# Lightmap reconstruction in nEXO with an internal $^{127}Xe$ source

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on behalf of the nEXO collaboration
LIght Detection In Noble Elements (LIDINE)
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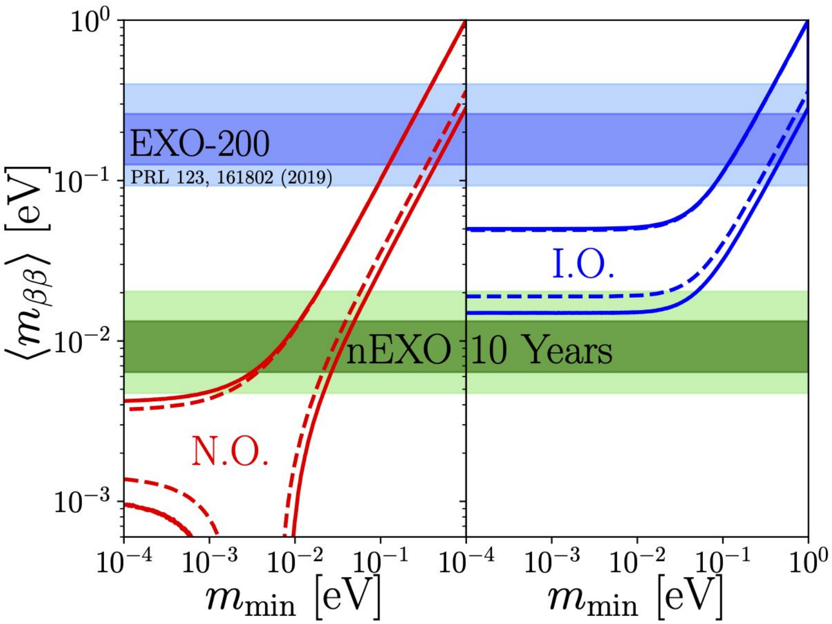
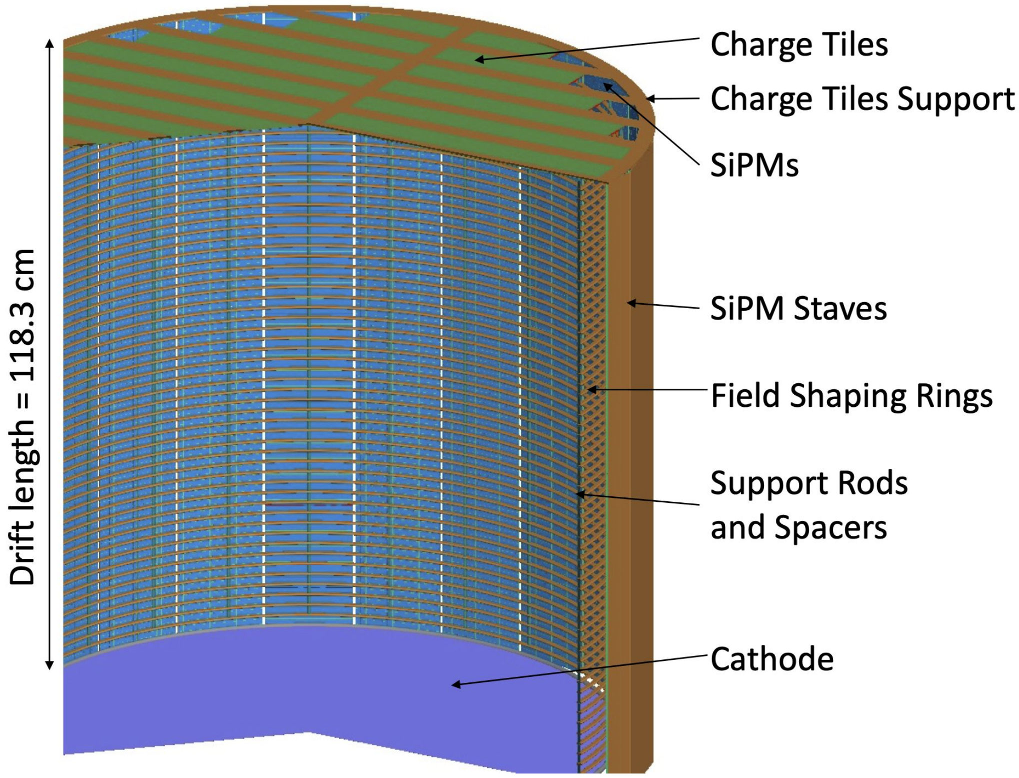
# Background: the nEXO Experiment

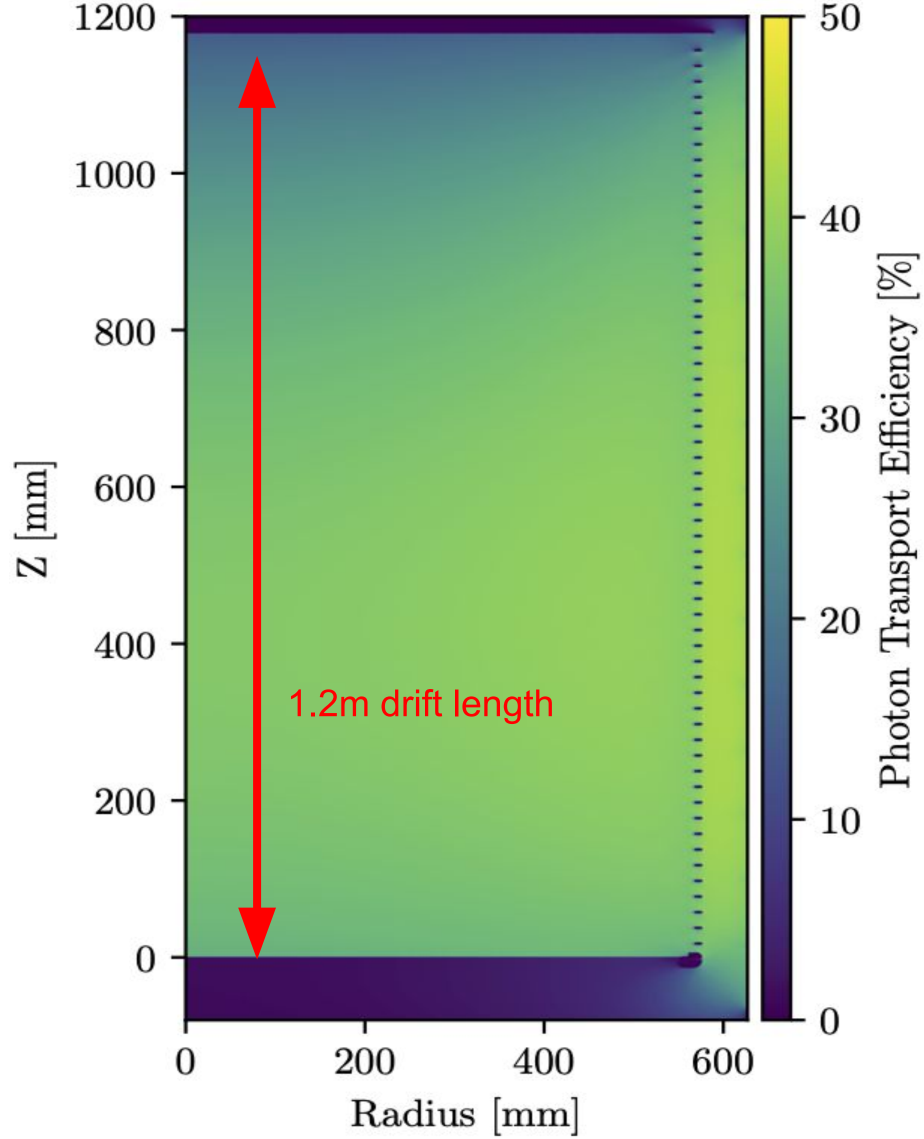
- Single phase time projection chamber (TPC) to search for neutrinoless double beta decay
- 5 tonnes liquid xenon enriched to 90% in $^{136}Xe$
- Half-life sensitivity > $10^{28}$ years [arXiv:2106.16243]



