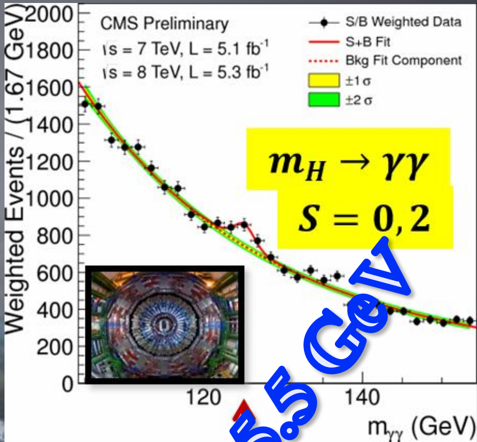
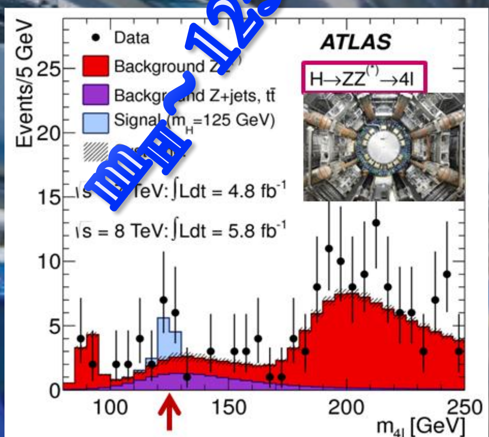
Update of the European Strategy for Particle Physics

Roy Aleksan
CERN
Feb. 22, 2013

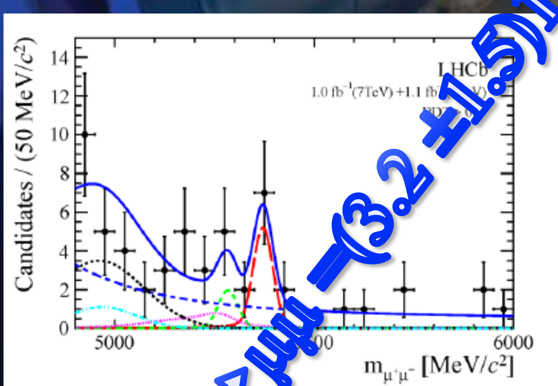
- The Frontiers of PP; what to do next?
- Next Accelerator Technology Challenges for PP
- Strategy
- Conclusion

Precision measurements
and
reaching higher energy

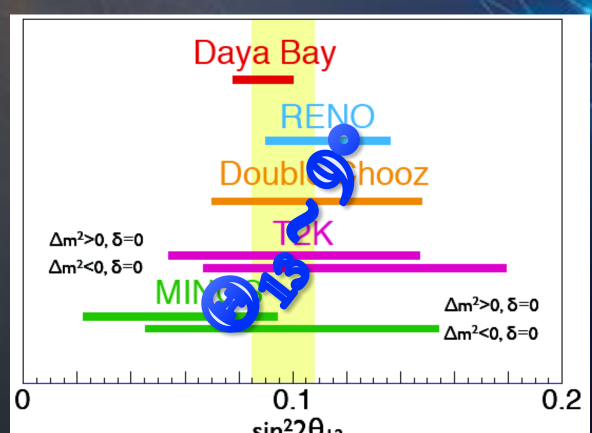




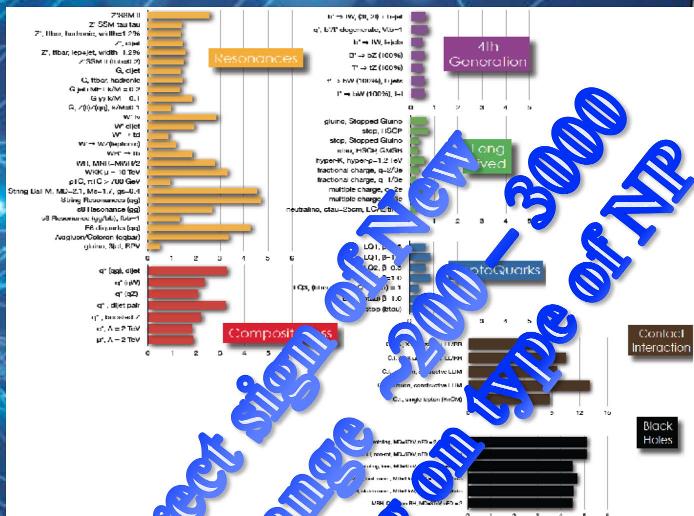
$m_H \sim 125.5$ GeV

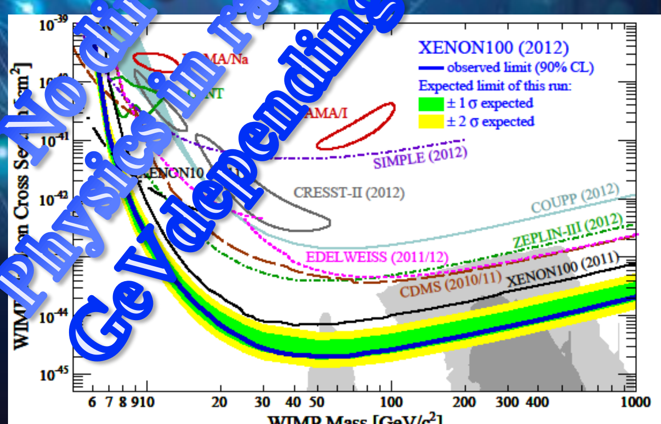


$B_s \to \mu\mu = (3.2 \pm 1.5)10^{-9}$



$\theta_{13} \sim 9°$





No direct sign of New Physics in range ~200 – 3000 GeV depending on type of NP

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Feb. 14, 2013

Update of the European Strategy for Particle Physics

Habemus Strategiam!

