



*Accelerating Science and Innovation*

ECFA HL-LHC Experiments Workshop

CERN Perspective

# 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.

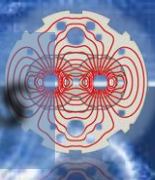
c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue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

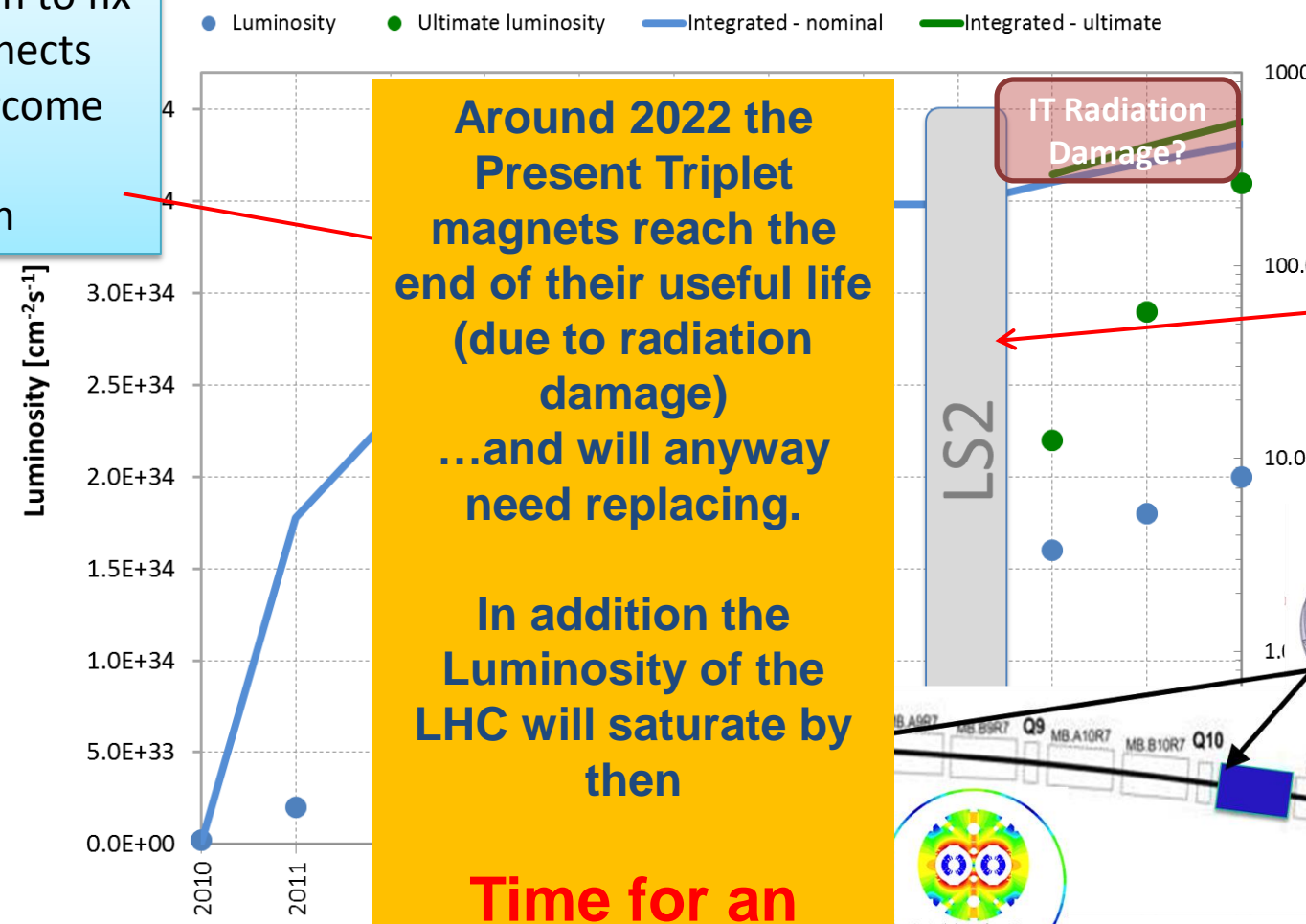




# Luminosity: Best Guess for the next 10 years



Shutdown to fix interconnects and overcome energy limitation

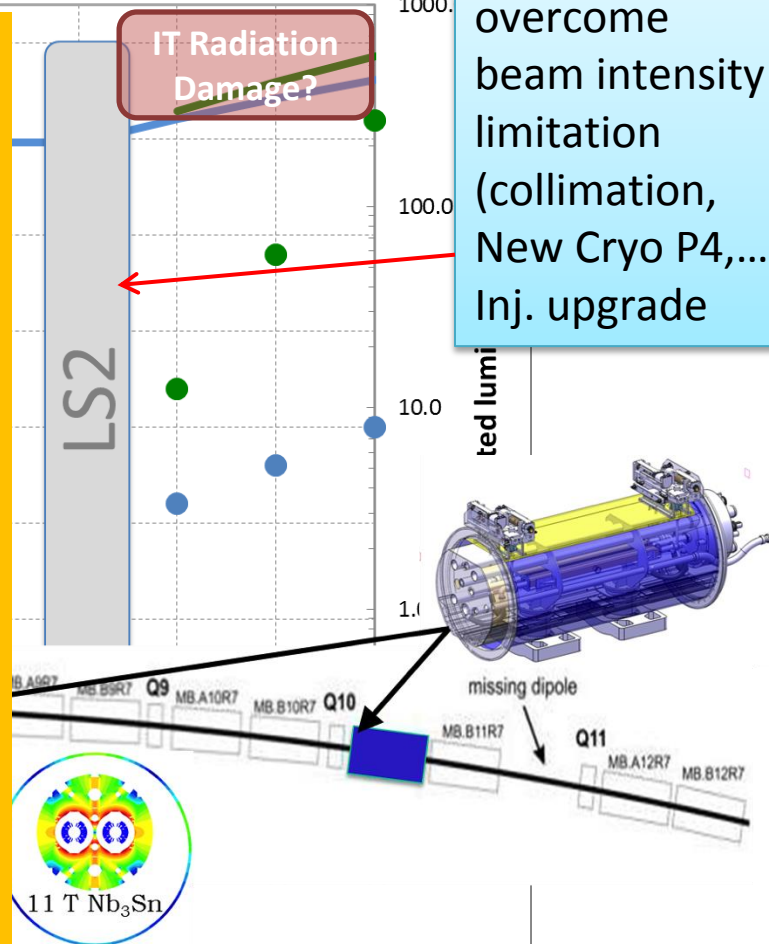


Around 2022 the Present Triplet magnets reach the end of their useful life (due to radiation damage) ...and will anyway need replacing.

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



