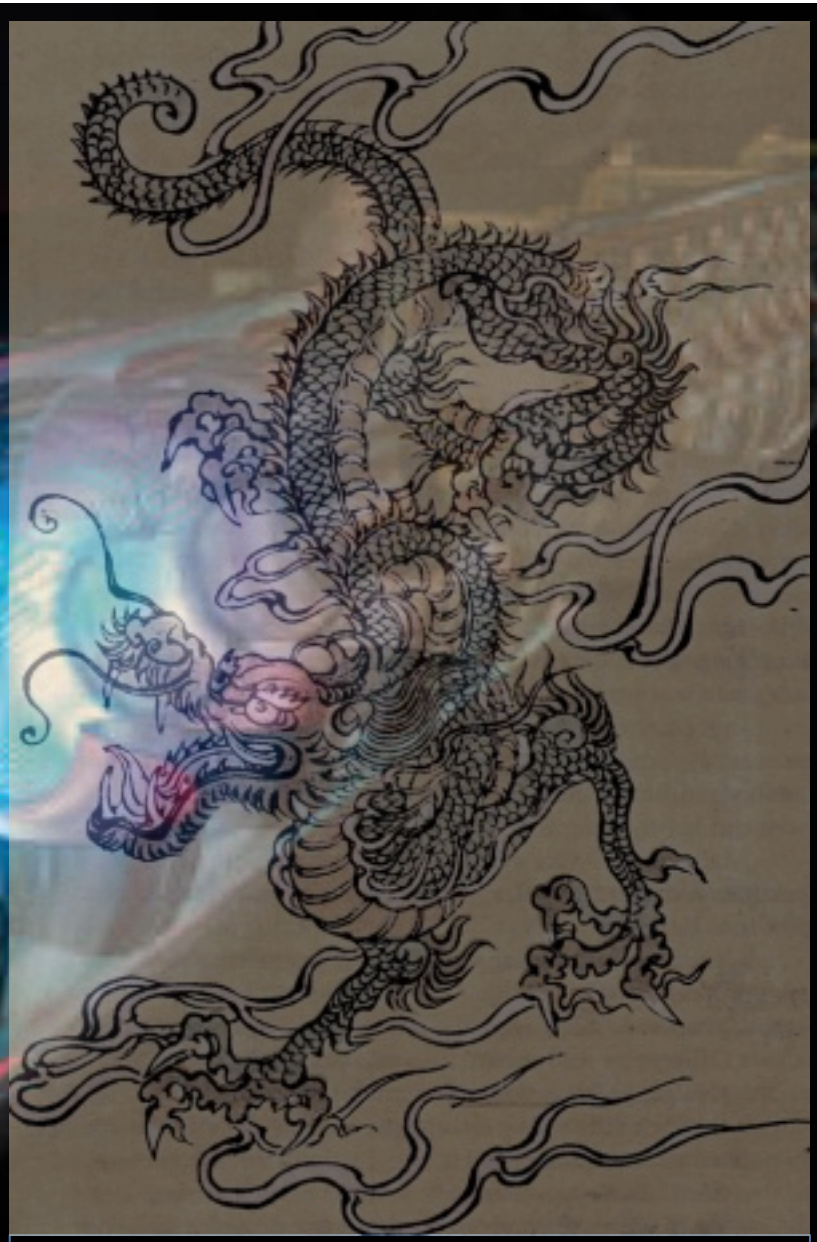
Francois Le Diberder



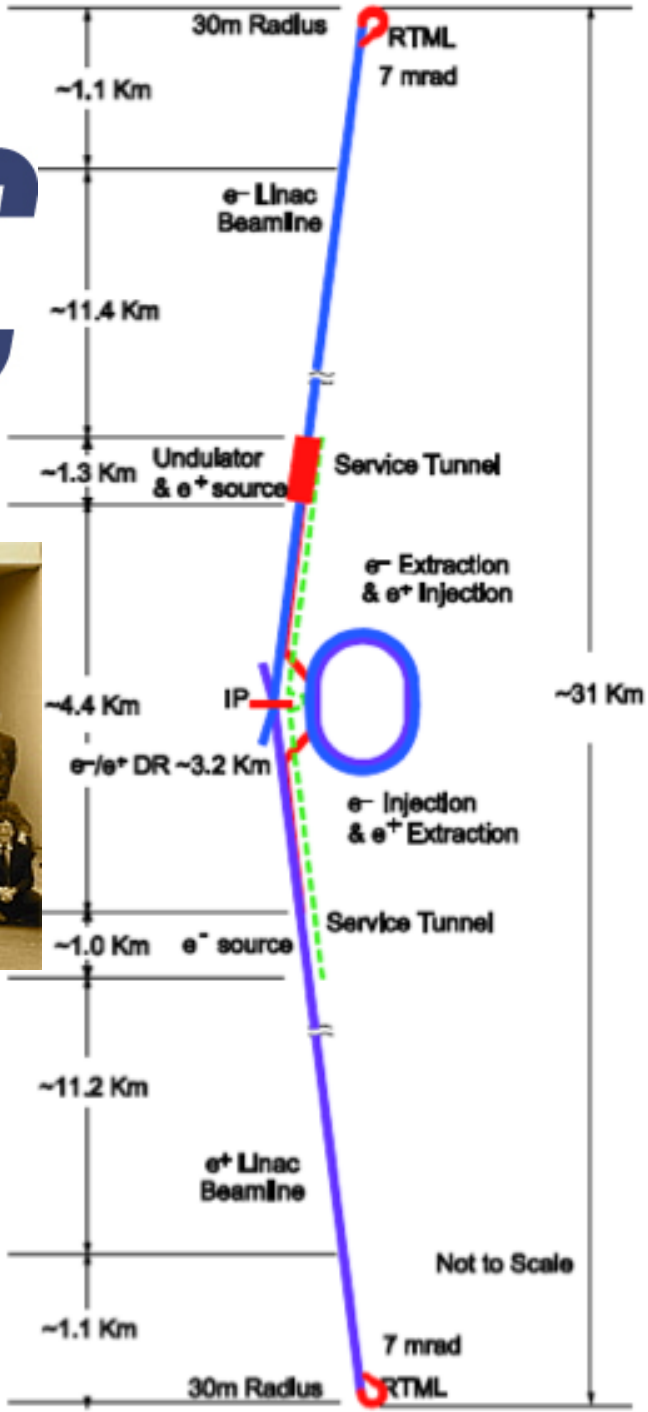
Future Linear Colliders

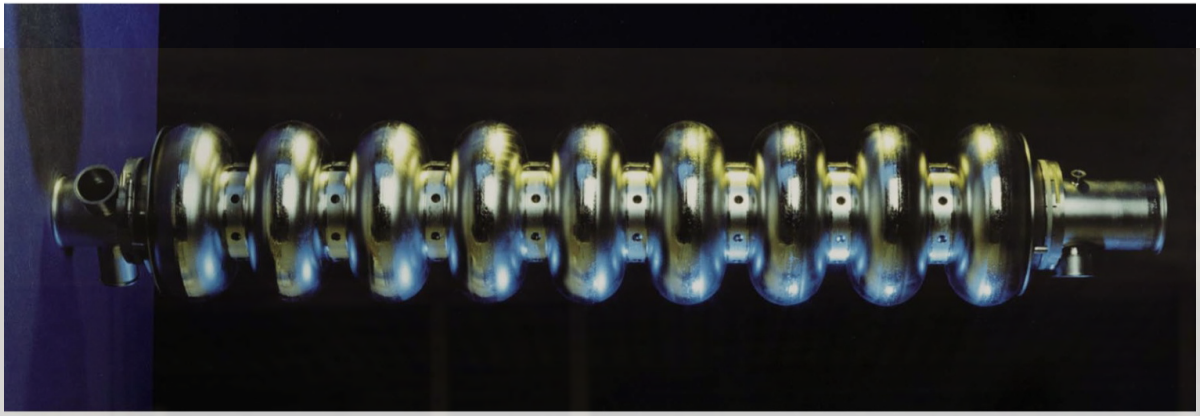
The Linear Collider Machines

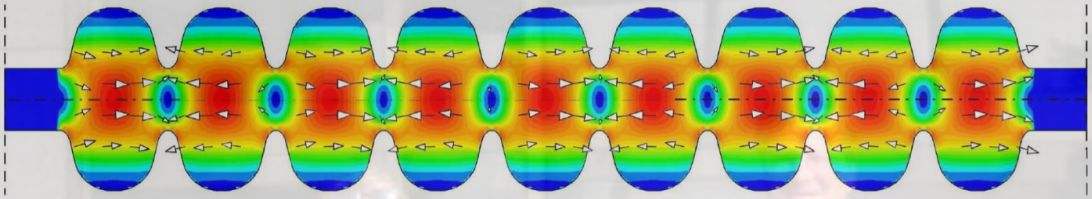
August 2004

November 2004

March 2005







2007

2011

2013*

ILC Technical Progress Report ("*interim report*")

AD&I

TDR Part I: R&D

~250 pages
Deliverable 2

TDR Part II Baseline Reference Report

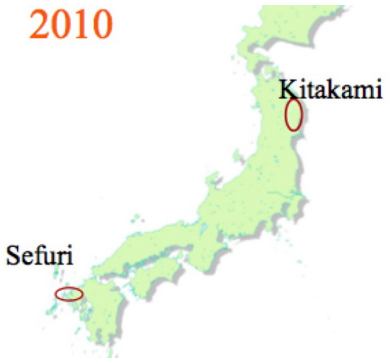
~300 pages
Deliverables 1,3 and 4

Technical Design Report

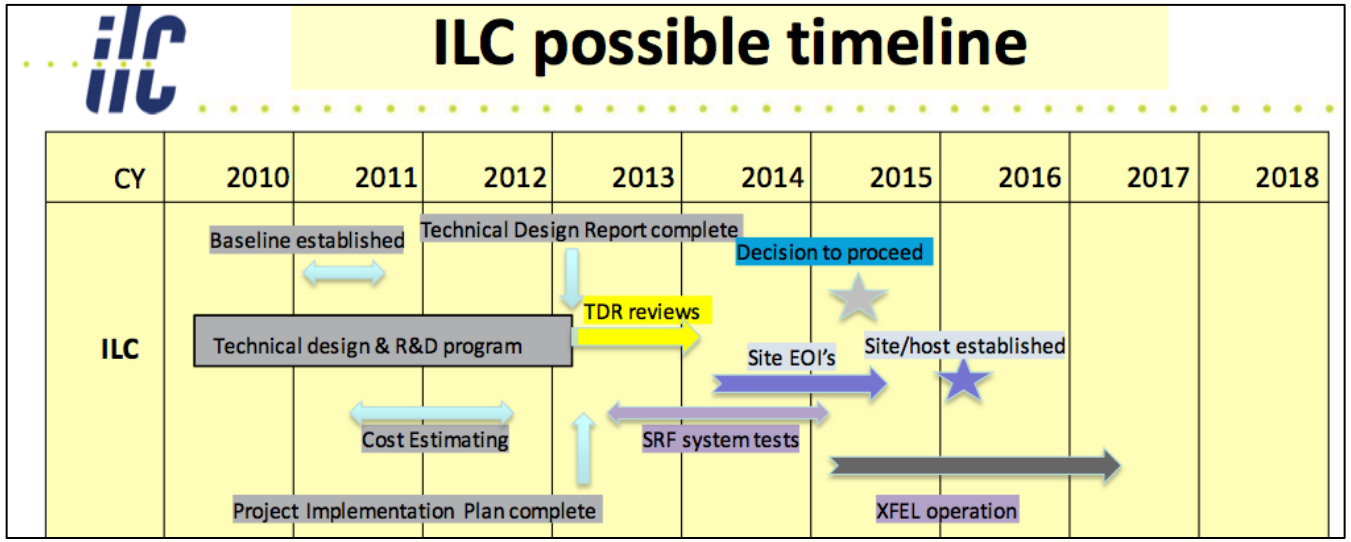
Reference Design Report

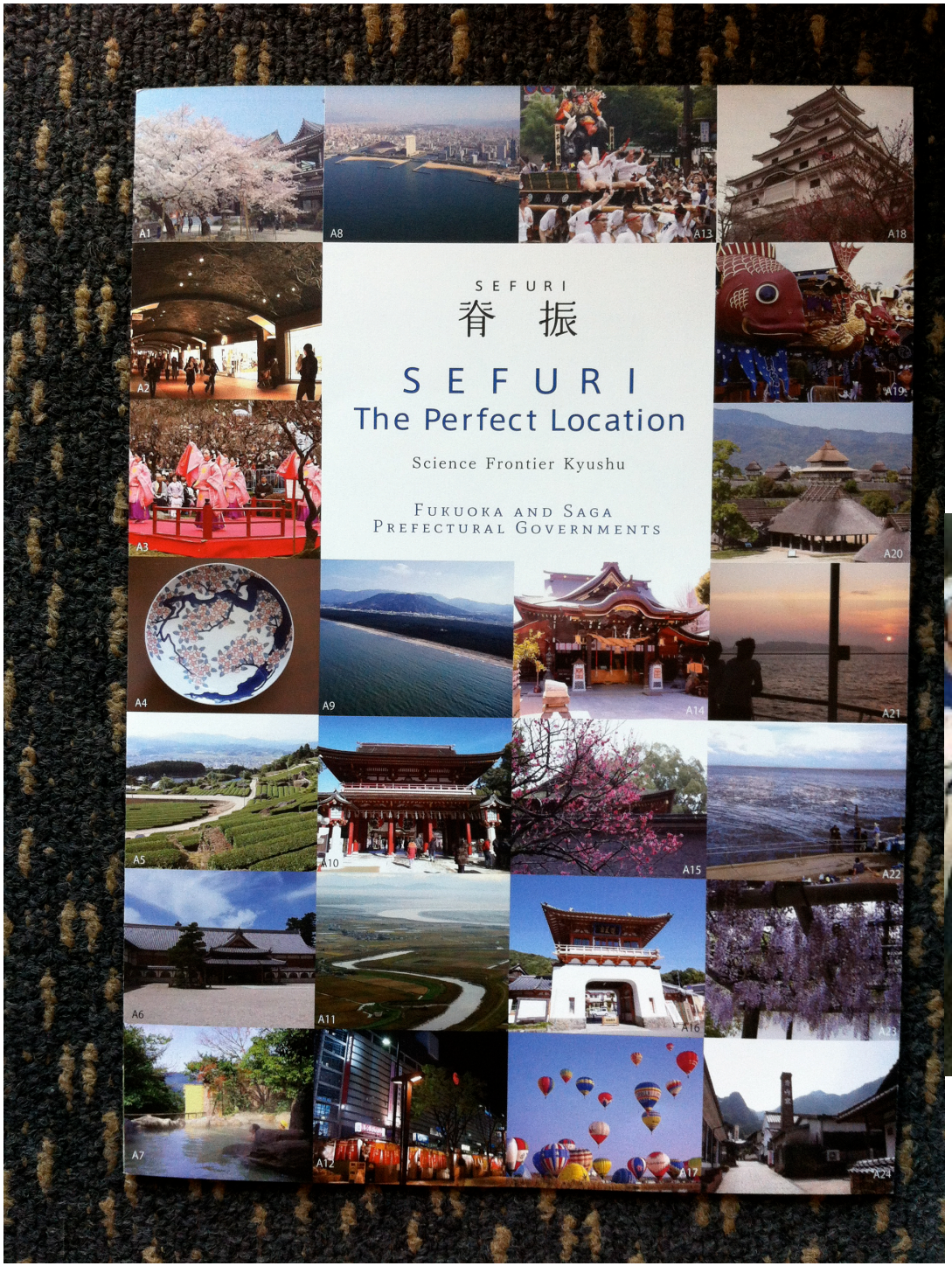
* end of 2012 – formal publication early 2013

AAA (Advanced Accelerator Association Promoting Science and Technology) consisting of 84 private companies and more than 30 public research institutions and Universities in Japan (since 2008)

