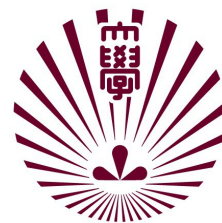


HEP 09 – ILC Heavy Flavors

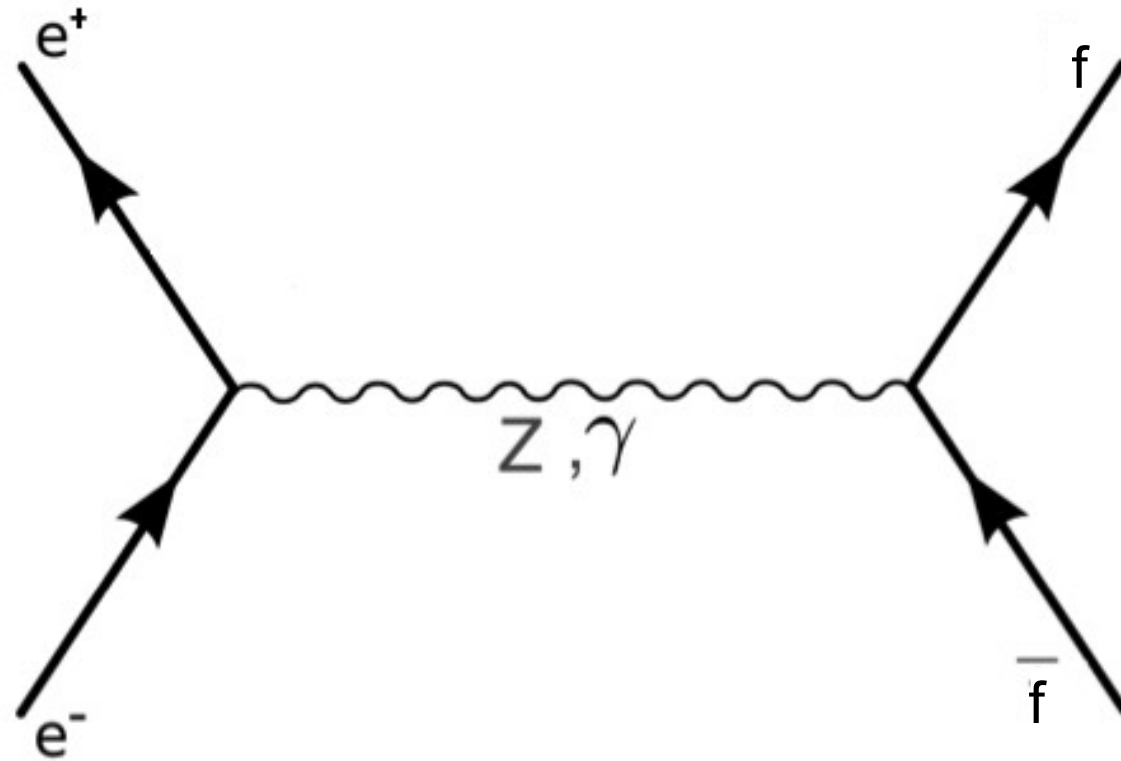


Partners:



Participants:

French Group			Japanese Group		
Name	Title	Lab./Organis. ²	Name	Title	Lab/Organis. ³
Roman Pöschl poeschl@lal.in2p3.fr	DR	IJCLab	Keisuke Fujii keisuke.fujii@kek.jp	Prof	KEK/IPNS
Adrian Irlès	Postdoc	IJCLab	Yutaka Hosotani	Prof	Osaka U.
Emi Kou	Dr	IJCLab	Daniel Jeans	Dr	KEK/IPNS
François Le Diberder	Dr	IJCLab	Yuichiro Kiyo	Dr	Juntendo U.
François Richard	Dr	IJCLab	Masakazu Kurata	Dr	KEK/IPNS
Paul Colas	Dr	CEA/IRFU	Yoshimasa Kurihara	Dr	KEK/IPNS
Maxim Titov	Dr	CEA/IRFU	Taikan Suehara	Dr	Kyushu U.
Boris Tuchming	Dr	CEA/IRFU	Yukinari Sumino	Dr	Tohoku U.
			Tomohiko Tanabe	Dr	U. Tokyo
			Junping Tian	Dr	U. Tokyo
			Hitoshi Yamamoto	Prof	Tohoku U.
			Akimasa Ishikawa	Dr	KEK/IPNS



Differential cross sections for (relativistic) di-fermion production*:

$$\frac{d\sigma}{d\cos\theta}(e_L^- e_R^+ \rightarrow f\bar{f}) = \Sigma_{LL}(1 + \cos\theta)^2 + \Sigma_{LR}(1 - \cos\theta)^2$$

$$\frac{d\sigma}{d\cos\theta}(e_R^- e_L^+ \rightarrow f\bar{f}) = \Sigma_{RL}(1 + \cos\theta)^2 + \Sigma_{RR}(1 - \cos\theta)^2$$

*add term $\sim \sin^2\theta$ in case of non-relativistic fermions e.g. top close to threshold

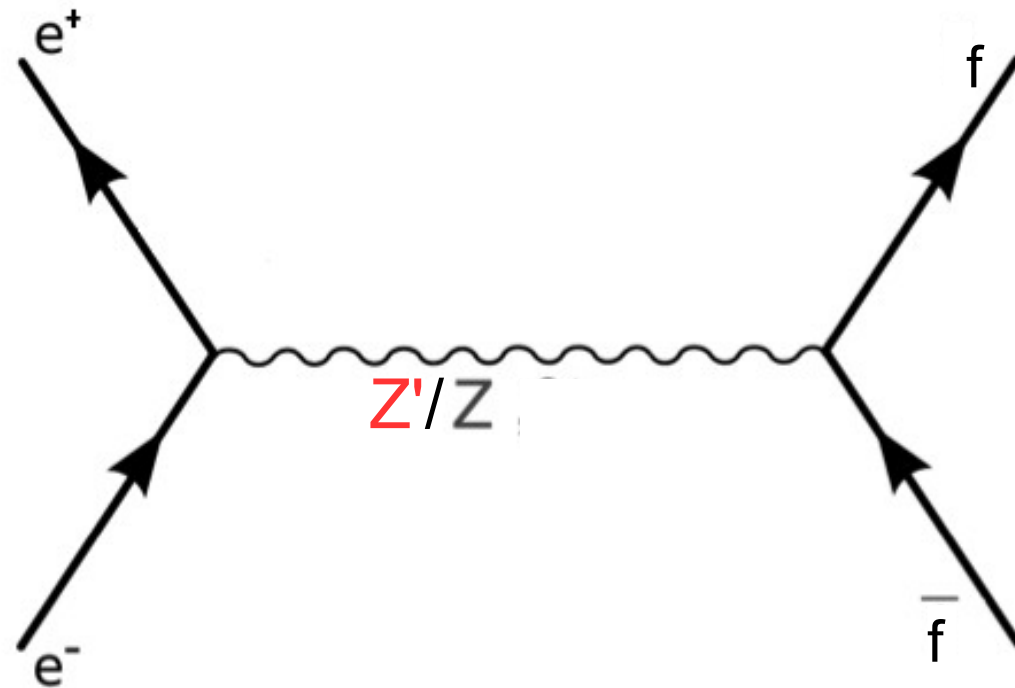
Σ_{IJ} are helicity amplitudes that contain couplings g_L, g_R (or g_V, g_A)

$\Sigma_{IJ} \neq \Sigma_{I'J'} \Rightarrow$ (characteristic) asymmetries for each fermion

