3^{rd} Generation Quark & EW Boson Couplings at the 250GeV stage of the ILC

This presentation is mainly based on arXiv:1710.07621 and https://pos.sissa.it/314/752/pdf.

Ryo Yonamine
for ILD concept group

Topic 1: 3rd generation quarks —> BSM

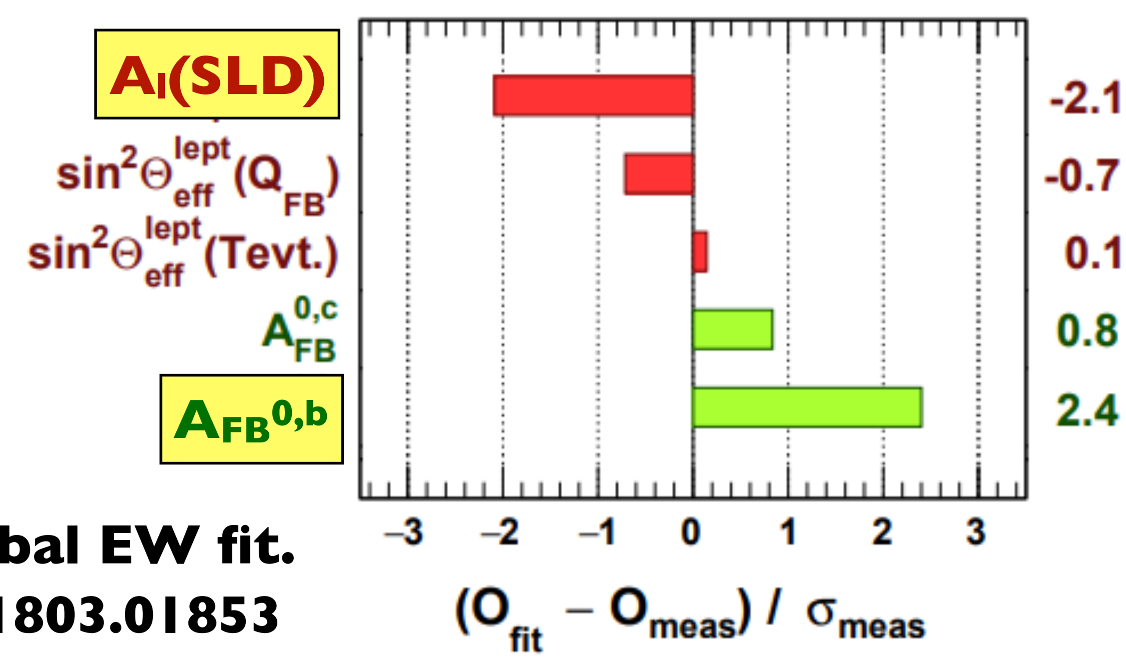
- **Top quark is the heaviest elementary particle in the SM.**
  - Expected to be strongly connected to EWSB mechanism.

- **Left bottom quark is heavy in the sense that the same SU(2)×U(1) multiplet as top quark. b-quark pair can be produced at 250GeV.**

- **Deviations on the EW couplings for the 3rd generation quarks are predicted in BSM theories (e.g. Z', warped extra dimensions).**

- **How about the right one? Right bottom quark also must be tested to check if there is non-standard behaviour or not.**
  - 3σ discrepancy between the value of $\sin^2\Theta_W$ from A^b_{FB} at LEP and the value from A_l at SLC.

