

HADES



MACHINE LEARNING APPROACH TO REMOVE CARBON CONTAMINATION

Niklas Schild

(TU Darmstadt)

Analysis Meeting

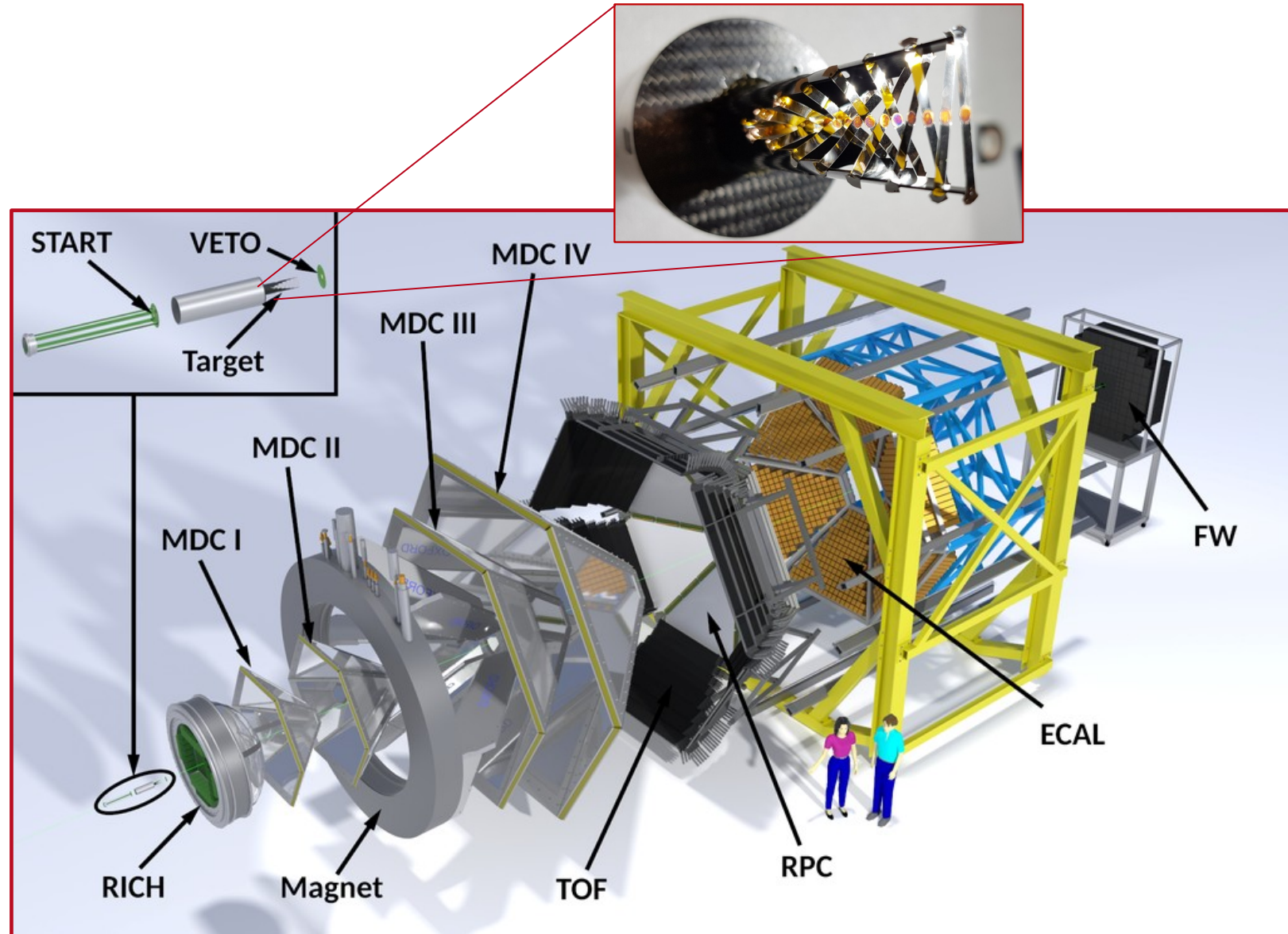
INTRODUCTION

This talk:

Focus on mar19

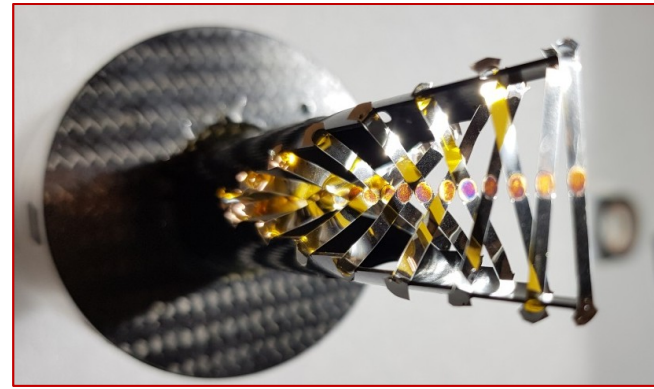
Ag+Ag $\sqrt{s_{NN}} = 2.55$ GeV

Ag+Ag $\sqrt{s_{NN}} = 2.42$ GeV

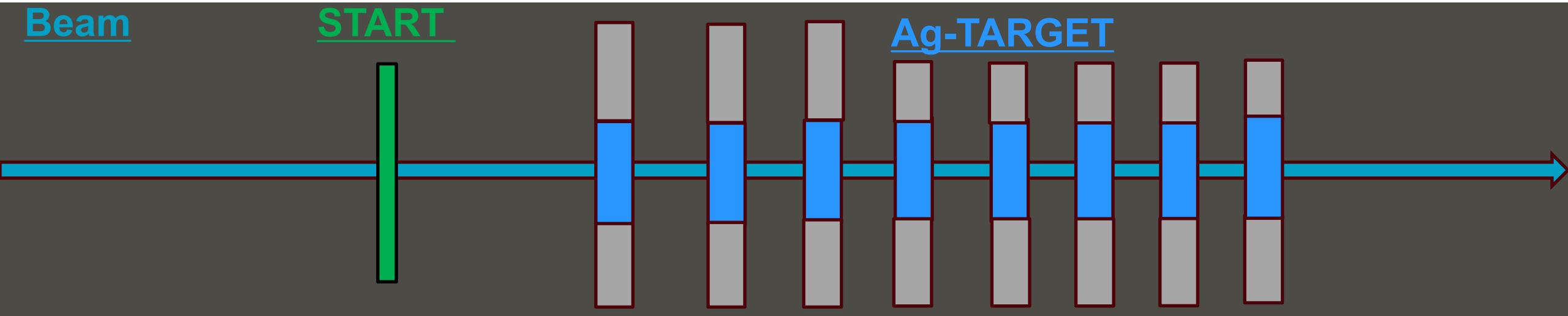


INTRODUCTION

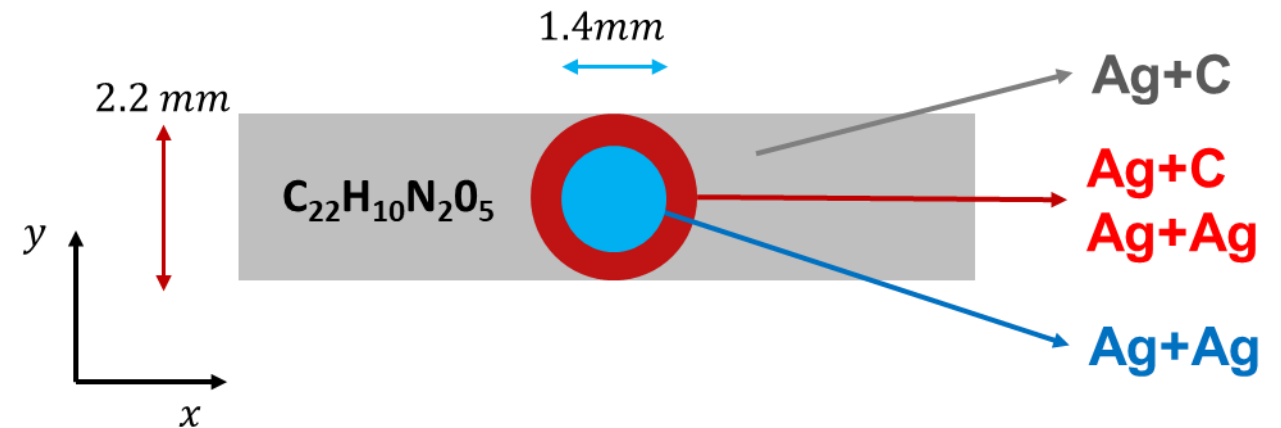
Target consists of 15 Segments with kapton structure material and center of Ag



*not drawn to scale

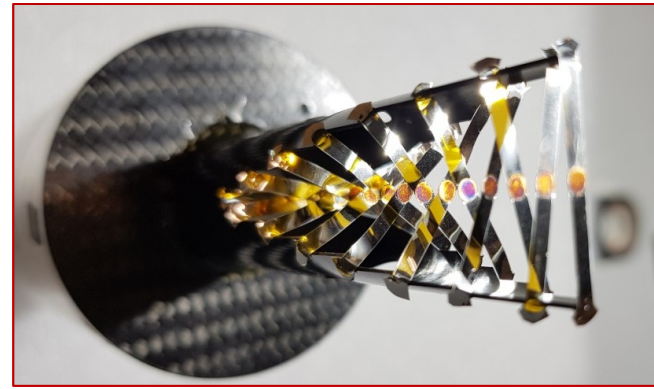


Possibilities for Ag+C collisions:

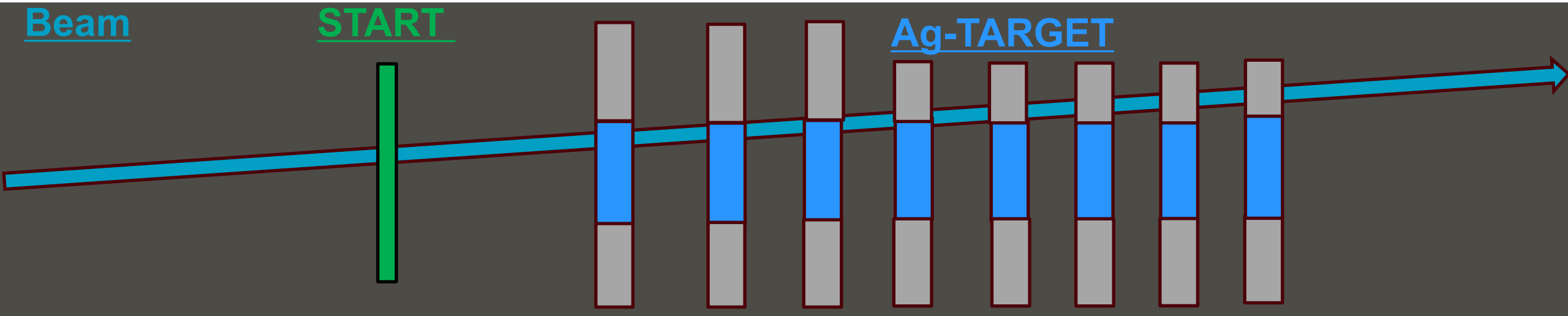


INTRODUCTION

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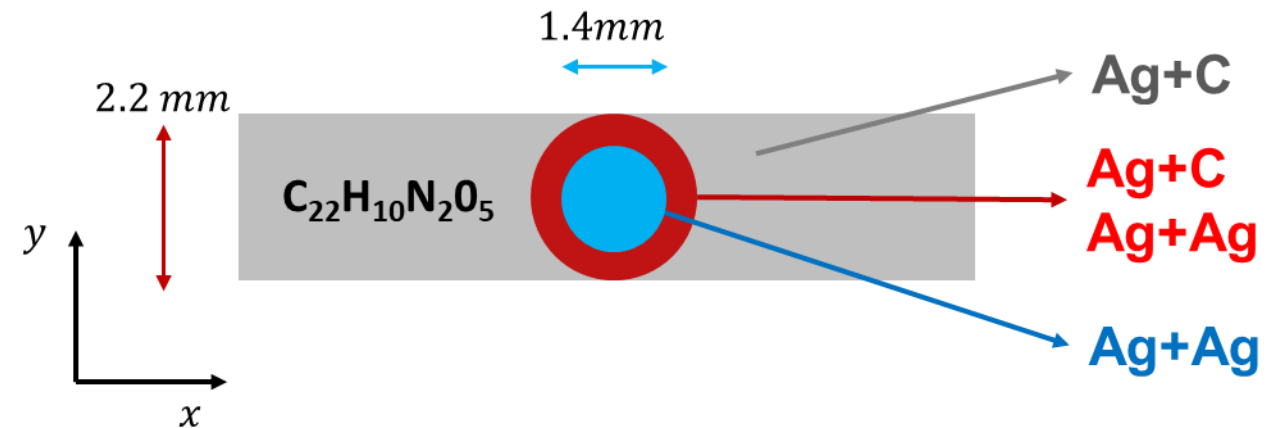


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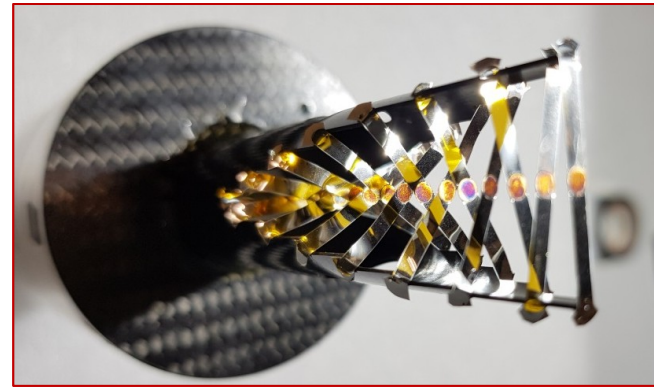
Possibilities for Ag+C collisions:

- Inclined beam

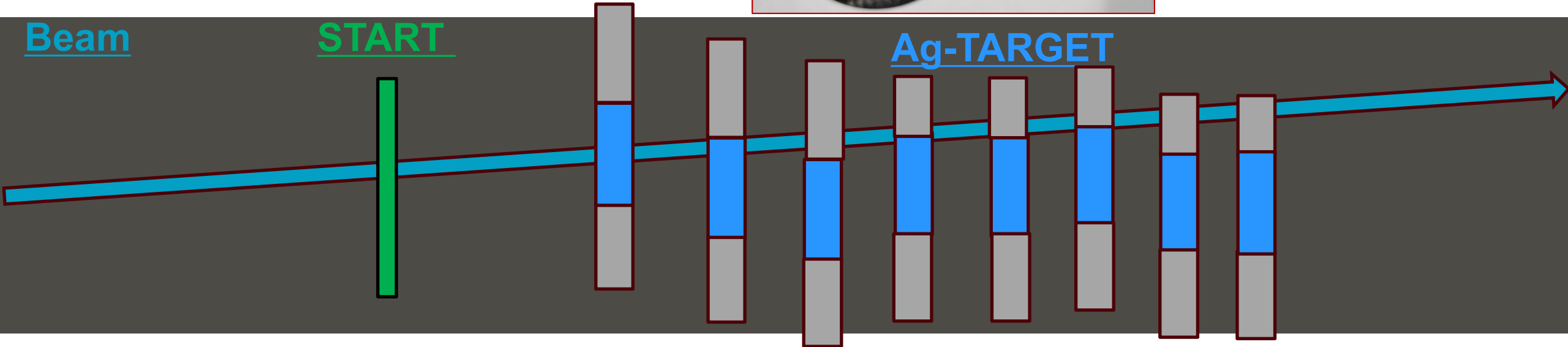


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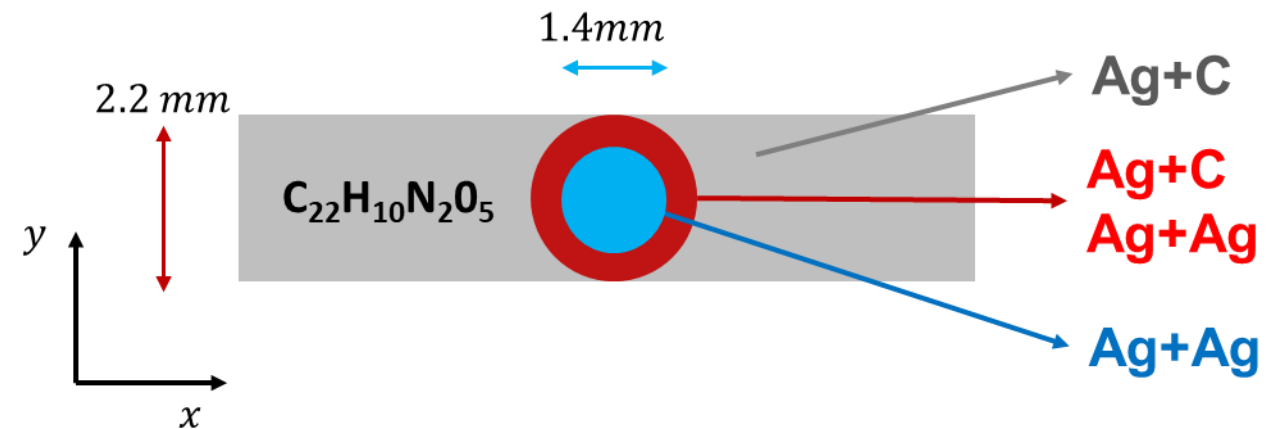


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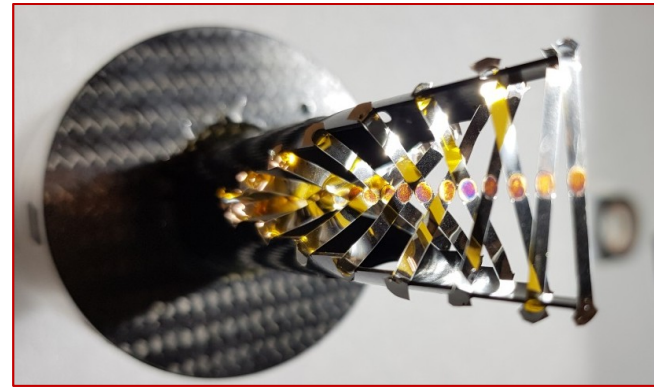
Possibilities for Ag+C collisions:

