NR and ER discrimination using ANN

17/09/2021

A. Prajapati

Configuration used for the simulation and reconstruction

- Noise Run : 3944
- Detector : LIME
- Detector dimension : 33 cm x 33 cm x 50 cm
- Camera : Orca Fusion
- Pixel width: 0.152 mm
- Algorithm : Chan Vese
- Diffusion length : 0-50 cm
- Gas Mixture: He:CF4
- Pressure: 1 atm
- Digitization without saturation
- ER energies:[2,4,6,8,10,12,14,16,18,20,26,30,36,40] keV
- NR energies:[3,6,10,12,14,16,18,20,26,30,35,40] keV
    - Energy deposited: [1.53, 3.7, 6.98, 8.7, 10.4, 12.3, 14.08, 15.92, 21.6, 25.37, 30.14, 34.98] keV

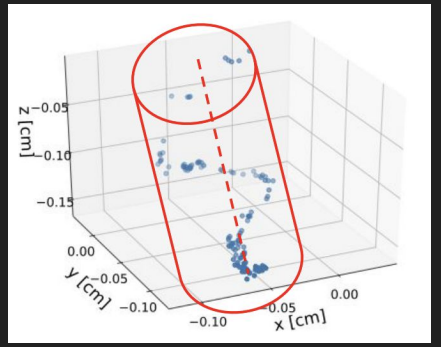
Observables

Observables for recoil identification in gas TPCs
arXiv:2012.13649v1

- Standard Deviation of Charge Distribution (SDCD):

$$SDCD = \sqrt{\frac{\sum_{i=1}^{N}(\mathbf{r_i} - \bar{\mathbf{r}})^2}{N}}.$$

- Charge Uniformity (ChargeUnif):
  - For each point within the charge distribution, find the average distance to all other points.
  - ChargeUnif is standard deviation of values computed in step 1.
- Maximum Density (MaxDen):
  - MaxDen is the value of most intense pixel. (After rebinning)
- Cylindrical Thickness (CylThick):
  - For each charge , calculate the squared distance from the principal axis.
  - CylThick is the sum of all squared distances.



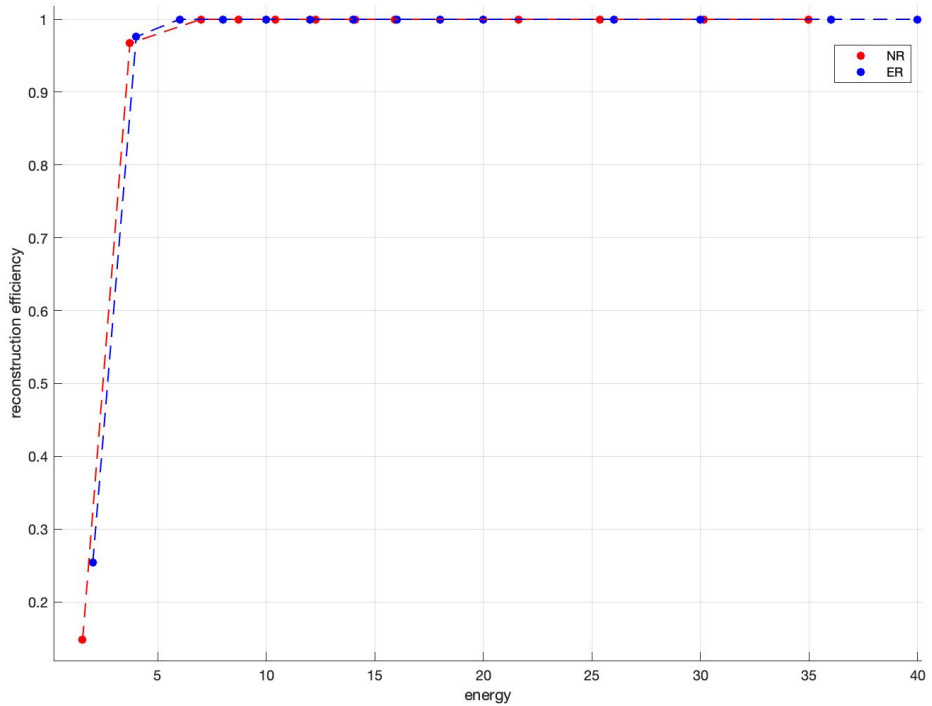
Source: Majd Ghrear presentation in Physics and Analysis meeting

Observables

- Length Along Principal Axis (LAPA):
  - Project all the points in the charge distribution on to the principal axis.
  - LAPA is the difference between maximum and minimum projected value.
- eta:
  - MaxDen divided by length (found by skeletonization)
- Light Density:
  - Ratio of sc_integral over sc_nhits
- Skeleton length (thin_track):
  - Length in pixels found by thinning
- Slimness:
  - Ratio of sc_width over sc_length

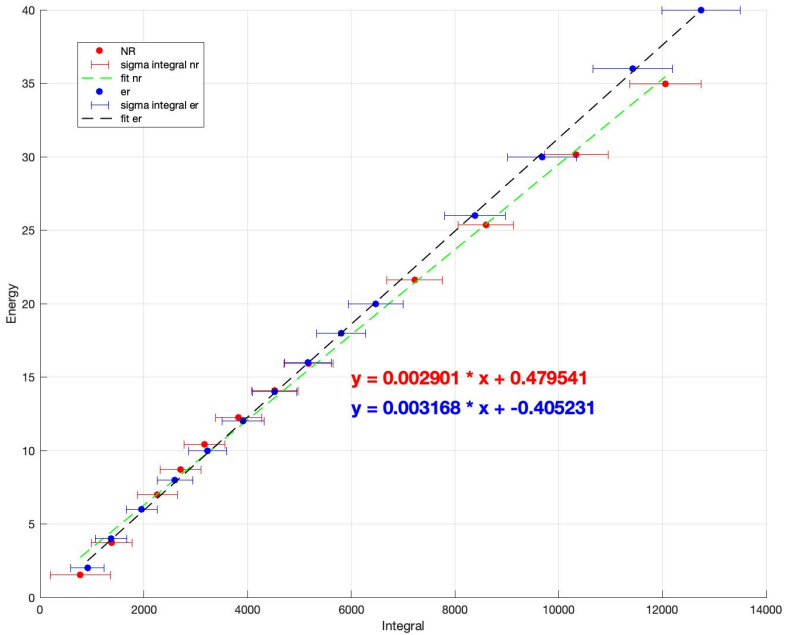
GEM-based TPC with CCD Imaging for Directional Dark Matter Detection
arXiv:1510.02170v3