$$g^Z := T_3 - Q\sin^2\theta_W$$

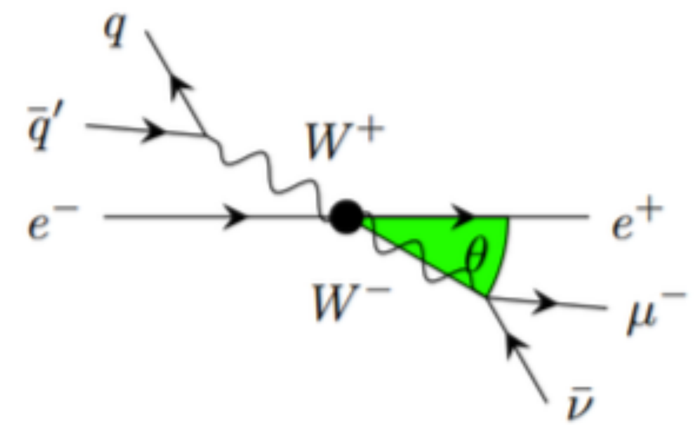


the global EW fit.
arXiv:1803.01853

Topic 2: EW Boson couplings —> BSM

- **Non-Abelian self-couplings of the W, Z and γ need more precise measurements.**
  - Only the triple gauge couplings (TGCs), namely WWZ, WWγ considered here.
  - Sufficient accurate measurements of TGCs can probe BSM.
  - 10^{-3} precision is necessary for the distinction of different Higgs-models

W pair production includes TGC.
Beam polarization disentangle WWZ and WWγ.

