







# Enhancing the L0 Muon Trigger ATLAS Work Package 2.2

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> NextGen Trigger All Hands Meeting November 26th, 2024











## Introduction to the Team

### Task leaders

## Engineer



**Oliver Kortner** 



Verena Martinez Outschoorn



Rimsky Rojas Caballero

- Project start focused on recruitment, hiring and ramping up of personnel
- Additional effort recruited including groups not previously involved in L0 Muon
  - New student research projects on NextGen Trigger include 2 doctoral, 3 masters and 2 bachelors students





10/26/2024

### Postdoc



Maria Carnesale

Nivedaa Dhandapani

Nadia Dobreva

## started summer 2024

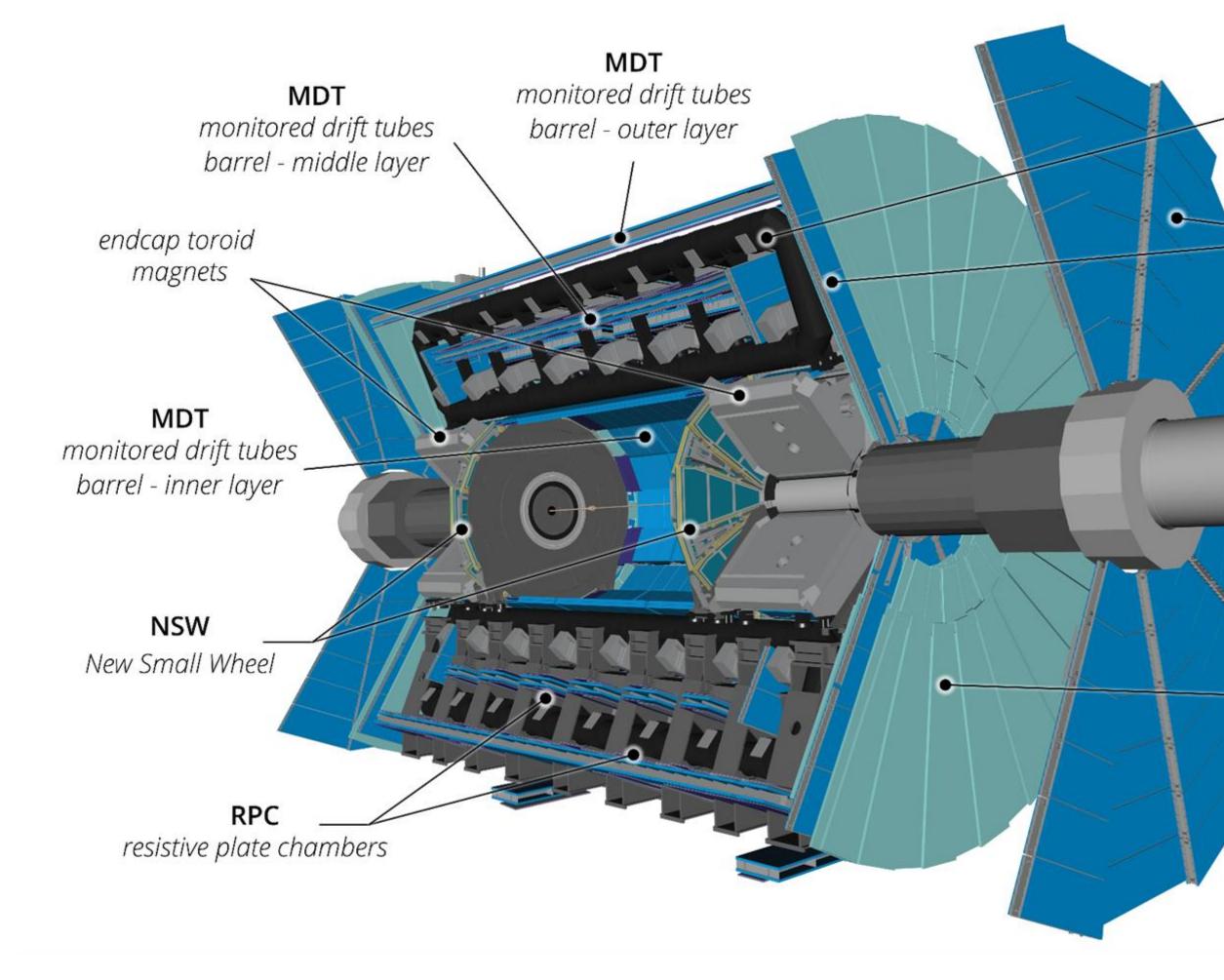
## starting spring 2025

PhD Students





# Introduction to the L0 Muon Trigger







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barrel toroid magnet

MDT monitored drift tubes endcap

TGC thin gap chambers endcap

## • Current first level of the muon trigger relies only on fast trigger detectors

 $\circ$  RPCs in the barrel region  $|\eta| < 1.05$ 

