

# Selecting Muon Identification Criteria for the Search for Doubly-Charged Higgs Signals

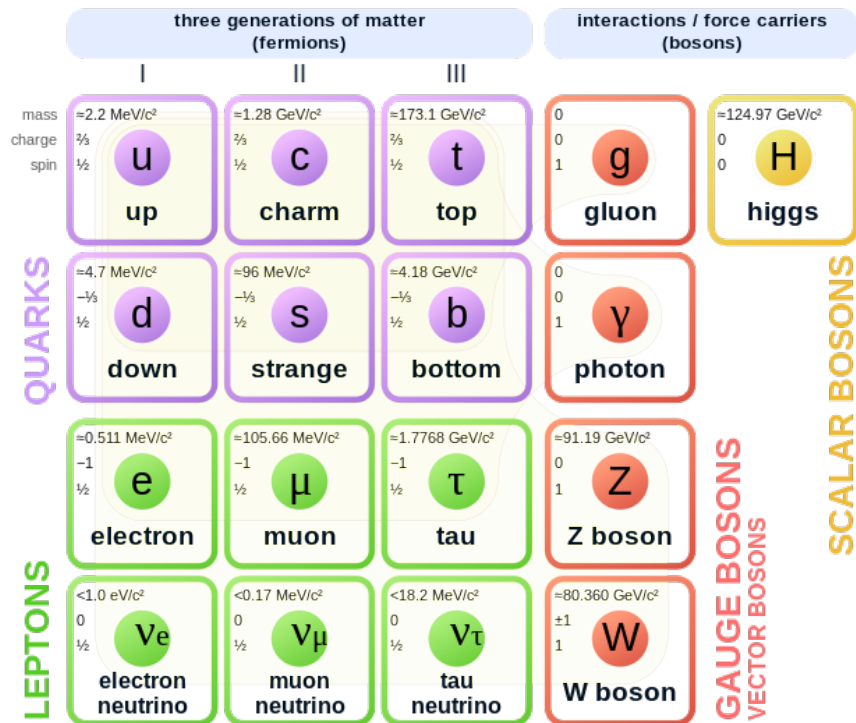
Gabi Kennedy Orive

K-State Physics REU 2023

# Standard Model



## Standard Model of Elementary Particles

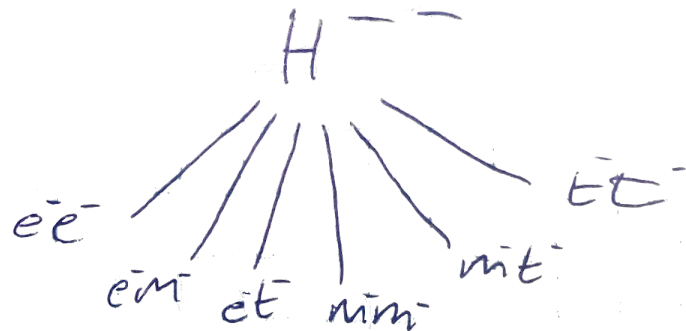
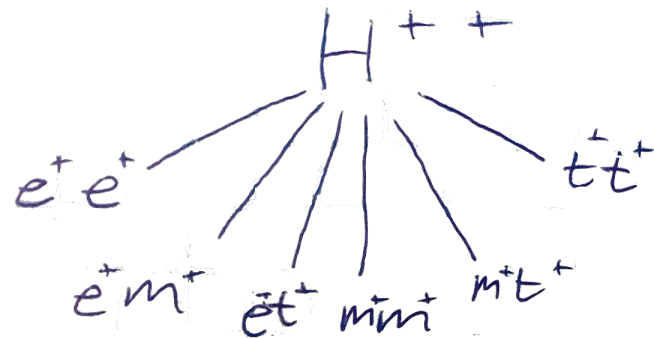


# Doubly-Charged Higgs

- The Type II Seesaw Leptogenesis Mechanism extends the Standard Model with a scalar triplet that has a doubly-charged component in order to explain neutrino masses<sup>1</sup>
- Find evidence of Doubly-Charged Higgs production
- Doubly-Charged Higgs come in pairs, one positive and one negative
- These Higgs can decay into any combination of electrons, muons, and taus
- Higgs can't be solely positively or negatively charged, must have friend to cancel it out
- $H^{++}H^{--}$

