DEEP UNDERGROUND NEUTRINO EXPERIMENT

First pointing results with ML and Trigger Primitives

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CERN

Premises

- Expected SN spectrum
- No noise in the simulation
- Only ES tracks, no background
- Truth for the training is the incoming neutrino direction.
  Electron direction makes more sense (almost ready).

Model

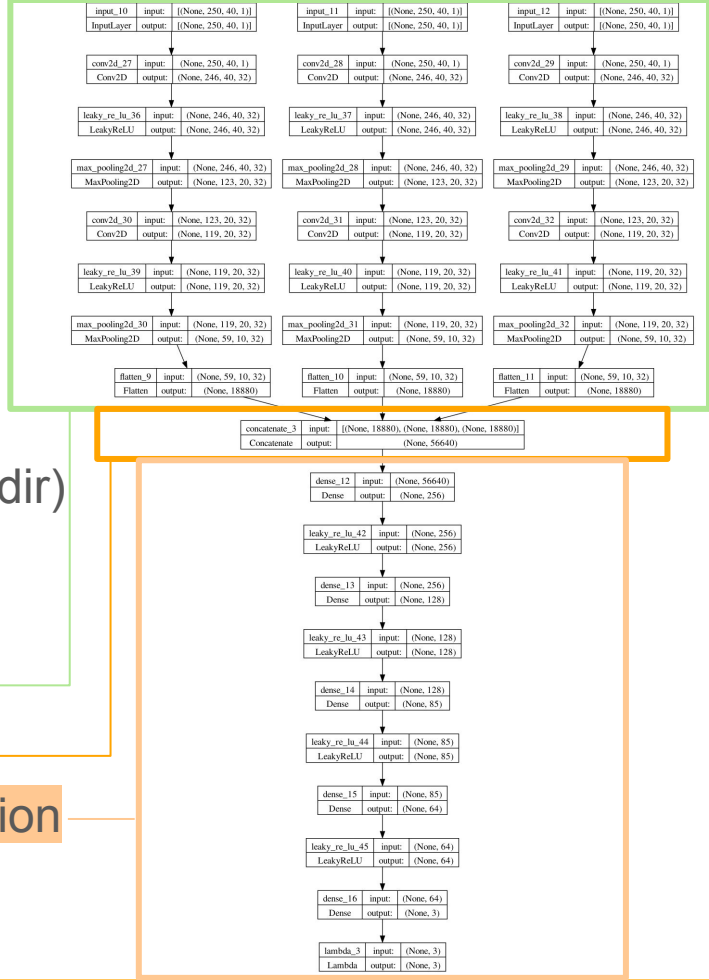
Input: 3 views x 250 ticks x 40 channels images.

Output: 3 numbers normalized to 1 (xyz)

Loss: 1-cos(ω) (ω≡the angle between true and reco dir)

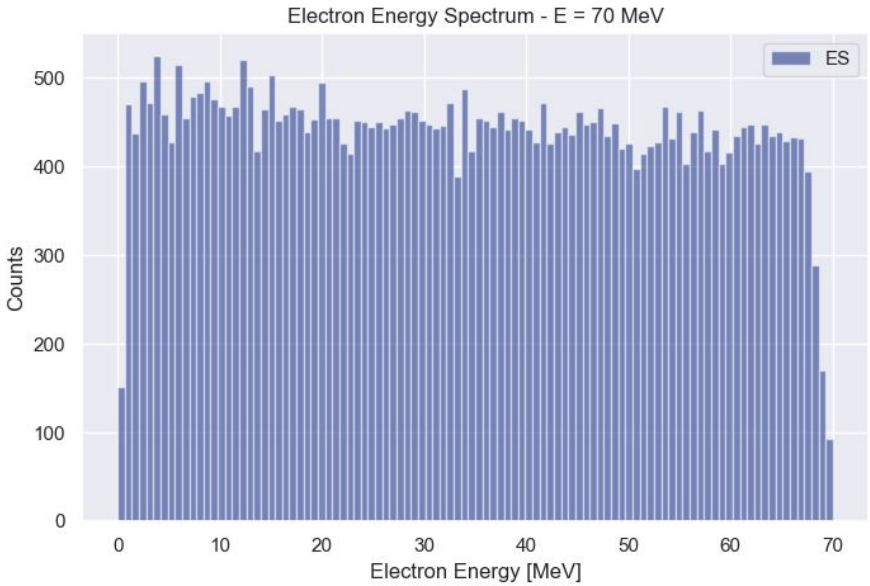
Architecture:

- 3 independent CNN branches
- Flatten -> Concatenation
- Unique DNN section that returns the final prediction



Training

- ~1.500 directions, ~200.000 individual tracks.
- Truth is the neutrino direction, not the individual electron one.
- Dataset generated using flat spectrum in the 30-70 MeV range. Electron energies are flat in the range (0, E_V), therefore high energy neutrinos can be used to agnostically train the NN across all energies.



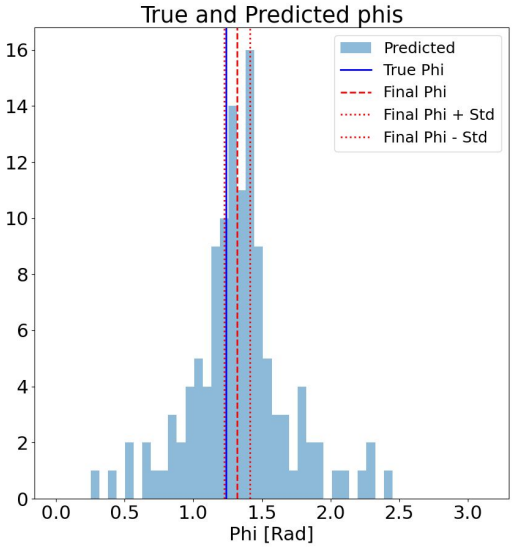
Testing

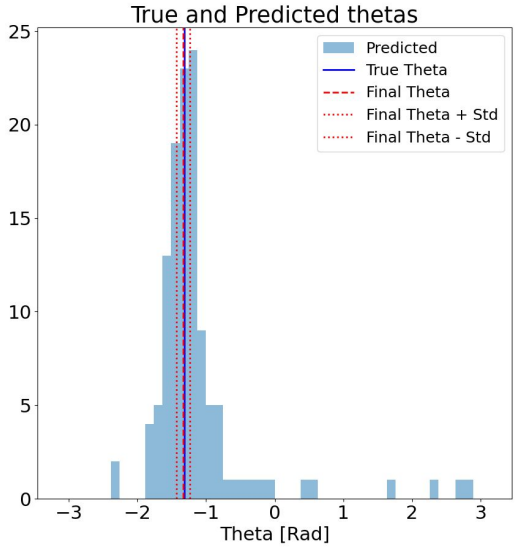
- 400 supernova burst
- Each burst contains 350 ES events, I can fully reconstruct ~220 (working for improving this).
- Per each burst I compute the predicted direction by sampling the log-likelihood with a MCMC method.

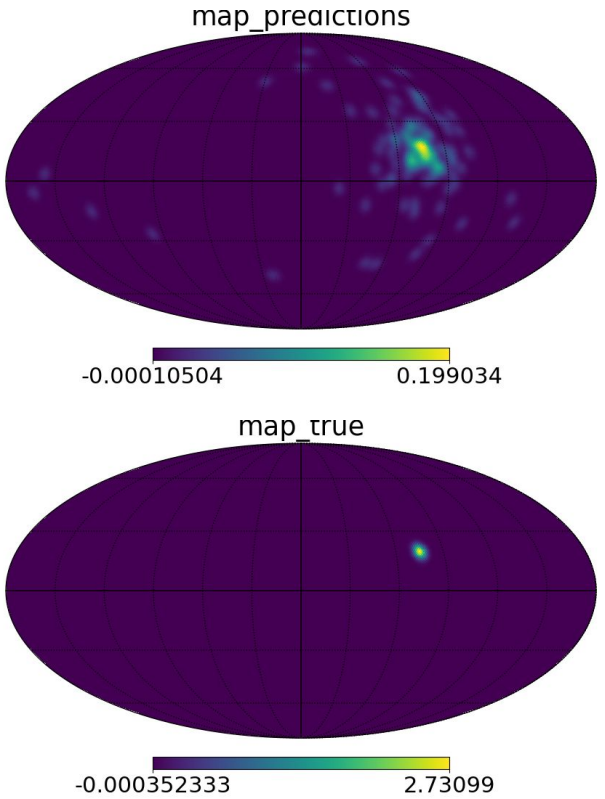
$$L = \prod_i e^{-\omega_i^2}$$

ω≡angle between measured and proposed direction

Some plots - A


True and Predicted phis
Predicted
True Phi
Final Phi
Final Phi + Std
Final Phi - Std
Phi [Rad]