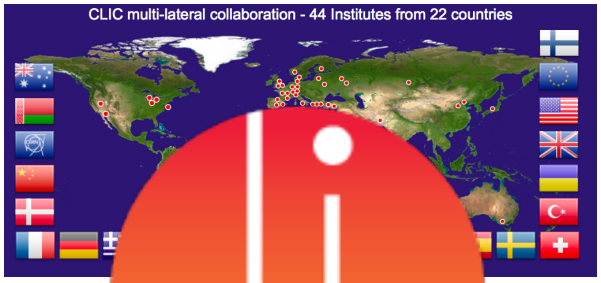


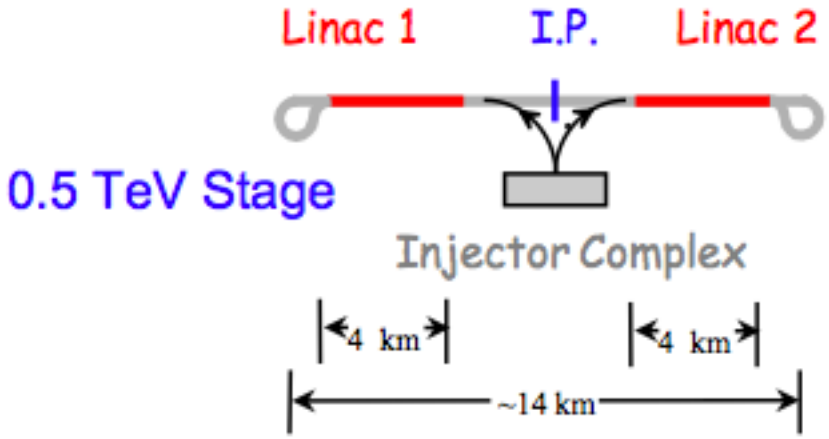

- Japanese Mountainous Sites -
Site-A
KITAKAMI
IWATE
TOHOKU district
SEFURI
Site-B
FUKUOKA
SAGA
KYUSHU district
Tokyo


ILC possible timeline
CY
2010
2011
2012
2013
2014
2015
2016
2017
2018
ILC
Baseline established
Technical Design Report complete
Decision to proceed
TDR reviews
Technical design & R&D program
Site EOI's
Site/host established
Cost Estimating
SRF system tests
Project Implementation Plan complete
XFEL operation

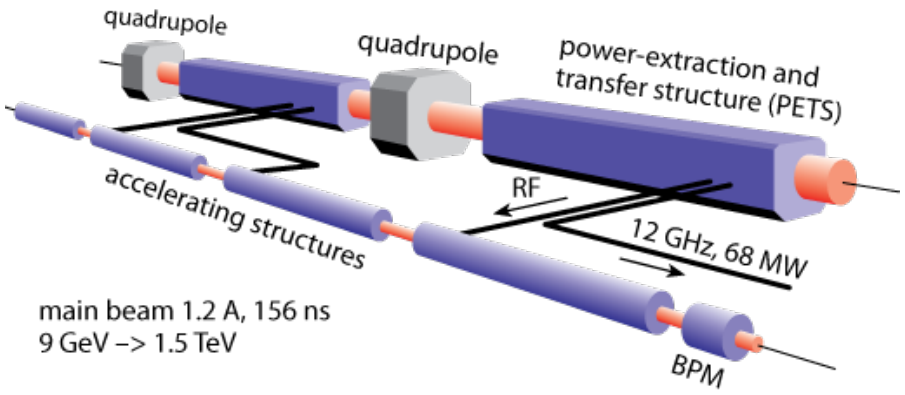


IN2P3 Physicist starting to dig the
ILC tunnel in Sefuri site, end of May 2012

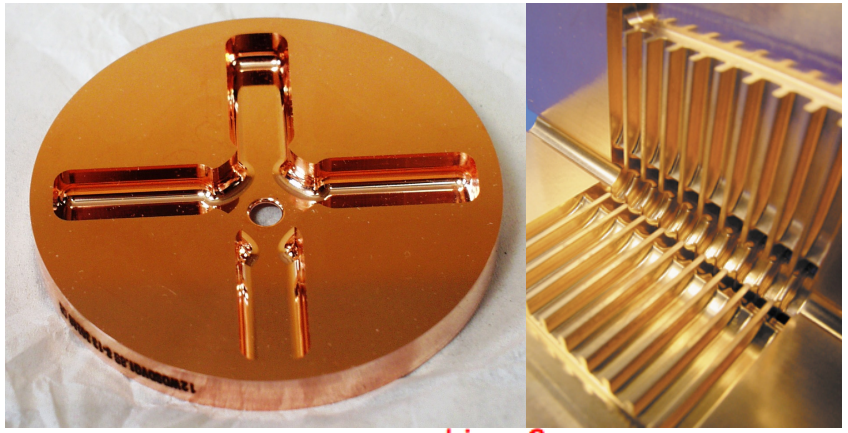




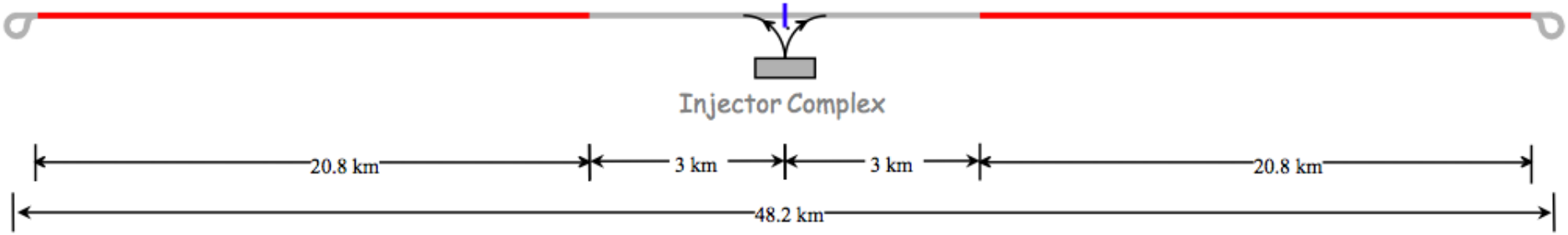
drive beam 100 A, 239 ns
2.38 GeV –> 240 MeV



main beam 1.2 A, 156 ns
9 GeV –> 1.5 TeV

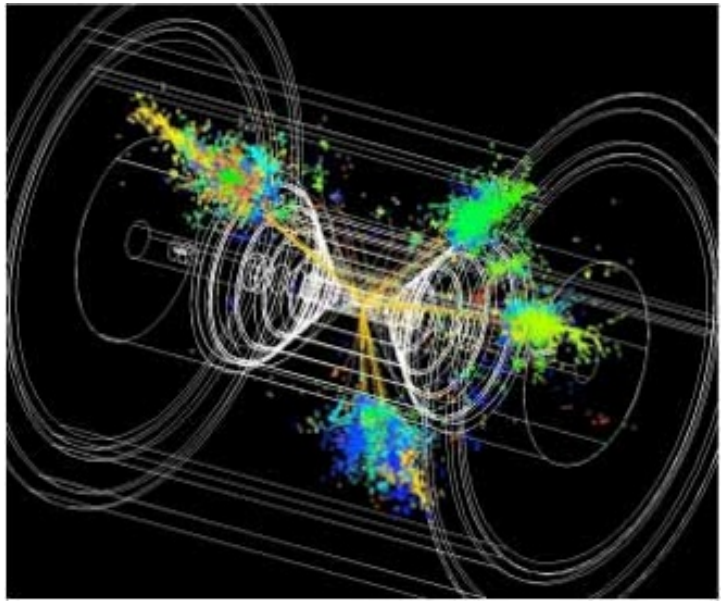


Linac 1 3 TeV Stage I.P. Linac 2

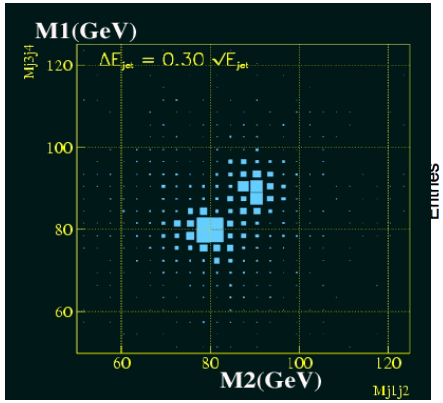


Two LC concepts: the ILC and CLIC communities are working together

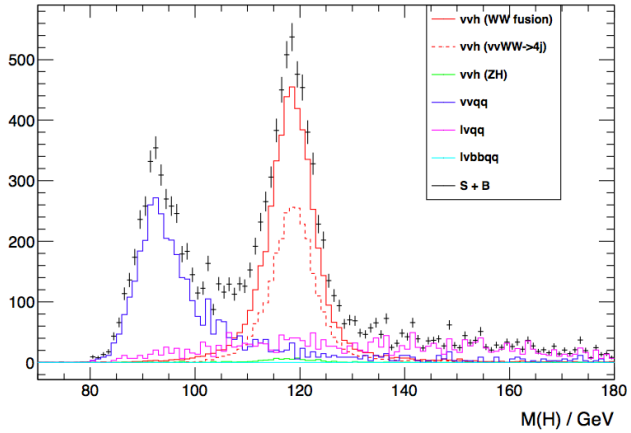
The Linear Collider Detectors

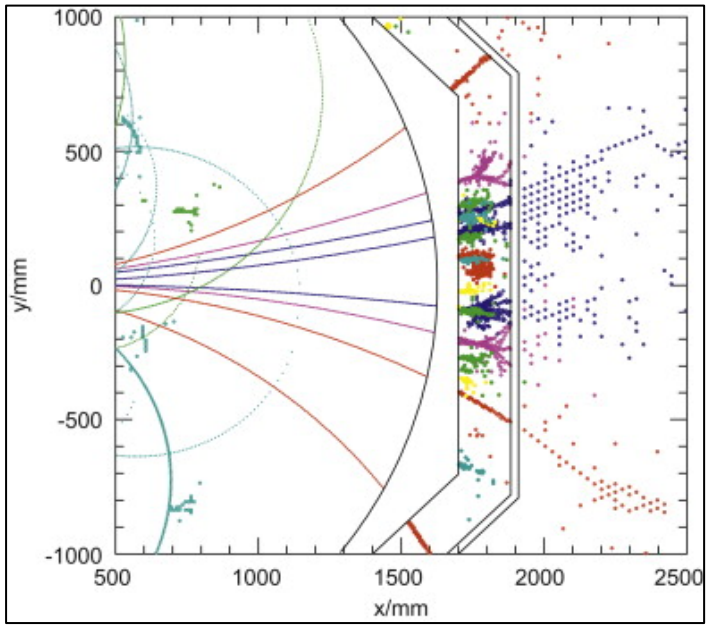


$e^+e^- \to \nu\bar{\nu}WW, \nu\bar{\nu}ZZ \quad W/Z \to jj$



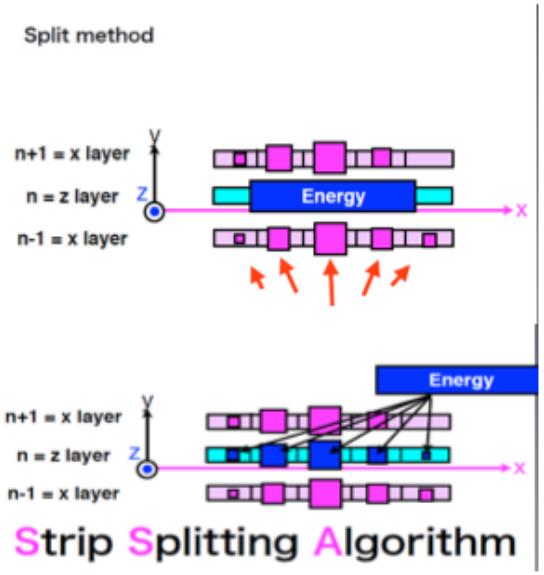
$e^+ + e^- \to \nu\bar{\nu}H \to \nu\bar{\nu}(WW^*) \to \nu\bar{\nu} + 4\text{jets}$

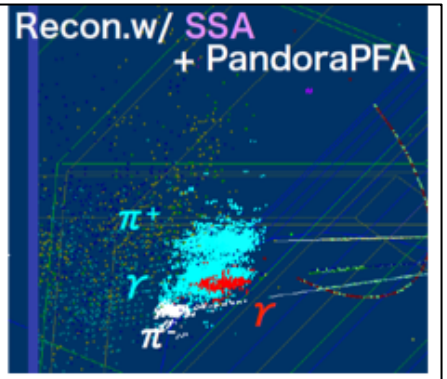




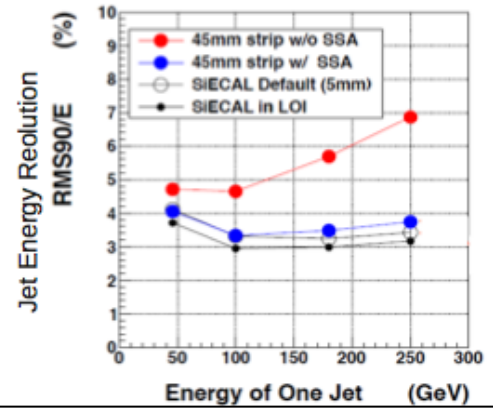
Split Strip Algorithm

Reconstruct strip-based calorimeter geometry
othogonal strips in successive layers



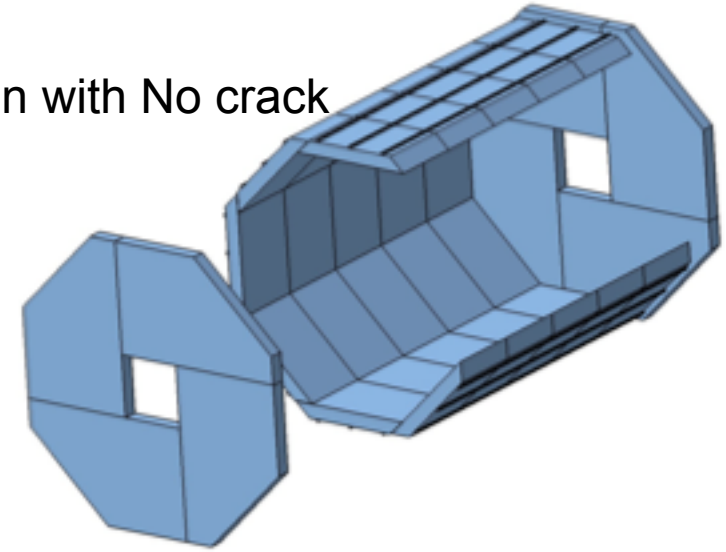


Recently a lot of good progress

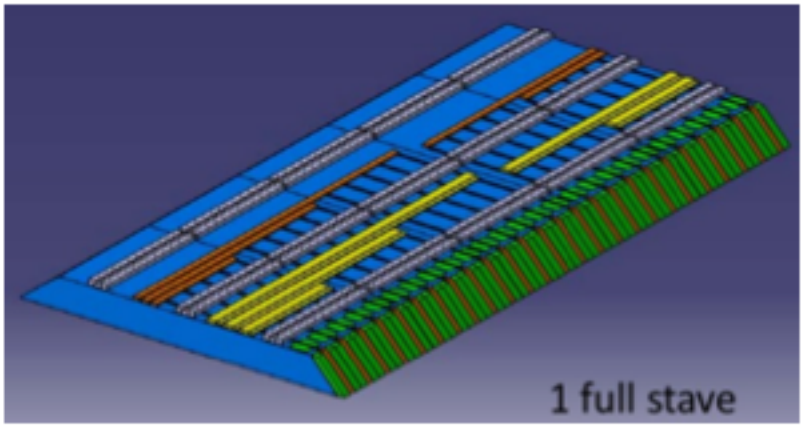


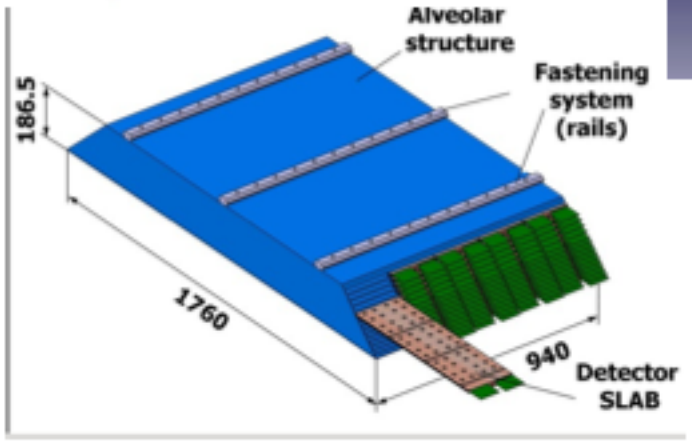
Novel approach: a very compact, tungstene-Silicium electromagnetic calorimeter

