BNL Colloquium - December 3, 2019

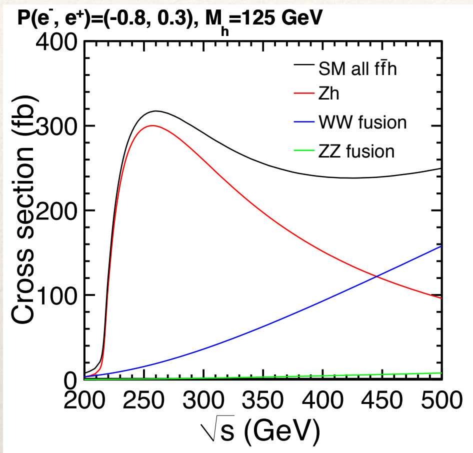
The International Linear Collider

Jim Brau
University of Oregon

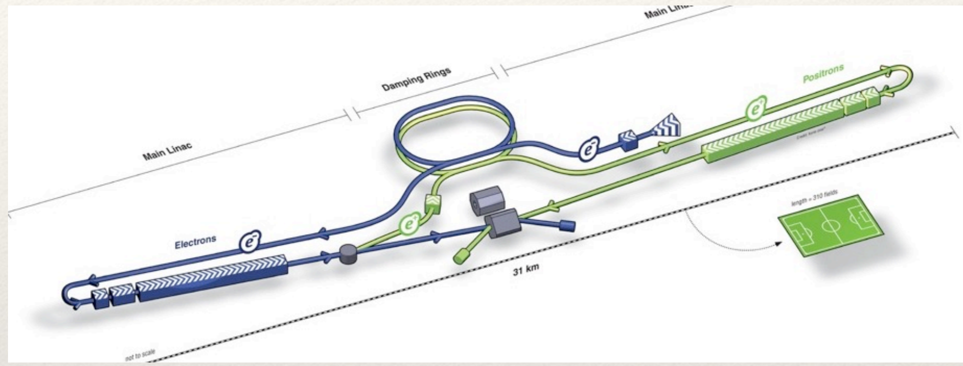
Ref: **arXiv:1903.01629**

The ILC

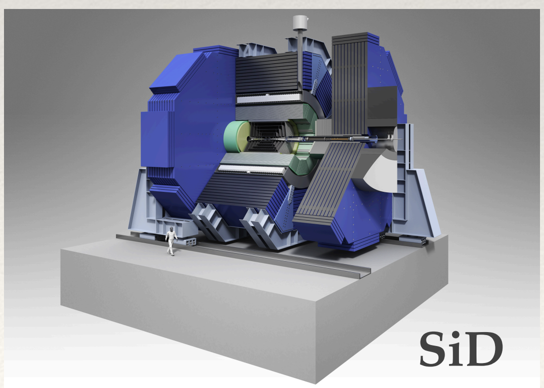
- Physics

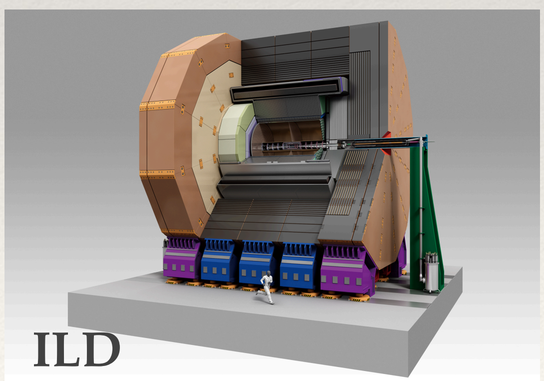


- Collider

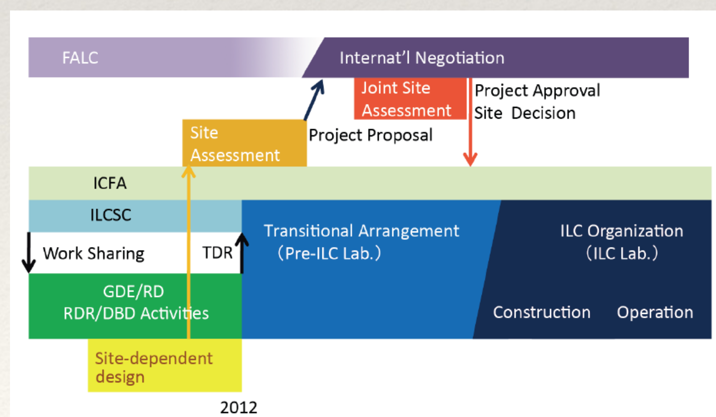


- Detectors





- Project Realization



Introduction - the ILC

- e^+e^- at 250 GeV addresses **compelling physics** questions:
  - EW symmetry breaking and Higgs physics,
  - Searches, more.
- ILC is **technically mature** with detailed, manageable cost estimate.
- Linear Colliders offer **natural evolution** to higher e^+e^- energy:
  - 350/380 GeV, 500 GeV, and higher.
- Upgradability well defined - **500 GeV ILC design** exists - TDR.
- **Political support** in Japan very strong with decision anticipated.

Higgs Boson - Discovery Tool for New Physics

P5 Science Driver:

"Use the Higgs boson as a new tool for discovery"

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Higgs boson is central to the mysteries of particle physics.

Many SM free parameters involve the Higgs boson mass, potential, and couplings - free parameters unexplained.

Higgs Boson - Discovery Tool for New Physics

P5 Science Driver:

"Use the Higgs boson as a new tool for discovery"

Higgs boson is central to the mysteries of particle physics.

Many SM free parameters involve the Higgs boson mass, potential, and couplings - free parameters unexplained.

The scalar Higgs field couples to all SM particles, and more strongly to the heaviest ones.

Radiative corrections from new physics or mixing with heavy particles at TeV masses will affect the properties of the 125 GeV Higgs boson.

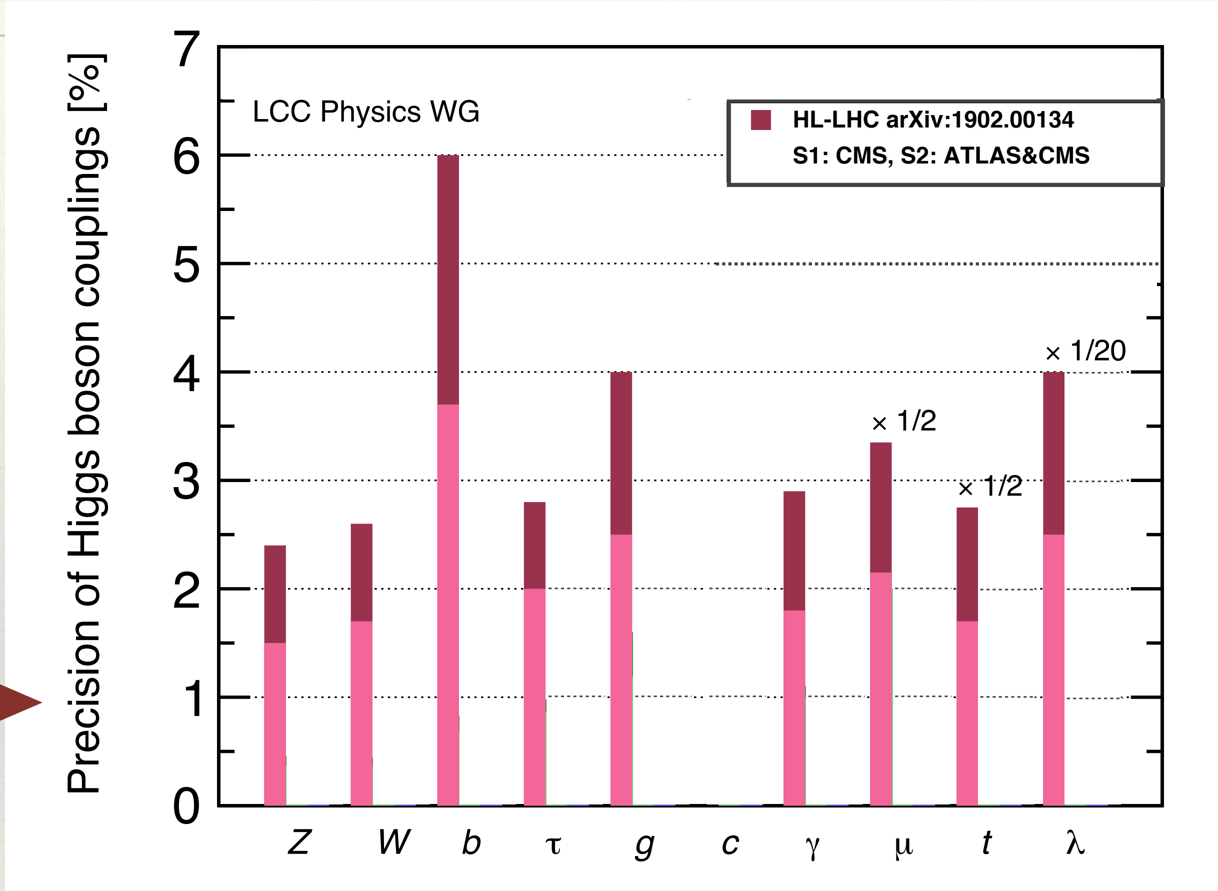
Scale of New Physics Effects

New physics effects from the mass scale ***M*** will appear as deviations from the Standard Model Higgs couplings with size $\sim m_h^2/M^2$.

Therefore, any model with ***M*** $\gtrsim$ 1 TeV predict effects of less than 10%.

Consequently, our goal must be for measurements with **1% precision** - across the whole range of Higgs boson couplings - pointing to nature of BSM (see later slides).

Future Reach of HL-LHC



- S1, current projection **/model-dependent**
- S2, improved. / **model-dependent** (HL-LHC adopted)

arXiv:1902:00134
arXiv:1903.01629

Model Dependent - Projections Assume:

Higgs boson has no decay modes beyond those predicted in the SM.

ILC can do much better with Model Independent measurements

Advantage of Higgs Studies at ILC

Very low backgrounds and simple reactions in e^+e^-.

Environment allows for detectors of unprecedented accuracy.

Also, all decay modes are observed in e^+e^-,

with small, calculable backgrounds.

Polarization enhances sensitivity.

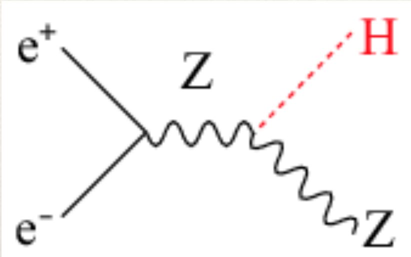
Higher precision, model-independent measurements feasible.

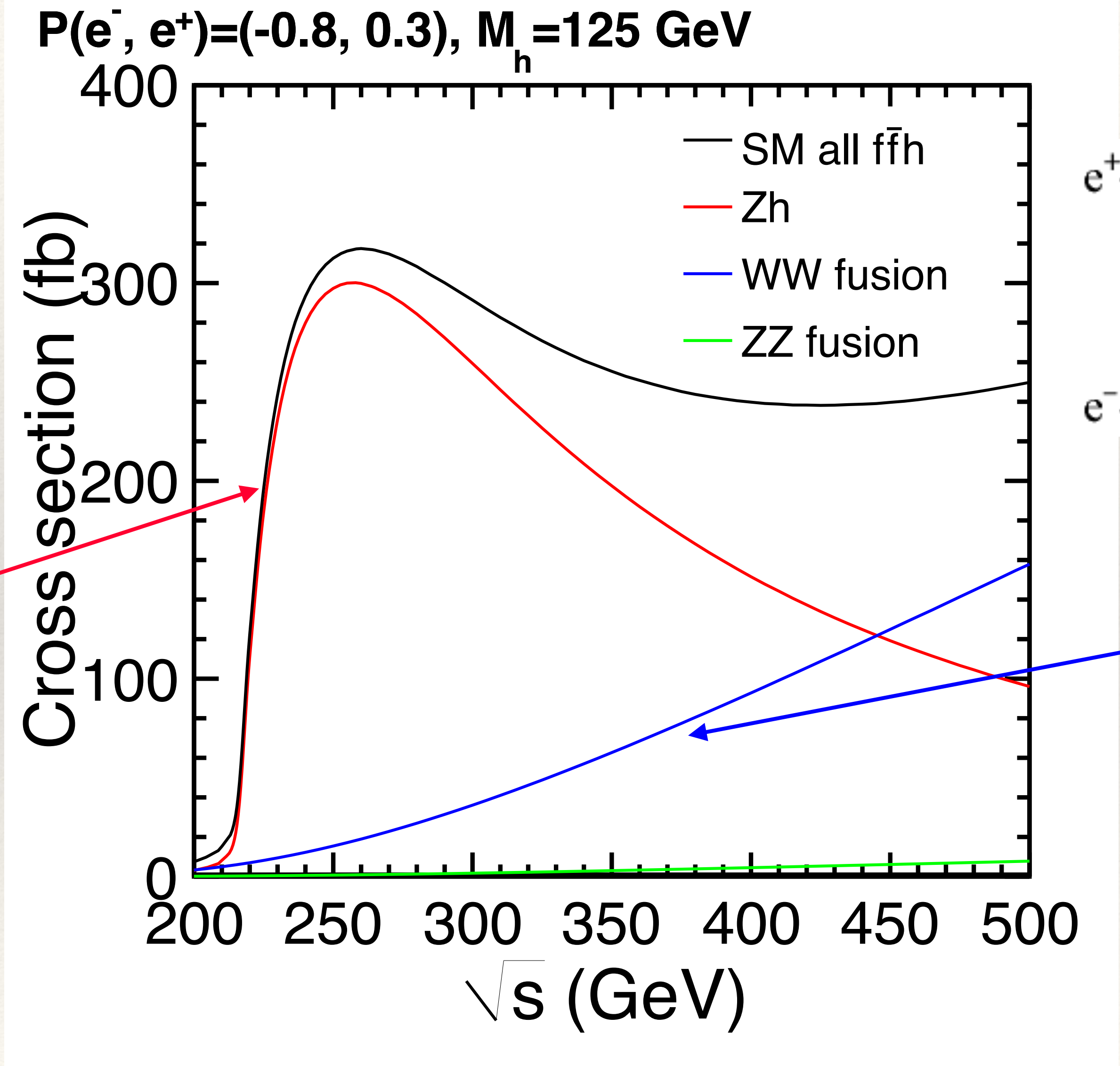
Sub-1% coupling measurements achievable.

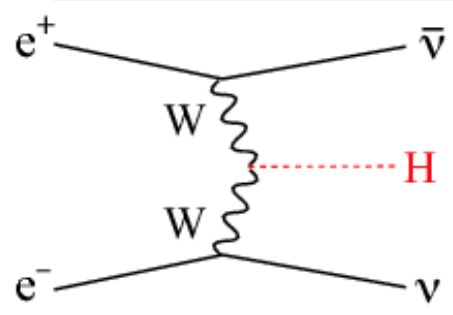
Energy extendability (to 500-1000 GeV) accesses

top Yukawa and triple-Higgs couplings

Higgs Boson Cross Section







Higgs-strahlung peaks and falls with center-of-mass energy

WW fusion rising with center-of-mass energy

Higgstrahlung at 250 GeV

Higgs Factory observes Higgs recoiling from a Z, with known CM energy⇓

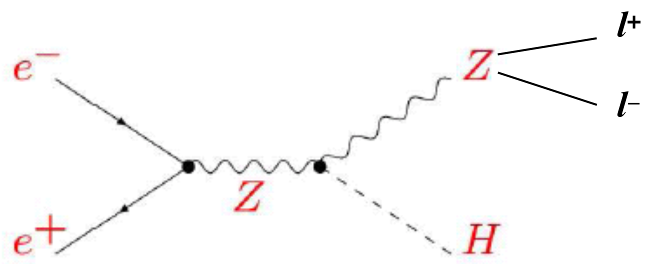
- powerful channel for unbiassed tagging of Higgs events
- measurement of even invisible decays

(⇓ - some beamstrahlung)

1. KNOWN INTIAL STATE

2. MEASURE Z→ l^+l^-

3. SELECT E(Z boson) = 110 GeV
M(recoil) = 125 GeV



4. MEASURE RECOIL
AND OBSERVE DECAY

Invisible decays are included

Higgstrahlung at 250 GeV

Higgs Factory observes Higgs recoiling from a Z, with known CM energy⇓

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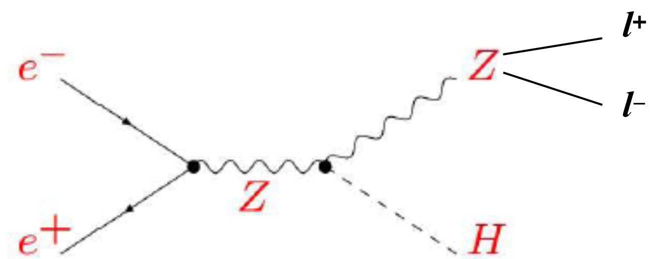