- Inclined beam
- Misaligned target segments

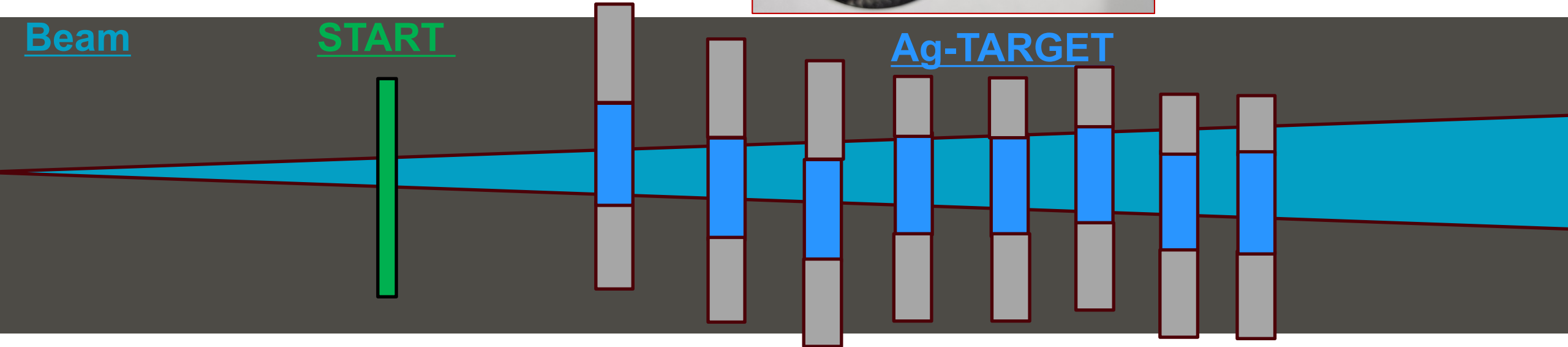


INTRODUCTION

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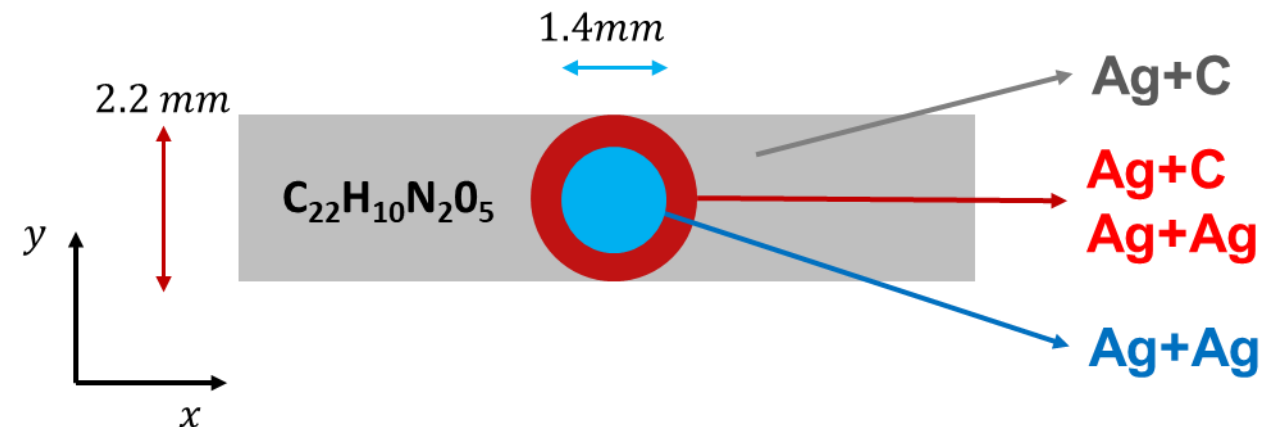


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Possibilities for Ag+C collisions:

- Inclined beam
- Misaligned target segments
- Beam divergence



INTRODUCTION

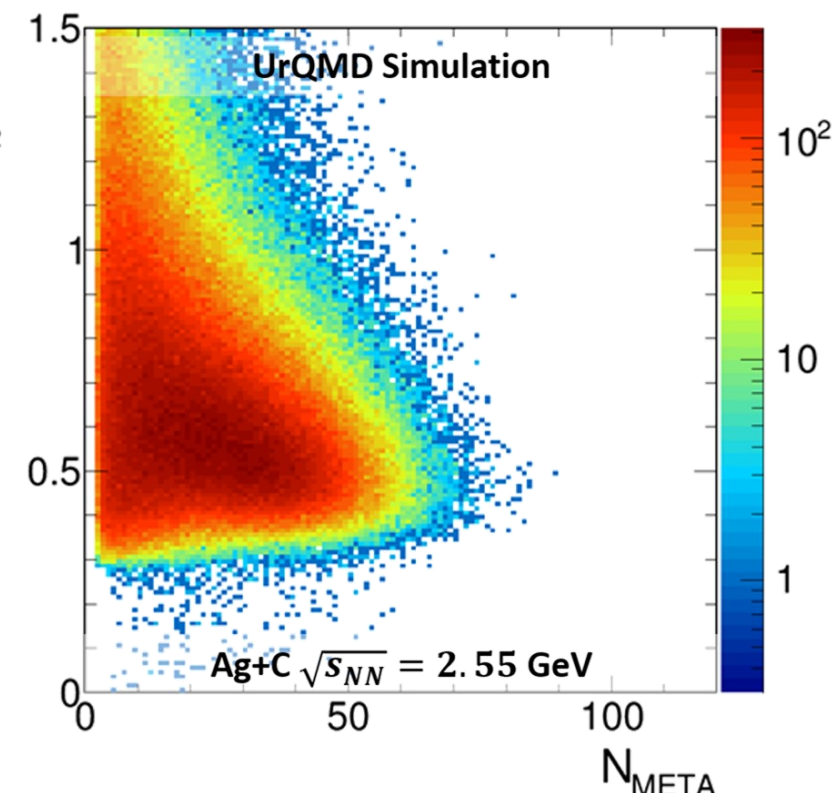
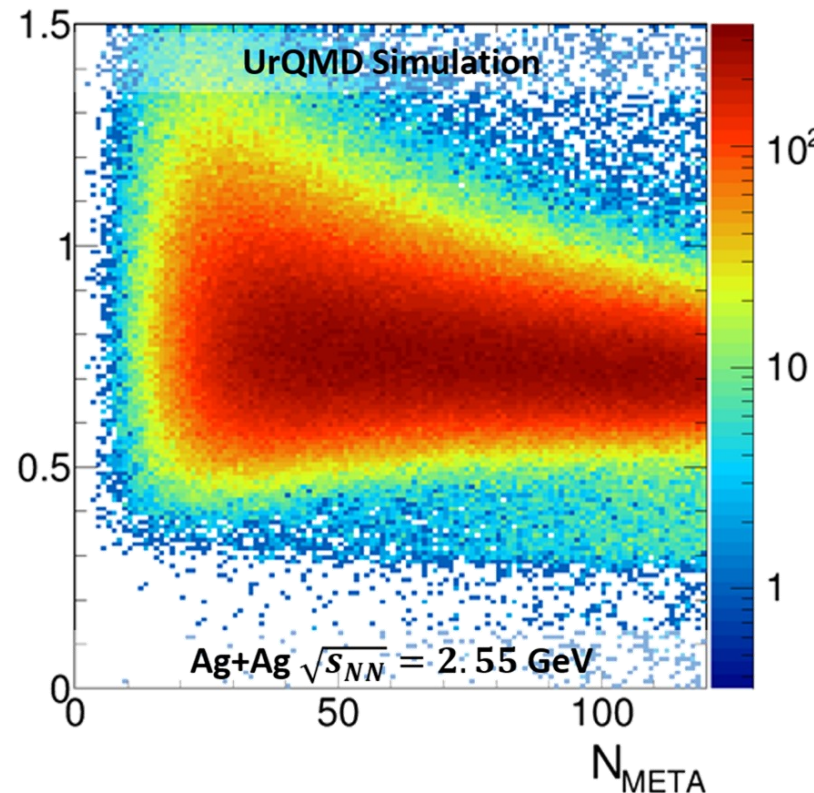
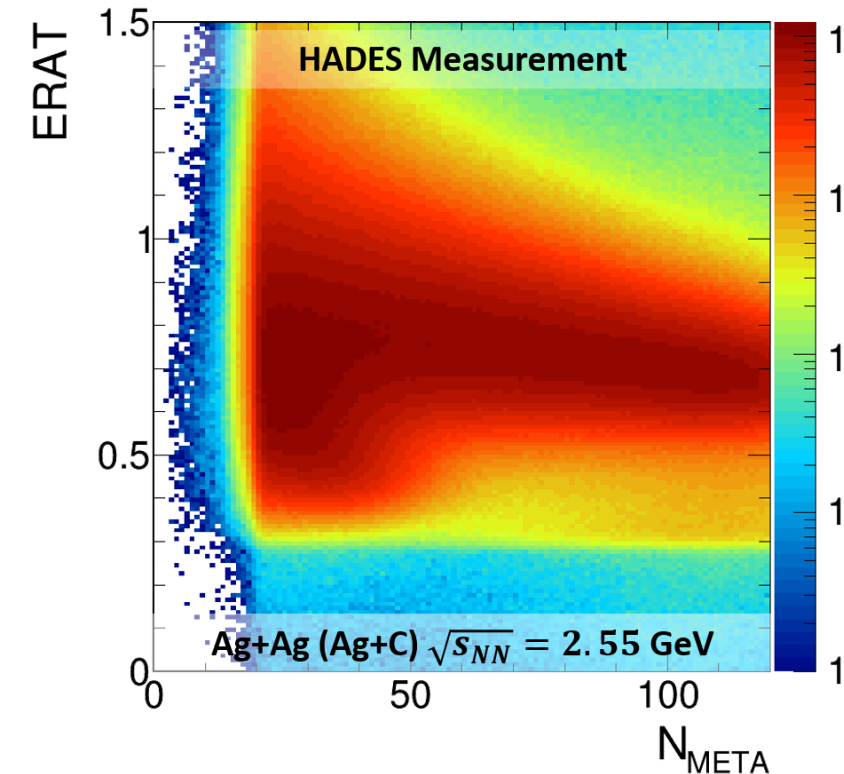


- Various observables show Ag+C contamination beyond ~ 30% centrality
- Visible in e.g. ERAT distribution
- No single observable able to sufficiently separate Ag+Ag from Ag+C

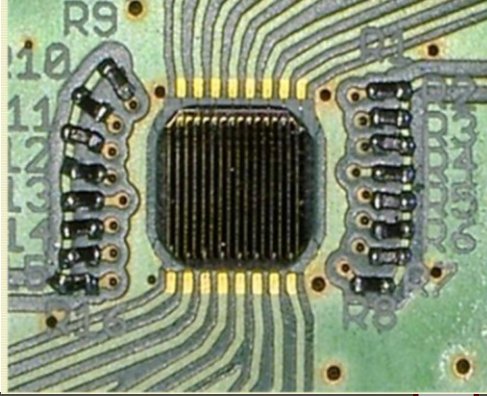
ERAT:

Ratio of transverse to longitudinal energy over all particles i

$$\text{ERAT} = \frac{\sum_{i=1}^N E_i \sin \varphi}{\sum_{i=1}^N E_i \cos \varphi}$$



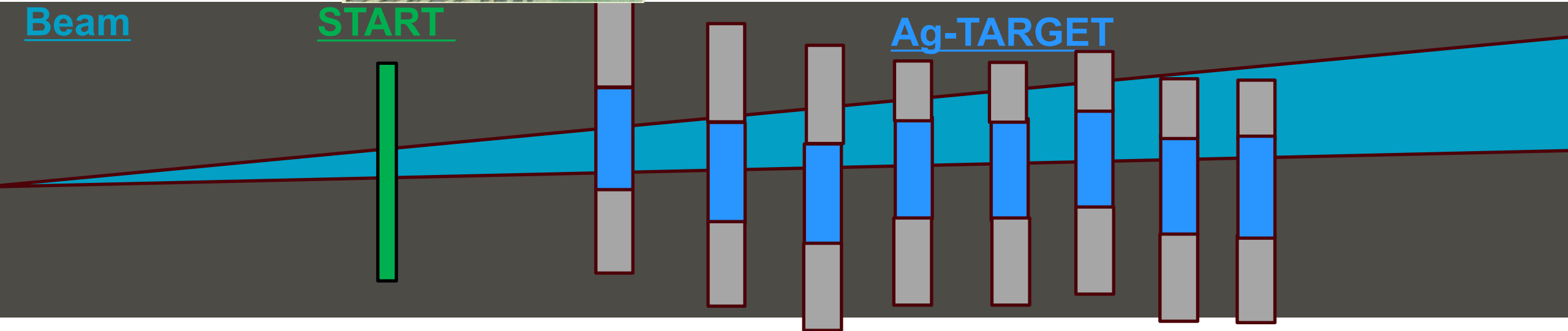
KEY IDEA



Correlate early segments with START hit position and extrapolate with machine learning

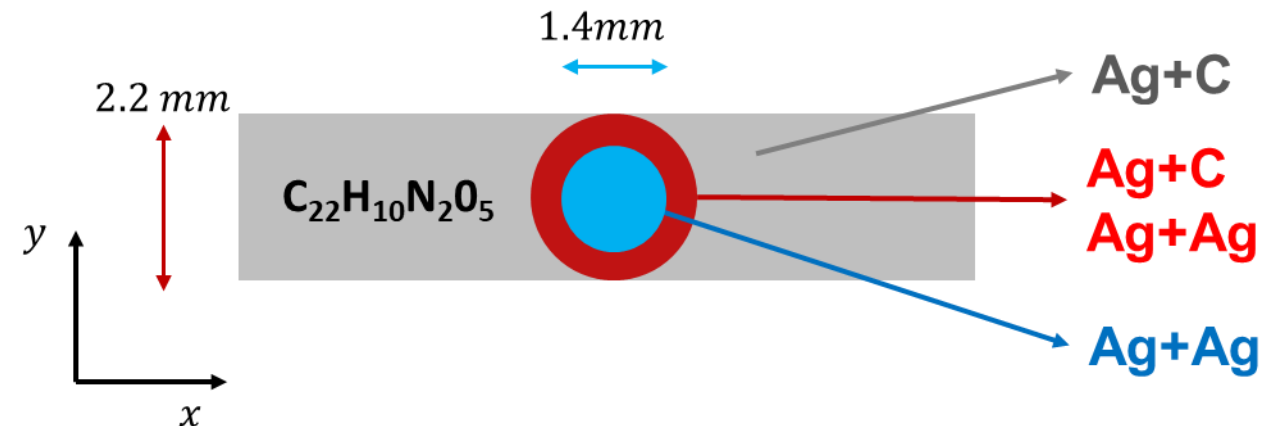


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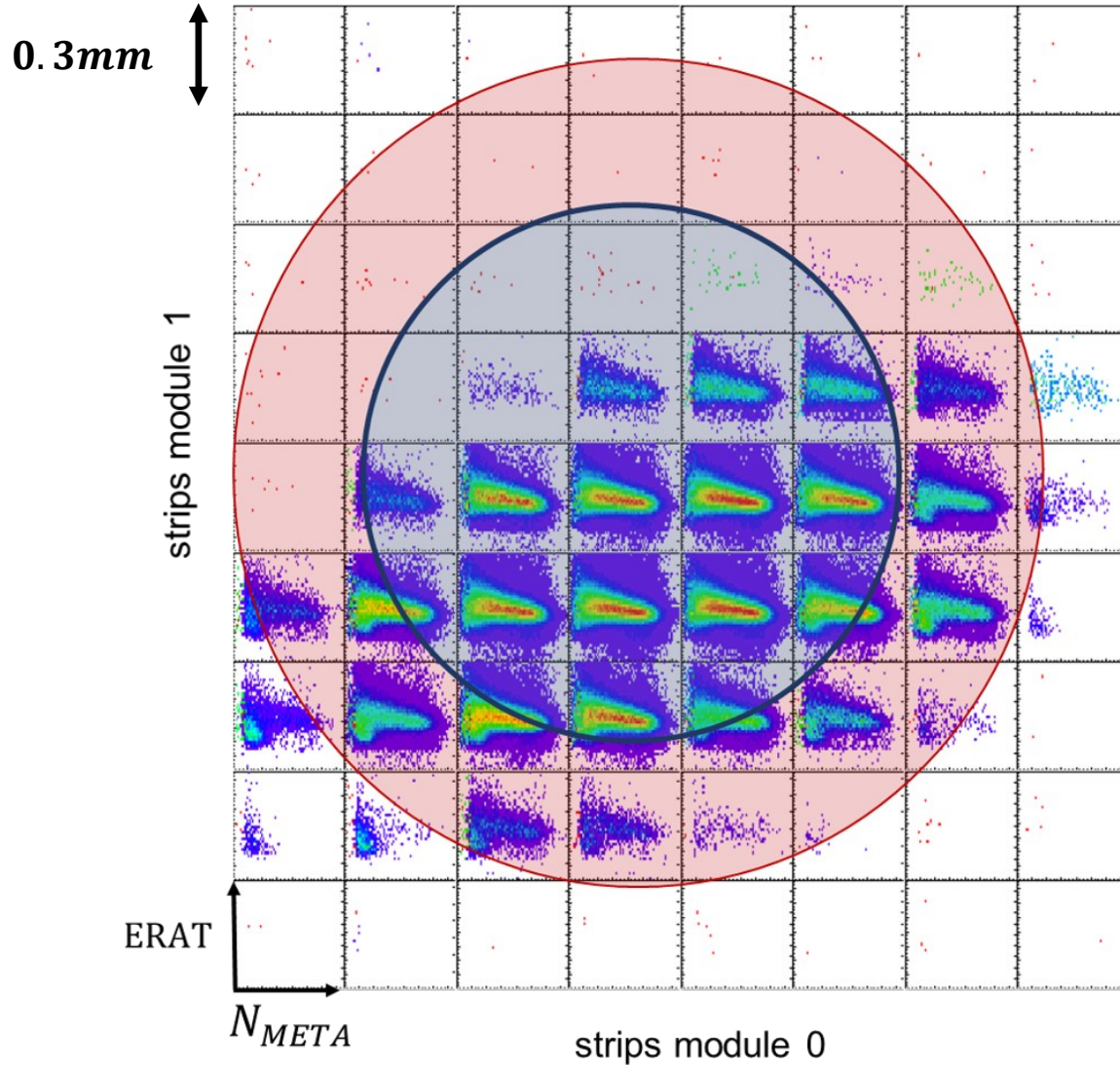
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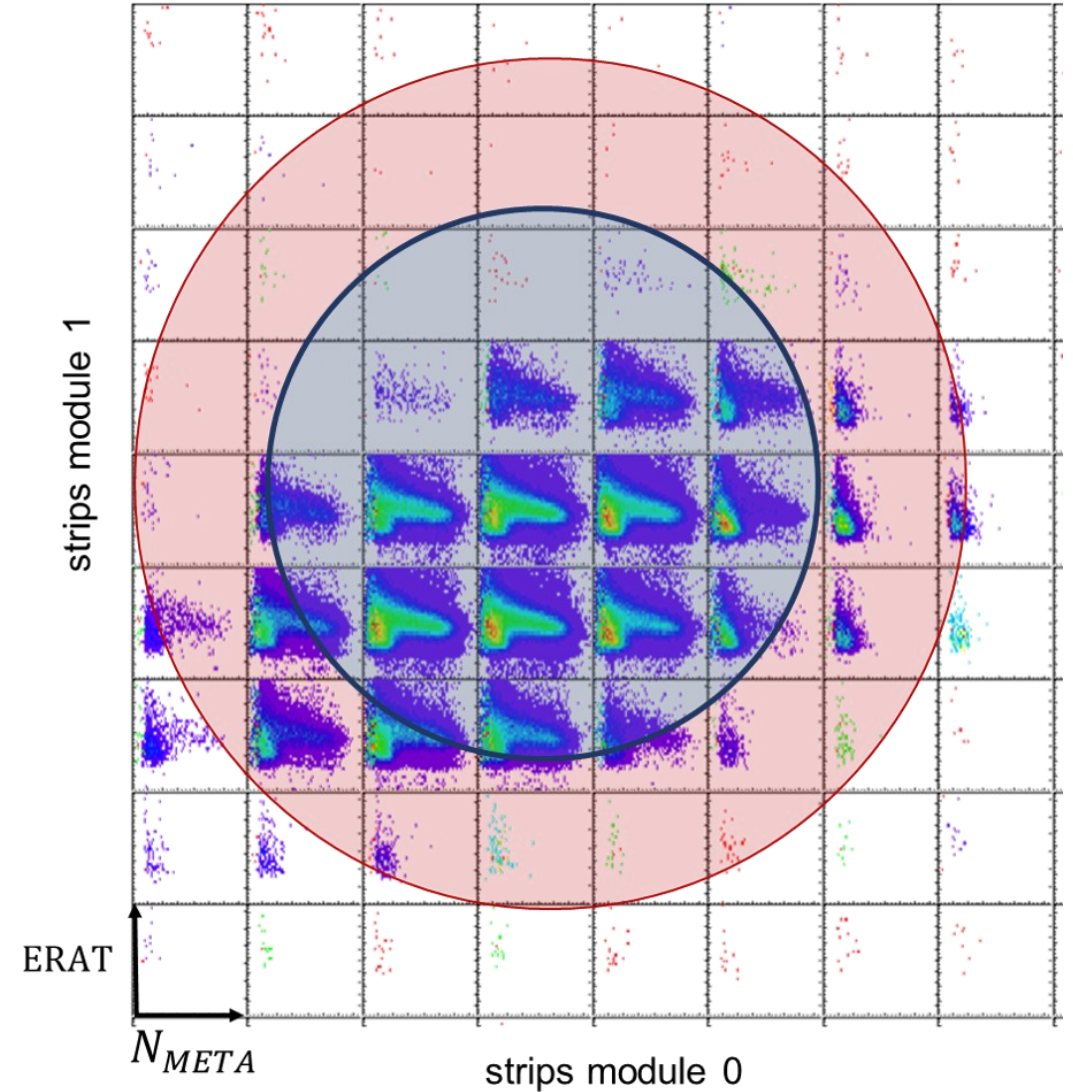