True and Predicted thetas
Predicted
True Theta
Final Theta
Final Theta + Std
Final Theta - Std
Theta [Rad]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map_true
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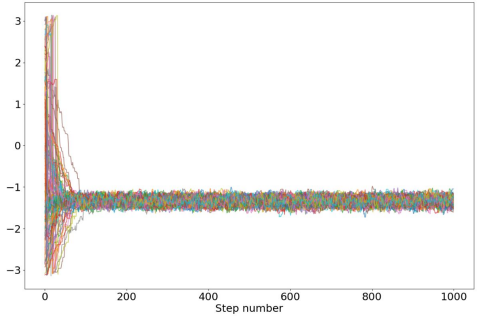
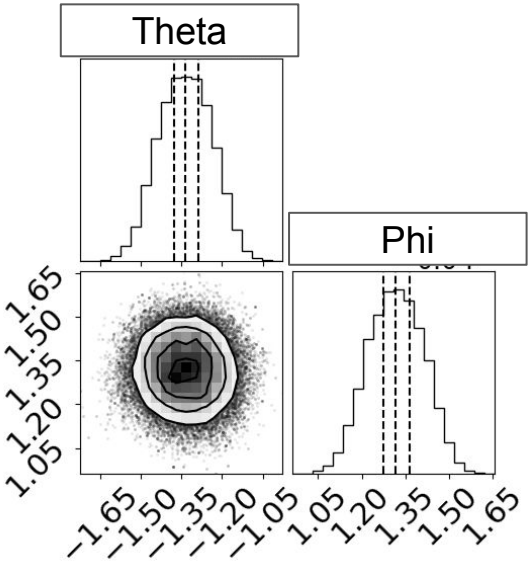
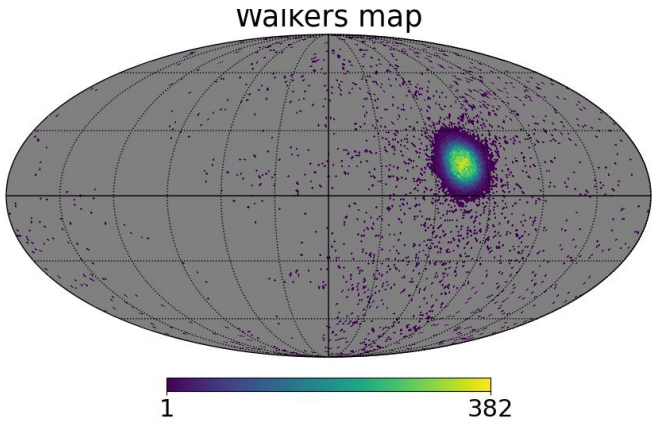
2.73099

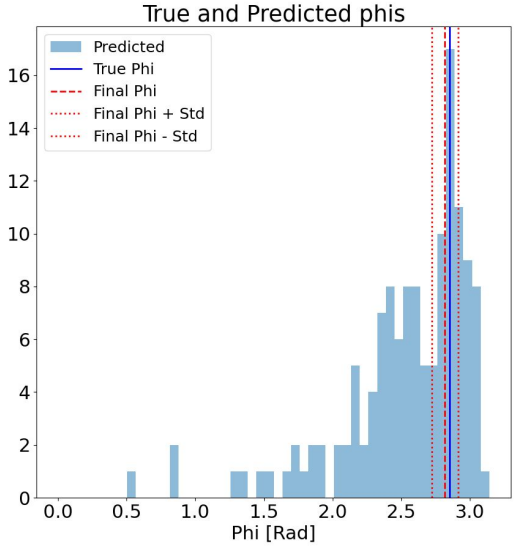
Some plots - A

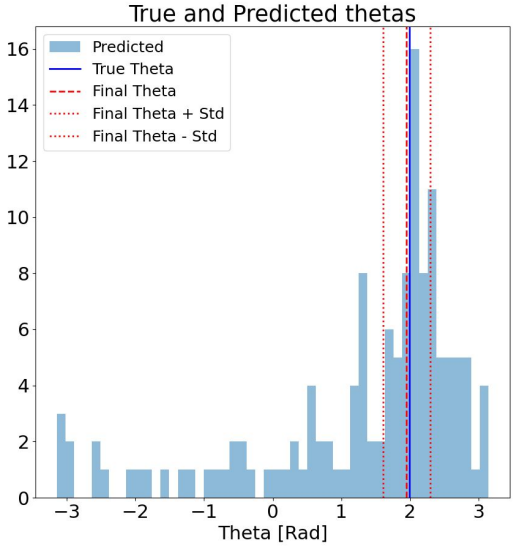


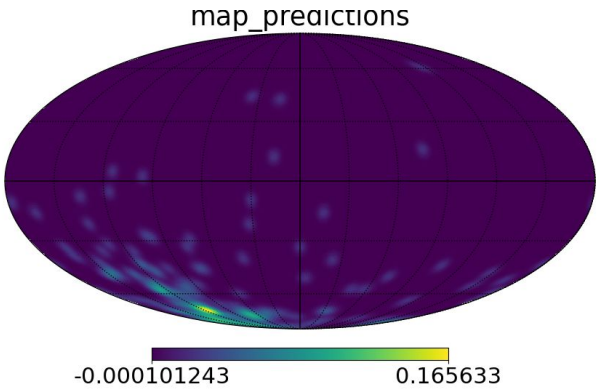




Some plots - B


True and Predicted phis
Predicted
True Phi
Final Phi
Final Phi + Std
Final Phi - Std
0
2
4
6
8
10
12
14
16
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Phi [Rad]


True and Predicted thetas
Predicted
True Theta
Final Theta
Final Theta + Std
Final Theta - Std
0
2
4
6
8
10
12
14
16
−3
−2
−1
0
1
2
3
Theta [Rad]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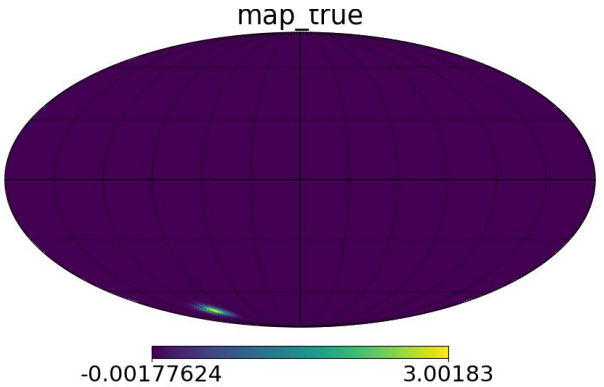
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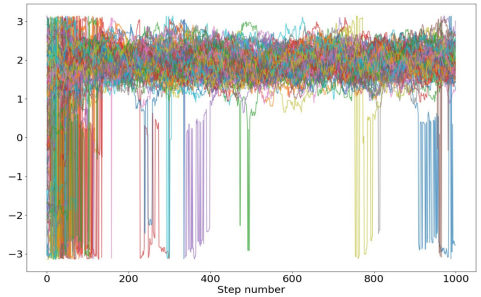
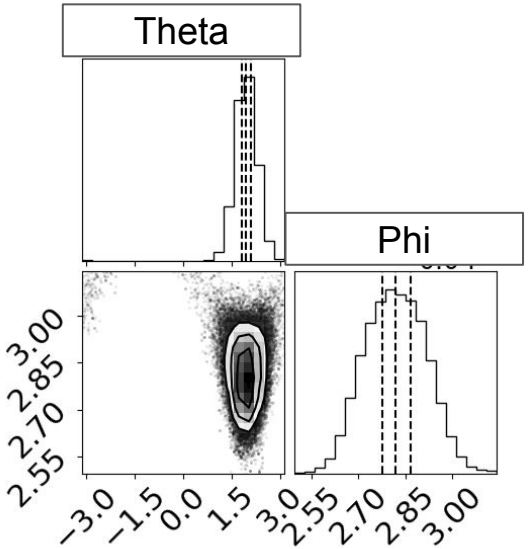
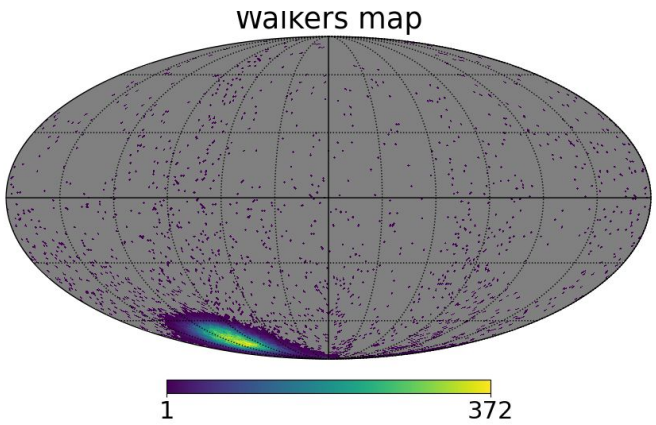
Some plots - B

