
CERN
Accelerating Science and Innovation
Strategy for Particle Physics
in Europe
and CERN

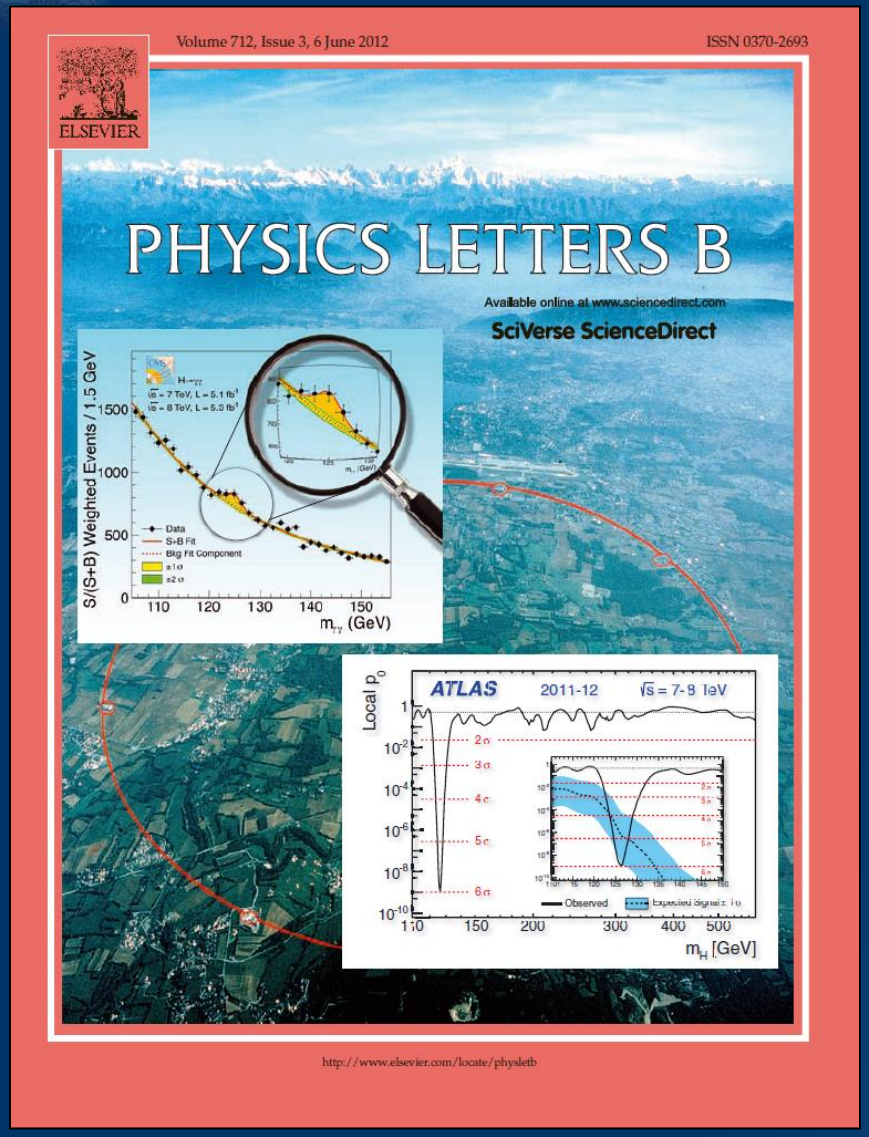
CERN Medium Term Plan

Objectives unchanged wrt previous years:

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

Highest priority

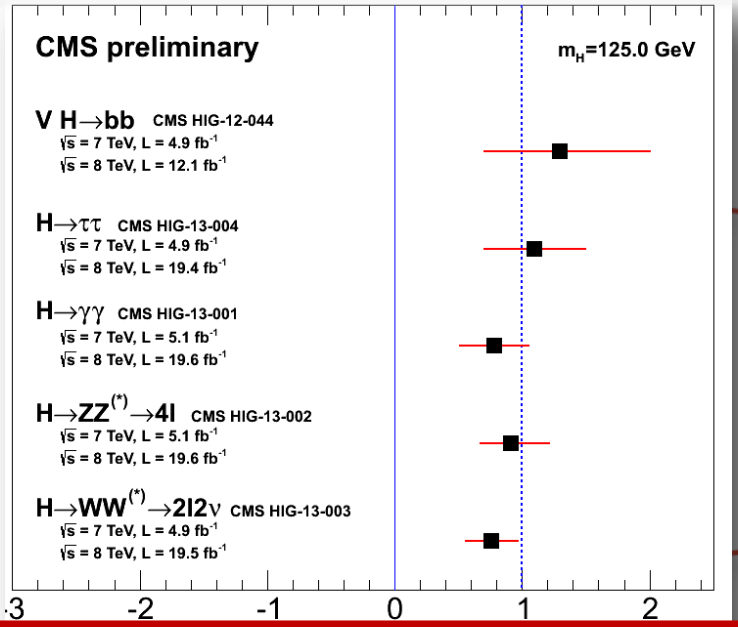
a remarkable year 2012



March 2013

We have a Higgs boson!

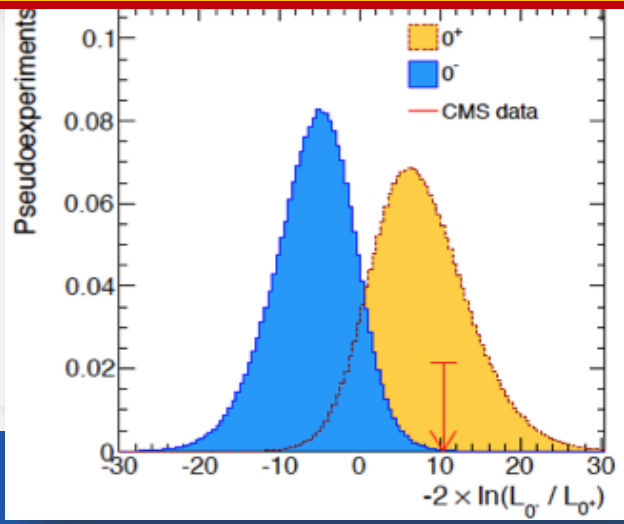
- But what kind of Higgs is it?
  - 5 main channels shown at right
    - All are determined at m=125 GeV except for the ZZ channel which uses the best fit m_{ZZ}=125.8
    - *Full combination with best combined mass value will result in different signal strengths than those seen here.*
- Consistent with SM
  - But can't rule out a BSM Higgs!



NEW

- New significance values:
  - H→ ZZ→4l: 6.7 σ (7.2 exp.)
  - H→ WW: 4.1 σ (5.1 exp.)
  - H→ γγ: 3.2 σ (4.2 exp.)
  - H→ ττ: 2.9 σ (2.6 exp.)
- New mass values
  - ZZ: m_H = 125.8 ± 0.5 (stat.) ± 0.2 (syst.)
  - γγ: m_H = 125.4 ± 0.5 (stat.) ± 0.6 (syst.)
  - ττ: $m_H = 120^{+9}_{-7}$ (stat+syst) GeV

It has the properties of a Higgs boson



… 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 programmme 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 coupli
- C
- Quark fermion couplings
- Yukawa direct measurement ttH: κ_t
- Test second generation fermion couplings: κ_μ
- Higgs self-couplings HHH: κ_H

Looking only at the studies of the Higgs Boson
There is much more physics beyond the Higgs