1. SELECTION OF TRAINING DATA

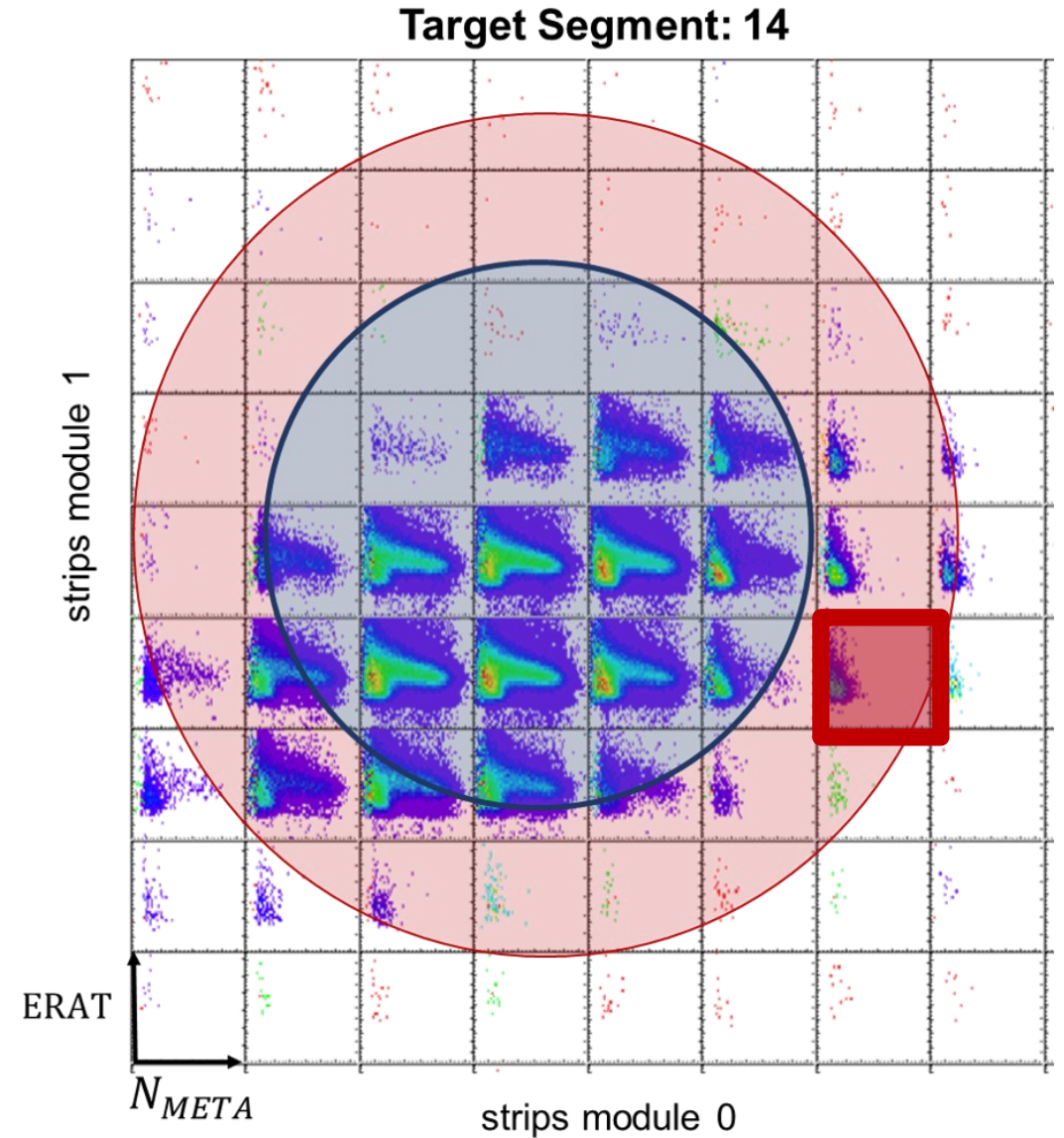
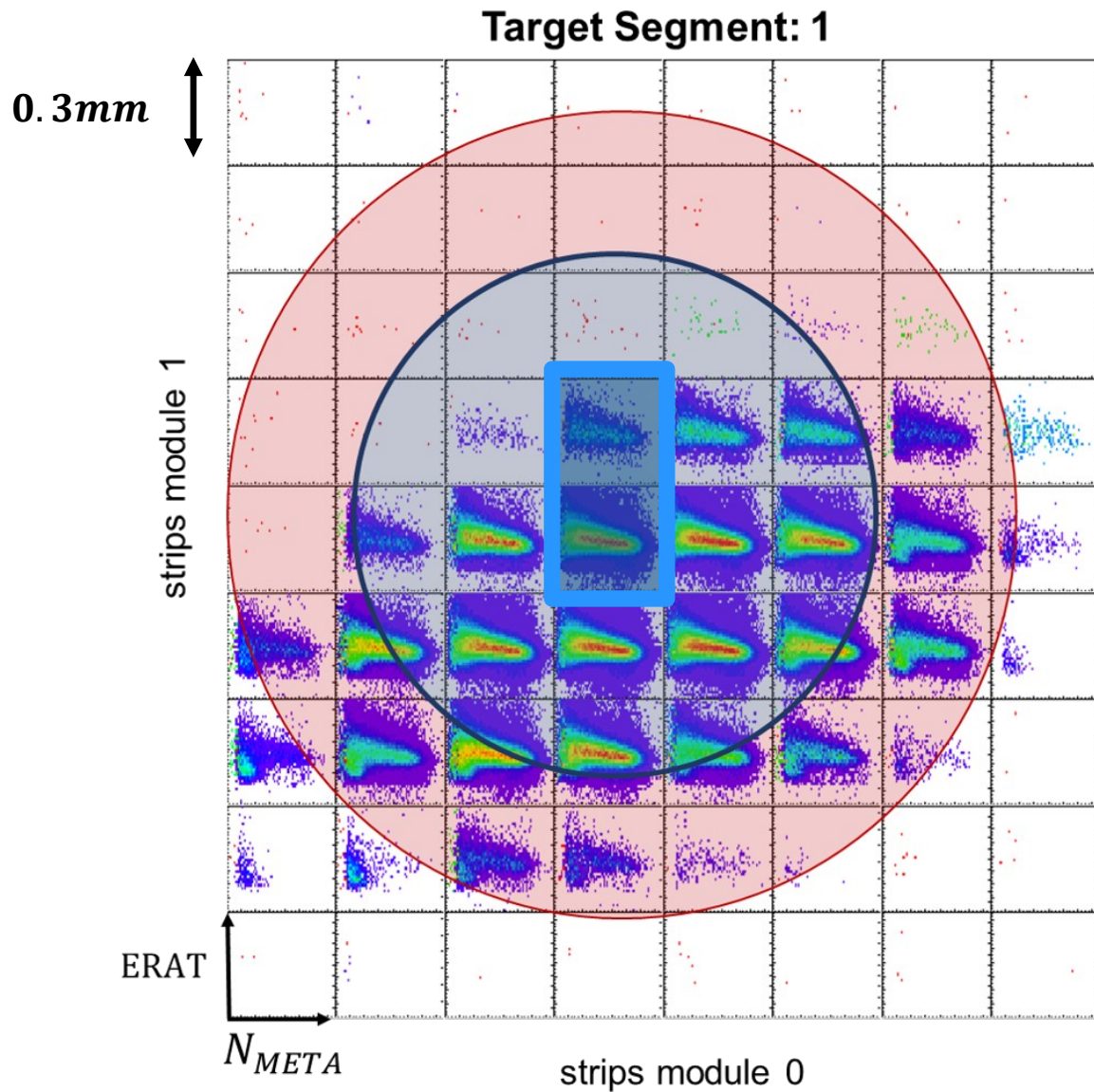
Target Segment: 1



Target Segment: 14




1. SELECTION OF TRAINING DATA



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- **Software version:** /cvmfs/hades.gsi.de/install/5.34.34/hydra2-5.6/defall.sh
 - **Generation 5 of march 19:** /lustre/hades/dst/mar19/gen5/
 - **Days 088-089 in Ag123Ag**
 - **Days 078-080 in Ag158Ag**
- } Stable beam position on START 
- **Min. bias event selection:**
 - kGoodVertexClust
 - kGoodSTART

- **START – Target Matching:**
- **Additional cut for Ag+C:**

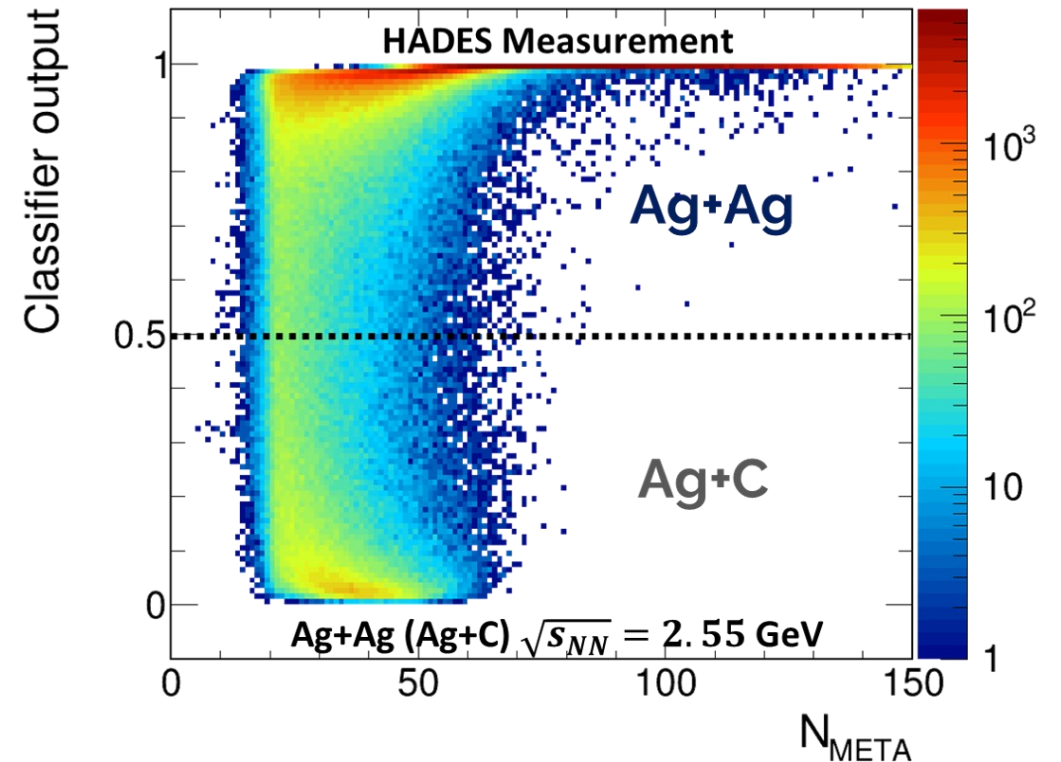
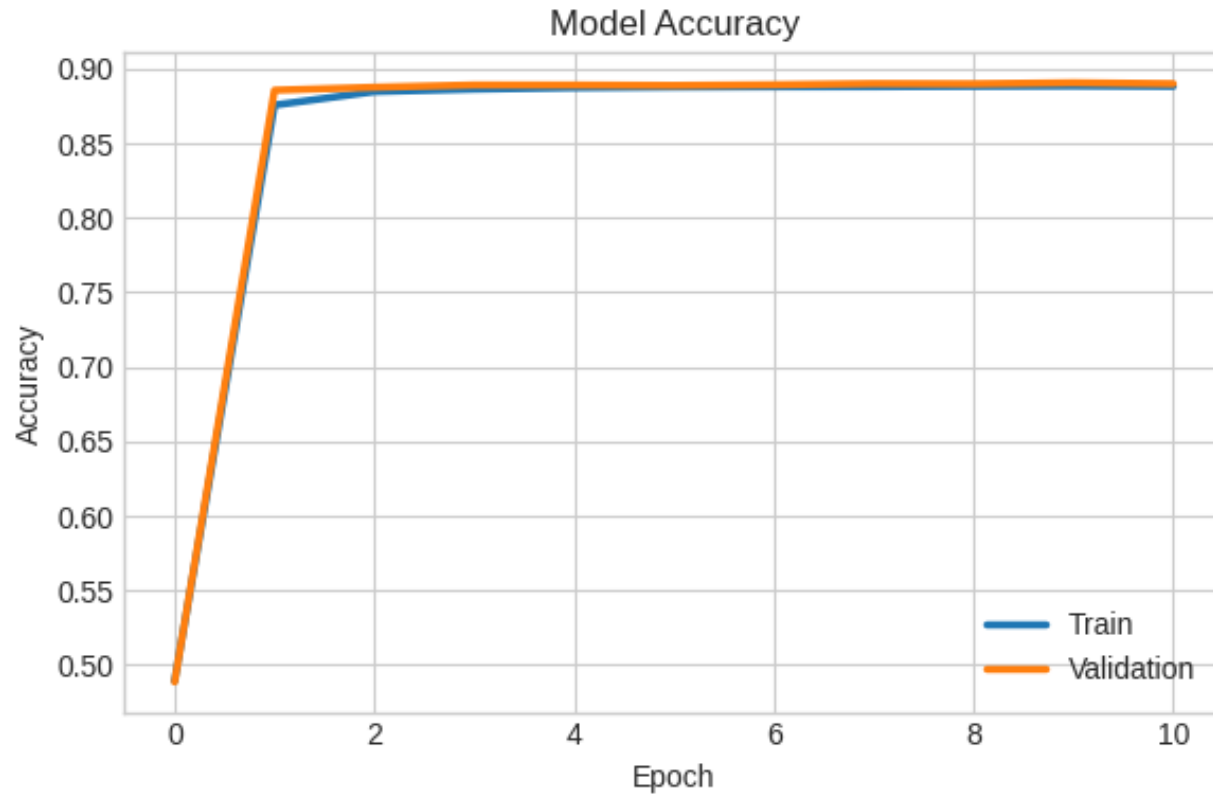
$$N_{META} < 60$$

Energy	System	Target Segment <i>t</i>	START hit (module 0, module 1)
1.23A GeV	Ag+C	1, 2, 11, 13, 14	(7, 4), (7, 3), (7, 2), (6, 1)
		3	(7, 3), (7, 2)
		4, 5, 7, 8, 9, 10, 12	(7, 4), (7, 3), (7, 2)
		6	(7, 2)
	Ag+Ag	0, 1	(3, 4), (3, 3)
1.58A GeV	Ag+C	2, 4, 6, 7, 8, 9, 10, 12	(0, 4), (1, 4), (7, 7), (7, 6), (6, 5)
		1, 3, 5, 11	(0, 4), (1, 4), (7, 7), (7, 6), (6, 5), (0, 5)
		13, 14	(0, 4), (1, 4), (7, 7), (7, 6), (6, 5), (6, 7), (6, 6), (5, 5)
	Ag+Ag	0, 1	(3, 8), (3, 7)

2. MODEL TRAINING



- Neural network successfully trained (~89% accuracy on training data)
- Model output between 0 and 1, with standard threshold at $p = 0.5$



3. MODEL EVALUATION - SIMULATION



- Full event simulation with transport models:
 - UrQMD
 - DCM-QGSM
 - Here: Even mix of 30 000 Ag+C and 30 000 Ag+Ag accepted events
- ➔ Simulations suggest slight favour towards pure Ag+Ag... but overall:

Successful separation between Ag+C and Ag+Ag

Accuracy
What overall proportion of predictions was correct?

Recall
What proportion of Ag+C was identified correctly?

Precision
What proportion of predicted Ag+C was really Ag+C?