• TGCs and NSW in the endcap region 1.05<|ŋ|<2.4

## • High-Luminosity upgrade to start operation in ~2030

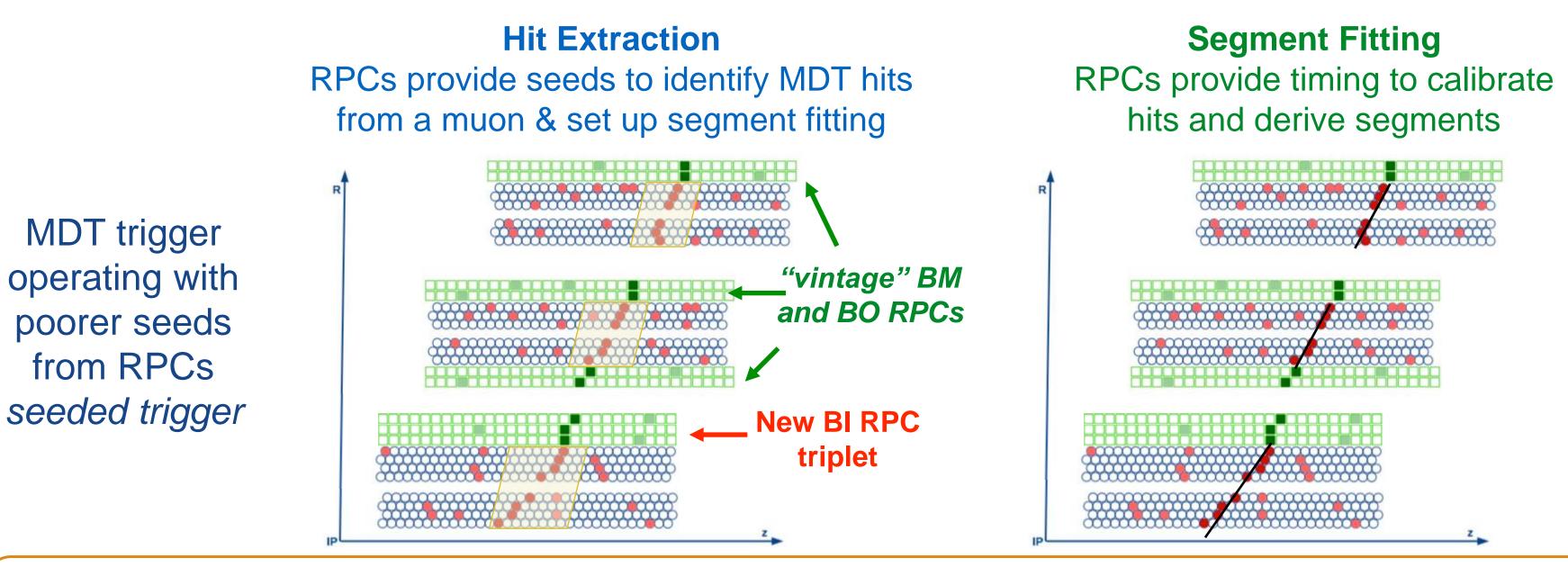
- Use precision measurements from MDT chambers in the first trigger level for the first time
- Additional layer of RPCs in the innermost barrel layer to improve the efficiency
- New electronics including modern FPGAs for trigger and readout



# **Goals: Improve Trigger Robustness**

## • Baseline L0 Muon trigger in ATLAS barrel relies on RPCs for best selectivity & performance

or coverage for new RPC chambers



MDT trigger without RPCs seedless trigger

Pattern recognition algorithms to identify the regions of interest with only MDT hits



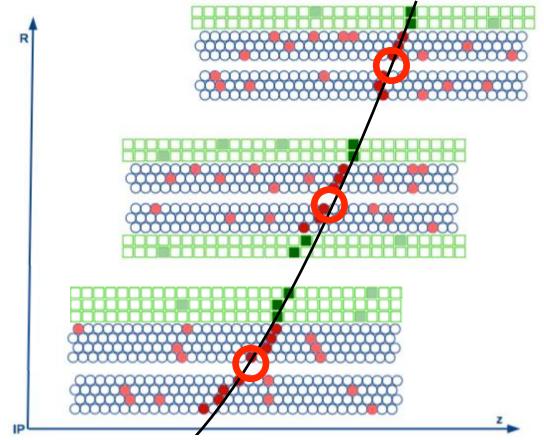


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Study different algorithms/approaches for L0 Muon triggers in case of reduced RPC performance

### **Momentum Estimation**

RPCs provide  $2^{nd}$  coordinate for the  $p_T$ estimate since B-field is non-uniform in phi