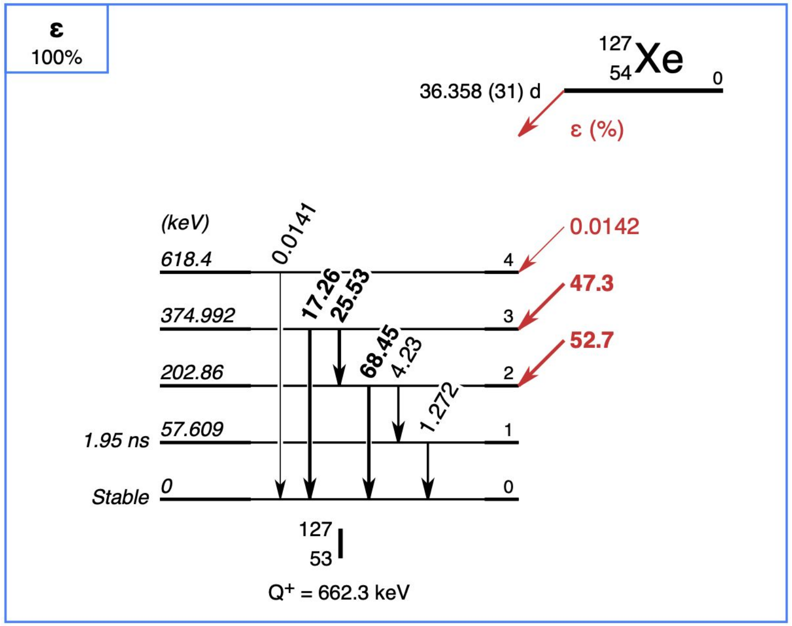
# Charge & Light Reconstruction

- Long drift length
  ⇒ **electron lifetime** correction
- Variation in photon transport efficiency
  ⇒ **lightmap** correction
- External gamma sources
  - Easy to deploy
  - Calibration over full energy range of interest
  - No risk of introducing backgrounds
  - Strong attenuation in skin xenon
  - Sacrifices livetime
- Internal alpha sources
  - Excellent resolution (~1%)
  - Illumination of entire detector volume
  - Sacrifices livetime

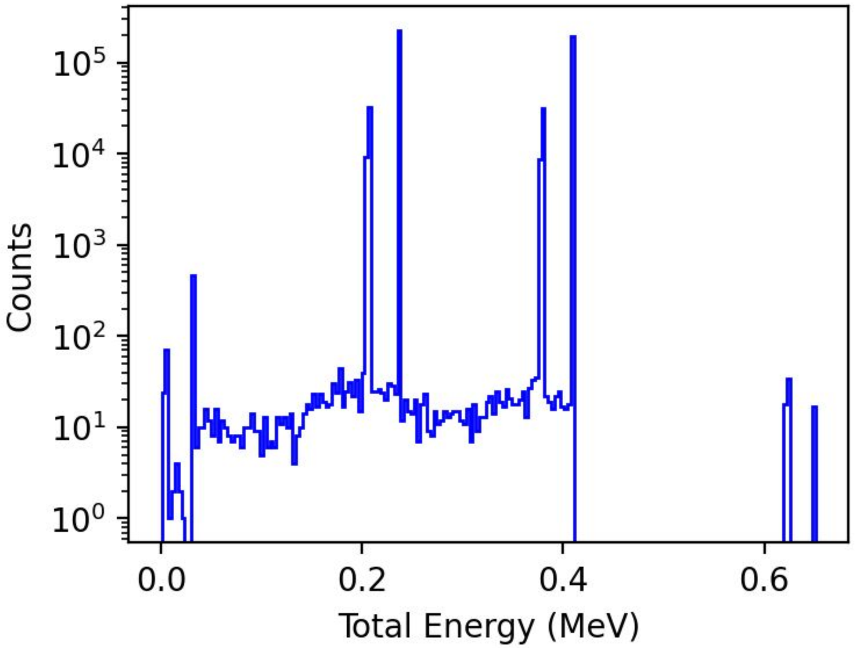


# Internal Calibration Sources: $^{127}$Xe

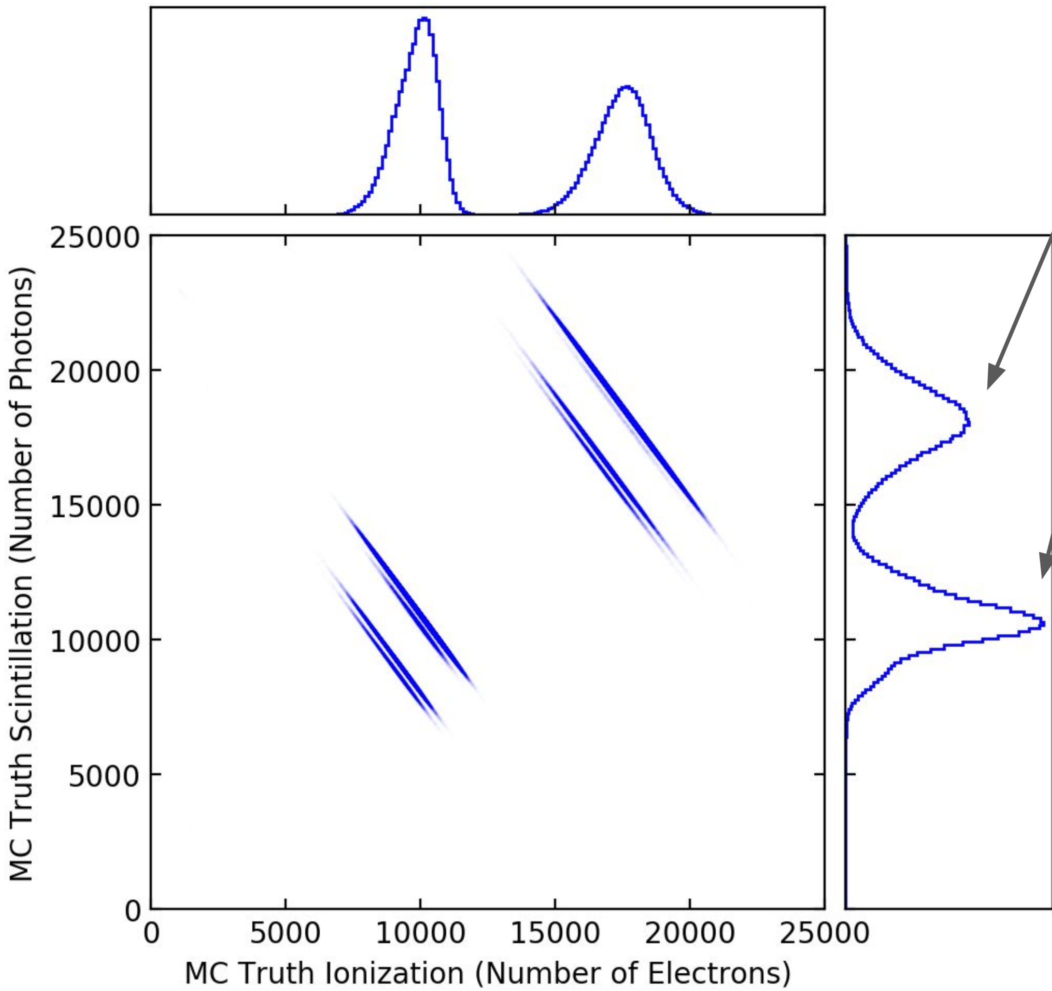
- Electron capture to excited states of $^{127}$I
- **36 day half-life, Q = 662 keV**
- Mixes uniformly throughout TPC
- Aim for ~1 Bq activity during calibration period
- No sacrifice of livetime required




