Future colliders, expectations and reality

Mihoko M. Nojiri

DISCRIMINATOR

(BUT NOT EXCUSE)

- Organizers give this title to me. (not me) I found it is funny that this role is given to someone living far away, and who does not sky much
- Not much physics today.
- It is not easy time to predict future, so I am going to talk about principle, history and current situations.
- I am currently a council member of Science Council of Japan(SCJ), so I am going to explain what it is, how it works, and my personal view its connection to ILC.

LIFE AND UNIVERSE AND ..

[one evening in 1971] I got frantically depressed in Innsbruck… When the stars came out I thought that someone ought to write a **Hitch-hiker's Guide to the Galaxy** because it looked a lot more attractive out there than it did around me."

- Ultimate goal of Particle Physics is to **answer the big questions of "Life and Universe and Everything".**
- **Otherwise it is too expensive.**
- **big questions:** origin of symmetry breaking, charge, gauge interactions, matter (including dark matter) …
- To achieve this role, we now have a very close tie of international collaboration and big facilities beyond a country.
- After the LHC, we are realizing the problem might be getting **beyond a single region…**

SOME HISTORY–SUCCESS OF EW PRECISION

ON HIGGS DISCOVERY

- Great success of field theory and standard model
  - Electroweak Precision

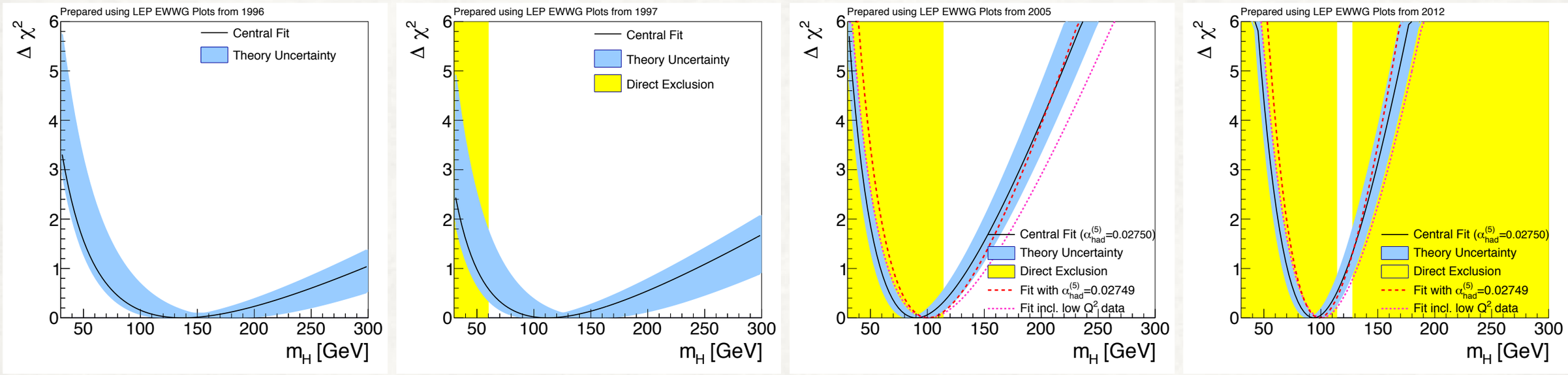


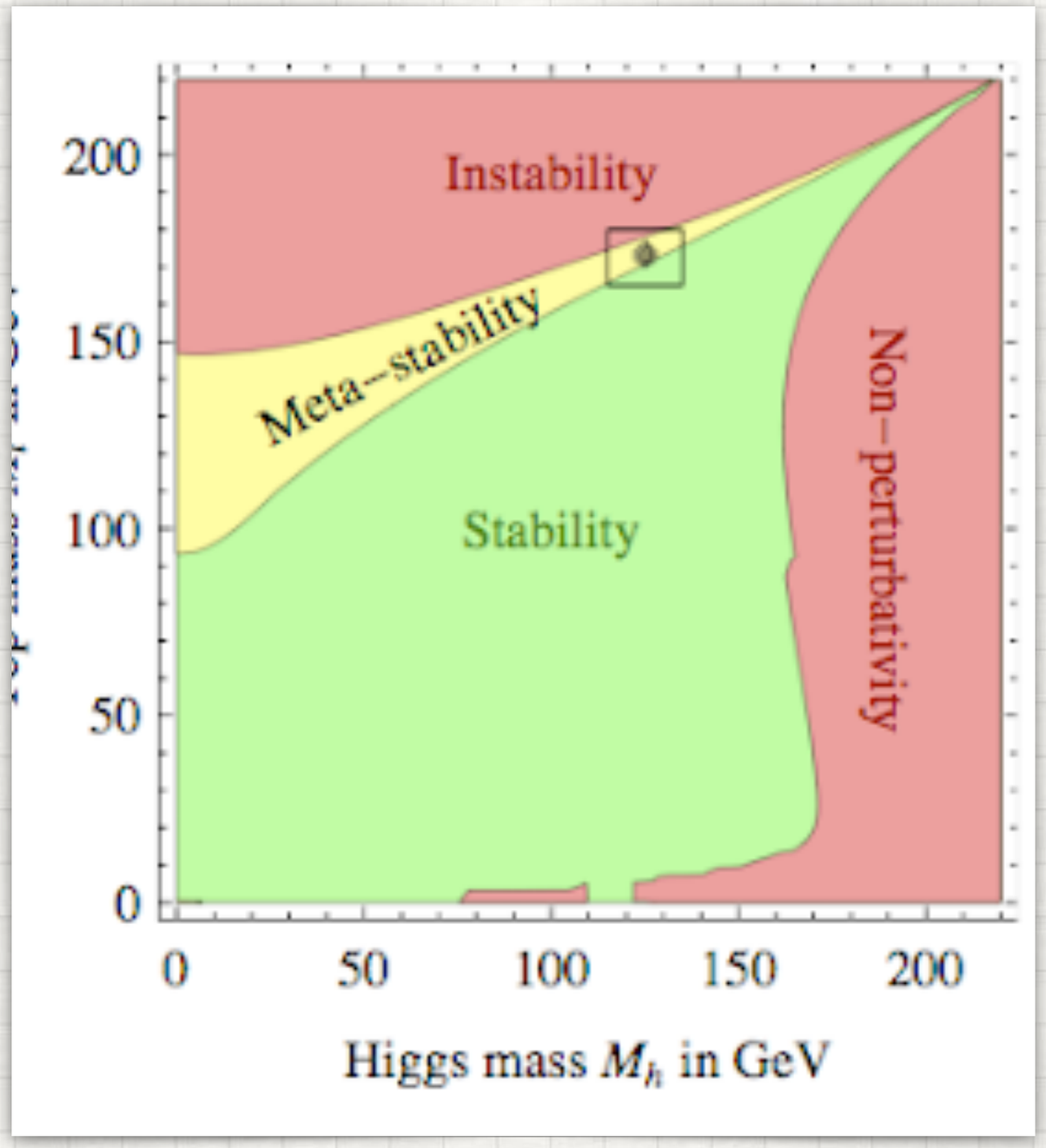
Figure 1.2: Historic development of the 'blue-band' plots [19], illustrating the estimate of the Higgs Boson mass in the Standard Model from electroweak precision measurements. The excluded area by direct searches is shown in yellow, while the blue band illustrate the χ^2 distribution of the global electroweak fit. The original plots have been remade for this article.

blue band plot shows precision measurements are indeed great.

