The FCC at CERN: A Feasible Circular Collider?

Christoph Paus, MIT

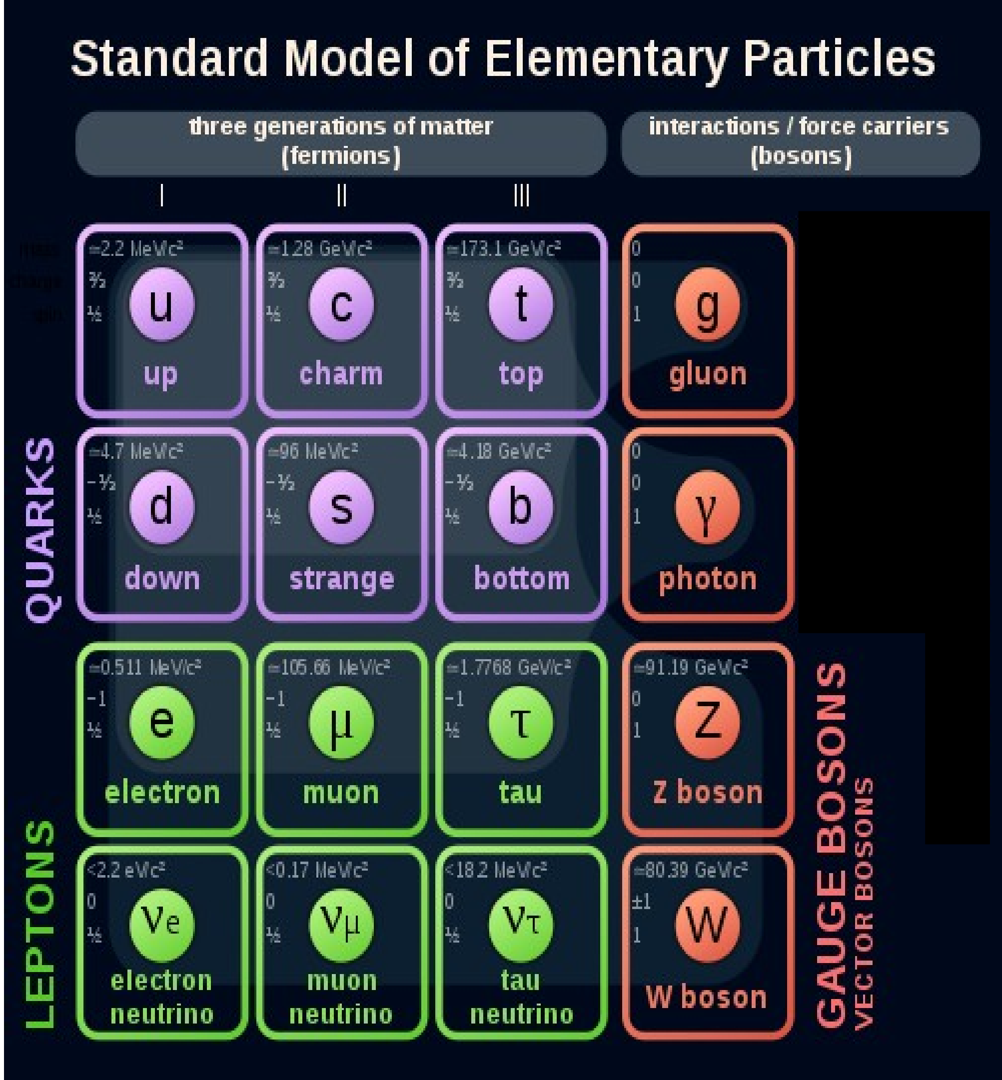
April 1, 2025
Physics Colloquium
at Stony Brook

The world...

as we knew it, 2011!

Last puzzle piece

- Z and W are really heavy, that does not work!
- How do they acquire mass?
- One more scalar particle… the Higgs



Then, this happened ...

ATLAS and CMS

found it!

The world…

as we know it today!

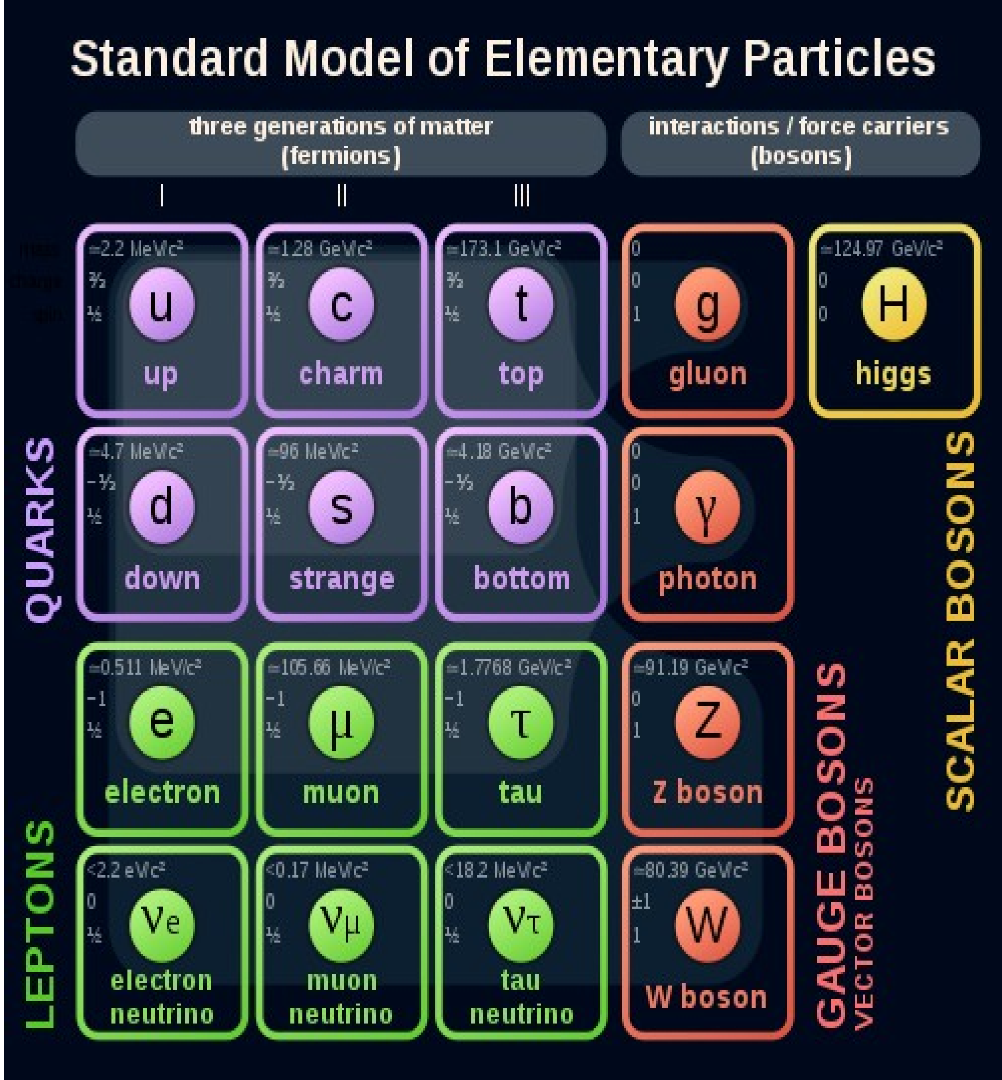
Comments

- It looks simple enough and complete, are we done?

Not at all:

- What is dark matter?
- How does gravity fit in?
- What about matter-antimatter asymmetry?
- The Higgs is weird… why 125 GeV?

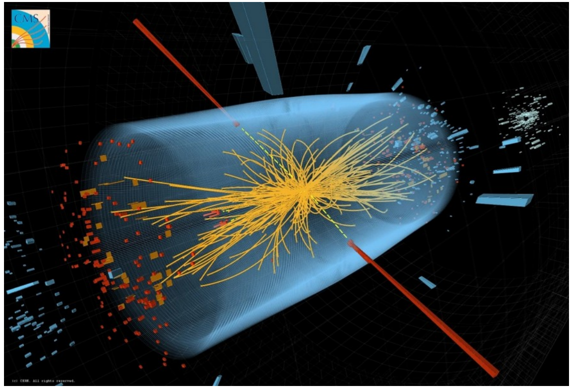
….



The Higgs boson

The Higgs is special

- Only scalar (spin=0) elementary particle
- Its mass is highly tuned (much lighter than the Planck scale) to make the standard model work (hierarchy problem)
- It gives all other elementary particles their mass, nobody else does something like that
- It it responsible to make the entire universe to have a non-zero vacuum expectation value
- Is the Higgs giving potential dark matter its mass as well? → window to dark world?



European Strategy Update 2013

After the Higgs discovery in 2012

- European strategy concluded in 2013

> In the coming decade, the LHC, including its high-luminosity upgrade, will remain the world's primary tool for exploring the high-energy frontier. Given the unique nature of the Higgs boson, there are **compelling scientific arguments for a new electron-positron collider operating as a "Higgs factory"**. Such a collider would produce **copious Higgs bosons in a very clean environment, would make dramatic progress in mapping the diverse interactions of the Higgs boson** with other particles and would form an essential part of a research programme that includes exploration of the flavour puzzle and the neutrino sector.

Higgs boson should be our focus using e^+e^-

Link: ESU 2013 report

European Strategy Update 2013

After the Higgs discovery in 2012

3. High-priority future initiatives

a) 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. Accomplishing these compelling goals will require innovation and cutting-edge technology:

- *the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors;*
- *Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.*

Conceptual Design Report and Feasibility Study!

Link: ESU 2013 report

What is a Higgs factory?

First stab

- A collider where you make many, many, Higgs bosons
- HL-LHC: ~180M Higgs bosons produced (60 pb) at 3 ab^{-1}
- … but the efficiency is low and there is a lot of background
- FCC-ee: ~2.2M Higgs bosons produced ...

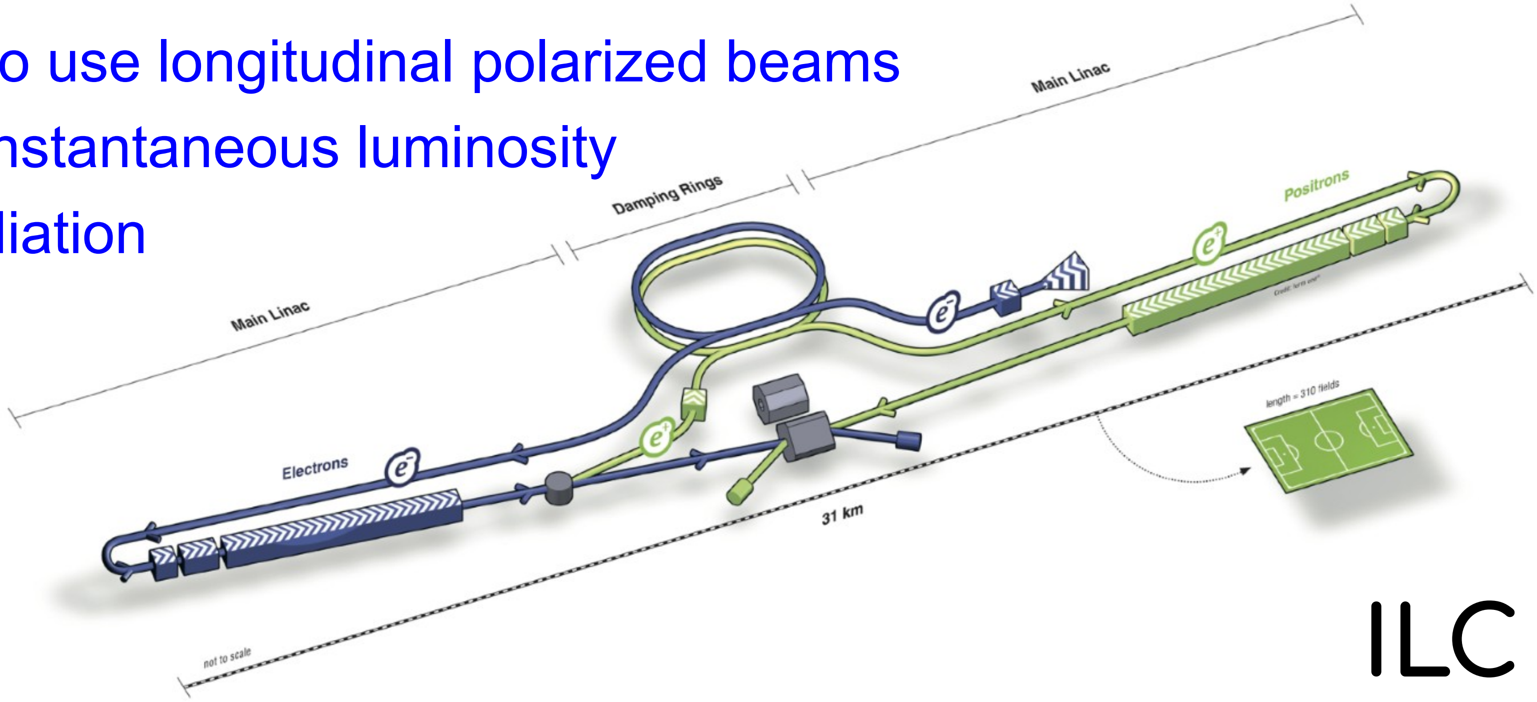
Refining

- Many Higgs bosons produced that can be efficiently used for analysis
- Background and general beam crossing environment matters
- Usefulness of the initial state cannot be understated
- Also non-Higgs physics is interesting

Candidates – Linear Colliders

ILC, C3, CLIC

- Energy reaches to TeV
- Easier to use longitudinal polarized beams
- Lower instantaneous luminosity
- Low radiation

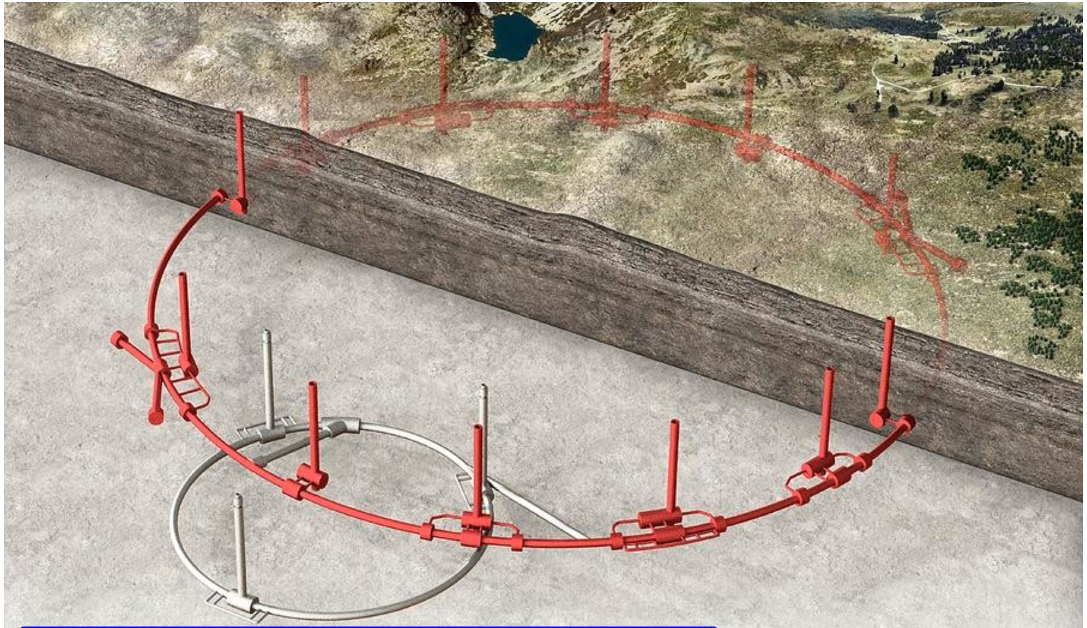


ILC

Candidates – Circular Colliders

FCC-ee, CEPC

- Beams circulate after collisions and instantaneous luminosity is high
- Several interaction regions
- Highest luminosity at Z/WW/ZH
- Synchrotron radiation limits energy range < 400 GeV



$$\frac{\Delta E_{syn}}{\text{revolution}} \propto \frac{E_{\text{beam}}^4}{R}$$

FCC

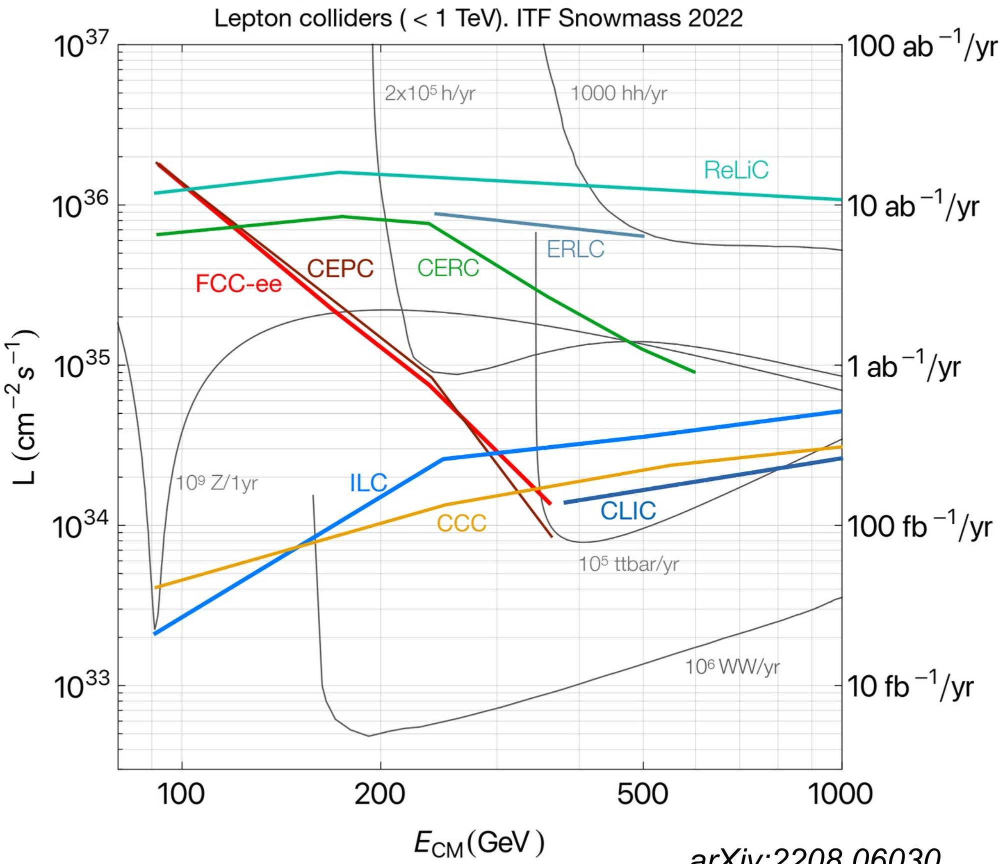
Higgs Physics Potential

Higgs Physics

- Driven by the number of Higgs bosons produced
- Linear and Circular options promise ~ same number of Higgses for proposed running

Non-Higgs physics?

