CND Neutron Detection

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CLAS Collaboration Meeting

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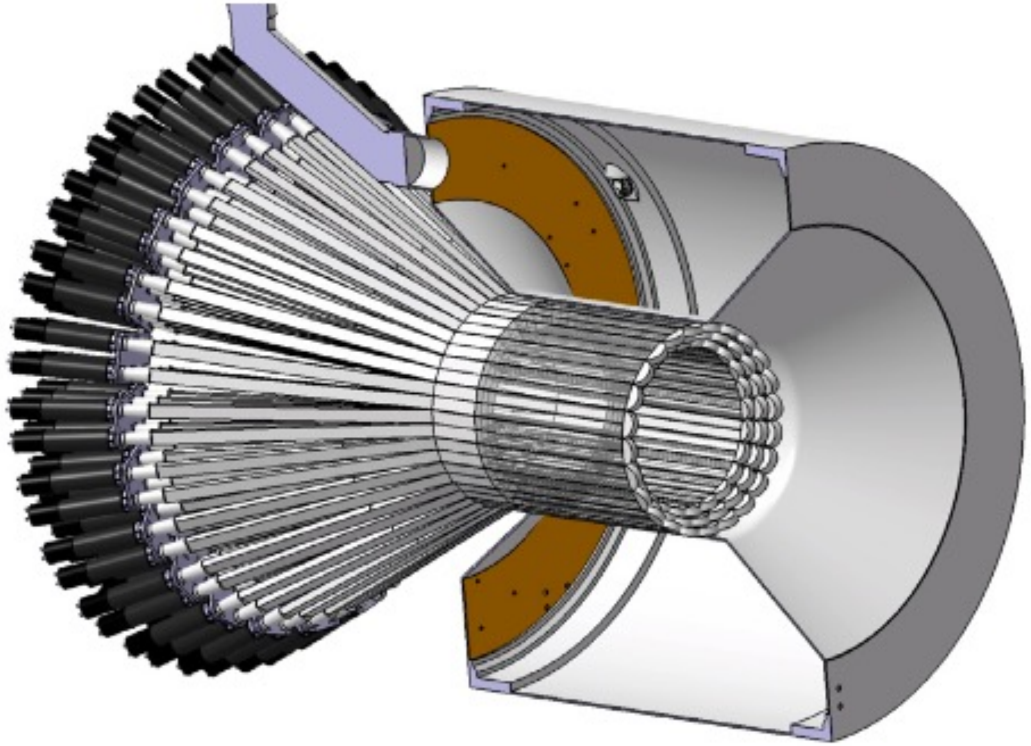
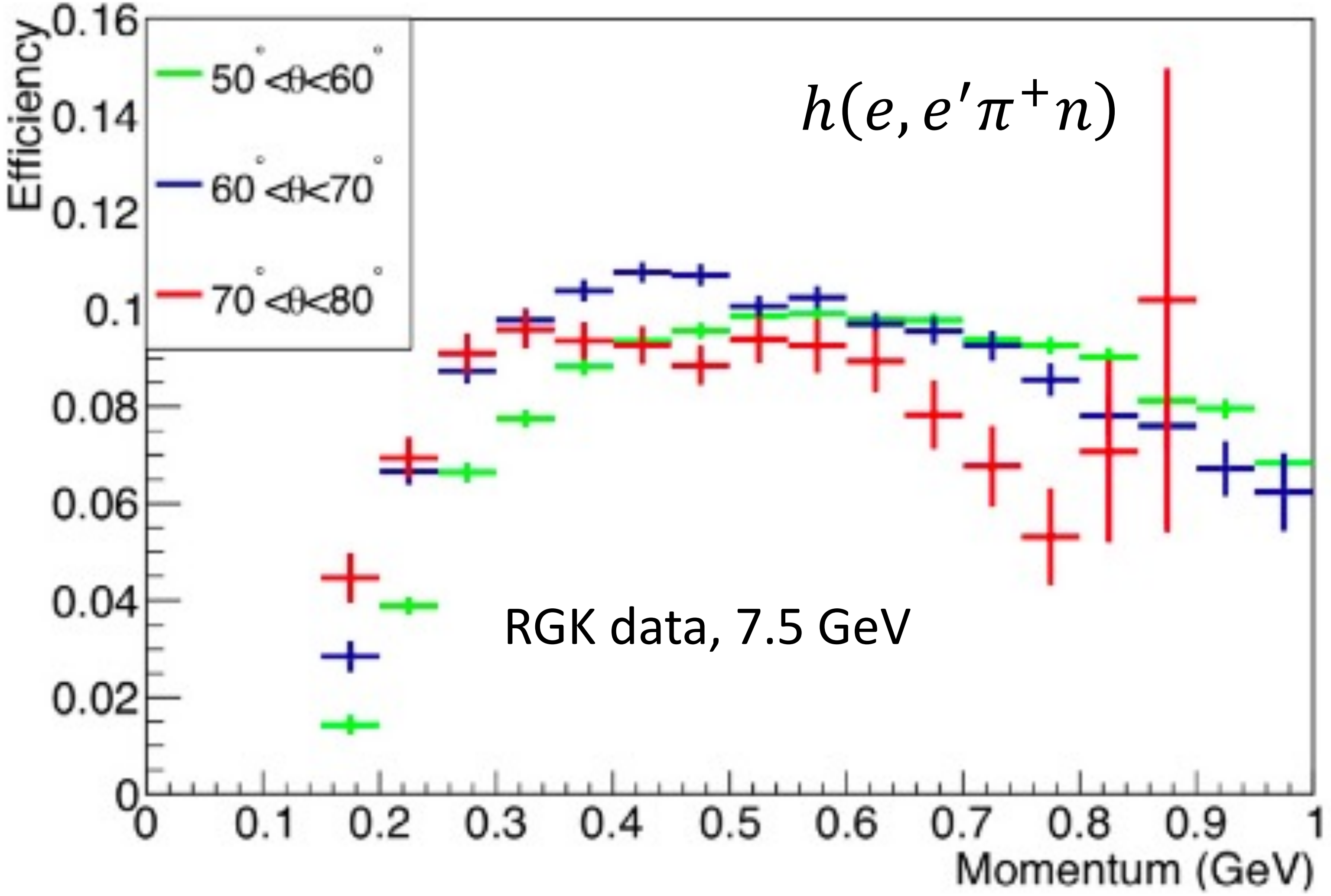
Overview



- Neutron Detection efficiency
- Development of neutron veto algorithm
  - Early stages
  - Development of ML with
- ML neutron detection with RGM data