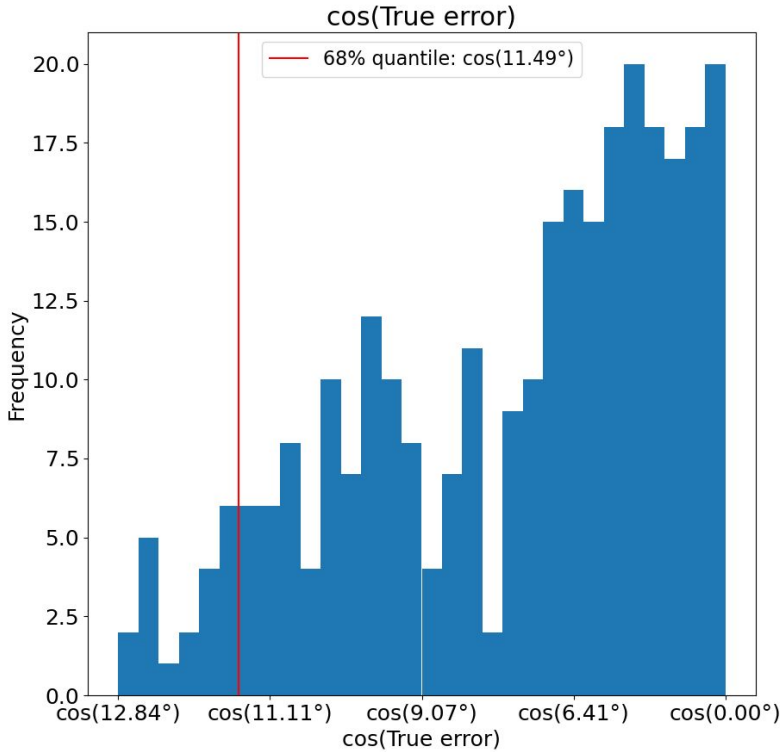


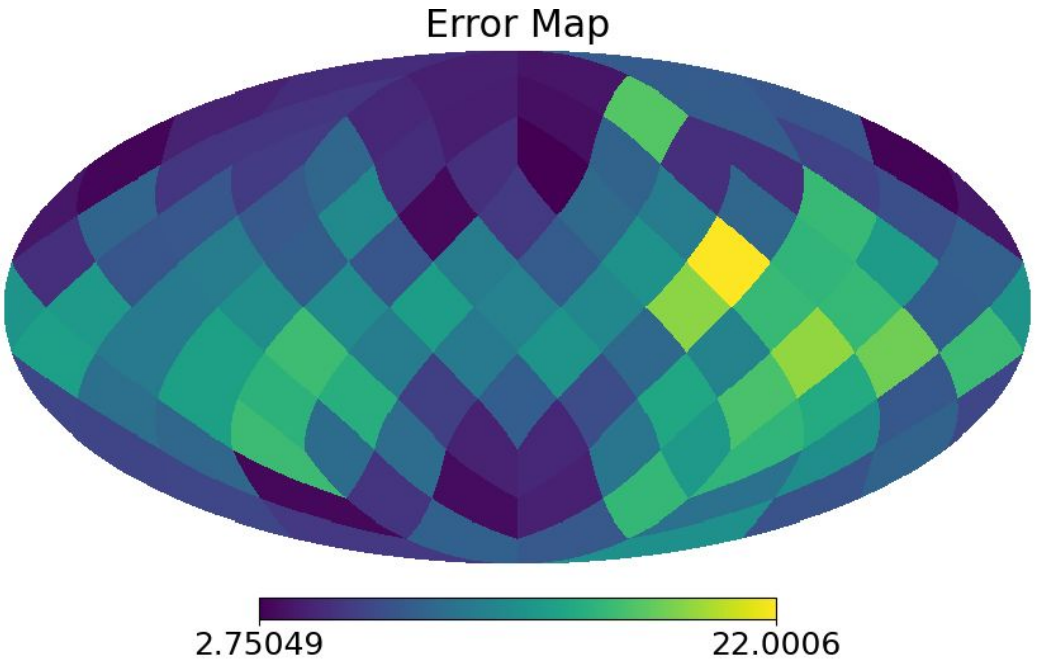




Results

True error = angle between the predicted and the MC true direction



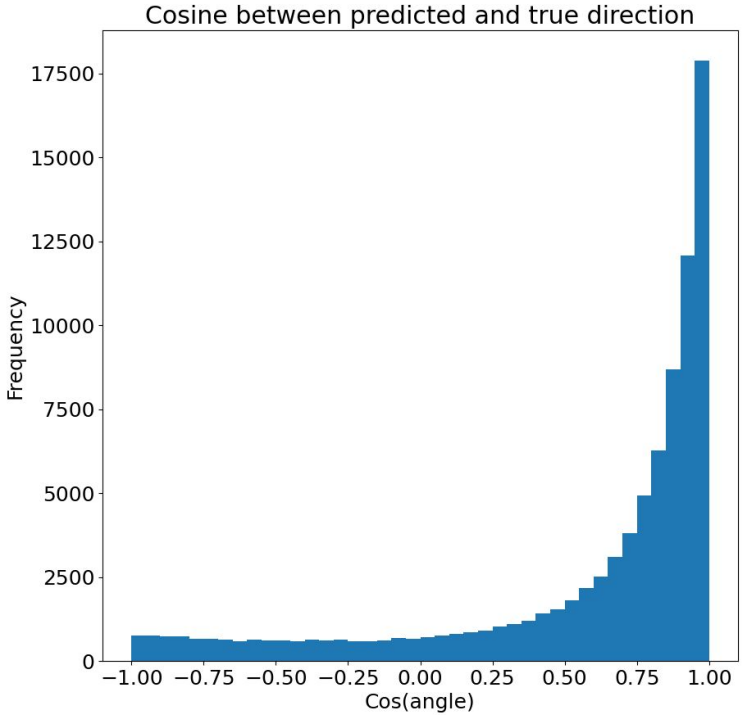


Conclusion

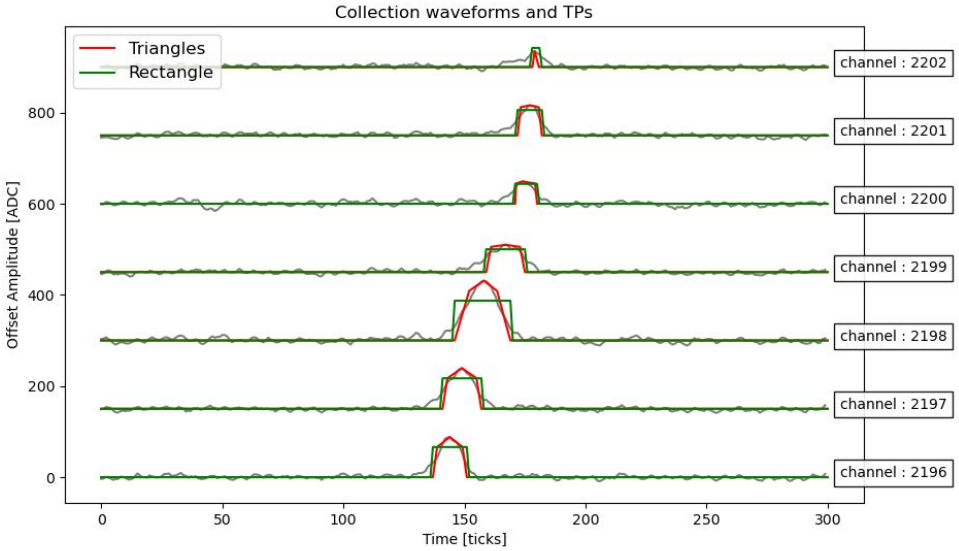
Resolution: 11.49 degrees

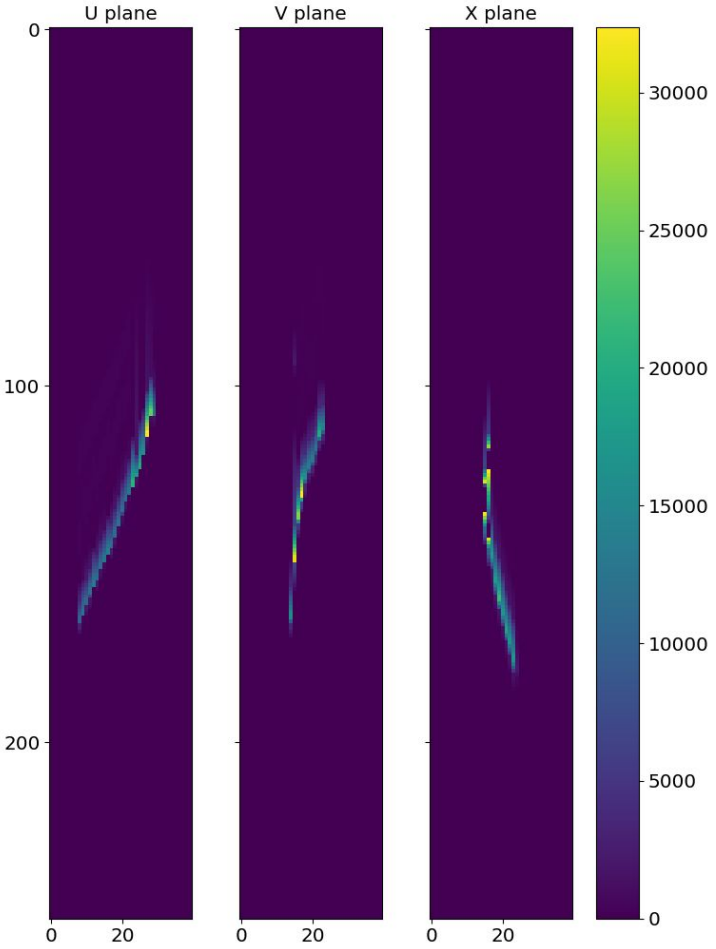
First results are promising, but will change. We have to:

- Use more SN burst to get smoother plots.
- Weight the likelihood with the energy.
- Take into account more realistic conditions (e.g. background contamination, CC contamination, noise…)

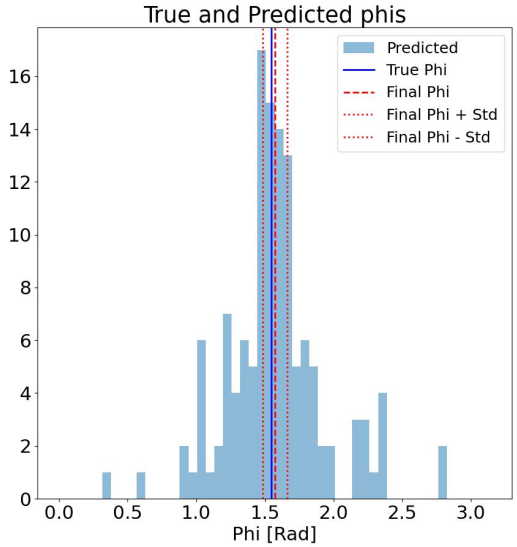