17 recommendations have been issued:

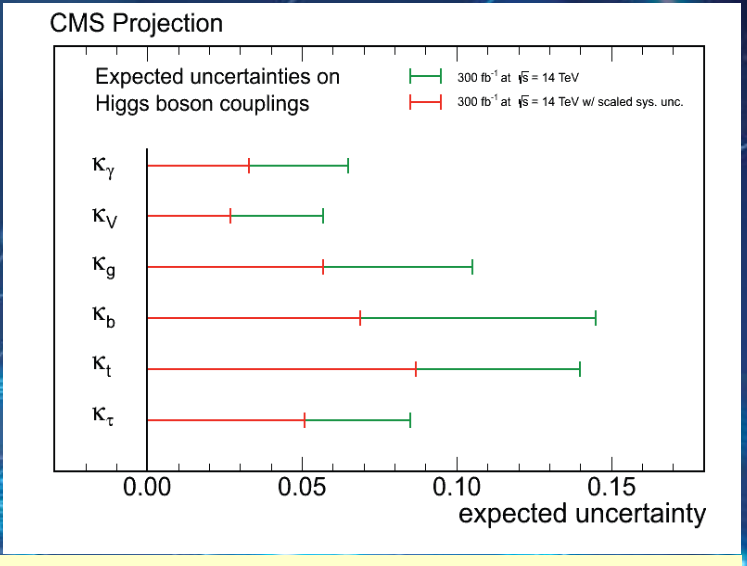
https://indico.cern.ch/getFile.py/access?resId=0&materialId=0&confId=217656

They have still to be endorsed by the CERN Council (March 20).

ElectroWeak Symmetry Breaking precision measurements

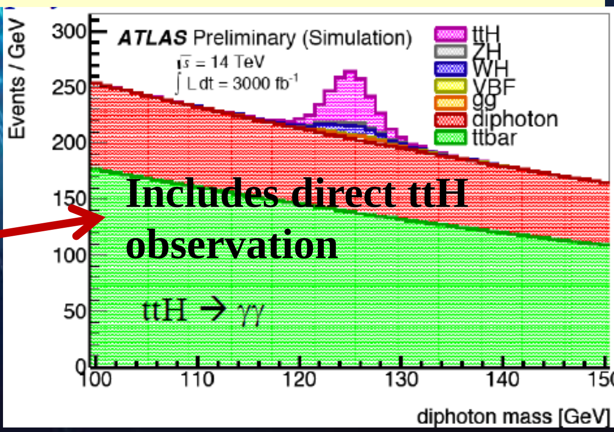
Accelerator → Physical quantity ↓	LHC $300fb^{-1}$ /exp	HL-LHC $3000fb^{-1}$ /exp
Approx. date	2021	2030-35?
N_H	1.7×10^7	1.7×10^8
Δm_H (MeV)	100	**50**
$\Delta\Gamma_H/\Gamma_H$	--	--
$\Delta\Gamma_{inv}/\Gamma_H$	Indirect (?)	Indirect (?)
$\Delta g_{H\gamma\gamma}/g_{H\gamma\gamma}$	6.5 – 5.1%	5.4 – **1.5%**
$\Delta g_{Hgg}/g_{Hgg}$	11 – 5.7%	7.5 – **2.7%**
$\Delta g_{Hww}/g_{Hww}$	5.7 – 2.7%	4.5 – **1.0%**
$\Delta g_{HZZ}/g_{HZZ}$	5.7 – 2.7%	4.5 – **1.0%**
$\Delta g_{HHH}/g_{HHH}$	--	**< 30%** (2 exp.)
$\Delta g_{H\mu\mu}/g_{H\mu\mu}$	<30%	<10%
$\Delta g_{H\tau\tau}/g_{H\tau\tau}$	8.5 – 5.1%	5.4 – **2.0%**
$\Delta g_{Hcc}/g_{Hcc}$	--	--
$\Delta g_{Hbb}/g_{Hbb}$	15 – 6.9%	11 – **2.7%**
$\Delta g_{Htt}/g_{Htt}$	14 – 8.7%	8.0 – **3.9%**
Δm_t (MeV)	800-1000	**500-800**
Δm_W (MeV)		**~10**

LHC is the benchmark Higgs Factory



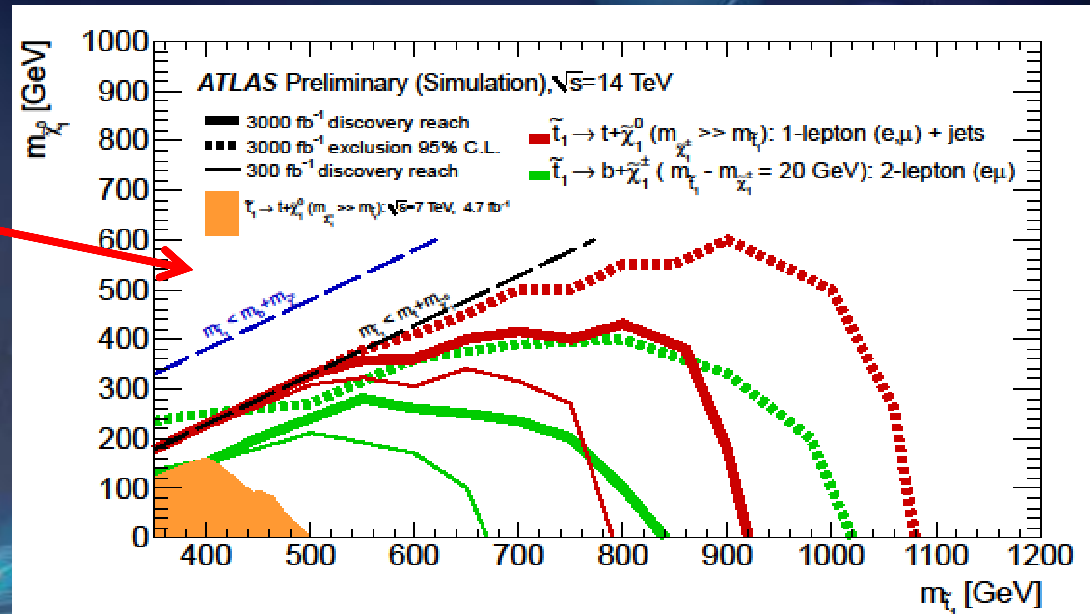
Coupling measurements with precisions:

- **in the range 6-15% with 300 fb^{-1}**
- **in the range 1-4% with 3000 fb^{-1b}**



