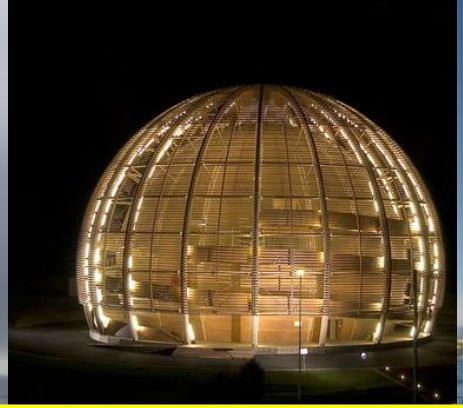
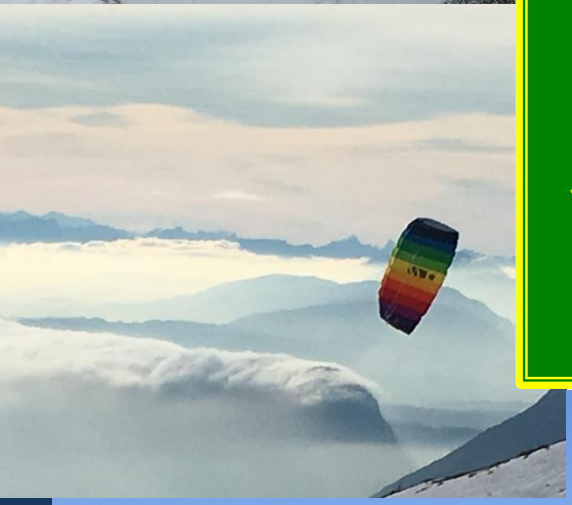
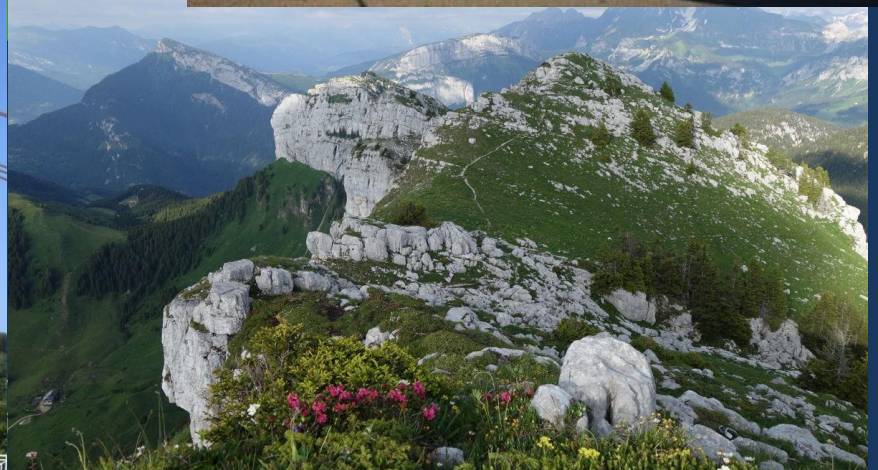




# HAPPY NEW YEAR 2019 !!!

# YEAR OF THE FCC !!!



# **Welcome** to the XIth FCC-ee **Work**shop*):

# THEORY AND EXPERIMENTS

*) **Work**: 107 (registered) participants for ~100 presentations

Organization: **congratulations and many thanks** to
-- J. Gluza, M. McCullough, C. Grojean + … (theory)
-- M. Dam, F. Bedeschi, W. Riegler and P. Azzi (experiments)
-- J. Hadre and N. Perrin

and many others

# We have gone a long way!

**2010-11-12 : ideas, wishes, basic concepts, (VHE-LHC, LEP3, TLEP), Higgs discovery**

**2013 ESPP2013 wants «ambitious post-LHC accelerator projet »**

**2014 Kick-off meeting**

**2018 ESPP contributions and CDR submitted**

➔ **FCC can be done! Starting with the e+ e- collider.**

**2019➔ Start of a new time towards realization**

**2019 FCC CDR prsentation 4-5 March at CERN;**
**Plenary Meeting (ESPP) Granada 13-17 May**
**FCC General meeting in 24-28 June in Brussels** https://indico.cern.ch/event/727555

