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Physics with forward protons in the CMS experiment

Testing the Standard Model and searching for hints of physics beyond it.

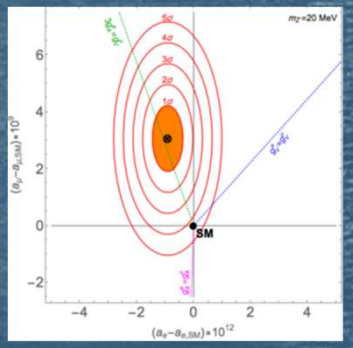
Overview

- Project description
  - Theoretical rationale.
  - The CMS and the PPS.
- The Setup
- Key results
  - The signal
  - The background
- Conclusion

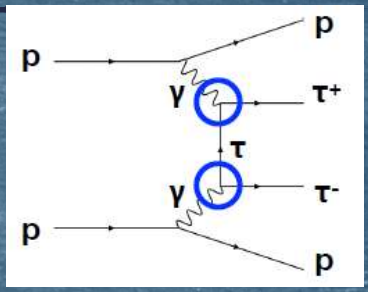
Project Description

Theoretical rationale

- Measuring lepton properties is a fundamental test to the SM.
- The anomalous magnetic moment (g-2) is one of this properties. (Arxiv:1310.7922)
- Less massive particles have given interesting results…
- But what about tau leptons…?



Project Description

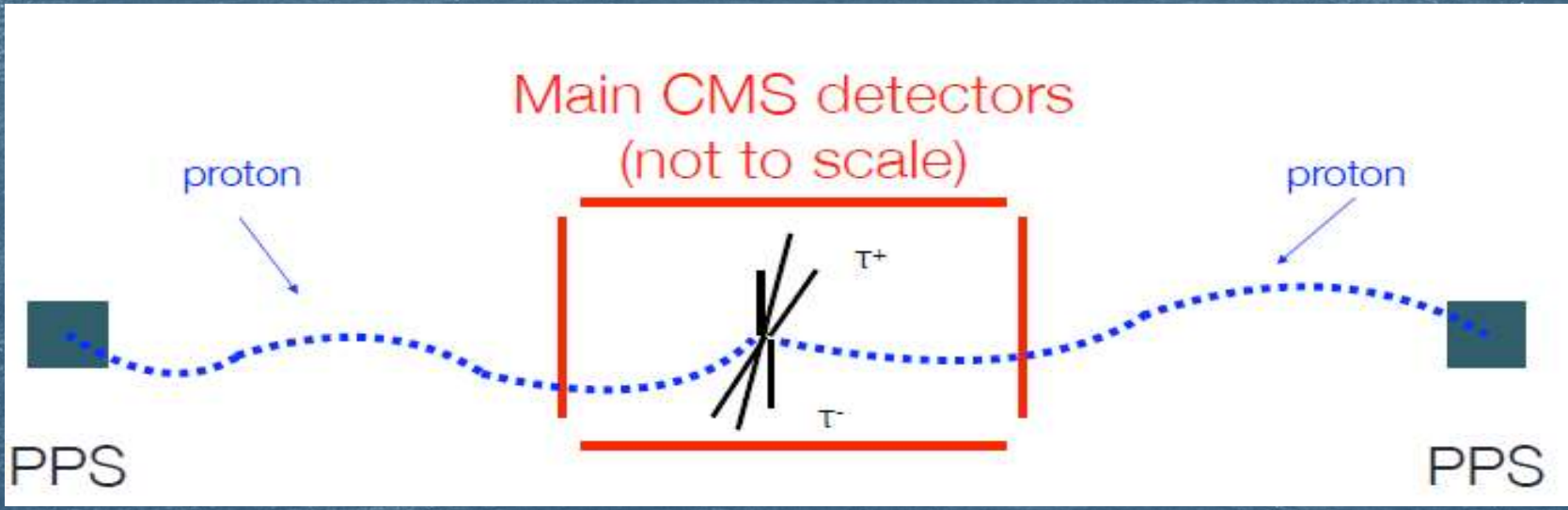


The CMS and the PPS…

- In the world of acronyms…
- The CMS detectors will "see" the taus, the PPS will "see" the protons…
- **Is it feasible to use forward protons to constrain the deviation from the Standard Model predicted cross-section?**
- But… how?