HIGGS DISCOVERY AND OUR VACUUM

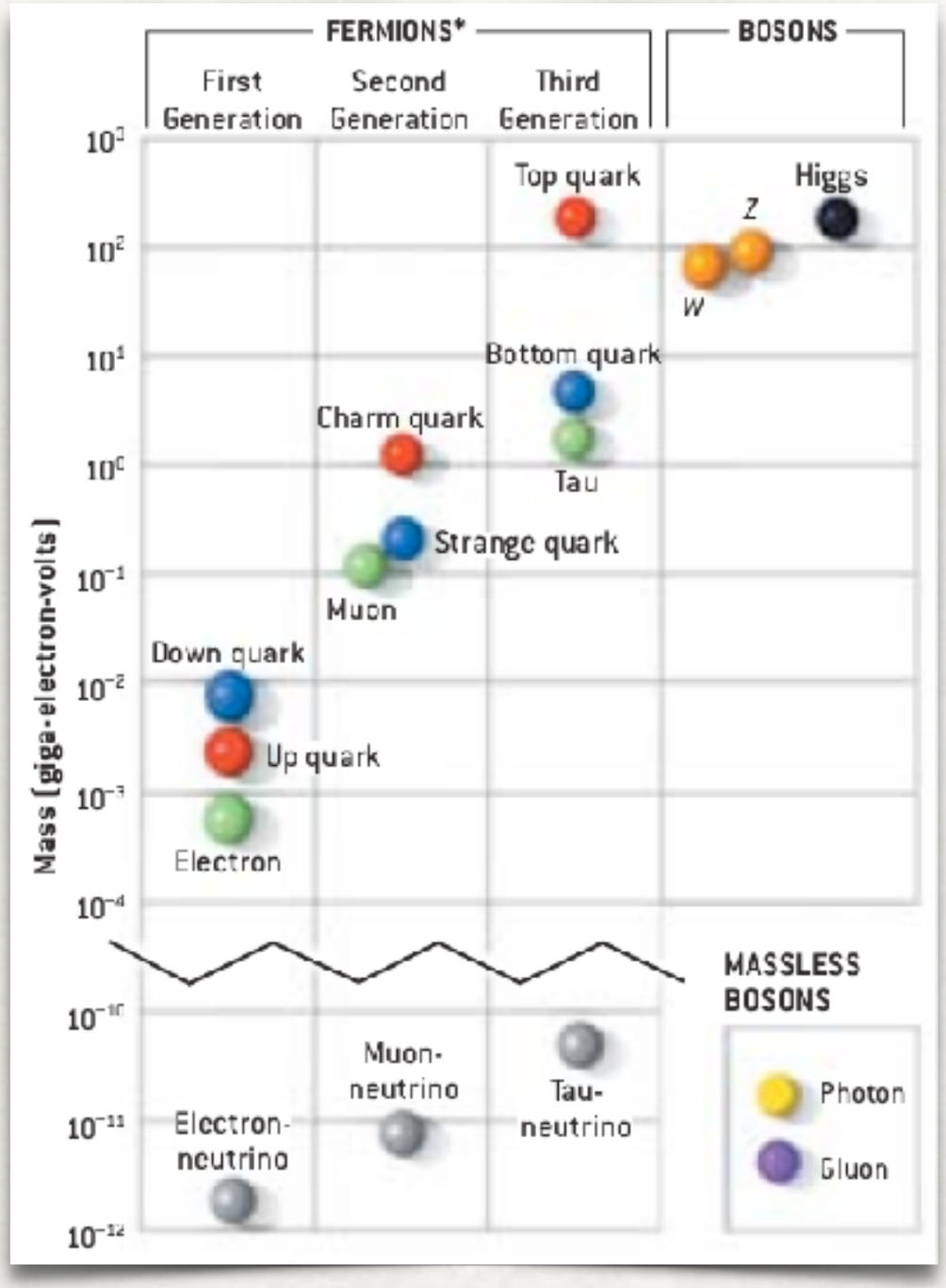
METASTABILITY

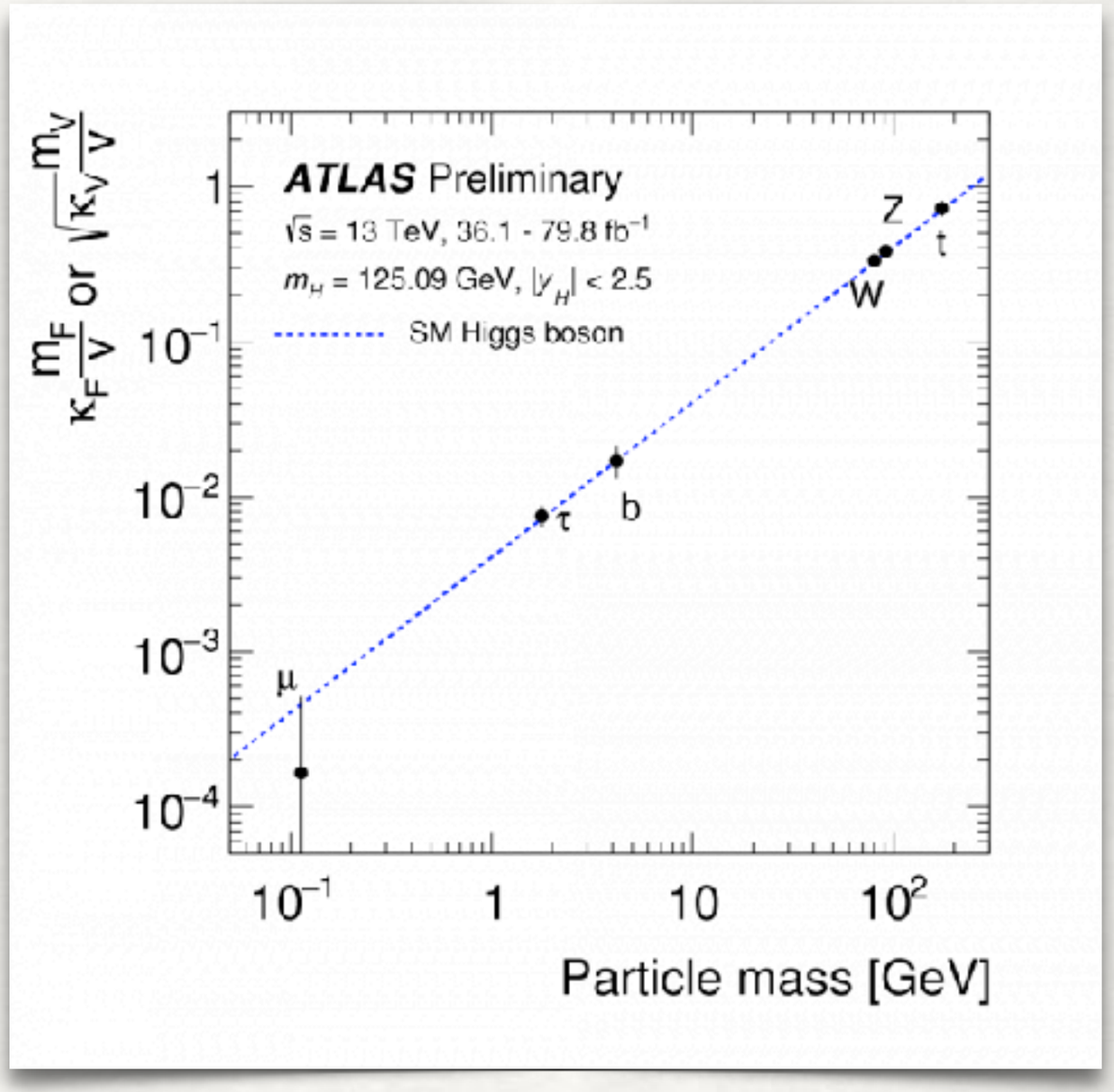
- Our vacum is not stable, but still in the metastability.
- The consideration of the history of our Universe. (Higgs dynamics at inflation, black hole and Higgs stability etc…ex.Kearney et al, Espinoza et al 2015, and soon ..)
- Require new particle? new theory? around λ~0.
- Importance of mt and Interaction of Higgs boson possible deviation from the SM



CURRENT STATUS OF HIGGS COUPLING MEASUREMENTS

GETTING DOWN TO THE SECOND GENERATION

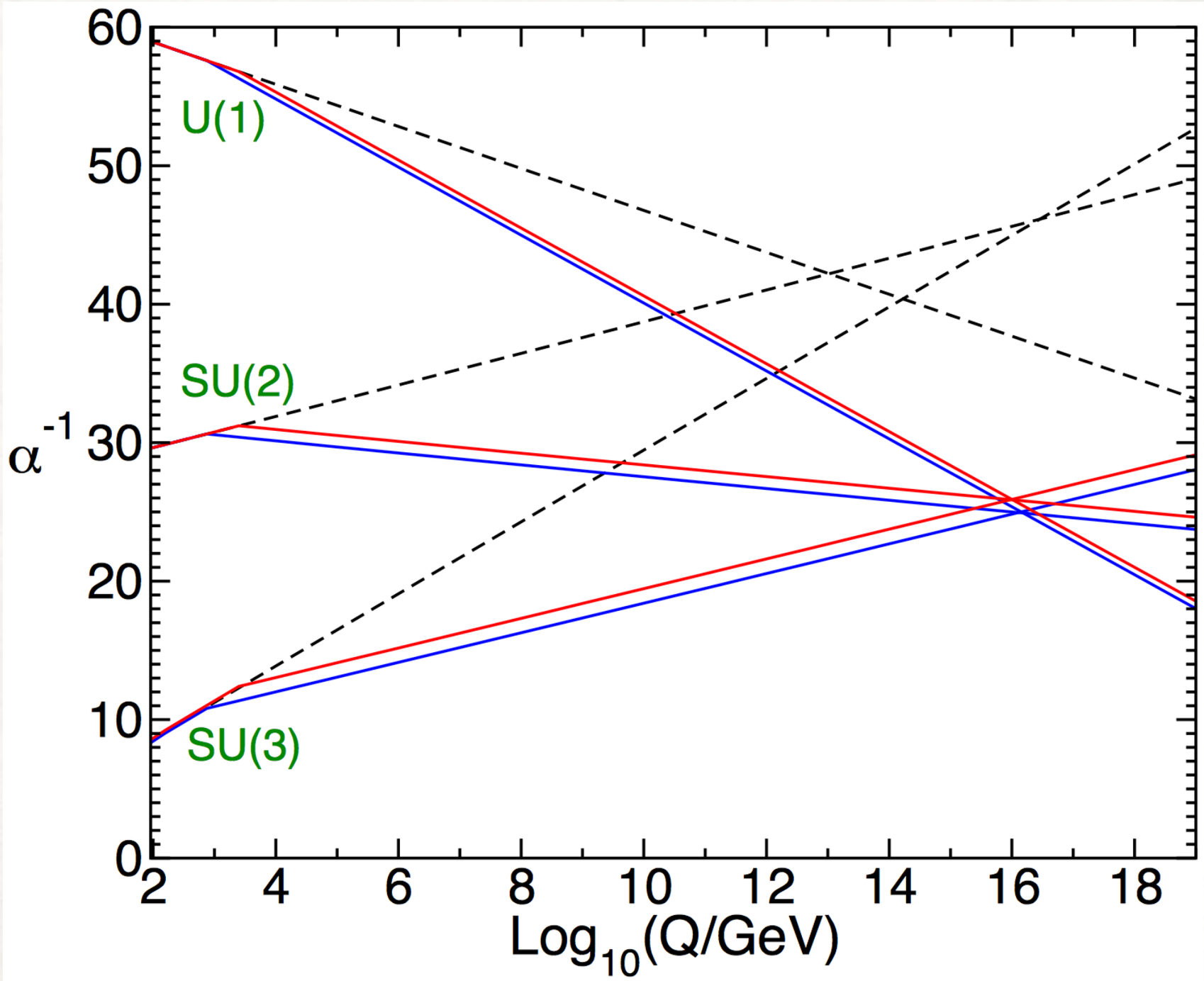




ATLAS-CONF-2018-031

GORDY KANE SCIENTIFIC AMERICAN 2003

EW PRECISION AT LEP
GAUGE COUPLING UNIFICATION IN SUSY



PRECISION IN LEPTON SECTOR

MUON ANOMALOUS MAGNETIC MOMENT

muon magnetic moment can be calculated theoretically and measured very precisely

up to n=5

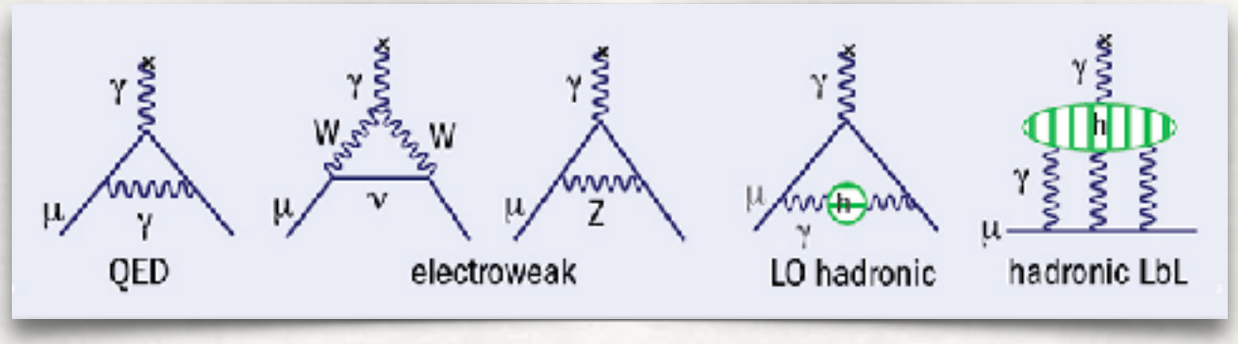
$$a_\mu(\mathrm{QED}) = \sum_{n=1}^{\infty} \left(\frac{\alpha}{\pi}\right)^n a_\mu^{(2n)}$$