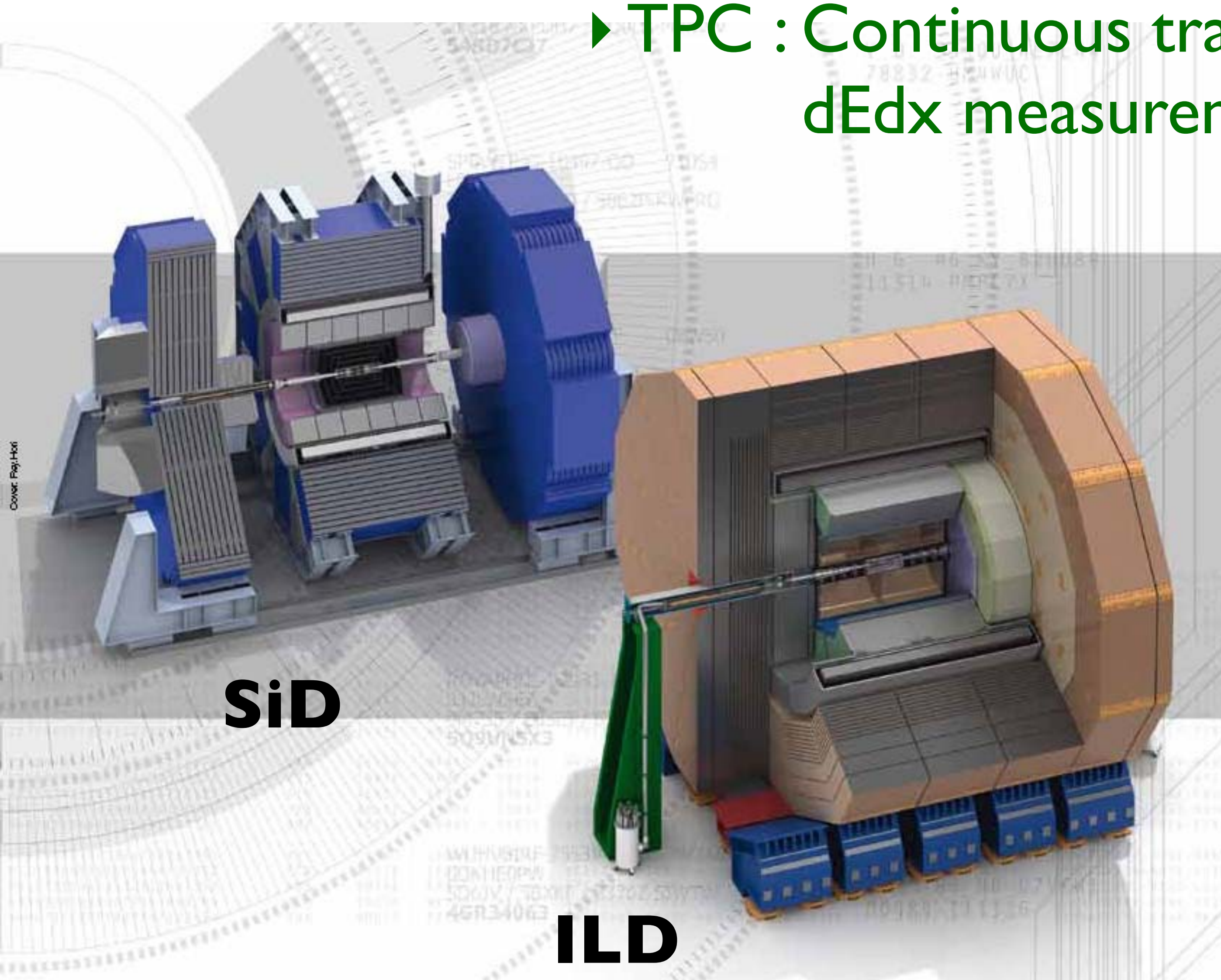


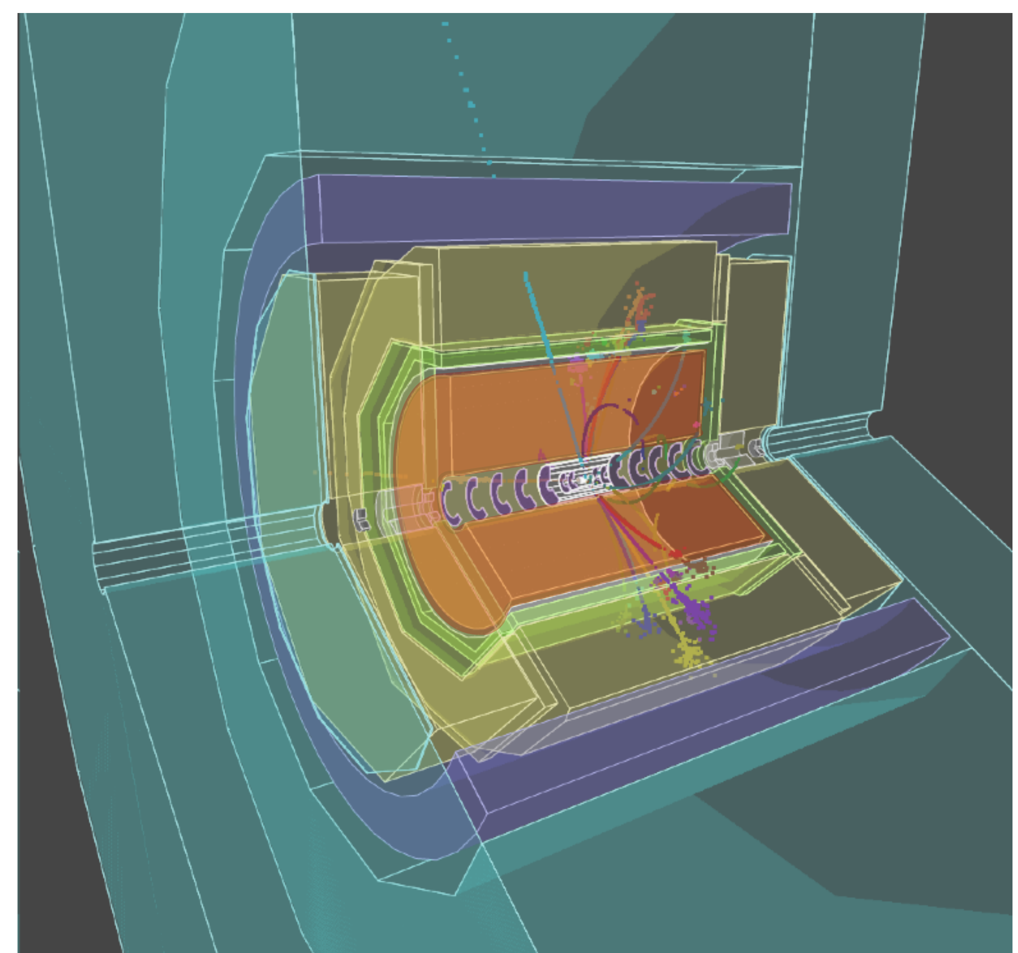
- **W pair production is also useful to measure average luminosity-weighted beam polarization by an angular fit technique.**
  - Strong dependence of the cross sections and angular distributions on the beam polarization. —> in situ beam polarization measurement.
  - I. Marchesini (http://www-library.desy.de/preparch/desy/thesis/desy-thesis-11-044.pdf)

ILC and ILD

- **ILC : e+ e- collider**
  - Controllable initial state (beam energy, polarization)
  - $\sqrt{s}$=250GeV, L=2000fb^{-1}, fraction $e_L p_R$67.5%, $e_R p_L$22.5%, $e_L p_L$5%, $e_R p_R$5%)
  - Precision measurements of Higgs couplings and SM parameters (this talk).
  - Extendable to 350GeV, 500 GeV, 1TeV.