# HL-LHC

- Approval Status
  - European Strategy
  - HL-LHC Project kick-off 11/11 Daresbury
- Schedule
  - LS2 duration
  - operational experience at 13/14 TeV
  - RLIUP workshop 29-30 Oct Archamps
- Resources



# 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**

ev 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, possibly a building or a monument, which is also partially enclosed by the white circle. 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

# Update of the European Strategy for Particle Physics

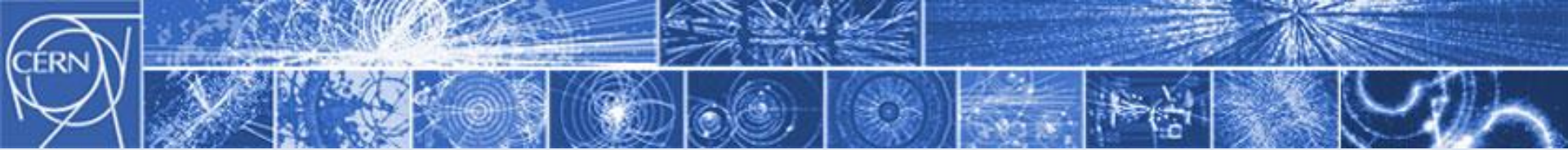
## High-priority large-scale scientific activities

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.

