



*Accelerating Science and Innovation*

The CERN Programme  
embedded in the European Strategy  
(to be approved May 30<sup>th</sup>)

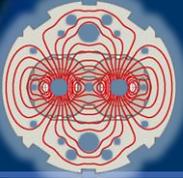
# CERN Medium Term Plan

Objectives unchanged wrt previous years:

- Full exploitation of LHC physics potential
- Unique fixed target physics program including approved upgrades
- Continuation of urgent consolidation needs
- Medical applications

Highest priority





# a remarkable year 2012



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ELSEVIER

## PHYSICS LETTERS B

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)  
SciVerse ScienceDirect

**S/(G+B) Weighted Events / 1.5 GeV**

**Local  $p_0$**

**ATLAS 2011-12  $\sqrt{s} = 7-9$  TeV**

<http://www.elsevier.com/locate/physletb>

**The Economist**

JULY 7TH - 13TH 2012 [Economist.com](http://economist.com)

In praise of charter schools  
Britain's banking scandal spreads  
Volkswagen overtakes the rest  
A power struggle at the Vatican  
When Lonesome George met Nora

# A giant leap for science

**Finding the Higgs boson**



March 2013

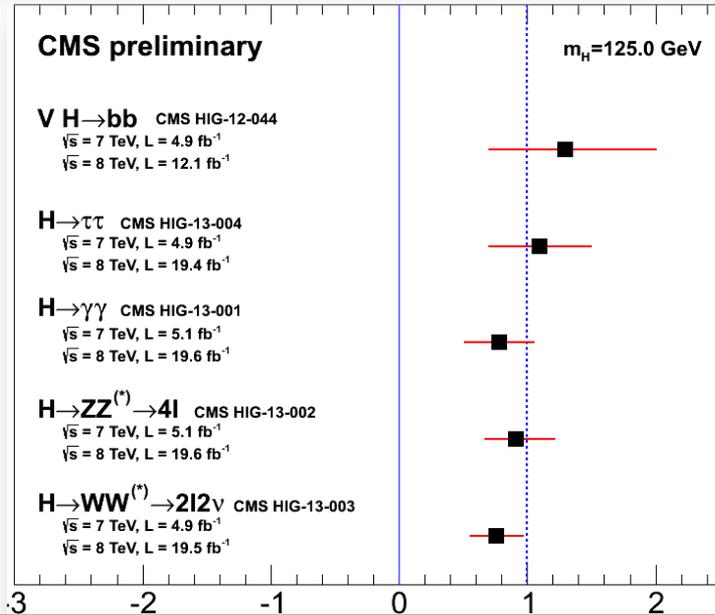
# We have a Higgs boson!

- But what kind of Higgs is it?
  - 5 main channels shown at right
    - All are determined at  $m=125$  GeV except for the ZZ channel which uses the best fit  $m_{ZZ}=125.8$
    - Full combination with best combined mass value will result in different signal strengths than those seen here.

Consistent with SM

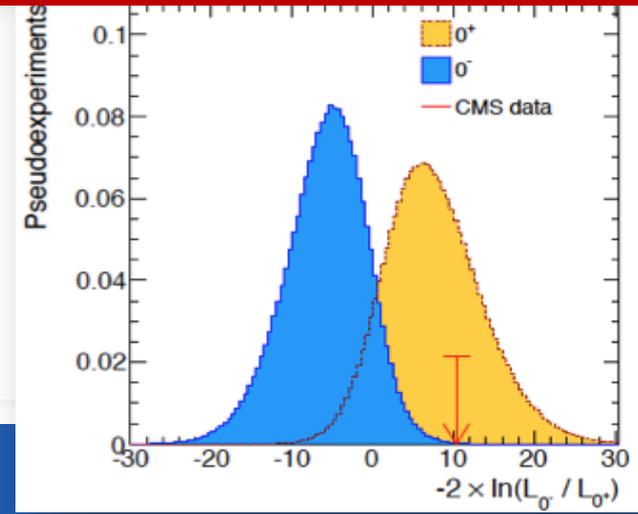
But can't rule out a BSM Higgs!

- New significance values:
  - $H \rightarrow ZZ \rightarrow 4l$ :  $6.7 \sigma$  (7.2 exp.)
  - $H \rightarrow WW$ :  $4.1 \sigma$  (5.1 exp.)
  - $H \rightarrow \gamma\gamma$ :  $3.2 \sigma$  (4.2 exp.)
  - $H \rightarrow \tau\tau$ :  $2.9 \sigma$  (2.6 exp.)
- New mass values
  - ZZ:  $m_H = 125.8 \pm 0.5$  (stat.)  $\pm 0.2$  (syst.)
  - $\gamma\gamma$ :  $m_H = 125.4 \pm 0.5$  (stat.)  $\pm 0.6$  (syst.)
  - $\tau\tau$ :  $m_H = 120^{+9}_{-7}$  (stat+syst) GeV



NEW

It has the properties of a Higgs boson



J. Incandela UCSB/CERN  
March 19, 2013 CMS Highlights 281st SPC Meeting, CERN



... but that's only the beginning !  
What's next ?

