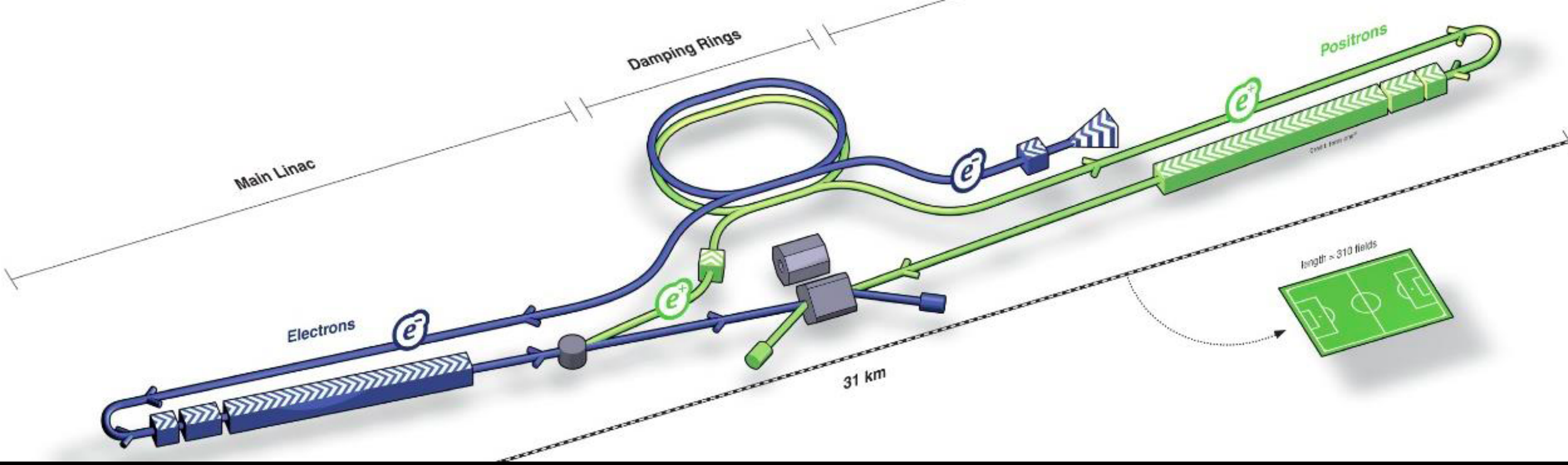



# Overview on the ILC project and political situation in Japan

Hitoshi Murayama (Berkeley, Kavli IPMU Tokyo)

ICNFP2020 Sep 5, 2020

BERKELEY CENTER FOR THEORETICAL PHYSICS

BERKELEY LAB

東京大学 THE UNIVERSITY OF TOKYO

UTIAS 東京大学国際高等研究所 THE UNIVERSITY OF TOKYO INSTITUTES FOR ADVANCED STUDY

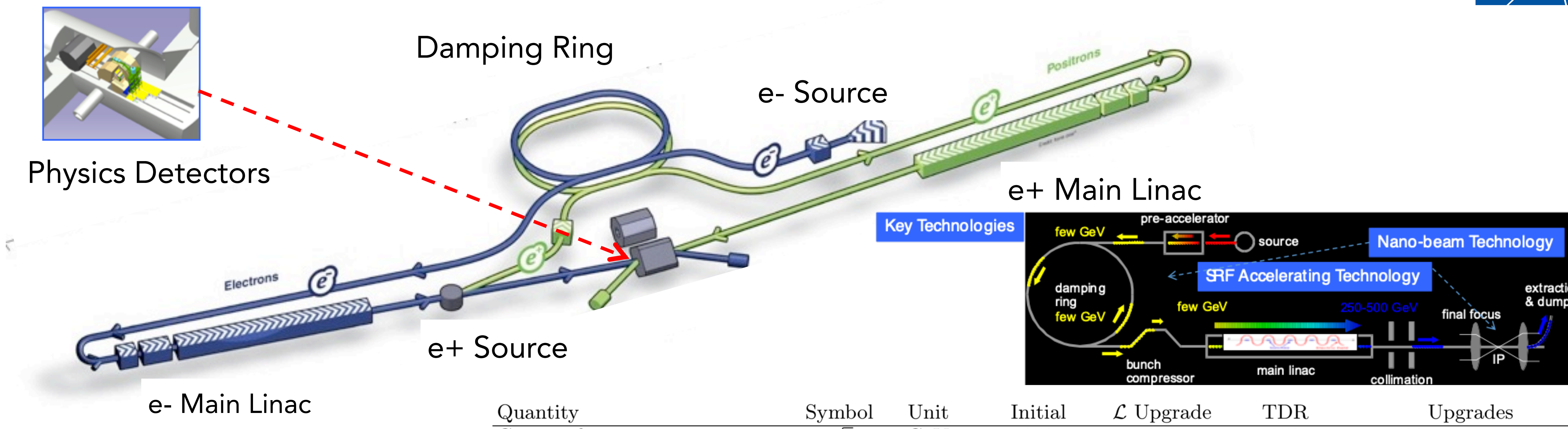
KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

# Outline

- Machine
- Physics
- Politics

# Machine

# ILC Design Overview




| Quantity | Symbol | Unit | Initial | $\mathcal{L}$ Upgrade | TDR | Upgrades | |
|---|---|---|---|---|---|---|---|
| Centre of mass energy | $\sqrt{s}$ | GeV | 250 | 250 | 250 | 500 | 1000 |
| Luminosity | $\mathcal{L}$ | $10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ | 1.35 | 2.7 | 0.82 | 1.8/3.6 | 4.9 |
| Polarisation for $e^-(e^+)$ | $P_-(P_+)$ | | 80 %(30 %) | 80 %(30 %) | 80 %(30 %) | 80 %(30 %) | 80 %(20 %) |
| Repetition frequency | $f_{\mathrm{rep}}$ | Hz | 5 | 5 | 5 | 5 | 4 |
| Bunches per pulse | $n_{\mathrm{bunch}}$ | 1 | 1312 | 2625 | 1312 | 1312/2625 | 2450 |
| Bunch population | $N_{\mathrm{e}}$ | $10^{10}$ | 2 | 2 | 2 | 2 | 1.74 |
| Linac bunch interval | $\Delta t_{\mathrm{b}}$ | ns | 554 | 366 | 554 | 554/366 | 366 |
| Beam current in pulse | $I_{\mathrm{pulse}}$ | mA | 5.8 | 5.8 | 8.8 | 5.8 | 7.6 |
| Beam pulse duration | $t_{\mathrm{pulse}}$ | $\mu$s | 727 | 961 | 727 | 727/961 | 897 |
| Average beam power | $P_{\mathrm{ave}}$ | MW | 5.3 | 10.5 | 10.5 | 10.5/21 | 27.2 |
| Norm. hor. emitt. at IP | $\gamma\epsilon_{\mathrm{x}}$ | $\mu$m | 5 | 5 | 10 | 10 | 10 |
| Norm. vert. emitt. at IP | $\gamma\epsilon_{\mathrm{y}}$ | nm | 35 | 35 | 35 | 35 | 30 |
| RMS hor. beam size at IP | $\sigma^*_{\mathrm{x}}$ | nm | 516 | 516 | 729 | 474 | 335 |
| RMS vert. beam size at IP | $\sigma^*_{\mathrm{y}}$ | nm | 7.7 | 7.7 | 7.7 | 5.9 | 2.7 |
| Luminosity in top 1 % | $\mathcal{L}_{0.01}/\mathcal{L}$ | | 73 % | 73 % | 87.1 % | 58.3 % | 44.5 % |
| Energy loss from beamstrahlung | $\delta_{\mathrm{BS}}$ | | 2.6 % | 2.6 % | 0.97 % | 4.5 % | 10.5 % |
| Site AC power | $P_{\mathrm{site}}$ | MW | 129 | | 122 | 163 | 300 |
| Site length | $L_{\mathrm{site}}$ | km | 20.5 | 20.5 | 31 | 31 | 40 |

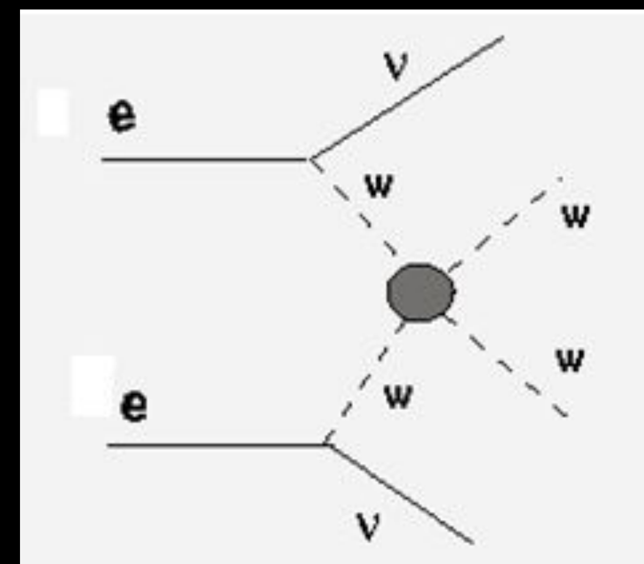
Luminosity upgrade to 10 Hz at 250 also considered

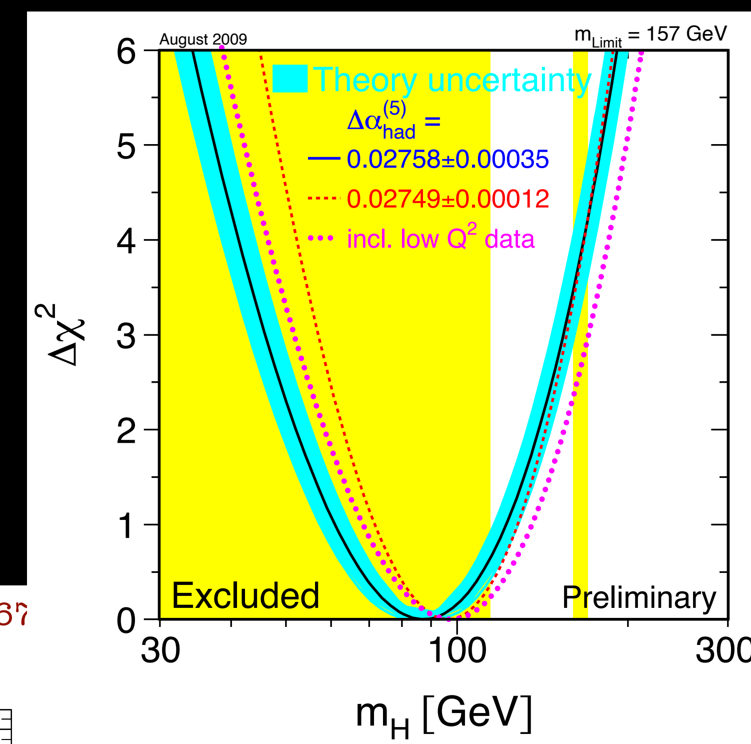


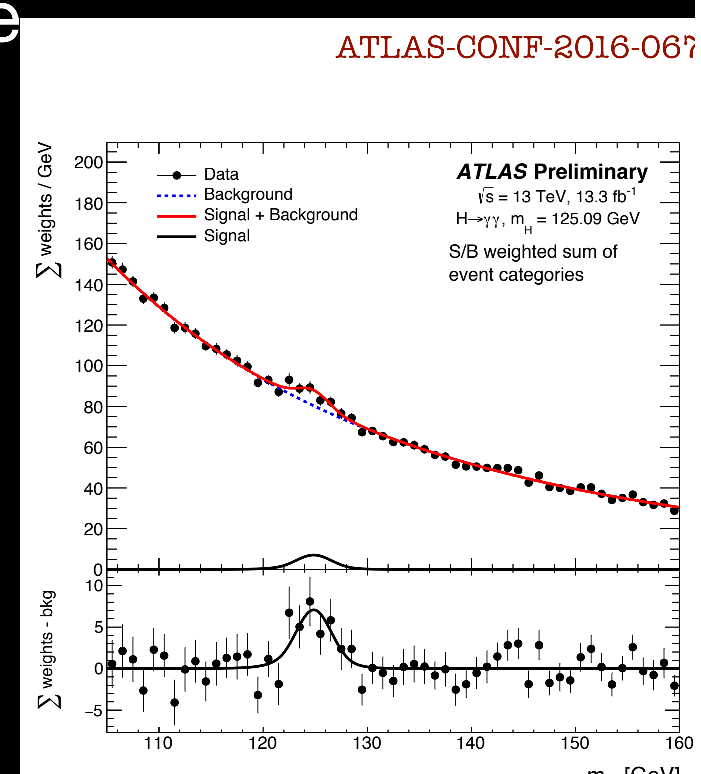
**Steinar Stapnes @ Granada**

# Why 250 GeV?

- 1980's: 1.5 TeV minimum
  - we didn't know whether EWSB was strongly or weakly coupled
- 2000's: 500 GeV
  - LEP told us it is likely to have a Higgs boson <250 GeV
- 2012: 250 GeV
  - $m_H$=125 GeV, *ZH* production possible at 250 GeV