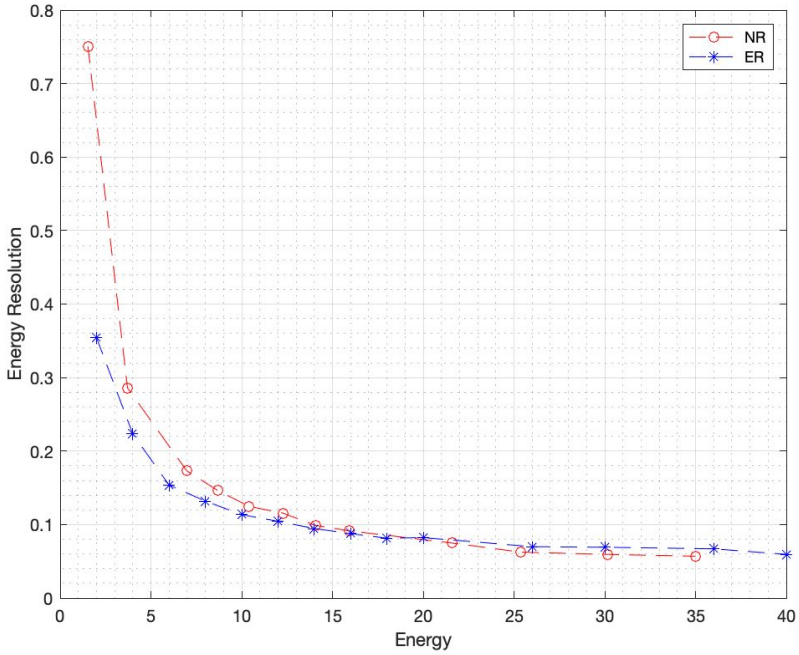
Reconstruction Efficiency



Reconstruction efficiency after 6 keV is 100%.

