WWdiff Focus Topic
how ILD can contribute

ECFA
European Committee for Future Accelerators

ECFA workshops on e+e- Higgs/EW/Top factory

Jenny List
A detector for Higgs Factories and beyond: ILD
CERN
15-17 January 2024

DESY.

WWdiff: General Motivation & Expert Team

Many thanks to all contributors!

- Constraints on gauge boson interactions = crucial ingredients to global interpretations, be it in SMEFT or in UV complete models

- new physics contributions to aTGCs and Higgs can be closely connected
  => complementary approaches

- coordinated by:
  - Jorge de Blas
  - Alexander Grohsjean

- further members:
  - Patrizia Azzi
  - Tim Barklow
  - Ansgar Denner
  - Wolfgang Kilian
 - JL
  - Frank Siegert

2 expert team meetings:
  - July 12
  - Sept 25

https://gitlab.in2p3.fr/ecfa-study/ECFA-HiggsTopEW-Factories/-/wikis/FocusTopics/WWdiff

Previous Studies I
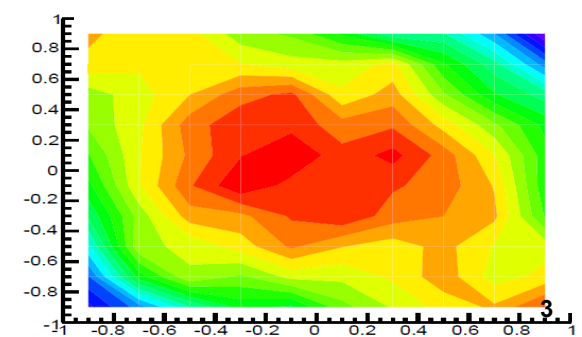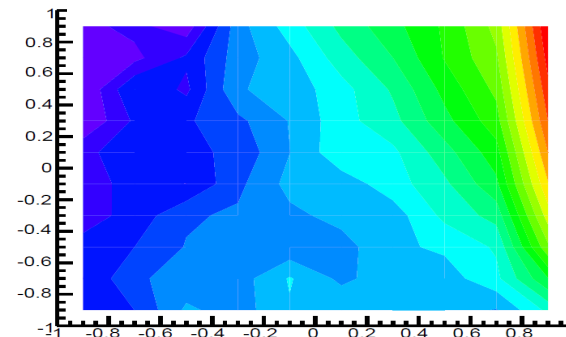## for future e+e- colliders

- Theory-level studies (Diehl et al ~2002!), optimal observables: most general set of CP conserving and CP violating triple-gauge boson couplings (28 real parameters!) can be constrained at a centre-of-mass energy of 500 GeV with polarised beams

- Detector-level simulations (Marc

  - 500 GeV and 1 TeV,

  - joint extraction of 3 TGCs (LE poalrisations

  - LO MC

  - restricted to WW -> munuqq

- 3 TGCs and their covariance matrix passed on to global interpretations, e.g. SMEFT fits
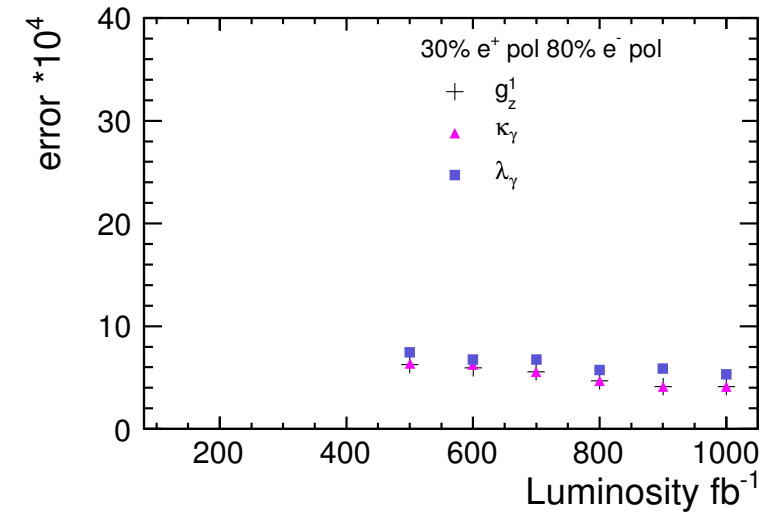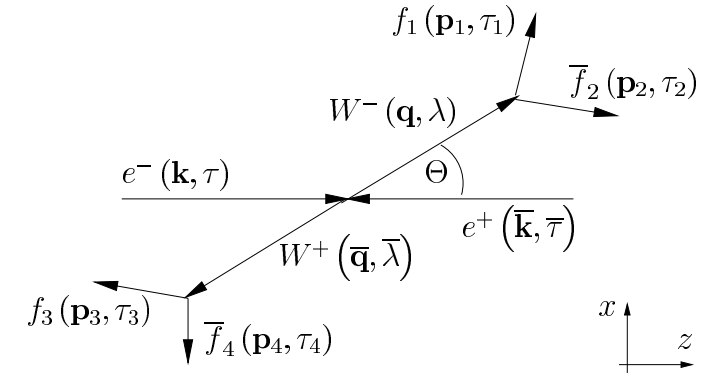
Previous Studies II