1. Sánchez Villamizar, Yozara. (2019)

# "Decay Model"



$$u^+u^+u^-u^-$$

# Aim of the Game

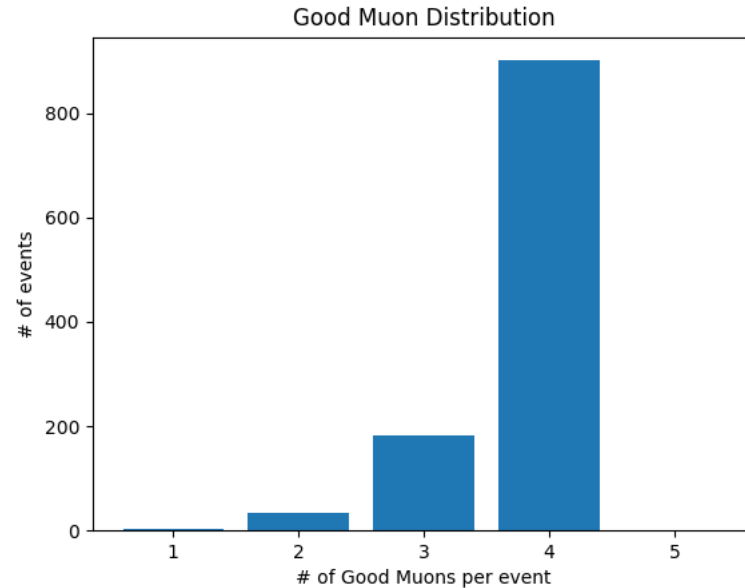
- We want to find the best way to define a “Good Muon” so we can better detect Doubly-Charged Higgs
- Working with loose, medium, and tight IDs to see which is the best fit
- Criteria for the original code is just the medium and tight ID
- Find a good place to put a  $p_T$  cut
  - Signal
    - $p_T > 40$  GeV
  - Background
    - $p_T > 20$  GeV

# Criteria (aka “Cuts”)

- Transverse Momentum ( $p_T$ )  $> 40$  GeV is the current cutoff for the signal data (output-1)
- $p_T > 20$  GeV is the cutoff for the background data (DY)
- Particle Flow Isolation (Iso) Cut Values
  - Tight
    - $\Delta R \leq 0.15$
  - Medium
    - $\Delta R \leq 0.20$
  - Loose
    - $\Delta R \leq 0.25$

# Counting Good Muons from Signal Data (with previous cuts)

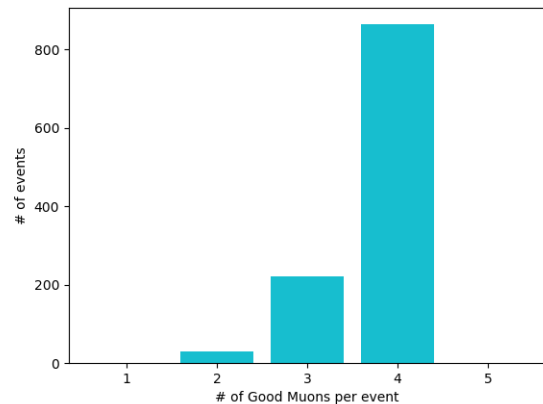
1 (+ or -)	2
2 (++, +-, or --)	34
3 (++- or +--)	181
4 (++--)	902
Total	42222



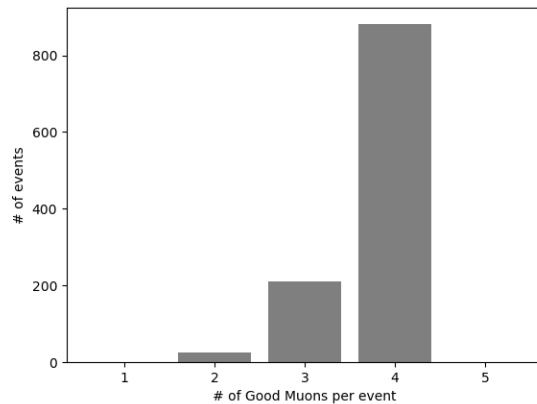
# New Criteria, Loose (Signal)