- Very different
- Precision Z and W program at circular collider
- Extension to higher energies feasible with linear colliders



arXiv:2208.06030

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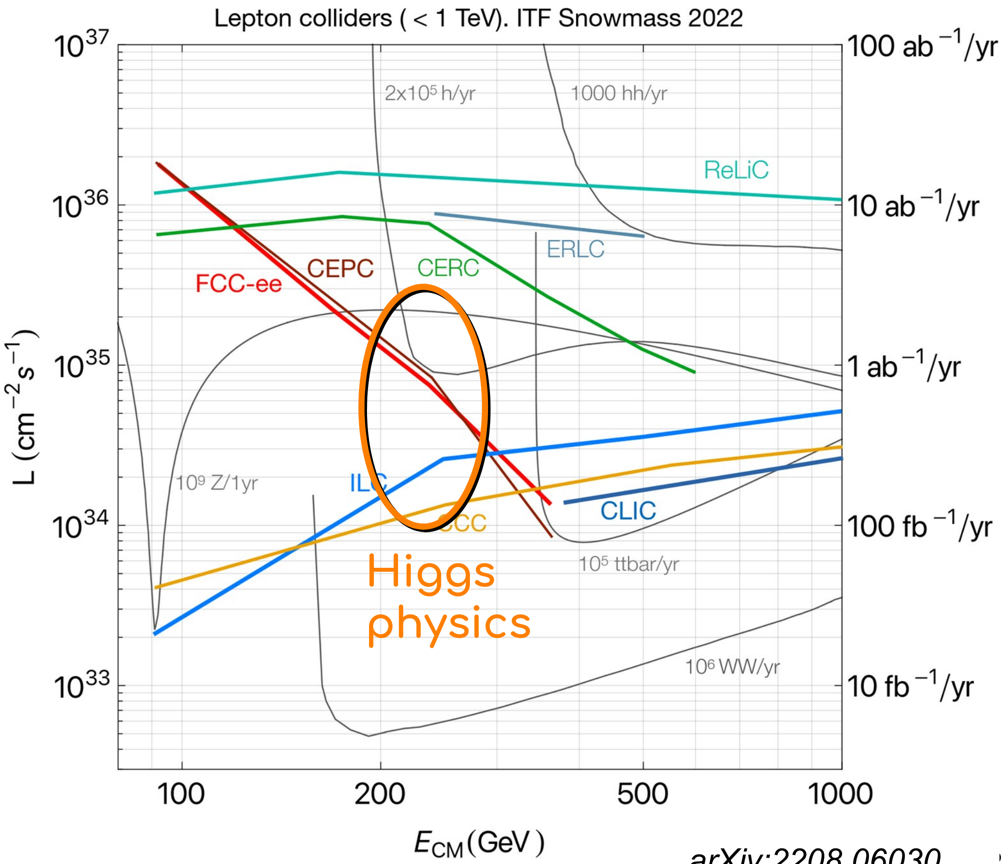

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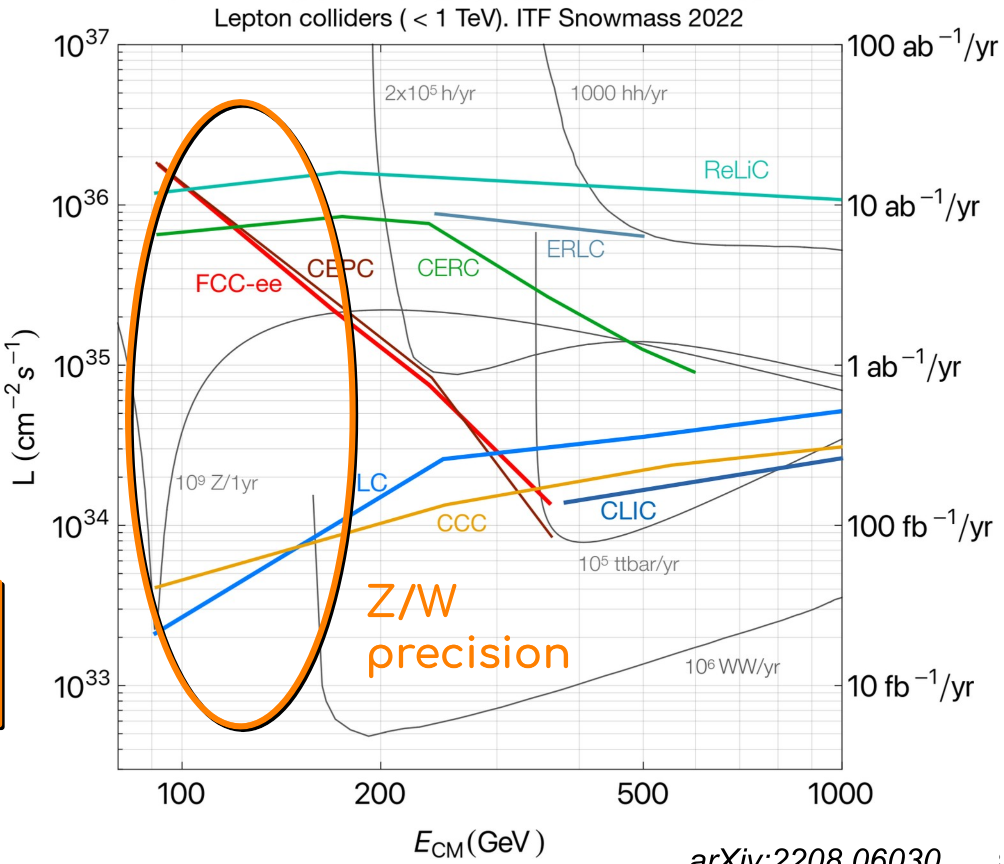

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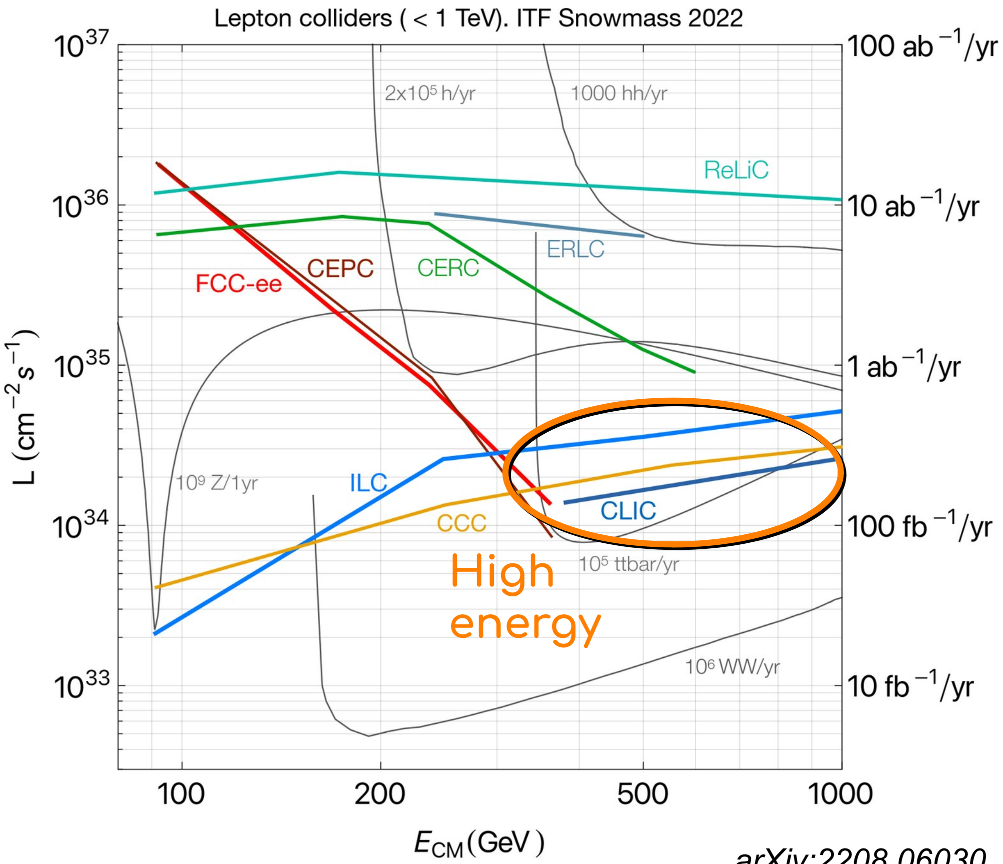

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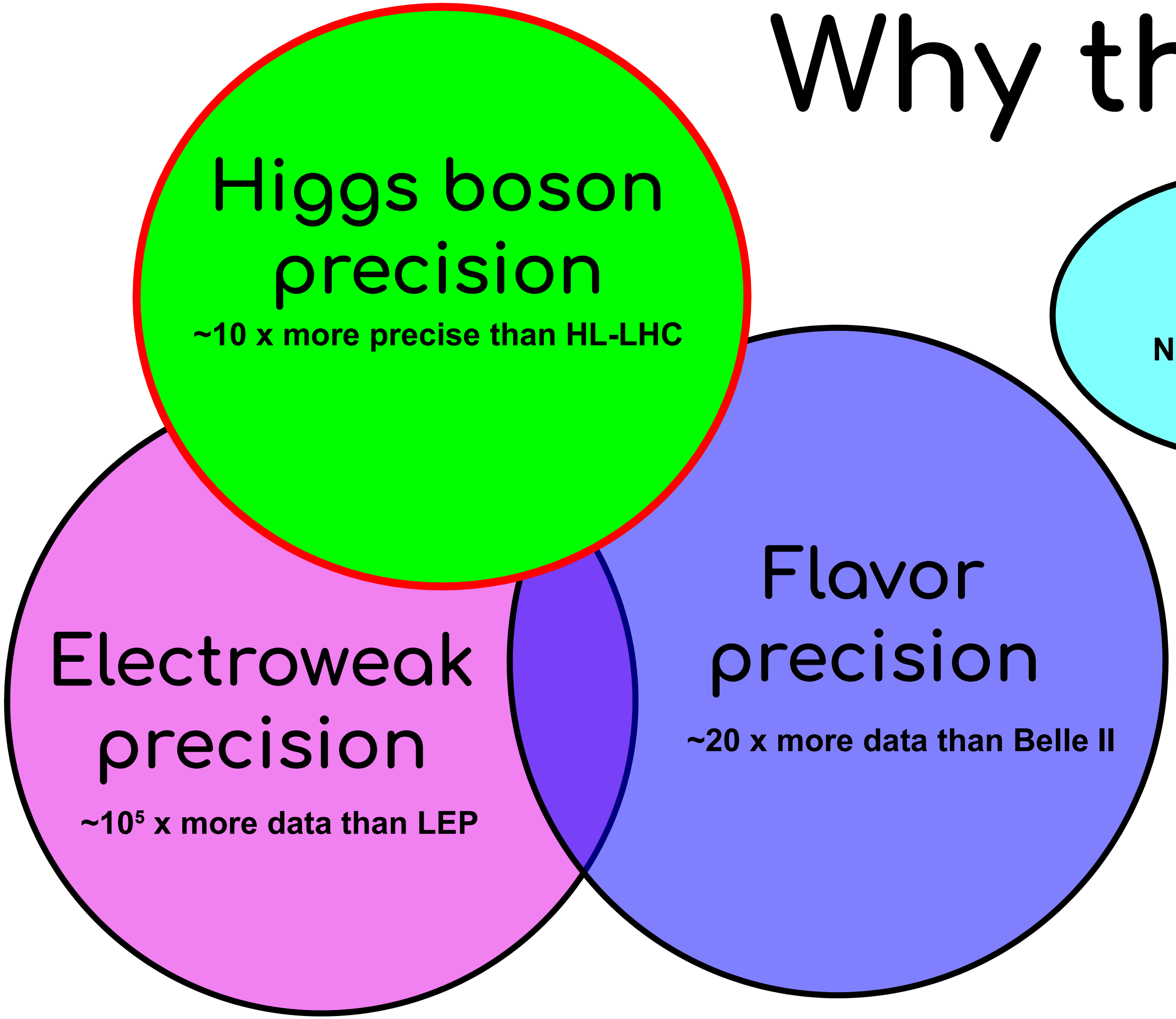
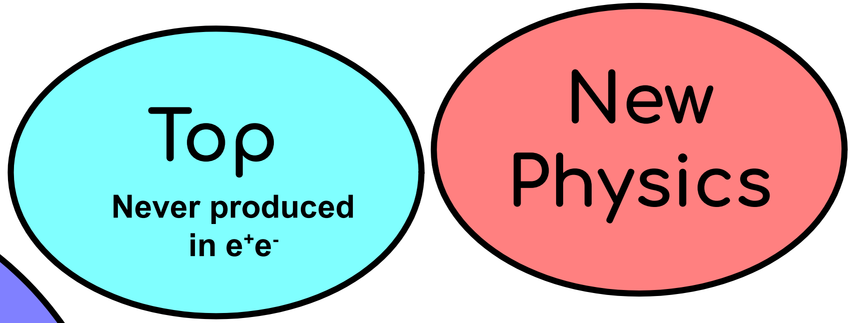
Why the FCC-ee?





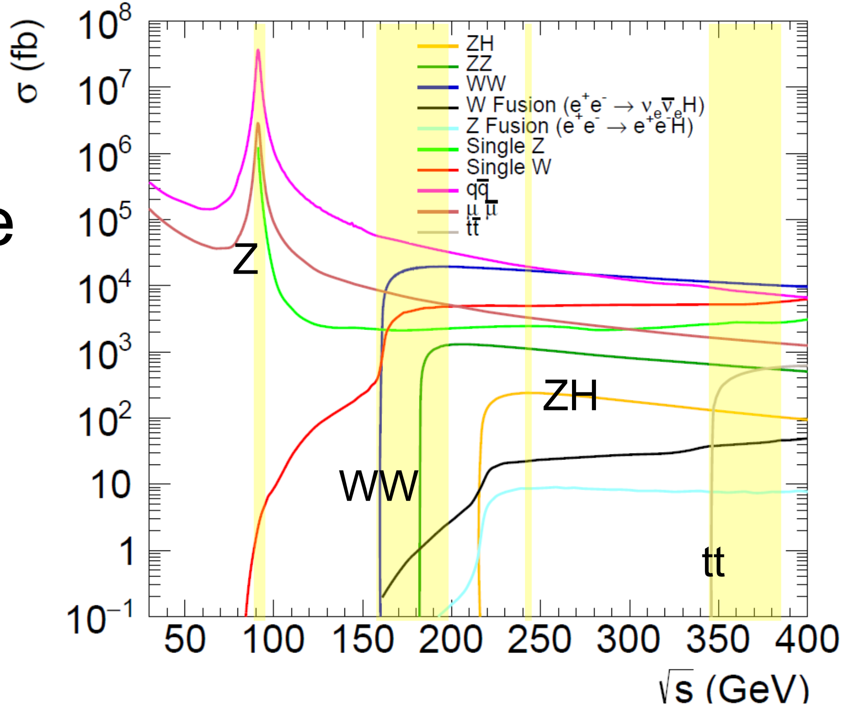
‘Low mass’ and high luminosity

↓

Kind of ‘Intensity frontier’

FCC-ee is a **precision machine**

FCC-ee Run Plan



The baseline run plan for FCC-ee

- Z run has most events followed by WW run
- The precision expected is extraordinary
  - Z: $1/\text{sqrt}(10^{12})$ = **10^{-6}**; WW: $1/\text{sqrt}(10^{8})$ = **10^{-4}**
- $O(10^6)$ Higgs bosons, ultra clean
- Top quark has never been studied at lepton collider

Working point	Z, years 1-2	Z, later	WW, years 1-2	WW, later	ZH	$t\bar{t}$	
$\sqrt{s}$ (GeV)	88, 91, 94		157, 163		240	340–350	365
Lumi/IP (10^{34} cm^{-2}s^{-1})	70	140	10	20	5.0	0.75	1.20
Lumi/year (ab^{-1})	34	68	4.8	9.6	2.4	0.36	0.58
Run time (year)	2	2	2	0	3	1	4
Number of events	$6\,10^{12}$ Z		$2.4\,10^{8}$ WW		$1.45\,10^6$ HZ + 45k WW → H	$1.9\,10^6$ $t\bar{t}$ +330k HZ +80k WW → H	

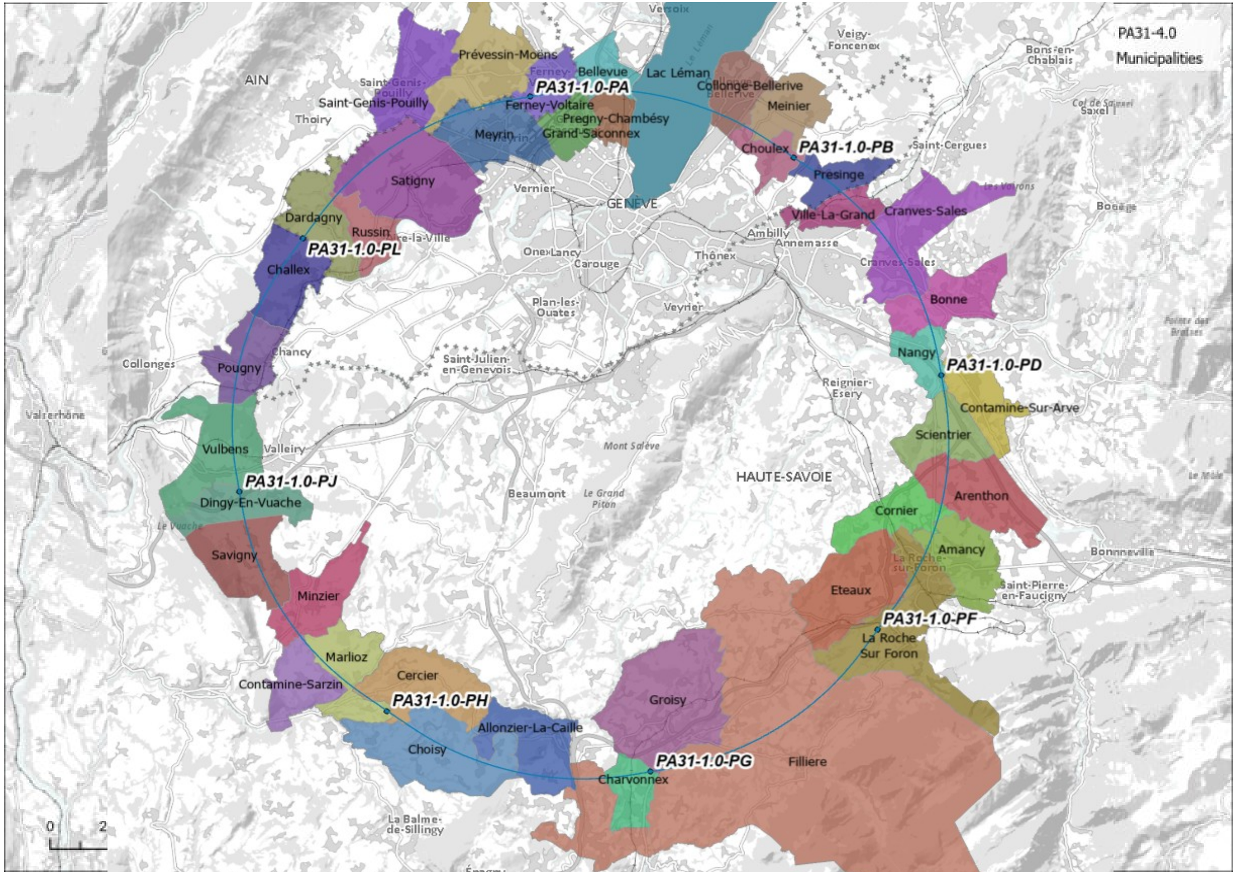
What is the FCC?

