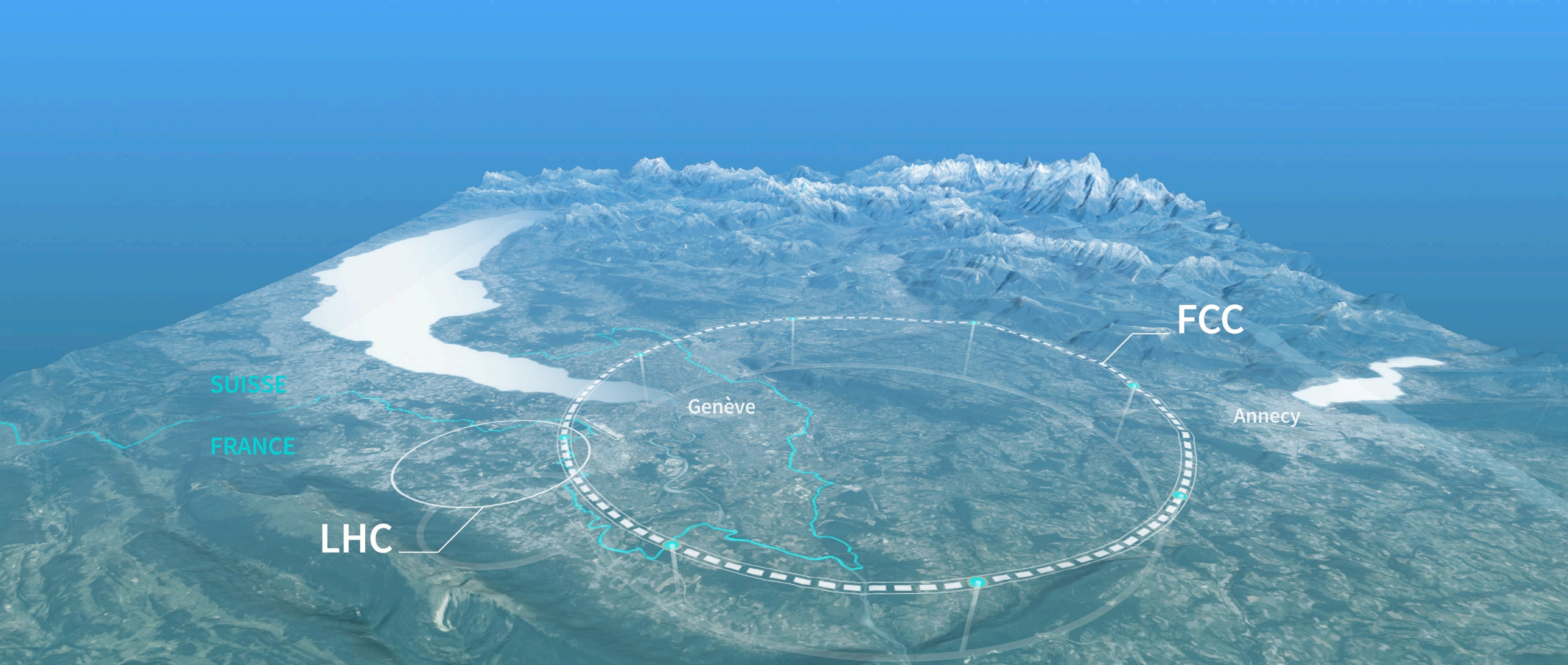
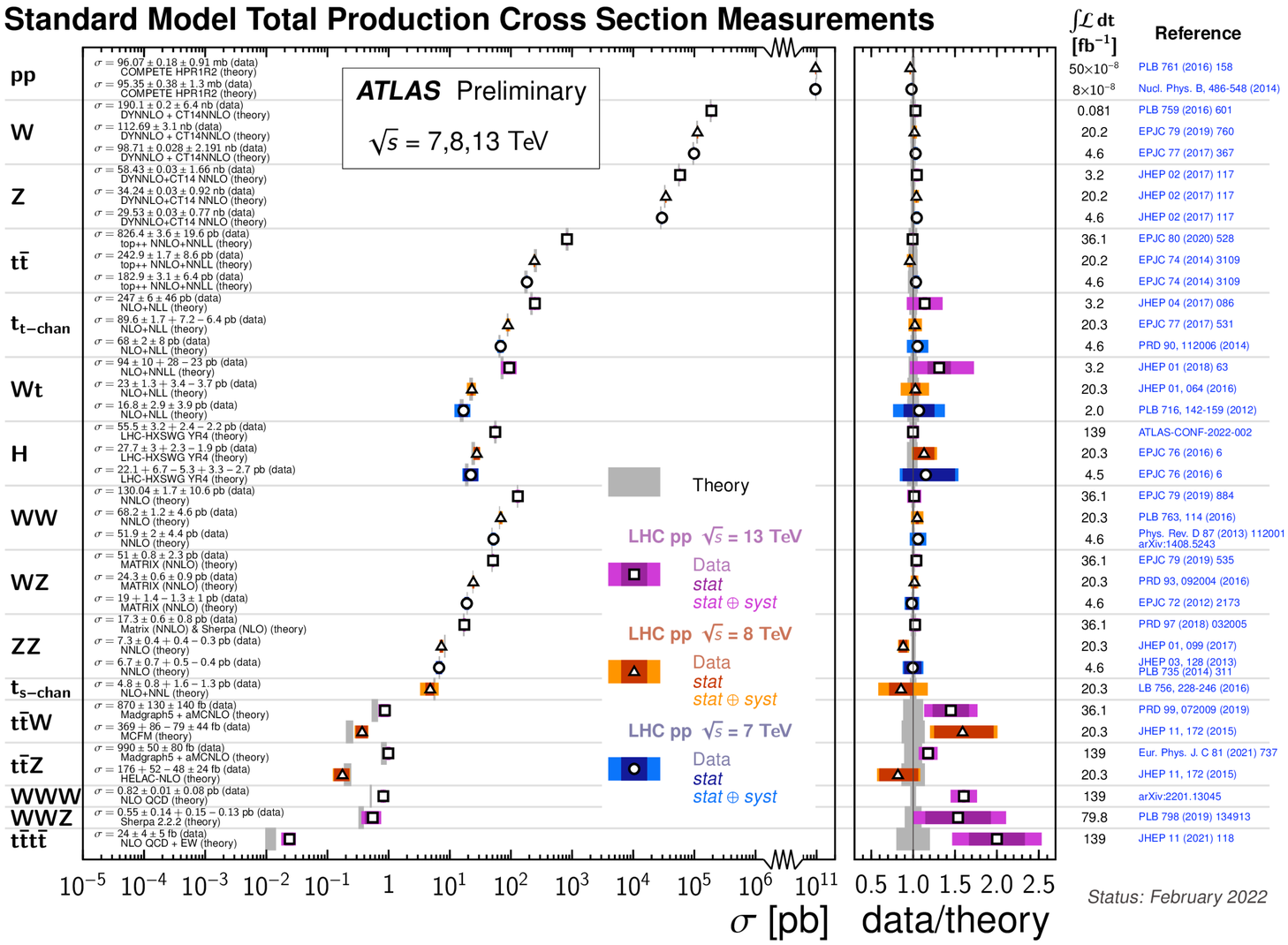


