Linear Colliders

A.De Roeck

CERN

Aspen Winter Conference 2005

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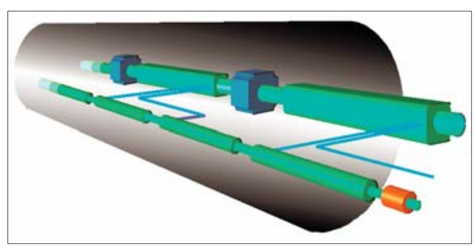
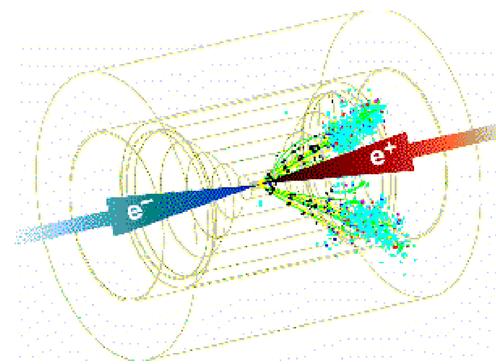
- Recent LC history
- The ILC: a TeV collider
- CLIC: a multi-TeV collider





Linear e+e- Colliders

Since end of 2001 there seems to be a worldwide consensus (ECFA/HEPAP/Snowmass 2001…)

⬇

The machine which will complement and extend the LHC best, and is closest to be realized is a Linear e+e- Collider with a collision energy of at least 500 GeV

PROJECTS:

⇒ TeV Colliders (cms energy up to 1 TeV) → Technology ~ready
August'04 ITRP: NLC/GLC/TESLA → ILC superconducting cavities

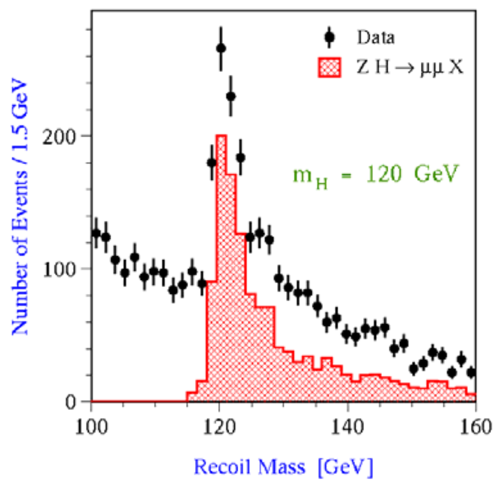
⇒ Multi-TeV Collider (cms energies in multi-TeV range) → R&D
CLIC (CERN + collaborators) → Two Beam Acceleration

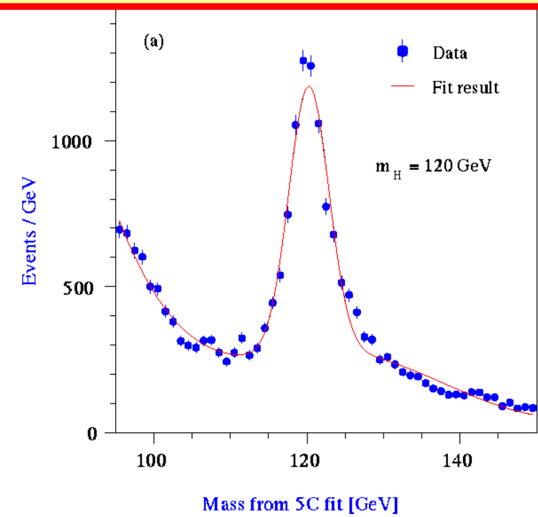
A LC is a Precision Instrument

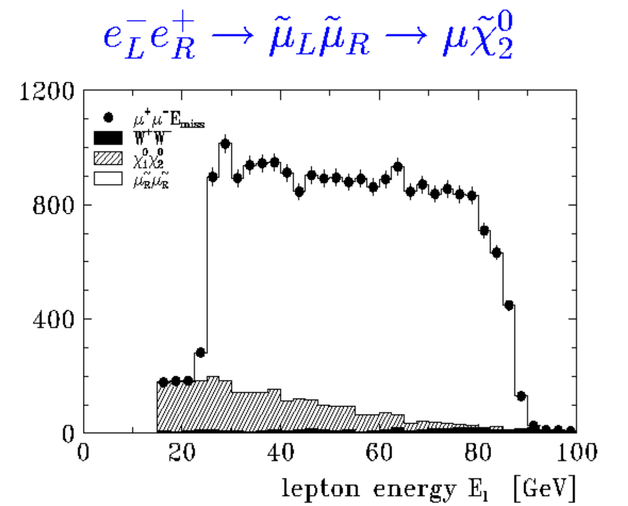
- Clean e+e- (polarized intial state, controllable √s for hard scattering)
- Detailed study of the properties of Higgs particles

  mass to 0.03%, couplings to 1-3%, spin & CP structure, total width (6%)
  factor 2-5 better than LHC/measure couplings in model indep. way
- Precision measurements of SUSY particles properties, i.e. slepton masses to better than 1%, if within reach
- Precision measurements a la LEP (TGC's, Top and W mass)
- Large indirect sensitivity to new phenomena (eg $W_L W_L$ scattering)

LC will very likely play important role to disentangle the underlying new theory







LC: Few More Examples

⇒Understanding SUSY

High accuracy of sparticle mass measurements relevant for reconstruction of SUSY breaking mechanism

⇒ Dark Matter

LC will accurately measure m_χ and couplings, i.e. Higgsino/Wino/Bino content

→ Essential input to cosmology & searches

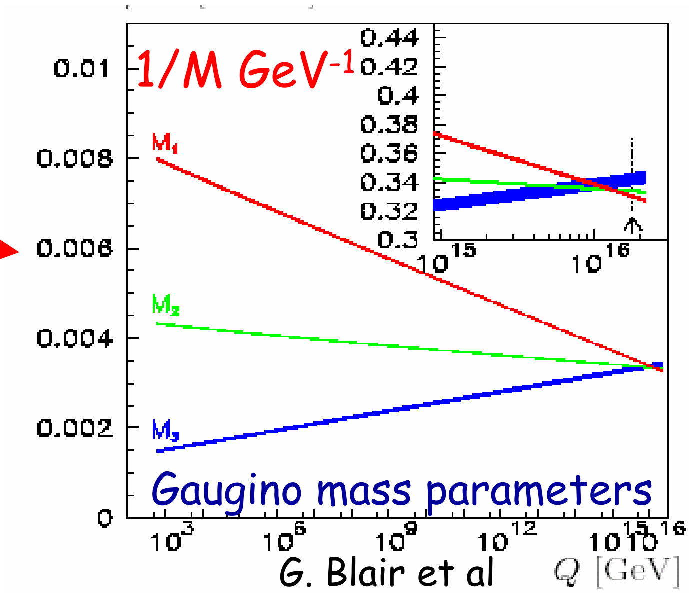
LC will make a prediction of $\Omega_{DM}h^2 \sim 3\%$ (SPS1a)

→A mismatch with WMAP/Planck would reveal extra sources of DM (Axions, heavy objects)

⇒ Quantum level consistency: M_H(direct)= M_H(indirect)?

$\Delta\sin^2\theta_W \sim 10^{-5}$ (GigaZ), $\Delta M_W \sim 6$ MeV (+theory progress)

→ ΔM_H (indirect) ~ 5%



'WMAP'	7 %
LHC	~15 %
'Planck'	~2 %
LC	~3 %

F. Richard/SPS1a

The next e+e-collider must be linear

C. Pagani LCWS04 Paris

- Synchrotron Radiation (SR) becomes prohibitive for electrons in a circular machine above LEP energies:

$$U_{SR}[\mathrm{GeV}] = 6 \cdot 10^{-21} \cdot \gamma^4 \cdot 1/r[\mathrm{km}]$$

U_{SR} = energy loss per turn
γ = relativistic factor
r = machine radius

- RF system must replace this loss, and r scale as E^2
- LEP @ 100 GeV/beam: 27 km around, 2 GeV/turn lost
- Possible scale to 250 GeV/beam i.e. E_{cm} = 500 GeV:
  - 170 km around
  - 13 GeV/turn lost

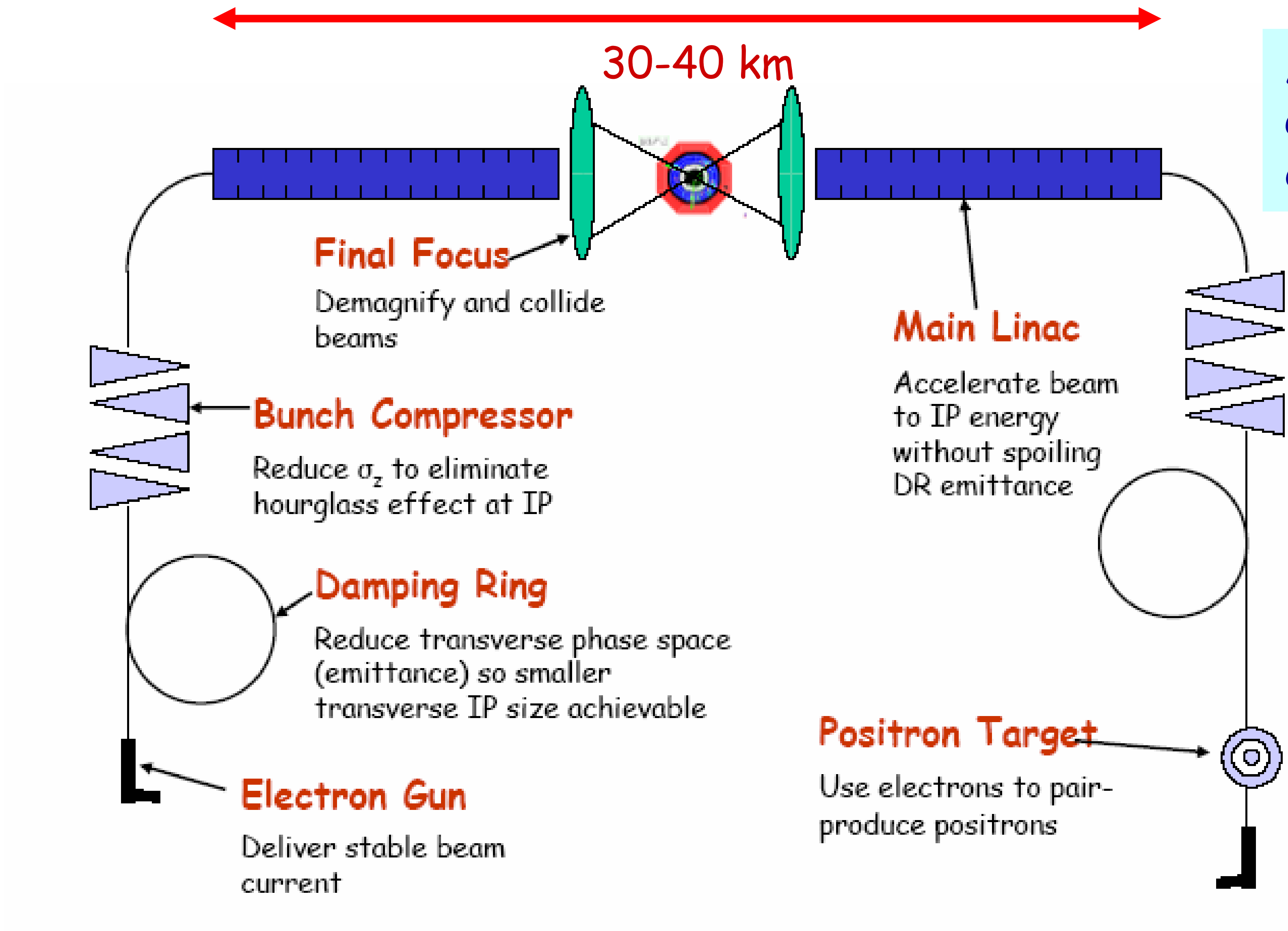
$\gamma_{250GeV} = 4.9 \cdot 10^5$

- Consider also the luminosity
  - For a luminosity of ~ $10^{34}/cm^2/second$, scaling from b-factories gives ~ 1 Ampere of beam current
  - 13 GeV/turn x 2 amperes = 26 GW RF power
  - Because of conversion efficiency, this collider would consume more power than the state of California in summer: ~ 45 GW