Key parameters

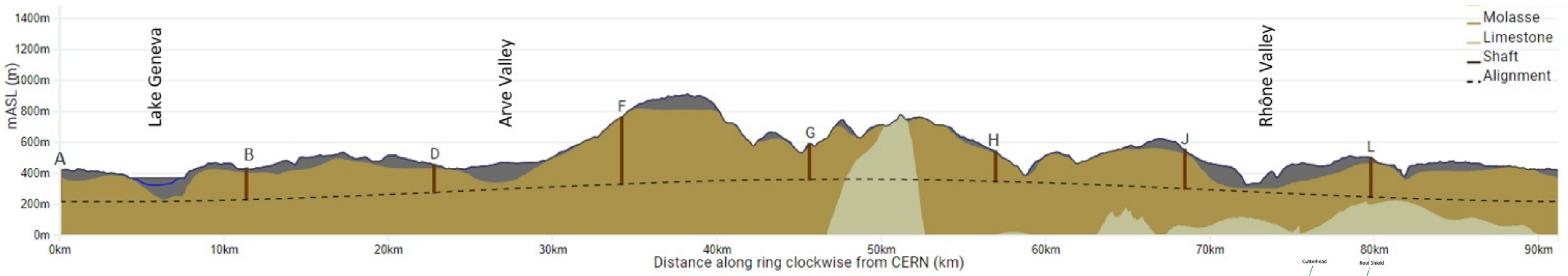
- 91 km tunnel (56 miles)
- About 80k magnets
  - Dipole, quadrupole, sextupole

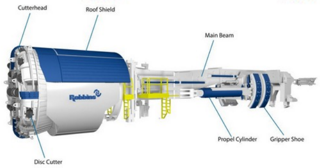
A staged program

- First FCC-ee phase: Higgs Factory push precision frontier
- Then FCC-hh period pushes energy frontier



What is the FCC?





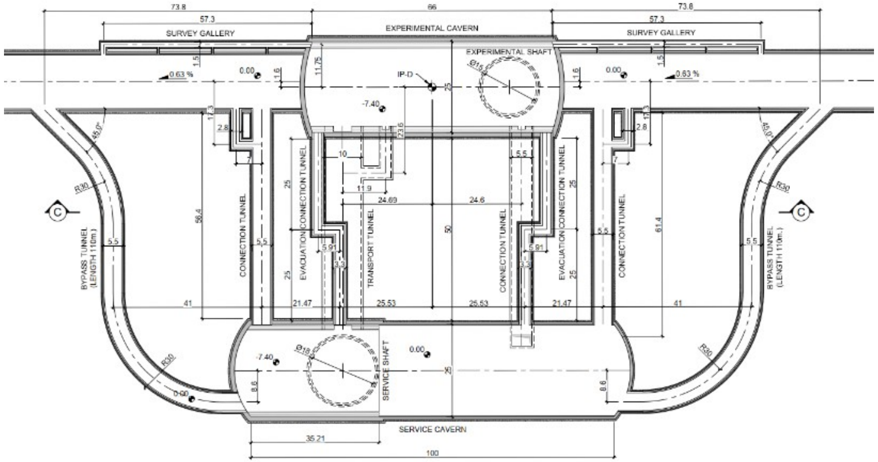
Massive civil engineering enterprise

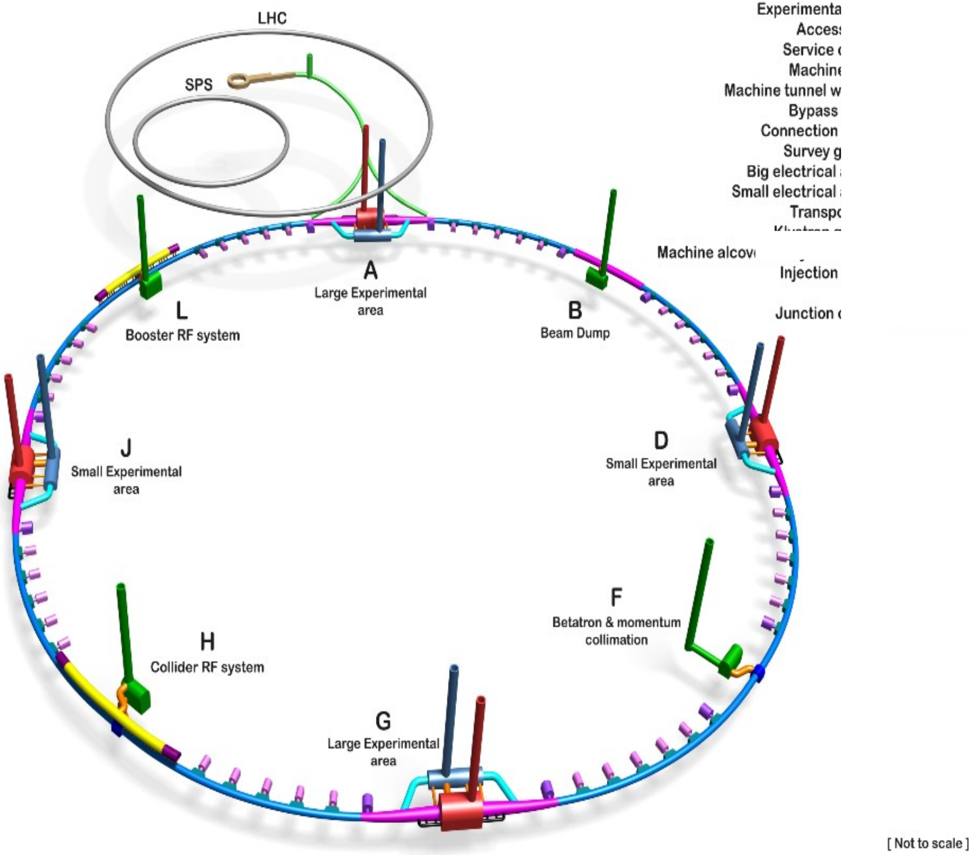
- Tunneling mainly in molasse/soft rock layer → fast, low-risk Tunnel Boring Machine construction
- Excavated volume: 6 million m^3 in situ, 8.5 million m^3 excavation material on surface
- Management of excavated materials is a complex topic in itself but well advanced
- CE designs of all underground structures developed
- Final vertical tunnel position of tunnel need detailed input on geological layer interfaces

What is the FCC?

Massive civil engineering enterprise

- CE designs of all underground structures developed

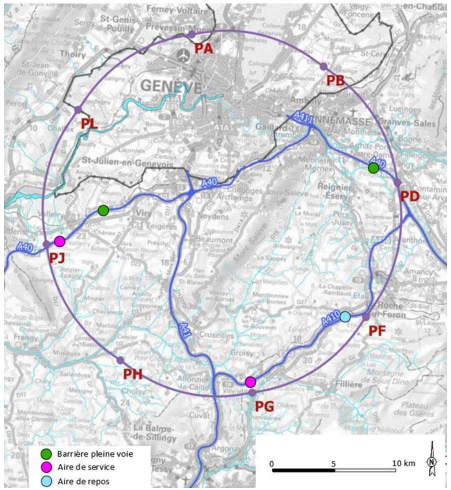


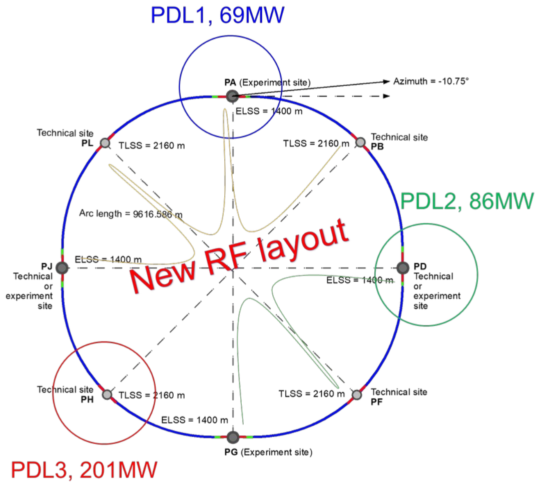


Civil engineering: streets and power

Accessibility

- Road accesses for all 8 sites conceived
- 4 possible motorway connections studied
- Less than 4 km of new roads or road improvements.





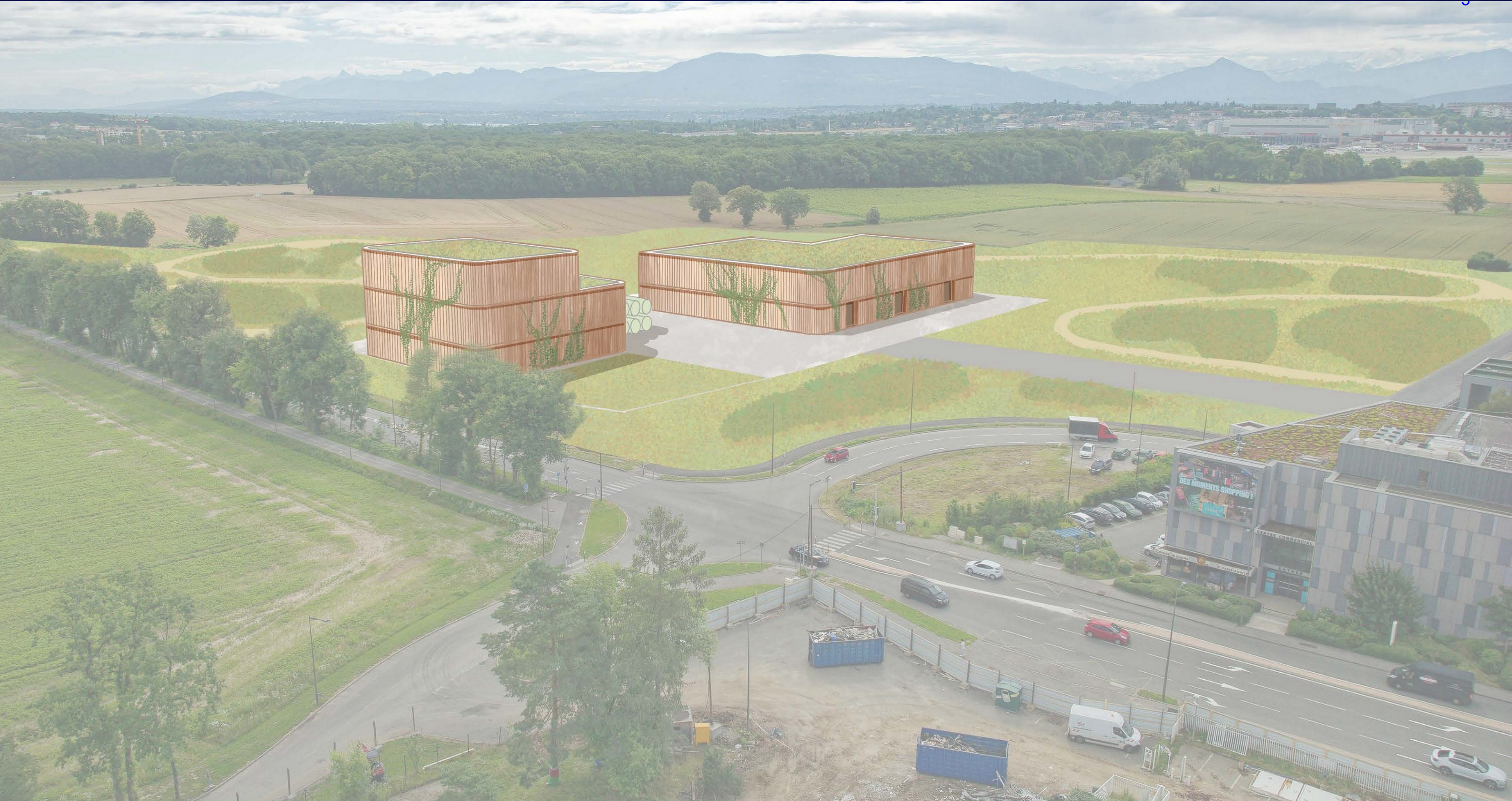
Electricity

- Construction: 7 local connections in France and 1 in Switzerland.
- Operation: 2 new connections to French electricity grid.
- Concept developed with RTE (French grid operator).
- Load has no significant impact on grid stability and resource needs.
- Further efforts are required to reduce energy needs and develop an “adaptive operation scheme” for both, FCC-ee and FCC-hh for increased economic and societal performance.

https://indico.cern.ch/event/1439509/contributions/6287215/attachments/2994411/5275491/FCC-250111700-JGU_PhysicsMeetingPresentationCERN_V0100.pdf


DES MOMENTS SHOPPING !
CENTRE COMMERCIAL
CUISINE INDIENNE
ET PAKISTANAISE
ENTREE

Caution: this image is not a design. It represents architectural concept opportunities only.



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What is the U.S. position?

The 2023 Decadal P5 report

Decadal DOE/NSF HEP prioritization panel

- After long community deliberations produced an excellent and overwhelmingly supported report in December 2023

P5 Recommendation 1

P5: *As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science.*

- *a) through g): HL-LHC, DUNE, Vera C Rubin, IceCube, DarkSide-20k, LHCb, …*

This means: finish what you started!

The 2023 Decadal P5 report

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P5 Recommendation 2 (continued)

P5: *Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future. [in priority order:]*

- *c) An off-shore Higgs factory, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility and design studies. Once a specific project is deemed feasible and well-defined (see also Recommendation 6), the US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US on-shore program in particle physics*

FCC-ee is a major priority for the future.

White House agreement

Joint statement was signed in the White house

Canada and CERN just (March 21, 2025) signed a similar agreement:

“Should the CERN Member States determine that the FCC is likely to be CERN’s next world-leading research facility following the High-Luminosity Large Hadron Collider, Canada intends to collaborate on its construction and physics exploitation, subject to appropriate domestic approvals.”

Open Science” was signed at The White House

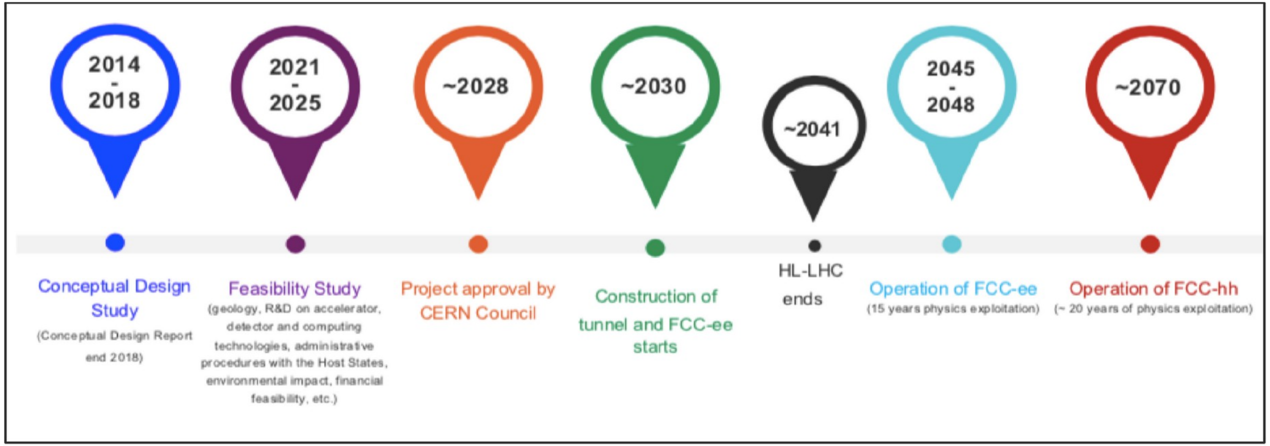
European Strategy Update 2025

FCC feasibility study was submitted yesterday

- No final text yet but …
- Mid term report of the FCC Feasibility study was substantial and got excellent reviews
- FCC-ee is the preferred CERN option for the future with a full scale feasibility study ‘completed’
- Community is largely behind the Higgs factory
- The how is still under some debate … FCC-ee versus Linear Collider ...

