Optical Data Reconstruction at the DUNE Near Detector 2x2 Demonstrator Using a Differentiable Surrogate

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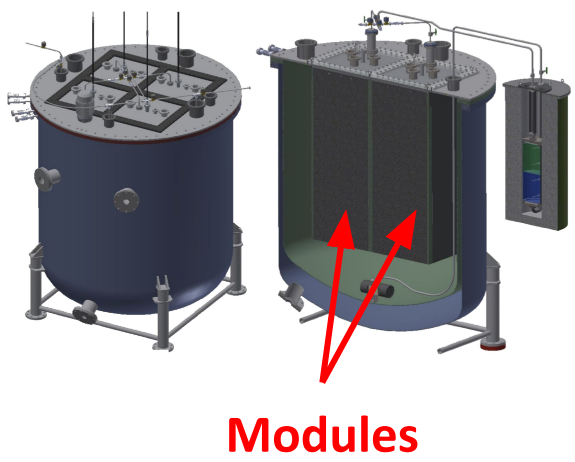
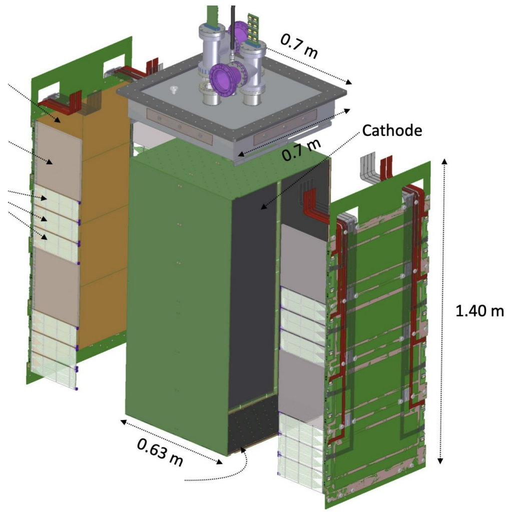
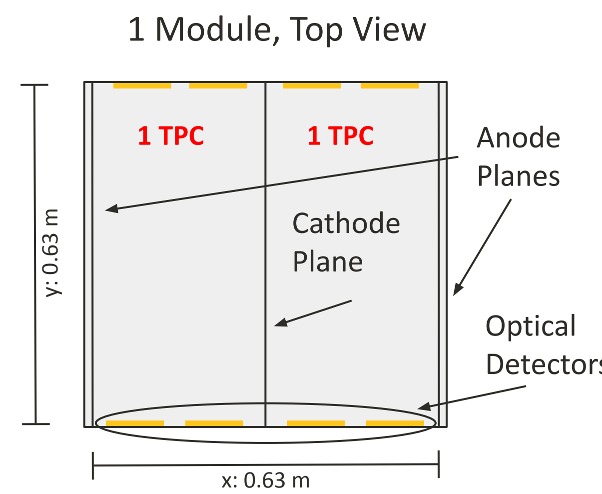
2x2 Detector

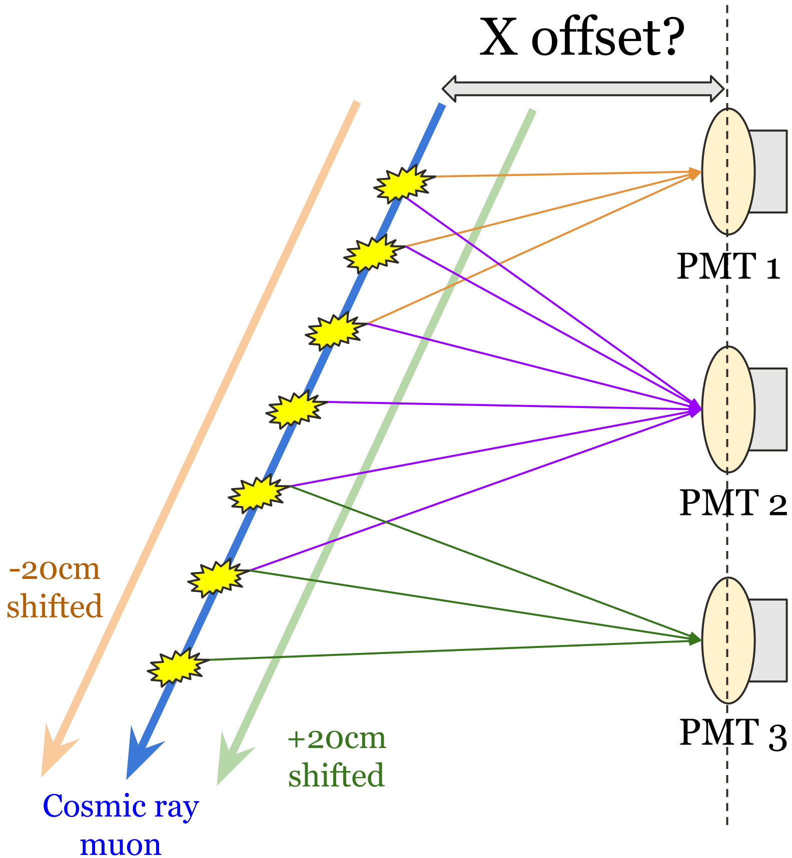
- Technology demonstrator for DUNE Near Detector
- 4 Modules, 8 Time Projection Chambers (TPCs)