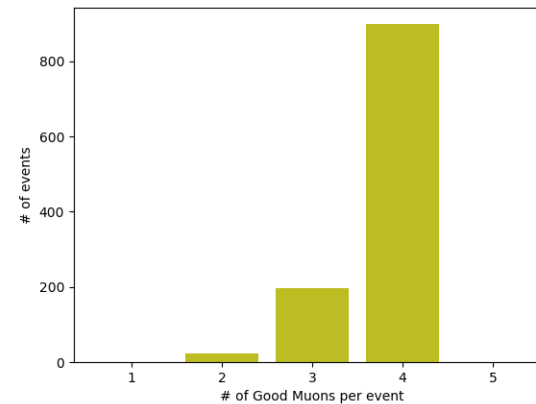
I1 Good Muon Distribution



I2 Good Muon Distribution



I3 Good Muon Distribution



1 (+ or -)	1
2 (++, +-, or --)	31
3 (++- or +-+)	222
4 (++--)	864
Total	4190

1 (+ or -)	1
2 (++, +-, or --)	26
3 (++- or +-+)	210
4 (++--)	881
Total	4212

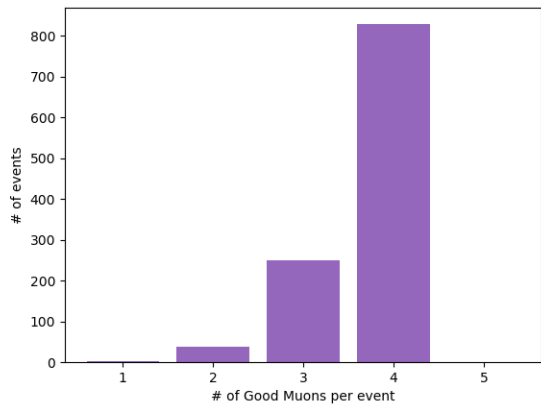
1 (+ or -)	1
2 (++, +-, or --)	23
3 (++- or +-+)	196
4 (++--)	898
Total	4232



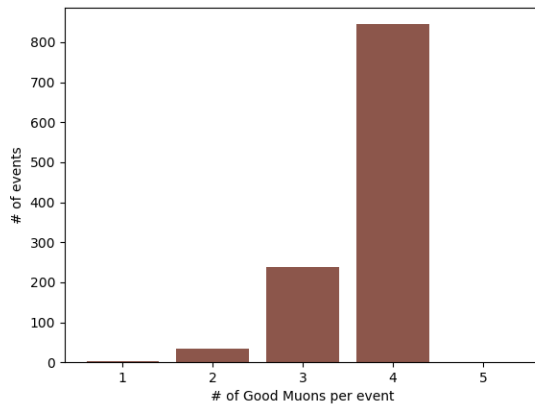
# New Criteria, Medium (Signal)