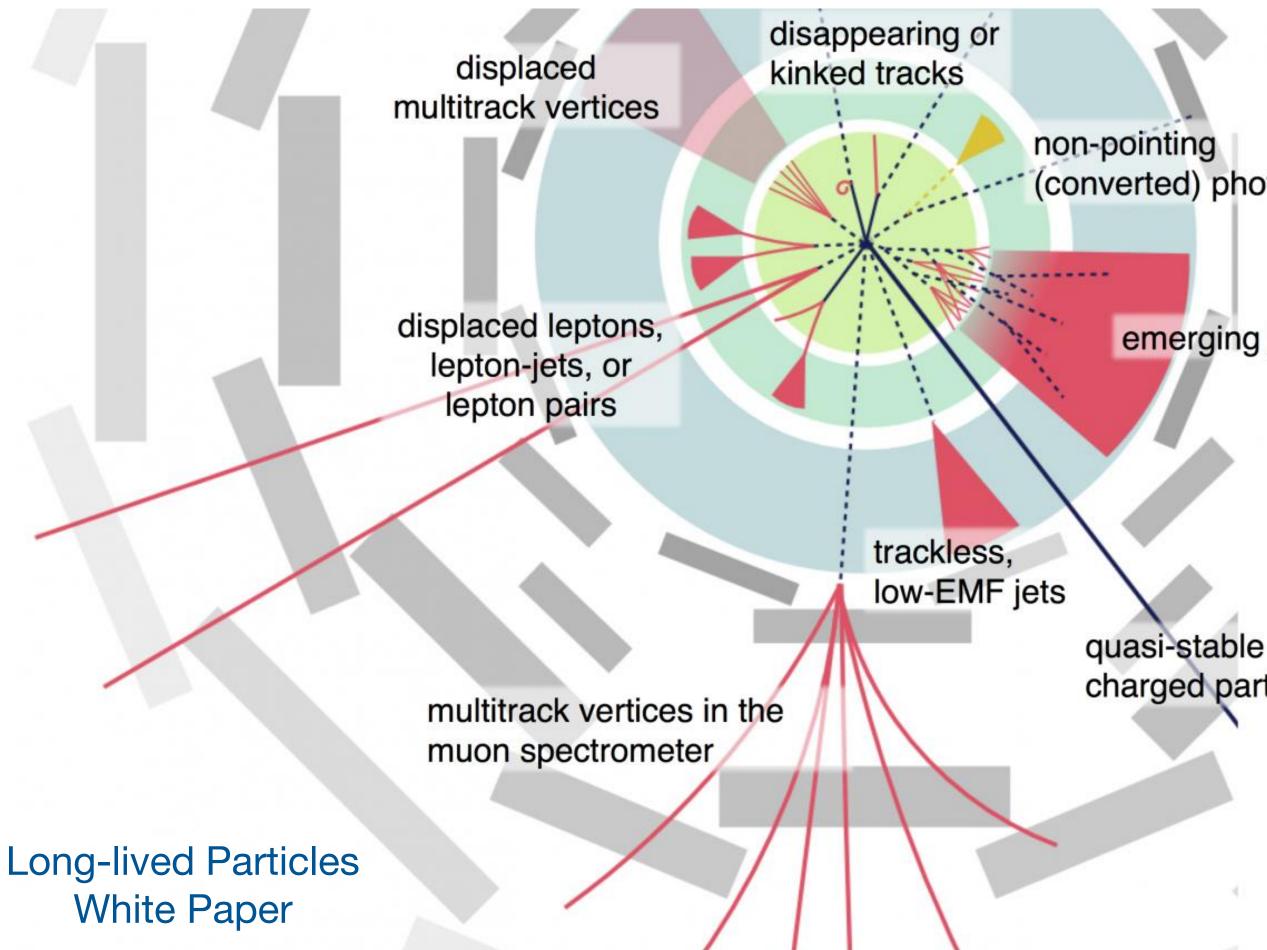


Timing of the muons to determine bunch crossing with Tile or only MDTs

Momentum estimation without a 2<sup>nd</sup> coordinate phi from RPCs



# **Goals: Triggers for Exotic Signals**







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(converted) photons

emerging jets

charged particles

## • Baseline L0 Muon trigger does not target exotic signatures from long-lived particles

• Dedicated muon triggers could enable new physics analyses or significantly enhance sensitivity

## • Developing new algorithms to target displaced muons

- From decays of long-lived particles signature of non-pointing muons
- Predicted by several models of new physics including dark photons, SUSY sleptons, RPV signals, Higgs portal models, hidden valley signals, etc.
- Many other ideas for signatures to explore in the future
  - Slow moving or highly ionizing particles, high muon multiplicity, nearby muons, etc

