Overview report for 2018 from the SPC

R. Keith Ellis
IPPP, Durham, UK

Remit=Charge

1. to make recommendations to the Council on the priorities of research programmes and the allocation of research effort both within the Laboratories of the Organization and extramurally;	MTP
2. to examine and make recommendations to the Council on the annual goals of the various scientific activities of the Organization;	MTP
3. to annually assess the achievements of the Organization with regard to the past year annual goals of the various scientific activities;	APR
4. to advise the Council from the point of view of scientific policy on the management and staffing of the Organization, including the visitors programme and the nomination of senior staff;	MTP
5. to advise the Council on any other matters which affect the scientific activities of the Organization.	Future Planning

Changing membership

Krzysztof Redlich(PL)

With heartfelt thanks for his contributions to the work of the SPC

→

Hiroaki Aihara(JP)

Experimentalist
Member D0,Belle,T2K,SDSS
Vice-President University of Tokyo
Science Council of Japan

+

Johannes Wessels(DE)

Experimentalist
Expert in Heavy Ion Physics
Deputy spokesperson ALICE experiment
2011-2016
Rector of Muenster University

2 new members, (because we replaced 2 rather than 3 last year).

SPC composition 2019

SPC members serve ad personam

- Hiroaki Aihara(JP)
- Laura Baudis (CH)
- Caterina Biscari (ES)
- Reinhard Brinkmann (DE)
- Robert Cousins(US)
- Keith Ellis (UK)
- Belen Gavela(ES)
- Beate Heinemann(DE)

- Mark Huyse(BE)
- Guido Martinelli (IT)
- Hugh Montgomery(US)
- Yossi Nir(IL)
- Valery Rubakov(RU)
- Heidi Schellman(US)
- Marie-Helene Schune(F)
- Johannes Wessels(DE)

- **Ex officio**
- Jorgen d'Hondt (BE)
- Francesco Forti (IT) (to 30.4.2019).
- Frank Simon(DE) (from 1.5.2019)
- Norbert Holtkamp(US)
- Jordan Nash(Australia)
- Karsten Riisager(DK)

Council delegates are free to nominate candidates for consideration for SPC membership at any time, but for consideration in 2019, best before 1.3.2019. Nominations remain on the list for 3 years.

Physics reports 2018

- 3/2018 “What we need to learn about the Higgs boson”, Y. Nir
- 5/2018 “Highlights of the Winter conferences”, A. Ceccucci
- 9/2018 “LHCb”, G. Passaleva
- 9/2018 “ATLAS”, K. Jakobs
- 9/2018 “ALICE”, F. Antinori
- 9/2018 “CMS”, R. Carlin
- 12/2018 “Future prospects for Heavy Ion Physics”, K. Redlich

Planning reports 2018

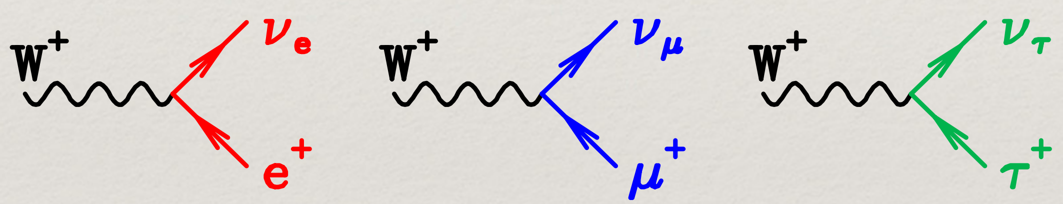
- 3/2018 “Report on the European Astro-particle Strategy, A. Masiero
- 3/2018 “ILC Preparation Planning in Europe by E-Jade” S. Stapner.
- 6/2018 “Result of cost and schedule review” N. Holtkamp
- 6/2018 & 9/2018 “Machine parameters and projected luminosity performance of proposed Future Colliders at CERN”,F. Bordry
- 9/2018 “Detailed report on LHCC”, F. Forti
- 9/2018 “Establishment of the Physics Preparatory Group”
- 9/2018 “Report from the European Particle Physics Communication Network and IPPOG”, S.Goldfarb (H-P. Beck)
- 12/2018 “Report on LHC and HL-LHC computing”,S. Campana
- 12/2018 “Detailed report on INTC”, K. Riisager

A question of scale?

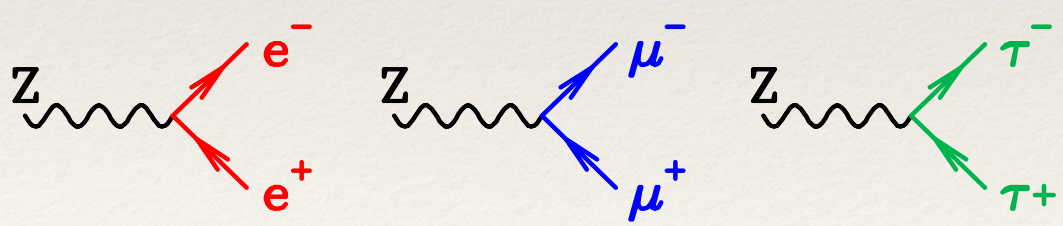
- In planning for future colliders it would be helpful to have an idea of the energy scale of potential next discoveries.
- This was very helpful in making the case for the LHC.
- No-lose theorems implied that below about 1 TeV,
    - There had to be either new physics (Higgs boson)
    - Or strong interaction dynamics.

Lepton Universality

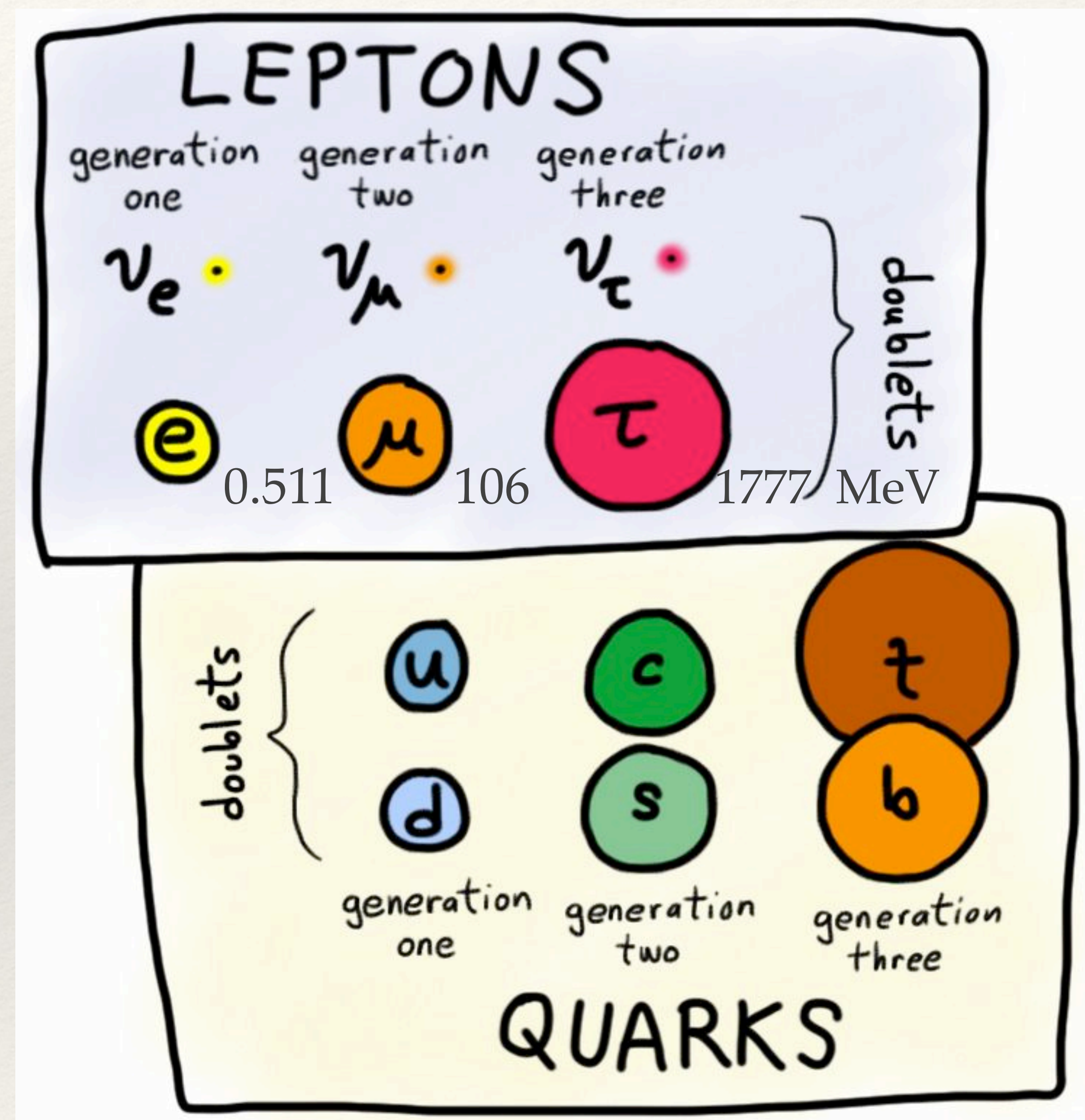
- Structure and strength of the couplings to gauge bosons are the same, despite the difference in mass.



