Reinterpretations in Experimental Particle Physics

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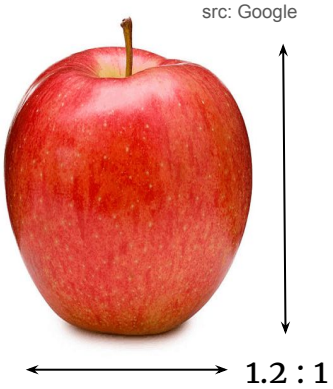
How do you search for a ‘Magic’ Apple?

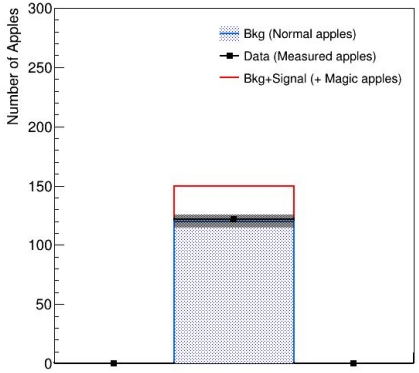
src: Google



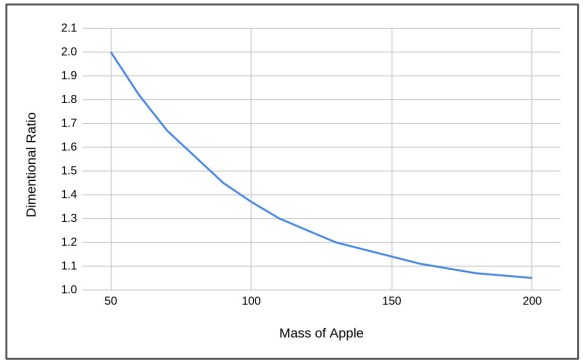
How do you search for a ‘Magic’ Apple?

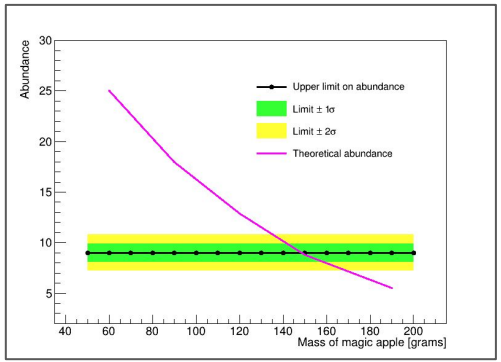
Implement cuts

Meaningful Inference!



Bkg = 120±5.6
Data = 122
Bkg+Sig = 150

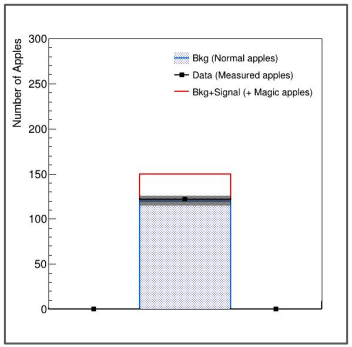


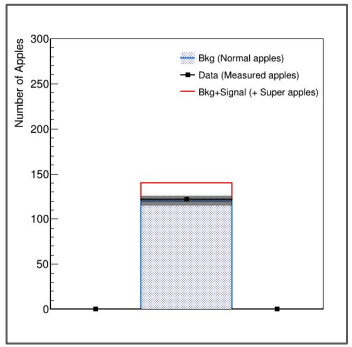


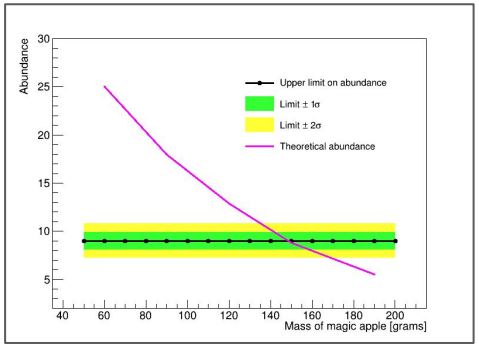
What about searching for a ‘Super’ Apple now?

