European Strategy Update

Report on the European Particle Physics Strategy Update

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As member of EPPSU Physic Preparatory Group

TRIUMF Science Week
18 August 2020

Strategy Update process

European Strategy Update

- The **Strategy Secretariat** was in charge of coordinating the update process.

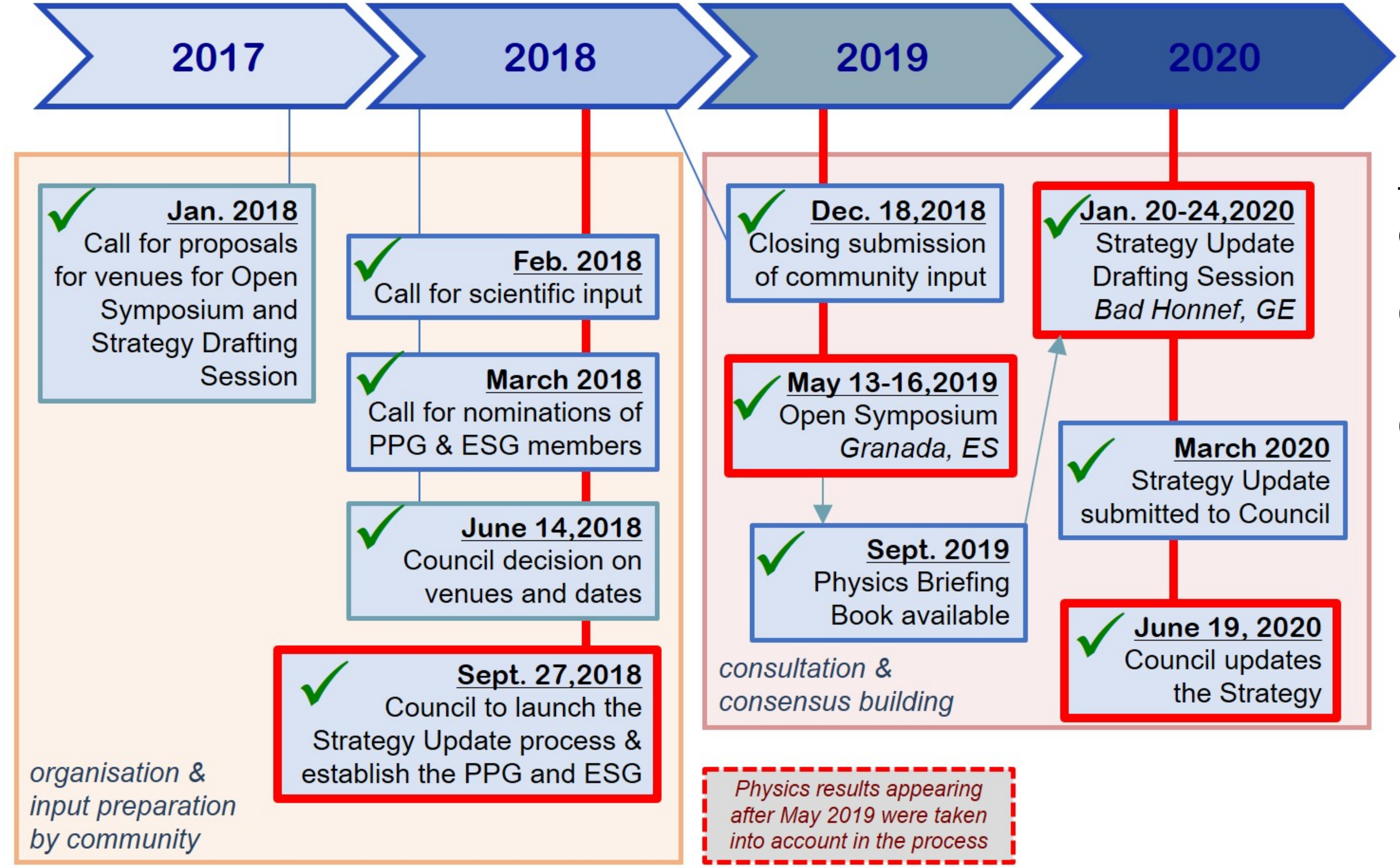
- The **Physics Preparatory Group** (PPG) was charged with preparing the scientific inputs to the strategy update: Physics briefing book.

- The Strategy Update document was drafted by the **European Strategy Group** (ESG).
  - Organized into 6 working groups.

- The **CERN Council** is the decision making body (representing 23 Member States of CERN).

- **CERN Director-General** is responsible for the implementation of the strategy, under the scrutiny of the CERN Council.

Strategy Update process



Two documents submitted to CERN Council:

(1) 2020 Update of the European Particle Physics Strategy

(2) Deliberation document (additional information explaining rational of each statement in the strategy document)

Strategy summary

European Strategy Update

The update to the European particle physics strategy consists of a total of 20 statements:

- 2 statements on **Major developments from the 2013 Strategy**
- 3 statements on **General considerations for the 2020 update**
- 2 statements on **High-priority future initiatives**
- 4 statements on **Other essential scientific activities for particle physics**
- 2 statements on **Synergies with neighbouring fields**
- 3 statements on **Organisational issues**
- 4 statements on **Environmental and societal impact**

Preamble and context

European Strategy Update

- Many mysteries of the universe remain to be explored, e.g. the nature of dark matter, the nature and properties of neutrinos, the preponderance of matter over antimatter, etc.
- Higgs boson is a unique particle that raises profound questions about fundamental laws of nature.
  - It provides a powerful experimental tool to study fundamental questions.
- Clear motivation to continue to explore unknown at an energy frontier collider.

- Ongoing successful LHC operation until end of 2024.
- SuperKEKB in Japan running since 2018.
  - New world record of instantaneous luminosity 2.4 x 1034 cm-2s-1 (June 2020).
- HL-LHC project approved in 2016 and its construction well-underway. Expected start ~ 2027.
- EIC going ahead in US at BNL, managed through BNL/JLAB partnership.
- ILC International Development Team being put in place to work towards the ILC “Pre-Lab” (on a scale of ~1.5 years).

Develop a strategy to significantly extend knowledge beyond the current limits, to drive innovative technological development, and to maintain Europe’s leading role in particle physics, within the global context.

Strategy summary

European Strategy Update

- Major developments from the 2013 Strategy
- General considerations for the 2020 update
- High-priority future initiatives
- Other essential scientific activities for particle physics
- Synergies with neighbouring fields
- Organisational issues
- Environmental and societal impact

** Letters used for itemizing statements are introduced for identification only, and do not imply prioritization.

Strategy summary

European Strategy Update

- **Major developments from the 2013 Strategy**
  (A) To maintain focus on successful completion and full exploitation of HL-LHC project.
  (B) To maintain support for long-baseline neutrino projects in Japan and US.

- **General considerations for the 2020 update**
  (A) To preserve Europe's scientific and technological leadership.
  (B) To strengthen Europe's unique ecosystem of research centres.
  (C) To cultivate global nature of particle physics research.

- **High-priority future initiatives**

- **Other essential scientific activities for particle physics**

- **Synergies with neighbouring fields**
  (A) Nuclear Physics - To maintain experimental capability and coordination with NuPECC.
  (B) Astrophysics - To strengthen synergies and cooperation with APPEC.

- **Organisational issues**
  (A) To establish framework for global projects in/out of Europe.
  (B) To Strengthen relations with European Commission.
  (C) To play an active role in Open Science policies and their implementation.

- **Environmental and societal impact**
  (A) To mitigate environment impact of particle physics research.
  (B) To invest in and support next generation of researchers.
  (C) To support knowledge and technology transfer.
  (D) To support public engagement, education and communication.

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Strategy summary

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High-priority future initiatives

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(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.*

The timely realisation of the electron-positron International Linear Collider (ILC) in Japan would be compatible with this strategy and, in that case, the European particle physics community would wish to collaborate.

(B) Innovative accelerator technology underpins the physics reach of high-energy and high-intensity colliders. It is also a powerful driver for many accelerator-based fields of science and industry. The technologies under consideration include high-field magnets, high-temperature superconductors, plasma wakefield acceleration and other high-gradient accelerating structures, bright muon beams, energy recovery linacs. ***The European particle physics community must intensify accelerator R&D and sustain it with adequate resources. A roadmap should prioritise the technology****, taking into account synergies with international partners and other communities such as photon and neutron sources, fusion energy and industry. Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.*