Forward-backward in angle, general left-right in cross section

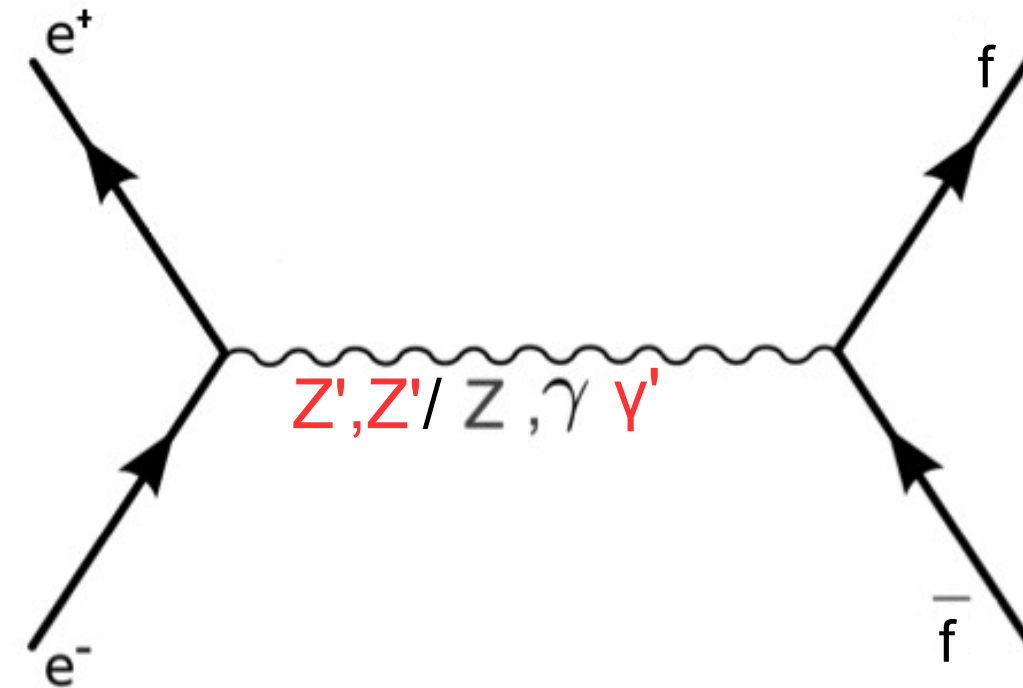
All four helicity amplitudes for all fermions only available with polarised beams

On the Z-pole



Sensitivity to Z/Z' mixing
 Sensitivity to vector (and tensor) couplings of the Z
 •the photon does not “disturb”

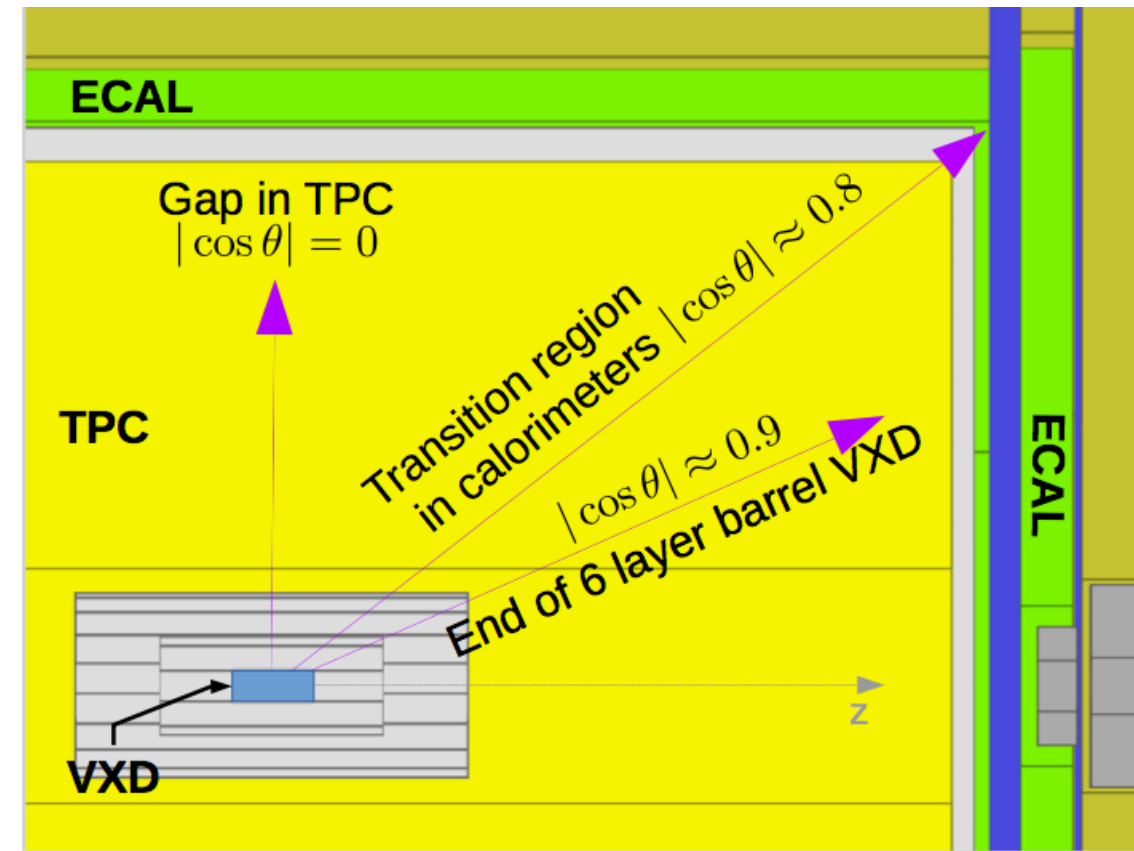
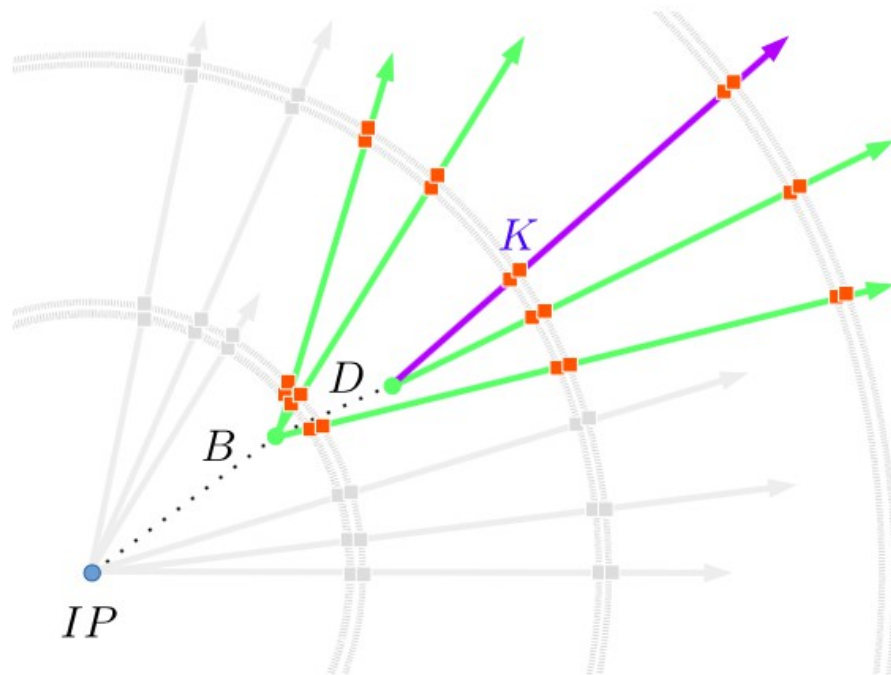
Above the Z-pole



Sensitivity to interference effects of Z and photon!!
 Measured couplings of photon and Z can be influenced by new physics effects
 Interpretation of result is greatly supported by precise input from Z pole

