

# Looking for leptophilic $Z'$ at the FCC-ee

- **Baibhab Pattnaik** (IFIC, University of Valencia/CSIC)

In collaboration with

Rebeca Gonzalez Suarez and Jose Zurita

SUSY 2024



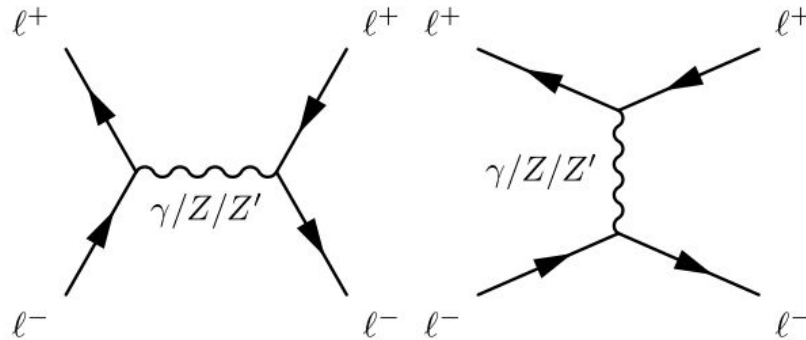
# Contents

- Motivation
- Improvement on LHC bounds?
- FCC-ee projections
- Improvements

# Leptophilic $Z'$

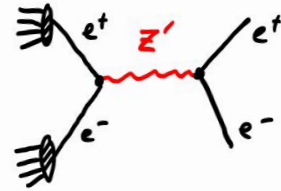
- Arises from an additional U(1) symmetry; anomaly free
- Electrically neutral, couples only to SM leptons
- Does not show up as a resonance at hadron colliders
- We focus on Le-Lmu and Le-Ltau models (models where  $Z'$  couples only to electron and muon flavours, and electron and tau flavours respectively )
- Mass range of interest: 10-365 GeV

See Dasgupta, Tao Han et al (2308.12804), Goudelis et al (2312.14103)