What is Data Reconstruction?



- Photons are produced along the trajectory
- PMT photoelectron (PE) spectrum is unique to a trajectory
- Can reconstruct X by inspecting the shifts
- Use SIREN to model PE spectrums

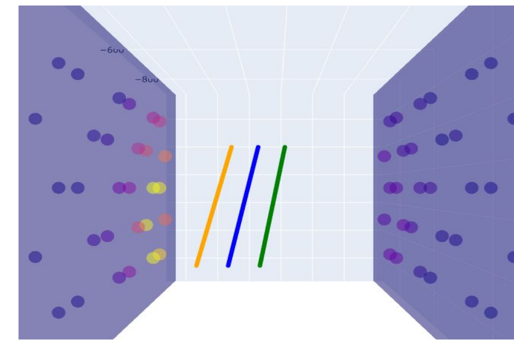
Reconstructing X-Position with SIREN

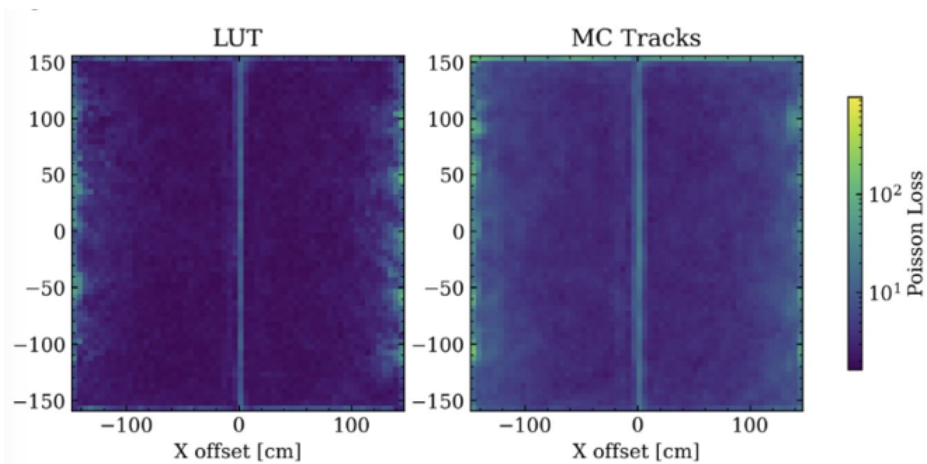
Assuming Poisson statistics from each PMT:

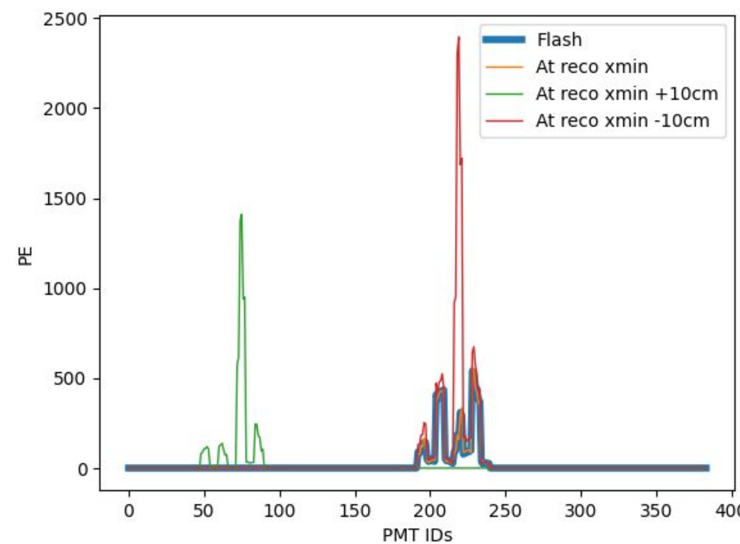
$$P(n_0, n_1, \ldots | x) = \prod^{PMTs} P_i$$

where $P_i(n_i|x) = \dfrac{e^{-\mu(x)}\mu(x)^{n_i}}{n_i!}$ (in discrete case)