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.***







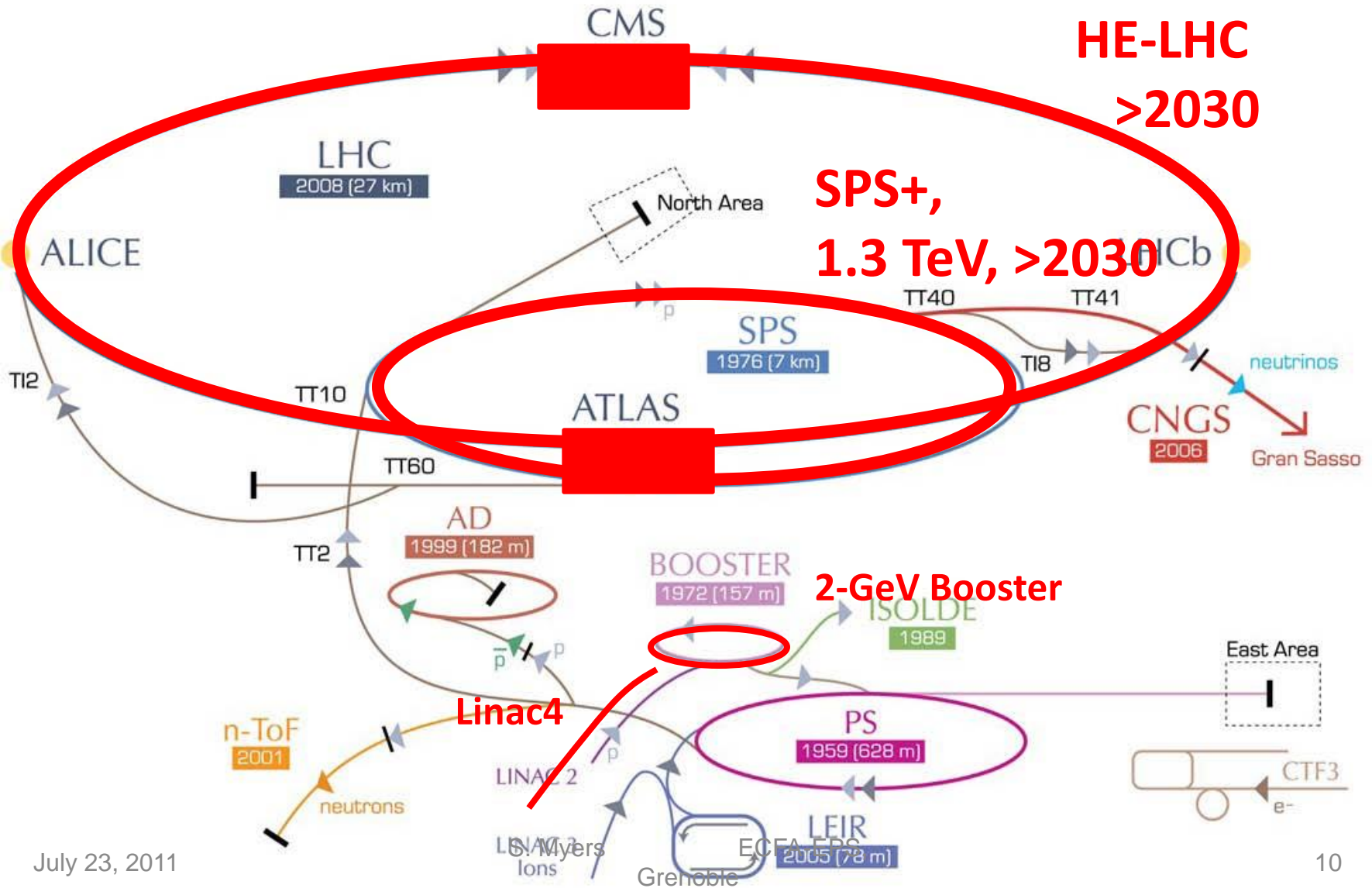
# High Energy Hadron – Hadron Colliders

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



# Very High Energy LHC

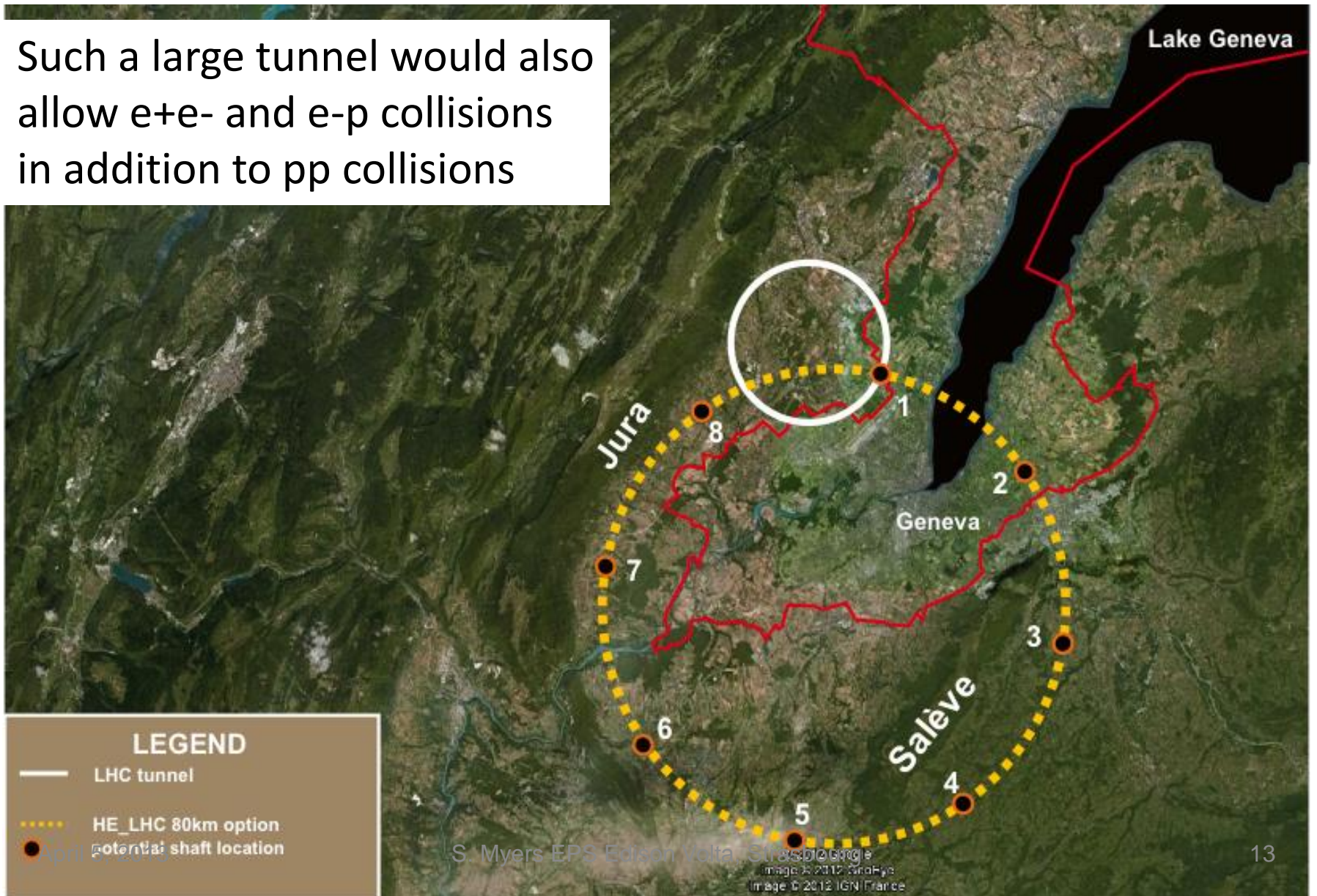
- **First studies on a new 80 – 100 km tunnel in the Geneva area**
  - **42 TeV** with 8.3 T using present LHC dipoles
  - **80 TeV** with 16 T based on Nb<sub>3</sub>Sn dipoles
  - **100 TeV** with 20 T based on HTS dipoles



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



# 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)

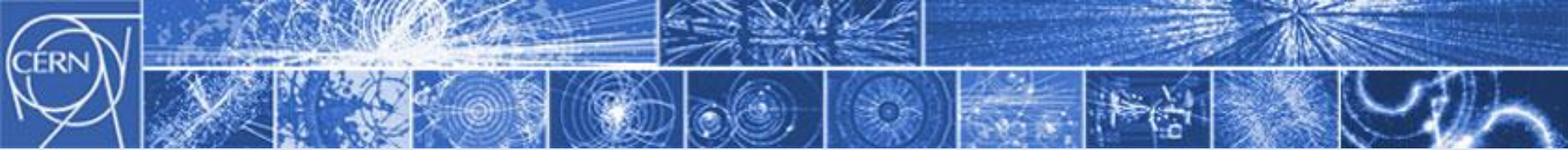
- HE-LHC → VHE-LHC

(“80-100 km” study)