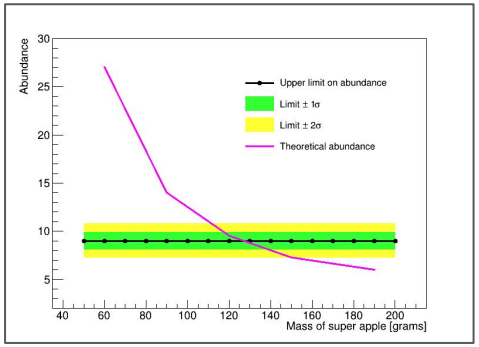
Reinterpretation of Magic Apple search

Using the result of magic apple search for constraining the super apple “model” now.







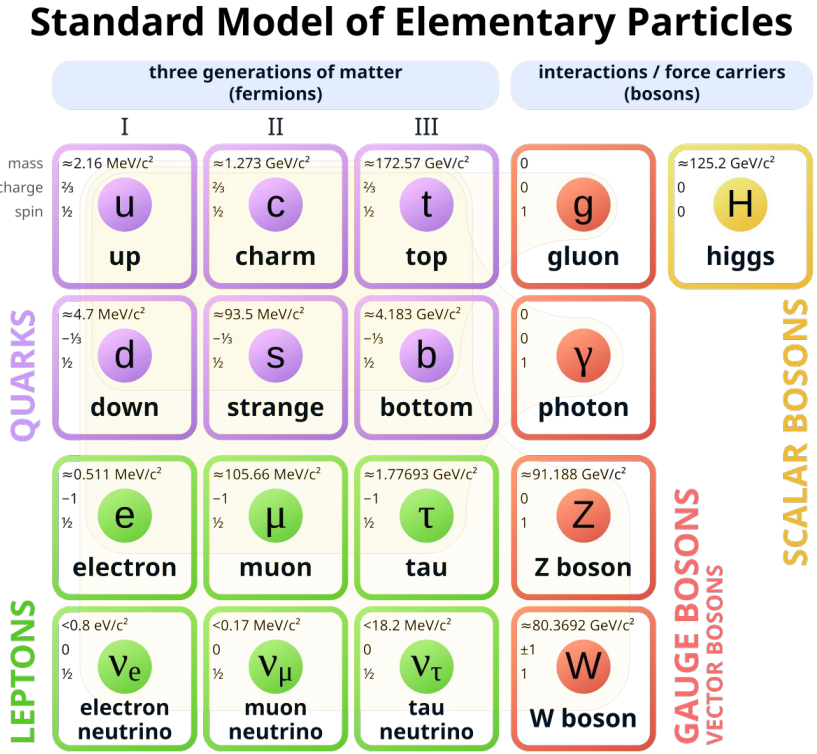


Let’s now apply the analogy to particle physics analyses

The Standard Model

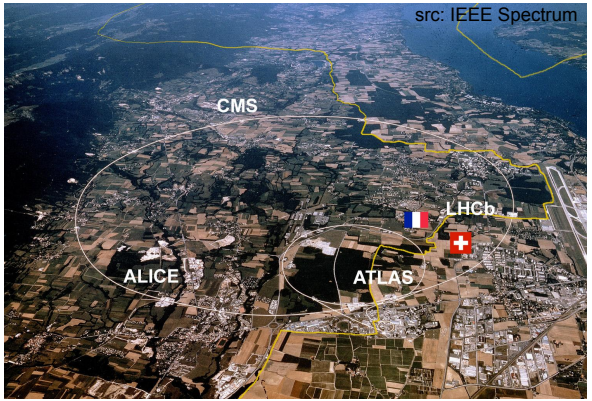
Standard model describes the fundamental particles in nature and the forces they interact through

Explains a wide range of phenomena such as stability of nucleus of atom, radioactivity, and particle interactions in high-energy experiments