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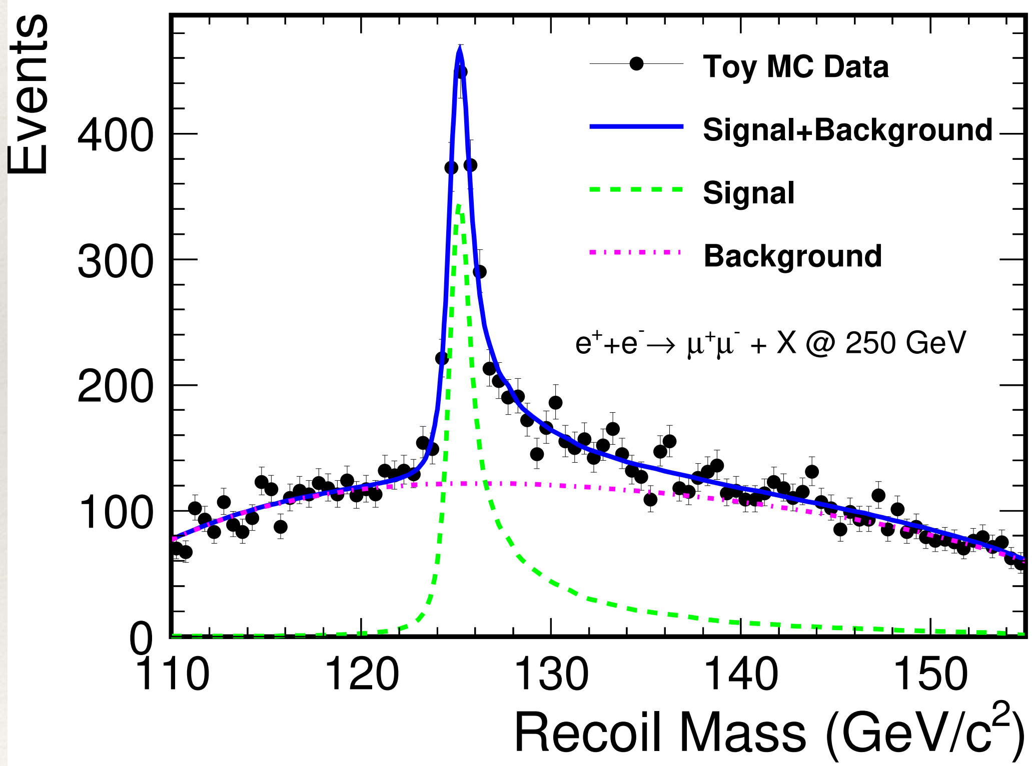
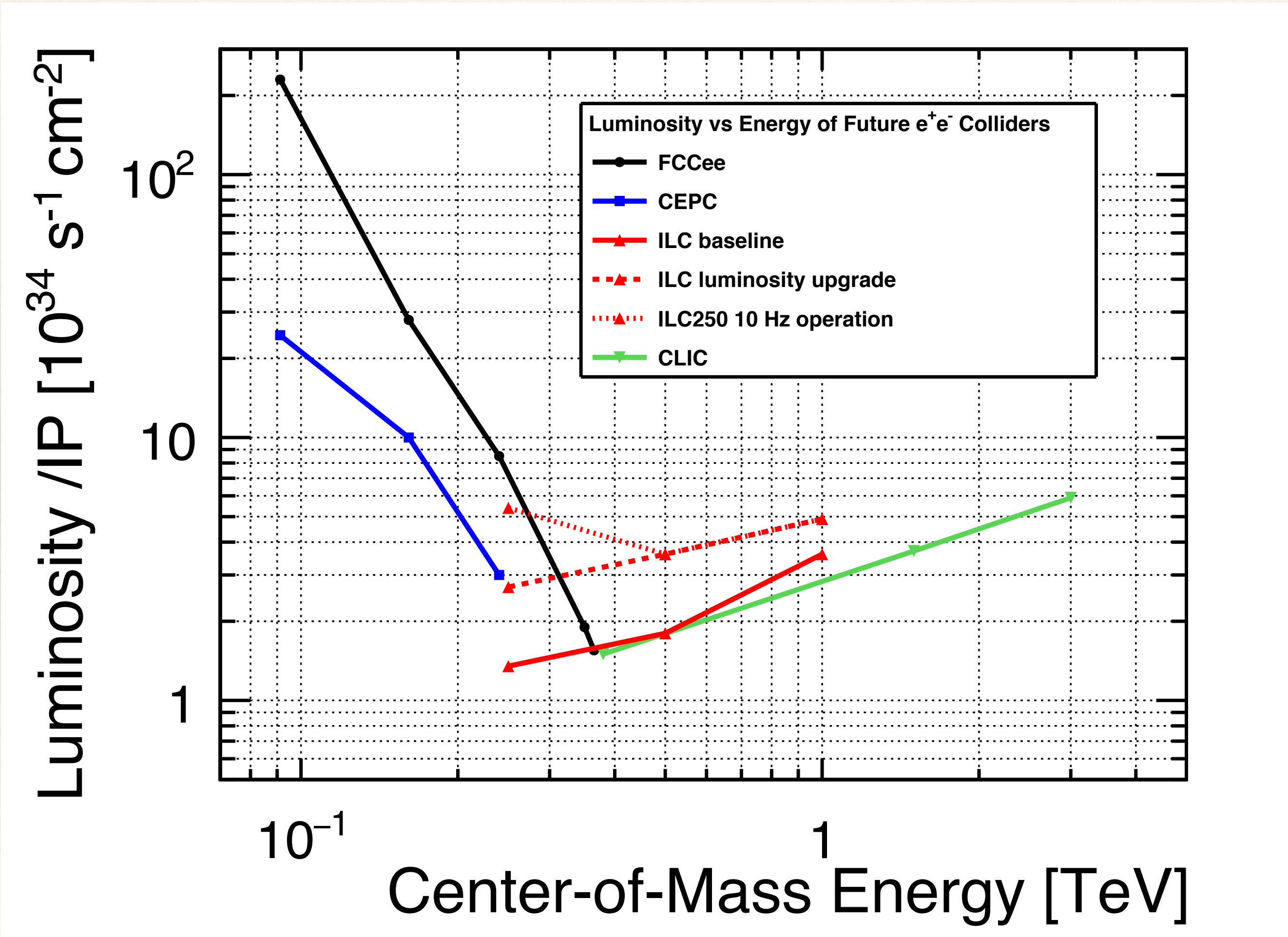


arXiv:1604.07524, PRD94 (2016) 113002

e^+e^- Higgs Factory proposals

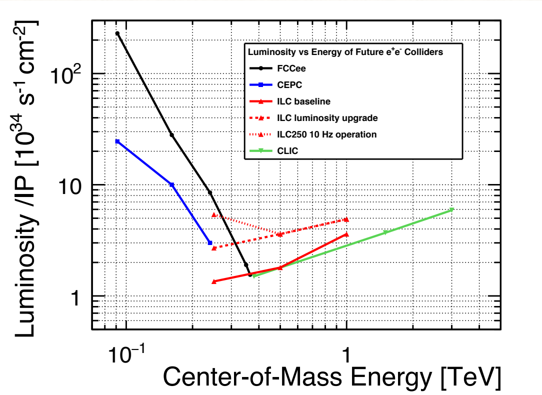
	√s	beam polarisation	∫Ldt for Higgs	R&D phase
ILC	0.1 - 1 TeV	e-: 80% e+: 30%	2000 fb^{-1} @ 250 GeV 200 fb^{-1} @ 350 GeV 4000 fb^{-1} @ 500 GeV	TDR completed in 2013
CLIC	0.35 - 3 TeV	e-: (80%) e+: 0%	1000 fb^{-1} @ 380 GeV 2500 fb^{-1} @ 1.5 TeV 5000 fb^{-1} @ 3 TeV	CDR completed in 2012
CEPC	90 - 240 GeV	e-: 0% e+: 0%	5600 fb^{-1} @ 240 GeV	CDR completed in 2018
FCC-ee	90 - 350 GeV	e-: 0% e+: 0%	5000 fb^{-1} @ 250 GeV 1700 fb^{-1} @ 350 GeV	CDR completed in Jan 2019

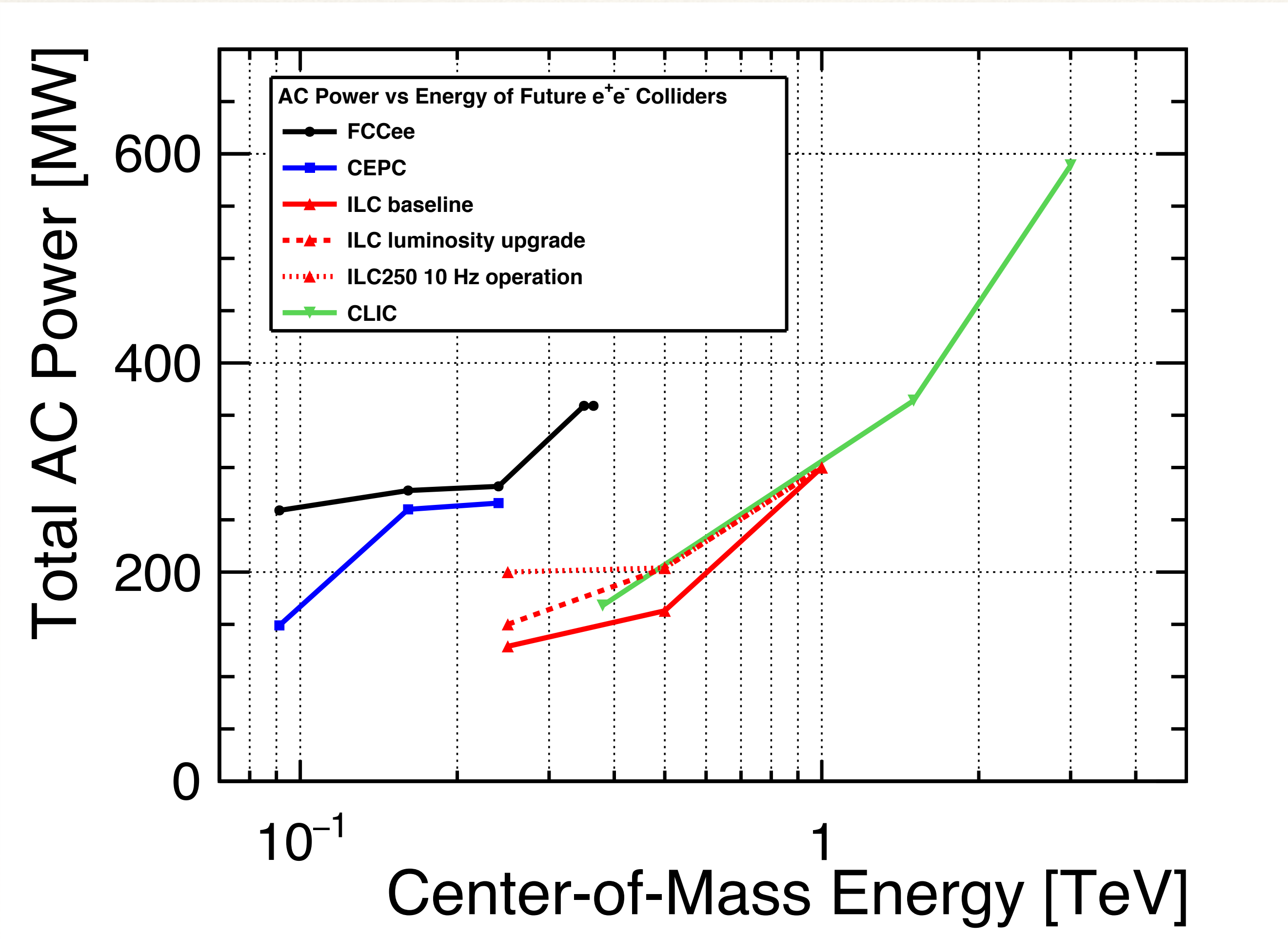
update based on J. Tian, LC School, DESY, 2018



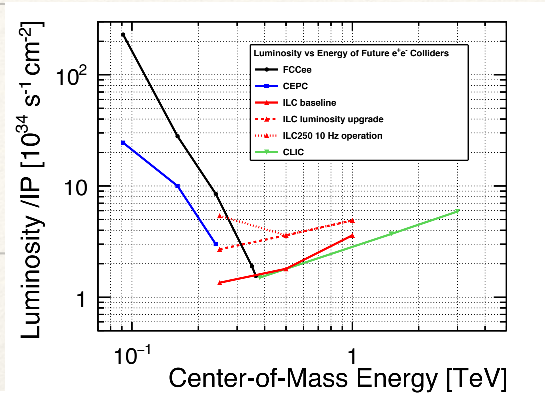
Linear and Circular Higgs Factory Parameters

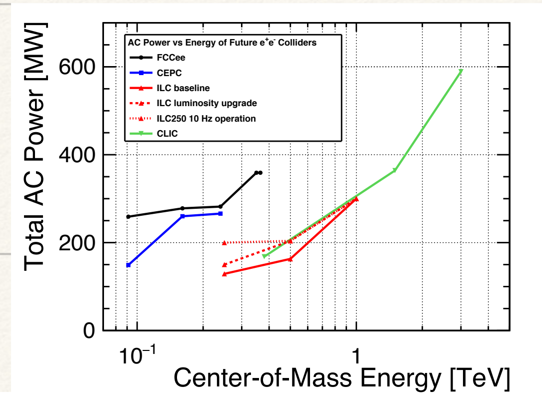
Linear and Circular Higgs Factory Parameters

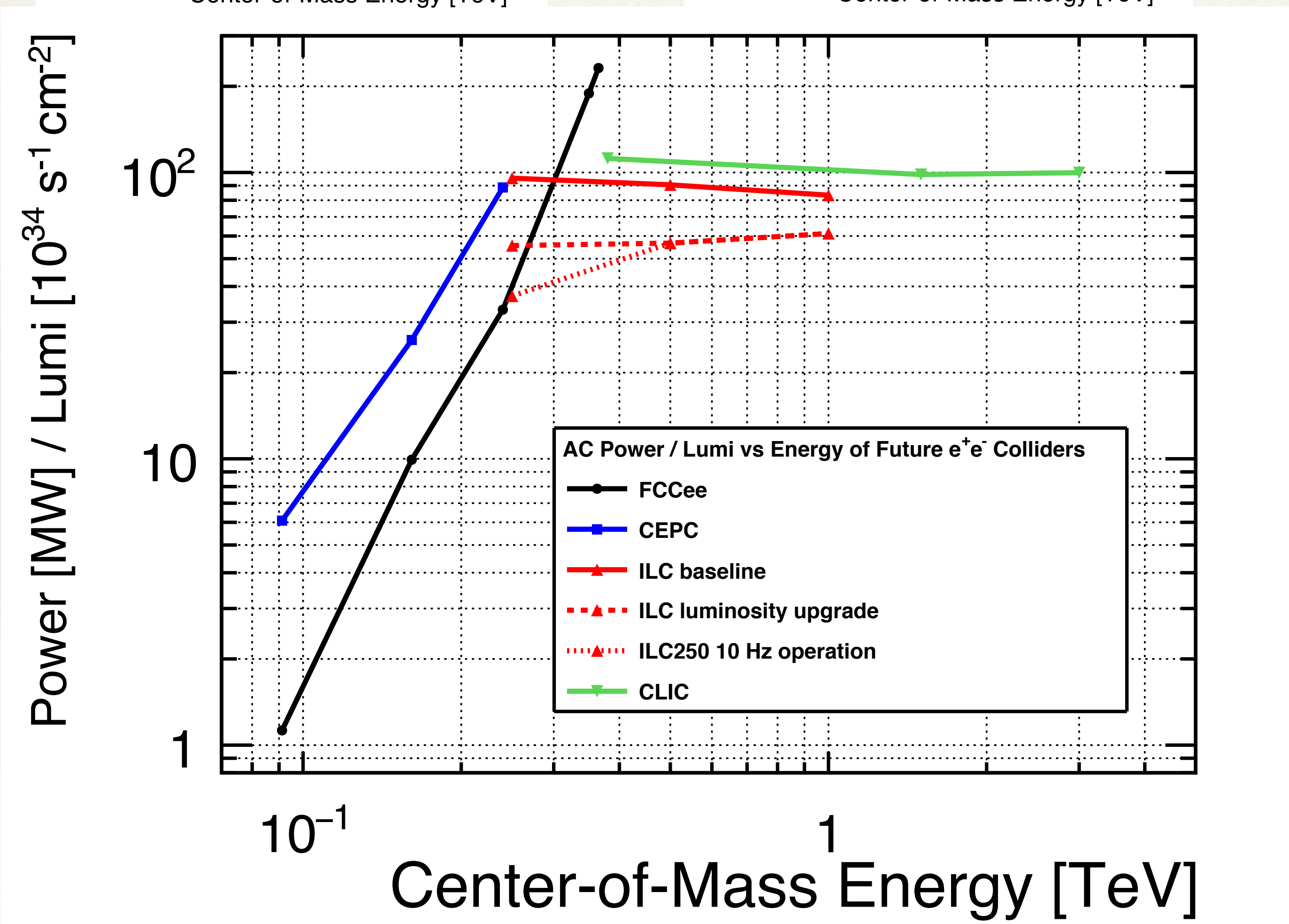




Linear and Circular Higgs Factory Parameter Comparison
Lumi & Power





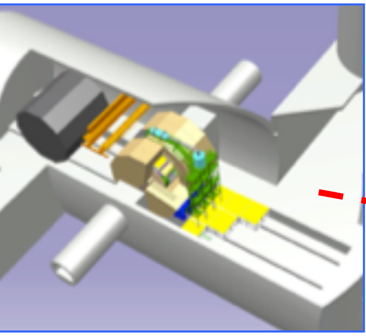


Linear Collider provides power efficient luminosity for > 250 GeV

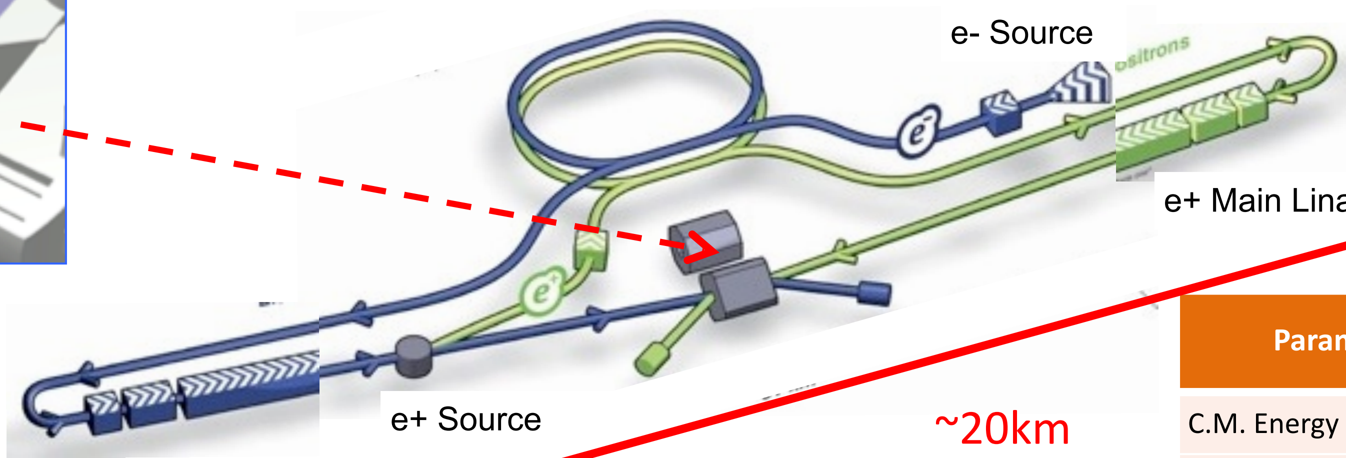
International Linear Collider (ILC)

