# 1st FCC Physics Workshop https://indico.cern.ch/event/550509/

16 Jan 2017, 09:00 → 20 Jan 2017, 18:00 Europe/Zurich

222-R-001 - Filtration Plant (CERN)

Alain Blondel (Universite de Geneve (CH)) ,
Christophe Grojean (DESY (Hamburg) and ICREA/IFAE (Barcelona)) ,
Matthew Philip Mccullough (CERN) , Max Klein (University of Liverpool (GB)) ,
Michelangelo Mangano (CERN) , Monica D'Onofrio (University of Liverpool (GB)) ,
Patrick Janot (CERN) , Patrizia Azzi (INFN Padova (IT)) , Werner Riegler (CERN)

Description Topics:

- Higgs
- QCD
- EW precision measurements
- Top and flavour
- BSM searches
- Relation with cosmology: DM and neutrino mass probes
- Experimental opportunities at the FCC and novel techniques
- Physics with Heavy Ion collisions
- Physics at beam dumps, injectors, or forward region detectors

**All sessions will be plenary, with an emphasis on the synergy and complementarity of the different components of the programme (ee, hh and eh).**

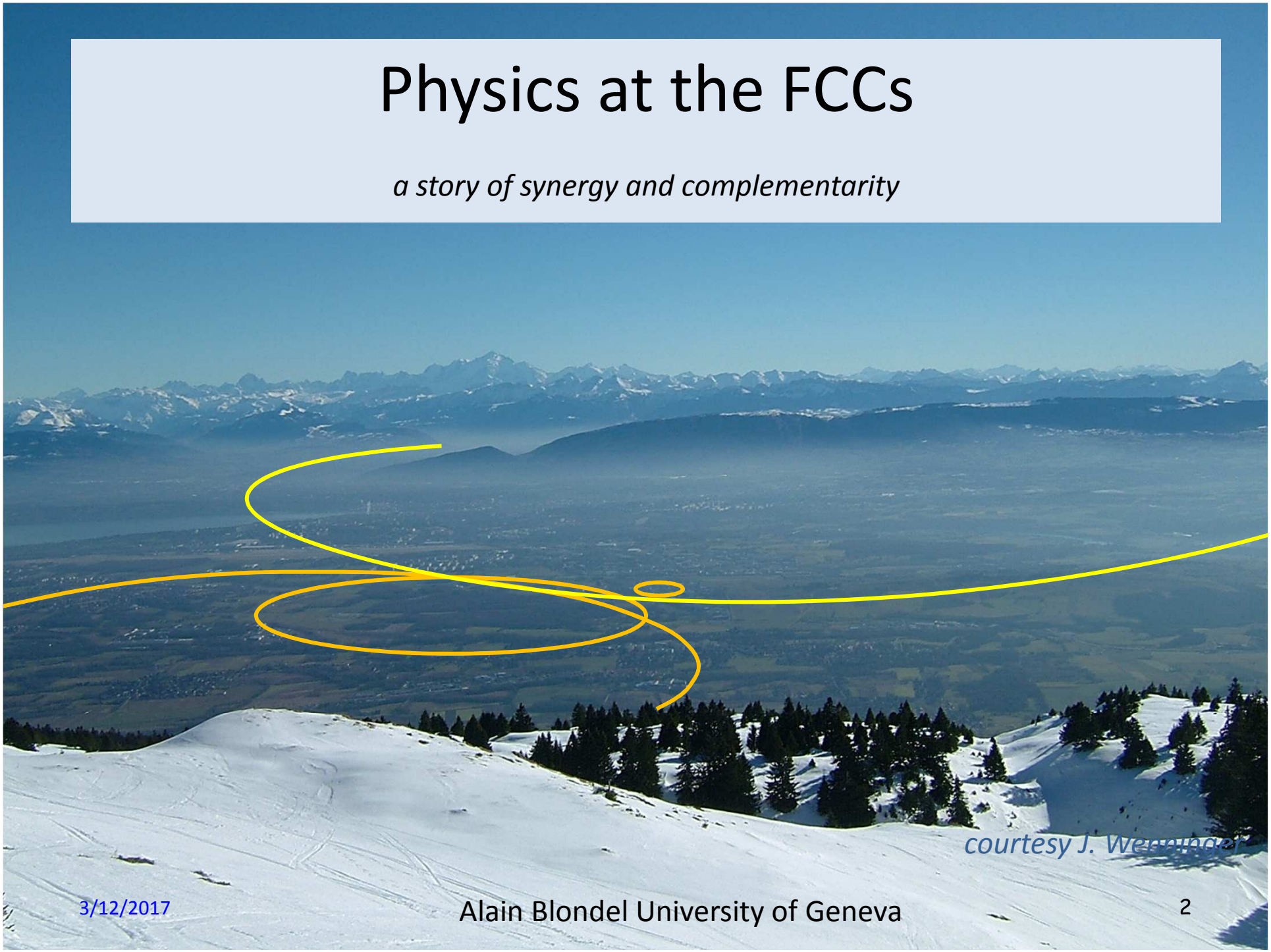
## Participant List

199 participants (registered + ~25% )

6 Swiss participants registered (+ >= 2 not registered… )

# Physics at the FCCs

*a story of synergy and complementarity*



# SYNERGY

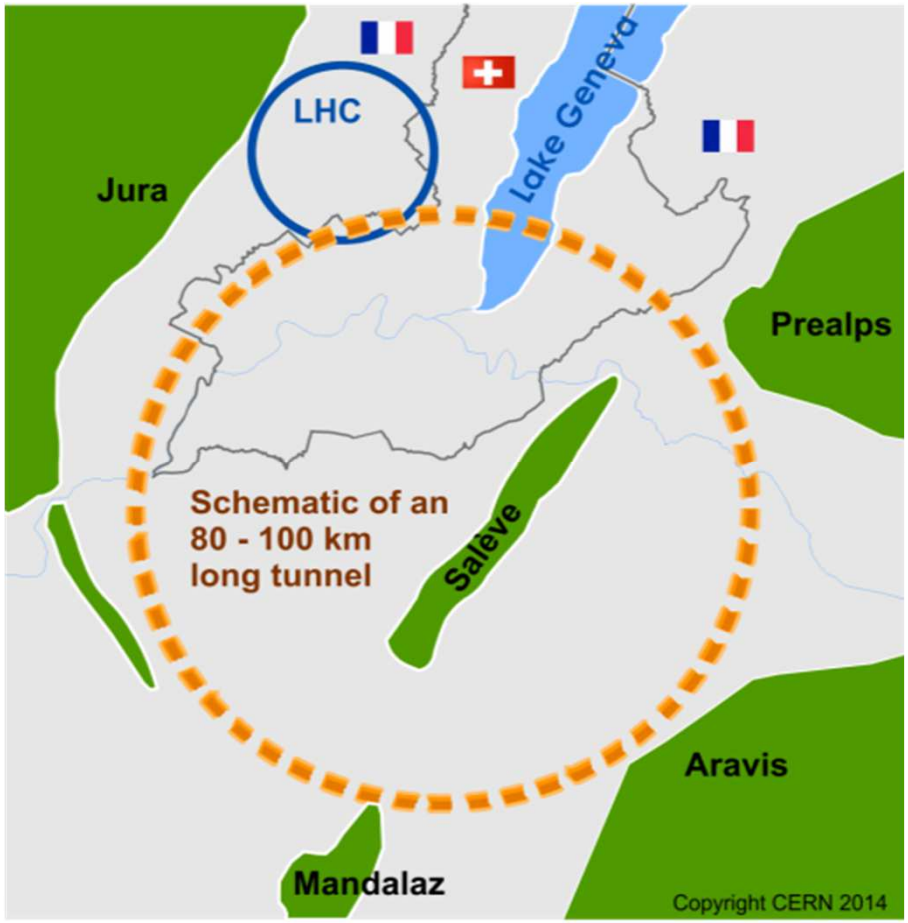
# Future Circular Collider Study - SCOPE
## CDR and cost review for the next ESU (2018)

