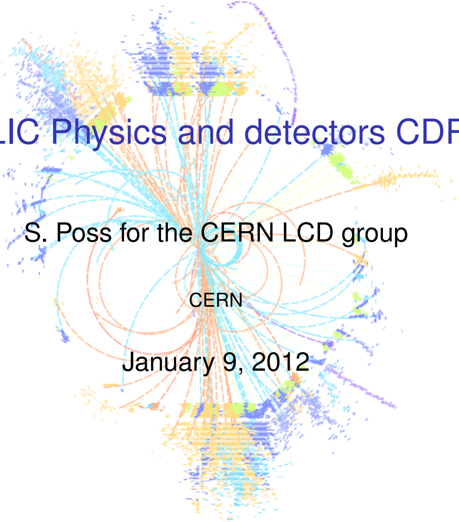


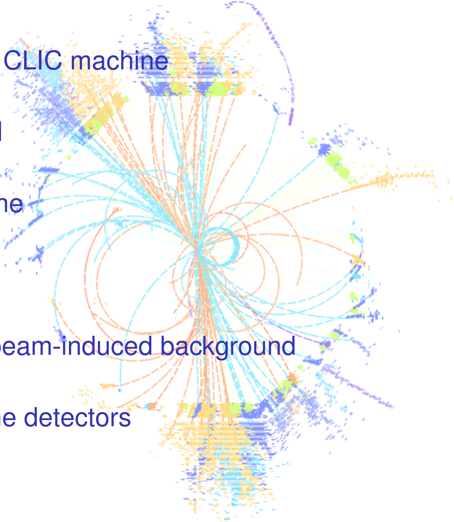
CLIC Physics and detectors CDR

S. Poss for the CERN LCD group

CERN

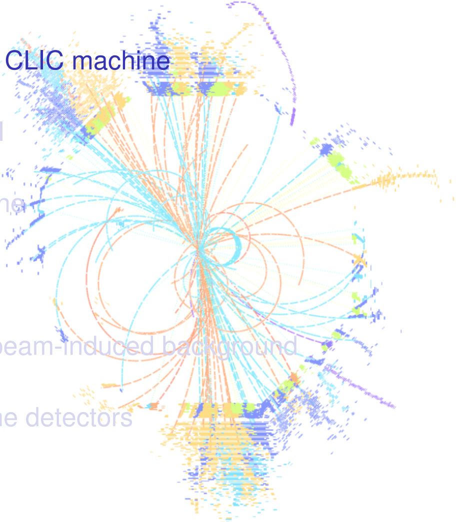
January 9, 2012

Outline



- Motivations for a CLIC machine
- Physics Potential
- The CLIC Machine
- The Detectors
- Suppression of beam-induced background
- Benchmarking the detectors
- Conclusion

Outline



Motivations for a CLIC machine

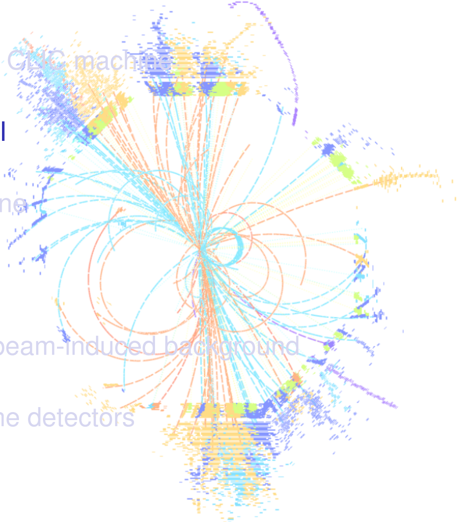
CLIC: Compact LInear Collider

- e^+e^- collisions up to $\sqrt{s} = 3$TeV c.m.
- Machine environment challenging

CLIC physics potential:

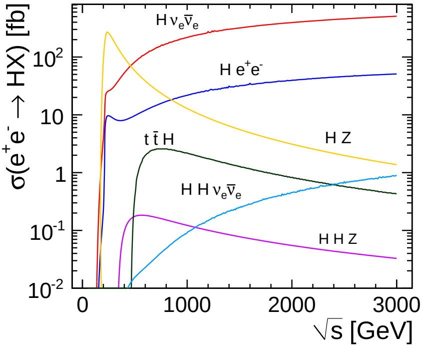
- Complementary to LHC
- Cleaner environment
- Precision Higgs physics, SUSY studies, etc.
- New physics beyond the LHC reach

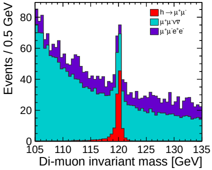
Outline

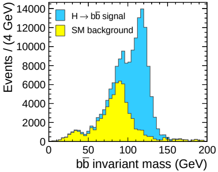


SM Higgs

High precision measurement of its fundamental properties: mass, total decay width, spin-parity quantum numbers, couplings to fermions and gauge bosons and self couplings





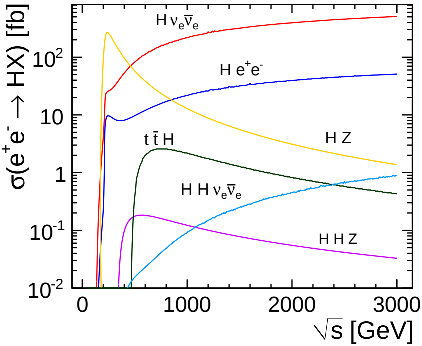


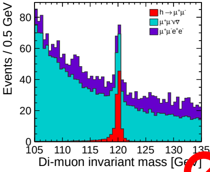
Coupling	precision at 3TeV
$g_{\mathrm{H}\to b\bar{b}}$	2%
$g_{\mathrm{H}\to c\bar{c}}$	3%
$g_{\mathrm{H}\to \mu\mu}$	15%

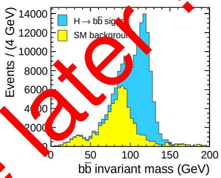
Ongoing studies for self coupling λ_{HHH}.

SM Higgs

High precision measurement of its fundamental properties: mass, total decay width, spin-parity quantum numbers, couplings to fermions and gauge bosons and self couplings







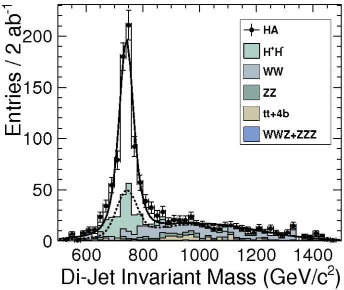
Coupling	precision at 3TeV
$g_{H\to b\bar{b}}$	2%
$g_{H\to c\bar{c}}$	3%
$g_{H\to\mu\mu}$	15%

More later!

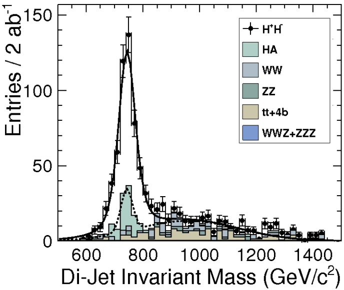
Ongoing studies for self coupling λ_{HHH}.

BSM Higgs

$e^+e^- \to HA \to b\bar{b}b\bar{b}$



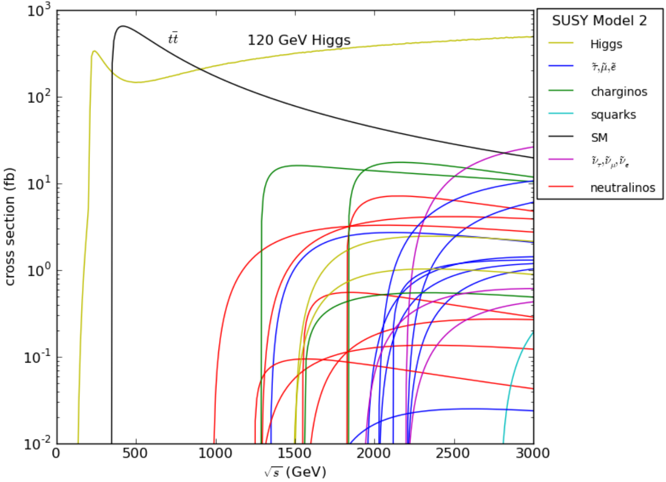
$e^+e^- \to H^+H^- \to t\bar{b}\bar{t}b$



	$\sigma(m)/m$	$\sigma(\Gamma)/\Gamma$
A/H	0.002	0.10
$H^\pm$	0.005	0.15

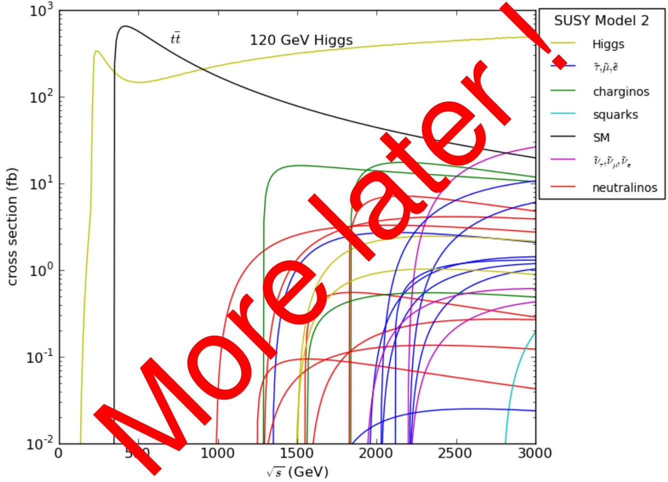
$\Rightarrow$ determination of $\sigma(\tan\beta)/\tan\beta < 0.06$.

