

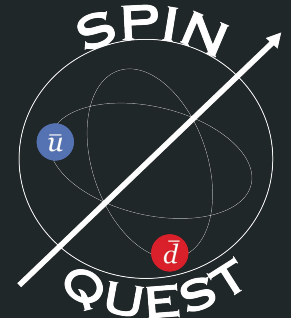
# Anomaly detection and data quality monitoring for spinQuest target and detector systems

Jordan Daniel Roberts  
Dustin Keller

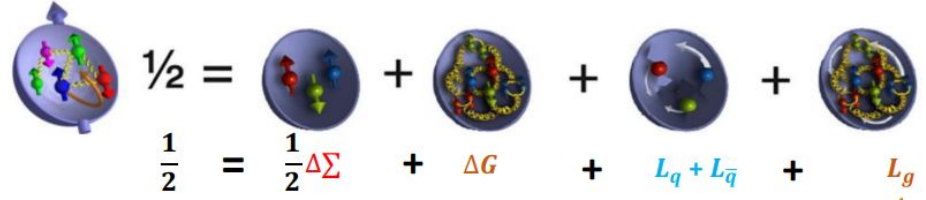


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Science



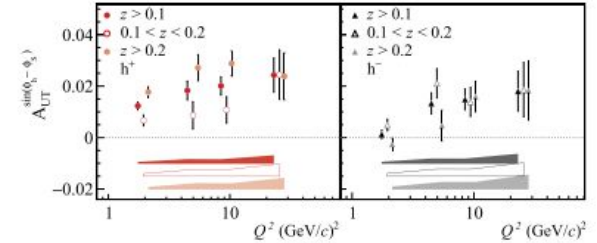
# Motivation



Jaffe-Manohar Sum Rule :  $\Delta S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$

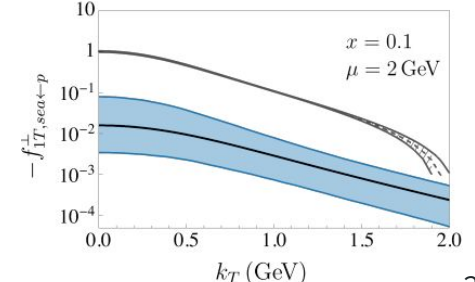
Ji's Sum Rule :  $\Delta S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q^z + J_g^z$

SIDIS Sivers at COMPASS

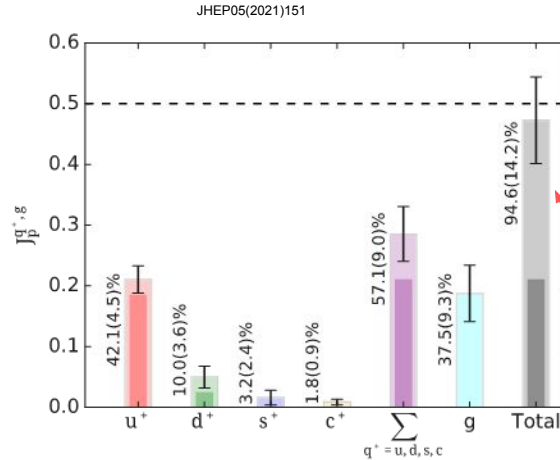
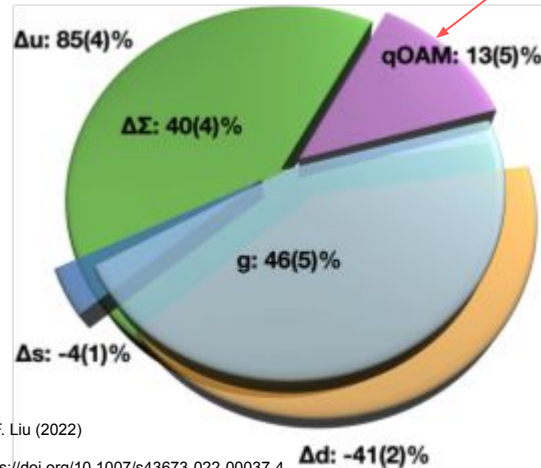
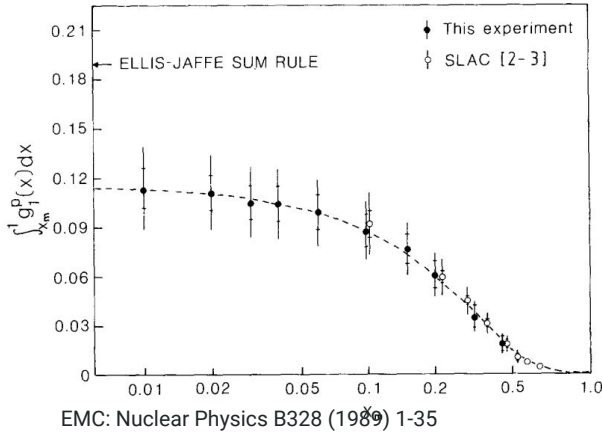


C. Adolph et al. / Physics Letters B 770 (2017) 138–145

JLAB



arXiv:2103.03270v1 [hep-ph] 4 Mar 2021

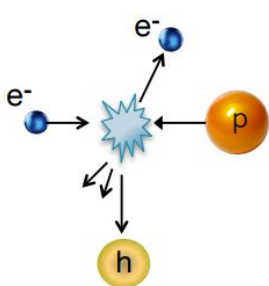


Spin decomposition. Transparent is sea.