Circulating beam power = 500 GW

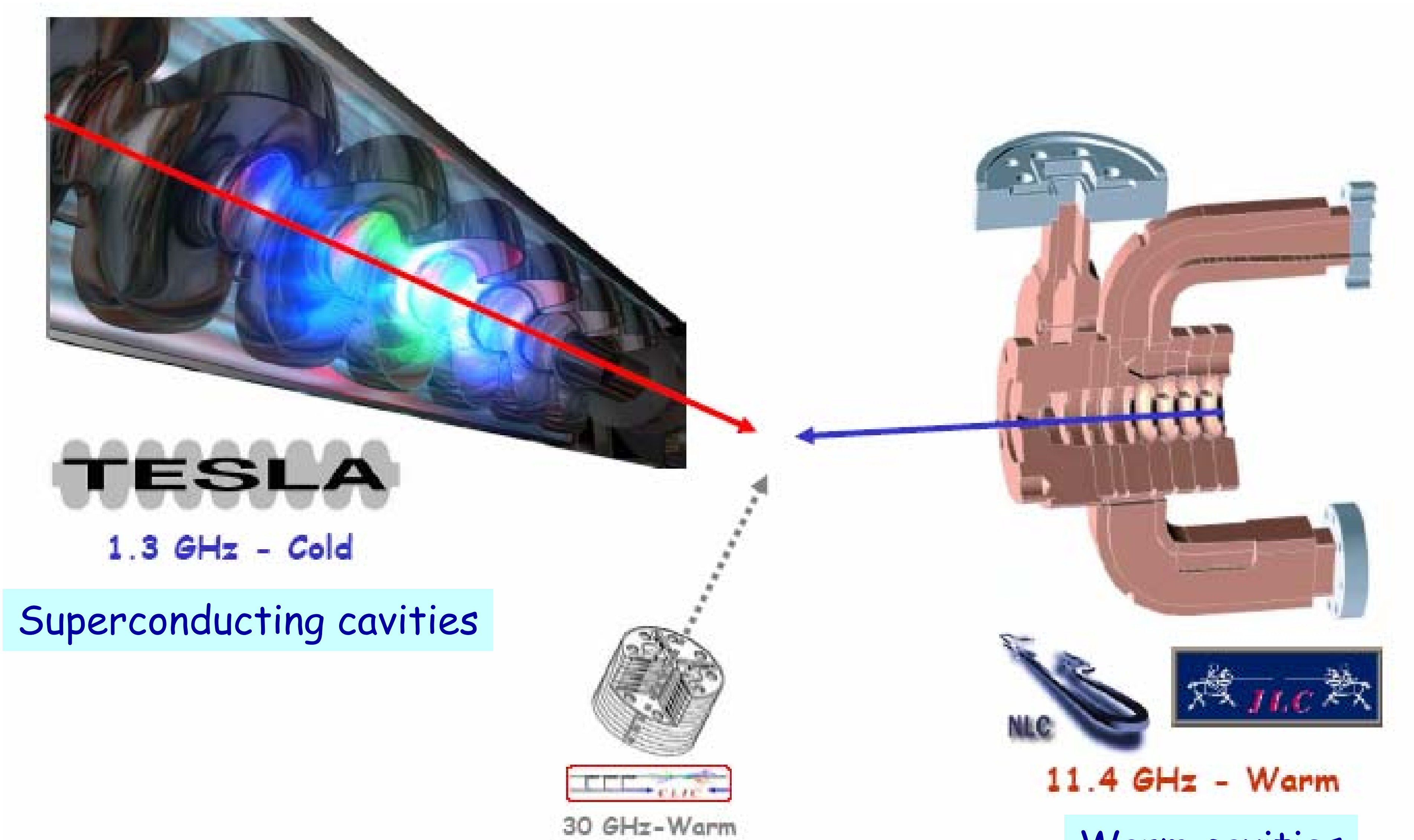
- Both size and power seem excessive

Generic Linear Collider



All collider elements are challenging

LC Competing technologies (spring 2004)



Superconducting cavities

Two beam acceleration

Warm cavities

Meanwhile: LC getting on the Roadmap

Study groups of ACFA, ECFA, HEPAP The next large accelerator-based project of particle physics should be a linear collider

US DOE Office of Science Future Facilities Plan: LC is first priority mid-term new facility for all US Office of Science

Major Funding Agencies Regular meetings concerning LC

ICFA (February 2004) reaffirms its conviction that the highest priority for a new machine for particle physics is a linear electron-positron collider with an initial energy of 500 GeV, extendible up to about 1 TeV, with a significant period of concurrent running with the LHC

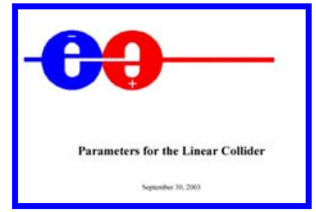
LCWS04 Paris (April 2004) publication of the document "understanding matter, space and time" by 2600 physicists, in support of a linear collider

EUROTEV selected by EC 9 MEuro for R&D for a LC

Very sizable community wants a e+e- Linear Collider

ILC Parameters & options

Several years of intense physics studies have led to:



- Baseline Linear Collider
  - Minimum energy of 500 GeV, with int. luminosity of 500 fb^{-1} in the first 4 years
  - Scan energies between from LEP2 till new energy range: 200-500 GeV with a luminosity ~ $\sqrt{s}$. Switch over should be quick (max 10% of data taking time)
  - Beam energy stability and precision should 0.1% or better.
  - Electron beam polarization with at least 80%
  - Two interaction regions should be planned for
  - Should allow for calibration running at the Z ($\sqrt{s}$ = 90 GeV)
  - Upgrade: Energy upgrade up to ~ 1 TeV with high luminosity should be planned
- Options beyond the baseline: enhance the physics reach
  - Running as an e-e- collider
  - Running as a eγ or $\gamma\gamma$ collider
  - Polarization of the positron beam
  - Running at Z^0 with a luminosity of several $10^{33}cm^{-2}s^{-1}$ (GigaZ)
  - Running at WW mass threshold with a luminosity of a few times $10^{33}cm^{-2}s^{-}$

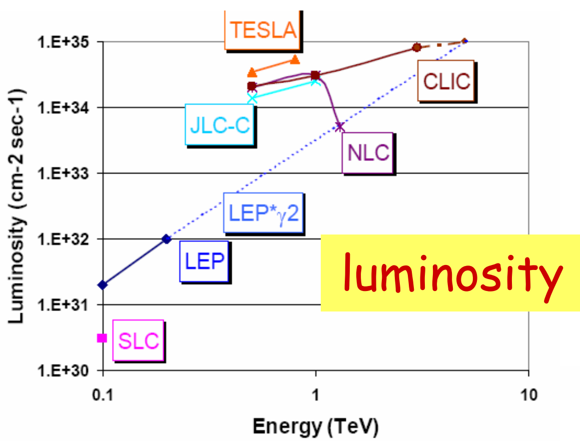
Machine Parameters

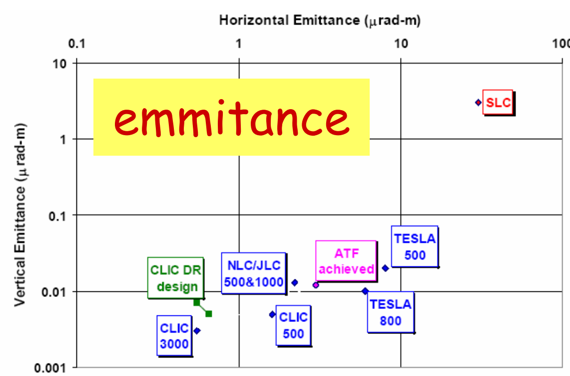
Table from ILC-Technical Review Comittee (2003)

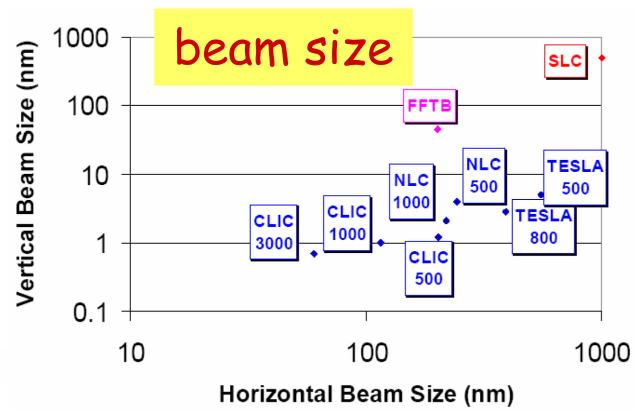
TABLE 2.1: Overall parameters

	TESLA		JLC-C		JLC-X/NLC[a]		CLIC	
Center of mass energy [GeV]	500	800	500	1000	500	1000	500	3000
RF frequency of main linac [GHz]	1.3		5.7	5.7/11.4[b]	11.4		30	
Design luminosity [10^{33} $cm^{-2}s^{-1}$]	34.0	58.0	14.1	25.0	25.0 (20.0)	25.0 (30.0)	21.0	80.0
Linac repetition rate [Hz]	5	4	100		150 (120)	100 (120)	200	100
Number of particles/bunch at IP [10^{10}]	2	1.4	0.75		0.75		0.4	
Number of bunches/pulse	2820	4886	192		192		154	
Bunch separation [nsec]	337	176	1.4		1.4		0.67	
Bunch train length [μsec]	950	860	0.267		0.267		0.102	
Beam power/beam [MW]	11.3	17.5	5.8	11.5	8.7 (6.9)	11.5 (13.8)	4.9	14.8
Unloaded/loaded gradient[c] [MV/m]	23.8 / 23.8[d]	35 / 35	41.8/31.5	41.8/31.5 / 70/55	65 / 50		172 / 150	
Total two-linac length [km]	30	30	17.1	29.2	13.8	27.6	5.0	28.0
Total beam delivery length [km]	3		3.7		3.7		5.2	
Proposed site length [km]	33		33		32		10.2	33.2
Total site AC power[e] [MW]	140	200	233	300	243 (195)	292 (350)	175	410
Tunnel configuration[f]	Single		Double		Double		Single	

http://www.slac.stanford.edu/xorg//ilc-trc/ilc-trchome.html







ITRP Recommendation to ICFA/ILCSC

ITRP Mission: select a technology
R&D to support both technologies
becomes too demanding on resources

International Technology Recommendation Panel Meeting
August 11 ~ 13, 2004. Republic of Korea

Conclusion at ICHEP Beijing August '04
$\Rightarrow$Both technologies mature
$\Rightarrow$Select the cold technology to continue

Some arguments in favor of cold

- The large cavity aperture and long bunch interval simplify operations, reduce the sensitivity to ground motion, permit inter-bunch feedback, and may enable increased beam current.
- The main linac and rf systems, the single largest technical cost elements, are of comparatively lower risk.
- The construction of the superconducting XFEL free electron laser will provide prototypes and test many aspects of the linac.
- The industrialization of most major components of the linac is underway.
- The use of superconducting cavities significantly reduces power consumption.

Note: technology selected, not a design

Endorsed by ICFA/ILCSC $\Rightarrow$ call project the International Linear Collider ILC

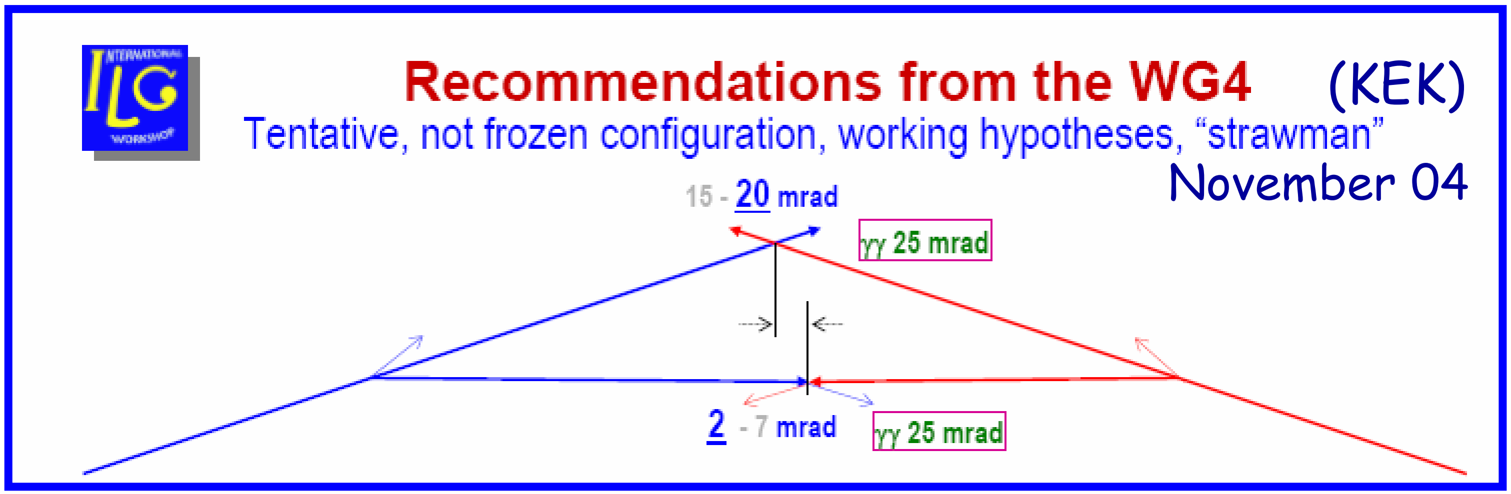
ILCSC = International Linear Collider Steering Committee

World wide effort on designing the ILC machine has started

First meeting at KEK November
  Discussion/study of the machine parameters, injector chain, beam delivery, interaction region etc., based on the NLC/JLC/TESLA experience
Next full meeting: Snowmass 14-27/8/05

E.g. discussions related to the machine-detector interface:
crossing angles, polarization measurements, luminosity measurements, backgrounds, constraints from special options, low angle tagging

e.g.



