Annual Update:

ML Applications to Improve Track Finding and Fitting at the Muon g-2 Experiment

Antony Hibbert 201069849
Supervisor: Joe Price
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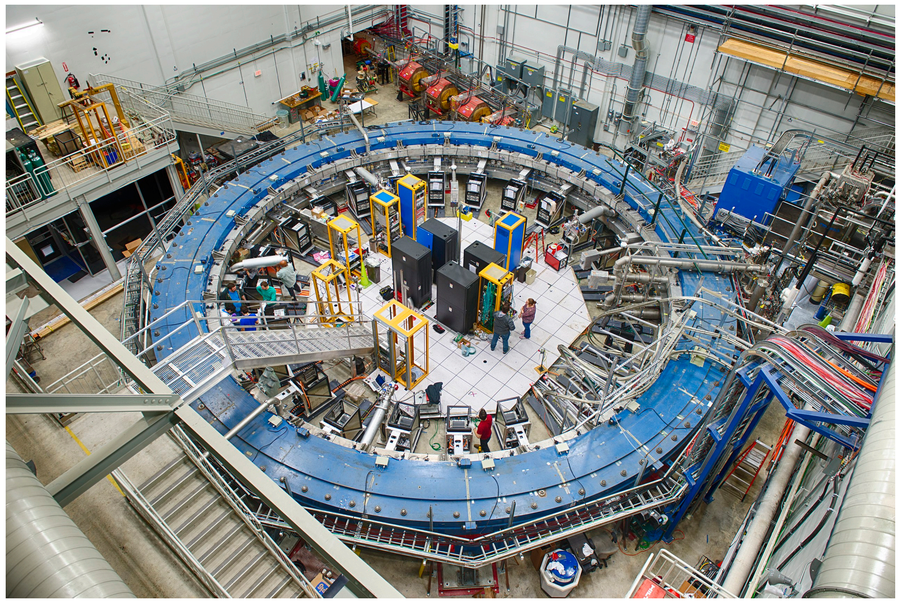
UNIVERSITY OF LIVERPOOL

Fermilab

(Very brief) g-2 Overview

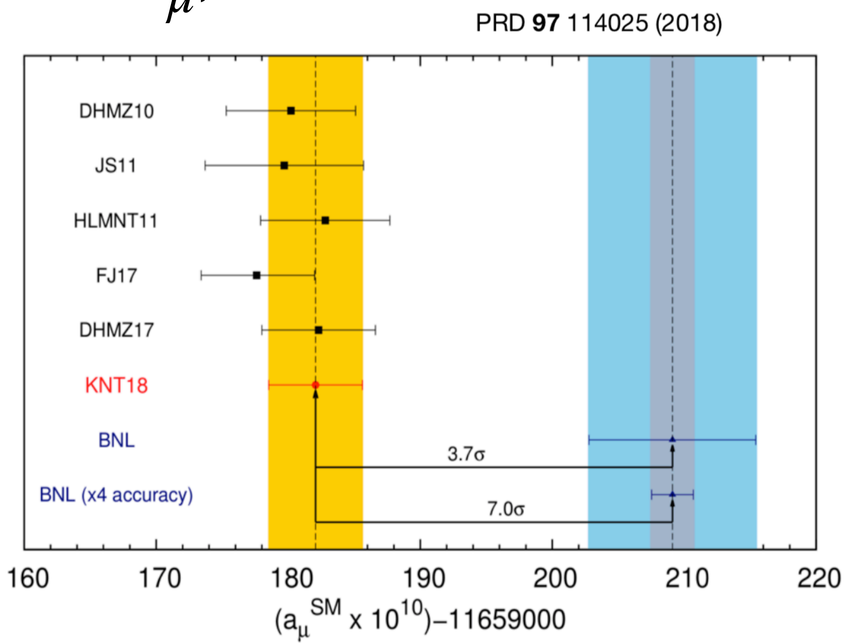
- Measures a_μ to a precision of 0.14ppm.
- High intensity beam of polarised muons provided by Fermilab accelerator division.
- Measure ω_a (through ω_s and ω_C) and ω_p