# Spin Asymmetries

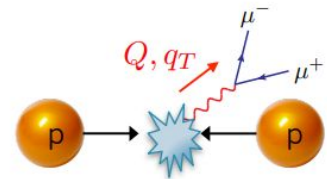
		Quark Polarization		
		U	L	T
Nucleon Polarization	U	$f_{1\uparrow} = \odot$	N/A	$h_{1\uparrow}^{\perp} = \odot - \ominus$ <i>Boer-Mulders</i>
	L	N/A	$g_{1L} = \odot - \ominus$ <i>Helicity</i>	$h_{1L}^{\perp} = \odot - \ominus$
	T	$f_{1T}^{\perp} = \odot - \ominus$ <i>Sivers</i>	$g_{1T}^{\perp} = \odot - \ominus$	$h_{1T} = \odot - \ominus$ $h_{1T}^{\perp} = \odot - \ominus$ <i>Transversity</i>

SIDIS

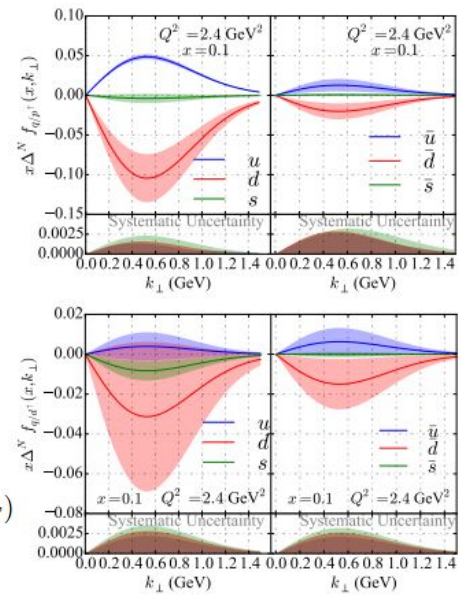


$$\sigma \sim f_{q/P}(x, k_T) D_{h/q}(z, k_T)$$

DY



$$\sigma \sim f_{q/P}(x_1, k_T) f_{\bar{q}/P}(x_2, k_T)$$



$$A_N^{DY} \propto \frac{\sum_q e_q^2 [f_1^q(x_1) \cdot f_{1T}^{\perp, \bar{q}}(x_2) + 1 \leftrightarrow 2]}{\sum_q e_q^2 [f_1^q(x_1) \cdot f_1^{\bar{q}}(x_2) + 1 \leftrightarrow 2]}$$

Quark correlator can be decomposed into 8 components (6 T-even and 2 T-odd terms) at leading-twist

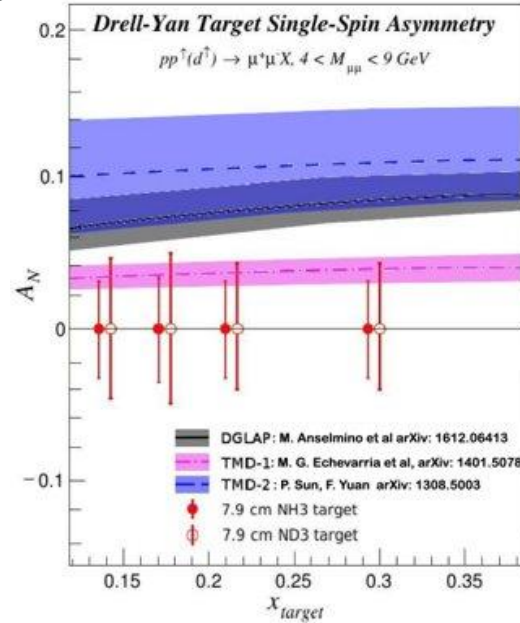
$$\begin{aligned} \Phi(x, k_T, P, S) = & f_1(x, k_T^2) \frac{\not{P}}{2} + \frac{h_{1T}(x, k_T^2)}{4} \gamma_5 [\not{S}_T, \not{P}] + \frac{S_L}{2} g_{1L}(x, k_T^2) \gamma_5 \not{P} + \frac{k_T \cdot S_T}{2M} g_{1T}(x, k_T^2) \gamma_5 \not{P} \\ & + S_L h_{1L}^{\perp}(x, k_T^2) \gamma_5 \frac{[k_T, \not{P}]}{4M} + \frac{k_T \cdot S_T}{2M} h_{1T}^{\perp}(x, k_T^2) \gamma_5 \frac{[k_T, \not{P}]}{4M} + i h_1^{\perp}(x, k_T^2) \frac{[k_T, \not{P}]}{4M} - \frac{\epsilon_T^{\kappa_T \triangleright T}}{4M} f_{1T}^{\perp}(x, k_T^2) \not{P} \end{aligned}$$

$$A_N = \frac{\sigma_L^{\uparrow} - \sigma_R^{\uparrow}}{\sigma_L^{\uparrow} + \sigma_R^{\uparrow}}$$

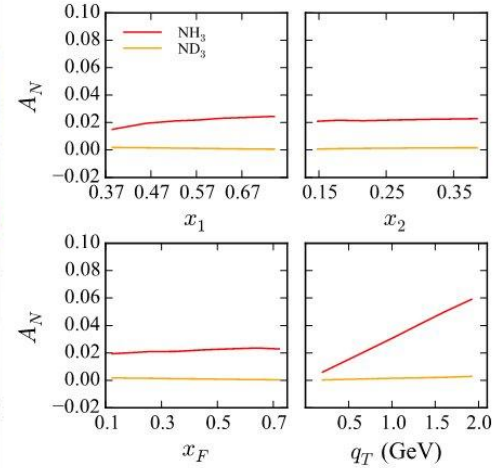
# SpinQuest

- Are the sea quarks orbiting around the spin axis of the nucleon?
- Testing QCD prediction
- Compare with other experiments
- Non-zero asym = sea quark OAM!
- SpinQuest will perform the first measurement of the Sivers asymmetry in Drell-Yan pp scattering from the sea quarks.