SUSY



Study chargino and neutralino masses by measuring kinematic endpoints of the energy distributions, in channels like $\widetilde{\chi}_2^0 \to h\widetilde{\chi}_1^0$

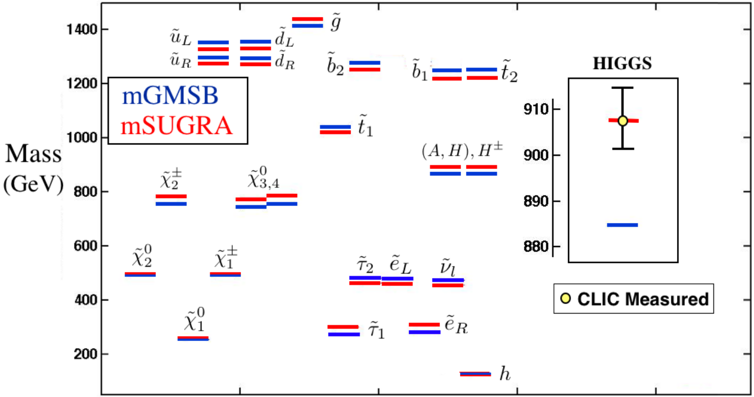
SUSY



Study chargino and neutralino masses by measuring kinematic endpoints of the energy distributions, in channels like $\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$

SUSY

Susy breaking models separation capability:



Other studies

- High scale stucture of SUSY
- Neutralino Dark Matter hypothesis
- Higgs strong interaction
- Z'
- Contact interaction
- Extra dimensions

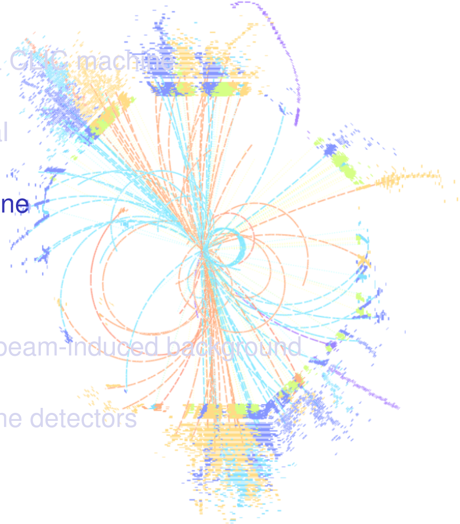
Physics potential summary

Machine 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

CLIC can

- extend the discovery reach of LHC,
- offer the opportunity of precise measurements of masses and couplings.

Outline



Motivations for a CLIC machine

Physics Potential

The CLIC Machine

The Detectors

Suppression of beam-induced background

Benchmarking the detectors

Conclusion

CLIC machine Conceptual Design Report

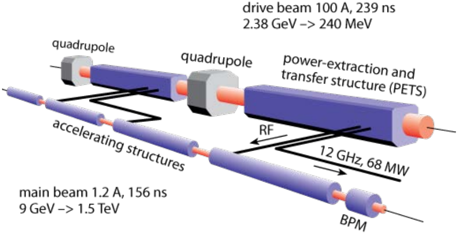
- Released later in 2012
- Addresses the 3TeV case, the most difficult
- Presents the different technical aspects of a CLIC machine
- Details the machine properties
- Demonstrates (with hardware tests) the feasibility of such machine

Here: brief overview of the CLIC properties

CLIC Technology

2 beam acceleration scheme:
drive beam and main beam

- Gradient 100 MV/m
- Energy: from few-hundred GeV upgradable in steps up to 3 TeV; R&D has focused on 3 TeV



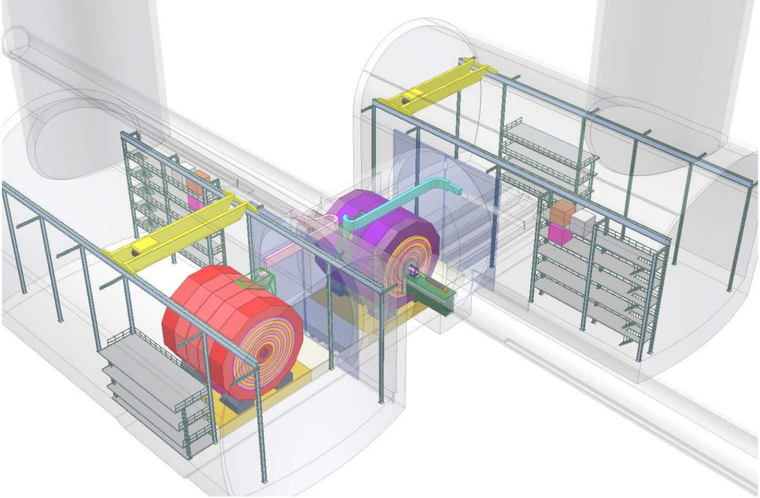
CLIC properties

	CLIC 0.5TeV	CLIC 3TeV
L $[\mathrm{cm}^{-2}\,\mathrm{s}^{-1}]$	2.3×10^{34}	5.9×10^{34}
Bunch crossing separation	0.5 ns	0.5 ns
Bunch crossings per train	354	312
Train repetition rate	50 Hz	50 Hz
Crossing angle	20mrad	20mrad

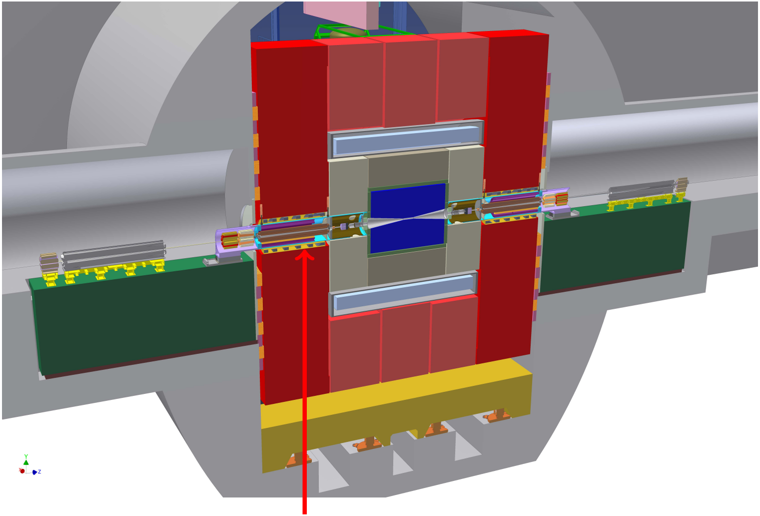
Whole bunch train in 156ns.

Machine Detector Interface

Push-Pull system:



Machine Detector Interface



Last accelerator element is IN the detector

Beam-induced backgrounds

	CLIC 0.5TeV	CLIC 3TeV
Nb $\gamma\gamma \to \mathrm{had}$/BX	0.2	3.2
Nb incoherant pairs/BX	0.8×10^5	3×10^5
Nb coherent pairs/BX	10^2	3.8×10^8

Very large beam-induced background rates!

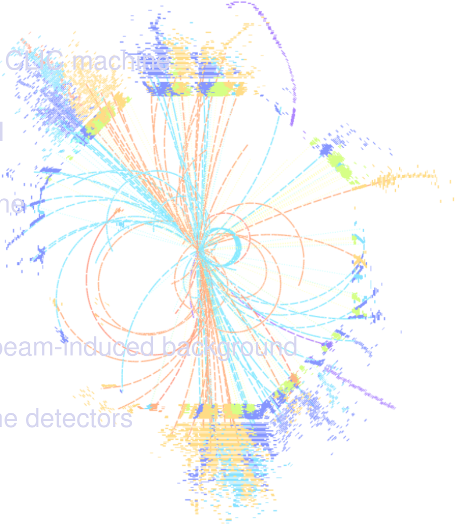
- Coherent pairs very forward
- Incoherent pairs mostly forward

$\to$ impact on the very forward detectors design

- $\gamma\gamma \to \mathrm{hadrons}$ all over the detector acceptance.

Need to deal with those

Outline



Required performance

- 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)
  $\sigma(E_j)/E_j = 5\% - 3.5\%$ for $E_j = 50\mathrm{GeV} - 1\mathrm{TeV}$

Particle Flow Paradigm

Jet energy:

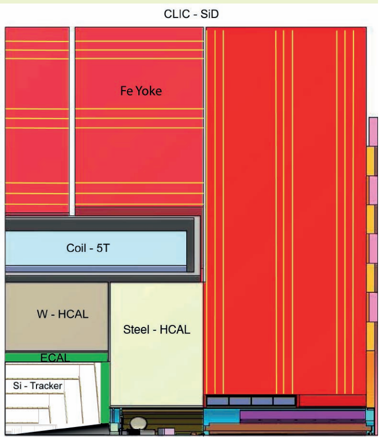
- 60% carried by charged particles
- 30% by photons
- 10% by long-lived neutral hadrons

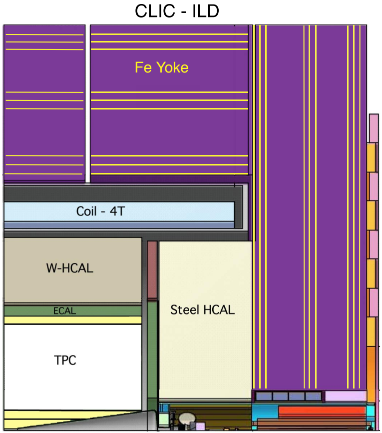
Particle Flow: reconstruction of the 4-momenta of all visible particles:

- momenta measured in the tracking detectors for charged particles
- energy measured in the calorimeters for photons and neutral hadrons

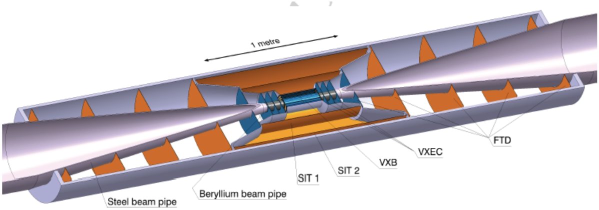
$\Rightarrow$ need for high precision tracking and high granularity calorimeters

Overview


CLIC - SiD
Fe Yoke
Coil - 5T
W - HCAL
Steel - HCAL
ECAL
Si - Tracker


CLIC - ILD
Fe Yoke
Coil - 4T
W-HCAL
ECAL
Steel HCAL
TPC

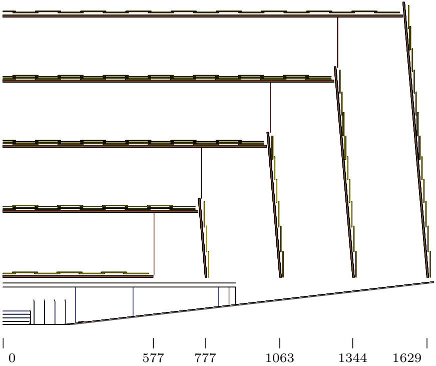
Vertex detector optimization



- $20 \times 20 \mu m$ pixel size
- 0.2% X_0 material per layer (very thin)
- Time stamping 10ns
- Triggerless readout
- Radiation level $< 10^{11} n_{eq} cm^{-2} year^{-1} \Leftarrow 10^4 \times$ lower than LHC

Challenging R&D project

Tracking in CLIC_SiD

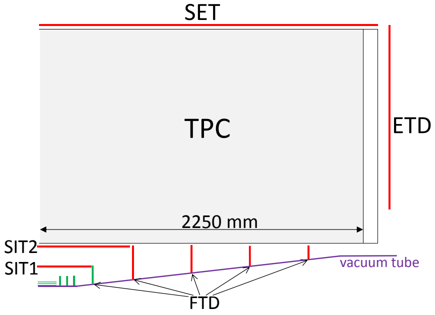


- All silicon tracking
- Efficiency ($p_T > 1$GeV): $> 99\%$
- Mom. resolution: $\sigma(\Delta(p_T)/p_T^2) < 2 \cdot 10^{-5}/\text{GeV}$

Compatible with requirements

Hardware development to be carried out to demonstrate this.