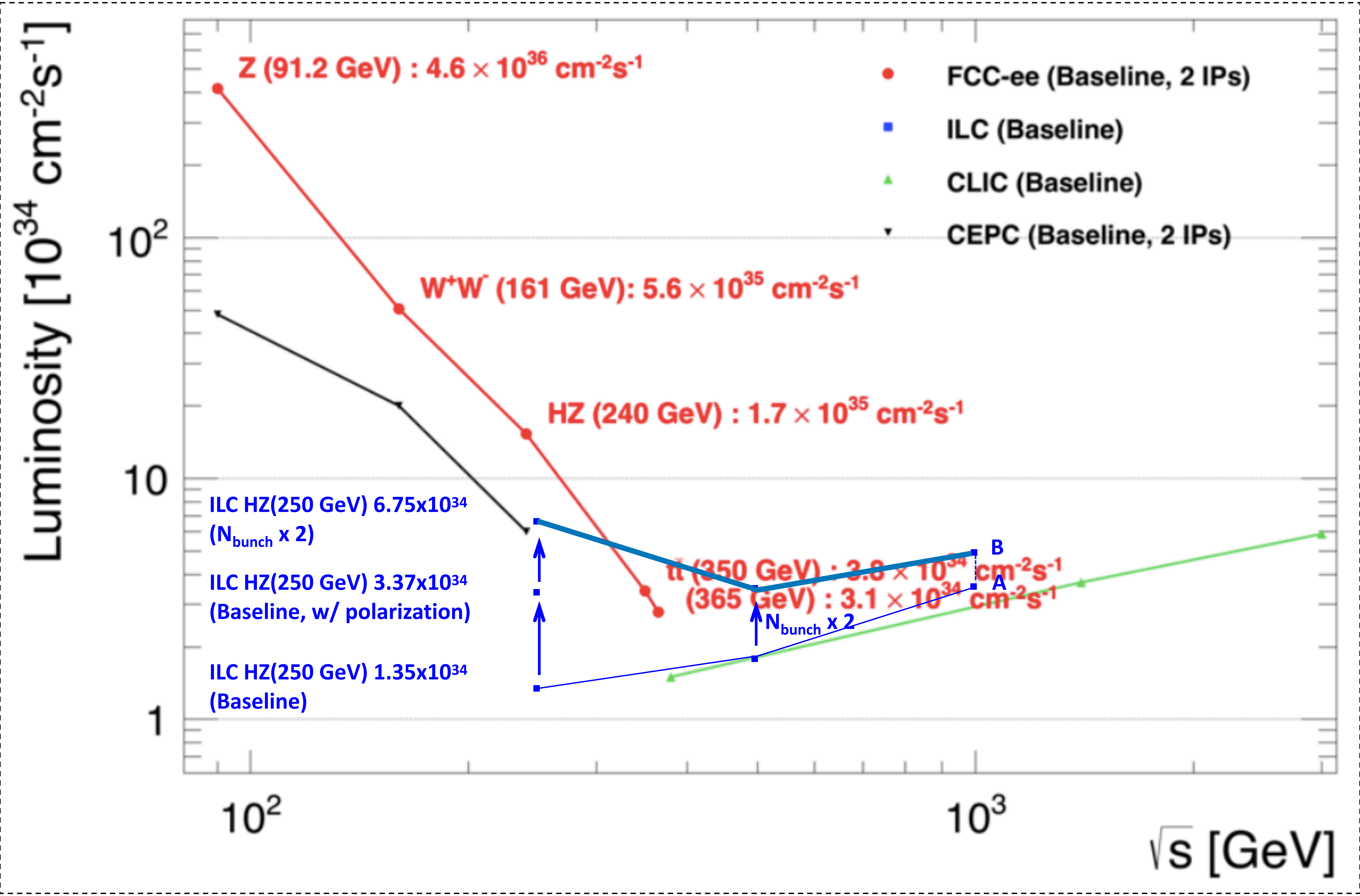


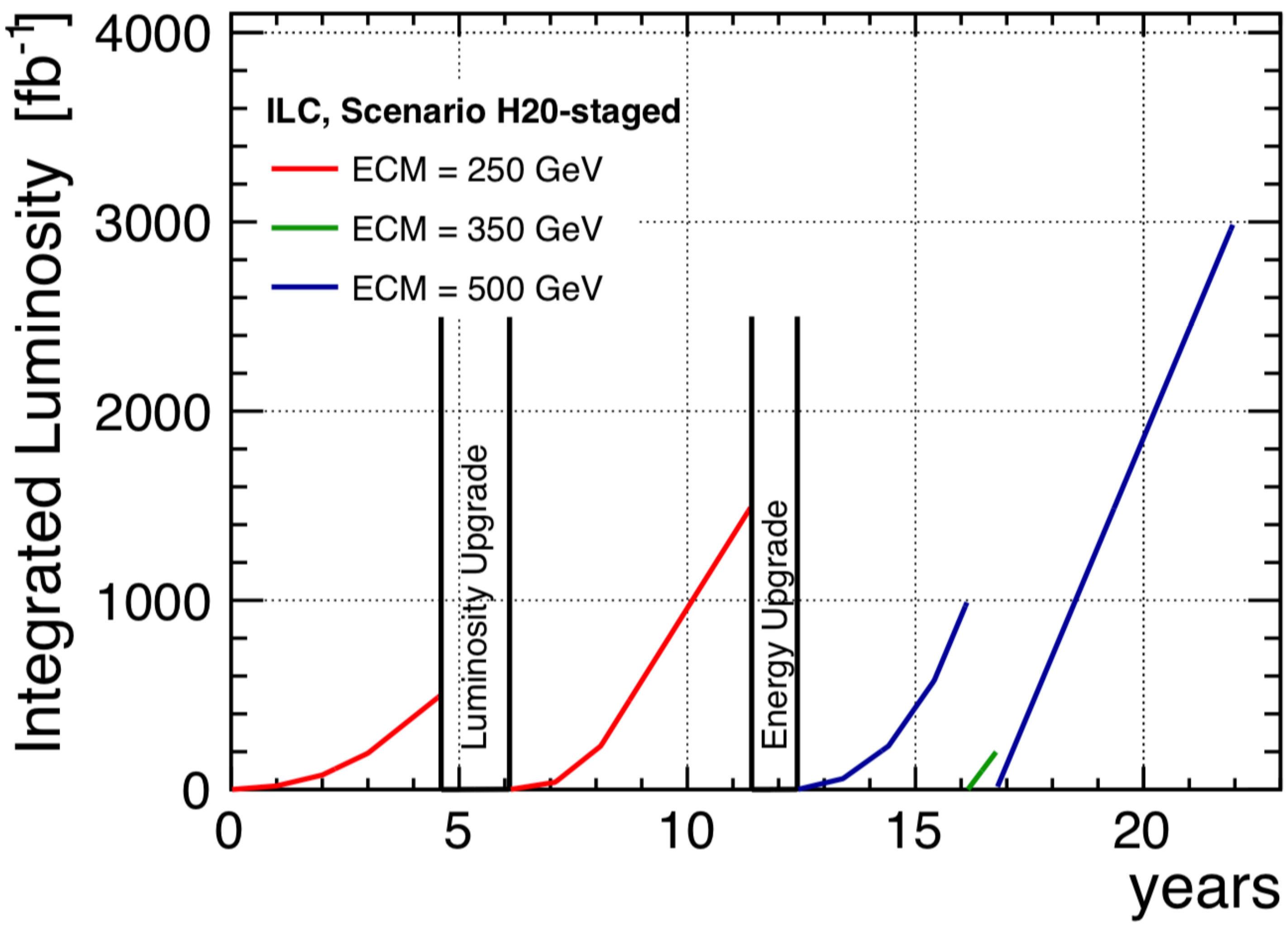
# Why linear & SCRF?

- Energy Upgrade
  - once there is a linear tunnel, we can extend it and/or put in new technology
- Polarization
  - longitudinal polarization is preserved in LINAC
- efficiency (power consumption)
  - superconducting cavity (chosen 2004)



Z (91.2 GeV) : 4.6 × 10^36 cm^-2s^-1
W+W- (161 GeV): 5.6 × 10^35 cm^-2s^-1
HZ (240 GeV) : 1.7 × 10^35 cm^-2s^-1
tt (350 GeV) : 3.8 × 10^34 cm^-2s^-1
(365 GeV) : 3.1 × 10^34 cm^-2s^-1
FCC-ee (Baseline, 2 IPs)
ILC (Baseline)
CLIC (Baseline)
CEPC (Baseline, 2 IPs)
ILC HZ(250 GeV) 6.75x10^34
(N_bunch x 2)
ILC HZ(250 GeV) 3.37x10^34
(Baseline, w/ polarization)
ILC HZ(250 GeV) 1.35x10^34
(Baseline)
N_bunch x 2
B
A
Luminosity [10^34 cm^-2s^-1]
√s [GeV]
10^2
10
1
10^2
10^3

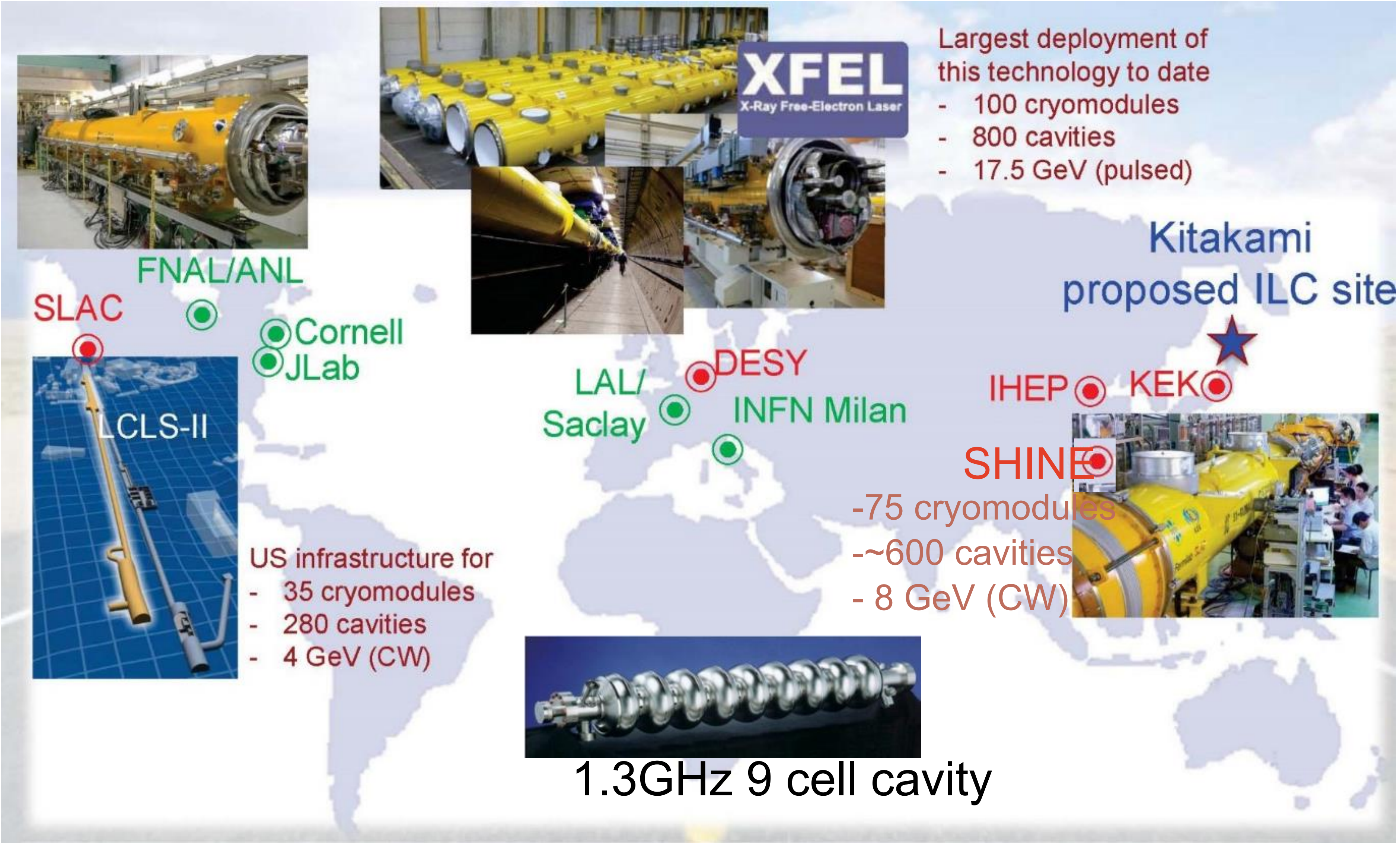
# ILC staging baseline




Model:

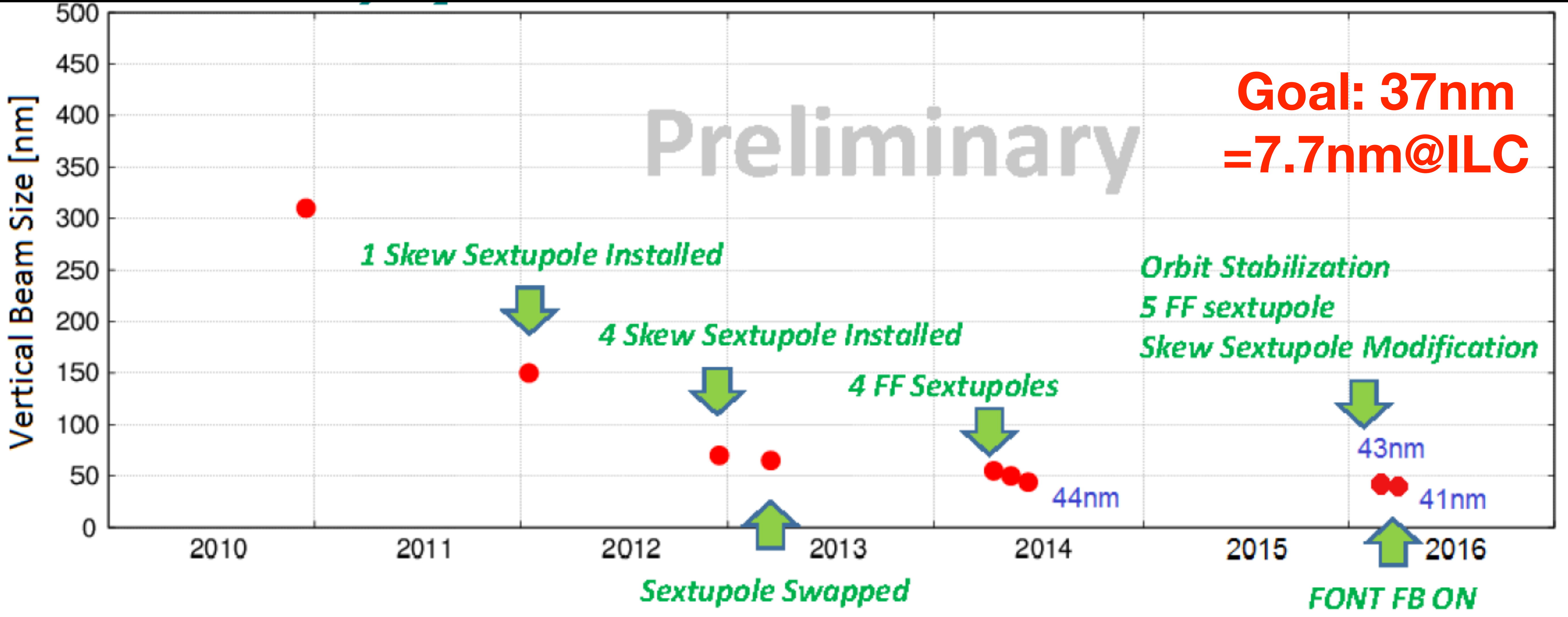
- 8 months running per year at 75% availability
- Technical stops and machine development are accounted for as 4 months downtime per year
- Commissioning is taken into account by a "year 0" for commissioning, and a 3 year ramp-up at 10%, 30%, and 60% of the nominal yearly luminosity
- After an energy upgrade, a new 2-year ramp up with 10% and 50% of nominal luminosity is assumed

