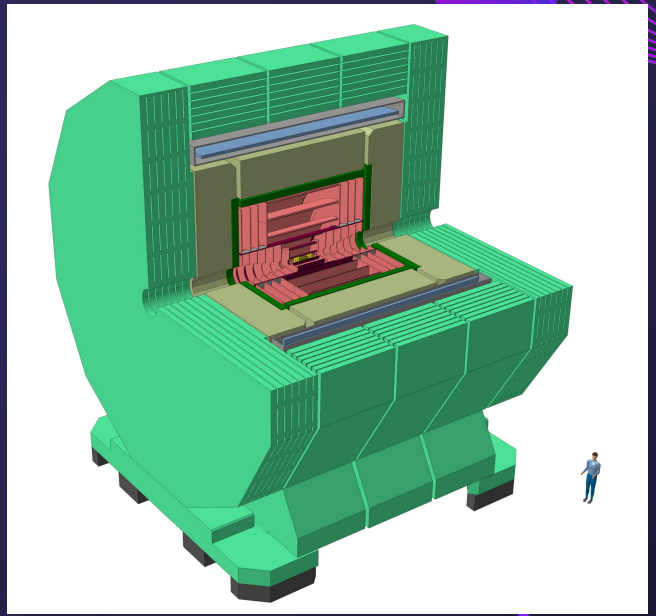
CLD: Creativity Lacking Dudes

Andrej, Karam and Rens

CLD detector

- Vertex detector
- E- Calorimeter
- H- Calorimeter
- Iron Yoke with Resistive Plate Chambers (RPC) for Muon ID



From presentation A. Sailer at FCC week 2022

CLD detector

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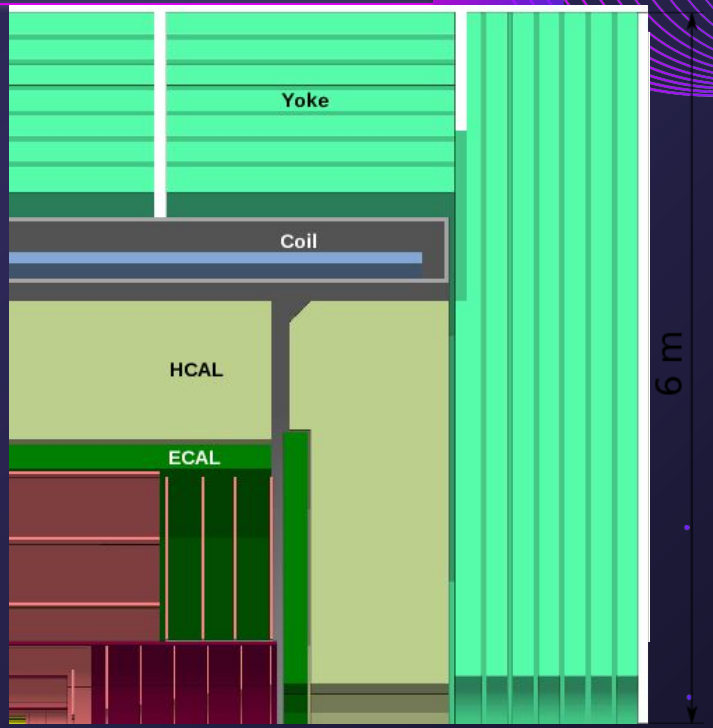
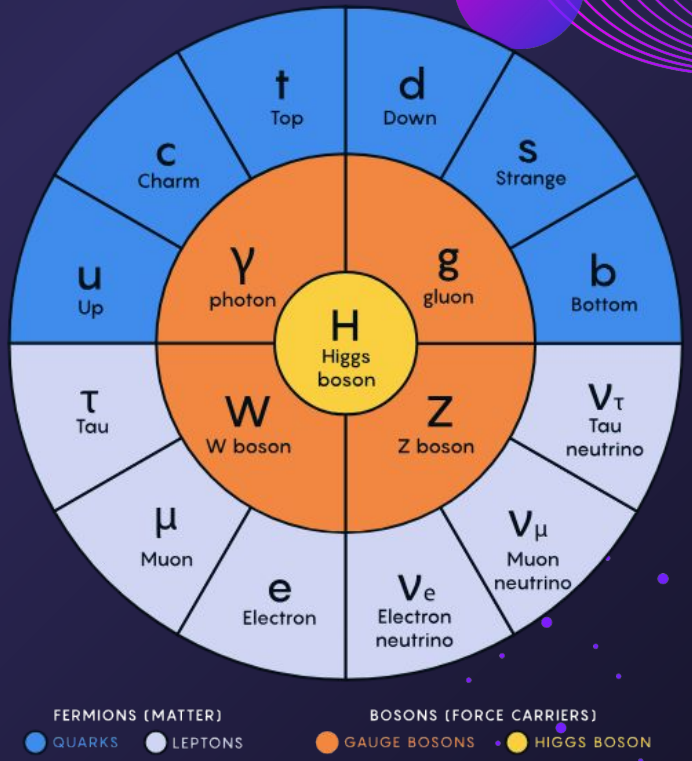


From presentation A. Sailer at FCC week 2022

Obligatory slide with the SM

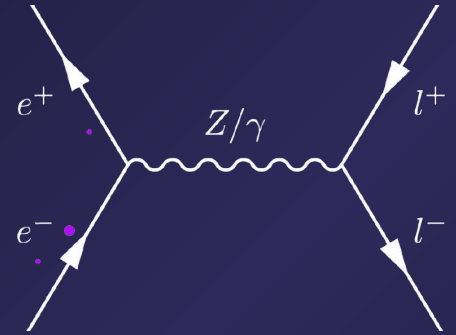
- The FCC-ee will surpass LEP's energies
- Significantly cleaner than hadron colliders (less background)
- Sufficient energies to further investigate Higgs interactions
- Great opportunity to search for violations of Lepton Flavour Universality

