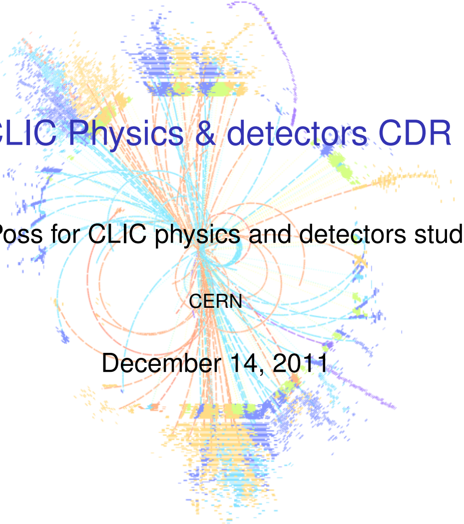


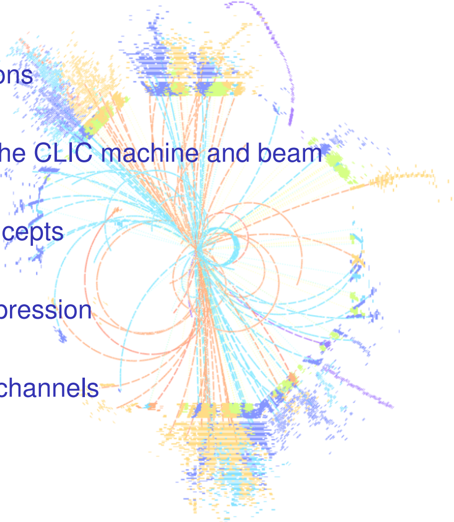
CLIC Physics & detectors CDR

S. Poss for CLIC physics and detectors study

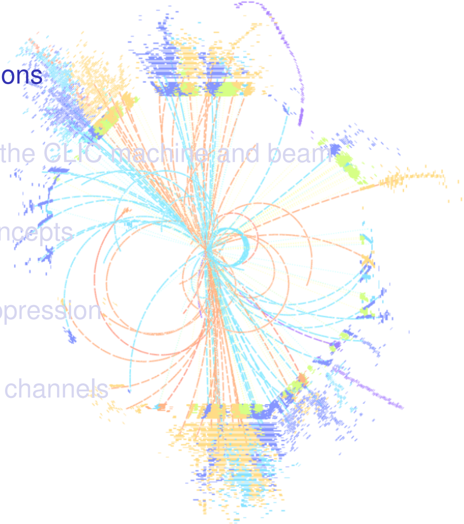
CERN

December 14, 2011

Outline



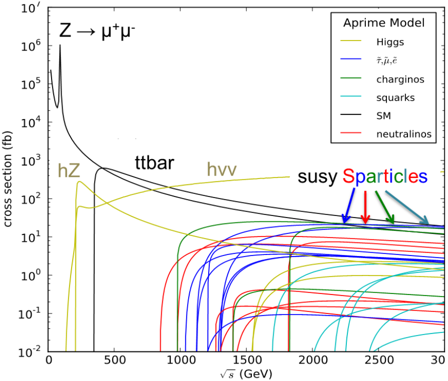
Outline



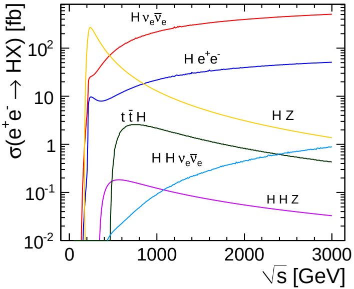
Physics Motivations

- Complementary to the LHC
- Complementary to the ILC (500 GeV)

