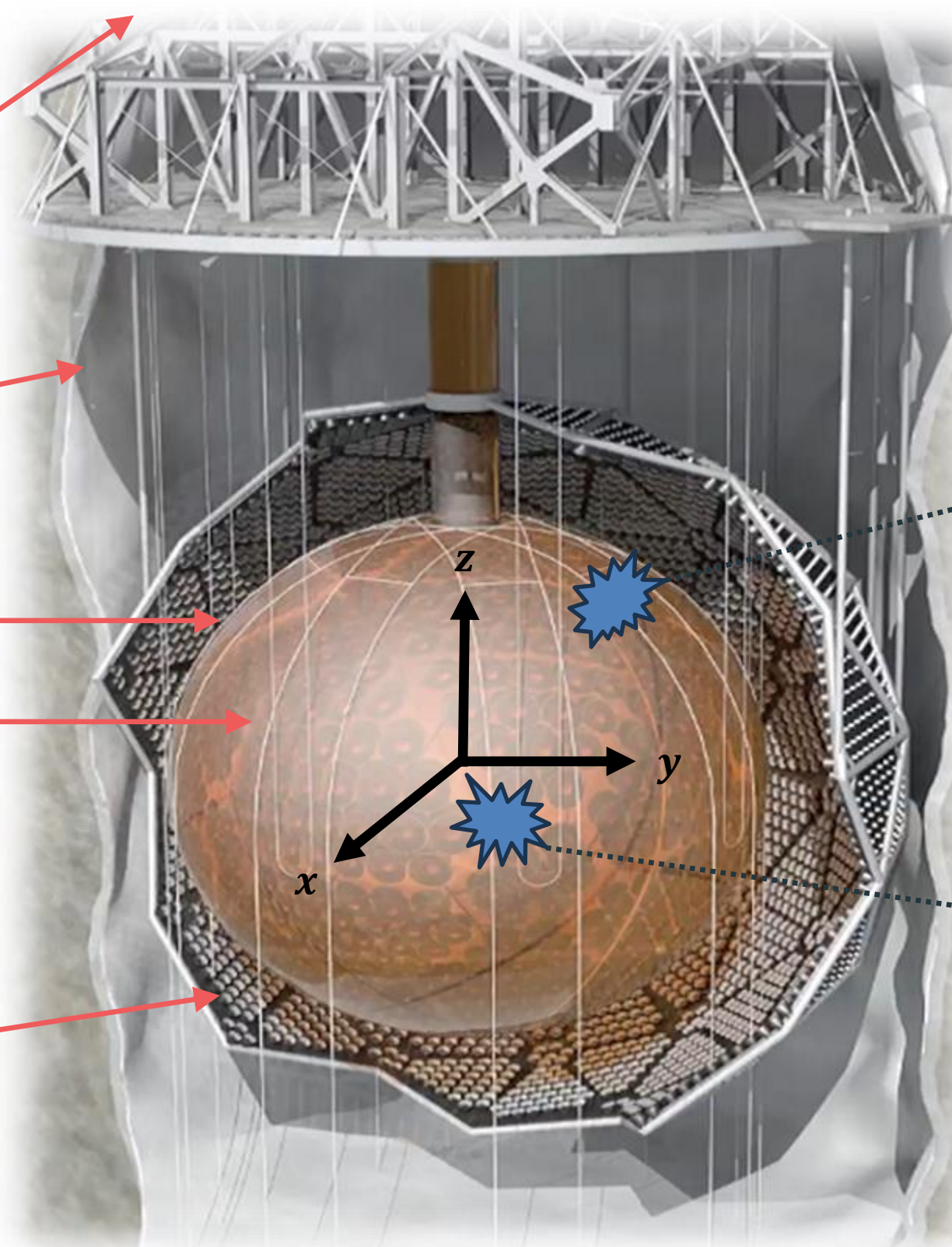
