The ILC Higgs Factory

Philip Burrows

John Adams Institute, Oxford University

Outline

- Introduction
- The Large Hadron Collider + the Higgs boson
- The Higgs factory
- The International Linear Collider (ILC)
- Higgs physics at ILC
- Project implementation and timeline

Large Hadron Collider (LHC)

Largest,

highest-energy

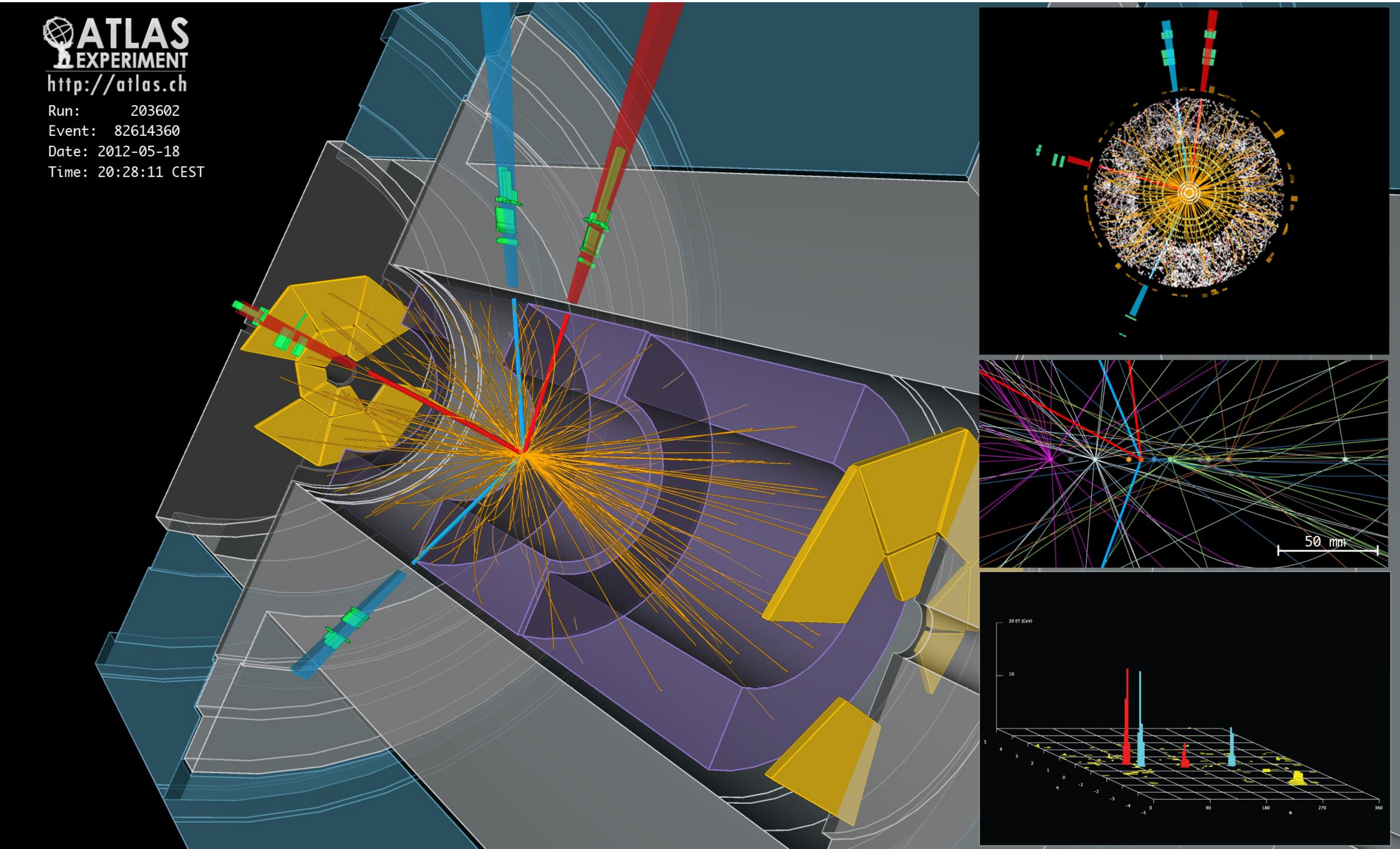
particle

collider

CERN,

Geneva

A Higgs boson?



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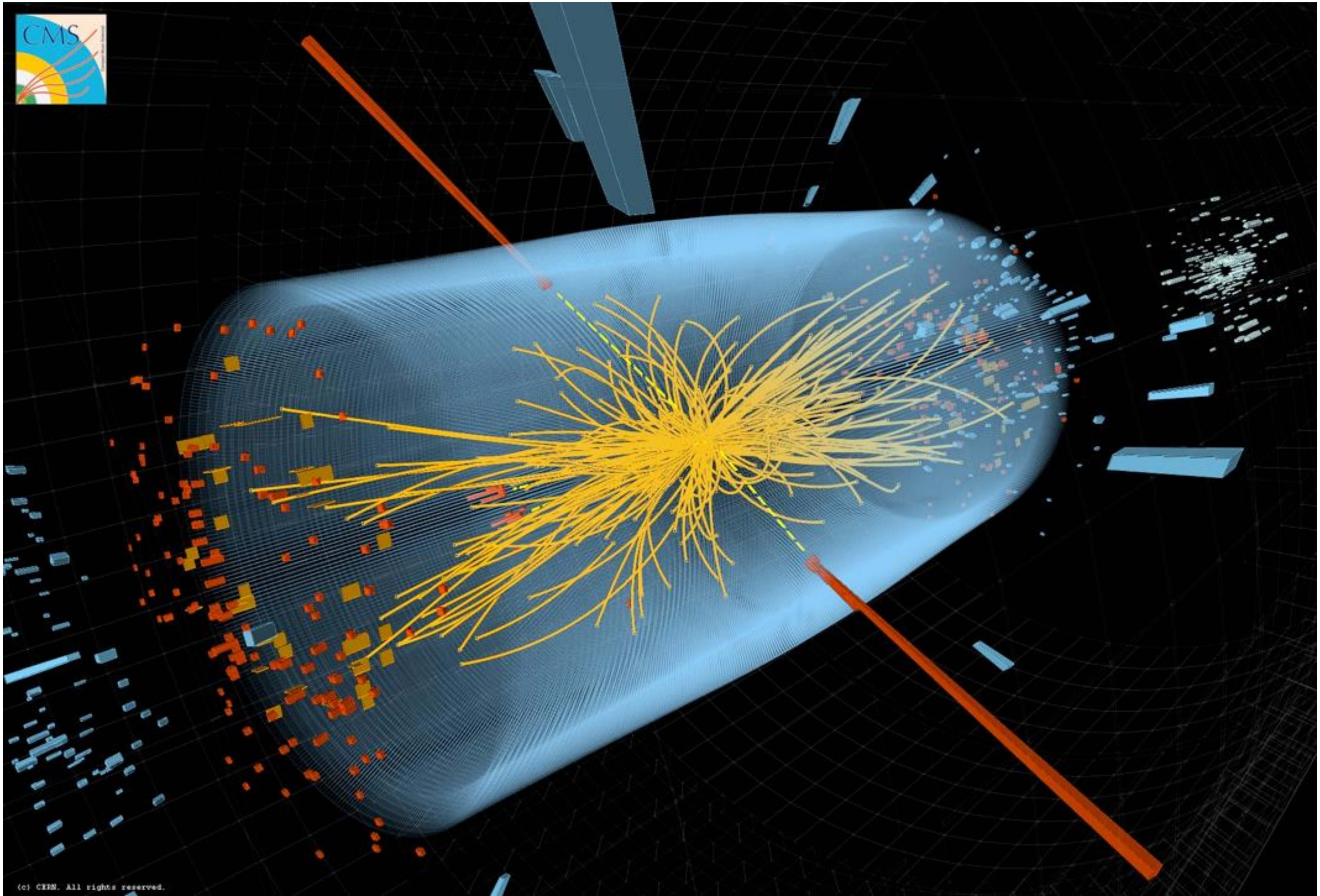
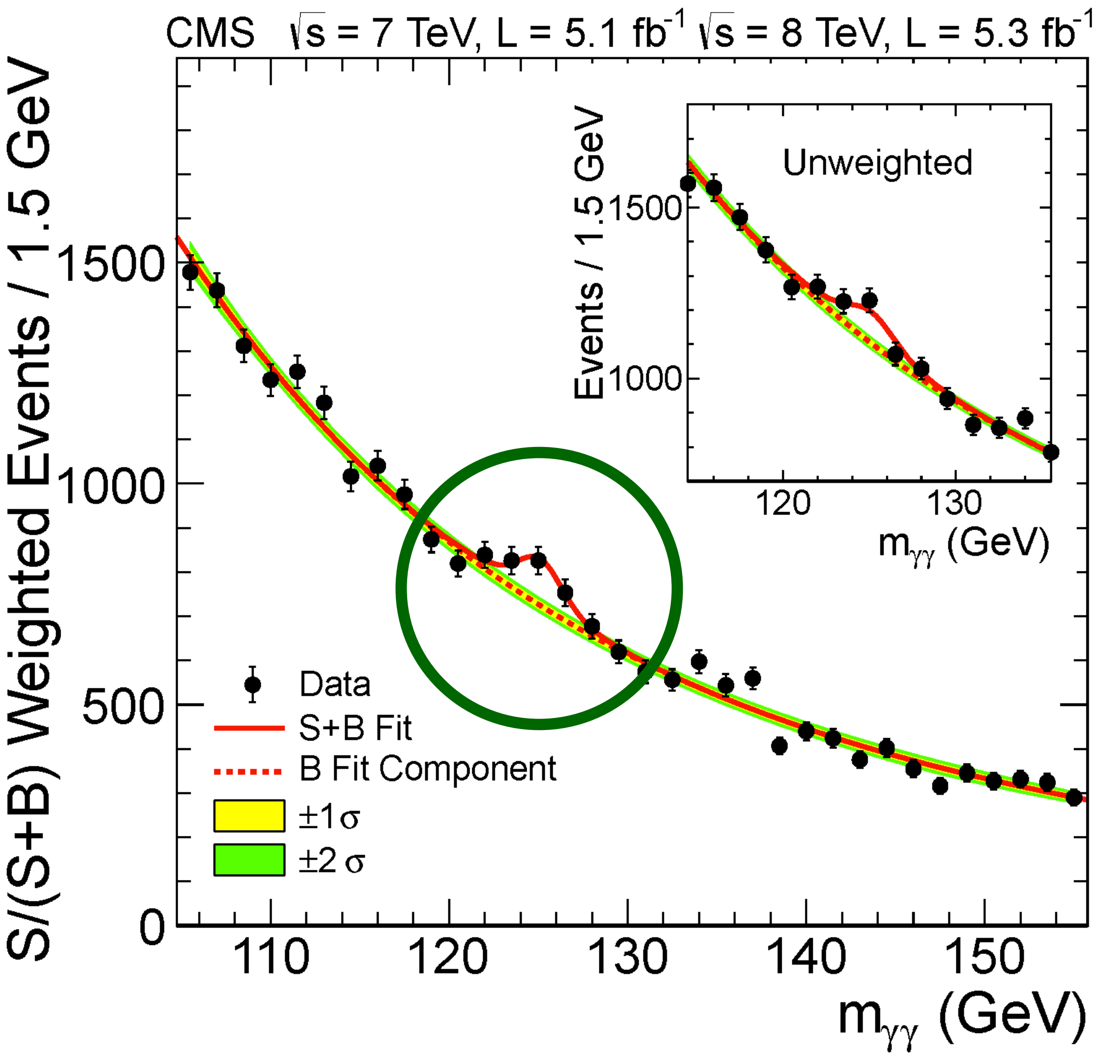


The 2012 discovery



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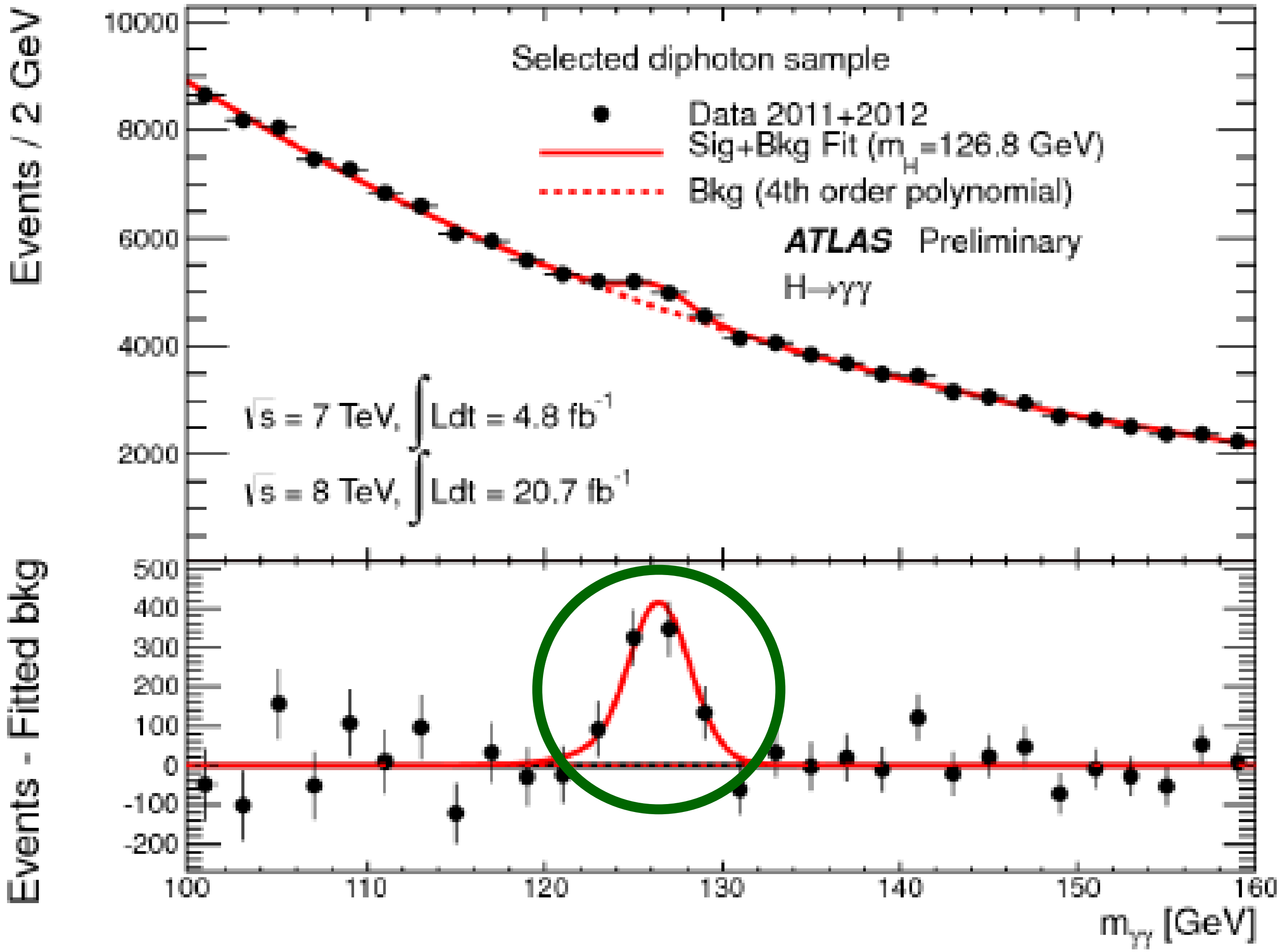
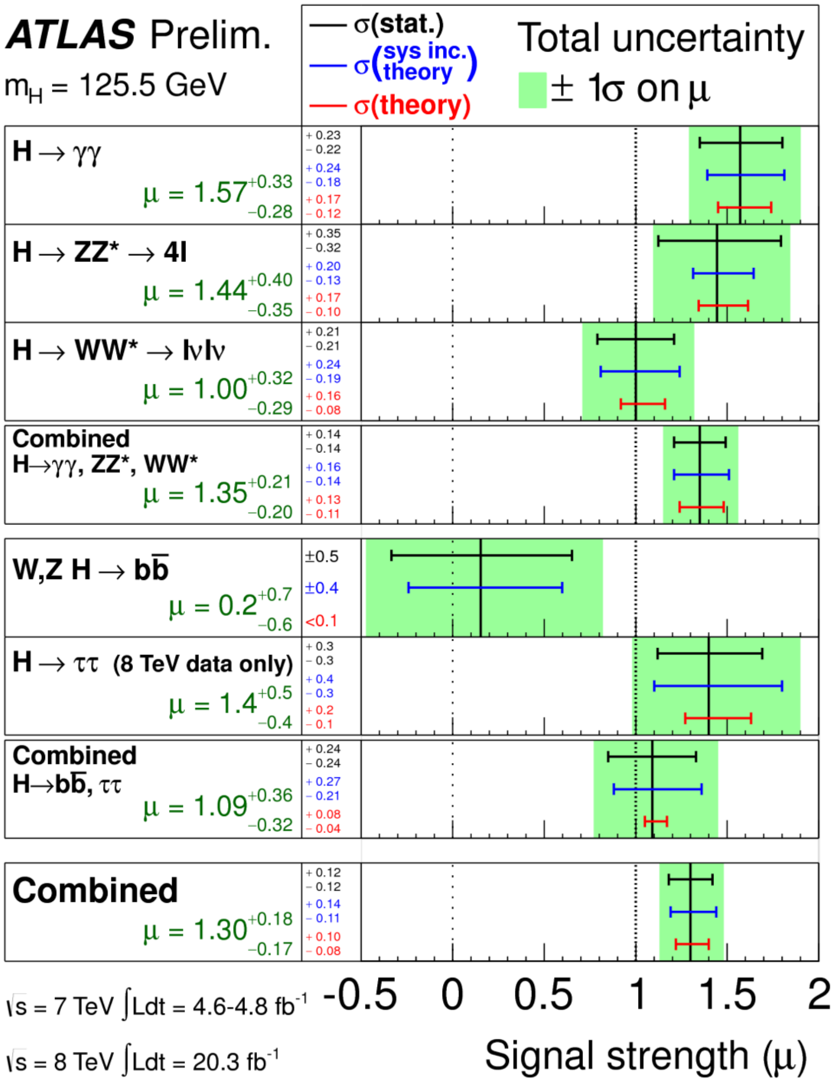


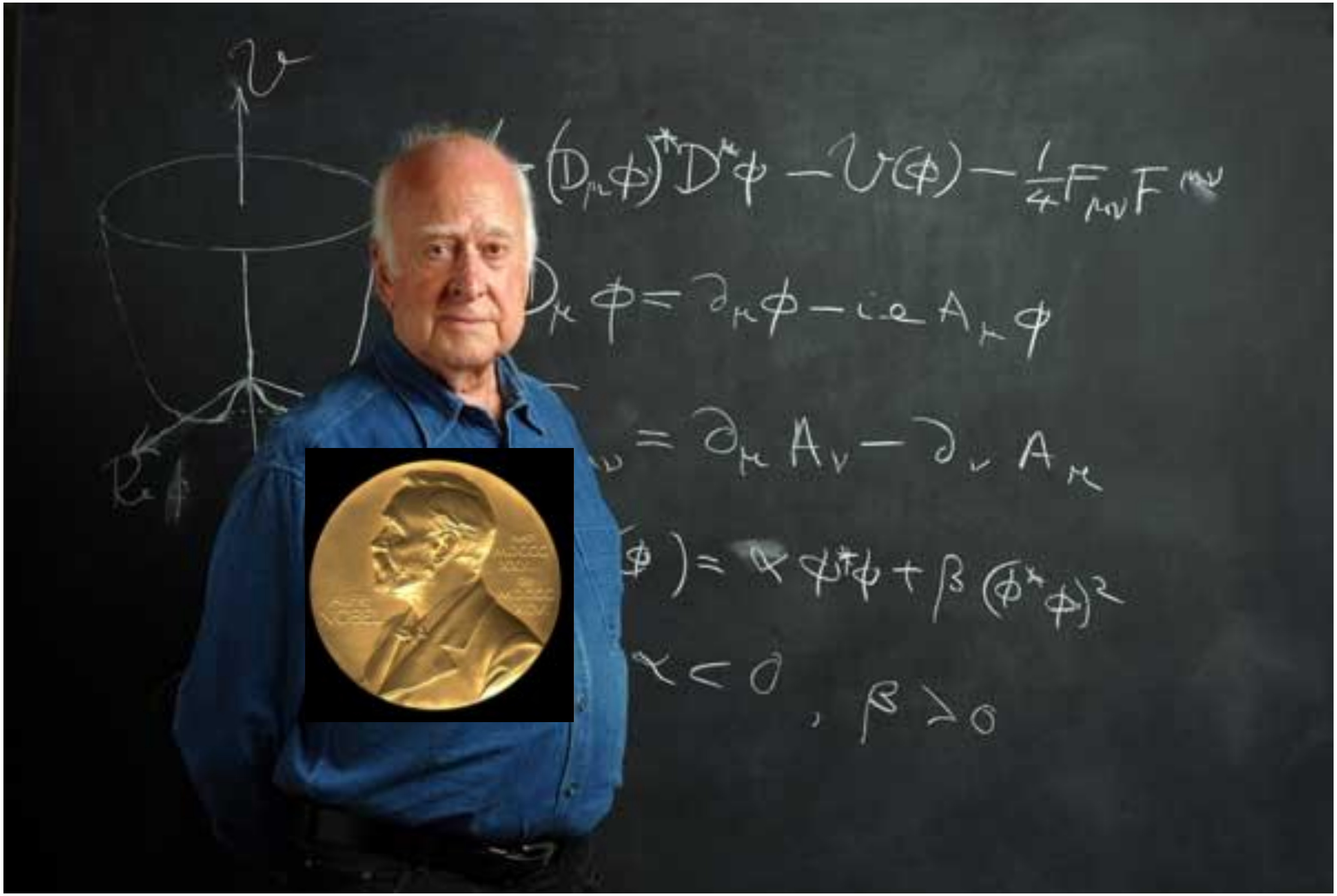
ATLAS status



ATLAS CONF 2014 009

Monica D'Onofrio, LHCC June 4 2014

It’s officially a Higgs Boson!