FCC-ee Schedule

From Fabiola's talk



1st stage collider FCC-ee:
electron-positron collisions 90-360 GeV: electroweak and Higgs factory
2nd stage collider FCC-hh:
proton-proton collisions at ~ 100 TeV

"Realistic" schedule taking into account:

- ❑ past experience in building colliders at CERN
- ❑ the various steps of approval process: ESPP update, CERN Council decision
- ❑ HL-LHC will run until ~ 2041

→ ANY future collider at CERN cannot start physics operation before ~ 2045 (but construction will proceed in parallel to HL-LHC operation)

Care should be taken when comparing to other proposed facilities, for which in most cases only the (optimistic) technical schedule is shown. In particular, studies related to **territorial implementation** (surface sites, roads, connection to water and electricty, environmental impact, admin procedures, etc.), which for FCC are being carried out in the framework of the Feasibility Studies, **take years.**

Case for precision

history repeats

Mercury’s Orbit

1609 – Johannes Kepler defined laws of planetary motion

- All orbits are ellipses
- Worked very well

1859 – Urbain Le Verrier

- Old data for Mercury showed an odd deviation
- Mercury orbit precessed faintly, but measurably: 5600”/century
- Other planets explain most, but 43”/century unexplained

1915 – Albert Einstein

- General relativity explains the missing 43”/century

https://www.astronomicalreturns.com/2020/05/the-mystery-of-mercurys-missing.html

Precise measurements matter!

Z boson – Neutral Current

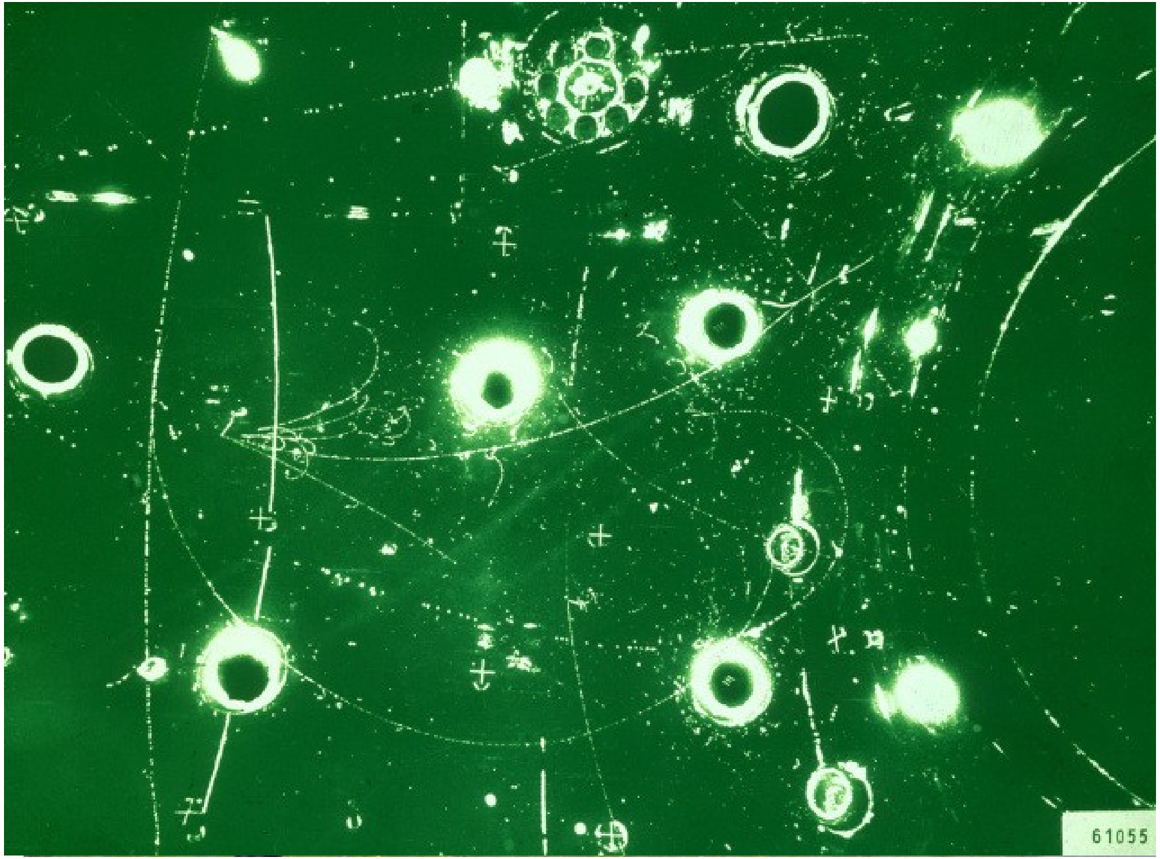
1961 – Sheldon Glashow

Unifies EM and Weak

- introduces neutral boson

1970ies – Gargamelle

- Amazing amount of data was taken in neutrino beam from 26 GeV protons
- Some rare neutral current events observed (1973)
- First indication of Z boson



https://cds.cern.ch/record/39470

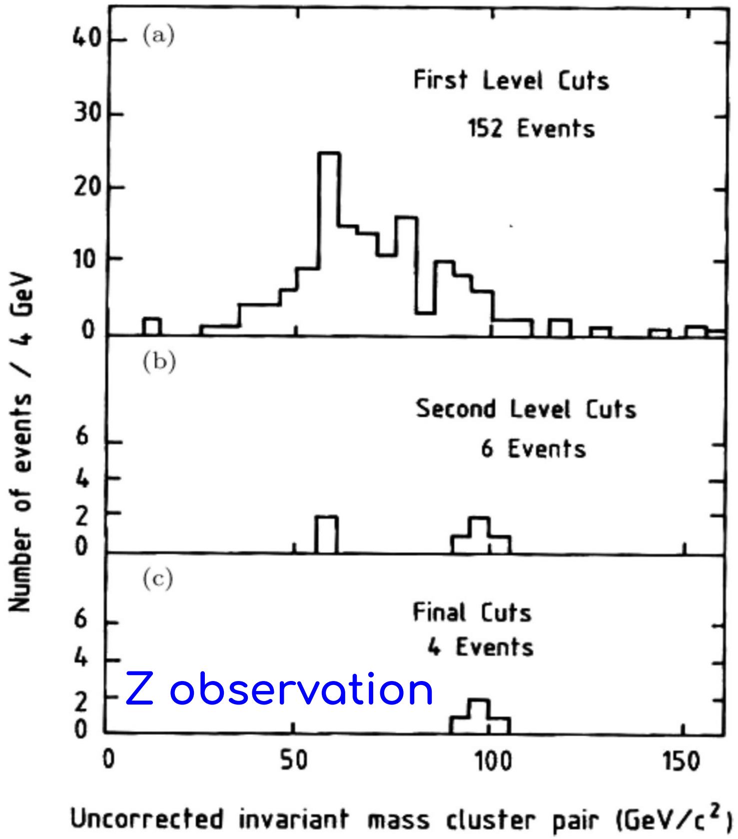
Discovery of Weak Bosons

1983 – UA1 and UA2 find W and Z bosons

- Direct discovery at SPS
- Special collider stochastic cooling

What next?

- Precise measurements are important, let's measure them
- ... and also, can we find the Higgs boson



Enters the LEP/LHC program

1989-2001 – LEP (e+e-)

- Precision machine
- Z and WW production
- Radiative corrections

2009-2042 – LHC (pp)

- Discovery machine
- Found the Higgs
- Measure the Higgs
- Searching for new physics

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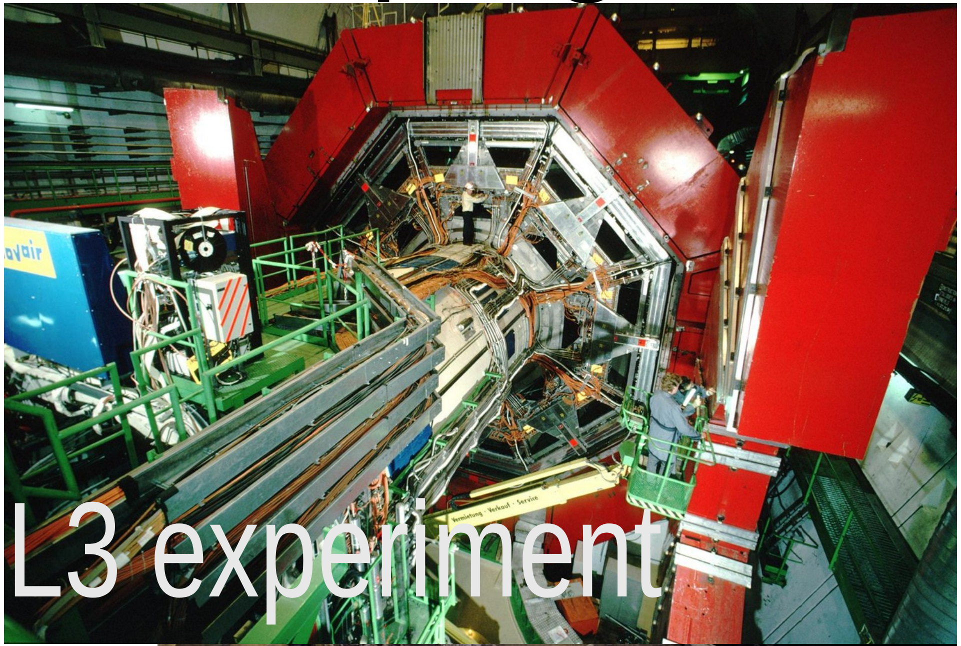

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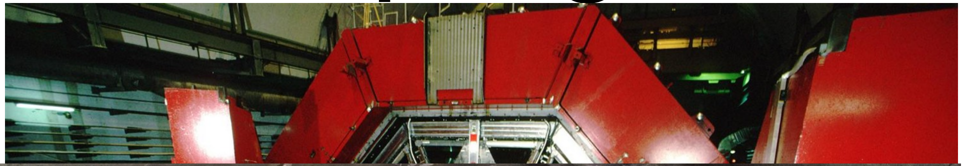

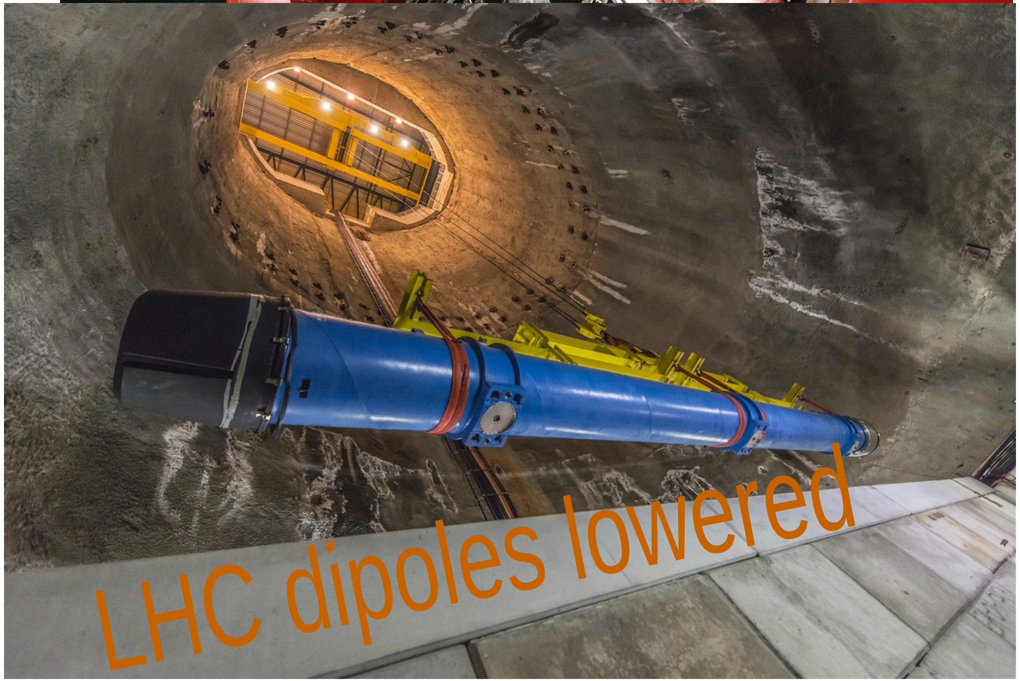

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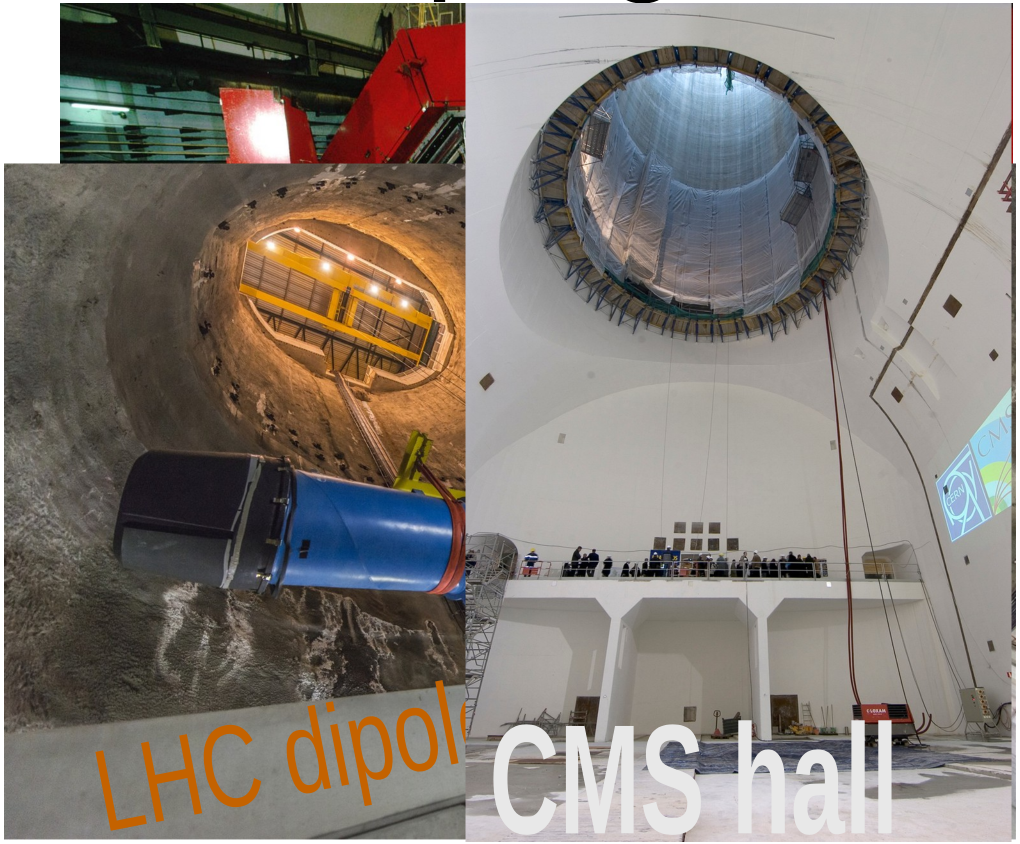

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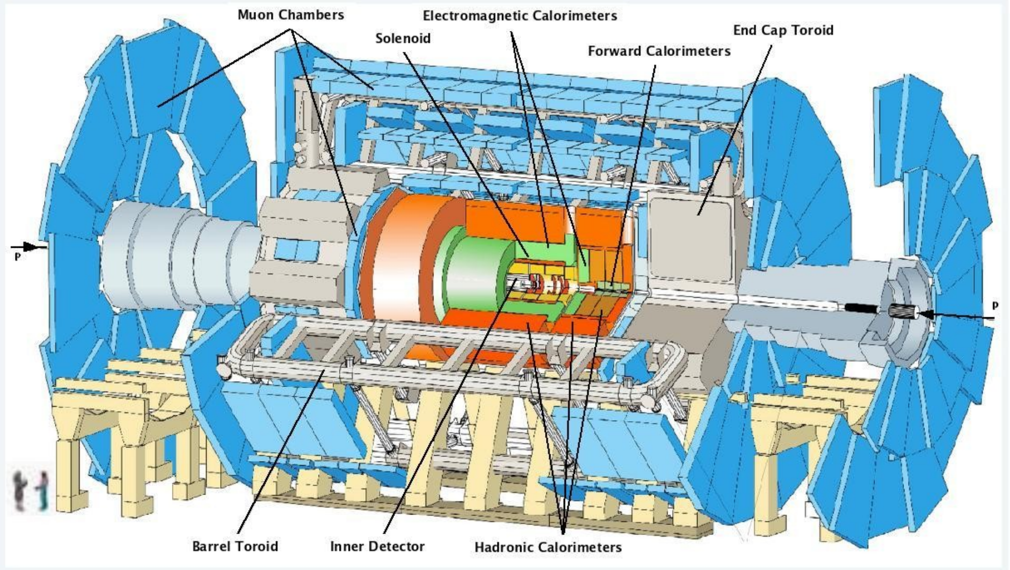
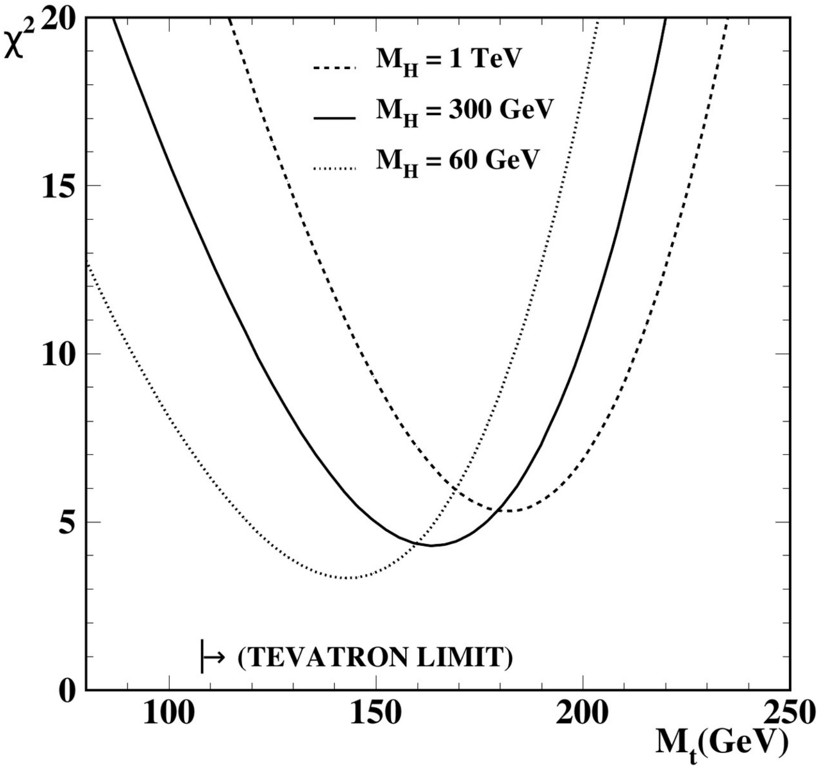