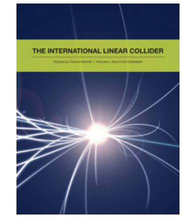
Design resulting from two decades of dedicated R&D

ILC TDR is 5-volumes, published 12 June 2013



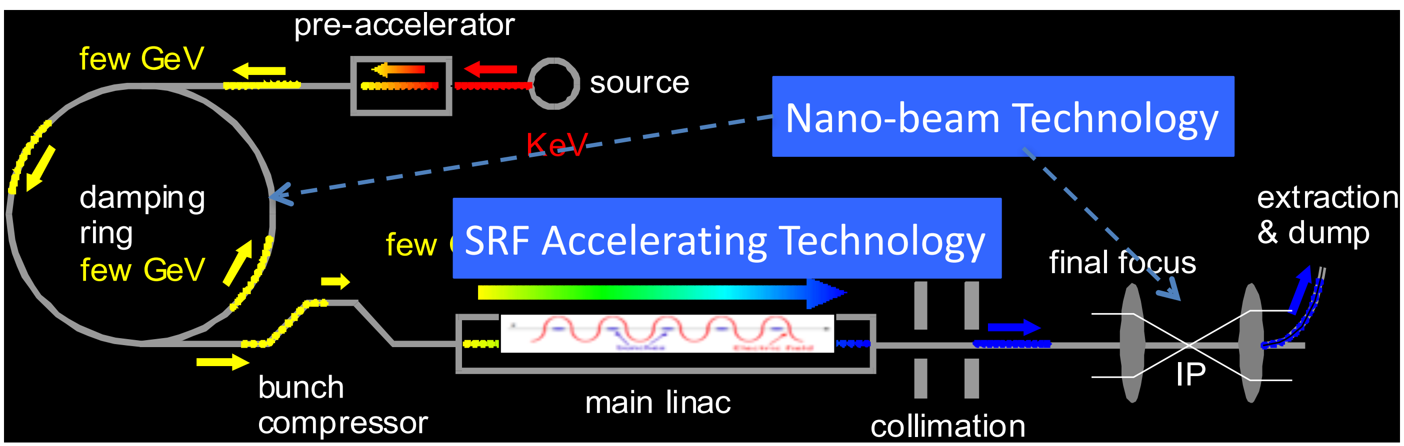
Physics Detectors





Parameter	Initial stage	TDR
C.M. Energy (GeV)	250	500
Length (km)	20	31
Luminosity (x10[34])	1.35 (2.7, 5.4)	1.8
Repetition (Hz)	5 (10)	5
Beam Pulse Period (ms)	0.73	0.73
Beam Current (mA in pulse)	5.8	5.8
Beam size (y) at FF (nm)	7.7	5.9
SRF Cavity Gr (MV/m), Q_0	31.5, 1x10 [10]	31.5, 1x10 [10]
Site Power (MW)	129	163

Key Technologies



Polarized electrons (± 80%) and positrons (± 30%)

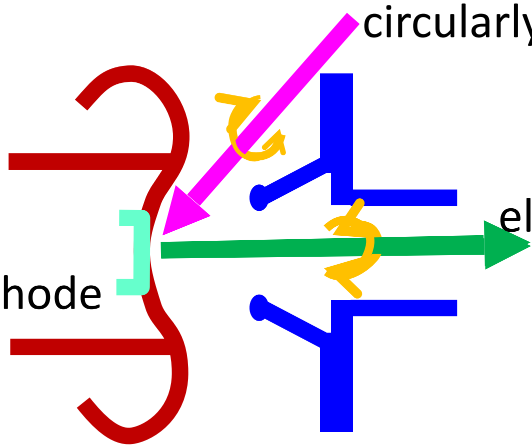
arXiv:1711.00568 arXiv:1903.01629

based on S. Michizono, 8 Nov 2017

Beam Sources -electron/positron-

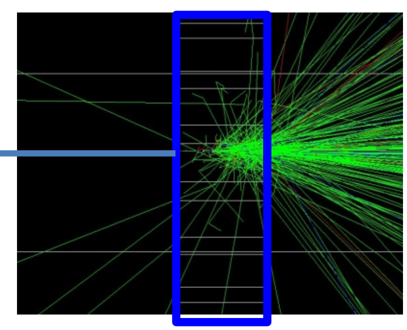
Polarized electron beams

based on S. Michizono, 8 Nov 2017



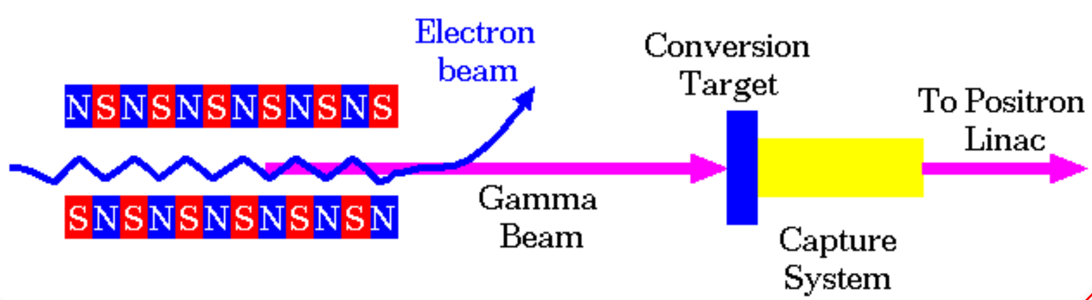
$$P \equiv \frac{N_L - N_R}{N_L + N_R} > 0.8$$

Undulator* positron source



Created via pair (e-/e+) production process

*Undulator is the insertion device (where the static magnetic field alternates) and produces γ ray



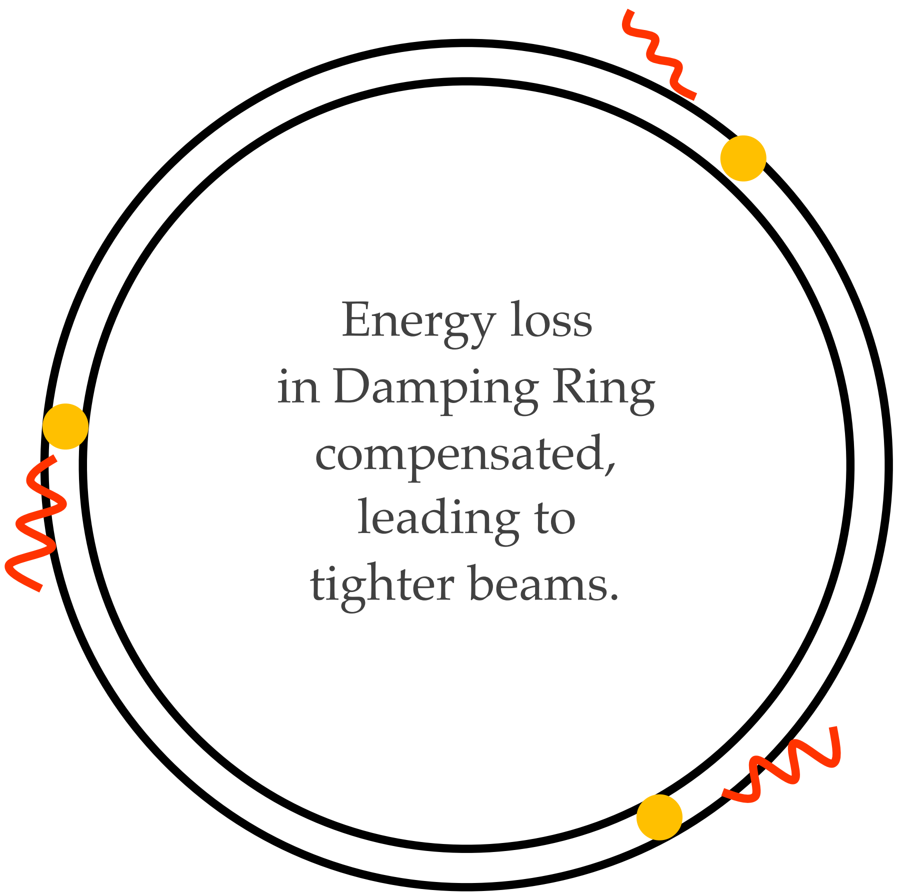
150 GeV e-, 150 m long undulator @ILC

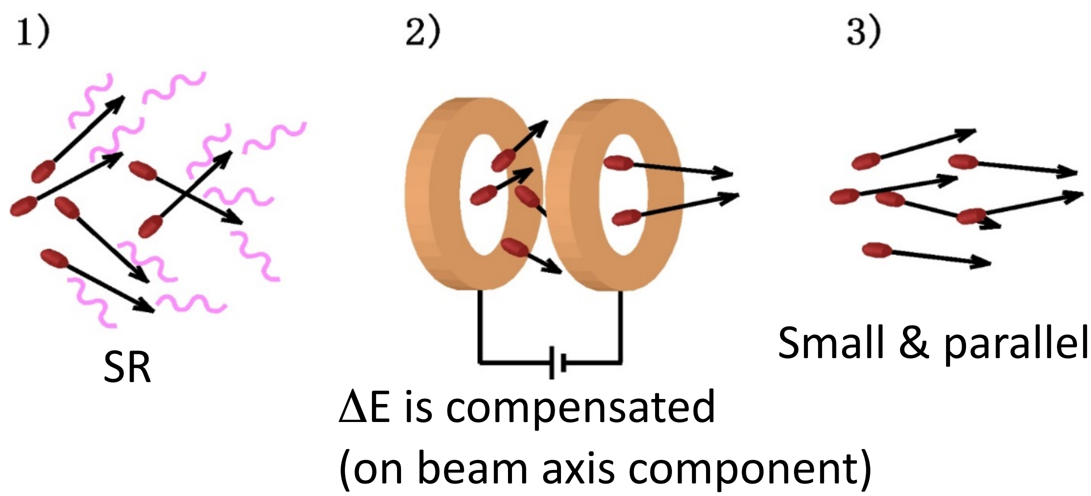
TDR: Polarized electrons (± 80%) and positrons (± 30%)

Damping Ring

e-/e+ beam will be focused down to a few nm at the IP.
Preparation of the high quality beams to make it possible

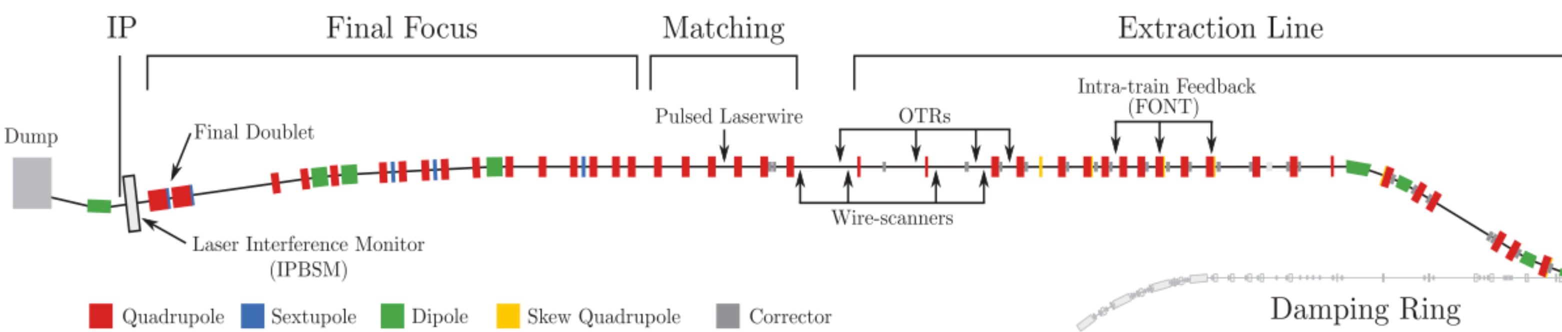
based on S. Michizono, 8 Nov 2017

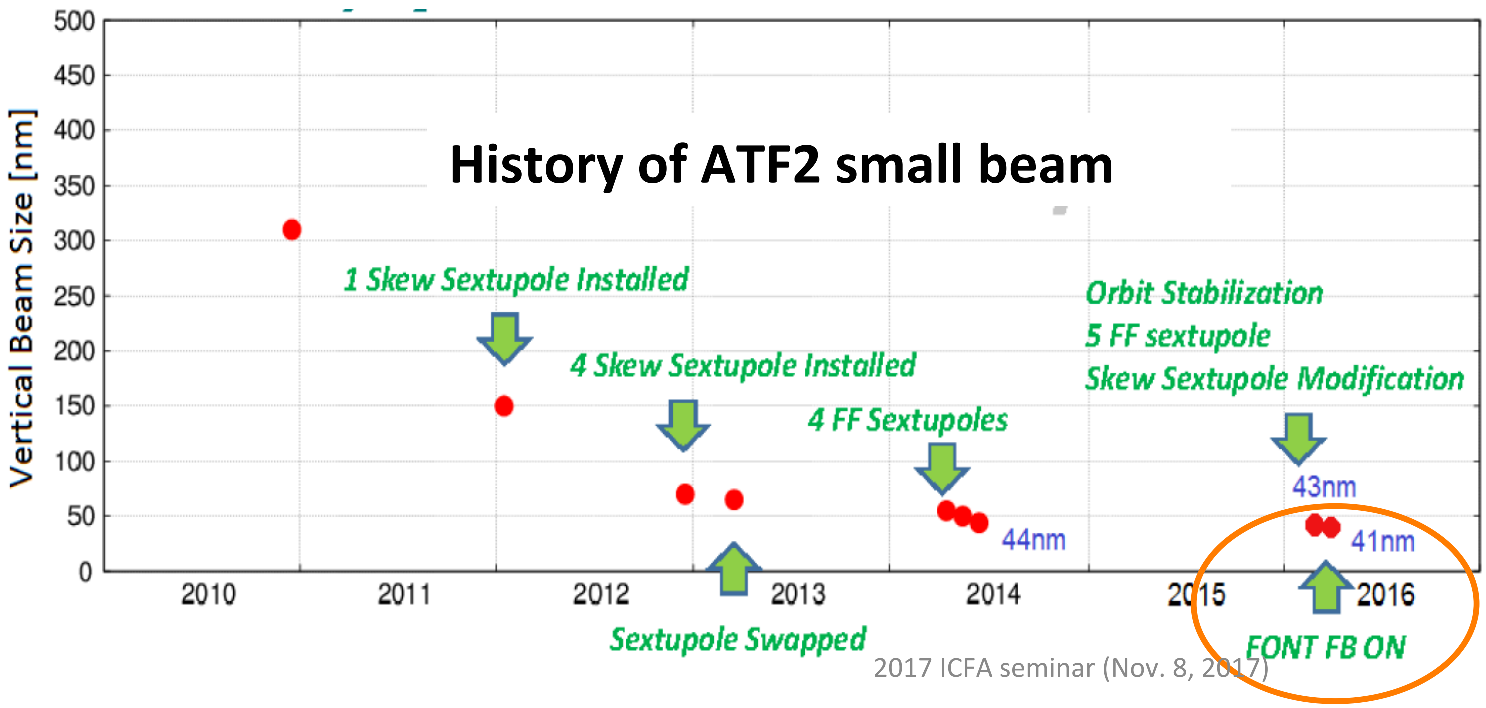




Progress in final focus beam at ATF2

- ATF2 Goal : **37** nm → ILC **6** nm
  - Achieved **41 nm** (2016)