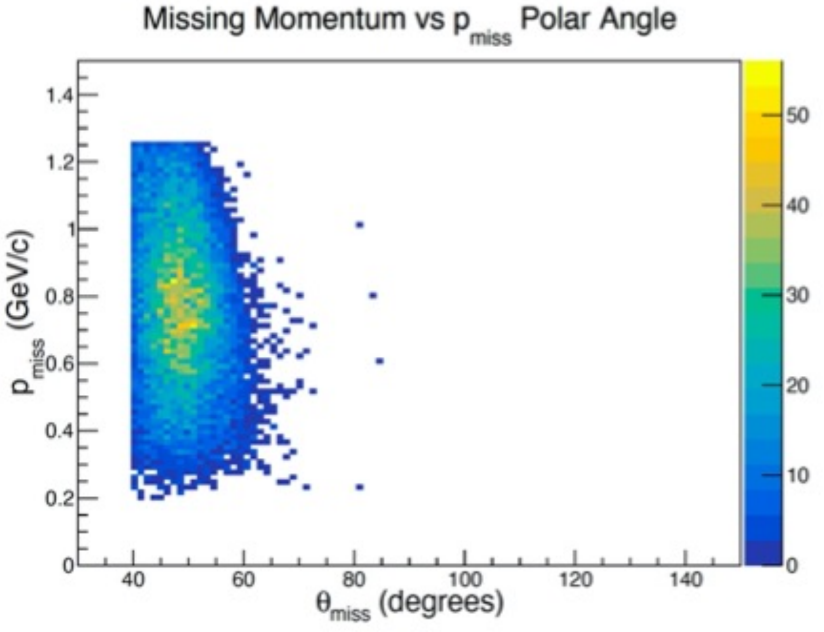
Detection Efficiency: early work



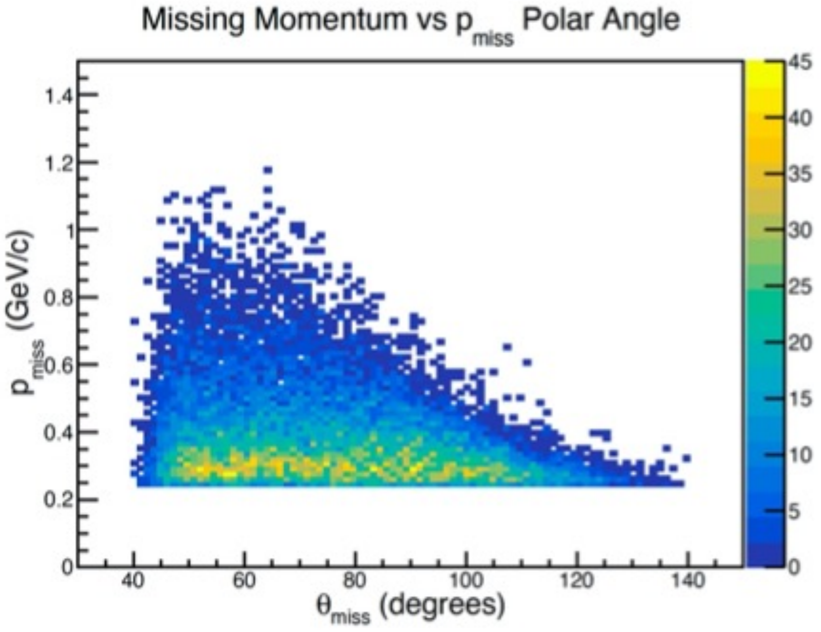
Chatagnon thesis, CLAS12 NIM paper

Detection Efficiency: Approach

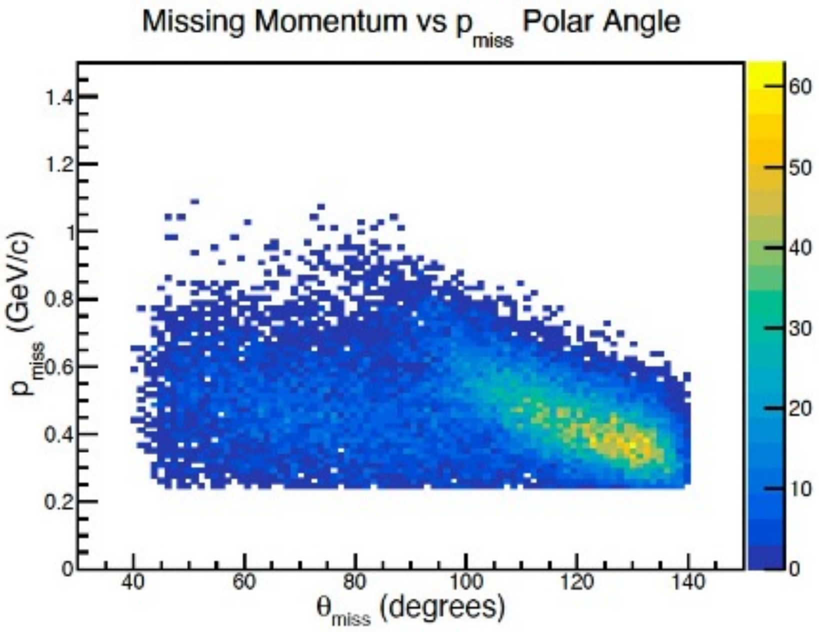
- Channels used: $h(e,e'\pi^+n)$, $d(e,e'p_{CD}n)$, $d(e,e'p_{FD}n)$
- Background subtraction