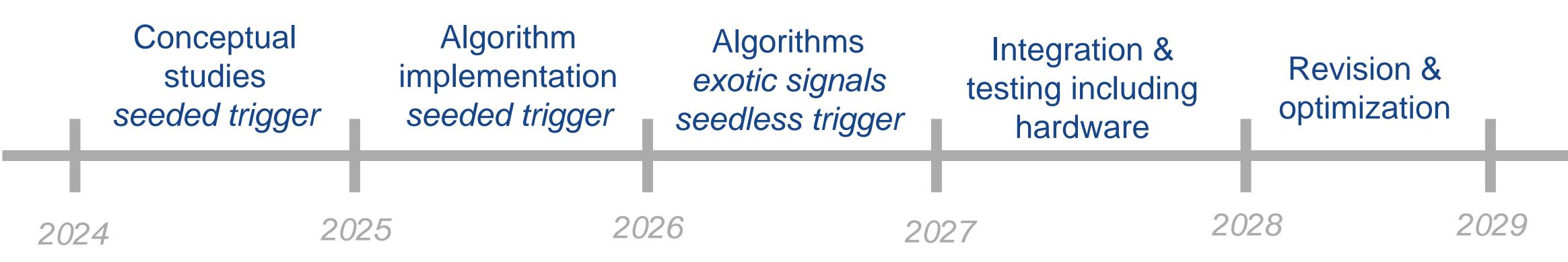








# **Project Timeline**



## Activities include algorithm development, implementation and hardware

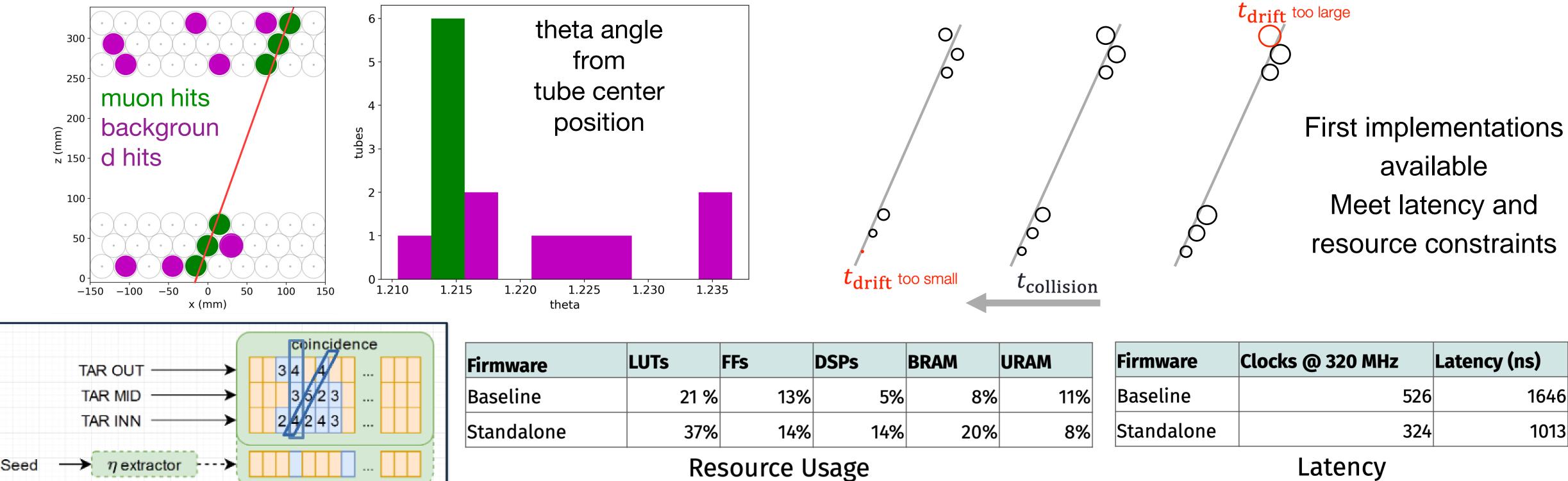
- Conceptual studies and algorithm development using simulation Focus on both robustness (seeded & seedless) and exotic signals
- Implementations of algorithms for FPGAs (RTL code)
- Evaluation of hardware needs
  - Meet latency and resource constraints
- Investigation of alternative possible hardware platforms
- Revision of algorithm implementations, optimizations and refinements to meet performance goals





## **Evolution of Current Trigger Using Standard Techniques**

• MDT pattern recognition using coincidences in roads Match to input from RPC seeds when available & use to select good seeds • Recover missing RPC seeds using only MDT information and fit for collision time (BCID)

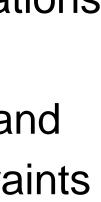


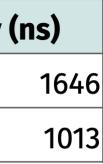


 $\eta$  distribution

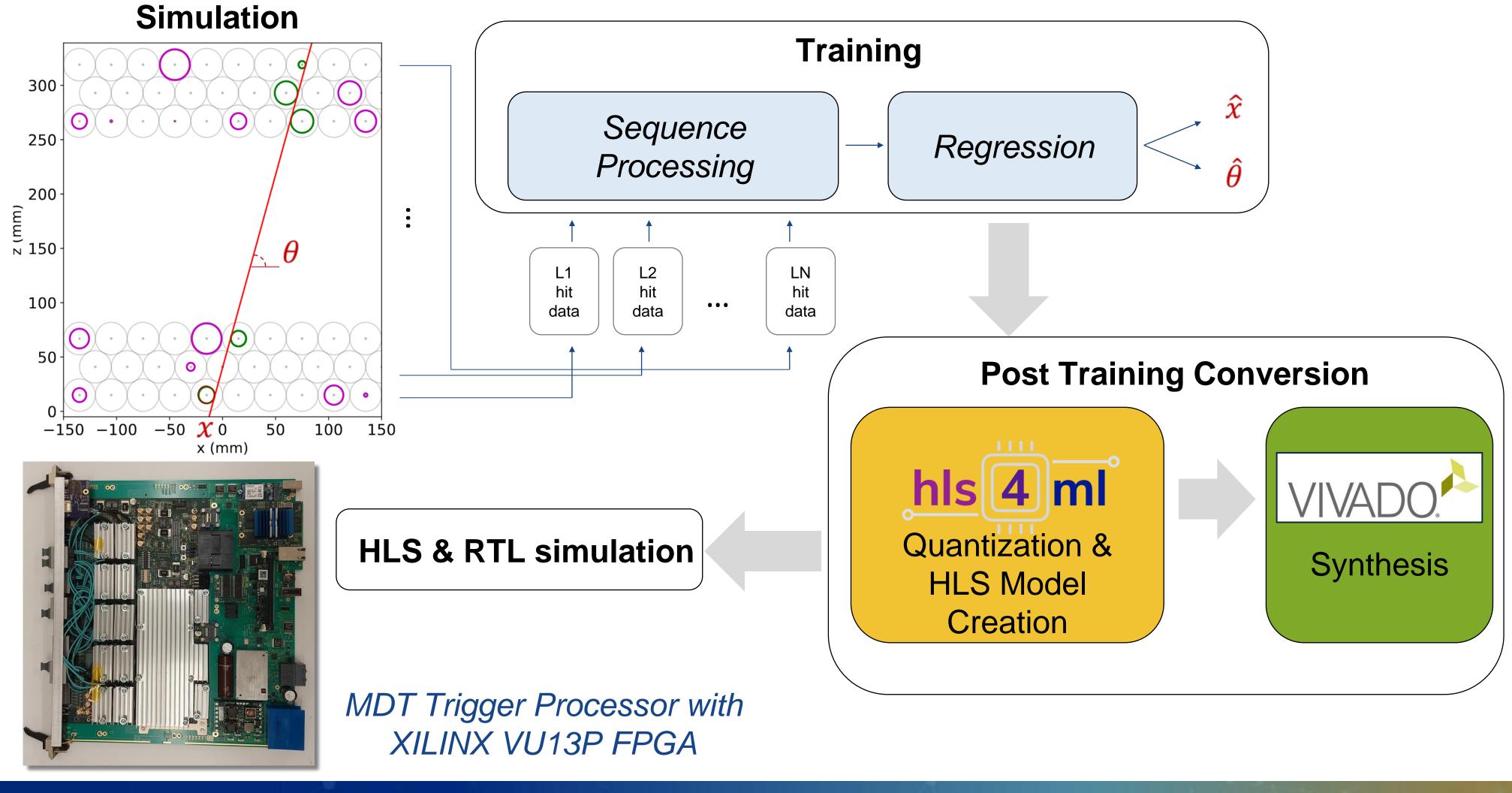
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14%	6 14%	20%	8%	Standalone	324	
					•	•