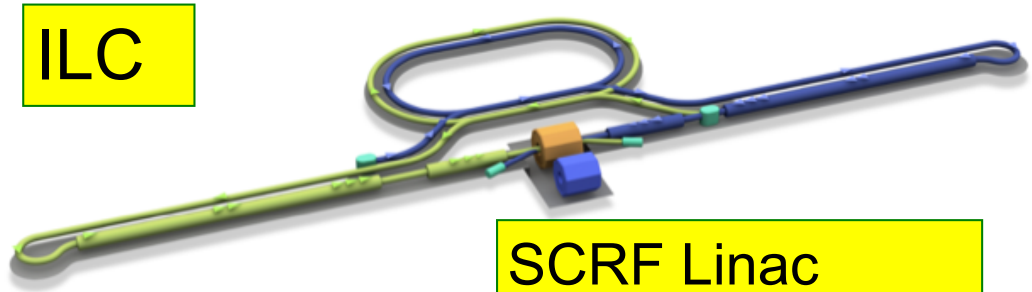




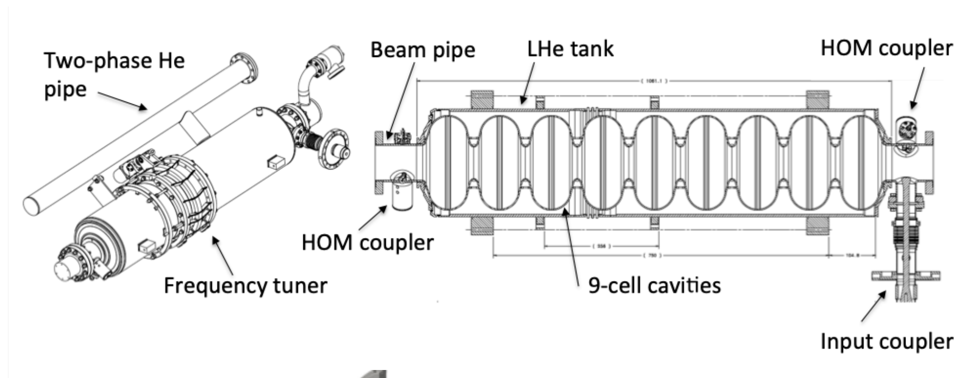
SCRF Industrialization required for ILC

Parameters	Value
C.M. Energy	250 GeV
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Av. field gradient	31.5(35) MV/m +/-20% **Q_0 = 1E10**
# 9-cell cavity	~8,000 (x 1.1)
# cryomodule	~900
# Klystron	~240

ILC



SCRF Linac (5km) x 2



High quality

~8,000 x 1.1(Yield = 90%)
~ 9,000 cavities of mass-production

Major Accelerators Under Construction

2010 ~

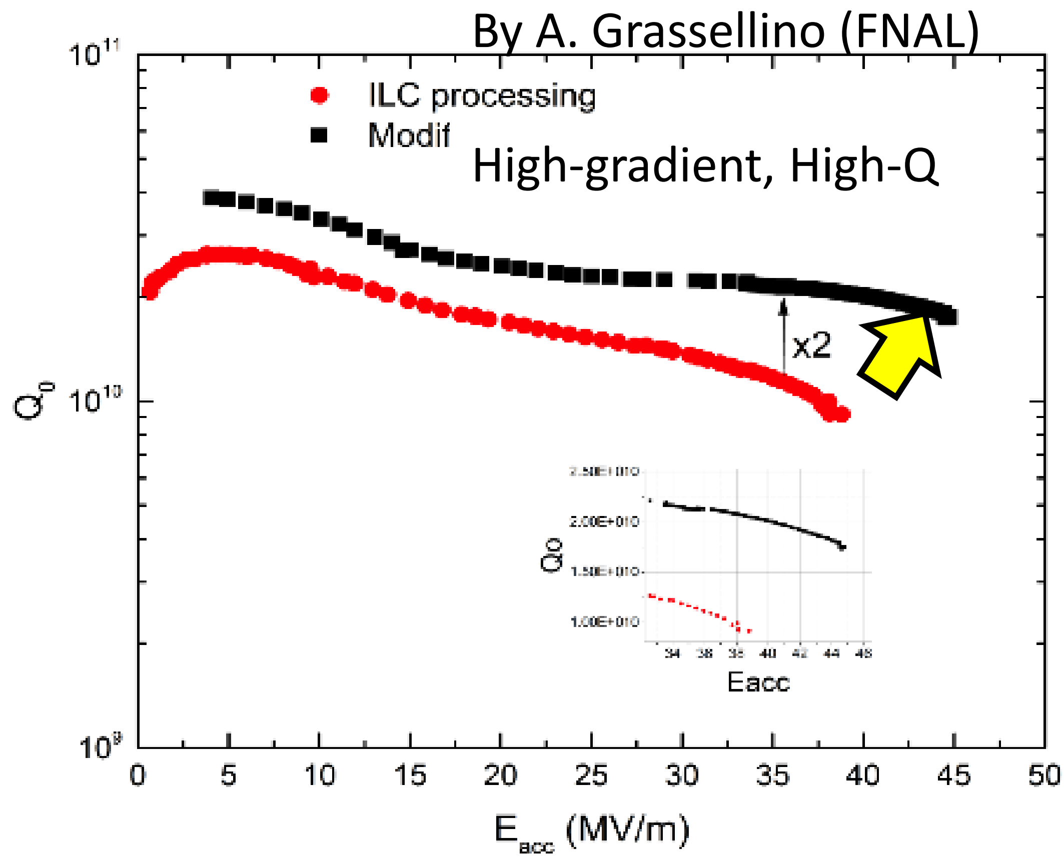
Project	Notes	# cavities
CEBAF-JLAB (US)	Upgrade 6.5 GeV => 12 GeV electrons	80
XFEL-Hamburg (EU)	18 GeV electrons – for Xray Free Electron Laser – Pulsed)	840
LCLS-II – SLAC (US)	4 GeV electrons –CW XFEL (Xray Free Electron Laser)	300
SPIRAL-II (France)	30 MeV, 5 mA protons -> Heavy Ion	28
FRIB – MSU 8US)	500 kW, heavy ion beams for nuclear astrophys	340
ESS (Sweden)	1 – 2 GeV, 5 MW Neutron Source ESS - pulsed	150
PIP-II–Fermilab (US)	High Intensity Proton Linac for Neutrino Beams	115
ADS- (China, India)	R&D for accelerator drive system	> 200
Globally Int. Effort		> 2000

SRF Accelerators in the World

SRF cavity fabrication for high gradient and high Q (N-Infusion) (with a new surface process provide by Fermilab)

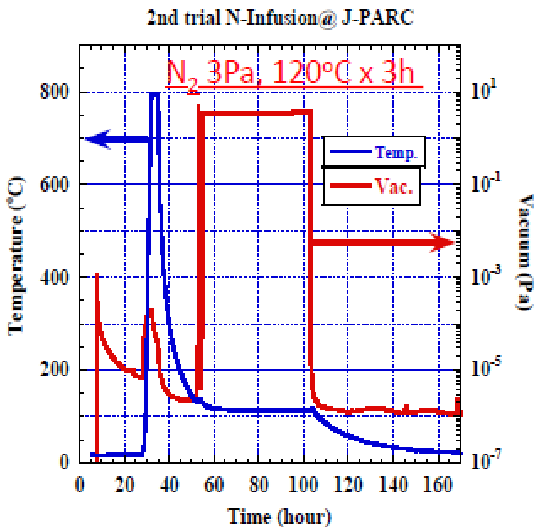
- High Q cavity enables the decrease in number of cryogenics leading to the cost reduction.
- FNAL researcher (A. Grassellino) found the new cavity preparation recipe having high Q and high gradient.
- We will demonstrate N-Infusion (High-gradient and High-Q) technology with 9-cell-cavities.

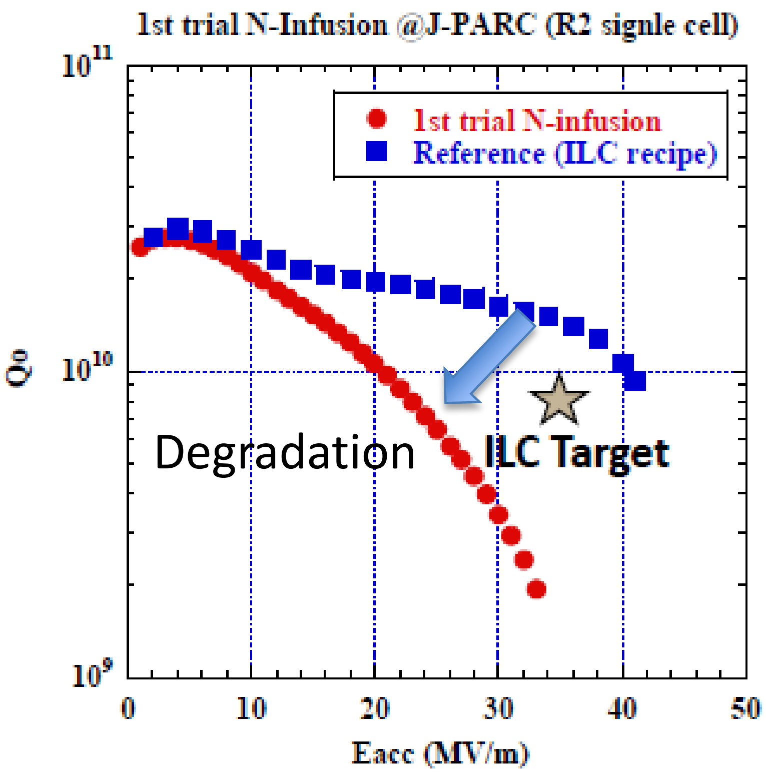
Preparation of clean-vacuum-furnace
+ N2dope



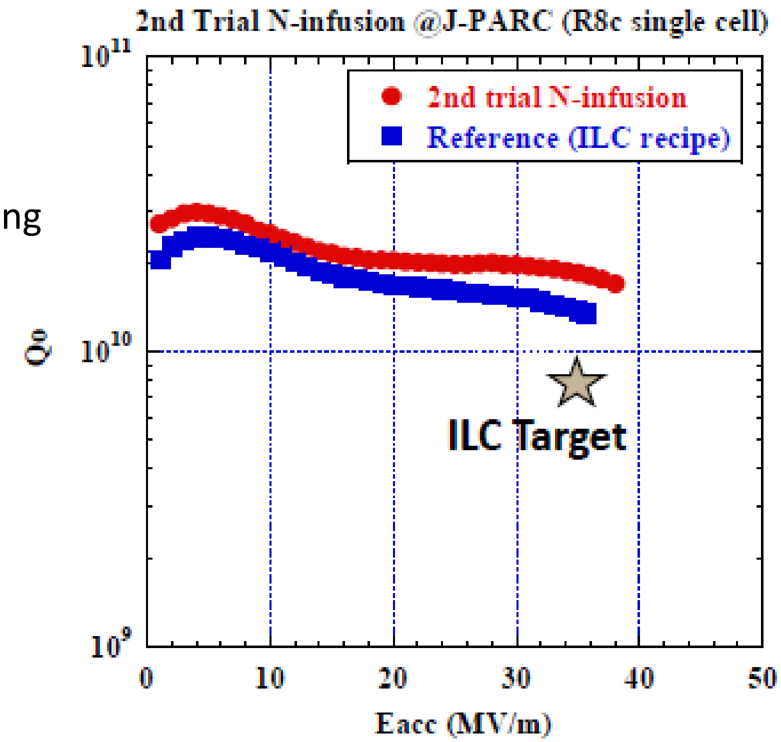
N-Infusion Result at KEK

- First trial of N-infusion showed degradation occurred at >5MV/m.
- Degradation seems to come from background vacuum during 120deg. N-Infusion.
- Background vacuum during N-Infusion was improved from 1.7e-2Pa to 1e-5Pa using larger turbo-molecular pump with reduced rotation speed.
- Second trial of N-Infusion was done with improved background vacuum during N-Infusion (120 deg.)
- It showed successful N-Infusion result (Q value +35% gradient +5%).





After the vacuum pumping system improvement



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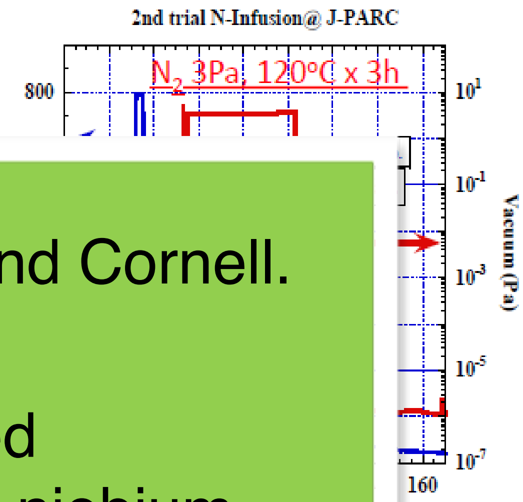
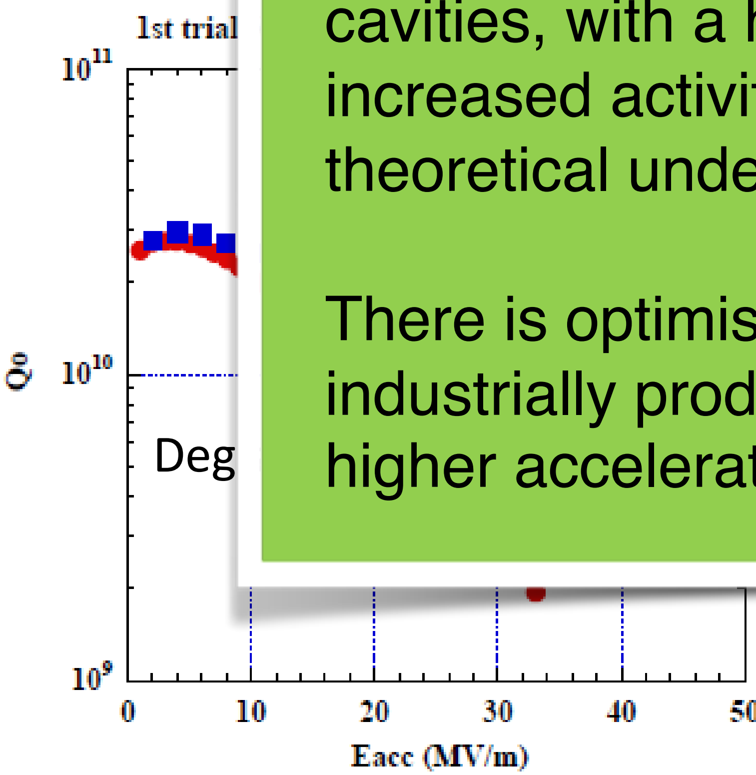
- Second tr
  during N-
- It showed

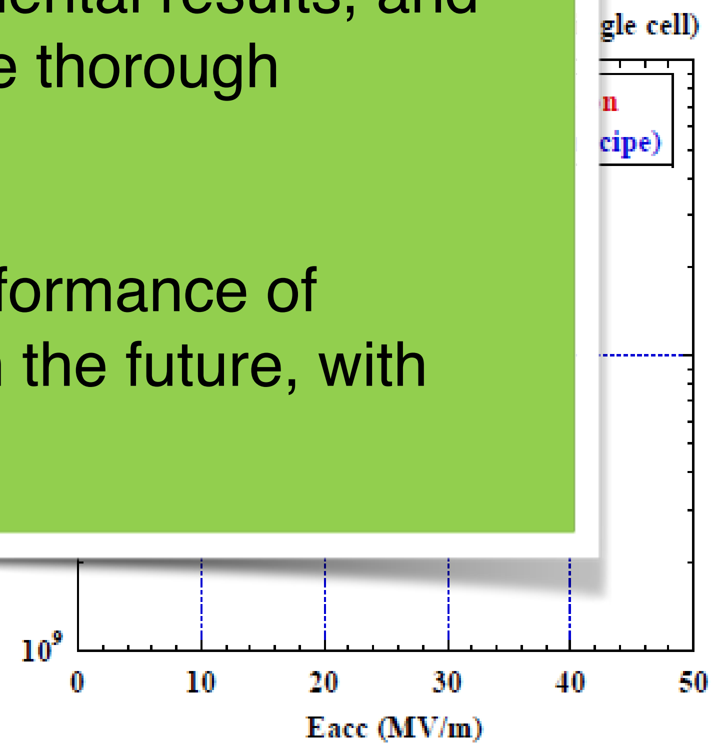


Fermilab success also repeated at JLAB and Cornell.

The infusion results have triggered renewed interest in research on highest gradients in niobium cavities, with a host of new experimental results, and increased activity to achieve a more thorough theoretical understanding.

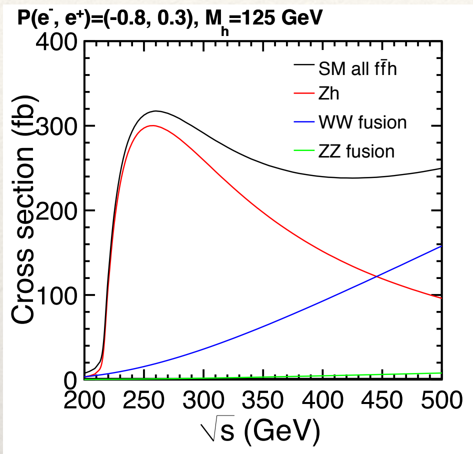
There is optimism for improved performance of industrially produced ILC cavities in the future, with higher accelerator gradients.