# FCC Study Scope and Structure

## Future Circular Colliders - Conceptual Design Study for next European Strategy Update (2018)

### Infrastructure

tunnels, surface buildings, transport (access roads), civil engineering, cooling ventilation, electricity, cryogenics, communication & IT, fabrication and installation processes, maintenance, environmental impact and monitoring,

### Hadron injectors

Beam optics and dynamics
Functional specs
Performance specs
Critical technical systems
Operation concept

### Hadron collider

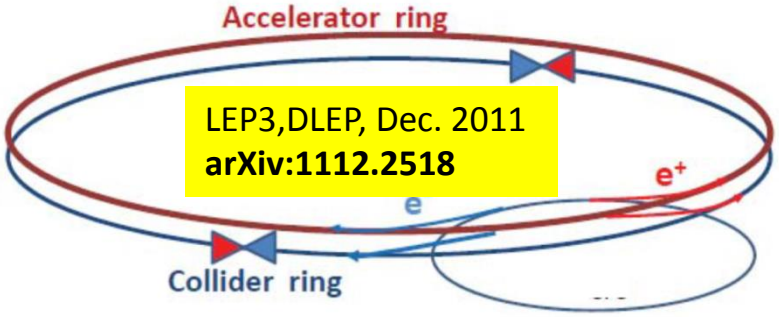
Optics and beam dynamics
Functional specifications
Performance specs
Critical technical systems
Related R+D programs
*HE-LHC comparison*
Operation concept
Detector concept
Physics requirements

### e+ e- collider

Optics and beam dynamics
Functional specifications
Performance specs
Critical technical systems
Related R+D programs
Injector (Booster)
Operation concept
Detector concept
Physics requirements

