CoEPP Annual Workshop
Cairns, 7-12 July 2013

The Future of the High Energy Frontier

(European Strategy of Particle Physics)

Picture: ©Ralph A. Clevenger/CORBIS

Peter Jenni, Freiburg and CERN

How could *I* tell?

All I can try to do is

- Reflect a bit on the past
- Recall some options
- And in particular base myself on the recent Update of the European Strategy for Particle Physics

In fact, this will be the main part:

European Strategy
for Particle Physics

Update of the European Strategy (ES) for Particle Physics

Brief recall of the procedure and bodies

Concentrate on the outcome of the closed ES drafting meeting which took place at the Ettore Majorana Foundation and Centre for Scientific Culture (EMFCSC) in Erice from 21 to 25 January 2013, and which was then endorsed by Council in its March meeting, and finally approved on 30th May 2013 in Brussels in a special Council meeting

I will highlight a very selective set of topics only, the full set of statements is be available at the web site below, which also contains links to the further detailed public information

Erice (Sicily), 750 m

http://europeanstrategygroup.web.cern.ch/europeanstrategygroup/

The time line of the strategy update

Autumn 2011	**CERN Council initiated an update exercise to the European Strategy for Particle Physics which was approved by a special Council Session held in Lisbon on 14th July 2006** **This included appointing formally a European Strategy Group (ESG) as well as a European Strategy Preparatory Group (ESPG) *by Council***
February 2012	**ESPG started collecting written input from community**
July 31st 2012	**Closing date for input to Open Symposium in Krakow**
10-12 Sep 2012	**Open Symposium in Krakow with more than 500 participants** http://espp2012.ifj.edu.pl/
October 15th 2012	**Closing date for community input to the Briefing Book**
21-25 Jan 2013	**2013 European Strategy Meeting in Erice produced a draft proposal to Council**
March 22nd 2013	**Council finalized the strategy document (very minor clarifications)**
May 30th 2013	**Final approval by Council in a special meeting in Brussels**

European Strategy Group (ESG)

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Bulgaria	Prof. L. Litov
Czech Republic	Prof. J. Chyla
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LAL	Dr A. Stocchi
NIKHEF	Prof. F. Linde
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Prof. F. Zwirner	SPC Chair
Dr M. Krammer	ECFA Chair
Dr Ph. Chomaz	Repres. EU Lab. Directors
Prof. E. Tsesmelis	Scientific Assistant

Invited - President of Council	Prof. A. Zalewska

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Candidate for Accession and Associate Member States

Israel	Prof. E. Rabinovici
Romania	Dr S. Dita
Serbia	H. E. Amb. U. Zvekic

Observer States

India	Prof. T. Aziz
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Former President of Council, Prof. M. Spiro

Erice, ESG, January 2013

The European Strategy Preparatory Group (ESPG) Members

Strategy Secretariat Members

Prof. T. Nakada	Scientific Secretary (Chair)
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Dr M. Krammer	ECFA Chair
Dr Ph. Chomaz	Repres. EU Lab. Directors
Prof. E. Tsesmelis	Scientific Assistant

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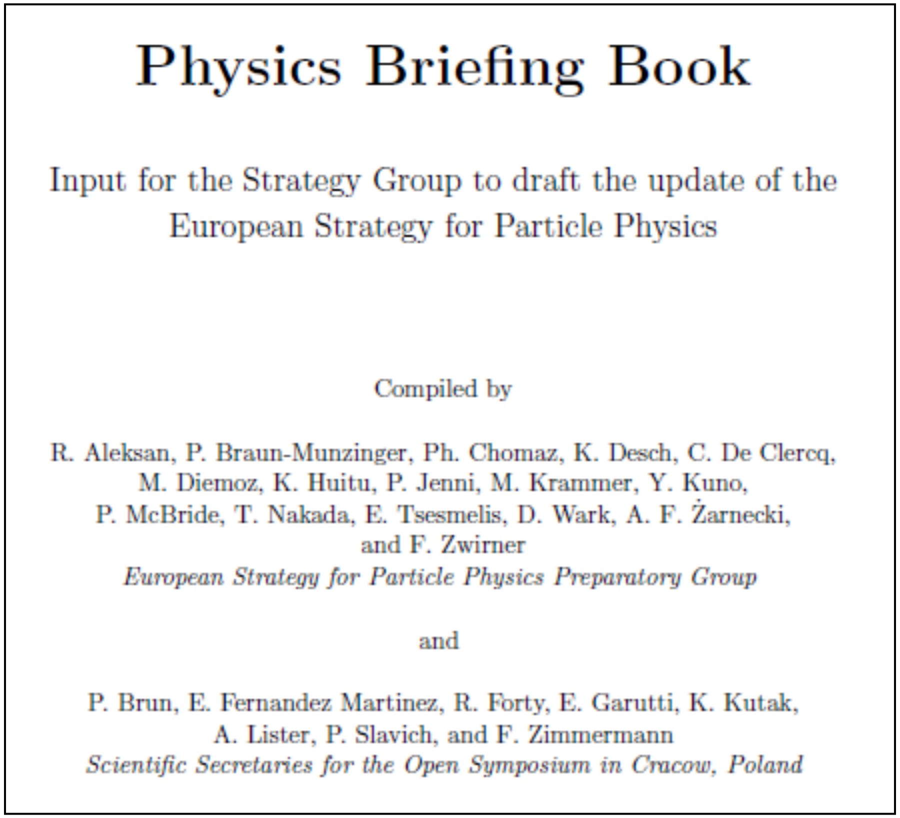
Prof. Y. Kuno (Asia)
Prof. P. McBride (Americas)



Physics Briefing Book

Input for the Strategy Group to draft the update of the
European Strategy for Particle Physics

Compiled by

R. Aleksan, P. Braun-Munzinger, Ph. Chomaz, K. Desch, C. De Clercq,
M. Diemoz, K. Huitu, P. Jenni, M. Krammer, Y. Kuno,
P. McBride, T. Nakada, E. Tsesmelis, D. Wark, A. F. Żarnecki,
and F. Zwirner
European Strategy for Particle Physics Preparatory Group

and

P. Brun, E. Fernandez Martinez, R. Forty, E. Garutti, K. Kutak,
A. Lister, P. Slavich, and F. Zimmermann
Scientific Secretaries for the Open Symposium in Cracow, Poland

Briefing Book

The Briefing Book contains in 220 pages a ‘digested summary’ of the scientific and technical input to the European Strategy update (from 177 contributions and the Krakow Open Symposium)

Chapter headings

1- Introduction
2- Energy Frontier
3- Physics of Flavour and Symmetries
4- Neutrino Physics
5- Strong Interaction Physics
6- Astroparticle and Non-accelerator Physics
7- Particle Physics Theory
8- Accelerator Science and Technology
9- Instrumentation, Computing and Infrastructure

CERN Council Strategy Group

OPEN SYMPOSIUM ON
EUROPEAN STRATEGY FOR
PARTICLE PHYSICS

September 10th - 12th, 2012 Kraków, Poland

Organized under the aegis of the European Strategy Preparatory Group by:

AGH University
of Science and Technology

Foundation for the AGH University
of Science and Technology

Institute of Nuclear Physics
Polish Academy of Sciences

The M. Smoluchowski
Scientific Consortium
”Matter-Energy Future”

European Strategy
Preparatory Group
Scientific Committee

Roy Aleksan
Peter Braun-Munzinger
Catherine De Clercq
Philippe Chomaz
Klaus Desch
Marcella Diemoz
Katri Huitu
Peter Jenni
Manfred Krammer
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http://espp2012.ifj.edu.pl

Honorary patronage:

The present (public) draft version of the Briefing Book is available at the link given before, and a final version will be published later

ES Working Groups on organizational and other matters

Working Group 1	**Mandate and organisational structure for the Council of the European Strategy and its implementation**
Working Group 2	**Organisational structure for European participation in global projects, including the role and definition of the National Laboratories and the CERN Laboratory in the European Strategy**
Working Group 3	**Relations with external bodies, in particular EU-related issues**
Working Group 4	**Knowledge and technology transfer, relations with industry**
Working Group 5	**Outreach, communication and education**

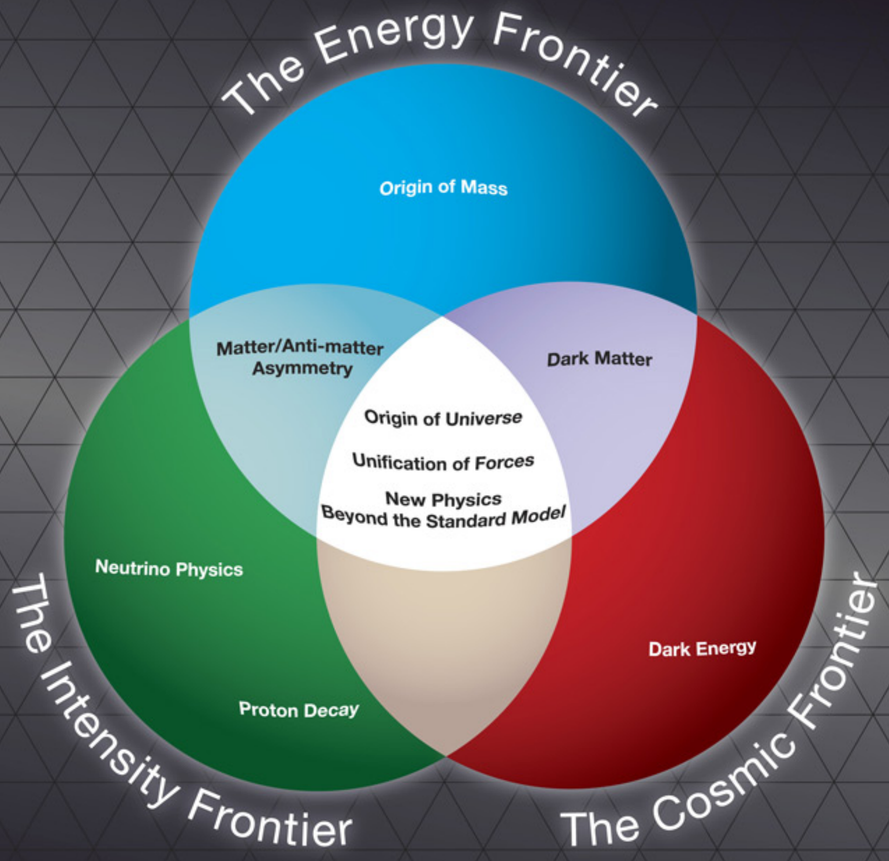
The membership of these WGs consisted of members from the ESG plus some external experts

The famous three pillars of particle physics

When considering the scientific input to update of the European Strategy for Particle Physics, the bodies were very much aware of this complementarity

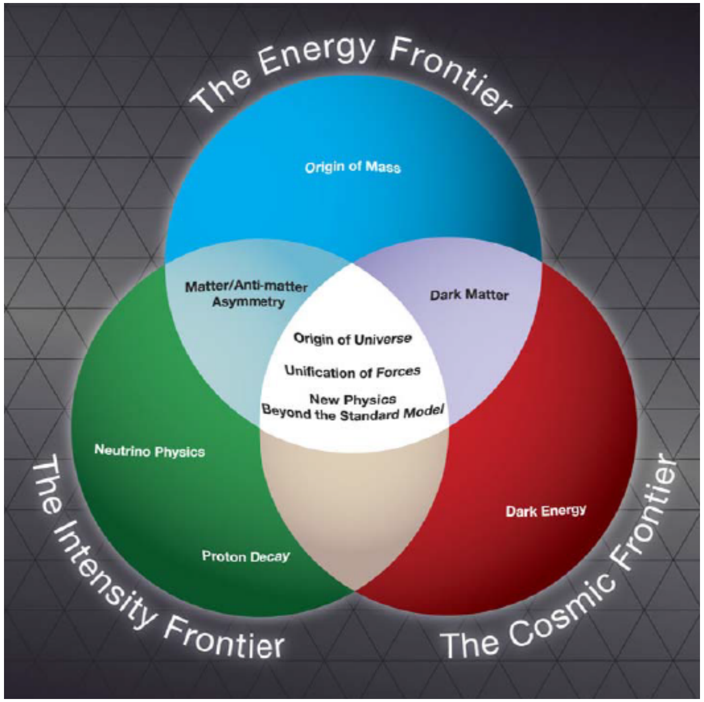
Another primordial consideration was the need to see the European Strategy within a global context of facilities worldwide, taking into account the global aspects of planning for future facilities

© P5: Particle Physics Project Prioritization Panel



(Note that non-accelerator particle physics such as p decay, $0\nu\beta\beta$ decay … are under astro-particle physics coordinated by ApPEC in Europe)

Before expanding further the high energy frontier, a short reminder on the high relevance of the intensity frontier for the future of particle physics



Beyond the Standard Model physics is probed by

- Neutrino physics
(~ already not fitting into the SM)

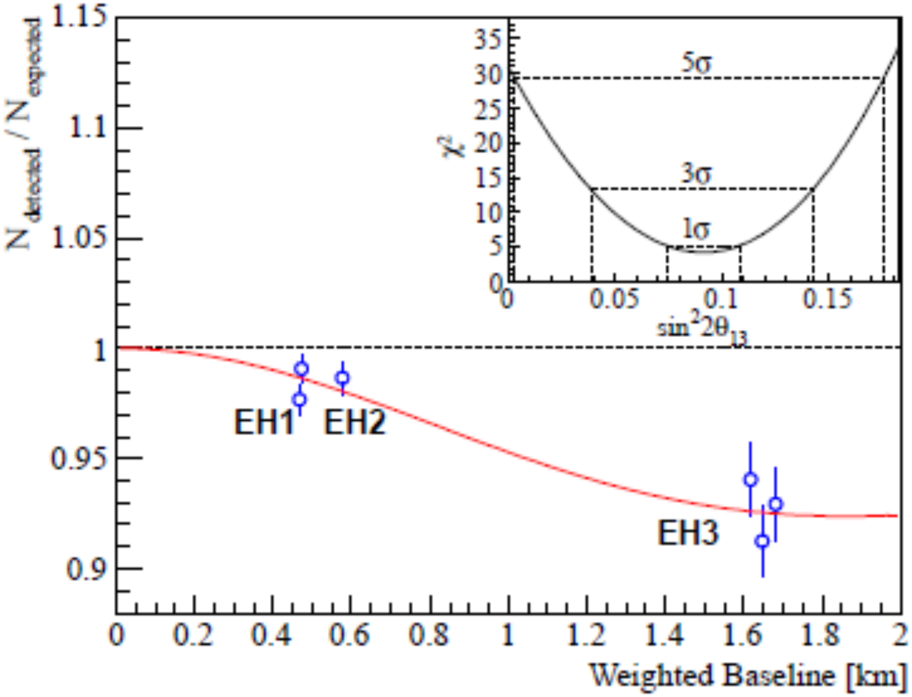
- Precision measurements on rare and forbidden processes of quarks and charged leptons in the Standard Model

Neutrino physics

The crucial new experimental input is the measurement of the clearly non-zero value of the third mixing angle θ_{13} for neutrino flavour mixing by several experiments

Shown here is the Daya Bay reactor experiment which observed a deficit of anti-ν_e at its 1.6 km far detectors leading to

$$\sin^2 2\theta_{13} = 0.092 \pm 0.016(\text{stat}) \pm 0.005(\text{syst})$$



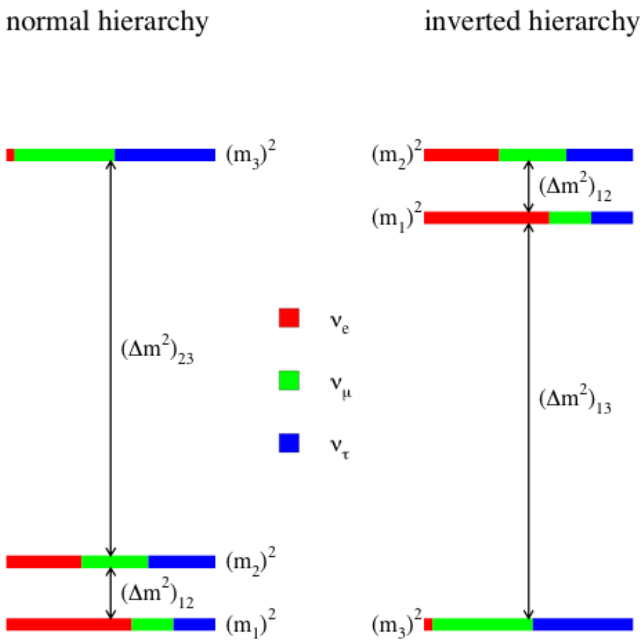
Phys. Rev. Lett. 108 (2012) 171803

Possible CP violation requires all three mixing angles to be non-zero

Mentioning here only large accelerator-based facilities, the goals of next generation long-baseline oscillation experiments:

- The mass hierarchy, that is , the sign of Δm^2_{31}
- The existence of leptonic CP violation in neutrino oscillations and the value of δ

There is in addition a world-wide rich activity of current and planned neutrino experiments: $0\nu\beta\beta$, reactor, atmospheric, short-baseline … (absolute mass, sterile neutrinos, Majorana nature, mass hierarchy…)

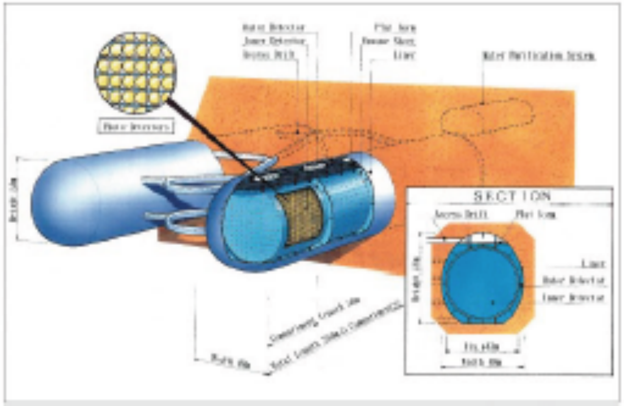


$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$$\begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \times \begin{pmatrix} c_{13} & 0 & \boxed{s_{13}e^{-i\delta}} \\ 0 & 1 & 0 \\ \boxed{-s_{13}e^{-i\delta}} & 0 & c_{13} \end{pmatrix} \times \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

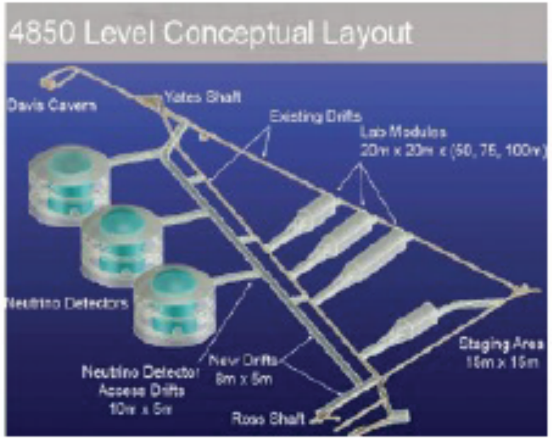
Three long-baseline options were considered for the European Strategy discussions

HyperK (Japan)



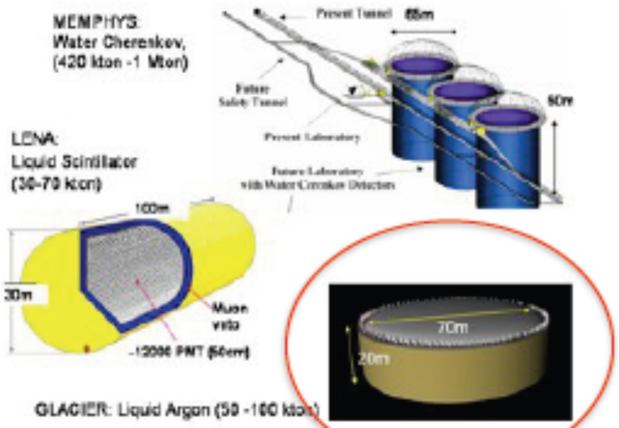
750 kW , 560kton WC, Tokai-Kamioka (295km)

LBNE (USA)



800 kW , 10kton-> 35kton LAr, Fermilab-Homestake(1300km)

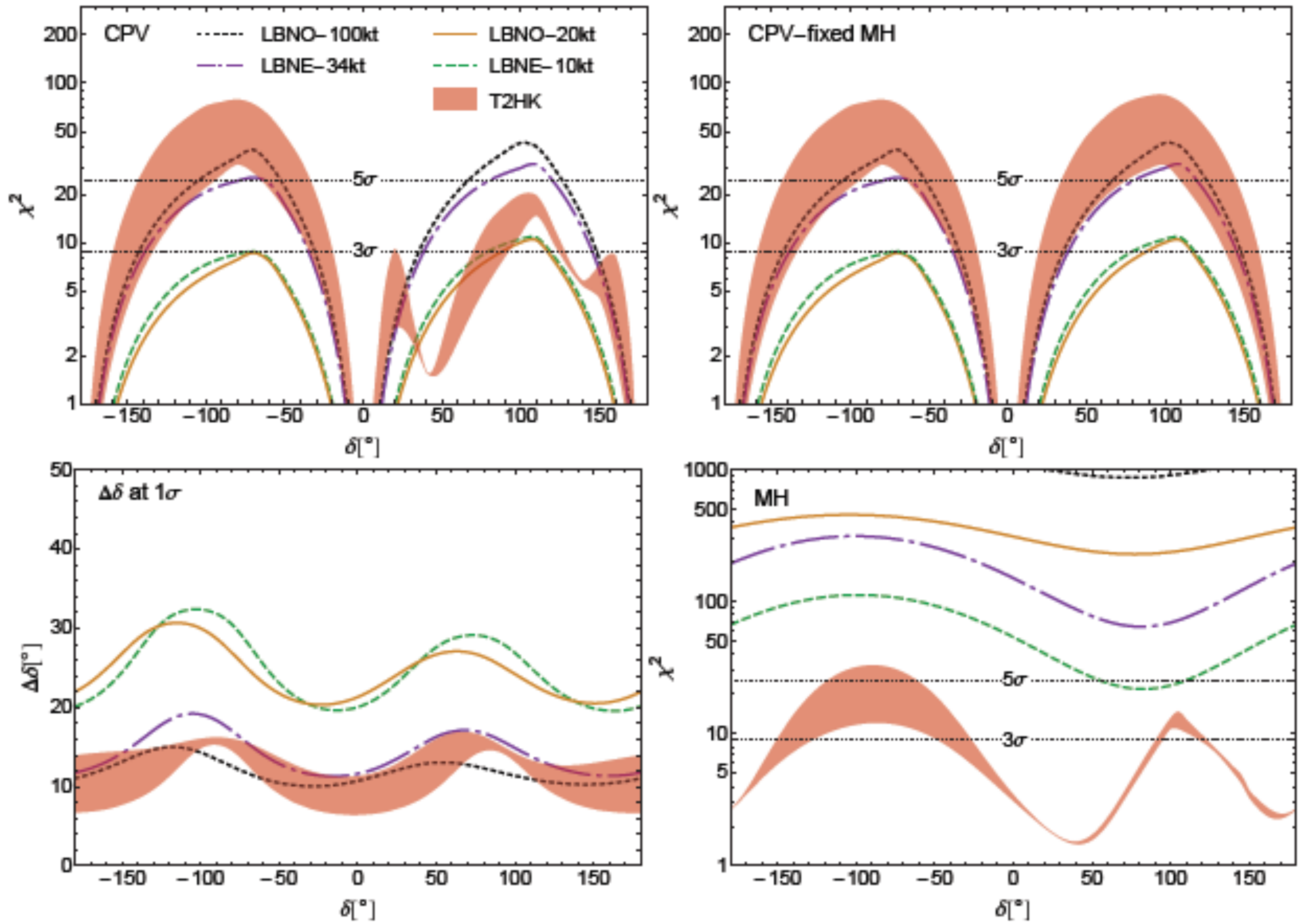
LBNO (Europe)



800 kW , 20kton-> 100kton LAr, CERN-Pyhäsalmi (2300km)

From P. Hernandez

Long-baseline neutrino experiments



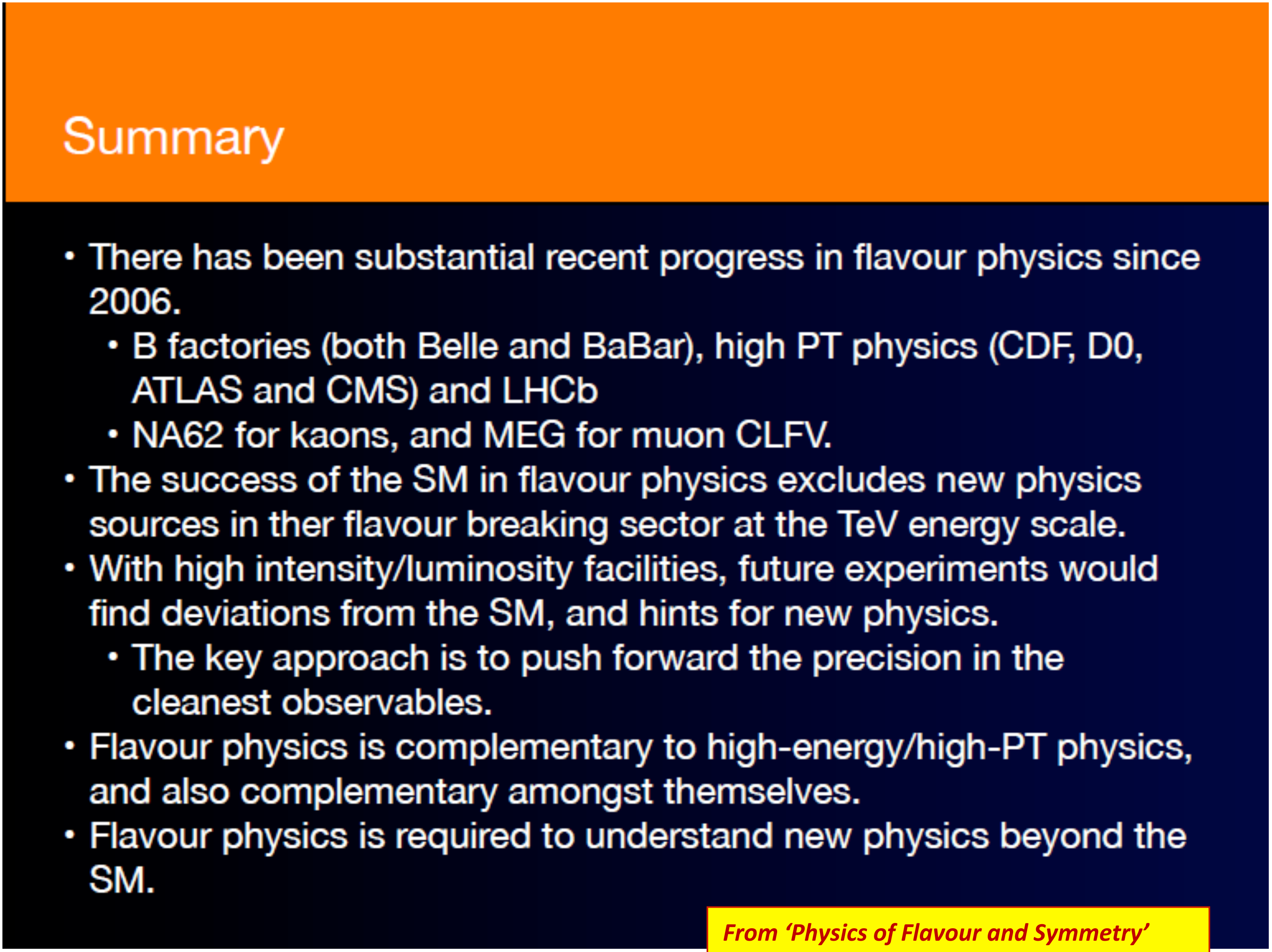
CP violating phase δ
Mass Hierarchy (sign of Δm^2_{31})

(LBNO, LBNE for 10y, T2HK for 5y)

See ES Briefing Book for references

Flavour and Symmetry

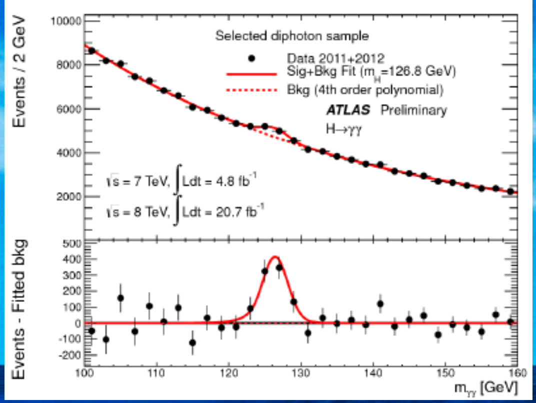
(Paintings of Kabuki actors)

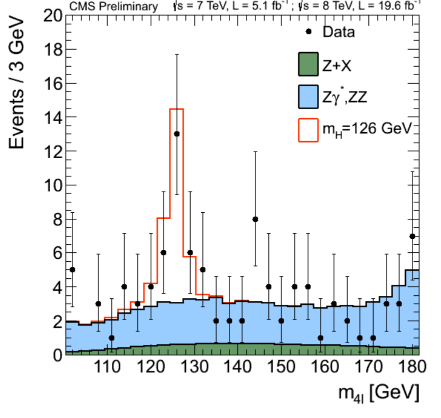


Summary

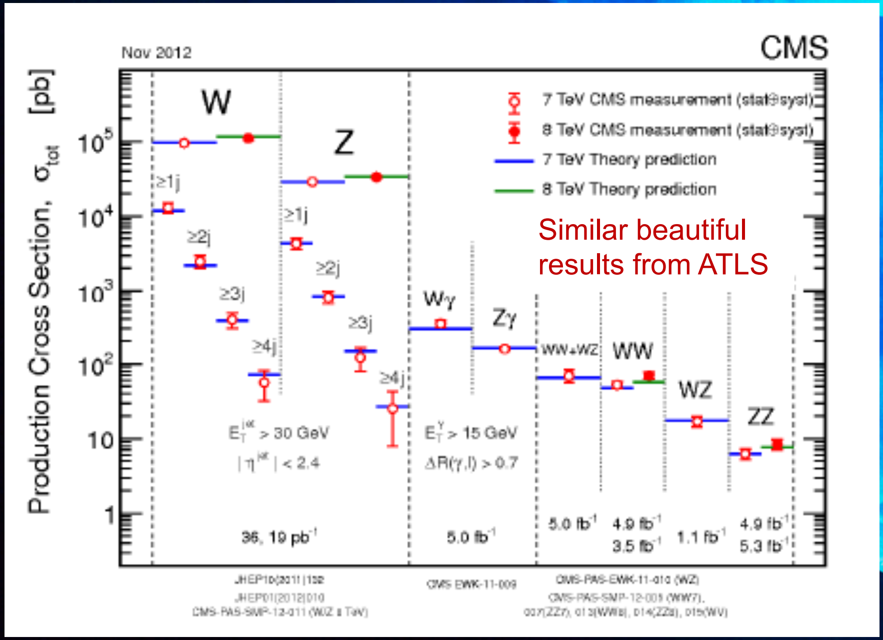
- There has been substantial recent progress in flavour physics since 2006.
  - B factories (both Belle and BaBar), high PT physics (CDF, D0, ATLAS and CMS) and LHCb
  - NA62 for kaons, and MEG for muon CLFV.
- The success of the SM in flavour physics excludes new physics sources in ther flavour breaking sector at the TeV energy scale.
- With high intensity/luminosity facilities, future experiments would find deviations from the SM, and hints for new physics.
  - The key approach is to push forward the precision in the cleanest observables.
- Flavour physics is complementary to high-energy/high-PT physics, and also complementary amongst themselves.
- Flavour physics is required to understand new physics beyond the SM.