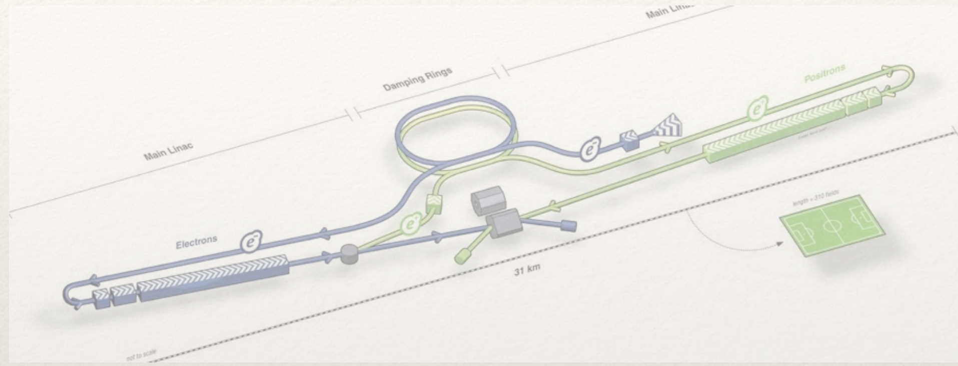


The ILC

- Physics



- Collider



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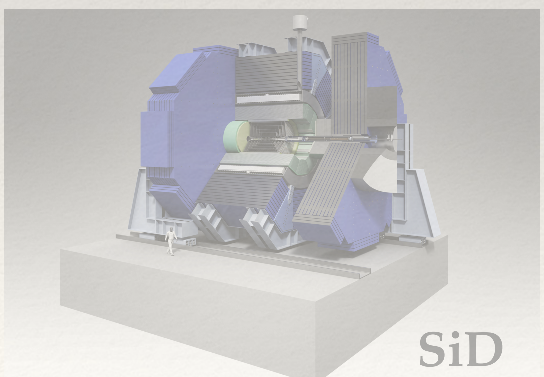

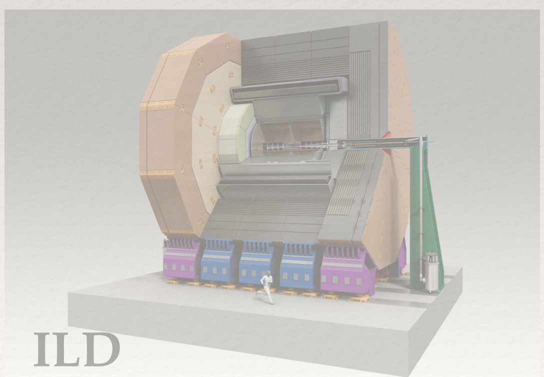

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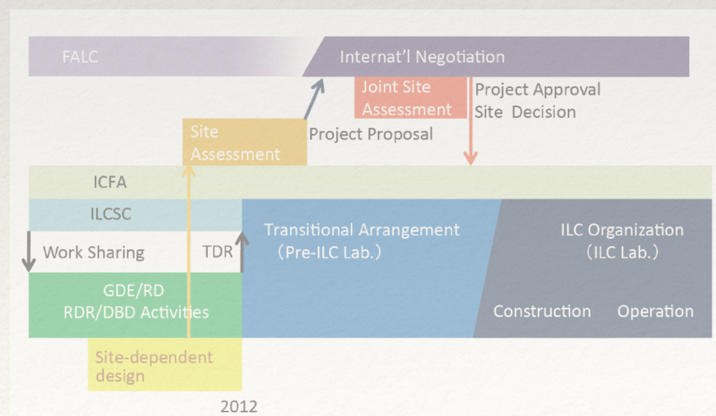


Higgs Couplings

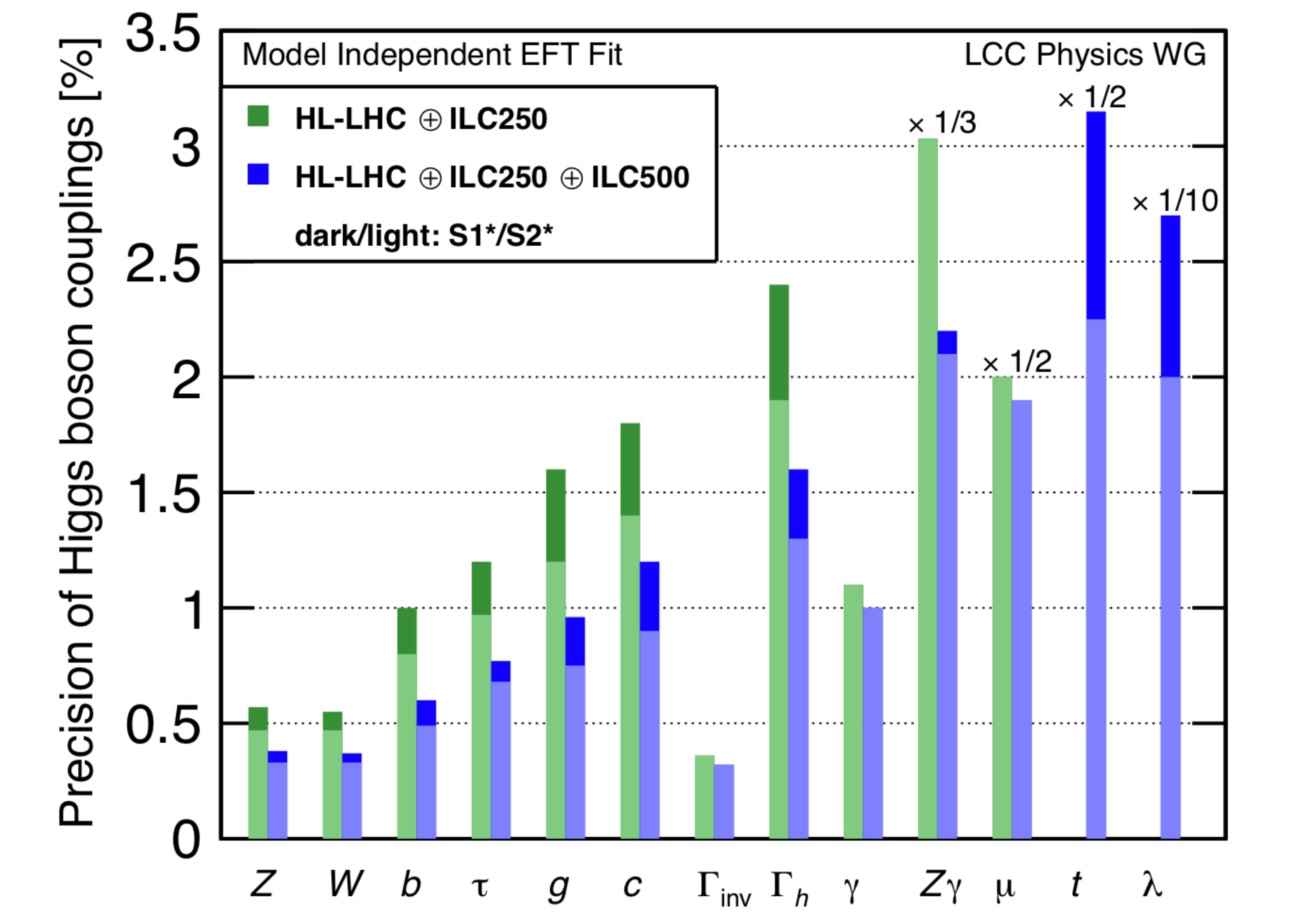
Effective Field Theory (EFT)

delivers **highly model-independent** Higgs couplings.

- Common κ (coupling modifier) analysis inherently model-dependent.
- EFT represents the effects of new physics on the Higgs boson and other SM observables by the most general linear combination of dimension-6 operators invariant under SU(2) x U(1).
- In special case of e^+e^- collisions, there are simplifications that reduce number of parameters.
- Determine some parameters with:
  - Precision Electroweak Observables (PEWO)
  - $e^+e^- \to W^+ W^-$ (triple gauge couplings)
  - LHC measurements of $\gamma\gamma$, ZZ^*, $Z\gamma$, $\mu^+\mu^-$

Phys. Rev D97, 053003 (2018)

Higgs Couplings (EFT)



arXiv:1903.01629

EFT Comparison of Polarization & Luminosity

Or Linear vs. Circular

Comparison of Higgs factory parameters using the **EFT** method (**% errors**).

Includes expected improvements in precision electroweak observables.

Not much difference: polarization makes up for luminosity

coupling	2/ab-250 Polarized	+4/ab-500 Polarized	5/ab-250 Unpolarized	+ 1.5/ab-350 Unpolarized
HZZ	0.50	0.35	0.41	0.34
HWW	0.50	0.35	0.42	0.35
Hbb	0.99	0.59	0.72	0.62
$H\tau\tau$	1.1	0.75	0.81	0.71
Hgg	1.6	0.96	1.1	0.96
Hcc	1.8	1.2	1.2	1.1
$H\gamma\gamma$	1.1	1.0	1.0	1.0
$H\gamma Z$	9.1	6.6	9.5	8.1
$H\mu\mu$	4.0	3.8	3.8	3.7
Htt	-	6.3	-	-
HHH	-	27	-	-
Γ_{tot}	2.3	1.6	1.6	1.4
Γ_{inv}	0.36	0.32	0.34	0.30

arXiv:1903.01629

Polarization Adds Sensitivity

- Measurement of helicity-dependent electroweak couplings.
- Suppression of backgrounds and enhancement of signals.
- Control of systematic uncertainties.

- **Increased sensitivity** relative to unpolarized collisions.

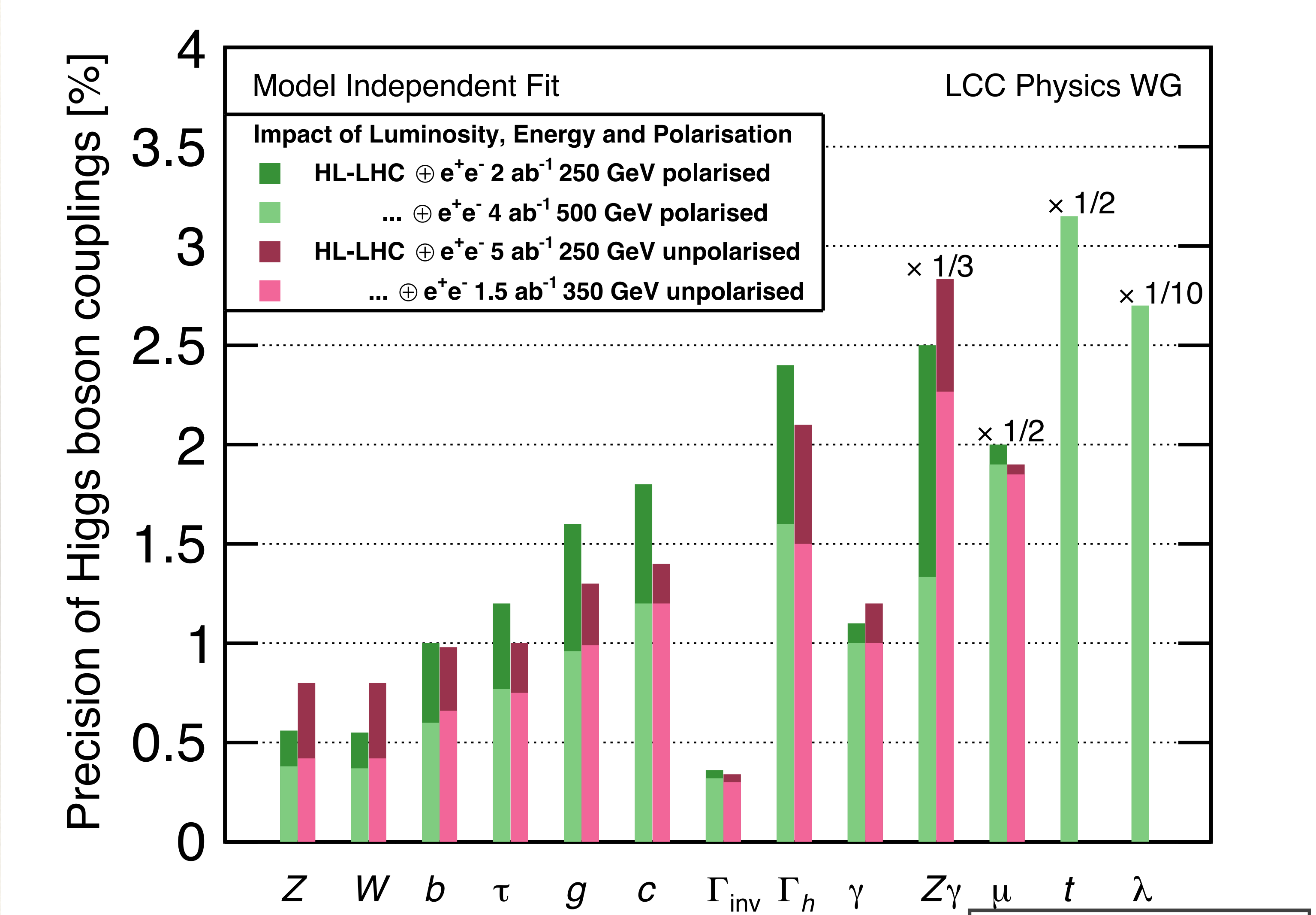
Polarization Trades Off Against Increased Luminosity

- Increased sensitivity relative to unpolarized collisions.

LC - current, unimproved projections (S1*)

validated by detailed simulation

see Tables XVIII and XIX of arXiv:1903.01629



arXiv:1903.01629

Polarization Trades Off Against Increased Luminosity

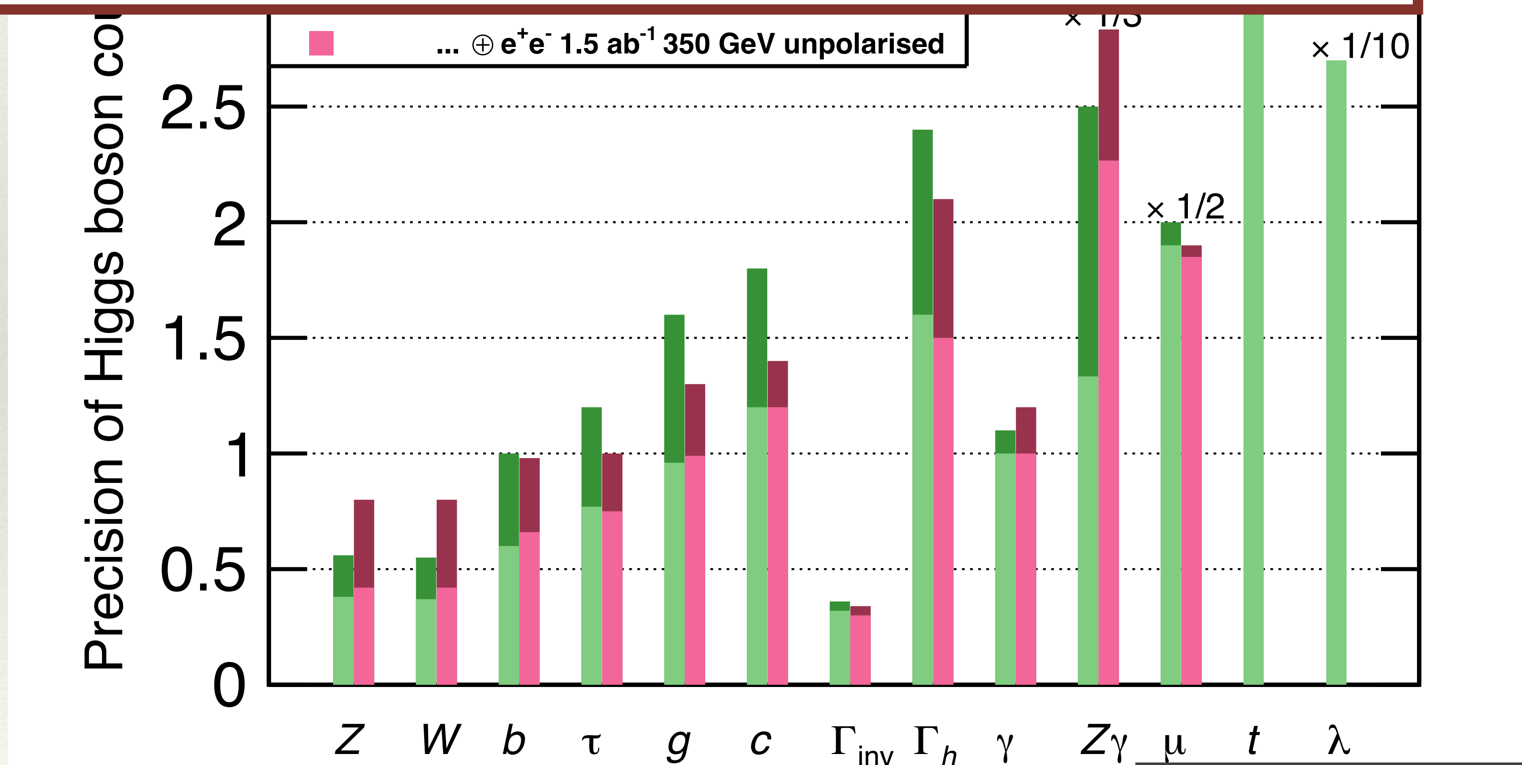
- Increased sensitivity relative to unpolarized collisions.