$H(e,e'\pi^+n)$

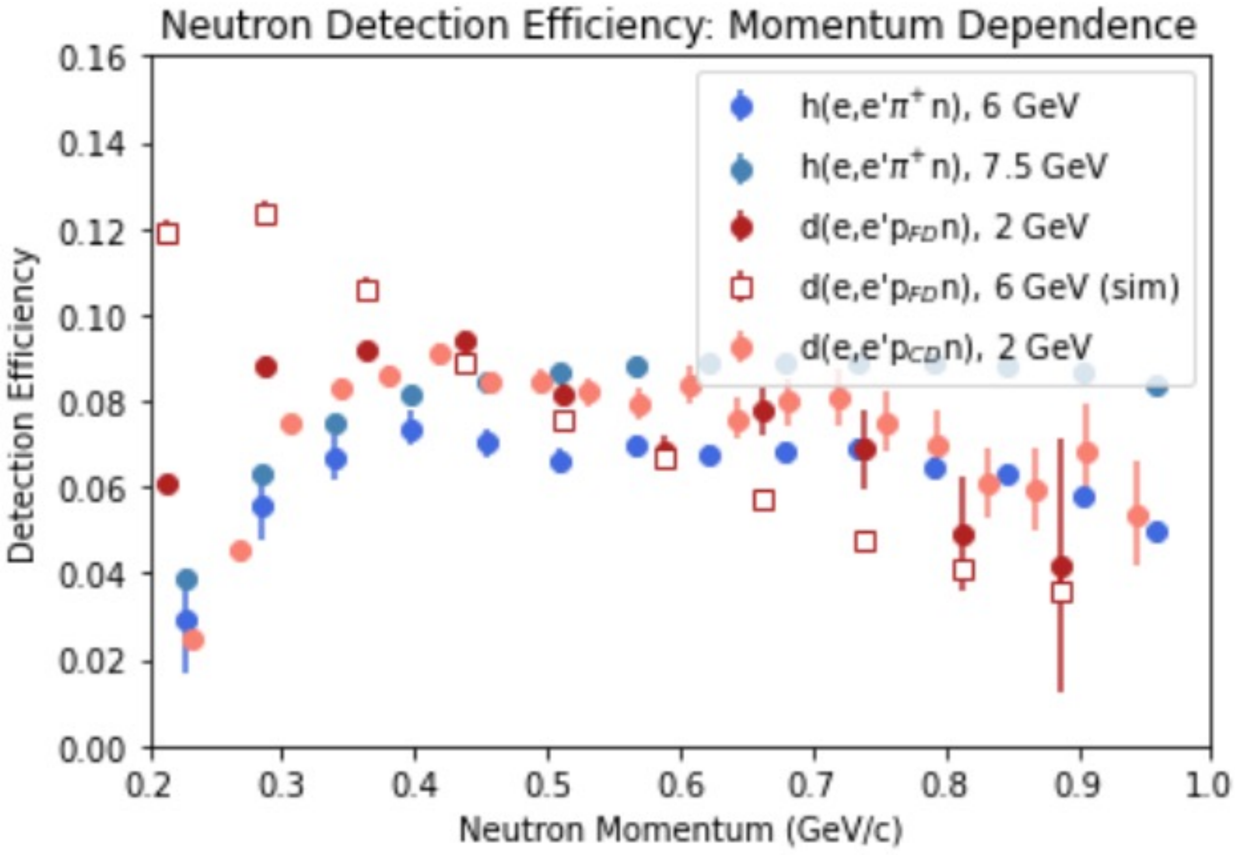


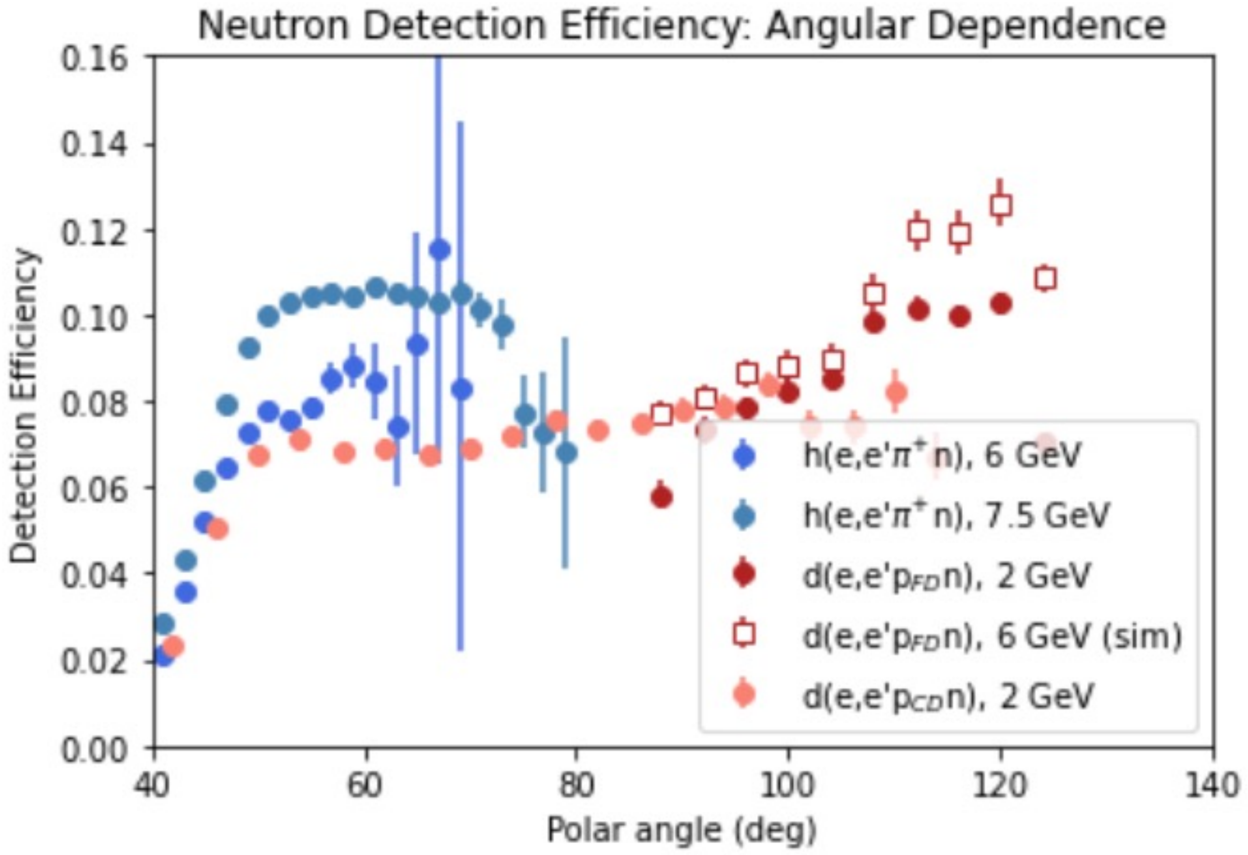
$D(e,e'p_{CD}n)$



$D(e,e'p_{FD}n)$

Detection Efficiency: results



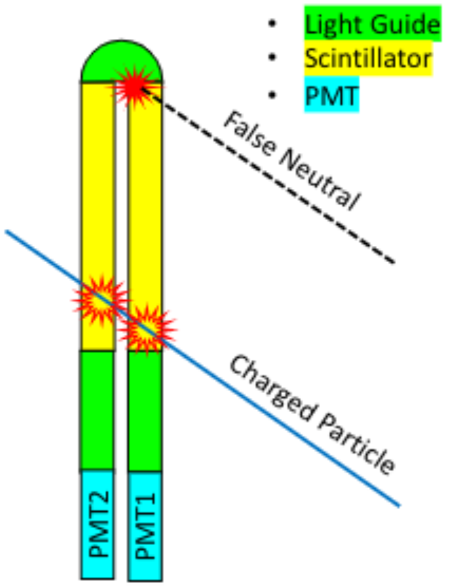


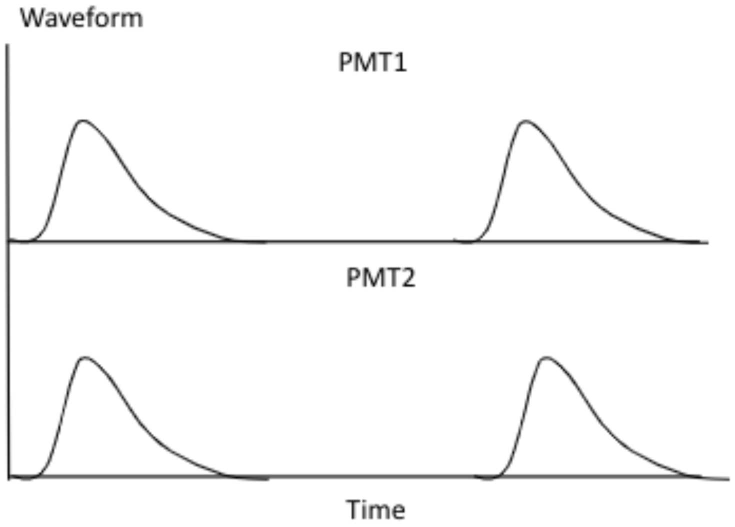
Neutron Veto

- CND neutron reconstruction
  - Clusters form neutral seed if unassociated with a CVT track
  - Neutrals considered to be only photons or neutrons
  - Velocity cut: $\beta < 0.8$ for neutron, $\beta > 0.8$ for photon
- Big problem: imperfect CVT efficiency means proton contamination
- Background sources
  - Double hits
  - Neutron and proton reconstructed in same place (cut on θ_{np})
  - Random co-incidence (off-time, etc.)
  - Charged particles
- Past work
  - Andrew Denniston: preliminary CND veto work
  - Adam Hobart: Machine learning for DVCS

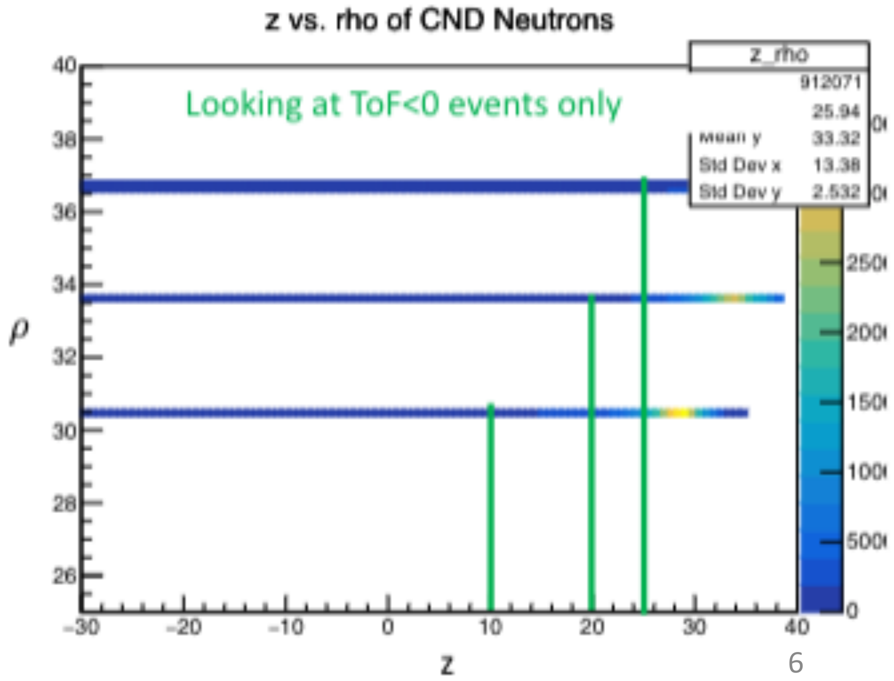
Background: double hits

- Charged particles may leave two hits with two sets of PMT signals
- Two PMT signals arrive at same time -> reconstructed near 40°
- Easily eliminated using z cut



