WWdiff Focus Topic

Jenny List
IDT-WG3 Open Physics Meeting
22 February 2024

DESY.

WWdiff: Quick Overview

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

Motivation

- 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

Expert Team (“done”)

- coordinated by: Jorge de Blas & Alexander Grohsjean
- further members: Patrizia Azzi, Tim Barklow, Ansgar Denner, Wolfgang Kilian, JL, Frank Siegert
- 2 meetings in 2023: July 12, September 25

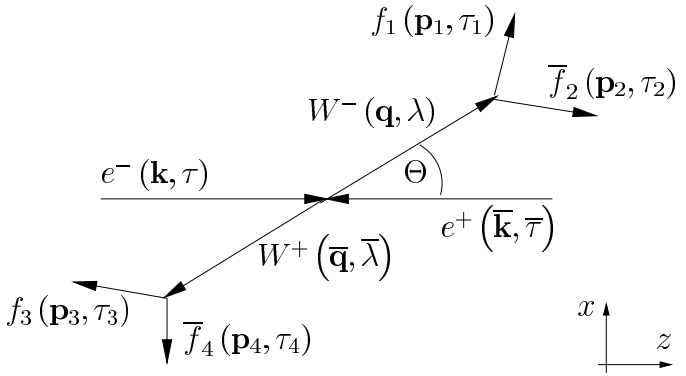
Now forming: team to work on this focus topic

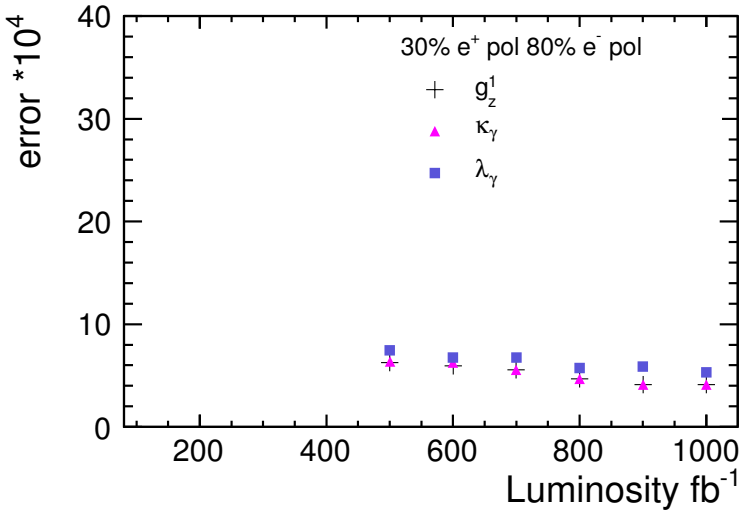
- Leonhard Reichenbach (CERN, CLD), Andre Silva & UE/JL (DESY, ILD), Jiayin Gu (Fudan, CEPC)
- coordinated by: Jorge de Blas & Alexander Grohsjean

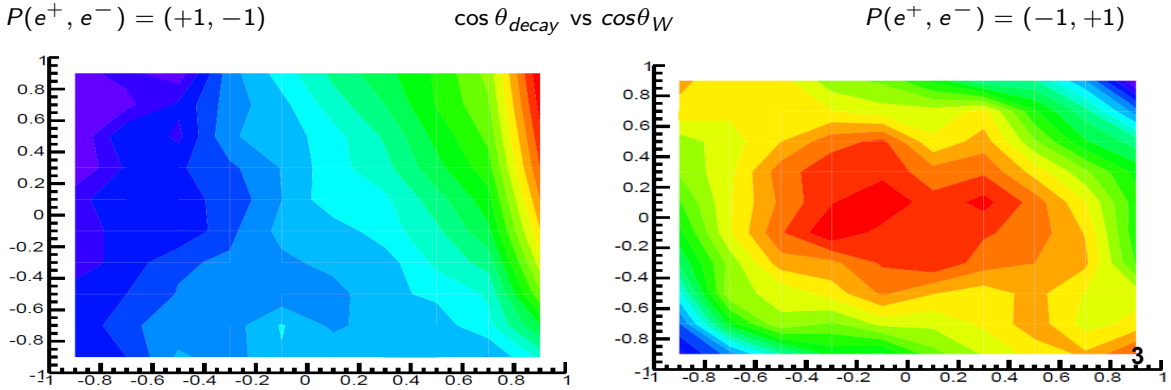
Previous Studies I

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 (Marchesini, Rosca, Barklow ~2011 ff):
  - 500 GeV and 1 TeV,
  - joint extraction of 3 TGCs (LEP parametrisation) and beam poalrisations
  - LO MC
  - restricted to WW -> munuqq and WW->enuqq
  - 3 TGCs and their covariance matrix passed on to global interpretations, e.g. SMEFT fits