FNAL\_UsersMeeting\_2023\_Liliet

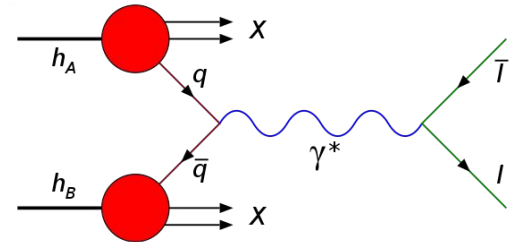


I. P. Fernando and D. Keller Phys. Rev. D.108.054007 (2023)



$$f^{\perp qDY}(x, p_T^2) = -f^{\perp qSIDIS}(x, p_T^2)$$

$$\frac{d^2\sigma}{dx_b dx_t} = \frac{4\pi\alpha^2}{x_b x_t s} \Sigma e_q^2 [\bar{q}_t(x_t) q_b(x_b) + q_t(x_t) \bar{q}_b(x_b)]$$



# Target System

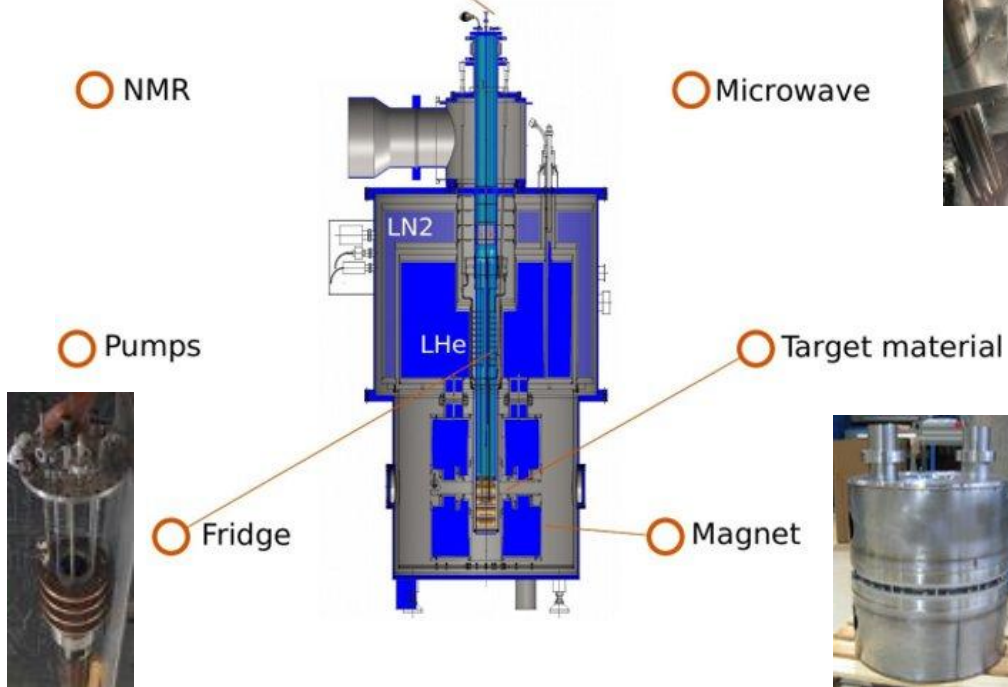


○ Insert



○ NMR

○ Microwave





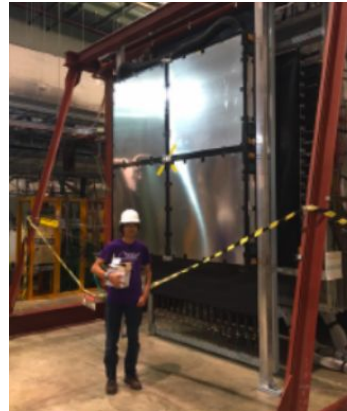
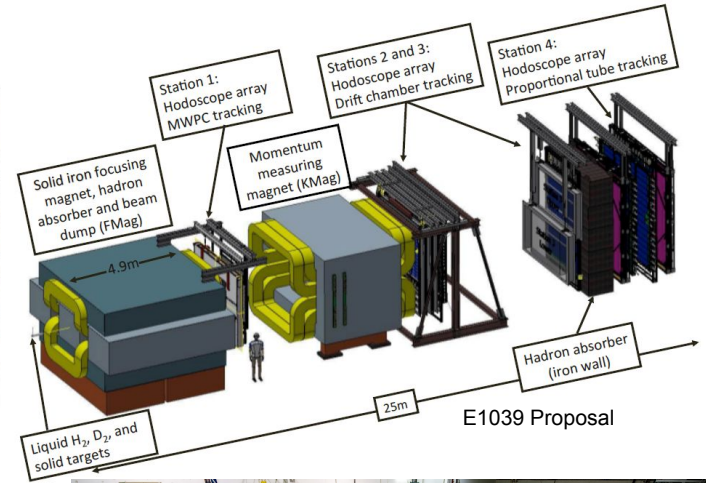
# The detector systems

## Beam

- 120 GeV Unpolarized Proton beam collides with polarized proton target
- 1 spill ~ 20-60,000 events in 4 seconds
  - max annual proton count is 7X10<sup>17</sup> protons/year
- Highest proton intensity ever attempted on a solid polarized target.

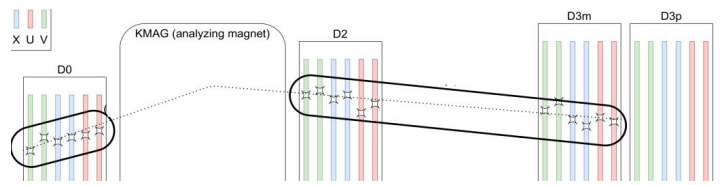
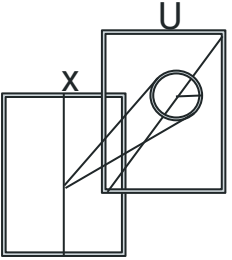
## Setup

- Cherenkov to measure beam intensity
- 4 drift chambers each with 6 detector planes.
- Paddle and Fiber Hodoscopes
  - There are 4 paddle hodoscopes stations
  - 2 Dark Photon (Fiber Hodo) Stations
- 4 layers of proportional tube planes for muon ID
- Triggers:
  - FPGA main trigger
  - Nim Trigger look for hits at the edges where DY is.
- TDC and ADC