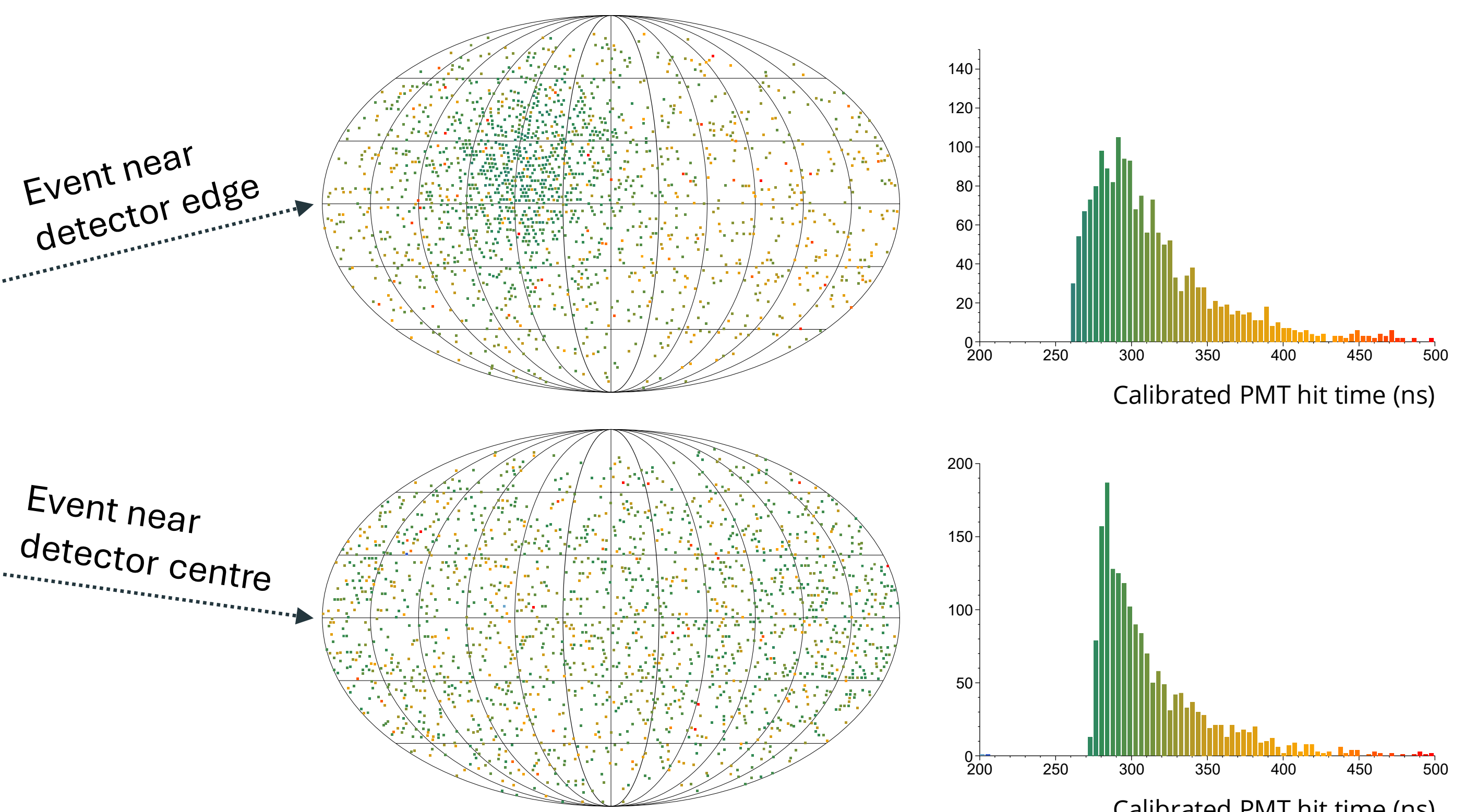