Use the clean environment to study hard-to-reach processes

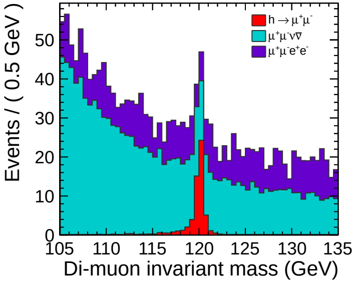


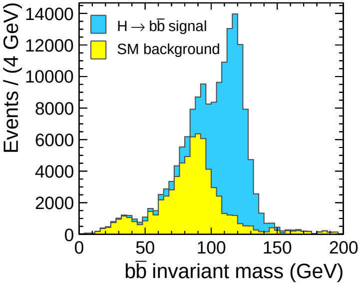
Higgs measurements



Access to low cross section and small BR processes

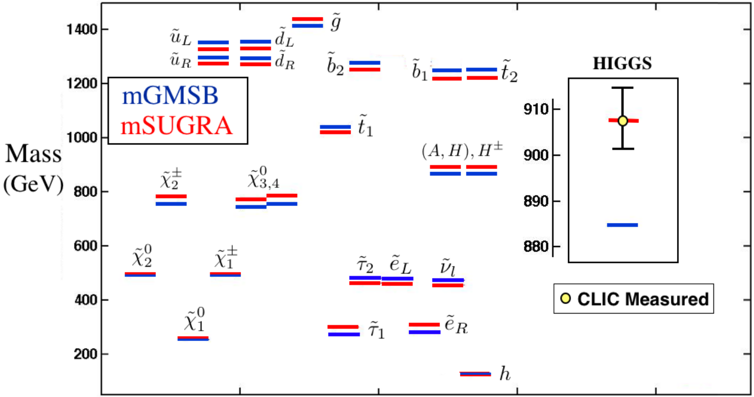
$$\sigma(h \to \mu\mu) \quad \to \quad \pm 15\%$$
$$\sigma(h \to b\bar{b}) \quad \to \quad \pm 0.2\%$$





SUSY

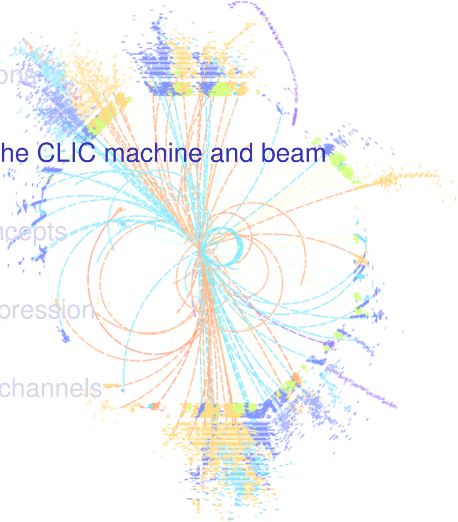
CLIC resolving power for SUSY breaking models:



New physics scenarios

New particle Luminosity	LHC14 100fb^{-1}	SLHC 1ab^{-1}	LC800 500fb^{-1}	CLIC3 1ab^{-1}
squarks [TeV]	2.5	3	0.4	1.5
sleptons [TeV]	0.3	-	0.4	1.5
Z' (SM couplings) [TeV]	5	7	8	20
2 extra dims M_D [TeV]	9	12	5-8.5	20-30
TGC (95%) (λ_γ coupling)	0.001	0.0006	0.0004	0.0001
μ contact scale [TeV]	15	-	20	60
Higgs compos. scale [TeV]	5-7	9-12	45	60

Outline



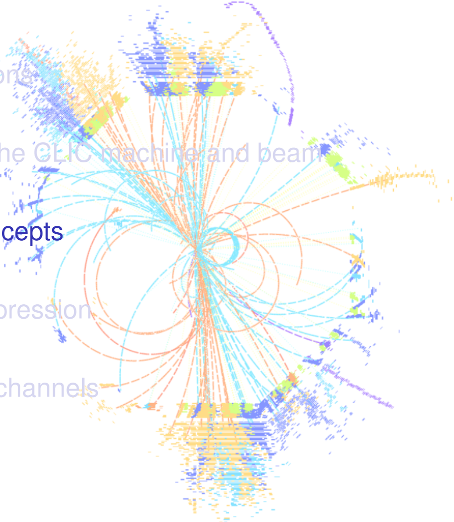
A particular beam structure

- CLIC: trains at 50Hz, 1 train is 312 bunches, 0.5ns apart: 156ns for full bunch train
- ILC: trains at 5Hz, 1 train is 1300 bunches, 700ns apart

	ILC 0.5TeV	CLIC 3TeV
L $[\mathrm{cm}^{-2}\,\mathrm{s}^{-1}]$	2×10^{34}	5.9×10^{34}
Crossing angle	14mrad	20mrad
BX separation	700ns	0.5ns
Nb $\gamma\gamma \to \mathrm{had}$/BX	0.2	3.2
Nb incoherant pairs/BX	1×10^5	3×10^5

Very large machine induced background rate and very short time between bunches!

