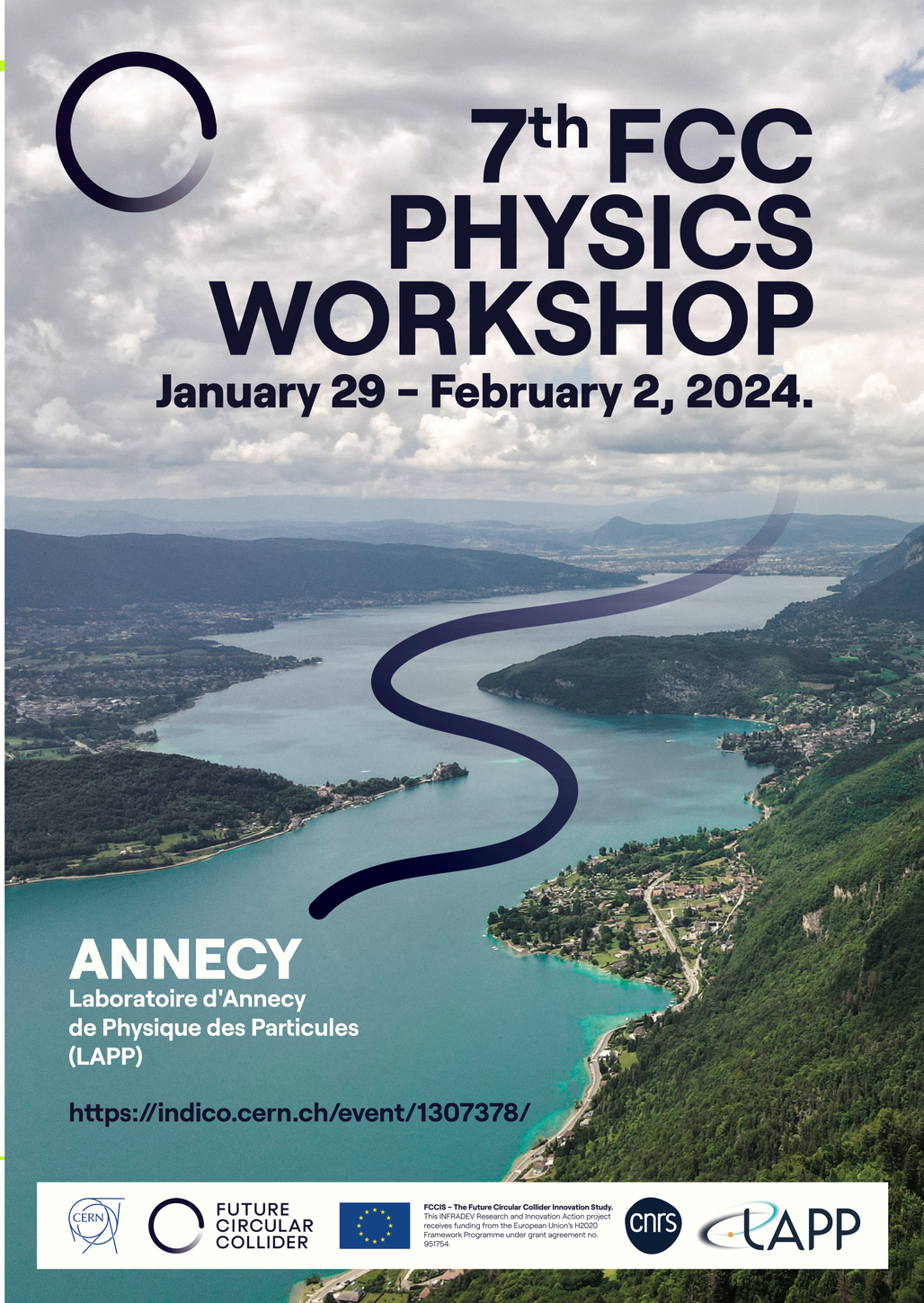
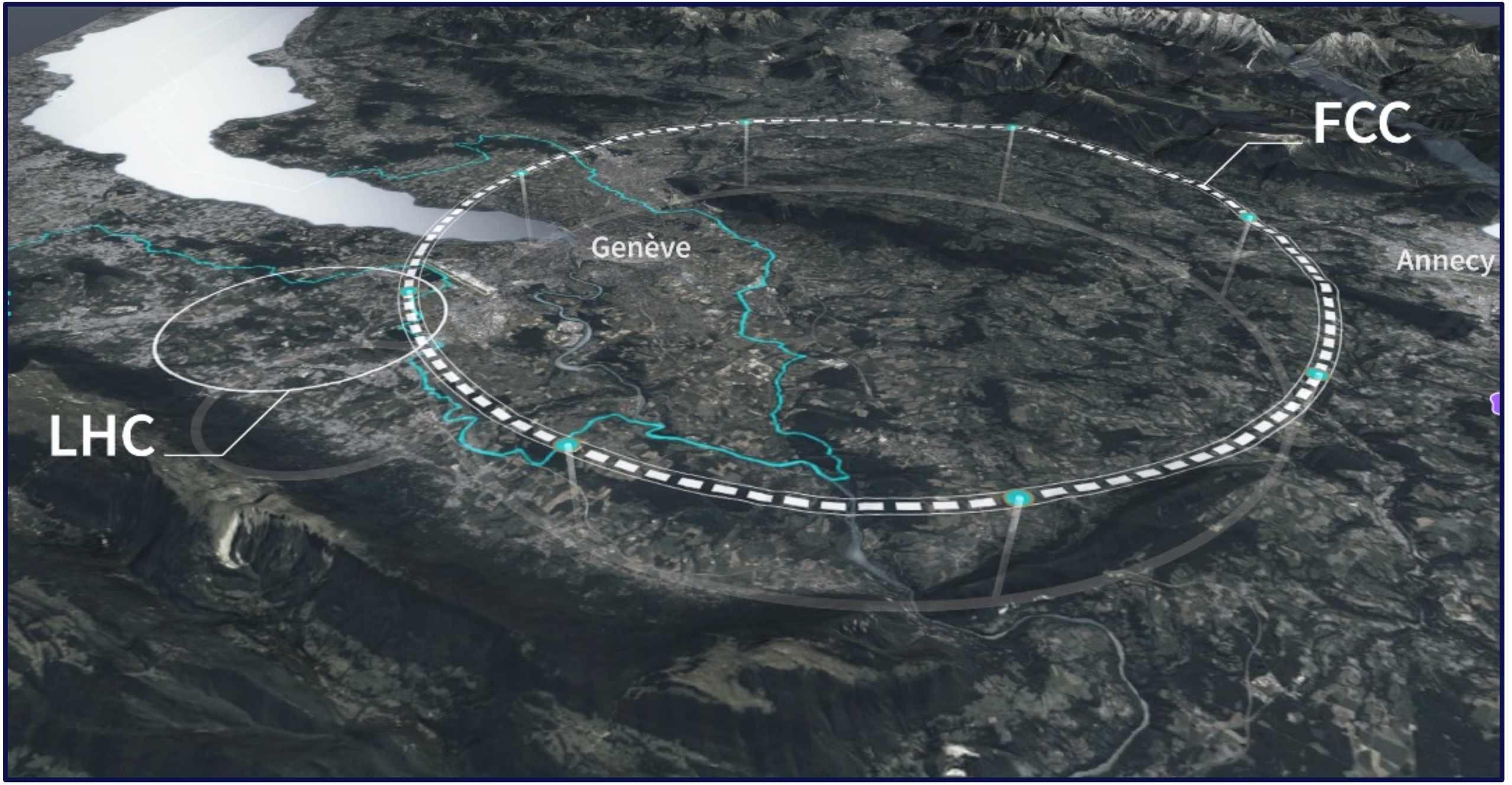