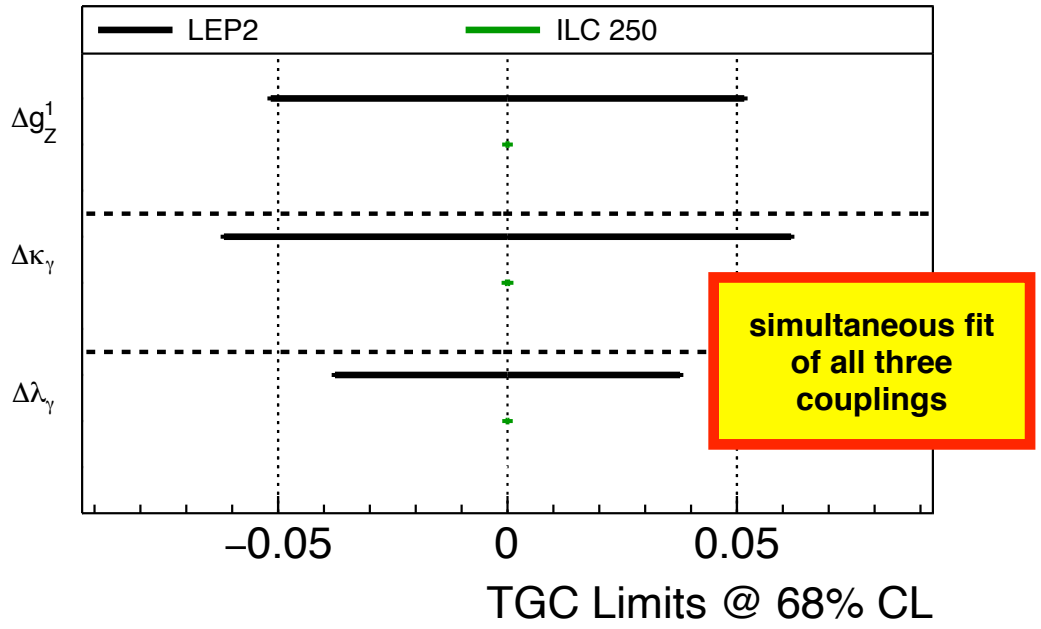


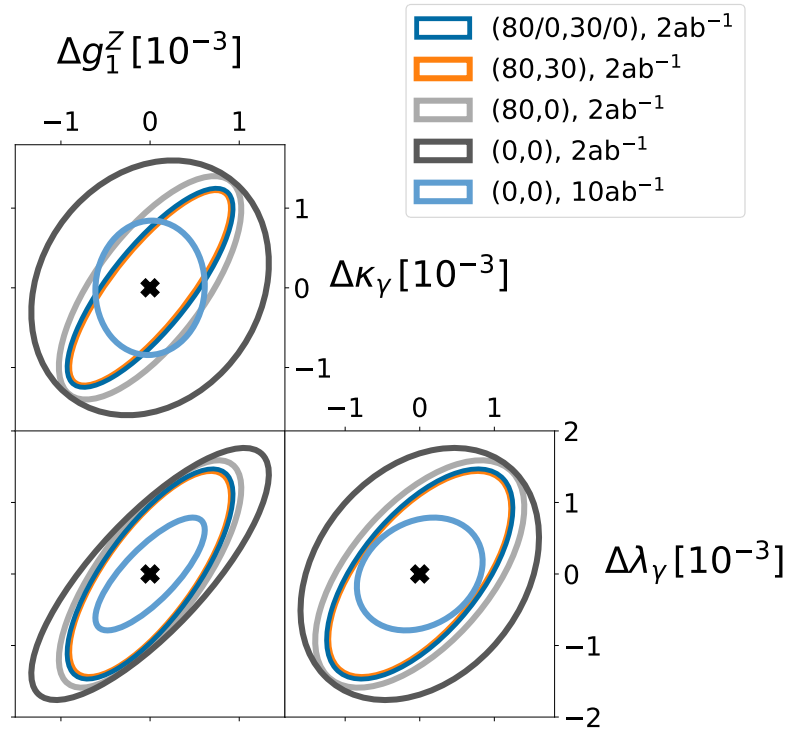


Previous Studies II

for future e+e- colliders

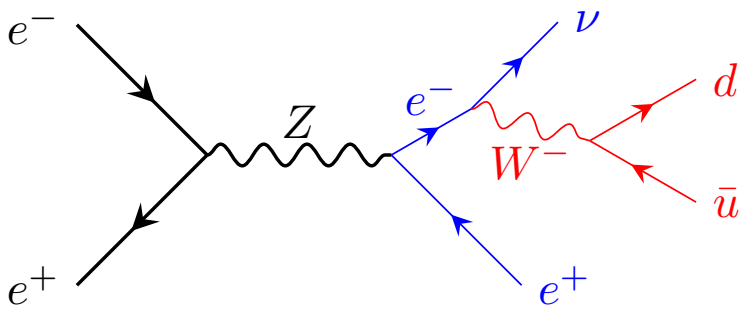
- Extrapolation to 250 GeV (Karl ~2018)
- More recently:
  - statistical optimal observables for all the CP even interactions contributing at LO in SMEFT used in global fits, (but only) based on theory-level distributions (de Blas et al).
  - **detailed study of ability to reduce impact systematics by combined fits to differential cross sections of 2f and 4f processes including many nuisance parameters at 250 GeV using LEP parametrisation (Beyer)**

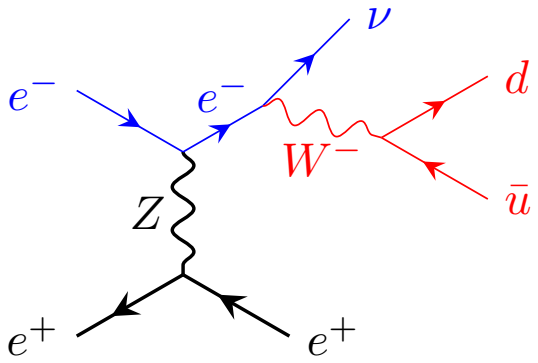




Goals

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?

Ressources to start from

is there more?

- last ILD qqlnu analysis: https://github.com/ILDAnaSoft/ILDbench_WWqqlnu
  => Graham Wilson…
- recent MC samples in ILD available at 250 GeV
  => will soon convert to mini-DST [1] incl. latest particle ID and flavour tag informations
- available MC samples from other detector concepts?

[1] MiniDST: high-level reconstructed information and MC truth, root-readable, cf https://github.com/ILDAnaSoft/miniDST

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Interested?
Sign up: http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=ECFA-WHF-FT-WWdiff

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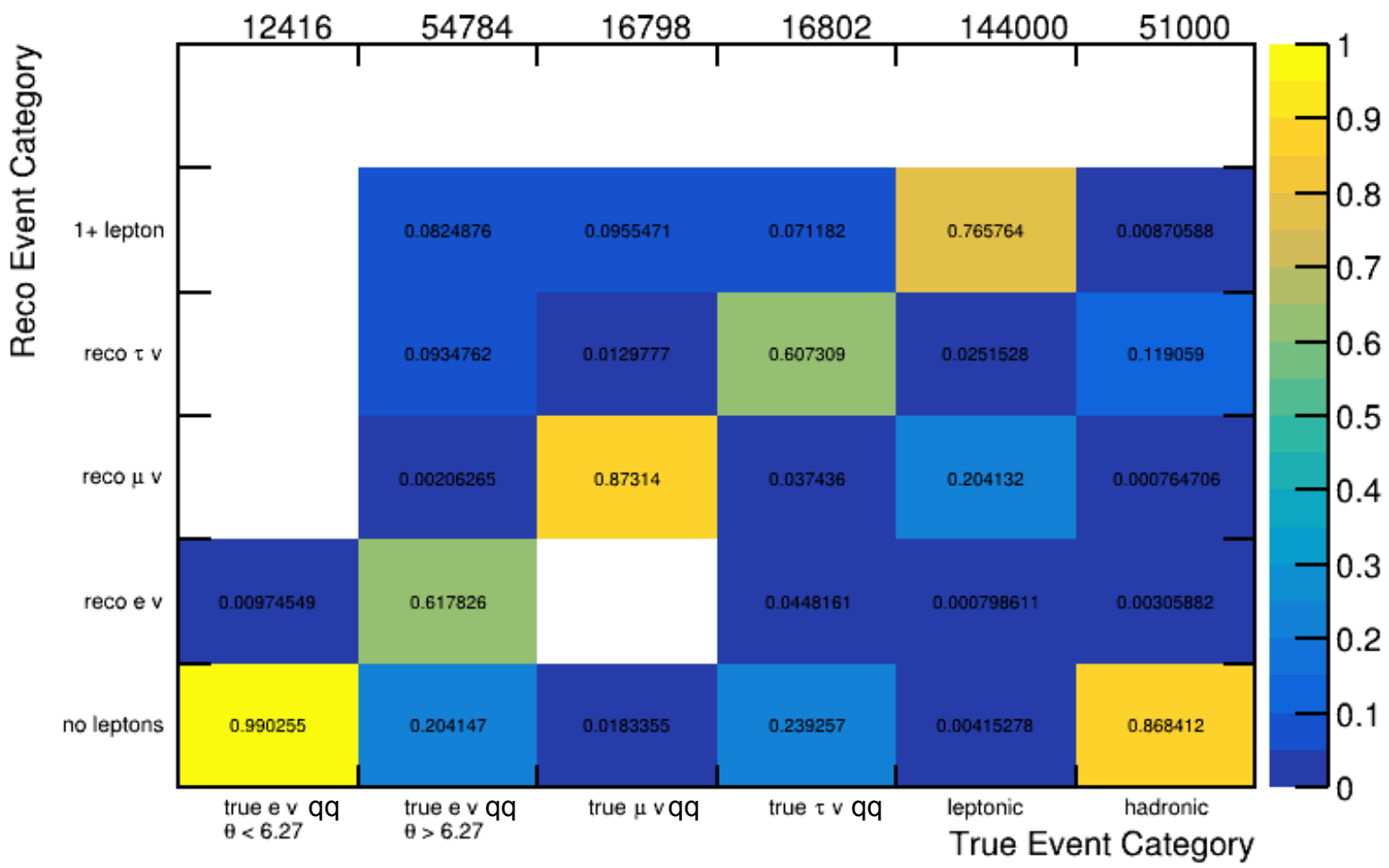
https://github.com/ILDAnaSoft/miniDST