Finger-printing the Higgs boson

Determine its ‘profile’:

- Mass
- Width
- Spin
- CP nature
- Coupling to fermions
- Coupling to gauge bosons
- Yukawa coupling to top quark
- Self coupling → Higgs potential

Finger-printing the Higgs boson

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another type of Higgs boson?

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→ Measurements of the Higgs couplings to the different species of quarks, leptons and gauge bosons are the key to answering these questions

Non-Standard Higgs couplings

Snowmass Higgs working group:

Decoupling limit:

If all new particles (except Higgs) are at a (high) high mass scale M

deviations from SM predictions
are of order m_H^2 / M^2

Non-Standard Higgs couplings

For M = 1 TeV, deviations of couplings from SM:

Model	κ_V	κ_b	κ_γ
Singlet Mixing	$\sim 6\%$	$\sim 6\%$	$\sim 6\%$
2HDM	$\sim 1\%$	$\sim 10\%$	$\sim 1\%$
Decoupling MSSM	$\sim -0.0013\%$	$\sim 1.6\%$	$< 1.5\%$
Composite	$\sim -3\%$	$\sim -(3-9)\%$	$\sim -9\%$
Top Partner	$\sim -2\%$	$\sim -2\%$	$\sim +1\%$

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Deviations in the range 1% → 10%

→ measurements must be significantly more precise to resolve such deviations

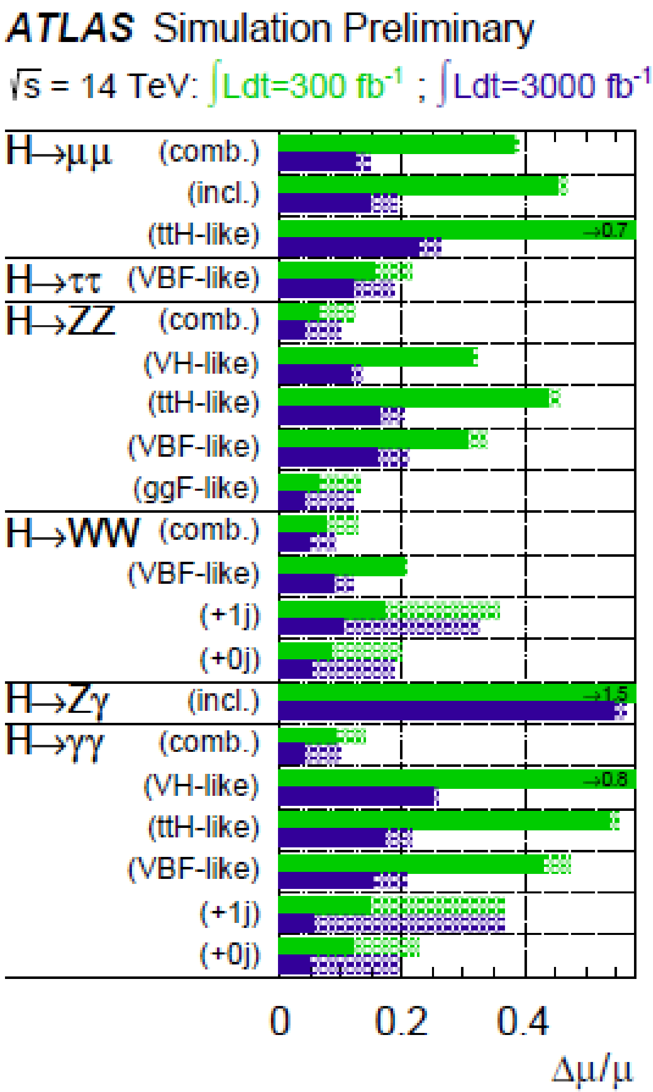
LHC projections

LHC projections

Currently, typically LHC projected precisions on Higgs coupling measurements assume that:

- **Standard Model is correct**
- **No non-Standard decay modes (total width = SM)**
- **Charm and top couplings deviate from SM by same factor**

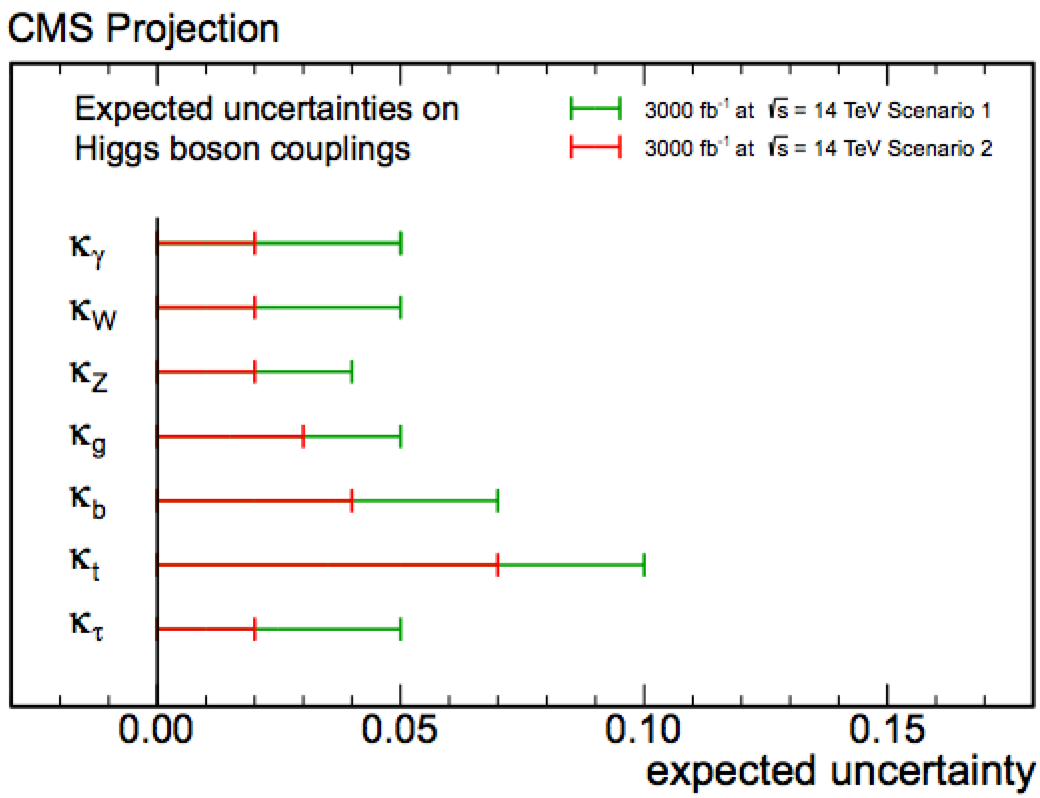
ATLAS projections



ATL PHYS PUB 2013 014

CMS projections

L (fb^{-1})	κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	$\kappa_{\mu\mu}$	BR_{SM}
300	[5, 7]	[4, 6]	[4, 6]	[6, 8]	[10, 13]	[14, 15]	[6, 8]	[41, 41]	[23, 23]	[14, 18]
3000	[2, 5]	[2, 5]	[2, 4]	[3, 5]	[4, 7]	[7, 10]	[2, 5]	[10, 12]	[8, 8]	[7, 11]



CMS-NOTE-2013-002

Yurii Maravin, LHCC Dec 2013

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Such assumptions are not necessary for Higgs coupling measurements at e+e- Higgs Factory …

‘Higgs factory’

- **e+e- collider:**

  linear collider

  storage ring

- **photon-photon collider:**

  usually considered as add-on to linear collider

- **muon collider:**

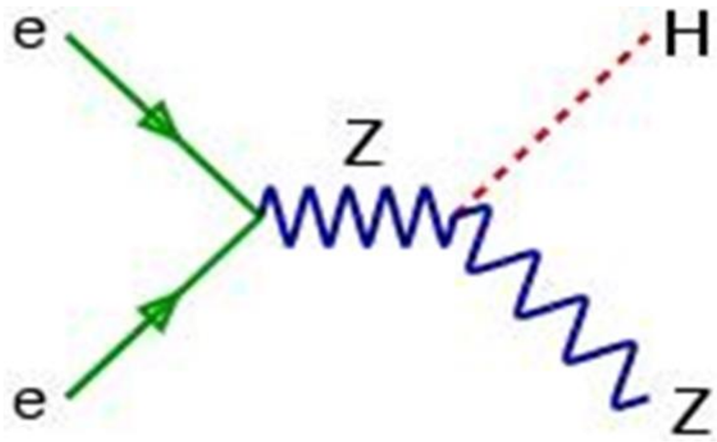
  usually considered as a next step beyond a future neutrino factory

e+e- Higgs factory

e+e- annihilations:

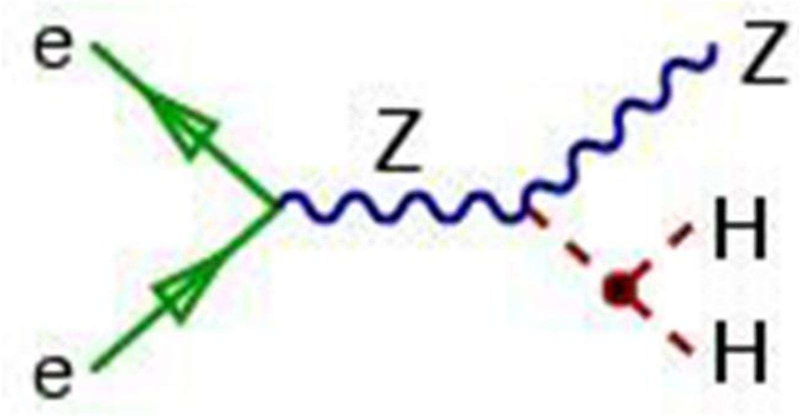
E > 91 + 125 = 216 GeV

E ~ 250 GeV



E > 91 + 250 = 341 GeV

E ~ 500 GeV



e^+e^- colliders

- Produce annihilations of point-like particles under controlled conditions:

e+e- colliders

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well defined centre of mass energy: 2E

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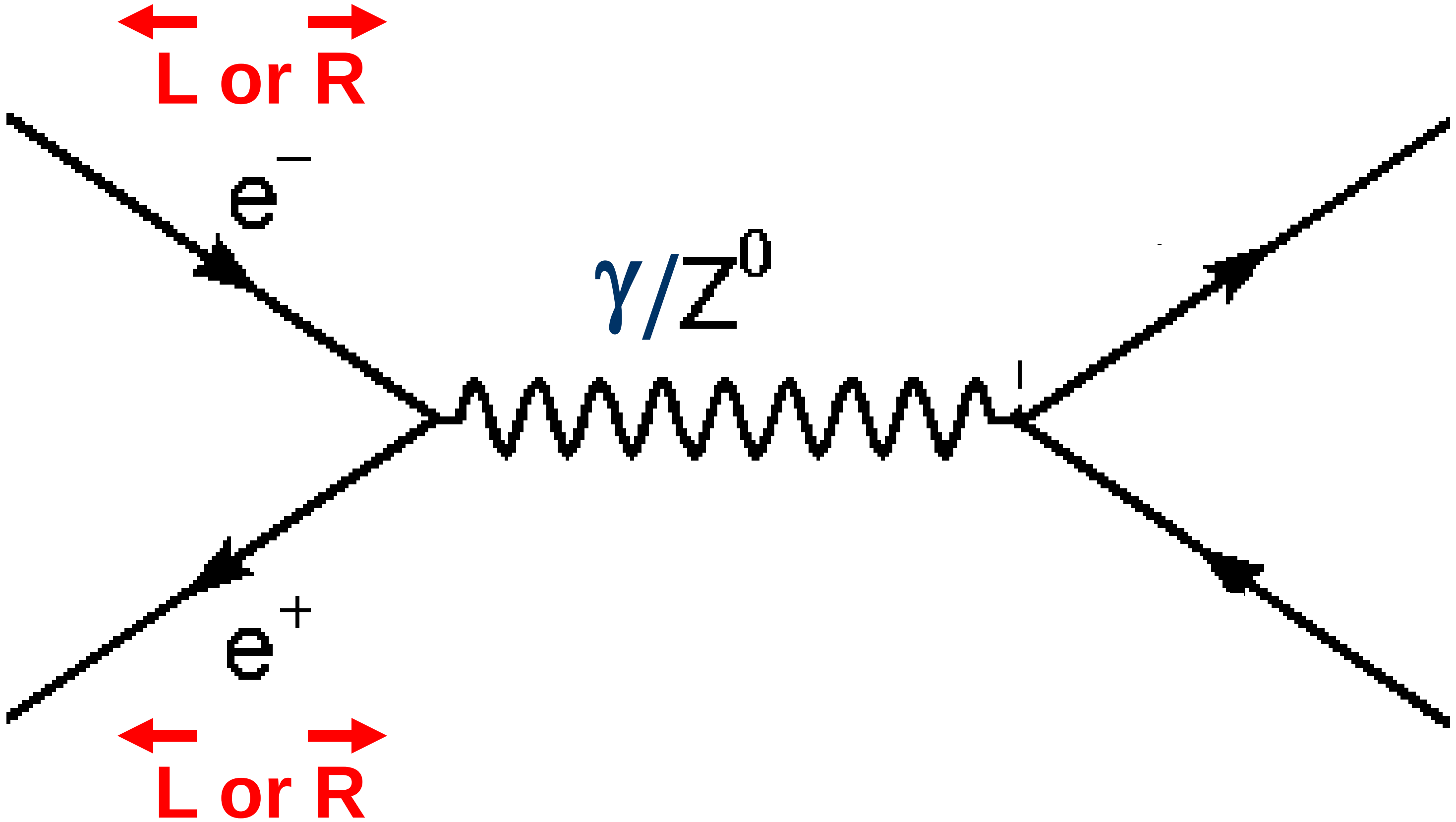
e+e- annihilations



e+e- colliders

- **Produce annihilations of point-like particles under controlled conditions:**

well defined centre of mass energy: 2E

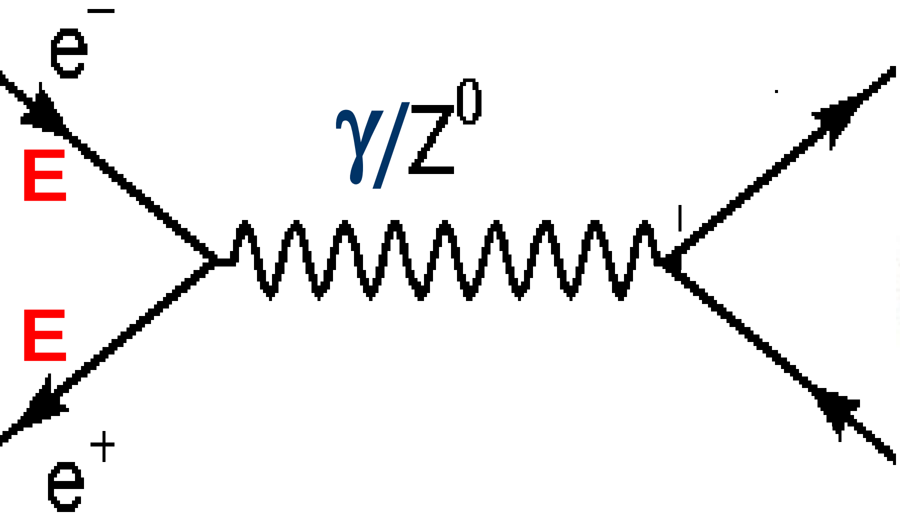
complete control of event kinematics:

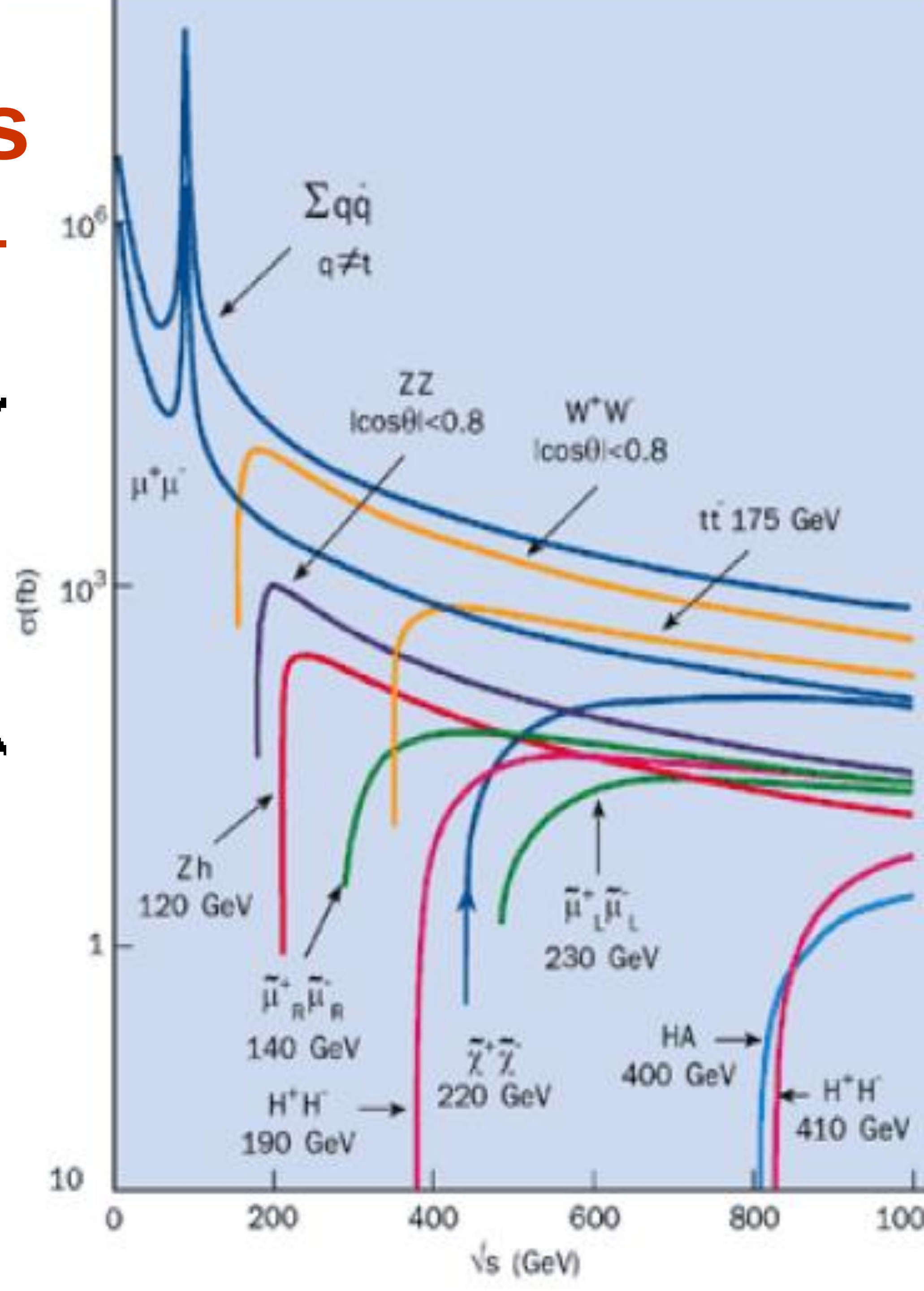
$p = 0$, $M = 2E$

polarised beam(s)