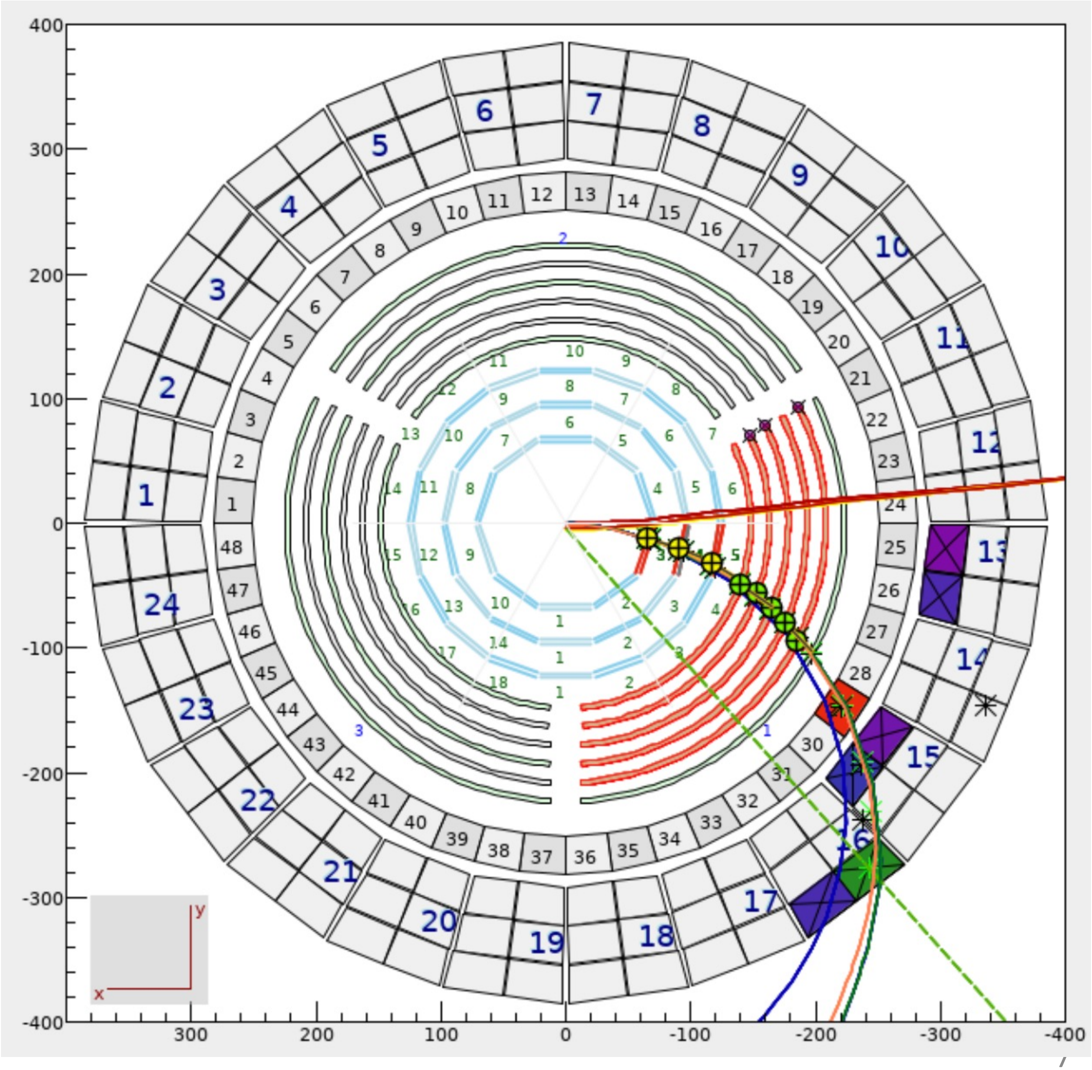


Hit Time = $t_{PMT1} + t_{PMT2} + c_t$
Hit Z = $t_{PMT1} - t_{PMT2} + c_z$



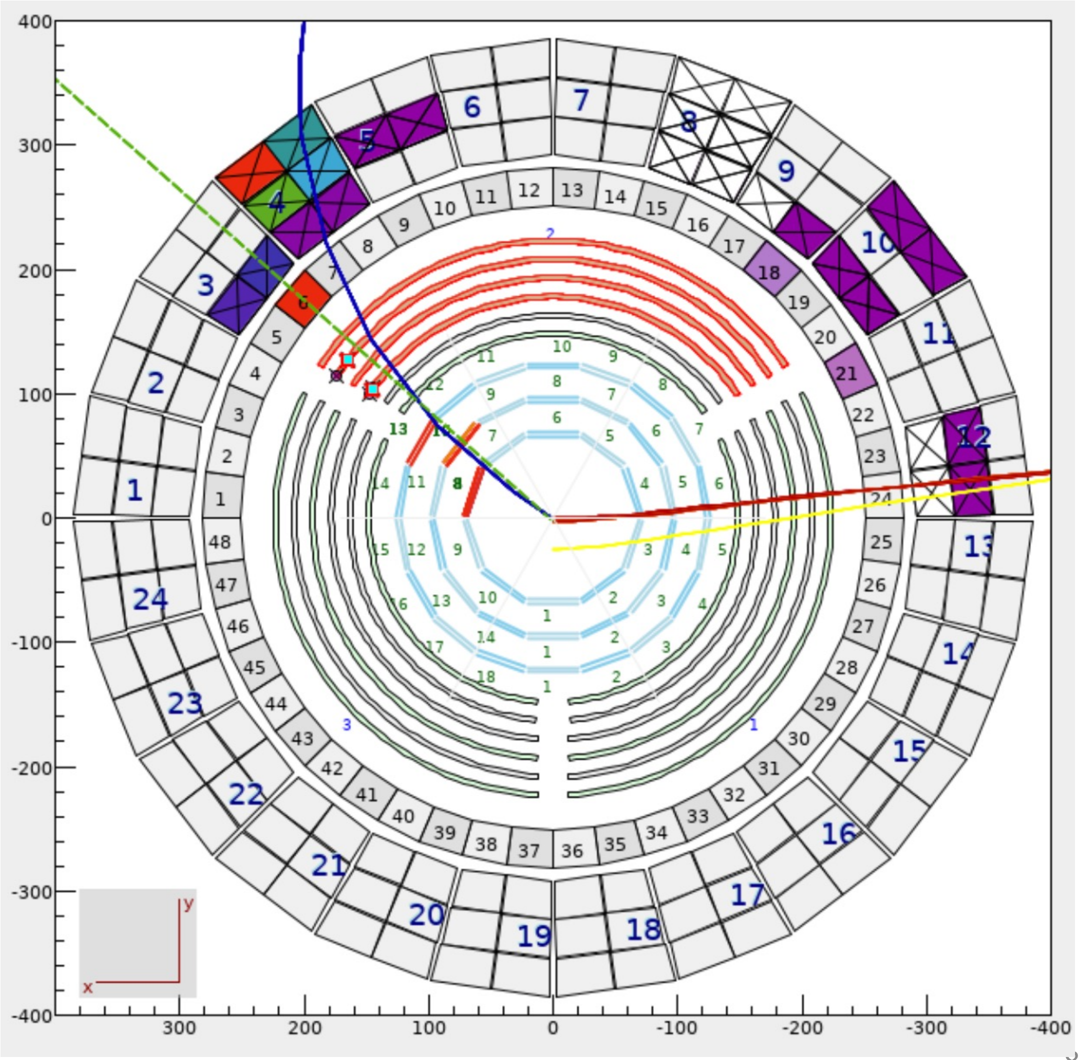
Background: CND hit not associated w/ track

- CND hits not associated with CVT track
- Proton associated with one CND cluster but not another
- Can cut on angle between neutron and proton



Background: protons misidentified as neutrons

- Imperfect CVT tracking efficiency
- Some protons mis-reconstructed as neutrons
- This is the main background source we seek to eliminate with ML



Neutron Veto: Development in Simulation

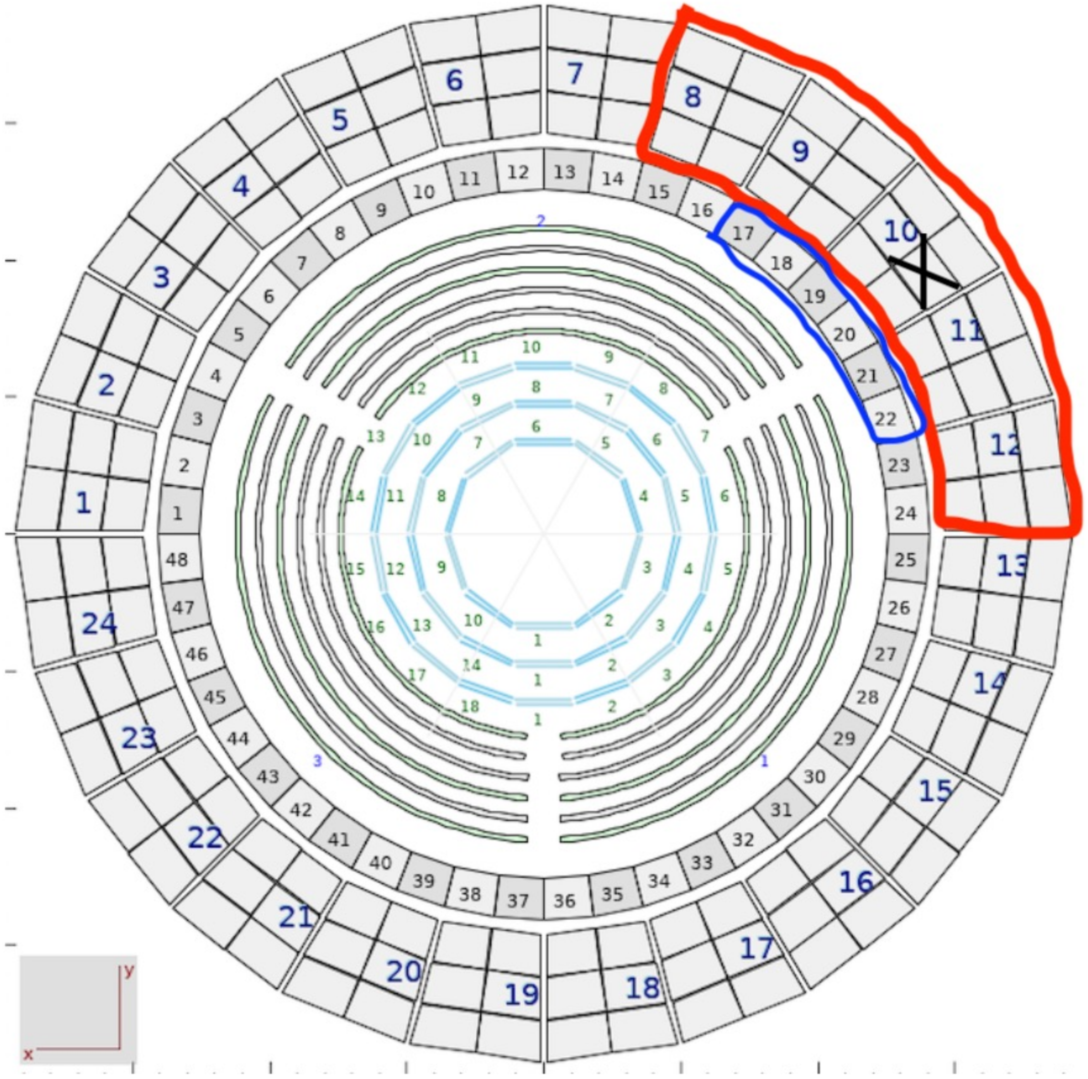
- Approach using Machine Learning: Boosted Decision Trees
  - Identify features that are best at distinguishing between real neutrons and “fake” neutrons (non-neutrons with neutron PID)
- Goal for features
  - Local, detector-level information
  - Avoid kinematic variables

Neutron Veto: Development in Simulation

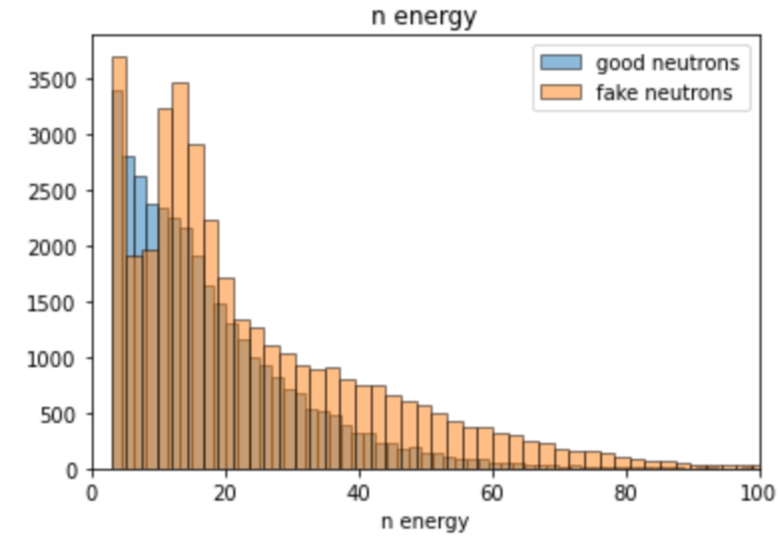
- Sample generation
  - Uniform *e′n* and *e′p* generators with nucleon momentum up to 1 GeV/c
  - Run through GEMC, generated momentum “truth” preserved
  - Added CLAS12 background from RG-A
- Good neutron sample (signal): agreement with generated momentum in *e′n*+bknd
- Fake neutron sample (background): all neutron PID in *e′p*+bknd