Outline



Physics Motivations

A few words on the CLIC machine and beam

The detector concepts

Background suppression

The benchmark channels

Summary

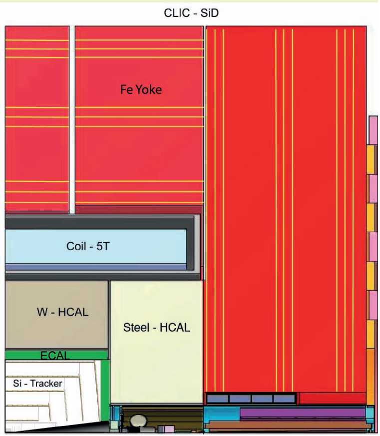
The detector requirements

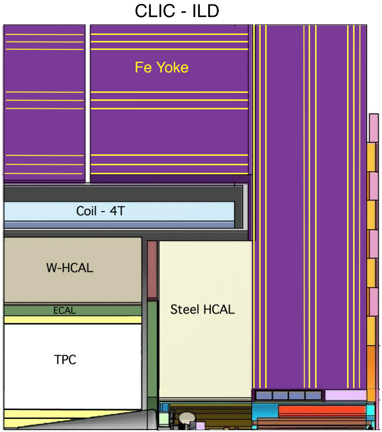
- Trigger less readout of full train: time stamping, multi-hit capacity, filtering algorithms during reconstruction
- High resolution pixel detector for displaced vertices identification:
  p = 1 Gev $\sigma_{d0} \sim 20\mu m$
  p = 100 GeV $\sigma_{d0} \sim 5\mu m$
- Momentum resolution:
  $\sigma(p_{\mathrm{T}})/p_{\mathrm{T}}^2 \sim 10^{-5}\mathrm{GeV}^{-1}$
- Good jet-energy resolution (W/Z separation)
  $\sigma(E_j)/E_j = 3.5\% - 5\%$ for $E_j = 50\mathrm{GeV} - 1\mathrm{TeV}$

The CLIC detectors

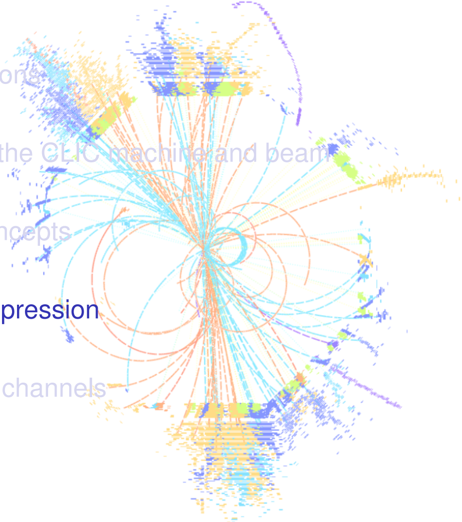
Main differences with ILC concepts:

- Denser barrel HCAL, using tungsten, $7.5\lambda_{\mathrm{I}}$
- Redesign of the vertex detector and forward region





Outline



Physics Motivations

A few words on the CLIC machine and beam

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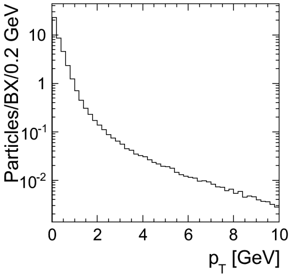
Summary

