The Update of the European Strategy for Particle Physics

M. Krammer

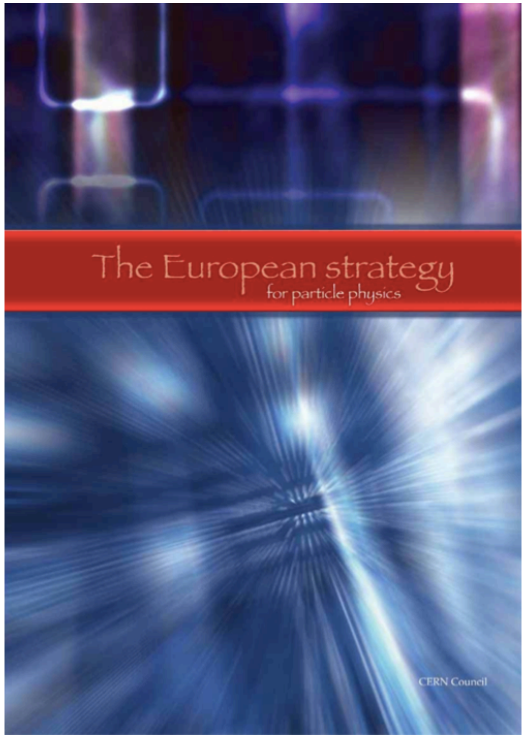
HEPHY, Vienna, Austria

NOBEL SYMPOSIA

The Nobel Symposium on LHC Results
Krusenberg, Sweden, May 13-17, 2013

The European Strategy for Particle Physics 2006

First strategy approved by the CERN Council 14th July2006
It contains 17 statements on scientific and organizational matters.



In 2006 the LHC was still under construction,
no hint for a Higgs at the Tevatron, no prediction for the energy scale of interest for an ILC, no country to host ILC,…

- Obviously, completion of the LHC machine was the highest priority (3)

Then encourage R&D to ensure engineering readiness when physics results are available for a decision:

- advanced accelerator for the CLIC and high performance magnets (4)
- ILC design (5),
- participation in a global neutrino program (6)
- Council will define and update the strategy based on proposals and observations from a dedicated scientific body that it shall establish for this purpose (11)

Time Line of the Update

- The update process started in 2011 by setting up the European Strategy Group (ESG) and the Preparatory Group by Council
- February 2012, Call for scientific input from the community
- September 2012: **Open Symposium** (Kracow)
- December 2012: **Scientific Briefing Book**
  by the Preparatory Group based on the community input
  (Open Symposium + written submissions)
- January 2013**: Strategy Group drafting session** (Erice)
  Draft of European Strategy Update written and submitted to Council
- March 2013: Council agreed on final draft with minor wording amendments

- May 30 2013: The Council will formally adopt the Strategy Update in a special European Strategy Session of the Council in Brussels

Committees and Working Groups

European Strategy Update

European Strategy Group (ESG)

Members

Member States Representatives

Austria	Prof. A. H. Hogang
Belgium	Prof. W. Van Doninck
Bulgaria	Prof. L. Litov
Czech Republic	Prof. J. Chyla
Denmark	Prof. J.J. Gaardhoje
Finland	Prof. P. Eerola
France	Prof. J. Martino
Germany	Prof. S. Bethke
Greece	Dr P. Rapidis
Hungary	Prof. P. Levai
Italy	Prof. F. Ferroni
Netherlands	Prof. S. De Jong
Norway	Prof. A. Read
Poland	Prof. J. Krolikowski
Portugal	Prof. G. Barreira
Slovakia	Dr L. Sandor
Spain	Prof. F. del Aguila
Sweden	Prof. B. Asman
Switzerland	Prof. K. Kirch
United-Kingdom	Prof. J. Butterworth

CERN - Director-General Prof. R. Heuer

Major European National Labs

CIEMAT	Dr C. Lopez
DESY	Prof. J. Mnich
IRFU	Dr Ph.Chomaz
LAL	Dr A. Stocchi
NIKHEF	Prof. F. Linde
LNF	Dr U. Dosselli
LNGS	Prof. S. Ragazzi
PSI	Dr L. Rivkin
STFC-RAL	Dr J. Womersley

Strategy Secretariat Members

Prof. T. Nakada	Scientific Secretary (Chair)
Prof. F. Zwirner	SPC Chair
Dr M. Krammer	ECFA Chair
Dr Ph. Chomaz	Repres. EU Lab. Directors
Prof. E. Tsesmelis	Scientific Assistant

Invited - President of Council Prof. A. Zalewska

Invitees

Candidate for Accession and Associate Member States

Israel	Prof. E. Rabinovici
Romania	Dr S. Dita
Serbia	H. E. Amb. U. Zvekic

Observer States

India	Prof. T. Aziz
Japan	Prof. Sh. Asai
Russian Federation	Prof. A. Bondar
Turkey	Prof. Dr M. Zeyrek
United-States	Prof. M. Shochet

EU	Dr R. Lecbychova
ApPEC	Dr S. Katsanevas
Chairman FALC	Prof. Y. Okaka
Chairman ESFRI	Dr B. Vierkorn-Rudolph
Chairman NuPECC	Prof. A. Bracco
JINR, Dubna	Prof. V. Matveev

Committees and Working Groups

European Strategy Update

The European Strategy Preparatory Group (ESPG) Members

Strategy Secretariat Members

Prof. T. Nakada	Scientific Secretary (Chair)
Prof. F. Zwirner	SPC Chair
Dr M. Krammer	ECFA Chair
Dr Ph. Chomaz	Repres. EU Lab. Directors
Prof. E. Tsesmelis	Scientific Assistant

SPC

Prof. R. Aleksan (FR)
Prof. P. Braun-Munzinger (DE)
Prof. M. Diemoz (IT)
Prof. D. Wark (UK)

ECFA

Prof. K. Desch (DE)
Prof. K. Huitu (FI)
Prof. A. P. Zarnecki (PL)
Prof. C. De Clercq (BE)

CERN

Dr P. Jenni

ASIA/AMERICAS

Prof. Y. Kuno (Asia)
Prof. P. McBride (Americas)

CERN-ESG-005
13 January 2013

Physics Briefing Book

Input for the Strategy Group to draft the update of the European Strategy for Particle Physics

Compiled by

R. Aleksan, P. Braun-Munzinger, Ph. Chomaz, K. Desch, C. De Clercq, M. Diemoz, K. Huitu, P. Jenni, M. Krammer, Y. Kuno, P. McBride, T. Nakada, E. Tsesmelis, D. Wark, A. F. Żarnecki, and F. Zwirner
European Strategy for Particle Physics Preparatory Group

and

P. Brun, E. Fernandez Martinez, R. Forty, E. Garutti, K. Kutak, A. Lister, P. Slavich, and F. Zimmermann
Scientific Secretaries for the Open Symposium in Cracow, Poland