Constraints from Precision

1993 – Before the top discovery

- Missing pieces in *minimal* standard model calculations were parameters m_H and m_t
- Dependence (large $m_t \rightarrow$ large m_H): quadratic in m_t and logarithmic in m_H
- m_t prediction after *obvious constraints* on m_H
- No constraint on m_H

	LEP	LEP + Collider and ν data
M_t (GeV)	$166^{+17}_{-19}{}^{+19}_{-22}$	$164^{+16}_{-17}{}^{+18}_{-21}$
$\alpha_s(M_Z^2)$	$0.120 \pm 0.006 \pm 0.002$	$0.120 \pm 0.006 \pm 0.002$
$\chi^2/(d.o.f.)$	3.5/8	4.4/11
$\sin^2\theta_{eff}^{lept}$	$0.2324 \pm 0.0005 {}^{+0.0001}_{-0.0002}$	$0.2325 \pm 0.0005 {}^{+0.0001}_{-0.0002}$
$1 - M_W^2/M_Z^2$	$0.2255 \pm 0.0019 {}^{+0.0005}_{-0.0003}$	$0.2257 \pm 0.0017 {}^{+0.0004}_{-0.0003}$
M_W (GeV)	$80.25 \pm 0.10 {}^{+0.02}_{-0.03}$	$80.24 \pm 0.09 {}^{+0.01}_{-0.02}$



CERN/PPE/93-157
26 August 1993

LEP Electroweak Working Group report
For EPS in Marseille 1993

Discovery of the top quark

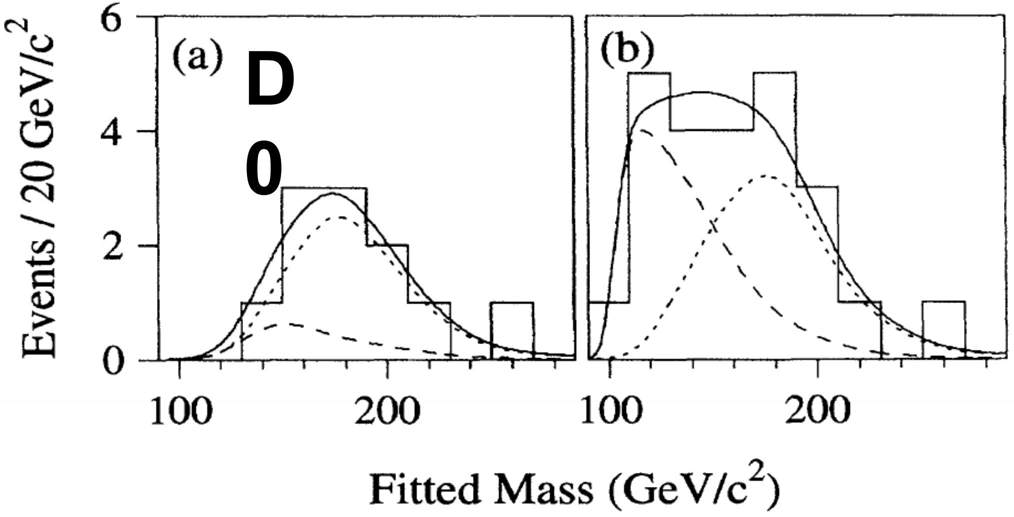
1994 – Evidence for the top quark

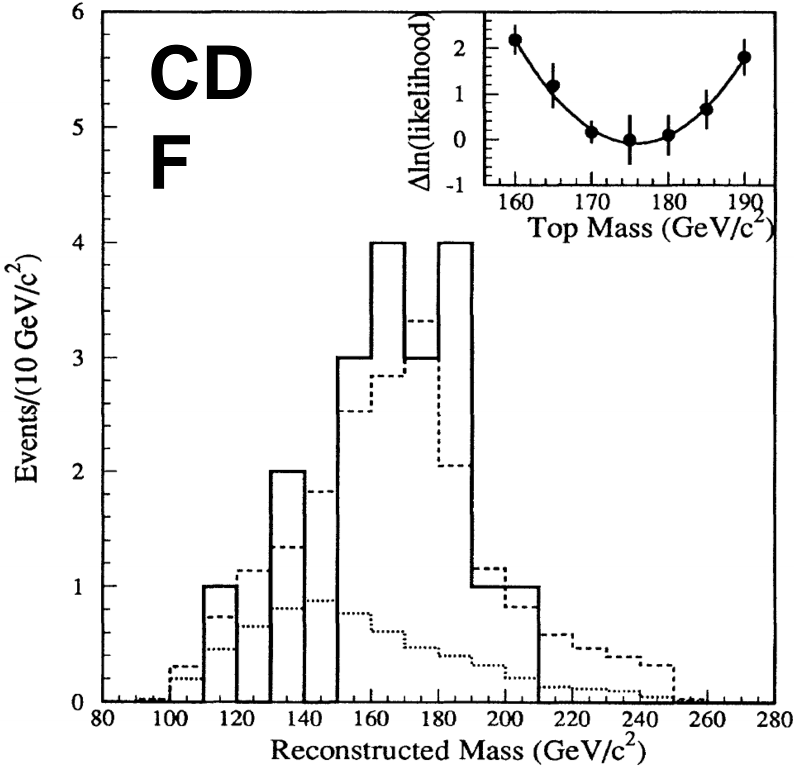
- CDF and D0 experiments see tantalizing hints

1995 – Observation of the top quark

- CDF and D0 announce the observation

Tevatron (pp̄) is a discovery machine

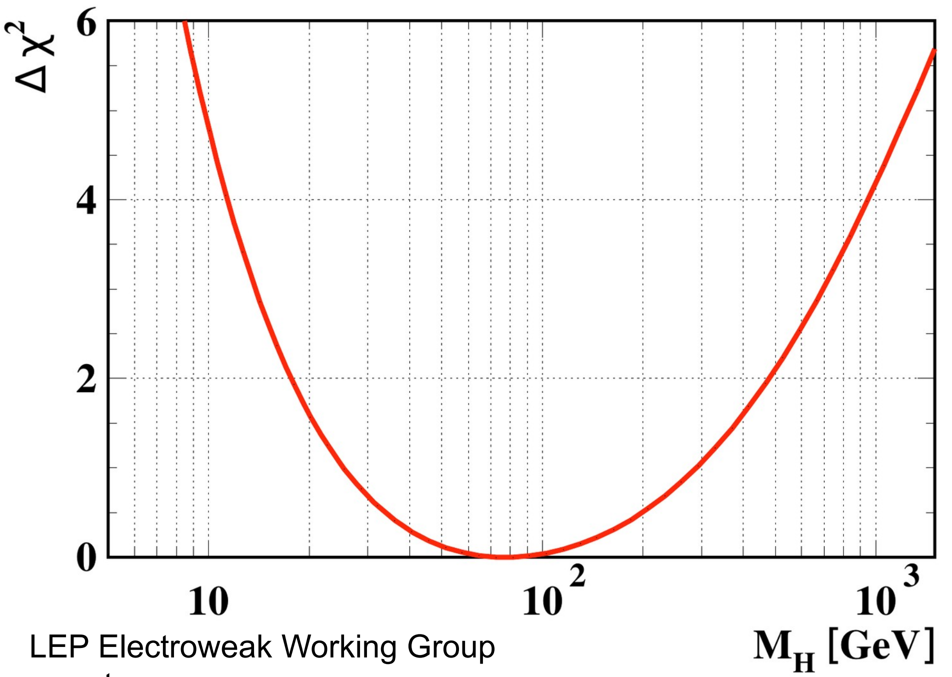




Constraints from Precision

1995 – After the top discovery

- Top quark was tied down enough* and all precision was brought to bear on the Higgs boson
- First plot indicated low Higgs boson mass but 10-1000 GeV still possible at 95% CL (note log scale!)
- The blueprint for Higgs constraints from precision data



LEP Electroweak Working Group report
For ICHEP in Glasgow 1994

CERN/PPE/94-187
25 November 1994

* evidence from CDF in April 1994:

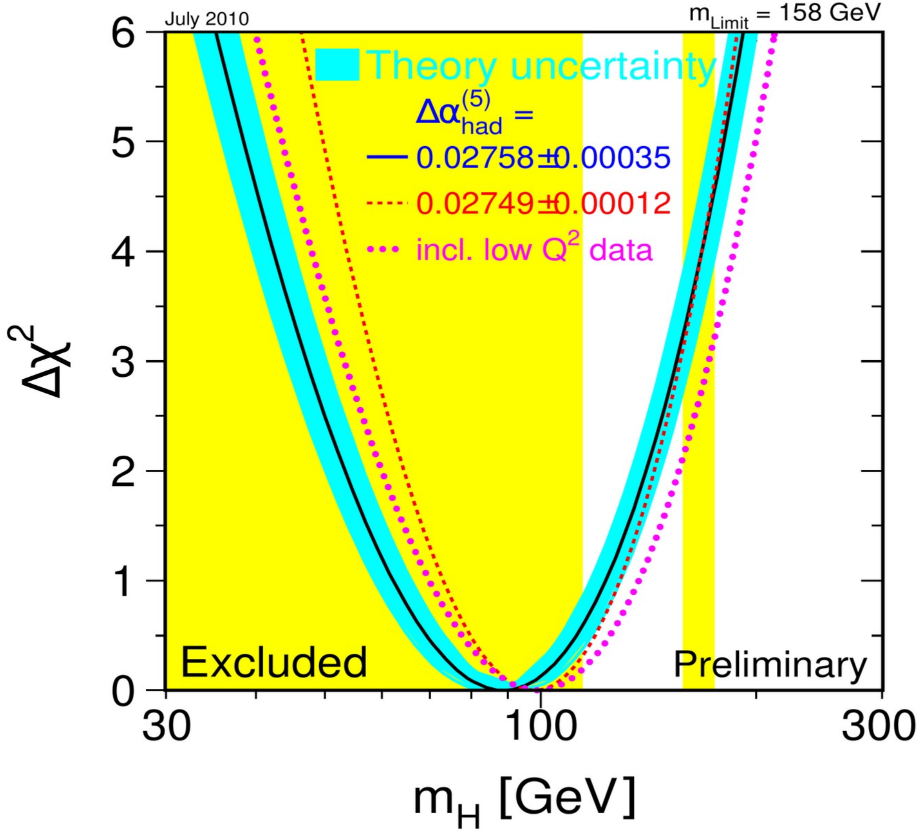
$$m_t = 174 \pm 10^{+13}_{-12}\ \text{GeV}$$

F. Abe *et al.*, Phys. Rev. Lett. 73 (1994) 225

Constraints from Precision

2010 – Years of hard work

- Discovery of the top quark at Tevatron
- More precise data added at LEP and SLC
- Measurement of m_W at LEP and Tevatron
- Comparing to data from neutrinos and various low Q^2 experiments … all is consistent



Final Electroweak Working Group report 2010:
https://arxiv.org/pdf/1012.2367v2.pdf

LEP/LHC

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FCC-ee/FCC-hh

FCC-ee Accelerator feats

Accelerator: Crab Waist Collisions

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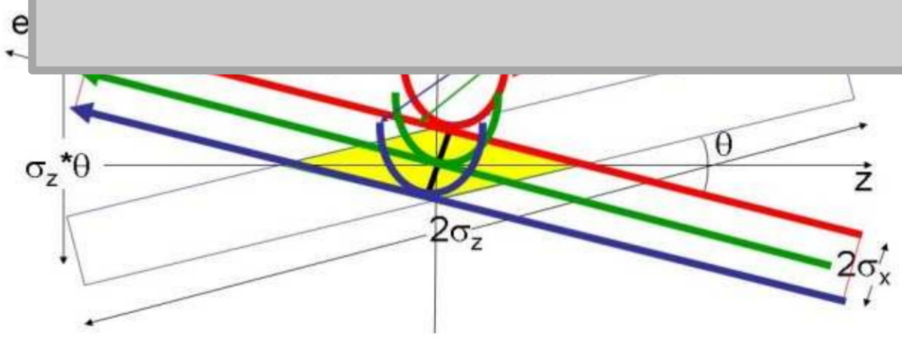
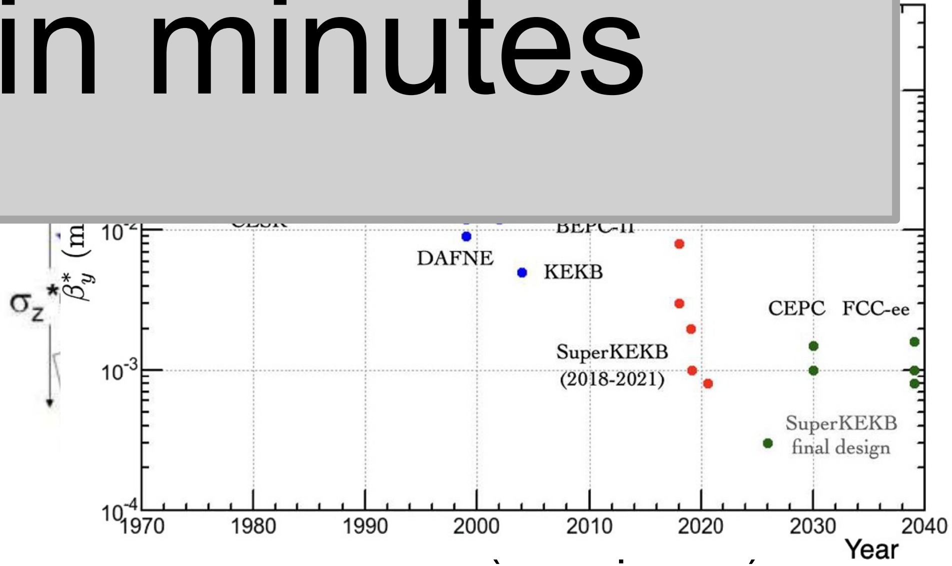
FCC-ee will accumulate all LEP data in minutes



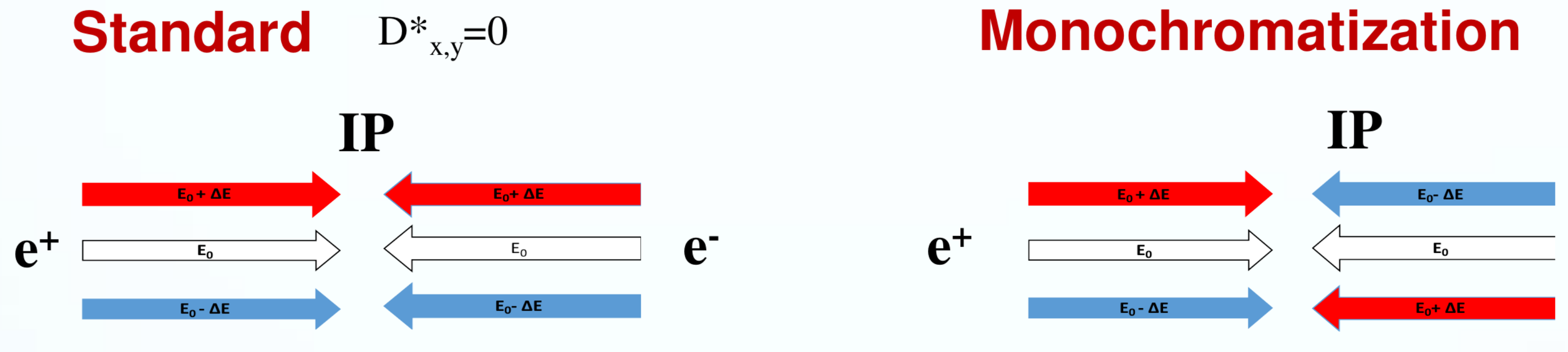
No crab waist (sextupol off)



Accelerator: Monochromatization

Innovative collision scheme

- Match higher beam energy on one beam with lower energy on the other beam
- Reduces the spread of collision energy substantially
- Will lead to some luminosity loss
- Proposed in 1975 but **never tested experimentally**



$$w = 2(E_b + \epsilon)$$

$$w = 2E_b + 0(\epsilon)^2$$

A. Renieri. Possibility of Achieving Very High-Energy Resolution in electron-Positron Storage Rings. LNF Report, LNF-75/6-R, 2 (1975)

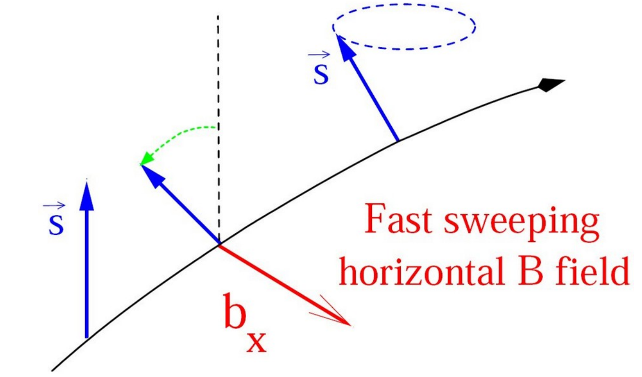
Accelerator: Calibration

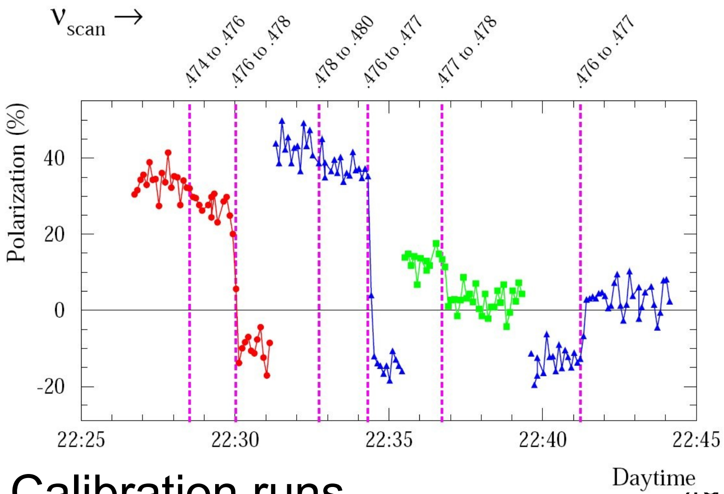
LEP energy calibration (resonant depolarization)