ay
eV
~ 30 fb^{-1}
sted at 30%
couplings

LHC
Upgrade
14 TeV
~ 3000 fb^{-1}

Update of the European Strategy for Particle Physics

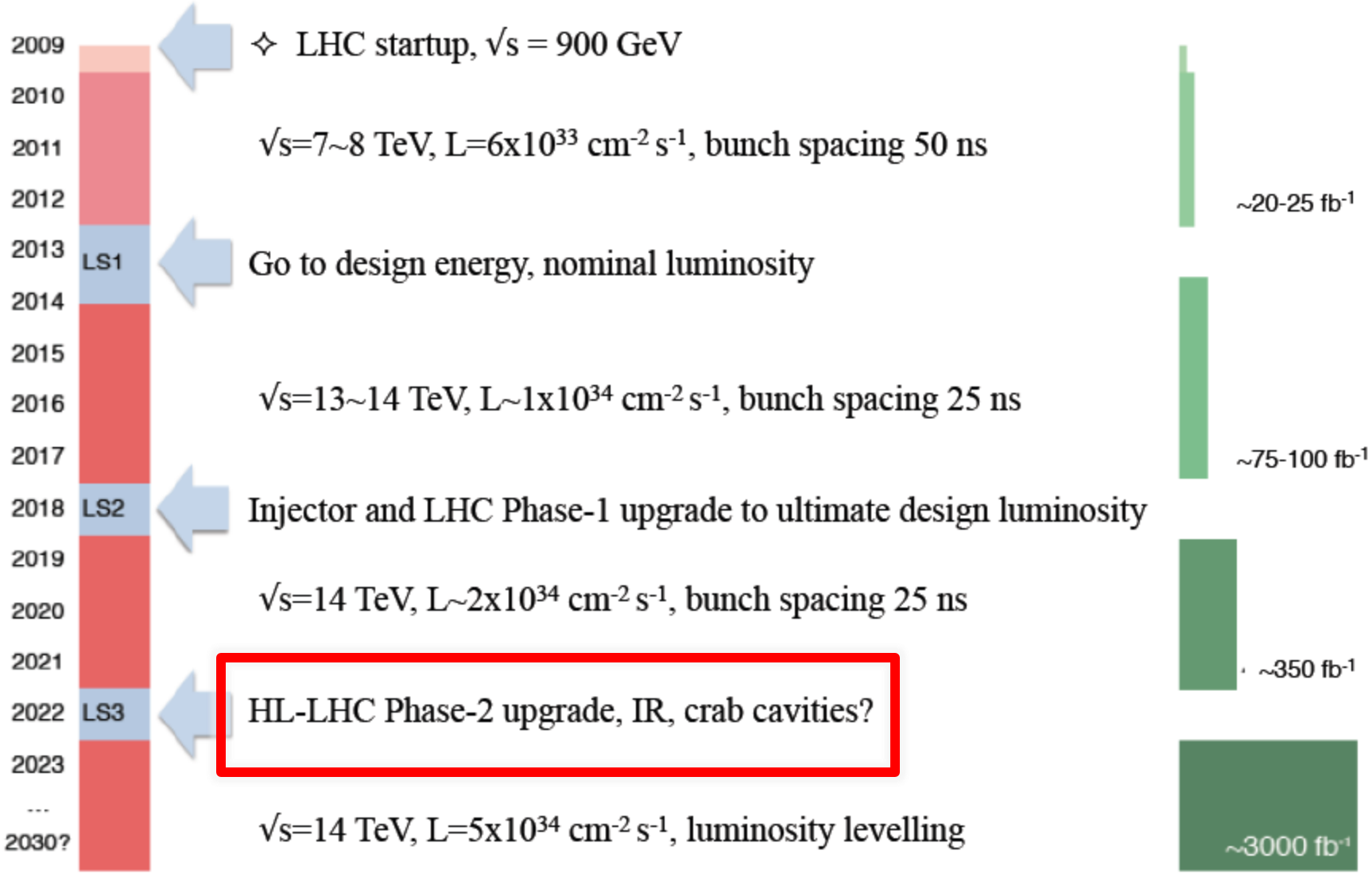
High-priority large-scale scientific activities

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.