The Future Circular Collider (FCC) at CERN

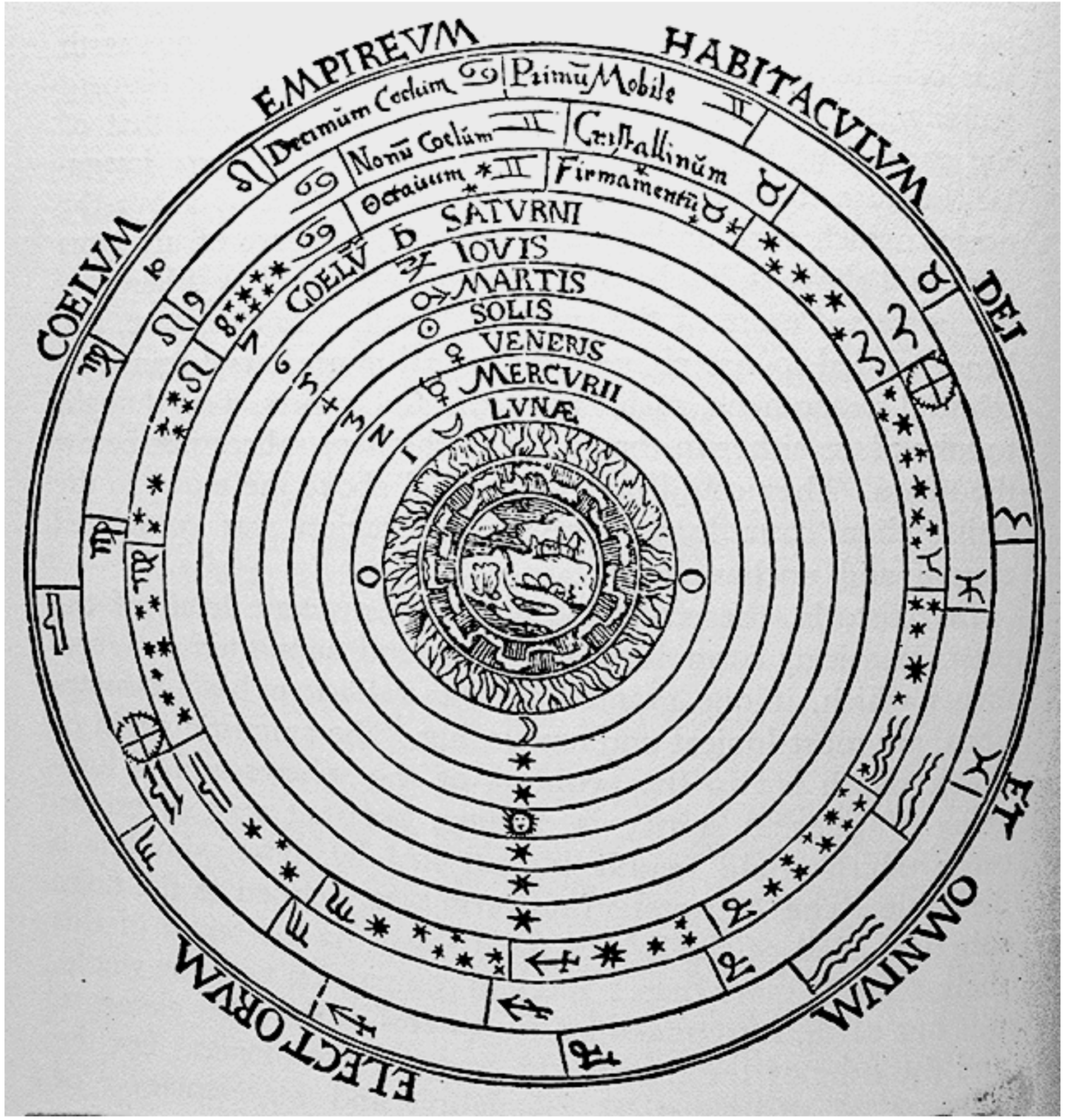
Rebeca Gonzalez Suarez (Uppsala University)