**Forming an international collaboration to study:**

- ***100 TeV pp*-collider (*FCC-hh*)**

  **→ ultimate goal defining infrastructure requirements**

- **$e^+e^-$ collider (*FCC-ee*)**
  potential first step $E_{CM}$=90-40GeV
  L/IP = $2.10^{36}$ (Z) -- $2.10^{34}$ (top)
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area



**FCC-ee may serve as spring board for the FCC-hh 100 TeV pp collider, bringing**

**-- a large tunnel,**

**-- infastructure,**

**-- cryogenics,**

**-- time,**

**-- addt'l physics motivations**

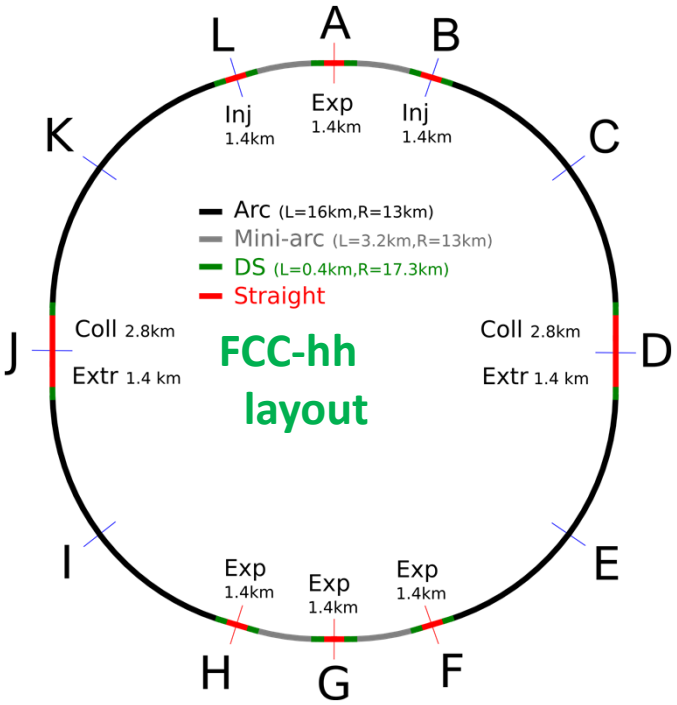