The SNO+ Experiment

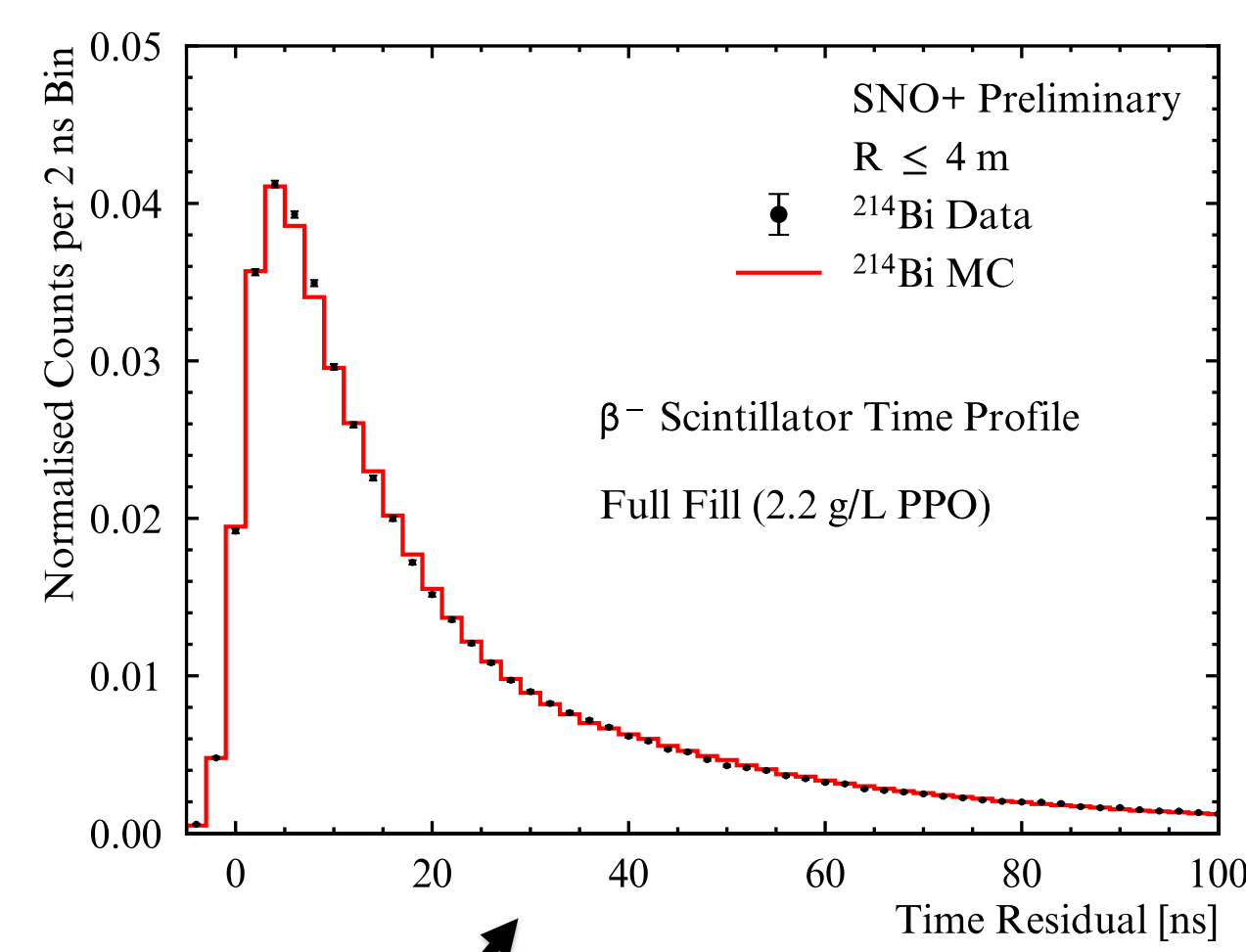
- Multipurpose neutrino physics experiment
- Located 2km underground at SNOLAB
 - ~6000m water equivalent, flat overburden
- Held within a large cavity filled with 7kt of ultrapure water for shielding
- 12m diameter spherical acrylic vessel (AV)
- AV filled with 780t of liquid scintillator
 - LAB (bulk solvent) + PPO (fluor)
 - High light yield; ~250 hits/MeV
- Surrounded by ~9400 photomultiplier tubes (PMTs) to detect light from interactions
 - 18m diameter PMT support structure



Event reconstruction uses the relative timing information of hit PMTs in an event



1. Maximum Likelihood Fitter



Time of flight (ToF) from candidate event position, $\vec{r}_{event} = (x, y, z)$, to hit PMT estimated by analytic light path calculator through media