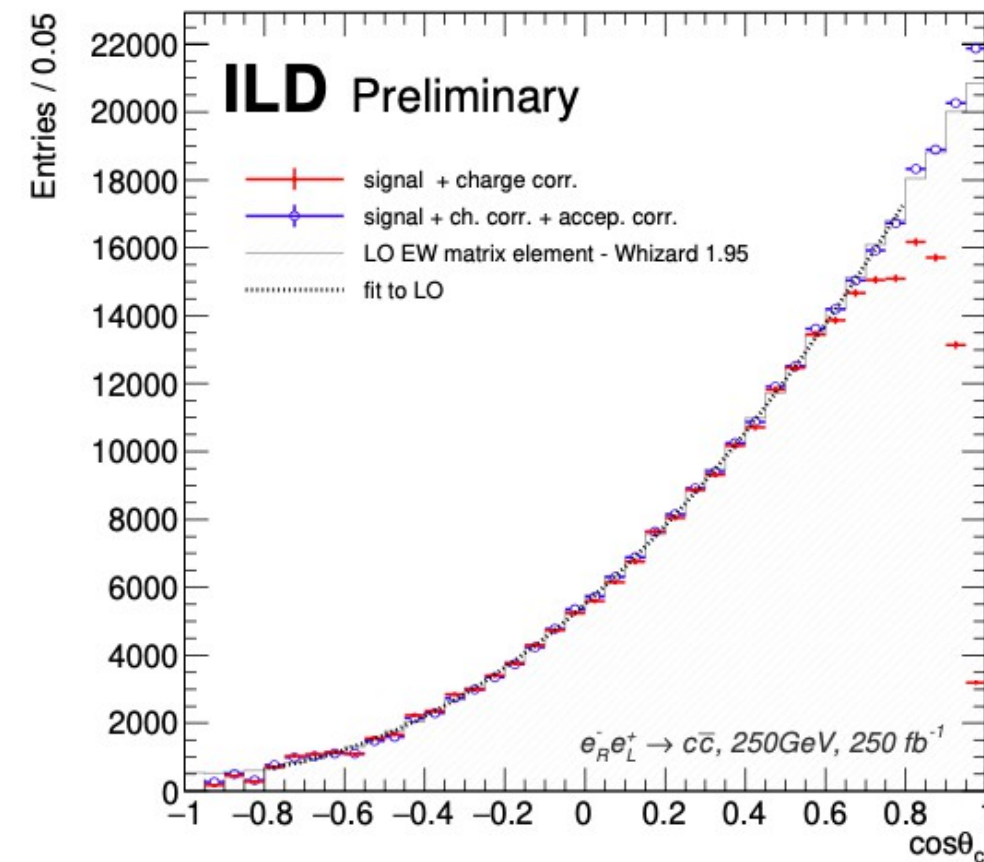
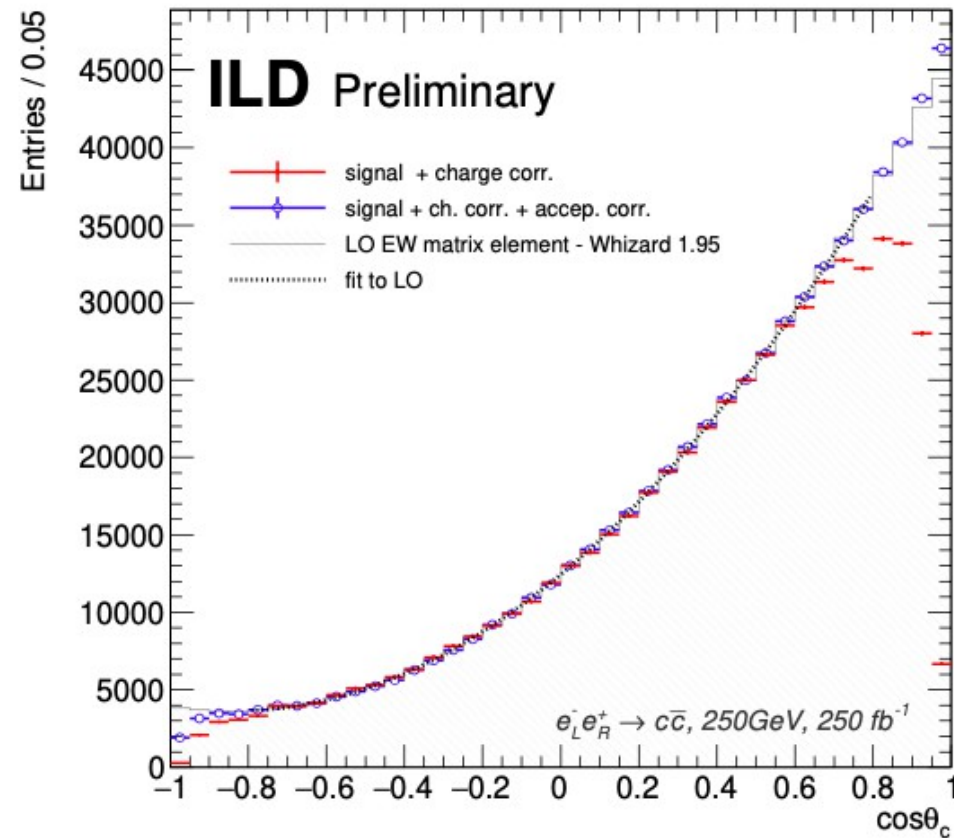
- Detailed simulations available at 250 GeV and 500 GeV
- New 250 GeV production of ILD to be explored!!!!
- So far no detailed simulation on Z-pole

- Two fermion processes are excellent benchmark reactions for (not only) Linear Collider Detectors
- Show weaknesses and optimization potential for LC Detectors



- Flavor Tagging
- Quark charge measurements
- Particle ID
- **Optimal exploitation of detector information with machine learning algorithms !?**
 - to be addressed

- Sources for experimental uncertainties
- Systematic studies to “eliminate” them before detector construction

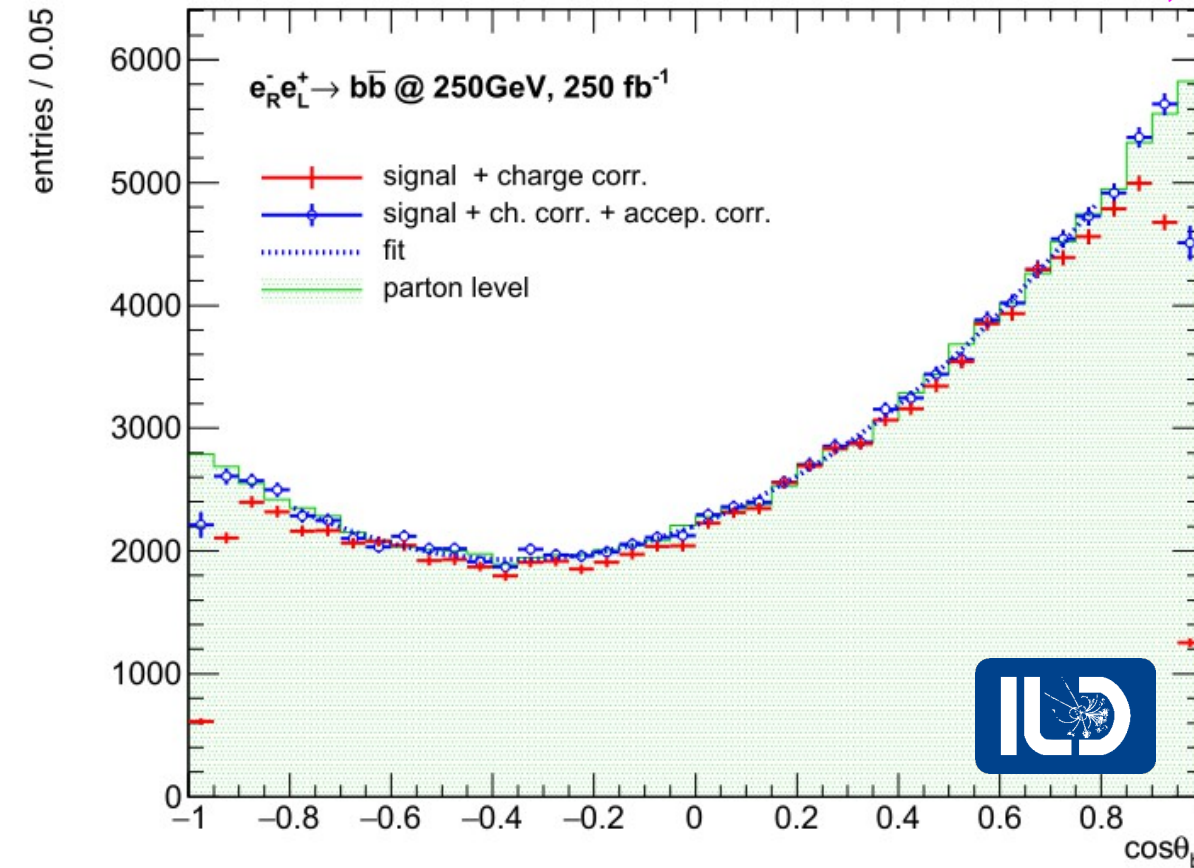
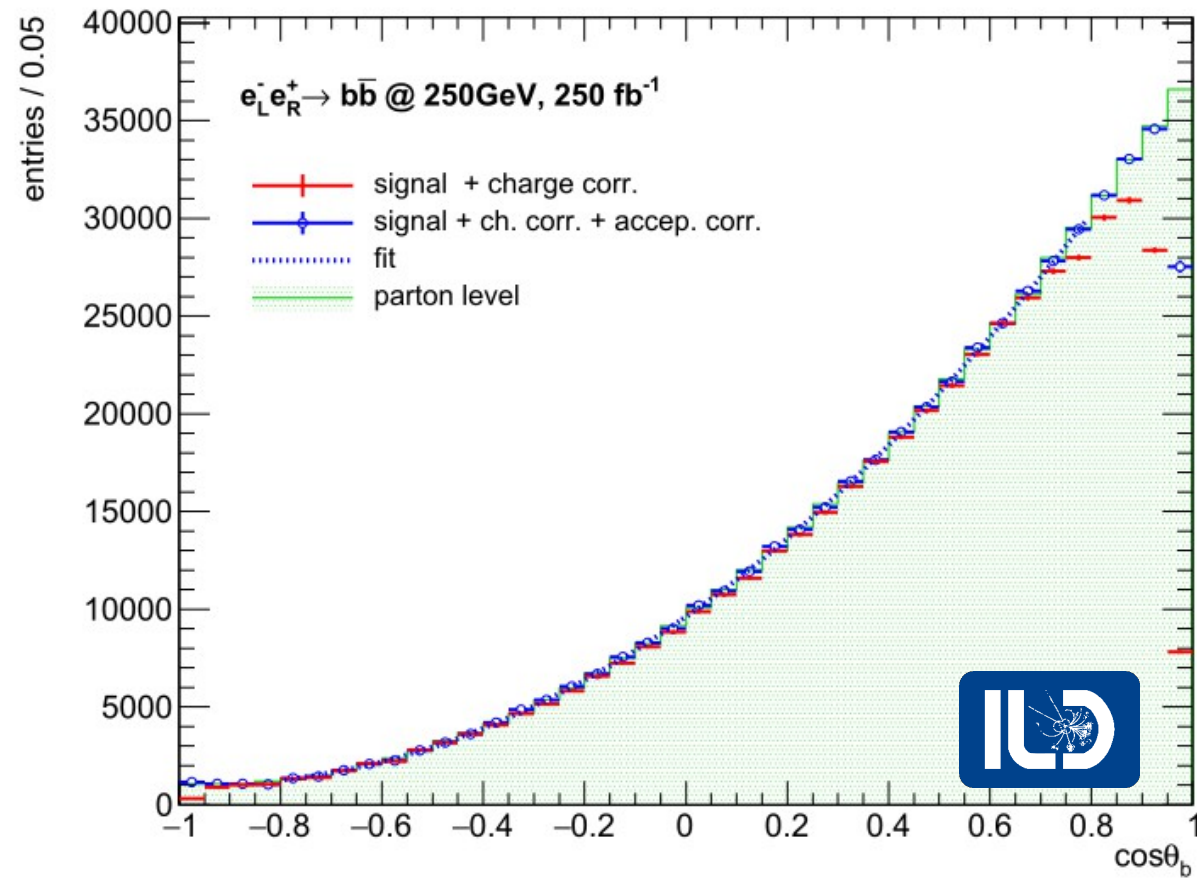