BR=(10.71±0.16)%   BR=(10.63±0.15)%   BR=(11.38±0.21)%

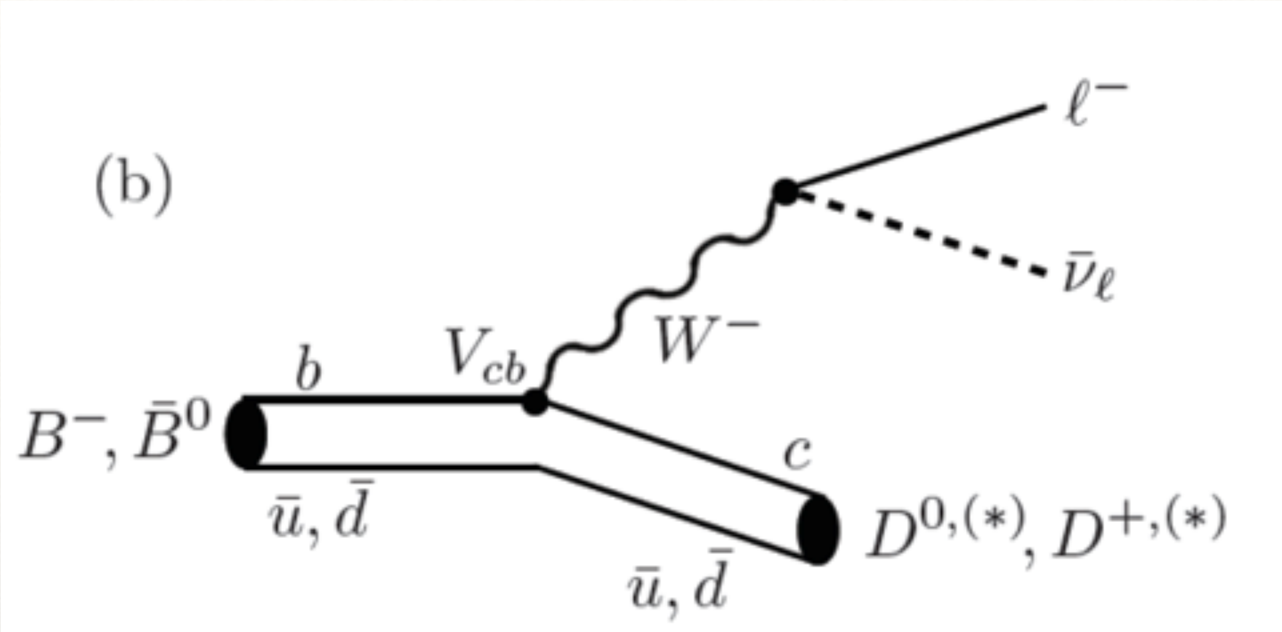


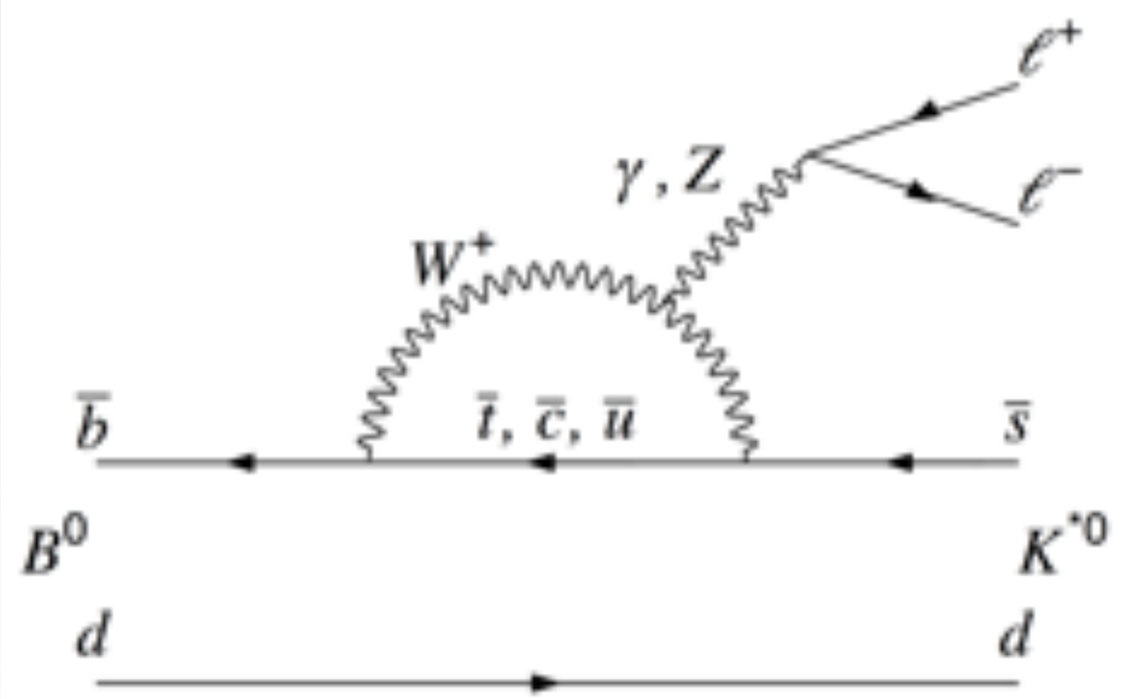
$\Gamma_{\mu\mu}/\Gamma_{ee}$=1.0009±0.0028 $\Gamma_{\tau\tau}/\Gamma_{ee}$=1.0019±0.0032