Geant4-simulated energy spectrum



# $^{127}Xe$ Charge & Light Production

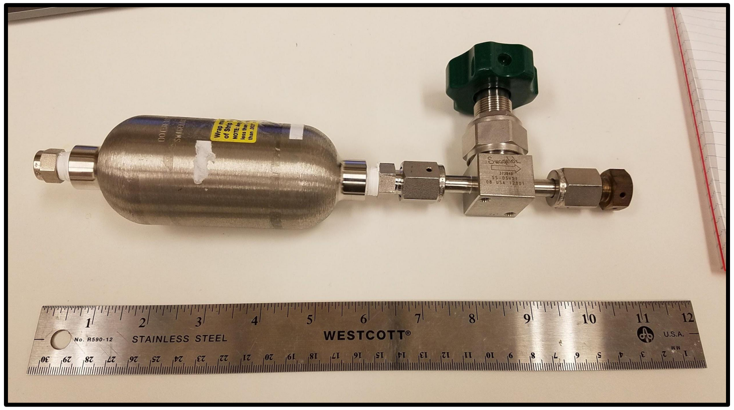



Substructure smeared into two peaks

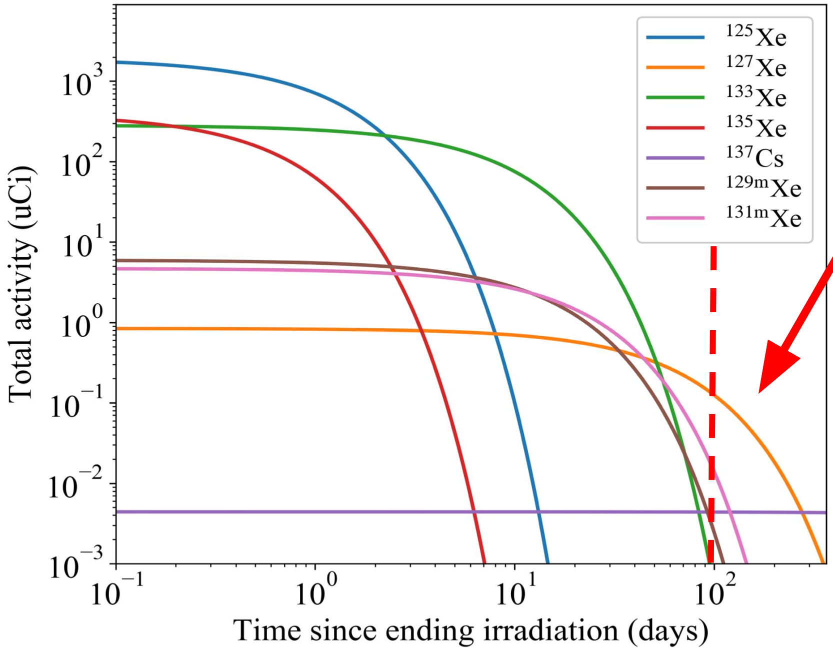
- Intrinsic peak width of ~10% due to recombination fluctuations
- Low energy peak near nEXO threshold of ~200 keV
- High energy peak well above threshold
- Well below 0vBB ROI

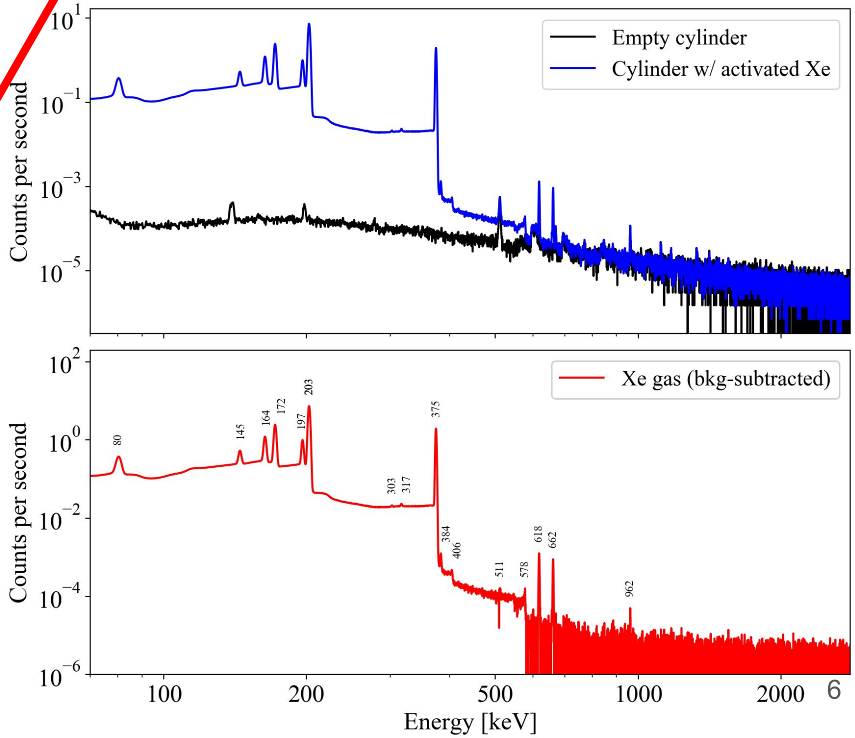
# Activation & Counting

- $^{127}Xe$ produced by neutron capture on $^{126}Xe$
- Sample cylinder containing 70g $^{nat}Xe$ gas (~0.1% $^{126}Xe$) irradiated at MNRC nuclear reactor facility
- Radioassay at MNRC & Stanford, HPGe counting at U. of Alabama to determine activity