- **ILD : One of detector concepts for ILC**
  - TPC : Continuous tracking (V0, kink tracks)
    dEdx measurement —> PID —> Flavour tagging





Simulation & Reconstruction

- **Whizard and ILD standard software : iLCSoft**
  - Beam spectrum and ISR included.
  - Full detector simulation
  - Individual particle reconstruction with Particle Flow approach.

- **Vertexing, Flavour tagging**
  - H—> bb, cc, gg
  - t —> bW
  - W —> cs, ud
  - Z —> bb, cc, ss, dd, uu

- **Vertex charge assignment**
  - Forward backward asymmetry

Topic 1: 3rd generation quarks (e+e- —> bbar)

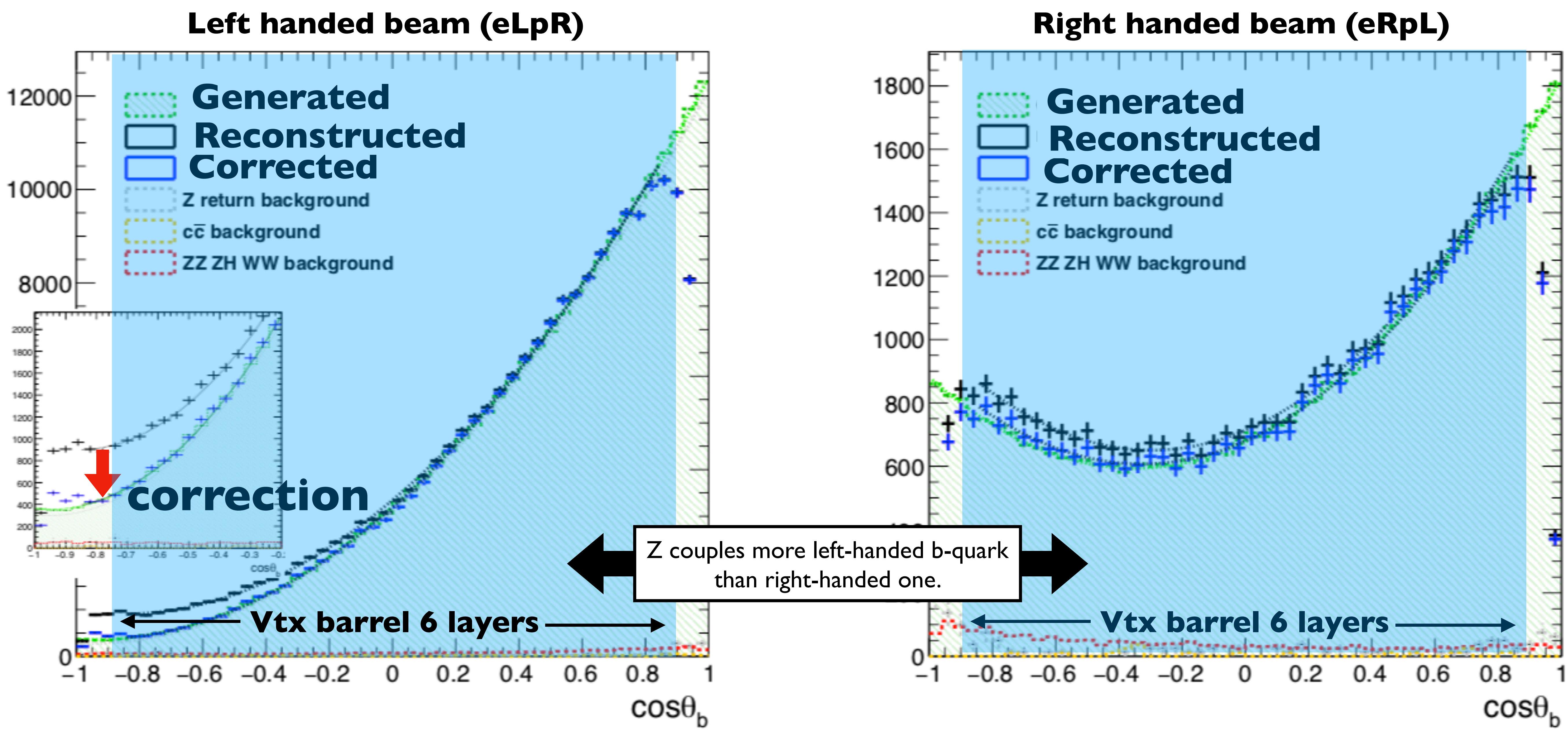
Right-handed b-quark coupling to Z

- **A BSM model can explain the LEP anomaly on $\sin\Theta_W$. It predicts a large correction for g_R^Z while g_L^Z remains small.**