**+ performance goals for FCC-hh**

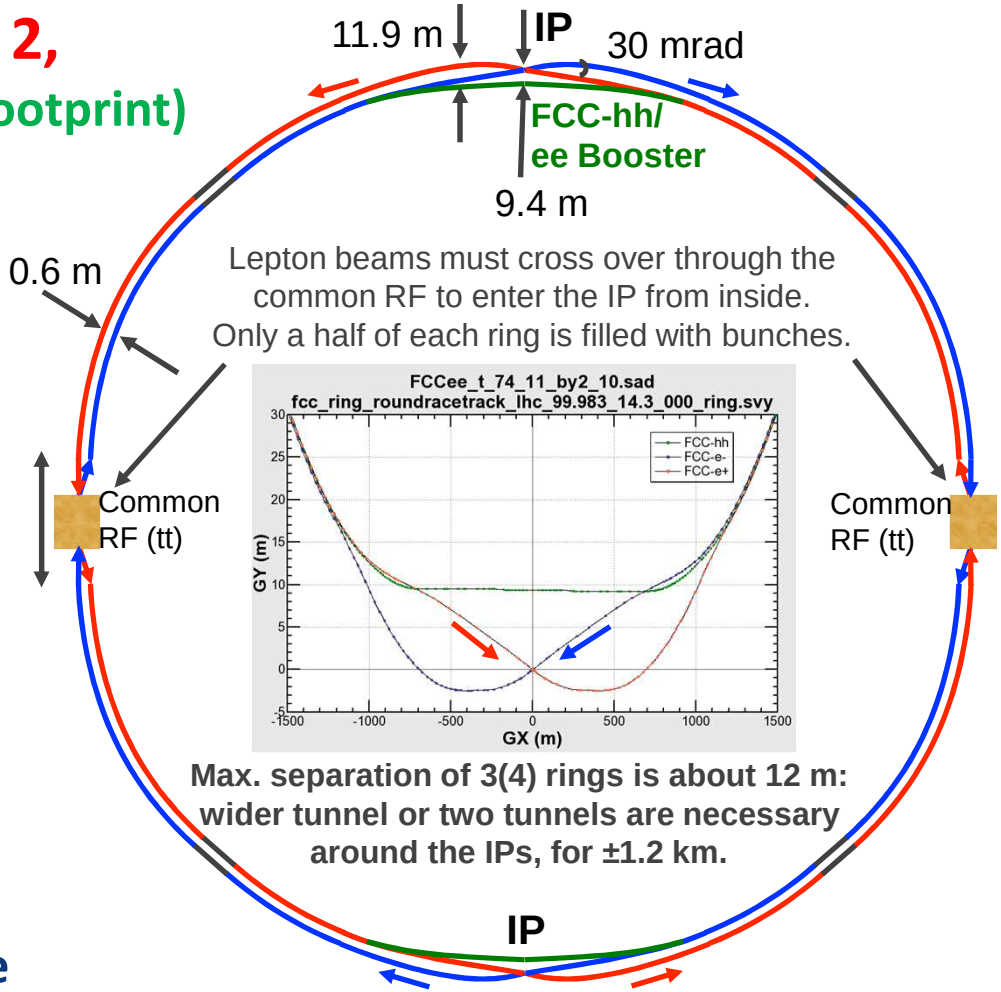
*Frank Zimmermann*

# common layouts for hh & ee

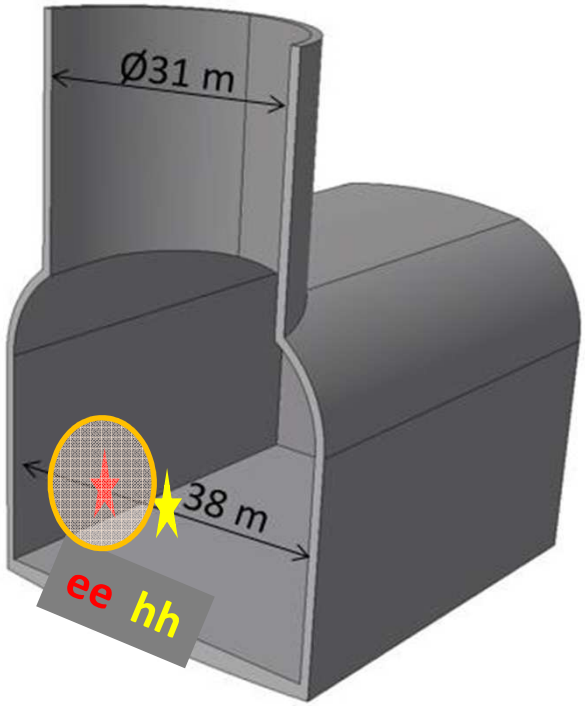
## FCC-ee 1, FCC-ee 2,

### FCC-ee booster (FCC-hh footprint)




- **2 main IPs in A, G for both machines**
- **asymmetric IR optic/geometry for ee to limit synchrotron radiation to detector**




**Sharing the FCC experimental caverns**
**(Prelim. layout as of FCC-Rome meeting)**

# PHYSICS COMPLEMENTARITY

**Some examples**

**Higgs Physics** -- ee → ZH fixes Higgs width and HZZ coupling ,
-- FCC-hh gives huge statistics of HH events for Higgs self-coupling