e+e- Higgs factories

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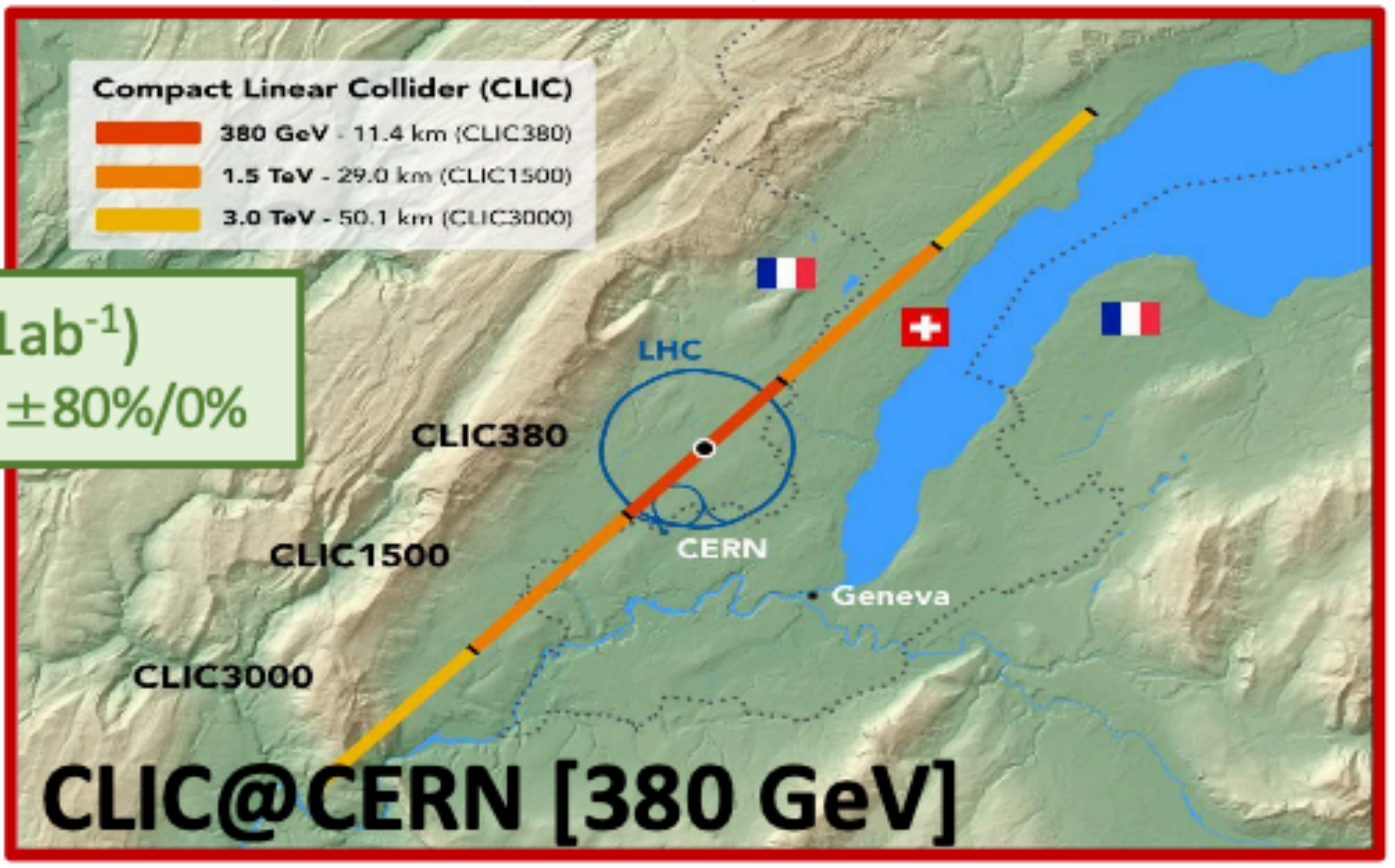
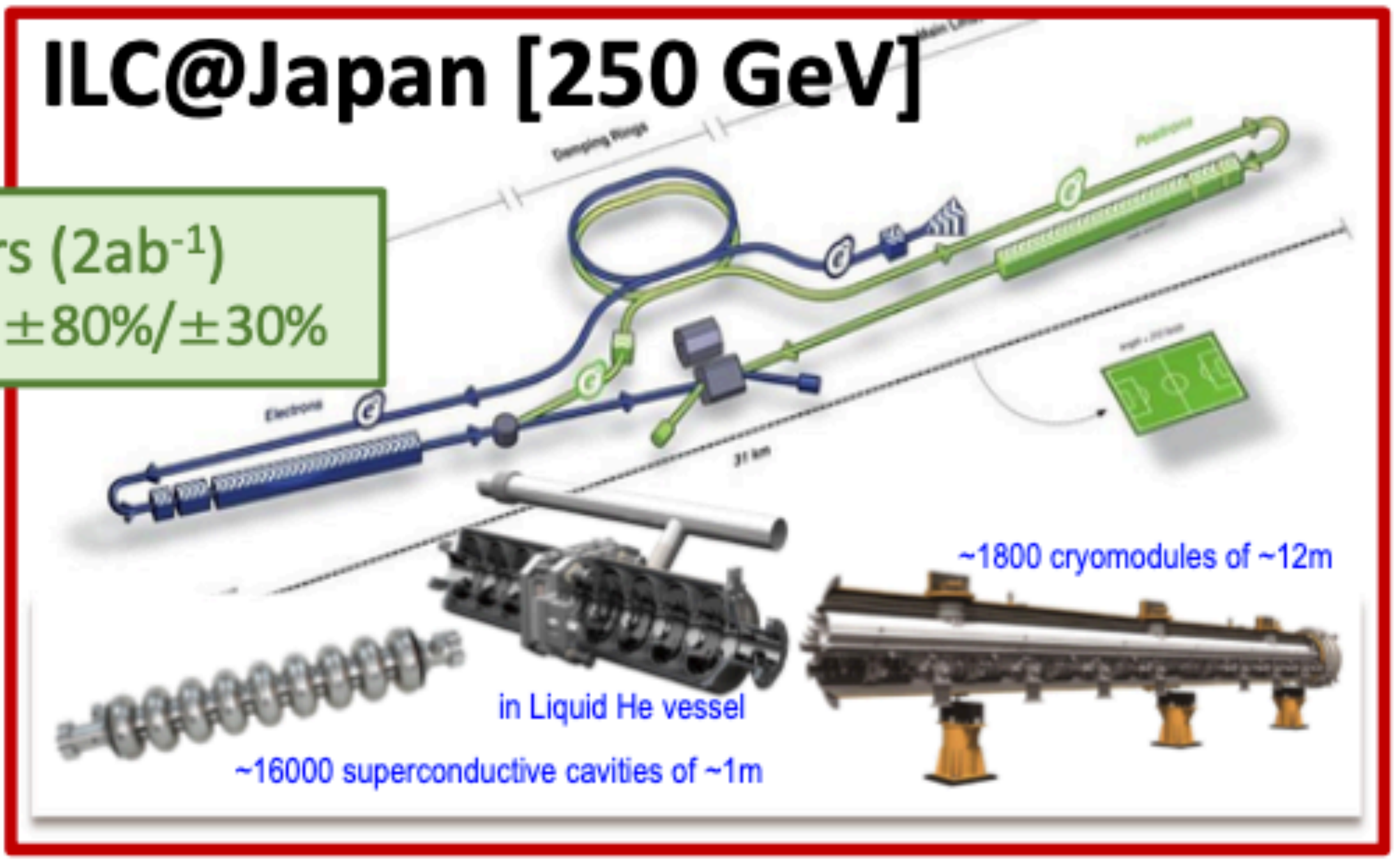
linear colliders

P. Burrows, M. Weber, P. Roloff, …



8 years ($1ab^{-1}$)
$\mathcal{P}(e^-/e^+) = \pm 80\%/0\%$



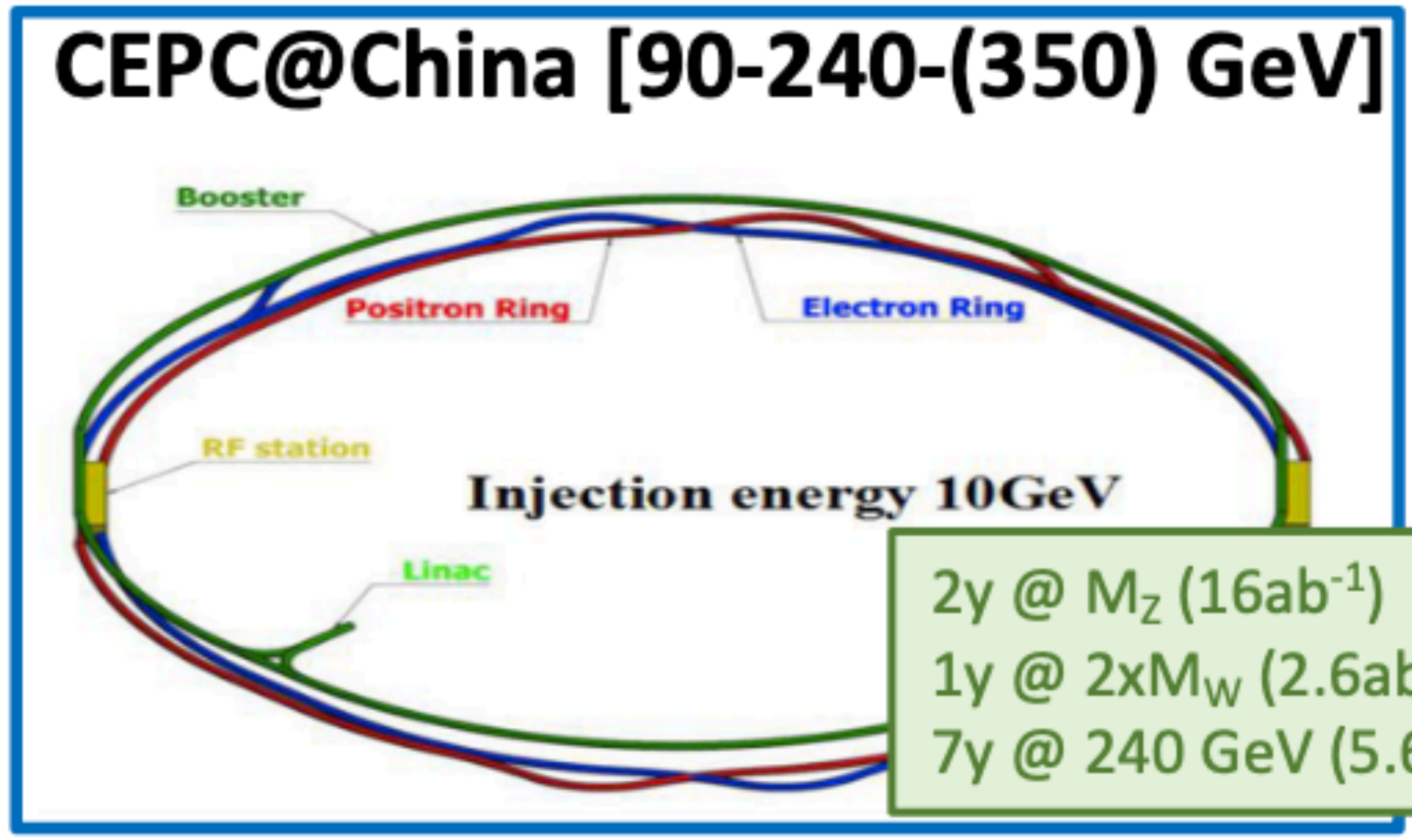
11.5 years ($2ab^{-1}$)
$\mathcal{P}(e^-/e^+) = \pm 80\%/\pm 30\%$