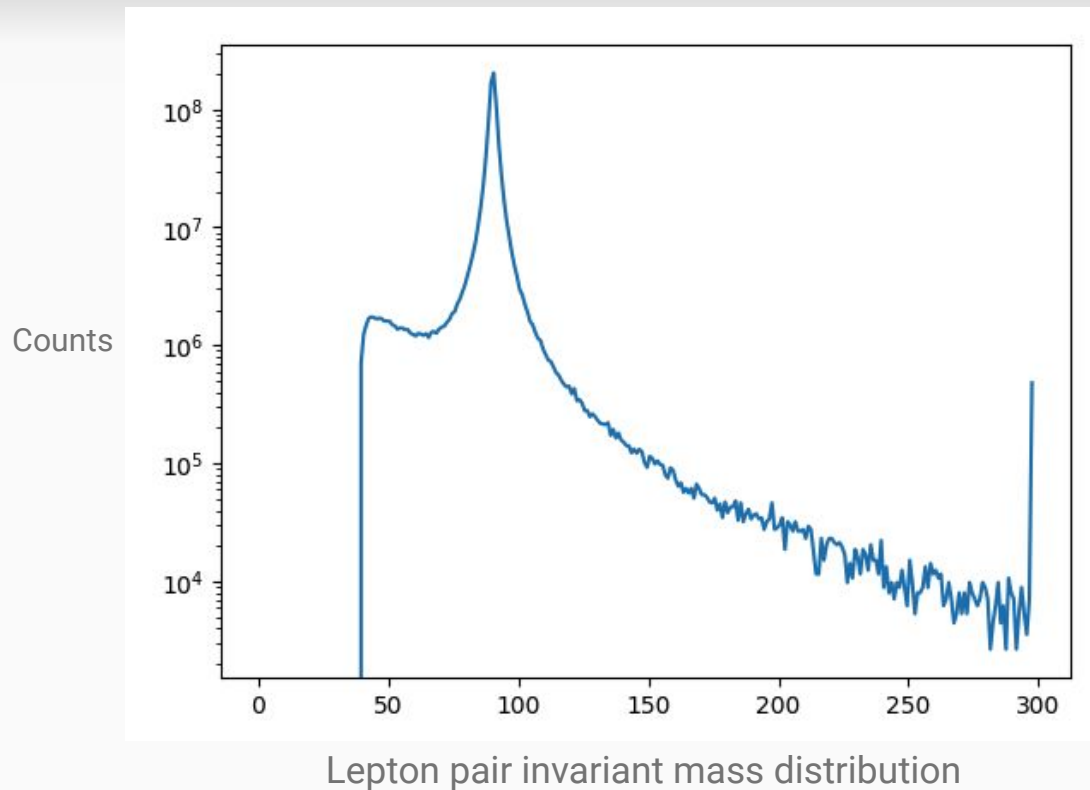


# Improvement on LHC limits?

- Leptons PDF from the proton (Nason et al:JHEP 08 (2020) 08, 019)
- Incorporating LUXPDF allows us to treat LHC as a “lepton collider”
- Typical cross-sections: order  $1\text{e-}6$  pb
- Background too high : no significance in unconstrained parameter space (plot in next slide)
- More statistics needed!

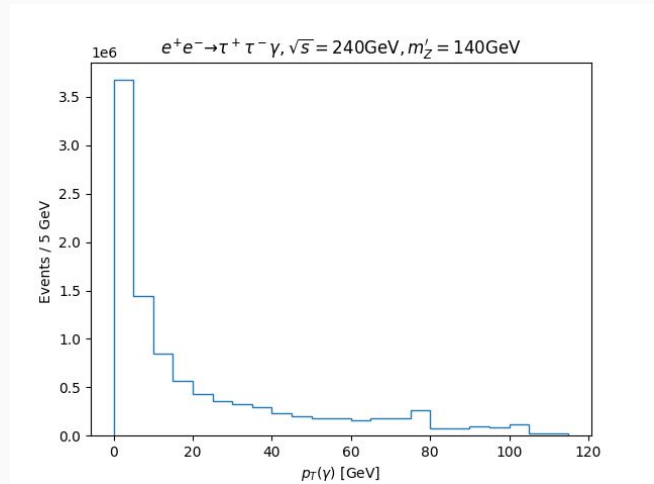
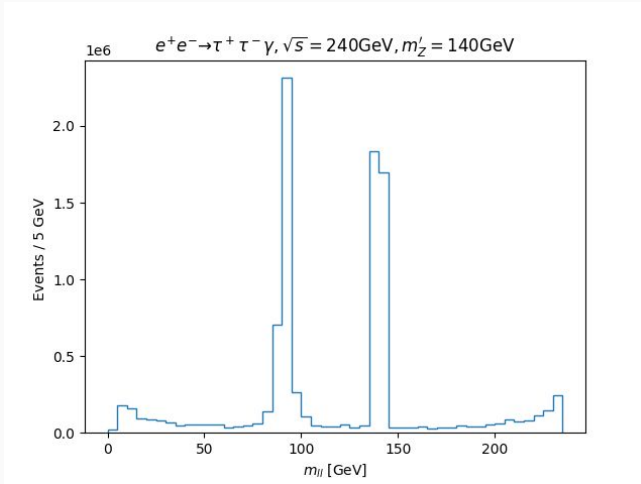
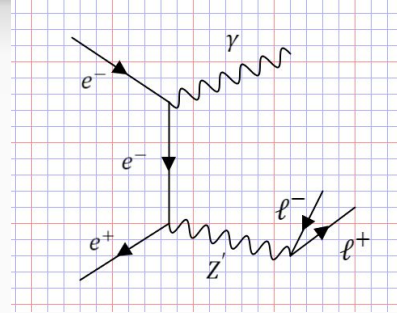


