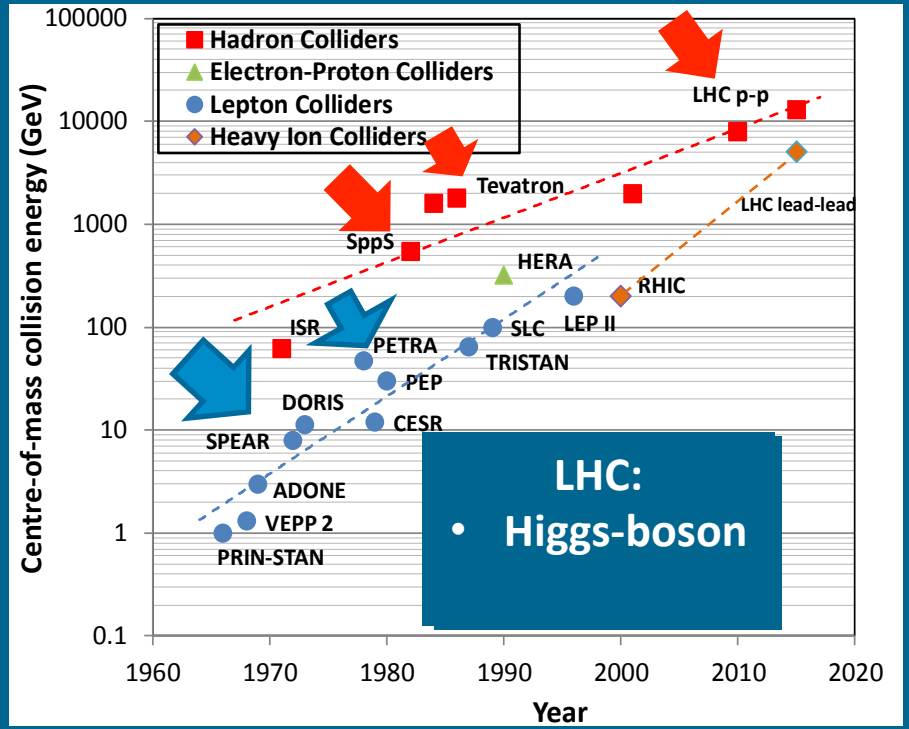
Future Circular Collider

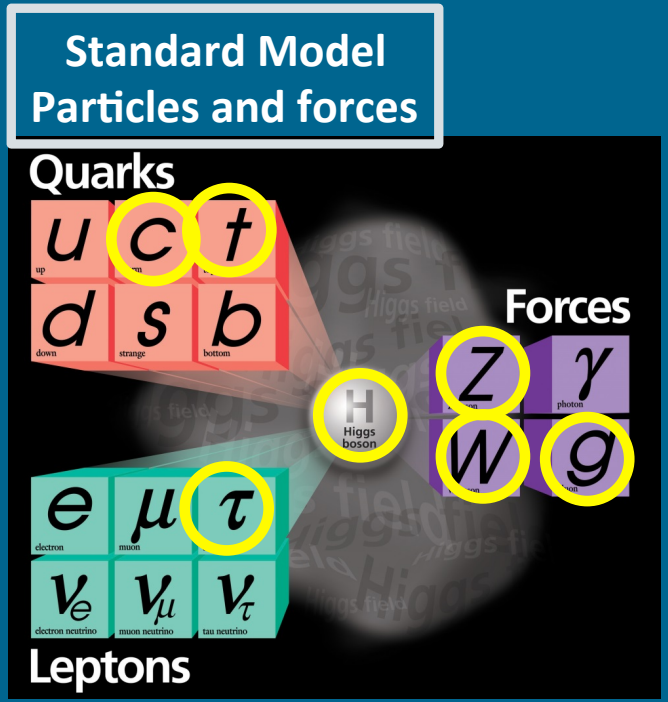
Designing a Future Circular Collider: Challenges & Perspectives

By Dr. Michael Benedikt

For the Greek HSTs: P. Charitos, E. Gazis

Discoveries by colliders, Πού βρισκόμαστε σήμερα?

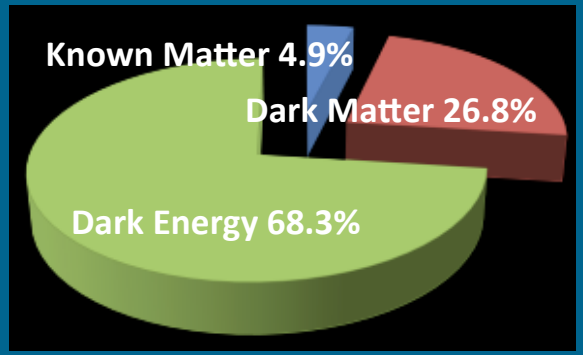


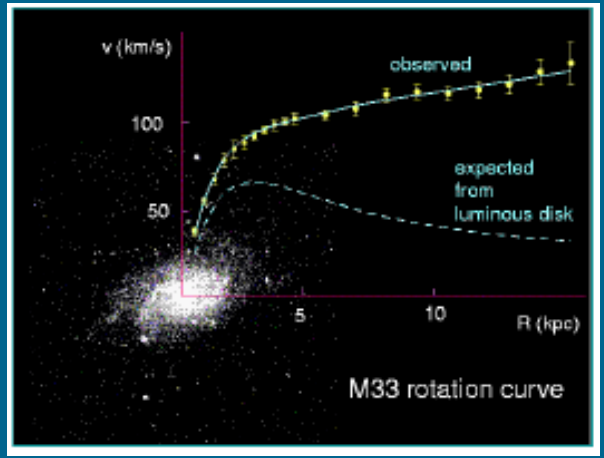


Colliders are powerful instruments in High Energy Physics for particle discoveries and precision measurements

Many open questions, Πού βρισκόμαστε σήμερα?

- Standard model describes known matter, i.e. 5% of the universe! **What about the remaining 95%?**





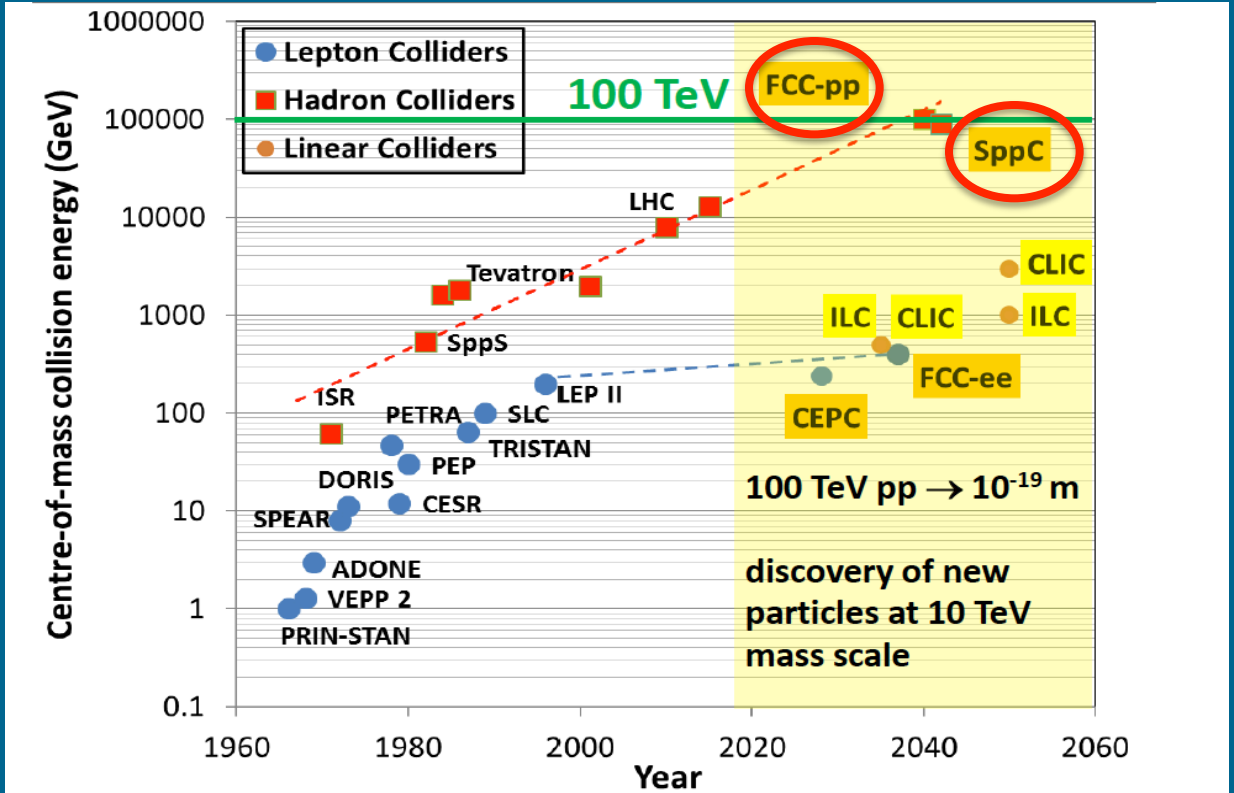
galaxy rotation curves, 1933 - Zwicky

- what is dark matter?
- what is dark energy?
- why is there more matter than antimatter?
- why do the masses differ by more than 13 orders of magnitude?
- do fundamental forces unify in single field theory?
- what about gravity?
- Is there a “world equation – theory of everything”? …

K. Borras

Roads to Discovery, Οι δρόμοι της Ανακάλυψης

Particle colliders are powerful instruments in physics for discoveries and high precision measurements that could reveal new phenomena.