Design with No crack

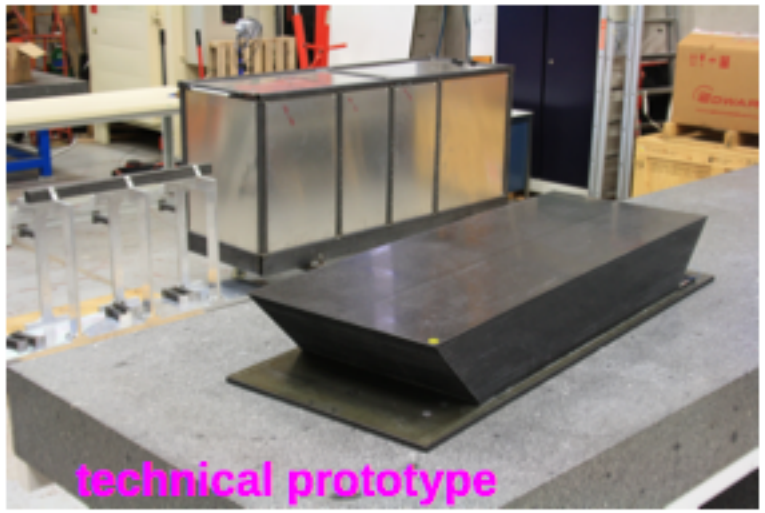


ECAL

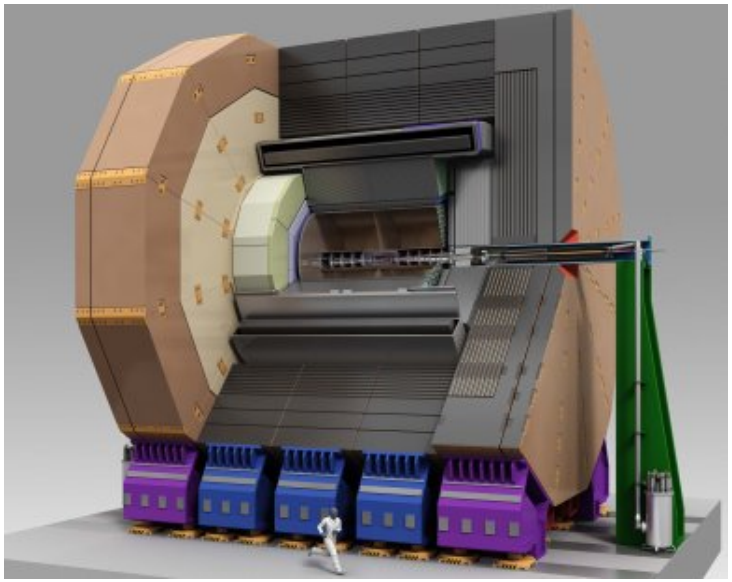




5 mm granularity
~10^8 readout channels



Y. Sugimoto



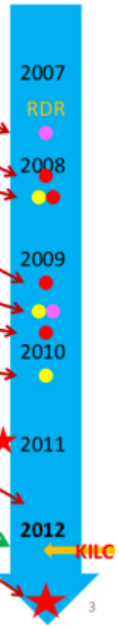
ID	Name	Duration
1	Ground breaking	0d
2	**Beam lines construction**	1954d
3	Tunnel	912d
4	Beamline harware install	912d
5	Beam line shield	60d
6	Start of beam commissioning	0d
7	BDS pre-commissioning	120d
8	Shield removal	10d
9	BDS ready for detectors	0d
10	**Experimental Hall**	1170d
11	Access tunnel	360d
12	Cavern	680d
13	Services	130d
14	**Detector construction on surface**	1890d
15	Surface assembly hall	390d
16	Detector assembly on surface	300w
17	Solenoid construction	720d
18	Solenoid surface test	60d
19	**Yoke pre-assembly**	1085d
25	**Detector assembly in cavern**	705d
26	**Yoke assembly**	570d
38	**Solenoid**	640d
49	**Barreal detectors**	535d
64	**Barrel inner detectors**	80d
67	**Endcap detectors**	260d
76	**QD0/FCALs install/cabling/test**	180d
82	**Commissioning**	210d

- Total construction time: ~8 years
- Detector underground construction: ~3 years

Detectors status, S. Yamada, KILC 2012

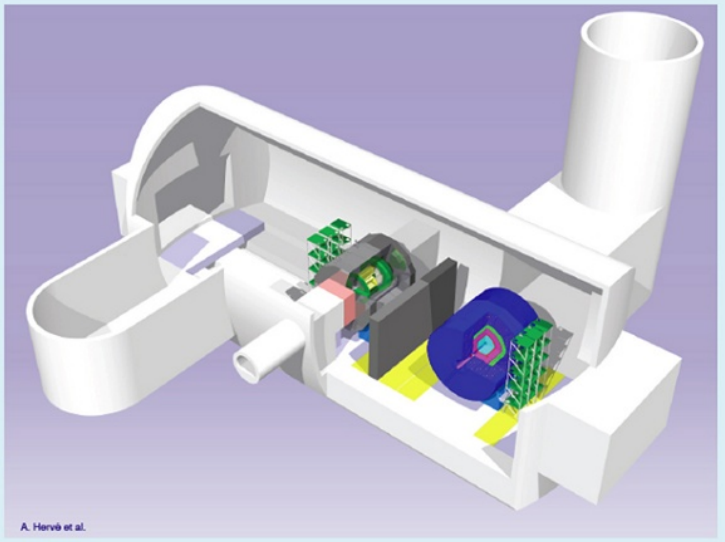
The time line of the LOI process

- **Oct. 2007: Call for LOIs was made by ILCSC**
- Jan. 2008: Detector management was formed
- Mar.2008: IDAG formed, 3 LOI groups known
- **Mar.2009: 3 LOIs submitted**
- Summer 09: **IDAG recommendation for validation and ILCSC's approval**
- Oct 2009: Work plan of the validated groups
- **Mar:2009: IDAG began monitoring the progress**
- End 2010: Interim report completed
- ***DBD outline to be monitored***
- End 2012: **Detailed Baseline Design Report**



2012/4/24 Sakue Yamada @ KILC12 @Daegu 3

Underground Cavern Design Study



The Linear Collider Input to the European Strategy

Linear Collider input to the European Strategy

One LC input among others: they will be several. This one is meant to **express** the community view.

Update

Timeline for the European Strategy Update

CERN Council (Brussels) - *Strategy finalized*

Open Symposium
Sept. 10-12 (Cracow, Poland)

Strategy Group drafting session
January 21-26 (Erice, Italy)

draft

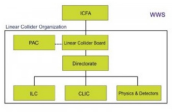
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12

2012 2013

(deadlines->)

Open Symposium
July 31

Strategy drafting session
Oct. 15



By accident, at about the time when the new CLICILC world organization takes place.

Linear Collider input to the European Strategy
Committee Members

Europe

James Brau,
Rohini Godbole,
Francois Le Diberder (chair),
Mark Thomson,
Harry Weerts,
Georg Weiglein,
James Wells,
Hitoshi Yamamoto.

Asia&America's

Brian Foster
Steinar Stapnes
Juan Fuster

ILC
CLIC
WWS

European Strategy

Report is about LC Physics Case with LHC having 300(0)fb^-1

Linear Collider input to the European Strategy

Report delivered

Last LHC input

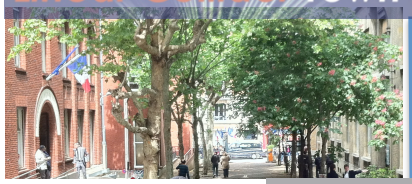
ICHEP 2012

Community feedback

Draft released

Community feedback

Linear Collider Town Hall Meeting



Strong delegation From Spain

draft

1 2 3 4 5 6 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12

2012 2013

Open Symposium
July 31

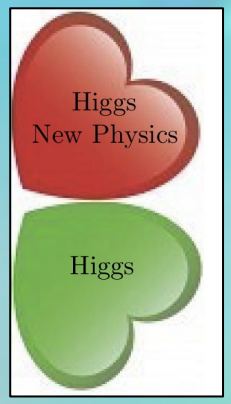
Strategy drafting session
Oct. 15

(deadlines->)

The Linear Collider Physics Case

Physics case studied since **20 years**, and next HEP priority since long

But we need the hard facts of LHC to confirm/infirm this Physics Case
The complementarity between LHC and LC have been demonstrated
In a 10-years collaborative effort.



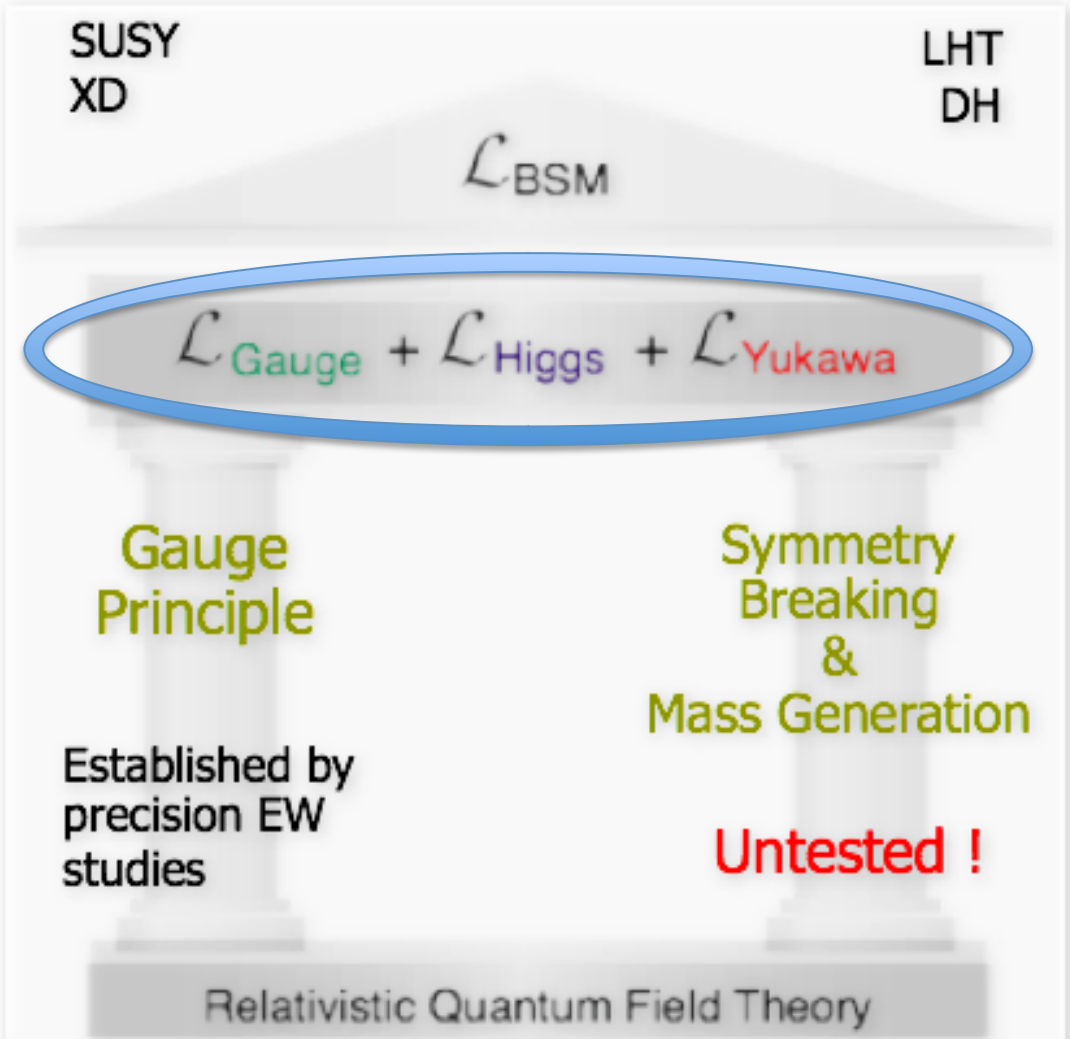
LC recently boosted by LHC (&Tevatron) hints for SM-like Higgs 125GeV

LHC

Will get confirmation by end of 2012 (or exclusion of SM-like Higgs)

In any case LHC-2012 will mark the end of a 30 years old hunt

SM:



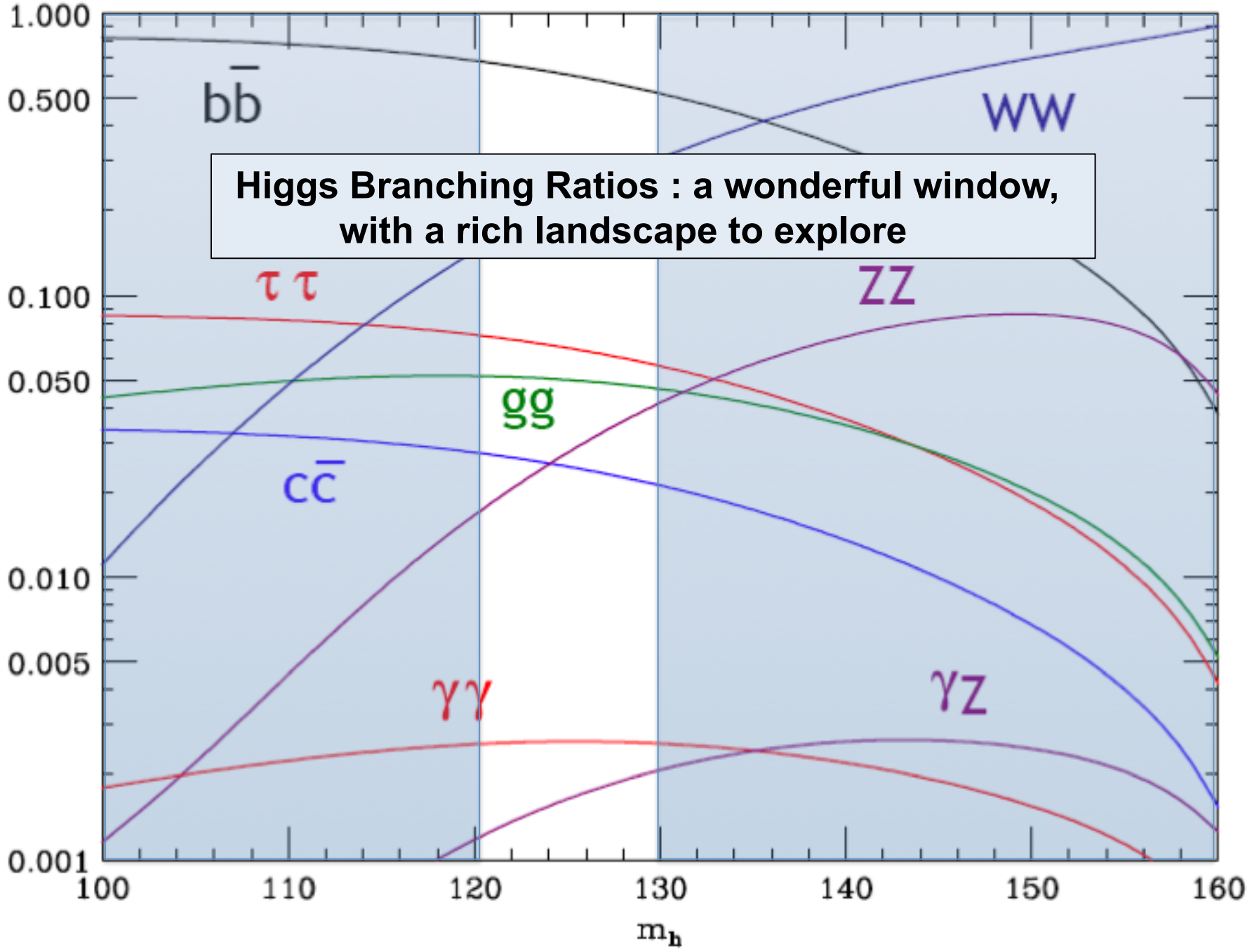
M. Peskin

But -- unlike the SU(3)xSU(2)xU(1) gauge symmetry, there is nothing sacred about the minimal Higgs model.

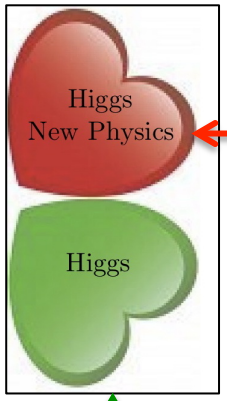
It is just a guess. There is no actual physics in it.

Reality could well be different. How would this show up in the HIggs properties?