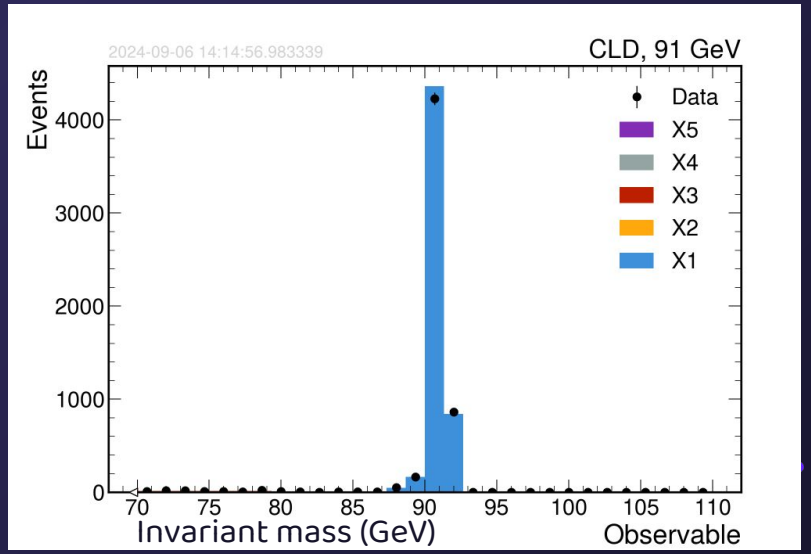


91 GeV

X1 Standard Model at 91 Gev

- Leptonic Z and photon decay
- Production of e^+ - positron, μ and anti-μ and combinations of e and μ
- Contributions from τ decay

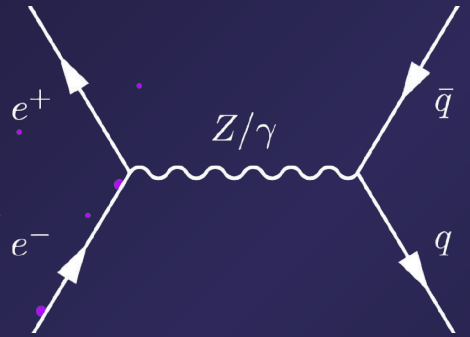


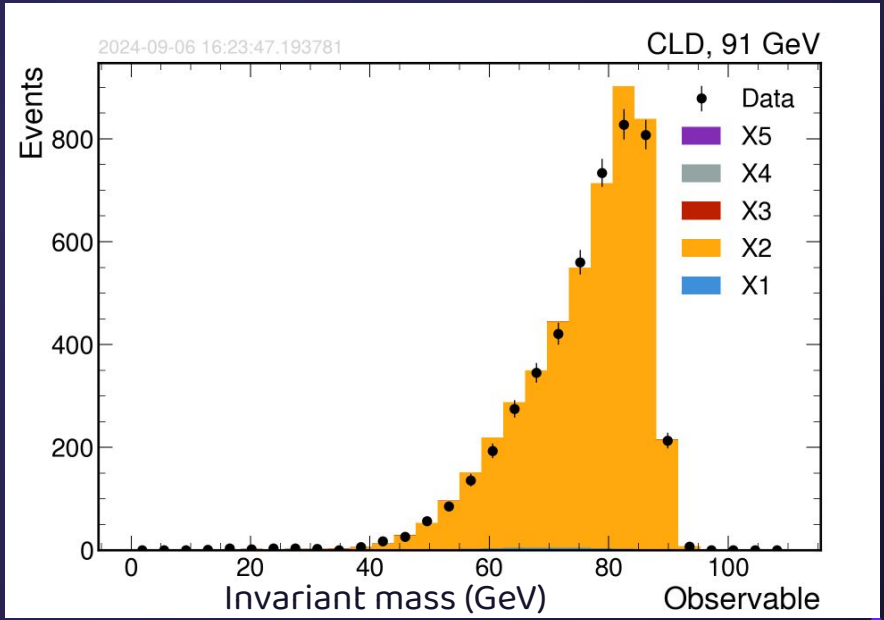


Invariant mass of 2 electrons

X2 Standard model at 91 GeV

- Jets production with a peak at M_{inv} ~ 85 GeV
- Hadronic Z/photon decay
- Mass deviation likely from detector uncertainties

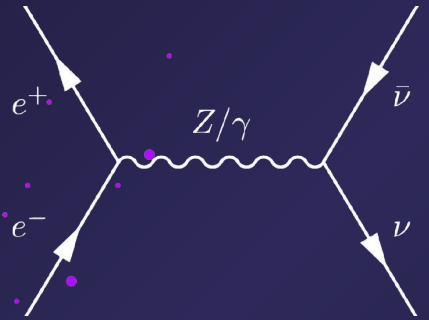


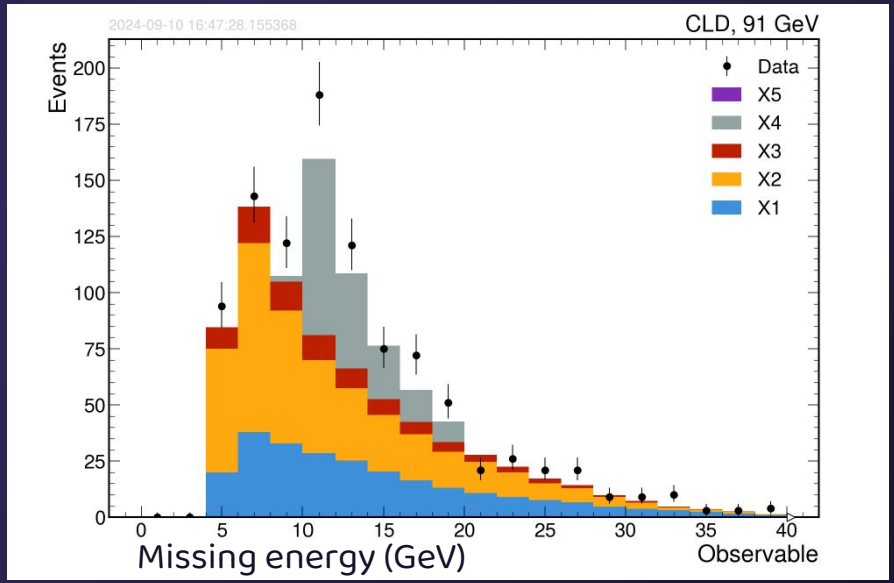


Number of events per invariant mass of jets for events with njets >= 2 and no leptons

X4 Standard model at 91 GeV

- X4 produces no leptons, jets or photons
- Significant amount of MET -> indication for neutrino productions
- Data deviates slightly, HNL production?