Preliminary studies from G. Loustau de Linares & D. Cieri





# **Exploring Approaches with Machine Learning**



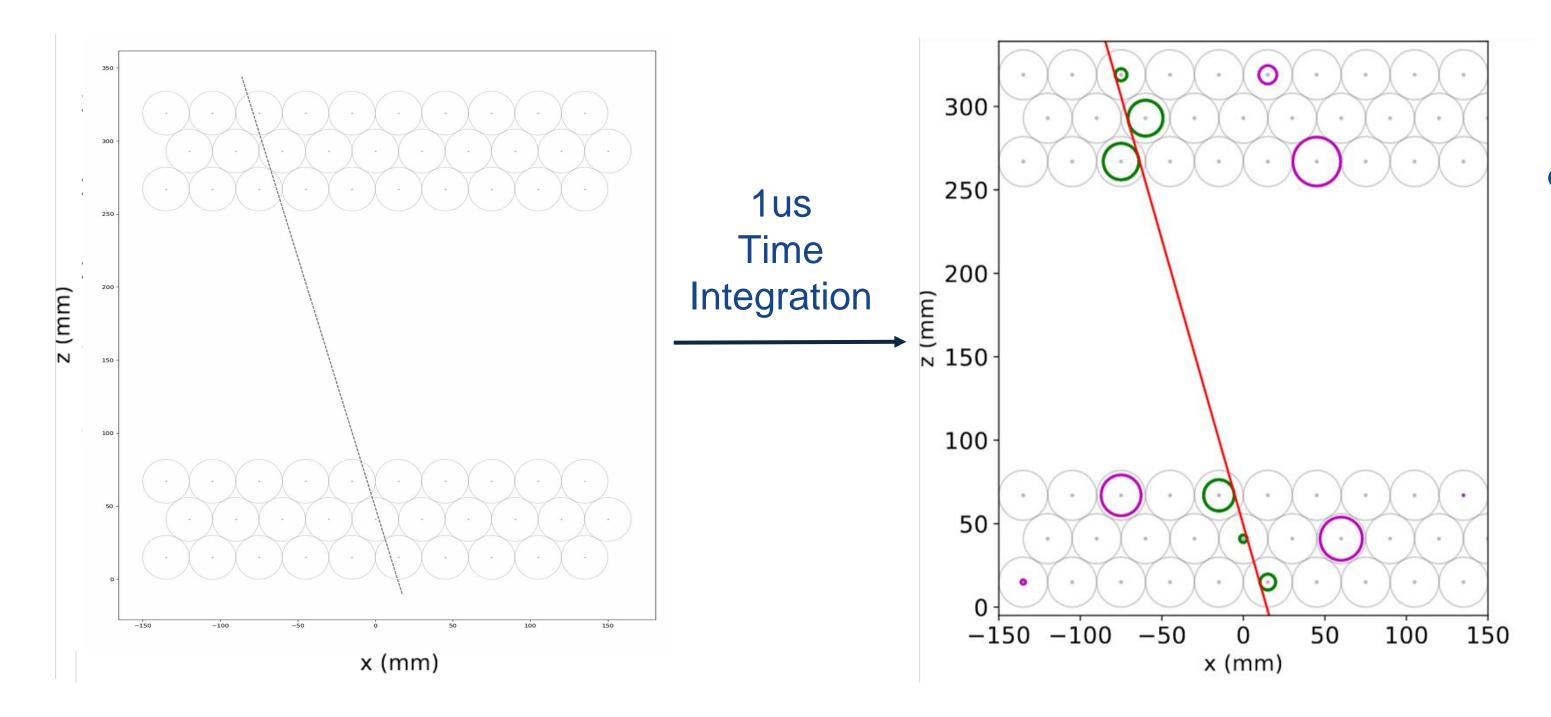




## **Development of Simulations**

• Toy simulations for rapid algorithm development and validation • Short turn around and easy to produce large samples

