Classification Without Labels (CWoLa) in CYGNO

Giuseppe Maria Oppedisano 19 - 09 - 2025

Idea

Weakly Supervised Discrimination

- Data driven discrimination between ER and NR
- Already used by ATLAS to solve the Data-MC mismatch
- Weak supervision framework allows us to train on mixed samples, while still learning Signal vs Background discrimination

The CWOLA Approach

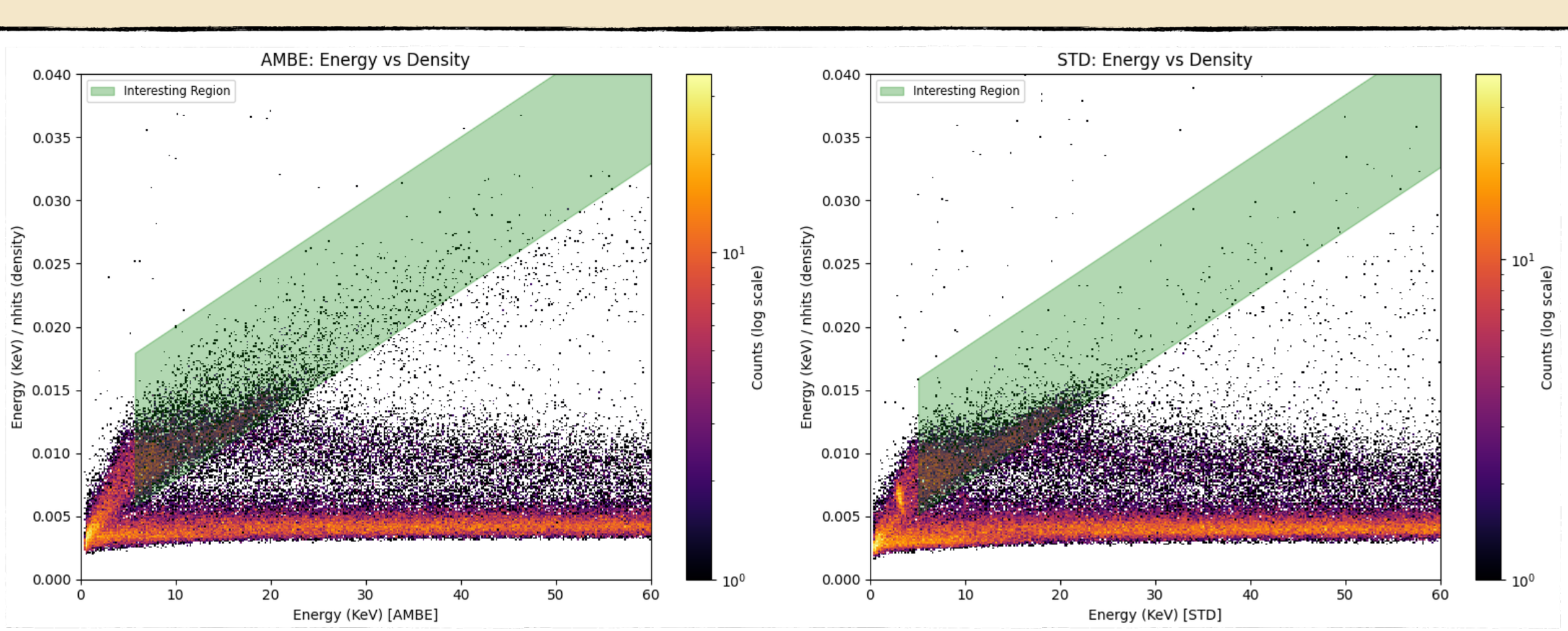
- Consider Two Mixtures with different signal fractions

$$p_{M_1}(\vec{x}) = f_1\, p_S(\vec{x}) + (1 - f_1)\, p_B(\vec{x}),$$

e.g. : AmBe → more NR

$$p_{M_2}(\vec{x}) = f_2\, p_S(\vec{x}) + (1 - f_2)\, p_B(\vec{x}),$$

e.g. : standard



The CWOLA Approach

- The optimal classifier for distinguishing those two misture is

$$L_{M_1/M_2}(\vec{x}) = \frac{f_1 p_S(\vec{x}) + (1-f_1) p_B(\vec{x})}{f_2 p_S(\vec{x}) + (1-f_2) p_B(\vec{x})} .$$