... it is a Higgs Boson !

... is it *the* Higgs Boson (of the Standard Model) ?  
or one of several ?

... its properties could give information  
on Dark Matter

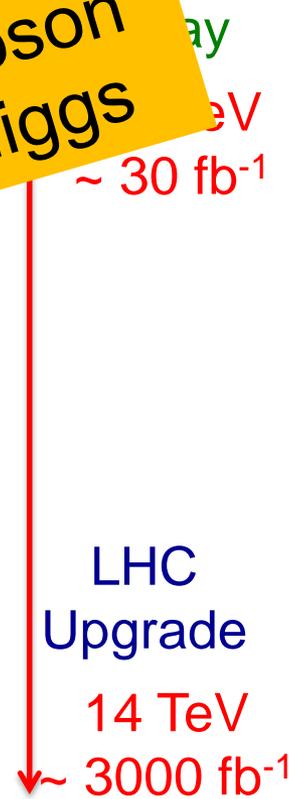
... its properties could give first hints  
on Dark Energy

Physics programme at the LHC  
beyond 2030

# The Couplings roadmap

Test Higgs boson couplings depending on available  $L$ :

- Total signal yield tested at 10-20%
- Couplings to **Fermions**
- Loop couplings
- **Charged Higgs** couplings
- **Looking only at the studies of the Higgs Boson**
- **There is much more physics beyond the Higgs**
- **Top quark fermion couplings**
- **Top quark direct measurement  $ttH$ :  $\kappa_t$**
- Test **second generation** fermion couplings:  $\kappa_\mu$
- **Higgs self-couplings** couplings  $HHH$ :  $\kappa_H$



# Update of the European Strategy for Particle Physics

## High-priority large-scale scientific activities

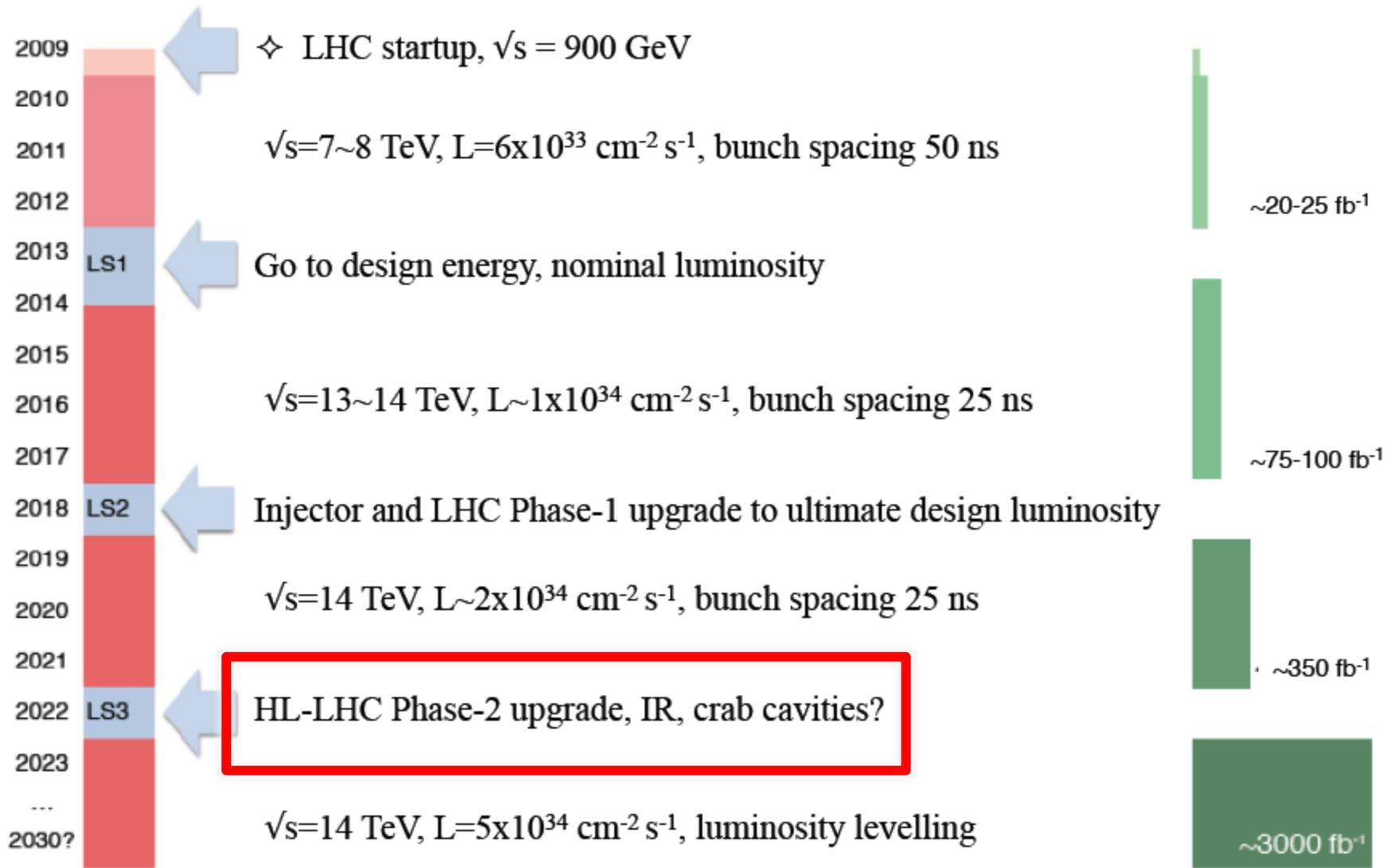
After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