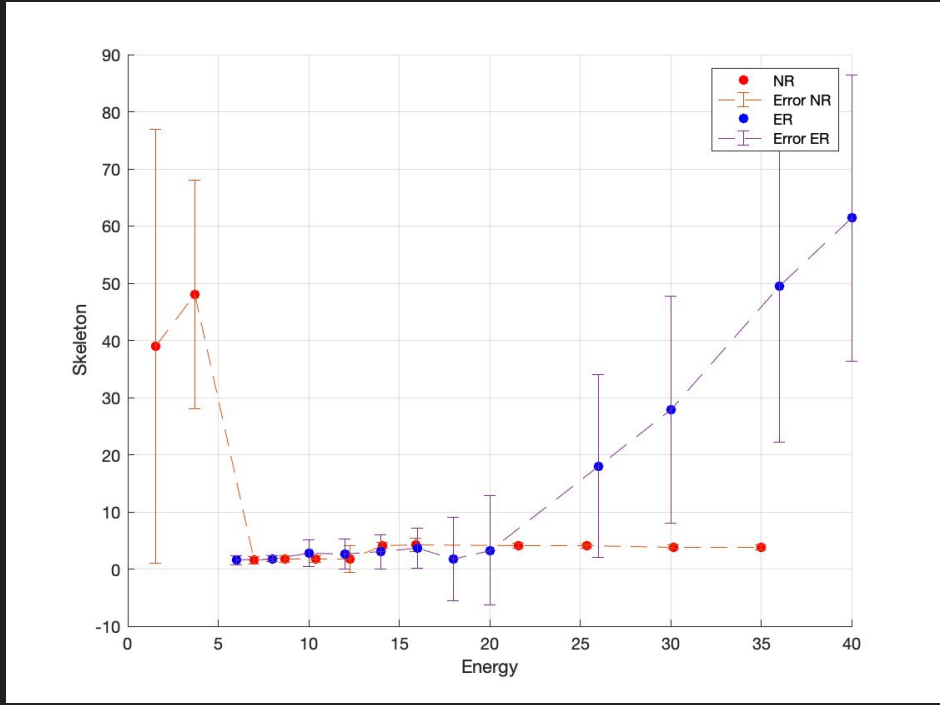
Energy Calibration and Resolution

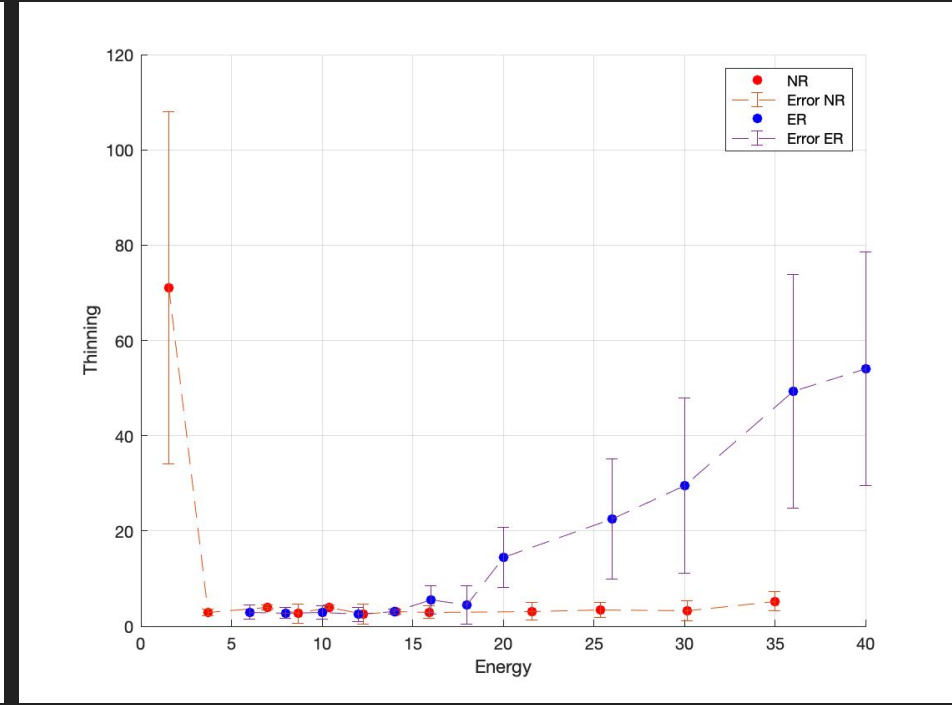




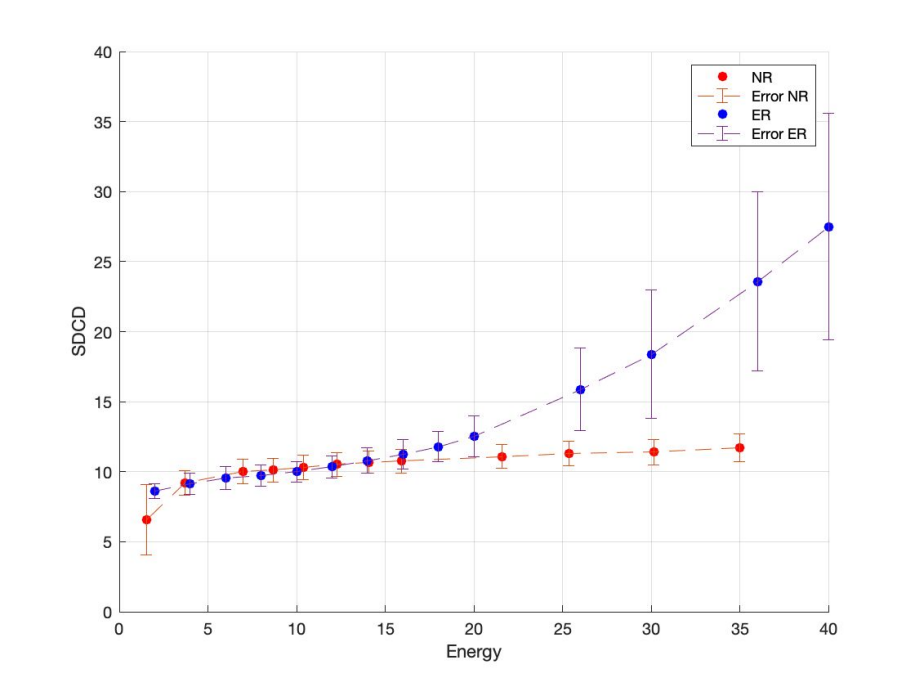
Energy Resolution = Sigma of the integral distribution/Mean of the integral distribution

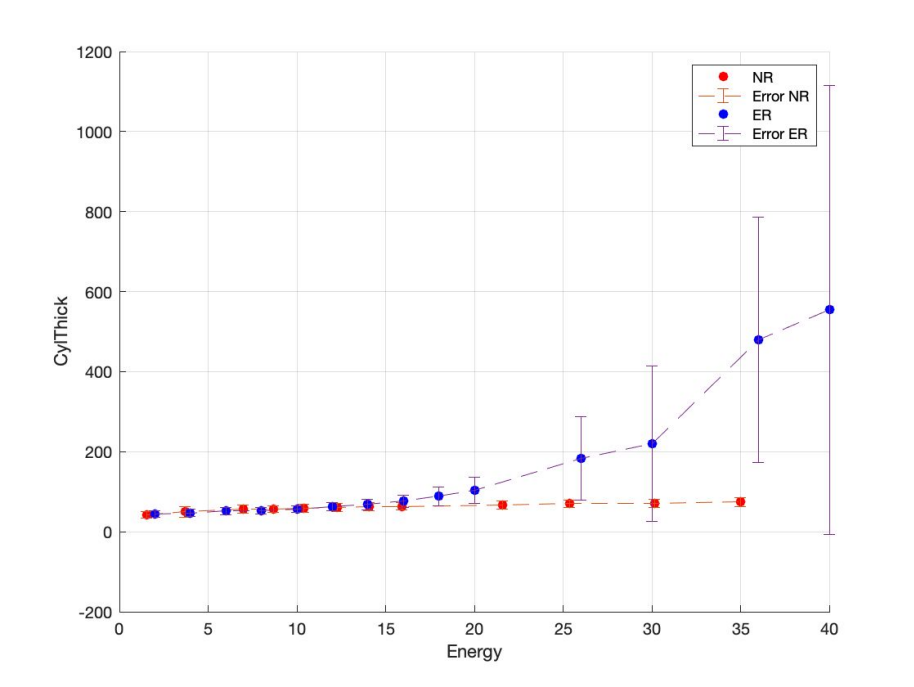
Skeleton vs Energy and Thinning vs Energy