Divide by p_B :

$$L_{M_1/M_2}(\vec{x}) = \frac{f_1 L_{S/B}(\vec{x}) + (1-f_1)}{f_2 L_{S/B}(\vec{x}) + (1-f_2)},$$

$$L_{S/B}(\vec{x}) = \frac{p_S(\vec{x})}{p_B(\vec{x})} .$$

Paper:

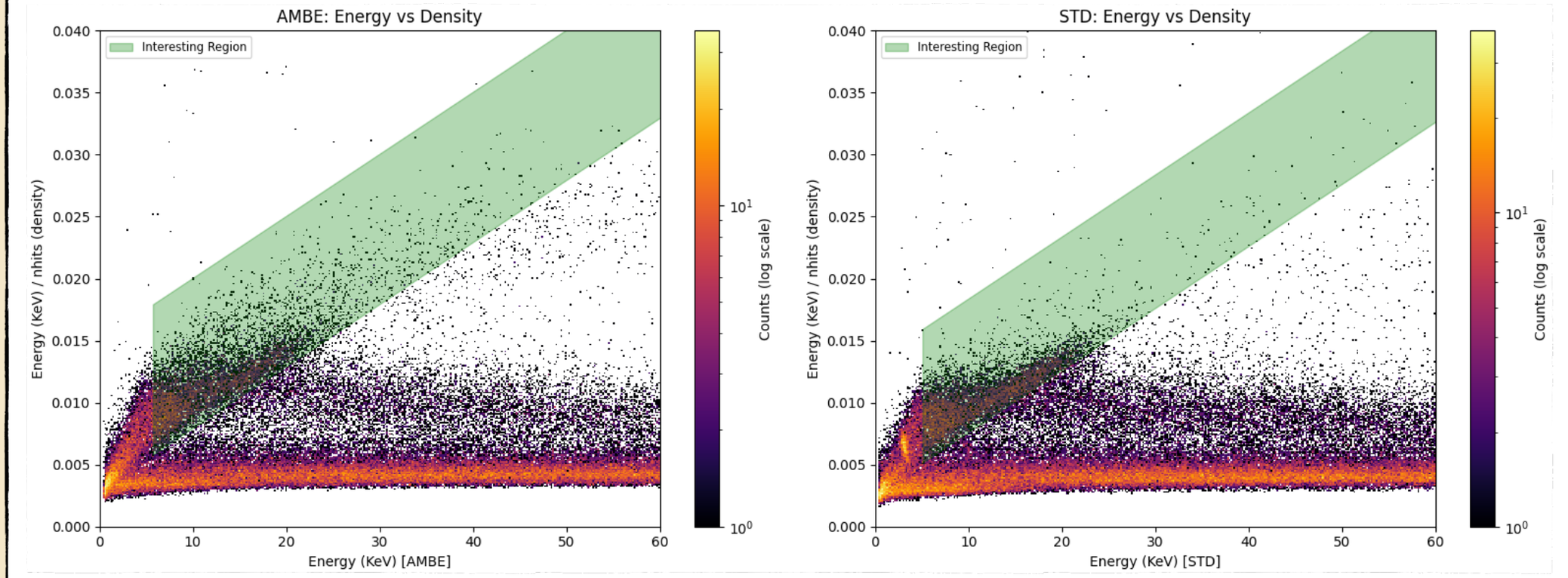
https://arxiv.org/abs/1708.02949

- Also optimal for distinguishing signal vs background!

