Study Overview & Status

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CERN
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Topics

- Motivation, Goal and Scope
- Parameters, Technologies
- EuroCirCol
- Study Organisation
- Outlook

Motivation

- **European Strategy for Particle Physics 2013:**

  "…to propose an ambitious post-LHC accelerator project….., CERN should undertake design studies for accelerator projects in a global context,…with emphasis on proton-proton and electron-positron high-energy frontier machines.…."

- **US P5 recommendation 2014:**

  "….A very high-energy proton-proton collider is the most powerful tool for direct discovery of new particles and interactions under any scenario of physics results that can be acquired in the P5 time window…."

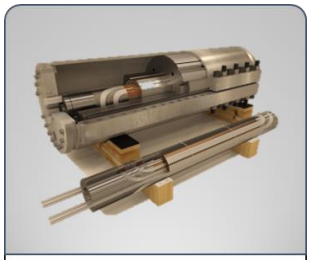
Goal of FCC Study

- **Conceptual Design Report**
- **By end 2018**
- **In time for next European Strategy Update**

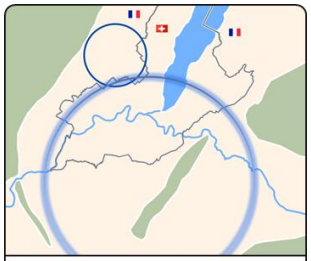
Scope: Accelerator & Infrastructure

Collider Designs

FCC-hh: **100 TeV pp collider as long-term goal**
→ defines infrastructure needs
FCC-ee: **e^+e^- collider**, potential intermediate step
FCC-he: **integration aspects** of pe collisions

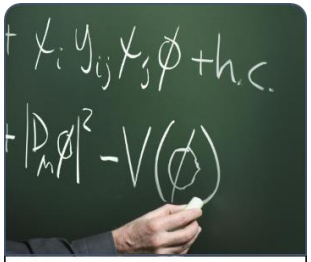

R&D Programs

Push key technologies
in dedicated R&D programmes e.g.
16 Tesla magnets for **100 TeV** pp in **100 km**
SRF technologies and RF power sources


Infrastructures

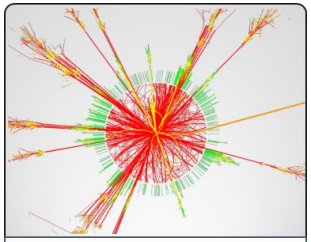
Tunnel infrastructure in Geneva area, linked to CERN accelerator complex
Site-specific, requested by European strategy

Scope: Physics & Experiments



Physics Cases

Elaborate and document
- Physics opportunities
- Discovery potentials



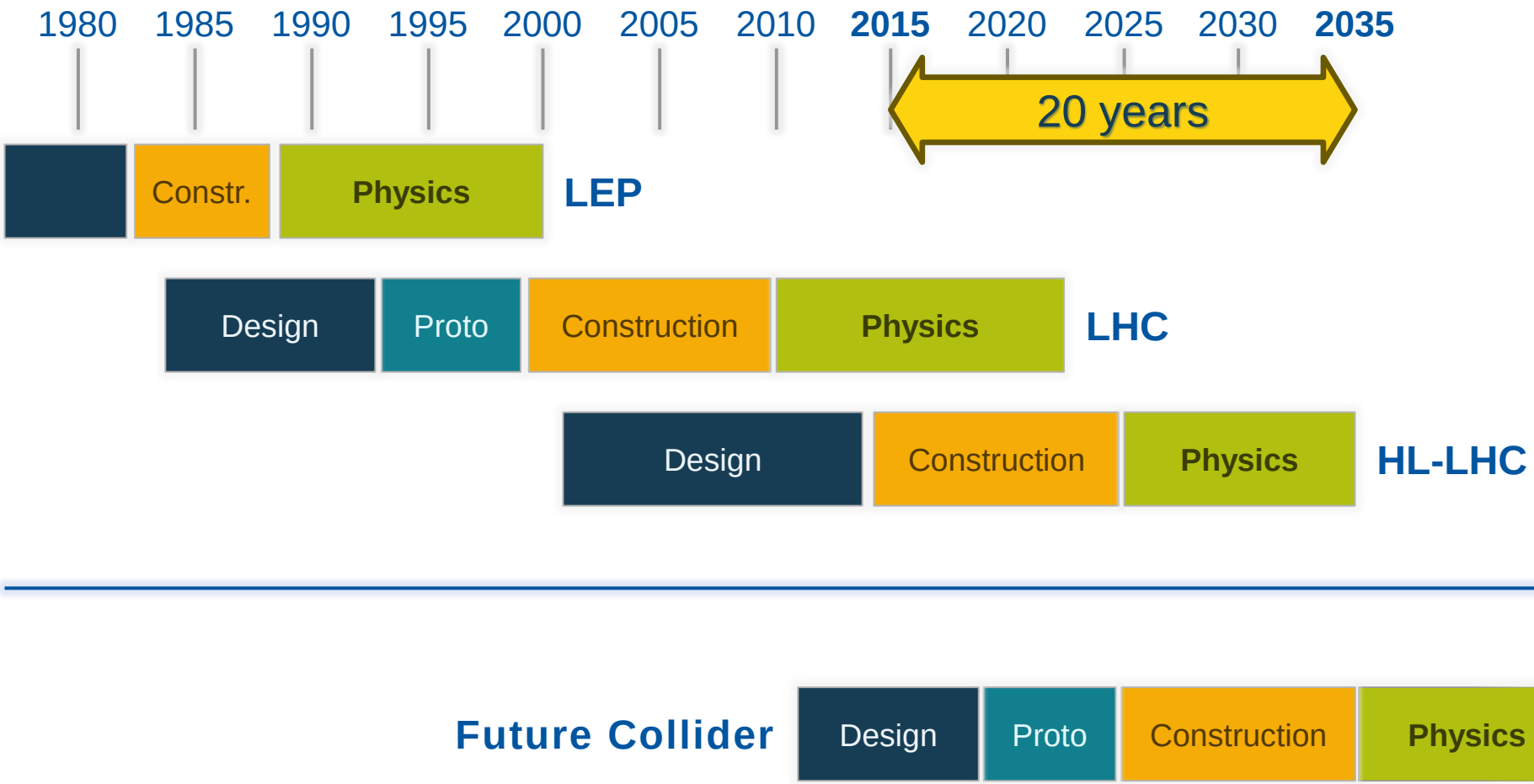
Experiments

Experiment concepts for hh, ee and he
Machine Detector Interface studies
Concepts for worldwide data services