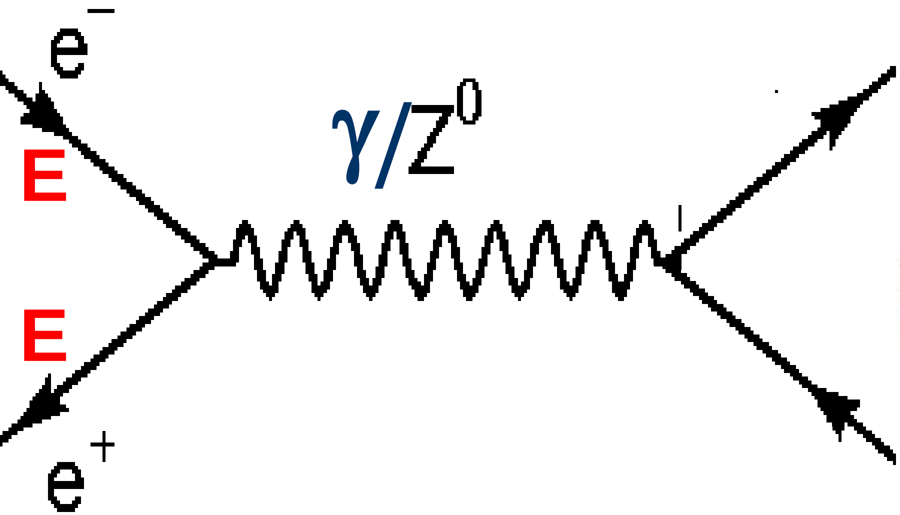
clean experimental environment

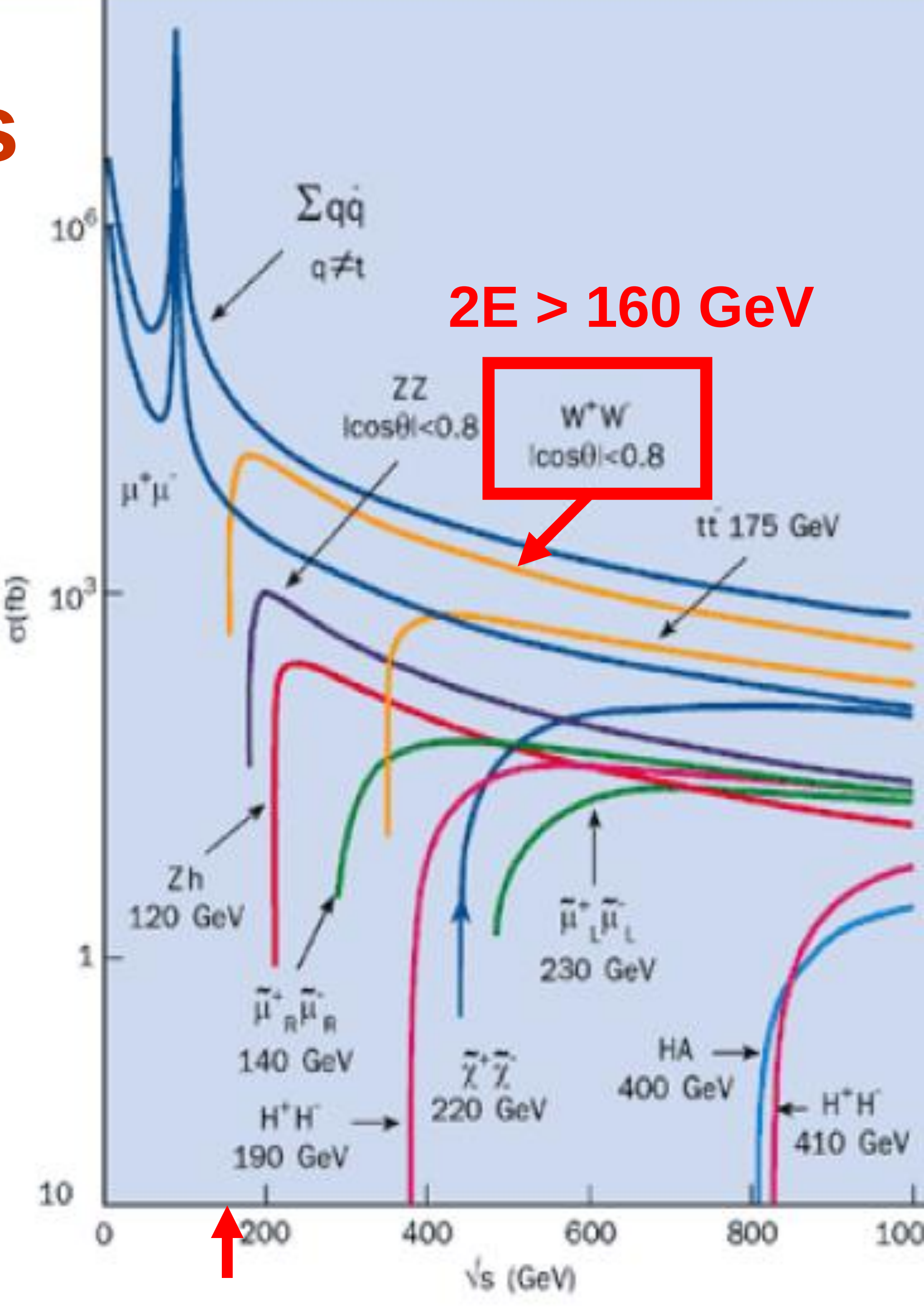
e+e- annihilations





e+e- annihilations





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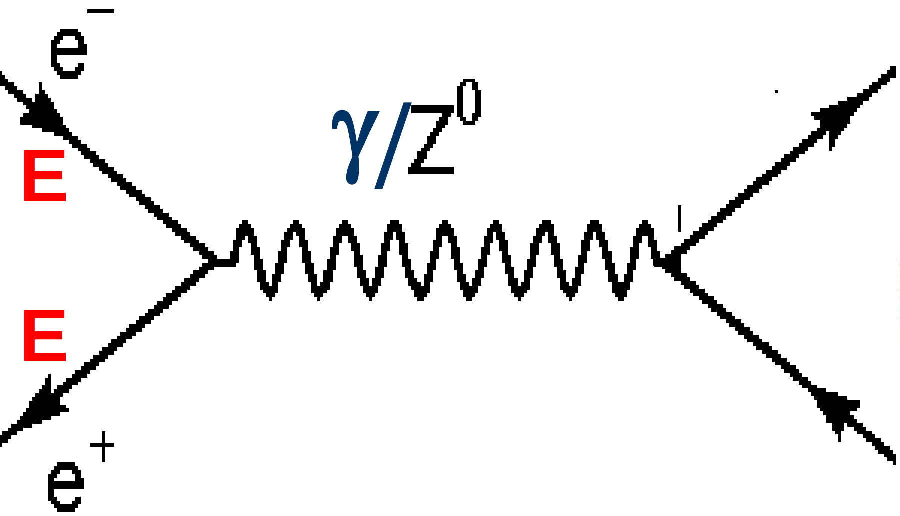

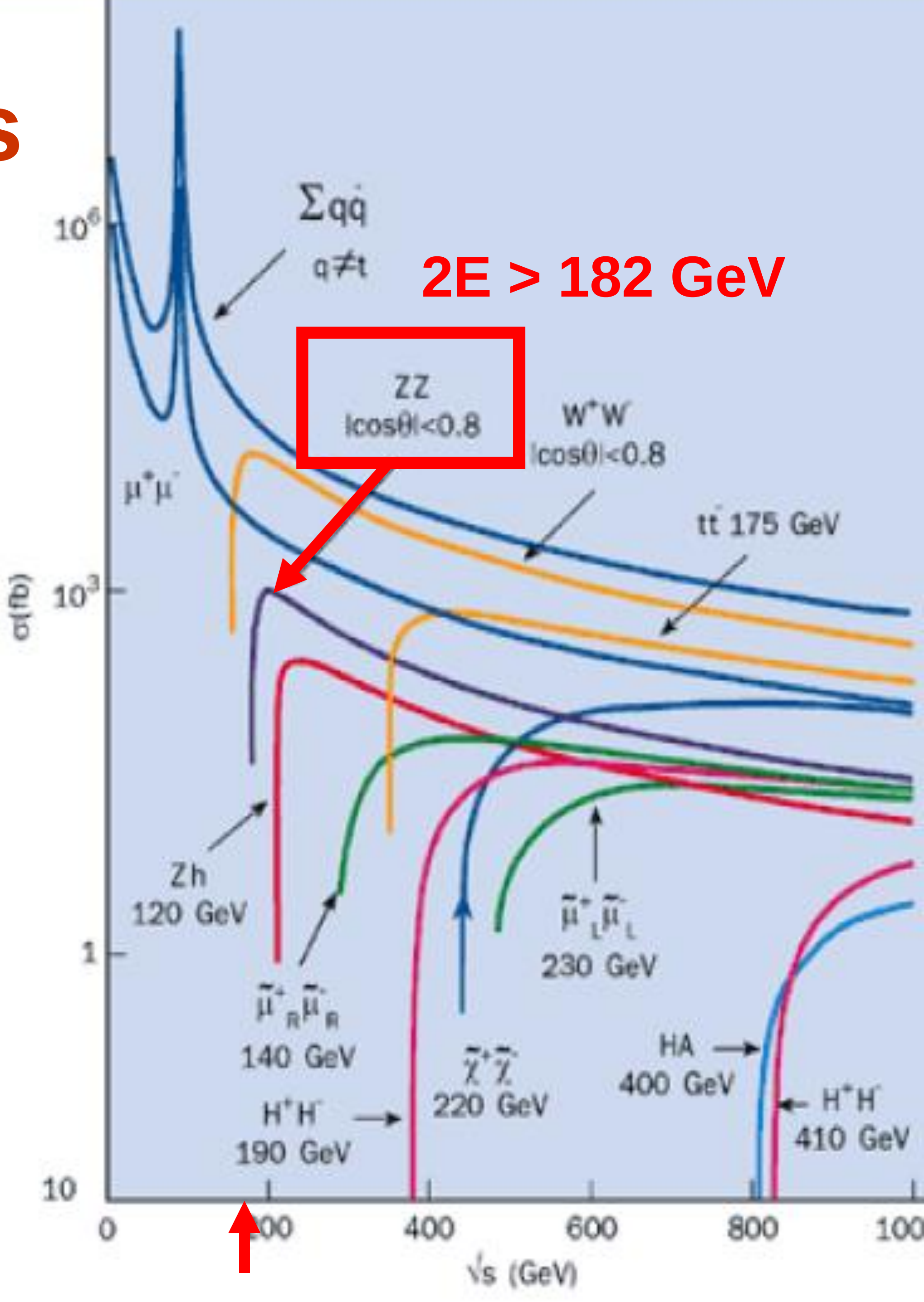

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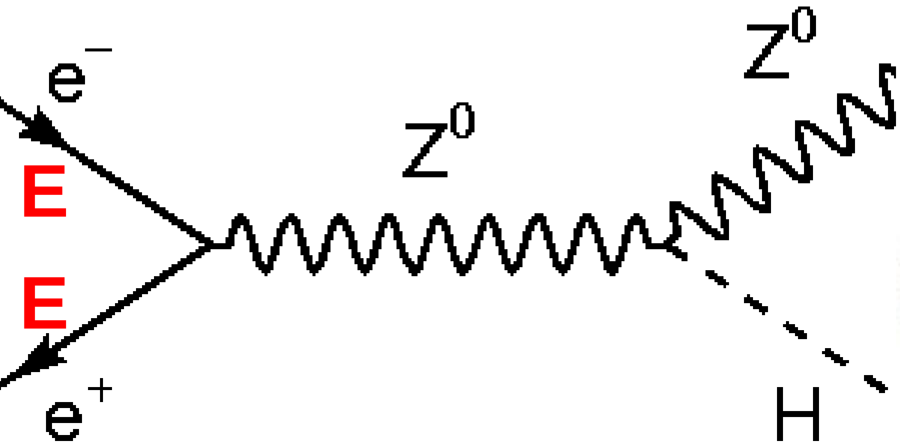
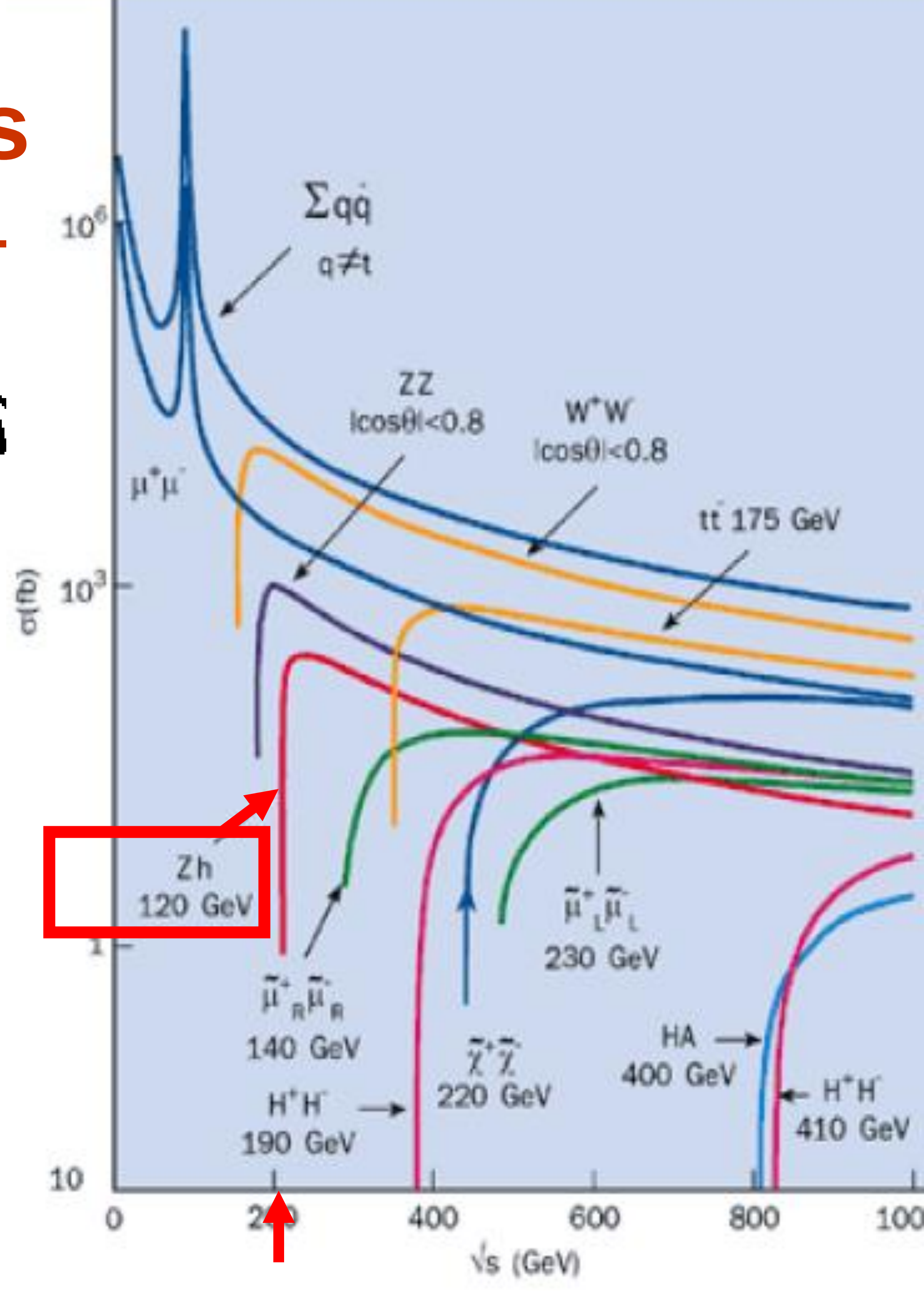


2E > 216 GeV



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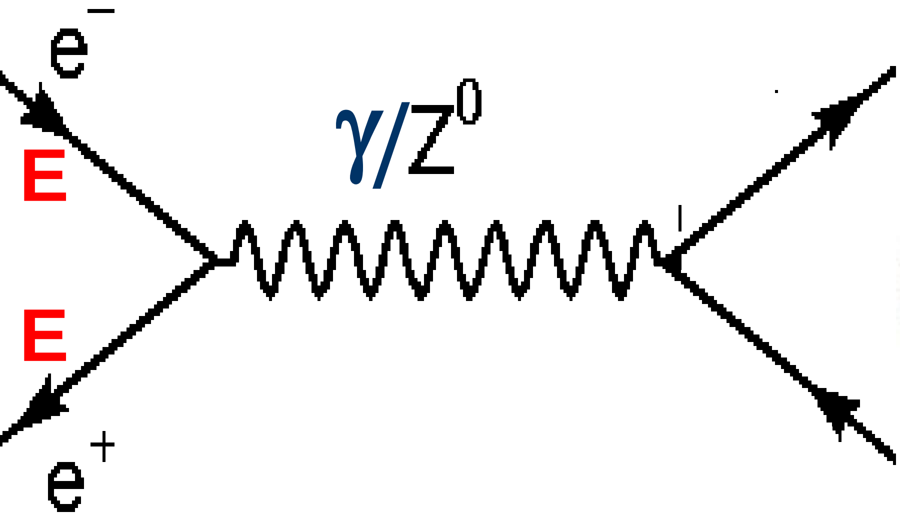

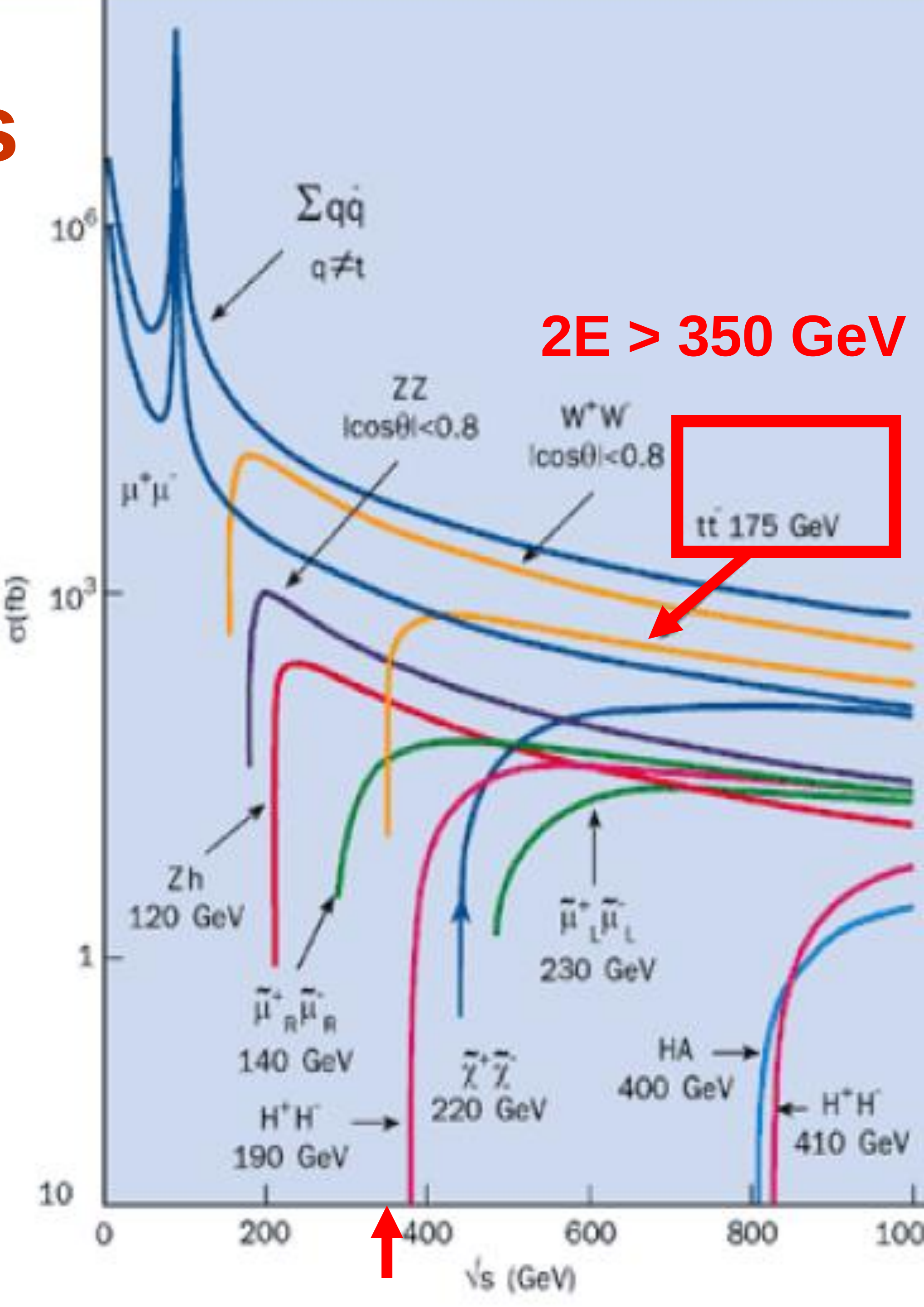

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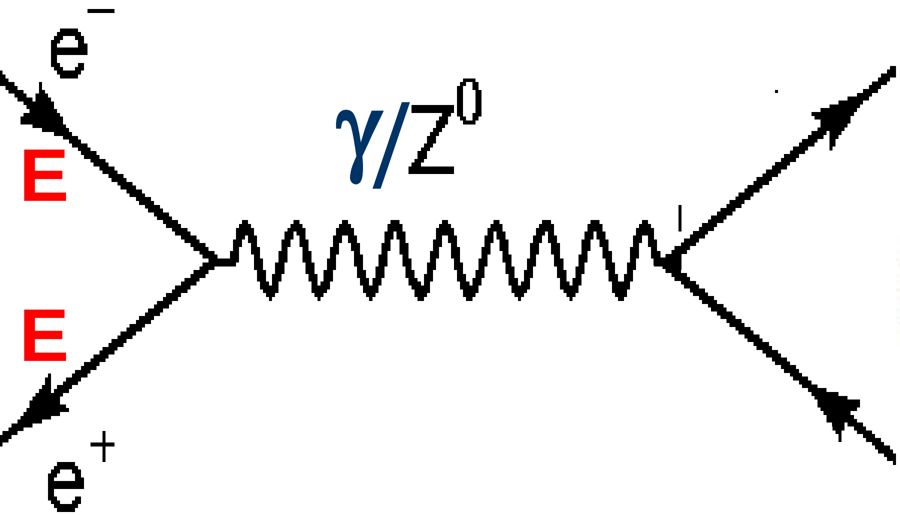

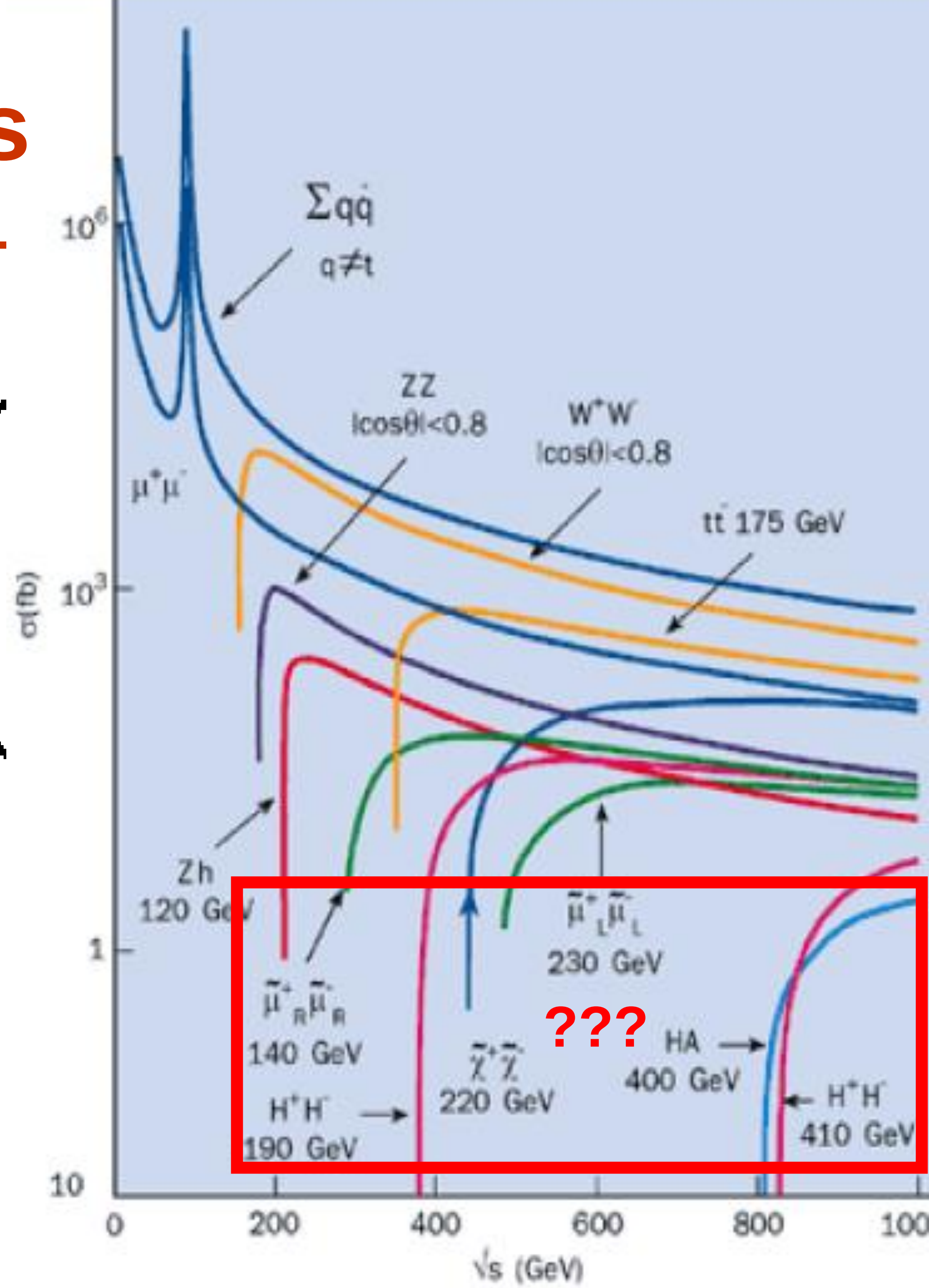

e+e- colliders

	ILC	ILC	ILC	CLIC	CLIC	CLIC	LEP3
√s [GeV]	250	500	1000	500	1500	3000	240
Luminosity $[10^{34}\ cm^{-1}s^{-1}]$	0.75	1.8	4.9	1.3	3.7	5.9	1 per IP
>0.99 √s fraction	87%	58%	45%	54%	38%	34%	100%
polarization e^-	80%	80%	80%	80%	80%	80%	-
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beam size σ_x [nm]	729	474	335	100	60	40	71000
beam size σ_y [nm]	7.7	5.9	2.7	2.6	1.5	1	320
Power [MW]	128	162	300	235	364	589	200

Wyatt

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L ~ 10^{34} (250 GeV) → 20,000 H / year

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European particle physics strategy 2013

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Europe looks forward to a proposal from Japan to discuss a possible participation.