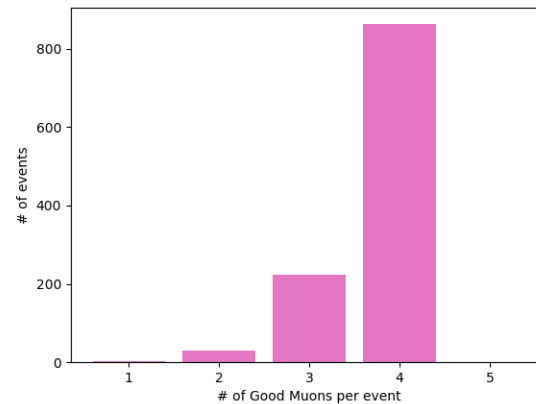
m1 Good Muon Distribution



m2 Good Muon Distribution



m3 Good Muon Distribution



1 (+ or -)	2
2 (++, +-, or --)	38
3 (+- or +--)	250
4 (++--)	828
Total	4145

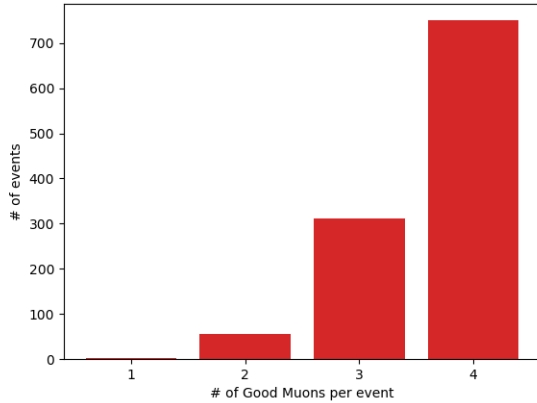
1 (+ or -)	2
2 (++, +-, or --)	33
3 (+- or +--)	238
4 (++--)	845
Total	4167

1 (+ or -)	2
2 (++, +-, or --)	30
3 (+- or +--)	224
4 (++--)	862
Total	4187

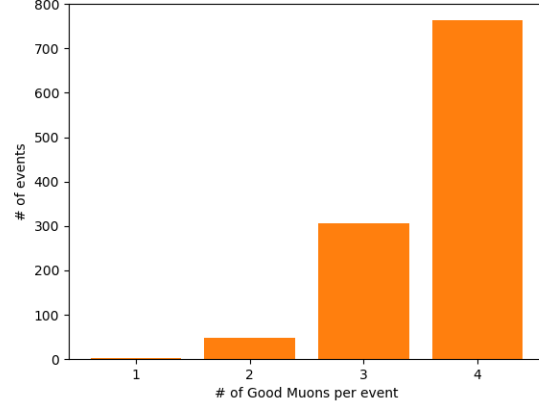
# New Criteria, Tight (Signal)