Background properties

Main problematic background: $\gamma\gamma \rightarrow \text{hadrons}$



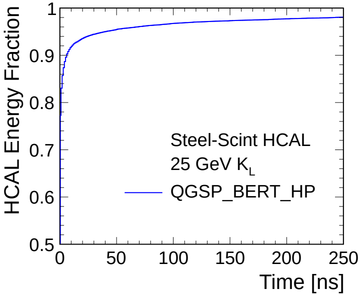
$\theta > 8^\circ$

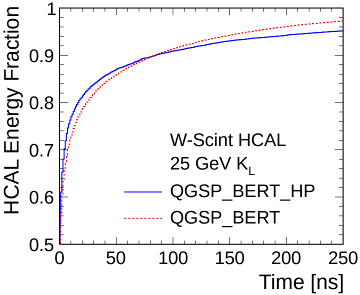
Entire bunch train (312BX):

- 5000 tracks $\rightarrow$ total track momentum: 7.3TeV
- Total calorimetric energy (ECAL+HCAL): 19TeV

Mostly low p_T

Background suppression: timing



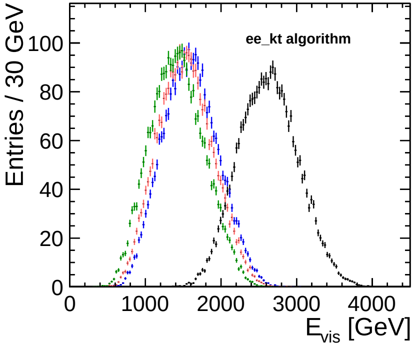


Subdetector	Reco. window	hit resolution
ECAL	10 ns	1 ns
HCAL Endcaps	10 ns	1 ns
HCAL Barrel	100 ns	1 ns
Silicon Detectors	10 ns	$10/\sqrt{12}$ ns

Background suppression: jet finder

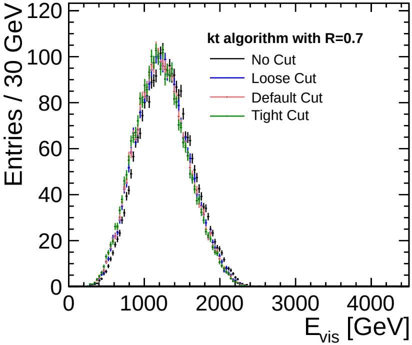
$e^+e^- \to \tilde{q}_R\bar{\tilde{q}}_R \to q\bar{q}\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$: 2 jets + missing energy

Durham k_T à la LEP:



- All particle clustered
- Timing cuts effective

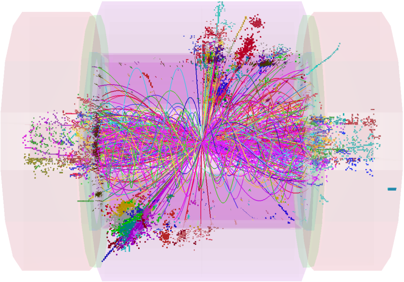
Hadron collider k_T:

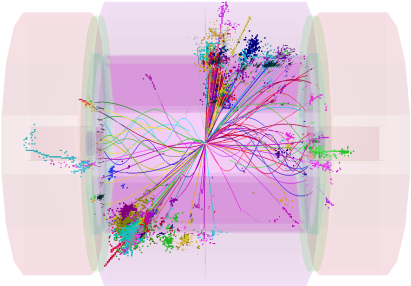


- Much of Bkg clustered with beam axis
- Timing cuts do less work
- Impact depends on event topology

Background suppression

E.g. $e^+e^- \to HH \to t\bar{b}b\bar{t}$:



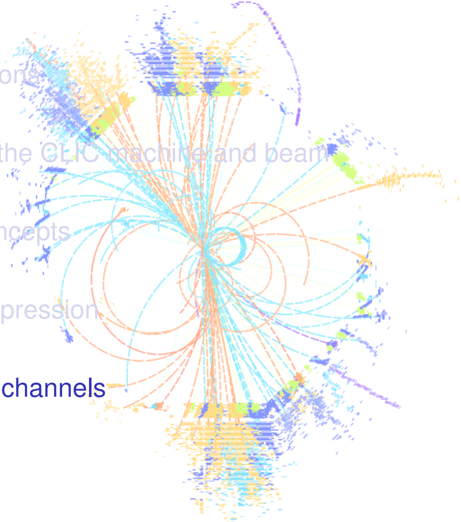


No cuts:
$\sim 1.2\text{TeV}$
10ns window

Tight timing cuts and jet finding:
$\sim 100\text{GeV}$

Using timing cuts and jet finding removes most of the background

Outline



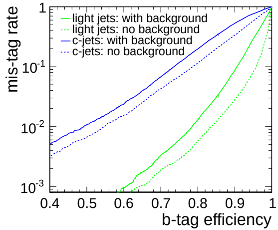
The benchmark channels

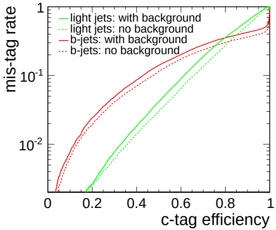
The benchmark channels used to assess detector performance:

- $e^+e^- \to h\nu_e\overline{\nu}_e, h \to \mu^+\mu^-, h \to b\overline{b}$ (SID),
- $e^+e^- \to H^+H^- \to t\overline{b}\overline{t}b$(ILD),
  $e^+e^- \to H^0A \to b\overline{b}b\overline{b}$ (ILD),
- $e^+e^- \to \widetilde{q}_R\overline{\widetilde{q}}_R \to q\overline{q}\widetilde{\chi}^0{}_1\widetilde{\chi}^0{}_1$ (ILD),
- $e^+e^- \to \widetilde{\ell}\overline{\widetilde{\ell}}(\ell = e, \mu, \nu_e)$ (ILD),
- $e^+e^- \to \widetilde{\chi}^\pm{}_1\widetilde{\chi}^\mp{}_1 \to W^+W^-\widetilde{\chi}^0{}_1\widetilde{\chi}^0{}_1$ (SID),
  $e^+e^- \to \widetilde{\chi}^0{}_2\widetilde{\chi}^0{}_2 \to hh\widetilde{\chi}^0{}_1\widetilde{\chi}^0{}_1$ (SID),
- $e^+e^- \to t\overline{t}$ (500 GeV, ILD).

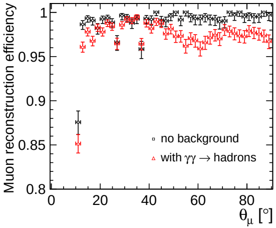
SM Higgs decays

Flavour tagging ($h \to b\bar{b}$):

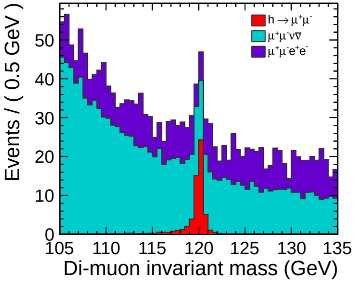


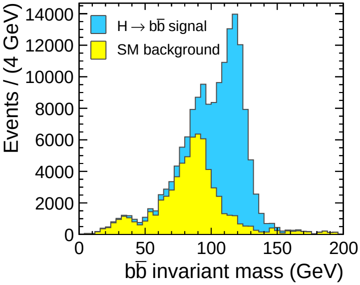


Muon reconstruction efficiency ($h \to \mu\mu$):



SM Higgs decays



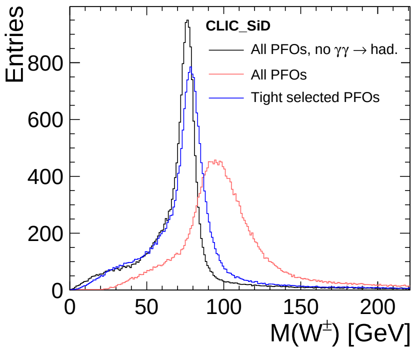


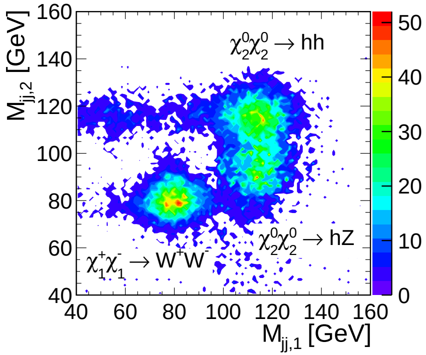
Cross section measurements:

- $\sigma(\sigma_{h\to b\bar{b}})/\sigma_{h\to b\bar{b}} = 0.22\%$ stat.
- $\sigma(\sigma_{h\to\mu^-\mu^+})/\sigma_{h\to\mu^-\mu^+} = 15.7\%$ stat.