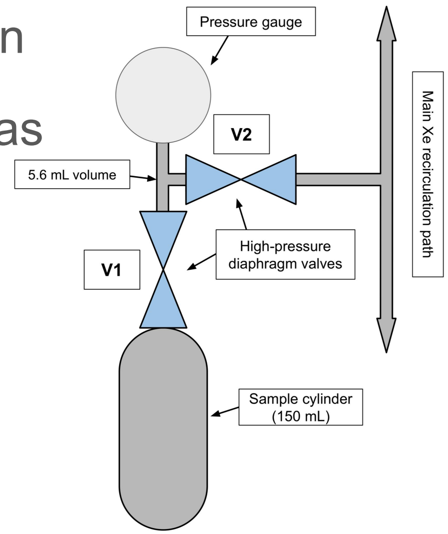

Dominant activity after ~100 days is from $^{127}Xe$

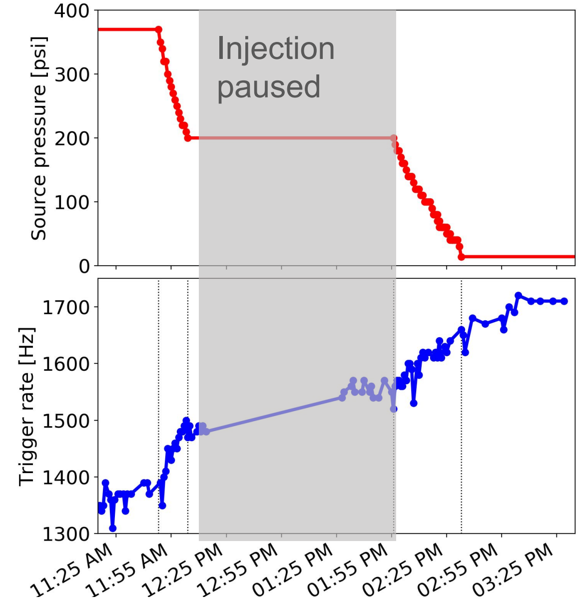


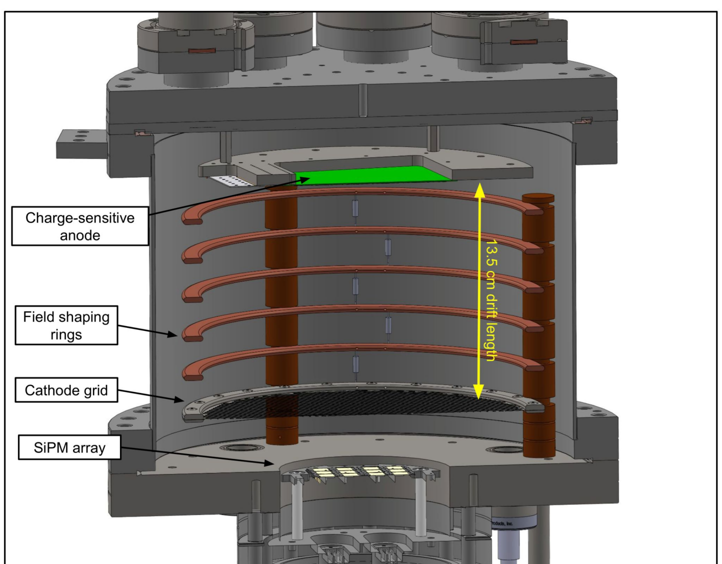



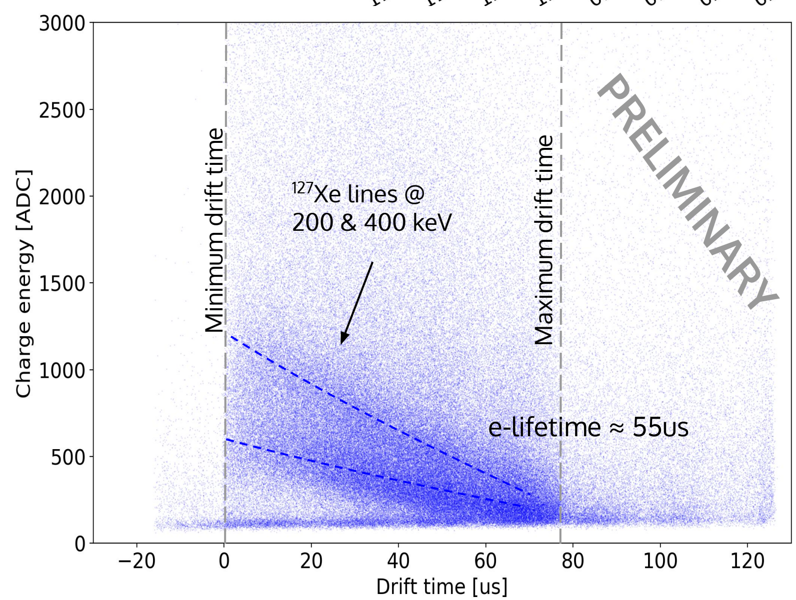
# Preliminary Results from Stanford TPC

- Injected $^{127}Xe$ during recirculation
- Delayed increase in trigger rate as $^{127}Xe$ mixes into TPC volume
- Events from both peaks clearly visible
- Full electron lifetime calibration results to be published soon