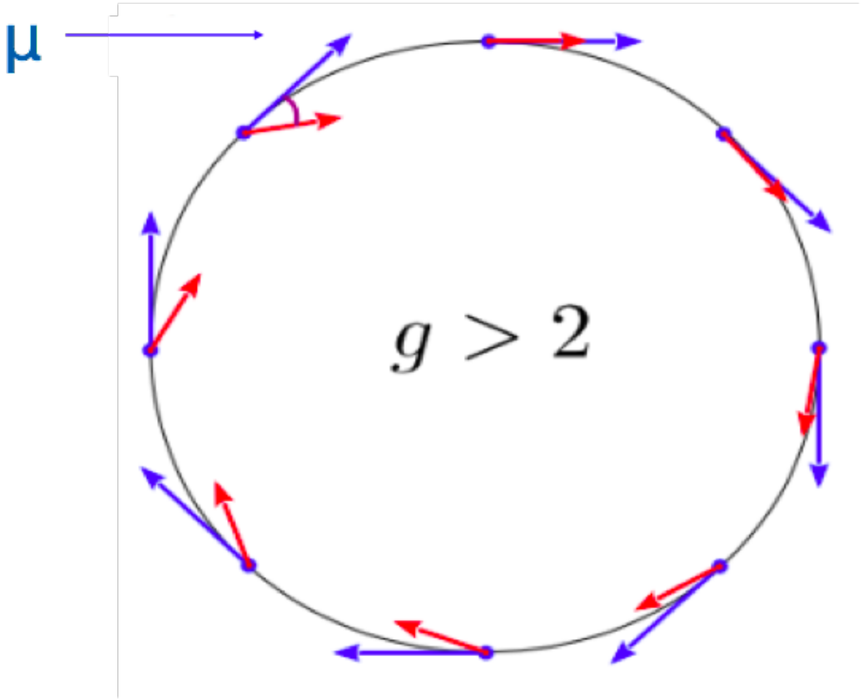
$$\omega_a = \omega_s - \omega_c = a_\mu \frac{eB}{mc}$$



- Determine muon g-factor via a_μ;

$$a_\mu \equiv \frac{(g-2)}{2}$$





Straw Trackers

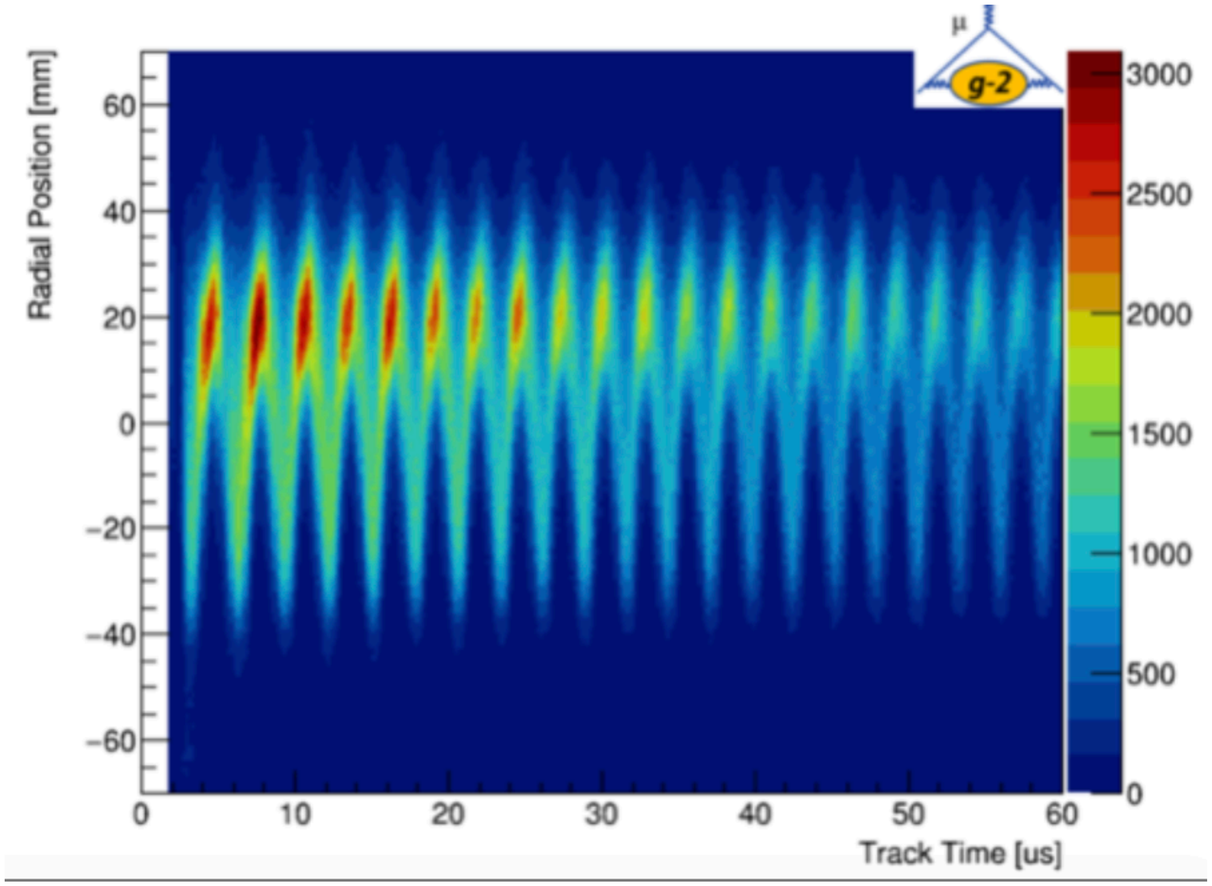
- **Main purpose to help us understand the systematics of ω_a**