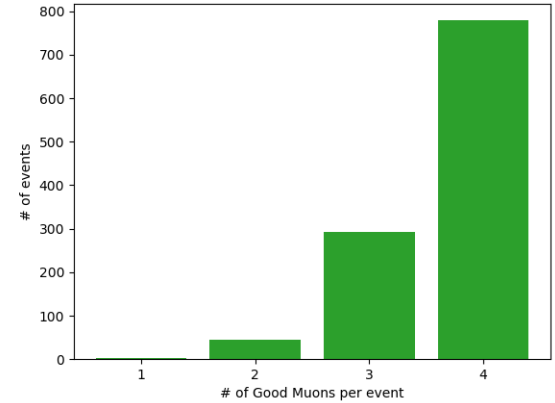
t1 Good Muon Distribution



t2 Good Muon Distribution



t3 Good Muon Distribution



1 (+ or -)	3
2 (++, +-, or --)	55
3 (+- or +--)	311
4 (++--)	750
Total	4046

1 (+ or -)	3
2 (++, +-, or --)	48
3 (+- or +--)	305
4 (++--)	763
Total	4066

1 (+ or -)	3
2 (++, +-, or --)	45
3 (+- or +--)	292
4 (++--)	779
Total	4085

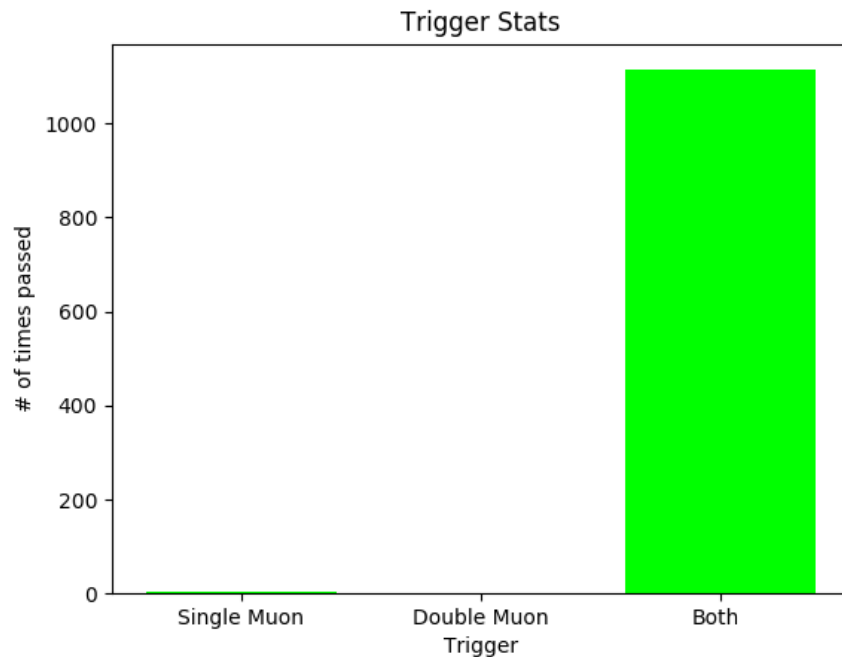
# Signal Triggers



Single Trigger	4
Double Trigger	1
Both	1114

By using only Single, we lose 1 event.  
By using only Double, we lose 4 events.  
By using both, we lose 5 events.

Using both presents 99.55% accuracy.



# Results (Signal)



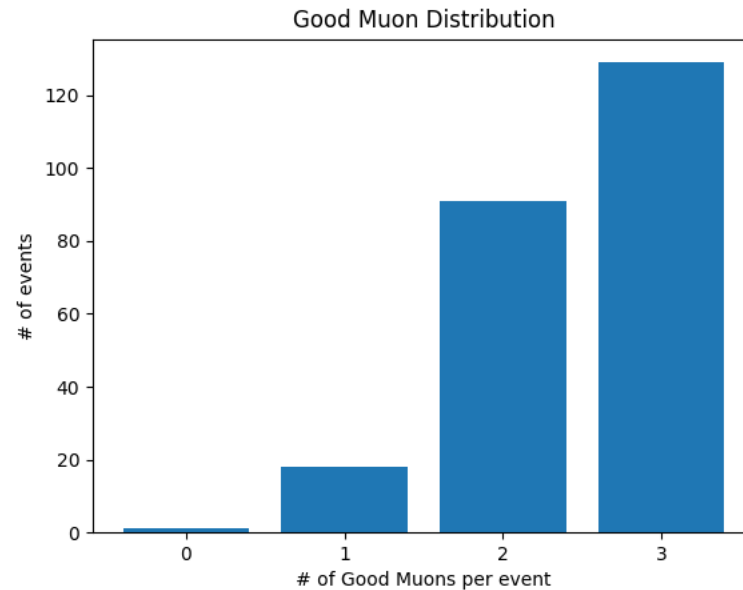
Integrated Luminosity (L)	137.6 fb <sup>-1</sup>
Cross Section (X)	0.03477 fb
Branching Ratio (R)	1
Acceptance (A)	0.803395889
Expected Number of mmmm Events	3.843728729

$$\text{Acceptance} = \frac{\text{\# of mmmm events that passed l3 cut}}{\text{total \# of events}} = \frac{898}{1119} = 0.803395889$$

$$\text{Expected \# of mmmm Events} = L * X * R^2 * A = 3.843728729$$

# Counting Good Muons from Given Background Data (with previous cuts)

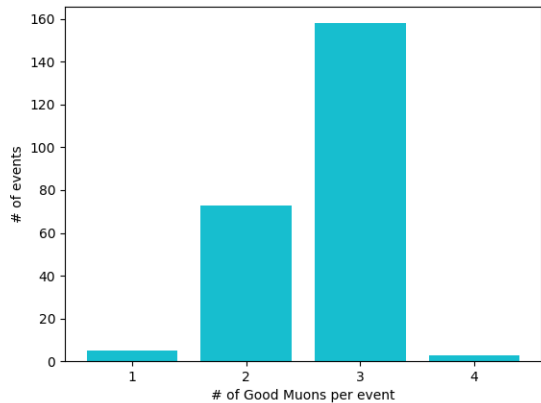
1 (+ or -)	18
2 (++, +-, or --)	91
3 (++- or +--)	129
4 (+++-)	0
Total	587