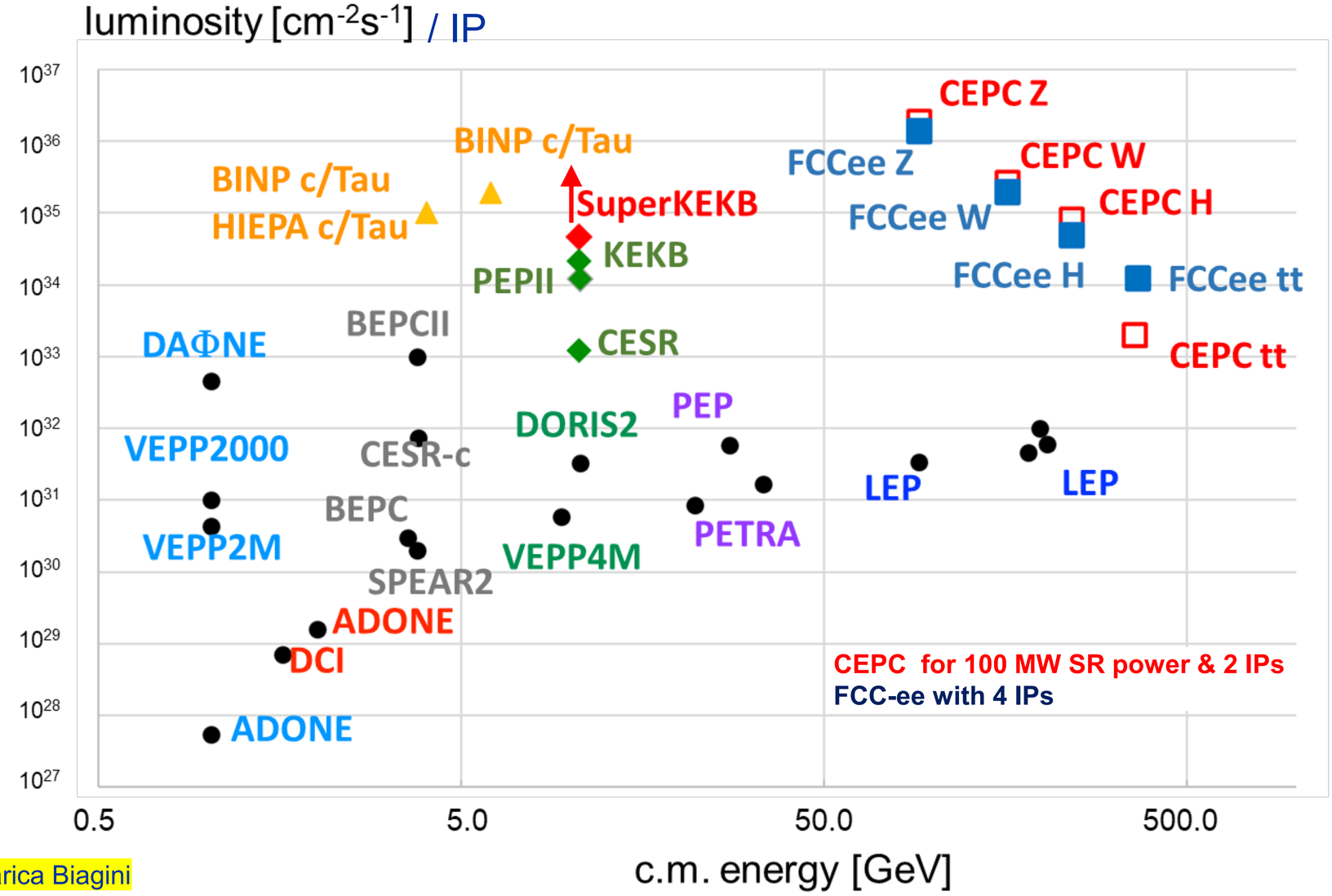
FCC