J. List, M. Peskin, D. Jeans, G. Wilson, T. Núñez, …

circular colliders

D. d'Enterria, A. Blondel, P. Janot, …

4y @ M_Z ($150ab^{-1}$)
1-2y @ $2xM_W$ ($10ab^{-1}$)
3y @ 240 GeV ($5ab^{-1}$)
5y @ $2xm_t$ ($1.5ab^{-1}$)



2y @ M_Z ($16ab^{-1}$)
1y @ $2xM_W$ ($2.6ab^{-1}$)
7y @ 240 GeV ($5.6ab^{-1}$)

J. Gao, M. Pandurovic, …

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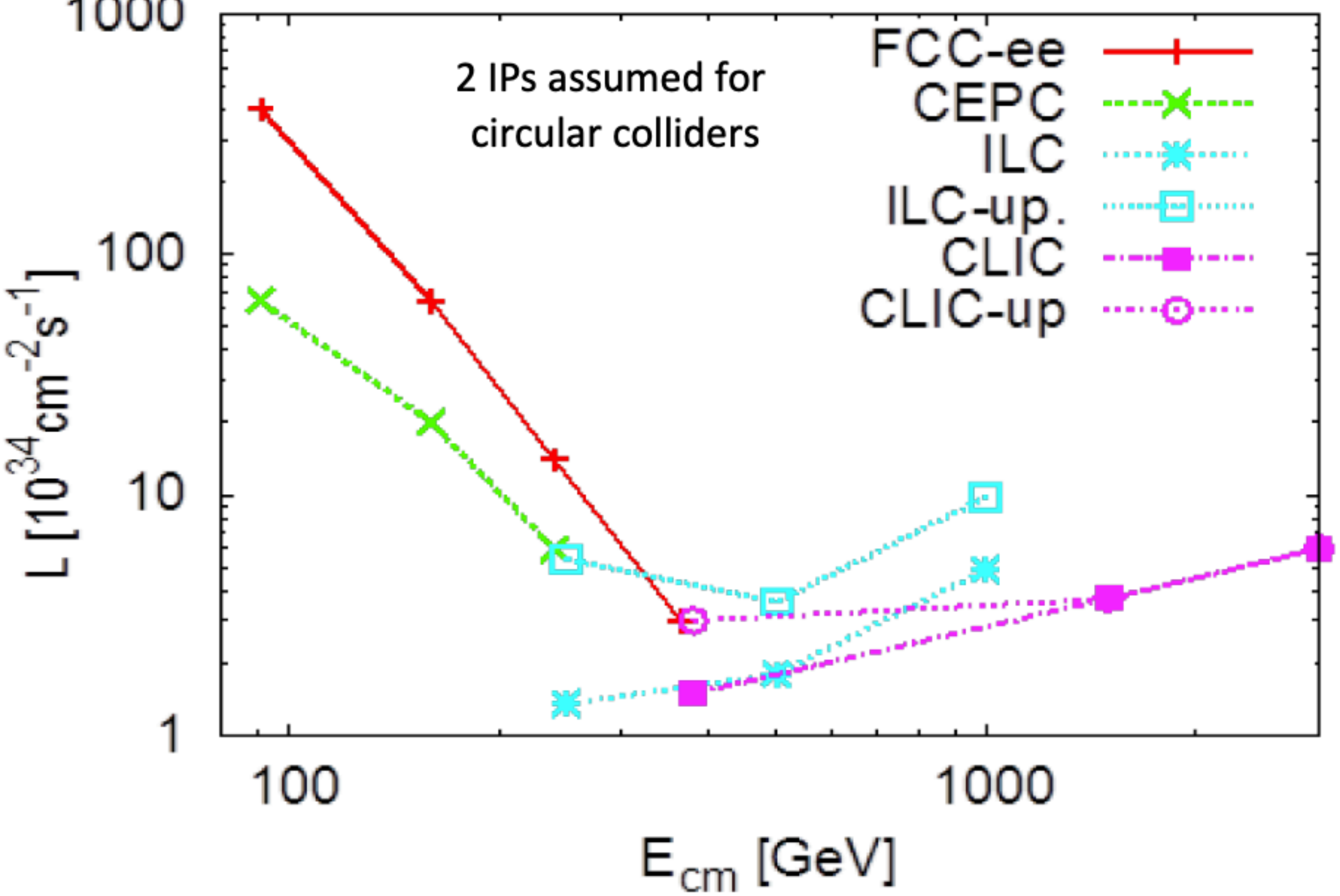
From J. D'Hondt

e^+e^- Higgs factories

arXiv:1910.11775

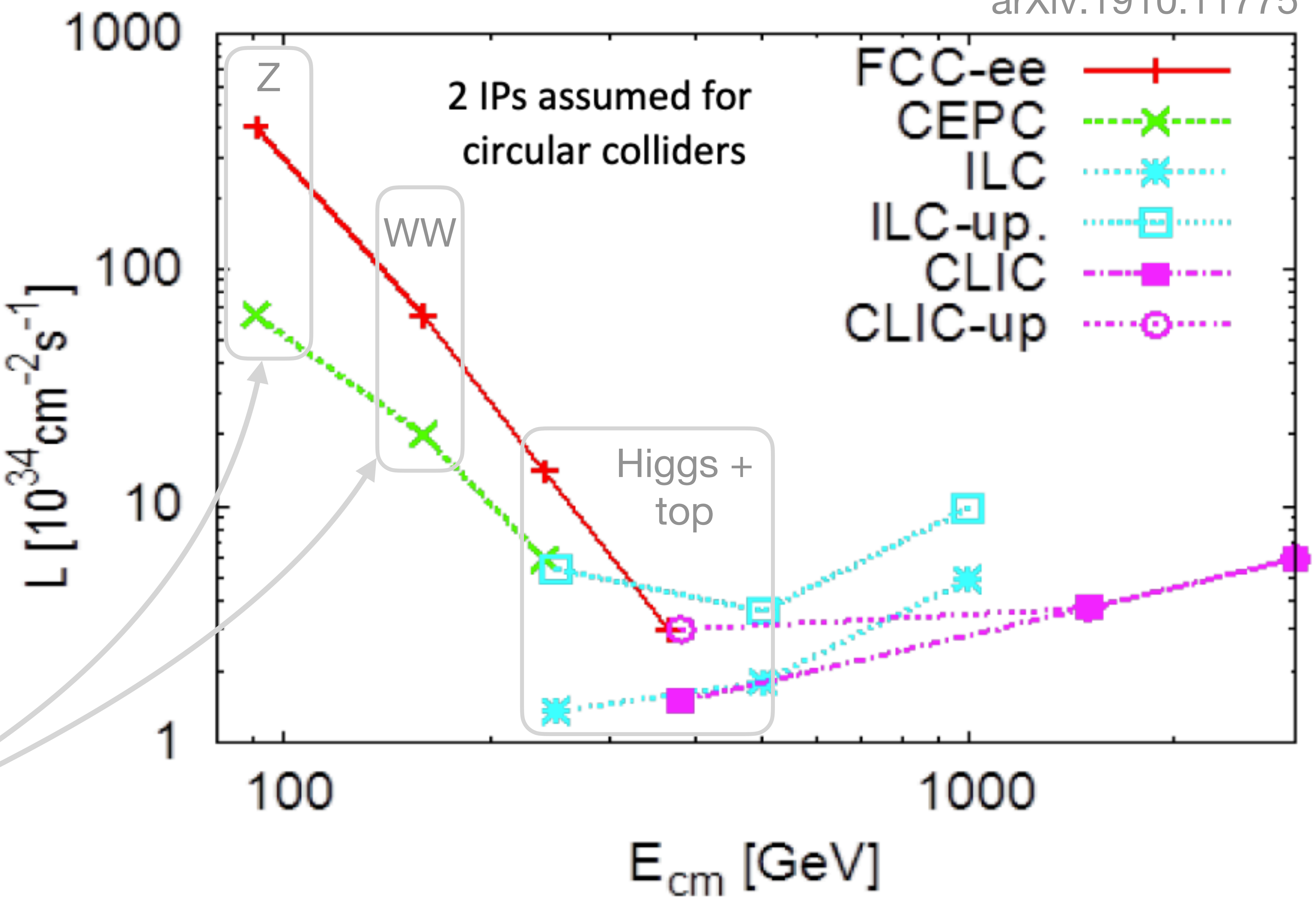


e+e- Higgs factories

Precision frontier

Energy frontier

arXiv:1910.11775



B/c/τ/EW factories

per detector	# Z	# B	# τ	# charm	# WW
LEP	4 x 10^6	1 x 10^6	3 x 10^5	1 x 10^6	2 x 10^4
SuperKEKB	—	10^{11}	10^{11}	10^{11}	—
FCC-ee	2.5 x 10^{12}	7.5 x 10^{11}	2 x 10^{11}	6 x 10^{11}	1.5 x 10^8