Full simulation study (with ILD concept)

- Experimental challenge: Measurement of c-quark charge on event-by-event basis

Long lever arm in $\cos \theta_c$ to extract from factors or couplings

$$\frac{d\sigma^I}{d\cos\theta} = S^I (1 + \cos^2 \theta) + A^I \cos \theta \quad I = L, R \quad \begin{array}{l} \text{Form factors/couplings} \\ \text{from S and A} \end{array}$$

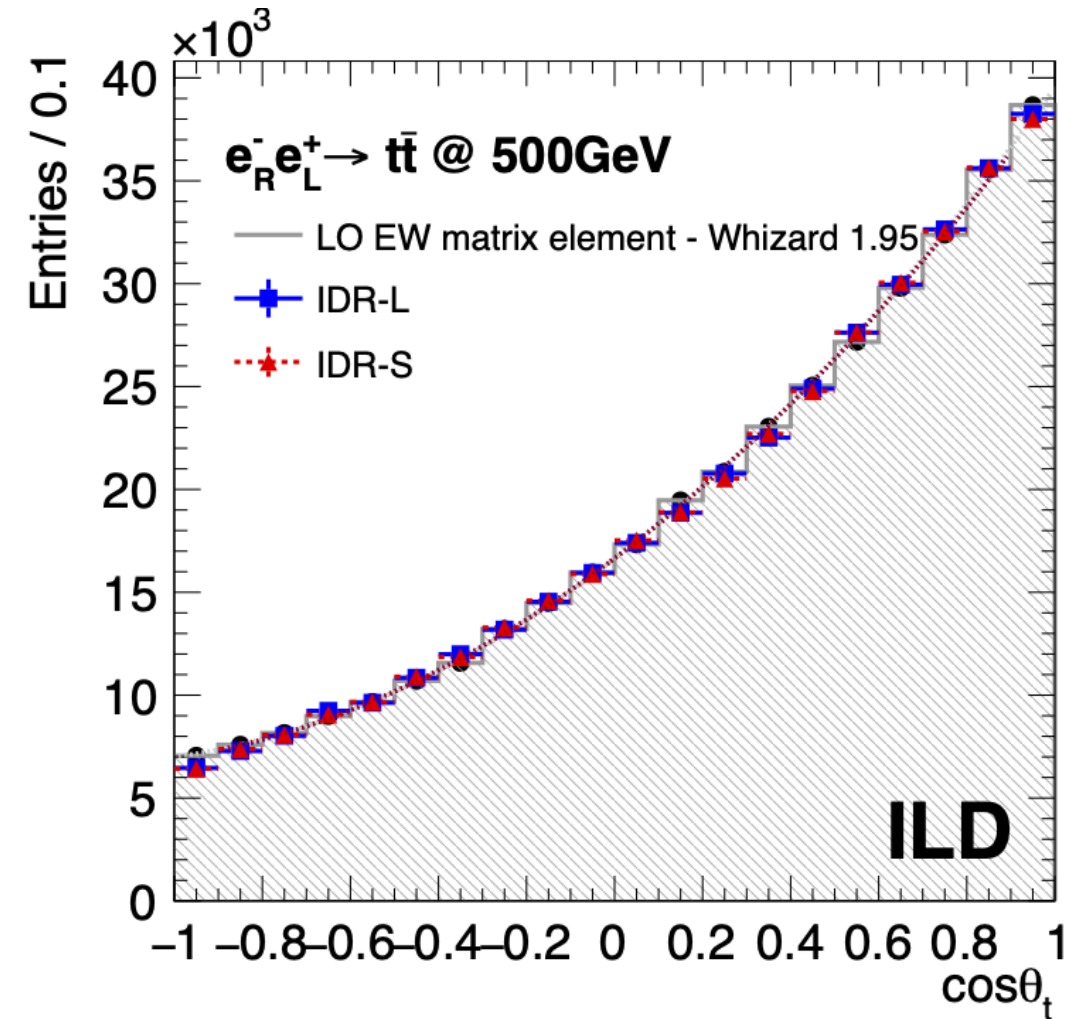
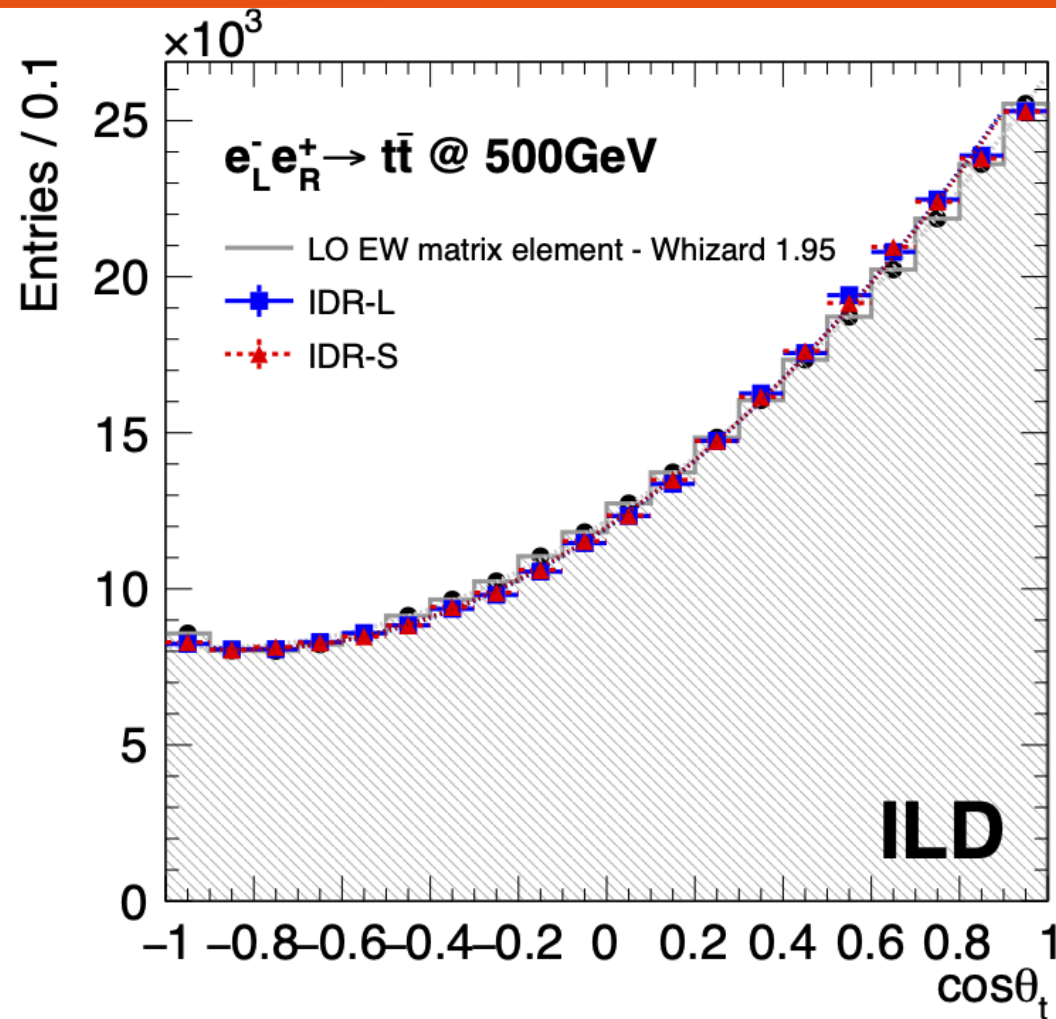