From 'Physics of Flavour and Symmetry' presented by Yoshitaka Kuno at the ES Erice

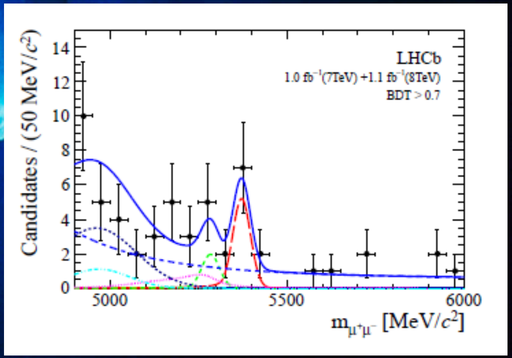




The High Energy Frontier



Similar beautiful results from ATLS



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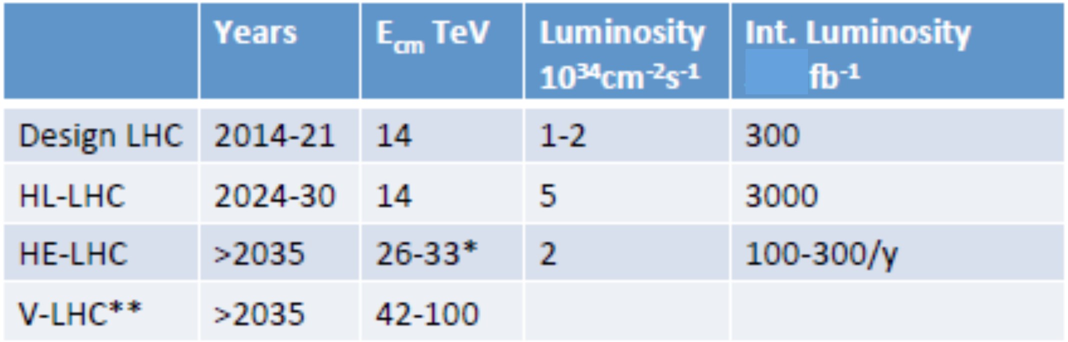
Collider options for the high energy frontier

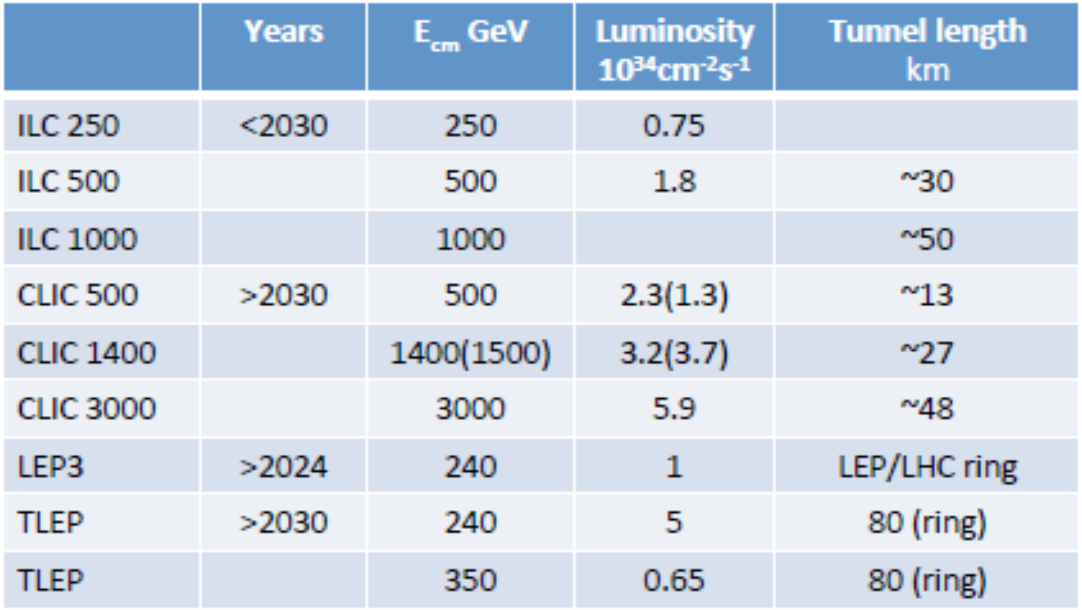
pp colliders



	Years	E_{cm} TeV	Luminosity $10^{34}cm^{-2}s^{-1}$	Int. Luminosity fb^{-1}
Design LHC	2014-21	14	1-2	300
HL-LHC	2024-30	14	5	3000
HE-LHC	>2035	26-33*	2	100-300/y
V-LHC**	>2035	42-100		

* 16-20 T dipole field
** 80 km Tunnel

e+e- colliders



	Years	E_{cm} GeV	Luminosity $10^{34}cm^{-2}s^{-1}$	Tunnel length km
ILC 250	<2030	250	0.75	
ILC 500		500	1.8	~30
ILC 1000		1000		~50
CLIC 500	>2030	500	2.3(1.3)	~13
CLIC 1400		1400(1500)	3.2(3.7)	~27
CLIC 3000		3000	5.9	~48
LEP3	>2024	240	1	LEP/LHC ring
TLEP	>2030	240	5	80 (ring)
TLEP		350	0.65	80 (ring)

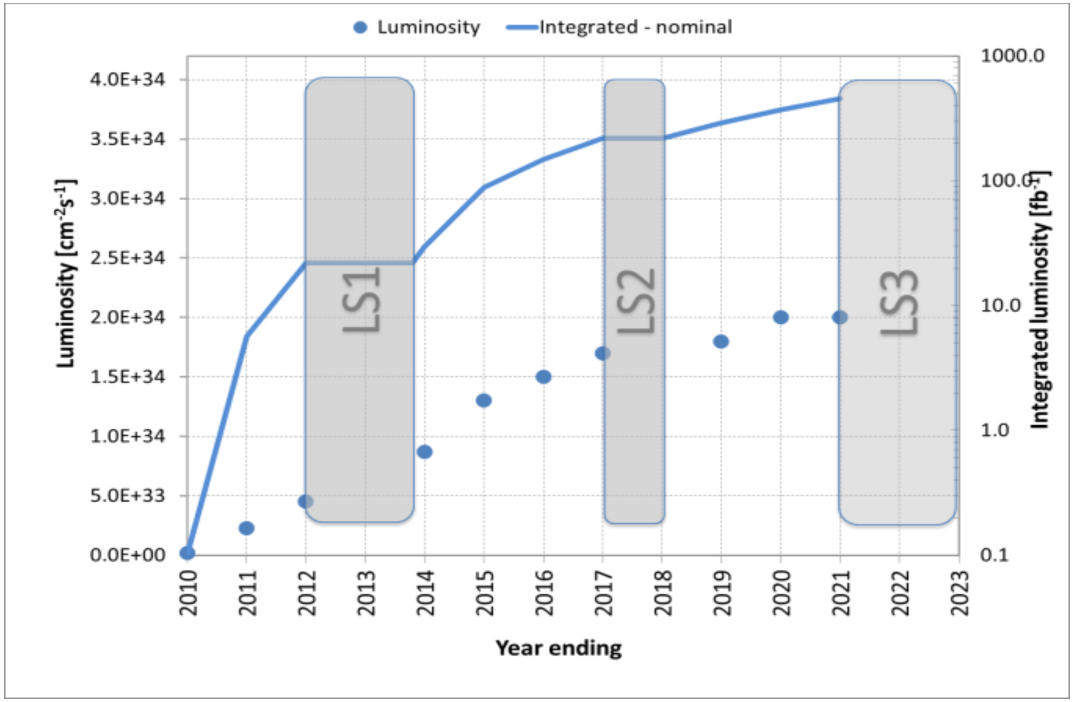
Other options:

$\mu^+\mu^-$ and $\gamma\gamma$ colliders with similar physics as e^+e^- colliders

LHeC for ep collisions

See ES Briefing Book for references

LHC

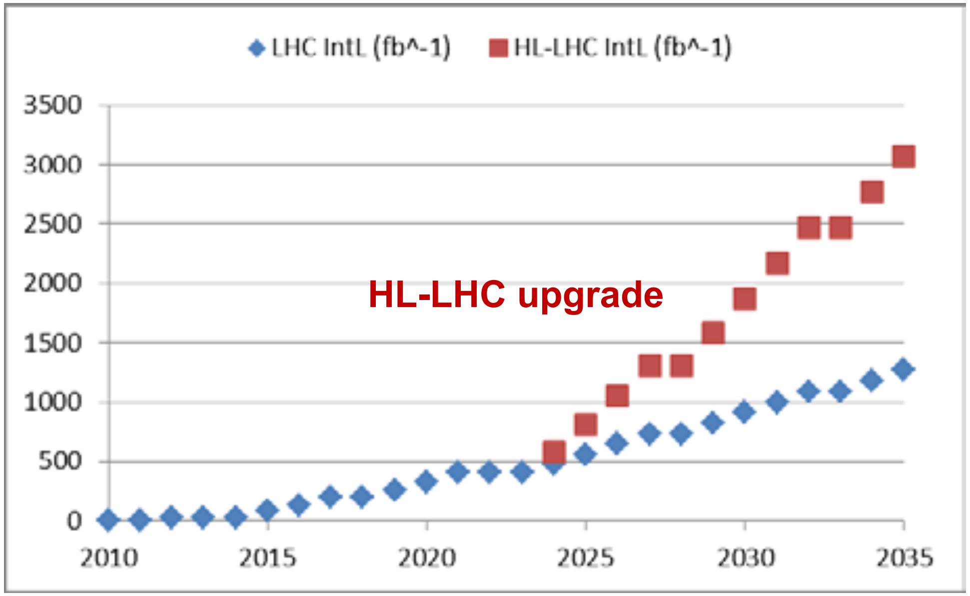


Nominal design performance
(dots: peak luminosity
line: total integrated luminosity)

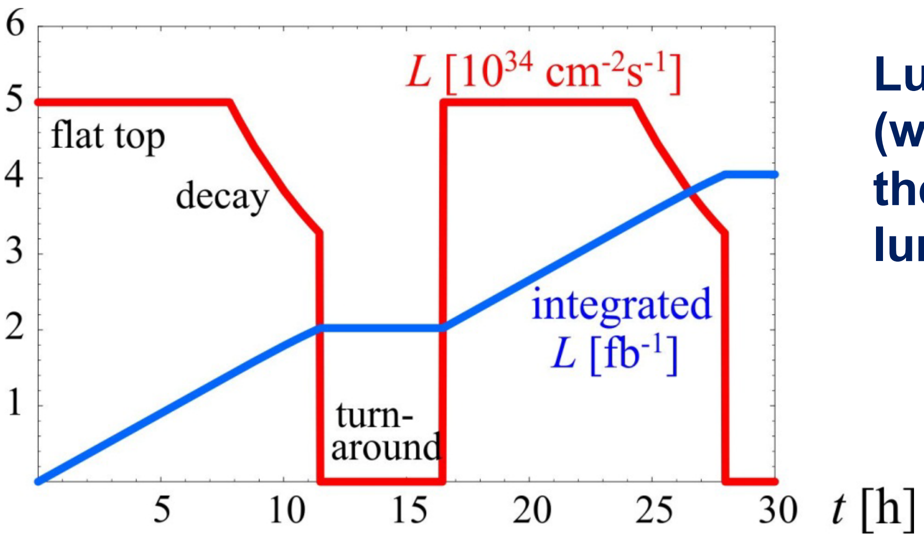
ES Open Symp. Contr. ID=153

High
Luminosity
LHC

Projected integrated luminosity



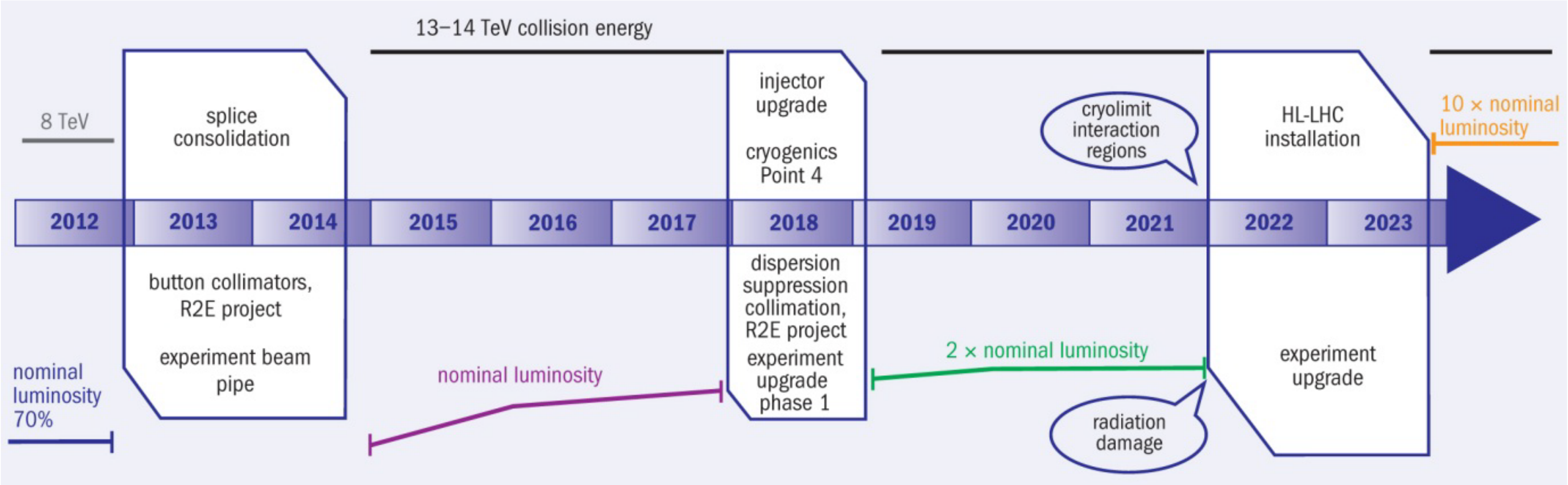
HL-LHC upgrade



Luminosity cycle for HL-LHC (with 'levelling', optimized for the experiments and integrated luminosity)

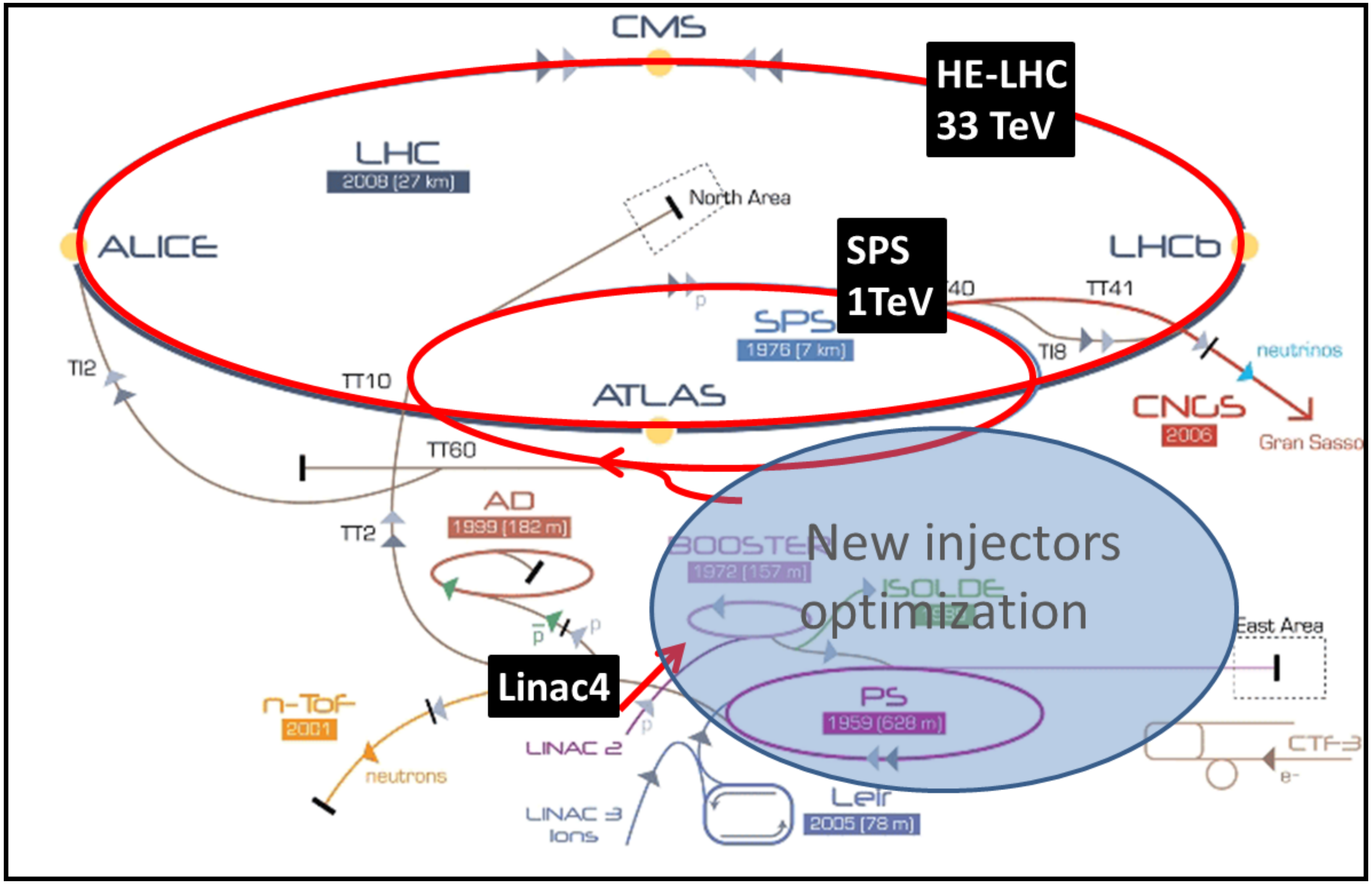
Baseline plan for reaching the HL-LHC phase

ES Open Symp. Contr. ID=153



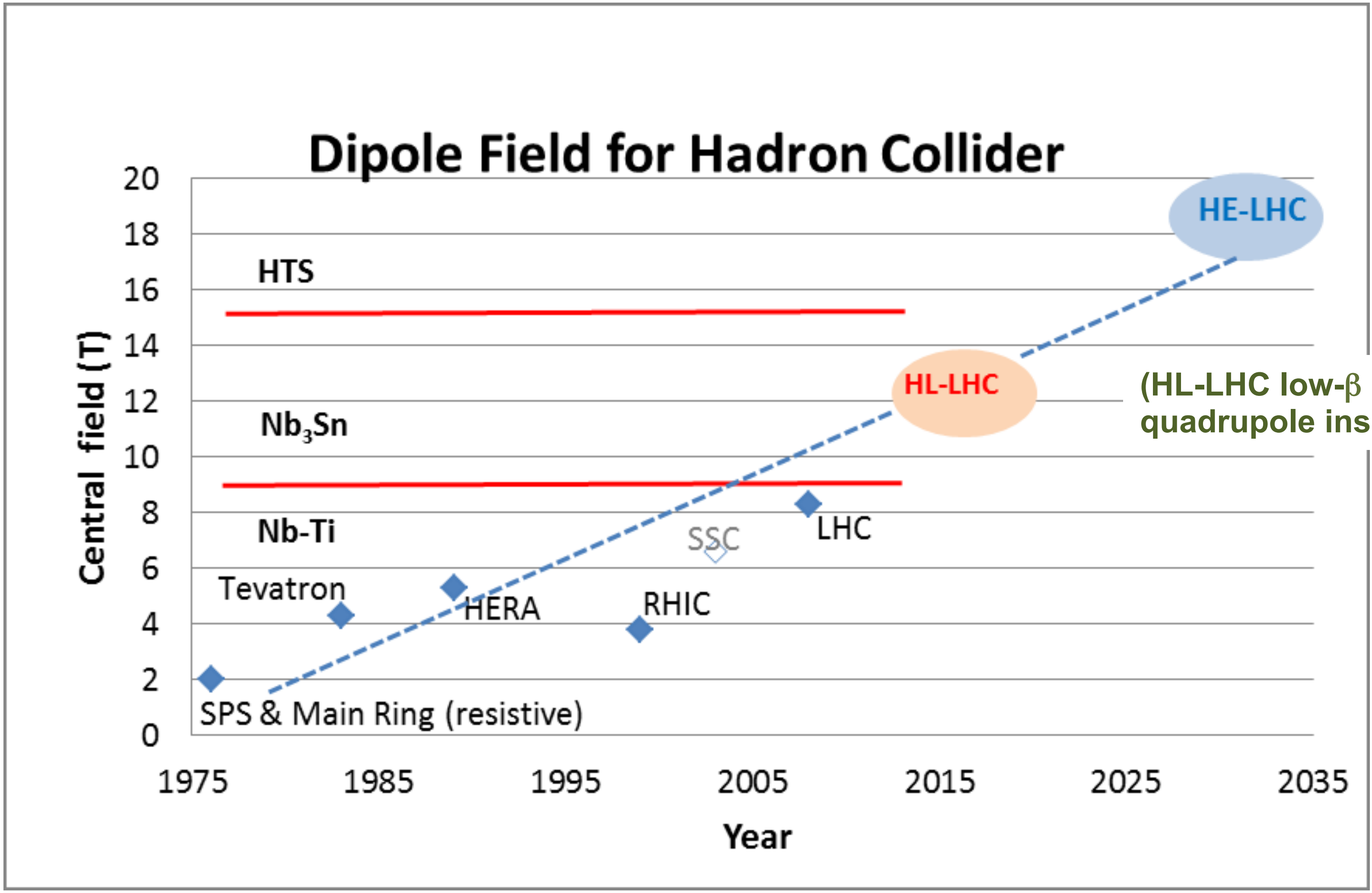
Higher energy hadron colliders

One option, called HE-LHC, would be to install a new collider in the present LHC tunnel, together with a fully upgraded injector chain



CERN-ATS-2012-237
ES Open Symp. Contr. ID=155

Higher energy hadron colliders require further progress in the developments of high-field magnets



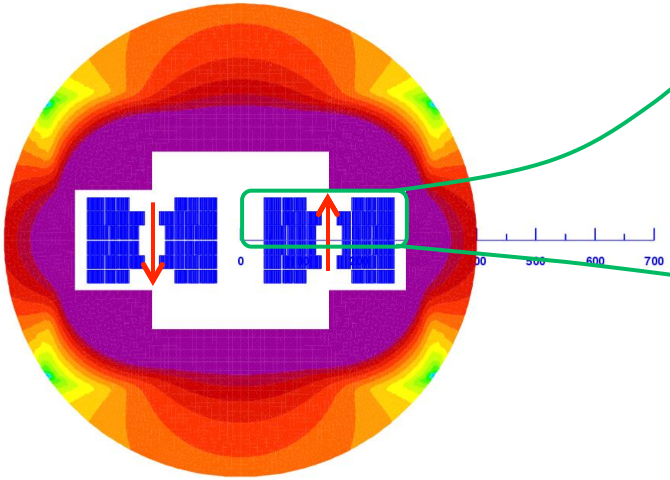
(HL-LHC low-β quadrupole insertions)

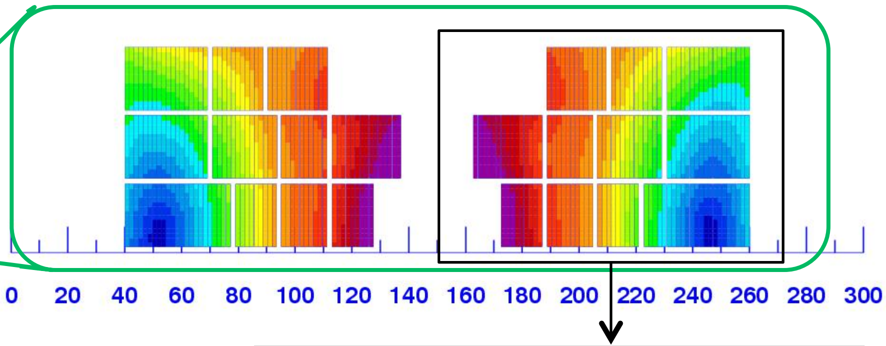
History of high-field magnets for hadron colliders

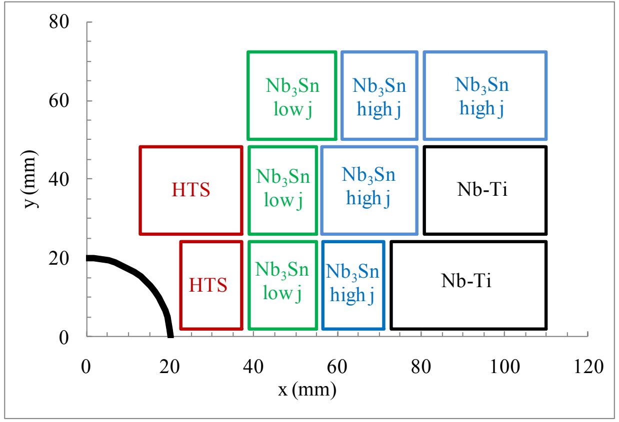
CERN-ATS-2012-237
ES Open Symp. Contr. ID=155

First conceptual layout of a 20 Tesla magnet that would fit into the LHC tunnel

L. Rossi and E. Todesco



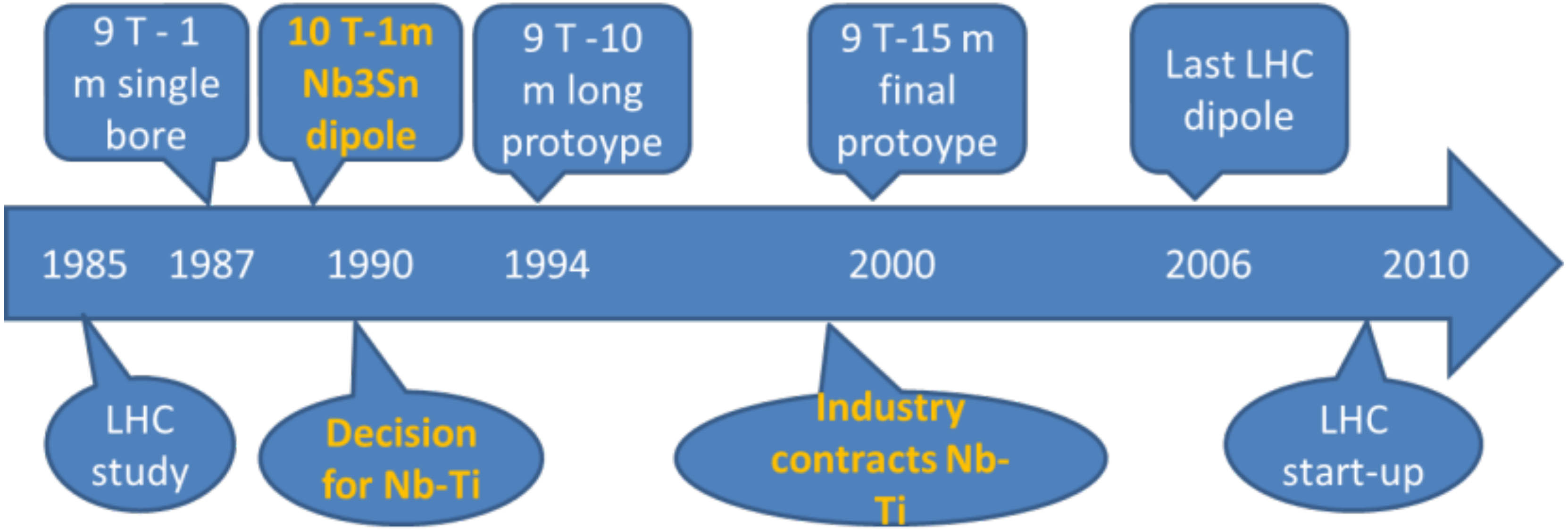




Material	N. turns	Coil fraction	Peak field	$J_{overall}$ (A/mm^2)
Nb-Ti	41	27%	8	380
Nb3Sn (high Jc)	55	37%	13	380
Nb3Sn (Low Jc)	30	20%	15	190
HTS	24	16%	20.5	380

Magnet design: 40 mm bore (depends on injection energy: > 1 Tev)
Very challenging but feasable: 300 mm inter-beam; anticoils to reduce flux
Approximately 2.5 times more SC than LHC: 3000 tonnes!
Multiple powering in the same magnet for FQ (and more sectioning for energy)
Certainly only a first attempt: cosϑ and other shapes will be also investigated

It took a long time to develop the magnets for LHC…



9 T - 1 m single bore

10 T-1m Nb3Sn dipole

9 T -10 m long protoype

9 T-15 m final protoype

Last LHC dipole

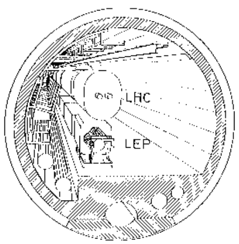
1985 1987 1990 1994 2000 2006 2010

LHC study

Decision for Nb-Ti

Industry contracts Nb-Ti

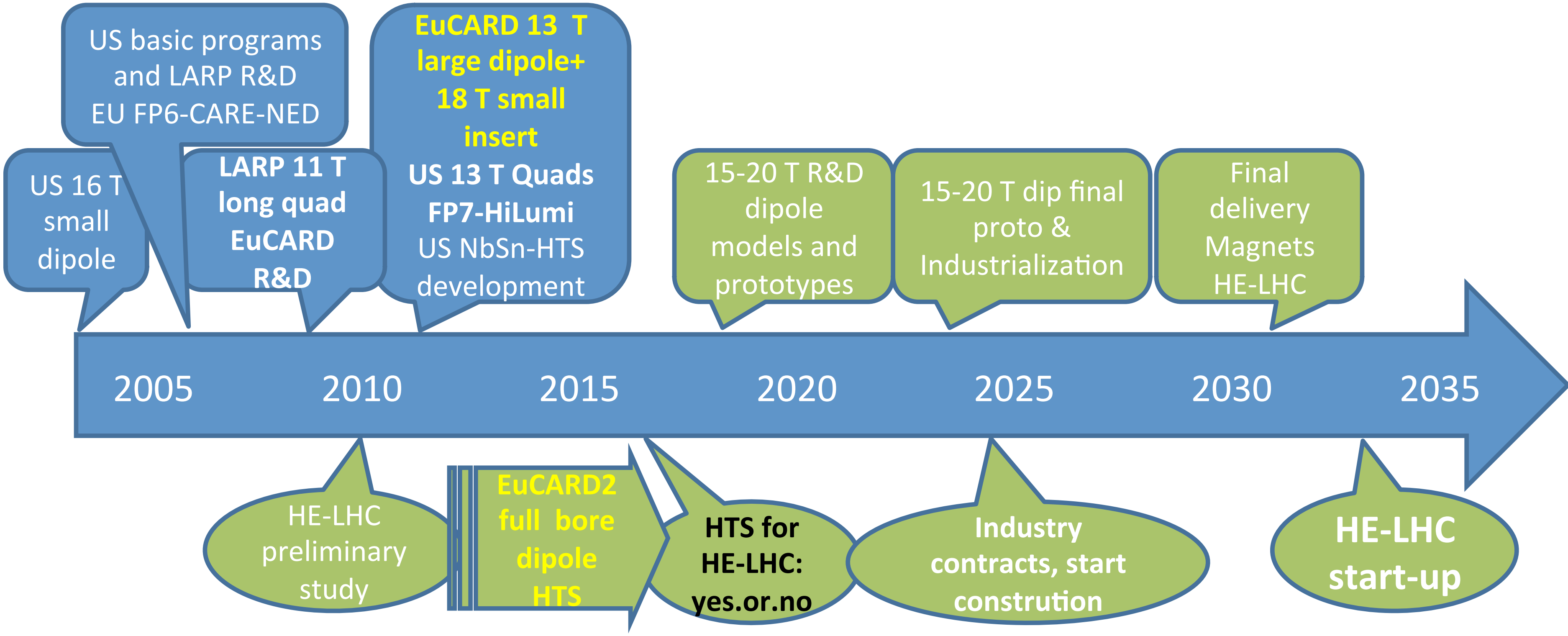
LHC start-up



LARGE HADRON COLLIDER
IN THE LEP TUNNEL

From L. Rossi, CERN

… so an intense R&D programme is required to continue rigorously now if HE-LHC should become a real option for following the HL-LHC in the 2030s



