



My Summer with US CMS PURSUE 2024

Luis Felipe Koehler Domingues



About me!

- Luis (he/him).
- From Rio de Janeiro, Brazil.
- Junior at Grinnell College.
- Physics/Math double major.
- Just a regular guy.
- Public transport enthusiast.
- Loves music and pop culture.
- PURSUE 2024 intern!



**Grinnell
College**

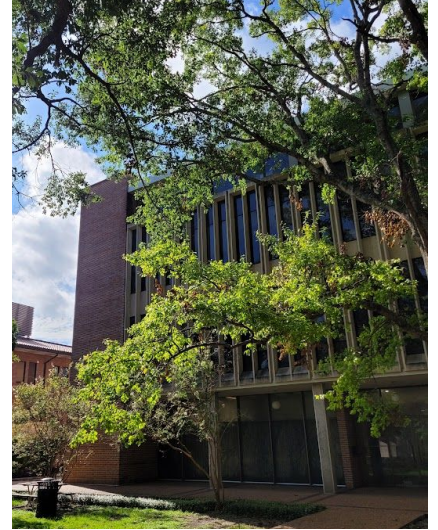
Fermilab

- 2 weeks of training in particle physics and programming tools.
- Lab visits and meeting researchers.
- Made friends!
- Saw bison!



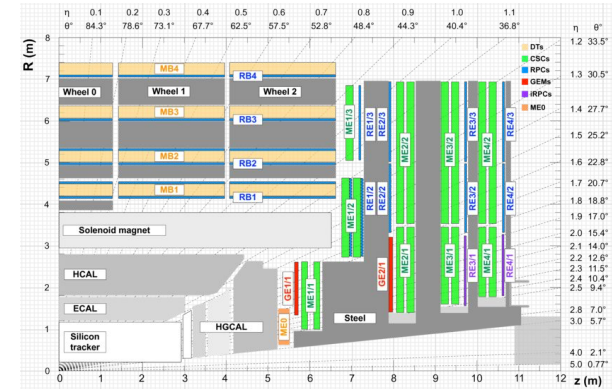
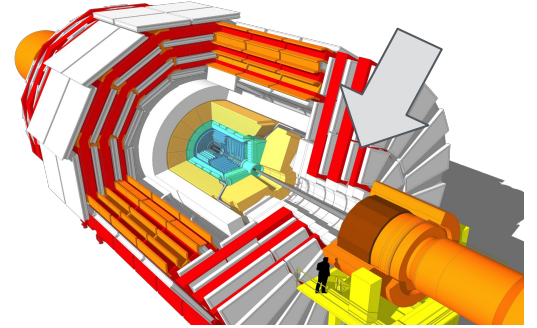
Rice University

- 8 weeks working on a CMS project.
- Amazing mentors Darin Acosta and Osvaldo Miguel Colin, who encouraged me and helped with any challenges.



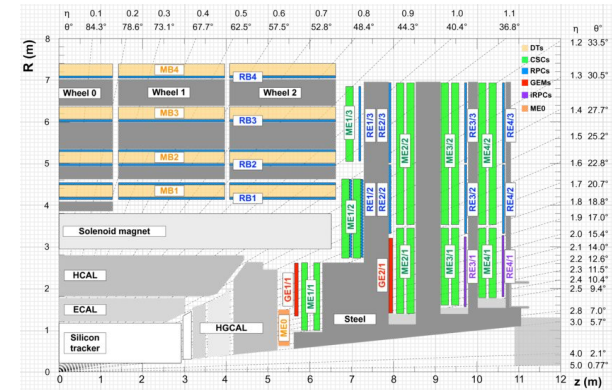
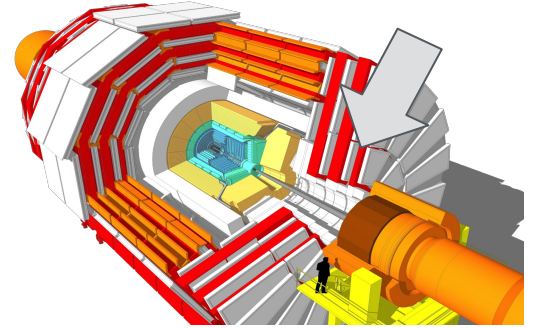
A bit of background

- 40 million LHC collisions at CMS every second → 100 Terabytes/s.
- Level 1 Trigger: electronic data filtering system: 40 MHz → 750 kHz (phase 2).
- The Endcap Muon Track Finder (EMTF) is part of the L1 Trigger and “detects” muon and possible muon-like objects at the CMS end caps.