**Search for Heavy Physics**
-- ee gives precision measurements ($m_Z$ $m_W$ to < 0.5 MeV, $m_{top}$ 10 MeV, etc…)
sensitive to heavy physics up to … 100 TeV
-- FCC-hh gives access to direct observation

**QCD** -- ee gives $\alpha_s \pm 0.0002$ ($R_{had}$ )
also H→gg events (gluon fragmentation!)
-- ep provides tructure functions and $\alpha_s \pm 0.0003$
-- all this improves the signal and background predictions
for new physics signals at FCC-hh

**Heavy Neutrinos** -- ee: powerful and clean, but flavour-blind
-- hh and eh more difficult, but potentially flavour sensitive
NB this is very much work in progress!!

## HIGGS PHYSICS

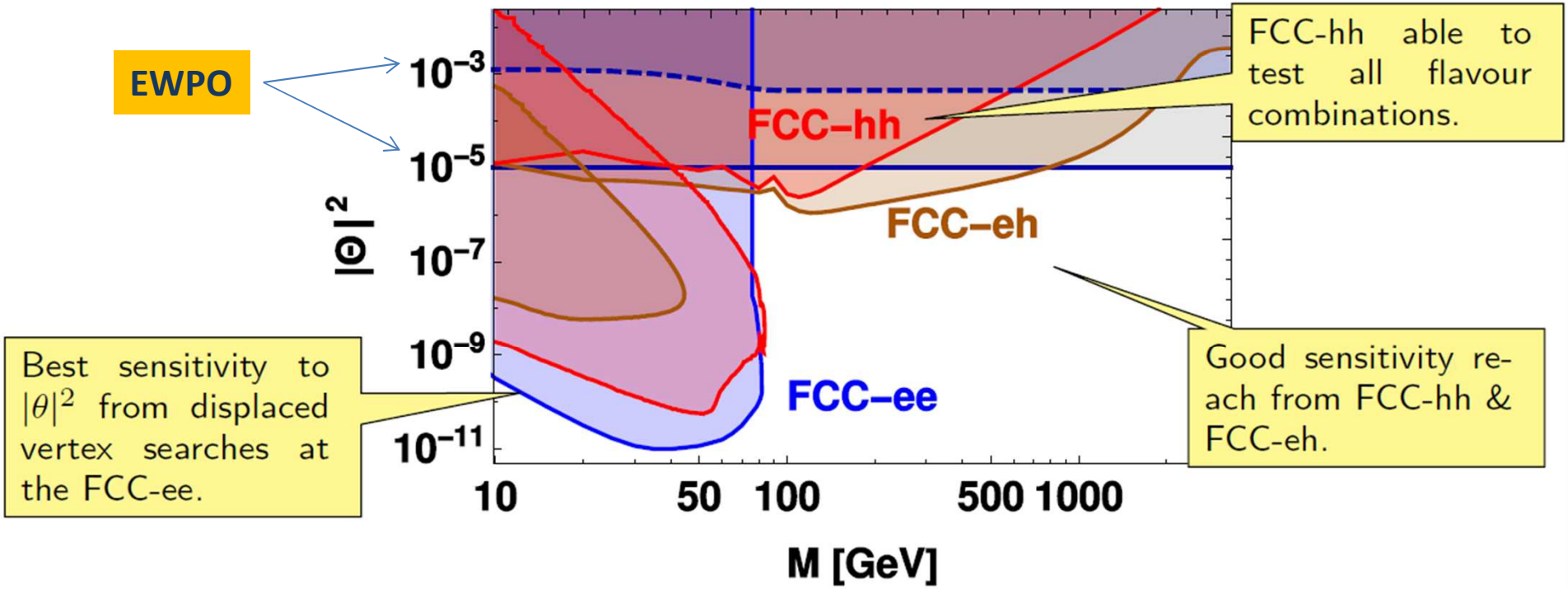
| $g_{Hxx}$ | FCC-ee | FCC-hh | FCC-eh | |
|---|---|---|---|---|
| ZZ | 0.15 % | | | |
| WW | 0.20% | | | |
| $\Gamma_H$ | **1%** | | 0.5%? | |
| $\gamma\gamma$ | 1.5% | **<1%** | | |
| $Z\gamma$ | -- | **1%** | | |
| tt | 13% | **1%** | | |
| bb | 0.4% | | 0.5% | |
| $\tau\tau$ | 0.5% | | | |
| cc | 0.7% | | 1.8% | |
| $\mu\mu$ | 6.2% | **2%** | | |
| uu,dd | H→ $\rho\gamma$? | H→ $\rho\gamma$? | | |
| ss | H→ $\phi\gamma$ ? | H→ $\phi\gamma$ ? | | |
| ee | ee → H? | | | |
| HH | 30% | **<5%?** | | |
| inv, exo | <0.45% | $10^{-6}$? | | |

