LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Central and exclusive production of $\tau^+\tau^-$ pairs at the **LHC** in the $\tau_h\tau_h$ decay channel

Hello!

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I am here because I love computation and particle physics. You can find me at fc58289@ aluno.fc.ul.pt

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I love particle and nuclear physics.
This is the 1st time I'm using ML.
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Process:

$$pp \rightarrow p'p' + \tau\ \tau$$

Taus detected by **CMS CT**

Tau decayment channels (denoting the one in **study**)

$$\begin{cases} \tau \rightarrow \tau_h \text{ (Reconstructed from } \textit{hadrons}) \\ \tau \rightarrow \nu_\mu + \mu + \overline{\nu}_\mu \\ \tau \rightarrow \nu_e + e + \overline{\nu}_e \end{cases}$$

Interaction via photons (γ)

pp repulsion leads to energy loss:

$$p_1 \leftrightarrow \xi_1 := \frac{P_{p_1} - P_{p_{1'}}}{P_{p_1}}$$

and small path deviation:

$$\theta_1, \theta_2 \sim 0$$

Protons require auxiliar detector, **PPS**

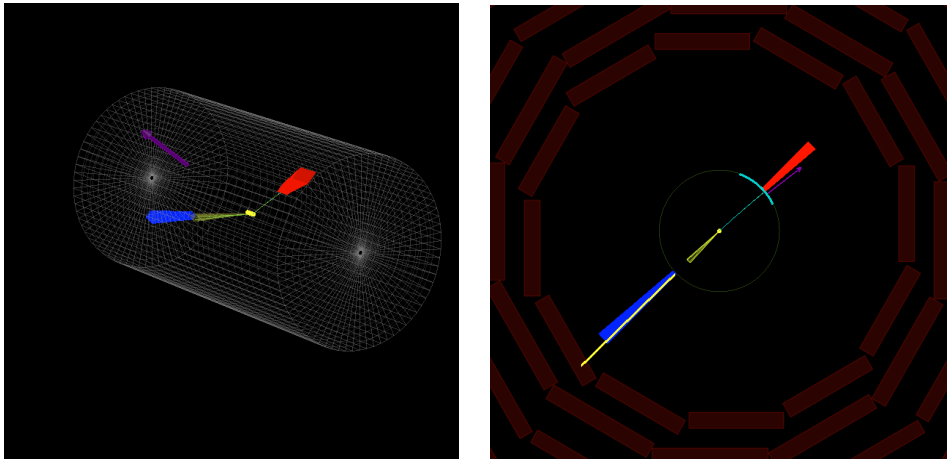


Fig.2 - Computer event display in CMS

CMS: *main detector*

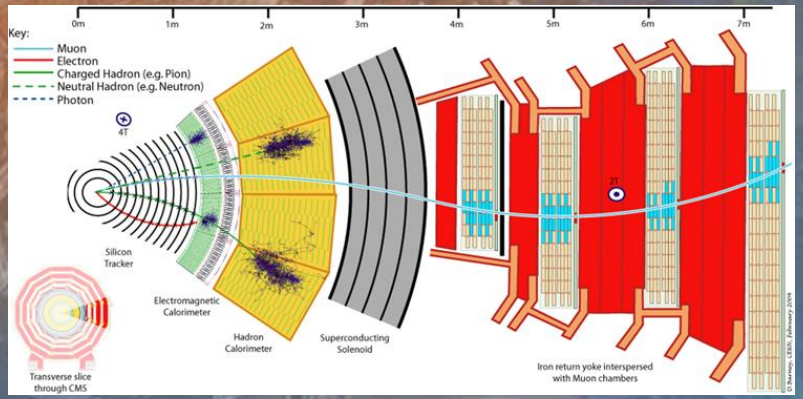


Fig.1 - Transversal view of a CMS section

- A detector at the LHC
  - 10 years to build
  - Higgs observation
  - LHC Run 3
- Compact **Muon** Solenoid
  - Many layers of mechanisms designed to measure energy and momenta
- Important variables derived
  - P , P_t , $M_x := \sqrt{2P_1P_2(1-cos\theta)}$, $Y_x := \frac{\log(\xi_1/\xi_2)}{2}$, $A := \frac{|\Delta\phi|}{\pi}$