> 200 pages

http://europeanstrategygroup.web.cern.ch/europeanstrategygroup/Briefing_book.pdf

Committees and Working Groups

European Strategy Update

Working Groups of ESG

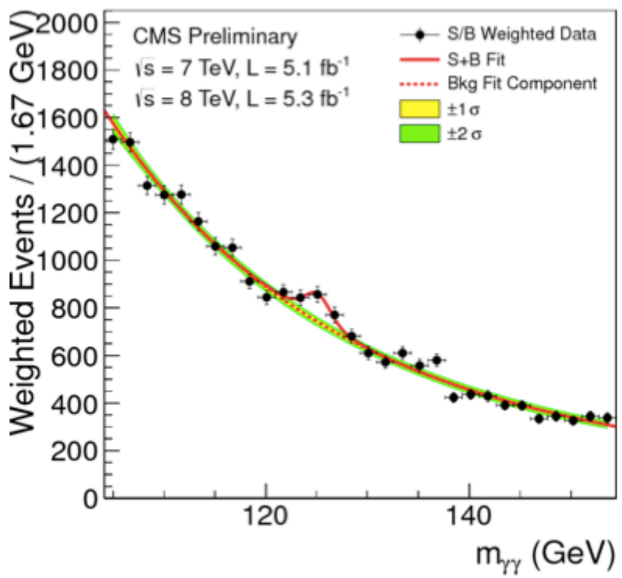
- Working Group 1:
  Organisational structure for the Council for the European Strategy and its implementation
- Working Group 2:
  Organisational structure for European participation in global projects. Role and definition of the National Laboratories and the CERN Laboratory in the European Strategy
- Working Group 3:
  Relations with external bodies, in particular EU-related
- Working Group 4:
  Knowledge and technology transfer, and relations with industry
- Working Group 5:
  Communication, outreach and education

Scientific Input

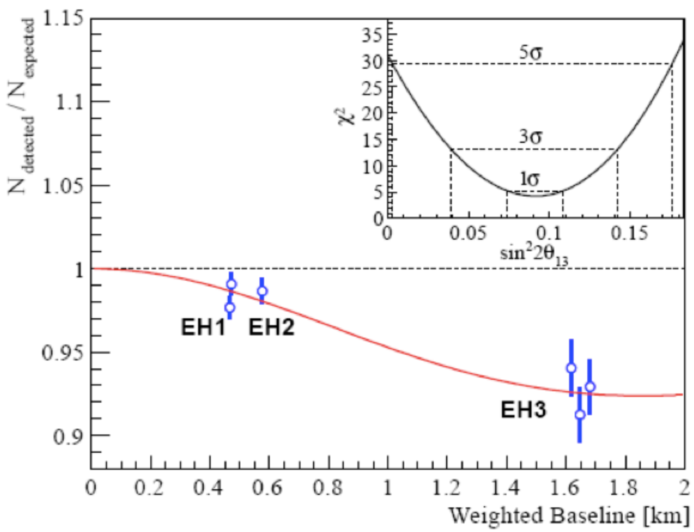
- ~160 written contribution received from individuals, collaborations, national institutes, countries.
- Large attendance during the open symposium (~500 participants)

A plethora of projects, facilities, new ideas were proposed and described. Many triggered by the two discoveries in 2012 (just in time).

Higgs Boson at 125 GeV:



Large θ_{13} neutrino mixing angle:



Proton Proton Colliders

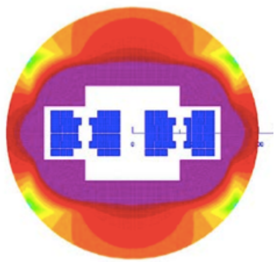
European Strategy Update

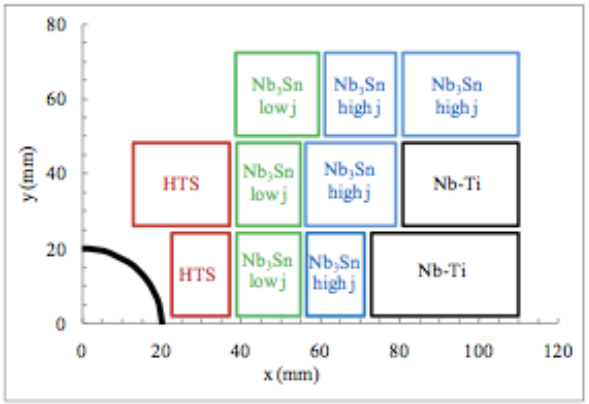
	Years	E_{cm} TeV	Luminosity $10^{34}cm^{-2}s^{-1}$	Int. Luminosity 300 fb^{-1}
Design LHC	2014-21	14	1-2	300
HL-LHC	2024-30	14	5	3000
HE-LHC	>2035	26-33*	2	100-300/y
V-LHC**	>2035	42-100		

* 16-20 T dipole field
** 80 km Tunnel

HE-LHC:
16 T magnets with classical low temperature superconducting magnets (Nb_3Sn) ➔26 TeV c.m.
To reach 20 T need high temperature superconductors (YBCO-123, BSCCO-2212) ➔33 TeV c.m.

A possible 20 T design:
(CERN-ATS-2012-237)