Tracking in CLIC_ILD



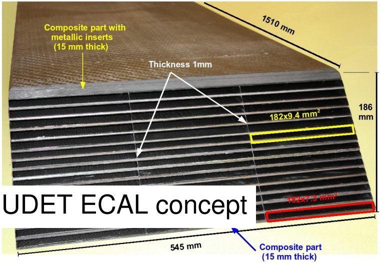
- Time Projection Chamber
- Completed by silicon layers
- Efficiency ($p_{\mathrm{T}} > 1\mathrm{GeV}$): $> 99\%$
- Mom. resolution: $\sigma(\Delta(p_{\mathrm{T}})/p_{\mathrm{T}}^2) \sim 2 \cdot 10^{-5}/\mathrm{GeV}$

Compatible with requirements

Hardware development to be carried out to demonstrate this.

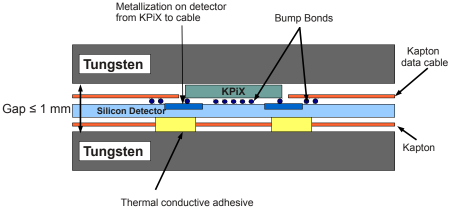
ECAL

	CLIC_ILD	CLIC_SiD
Absorber/Active element	Tungsten / Si Pads	Tungsten / Si Pads
Sampling layers	$30(20\times 2.1, 10\times 4.2)$	$30(20\times 2.1, 10\times 5)$
Cell size (mm^2)	5.1×5.1	3.5×3.5
X_0 and λ_I	23 & 1	26 &1



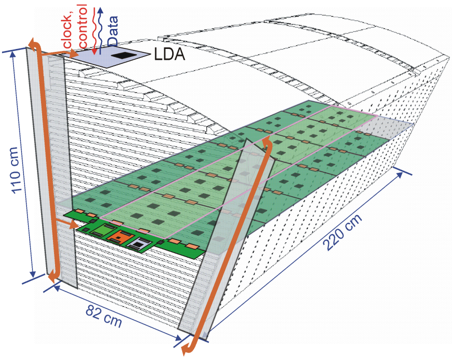
EUDET ECAL concept

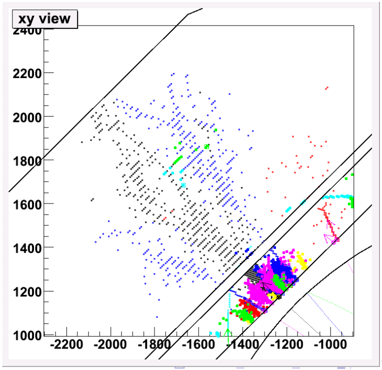
SiD design:



HCAL

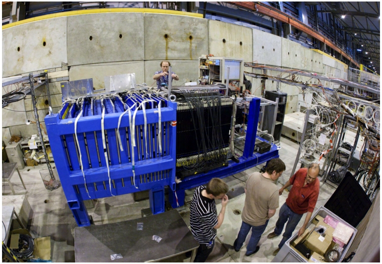
Absorber (Barrel/Endcap)	Tungsten / Steel
Sampling layers (B/E)	$75 \times$ 10mm/ $60 \times$ 20mm
Cell size (mm^2)	30×30 (SiPM), 10×10 (RPC)
λ_I	7.5

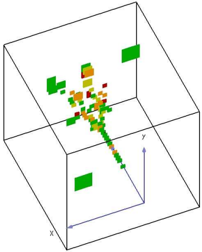




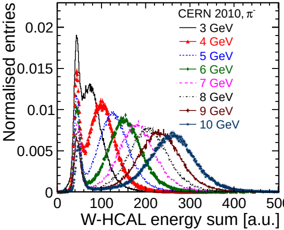
CALICE beam tests for W-HCAL

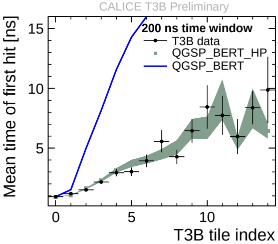
Validation of GEANT4 simulation for hadronic showers in tungsten



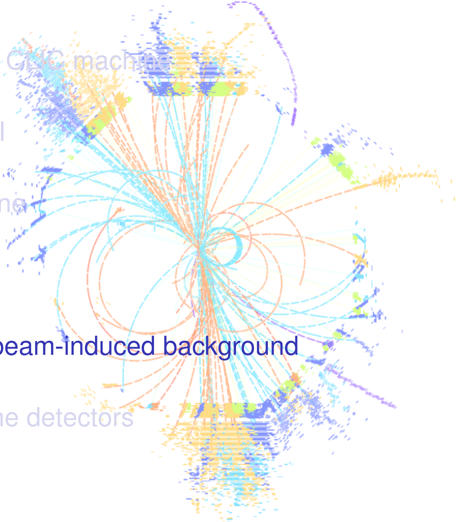


Test beam period in 2010-2011
Analysis ongoing





Outline



Motivations for a CLIC machine

Physics Potential

The CLIC Machine

The Detectors

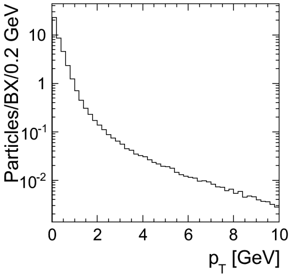
Suppression of beam-induced background

Benchmarking the detectors

Conclusion

Background properties

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



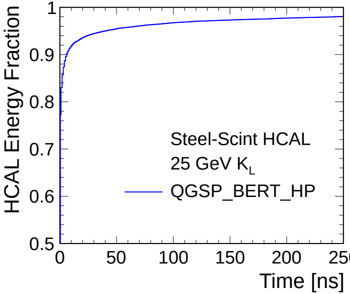
$\theta > 8^\circ$

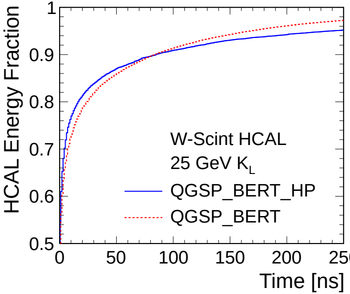
Entire bunch train (312BX):

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

Mostly low p_T

Timing cuts





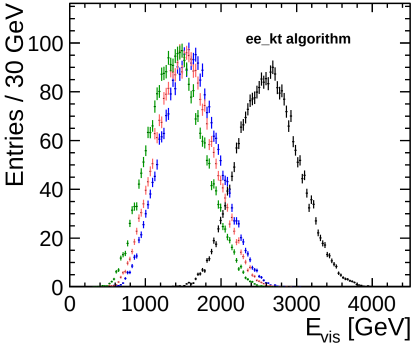
Subdetector	Reco. window	hit resolution
ECAL	10 ns	1 ns
HCAL Endcaps	10 ns	1 ns
HCAL Barrel	100 ns	1 ns
Silicon Detectors	10 ns	$10/\sqrt{12}$ ns
TPC	entire bunch train	n/a

Additionnal timing cuts applied on reconstructed particles.

Jet finder

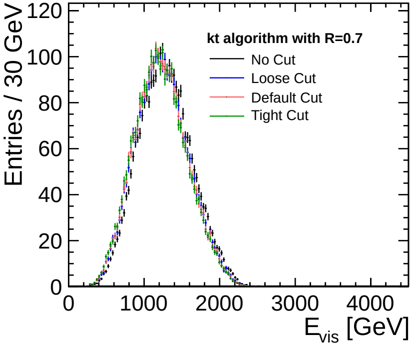
$e^+e^- \rightarrow \tilde{q}_R\bar{\tilde{q}}_R \rightarrow q\bar{q}\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$: 2 jets + missing energy

Durham k_{T} à la LEP:



- All particle clustered
- Timing cuts effective

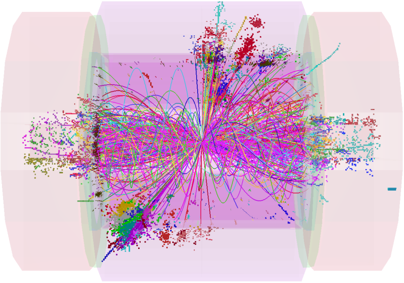
Hadron collider k_{T}:



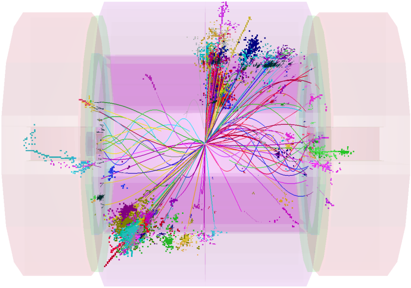
- Much of Bkg clustered with beam axis
- Timing cuts do less work
- Impact depends on event topology

