Prospects for electroweak precision measurements and triple gauge couplings at a staged ILC.

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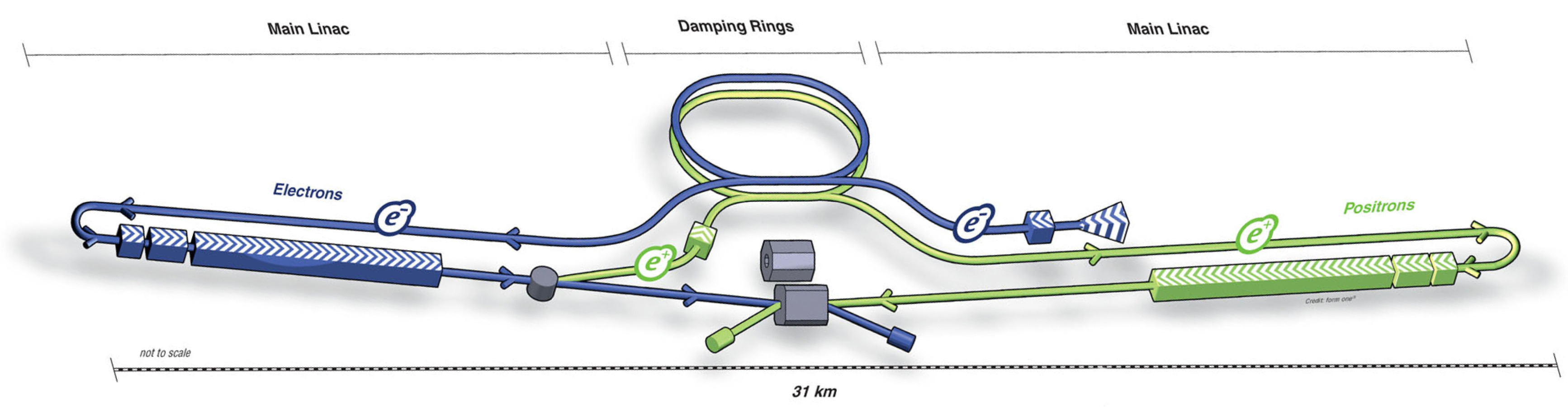
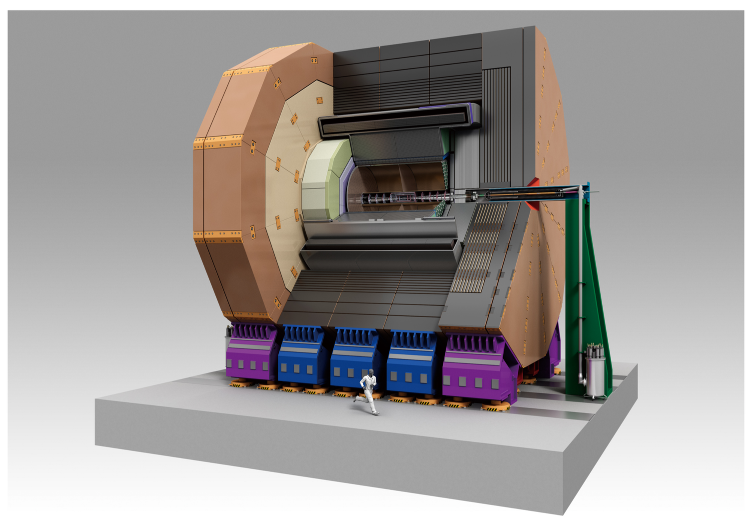
International Linear Collider ILC



- Future linear e^+e^- Collider
- @ $\sqrt{s} \rightarrow$ 250-500 GeV (upgradable to 1 TeV)
- Construction under political consideration in the Kitakami region, Prefecture Iwate, Japan
- e^+ and e^- beam are polarized: $P_{e^-} = \pm 80\%$, $P_{e^+} = \pm 30\%$
- Switch of polarization sign (helicity reversal) $\rightarrow$ choice of spin configuration