PPS: *aux. detector*

- **Precision** Proton Spectrometer
- Located *200m* from CMS' tips

- **Symmetrical**
- Composed of timing/ **tracking** stations and guiding **magnets**
- **We only studied events with 1 p in the final state**

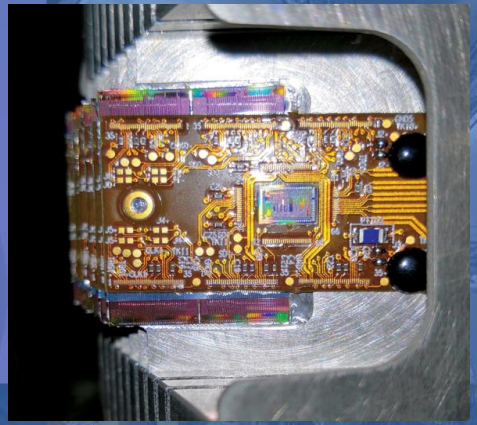
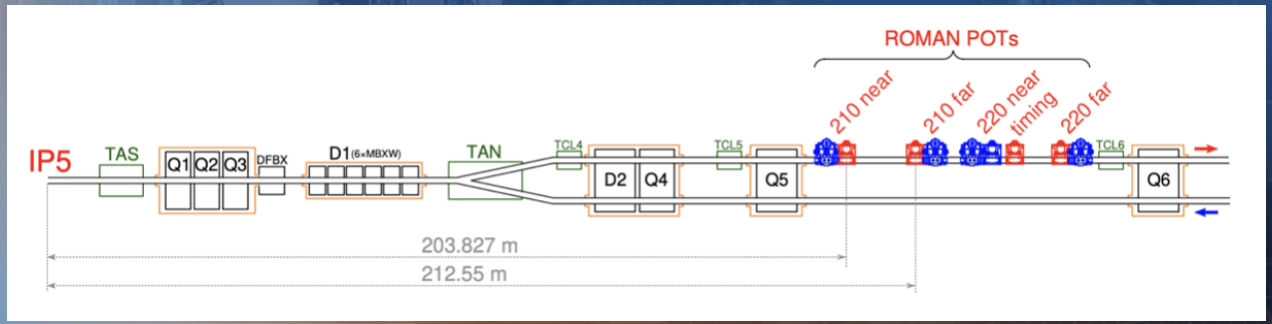


Fig.3 – PPS Tracking Station

- Detects protons with $\xi \in [0.03\ ;\ 0.2]$
- $M_x := \sqrt{s\,\xi_1\xi_2}$, $\sqrt{s} = 13\ TeV$

- Proton **package** use combined with high density of interactions in short periods leads to pile-up!

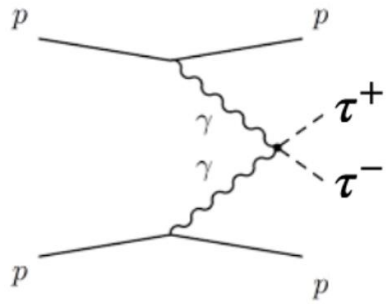


1. Sample Treatment

Strategy

Channel
content

Signal
The signal is the central and exclusive production of tau pairs.

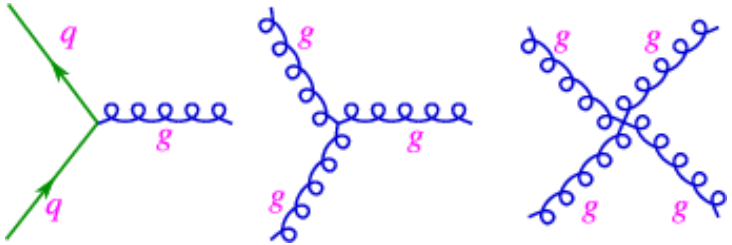


Background
The background encompasses all other processes; we focus on the three primary backgrounds: Drell-Yan, QCD, and ttJets.