LC Time Scales

R. Heuer LCWS04

ILCSC Road Map

2004 Technology recommendation (done)

Start Global Design Initiative/Effort (GDI/GDE): central team director job as been offered a few days ago

2005 Conceptual Design Report for Linear Collider

Start Global Design Organization (GDI/GDO)

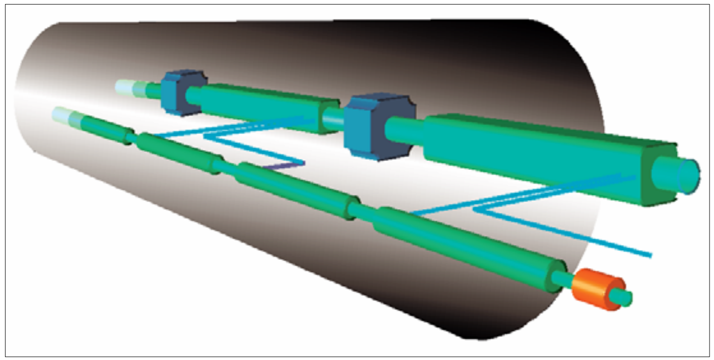
2007 Technical Design Report for a Linear Collider

2008 Site selection

2009/2010 Construction could start (if budget approved)

→ First collisions in 2014/2015?

CLIC Compact LInear Collider



CERN +

- BERLIN Technical University (Germany) : Structure simulations GdfidL
- Finnish Industry (Finland) : Sponsorship of a mechanical engineer
- INFN / LNF (Italy): CTF3 delay loop, transfer lines & RF deflectors
- JINR & IAP (Russia): Surface heating tests of 30 GHz structures
- KEK (Japan): Low emittance beams in ATF
- LAL (France) : Electron guns and pre-buncher cavities for CTF3
- LAPP/ESIA (France) : Stabilization studies
- LLBL/LBL (USA) : Laser-wire studies
- North Western University (Illinois) : Beam loss studies & CTF3 equipment
- RAL (England) : Lasers for CTF3 and CLIC photo-injectors
- SLAC (USA) : High Gradient Structure testing, structure design, CTF3 drive beam injector design
- UPPSALA University (Sweden) : Beam monitoring systems for CTF3

CLIC

- An e+e- linear collider optimized for a cms energy of 3 TeV with a luminosity of ≅ 10^{35} $cm^{-2}s^{-1}$
- Aim: 3 TeV complementing LHC/TeV class LC and breaking new ground, with a final stage up to 5 TeV
- To achieve this with reasonable cost (less than ~35 km) and not to many active elements

  →High accelerating gradient: ~ 150 MV/m
  two beam acceleration (TBA)

  → High beamstrahlungs regime to reach
  high luminosity

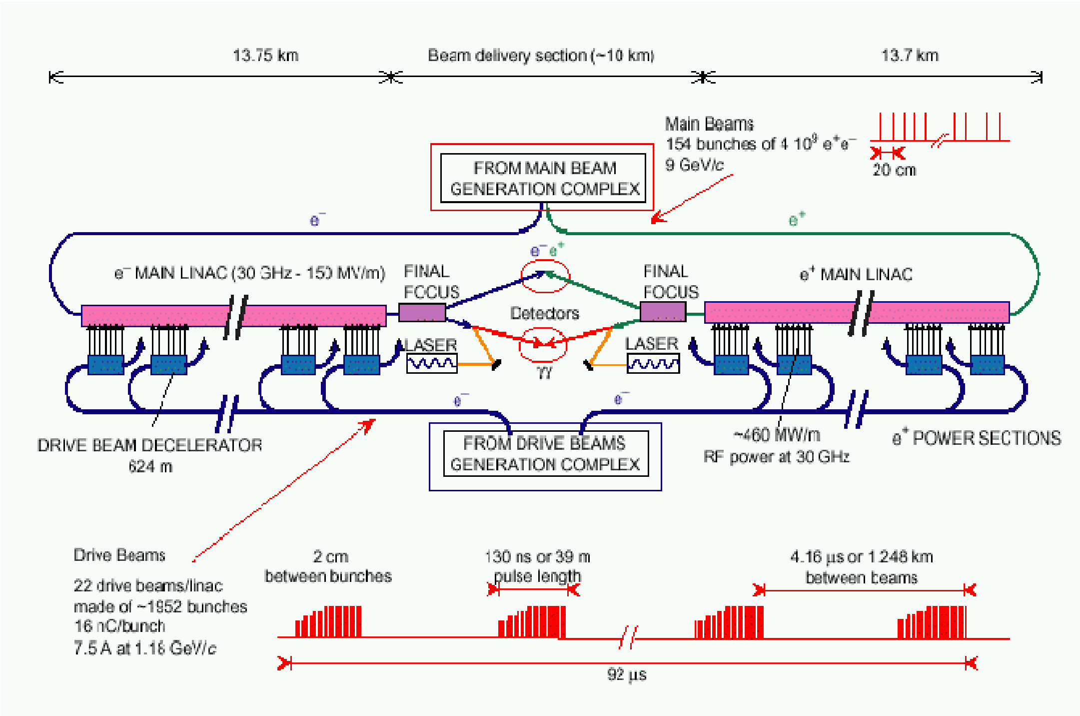
  →Challenging beam parameters and machine
  requirements (nm stability, strong final focus, 30GHz accelerating structures)

  ⇒ CLIC TBA to date the only known way to reach multi-TeV

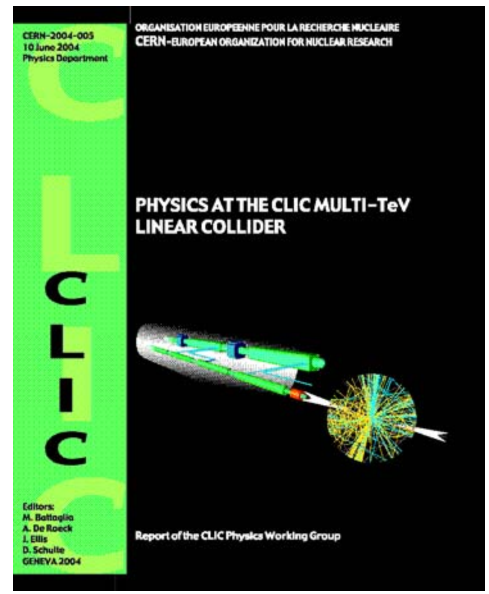
Comparison with ILC		
•TESLA	500 GeV	25MV/m
	800 GeV	35MV/m
• Future ILC study?:		44MV/m

- Test facilities CTF2 ('96-'02): 150-193 MV/m in TBA (16 ns pulses)
  CTF3 ('02-'09): Test of drive beam, R1's/ R2's of TRC (2003)

CLIC: a Multi-TeV Linear Collider



Physics case for CLIC documented in CERN yellow report CERN-2004-005 (June) and hep-ph/0412251

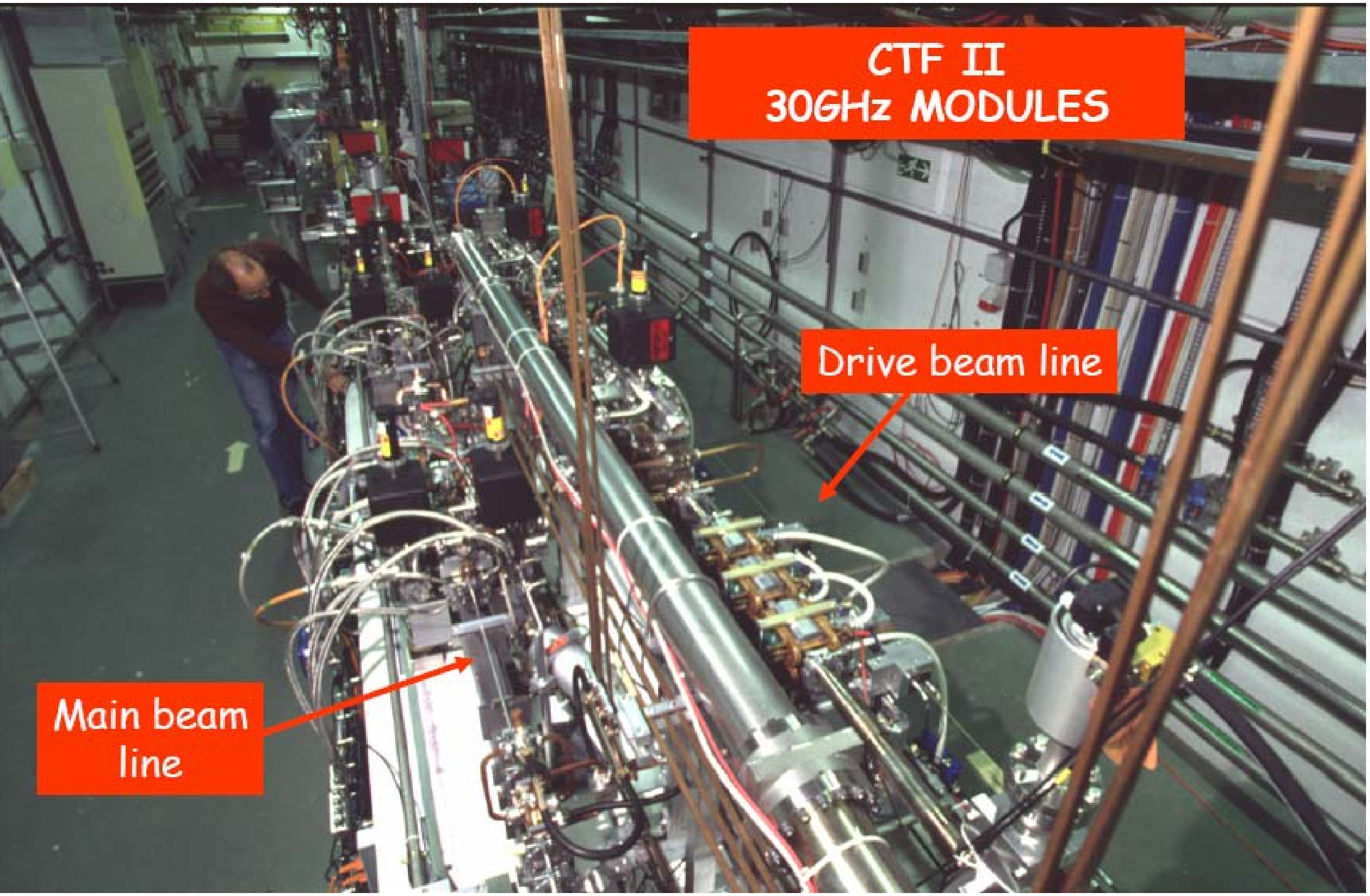


⇒CERN: accelerate CLIC R&D support to evaluate the technology by 2009 with extra external contributions ⇒ CLIC collaboration.

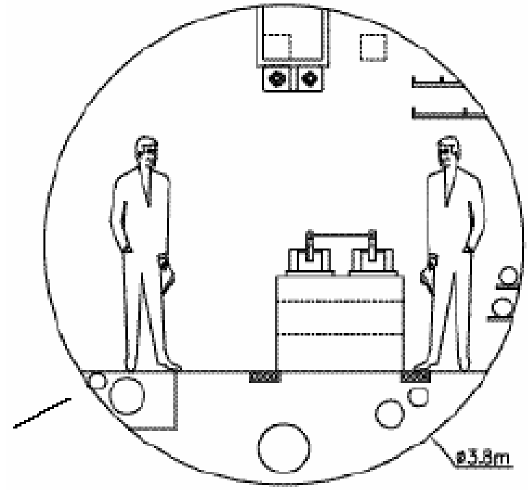
FAQs:

- CLIC technology O(5) years behind ILC
- CLIC can operate from 90 GeV→ 3 (5) TeV .