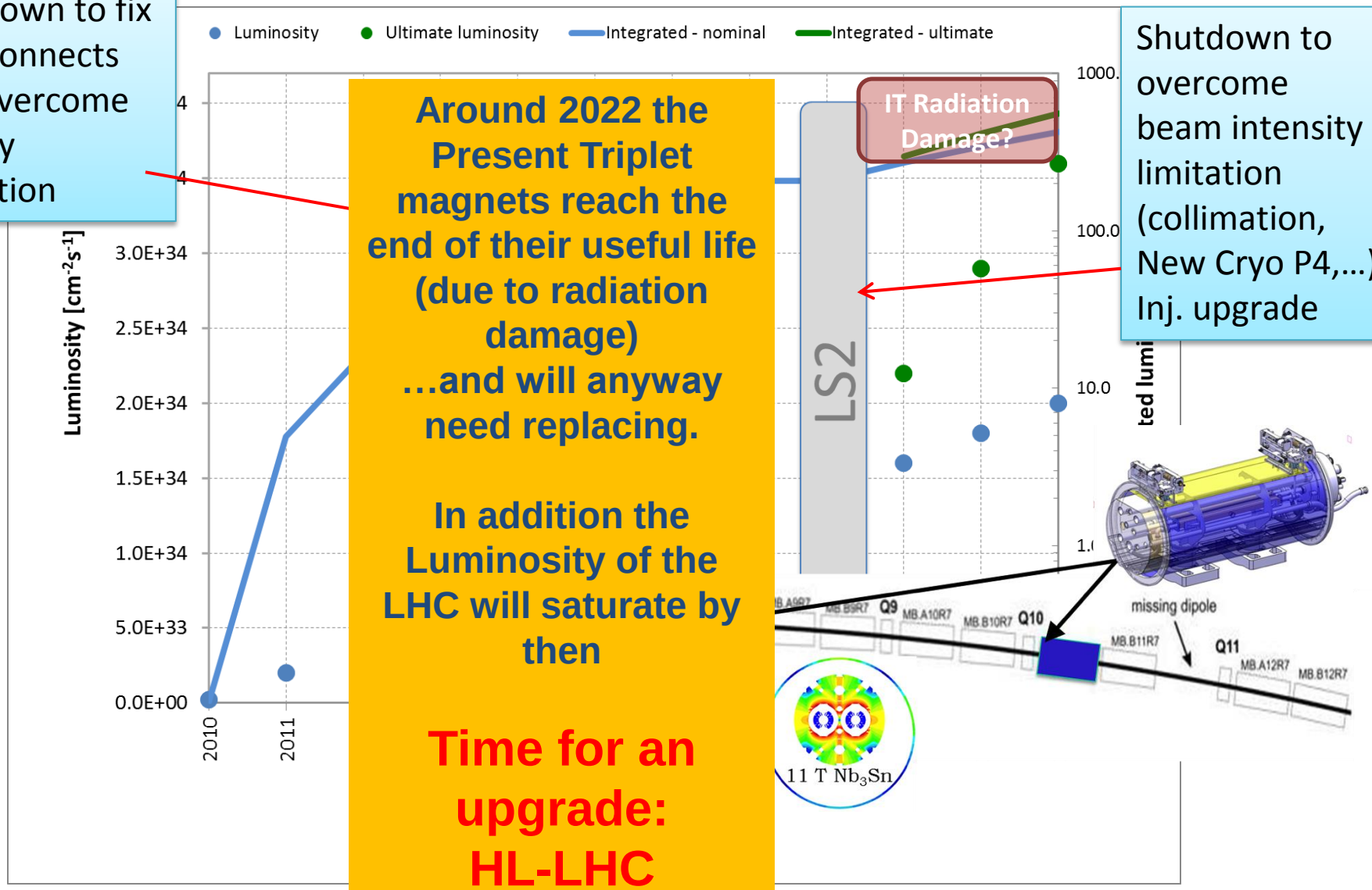
The LHC roadmap to fully exploit the physics potential



Luminosity: Best Guess for the next 10 years

Shutdown to fix interconnects and overcome energy limitation

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



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

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 ~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 progra
with th

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)


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

Deliberation document on the European Strategy for Particle Physics

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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