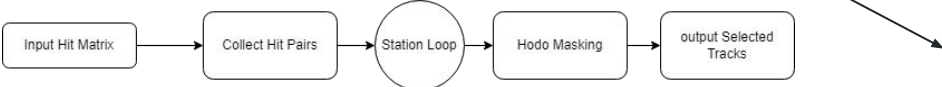


# Geometric

# Type of reconstruction

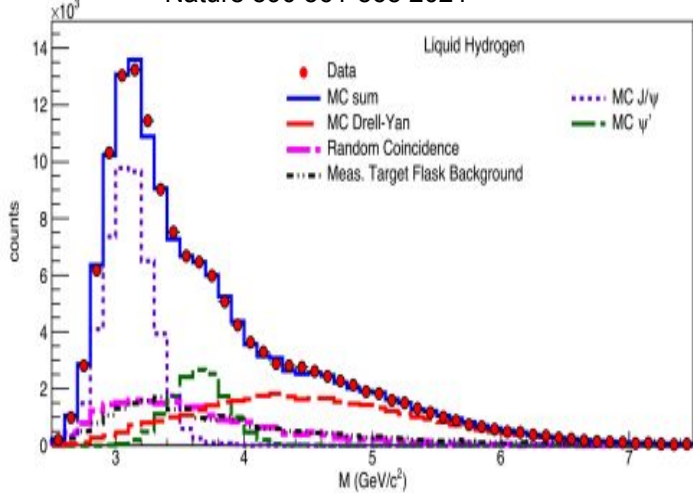


Eric Fuchey Status of GPU-based online reconstruction program

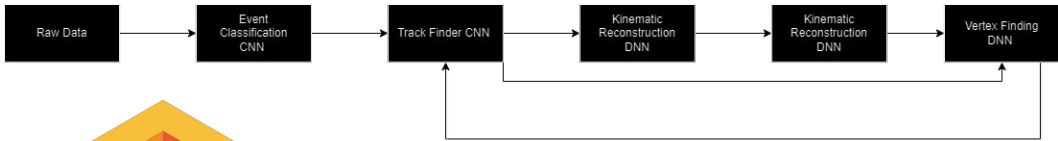


Precision 92%  
Recall 9%

Nature 590 561-565 2021



# Machine Learning Model

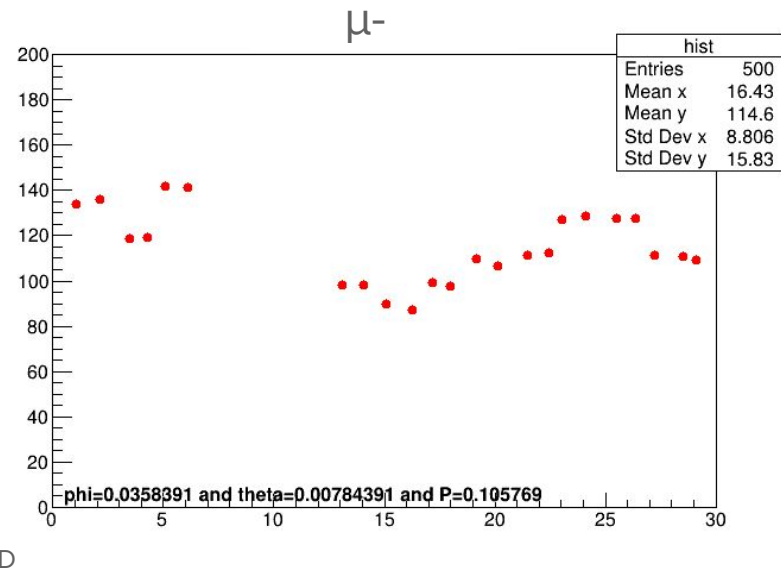
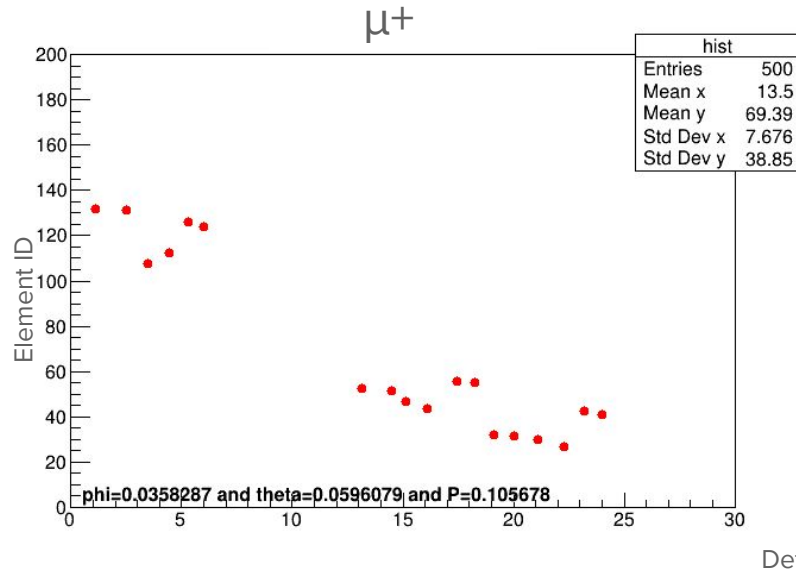