src: Wikipedia

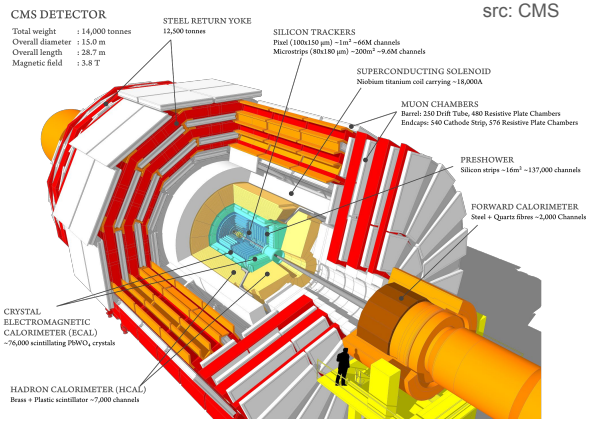
LHC and CMS



27 km ring, 100 m underground

Collides protons at 13.6 TeV

Collision every 25 ns



15×15×21 m detector

Detects the different particles coming out of the collision process

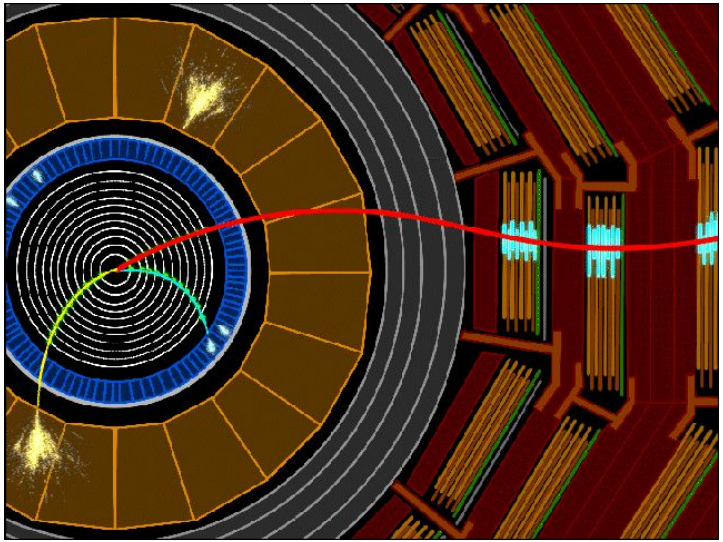
Fun fact: Mosquito (10^23 atoms) : ~TeV energy!