The situation

- After decades, we have a model that works, is robust, thoroughly tested, and provides very precise predictions
- It works great



But we had other predictive, scientific models that worked great while also being inherently wrong.



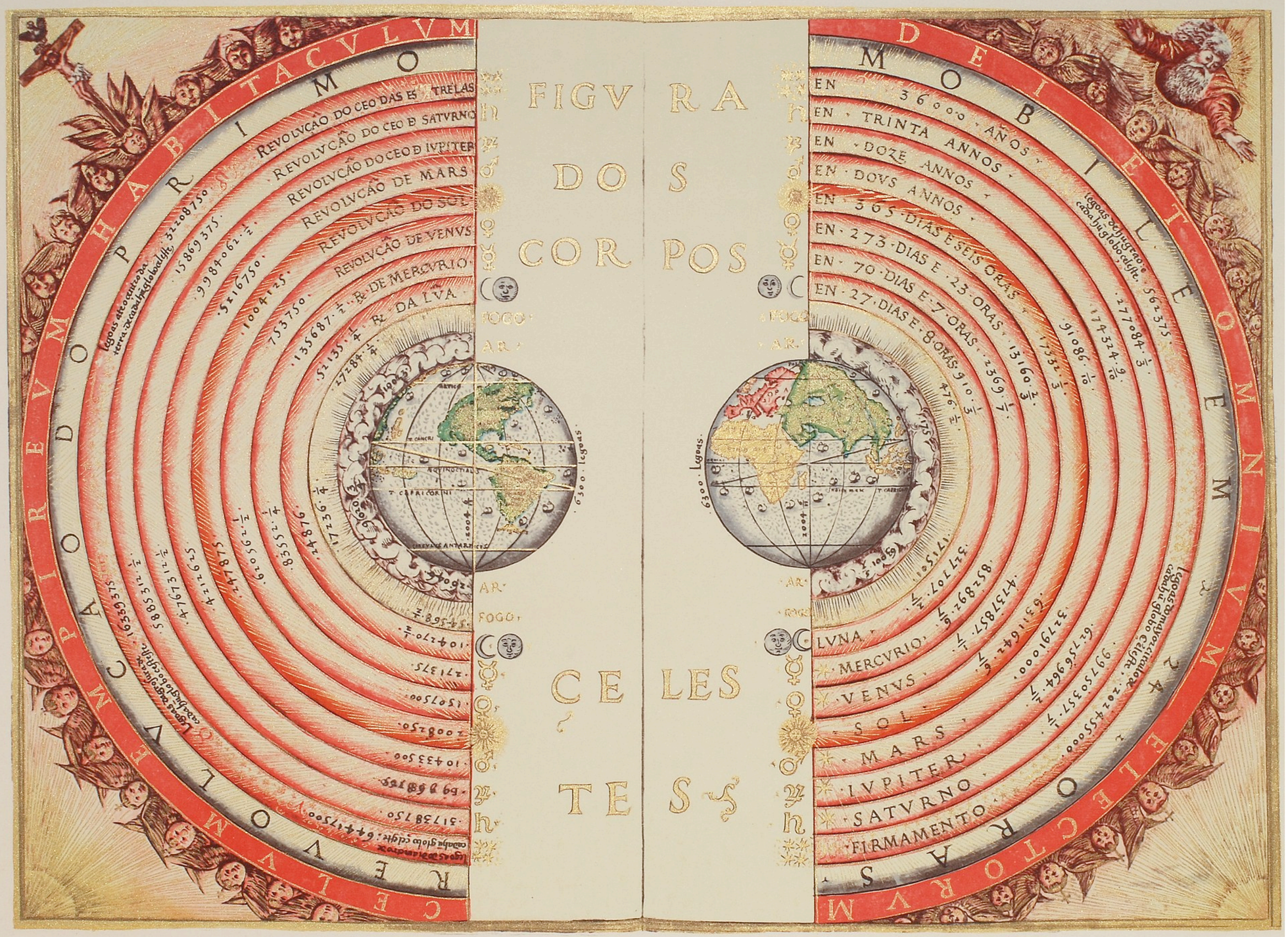
Aristotelian Ptolemaic system was remarkably plausible and powerful as a scientific theory but had some “imperfections”: the paths of the Sun, Moon, and planets as observed from Earth are not circular.