# SCRF accelerators



# nano beam

## KEK Accelerator Test Facility 2 (ATF2)




extremely small beam to achieve high luminosity
at low power & cost

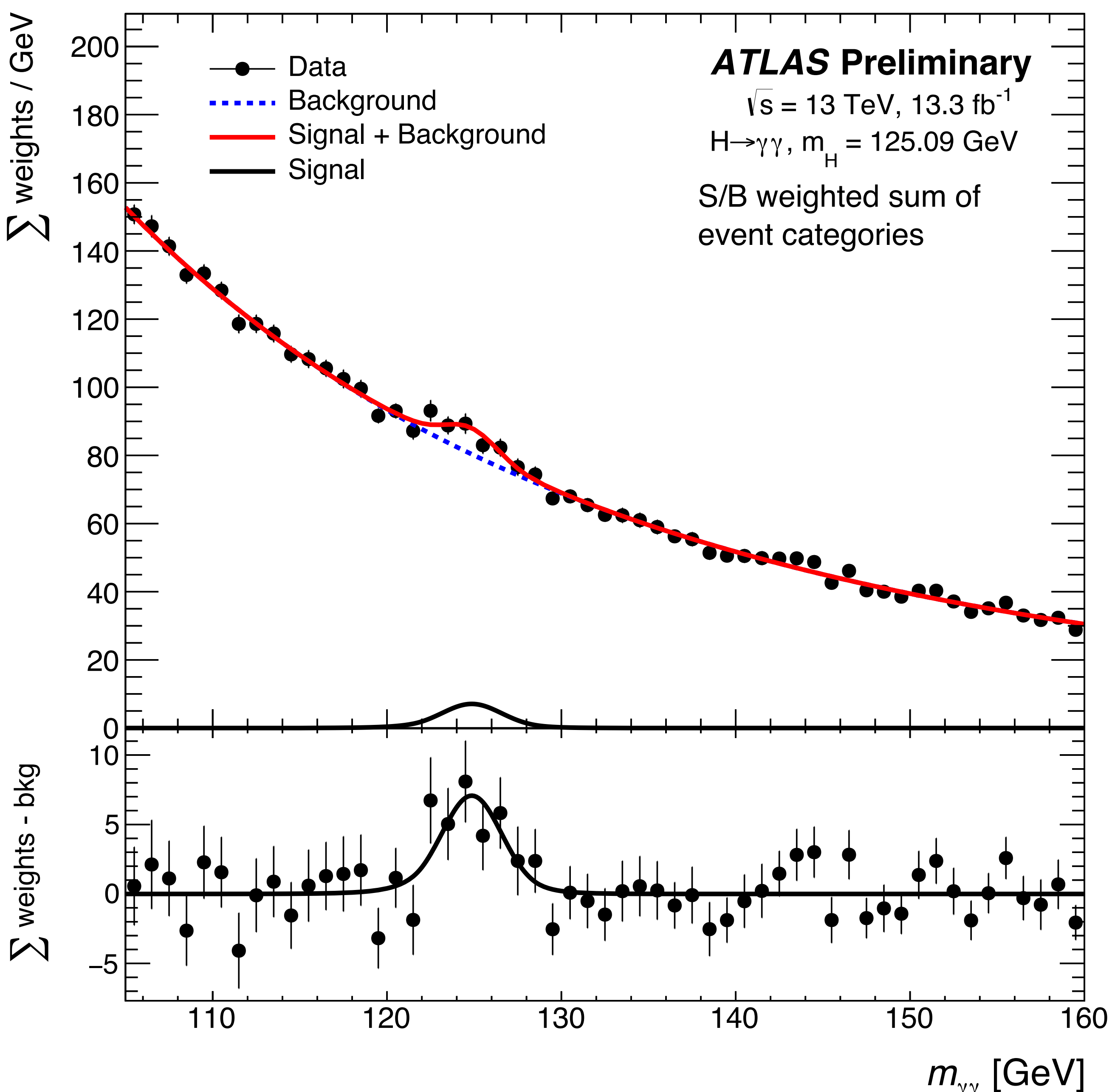
# future upgrades

| | | |
|---|---|---|
| ILC | Nb 40MV/m<br>$Nb_3Sn$ 100MV/m | 1TeV<br>3TeV |
| CLIC | 100MV/m | 3TeV |
| PWFA | 1GV/m | 30TeV |
| fixed target | extracted beam | light dark matter search? |

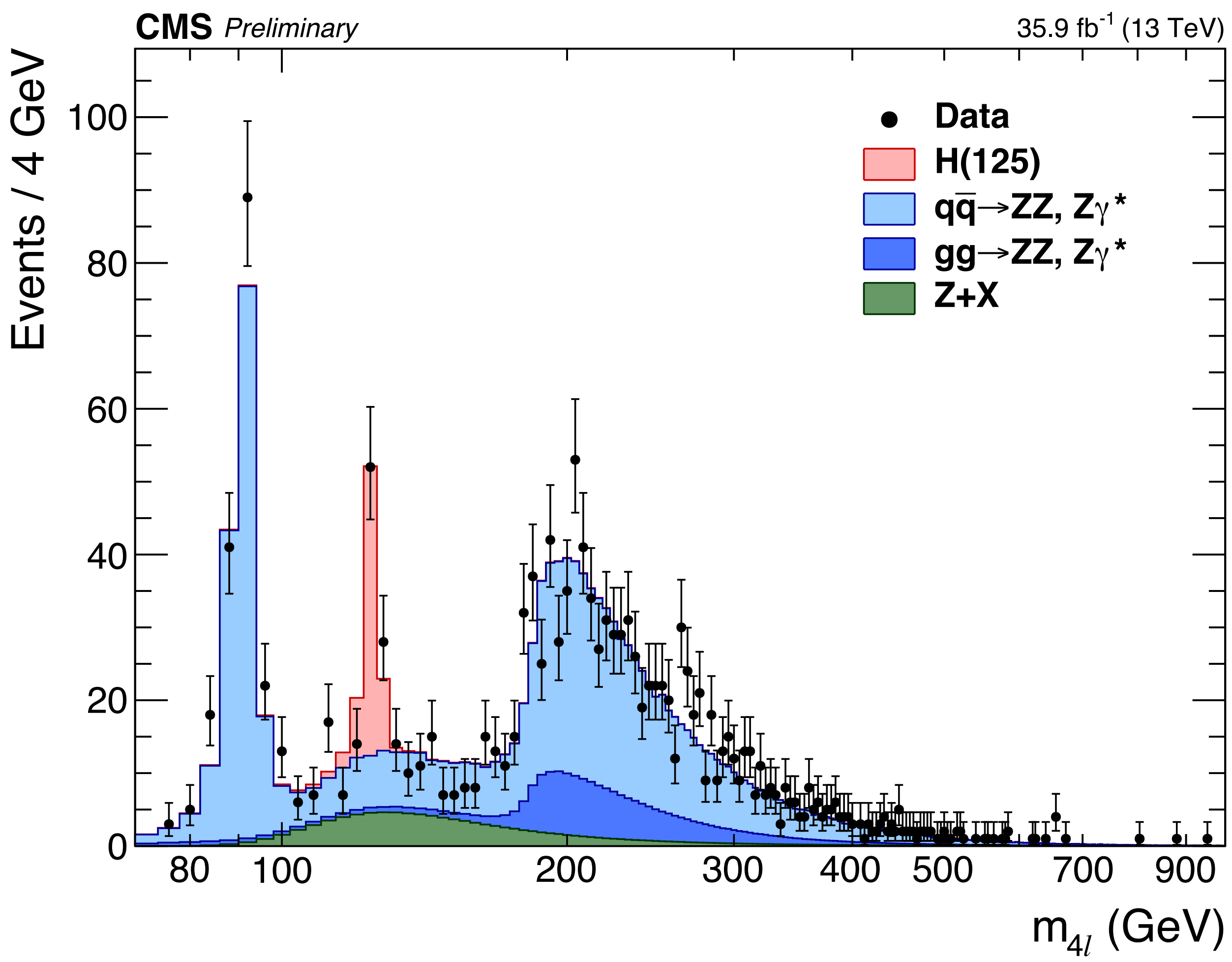
# Physics

# Higgs exists!

ATLAS-CONF-2016-067

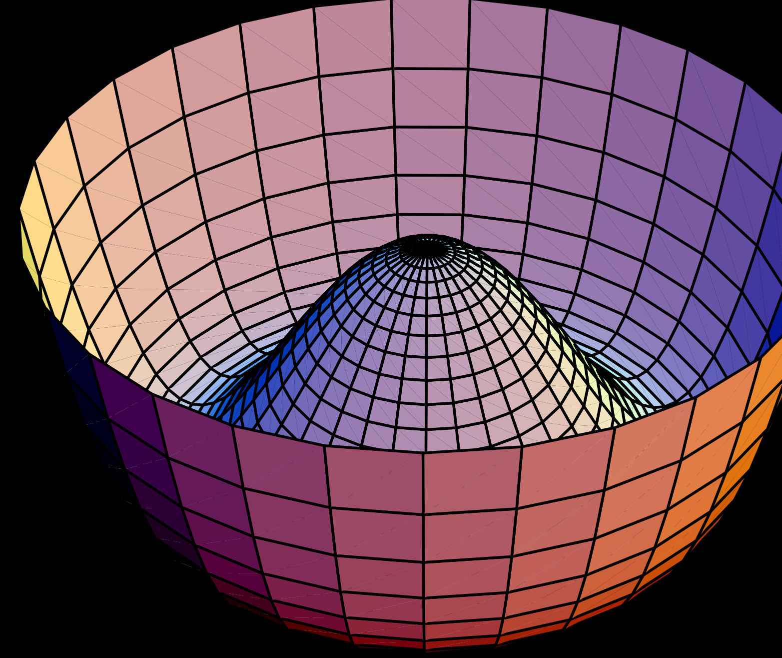



CMS-HIG-16-041




Jónatan Piedra

# *I hated it!*



- Higgs boson is the *only spin 0 particle* in the standard model
  - we have never seen one before
  - one of its kind, no context
  - but does the most important job
- looks very artificial
- we still don't know *dynamics* behind the Higgs condensate
- *Higgsless theories*: now dead

# Context for Scalar Bosons?

Supersymmetry

- Higgs just one of *many* scalar bosons
- SUSY loops make $m_h^2$ negative
- superpartners

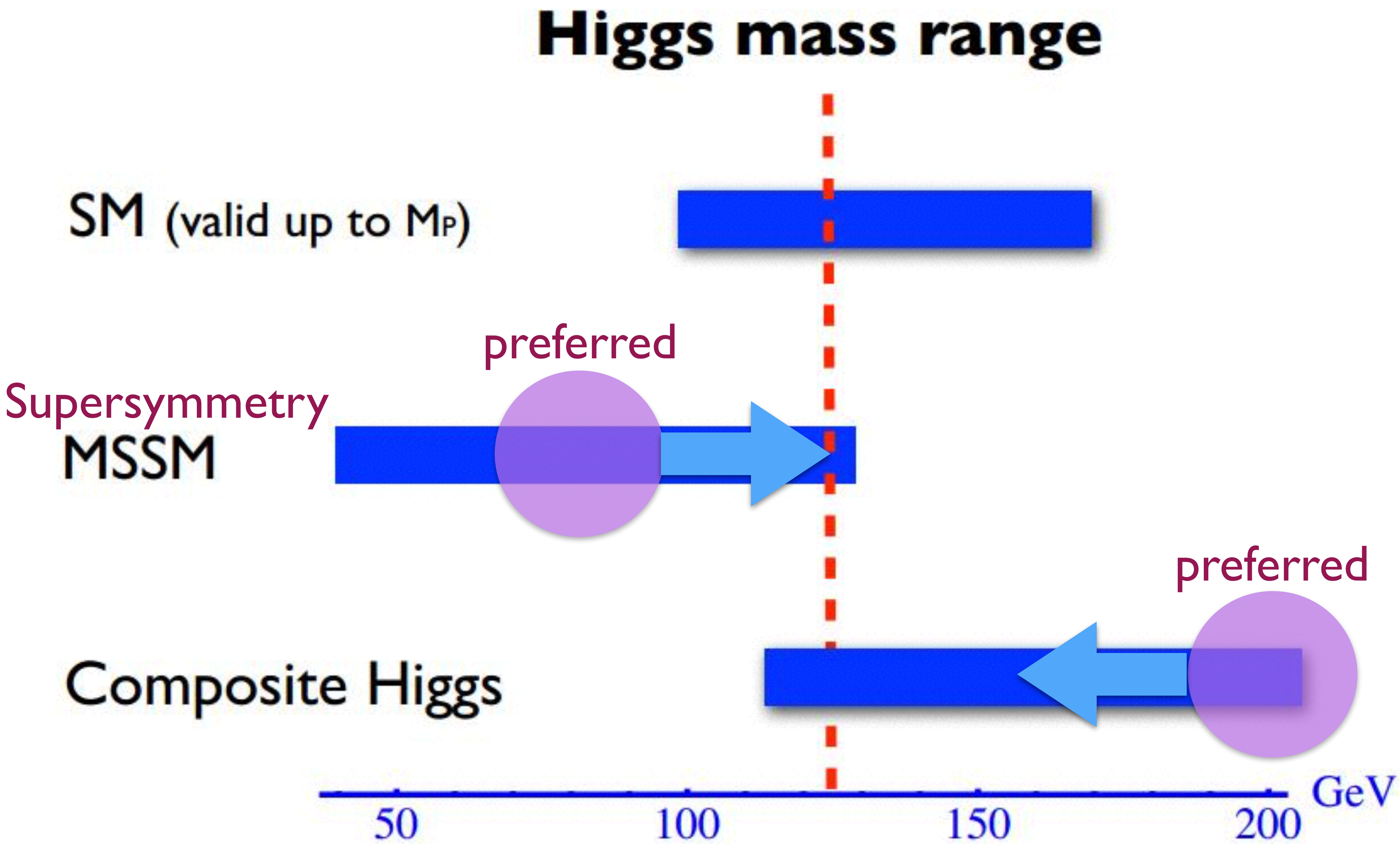
composite

- spins cancel among constituents
- condensate by a strong attractive force, holography
- top partner, pNGBs, vector-like quarks

Extra dimension

- Higgs spinning in extra dimensions
- new forces from particles running in extra D
- KK particles