Snowmass executive summary 2013

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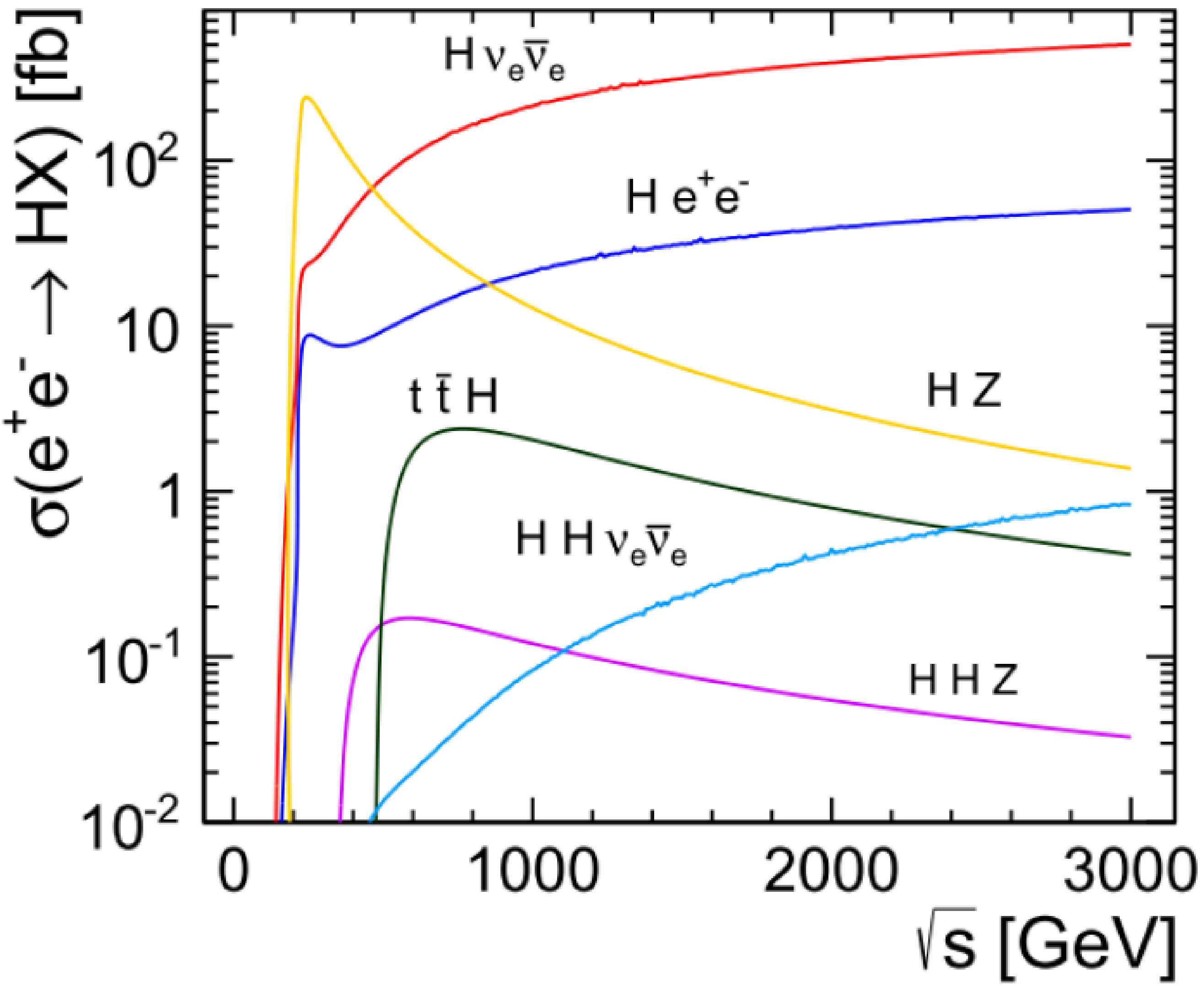
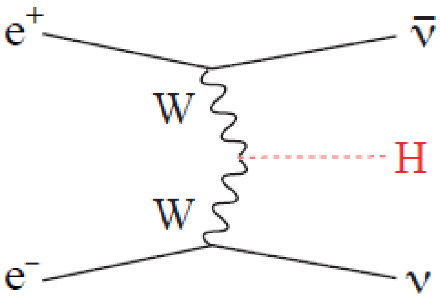
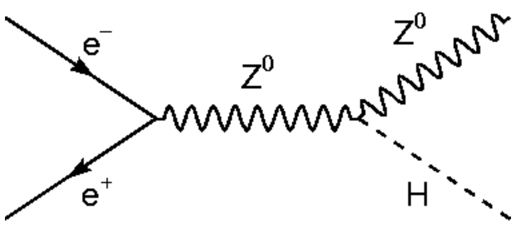
e+e- Higgs Factory







ILC Higgs Factory Roadmap

250 GeV:

- **Mass, Spin, CP nature**
- **Absolute meas. of HZZ**
- **BRs Higgs → qq, ll, VV**

350 GeV:

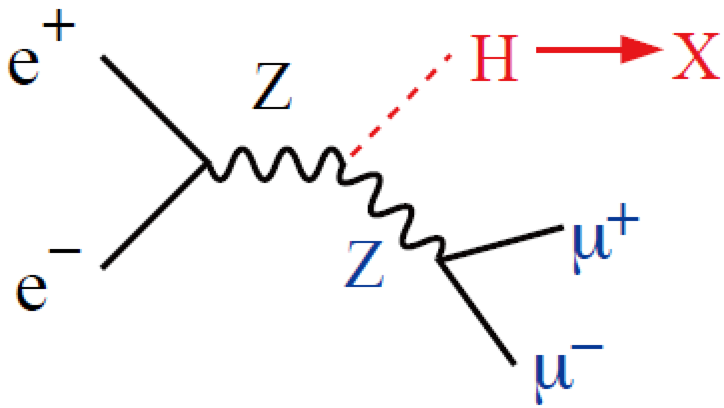
- **Top threshold: mass, width, anomalous couplings …**
- **(more stats on Higgs BRs)**

500 GeV:

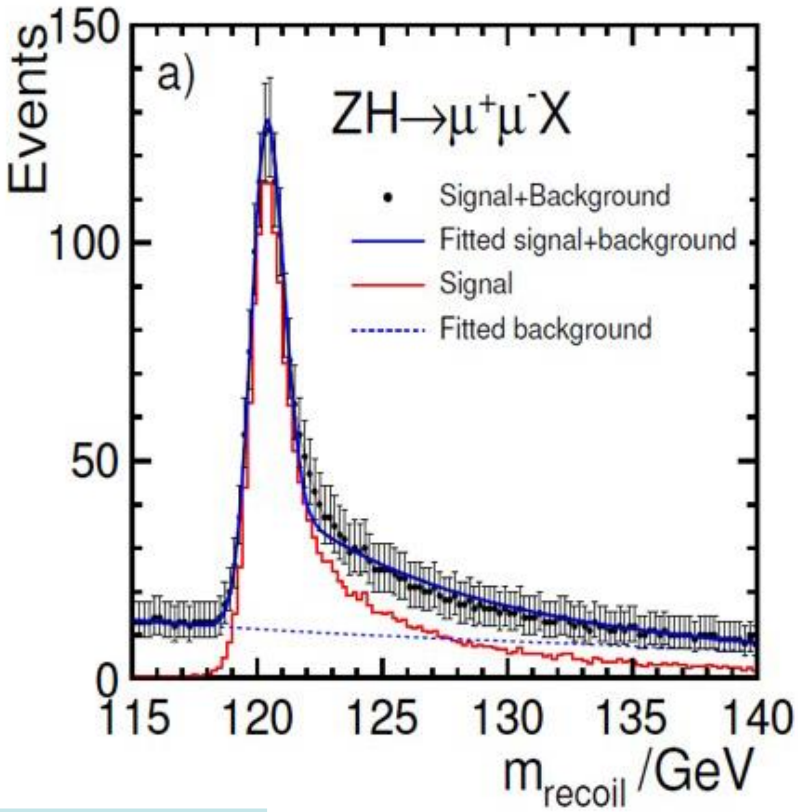
- **HWW coupling → total width → absolute couplings**
- **Higgs self coupling**
- **Top Yukawa coupling**

→ 1000 GeV: as motivated by physics

Higgs mass measurement



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



Recoil mass:
- independent of Higgs decay

Discovery mode for 'H' decay to weakly-interacting particles

$$250\,\mathrm{fb}^{-1} @ 250\,\mathrm{GeV}$$

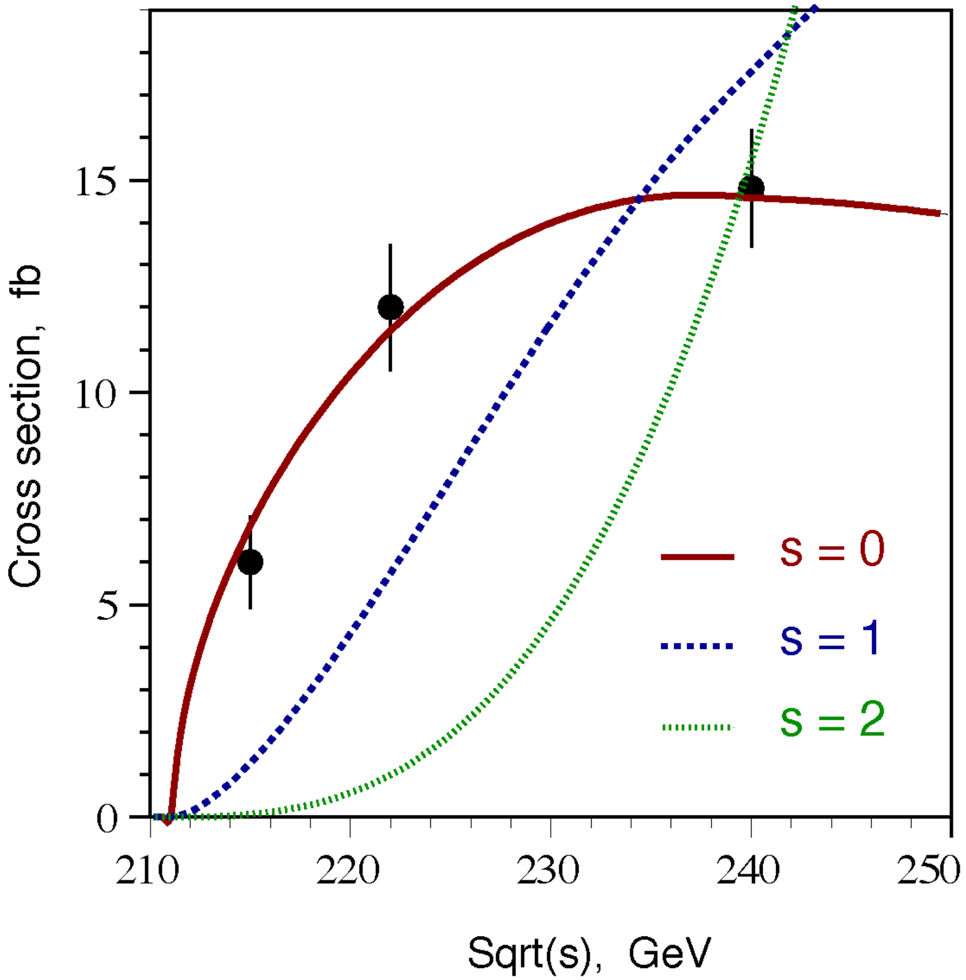
$$\Delta\sigma_H/\sigma_H = 2.5\%$$

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

(Fujii)

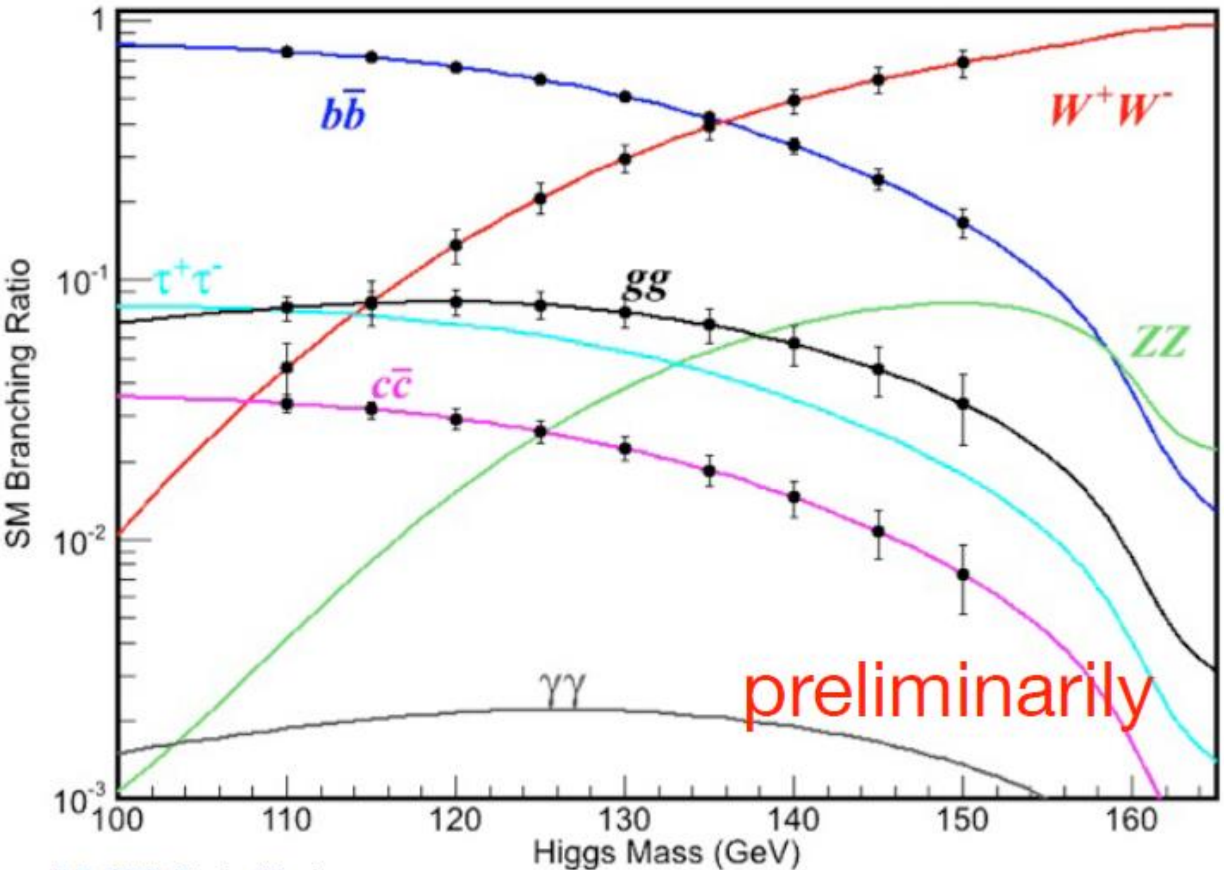
Higgs spin determination

Rise of cross-section near threshold



(TESLA TDR)

Higgs branching ratios determination (1)



ILD DBD Study (Ono)

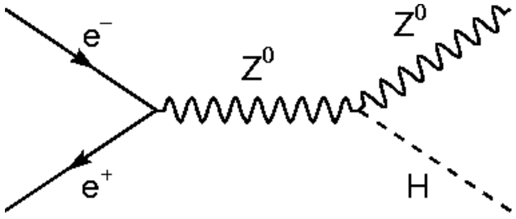
(ILC TDR)

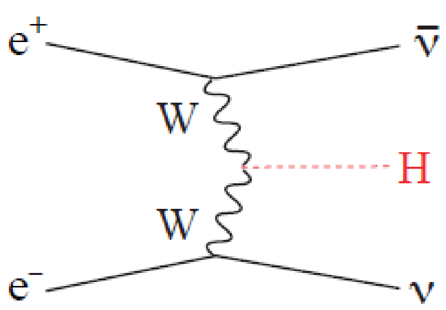
$$250\ \mathrm{fb}^{-1}@250\ \mathrm{GeV}$$
$$m_H = 120\ \mathrm{GeV}$$

	@ 250 GeV
process	ZH
luminosity · fb	250
cross section	2.5%
	σ·Br
H-->bb	1.0%
H-->cc	6.9%
H-->gg	8.5%
H-->WW*	8.2%
H-->ττ	4-6%
H-->ZZ*	28%
H-->γγ	23-30%

Higgs branching ratios determination (2)

measurements (independent)	precision
$X_1 = \sigma_{ZH} \cdot \mathrm{Br}(H \to b\bar{b})$ @ 250 GeV	1.0%
$X_2 = \sigma_{ZH} \cdot \mathrm{Br}(H \to c\bar{c})$ @ 250 GeV	6.9%
$X_3 = \sigma_{ZH} \cdot \mathrm{Br}(H \to gg)$ @ 250 GeV	8.5%
$X_4 = \sigma_{ZH} \cdot \mathrm{Br}(H \to WW^*)$ @ 250 GeV	8.2%
$X_5 = \sigma_{ZH} \cdot \mathrm{Br}(H \to b\bar{b})$ @ 500 GeV	1.6%
$X_6 = \sigma_{ZH} \cdot \mathrm{Br}(H \to c\bar{c})$ @ 500 GeV	11%
$X_7 = \sigma_{ZH} \cdot \mathrm{Br}(H \to gg)$ @ 500 GeV	13%
$X_8 = \sigma_{\nu\bar{\nu}H} \cdot \mathrm{Br}(H \to b\bar{b})$ @ 500 GeV	0.60%
$X_9 = \sigma_{\nu\bar{\nu}H} \cdot \mathrm{Br}(H \to c\bar{c})$ @ 500 GeV	4.0%
$X_{10} = \sigma_{\nu\bar{\nu}H} \cdot \mathrm{Br}(H \to gg)$ @ 500 GeV	4.9%
$X_{11} = \sigma_{\nu\bar{\nu}H} \cdot \mathrm{Br}(H \to WW^*)$ @ 500 GeV	3.0%
$X_{12} = \sigma_{ZH}$	2.5%





(Fujii / ILC TDR)

Total Width and Coupling Extraction

One of the major advantages of the LC

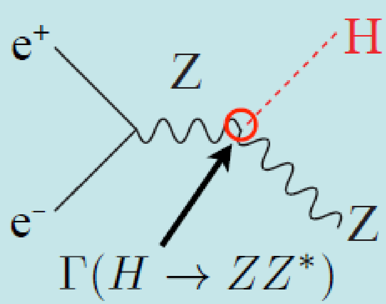
To extract couplings from BRs, we need the total width:

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

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

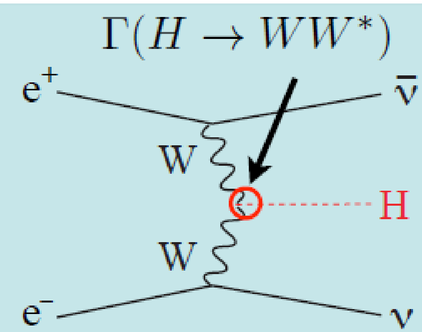
$$\Gamma_H = \Gamma(H \to AA)/BR(H \to AA)$$

In principle, we can use the 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