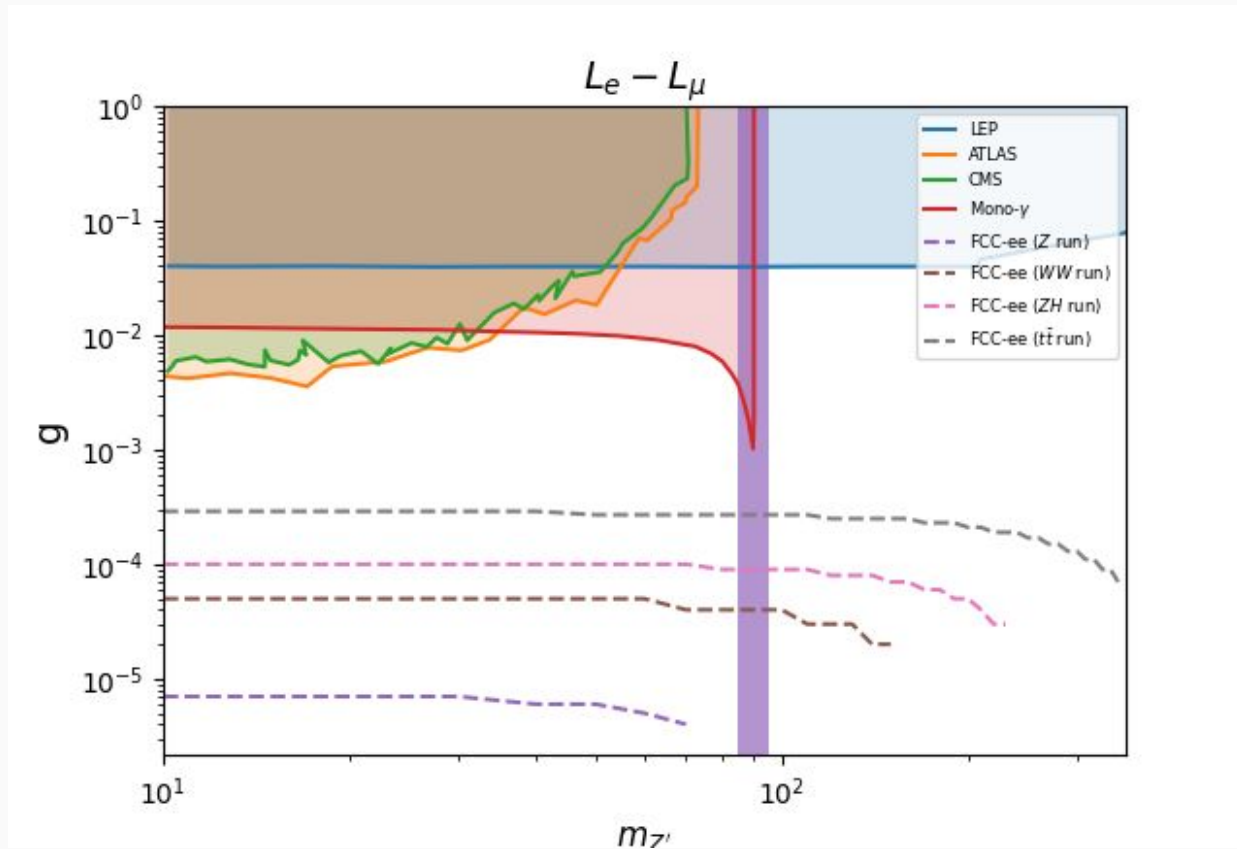
# Background



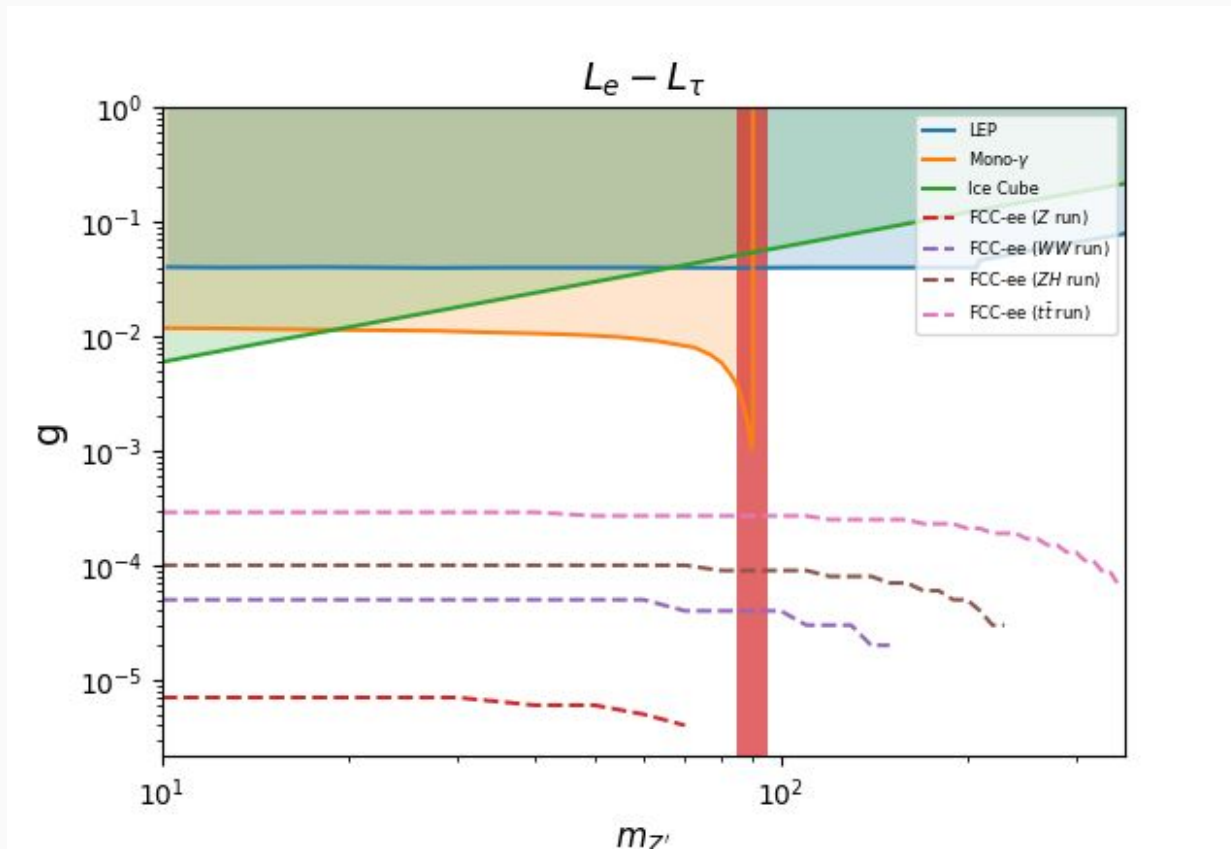
# FCC-ee sensitivity

- $e^+ e^- \rightarrow Z' + \gamma$
- Signal: 2 leptons +  $\gamma$
- Main backgrounds: 2 leptons +  $\gamma$   
4 leptons +  $\gamma$   
(final state)





(naively preliminary) FCC-ee sensitivity for four different runs. The lines correspond to 10 signal events. Shaded region around Z mass suffers from high bg and interference effects



(naively preliminary) FCC-ee sensitivity for four different runs. The lines correspond to 10 signal events. Shaded region around Z mass suffers from high  $bg$  and interference effects



## Pipeline:

### Background inclusion

- Calculate signal and background cross-sections on MG5
- Use PYTHIA8 and DELPHES to take showering and detector effects into account
- Cuts taken from DELPHES idea card used for analysis:
  - $l = e, \mu: p_T > 0.5 \text{ GeV}, |\eta| \leq 2.56, \Delta R(l, X) > 0.5, \epsilon_e = 0.99$
  - $\gamma: E > 2 \text{ GeV}, p_T > 0.5, |\eta| < 3.0, \Delta R(\gamma, X) > 0.5, \epsilon_\gamma = 0.99$
  - $\tau: p_T > 1 \text{ GeV}, |\eta| \lesssim 3.0, \Delta R(\tau, X) > 0.5, \epsilon_e = 0.85$  .

## Pipeline:

### Background inclusion

- Calculate signal and background cross-sections on MG5
- Use PYTHIA8 and DELPHES to take showering and detector effects into account
- Final analysis is performed using Madananalysis
- Invariant mass of dilepton pair data used to obtain significance:  $Z = (\text{signal events}) / \text{Sqrt}(\text{signal events} + \text{background events})$
- Plots shown for  $Z > 2$