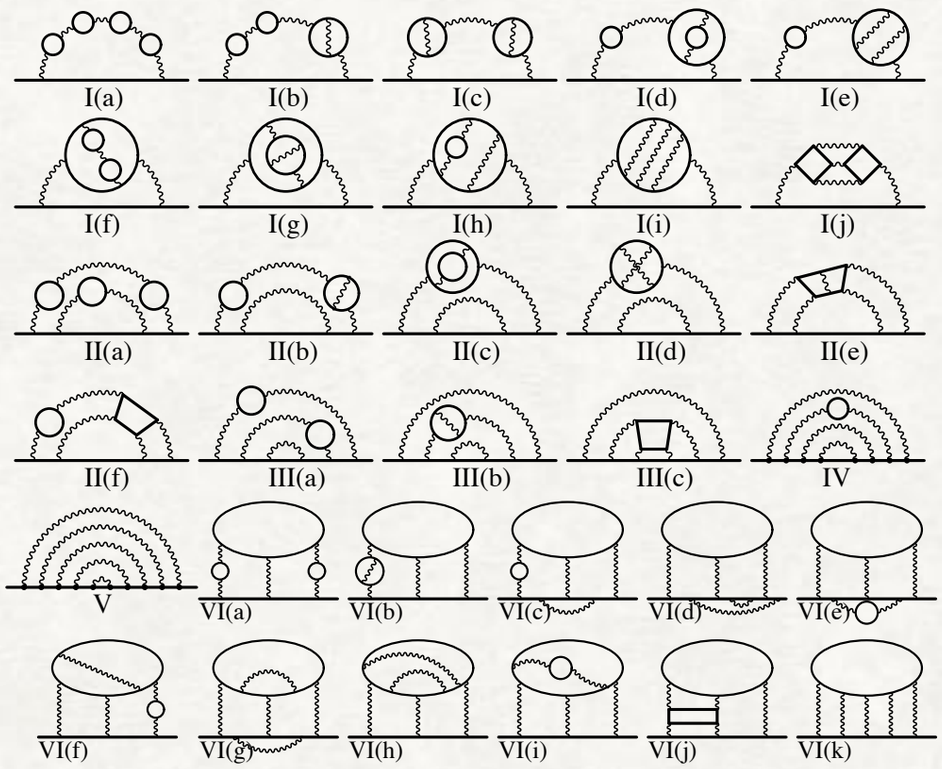
Aoyama, Hayakawa, Kinoshita, Nio PRL 109(2012)111

$$a_\mu^{(2)} = 0.5,$$

$$a_\mu^{(4)} = -0.328\ 478\ 965\ 579\ \ldots + 1.094\ 258\ 312\ 0\ (83)$$

$$+ 0.780\ 79\ (15) \times 10^{-4}$$





Keshavarzi, Nomura, Teubner 1802.02995 reevaluation hadronic contributions

$$a_\mu(\mathrm{exp}) - a_\mu(\mathrm{SM}) = 249\ (87) \times 10^{-11}.$$ 3.7 **σ**

We still do not know why

FUTURE COLLIDERS

MANY E+E- PROPOSAL

- ILC cost 635.0-702.8 Gyen($6~7bn assuming 1US$=100JPY 1€=1.15US$)
  - (technology ready, proposed to government, MEXT asked KEK to form international discussions)
- On the other hand
  - CEPC $6bn
  - CLIC 6BCHF (initial)
  - FCC-ee (11BCHF) → FCC-hh included 28BCHF(compared with 5BCHF for LHC) :comparison to the CERN baseline budget

LC NEWSLINE

THE NEWSLETTER OF THE LINEAR COLLIDER COMMUNITY

14 MARCH 2019

DIRECTOR'S CORNER

Decision on the International Linear Collider: “Not what we had hoped for but progress nevertheless”

“Today we did not get the green light we hoped for, but nevertheless there was a significant step forward with a strong political statement and, for the first time, a declaration of interest in further discussions by a senior member of the executive. We will continue to push hard, ” said Lyn Evans, Director of the Linear Collider Collaboration.

KEK
High Energy Accelerator Research Organization

Summary and Outlook

- Japanese MEXT released its statement on March 7 at the LCB meeting in Tokyo.
  - MEXT has not yet reached declaration for hosting the ILC in Japan at this moment.
  - MEXT will continue to discuss the ILC project with other governments having an interest in the project.

- Supplemental message has been given by the ILC Federation of Diet Members
  - “we have to separate the infrastructure part that is natural to be taken up by the host country and the apparatus part that is natural to be internationally cost-shared among technically competent countries.”
  - “the next mission for politics is to secure the budget for the construction.”

- Actions to be taken in Japan:
  - International discussions at the government level ← MEXT
  - Funding plan ← Legislative sector + MEXT + other ministries
  - International working group ← KEK
  - Obtaining support from the broader academic community in Japan ← KEK and Japanese HEP community
  - European Strategy ← International ILC community

- Now MEXT is strongly involved in the ILC project.
  MEXT + legislative sector + KEK and physics community + industrial sector + local governments

From Masanori Yamauchi’s talk in Linear Collider Community Meeting 8-9 April 2019

Processes and Approximate Timelines Toward Realization of ILC (Physicists' view)

Restricted

2018.12 2019.3 2020.5 2024-

Government Level

MEXT panel

Summarize opinions of relevant ministries

Announcement by Japanese government

Discussion among governments
Exchange of information

Strengthen US-Japan Discussion Group, cost reduction R&D, governance discussion

Establish Discussion Group with the European partners

Start negotiations among governments on international sharing

Agreement on governance, operation, sharing of cost and human resources

Full-scale negotiation among governments – specification of conditions and processes

Critical decision process

MOU among research labs on start of the preparation phase under approval by each government

ILC pre-lab (4 years)

Start construction of ILC

Final agreement among governments on construction

Oct. 2019

Next Roadmap by MEXT

SCJ committee on ILC

SCJ Master Plan

3/7

Physicists Level

LCB/ICFA mtgs. @ Tokyo

EPPSU submitted to CERN

European Particle Physics Strategy Update

Draft proposal by researchers on international cost sharing

Establish KEK International WG
Produce draft for international sharing of human and material resources

Talks with other countries

Good enough design for the final approval of construction, resolution of remaining technical issues

* ICFA: international organization of researchers consisting of directors of world's major accelerator labs and representatives of researchers
* ILC pre-lab: International research organization for the preparation of ILC based on agreements among world's major accelerator labs such as KEK, CERN, FNAL, DESY etc.

From Masanori Yamauchi's talk in Linear Collider Community Meeting 8-9 April 2019

SCIENCE COUNCIL OF JAPAN

SCJ established in January 1949 : "special organization" under the jurisdiction of the Prime Minister, operating independently of the government, for the purpose of promoting and enhancing the field of science, and having science reflected in and permeated into administration, industries and people's lives. (Science include humanities and social science)

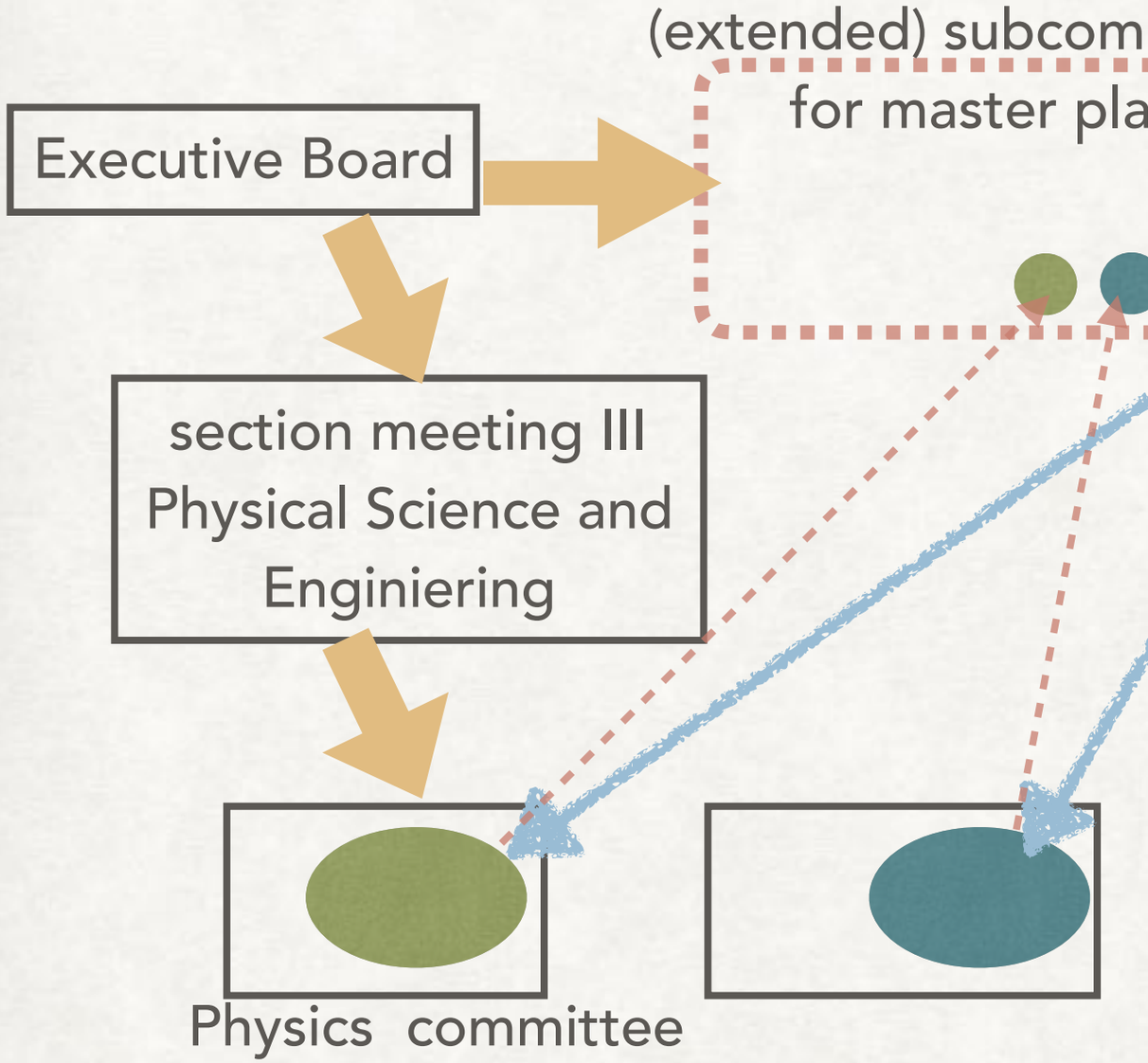
Science Council of Japan (SCJ) : **210 Council Members** and **some 2,000 Members**.