Gauginos

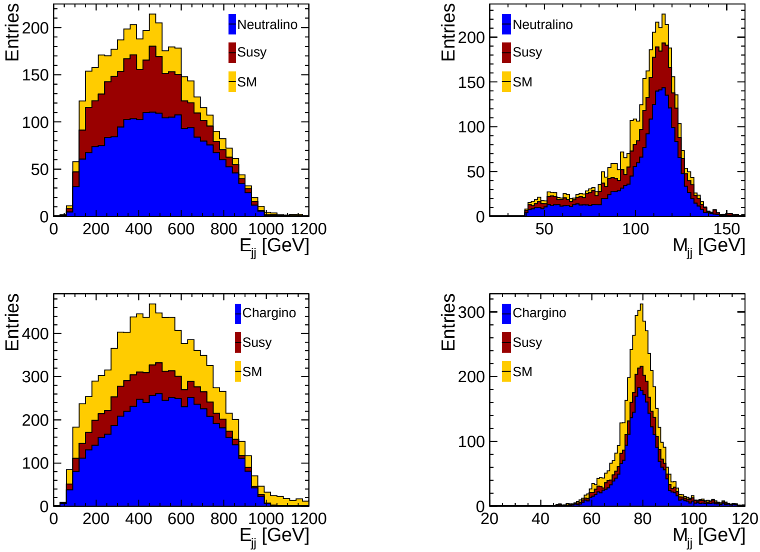
$e^+e^- \to \tilde{\chi}^{\pm}{}_1\tilde{\chi}^{\mp}{}_1 \to W^+W^-\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$ and $e^+e^- \to \tilde{\chi}^0{}_2\tilde{\chi}^0{}_2 \to hh\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$





Test of jet energy resolution

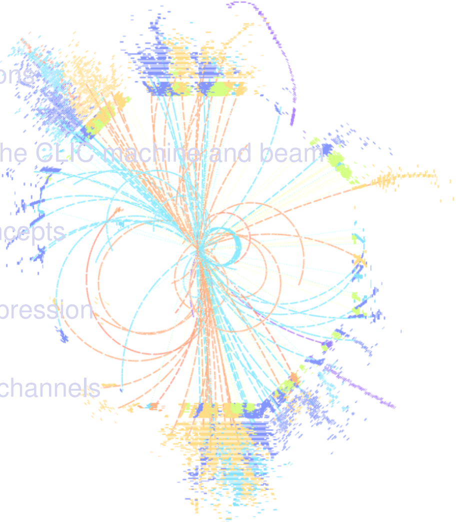
Gauginos


Entries
Neutralino
Susy
SM
E_{jj} [GeV]
0
50
100
150
200
0
200
400
600
800
1000
1200
Entries
Neutralino
Susy
SM
M_{jj} [GeV]
50
100
150
Entries
Chargino
Susy
SM
E_{jj} [GeV]
100
200
300
400
Entries
Chargino
Susy
SM
M_{jj} [GeV]
20
40
60
80
100
120
300

Gauginos

Parameter 1	Uncertainty	Parameter 2	Uncertainty
$M(\tilde{\chi}_1^{\pm})$	6.3 GeV	$\sigma(\tilde{\chi}_1^{+}\tilde{\chi}_1^{-})$	2.2%
$M(\tilde{\chi}_1^{0})$	3.0 GeV	$\sigma(\tilde{\chi}_1^{+}\tilde{\chi}_1^{-})$	1.8%
$M(\tilde{\chi}_2^{0})$	7.3 GeV	$\sigma(\tilde{\chi}_2^{0}\tilde{\chi}_2^{0})$	2.9%