Project Description

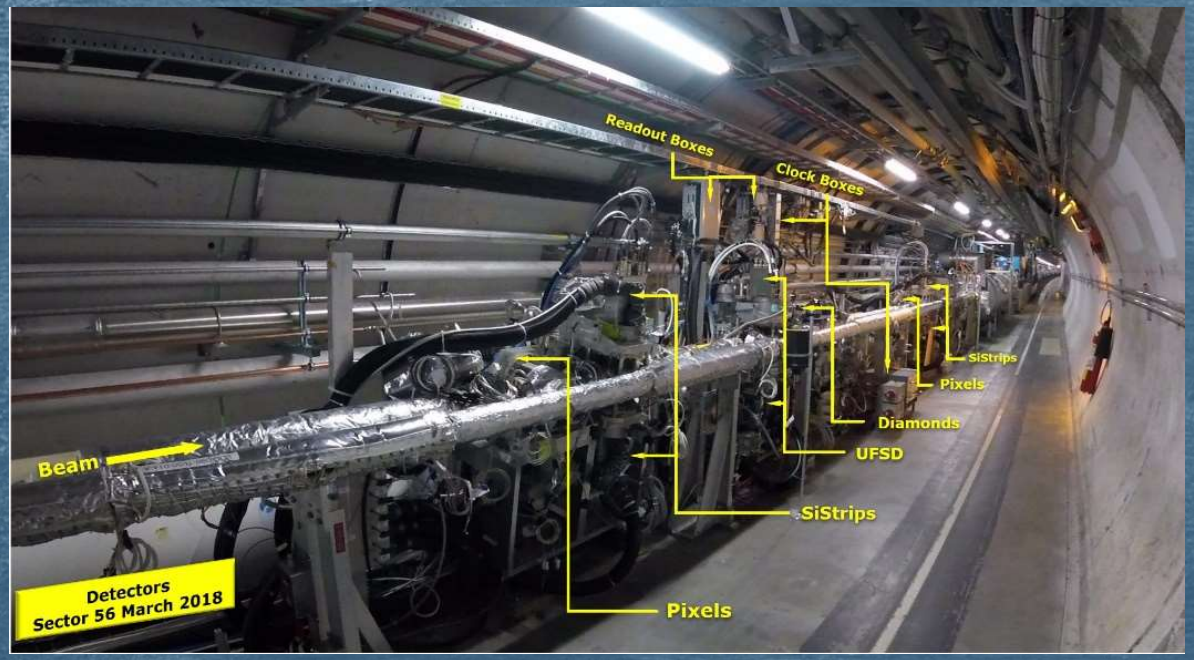
The CMS and the PPS… continued…

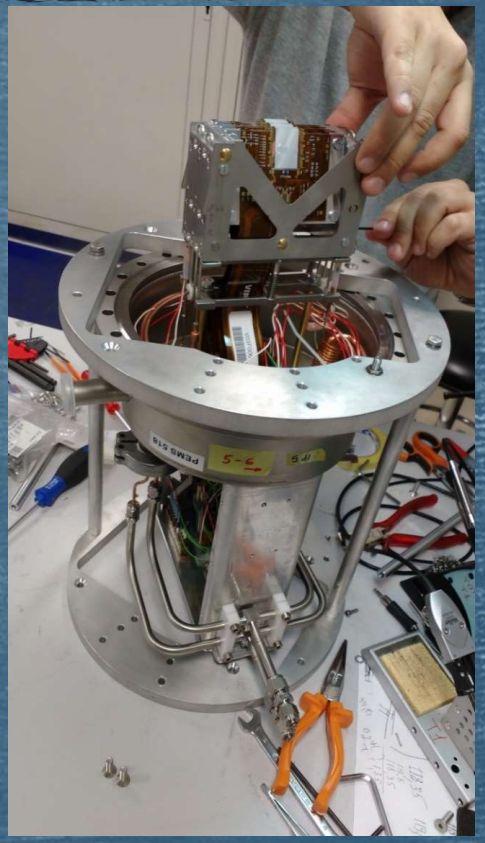


So… a 4 year-old could do it?…

Project Description

The CMS and the PPS… continued…





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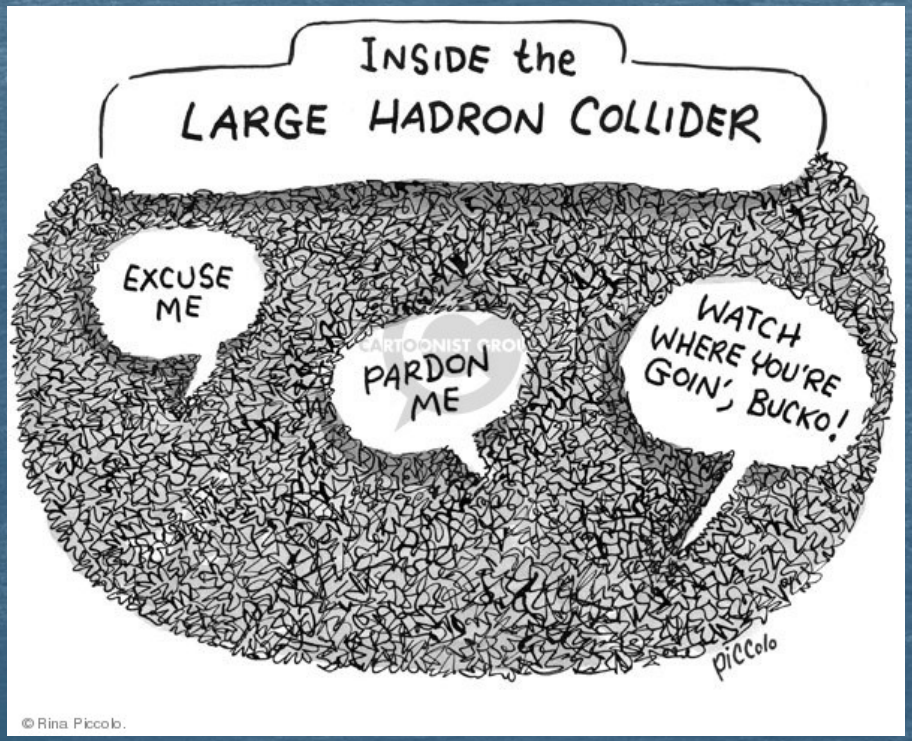


The Setup

The (Simulated) Signal

- We simulated **10 000 events with ξ(proton)>0.03 and pT(tau)>100Gev.** (simulated using CEPGEN; Arxiv: 1808.06059).
  - **ξ(proton) in the fractional momentum loss of the proton**.
- Only hadronic decay modes were studied.