Search of new particles

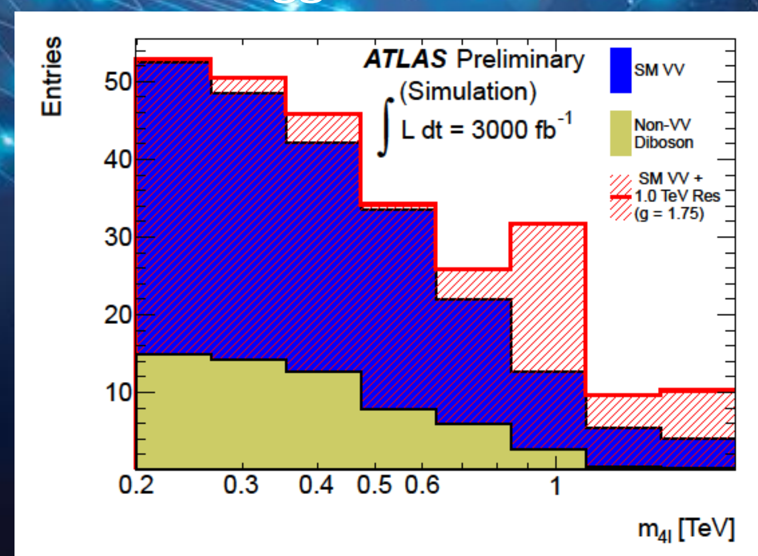
- Sensitivity on SUSY can be signicantly improved … in particular for stop



- High energy and luminosity are necessary to probe the $V_L V_L$ scattering and verify that unitarity is preserved, thanks to the « Higgs » discovered

A statistical presicion of 15% on the SM VBS contribution (i.e. VV+ 2 forward jets) can be obtained with HL-LHC

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



Recommendations from European Strategy Group

High-priority large-scale scientific activities (1)

Recommendation #1

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.*

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

- ➢ Strong R&D on these issues is necessary
- ➢ Very substantial programme ⇨ collaborative R&D needed
- ➢ All this work is a first step toward higher energy

- ➢ **Increase beam current ⇨ protect SC dipole (diffracted protons)**

  8T-15m ⇨ 11T-11m dipoles

- ➢ **Reduce beam size at IP ⇨ Larger aperture quads near IP**

  Change Quadrupole Triplets ⇨ 140T/m, 150mm (13T, 8m)

- ➢ **Protect Electrical Distribution Feedbox's (DFBX)**

  ⇨ 2×100 kA ~500m *HTS links*

- ➢ **Improve and adjust the luminosity with beam overlap control**

  ⇨ SC RF «Crab» Cavity, for p-beam rotation at fs level!

Recommendations from European Strategy Group (cont'd)

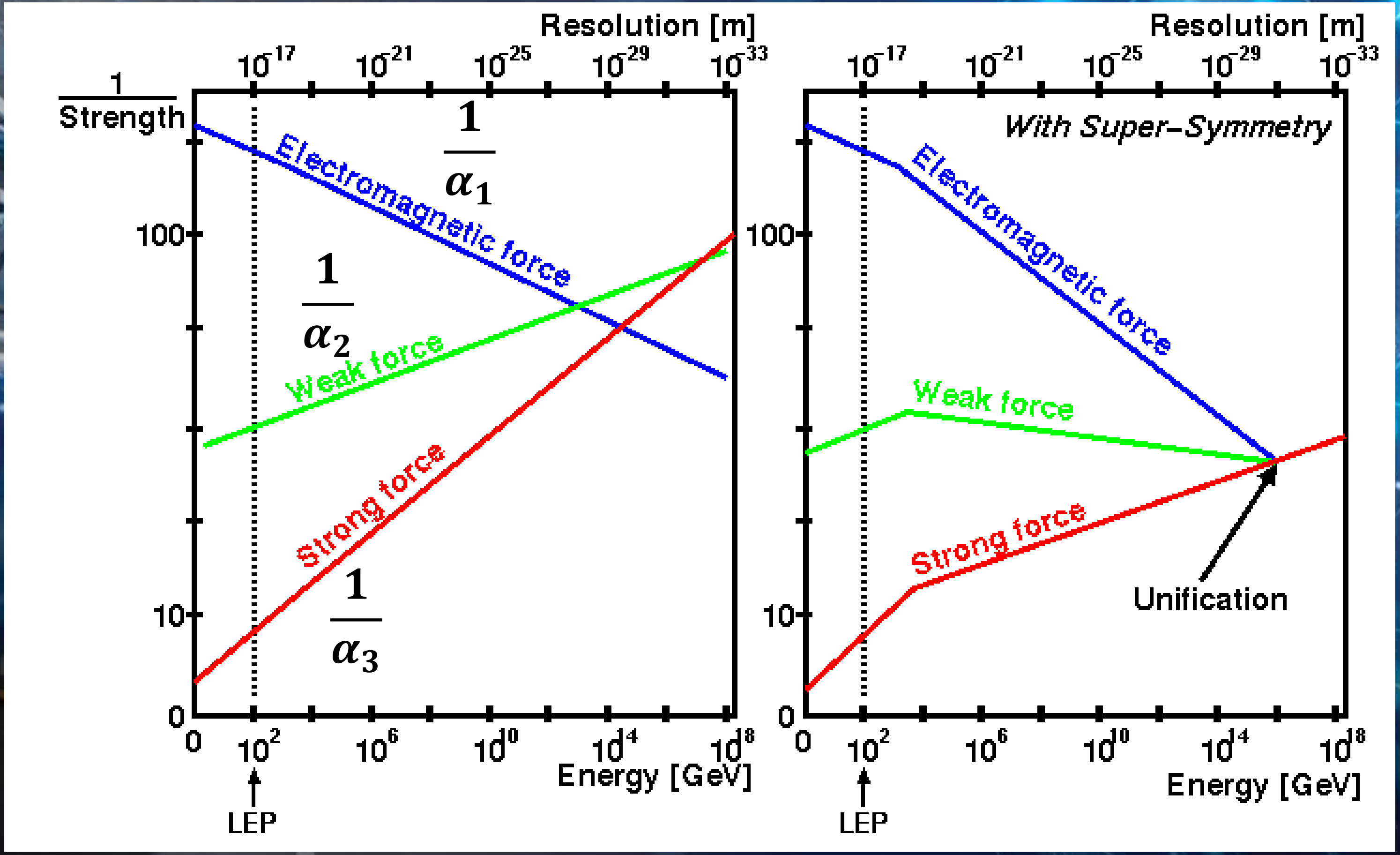
High-priority large-scale scientific activities (2)

Recommendation #2

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.*

Grand unification of Interactions (Strong, Weak, Electromagnetic)

Additionnal particles (such as supersymmetric partners) with energy scales of TeVs affect the running of the coupling constants

