Future Circular Collider Study

Status and Accelerator R&D Plans

Michael Benedikt

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Outline

- Future Circular Collider Study Scope
- Collaboration Status
- FCC H2020 EuroCirCol DS proposal
- Accelerator R&D Areas
- Conclusions

Scope (i)

A conceptual design study of **options for a future high-energy frontier circular collider** at CERN for the post-LHC era shall be carried out, implementing the request in the 2013 update of the European Strategy for Particle Physics.

Many results of the study will be **site independent**.

The design study shall be **organised on a world-wide international collaboration** basis **under the auspices of the European Committee for Future Accelerators (ECFA)** and shall be available in time for the next update of the European Strategy for Particle Physics, foreseen by 2018.

Slide from R. Heuer, FCC ICB 9.9.14

Scope (ii)

The **main emphasis** of the conceptual design study shall be the **long-term goal of a hadron collider with a centre-of-mass energy of the order of 100 TeV in a new tunnel of 80 - 100 km circumference** for the purposes of studying physics at the highest energies.

The conceptual design study shall **also include a lepton collider and its detectors, as a potential intermediate step** towards realization of the hadron facility. Potential synergies with linear collider detector designs should be considered.

Options for e-p scenarios and their impact on the infrastructure shall be examined at conceptual level.

The study shall include **cost and energy optimisation, industrialisation aspects and provide implementation scenarios, including schedule and cost profiles**.

Slide from R. Heuer, FCC ICB 9.9.14

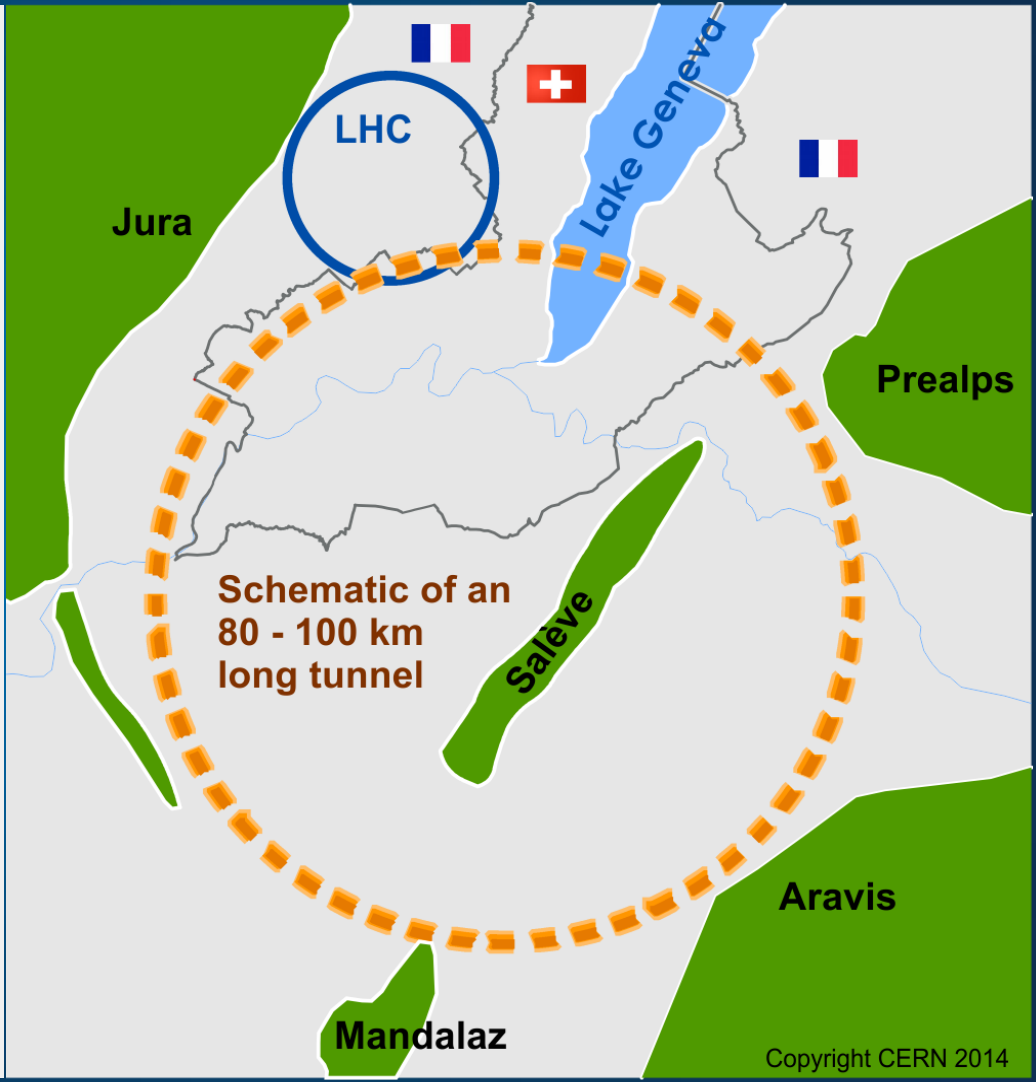
Future Circular Collider Study - SCOPE
CDR and cost review for the next ESU (2018)