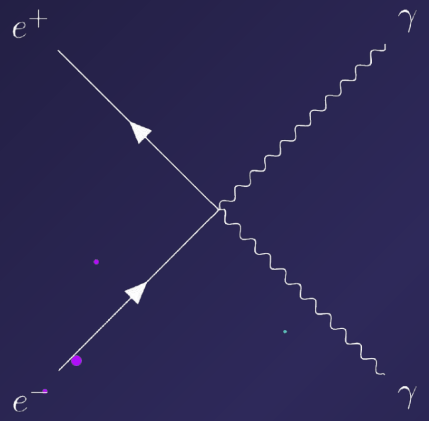


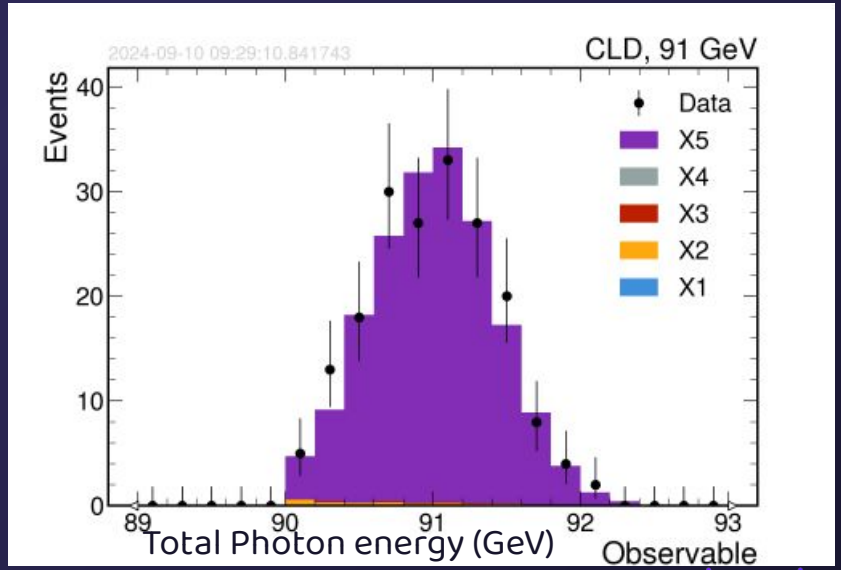


MET with cut > 5 GeV

X5 standard model at 91 GeV

- Electron-positron annihilation (no leptons detected)
- M_{inv} ~ 90 GeV from 2 photons $\Delta\varphi = 180°$

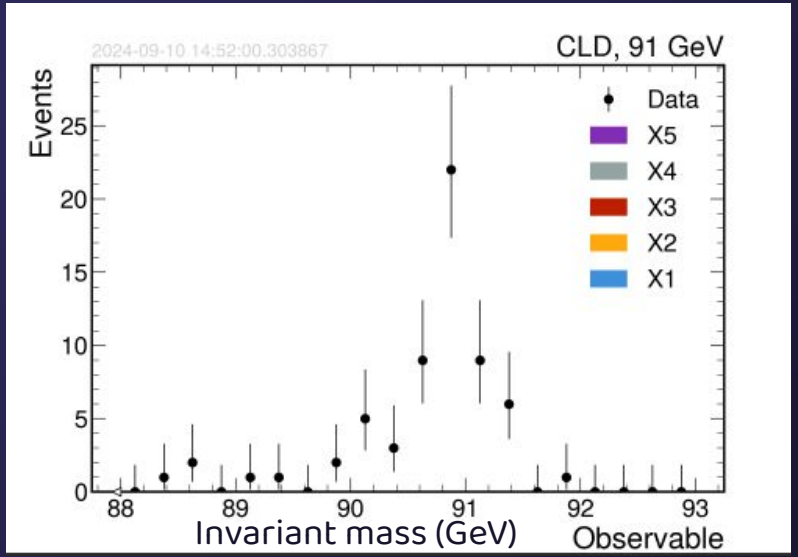




Number of events for 2 photon events as a function of combined energy

New Physics at 91 GeV?

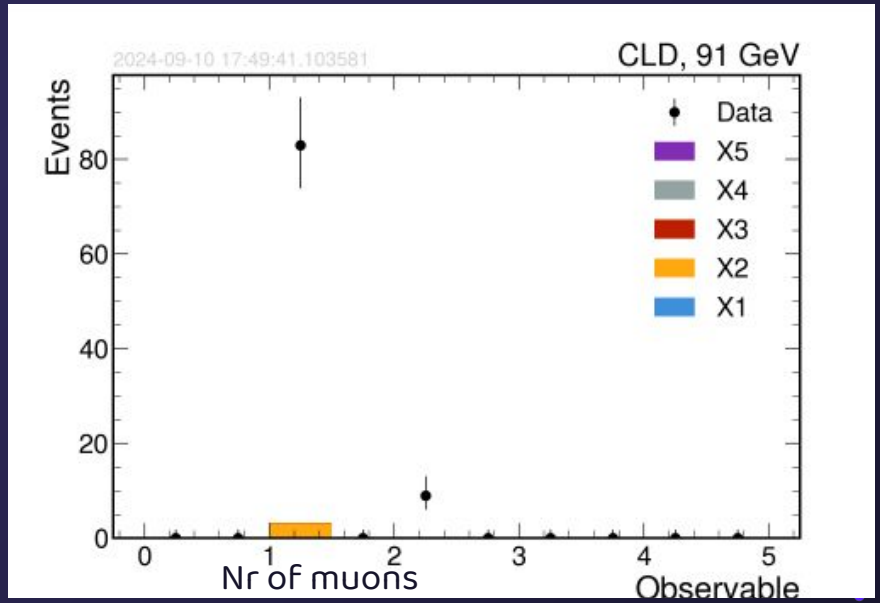
- Excess in invariant mass calculated from electron-muon pair
- Possible new particle Z' of mass ~ 91 GeV
- New particle would break flavour symmetry (may decay into neutrinos)



Nr of events as a function of the invariant mass for events with 1 e and 1 μ

New Physics at 91 GeV?