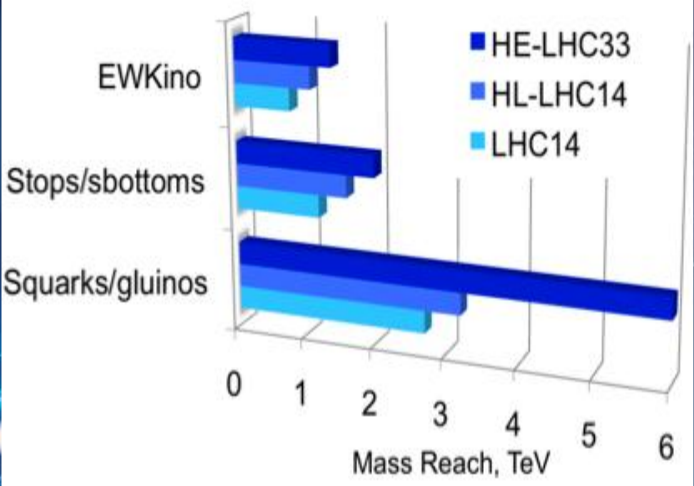


Need to explore higher energy regions (up to ~10 TeV)

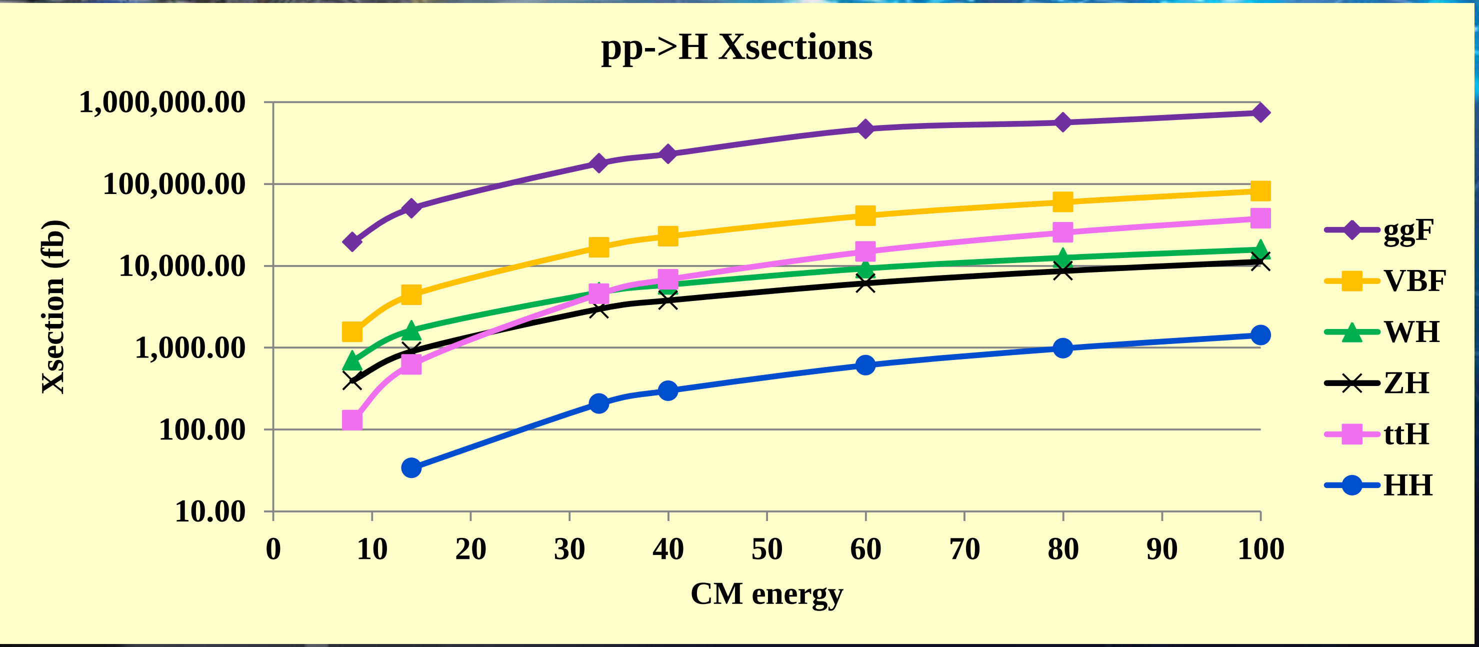
Whatever is found or not, reaching higher energies is unavoidable

To search for new particles up to 10 TeV, very high energy (>50TeV) is necessary

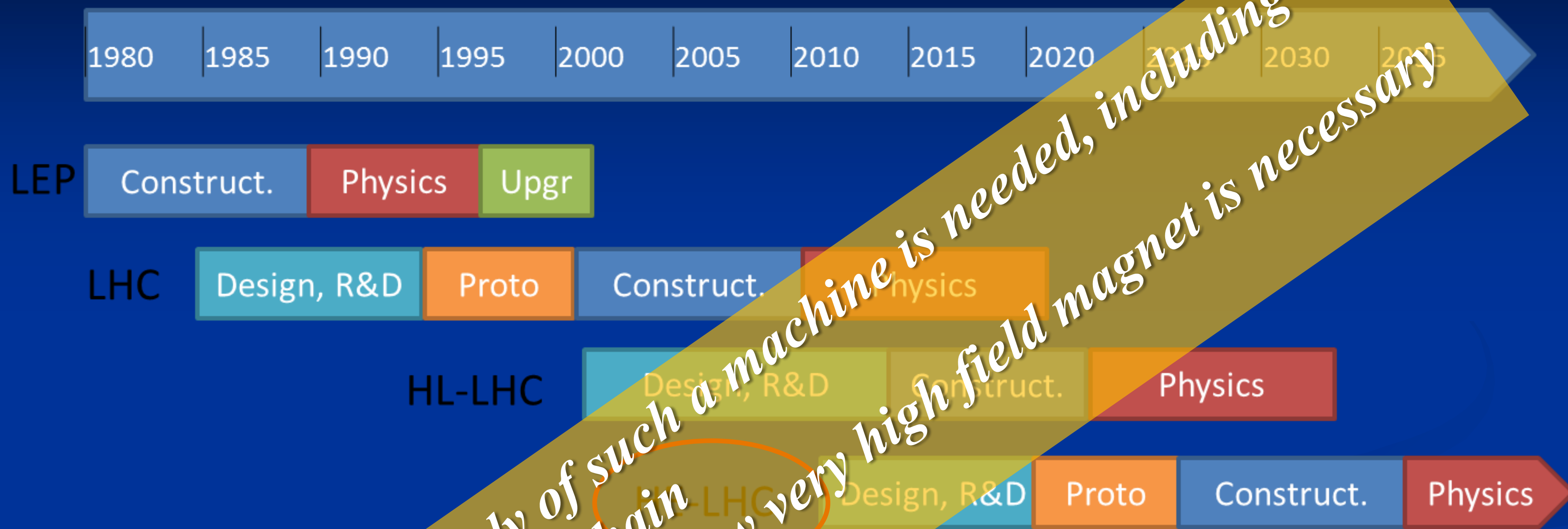
To probe $V_L V_L$ scattering up to 10 TeV region, very high energy is necessary