Motivation for launching the study – A global vision for the future of particle physics

"CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines." -European Strategy for Particle Physic

"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..." -US Particle Physics Strategy (P5)

"...ICFA supports studies of energy frontier circular colliders and encourages global coordination..." -ICFA

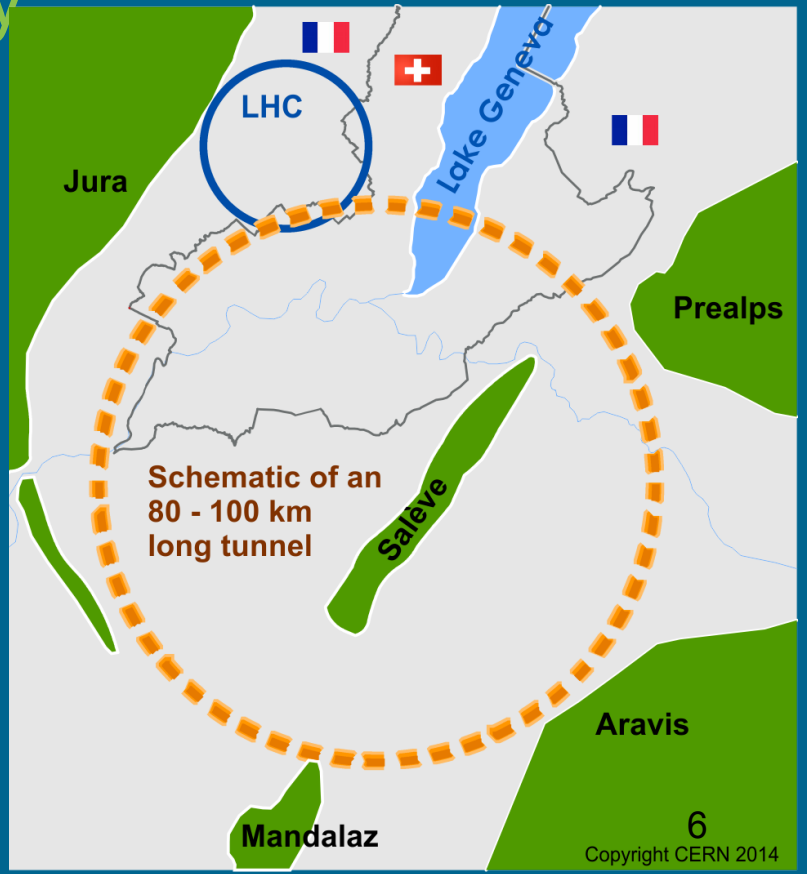
Expanding our Horizons

Future Circular Collider Study

International collaboration with CERN as host laboratory:

exploring the feasibility of several particle collider scenarios with the aim of significantly expanding the current energy and luminosity frontiers.

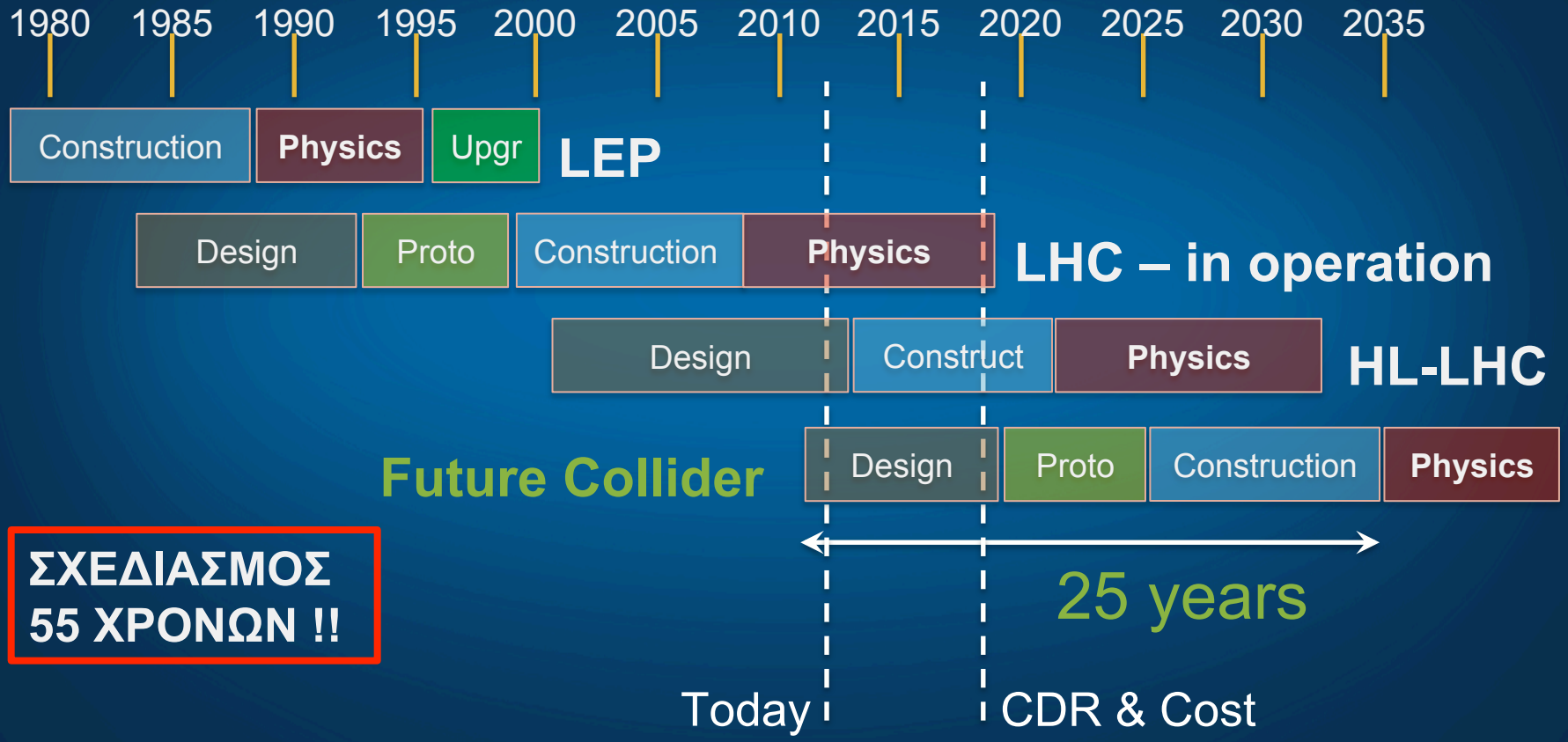
- 100 TeV pp-collider and alternative e+e- collider as potential first step
- High-Energy LHC scenario
- 100 km tunnel infrastructure in Geneva area



Strategic Goals

1. Make funding bodies aware of strategic needs for research community (ΕΝΗΜΕΡΩΣΗ ΓΙΑ ΧΡΗΜΑΤΟΔΟΤΗΣΗ)
2. Provide sound basis to policy bodies to establish long-range plans in European research area (ΣΤΡΑΤΗΓΙΚΗ ΓΙΑ ΕΡΕΥΝΑ ΣΤΗΝ ΕΥΡΩΠΗ)
3. Strengthen capacity and effectiveness in high-tech domains (ΠΡΟΩΘΗΣΗ ΥΨΗΛΗΣ ΤΕΧΝΟΛΟΓΙΑΣ)
4. Provide a basis for long-term attractiveness of Europe as research area (ΔΙΑΤΗΡΗΣΗ ΤΗΣ ΕΥΡΩΠΑΪΚΗΣ ΠΡΩΤΟΠΟΡΙΑΣ ΣΤΗΝ ΕΡΕΥΝΑ)

HEP Timescale



ΣΧΕΔΙΑΣΜΟΣ 55 ΧΡΟΝΩΝ !!