- Events simulated **with and without pileup**.

The Setup

The (Real) Background

- In these Data sets we used **6% of the data collected by the PPS** proton detectors during the 2016-2018 LHC run.

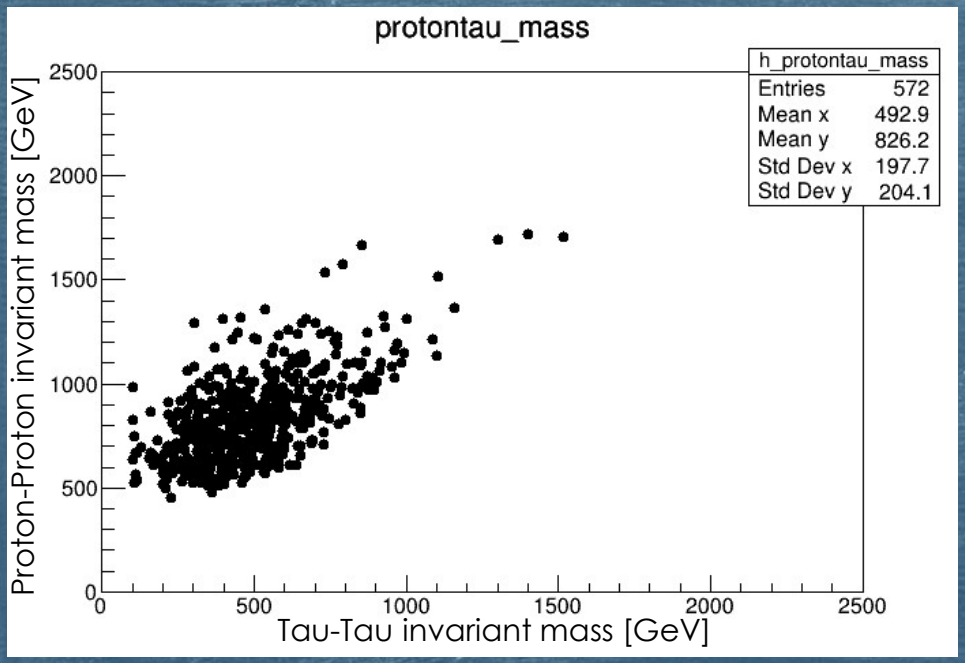
- Following a couple of papers from the CMS collaboration (Arxiv: 1803.06553v2 and 1611. 06594v2) about **80% of the background comes from QCD** multijets…(and random protons due to pileup!)
- And the **same-charge events are almost entirely (~95%) QCD**…
- So, we used same-sign events from the real data to study the main background.