Lepton non-Universality

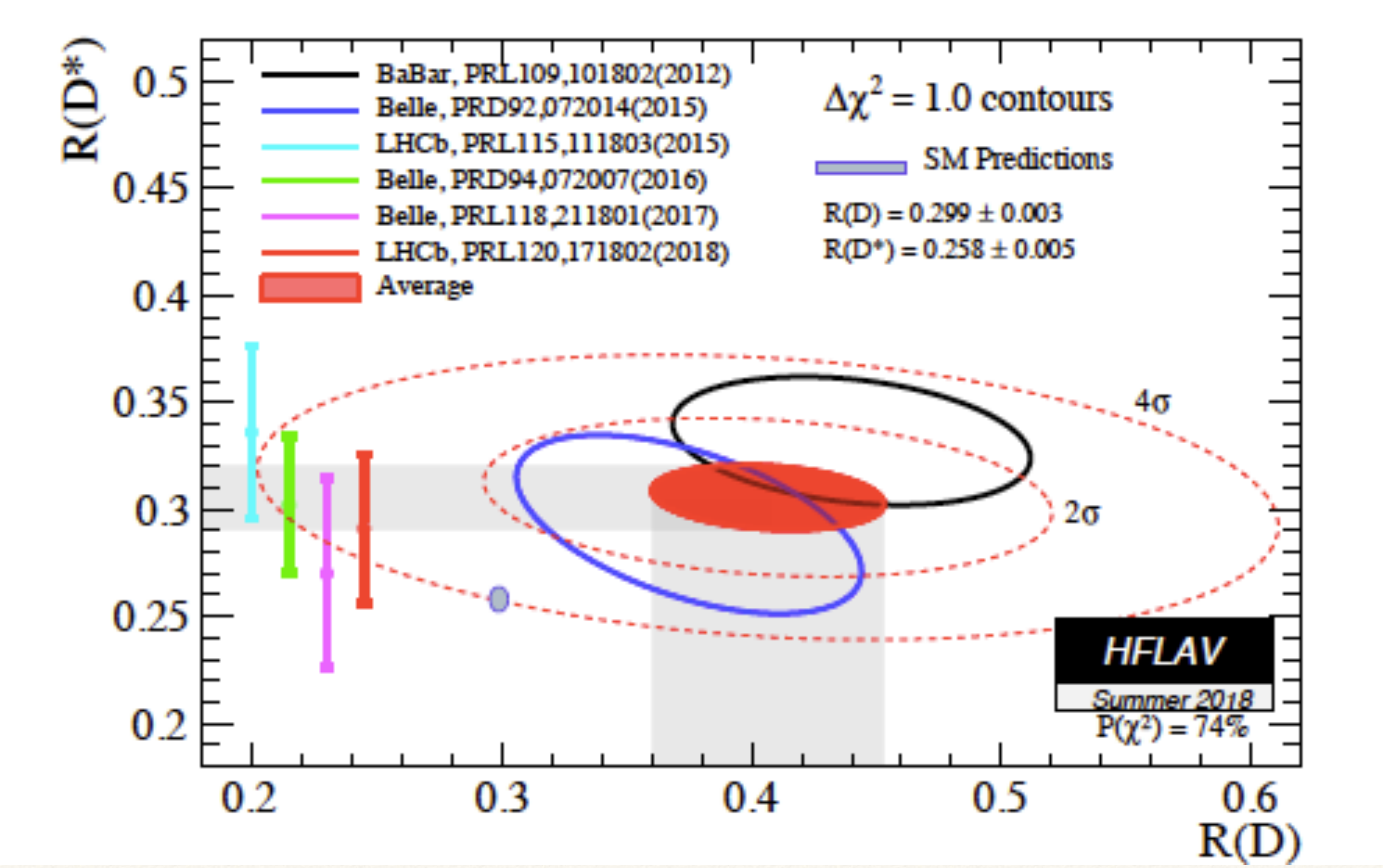
- Two main classes of decays have been studied
- $B^0 \rightarrow D^{*-} l^+ \nu$, tree level decay
- b →s l+ l- decays, e.g. $B^0 \rightarrow K^{*0}$ l+l-, Flavour changing neutral current.





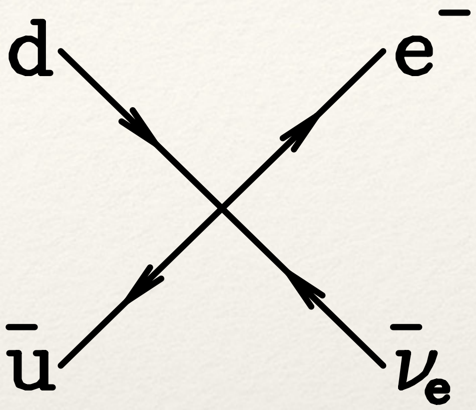
Results for the tree-level process

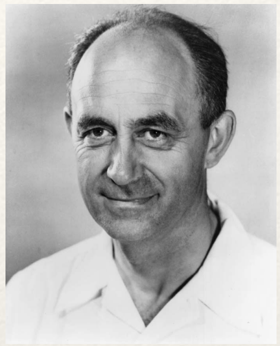
$$R(D^{(*)}) = \frac{\Gamma(B \to D^{(*)} \tau \bar{\nu})}{\Gamma(B \to D^{(*)} \ell \bar{\nu})}$$



Measurement still 3.8sigma away from the standard model.

Perturbative Unitarity constraint on Fermi theory





- In Fermi's theory of beta decay the Lagrangian is, $\mathscr{L} = \frac{G_f}{\sqrt{2}} \bar{u}(p_u)\gamma^\mu \gamma_L u(p_d)\, \bar{u}(p_e)\gamma_\mu \gamma_L u(p_\nu)$
- perturbative unitarity places the limit on the Fermi theory of $s_{critical} < \frac{8\pi\sqrt{2}}{G_F}$ $\sqrt{s_{critical}} < 1.75\ \text{TeV}$
  This constraint is satisfied by the discovery of the W-boson with mass 81.4 GeV
- A similar argument applied to WW scattering implies for the mass of Higgs boson $M_H < \sqrt{\left(\frac{8\sqrt{2}\pi}{3G_f}\right)} \approx 1 TeV$

Could B-physics be suggesting a new scale?

- The B-physics anomalies have not yet reached the level of 5 sigma.
- If they were to persist, perturbative unitarity can be used to set the scale of the new physics, just as it did for the Fermi theory.
- Unfortunately the loop-level perturbative unitarity constraints are not very stringent.
- Using the operator $\mathscr{L} = \frac{1}{\Lambda_{D*}^2} 2\bar{c}_L \gamma^\mu b_L \; \bar{\tau}_L \gamma_\mu \nu_L$
- Perturbative unitarity limits are $s_c^{D*} = 9.2 \text{ TeV}$ for tree-level process and $s_c^{R_{K^*}} = 84 \text{ TeV}$ for the loop level processes.

Allanach et al, 1710.0636, Di Luzio, Nardecchia, 1706.01868,

Input Information needed

- Machine parameters, luminosities for possible CERN machines etc. ✓
- Estimates at a similar level of detail for non-CERN sponsored machines, ILC, CEPC, (electron-ion collider), (muon collider). ✓
- Physics capabilities of all machines. Strategy input
- The issue of timeline, at least at the level of Technically driven schedule, (without financial or other constraints). Strategy input
- Estimate of starting date. Strategy input
- Estimate of costs. Strategy input

Machine Parameters and Projected Luminosity Performance of Proposed Future Colliders at CERN

CERN-ACC-2018-0037 arXiv:1810.13022

F. Bordry, M. Benedikt, O. Brüning, J. Jowett, L. Rossi, D. Schulte, S. Stapnes, F. Zimmermann,
CERN, Geneva, Switzerland

Keywords: Hadron Colliders, Lepton Colliders, Lepton-Hadron Colliders, Luminosity, Run Time, Availability, Efficiency

Abstract

In response to a request from the CERN Scientific Policy Committee (SPC), the machine parameters and expected luminosity performance for several proposed post-LHC collider projects at CERN are compiled: three types of hadron colliders (HL-LHC upgrade, FCC-hh and HE-LHC), a circular lepton collider (FCC-ee), a linear lepton collider (CLIC), and three options for lepton-hadron colliders (LHeC, HE-LHeC, and FCC-eh). Particular emphasis is put on availability, physics run time, and efficiency. The information contained in this document was presented at the SPC Meeting of September 2018. It will serve as one of the inputs to the 2019/20 Update of the European Strategy for Particle Physics.