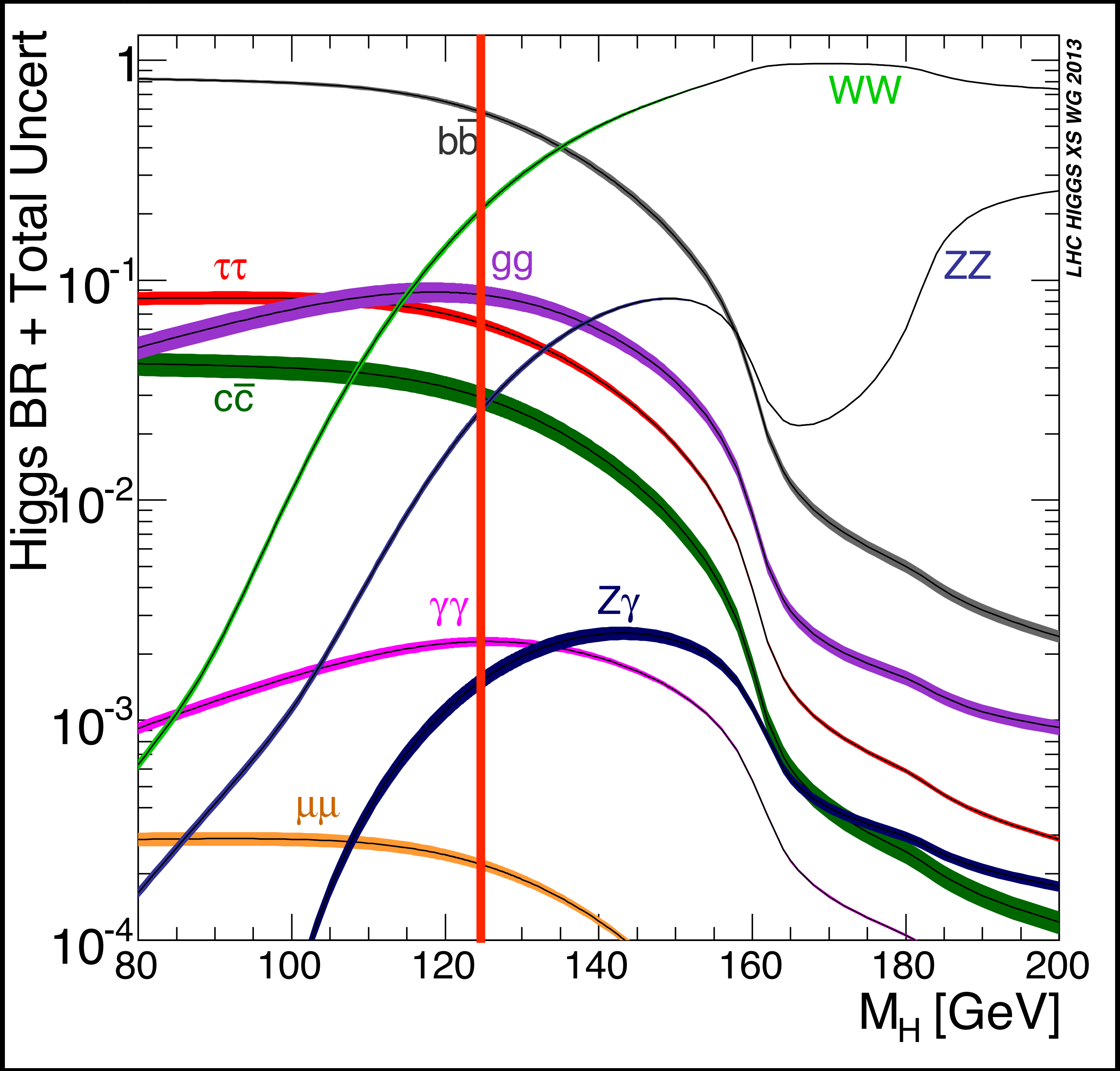
a different "naturalness" argument




By A Pomarol

Hyung Do Kim

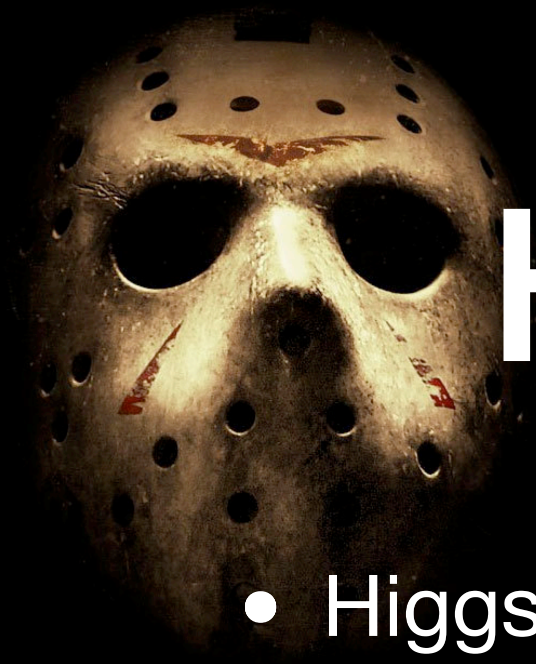
# dream case for experiments




*stupid not to do this!*

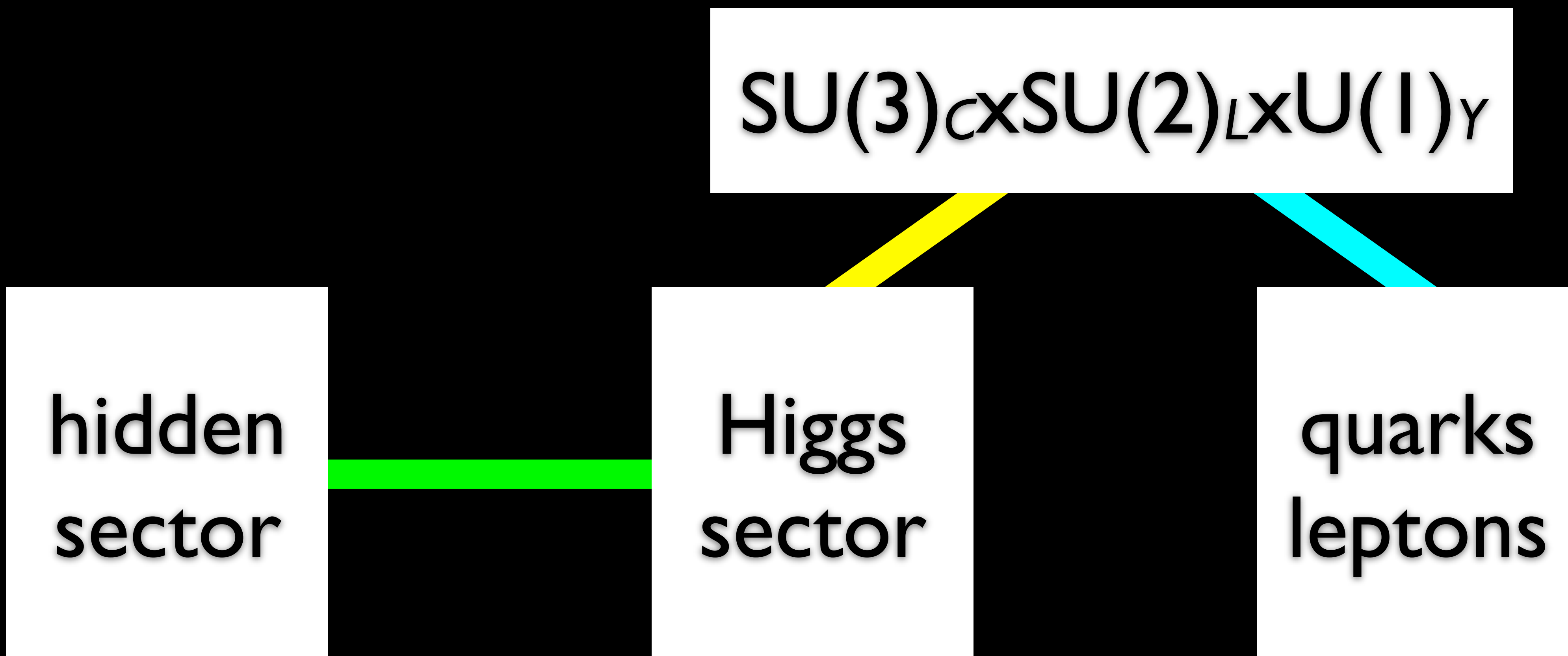
# History of Colliders

1. precision measurements of neutral current (*i.e.* polarized *e+d*) predicted $m_W$, $m_Z$
2. UA1/UA2 discovered *W*/*Z* particles
3. LEP *nailed* the gauge sector
1. precision measurements of *W* and *Z* (*i.e.* LEP + Tevatron) predicted $m_H$
2. LHC discovered *a Higgs particle*
3. LC *nails* the Higgs sector?
1. precision measurements at LC predict ???



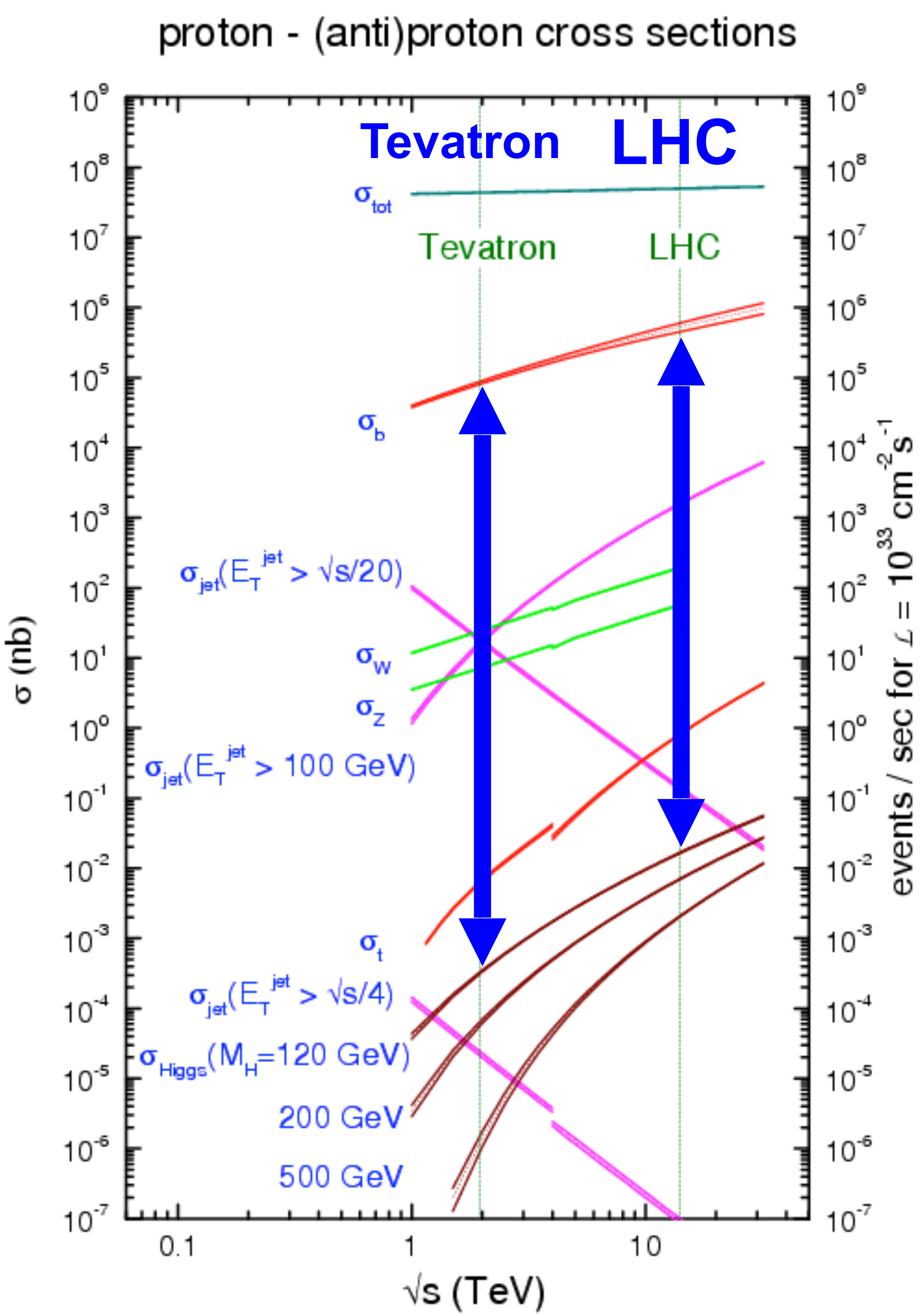
# Higgs as a portal

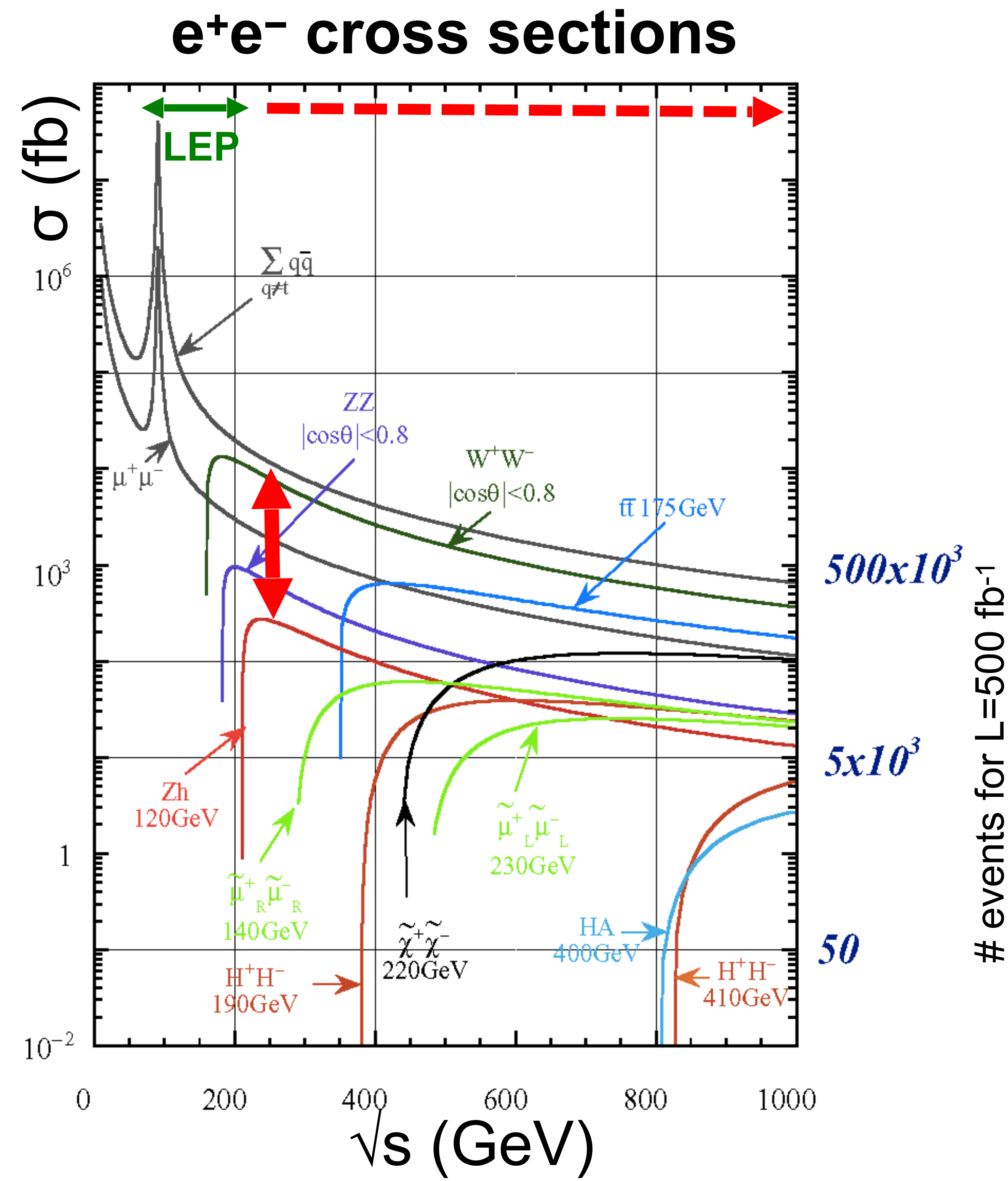
- Higgs boson may connect the Standard Model to other "sectors"