First Steps - ALL WORK IN PROGRESS -

Channel classification via number / flavour of isolated leptons (Andre Silva)

- Number of reconstructed isolated leptons usind IsolatedLeptonTagger from MarlinReco/Analysis as provided on miniDST
- hadronic: 87% no isolep found, 12% a (fake) tau found
- leptonic: 77% 2 isolep found, missing cases mostly taus
- taunuqq: 61% tau found, 24% 0 isolep found
- munuqq: 87% mu found, 10% additional isolep found
- enuqq:
  - large # of very forward e from single-W diagrams
  - theta > 6.27^{deg} : 62% e found 20% no lep, 9% (fake) tau found, 8% additional iso lep found



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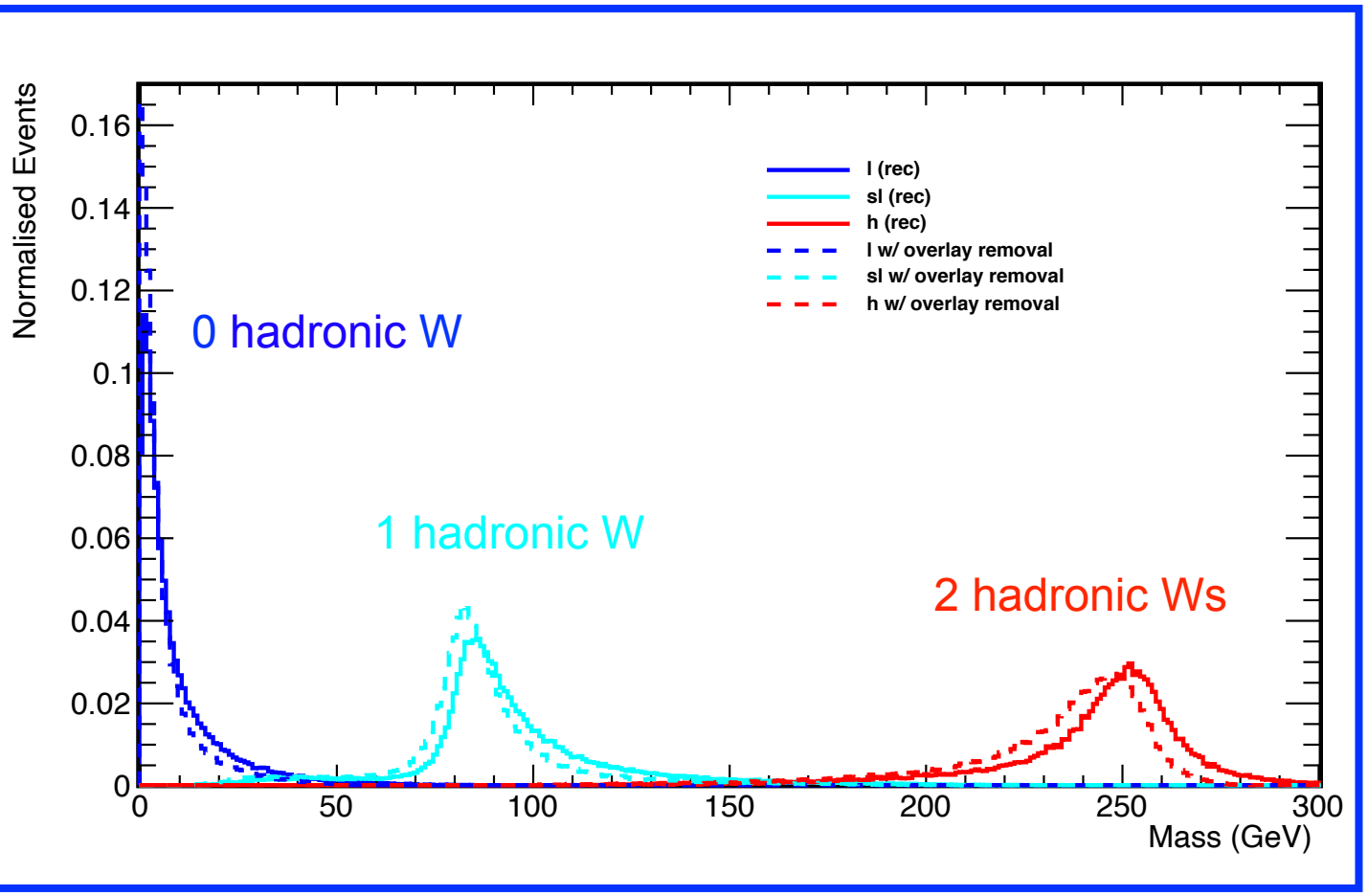
Channel classification - invariant mass of hadronic system (Andre Silva)

- invariant mass of all PFOs after removing found isolated leptons and isolated photons (ISR)



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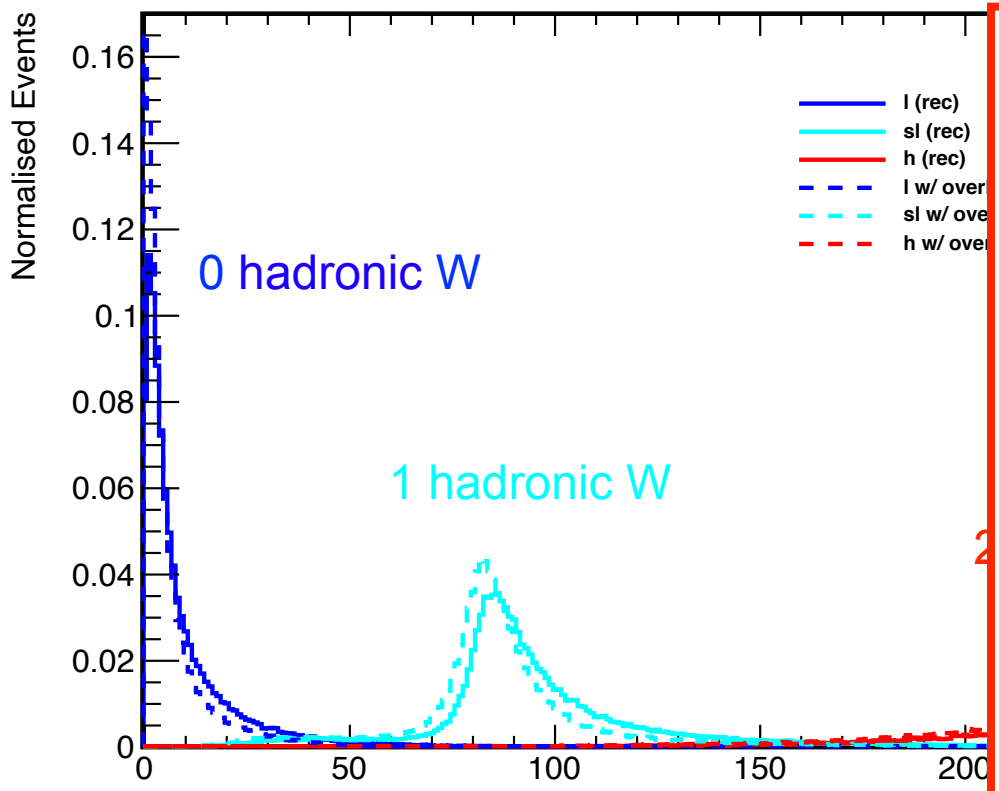

