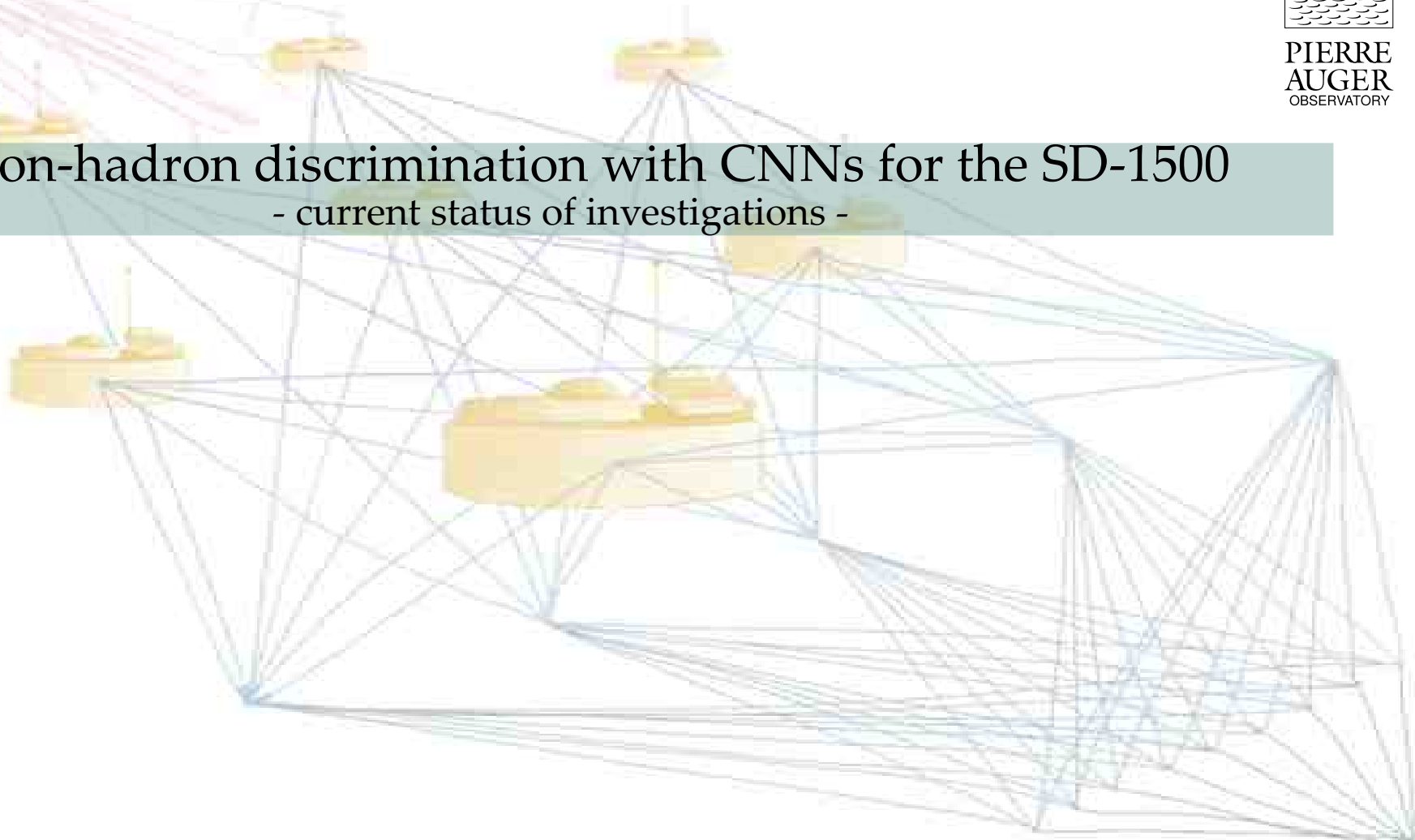
Photon-hadron discrimination with CNNs for the SD-1500

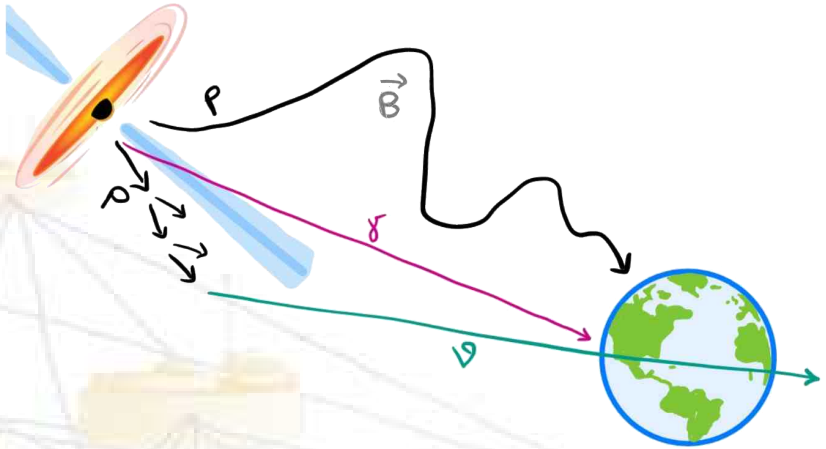
- current status of investigations -

Fiona Ellwanger,
Ralph Engel,
Markus Roth,
David Schmidt,
Darko Veberic



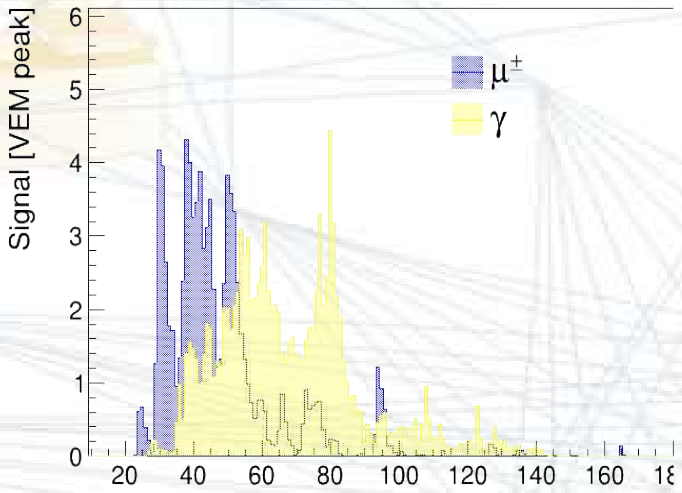
Ultra-high energy photons

- Many models for the origin of cosmic rays predict also UHE γs
- γs directly point back to their source
- No UHE γs have been identified so far



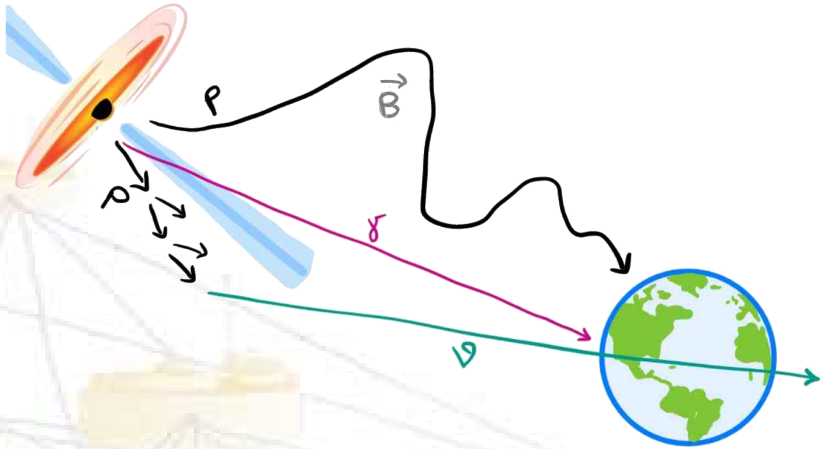
UHE γs at the Pierre Auger Observatory

- 10^{18} – 10^{20} eV
- Distances up to ~Mpc can be probed
- Signature of UHE γs: almost purely electromagnetic shower composition
  - Steeper falling of the LDF
  - Slower rise in the signal of one station