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 LHC roadmap to fully exploit the physics potential

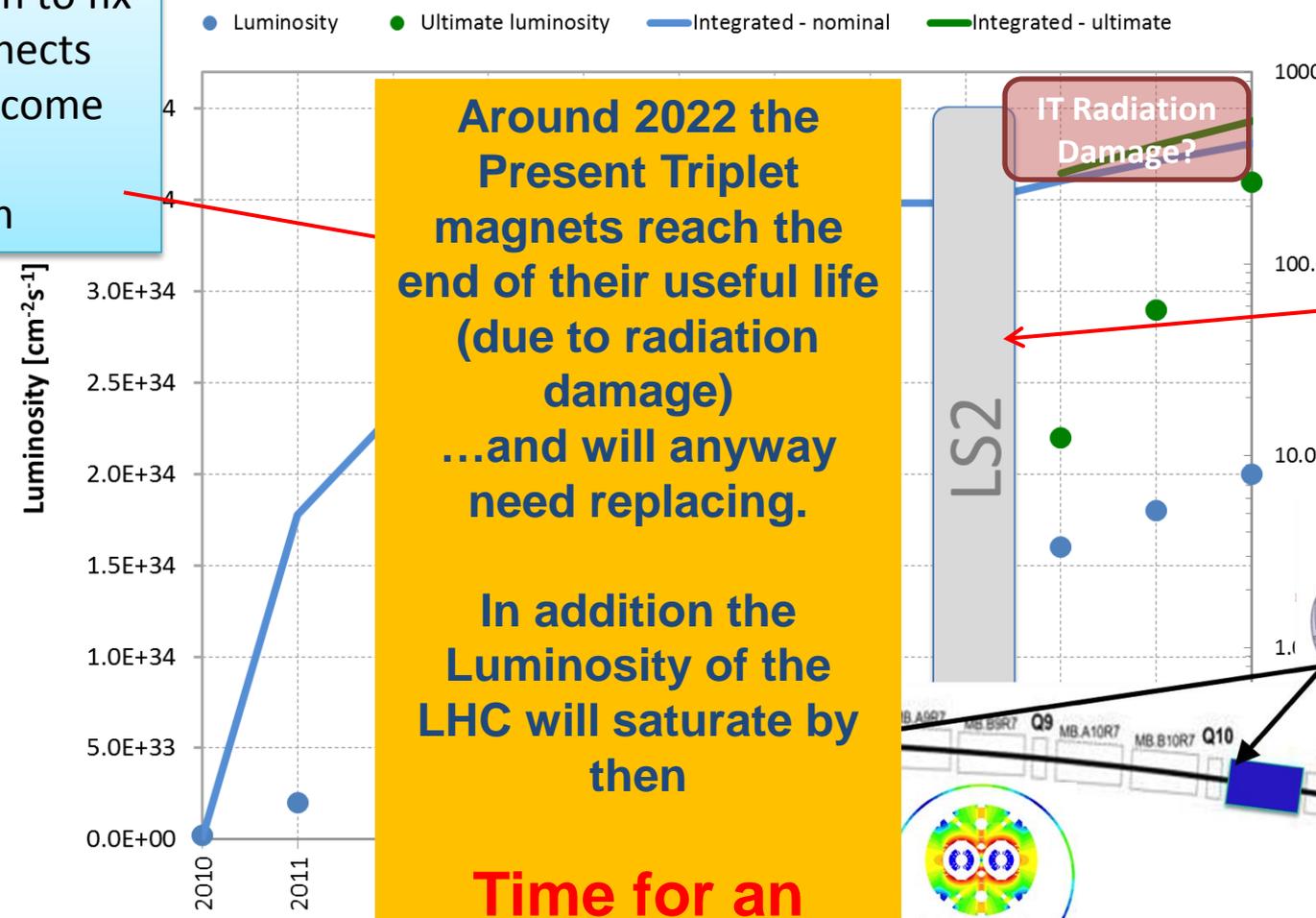




# Luminosity: Best Guess for the next 10 years



Shutdown to fix interconnects and overcome energy limitation

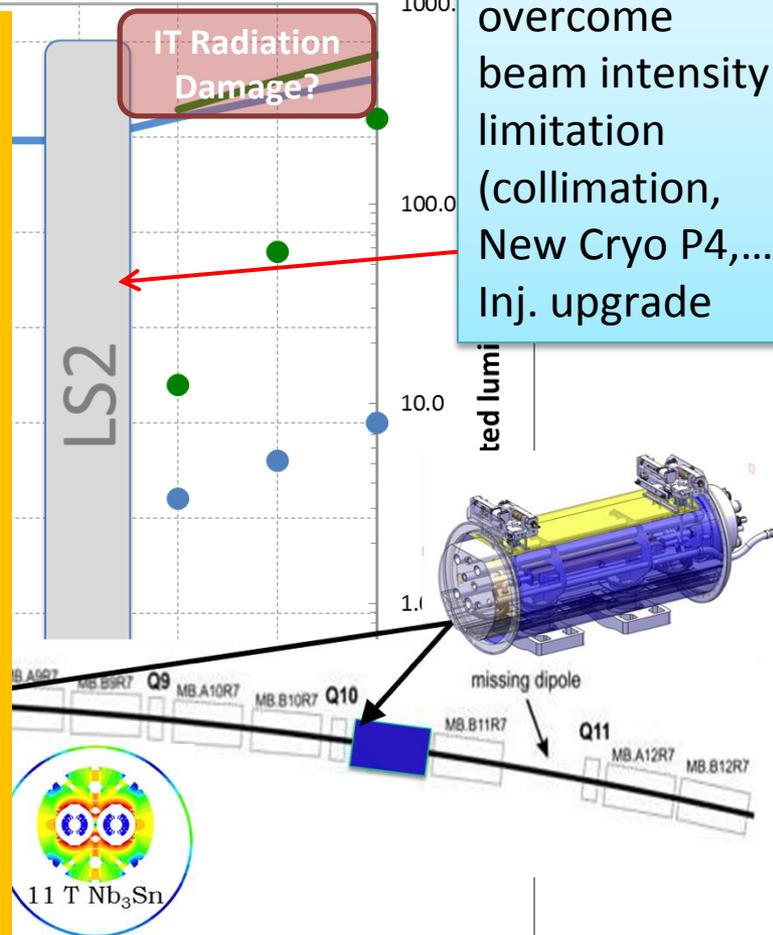


Around 2022 the Present Triplet magnets reach the end of their useful life (due to radiation damage) ...and will anyway need replacing.

In addition the Luminosity of the LHC will saturate by then

Time for an upgrade: HL-LHC

Shutdown to overcome beam intensity limitation (collimation, New Cryo P4,...) Inj. upgrade



# LHC and Injectors 2013/14

- LS1 ongoing as planned
- Restart of accelerator chain in 2014
  - mid June PSB, Isolde
  - mid July east area
  - mid October SPS
- Restart LHC 2015 (commissioning, then physics)



# Computing Technologies: the Grid

After filtering, CERN detectors select  $\sim 200$  interesting collisions per second.

Several MBs of data to be stored for each collision...

 more than 25 Petabytes/year of data!

**Grid and continuation  
of its Global Collaboration  
vital for the programme**

8 Megabyte (8MB)  
A digital photo

1 Gigabyte (1GB)  
= 1000MB  
A DVD movie

1 Terabyte (1TB)  
= 1000GB  
World annual  
book production

> 25 Petabytes (25PB)  
= 25000TB  
Annual LHC data output

CERN, home of the World Wide Web, is a driving force  
in Grid Computing

# LHC

## Key message

There is a program  
with the

**Upgrades to accelerator complex,  
detectors, and computing Grid are  
vital to fully exploit the physics potential of LHC**

14 TeV design luminosity

*14 TeV high luminosity (HL-LHC)*

An aerial photograph of a rural landscape, likely in Europe, showing a patchwork of agricultural fields in various shades of green and brown. A large, thin white circle is drawn over the center of the image, encompassing a significant portion of the landscape. The text "beyond LHC?" is written in a bold, yellow, sans-serif font across the middle of the circle. In the lower right quadrant, there is a small, circular structure that resembles a particle accelerator or a similar facility. The overall scene is a mix of natural and human-made elements, with a river or stream visible in the upper right corner.

beyond LHC ?