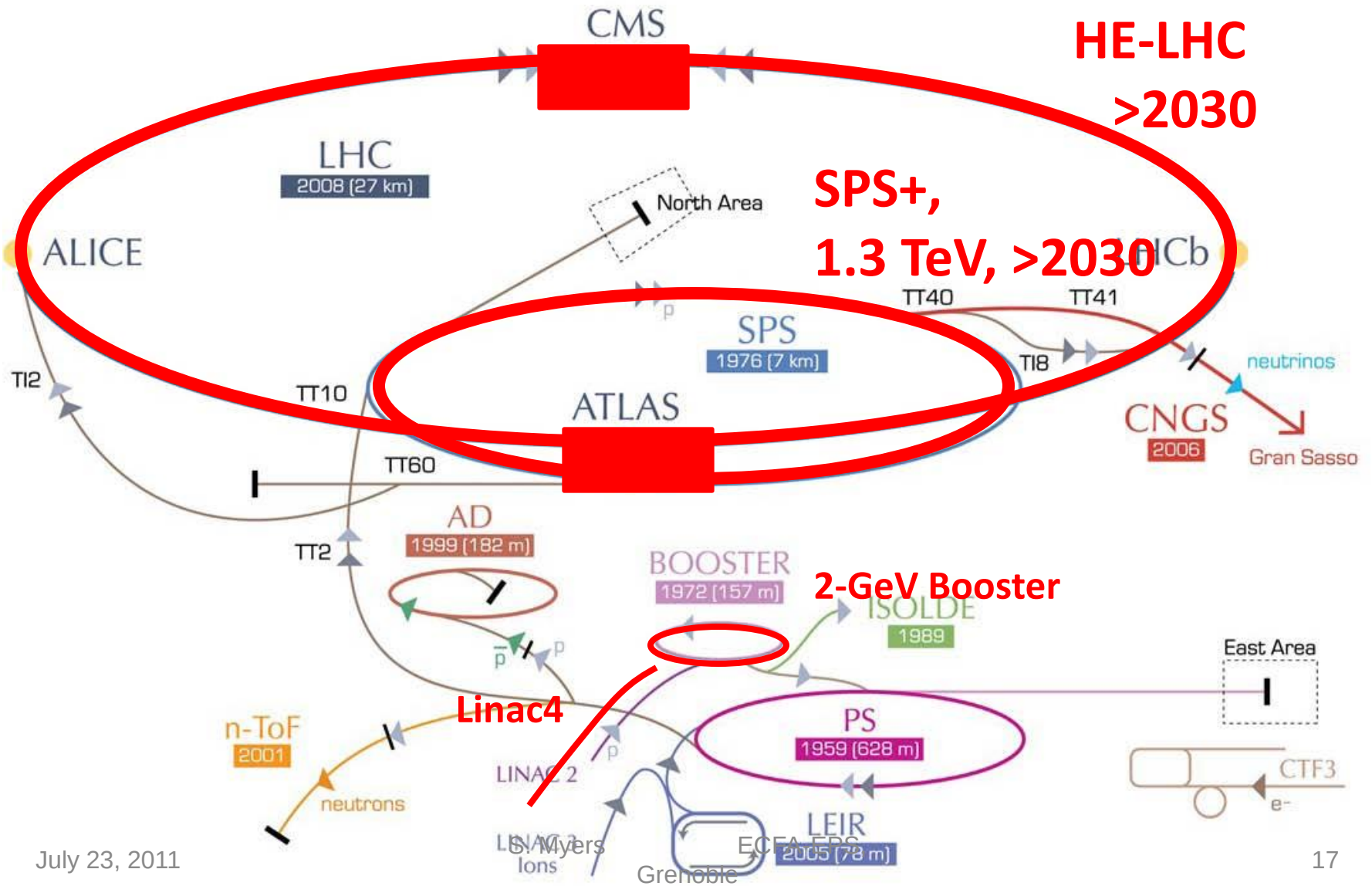
High Energy Hadron – Hadron Colliders

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_3Sn dipoles**
  - **100 TeV with 20 T based on HTS dipoles**