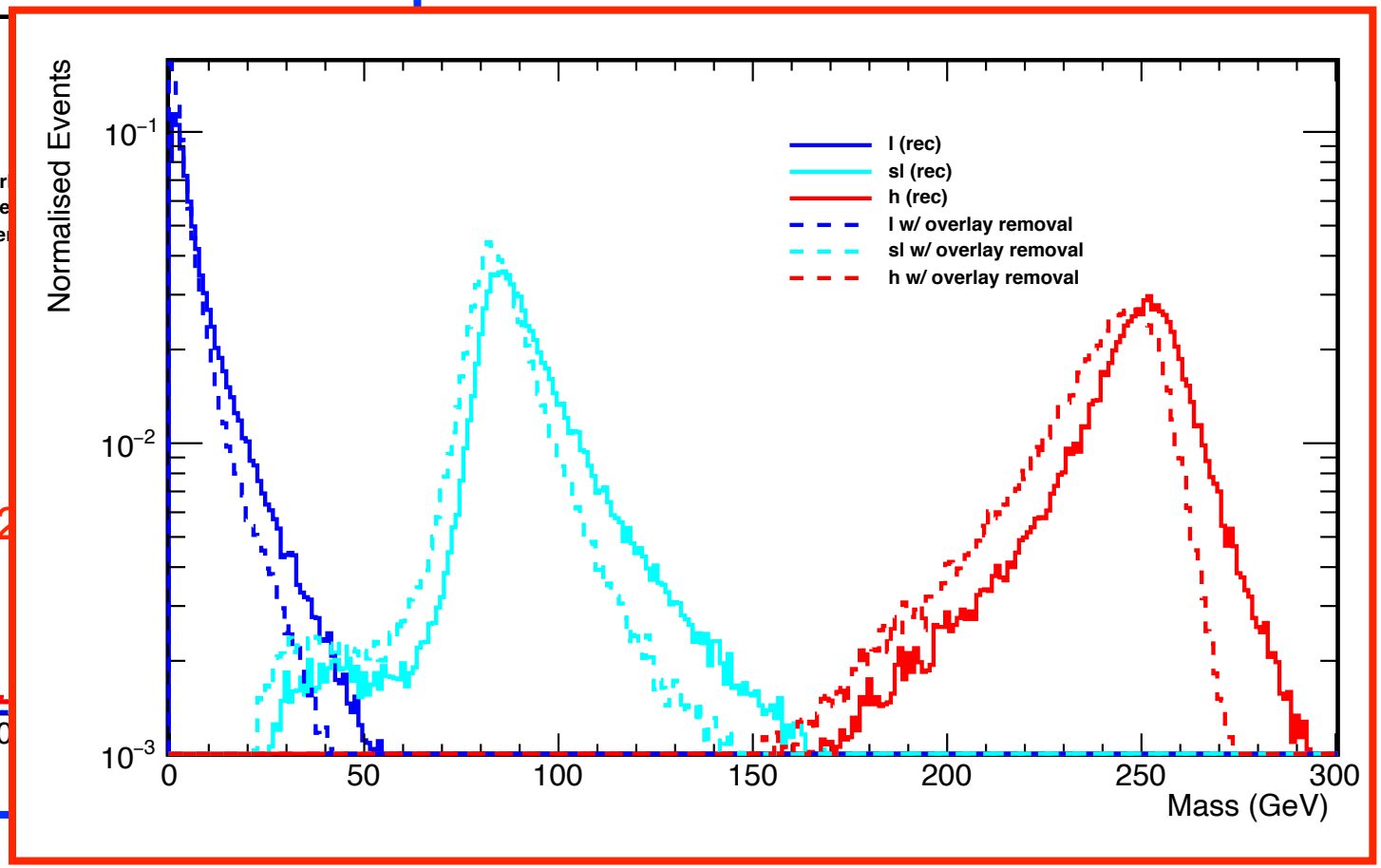

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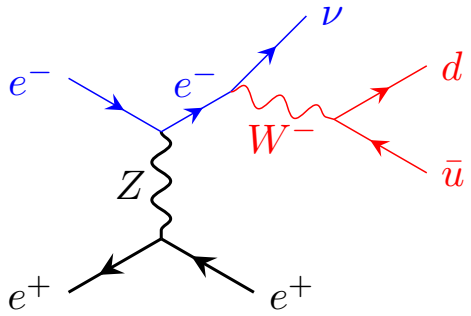
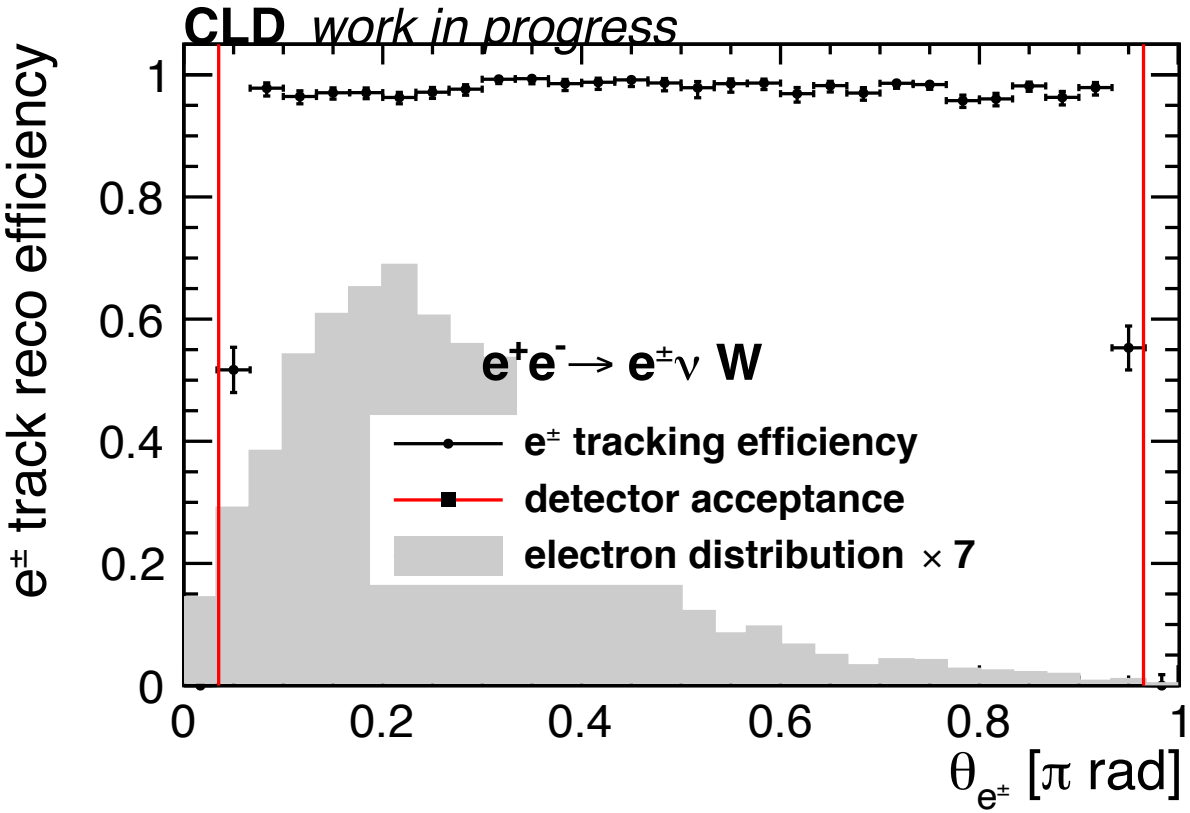
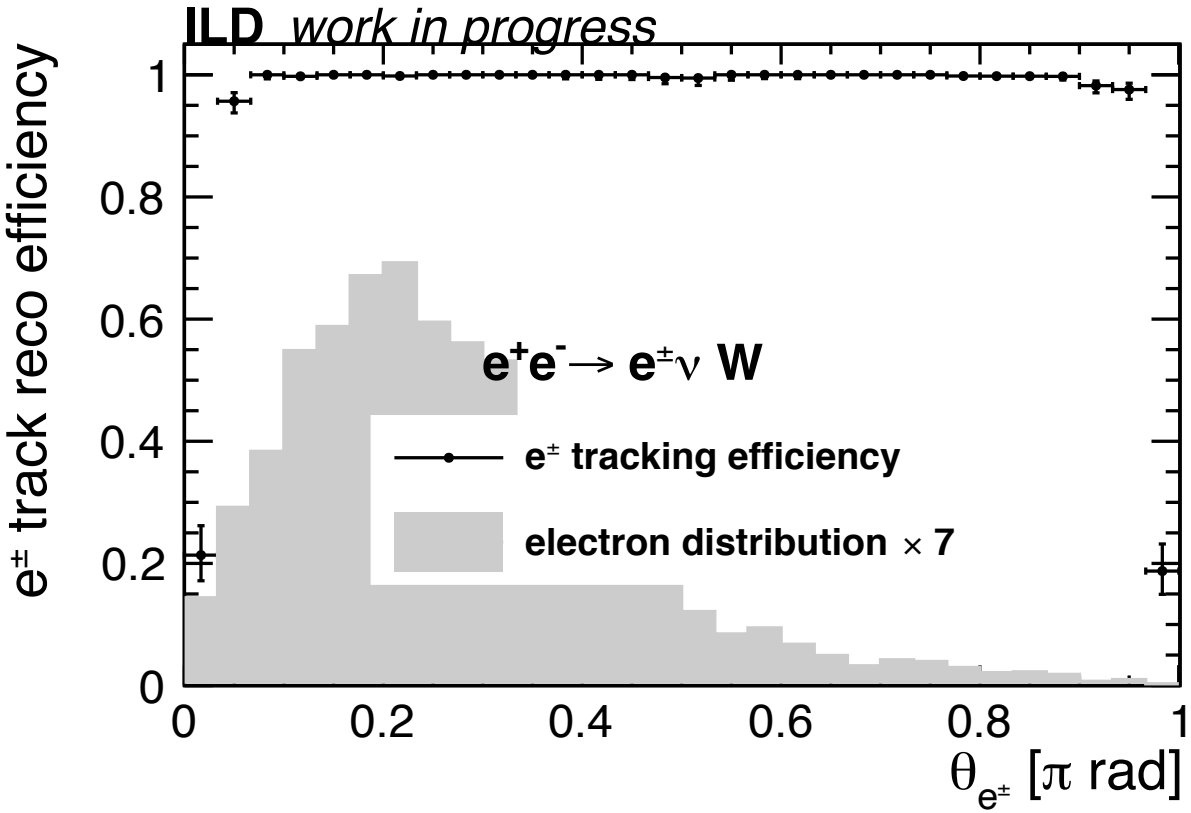
The enuqq channel - WW and singleW - tracking efficiency (Leonhard Reichenbach)