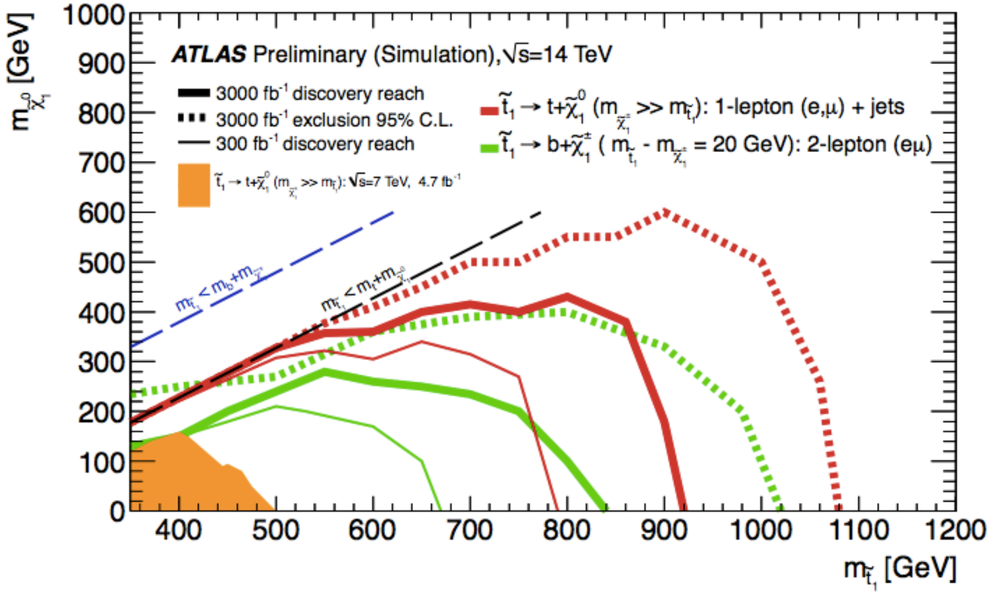


Replace SPS by 1 TeV SC ring, etc…

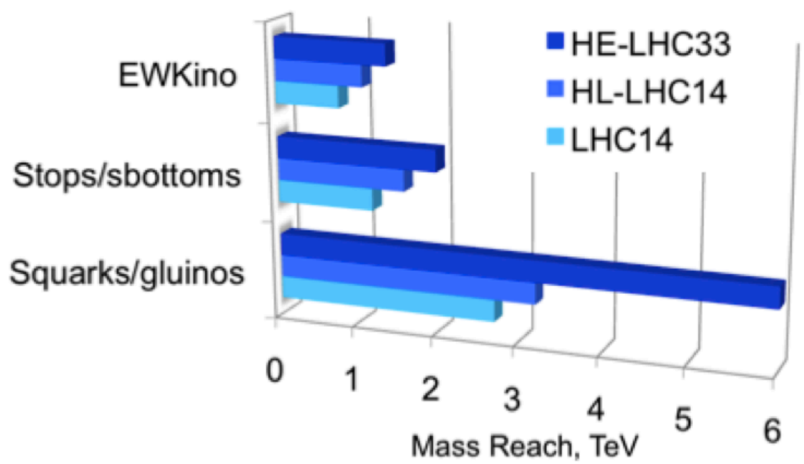
Proton Proton Colliders

Expected discovery reach for LHC14, HL-LHC14 and at higher energy of 33 TeV (HE-LHC33)

Discovery reach/exclusion limits stop-LSP mass plane:



"Indicative" average mass reaches:

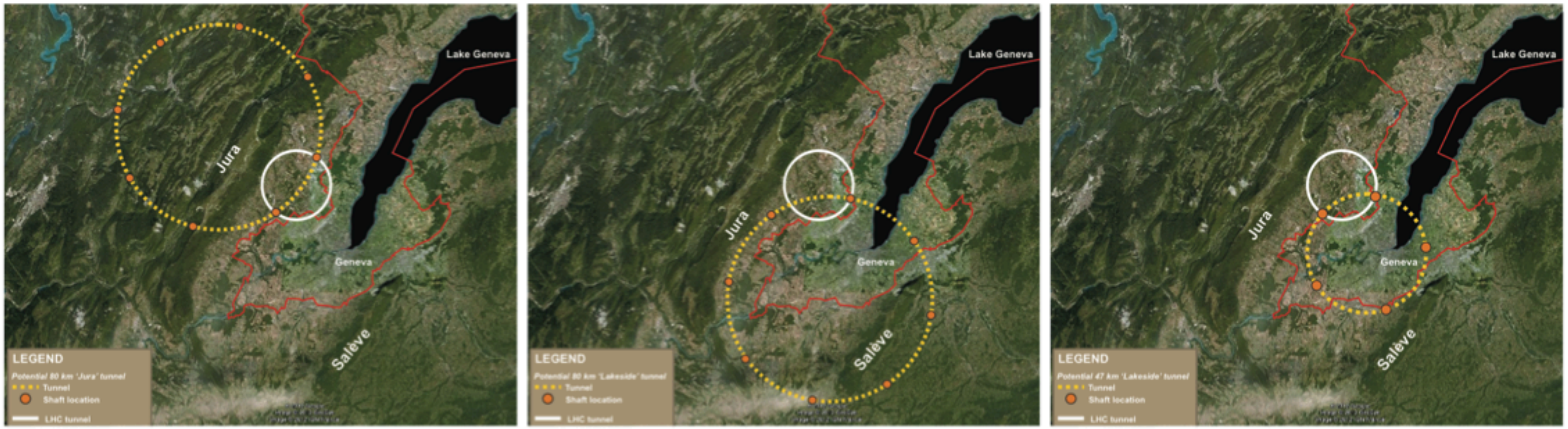


Proton Proton Colliders

V-LHC:

New “80 km” tunnel, early stage of discussion, geological feasibility study:

80 km Jura | 80 km Lakeside | 47 km Lakeside



In an 80 km tunnel:

- 42 TeV with 8.3 T (present LHC dipoles technology)
- 80 TeV with 16 T (high field based on Nb3Sn)
- 100 TeV with 20 T (very high field based on HTS)

If tunnel diameter is larger than LEP/LHC (3.8 m) dipoles could be larger and 20 T no hard limit.

Electron-Positron Colliders

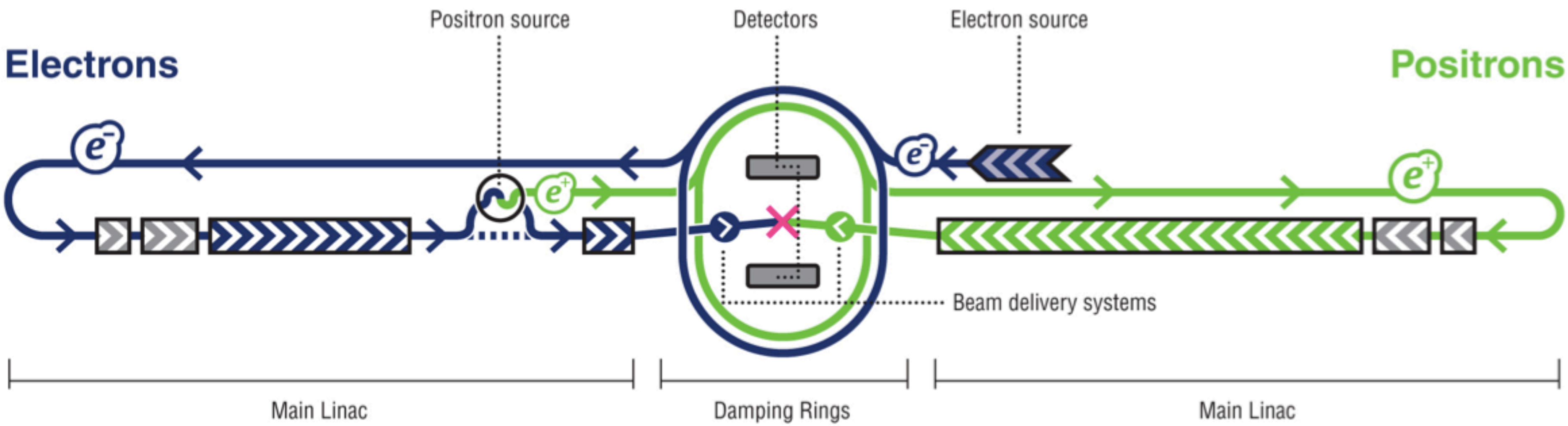
	Years	E_{cm} GeV	Luminosity $10^{34} cm^{-2} s^{-1}$	Tunnel length km
ILC 250	<2030	250	0.75	
ILC 500		500	1.8	~30
ILC 1000		1000		~50
CLIC 500	>2030	500	2.3(1.3)	~13
CLIC 1400		1400(1500)	3.2(3.7)	~27
CLIC 3000		3000	5.9	~48
LEP3	>2024	240	1	LEP/LHC ring
TLEP	>2030	240	5	80 (ring)
TLEP		350	0.65	80 (ring)