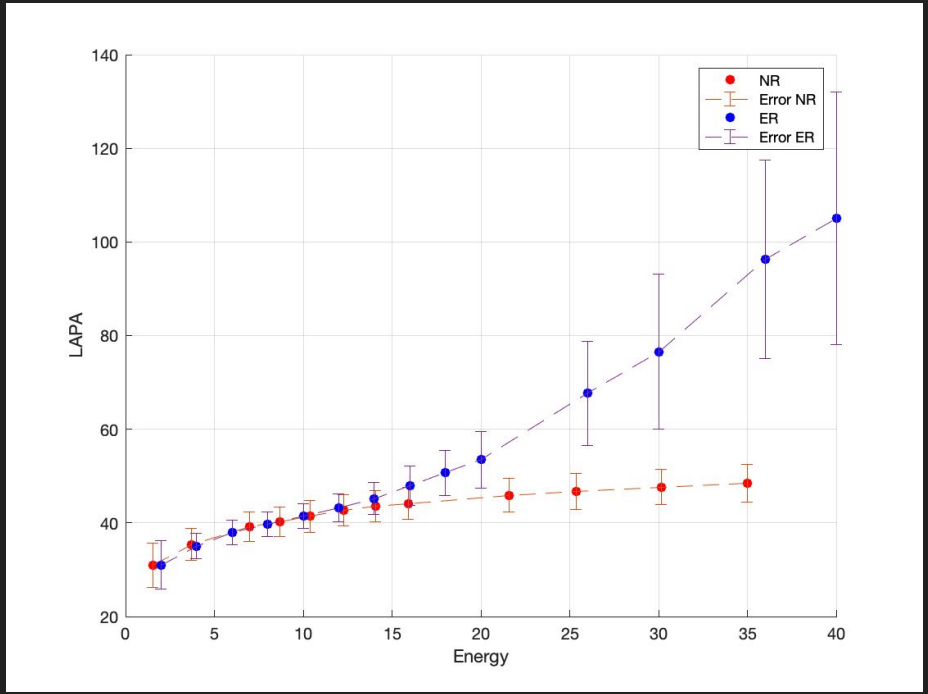


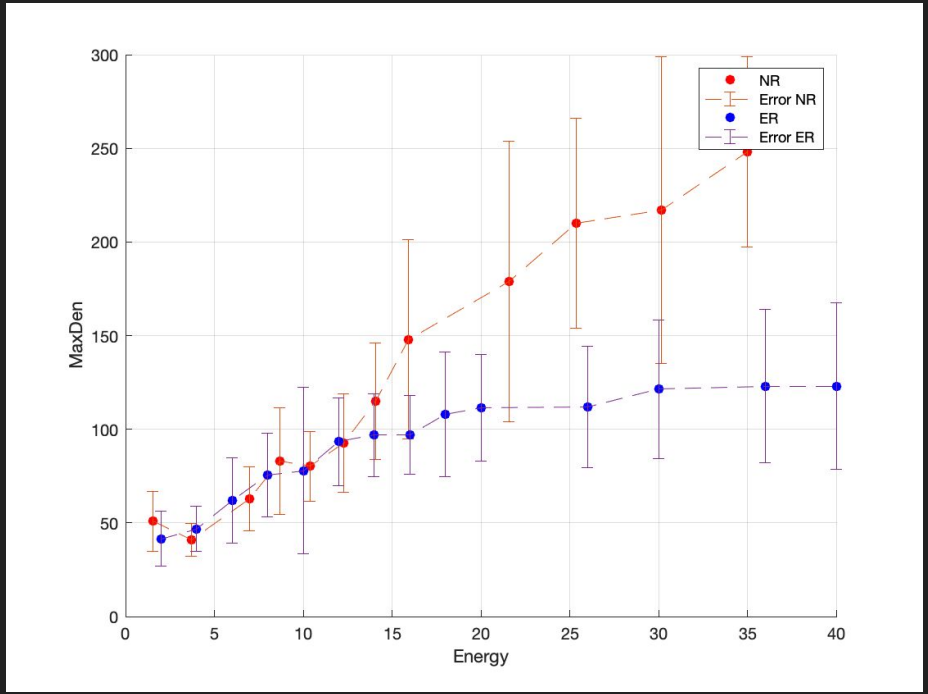
SDCD vs Energy and CylThick vs Energy



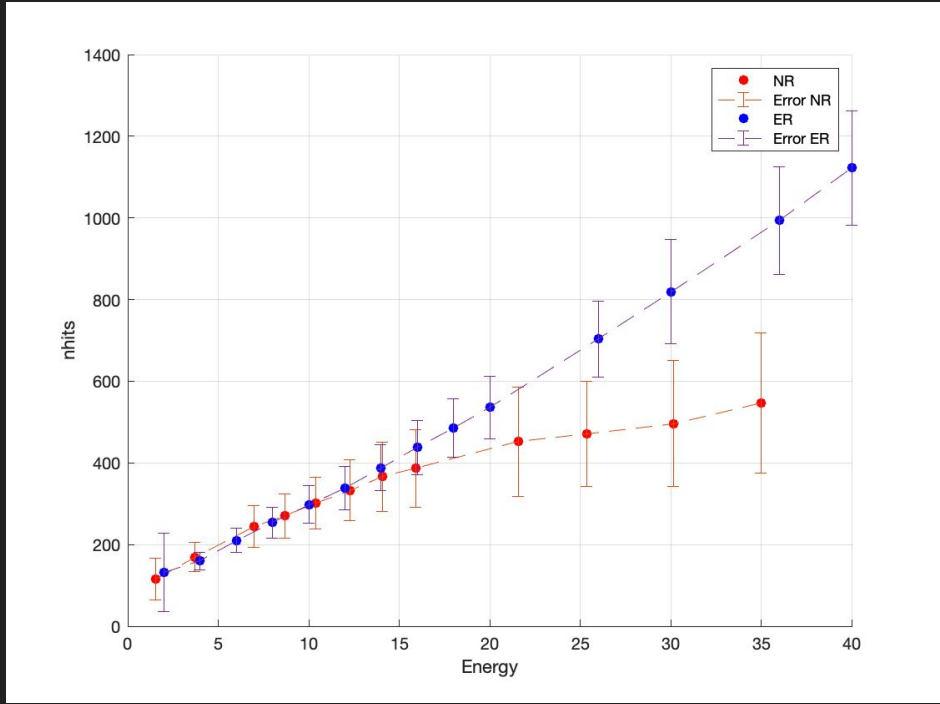


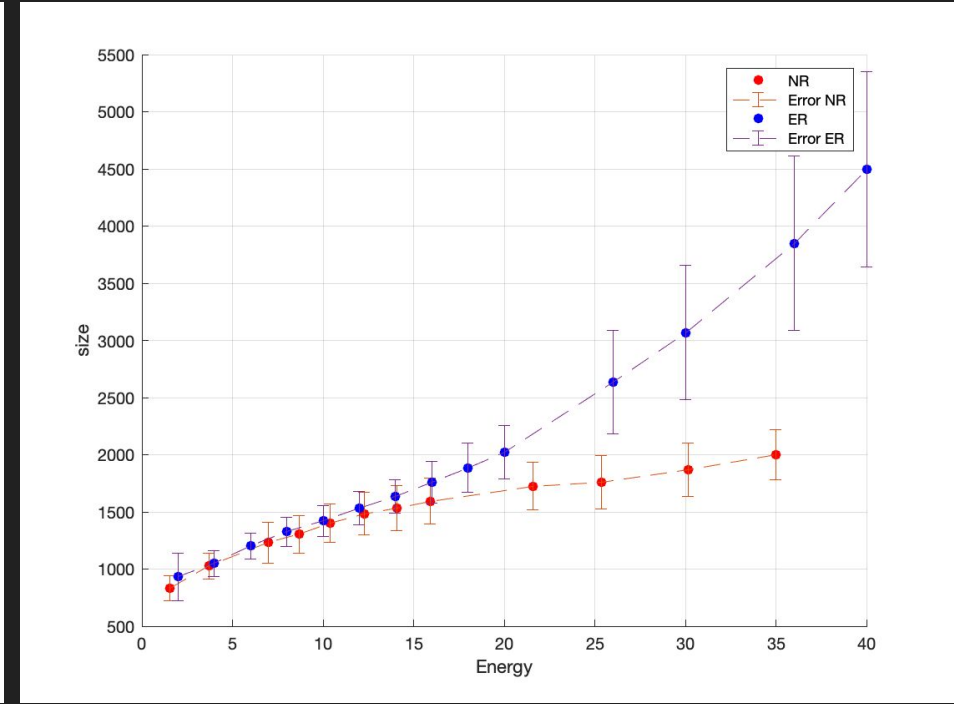
LAPA vs Energy and MaxDen vs Energy



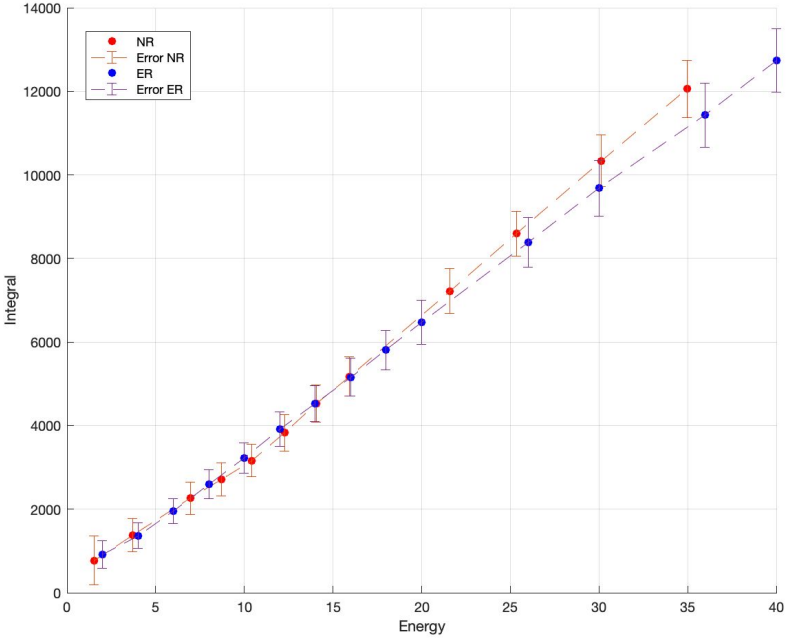


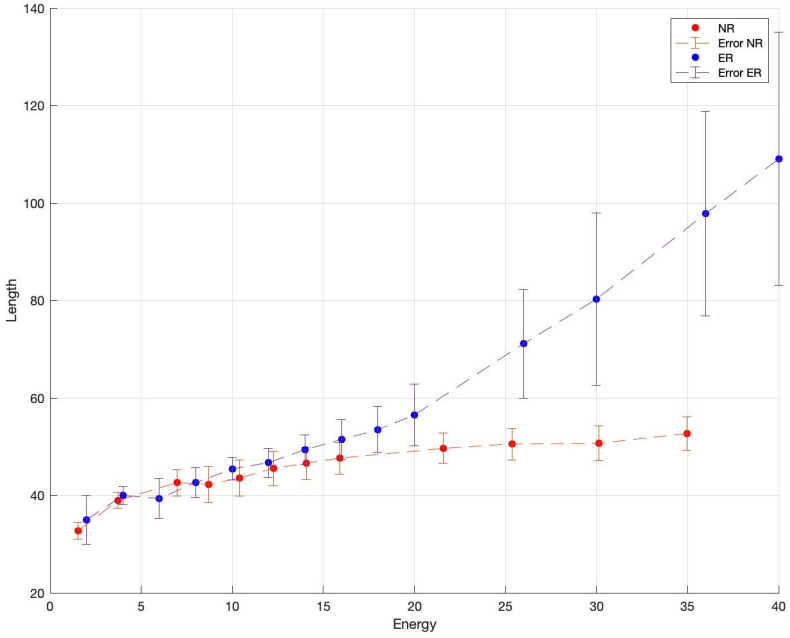