Forming an international collaboration to study:

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

- **e^+e^- collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area



Collaboration forming process in 2014

- **FCC kick-off meeting in Geneva**
  - **Inform international community**
  - **Launch discussions on collaboration, scope, etc.**

- **Preparation of legal framework for collaboration**
  - **General Memorandum of Understanding**
  - **Specific Addenda adapted for each contribution**

- **Prepar. meeting for Intern'l Collaboration Board**
  - **9-10 September 2014 at CERN**
  - **Work status, governance structure, organisation**

- **Preparation of FCC Design Study proposal "EuroCirCol" for EC Horizon 2020 DS call**
  - **Submitted to EC on September 2nd 2014**

FCC Kick-Off Meeting
February 2014

Preparation meeting for ICB

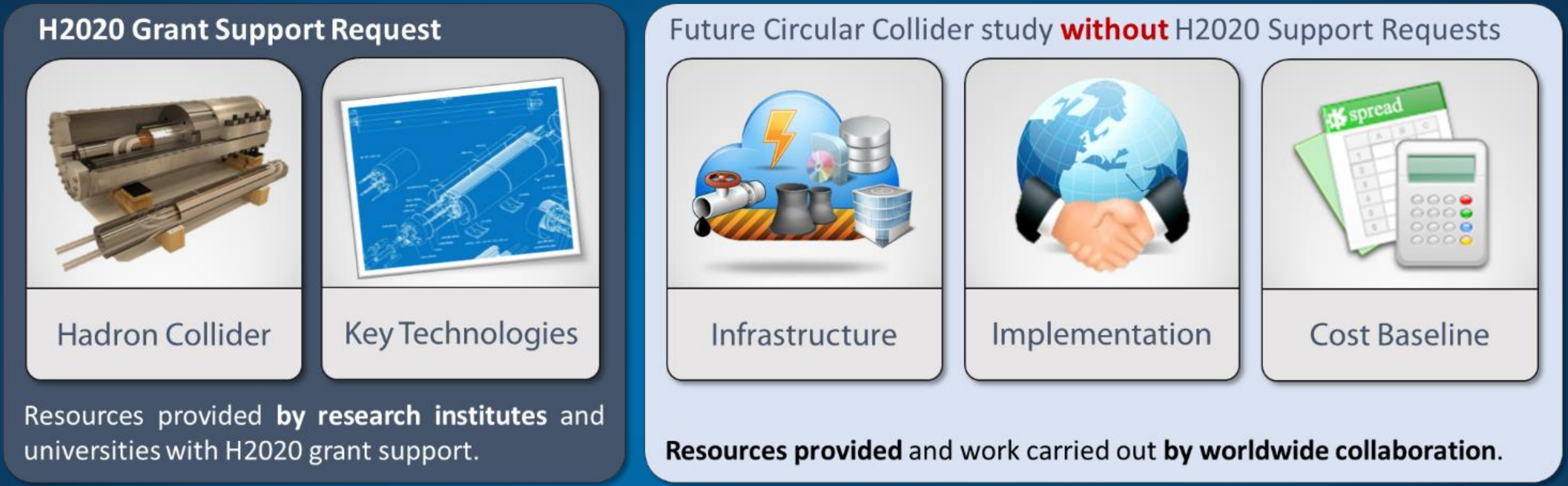
- September 9th and 10th 2014 at CERN
- http://indico.cern.ch/event/333236/
- ~90 participants from ~70 institutes
- Discussion of
  - Study organisation
  - Governance structure
  - Work and collaboration status
  - Presentations of potential contributions by participants
- Prior to ICB meeting appointment of interim chair of FCC collaboration board: Leonid Rivkin.
  - Definitive governance structure foreseen to be confirmed at **FCC yearly workshop, 23rd – 27th March 2015,** Washington DC