- **Tracks decay particles (e^+)**

$$\mu^{\mp} \rightarrow e^{\mp} + \nu_{\mu}(\overline{\nu}_{\mu}) + \overline{\nu}_{e}(\nu_{e})$$

- **Help build up muon spatial distribution**

- **Allows study into betatron motion**

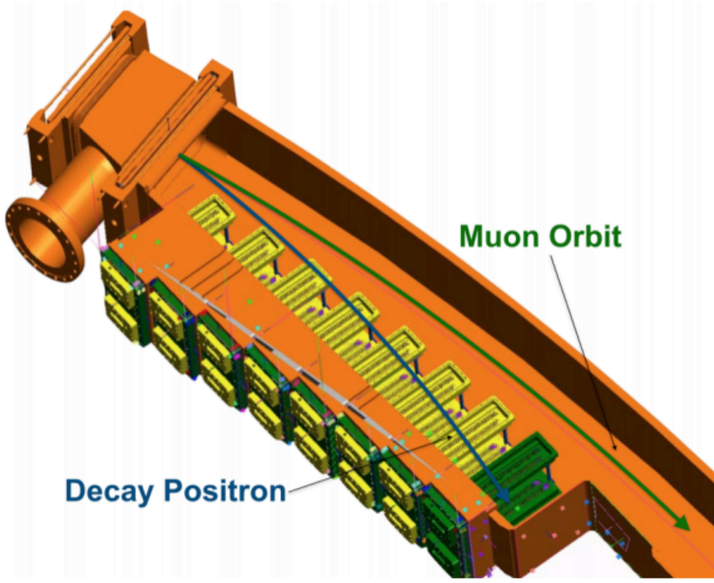


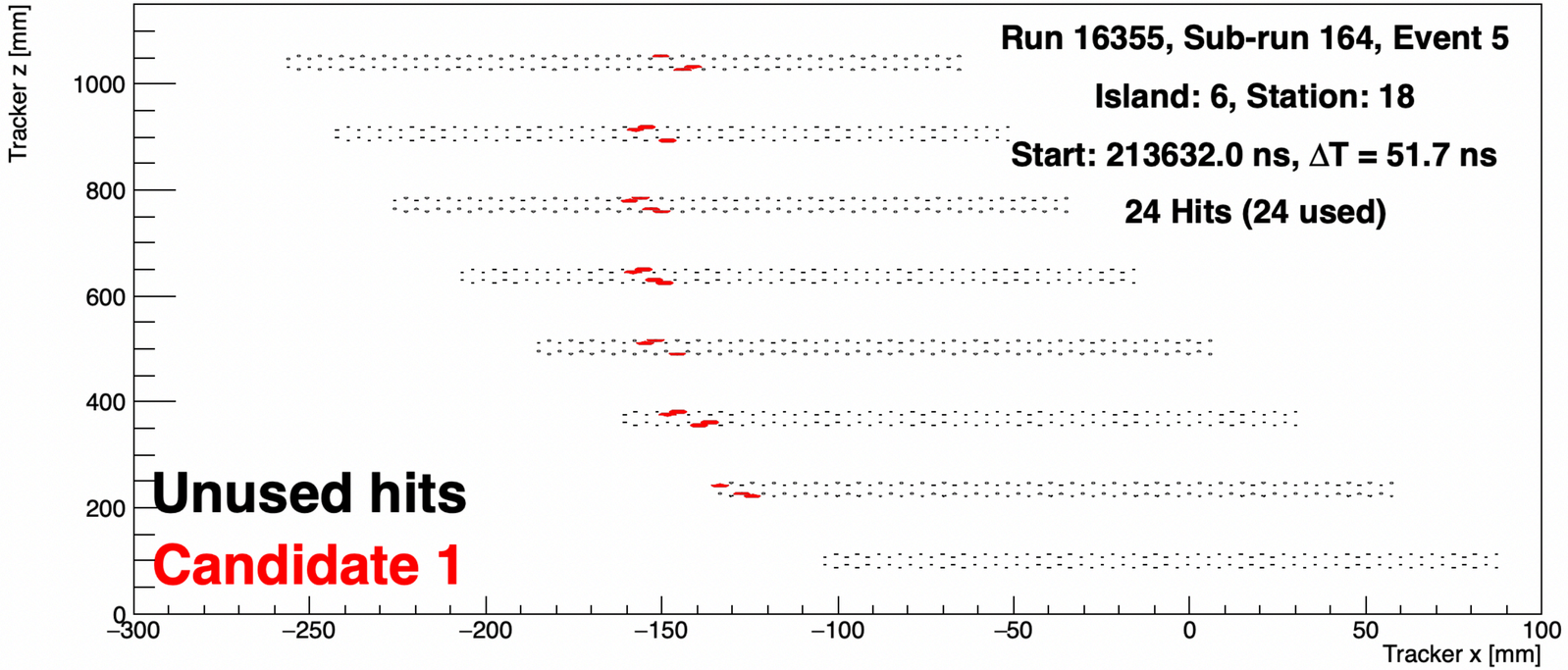
Straw Trackers