CTF2: CLIC Test Facility 2



CLIC TUNNEL
CROSS-SECTION



Demonstrated that 2 beam acceleration works
Reached up to 190 MV/m for short pulses (16ns)

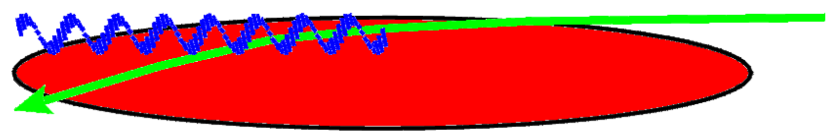
CLIC Parameters & Backgrounds

CLIC 3 TeV e+e- collider with a luminosity ~ $10^{35}cm^{-2}s^{-1}$ (1 ab^{-1}/year)

CLIC parameters

			old	new
E_{cm}	[TeV]	0.5	3	3
$\mathcal{L}$	$[10^{34}cm^{-2}s^{-1}]$	2.1	10.0	8.0
$\mathcal{L}_{0.99}$	$[10^{34}cm^{-2}s^{-1}]$	1.5	3.0	3.1
f_r	[Hz]	200	100	100
N_b		154	154	154
Δ_b	[ns]	0.67	0.67	0.67
N	$[10^{10}]$	0.4	0.4	0.4
σ_z	[μm]	35	30	35
ϵ_x	[μm]	2	0.68	0.68
ϵ_y	[μm]	0.01	0.02	0.01
σ_x^*	[nm]	202	43	≈ 60
σ_y^*	[nm]	≈ 1.2	1	≈ 0.7
δ	[%]	4.4	31	21
n_γ		0.7	2.3	1.5
$N_\perp$		7.2	60	43
N_{Hadr}		0.07	4.05	2.3
N_{MJ}		0.003	3.40	1.5

CLIC operates in a regime of high beamstrahlung



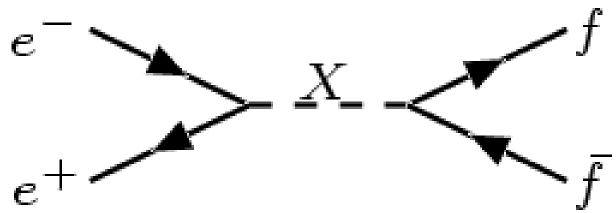
Time between 2 bunches = 0.67ns

Expect large backgrounds
# of photons/beam particle
- e+e- pair production
- γ γ events
- Muon backgrounds
- Neutrons
- Synchrotron radiation

Expect distorted lumi spectrum

Precision Measurements

Taking into account backgrounds, lumi spectrum, detector…

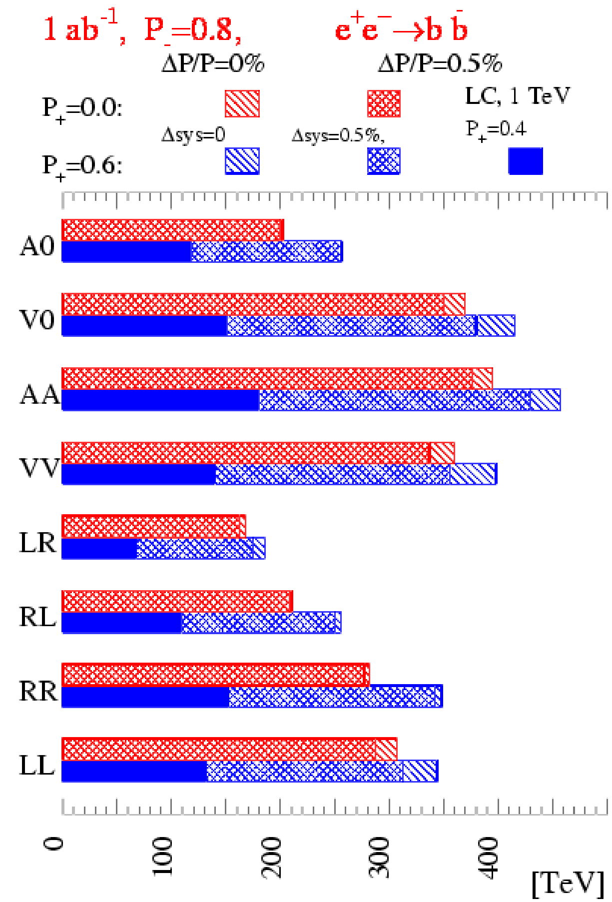


Measure $\sigma_{b\bar{b}}$, $A_{FB}^{\mu^+\mu^-}$ and $A_{FB}^{b\bar{b}}$

Examples: $\frac{\delta\sigma_{b\bar{b}}}{\sigma_{b\bar{b}}} = 0.012/\ 1\ \text{ab}^{-1}$

$$\frac{\delta A_{FB}^{\mu^+\mu^-}}{A_{FB}^{\mu^+\mu^-}} = 0.018/\ 1\ \text{ab}^{-1}$$

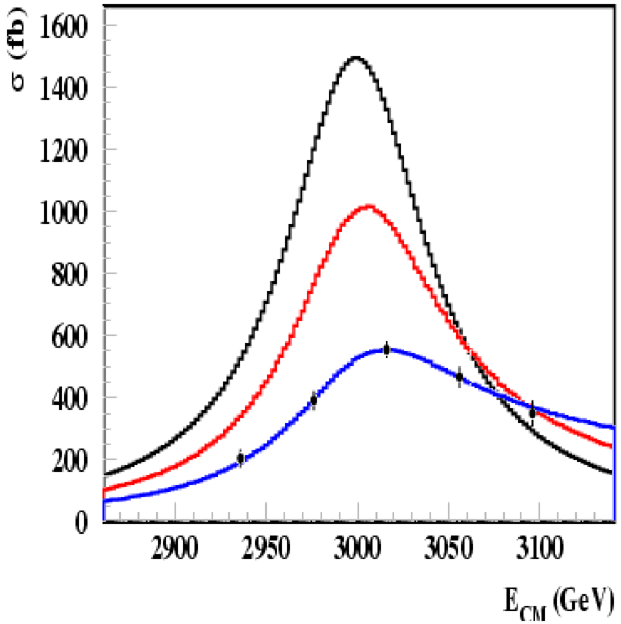
Observable	Relative Stat. Accuracy $\delta\mathcal{O}/\mathcal{O}$ for 1 ab^{-1}
$\sigma_{\mu^+\mu^-}$	± 0.010
$\sigma_{b\bar{b}}$	± 0.012
$\sigma_{t\bar{t}}$	± 0.014
$A_{FB}^{\mu\mu}$	± 0.018
A_{FB}^{bb}	± 0.055
A_{FB}^{tt}	± 0.040



E.g.: Contact interactions:
Sensitivity to scales up to 100-800 TeV

Resonance Production

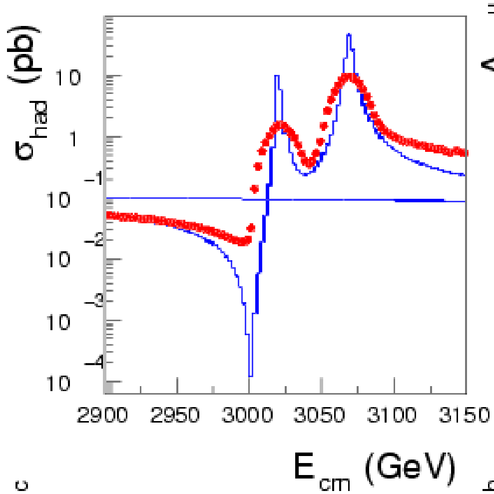
Resonance scans, e.g. a Z′

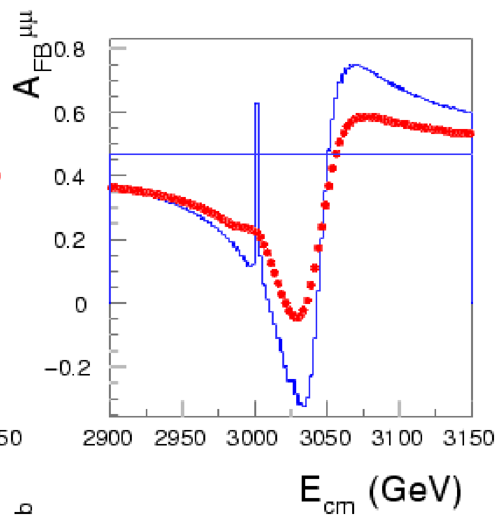


FIT ACCURACY

Observable	Breit Wigner	CLIC.01	CLIC.02
$M_{Z'}$ (GeV)	$3000 \pm .12$	$\pm .15$	$\pm .21$
$\Gamma(Z')/\Gamma_{SM}$	$1. \pm .001$	$\pm .003$	$\pm .004$
σ^{eff}_{peak} (fb)	1493 ± 2.0	564 ± 1.7	669 ± 2.9

1 $ab^{-1} \Rightarrow \delta M/M \sim 10^{-4}$ & $\delta\Gamma/\Gamma = 3.10^{-3}$



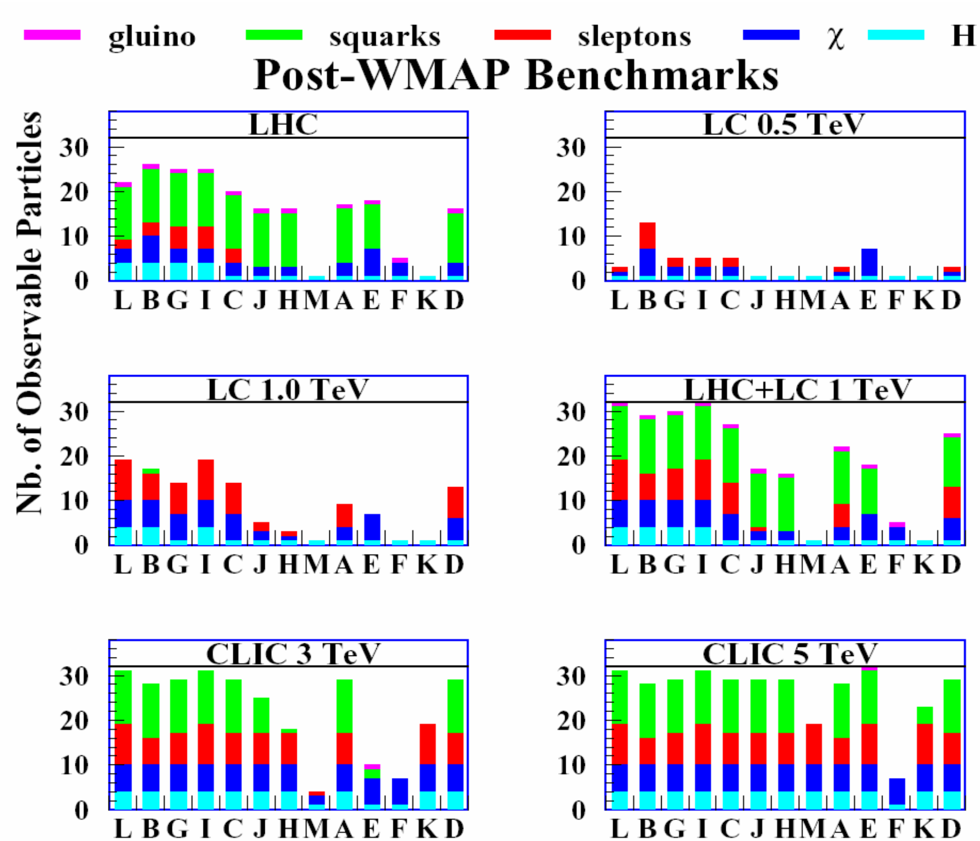


Degenerate resonances e.g. D-BESS model

Can measure ΔM down to 13 GeV

Smeared lumi spectrum allows still for precision measurements

Supersymmetry



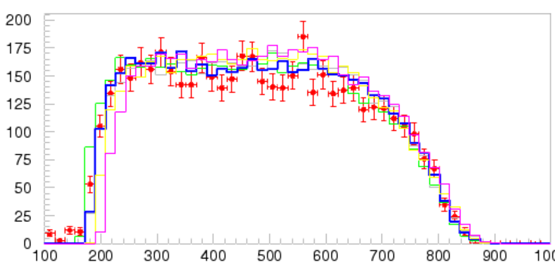
(Battaglia at al hep-ph/0306219)

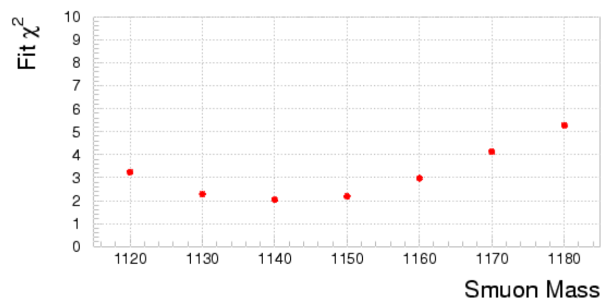
E.G. $m_{1/2} = 1500$ GeV, $m_0 = 420$ GeV, $\tan\beta = 20$, $A = 0$ GeV, $sign(\mu) > 0$ (mSUGRA) (point H)

$\Rightarrow M_{\tilde{\mu}} = 1150$ GeV

Measure inclusive muon spectrum in $\tilde{\mu} \rightarrow \mu\chi^0$

$$\Rightarrow E_{max/min} = \frac{E_{beam}}{2}\left(1 - \frac{M^2_{\chi^0}}{M^2_{tilde\mu}}\right) \times \left(1 \pm \sqrt{1 - \frac{M^2_{\tilde{\mu}}}{E^2_{beam}}}\right)$$





sparticles that can be detected
Higher mass precision at LC vs LHC

Mass measurements to O(1%) for smuons

Summary: Physics at CLIC

Measurements at CLIC (5 TeV / 1 ab^{-1})

Higgs (Light)	λ_{HHH} to $\sim 5-10\%$ (5 ab^{-1})
Higgs (Light)	$g_{H\mu\mu}$ to $\sim 3.5-10\%$ (5 ab^{-1})
Higgs (Heavy)	2.0 TeV (e^+e^-) 3.5 TeV ($\gamma\gamma$)
squarks	2.5 TeV
sleptons	2.5 TeV
Z' (direct)	5 TeV
Z' (indirect)	30 TeV
l^*, q^*	5 TeV
TGC (95%)	0.00008
Λ compos.	400 TeV
$W_L W_L$	>5 TeV
ED (ADD)	30 TeV (e^+e^-)
	55 TeV ($\gamma\gamma$)
ED (RS)	18 TeV (c=0.2)
ED (TeV^{-1})	80 TeV
Resonances	$\delta M/M, \delta\Gamma/\Gamma \sim 10^{-3}$
Black Holes	5 TeV