- Questions I will try to answer:
  - What is the FCC?
  - Why the FCC?
  - Recent developments
- Using slides from the FCC Physics workshop last week.




FCC
Genève
Annecy
LHC

Stage 1: FCC-ee – 2nd highest luminosity collider



Marica Biagini

~ same accelerator design as twin machine CEPC

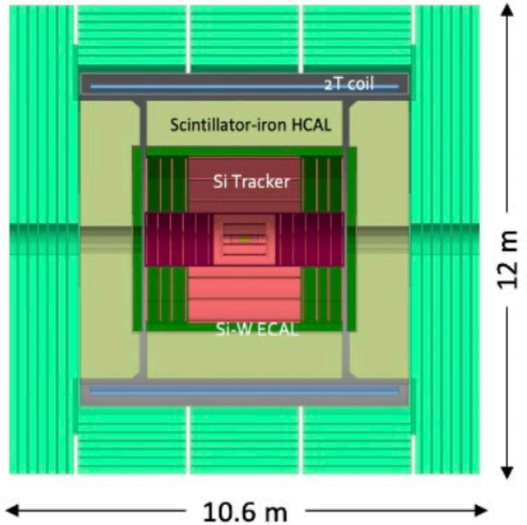
a few differences

	FCC-ee	CEPC
#IPs	4 or 2	2
collider SRF up to ZH	400 MHz, 1- & 2-cell, Nb/Cu, 4.5 K	650 MHz, 2-cell, Nb, 2 K
collider SRF ttbar	800 MHz 5-cell, Nb, 2 K	650 MHz, 5-cell, Nb, 2 K
booster SRF	800 MHz 5-cell, Nb, 2 K	1.3 GHz, 9-cell, Nb, 2 K
top-up	in collider	in booster

FCCee Detector Concepts

Defined by Calorimetry

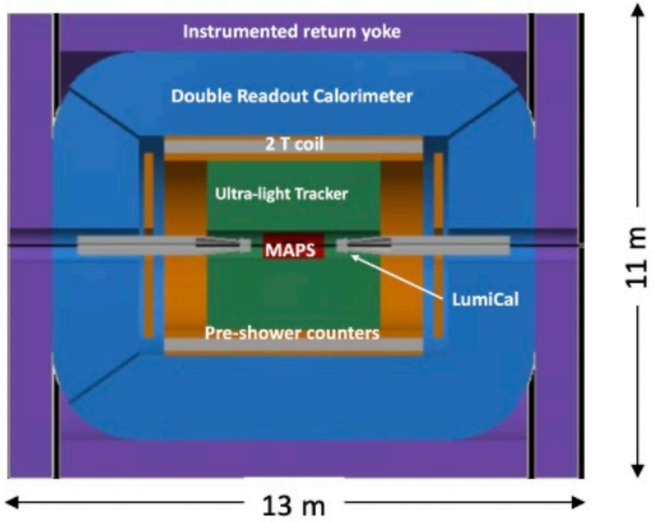
CLD



- Well established design
  - ILC -> CLIC detector -> CLD
- Full Si vtx + tracker
- CALICE-like calorimetry;
- Large coil, muon system
- Engineering still needed for operation with continuous beam (no power pulsing)
  - Cooling of Si-sensors & calorimeters
- Possible detector optimizations
  - σ_p/p, σ_E/E
  - PID ($\mathcal{O}$(10 ps) timing and/or RICH)?