Precision 99%  
Recall 54%

$$\text{Precision} = \frac{TP}{TP + FP}$$

$$\text{Recall} = \frac{TP}{TP + FN}$$

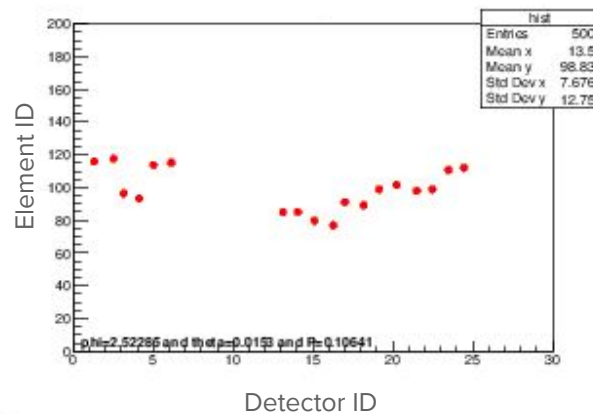
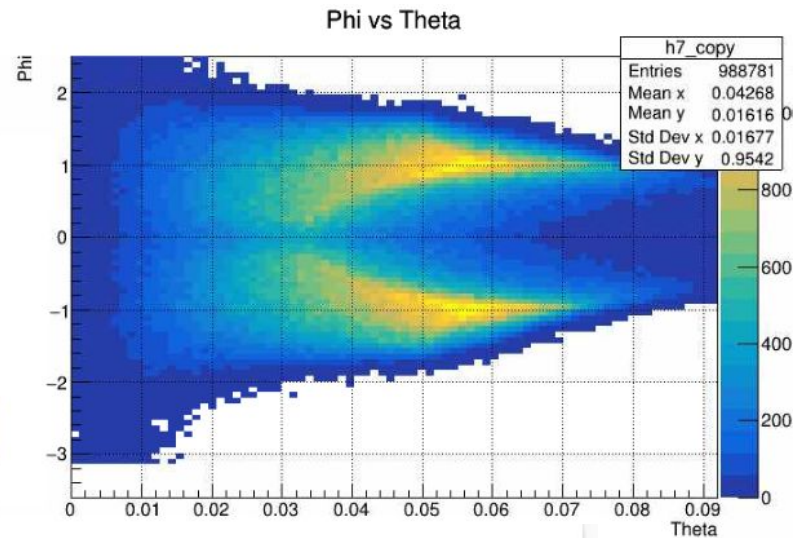
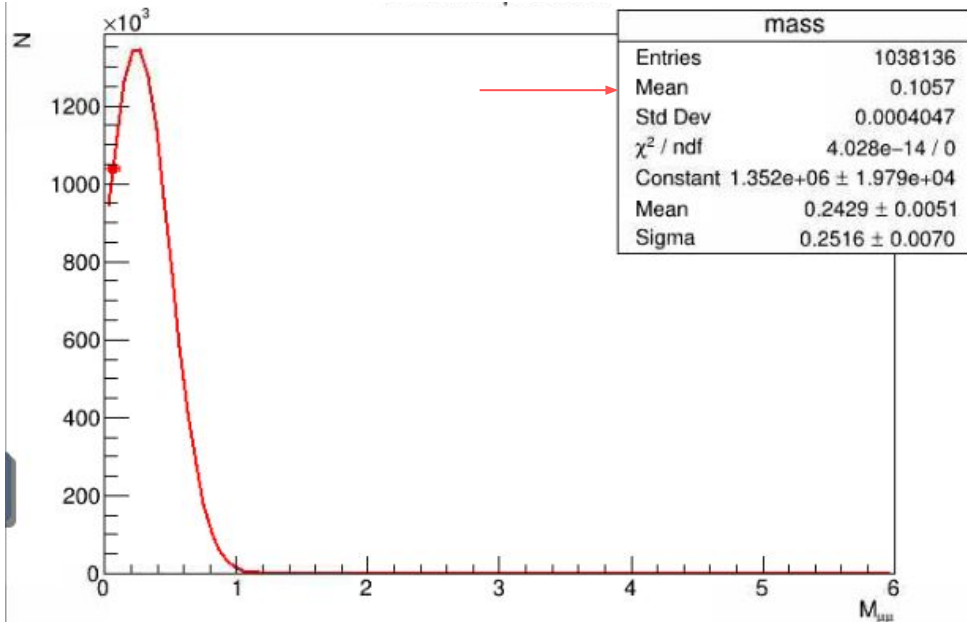
# Hit Patterns



- Is there a pattern in the hits displayed?
- Is there a relationship between the localized position and the angle?
- Can machine learning predict the sign of the muon?



# Hit Pattern study

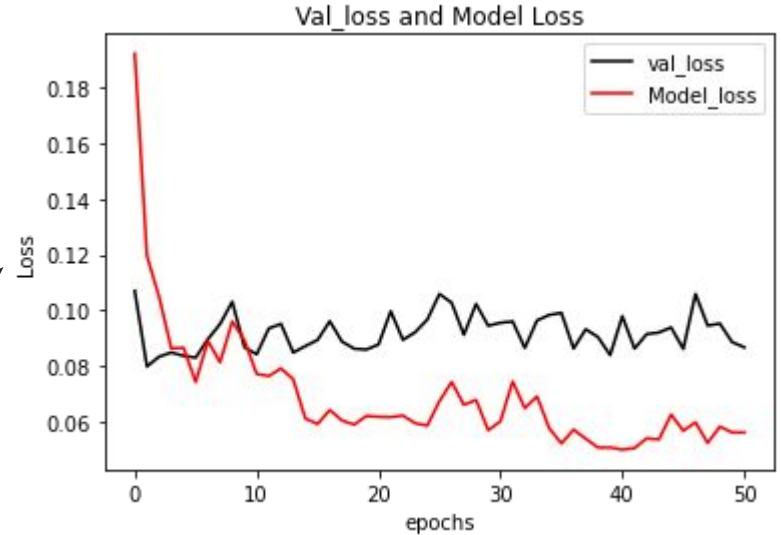


# Model

Phi , Theta, Four Momentum, PID, Event#

```
0.991629,0.0513702,0.105598,0,6  
-0.559521,0.0490154,0.105541,0,13  
-0.556647,0.0420462,0.106102,0,14  
-0.812453,0.0406681,0.105944,0,15  
-0.378999,0.0429428,0.105349,0,16  
-1.27328,0.0501542,0.105754,0,20  
0.989319,0.0586106,0.105904,0,23  
-0.653622,0.0419365,0.105259,0,27  
0.50292,0.0528388,0.105638,0,29  
1.392,0.0556353,0.10604,0,30  
1.31073,0.0592074,0.106058,0,34  
0.116728,0.0497964,0.105463,0,35  
-0.198325,0.0403822,0.105374,0,39  
0.973388,0.0414214,0.106282,0,43  
0.670773,0.0432126,0.106099,0,44  
-0.910147,0.046372,0.105985,0,50  
-1.56327,0.0484124,0.105716,0,56  
0.97819,0.0513824,0.105962,0,58  
0.920511,0.0511227,0.105956,0,59  
-1.00036,0.0421724,0.105629,0,63  
-0.494913,0.0567432,0.105581,0,64  
1.08625,0.0578131,0.105262,0,66  
0.000980956,0.0499779,0.105622,0,69  
-0.489169,0.0514293,0.105624,0,75  
-0.815407,0.0440034,0.105894,0,78  
0.839154,0.0548899,0.105566,0,86  
1.16663,0.0525,0.105423,0,90  
0.0201143,0.0486023,0.105562,0,92  
0.897548,0.052883,0.105035,0,93  
-0.694223,0.0535002,0.106685,0,95  
0.910735,0.047556,0.106166,0,103  
1.24886,0.0524227,0.105024,0,105  
-1.54286,0.0425361,0.105042,0,108  
0.60654,0.0573015,0.105000,0,110
```