International Large Detector ILD

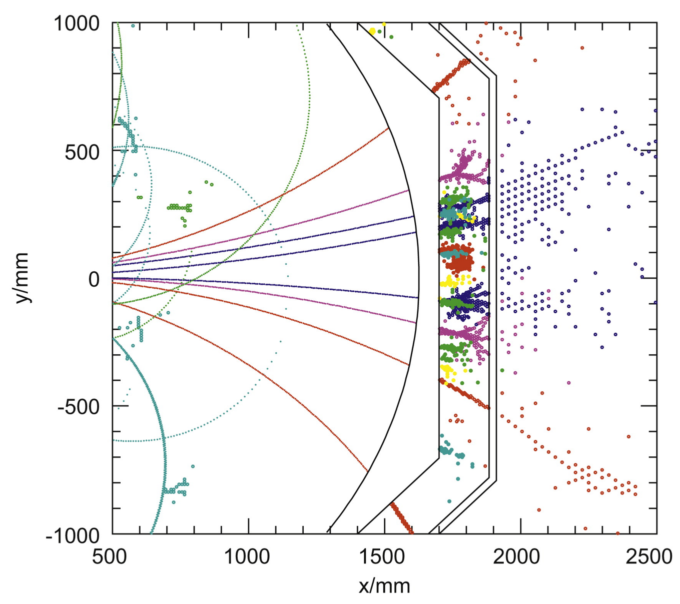


Requirements on the ILD detector performance:

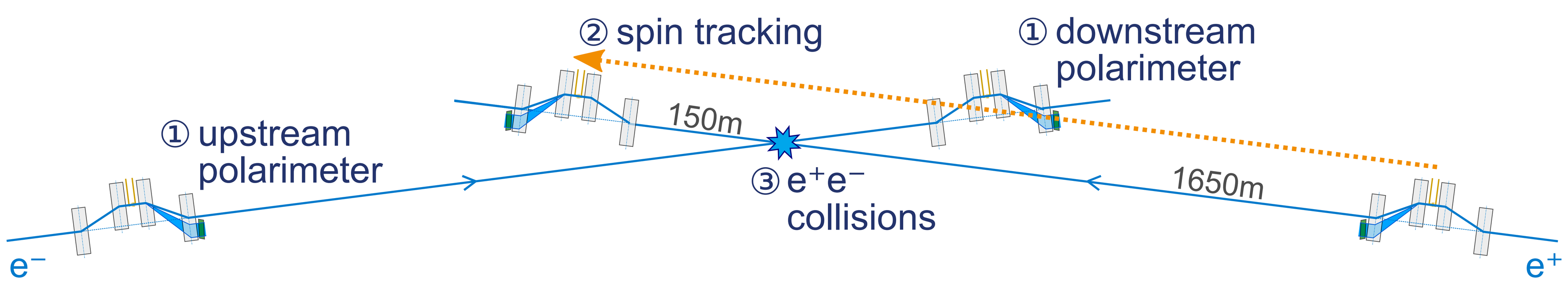
- Vertex detector with a point resolution of better than $3\,\mu$m
- High tracking performance: $\sigma_{1/p_T} \approx 2 \cdot 10^{-5}$ GeV^{-1}
- Jet-energy resolution of $\sigma_E/E \approx 3-4\%$ $\rightarrow$ separation of hadronic decays from Z and W

Features of the ILD detector:

- A large volume time projection chamber with up to $\mathcal{O}(200)$ points per track
  - Efficient pattern recognition with a minimal material budget
  - allows a dE/dx based particle identification
- Calorimeter optimized for *particle flow*
  - reconstruction of individual particles in jets

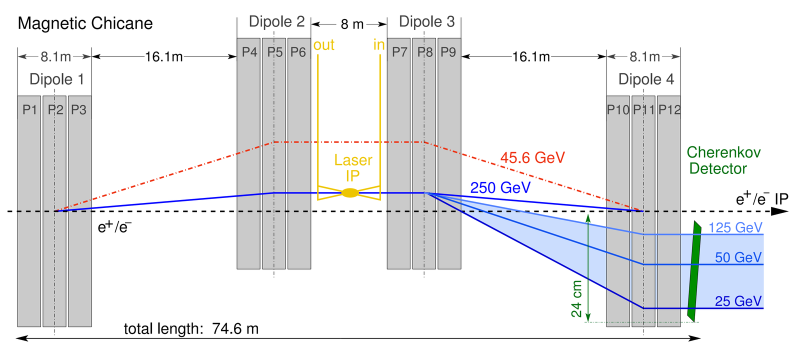


Polarimetry

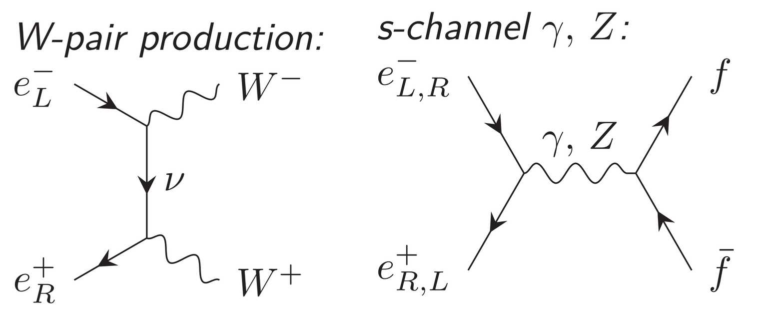


Combination of 2 measurements

1. The time-resolved beam polarization: Measured with 2 laser-Compton polarimeters before and after the e^-e^+ IP
2. The luminosity-weighed averaged polarization: Calculated from the cross section measurement of well known standard model processes