- **vs polar angle** for electron/positron (on eLpR sample, i.e. singleW dominated)





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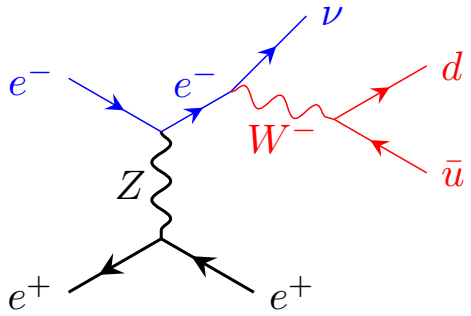
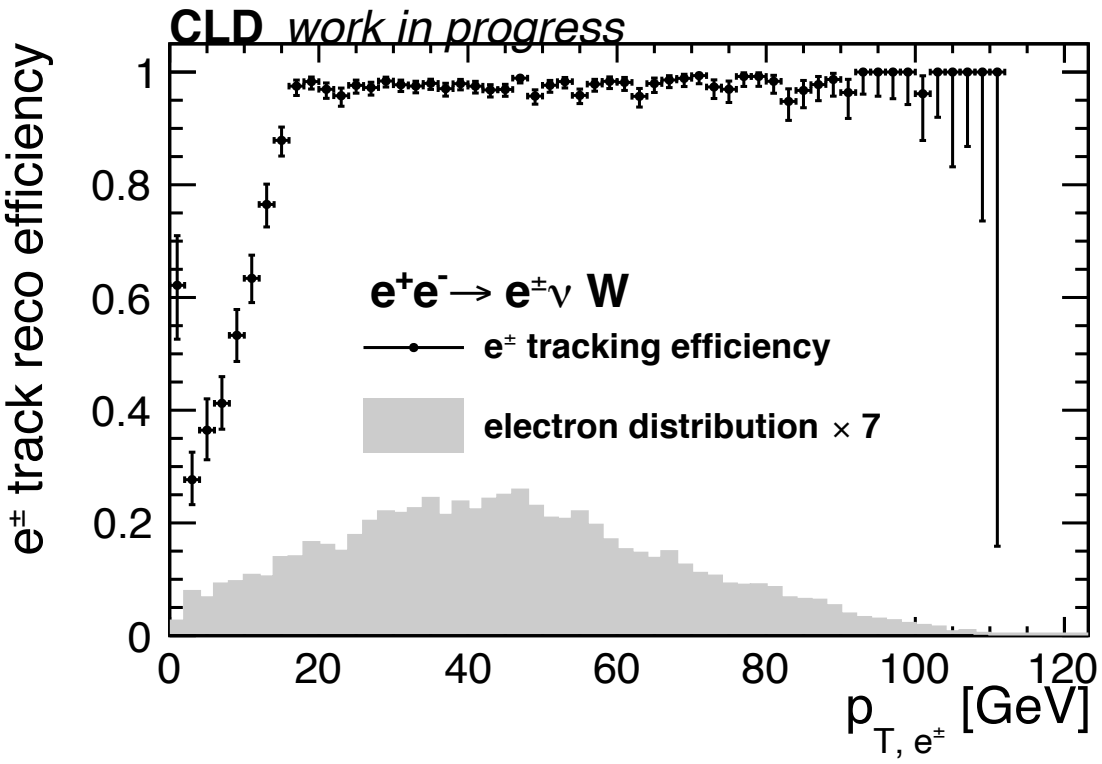
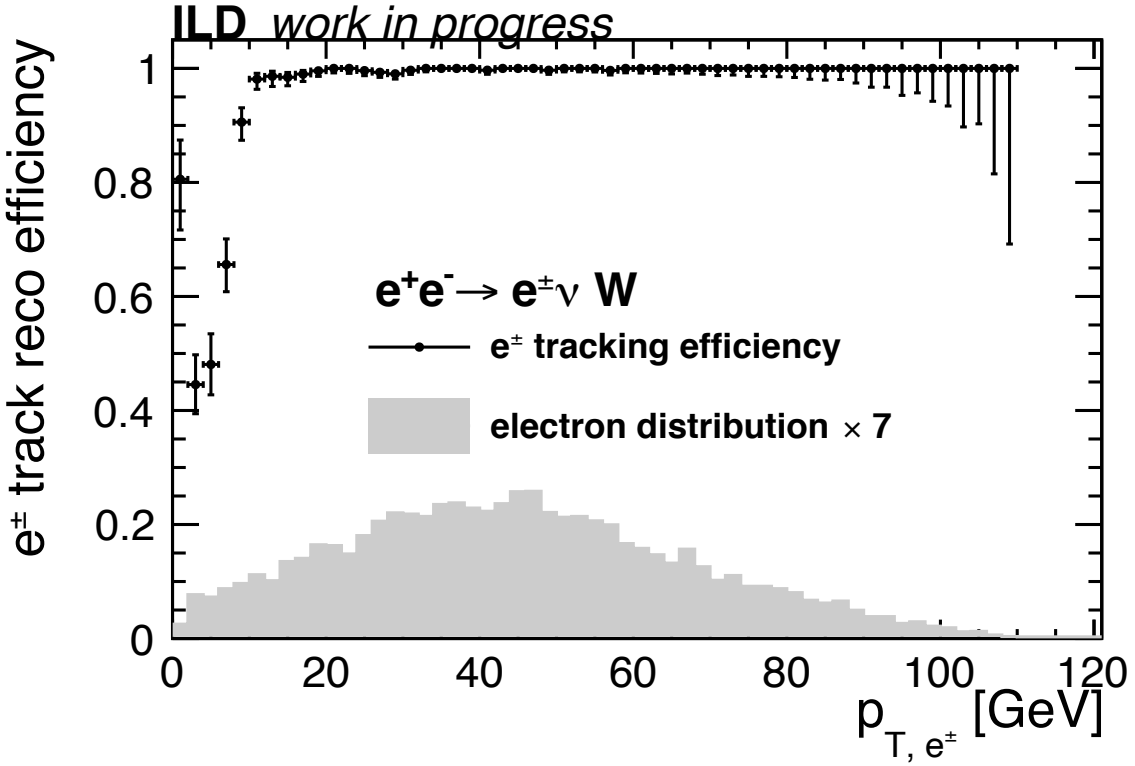