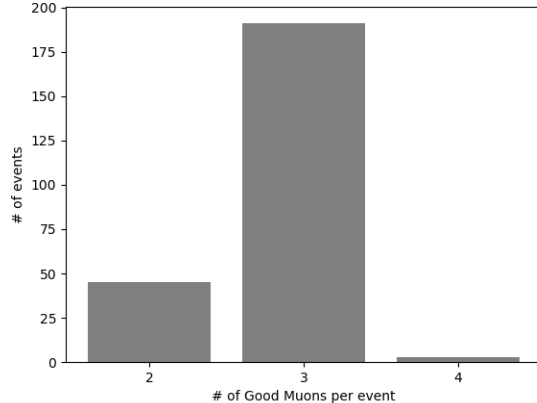
# New Criteria, Loose (Background)



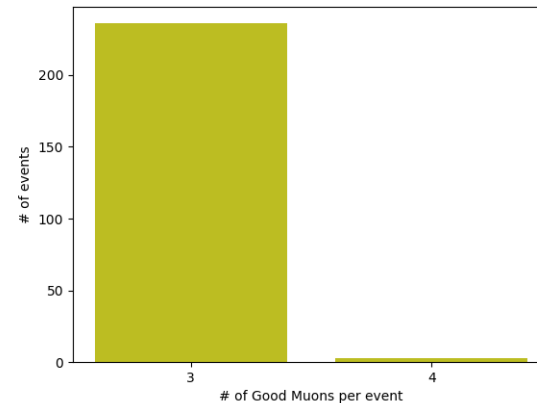
I1 Good Muon Distribution



I2 Good Muon Distribution



I3 Good Muon Distribution



1 (+ or -)	5
2 (++, +-, or --)	73
3 (+- or +--)	158
4 (++--)	3
Total	637

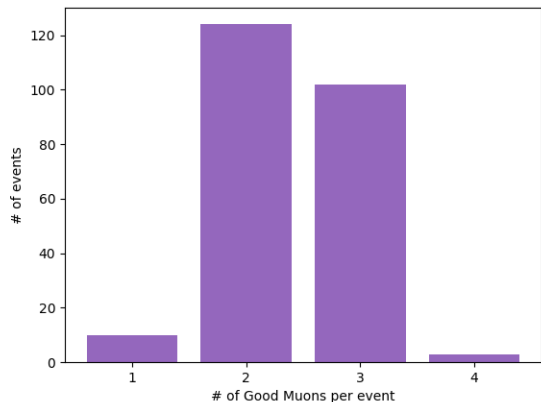
1 (+ or -)	0
2 (++, +-, or --)	45
3 (+- or +--)	191
4 (++--)	3
Total	675

1 (+ or -)	0
2 (++, +-, or --)	0
3 (+- or +--)	236
4 (++--)	3
Total	720

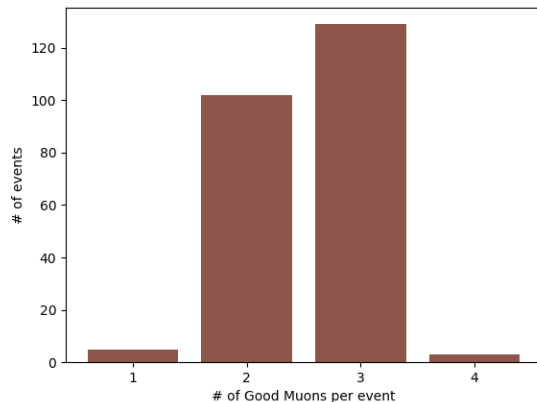
# New Criteria, Medium (Background)