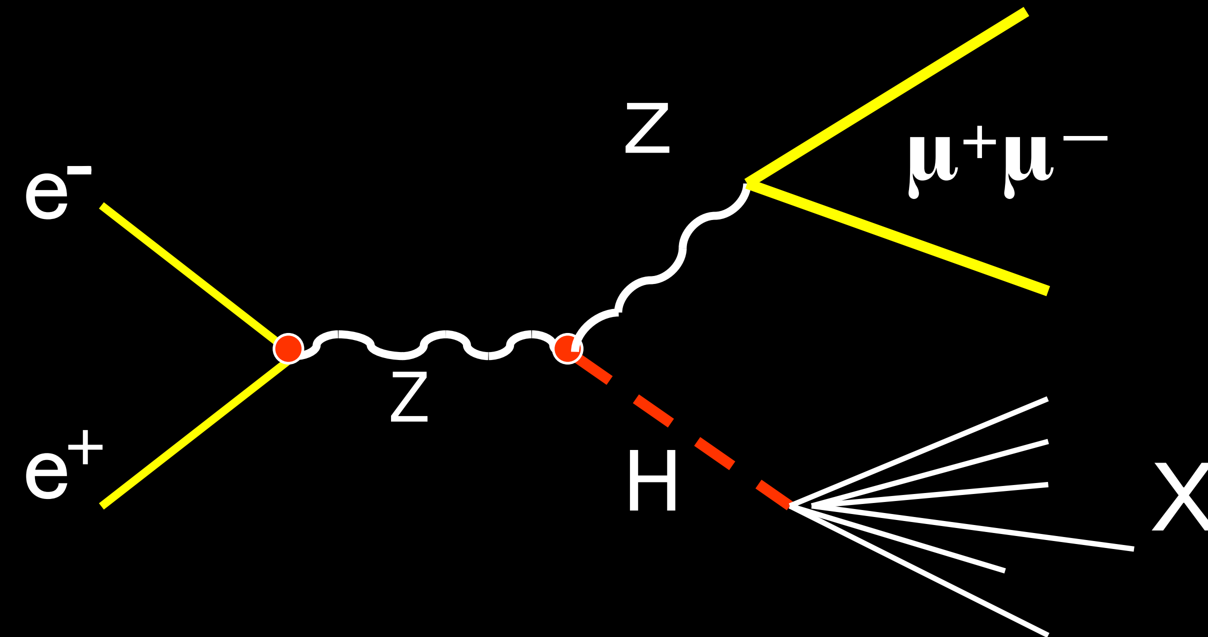

$$\mathcal{L} = \mathcal{O}_{hidden} H^\dagger H$$

# Cross Sections



# Holistic

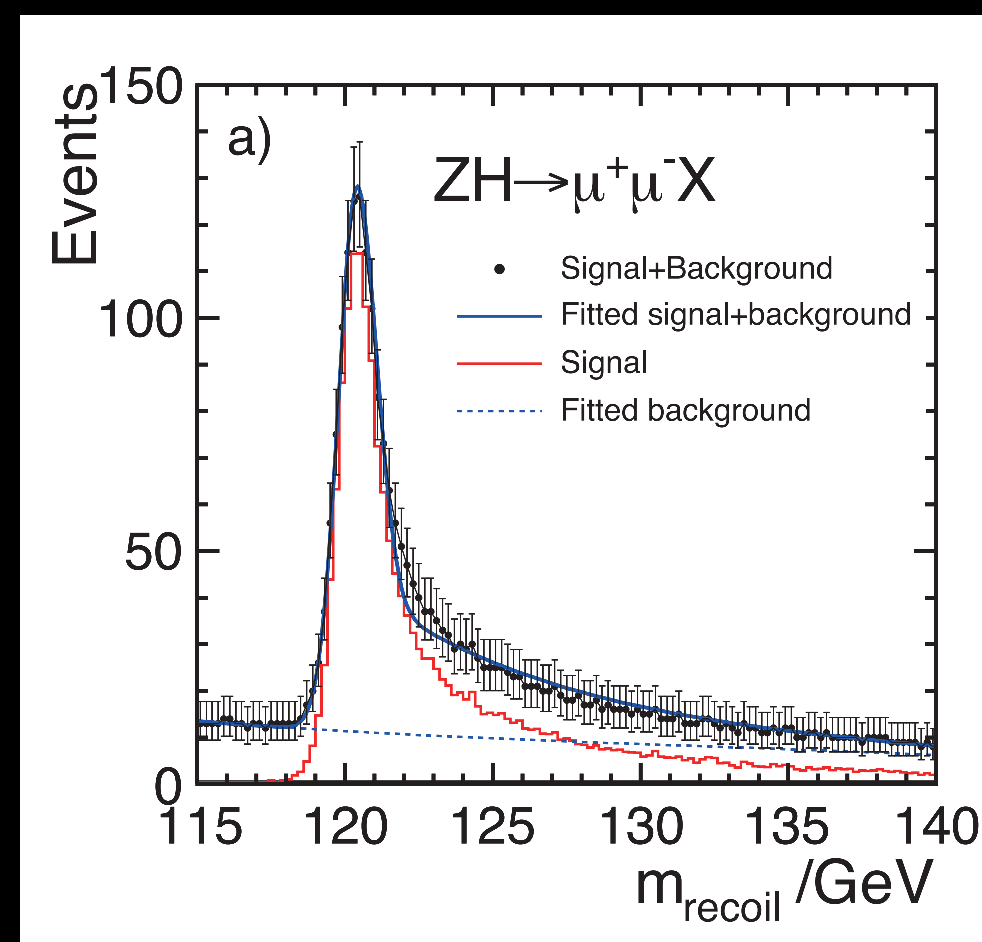


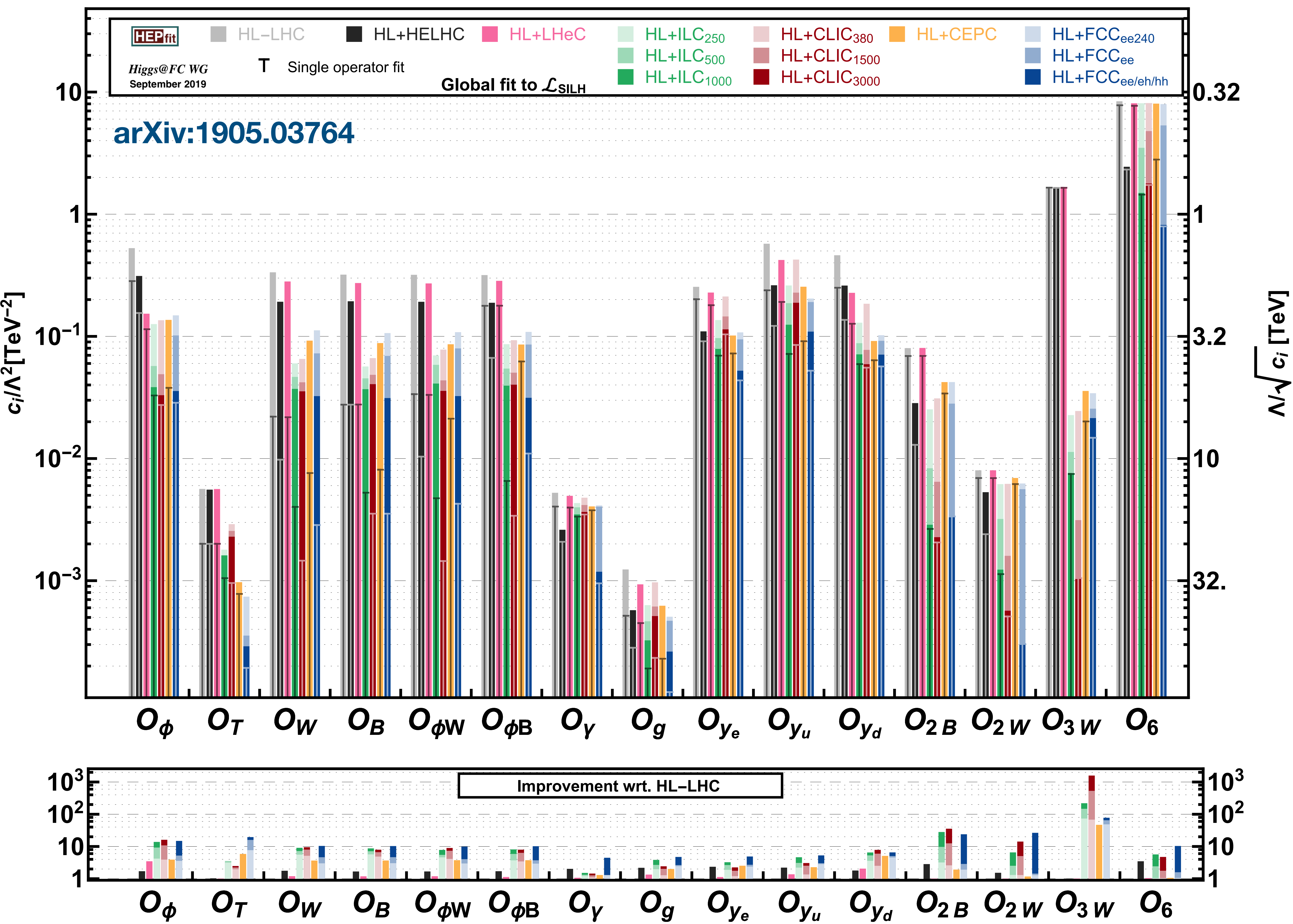

- simple kinematics

$$M_X{}^2 = (E_{CM} - E_{\mu\mu})^2 - \mathbf{P}_{\mu\mu}{}^2$$

$$m^2_{\text{recoil}} = m^2_Z + s - 2\sqrt{s}E_Z$$

- no loss of the longitudinal momentum (modulo photon emission)
- can make use of all final states
  - not just easily identifiable particles (i.e. leptons@LHC)
- capture all information for a given event