• Hit arrival time sequence as expected from the detector





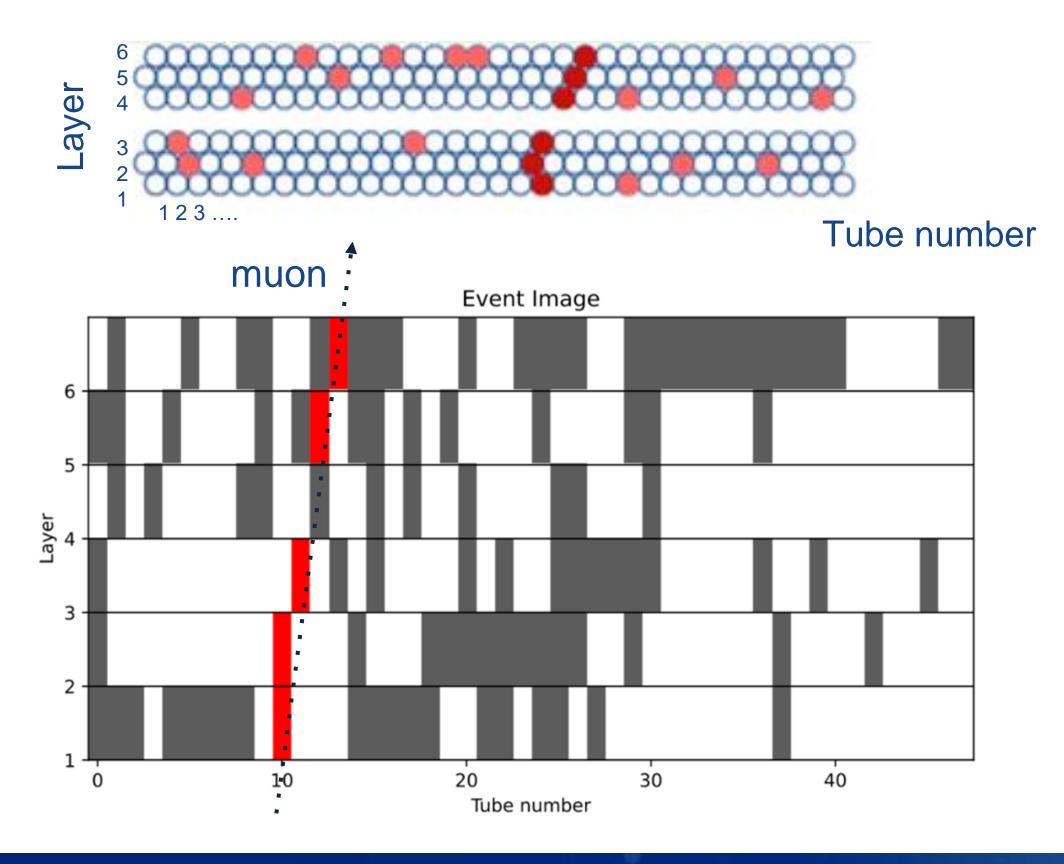
## • Also developing realistic simulations for expected signals and conditions

- Full geometry including new detectors
- Backgrounds from data similar to HL-LHC conditions (detector regions and periods with high rates)