FCC-hh Key Parameters

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 x 10^{34}**	1 x 10^{34}
Energy/beam [GJ]	**8.4**	0.39
Synchr. rad. [W/m/apert.]	28.4	0.17
Bunch spacing [ns]	25 (5)	25

Tevatron (closed)

Circumference: **6.2 km**

Energy: **2 TeV**

Large Hadron Collider

Circumference: **27 km**

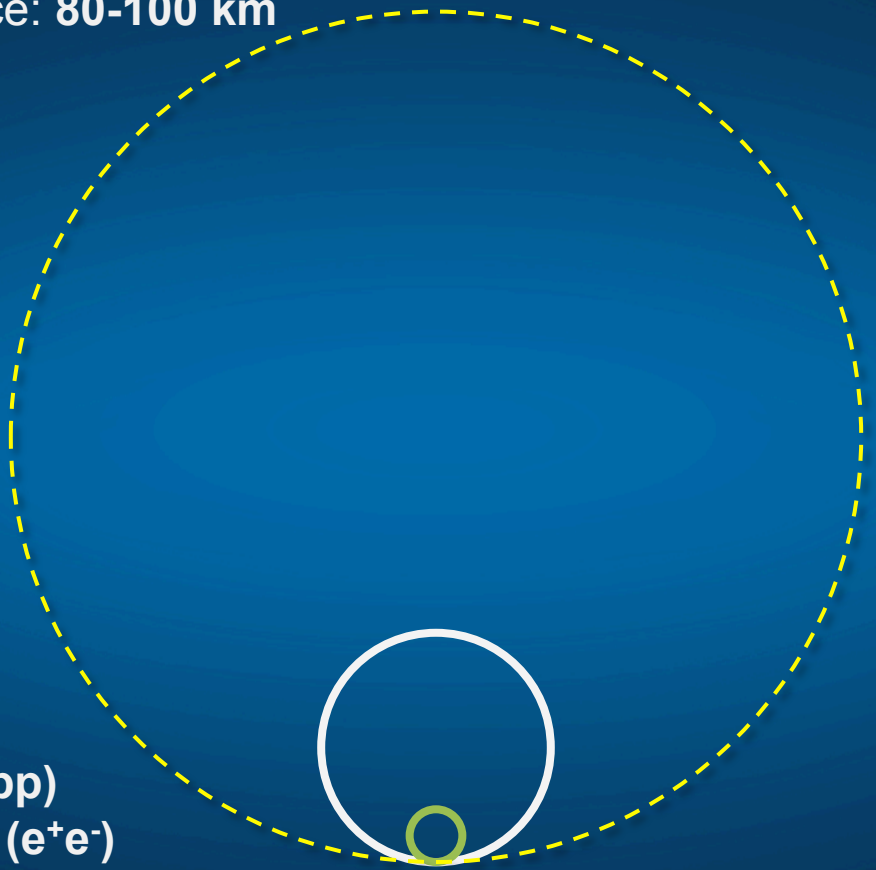
Energy:

- 14 TeV (pp)

- 209 GeV (e^+e^-)

Future Circular Collider

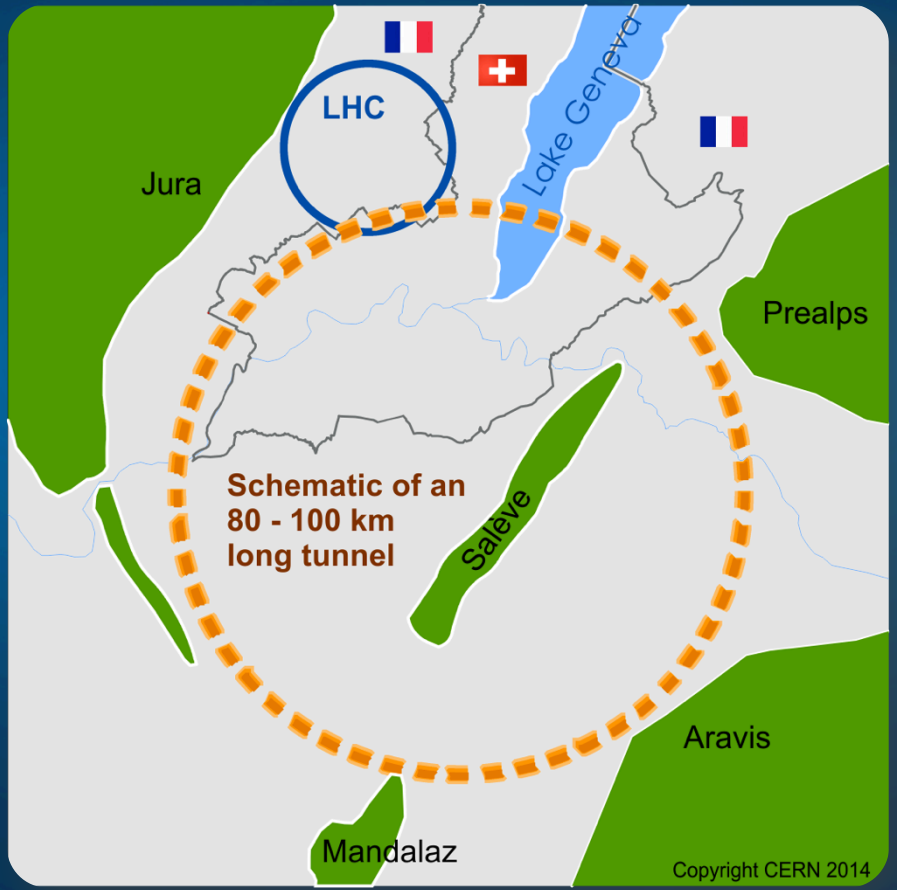
Circumference: **80-100 km**



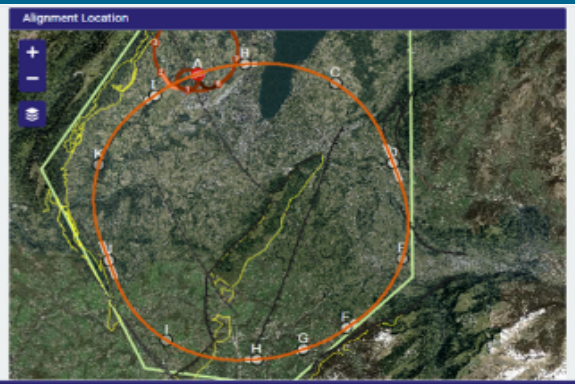
Energy:

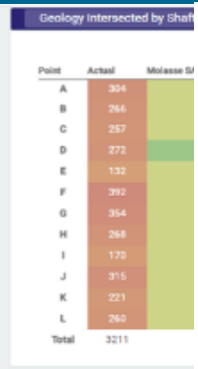
- **100 TeV (pp)**
- **>350 GeV (e^+e^-)**