Complementary to proton-proton colliders, precision measurements at high energy:

- Initial state known, full kinematic reconstruction
- Low backgrounds, no trigger – record all collisions
- Precise theoretical predictions

International Linear Collider

Two single beam linacs with superconducting RF cavities (~40 MV/m)

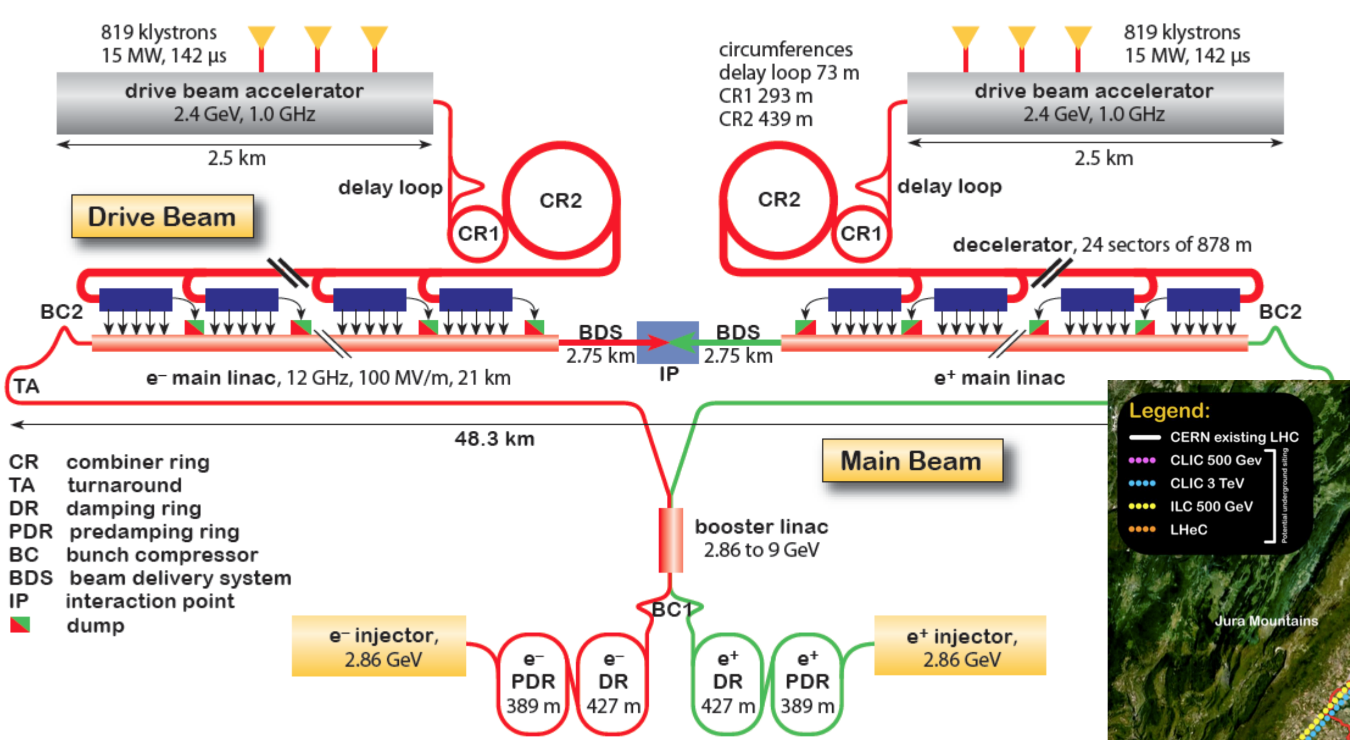


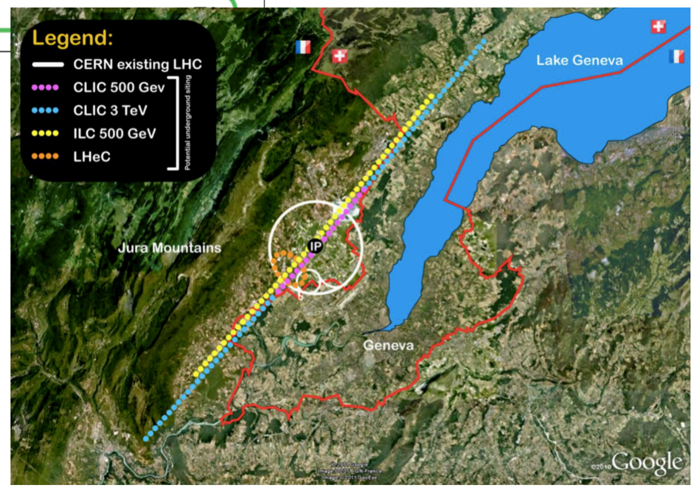
Project at TDR level, key technologies in hand after extensive R&D,
Industrial production of cavities established (e.g. XFEL),
For 500 GeV c.m. length of facility is ~ 30 km
Strong Japanese initiative to host ILC.
Japanese sites under investigation - site decision foreseen for July 2013!

Compact Linear Collider

European Strategy Update

Two beam acceleration: low energy, high current drive beam powers RF cavities of main linac (cavities ~100 MV/m), energy up to 3 TeV c.m. in stages.

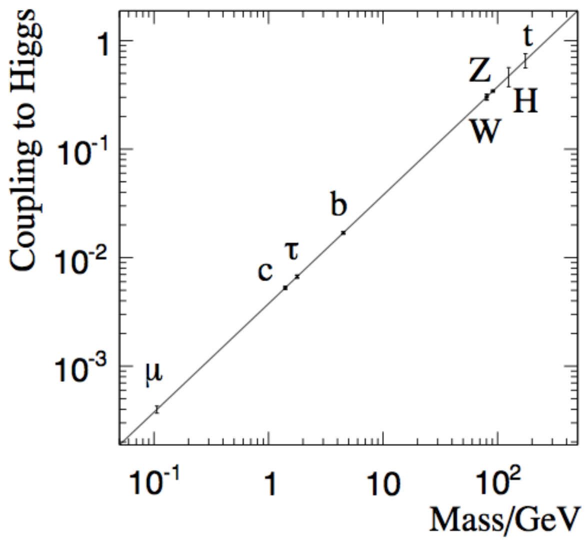


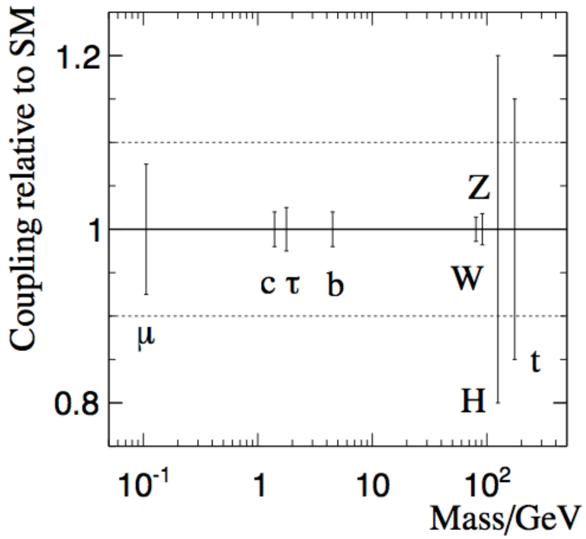


Project at CDR level,
Prove of principle of two beam acceleration
(Proposal for a Clystron version for start up at low energy)