Sometimes Government requests specific reports from SCJ. In such case special committee is established. (ex "ILC committee")

<Master Plan> is SCJ activity to list up the large research plan with high academic value of each academic field. (—not related for funding but hoping government recognize them.) MEXT Minister suggested the ILC to be evaluated in this process to provide an evidence of getting support by the broader academic community in Japan.

MASTER PLAN DISCUSSION IN SCJ

(IT IS BOTTOM UP AND A YEAR LONG PROCESS)



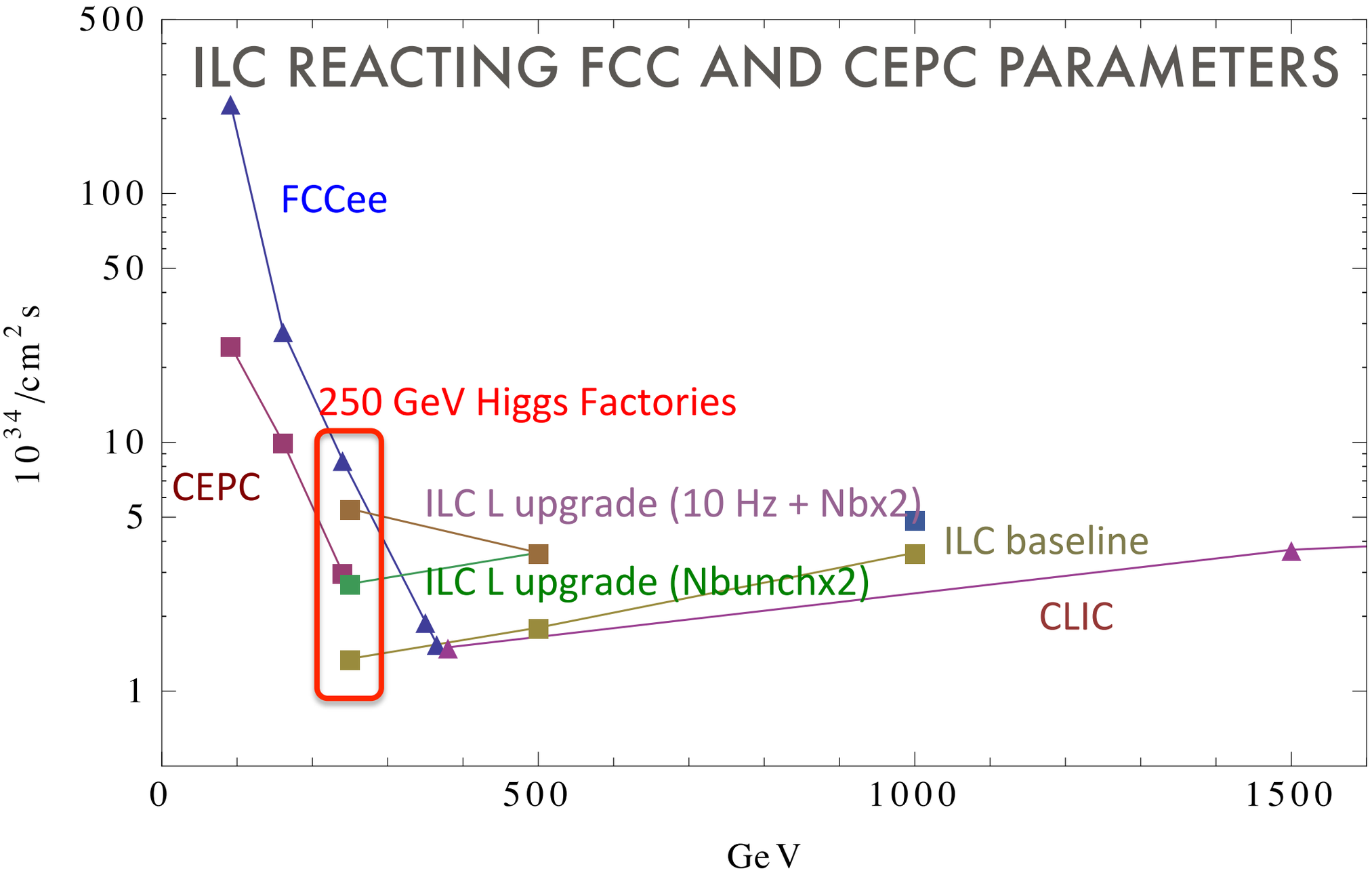
Main task of the subcommittee is to determine the rule that works for all subfields

40 COMMITTEES BASED ON FIELD OF SPECIALITY

-> sub-subcommittees for master plan
up to 10 members each

Other field, such as
chemistry, engineering…

Altogether ~400 scientist of all field are involved to the process.



- FCCee/CEPC are for 1 IP (their CDR have 2 IPs)
- ILC Higgs Factory numbers do not include effective x～2.5 by polarization
- ILC 10 Hz collision reaquires ~ILC500

Cost of $\mathcal{L}$ upgrade ($2.7x10^{34}$): ～6% of initial construction cost
10 Hz repetition rate upgrade requires ~ ILC500

YUKAWA COUPLING AT FUTURE COLLIDERS

polarization is important

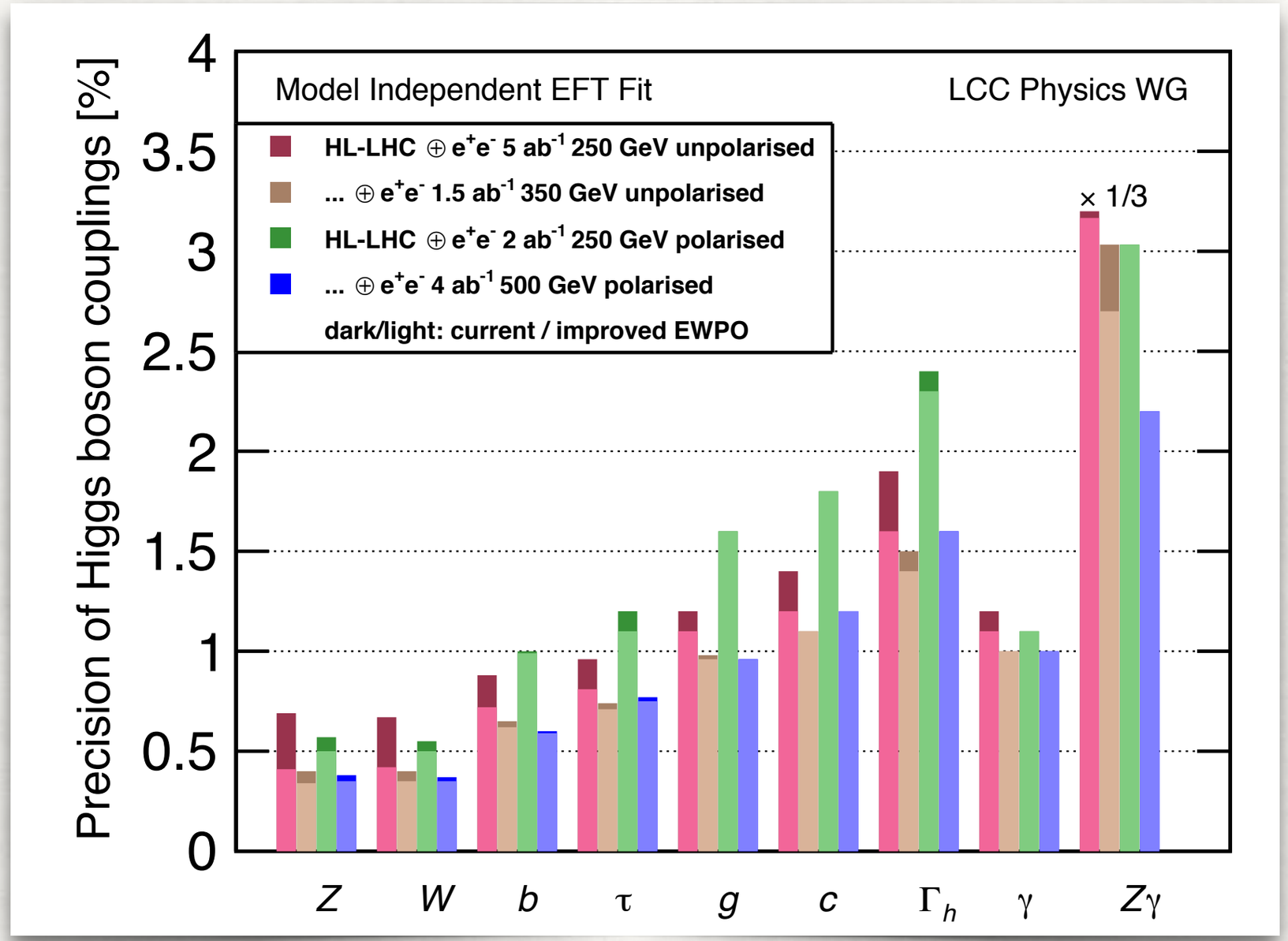


FIG. 77: Impact of improved electroweak precision observables on the projected precisions for various Higgs couplings for the combinations of luminosity, energy and polarisation from Tab. XIX. For the unpolarised cases, EWPO projections from the FCC-ee CDR [284] have been assumed, while for the polarised case only an improved precision for A_ℓ is assumed. Couplings for which there is no improvement due to improved EWPO have been omitted from the figure. The notation of the figure is the same as that in Fig. 75.