# **Algorithm Development R&D: Robustness**

## • Investigating pattern recognition algorithms to identify the regions of interest using MDT hits

• Exploring the use of CNNs building images with the detector granularity

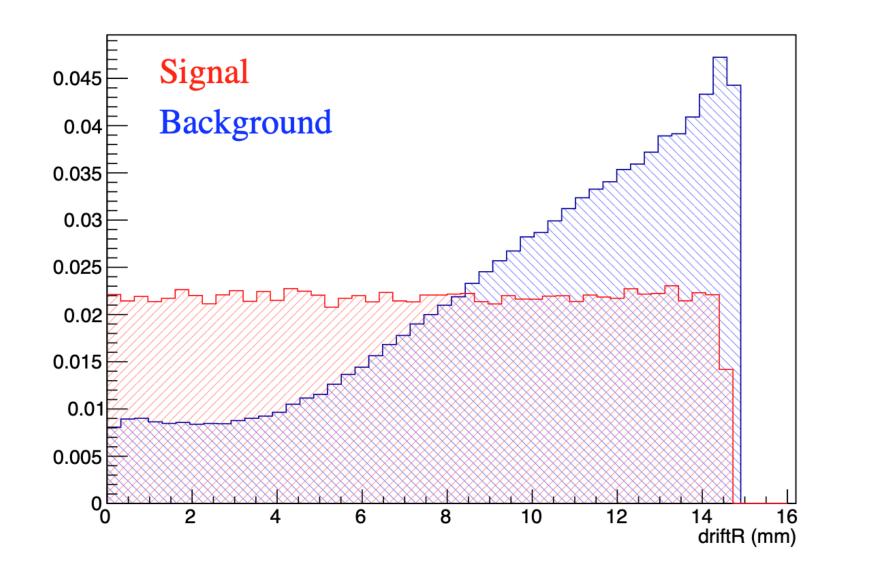


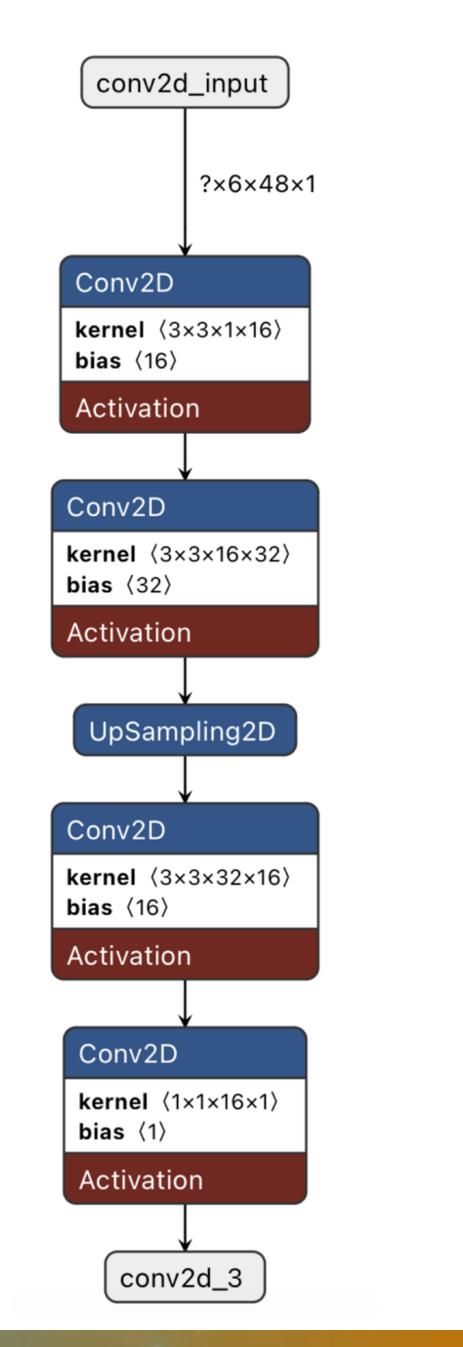




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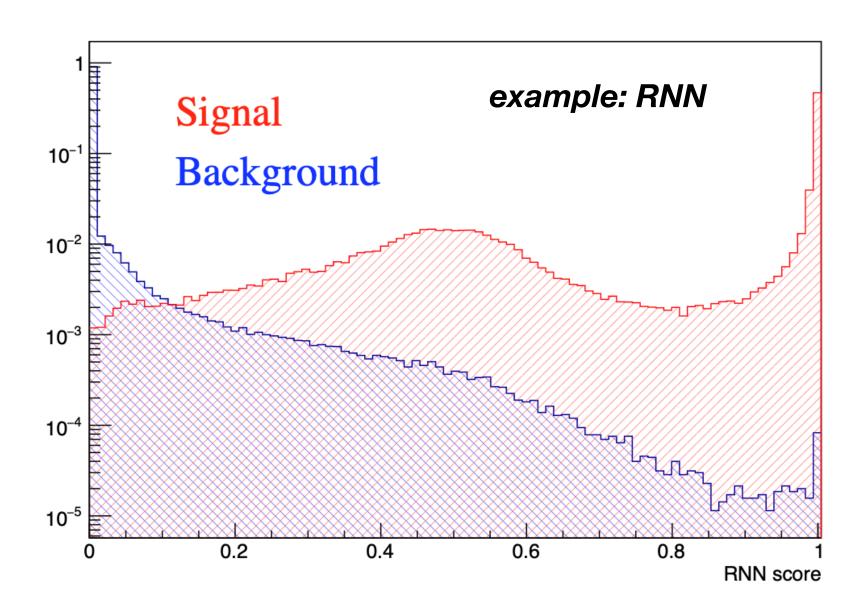
- Distinguish muon hits from backgrounds