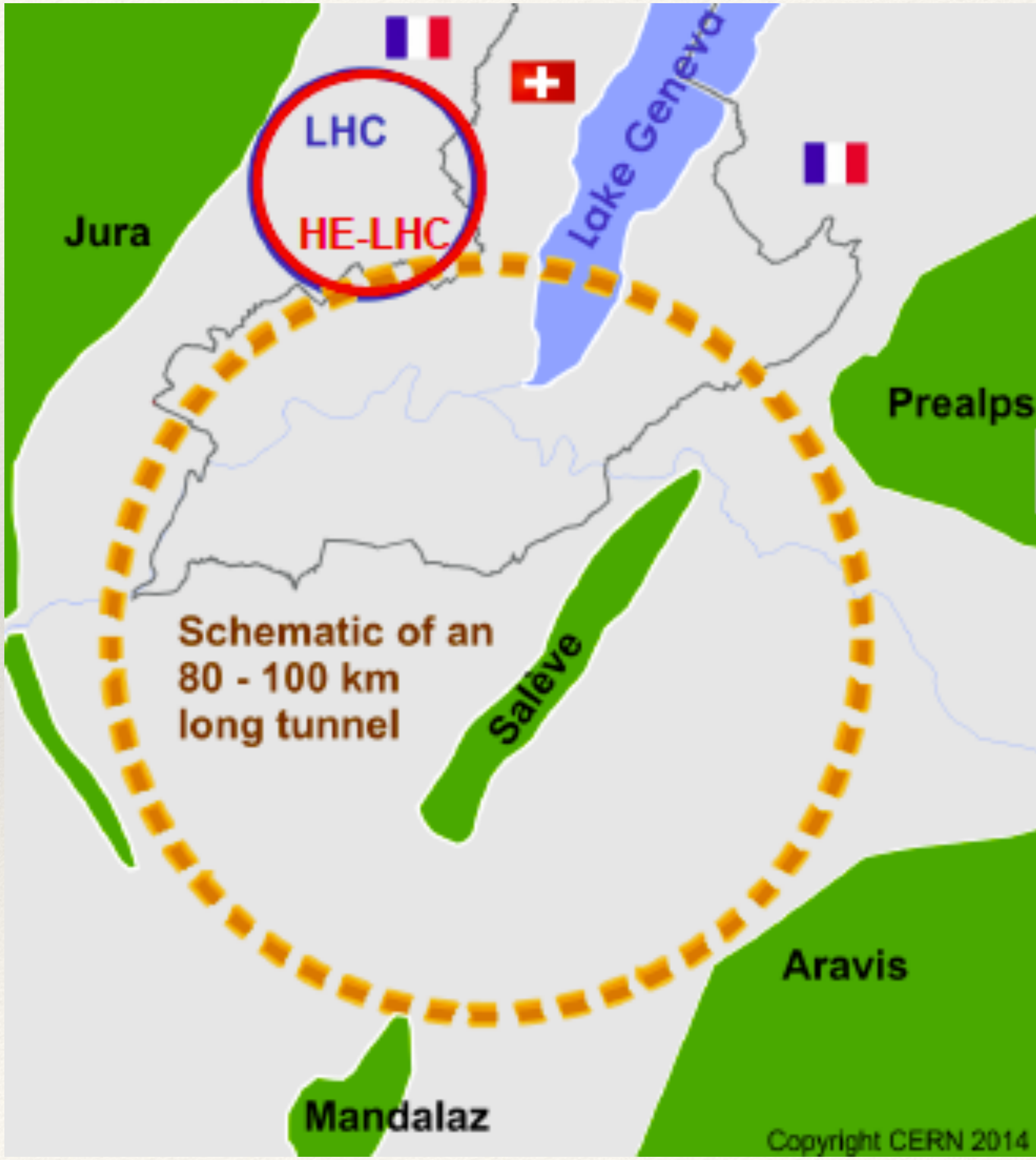
Possible future CERN Machines

- HL-LHC @ $\sqrt{s}$=14 TeV (approved machine, but included for baselining purposes)
- FCC-hh @ $\sqrt{s}$=100 TeV (including Heavy Ions)
- HE-LHC @ $\sqrt{s}$=27 TeV (including Heavy Ions)
- FCC-ee @ $\sqrt{s}$=~91,~161,~240,~365 GeV
- CLIC-ee @ $\sqrt{s}$=0.38 TeV, 1.5TeV, 3TeV)
- LHeC ep@ $\sqrt{s}$=1.3 TeV
- HE-LHeC ep@ $\sqrt{s}$=1.7 TeV
- FCC(eh) ep@ $\sqrt{s}$=3.5TeV

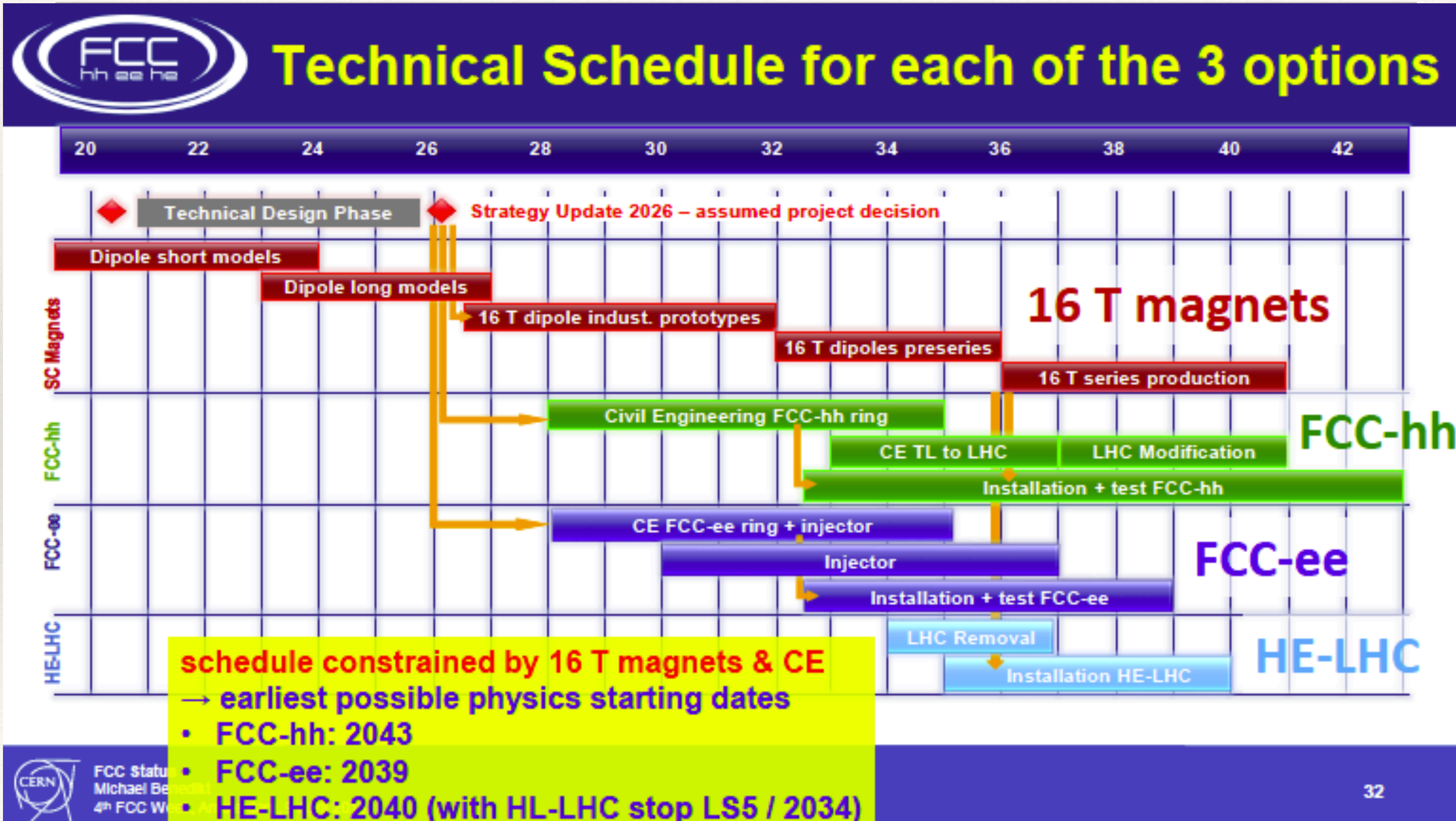
"Particular emphasis is put on availability, physics run time and efficiency"

FCC-hh & (HE)LHC

- FCC-hh: Integrate 20 ab^{-1} in 25 years
- (HE)LHC: Integrate 10 ab^{-1} in 20 years.