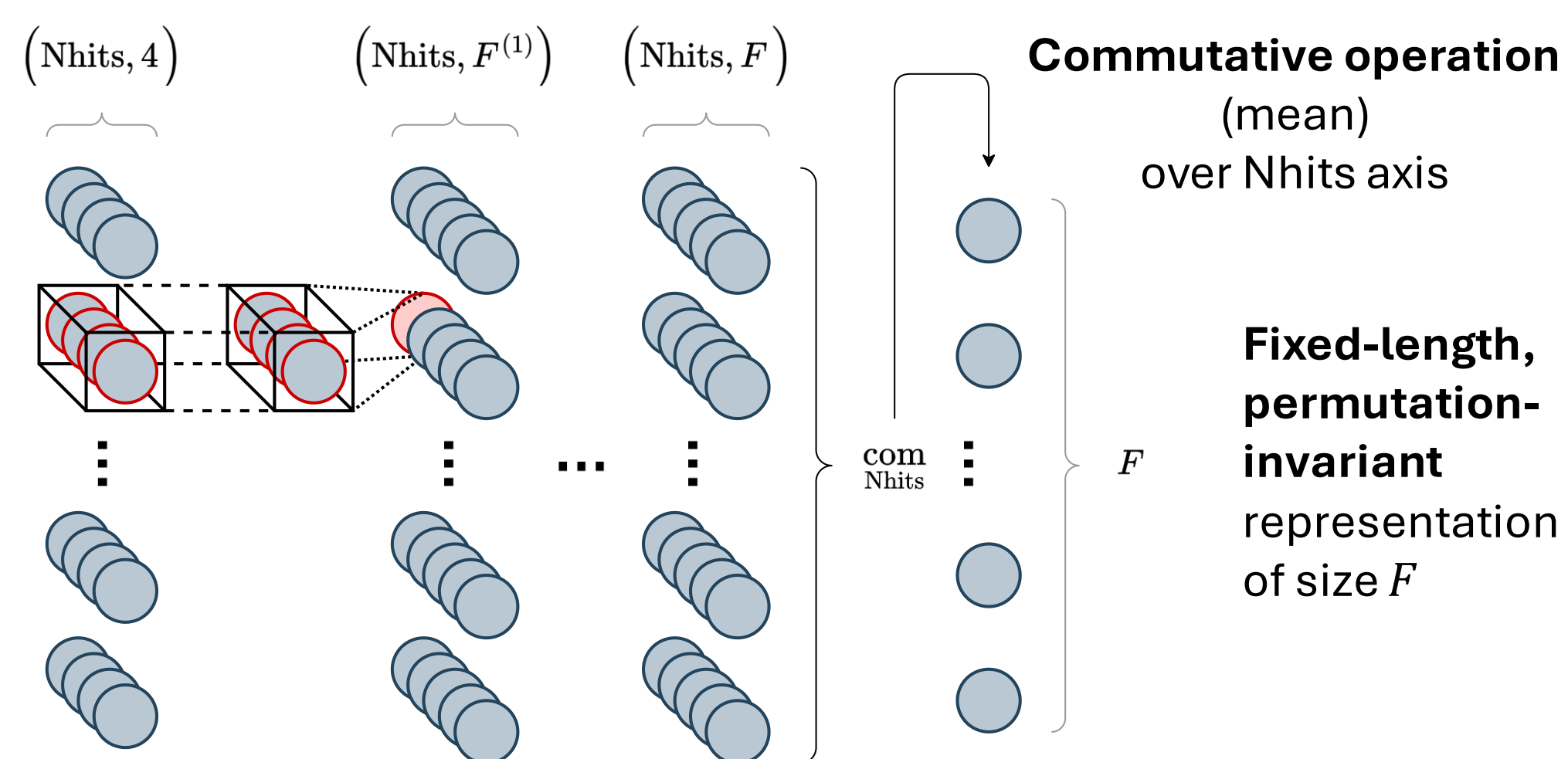
(observable)

Averaged distribution of **time residuals** = $t_{hit} - t_{event} - t_{ToF}$ derived from MC

Optimize event position and **time** for likelihood that observed time residual distribution drawn from this PDF; product over the **number of hit PMTs (Nhits)**