Full simulation study (with ILD concept), Benchmark reaction

- Experimental challenges:
 - Measurement of b-quark charge on event-by-event basis
 - Control of detector acceptance

Long lever arm in $\cos \theta_b$ to extract form factors or couplings

$$\frac{d\sigma^I}{d\cos\theta} = S^I (1 + \cos^2\theta) + A^I \cos\theta \quad I = L, R \quad \text{Form factors/couplings from S and A}$$



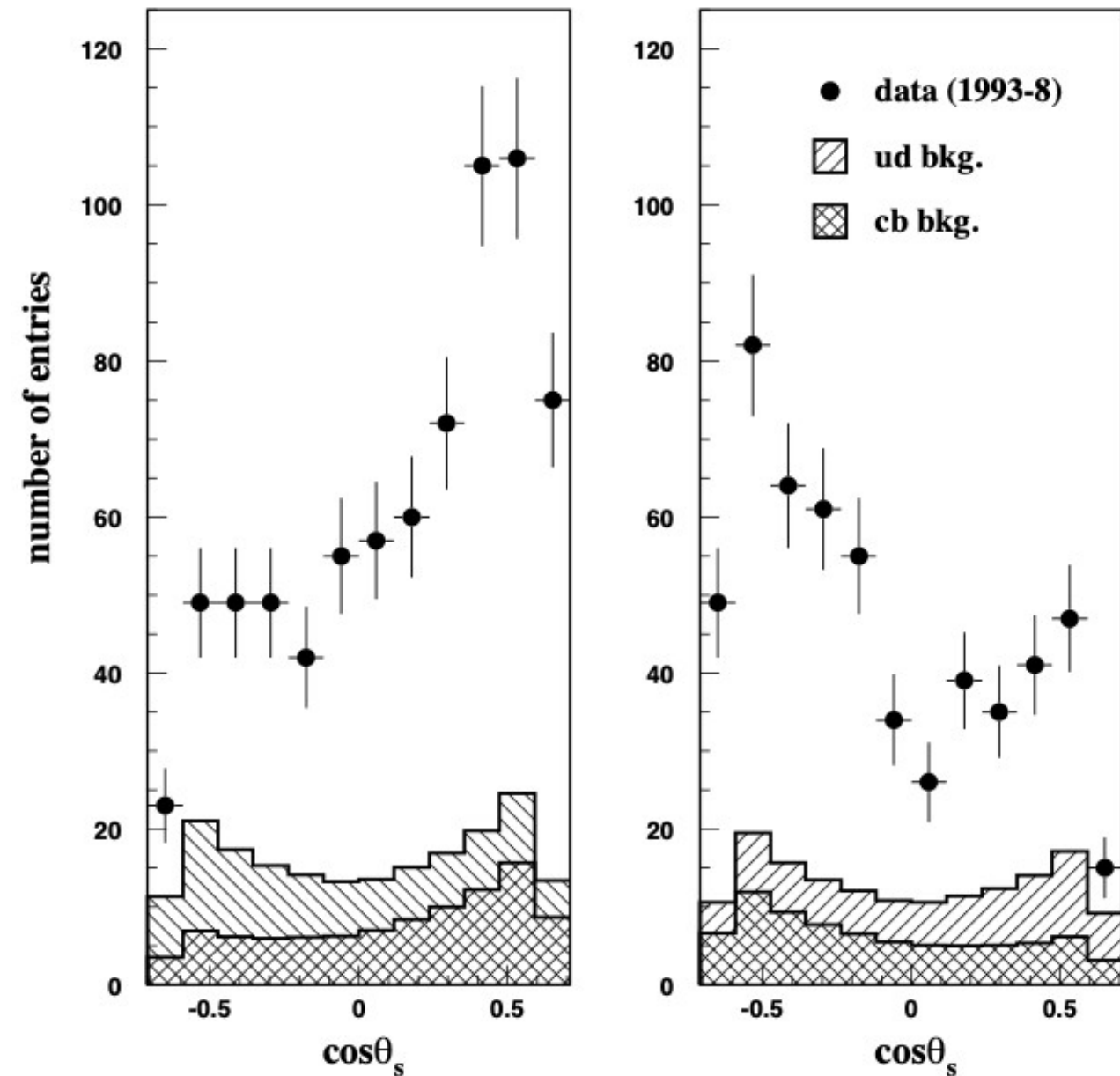
ILD-NOTE-2019-007

- [Benchmark study for ILD-IDR \(Interim Design Report\), arxiv:2003.01116](#)
- [Collaboration between IJCLab-Orsay and Tohoku University](#)
 - Master thesis of Yuichi Okugawa Tohoku University, graduated March 2020
 - Master 1 internship of Victor Lohezic (UPSaclay) in Summer 2019
 - Reminder: Master thesis of Yo Sato, graduated March 2018
 - More on cooperation UPSaclay and Tohoku University, see later