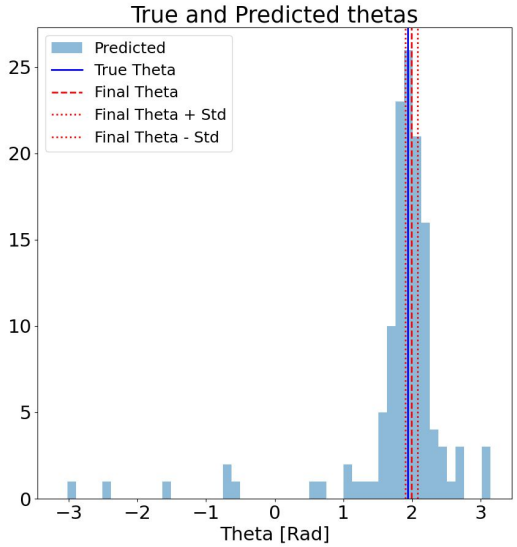
BACKUP

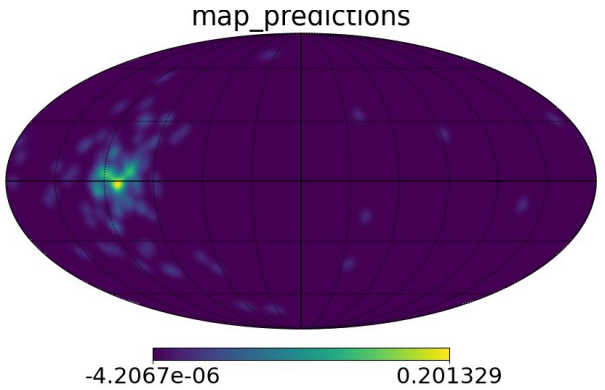

Collection waveforms and TPs
Triangles
Rectangle
channel : 2202
channel : 2201
channel : 2200
channel : 2199
channel : 2198
channel : 2197
channel : 2196
Offset Amplitude [ADC]
Time [ticks]

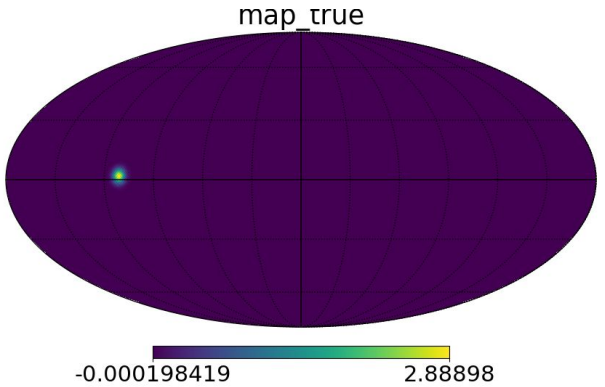

U plane
V plane
X plane

Some beautiful plots - 2724









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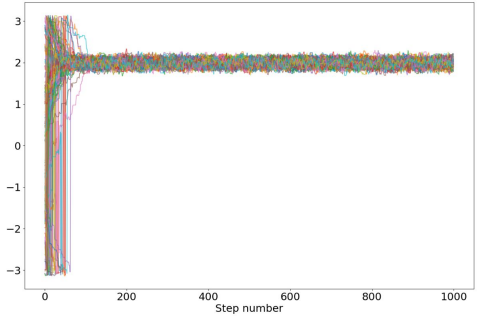
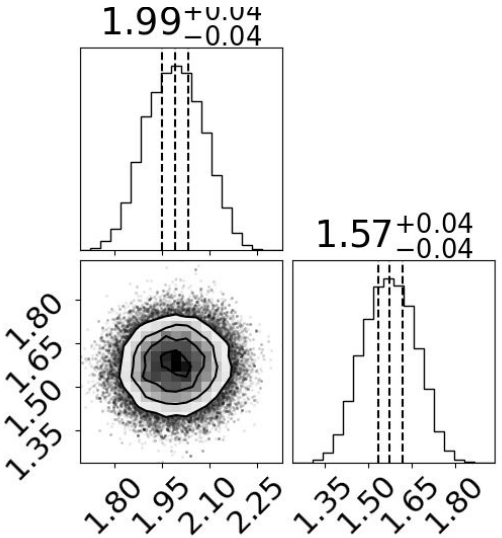
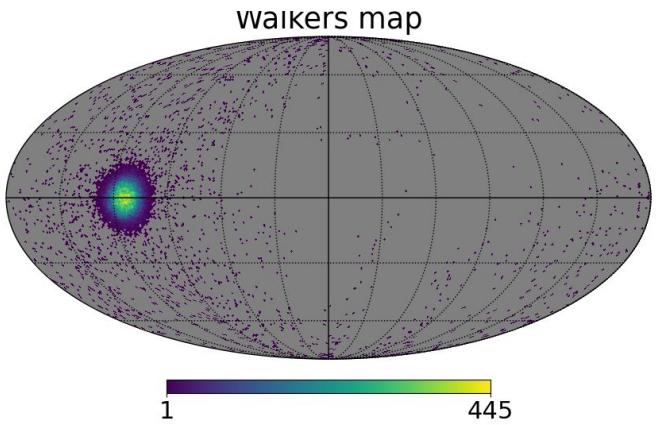
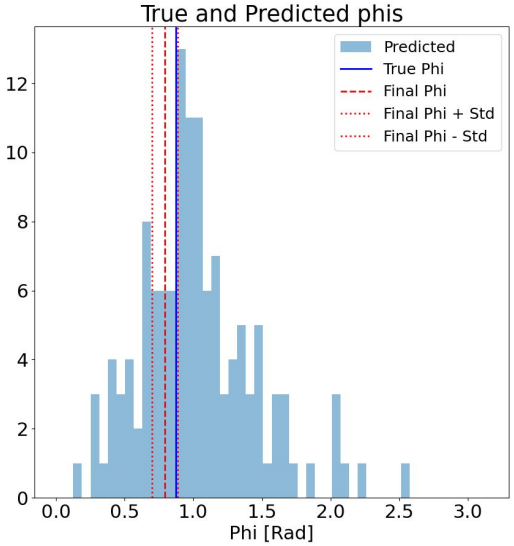
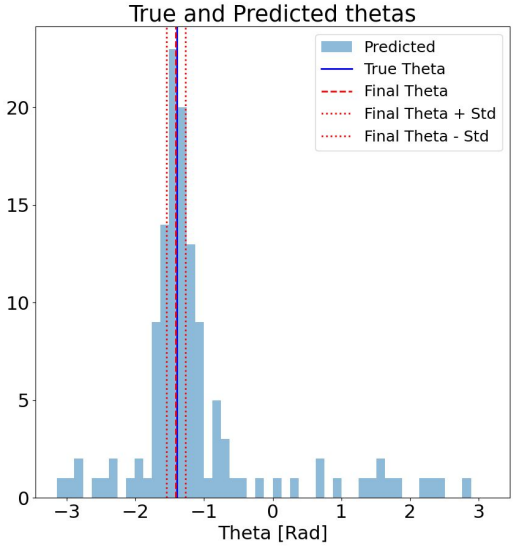