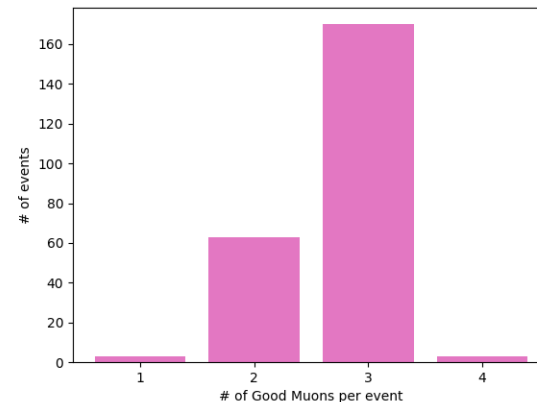
m1 Good Muon Distribution



m2 Good Muon Distribution



m3 Good Muon Distribution



1 (+ or -)	10
2 (++, +-, or --)	124
3 (+- or +--)	102
4 (++--)	3
Total	576

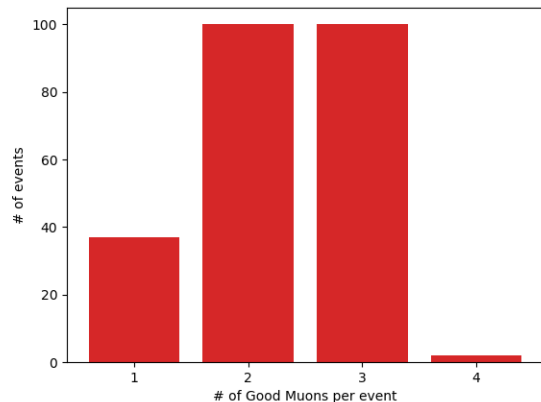
1 (+ or -)	5
2 (++, +-, or --)	102
3 (+- or +--)	129
4 (++--)	3
Total	608

1 (+ or -)	3
2 (++, +-, or --)	63
3 (+- or +--)	170
4 (++--)	3
Total	651

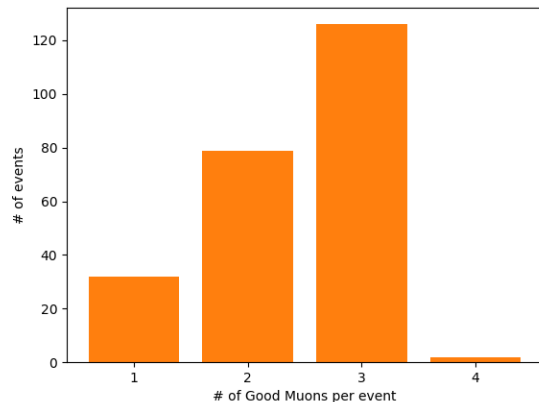
# New Criteria, Tight (Background)



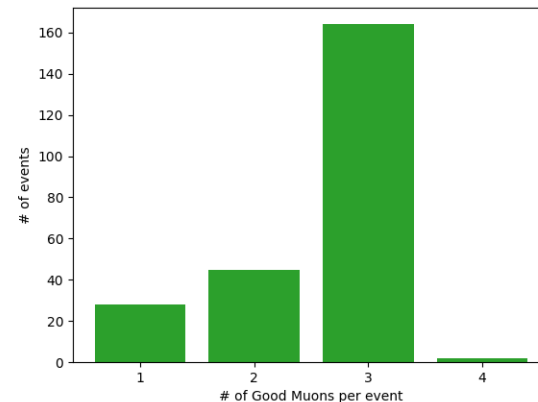
t1 Good Muon Distribution



t2 Good Muon Distribution



t3 Good Muon Distribution



1 (+ or -)	37
2 (++, +-, or --)	100
3 (++- or +--)	100
4 (++--)	2
Total	545

1 (+ or -)	32
2 (++, +-, or --)	79
3 (++- or +--)	126
4 (++--)	2
Total	576

1 (+ or -)	28
2 (++, +-, or --)	45
3 (++- or +--)	164
4 (++--)	2
Total	618



# Results (Background)



Integrated Luminosity (L)	137.6 fb <sup>-1</sup>
Cross Section (X)	6225420 fb
Branching Ratio (R)	1/3
Acceptance (A)	8.7565x10 <sup>-8</sup>
Expected Number of mmmm Events	25.0032764

$$\text{Acceptance} = \frac{\text{\# of mmmm events that passed l3 cut}}{\text{total \# of events}} = \frac{3}{34260219} = 8.7565 \times 10^{-8}$$