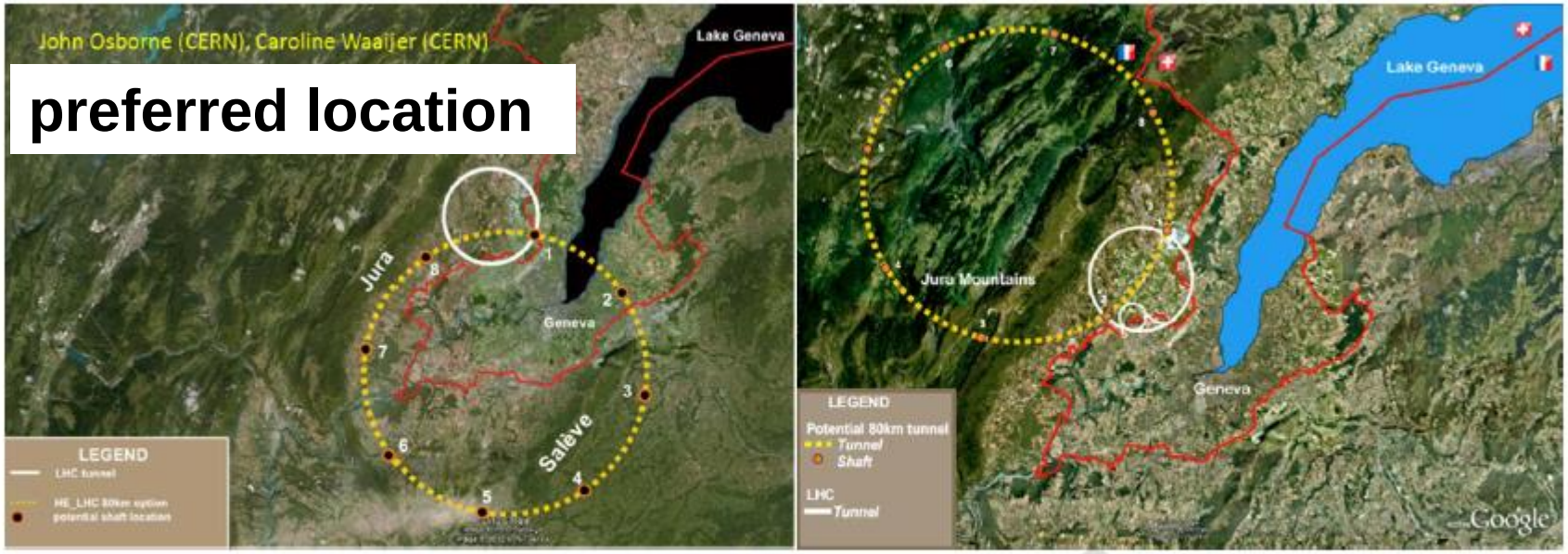
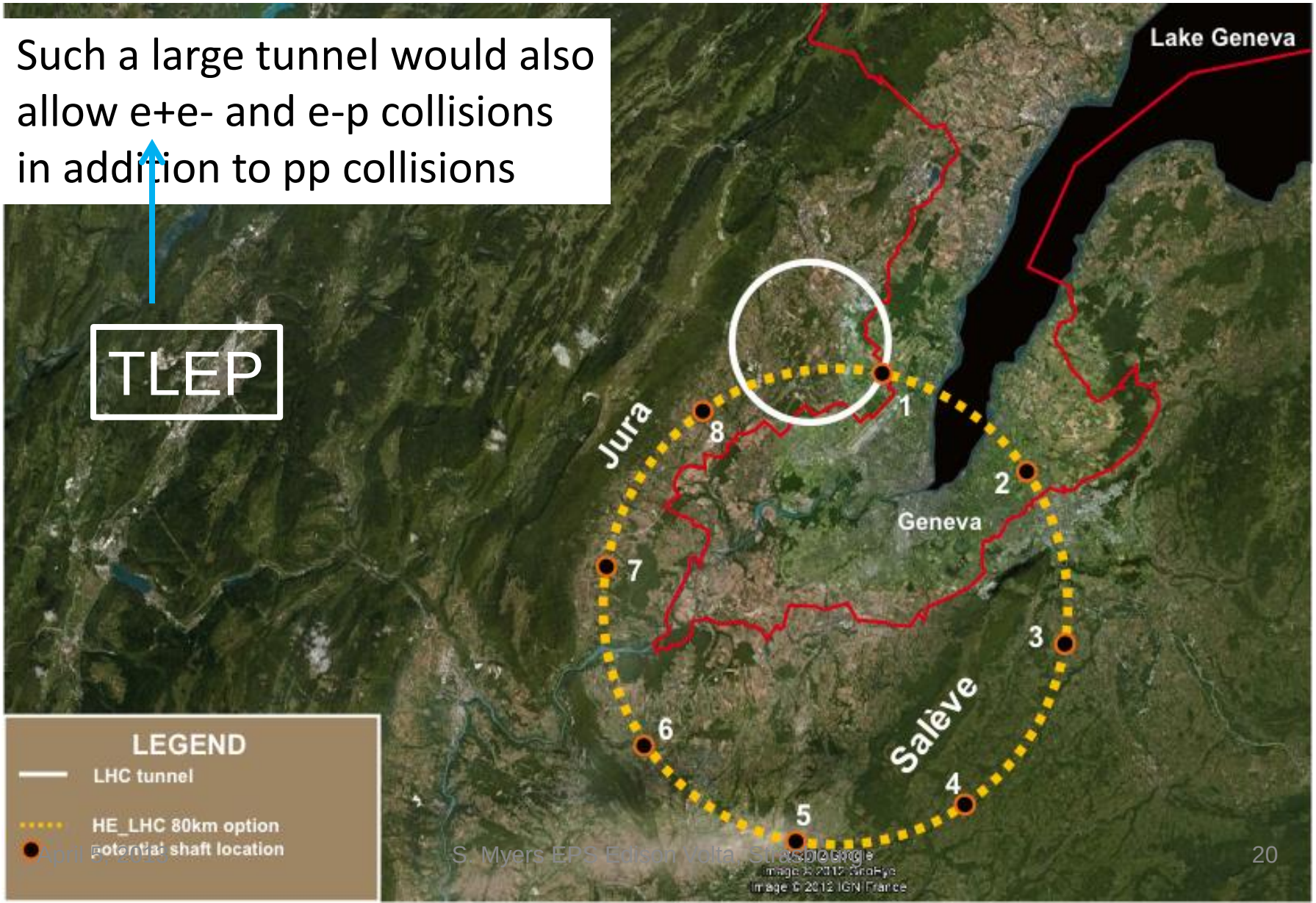


