ILC Detector Related Activities at IN2P3 : Introduction and Project Overview

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CONSEIL SCIENTIFIQUE DE L'IN2P3, Paris, 30 & 31 Janvier 2014

Outline

- *ILC project*
- *ILC running parametres and conditions*
- *Selected physics motivations*
- *Overview of detector concepts*
- *IN2P3 areas of activities*
- *Summary*

⋇ Main sources:
- B. Barish & J. Brau: *The International Linear Collider*, arXiv: 1311.3397v1 (physics.acc-ph), 14 Nov. 2013
- ILC Technical Design Report, 5 vol. (2013), CERN-ATS-2-13-037
- D.M. Asner et al. : *ILC Higgs White Paper*, arXiv:1310.0763v2 [hep-ph] 23 Oct. 2013
- D.M. Asner et al. : *ILC Top-quark White Paper*, arXiv:1307.8265v3 [hep-ex] 30 Dec. 2013

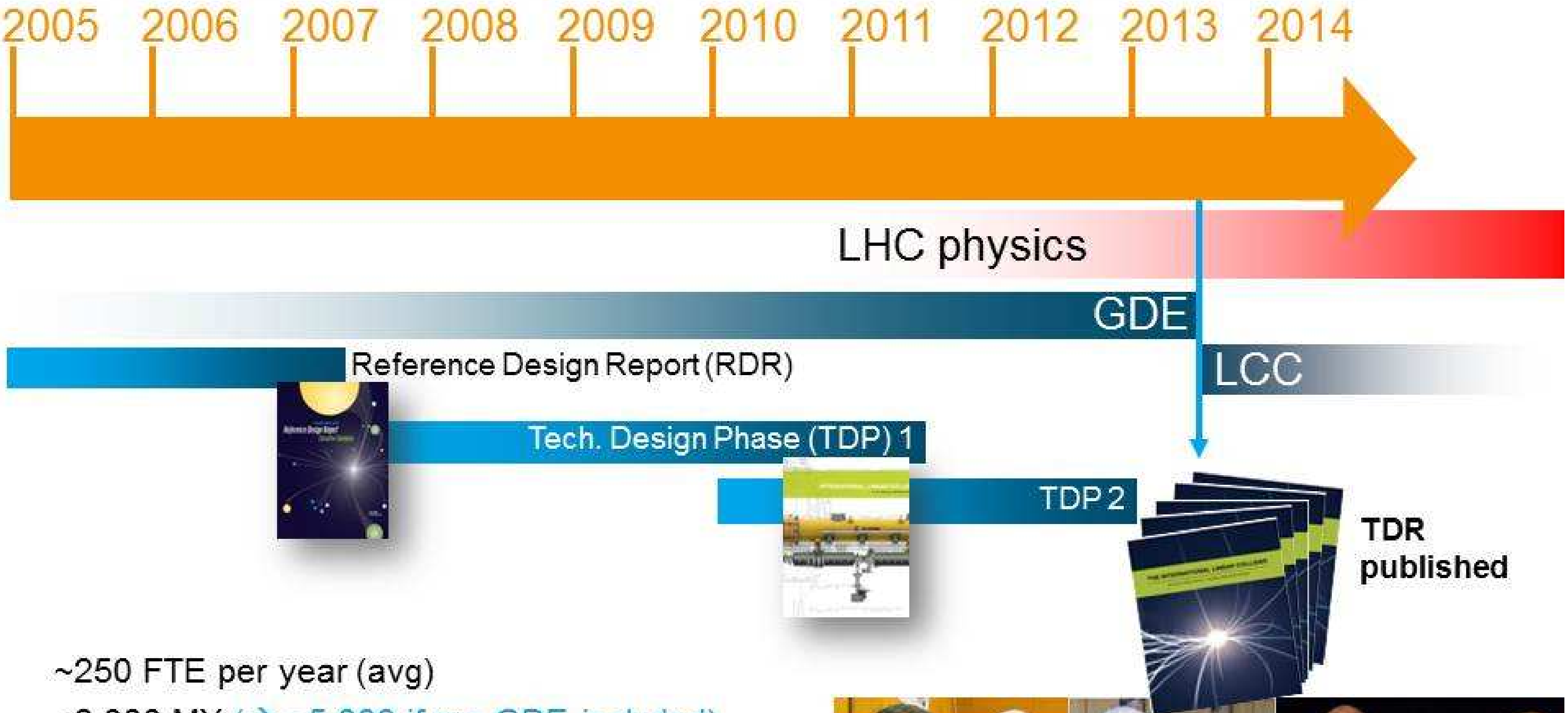
The ILC Project : Prominent Aspects

- ILC BASIC PARAMETRES :
  - ⋇ e^+e^- collisions at a **tunable c.m. energy** of 200 to 500 GeV, extendable to $\sim$ 1 TeV
  - ⋇ **Luminosity** $\gtrsim$ O(10^{34}) $cm^{-2} \cdot s^{-1}$ (∼ $10^3 \times$ SLC)
  - ⋇ Both beams with **tunable polarisation**

- MACHINE, DETECTOR AND PHYSICS STUDIES PERFORMED SINCE THE '90S :
  - ⋇ **R&D on accelerator** has demonstrated its feasibility :
    Technical Design Report **(TDR)** delivered in Dec. 2012 $\longrightarrow$ official publi. in June 2013
  - ⋇ **R&D on experiments** (detectors) has $\pm$ demonstrated their feasibility :
    Detailed Baseline Design **(DBD)** delivered in February 2013
  - ⋇ **Physics potential** reliably evaluated

- LONG RANGE WORLD WIDE COORDINATED EFFORT :
  - ⋇ Global Design Effort **(GDE)** until 2013 (chairman: B. Barish/CalTech)
  - ⋇ Linear Collider Collaboration **(LCC)** since February 2013 (chairman: L. Evans/CERN)

GDE Timeline



~250 FTE per year (avg)

~2,000 MY (→ ~5,000 if pre-GDE included)

~300 M$ globally

Global Event
June 12

ilc

Nick Walker | ILC Status – DESY WA | 20.08.13 | Page 13

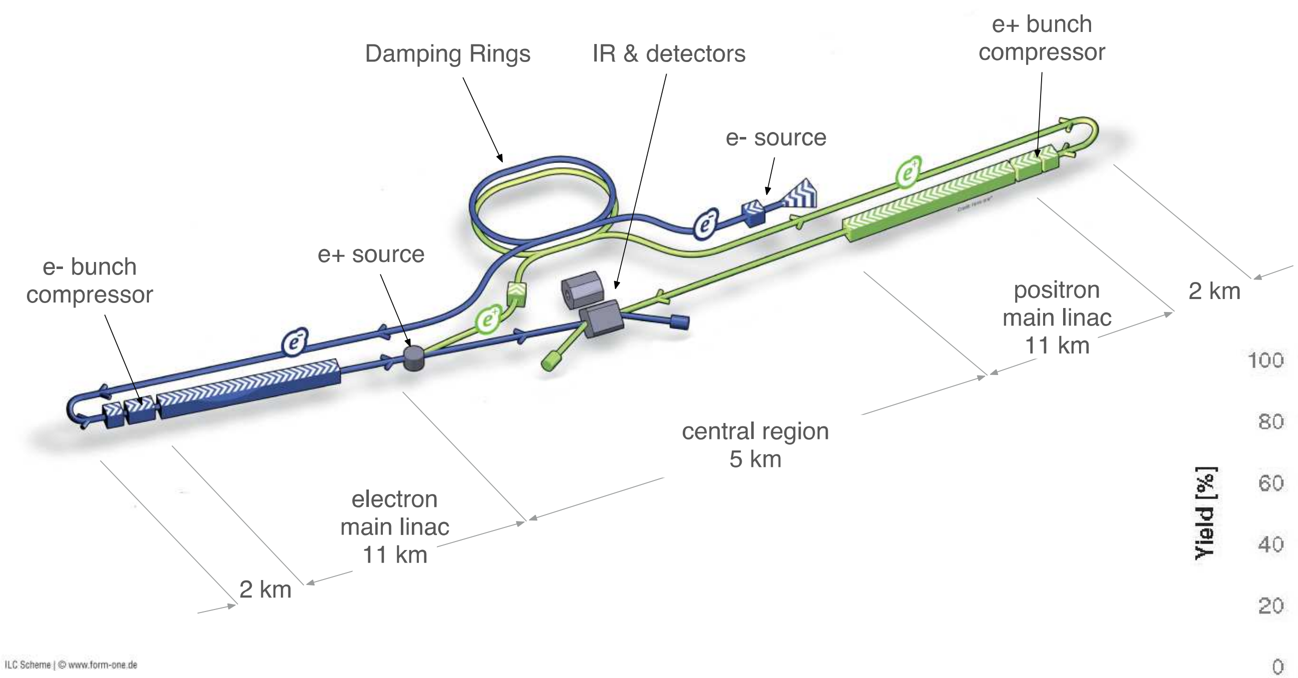
DESY

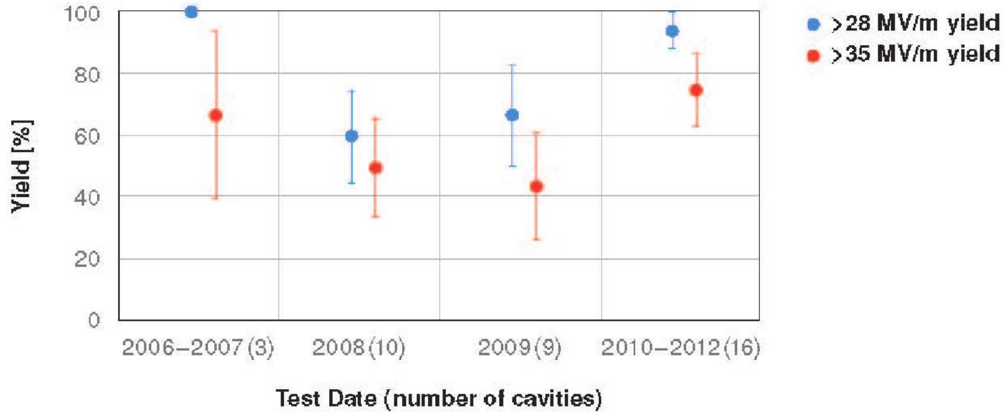
The ILC Project : The International Context

- **The situation in Japan :**
  - ⋇ Japan has been very proactive in promoting the ILC to be built in the country
  - ⋇ Japanese government is examining how it could host the ILC
    - ∘ Site has been decided : Kitakami mountains in North of Japan ▷
    - ∘ Team of Diet members examining ILC issues since 2008
      ↪ followed monthly lectures on HEP
    - ∘ Recently: government has announced the creation of its own ILC-budget for FY'14

- **The situation outside of Japan :**
  - ⋇ The perspective of an ILC in Japan was integrated in the 2013 update of the EU strategy for HEP (statement Nr.3)
  - ⋇ Countries are getting contacted by Japanese gvt representatives
    ↪ discussions will start soon on possible contributions
  - ⋇ Final decision for constructing ILC (or not ...) expected in ∼ 3-5 years
  - ⋇ Start of physics expected by the end of next decade