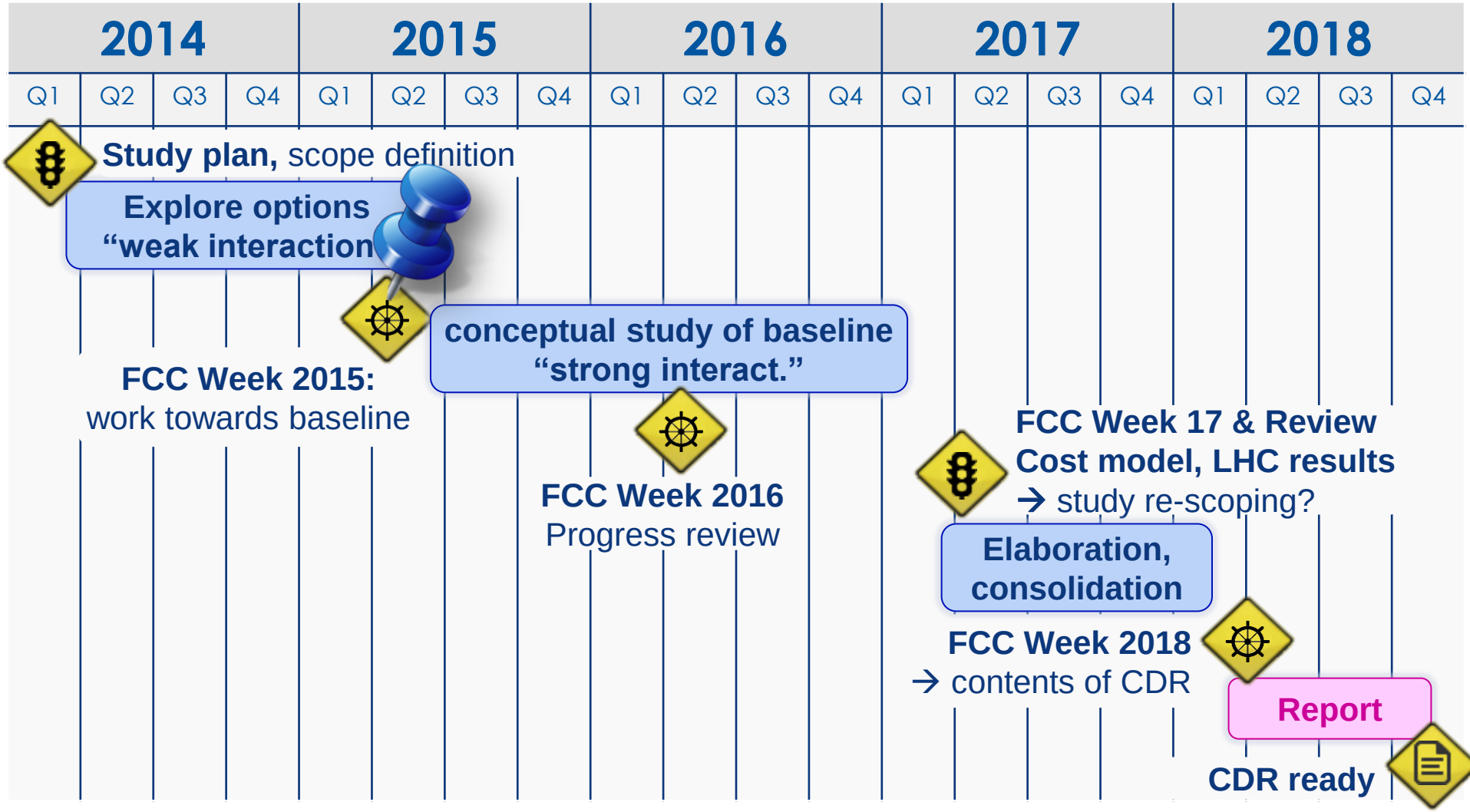
Cost Estimates

Overall cost model
Cost scenarios for collider options
Including infrastructure and injectors
Implementation and governance models