  - A. Djouadi et. al., https://arxiv.org/pdf/hep-ph/0610173.pdf
  - ~25±10% shift from SM expected on g_R^Z.

- **Measurement : b-quark polar angular spectrum**
  - Key1 : b quark (charge) identification. PID and flavour tag are essential.
    - sum of all charges associated to the B-hadron
    - charge of the kaons found in a b-jet.
  - Key2 : b-quark charge assignment correction technique.
    - Implemented a method to correct for the b-quark charge mis-assignments, which requires no external inputs, but uses # of events in which only one b-quark charge is correctly assigned.
      See more details : S. Bilokin *et al.* arXiv:1709.04289

b-quark angular spectrum

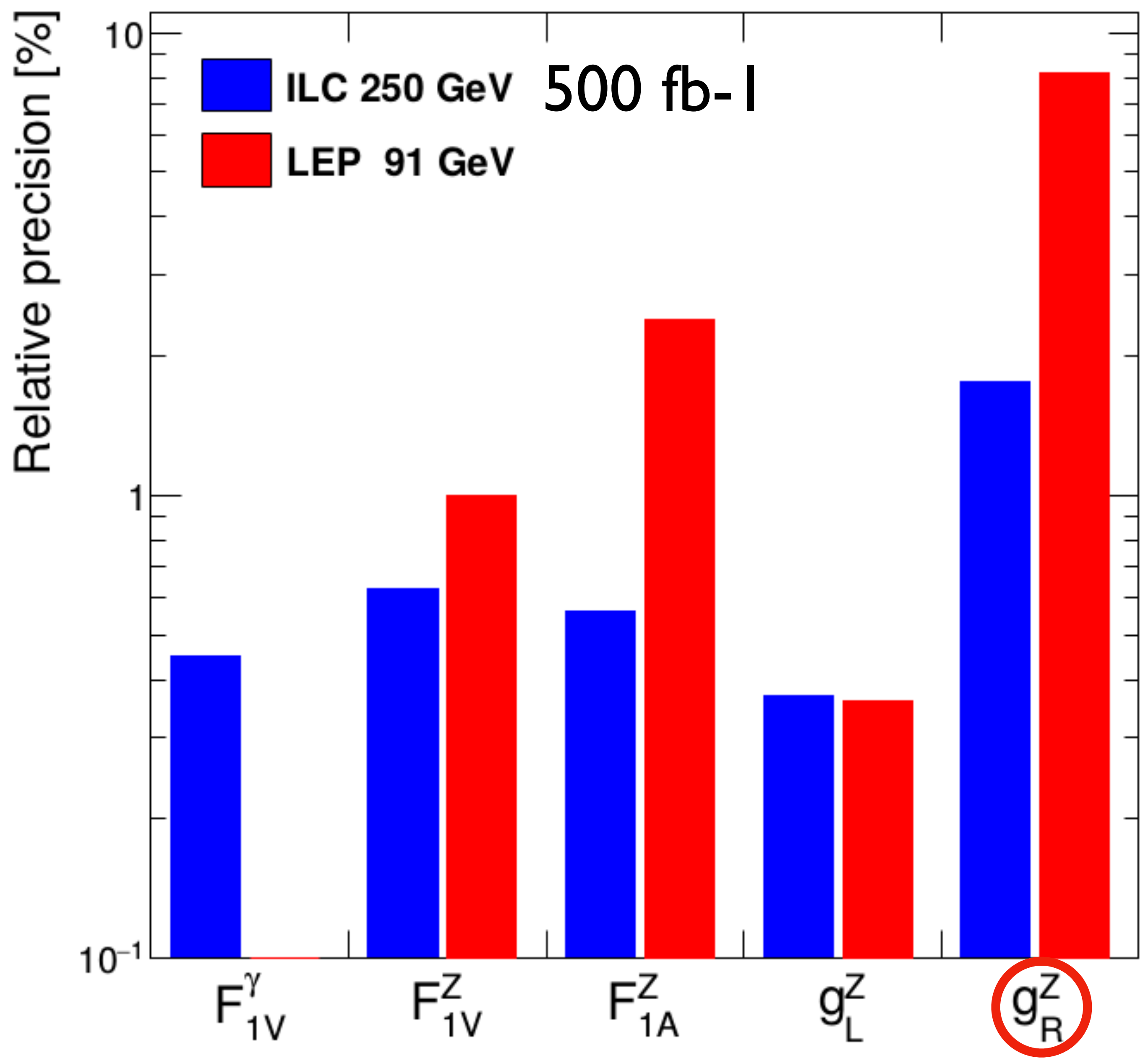
$\sqrt{s}$ = 250GeV, L = 250fb^{-1} for each polarization