Logic (“roadmap”): exploit synergy effects

between HL-LHC, HE-LHC, VHE-LHC,

in particular high field magnet development



# 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.

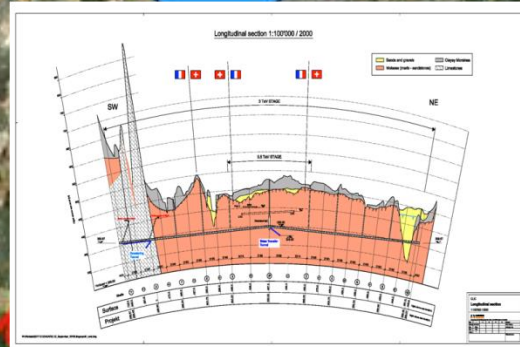
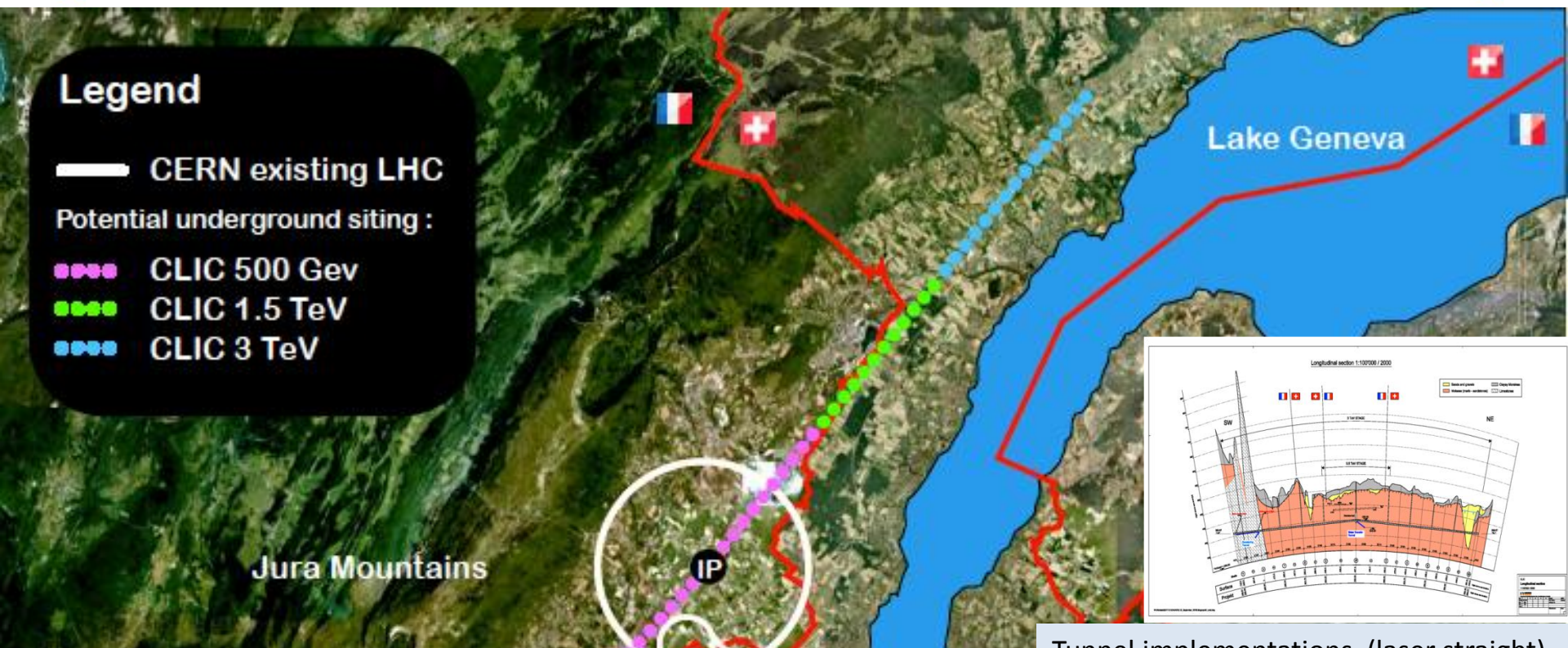
- Higgs couplings, in particular **self coupling**
- precision studies of Z, W, and **Top**
- new physics phenomena

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

# 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 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 **International Linear Collider (ILC) has been proposed**, 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**



# Update of the European Strategy for Particle Physics

CERN:

- enable large scale detector development and tests for neutrino detectors

and

- perform study for a possible neutrino test beam

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.***



## **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**