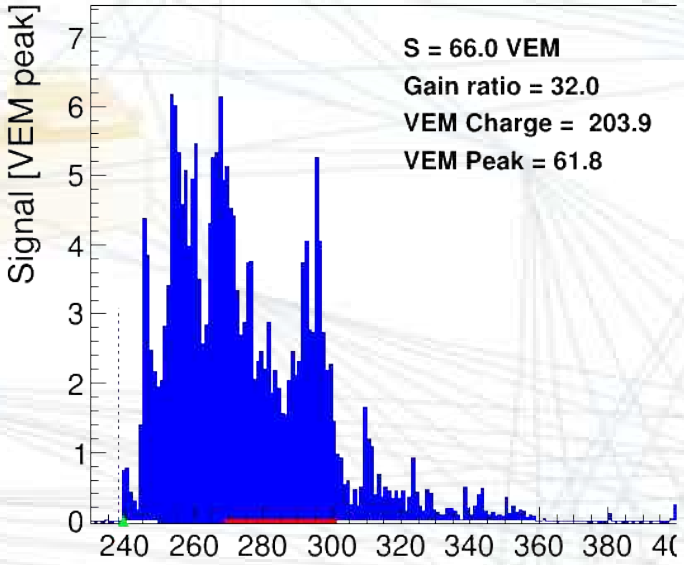
Ultra-high energy photons

- Some models for the origin of cosmic rays predict also UHE γs (*low flux however :(*)
- γs directly point back to their source
- No UHE γs have been identified so far



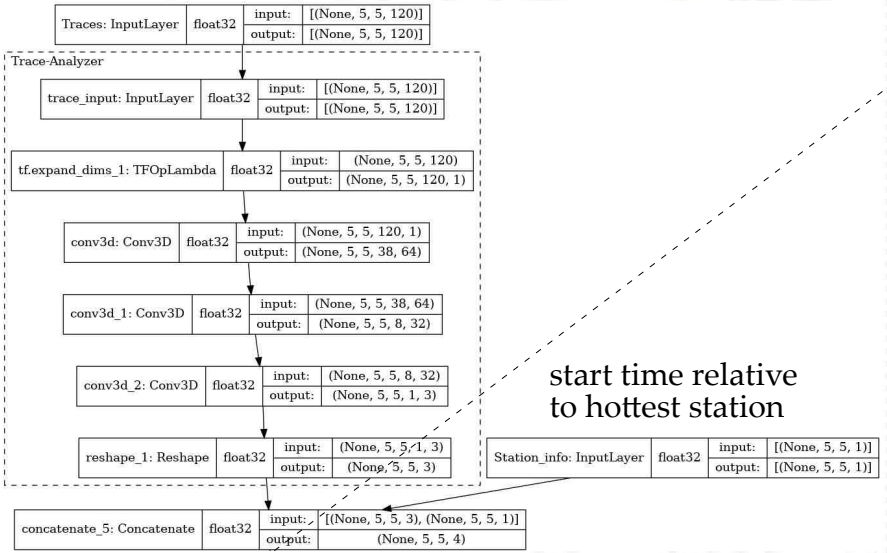
UHE γs at the Pierre Auger Observatory

- 10^{18} – 10^{20} eV
- Distances up to ~Mpc can be probed
- Signature of UHE γs: almost purely electromagnetic shower composition
  - Steeper falling of the LDF
  - Slower rise in the signal of one station