nhits vs Energy and size vs Energy



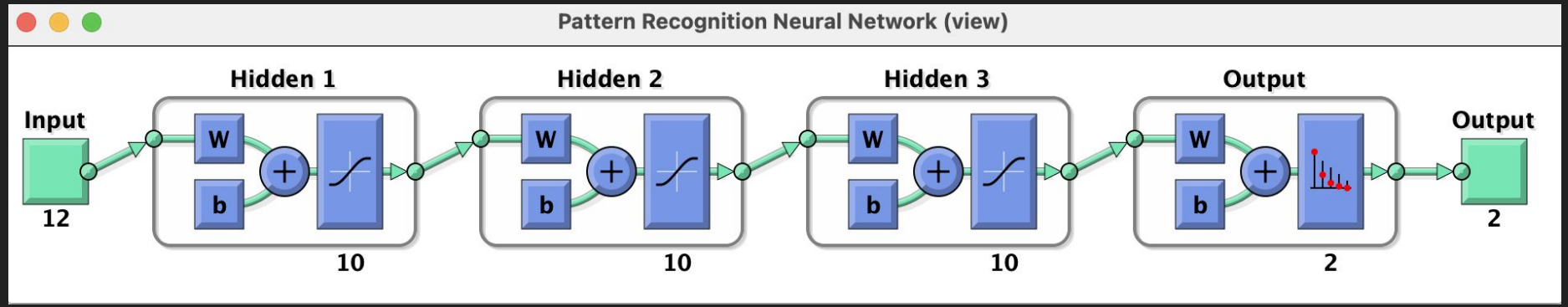


Integral vs Energy and Length vs Energy





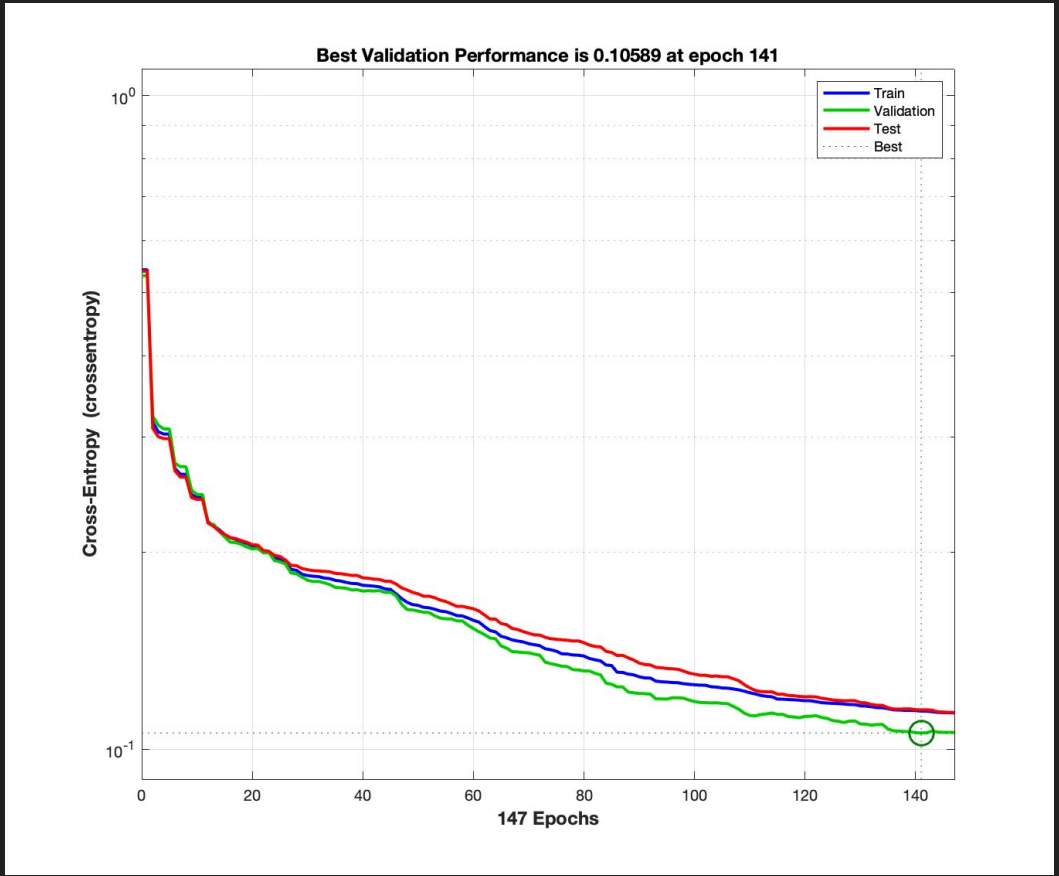
Discrimination using patternnet



Inputs: skel_track, SDCD, CylThick, LAPA, MaxDen, eta, sc_size, sc_nhits, sc_integral, sc_length, delta, slimness
Output: NR, ER