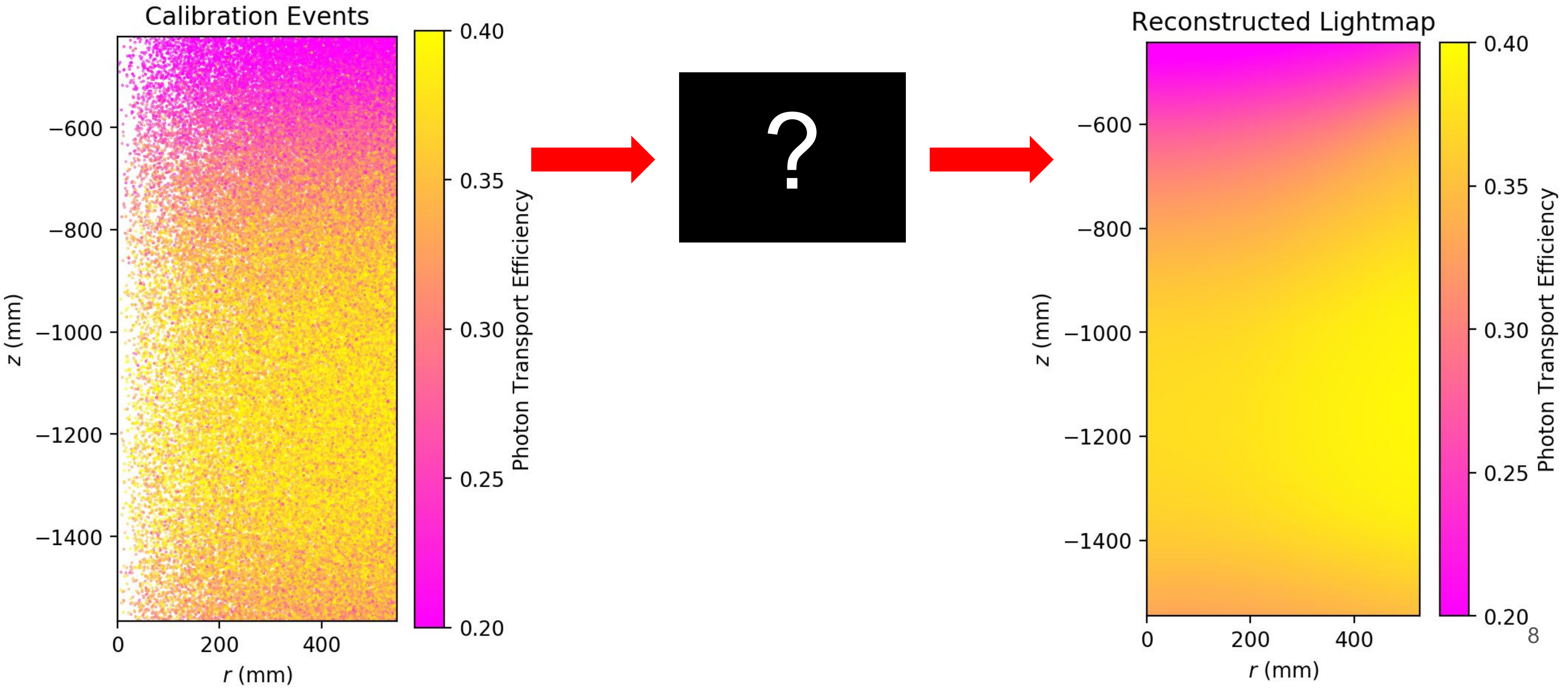



# Lightmap Reconstruction from Calibration Data

1. Compute efficiency for each event
2. Feed ***(x,y,z,eff)*** into a function that fits efficiency throughout entire volume
3. Produce continuous map of light collection efficiency



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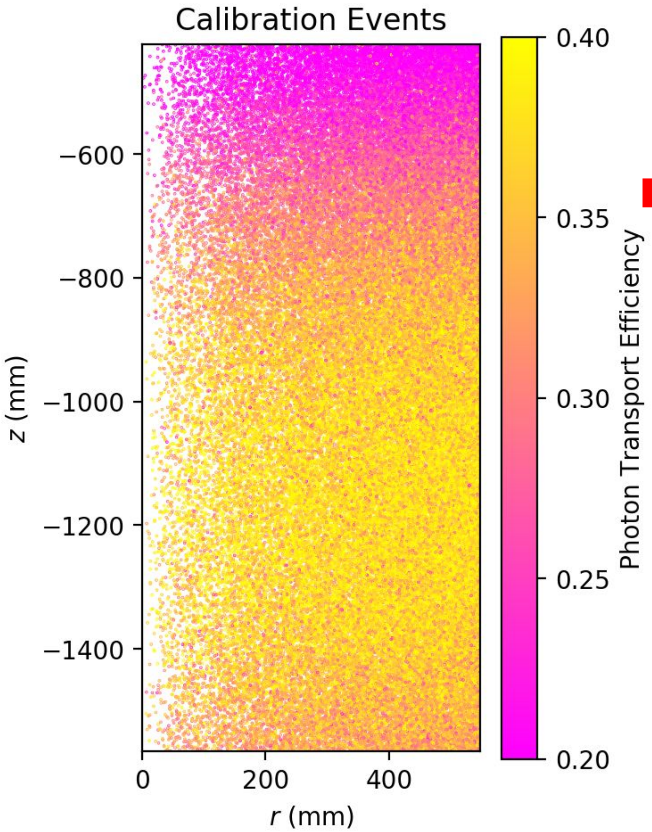