For Higgs coupling measurements, polarization compensates for lower 250 GeV integrated luminosity (2 vs 5 ab^{-1}) by
1.) increased rates, and
2.) removing some correlations between EFT operators.

projections (S1*)

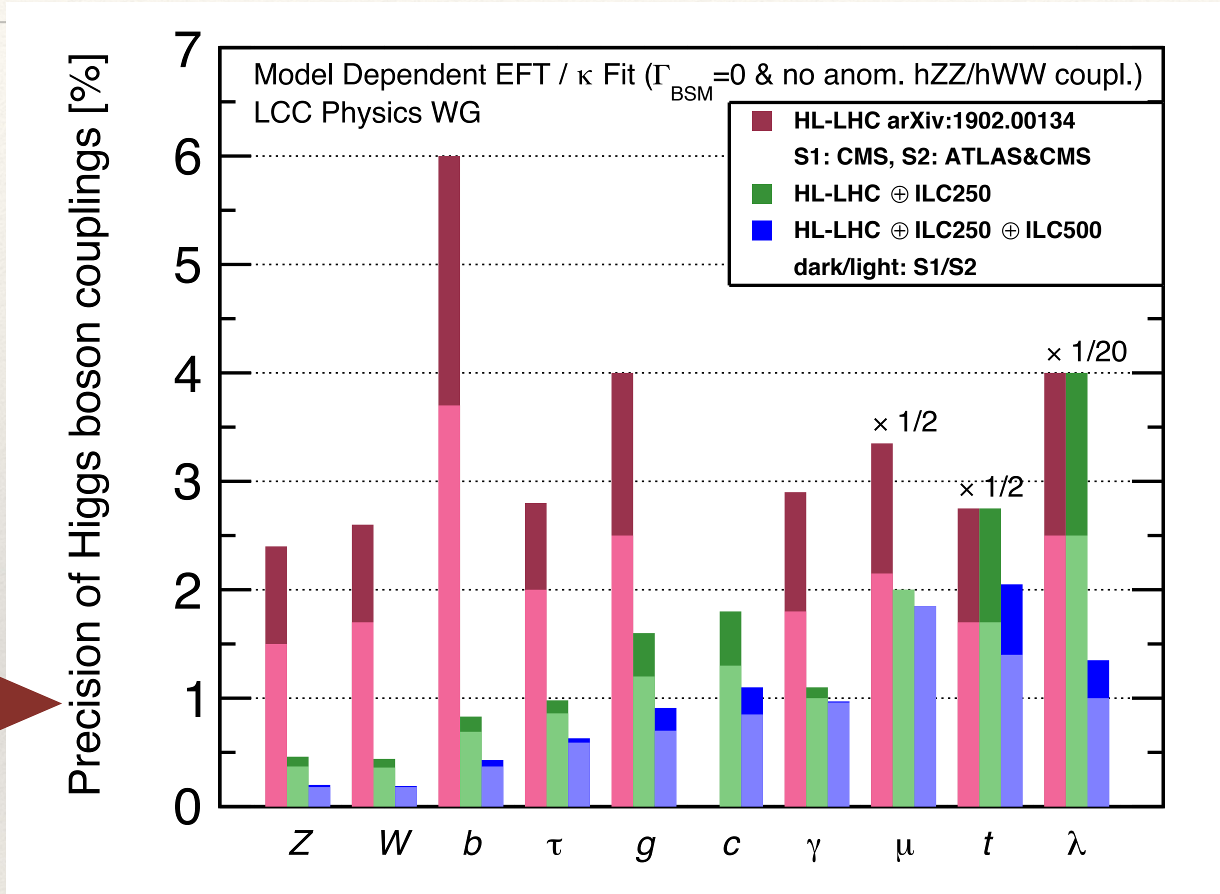
validated by detailed simulation

see Tables XVIII and XIX of arXiv:1903.01629



arXiv:1903.01629

HL-LHC Comparison (model-dependent)



1 %

- S1, current projection
- **/model-dependent**
- S2, improved
- **/model-dependent** (HL-LHC adopted)

arXiv:1903.01629

Assume:

1.) Higgs boson has no decay modes beyond those predicted by SM,

2.) Higgs boson WW & ZZ couplings modified only by rescaling.

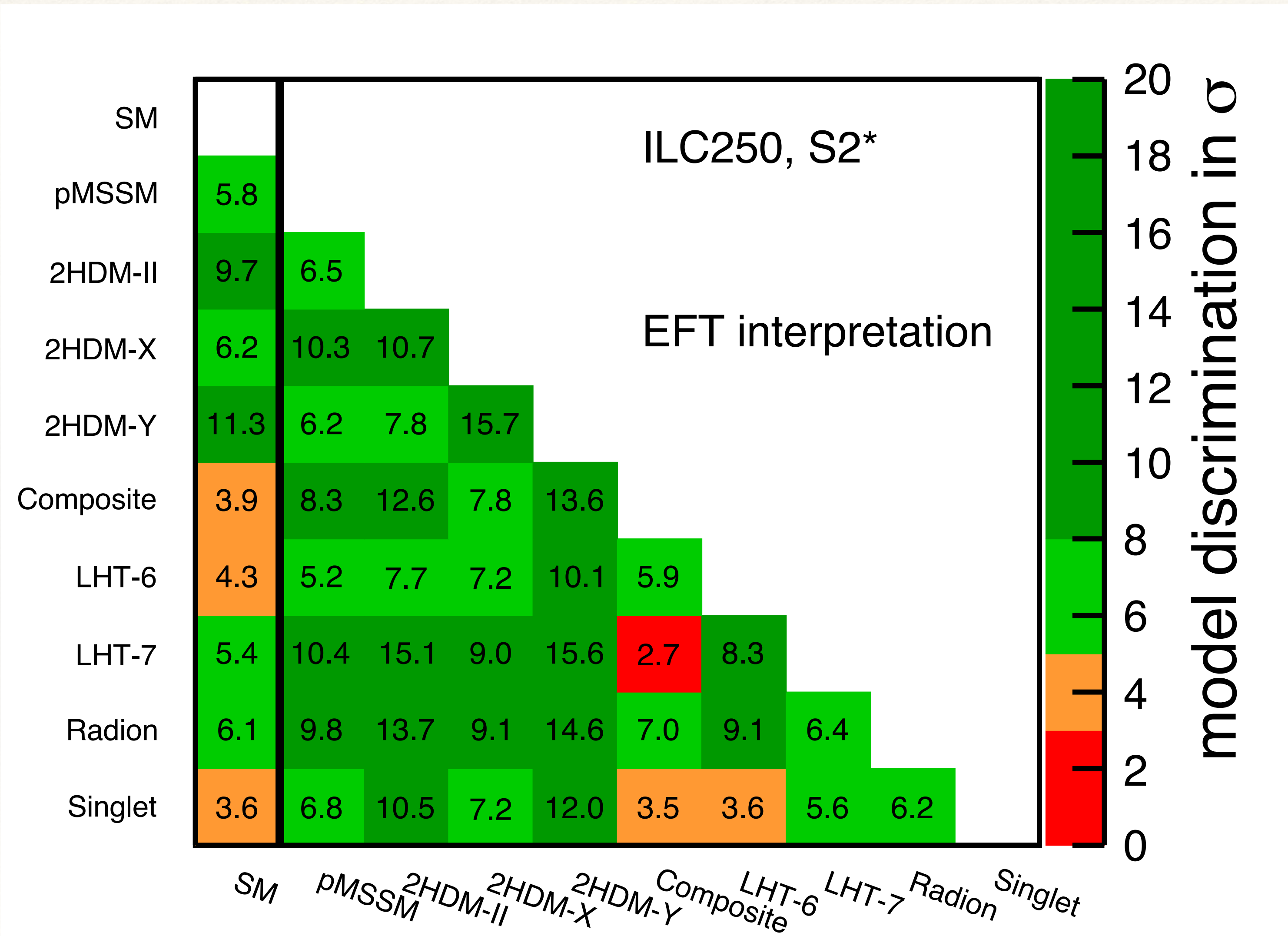
Testing New Physics Models

- Studied nine(9) models that are unlikely to be discovered by HL-LHC.
  - Masses beyond reach.

1. pMSSM SUSY [34]; high colored masses: m(bino) =3:4 TeV, m(gluino) = 4 TeV.
2. Type II 2-Higgs-doublet [36]; heavy Higgs bosons at 600 GeV and tan β = 7.
3. Type X 2-Higgs-doublet [36]; heavy Higgs bosons at 450 GeV and tan β = 6.
4. Type Y 2-Higgs-doublet [36]; heavy Higgs bosons at 600 GeV and tan β = 7.
5. Composite Higgs MCHM5, f = 1.2 TeV [38]; lightest new particle vectorlike top partner T at 1.7 TeV and very small single production.
6. Little Higgs with T-parity [39]; f = 785 GeV and top partner T at 2 TeV.
7. Little Higgs with T-parity [40]; f = 1 TeV and option B for light-quark Yukawa couplings; top partner T mass of 2.03 TeV.
8. Higgs-radion mixing [41]; radion mass is 500 GeV; other relevant extra-dimensional states can be at multi-TeV masses.
9. Model with Higgs singlet added to SM, motivated by EW baryogenesis with portal to dark matter sector [42]; singlet mass is 2.8 TeV, with mixing as permitted by decoupling.

arXiv:1710:07621

Model Discrimination - 250 GeV



- S1*, current projection **/model-independent**
- S2*, improved **/model-independent**

arXiv:1710.07621

The Broader Physics Program

The physics opportunities of the ILC emphasizes precise measurement of **most** **Higgs boson couplings.**

These are the centerpiece and FIRST PRIORITY.

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But the ILC also provides:

- search for **exotic modes of Higgs boson decay**
- search for **dark matter particles and other invisible states**
- search for **heavy resonances** through 2-fermion processes
- precise study of **W boson interactions** in $e^+e^- \rightarrow W^+W^-$

240 / 250 GeV

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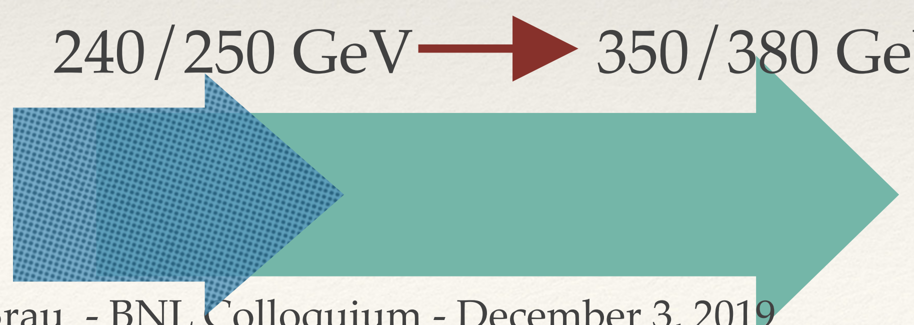
  - precise measurement of **top quark electroweak couplings**



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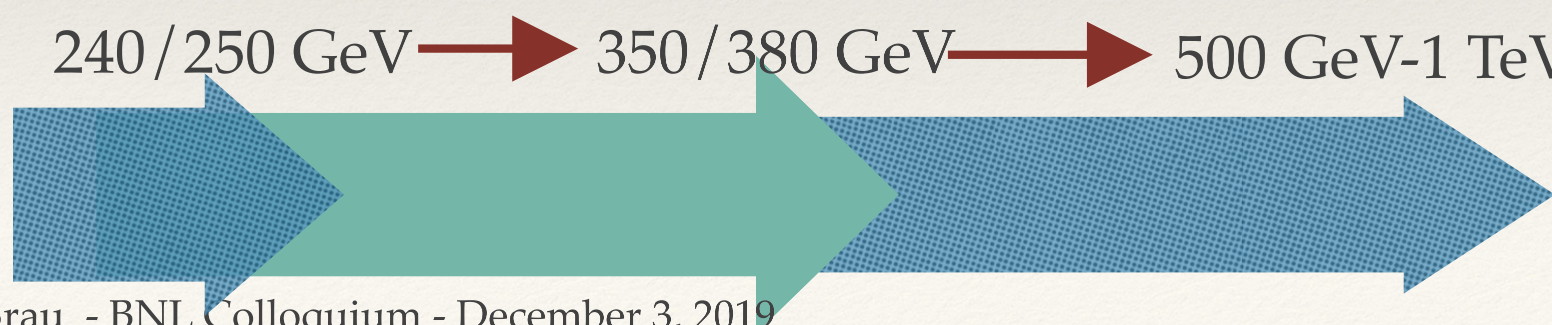
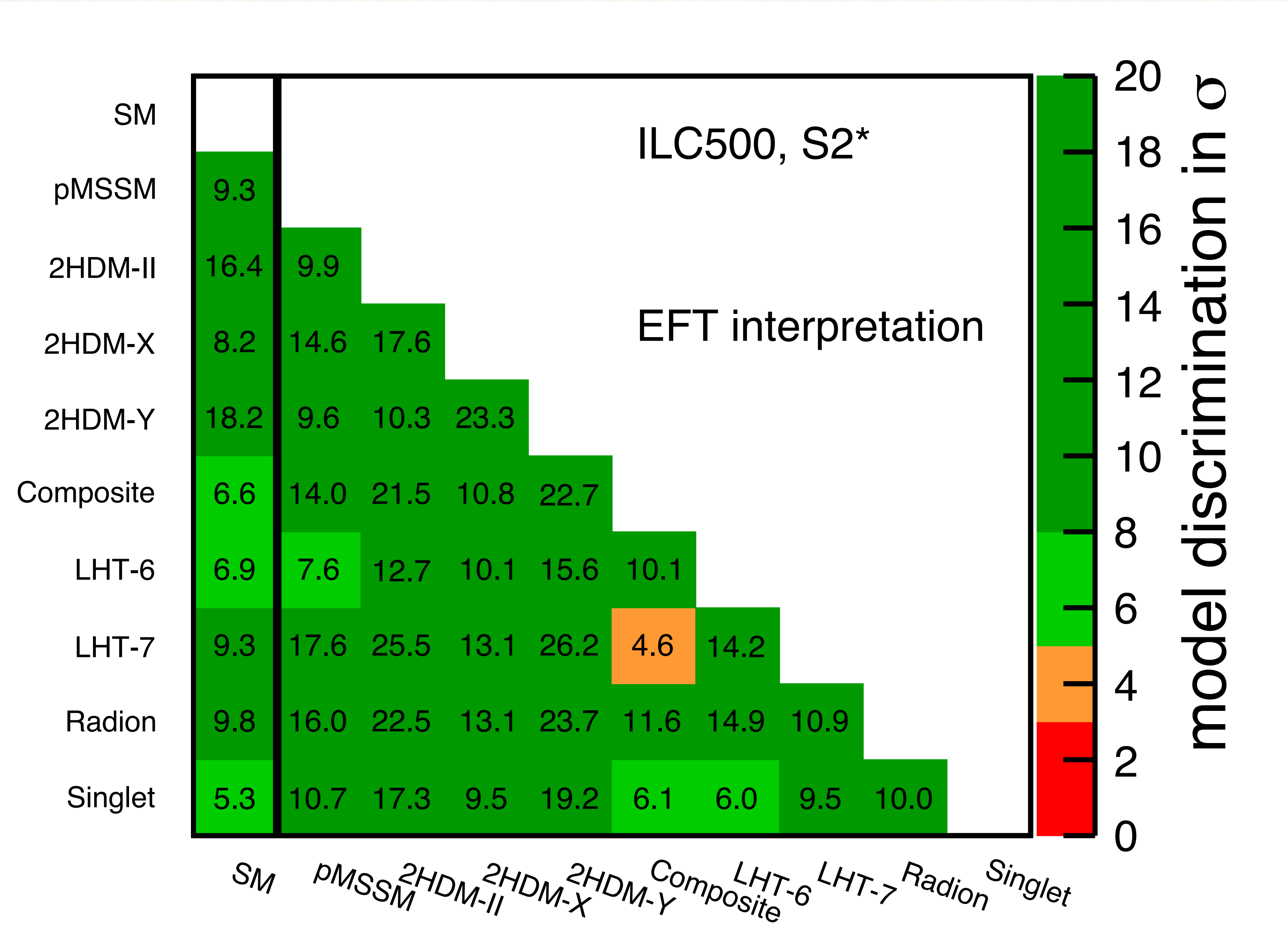
  - precise measurement of the **top quark mass**
  - precise measurement of **top quark electroweak couplings**
    - precise measurement of **top quark Yukawa coupling (tth)**
    - measurement of the **triple Higgs boson coupling**



Model Discrimination (250+500)

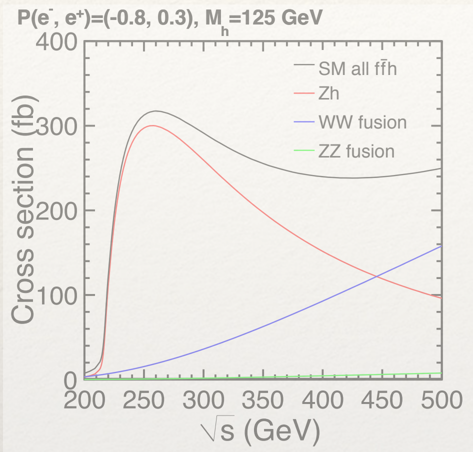


- S1*, current projection **/model-independent**
- S2*, improved **/model-independent**

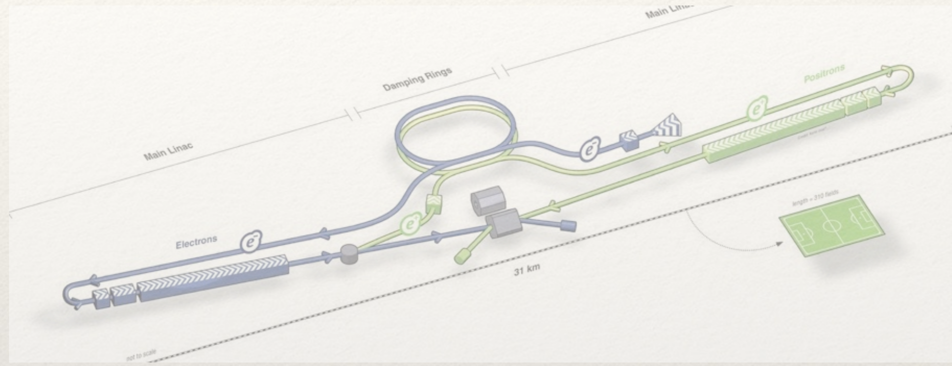
arXiv:1710.07621

The ILC

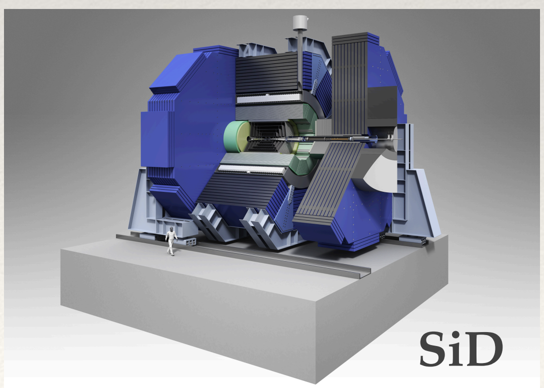
- Physics

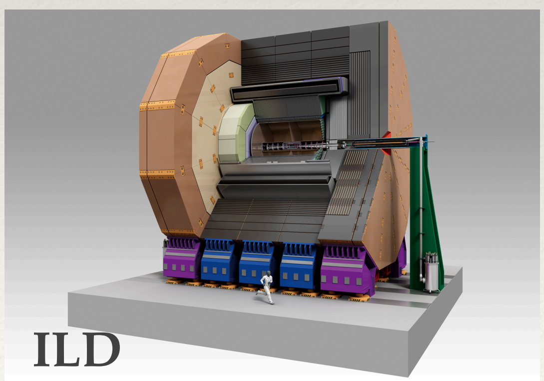


- Collider

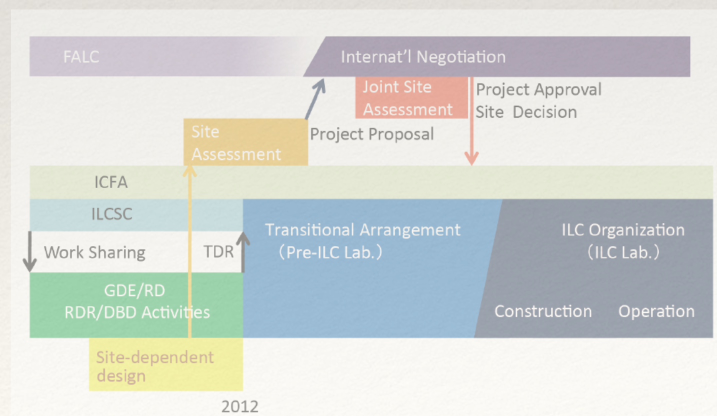


- Detectors



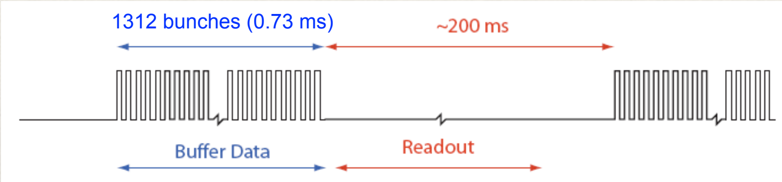


- Project Realization



ILC Experimental Advantages

- Radiation damage is mostly not an issue (except very forward)
  - collisions dominated by electroweak processes
- Trigger-less operation - record every interaction (<6Gb/sec)
- Bunch train structure allows pulse power w/ gas cooling