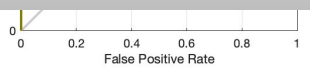
Discrimination at all energies [2-40 keV]

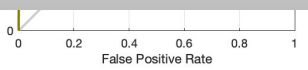
- All the variables shown earlier were given as input along with delta and slimness
- Pattern net with 3 hidden layers of size [10,10,10] neurons were used.
- Data division [90:5:5]
- Training algorithm
  - Scaled conjugate gradient
- Loss: Cross entropy

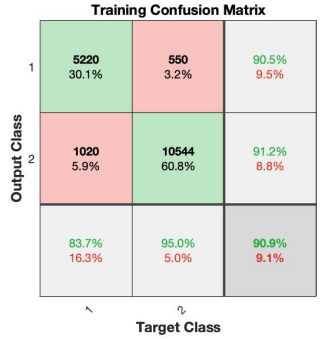


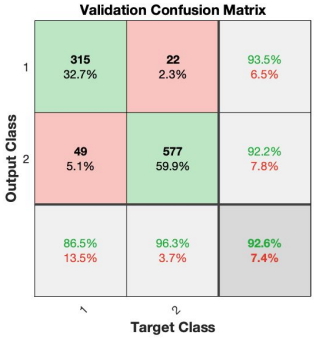
Discrimination at all energies

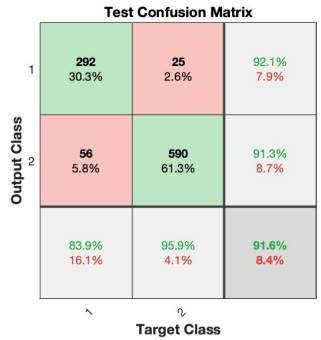
ACTUAL VALUES	PREDICTIVE VALUES: Uninfected	PREDICTIVE VALUES: Infected
Uninfected	TP	FN
Infected	FP	TN