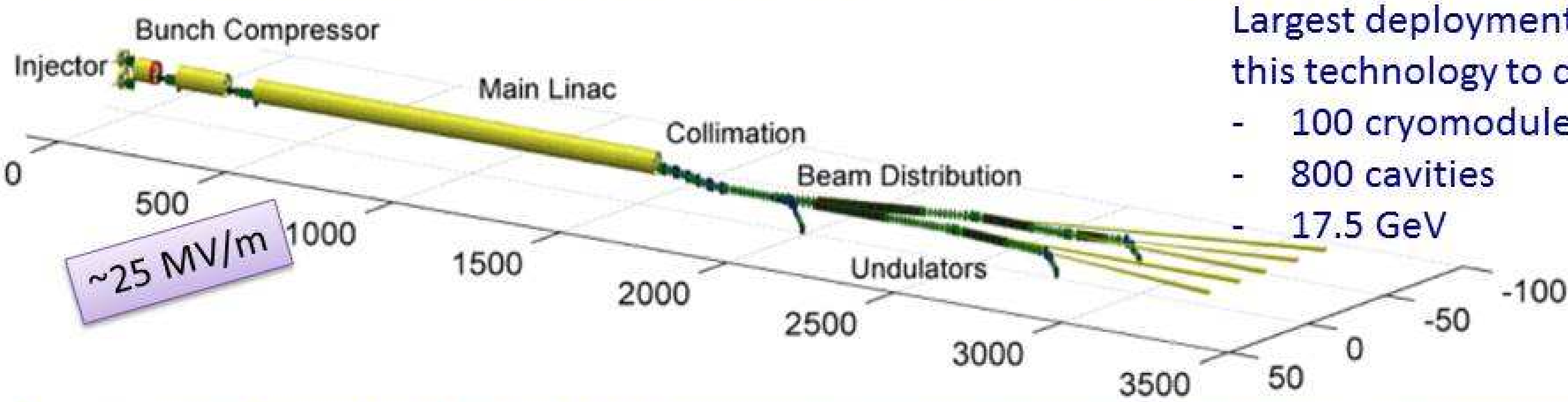
Overview of the ILC Machine





- MACHINE TECHNOLOGICAL MATURITY :
  - All major technical problems solved, e.g. cavity gradient, quality factor & industrial yield
  - But R&D still needed to improve & optimise the machine design realism and to reduce the cost
  - IN2P3 accelerator groups strongly involved in cavity powering (klystrons/couplers),
    while CEA strongly involved in cryomule production (XFEL)
  - IN2P3 groups involved in beam instrumentation close to IP
- XFEL LINAC ($\cong$ 1/10 ILC LINAC) UNDER CONSTRUCTION AT DESY,
  BASED ON SCRF CAVITIES PROVIDING A GRADIENT ($\sim$ 25 MV/M) ADAPTED TO ILC UNTIL $\sim$ 350 GEV

European XFEL @ DESY



Largest deployment of this technology to date

- 100 cryomodules
- 800 cavities
- 17.5 GeV

Institute	Component Task
CEA Saclay / IRFU, France	Cavity string and module assembly; cold beam position monitors
CNRS / LAL Orsay, France	RF main input coupler incl. RF conditioning
DESY, Germany	Cavities & cryostats; contributions to string & module assembly; coupler interlock; frequency tuner; cold-vacuum system; integration of superconducting magnets; cold beam-position monitors
INFN Milano, Italy	Cavities & cryostats
Soltan Inst., Poland	Higher-order-mode coupler & absorber
CIEMAT, Spain	Superconducting magnets
IFJ PAN Cracow, Poland	RF cavity and cryomodule testing
BINP, Russia	Cold vacuum components

The ultimate 'integrated systems test' for ILC. Commissioning with beam 2nd half 2015

Machine Parametres from 200 to 1000 GeV

- **Staged operation of the machine, e.g. 250 GeV $\rightarrowtail$ 350/500 GeV $\rightarrowtail$ 500/350 GeV**
- Luminosities calculated with several conservative assumptions (e.g. power)

			Baseline 500 GeV Machine			1st Stage	L Upgrade	E_{CM} Upgrade	
								A	B
Centre-of-mass energy	E_{CM}	GeV	250	350	500	250	500	1000	1000
Collision rate	f_{rep}	Hz	5	5	5	5	5	4	4
Electron linac rate	f_{linac}	Hz	10	5	5	10	5	4	4
Number of bunches	n_b		1312	1312	1312	1312	2625	2450	2450
Bunch population	N	$\times 10^{10}$	2.0	2.0	2.0	2.0	2.0	1.74	1.74
Bunch separation	Δt_b	ns	554	554	554	554	366	366	366
Pulse current	I_{beam}	mA	5.8	5.8	5.8	5.8	8.8	7.6	7.6
Main linac average gradient	G_a	MV m^{-1}	14.7	21.4	31.5	31.5	31.5	38.2	39.2
Average total beam power	P_{beam}	MW	5.9	7.3	10.5	5.9	21.0	27.2	27.2
Estimated AC power	P_{AC}	MW	122	121	163	129	204	300	300
RMS bunch length	σ_z	mm	0.3	0.3	0.3	0.3	0.3	0.250	0.225
Electron RMS energy spread	$\Delta p/p$	%	0.190	0.158	0.124	0.190	0.124	0.083	0.085
Positron RMS energy spread	$\Delta p/p$	%	0.152	0.100	0.070	0.152	0.070	0.043	0.047
Electron polarisation	P_-	%	80	80	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30	20	20
Horizontal emittance	$\gamma\epsilon_x$	µm	10	10	10	10	10	10	10
Vertical emittance	$\gamma\epsilon_y$	nm	35	35	35	35	35	30	30
IP horizontal beta function	β^*_x	mm	13.0	16.0	11.0	13.0	11.0	22.6	11.0
IP vertical beta function	β^*_y	mm	0.41	0.34	0.48	0.41	0.48	0.25	0.23
IP RMS horizontal beam size	σ^*_x	nm	729.0	683.5	474	729	474	481	335
IP RMS veritcal beam size	σ^*_y	nm	7.7	5.9	5.9	7.7	5.9	2.8	2.7
Luminosity	L	$\times 10^{34}$ cm^{-2}s^{-1}	0.75	1.0	1.8	0.75	3.6	3.6	4.9
Fraction of luminosity in top 1%	$L_{0.01}/L$		87.1%	77.4%	58.3%	87.1%	58.3%	59.2%	44.5%
Average energy loss	δ_{BS}		0.97%	1.9%	4.5%	0.97%	4.5%	5.6%	10.5%
Number of pairs per bunch crossing	N_{pairs}	$\times 10^3$	62.4	93.6	139.0	62.4	139.0	200.5	382.6
Total pair energy per bunch crossing	E_{pairs}	TeV	46.5	115.0	344.1	46.5	344.1	1338.0	3441.0

ILC Physics : Main Aspects

- PROMINENT ADVANTAGES OF THE MACHINE :
  - ⋇ **Well defined initial state** : E_{cm}, P_{e^-}, P_{e^+}, J, ...
  - ⋇ Tunable E_{cm} and $P_{e^\pm}$:
    $\hookrightarrow$ threshold scan, signal enhancement & (SM) background suppression
  - ⋇ **Low prompt interaction rate** : few Hz (10^9 Hz at LHC) with O(1) % of them creating Higgs
  - ⋇ **Modest machine background** ($\sim 10^3$ less than LHC)
    $\hookrightarrow$ Detector performances barely compromised for running conditions

  $\Rrightarrow$ **priority given to precision and sensitivity, no trigger filtering**

- PROMINENT PHYSICS OBJECTIVES : HIGGS-SECTOR, DM, MATTER-ANTIMATTER ASYM, ...
  - ⋇ **Higgs sector :** extensive and high-precision study of Higgs parametres
    $\Rrightarrow$ direct access to Higgs couplings (complementary to LHC which measures Br and $\sigma \cdot Br$)
    $\hookrightarrow$ Higgs properties against SM predictions $\rightarrowtail$ access to BSM physics ?
  - ⋇ **top-quark sector :** extensive study of the nature & role of the heaviest known particle
    e.g. unique measurement of the genuine top mass via threshold scan around 350 GeV
  - ⋇ **BSM physics** search or / and characterisation, guided or not by LHC discoveries

Physics Processes Addressed at the ILC

- 2 STEPS IN MAXIMAL E_{CM} (AND LUMINOSITY) REACHABLE :
  - **Baseline :** $E_{CM} \sim$ 500 GeV with possibility to run at lower energies
    $E_{CM} \sim$ 250 GeV (Higgs prod. threshold) , $E_{CM} \sim$ 350 GeV (top-quark pair prod. threshold)
  - **Possible upgrades** $\rightarrowtail$ $E_{CM} \sim 10^3$ GeV, L x 4 (?), P_{e+}, Giga-Z
- EXAMPLES OF SM AND (HYPOTHETICAL) BSM PROCESSES ADDRESSED AT VARIOUS E_{CM} SETTINGS

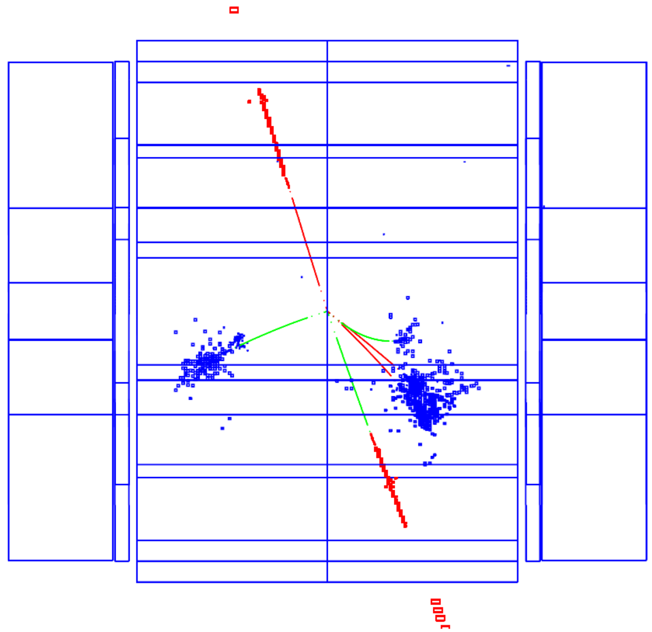
Energy	Reaction	Physics Goal
91 GeV	$e^+e^- \to Z$	ultra-precision electroweak
160 GeV	$e^+e^- \to WW$	ultra-precision W mass
250 GeV	$e^+e^- \to Zh$	precision Higgs couplings
350–400 GeV	$e^+e^- \to t\bar{t}$	top quark mass and couplings
	$e^+e^- \to WW$	precision W couplings
	$e^+e^- \to \nu\bar{\nu}h$	precision Higgs couplings
500 GeV	$e^+e^- \to f\bar{f}$	precision search for Z'
	$e^+e^- \to t\bar{t}h$	Higgs coupling to top
	$e^+e^- \to Zhh$	Higgs self-coupling
	$e^+e^- \to \tilde{\chi}\tilde{\chi}$	search for supersymmetry
	$e^+e^- \to AH, H^+H^-$	search for extended Higgs states
700–1000 GeV	$e^+e^- \to \nu\bar{\nu}hh$	Higgs self-coupling
	$e^+e^- \to \nu\bar{\nu}VV$	composite Higgs sector
	$e^+e^- \to \nu\bar{\nu}t\bar{t}$	composite Higgs and top
	$e^+e^- \to \tilde{t}\tilde{t}^*$	search for supersymmetry