Background types

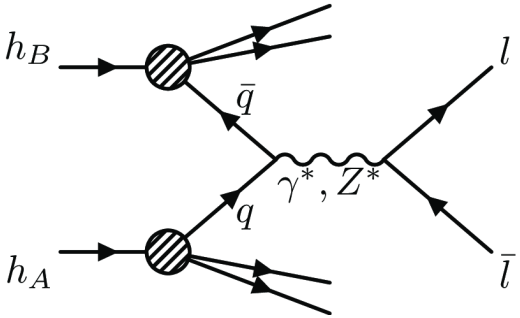
Drell-Yan

- Production of a lepton (namely tau) pairs
- Mediated by Z boson/virtual γ , thus not necessarily back to back: $\theta<90°$



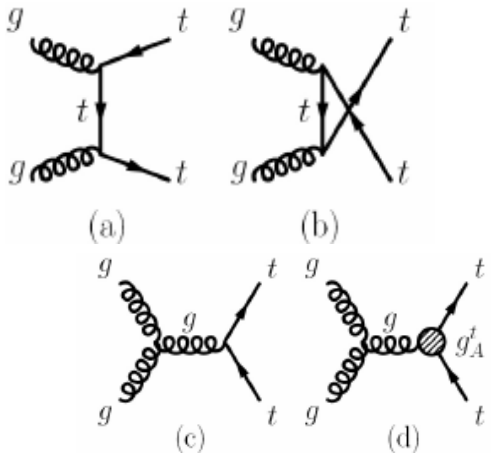
ttJets

- Involves the production of pairs of top quarks.
- These top quarks subsequently decay into various particles.
- Back to back events



QCD

- It involves quarks, gluons, or quark-gluon pairs.
- Produces low-energy particle clusters called jets.
- Back to back events



Phases
description

Phase 0 – Background, Signal
Sample filtration via a Superficial Trigger (primarily relies on linear momentum but also considers events with two taus).
Generally, events with less than 35 GeV of linear momentum do not pass this Trigger.

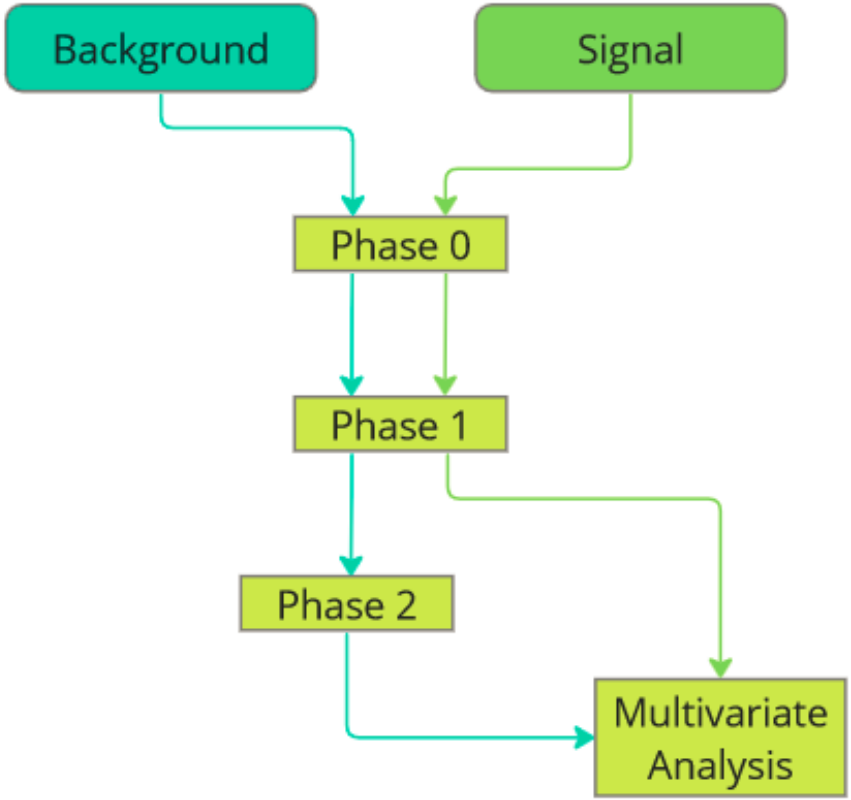
Phase 1 – Background, Signal
Three criteria were enforced for events to be selected in this phase: meeting the conditions for tauID, having a linear momentum exceeding 40 GeV, and exhibiting opposite charges.

The utilization of linear momentum was once more employed to mitigate the low Trigger efficiency.

Phase 2 - Background
In this stage, there was proton enrichment—a statistical process in which we match some of the protons detected in events over the course of 2018 with our simulated events.

Project structure

The background lacks simulated protons because, unlike the signal with a straightforward ξ formula, simulating background protons is considerably more complex.