It will also allow more precise SM measurements



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



Either using existing LEP/LHC tunnel to reach 26-32 TeV collisions

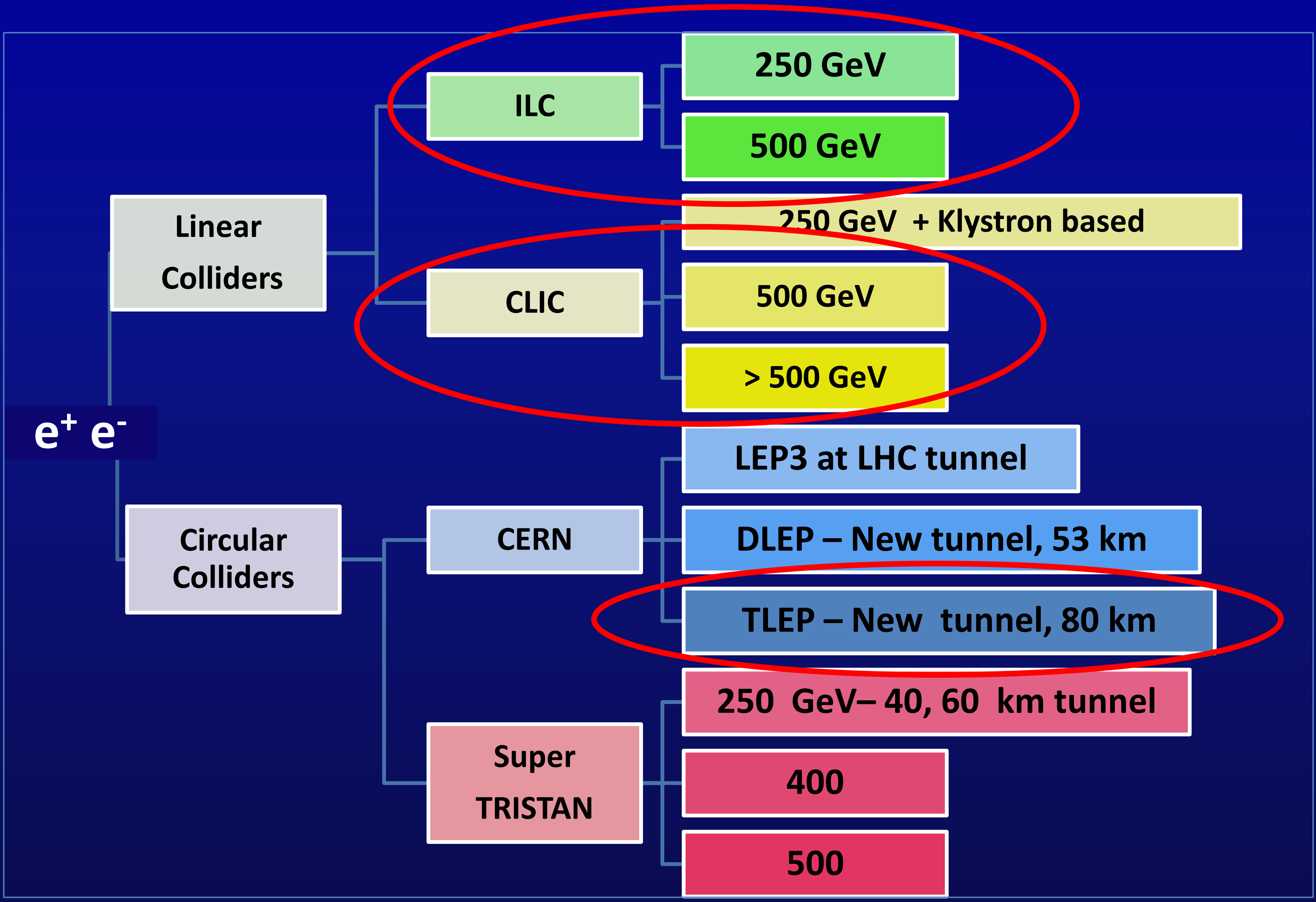
The detailed study of such a machine is needed, including the complete injection chain

Strong R&D on these new very high field magnet is necessary ⇨ collaborative R&D needed

Or build (or reuse) a 80km tunnel to reach 80-100 TeV collisions ⇨ more detailed study of such a tunnel needed

In both cases, SC challenge to develop 16-20 Tesla magnets! Magnets for HL_LHC is an indispensible first step

e^+e^- colliders «clean HIGGS FACTORIES»

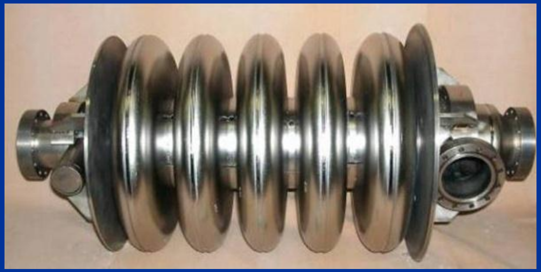


TLEP Ring e^+e^- collider: Primary Cost Driver

Tunnel: ~60% cost

Building on existing technologies and experience (LEP, KEKB, PEPII…)