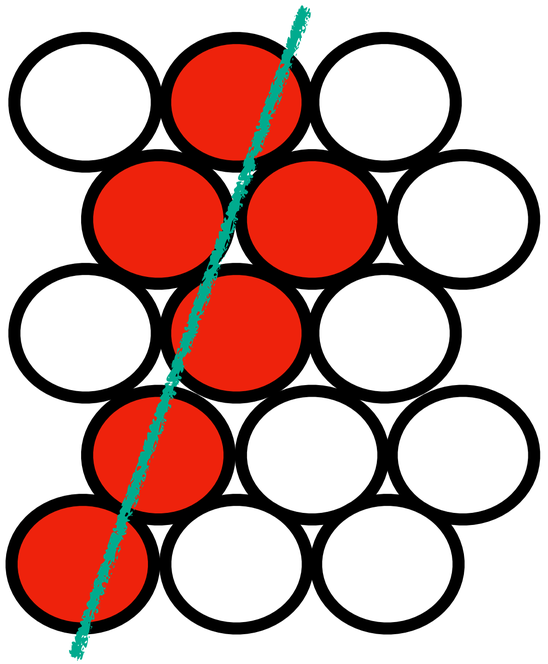
- **2 Stations of 1024 straws.**
  8 modules, 2 views, 2 layers, 31 straws per layer.

- **Straws filled with 50:50 Ar:Ethane gas with central wire.**
  Positrons induce a current in the central wire.

- **‘Hits’ build up a trajectory.**
  Some events are far more complicated than others, however.