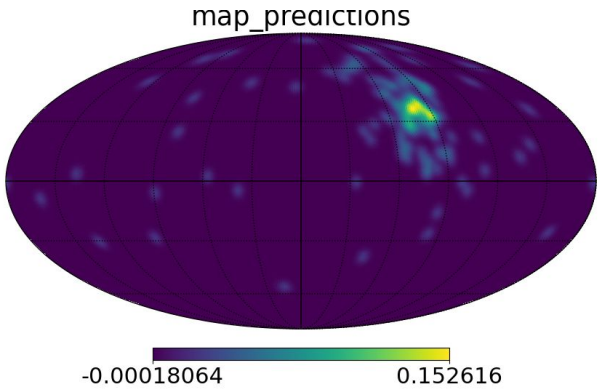


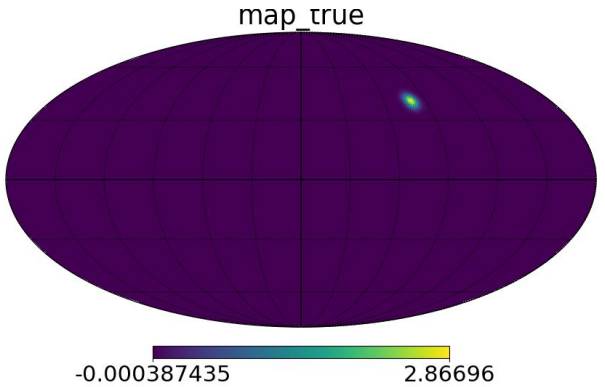


Some beautiful plots - 2734

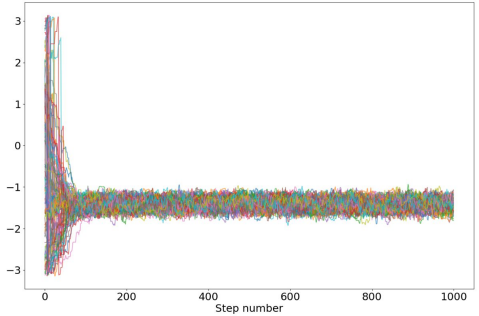


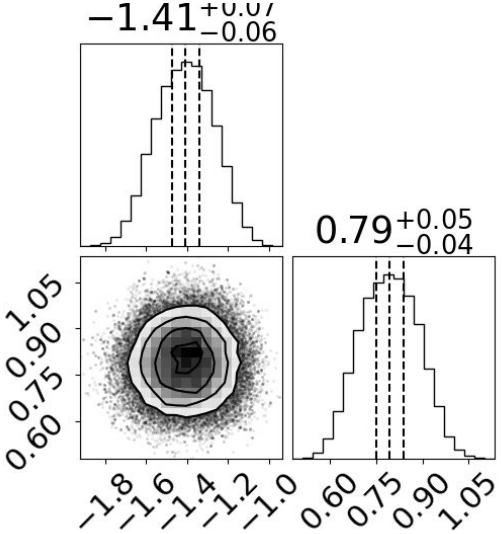


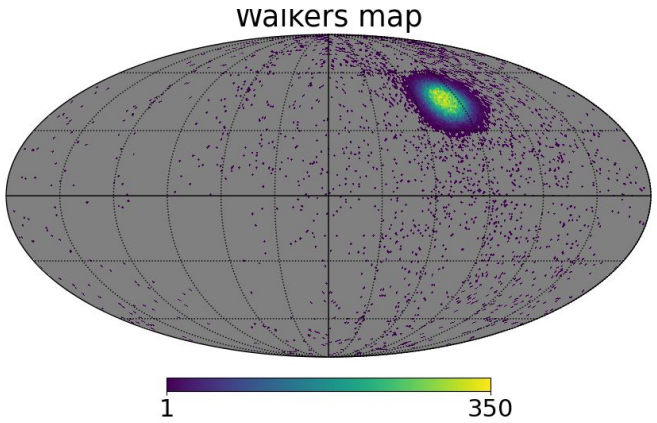




Some beautiful plots - 2734







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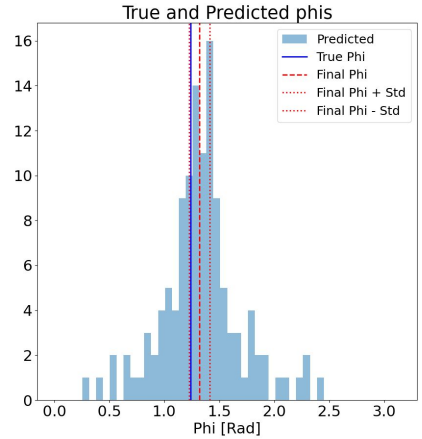

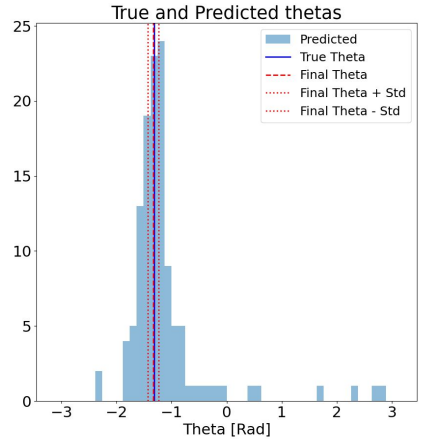

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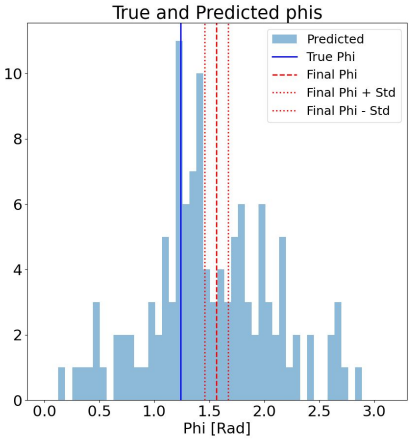

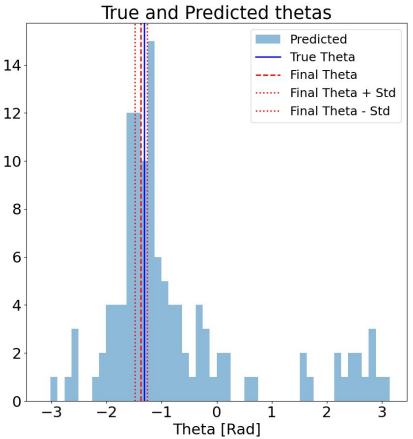

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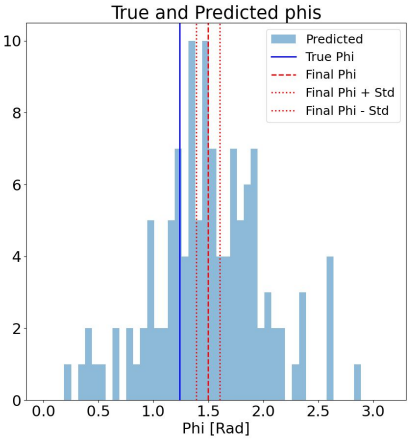