Higgs Production at 250 GeV : Final State Topology

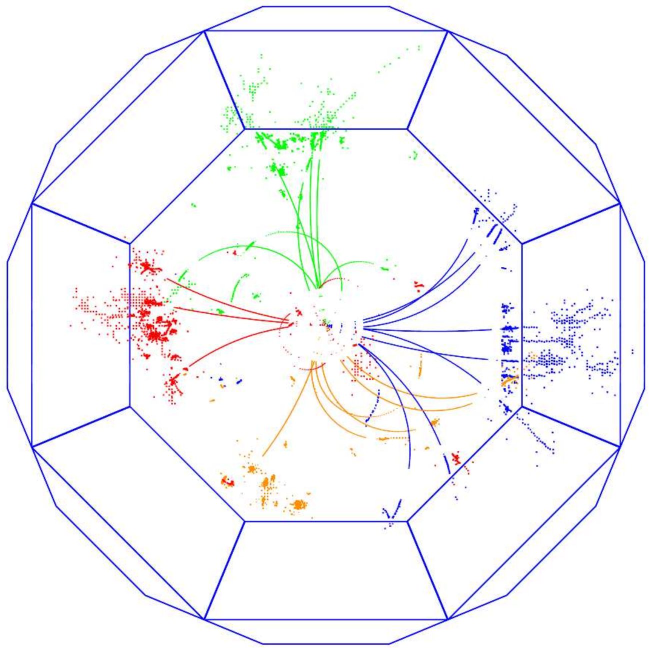
- CLEAN FINAL STATES ALLOW FOR HIGH S/B & PRECISE MEASUREMENTS

  Ex: $e^+e^- \longrightarrow HZ$

- YOZ VIEW OF COLLISION WHERE :
  - $Z \longrightarrow \mu^+\mu^-$
  - $H \longrightarrow \tau^+\tau^-$



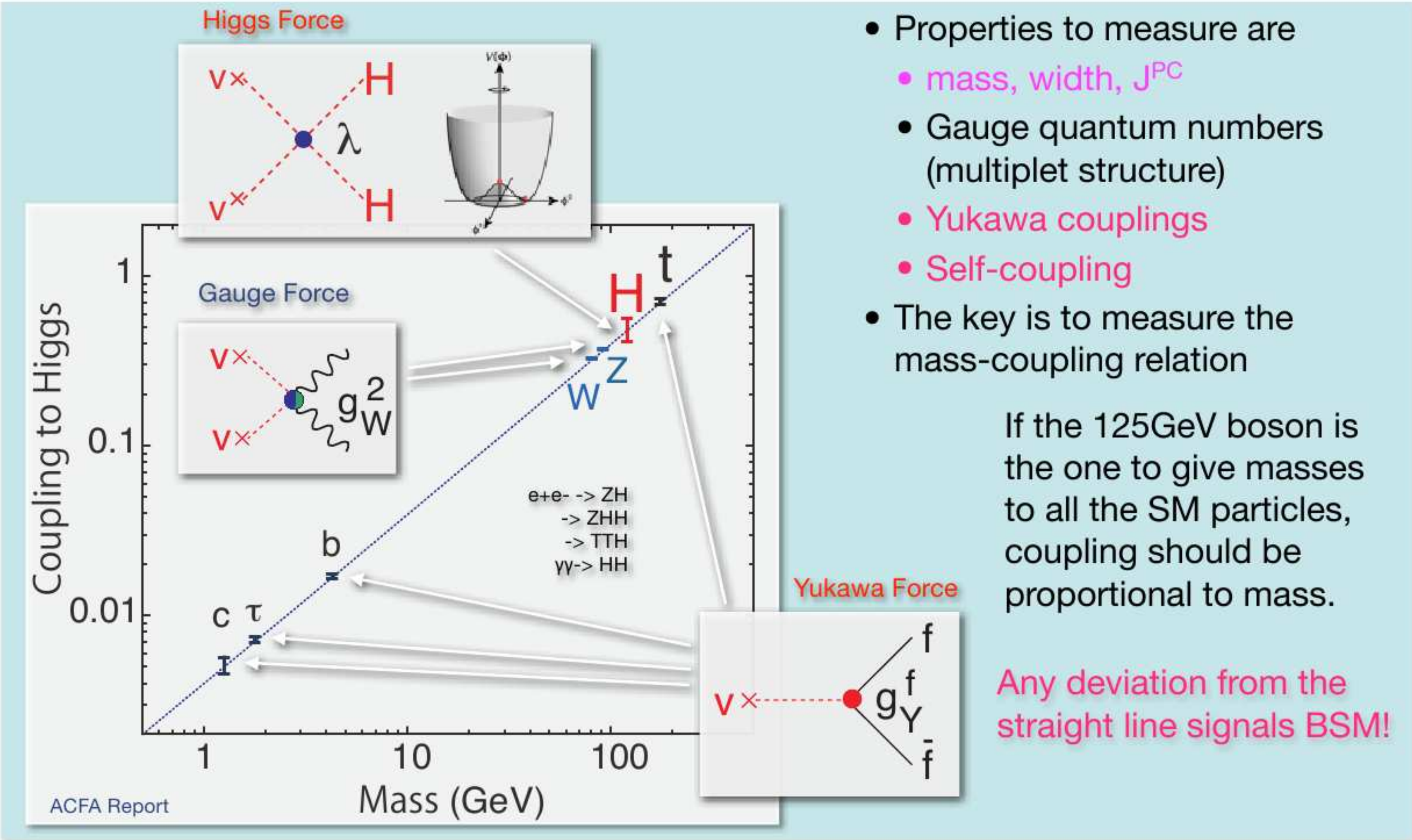
- XOY VIEW OF COLLISION WHERE :
  - $Z \longrightarrow b\bar{b}$
  - $H \longrightarrow b\bar{b}$



Higgs Properties Accessible at the ILC

- HIGGS BOSON PRODUCTION AT ILC $\simeq$ 1% OF ALL NON-QED HARD SCATTERING FINAL STATES

  at LHC : Higgs production rate is $\sim$ O($10^{-9/-10}$) of all physics final states

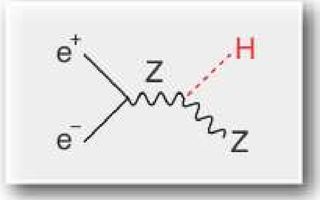


- COUPLINGS ARE OF PARTICULAR IMPORTANCE AS THEY ARE A WINDOW TOWARDS BSM PHYSICS

Higgs Boson Measurements : Complementary E_{cm} & Processes

ZH @ 250 GeV (~MZ+MH+20GeV) :

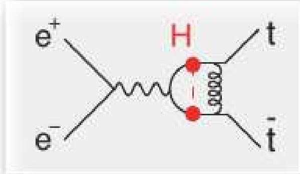
- Higgs mass, width, J^{PC}
- Gauge quantum numbers
- Absolute measurement of HZZ coupling (recoil mass) -> couplings to H (other than top)
- BR(h->VV,qq,ll,invisible) : V=W/Z(direct), g, γ (loop)

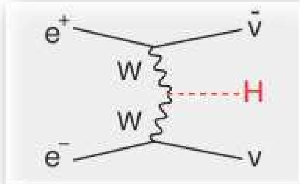


ttbar @ 340-350GeV (~2mt) : ZH meas. Is also possible

- Threshold scan --> theoretically clean mt measurement: $\Delta m_t(\overline{MS}) \simeq 100\,\mathrm{MeV}$
  --> test stability of the SM vacuum
  --> indirect meas. of top Yukawa coupling
- AFB, Top momentum measurements
- Form factor measurements

γ γ → HH @ 350GeV possibility



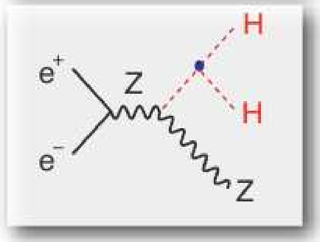


vvH @ 350 - 500GeV :

- HWW coupling -> total width --> absolute normalization of Higgs couplings

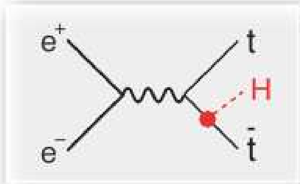
ZHH @ 500GeV (~MZ+2MH+170GeV) :

- Prod. cross section attains its maximum at around 500GeV -> Higgs self-coupling



ttbarH @ 500GeV (~2mt+MH+30GeV) :

- Prod. cross section becomes maximum at around 800GeV.
- QCD threshold correction enhances the cross section -> top Yukawa measurable at 500GeV concurrently with the self-coupling



We can complete the mass-coupling plot at ~500GeV!

- DATA TAKING AT $E_{cm} \simeq$ 250 GEV & 500 GEV **as well as at 350 GeV (top-quark)**

Total Width and Coupling Extraction

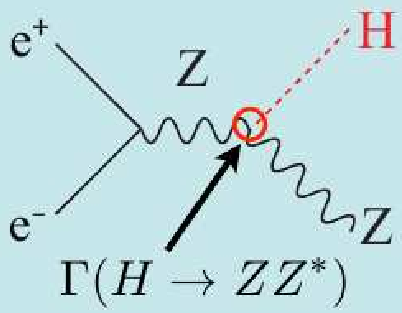
To extract couplings from BRs, we need the total width:

$$g^2_{HAA} \propto \Gamma(H \to AA) = \Gamma_H \cdot BR(H \to AA)$$

To determine the total width, we need at least one partial width and corresponding BR:

$$\Gamma_H = \Gamma(H \to AA)/BR(H \to AA)$$

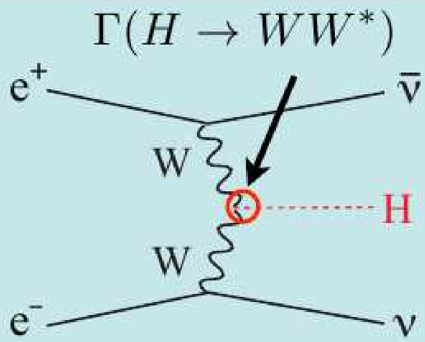
In principle, we can use A=Z, or W for which we can measure both the BRs and the couplings:



$BR(H \to ZZ^*)$

BR=O(1%): precision limited by low stat. for H->ZZ* events

$250\,\mathrm{fb}^{-1}$@$250\,\mathrm{GeV}$
$\Delta\Gamma_H/\Gamma_H \simeq 20\%$