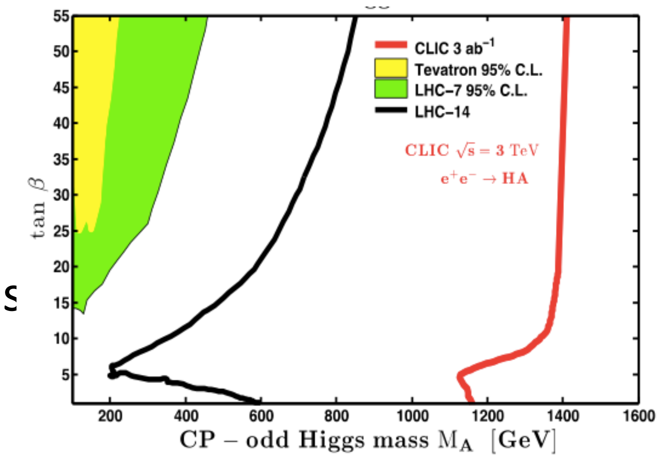
Linear Colliders

ILC: Expected precision achievable (Higgs couplings)





CLIC: e.g. SUSY Higgs Mass reach

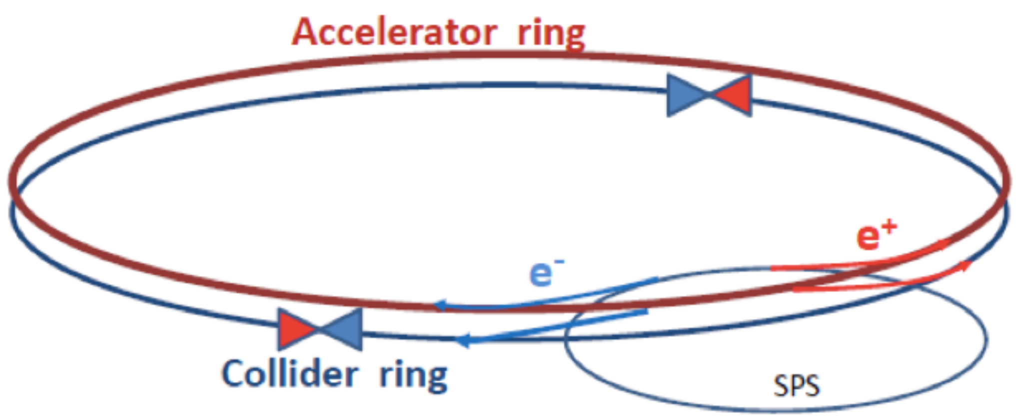


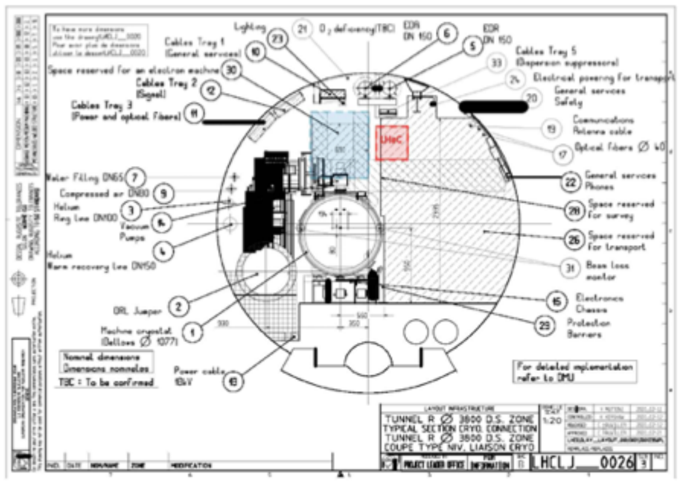
Indirect sensitivity to BSM through
Loop corrections (probe compositenes
Λ_{comp} = 45/60 TeV (at 0.5/3 TeV)

Circular e^+e^- Colliders

Advantages: very high luminosity achievable, more than one IP, mature technology
Disadvantages: Beamstrahlung limits beam life time, limited energy reach – not upgradable

LEP3: 240 GeV c.m., Double ring in LEP/LHC tunnel, first ring accelerates e^+e^- to operating energy, injection every few minutes into low emittance collider ring,
proposal to install LEP3 before or just after HL-LHC and use ATLAS and CMS as detectors.