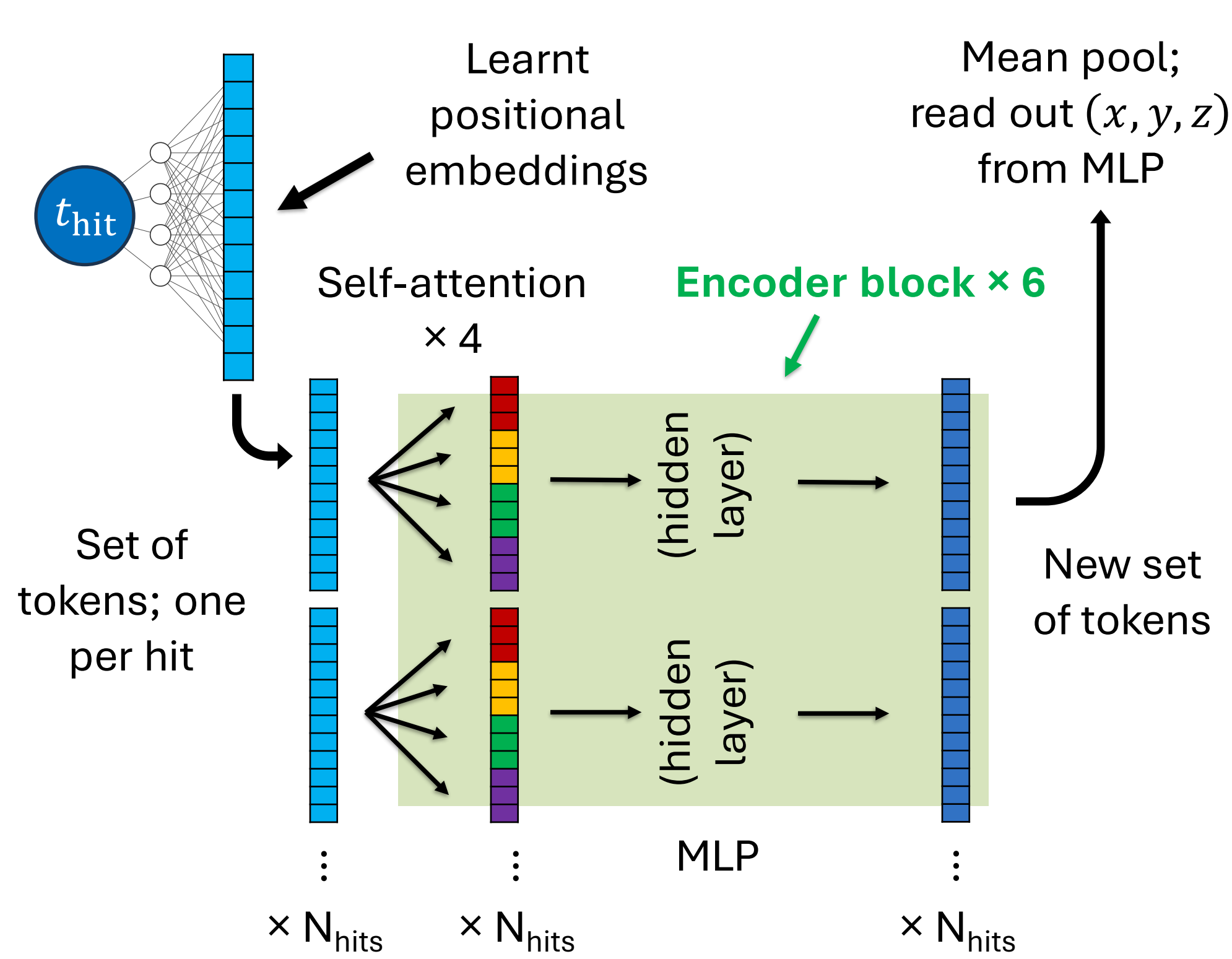
2. Convolutional Neural Network

- Network consists of a **1x1 convolutional feature extractor**
- Input is the **set of PMT hit information**, $(x_{hit}, y_{hit}, z_{hit}, t_{hit})$, containing each hit PMT in the event