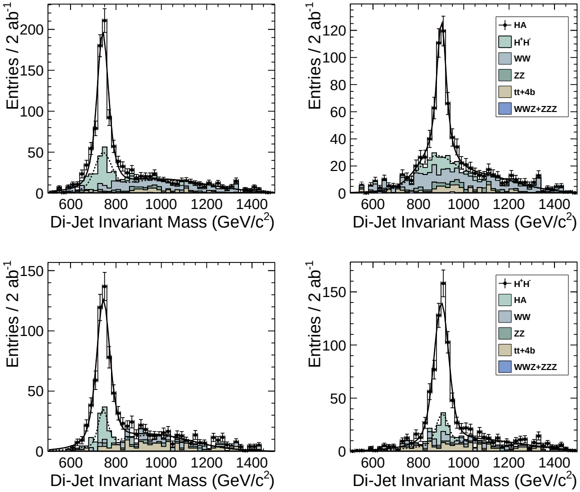
Outline



Summary

- Physics and detectors CDR is finalized: `https://edms.cern.ch/document/1176246`
- Signatories list is open, please show support: `https://indico.cern.ch/conferenceDisplay.py?confId=136364`
- Will be printed in Feb. 2012
- Additionnal volume next year: staged energy approach for 500GeV, 1.5TeV, 3TeV

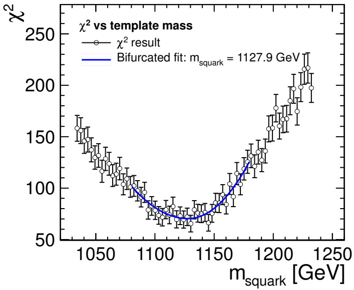
Heavy Higgs: $H^0A \to b\bar{b}b\bar{b}$, $H^+H^- \to t\bar{b}b\bar{t}$

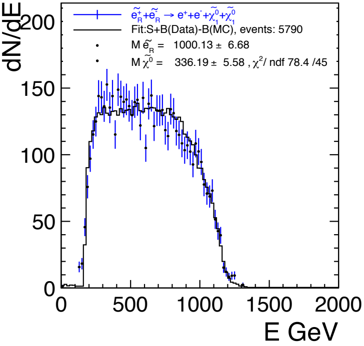


Statistical accuracy $\sigma(M)/M \sim 0.3\%$.

$\Rightarrow$ Evaluation of b-tagging and heavy jet reconstruction

Squarks and Sleptons





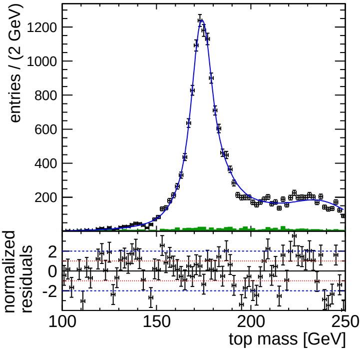
$$\sigma(m_{\tilde{q}_R})/m_{\tilde{q}_R} = 0.5\%$$

$$\sigma(m_{\tilde{\mu}_R})/m_{\tilde{\mu}_R} = 0.6\%$$
$$\sigma(m_{\tilde{e}_R})/m_{\tilde{e}_R} = 0.3\%$$
$$\sigma(m_{\tilde{\chi}_1^0})/m_{\tilde{\chi}_1^0} = 1-2\%$$

$\Rightarrow$ Tests of jet reconstruction and Particle ID

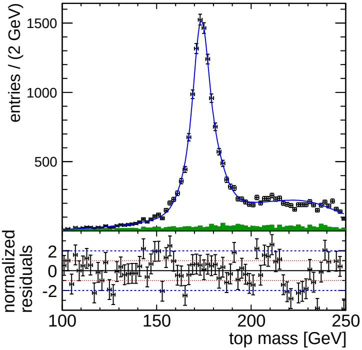
Top physics at 500GeV

Semi-leptonic decay:



Top mass (GeV)	Top width (GeV)
174.28 ± 0.09	1.55 ± 0.26

Fully-hadronic decay:



Top mass (GeV)	Top width (GeV)
174.07 ± 0.08	1.33 ± 0.22

$\Rightarrow$ Compares well with ILC