SLD Analysis at Z Pole

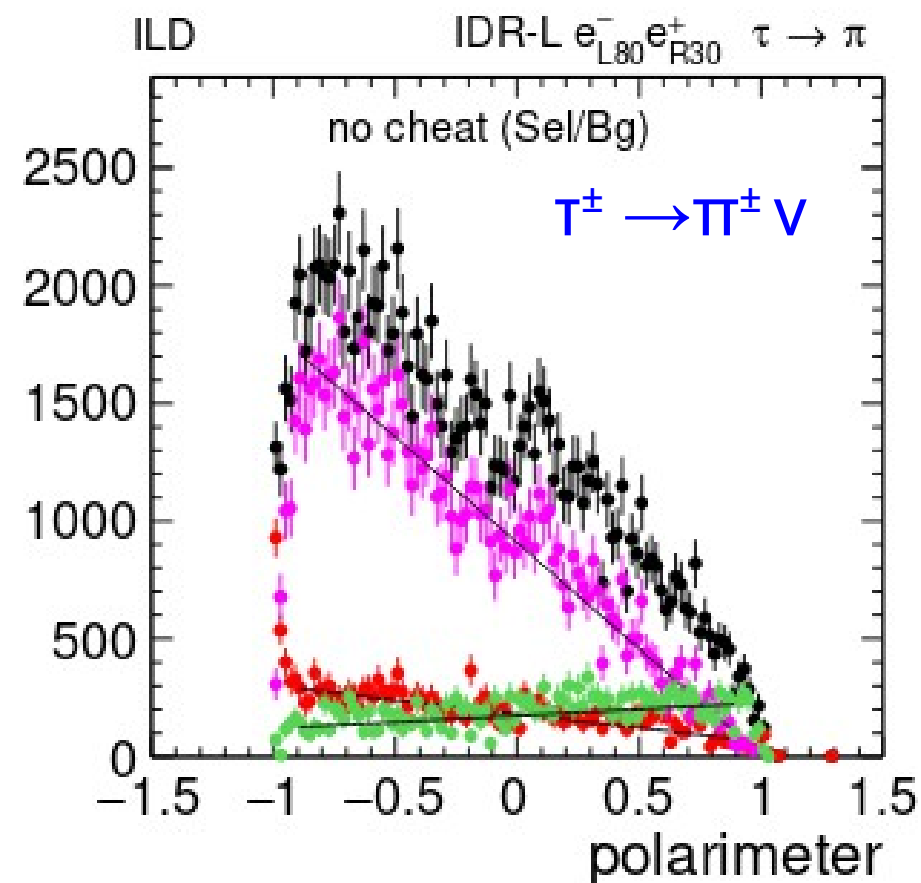
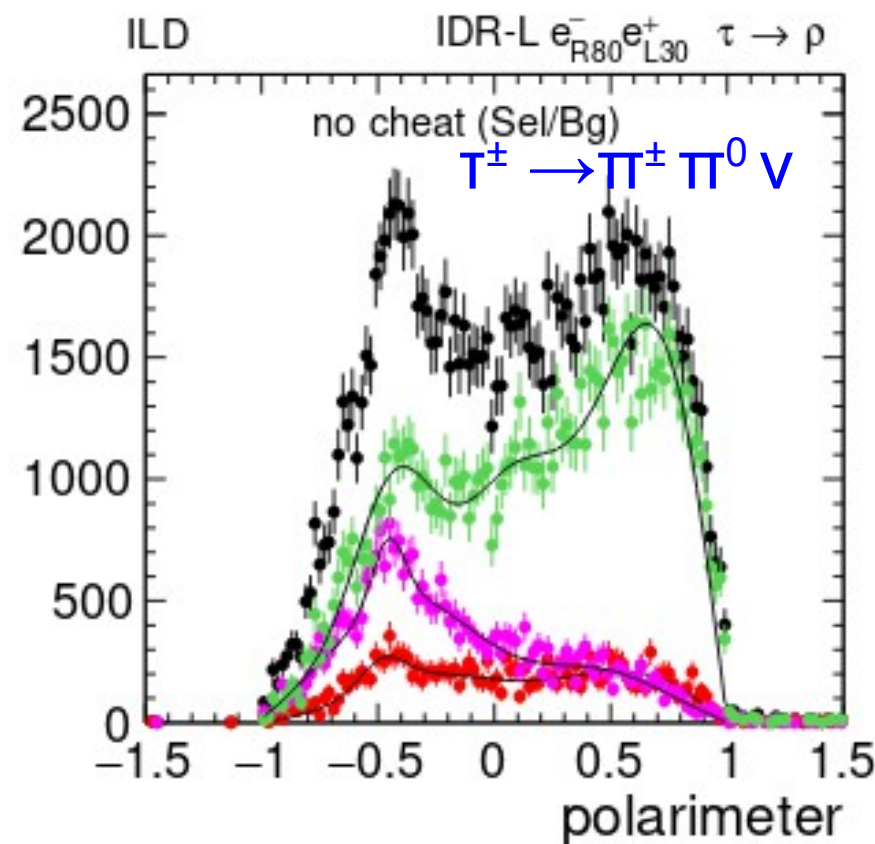
neg. polarization

pos. polarization

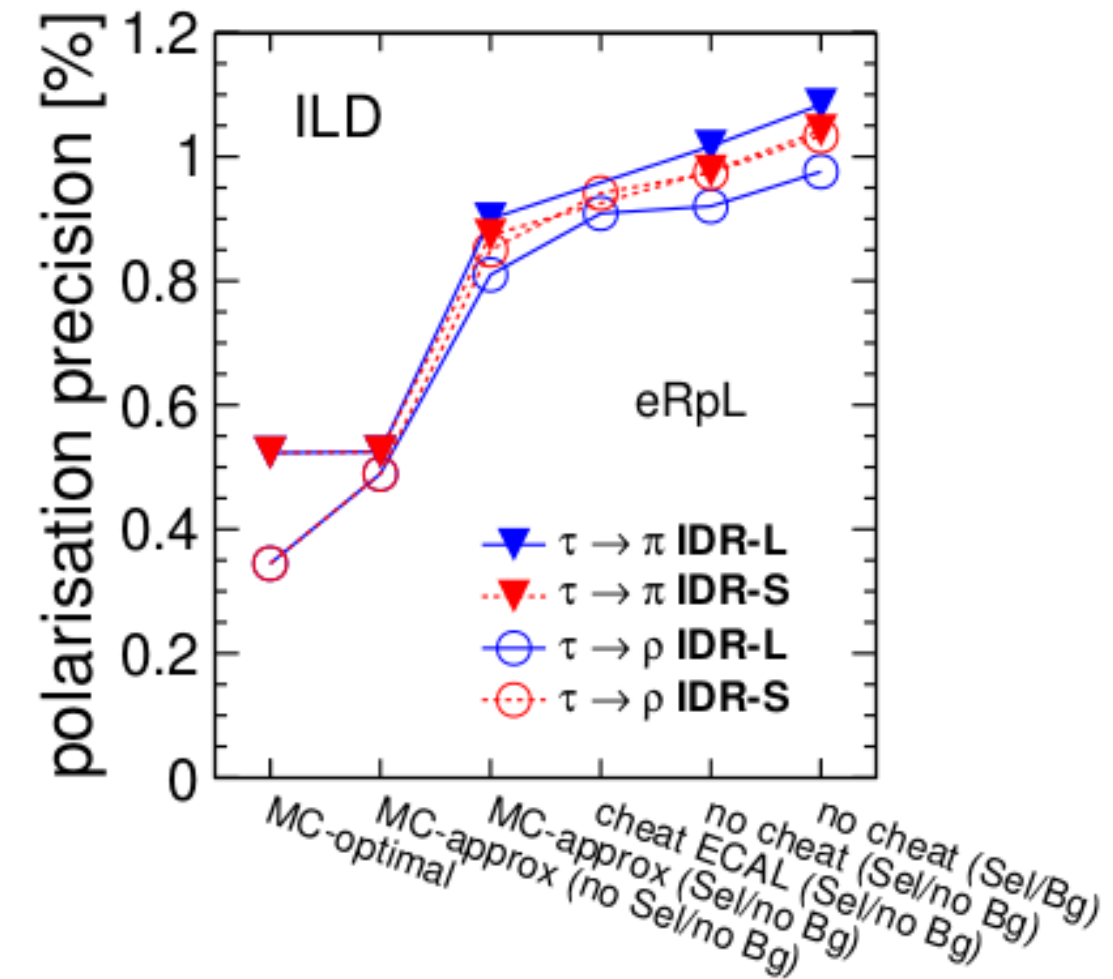


- Extend the heavy quark analyses to light quarks to get full picture
- Optimise vertexing and particle ID with full simulation studies
 - Analysis and hardware competences in IN2P3 (French) groups
 - Can timing help?

- Challenging analysis due to high tau boost
 - event reconstruction & selection
 - τ polarisation measurement
 - detector optimisation