$BR(H \to WW^*)$

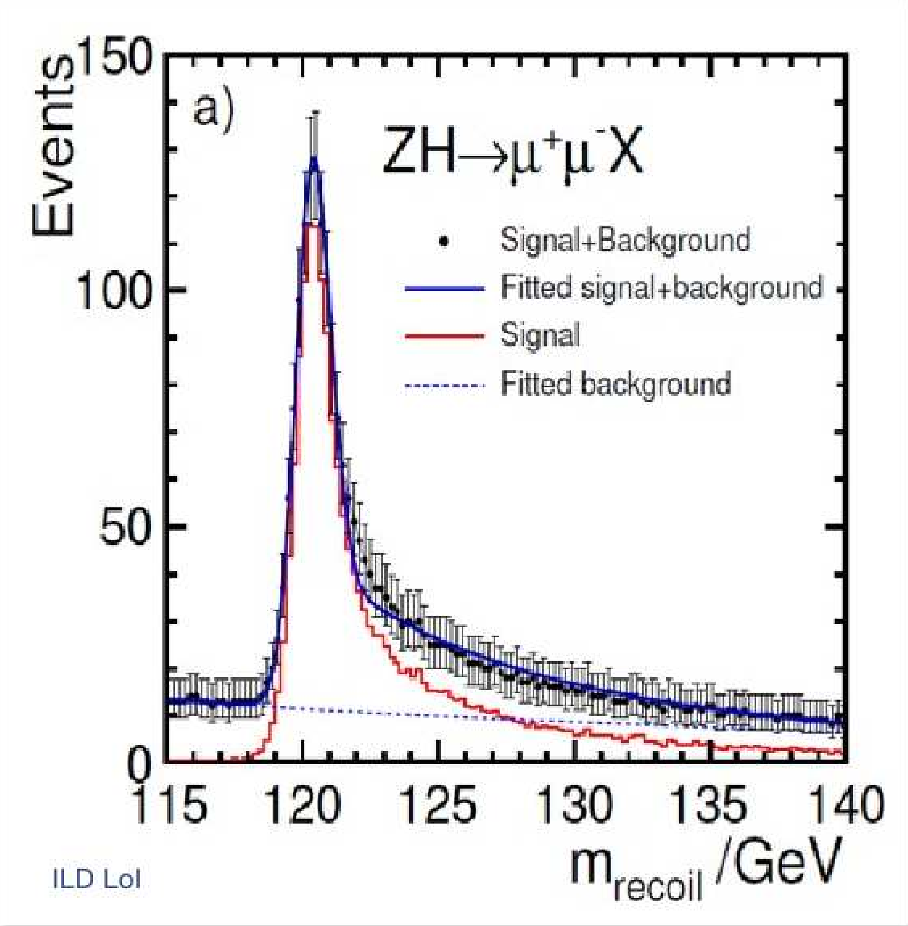
More advantageous but not easy at low E

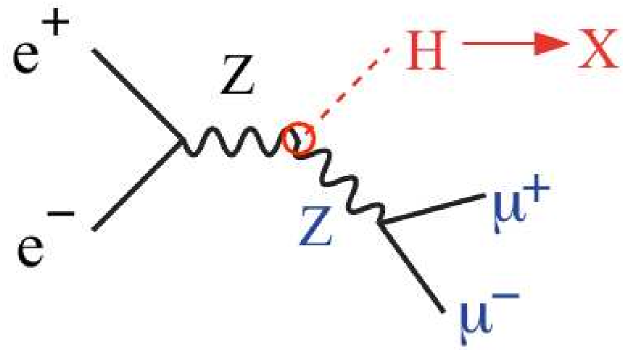
$250\,\mathrm{fb}^{-1}$@$250\,\mathrm{GeV}$
$\Delta\Gamma_H/\Gamma_H \simeq 11\%$

C.F.Durig, Helmholtz Alliance 6th WS, Dec. 2012

Measurements Achievable at $E_{cm} \simeq 250$ GeV

Recoil Mass





$$M_X^2 = (p_{CM} - (p_{\mu^+} + p_{\mu^-}))^2$$

Invisible decay detectable!

$250\,\mathrm{fb}^{-1}@250\,\mathrm{GeV}$ $\quad m_H = 125\,\mathrm{GeV}$

$$\Delta\sigma_H/\sigma_H = 2.6\%$$

$$\Delta m_H = 30\,\mathrm{MeV}$$

$BR(\mathrm{invisible}) < 1\%\,@\,95\%\,\mathrm{C.L.}$

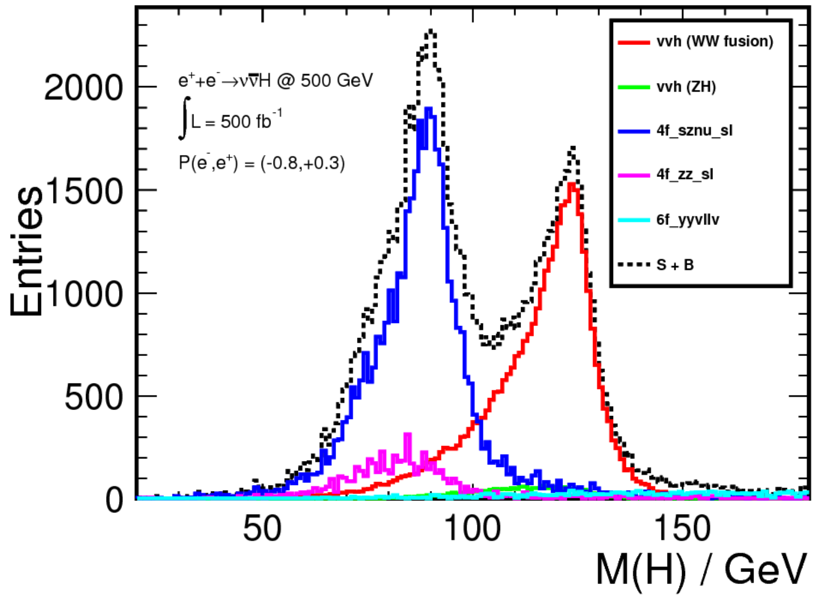
scaled from mH=120 GeV

Model-independent absolute measurement of σ_{ZH} (the HZZ coupling)

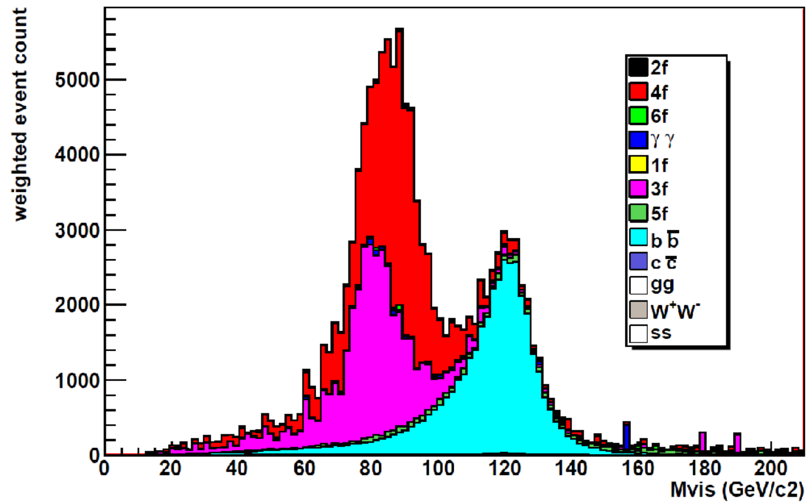
WW-Fusion Final State Identification at E_{cm} = 500 GeV and 1 TeV

- DIJET & VISIBLE MASS DISTRIBUTIONS
  IN FINAL STATES PRODUCED VIA WW-FUSION
  $$e^+e^- \longrightarrow \nu\bar{\nu}H$$

- DIJET MASS DISTRIBUTION :
  - E_{cm} = 500 GeV
  - $P(e^-) / P(e^+)$ = -80 % / + 30 %
  - $H \longrightarrow b\bar{b}$

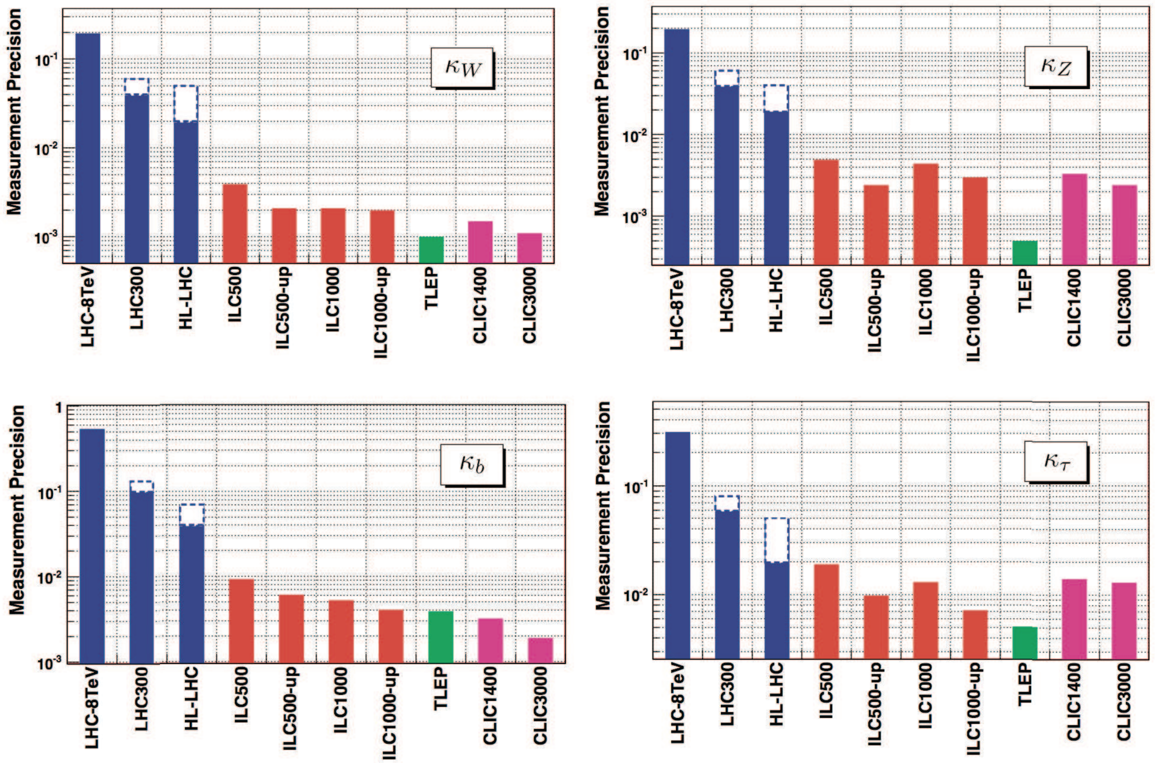


- VISIBLE MASS DISTRIBUTION :
  - E_{cm} = 1 TeV
  - $P(e^-) / P(e^+)$ = -80 % / + 20 %
  - $H \longrightarrow b\bar{b}$



ILC Potential : Precision on Higgs Couplings

- ILC POTENTIAL EXTENSIVELY EXAMINED BY US COMMUNITY THROUGH SNOWMASS PROCESS :
  - ⁂ Snowmass final studies : August 2013
  - ⁂ Contributors from all over the world (including IN2P3 community)
  - ⁂ White papers written (public)
  - ⁂ Comparison to LHC potential (and TLEP)
  - ⁂ Objective : recommandations to DoE about the US HEP strategy for the upcoming decade