Energy frontier (hadron) colliders

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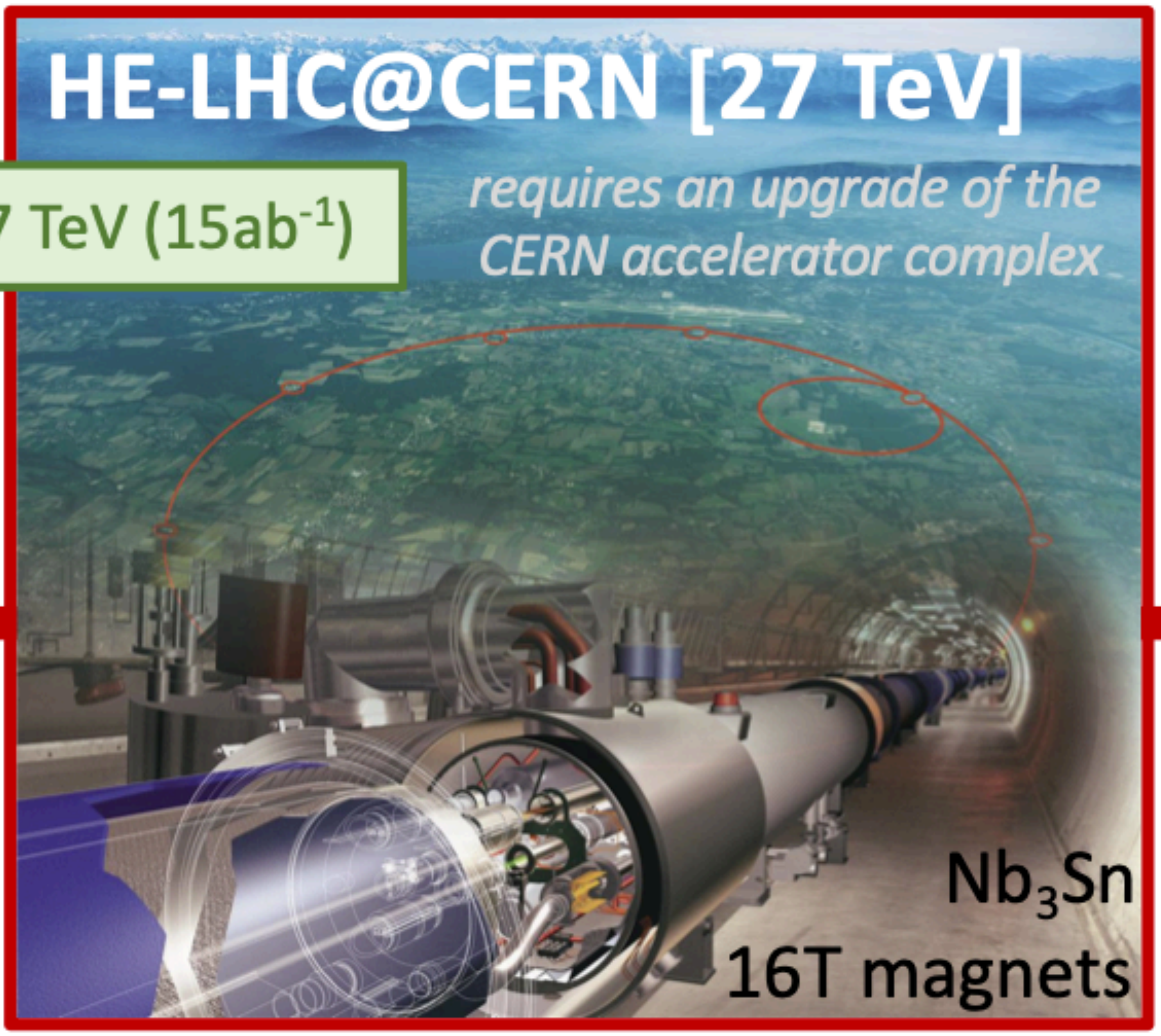
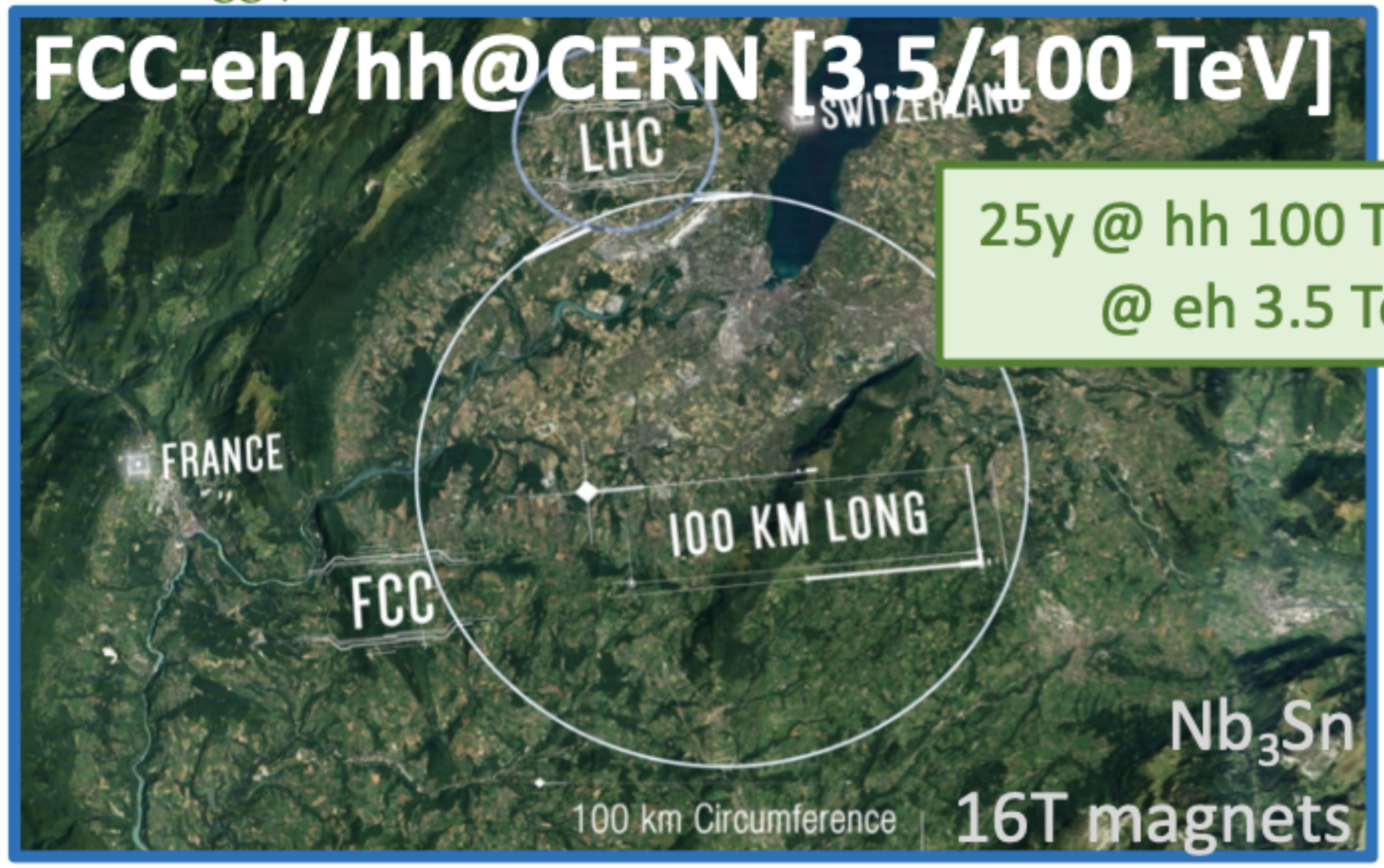
Direct BSM searches at the highest energies
e.g. addressing the naturalness puzzle

20y @ 27 TeV ($15ab^{-1}$)