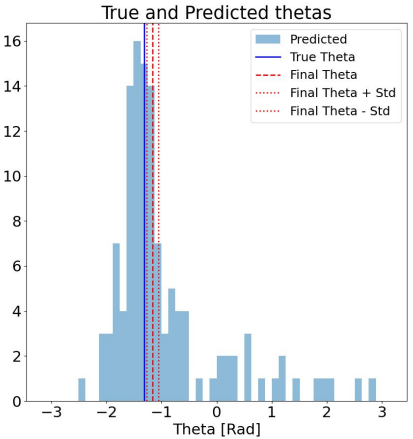

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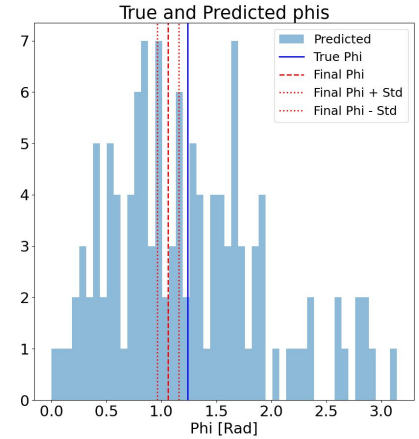

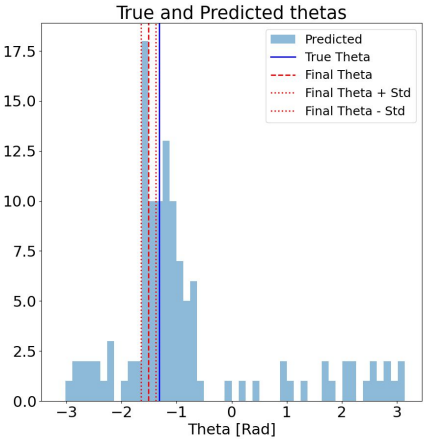

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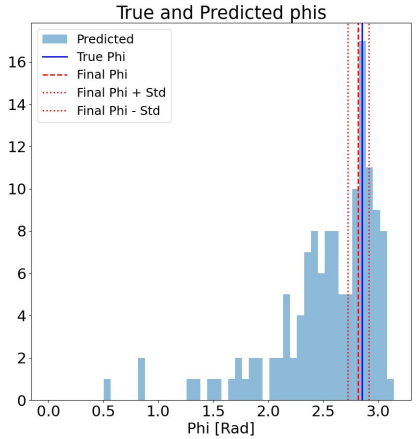

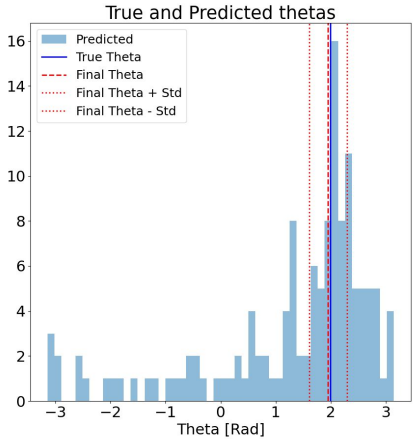

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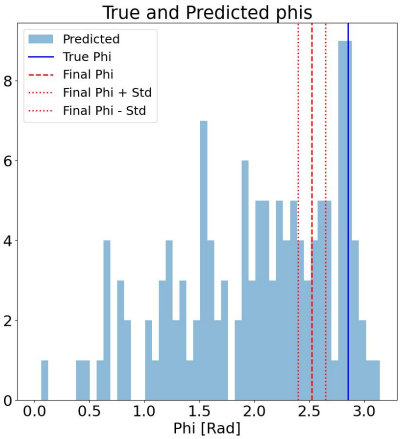

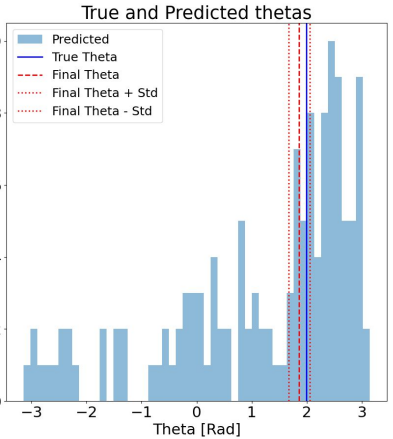

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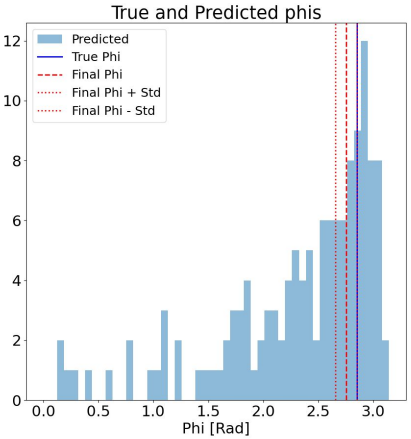

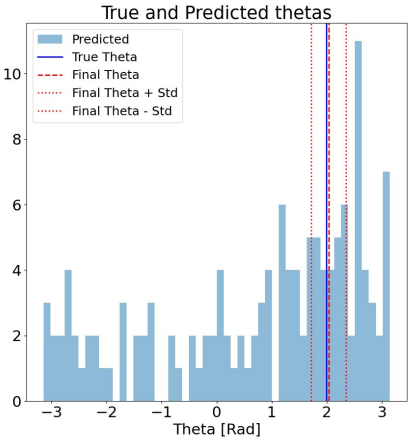

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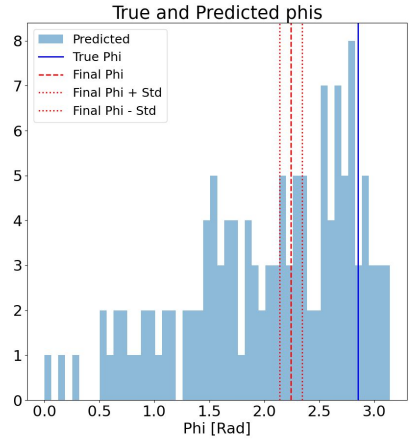
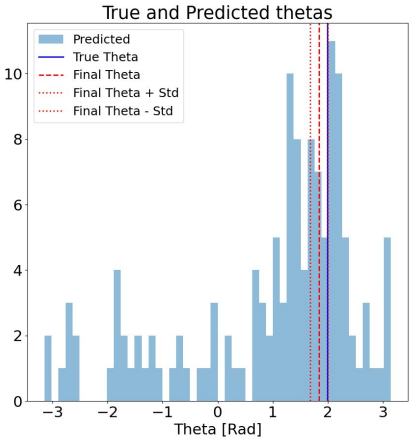
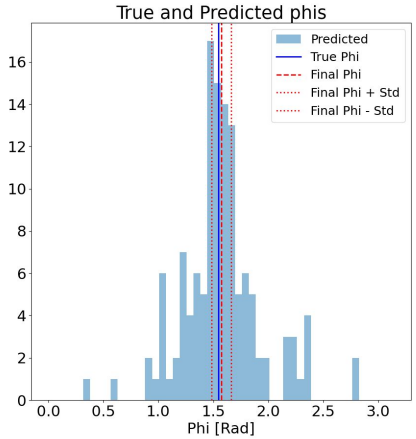
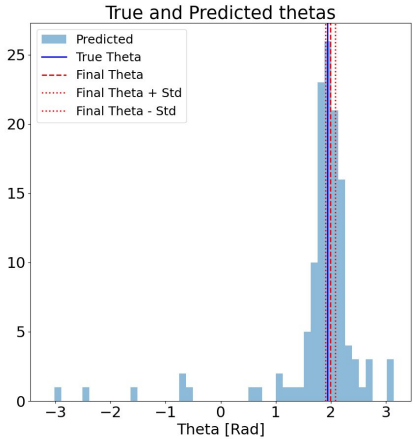




