

# Working Group 4

## TopPhysics@FCC-ee

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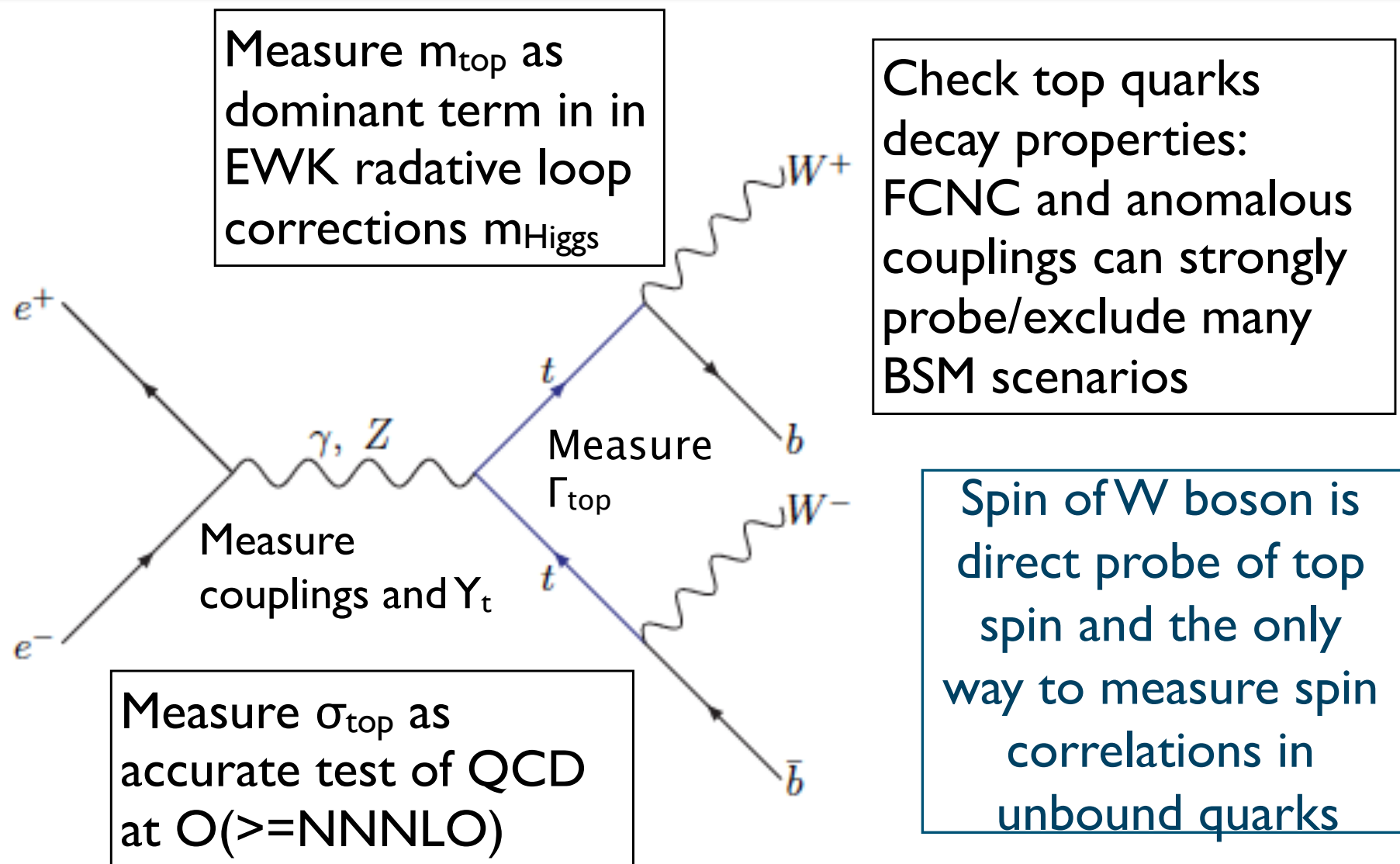
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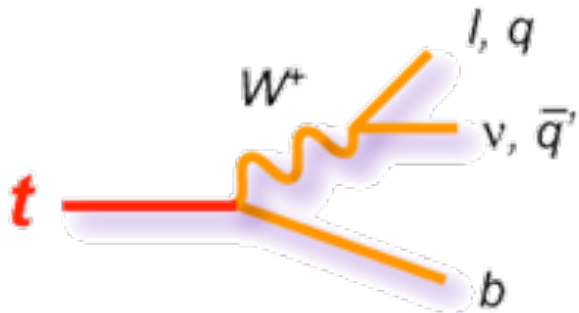
# Top Physics at FCC-ee