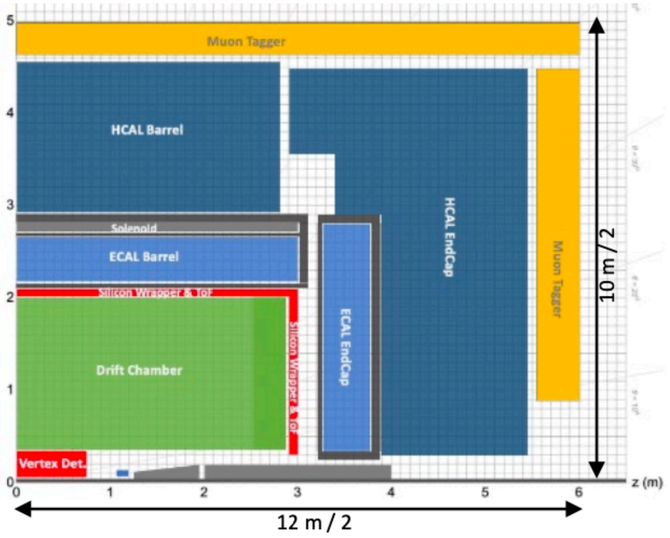
CDR

IDEA



- A bit less established design
  - But still ~15y history
- Si vtx detector; ultra light drift chamber with powerful PID; compact, light coil;
- Monolithic dual readout calorimeter;
  - Possibly augmented by crystal ECAL
- Muon system
- Very active community
  - Prototype designs, test beam campaigns, …

ALLEGRO



- The “new kid on the block”
- Si vtx det., ultra light drift chamber (or Si)
- High granularity Noble Liquid ECAL as core
  - Pb/W+LAr (or denser W+LKr)
- CALICE-like or TileCal-like HCAL;
- Coil inside same cryostat as LAr, outside ECAL
- Muon system.
- Very active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, …
  - Software & performance studies

FUTURE CIRCULAR COLLIDER

FCC-ee: main machine parameters

F. Gianotti

Parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45.6	80	120	182.5
beam current [mA]	1270	137	26.7	4.9
number bunches/beam	11200	1780	440	60
bunch intensity [10^{11}]	2.14	1.45	1.15	1.55
SR energy loss / turn [GeV]	0.0394	0.374	1.89	10.4
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.1/0	2.1/9.4
long. damping time [turns]	1158	215	64	18
horizontal beta* [m]	0.11	0.2	0.24	1.0
vertical beta* [mm]	0.7	1.0	1.0	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.71	1.59
vertical geom. emittance [pm]	1.9	2.2	1.4	1.6
horizontal rms IP spot size [μm]	9	21	13	40
vertical rms IP spot size [nm]	36	47	40	51
beam-beam parameter ξ_x / ξ_y	0.002/0.0973	0.013/0.128	0.010/0.088	0.073/0.134
rms bunch length with SR / BS [mm]	5.6 / 15.5	3.5 / 5.4	3.4 / 4.7	1.8 / 2.2
luminosity per IP [10^{34} $cm^{-2}s^{-1}$]	140	20	5.0	1.25
total integrated luminosity / IP / year [ab^{-1}/yr]	17	2.4	0.6	0.15
beam lifetime rad Bhabha + BS [min]	15	12	12	11
	4 years 5 x 10^{12} Z LEP x 10^5	2 years > 10^8 WW LEP x 10^4	3 years 2 x 10^6 H	5 years 2 x 10^6 tt pairs

- x 10-50 improvements on all EW observables
- up to x 10 improvement on Higgs coupling (model-indep.) measurements over HL-LHC
- x10 Belle II statistics for b, c, τ
- indirect discovery potential up to ~ 70 TeV
- direct discovery potential for feebly-interacting particles over 5-100 GeV mass range

Up to 4 interaction points → robustness, statistics, possibility of specialised detectors to maximise physics output

The Physics Program of a ***Higgs-Top-Electroweak*** Factory

How I see it today

Karlsruhe Institute of Technology

Electroweak Pillar

Electroweak Precision & Discovery

Precision measurements as a probe of New Physics at high scales.

Flavour Physics

The next generation Flavour Factory: Solving flavour puzzles with extreme statistics (10x Belle II).

Direct Searches

Weakly coupled lighter BSM particles with high statistics.

Higgs Pillar

Model-independent study of all accessible couplings to high precision.

The Higgs Width:
Connects higher-E pillars!

Top Pillar

Precise and theoretically well-defined measurement of top quark mass.