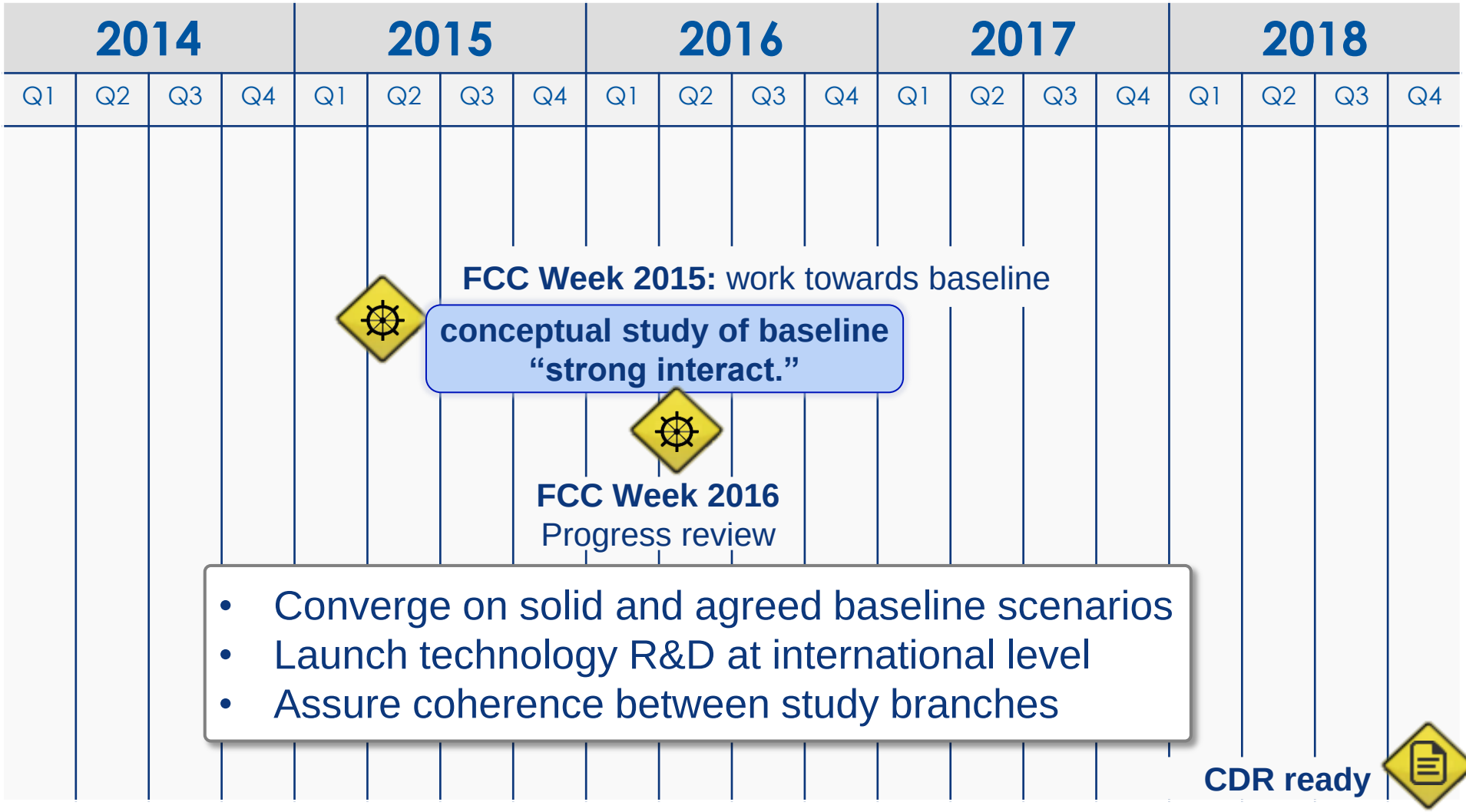
CERN Circular Colliders + FCC



Study time line towards CDR



Focus on Study-Phase 2



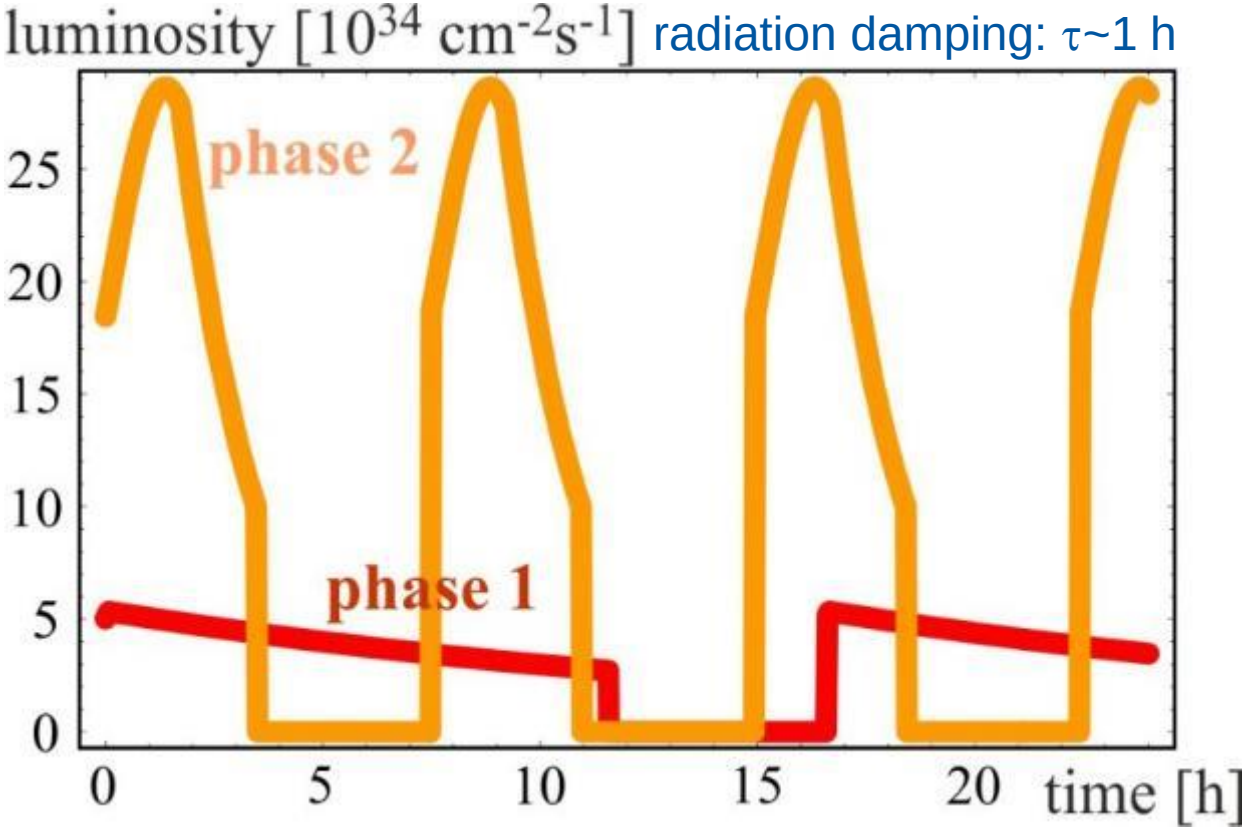
Key Parameters FCC-hh

Parameter	FCC-hh	LHC
Energy [TeV]	100 c.m.	14 c.m.
Dipole field [T]	16	8.33
# IP	2 main, +2	4
Luminosity/IP_{main} [$cm^{-2}s^{-1}$]	5 - 25 x 10^{34}	1 x 10^{34}
Stored energy/beam [GJ]	8.4	0.39
Synchrotron rad. [W/m/aperture]	28.4	0.17
Bunch spacing [ns]	25 (5)	25

FCC-hh Luminosity Goals

- **Two parameter sets for two operation phases:**
  - **Phase 1 (baseline): 5 x 10^{34} $cm^{-2}s^{-1}$ (peak),**
    250 fb^{-1}/year (averaged)
    2500 fb^{-1} within 10 years (~HL LHC total luminosity)
  - **Phase 2 (ultimate): ~2.5 x 10^{35} $cm^{-2}s^{-1}$ (peak),**
    1000 fb^{-1}/year (averaged)
    ➔ 15,000 fb^{-1} within 15 years
  - **Yielding total luminosity O(20,000) fb^{-1} over ~25 years of operation**

FCC-hh luminosity evolution 24 h



for both phases:

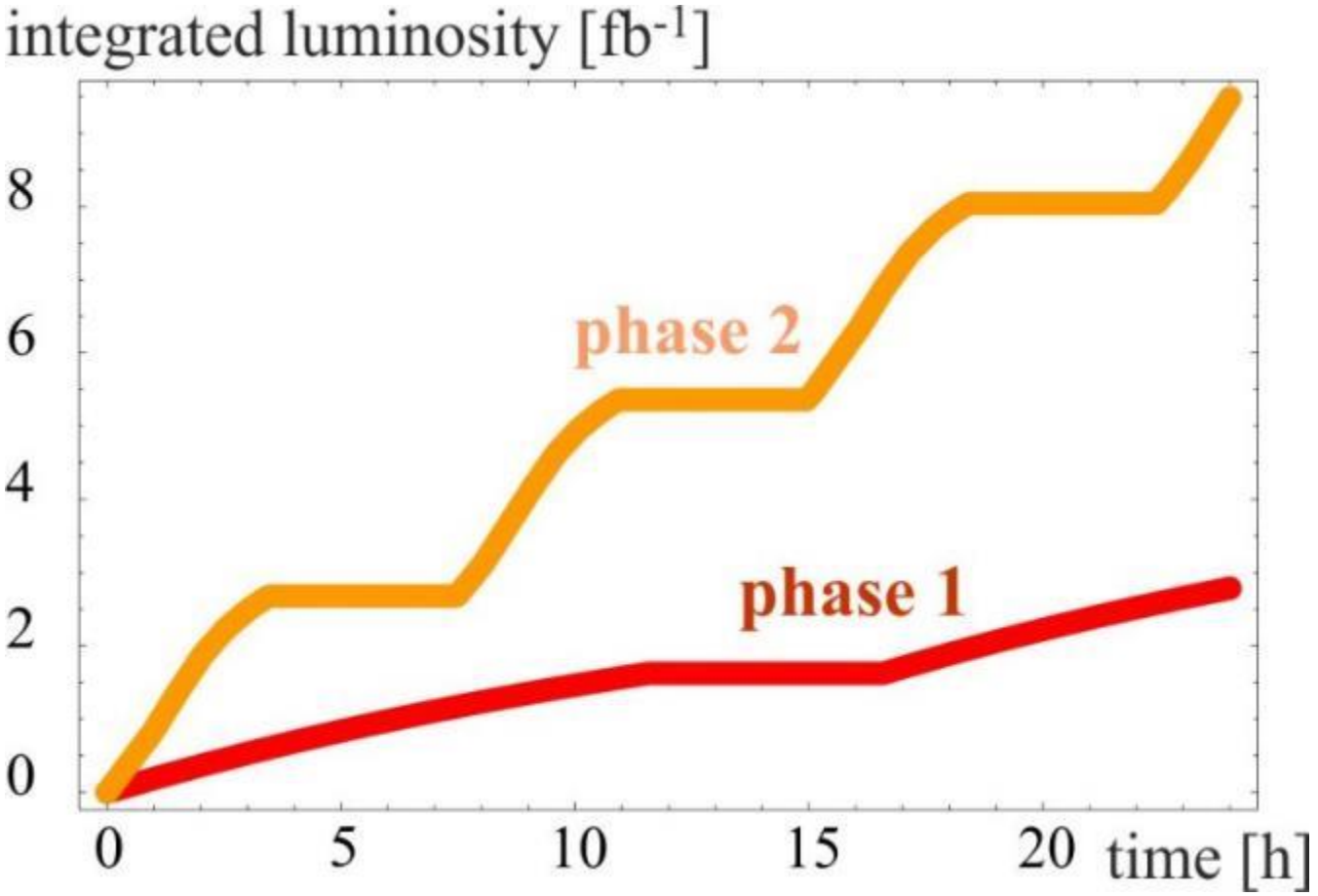
beam current 0.5 A unchanged!

total synchrotron radiation power ~5 MW.

phase 1: β^*=1.1 m, ΔQ_{tot}=0.01, t_{ta}=5 h

phase 2: β^*=0.3 m, ΔQ_{tot}=0.03, t_{ta}=4 h

FCC-hh Integrated Luminosity/day



phase 1: β*=1.1 m, ΔQ_{tot}=0.01, t_{ta}=5 h

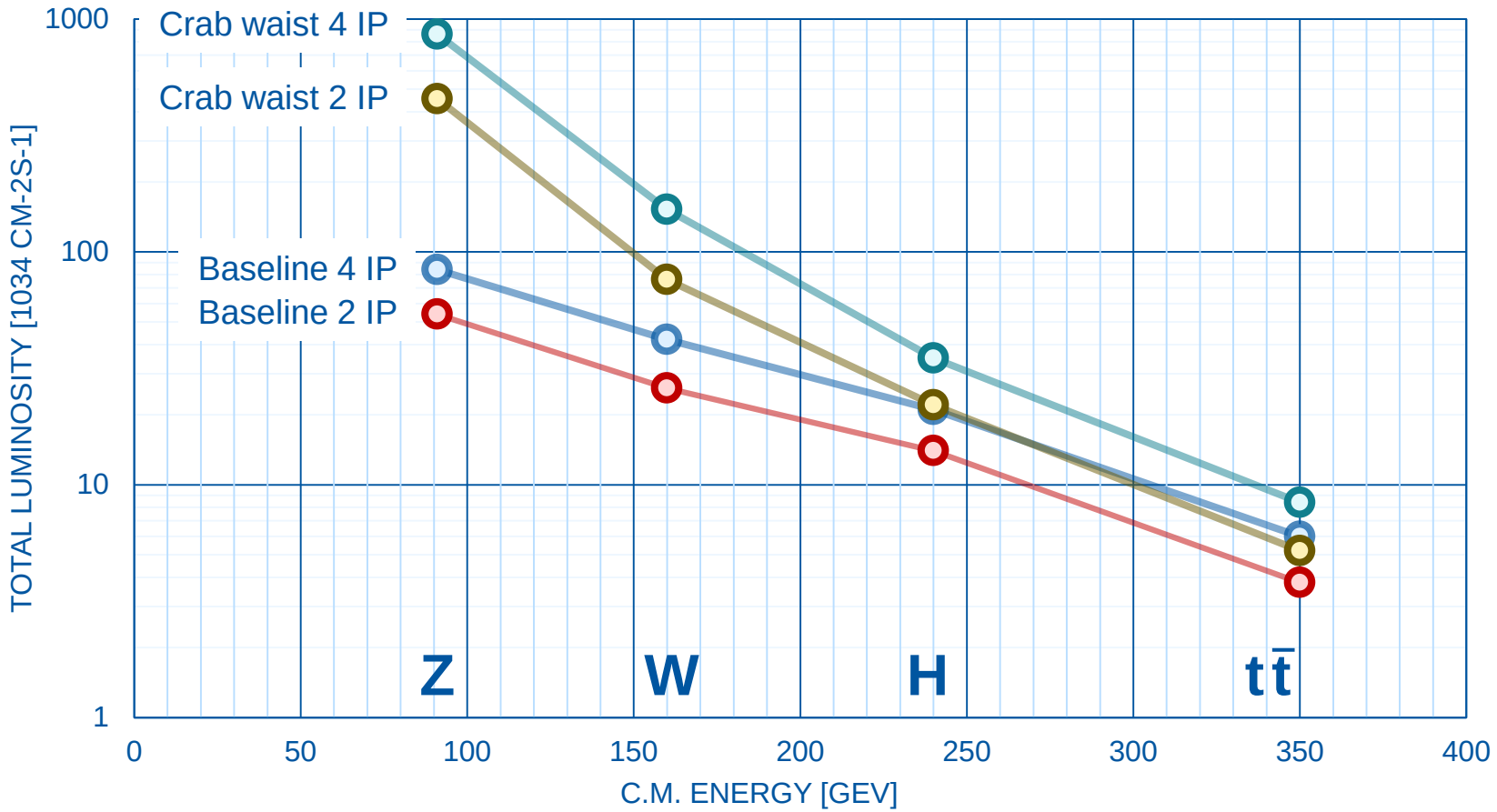
phase 2: β*=0.3 m, ΔQ_{tot}=0.03, t_{ta}=4 h