Figure 9. Two possible location, upon geological study, of the 80 km ring for a Super HE-LHC (option at left is strongly preferred)

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)x(80/27) =

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

- HE-LHC → VHE-LHC

("80 km" study together with TLEP)

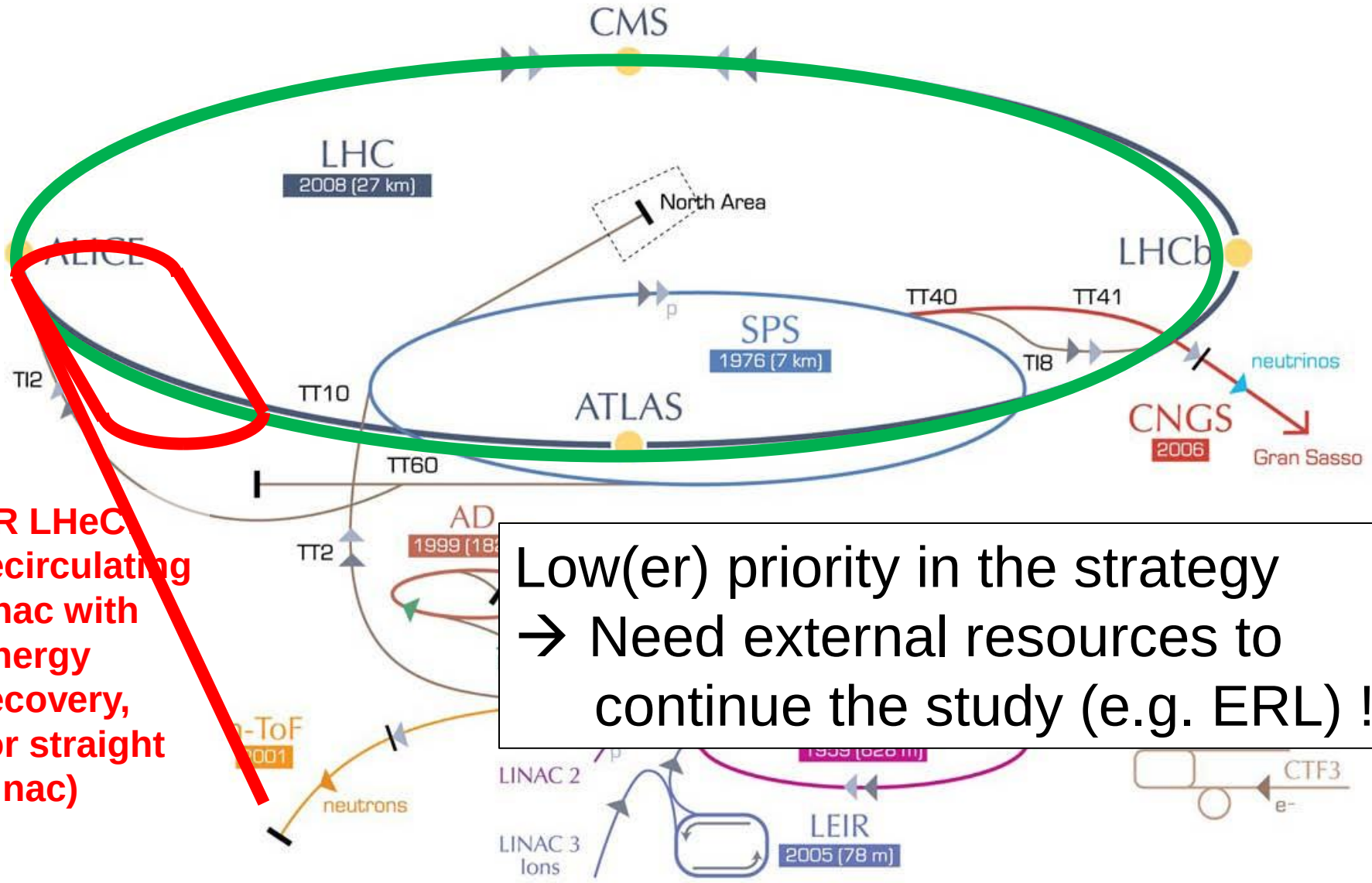
Logic ("roadmap"): exploit synergy effects between HL-LHC, HE-LHC, VHE-LHC (and TLEP), in particular high field magnet development

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) !