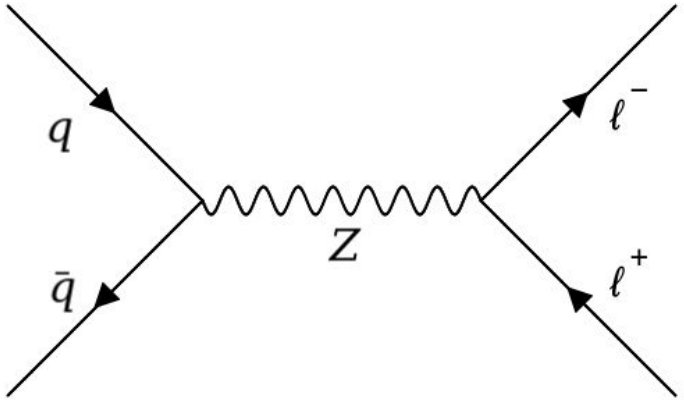
CMS Detector

The collisions produce particles which leave signatures in detectors

Algorithms used to reconstruct the particles from the signatures

Analyse the particles to infer the process occuring at the time of collision





Credit: Prachurjya Hazarika

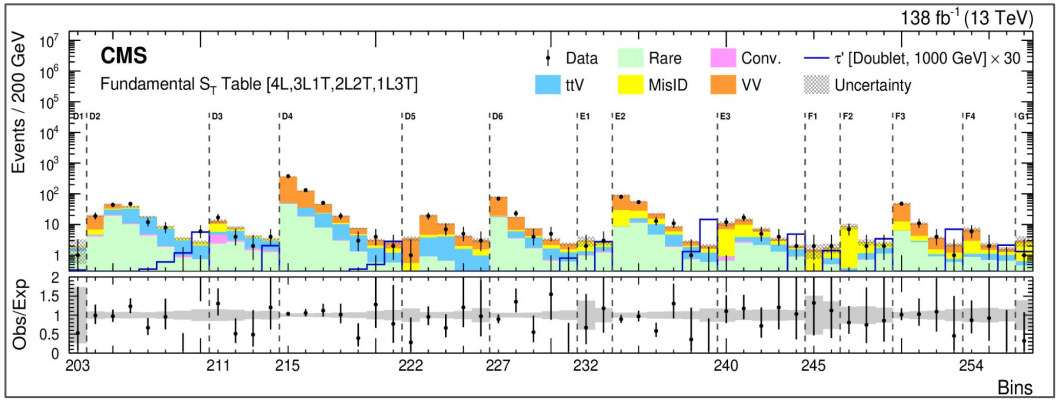
CMS Multilepton Search

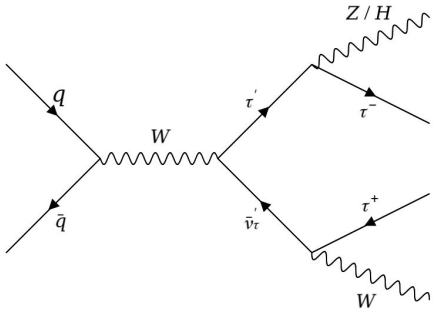
CMS performed a multilepton search (PRD 105,112007 (2022))

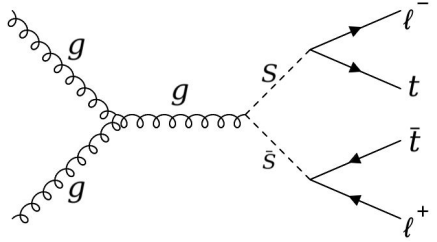
Constraints on VLL τ-like singlet/doublet, Type-III Seesaw, LQ models

Additionally model-independent results provided in ~1200 SRs

[Observation, Background, Bkgd Uncertainty]







Strategy

Want to reinterpret the results from the search on a new VLL μ-like model

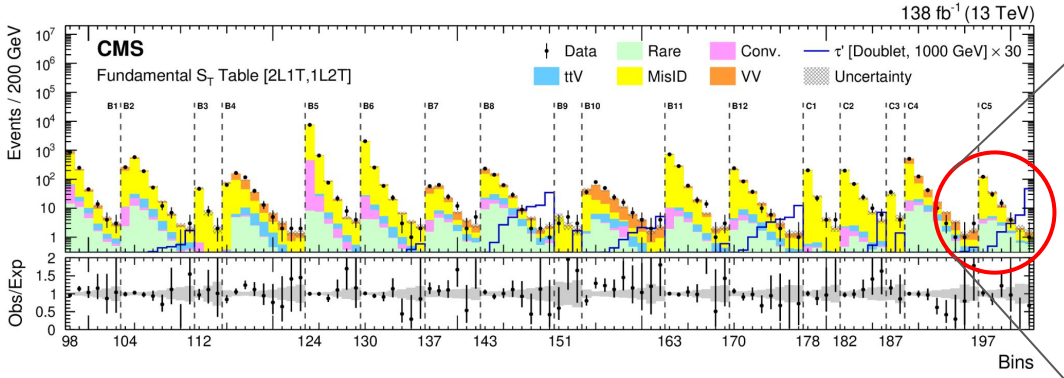
However, need to validate my selections!

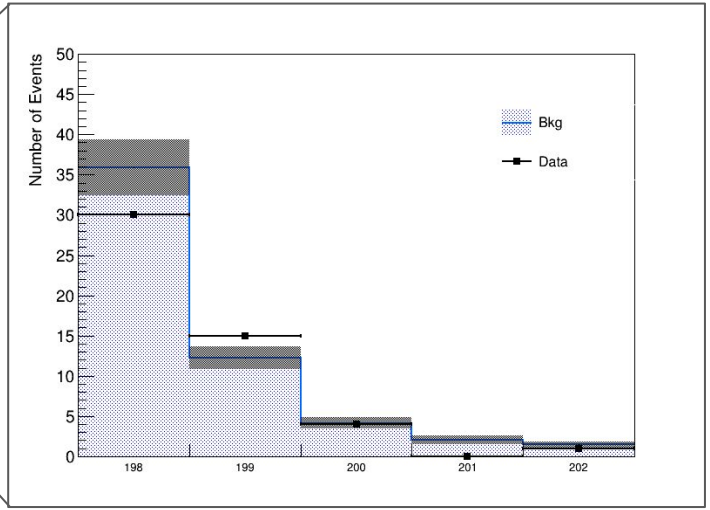
Do this part first!