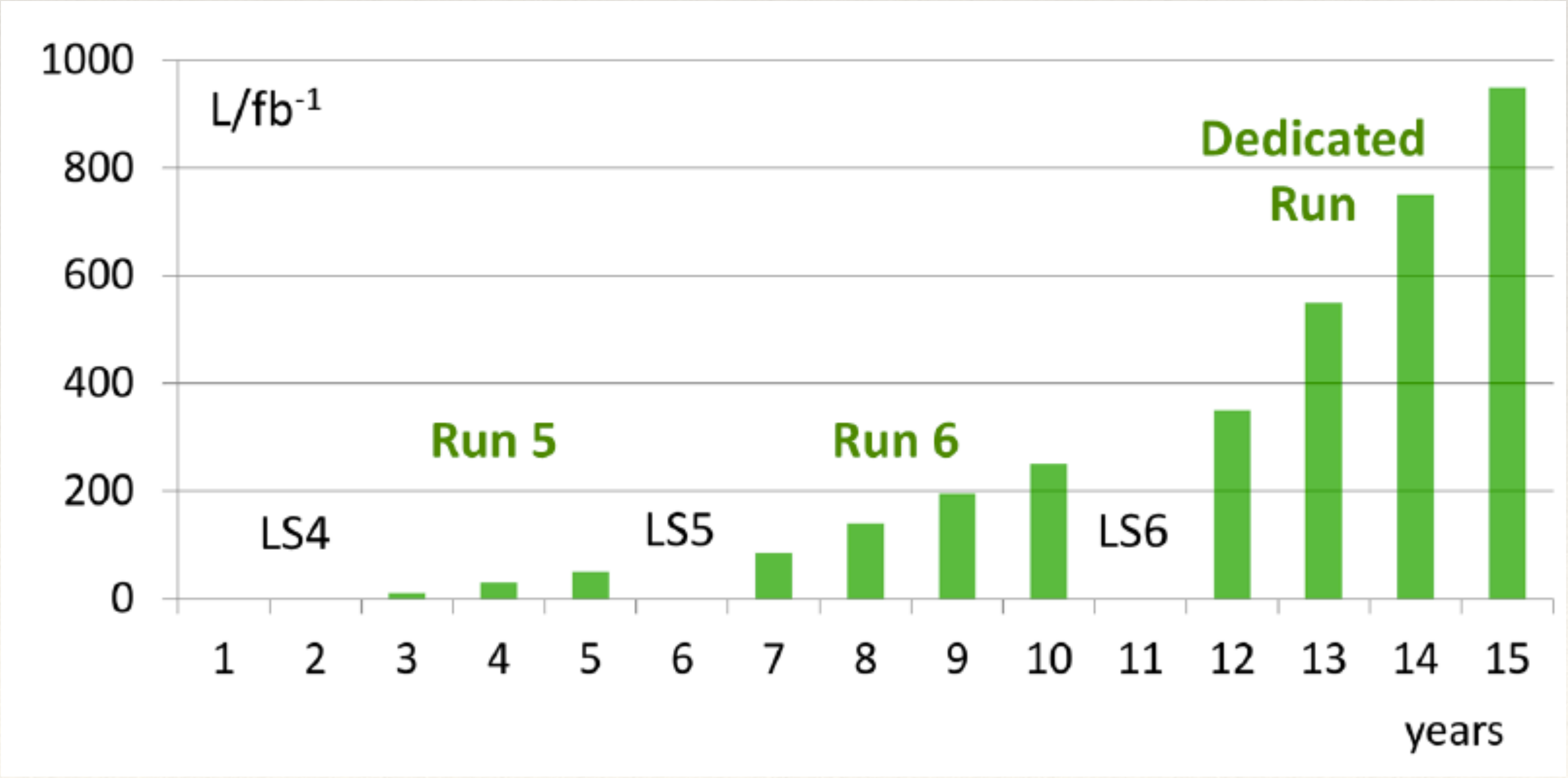


Technically driven Schedule



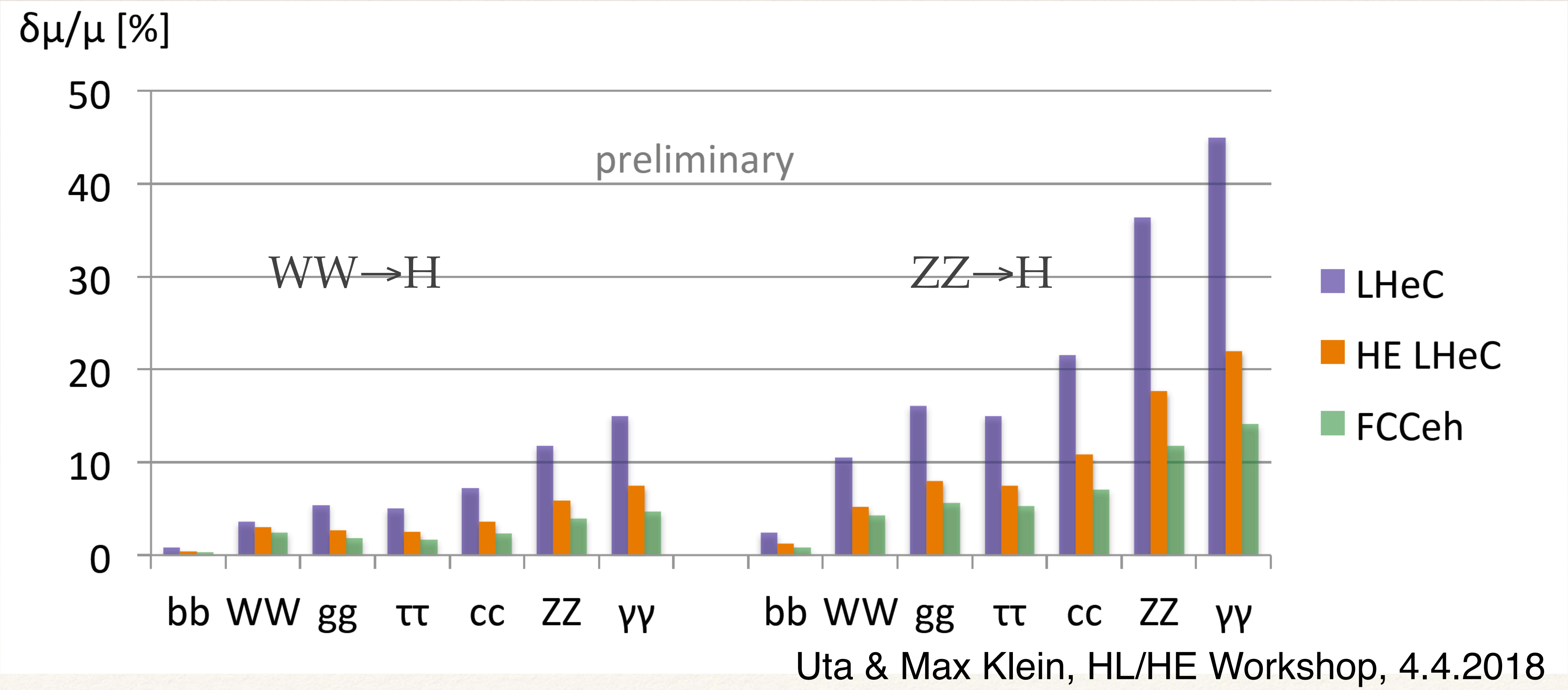
LHeC

- This is a machine that could run concurrently with HL-LHC and with a dedicated run after the conclusion of HL-LHC
- With the dedicated run, it could accumulate almost 1 ab^{-1}
- Advantages for Higgs physics, no-pileup, clean signal to background.