US 16 T
small
dipole

US basic programs
and LARP R&D
EU FP6-CARE-NED

LARP 11 T
long quad
EuCARD
R&D

EuCARD 13 T
large dipole+
18 T small
insert
US 13 T Quads
FP7-HiLumi
US NbSn-HTS
development

15-20 T R&D
dipole
models and
prototypes

15-20 T dip final
proto &
Industrialization

Final
delivery
Magnets
HE-LHC

2005 2010 2015 2020 2025 2030 2035

HE-LHC
preliminary
study

EuCARD2
full bore
dipole
HTS

HTS for
HE-LHC:
yes.or.no

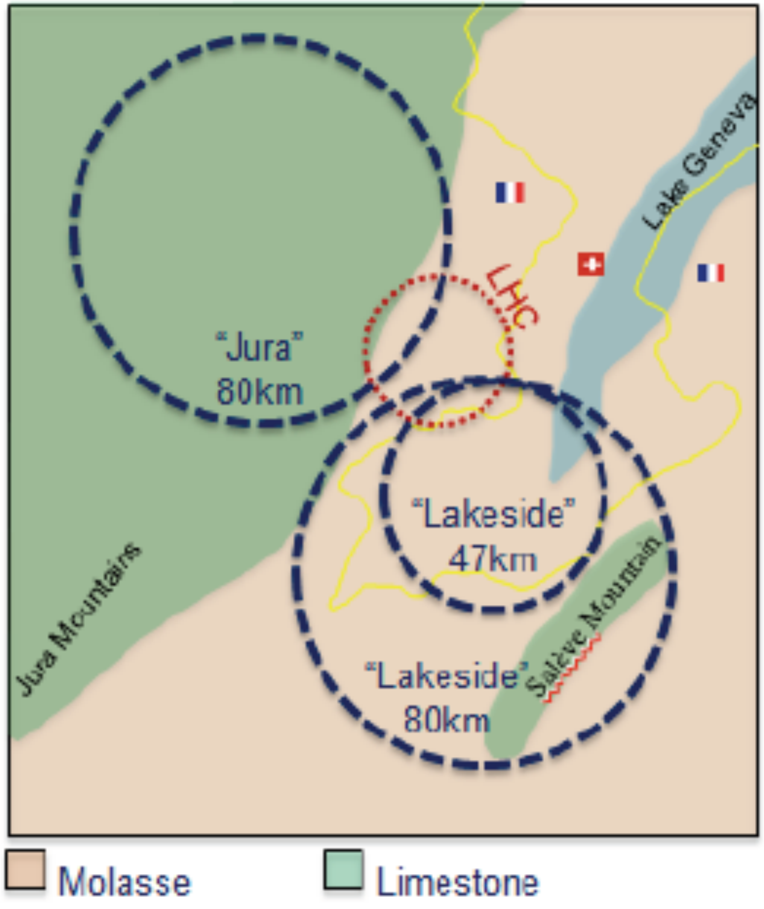
Industry
contracts, start
constrution

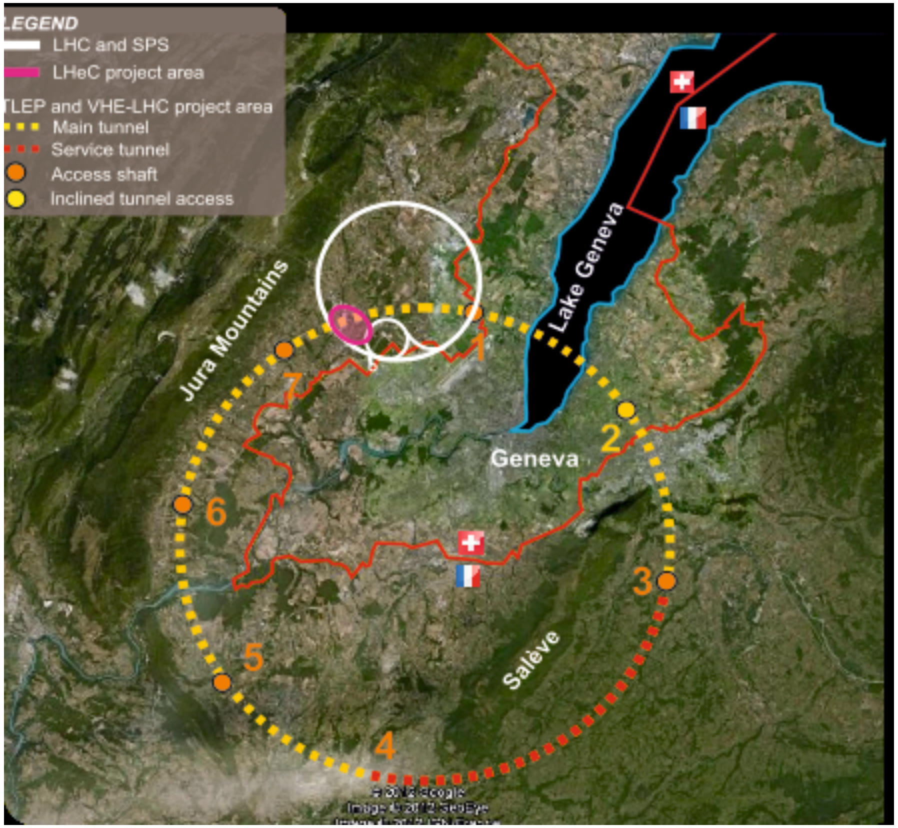
HE-LHC
start-up

HL-LHC work as a test bed

From L. Rossi, CERN

Looking further ahead, options for a new ring tunnel



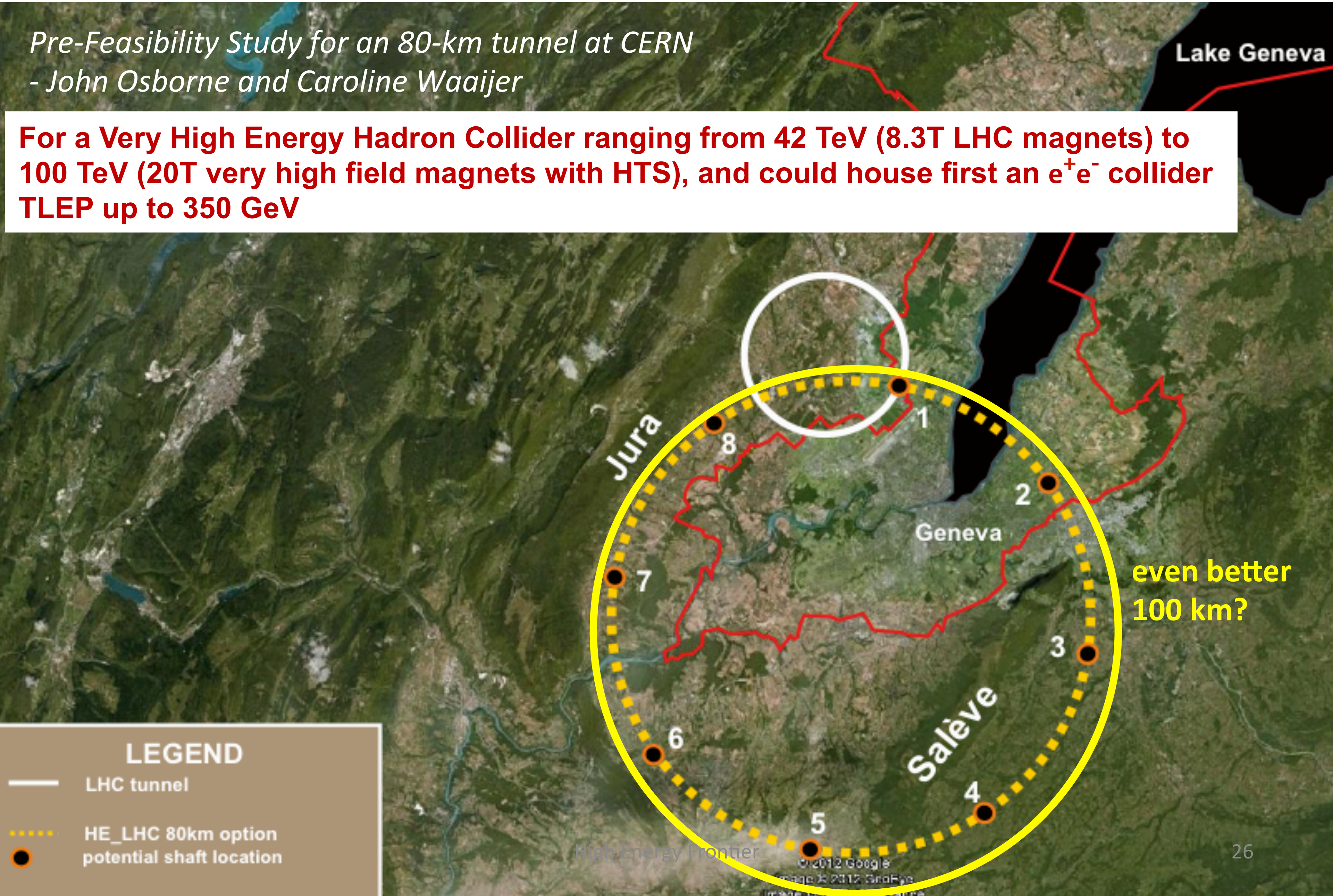


ES Open Symp. Contr. ID=165,
CERN-ATS-2012-237

Lake-side option kept for further studies

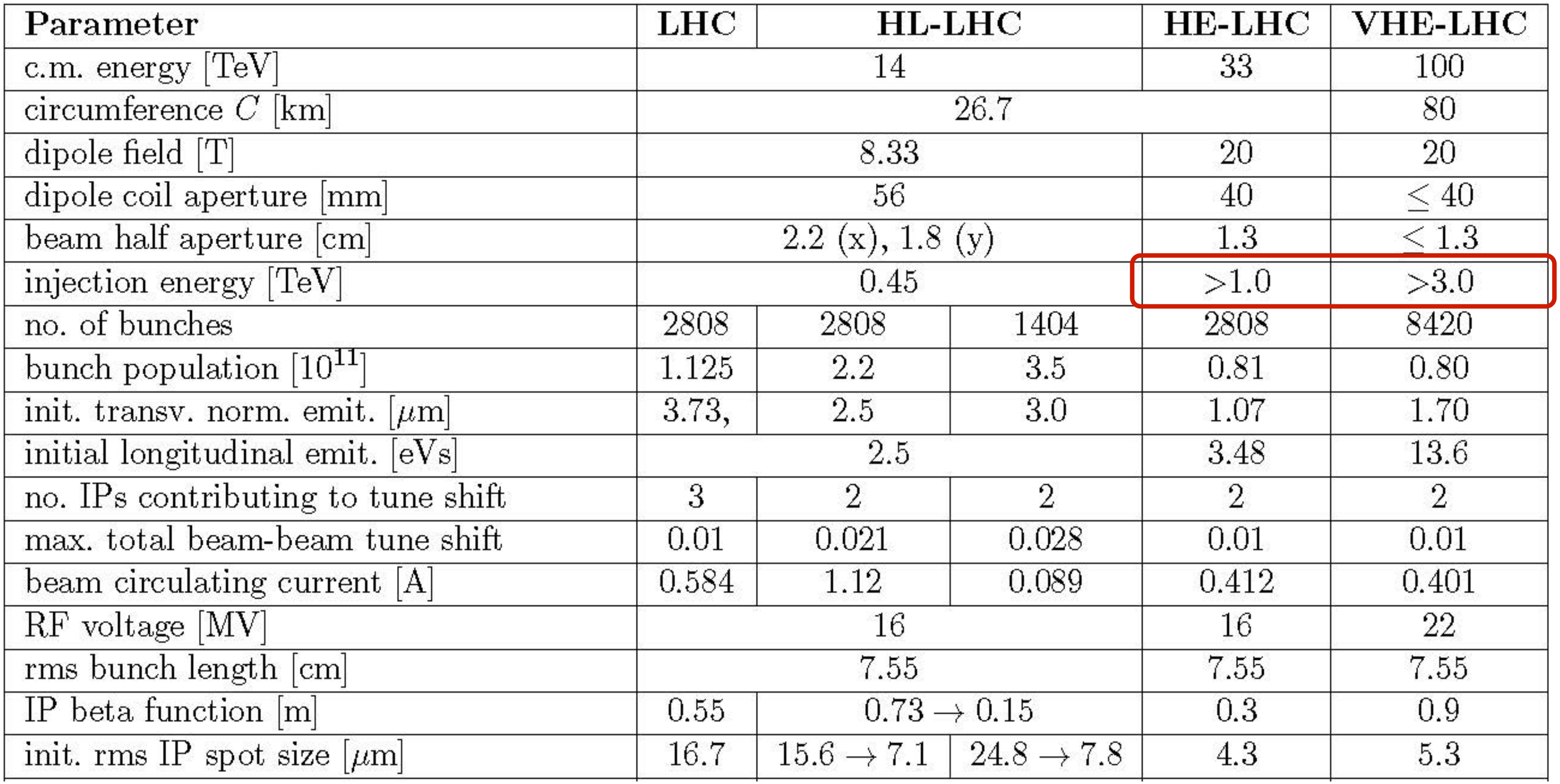
Pre-Feasibility Study for an 80-km tunnel at CERN
- John Osborne and Caroline Waaijer

For a Very High Energy Hadron Collider ranging from 42 TeV (8.3T LHC magnets) to 100 TeV (20T very high field magnets with HTS), and could house first an e^+e^- collider TLEP up to 350 GeV



even better
100 km?

Parameters for the hadron collider ‘family’ at CERN



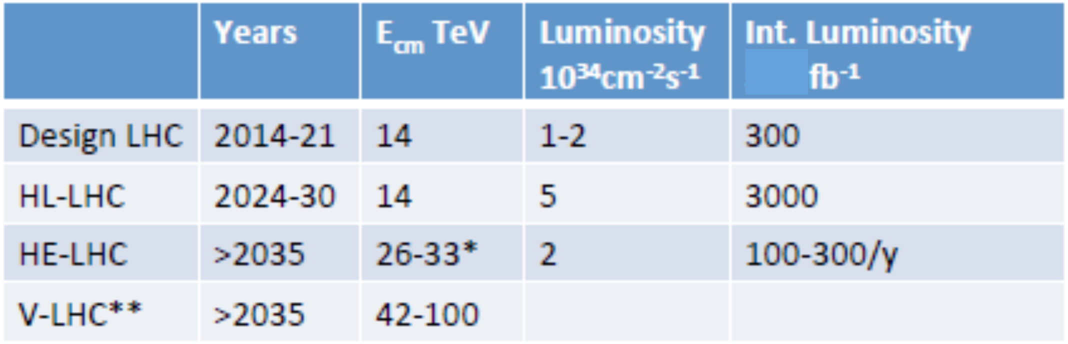
Parameter	LHC	HL-LHC		HE-LHC	VHE-LHC
c.m. energy [TeV]	14			33	100
circumference C [km]	26.7				80
dipole field [T]	8.33			20	20
dipole coil aperture [mm]	56			40	≤ 40
beam half aperture [cm]	2.2 (x), 1.8 (y)			1.3	≤ 1.3
injection energy [TeV]	0.45			>1.0	>3.0
no. of bunches	2808	2808	1404	2808	8420
bunch population $[10^{11}]$	1.125	2.2	3.5	0.81	0.80
init. transv. norm. emit. [μm]	3.73,	2.5	3.0	1.07	1.70
initial longitudinal emit. [eVs]	2.5			3.48	13.6
no. IPs contributing to tune shift	3	2	2	2	2
max. total beam-beam tune shift	0.01	0.021	0.028	0.01	0.01
beam circulating current [A]	0.584	1.12	0.089	0.412	0.401
RF voltage [MV]	16			16	22
rms bunch length [cm]	7.55			7.55	7.55
IP beta function [m]	0.55	$0.73 \rightarrow 0.15$		0.3	0.9
init. rms IP spot size [μm]	16.7	$15.6 \rightarrow 7.1$	$24.8 \rightarrow 7.8$	4.3	5.3

Stored energy [MJ]	362	694	601	4573
Peak luminosity [10^{34} cm^{-2}s^{-1}]	1	(7.4)	5	5

O.Dominguez, L.Rossi, F.Zimmermann

Collider options for the high energy frontier

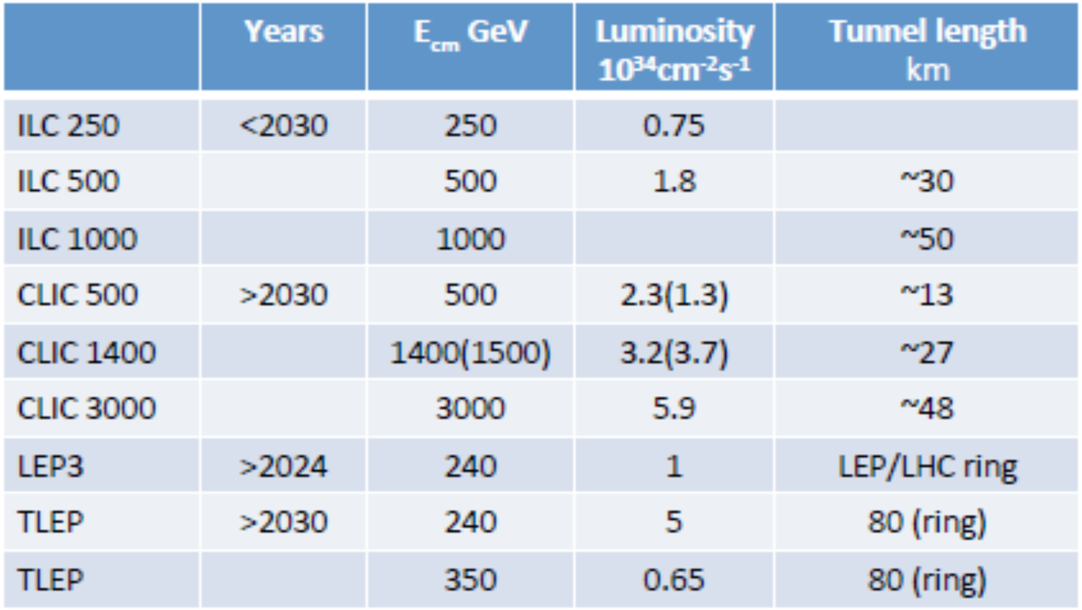
pp colliders



	Years	E_{cm} TeV	Luminosity $10^{34}cm^{-2}s^{-1}$	Int. Luminosity fb^{-1}
Design LHC	2014-21	14	1-2	300
HL-LHC	2024-30	14	5	3000
HE-LHC	>2035	26-33*	2	100-300/y
V-LHC**	>2035	42-100		

* 16-20 T dipole field
** 80 km Tunnel

e+e- colliders



	Years	E_{cm} GeV	Luminosity $10^{34}cm^{-2}s^{-1}$	Tunnel length km
ILC 250	<2030	250	0.75	
ILC 500		500	1.8	~30
ILC 1000		1000		~50
CLIC 500	>2030	500	2.3(1.3)	~13
CLIC 1400		1400(1500)	3.2(3.7)	~27
CLIC 3000		3000	5.9	~48
LEP3	>2024	240	1	LEP/LHC ring
TLEP	>2030	240	5	80 (ring)
TLEP		350	0.65	80 (ring)

Other options:

$\mu^+\mu^-$ and $\gamma\gamma$ colliders with similar physics as e^+e^- colliders

LHeC for ep collisions

See ES Briefing Book for references

ilc international linear collider

ES Open Symp. Contr. ID=73,
ES Open Symp. Contr. ID=121

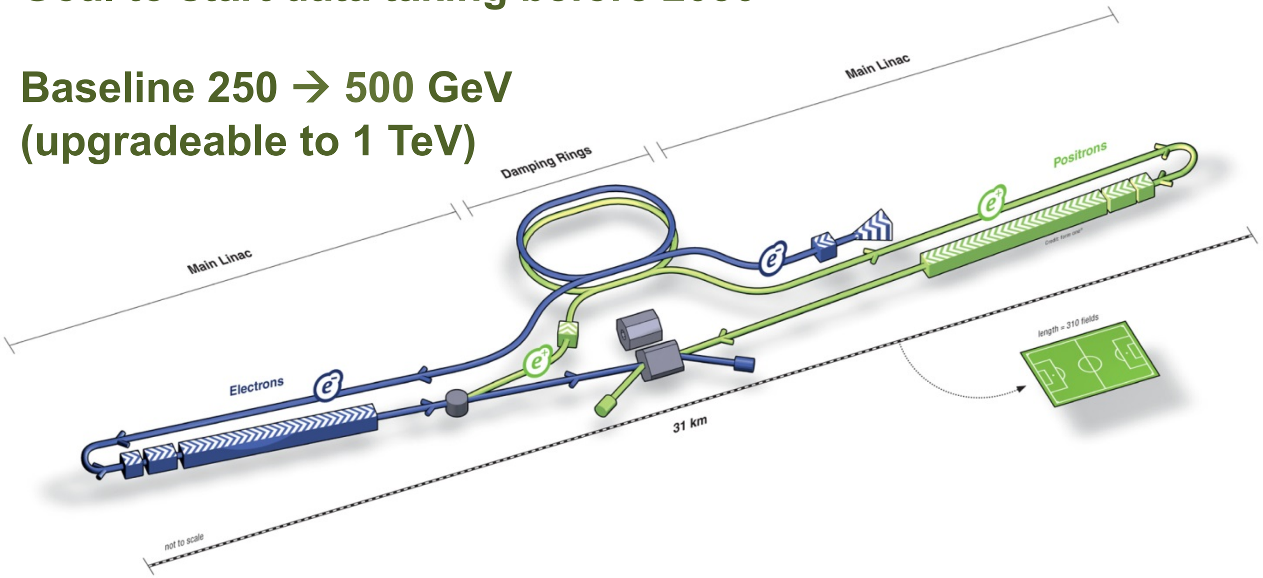
Mature detailed TDR studies based on extensive R&D

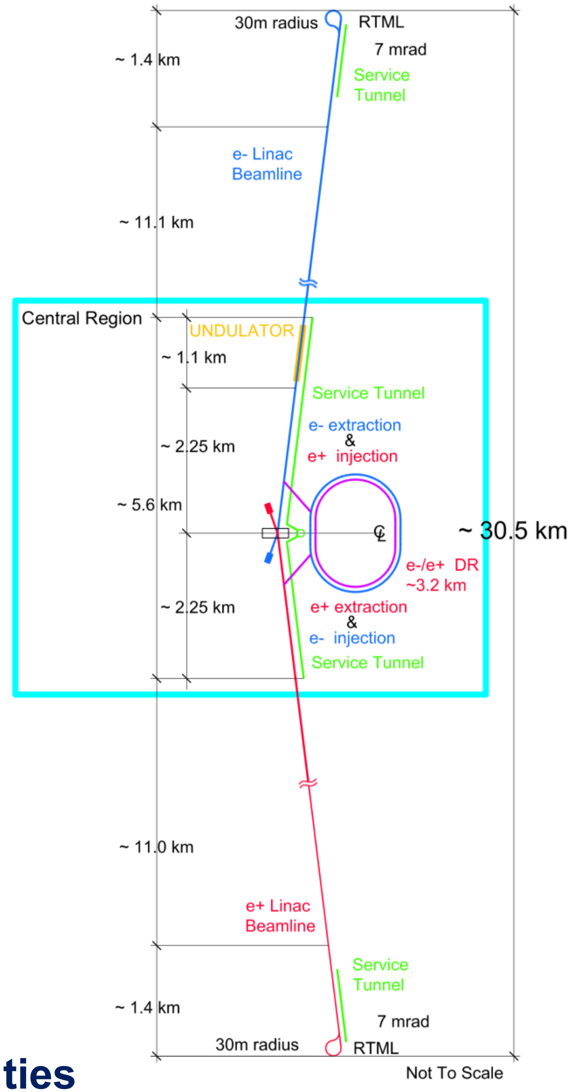
Industrial production of cavities (established for XFEL)

Major Japanese community initiative to host ILC as a global project, site decision for the proposal to be decided in July 2013

Goal to start data taking before 2030

Baseline 250 → 500 GeV
(upgradeable to 1 TeV)





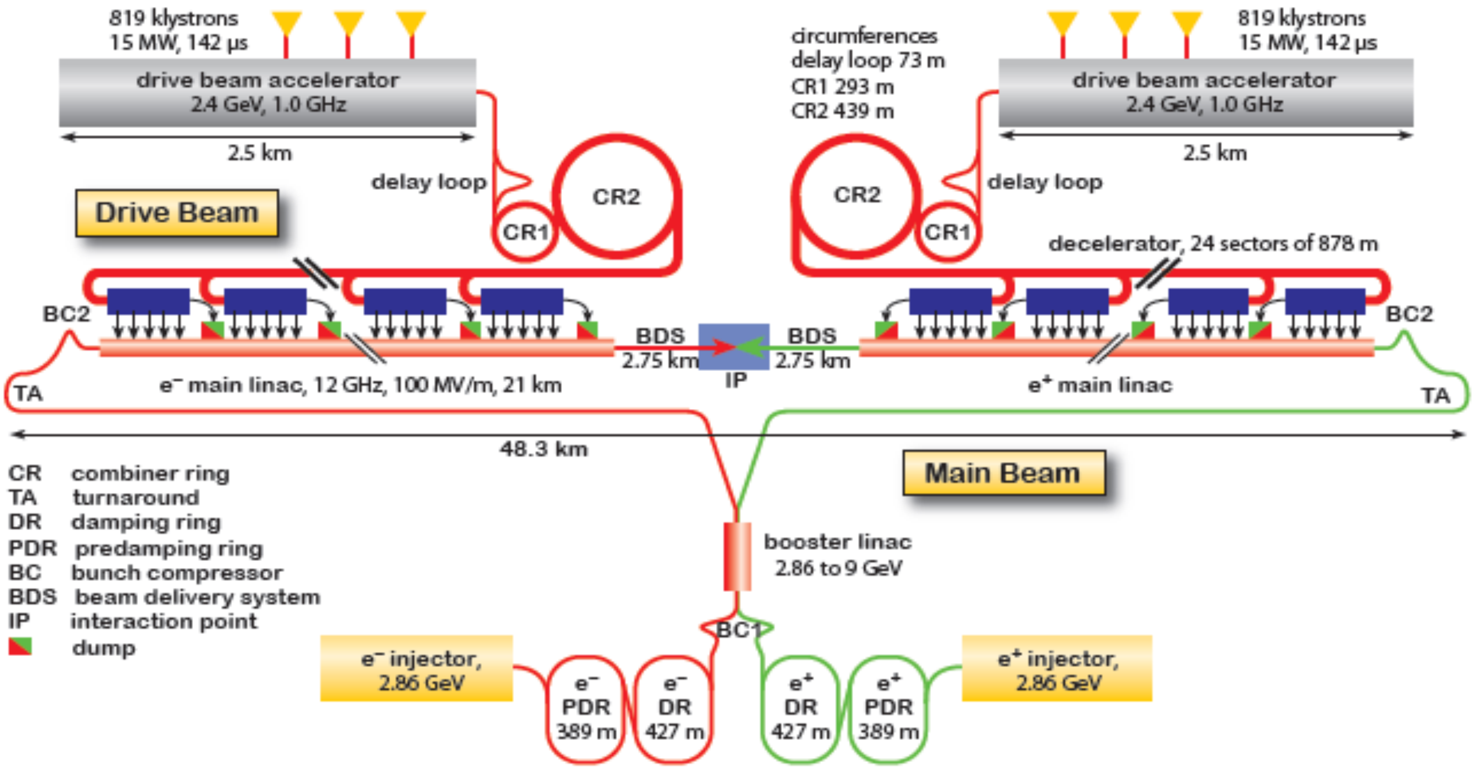
Two single beam linacs with 40 MV/m superconducting RF cavities

Compact Linear Collider CLIC

Detailed CDR studies based on extensive R&D

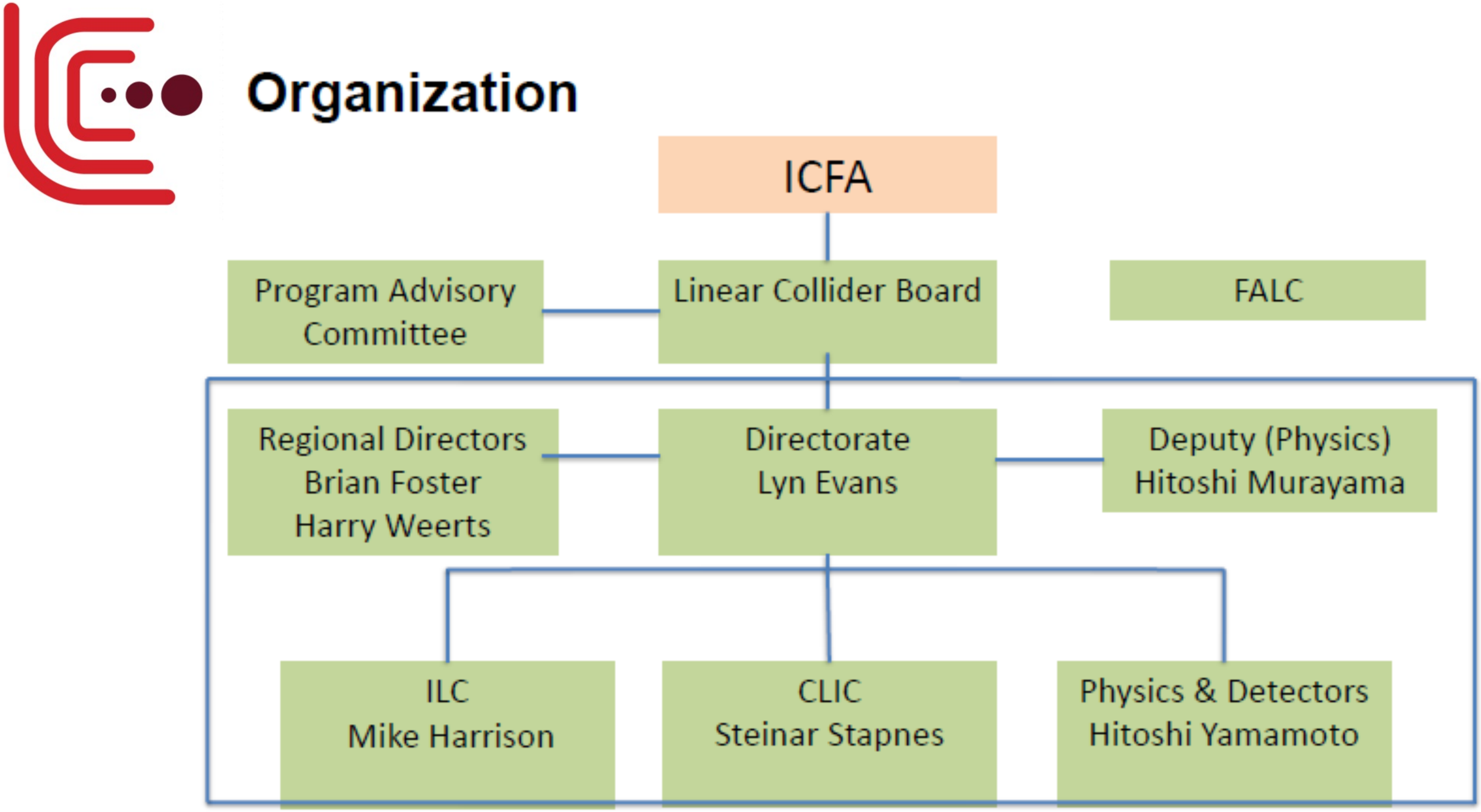
Prove of principle of the two-beam acceleration