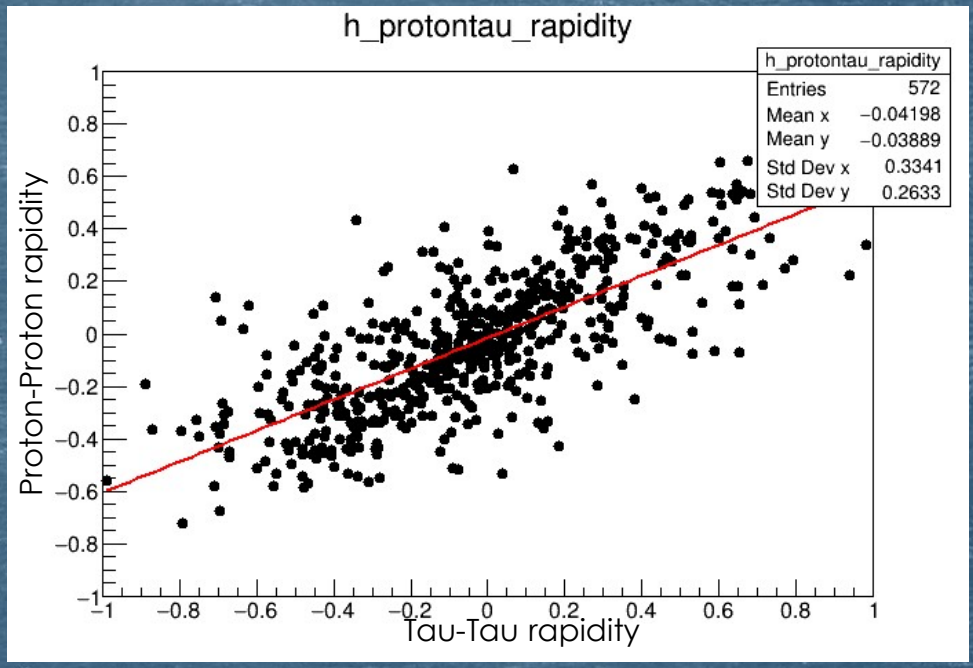
The Setup

What did we look for?

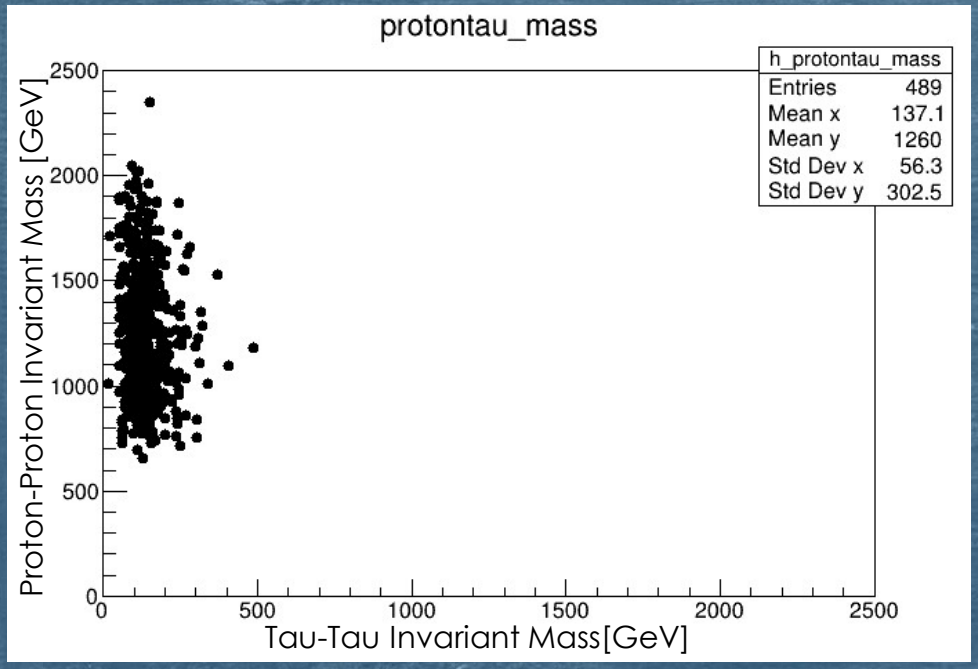
- We imposed some conditions on the events to be looked at:
  - One proton on each arm of the PPS detector;
  - We reduced all the multi-step tau confirmation to a simple binary tau_id.
- We used simulated data to try to find the correlation between the proton and the tau dynamics:
  - $M = \sqrt{s\,\xi_1\,\xi_2}$
  - $Y = \frac{1}{2}\log\frac{\xi_1}{\xi_2}$