Process [250 GeV]	$A_{\rm RL}^{\rm LR}$	σ_0[pb]
$e^+e^- \rightarrow W^+W^- \rightarrow q\bar{q}l\nu$	0.982	4.74
$e^+e^- \rightarrow Z \rightarrow q\bar{q}$	0.289	50.1
$e^+e^- \rightarrow e^-\bar{\nu}W^+ \rightarrow e^-\bar{\nu}q\bar{q}$	0.983	1.29
$e^+e^- \rightarrow e^+\nu W^- \rightarrow e^+\nu q\bar{q}$	0.983	1.29
⋮	⋮	⋮



$A_{\rm RL}^{\rm LR} := \frac{\sigma_{LR}-\sigma_{RL}}{\sigma_{LR}+\sigma_{RL}}$ $\quad \sigma_0 := \frac{1}{4}\sum \sigma_{\{R,L\}}$

⇒ The aim to reach the permille-level precision $\Delta P/P = 0.1\%$

Simultaneous Chiral Cross Section Determination

The measurement of the luminosity-weighted averaged polarization depends strongly on a precise knowledge of the chiral cross sections.

In order not to rely on theoretical calculations alone, the total chiral cross section can be determined simultaneously with the polarization from the differential chiral cross section measurement.

Defining the unpolarized cross section scaling α and the asymmetry discrepancy β for each process and channel:

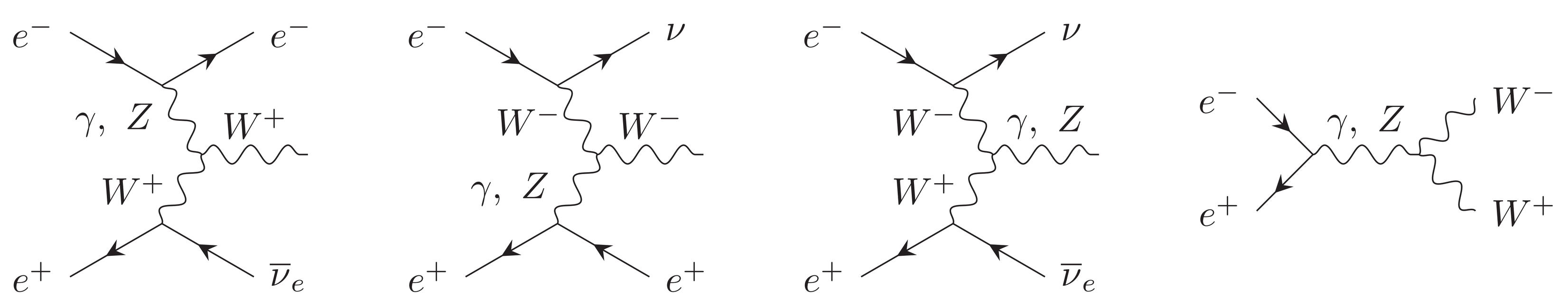
$$\sigma_0 \longrightarrow \alpha \cdot \sigma_0$$
$$A \longrightarrow A + \beta$$

- ✓ Simultaneous determination of the 4 beam polarizations and the 28 pseudo nuisance parameter possible
- ✓ All pseudo nuisance parameter correctly determined
- ✓ No effect on the polarization precision
- ⇒ Results for the precision of the polarization and chiral cross section measurement are in the order of 0.01% @$\sqrt{s} = 250$ GeV and $\mathcal{L}_I = 2000\,\text{fb}^{-1}$