ES Open Symp. Contr. ID=99



Two-beam acceleration system with a low energy high current drive beam powering the RF cavities at 100 MV/m of the main linac, energy upgradable in stages 500 – 3000 GeV

Common organization within the Linear Collider Collaboration has been set in place recently



Organization

ICFA

Program Advisory Committee

Linear Collider Board

FALC

Regional Directors
Brian Foster
Harry Weerts

Directorate
Lyn Evans

Deputy (Physics)
Hitoshi Murayama

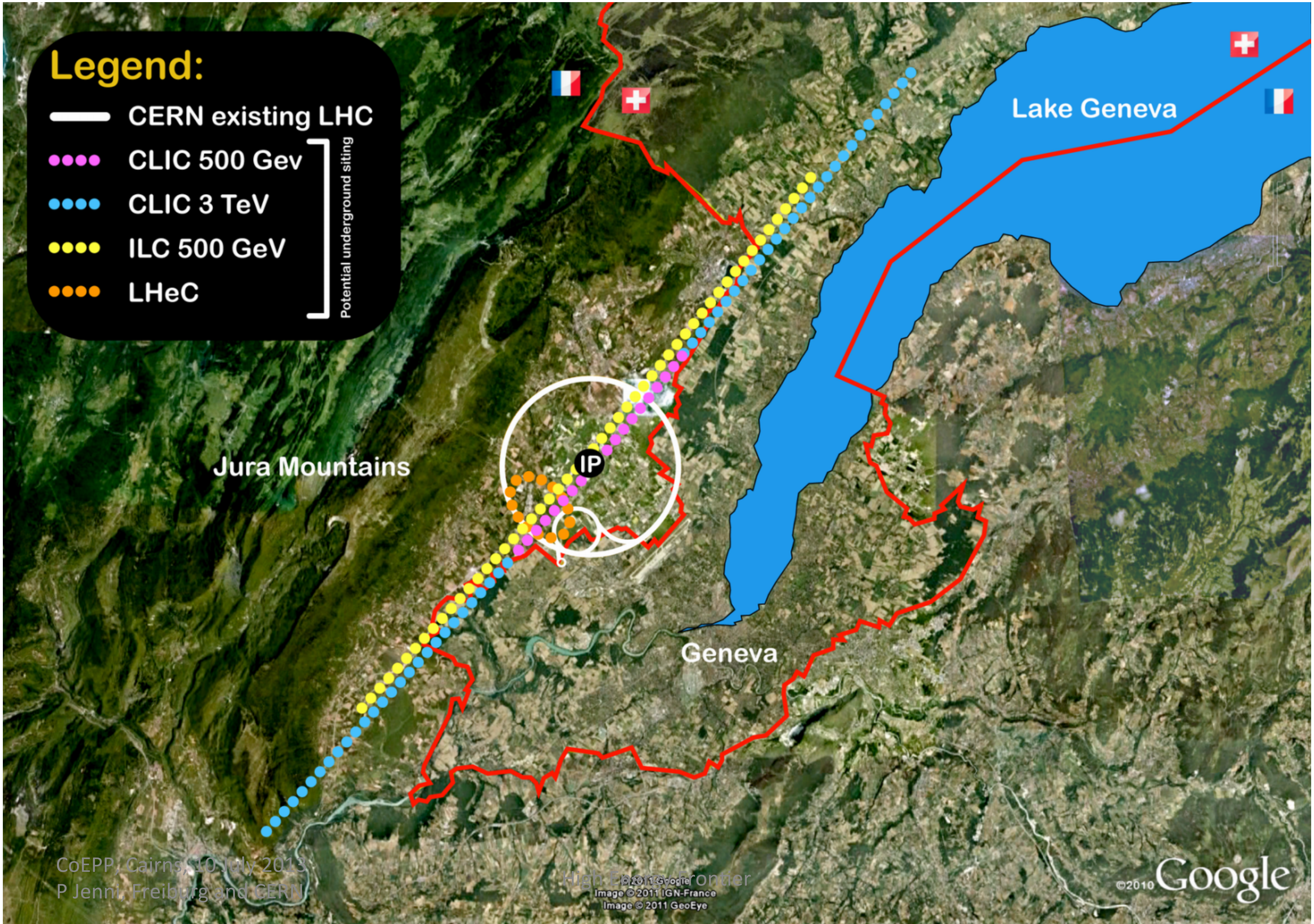
ILC
Mike Harrison

CLIC
Steinar Stapnes

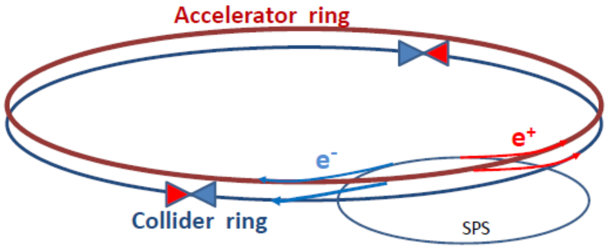
Physics & Detectors
Hitoshi Yamamoto

Indicating the Scale for Liner Colliders

(Taken from C. Biscari, ‘High Energy Accelerators’, Krakow ES Symposium)



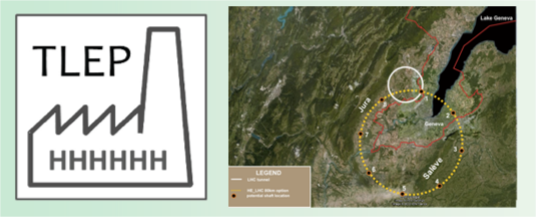
Circular e+e- Colliders



Strong revival of interest in 'conventional' Circular Colliders:

-Very high luminosities achievable

-More than one experiment



LEP3: 240 GeV machine in the LHC tunnel

TLEP: 350 GeV machine in a new 80 km tunnel

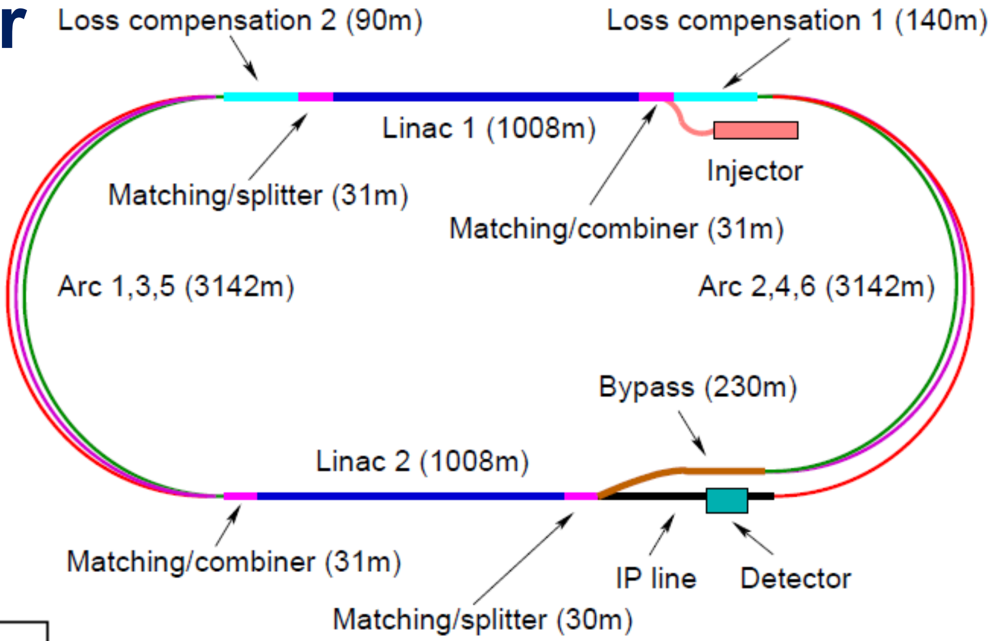
	LEP3	**TLEP**
circumference	26.7 km	80 km
max beam energy	120 GeV	175 GeV
max no. of IPs	4	4
luminosity at 350 GeV c.m.	-	0.7×10^{34} cm^{-2}s^{-1}
luminosity at 240 GeV c.m.	10^{34} cm^{-2}s^{-1}	5×10^{34} cm^{-2}s^{-1}
luminosity at 160 GeV c.m.	5×10^{34} cm^{-2}s^{-1}	2.5×10^{35} cm^{-2}s^{-1}
luminosity at 90 GeV c.m.	2×10^{35} cm^{-2}s^{-1}	10^{36} cm^{-2}s^{-1}

ES Open Symp. Contr. ID=138, 157, 173

Electron Proton Collider

Detailed CDR has been published

Option of eA collisions



parameter [unit]	LHeC	
species	e	p, $^{208}\mathrm{Pb}^{82+}$
beam energy (/nucleon) [GeV]	60	7000, 2760
bunch spacing [ns]	25, 100	25, 100
bunch intensity (nucleon) [10^{10}]	0.1 (0.2), 0.4	17 (22), 2.5
beam current [mA]	6.4 (12.8)	860 (1110), 6
rms bunch length [mm]	0.6	75.5
polarization [%]	90 (e^+ none)	none, none
normalized rms emittance [μm]	50	3.75 (2.0), 1.5
geometric rms emittance [nm]	0.43	0.50 (0.31)
IP beta function $\beta^*_{x,y}$ [m]	0.12 (0.032)	0.1 (0.05)
IP spot size [μm]	7.2 (3.7)	7.2 (3.7)
synchrotron tune Q_s	—	1.9×10^{-3}
hadron beam-beam parameter	0.0001 (0.0002)	
lepton disruption parameter D	6 (30)	
crossing angle	0 (detector-integrated dipole)	
hourglass reduction factor H_{hg}	0.91 (0.67)	
pinch enhancement factor H_D	1.35 (0.3 for e^+)	
CM energy [TeV]	1.3, 0.81	
luminosity / nucleon [10^{33} cm^{-2}s^{-1}]	1 (10), 0.2	

Interaction point 2 (now ALICE) with LHC

Two 10 GeV linac accelerators in an energy recovery race-track configuration, three turns giving 60 GeV e^- or e+

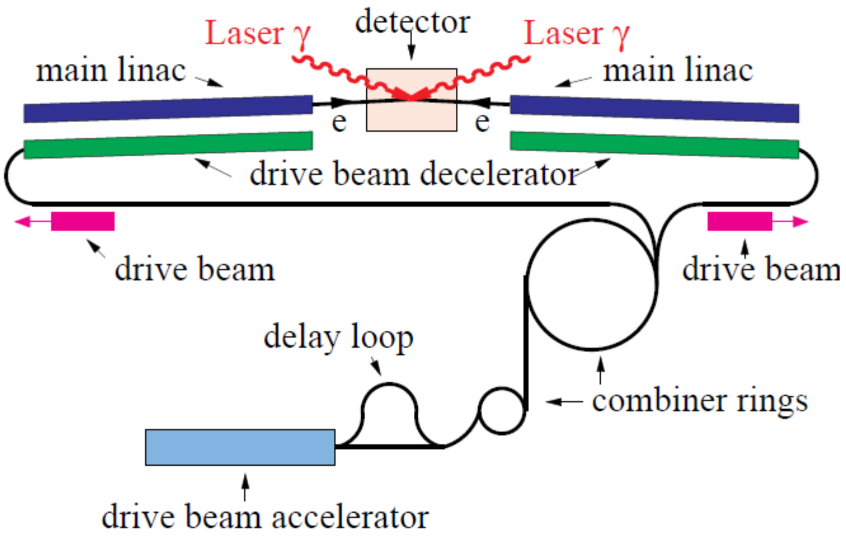
Can reach Q^2_{max} ~ 1 TeV^2

ES Open Symp. Contr. ID=147, 156, 175

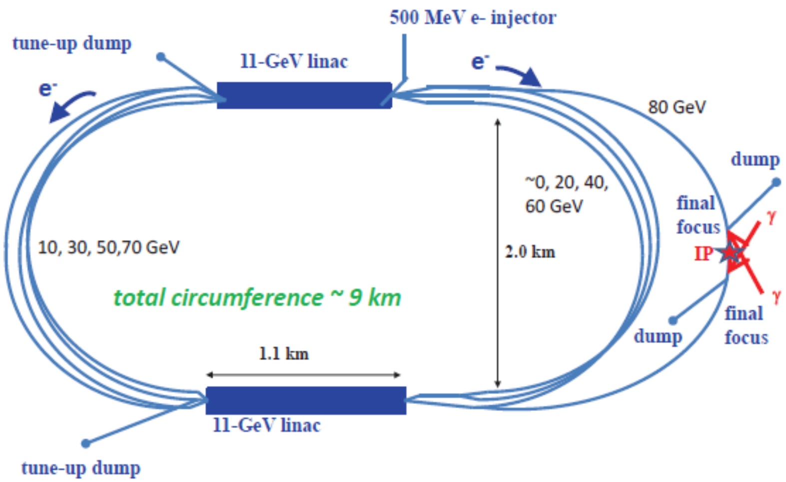
γγ collider options

Technology challenge of a high-power laser back-scatter system

CLIC technology based



SAPPHiRE
‘a small γγ Higgs factory’

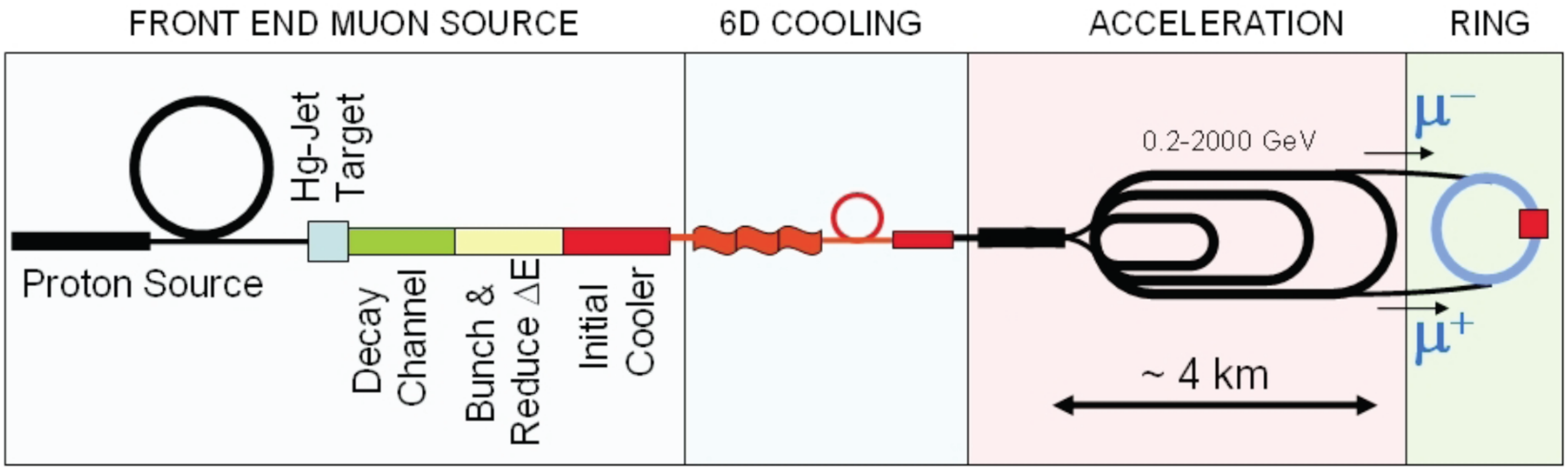


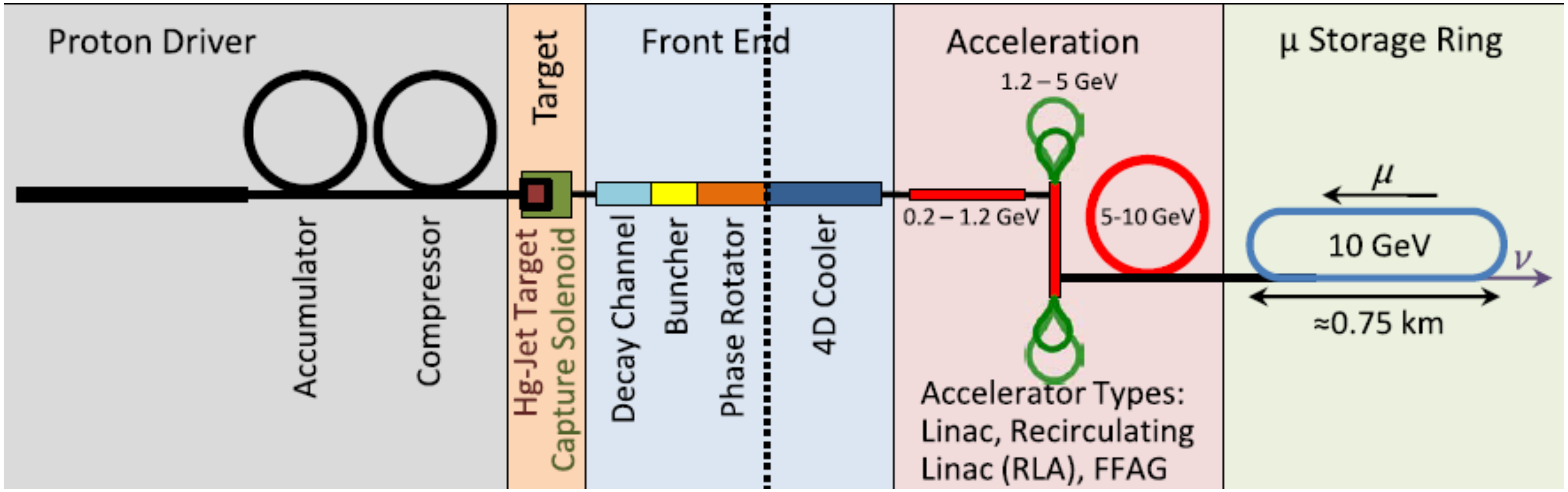
γγ collisions at Vs = 125.5 GeV (s-channel Higgs production)

ES Open Symp. Contr. ID=145

Muon Collider / Neutrino Factory

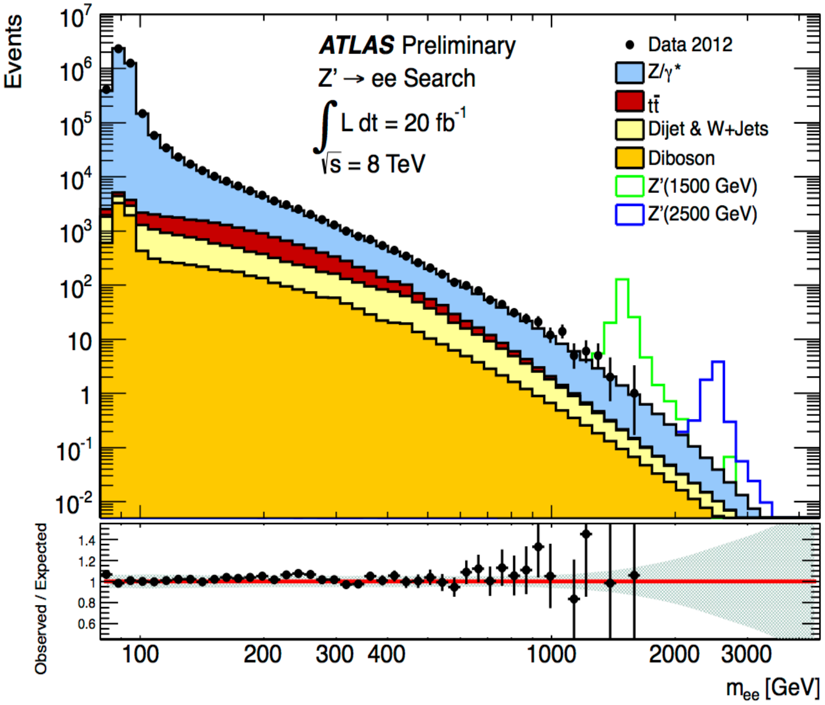
Many technical challenges, interesting potential (s-channel H production)



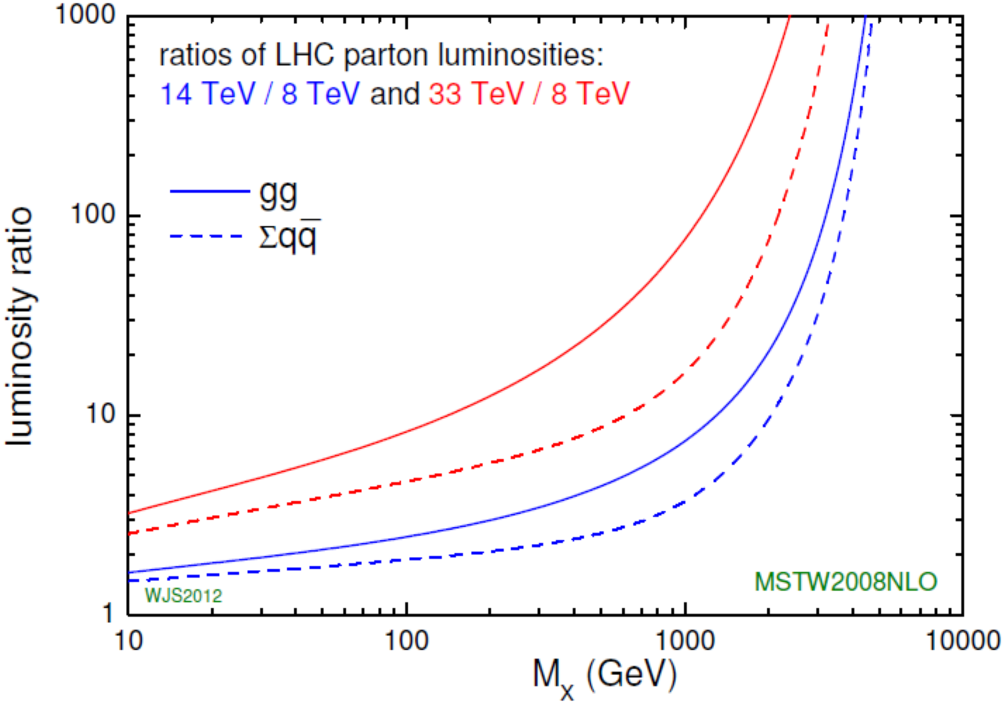


Turning to some physics remarks now …

Hadron colliders are the only realistic option to access very high-mass objects directly, and increasing the collision energy extends the mass reach most strongly



ATLAS-CONF-2013-017



W J Stirling

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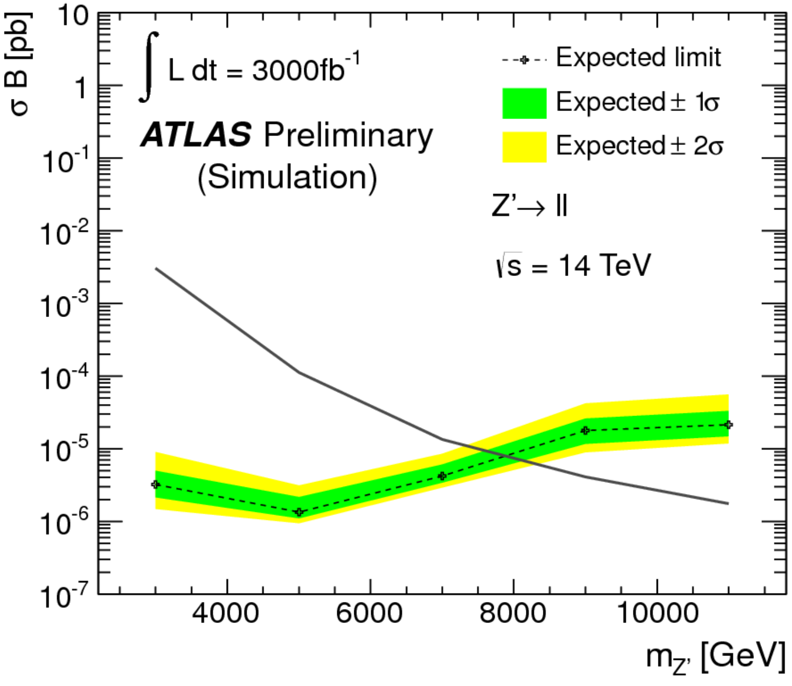
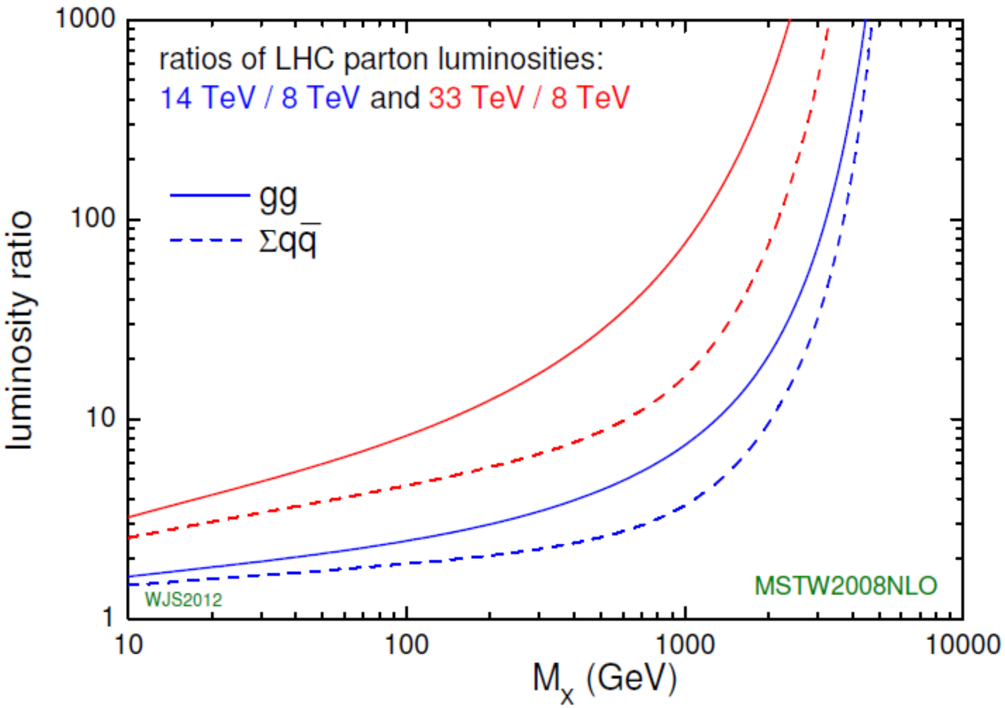


ATLAS-PHYS-PUB-2013-003

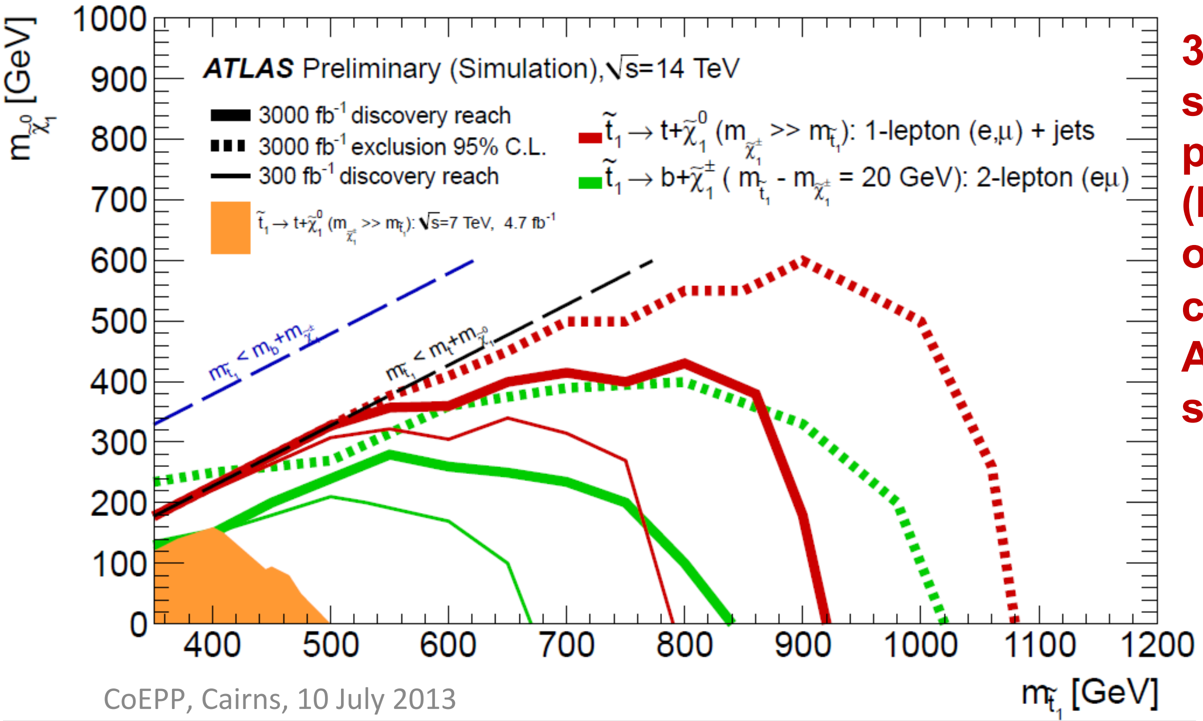


W J Stirling

Beyond Standard Model reach for the HL-LHC

A factor 10 in luminosity gives further room for discoveries:

- Moderate gain in the searches of strongly coupled heavy objects. Typical improvement of about 20% in the mass reach.
- Substantial improvement in probing new states with smaller couplings than those assumed by sequential SM.
- Substantial improvement in probing new states beyond the kinematical reach of 14 TeV through precise measurement of the Higgs properties.