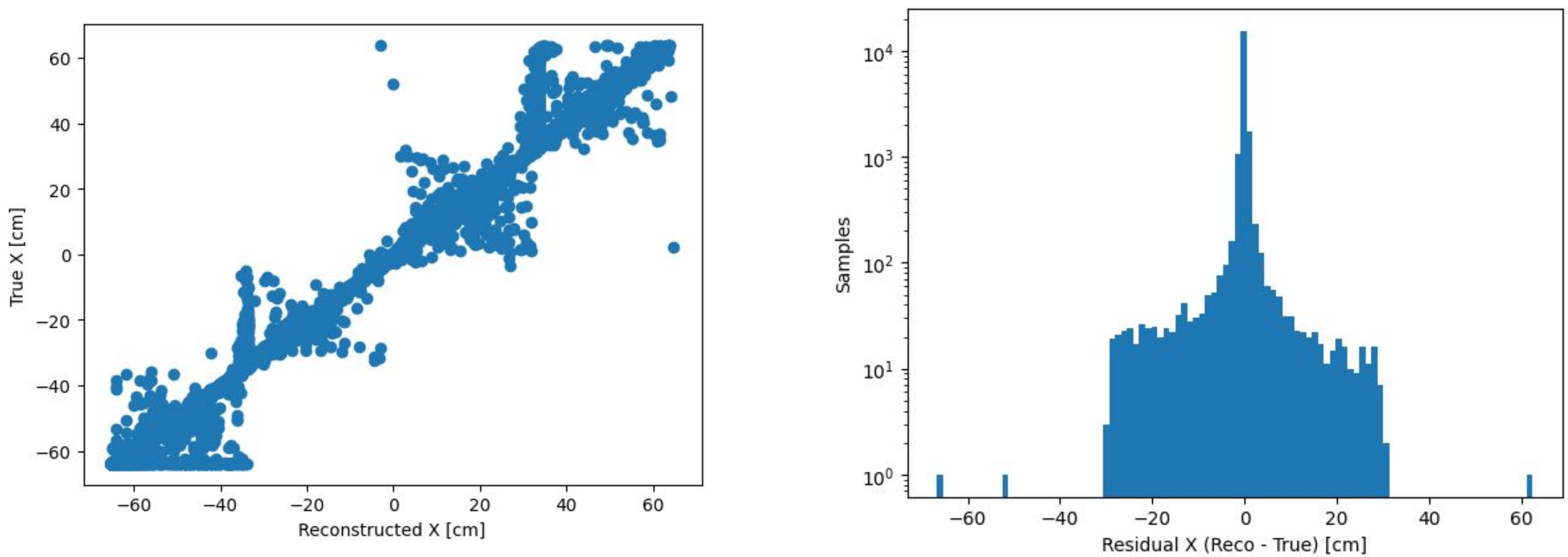
Maximum likelihood estimate of *x*: $-\log\left(P(n_0, n_1, \ldots | x)\right) = -\sum_i^{PMTs} \log\left(P_i\right)$