Experimental conditions at CLIC are more challenging than at LEP, or ILC

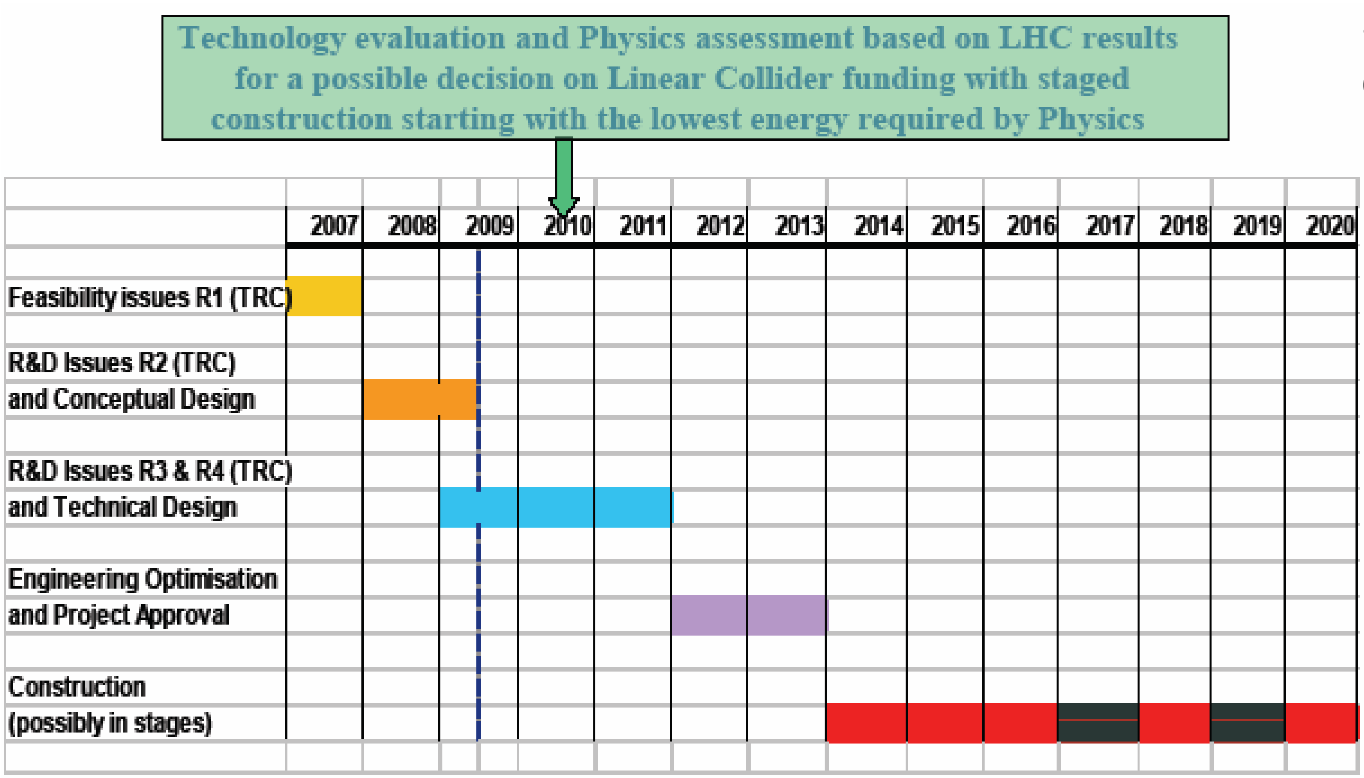
Physics studies for CLIC have included the effects of the detector, and backgrounds e.g e+e- pairs and $\gamma\gamma$ events.

Benchmark studies show that CLIC will allow for precision measurements in the TeV range

CLIC has a very large physics potential, reach beyond that of the LHC.

Urgent: Detector R&D will be needed: Tracking with good time stamping, improved calorimetry, mask area,...

CLIC: shortest and technically limited schedule



J.P. Delahaye
Gif 2004

Assumes extra resources via CLIC collaboration

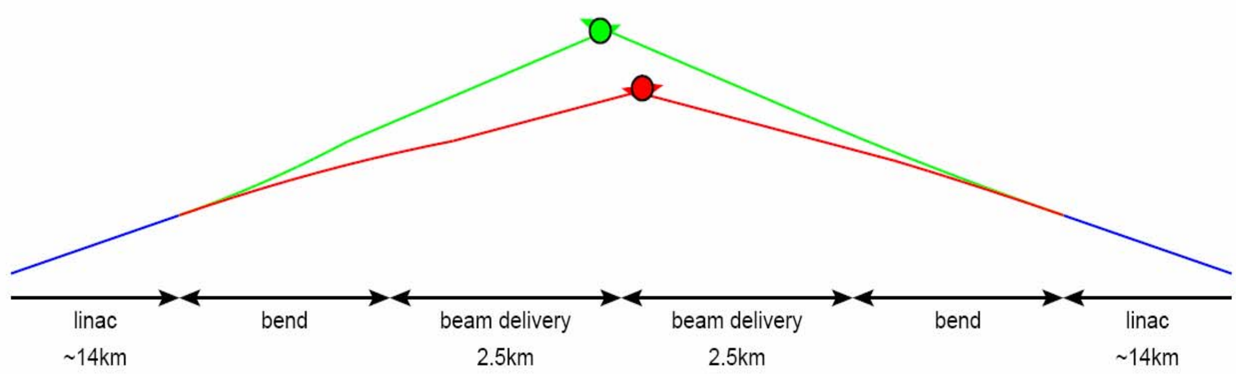
CLIC is working together with ILC on common issues
CARE, EuroTeV

Technological issues (R1/R2) for CLIC are being addressed with the CLIC Test Facility CTF3 @ CERN

- Aim to get all necessary results by 2009 and produce a CDR
- By 2009 first results of the LHC should start shaping the physics landscape

Multi-TeV collider

- Machine Detector Interface related issues to keep in mind if one plans for a facility that can be upgraded to a multi-TeV collider in future
  - crossing angle needed of ~20 mrad (multi-bunch kink stability)
  - Present design: Long collimator syst. and final focus (2.5 km each side)
  - Energy collimators most important.
    Fast kicker solution not applicable. Maybe rotating collimators …
  - Gentle bending to reduce SR & beam spot growth→ construct the linacs already under an angle of ~ 20 mrad
  - Internal geometry differences of the collimation system and final focus, allow for enough space in the tunnels (O(m))

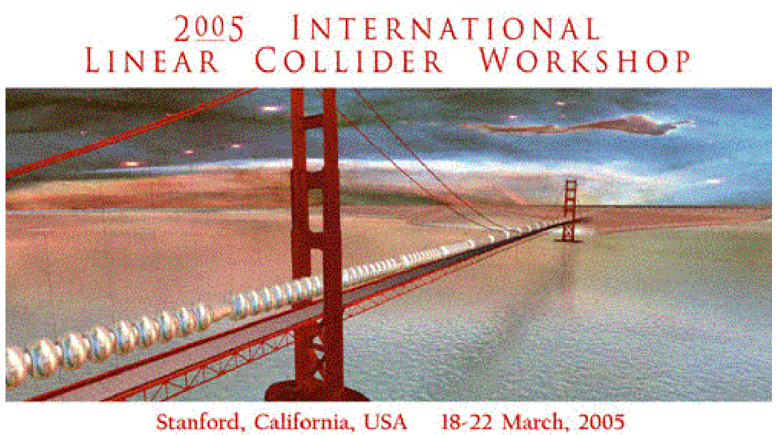


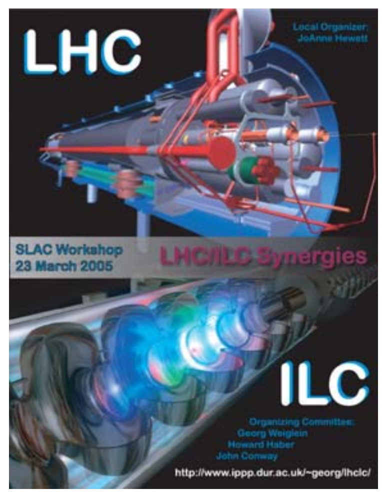
Summary

- LC physics and accelerator community has a lot of momentum
- ILC design starting to take shape
  - Machine to produce a CDR soon
  - All regions actively involved in its preparation
- Roadmap aims for a decision/start construction around 2009
  - First LHC data should be available by then
- CLIC multi-TeV study aims at proof of feasibility/CDR by 2009

Interesting times ahead !!

Important meeting grounds in 2005

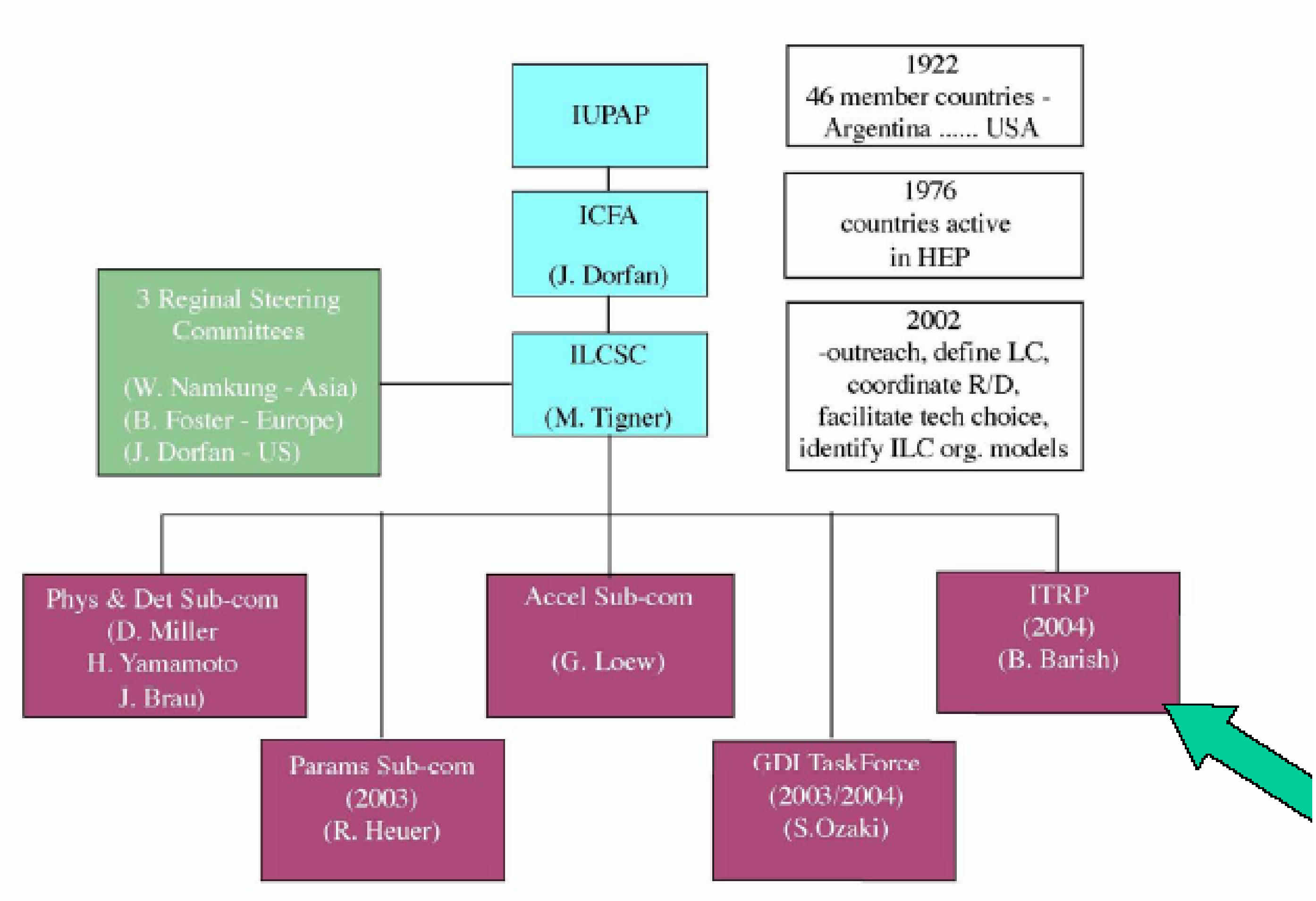




Snowmass
ALCPG/ILC
14-27/8

Aspen
Collider Physics from the Tevatron to the LHC to the nLinear Collider
15/8-11/9