Expected performance

Simple Estimate of AmBe Induced events

- Consider the expected region for NR in the energy-density plane (GREEN)



- The expected NON NR events can be inferred from STD runs

$$\mu = \frac{N_{STD}}{E_{STD}} E_{AmBe} \quad \Rightarrow \quad X = N_{AmBe} - \mu, \quad \Rightarrow \quad AF_e = \frac{X}{N_{AmBe}}$$

Expected performance

Simple Estimate of AmBe Induced events

- The fraction of events attributable to AmBe is:

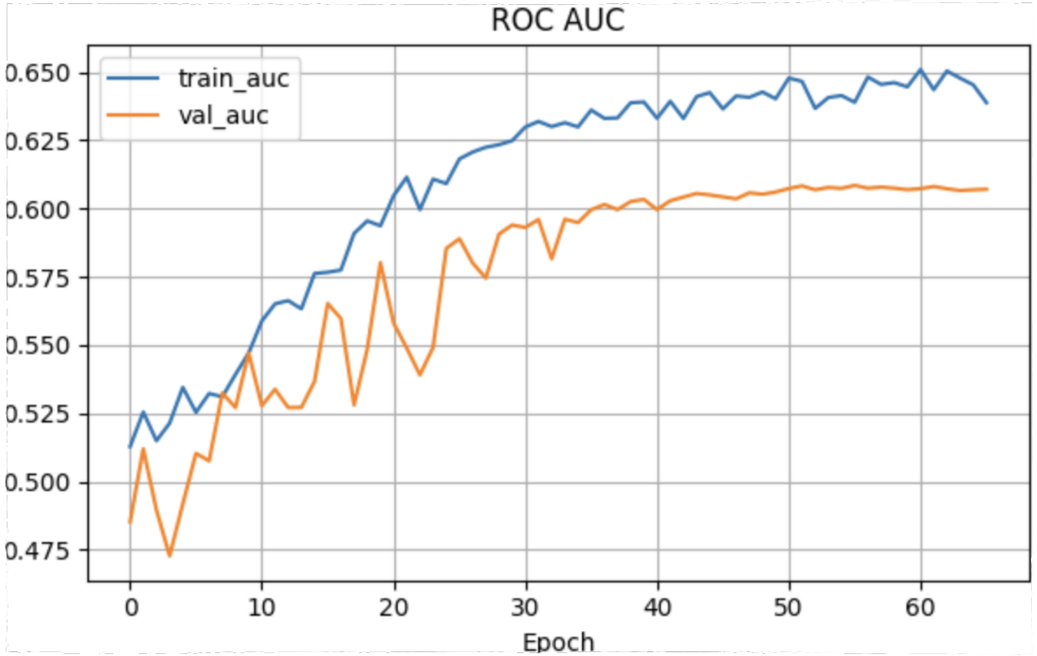
$$AF_e = (32.0 \pm 0.9)\,\%$$

- Therefore the mixture can be modelled as:

$$p_{AmBe}(x) \;=\; \alpha\, S(x) + (1-\alpha)\, B(x), \qquad \alpha = AF_e,$$

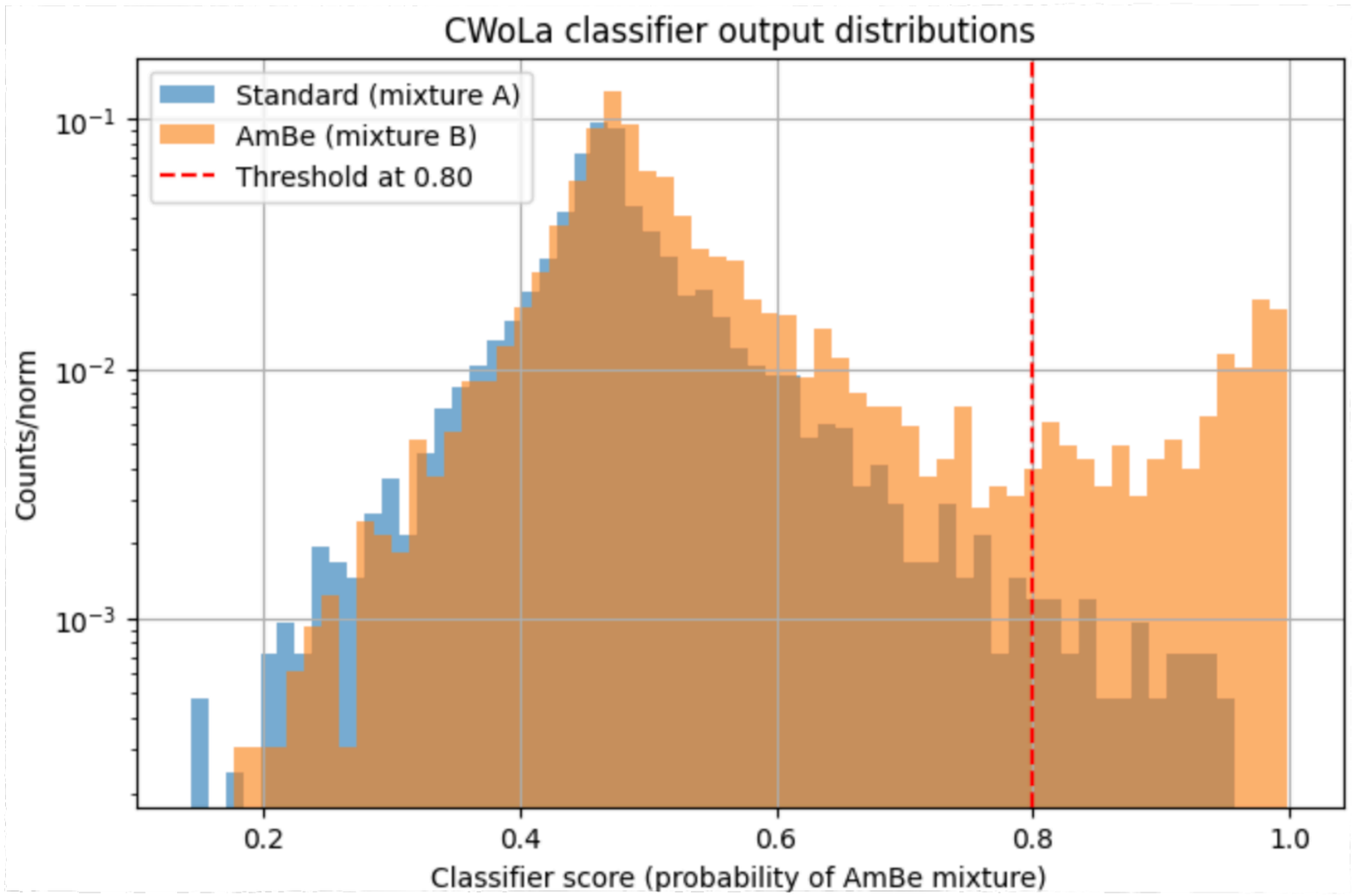
- The Maximum AUC achievable for the model is

$$\mathrm{AUC}_{\max} \;=\; (1-\alpha)\cdot 0.5 + \alpha \cdot 1.0 \;=\; 0.5 + \frac{\alpha}{2} \;=\; 0.660 \pm 0.005$$