**e- p option:** Physics, Integration, additional requirements

# FCC Kick-off Meeting

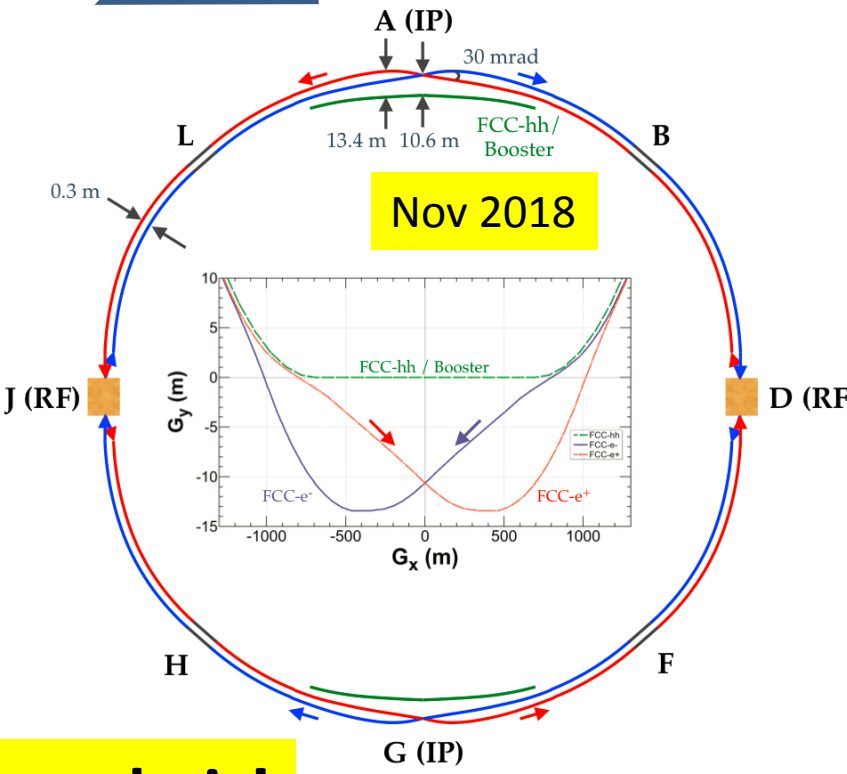



**TLEP: arXiv:1208.0504**
**TLEP physics case: arXiv:1308.6176**

**Design Study**

**FCC-ee CDR: baseline design choices**

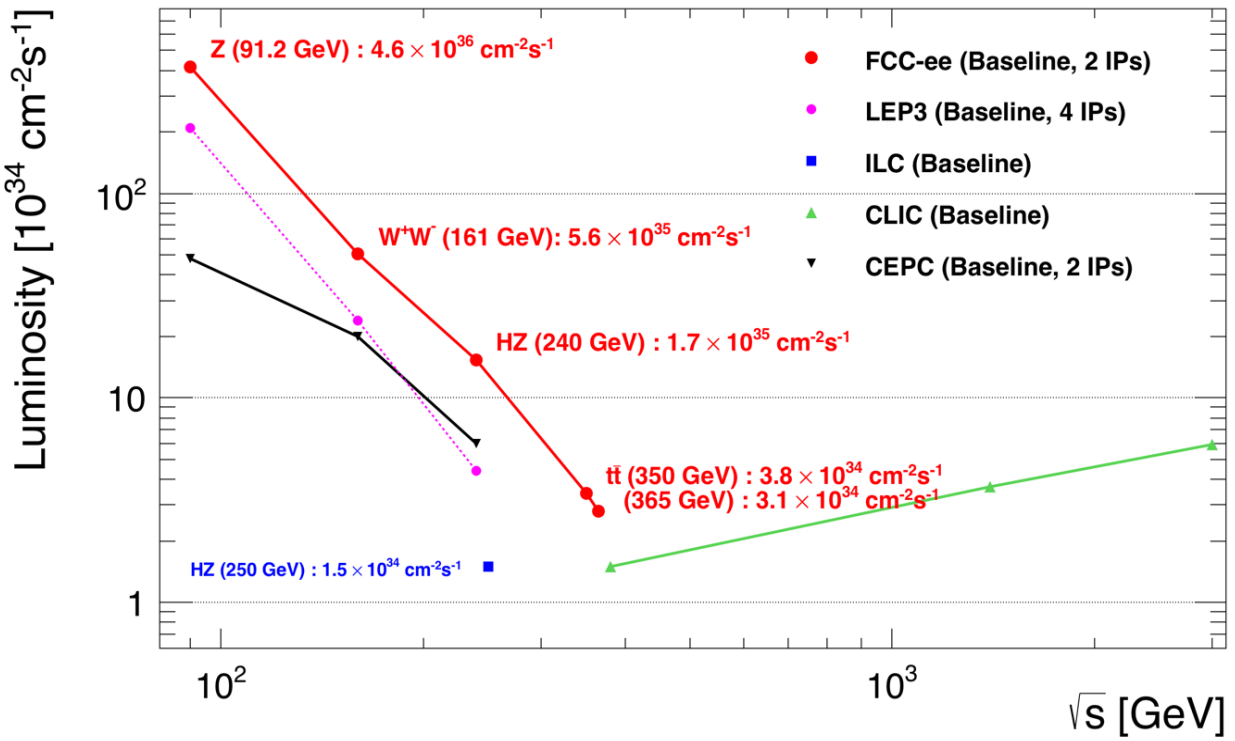
-- **Follows footprint of FCC-hh, except around IPs**
-- **~100 km to reach $\bar{t}t$ production**
-- **Double ring (e+, e-) collider, multi-bunch**
-- **Top-up injection for high efficiency**
→ high-energy injector in collider tunnel
-- **Crab-waist optics** to maximize luminosity @Z, W, H
30 mrad crossing angle
-- **Asymmetric interaction region layout and optics**
Limits synchrotron radiation in the detector
-- **Two interaction points (IP) in A and G**
***4 IPs to be studied -- significant layout changes.***
-- **50 MW/beam Synchrotron Radiation power :**
at all energies
-- **Continuous $E_{CM}$ calibration at Z and W (100 keV)**
based on resonant transverse depolarization
polarimeter, wigglers, RF kicker
Only one RF section at these energies.




**We can do it!**

# FCC-ee

Z WW HZ tt




**Event statistics :**

| | | | | | $E_{CM}$ errors: |
|---|---|---|---|---|---|
| Z peak | $E_{cm}$ : 91 GeV | $5\ 10^{12}$ | e+e- → Z | LEP x $10^5$ | 100 keV |
| WW threshold | $E_{cm}$ : 161 GeV | $10^8$ | e+e- → WW | LEP x $2.10^3$ | 300 keV |
| ZH threshold | $E_{cm}$ : 240 GeV | $10^6$ | e+e- → ZH | Never done | 1 MeV |
| tt threshold | $E_{cm}$ : 350 GeV | $10^6$ | e+e- → tt | Never done | 2 MeV |