Application of RNN for Track Finding and Fitting

- **RNN under development to improve track finding and fitting**
  - ***Approach based on multiple LSTM layers***
  - ***Requires testing dataset & corresponding truth information***

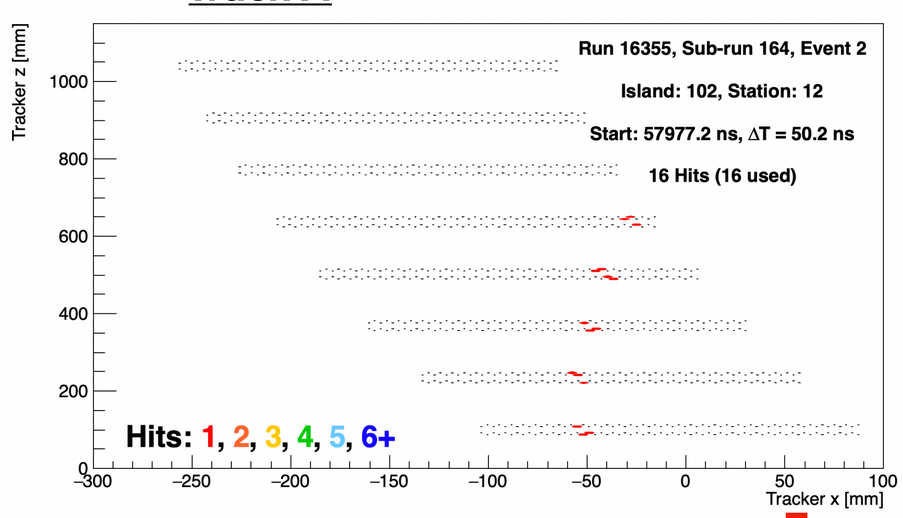
- **Initial training was done on 2D pseudo data**
  - ***Simulated hits located at the vertical centre of straws.***
  - ***This approach was found insufficient in preliminary tests***

- **Realistic synthetic data has been produced using real run 1 production data**
  - ***Merging of two well defined tracks onto one 'time island'***
  - ***Initial, real tracks represent truth information***

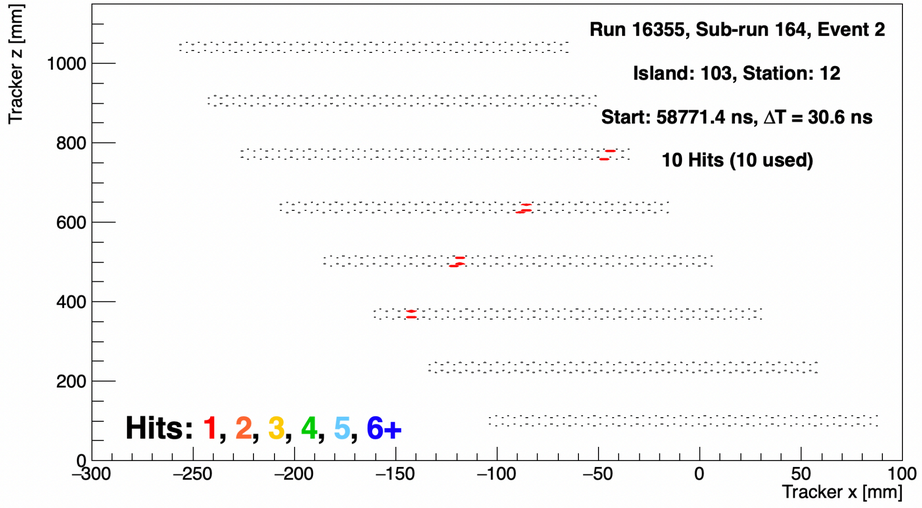
- **Noise and "cross-talk" simulations included in dataset for realism**

- **Ideal, 'well defined' tracks picked using steerable parameters:**
  - ***Late in fill, minimum of four hits, passing a minimum of four modules***