for future e+e- colliders

- Extrapolation to 250 GeV (Karl ~2018)

- More recently:

  - statistical optimal observables for all the CP even interactions contributing at LO in SMEFT used in global fits, (but only) based on theory-level distributions (de Blas et al).

  - detailed study of ability to reduce impact systematics by combined fits to differential cross sections of 2f and 4f processes including many nuisance parameters at 250 GeV using LEP parametrisation (Beyer)

TGC Limits @ 68% CL
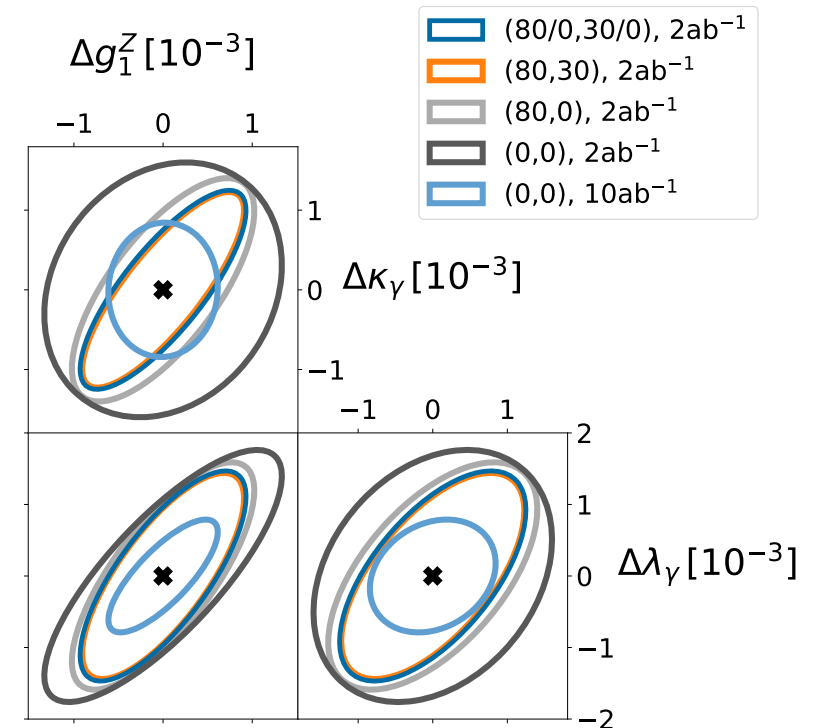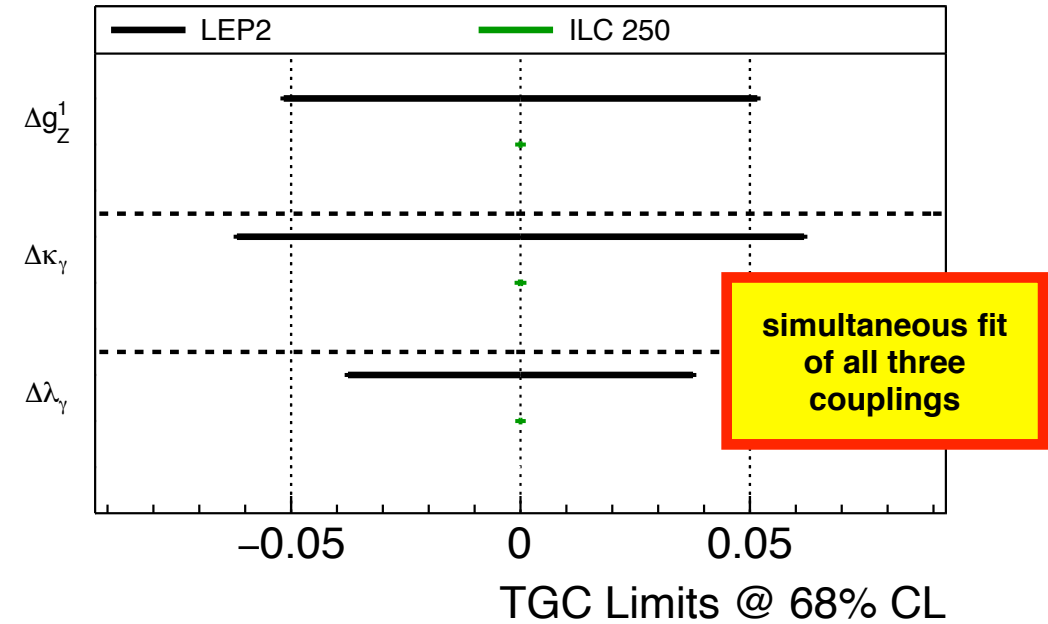
Goals
of this focus topic