Centrality	Model	Accuracy (%)	Recall (%)	Precision (%)
30–40%	UrQMD	90.6	95.1	83.5
	DCM-QGSM	89.3	96.9	81.8
40–50%	UrQMD	87.2	96.1	85.5
	DCM-QGSM	82.7	97.4	80.3

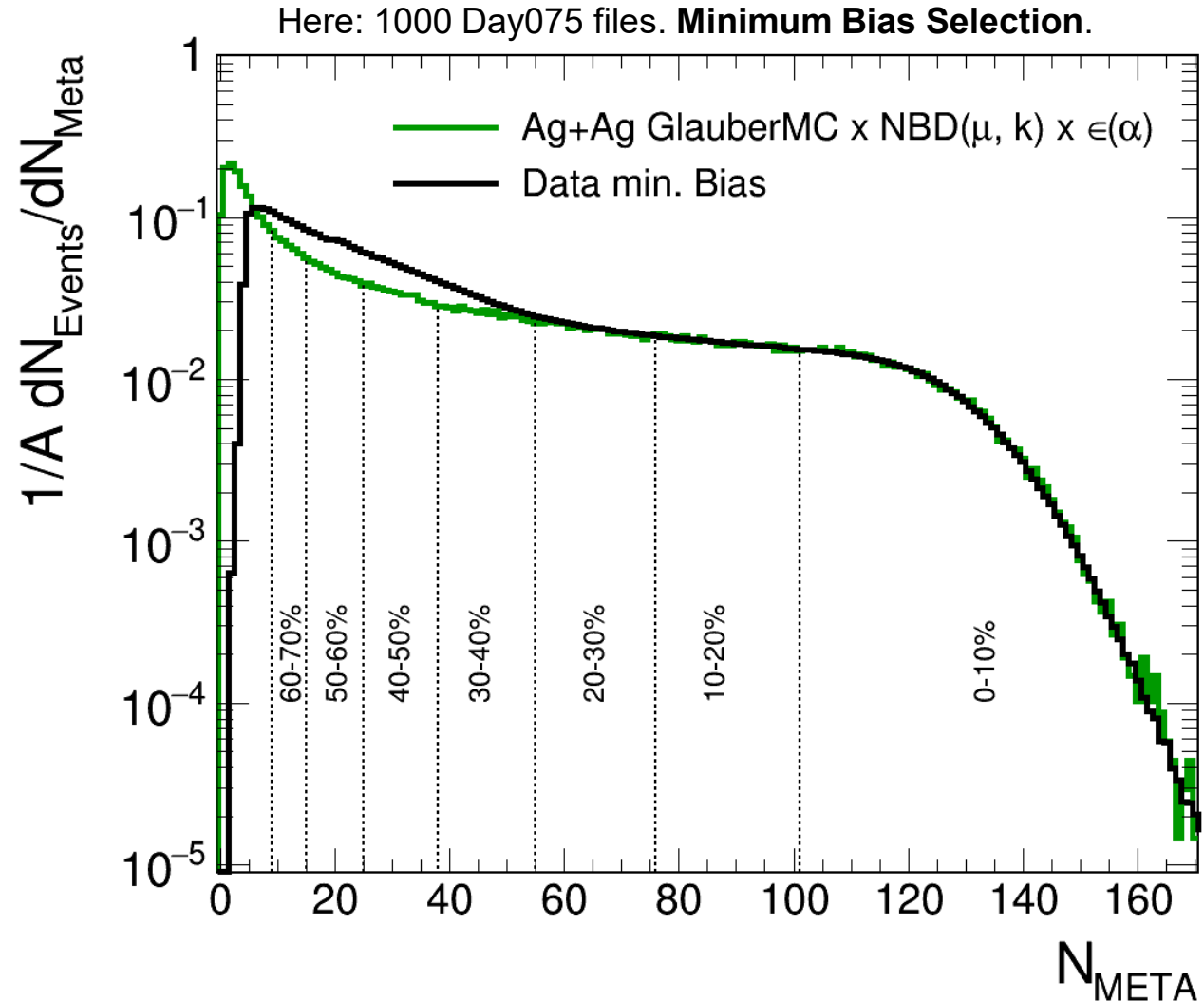
3. MODEL EVALUATION - SIMULATION



- Compare minimum bias TOF+RPC distribution with Glauber Model*

μ	k	α
0.81	41.9	4.1 E-6

$$A = \int_{70}^{160} \frac{dN}{dN_{Meta}} dN_{Meta}$$



3. MODEL EVALUATION - SIMULATION



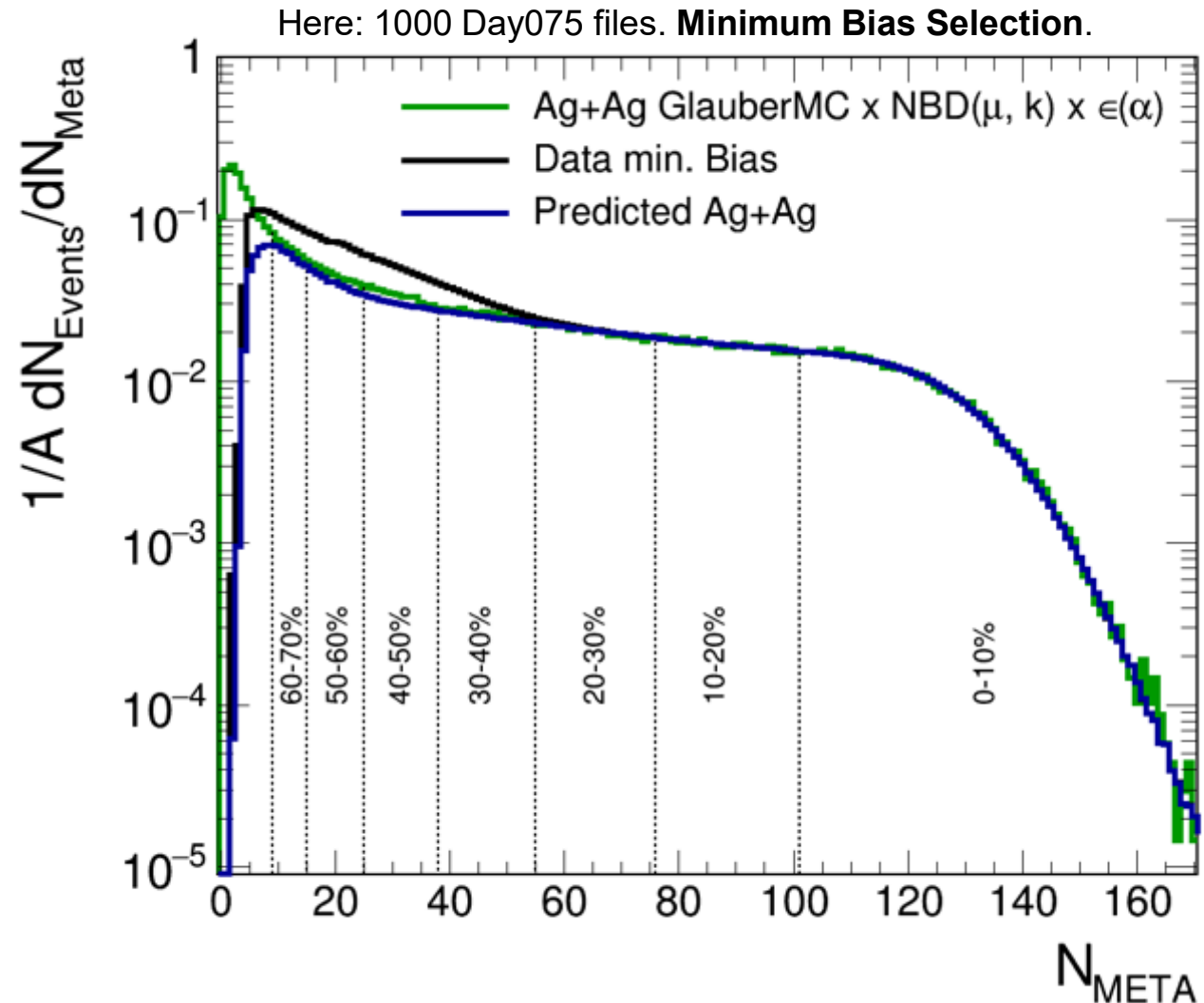
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Predicted Ag+Ag align significantly better with GlauberMC



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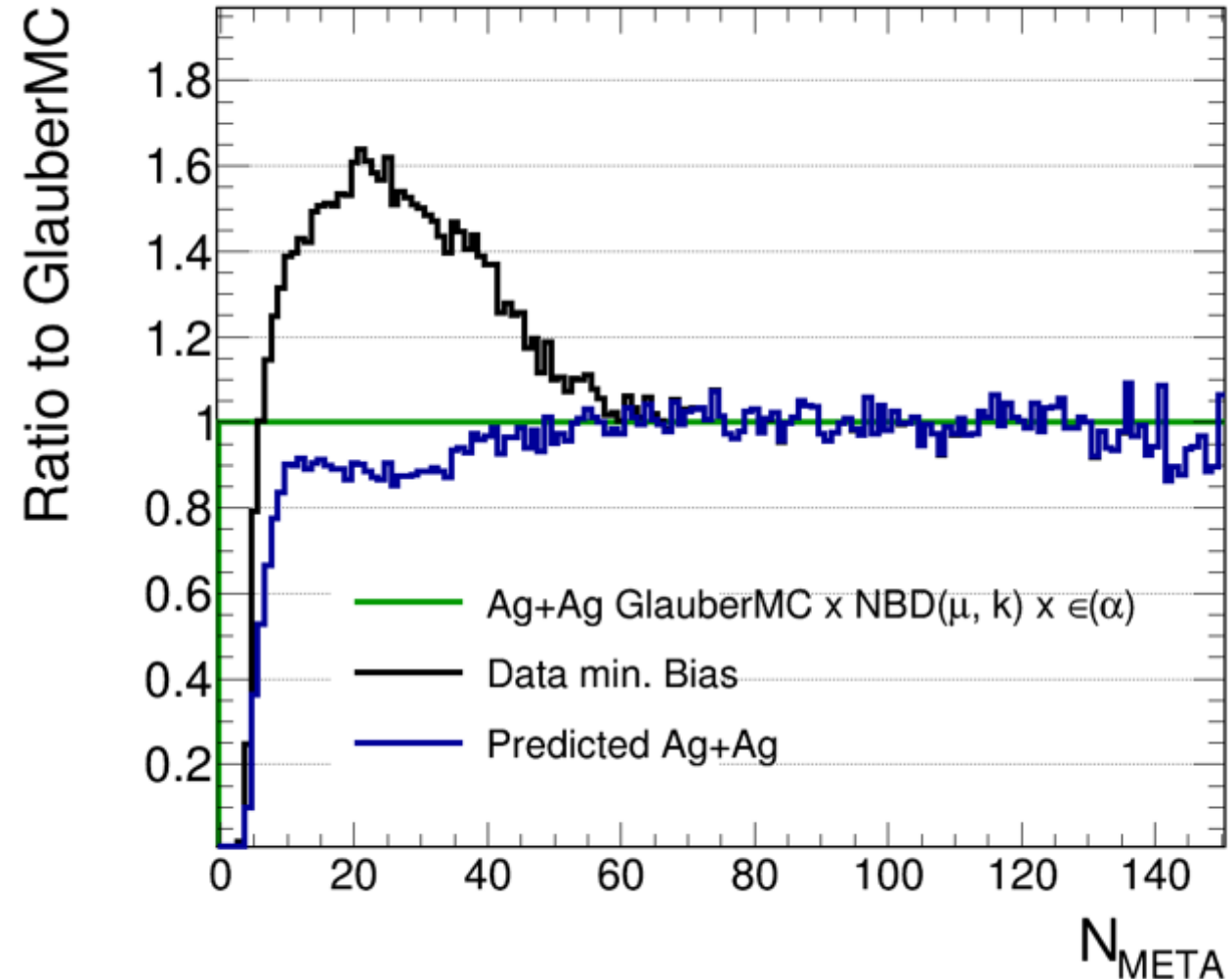


Predicted Ag+Ag align significantly better with GlauberMC



Model appears to show similar tendency to favour Ag+Ag purity

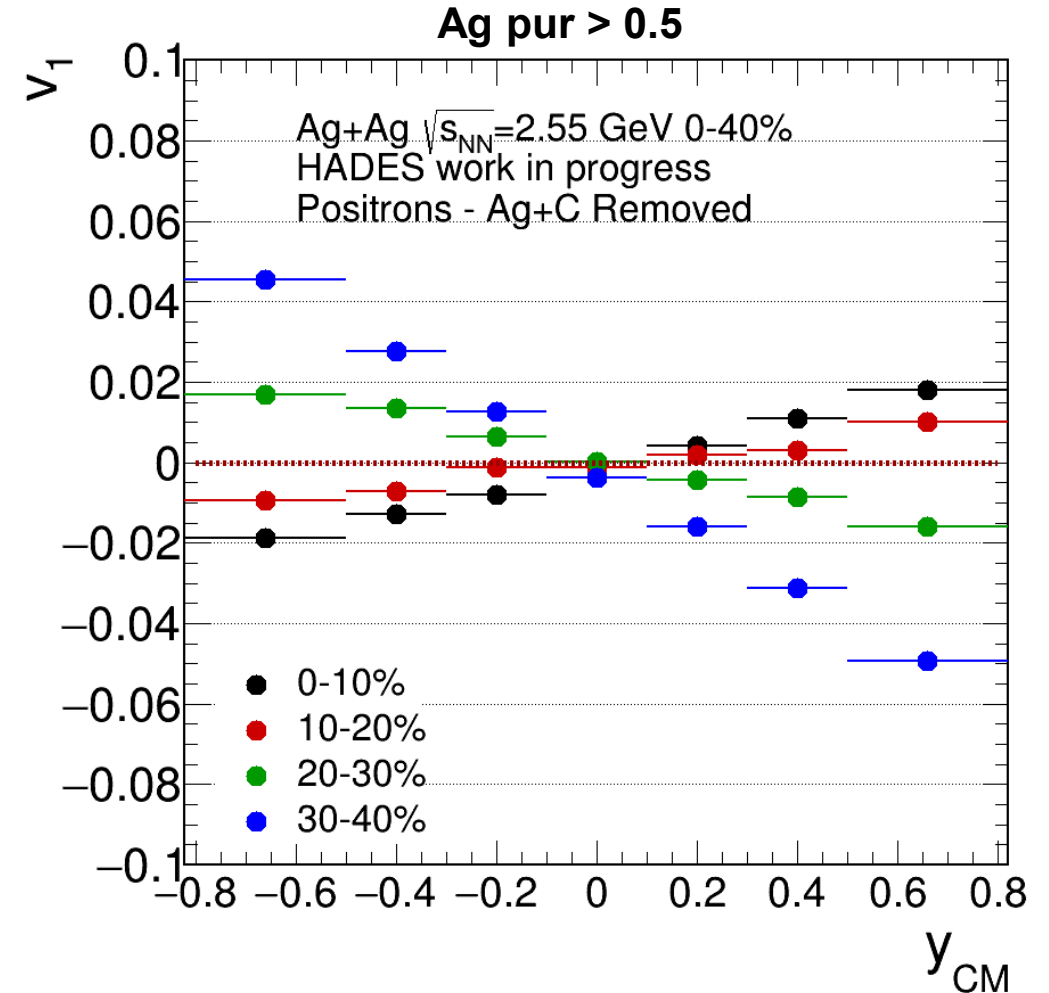
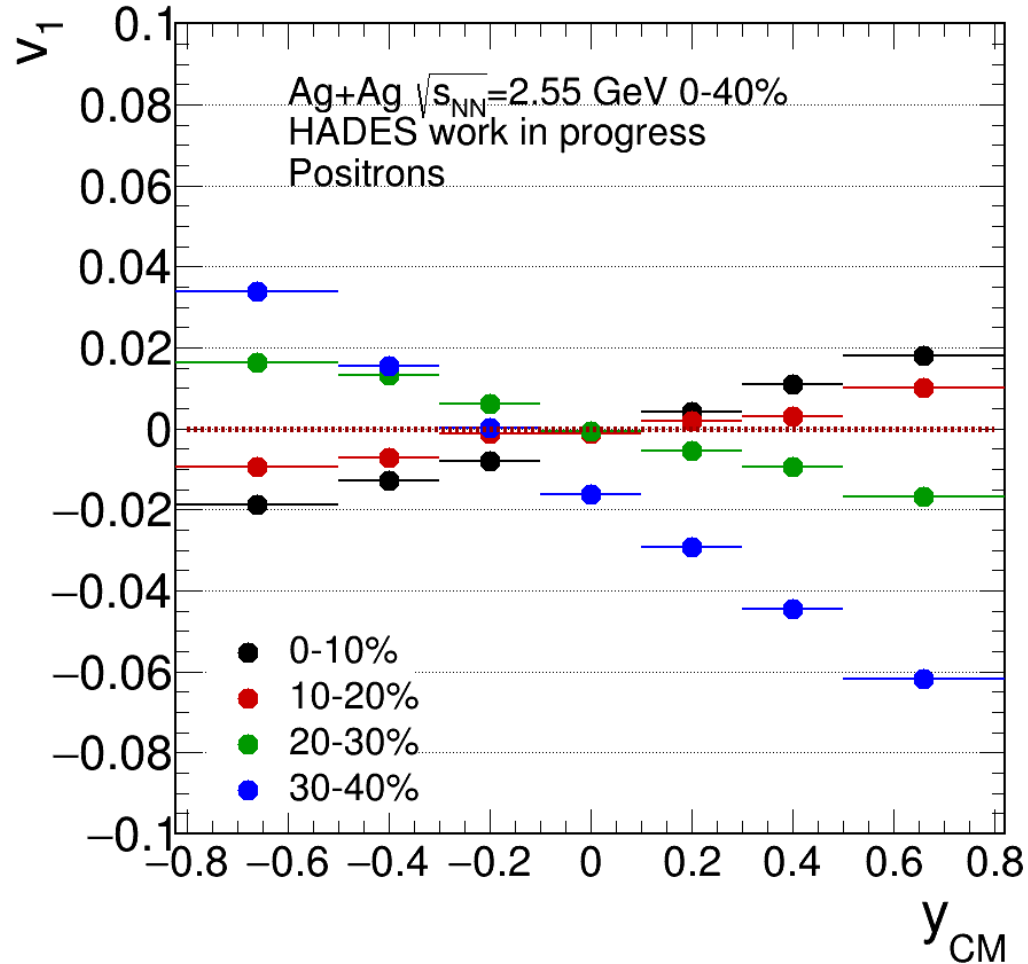
Here: 1000 Day075 files. **Minimum Bias Selection.**