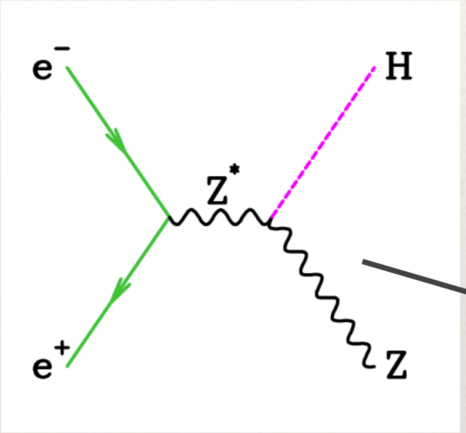
FCC-eh

- FCC-eh could deliver 1.2 ab^{-1} in ten years
- The impact of LHCeC(1ab^{-1}), (HE)LHeC(2ab^{-1}) and FCC-eh(2ab^{-1}) on Higgs physics is shown below.
- Good performance for H->bb,cc,$\tau\tau$

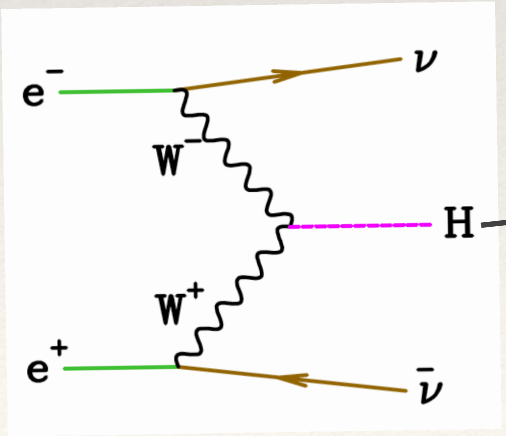


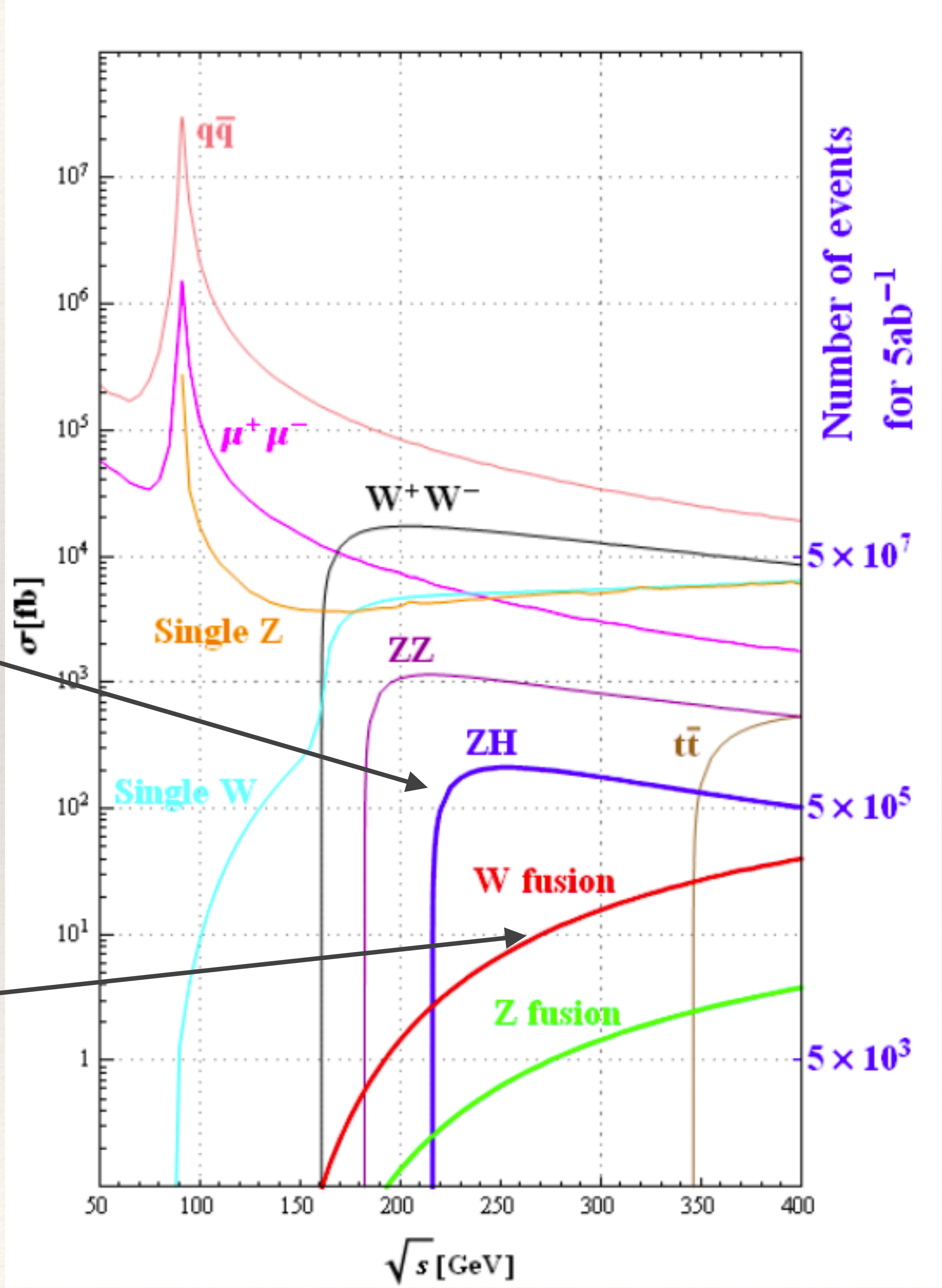
e^+e^- machines & Higgs bosons

- At √s~240 GeV produce the Higgs boson in association with a Z

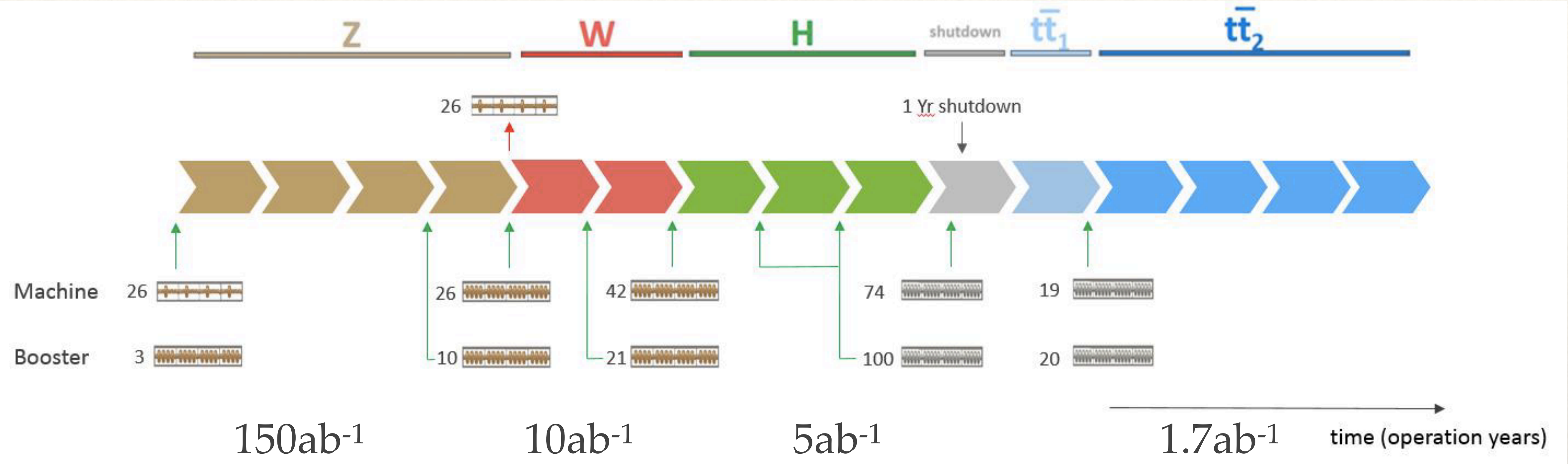


- At higher energy produce H by fusion of W-bosons (and Z)