# Background inclusion

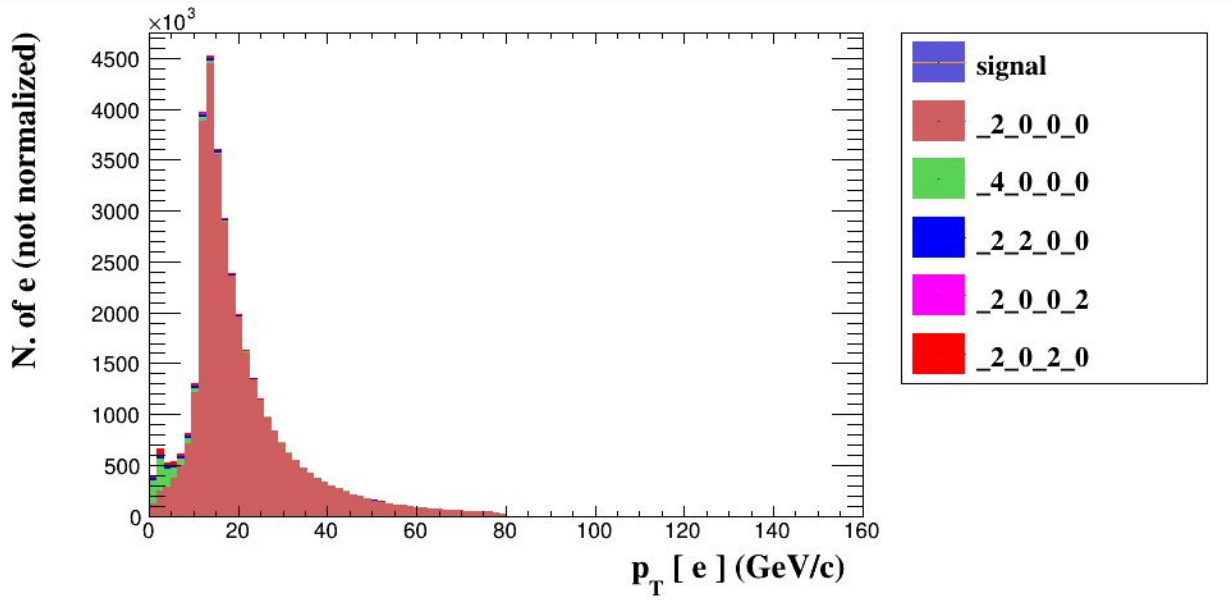
$$e^+ e^- \longrightarrow e^+ e^- \gamma$$

Backgrounds:

- SM process
- $e^+ e^- e^+ e^- \gamma$ ,  $e^+ e^- \mu^+ \mu^- \gamma$ ,  $e^+ e^- t^+ t^- \gamma$ ,  $e^+ e^- \nu \nu \gamma$
- Obtain events for each process, set cuts based on particle kinematics to effectively reject background