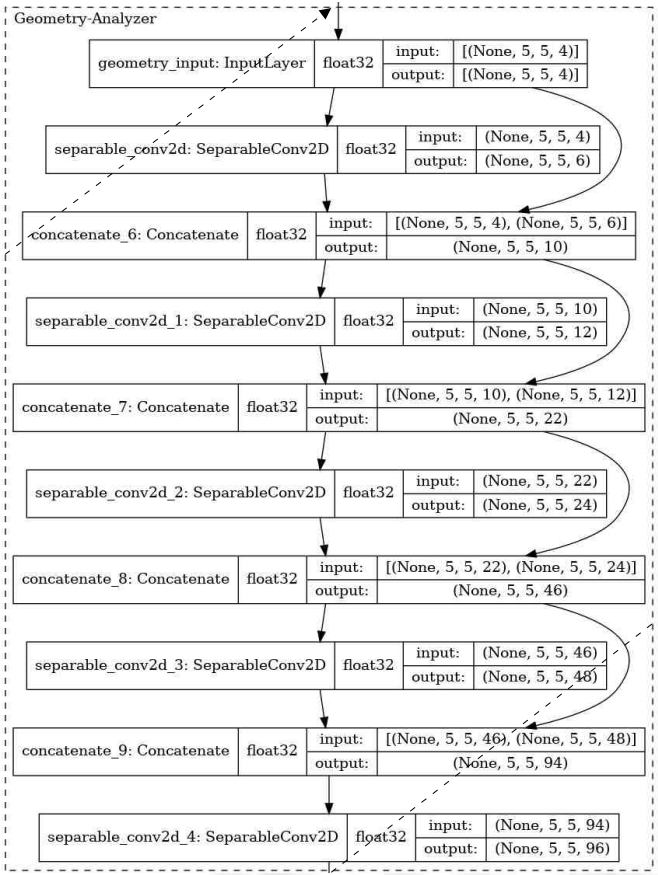


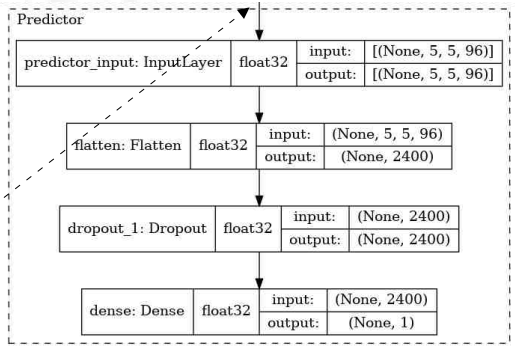
The network architecture

$$\frac{\lg(S/\mathrm{VEM}+1)}{\lg(101)}$$



start time relative to hottest station

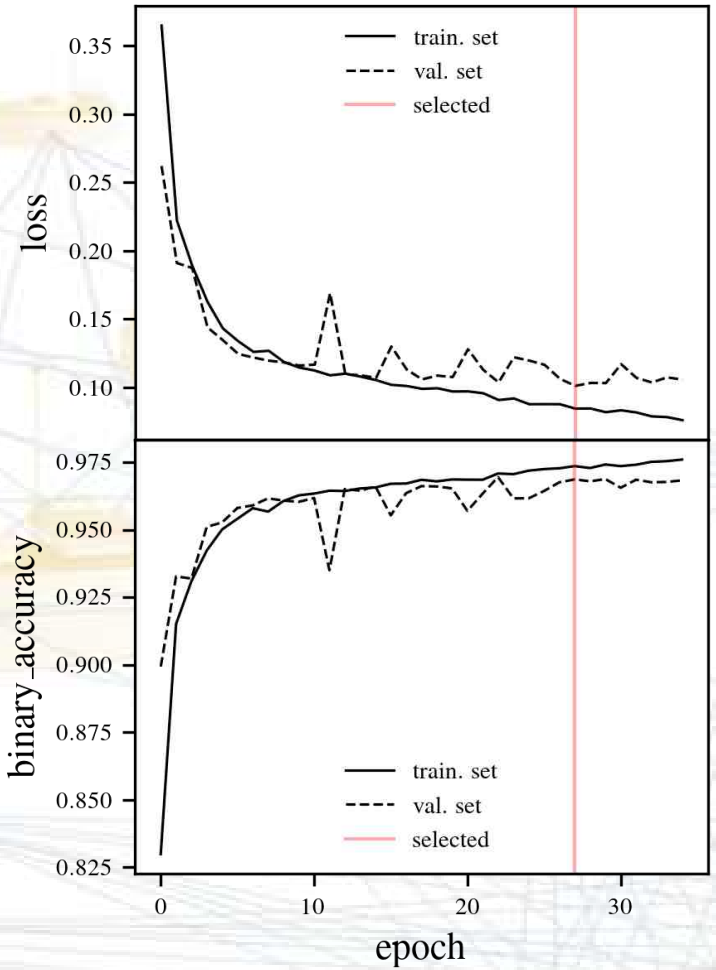




31 726 trainable parameters

The network training

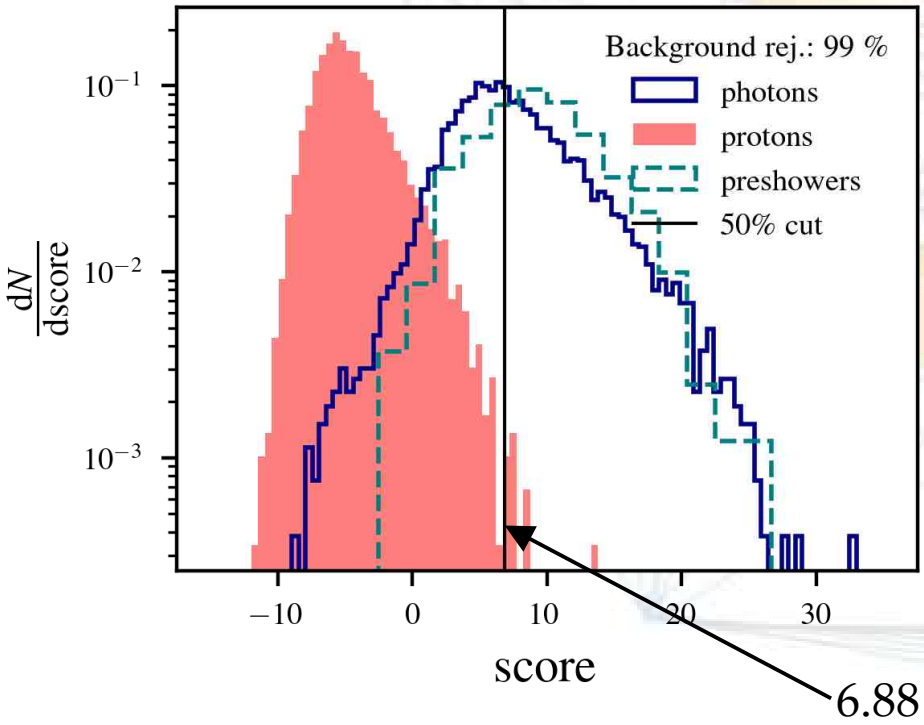
- loss: binary crossentropy
- training data ($18 < \lg(E/\mathrm{eV}) < 20.2$):
  - ~41 000 Photons (Offline from 4.10.23)
  - ~43 000 Protons (Offline from 17.08.23)
  - **New simulations are almost done …**



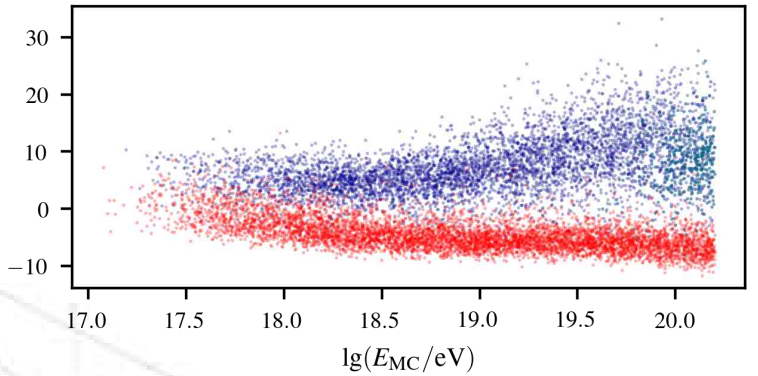
Evaluation of the network

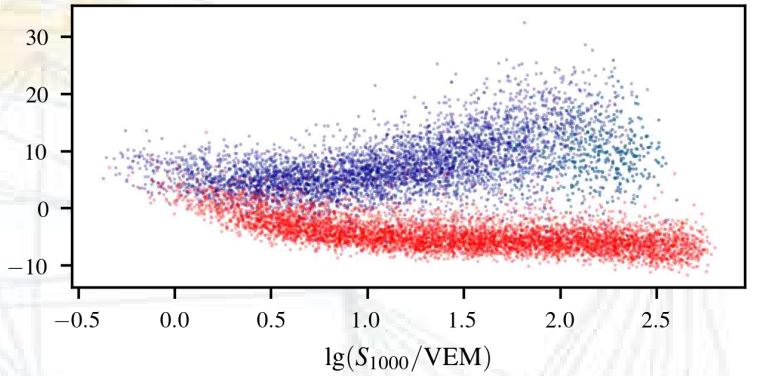
$17 < \lg(E/\mathrm{eV}) < 20.2$

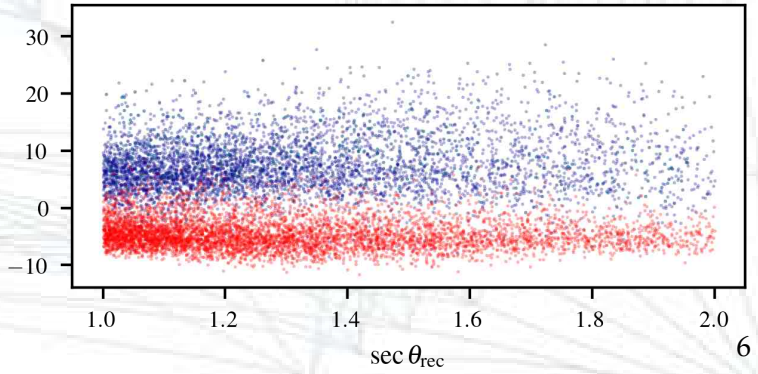
- 6219 Protons (Offline from 8.04.24)
- 5561 Photons (Offline from 8.04.24)



