



# PHYSICS AT **LHC** AND BEYOND

August 10-17, 2014, Quy-Nhon, Vietnam

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## Round-table: Discussion on Future Machines

**With the discovery of the Higgs Boson**



**Self-consistent model (SM) accounting for all Particle Physics phenomena at presently accessible energy**

**but does not explain major issues**

**Mass of neutrino (in the most general way)  
Baryon Asymmetry of Universe  
Dark Matter, Dark Energy**

**Unification of all interactions**



**New Physics must exist ... but at which energy scale?**

**Energy Frontier: Direct Exploration of Higher Energy Scales**

**Precision Frontier: Ultra-precise measurements of the SM and rare process studies**

**Both frontiers require very large scale  $e^+e^-$  and h-h facilities**

⇒ **Large resources (human and technical) needed**

⇒ **Large costs (probably at the ten or tens G€)**



**At most 1 such large project in the world  
Its construction, operation, upgrades will span over the next  
40-50 years**



**Vital to make the right choice (no second thought once started)**



**Essential to include all reasonably obtainable information in the  
decision making process**

- ⇒ Results from operating facilities
- ⇒ Accelerator Design Studies
- ⇒ Physics and Detector Studies

Necessary for making an educated decision

**LHC results @ 13-14 TeV**  
 **$\nu$ -Physics : mass hierarchy and maybe first CP results**  
**Flavor Physics @ LHC and superKEKB**  
**FCC/CepC studies complementing ILC/CLIC studies**  
**Studies of Long Baseline  $\nu$ -facilities**

**2018: Seems an appropriate time scale for updating the Strategy in Europe**

**Concentrate most European efforts toward a single very large scale project ( for HE/precision frontier)**

# High-priority large-scale scientific activities

## 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.*

## 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.*

LHC and its  
upgrades

FCC(hh, ee, ep),  
CLIC

# High-priority large-scale scientific activities

## 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.*

## 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 long-baseline neutrino projects in the US and Japan.*

ILC, FCCee,  
CeEP

LBNE, HyperK,  
LBNO, ESS-νSB

⇒ In the meantime, vital to strengthen R&D both for conceptual Designs and technical prototyping



□ FCC (Europe) and CepC (China) Designs

□ Main R&D areas

⇒ Magnet R&D: Nb<sub>3</sub>Sn and HTS

⇒ High Gradient in CW and pulsed modes

- SC: > 40 MV/m (pulsed) , >20 MV/m (CW)
- NC: >100 MV/m (12GHz), >10 GV/m (PWFA)



**ESGARD is overseeing a set of project to be submitted to the EC**

**DS**

- **FCC**
- **First e<sup>-</sup> PWF accelerator (1-5 GeV) for pilot applications**
- **v-SB using ESS infrastructure**

**R&D**

- **Resonant L-PWF acceleration scheme**
- **High brightness ( $B > 10^{15}$  A /m<sup>2</sup>) electron beam with Beam Driven PWFA**