Background suppression

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



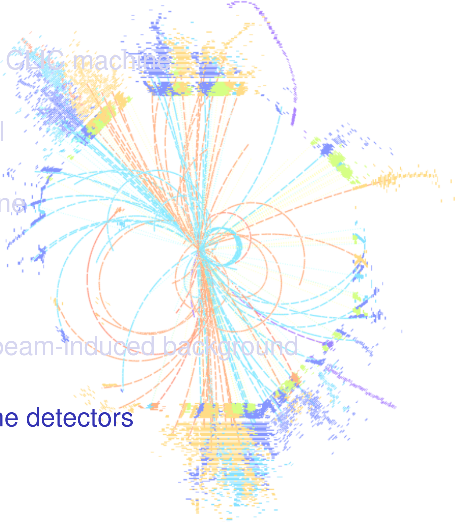
No cuts:
$\sim 1.2\text{TeV}$
10ns window



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

Using timing cuts and jet finding removes most of the background

Outline



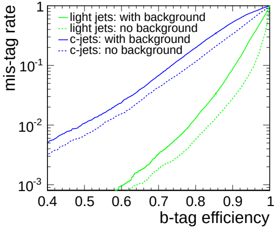
Benchmark channels

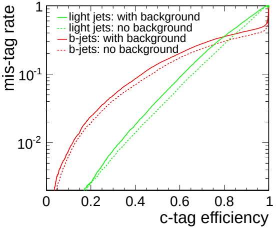
The benchmark channels used to assess detector performance:

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

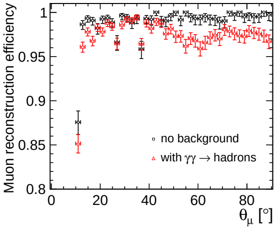
SM Higgs decays

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

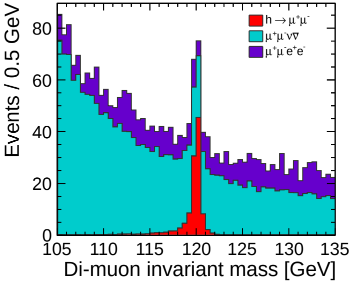


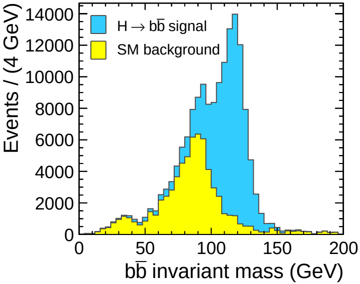


Muon reconstruction efficiency ($h \to \mu\mu$):



SM Higgs decays

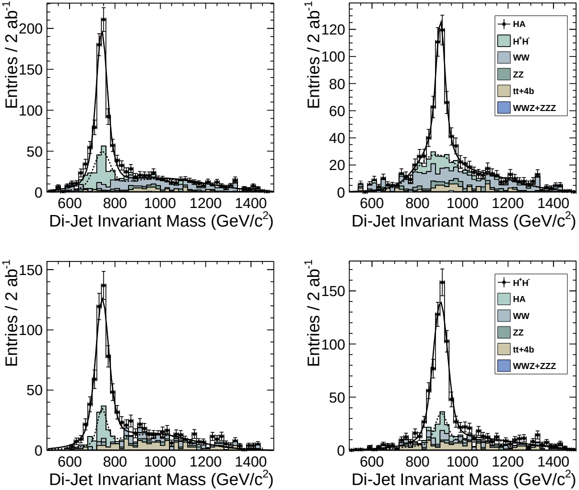




Cross section measurements:

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

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



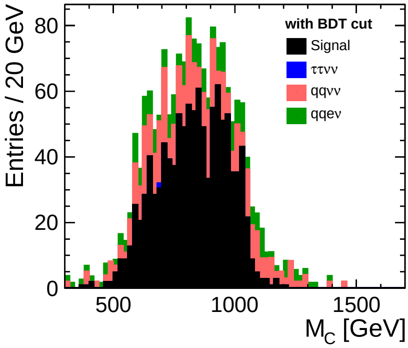
Statistical accuracy $\sigma(M)/M \sim 0.3\%$.

$\Rightarrow$ Evaluation of b-tagging and high energy jet reconstruction

Squarks: $e^+e^- \rightarrow \tilde{q}_R\bar{\tilde{q}}_R \rightarrow q\bar{q}\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$

Used for jet and missing energy reconstruction studies (see background treatment)

Measuring $M_C = \sqrt{2(E_1E_2 + \vec{p}_1.\vec{p}_2)}$, $M_C^{max} = \frac{m_{\tilde{q}}^2 - m_{\chi}^2}{m_{\tilde{q}}}$:



Selection cuts applied

From template fit using $2ab^{-1}$ ($\approx$ 4 years):

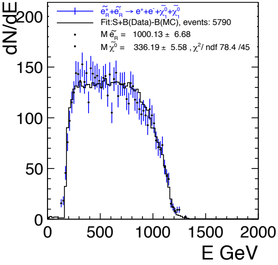
$\sigma(m_{\tilde{q}})/m_{\tilde{q}}$	0.5%
$\sigma(\text{xsec})/\text{xsec}$	5%

Very high stat. precision!

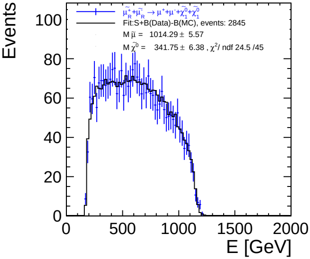
Sleptons: $e^+e^- \to \tilde{\ell}\bar{\tilde{\ell}} \, (\ell = e, \mu, \nu_e)$

Probe of lepton ID and reconstruction

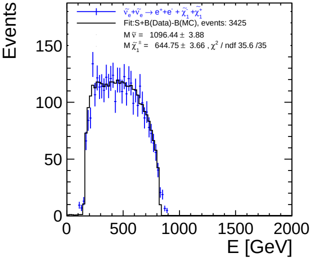
Selectrons



Smuons



Sneutrinos



Mass obtained from the end points

Sleptons: $e^+e^- \to \tilde{\ell}\bar{\tilde{\ell}} \, (\ell = e, \mu, \nu_e)$

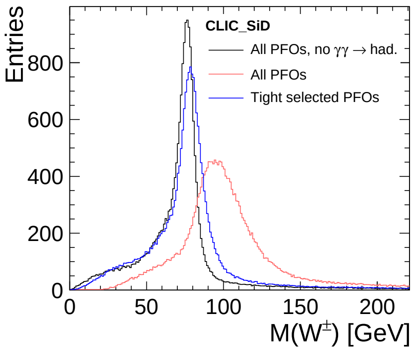
With $2ab^{-1}$:

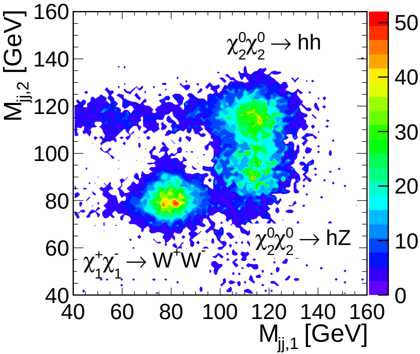
process	$\sigma(\text{xsec})/\text{xsec}$	$\sigma(m_{\tilde{\ell}})/m_{\tilde{\ell}}$
$e^+e^- \to \tilde{\mu}_R \bar{\tilde{\mu}}_R \to \mu^+\mu^- \tilde{\chi}^0{}_1 \tilde{\chi}^0{}_1$	2.8%	0.6%
$e^+e^- \to \tilde{e}_R \bar{\tilde{e}}_R \to e^+e^- \tilde{\chi}^0{}_1 \tilde{\chi}^0{}_1$	0.8%	0.3%
$e^+e^- \to \tilde{\nu}_e \bar{\tilde{\nu}}_e \to e^+e^- \tilde{\chi}_1^+ \tilde{\chi}_1^-$	$\sim 2.4\%$	$\sim 0.4\%$
$e^+e^- \to \tilde{e}_L \bar{\tilde{e}}_L \to e^+e^- \tilde{\chi}^0{}_2 \tilde{\chi}^0{}_2$	$\sim 7.0\%$	-

Very high stat. precision!

Gauginos

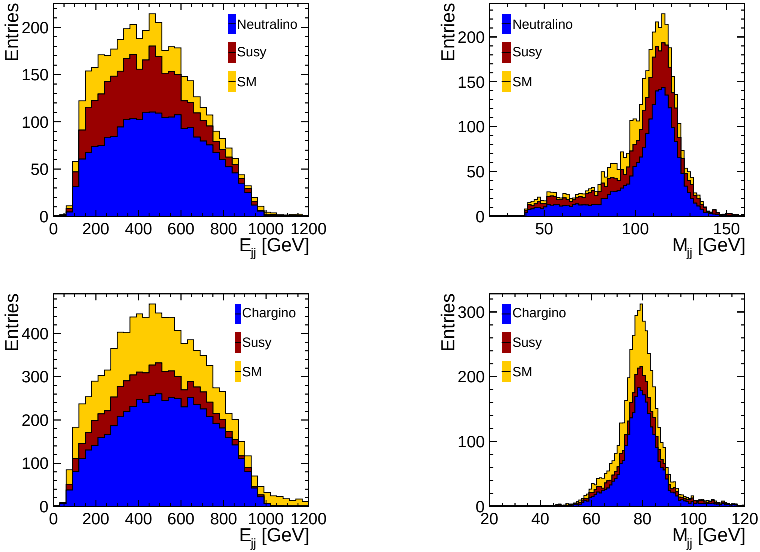
$e^+e^- \to \tilde{\chi}^{\pm}{}_1\tilde{\chi}^{\mp}{}_1 \to W^+W^-\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$ and $e^+e^- \to \tilde{\chi}^0{}_2\tilde{\chi}^0{}_2 \to hh\tilde{\chi}^0{}_1\tilde{\chi}^0{}_1$