3. MODEL EVALUATION - DATA



Positrons

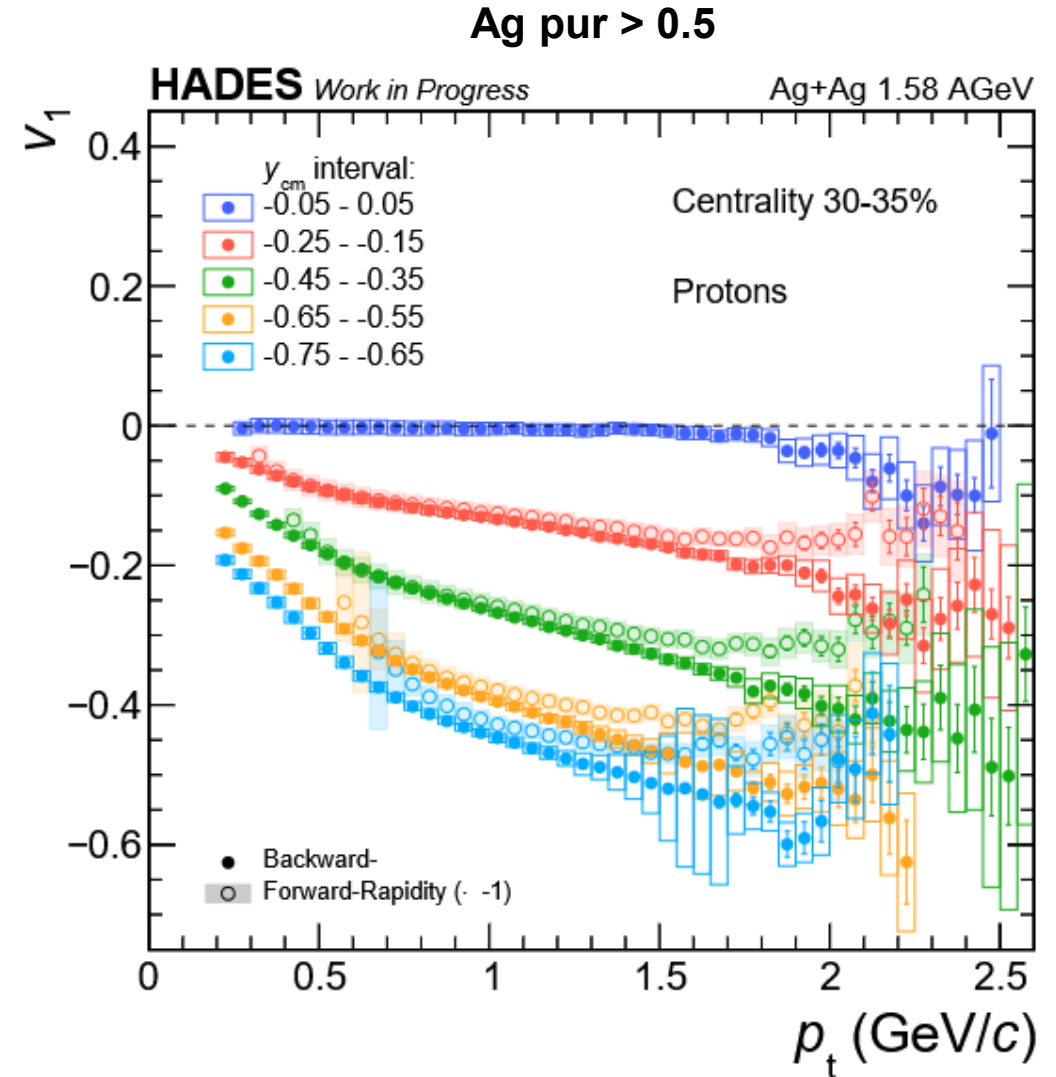
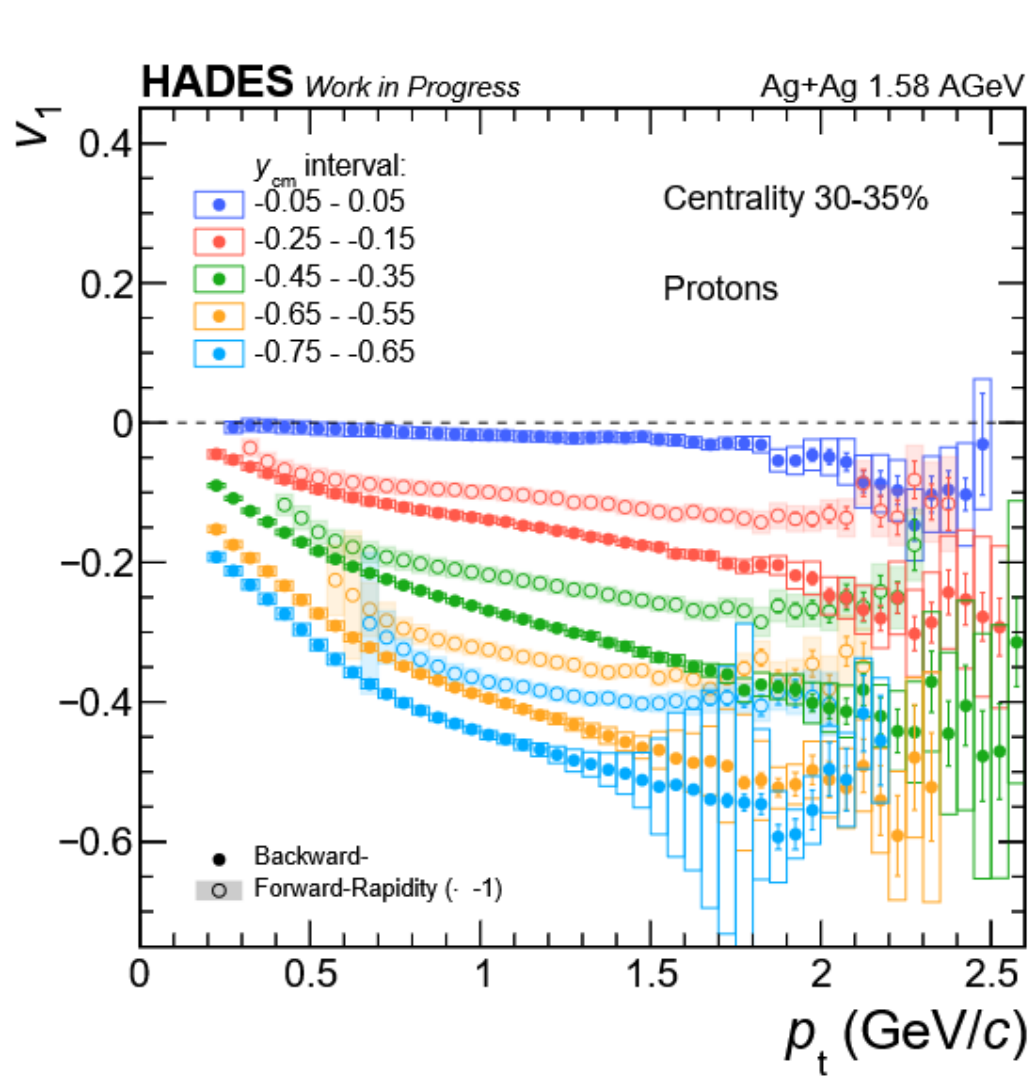


3. MODEL EVALUATION - DATA

p

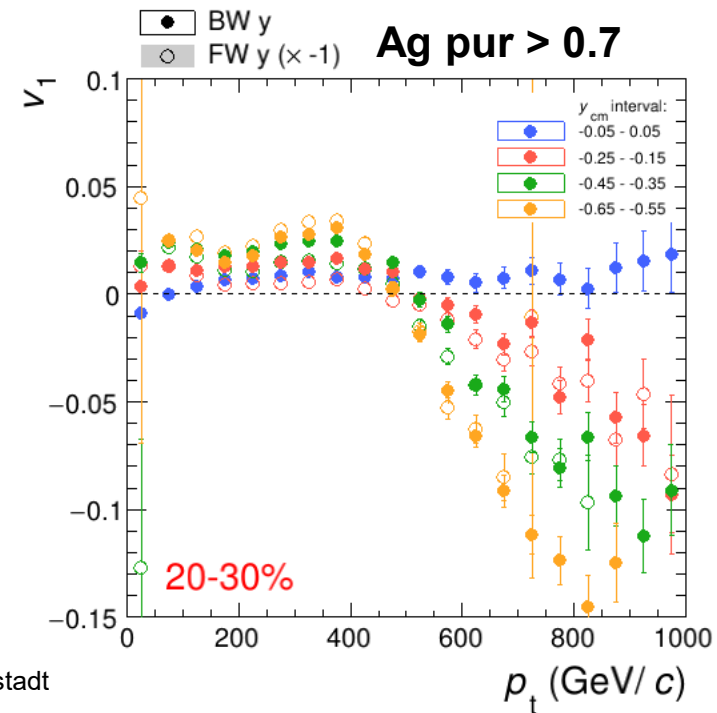
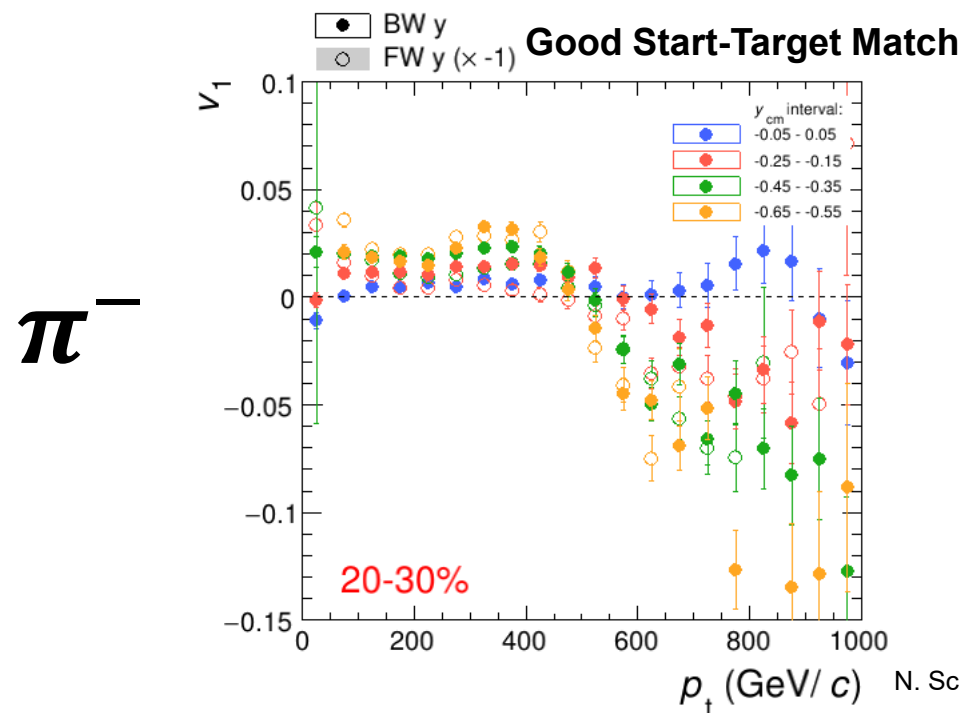
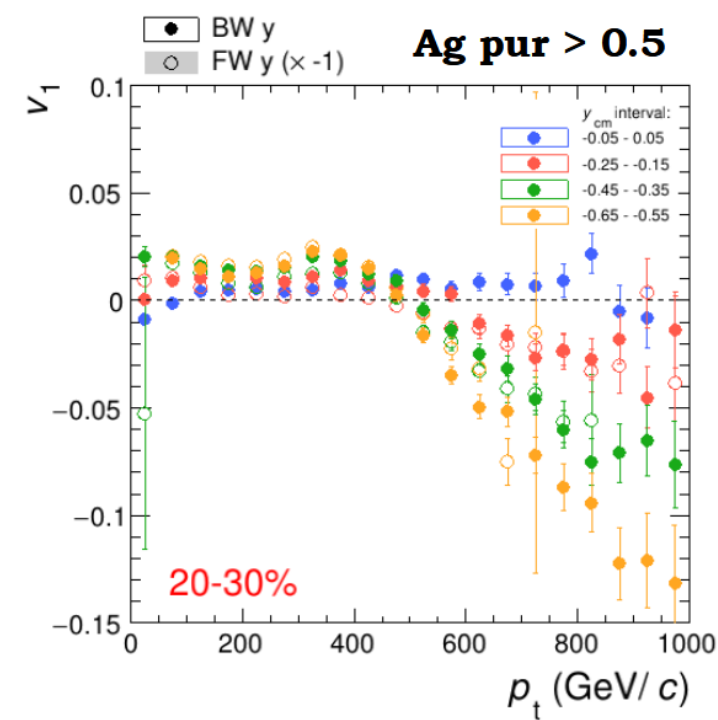
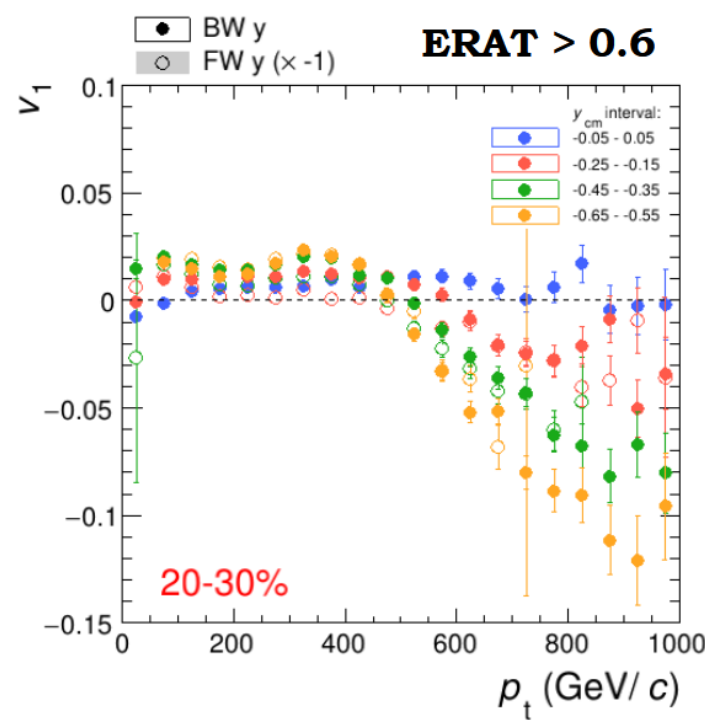
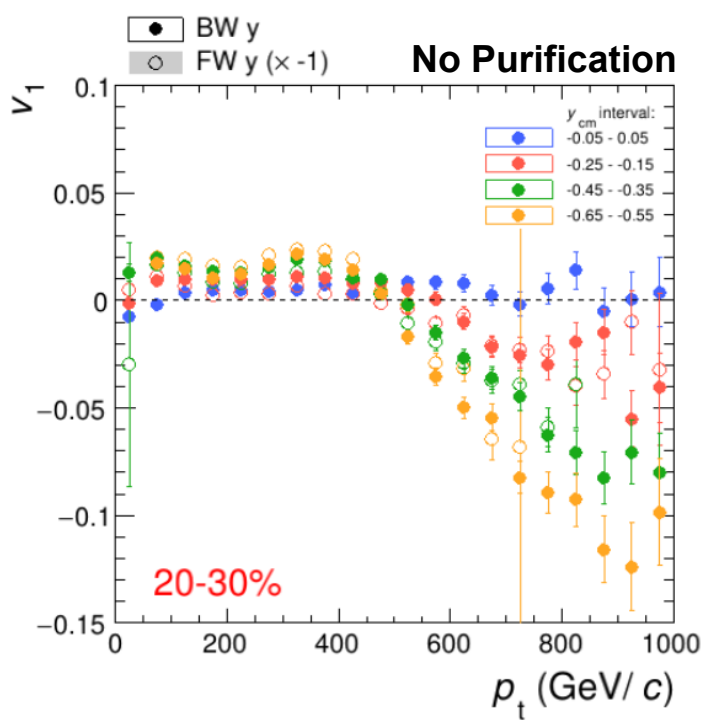