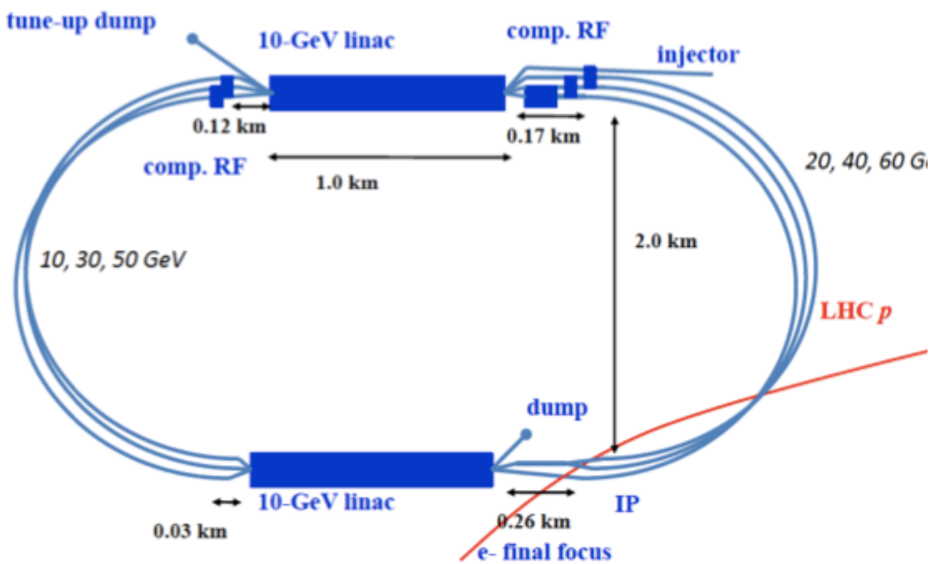




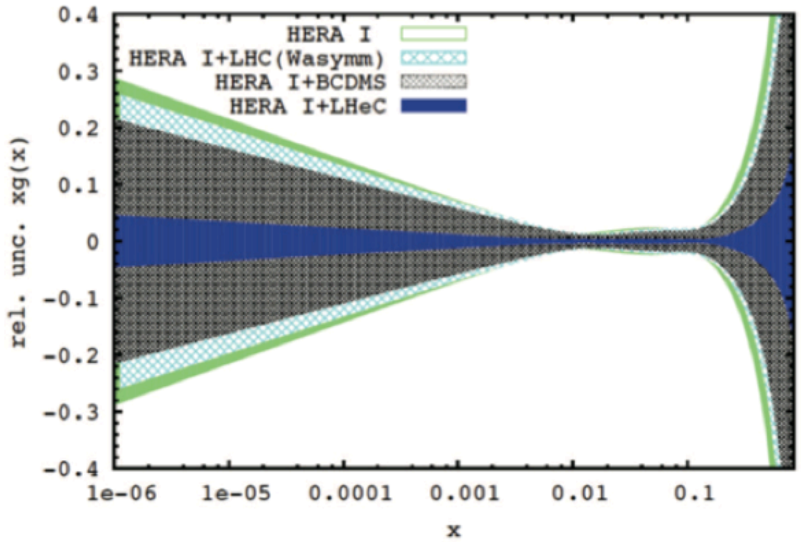
TLEP: Circular e^+e^- collider in new 80 km tunnel, to be used later for pp collision (as with LEP, LHC), achievable energy 350 GeV (ttbar threshold).

Electron Proton Collider

LHeC: 10 GeV linear accelerator with energy recovery, "Race track" configuration: 10 GeV x2 x3 = 60 GeV e^-, e^+
Q^2_{max} ~ 1 TeV^2, additional eA option



Relative uncertainty of the gluon distribution at Q^2=1.9 GeV^2 (blue LHeC):

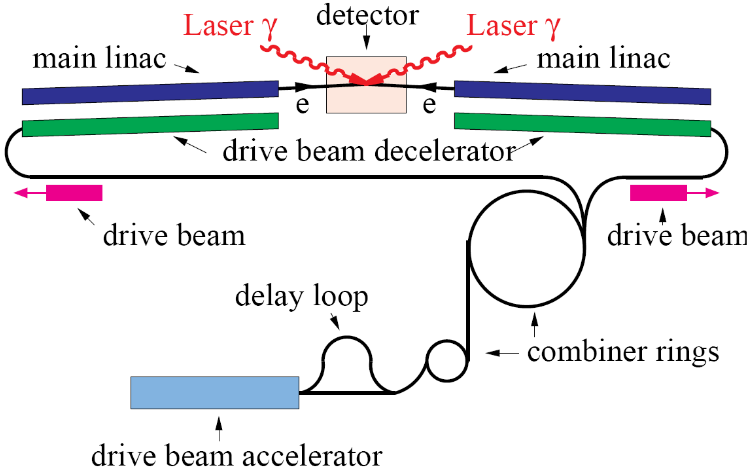


Very detailed CDR published.

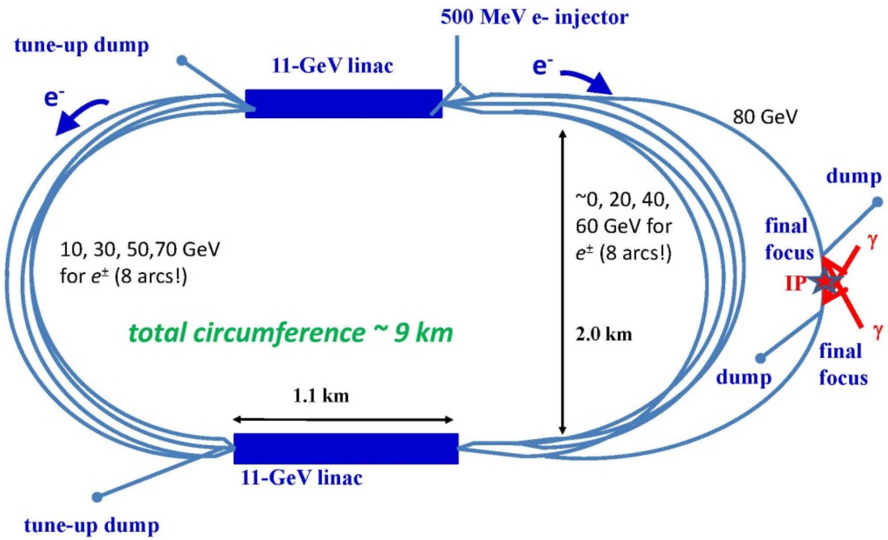
Photon Photon Colliders

Photon-Photon collisions at √s = 125 GeV to produce Higgs (s-channel)
Advantages: lower beam energy, no positron source needed
High power laser back-scatter system (6 x 10^{21} Wm^{-2})

CLIC based:

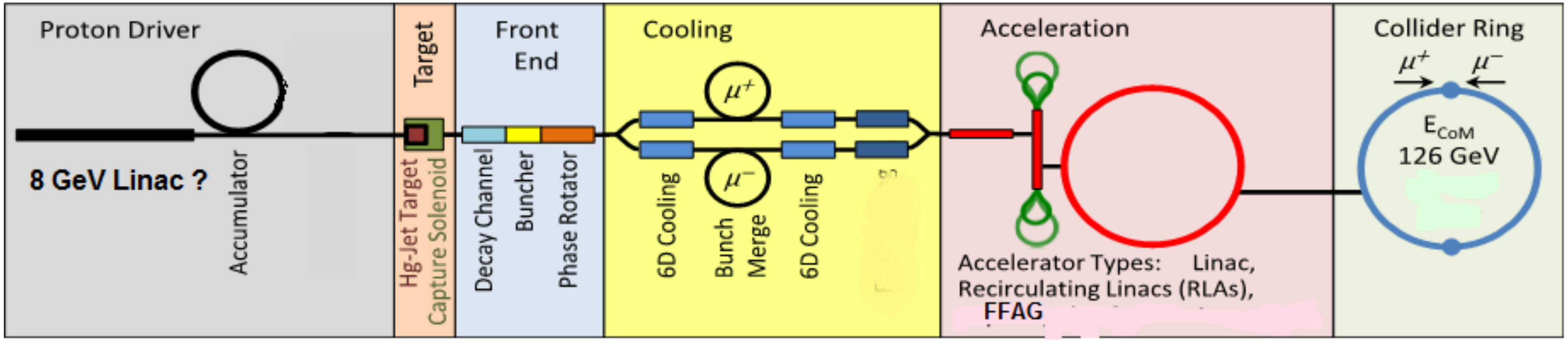


SAPPHiRE:



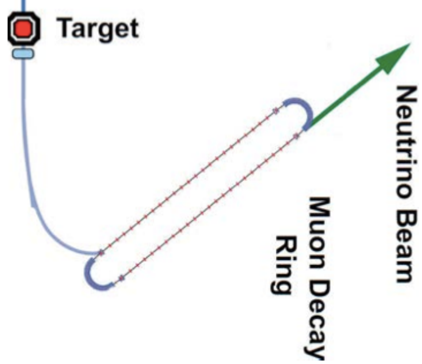
Muon Collider

Muon collider as Higgs factory, precursor or follow-on of neutrino factory.