MoU Status 8. September 2014

- **20 MoUs signed,** 15 further agreed, pending signatures

- ALBA/CELLS, Spain
- BINP, Russia
- CBPF, Brazil
- CIEMAT, Spain
- Cockcroft Institute, UK
- CSIC/IFIC, Spain
- DESY, Germany
- EPFL, Switzerland
- Hellenic Open U, Greece
- JAI/Oxford, UK
- KEK, Japan
- King's College London, UK
- MEPhI, Russia
- Sapienza/Roma, Italy
- TU Darmstadt, Germany
- TU Tampere, Finland
- U. Geneva, Switzerland
- U. Iowa, USA
- U. C. Santa Barbara, USA
- U Silesia, Poland

EuroCirCol: FCC H2020 DS proposal: Scope



EuroCirCol forms the **heart of the hadron collider design** and the feasibility study of its key technologies, as **suggested also by the SPC.**

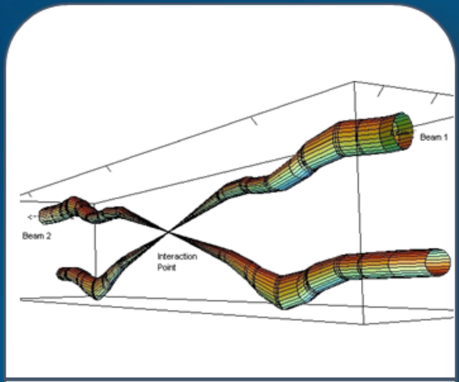
Work includes infrastructure aspects, mode for implementation and cost baseline.