Key Parameters FCC-ee

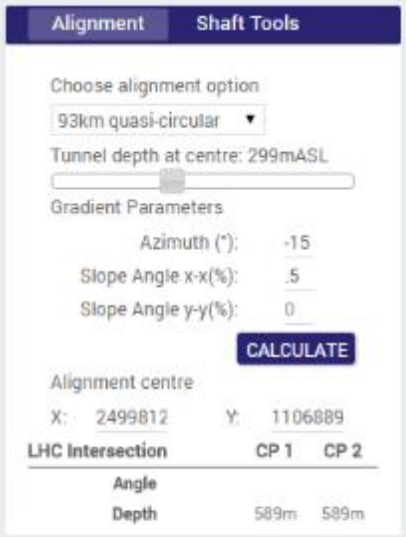
Parameter	FCC-ee			LEP2
Energy/beam [GeV]	45	120	175	105
Bunches/beam	13000-60000	500-1400	51- 98	4
Beam current [mA]	1450	30	6.6	3
Luminosity/IP x 10^{34} $cm^{-2}s^{-1}$	**21 - 280**	**5 - 11**	**1.5 - 2.6**	0.0012
Energy loss/turn [GeV]	0.03	1.67	7.55	3.34
Synchrotron Power [MW]	100			22
RF Voltage [GV]	0.3-2.5	3.6-5.5	11	3.5

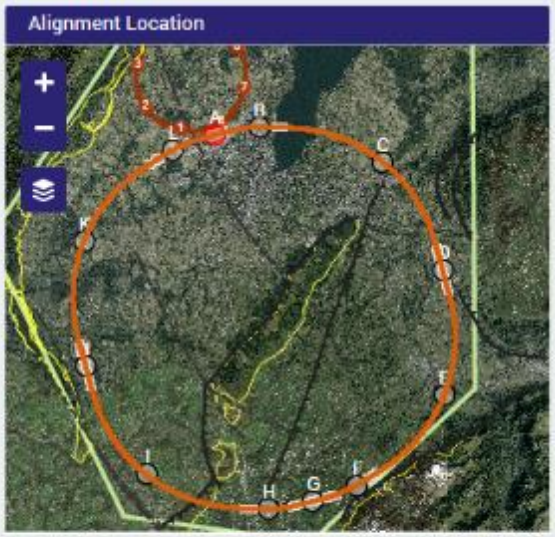
Dependency: crab-waist vs. baseline optics and 2 vs. 4 IPs

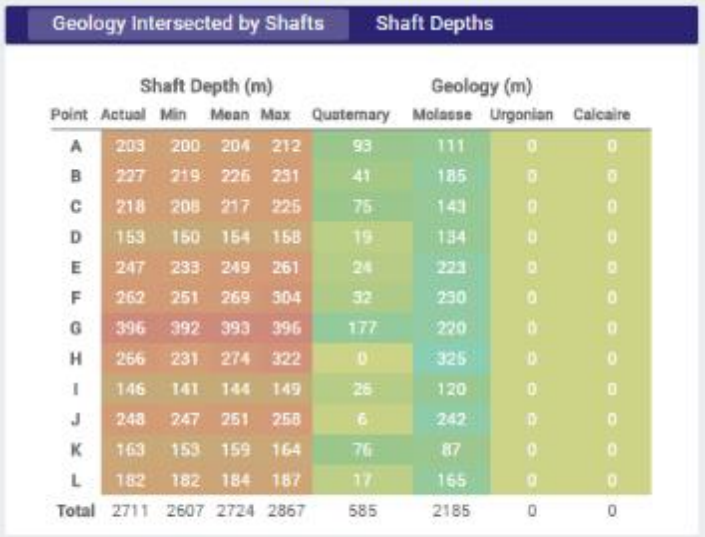
FCC-ee: Luminosity vs. Energy



Geology Studies – Example 93 km







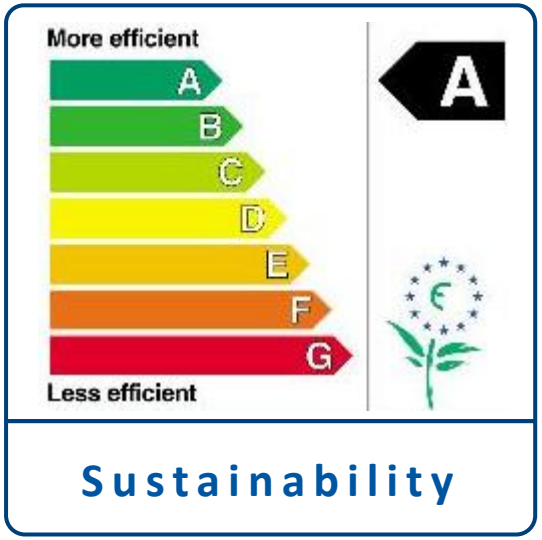
	Shaft Depth (m)				Geology (m)			
Point	Actual	Min	Mean	Max	Quaternary	Molasse	Urgonian	Calcaire
A	203	200	204	212	93	111	0	0
B	227	219	226	231	41	185	0	0
C	218	208	217	225	75	143	0	0
D	153	150	154	158	19	134	0	0
E	247	233	249	261	24	223	0	0
F	262	251	269	304	32	230	0	0
G	396	392	393	396	177	220	0	0
H	266	231	274	322	0	325	0	0
I	146	141	144	149	26	120	0	0
J	248	247	251	258	6	242	0	0
K	163	153	159	164	76	87	0	0
L	182	182	184	187	17	165	0	0
Total	2711	2607	2724	2867	585	2185	0	0