- The strength of the FCC-ee program is to be able to span several centre of mass energies: from Tera-Z to 350 GeV and maybe up to a 500 GeV option.
- Where/when does top physics come in the program?
  - @350 GeV: cross section  $t\bar{t}$ : 0.5 pb
    - dedicated run at/around  $2m_{\text{top}}$  'Mega-Top'
    - $2 \text{ ab}^{-1} = 1\text{M top pairs}$ 
      - with 4 IP: 0.5 year/IP D'Enterra arxiv:1601.06640
  - Single top quark sample: by product of 240 GeV run at HZ
  - Higher energy runs?:  $t\bar{t}H$  becomes accessible @500 GeV

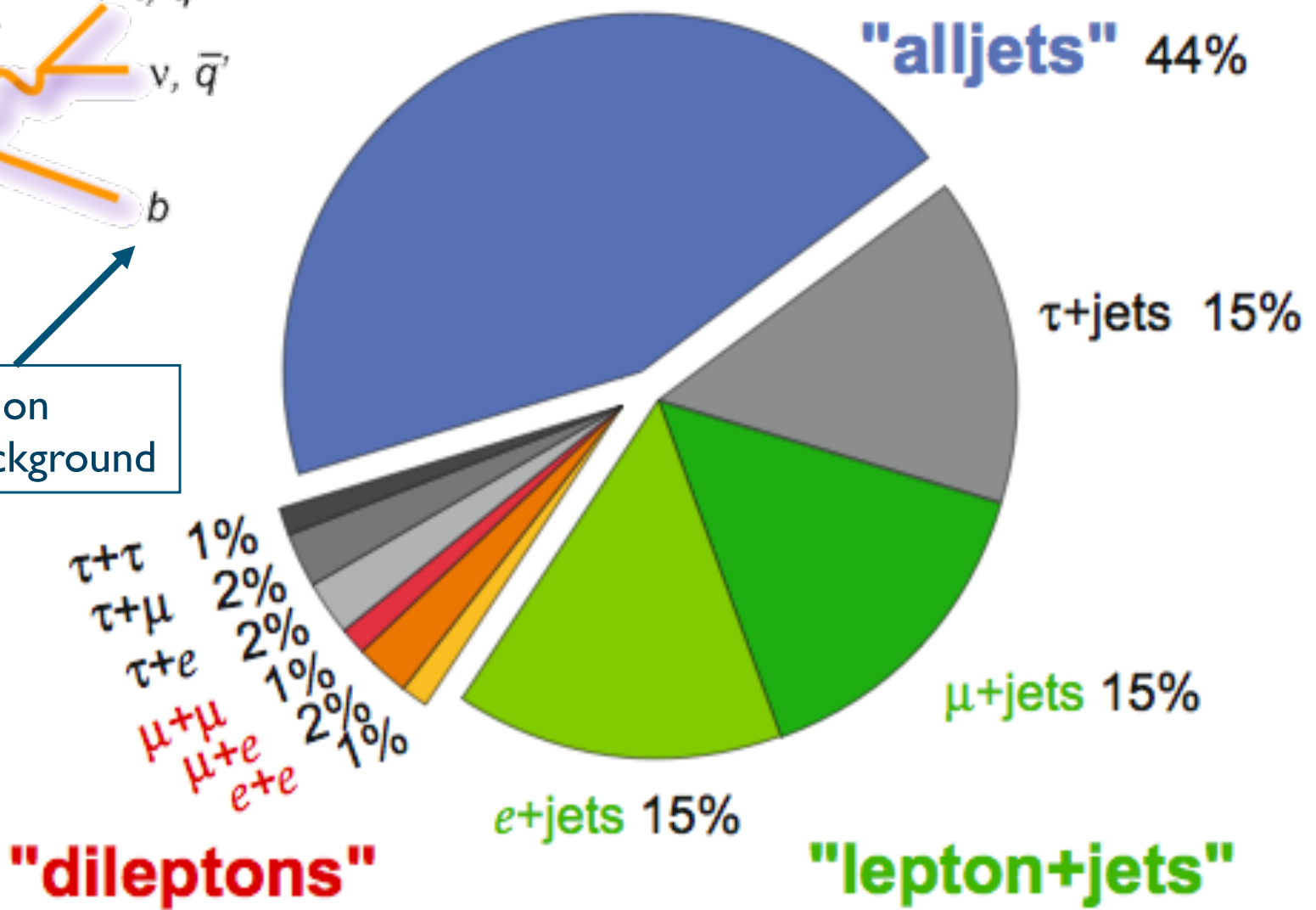
# The case of the top quark



# Top quark pair production & decay

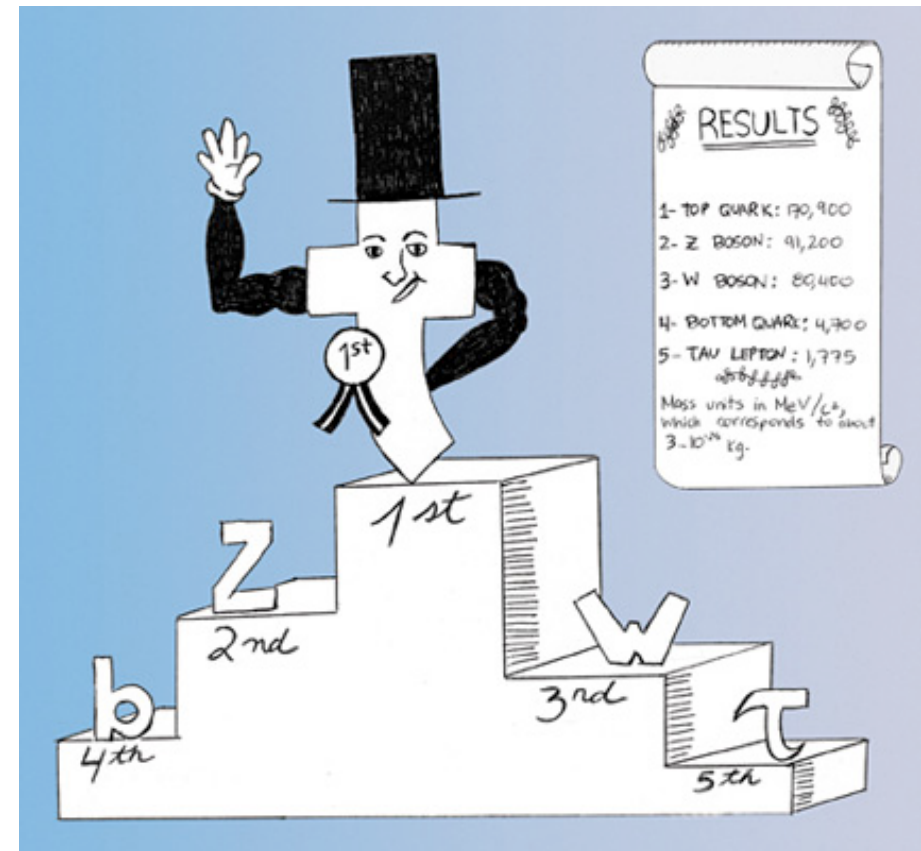


B-quark identification  
used to reduce background



# FCC-ee 'dream' top physics program

- High priority topics that need attention in the coming year
  - studies obvious potential as clearly important
  - or: further studies would improve assessment real potential
- We have a to-do list (with open topics!)
  - Plan to update but already much information available on top physics group page: <https://tlep.web.cern.ch/content/wg4-exp>



*In the mass competition the top quark remains the winner even after the Higgs discovery :)*

# top physics wish list

- FCC-ee at  $2m_{\text{top}}$  350 GeV:
  - top mass measurement around threshold @350GeV
  - intertwined with mass but dedicated measurement could improve sensitivity:
    - top  $Y_t$  measurement
    - top width
  - Rare decays
  - FCNC
  - Anomalous couplings
  - Forward-backward asymmetry
- Single top physics @240GeV:
  - higher integrated luminosity will really help here
  - direct measurement  $V_{tb}$
  - Anomalous couplings FCNC
    - also @240 GeV
  - Interference  $t\bar{t}/WbWb$  and single top production is open topic
    - needs further exploration and interaction with pheno group
  - The case for 500 GeV run
    - direct extraction of  $Y_t$  from  $t\bar{t}H$
    - any other BSM signal to look for?