Snowmass Higgs report

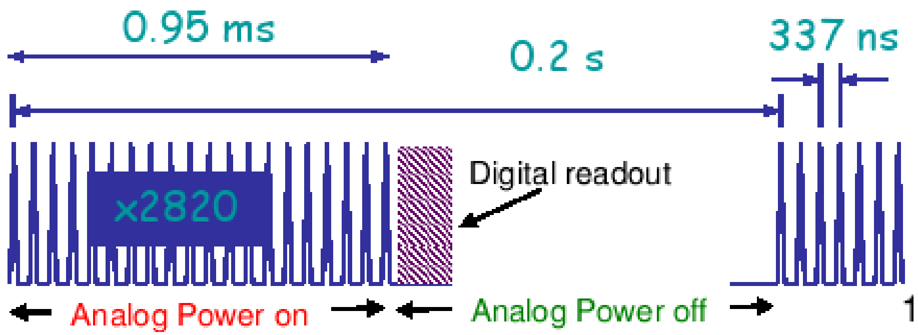
ILC Higgs White Paper	arXiv:1310.0763
ILC Electroweak White Paper	arXiv:1307.3962
ILC Top Quark White Paper	arXiv:1307.8265
ILC BSM White Paper	arXiv:1307.5248
CLIC Physics White Paper	arXiv:1307.5288

▷ ▷ ▷ **Strong physics potential of ILC highlighted as a unique opportunity for the US HEP community**

Development of Detectors Suited to ILC : General Features

- MACHINE ENVIRONMENT:
  - ⁂ ILC machine environment is much milder than LHC standards
    - ◦ radiation load $\lesssim 10^{-3}$ LHC values
    - ◦ hard process final states $\sim$ few Hz (neglecting pure EM interactions)
  - ⁂ Major consequence on detector optimisation (different from LHC) :
    - ◦ detector components optimised for physics driven requirements : precision, sensitivity, no trigger, ...
    - ◦ compromises to accommodate running conditions are modest

- ILC BEAM TIME STRUCTURE :
  - ⁂ beam structured in bunches separated by $\sim$ 0.5 μs
    and grouped into $\lesssim$ 1 ms long trains
  - ⁂ bunch trains separated by $\sim$ 200 ms beamless periods



$\Rrightarrow$ beam time structure exploited to power cycle the detector

$\Rrightarrow$ average power reduced by factor $\gtrsim$ 50

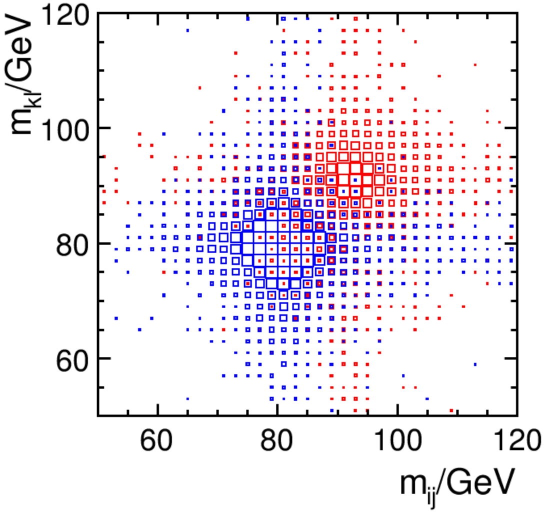
$\Rrightarrow$ SPECIFIC R&D REQUIRED

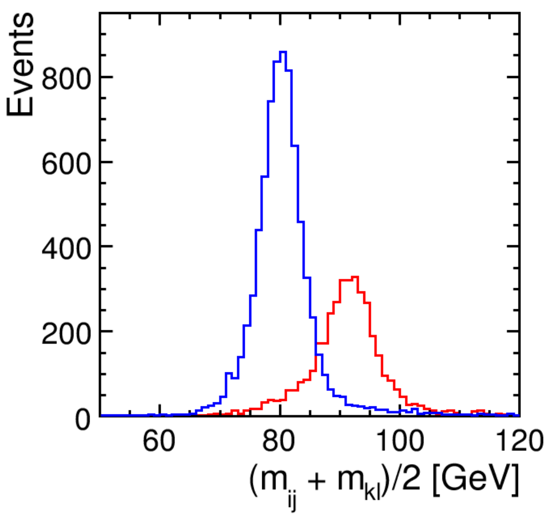
Development of Detectors Suited to ILC : Driving Parametres

- HIGH RESOLUTION JET ENERGY & FLAVOUR RECONSTRUCTION

  + HIGH RESOLUTION DI-JET MASS DETERMINATION:

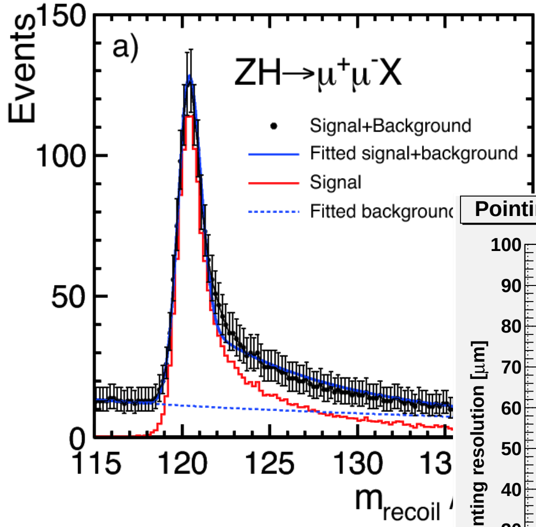
  - ⋇ PFA technique developed to meet this challenge
  - ⋇ highly granular ECAL & HCAL mandatory ($\Delta E_{jet}/E_{jet} \simeq$ 3-4% at 100 GeV
    $\hookrightarrow$ distinguish W from Z di-jets) $\rightarrowtail$





- CHARGED TRACK RECONSTRUCTION :

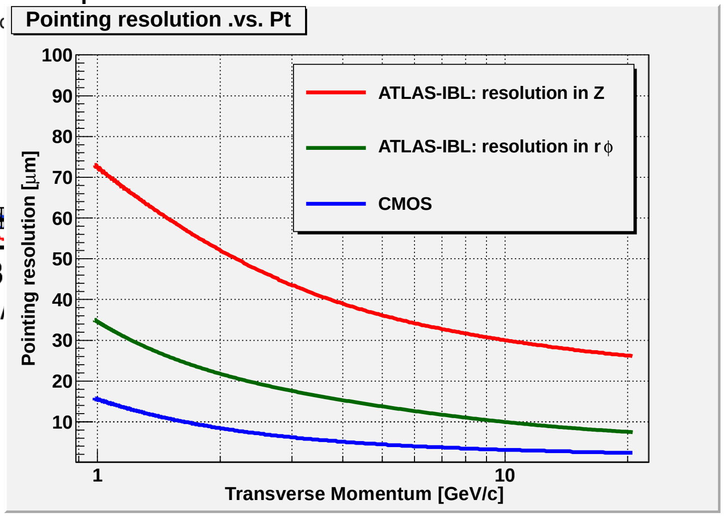
  - ⋇ $\Delta P_t/P_t$ driven by reconstruction of Z decays in $e^+e^- \rightarrowtail ZH$ where Z $\rightarrowtail \mu^+\mu^-$
  - ⋇ very light, high resolution tracker(s) inside strong magnetic field $\rightarrowtail$



- HIGH EFFICIENCY & PURITY FLAVOUR TAGGING

  - ⋇ charm decays in beam pipe
  - ⋇ B, D decays inside jets
  - ⋇ electric charge determination of displaced vertices $\rightarrowtail$

  $\Rrightarrow$ very light, highly pixelated vertex detector



Detection Performance Requirements vs Benchmark Process

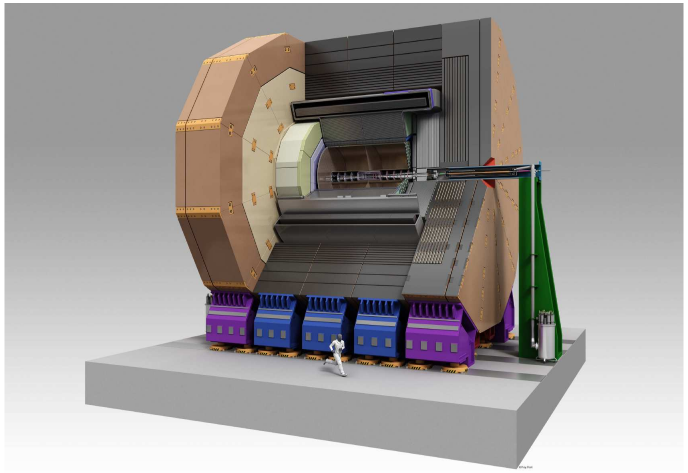
Physics Process	Measured Quantity	Critical System	Physical Magnitude	Required Performance
Zhh $Zh \rightarrow q\bar{q}b\bar{b}$ $Zh \rightarrow ZWW^*$ $\nu\bar{\nu}W^+W^-$	Triple Higgs coupling Higgs mass $B(h \rightarrow WW^*)$ $\sigma(e^+e^- \rightarrow \nu\bar{\nu}W^+W^-)$	Tracker and Calorimeter	Jet Energy Resolution $\Delta E/E$	3% to 4%
$Zh \rightarrow \ell^+\ell^- X$ $\mu^+\mu^-(\gamma)$ $Zh + h\nu\bar{\nu} \rightarrow \mu^+\mu^- X$	Higgs recoil mass Luminosity weighted E_{cm} $BR(h \rightarrow \mu^+\mu^-)$	μ detector Tracker	Charged particle Momentum Resolution $\Delta p_t/p_t^2$	$5 \times 10^{-5}(GeV/c)^{-1}$
$Zh, h \rightarrow b\bar{b}, c\bar{c}, b\bar{b}, gg$	Higgs branching fractions b-quark charge asymmetry	Vertex	Impact parameter	$5\mu m \bigoplus$ $10\mu m/p(\mathrm{GeV/c})\sin^{3/2}\theta$
SUSY, eg. $\tilde{\mu}$ decay	$\tilde{\mu}$ mass	Tracker Calorimeter μ detector	Momentum Resolution Hermiticity	

See Detector Baseline Design document for details

ILC Detector Activities at IN2P3

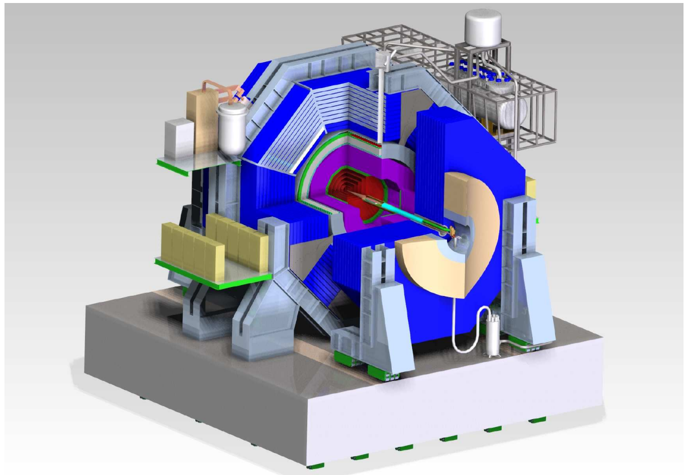
- DETECTOR R&D WORLD-WIDE COORDINATED :
  - Goal : proof of principle of detector feasibility
  - 2 complementary experimental approaches $\rightarrowtail$ detector concepts
    - ILD : largest detector, main tracker $\equiv$ TPC
    - SiD : most compact, main tracker $\equiv$ Si μstrips
    - operated in push-pull mode