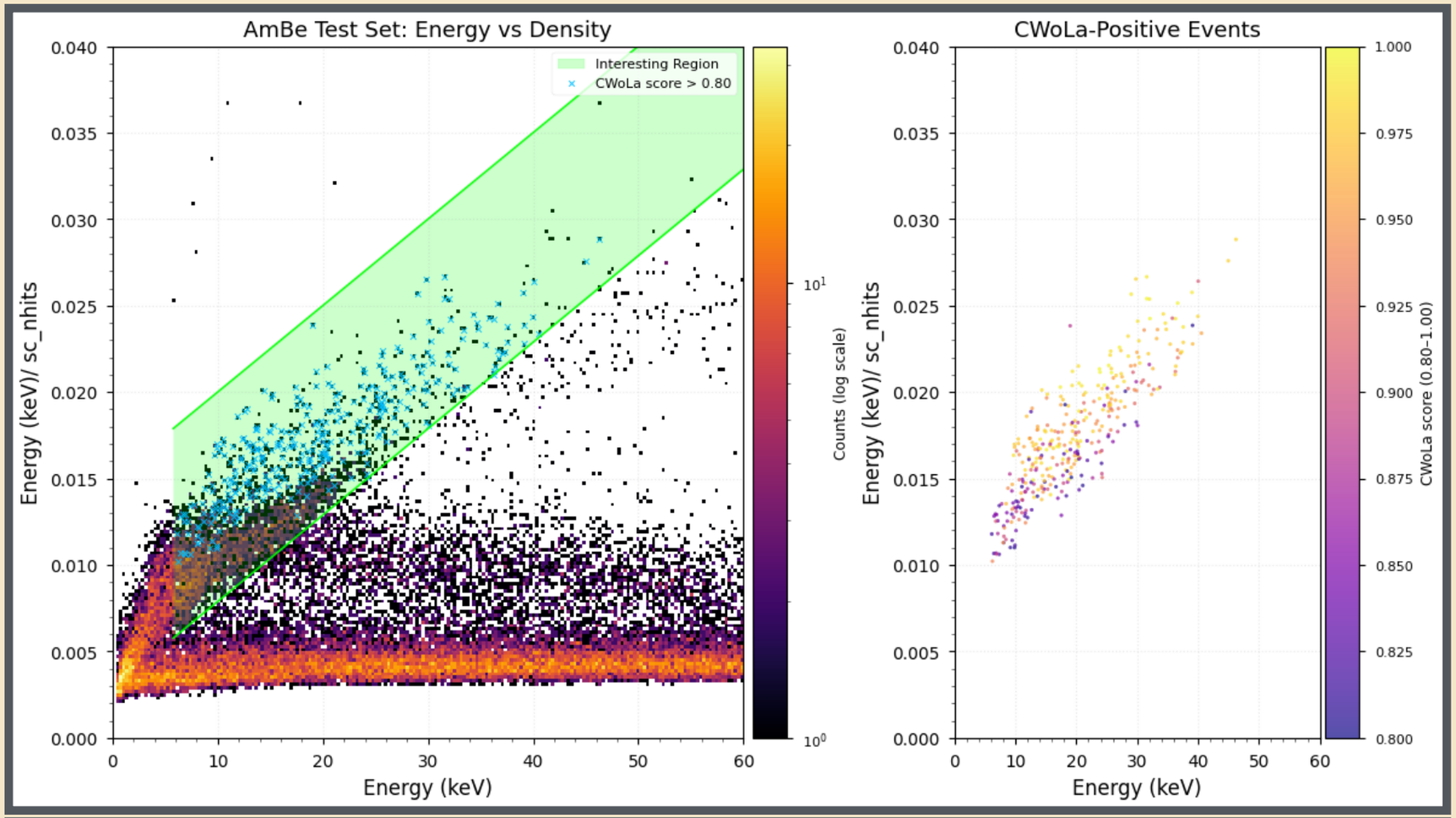
←—Train and Validation performance approaches 0.66