Successful LDF
$\Theta_{rec} < 60^{o}$



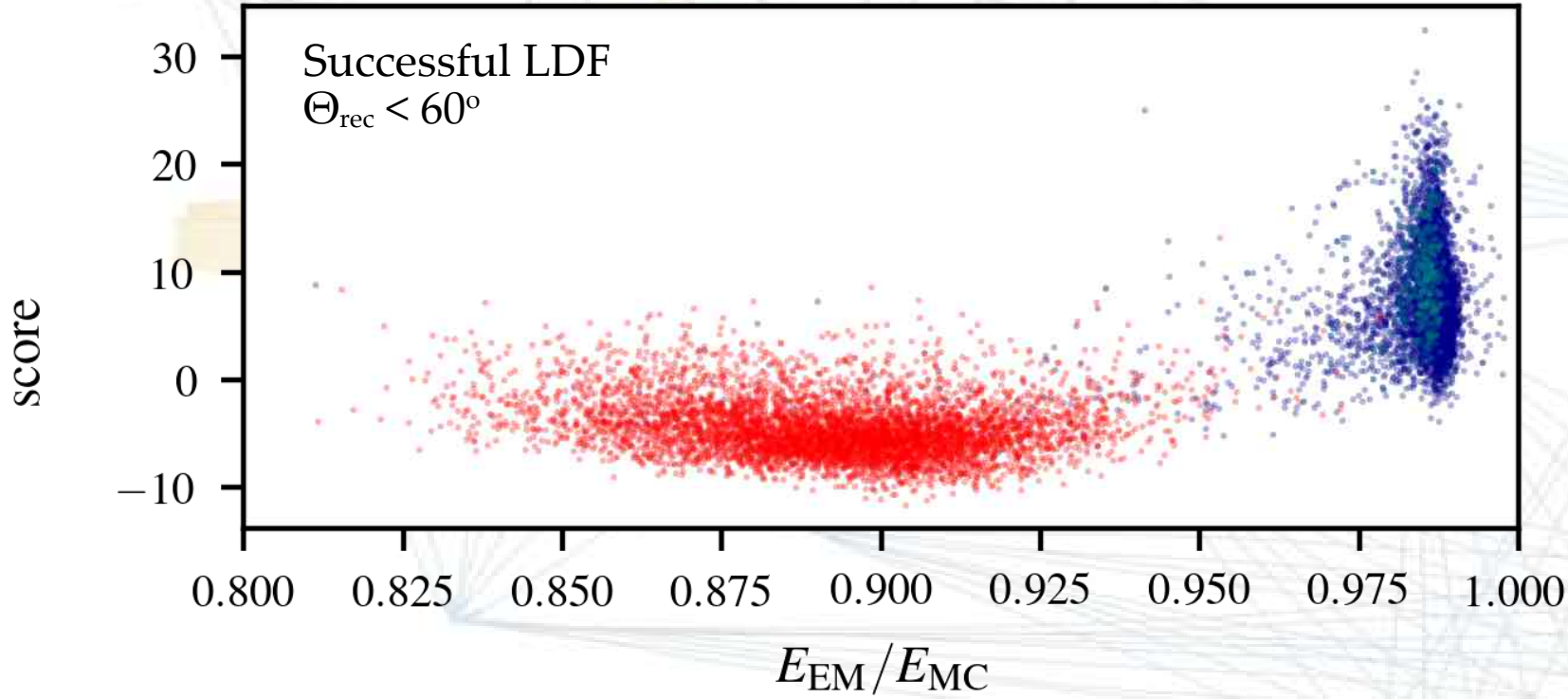




Evaluation of the network

$17 < \lg(E/\mathrm{eV}) < 20.2$

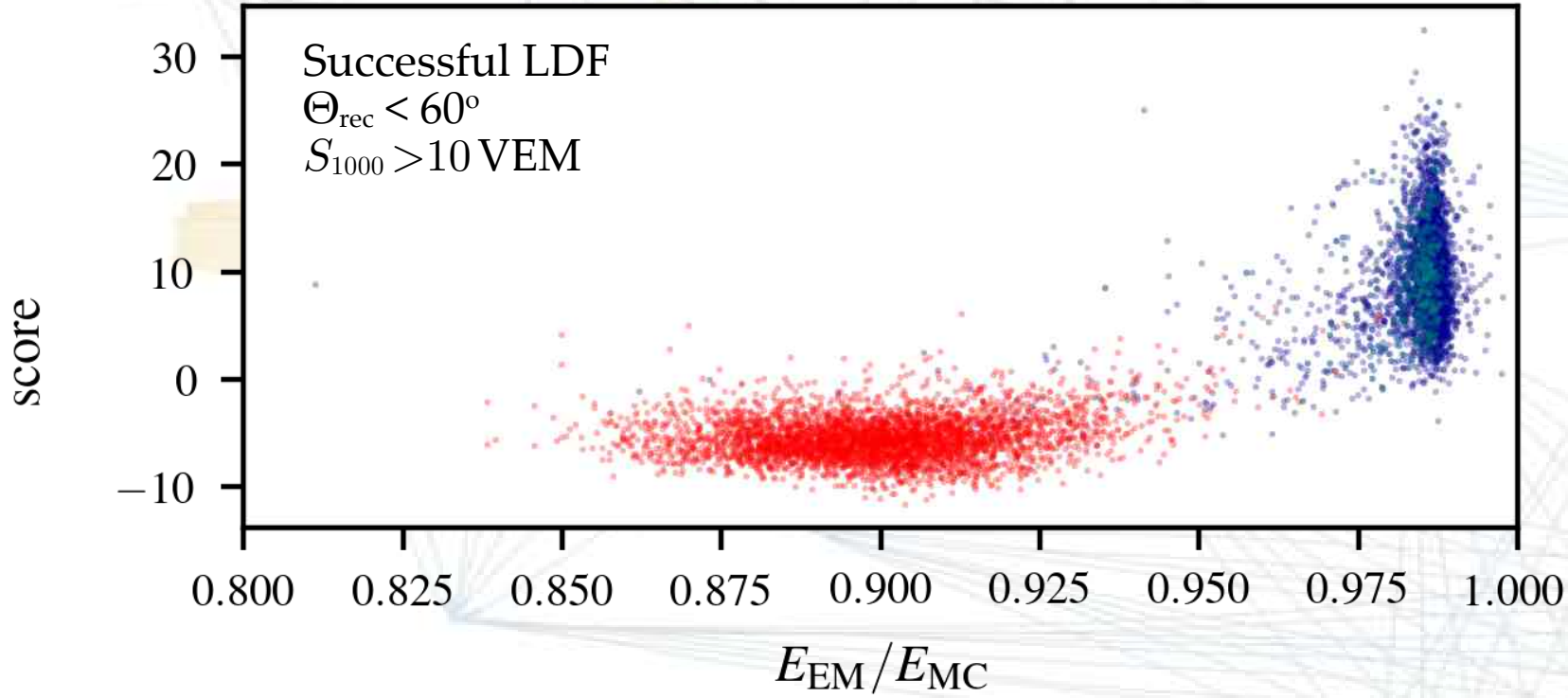
- 6219 Protons (Offline from 8.04.24)
- 5561 Photons (Offline from 8.04.24)



Evaluation of the network

$17 < \lg(E/\mathrm{eV}) < 20.2$

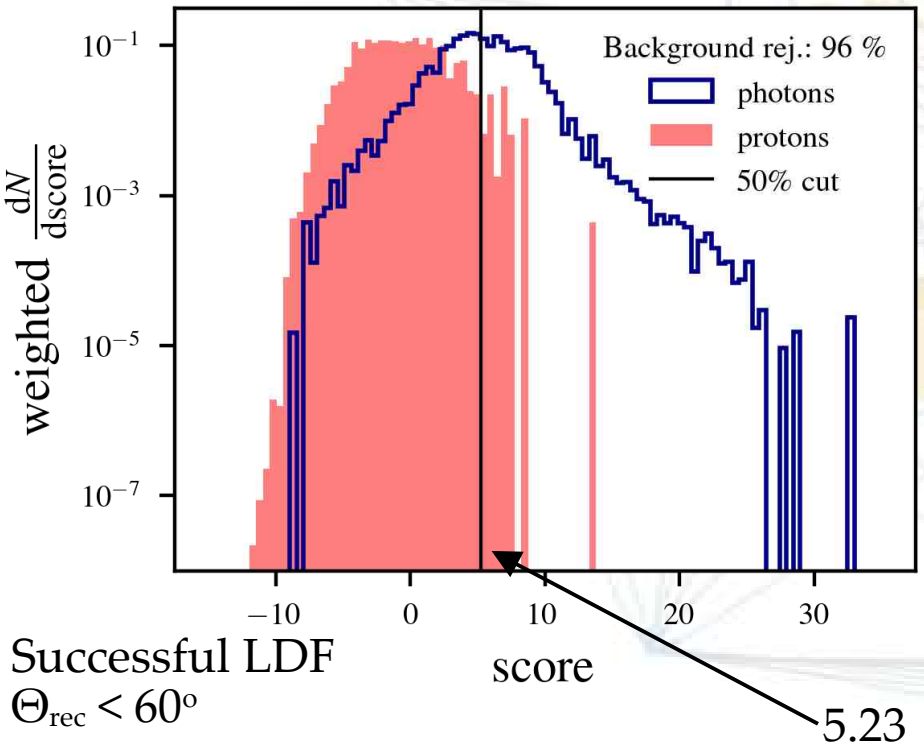
- 6219 Protons (Offline from 8.04.24)
- 5561 Photons (Offline from 8.04.24)



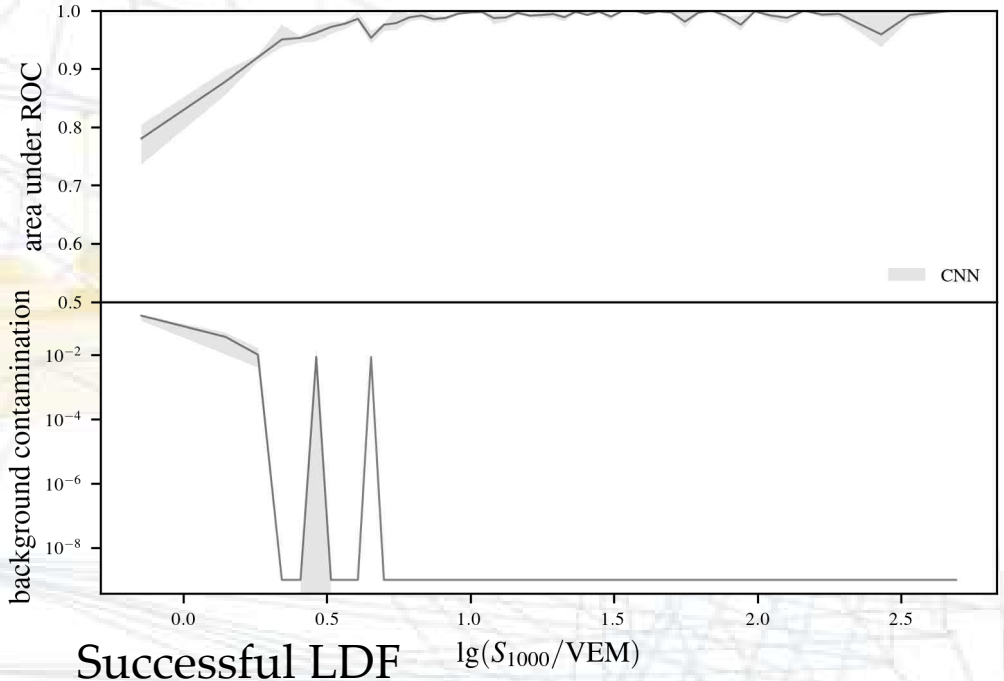
Evaluation of the network

$17 < \lg(E/\mathrm{eV}) < 20.2$

- Weight photons to source spectrum [spectral index -2]
- Weight protons to observed spectrum [spectral index -3]