Developing Organization



International Technical Review Panel

Summary: CLIC vs Hadron Colliders

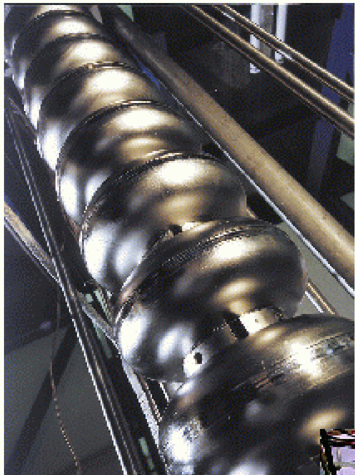
ADR, F. Gianotti, J. Ellis hep-ph/0112004
U. Bauer et al. hep-ph/0201227
+ updates

Process	LHC 14 TeV 100 fb^{-1}	SLHC 14 TeV 1000 fb^{-1}	VLHC* 200 TeV 100 fb^{-1}	CLIC 3-5 TeV 1000 fb^{-1}
squarks (TeV)	2.5	3	20.	1.5-2.5
sleptons (TeV)	0.34			1.5-2.5
Z' (TeV)	5.4	6.5	30-40	20-30
q^* (TeV)	6.5	7.5	70-75	3-5
l* (TeV)	3.4			3-5
ED (ADD/2D/TeV)	9	12	65	30-55
$W_L W_L$	3.4 σ	$>$ 4.0 σ	30 σ	70-90 σ
TGC (95%)	0.0014	0.0006	0.0003	0.00013- 0.00008
Λ Compos (TeV)	30	40	100	300-400

CLIC Comparable to VLHC

* Very Large Hadron Collider: 233 km Circumference

Linear Colliders



TESLA
Superconducting Cavity

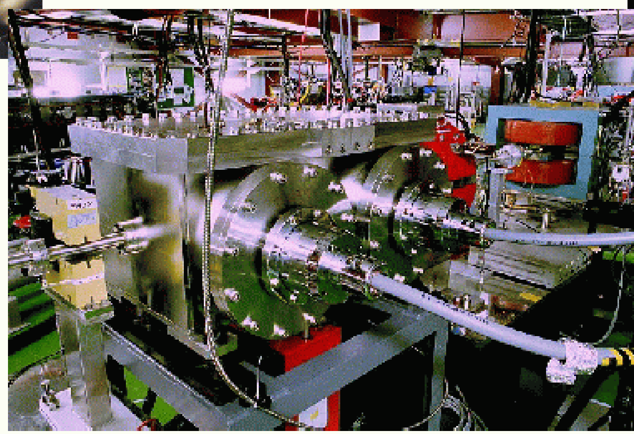
Europe

USA

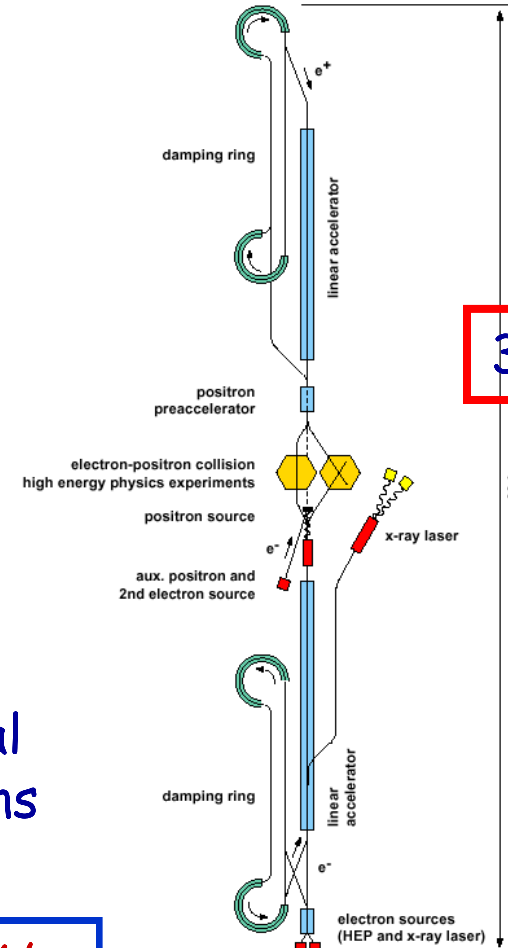
NLC
High Power
Klystron

Japan

GLC
Accelerator
Test Facility



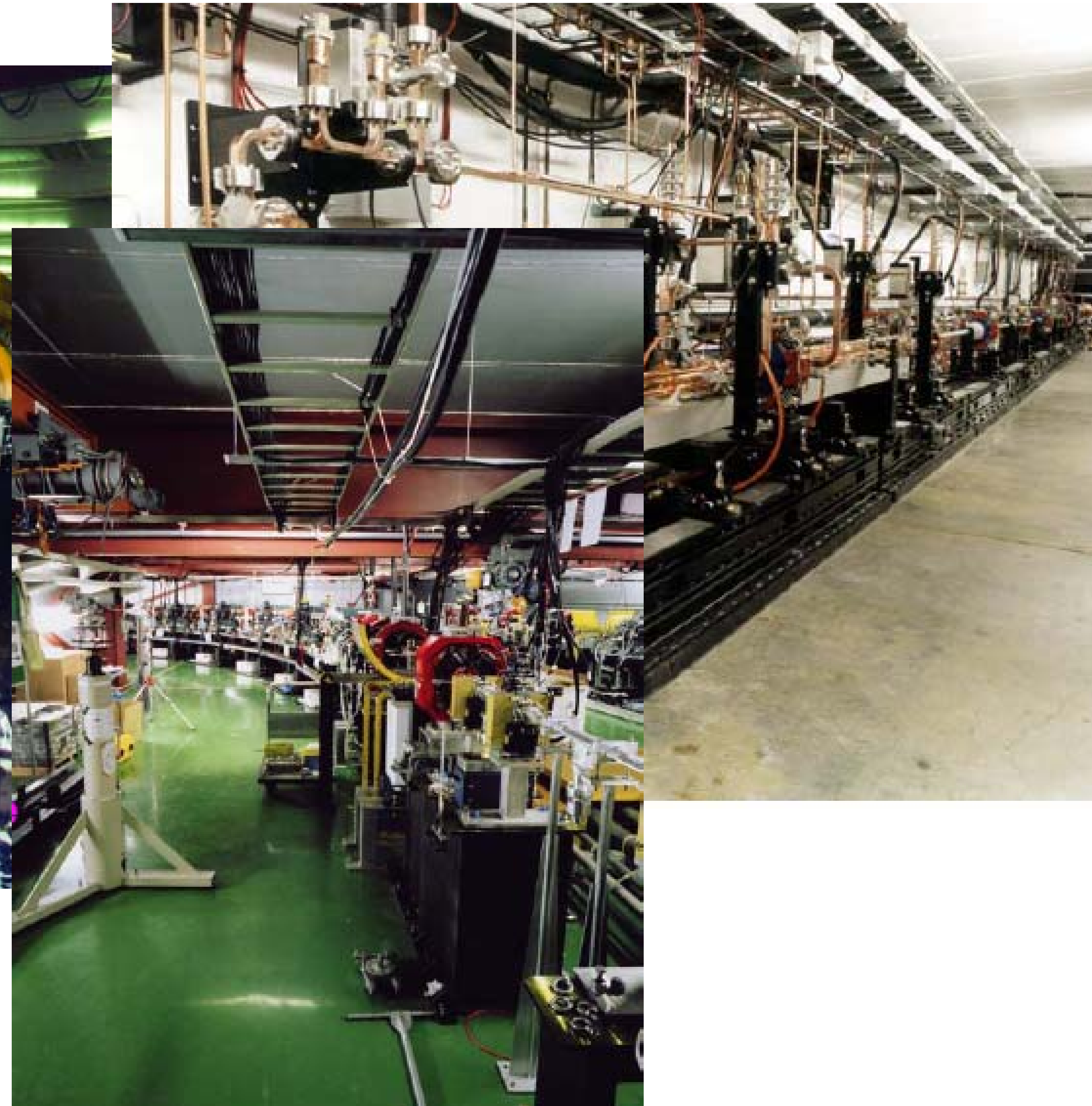
International
collaborations



33 km

TESLA/NLC/GLC: 90 GeV →1 TeV with 35-70 MV/m

CERN: CLIC Two-Beam acceleration scheme to reach >3TeV with 150 MV/m



Official Time Schedule

2005.2	Decide the director and location of **Central GDI**
2005.	Establish Regional GDIs
2005.8	Decide the **design outline in Snowmass Workshop** (acc.gradient, 1 or 2 tunnel, dogbone/small DR, e^+generation etc)
2005 end	Complete **CDR** with rough cost/schedule
2007 end	Complete **TDR**, role of regions, start site selection
2008	Decide the site, budget approval
2009	Ground breaking
2014	Commissioning starts

Development of 45MV/m

- Single-cell test in Dec 2004
- Individual vertical test of four 9-cell cavities **by Sep.2005**
  - Just in time for CDR completion
  - In existing facilities (AR east)
  - If expected performance not obtained,
    $\Rightarrow$ change to slower plan for ILC 2nd stage
- Cryomodule test by end of 2006 $\Rightarrow$ STF Phase 1
- Industrial design by TDR

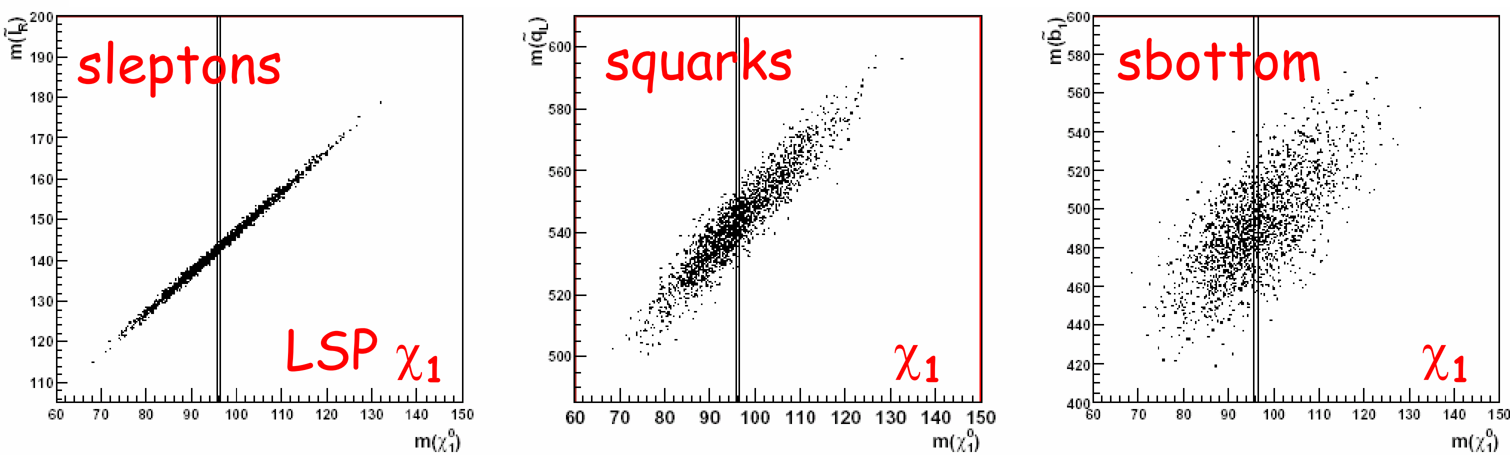
LHC/LC Complementarity

http://www.ipp.dur.ac.uk/~georg/lhclc/

- The complementarity of the LHC and LC results has been studied by a working group and has produced a huge document (>450 pages, G. Weiglein principal editor, finishing stage…)
- Working group contains members from LHC and LC community + theorists
- Most meetings at CERN (one in the US)

Conclusion: lot to gain for analysis of BOTH machines if there is a substantial overlap in running time.