- Validate by reproducing existing limit.
  1) Generate VLL doublet signal simulation
  2) Implement detector effects using the efficiency maps
  3) Implement exact analysis selections from PRD 105,112007 (2022)
  4) Implement code to calculate upper limits

Background and Data

Background and data obtained from the search.





doi:10.1103/PhysRevD.105.112007

However, I need signal!

Simulating Signal

Generate samples via MadGraph, Pythia and Delphes

VLL τ-like signal ($m_{\tau'}$ = 600 GeV)

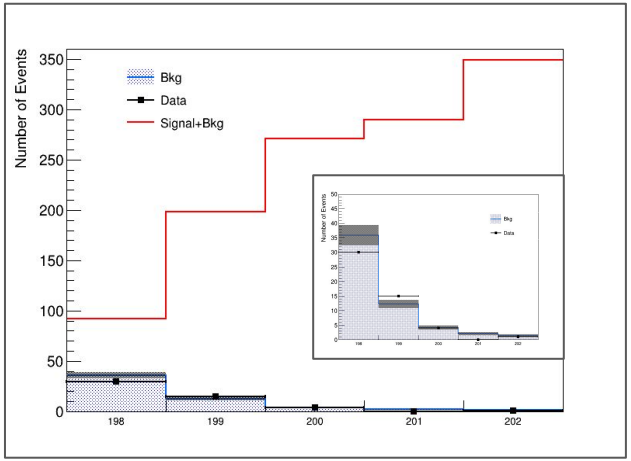
100k events generated

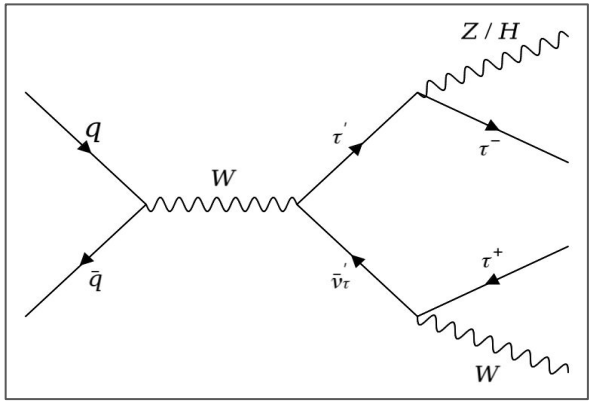
Bins	Exp (σB) limit	Production (σB)	
198	0.928	0.0149	Not Excluded
198 - 202	0.00264	0.0149	Excluded

This means that a 600 GeV τ' cannot exist.

However, analysis needs to be done systematically

- All masses
- All available SRs





Efficiency Maps

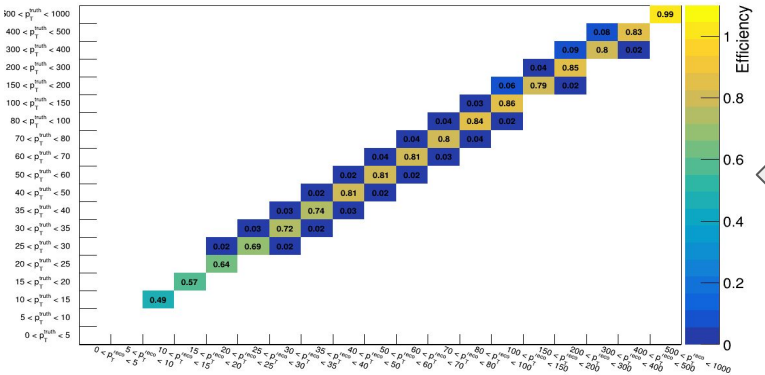
Used to obtain reco yield from gen-level yield via efficiency maps.

The number on each bin shows probability of the particle with its p_T falling in the corresponding gen p_T bin to be reconstructed as one in the corresponding reco p_T bin.