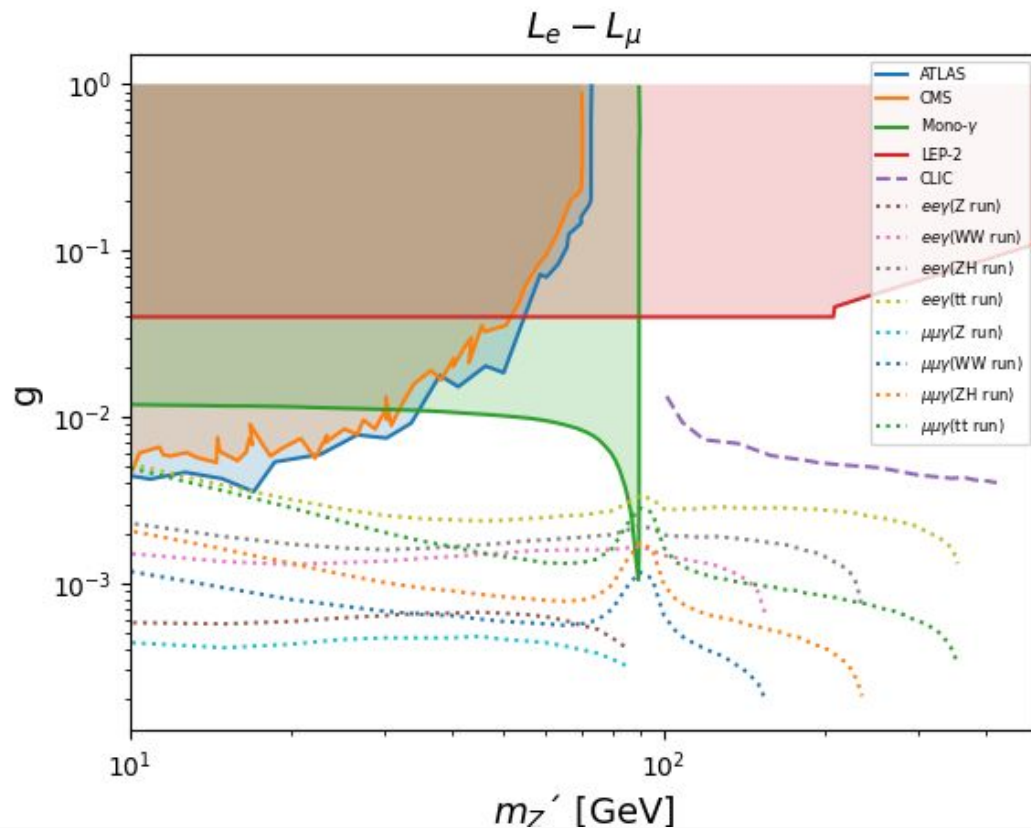
$$e^+ e^- \rightarrow e^+ e^- \gamma$$

Background inclusion

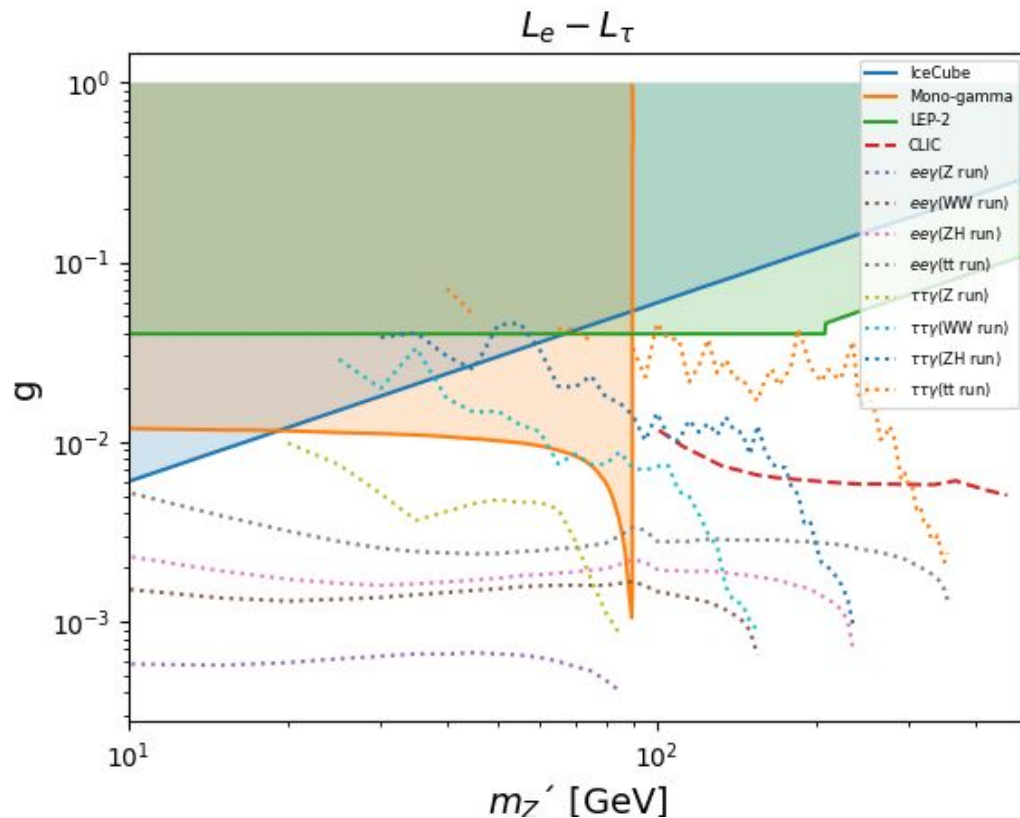


A  $p_T$  cut on electrons get rid of some 4e and 2e2nu backgrounds

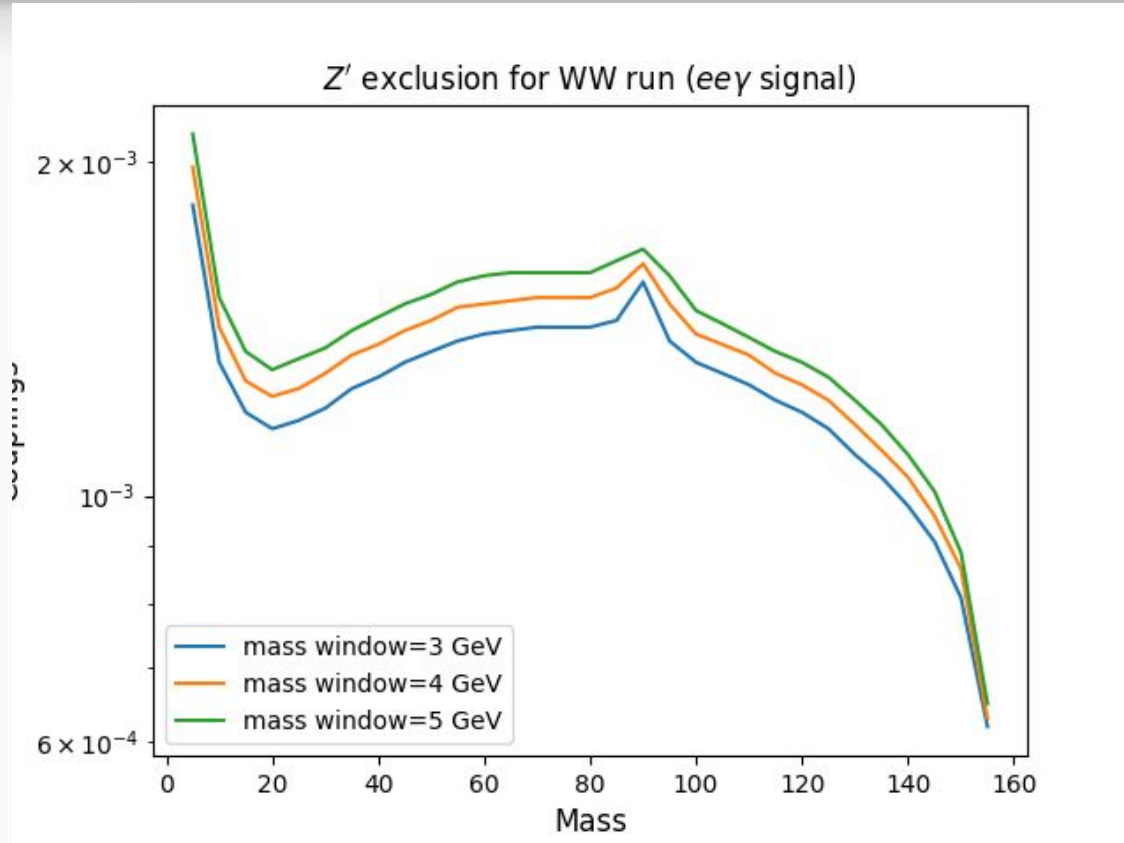
# Sensitivity plots



# Sensitivity plots



# Mass window dependence



# Conclusions

- FCC can probe a LOT of existing parameter space for leptophilic  $Z'$  models
- Some detector optimization (improved mass window) could lead to even better results