- Relatively low event rates
- Elementary interactions at known E_{cm} (e.g. e+e- → Z H)
- Democratic Cross sections (e.g. $[e^+e^- \rightarrow ZH] \sim 1/2\, [e^+e^- \rightarrow d\bar{d}]$)
- Highly Polarized Electron Beam (~ 80% - & positron pol. 30%)
- Tunable center-of-mass energy

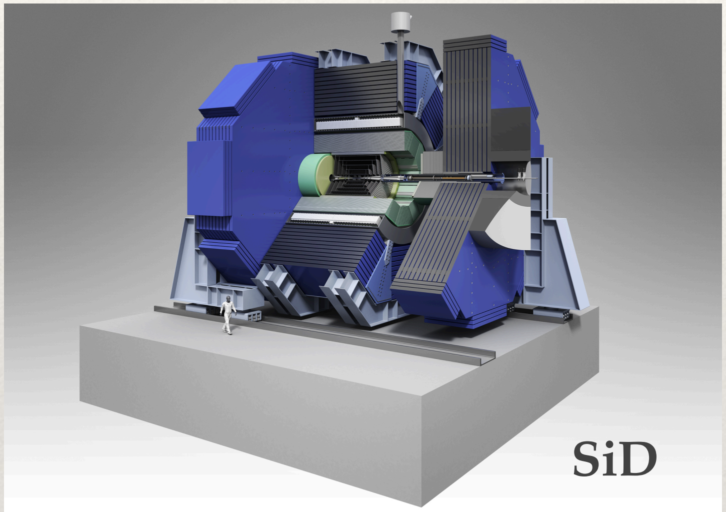
- THESE FEATURES ENHANCE PRECISION MEASUREMENTS

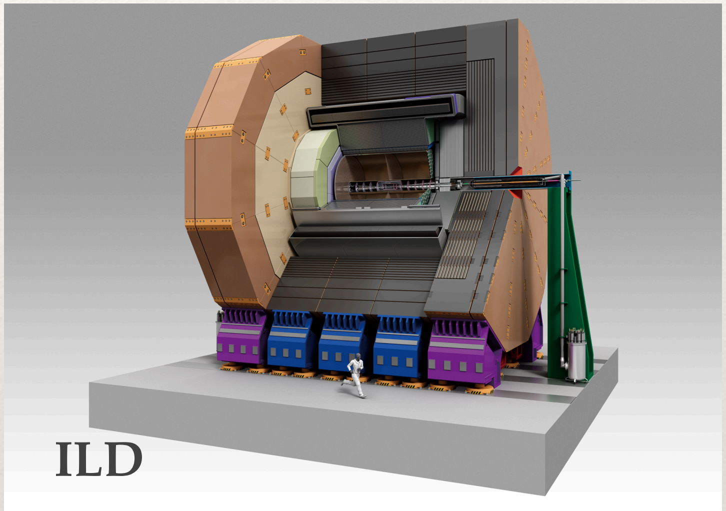
Physics Drives Detector Requirements

Physics Process	**Measured Quantity**	**Critical System**	**Critical Detector Characteristic**	**Required Performance**
$H \to b\bar{b}, c\bar{c}, gg, \tau\tau$ $b\bar{b}$	Higgs branching fractions b quark charge asymmetry	Vertex Detector	Impact parameter ⇒ Flavor tag	$\delta_b \sim 5\mu m \oplus 10\mu m / (p \sin^{3/2}\theta)$
ZH→$\ell^+\ell^-$X $\mu^+\mu^-\gamma$ $ZH + H\nu\bar{\nu} \to \mu^+\mu^- X$	Higgs Recoil Mass Lumin Weighted E_{cm} BR (H →μμ)	Tracker	Charge particle momentum resolution, $\sigma(p_t)/p_t^2$ ⇒ Recoil mass	$\sigma(p_t)/p_t^2 \sim few \times 10^{-5} GeV^{-1}$
ZHH $ZH \to q\bar{q}b\bar{b}$ ZH→ZWW* $\nu\bar{\nu}W^+W^-$	Triple Higgs Coupling Higgs Mass BR (H → WW*) σ(e+e- → νν W+W-)	Tracker & Calorimeter	Jet Energy Resolution, σ_E/E ⇒ Di-jet Mass Res.	~3% for E_{jet} > 100 GeV $30\% / \sqrt{E_{jet}}$ for E_{jet} < 100 GeV
SUSY, eg. $\tilde{\mu}$ decay	$\tilde{\mu}$ mass	Tracker, Calorimeter	Momentum resolution, Hermiticity ⇒ Event Reconstruction	Maximal solid angle coverage

Detectors

- Two Validated detector concepts.
- Complementary: tracking technology, magnetic field, calorimetry, etc.



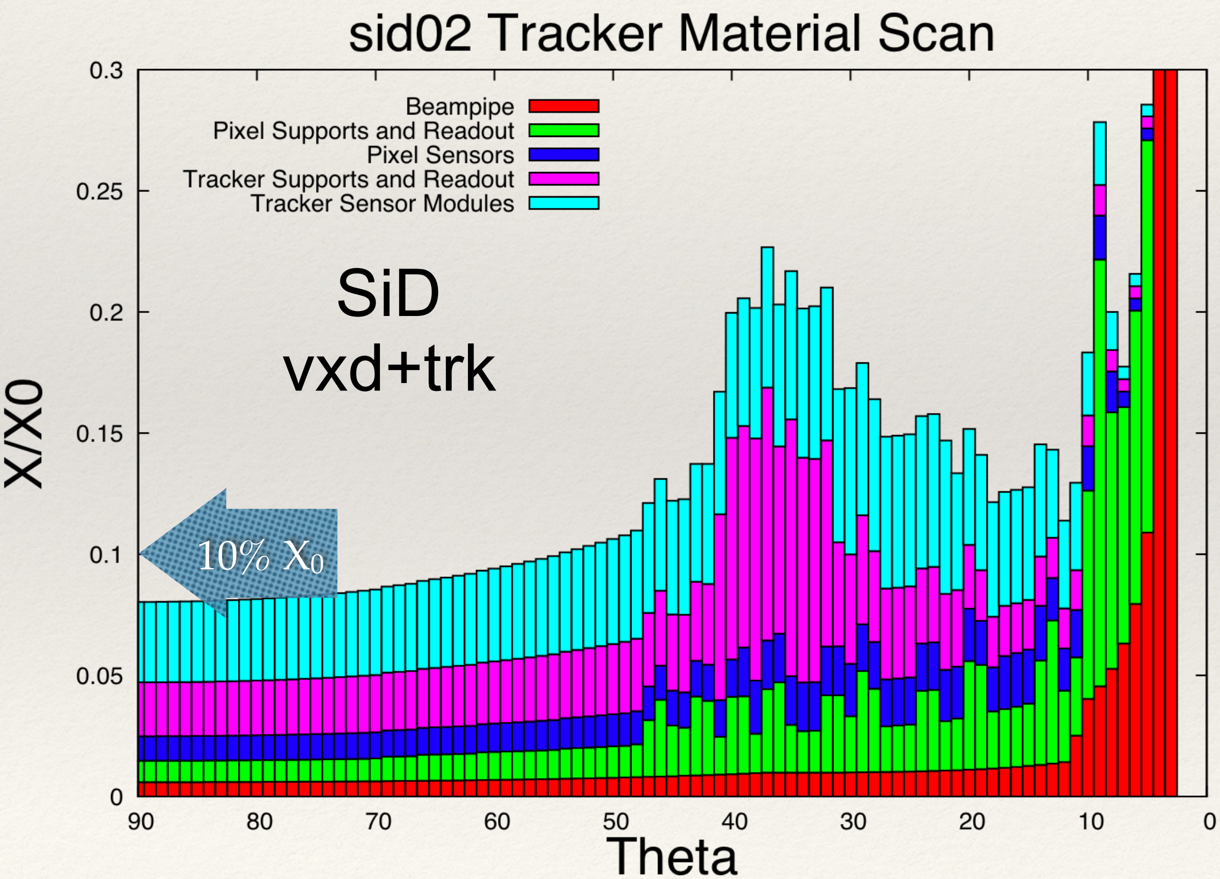


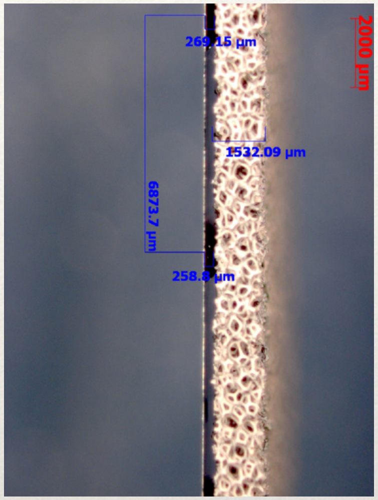
SiD		ILD
Silicon	Tracking	TPC w/ silicon
6.0 m	Outer Radius	7.8 m
5 Tesla	B Field	3.5 Tesla

Design Goals:
- High efficiency
- High resolution
- Low fake rate
- Control of systematics

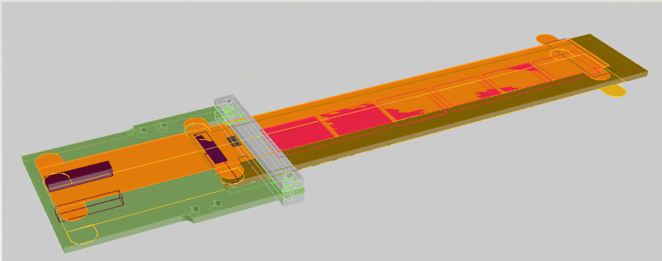
Silicon tracking w/ gas cooling → Low material

- Linkage between readout/mechanics/powering/cooling studies.
- Maintain low mass construction.
- Tracking material from SiD design:

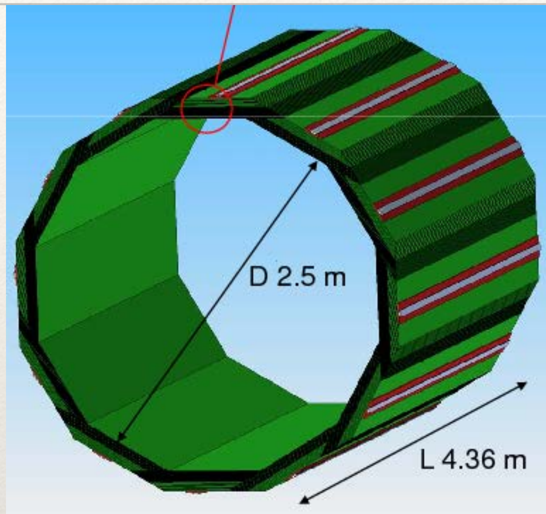


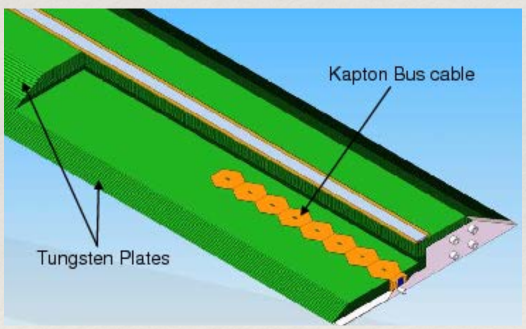


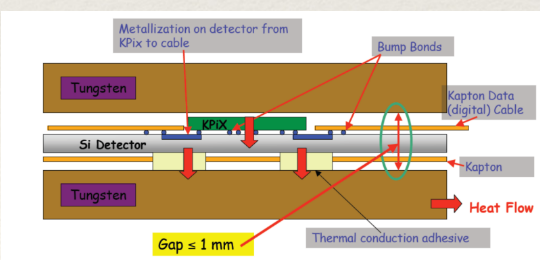
SiC foam,
J. Goldstein



Silicon-tungsten ECal - very high granularity

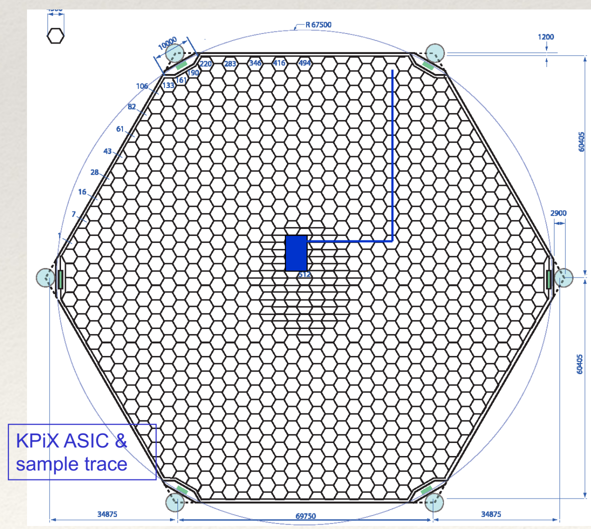


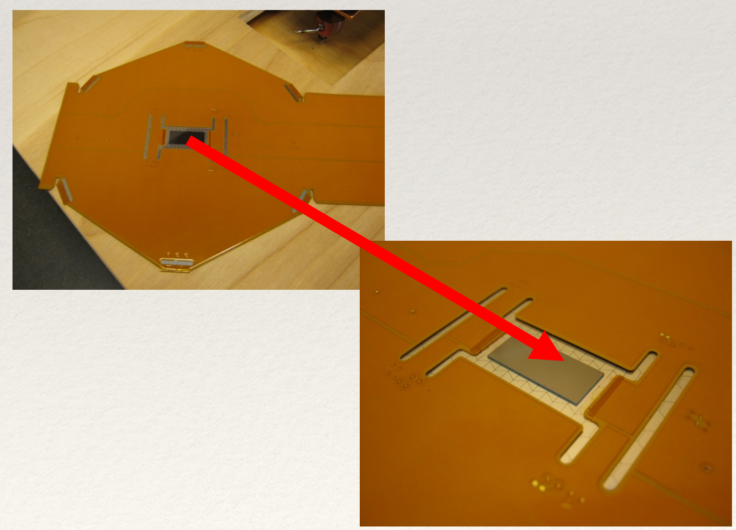




SiD ECal Design

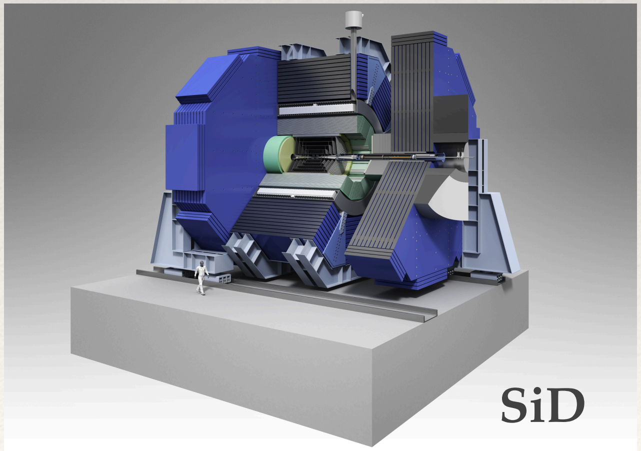
- 6 inch wafers
- 1024 13 mm^2 pixels
- KPiX readout and cable are bump-bonded directly to sensor
- 1 mm readout gaps -> 13 mm effective Moliere radius
- . Tungsten plates thermal bridge to edge cooling
- . Feeds Particle Flow (~3% jet resolution at 100 GeV)
- . EM resolution: 17%/sqrt(E)