$$\text{Expected \# of mmmm Events} = L * X * R * A = 25.0032764$$

# Expected Number of mmmm Events

## Background

Expected Number of mmmm Events	25.0032764
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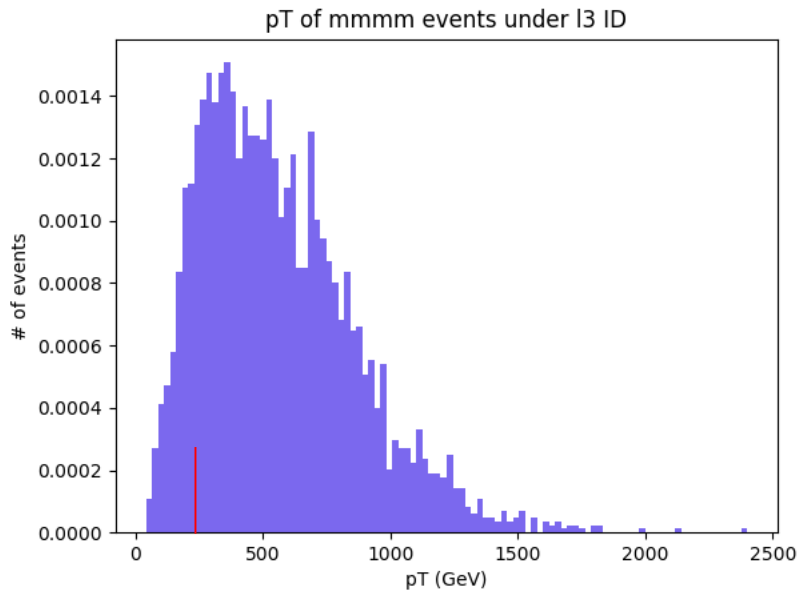
## Signal

Expected Number of mmmm Events	3.843728729
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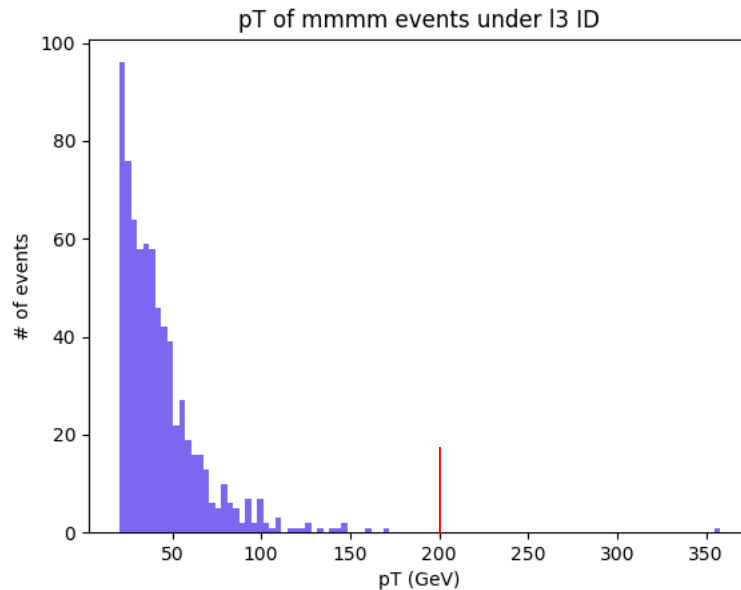
# Transverse Momentum Graphs



Signal



Background



$p_T < 200$  GeV

# Conclusions & Future Work



## Conclusions

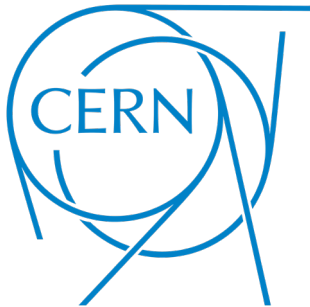
- $p_T < 200$  GeV cut
- Loose Iso3 seems to be the best choice for ID
- Without more work, differentiating Signal muons from Background muons will be difficult

## Future Work

- Apply the  $p_T$  cut
- Continue testing with different criteria
- Compare with results of testing with electrons and taus
- Checking other background examples

# Thank you

- Dr. Andrew Ivanov
- Reese Sanders
- Kim Coy, Dr. Loren Greenman, Dr. JT Laverty
- You!



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# Questions