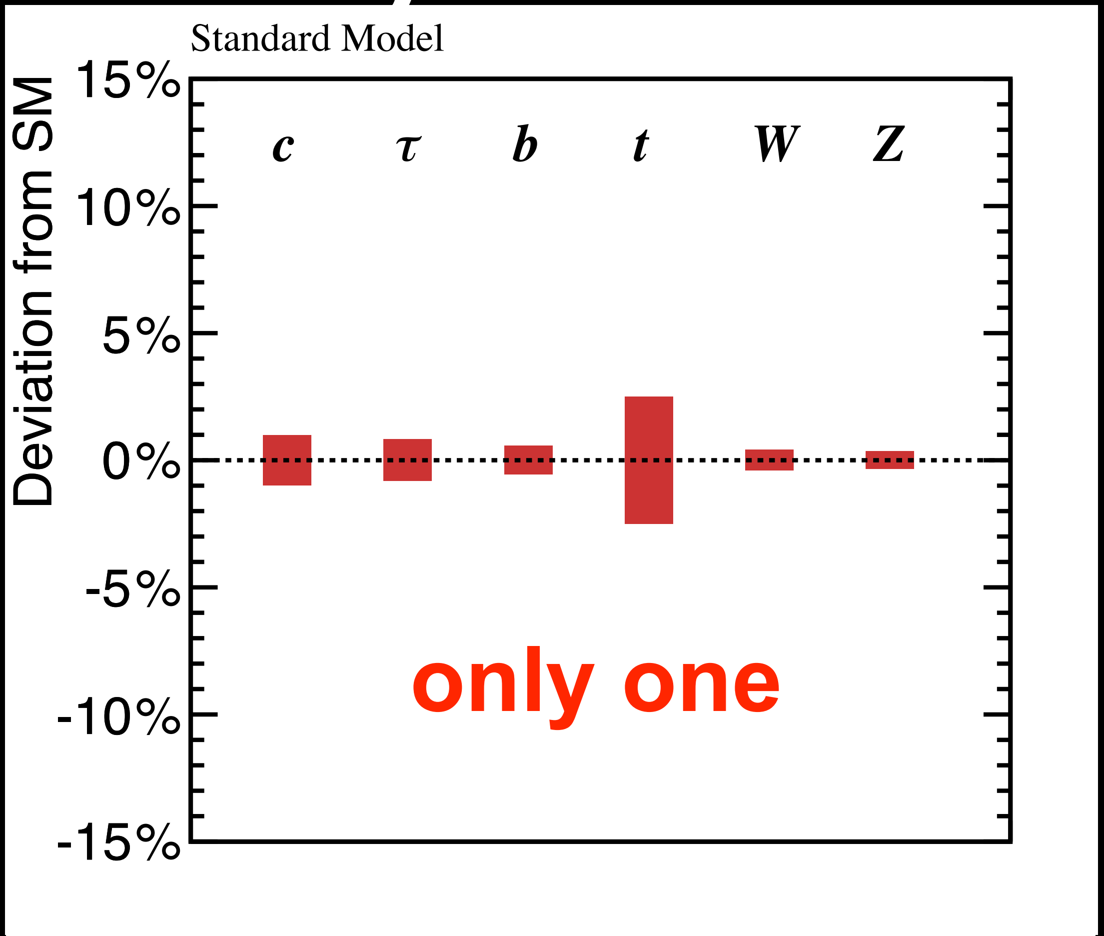


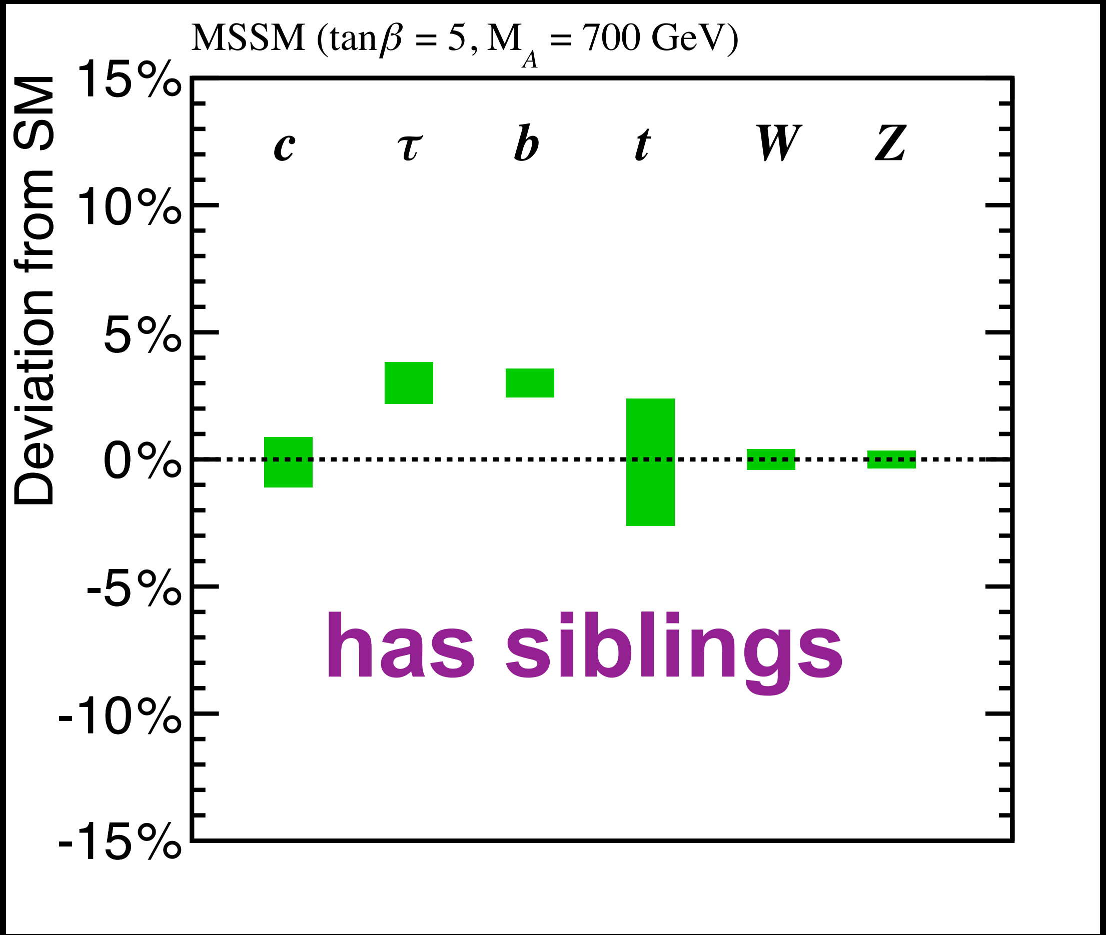
HEPfit
Higgs@FC WG
September 2019
HL–LHC
HL+HELHC
HL+LHeC
HL+ILC250
HL+ILC500
HL+ILC1000
HL+CLIC380
HL+CLIC1500
HL+CLIC3000
HL+CEPC
HL+FCCee240
HL+FCCee
HL+FCCee/eh/hh
T Single operator fit
Global fit to $\mathcal{L}_{SILH}$
arXiv:1905.03764
$c_i/\Lambda^2[\mathrm{TeV}^{-2}]$
$\Lambda/\sqrt{c_i}$ [TeV]
10
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
0.32
1
3.2
10
32.
$O_\phi$ $O_T$ $O_W$ $O_B$ $O_{\phi W}$ $O_{\phi B}$ $O_\gamma$ $O_g$ $O_{y_e}$ $O_{y_u}$ $O_{y_d}$ $O_{2B}$ $O_{2W}$ $O_{3W}$ $O_6$
Improvement wrt. HL–LHC
$10^3$
$10^2$
10
1

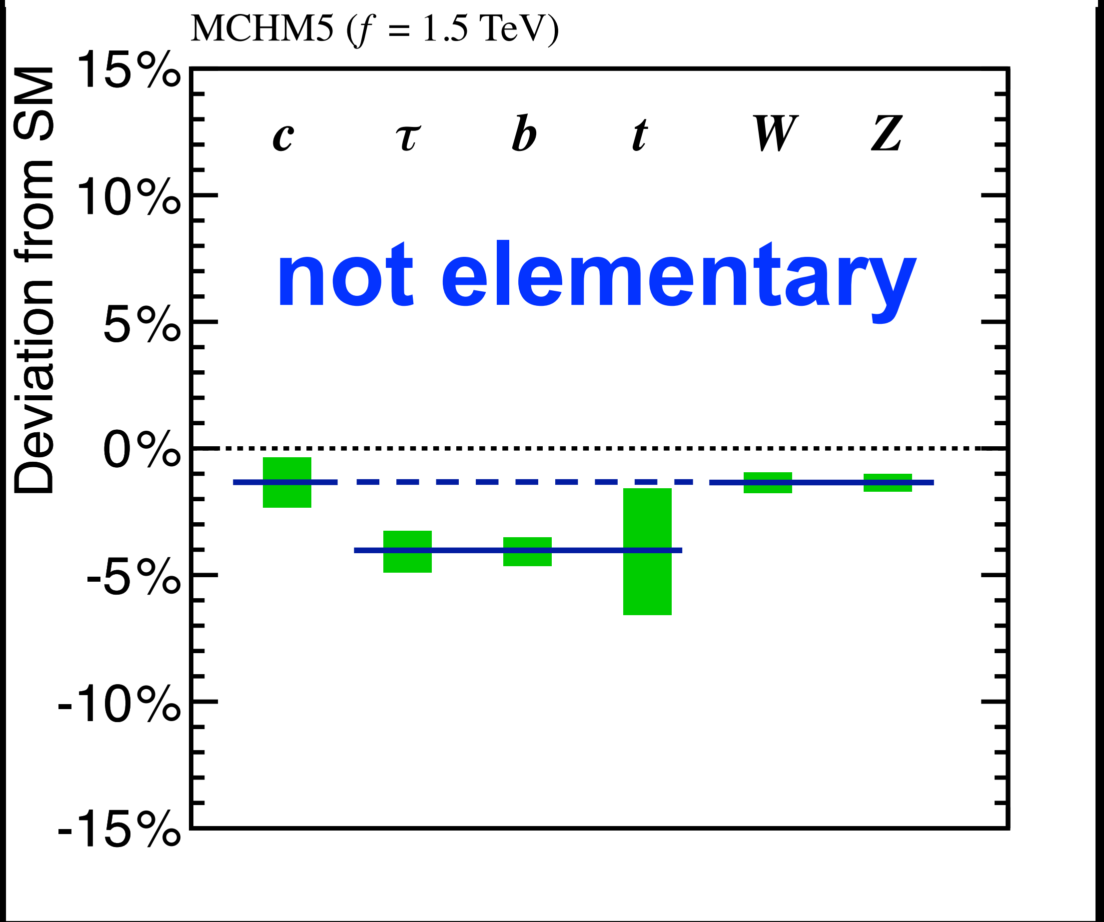
# What is Higgs really?

Only one? (SM)
has siblings? (2DHM)
not elementary?