ILD



- 8 IN2P3 PHYSICS GROUPS + OMEGA ACTIVE SINCE $>$ DECADE
  - SiW ECAL : LLR, LAL, LPSC, LPNHE, LPCC, OMEGA
  - GRPC & μMegas HCAL : IPNL, LAPP, LLR, OMEGA
  - VXD : IPHC
  - Others :
    - ROC for calorimetres developed outside of IN2P3
    - detector integration and costing
    - R&D and phys. studies coordination tasks
  - IN2P3 activities predominantly in ILD (not restrictive)

SiD



- EXTENSIVE PERFORMANCE ASSESSMENTS CARRIED OUT :
  - Proof of principle level reached $\Rrightarrow$ **Still missing :** *real scale* engineering prototypes

SUMMARY

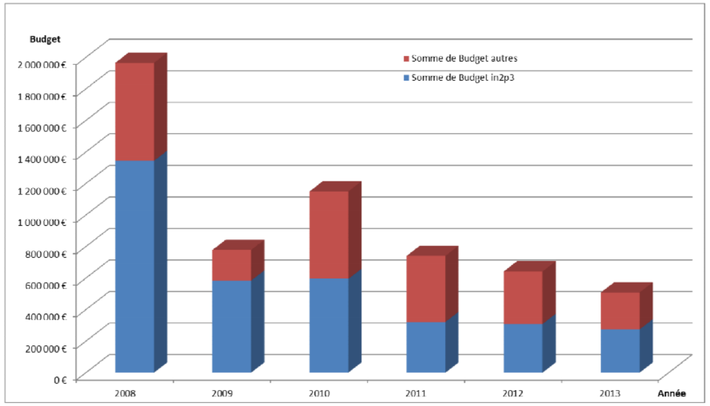
- ILC project has reached necessary maturity to decide its construction in the coming few years
- Well established, rich and strong physics case
- Japan willing to host the ILC (site known, budget line created, Abenomix context ...)

  ⇛ opportunity for HEP ⟼ ILC community getting prepared

  ⇛ government expected to take action soon and approach potential partner countries

- IN2P3 has been among the most effective institutions in demonstrating the feasibility of the high precision detectors required, using ground breaking approaches

- **Scientific production :**
  - ⋇ Theses : 16 defended since 2008, 9 under way
  - ⋇ Publications : $>$ 100 publications since 2008
  - ⋇ Reference devices : EUDET and AIDA EU projects
  - ⋇ Spin-offs : HEP, hadrontherapy, astroparticle physiscs, ...



- FORTHCOMING TALKS WILL REVIEW AND ILLUSTRATE IN2P3 ACHIEVEMENTS, EXPERTISE AND PLANS

BACK-UP SLIDES

HIggs Characterisation Oriented Machine Program

A comprehensive Higgs program requires running at multiple energies:

250 GeV: tagged Higgs, branching ratios

350-500 GeV: W fusion production, absolute normalization of the couplings

> 700 GeV: Higgs coupling to top

> 700 GeV: Higgs self-coupling

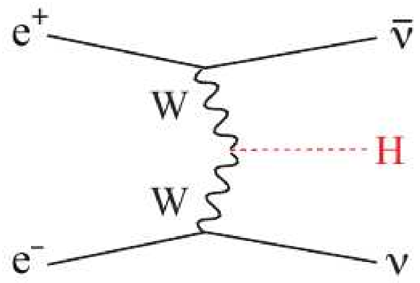
The energy stages of ILC will allow us to carry out this program.

Precisions Achievable

E_{cm} [GeV]	independent measurements	relative error
250	σ_{ZH}	2.6%
	$\sigma_{ZH} \cdot Br(H \to b\bar{b})$	1.2%
	$\sigma_{ZH} \cdot Br(H \to c\bar{c})$	8.3%
	$\sigma_{ZH} \cdot Br(H \to gg)$	7.0%
	$\sigma_{ZH} \cdot Br(H \to WW^*)$	6.4%
	$\sigma_{ZH} \cdot Br(H \to \tau^+\tau^-)$	4.2%
	$\sigma_{\nu\bar{\nu}H} \cdot Br(H \to b\bar{b})$	10.5%
500	σ_{ZH}	3.0%
	$\sigma_{ZH} \cdot Br(H \to b\bar{b})$	1.8%
	$\sigma_{ZH} \cdot Br(H \to c\bar{c})$	13%
	$\sigma_{ZH} \cdot Br(H \to gg)$	11%
	$\sigma_{ZH} \cdot Br(H \to WW^*)$	9.2%
	$\sigma_{ZH} \cdot Br(H \to \tau^+\tau^-)$	5.4%
	$\sigma_{\nu\bar{\nu}H} \cdot Br(H \to b\bar{b})$	0.66%
	$\sigma_{\nu\bar{\nu}H} \cdot Br(H \to c\bar{c})$	6.2%
	$\sigma_{\nu\bar{\nu}H} \cdot Br(H \to gg)$	4.1%
	$\sigma_{\nu\bar{\nu}H} \cdot Br(H \to WW^*)$	2.4%

$250\,\mathrm{fb}^{-1}$@$250\,\mathrm{GeV}$
$+500\,\mathrm{fb}^{-1}$@$500\,\mathrm{GeV}$
$m_H = 125\,\mathrm{GeV}$

ILD DBD Full Simulation Study



comes in as a powerful tool!

$$\Delta\Gamma_H/\Gamma_H \simeq 5\%$$

Mode	ΔBR/BR
bb	2.2 (2.9)%
cc	5.1 (8.7)%
gg	4.0 (7.5)%
WW*	3.1 (6.9)%
τ τ	3.7 (4.9)%

The numbers in the parentheses are as of $250\,\mathrm{fb}^{-1}$@$250\,\mathrm{GeV}$

Higgs Characterisation Oriented Machine Program

Can one comparably quantify the opportunity of the ILC ?

Attitude of the ILC Higgs White paper:

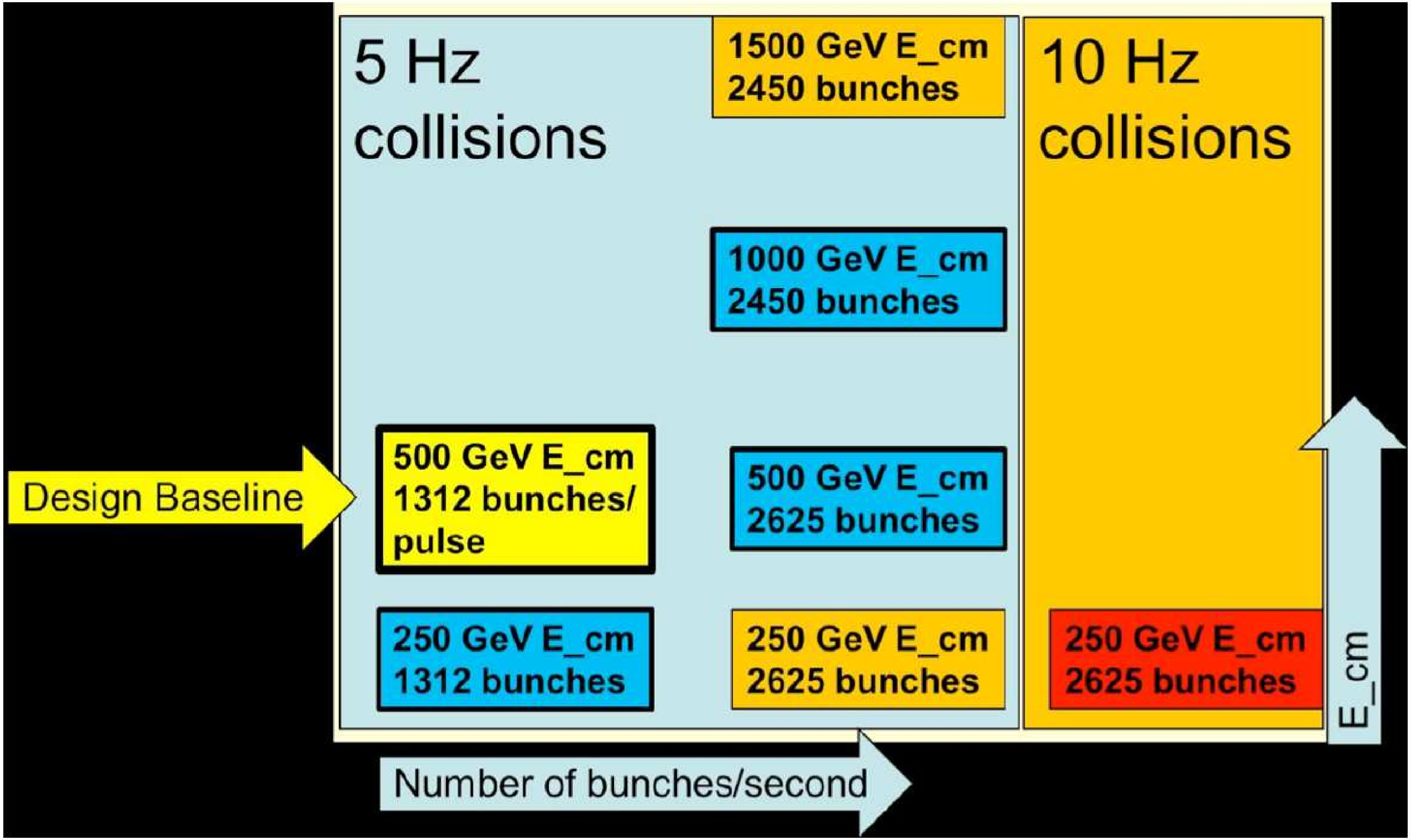
Consider the long-term ILC program.

The TDR is the beginning. It sets a new level of accuracy dominated by statistical errors.

Improve the TDR uncertainties by more running, and by luminosity upgrades foreseen in the TDR.