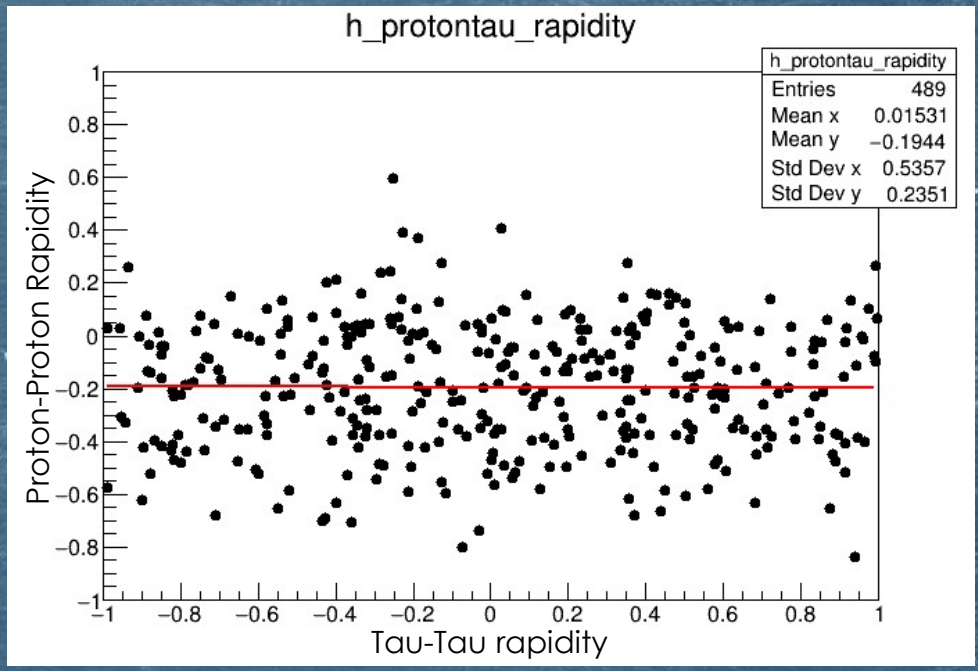
Key Results (Signal points – No PU)





Key Results Background points – Real data





Key Results – An axe or a scalpel?

- Choosing a cut in the Mass and a cut in the rapidity...
- But beware of the numbers! They need yet to be normalized to the cross section!

Rapidity	Mass	#Signal/sqrt(#background)
-0.6/0.4	500	218
	550	119
	600	84
	650	73.88
	700	56.57
-0.6/0.2	500	205
	550	112
	600	79
	650	69.7
	700	53.44
-0.4/0.4	500	211
	550	162.4
	600	97.96
	650	82.66
	700	62.75
-0.4/0.2	500	198
	550	152.5
	600	91.8
	650	77.66
	700	59