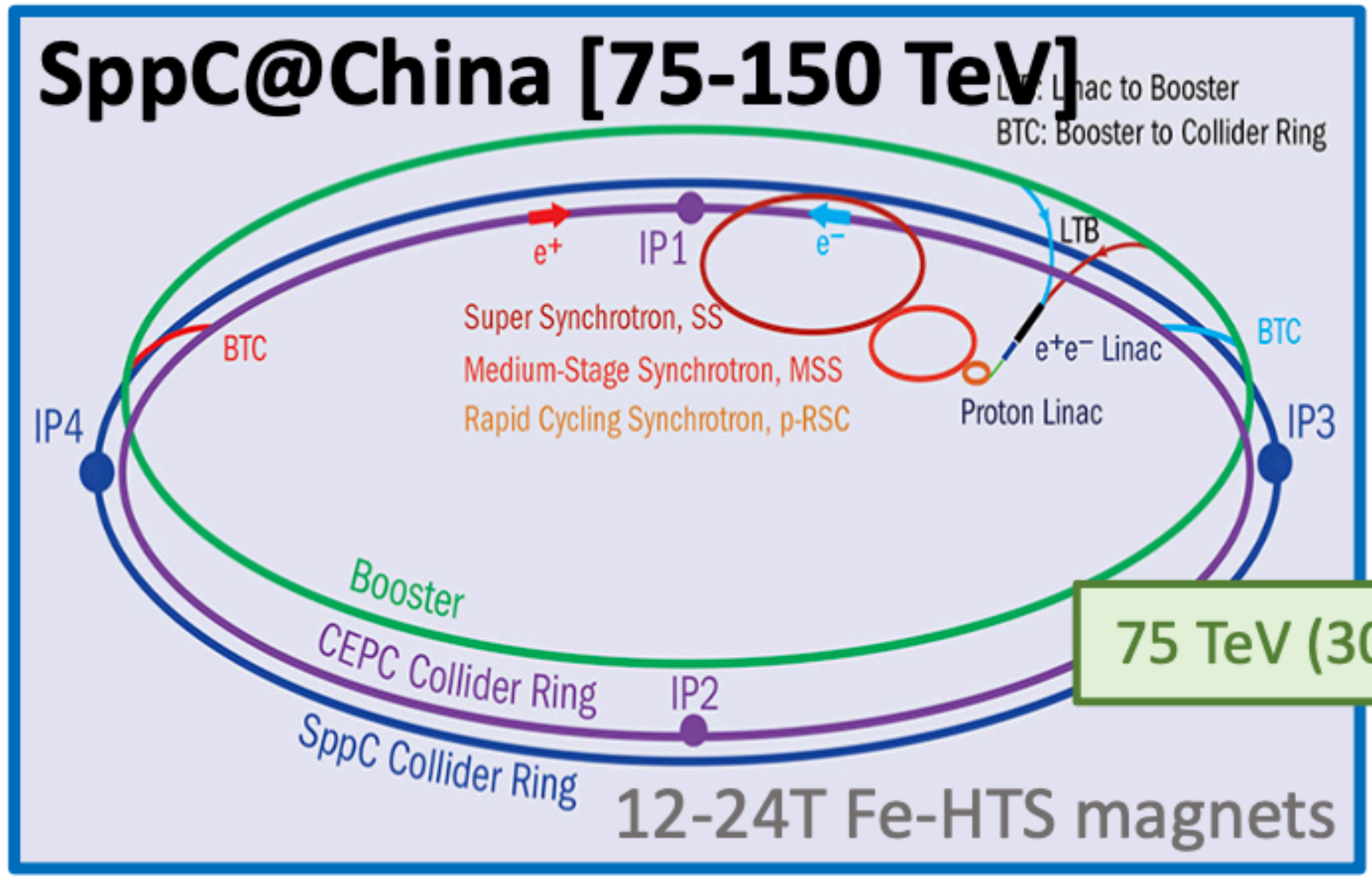


M. Selvaggi, …



25y @ hh 100 TeV ($30ab^{-1}$)
@ eh 3.5 TeV ($2ab^{-1}$)

E



75 TeV ($30ab^{-1}$)

numbers assume 2 IPs for each collider (only one for FCC-eh)

From J. D'Hondt

Physics prospects of future colliders

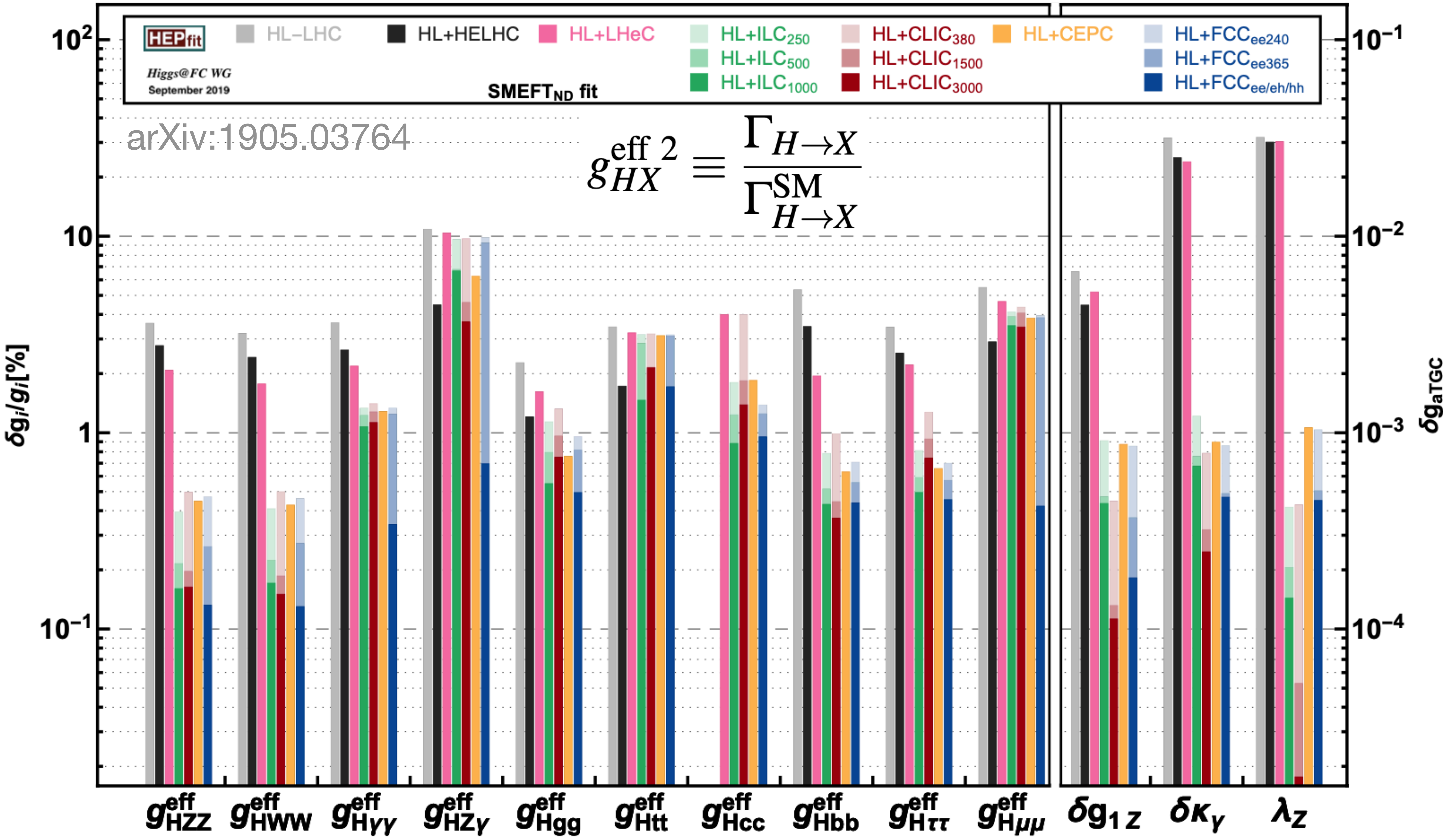
European Strategy Update

Electroweak & Higgs
Flavour
Beyond the SM
Dark sector
Strong interactions
Neutrino

Physics prospects of future colliders

European Strategy Update

Sensitivity to deviations in effective Higgs couplings
(global EFT fit – dim-6 SM Effective Field Theory)



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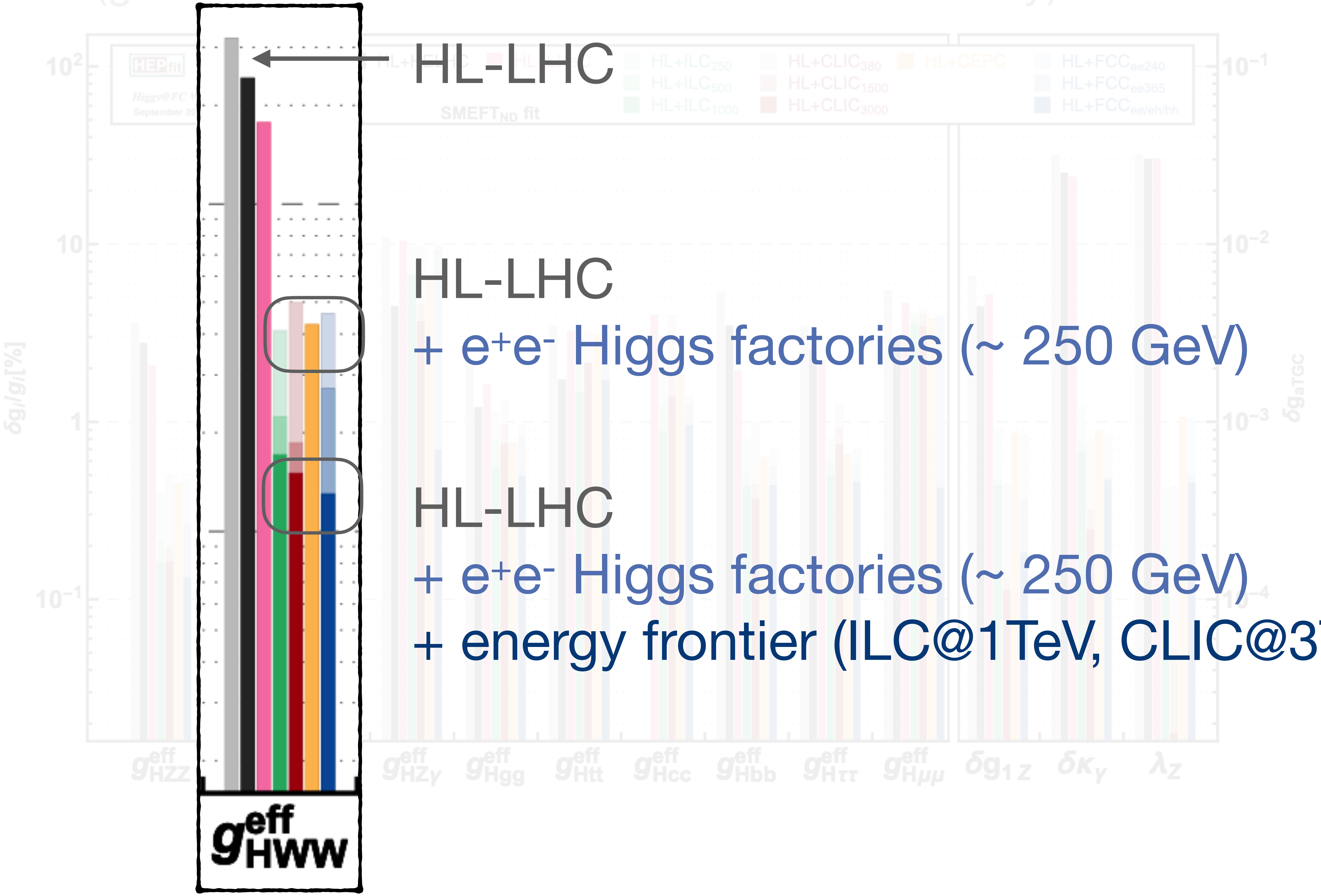