Using SC cavities

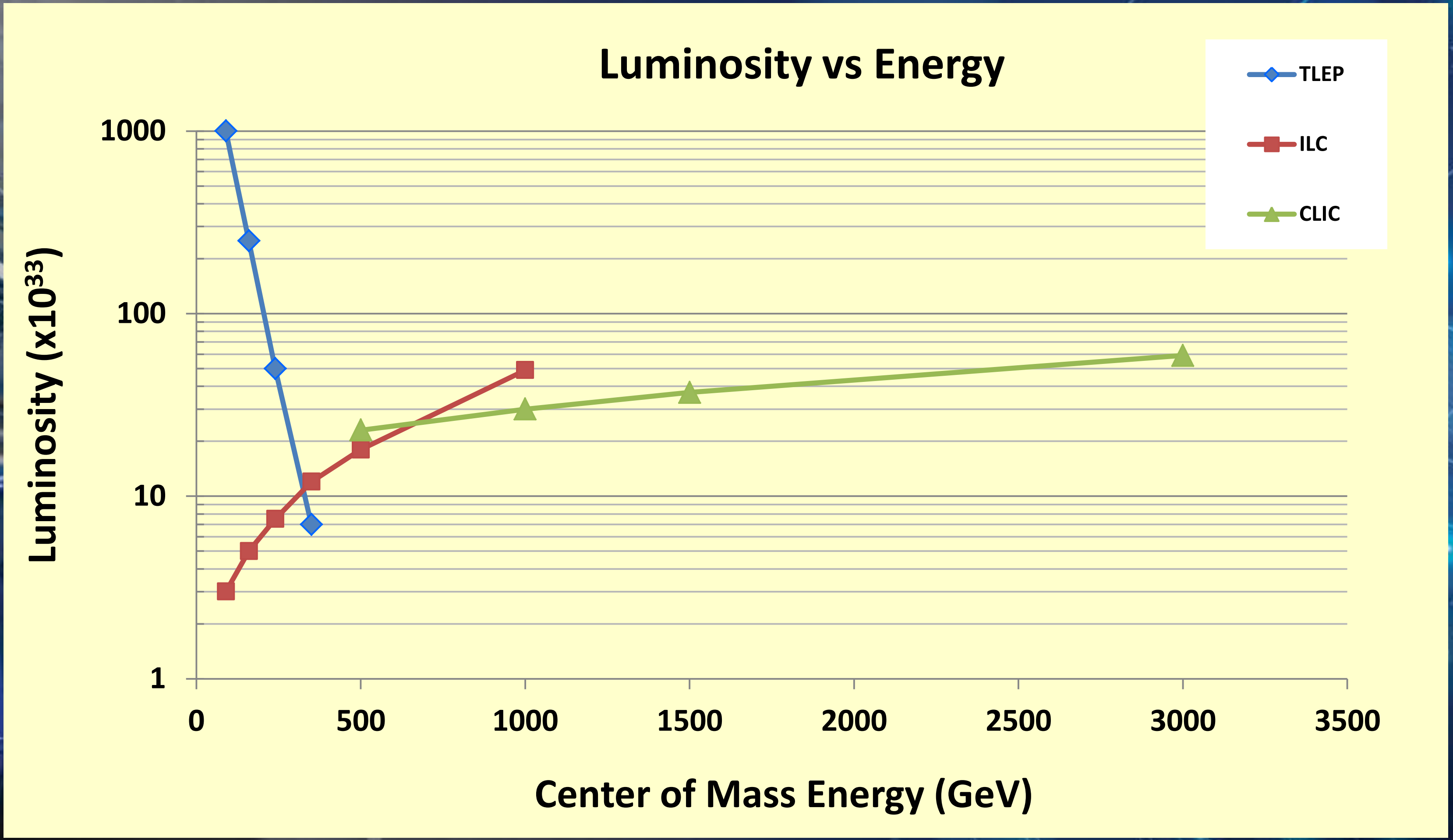


Could cover a wide range of energy up to 350 Gev collision energy.

Energy CM (GeV)	90	240	350
Luminosity ($x10^{34}cm^{-2}s^{-1}$)	100	~5	~0.7
Cavity Gradient (MV/m)	20	20	20
#5-cell SC cavities	100	300	600
Beam lifetime (mn)	37	16	27
Total AC power (MW)	250	250	250

Most parameters have been achieved or are planned at SuperKEKB

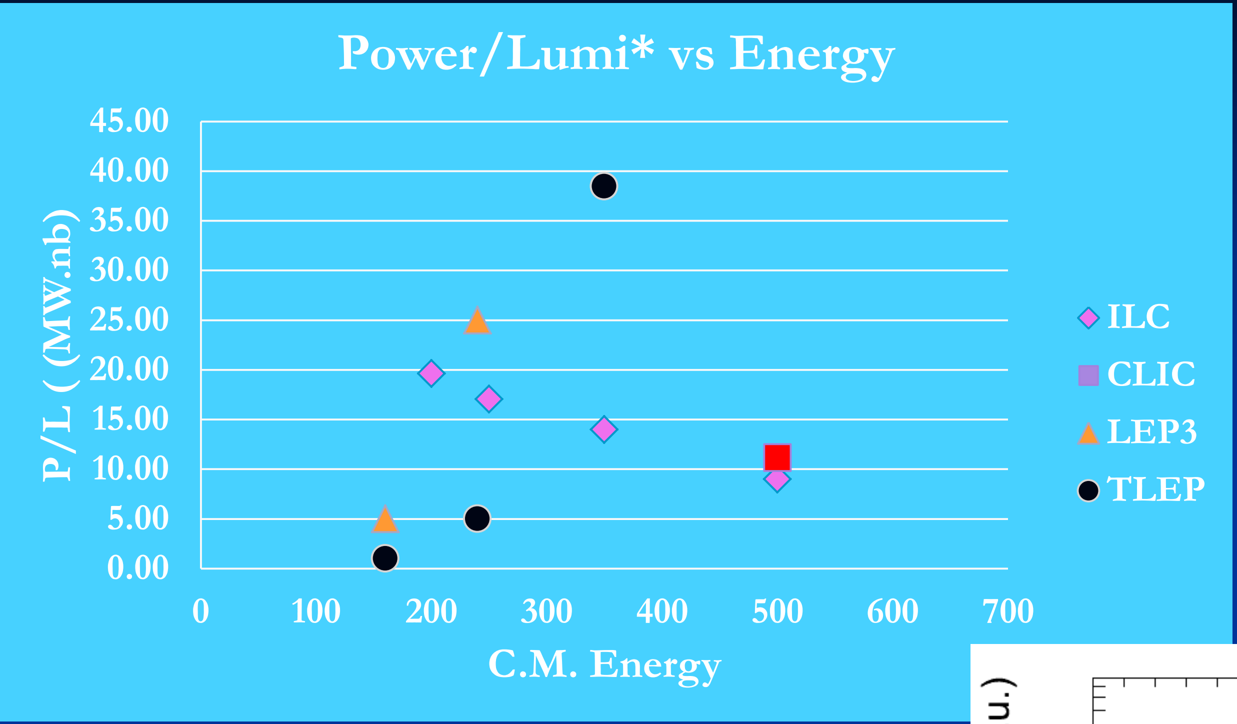
ElectroWeak Symmetry Breaking precision measurements require very high luminosity