- Excess of muons and electrons at large displacement
(|r| > 500 mm or |z|>500mm)

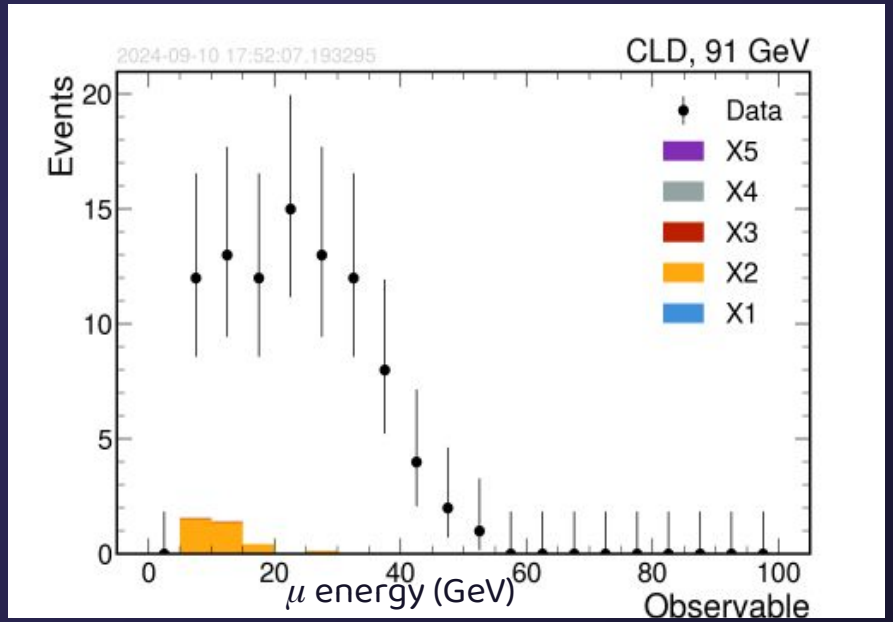


Nr of muons at displacements |r| > 500 mm or |z|>500mm)

New Physics at 91 GeV?

- Excess of muons and electrons at large displacement
  (|r| > 500 mm or |z|>500mm)

- Could be a long lived particle like a HNL or a dark matter candidate



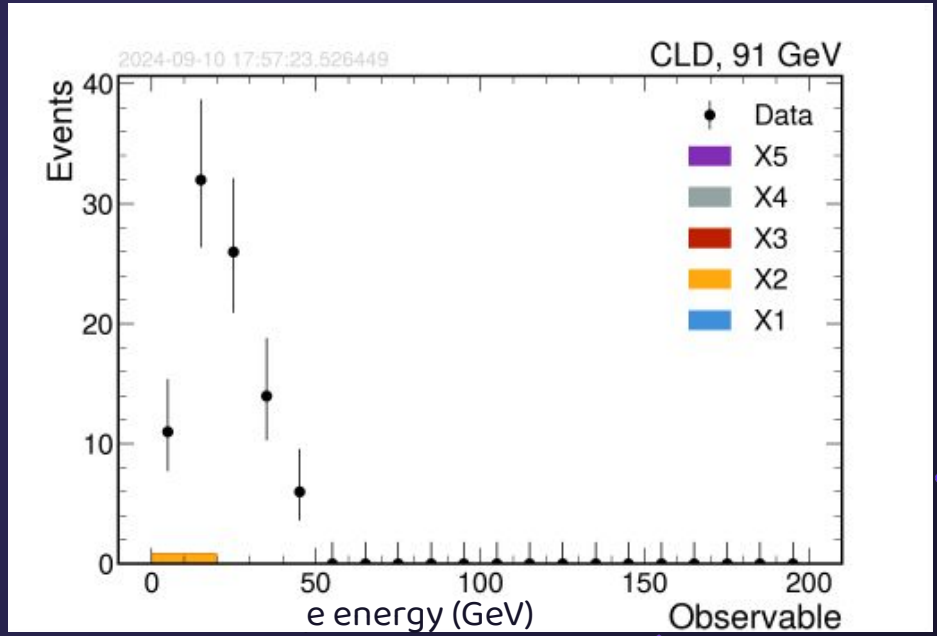
Muon energy at displacements |r| > 500 mm or |z|>500mm)

New Physics at 91 GeV?

- Excess of muons and electrons at large displacement
  (|r| > 500 mm or |z|>500mm)

- Could be a long lived particle like a HNL or a dark matter candidate

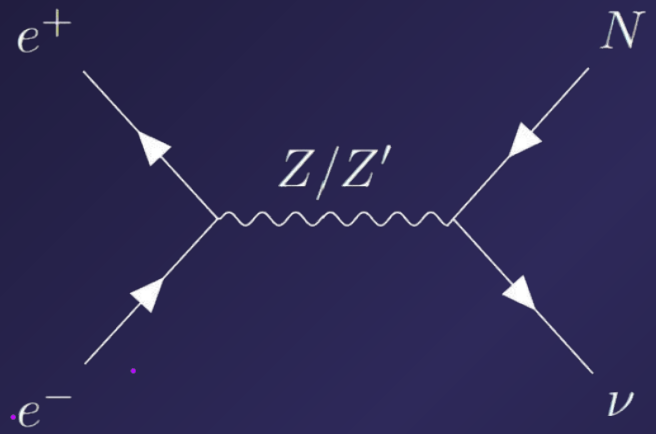
- It decays into an e or μ.
  Invariant mass ~20 GeV

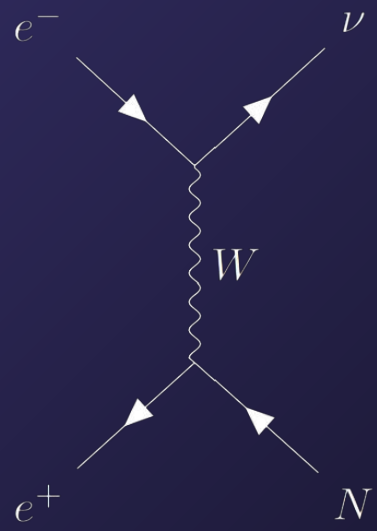


Electron energy at displacements |r| > 500 mm or |z|>500mm)

New Physics at 91 GeV?