# What's next?

- Portal to dark sector? Can lead to dark showers and long-lived final states (explored for Belle-II, see Kahlhoefer et al (2203.08824))

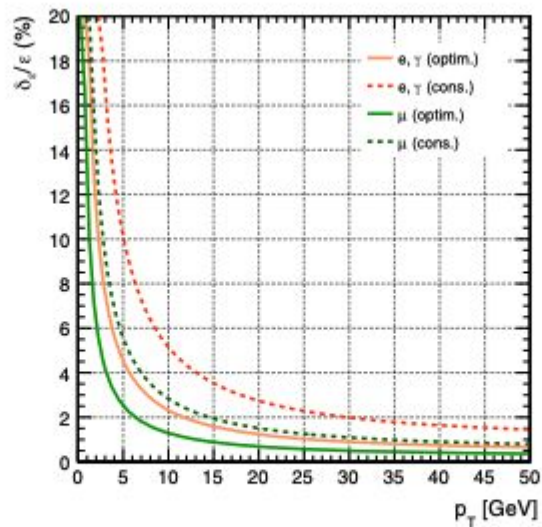
**STAY TUNED!**

Thank you!



Backup slides





**Fig. 4.4** The uncertainty on the reconstruction efficiency of electrons, photons and muons as a function of transverse momentum. An optimistic (solid) and a conservative (dashed) scenario are considered