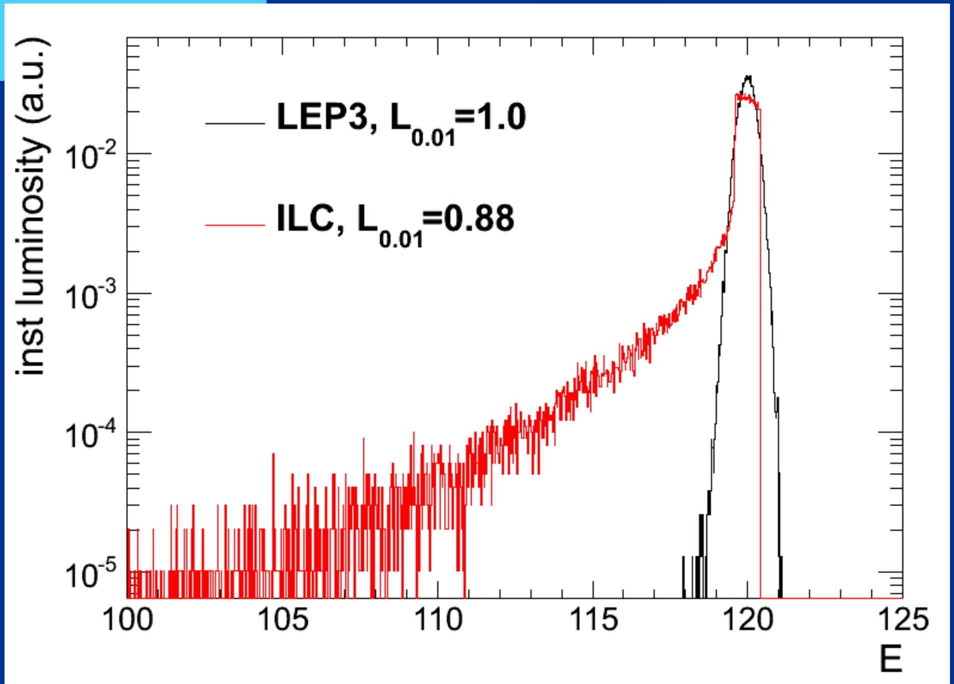
ElectroWeak Symmetry Breaking precision measurements

Accelerator → Physical quantity ↓	HL-LHC $3000 fb^{-1}$ /exp	ILC (250) $250 fb^{-1}$	ILC (250+350+1000)	LEP3 240 4 IP	TLEP 240 +350 4 IP
Approx. date	2030-35	2030-35?	>2045?	2035?	2035?
N_H	1.7×10^8	$5\ 10^4$ ZH	(10^5 ZH) ($1.4\ 10^5$ Hvv)	$4\ 10^5$ZH	$2\ 10^6$ ZH
Δm_H (MeV)	50	35	35	26	7
$\Delta\Gamma_{H/}\Gamma_H$	--	10%	3%	4%	1.3%
$\Delta\Gamma_{inv/}\Gamma_H$	Indirect (?)	1.5%	1.0%	0.35%	0.15%
$\Delta g_{H\gamma\gamma}/g_{H\gamma\gamma}$	1.5%	--	5%	3.4%	1.4%
$\Delta g_{Hgg}/g_{Hgg}$	2.7%	4.5%	2.5%	2.2%	0.7%
$\Delta g_{Hww}/g_{Hww}$	1.0%	4,3%	1%	1.5%	0.25%
$\Delta g_{HZZ}/g_{HZZ}$	1.0%	1.3%	1.5%	0.65%	0.2%
$\Delta g_{HHH}/g_{HHH}$	< 30% (2 exp.)	--	~30%	--	--
$\Delta g_{H\mu\mu}/g_{H\mu\mu}$	<10%	--	--	14%	7%
$\Delta g_{H\tau\tau}/g_{H\tau\tau}$	2.0%	3,5%	2.5%	1.5%	0.4%
$\Delta g_{Hcc}/g_{Hcc}$	--	3,7%	2%	2.0%	0.65%
$\Delta g_{Hbb}/g_{Hbb}$	2.7%	1.4%	1%	0.7%	0.22%
$\Delta g_{Htt}/g_{Htt}$	3.9%	--	15%	--	30%
Δm_t (MeV)	500-800	--	20	--	20
Δm_W (MeV)	~10	--	~6	--	< 1

An important parameter is the power per unit of luminosity



*Luminosity not corrected for peak1% factor



Although based on strong experience in building circular collider, several challenges have to be overcome:

Beamstrahlung:

⇨ Beam lifetime reduction (should not be much smaller than bhabha limits

⇨ Need to study the energy acceptance of the collider (2%)

Bremstrahlung:

⇨ Need to study heat extraction and radiation damage and shielding issues

Top up ring:

⇨ Need to study the injection system

- *Idea is rather new triggered by low Higgs mass but based on long and mature experience in circular colliders*
- *superKEKB is a very effective technology test case*
- *Promising possibility ⇨ need to set up a international study*

Explore synergies for
VLCC (Very Large Collider Complex)
e^+e^-, pp, ep?

Many other accelerator R&D topics have not been discussed here e.g. e-p collider, γγ collider, plasma acceleration…
They should not be forgotten…

…but at present either the physics reach is deemed limited and/or lead time seems too long

Proton-proton and electron-positron colliders appear as most promissing/practical options

Recommendations from European Strategy Group (cont'd)

High-priority large-scale scientific activities (3)

Recommendation #3

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*.

Recommendations from European Strategy Group (cont'd)

High-priority large-scale scientific activities (4)

Recommendation #4

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 neutrino projects in the US and Japan.*

Conclusion

- The last few years were very exciting
- Many teams have contributed to this success, they have to be warmly congratulated
- Thanks to this work, Prospects for the Future looks very promising, with many new ideas emerging
- The Strategy is an opportunity to bring these ideas on the table and provide further momentum toward our quest for understanding the fundamental laws of the Universe
- The Strategy is an important opportunity to open up a long term ambitious vision for Particle Physics in Europe
- Accelerator R&D is vital to enable the realization of our vision and should be at the highest priority topic of our strategy

My Conclusion

- A Very Large Collider Complex (VLCC), such as VHE-LHC/TLEP or HE-LHC/LEP3, possibly with an e-p option, is a very promising and exciting possible roadmap for frontier leading science in Europe
- Europe needs to study these options vigorously by setting up a coordinated international study consortium for
  - Physics studies
  - Accelerator studies
  - Detector studies
    - Including Computing needs
- Europe should create a collaborative framework to carry out the required technology R&D