S. Bilokin, https://pos.sissa.it/314/752/pdf

g_L^Z, g_R^Z, g_L^γ, g_R^γ (F^L_{1V}, F^L_{1A}, F^R_{1V}, F^R_{1A}) are extracted by fitting these spectra.

Fitting result compared to LEP



~5 times better precision for $g_R{}^Z$ at ILC than the one at LEP is expected.

This result shows 250GeV-ILC can clearly distinguish the model.

Topic 2: EW Boson couplings

TGC parameters to be measured

General form of WWV couplings from (1) Lorentz invariance

(V = γ, Z)

[1], [2], [3], [4], [5], [6], [7] : Operators

$$\frac{\mathscr{L}^{\text{eff}}_{WWV}}{g_{WWV}} = i g_1^V [1] + i\kappa_V [2] + \frac{i\lambda_V}{m_W^2}[3] - g_4^V [4] + g_5^V [5] + i\tilde{\kappa}_V [6] + \frac{i\tilde{\lambda}_V}{m_W^2}[7]$$

g_1, κ, λ : C-, P- conserving

g_5 : C-, P- violating

$g_4, \tilde{\kappa}, \tilde{\lambda}$: CP violating

+ (2) focusing on C and P conservation terms

CP-violating effect is separately measurable.

+ (3) SU(2)×U(1) symmetry

$$g_1^\gamma = 1$$

$$\kappa_Z = -(\kappa_\gamma - 1)\tan^2\theta_W + g_1^Z$$

$$\lambda_Z = \lambda_\gamma$$

→ $g_1^Z, \kappa_\gamma, \lambda_\gamma$

ILC 250 GeV result (ILD) expectation

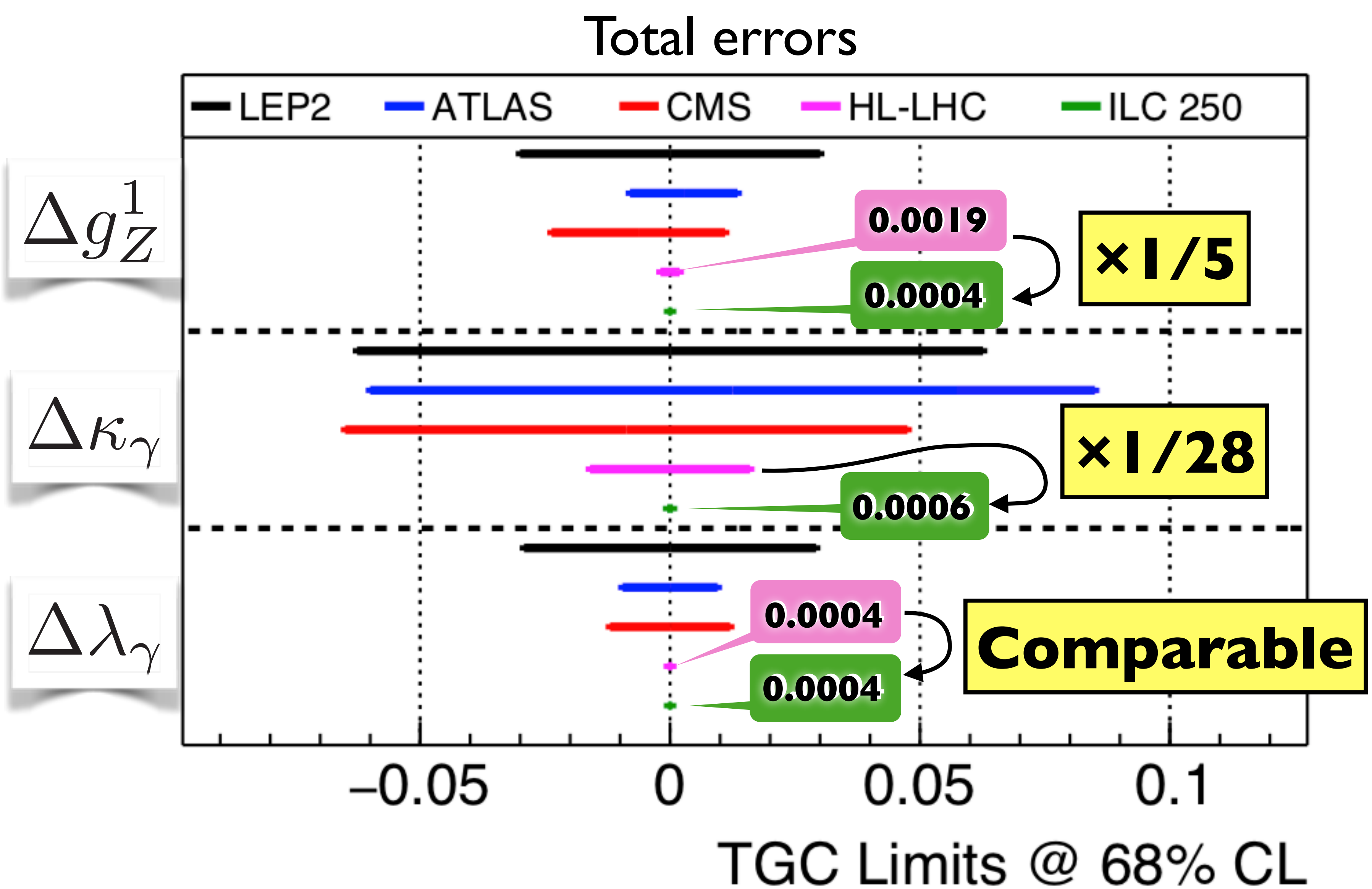
- **Full ILD study is work in progress.**
  - No results available yet.

- **For now, 500GeV (ILD) results is extrapolated to 250GeV.**
  - ILD 500 GeV result referred here :
    I. Marchesini, http://www-library.desy.de/preparch/desy/thesis/desy-thesis-11-044.pdf
  - Scaling factors :
    (1) Statistics : $1/\sqrt{(\sigma L)}$
    (2) Energy dependence of SU(2)×U(1) diagram cancellation : $1 / s^2$

or 1/s??

Precision estimation

arXive:1710.07621



Goal : 10^{-3}

Hopeful sign!

LEP2: √s=200GeV, 0.68fb-1, **Phys. Lett. B614, 7 (2005)**
ATLAS: √s=7TeV, 4.6 fb-1, **arXiv:1410.7238**
CMS : ??
HL-LHC (CMS):14TeV, 3000 fb-1, **https://cds.cern.ch/record/1510150/files/ATL-PHYS-SLIDE-2013-042.pdf**
ILC: √s=250GeV, 2000 fb-1

Conclusions

- **250GeV ILC will be powerful tool for searching BSM.**
  - Beam polarization is essential.
  - Not only Higgs precision measurements but also the other SM paramters' precise measurements for BSM are expected.