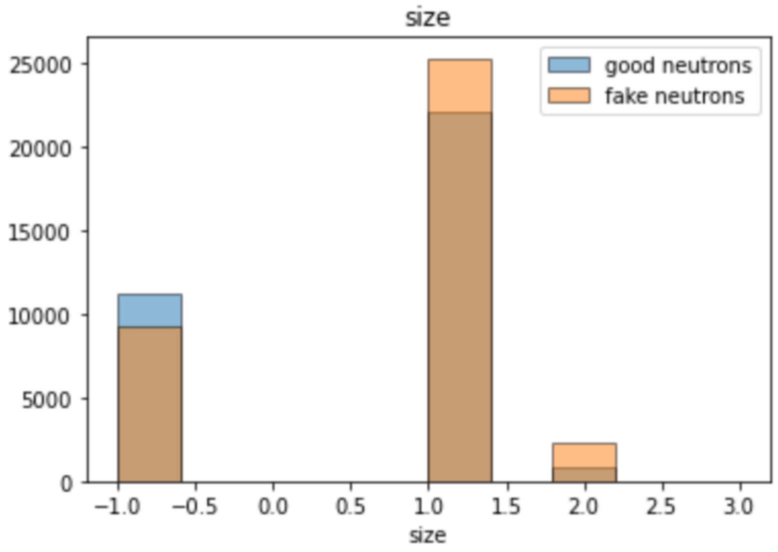
Neutron Veto: simulation feature list

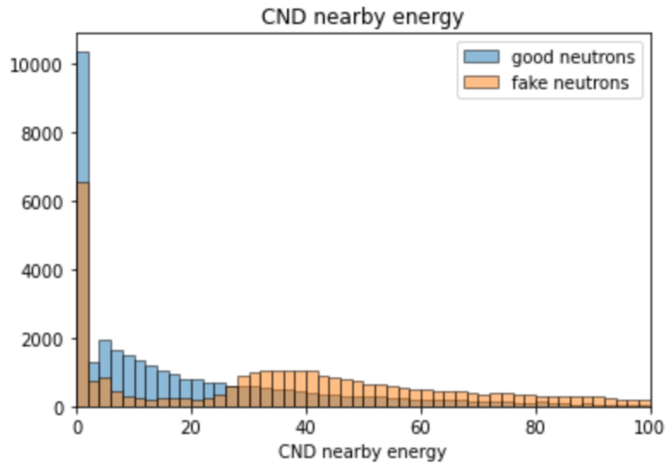
- Number of hits in 5 CND sectors closest to neutron
- Energy deposition in 5 CND sectors closest to neutron
- Number of hits in CND cluster
- Neutron energy
- CND layer multiplicity
- Number of hits in 6 CTOF components closest to neutron
- Energy deposition in 6 CTOF components closest to neutron