- 90 – 100 km fits geological situation well, better than a smaller ring size
- LHC suitable as potential injector

Push Technologies

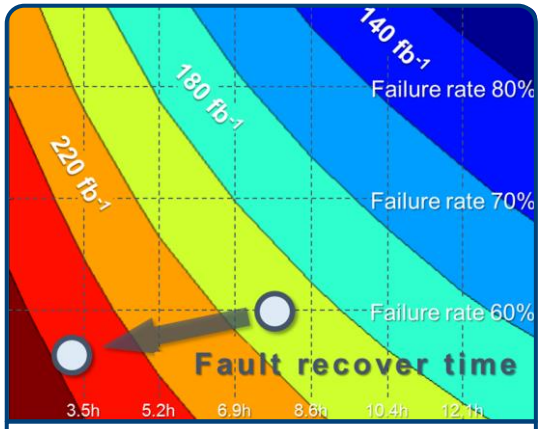
Scale Up versus Scale Out

- Scale-out of available technologies without advancement leads to unsustainable and inadequate performance
- Mandatory to use large projects to develop new technologies



Sustainability

Cost effective operation:
Personnel and material resources
Energy efficiency



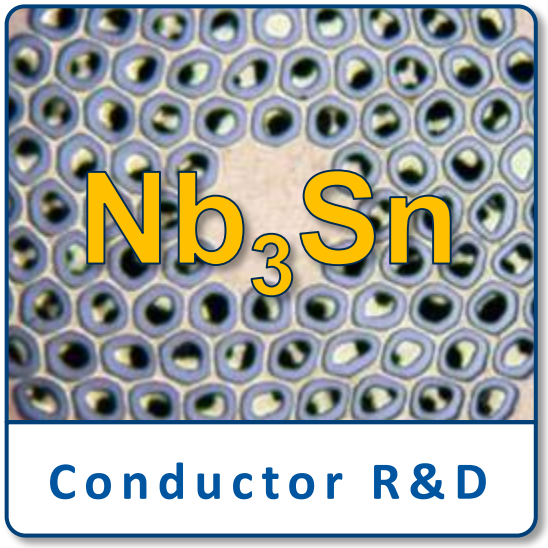
Availability

Number of subsystems requires breakthrough in reliability, availability

Economy

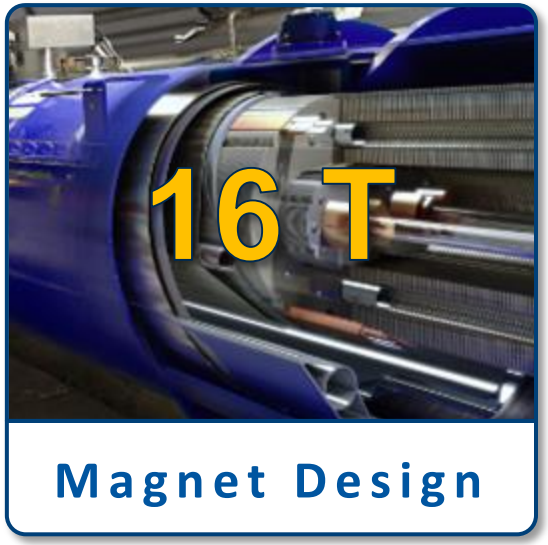
Diversify technology sources to control risk
Economic return to society is mandatory

Key Technology R&D - HFM



Conductor R&D

- Increase critical current density
- Obtain high quantities at required quality
- Material Processing
- Reduce cost



Magnet Design

- Develop 16T short models
- Field quality and aperture
- Optimum coil geometry
- Manufacturing aspects
- Cost optimisation

Key Technology R&D - RF

Superconducting RF

- Cavity R&D for large Q_0, high gradient, acceptable cryo power
- Multilayer additive manufacturing combining Cu and LTS materials
- High quality over large surfaces

Power Conversion

- Push Klystrons far beyond 70% efficiency
- Increase power range of solid-state amplifiers
- High reliability for high multiplicity


EuroCirCol
A key to New Physics

EuroCirCol EU Horizon 2020 Grant

EC contributes with funding to FCC-hh study

H2020 EuroCirCol

Hadron Collider

Key Technologies

Resources provided **by research institutes and universities with H2020 grant support**.

Future Circular Collider study **without** H2020 Support Requests

Infrastructure

Implementation

Cost Baseline

Resources provided and work carried out **by worldwide collaboration**.

- Core aspects of hadron collider design: arc & IR optics design
- Feasibility study of key technologies:
  16 T magnet program, cryogenic beam vacuum system