Our model

Also has some “small imperfections”

- Neutrinos have nonzero masses
- The masses of the other particles are weird
- It cannot describe a couple of important effects
  - Dark matter, dark energy, gravitation
- It has some tuning and hierarchy problems…

Leon Lederman’s speculative laundry list for the LHC Nature Review Article: “Beyond the standard model with the LHC” (2007)



This model was canon from the year 150 until the 16th century

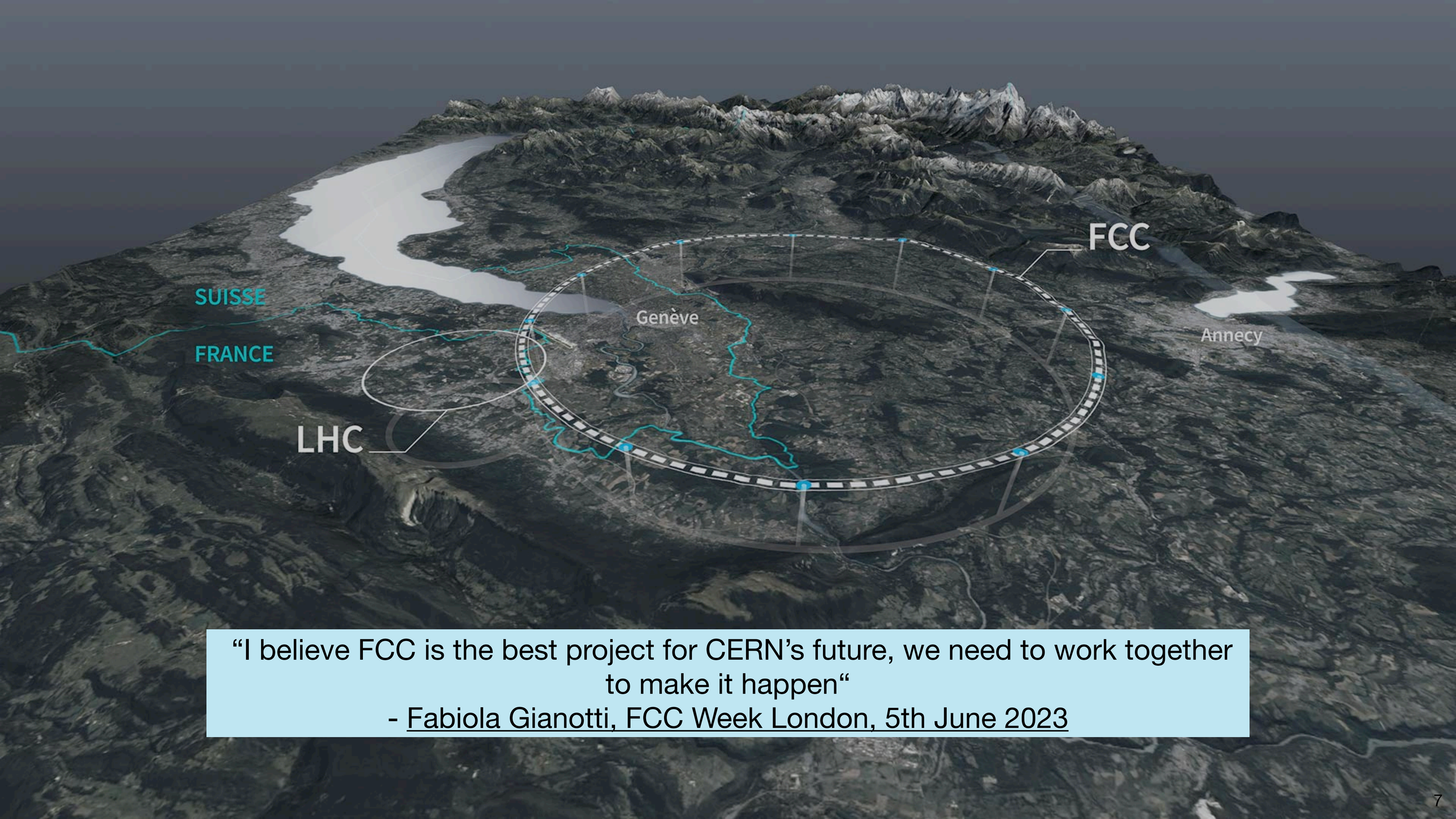
Let's not take that long this time!

What do we have?