# Threshold scan - Ultimate sensitivity

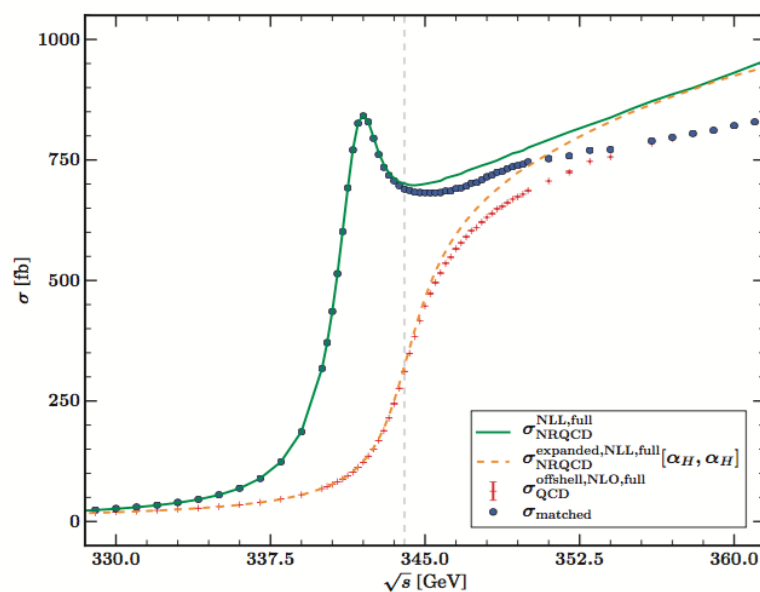
Top threshold matching in the WHIZARD code (J.Reuter et al, '16)

Monte Carlo implementation of  $e^+e^- \rightarrow t\bar{t}$  at and above threshold at NLO

At threshold: TOPPIK code, with the  $t\bar{t}\gamma$  and  $t\bar{t}Z$  vertices given by NR form factors

Beyond threshold: relativistic NLO QCD factorizing top production and decay

Matching: add NLL and NLO and subtract  $\mathcal{O}(\alpha_S)$  from expanded NLL



See talk by Gennaro Corcella

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# Results since last workshop

- FCNC in hadronic channel
- top (anomalous) couplings to Z and  $\gamma$
- Composite Higgs from top couplings

hadronic top twice as sensitive to  $BR(\text{top})^{\text{FCNC}}$  as leptonic top

(leptonic channel)	(100 $fb^{-1}$ )	( hadronic )
$\sqrt{s}$ (GeV)	240	
$Br(t \rightarrow q\gamma)$	$5.9 \times 10^{-4}$	$3.3 \times 10^{-4}$
$Br(t \rightarrow qZ) (\sigma_{\mu\nu})$	$8.8 \times 10^{-4}$	$4.3 \times 10^{-4}$
$Br(t \rightarrow qZ) (\gamma\mu)$	$1.4 \times 10^{-3}$	$8.8 \times 10^{-4}$