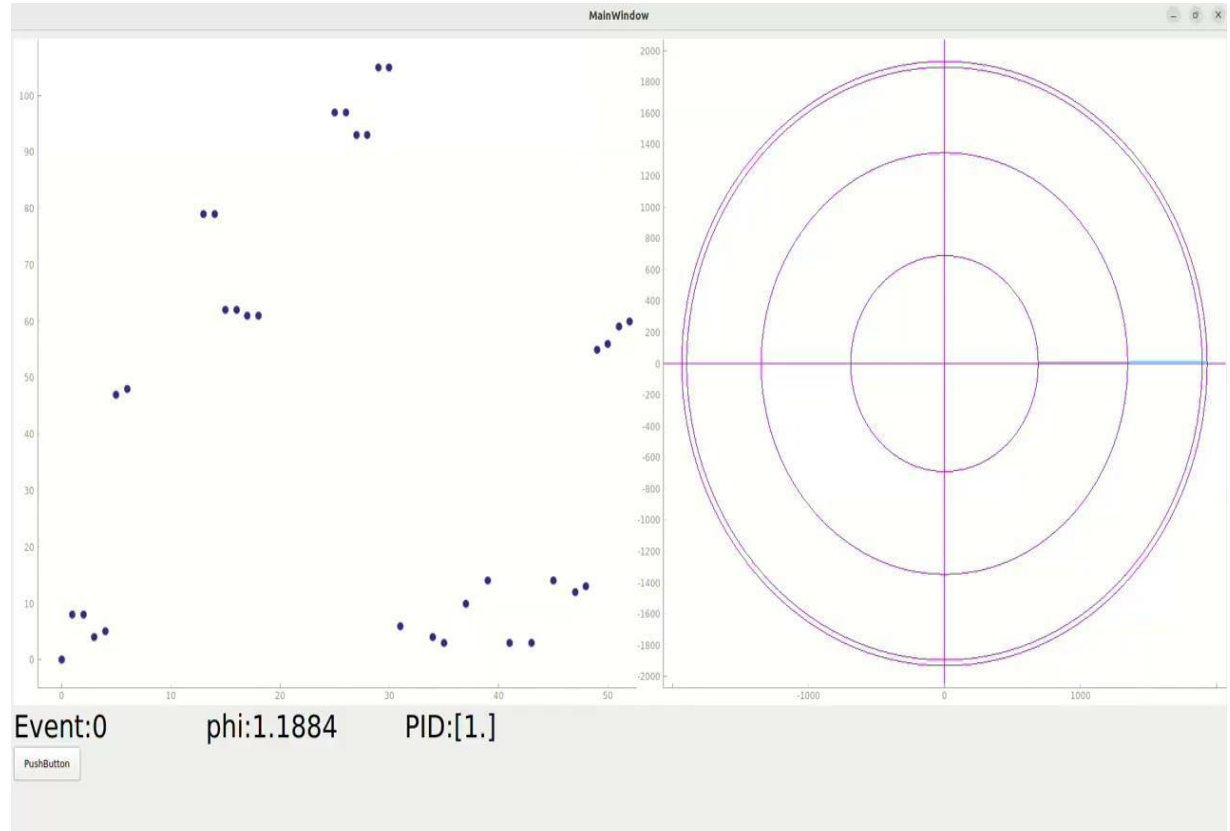
Machine  
Model



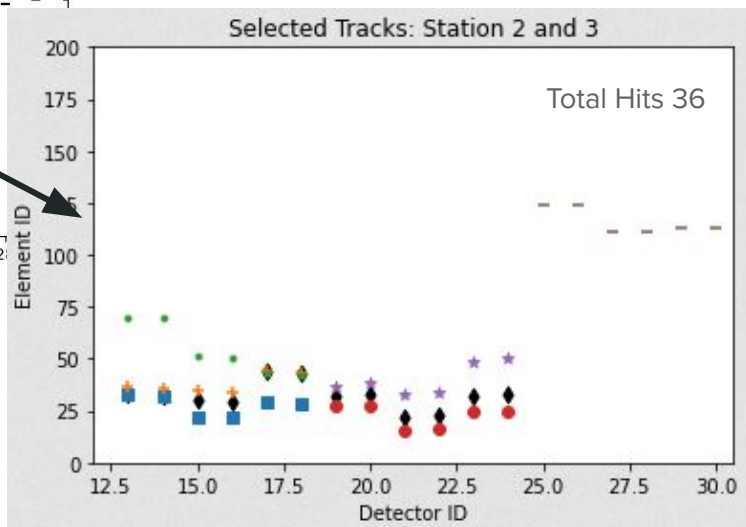
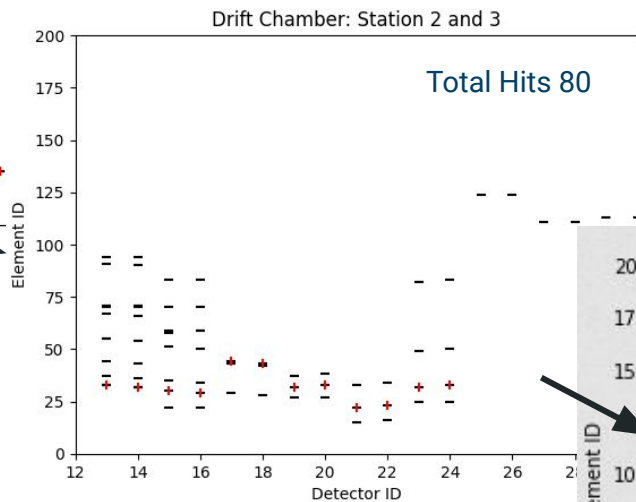
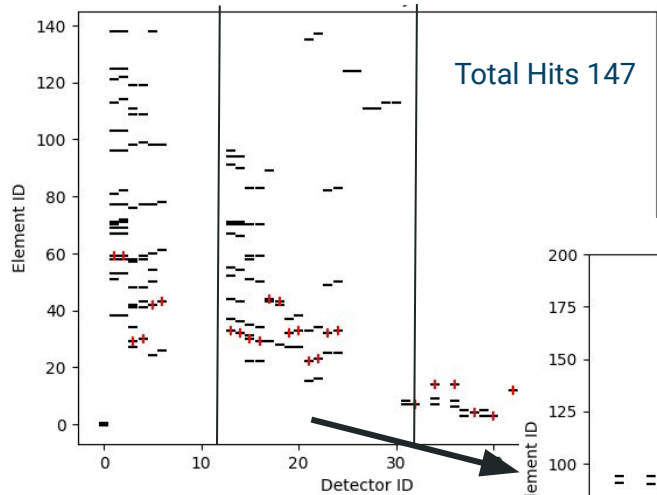
1 is positive  
0 is negative