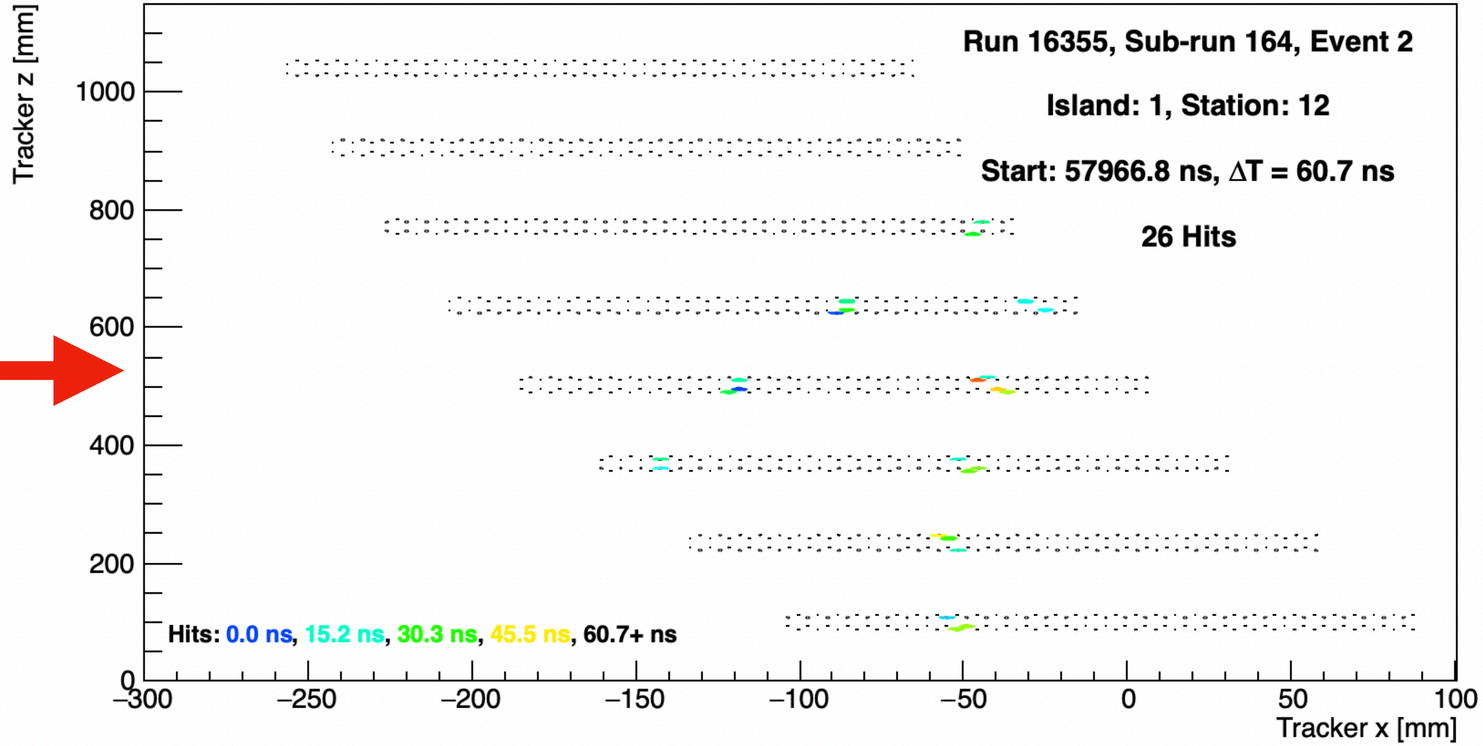
Track A



Track B

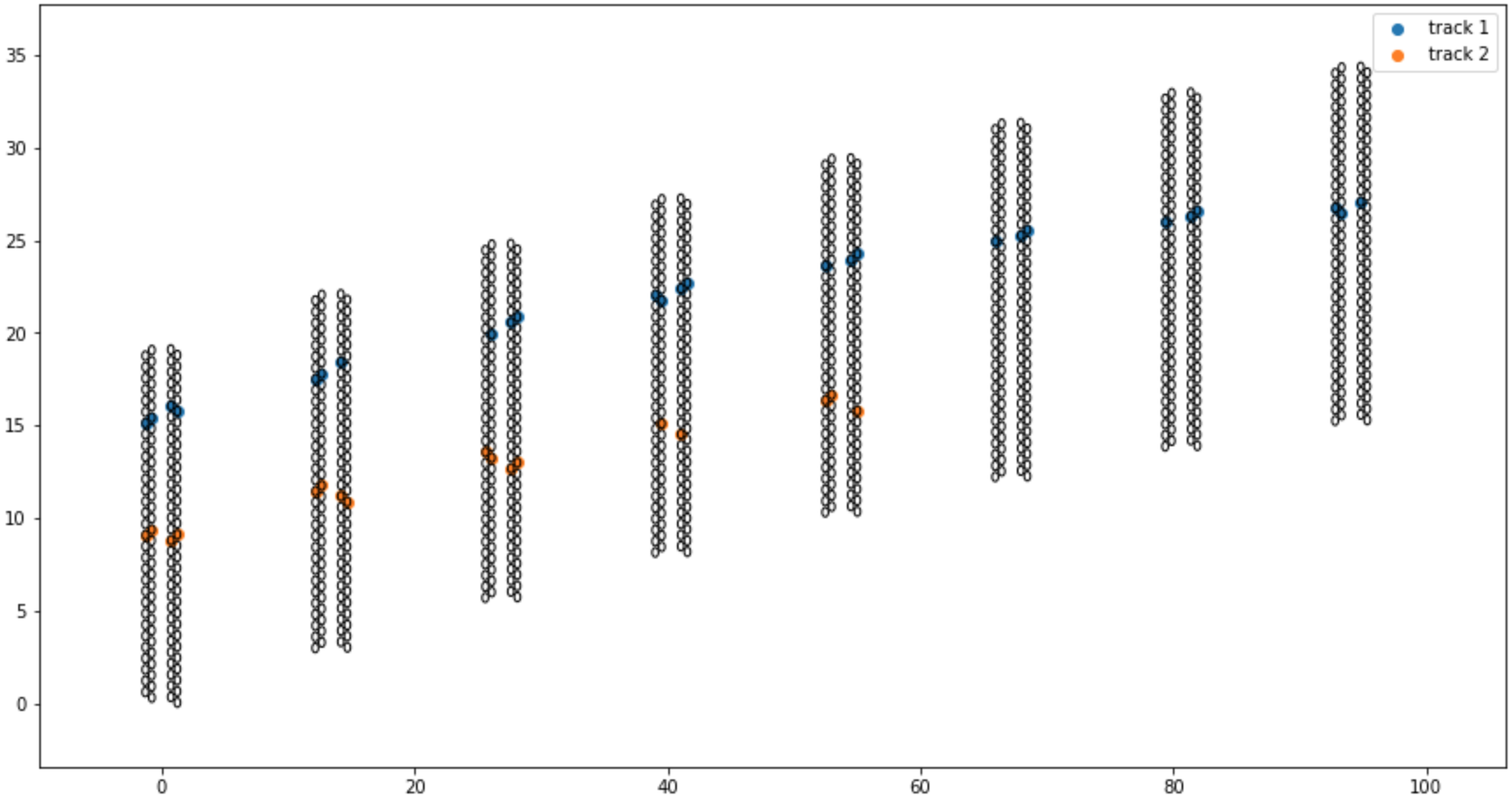


Combined Tracks



An example of a synthetic time island in the RNN structure.

- Track 1 and 2 are distinct real data tracks
- Noise and crosstalk not included in this case



- The RNN has successfully found both tracks correctly.
- Synthetic dataset is then re-tracked with incumbent tracking algorithm for direct comparison with RNN

Direct Performance Comparison

- **Tracking performance on the same synthetic dataset.**

- **Noise and crosstalk are included in the dataset**

	Main Tracking		ML track finding
True hits assigned correctly (for found tracks)	**88.4%**		**92.5%**
Wrongly assigned hits	**5.8%**		**2.8%**
Tracks found [and split tracks] out of 1970 tracks	**2167 [149] (110.0%)**		**1799 [6] (91.3%)**
Fully-correct tracks found (and fraction of total tracks)	**1379 (70.0%)**		**1330 (67.4%)**