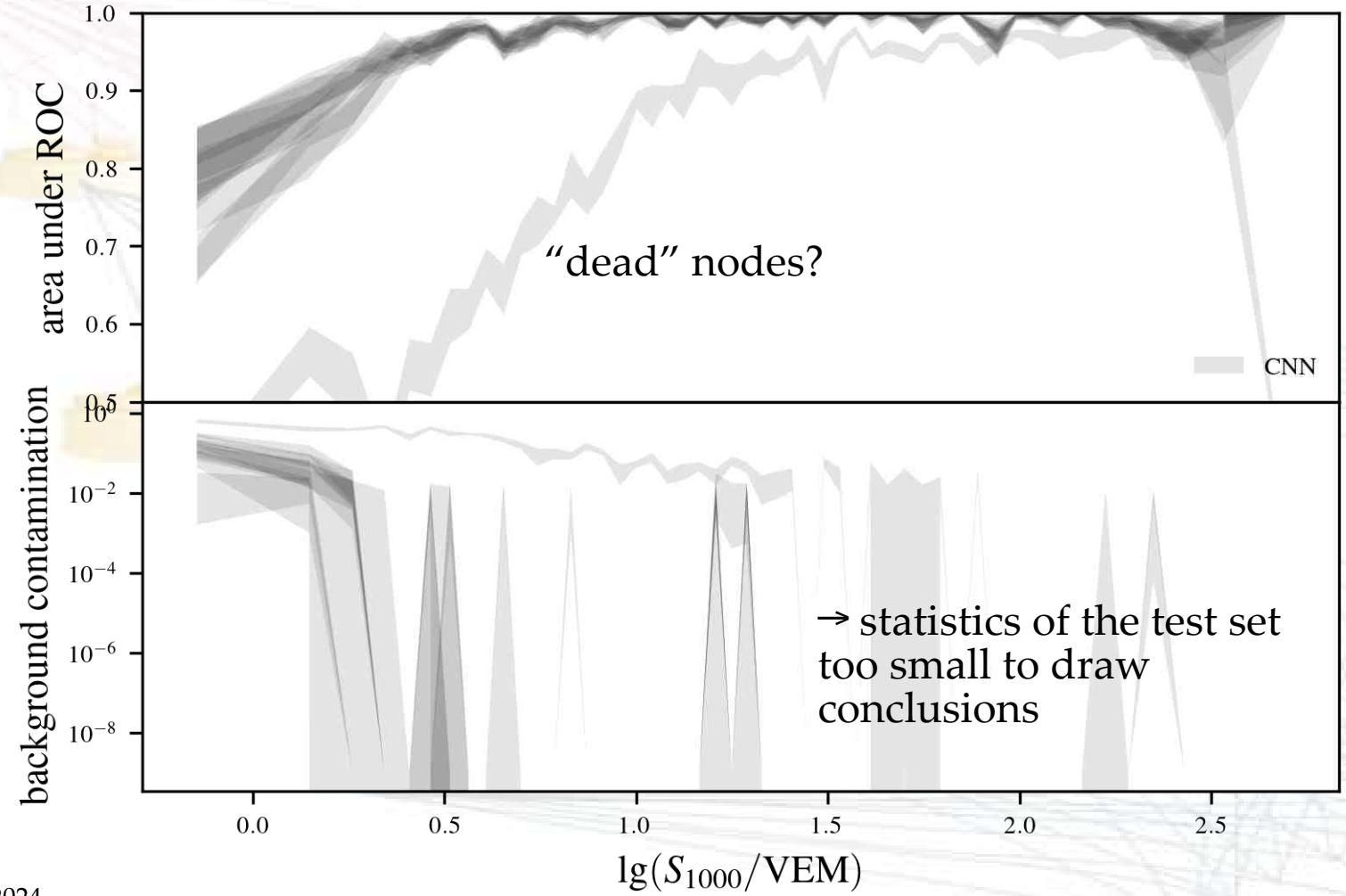


Successful LDF
$\Theta_{rec} < 60^{o}$

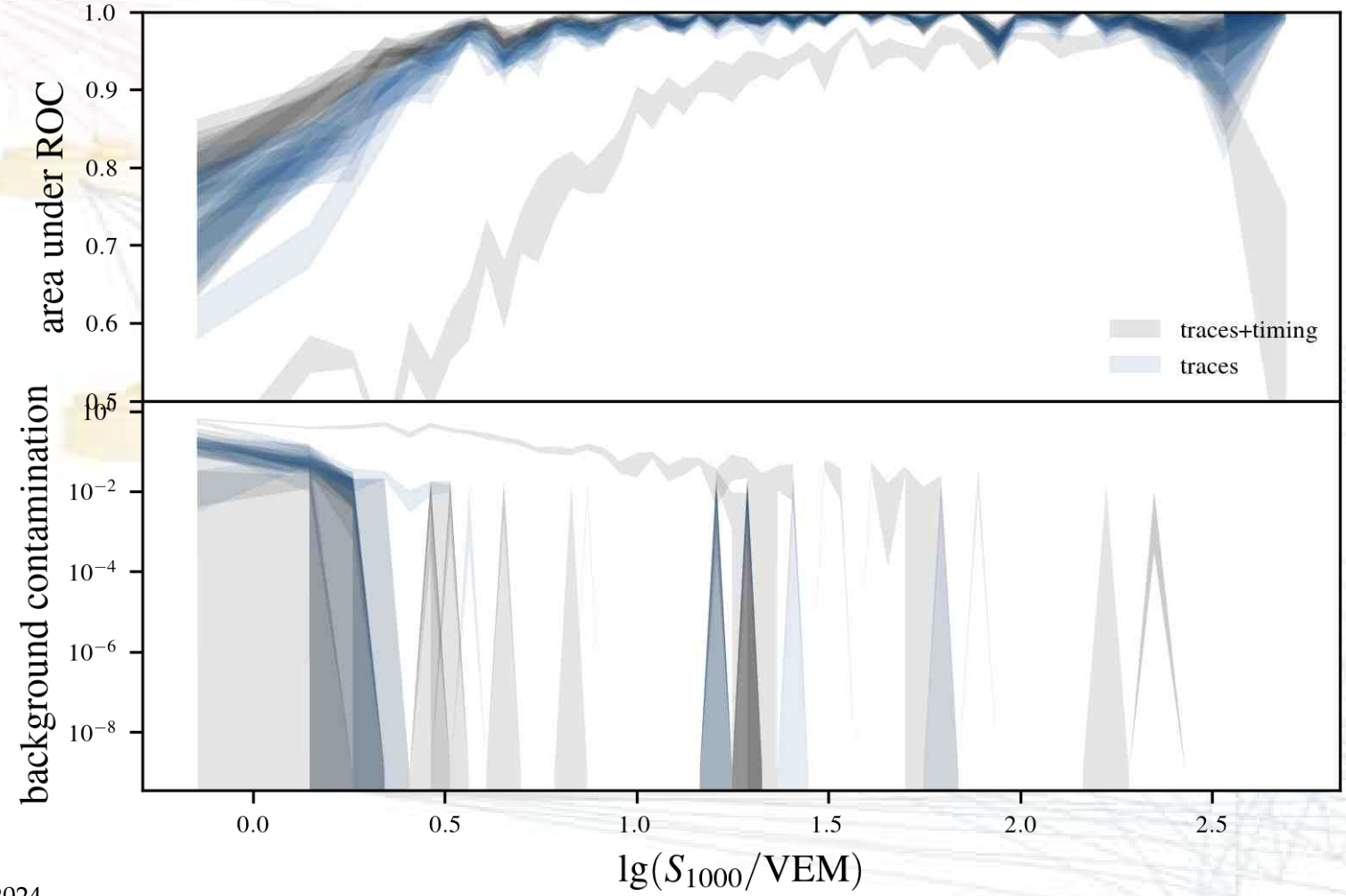


Successful LDF

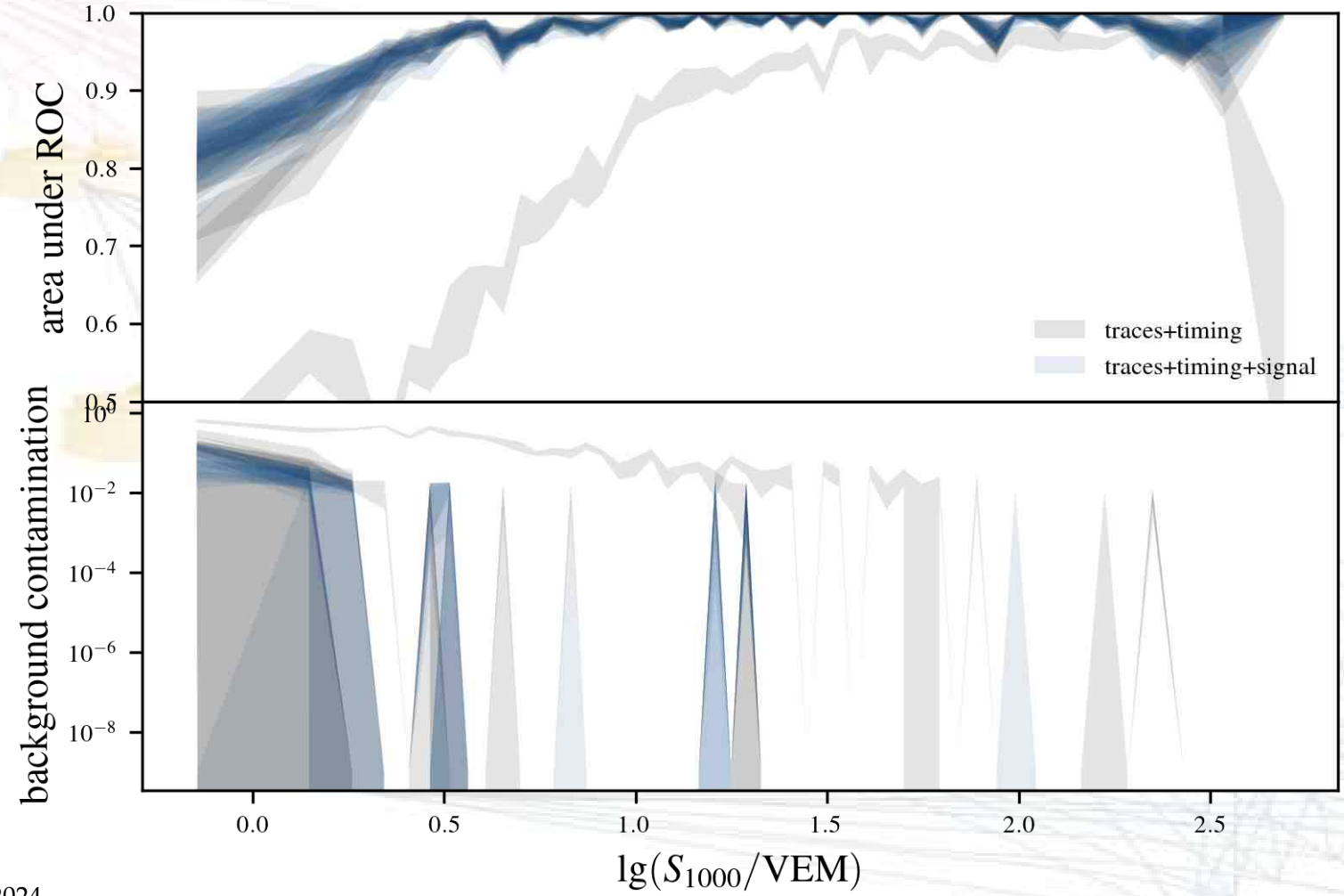
Evaluation of the network



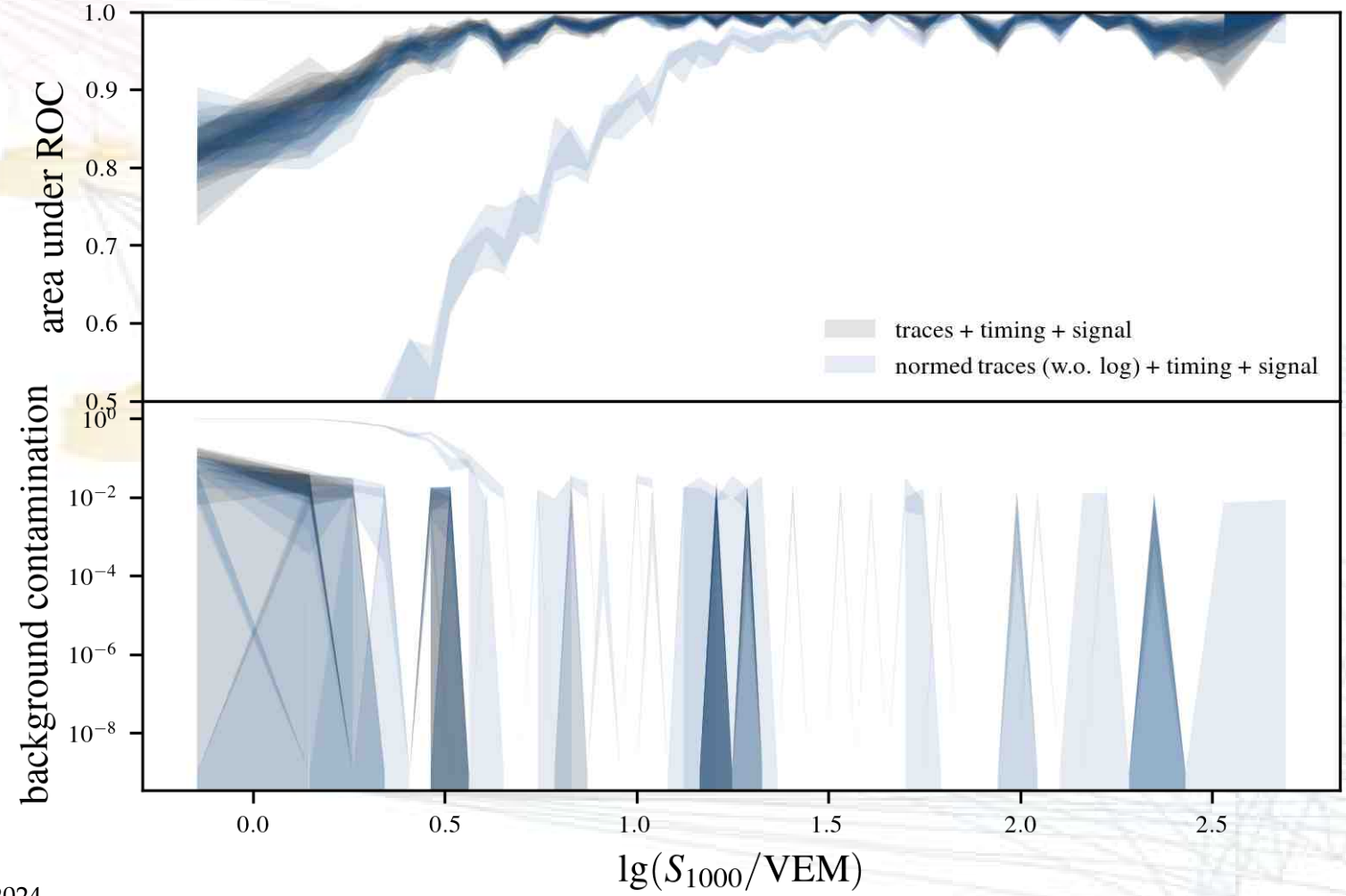
Evaluation of the network



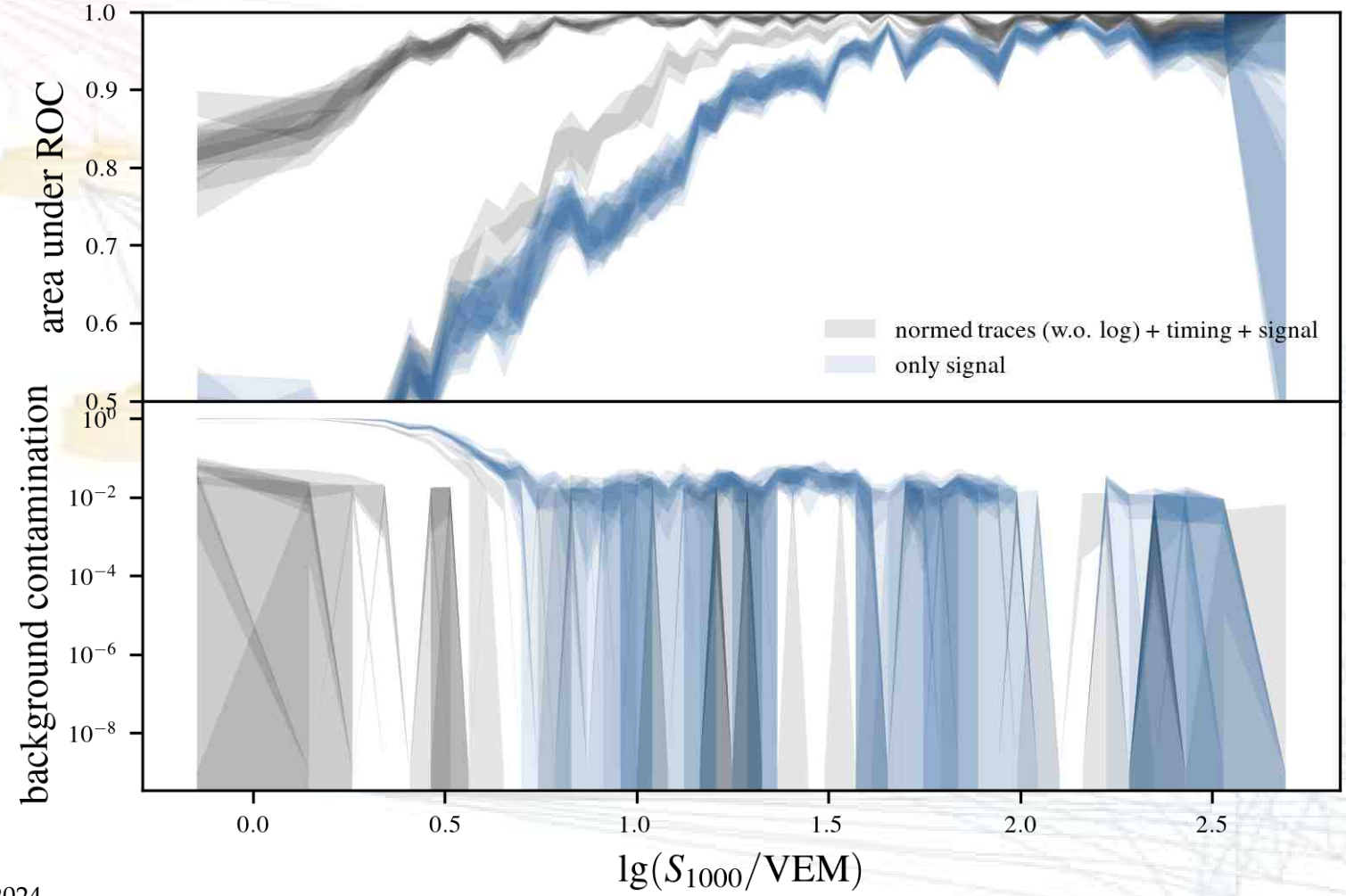