1903.01629

YUKAWA COUPLING AT FUTURE COLLIDERS

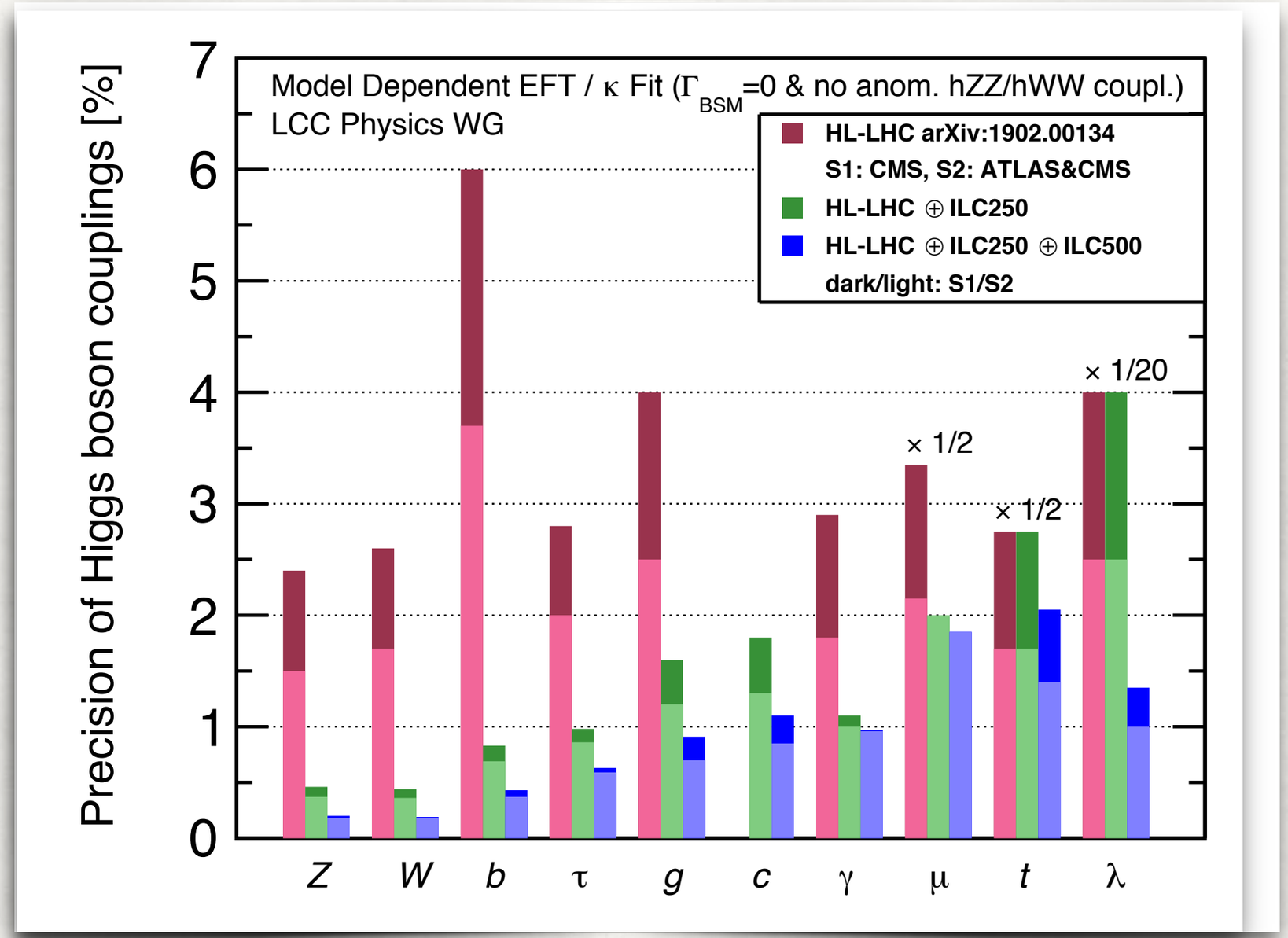
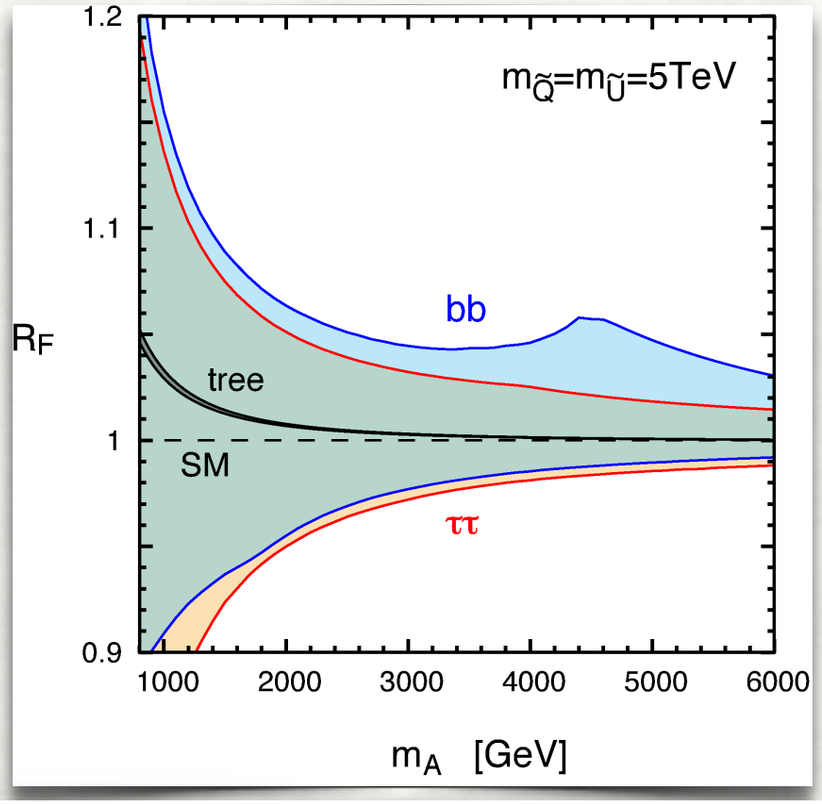
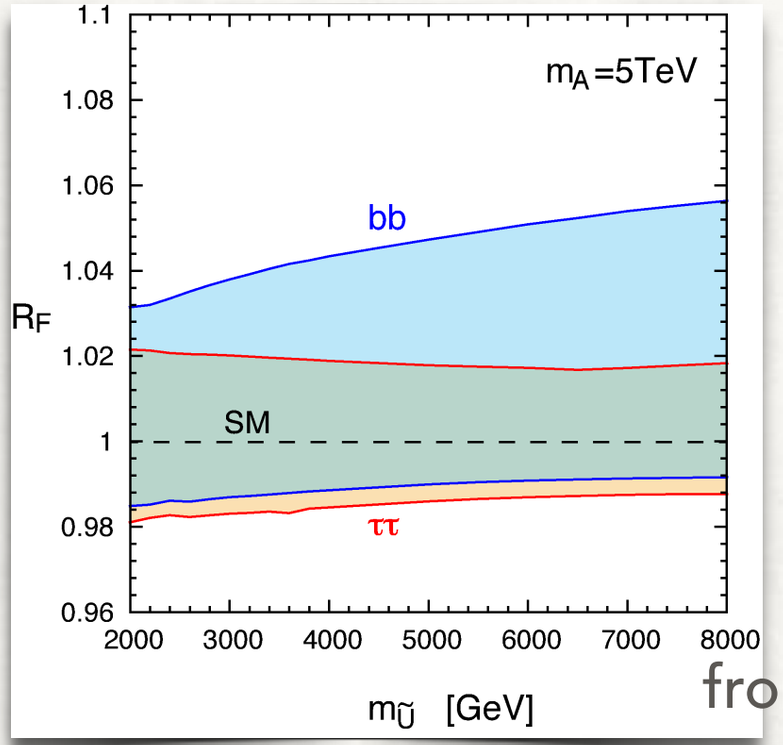


FIG. 78: Projected Higgs boson coupling uncertainties for the LHC and ILC using the model-dependent assumptions appropriate to the LHC Higgs coupling fit. The dark and light red bars represent the projections in the scenarios S1 and S2 presented in Ref. [126]. The dark and light green bars represent the projections in the ILC scenarios S1 and S2 described in the text. The dark and light blue bars show the projections for scenarios S1 and S2 when data from the 500 GeV run of the ILC is included. The notation of the figure is the same as that in Fig. 75.

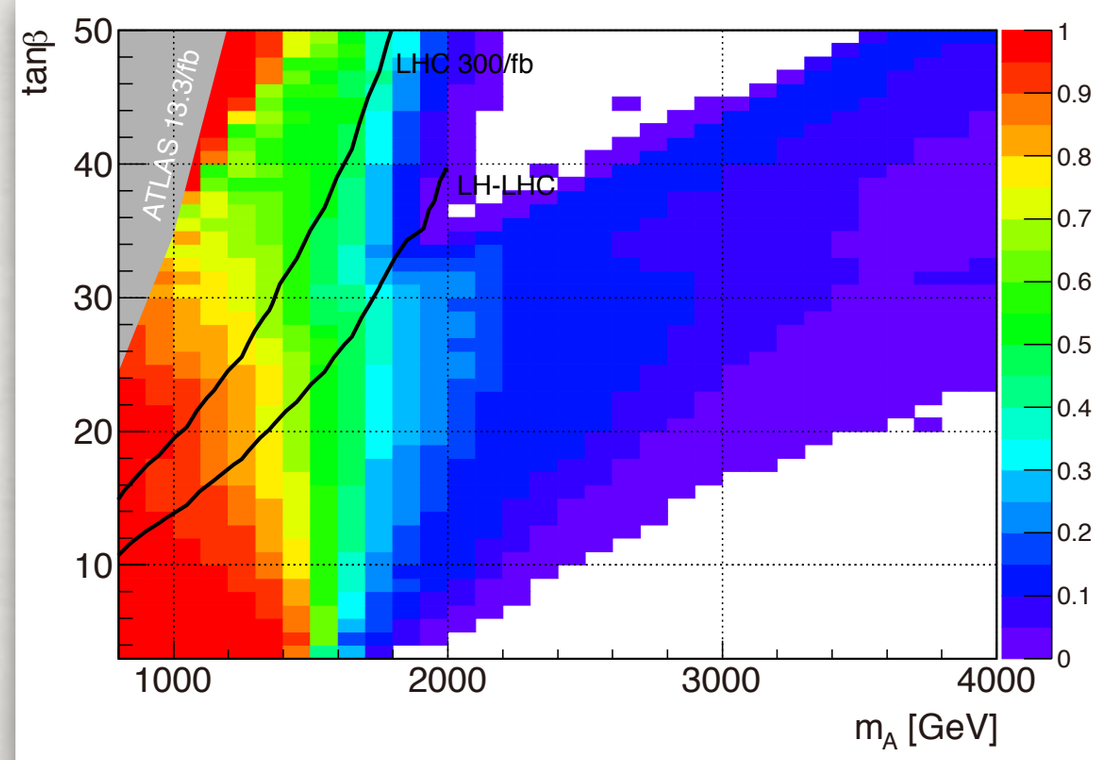
HIGGS FACTORY VS HIGH ENERGY COLLIDERS?