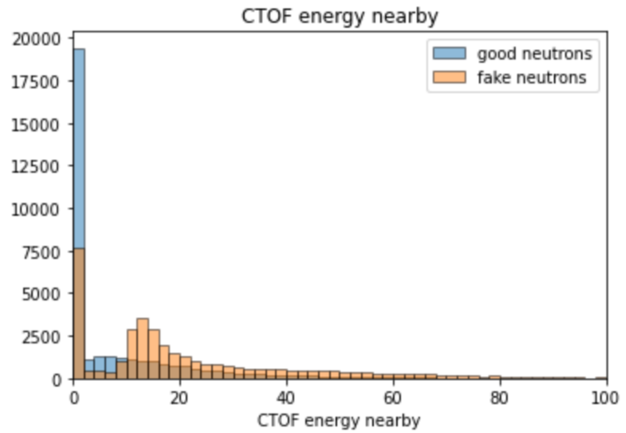


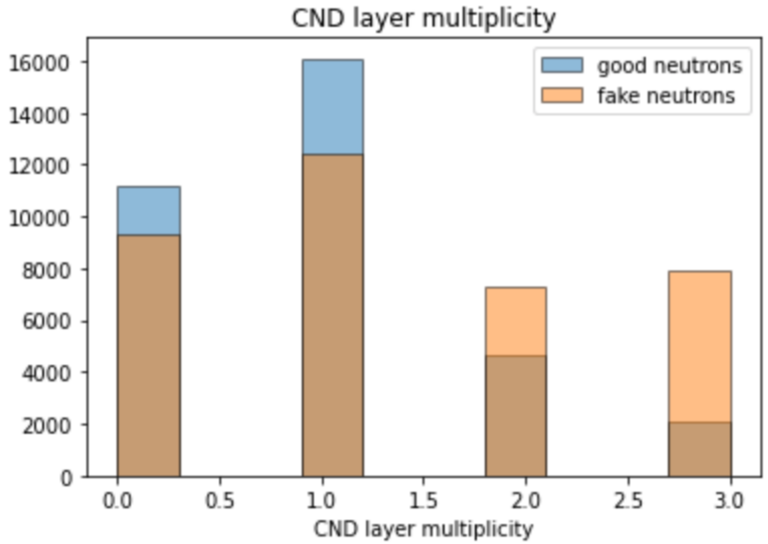
Neutron Veto: sim feature list

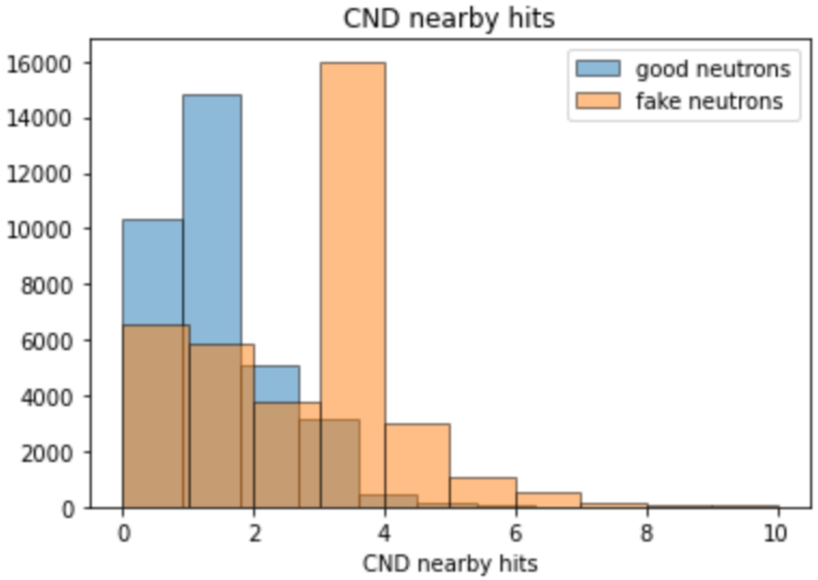


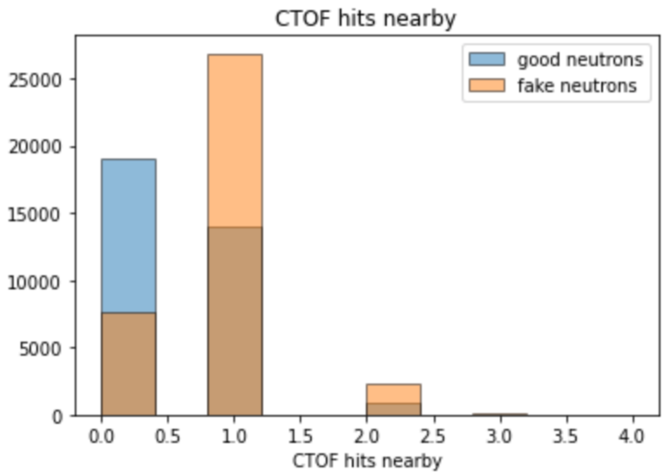




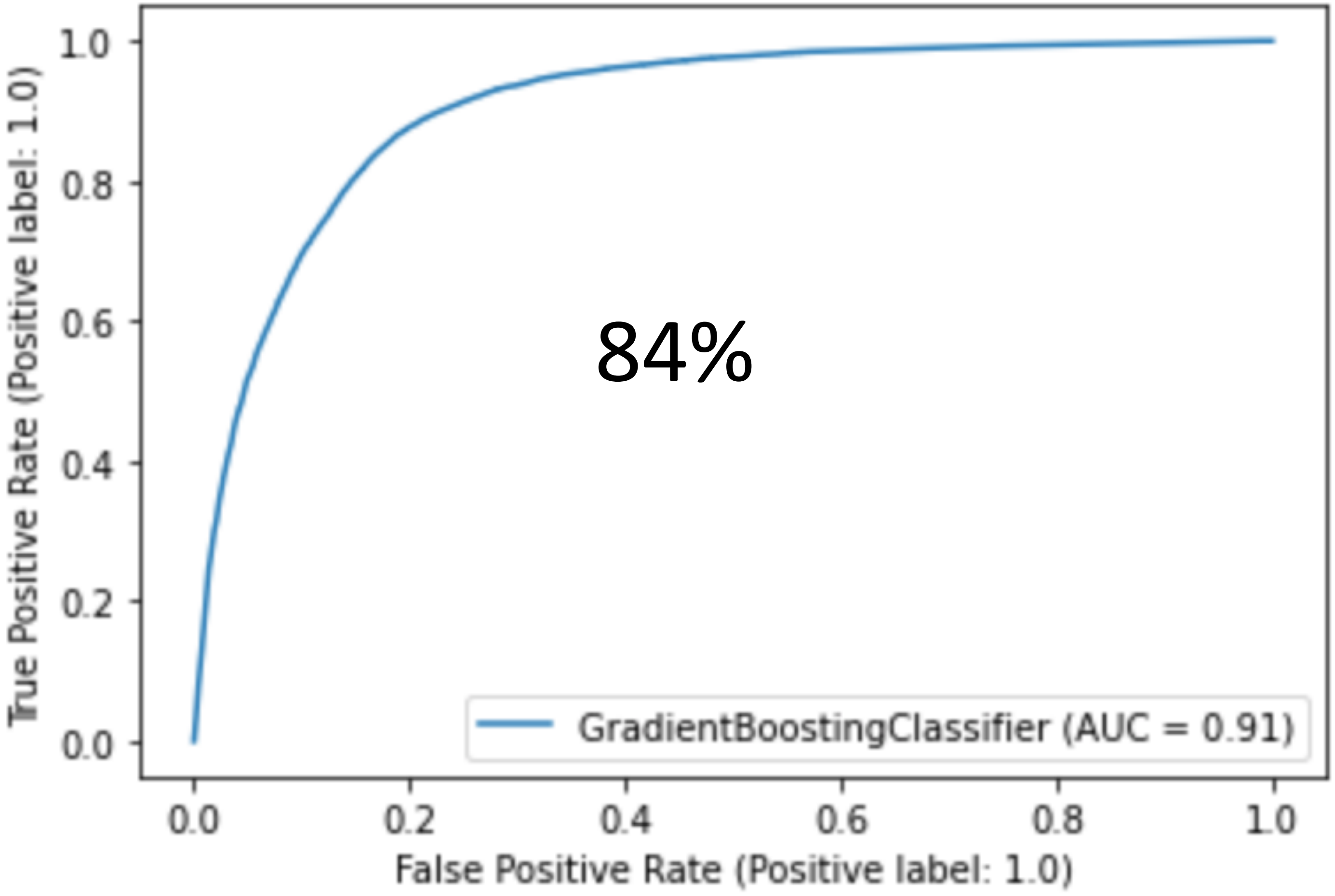








Neutron veto: simulation results



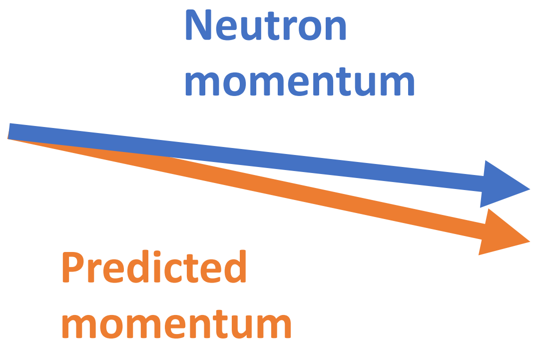
	feature	importance
3	hits_nearby7	0.400353
5	CTOF energy nearby	0.398342
4	avg energy per hit7	0.084178
1	layermult	0.055034
0	n energy	0.050658
6	CTOF hits nearby	0.006834
2	size	0.004600

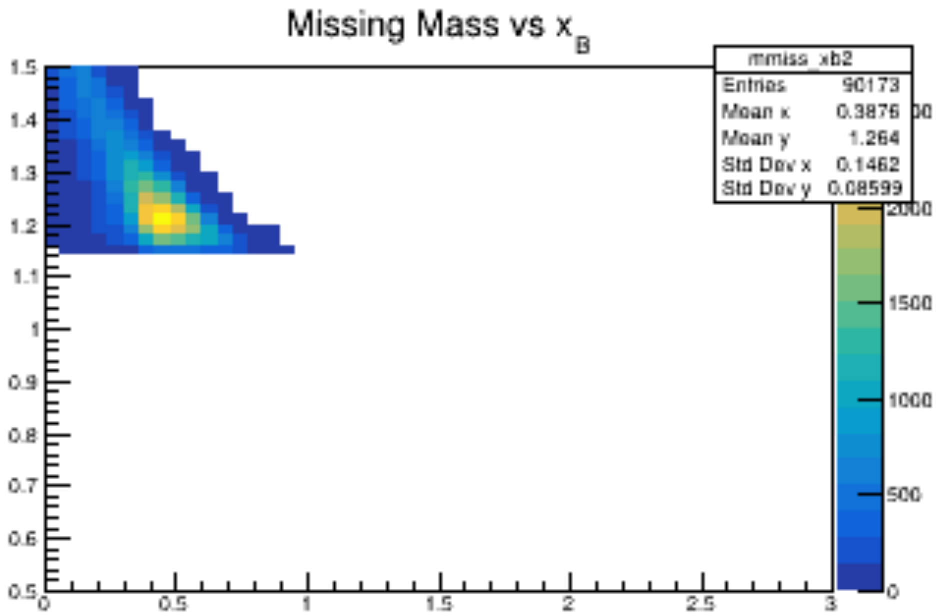
Neutron Veto: data approach

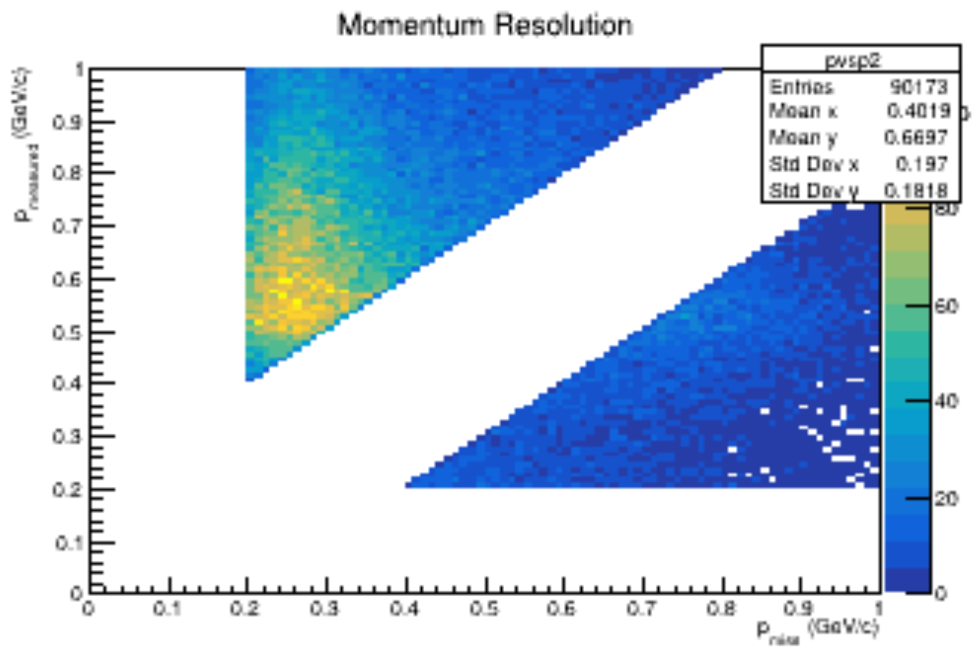
- Available exclusive channels
  - $h(e, e'\pi^+ n)$
  - $d(e, e' p_{CD} n)$ (2 GeV, 6 GeV)
  - $d(e, e' p_{FD} n)$ (2 GeV, 6 GeV)
  - $d(e, e' p p \pi^-)$
- Select good and false neutrons
  - Start with $d(e, e' p_{CD} n)$ QE channel (higher stats)
  - Calculate expected neutron momentum with momentum conservation
  - Train ML to separate neutrons vs bad neutrons

Neutron Veto: good neutrons (signal)

- $\cos\theta_{n,pred} < 0.8$
- $|\, p_{miss} - p_n \,| > 0.2$ GeV/c
- $M_{miss} > 1.15$ GeV/c