- Transverse polarization builds up automatically (Sokolov-Ternov)
- Monitor transverse polarization level
- Kick precessing electrons with periodic magnetic field and tune frequency which destroys polarization resonantly (frequency → β_e)
- 0.5 MeV on 45 GeV beams (main uncertainty extrapolation over time and other energies)

FCC-ee calibration in situ (on steroids)

- Pilot bunch is used while taking data: ~20 keV



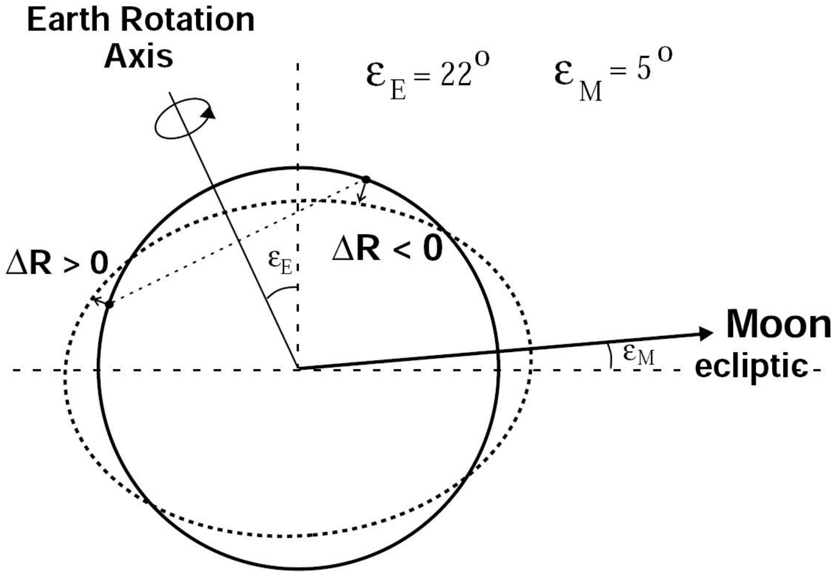


Calibration runs

LEP calibration nightmares

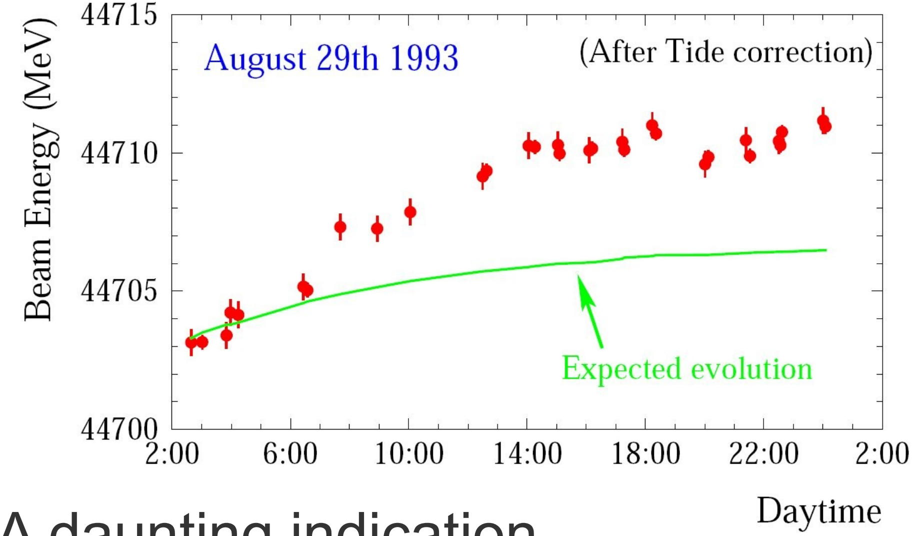
Part 1

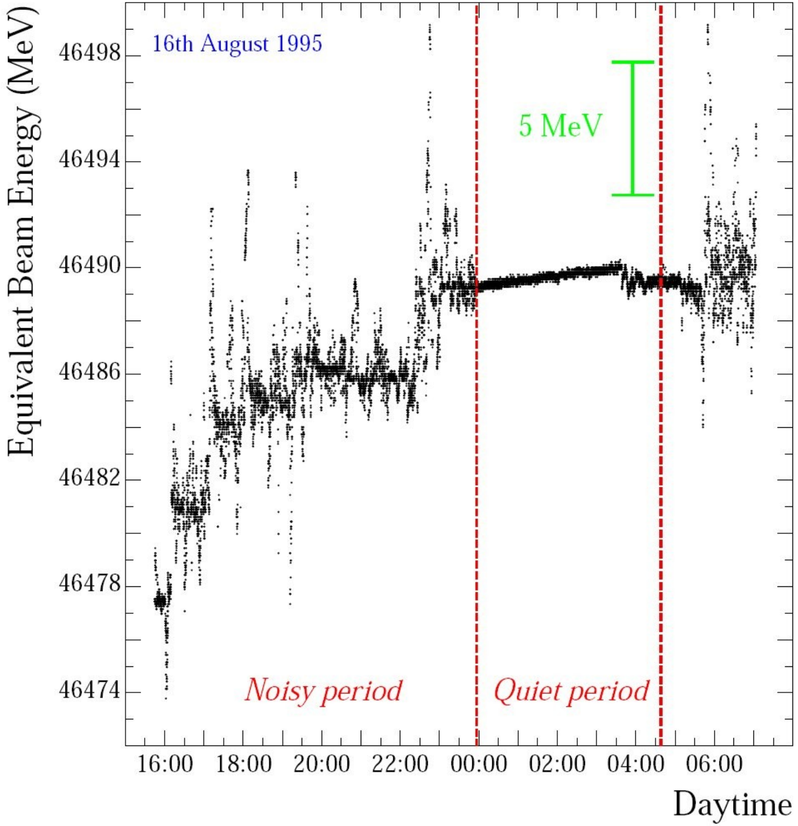
- calibration changes sensitive to
  fluctuations in first calibrations e



LEP calibration nightmares

Part 2





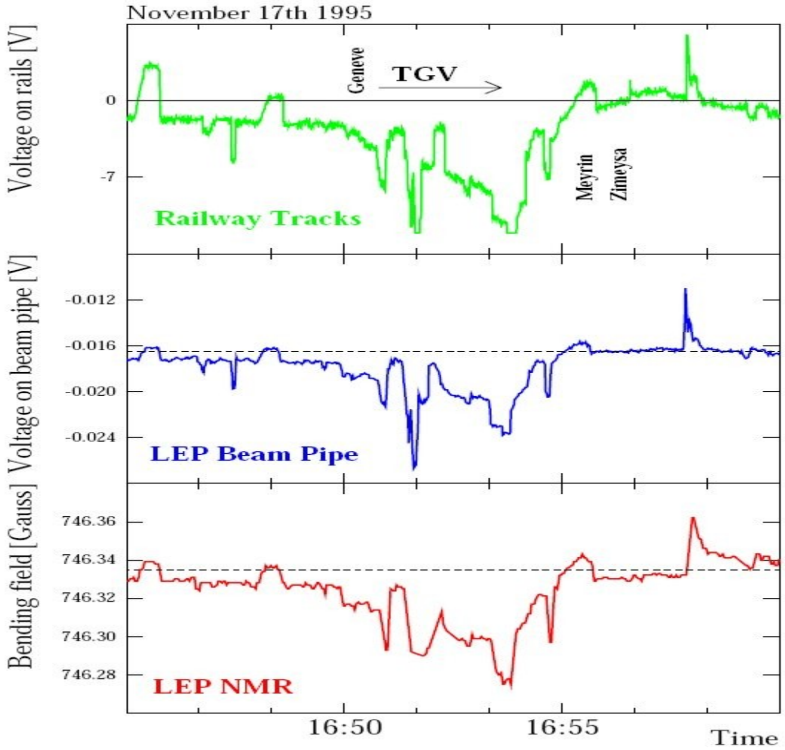
A daunting indication

- will remain unexplained for 2 years ….
- until undergrad from Aachen comes out for the summer

Smoking gun: it’s a man made problem

LEP calibration nightmares

The French DC trains caused the problem



1 A current on beampipe

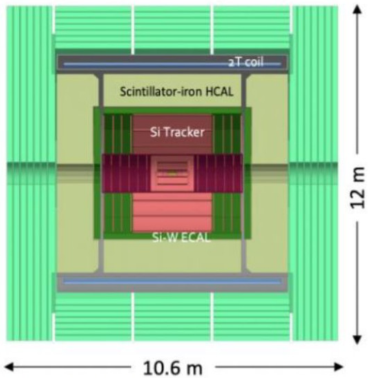
FCC-ee
Detector feats

Basic Detector Designs

Detector Benchmarks

ALLEGRO

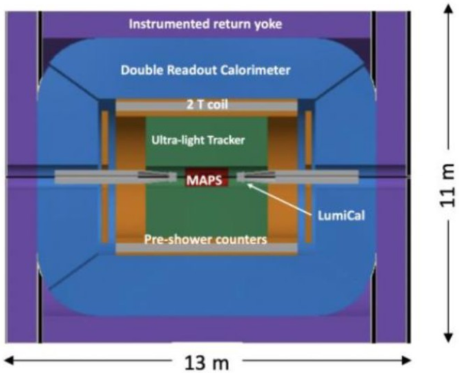
CLD



- 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)?

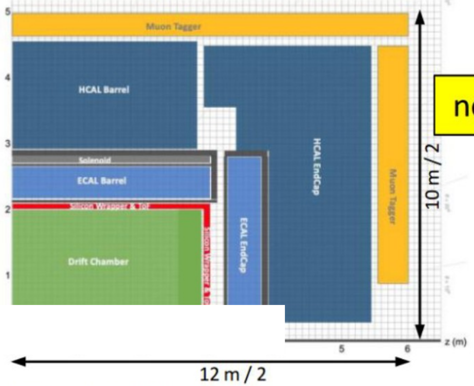
CDR

IDEA



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

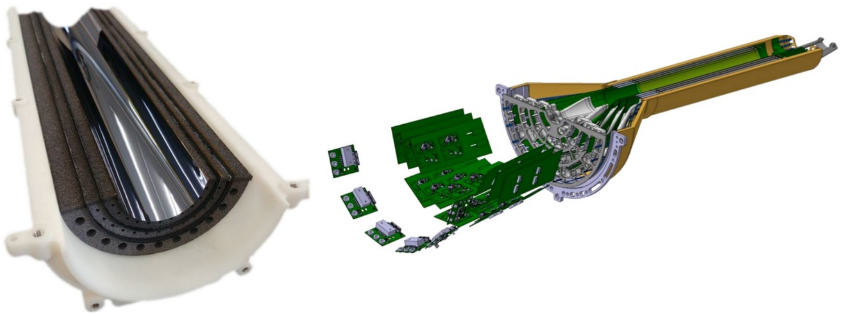
Noble Liquid ECAL based



new

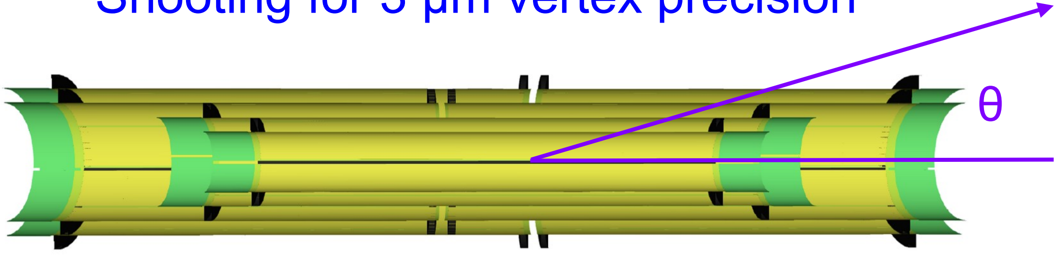
- A design in its infancy
- Si vtx det., ultra light drift chamber (or Si)
- High granularity Noble Liquid ECAL as core
  - Pb/W+LAr (or denser W+LKr)
- CALICE-like or TileCal-like HCAL;
- Coil inside same cryostat as LAr, outside ECAL
- Muon system.
- Very active Noble Liquid R&D team
  - Readout electrodes,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

Vertex detector – Ultralight

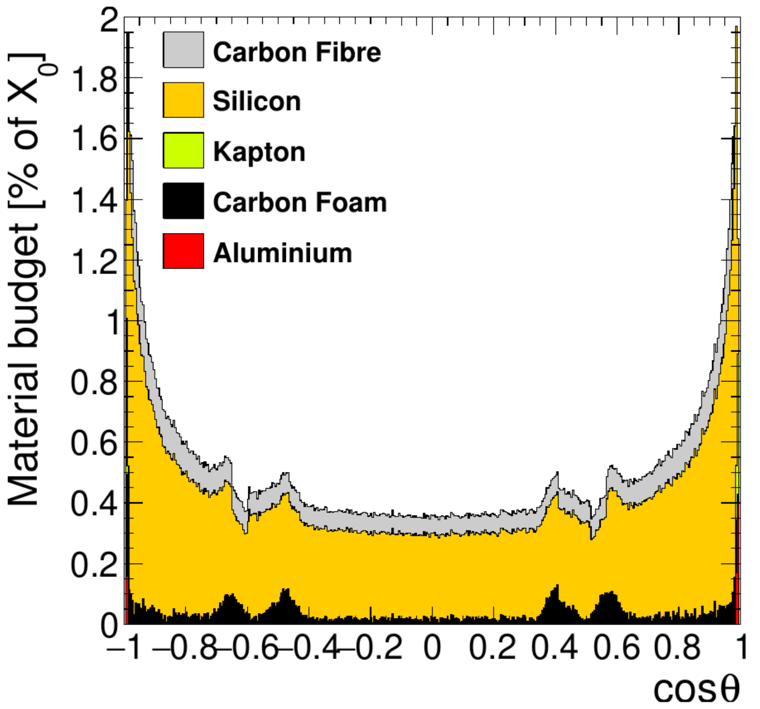


CMOS MAPS detectors

- **Monolithic Active Pixel Sensor**
- Very low material budget
- Bendable to be truly half cylinder
- Very low power consumption due to onboard electronic
- Can be air cooled at the FCC-ee
- Shooting for 3 μm vertex precision



Full four layer layout



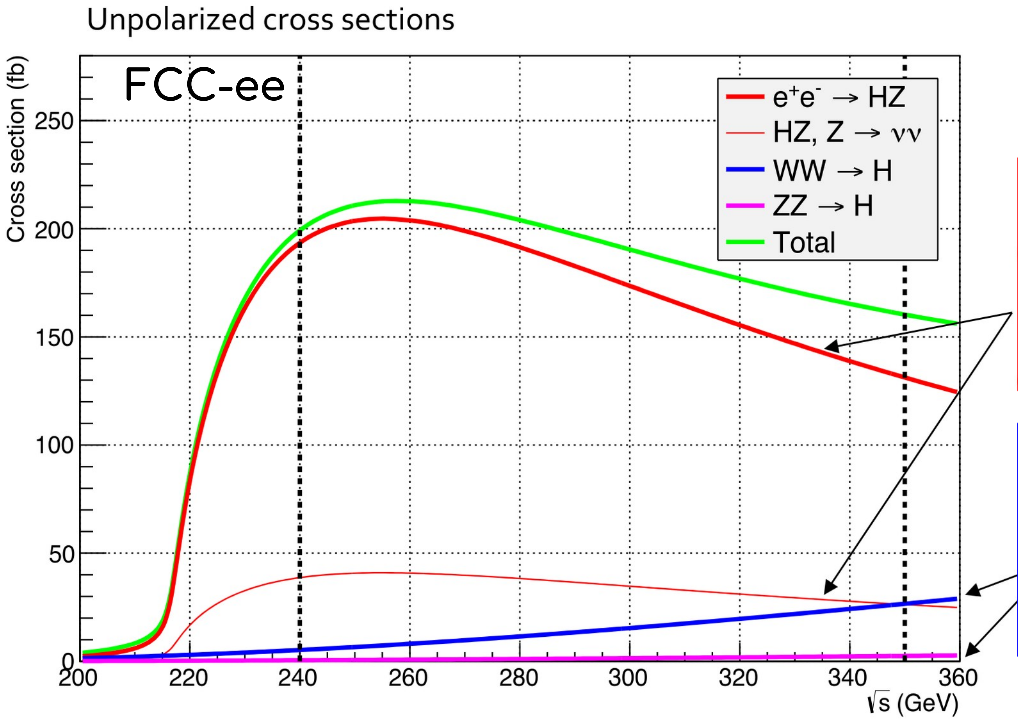
Higgs Physics Highlights

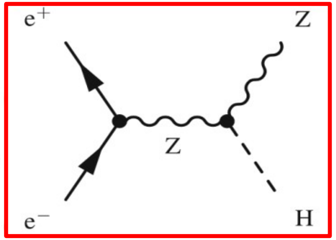
Higgs Physics at e+e- Colliders

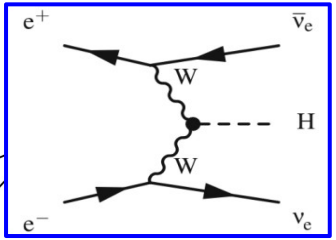
ZH Threshold turns on at 91 + 125 GeV = 216 GeV and reaches a maximum at around 255 GeV