Next decades

# Road beyond Standard Model

At the energy frontier through synergy of

hadron - hadron colliders (LHC, (V)HE-LHC?)

lepton - hadron colliders (LHeC ??)

lepton - lepton colliders (LC (ILC or CLIC) ?)

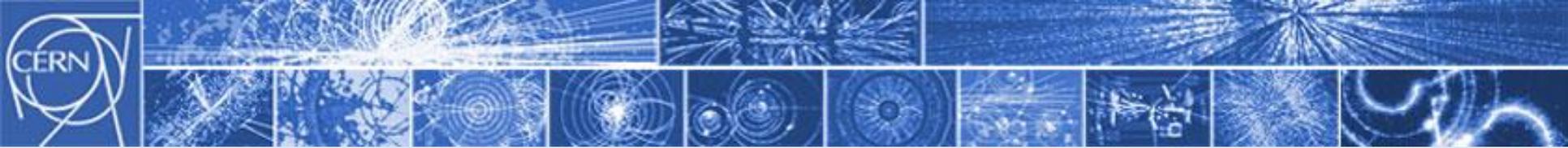
LHC results vital to guide the way at the energy frontier

## 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.

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.***

**This covers all colliders mentioned before, albeit with different priority**



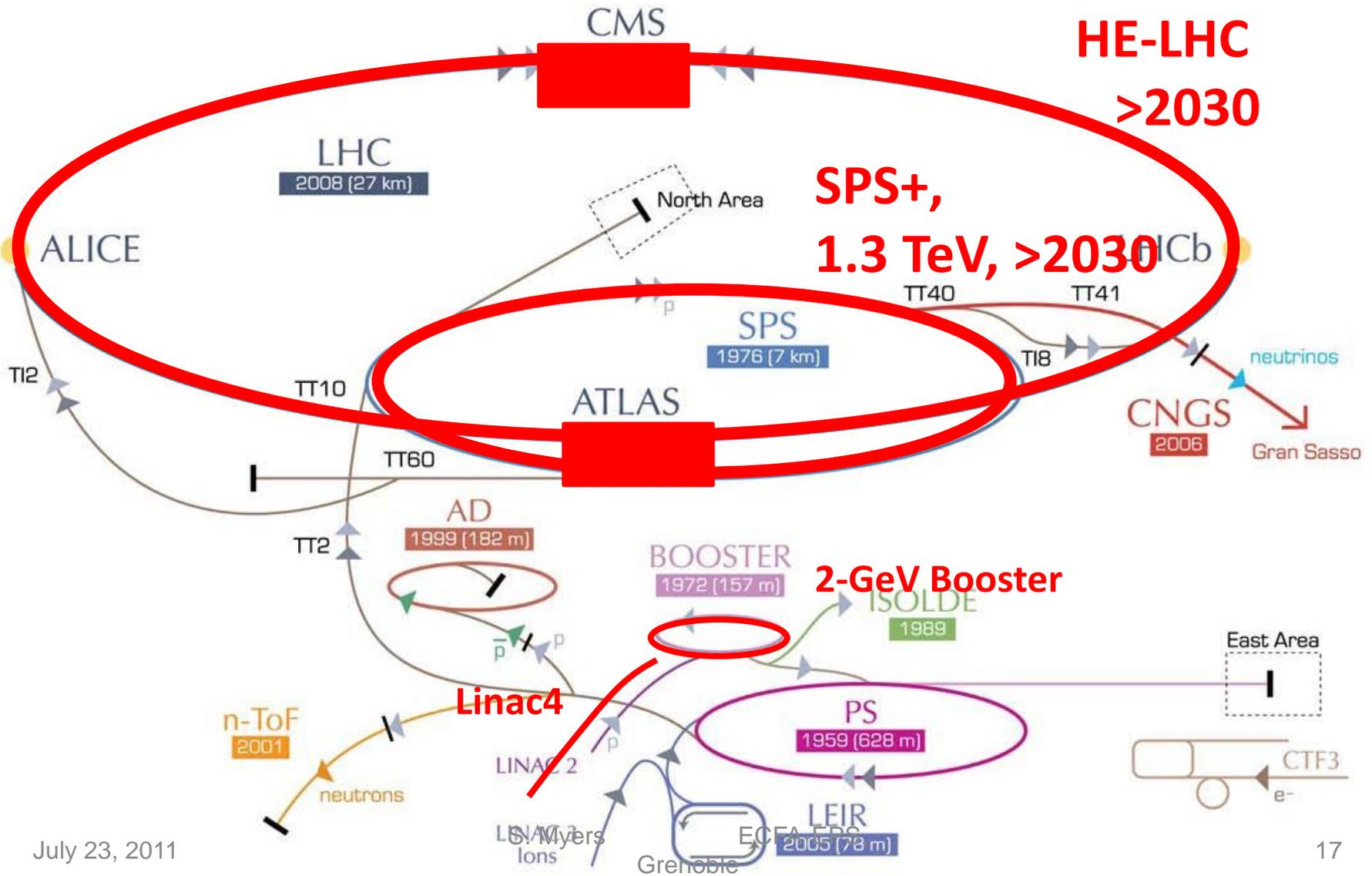
# High Energy Hadron – Hadron Colliders

HE – LHC and VHE-LHC

Study of New Physics Phenomena