SUSY loop correction to the Higgs does not decouple easily

from 1502.03959



Assumption for ILC:

δ BR(b b / WW) = 1.3%

δ BR(τ τ / WW) = 1.9%

[Courtesy of M. Endo, based on 1502.03959]

FCC AND ILC SENSITIVITY TO 3 POINT COUPLING

DONEC QUIS NUNC

- Some dependence on the Higgs 3 point coupling as well.
- Polarization must be persuaded
- Difference between proposed luminosity may not be so crucial as they change all time.
- FCC-hh sensitivity is much less than <10%

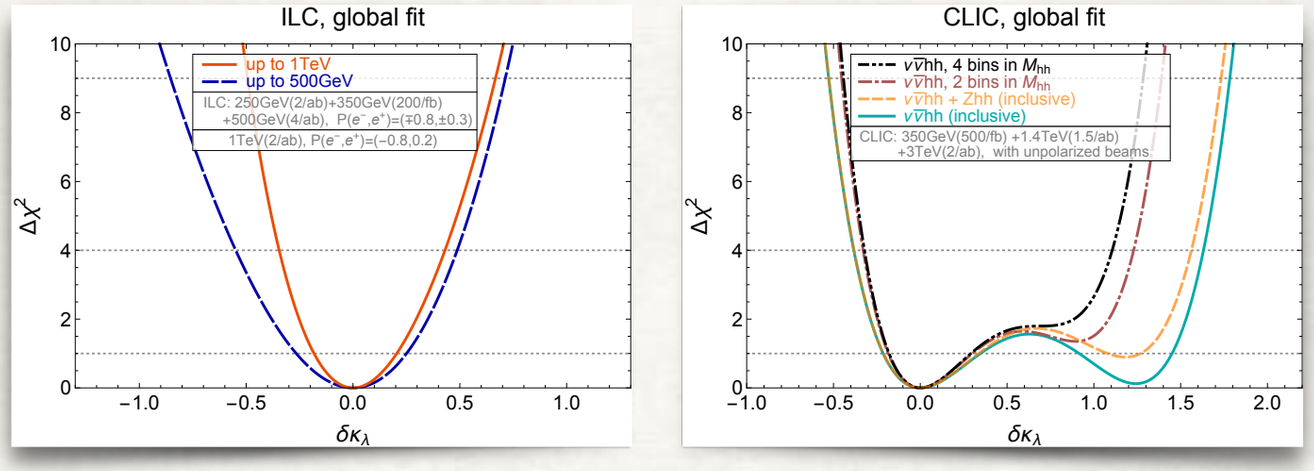


Figure 10: Chi-square as a function of $\delta\kappa_\lambda$ for the high-energy ILC (left) and CLIC (right) benchmarks. The results are obtained through a global analysis, profiling over all other EFT parameters.

from 1711.03978

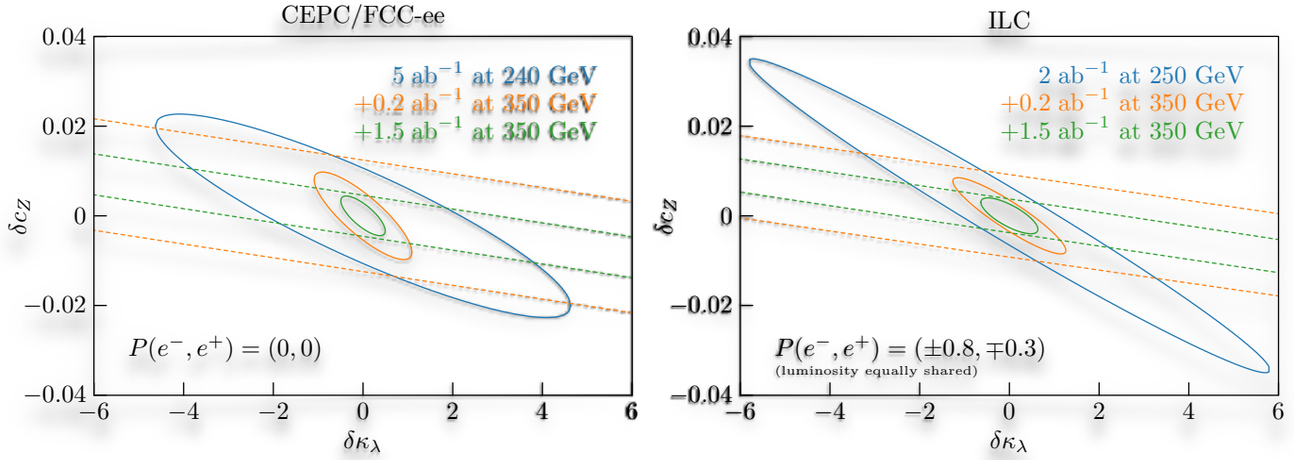


Figure 4: Global constraints on δc_Z and $\delta\kappa_\lambda$, obtained from single Higgs measurements at circular colliders (left panel) and ILC (right panel), illustrating the improvement brought by 350 GeV runs. Dashed lines are for the latter only, while solid lines combined them with the 240/250 GeV one.

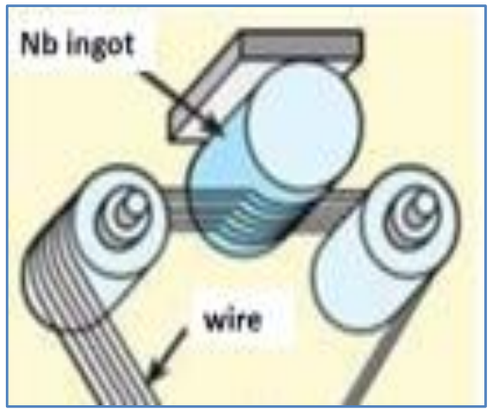
COST REDUCTION IS IMPORTANT

ILC Cost-Reduction R&D in US-Japan Cooperation on SRF Technology

Based on recent advances in technologies;

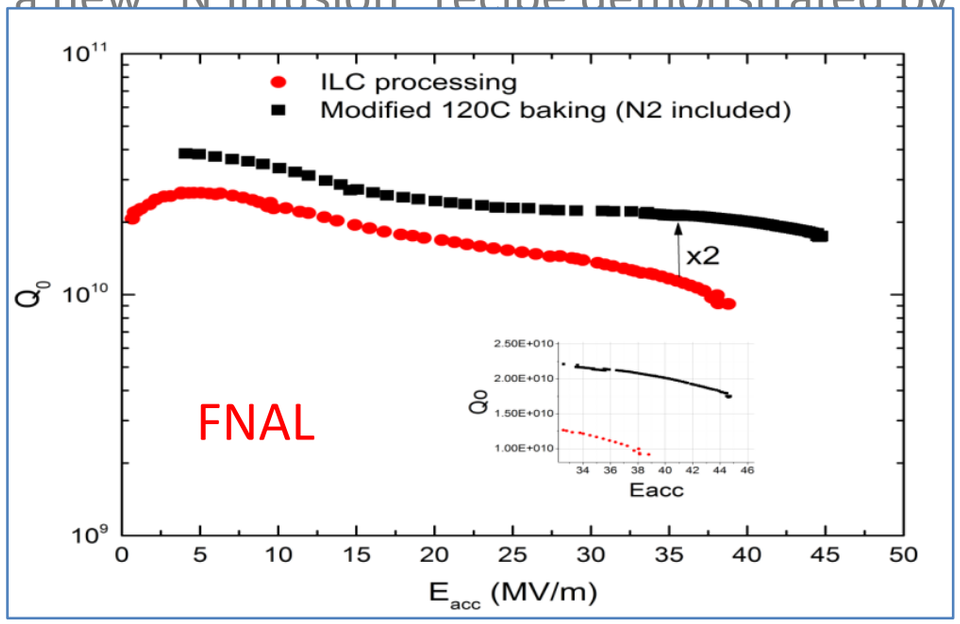
– Nb material/sheet by direct-slice

- w/ optimum Nb purity and clean surface

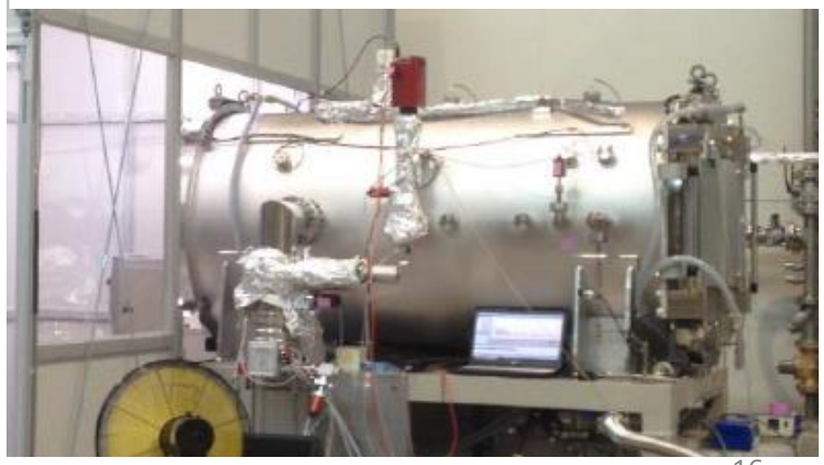


– SRF cavity fabrication for high-Q and high-G

-w/ a new "N Infusion" recipe demonstrated by **Fermilab**



Vacuum furnace for N-infusion (KEK)

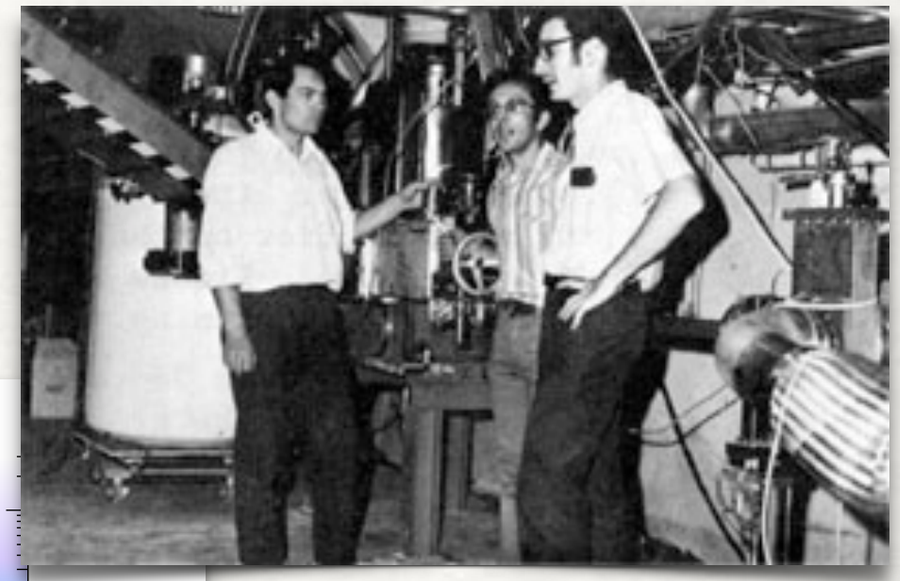


FCC-hh “pipetron taking a shape”

It is certainly great if we have one

See http://www.slac.stanford.edu/pubs/snowmass96/PDF/ACC049.PDF for pipetron (written by Ernst Malamud.)