- Main objective:
  understand the full potential of e+e- colliders wrt gauge boson interactions,
  using the full differential information from W-pair and **single-W events**
  to extract CP even and CP odd couplings,
  based on detailed detector simulation with assessments of systematic uncertainties,
  at all centre-of-mass energies.

- Also important:
  establish the complementarity with HL-LHC and to clarify gain expected at future e+e- colliders.
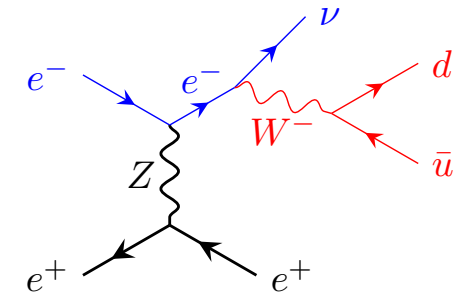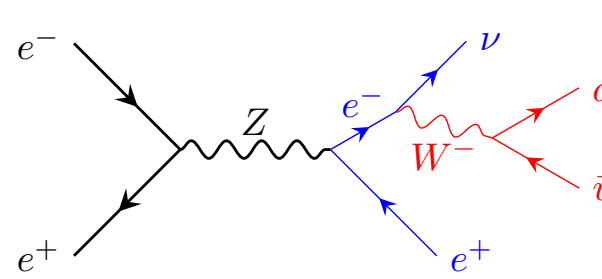
Theory state-of-the-art
of this focus topic

- LEP2 times:
  - differential cross section for W-pair production including W decays only known within the double-pole approximation,
  - implemented in YFSWW and RacoonWW

- Later:
  - complete electroweak O(alpha) corrections in the SM calculated for some charged-current four-fermion production processes
  - available in unpublished Racoon4f.
  - on top: also the LL ISR effects beyond O(alpha) in the structure-function approach

- SM extensions like the dimension-six SMEFT:
  - doable thanks to UFO models at LO
  - automated calculation of NLO QCD corrections via the UFO model SMEFT@NLO.
  - automated calculation of NLO electroweak corrections will be completed and available in Madgraph and Whizard (expected to be large at high energies)

To-dos
where you can join!

- full detector simulation WW and single-W processes at all energies

  - event selection - all channels, incl. qqqq and single-W (forward electrons!)

  - reconstruction of decay and production angles and (statistically) optimal observables

  - systematic uncertainties / nuisance parameters

- definition of interface between global interpretations and experimental studies, incl. systematics, nuisance parameters etc

- extension of global interpretations - and the required experimental inputs! - to CP violating couplings

- interplay / combination with HL-LHC - any chance of updated projections?

- simple PR message: which energy scales can we probe with these measurements?

Activities so far

is there more?

- last ILD qqlnu analysis: https://github.com/ILDAnaSoft/ILDbench_WWqqlnu
  => Graham Wilson…

- recent MC samples in ILD available at 250 GeV

- available MC samples from other detector concepts?

- work in the context of PhD thesis Leonhard Reichenbach (U Bonn / CERN, mainly CLD)

  - improve tracking for electrons, especially in the forward region (GSFs, use info from reconstructed Brems photons…?), understand role of material budget

- work in the context of Master thesis Andre Silva (U Coimbra / DESY, ILD)

  - semileptonic event selection at 250 GeV

- fully hadronic channel: some synergies with U Einhaus' work for CKMWW topic

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> **differential WW cross-section needed as input for next generation SMEFT fit of Higgs & EW sector - we should not leave this to theorists!**