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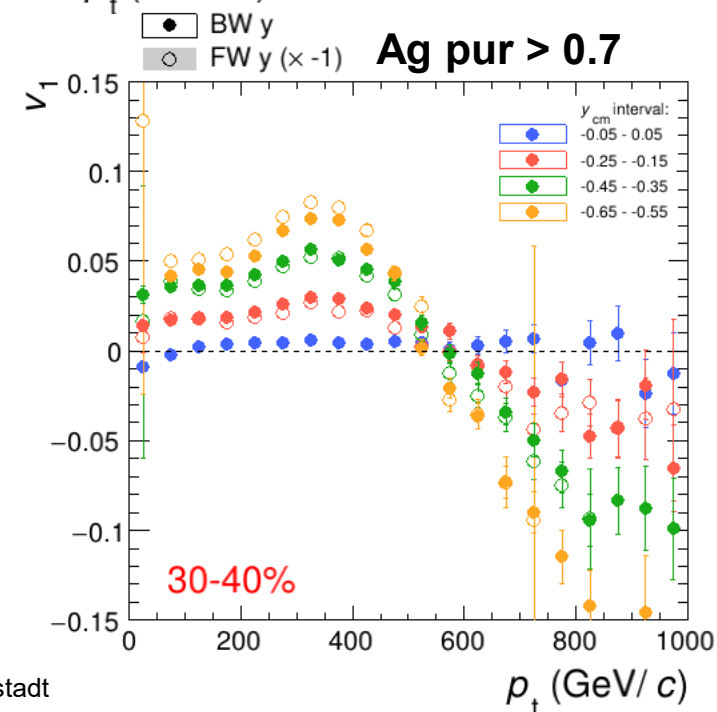
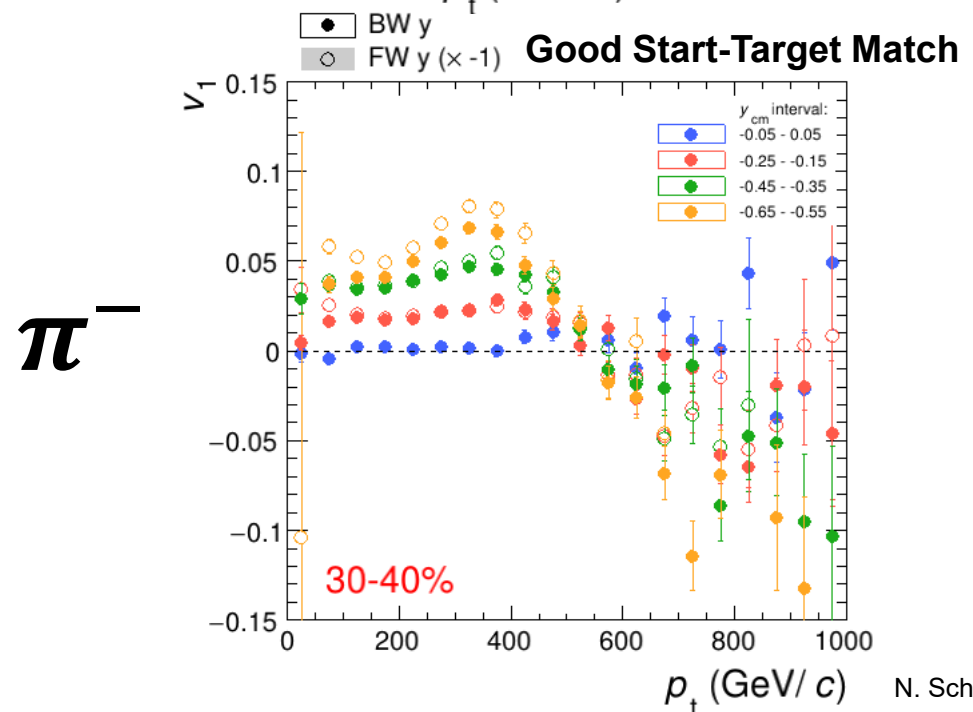
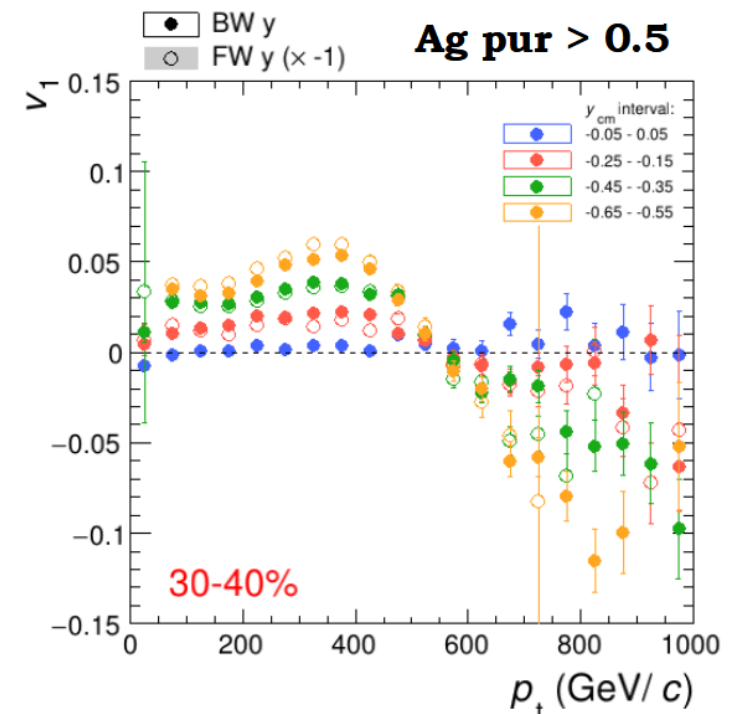
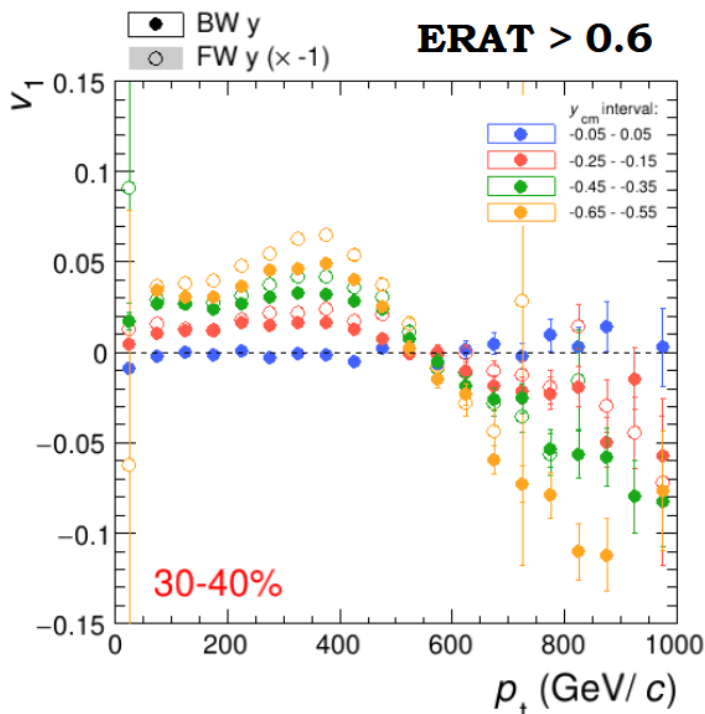
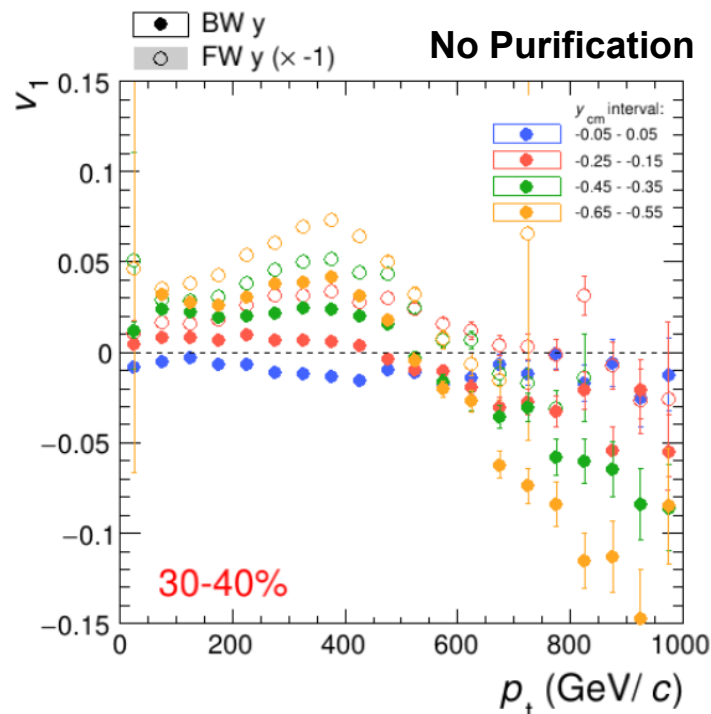


Ag pur > 0.5

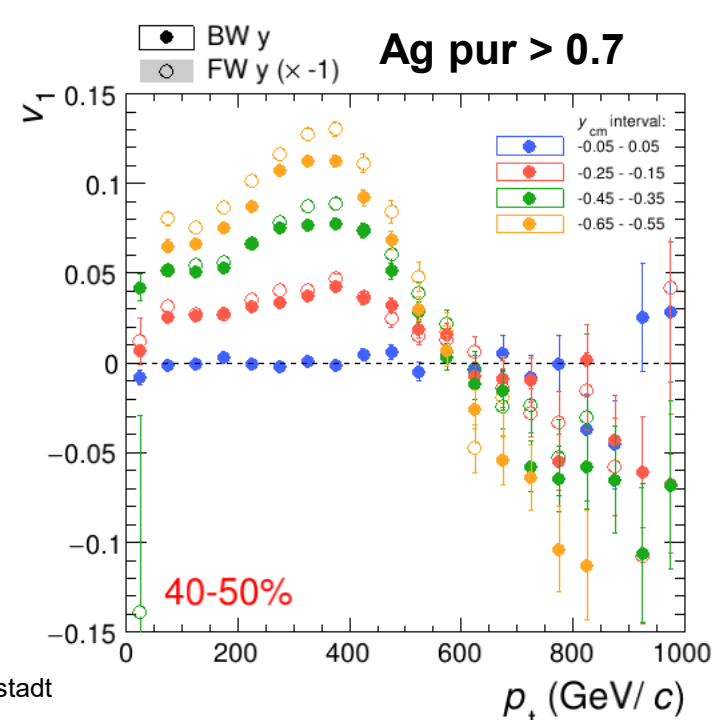
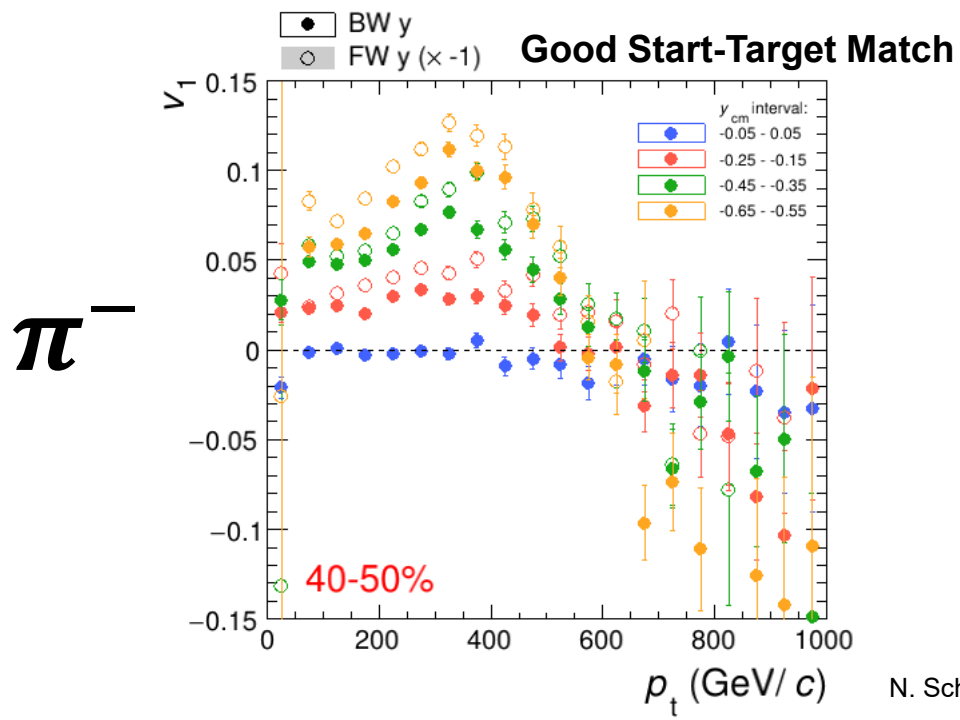
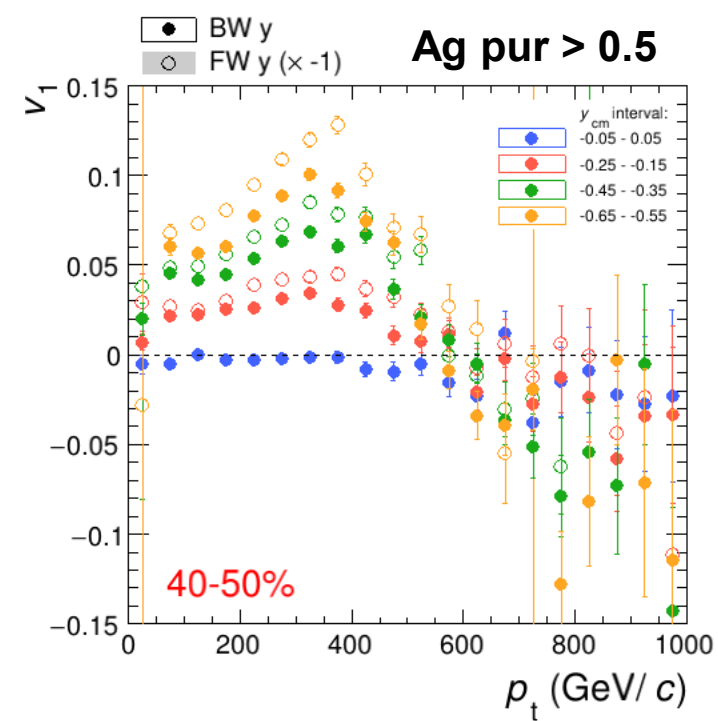
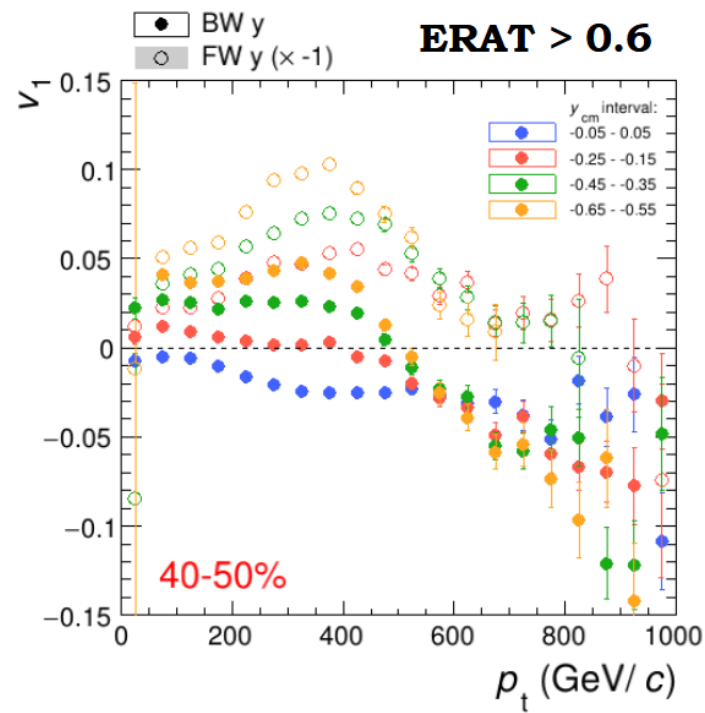
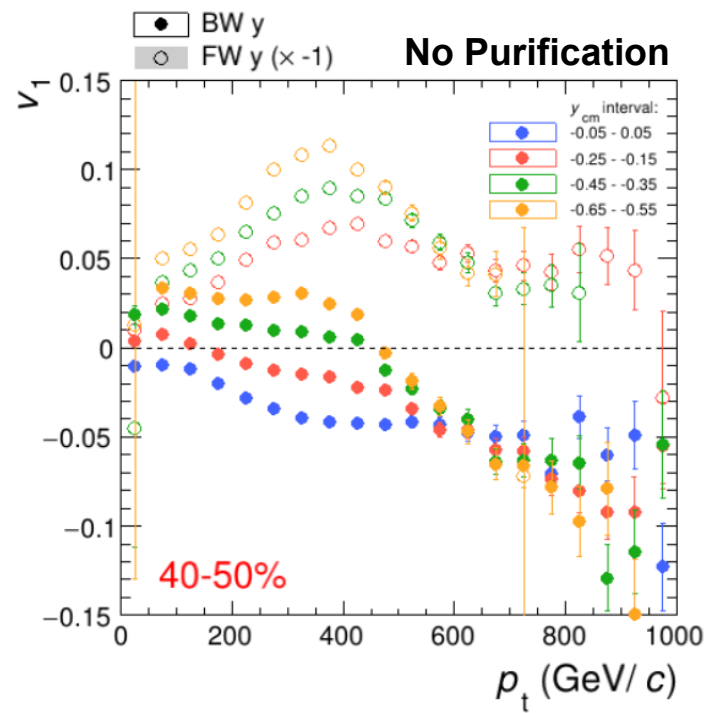
3. MODEL EVALUATION - DATA



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CONCLUSION



Model brings significant improvement in semi-central centralities

- While not perfect, it can allow extension of analyses to at least 40% centrality
 - ➔ Employ in dilepton analysis to maximize statistics
 - ➔ Estimate on systematics can be made by varying decision threshold p

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HOW TO USE

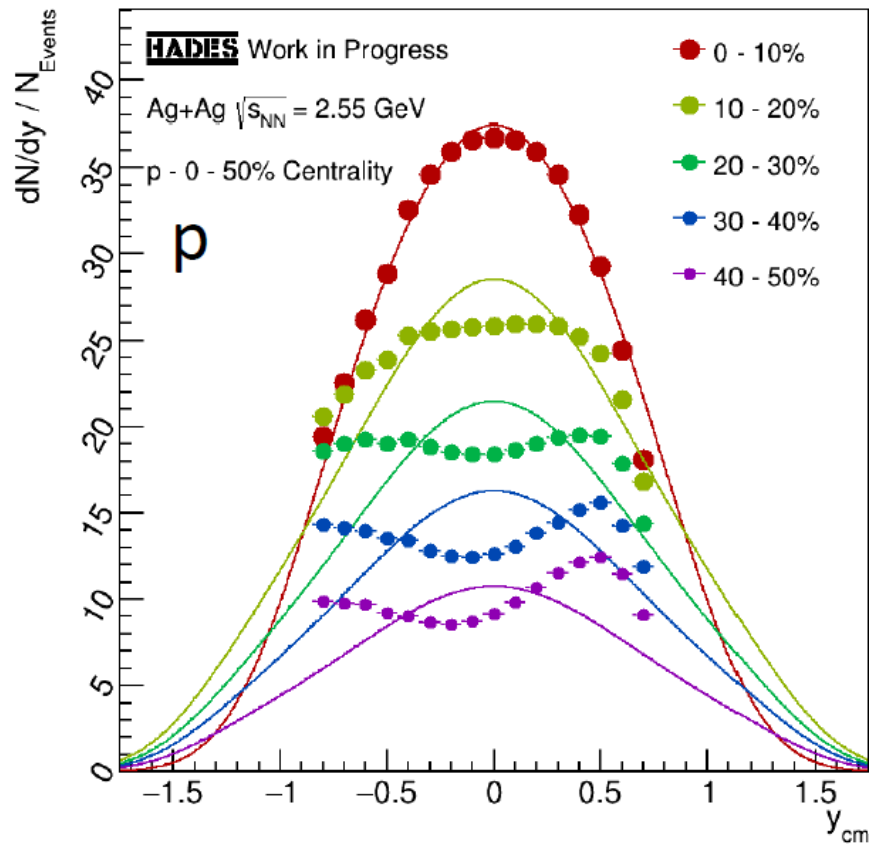
- Code and analysis details are in dedicated analysis note
- **Test it yourself:** </u/nschild/Niklas/Publication/CarbonRemoval/MacroPort/>

Model predictions exist for all
mar19 accepted files

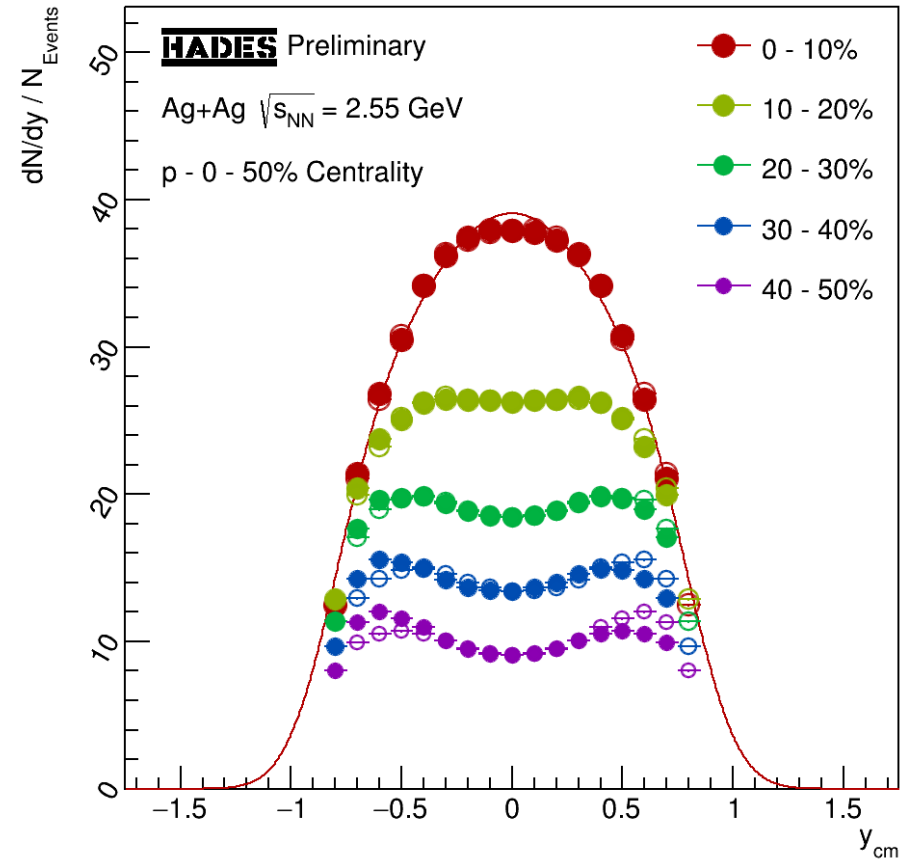
You can also manually select
START-Target correlations to
get small „pure“ sample