One should be prepared to see new phenomena

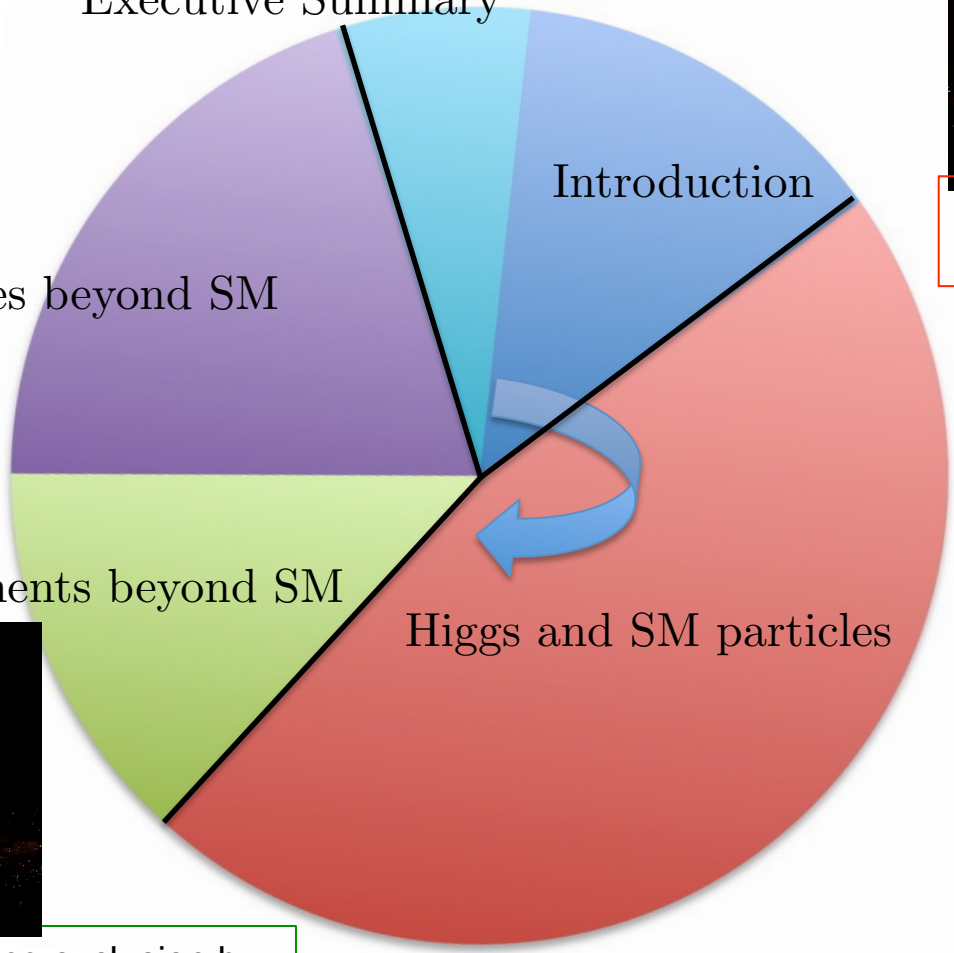

Higgs Branching Ratios : a wonderful window, with a rich landscape to explore
1.000
0.500
0.100
0.050
0.010
0.005
0.001
bb̄
WW
ZZ
ττ
gg
cc̄
γγ
γZ
100
110
120
130
140
150
160
m_h

Linear Collider input to the European Strategy



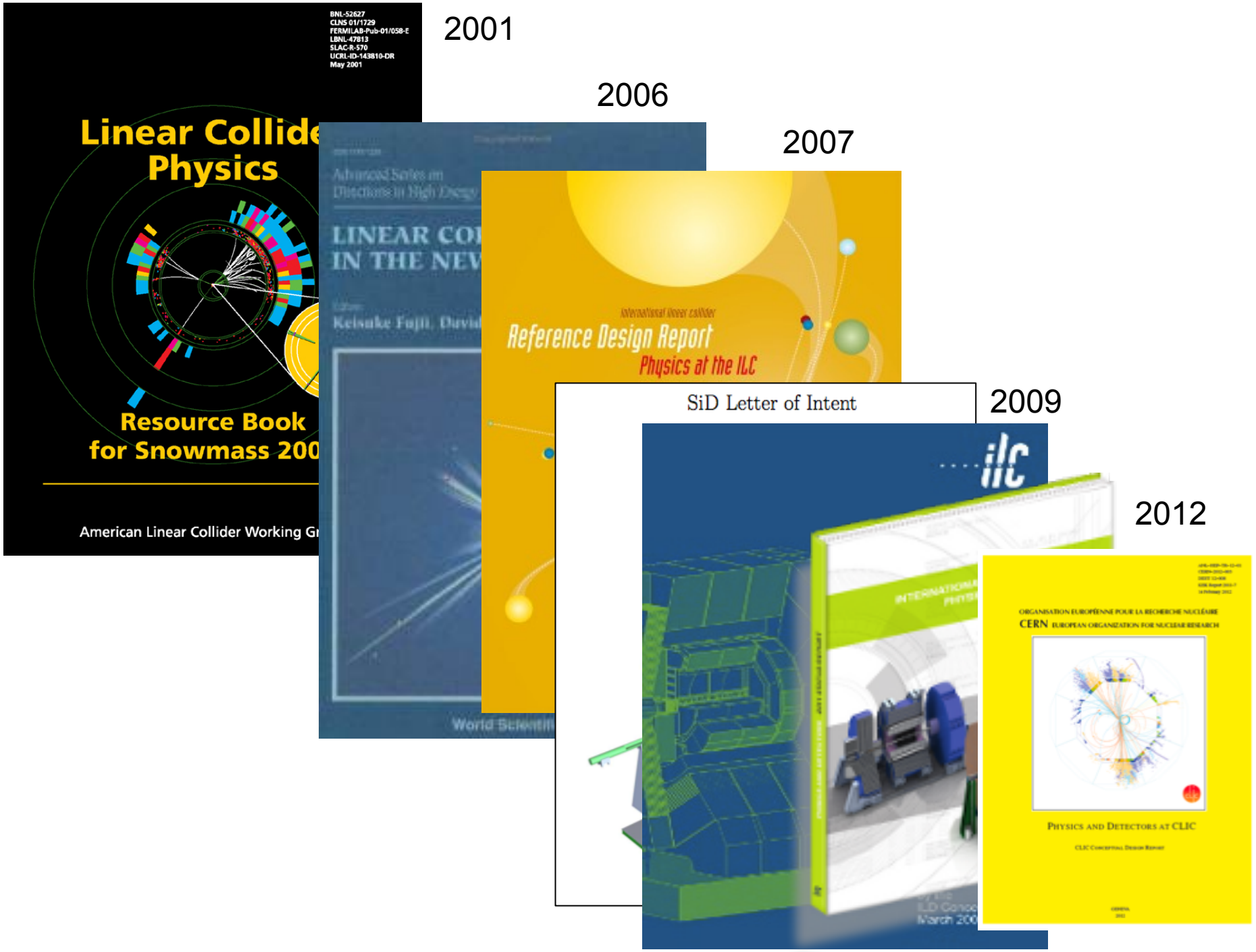
May have to await first year of 13 TeV data taking

not stressed



Meaning, at least no looming exclusion by mid 2012, emphasis will obviously depend on the status of the Higgs searches.

Energy/GeV	250	350	500	1000	1500	3000
Lumi [x10^{34} cm^{-2}s^{-1}]	0.75	1.0	1.8	3.6	2.3	5.9
Int Lumi [fb]	250	350	500	1000	1500	2000


2001
BNL-52627
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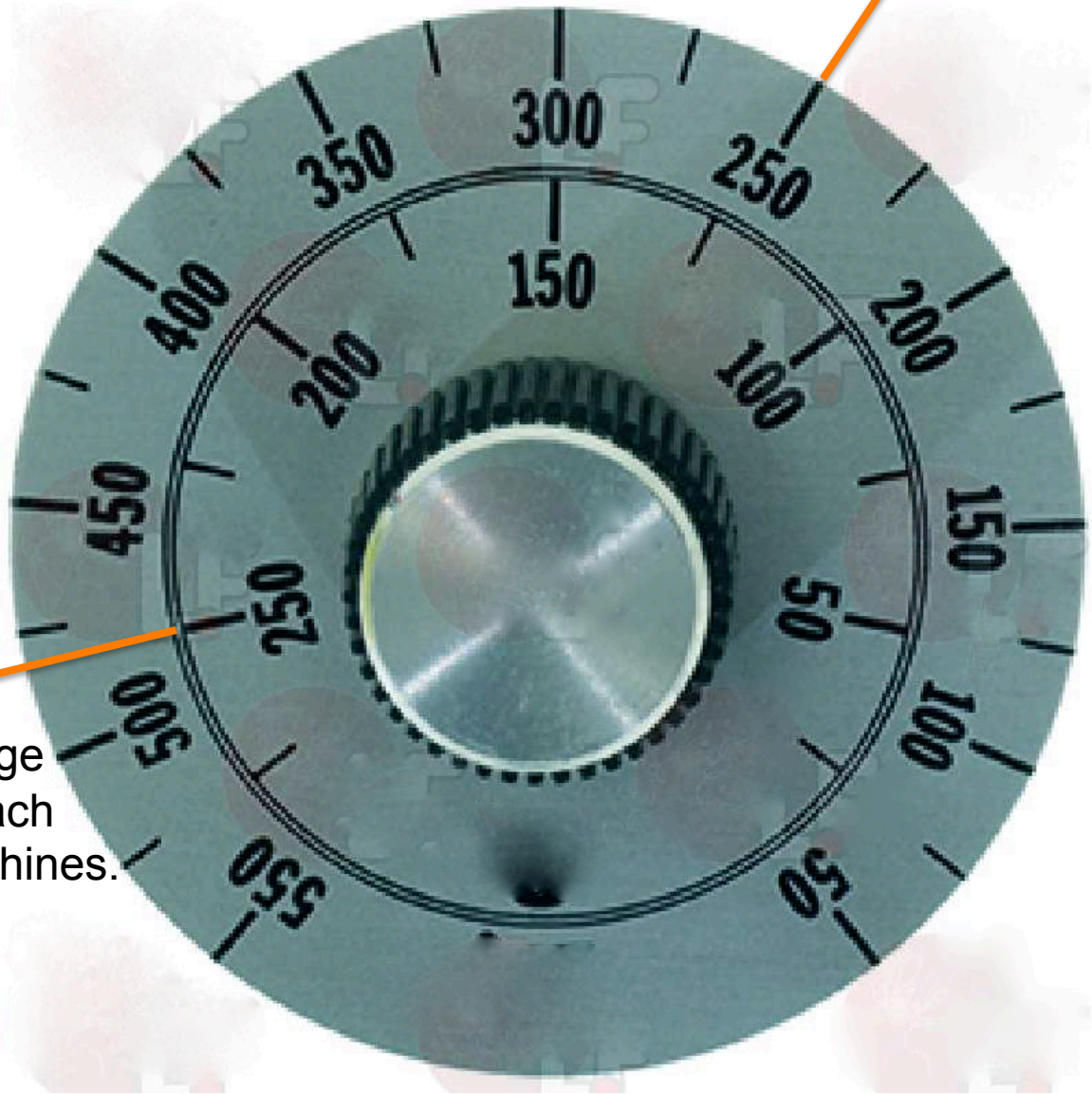
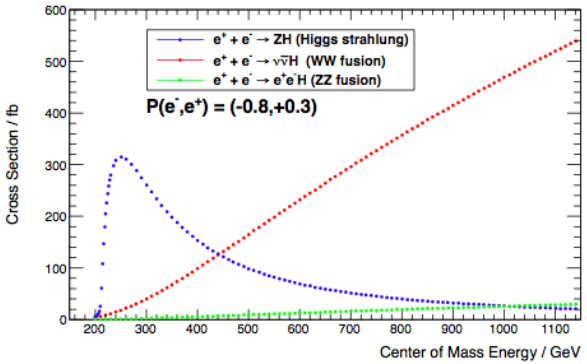
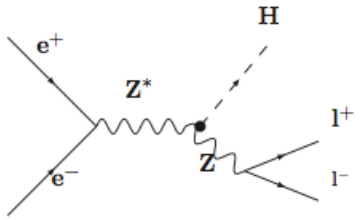
LBNL-47813
SLAC-R-570
UCRL-ID-143810-DR
May 2001
Linear Collide
Physics
Resource Book
for Snowmass 200
American Linear Collider Working Gr
2006
Advanced Series on
Directions in High Energy
LINEAR CO
IN THE NEW
Keisuke Fujii, David
World Scientif
2007
International linear collider
Reference Design Report
Physics at the ILC
2009
SiD Letter of Intent
ilc
March 200
2012
ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
PHYSICS AND DETECTORS AT CLIC



This energy range is within the reach of circular machines.

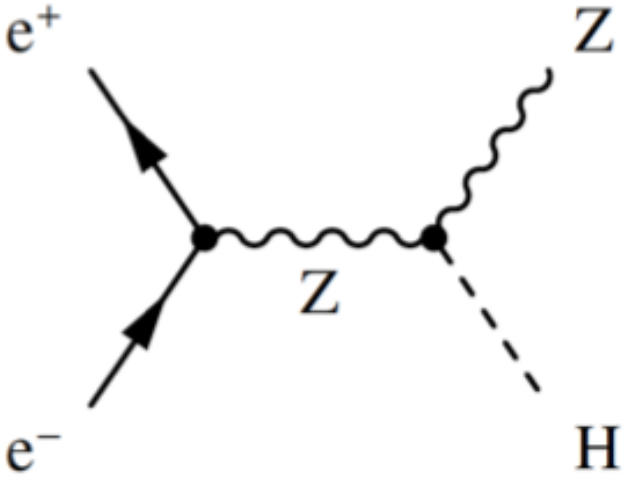


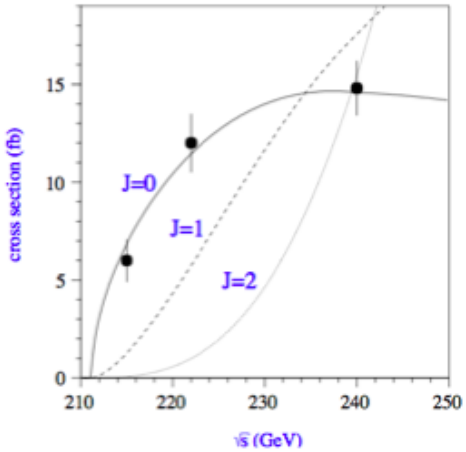
Higgs-strahlung Process:

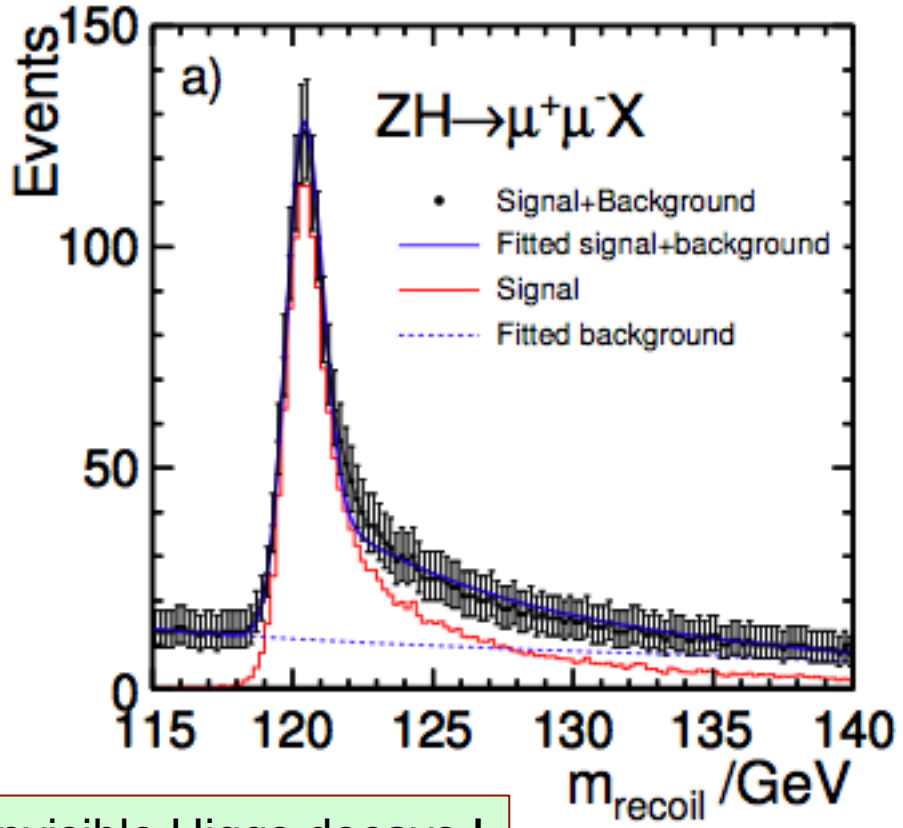


$$M_H^2 = (\sqrt{s} - E_Z)^2 - P_Z^2$$

$$g_{ZZH}^2 \propto \sigma = N/L\epsilon$$







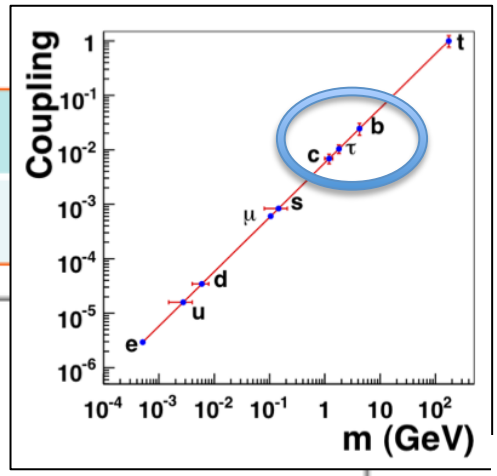
Invisible Higgs decays !