- A relatively new particle that is quite special, our newest exploration tool
- Decades of collider expertise to build on top of
- The largest community we ever had
- A few options on the table (linear, circular, lepton, hadron)
- Priorities

2020 European Strategy Update
"An electron-positron Higgs factory is the highest-priority next collider.
For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy."
(European Strategy Update brochure)

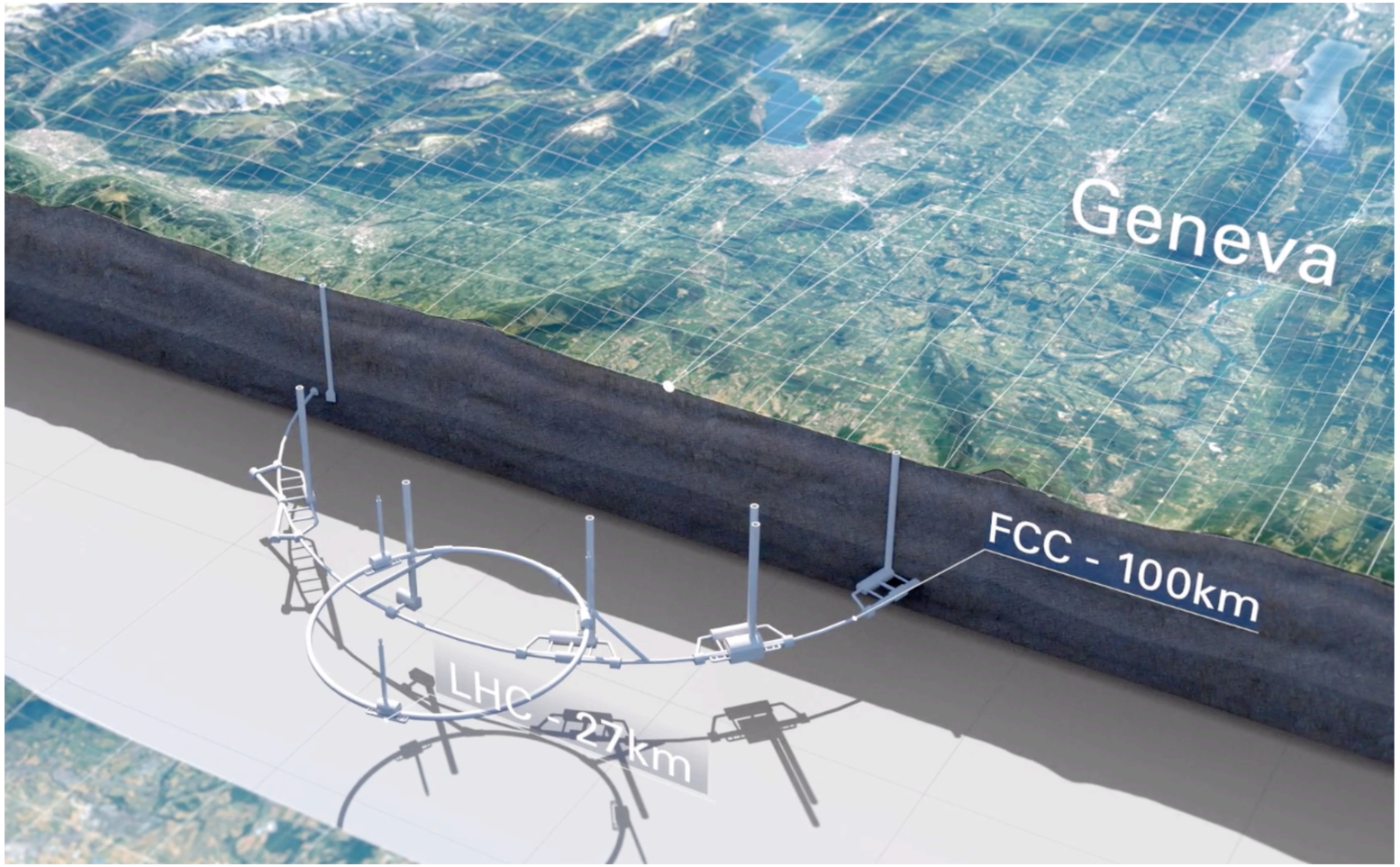
Snowmass 2021
"The intermediate future is an $e+e-$ Higgs factory, either based on a linear (ILC, C3) or circular collider (FCC-ee, CepC).
In the long term EF envision a collider that probes the multi-TeV scale, up or above 10 TeV parton center-of-mass energy (FCC-hh, SppC, Muon Coll.)"
(Energy Frontier Plenary by Alessandro Tricoli)



"I believe FCC is the best project for CERN's future, we need to work together to make it happen"
- Fabiola Gianotti, FCC Week London, 5th June 2023

What is FCC?

Future Circular Collider at CERN



- Linked to the LHC accelerator chain
- Implemented in stages, one e+e- precision machine, followed by a high-energy hadron collider

Why?