Direct Performance Comparison

	Main Tracking	ML track finding
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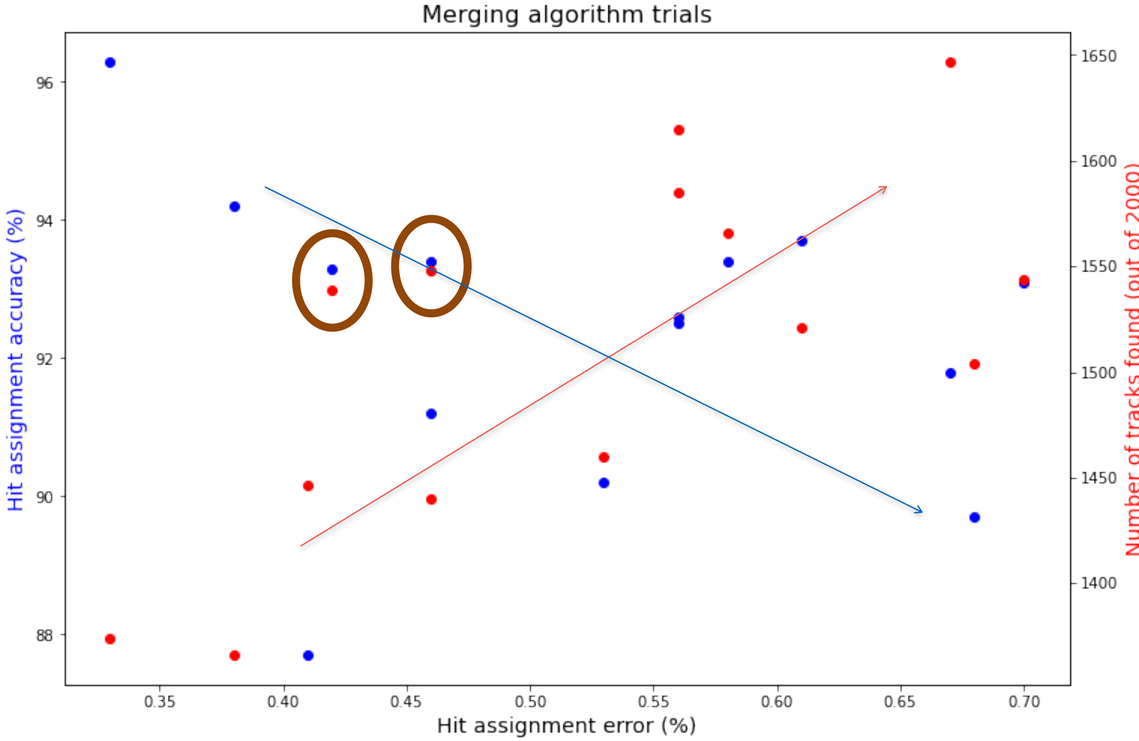
Merging algorithm was tuned in the low error range

- **RNN is more conservative, leading to a smaller assignment error..**
- **However, this can be tuned as necessary:**
  - ***For example, tuned to highest number of correctly found tracks..***
- **The tracks found with the RNN are more 'complete'.**



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- **Conservative approach of RNN is less error prone…**
- **However, the main tracking produces more high purity tracks.**
- **The main tracking is more confident, and as such finds more tracks but makes more errors.**
  - **This leads too more ‘fully correct’ tracks found in main tracking, however…**
  - **Still not *many* more fully correct tracks found (~2.6% improvement).**

Direct Performance Comparison

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Based on preliminary results, using the our higher purity RNN we would have:

- **~19% fewer candidates**
  - **Low quality candidates would likely not make QC anyway.**
  - **Save ~15% on Geant iterations and computing resources**
- **A loss of ~2.6% fully correct candidates.**
  - **We could tune this away, if necessary.**
- **Smarter track finding at higher occupancy and complexity**

Remaining Questions

- **We are still missing the full picture**
  - **We have yet to check how many tracks make the QC**
    - ***Do the RNN tracks pass the QC more frequently than main tracking?***
  - **How relevant are these improvements in high occupancy fills?**
    - ***How frequent are islands made with pileup >= 2?***

- **Creation of more diverse synthetic datatypes required:**
  - **Implementation of isolated tracks over real time islands. Does the main tracking or RNN select the isolated tracks correctly?**
  - **Generation of simpler events to prove the RNN has similar or greater prospects in lower occupancy and complexity fills.**

- **Implementation of RNN code for production.**
  - **Still working on the early stages, with lots of challenges associated with implementation.**
  - **Some expert help will be required here.**

Thank you for listening!

Any questions?