Frank Zimmermann, UPHUK4 Bodrum 2010

Lepton – Lepton Colliders

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

Both projects are global endeavours

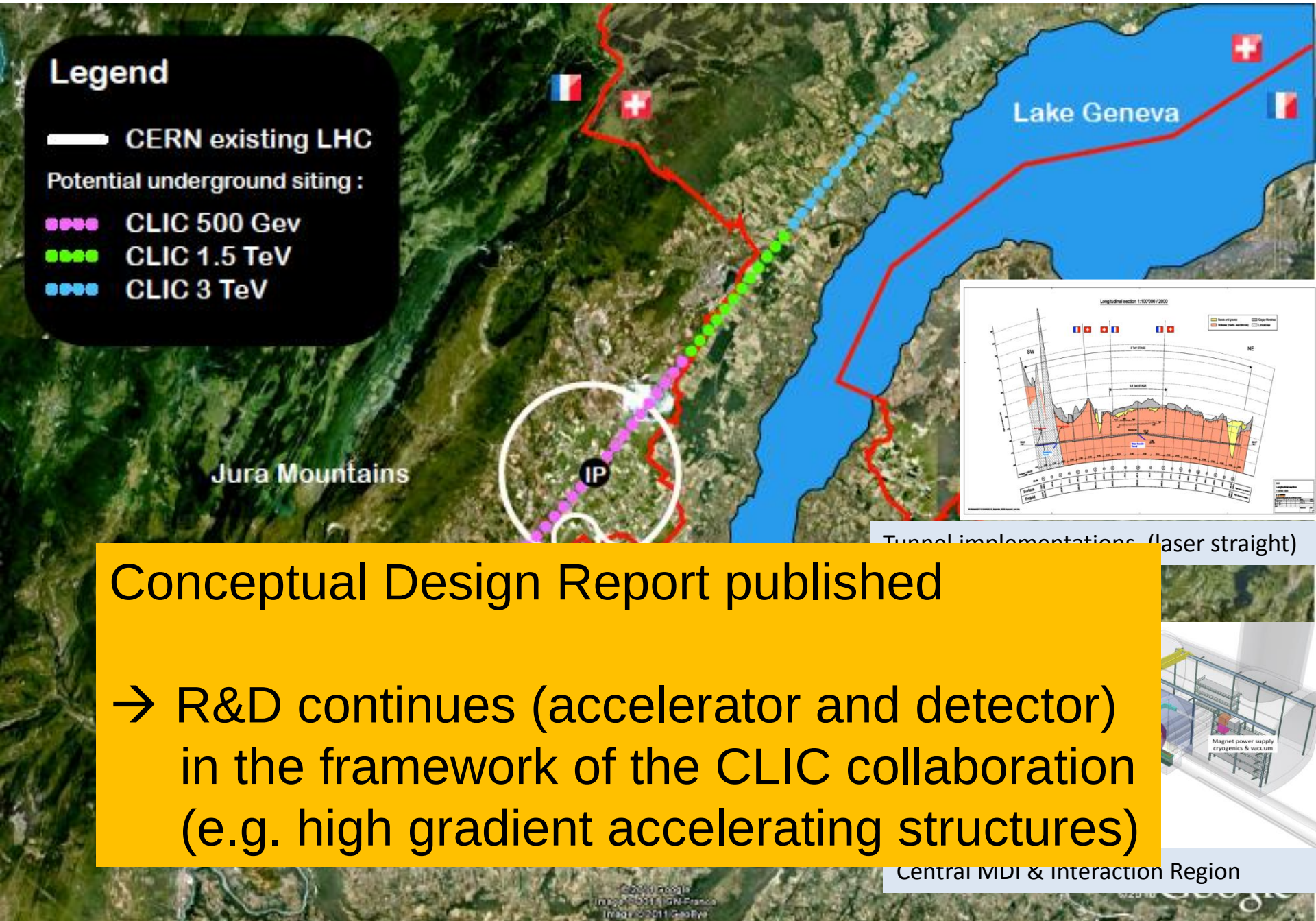
and at CERN part of the LC effort

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

CLIC near CERN



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 [illegible] commitment, the following four activities have been identified [illegible] highest priority.

e) There is a strong scientific [illegible] electron collider, complementary to [illegible] properties of the Higgs boson and other [illegible] precision and whose energy can be upgraded. [illegible] 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

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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 and DIRAC 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,
CERN ready to participate