Total, +ve helicity tau, -ve helicity tau, background

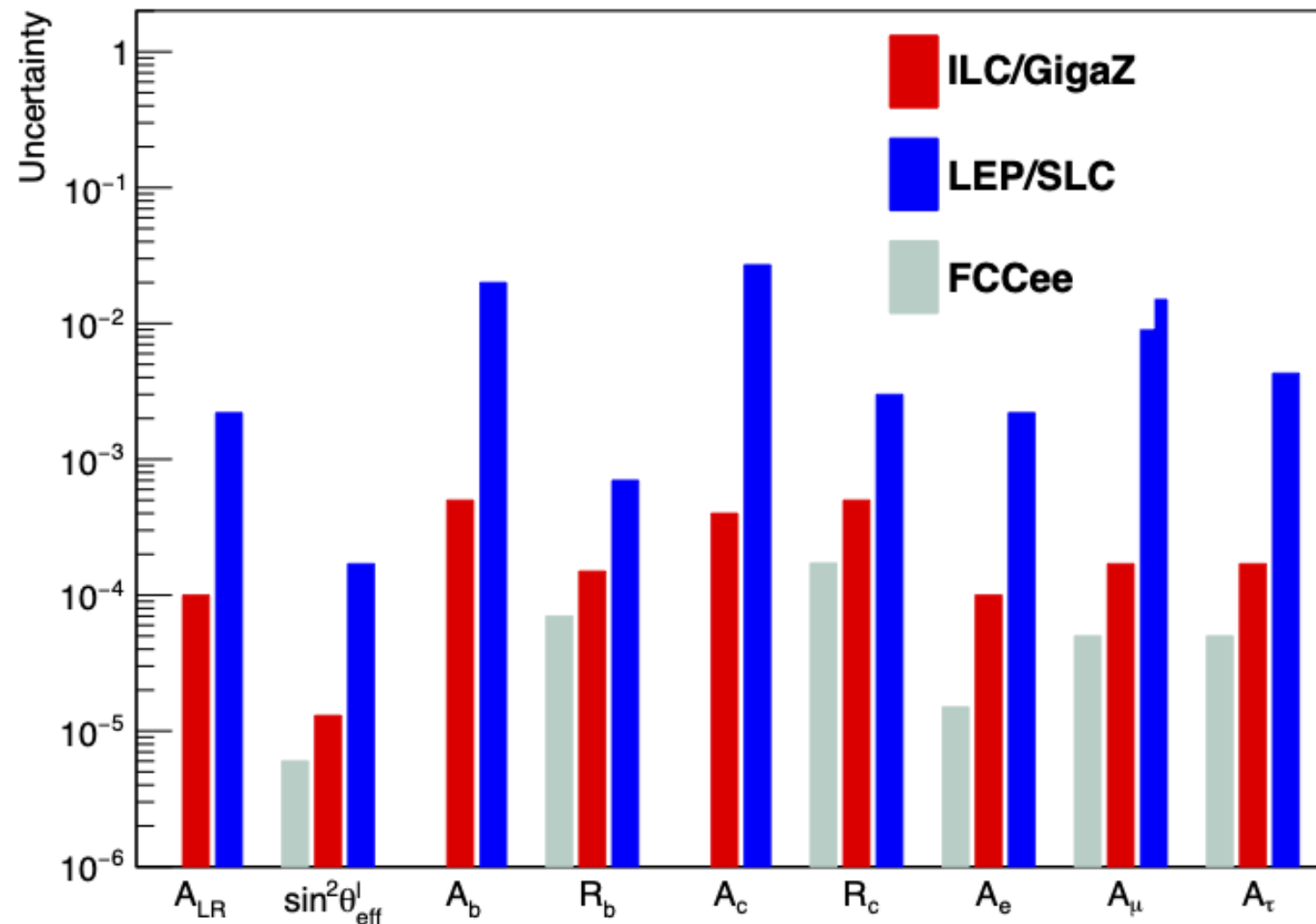


Understanding the contributions to experimental measurement precision

Note : Elaboration of common interest with study of EMD/MDM determination
 In $e^+e^- \rightarrow \tau\tau$ at Belle II

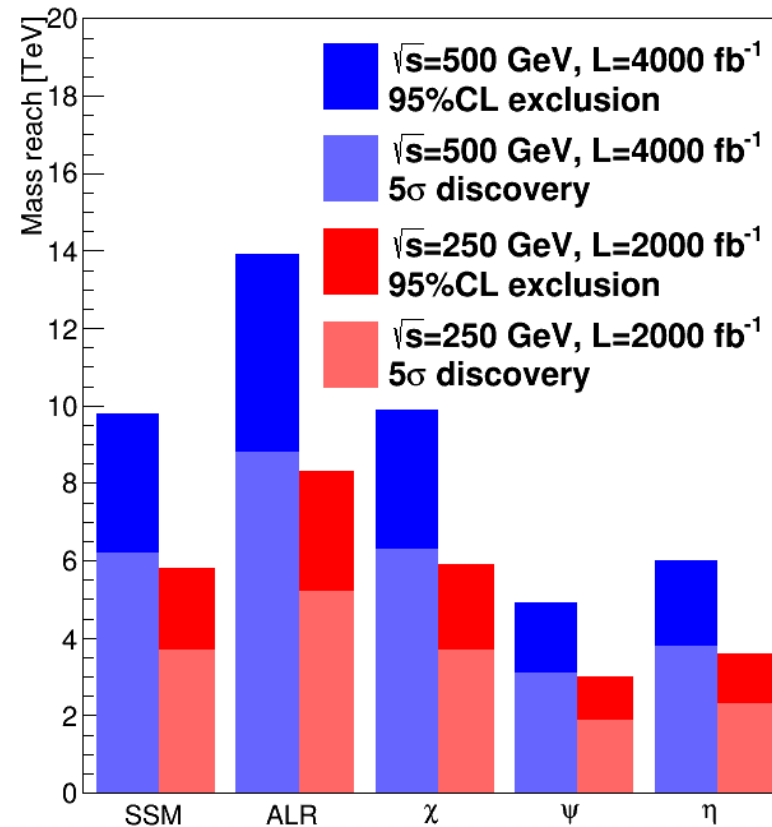
Arxiv:1908.11299

Arxiv:1905.00220

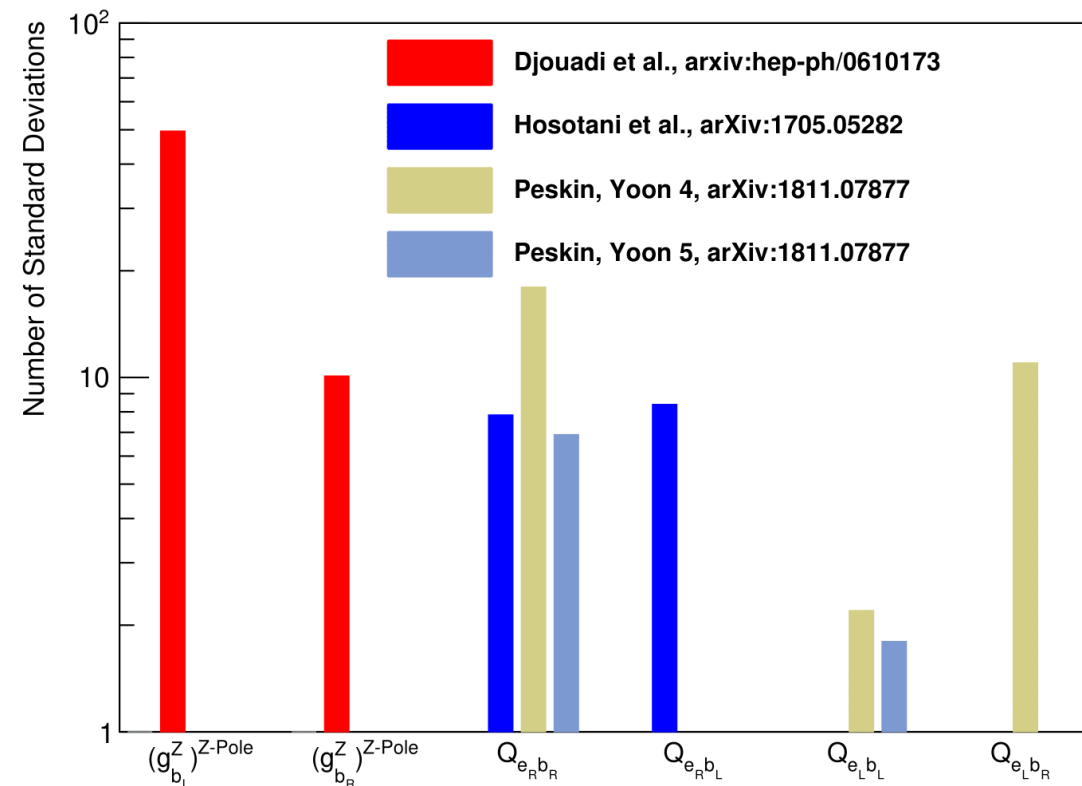


- Precise measurement of
 - Ten times better than LEP/SLD and competitive with FCC
 - **Polarisation compensates for ~30 times luminosity**
 - ... and A_{LR} at LC can benefit from hadronic Z decays
 - **No assumption on lepton universality at LC**
- Complete test of lepton universality
 - Precisions of order 0.05%
- Based on extrapolations from detailed simulations at higher energies
 - See above
- **Detailed simulations needed to scrutinise potential**