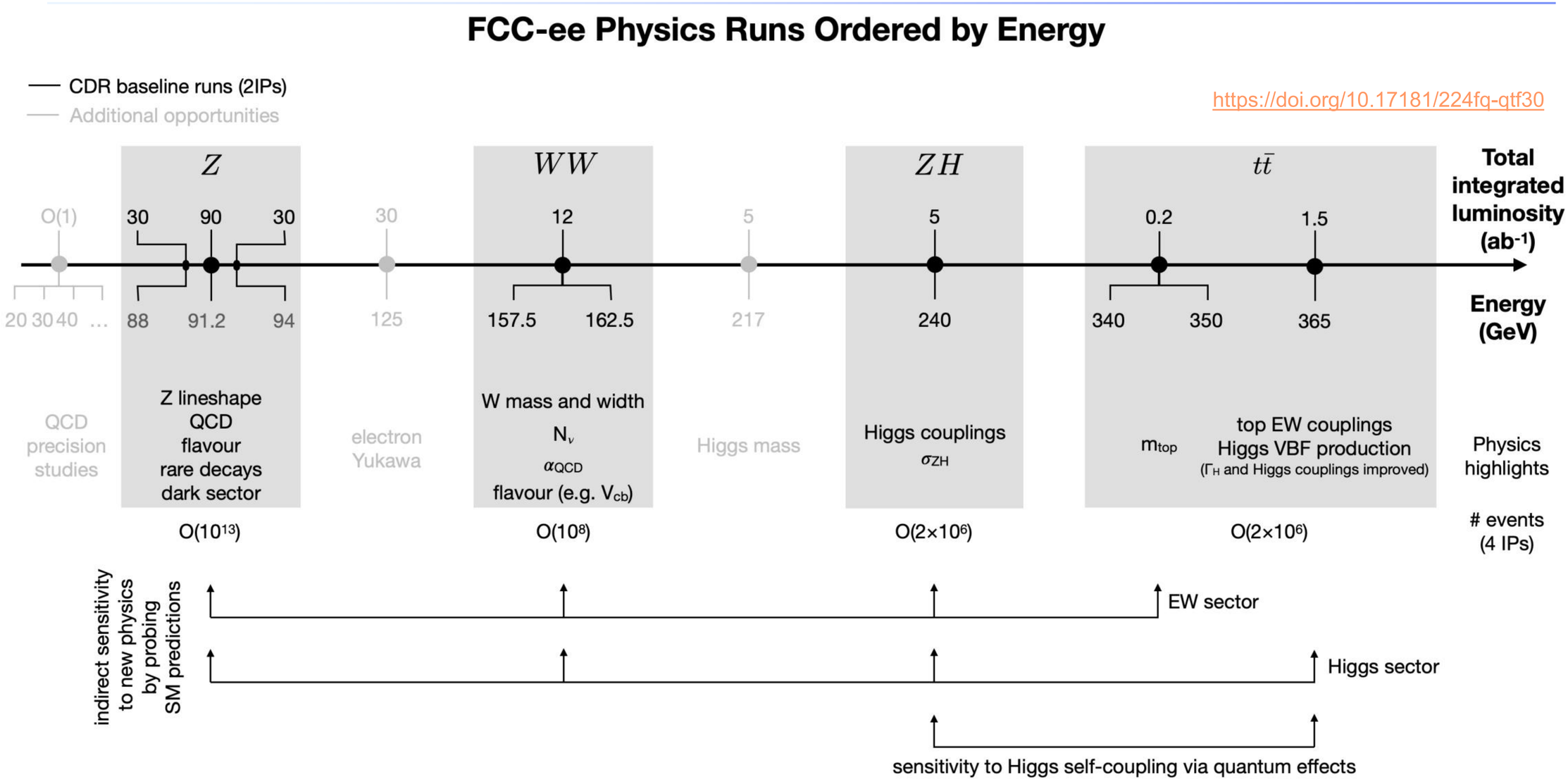
Top as a BSM probe: Sensitivity due to high mass.

The combination of all three pillars provides compelling discovery potential - and you need all three to cover the broadest possible range.

Frank Simon (frank.simon@kit.edu)