5 Work Packages

CEA

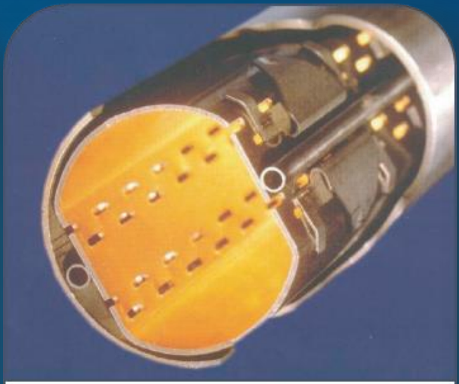
Arc Design

UOXF



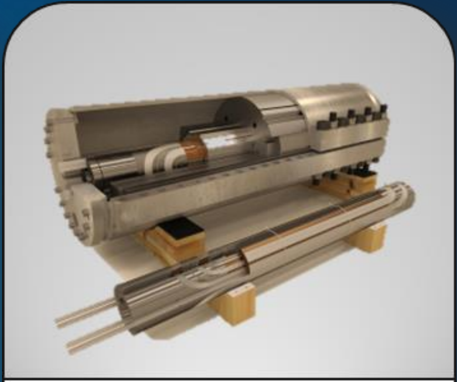
EIR Design

ALBA



Cryo Beam Vacuum

CERN



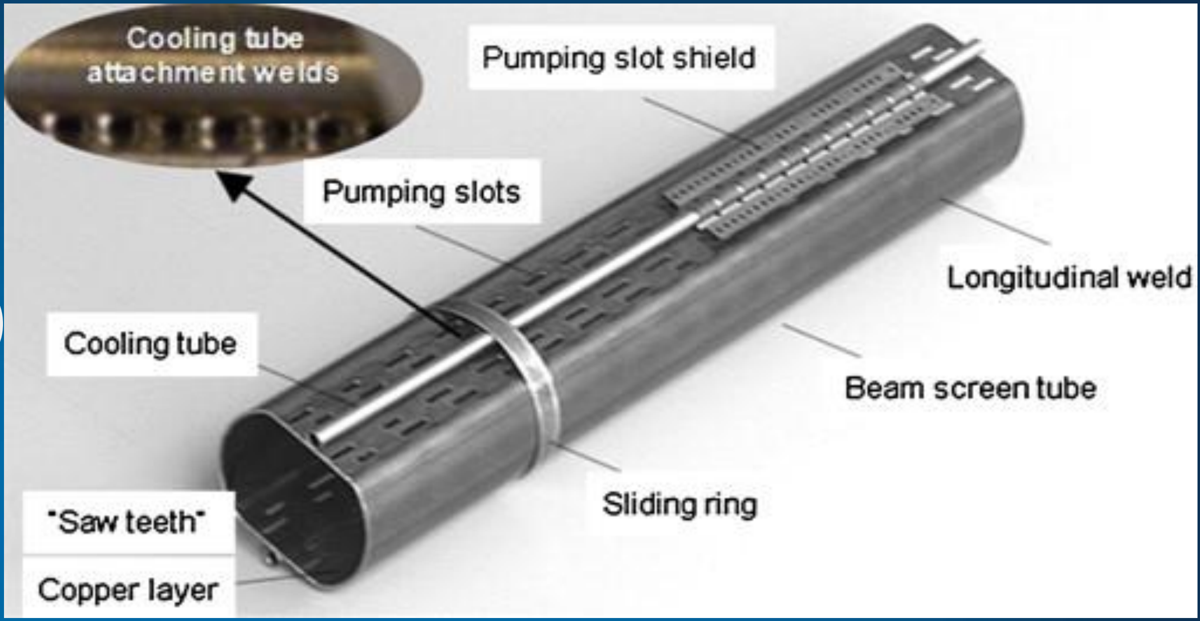
High Field Magnet

Management and Coordination

- Arc Design & Cryo Beam Vacuum + High Field magnets → **Cost optimization**
- Experimental Interaction Region Design → **Performance optimization**