# visualization

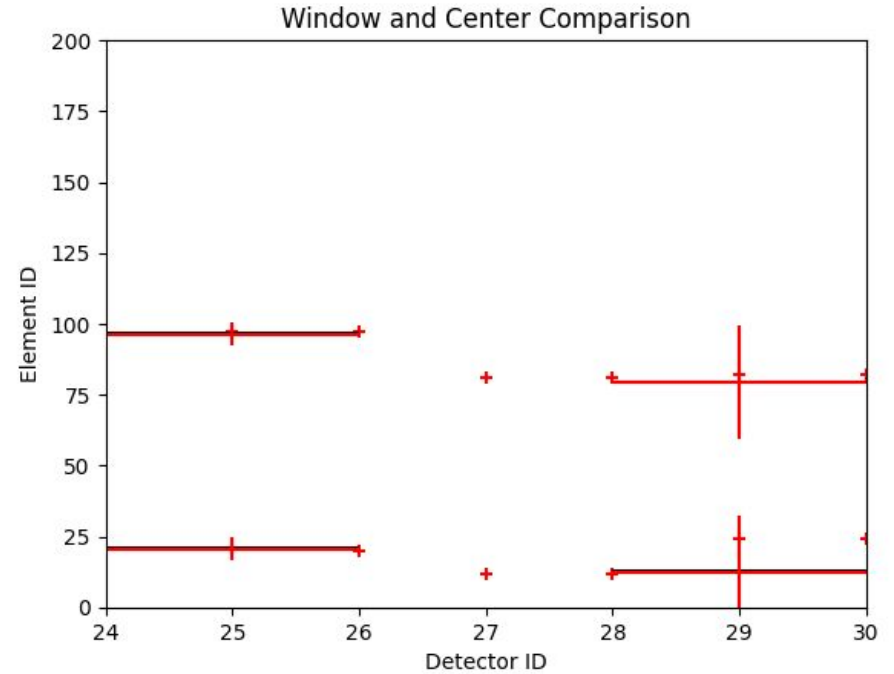
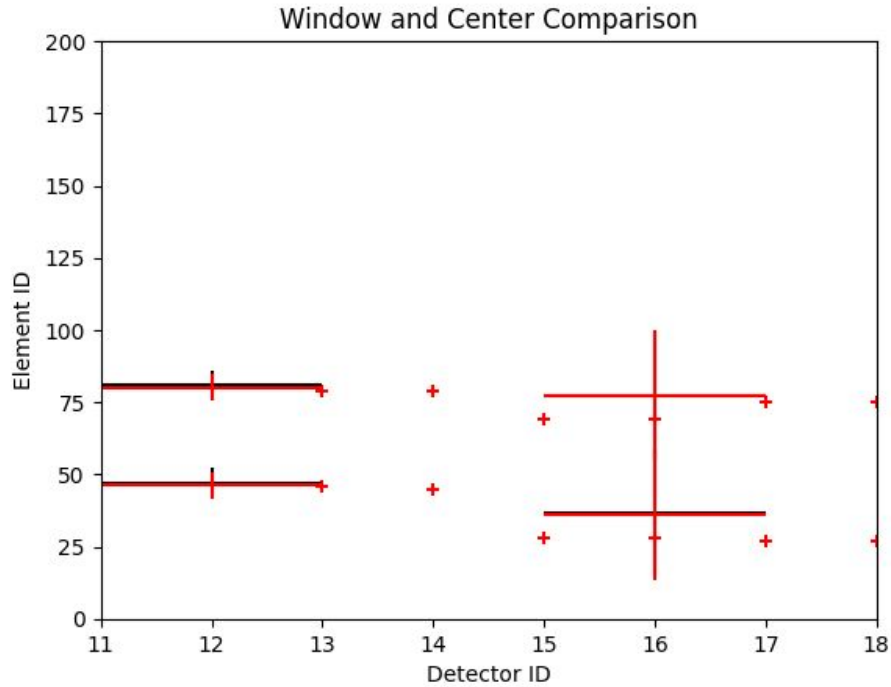
- Pyqt for lightweight display.
- Can read in data from machine models.
- Display and update plots.