$BR(H \to WW^*)$

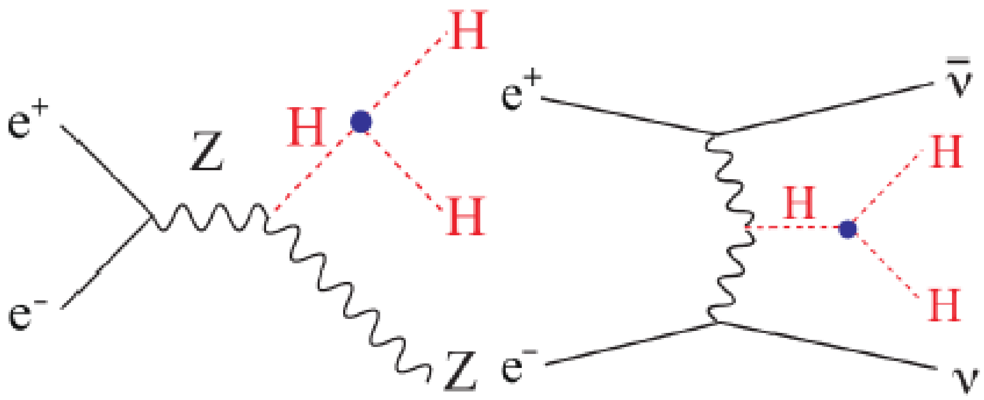
More advantageous but not easy at low E

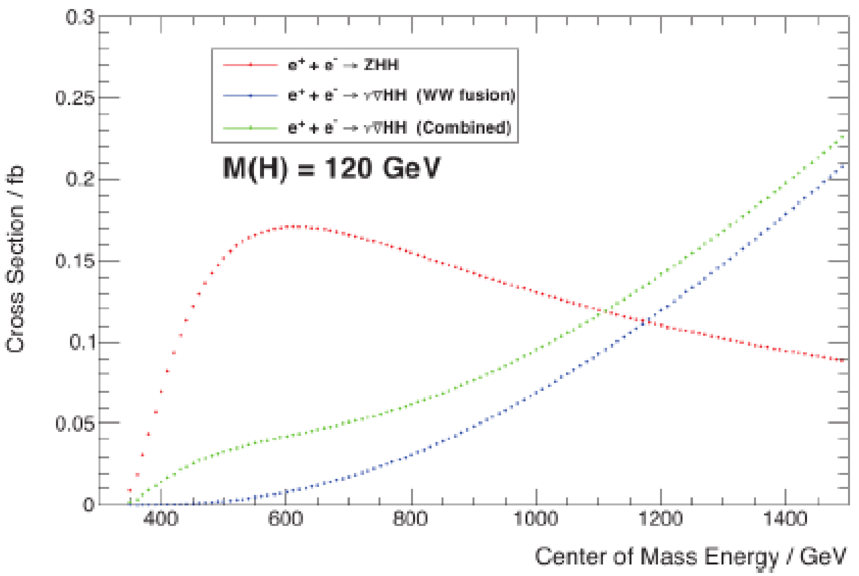
$250\,\mathrm{fb}^{-1}$@$250\,\mathrm{GeV}$

$\Delta\Gamma_H/\Gamma_H \simeq 10\%$

Jenny List's talk

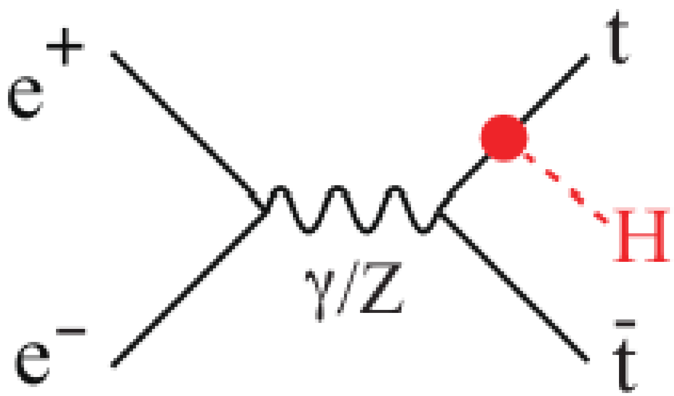
Higgs self-coupling determination

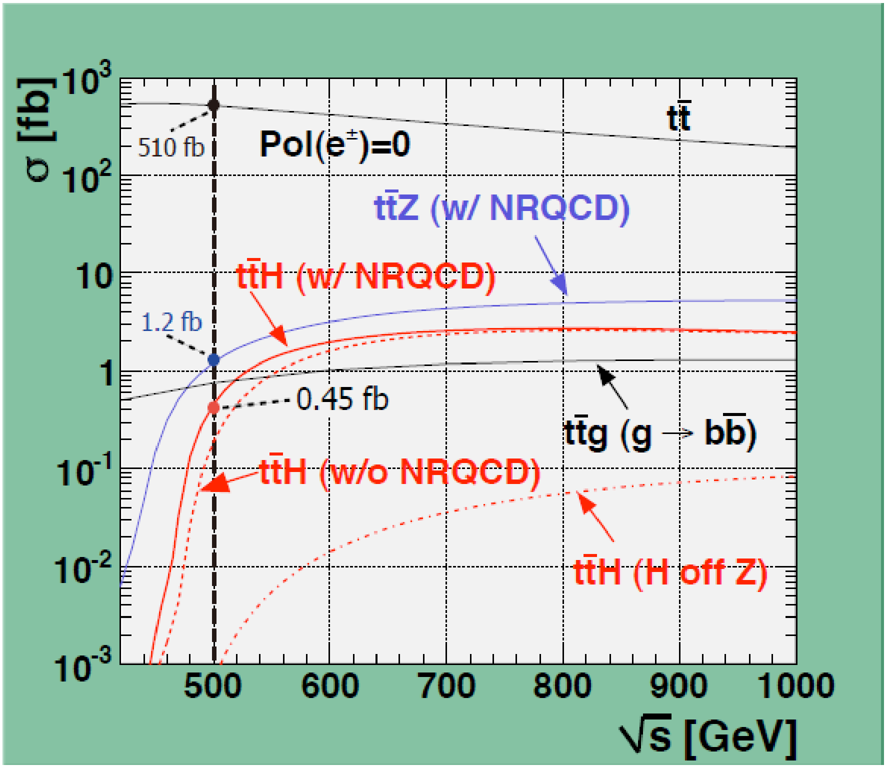




$\sqrt{s}$ (GeV) L (fb^{-1})	500 500	500 1600	500+1000 500+1000	500+1000 1600+2500
$\Delta\lambda/\lambda$	83%	46%	21%	13%

Higgs top-coupling determination





$$1\,\mathrm{ab}^{-1} @ 500\,\mathrm{GeV}$$

$$\Delta g_Y(t)/g_Y(t) = 10\,\%$$

(Price, Roloff)

ILC roadmap

Baseline:	**250 fb^{-1}**	**@ 250 GeV**	**3 years**
	500 fb^{-1}	**@ 500 GeV**	**3 years**
	1000 fb^{-1}	**@ 1000 GeV**	**3 years**

ILC roadmap

Baseline:	**250 fb^{-1}**	**@ 250 GeV**	**3 years**
	500 fb^{-1}	**@ 500 GeV**	**3 years**
	1000 fb^{-1}	**@ 1000 GeV**	**3 years**

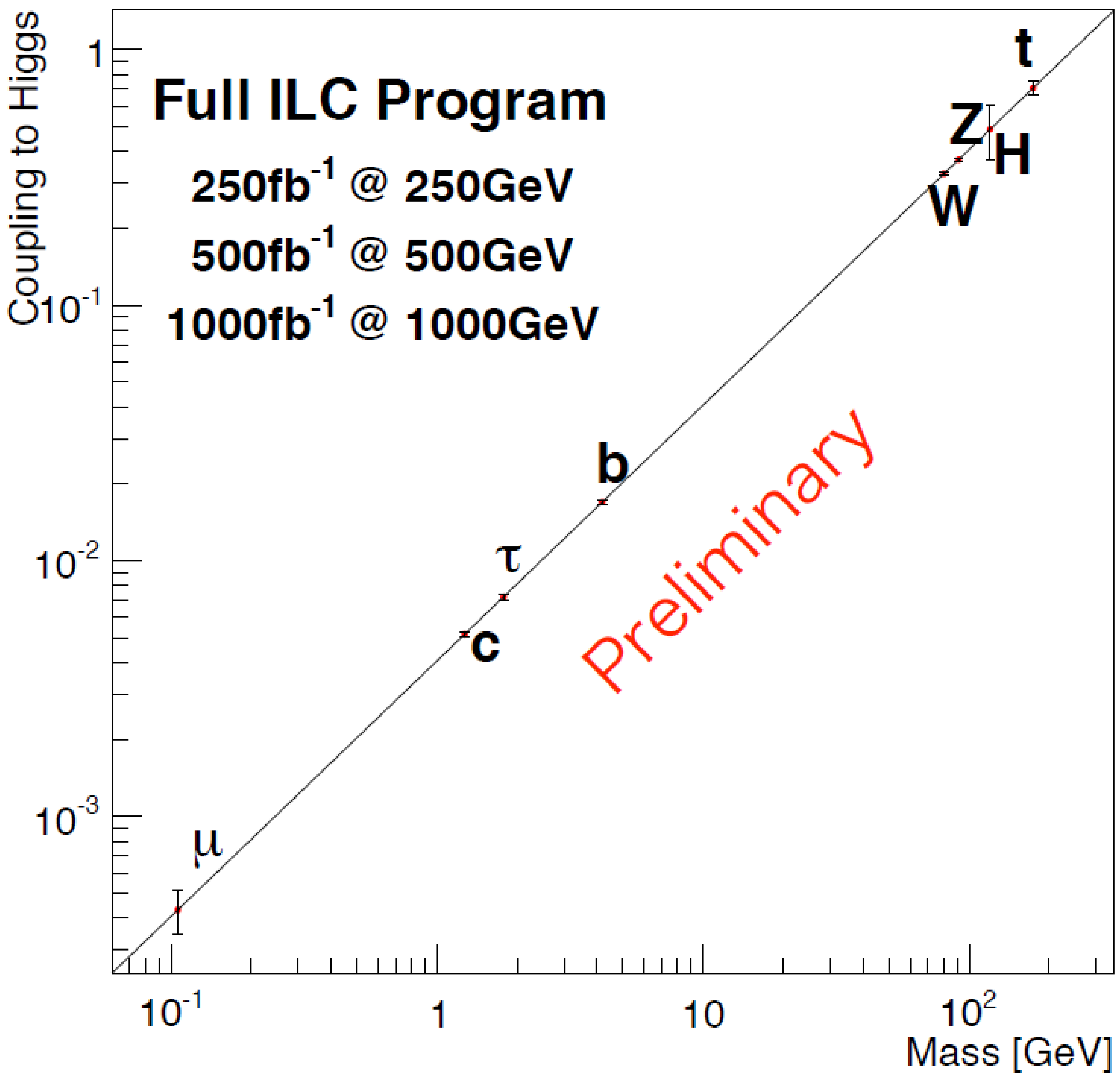
Followed by luminosity upgrade:

'HL-ILC':	**+900 fb^{-1}**	**@ 250 GeV**	**+3 years**
	+1100 fb^{-1}	**@ 500 GeV**	**+3 years**
	+1500 fb^{-1}	**@ 1000 GeV**	**+3 years**

ILC baseline precisions

$\sqrt{s}$ and $\mathcal{L}$ (P_{e^-}, P_{e^+})	250 fb^{-1} at 250 GeV (-0.8,+0.3)		500 fb^{-1} at 500 GeV (-0.8,+0.3)				1 ab^{-1} at 1 TeV (-0.8,+0.2)		
	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$	$t\bar{t}h$	Zhh	$\nu\bar{\nu}h$	$t\bar{t}h$	$\nu\bar{\nu}hh$
$\Delta\sigma/\sigma$	2.6%	-	3.0	-		42.7%			26.3%
BR(invis.)	$<$ 0.9 %	-	-	-	-				
mode	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$								
$h \to b\bar{b}$	1.2%	10.5%	1.8%	0.7%	28%		0.5%	6.0%	
$h \to c\bar{c}$	8.3%	-	13%	6.2%			3.1%		
$h \to gg$	7.0%	-	11%	4.1%			2.3%		
$h \to WW^*$	6.4%	-	9.2%	2.4%			1.6%		
$h \to \tau^+\tau^-$	4.2%	-	5.4%	9.0%			3.1%		
$h \to ZZ^*$	19%	-	25%	8.2%			4.1%		
$h \to \gamma\gamma$	34%	-	34%	23%			8.5%		
$h \to \mu^+\mu^-$	100%	-	-	-			31%		

Higgs coupling map



(Fujii)

ILC baseline + HL-ILC precisions

$\sqrt{s}$ and $\mathcal{L}$ (P_{e^-}, P_{e^+})	1150 fb^{-1} at 250 GeV (-0.8,+0.3)		1600 fb^{-1} at 500 GeV (-0.8,+0.3)				2.5 ab^{-1} at 1 TeV (-0.8,+0.2)		
	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$	$t\bar{t}h$	Zhh	$\nu\bar{\nu}h$	$t\bar{t}h$	$\nu\bar{\nu}hh$
$\Delta\sigma/\sigma$	1.2%	-	1.7	-		23.7%			16.7%
BR(invis.)	$<$ 0.4 %	-	-	-			-		
mode	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$								
$h \to b\bar{b}$	0.6%	4.9%	1.0%	0.4%	16%		0.3%	3.8%	
$h \to c\bar{c}$	3.9%	-	7.2%	3.5%			2.0%		
$h \to gg$	3.3%	-	6.0%	2.3%			1.4%		
$h \to WW^*$	3.0%	-	5.1%	1.3%			1.0%		
$h \to \tau^+\tau^-$	2.0%	-	3.0%	5.0%			2.0%		
$h \to ZZ^*$	8.8%	-	14%	4.6%			2.6%		
$h \to \gamma\gamma$	16%	-	19%	13%			5.4%		
$h \to \mu^+\mu^-$	46.6%	-	-	-			20%		

Model-independent couplings extraction

33 input measurements

11-parameter fit

$$\chi^2 = \sum_{i=1}^{i=33} (\frac{Y_i - Y_i'}{\Delta Y_i})^2 ,$$

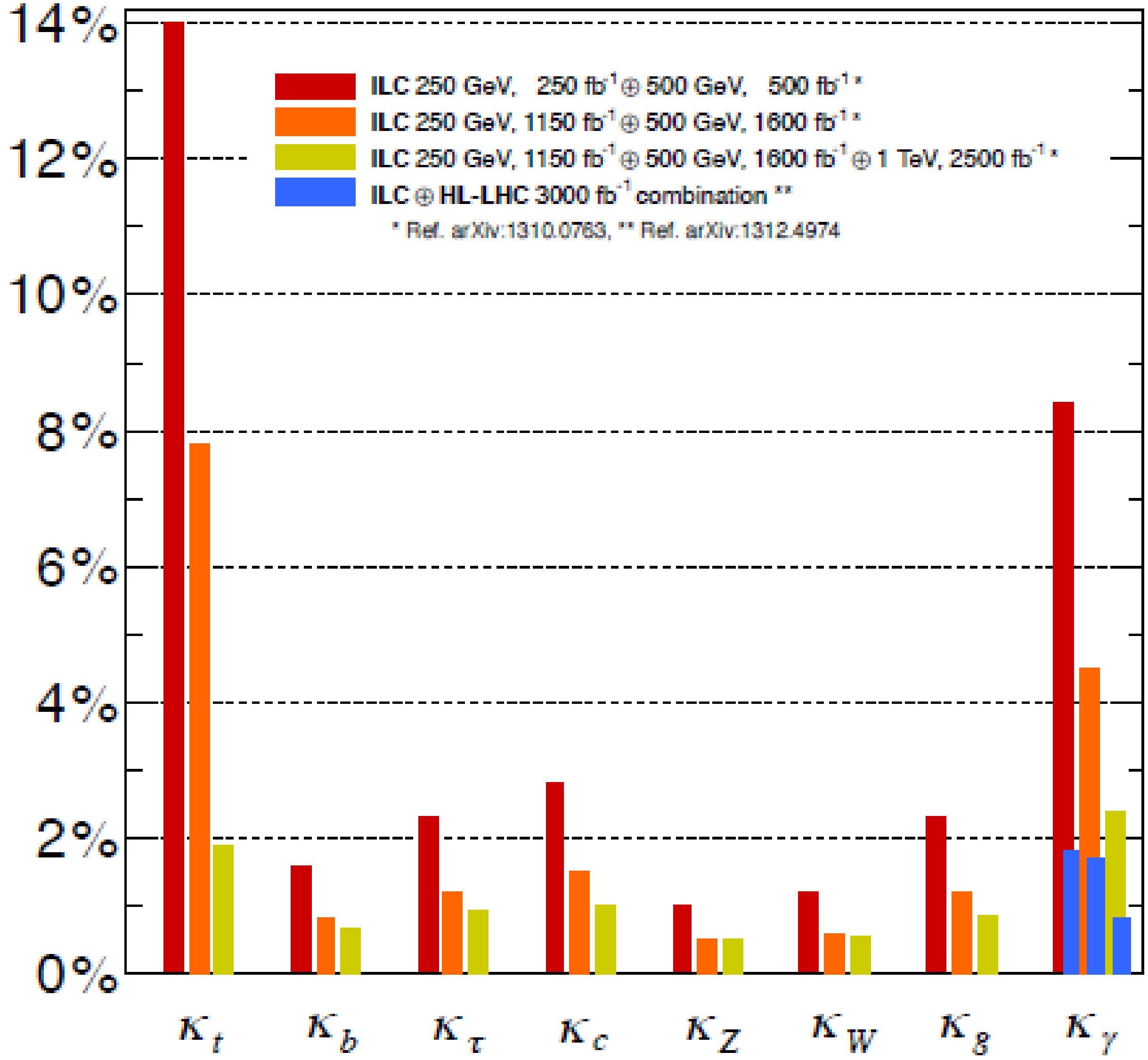
$$Y_i' = F_i \cdot \frac{g^2_{HZZ} g^2_{Hb\bar{b}}}{\Gamma_0}, \text{ or } Y_i' = F_i \cdot \frac{g^2_{HWW} g^2_{Hb\bar{b}}}{\Gamma_0}, \text{ or } Y_i' = F_i \cdot \frac{g^2_{Htt} g^2_{Hb\bar{b}}}{\Gamma_0}$$

$$F_i = S_i G_i \quad \text{where } S_i = (\frac{\sigma_{ZH}}{g^2_Z}),\ (\frac{\sigma_{\nu\bar{\nu}H}}{g^2_W}),\ \text{or } (\frac{\sigma_{t\bar{t}H}}{g^2_t}),\ \text{and } G_i = (\frac{\Gamma_i}{g^2_i}) .$$

Model-independent couplings

	ILC(250)	ILC(500)	ILC(1000)	ILC(LumUp)
$\sqrt{s}$ (GeV)	250	250+500	250+500+1000	250+500+1000
L (fb^{-1})	250	250+500	250+500+1000	1150+1600+2500
$\gamma\gamma$	18 %	8.4 %	4.0 %	2.4 %
gg	6.4 %	2.3 %	1.6 %	0.9 %
WW	4.8 %	1.1 %	1.1 %	0.6 %
ZZ	1.3 %	1.0 %	1.0 %	0.5 %
$t\bar{t}$	–	14 %	3.1 %	1.9 %
$b\bar{b}$	5.3 %	1.6 %	1.3 %	0.7 %
$\tau^+\tau^-$	5.7 %	2.3 %	1.6 %	0.9 %
$c\bar{c}$	6.8 %	2.8 %	1.8 %	1.0 %
$\mu^+\mu^-$	91%	91%	16 %	10 %
$\Gamma_T(h)$	12 %	4.9 %	4.5 %	2.3 %
hhh	–	83 %	21 %	13 %
BR(invis.)	< 0.9 %	< 0.9 %	< 0.9 %	< 0.4 %

Model-independent couplings



Comparison with LHC

LHC does not project making model-independent Higgs coupling measurements

LHC projections assume the Standard Model and estimate precision relative to SM couplings, also assuming charm follows top

Model-dependent couplings extraction

7 Parameter HXSWG Benchmark *

Mode	LHC 300 fb^{-1}	LHC 3000 fb^{-1}
$\gamma\gamma$	$(5-7)\%$	$(2-5)\%$
gg	$(6-8)\%$	$(3-5)\%$
WW	$(4-5)\%$	$(2-3)\%$
ZZ	$(4-5)\%$	$(2-3)\%$
$t\bar{t}$	$(14-15)\%$	$(7-10)\%$
$b\bar{b}$	$(10-13)\%$	$(4-7)\%$
$\tau^+\tau^-$	$(6-8)\%$	$(2-5)\%$

* Assume $\kappa_c = \kappa_t$ & $\Gamma_{tot} = \sum_{\text{SM decays } i} \Gamma_i^{SM} \kappa_i^2$

Comparison with LHC

LHC does not project making model-independent Higgs coupling measurements

LHC projections assume the Standard Model and estimate precision relative to SM couplings, also assuming charm follows top

For purpose of comparison, can follow same model-dependent procedure for ILC …

Model-dependent couplings extraction

7 Parameter HXSWG Benchmark *

	LHC	
Mode	300 fb^{-1}	3000 fb^{-1}
$\gamma\gamma$	$(5-7)\%$	$(2-5)\%$
gg	$(6-8)\%$	$(3-5)\%$
WW	$(4-5)\%$	$(2-3)\%$
ZZ	$(4-5)\%$	$(2-3)\%$
$t\bar{t}$	$(14-15)\%$	$(7-10)\%$
$b\bar{b}$	$(10-13)\%$	$(4-7)\%$
$\tau^+\tau^-$	$(6-8)\%$	$(2-5)\%$

ILC(1000)	ILC(LumUp)	
250+500+1000	250+500+1000	$\sqrt{s}$ (GeV)
250+500+1000	1150+1600+2500	L (fb^{-1})
3.8 %	2.3 %	
1.1 %	0.7 %	
0.3 %	0.2 %	
0.5 %	0.3 %	
1.3 %	0.9 %	
0.6 %	0.4 %	
1.3 %	0.7 %	

* Assume $\kappa_c = \kappa_t$ & $\Gamma_{tot} = \sum_{\text{SM decays } i} \Gamma_i^{SM} \kappa_i^2$