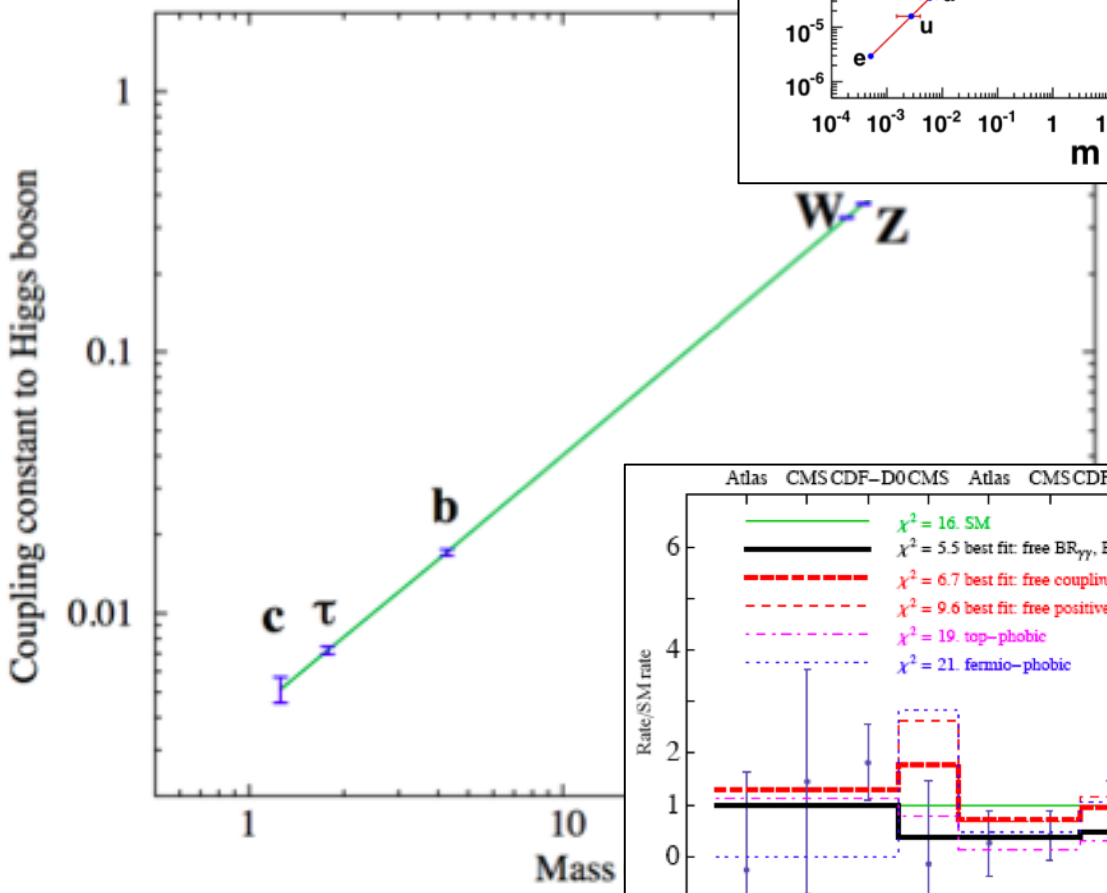
$$\Gamma_H = \frac{\Gamma(H \to WW^*)}{BR(H \to WW^*)}$$

← from WW fusion cross section

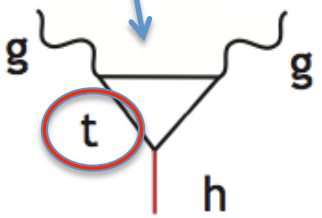
← from BR measurement

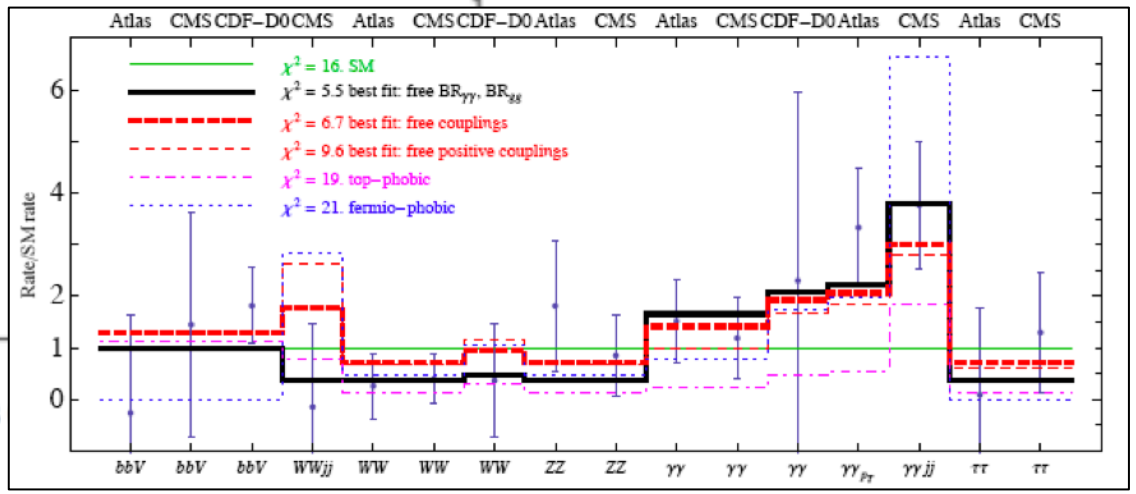
Energy/GeV	350
Γ_H recoil	7 %

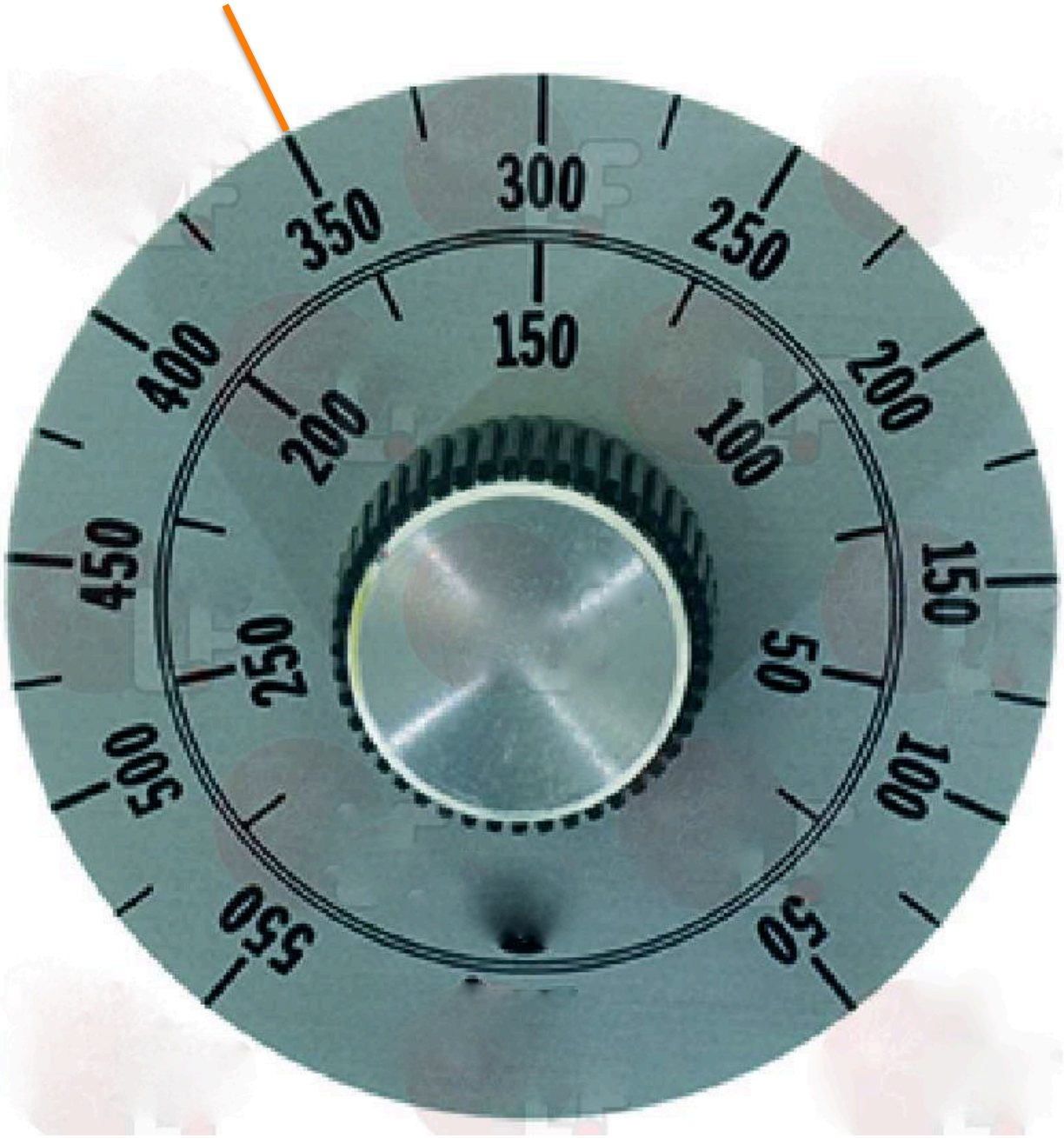




5%



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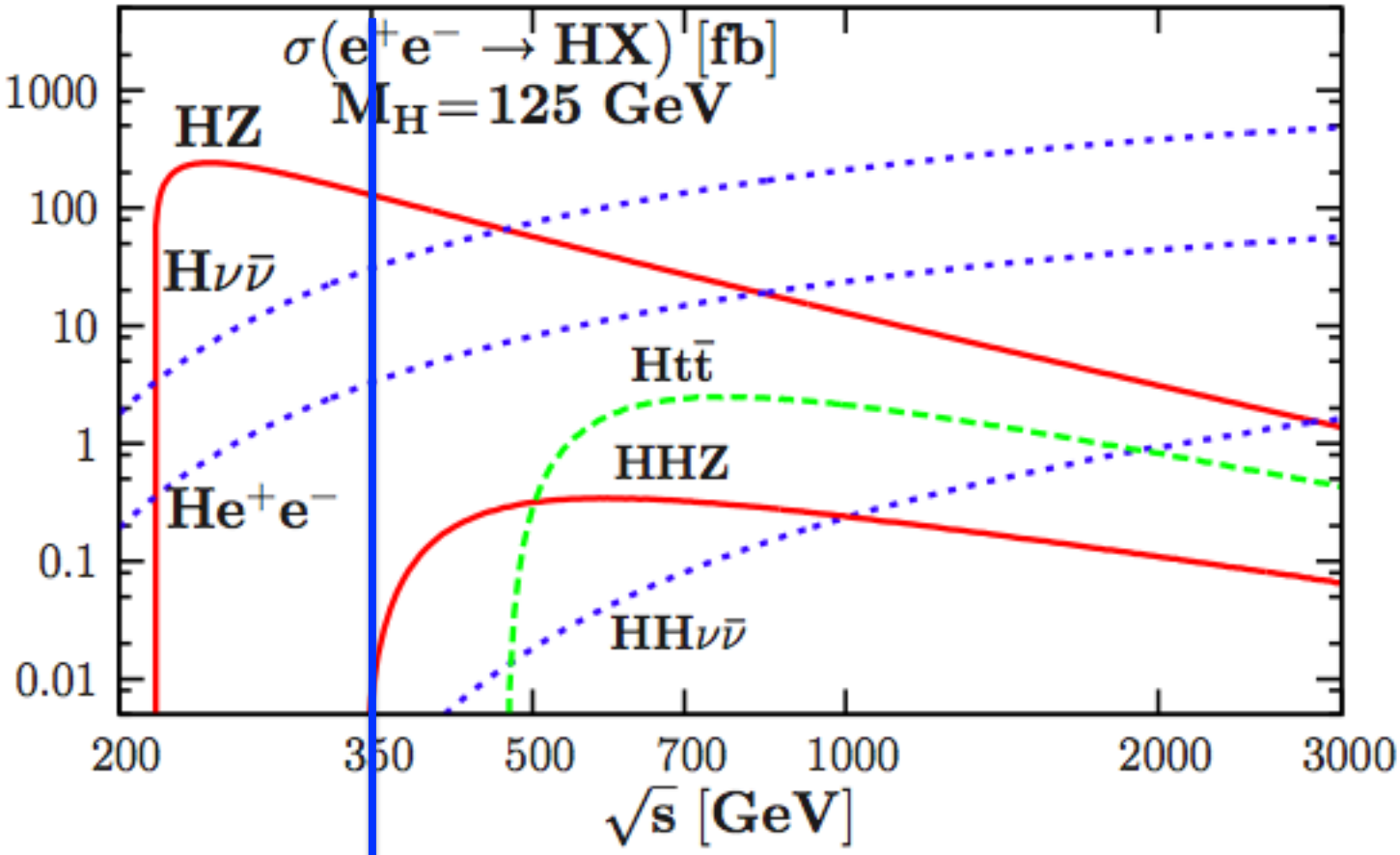
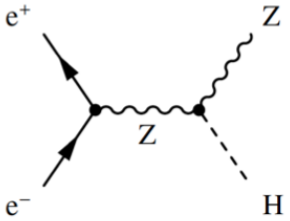
Two simultaneous thresholds : $t\bar{t}$ and HHZ