- HNL production can be mediated by Z, Z' or W

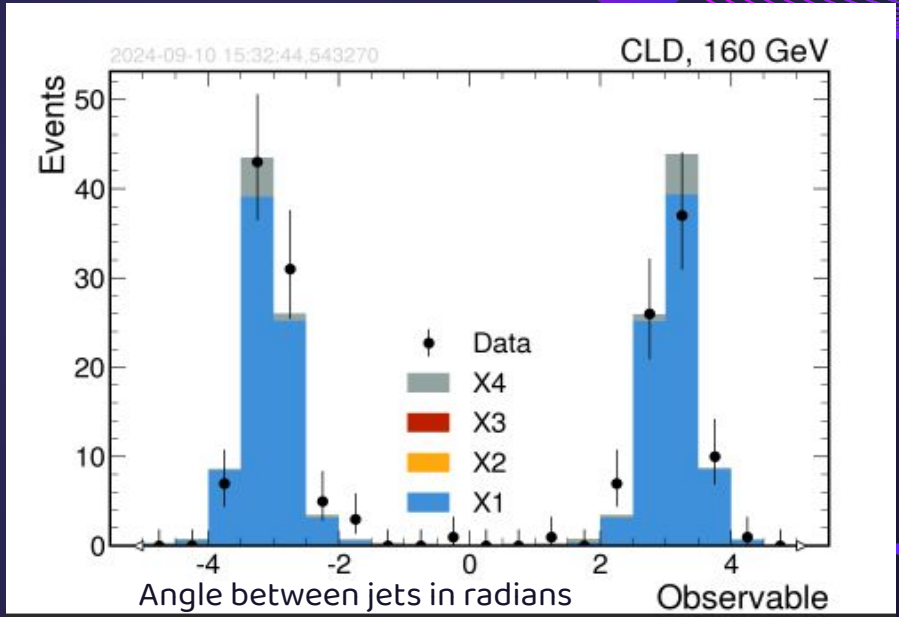




160 GeV

X1 Standard model at 160 GeV

- X1 has pairs of btag jets with $\Delta\varphi = 180°$



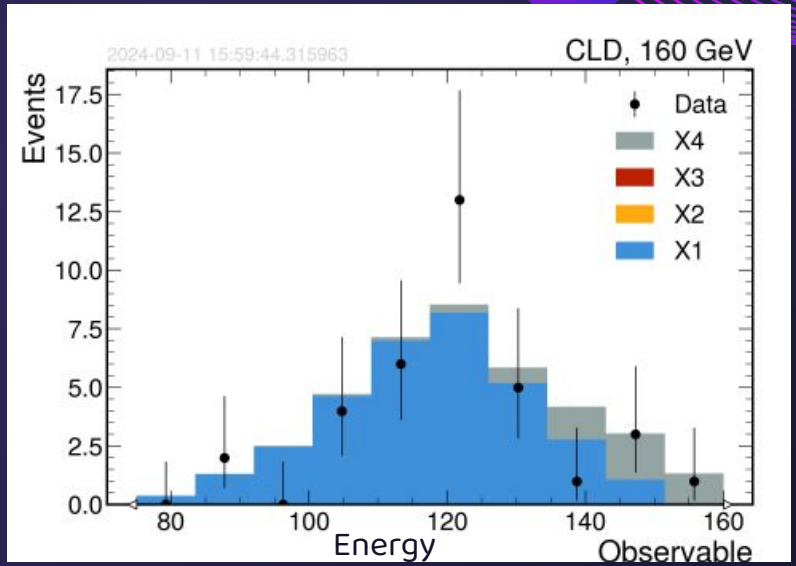
b-jets

X1 Standard model at 160 GeV

- X1 has pairs of btag jets with $\Delta\varphi = 180°$

- Invariant mass of b-jets indicates Higgs to b-pair

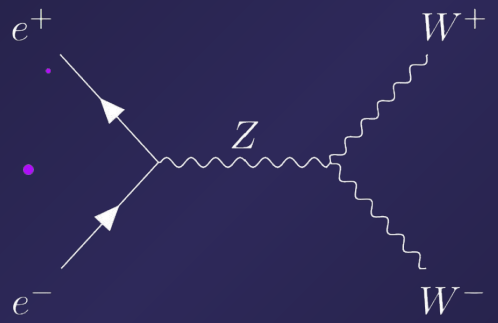
  Including Missing Transverse Energy (MET): $M_H \sim 120$ GeV

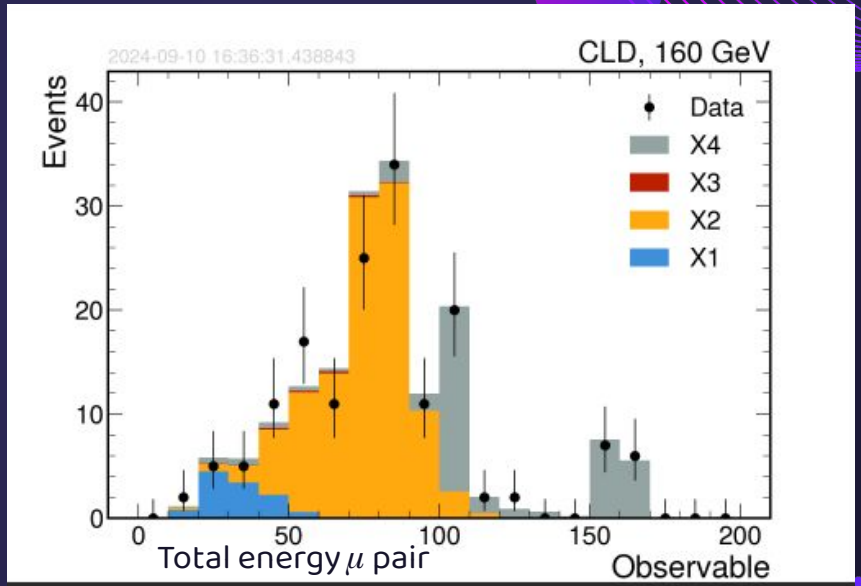


Reconstructed energy of 2 b-jets

X2 standard model at 160 GeV

- We found X2 events with 0 - 3 jets
- X2 also has events with 0 - 2 leptons or photons
- X2 can be WW production decaying hadronically or leptonically
- Confirmed by invariant mass muons