My Conclusion

- Ambitious milestones should be set up
  - ➢ CDR in 2 years
  - ➢ TDR in 5 years, in a timely fashion with an update of the European Strategy in 2017-18, after the first round of operation of the LHC@13-14 TeV
- A possible timeline should be discussed

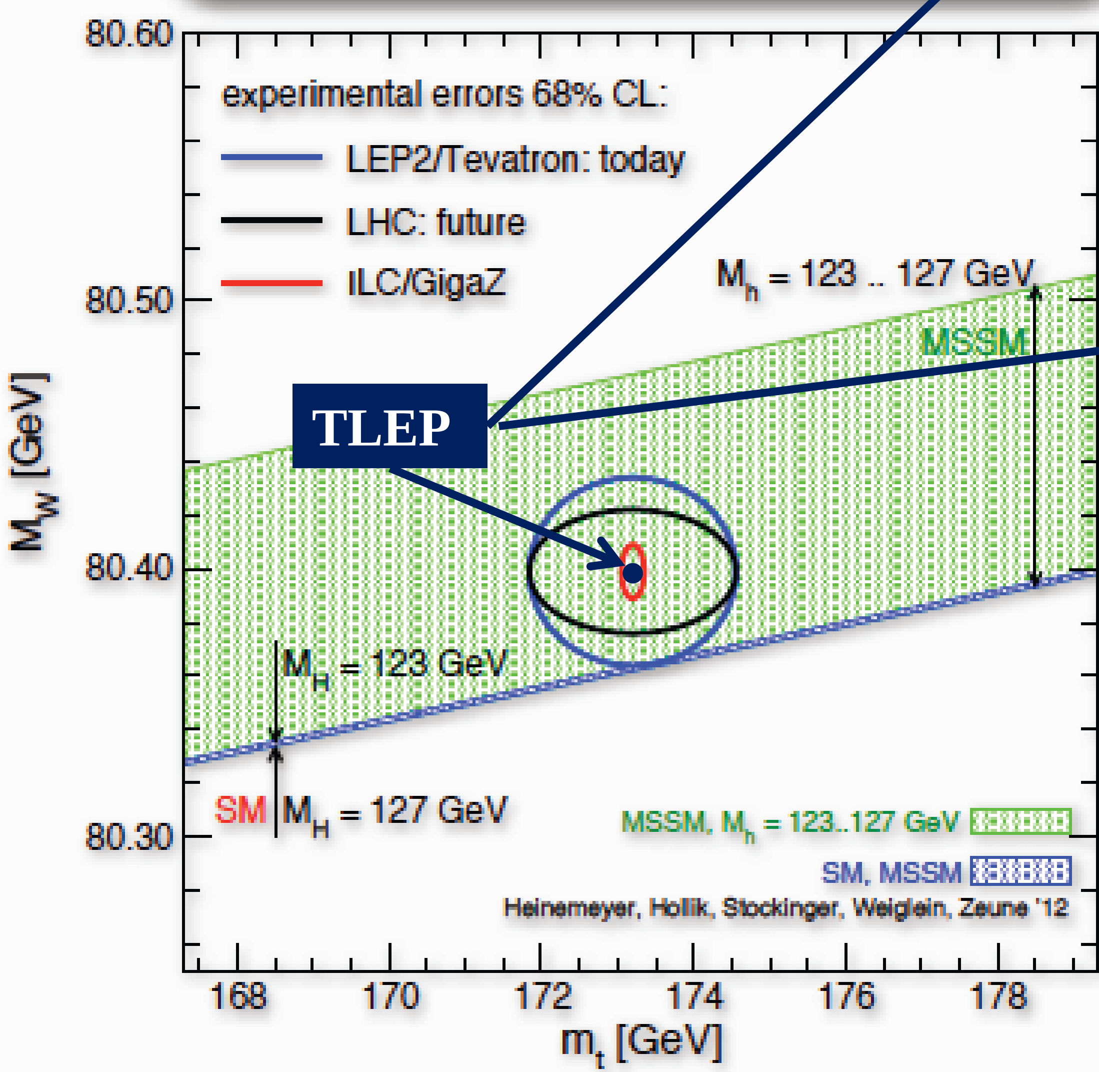
	2010	2015	2020	2025	2030	2035	2040
LHC							
HL-LHC		R&D + constr					
TLEP*			Design + R&D + construction				
VHE-LHC*			Design + R&D + construction				

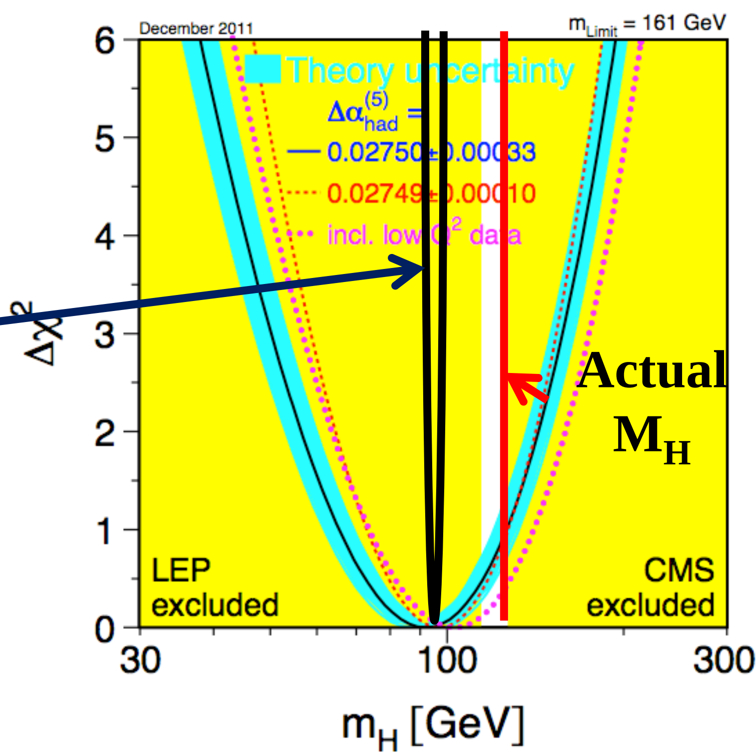
*tentative timeline; similar timeline applies for LEP3/HE-LHC but installation requires stopping LHC

My Conclusion

Indirect: M_H=94.0 ± 1.5
Direct: M_H=125.500 ±0.007

Extending the concept to a BSM framework, and projections:





Note: This is indicative, a careful analysis still to be carried out

My Conclusion

Habemus Cogitationes!