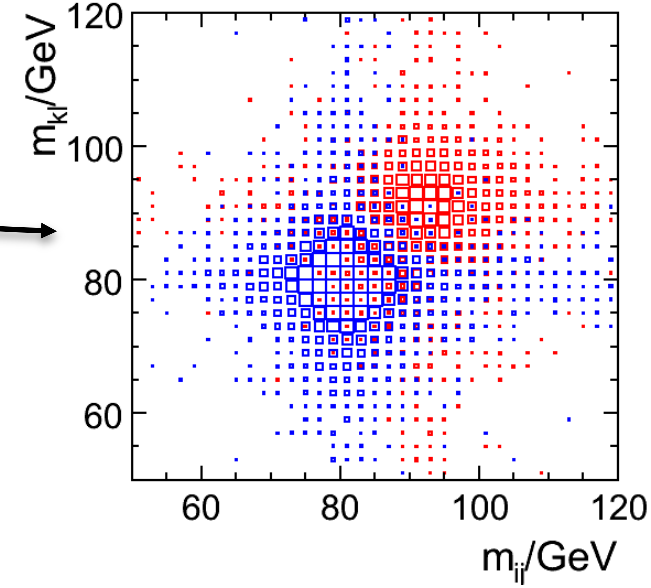
Looking for charginos/neutralinos

$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \to W^+W^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$$

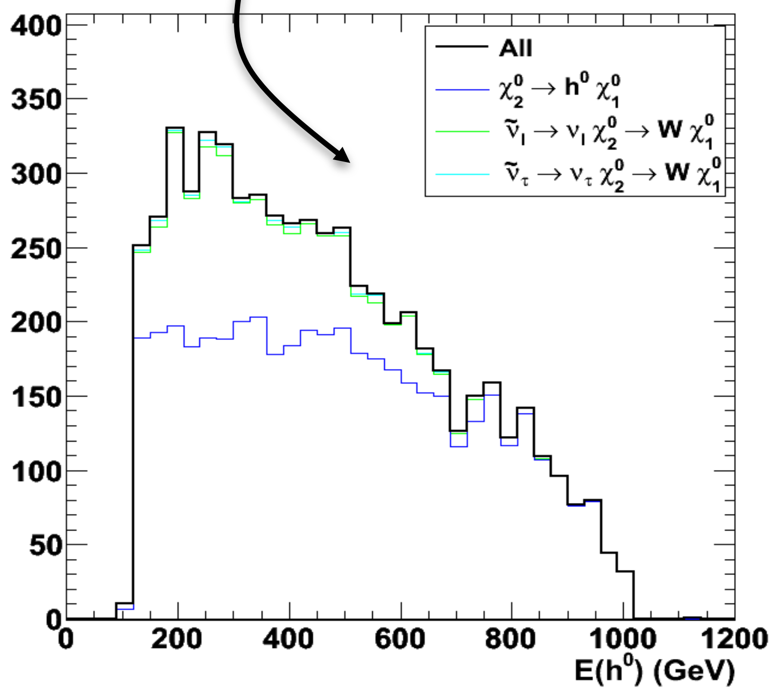
$m_{\tilde{\chi}^0_{1,2,3,4}} = 340.3,\ 643.1\ ,905.5,\ 916.7$ GeV
$m_{\tilde{\chi}^\pm_{1,2}} = 643.2,\ 916.7$ GeV
$m_h = 118.52$ GeV

Gives two energetic bosons, hence the final state is 4 jets (or 2l+2ν) and missing energy. Good test bench for PFA.

ILD studies at 1 TeV



$$\tilde{\chi}_2^0\tilde{\chi}_2^0 \to hh\tilde{\chi}_1^0\tilde{\chi}_1^0$$
$$\tilde{\chi}_2^0\tilde{\chi}_2^0 \to hZ\tilde{\chi}_1^0\tilde{\chi}_1^0$$



2 bosons + missing energy. Irreducible bkg from sneutrino decays and effect of beamstrahlung are relevant.

Detector requirements:

1. Dijet mass resolution in high multiplicity events
2. Missing energy

Conclusions

Conclusions

We have proposed a few benchmark channels to test the detector performance in Volume 3 of the CLIC CDR.

The plan is to generate MC samples including the most up-to-date detector description, beamstrahlung and backgrounds. Evaluate the performance of the reconstruction (tracking, PID, flavour tagging,…) and quote the sensitivity to the relevant physics parameters for the benchmark channels → CDR, Volume 3, Chapter 14.

We also would like to have an estimation on how the sensitivity to the relevant physics parameters, depends on a worse/better detector performance → feedback to the detector design.

Backup

Introduction

LHC will show the way, but as we wait for some indication, the safest option is to plan for the highest possible energy → **CLIC (3 TeV) CDR**

However, this is not the easiest option in terms of machine&detector(s) design and physics analysis.

Not all events are produced at the relevant energy: significant beamstrahlung →needs to be measured.

Particle multiplicity at low angles is significantly increased → large background, requires special design at low Radius.

CLIC bunch structure (0.5 ns separation) → significant event overlap in detectors, need time stamping.

Taking into account all the above, two detector designs are going to be described in the CDR:

- CLIC_ILD
- CLIC_SiD

	CLIC_SiD	CLIC_ILD
Vertex detector	inner radius 2.7 cm 5 single barrel layers 6 single layer forward disks	inner radius 3.1 cm 3 double layers 3 double layer pixel forward disks
Tracker	Si, unchanged	TPC, unchanged
ECAL	unchanged	unchanged
HCAL Barrel	W+Scintillator, 3x3 cm tiles 7.5 Λ_i 1 cm plates W+RPC, 1x1 cm tiles 7.5 Λ_i 1 cm plates	W+Scintillator, 3x3 cm tiles 7.5 Λ_i 1 cm plates
HCAL Endcap	Fe+Scintillator, 3x3 cm tiles 7.5 Λ_i 2 cm plates Fe+RPC, 1x1 cm tiles, 7.5 Λ_i 2 cm plates	Fe+Scintillator, 3x3 cm 7.5 Λ_i 2 cm plates
Coil	5T, Radius=2.68 m	4T, Radius=3.35 m