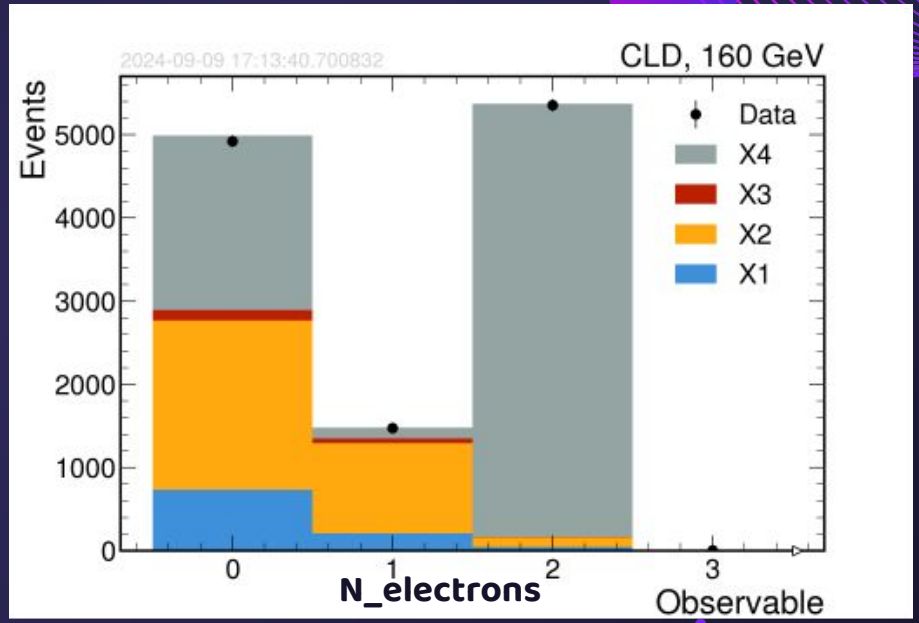




no photons, jets and electrons, just 2 muons

X3 standard model at 160 GeV

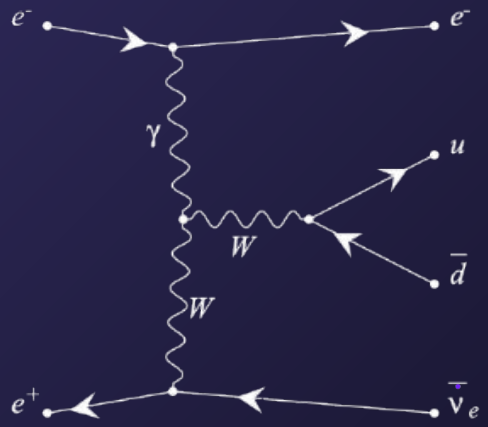
- For 0 jets:
  - Either 0 e and 1 μ
  - Or 1e and 0 μ
- For 1 jet:
  - 1 e with or without a μ
- For 2 jets:
  - No leptons nor photons
- Highly suppressed but has similar characteristics as X2 (WW decay).



Cut: 0 jets

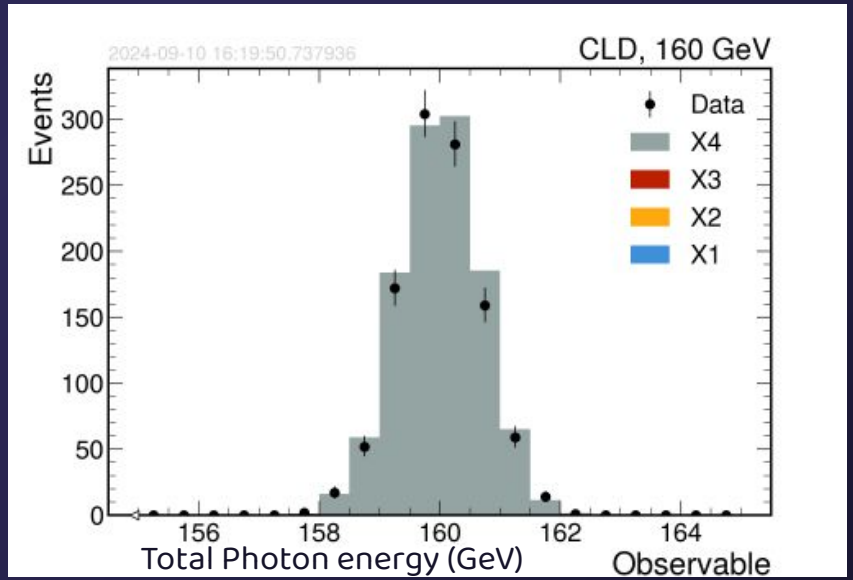
X3 standard model at 160 GeV

- This process may indicate a single W production
  - If no jets detected, there is one lepton
  - One or two jets possible
  - Overlapping signals with X2 (WW decay)
  - Three missing particles cause wide uncertainty in energy, so W mass is not reconstructable



X4 standard model at 160 GeV

- For X4 there is a clear peak in the Invariant mass calculated from 2 photons (~160 GeV) at $\Delta\varphi = 180°$
- X4 is electron-positron annihilation
- Additionally X4 produces lepton pairs and jets at $\Delta\varphi = 180°$ with invariant mass at 160 GeV



Number of events for 2 photon events as a function of combined energy

240 GeV

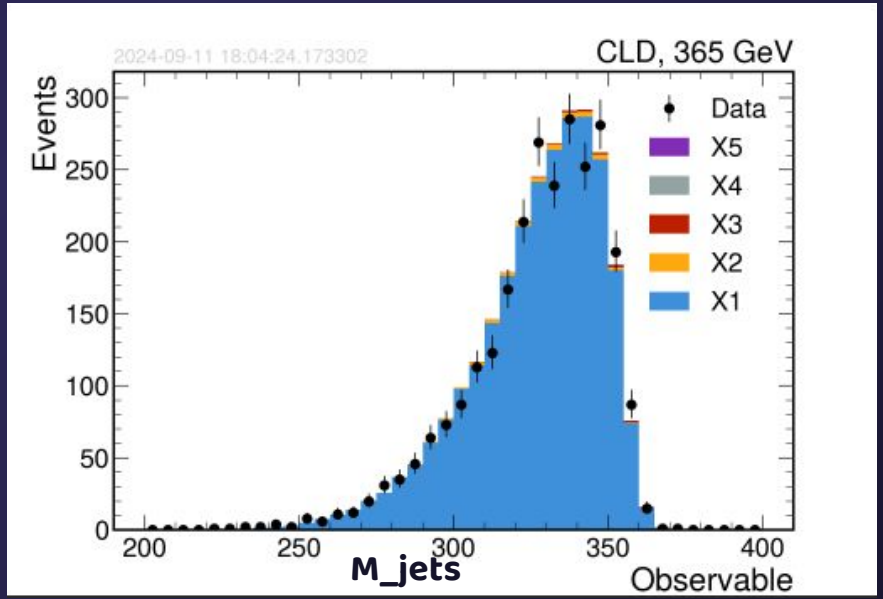
Processes at 240 GeV

- Preliminary results suggest that H-Z, W-W and Z-Z pair could be produced
- Results are still in the oven (let em cook)