**Great energy range for the heavy particles of the Standard Model.**

# FCC contributions to the Strategy

Dear Colleagues,

We are very pleased to share with you the FCC input, which we submitted to the European Particle Physics Update 2018 yesterday evening.
The brief documents highlighting the FCC-ee, FCC-hh, HE-LHC and the integral FCC programme can be accessed at https://fcc-cdr.web.cern.ch
On 15 January 2019 this site will also contain the links to the preprint versions of the FCC Conceptual Design Reports. Four volumes have been submitted for open access publication to the European Physics Journal C and Special Topics editions.
The site https://fcc-cdr.web.cern.ch will serve as a collection of relevant FCC design reports and associated documents also in the future. (…)
A press release will follow on the 15th of January after the official submission of the FCC CDR.
In the meantime, please inform us fcc.communications@cern.ch
regarding any media queries in order to coordinate all communication with CERN's Press Office.
We would like to thank you all for your continued commitment to this study and wish you all a peaceful Christmas time and a Happy New Year!
**Michael Benedikt**
**Frank Zimmermann**

dear FCC-ee design study members and supporters,

we are pleased to inform you that the FCC-study 10 page documents have been submitted to the European Strategy
You can find them here https://fcc-cdr.web.cern.ch/

or the individual pdfs:

https://fcc-cdr.web.cern.ch/reports/EPPSU18_FCCint.pdf
https://fcc-cdr.web.cern.ch/reports/EPPSU18_FCCee.pdf
https://fcc-cdr.web.cern.ch/reports/EPPSU18_FCChh.pdf

**NB if you have not received at least one of these messages** you should register to the FCC design study for news, for instance by going to the FCC-ee web site

# 1 Scientific Context

Particle physics has arrived at an important moment of its history. The discovery of the Higgs boson, with a mass of 125 GeV, completes the matrix of particles and interactions that has constituted the "Standard Model" for several decades. This model is a consistent and predictive theory, which has so far proven successful at describing all phenomena accessible to collider experiments. On the other hand, **several experimental facts require the extension of the Standard Model** and **explanations are needed for observations** such as the abundance of matter over antimatter, the striking evidence for dark matter and the non-zero neutrino masses. Theoretical issues that need to be addressed include the hierarchy problem, the neutrality of the Universe, the stability of the Higgs boson mass upon quantum corrections and the strong CP problem.

# Is it the end?

Certainly not!

-- Dark matter

-- Baryon Asymmetry in Universe

-- Neutrino masses

are experimental proofs that there is more to understand.

**We must continue our quest**

**HOW?**

**Direct observation of new particles** (but not only!)

**New phenomena** (Neutral currents, CP violation, neutrino oscillations…)

**Deviations from precise predictions**

(ref. Uranus to Neptune, top and Higgs preds from LEP/SLC/Tevatron/B factories, g-2, etc…)

## 5 Challenges

The ultra-high-luminosity energy-frontier circular lepton collider entails **only a limited set of uncertainties** that could adversely impact the project implementation. They **can all be addressed through a well-focused R&D** programme **and with an early start of the project preparatory phase**. Collaboration with and commitments by the host states are of prime importance for the development of the administrative and procedural frameworks and to prepare the project. The greatest remaining challenge is the creation of a world-wide consortium of scientific contributors who reliably commit resources to the development and preparation of the FCC-ee science project from 2020 onwards.

# Theoretical challenges

FCC-ee proposes a HUGE step in statistical precision w.r.t. LEP/SLC/Tevatron/LHC
(up to factor 400 sqrt(N) improvement)
Also rare processes at the level of $10^{-12}$ of Z decays ($10^{-8}$ for W, $10^{-6}$ for H and top)
→ need to know rare SM processes at that kind of level!

Experiment (i.e. accelerator physics + experimental physics) will work hard to make sure this is matched by experimental systematics and experimental backgrounds

**This is a huge challenge for the theoretical community!**

QED
QCD
EW
Multi-loop calculations

**THIS IS EXPLICITELY INSCRIBED IN THE ESPP SUBMISSIONS AS CRITICAL CHALLENGE**

| | | |
|---|---|---|
| Insufficient level of theoretical precision and accuracy. | Full exploitation of machine's capabilities depends on accurate theoretical predictions of SM phenomena at levels where higher-order contributions become significant. | Set up an international collaboration, leveraging existing world-wide HEP computing infrastructures, to develop the tools and to carry out the necessary computations. This effort is assumed to require substantial committed engagement of personnel by the collaborating institutes during the design, construction and operation phases. |