2724

all





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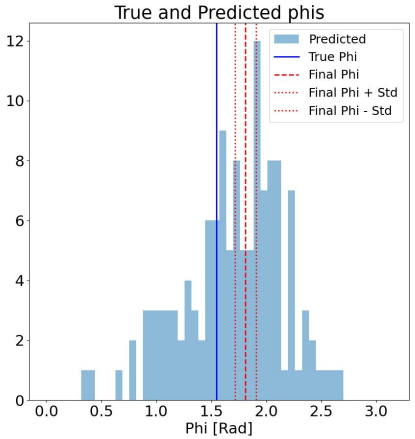
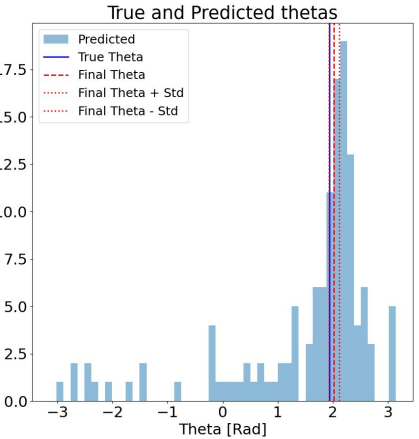
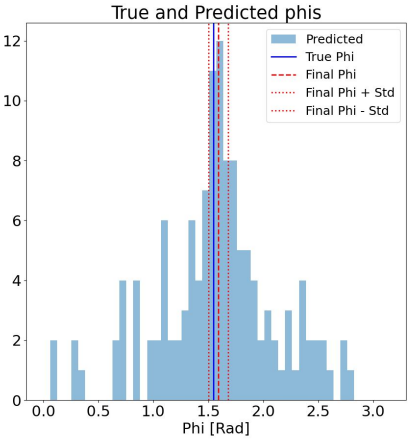
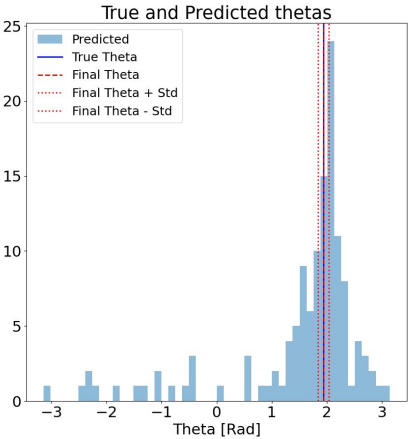




noV





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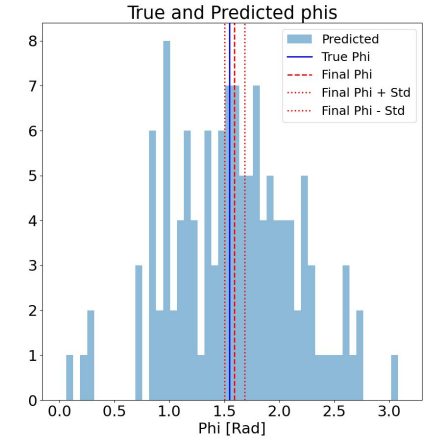
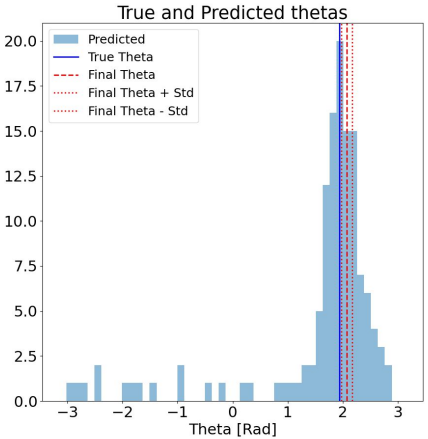
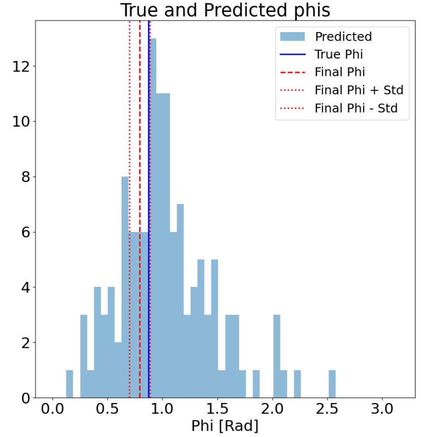
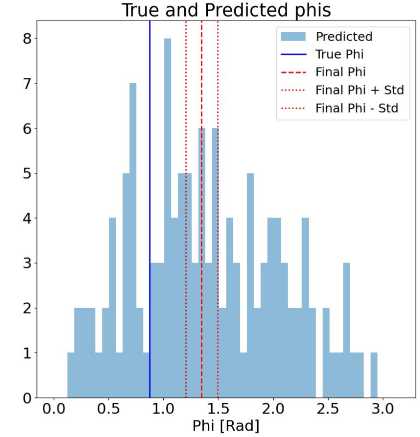
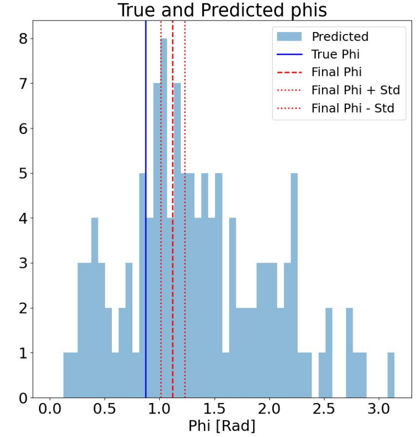