Test of jet energy resolution

Gauginos


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

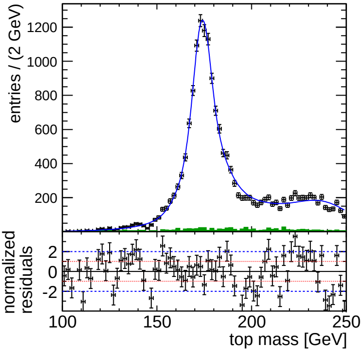
Gauginos

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%

Top physics at 500 GeV

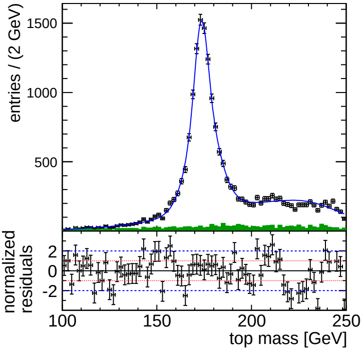
Needed change in design of the vertex detector region

Semi-leptonic decay:



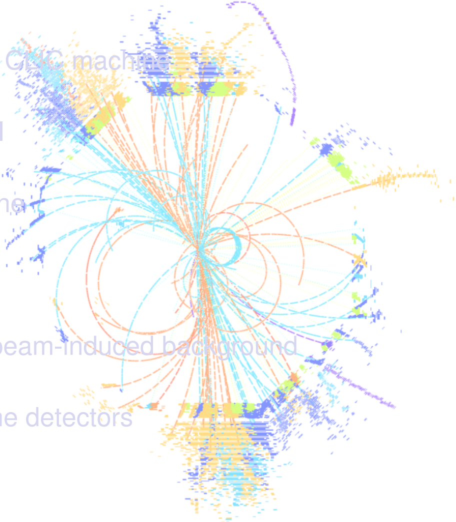
Top mass (GeV)	Top width (GeV)
174.28 ± 0.09	1.55 ± 0.26

Fully-hadronic decay:



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

Outline



Overview

- Introduced the CLIC machine
- Presented the CLIC detectors concept
- Assessment of the physics potential of a future multi-TeV e^+e^- collider was made, specificaly at 3TeV
- Physics signals with mass scale $100 - 1500$GeV can be extracted with good precision
- Shown that it's possible to deal with the beam-induced background
- CDR physics and detector study part of a world-wide effort, broad international participation
- Further in-depth studies and hardware R&D for the CLIC detectors are forseen: more detailed simulation, different c-m-e studied
- Follow up of LHC results

Signatory list

You are cordially invited to subscribe to the CDR Signatories List:

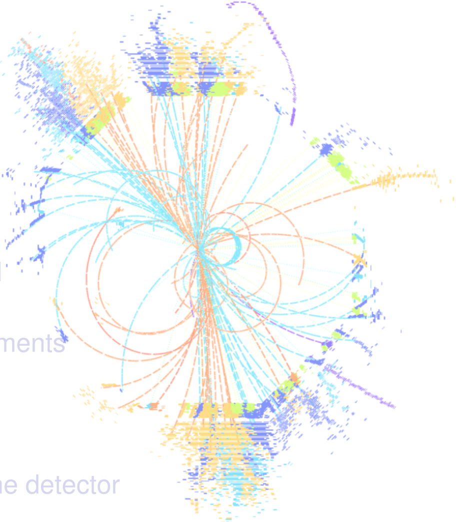
- *If you have made contributions to the CLIC accelerator or the Linear Colliders Physics and Detector studies, or intend to contribute in the future,*

OR / AND

- *If you wish to express support to the physics case and the study of a multi-TeV Linear Collider based on the CLIC technology, and its detector concepts.*

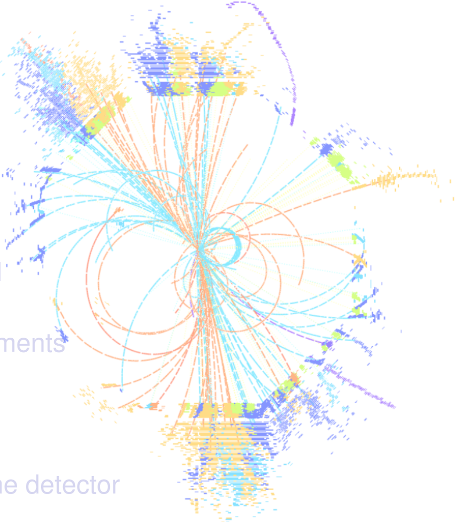
https://indico.cern.ch/conferenceDisplay.py?confId=136364

Outline



Backup slides

Outline



Generation

Use WHIZARD:

- Computes proper matrix elements at tree level (OMEGA)
- Explicit up to 6 fermion final states
- Handles SUSY (LesHouches)
- Writes out stdhep (format used for simulation)
- Common for the 2 detectors

Use PYTHIA for $\mathrm{t\bar{t}}$, WW, ZZ as final states in WHIZARD have no width

Simulation

2 detectors $\rightarrow$ 2 sim software

- Mokka (ILD): Calls G4, Detector geometry obtained from MySQL DB (!!)
- SLIC (SiD): wrapper around G4, detector geometry imported using compact XML
- Both use the LCIO event format

Frameworks are going to be merged eventually, work ongoing

Handling background in the software

$\gamma\gamma$ bkg overlayed on top of simulated events

- Simulate the bkg separately
- For 1 signal event, read N events of bkg (Poisson distribution, $\mu = 3.2$) $\times$ 60 BX
- Merge the clusters
- Save the resulting collections (containers)

Reconstruction

As for simulation: 2 frameworks

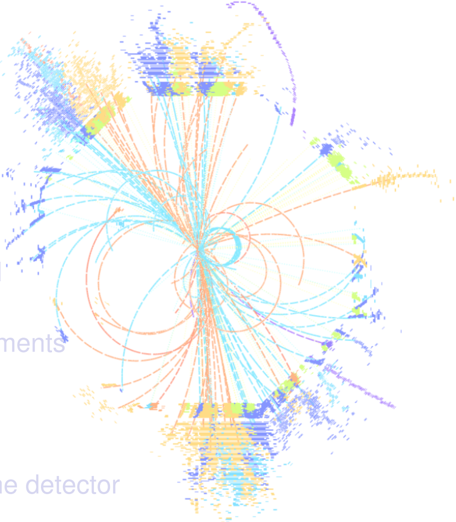
- Marlin (ILD): C++
- `org.lcsim`: JAVA
- Usual modular algorithm/tools structure (e.g. GAUDI)
- Use the LCIO event format

Using the GRID: ILCDIRAC

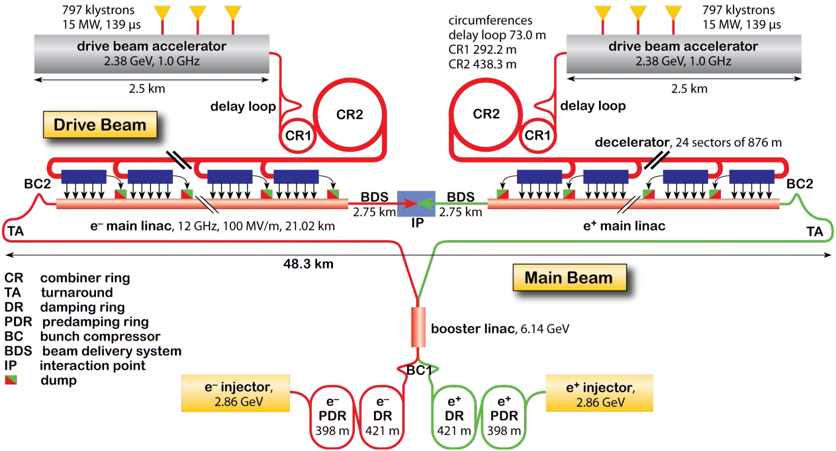
Grid production tool based on DIRAC

- Extented to fit the CLIC study use case: application handling, data, etc.
- $>$ 4million jobs in 1 year
- Now also used for the ILC_SiD studies

Outline



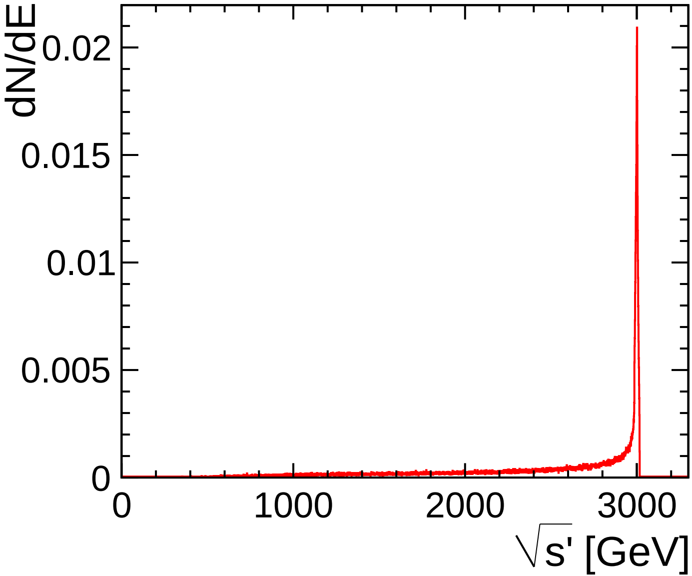
Accelerator complex



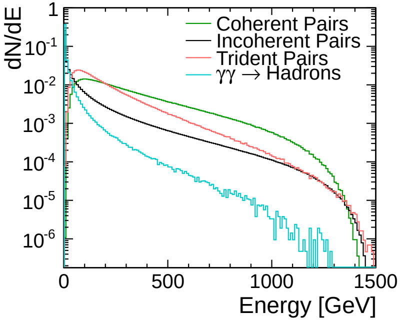
CLIC numerical properties

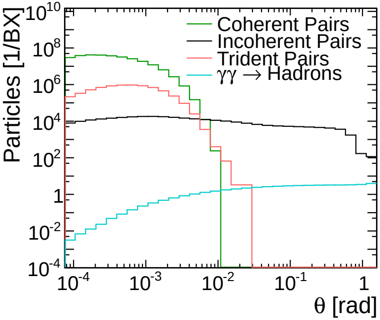
Acceleration field	100MV/m
RF frequency of the main linac	12GHz
Beam focusing at IP	68μm
Charge per bunch	3.7×10^9
Bunch interval	0.5 ns
Bunch per train	312
Linac repetition rate	50Hz
Beam power	14MW
Normalized vertical emittance	2×10^{-8}mrad
Vertical beam size (IP)	1nm
Horizontal beam size (IP)	40nm
Total power consumption	560MW

Luminosity spectrum



Beam-induced background





Beam halo muons estimated to be $\sim$ 1 per 20 BX: neglected

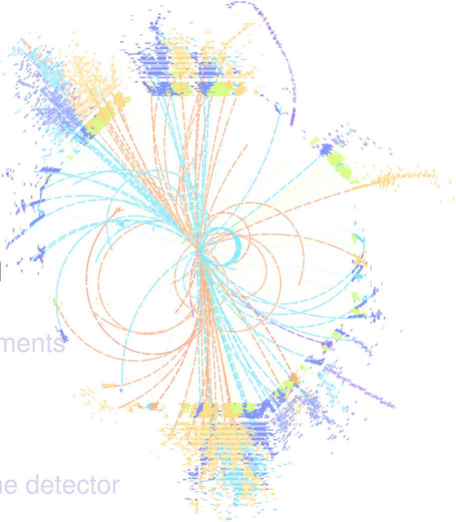
Beam Polarization

Not studied in this document, planned for volume 3.