He, by the way, was involved E-36 the first collaboration with Soviet Union in Fermilab, in 1972



From FermiLab Library

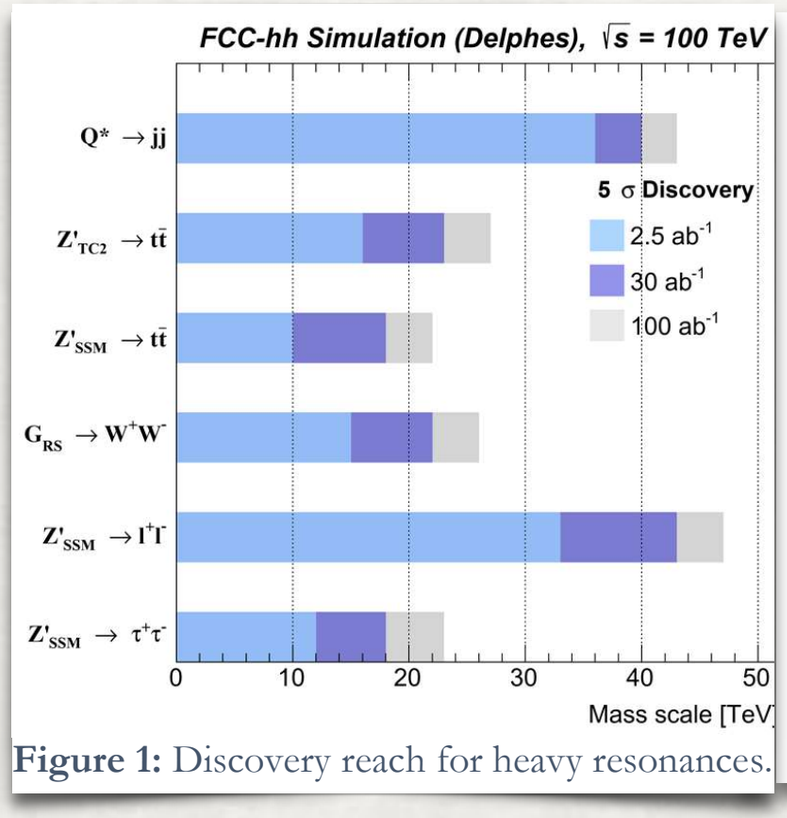
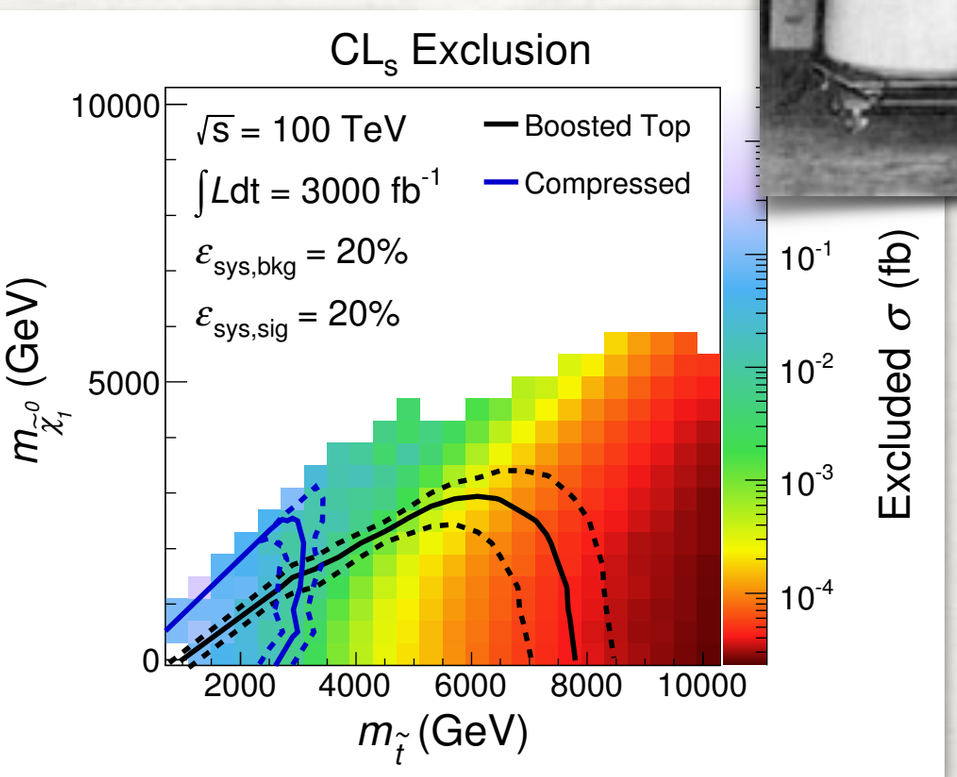


Figure 1: Discovery reach for heavy resonances.



1606.00947

BUT IT IS NOT CLEAR IF WE SATISFY

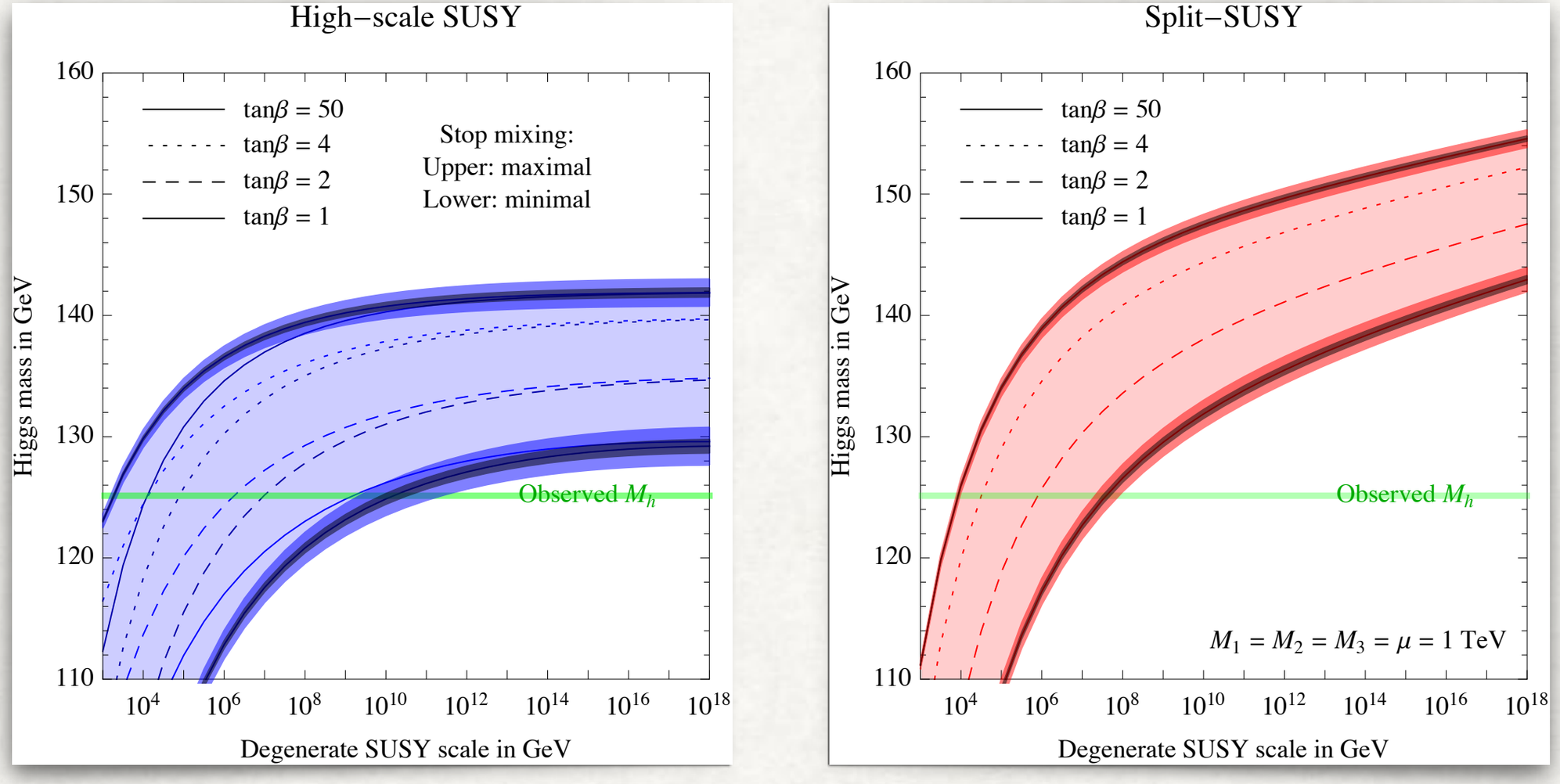
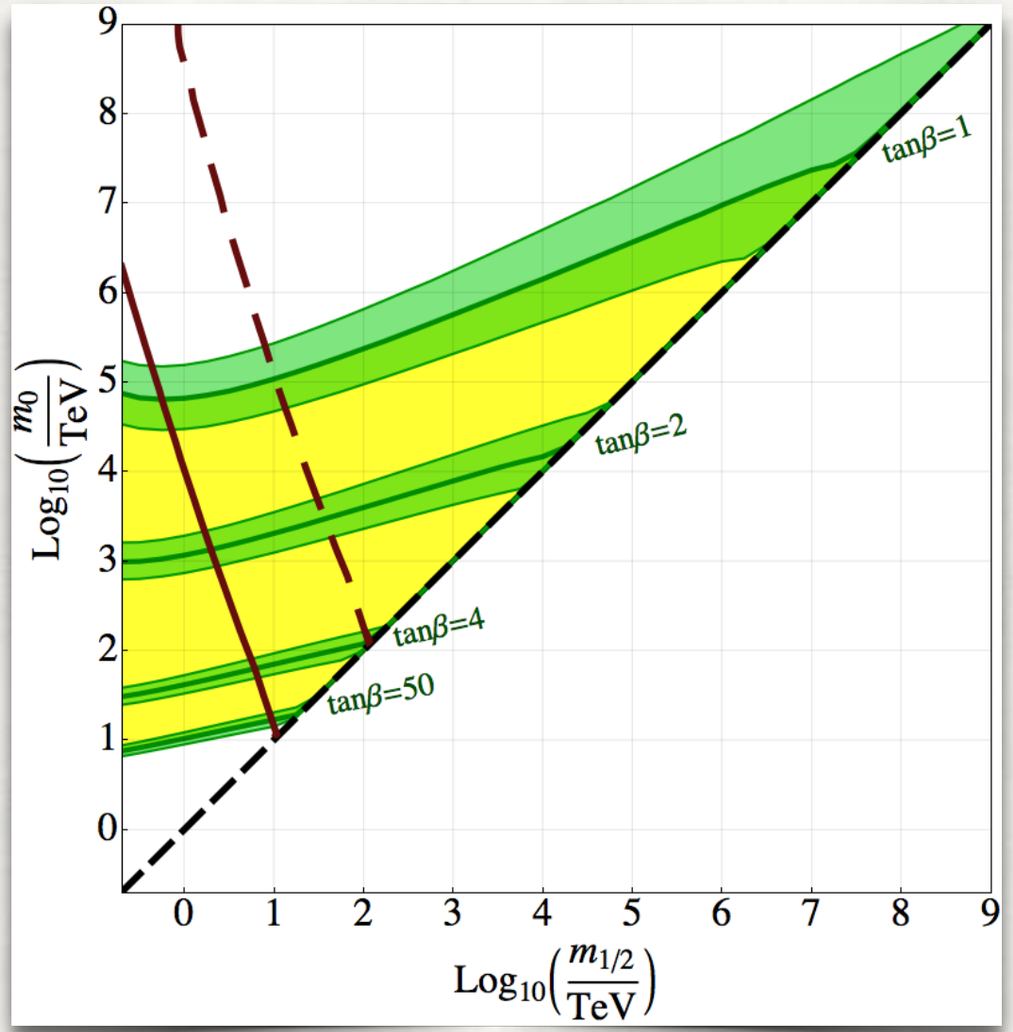