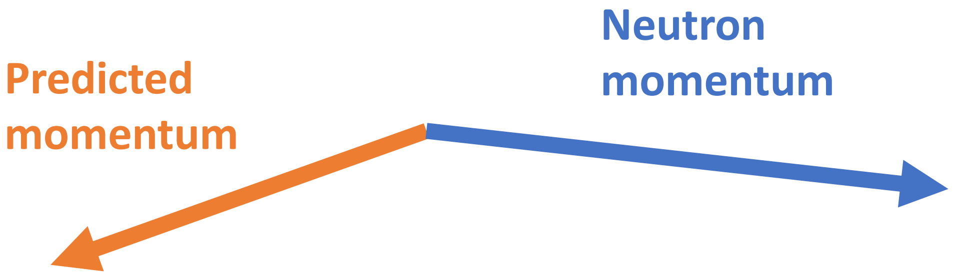


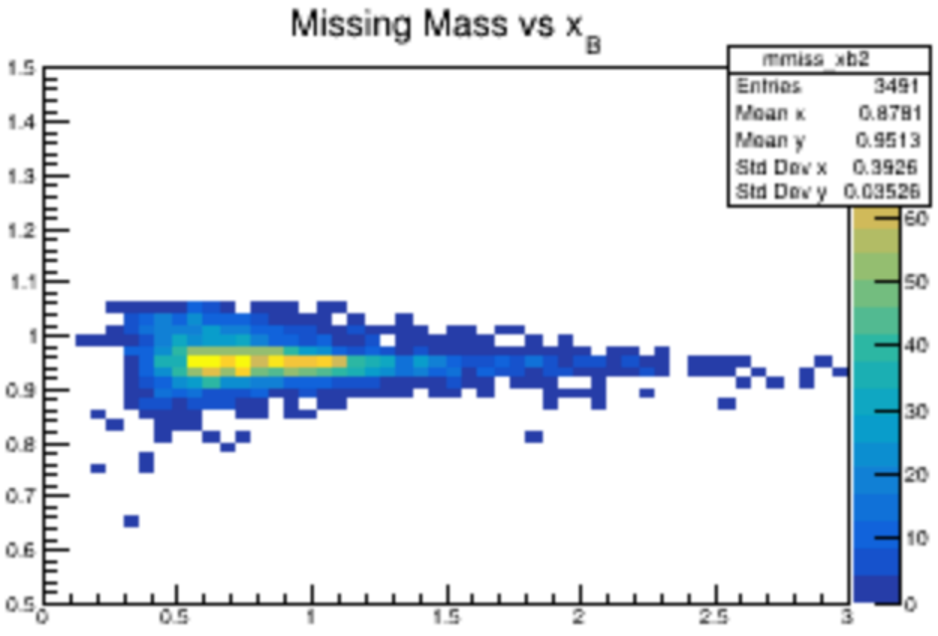


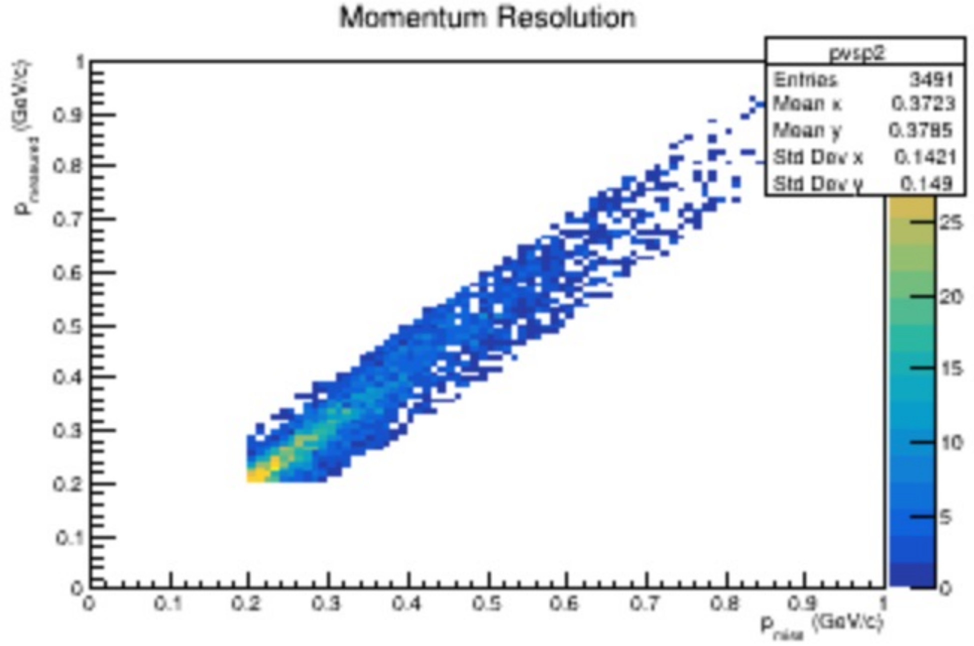


Neutron Veto: non-neutrons (background)

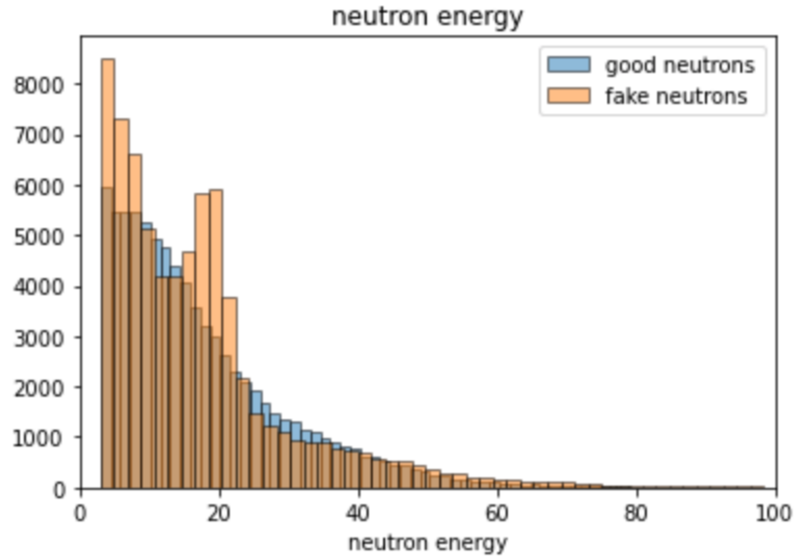
- $\cos \theta_{n,pred} > 0.9$
- $| p_{miss} - p_n | < 0.1$ GeV/c
- $M_{miss} < 1.05$ GeV/c