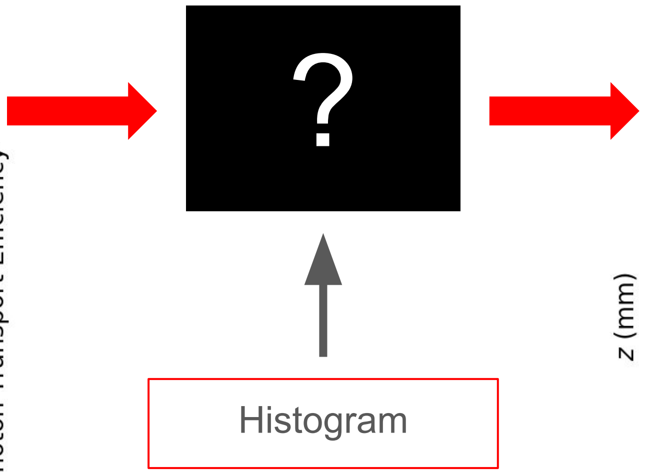


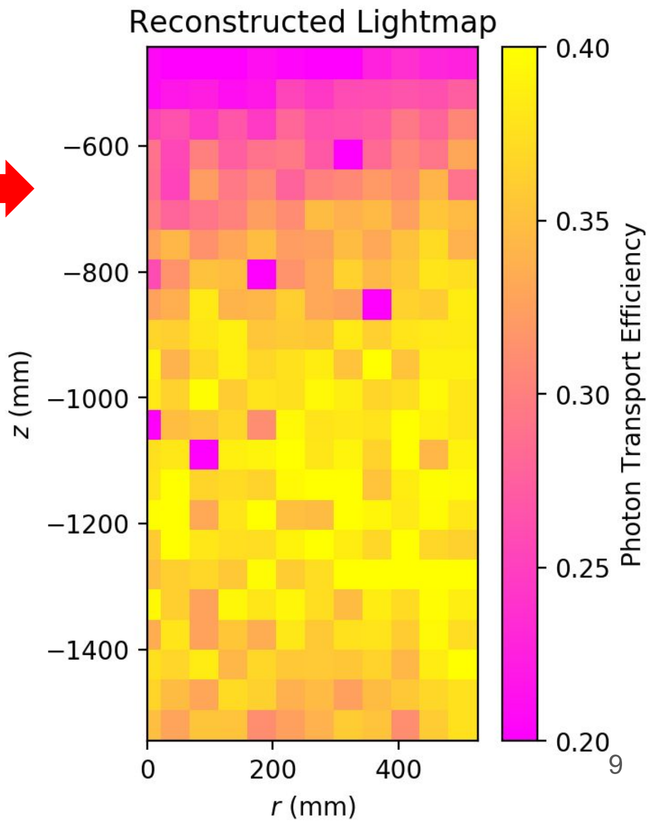

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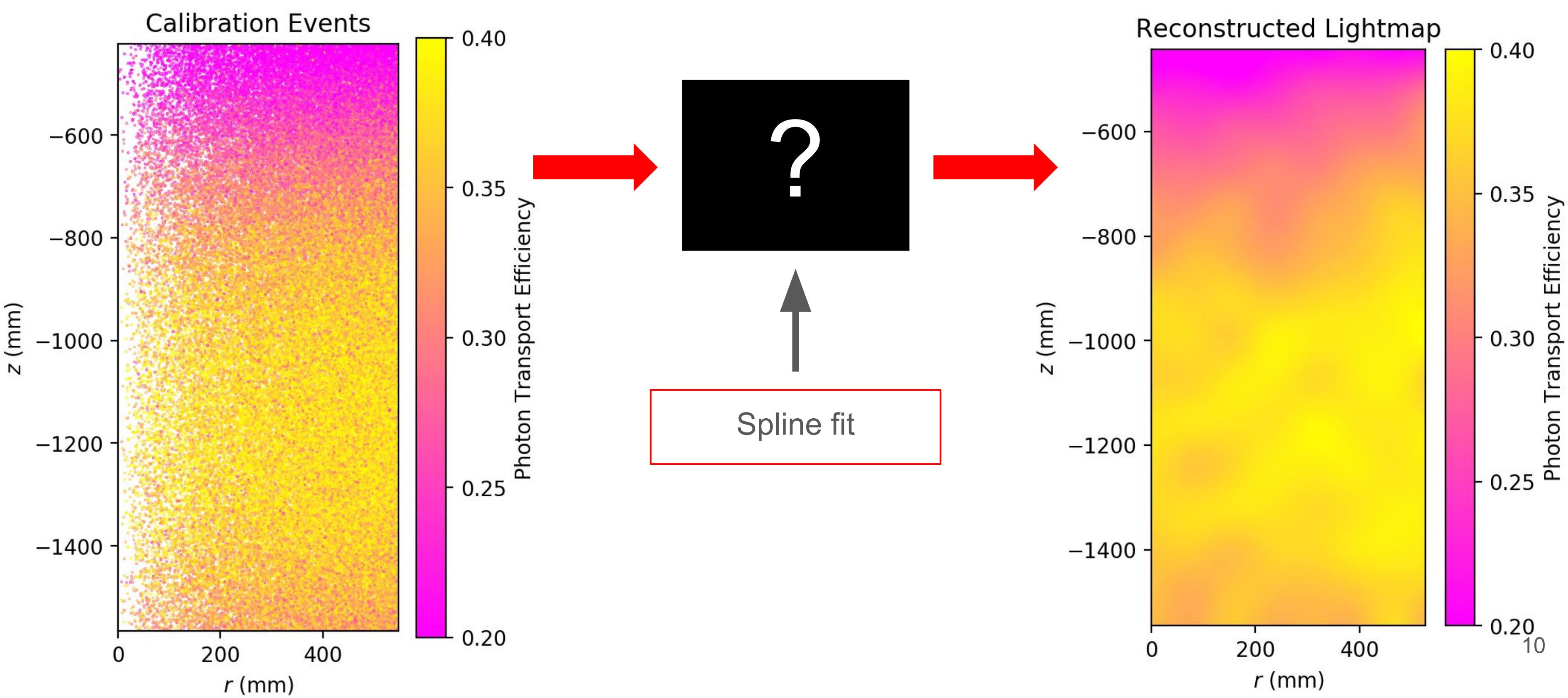

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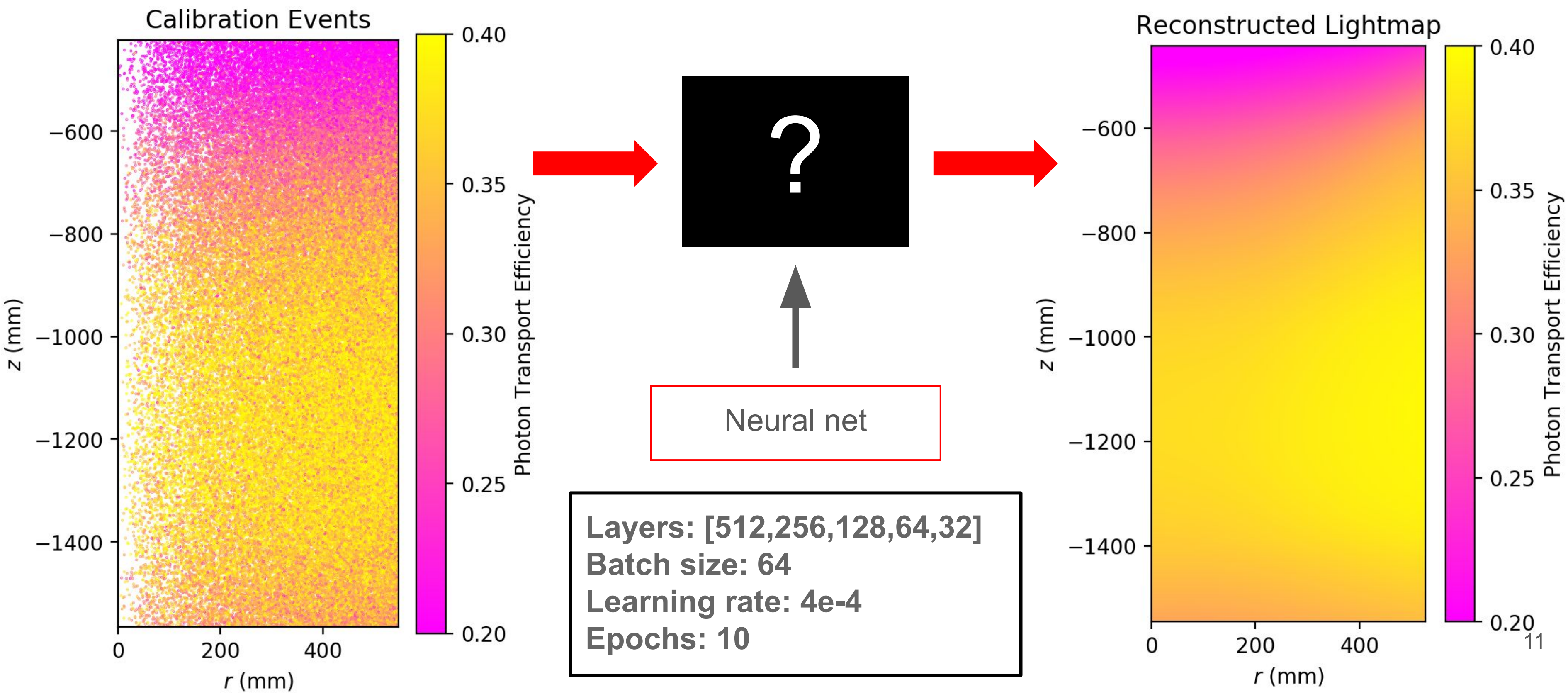
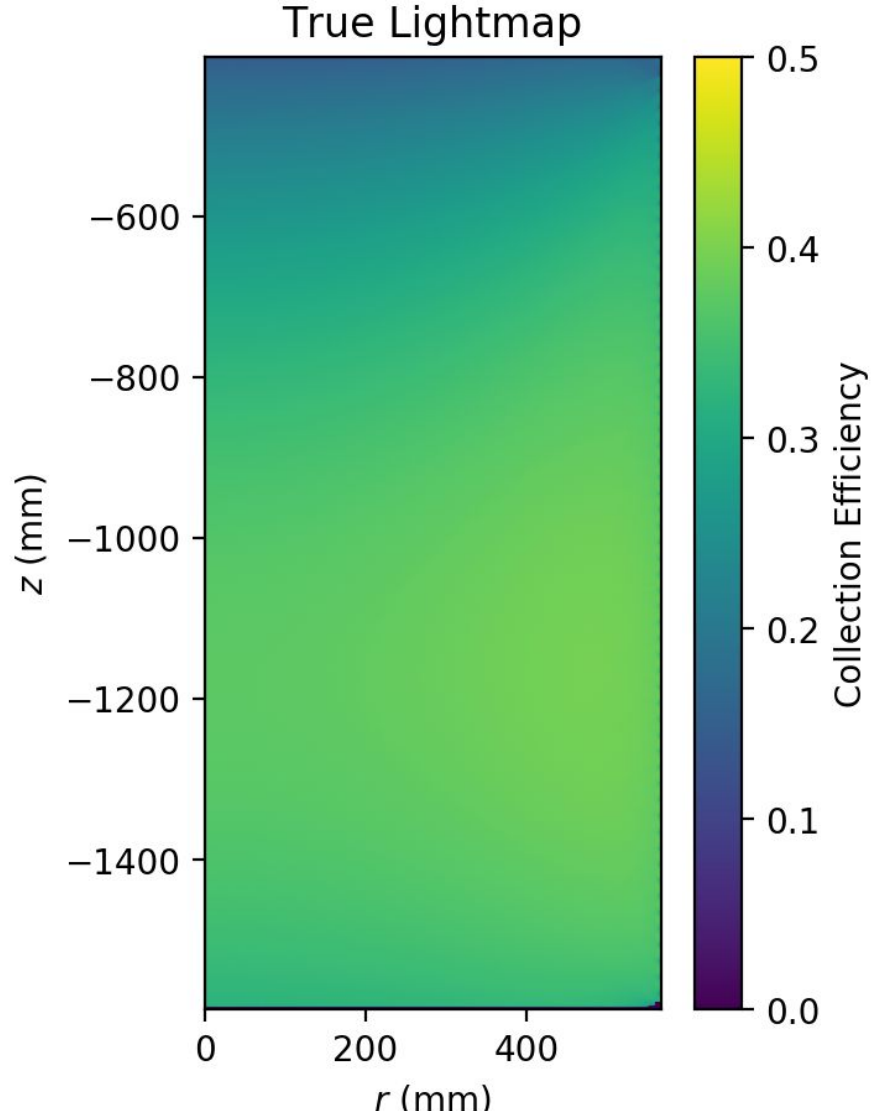