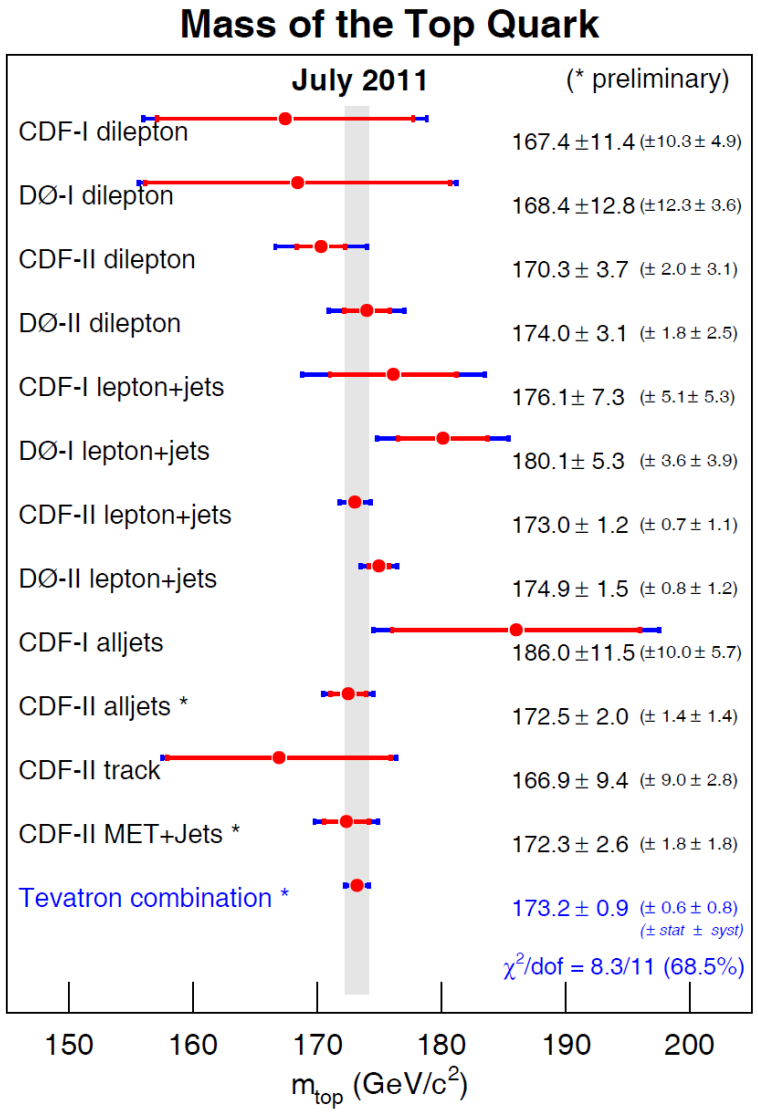


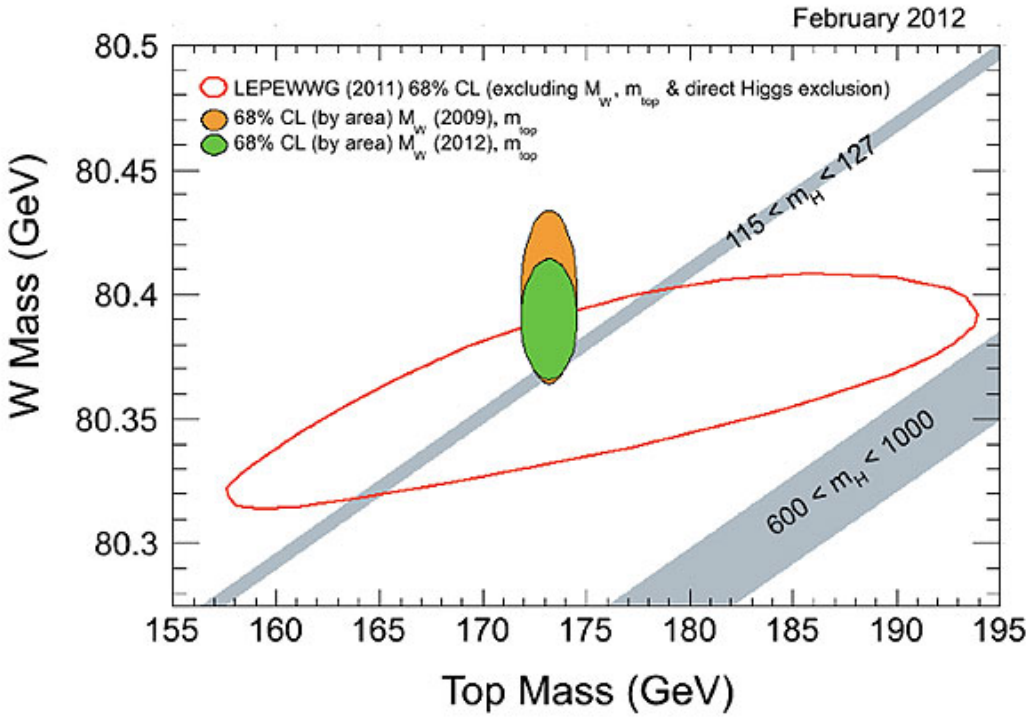
$t\bar{t}$ threshold

350 GeV is the entrance to top world

Energy/GeV	250	350
Cross section [fb]	250	130
Int Lumi [fb^{-1}]	250	350
N(ZH) Events	62500	45500

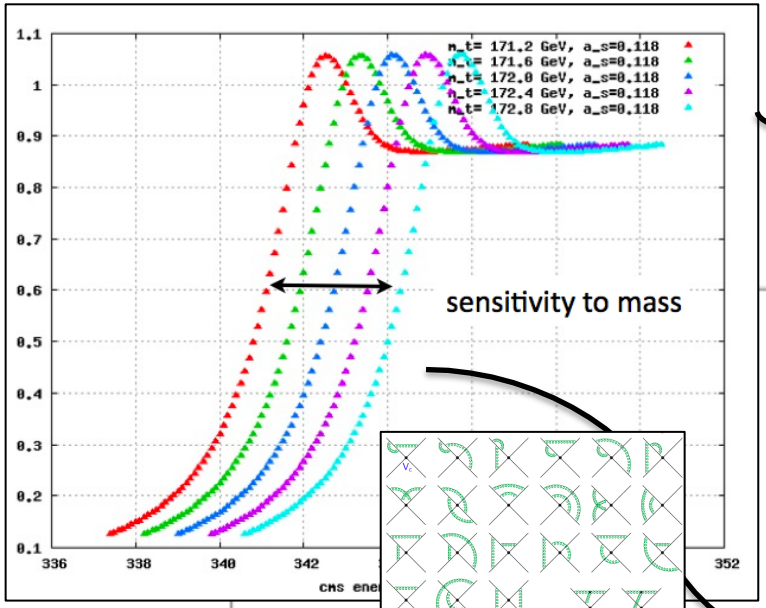


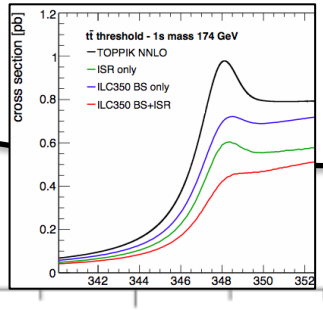




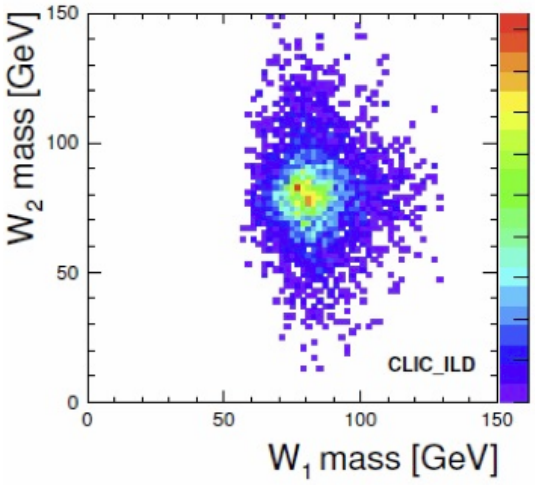
Current educated belief: LHC will not bring much improvement to the top mass determination.

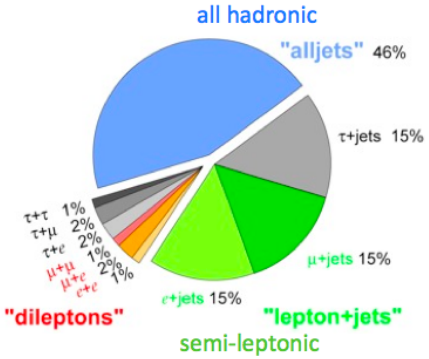
Systematics limited (exp&the) at about 1GeV

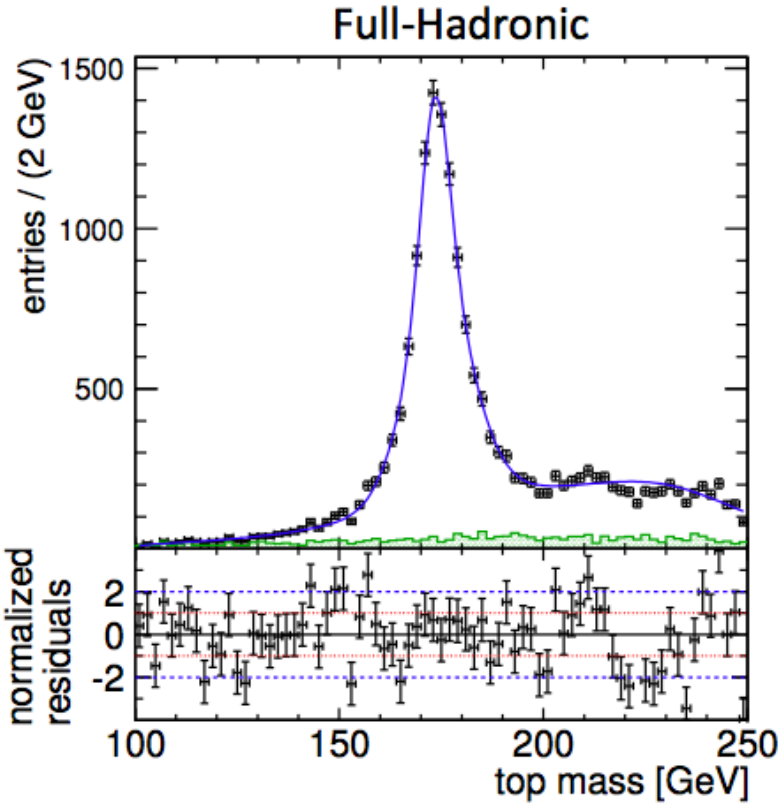




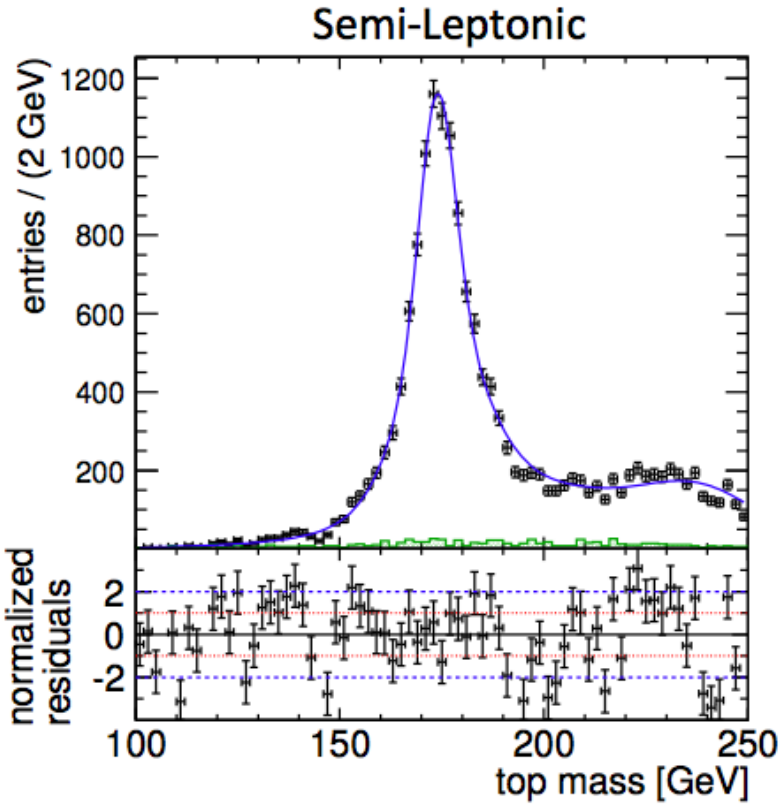
Tour de force

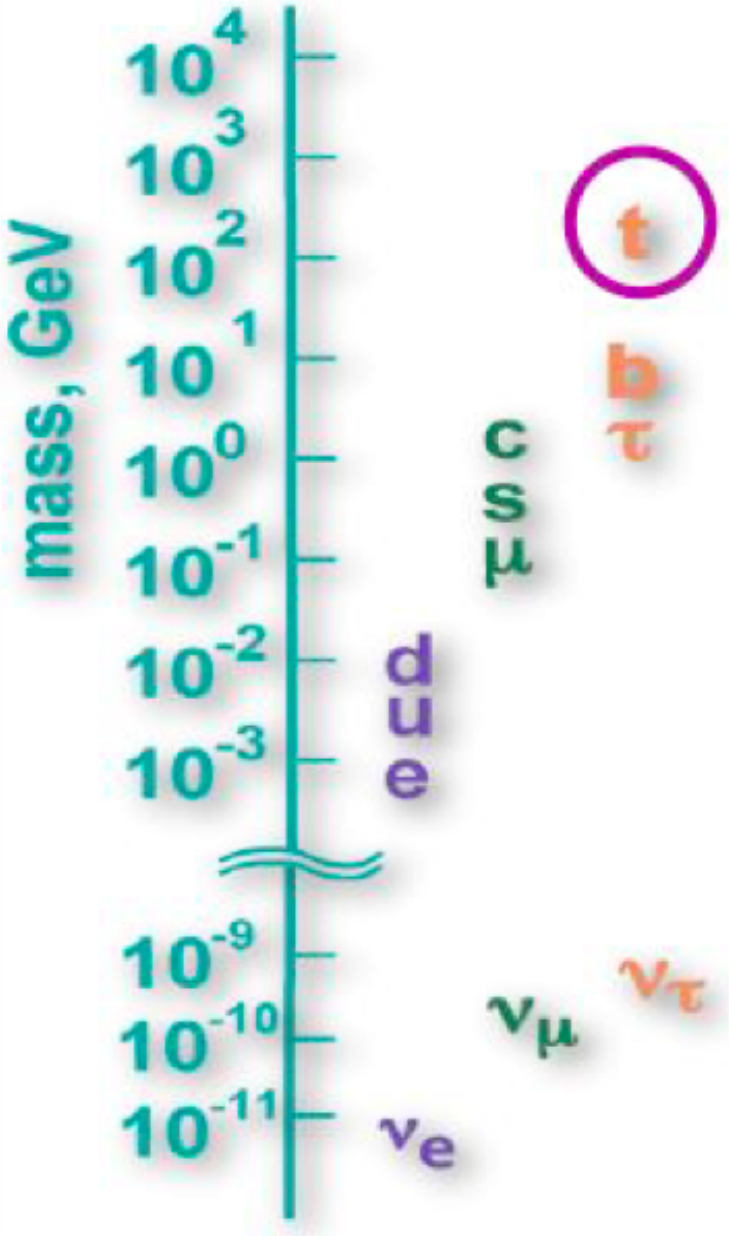

W_2 mass [GeV]
W_1 mass [GeV]
CLIC_ILD


all hadronic
"alljets" 46%
τ+jets 15%
μ+jets 15%
e+jets 15%
"dileptons"
"lepton+jets"
semi-leptonic


Full-Hadronic
entries / (2 GeV)
normalized residuals
top mass [GeV]

100 fb^{-1}

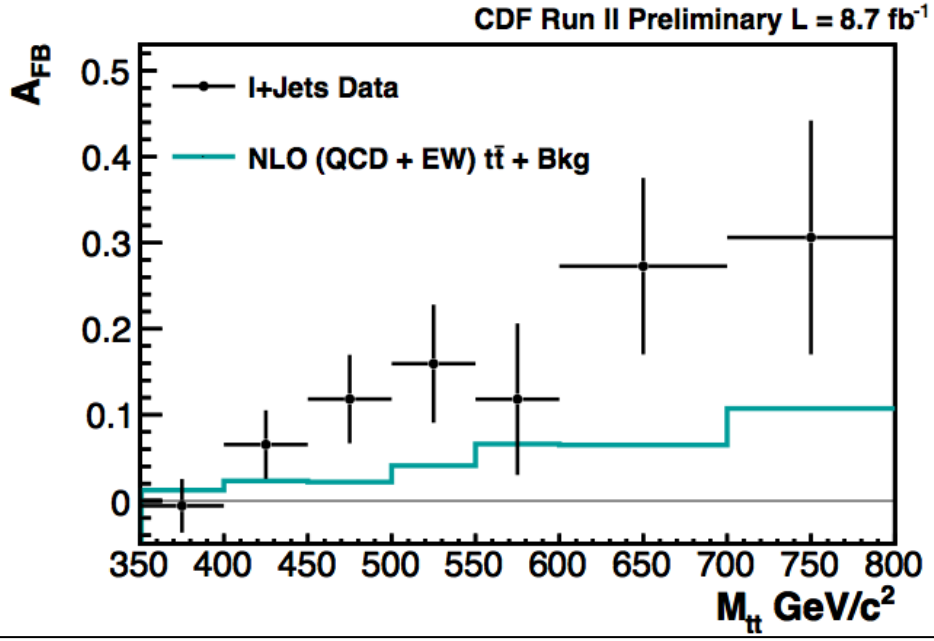

Semi-Leptonic
entries / (2 GeV)
normalized residuals
top mass [GeV]



$$A_{FB}^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

Lorentz invariant
same as A^{ttbar}_{FB}

$$\Delta y = y_t - y_{\bar{t}}$$



$$A_{FB} = \frac{N_{top}(\cos\theta > 0) - N_{top}(\cos\theta < 0)}{N_{top}(\cos\theta > 0) + N_{top}(\cos\theta < 0)}$$ (top direction)

$$A_{LR} = \frac{N_{top}(e_L^-) - N_{top}(e_R^-)}{N_{top}(e_L^-) + N_{top}(e_R^-)}$$ (e^- polarization flip)