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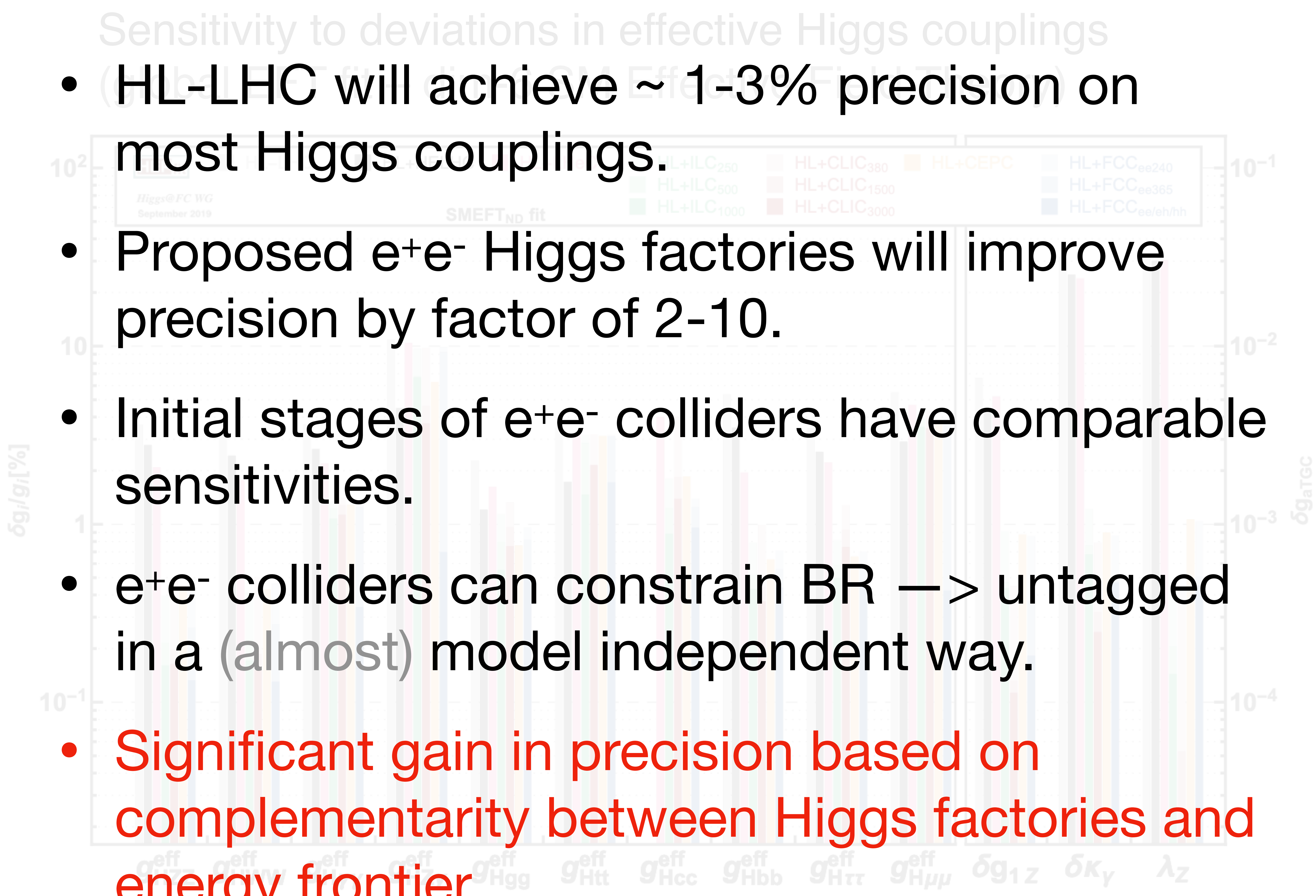
Physics prospects of future colliders



- HL-LHC will achieve ~ 1-3% precision on most Higgs couplings.
- Proposed e^+e^- Higgs factories will improve precision by factor of 2-10.
- Initial stages of e^+e^- colliders have comparable sensitivities.
- e^+e^- colliders can constrain BR —> untagged in a (almost) model independent way.
- Significant gain in precision based on complementarity between Higgs factories and energy frontier.

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Physics prospects of future colliders

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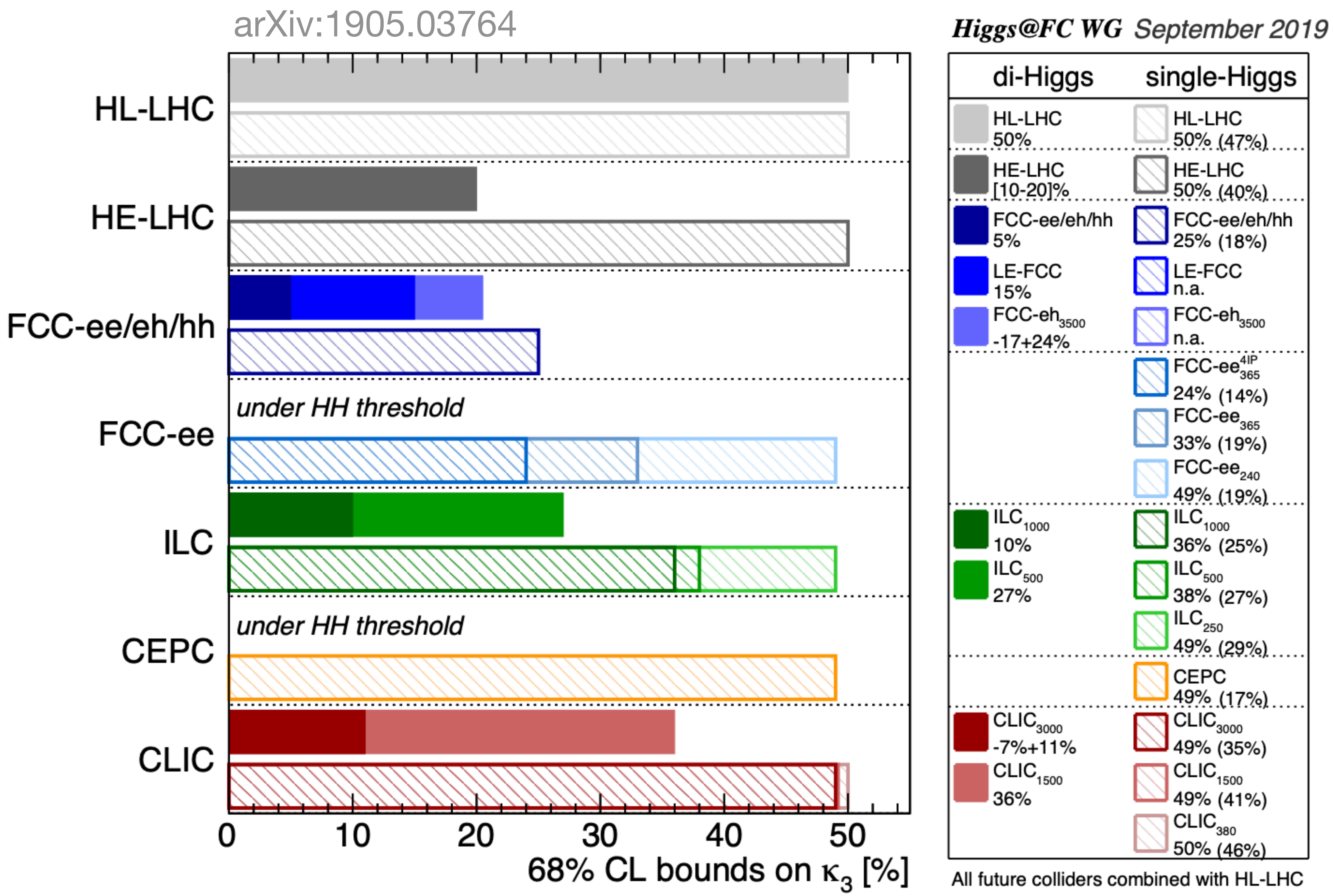

Electroweak & Higgs
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Complementarity between
lower-energy e^+e^- colliders (single-H)
and
higher-energy colliders (double-H)