Model-dependent couplings extraction

7 Parameter HXSWG Benchmark *

Mode	LHC 300 fb^{-1}	LHC 3000 fb^{-1}	ILC(1000)	ILC(LumUp)	
			250+500+1000	250+500+1000	$\sqrt{s}$ (GeV)
			250+500+1000	1150+1600+2500	L (fb^{-1})
$\gamma\gamma$	$(5-7)\%$	$(2-5)\%$	3.8 %	2.3 %	
gg	$(6-8)\%$	$(3-5)\%$	1.1 %	0.7 %	
WW	$(4-5)\%$	$(2-3)\%$	0.3 %	0.2 %	
ZZ	$(4-5)\%$	$(2-3)\%$	0.5 %	0.3 %	
$t\bar{t}$	$(14-15)\%$	$(7-10)\%$	1.3 %	0.9 %	
$b\bar{b}$	$(10-13)\%$	$(4-7)\%$	0.6 %	0.4 %	
$\tau^+\tau^-$	$(6-8)\%$	$(2-5)\%$	1.3 %	0.7 %	

~10 x LHC sensitivity

* Assume $\kappa_c = \kappa_t$ & $\Gamma_{tot} = \sum_{\text{SM decays } i} \Gamma_i^{SM} \kappa_i^2$

Non-Standard Higgs couplings

For M = 1 TeV, deviations of couplings from SM:

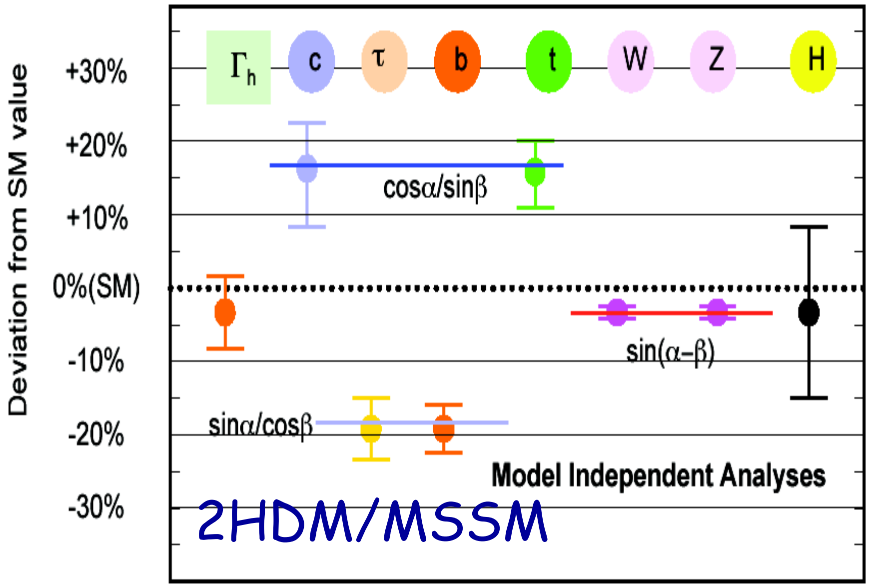
Model	κ_V	κ_b	κ_γ
Singlet Mixing	$\sim 6\%$	$\sim 6\%$	$\sim 6\%$
2HDM	$\sim 1\%$	$\sim 10\%$	$\sim 1\%$
Decoupling MSSM	$\sim -0.0013\%$	$\sim 1.6\%$	$< 1.5\%$
Composite	$\sim -3\%$	$\sim -(3-9)\%$	$\sim -9\%$
Top Partner	$\sim -2\%$	$\sim -2\%$	$\sim +1\%$

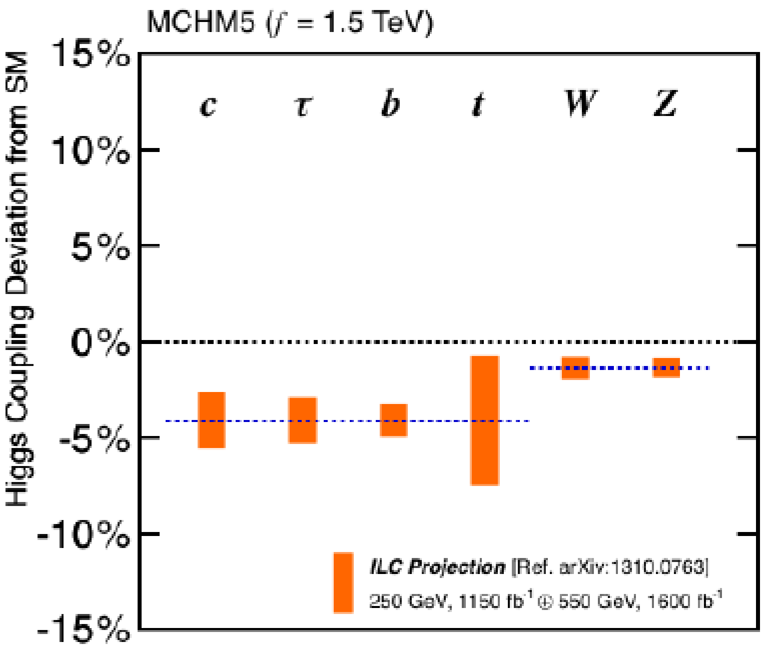
Deviations in the range 1% → 10%

→ measurements must be significantly more precise to resolve such deviations

Specific beyond-SM examples

Composite Higgs
(MCHM5)



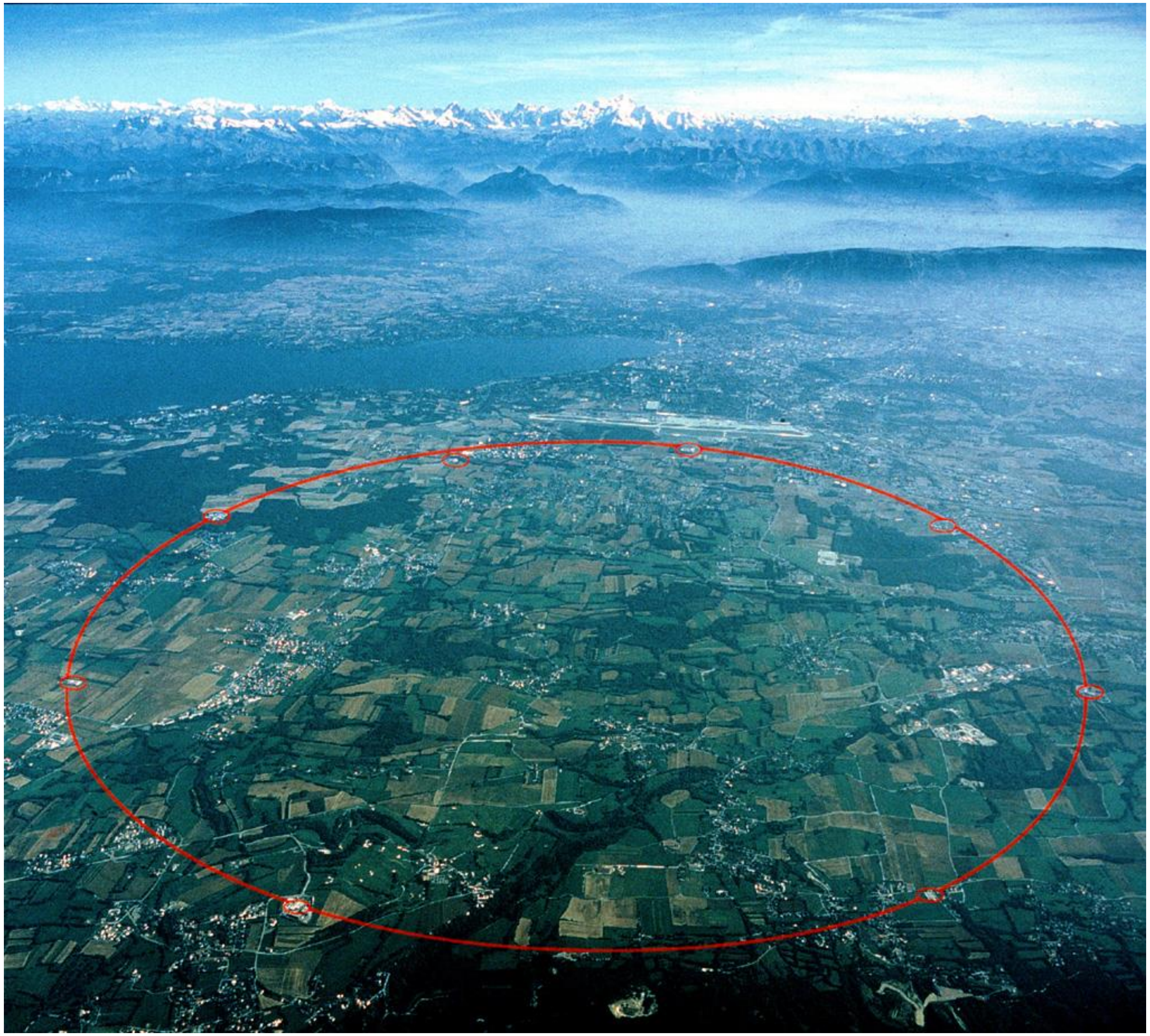


Zivkovic et al

Simulated ILC measurements

The accelerator

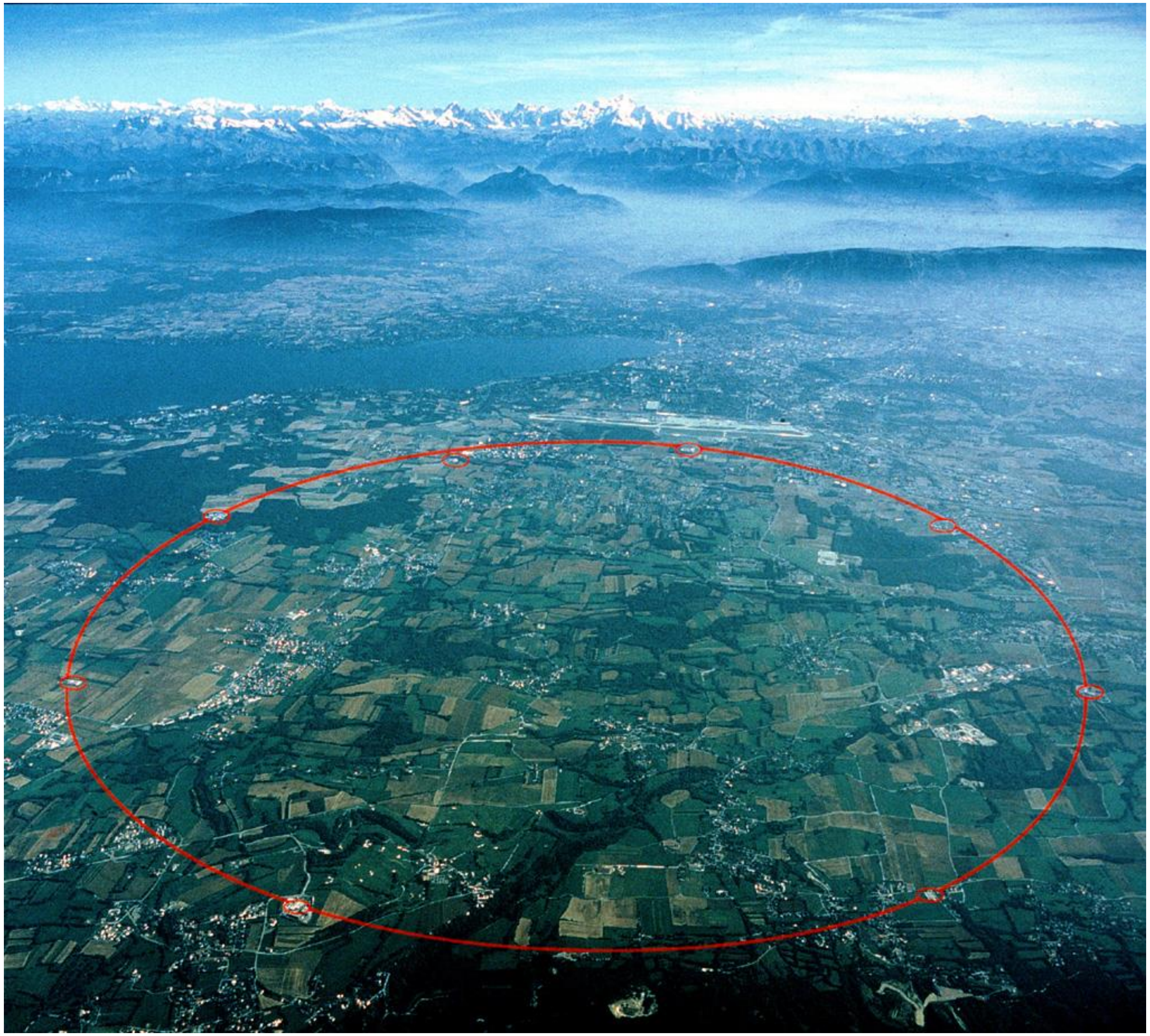
Large Electron Positron collider (RIP)



0.1 TeV

beams

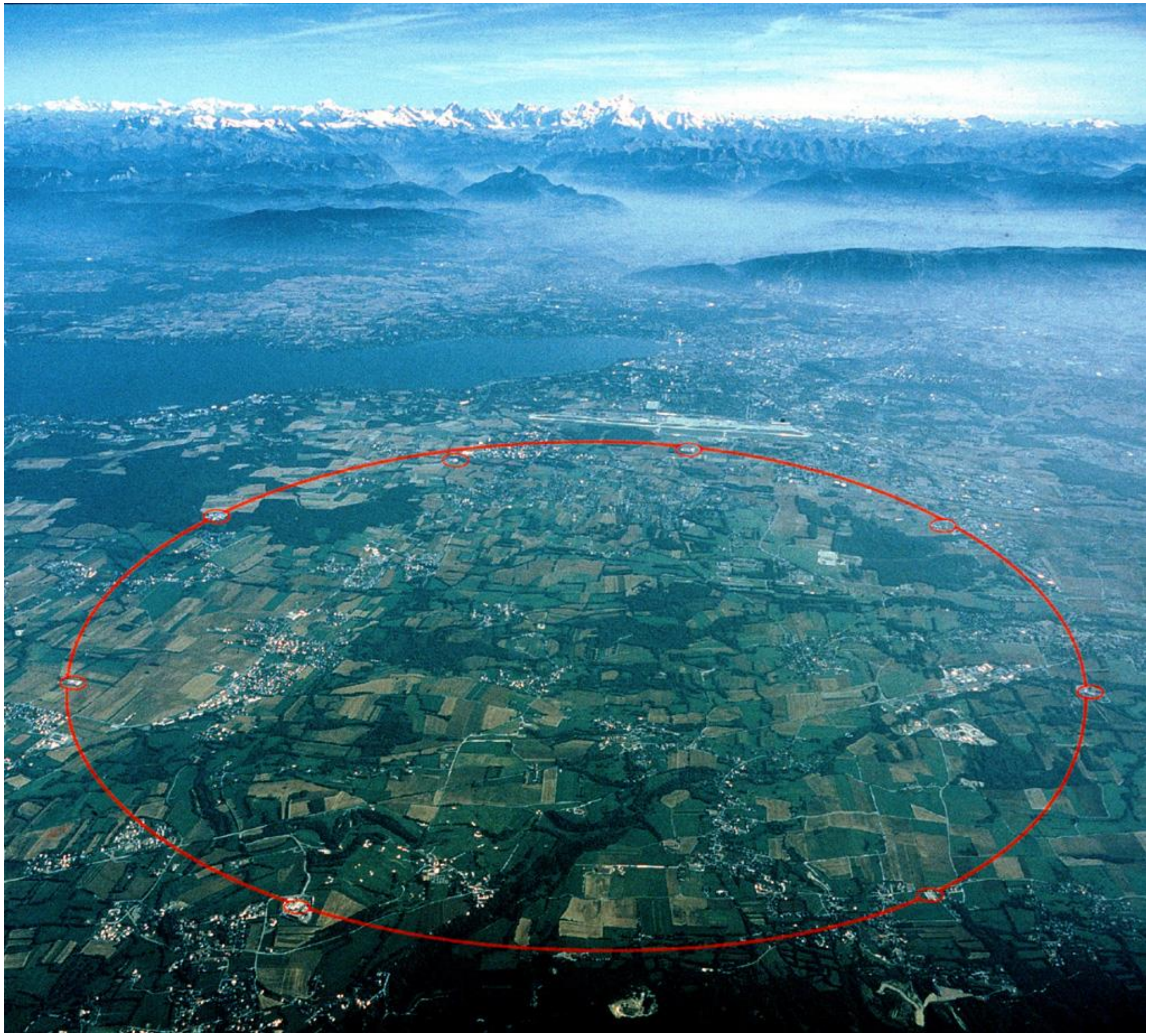
Large Electron Positron collider (RIP)



0.1 TeV beams

Synch rad → 18 MW

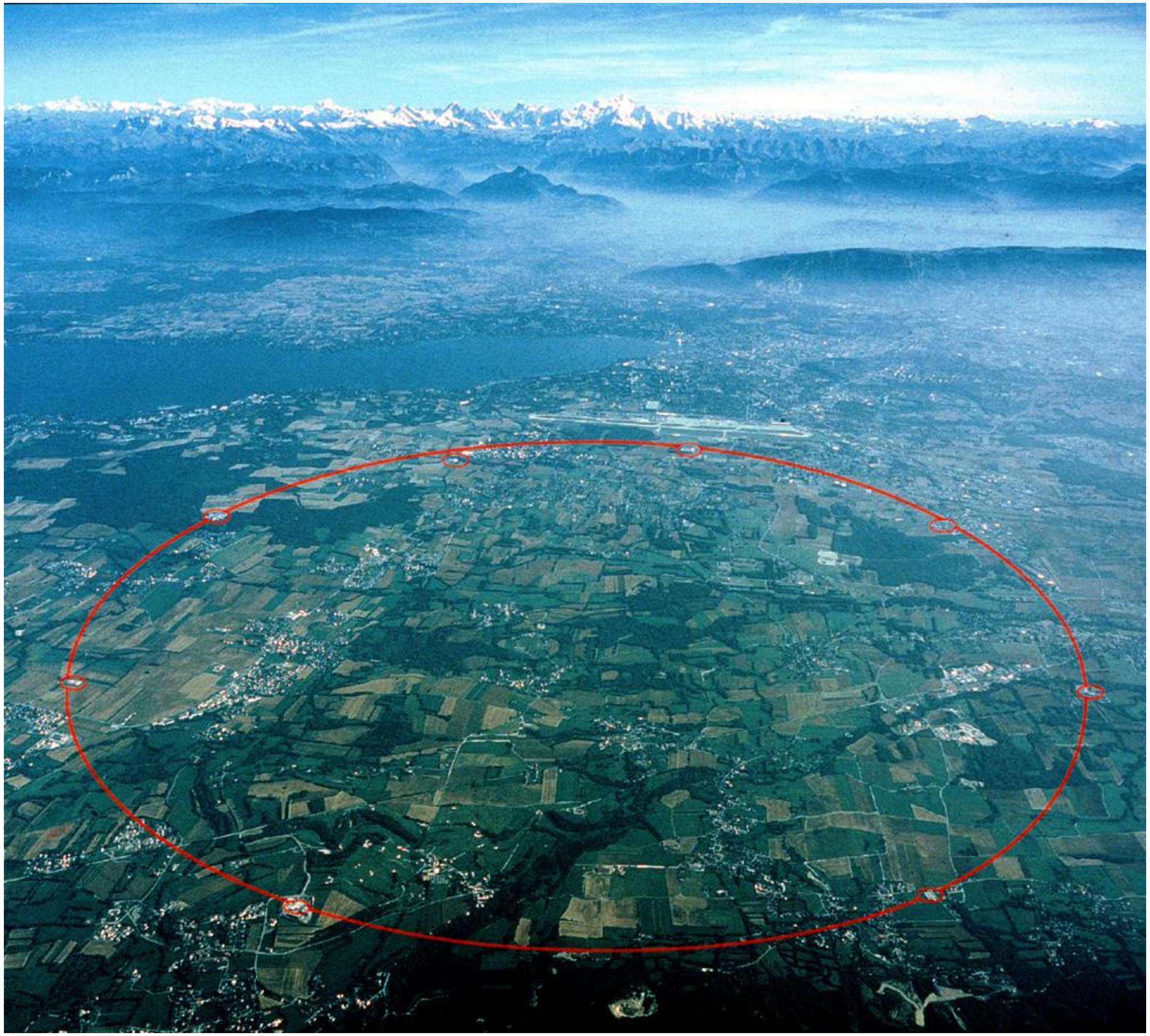
Super Large Electron Positron collider?



0.2 TeV

beams?

Super Large Electron Positron collider?



0.2 TeV beams?

Synch rad → 300 MW

Super Large Electron Positron collider?

0.2 TeV

beams?