- **vs pt** for electron/positron (on eLpR sample, i.e. singleW dominated)





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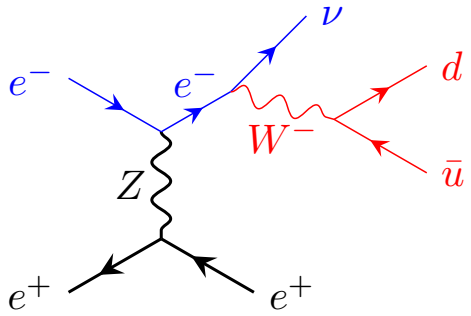

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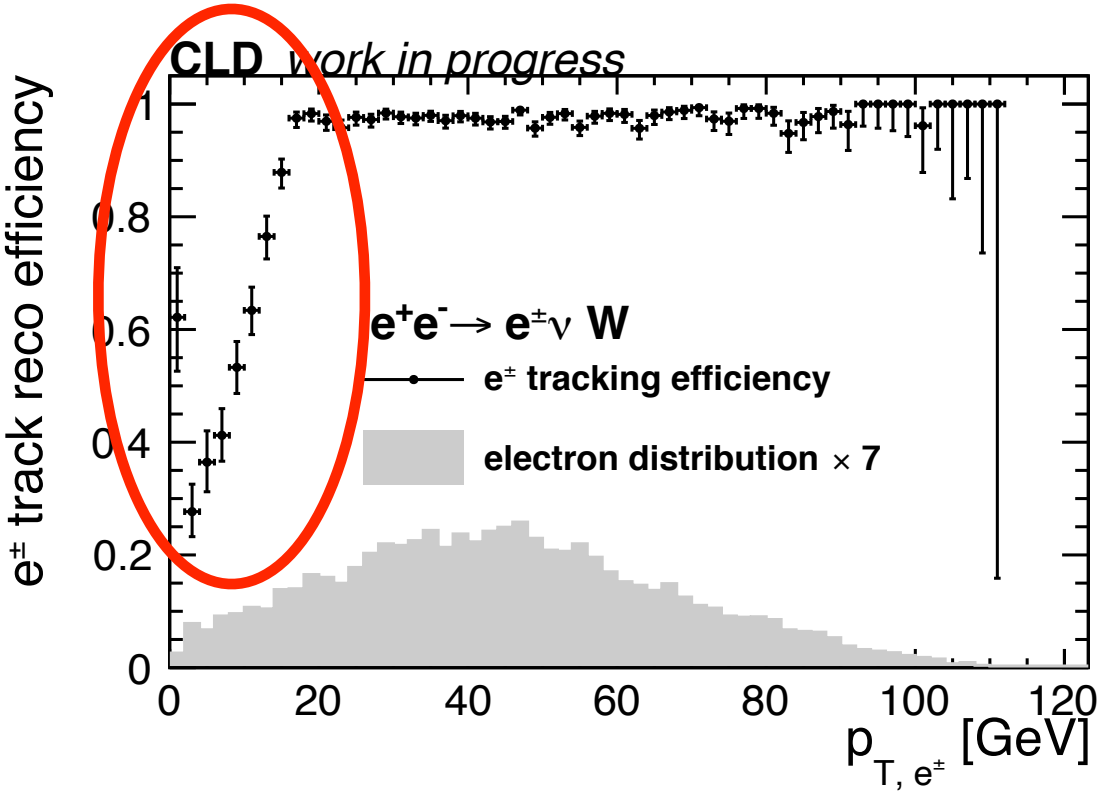
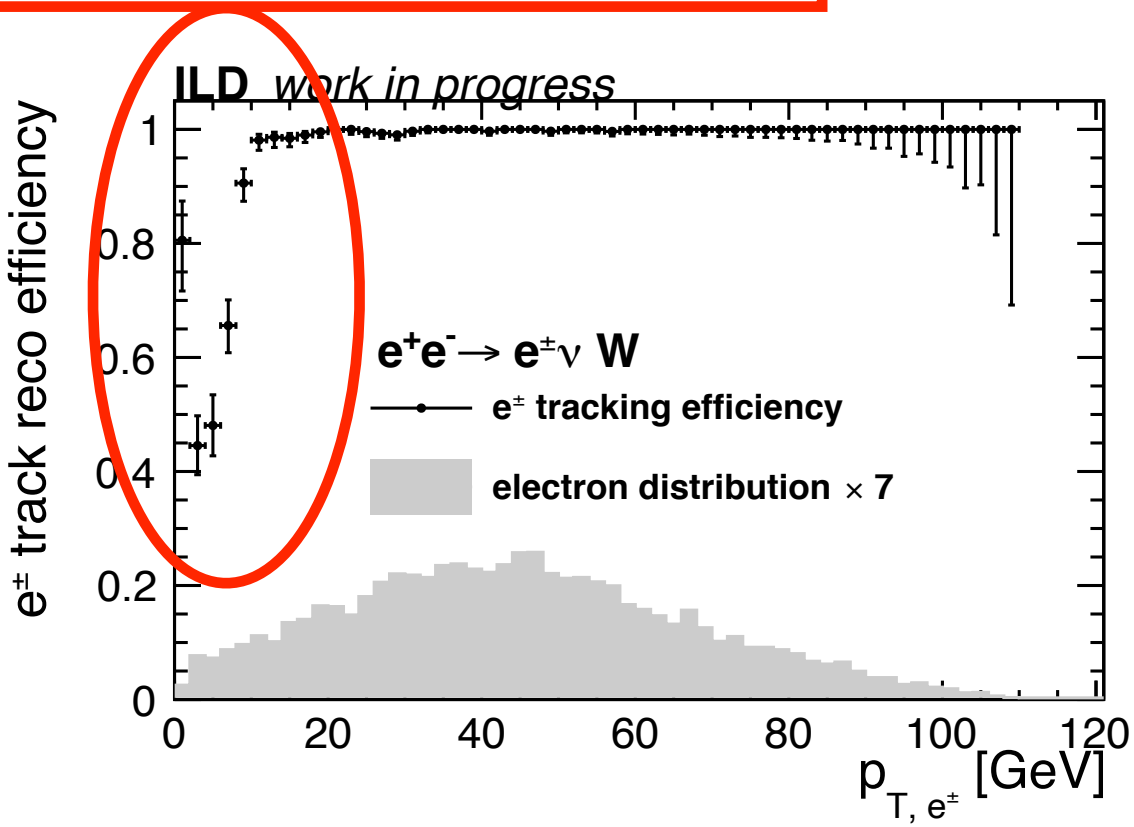
Looks worse than official CLD / ILD performance, however no cos(theta) cut applied here