Synchrotron rad. & beam screen

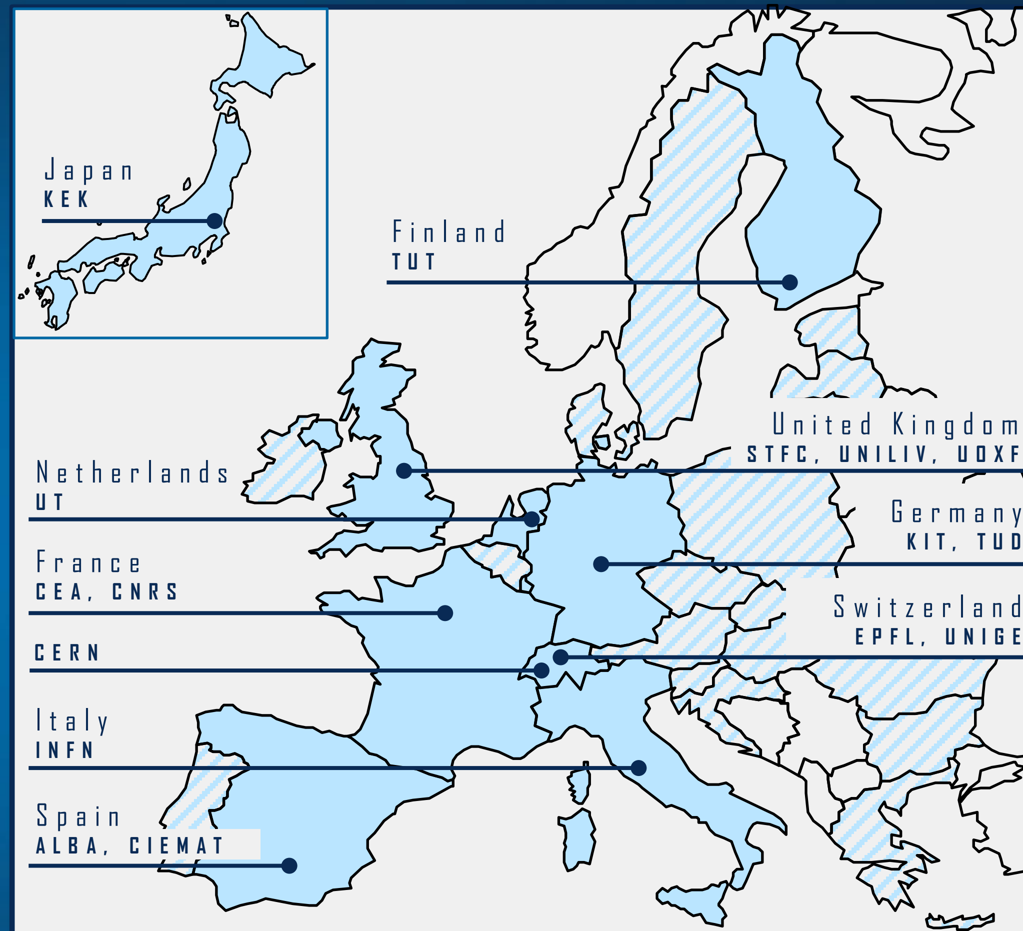
High synchrotron radiation load (SR):
~30 W/m/beam (@16 T)
→ 5 MW total in arcs



- **Beam screen to capture SR and "protect" cold mass**
- **Power mostly extracted at beam screen temperature;**
- **Only minor part going to magnets at 2 – 4 K**
- **Optimisation of BS temperature (~50 K?), space, vacuum, impedance, e-cloud required.**