Physics prospects of future colliders

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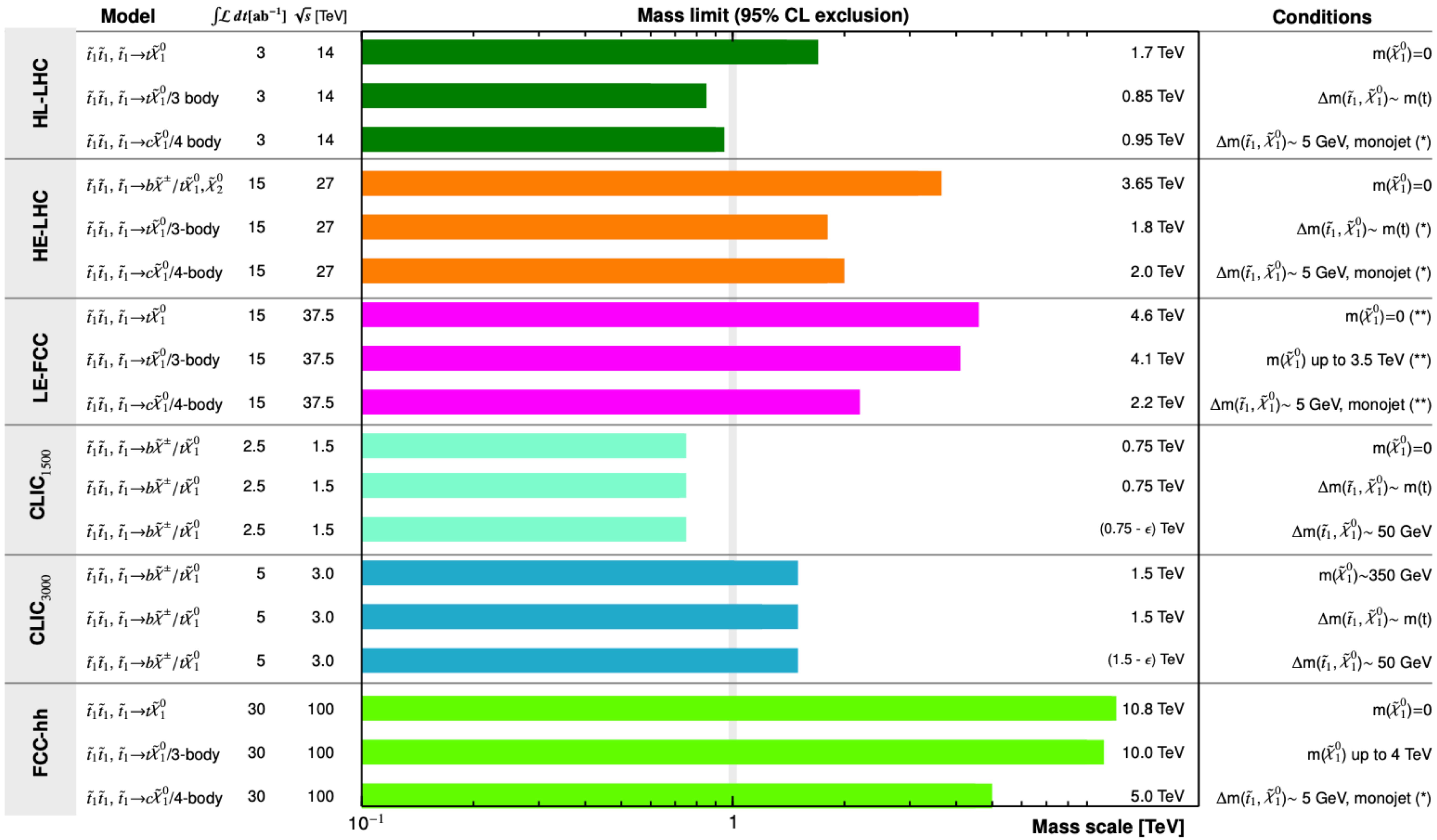
All Colliders: Top squark projections

(R-parity conserving SUSY, prompt searches)



(*) indicates projection of existing experimental searches

(**) extrapolated from FCC-hh prospects

ϵ indicates a possible non-evaluated loss in sensitivity

ILC 500: discovery in all scenarios up to kinematic limit $\sqrt{s}/2$

Electroweak & Higgs
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Proton colliders increase reach by an order of magnitude.

Other essential scientific activities for particle physics

European Strategy Update

(A) […] A diverse programme that is complementary to the energy frontier is an essential part of the European particle physics Strategy. *Experiments in such diverse areas that offer potential high-impact particle physics programmes at laboratories in Europe should be supported, as well as participation in such experiments in other regions of the world*.

(B) […] *Europe should continue to vigorously support a broad programme of theoretical research covering the full spectrum of particle physics from abstract to phenomenological topics*. […]

(C) […] To prepare and realise future experimental research programmes, the community must maintain a strong focus on instrumentation. […] *The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels. […]*

(D) […] *The community must vigorously pursue common, coordinated R&D efforts in collaboration with other fields of science and industry to develop software and computing infrastructures that exploit recent advances in information technology and data science*.

Summary

European Strategy Update

- On June 19, 2020 CERN’s Council unanimously approved the update the European Strategy for particle physics.

- The European vision is to prepare a Higgs factory, followed by a future hadron collider with sensitivity to energy scales an order of magnitude higher than those of the LHC.
  - Given the scale of long-term projects, the European plan needs to be coordinated with other regions of the world.
  - A further update of the Strategy should be foreseen in the second half of this decade when results of the feasibility study for the future hadron collider are available and ready for decision.

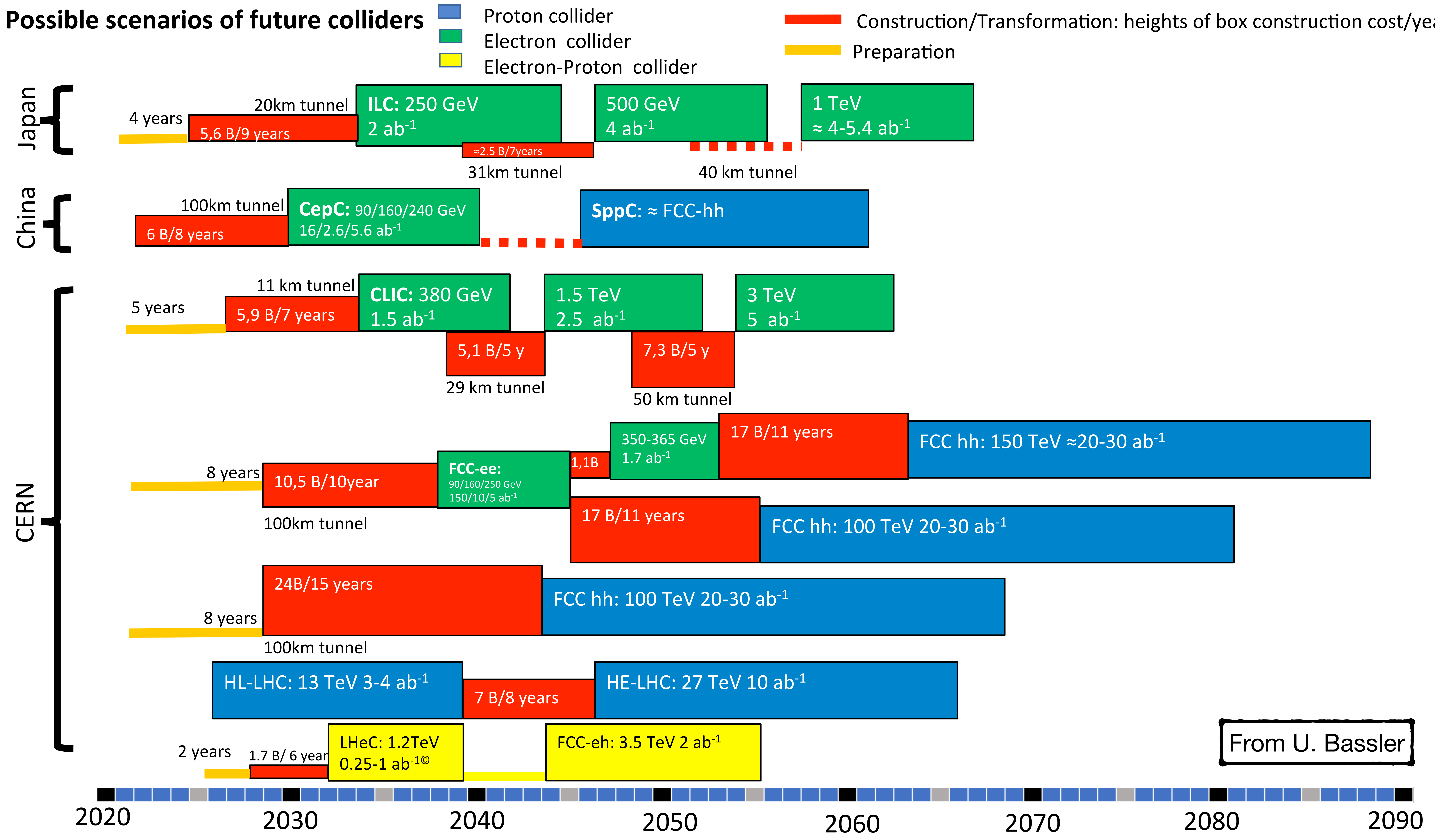
- To remain attractive and dynamic, the field needs to address important technical, environmental and societal challenges, as well as meet the aspirations of the next generation of researchers.

The updated European strategy is an ambitious, yet realistic strategy focussed on both near and long-term priorities for the field.

Within the scope of this strategy there are several ways in which TRIUMF and the Canadian community can engage in the future of particle physics.