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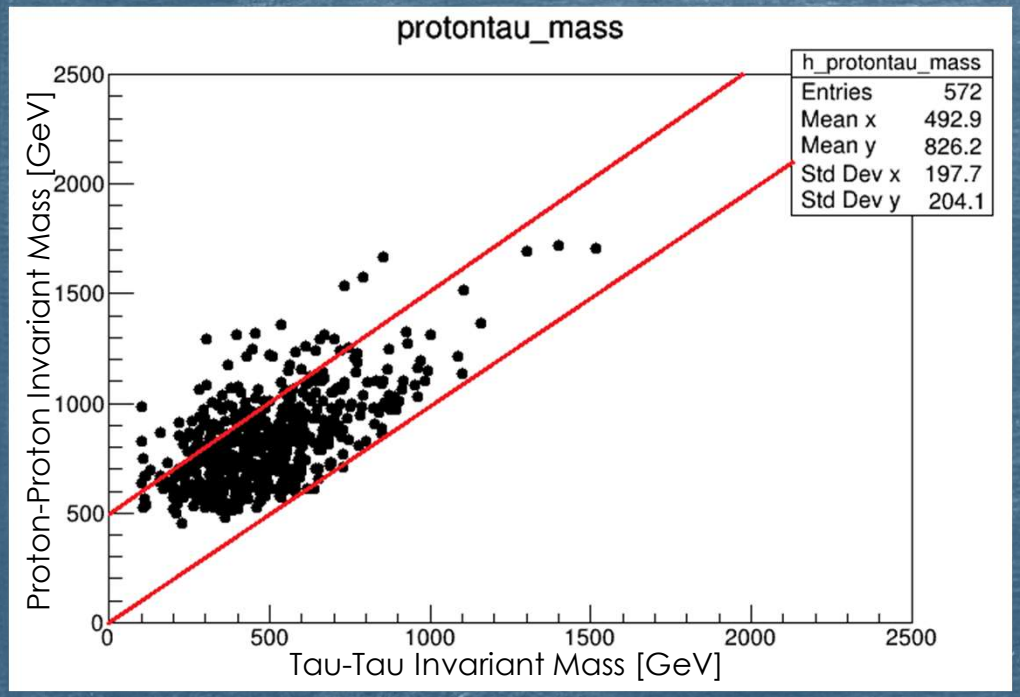
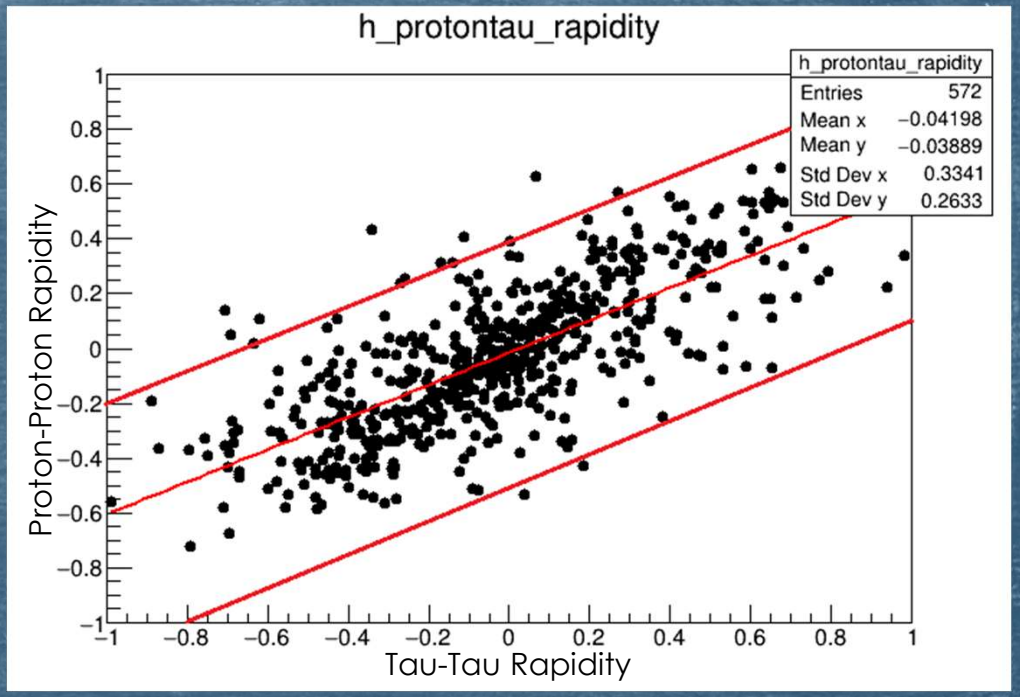
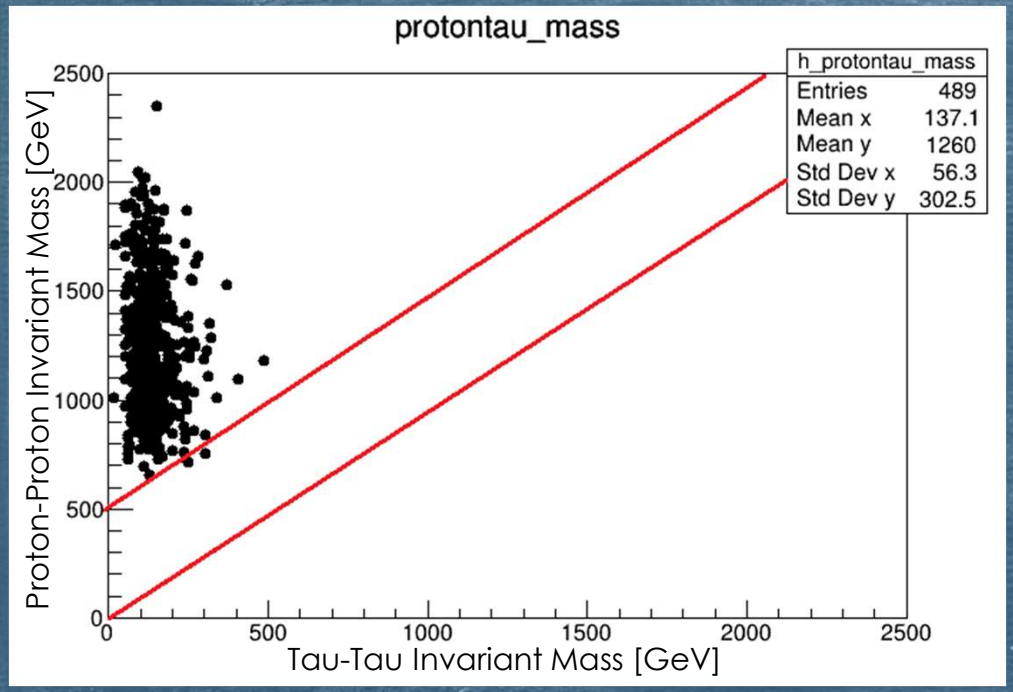
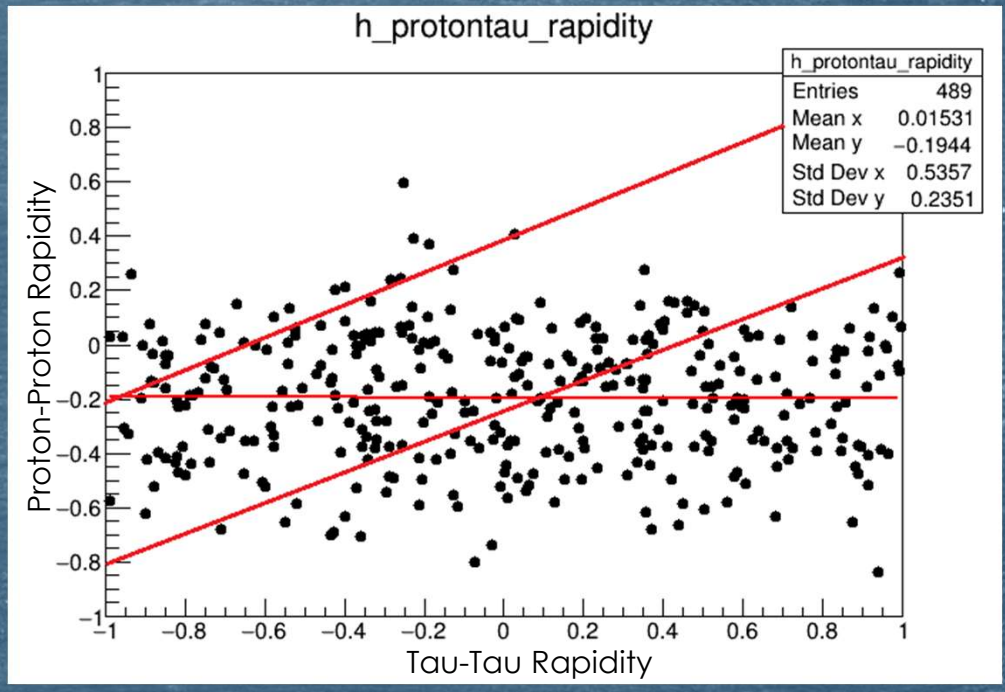