Vector boson fusion rises steadily but is small

FCC-ee: most Higgses at 240 GeV for FCC-ee considering lumi profile







arXiv:1308.6176

Higgs Physics at e^+e^- Colliders

Leading strategy

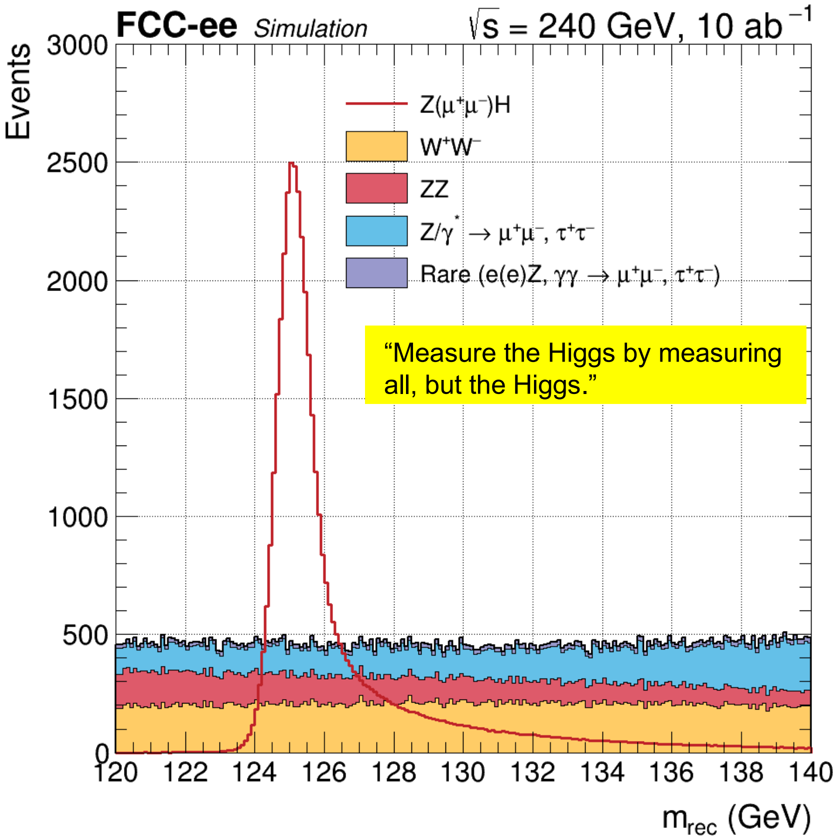
- **Reconstruct Z boson (leptons or jets)**
- Recoil mass peaks sharply at Higgs mass

$$m^2_{\rm recoil} = (\sqrt{s} - E_{ff})^2 - p^2_{ff}$$
$$= s + m^2_{\rm Z} - 2E_{ff}\sqrt{s} \approx m^2_{\rm H}$$

- Direct Higgs reconstruction not required, model independent σ_{ZH} measurement
- Dominant background: WW, ZZ and Z/γ*

Challenges

- Detectors: resolution, tracking, vertexing, timing, angular
- Flavour tagging for Higgs couplings
- Jet reconstruction algorithms

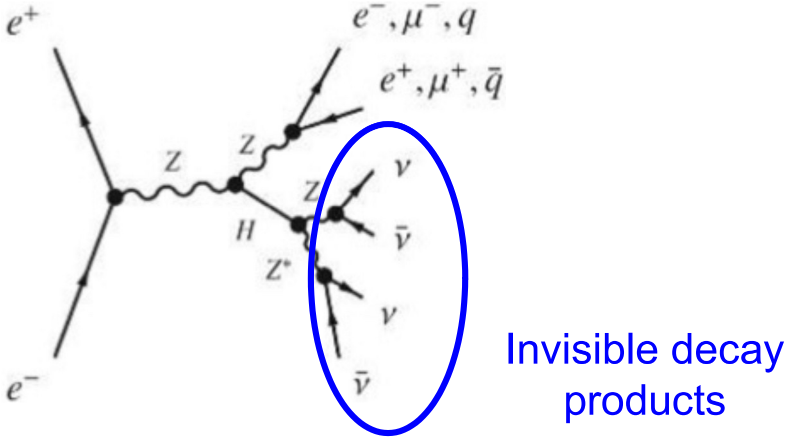


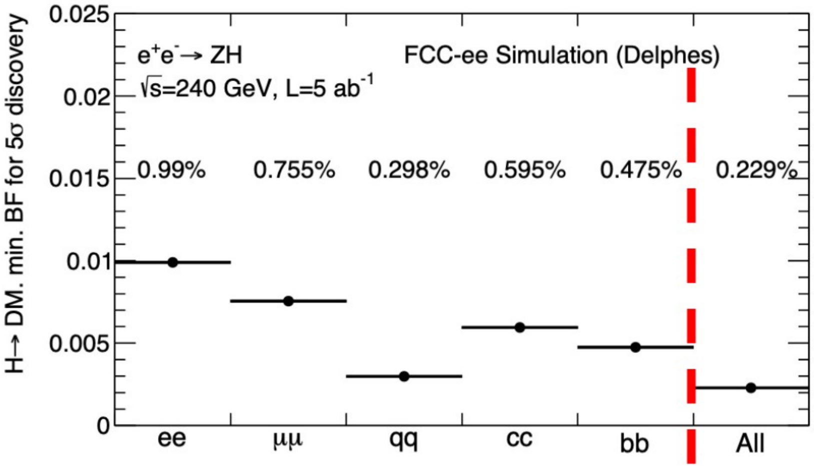
This plot does not work at hadron colliders.

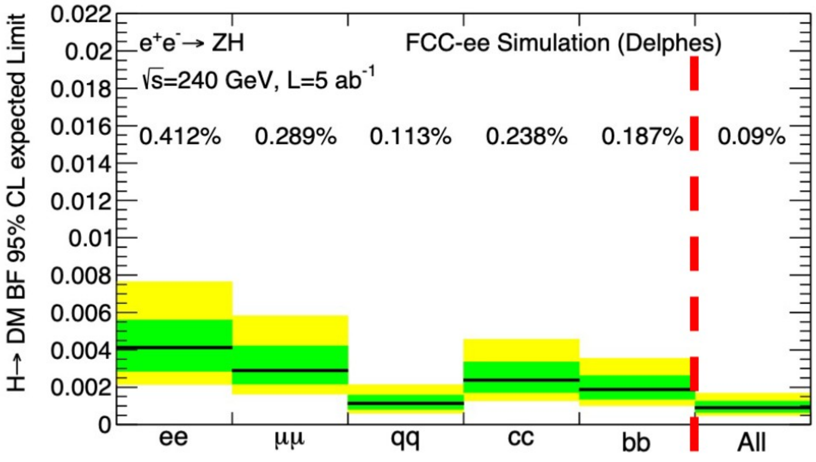
Higgs Invisible Width

Higgs boson: portal to dark world?

- **Reconstruct recoil mass**
- Require no more activity beyond Z boson
- Measure H→ZZ→νννν
- Then remove as SM background







Precision - Higgs

Points to note

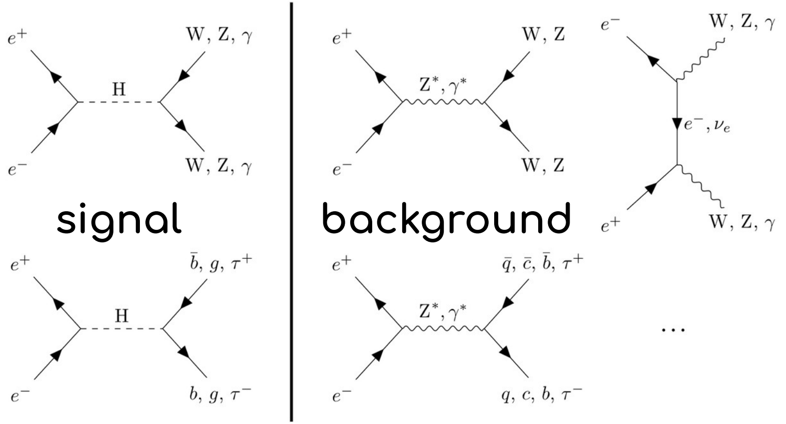
- These are relative uncertainties in %
- All measurements are statistically limited
- All neutrino decay in reach
- Strange quark coupling closer

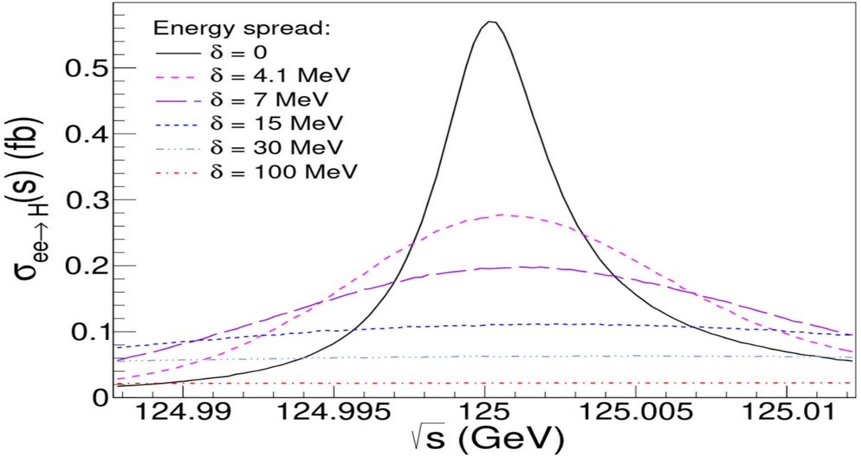
$\sqrt{s}$	240 **GeV**		365 **GeV**	
channel	**ZH**	**WW → H**	**ZH**	**WW → H**
ZH → any	±0.31		±0.52	
γH → any	±150			
H → bb	±0.21	±1.9	±0.38	±0.66
H → cc	±1.6	±19	±2.9	±3.4
H → ss	±120	±990	±350	±280
H → gg	±0.80	±5.5	±2.1	±2.6
$H \to \tau\tau$	±0.58		±1.2	±5.6 $^{(*)}$
$H \to \mu\mu$	±11		±25	
$H \to WW^*$	±0.63		±1.8 $^{(*)}$	±2.1 $^{(*)}$
$H \to ZZ^*$	±2.6		±8.3 $^{(*)}$	±4.6 $^{(*)}$
$H \to \gamma\gamma$	±3.6		±13	±15
$H \to Z\gamma$	±11.8		±22	±23
$H \to \nu\nu\nu\nu$	±25		±77	

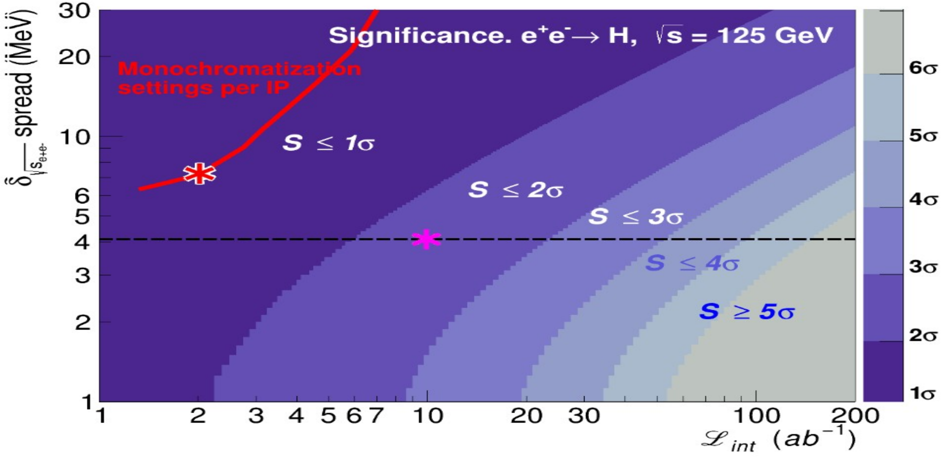
Higgs Electron Yukawa Coupling

Measure e+e- → H →e⁺e⁻: how?

- Γ_H is 4.1 MeV, measure m_H at MeV level
- Dial collider E_{CM} to m_H
- **Monochromatize** energy: ~ 4 MeV spread
- Signal is tiny and background is very large
- 1.3 std significance per IP and per year







arXiv:2107.02686

Electroweak Key Performance

Electroweak precision - Z

Observable	present value	±	uncertainty	FCC-ee **Stat.**	FCC-ee Syst.	Comment and leading uncertainty
m_Z (keV)	91 186 700	±	2000	**4**	100	From Z line shape scan Beam energy calibration
Γ_Z (keV)	2 495 200	±	2300	**4**	12	From Z line shape scan Beam energy calibration
$1/\alpha_{QED}(m_Z^2)$ $(\times 10^3)$	128 952	±	14	**3.9** **0.8**	small small (tbc)	From A_{FB}^{μ} off peak [48] From $\mathcal{R}_{e^-/\ell^\pm}(\theta)$ on peak [49] QED&EW uncert. dominate
σ_{had}^0 (pb)	41 541	±	37	**0.1**	0.8	Peak hadronic cross section luminosity measurement

Impressive improvements

- Systematic uncertainties are large but still conservative

Electroweak precision - W

Observable	present value	±	uncertainty	FCC-ee **Stat.**	FCC-ee syst.	Comment and leading uncertainty
m_W (MeV)	80 360.2	±	9.9	**0.18**	0.16	WW threshold scan Beam energy calibration
Γ_W (MeV)	2 085	±	42	**0.27**	0.2	WW threshold scan Beam energy calibration
$\mathcal{B}(W \to e\nu_e) \times 10^4$	1071	±	16	**0.13**	0.10	From WW and ZH threshold luminosity
$\mathcal{B}(W \to \mu\nu_\mu) \times 10^4$	1063	±	15	**0.13**	0.10	From WW and ZH threshold luminosity
$\mathcal{B}(W \to \tau\nu_\tau) \times 10^4$	1138	±	21	**0.13**	0.15	From WW scan ZH threshold luminosity
$g_Z^{\nu_e}$	1.06	±	0.18	**0.007**	small	From WW threshold

Impressive improvement in precision

- Systematic uncertainties are not dominant

SMEFT

Generically beyond SM

Global use of precision measurements

Theory … needs to come up with lots of calculations

- Present theory calculations do not match experimental precision
- Intense program needs to start soonish, so exp. precision can be fully used

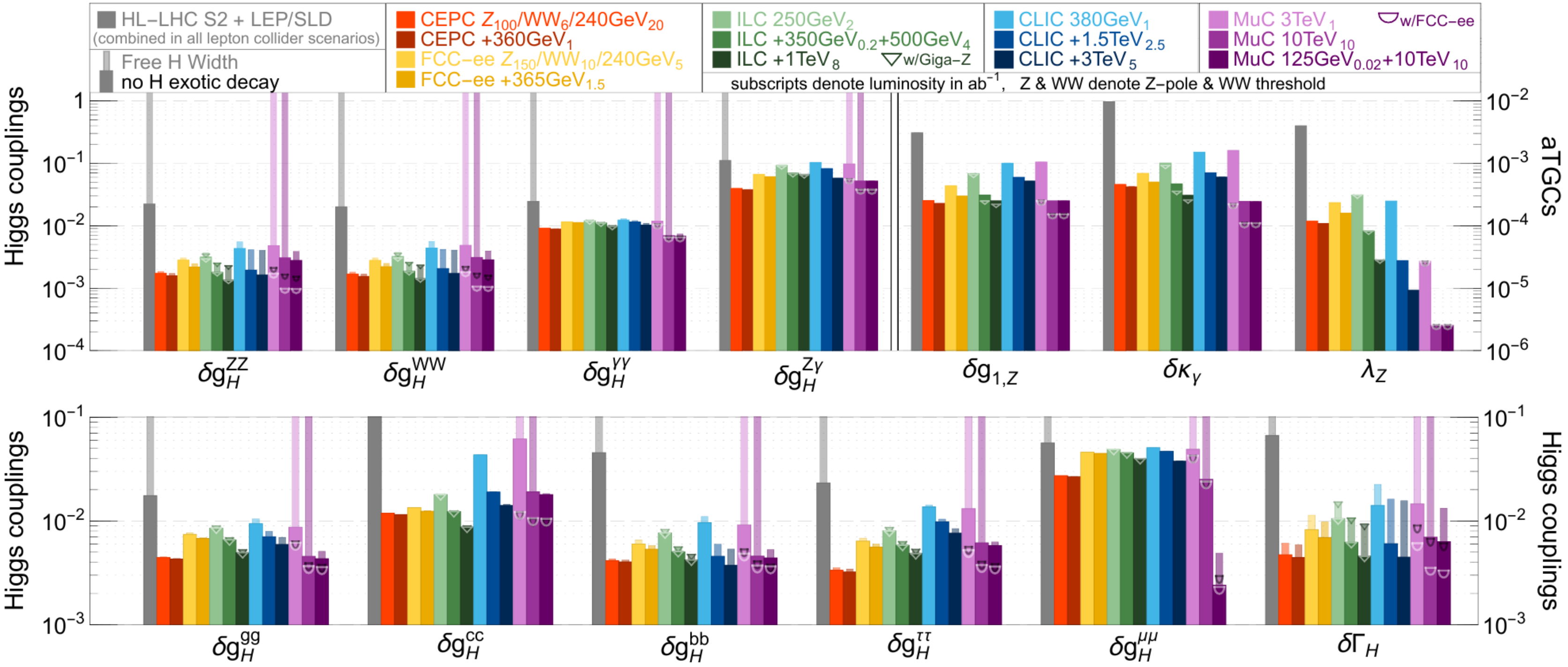
SMEFT

- **SMEFT – S**tandard **M**odel **E**ffective **F**ield **T**heory
- Systematic approach to characterize potential deviations from the Standard Model in terms of operators

Status

- Can be done at various orders, for now leading order (NLO under way)
- All measurements can be included and lead to best possible constraints overall