# Hit selection Study



# Window study





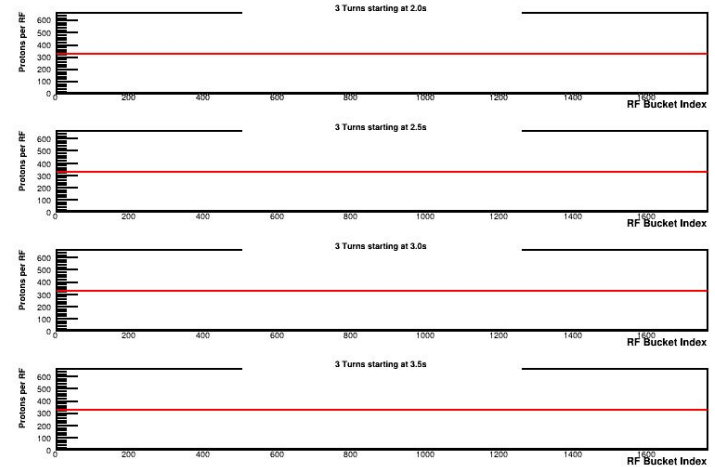
# Next

## Display Information from the trigger



## Integrate Information from the BIM

Wed Dec 22 08:05:35 2021  
SeaQuest Spill Number: 897494  
Duty Factor @53MHz = 6553.50%  
Turn13 = 2.0, Bunch13 = 84, NBSYD = 1.0  
G2SEM = 3.39E+08, G2SEM/QIESum = 9.22



# Summary

- SpinQuest will extract the sivers function to study the orbital angular momentum of the hadron.
- A non-zero orbital angular momentum correlates to the spin contribution of the sea.
- Asymmetries are the focus of the experiment and guarding against false asymmetries is vital. The solution is GPU acceleration and online monitoring/visualization.
- An online monitoring and visualization scheme is being developed for SpinQuest launch that will:
  - Aid shift workers recognize anomalies.
  - Produce quick analysis using gpu acceleration.
  - Use AI to detect anomalies and alert workers.

# Thank you

## Join The Effort

Contact:

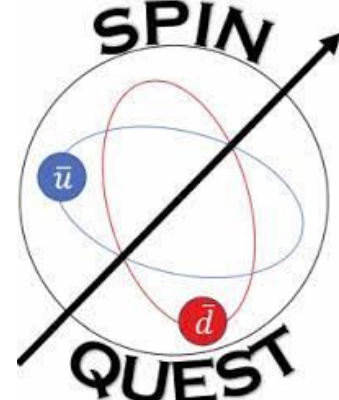
**Dustin Keller [UVA]** (dustin@virginia.edu)[Spokesperson]

**Kun Liu [LANL]** (liuk.pku@gmail.com) ([Spokesperson])

Look us up!

<https://spinqest.fnal.gov/>

<http://twist.phys.virginia.edu/E1039/>

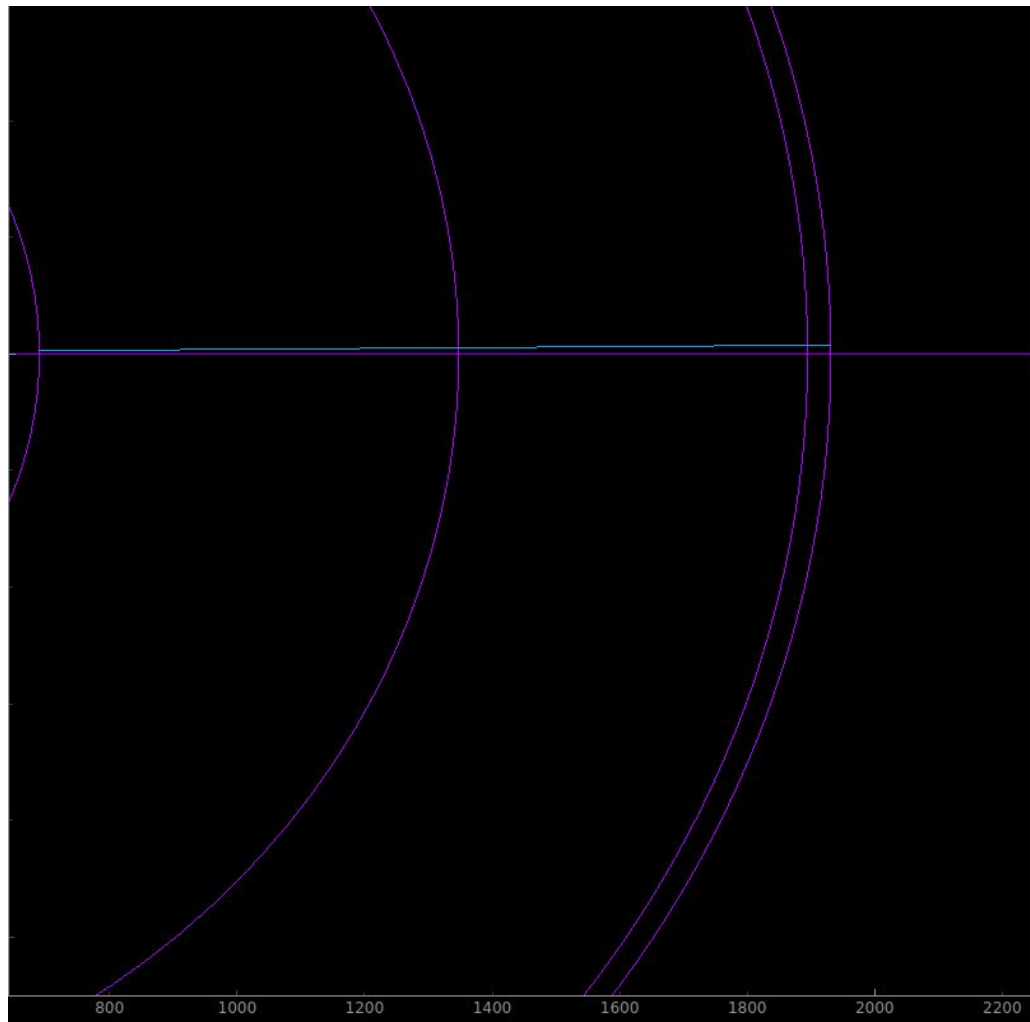


# Backup

# Hit pattern study fix theta

WIP





Precision — Out of all the examples that were predicted as positive, how many are positive?

Recall — Out of all the positive examples, how many were predicted as positive?