Events passing each condition

Data Treatment

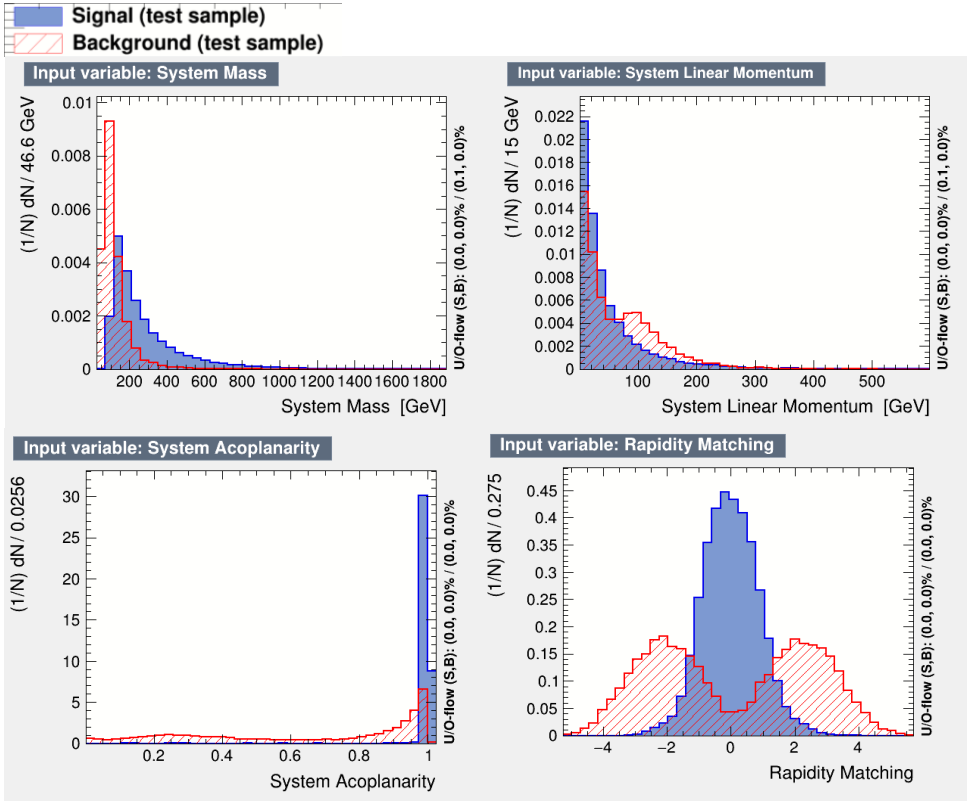
	Background Events	Signal Events	Signal/Background
	67635136	28	4×10^{-7}
τ_{ID}	126288	17	1.3×10^{-4}
p>40 GeV	76823	15	2.0×10^{-4}
Opposite Charges	40065	14	3.6×10^{-4}
Events with 1 proton	18430	8	4.3×10^{-4}

2. Multivariate Analysis

Results

The input variables for the multivariate analysis were:

- System Mass
- System Linear Momentum
- System Acoplanarity
- Linear Momentum of each Tau
- Lost Energy of each Direction
- Rapidity Matching