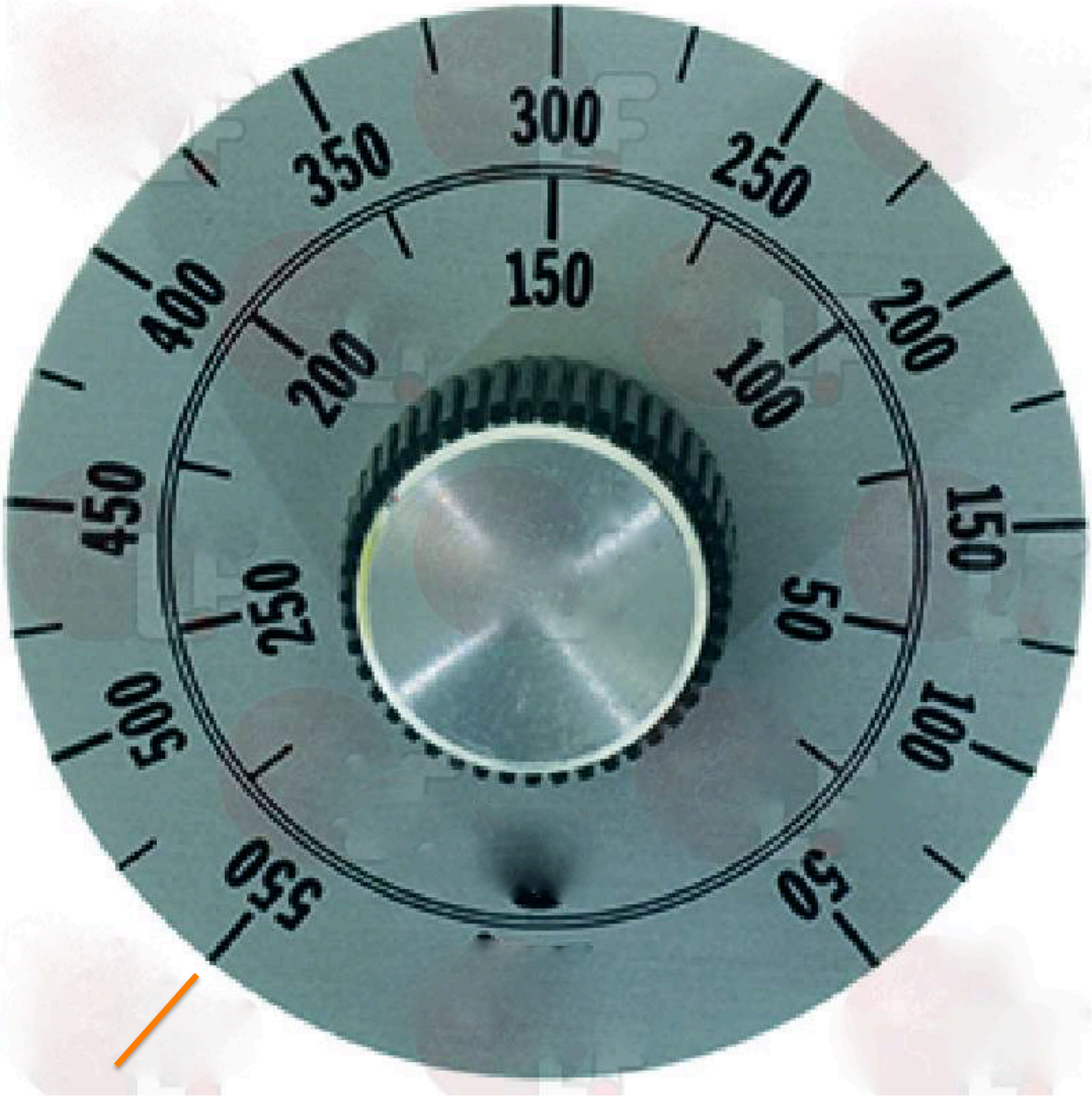
Semileptonic decay mode :
$t\bar{t} \to (bW)(b\bar{W}) \to (bqq)(b\bar{l}\nu)$

Lepton gives top charge

Energy/GeV	250	350
$\Delta(\sigma)/\sigma$	3.0 %	3.7 %
→ $\Delta(g_{HZZ})/g_{HZZ}$	1.5 %	1.8 %

H→bb: Δ(BR)/BR	2.7 %	2.3 %
H→cc: Δ(BR)/BR	9 %	6.5 %
H→gg: Δ(BR)/BR	10 %	7 %
H→ττ: Δ(BR)/BR	~6 %	6 %
H→WW*: Δ(BR)/BR	~5 %	~4 %

Δ(mH) recoil	30 MeV	80 MeV
Δ(mH) direct	-	40 MeV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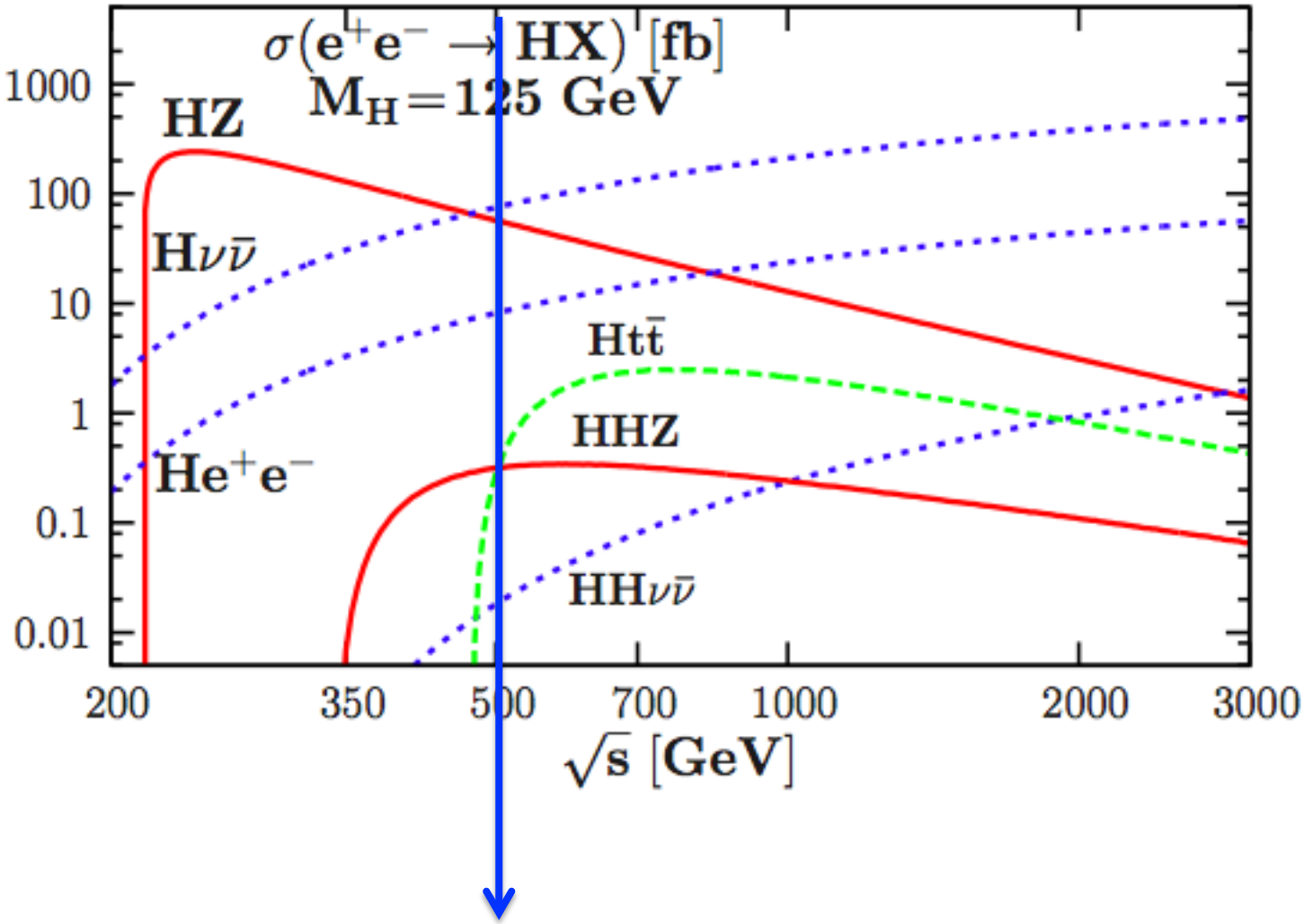
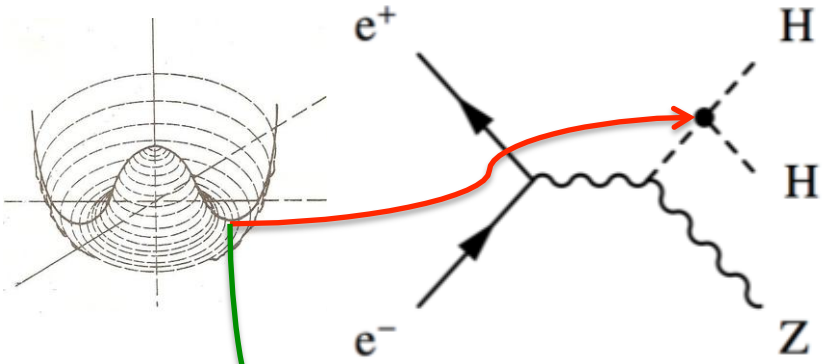
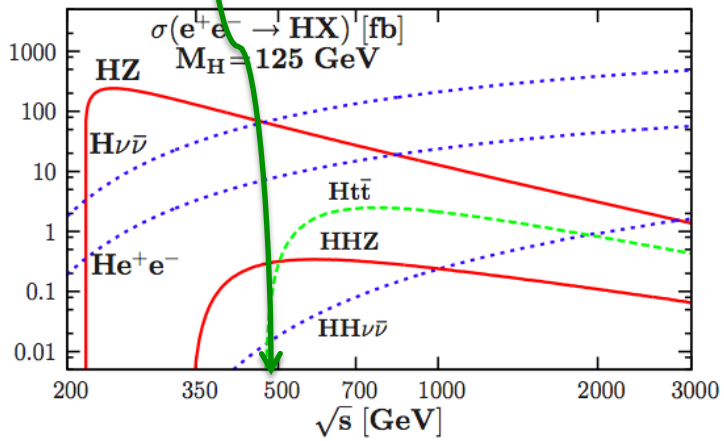
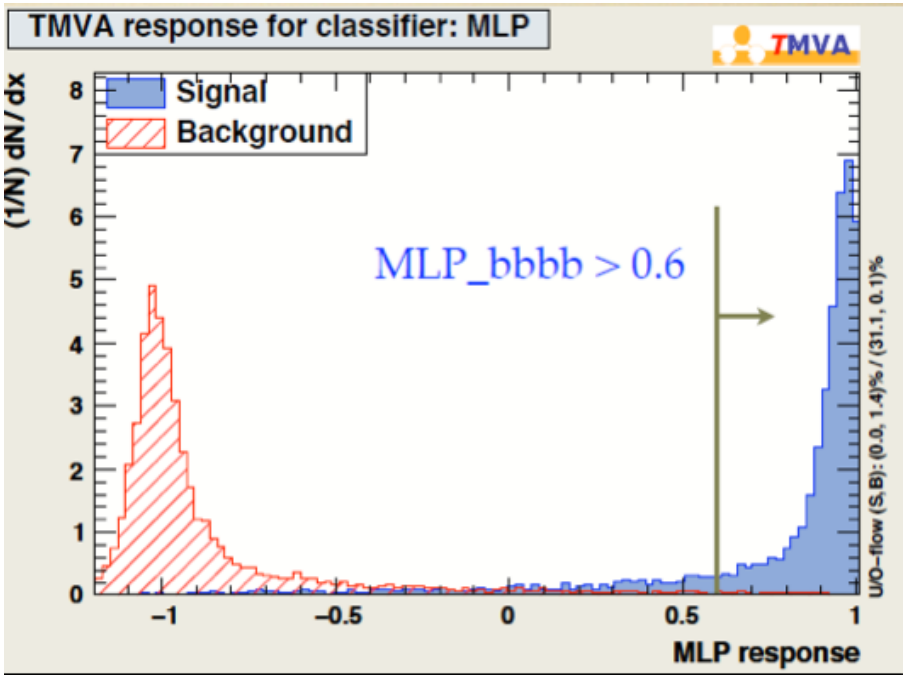


500 GeV is the portal to the whole SM



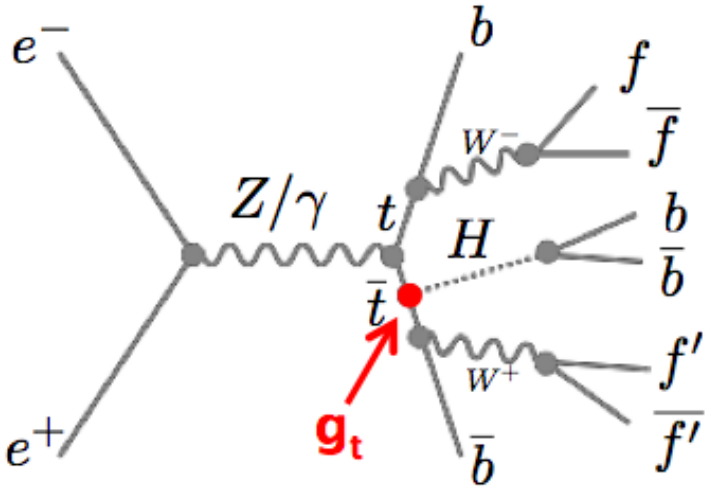


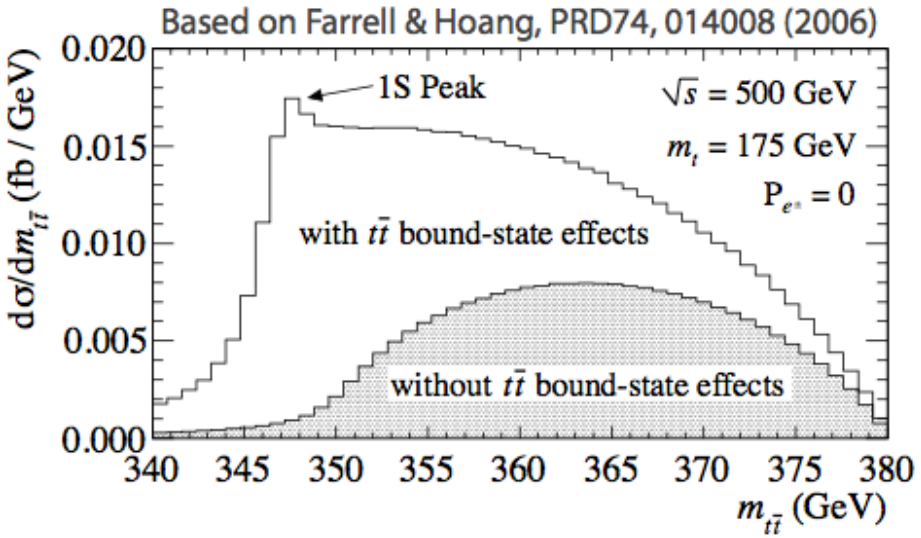


Decay mode	BR.	# events in 1 ab^{-1}
qqbbbb	32%	146
ννbbbb	9%	42
qqbbWW*->qqbbqqqq	6%	28
llbbbb	4%	19
qqbbWW*->qqbbqqlν	3%	14
qqbbWW*->qqbblνqq	3%	14
others	43%	194
tt -> bbqqqq		~800,000
ZZZ, ZZH -> qqbbbb		~600

Energy (GeV)	Modes	signal	background	significance	
				excess (I)	measurement (II)
500	$ZHH \to (l\bar{l})(b\bar{b})(b\bar{b})$	6.4	6.7	2.1σ	1.7σ
500	$ZHH \to (\nu\bar{\nu})(b\bar{b})(b\bar{b})$	5.2	7.0	1.7σ	1.4σ
500	$ZHH \to (q\bar{q})(b\bar{b})(b\bar{b})$	8.5	11.7	2.2σ	1.9σ
		16.6	129	1.4σ	1.3σ