BACKUP

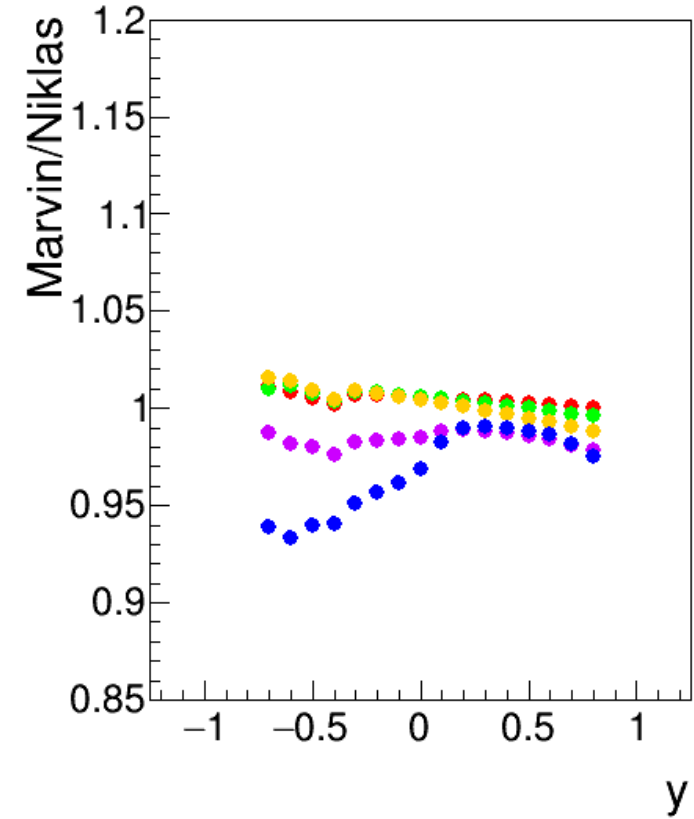
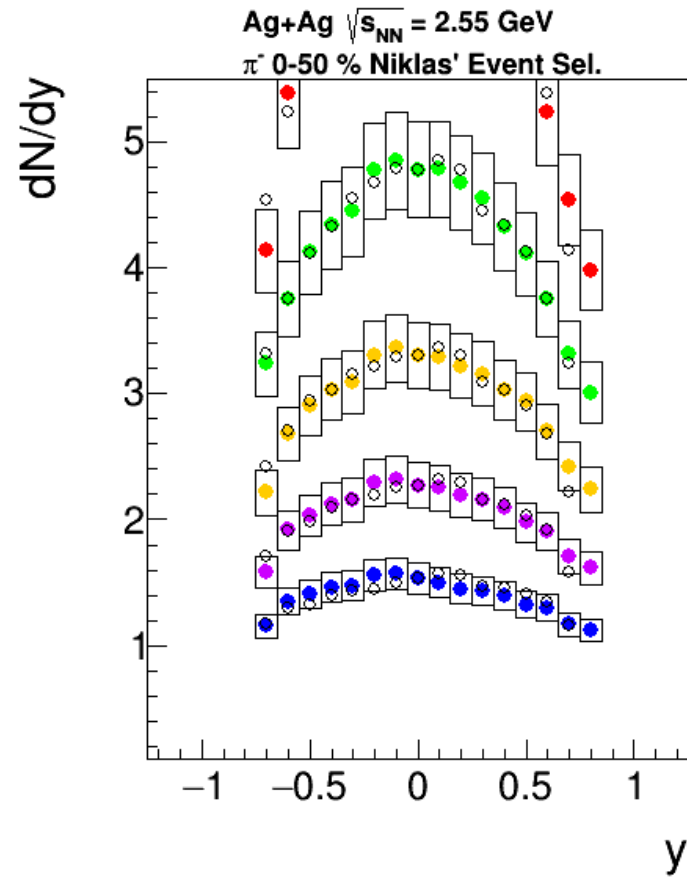
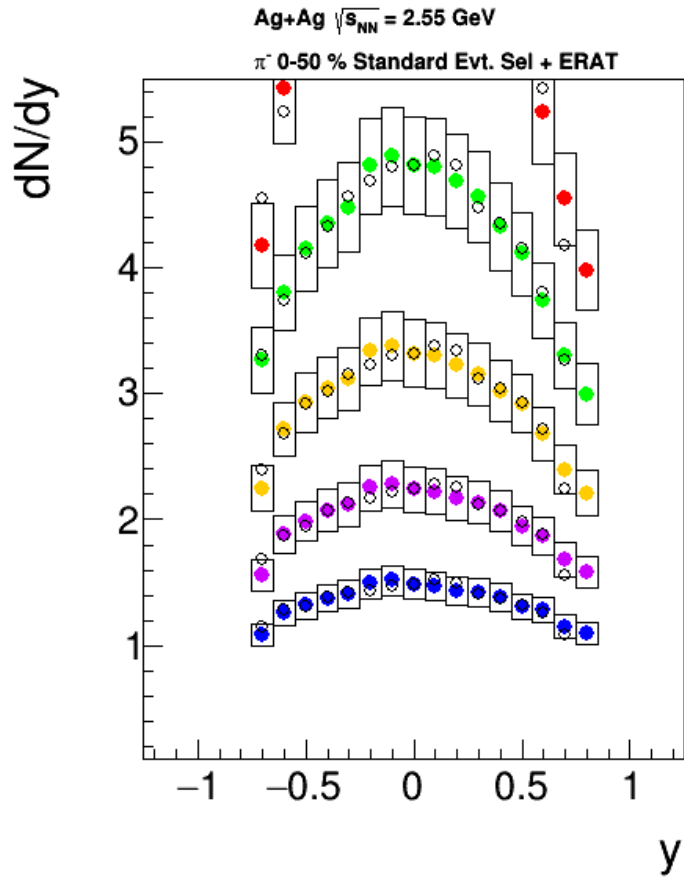
MODEL EVALUATION - DATA



Ag pur > 0.5



MODEL EVALUATION - DATA

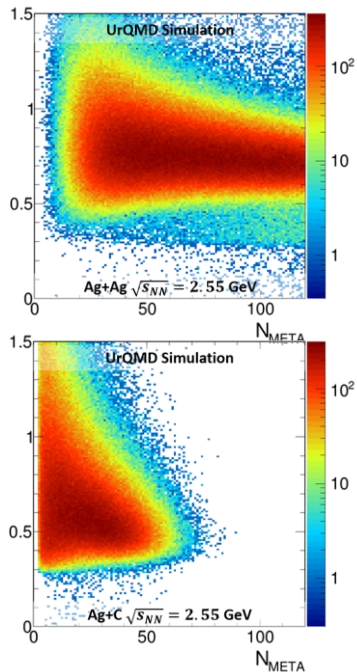


1. SELECTION OF TRAINING DATA



Energy	Ag+C		Ag+Ag	
	Accepted	Rejected	Accepted	Rejected
1.23A GeV	148 424	46 115	450 000	105 000
1.58A GeV	293 302	206 530	700 000	378 299

- Balanced selection between **Ag+C vs Ag+Ag** as well as **accepted vs rejected** events



Need some more Ag+Ag events due to different multiplicity distribution

Model main focus on accepted events

But include some rejected events for more general applicability

2. MODEL ARCHITECTURE



Input Features

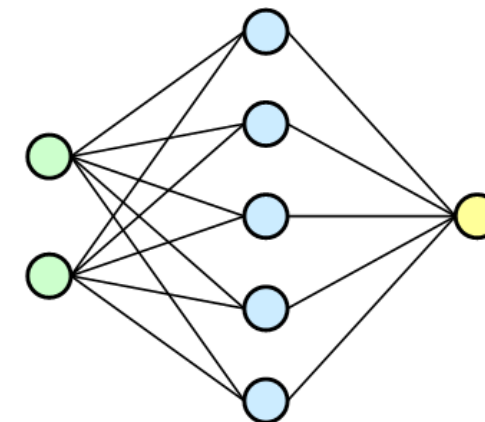
- N_{TOF} : Number of hits in the TOF detector.
- N_{RPC} : Number of hits in the RPC detector.
- N_{Tracks} : Number of reconstructed tracks after the standard track selection.
- **Average Particle Rapidity**: Mean rapidity of all reconstructed particles within the event.
- **Average Transverse Momentum**: Mean transverse momentum of all reconstructed particles.
- **Average Rapidity**: Event-wise average rapidity of all detected particles.
- **Total Mass**: Sum of the reconstructed particle masses.
- **ERAT**: Ratio of total transverse to longitudinal energy, as defined in equation 1.
- **Sector Correction ID**: Integer identifier encoding the number of active sectors contributing to the event.
- **IsRejected**: Boolean flag indicating whether the event failed any of the standard event selection criteria.



Fully-connected feed-forward neural network

- 3 Hidden layers: 148, 148, 138 neurons
- Activation function: $\tanh()$
- Optimiser: Adam
- Loss function: Categorical cross-entropy

- Model training and predictions made in Python (version 3.6.1) with Keras library
→ output saved in ROOT TTree



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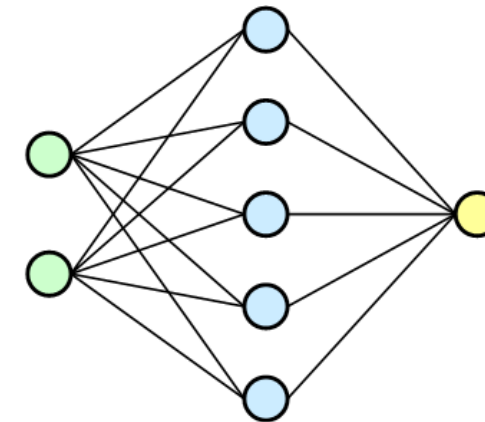
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Essential as they may impact the other event characteristics



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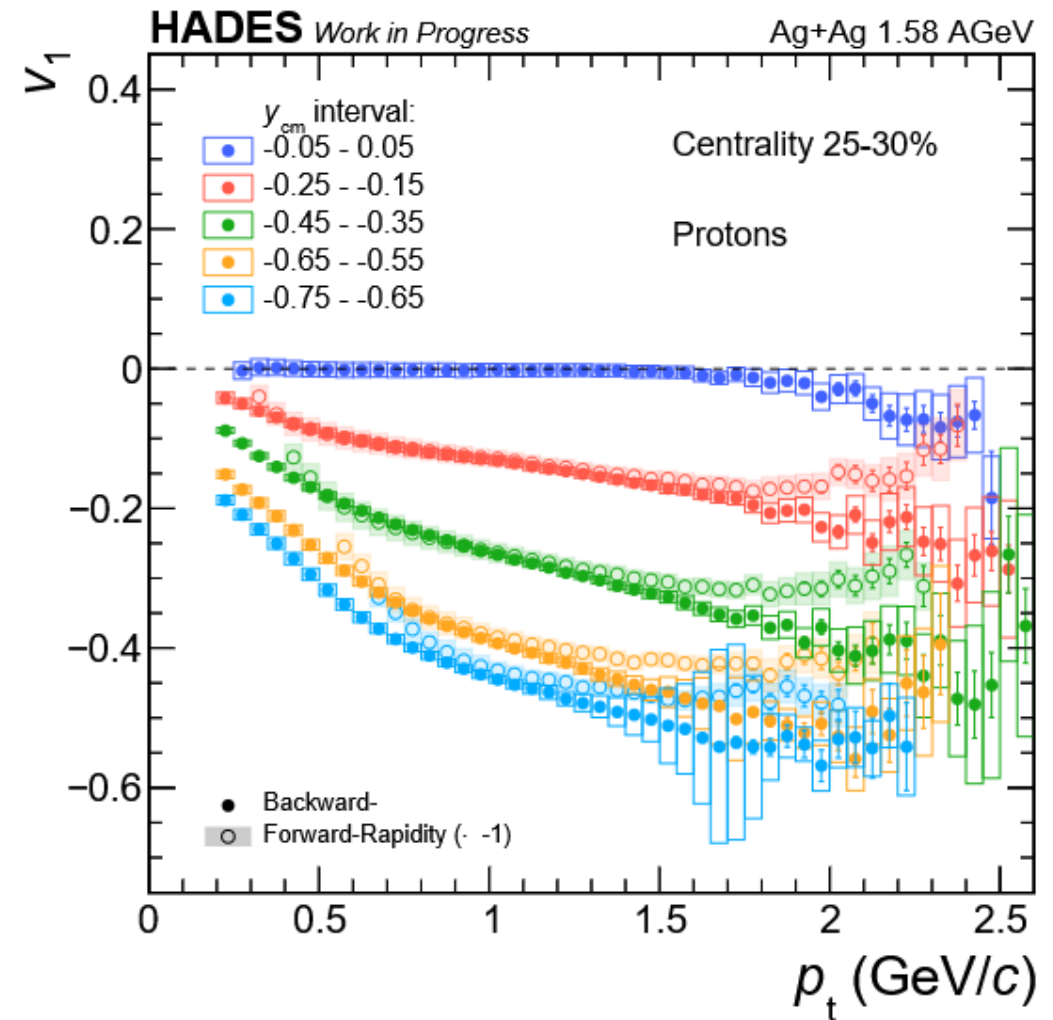
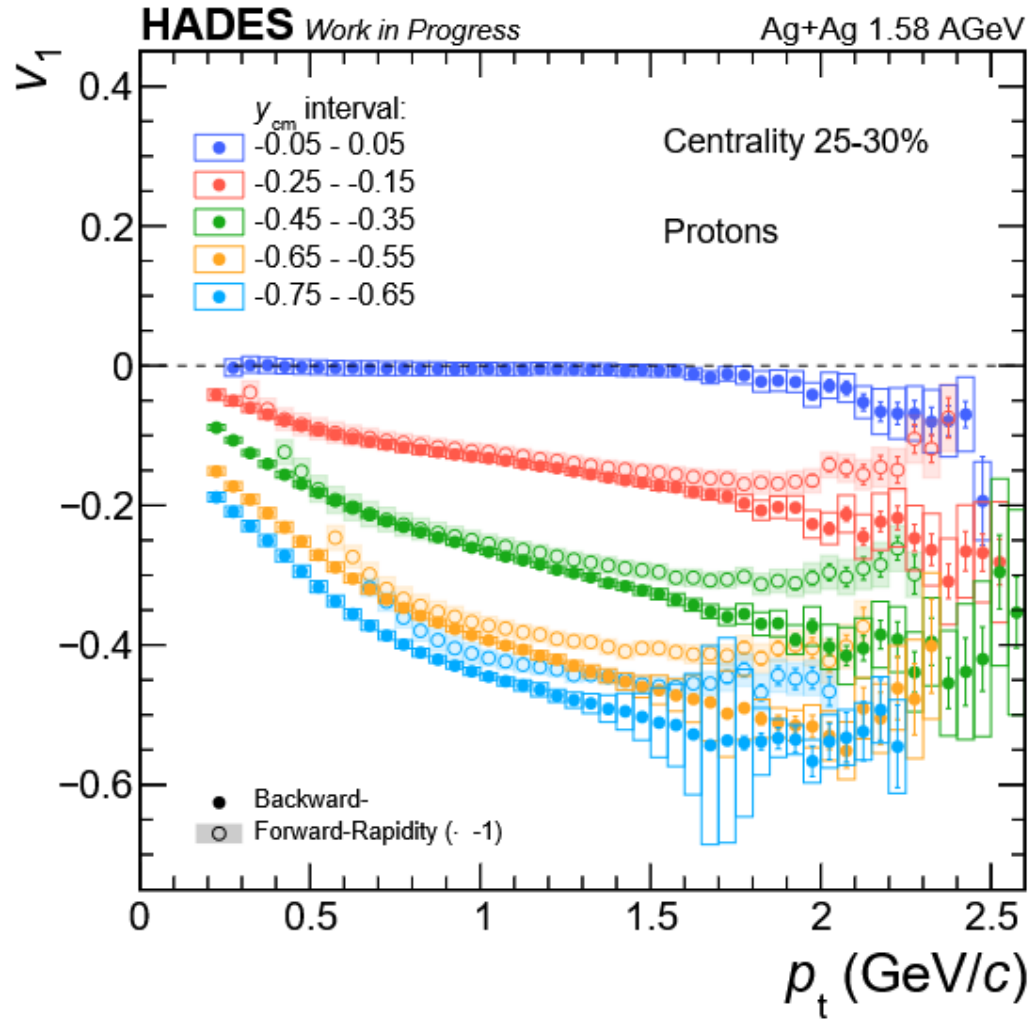
3. MODEL EVALUATION - DATA