Acceptance rate, on both parameters: >82%, for one proton on each arm and 2 opossite sign taus

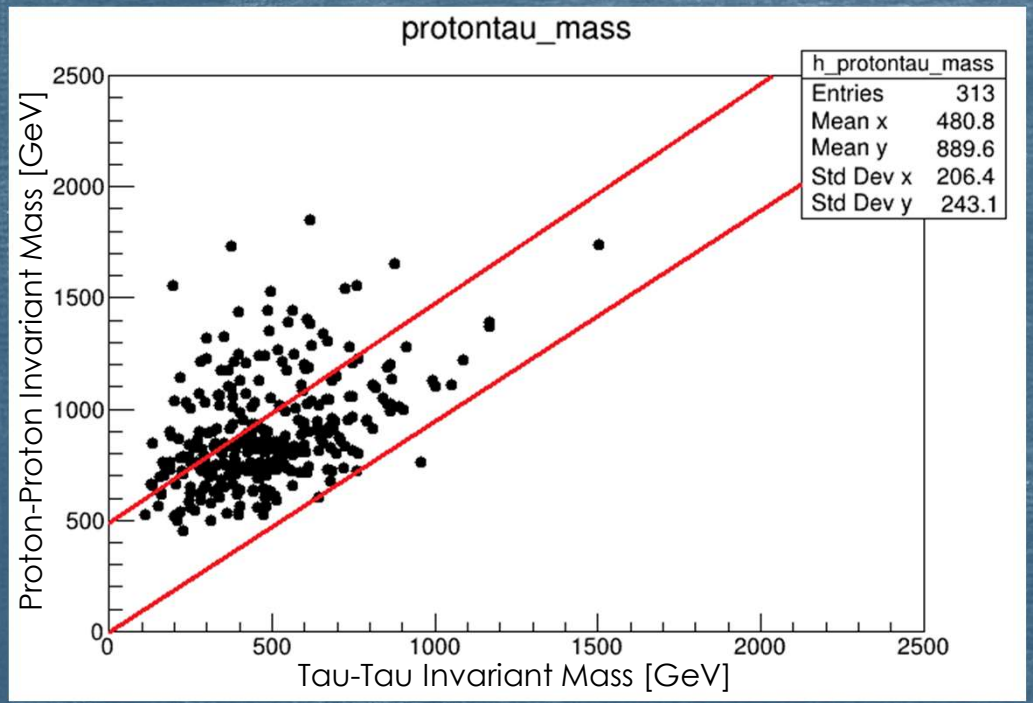
Key Results Background points – Real data