χ^2 / NDF		753.43 / 708	
Parameter [10^{-4}]		Parameter [10^{-4}]	
$\Delta P_{e^-}^-$	3.4	$\Delta P_{e^+}^-$	2.9
$\Delta P_{e^-}^+$	1.3	$\Delta P_{e^+}^+$	3.9
$\Delta\alpha_{W^+}(e\nu l\nu)$	12	$\Delta\beta_{W^+}(e\nu l\nu)$	6.2
$\Delta\alpha_{W^-}(e\nu l\nu)$	12	$\Delta\beta_{W^-}(e\nu l\nu)$	13
$\Delta\alpha_{W^+}(e\nu q\bar{q})$	7.5	$\Delta\beta_{W^+}(e\nu q\bar{q})$	3.6
$\Delta\alpha_{W^-}(e\nu q\bar{q})$	7.5	$\Delta\beta_{W^-}(e\nu q\bar{q})$	7.6
$\Delta\alpha_{WW}(q\bar{q}q\bar{q})$	5.6	$\Delta\beta_{WW}(q\bar{q}q\bar{q})$	1.6
$\Delta\alpha_{WW}(l\nu l\nu)$	12	$\Delta\beta_{WW}(l\nu l\nu)$	4.9
$\Delta\alpha_{WW}(l\nu q\bar{q})$	5.4	$\Delta\beta_{WW}(l\nu q\bar{q})$	1.4
$\Delta\alpha_{ZZ}(q\bar{q}q\bar{q})$	10	$\Delta\beta_{ZZ}(q\bar{q}q\bar{q})$	12
$\Delta\alpha_{ZZ}(llll)$	28	$\Delta\beta_{ZZ}(llll)$	34
$\Delta\alpha_{ZZ}(llq\bar{q})$	9.8	$\Delta\beta_{ZZ}(llq\bar{q})$	12
$\Delta\alpha_{ZZWW}(q\bar{q}q\bar{q})$	5.8	$\Delta\beta_{ZZWW}(q\bar{q}q\bar{q})$	2.9
$\Delta\alpha_{ZZWW}(l\nu l\nu)$	12	$\Delta\beta_{ZZWW}(l\nu l\nu)$	8.1
$\Delta\alpha_{Z}(q\bar{q})$	1.6	$\Delta\beta_{Z}(q\bar{q})$	3.3
$\Delta\alpha_{Z}(l^+l^-)$	2.4	$\Delta\beta_{Z}(l^+l^-)$	4.2

Triple Gauge Couplings (TGC)

Leading Feynman Diagrams:



Simulataneous Fit of three Triple Gauge Couplings within a EFT

$$\frac{\partial\sigma}{\partial\theta}(\delta g, \delta\kappa, \delta\lambda) / \frac{\partial\sigma_{\rm SM}}{\partial\theta} = 1 + A(\theta)\cdot\delta g + B(\theta)\cdot\delta\kappa + C(\theta)\cdot\delta\lambda + D(\theta)\cdot\delta g^2 + E(\theta)\cdot\delta\kappa^2 + F(\theta)\cdot\delta\lambda^2 + G(\theta)\cdot\delta g\cdot\delta\kappa + H(\theta)\cdot\delta g\cdot\delta\lambda + I(\theta)\cdot\delta\kappa\cdot\delta\lambda$$

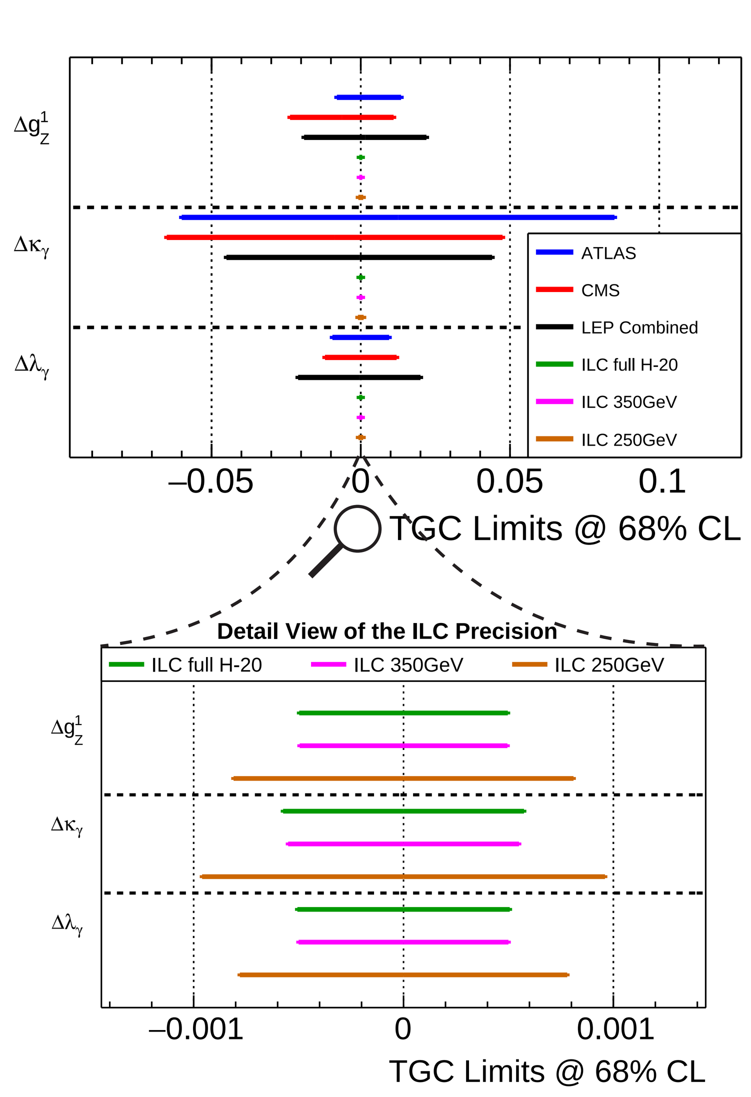
$$\delta g := g_Z^1(\text{data}) - g_Z^1(\text{SM})$$
$$\delta\kappa := \kappa_\gamma(\text{data}) - \kappa_\gamma(\text{SM})$$
$$\delta\lambda := \lambda_\gamma(\text{data}) - \lambda_\gamma(\text{SM})$$