Separate efficiency maps for:

- e, μ and τ_h(1p and 3p)
- Barrel, transition and endcap region of detector
- e/μ with tau mother and boson mother

⋮



Muon
Barrel ($|\eta| \leq 1.1$)
Tau Mother
dR High ($dR_{min} > 0.2$)

Signal Regions

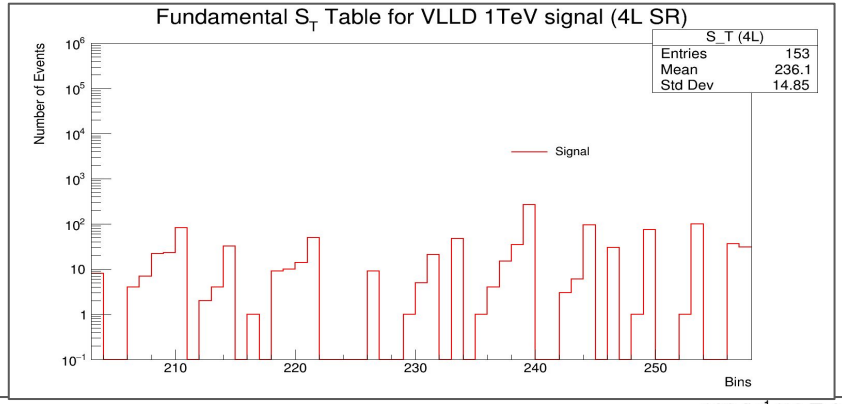
Signal yield calculated for each SR in the S_T distribution table.