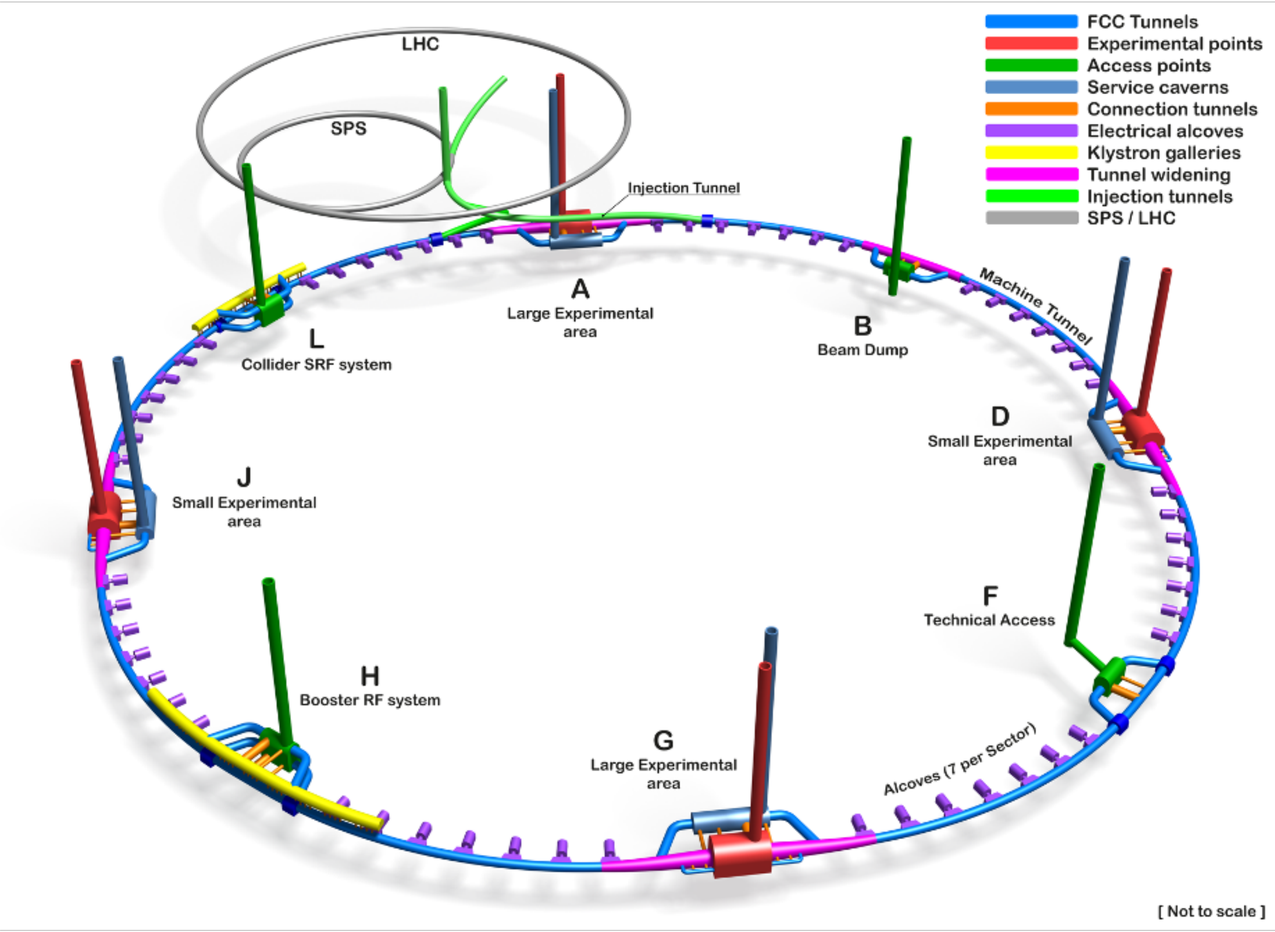
Accessing two physics frontiers

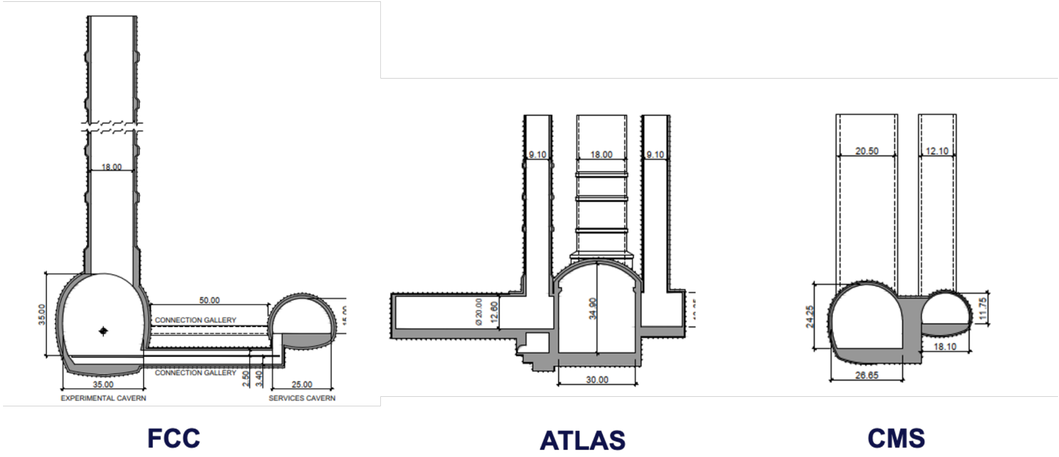
- **INTENSITY FRONTIER Precision (electron-positron)**
  - **1st stage collider, FCC-ee:** electron-positron collisions 90-360 GeV
  - Construction: 2033-2045 / Physics operation: **2048**-2063
  - Stress-test the SM limits → Indirect / low mass BSM sensitivity
- **ENERGY FRONTIER Discovery (hadron-hadron)**
  - **2nd stage collider, FCC-hh:** proton-proton collisions at ≥ 100 TeV
  - Construction: 2058-2070 / Physics operation: ~ 2070-**2095**
  - Maximizing potential for BSM discovery → Direct / high mass BSM sensitivity