FCC-ee

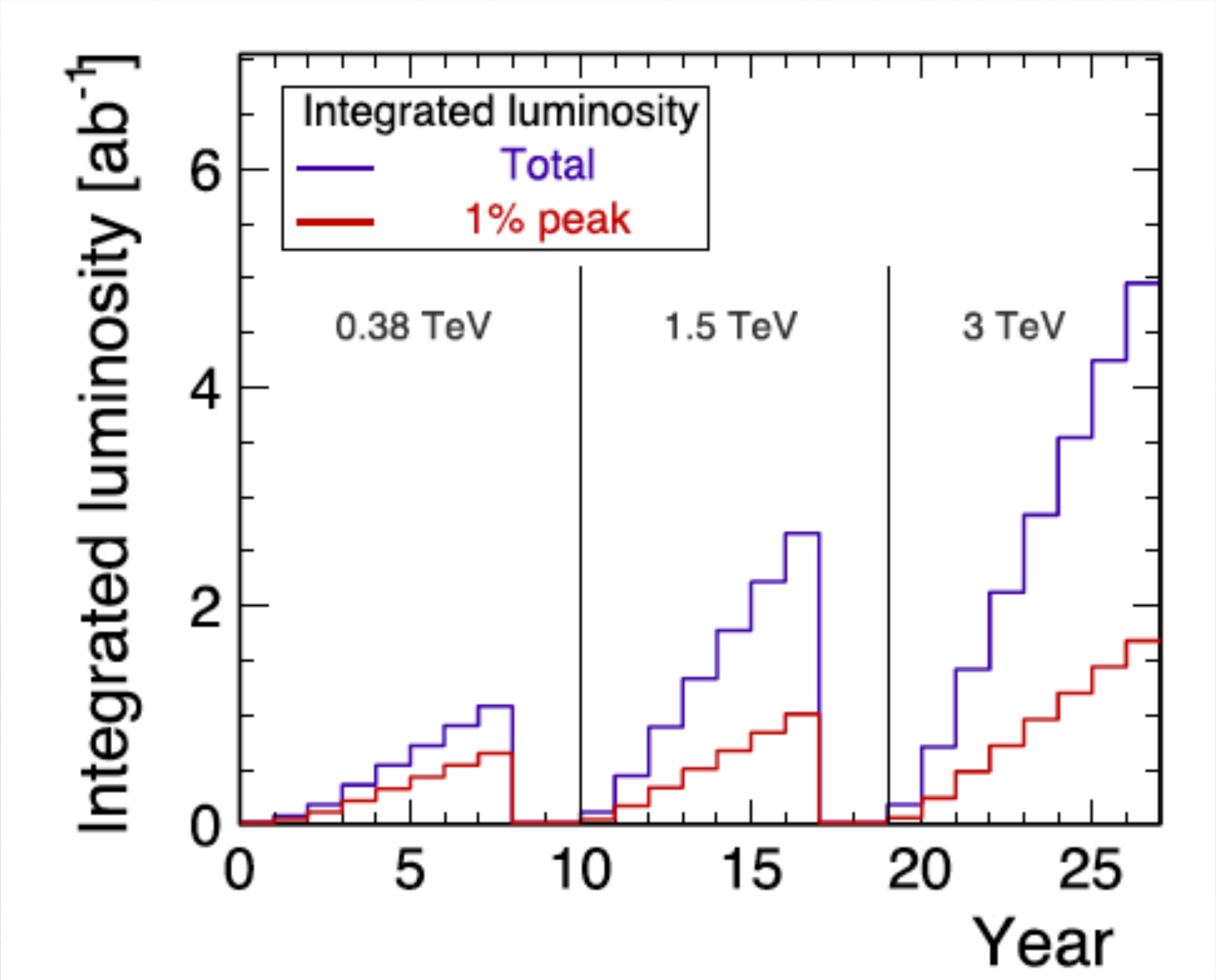


- Program foresees running at four energies
- Each chevron corresponds to a year of running

5 ab^{-1} foreseen in 3 years of running at $\sqrt{s}$=250 GeV

CLIC

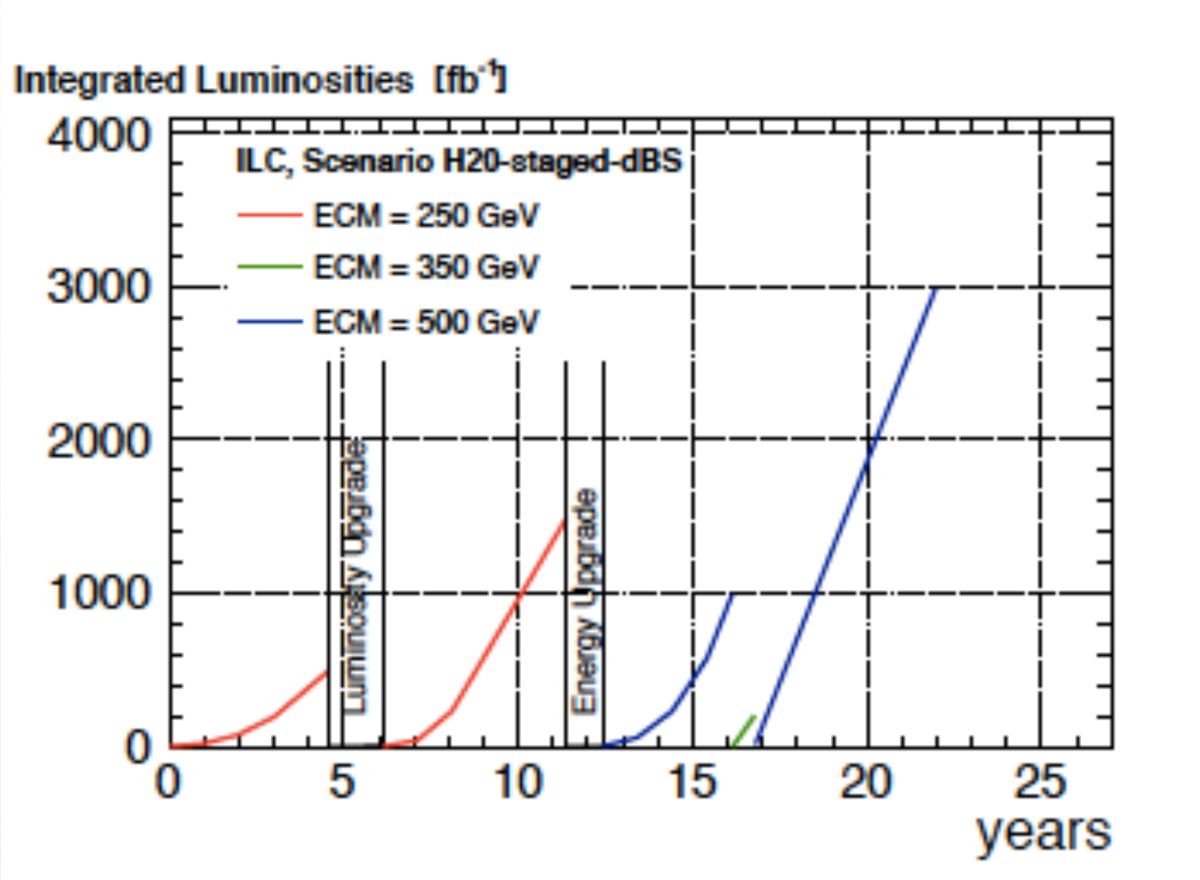
- Integrated luminosity
- 180fb^{-1}/year @ $\sqrt{s}$=0.38 TeV
- 444fb^{-1}/year @ $\sqrt{s}$=1.5 TeV
- 720fb^{-1}/year @ $\sqrt{s}$=3 TeV



5 fb^{-1} in 8 years of running at $\sqrt{s}$=3 TeV

ILC

- Necessary prerequisites: A positive statement from Japan, recommendation from strategy update for European Funding.
- 2019-2022 preparation phase,
    - The preparation phase focuses on preparation for construction and agreement on the definition of deliverables and their allocation to regions.
- Construction phase 2023 and beyond
    - Resources needed in Europe estimated to ~25 MCHF/year (material) and 60 FTE/year (personnel), ramping up from 2019
- SPC view — "In view of CERN commitments in these years this funding would have to come in large part from outside the CERN budget."



arXiv:1710.07621 two staged scenarios for ILC running

2 ab^{-1} foreseen in 11 years of running at $\sqrt{s}$=250 GeV

CEPC

IHEP-CEPC-DR-2018-01

IHEP-AC-2018-01

- Decade long plan for the CEPC
- Integrated luminosity for two interaction points.
- "Construction will start in 2022 in the government's 14th Five-Year Plan and continue in the 15th Five-Year Plan. Construction will be completed by 2030."