Example: at LHC masses of the measured particles are strongly correlated with the mass of the lightest neutralino



Largely improve LHC mass measurements when LC χ_1^0 value is used

Summary: Indicative Physics Reach

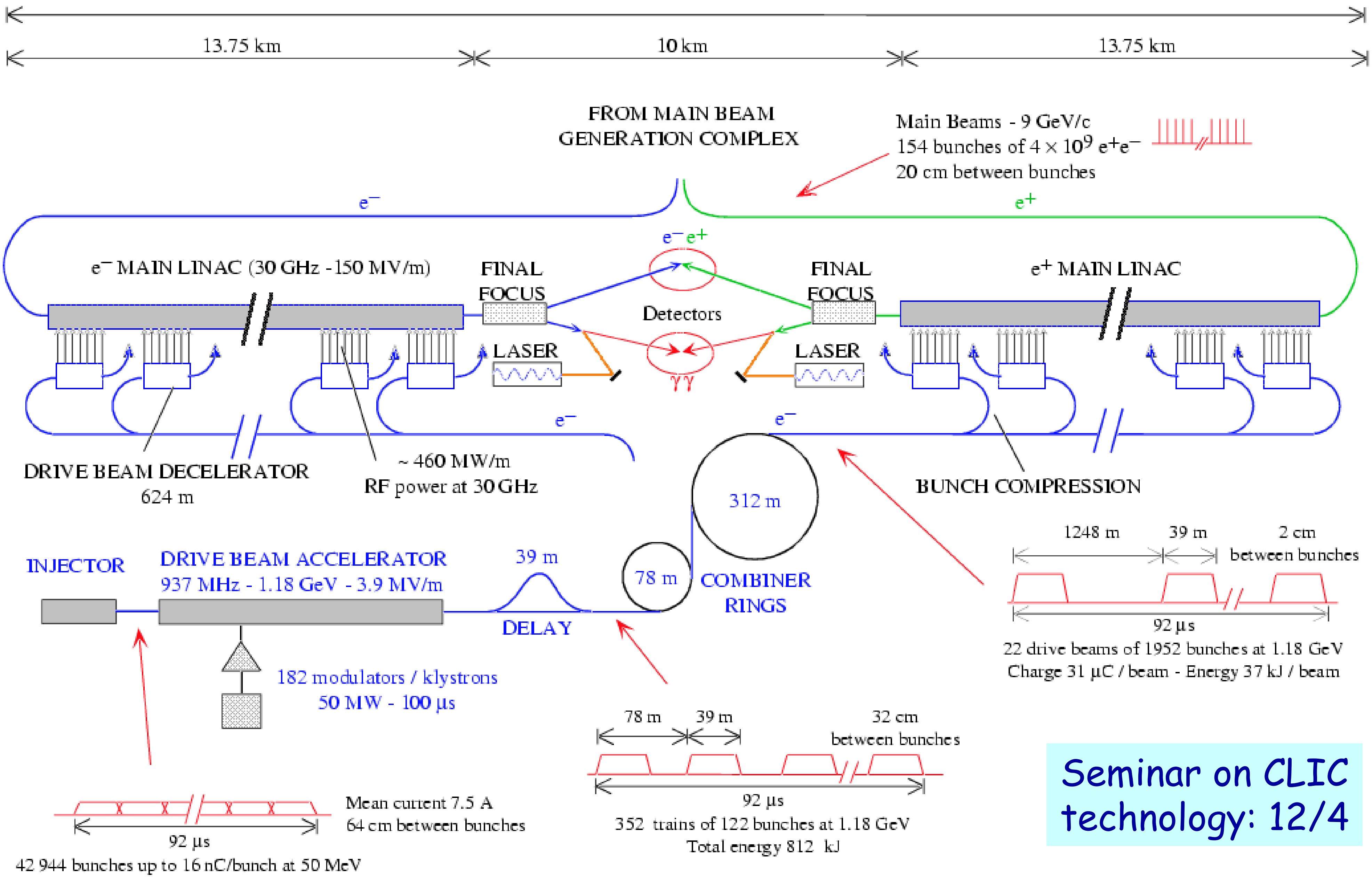
Ellis, Gianotti, ADR
hep-ex/0112004+ few updates

Units are TeV (except $W_L W_L$ reach)
☞ Ldt correspond to 1 year of running at nominal luminosity for 1 experiment

PROCESS	LHC 14 TeV 100 fb^{-1}	SLHC 14 TeV 1000 fb^{-1}	28 TeV 100 fb^{-1}	VLHC 40 TeV 100 fb^{-1}	VLHC 200 TeV 100 fb^{-1}	LC 0.8 TeV 500 fb^{-1}	LC 5 TeV 1000 fb^{-1}
Squarks	2.5	3	4	5	20	0.4	2.5
$W_L W_L$	2σ	4σ	4.5σ	7σ	18σ	6σ	30σ
Z'	5	6	8	11	35	8†	30†
Extra-dim (δ=2)	9	12	15	25	65	5-8.5†	30-55†
q*	6.5	7.5	9.5	13	75	0.8	5
Λcompositeness	30	40	40	50	100	100	400
TGC (λ_γ)	0.0014	0.0006	0.0008		0.0003	0.0004	0.00008

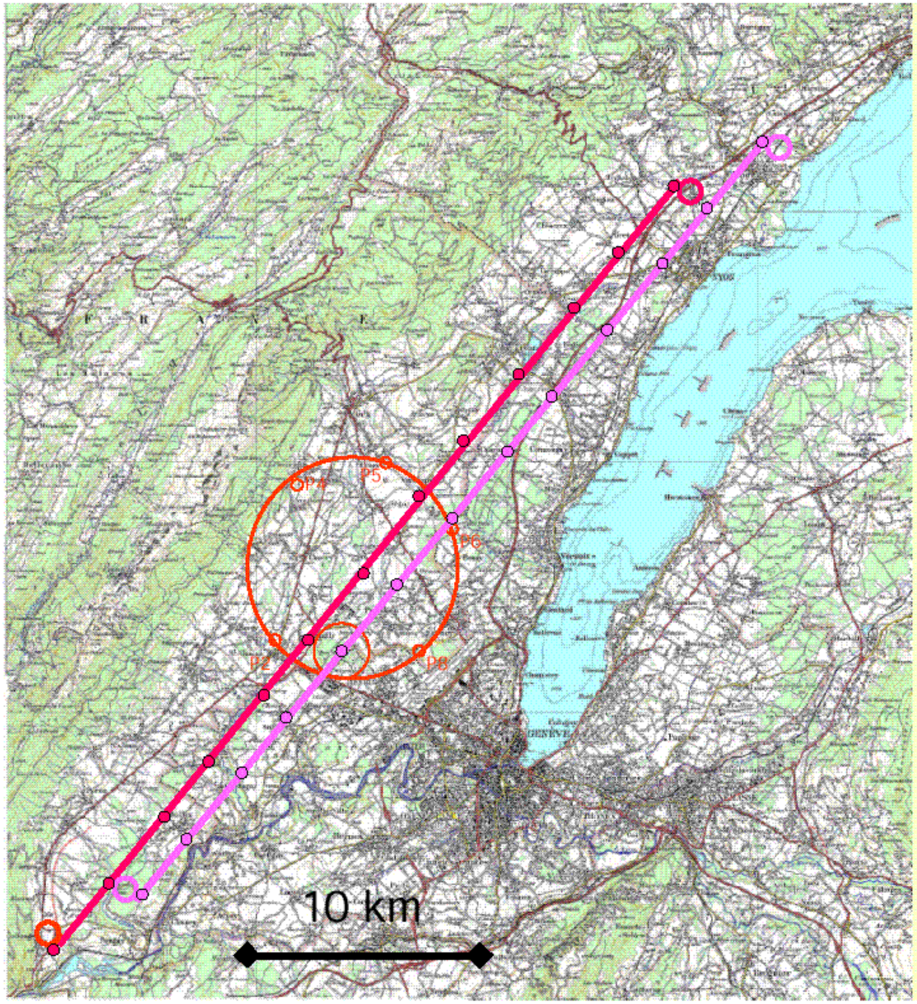
† indirect reach
(from precision measurements)

Don't forget: (much) better precision at an e+e- machine



Seminar on CLIC technology: 12/4

Building CLIC at CERN?



It is possible!

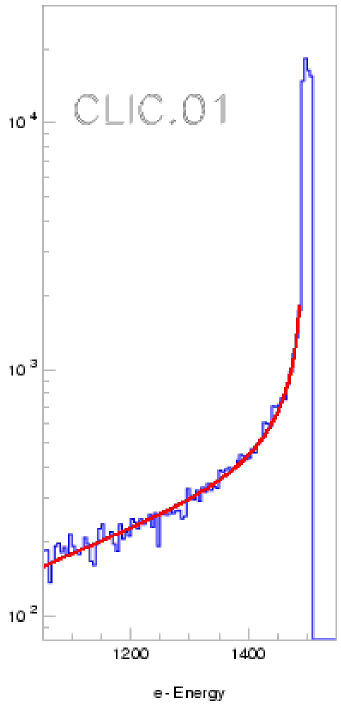
Geological analyses show that there is a contineous stretch of 40 km parallel to the Jura and the lake, with good geological conditions.

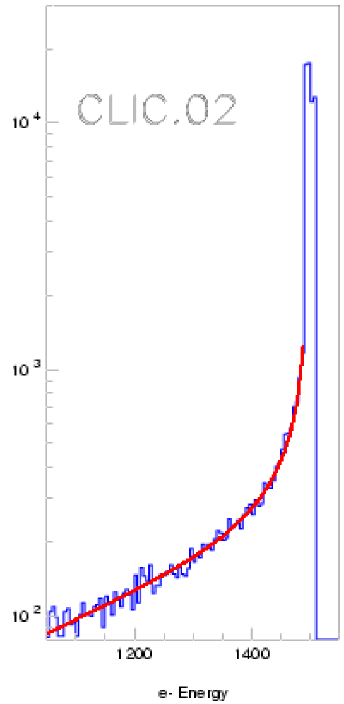
Reminder

The CLIC study is a site independent feasibility study aiming at the development of a realistic technology at an affordable cost for an e± Linear Collider in the post-LHC era for Physics in the multi-TeV center of mass colliding beam energy range.

Luminosity Spectrum

Spectra for CLIC studies (sharper $\leftrightarrow$ high lumi)

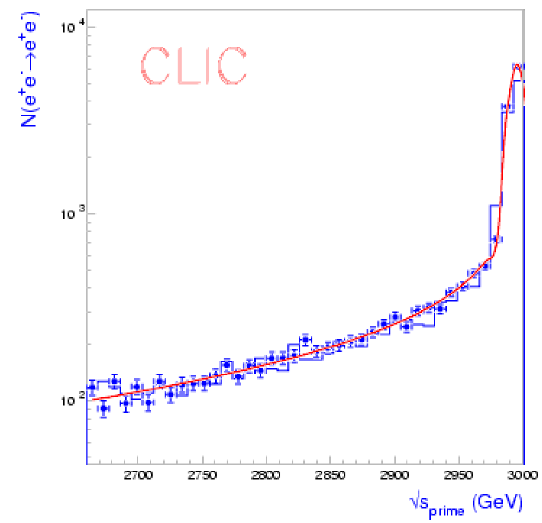




CLIC.01: $\mathcal{L} = 1.05 \times 10^{35}$ CLIC.02: $\mathcal{L} = 0.40 \times 10^{35}$

Energy loss due to beam-beam interactions

Reconstructed $\sqrt{s'}$ Spectrum from Bhabha Angles



Preliminary Results: expect accuracy $\frac{\delta\sqrt{s'}}{\sqrt{s}} \simeq 10^{-4}$ for 100 fb^{-1}

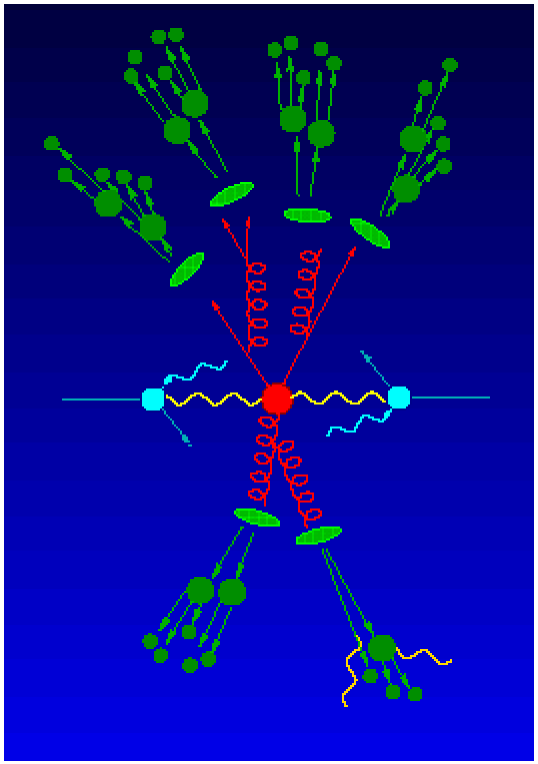
Luminosity within 1% & 5% of c.m. energy

Energy (TeV)	0.5	1	3	5
$\mathcal{L}$ in 1% $\sqrt{s}$	71%	56 %	30%	25%
$\mathcal{L}$ in 5% $\sqrt{s}$	87%	71 %	42%	34%