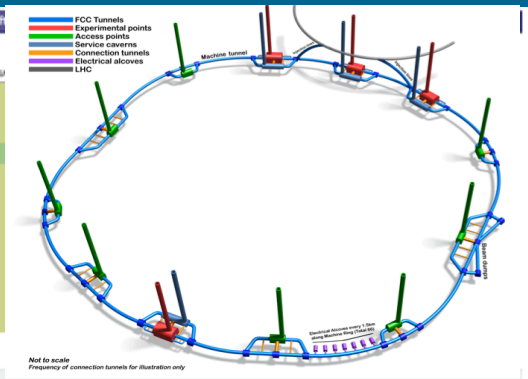
Baseline Layout for Study

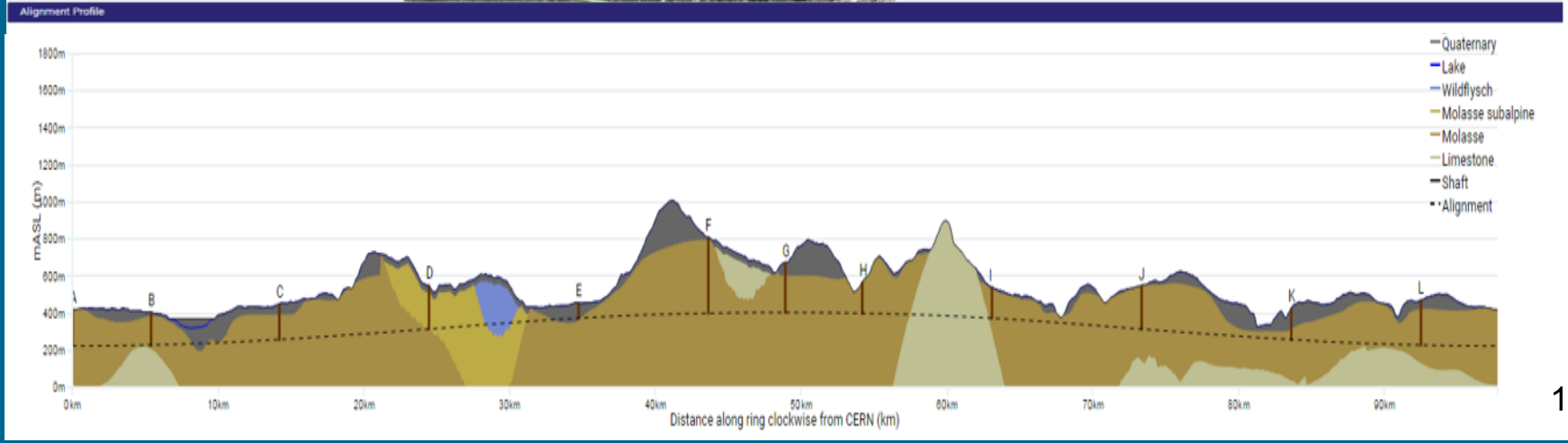


Geology and Civil Engineering studies
Implementation of the 100 km tunnel

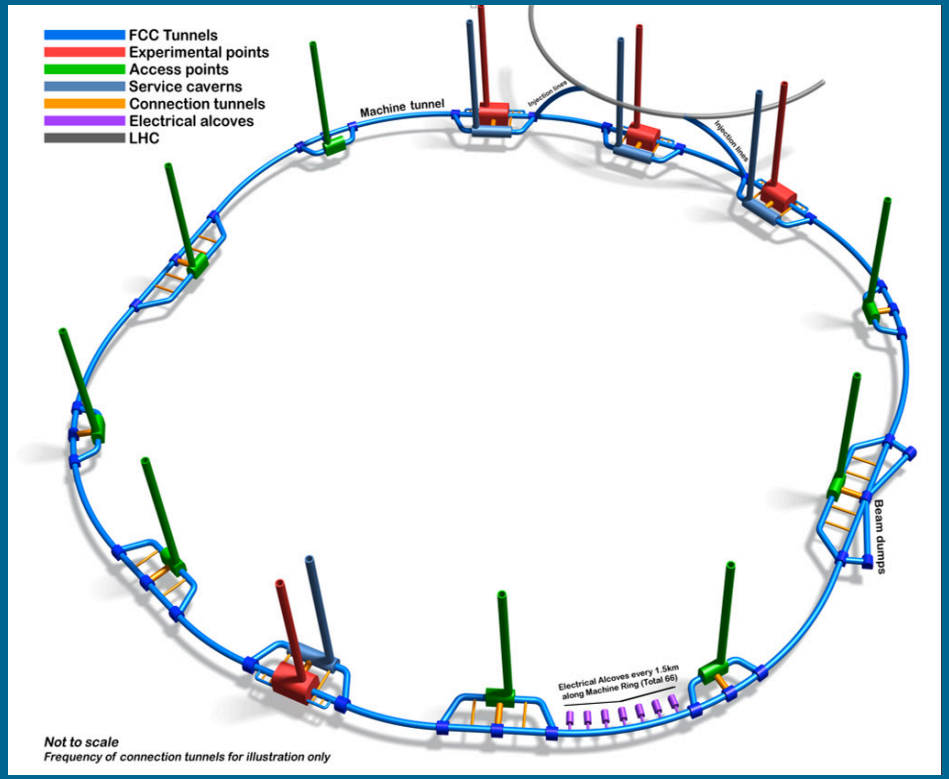








Future Circular Collider - Tunnel Layout, Τεχνικά Χαρακτηριστικά



100 km tunnel - 6 m inner diameter

4 large experimental caverns

8 service caverns

12 x 4 vertical shafts

2 transfer tunnels (10 km)

2 beam dump tunnels (4 km)

Different technological domains covered by the FCC study:

- Designs for future colliders.

- Tunnel Infrastructure in Geneva area.

- Technologies pushed in dedicated R&D programs.

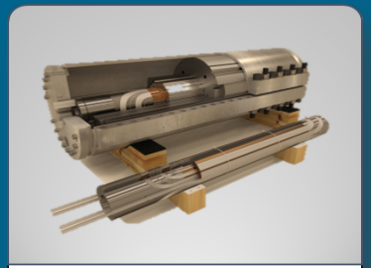
- Discovery areas.

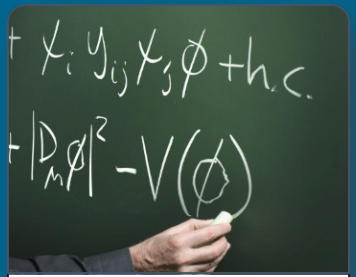
- Design of new detectors.

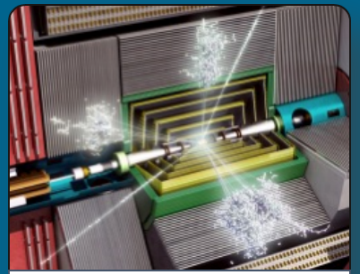
- Overall cost models.

Collider Designs


Infrastructures


R&D Programs

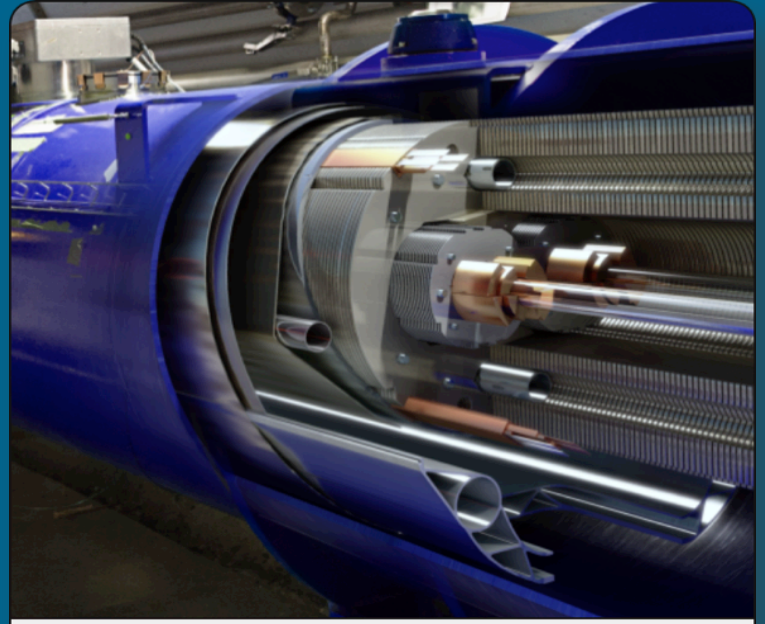

Physics Cases


Experiments

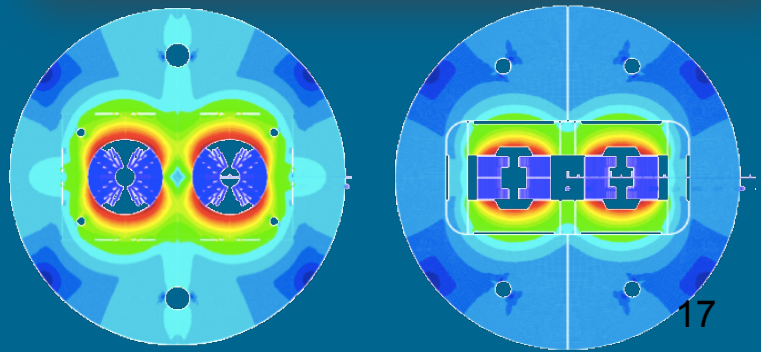
Cost Estimates

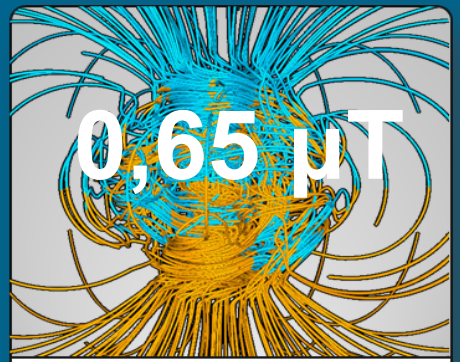
FCC high-field magnets

- FCC requires 16 T magnets
- Design with sufficient aperture (50 mm)
- Meet operation requirements
  - margins,
  - field quality and stability,
  - cycled operation,
  - equipment protection,
  - reliability and maintenance