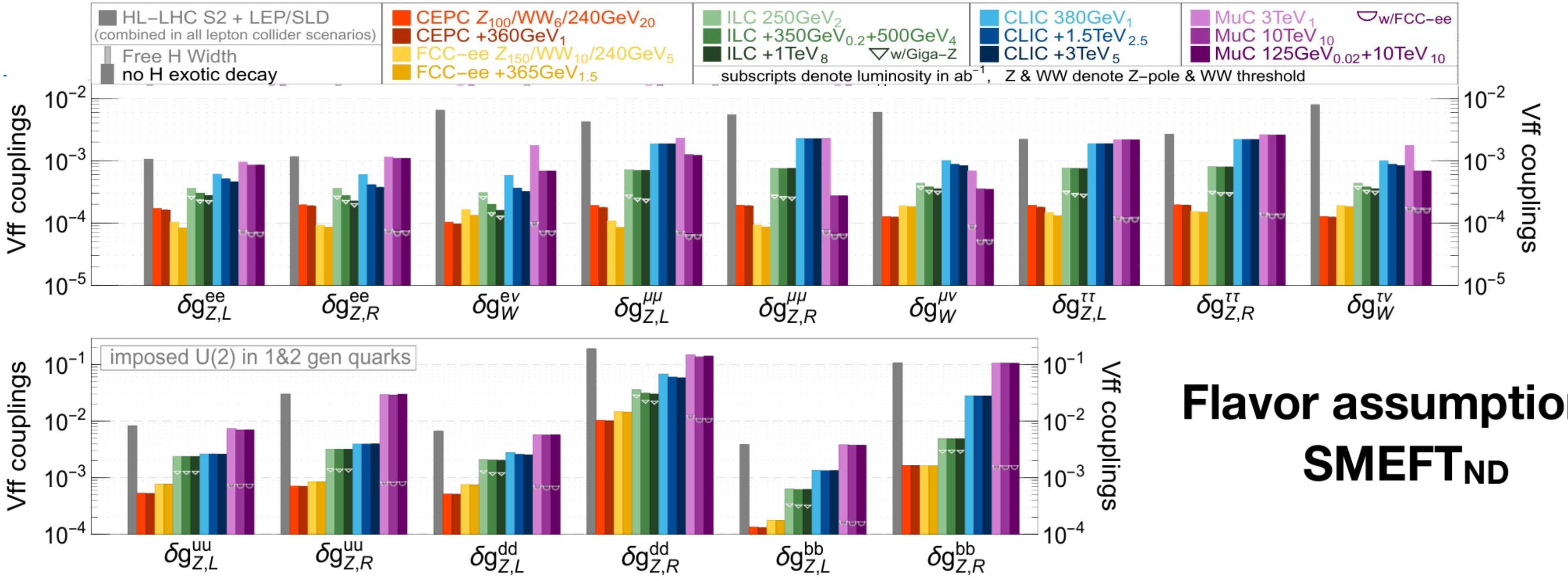
Higgs Couplings Precision



Not very dependent on the e^+e^- option

- Sensitivity to Higgs coupling is mostly around a percent
- Details of the uncertainties are dependent on the specific implementations

Electroweak Couplings Precision

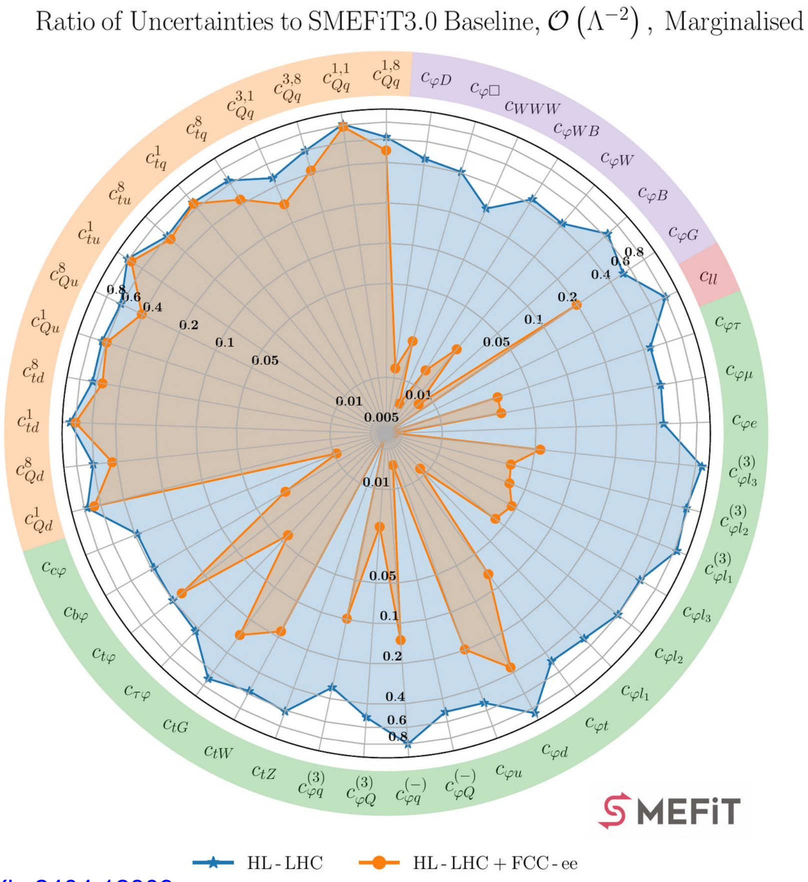


Flavor assumptions: SMEFT$_{ND}$

Electroweak couplings much improved (as expected) for e^+e^- options

- Important implications about reducing correlations between the EW and Higgs coefficients

Improvements in couplings



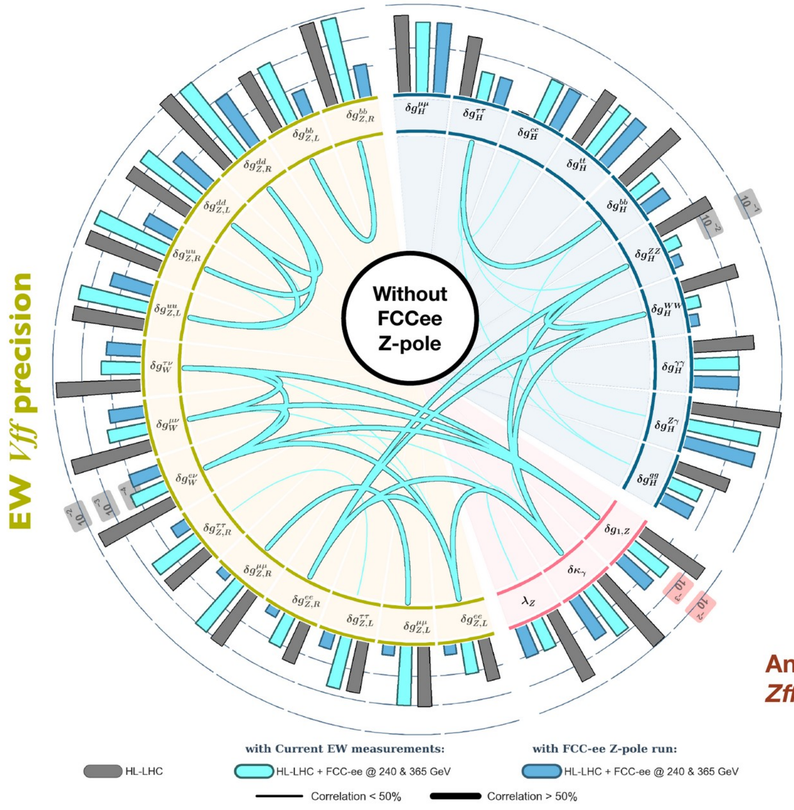
Circular plots are nice

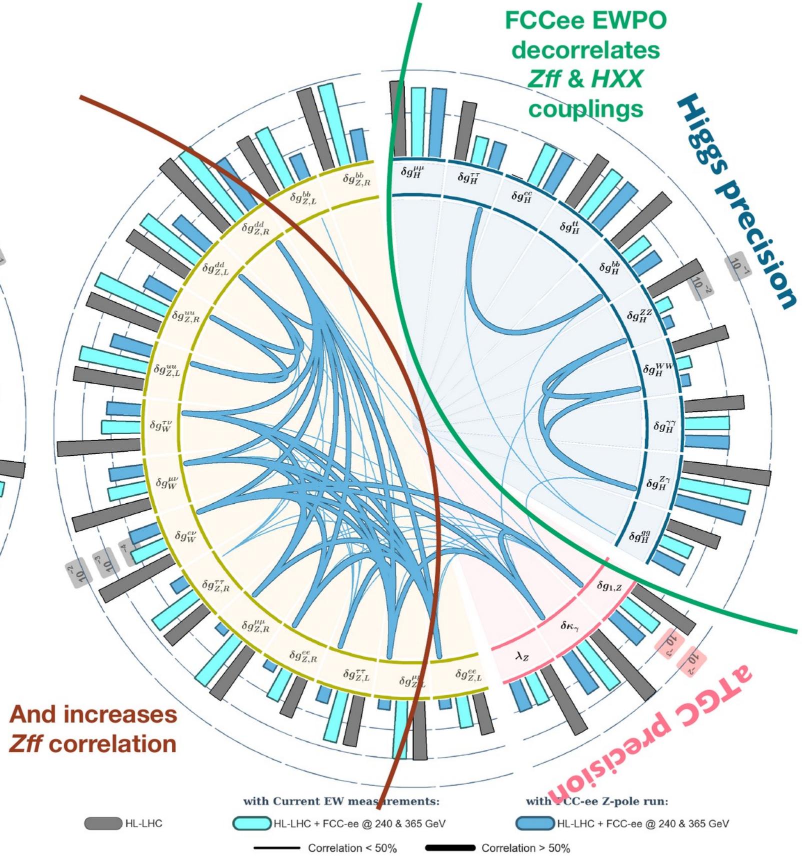
- Shows improvement of precision on couplings with respect to the expected precision from HL-LHC
- Fit to HL-HLC + FCC-ee includes simultaneously EW, Higgs and top measurements

two-light-two-heavy operators (orange),
two-fermion operators (green),
purely bosonic operators (purple), and
the four-lepton operator $c_{\ell\ell}$ (red).

arXiv:2404.12809

Correlations between couplings



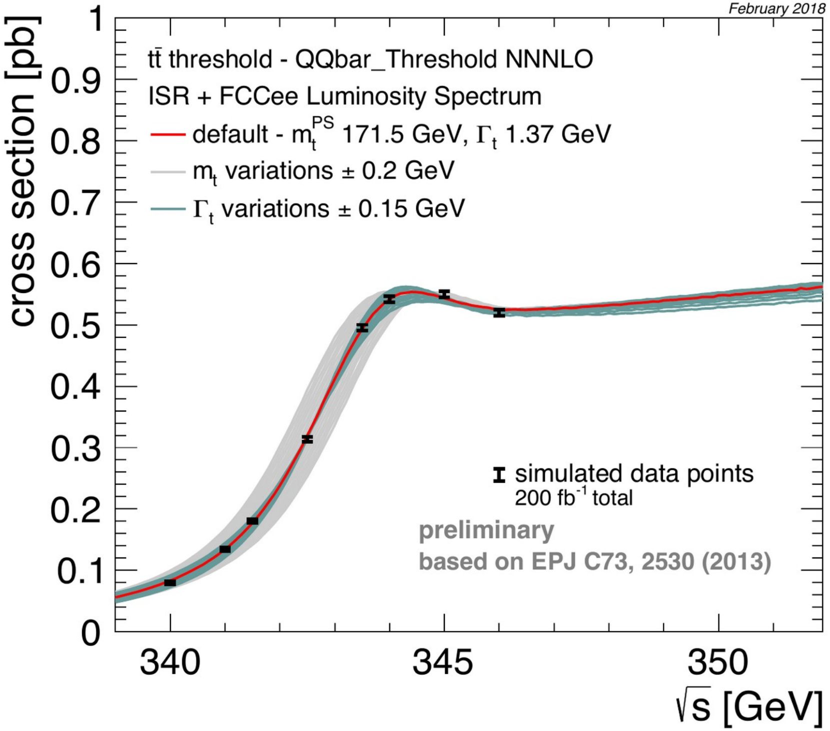


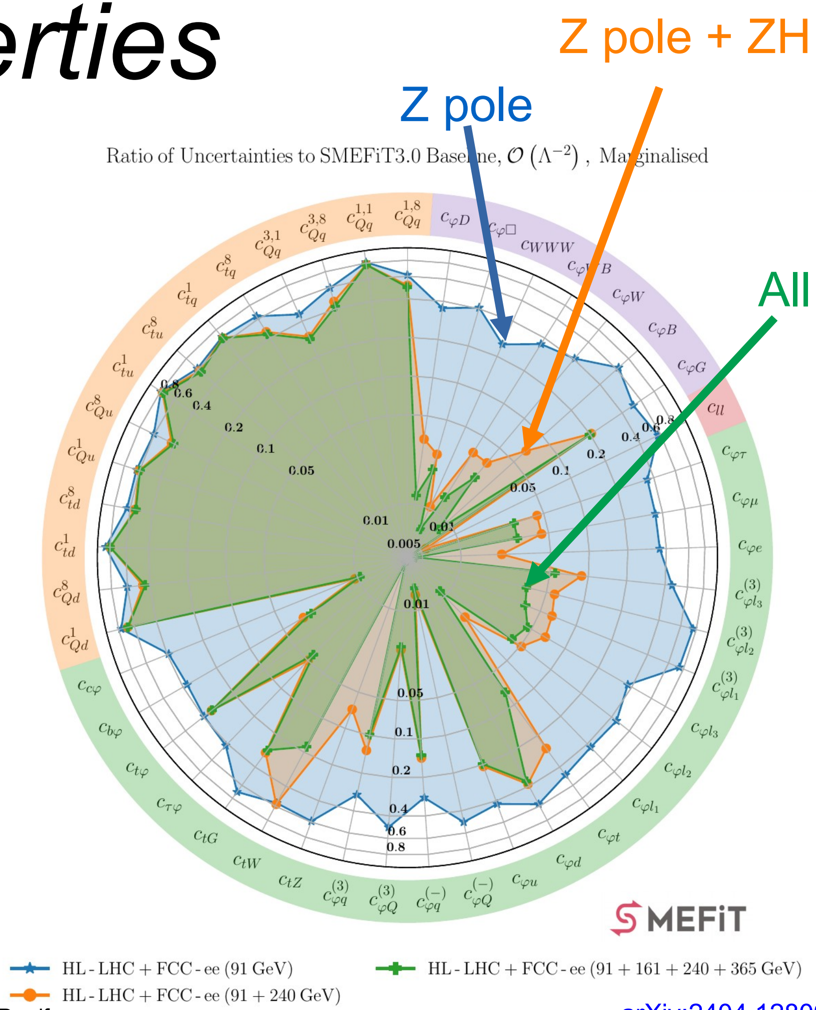
https://indico.cern.ch/event/1439509/contributions/6286783/attachments/2997068/5280355/Global_fits_FCC_deBlas.pdf

Top Properties

Top mass and width

- Expected Δm_t (stat) ~ 17 MeV; $\Delta\Gamma_t$ (stat) ~ 45 MeV





https://indico.cern.ch/event/1439509/contributions/6286667/attachments/2995357/5277099/top_FCC_jan25_MD.pdf

arXiv:2404.12809

Beyond the Standard Model Physics

Dark Sector: Axion-Like Particles

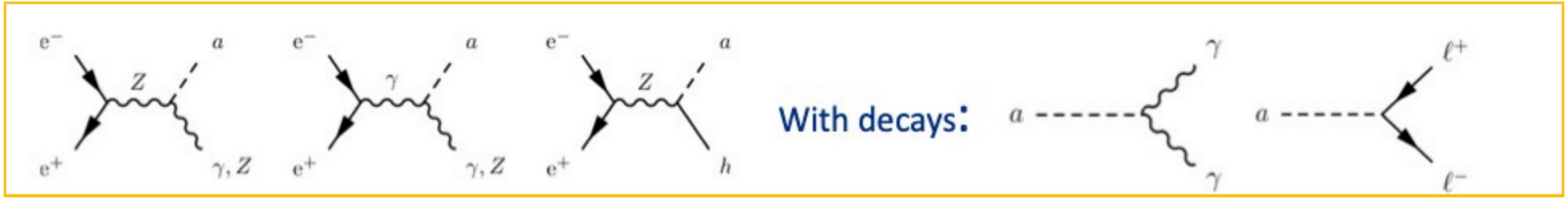
Dark Sectors

- Going to lower energy from LHC
- → use the event counts and look for lower masses: intensity frontier

Case Study: Axion-like Particles

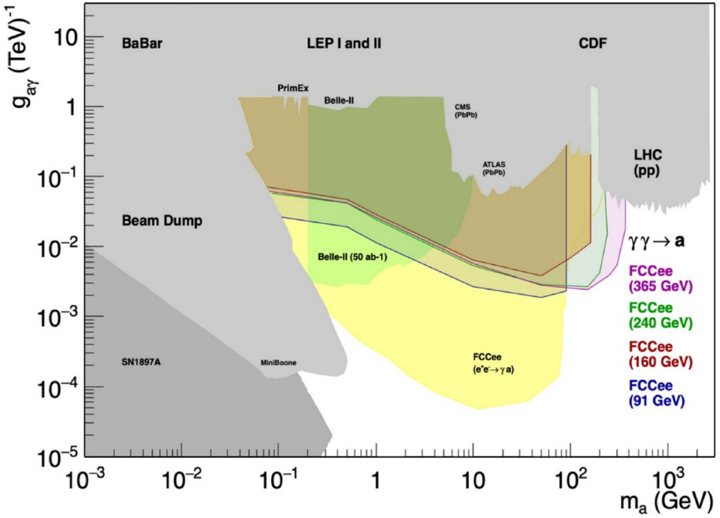
BOSTON UNIVERSITY

"Standard" approach:



- $\gamma\gamma \to a$ extends current LHC limits for m_a = 5 – 350GeV by 2(O) magnitude
- $e^+ e^- \to Z \to \gamma a$ extends current LHC limits for m_a = 0.1 – 90 GeV by 3(O) magnitude

For low ALP mass, sophisticated detectors & techniques are needed to isolate the overlapping photons



Conclusions

The case for the FCC is strong

- FCC feasibility study is complete and in review since yesterday
- CERN and U.S. strongly support the FCC-ee program
- FCC-ee produces ~2.2M Higgs bosons *in pristine conditions*: strong program
- Extraordinary electroweak and flavor precision, top, and BSM programs
- Accelerator in an impressive advanced state of planning
- Detector design ideas developed matching requirements
- New ideas for even better solutions are under way

Work that needs doing

- Work on systematics and theory essential
- New detector technology should be supported