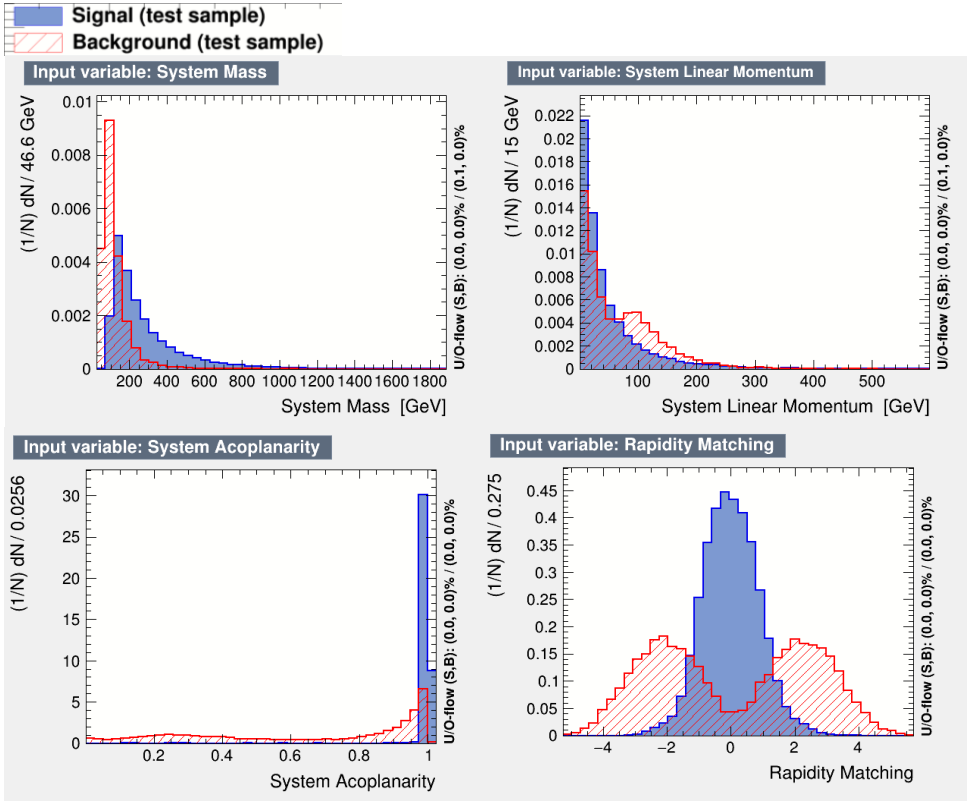
Multivariate Analysis

System Mass:

- The single peak (similar to the combined mass of both taus)is due to the Z boson process w.

System Linear Momentum:

- The background's momentum has two peaks, one from the Z boson in the DY process and another from back-to-back processes.

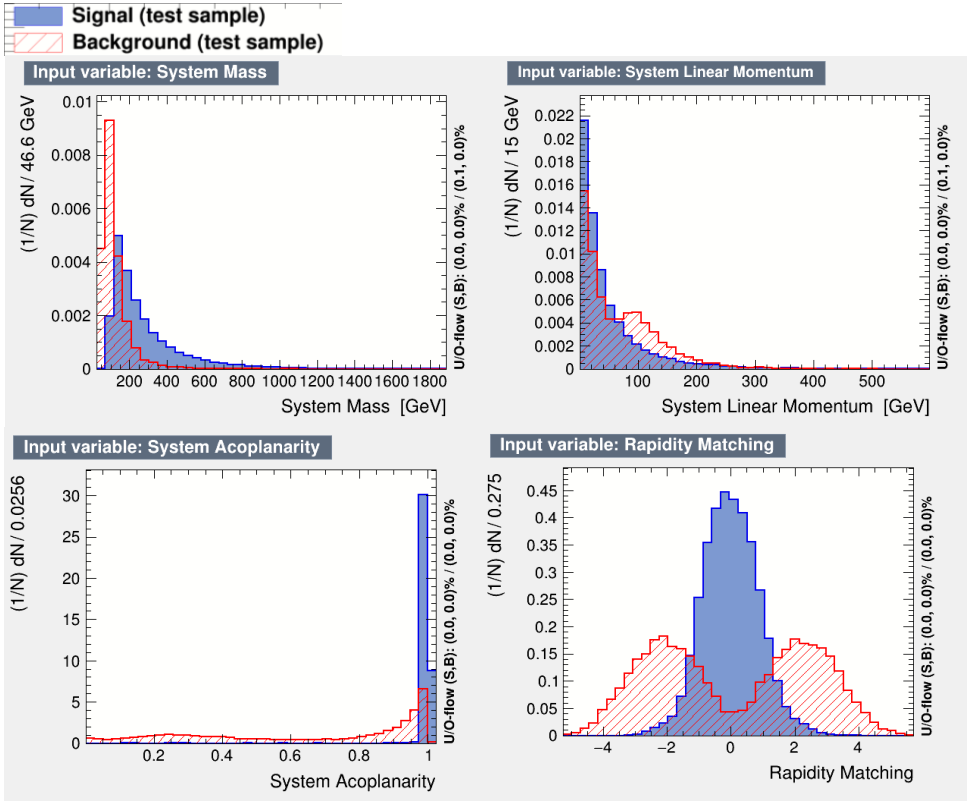


System Acoplanarity:

- In the background, two peaks appear: one from DY processes and a higher one in the signal due to its back-to-back nature.