3° generation squark have low x-sect: with 3000 fb^{-1} exclude the parameter space for a light stop (below 1 TeV) no matter the value of the LSP mass... A definitive challenge to SUSY & naturalness). And in case of discovery enough statistics for further studies...

From 'High Energy Frontier' presented by Marcella Diemoz at the ES Erice

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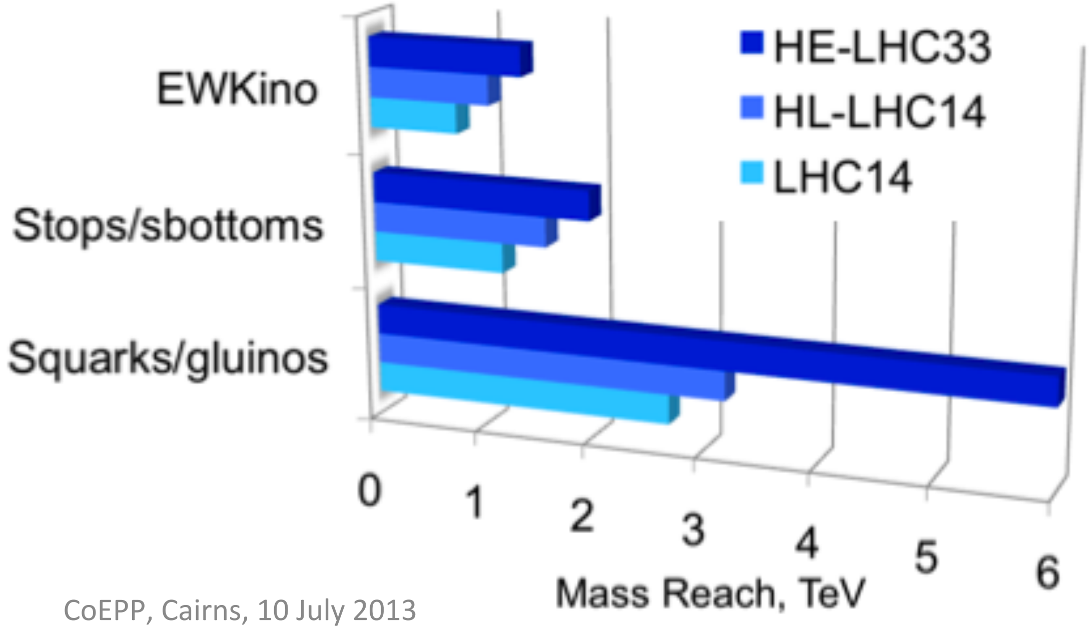

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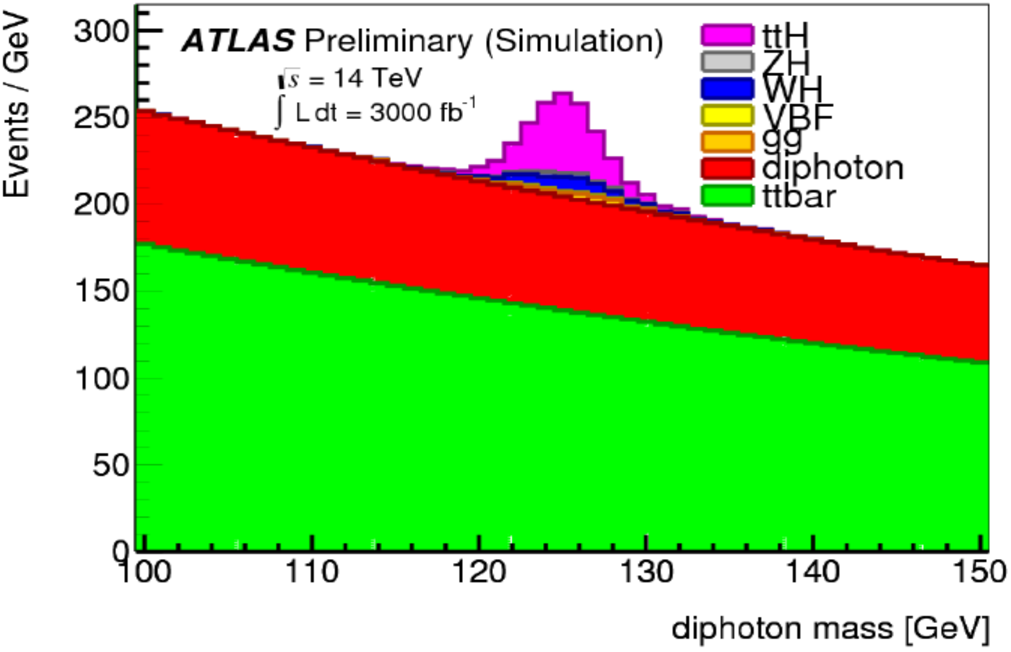
ES Open Symp. Contr. ID=141, 174

ES Open Symp. Contr. ID=144, 177

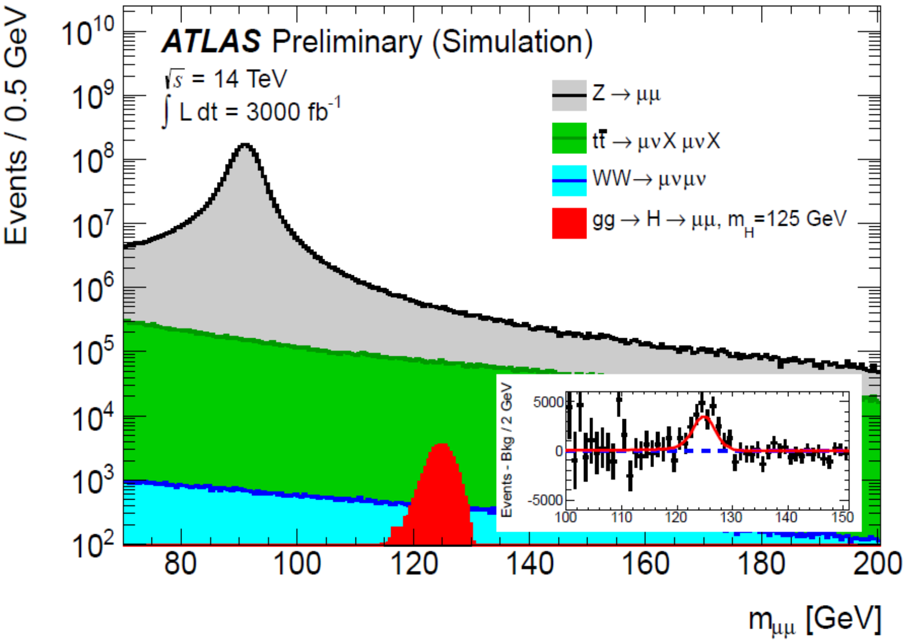
Standard Model physics examples for pp and e+e-

Examples from the HL-LHC Higgs studies of ATLAS and CMS

ES Open Symp. Contr. ID=141, 174



ttH(γγ)

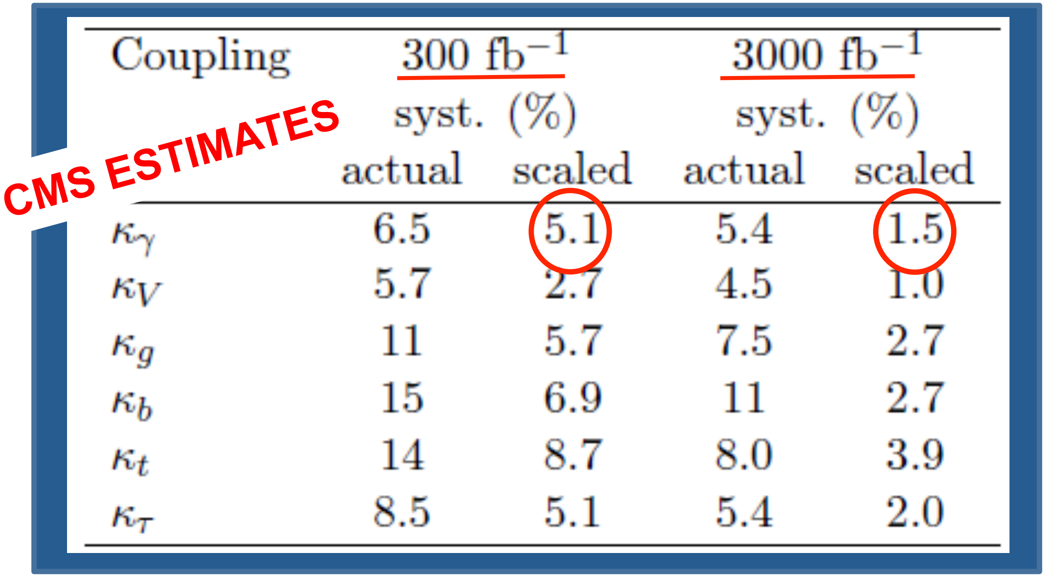


H(μμ)

Access to rare production and decay processes

Profit from statistics:

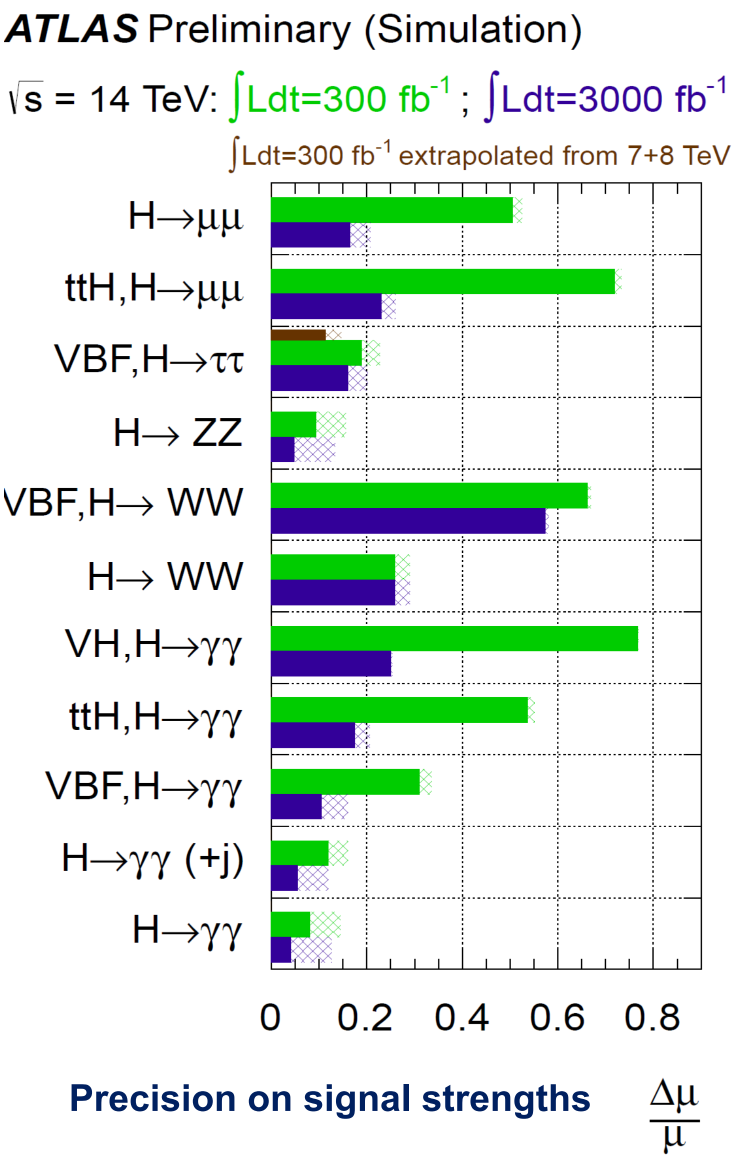
- rare H production channels
- rare H decay channels
- H couplings
- Higgs self coupling (HH detection)
- VBS: dynamics of EWSB (is it SM?)
- New physics with suppressed couplings



CMS ESTIMATES

Coupling	300 fb^{-1}		3000 fb^{-1}	
	syst. (%)		syst. (%)	
	actual	scaled	actual	scaled
κ_γ	6.5	5.1	5.4	1.5
κ_V	5.7	2.7	4.5	1.0
κ_g	11	5.7	7.5	2.7
κ_b	15	6.9	11	2.7
κ_t	14	8.7	8.0	3.9
κ_τ	8.5	5.1	5.4	2.0

ES Open Symp. Contr. ID=144, 177



Precision on signal strengths

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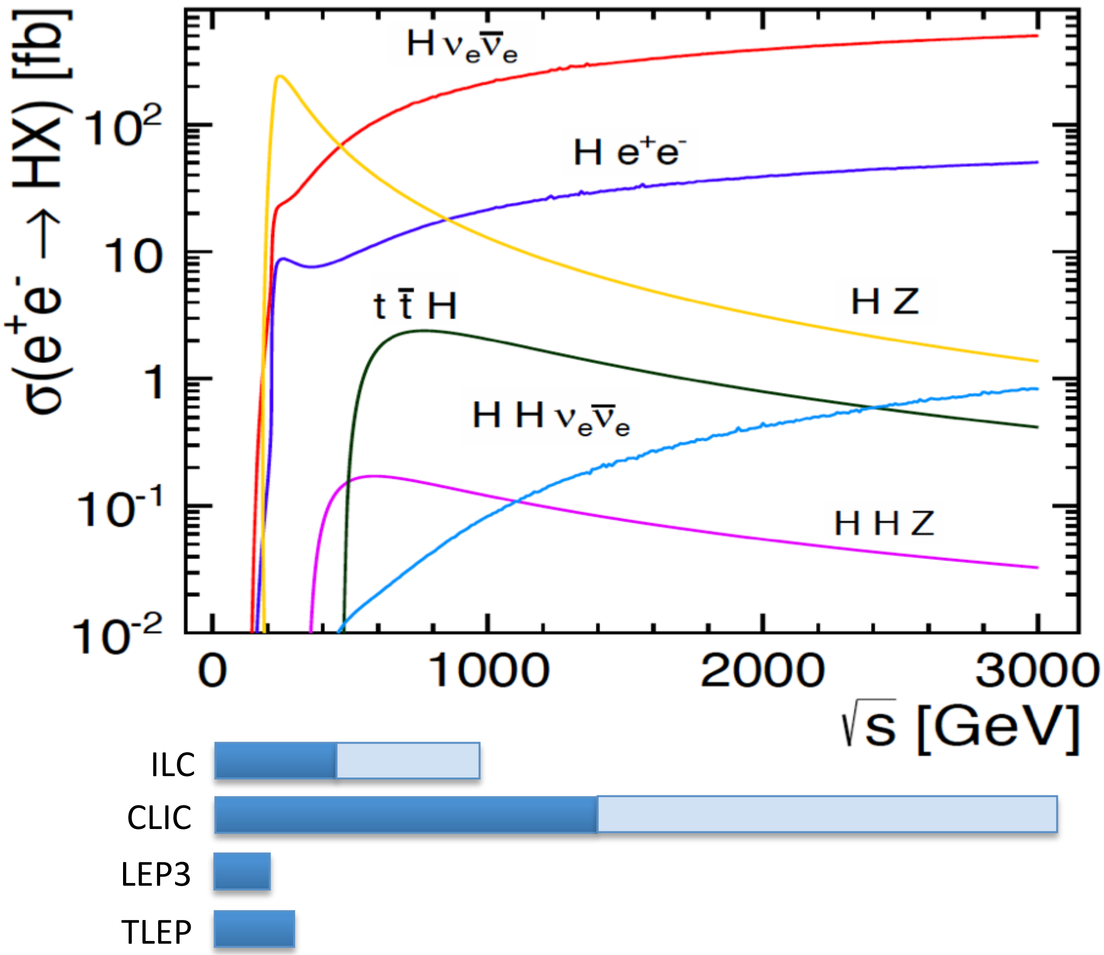
Precision Higgs measurements at e+e-

From 'High Energy Frontier' presented by Marcella Diemoz at the ES Erice



ZH ev
$H\nu_e\bar{\nu}_e$

Mass
g_Z (m.i.)
BR´s
(LHC)-invisible

$\sigma(e^+e^-$
Int. $\mathcal{L}$
ZH ev
$H\nu_e\bar{\nu}$

Γ_{tot}

ZH ev
$H\nu_e\bar{\nu}_e$

g_t (ILC,CLIC)

Int. $\mathcal{L}$
ZH eve
$H\nu_e\bar{\nu}_e$

g_{HHH} (ILC500)

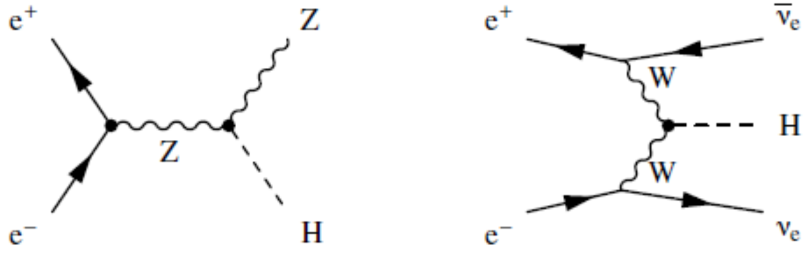
$\sigma(e^+e^-$
Int. $\mathcal{L}$
ZH ev
$H\nu_e\bar{\nu}$

g_{HHH} (ILC1000, CLIC)

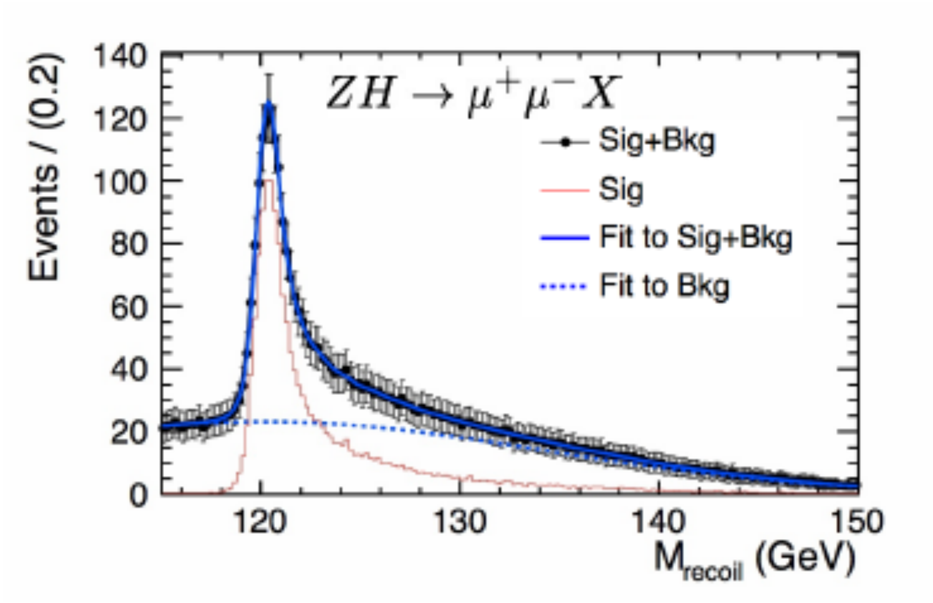
Many processes at different √s needed & accessible
HZ (at 250-350 GeV): recoil mass as anchor for model-independence

LC Higgs physics

ES Open Symp. Contr. ID=69



	250 GeV	350 GeV	500 GeV	1 TeV	1.5 TeV	3 TeV
$\sigma(e^+e^- \to ZH)$	240 fb	129 fb	57 fb	13 fb	6 fb	1 fb
$\sigma(e^+e^- \to H\nu_e\bar{\nu}_e)$	8 fb	30 fb	75 fb	210 fb	309 fb	484 fb
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}	500 fb^{-1}	1000 fb^{-1}	1500 fb^{-1}	2000 fb^{-1}
# ZH events	60,000	45,500	28,500	13,000	7,500	2,000
# $H\nu_e\bar{\nu}_e$ events	2,000	10,500	37,500	210,000	460,000	970,000



ILC/CLIC

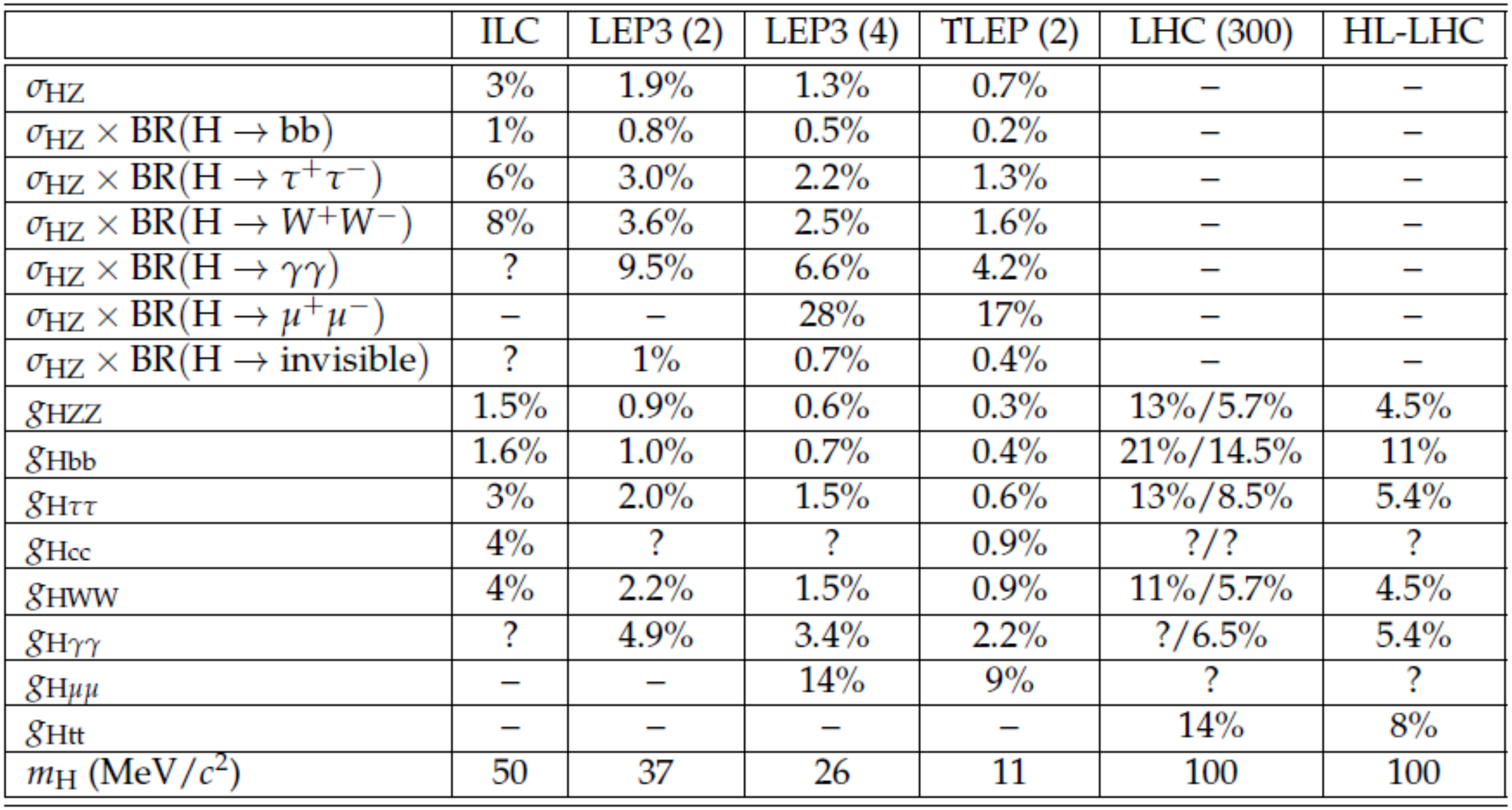
The Higgs boson mass can
from the direct reconstruction
a factor of two better than cu
determined from a scan of the
boson and its decay products.

Typical recoil mass distribution, for model-independent H studies

250/350 fb^{-1} **500 fb^{-1}** **1000 fb^{-1}**

Global summary table (as compiled by TLEP)

ES Open Symp. Contr. ID=171, 173

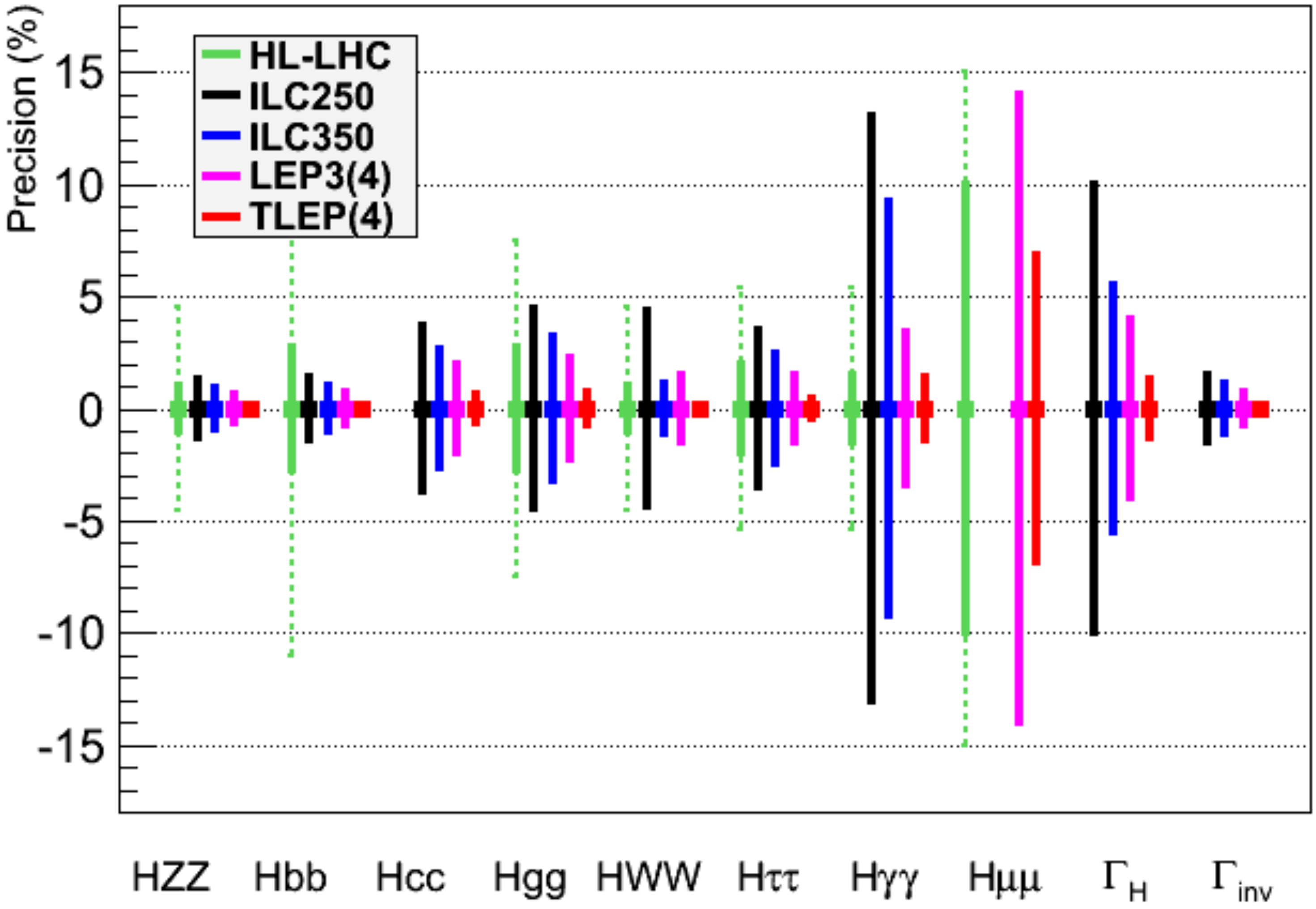


	ILC	LEP3 (2)	LEP3 (4)	TLEP (2)	LHC (300)	HL-LHC
σ_{HZ}	3%	1.9%	1.3%	0.7%	–	–
$\sigma_{HZ} \times BR(H \to bb)$	1%	0.8%	0.5%	0.2%	–	–
$\sigma_{HZ} \times BR(H \to \tau^+\tau^-)$	6%	3.0%	2.2%	1.3%	–	–
$\sigma_{HZ} \times BR(H \to W^+W^-)$	8%	3.6%	2.5%	1.6%	–	–
$\sigma_{HZ} \times BR(H \to \gamma\gamma)$	?	9.5%	6.6%	4.2%	–	–
$\sigma_{HZ} \times BR(H \to \mu^+\mu^-)$	–	–	28%	17%	–	–
$\sigma_{HZ} \times BR(H \to \text{invisible})$	?	1%	0.7%	0.4%	–	–
g_{HZZ}	1.5%	0.9%	0.6%	0.3%	13%/5.7%	4.5%
g_{Hbb}	1.6%	1.0%	0.7%	0.4%	21%/14.5%	11%
$g_{H\tau\tau}$	3%	2.0%	1.5%	0.6%	13%/8.5%	5.4%
g_{Hcc}	4%	?	?	0.9%	?/?	?
g_{HWW}	4%	2.2%	1.5%	0.9%	11%/5.7%	4.5%
$g_{H\gamma\gamma}$	?	4.9%	3.4%	2.2%	?/6.5%	5.4%
$g_{H\mu\mu}$	–	–	14%	9%	?	?
g_{Htt}	–	–	–	–	14%	8%
m_H (MeV/c^2)	50	37	26	11	100	100

Notes

- LHC and e^+e^- measurements are not directly comparable
- ILC shown for 250/350 GeV, see previous slide for ILC/CLIC
- (2) and (4) for LEP3 and TLEP mean 2 or 4 experiments combined, assuming CMS performance enhanced with upgraded b and c tagging
- Current knowledge of theory systematics below 1% have been questioned

Tentative Higgs coupling summary (from the previous table)



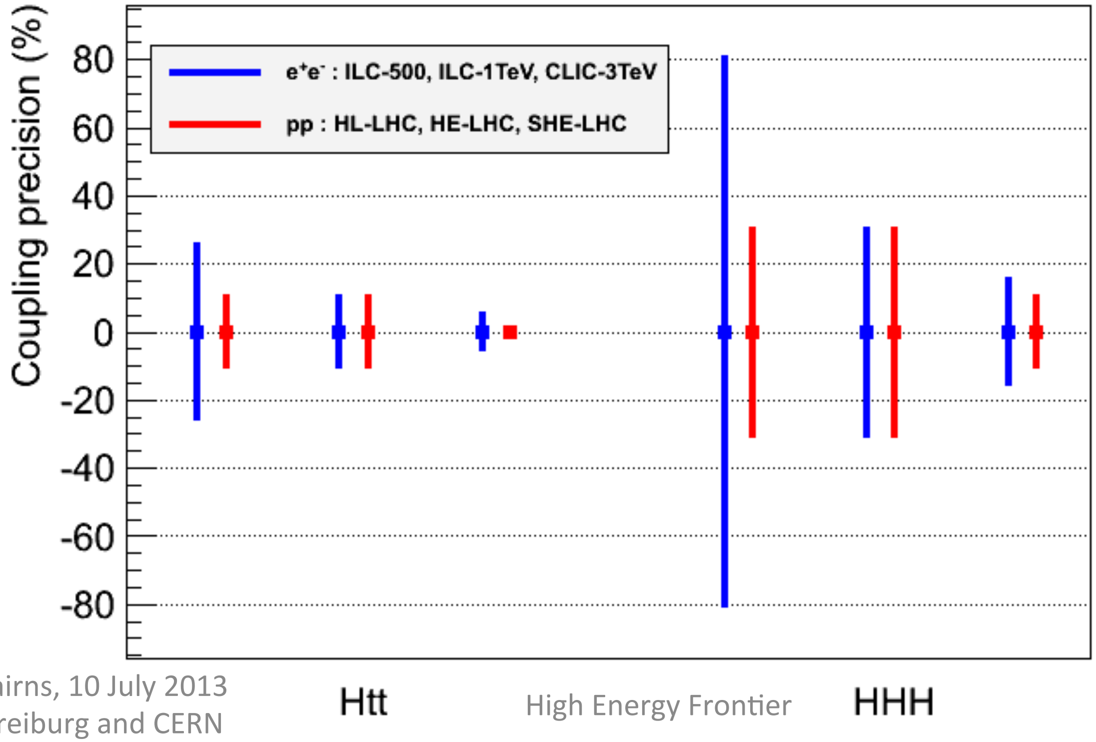
P Janot, TLEP

Looking even further ahead for Higgs couplings…

	σ(14 TeV)	R(33)	R(40)	R(60)	R(80)	R(100)
ggH	50.4 pb	3.5	4.6	7.8	11.2	14.7
VBF	4.40 pb	3.8	5.2	9.3	13.6	18.6
WH	1.63 pb	2.9	3.6	5.7	7.7	9.7
ZH	0.90 pb	3.3	4.2	6.8	9.6	12.5
ttH	0.62 pb	7.3	11	24	41	61
HH	33.8 fb	6.1	8.8	18	29	42