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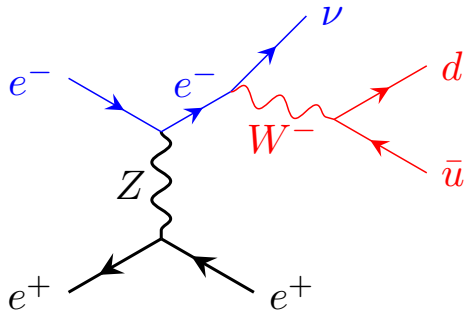

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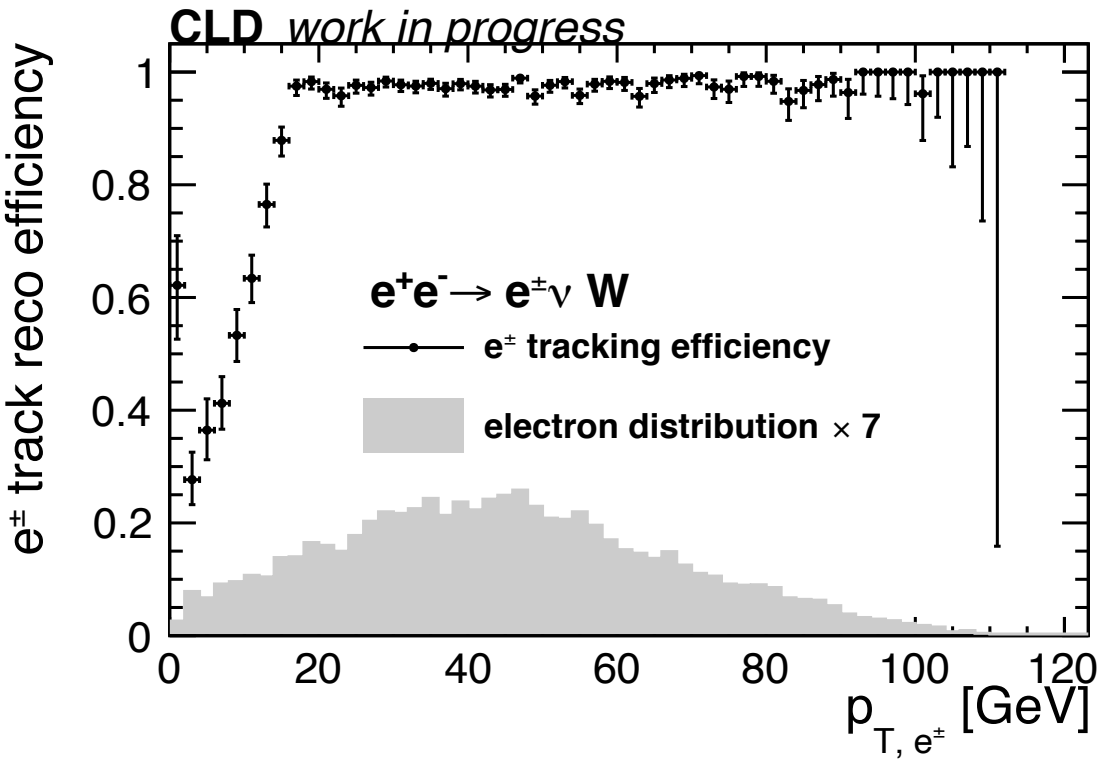

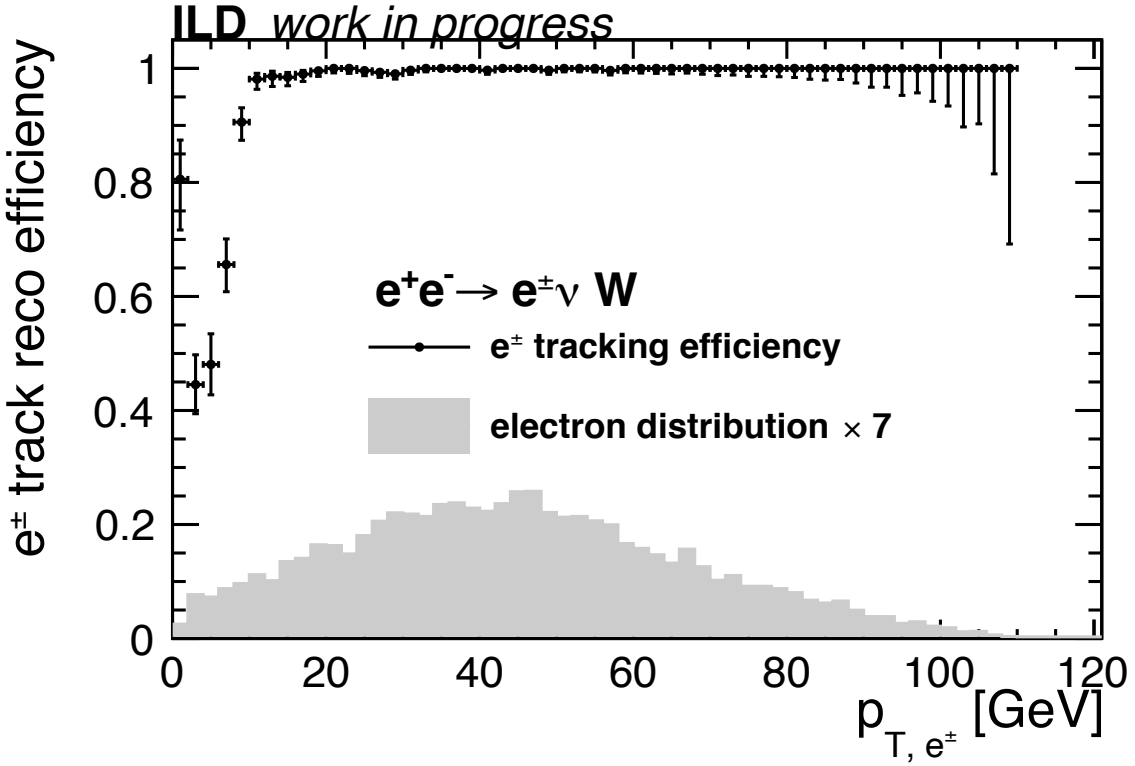

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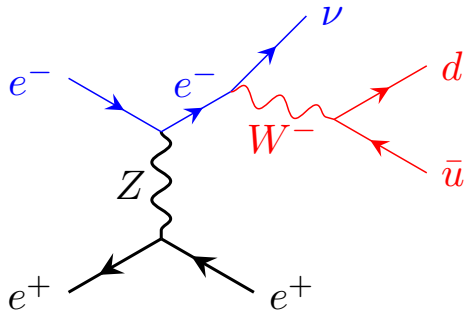