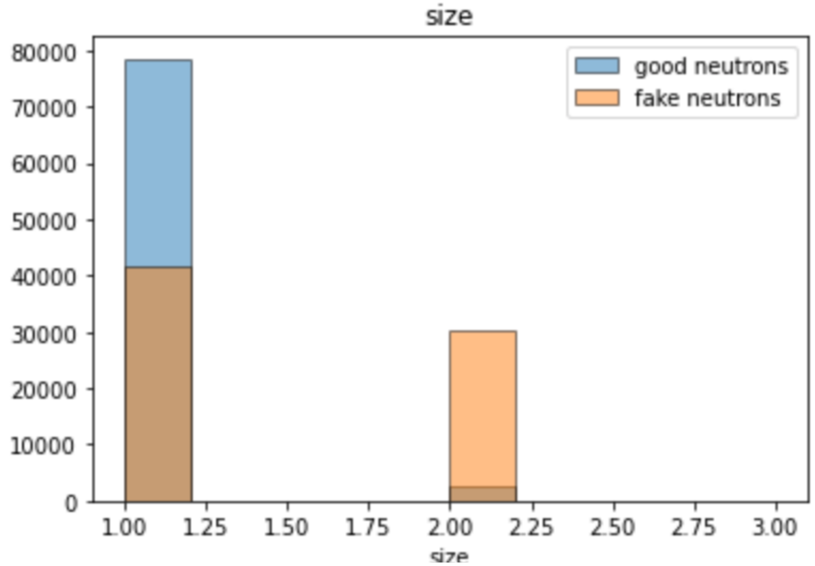


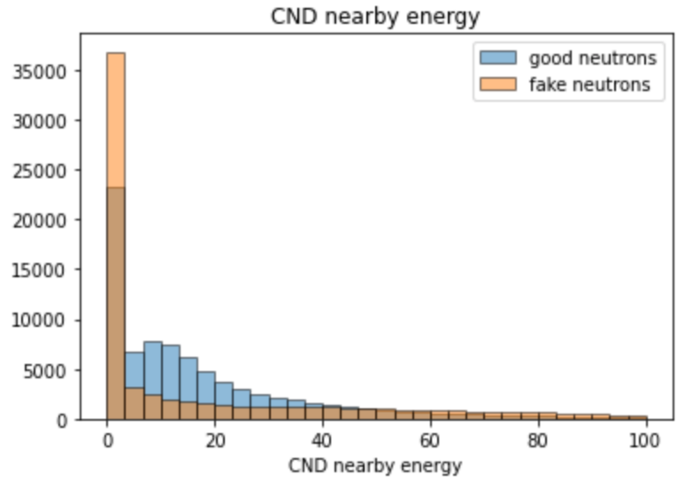


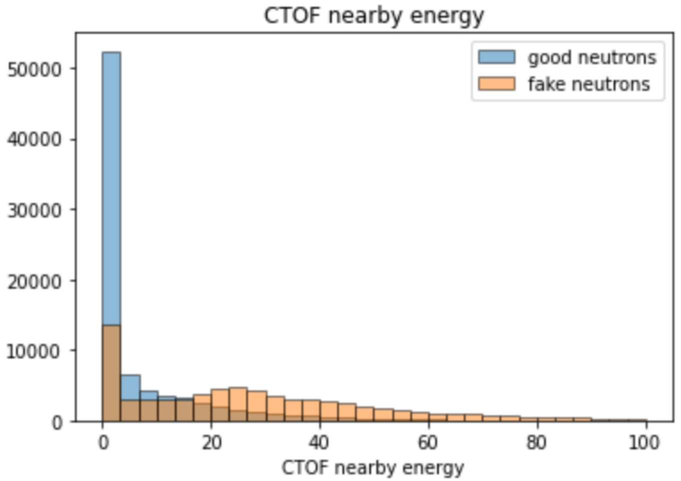


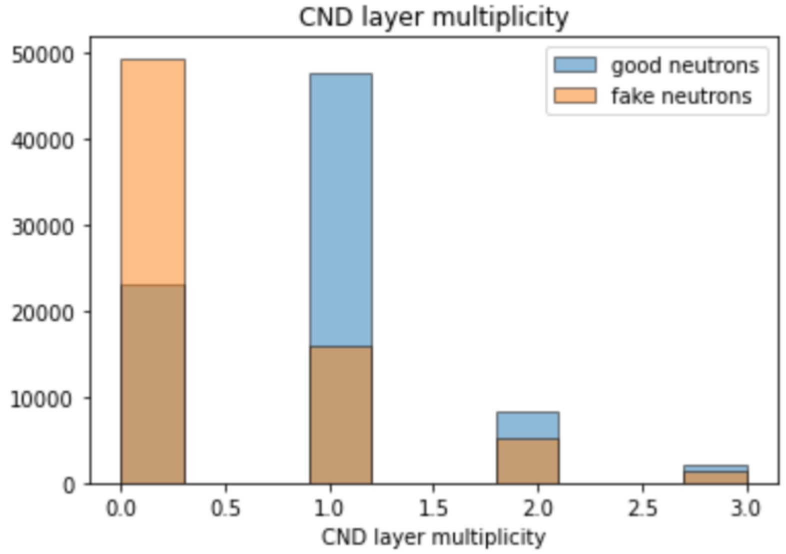
Neutron Veto: feature list

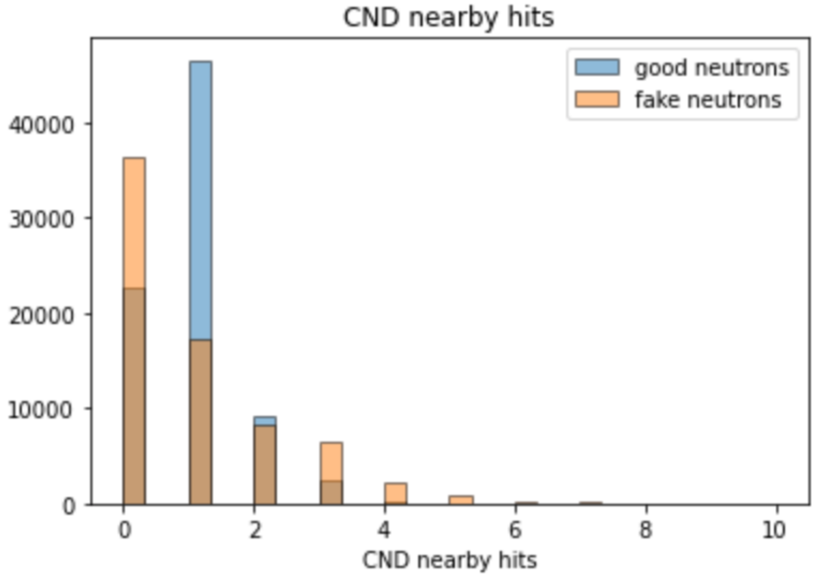


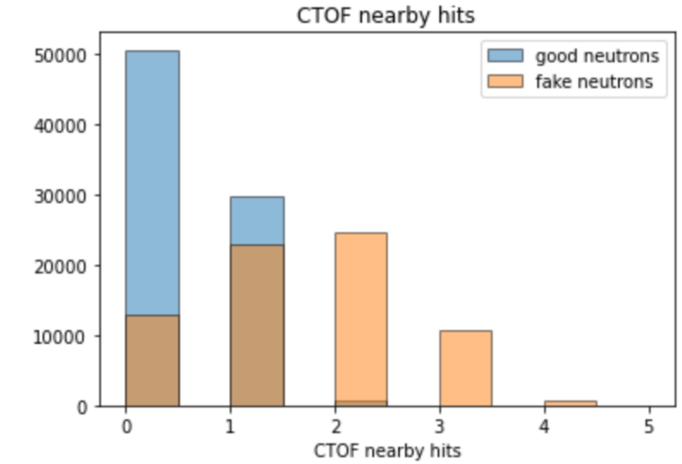




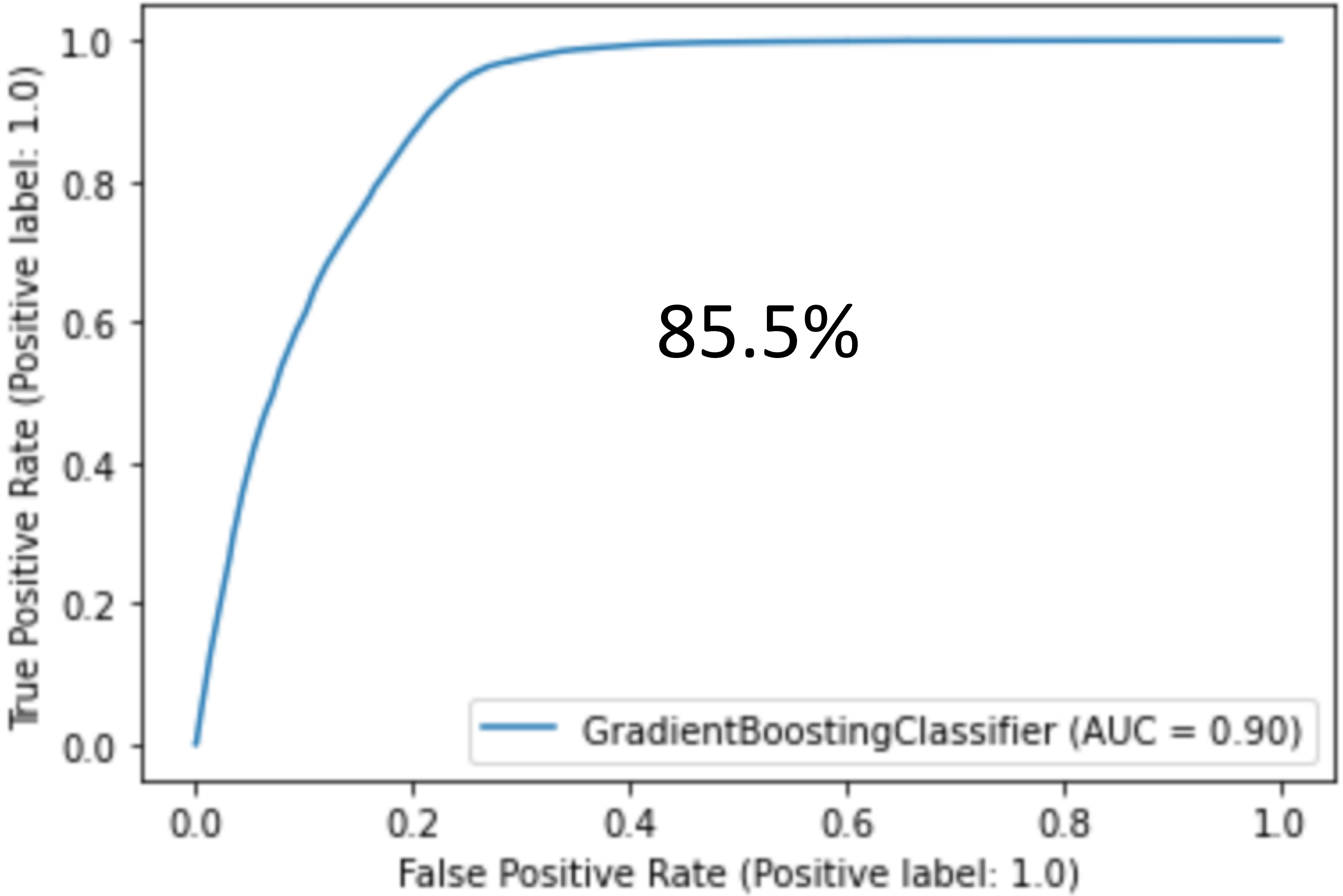








Neutron Veto: Results



	feature	importance
6	CTOF nearby hits	0.558750
2	size	0.157170
3	CND nearby hits	0.100631
5	CTOF nearby energy	0.056925
0	neutron energy	0.046822
1	CND layer multiplicity	0.043617
4	CND nearby energy	0.036085

Next Steps

- Detection Efficiency
  - Re-run with pass2 reconstruction
  - CLAS analysis note
- Neutron Veto ML Algorithm
  - Channel to focus on protons mis-reconstructed as neutrons (e.g. $d(e, e'pp\pi^-)$)
  - Continue search for good features (e.g. number of nearby hits in CVT)
  - Cross-tests on different data sets