main challenge: High-Field Magnets

# HE-LHC – LHC modifications



# HE-LHC

- HE-LHC dipole design will piggy back on the high gradient quadrupole R&D needed for HL-LHC
  - Would allow an increase in energy by factor of 2-2.5

# Beyond High Energy LHC

- **First studies on a new 80 km tunnel in the Geneva area**
  - **42 TeV** with 8.3 T using present LHC dipoles
  - **80 TeV** with 16 T based on Nb<sub>3</sub>Sn dipoles
  - **100 TeV** with 20 T based on HTS dipoles

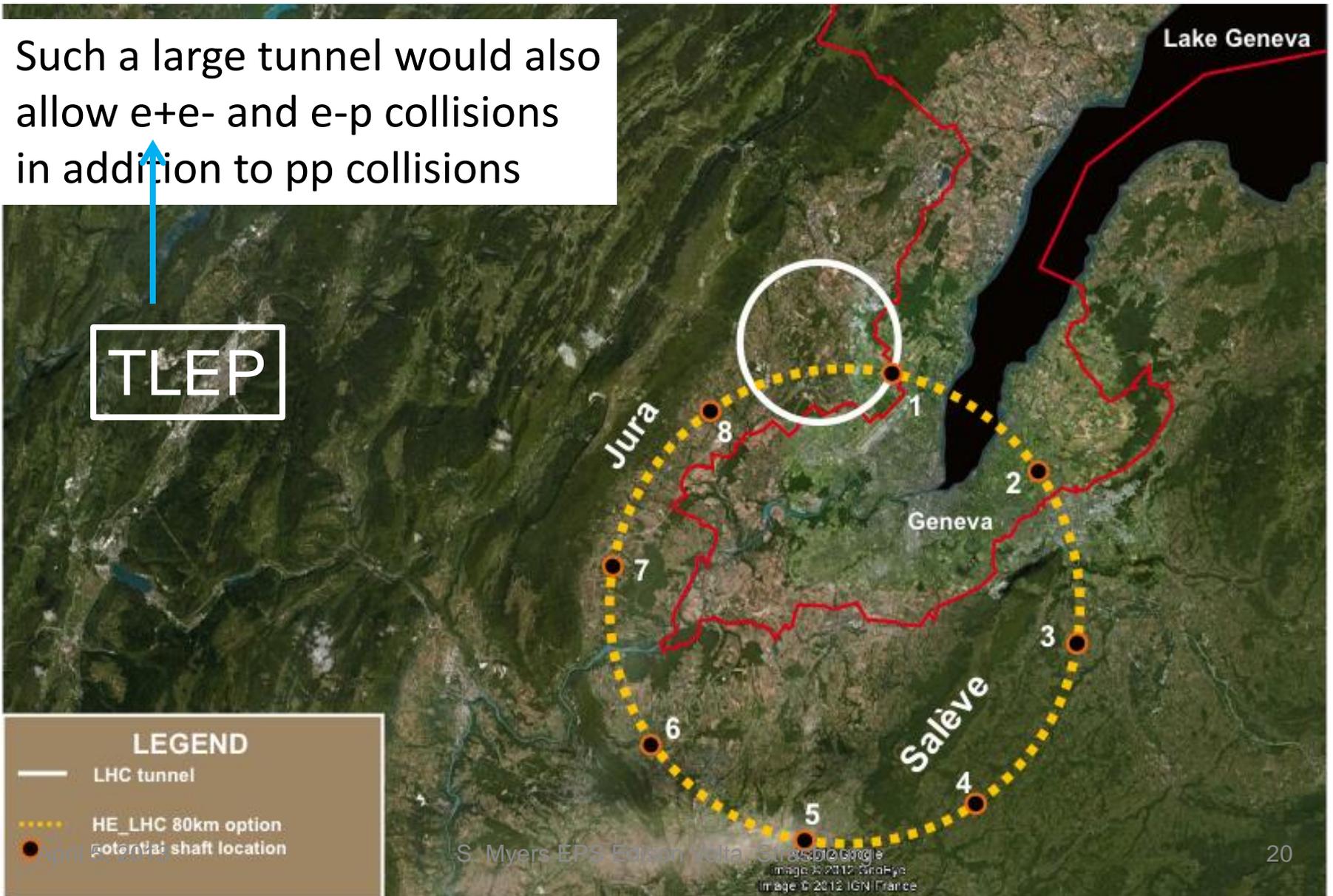


Figure 9. Two possible location, upon geological study, of the 80 km ring for a Super HE-LHC (option at left is strongly preferred)