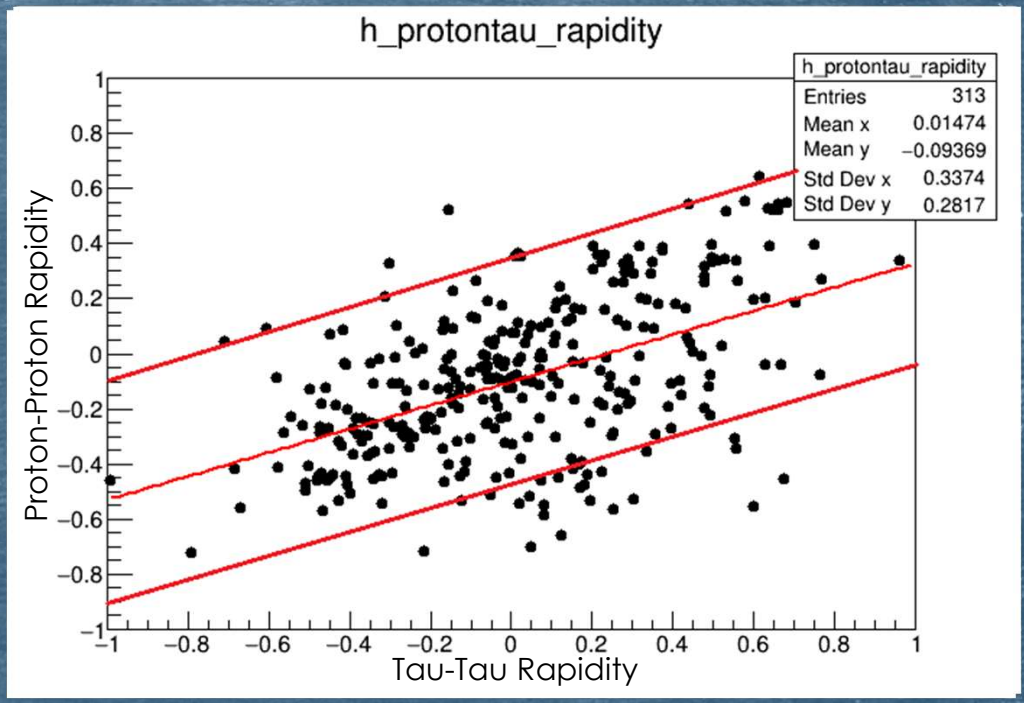




Exclusion rate, on both parameters: >99.7%, for one proton on each arm and 2 same sign taus

Key Results: Things do tend to pile up!





Acceptance rate, on both parameters: >69%, for one proton on each arm and 2 opossite sign taus

Key Results: Calculations

- **How well the same-sign tau events reproduce the background?**

- Using a statistical correction, we can estimate that for one background event, the **background is underestimated by ~34%**
  - $N(OS, Id1) = N(SS, Id1) \times \frac{N(OS,Id0)}{N(SS,Id0)}$

Where:

- N(OS,Id1) is the number of events that produce opposite sign taus that pass all the Id tests;
- N(SS,Id1) is the number of events that produce same sign taus that pass all the Id tests;
- N(OS,Id0) is the number of events that produce opposite sign taus that fail some of the Id tests;
- N(SS,Id0) is the number of events that produce same sign taus that fail some of the Id tests;

Key Results: Calculations

- What do we expect to see?
  - Given **L=6.5 fb^{-1}** (6% of the total data of the run).
  - **e*A~2%**
  - with a 95% confidence interval we expect, **for a 1-event background**, to find **less than 4.74 events in the data**.
  - Subtracting the expected background (1+ 0.34) we expect **less than 3.4 events in the signal** (95% conf. level).

- Note that this is based on Poisson statistics and with no systematics!

Key Results: Calculations

- We can now make an upper limit prediction on the cross section, σ, for a 95% conf. level:
  - $N_{signal} = (e \times A) \times L \times \sigma$ ⇔ **σ< 26fb**

Conclusion

- The objective of this work was achieved: **this may be a viable way to constrain the deviation from the SM prediction of the cross section.**
- The analysis should be done with **more data** in order to achieve statistical significance, and to better the sensitivity.
- The statistical analysis is over-simplified.
- And there is a lot of room for improvement, namely using more **systematic methods in the cut choice**.
- And **the future**… Can the use of precise measurement of the "time of flight" of the protons in the PPS help us to pinpoint the "signal" ones more accurately?

At least I'm not a biologist!