Nickname	Ecm(1) (GeV)	Lumi(1) (fb^{-1})	+	Ecm(2) (GeV)	Lumi(2) (fb^{-1})	+	Ecm(3) (GeV)	Lumi(3) (fb^{-1})
ILC(250)	250	250						
ILC(500)	250	250		500	500			
ILC(1000)	250	250		500	500		1000	1000
ILC(LumUp)	250	1150		500	1600		1000	2500

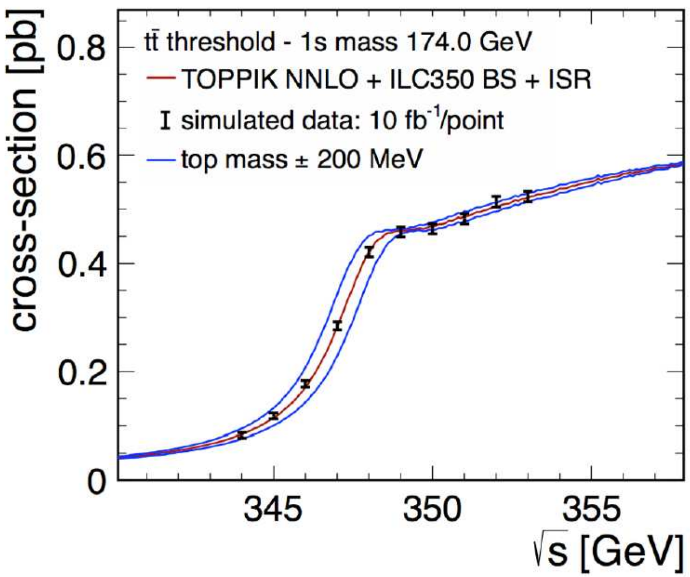
ILC Upgrades Envisaged

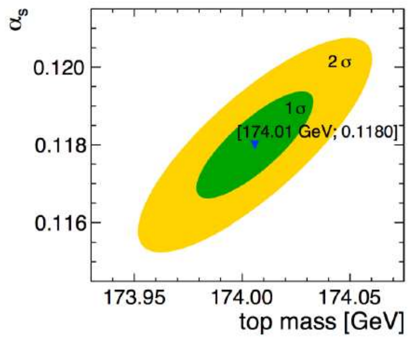


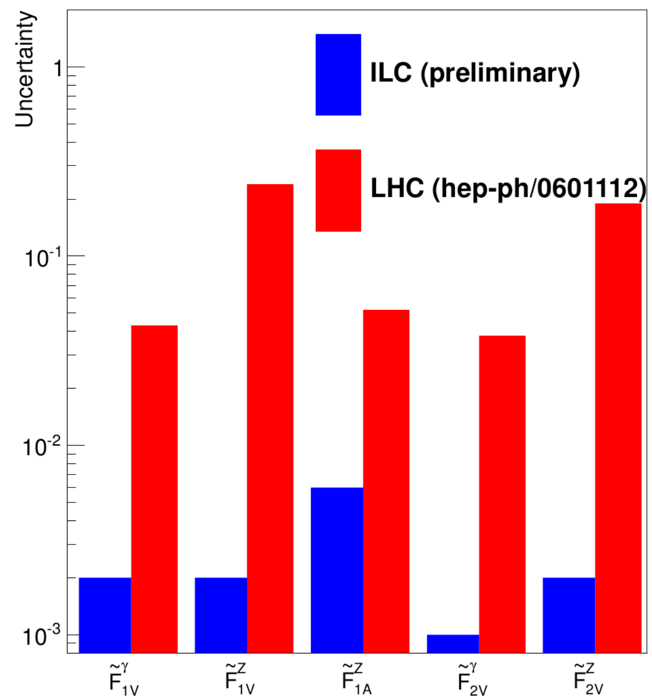
Top Physics

- **Most important goals of the ILC program on the top quark are :**
  - ⋇ measure the genuine top quark mass $\equiv$ fundamental parametre
  - ⋇ search for signals of top-Higgs compositeness

    (similar opportunities may exist w.r.t. W-boson)
  - ⋇ search for non-SM $\gamma/Zt\bar{t}$ couplings $\rightarrowtail$ form factors (polarisation !)



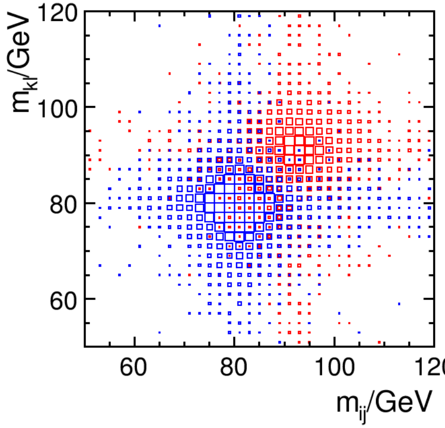


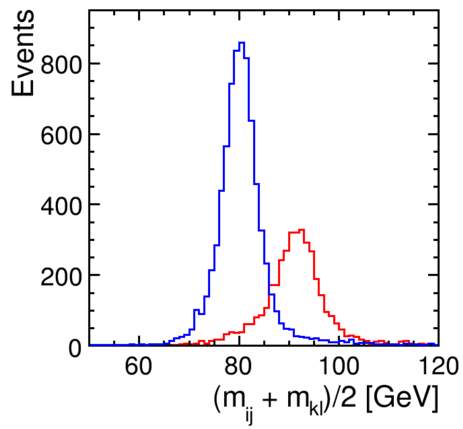


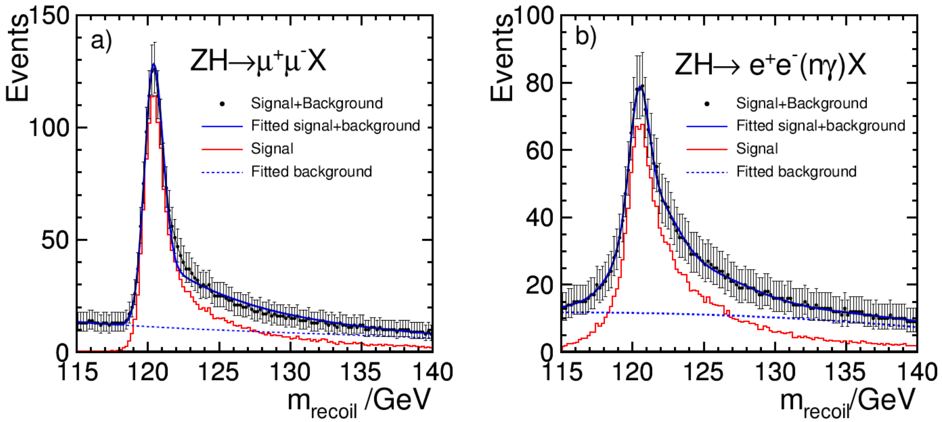
$$\Delta[m_t(\overline{MS}, m_t)] \sim 100 \text{ MeV}$$

Experimental Challenges Addressed

- **Particle Flow** : reconstruct ALL particles individually
  - ⋇ topological reconstruction of multi-jet events
    - $\Rrightarrow$ R&D on highly segmented calorimeters : ECAL (24 layers) & HCAL (48 layers)
    - ▷ Ex: W/Z separation in $\nu\nu WW/ZZ$ final states
      $\Rrightarrow$ $\Delta E/E \simeq$ 3-4% at 100 GeV

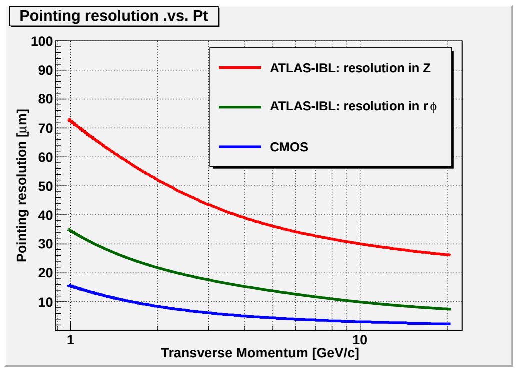


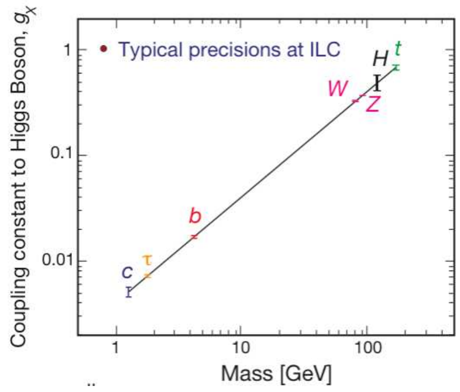




- **High resol. charged part. momentum reconstr.**:
  - ⋇ R&D on very light high resolution tracking system : mainly TPC (ILD) (also Si-strips)
    - ▷ Ex: $e^+e^- \rightarrowtail ZH \Rrightarrow M_H^2 = S + M_Z^2 - 2 \cdot E_Z \cdot \sqrt{S}$
      $\Rrightarrow$ $\sigma_{1/P_t} \simeq 2 \cdot 10^{-5} GeV^{-1}$

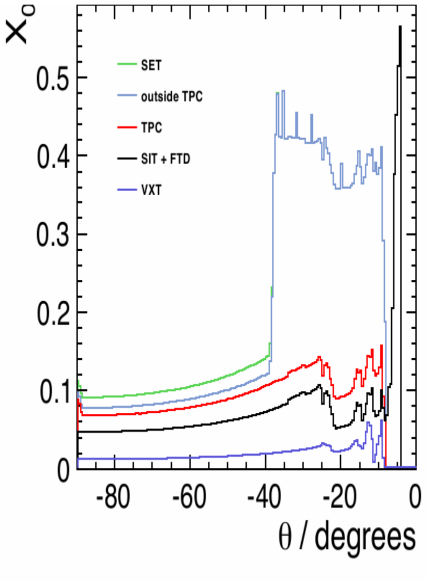
- **Highly granular and light vertex detector**:
  - ⋇ R&D on new pixel techno. & ultra-light mechanical supports
    - ▷ Ex: Hxx couplings from $e^+e^- \rightarrowtail ZH$
      $\Rrightarrow$ $\sigma_{IP} \lesssim 5 \oplus 10/p \cdot sin^{3/2}\theta \ \mu m$

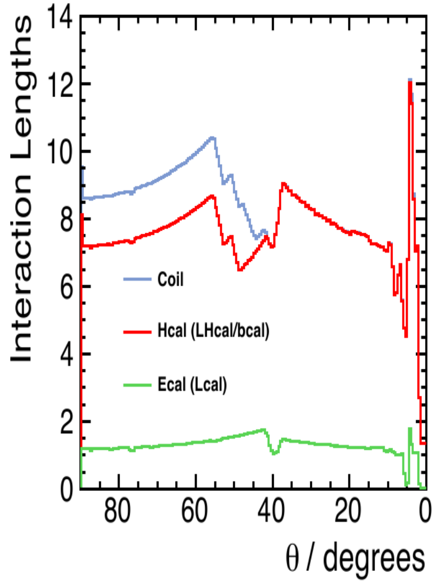


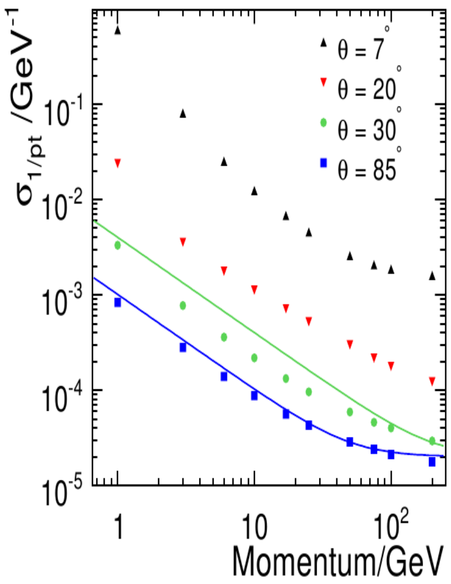


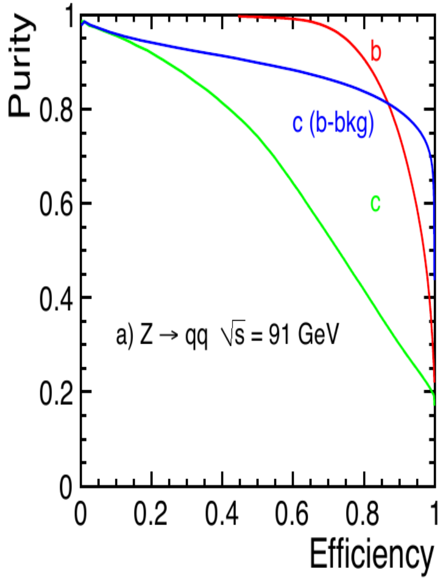
▷▷▷ **Power cycling ($\equiv$ saving) exploiting machine duty cycle ($<$ 1%)**