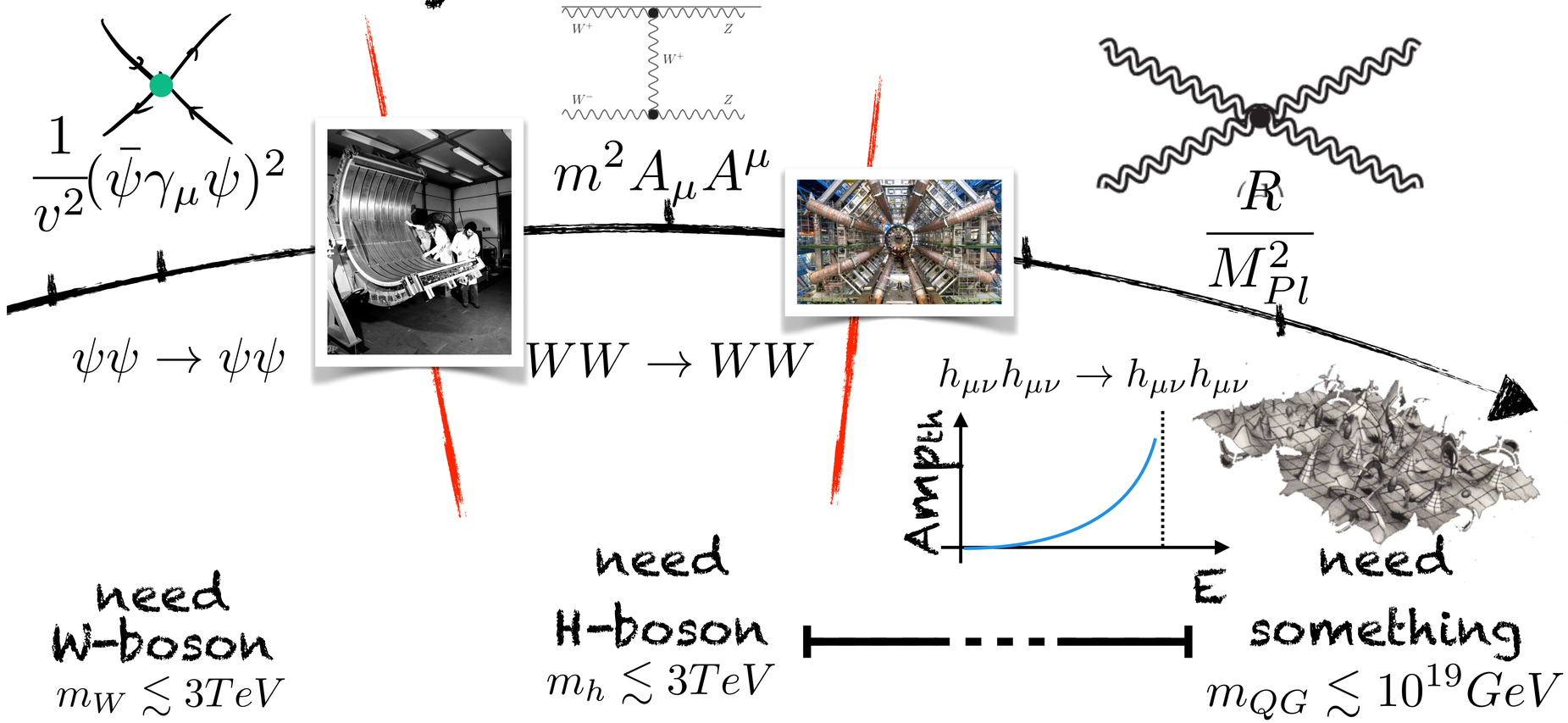
Institute for Data Processing and Electronics

A Possible Extended Physics Programme



No Lose Theorems

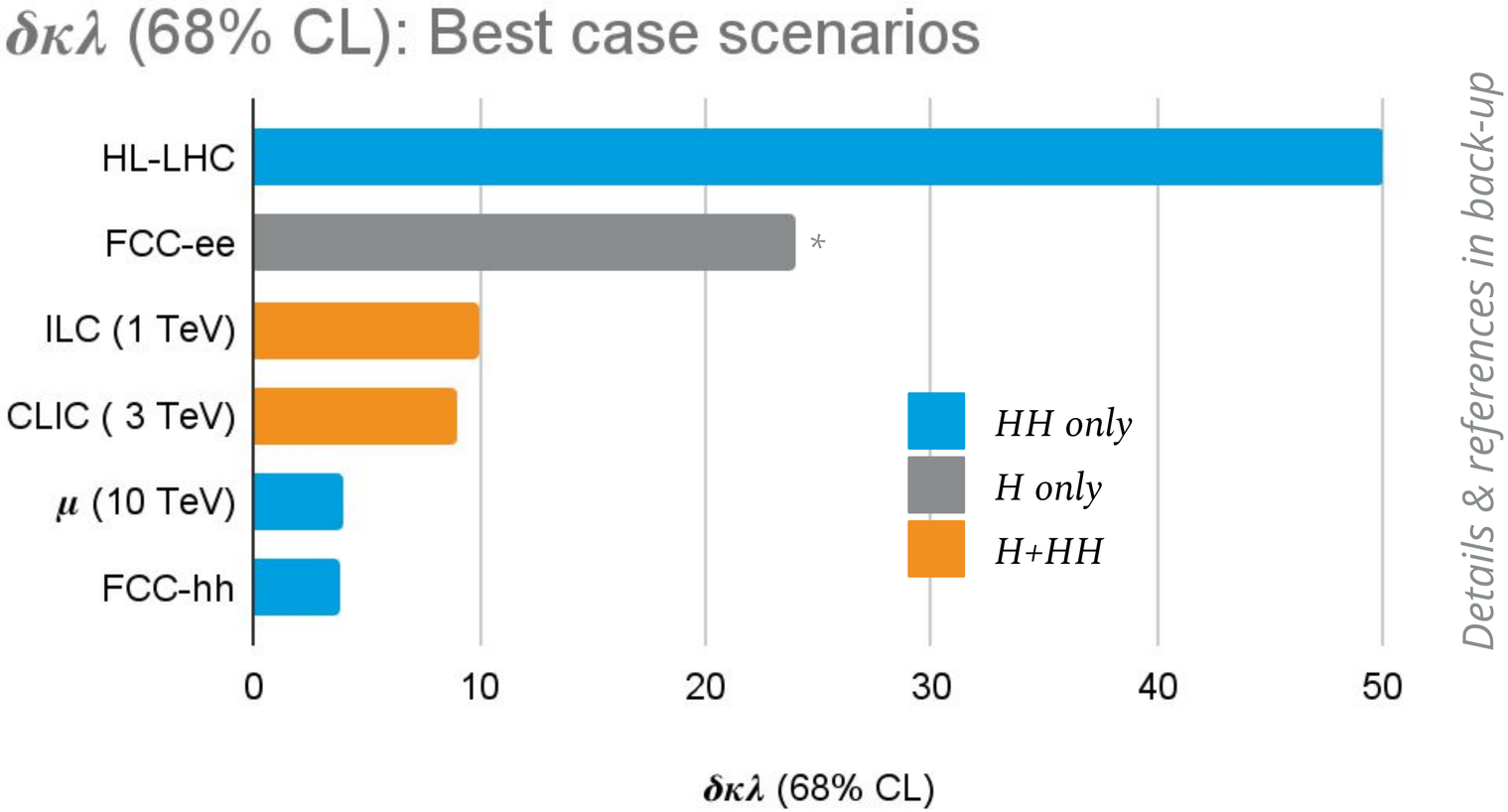
HEP: a history of guaranteed discoveries