Strength

In shared infrastructure

- Making use of the current acceleration chain
- Using one tunnel (and one set of caverns) for both stages
  - Following LEP-LHC model
  - 90.7 km ring, 8 surface points





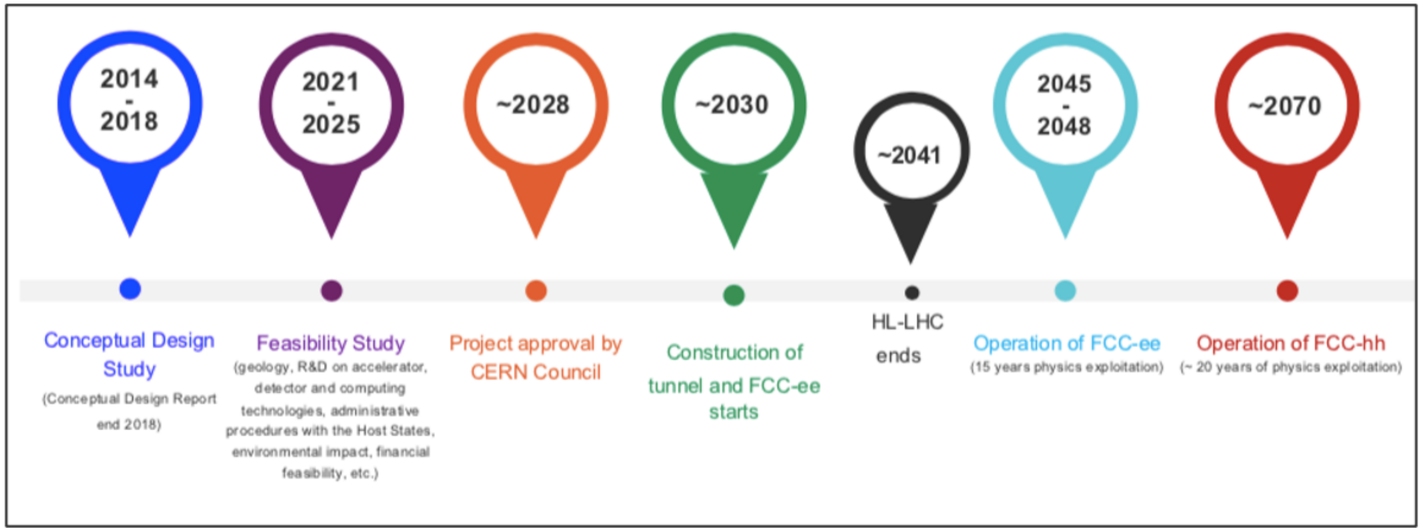
FCC ATLAS CMS

- **4 Experimental areas** 2 large (> ATLAS) & 2 small (~CMS)
- Deepest shaft: 400m
- Average shaft depth: 243m

Strength

In size and timescale

Surprise!



- FCC-ee technology is mature → construction in parallel to HL-LHC operation
- Physics a few years after the HL-LHC (2045-2048)
  - Continuity for multiple generations of high energy physicists guaranteed
  - **Only proposed facility that can accommodate the size of the CERN community**
- Two-stage approach
  - Allows to spread the cost of the (more expensive) FCC-hh over more years
  - 20 years of R&D work towards affordable magnets
  - Optimization of overall investment by reusing civil engineering and large part of the technical infrastructure

Strength

In physics potential

Introductory Remarks - F. Gianotti

	√s	L /IP ($cm^{-2}\,s^{-1}$)	Int L/IP/y (ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	182×10^{34} 19.4 7.3 1.33	22 2.3 0.9 0.16	2-4 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	$5\text{-}30 \times 10^{34}$ 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39TeV	3×10^{29}	100 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	$1.5\ 10^{34}$	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	$0.5\ 10^{34}$	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb

Could be 20 years
Baseline now 4 IPs

The LHC is targeting 32 years now, so 25 may be pessimistic

	Z pole (90)	H pole (125)?	WW (160)	ZH (240)	tt (365)
Years	8	5	2	3	5
Events	8T	8k	300M	2 M	2 M