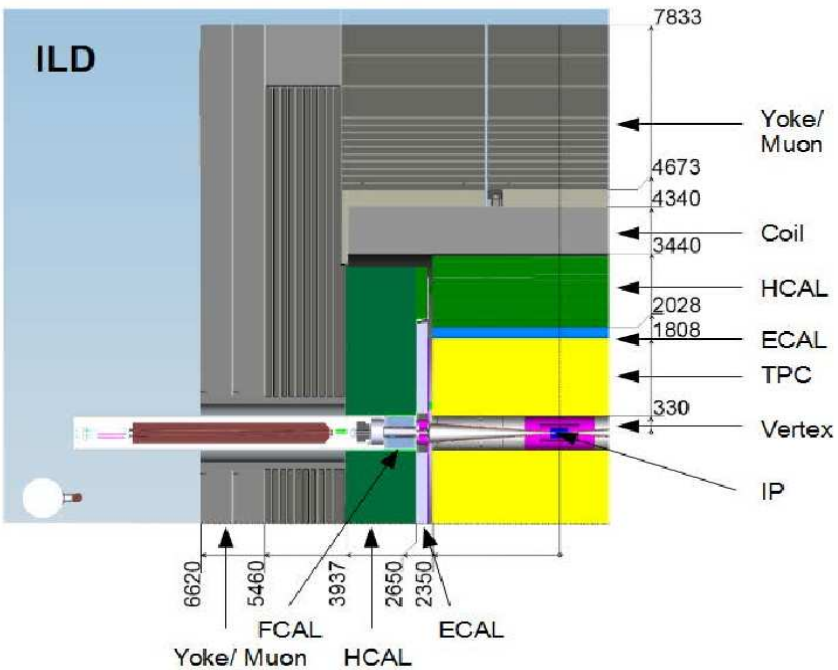
Detector Characteristics

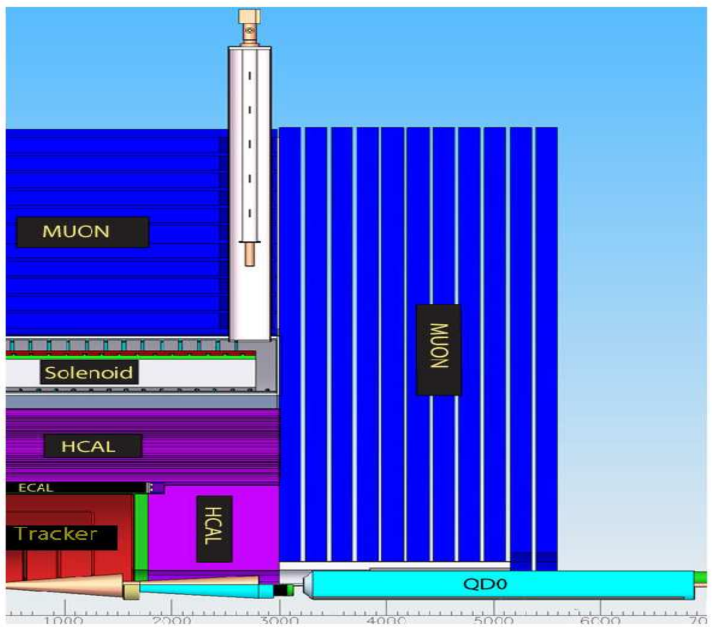




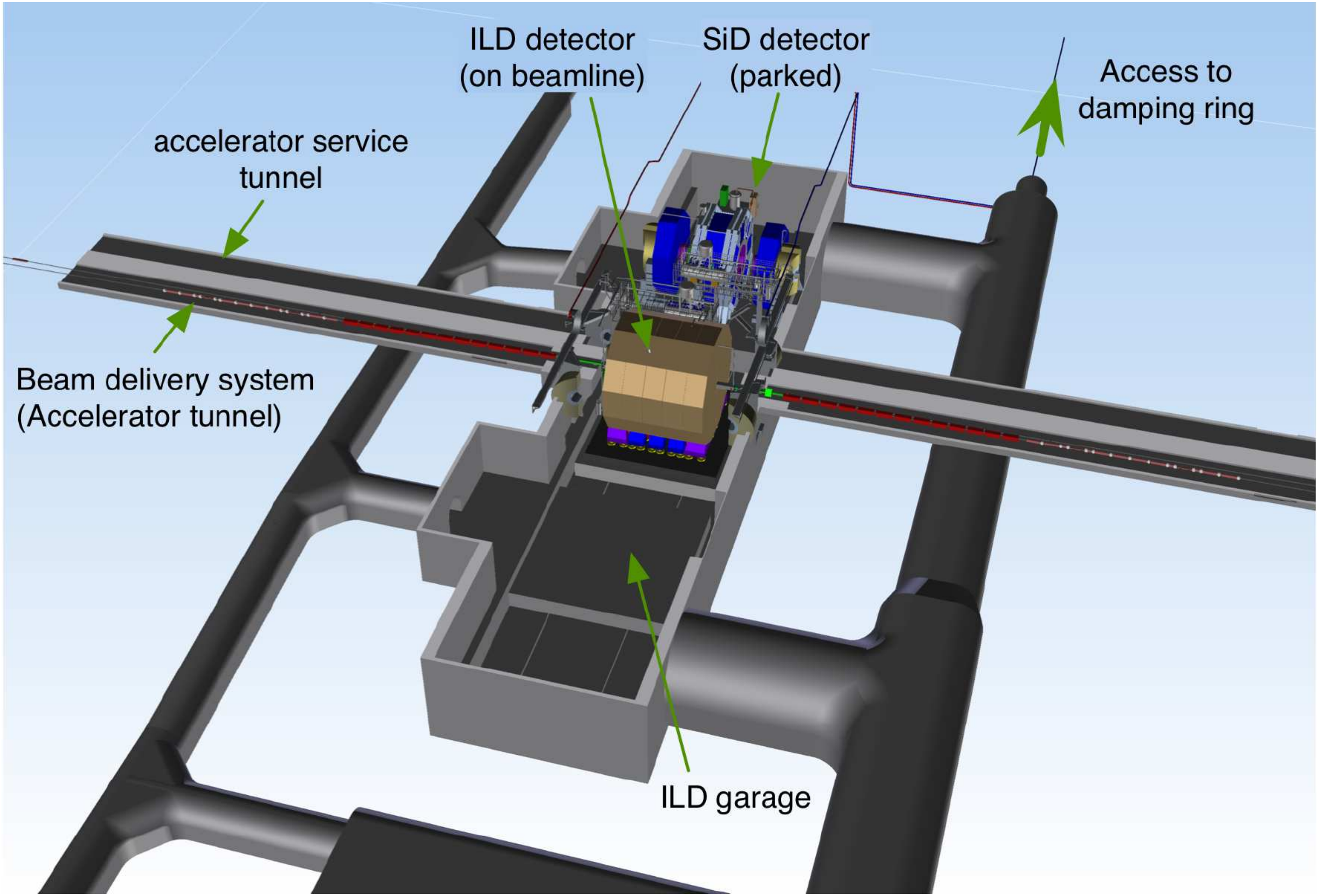








Interaction Region



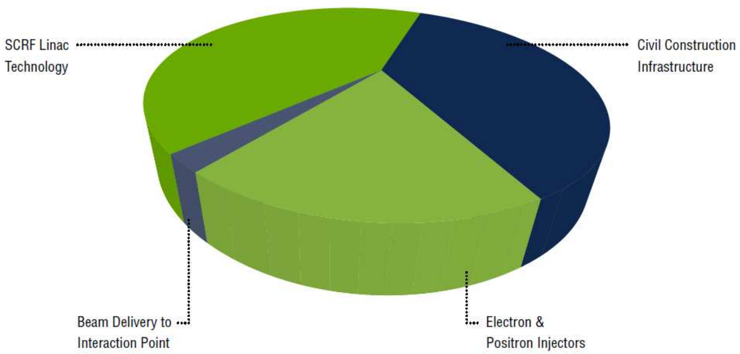
Refereence Design Report :ILC Machine Costing

What are the numbers?

The following figures are the base VALUE and LABOUR quantities that can be translated into costs, by using a given national costing method:

SHARED VALUE =	4.87 Billion ILC VALUE UNITS
SITE-DEPENDENT VALUE =	1.78 Billion ILC VALUE UNITS
TOTAL VALUE = *(shared + site-dependent)*	**6.65 Billion ILC VALUE UNITS**
LABOUR =	22 million person-hours = 13,000 person-years (assuming 1700 person-hours per person-year)
1 ILC VALUE UNIT =	1 US Dollar (2007) = 0.83 Euros = 117 Yen

An approximate breakdown of the ILC estimate by main categories.



What does the estimate include and exclude?

The VALUE and LABOUR amounts include:

- construction of a 500 GeV machine and the essential elements to enable an optional future upgrade to 1 TeV;
- tooling-up industry, final engineering designs, and construction management;
- construction of all conventional facilities including tunnels, surface buildings, detector assembly buildings, underground experimental halls, and access shafts; and
- explicit labour including that for management and administrative personnel.

The VALUE and LABOUR amounts exclude:

- engineering, design or preparation activities that must be accomplished before project funding (such as R&D), proof-of-principle, and prototype tests;
- surface land acquisition or underground easement costs;
- detectors, which are assumed to be funded by a separate agreement;
- contingencies for risks; and
- escalation (inflation).

Alternatives à l'ILC

- PLUSIEURS ALTERNATIVES À L'ILC ONT ÉTÉ CONSIDÉRÉES : CLIC, TLEP, ...

  $\hookrightarrow$ PLUSIEURS CRITÈRES ENTRENT EN JEU DANS LA COMPARAISON

- 5 critères principaux :
  - ⋇ maturité du projet sous-jacente aux performances annoncées (coût, accélérateur, détecteurs)
  - ⋇ calendrier et opportunité scientifique
  - ⋇ cadre politique favorable à la réalisation du projet $\Rrightarrow$ opportunité
  - ⋇ valeur ajoutée scientifique du projet par rapport aux projets plus avancés
  - ⋇ prise en compte des conditions économiques : P et bridage des performances

- 3 critères annexes :
  - ⋇ forces et expertises des communautés intéressées (dans les 3 régions)
  - ⋇ degré de consensus mondial pour le projet
  - ⋇ impact sur le renforcement politique de la discipline