- Exceptional story, but science is not about no lose theorems
- What will we learn from this exploration?

Overview of Higgs self-coupling limits & prospects

- At LHC we set limits: -0.4 < κ_λ < 6.3 (*ATLAS-HDBS-2022-03*)
- Only at future colliders we will reach a precision measurement



Details & references in back-up

** For FCC-ee the Higgs self-coupling is measured indirectly via one loop-effect in the ZH process*

The alignment of stars towards FCC-ee

Started two European Strategy Updates ago (2011-2013)

- **Experimentally:** Discovery of the Higgs boson
  - Light enough to be produced at circular e^+e^- colliders with $\sqrt{s}$ = 240 GeV
- **Technologically:** High-luminosity B factories are a success
  - The Higgs boson can be produced copiously at circular e^+e^- colliders
- **Scientifically:** No new physics at the LHC at the TeV scale with strong/EW couplings
  - Further limits the physics potential of TeV-class linear colliders
  - Calls for a collider programme able to explore both the intensity and the energy frontiers
- **Opportunistically:** A 100 km pp collider is proposed for the long-term future of CERN
  - It is also exactly what is needed for an e^+e^- collider
    - To reach and exceed the top-pair threshold
    - To make breakthroughs at the intensity frontier
    - To enable $\sqrt{s}$ measurement with resonant depolarisation up to the WW threshold
  - Complementary & synergistic with the pp collider (infrastructure, budget, science, …)

The alignment of stars towards FCC-ee

Perfect alignment is being reached as we speak (2020-2024)

- **Politically, in Europe:**
  - 2020: The ESU places an e+e- Higgs factory as the highest priority next collider
  - 2021: The FCC (ee + hh) Feasibility Study is ordered and funded by CERN Council
  - 2023: The Feasibility mid-term report is reviewed by the CERN SPC and the FC
    - Report shows spectacular progress; Very positive evaluation and feedback
    - We ought to be collectively very proud of this achievement

- **Politically, in the US:**
  - 2023: The P5 committee strongly recommends an offshore e^+e^- Higgs factory

With significant funding recommended

Figure 2 – Construction in Various Budget Scenarios

Index: N: No Y: Yes R&D: Recommend R&D but no funding for project C: Conditional yes based on review P: Primary S: Secondary
Delayed: Recommend construction but delayed to the next decade
Can be considered as part of ASTAE with reduced scope

US Construction Cost >$3B

Scenarios	Less	Baseline	More	Science Drivers: Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
on-shore Higgs factory	N	N	N		P	S		P	P	
$1–3B										
off-shore Higgs factory	Delayed	Y	Y		P	S		P	P	
ACE-BR	R&D	R&D	C	P				P	P	

The alignment of stars towards FCC-ee

Perfect alignment is being reached as we speak (2020-2024)

- **Politically, in China (CEPC):**

Current plans
- ❑ TDR release: Dec 2023
- ❑ Engineering Design Report: 2024-2027
- ❑ Application for 5-year funding: 2025
- ❑ Construction: 2027-2035
- ❑ Start of operation: 2036