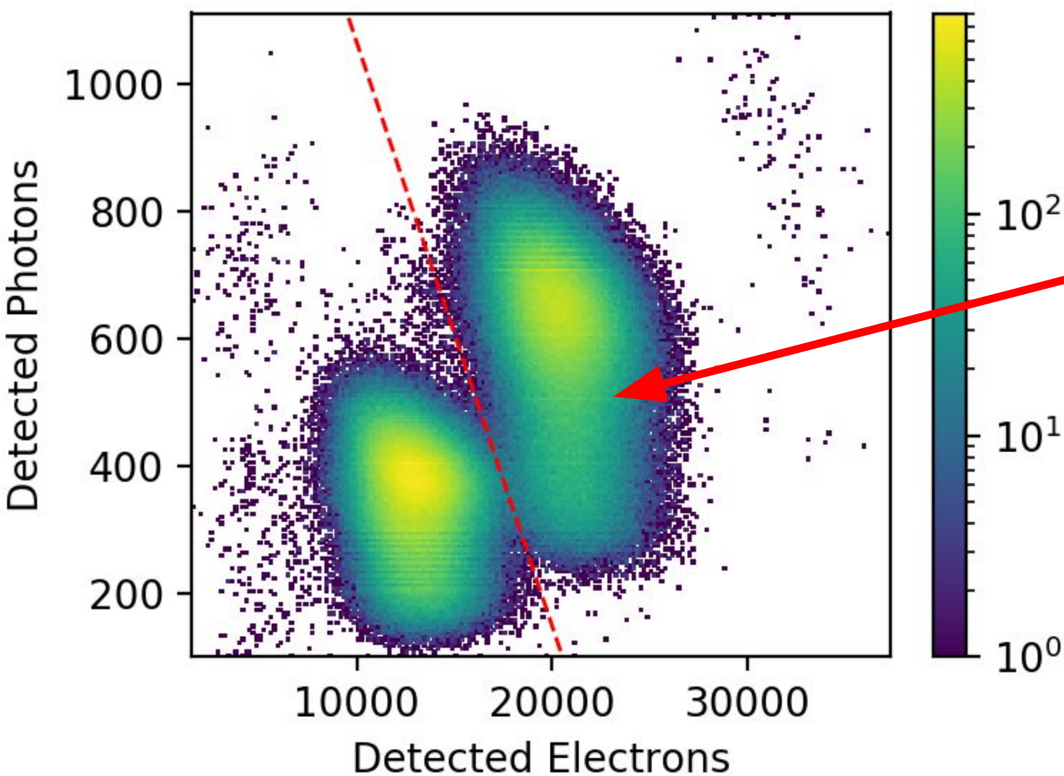
# Simulating $^{127}Xe$ Data in nEXO

- Simulations using Geant4-based **`nexo-offline`** simulation package
- Detailed geometry and NEST software to model charge and light production in TPC
- "Truth" lightmap produced using Chroma, GPU-based ray tracing software
- **Binomial sampling** of detected photons for each simulated event
- **Poisson fluctuations** added, representing correlated avalanches