Khanpour at al. 1408.2090

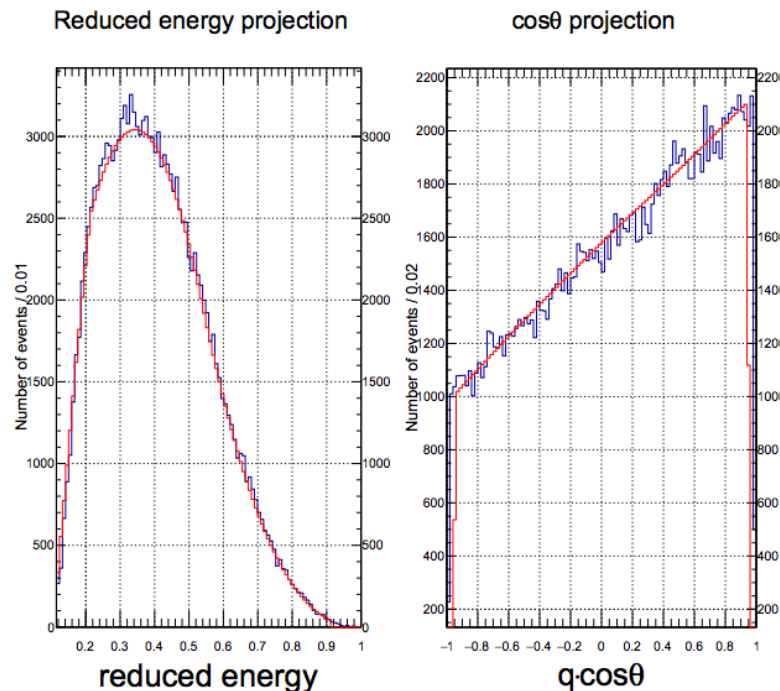
See talk by Barbara Mele

- Many more nice results in Fulvio Piccinini talk



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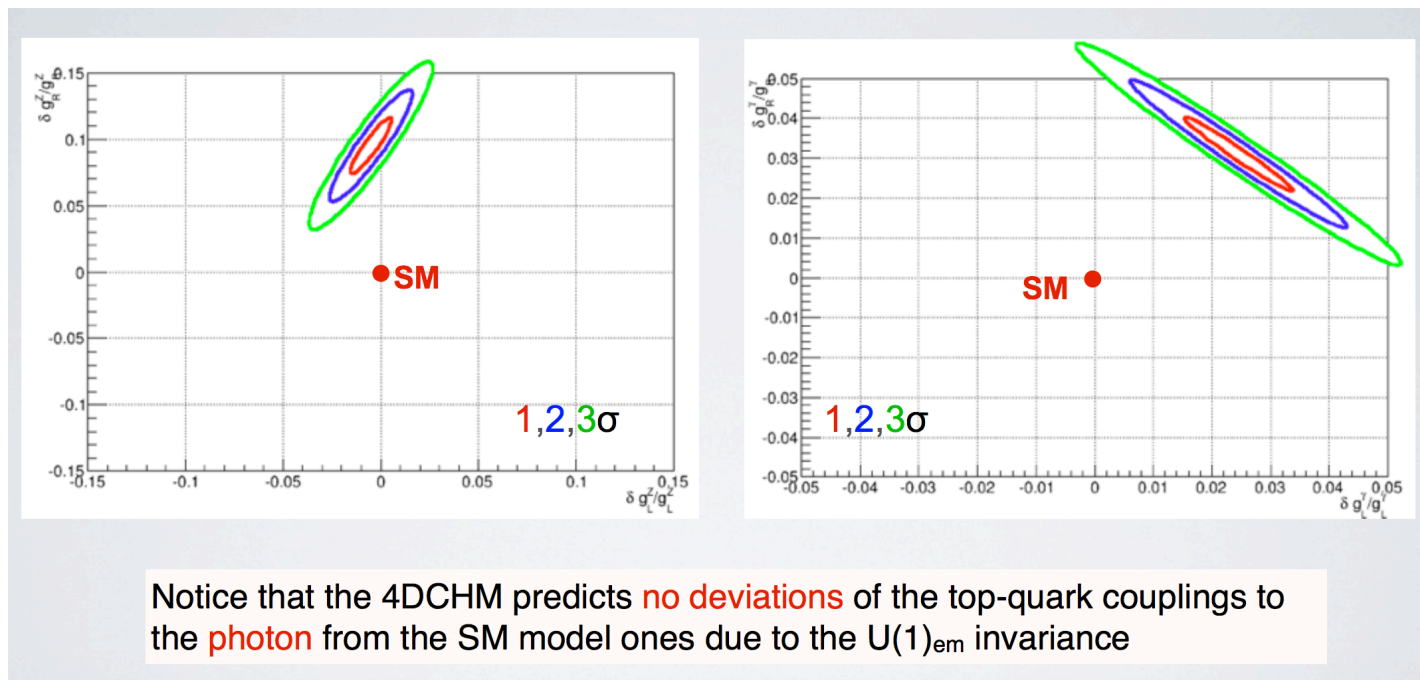
- SM signal and background distributions are fixed
- BSM correction coefficients  $\delta A_Z$ ,  $\delta B_Z$  are the free parameters of the fit
- $|\cos \theta| < 0.96$
- $x < 0.9$
- Analogous fit for the electrons (see the backup)

- Many nice results and details in Fulvio Piccinini talk

See talk by Nicolo Foppiani

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- Many more nice results in Fulvio Piccinini talk

See talk by Stefania De Curtis

# Top Group plans

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- Now that full software is in place, having documented software examples and ‘standard’ samples will facilitate young people joining this effort
  - many samples can easily be shared
  - will reduce learning curve so increase physics output
  - making plans regarding documentation etc
- Continue constructive collaboration with W and Z groups
- Top quark and BSM intimately intertwined
  - opportunities to gain strength here should be explored
- In the case of top physics, the synergy with ILC community could be explored as the physics case is very similar.
  - Can we strengthen and profit from this?



# What next?

- Wish list of studies updated
  - Soon to appear on WG4 twiki
  - Can provide starting points for interested experimentalists
  - Now is time to focus on mass measurement
  - Providing synergy with pheno and theory community
- Many fresh new ideas from FCC-ee Mini-Workshop: "Physics Behind Precision"
  - want to keep momentum and push forward
  - doubled convener team :)