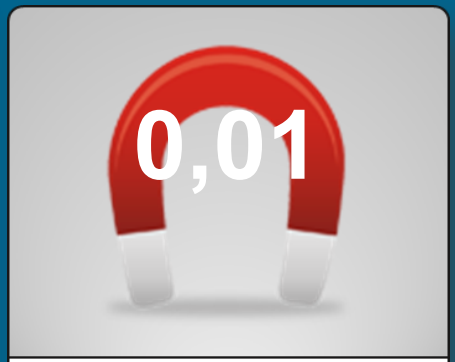
Cut through accelerator magnet





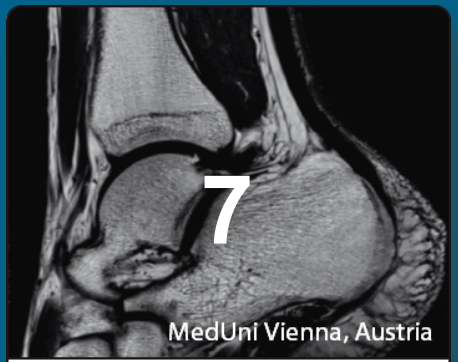
Earth Magnetic Field

Magnetic Button

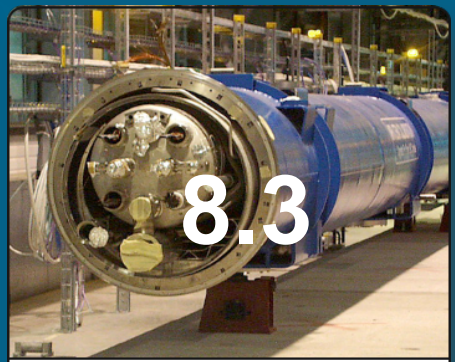


Iron Magnet

M R I



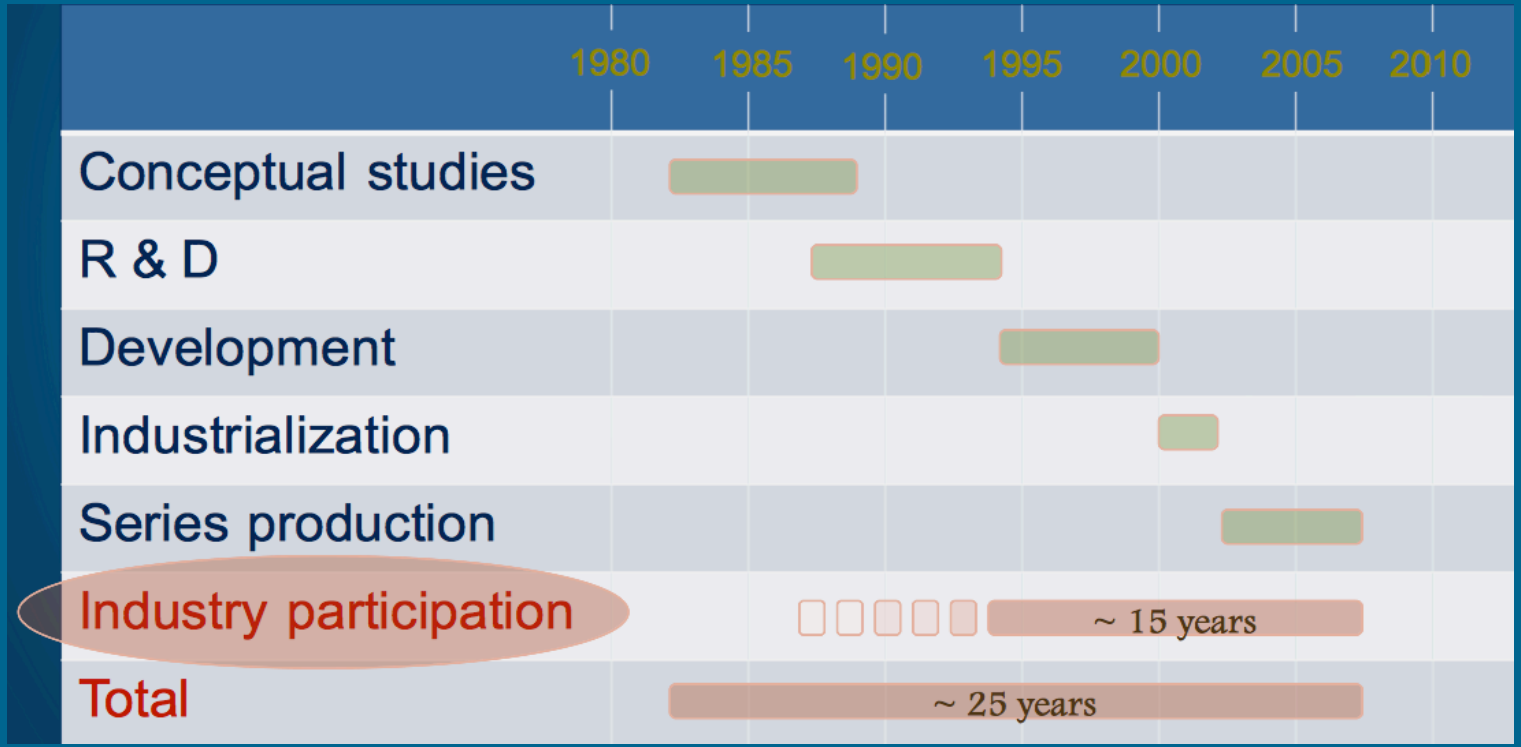
Ultra high-field MRI



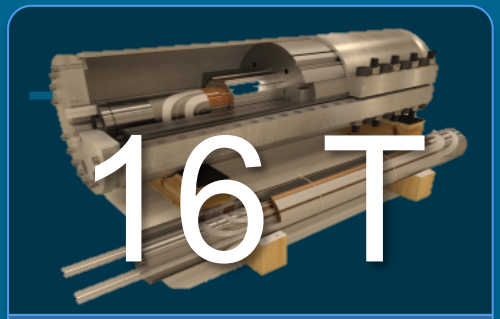
LHC Dipole Magnet

Time Indicator Superconducting magnets

LHC magnets – from concept to series production



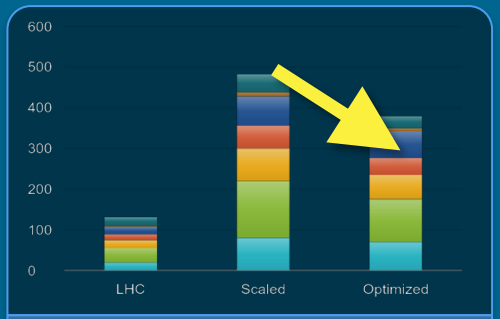
Push Novel Technologies



High-field Magnets

Novel Materials and Processes

Large-scale Cryogenics

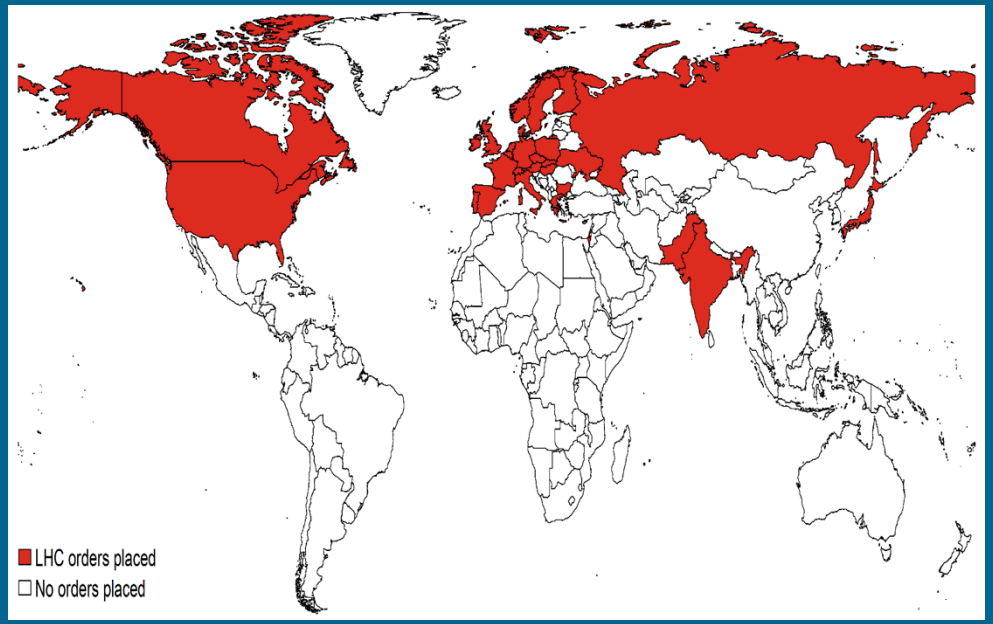


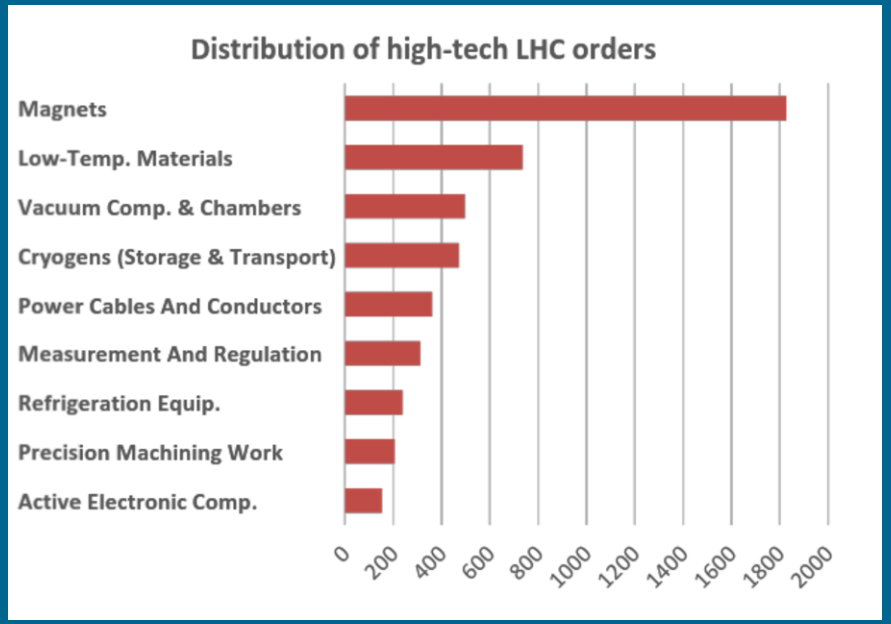