BACKUP

High-priority future initiatives



Future developments

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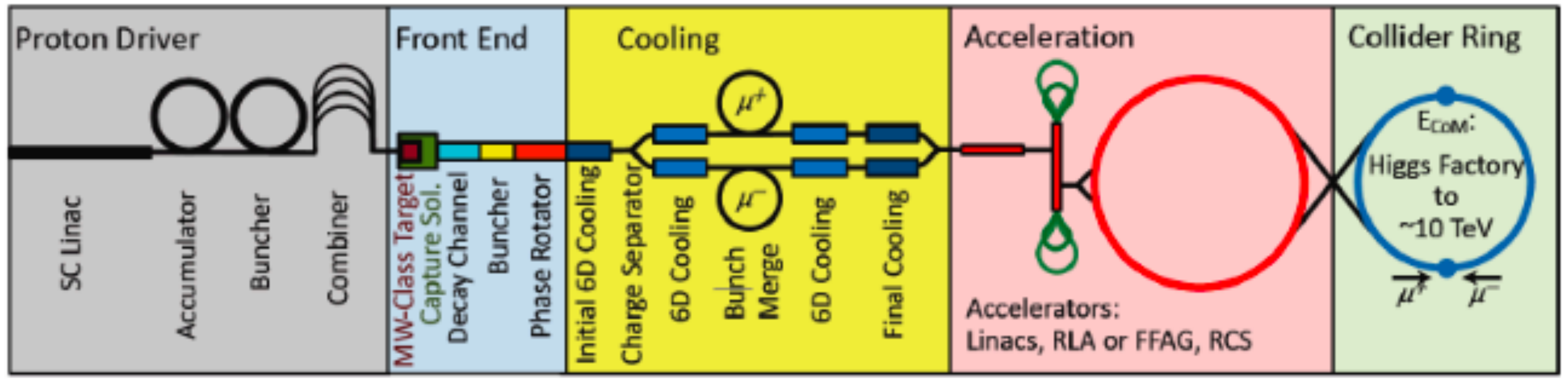
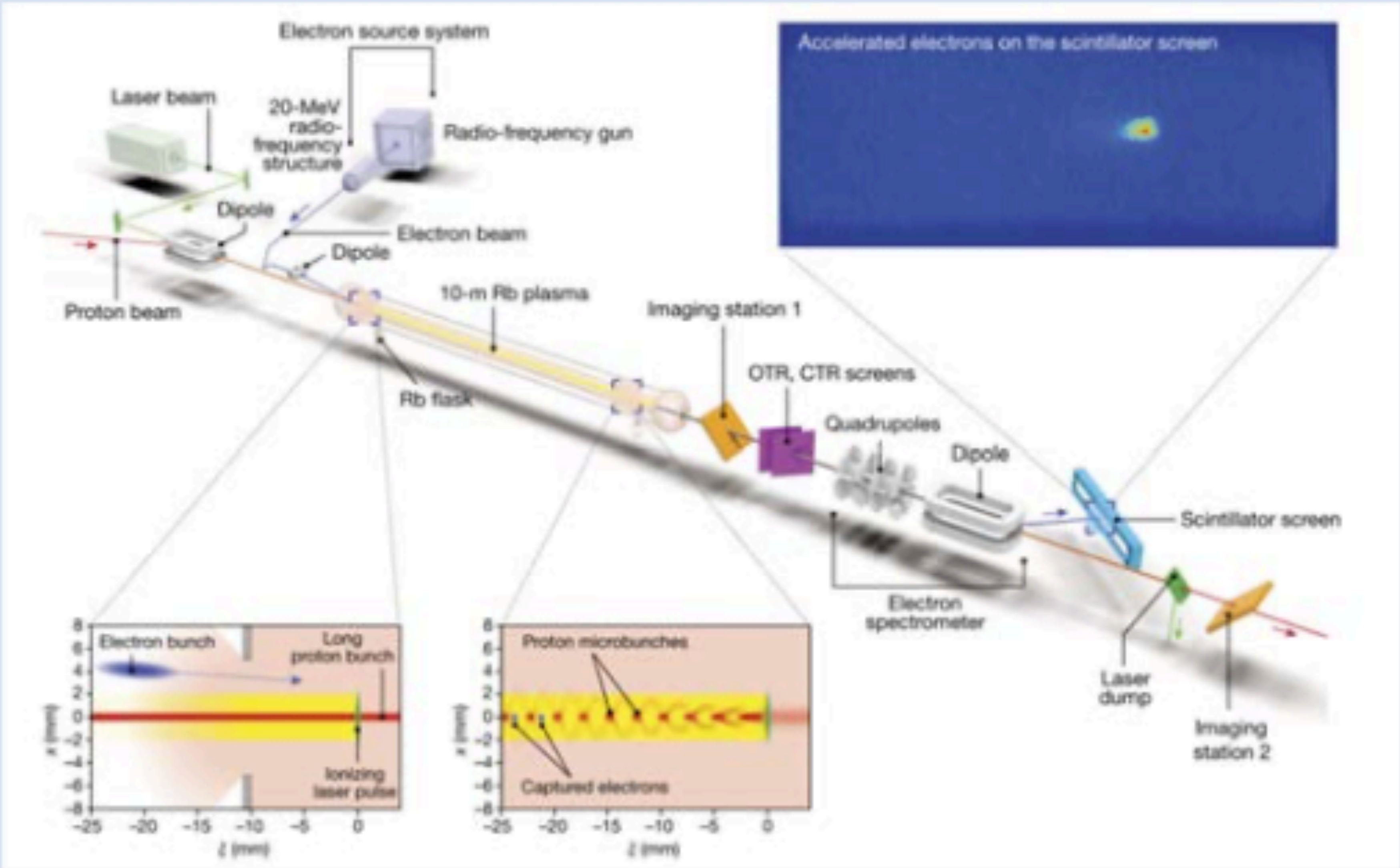
Very interesting R&D projects

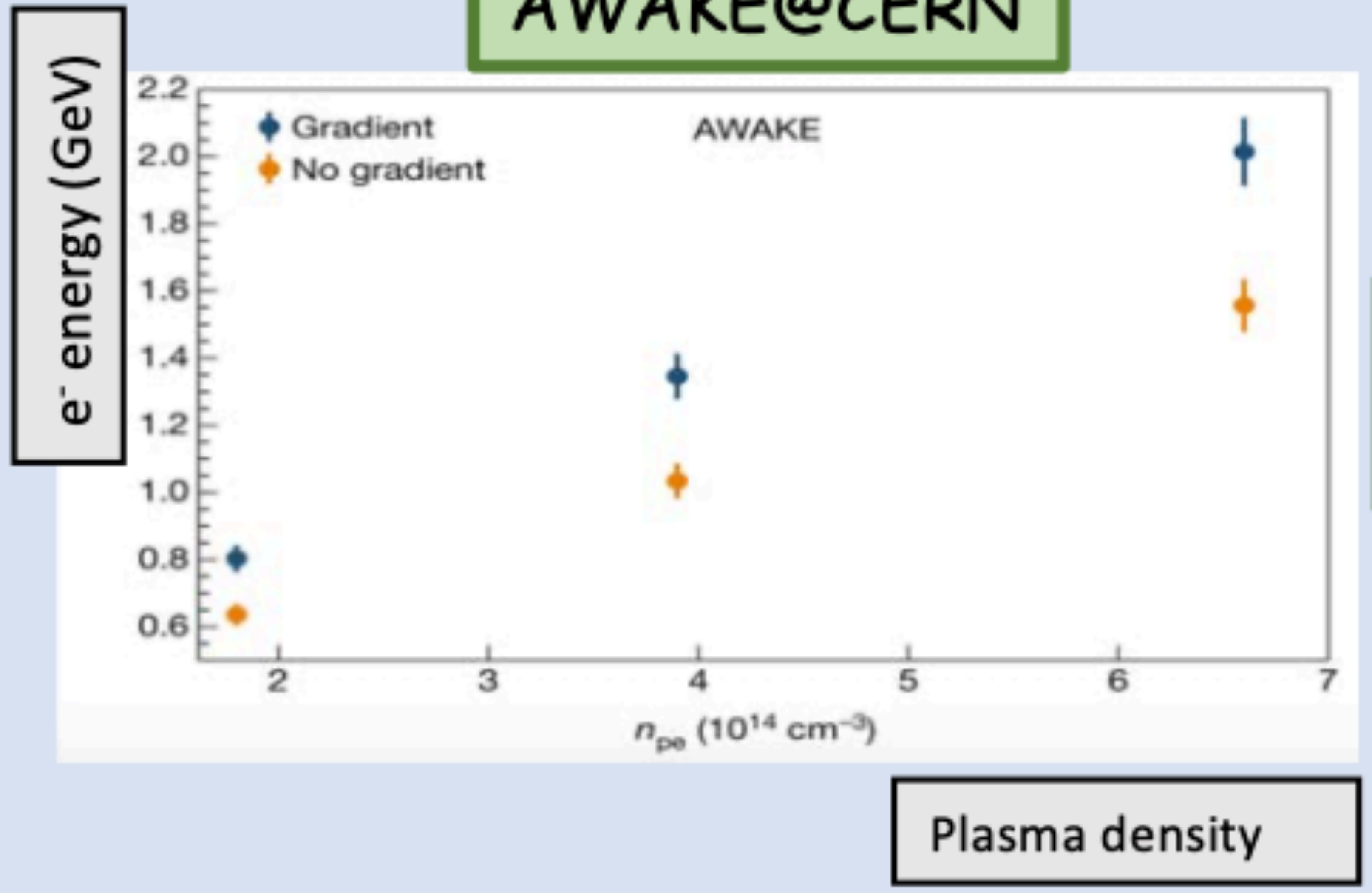
- Muon collider:
  - from proton beam (rcooling success: MICE)
  - from e+e- production (LEMMA)
- Plasma wakefield acceleration:
  - High gradients possible: ~100 GV/m
  - R&D progressing well but many challenges

Muon-based technology represents a unique opportunity for the future of high energy physics research: the multi-TeV energy domain exploration.





AWAKE@CERN



Achieved 2 GeV over 10m
Gradient 200 MV/m