Evaluation Results

15/15

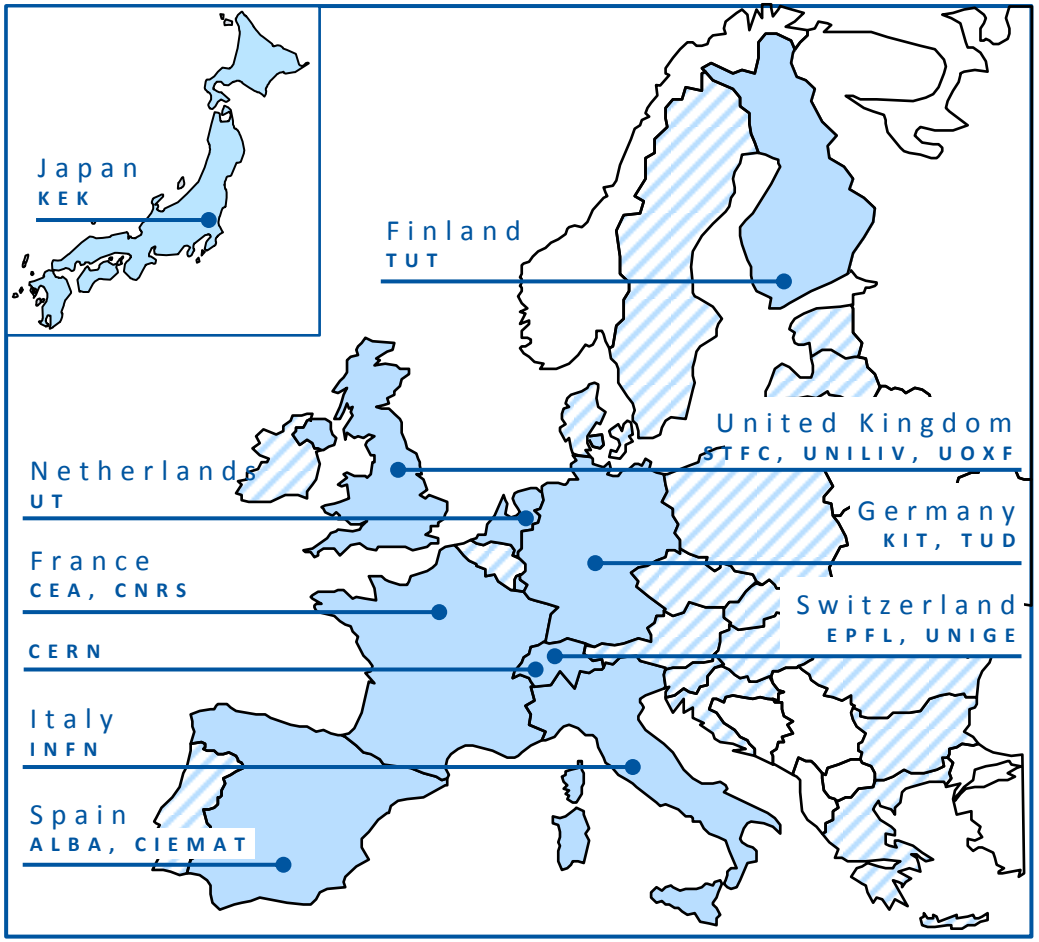
Quotes

- Science is excellent
- Project is ambitious and shows innovation potential
- Objectives are clear and approach is credible
- Will have impact on other disciplines and industry
- Key element of European Strategy on Particle Physics

Recognition of FCC Study by European Commission

EuroCirCol Consortium + Associates

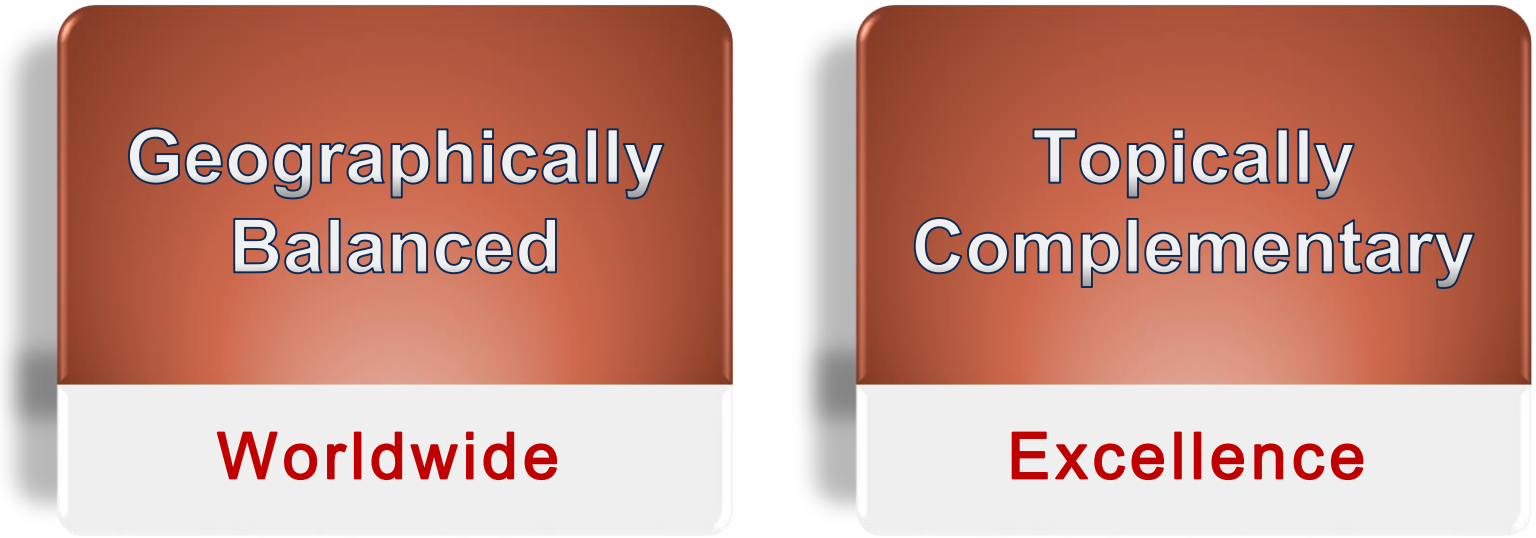
CERN	IEIO
TUT	Finland
CEA	France
CNRS	France
KIT	Germany
TUD	Germany
INFN	Italy
UT	Netherlands
ALBA	Spain
CIEMAT	Spain
STFC	United Kingdom
UNILIV	United Kingdom
UOXF	United Kingdom
KEK	Japan
EPFL	Switzerland
UNIGE	Switzerland
NHFML-FSU	USA
BNL	USA
FNAL	USA
LBNL	USA