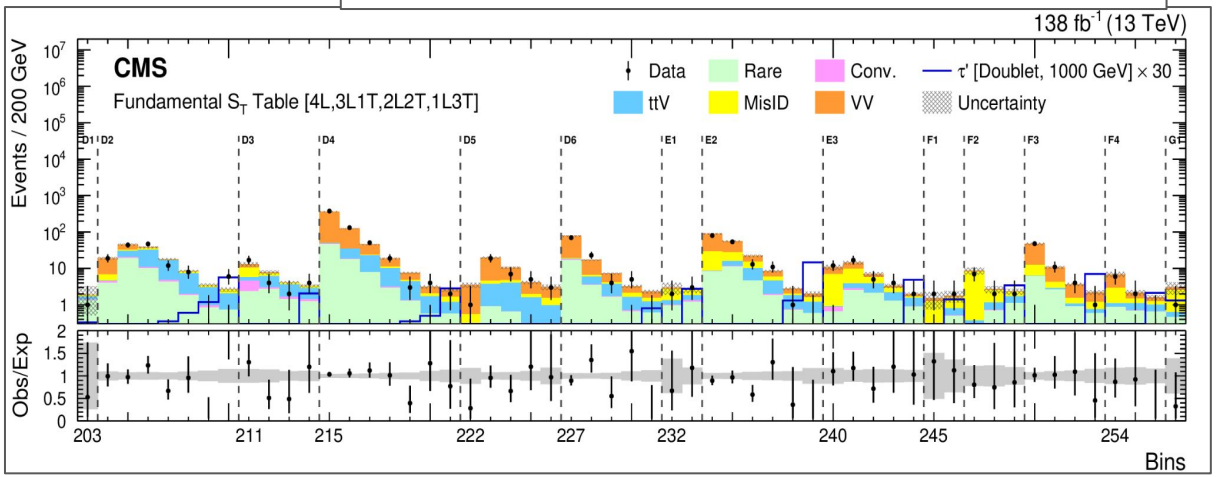
S_T: $L_T + H_T + p_T^{miss}$

L_T: Scalar p_T sum of all selected leptons

H_T: Scalar p_T sum of all jets

Using the signal, bkg and data to obtain limits and constrain model

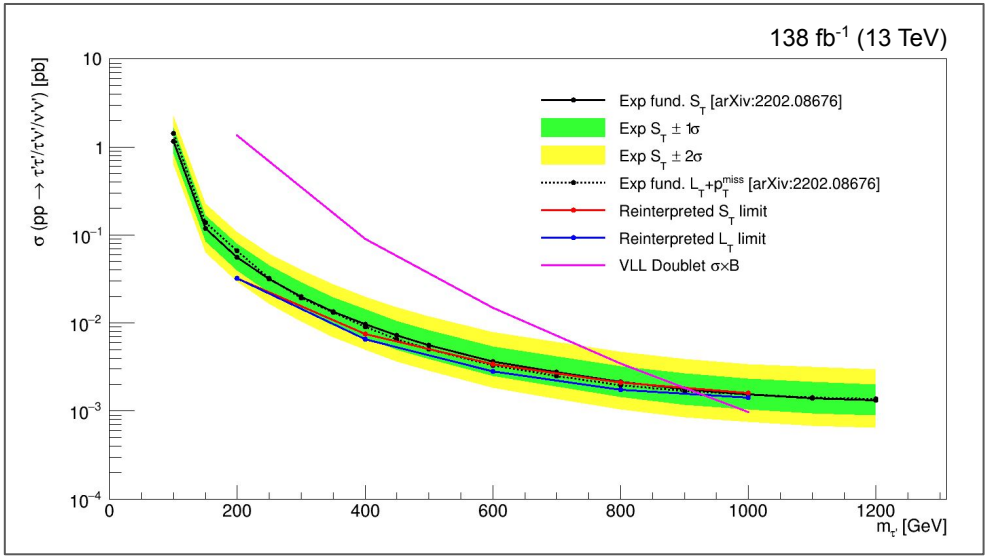




Obtaining Limits

Upper limit on the cross-section calculated using the S_T and $L_T+p_T^{miss}$ tables compared to the corresponding limits from the paper.

Exclusion at 900 GeV, consistent with reinterpreted limits and those from the paper.



Therefore, my analysis strategy is validated and my results are trustworthy!

VLL Mu-like Analysis

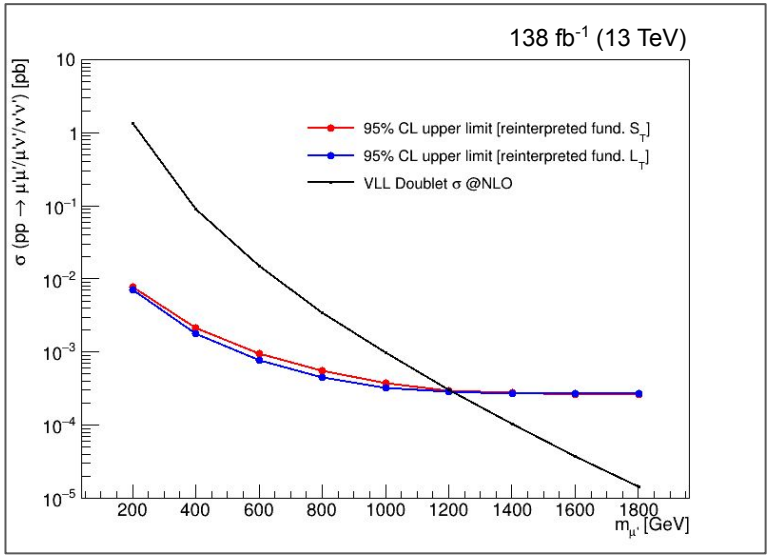
No published limits to the model yet.

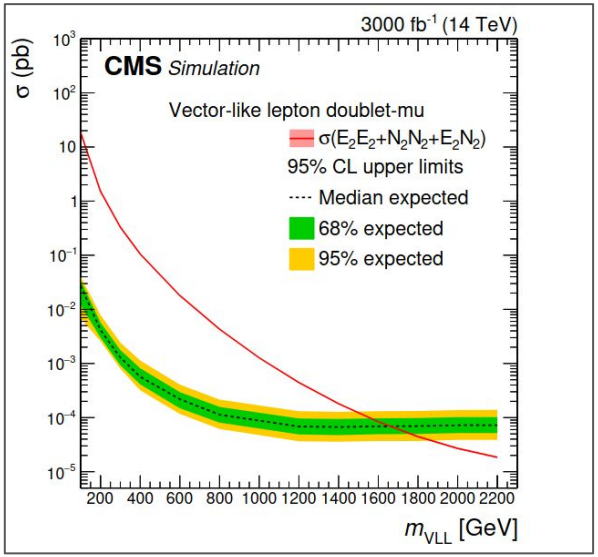
Implement the workflow for VLL mu-like model.

Exclusion at 1.2 TeV.

CMS Review paper talks about expected limit at HL-LHC.

arXiv:2405.17605





Summary

- Many high-energy physics experiments do searches and produce results regularly
- These results can be repurposed to explore other phenomena via reinterpretation
- It is an involved process and contains of following steps:
    - Generate signal for the new model
    - Implement detector effects
    - Put the exact selections as the original search
    - Calculate limits for the model

Thank you!