Synch

rad →

300 MW

Linear Colliders for electrons + positrons

Stanford

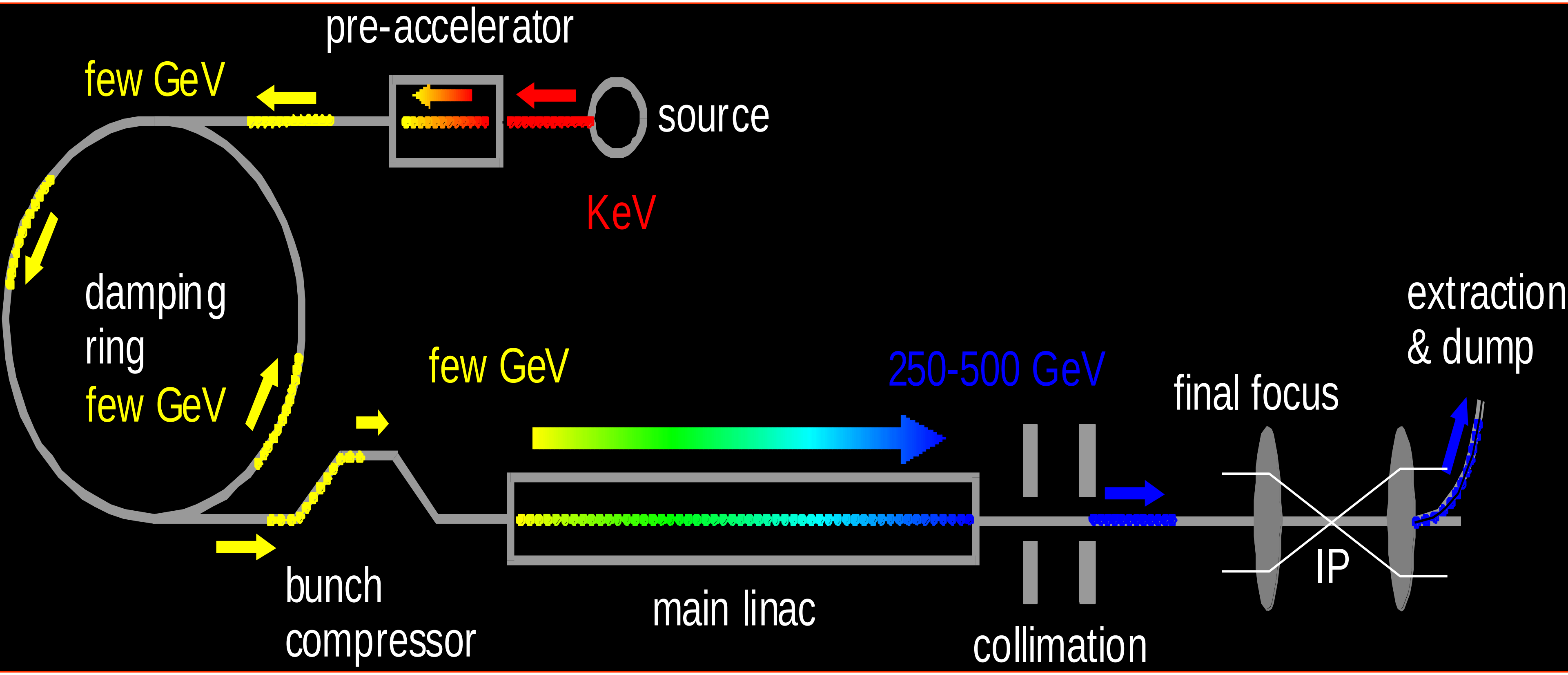
Linear

Accelerator

Center

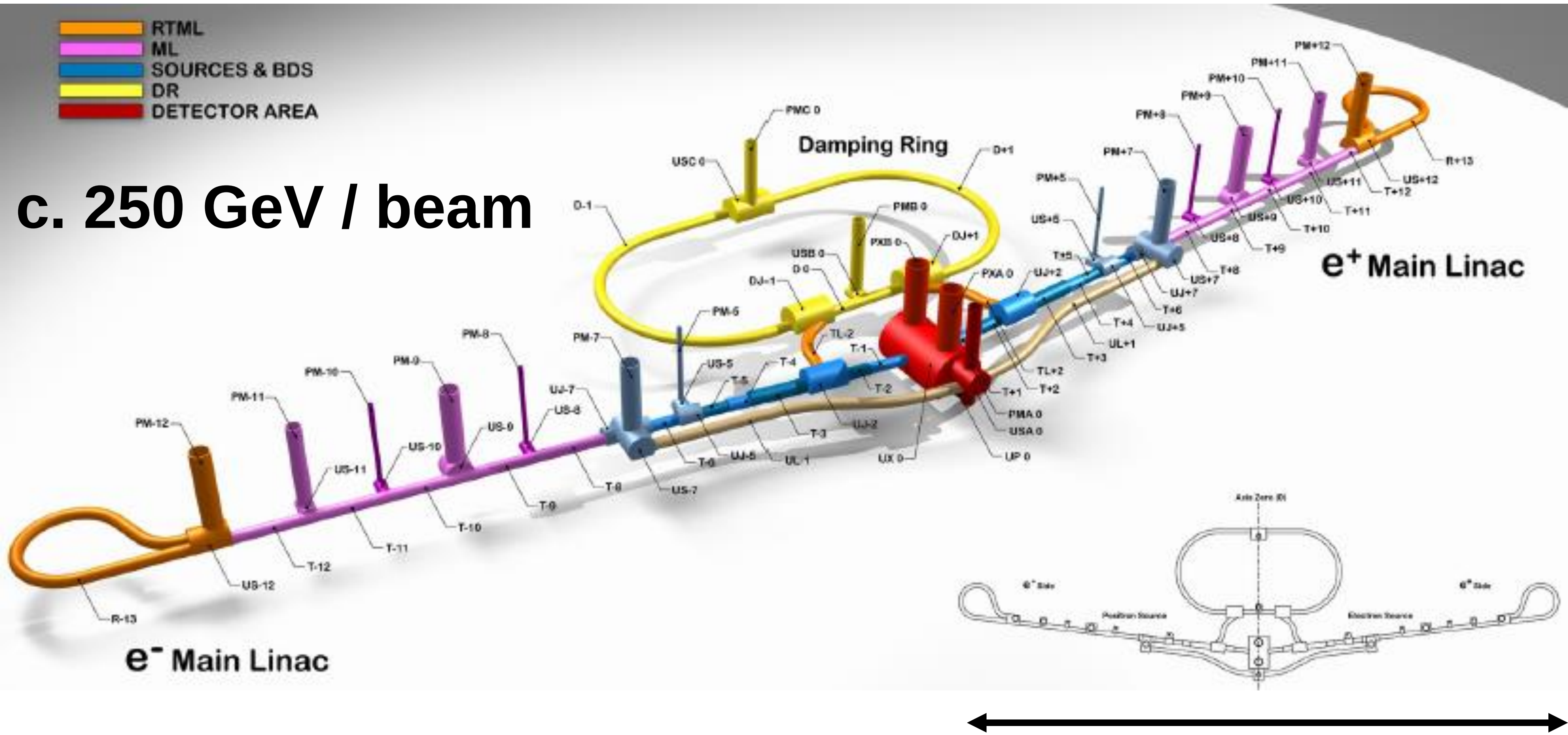
(California)

Designing a Linear Collider



International Linear Collider (ILC)

c. 250 GeV / beam

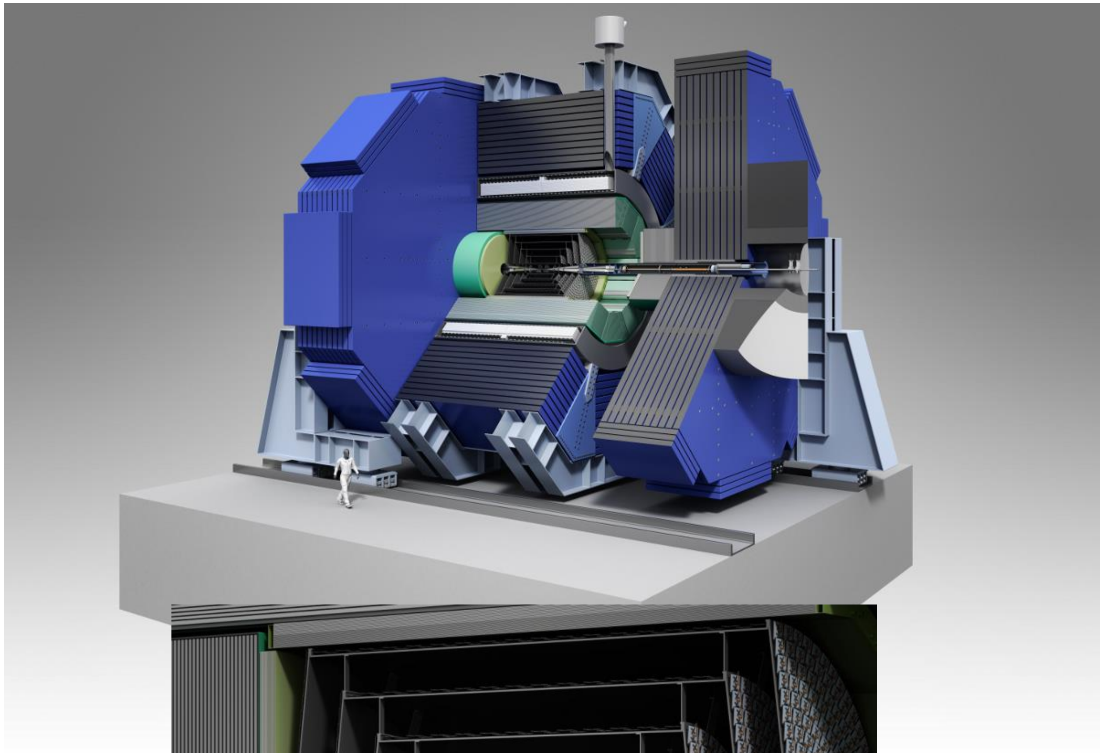


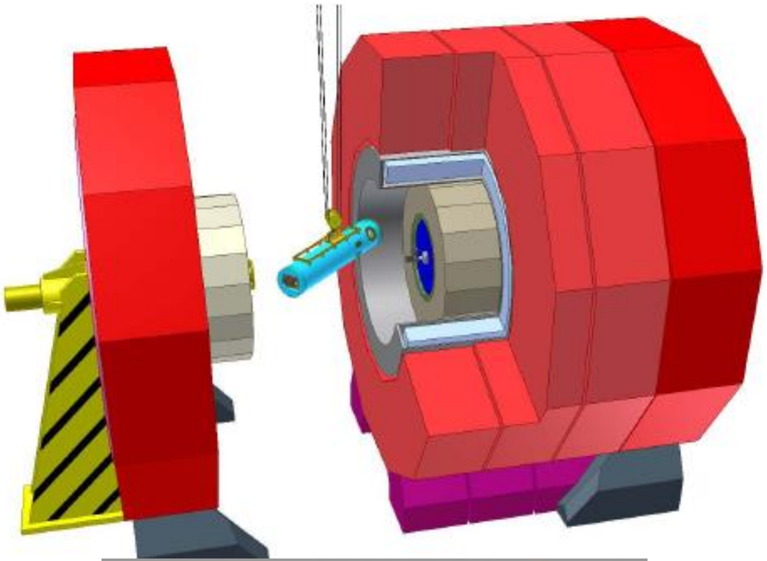
31 km

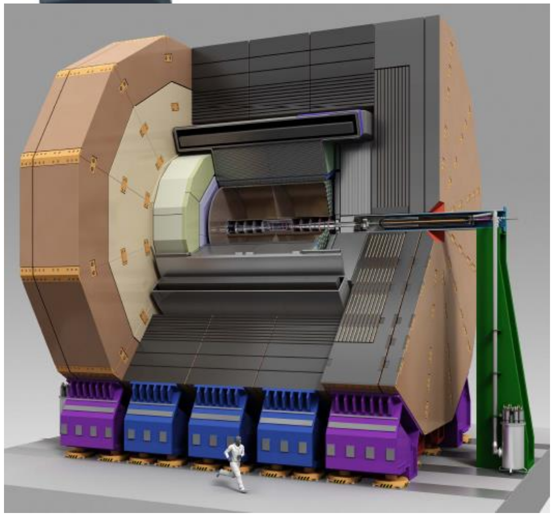
Beam parameters

	ILC (500)	
Electrons/bunch	0.75	10**10
Bunches/train	2820	
Train repetition rate	5	Hz
Bunch separation	308	ns
Train length	868	us
Horizontal IP beam size	655	nm
Vertical IP beam size	6	nm
Longitudinal IP beam size	300	um
Luminosity	2	10**34

ILC Detectors







ILC project status

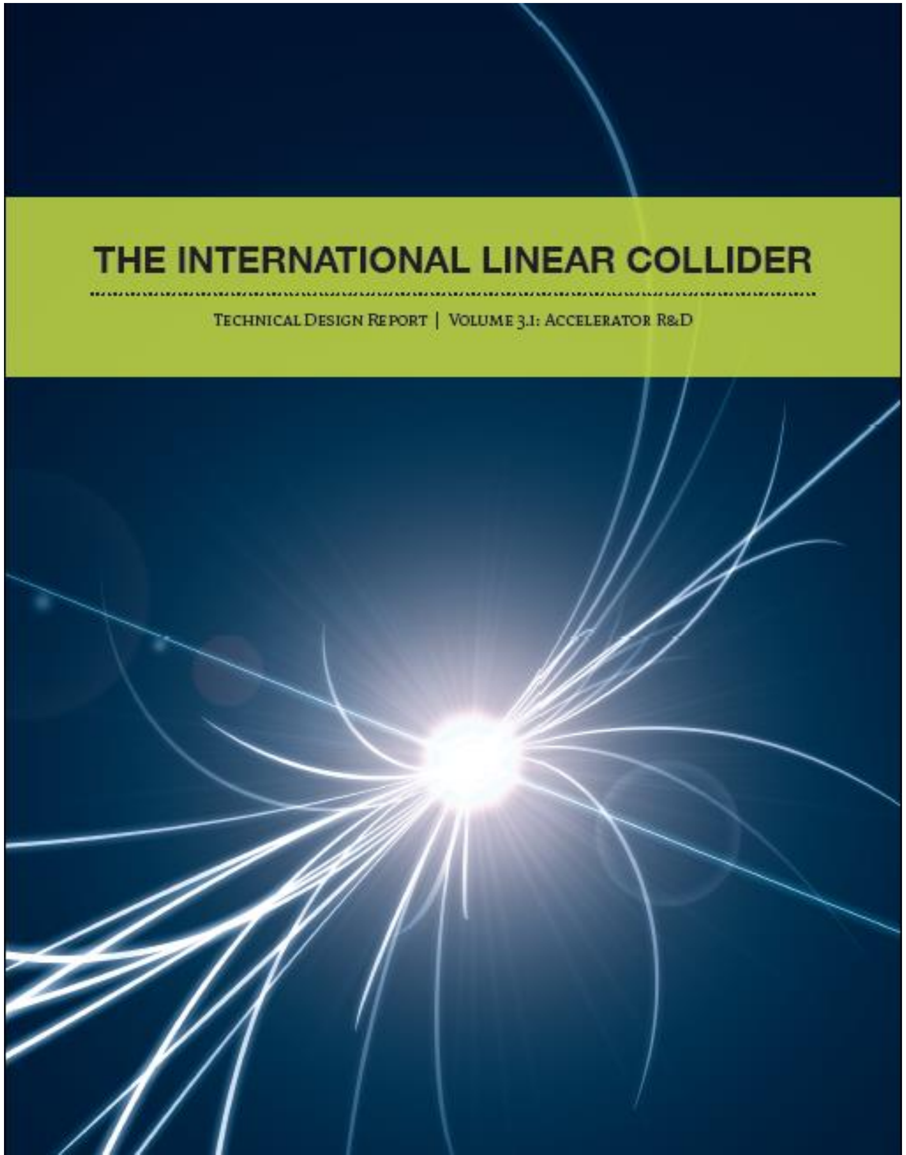
- 2005-12 ILC run by Global Design Effort (Barish)
- C. 500 accelerator scientists worldwide involved
- A Reference Design Report (RDR) was completed in 2007

  including a first cost estimate
- 2008-12 engineering design phase

  major focus on risk minimisation + cost reduction
- Technical Design document released end 2012

  revised cost estimate + project implementation plan

ILC Technical Design Report



John Adams Institute leadership

Part I:

ILC R&D IN THE TECHNICAL DESIGN PHASE

Part II:

THE ILC BASELINE DESIGN

Editors:

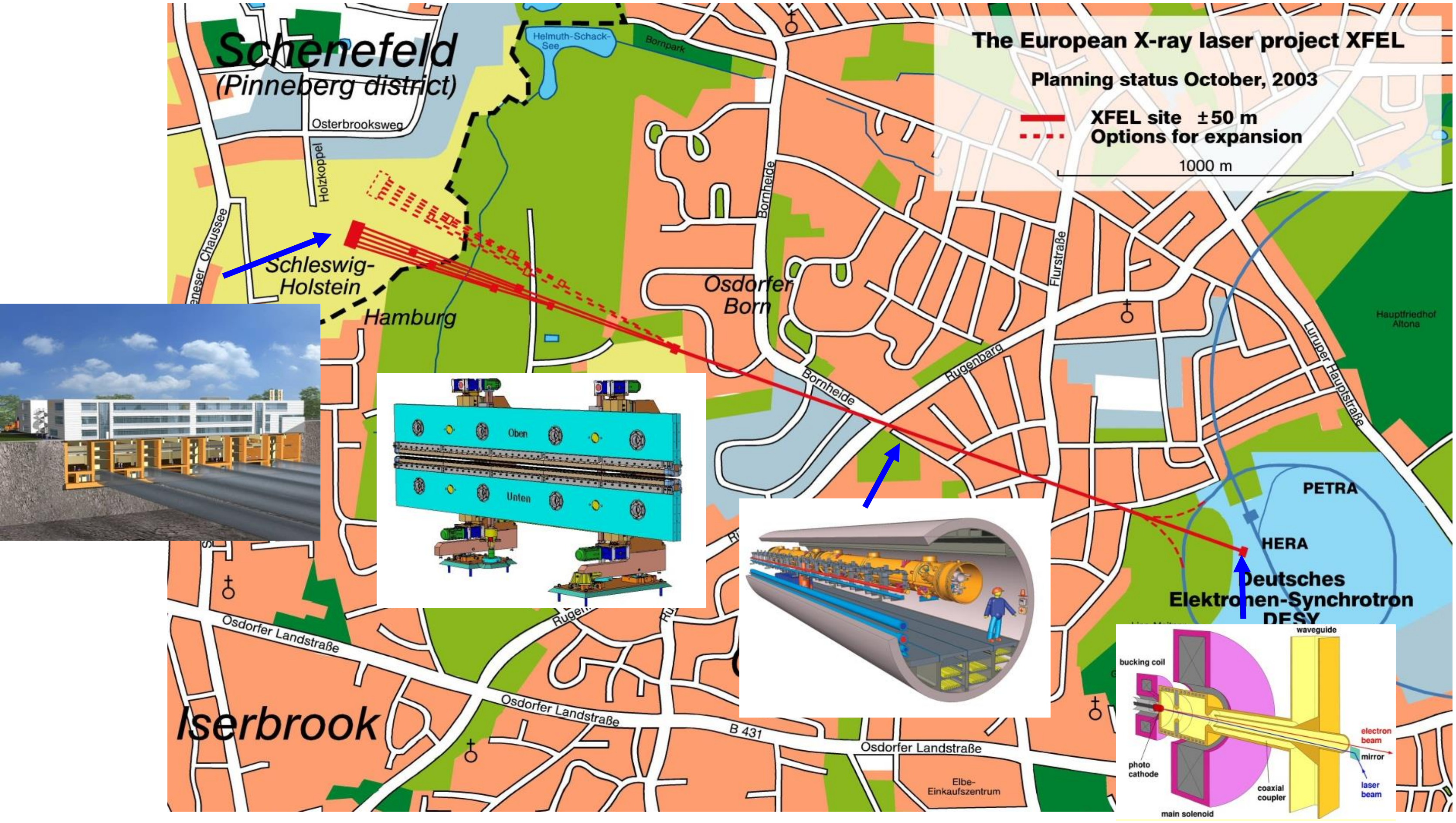
Phil BURROWS, John CARWARDINE, Eckhard ELSEN,
Brian FOSTER, Mike HARRISON, Hitoshi HAYANO,
Nan PHINNEY, Marc ROSS, Nobu TOGE,
Nick WALKER, Akira YAMAMOTO, Kaoru YOKOYA

Technical Editors:

Maura BARONE, Benno LIST

European X-FEL at DESY

3.4km



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- Technical Design document released end 2012

  revised cost estimate + project implementation plan
- Lyn Evans assumed project leadership 2013

  Japan preparing implementation of ILC at Kitakami

Yamauchi

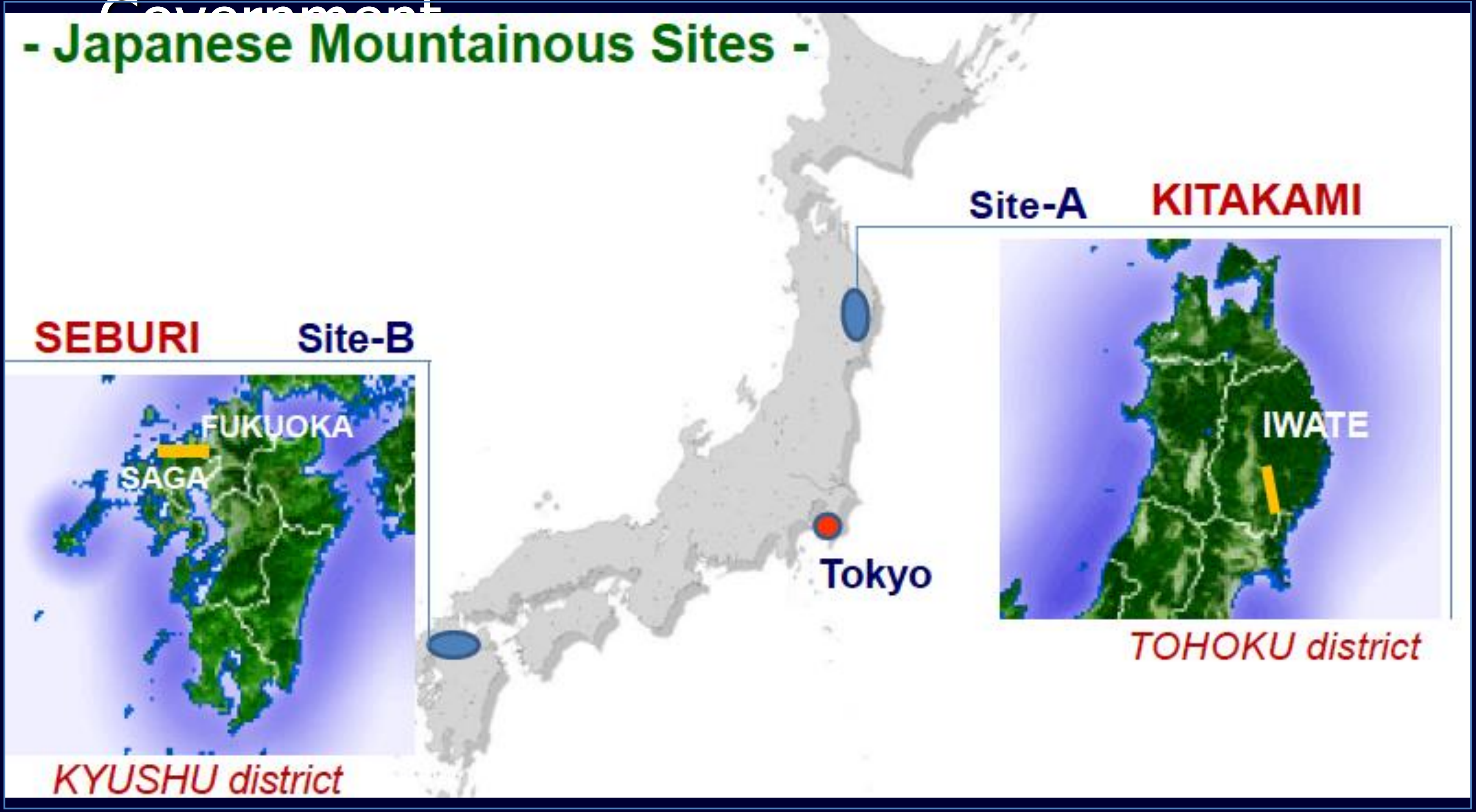
ILC Plan in Japan

- Japanese HEP community proposes to host ILC based on the “staging scenario” to the Japanese Government.
  - ILC starts as a 250GeV Higgs factory, and will evolve to a 500GeV machine.
  - Technical extendability to 1TeV is to be preserved.