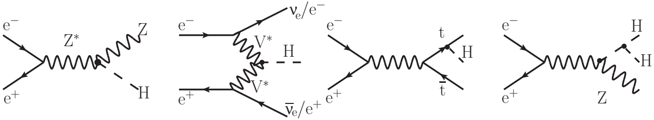
Polarized electron beam up to 80%.

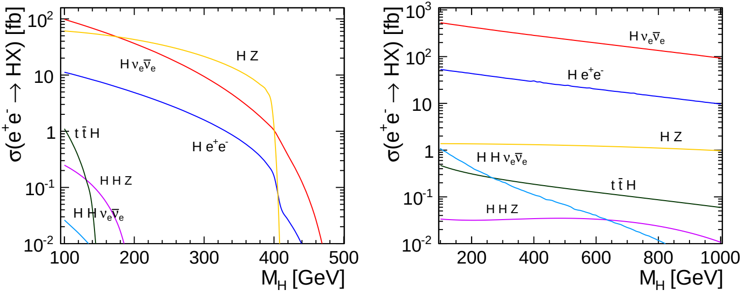
Polarized positron beam $\sim 30\%$ planned for a later stage

Outline



Higgs production





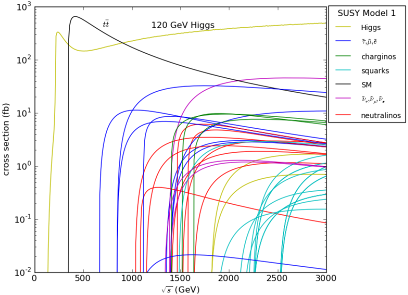
Higgs sensitivity

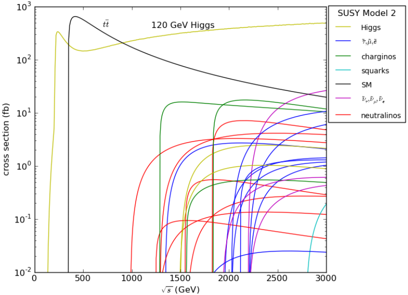
- $g_{\mathrm{H}\to\mu\mu}$: 15% for 4 years
- $g_{\mathrm{H}\to\mathrm{b\bar{b}}}$: 0.22% on $\sigma \times B$. Theoretical uncertainties are dominating: $\pm 2-4\%$
- $g_{\mathrm{H}\to\mathrm{c\bar{c}}}$: 3.24% on $\sigma \times B$. With theoretical uncertainty: $\pm 3-6\%$

Other searches:

- Trilinear couplings: $\mathrm{e^+e^-} \to \nu_e \bar{\nu}_e HH$ (WW fusion)
- Anomalous Higgs couplings

SUSY Models



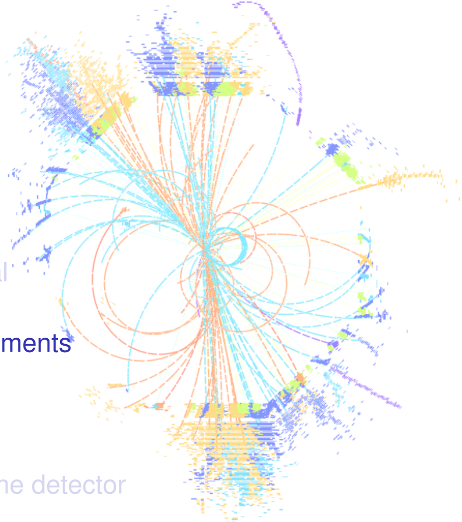


Precise measurement of fundamental parameters

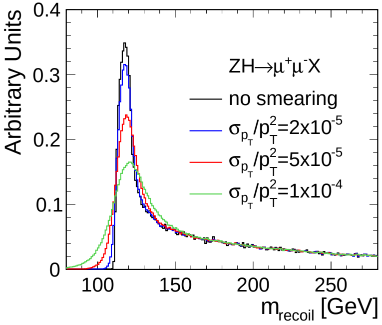
Tests of the high-scale structure of the theory (GUT)

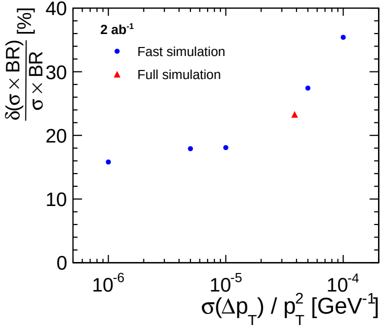
Testing the neutralino dark matter hypothesis