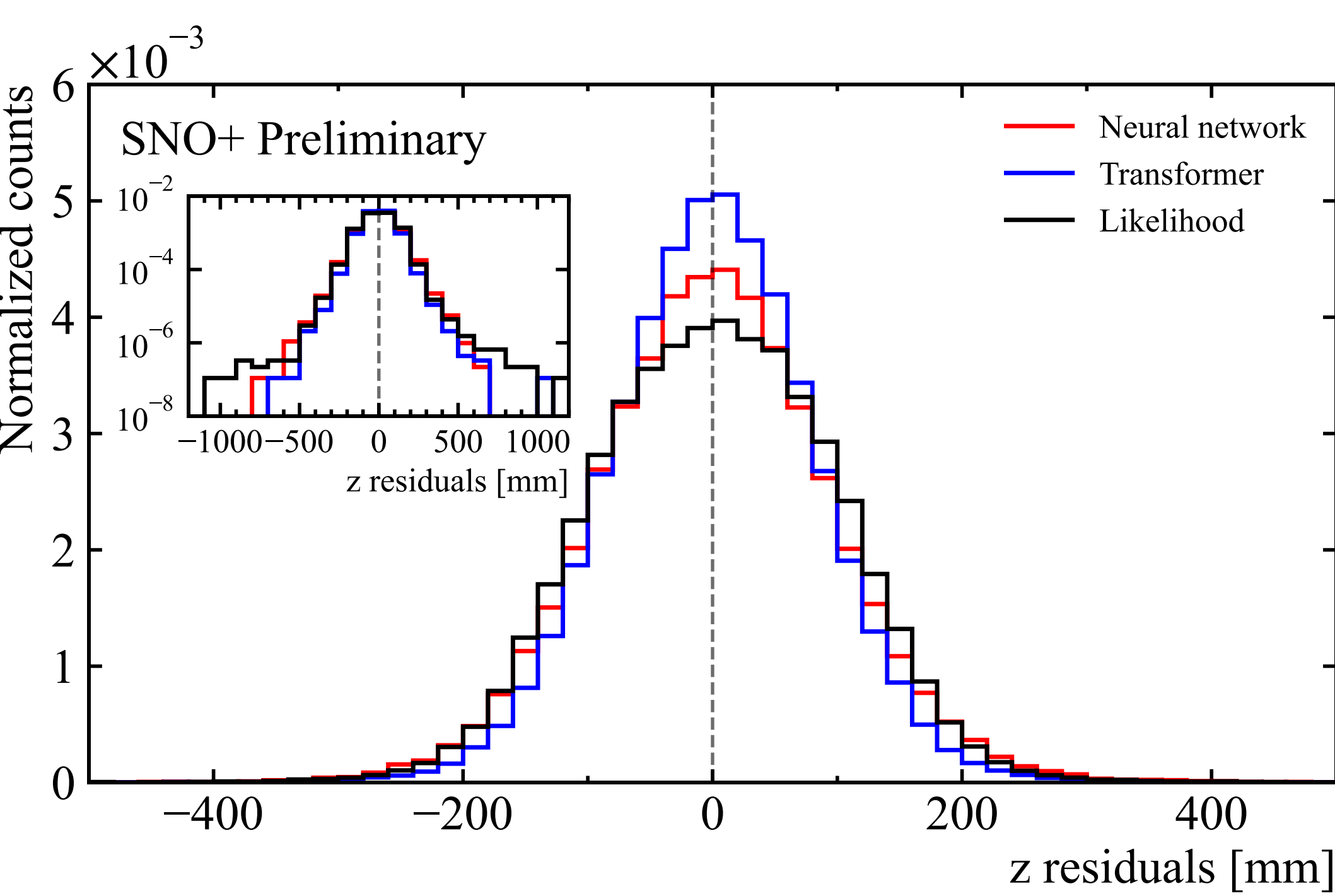


- New representation is fed to a standard fully-connected neural network which predicts the **Cartesian coordinates of the event position, \vec{r}_{event}**

3. Transformer Neural Network



Results



Method	Inference time (per event)	
	CPU [event-by-event]	GPU [batched]
Neural network	~10 ms	< 1 ms
Transformer	~170 ms	< 1 ms
Likelihood	~150 ms	N/A

- **Total residual** (reconstructed - true value) distribution shown for the **z coordinate** (longitudinal axis through detector) and **r** ($|\vec{r}_{event}|$) [top row]
- **Bias and resolution** shown for **z** and **r** as a function of the **true event energy** and **true event radius**
- **Resolution** defined as FWHM of residual distribution [middle row]
- **Bias** defined as sample mean [bottom row]