Threshold Evaluation

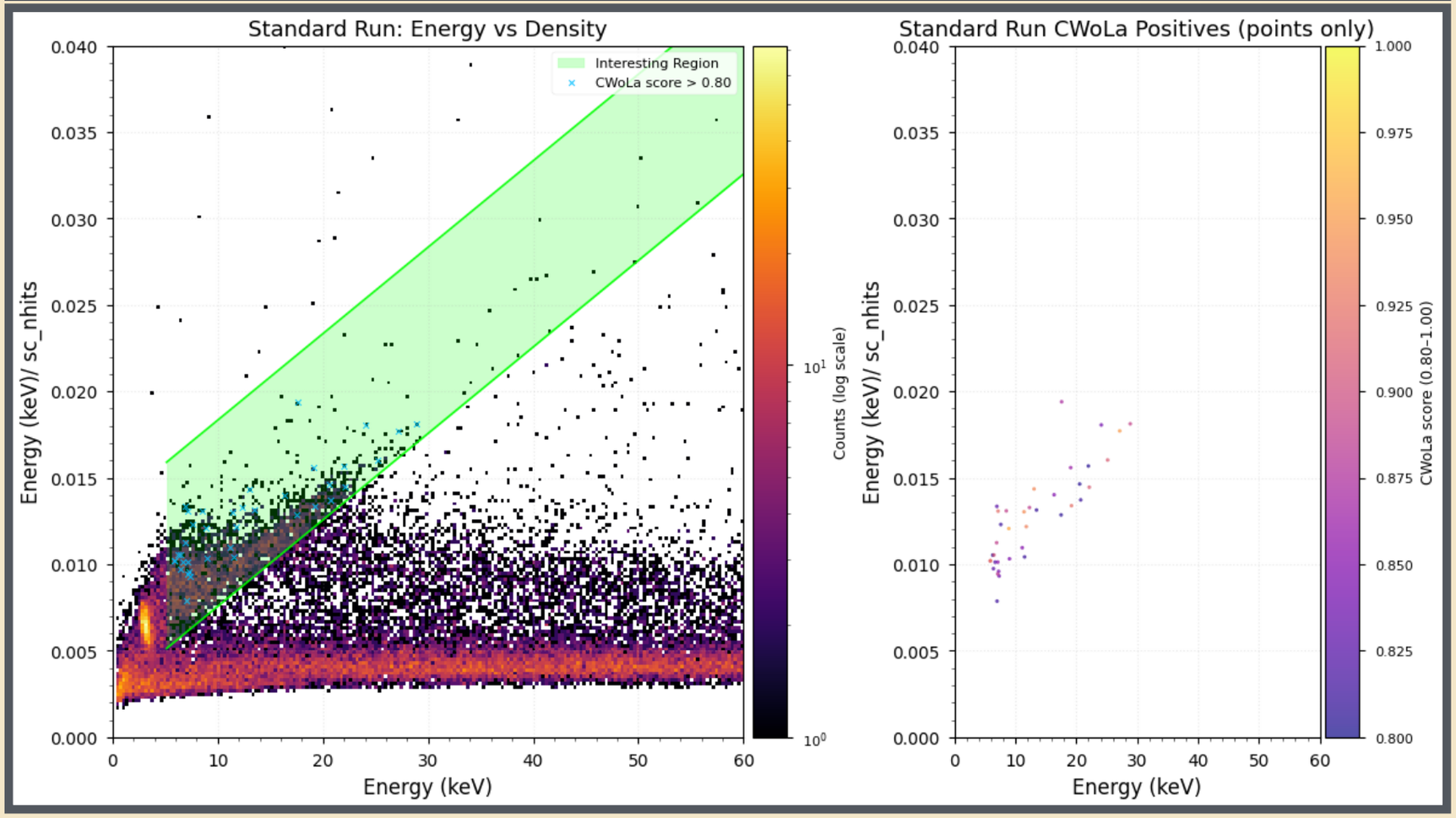


- High score events → NR
- Treshold manually set

Evaluation

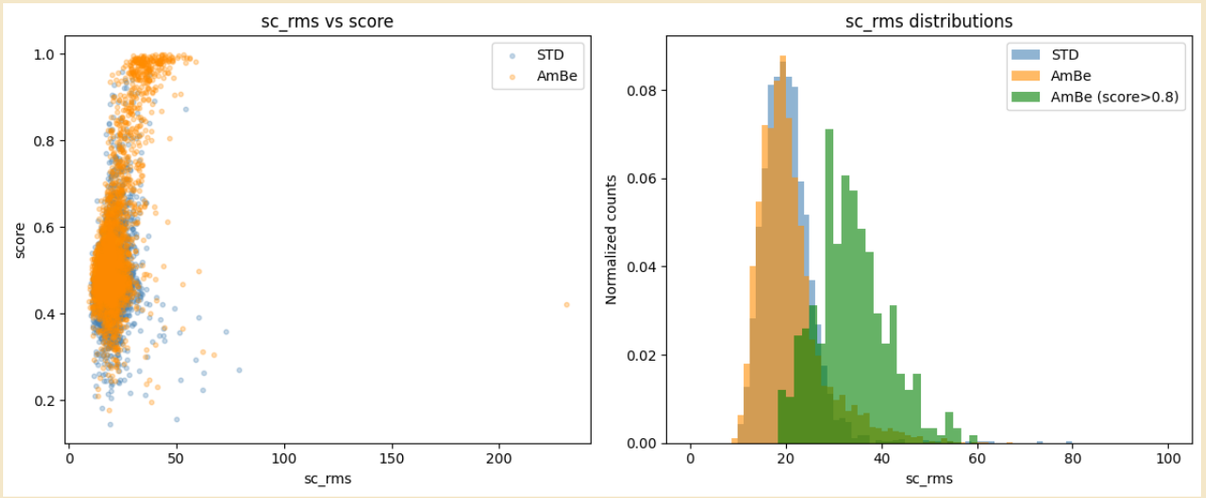