Advantages of μ over e: smaller facility, very low synchrotron radiation, smaller energy spread, s-channel Higgs production ~m²

νSTORM as entry-point:



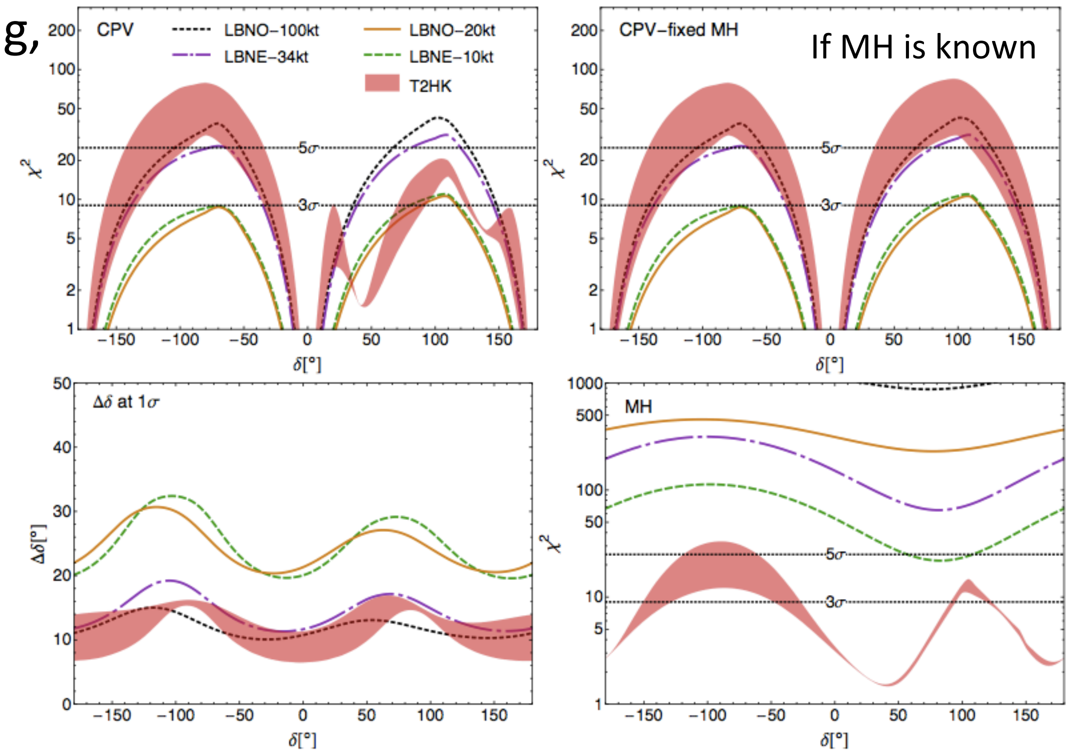
Neutrino Experiments

- **Long Baseline Neutrino Experiment with conventional beams**

Discovery potential for CP violating,
Precision for δ measurement
and sensitivity to Mass Hierarchy:

LBNO…Europe,
LBNE…US,
T2HK…Japan

Figure shows values
LBNO, LBNE for 10y,
T2HK for 5y



- Experiments to address (answer!) the question of **sterile Neutrinos**:
  νSTORM, ICARUS/NESSIE (possibly at CERN)

The Update of the European Strategy 2013

Excerpt from the Strategy Update

Official text highlighted, interpretations are my own, however trying to reflect the consensus.

General Issues

17 points, labeled a – q, numbers were avoided on purpose, not to give the impression of a pure priority list

Each point introduced by a statement followed by a recommendation (in italics)

General Issues:

a) The success of the LHC is proof of the effectiveness of the European organisational model for particle physics, founded on the sustained long-term commitment of the CERN Member States and of the national institutes, laboratories and universities closely collaborating with CERN. *Europe should preserve this model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.*

b) The scale of the facilities required by particle physics is resulting in the globalisation of the field. *The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.*

Scientific Activities

European Strategy Update

The strategy update must strike a balance between maintaining the diversity of the scientific program and setting priorities since the available resources are limited.

- Only large scale projects/facilities of global and supra-regional dimension are prioritized
- Competitive small and medium size projects (national, regional) are important to keep the diversity of our field, since a breakthrough often emerges in unexpected areas

> 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.

A priori these 4 activities are not prioritized, it is meant that all 4 should be pursued – a challenge the CERN mid (and long) term plan has to address!

High-Priority Large-Scale Scientific Activities

European Strategy Update

LHC and HL-LHC:

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.*

High-Priority Large-Scale Scientific Activities

Ad c):

Obviously this priority activity is the highest among the four - “primus inter pares”.

The work and input from the four experiments (ALICE, ATLAS, CMS and LHCb) have made the case for HL-LHC and a target integrated luminosity of 10 times. **The strategy recommends to go for the full upgrade, i.e. 3ab^{-1}, without compromises!**

This is a big “new” project. Huge work ahead, upgrade of LHC and upgrade of the detectors, funding to be secured, etc.
It is the next big challenge for particle physics **world-wide → contributions from other regions than Europe are crucial.**

High-Priority Large-Scale Scientific Activities

European Strategy Update

Design studies and R&D for post-LHC projects:

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-Priority Large-Scale Scientific Activities

Ad d):

Europe has a vision for CERNs future as the laboratory at the forefront of particle physics. This statement sees the future in the **energy frontier**.

More scientific input is needed before one can decide on a next large machine at CERN.
For the next strategy update in 5 to 6 years we should be in the position to propose an ambitious post-LHC accelerator project at CERN. Therefore we need to make studies in sufficient details on physics, technologies, feasibility and cost for machines such as CLIC, HE-LHC, V-LHC, T-LEP (in connection with V-LHC).

The strategy encourages accelerator R&D for **proton-proton and electron-positron colliders**, and consequently mentions explicitly **high-field magnets and high-gradient accelerating structures.**

ECFA is discussing possible future studies on these facilities.

High-Priority Large-Scale Scientific Activities

International Linear Collider:

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.*

High-Priority Large-Scale Scientific Activities

Ad e):

This is a strong statement in favor of the ILC and in particular of the Japanese initiative.

The strategy supports a machine with an initial energy of 250 GeV to perform precise and model-independent measurements of the Higgs branching ratios, with sensitivity to most decay modes at the percent level (complementary to LHC).

Energy upgradability of the ILC is seen as major asset!

At 350 GeV, perform precision tests of the top quark properties.
At 500 GeV and higher, explore further Higgs properties and search for new phenomena that may have escaped detection at the LHC.

Many European groups are very interested in participating in the ILC project. Expect Japanese government to comes forward with a clear plan for hosting the ILC in Japan and an invitation for Europe to participate.