Consortium & third countries

Short Name	Country
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



EuroCirCol consortium, federating 16 partners, 1 from Japan and 1 IEIO

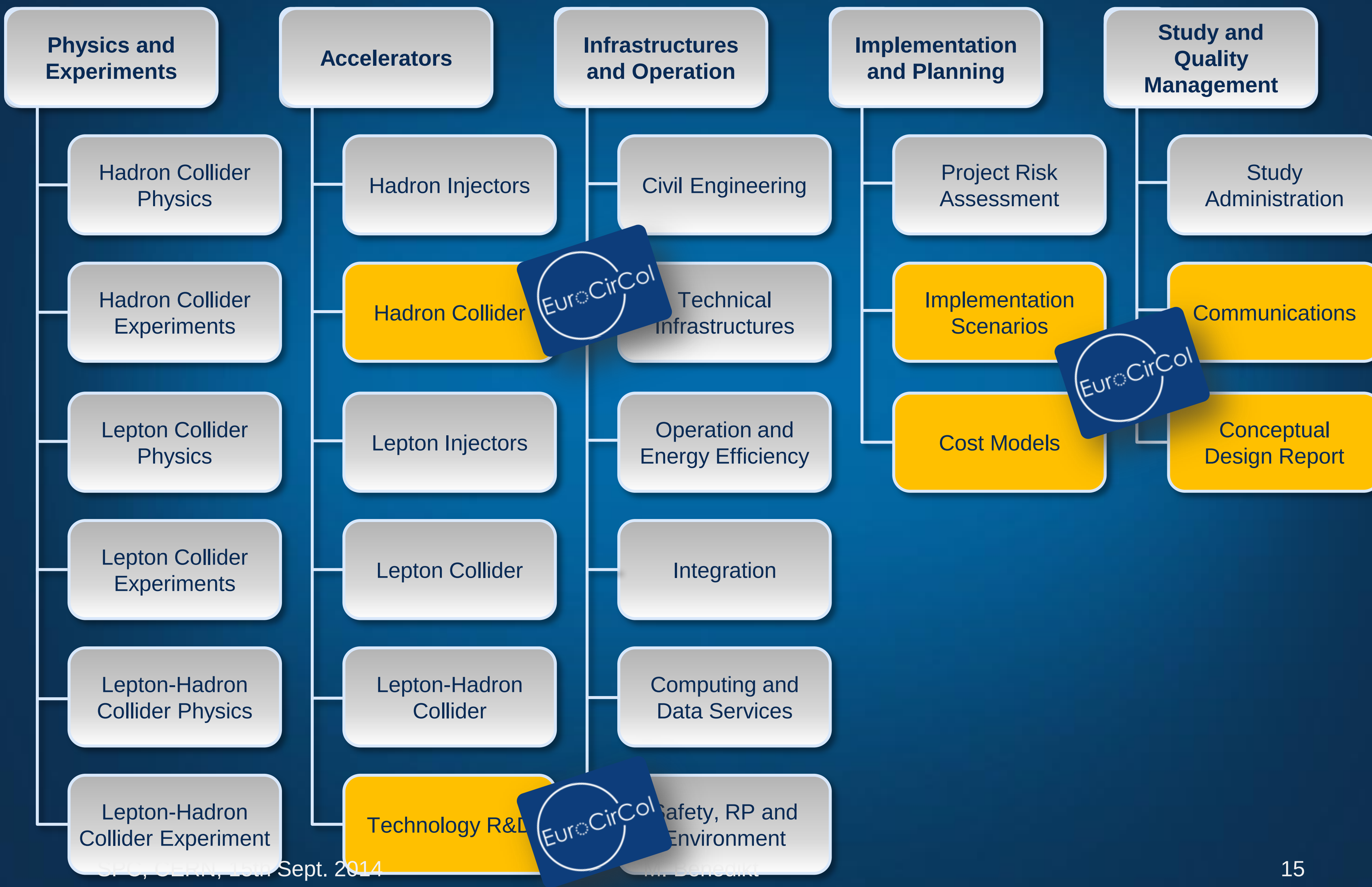
EPFL and **UNIGE** are beneficiaries, not requesting EC funding.
Funding ensured by the Swiss State Secretariat for Research and Education.

KEK joins as beneficiary, not requesting any EC funding and comes up for its committed resources.

Associated US Partners

NHFML /FSU	**Explore potential to double Jc of superconducting Nb_3Sn at 16 T**. Propose improvements in strand architecture and reaction optimization. Material research in **BSCCO-2212** as alternative to A15 and high field magnet technology using HTS materials.
BNL	Participate in the study of **magnet coil design concepts** (common coils, racetrack) and in the engineering for a US-based 16 T model. Develop **YBCO HTS** technology for **high field inserts** for 20 T option or for use in high heat load/radiation cases.
FNAL	Participate in the study of **magnet coil design concepts** (cos-theta, collars) and in the engineering for a US-based 16 T model. Prepare tooling for model construction. Develop **BSCCO-2212 HTS** magnet technology for **high field inserts** for 20 T option.
LBNL	Participate in the study of **magnet coil design concepts** (blocks, canted-cosinus-theta) and in the engineering for a US-based 16 T model. Develop **BSCCO-2212 HTS** magnet technology for **high field inserts**.