**hh, eh precisions assume ee measurements!**

# Summary

**Another example of Synergy and complementarity**
**while ee covers a large part of space very cleanly ,**
**its either 'white' in lepton flavour or the result of EWPOs etc**
**Observation at FCC –hh or eh would test flavour mixing matrix!**

- Systematic assessment of heavy neutrino signatures at colliders.
- First looks at FCC-hh and FCC-eh sensitivities.
- Golden channels:
  - **FCC-hh:** LFV signatures and displaced vertex search
  - **FCC-eh:** LFV signatures and displaced vertex search
  - **FCC-ee:** Indirect search via EWPO and displaced vertex search






detailed study required for all FCCs – especially FCC-hh to understand feasibility at all

# Complementarity

Proposed physics topics to be used in the study of **synergy/complementarity** among experiments **at FCC-hh/ee/eh**

| Subject | | ee | hh | he |
|---|---|---|---|---|
| **Higgs Physics** | precision studies<br>higher dimension operators<br>composite Higgs<br>rare and exotic decays<br>multiple Higgs production<br>extra Higgs bosons | | | |
| **Interface with Cosmology** | Dark matter<br>baryogenesis<br>right-handed/(almost) sterile neutrinos | | | |
| **Electroweak Sym. Breaking** | WW scattering<br>supersymmetry<br>extra dimensions<br>composite models | | | |
| **Flavour Changing** | rare H,Z,W,top decays<br>lepton flavor violation | | | |
| **Extensions of the SM** | extra vector-like fermions<br>$SU(2)_R$ models<br>leptoquarks | | | |
| **QCD** | Perturbation theory, structure functions<br>Modelling final states | | | |
| **EW/SM precision issues** | precision measts ($m_Z$,$m_W$,$m_t$,$\alpha$,$\alpha_s(m_Z)$,$\sin^2\theta_W$.$R_b$...<br>higher-order EW corrections<br>W,Z triple and quadruple couplings<br>top (anomalous) couplings<br>charm/bottom flavor studies | | | |

# CONCLUSIONS

The FCC machines offers the broadest discovery potential, by exploration of new domains of

-- both **direct search**,

and

-- **precision**

-- at high energy and

-- at very small couplings

**The synergy is crucial in making the project feasible**

# 12 CDR Volumes (9 + 3 Annex)

**Preliminary** layout of CDR (work in progress)

**all to be printer-ready by end 2018!**

**FCC overview**


M. Benedikt

Overview of the project.
The big physics questions and how FCC will address them.
ee,hh, AA, eh,HE physics capabilities and complementarities

**JOIN US!**

# 2nd FCC Physics Workshop

15-19 January 2018
CERN
Europe/Zurich timezone

Se

**Starts** 15 Jan 2018 09:00
**Ends** 19 Jan 2018 18:00
Europe/Zurich

CERN
503-1-001 - Council Chamber

## Materials

There are no materials yet.