Power Efficiency

Reliability & Availability

Global Scale Computing

- Approx. 1400 firms located in 30 countries have collaborated with CERN for the LHC project during 1995-2008



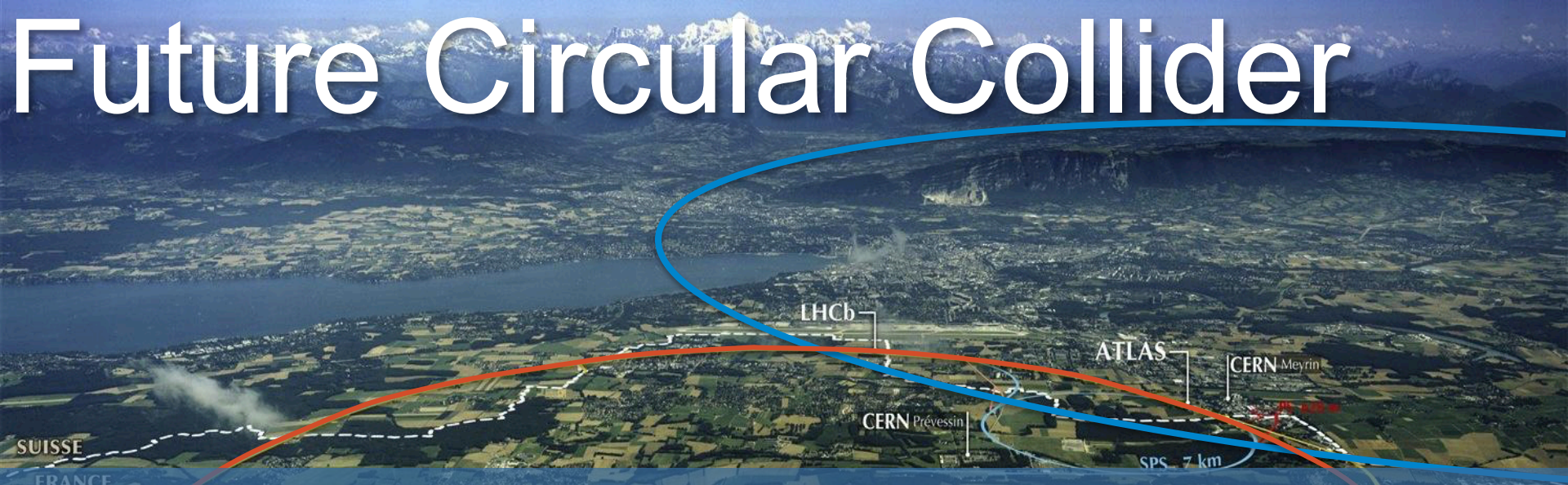


FCC collaboration status

- 116 research centers & universities
- European Commission
- 32 countries
- 22 companies

- Geographically balanced
- Topically complementary
- Promote ownership among Participants

Future Circular Collider

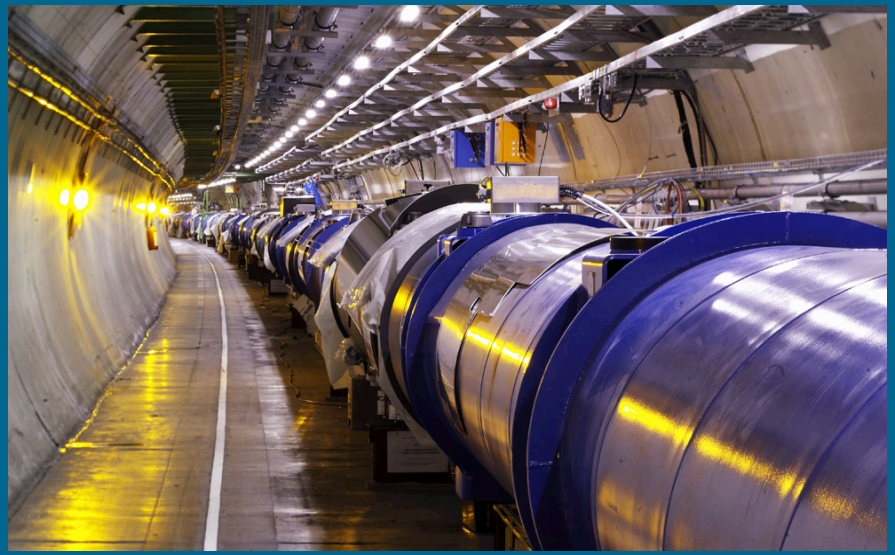


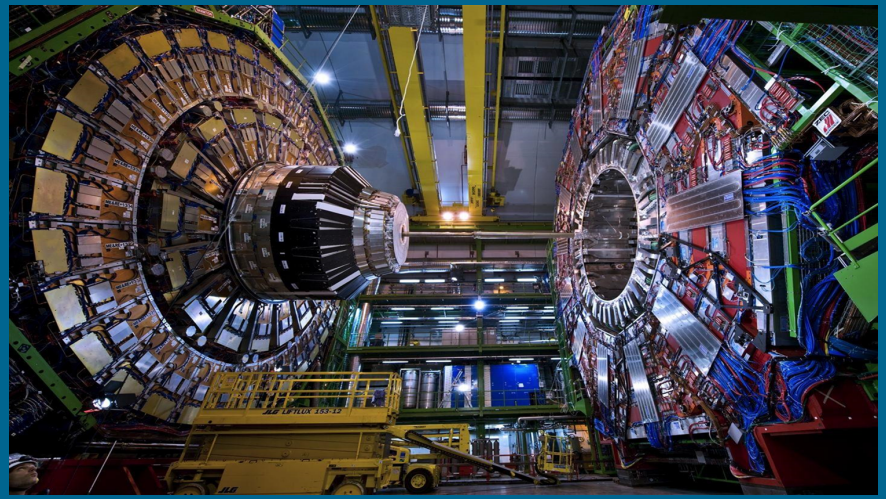
Large scale research and technical infrastructure
conceptual design study 2014 – 2019.