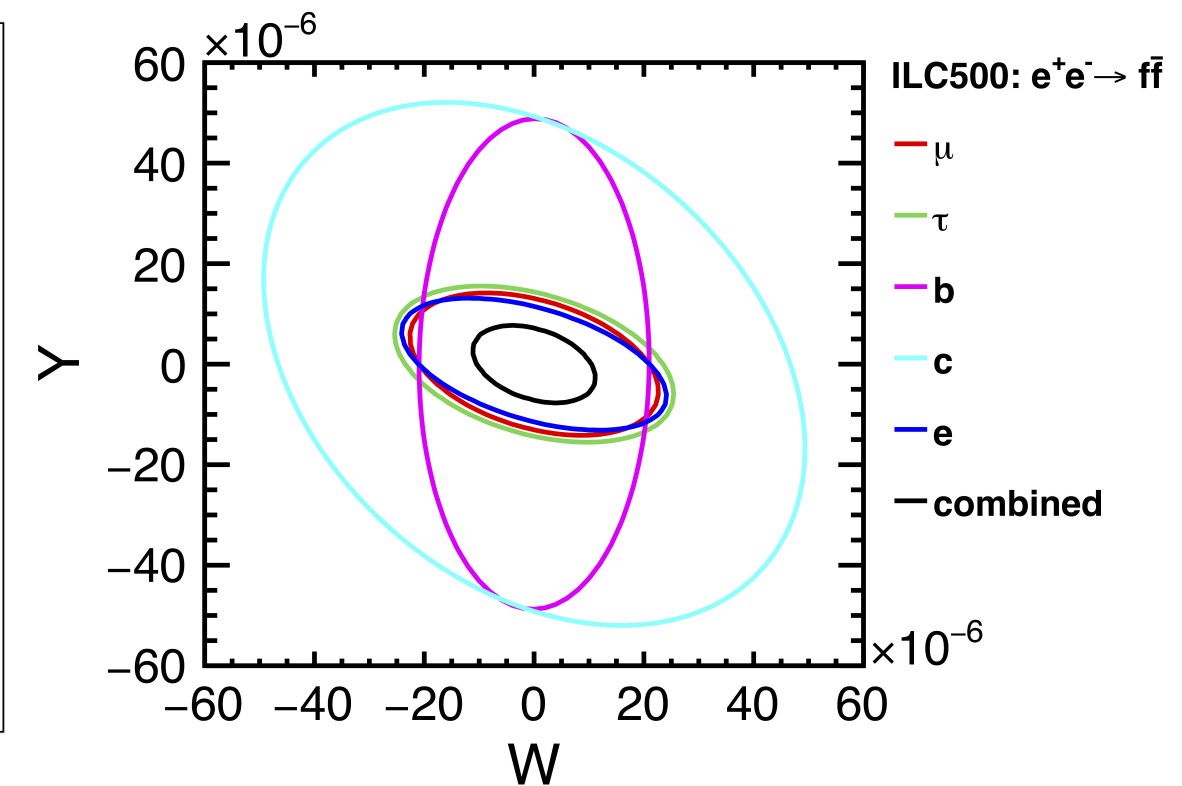
- Two fermion processes are sensitive to effects of new physics
 - New Z' bosons and new gauge symmetries



Mass reach for new vector bosons



Sensitivity to new physics in Randall-Sundrum Models
Collaboration with Y. Hosotani



New particles in loops
Oblique parameters

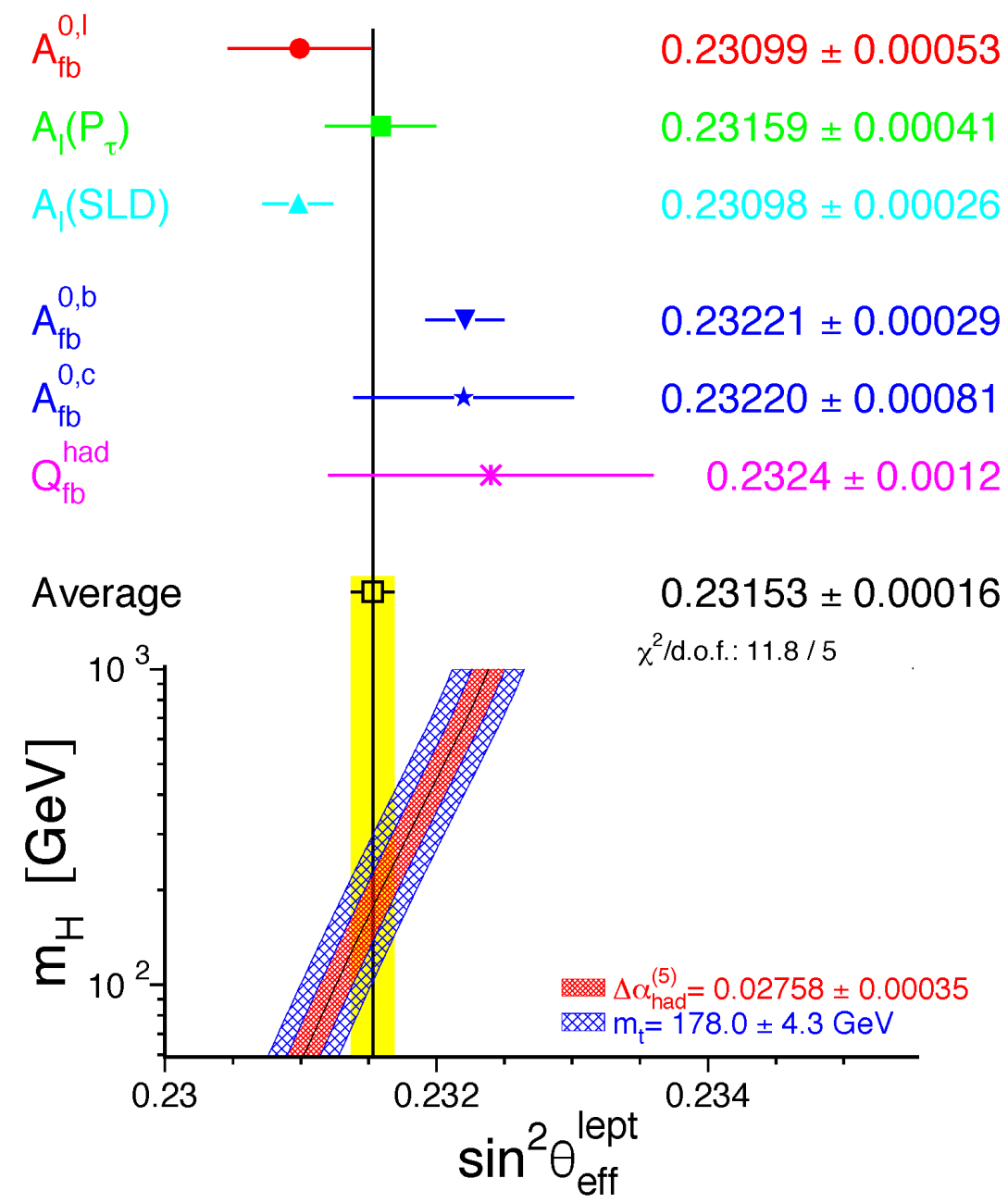
- All this requires precise Standard Model calculations
 - Paper on NLO elw. to $e^+e^- \rightarrow t\bar{t}$ in preparation (Y. Kurihara (KEK), E. Kou (IJCLab) and B. Mecaj (Uni Mainz))
 - Need three (?) loop electroweak corrections for all $e^+e^- \rightarrow f\bar{f}$ processes!

- Studies on 2f fermion processes bear rich potential for detector optimisation and discovery of new physics
- Very active collaboration between French and Japanese groups in international framework
 - Contribution to detector optimisation of ILD
 - Visible contributions to LCC input to European Strategy and corresponding national strategies
 - Regular presentation of results at international conferences and workshops
 - Common publications, some arxiv notes have to be turned into peer reviewed publication in coming funding period
 - LIA is instrumental to foster this collaboration
- Recent highlight successful completion of Master Thesis of Yuichi Okugawa of Tohoku University
 - Co-supervised by R.P.
 - Yuichi continues as PhD student at Tohoku
 - Effort going on to turn this thesis into a double-diploma with a long stay at IJCLab/UPSaclay from autumn on
- New opportunity for scientific exchange between France and Japan
 - MOU between UPSaclay and Tohoku University is about to be signed
 - It is fair to say that collaboration within TYL/FJPPL was the motor of this agreement
 - Will try to understand in coming weeks out how TYL/FJPPL can benefit from this agreement
 - PhD of Yuichi in this framework (although dedicated agreement on PhD thesis necessary → in the making)
 - Deadline for grant application in June 2020

Description	€/unit	Nb of units	Total (€)	Requested to ⁴ :
Visit to Japan	150/day	10 days	1500	IN2P3
Travel	1000	1 travel	1000	IN2P3
Total			2500	
Funding Request from KEK				
Description	k¥/Unit	Nb of units	Total (k¥)	Requested to:
Visit to France	20/day	56 days	1120	KEK
Travel	160	8 travels	1280	KEK

Remark: May ask for additional funding for a one month visit to get Yuichi “as early as possible” to France. Will become clearer between now and end of June

Backup



Most precise single Individual determination of $\sin^2 \theta_{\text{eff}}^l$ from SLC
 Left-right asymmetry of leptons

Most precise measurement of $\sin^2 \theta_{\text{eff}}^l$ from forward backward asymmetry A_{FB}^b in $ee \rightarrow bb$ at LEP
 :

Most precise determinations of $\sin^2 \theta_{\text{eff}}^l$ differ significantly
 Requires verification
Heavy quark effect?