- **Topic1: 3rd generation quark**
  - 250GeV ILC can investigate b quark (L, R) and put the final word on the long-standing 3σ discrepancy between value of sin2Θw derived from the b forward backward asymmetry at LEP and the value obtained at the SLC.

- **Topic2: EW boson coupling**
  - 10^{-3} level TGC measurements are feasible. Full simulation study is work in progress. Stay tuned.

Backup

Run scenarios

arXiv:1710.07621

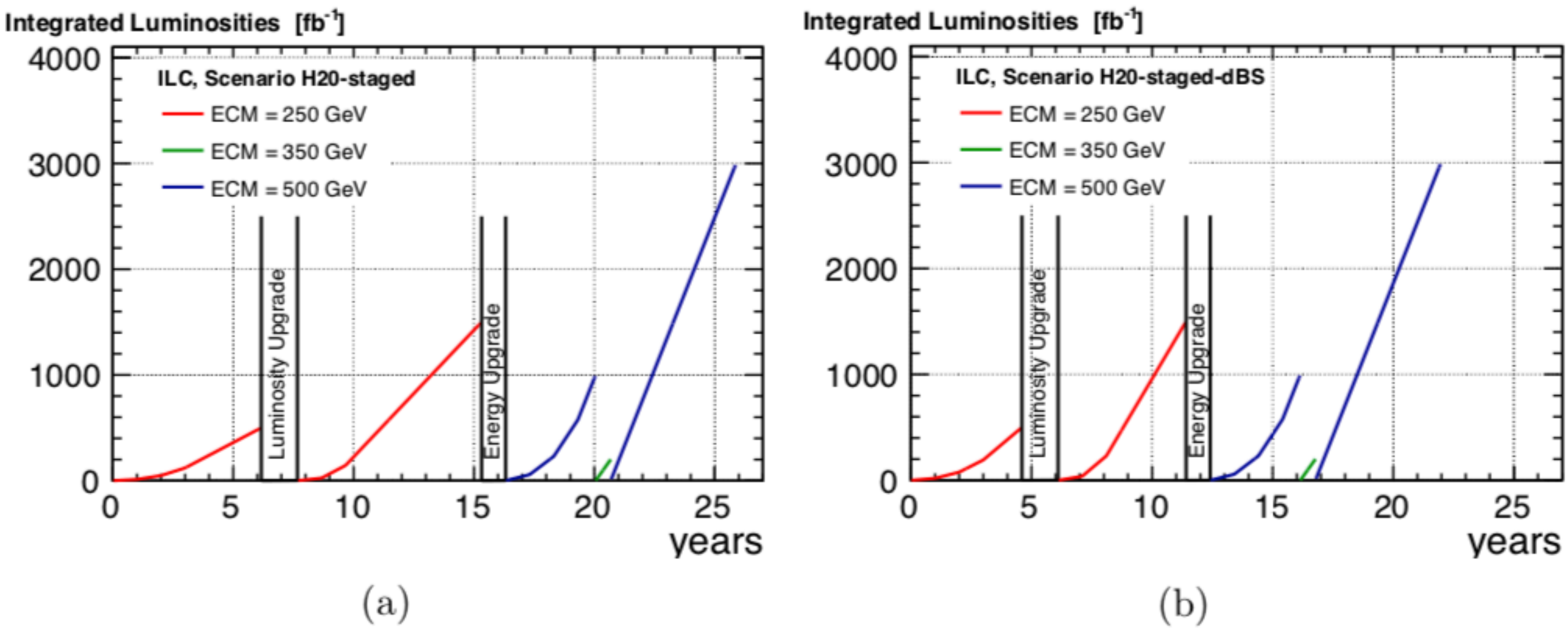


Figure 2: Run plan for the staged ILC starting with a 250-GeV machine under two different assumptions on the achievable instantaneous luminosity at 250 GeV. Both cases reach the same final integrated luminosities as in Fig. 1.

Slide from S. Bilokin at ICHEP 2018