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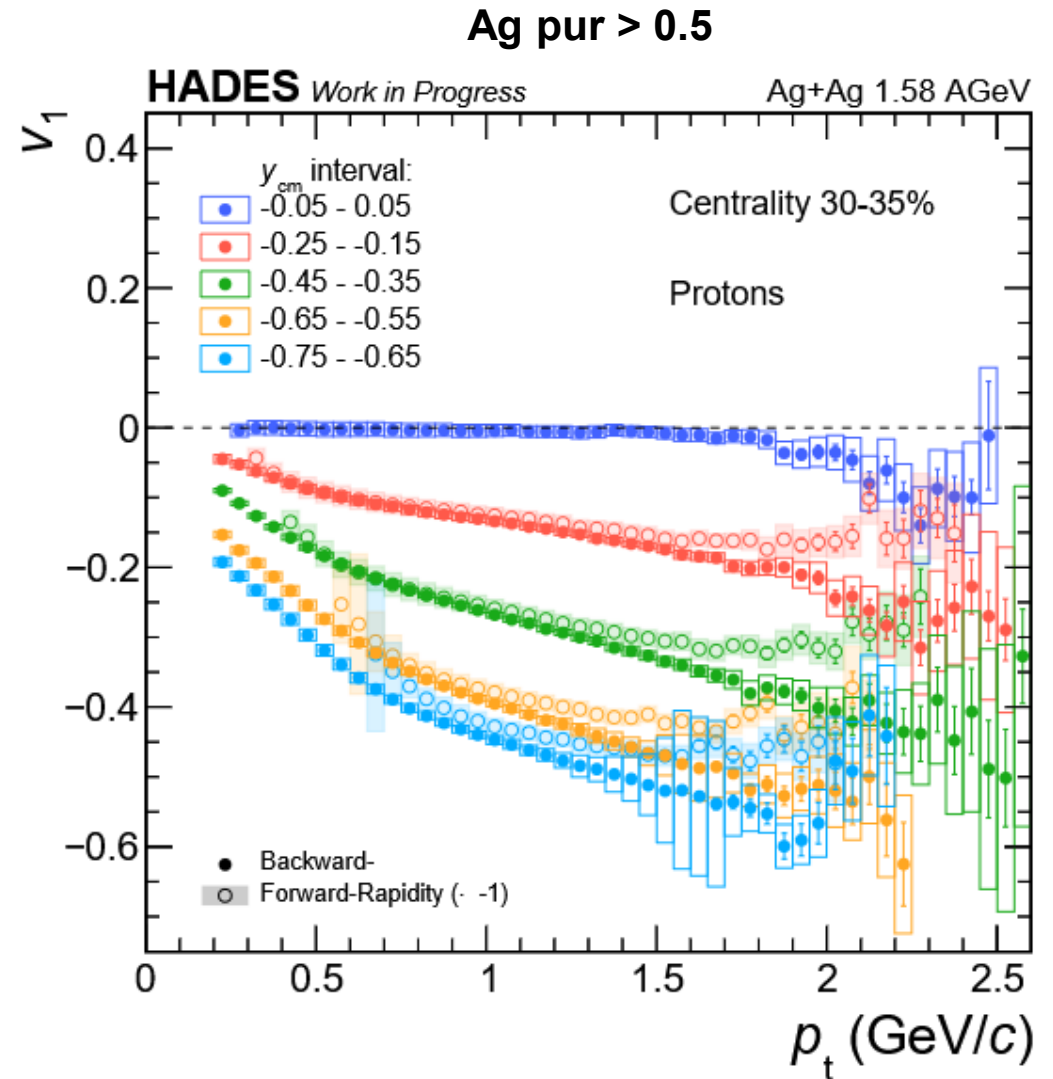
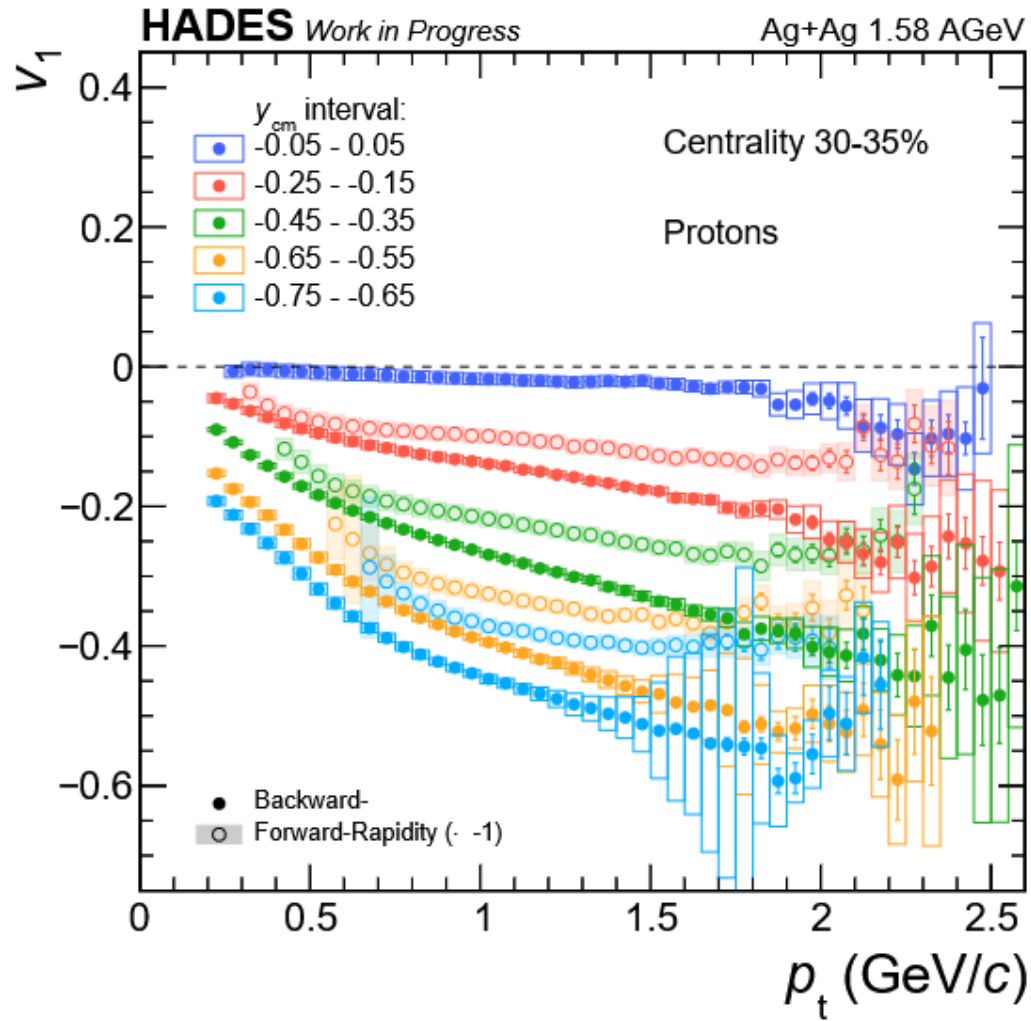


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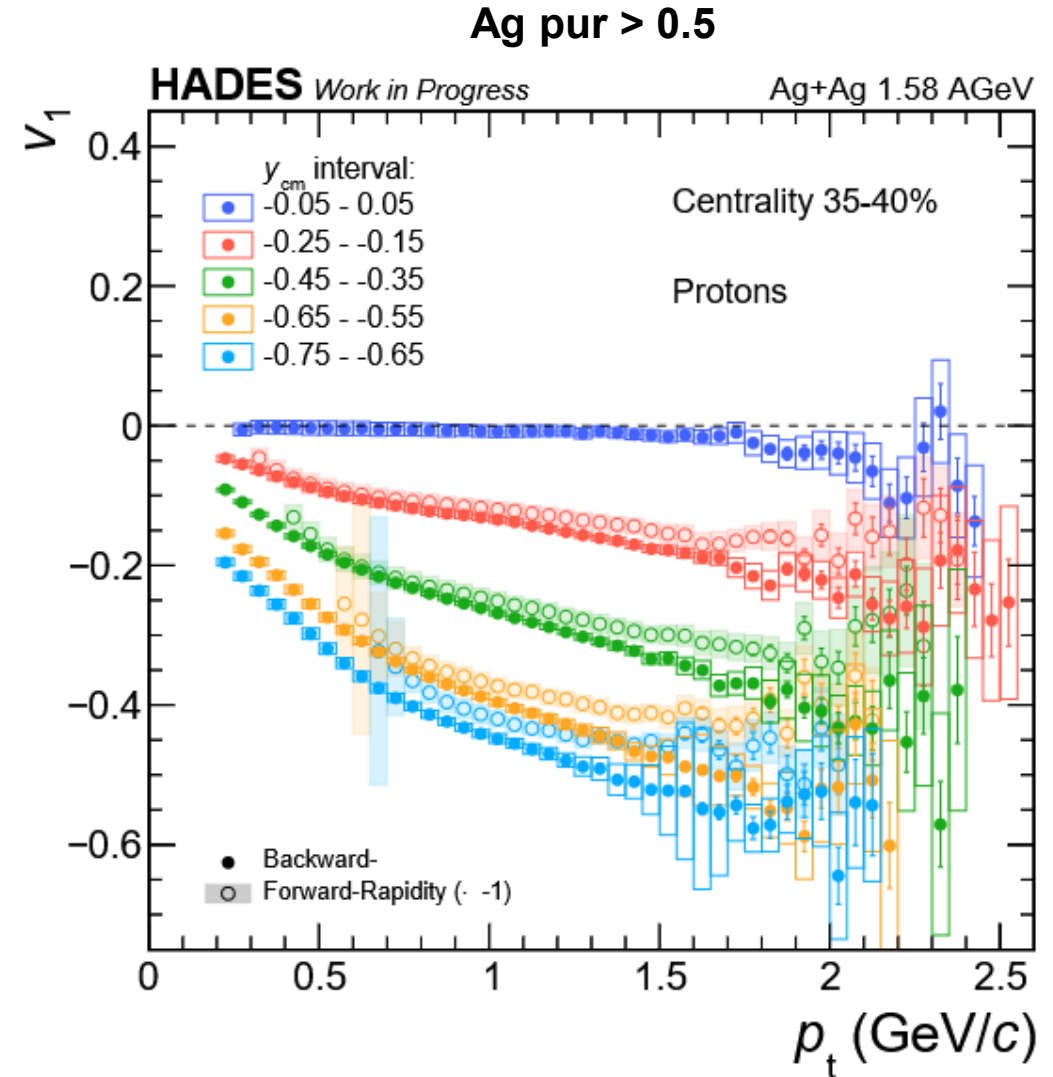
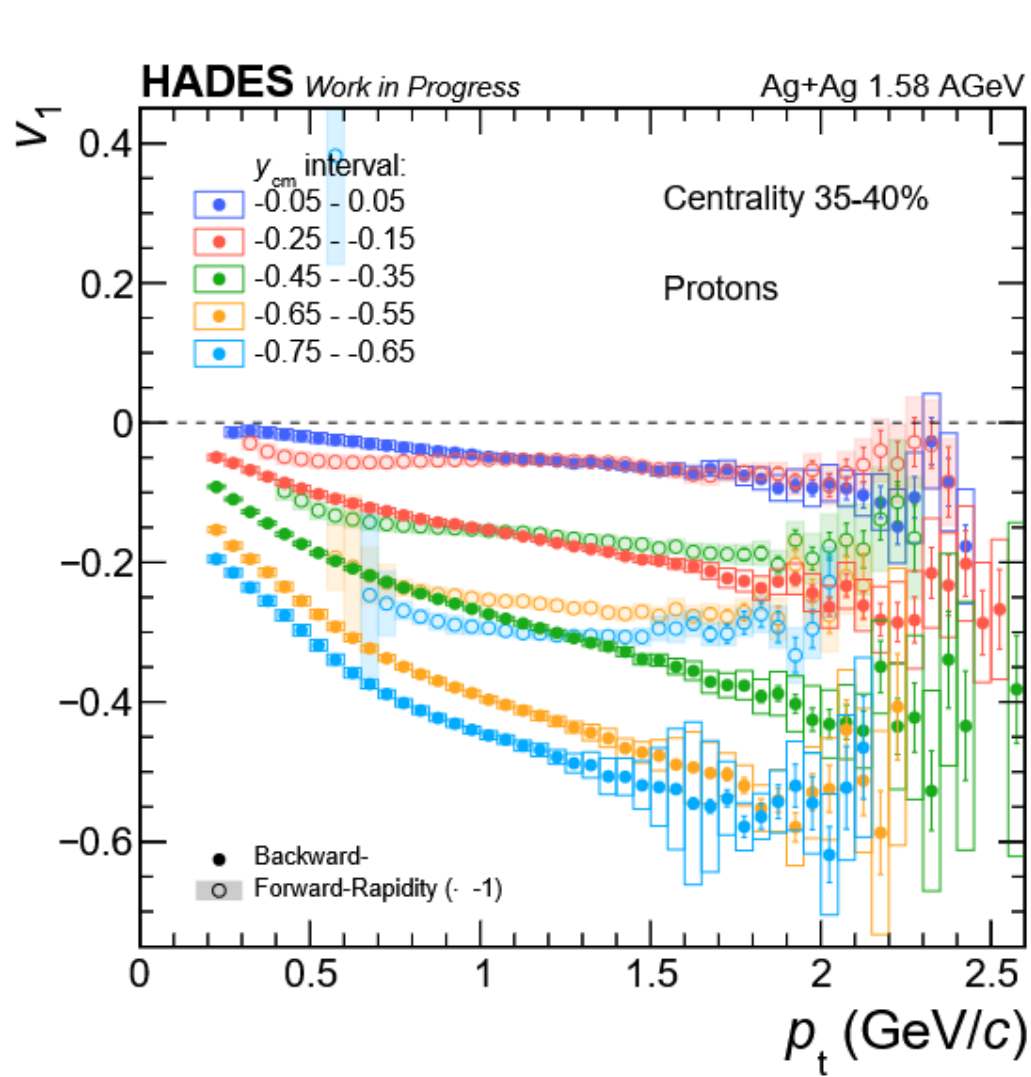


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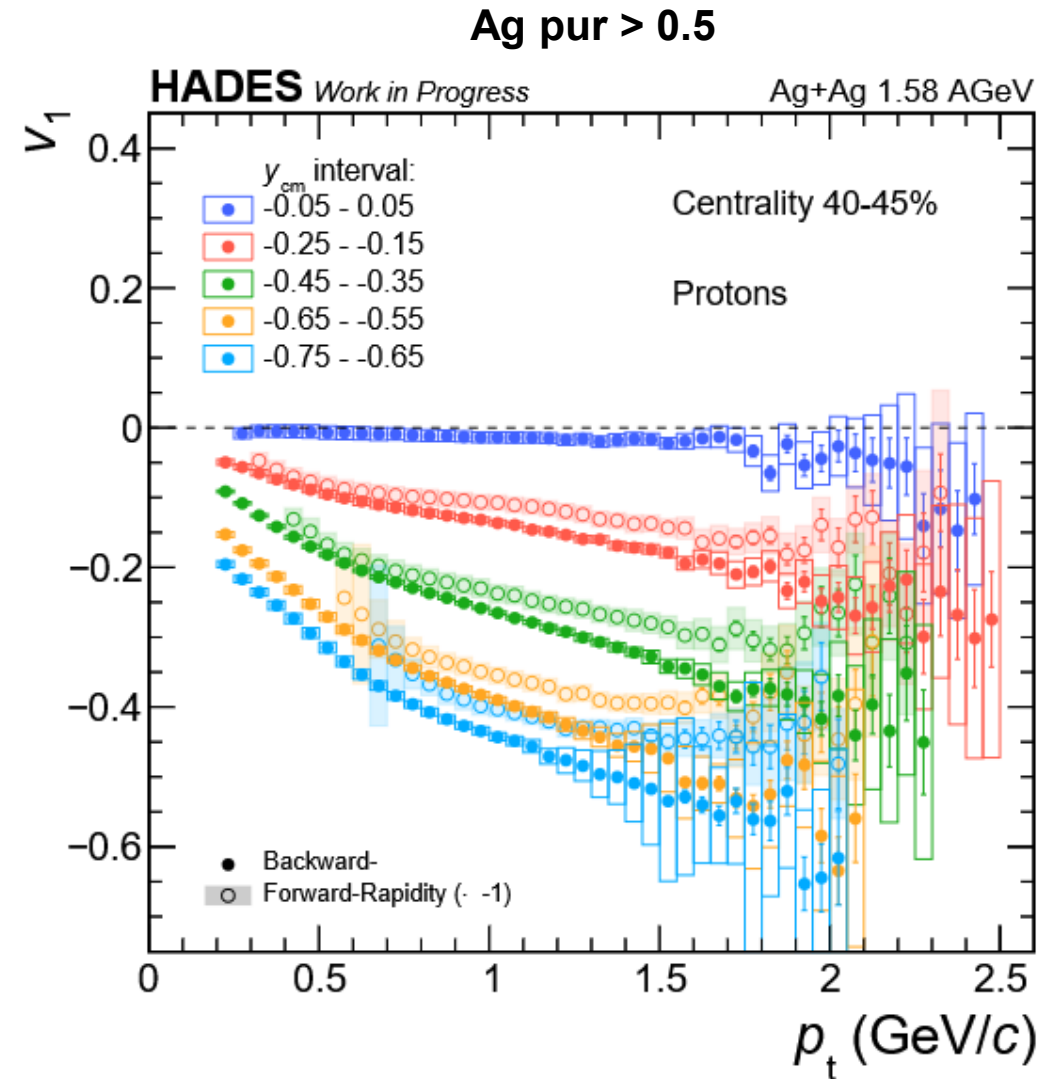
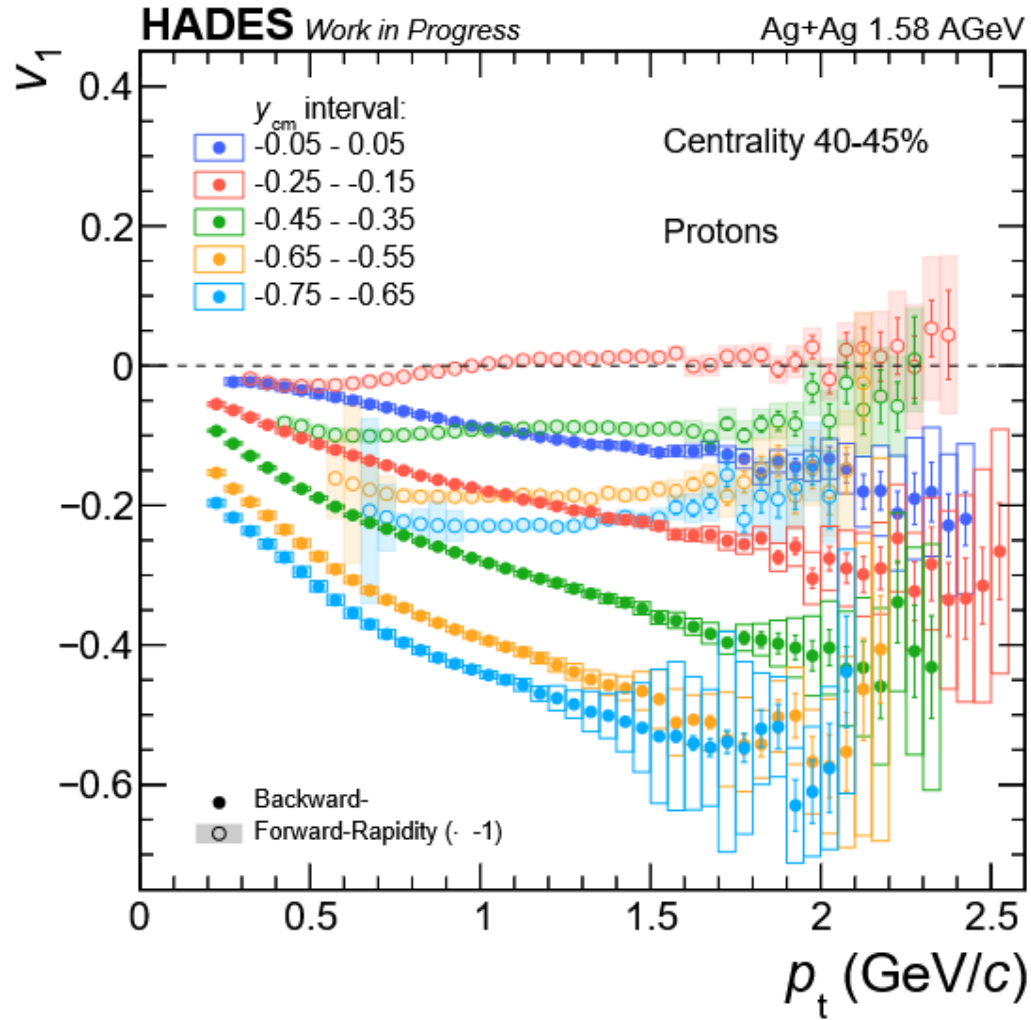


3. MODEL EVALUATION - DATA

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