Lumi 1920 fb-1, sqrt(s) = 250 GeV
Lumi 2670 fb-1, sqrt(s) = 500 GeV

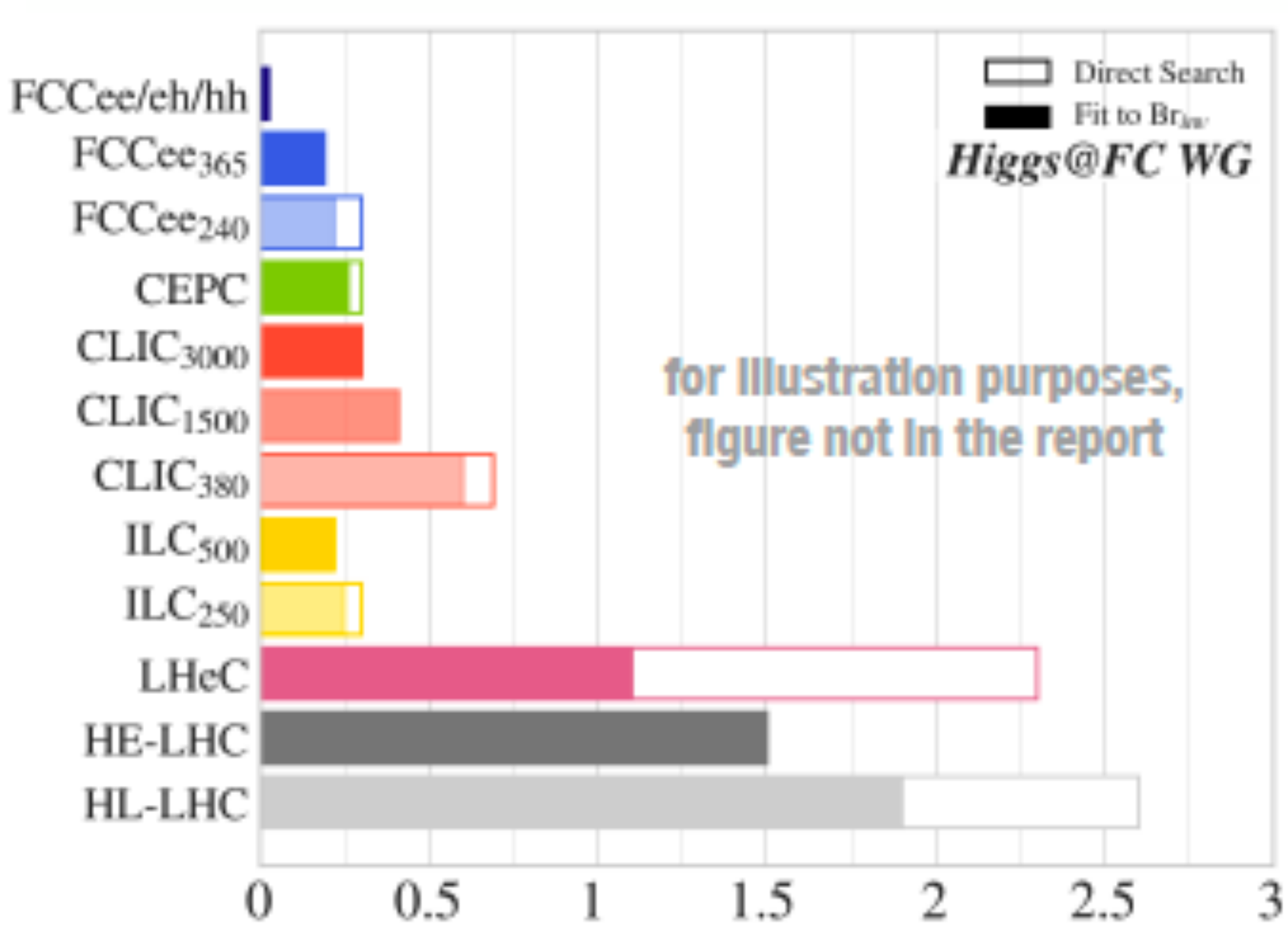


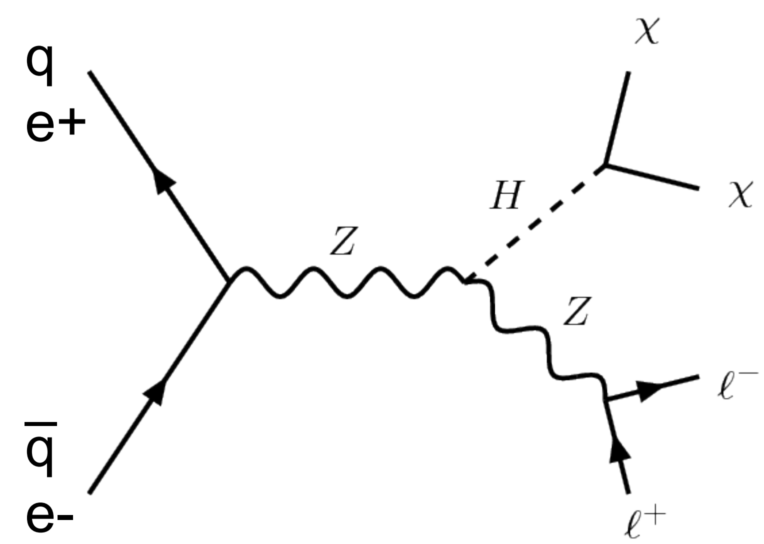



# twin Higgs, dark sector

## Invisible H decays: H→$E_T^{miss}$

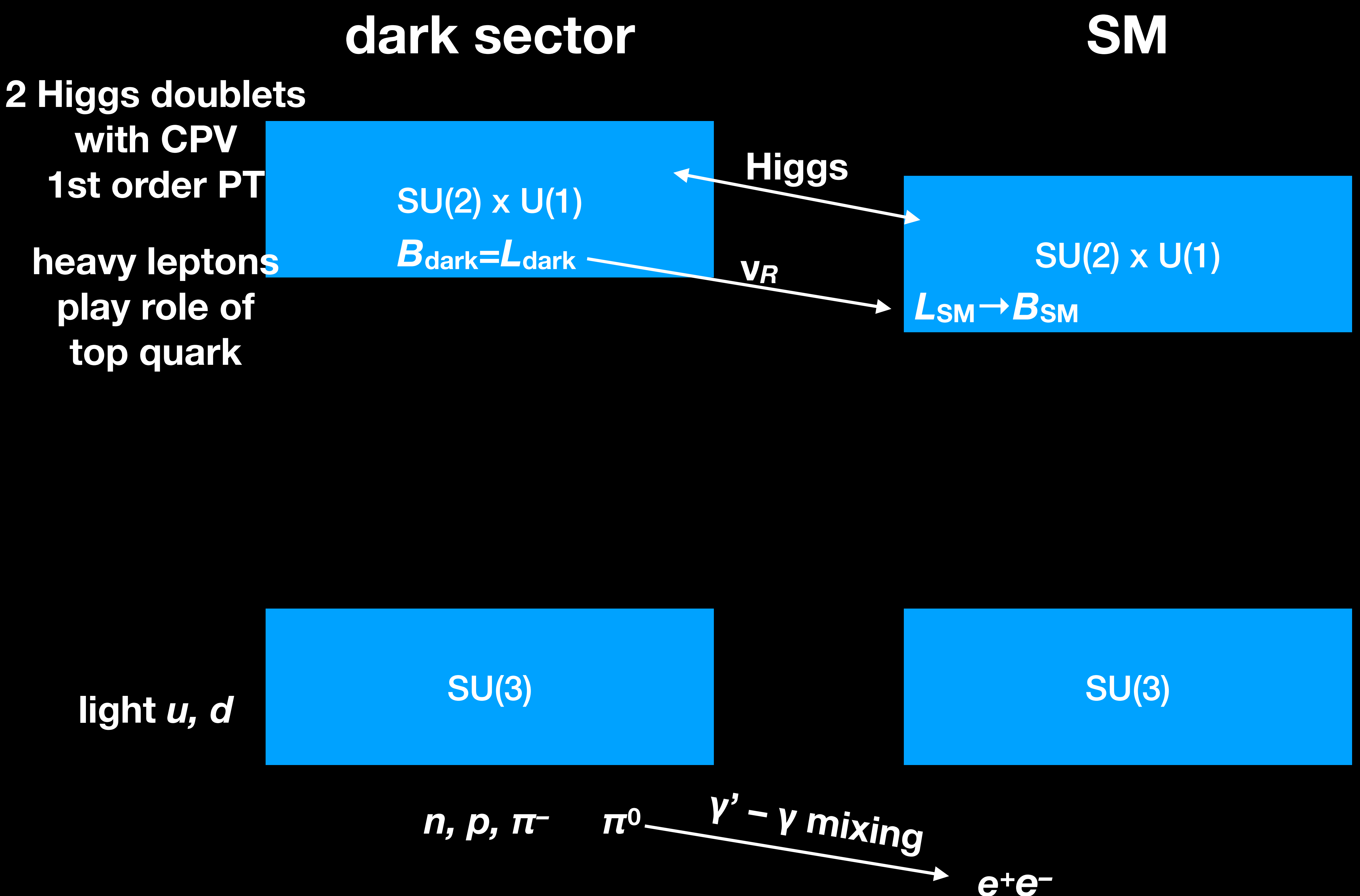



**Direct searches dominate sensitivity**

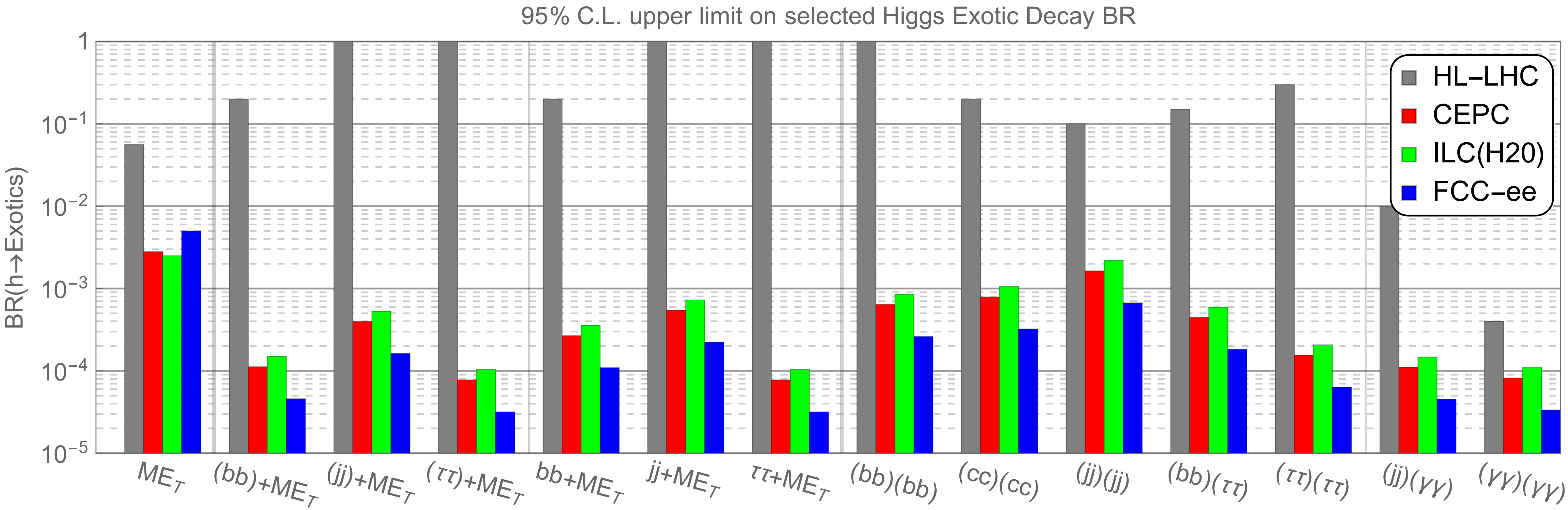
- **HL-LHC will have sensitivity to ~2.6%**
- **e+e- colliders improve to ~0.3%**
- **FCC-hh probes below SM value: ~0.025%**

# baryogengesis + DM



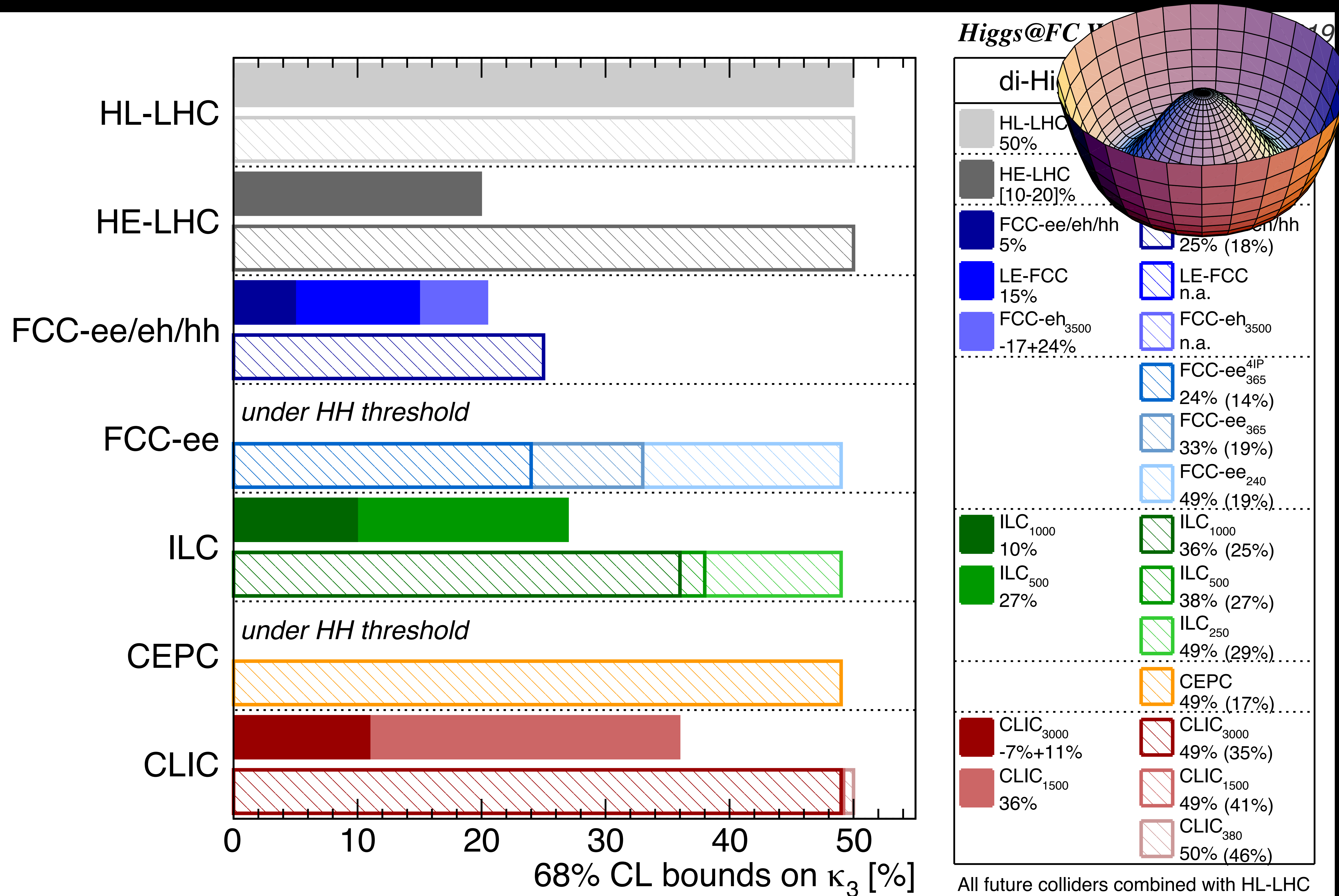

Eleanor Hall, Thomas Konstandin, Robert McGehee, HM + Géraldine Servant
arXiv:1911.12342

# Higgs →dark sector →SM




**Zhen Liu, Lian-Tao Wang, Hao Zhang, arXiv:1612.09284**

# Why is Higgs condensed?



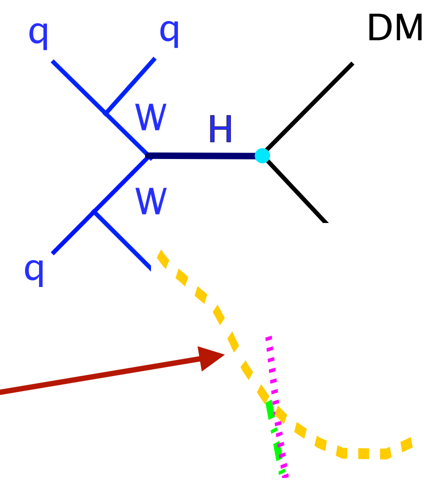
# Higgs portal, plot for direct searches

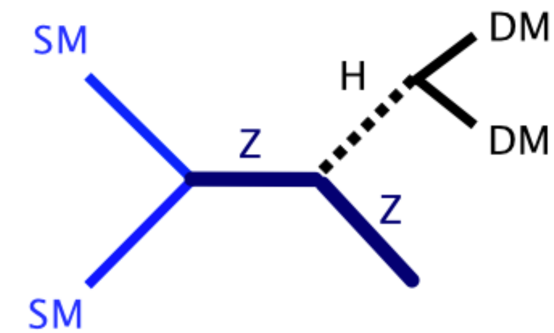
- Limits on BR can be translated to limits in the DM-nucleon plane

$$\sigma_{\chi N} = \Gamma_{\rm inv} \frac{8 m_N^4 f_N^2}{v^2 \beta m_h^3 (m_\chi + m_N)^2} g_\chi\left(\frac{m_h}{m_\chi}\right), \qquad (15)$$

arXiv:1708.02245

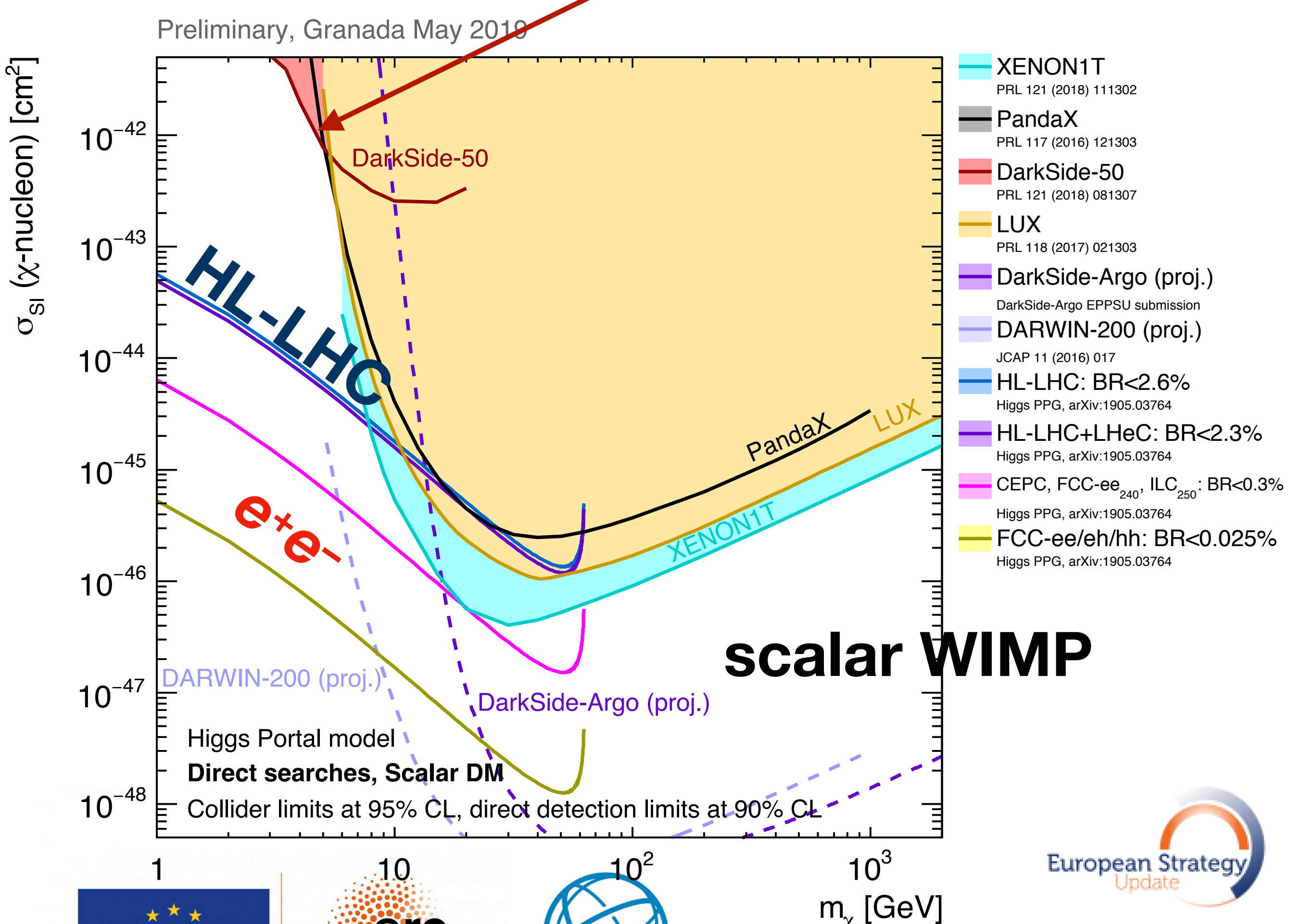
where $g_S(x) = 1$, $g_f(x) = 2/(x^2-4)$, $\beta = \sqrt{1 - 4m_\chi^2/m_h^2}$, $v = 246$ GeV