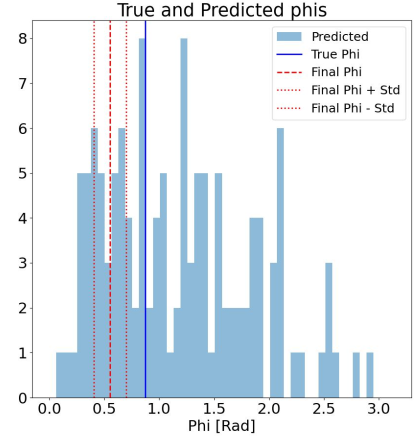


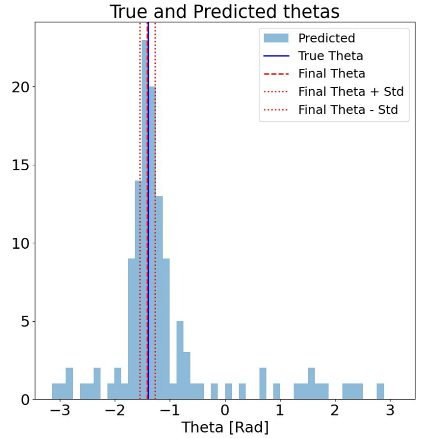
2734 all | noU | noV | noX

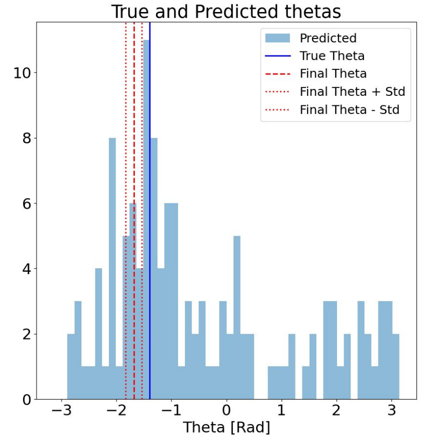


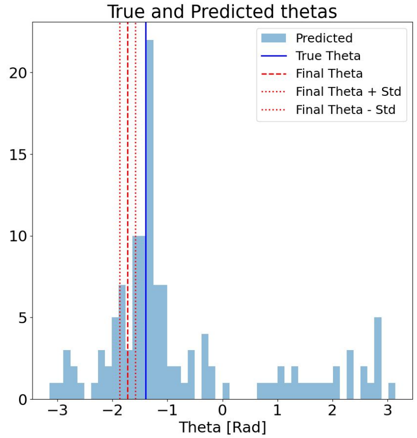


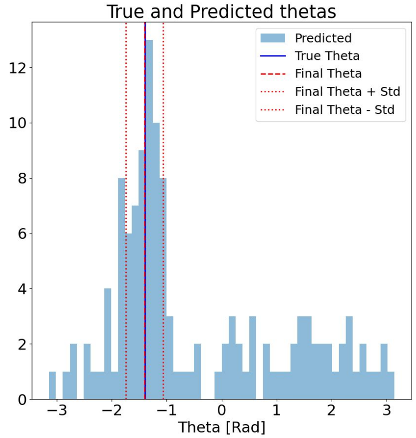




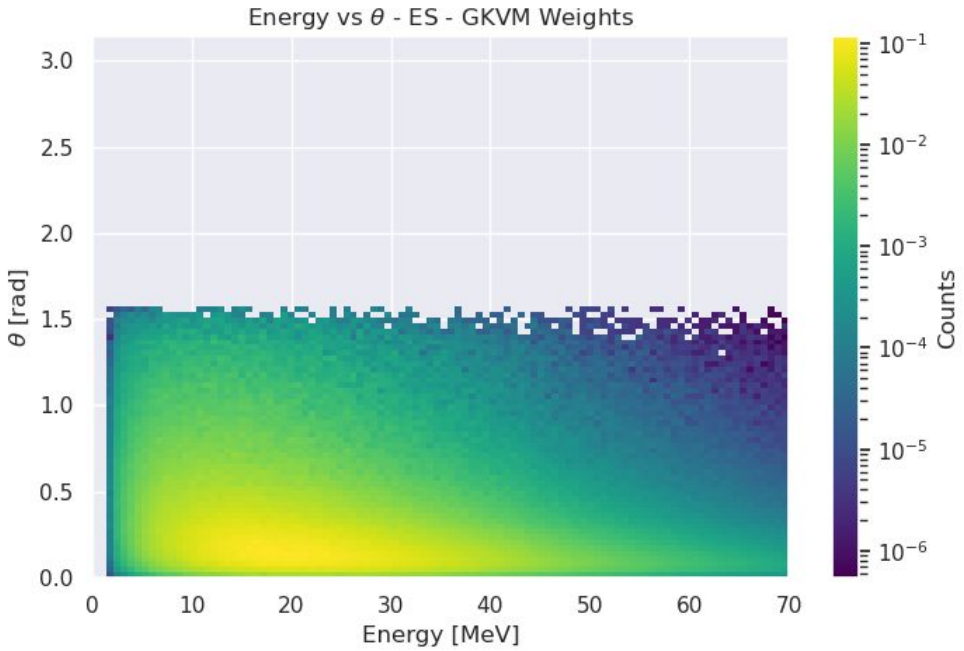


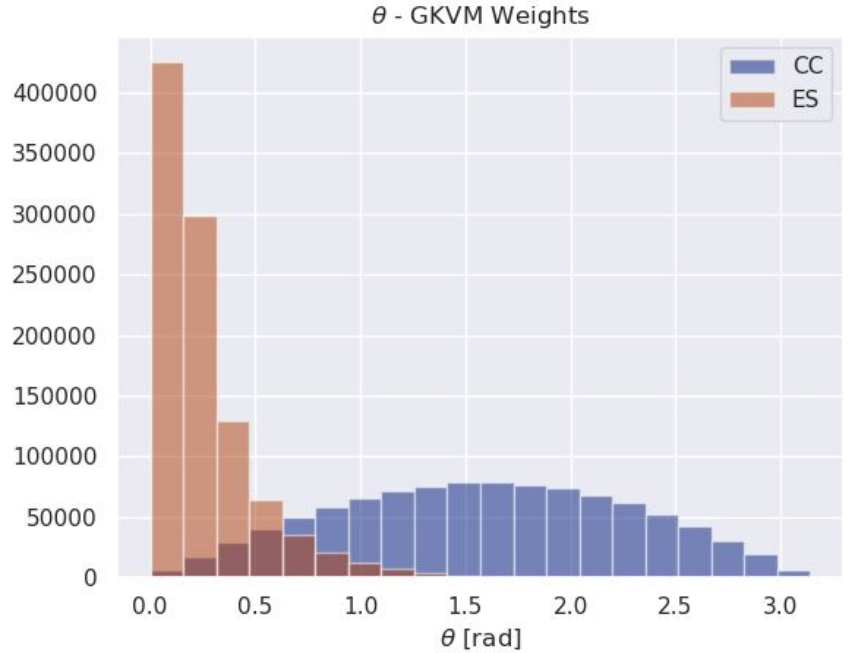




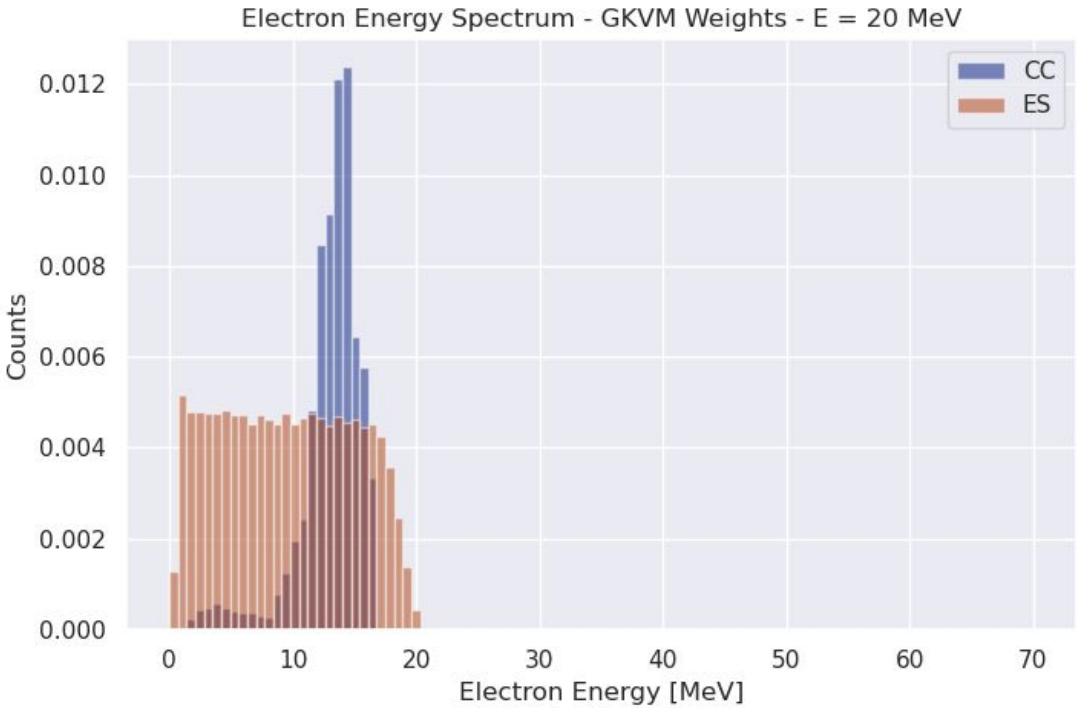


Training

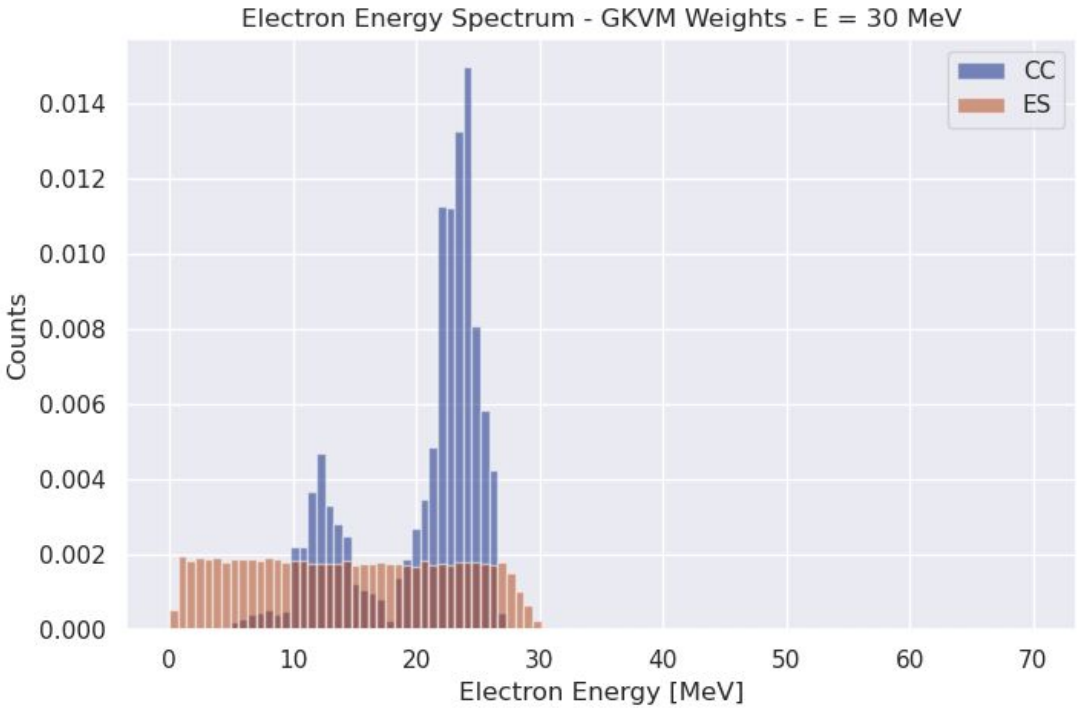

Energy vs θ - ES - GKVM Weights
θ [rad]
Energy [MeV]
Counts


θ - GKVM Weights
CC
ES
θ [rad]

Training


Electron Energy Spectrum - GKVM Weights - E = 20 MeV
CC
ES
Counts
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
10
20
30
40
50
60
70
Electron Energy [MeV]

Training


Electron Energy Spectrum - GKVM Weights - E = 30 MeV
CC
ES
Counts
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
10
20
30
40
50
60
70
Electron Energy [MeV]

Titolo della slide

Testo della slide

Titolo della slide

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