Rapidity Matching:

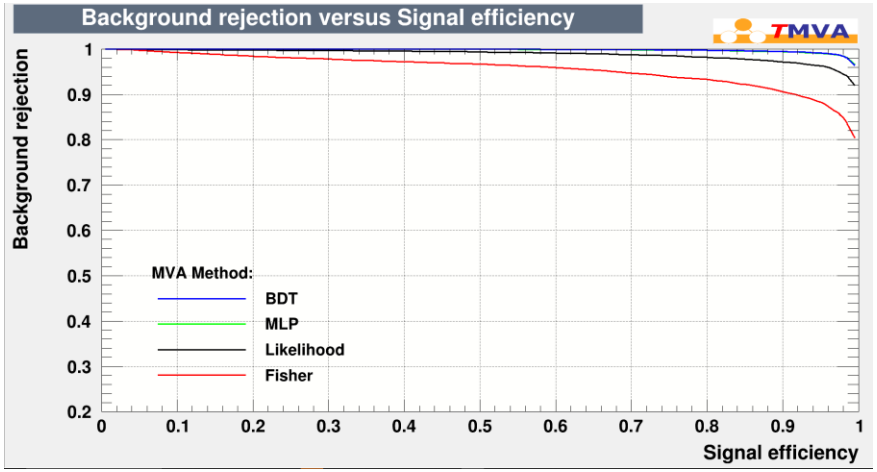
- Refers to the comparison between event rapidity and proton ξ calculated rapidity.

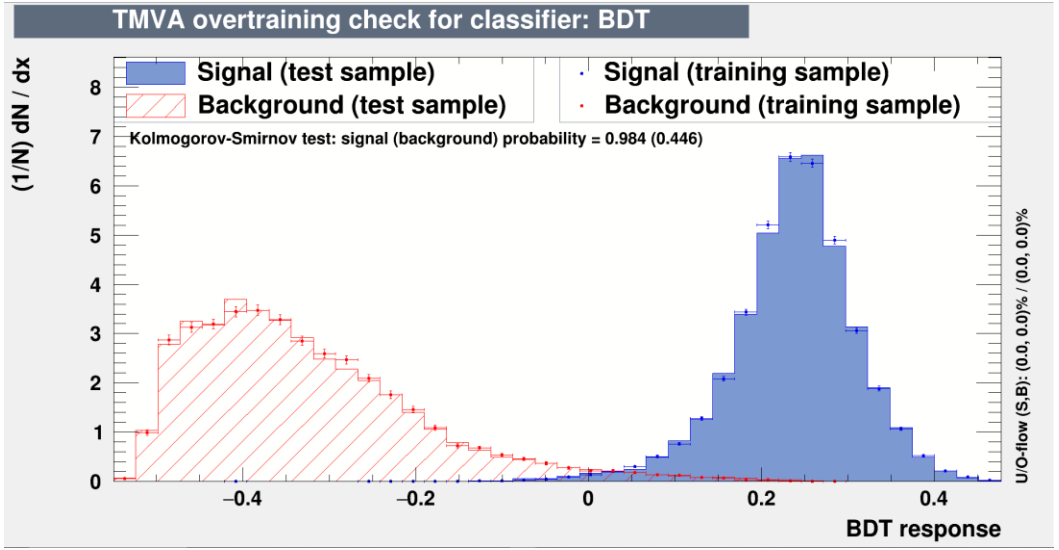


Multivariate Analysis

Output Results

Multivariate Analysis





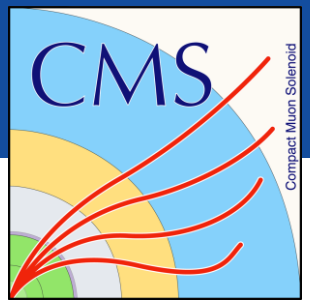
Conclusion

$$pp \rightarrow p'p' + \tau\tau$$

- ✓ Final state hadronic τ
- ✓ Single proton in PPS
- ✓ Pile Up accounted

- ✓ Three different background types
- ✓ Filtering phases
- ✓ Proton enrichment
- ✓ Multivariate Ananlysis

- ✓ Separation of background and signal for future work



Thanks!

Any questions?

Input Variables Graphs

Multivariate Analysis