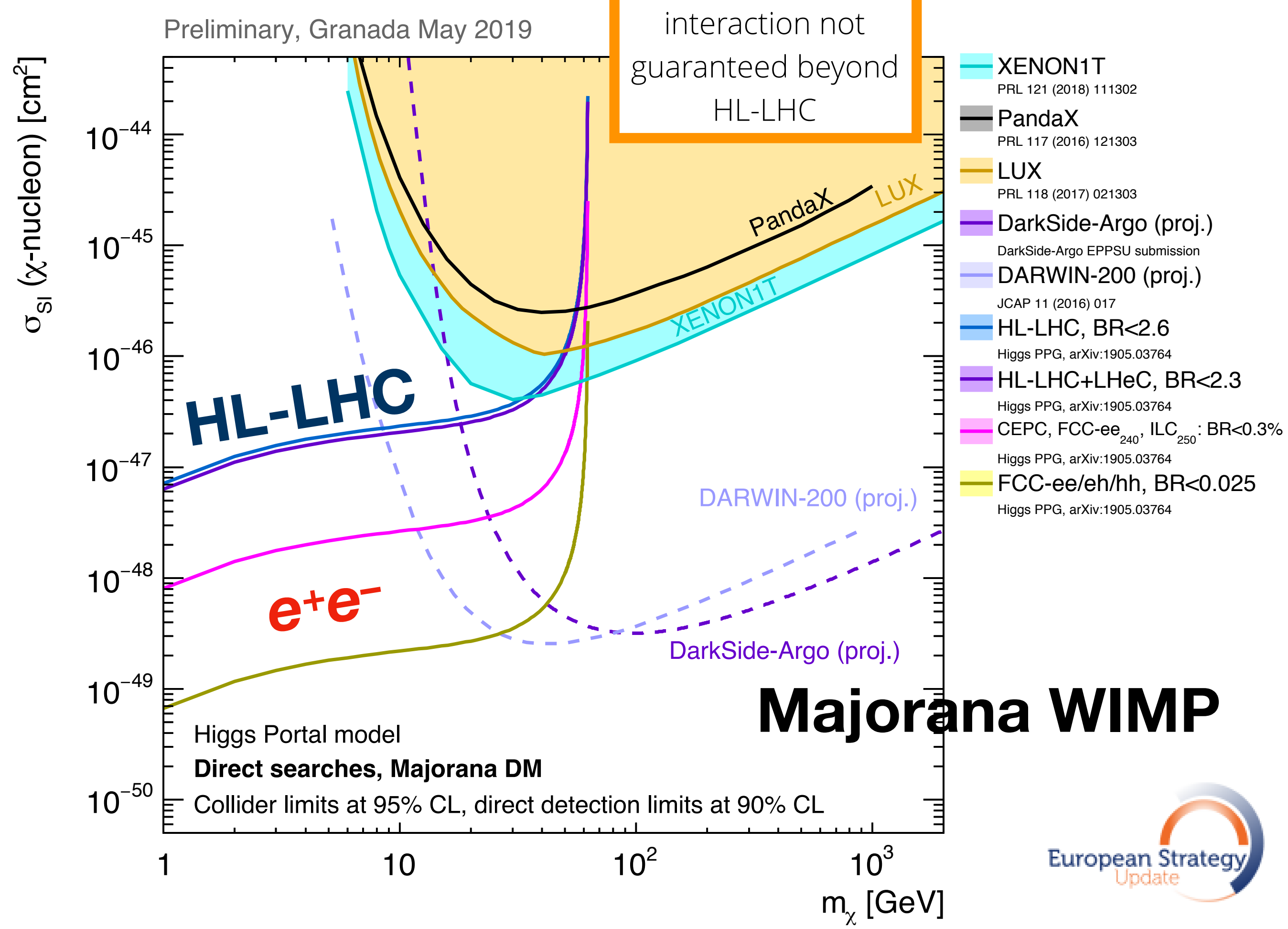



direct detection limits

Caveat: EFT validity in Higgs-DM interaction not guaranteed beyond HL-LHC



# Politics

March 27, 2013

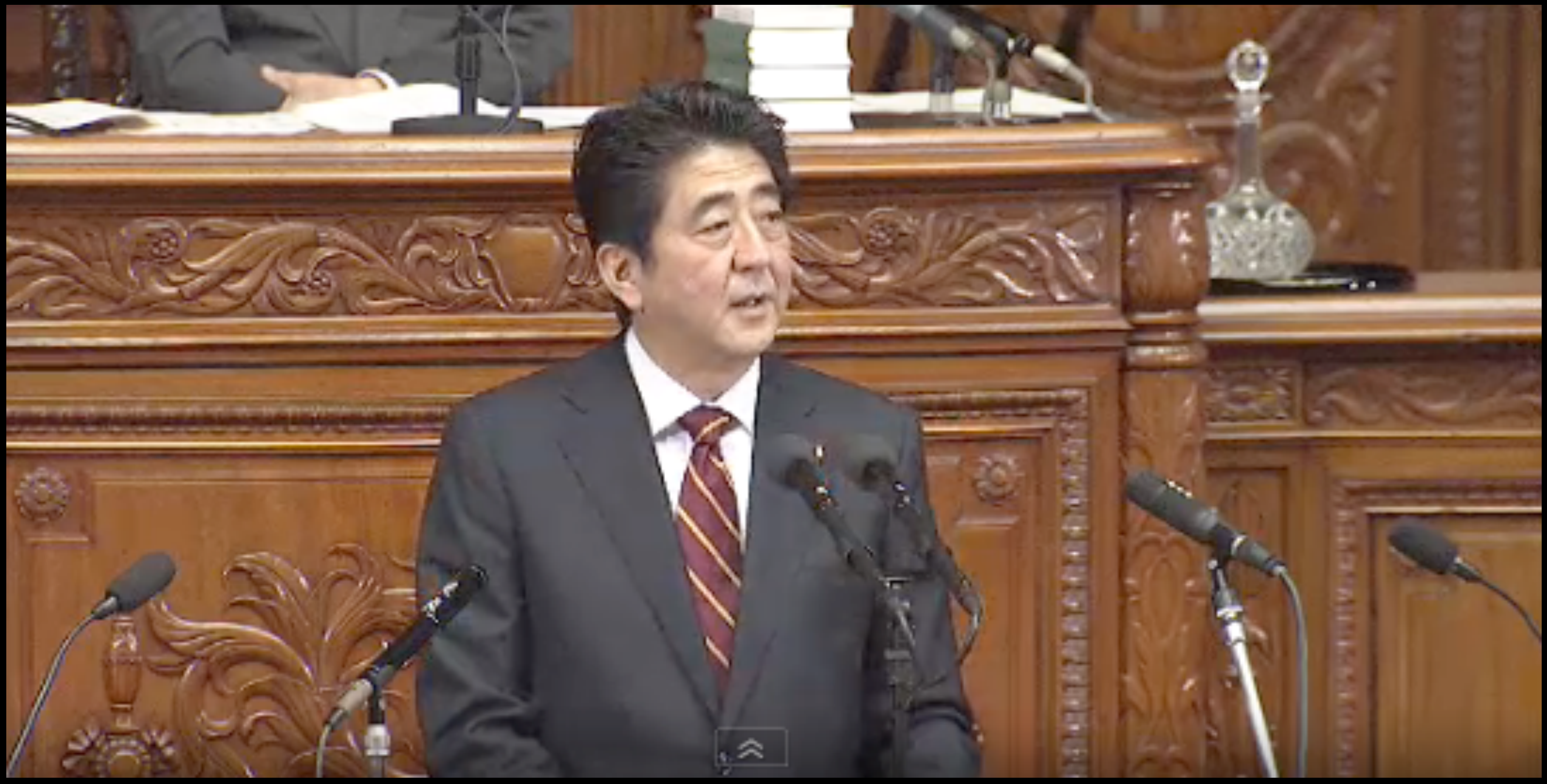
*Federation of Diet members to promote a construction of international laboratory for LC*

>20% of Diet members signed up to support ILC


strong support from politicians, industry, regions

# Speech by PM Abe Feb 28, 2013

- *'Japan is driving global innovation in cutting-edge areas, including among others the world's first production test of marine methane hydrate, a globally unparalleled rocket launch success rate, and our attempts to develop the most advanced accelerator technology in the world.'*



PM Abe at the 83rd session of Diet

# a fact

- a committee reported to Japanese government back in 2014
  - “no way to make a decision on ILC before knowing results from LHC Run II”
  - since then, multitude of committees in Japan
  - they all concluded by the end of 2019
- no more excuses!

# a fact

- Japan does not have CD process like in US
- When she “decides”, it is final: all or nothing
- makes it very difficult for Japan to initiate a process
- how do we decouple “interest to host” vs “commit”?
- “Pre-Lab”: organization to “prepare for ILC”
- April 2022-2026 for site-specific design and governance models, international negotiations
- 2026- construction
- EoI in 2023? LoI in 2024? TDR in 2027?
- need detector studies now

# 2020 Strategy Statements

## 3. High-priority future initiatives

**It is essential for particle physics in Europe and for CERN to be able to propose a new facility after the LHC**

- There are two clear ways to address the remaining mysteries: Higgs factory and exploration of the energy frontier
- Europe is in the privileged position to be able to propose both: CLIC or FCCee as Higgs factory, CLIC (3 TeV) or FCChh (100 TeV) for the energy frontier
- The dramatic increase in energy possible with FCChh leads to this technology being considered as the most promising for a future facility at the energy frontier.
- It is important therefore to launch a feasibility study for such a collider to be completed in time for the next Strategy update, so that a decision as to whether this project can be implemented can be taken on that timescale.

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.*

**Dr. Chris Fall**
**Director of the DOE**
**Office of Science**

The SC is reorganizing operations to create an integrated and comprehensive international strategy across all SC programs and their international partners to ensure coordination on large strategic goals. The SC is hopeful that Japan will commit to an ILC, a project that would span many programs within the SC. The EPPSU is also considering an ILC.

at HEPAP meeting, July 10, 2020

2nd August, 2020

# Preparation for the ILC Pre-Lab

**Adopted from proposal to ICFA by the Linear Collider Board, 31 July 2020**
**Confirmed by ICFA, 2nd August, 2020**

## Preamble

In its Statement on February 22nd 2020, the International Committee for Future Accelerators (ICFA) stated that "ICFA advocates establishment of an international development team to facilitate transition into the preparatory phase" for the construction of the ILC in Japan and asked the Linear Collider Board (LCB) to work out a proposal for the transition team.

Following the proposal by LCB, as the first step towards the preparatory phase of the ILC project, ICFA will establish the ILC International Development Team (Team). This document elaborates the terms of reference of the Team.

The Team will replace the LCB/LCC organization, whose mandate ended on June 30th 2020.

## Terms of reference

### Mandate

The mandate of the Team is to prepare the ILC Pre-Lab without pre-empting the work of the Pre-Lab. The mandate includes:

- clarifying the function and organization of the ILC Pre-Lab based on the KEK International Working Group report,
- developing a common understanding for the condition to start the ILC Pre-Lab,
- providing an international framework for the ILC accelerator effort and coordinating further R&D and engineering design work for the ILC in order to sustain the community effort and to guarantee a smooth transition to the ILC Pre-Lab phase,
- providing an international framework for the ILC physics and detector activities and coordinating physics and detector R&D effort in order to sustain the community effort and guarantee a smooth transition to the ILC Pre-Lab phase,
- negotiating with international partners (e.g. universities, national and regional laboratories) for resources needed for the ILC Pre-Lab, and
- providing necessary information to the national authorities to support their discussion of the establishment of the ILC Pre-Lab.

The Team will regularly report its activities to ICFA.

### Structure and Function

The Team is hosted by KEK and consists of the Executive Board (EB) and three Working Groups (WG1, WG2 and WG3):

- The EB comprises a chair, three members reflecting the three regions contributing to the ILC effort (Americas, Asia-Pacific and Europe) and three ex-officio members (KEK liaison officer and Chairs of WG2 and WG3, whereas WG1 is chaired by the EB Chair). The EB members are appointed by ICFA. The EB has the overall responsibility for the Pre-Lab preparation; some of the work will be carried out at KEK.
- WG1 carries out the main task of the Team, i.e. working out the function and organizational structure for the Pre-Lab, as well as supporting the preparation of Memoranda of Understanding (MoUs) among the national laboratories and other interested parties needed for the operation of the Pre-Lab, and supporting discussions at the national authority level.
- The membership is established by the EB and includes the EB members. It is chaired by the EB Chair.
- WG2 conducts the ILC accelerator and facility work. It is responsible for continuing the accelerator and facility work as previously carried out under the LCC framework. The WG2 effort will be taken over by the ILC Pre-Lab when it will become operational. The members are appointed by the EB.
- WG3 carries out the ILC physics and detector activities. It continues the study of the ILC physics capabilities and detector efforts as previously carried out under the LCC framework, reflecting the on-going progress of the field. It guides the community to be ready when the ILC Pre-Lab will establish its physics program. The members are appointed by the EB.

### Resources

Limited funding is required to support the EB activities in personnel and operational costs as well as for administrative work. The LCB proposes that the required support will come from the host laboratory, KEK, as well as other interested international partners, moderated by the Funding Agencies for Large Colliders (FALC), in a similar way that the LCC activities were supported.

### KEK's role as a host

KEK hosts the Team and provides support that includes:

- office space and necessary utilities in the Tsukuba campus, and
- administrative and travel support as agreed by KEK and the Team.

### Timeframe

The Team will commence preparation for the ILC Pre-Lab as soon as it is established by ICFA and finish its mandate and term with the start of the Pre-Lab operation. It is anticipated that the work will be completed in one to one and a half years. If the activity is not completed by the end

**Structure and Function**

The Team is hosted by KEK and consists of the Executive Board (EB) and three Working Groups (WG1, WG2 and WG3):

- The EB comprises a chair, three members reflecting the three regions contributing to the ILC effort (Americas, Asia-Pacific and Europe) and three ex-officio members (KEK liaison officer and Chairs of WG2 and WG3, whereas WG1 is chaired by the EB Chair). The EB members are appointed by ICFA. The EB has the overall responsibility for the Pre-Lab preparation; some of the work will be carried out at KEK.
- WG1 carries out the main task of the Team, i.e. working out the function and organizational structure for the Pre-Lab, as well as supporting the preparation of Memoranda of Understanding (MoUs) among the national laboratories and other interested parties needed for the operation of the Pre-Lab, and supporting discussions at the national authority level.
- The membership is established by the EB and includes the EB members. It is chaired by the EB Chair.
- WG2 conducts the ILC accelerator and facility work. It is responsible for continuing the accelerator and facility work as previously carried out under the LCC framework. The WG2 effort will be taken over by the ILC Pre-Lab when it will become operational. The members are appointed by the EB.
- WG3 carries out the ILC physics and detector activities. It continues the study of the ILC physics capabilities and detector efforts as previously carried out under the LCC framework, reflecting the on-going progress of the field. It guides the community to be ready when the ILC Pre-Lab will establish its physics program. The members are appointed by the EB.

**Resources**

Limited funding is required to support the EB activities in personnel and operational costs as well as for administrative work. The LCB proposes that the required support will come from the host laboratory, KEK, as well as other interested international partners, moderated by the Funding Agencies for Large Colliders (FALC), in a similar way that the LCC activities were supported.

**KEK's role as a host**

KEK hosts the Team and provides support that includes:

- office space and necessary utilities in the Tsukuba campus, and
- administrative and travel support as agreed by KEK and the Team.

**Timeframe**

The Team will commence preparation for the ILC Pre-Lab as soon as it is established by ICFA and finish its mandate and term with the start of the Pre-Lab operation. It is anticipated that the work will be completed in one to one and a half years. If the activity is not completed by the end of 2021, ICFA will need to evaluate the progress and to decide how to proceed.

# Conclusions

- European Strategy Update: Higgs factory highest priority
- ILC only option realizable in ~15 year time scale
  - 250 GeV 2 $ab^{-1}$ as a starter
- mature machine design
  - great physics case both Higgs & new physics
  - political support in Japan and US
  - long-term facility to 500 GeV, 1 TeV, 3 TeV, 30 TeV
- fixed target for dark matter searches etc
- pre-lab 2022-2026 with “GDE-level funding”
- International Development Team (IDT) to bridge the gap
- expect EoI for detector concepts in a few years
- need studies on physics and detector *now*!


I WANT YOU
FOR
THE ILC
NEAREST RECRUITING STATION