High-Priority Large-Scale Scientific Activities

European Strategy Update

Neutrino Programme:

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.*

Ad f): It is important to reconstitute a neutrino physics activity at CERN, in order to provide technical expertise, support and focus for Europe to play a leading role in the forthcoming experiments – not necessarily hosted in Europe.
Note the emphasis on "long baseline"!

High-Priority Large-Scale Scientific Activities

European Strategy Update

The grounds for not including other projects (i.e. LHeC, LEP3, photon-photon colliders, and muon colliders) were the state of particle physics at the time of the update, the balance between the required human and financial resources and the expected availabilities, the time-scale and compatibility with other projects and technological maturity.

Other Scientific Activities

Statements g) to k) defines other scientific activities which are essential for HEP, but do not need a prioritization. These are:

- **Theory**: Support for a vibrant theoretical physics program, including high-performance computing and software development.
- **Experiments studying quark flavour physics, investigating dipole moments, searching for charged- lepton flavour violation and performing other precision measurements at lower energies, such as those with neutrons, muons and antiprotons**: support experiments with unique reach, "diversity"
- **Instrumentation, state-of-the-art infrastructure at CERN**, National institutes, laboratories and universities: maintain and further develop, engineering capabilities for the R&D programs
- **Non-accelerator experiments at the overlap of particle and astroparticle physics**, such as searches for proton decay, neutrinoless double beta decay and dark matter, and the study of high-energy cosmic-rays: CERN should seek a closer collaboration with ApPEC on detector R&D
- **Research at the boundary between particle and nuclear physics**: CERN Laboratory should maintain its capability to perform unique experiments and work with NuPECC on topics of mutual interest.

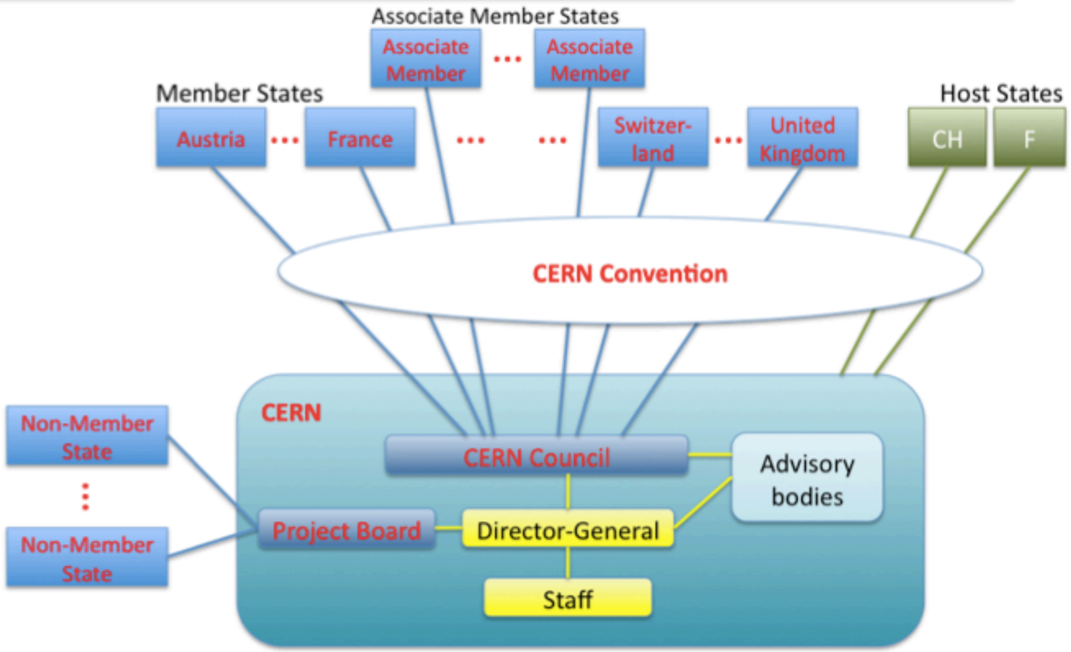
Organisational Issues

European Strategy Update

l) Future major facilities in Europe and elsewhere require collaboration on a global scale. *CERN should be the framework within which to organise a global particle physics accelerator project in Europe, and should also be the leading European partner in global particle physics accelerator projects elsewhere. Possible additional contributions to such projects from CERN's Member and Associate Member States in Europe should be coordinated with CERN.*

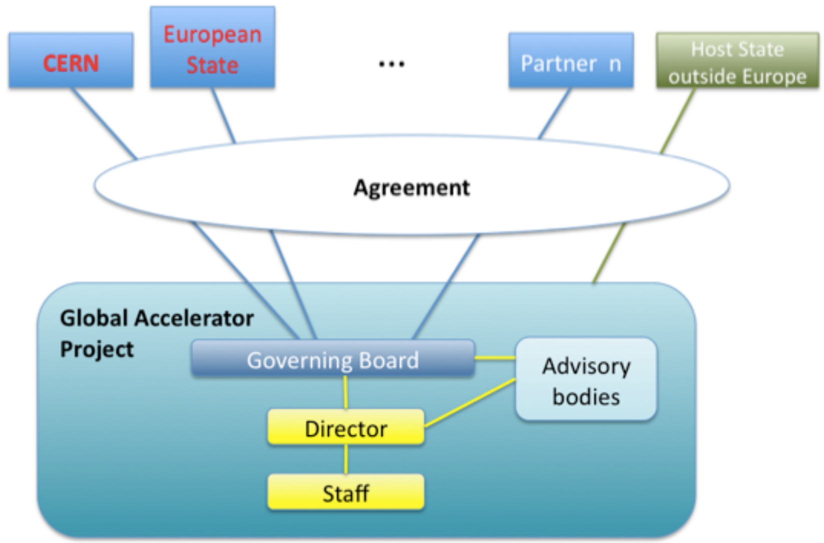
WG 2 discussed the implications of future global facilities at CERN and anywhere in Europe.

A possible (obvious) governance Model for a global accelerator project **in Europe:** (from summary document of WG2):



Organisational Issues

And **outside Europe**?
Also in this case CERN should be the leading European partner (Europe speaks with "one voice"). This should not hamper additional contributions from Europe, but they should be coordinated **WITH** (and not by) CERN.
A possible model (from WG2):



Following the Strategy adoption in 2006, CERN Council has already approved a set of statements as a framework for Europe's possible future participation in global accelerator projects to be constructed elsewhere, CERN is willing to coordinate broad European participation.

Summary

The Strategy Update is the result of a systematic and exhaustive discussion involving the whole particle physics community in Europe and elsewhere.

In all the discussions science was placed first!

I would like to acknowledge the patience and thoroughness of the chairman of the Strategy Secretariat Tatsuya Nakada.

Questions:

- Is large scale particle physics sustainable with ever increasing project sizes?
  In terms of: Complexity and duration of projects
  Cost
  Energy consumption
- What can and should we do to justified the investments in our field?
  Science curiosity – will this be sufficient?
  Benefits for society – there are many!

Thank You!