# Cuts & Peak Selection

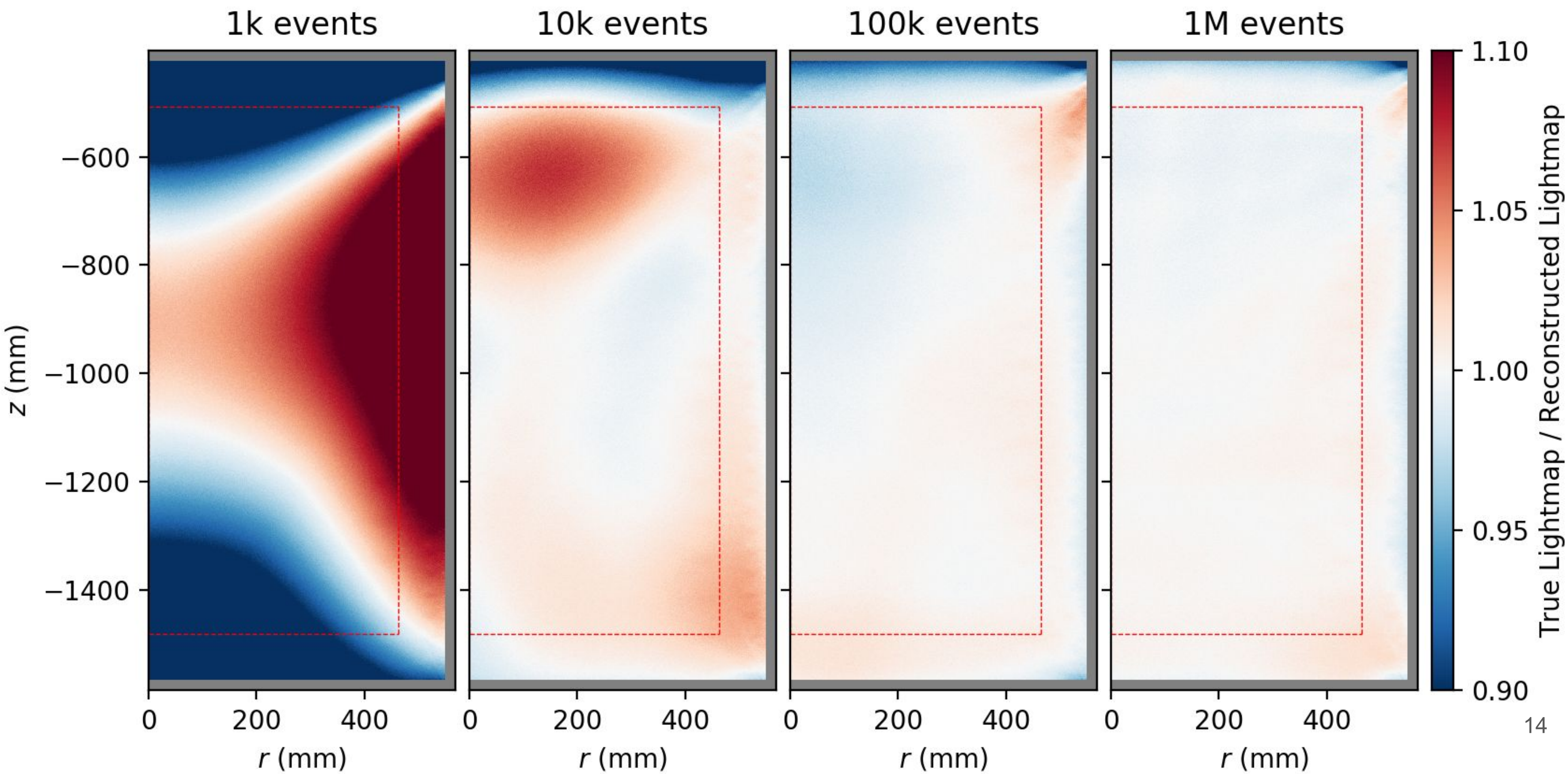
- 20 mm standoff cut
- Diagonal peak selection cut in raw detected photons & detected electrons
- Scale efficiency by the expected number of scintillation photons from NEST
- Adding lower energy peak doubles the number of calibration events




Uncorrected light signal smeared by position dependent photon transport efficiency

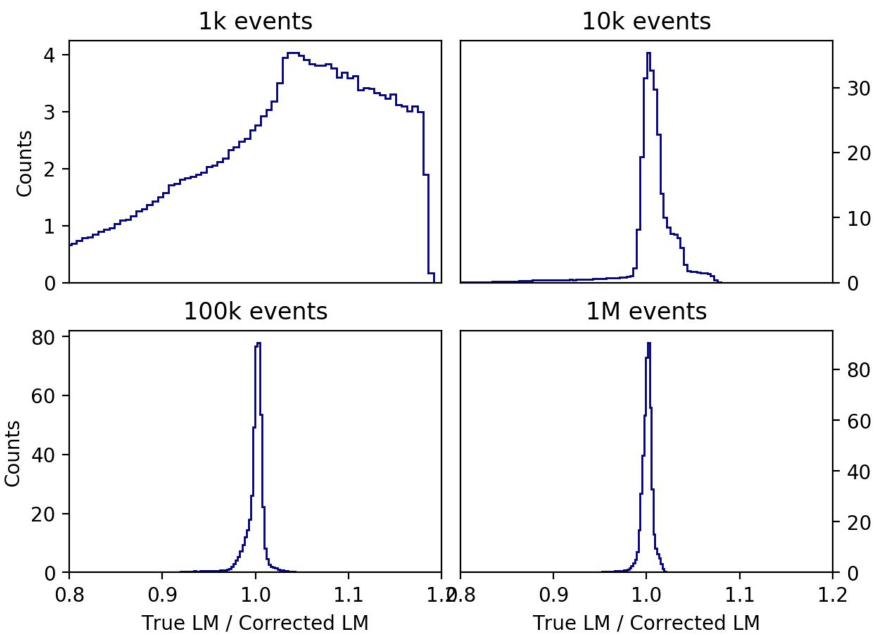
# Results - Reconstructed Lightmap

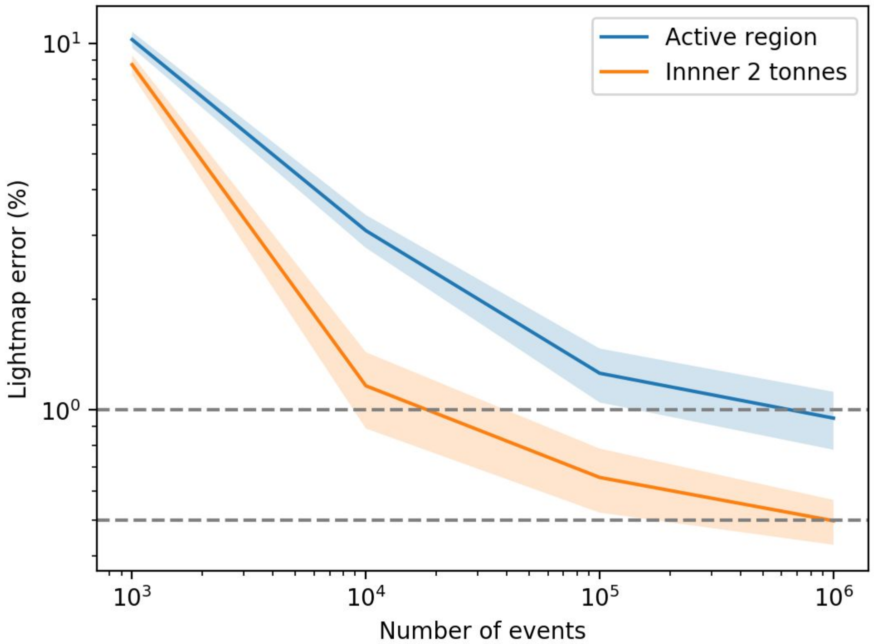
- Systematic errors that depend on the true lightmap
  - With few training events, NN tends toward uniformity
  - Regions of greater deviation have larger systematic reconstruction errors
- Errors recede with more calibration events, and are outside inner 2 tonnes



# Results - Uncertainty in Reconstructed Lightmap

- 0.5% error in inner 2 tonnes with 1M events (~2 weeks at 1 Bq)
- Improvement slows with larger datasets as calibration data is limited by source width
- Systematic errors visible in smaller datasets disappear with more events
- Significantly better performance toward TPC center where penetration of external gammas is limited



# Conclusions

- nEXO requires position-dependent calibrations of the light response to optimize energy resolution
- An internal $^{127}Xe$ source avoids some of the drawbacks of other sources
- Activation and implementation of an internal $^{127}Xe$ source has been studied at Stanford
- Simulations of $^{127}Xe$ decays in nEXO have been used to project the reconstructed lightmap accuracy for various dataset sizes
- At 1 Bq, 0.5% lightmap error in inner 2 tonnes achievable in ~2 weeks

# The nEXO Collaboration


nEXO
Collaboration Meeting Dec 2020

# The nEXO Collaboration

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