Reconstructing X-Position with SIREN

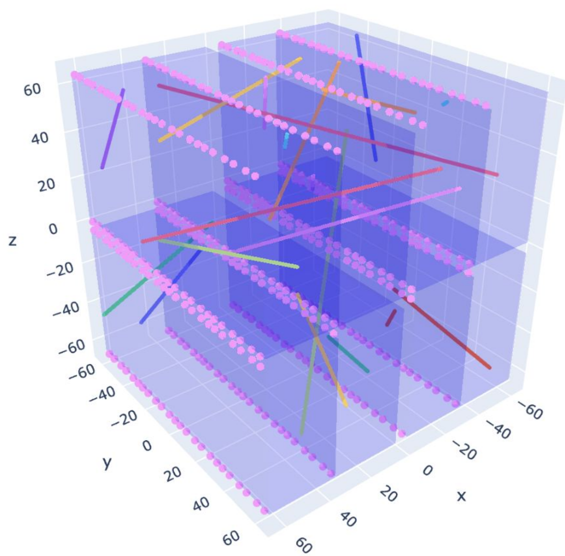


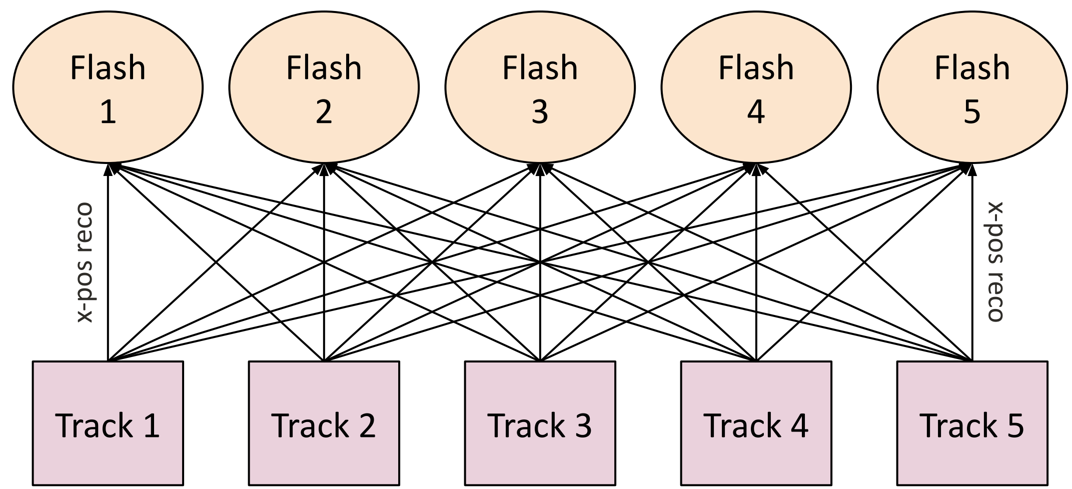
*Statistics Computed On 20k Simulated Tracks

Flash Matching: Reconstruction on Multiple Tracks

We observe around 20 events per second.

Task: Correctly associate optical and charge signals in a more dense data environment, and reconstruct x-positions.



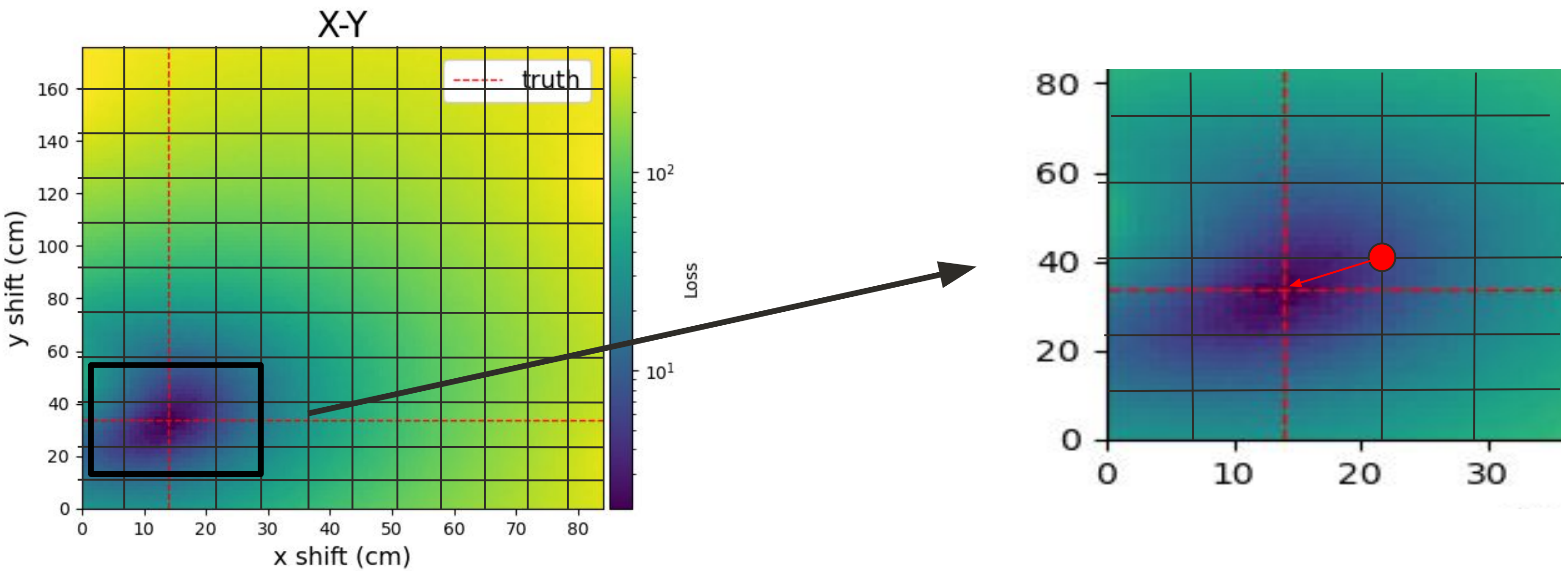


n^2 possible matches

Flash Matching: Reconstruction on Multiple Tracks

1. Coarse Loss Scan

2. Gradient Descent on Top Matches



Select the top 2 hypothesis flashes for each track.