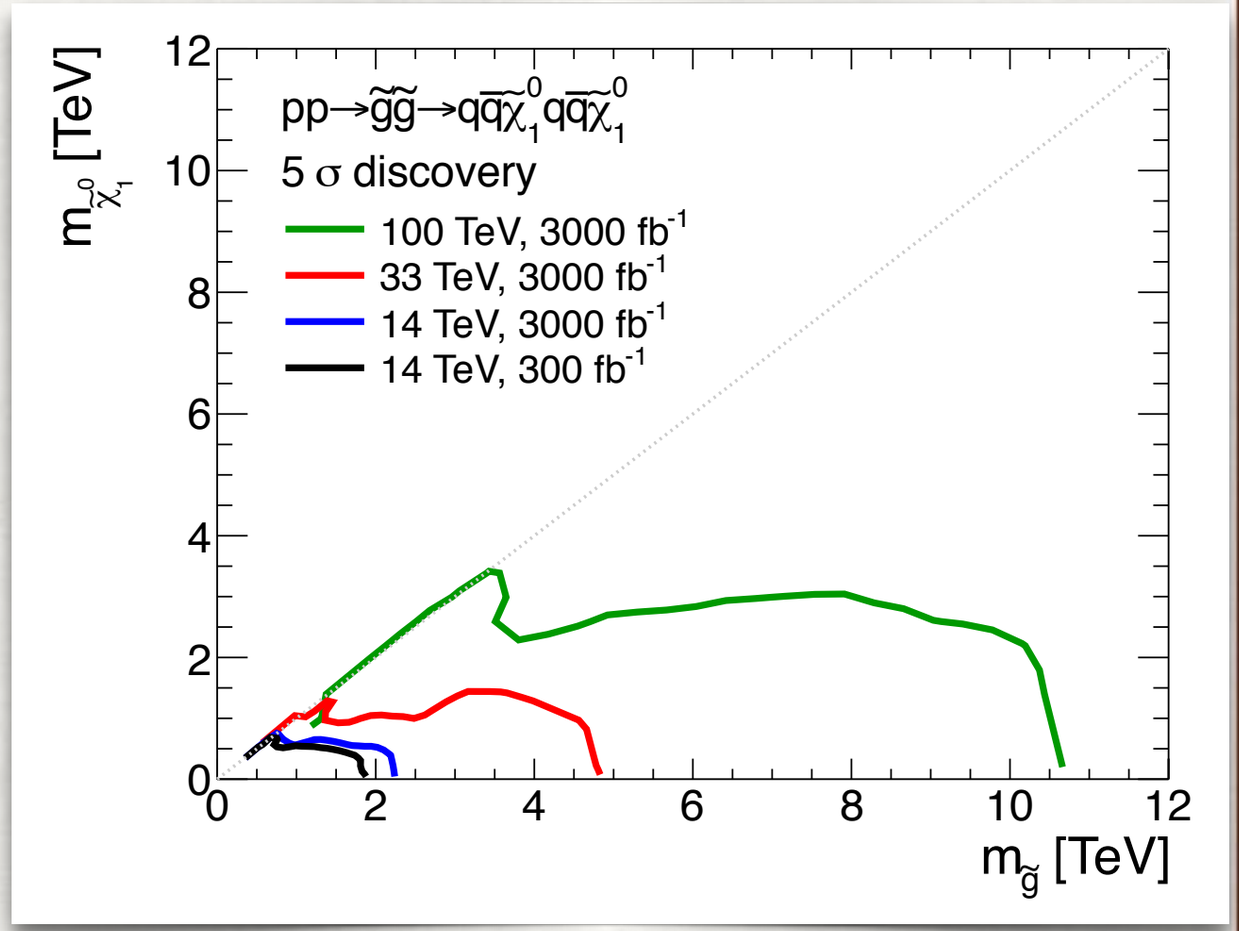
Fig. 3: Higgs mass predictions as a function of the supersymmetry breaking soft mass scale and the Higgs sector parameter $\tan\beta$, taken from [51]. In the High-Scale scenario all soft masses $\mu, \widetilde{M}_{1/2}, \widetilde{m}_0$ are varied together, whereas in the Split SUSY scenario $\mu, \widetilde{M}_{1/2}$ are kept at 1 TeV and only the scalar soft masses $\widetilde{m}_0$ are varied.

GAUGE COUPLING UNIFICATION WITH SUSY AND SUSY SCALE?

assume gauge coupling Unification



Mni-split Arvantaki et al 1210.0555
(but threshold correction would change the picture completely.



from 1606.00947 Physics
at a 100TeV pp collider

REACH DEPENDS ON SYSTEMATICS

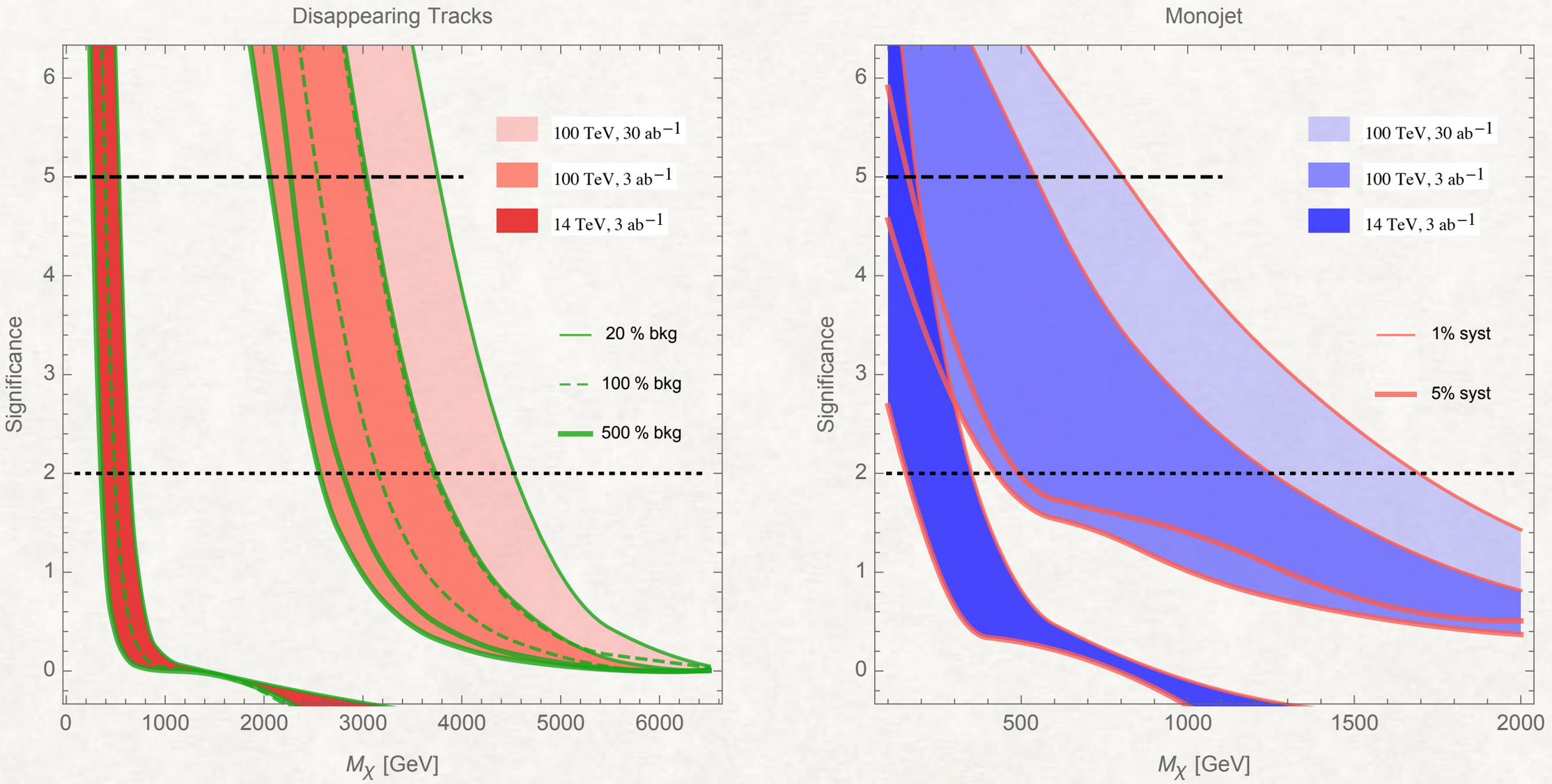


Fig. 46: *Reach of disappearing tracks (left) and monojet (right) searches [348].*

Great progress in last 20 years in the field of QCD: maching, jet physics, N^nLO
To use full luminosity of FCC-ee, EW correction also have to calculated extensively.

ON CONVINCING OTHER FIELDS

- Big picture (how higgs and dark matter involved in the model, Baryon and lepton number), **curiosity driven(long lived, invisibles, elephants?...)** Physics output is important.

- New projects require **real international involvements.** Express International interest/organization/management. We have strong record on that.

- Cost Reduction/Environmental issue.

- **Understand/Support/Promote Other scientific field, because they are equally important.**

That is it!