Cross-section ratios at pp colliders w.r.t. the 14 TeV LHC

ES Open Symp. Contr. ID=176

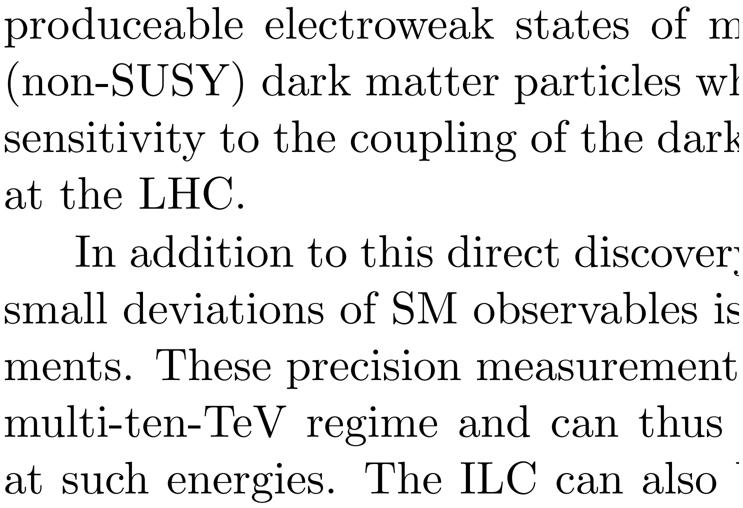


Ultimate precisions for Htt and HHH couplings for three generations of e+e- (blue) and pp (red) colliders

P Janot, TLEP

There are many examples of e+e- precision measurements to test the consistency and stability of the Standard Model

Prime example is the top mass measurement



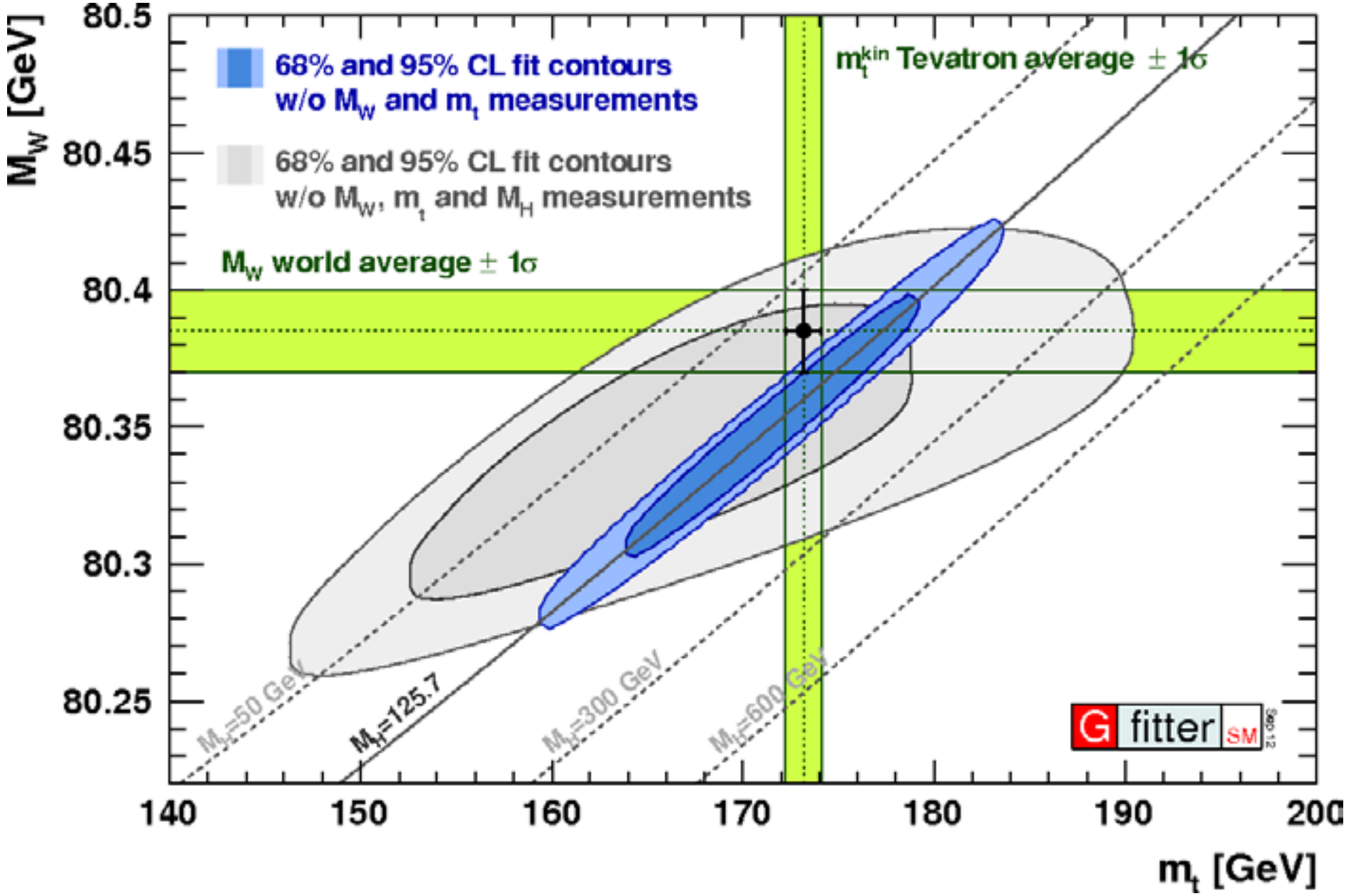
produceable electroweak states of m
(non-SUSY) dark matter particles w
sensitivity to the coupling of the dark
at the LHC.

In addition to this direct discover
small deviations of SM observables i
ments. These precision measurement
multi-ten-TeV regime and can thus
at such energies. The ILC can also

- Δm_{top} = 20 MeV (stat.)
  100 MeV (theo.)
- $\Delta\Gamma_{top}$ = 30 MeV

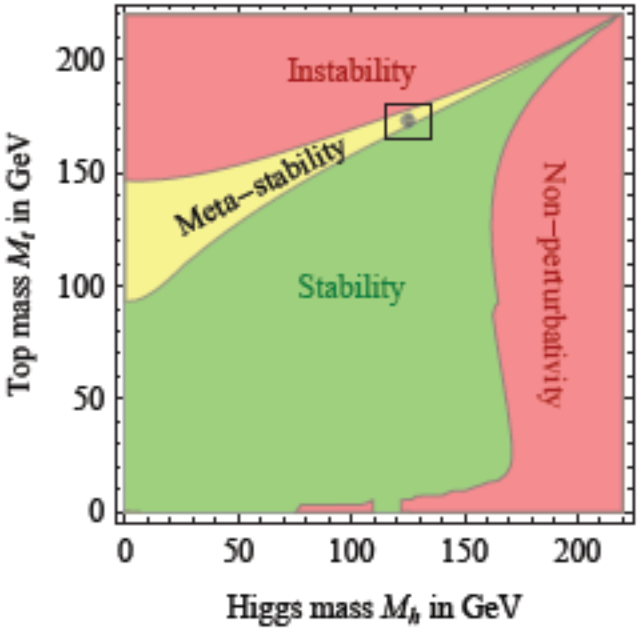
ES Open Symp. Contr. ID=69

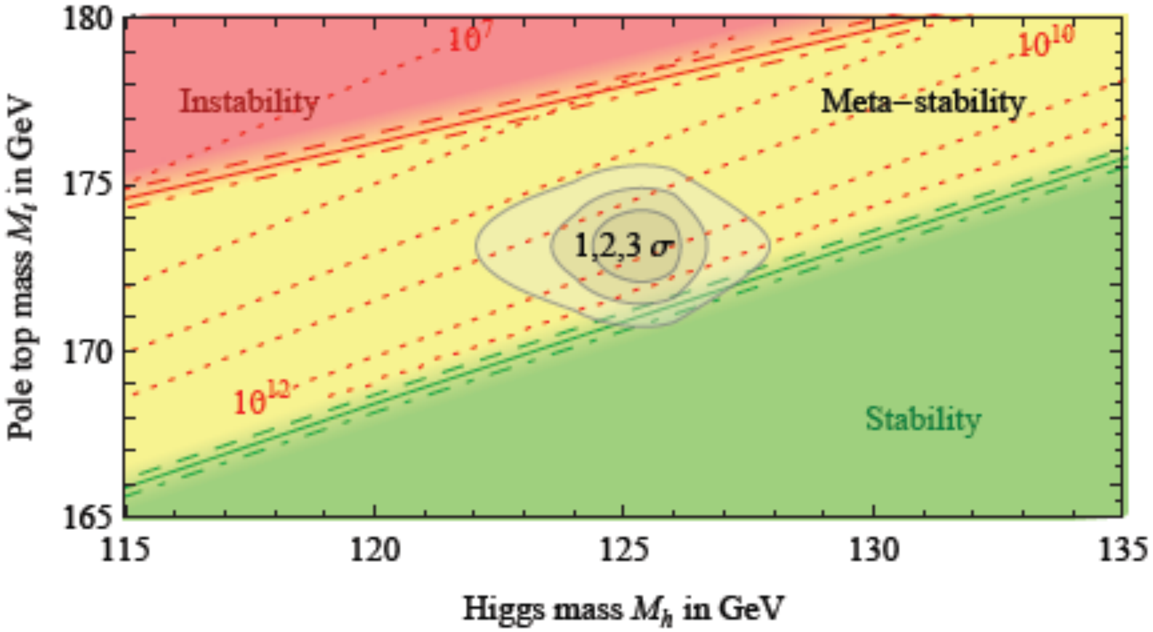
Test further the consistency of the SM w.r.t. the present situation



Gfitter group

Test further the vacuum stability of the SM w.r.t. the present situation





G Degrassi et al
arXiv: 1205.6497v1[hep-ph]

Update of the European Strategy for Particle Physics

(Worked out in draft form at Erice, 21 - 25 January 2013, formally approved now on 30th May 2013 in Brussels)

The format of the document is such that the statements for each point are given in normal text, and then *the recommended actions in italics*

The points are labled from a) …. to …. q) such that they can be referred to easily; it is NOT to be taken as an overall priority ordering

In what follows, only parts are reproduced, and highlights in bold/colour are my own!

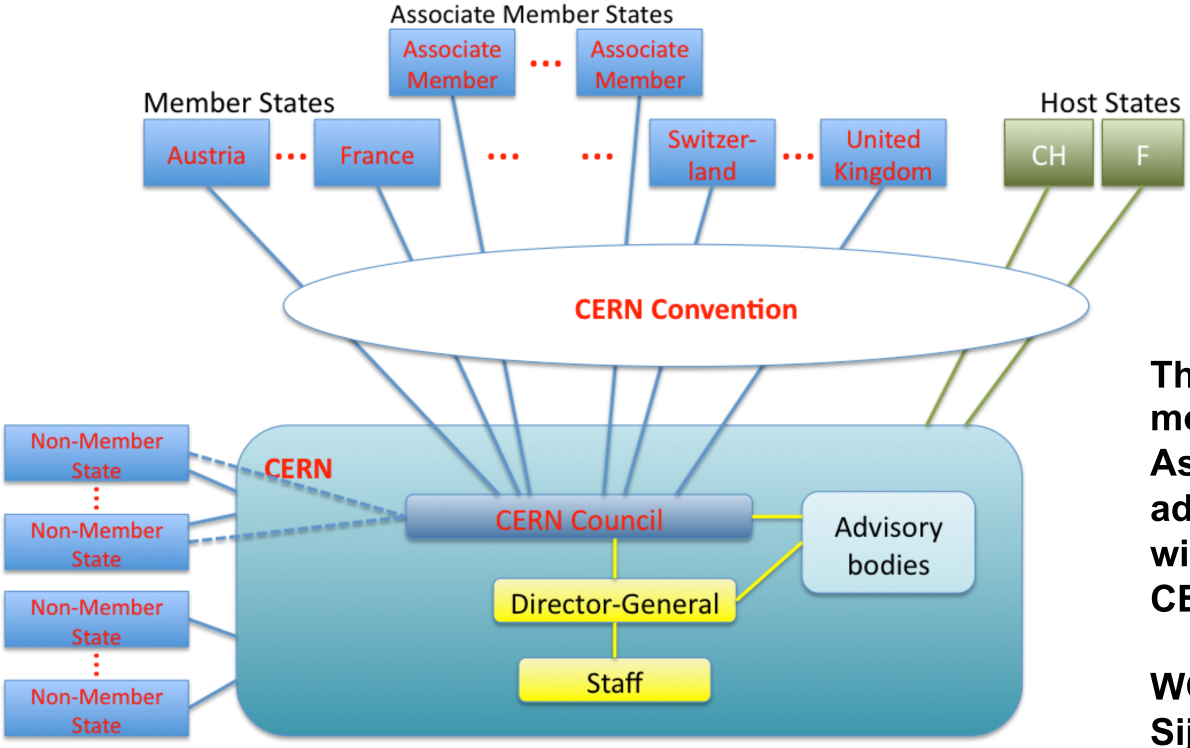
Entrance to the former San Domenico monastery with the Paul Dirac Lecture Hall where the ES meeting took place

General issues

ESPP 2013 statement approved by Council

a) The success of the LHC is proof of the effectiveness of the European organisational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN.

Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.



The current CERN governance model, including Member States, Associate Member States and ad-hoc partners with and without observer status in CERN Council

WG2 presentation by its convener Sijbrand de Jong

ESPP 2013 statement approved by Council

b) The scale of the facilities required by particle physics is resulting in the globalisation of the field.

The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.

My personal comments

This a very important statement for our field, and when it comes to concrete considerations it is by far not obvious how to implement in the best interest for the whole community

Europe can only act as a useful strong partner in a global context when it maintains CERN as focal point for its HEP community

High-priority large-scale scientific activities

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

ESPP 2013 statement
approved by Council

c) The **discovery of the Higgs boson** is the start of a major programme of work to measure this particle's properties with the **highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier**. The LHC is in a unique position to pursue this programme.

Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.

My personal
comments

It could not be more explicit!
This 'result' was not given in advance, and the ATLAS and CMS inputs, as well as the ones from LHCb and ALICE, were very important for that
(now 'we LHC people' have to continue to deliver though… !)

ESPP 2013 statement
approved by Council

d) **To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available.**

CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. *These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures,* ***in collaboration with national institutes, laboratories and universities worldwide.***

My personal
comments

This is to be understood as going clearly beyond 'only' technology R&D studies, by including all aspects of a future high energy frontier facility road map, and by keeping well in mind the 'global context'

ESPP 2013 statement approved by Council

e) **There is a strong scientific case for an electron-positron collider**, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and **whose energy can be upgraded**. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. **The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate.**

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

My personal comments

Council can only discuss the needed resources and implications of a participation in a global ILC project in Japan when an official proposal is on the table, but there is no doubt that there is considerable interest for it in the European community

However, the future of CERN must remain secured, as said before, while contributing to healthy physics activities in other regions

Via San Francesco, the only long straight street in Erice

ESPP 2013 statement approved by Council

f) Rapid progress in neutrino oscillation physics, with significant European involvement, has established a **strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy** in the neutrino sector.

CERN should develop a neutrino programme to pave the way for a ***substantial European role in future long-baseline experiments****. **Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan**.*

My personal comments

I think the message is clear, I have no further comment…

The Norman Castle and the Castello Pepoli Erice

All the next sections are very important as well, but regrettably there is no time to report in full on them here (only the headings, and some selected parts are shown, please read the full draft text!)

Other scientific activities essential to the particle physics programme

g) **Theory is a strong driver of particle physics ….**

h) Experiments studying quark flavour physics, investigating dipole moments, searching for charged lepton flavour violation and performing other precision measurements at lower energies ... **may give access to higher energy scales** … **They can be based in national laboratories**…
Experiments in Europe with unique reach should be supported, as well as participation in experiments in other regions of the word.

i) The success of particle physics experiments, such as those required for the high-luminosity LHC, relies on **innovative instrumentation, state-of-the-art infrastructures and large-scale data-intensive computing…**

j) A range of important non-accelerator experiments take place at **the overlap of particle and astroparticle physics**… (close collaboration with ApPEC)

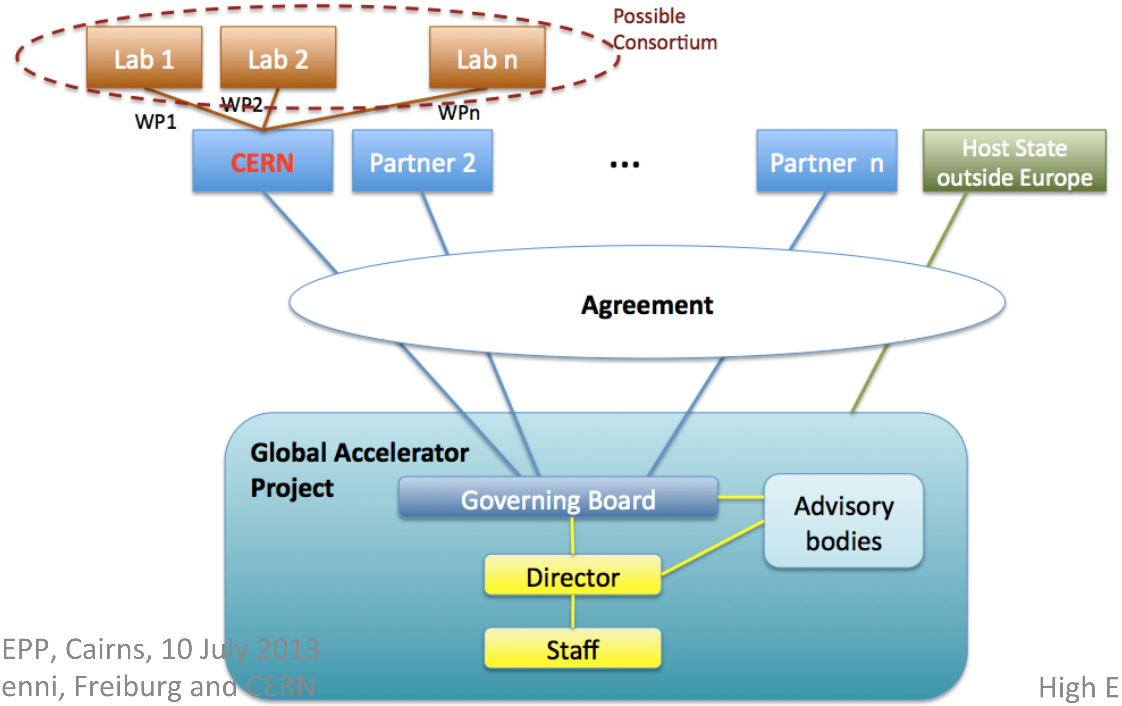
k) A variety of **research lines at the boundary between particle and nuclear physics** require dedicated experiments. … *CERN should continue to work with NuPECC on topics of mutual interest.*

Organisational issues

ESPP 2013 statement
approved by Council

I) **Future major facilities in Europe and elsewhere require collaboration on a global scale.**

CERN should be the framework within which to organise a global particle physics accelerator project in Europe, and should also be the leading European partner in global particle physics accelerator projects elsewhere. Possible additional contributions to such projects from CERN's Member and Associate Member States in Europe should be coordinated with CERN.



Example of possible participation of European national laboratories through CERN in global projects outside Europe

WG2 presentation by its convener Sijbrand de Jong

m) **A Memorandum of Understanding has been signed by CERN and the European Commission, and various cooperative activities are under way…**

… *CERN and the particle physics community should strengthen their relations with the European Commission …*

Wider impact of particle physics

n) **Sharing the excitement of scientific discoveries with the public …**
is part of our duty as researchers….

o) **Knowledge and technology developed for particle physics research…**

p) **Particle physics research requires a wide range of skills and knowledge…**

Concluding recommendations

ESPP 2013 statement approved by Council

q) **This is the first update of the European Strategy for Particle Physics**. It was prepared by the European Strategy Group based on the scientific input from the Preparatory Group with the participation of representatives of the Candidate for Accession to Membership, the Associate Member States, the Observer States and of other organisations. **Such periodic updates at intervals of about five years are essential.**

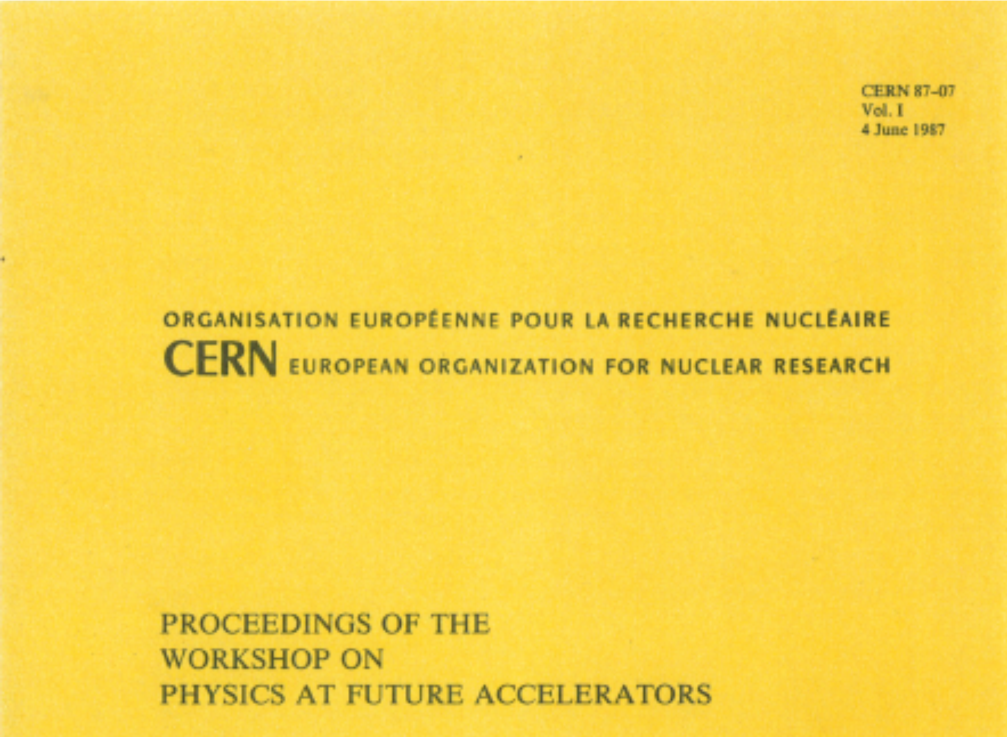
Updates should continue to be undertaken according to the principles applied on the present occasion. The organisational framework for the Council Sessions dealing with European Strategy matters and the mechanism for implementation and follow-up of the Strategy should be revisited in the light of the experience gained since 2006.

My personal comments

We arrived at point q), that's it…

One of the many nice restaurants and bars in Erice, but closed in January…

Some history: 26 years ago …
La Thuile 7 – 13 January 1987
(Carlo Rubbia's Long Range Planning Committee)



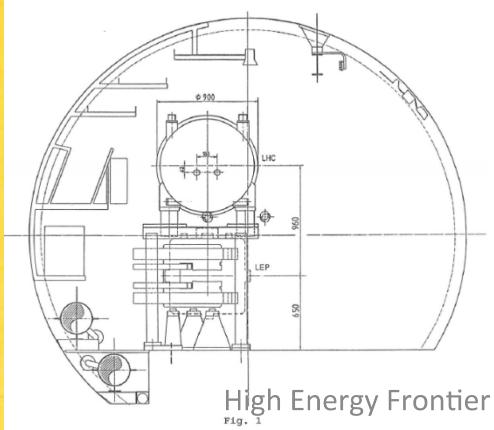
CERN 87-07
Vol. I
4 June 1987

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

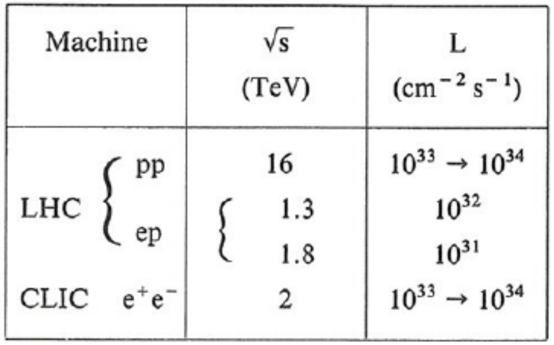
PROCEEDINGS OF THE
WORKSHOP ON
PHYSICS AT FUTURE ACCELERATORS

La Thuile (Italy) and Geneva (Switzerland)
7 – 13 January 1987

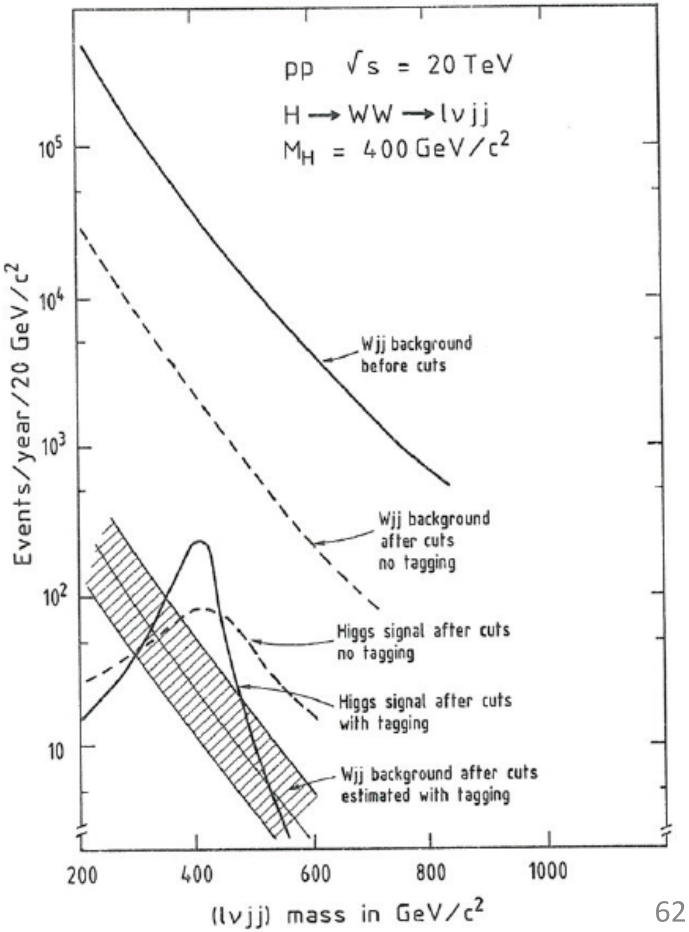
Vol. I



Collider parameters



Machine		$\sqrt{s}$ (TeV)	L ($cm^{-2} s^{-1}$)
LHC	pp	16	$10^{33} \rightarrow 10^{34}$
	ep	1.3	10^{32}
		1.8	10^{31}
CLIC	e^+e^-	2	$10^{33} \rightarrow 10^{34}$

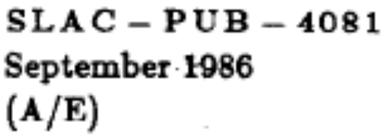


Time line of the LHC project

1984	Workshop on a Large Hadron Collider in the LEP tunnel, Lausanne.
1987	Workshop on Physics at Future Accelerators, La Thuile, Italy. The Rubbia “Long-Range Planning Committee” recommends the Large Hadron Collider as the right choice for CERN’s future.
1990	European Committee for Future Accelerators (ECFA) LHC Workshop, Aachen (discussion of physics, technologies and designs for LHC experiments)
1992	General Meeting on LHC Physics and Detectors, Evian les Bains (4 general-purpose experiment designs presented along with their physics performance)
1993	Three Letters of Intent submitted to the CERN peer review committee LHCC. ATLAS and CMS selected to proceed to a detailed technical proposal.
1994	The LHC accelerator approved for construction
1996	ATLAS and CMS Technical Proposals approved.
1997	Formal approval for ATLAS and CMS to move to construction (materials cost ceiling of 475 MCHF)
1997	Construction commences (after approval of detailed engineering design of subdetectors (magnets, inner tracker, calorimeters, muon system, trigger and data acquisition))
2000	Assembly of experiments commences, LEP accelerator is closed down to make way for the LHC.
2008	LHC experiments ready for pp collisions. LHC starts operation. An incident stops LHC operation.
2009	LHC restarts operation, pp collisions recorded by LHC detectors
2010	LHC collides protons at high energy (centre of mass energy of 7 TeV)
2012	LHC operates at 8 TeV: discovery of a Higgs-like boson.