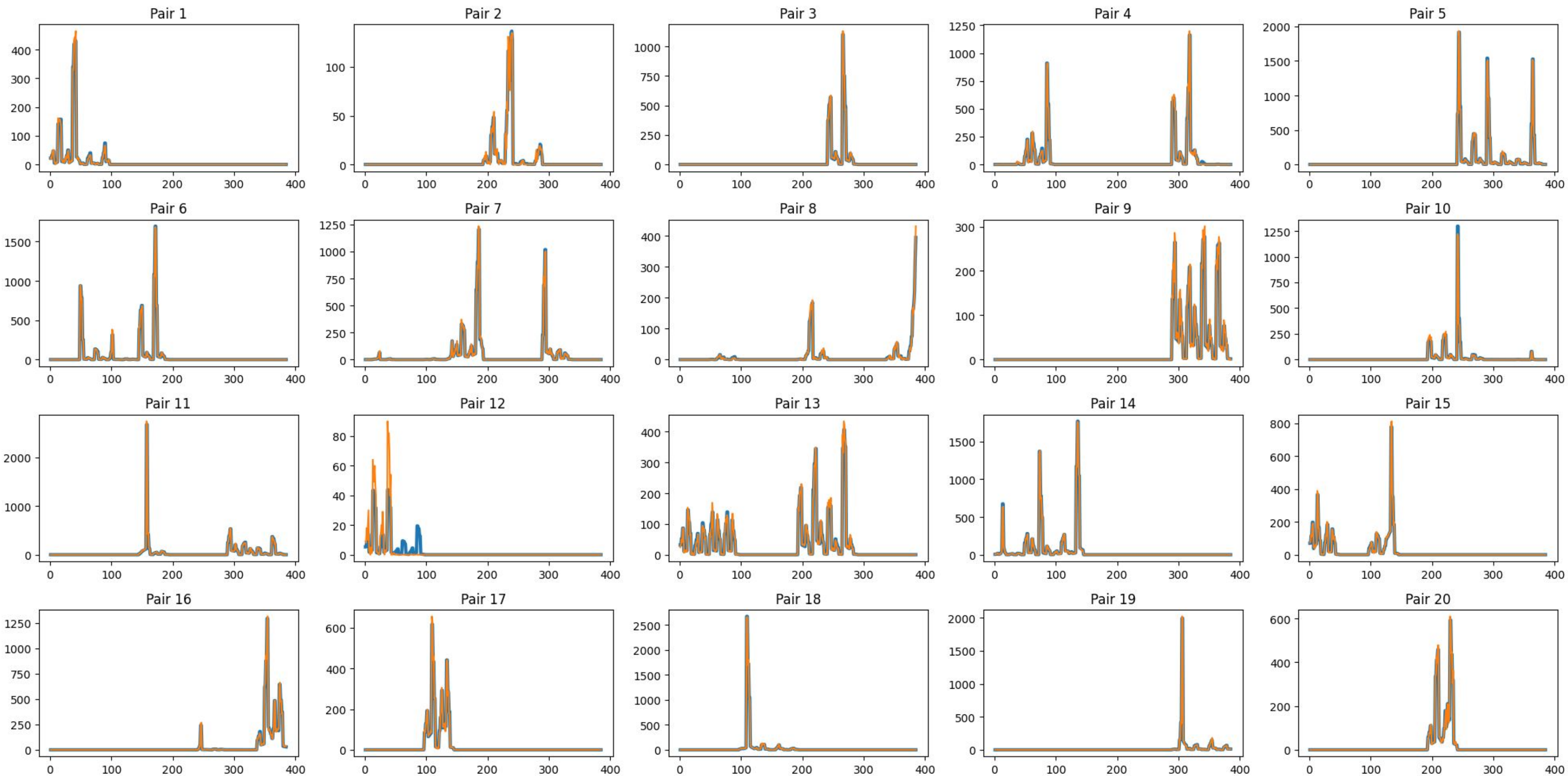
Start from lowest value in coarse scan. Choose flash with lowest final loss.

Flash Matching - 1 Event

X-axes: PMT IDs

Y-axes: **Optimal PE Spectrum Match**

True PE Spectrum



Conclusion

- SIREN can be useful for data reconstruction tasks
  - **Isolated X-position Reconstruction**
  - **Flash Matching** (charge/optical signal pair association, x-position reconstruction)
- Next Steps:
  - Test this on real data as the 2x2 demonstrator begins collection