From CERN DG New Year's address

Should we change our plans ? NO

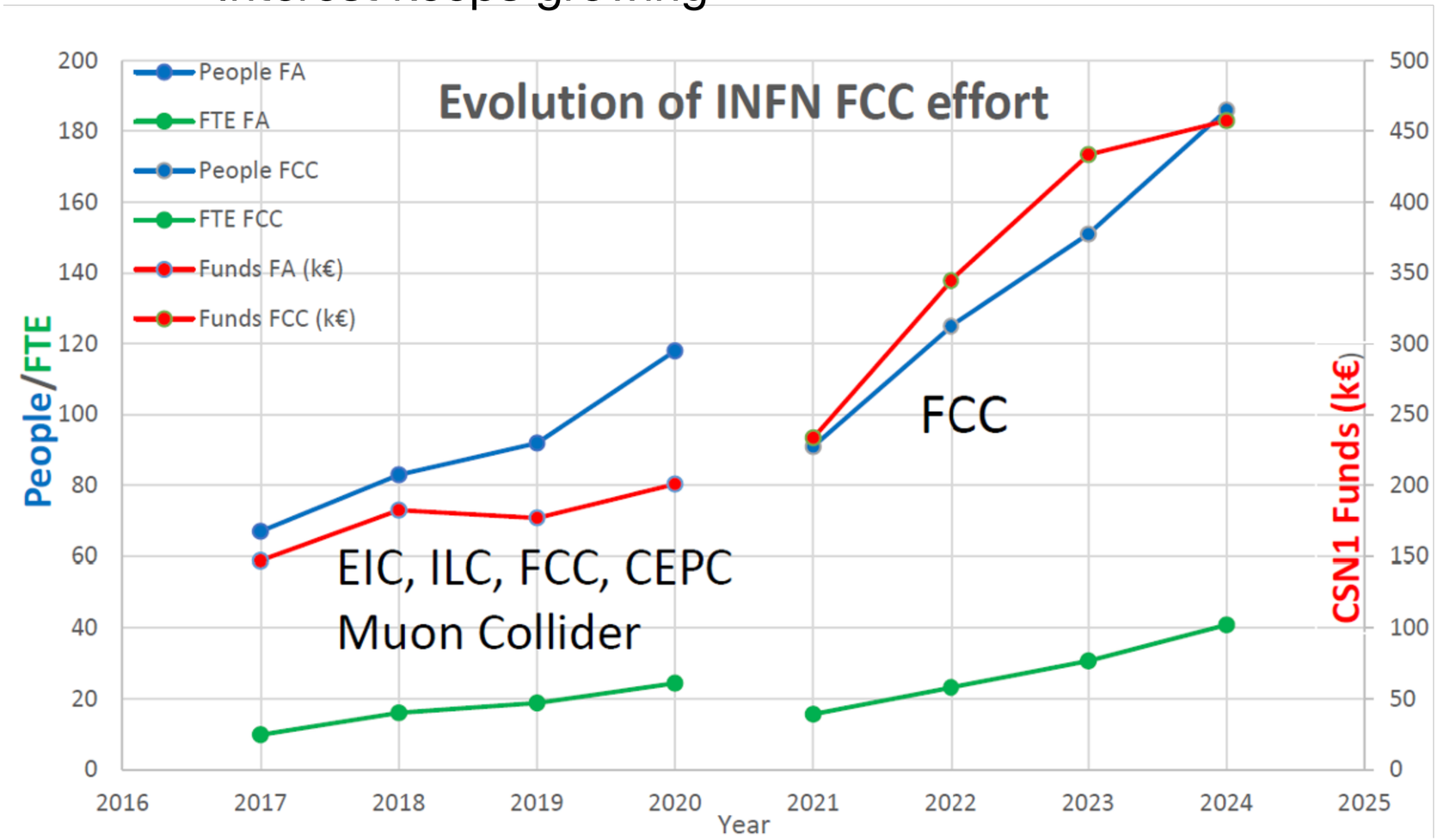
Should we accelerate our planning ? YES

→ CERN Directorate will discuss these matters with the CERN Council in the coming months

  - First visible effects of this possible acceleration
    - Feasibility final report must be produced this year (and delivered beginning 2025)
    - Acceleration may come with more resources (or not)
    - But will certainly come with more work to do until the approval

INFN support

- Line of research on future accelerators created in 2016
  - Interest keeps growing



More resources from:

- CSN5 grants
  - ARCADIA
  - Hidra2
- EU grants
  - EuroCircol
  - FCC-IS
  - AIDAinnova
  - Attract, µRTubes
  - EURO-LABS
  - Eurizon
  - FEST

Examples of Tasks

- Some examples of open tasks
  - Study Particle Flow performance of CLD with/without ARC detector
  - Exercise the background overlay tools and migrate it to an EDM4HEP native algorithm
  - CLD flavor tagging algorithm
    - edm4hep migration, training upon geometry change, adaptation of the Delphes flavor tagging algo to CLD
  - Tau reconstruction
  - IDEA drift chamber digitization and tracking
    - edm4hep data format extension
  - ALLEGRO muon system implementation
  - Technical maintenance of existing packages, e.g. k4RecCalorimeter, k4Gen, …
  - Central implementation of detector performance production routines
  - **Prepare and maintain Full Sim physics analyses** (with CLD first, applied to other detectors with minimal changes)
- Contact us if you wish to contribute!

Conclusions

- FCC is a future Higgs-Top-Electroweak factory.
- Many important measurement, order of magnitude improvement, but no guaranteed new physics discoveries.
- It is important to discuss this at Nikhef in view of the European Strategy Update.
- It would be good to get some involvement in the future collider program.