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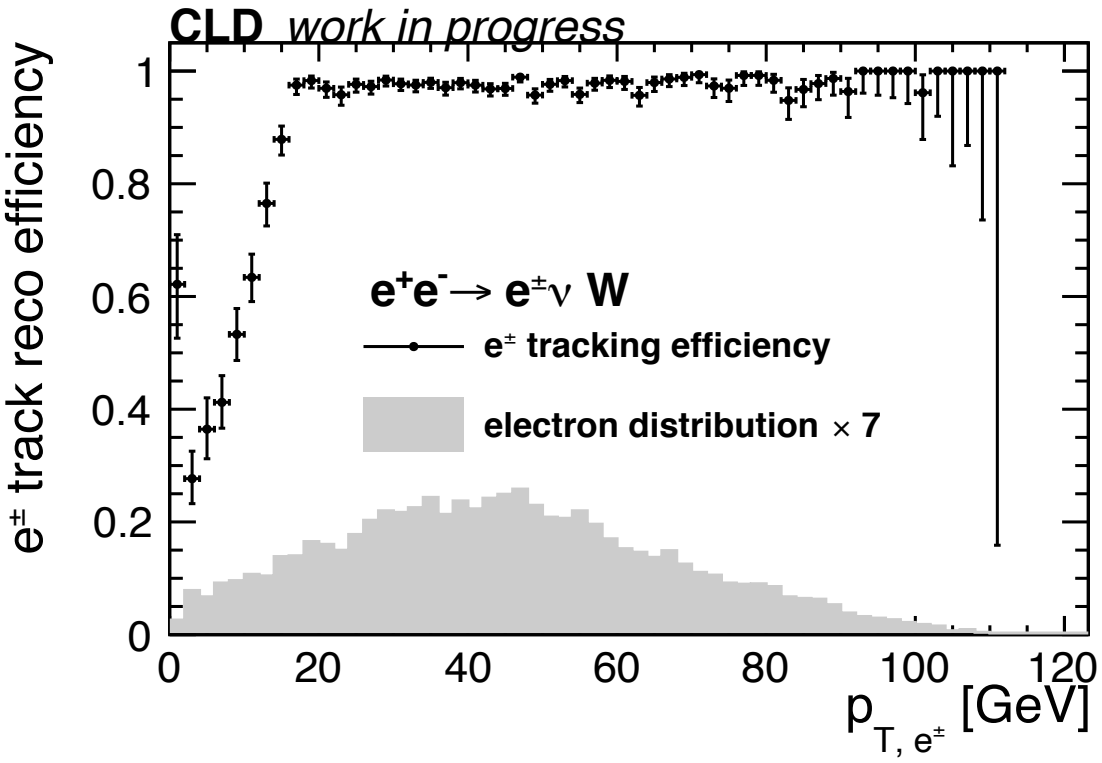
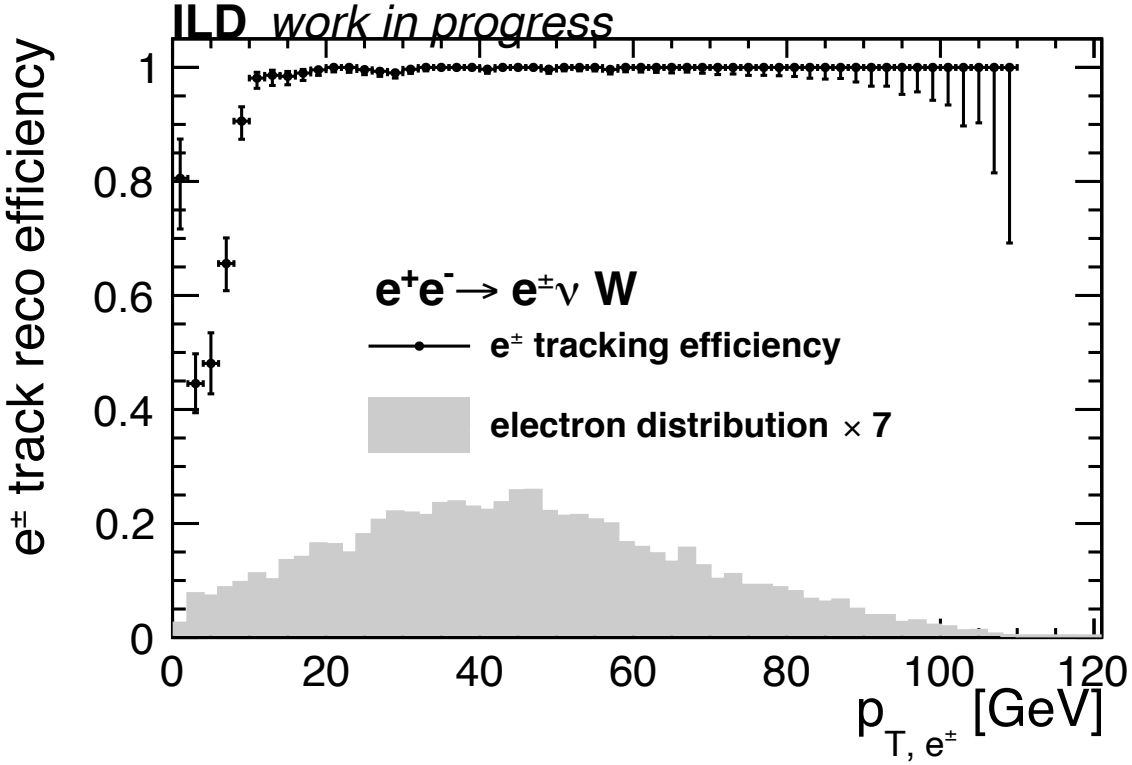
KEY POINT: same analysis run on CLD and ILD - thanks to Key4HEP
=> THIS is a perfect example for joint work in the ECFA study!





Beyond the first steps

Interfacing experimental projections to global interpretation

- these analyses will proceed to
  - select WW and singleW events from full SM background
  - reconstruct W kinematics => production and decay angles (all five)
- **how will we then interface to global fits?**
  - provide projections on differential cross-sections?
    => even 3D differential challenging in terms of MC statistic, 5D hopeless?
  - optimal observables?
    => unclear how to treat systematic uncertainties - and in particular their reduction via nuisance parameters?

need a discussion here, to culminate into a concrete prescription which data
- format, binning, central values, statistical and systematical covariance matrices, … -
should be provided for input to global fits?

=> next topical meeting of WWdiff?

Conclusions
and outlook

- **work on WWdiff focus topic has started**
- but coverage is “thin” and partiallly very short-term (eg master student)
  => more active people very much welcome
  => get in touch and/or sign up on mailing list
- tools, MC samples to get started are there
- more MC samples from other detectors would be highly welcome - coherent analysis of data from different detector concepts **IS POSSIBLE thanks to Key4HEP**
- **need to define interface between experimental projections & global fits**

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