Consortium Beneficiaries, signing the Grant Agreement

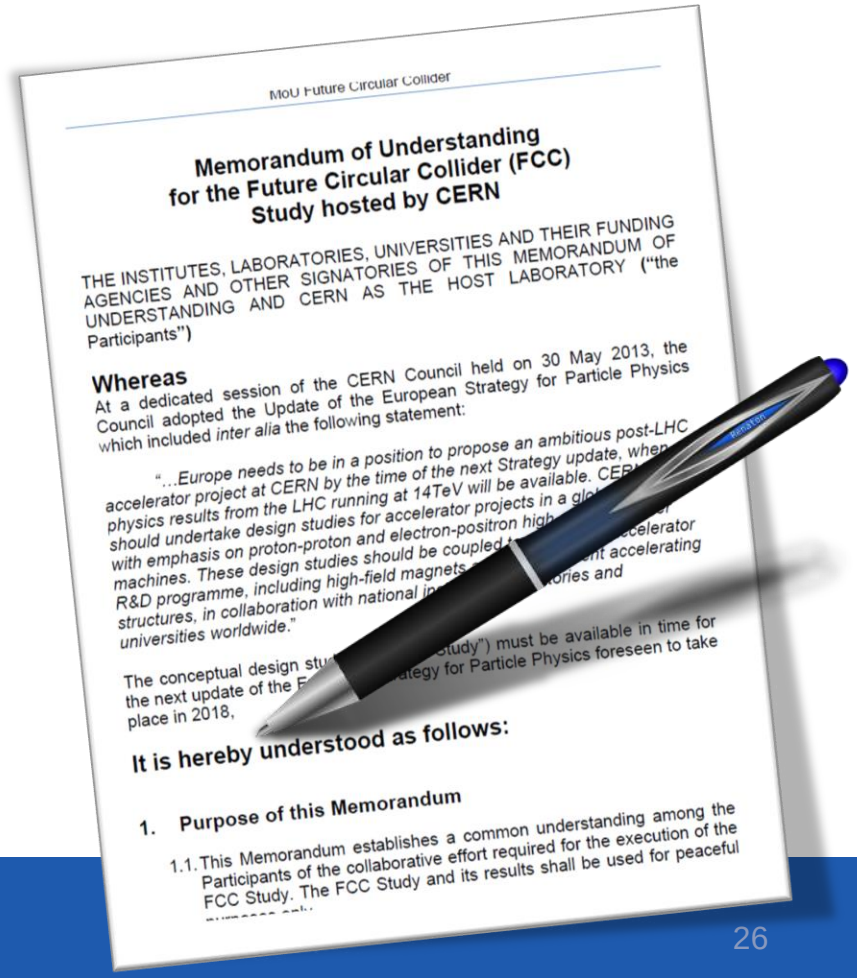
Study Setup

- Carried out by global collaboration
- Universities, laboratories & industry worldwide
- Hosted by CERN



The FCC Collaboration

- A **consortium** of partners based on a **Memorandum Of Understanding** (MoU)
- Working together on a **best effort basis**
- **Self governed**
- **Incremental & open** to academia and industry
- **Specific contributions** detailed in **Addendum**


MoU Future Circular Collider

Memorandum of Understanding for the Future Circular Collider (FCC) Study hosted by CERN

THE INSTITUTES, LABORATORIES, UNIVERSITIES AND THEIR FUNDING AGENCIES AND OTHER SIGNATORIES OF THIS MEMORANDUM OF UNDERSTANDING AND CERN AS THE HOST LABORATORY ("the Participants")

Whereas

At a dedicated session of the CERN Council held on 30 May 2013, the Council adopted the Update of the European Strategy for Particle Physics which included *inter alia* the following statement:

"...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 14TeV 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 efficient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide."

The conceptual design study ("Study") must be available in time for the next update of the European Strategy for Particle Physics foreseen to take place in 2018,

It is hereby understood as follows:

1. **Purpose of this Memorandum**

1.1. This Memorandum establishes a common understanding among the Participants of the collaborative effort required for the execution of the FCC Study. The FCC Study and its results shall be used for peaceful

Collaboration Status

- 51 institutes
- 19 countries
- EC participation

51 FCC collaboration members & CERN as host institute, 22 March 2015

ALBA/CELLS, Spain
Ankara U., Turkey
U Bern, Switzerland
BINP, Russia
CASE (SUNY/BNL), USA
CBPF, Brazil
CEA Grenoble, France
CEA Saclay, France
CIEMAT, Spain
CNRS, France
Cockcroft Institute, UK
U Colima, Mexico
CSIC/IFIC, Spain
TU Darmstadt, Germany
DESY, Germany
TU Dresden, Germany
Duke U, USA
EPFL, Switzerland
GWNU, Korea
U Geneva, Switzerland
Goethe U Frankfurt, Germany
GSI, Germany
Hellenic Open U, Greece
HEPHY, Austria
IFJ PAN Krakow, Poland
INFN, Italy
INP Minsk, Belarus
U Iowa, USA
IPM, Iran
UC Irvine, USA
Istanbul Aydin U., Turkey
JAI/Oxford, UK
JINR Dubna, Russia
FZ Jülich, Germany
KAIST, Korea
KEK, Japan
KIAS, Korea
King's College London, UK
KIT Karlsruhe, Germany
Korea U Sejong, Korea
MEPhI, Russia
MIT, USA
NBI, Denmark
Northern Illinois U., USA
NC PHEP Minsk, Belarus
U. Liverpool, UK
PSI, Switzerland
Sapienza/Roma, Italy
UC Santa Barbara, USA
U Silesia, Poland
TU Tampere, Finland

Study Coordination Group

Study Lead	Hadron Collider **Physics** & **Experiments**	Lepton Collider **Physics** & **Experiments**	ep **Physics**, **Experiment**, IP Integration
M. Benedikt F. Zimmermann	A. Ball, F. Gianotti, M. Mangano	A. Blondel, J. Ellis, C. Grojean, P. Janot	M. Klein, O. Bruning

Hadron **Injectors**	**Hadron Collider**	Lepton **Injectors**	**Lepton Collider**
B. Goddard	D. Schulte, M. Syphers	Y. Papaphilippou	F. Zimmermann, J. Wenninger, U. Wienands

Accelerator Technologies **R&D**	**Special Technologies**	**Infrastructures** & **Operation**	**Costing** & **Planning**
L. Bottura, E. Jensen, L. Tavian	JM. Jimenez	P. Lebrun, P. Collier	P. Lebrun, F. Sonnemann

Further enlargement of coordination group and study teams with international partners

Information Management in FCC
http://cern.ch/fcc

Documents and Publications

Study internal
CERN **EDMS**

- Notes, drawings, slides, minutes
- Source files of scientific papers
- **http://cern.ch/fcc-edms**

Public documents
CERN **CDS**

- PDF of scientific papers,
  public slides, official reports, videos
- **http://cern.ch/cds** > R&D and Studies
  > Future Circular Collider Documents

Collaborative Work Platform

Meetings

- Structure in CERN Indico
- **http://cern.ch/fcc-meetings**

Collaboration Tools

- Institutes and work breakdown overview
- Growing platform for information exchange
- **http://cern.ch/fcc/collaboration**

Access to Collaboration Services

Collaboration members can subscribe to one of the following e-groups to gain access to IT services at **http://cern.ch/egroups**

E-group Name:
fcc-collider-hadron
fcc-collider-lepton
fcc-experiments-hadron
fcc-experiments-lepton
fcc-infrastructures
fcc-injectors-hadron
fcc-injectors-lepton

Outlook 2015

- **Freeze baselines parameters** and concepts
  - Colliders, injectors and infrastructures
- Put **Nb_3Sn/16 T magnet program** on solid feet
- Define and **launch selected** technology **R&D programmes**
- Reinforce **physics and detector simulations**
- Pursue **MDI and experiment studies**
- Further **enlarge our global FCC collaboration**

This 1st FCC Week should

- **Stimulate exchange** between participants of all study areas
- **Strengthen the collaboration** network
- **create fruitful discussions** towards our common goal

Have a Great Week!