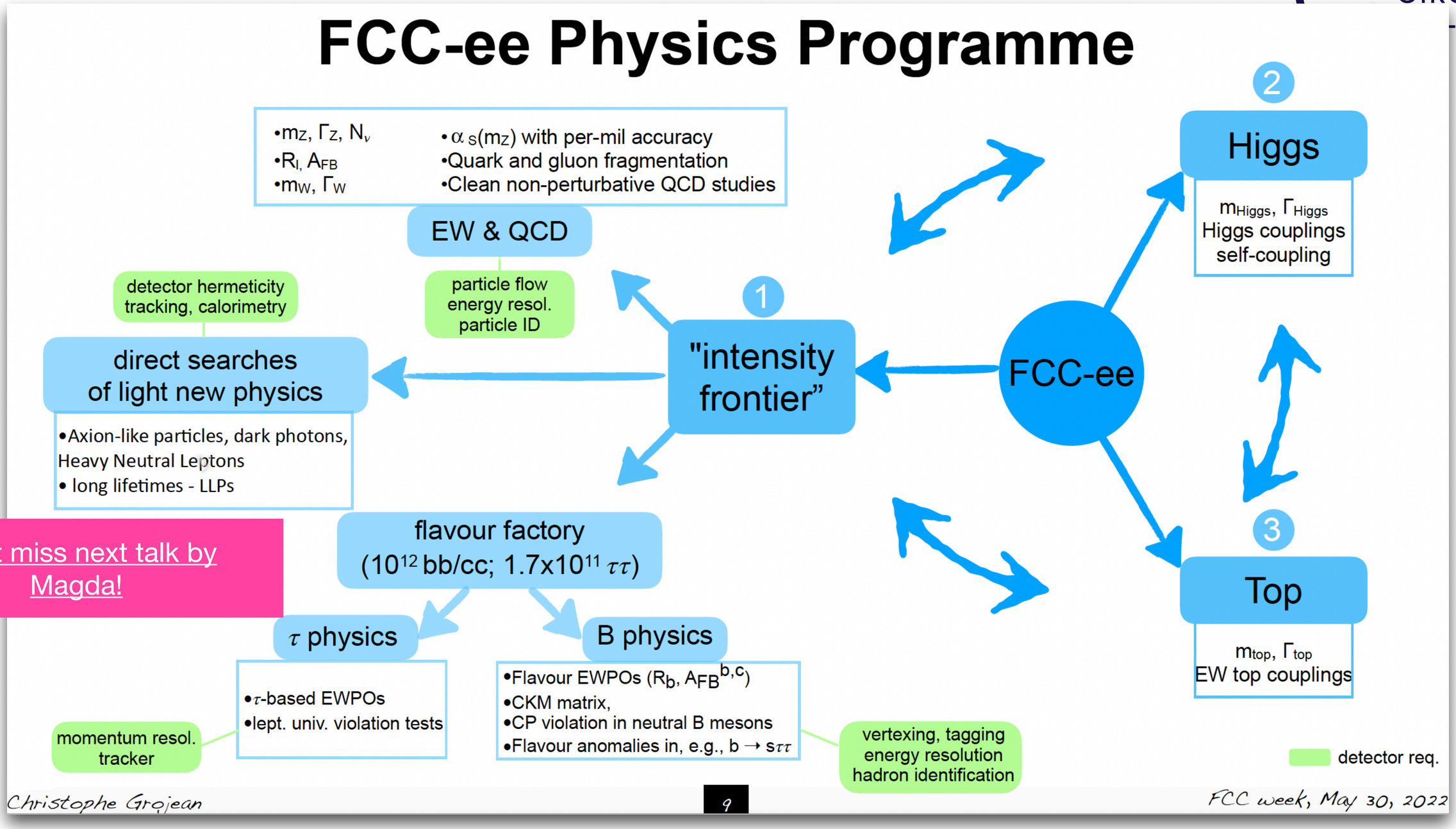
Detector requirements from physics - M. Selvaggi

- FCC-ee : highest luminosities at Z, W, ZH of all proposed Higgs and EW factories; indirect discovery potential up to ~70 TeV, options for direct BSM searches for feebly interacting particles
- FCC-hh: direct exploration of next energy frontier (~ x10 LHC) and unparalleled measurements of low-rate and “heavy” Higgs couplings (ttH, HH)
  - heavy-ion collisions and, possibly, ep/e-ion collisions

"FCC physics case: the once, the now and the future" - Christophe Grojean

FUTURE CIRCULAR COLLIDER

FCC-ee Physics Programme



Don't miss next talk by Magda!

Feasibility study (2021-2025)

What are we doing now?

- There is a set of deliverables and we are working on them:
  - Some are related to infrastructure and environment, others to administration
  - Others are purely R&D
  - There is of course work in cost estimates, as well as investigation of the funding model needed to enable the project, along with many funding discussion
- But there is much work to do also regarding the consolidation of the physics case, detector concepts and technologies.
  - Sweden is very active in that area, with leading scientific roles and multiple master theses exploring different BSM scenarios
  - **The FCC Week in London last week made it clear that FCC is the way to go for CERN member states, and now is a great time to join in and contribute!**

"This project is supported from the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754."