Evaluation of the network



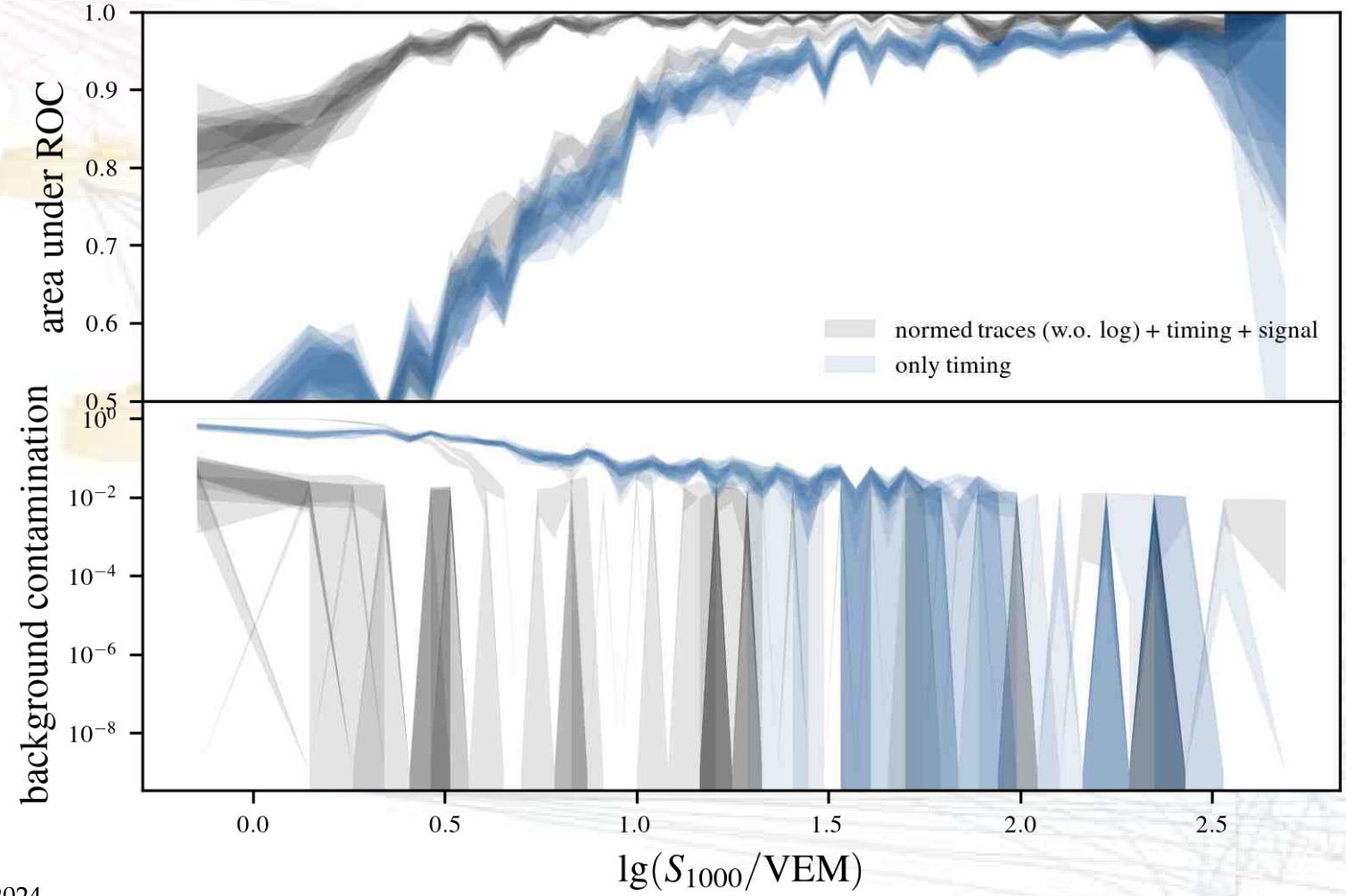
Evaluation of the network



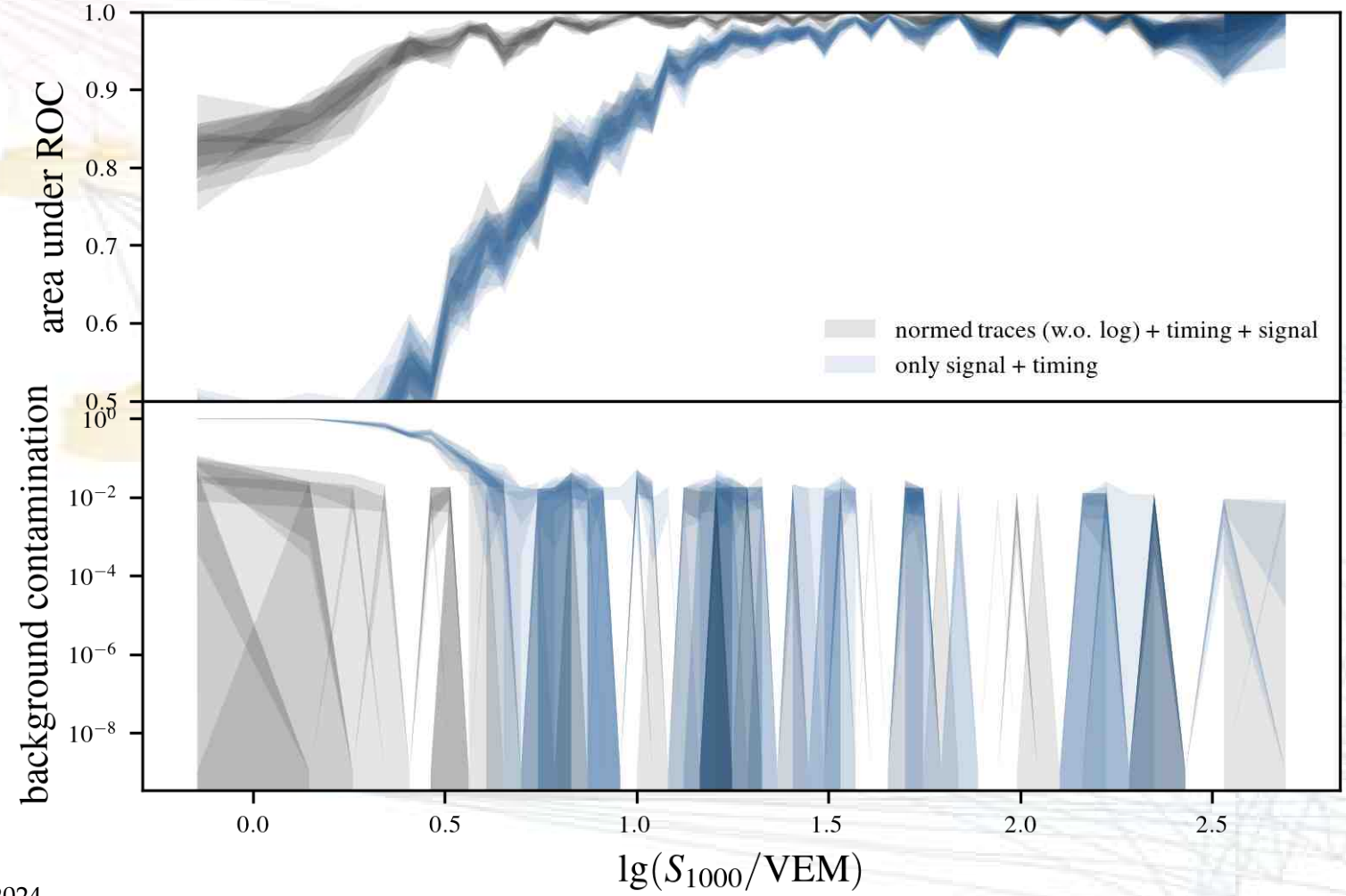
Evaluation of the network



Evaluation of the network

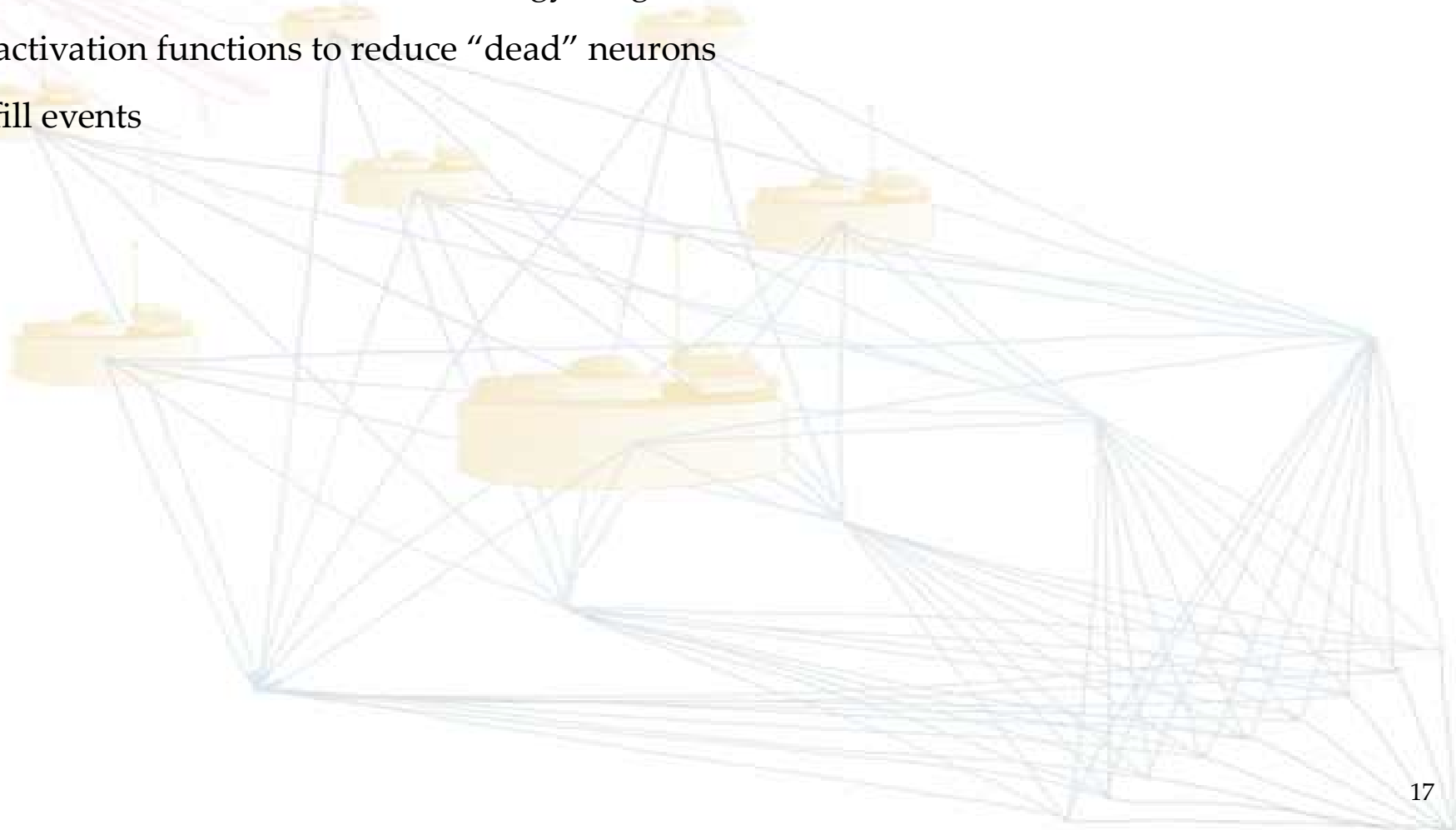


Evaluation of the network



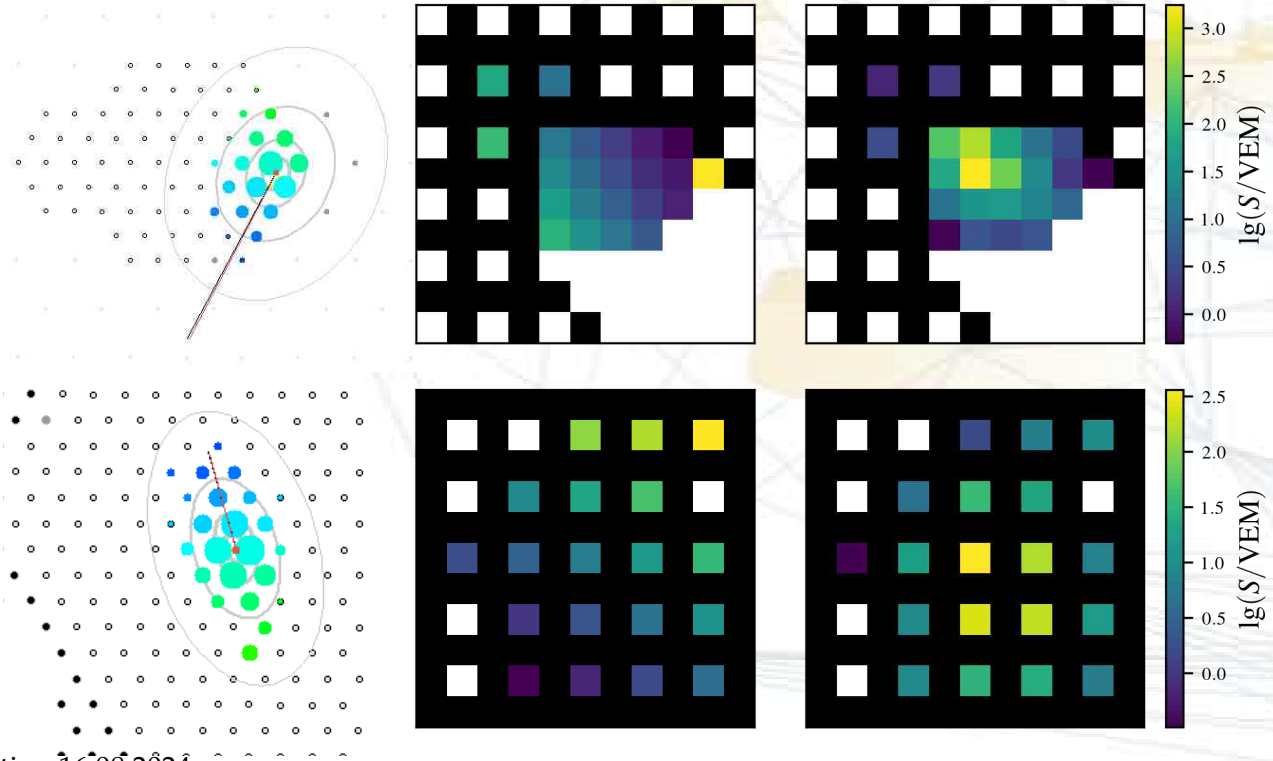
Next steps:

- Train with new simulations and extended energy range
- Study other activation functions to reduce “dead” neurons
- Extend to infill events



Next steps:

- Train with new simulations and extended energy range
- Study other activation functions to reduce “dead” neurons
- Extend to infill events



Next steps:

- Train with new simulations and extended energy range
- Study other activation functions to reduce “dead” neurons
- Extend to infill events
- Add additional detectors (SSD, SPMT, RD)
- Look at asymmetry, curvature, … for photons
- What would be a good metric to compare models?