365 GeV

X1 Standard Model at 365 GeV

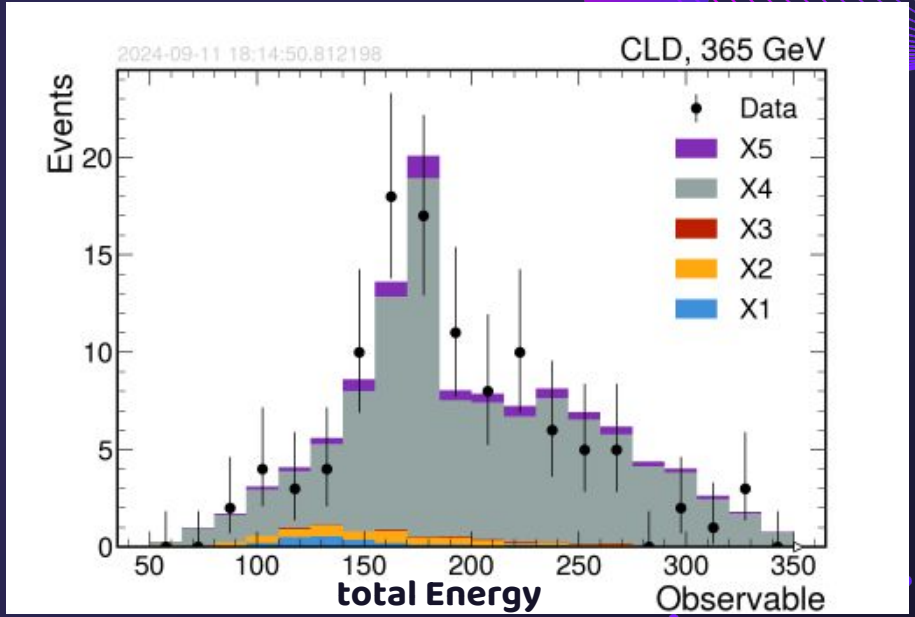
- 6 jets chosen with at least one btag
- Reconstructed mass of all jets indicates a t-pair production.



Invariant mass of reconstructed jets

X4 Standard Model at 365 GeV

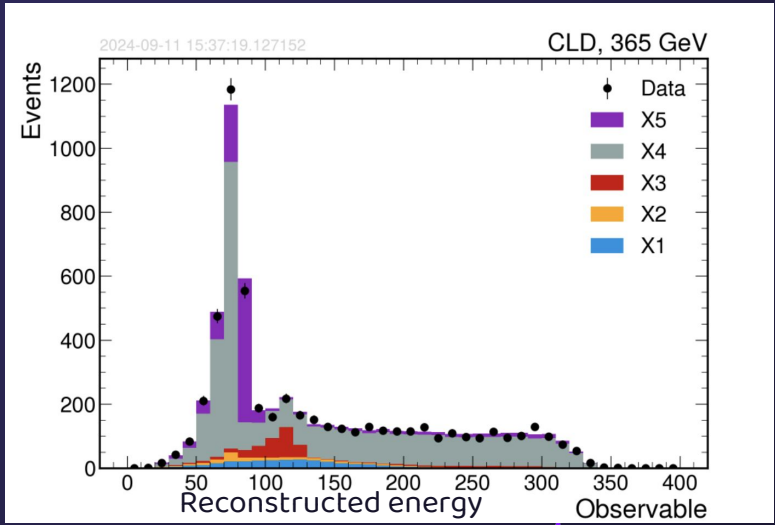
- Slight bump at 160 GeV, indicating W-W production



2 photons

X4 Standard Model at 365 GeV

- Slight bump at 160 GeV, indicating W-W production
- Combing these results shows that
  - X4 is W-W production
  - X5 is Z-Z or Z-H production
- Note:
  - Higgs production is involved in X3
  - Slight bump in X2 around W-mass