EuroCirCol inside FCC



Accelerator Technology R&D

- Excerpt from FCC Work Breakdown Structure

1.6.1	**16 T Superconducting Magnet Program**	**preliminary - institutes to be confirmed**
1.6.1.1	**Accelerator magnet design study for hadron collider**	CIEMAT, UT, KEK, TUT, CEA, INFN
1.6.1.2	**Nb3Sn material R&D**	UT, KEK, UNIGE
1.6.1.3	16 T short model construction	
1.6.1.4	16 T support technologies	
1.6.1.5	Magnet/collider integration studies	
1.6.2	**20 T Superconducting Magnet Program**	
1.6.2.1	5 T HTS insert	
1.6.2.2	HTS Material R&D	
1.6.2.3	20 T magnet design	
1.6.5	**Injector/Booster Magnet Program**	KEK
1.6.5.1	Superferric HTS magnet	
1.6.5.2	Superferric HTS short model	
1.6.5.3	Performance of ramped SC magnets	
1.6.3	**100 MW RF Program**	KEK
1.6.3.1	Cavity design and production technologies	CI
1.6.3.2	Optimisation of cryogenic power consumption	
1.6.3.3	Multi-beam klystron demonstrator	
1.6.3.4	Klystron working point for optimum efficiency	
1.6.3.5	Cryo-module and ancillary systems design	
1.6.4	**Specific Technologies Program**	
1.6.4.1	More efficient, compact and higher capacity helium cryo-plants	
1.6.4.2	Non conventional cryogen mixtures for efficient refrigeration below 100 K	
…	…	

High-field magnet R&D (FCC-hh)

- **Baseline is 16T Nb_3Sn technology for ~100 TeV c.m. in ~100 km**

Develop Nb_3Sn-based 16 T dipole technology (at 4.2 K?),
- conductor developments
- short models with sufficient aperture (40 – 50 mm) and
- accelerator features (margin, field quality, protect-ability, cycled operation).

Goal: 16T short dipole models by 2018/19 (America, Asia, Europe)

- **In parallel HTS development targeting 20 T (option and longer term)**

Goal: Demonstrate HTS/LTS 20 T dipole technology:
- 5 T insert (EuCARD2), ~40 mm aperture and accelerator features
- Outsert of large aperture ~100 mm, (FRESCA2 or other)

- High-field SC magnet R&D for FCC will be a “natural” continuation of HL-LHC developments and ensure continuation of of long-lasting worldwide research efforts and efficient use of past investments

RF R&D plans

- **SC cavity R&D**
  - Large Q_0 at high gradient and acceptable cryogenic power!
  - E.g.: Recent promising results at 4 K with Nb_3Sn coating on Nb at Cornell, $800\ ℃ \div 1400\ ℃$ heat treatment at JLAB, beneficial effect of impurities observed at FNAL.
  - **Relevant for many other accelerator applications**
- **High efficiency RF power generation from grid to beam**
  - Amplifier technologies
  - Klystron efficiencies beyond 65%, alternative RF sources as Solid State Power Amplifier or multi-beam IOT, **Relevant for all high power accelerators, intensity frontier**
- **Overall RF system reliability**

R&D Goal is optimization of overall system efficiency and cost. Power source efficiency, low loss high gradient SC cavities, operation temperature vs. cryogenic load, total system cost and dimension.

Cryogenics related R&D

- **Both machine options hh and ee have large cryogenic cooling requirements.**
- **Optimizations of overall system concept and operating temperatures is of key importance.**

- **Large size helium cryogenic plants**
  - Efficiency
  - Size and compactness
  - **Higher capacity (factor 2-4 w.r.t. LHC installations)**

- **Non conventional cryogen mixtures**
  - Temperature range of interest ~30 - 100 K
  - More efficient refrigeration
  - **Nelium (Ne-He) as potential candidate**

Study Time Line

Explore options, now – spring 2015:

- Investigate **different options** in all technical areas, **taking a broad view**
- Deliverables: description/comparison of options with relative merits/cost, **understand relative impact of options on overall study/project**
- FCC workshop to converge to common baseline with small number of options
- **1st Yearly FCC Workshop 23 – 27 March 2015, Washington DC**
- Followed by review ~2 months later, begin June 2015

Summary

- Good progress is made in forming an International FCC collaboration.
- An H2020 DS proposal, focused on the FCC hadron collider design has been submitted to EC.
- Main technology R&D areas have been identified and a work plan is being established with potential partners.