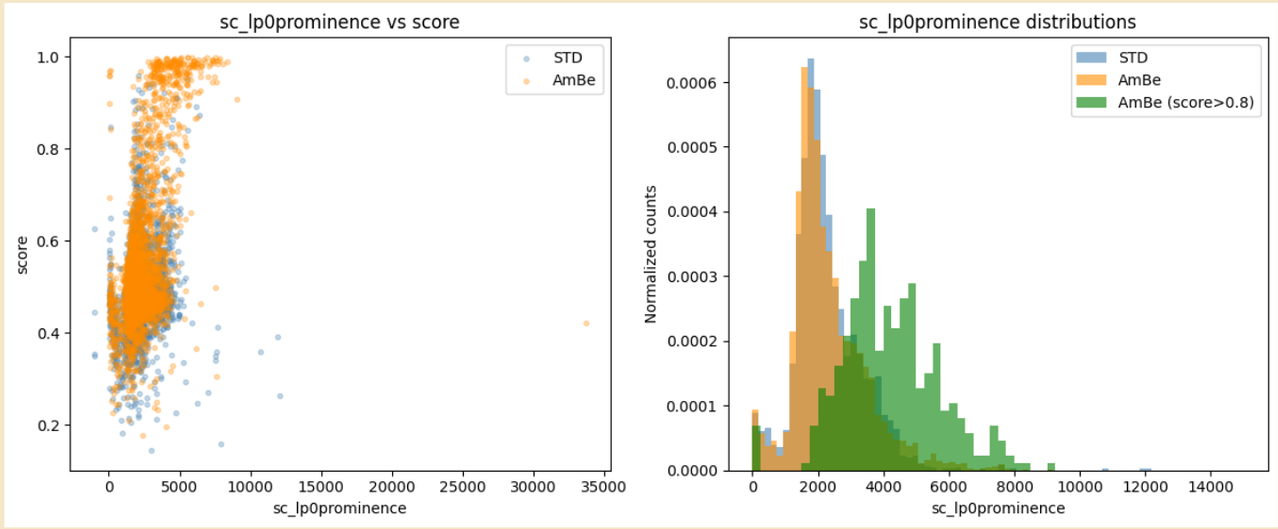
← AmBe

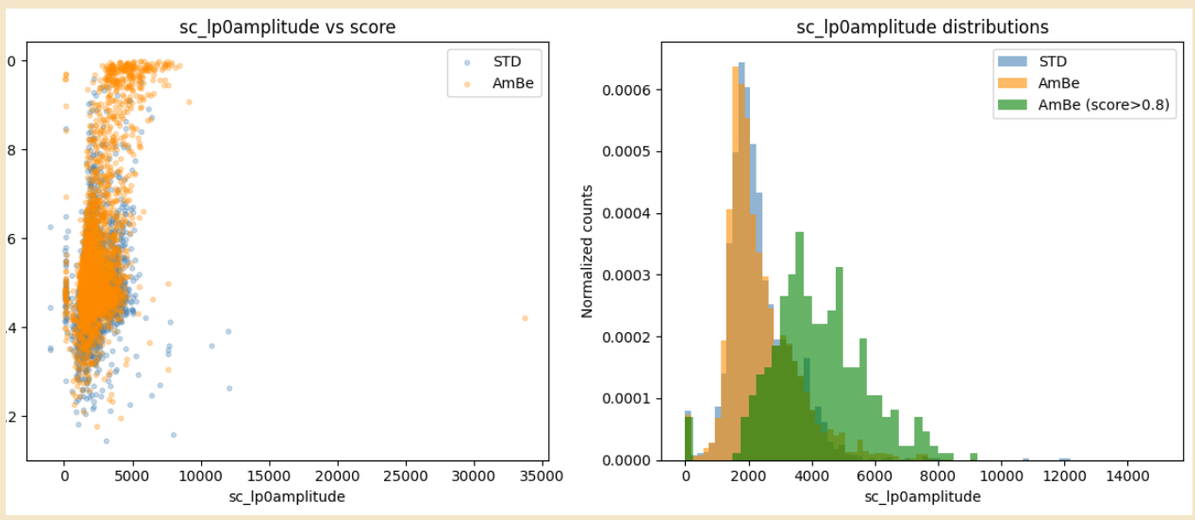


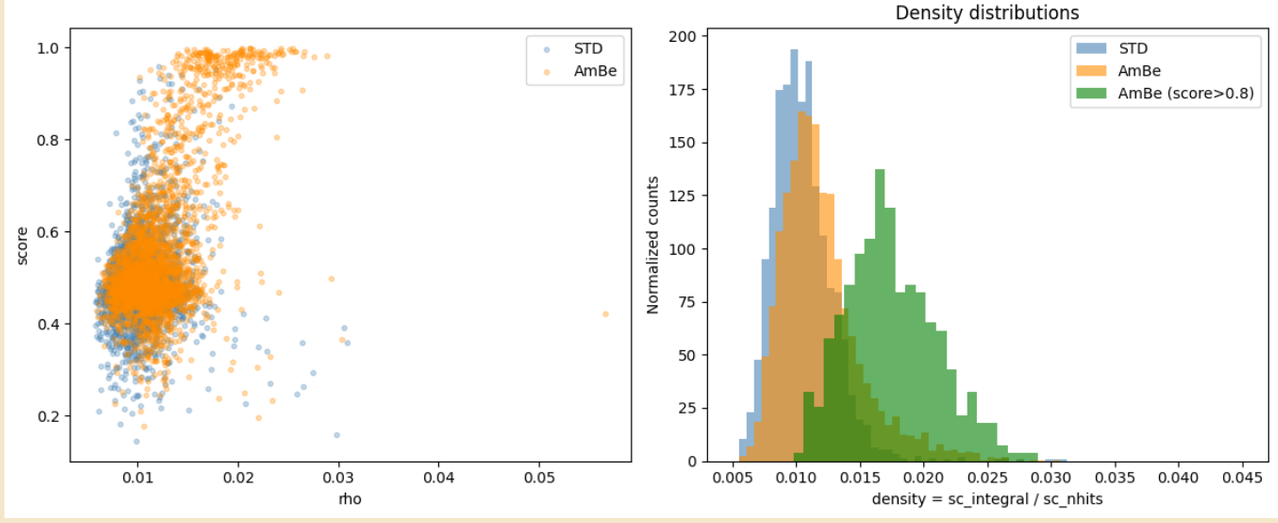
← STD

What is the network learning?









Correlation with score

density	0.585523
sc_rms	0.565696
sc_lp0prominence	0.531486
sc_lp0amplitude	0.524940

THANKS FOR THE ATTENTION