# Experimental Challenges

We have demonstrated that e+e- experimentation on the FCC-ee can be done.
Designs were dominated by those inherited from LEP and ILC/CLIC (~$10^6$ event statistics)

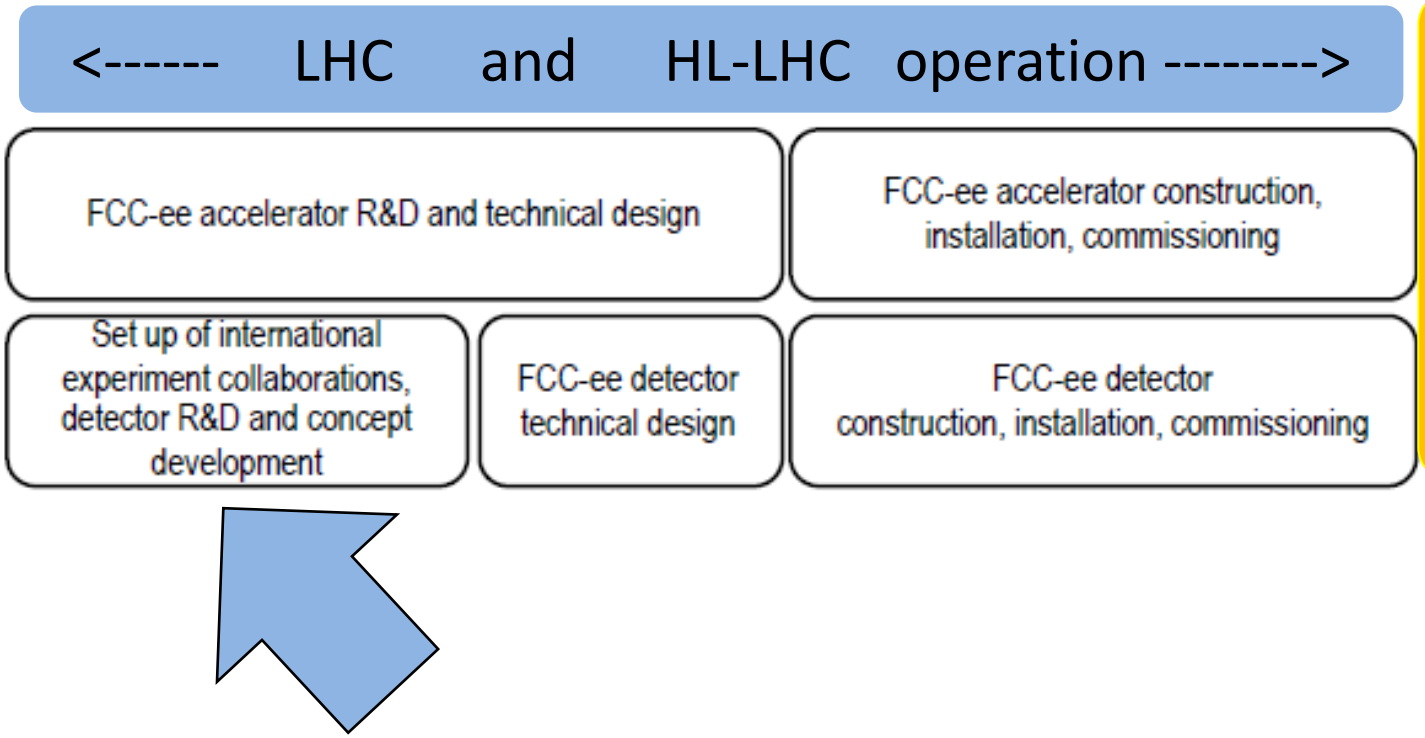
-- however there remains considerable challenges matching the design with the precision and sensitivity goals

-- some very rare (or precise) physics might require dedicated designs and associated R&D

-- considerable progress is being made for HL-LHC upgrade and for very sensitive experiments (e.g. MEG, mu3e) from which we should learn/benefit

**Optimizing the detectors for FCC-ee requires leveraging**
**ideas, compentence and creativity of the whole experimental community**
**need tools and software support, → simulations (full, fast, clever)**
**→ start moving to the next step**

**ESPP 2020**




**Start exploring this step this week**