# VHE-LHC

Such a large tunnel would also allow  $e^+e^-$  and  $e$ - $p$  collisions in addition to  $pp$  collisions

TLEP



# HE-LHC and VHE-LHC

- VHE-LHC needs a (at least) 80km tunnel

In conjunction with the high field magnets would

allow a factor of  $(2-2.5) \times (80/27) =$

6-7.5 times LHC (42- 52 TeV/beam)

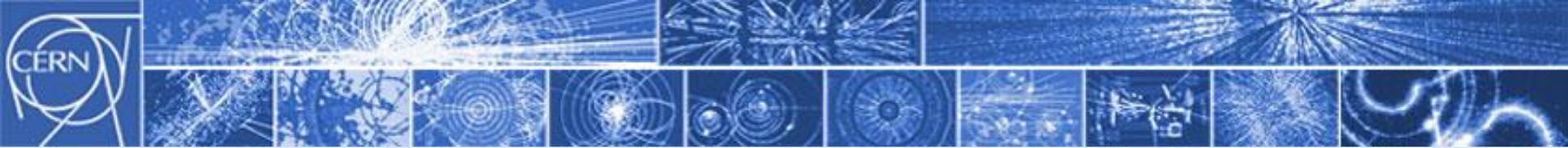
- HE-LHC → VHE-LHC

(“80 km” study together with TLEP)

Logic (“roadmap”): exploit synergy effects

between HL-LHC, HE-LHC, VHE-LHC (and TLEP),

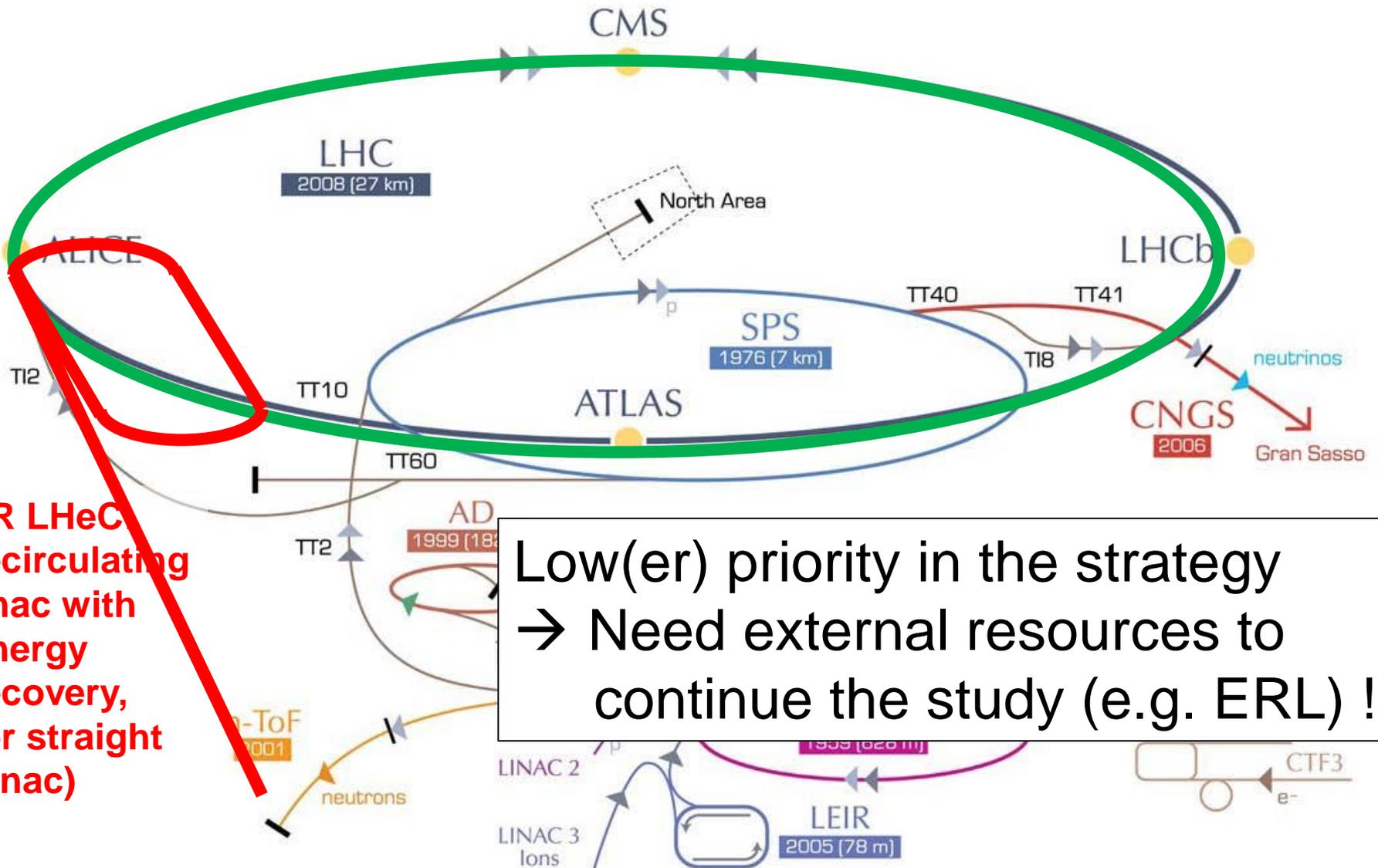
in particular high field magnet development