# **Algorithm Development R&D with ML**

- recognition
- Also using machine learning methods for momentum estimation

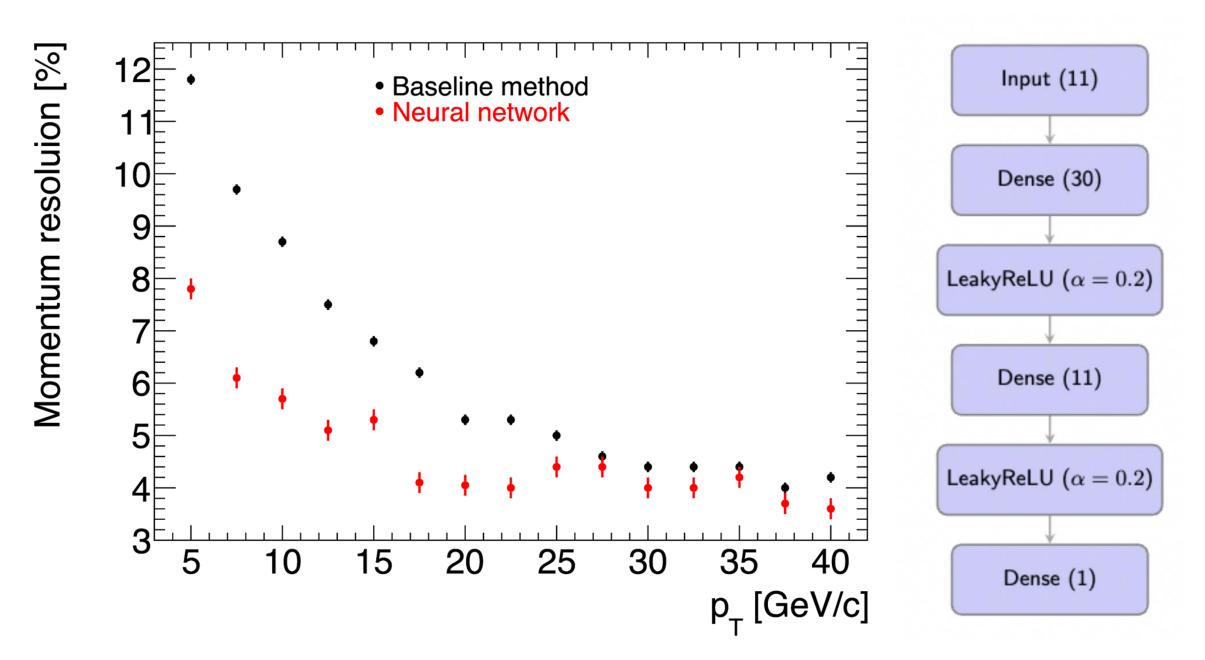




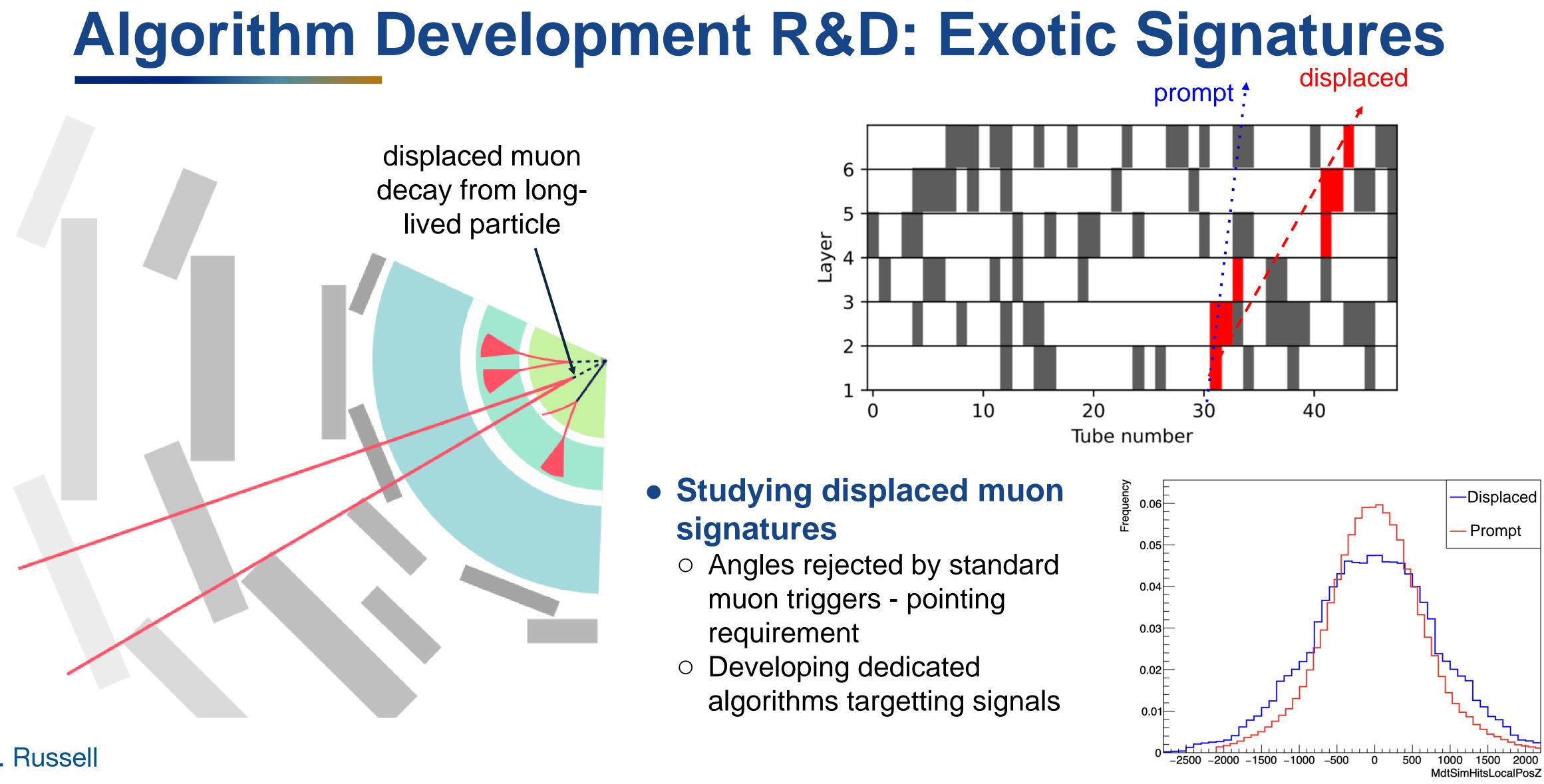
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## • Exploring algorithms more suitable for sparse data such as RNNs and GNNs for pattern

• Preliminary results show improvements in performance with Neural Networks with a few dense layers



Preliminary studies from F. Resende (TUM, Bachelors student)



### H. Russell



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## **Algorithm Implementation**

- **Progress on the implementation**
- **HLS conversion and RTL simulation** • Main goal is to ensure code runs as expected
- All tools and code available in containers
- Synergy with WP1 to use the provided infrastructure and use the software tools

Pipeline Jobs 8 Failed Jol	bs 2	Tests 0				
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sim:atlas_mdt_B3_BI	3					
Sim:atlas_nsw	3			Example issue identified		





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## • Automation of workflow including producing simulation, training algorithm, performing

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<ul> <li>kaniko-image.gitlab-ci.yml</li> <li>README.md</li> <li>model_1</li> <li>myproject_prj</li> <li>v ngt2.2-toy-simulation</li> </ul>	Reshape flatten_5       input: (1, 70, 3) output: (210,)       output (210,): fixed<10,2,TRN,WRAP,0>       37       ## Using the image         38       The nvidia card will be mounted and accessibly you check the card usage before launching you         99         40       nvidia-smi	
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# **Summary and Outlook**

- Priorities of 2024
  - Hiring of personnel including an engineer and postdoc and two PhD students
  - Ramping up simulation and algorithm design effort
  - Advancing on infrastructure for implementation as the resources become available from WP1
- Investigating possible use of Machine Learning approaches
  - Preliminary results are promising for pattern recognition and momentum estimation

## Priorities for 2025

- Further development of algorithms
- Focus shifting towards implementations for hardware
- Eager to use computational resources that will become available from WP1
- Investigating alternative ideas second coordinate along drift tube
  - Using twin tubes or information from the outer layer of the Tile calorimeter





## Main objective is to design and implement new algorithms to extend the L0 Muon trigger

• Focus on improving the robustness and extending to new signatures such as long-lived particle decays