It took a long time, and we already had a tunnel…

Another example where we have to be even more patient…



SLAC – PUB – 4081
September 1986
(A/E)

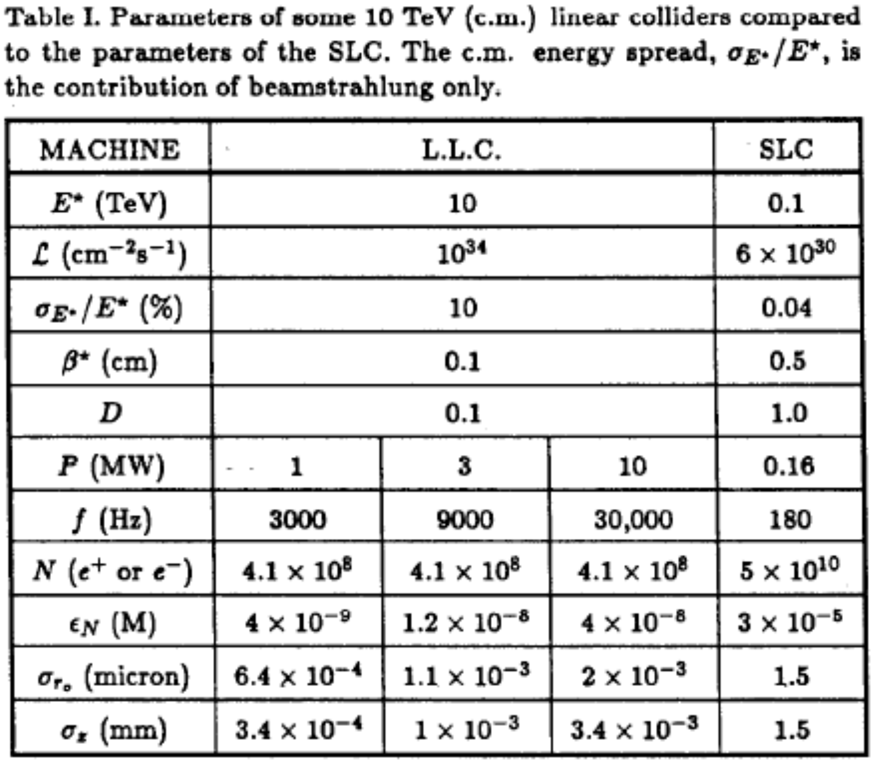
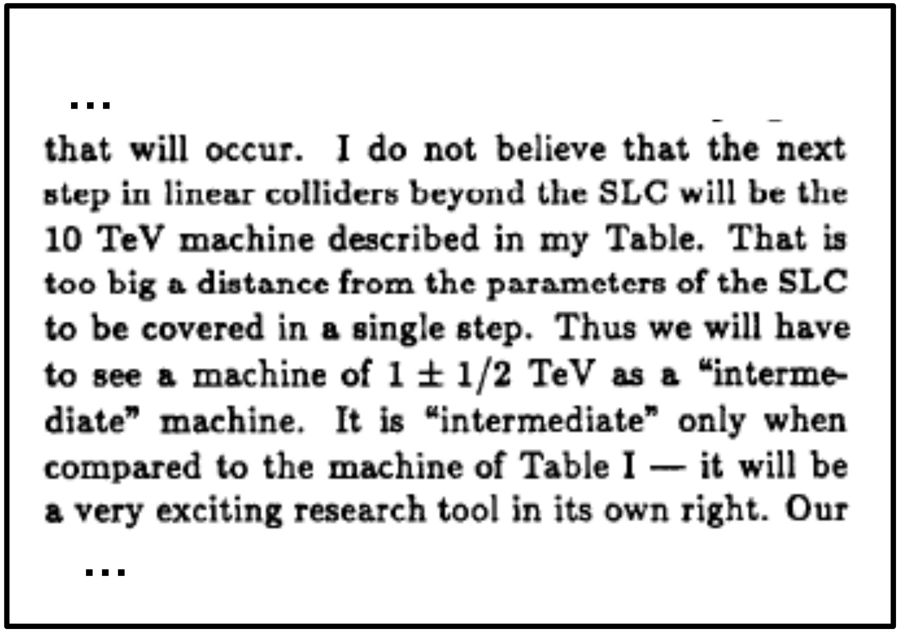


Table I. Parameters of some 10 TeV (c.m.) linear colliders compared to the parameters of the SLC. The c.m. energy spread, σ_{E^*}/E^*, is the contribution of beamstrahlung only.

MACHINE	L.L.C.			SLC
E^* (TeV)	10			0.1
$\mathcal{L}$ ($\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	10^{34}			6×10^{30}
σ_{E^*}/E^* (%)	10			0.04
β^* (cm)	0.1			0.5
D	0.1			1.0
P (MW)	1	3	10	0.16
f (Hz)	3000	9000	30,000	180
N (e^+ or e^-)	4.1×10^8	4.1×10^8	4.1×10^8	5×10^{10}
ϵ_N (M)	4×10^{-9}	1.2×10^{-8}	4×10^{-8}	3×10^{-5}
σ_{r_o} (micron)	6.4×10^{-4}	1.1×10^{-3}	2×10^{-3}	1.5
σ_z (mm)	3.4×10^{-4}	1×10^{-3}	3.4×10^{-3}	1.5



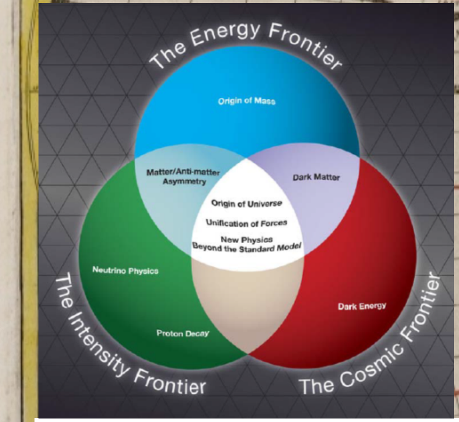
…

that will occur. I do not believe that the next step in linear colliders beyond the SLC will be the 10 TeV machine described in my Table. That is too big a distance from the parameters of the SLC to be covered in a single step. Thus we will have to see a machine of 1 ± 1/2 TeV as a "intermediate" machine. It is "intermediate" only when compared to the machine of Table I — it will be a very exciting research tool in its own right. Our

…

Burt Richter

The journey into new physics territory at the high-energy frontier has only just begun with the LHC, nevertheless…



… we need to make timely plans and courageous decisions on a global scale in order to 'plant the right seeds for the future', also beyond LHC

Thank you for your attention

J Blaeu 1664

Backup

CERN Press Release 30th May 2013:

Key points of the strategy are that Europe, and the European particle physics community, should:

Exploit its current world-leading facility for particle physics, the LHC, to its full potential over a period of many years, with a series of planned upgrades;

Continue to develop novel techniques leading to ambitious future accelerator projects on a global scale;

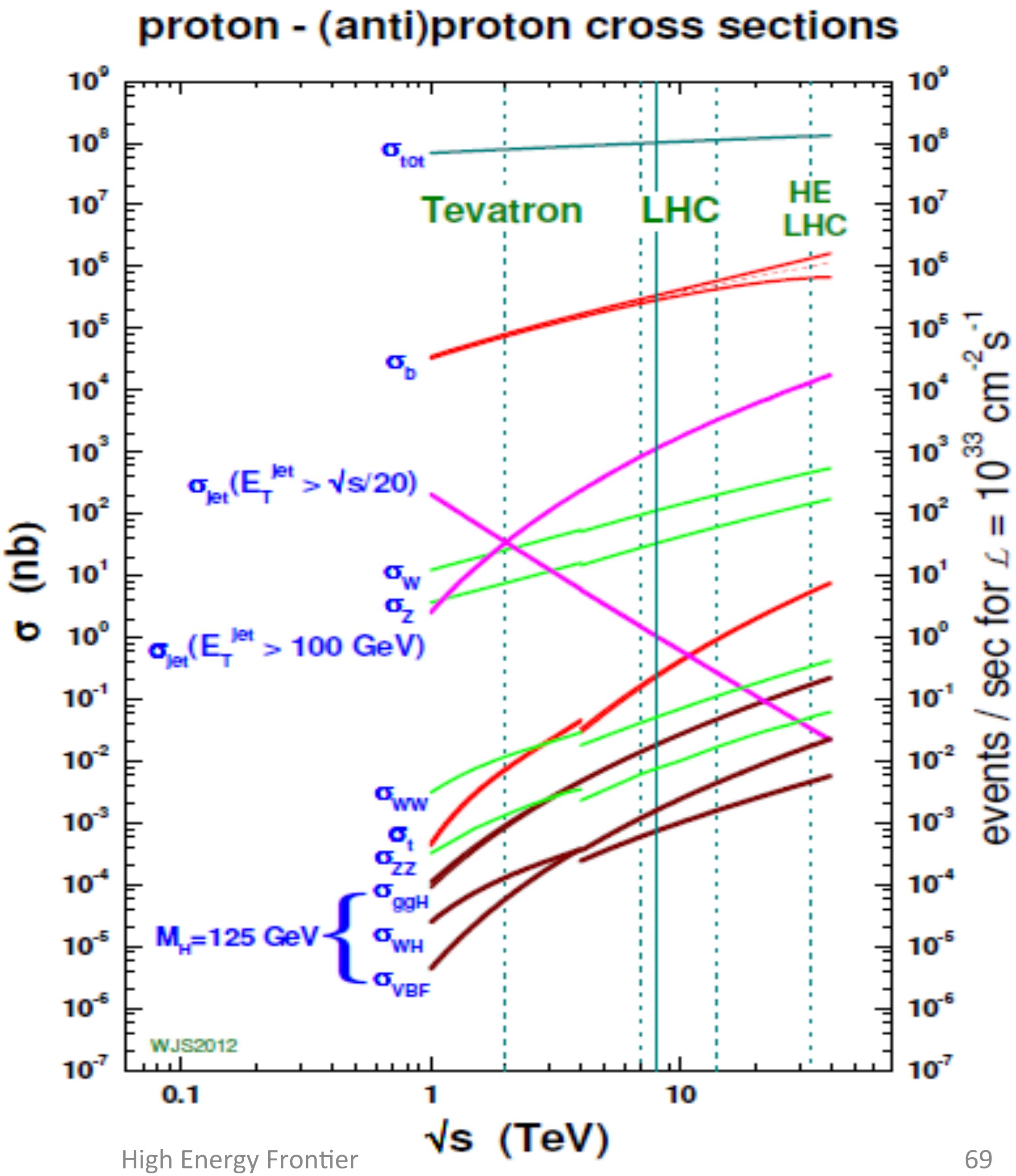
Be open to engagement in a range of unique basic physics research projects alongside the LHC;

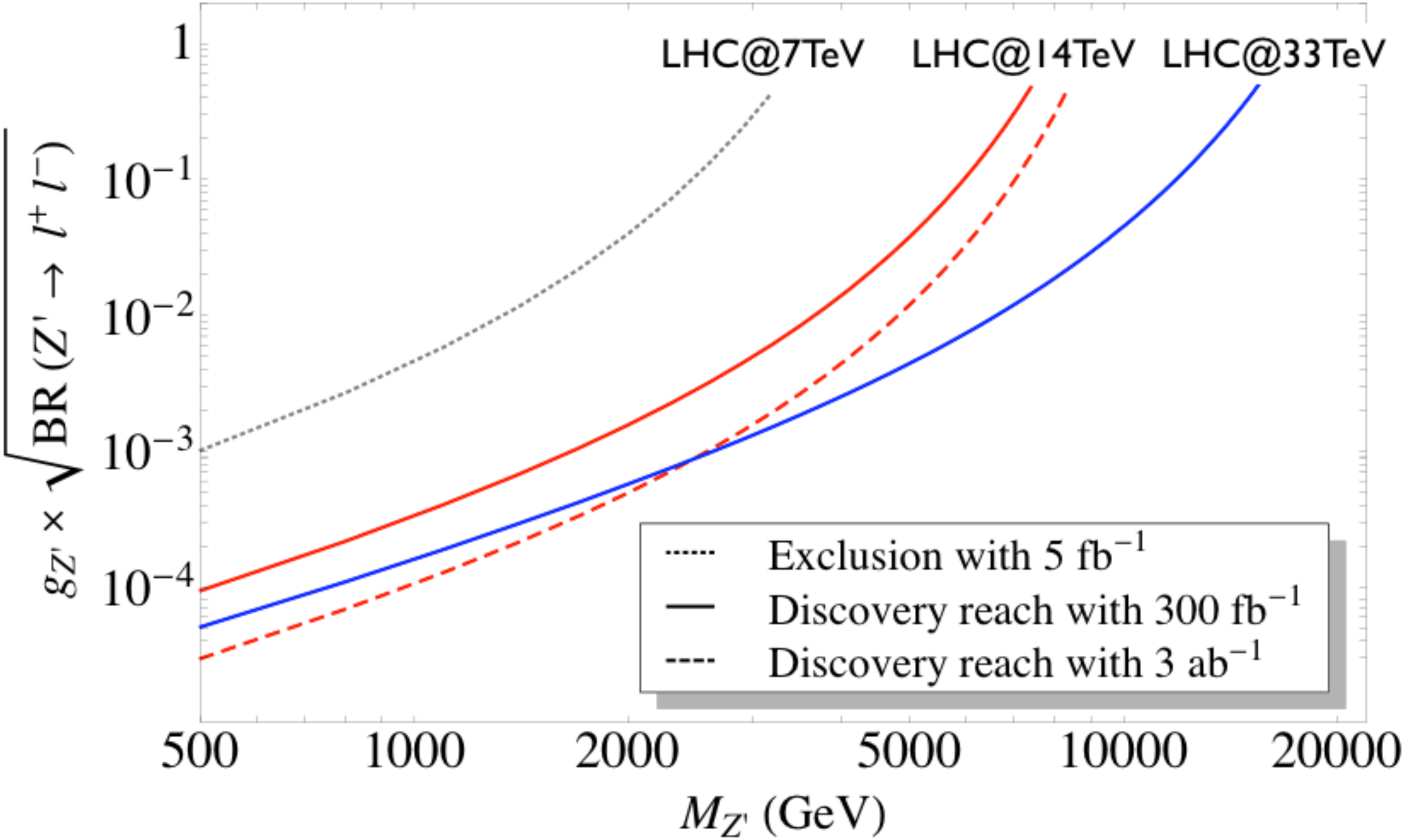
Be open to collaboration in particle physics projects beyond the European region;

Maintain a healthy base in fundamental physics research, with universities and national laboratories contributing to a strong European focus through CERN;

Continue to invest substantial effort in communication, education and outreach to engage global publics with science.

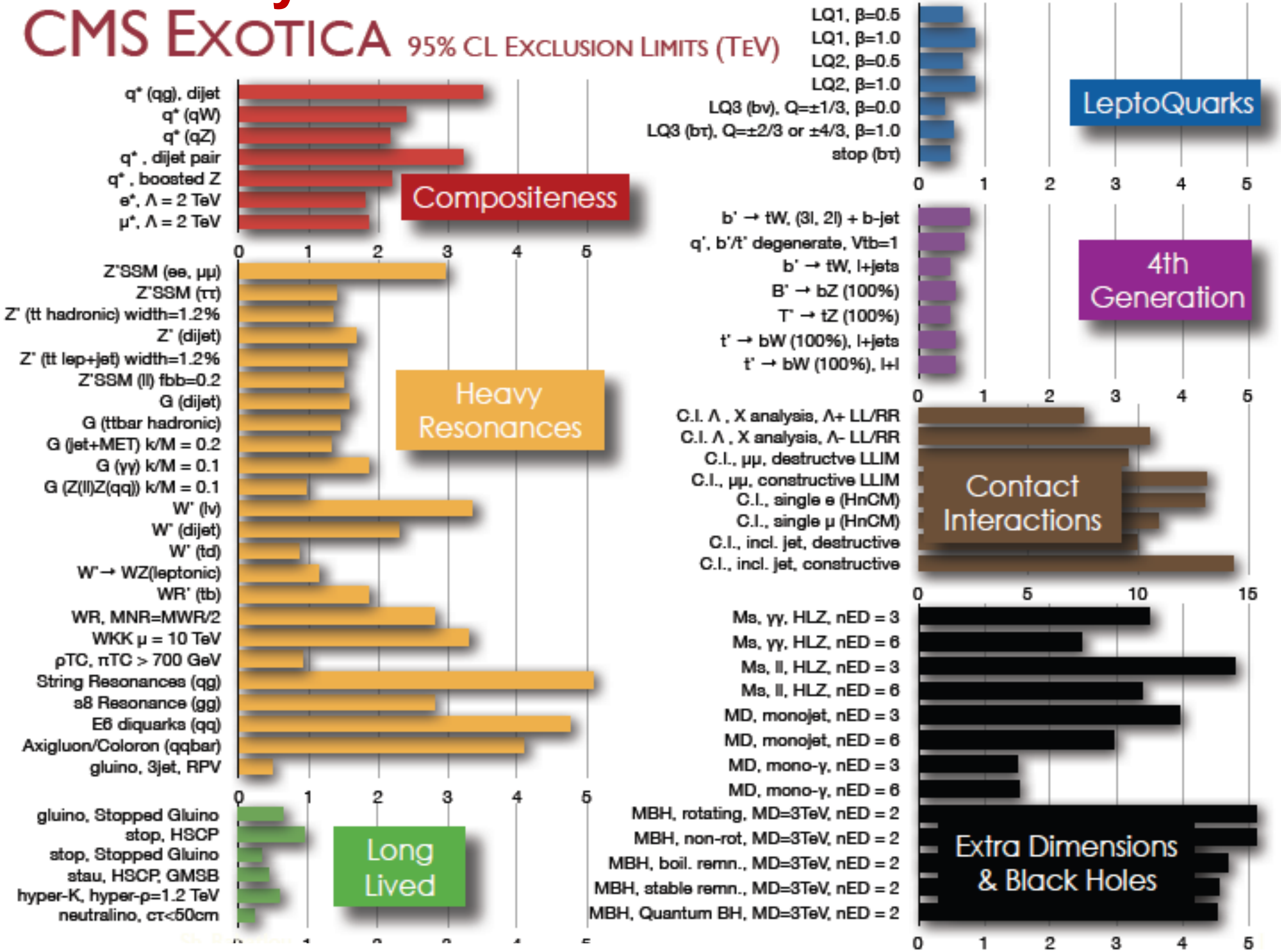
	nominal LHC	HE-LHC
beam energy [TeV]	7	16.5
dipole field [T]	8.33	20
dipole coil aperture [mm]	56	40-45
#bunches / beam	2808	1404
bunch population [10^{11}]	1.15	1.29
initial transverse normalized emittance [μm]	3.75	3.75 (x), 1.84 (y)
number of IPs contributing to tune shift	3	2
maximum total beam-beam tune shift	0.01	0.01
IP beta function [m]	0.55	1.0 (x), 0.43 (y)
full crossing angle [μrad]	285 (9.5 $\sigma_{x,y}$)	175 (12 σ_{x0})
stored beam energy [MJ]	362	479
SR power per ring [kW]	3.6	62.3
longitudinal SR emittance damping time [h]	12.9	0.98
events per crossing	19	76
peak luminosity [10^{34} cm^{-2}s^{-1}]	1.0	2.0
beam lifetime [h]	46	13
integrated luminosity over 10 h [fb^{-1}]	0.3	0.5


proton - (anti)proton cross sections
σ (nb)
events / sec for $\mathcal{L} = 10^{33}$ cm^{-2}s^{-1}
√s (TeV)
0.1
1
10
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
Tevatron
LHC
HE LHC
σ_{tot}
σ_b
$\sigma_{jet}(E_T^{jet} > \sqrt{s}/20)$
σ_W
σ_Z
$\sigma_{jet}(E_T^{jet} > 100$ GeV$)$
σ_{WW}
σ_t
σ_{ZZ}
σ_{ggH}
σ_{WH}
σ_{VBF}
M_H=125 GeV
WJS2012


LHC@7TeV
LHC@14TeV
LHC@33TeV
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$g_{Z'} \times \sqrt{\mathrm{BR}\,(Z' \to l^+ l^-)}$
500
1000
2000
5000
10000
20000
$M_{Z'}$ (GeV)
Exclusion with 5 fb^{-1}
Discovery reach with 300 fb^{-1}
Discovery reach with 3 ab^{-1}

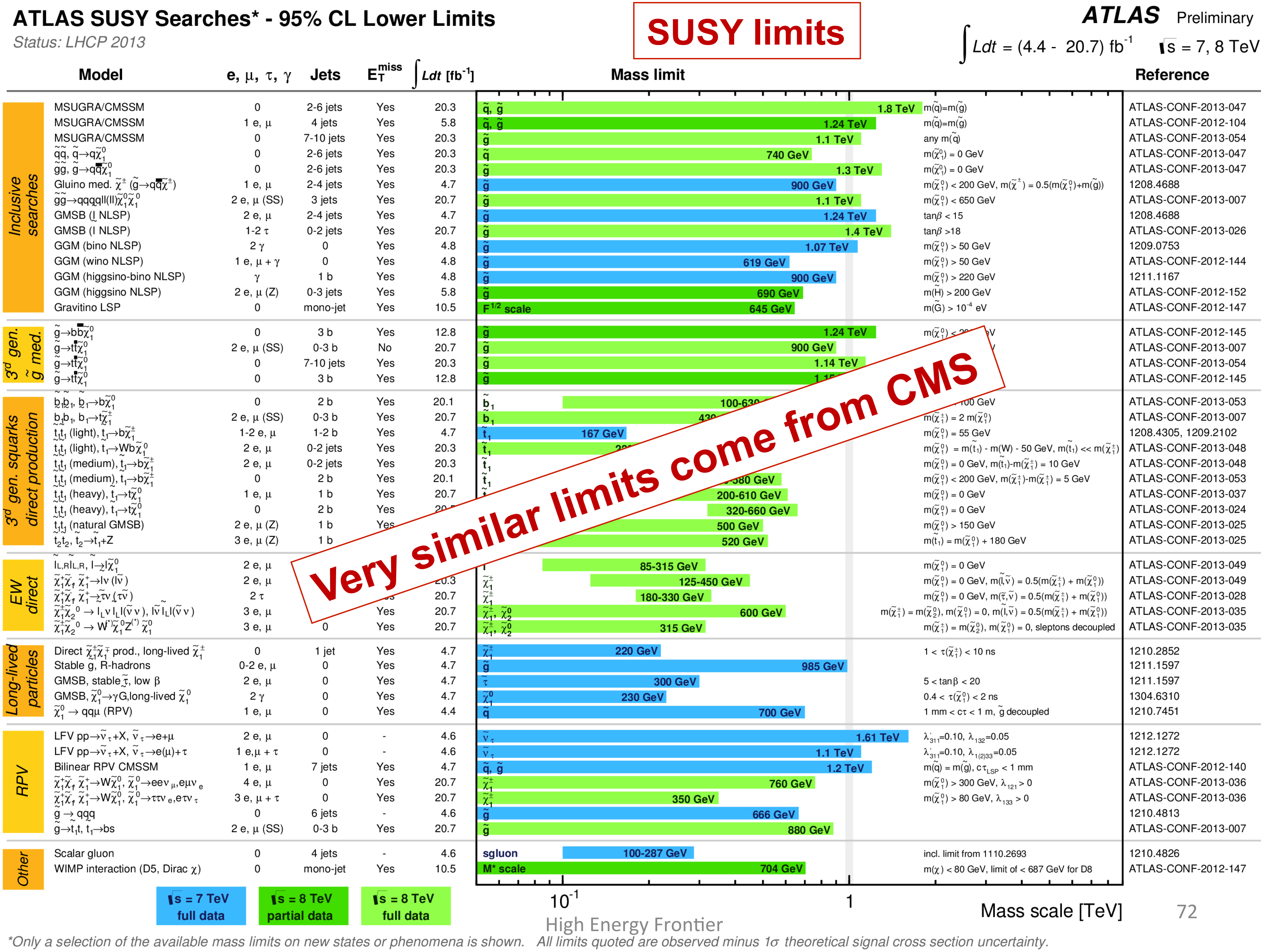
LHC today

Similar results exist from ATLAS



(TeV) **(TeV)**

SUSY limits



ATLAS SUSY Searches* - 95% CL Lower Limits

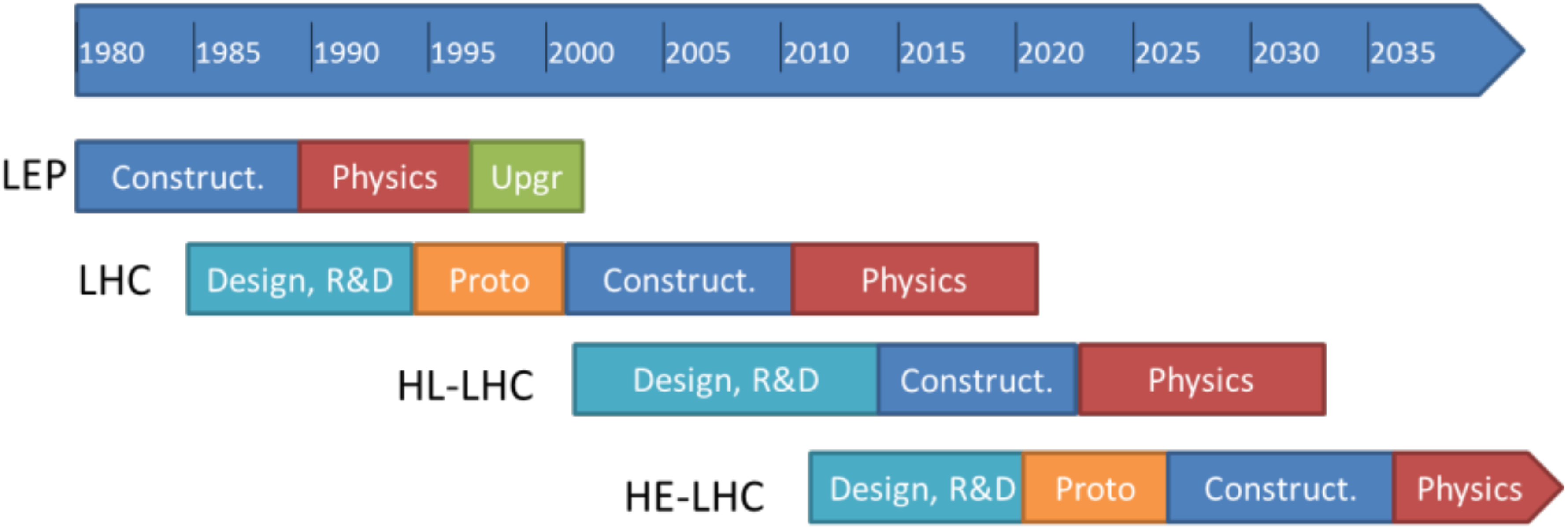
Status: LHCP 2013

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int Ldt\ [\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.8 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	4 jets	Yes	5.8	$\tilde{q}, \tilde{g}$ 1.24 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2012-104
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-054
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-047
	Gluino med. $\tilde{\chi}^\pm$ ($\tilde{g}\to q\bar{q}\tilde{\chi}^\pm$)	1 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{\chi}^\pm) = 0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	1208.4688
	$\tilde{g}\tilde{g}\to qqqqll(ll)\tilde{\chi}_1^0\tilde{\chi}_1^0$	2 e, μ (SS)	3 jets	Yes	20.7	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ < 650 GeV	ATLAS-CONF-2013-007
	GMSB ($\tilde{l}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$ < 15	1208.4688
	GMSB (l NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	0	Yes	4.8	$\tilde{g}$ 1.07 TeV	$m(\tilde{\chi}_1^0)$ > 50 GeV	1209.0753
	GGM (wino NLSP)	1 e, μ + γ	0	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$ > 50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$ > 220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$ > 200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{G}) > 10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	12.8	$\tilde{g}$ 1.24 TeV	$m(\tilde{\chi}_1^0)$ < 20[illegible]eV	ATLAS-CONF-2012-145
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	2 e, μ (SS)	0-3 b	No	20.7	$\tilde{g}$ 900 GeV	[illegible]	ATLAS-CONF-2013-007
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.14 TeV	[illegible]	ATLAS-CONF-2013-054
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	3 b	Yes	12.8	$\tilde{g}$ 1.15[illegible]	[illegible]	ATLAS-CONF-2012-145
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-630 [illegible]	[illegible] 100 GeV	ATLAS-CONF-2013-053
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 430 [illegible]	$m(\tilde{\chi}_1^\pm) = 2\,m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 167 GeV	$m(\tilde{\chi}_1^0)$ = 55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 22[illegible]	$m(\tilde{\chi}_1^0) = m(\tilde{t}_1) - m(W) - 50$ GeV, $m(\tilde{t}_1) << m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ [illegible]	$m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{t}_1)-m(\tilde{\chi}_1^\pm)$ = 10 GeV	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$ [illegible]380 GeV	$m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^\pm)$ = 5 GeV	ATLAS-CONF-2013-053
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	200-610 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20[illegible]	320-660 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	[illegible]	500 GeV	$m(\tilde{\chi}_1^0)$ > 150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e, μ (Z)	1 b	[illegible]	[illegible]	520 GeV	$m(\tilde{t}_1) = m(\tilde{\chi}_1^0)$ + 180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{l}_{L,R}\tilde{l}_{L,R}$, $\tilde{l}\to l\tilde{\chi}_1^0$	2 e, μ	[illegible]	[illegible]	[illegible]	85-315 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{l}\nu(l\tilde{\nu})$	2 e, μ	[illegible]	[illegible]	20.3	$\tilde{\chi}_1^\pm$ 125-450 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{l},\tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	[illegible]	[illegible]	20.7	$\tilde{\chi}_1^\pm$ 180-330 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{\tau},\tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \to \tilde{l}_L\nu\tilde{l}_Ll(\tilde{\nu}\nu), l\tilde{\nu}\tilde{l}_Ll(\tilde{\nu}\nu)$	3 e, μ	[illegible]	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 600 GeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0) = 0$, $m(\tilde{l},\tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \to W^{(*)}\tilde{\chi}_1^0 Z^{(*)}\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 315 GeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0) = 0$, sleptons decoupled	ATLAS-CONF-2013-035
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	0	1 jet	Yes	4.7	$\tilde{\chi}_1^\pm$ 220 GeV	$1 < \tau(\tilde{\chi}_1^\pm) < 10$ ns	1210.2852
	Stable $\tilde{g}$, R-hadrons	0-2 e, μ	0	Yes	4.7	$\tilde{g}$ 985 GeV		1211.1597
	GMSB, stable $\tilde{\tau}$, low β	2 e, μ	0	Yes	4.7	$\tilde{\tau}$ 300 GeV	$5 < \tan\beta < 20$	1211.1597
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	0	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	$0.4 < \tau(\tilde{\chi}_1^0) < 2$ ns	1304.6310
	$\tilde{\chi}_1^0 \to qq\mu$ (RPV)	1 e, μ	0	Yes	4.4	$\tilde{q}$ 700 GeV	1 mm < cτ < 1 m, $\tilde{g}$ decoupled	1210.7451
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e, μ	0	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 e,μ + τ	0	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$ 1.2 TeV	$m(\tilde{q}) = m(\tilde{g})$, $c\tau_{LSP}$ < 1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\nu_\mu, e\mu\nu_e$	4 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm$ 760 GeV	$m(\tilde{\chi}_1^0)$ > 300 GeV, λ_{121} > 0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\nu_e, e\tau\nu_\tau$	3 e, μ + τ	0	Yes	20.7	$\tilde{\chi}_1^\pm$ 350 GeV	$m(\tilde{\chi}_1^0)$ > 80 GeV, λ_{133} > 0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6 jets	-	4.6	$\tilde{g}$ 666 GeV		1210.4813
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	m(χ) < 80 GeV, limit of < 687 GeV for D8	ATLAS-CONF-2012-147

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Very similar limits come from CMS

The super-exploitation of the CERN complex: Injectors, LEP/LHC tunnel, infrastructures