Energy/GeV	**500**
$\Delta\lambda/\lambda$	<50 %

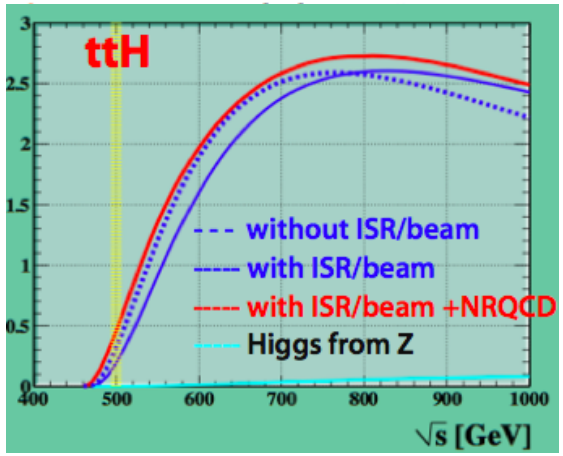




6-jet + lepton cut flow

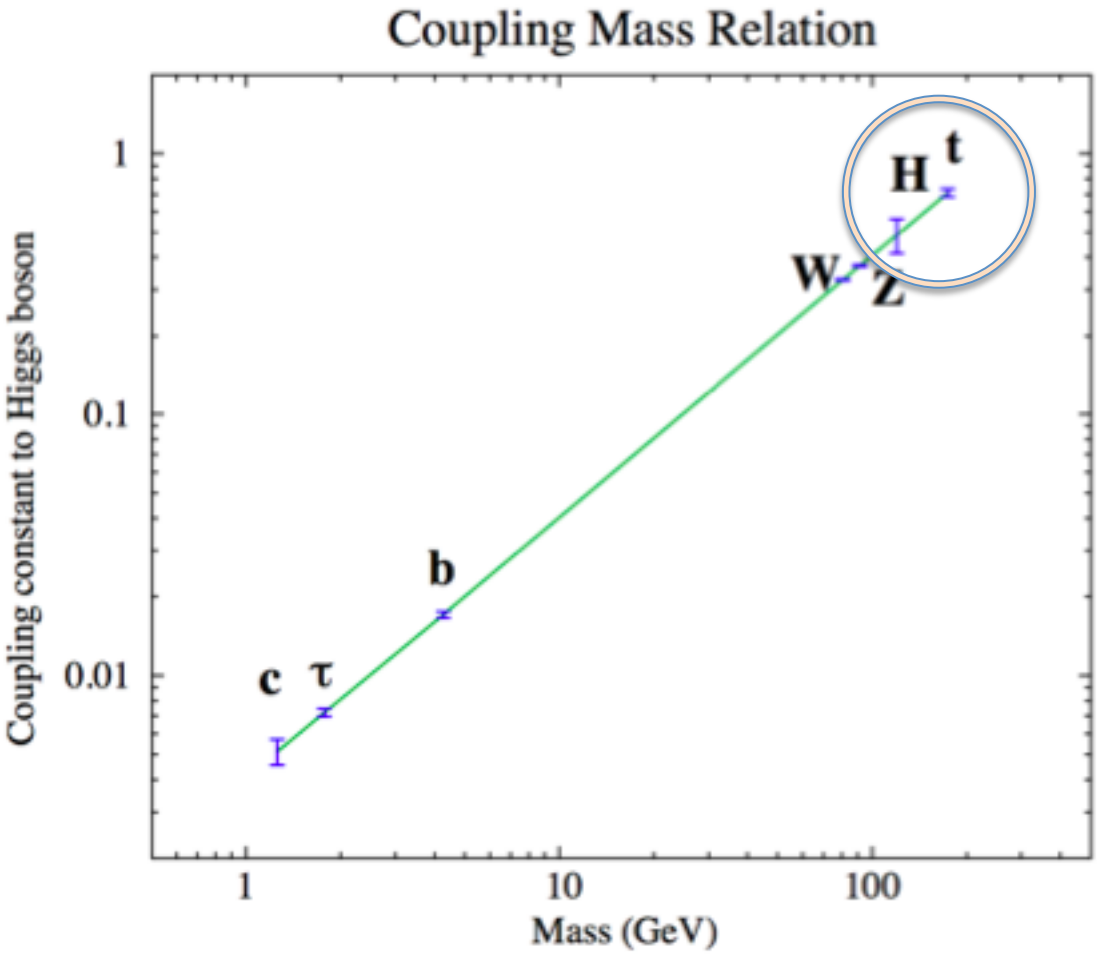
L = 1 ab^{-1}, polarized beams

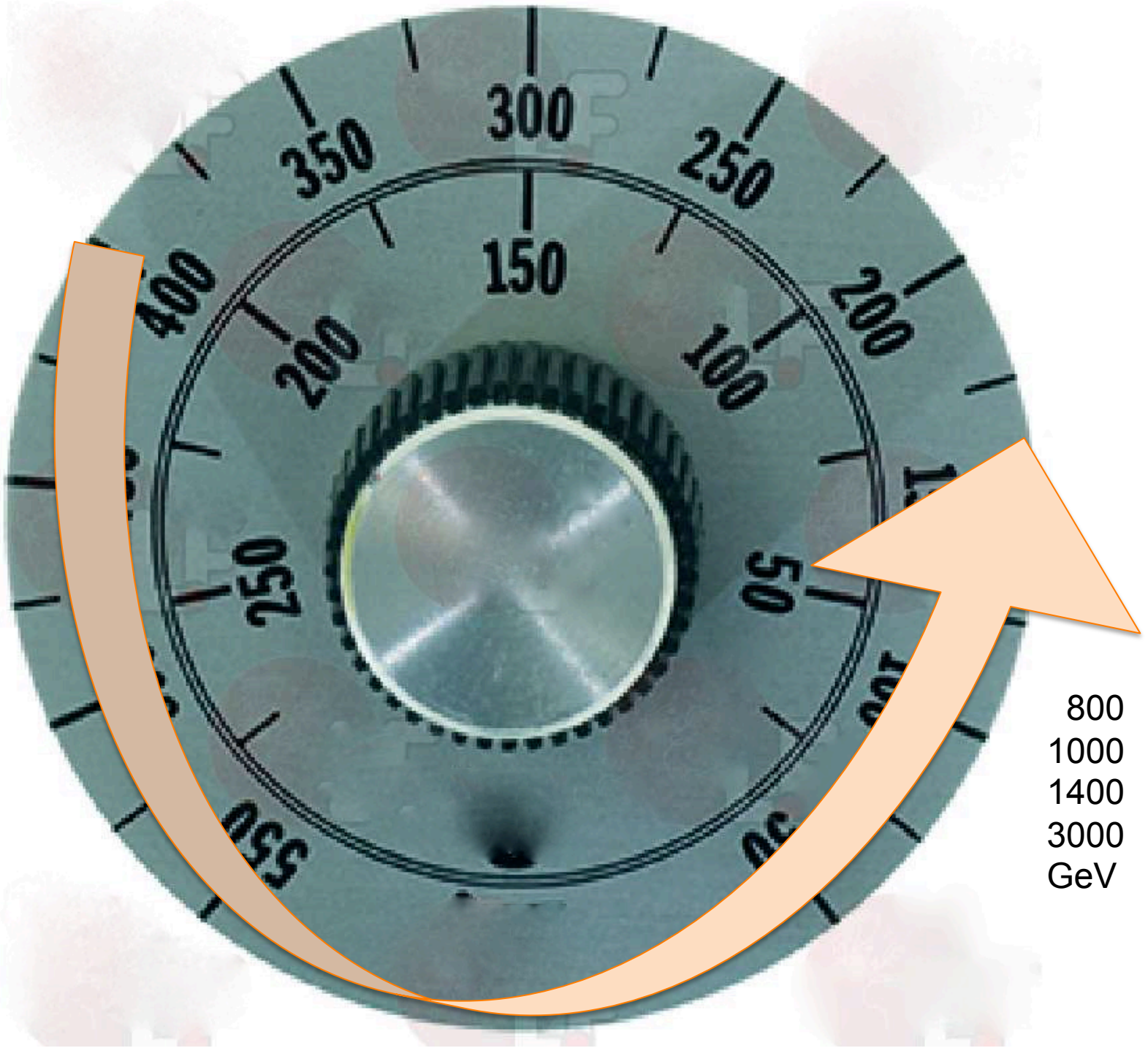
cut \ sample	ttH (6J)	ttH (8J/4J)	tt	ttZ	ttg*-> ttbb	significance
no cuts	282.	358.	980739.	2407.	1160.	0.3
# isolated lepton = 1	180.	49.0	340069.	791.	398	0.3
thrust < 0.77	146.	37.7	144999.	617.	266.	0.4
$Y_{5->4}$ > 0.005	126.	25.8	12298.	416.	114.	1.1
4x btag	49.0	4.2	173.	53.3	37.8	2.8
mass cuts	39.5	1.6	23.0	33.9	13.2	3.7



Energy/GeV	500
$\Delta(g_{Htt})/g_{Htt}$	~10 %?
$\Delta(g_{HWW})/g_{HWW}$	1.2 %

A 500+ GeV Linear Collider can cover
most accessible Higgs couplings

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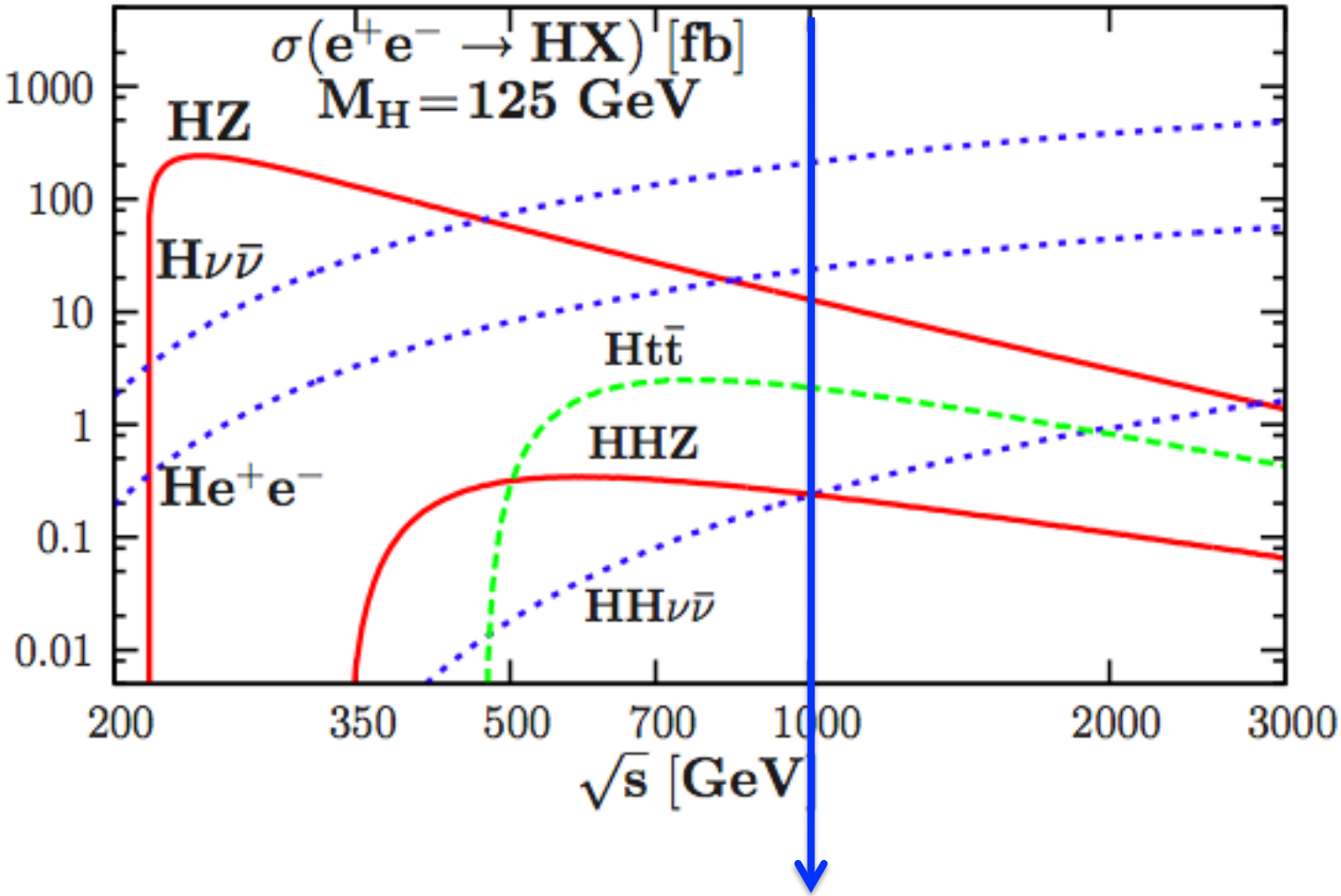
50
550
50
800
1000
1400
3000
GeV



1000 GeV is the Vector-Vector world

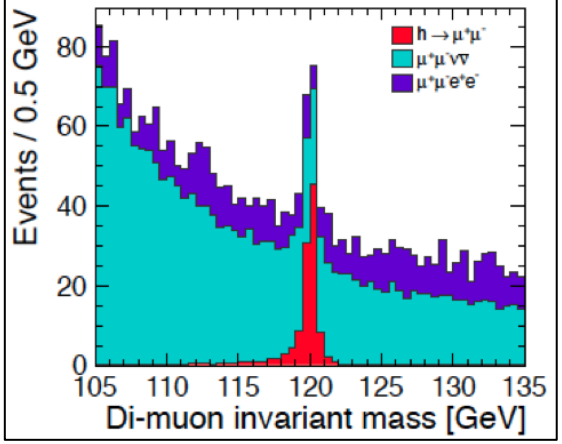
Significant improvements.

Energy/GeV	350	1 TeV
Γ_H recoil	7 %	3.5 %

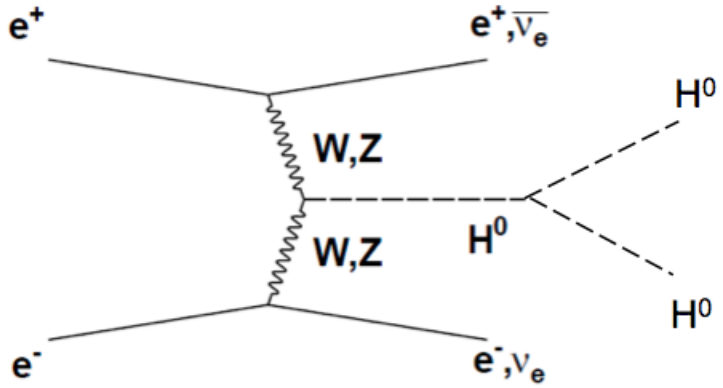
Energy/GeV	3000
H→bb: Δ(BR)/BR	2 %
H→cc: Δ(BR)/BR	3 %
H→μμ: Δ(BR)/BR	15 %

Energy/GeV	250	350
H→bb: Δ(BR)/BR	2.7 %	2.3 %
H→cc: Δ(BR)/BR	9 %	6.5 %
H→gg: Δ(BR)/BR	10 %	7 %
H→ττ: Δ(BR)/BR	~6 %	6 %
H→WW*: Δ(BR)/BR	~5 %	~4 %

15% stat. precision on σ(H→μμ) requires forward electron tagging to suppress background



Energy/GeV	500	1000	1500	3000
Int Lumi [fb]	500	1000	1500	2000
Cross section [fb]	80	220	320	510
N(Hνν) Events	4E4	2E5	5E5	1E6



Energy/GeV	1400	3000
$\Delta\lambda/\lambda$	<20 %	<25 %

A 1000+ GeV Linear Collider can cover
all accessible Higgs couplings
and the whole Standard Model

	250	350	500	>1.5 TeV
g_{HWW}	?	?	1.2 %	?
g_{HZZ}	1.5 %	1.8 %		
g_{Hbb}	1.3 %	1.1 %		
g_{Hcc}	4.5 %	3.2 %		1.5 %
$g_{H\tau\tau}$	~3 %	~3 %		?
g_{Htt}	-	-	10 %	?
$g_{H\mu\mu}$	-	-		8 %
$\lambda_{(HHH)}$	-	-	<50 %	<20 %

A very rich program: many aspects not mentioned here, like:
W mass, VV scattering, searches for New Physics, GigaZ …

We expect that in 2012 LHC will rule out or discover the Standard Model(?) Higgs Boson.

The physics case for Future Linear Colliders is Compelling with or without Higgs.

However, if the Higgs boson is discovered by LHC, there will be a strong boost for moving forward in a Global LC Project.

The HEP community should be ready for this.

Future Linear Colliders