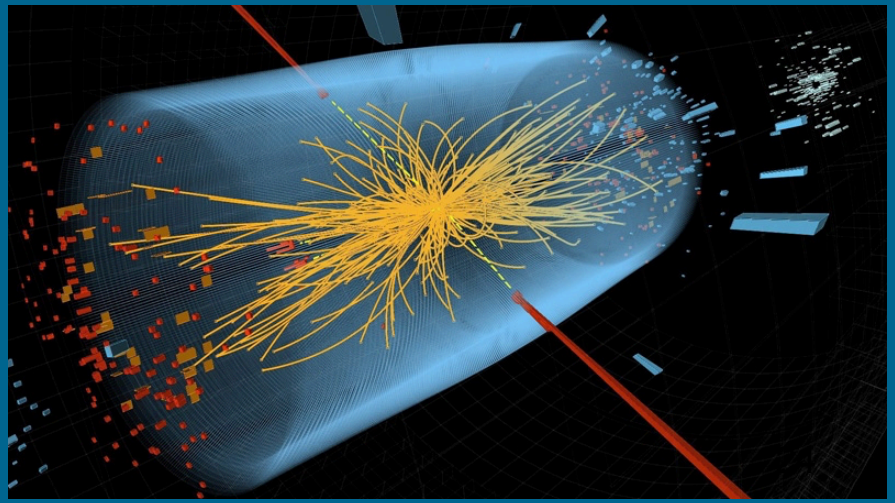
Driven by international contributions
Establish long-term liaisons with industry.

Strengthen long-term attractiveness of Europe
as leading large-scale research location


LHCb
ATLAS
CERN
SUISSE
FRANCE
CMS
LHC
ALICE
LHC 27 km



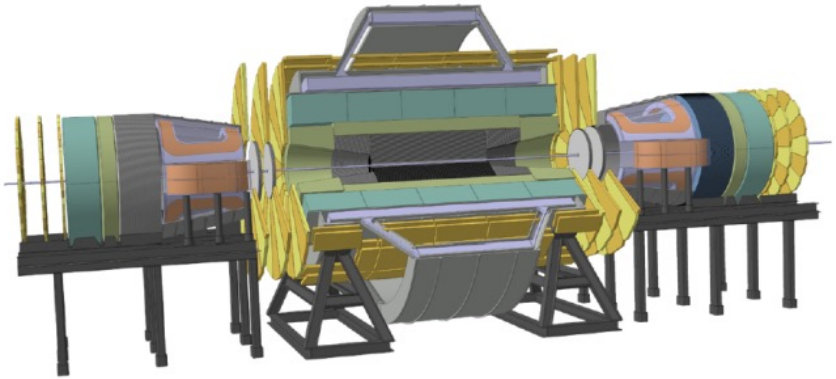




FCC-hh detector – new reference design

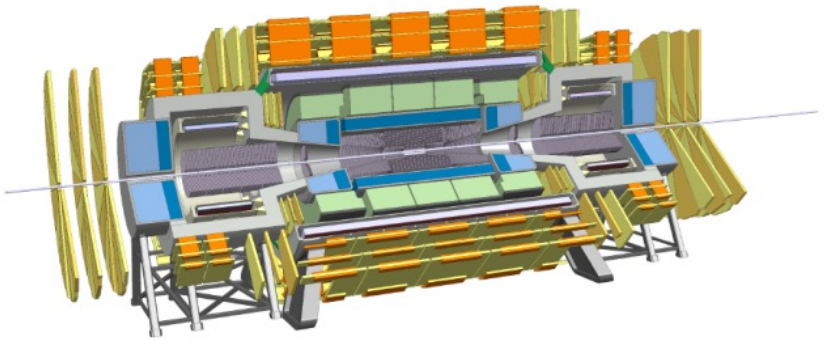
6T, 12m bore solenoid, 10Tm dipoles, shielding coil