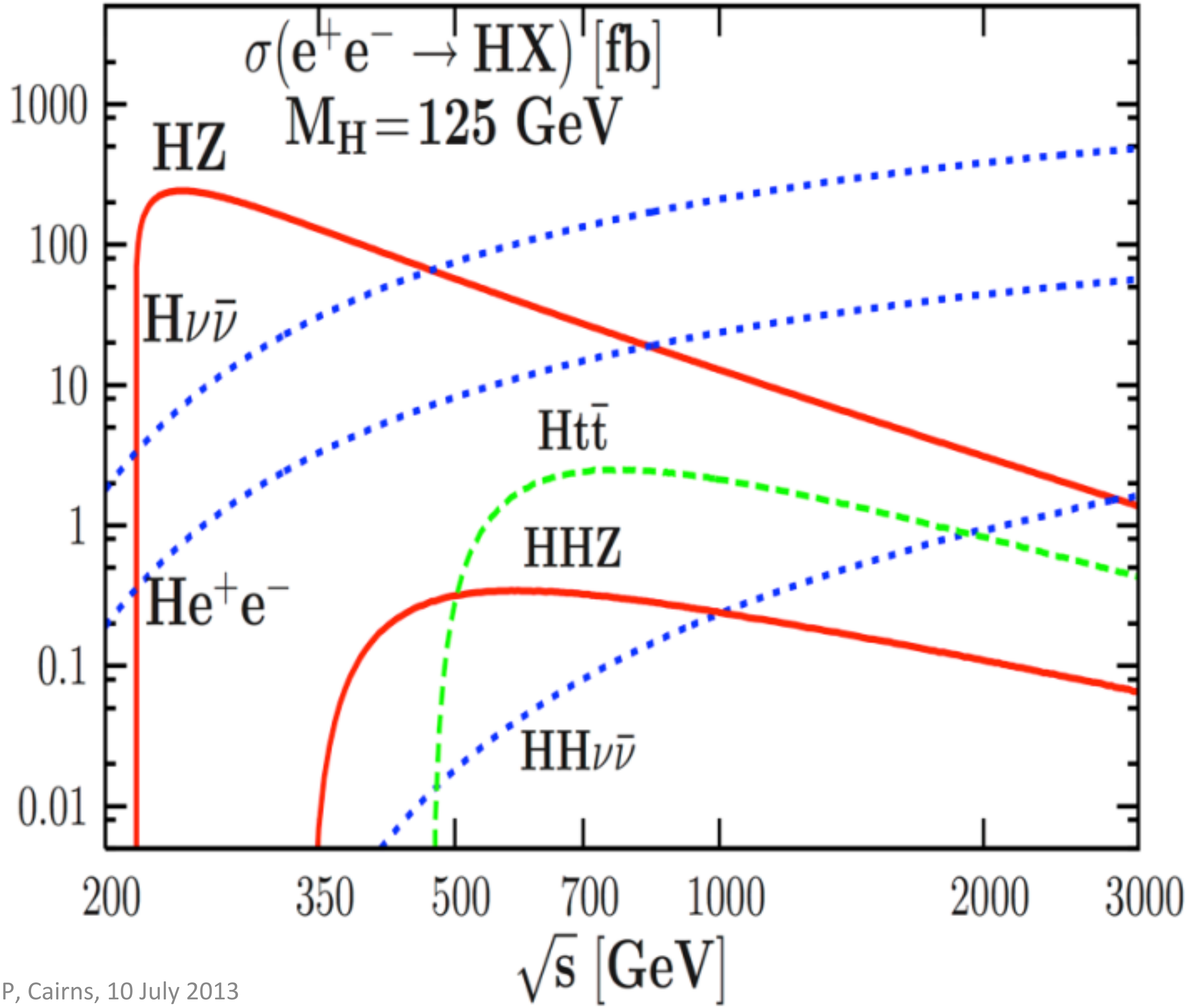
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035

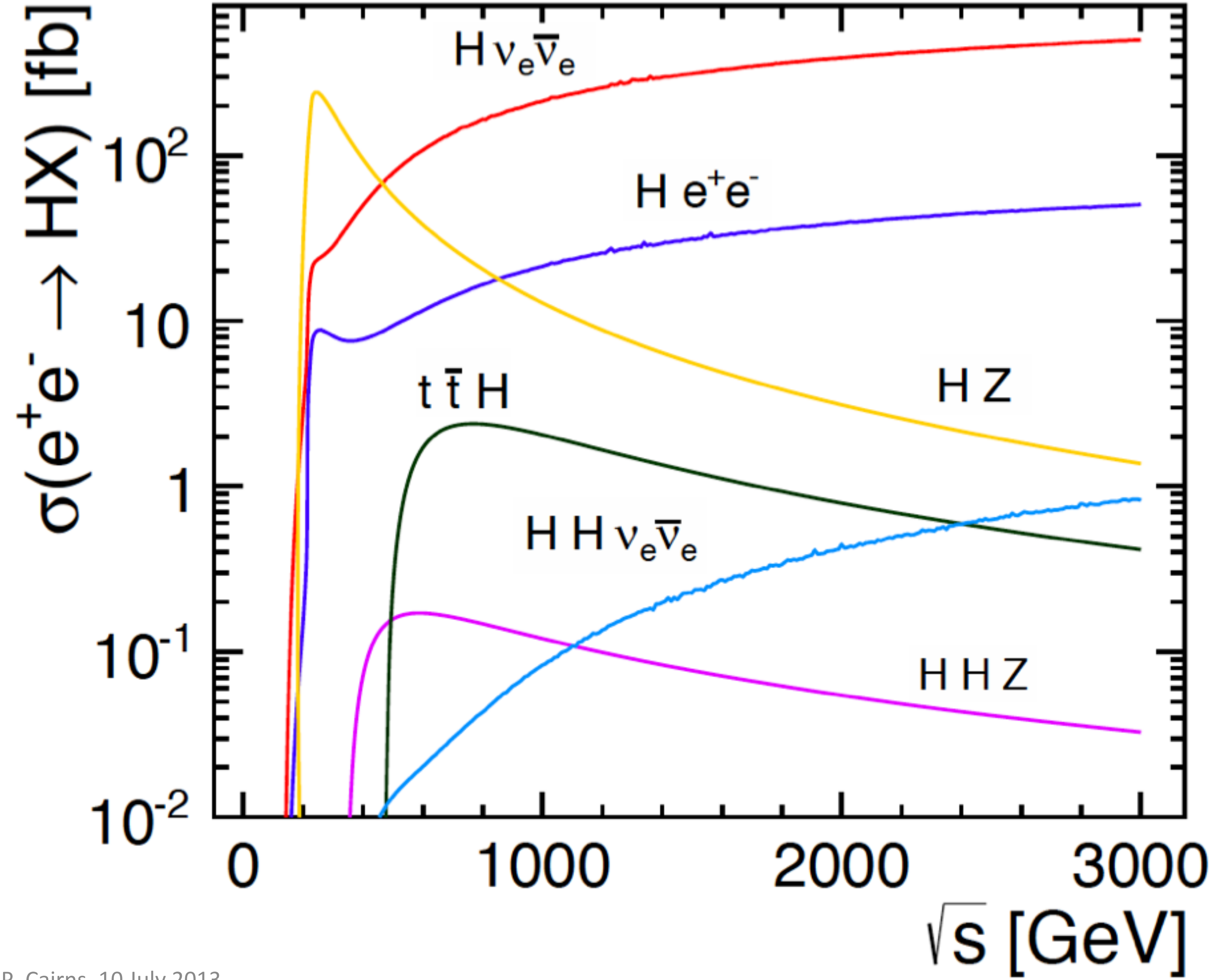
LEP: Construct. | Physics | Upgr

LHC: Design, R&D | Proto | Construct. | Physics

HL-LHC: Design, R&D | Construct. | Physics

HE-LHC: Design, R&D | Proto | Construct. | Physics


$\sigma(e^+e^- \to HX)$ [fb]
$M_H = 125$ GeV
HZ
$H\nu\bar{\nu}$
He^+e^-
$Ht\bar{t}$
HHZ
$HH\nu\bar{\nu}$
1000
100
10
1
0.1
0.01
200
350
500
700
1000
2000
3000
$\sqrt{s}$ [GeV]


$\sigma(e^+e^- \rightarrow HX)$ [fb]
10^2
10
1
10^{-1}
10^{-2}
0
1000
2000
3000
$\sqrt{s}$ [GeV]
$H\nu_e\bar{\nu}_e$
He^+e^-
$t\bar{t}H$
HZ
$HH\nu_e\bar{\nu}_e$
HHZ

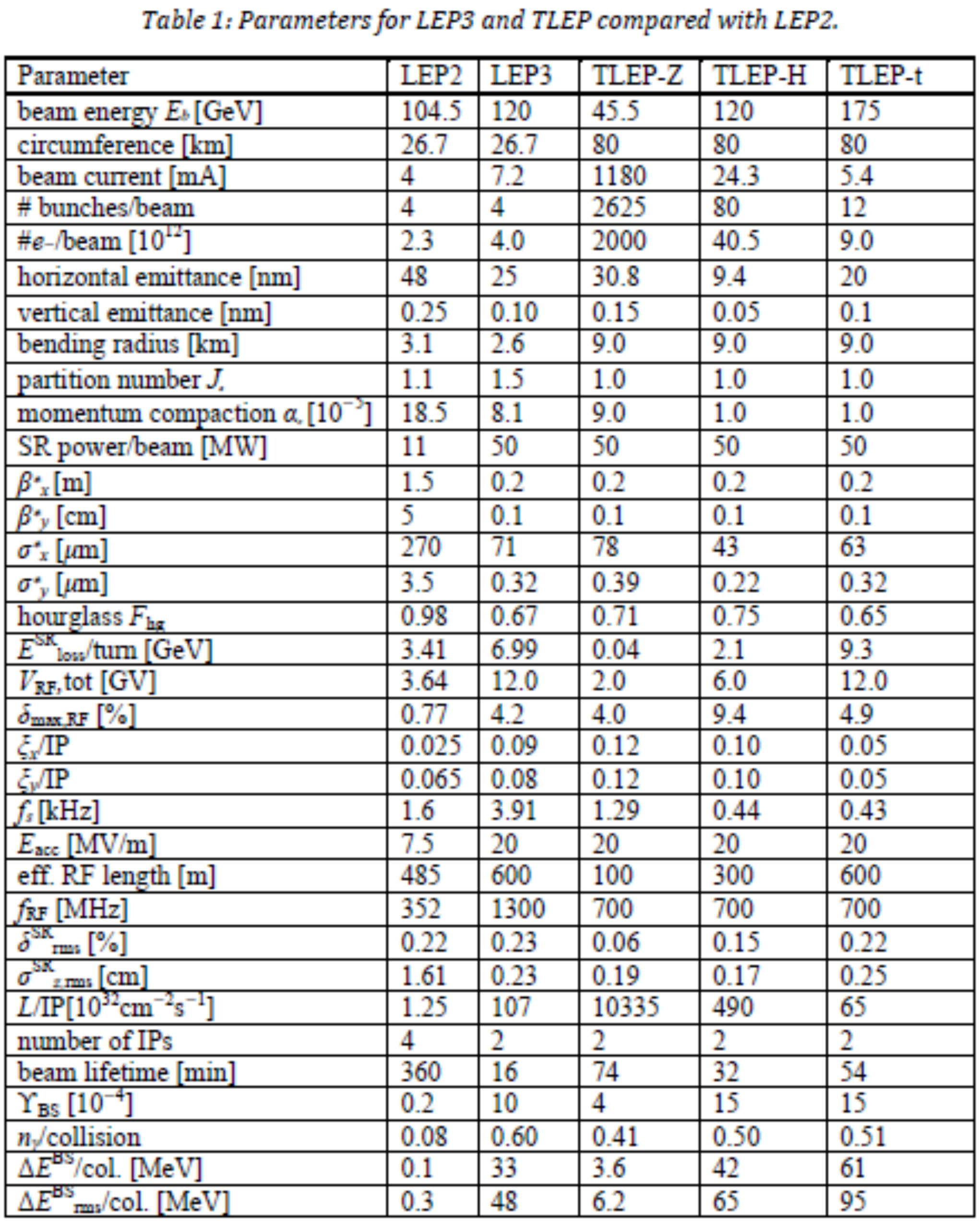


Table 1: Parameters for LEP3 and TLEP compared with LEP2.

Parameter	LEP2	LEP3	TLEP-Z	TLEP-H	TLEP-t
beam energy E_b [GeV]	104.5	120	45.5	120	175
circumference [km]	26.7	26.7	80	80	80
beam current [mA]	4	7.2	1180	24.3	5.4
# bunches/beam	4	4	2625	80	12
#e–/beam [10^{12}]	2.3	4.0	2000	40.5	9.0
horizontal emittance [nm]	48	25	30.8	9.4	20
vertical emittance [nm]	0.25	0.10	0.15	0.05	0.1
bending radius [km]	3.1	2.6	9.0	9.0	9.0
partition number J_ε	1.1	1.5	1.0	1.0	1.0
momentum compaction α_c [10^{-5}]	18.5	8.1	9.0	1.0	1.0
SR power/beam [MW]	11	50	50	50	50
β^*_x [m]	1.5	0.2	0.2	0.2	0.2
β^*_y [cm]	5	0.1	0.1	0.1	0.1
σ^*_x [μm]	270	71	78	43	63
σ^*_y [μm]	3.5	0.32	0.39	0.22	0.32
hourglass F_{hg}	0.98	0.67	0.71	0.75	0.65
$E^{SK}{}_{loss}$/turn [GeV]	3.41	6.99	0.04	2.1	9.3
V_{RF},tot [GV]	3.64	12.0	2.0	6.0	12.0
$\delta_{max,RF}$ [%]	0.77	4.2	4.0	9.4	4.9
ξ_x/IP	0.025	0.09	0.12	0.10	0.05
ξ_y/IP	0.065	0.08	0.12	0.10	0.05
f_s [kHz]	1.6	3.91	1.29	0.44	0.43
E_{acc} [MV/m]	7.5	20	20	20	20
eff. RF length [m]	485	600	100	300	600
f_{RF} [MHz]	352	1300	700	700	700
$\delta^{SK}{}_{rms}$ [%]	0.22	0.23	0.06	0.15	0.22
$\sigma^{SK}{}_{z,rms}$ [cm]	1.61	0.23	0.19	0.17	0.25
L/IP[10^{32}cm^{-2}s^{-1}]	1.25	107	10335	490	65
number of IPs	4	2	2	2	2
beam lifetime [min]	360	16	74	32	54
Υ_{BS} [10^{-4}]	0.2	10	4	15	15
n_γ/collision	0.08	0.60	0.41	0.50	0.51
ΔE^{BS}/col. [MeV]	0.1	33	3.6	42	61
$\Delta E^{BS}{}_{rms}$/col. [MeV]	0.3	48	6.2	65	95

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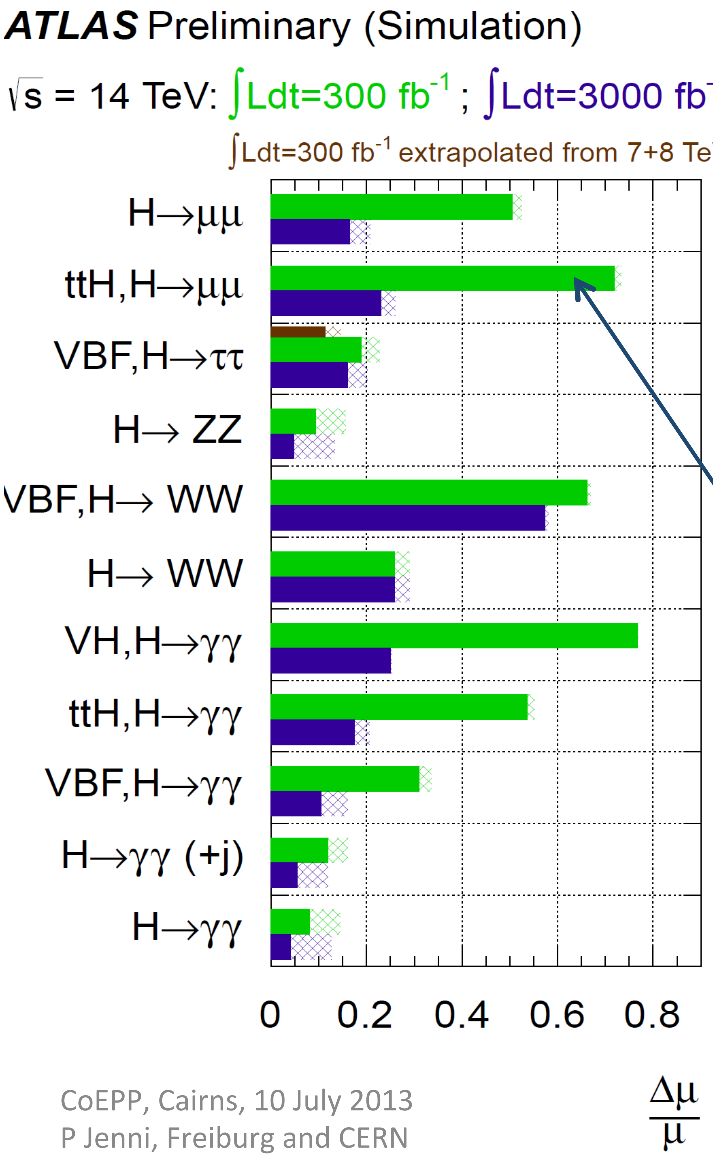
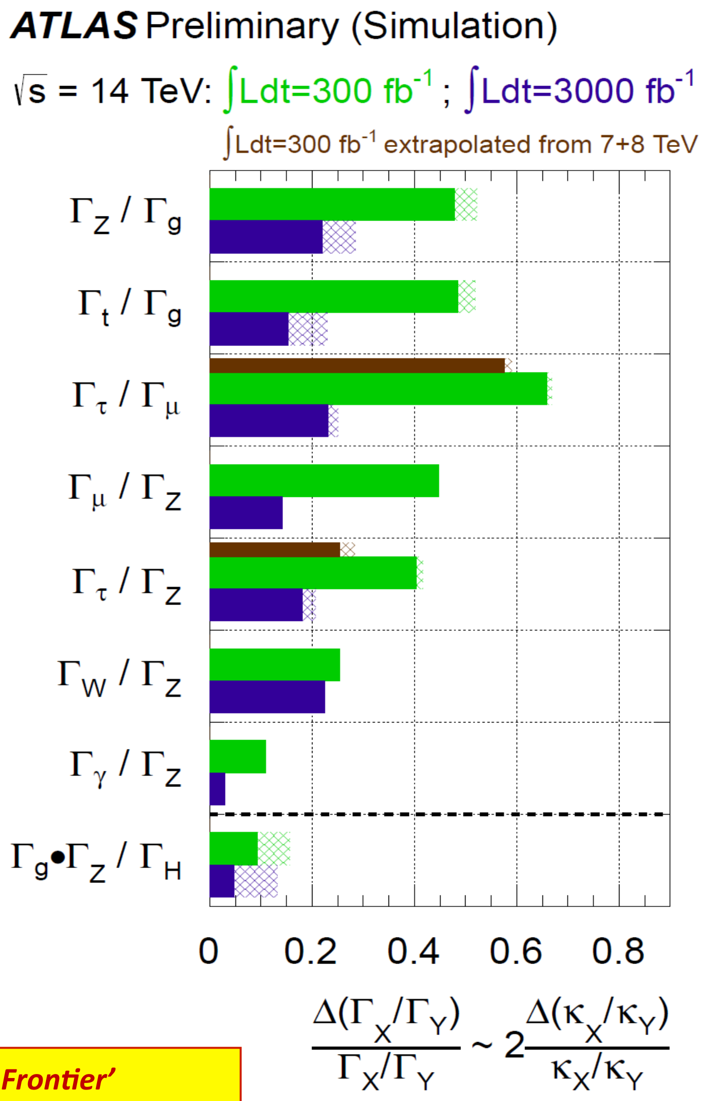
High Lumi: precision



Solid region: errors without current theoretical systematics



From 'High Energy Frontier' presented by Marcella Diemoz

Sensitivity to Vector Boson Scattering at HL-LHC

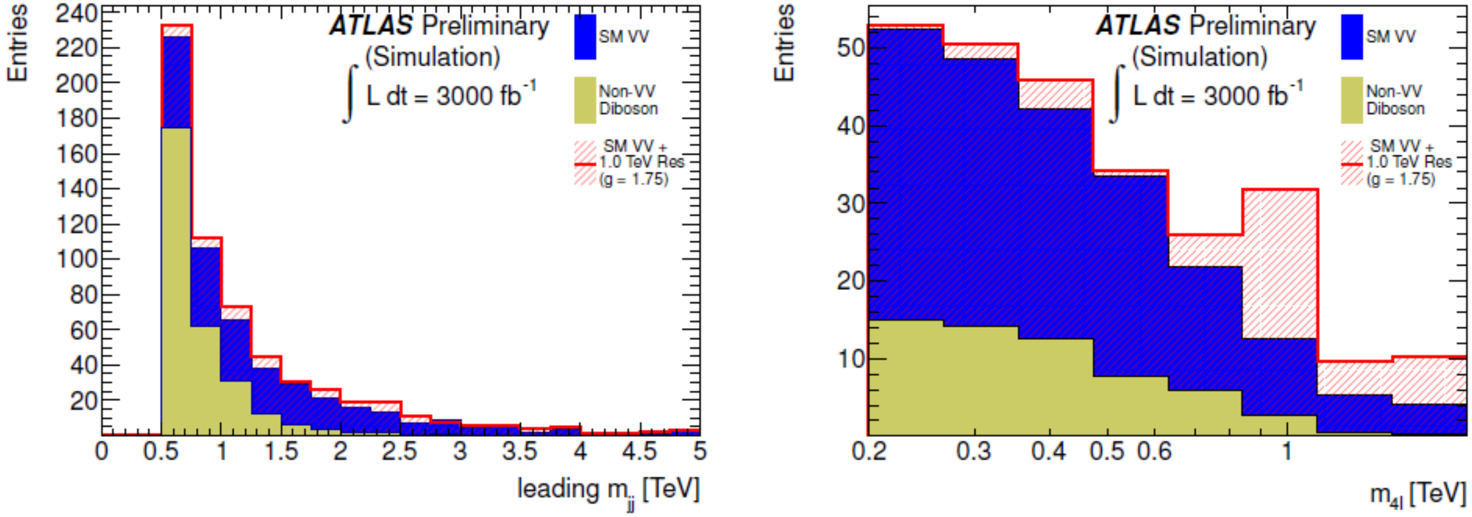
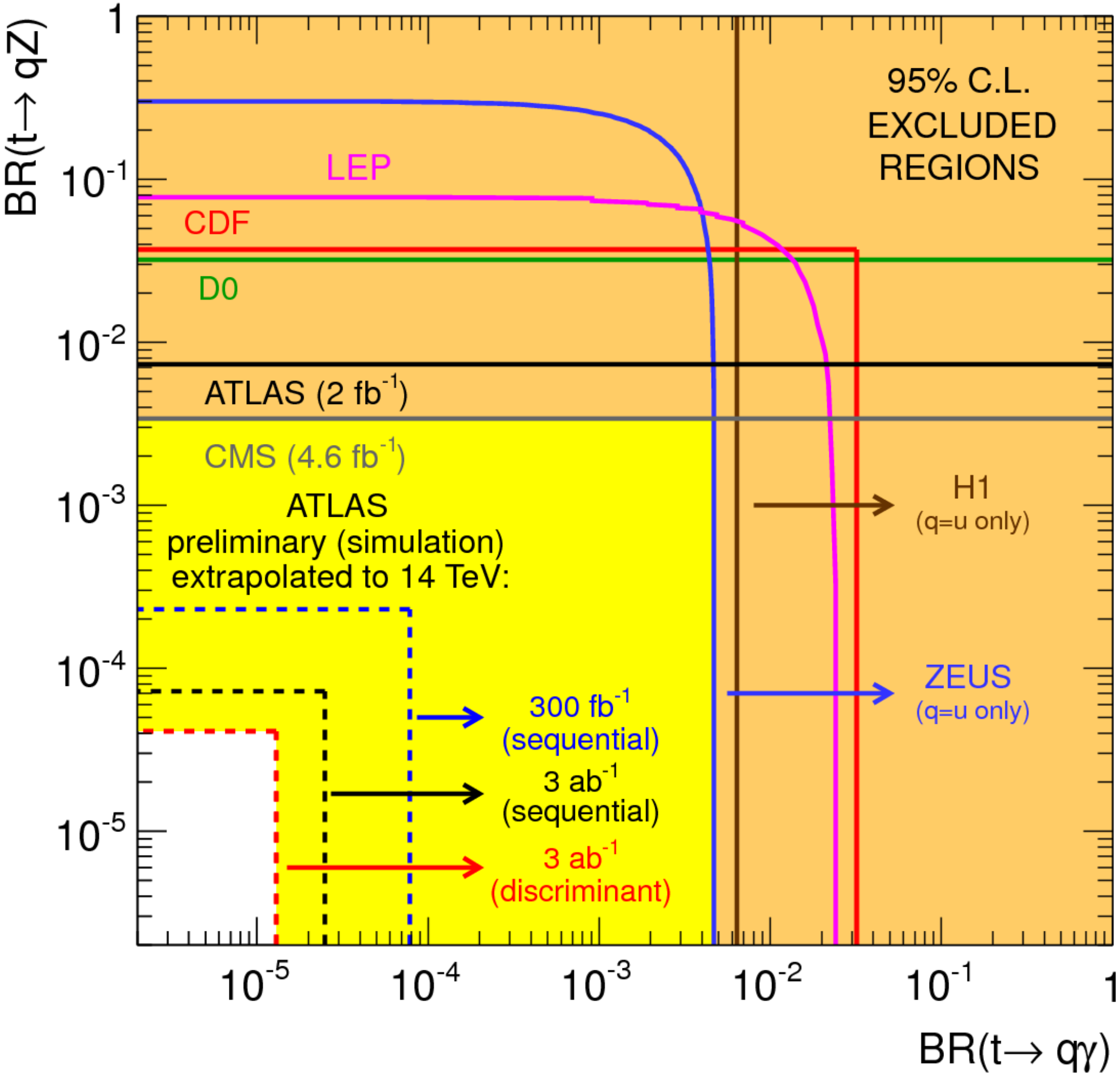


Figure 2: The leading jet-jet invariant mass (m_{jj}) distribution for simulated events in the $pp \to ZZ + 2j \to \ell\ell\ell\ell + 2j$ channel (left), and the reconstructed 4-lepton mass ($m_{4\ell}$) spectrum for this channel after requiring $m_{jj} > 1$ TeV (right). The spectra are normalized to 3000 fb^{-1}.

model	300 fb^{-1}	3000 fb^{-1}
$m_{\text{resonance}} = 500$ GeV, $g = 1.0$	2.4σ	7.5σ
$m_{\text{resonance}} = 1$ TeV, $g = 1.75$	1.7σ	5.5σ
$m_{\text{resonance}} = 1$ TeV, $g = 2.5$	3.0σ	9.4σ

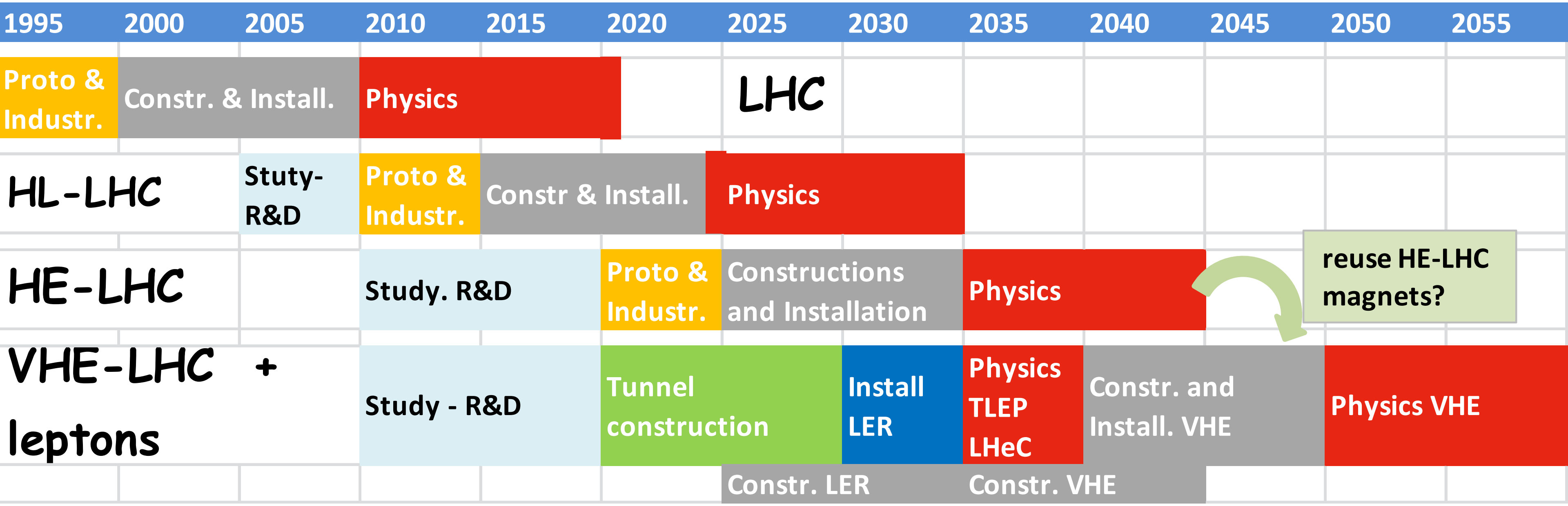
Table 5: Summary of expected sensitivity to anomalous VBS ZZ signal at $\sqrt{s} = 14$ TeV, quoted in the terms of the expected number of Gaussian σ in significance.

ATLAS-PHYS-PUB-2012-005



1
10^-1
10^-2
10^-3
10^-4
10^-5
BR(t→ qZ)
10^-5
10^-4
10^-3
10^-2
10^-1
1
BR(t→ qγ)
95% C.L.
EXCLUDED
REGIONS
LEP
CDF
D0
ATLAS (2 fb^-1)
CMS (4.6 fb^-1)
ATLAS
preliminary (simulation)
extrapolated to 14 TeV:
300 fb^-1
(sequential)
3 ab^-1
(sequential)
3 ab^-1
(discriminant)
H1
(q=u only)
ZEUS
(q=u only)

In principle a plan for all (?) is possible (for LHC exploitation): **2018-2020 is critical time**



1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055
Proto & Industr.	Constr. & Install.		Physics			**LHC**						
HL-LHC		Stuty-R&D	Proto & Industr.	Constr & Install.	Physics							
HE-LHC			Study. R&D		Proto & Industr.	Constructions and Installation		Physics			reuse HE-LHC magnets?	
VHE-LHC + leptons			Study - R&D		Tunnel construction		Install LER	Physics TLEP LHeC	Constr. and Install. VHE		Physics VHE	
						Constr. LER		Constr. VHE				

- According to Physics needs, the 80 km tunnel can:
  - Be alternative to HE-LHC
  - Or complementary to HE-LHC
  - Accomodating at negligible extra-cost TLEP and VLHeC (this last at 50GeV/5TeV and 350 GeV/50-100 TeV)
  - Skipping TLEP/VLHeC may shorten 5-10 years VHE-LHC

Slide from Lucio Rossi, CERN

Erice ES meeting procedure

The content and the scientific arguments of all the 8 chapters of the Briefing Book were presented and discussed in detail on the first two days of the meeting

The third day was devoted to the presentation and discussion of the organizational and other matters covered by WG1 to WG5

The proposed strategy update was then elaborated during the last two days in an iterative process (*), arriving at a consensus

(*) The excellent steering and preparatory work of the Strategy Secretariat led by T Nakada with the SPC Chair F Zwirner, the ECFA Chair M Krammer and the representative of EU Lab Directors Ph. Chomaz deserves special mentioning!