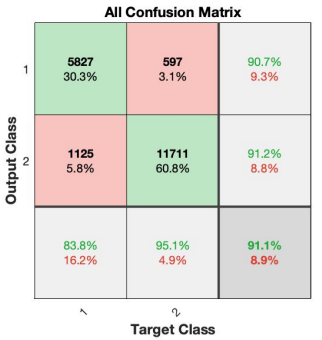




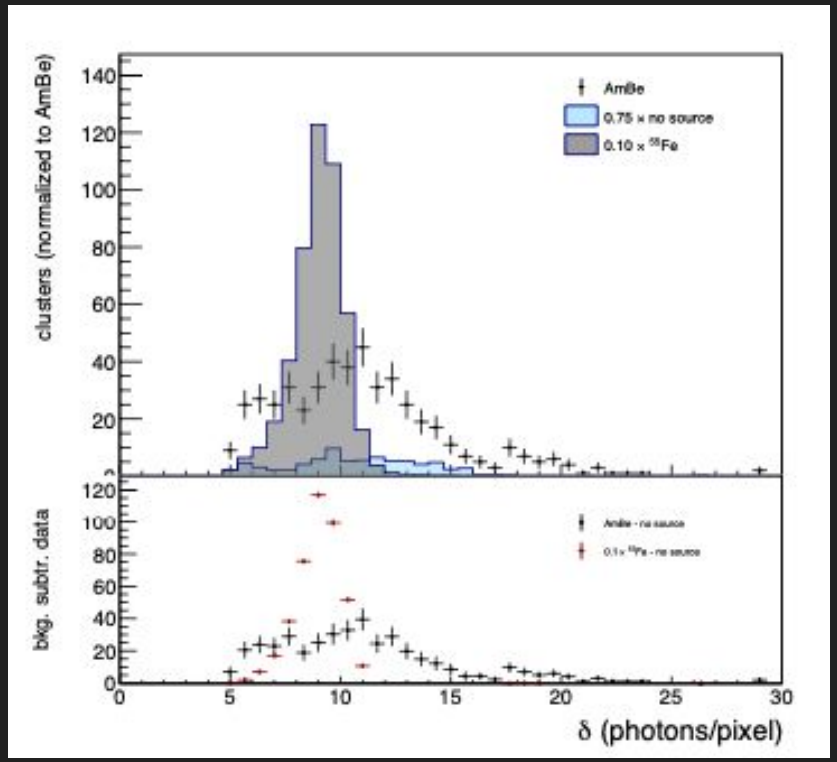


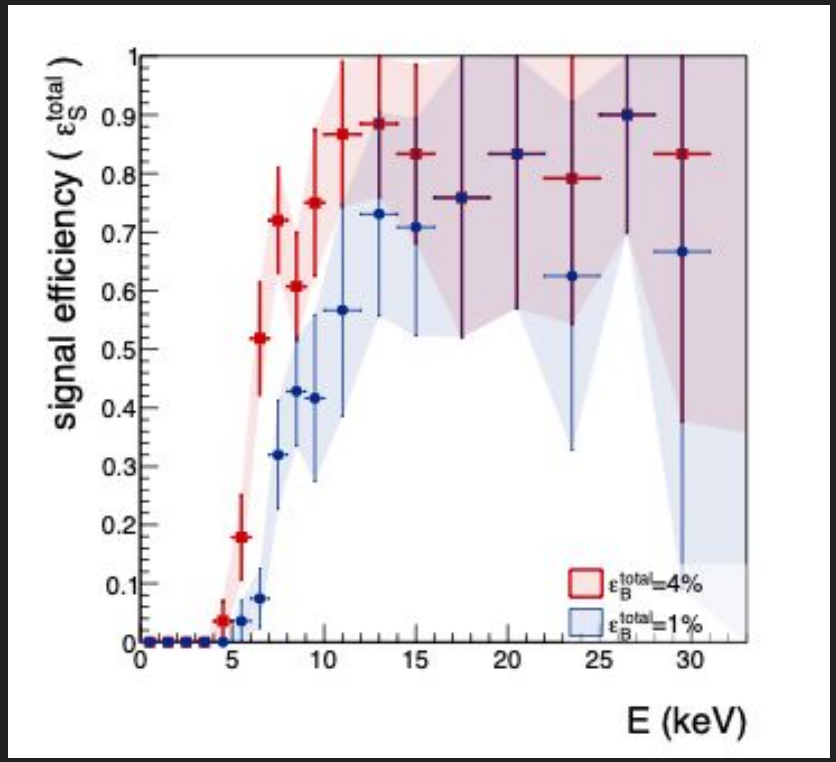




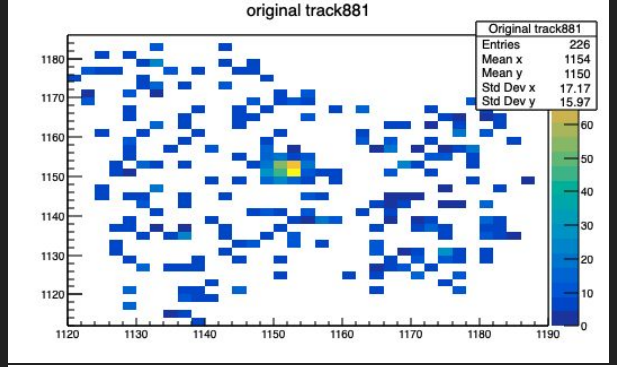


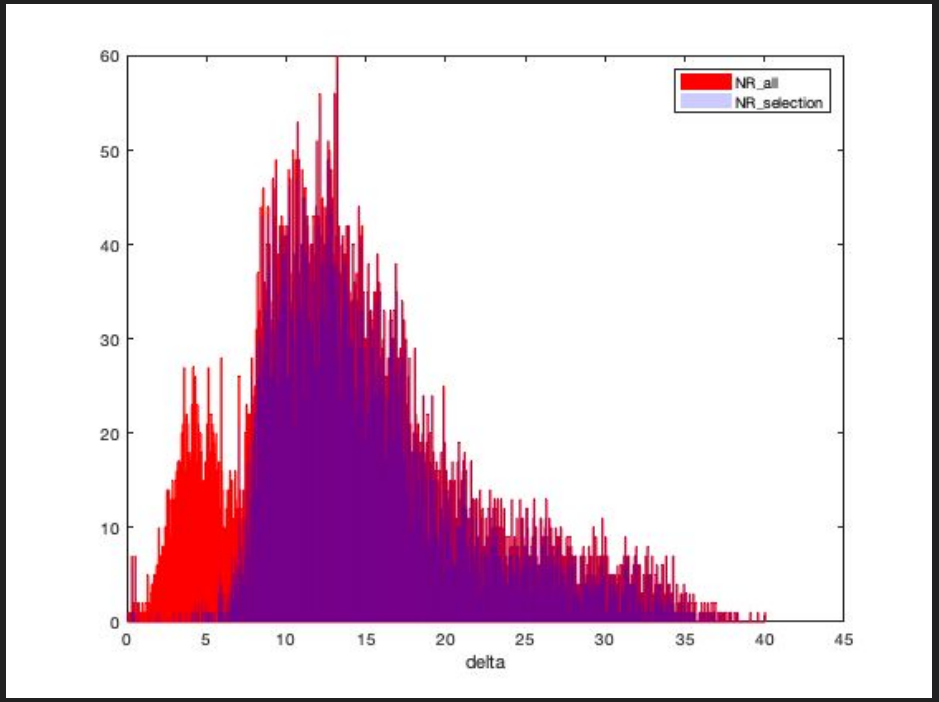
6 keV ER discrimination from NR

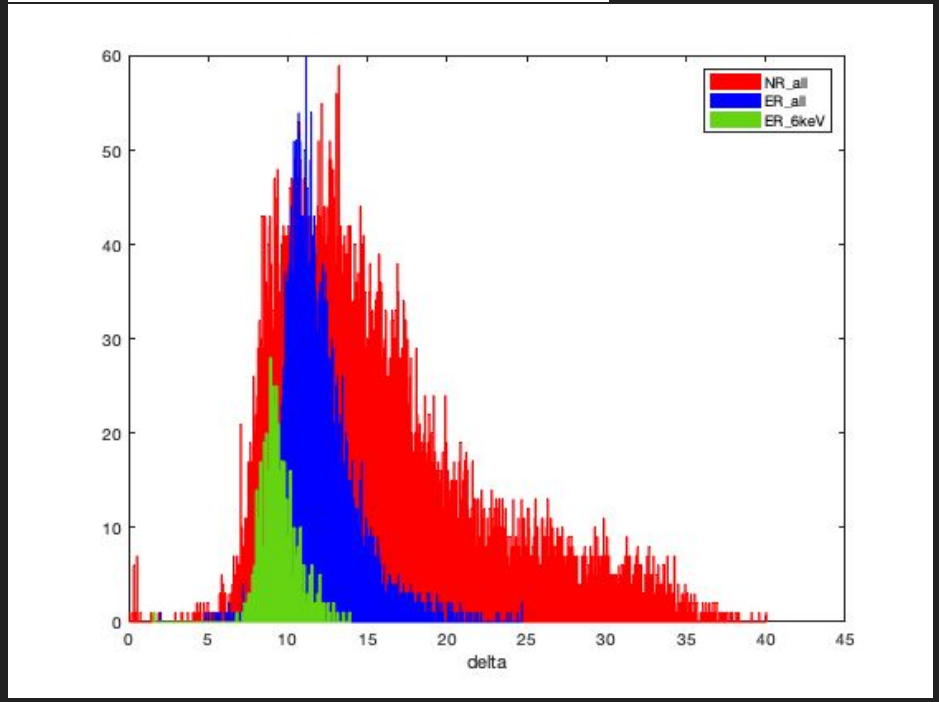




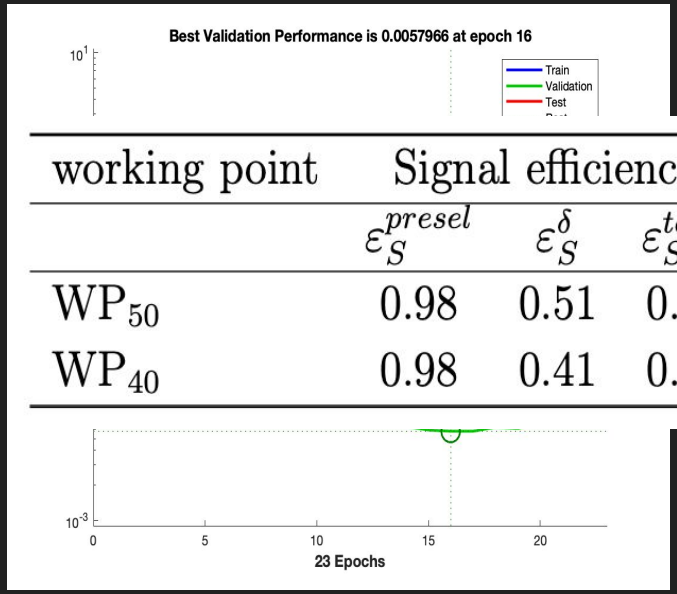
Delta


original track881
Original track881
Entries 226
Mean x 1154
Mean y 1150
Std Dev x 17.17
Std Dev y 15.97