Only 2 jets

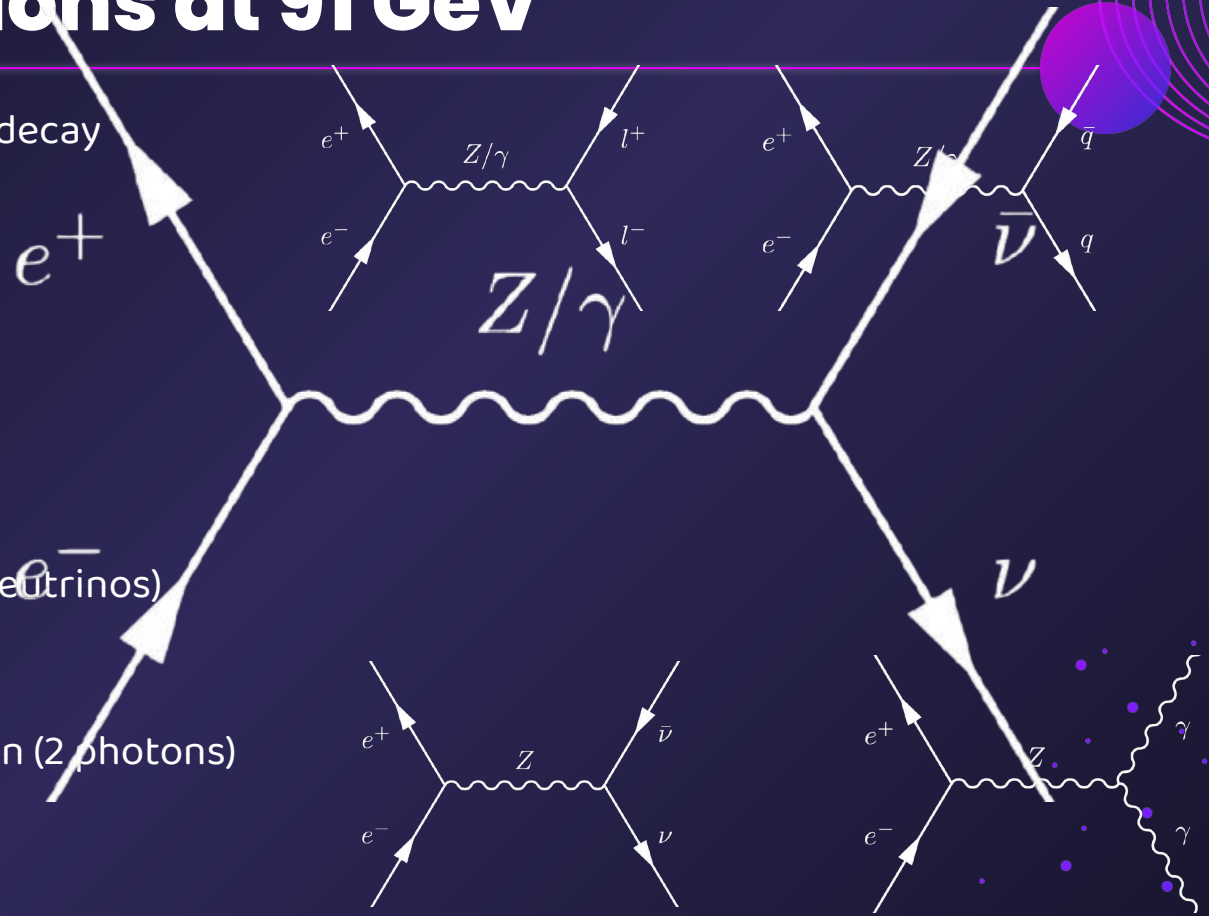
Thank you
for your attention

References

- N. Baccheta, J. -J. Blaising, E. Brondolin et al. (2019) *CLD - A Detector Concept for the FCC-ee*, arXiv:1911.12230
- A. Sailer and P. Roloff, *The CLD Detector Concept,* Presentation for FCC week 2022

Conclusions at 91 GeV

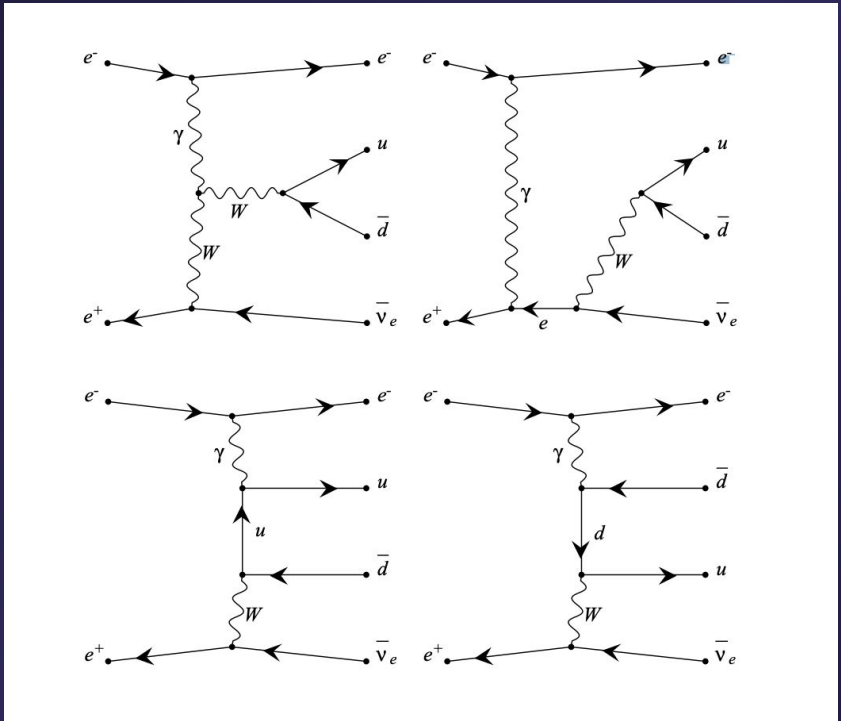
- X1: leptonic Z decay
- X2: Z hadronic
- X3: ?
- X4: Invisible (neutrinos)
- X5: Annihilation (2 photons)

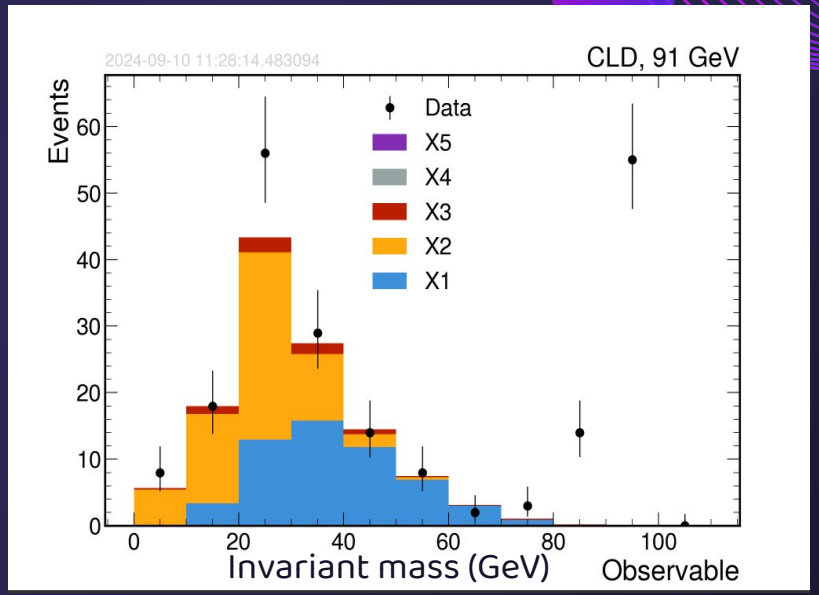


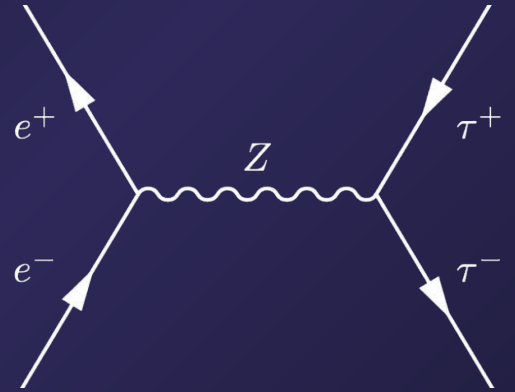
Processes at 160 GeV

- X1: Higgs b + b_bar production
- X2: WW production
- X3: Single W production
- X4: Annihilation

Single W production for 160 GeV??




2024-09-10 11:28:14.483094
CLD, 91 GeV
Events
Data
X5
X4
X3
X2
X1
0
10
20
30
40
50
60
0
20
40
60
80
100
Invariant mass (GeV)
Observable


e^+
e^-
Z
τ^+
τ^-