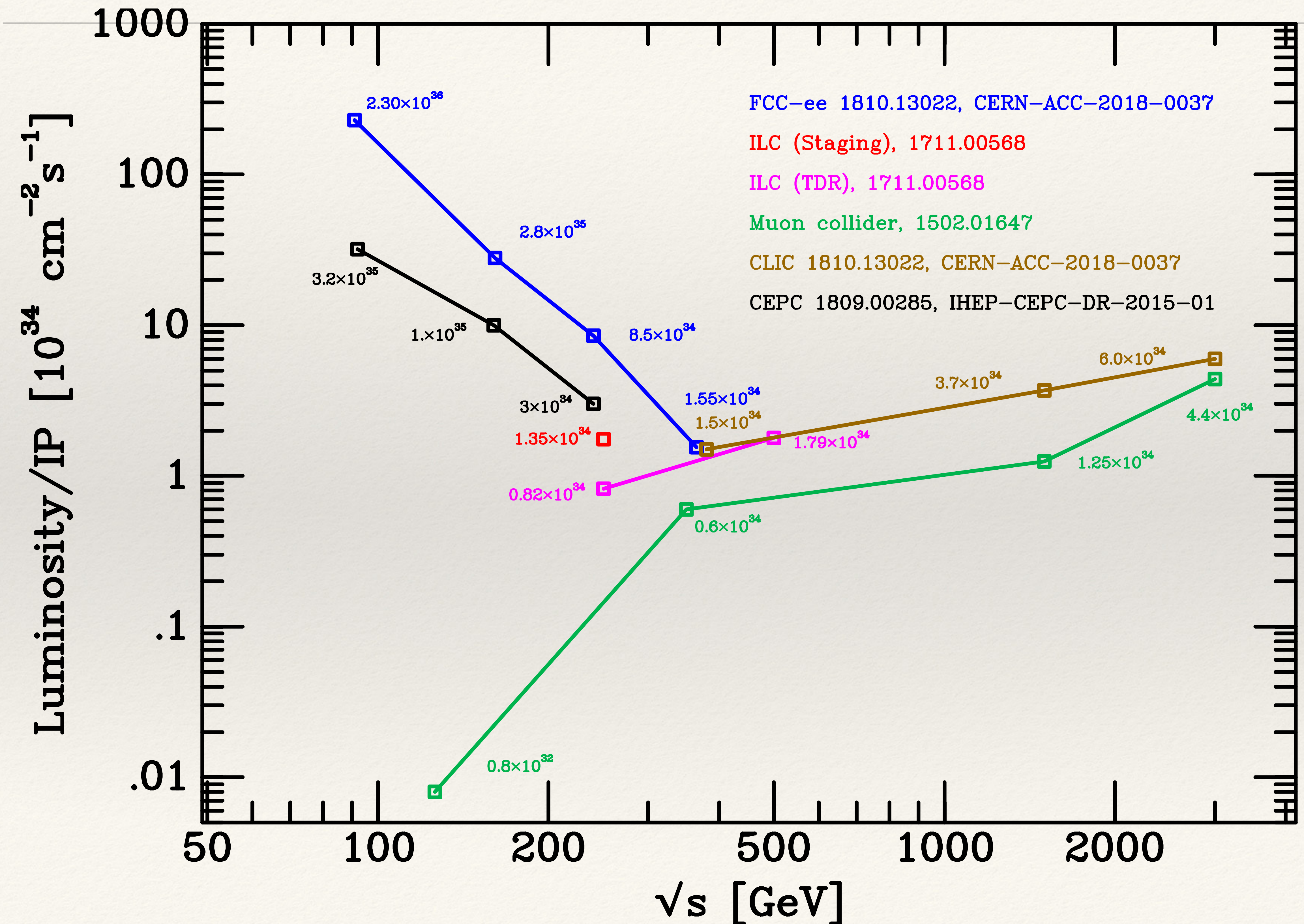
Table 3.1: CEPC 10-year operation plan

Particle	$E_{c.m}$ (GeV)	L per IP (10^{34} cm^{-2}s^{-1})	Integrated L per year (ab^{-1}, 2 IPs)	Years	Total Integrated L (ab^{-1}, 2 IPs)	Total no. of particles
H	240	3	0.8	7	5.6	1×10^6
Z	91	32 (*)	8	2	16	7×10^{11}
W^+W^-	160	10	2.6	1	2.6	1.5×10^7

(*) Assuming detector solenoid field of 2 Tesla during Z operation

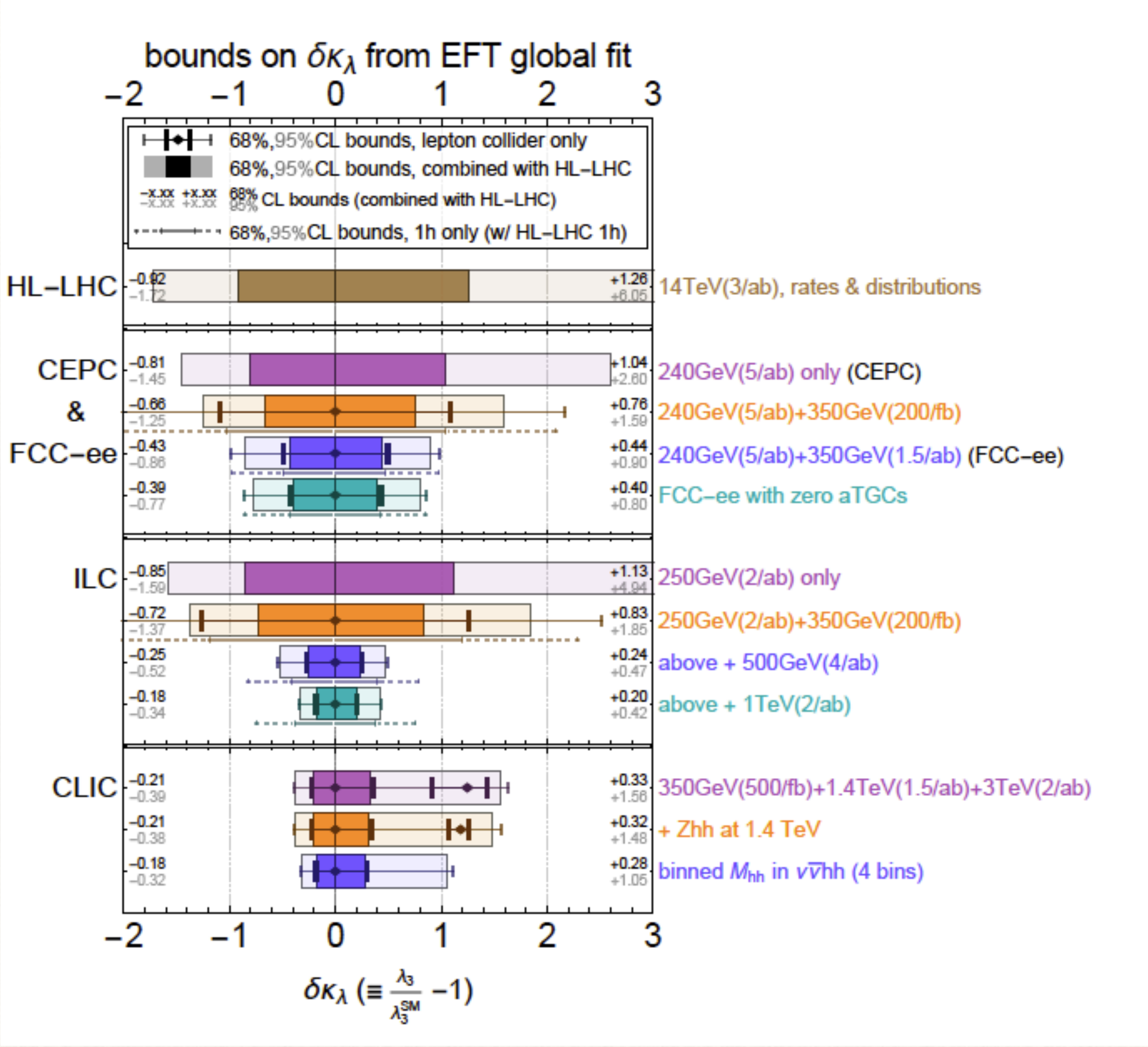
N[events per year] = Lumi[$fb^{-1}yr^{-1}$] σ[fb]

Summary plot: Luminosity at lepton colliders



Bounds on the triple Higgs coupling with lepton colliders

- Bounds obtained in the framework of effective field theory.
- Low energy machines allow for a 40% precision on the extraction of the Higgs trilinear coupling.
- The higher energy machines achieve 20% precision.



1711.03978

2019!

- Premature to draw conclusions before all the information is in.

Richard Feynman -11/5/1918

“It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong.”