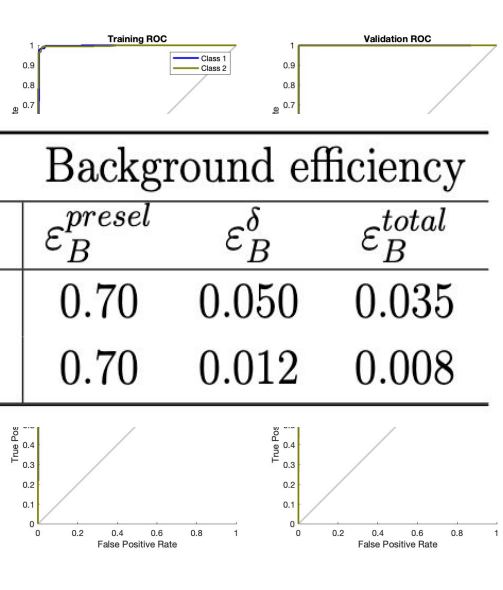

NR_all
NR_selection
delta


NR_all
ER_all
ER_6keV
delta

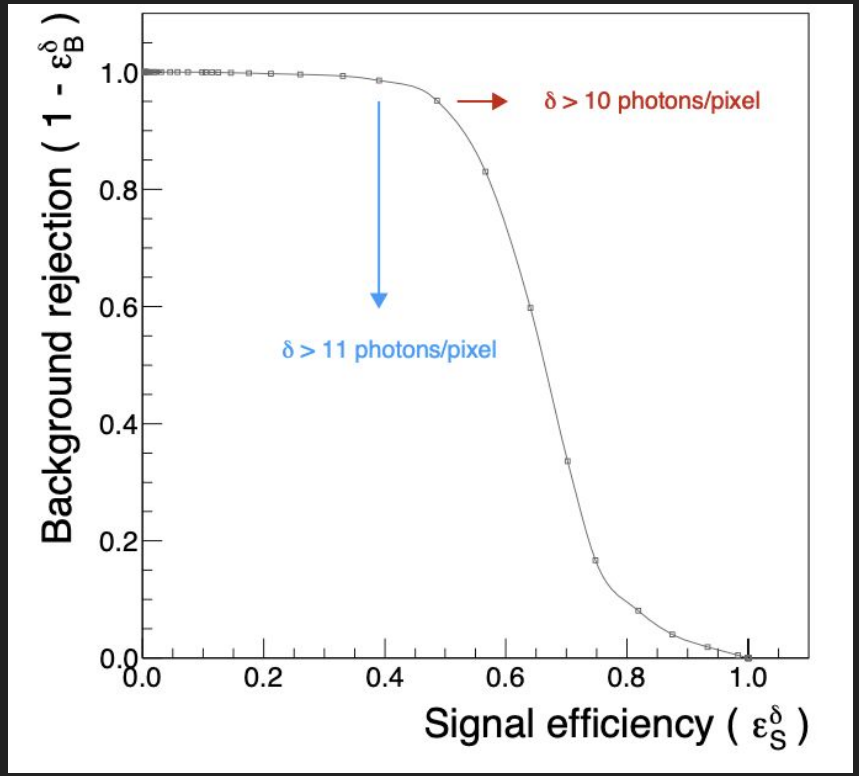
6 keV ER discrimination from NR with delta only

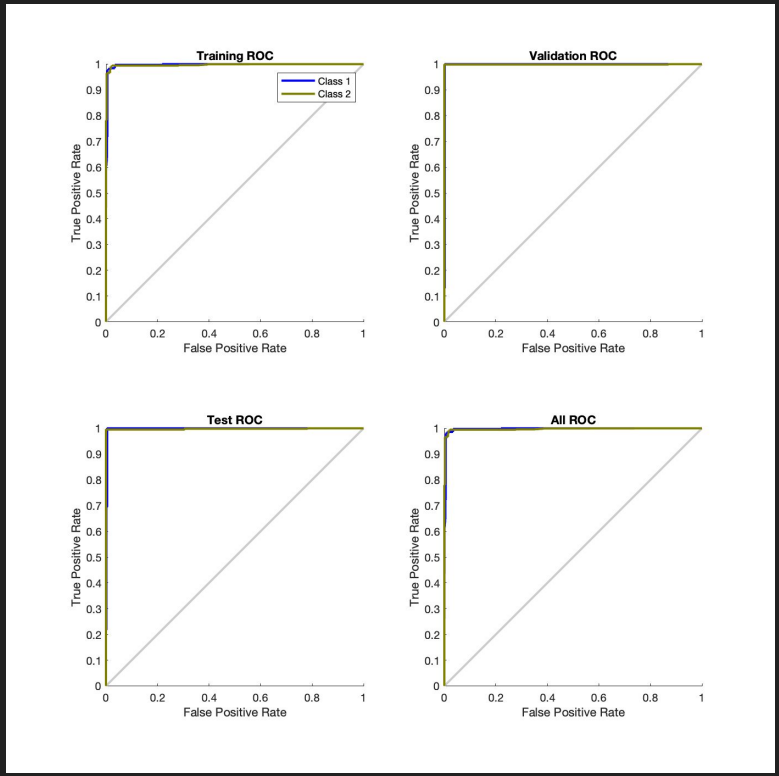


working point	Signal efficiency			Background efficiency		
	ε_S^{presel}	ε_S^{δ}	ε_S^{total}	ε_B^{presel}	ε_B^{δ}	ε_B^{total}
WP_{50}	0.98	0.51	0.50	0.70	0.050	0.035
WP_{40}	0.98	0.41	0.40	0.70	0.012	0.008



Cut on delta and ROC curve





6 keV ER discrimination from NR [2-40 keV]