→ 65 GJ Stored Energy
→ 28m Diameter
→ >30m shaft
→ Multi Billion project

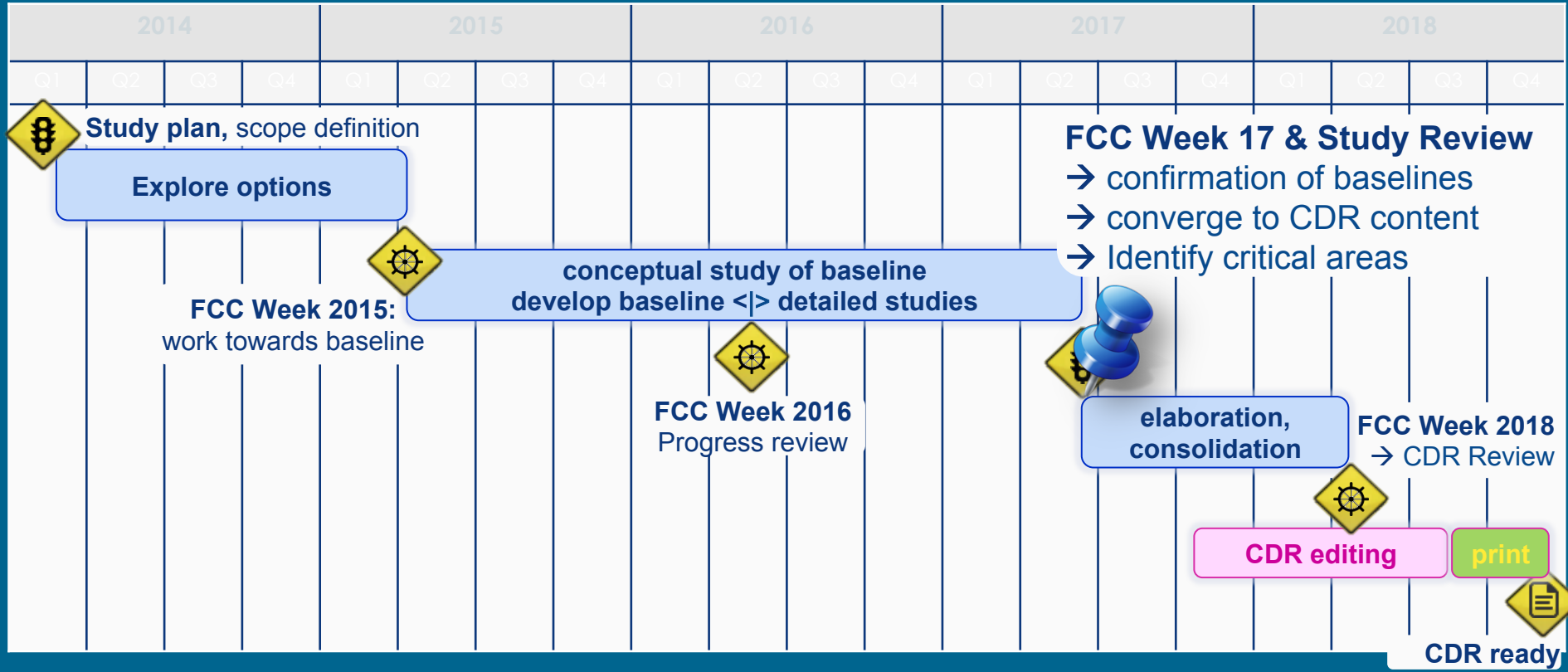


4T, 10m bore solenoid, 4T forward solenoids , no shielding coil

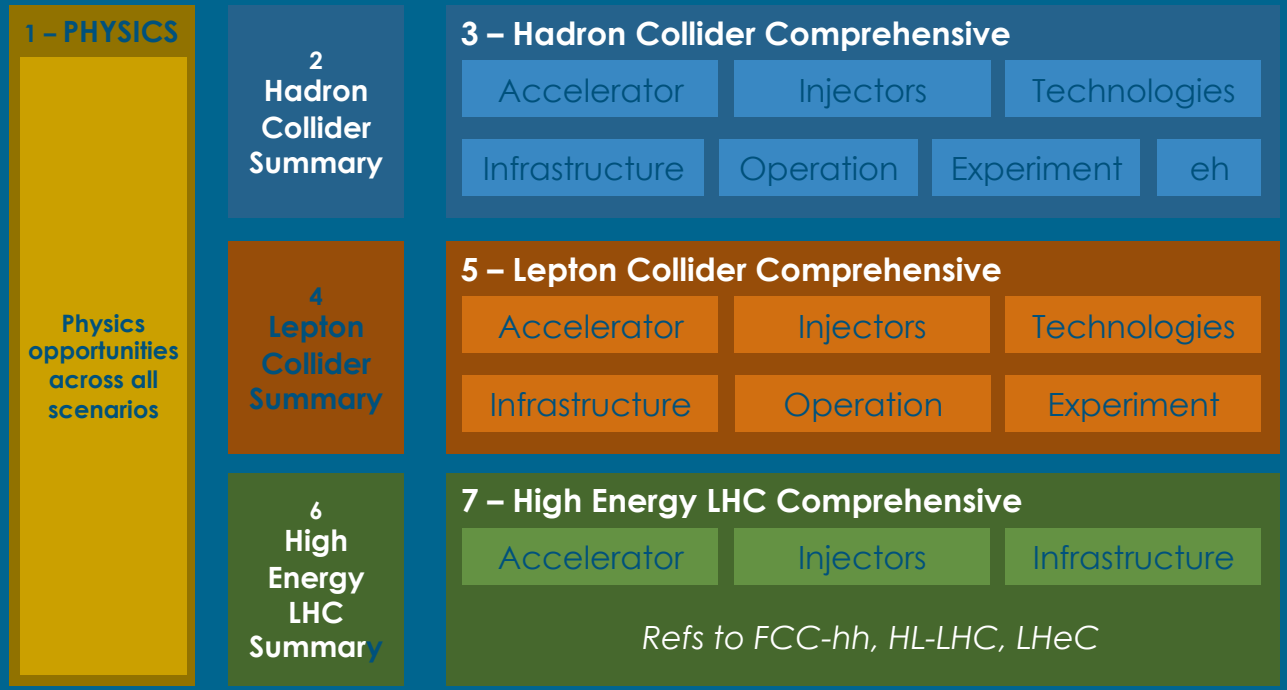
→ 14 GJ Stored Energy
→ Rotational symmetry for tracking !
→ 20m Diameter (≈ ATLAS)
→ 15m shaft
→ ≈ 1 Billion project



CDR Study Timeline



Conceptual Design Report



- **Required for end 2018, as input for European Strategy Update**
- **Common physics summary volume**
- **Three detailed volumes FCChh, FCCee, HE-LHC**
- **Three summary volumes FCChh, FCCee, HE-LHC**

FCC Advisory Committee

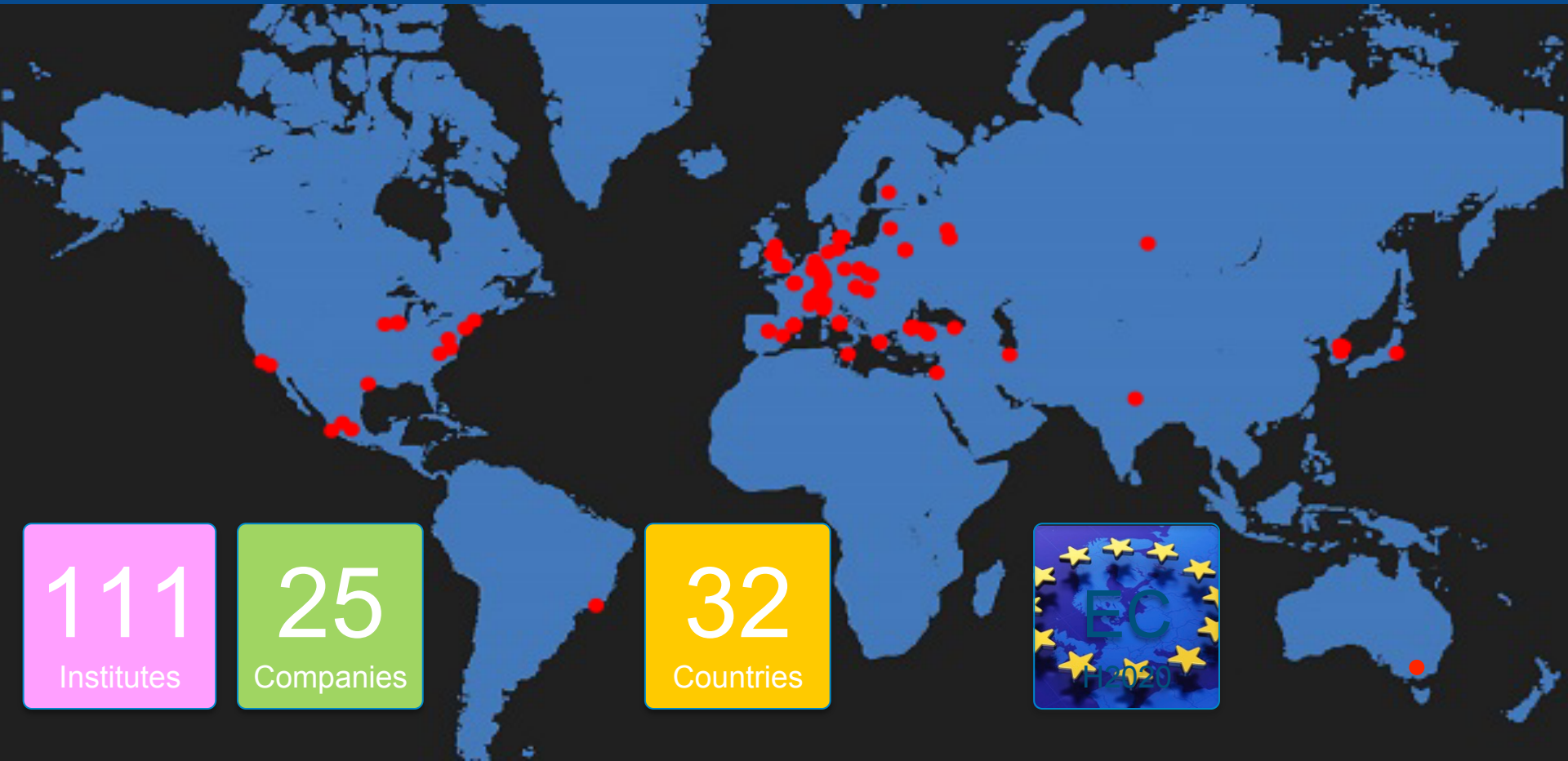
- IAC composition to cover all study areas, 17 members
- Important role as expert review committee for study and CDR preparation

	FCC International Advisory Committee			
Chair	**Dissertori**	Guenther	ETHZ	CH
Physics Experiments	**Diemoz**	Marcella	INFN	IT
	Egorychev	Victor	ITEP	RU
	Herten	Gregor	U. Freiburg	GE
	Quigg	Chris	FNAL	US
	Parker	Andrew	U. Cambridge	UK
Accelerator Design	**Assmann**	Ralph	DESY	GE
	Biscari	Caterina	ALBA-CELLS	ES
	Fischer	Wolfram	BNL	US
	Shiltsev	Vladimir	FNAL	US
Technology and Infrastructure	**Lebrun**	Philippe	JUAS	FR
	Minervini	Joe	MIT	US
	Mosnier	Alban	CEA	FR
	Ross	Marc	SLAC	US
	Seidel	Mike	PSI	CH
	Watson	Tim	ITER	ITER
	Yamamoto	Akira	KEK	JP

Study reviews towards CDR

- FCC week for presentation of information, followed by executive review session to discuss key issues.
- FCC week Berlin & 29/30 June @ CERN.
- FCC week 2018 (9-13 April 2018, Amsterdam) + mid-May @CERN.

Collaboration & Industry Relations



ΕΛΛΗΝΙΚΗ ΣΥΜΜΕΤΟΧΗ

ΣΤΗ ΜΕΣΗ ΚΑΙ ΣΤΗΝ ΑΝΩΤΑΤΗ ΕΚΠΑΙΔΕΥΣΗ ΕΝΑΠΟΚΕΙΤΑΙ Η ΠΡΟΩΘΗΣΗ ΚΑΙ ΕΜΠΝΕΥΣΗ ΤΩΝ ΝΕΩΝ ΕΠΙΣΤΗΜΟΝΩΝ ΣΕ ΤΕΤΟΙΑ ΜΕΛΛΟΝΤΙΚΑ ΠΡΟΓΡΑΜΜΑΤΑ ΠΟΥ ΔΗΜΙΟΥΡΓΟΥΝ ΣΥΝΘΗΚΕΣ:

- ΥΨΗΛΗΣ ΕΚΠΑΙΔΕΥΣΗΣ
- ΠΡΟΗΓΜΕΝΗΣ ΤΕΧΝΟΛΟΓΙΑΣ
- ΑΝΑΒΑΘΜΙΣΗΣ ΤΗΣ ΟΙΚΟΝΟΜΙΑΣ