Outline

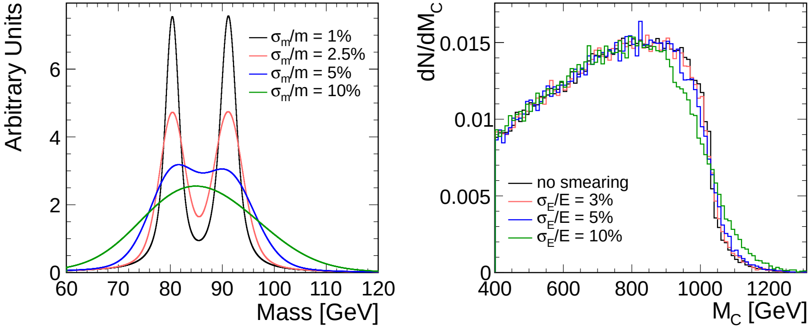


Track momentum resolution

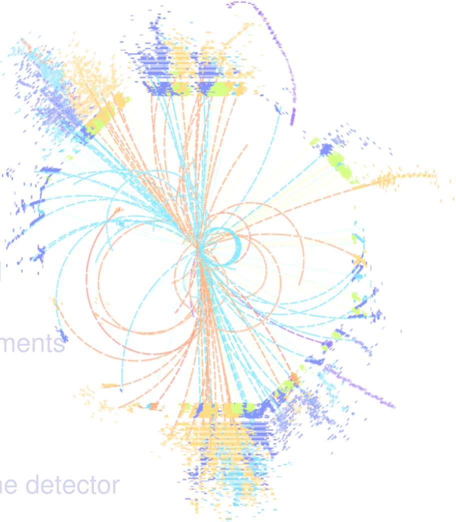




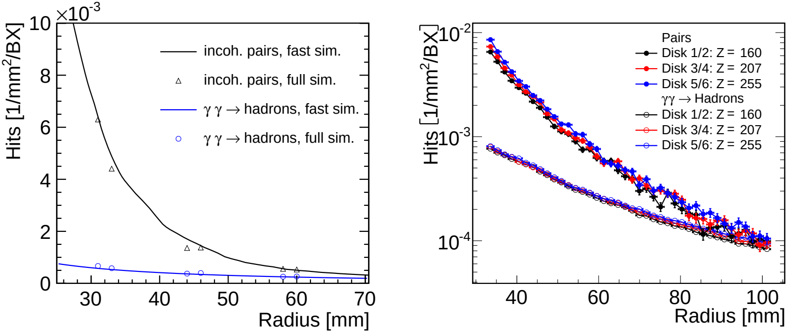
Jet energy resolution



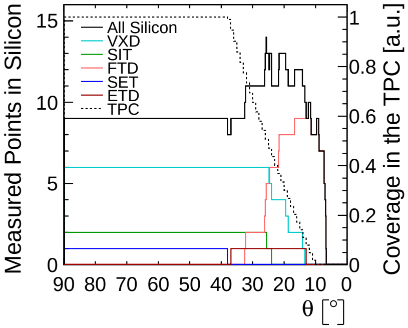
Outline

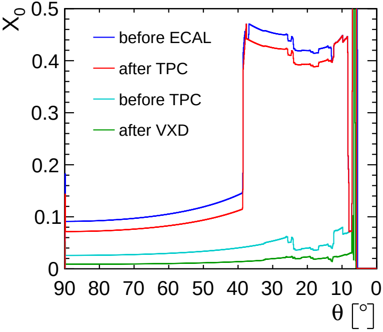


Vertex detector

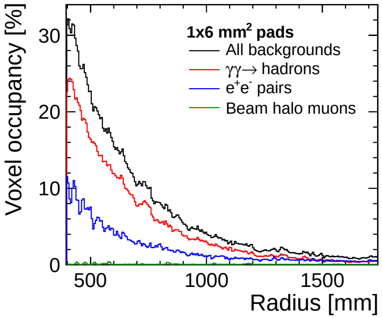


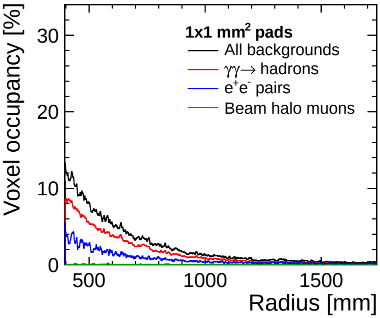
Tracking detectors: ILD TPC



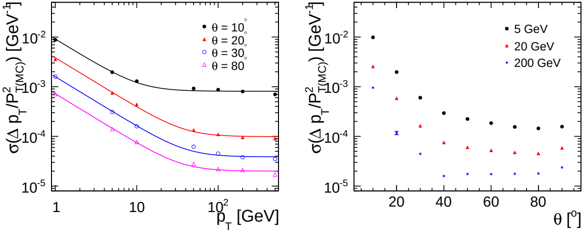


Occupancy in the TPC

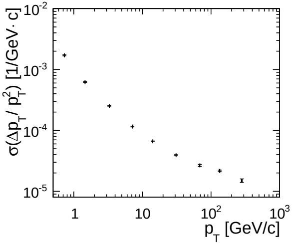




Tracking performance in the TPC



Single muons

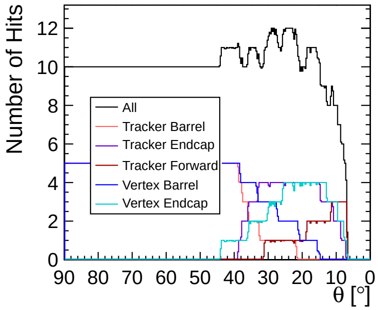


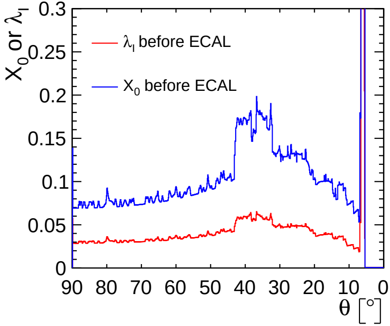
$t\bar{t}$ events

$$\sigma(\Delta p_{\mathrm{T}}/p_{\mathrm{T}}^2) = a \oplus \frac{b}{p \sin\theta}$$

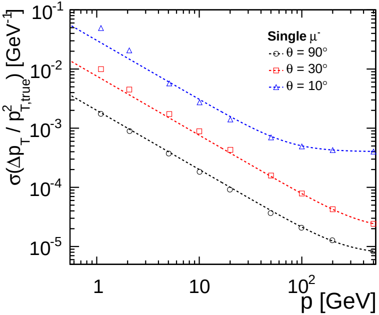
θ [°]	a [GeV^{-1}]	b
10	$8.19 \cdot 10^{-4}$	$9.07 \cdot 10^{-3}$
20	$9.86 \cdot 10^{-5}$	$3.83 \cdot 10^{-3}$
30	$3.87 \cdot 10^{-5}$	$1.59 \cdot 10^{-3}$
80	$1.97 \cdot 10^{-5}$	$7.22 \cdot 10^{-4}$

Tracking detectors: SiD silicon layers





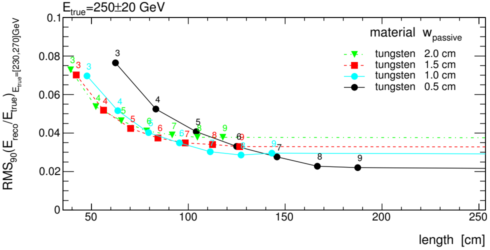
Tracking performance in CLIC_SiD

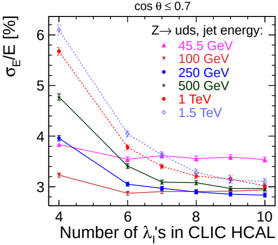


θ [°]	a $[\mathrm{GeV}^{-1}]$	b
90	$7.3 \cdot 10^{-6}$	$2.0 \cdot 10^{-3}$
30	$1.9 \cdot 10^{-5}$	$3.8 \cdot 10^{-3}$
10	$4.0 \cdot 10^{-4}$	$5.3 \cdot 10^{-3}$

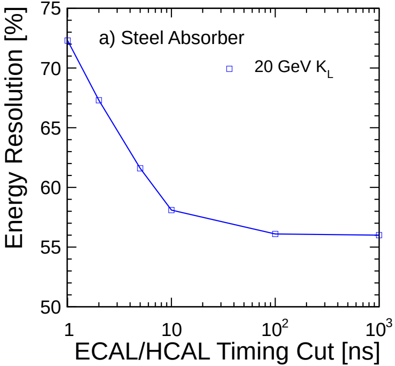
Calorimetry

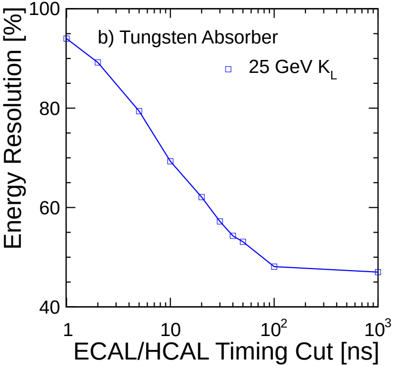
Material	λ_I [cm]	X_0 [cm]	λ_I/X_0
Fe	16.77	1.76	9.5
W	9.95	0.35	28.4



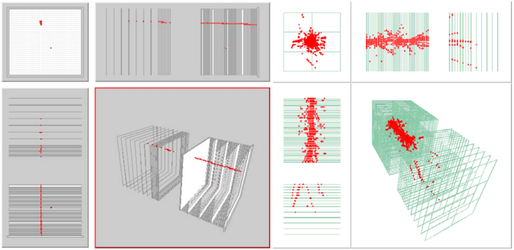


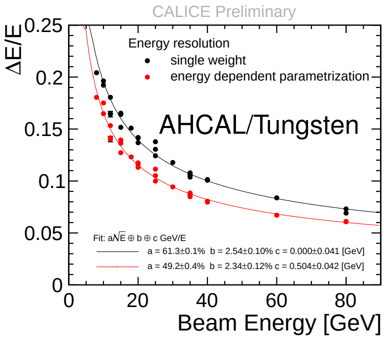
Timing

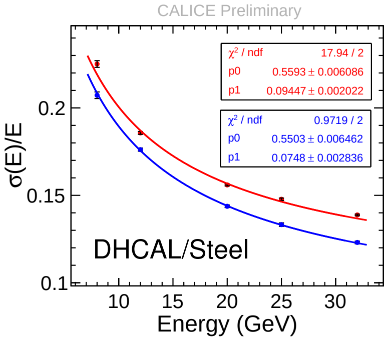

a) Steel Absorber
20 GeV K_L
Energy Resolution [%]
ECAL/HCAL Timing Cut [ns]
75
70
65
60
55
50
1
10
10^2
10^3


b) Tungsten Absorber
25 GeV K_L
Energy Resolution [%]
ECAL/HCAL Timing Cut [ns]
100
80
60
40
1
10
10^2
10^3

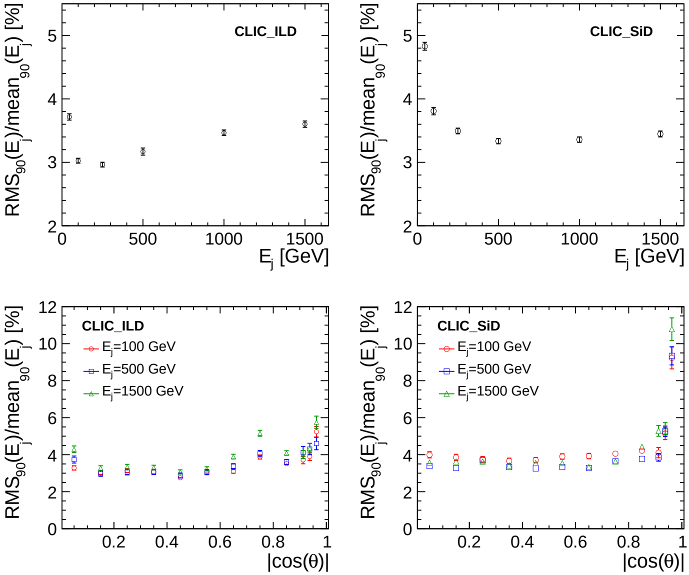
CALICE results



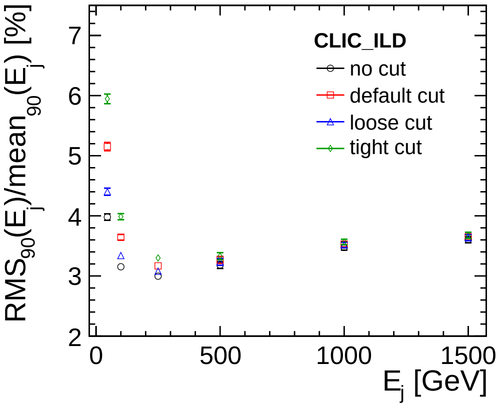




Calorimeter performance



Resolution vs timing in calorimeter



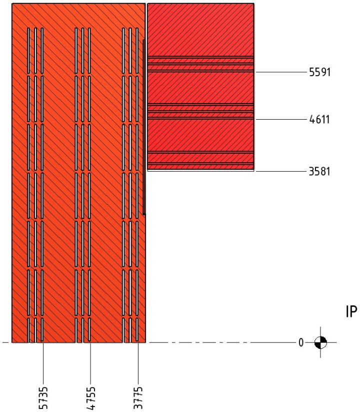
Magnets

	Nominal magnetic field (T)	Free bore (mm)	Magnetic length (mm)	Cold mass weight (tons)
CLIC_SiD	5.0	5480	6230	170
CLIC_ILD	4.0	6850	7890	210

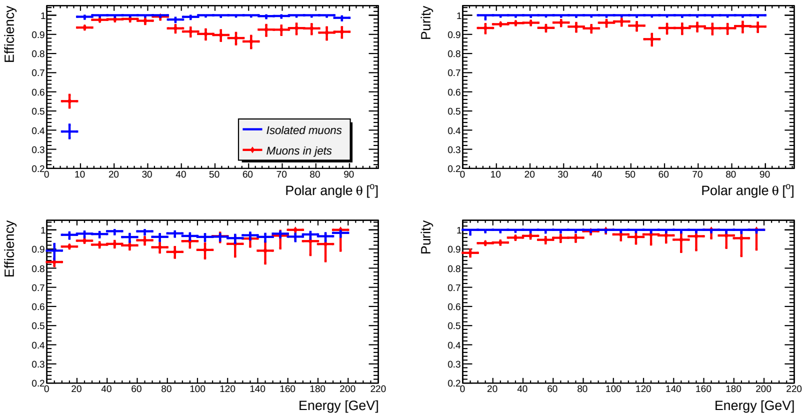
- Similar to the CMS solenoid in design
- Aluminium stabilized superconductor
- Multi-layer and multi-module coil
- Helium cooling