Yamauchi

ILC Plan in Japan

- Japanese HEP community proposes to host ILC based on the "staging scenario" to the Japanese Government



LDP (Liberal Democratic Party) Victory in the lower-house election in Oct, 2012

Our new prime minister
Shinzo Abe

LDP policy document
for the election

LDP took power in Dec 2012

The ILC appears twice explicitly in the policy document:

- Science and technology policies
- Creation of top-class research centers

Yamamoto, HEPAP, 11/3/13

ILC in Japan?

meeting of Lyn Evans and Prime Minister Abe, March 27, 2013

Possible Timeline

- July 2013
  - Non-political evaluation of 2 Japanese candidate sites complete, followed by down-selecting to one
- End 2013
  - Japanese government announces its intent to bid
- 2013~2015
  - Inter-governmental negotiations
  - Completion of R&Ds, preparation for the ILC lab.
- ~2015
  - Inputs from LHC@14TeV, decision to proceed
- 2015~16
  - Construction begins (incl. bidding)
- 2026~27
  - Commissioning

Yamamoto, HEPAP, 11/3/13

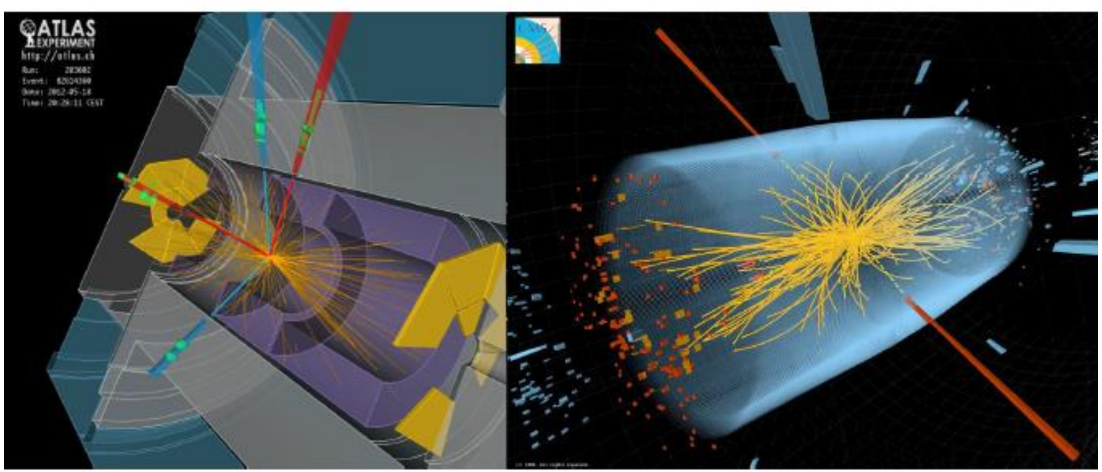
PPAP recommendation

The UK Particle Physics Roadmap

Particle Physics Advisory Panel:

P. N. Burrows, C. Da Via, E. W. N. Glover, P.R. Newman, J. Rademacker, C. Shepherd-Themistocleous, W.J. Spence, M. A. Thomson and M. Wing

7/11/12



‘It is essential that the UK engages with the Higgs Factory initiative and positions itself to play a leading role should the facility go ahead.’

Extra material follows

Model-independent couplings

Facility	ILC			ILC(LumiUp)	TLEP (4 IP)		CLIC		
$\sqrt{s}$ (GeV)	250	500	1000	250/500/1000	240	350	350	1400	3000
$\int \mathcal{L}dt$ (fb^{-1})	250	+500	+1000	$1150+1600+2500^{\ddagger}$	10000	+2600	500	+1500	+2000
$P(e^-, e^+)$	$(-0.8, +0.3)$	$(-0.8, +0.3)$	$(-0.8, +0.2)$	(same)	$(0, 0)$	$(0, 0)$	$(0, 0)$	$(-0.8, 0)$	$(-0.8, 0)$
Γ_H	12%	5.0%	4.6%	2.5%	1.9%	1.0%	9.2%	8.5%	8.4%
κ_γ	18%	8.4%	4.0%	2.4%	1.7%	1.5%	–	5.9%	<5.9%
κ_g	6.4%	2.3%	1.6%	0.9%	1.1%	0.8%	4.1%	2.3%	2.2%
κ_W	4.9%	1.2%	1.2%	0.6%	0.85%	0.19%	2.6%	2.1%	2.1%
κ_Z	1.3%	1.0%	1.0%	0.5%	0.16%	0.15%	2.1%	2.1%	2.1%
κ_μ	91%	91%	16%	10%	6.4%	6.2%	–	11%	5.6%
κ_τ	5.8%	2.4%	1.8%	1.0%	0.94%	0.54%	4.0%	2.5%	<2.5%
κ_c	6.8%	2.8%	1.8%	1.1%	1.0%	0.71%	3.8%	2.4%	2.2%
κ_b	5.3%	1.7%	1.3%	0.8%	0.88%	0.42%	2.8%	2.2%	2.1%
κ_t	–	14%	3.2%	2.0%	–	13%	–	4.5%	<4.5%
BR_{inv}	0.9%	$< 0.9\%$	$< 0.9\%$	0.4%	0.19%	$< 0.19\%$			

Key challenges

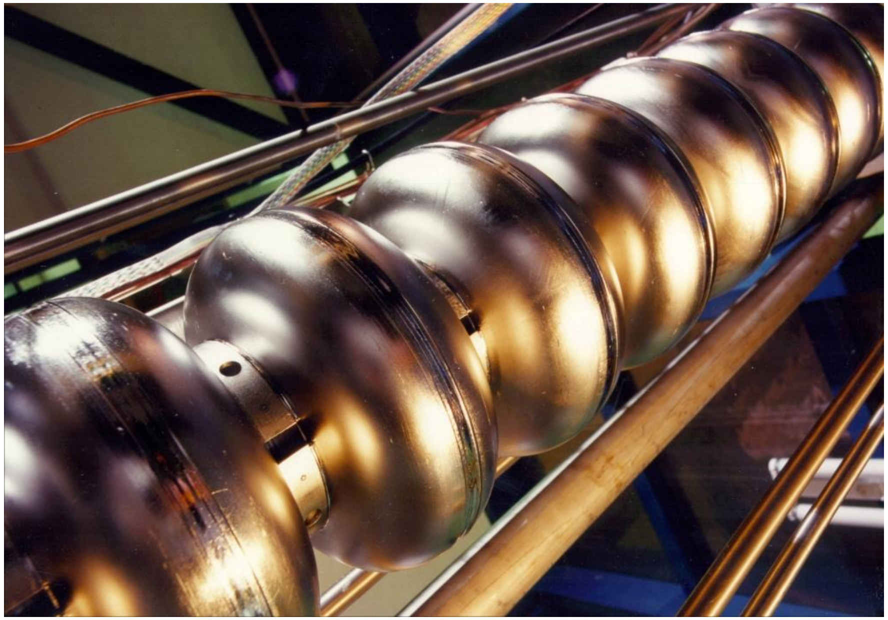
- **Energy:**

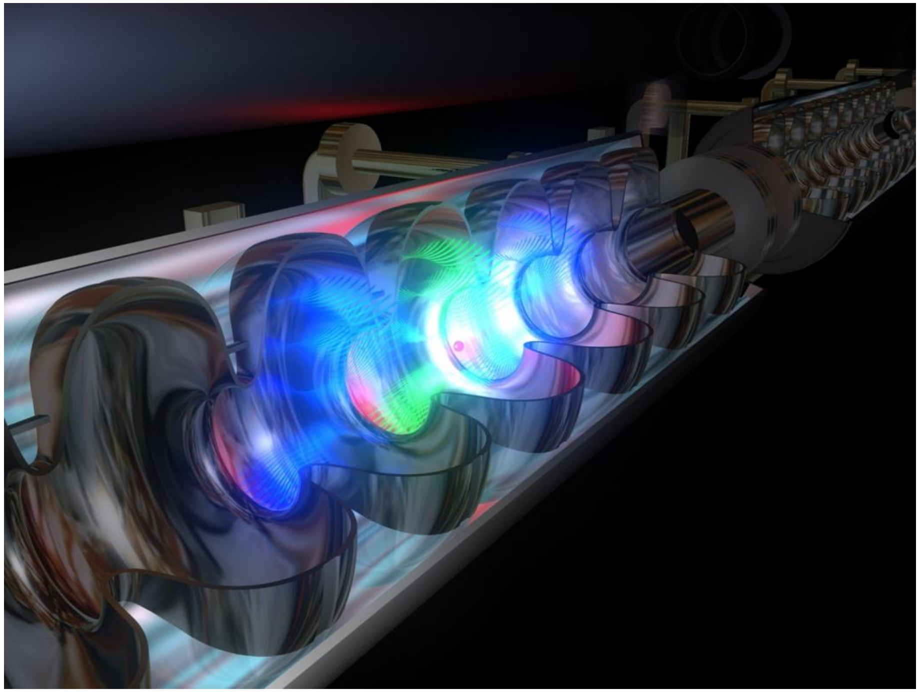
  sustain high gradients

  > 30 MeV/m

- **Luminosity:**

Niobium Accelerating Cavities





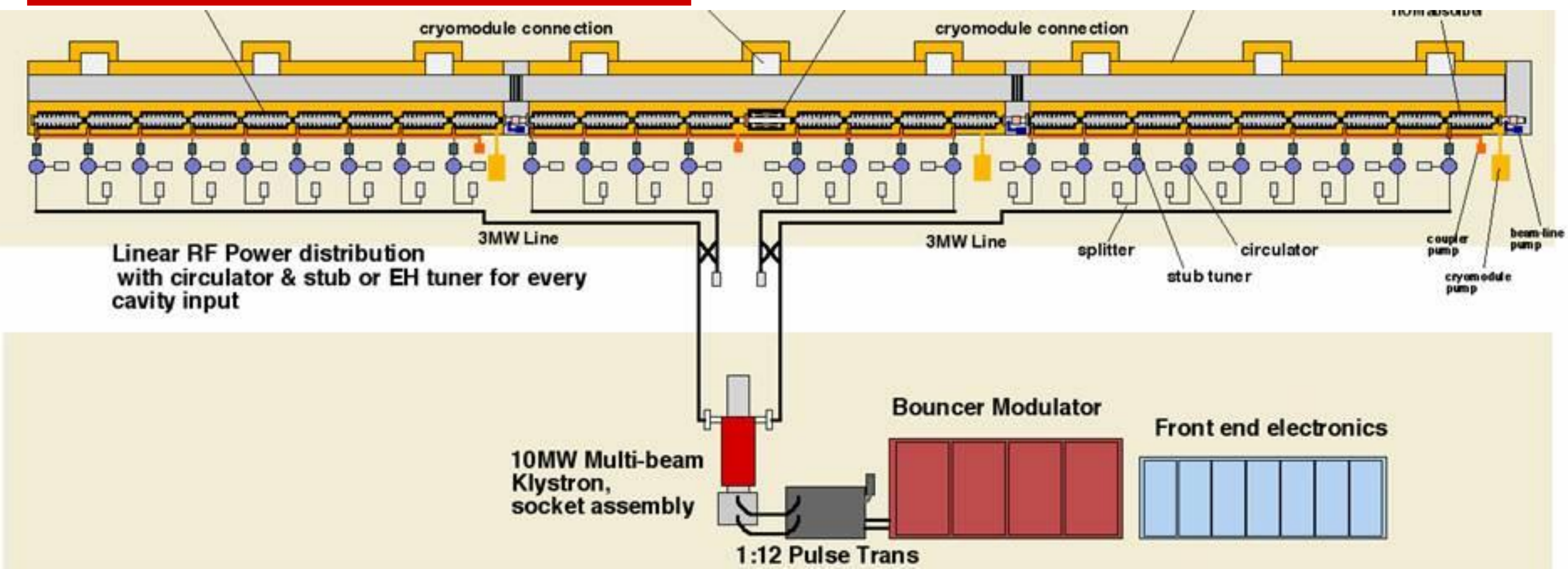
TM010 mode

Niobium Accelerating Cavities

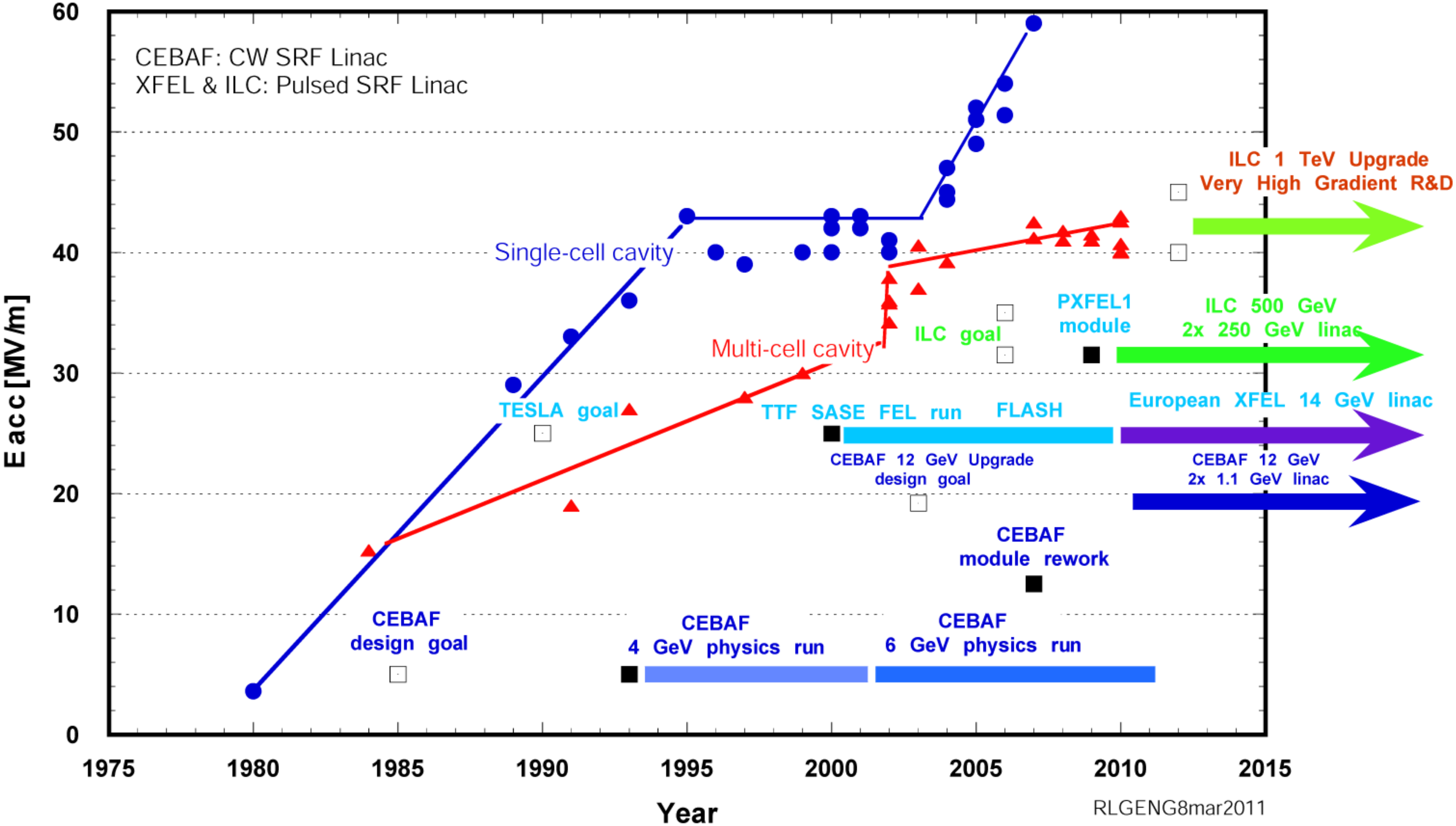
c. 20,000 needed

Niobium Accelerating Cavities

c. 20,000 needed



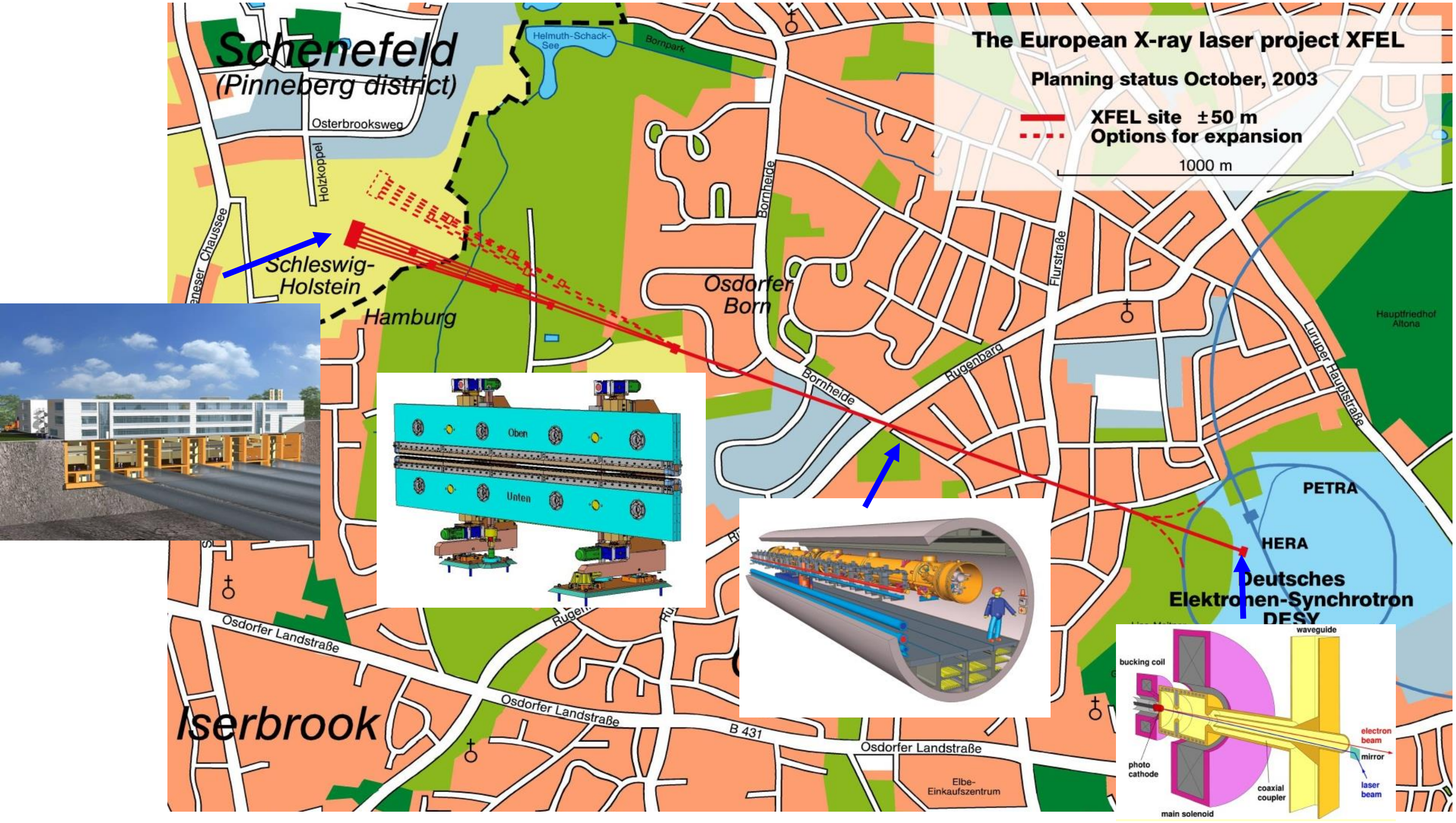
Niobium Accelerating Cavities



Courtesy: R. Geng

European X-FEL at DESY

3.4km



Key challenges

- **Energy:**
  sustain high gradients
  > 30 MeV/m

- **Luminosity:**
  goal is
  > 1034 / cm**2/ s**

ILC Cost Estimate (February 2007)

- **shared value = 4.87 Billion ILC Value Units**
- **site-dependent value = 1.78 Billion ILC Value Units**
- **total value = 6.65 Billion ILC Value Units**

  (shared + site-dependent)

- **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

ILC value breakdown