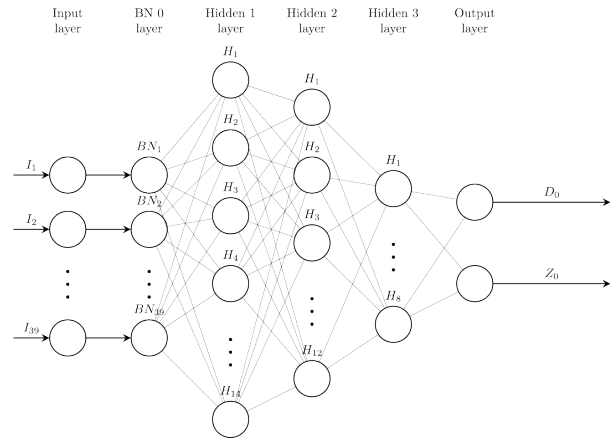
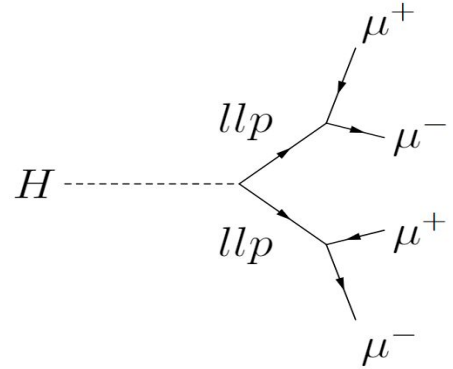
A bit of background

- Many models beyond the standard model predict long-lived particles (LLPs) and heavy, stable, charged particles (HSCPs).
- EMTF is not looking for those!



My Project

- Measuring properties of exotic charged particles at the EMTF using neural networks.
- Used Monte Carlo techniques to simulate events.
- Unpacked data and trained neural networks with different architectures.
- Analyzed model performance.




What I learned



- Improved my coding skills in Python, C++, as well as Unix commands and Git, and particle physics-specific tools such as ROOT.
- Learned widely-used machine learning packages such as Keras and TensorFlow.
- Monte Carlo simulations, CMSSW, and computing clusters.
- Particle Physics and the internal workings of CMS.
- Real-world High Energy Particle physics research.
- Networked with researchers and other mentees.
- Received grad school guidance.

What I learned (part 2!)

- Improved my communication skills with final presentation and poster.
- Had the opportunity to present my research at the Gulf Coast Undergraduate Research Symposium.
- Increased confidence in my research skills :)




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Measuring Properties of Exotic Charged Particles at the L1 Trigger of CMS

Luis Felipe Koehler Domingues¹ Darin Acosta² Osvaldo Miguel Colin²

¹Grinnell College ²Rice University



Introduction

- LHC collisions of proton bunches at CMS occur 40 million times per second. The Endcap Muon Track Finder (EMTF) is part of the **L1 Trigger**, an electronics system that selects data 40 MHz \rightarrow 750 kHz (phase 2 upgrade).
- Many models predict **long-lived particles (LLPs)** and **heavy, stable, charged particles (HSCPs)** [1].
- LLPs can decay **away from the collision center**, complicating the measurement of their properties.
- New timing information from RPCs allows measurements of the HSCPs **low relative speeds** ($\beta - 1 \ll 1$).

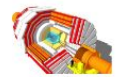
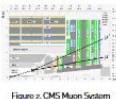



Figure 1. Cut-out of CMS from bbl Figure 2. CMS Muon System

Methods

- Particle guns were developed for Monte Carlo simulations according to the following decay:

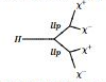
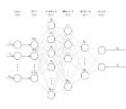
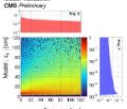
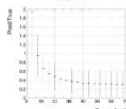
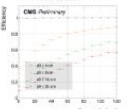


Figure 3. Decay pattern where H is a heavy scalar and γ is an HSCP (for β) or a muon (for Z_0).

- The **neural networks** take in from muon detectors:
 - For Z_0 :
 - # from track and 12 hits;
 - # from track and 12 hits;
 - Quality from track and 6 hits;
 - Bend values for 6 hits.
 - For β :
 - 5-bx timing values from CSCs (~ 25 ns);
 - 4 sub-bx timing values from RPCs ($\frac{1}{2}$ of bx).

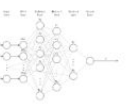
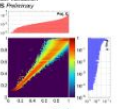
Z_0 Results

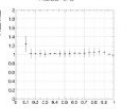
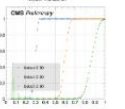



Predictions Energy

β Results

Predictions Energy

- We found that regressing over $\frac{1}{\beta}$ led to better results.
- The prediction tends to **underestimate Z_0** . This average behavior can be corrected through **calibration**, but the **high standard deviation** is unwanted.
- The challenges in measuring Z_0 might have arisen from a relatively low spatial resolution and the fact that the muon chambers are distant from the decay.

Conclusion

- Neural Networks at EMTF can **efficiently measure the relative speeds of HSCPs** with standard deviations of the order of 10%.
- However, these β values are based on a **crude model**. Tests with CMSiSW simulations are needed to validate the model.
- Work remains to be done in the measurement of the longitudinal displacement of the muon, which includes average standard deviations around 30 %.

References

[1] ATLAS Collaboration. Search for heavy charged long-lived particles in proton-proton collisions at \sqrt{s} up to 13 TeV using the muon spectrometer with the anti- k_R algorithm. Phys. Rev. D, 104:032004, 2021. doi:10.1103/PhysRevD.104.032004.

[2] G. Collares and Francis M. Chang. Precision and accuracy measurements with deepnets in the CMS experiment. Journal of Physics: Conference Series, 2020. doi:10.1088/1742-6596/1397/1/012001.

Acknowledgments

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Last slide :)



Thank you!
Any questions?