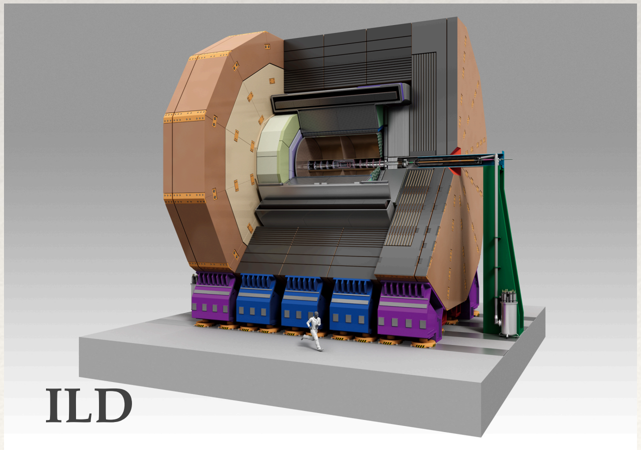




Detector Requirements Achieved in Designs

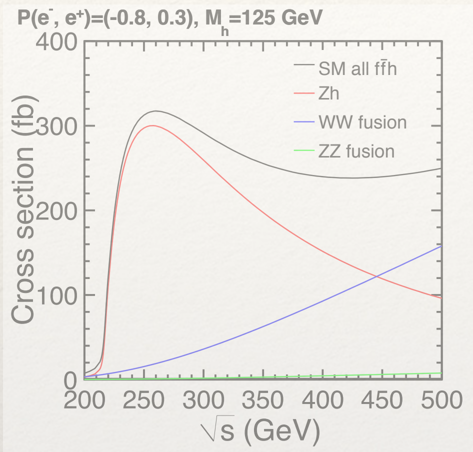
- Clean events with low backgrounds enable unprecedented detector performance motivated by physics goals.
  - High granularity
  - Dense integration
  - Super light materials
  - Low power/pulse power
  - Air cooling



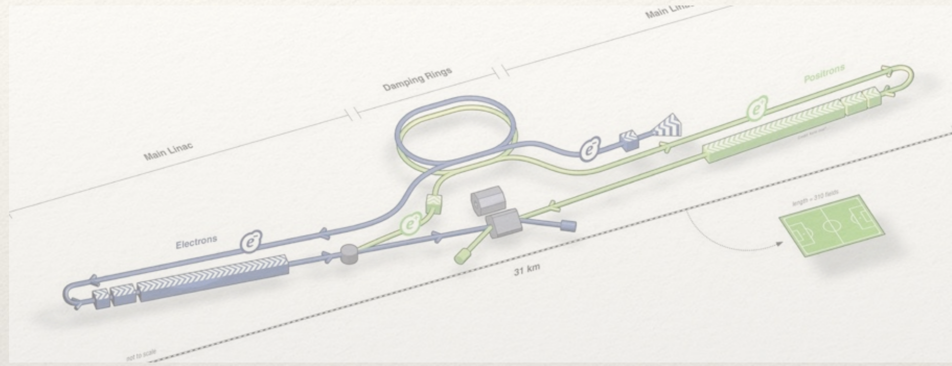


The ILC

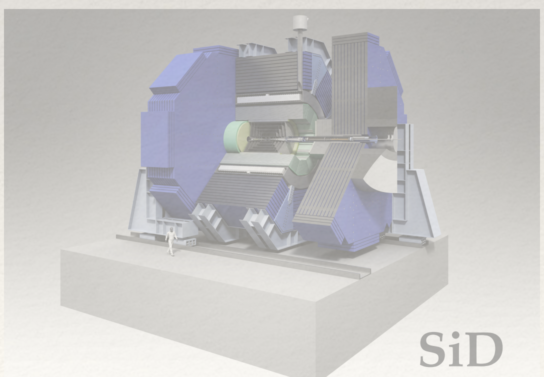
- Physics

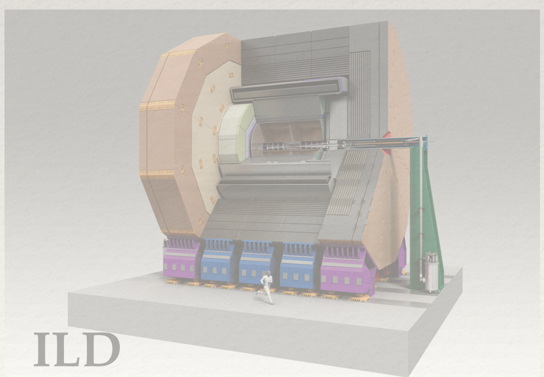


- Collider

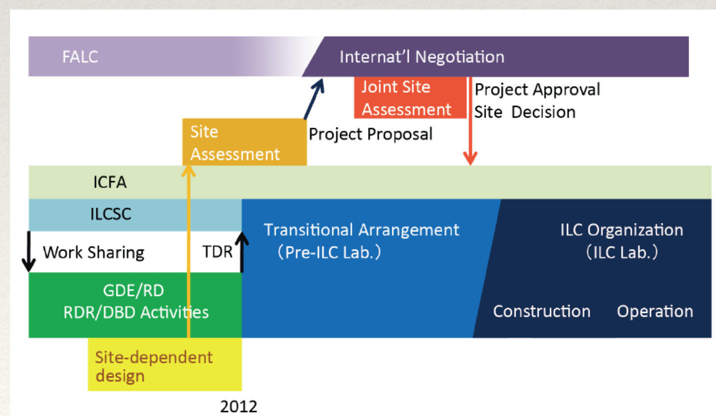


- Detectors





- Project Realization



2019 Progress Toward a Project Start

- MEXT report to March ICFA/LCB meeting
- Diet statement to ICFA in March
- MEXT statement at March Diet meeting
- Delegation international visits/discussions in Washington DC, Paris, Berlin
- Science Council of Japan Master Plan process
    - Master Plan will be announced January, 2020
- MEXT Roadmap
    - Roadmap will follow announcement of Master Plan

What happened in March: (1) Statement by MEXT at LCB

KEK High Energy Accelerator Research Organization

reported by M. Yamauchi, Oct 2019

- Following the opinion of the SCJ, **MEXT has not yet reached declaration for hosting the ILC in Japan at this moment.** The ILC project requires further discussion in formal academic decision-making processes such as **the SCJ Master Plan**, where it has to be clarified whether the ILC project can gain understanding and support from the domestic academic community.

- MEXT will pay close attention to the progress of the discussions at the European Strategy for Particle Physics Update.

- The ILC project has certain scientific significance in particle physics particularly in the precision measurements of the Higgs boson, and also has possibility in the technological advancement and in its effect on the local community, although the SCJ pointed out some concerns with the ILC project. Therefore, considering the above points, **MEXT will continue to discuss the ILC project with other governments having an interest in the ILC project.**

What happened in March: (2) Message from the Federation of the Diet Members

reported by M. Yamauchi, Oct 2019

- I believe the ILC should be realized through politically-led efforts, cutting across different ministries and agencies. As such, **we're proceeding to realize a budgeting as a national project with a separate budget outside of the regular science and technology budget.**

- **On the international cost sharing, we have to separate the infrastructure part of civil engineering and conventional equipment 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.**

- As the environment has ripened socially, politically, and administratively, **the next mission for politics is to secure the budget for the construction.** In parallel, with the government's administrative process, we will begin in earnest from our role as political and legislative body to obtain the necessary budget for construction.

What happened in March: (3) Actions to be done by MEXT

reported by M. Yamauchi, Oct 2019

Answers given by MEXT at the Diet session on March 13, 2019.

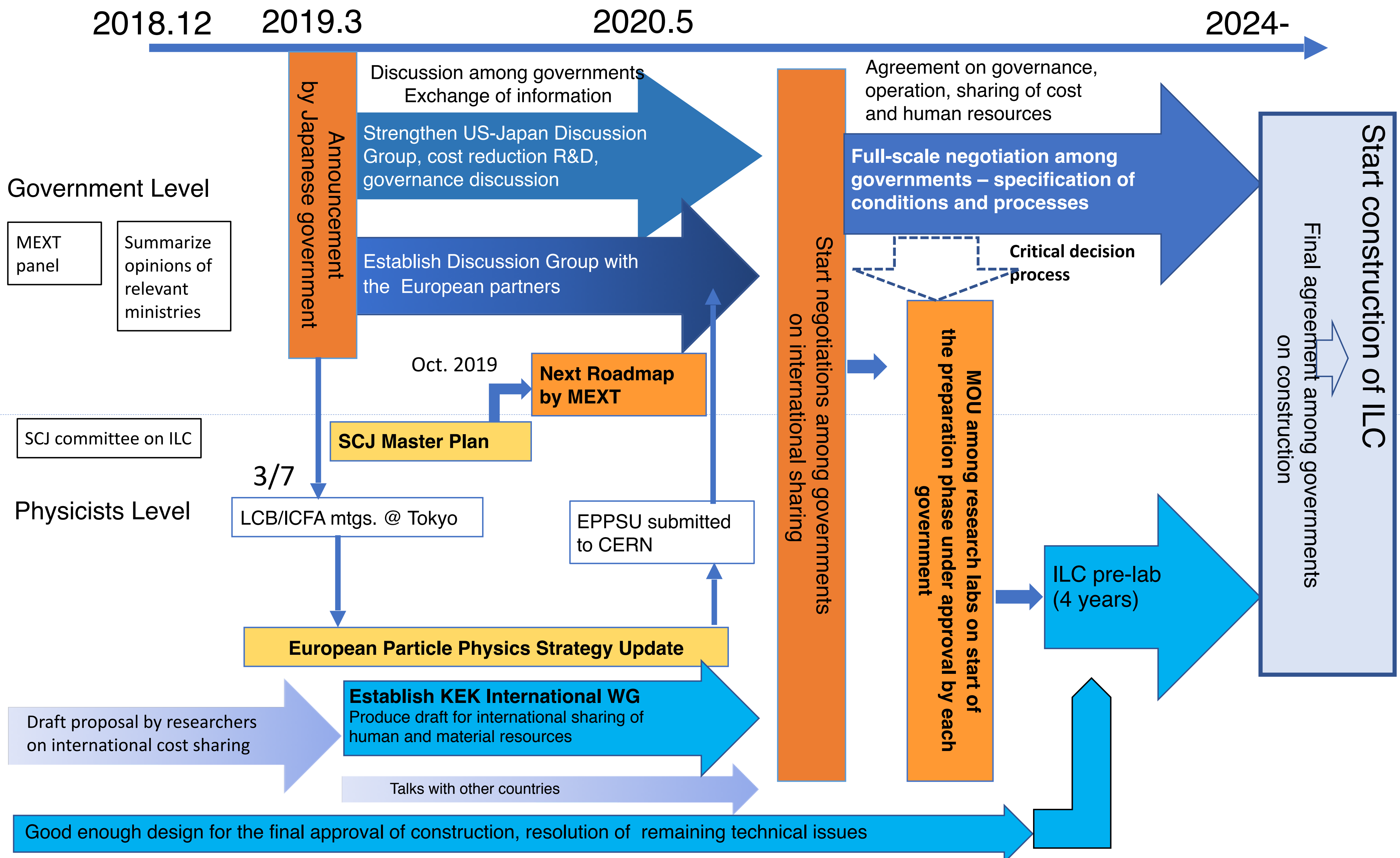
- In the future, while paying close attention to the progress of discussions on the European Elementary Particle Physics Strategy, we would like to deepen **discussions with France and Germany** at the governmental level, by proposing, for instance, to establish a standing discussion group similar to the one with the US. (Mr.Isogai)

- So, also for the ILC project, we expect there will be **a working group** discussions within the community of domestic and foreign researchers up in the High Energy Accelerator Research Organization, so-called KEK, and at its initiative, hers will proceed regarding international cost sharing, etc. (Mr.Isogai)

- As I mentioned earlier, I am also aware that this is a project of great significance both from the academic research point of view and from the perspective of regional revitalization. Therefore, I would like to **continue our investigations, closely collaborating with related communities while keeping an eye on the international situation.** (Minister Shibayama)

M. Yamauchi, April 8, Lausanne

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



＊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.

SCJ Master Plan/MEXT Roadmap

- Science Council of Japan (SCJ) is an organization that represents the Japanese scientists. It has no policy-making or budgetary authority.
- SCJ calls for proposals of large-scale research projects every three years, and recommends "priority programs" to MEXT. In the latest one in 2017, 20 programs were selected from 200 proposals.
- MEXT Minister suggested ILC be evaluated to provide evidence of support by broader Japanese academics. ILC proposal was submitted.
- SCJ selected ILC for long list after 1/3 screening and invited ILC for "interview."
- Results of final evaluation will be publicized officially in February 2020.
- Previous 2017 Master Plan/Roadmap process, MEXT made its own selection starting from the SCJ long list to create MEXT Roadmap.

ILC International Working Group

M. Yamauchi, Oct 2019

- KEK organizes the international working group for ILC with close consultation with MEXT.
  - Members:
    - Klaus Desch (Bonn)
    - Andy Lankford (UC Irvine)
    - Kajari Mazumdar (TIFR)
    - Patricia McBride (Fermilab)
    - Shin Michizono (KEK)
    - Yasuhiro Okada (KEK, Chair)
    - Claude Vallee (Marseille)
  - Mandate: Update ILC-PIP to describe:
    - ✓ Model of international cost-sharing for construction and operation of ILC
    - ✓ Organization and governance of the ILC Laboratory
    - ✓ International share of the remaining technical preparation
  - KEK received the report from the Working Group in September, and sent the KEK's recommendation to MEXT based on the report.

First meeting in Granada, Spain (May 17)

Outline of the KEK's recommendations

M. Yamauchi, Oct 2019

- International cost-sharing
  - Civil engineering and land acquisition are responsibility of the host state.
  - Accelerator components should be provided by all the member states as in-kind contributions
  - The operational cost should be shared among the member states.

- Organization and governance
  - An evolutionary model: ILC Pre-Lab to ILC Laboratory
  - Pre-Lab should be promptly established through laboratory-label MoU's. Its mandate is to coordinate the preparatory tasks and to assist the inter-governmental negotiations.
  - After an inter-governmental agreement, the Pre-Lab is expected to transition into a full ILC Laboratory.
  - Planning of the Pre-Lab should start as soon as possible.

- Intentional sharing of the remaining technical preparation
  - A technical preparation plan is presented with identification of potential international collaboration partners.

Annual International Workshops on Future Linear Colliders

2019 LINEAR COLLIDER WORKSHOP

- **October 28-Nov 1, 2019 - Sendai, Japan, LCWS2019**

- **2018 -Arlington, Texas**
- **2017 - Strasbourg, France**

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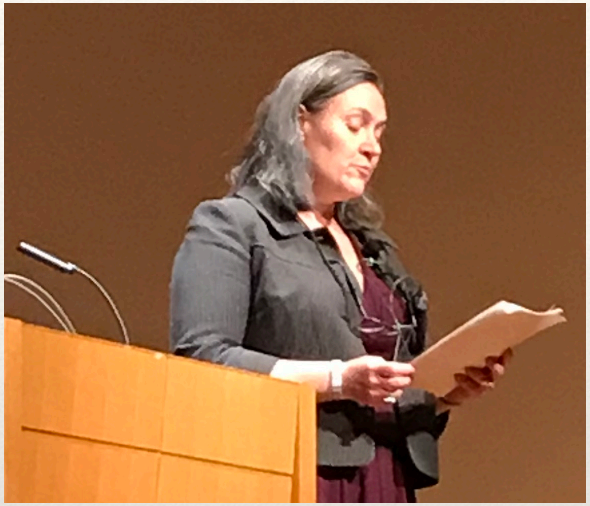

Melinda Pavek, Director of Science, Innovation and Development, US Embassy, Tokyo

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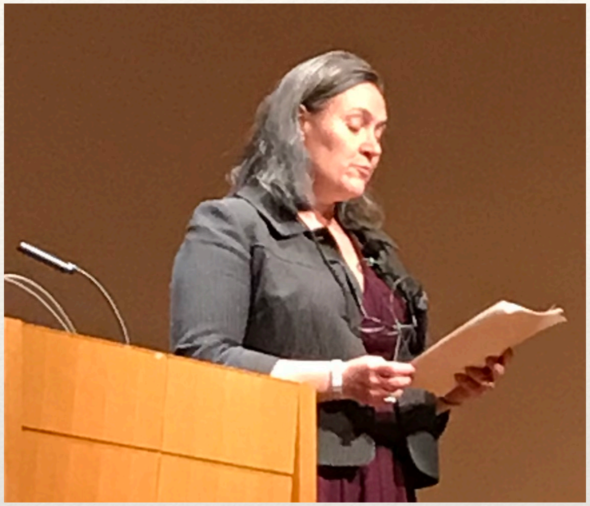

Melinda Pavek, Director of Science, Innovation and Development, US Embassy, Tokyo

"the U.S. Department of State is ready to assist our partner agencies in developing the next major particle physics facility in Japan—the ***International Linear Collider.****"*

ILC References

- **International Linear Collider Technical Design Report**
  arXiv:1306.6327 – Volume 1: Executive Summary
  arXiv:1306.6352 – Volume 2: Physics
  arXiv:1306.6353 – Volume 3.I: Accelerator R&D in the Technical Design Phase
  arXiv:1306.6328 – Volume 3.II: Accelerator Baseline Design
  arXiv:1306.6329 – Volume 4: Detectors
- **Physics Case for the 250 GeV Stage of the International Linear Collider**
  arXiv:1710.07621
- **The International Linear Collider Machine Staging Report 2017**
  arXiv:1711.00568
- **The International Linear Collider: A Global Project**
  arXiv:1903.01629
- **Tests of the Standard Model at the International Linear Collider**
  arXiv:1908.11299v2

Conclusion

- ILC is **technically sound**, ready for **construction start**.
- Staged ILC offers excellent science from **first stage** (250 GeV)
  - TeV-scale BSM physics impacts Higgs boson couplings at the **percent level.** (*polarization and model-independence critical*)
  - **Higher energy** upgrades will extend physics program.
  - All LHC scenarios leave a compelling **ILC discovery potential.**
- Multi-year intensive evaluation in Japan nearing completion.
- Looking for **high-level "signal"** soon within Japanese Ministry and scientific community.

Ref: arXiv:1903.01629