Muon system

Installed in the return yoke of the magnet



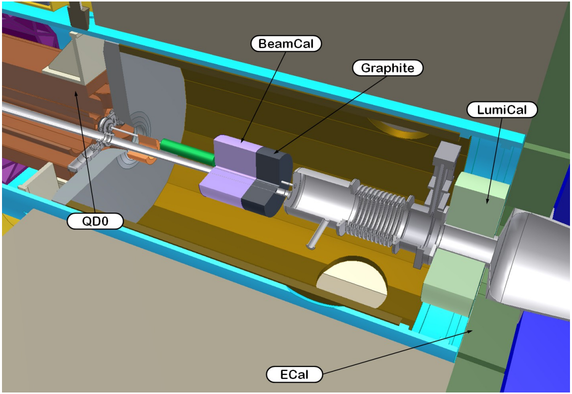
Muon system


Efficiency
Polar angle θ [°]
Isolated muons
Muons in jets
Purity
Polar angle θ [°]
Efficiency
Energy [GeV]
Purity
Energy [GeV]

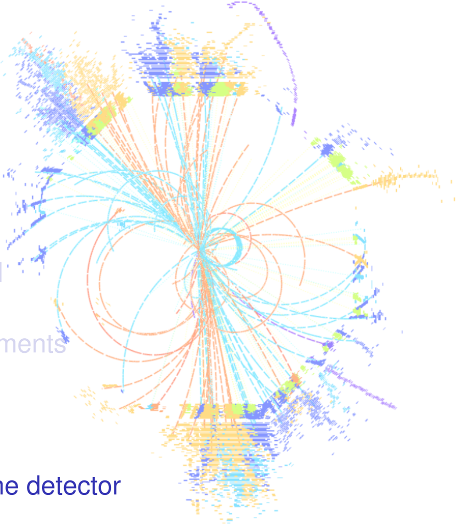
Very forward calorimeters: LumiCal and BeamCal

- LumiCal: measurement of the luminosity
- BeamCal: fast estimation of the luminosity and tagging of high energy electrons

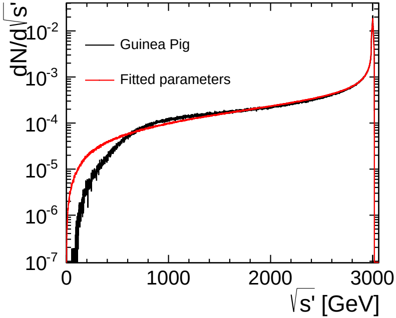
Both are electromagnetic sampling calorimeters, using W as absorber

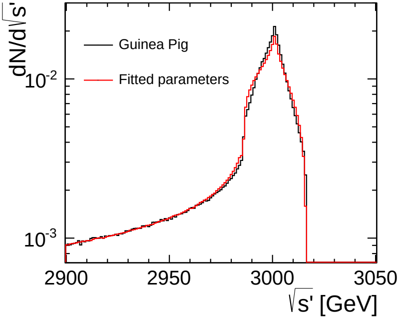


Outline



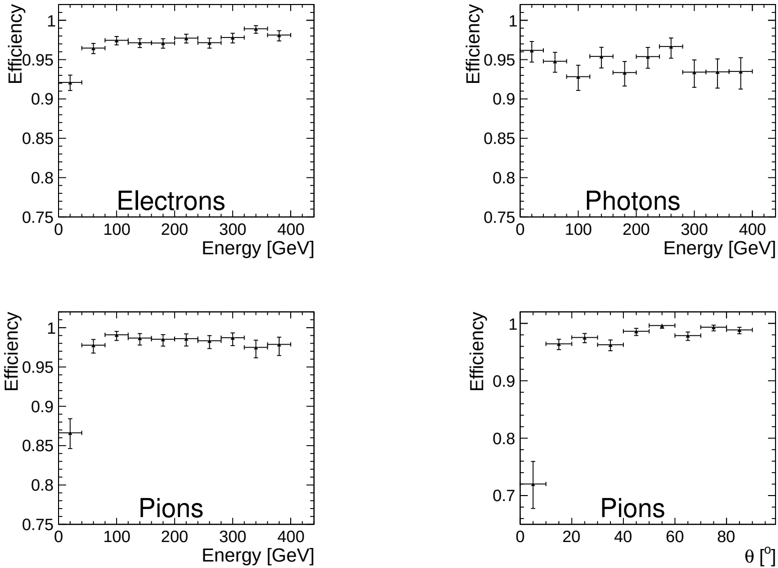
Luminosity spectrum measurement



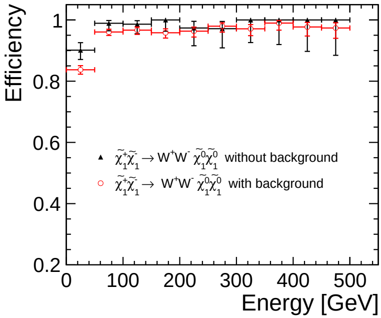


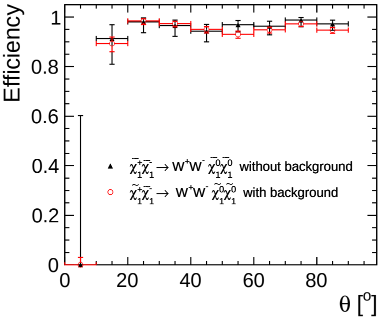
Impact on physics observable very small.

Particle ID performance



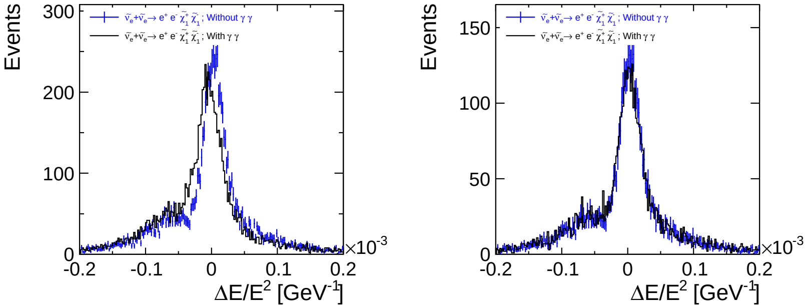
Particle ID performance: Muons





Electron energy resolution

Effect of the $\gamma\gamma$ background:



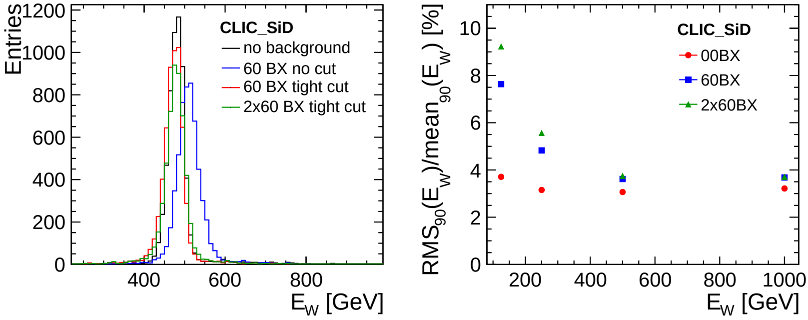
Core:

$\Delta E/E^2 =\sim 1.5 \times 10^{-5}\text{GeV}^{-1}$

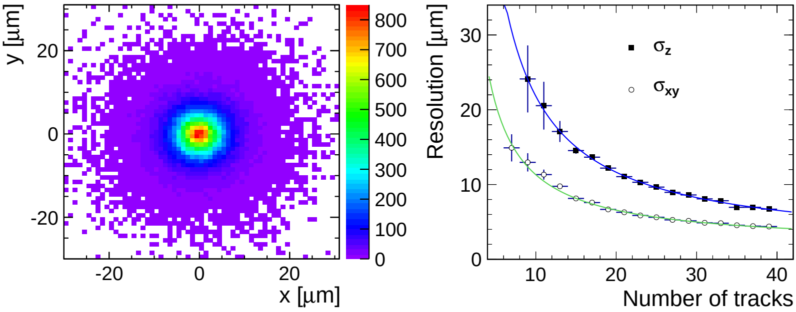
Tails: $\Delta E/E^2 = 5 - 8 \times 10^{-5}\text{GeV}^{-1}$

Bump due to failure in recovering the Bremstrahlung and FSR photons

Effect of $\gamma\gamma$ bkg

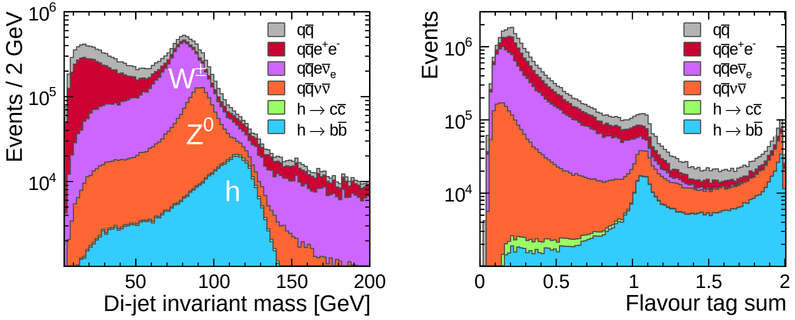


Primary vertex position resolution



Flavour tagging

LCFI collaboration, uses ZVTOP vertex finder and multi-variate method (NNET)



Flavour tagging

	$H \to b\bar{b}$	$H \to c\bar{c}$
Signal purity	65.4%	24.1%
Signal efficiency	54.6%	15.2%
cross section		
statistical uncertainty	0.22%	3.24%