# Lepton – Hadron Collider LHeC

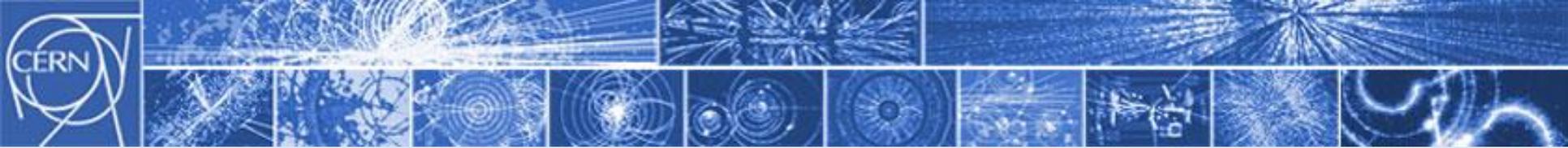
QCD, Leptoquarks?

# LHeC option: LR



LR LHeC  
recirculating  
linac with  
energy  
recovery,  
(or straight  
Linac)

Low(er) priority in the strategy  
→ Need external resources to continue the study (e.g. ERL) !



# Lepton – Lepton Colliders



# Linear $e^+e^-$ Colliders: ILC / CLIC

Both projects are global endeavours  
and at CERN part of the LC effort

Wide range of Physics topics, e.g.

- Higgs couplings, in particular **self coupling**

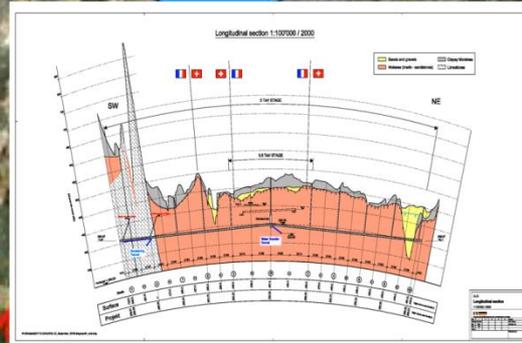
- precision studies of Z, W, and **Top**

- new physics phenomena

Very interesting after the discovery of a Higgs Boson

**Legend**

- CERN existing LHC
- Potential underground siting :
- CLIC 500 GeV
- CLIC 1.5 TeV
- CLIC 3 TeV



Tunnel implementations (laser straight)

Conceptual Design Report published

→ R&D continues (accelerator and detector) in the framework of the CLIC collaboration (e.g. high gradient accelerating structures)



Central MDI & Interaction Region

# Deliberation document on the European Strategy for Particle Physics

## High-priority large-scale scientific activities

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

e) There is a strong scientific case for a new linear collider, complementary to the LHC, for the study of the properties of the Higgs boson and other particles with high precision and whose energy can be upgraded. The **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.**

**at CERN ILC efforts will continue in the framework of the LC efforts**



# Deliberation document on the European Strategy for Particle Physics

Study performed for a dedicated neutrino area at the SPS:

- To enable large scale detector development and tests for neutrino detectors and/or
- To install a short baseline experiment

Decision to be taken in the framework of the next 5-years plan 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.***



# Fixed Target Program (examples)

- HIE-Isolde as approved and ongoing
- AD and ELENA as approved; extension for GBAR and addition of a storage ring under consideration
- n-TOF (with EAR2) as approved
- CNGS terminated
- high gradient accelerator R&D (“AWAKE”)



## **Key message**

**Program at the energy frontier with the LHC for at least 20 years**

**R&D, Studies for the next projects ongoing**

**Global collaboration vital**