Luminosity spectrum not as sharply peaked as e.g. at LEP

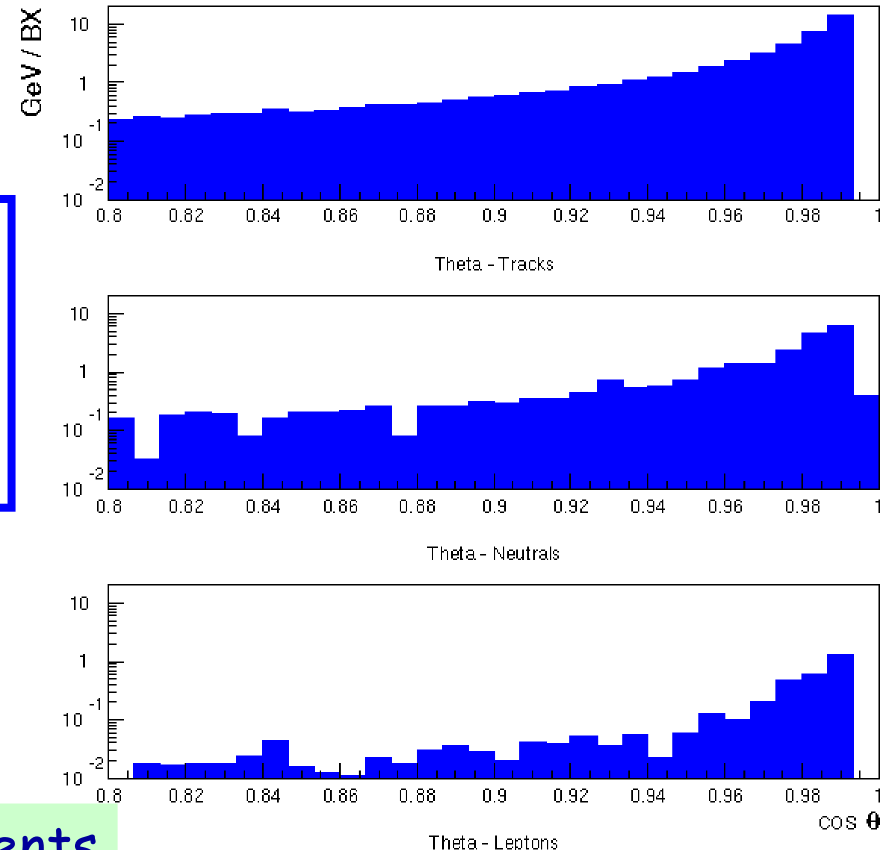
$\gamma\gamma$ Background

$\gamma\gamma \rightarrow$ hadrons: 4 interactions/bx with W_{HAD}>5 GeV



Particles accepted within θ > 120mrad

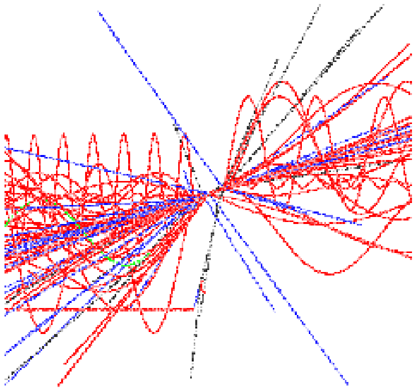
Neutral and charged energy as function of cosθ per bx

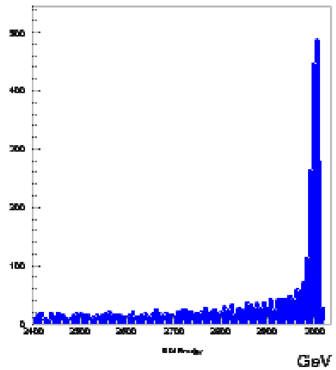


For studies: take 20 bx and overlay events

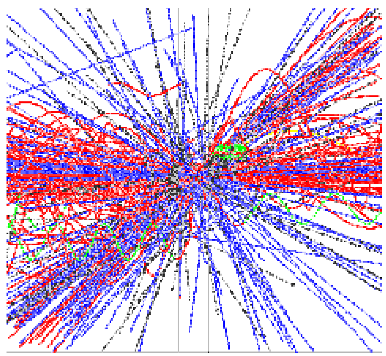
Most activity at small angles

CLIC Tools for Background/Detector

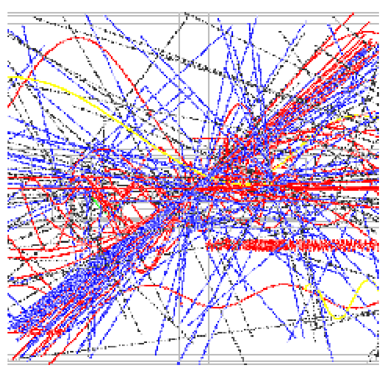




Physics generators (COMPHEP PYTHIA6,…)
+ CLIC lumi spectrum (CALYPSO)



+ $\gamma\gamma\rightarrow$ hadrons background
e.g. overlay 20 bunch crossings
(+ e+e- pair background files…)



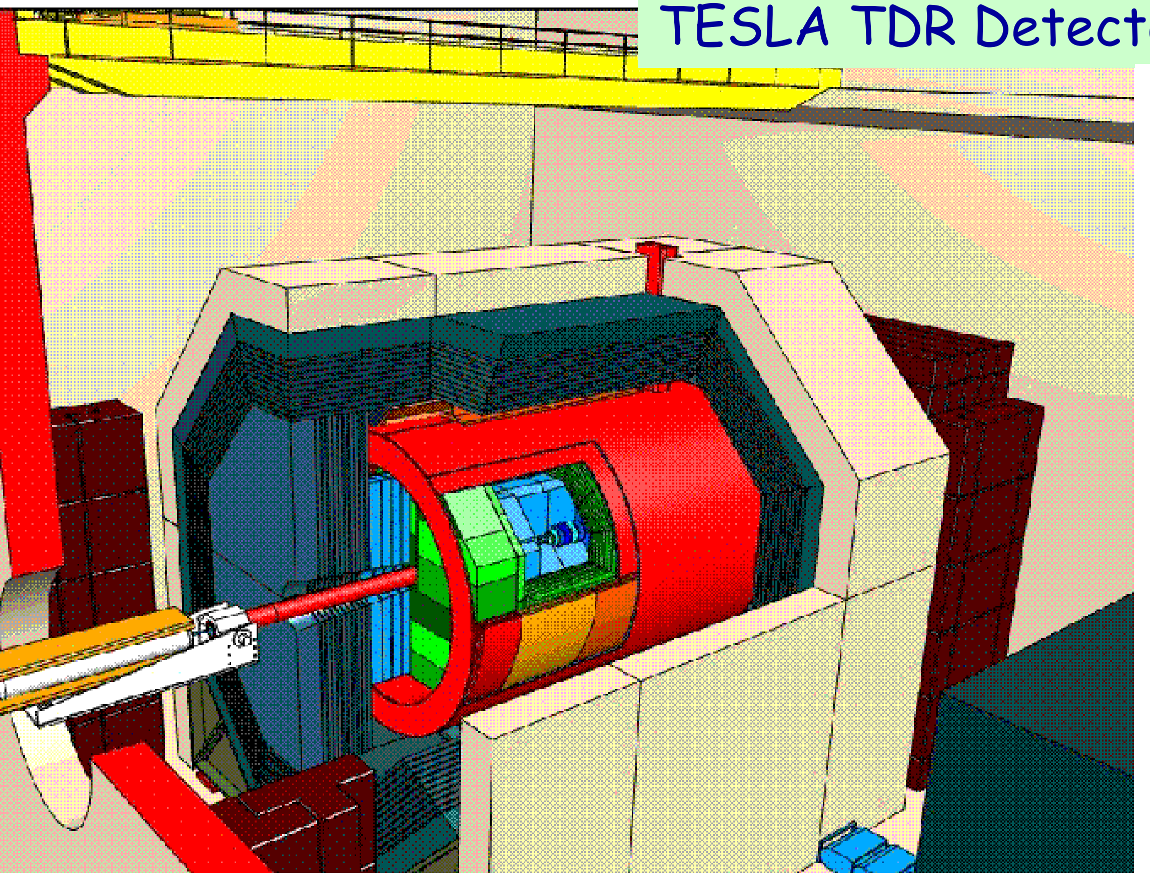
Detector simulation

- SIMDET (fast simulation)
- GEANT3 based program

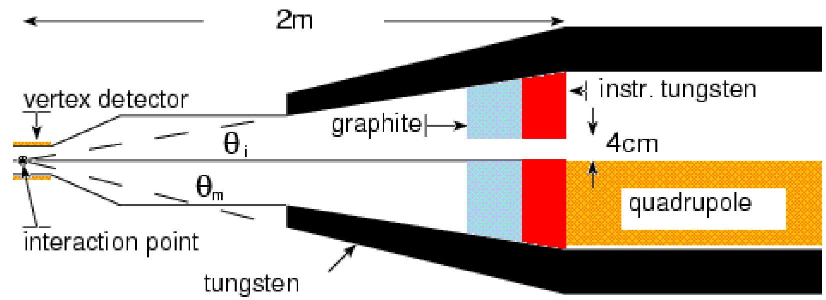
$\Rightarrow$Study benchmark processes

A Detector for a LC

TESLA TDR Detector



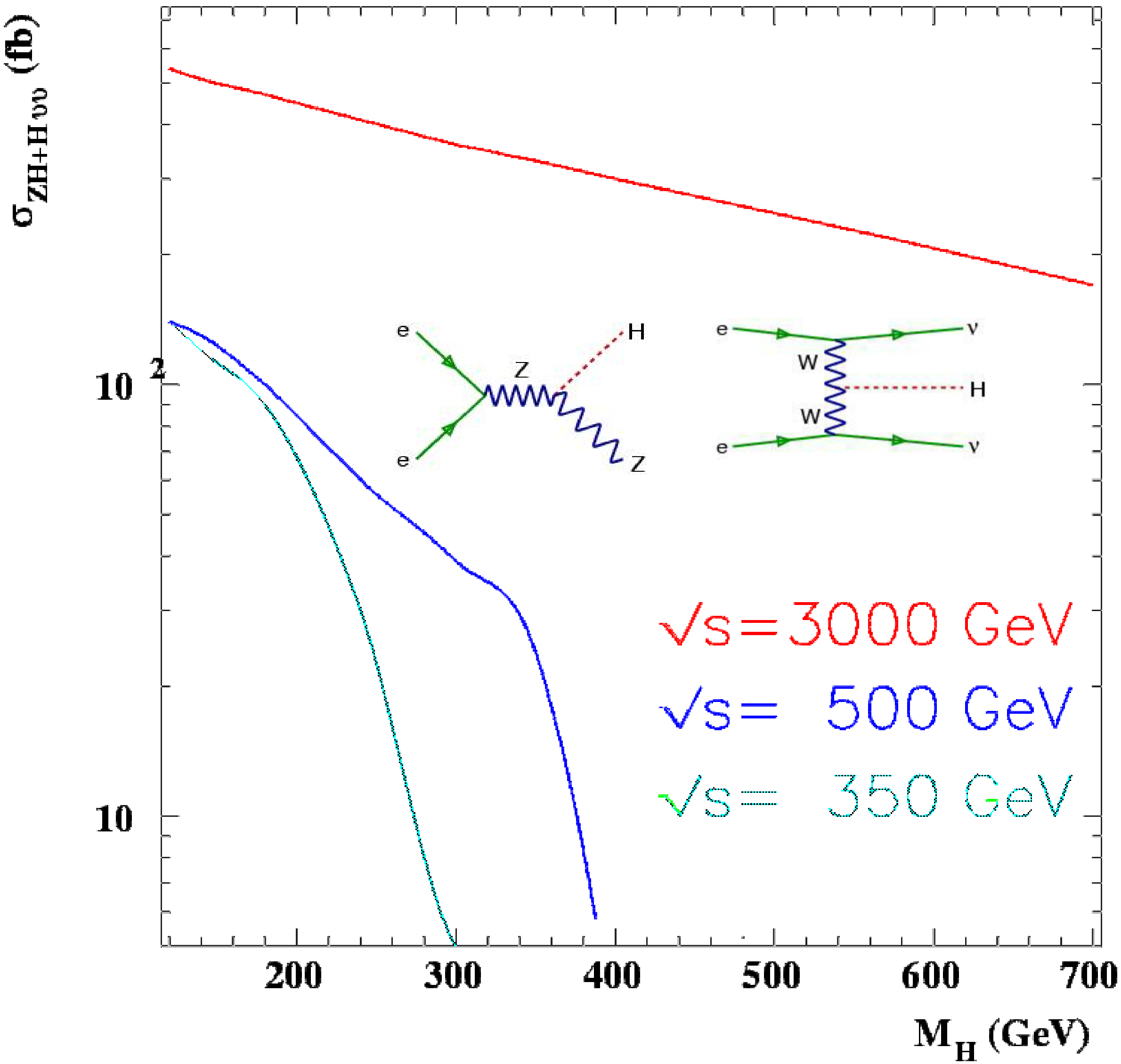
Background at the IP enforces use of a mask



CLIC: Mask covers region up to 120 mrad
Energy flow measurement possible down to 40 mrad

~TESLA/NLC detector qualities: good tracking resolution, jet flavour tagging, energy flow, hermeticity,...

Higgs Production



Cross section at 3 TeV:

- Large cross section at low masses
- Large CLIC luminosity

→Large events statistics

- Keep large statistics also for highest Higgs masses

Low mass Higgs:
400 000 Higgses/year

45K/100K for 0.5/1 TeV LC

Higgs: Strength of a multi-TeV collider

- Precision measurements of the quantum numbers and properties of Higgs particles, for large Higgs mass range
- Study of Heavy Higgses (e.g. MSSM H,A,$H^{\pm}$)
- Rare Higgs decays, even for light Higgs
- Higgs self coupling over a wide range of Higgs masses
- Study of the CP properties of the Higgs…

Parameter	M_H **(GeV)**	$\delta X/X$
$\delta g_{Htt}/g_{Htt}$	120–180	0.05–0.10
$\delta g_{Hbb}/g_{Hbb}$	180–220	0.01–0.03
$\delta g_{H\mu\mu}/g_{H\mu\mu}$	120–150	0.03–0.10
$\delta g_{HHH}/g_{HHH}$	120–180	0.07–0.09
g_{HHHH}	120	$\neq 0$ (?)