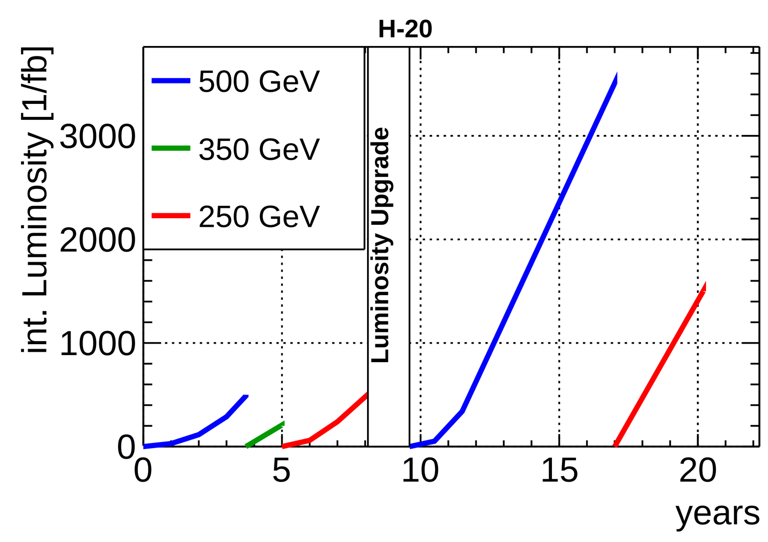
Precision of the Triple Gauge Couplings Fit, shown for $\mathcal{L}_{\rm ILC} = 2\,\text{ab}^{-1}$:

ILD full simulation [1]		Extrapolations	
$E_{\rm CMS}$	500 GeV	250 GeV	350 GeV
Δg_Z^1	$4.3 \cdot 10^{-4}$	$8.1 \cdot 10^{-4}$	$5.0 \cdot 10^{-4}$
$\Delta\kappa_\gamma$	$4.4 \cdot 10^{-4}$	$9.6 \cdot 10^{-4}$	$5.5 \cdot 10^{-4}$
$\Delta\lambda_\gamma$	$4.1 \cdot 10^{-4}$	$7.8 \cdot 10^{-4}$	$5.0 \cdot 10^{-4}$

- Similar to the chiral cross section, also the Triple Gauge Coupling measurement depends strongly on the beam polarization
- So TGC can and have to be determined simultaneously with the polarization measurement

Comparison of the TGC Precision





- Aim for roughly 2 orders of magnitude better precision of the Triple Gauge Couplings than the current limit after the full ILC run [1]
- Even with 250GeV run alone, a comparable precision can be reached
- The LHC results are Limits for $\sqrt{s} = 8$ TeV data and an integrated luminosity of $\mathcal{L}_I = 20.3\,\text{fb}^{-1}$ and $\mathcal{L}_I = 19.4\,\text{fb}^{-1}$ for ATLAS and CMS, respectively [2]
- The LEP results are combined ALEPH, L3 and OPAL results [3]

References

[1] I. Marchesini, *Triple Gauge Couplings and Polarization at the ILC and Leakage in a Highly Granular Calorimeter*, PhD Thesis, University of Hamburg, 2011 (DESY-THESIS-2011-044), http://www-library.desy.de/cgi-bin/showprep.pl?desy-thesis-11-044

[2] Limits on anomalous triple and quartic gauge couplings: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC

[3] T. L. C. ALEPH, DELPHI, L3, OPAL, and the LEP TGC Working Group, *A combination of results on charged triple gauge boson couplings measured by the LEP experiments*, LEPEWWG/TGC/2005-01.