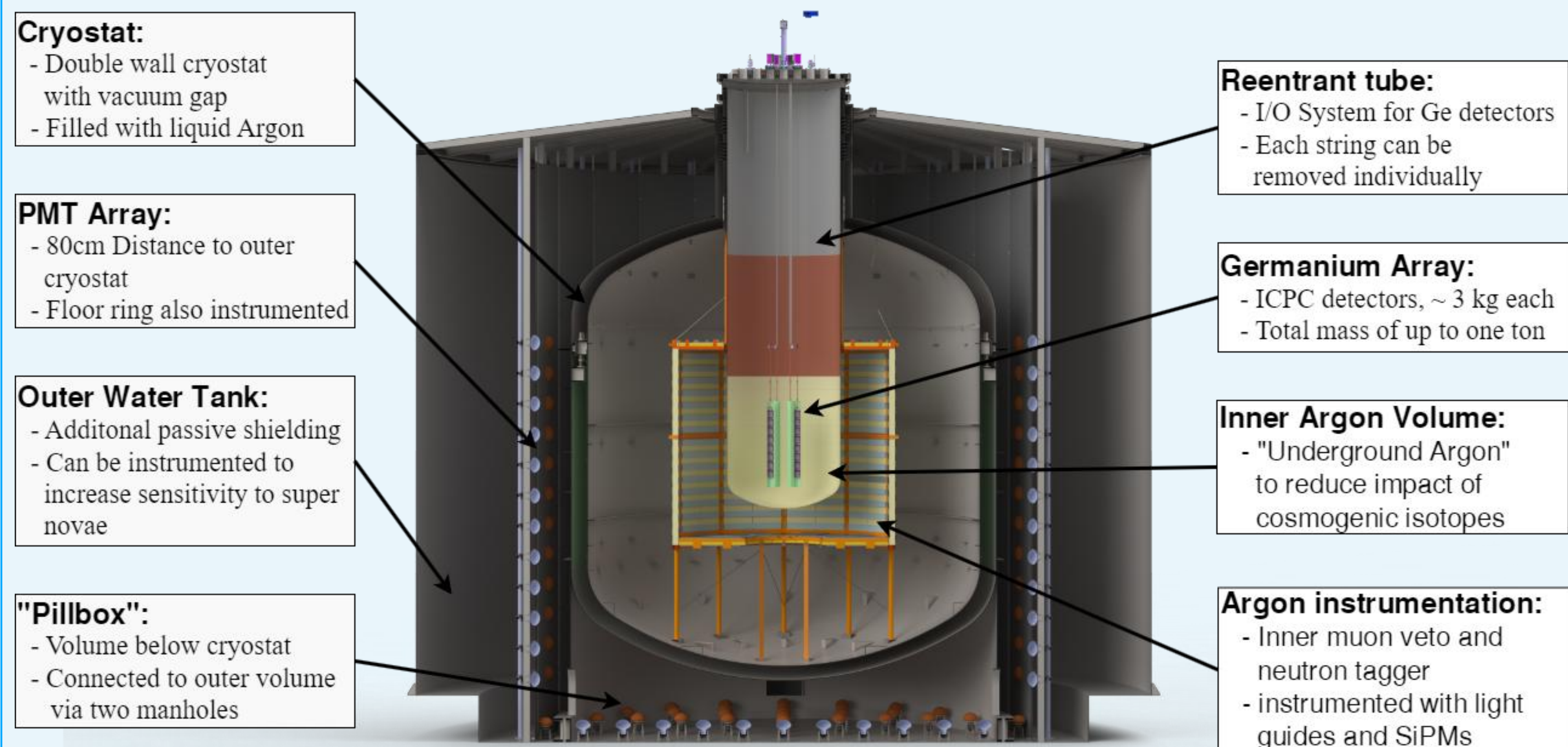


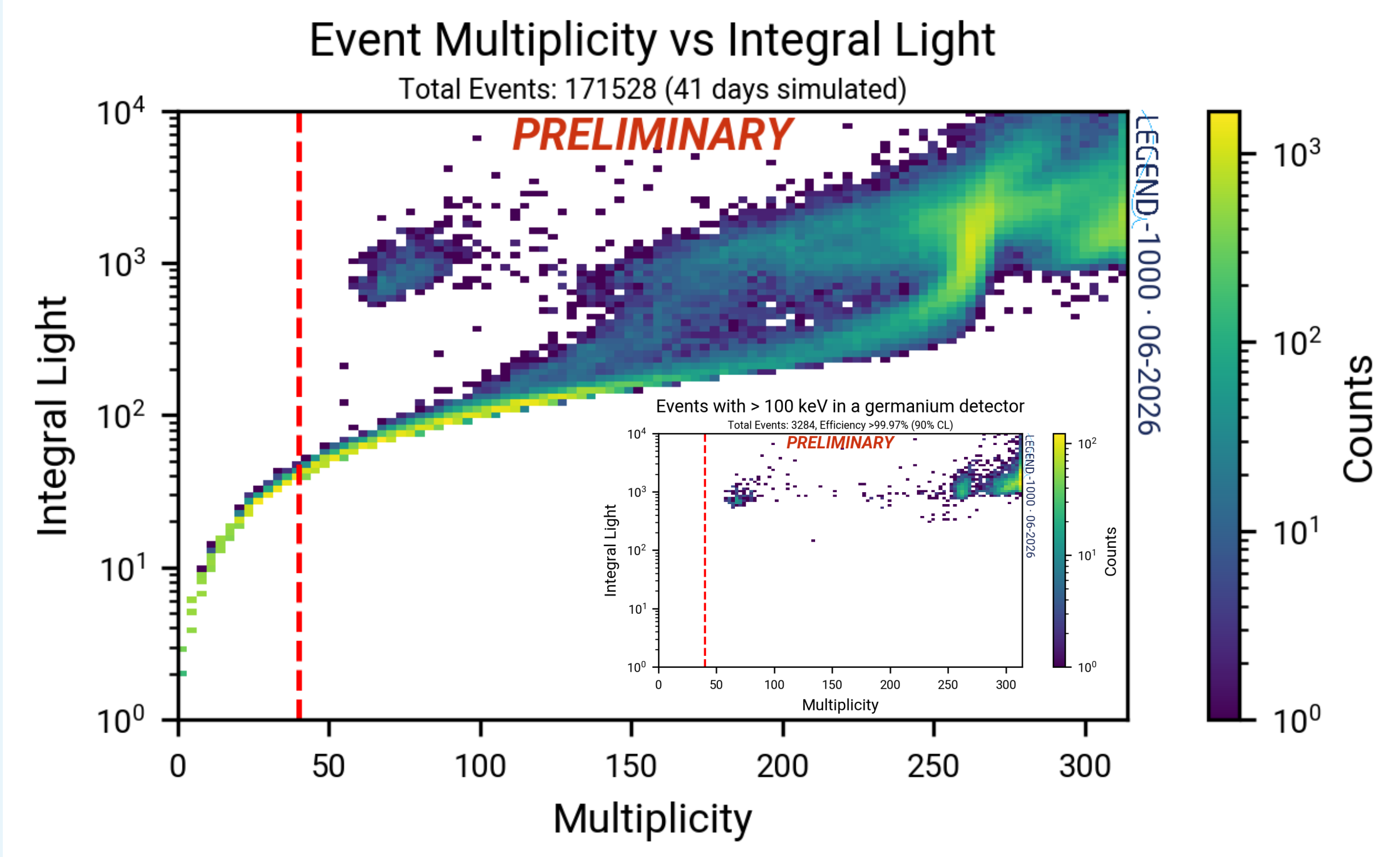


## The LEGEND 1000 Setup



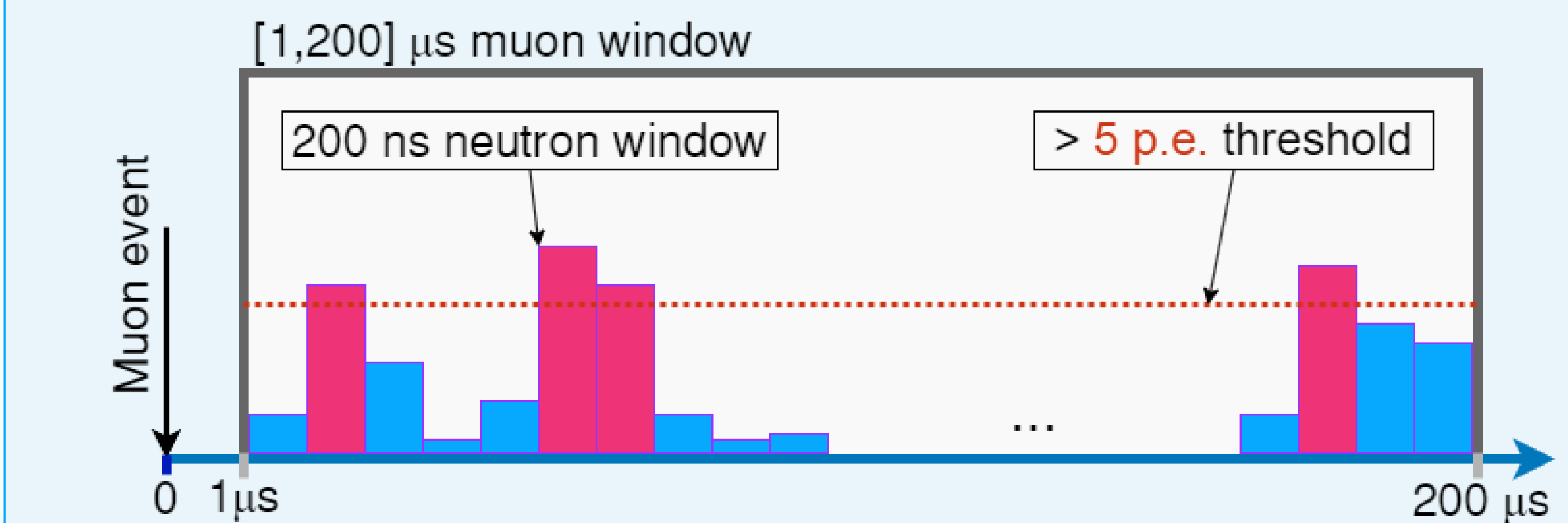
## Muon Veto Performance

Simulated muon veto events (integral light vs. multiplicity) of the LEGEND1000 muon veto. Visible is the main branch, as well as a secondary branch caused by the pillbox. Multiplicity cut will be placed at 40, lower limit of efficiency: 99.9% (95%C.L.). Inset shows the subset of dangerous events that deposited energy in the germanium detectors.



## Neutron Tagger

→ Identify possible  $^{77m}\text{Ge}$  productions via correlated triggering scheme: After a muon event a window of  $200\mu\text{s}$  is opened. Within this window, whenever more than 5 p.e. are detected within a period of  $200\text{ns}$ , a neutron event is considered to be found. If within this  $200\mu\text{s}$  five other neutrons are detected (see scheme below), the event is flagged as possible  $^{77m}\text{Ge}$  producing which leads to a veto period of six minutes ( $5\tau$  of  $^{77m}\text{Ge}$ ).



→ Use figure of merit (FOM), which represents the mean sensitivity, to estimate performance<sup>1</sup>:

$$\text{FOM}[Z_0|1] = \sqrt{1((s+b)\ln(1+\frac{s}{b})-s)}$$

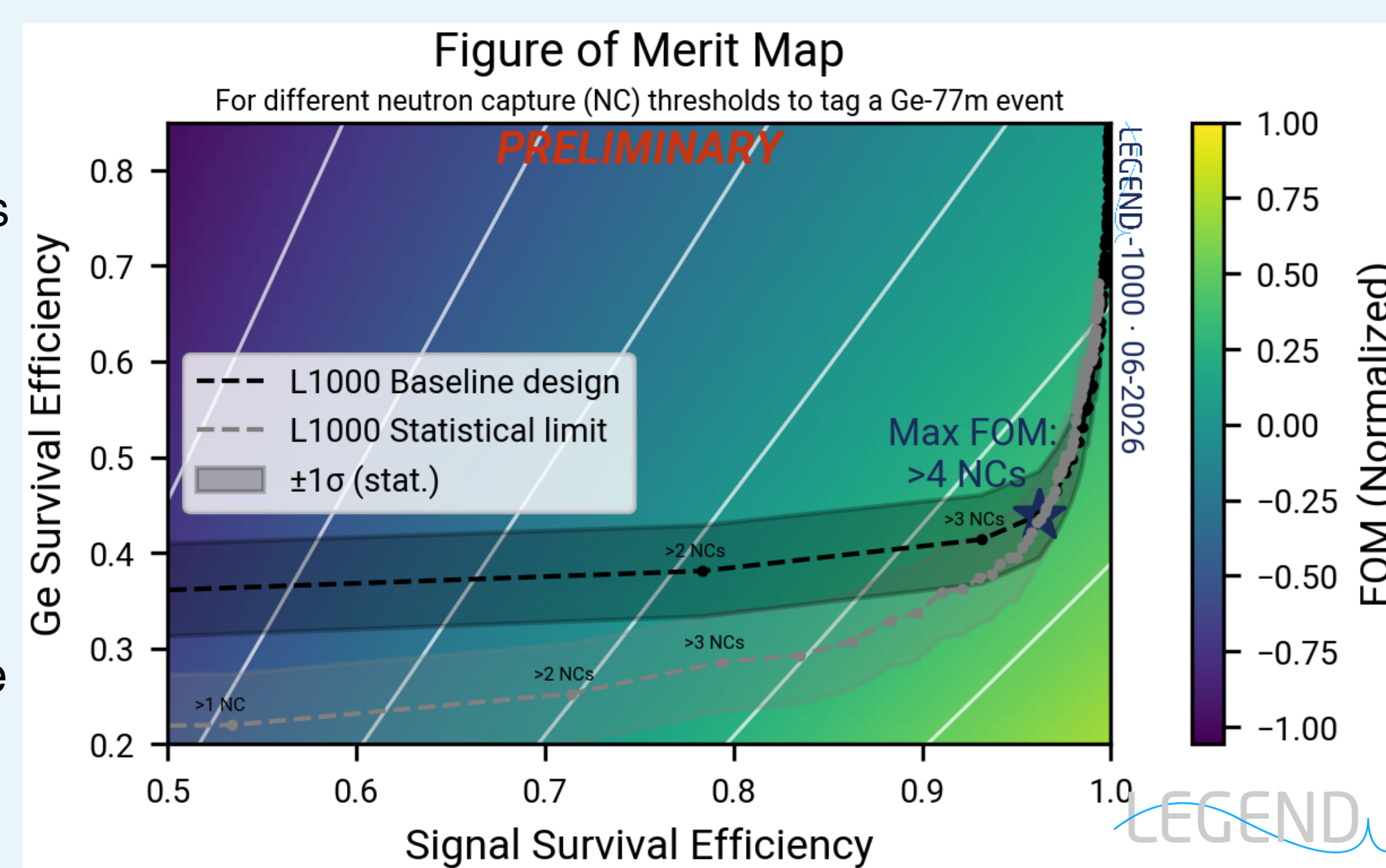
$$s = \frac{\ln(2)N_A}{m_{76}} \epsilon_{\text{tot}} \epsilon_{\frac{1}{2}} \cdot \epsilon_{\text{uncor}}$$

$$b = \epsilon\Delta E(\text{BI}^{77m\text{Ge}} \cdot \epsilon_{77m\text{Ge}} + \text{BI}^{\text{other}}) \cdot \epsilon_{\text{uncor}}$$

- $\epsilon$  → Exposure
- $\epsilon_{\text{tot}}$  → signal survival rate of LEGEND model
- $T_{1/2}$  → Half-life of  $0\nu\beta\beta$
- $\epsilon_{\text{uncor}}$  → Signal survival rate of  $^{77m}\text{Ge}$  cut
- $\Delta E$  → Energy resolution
- $\text{BI}^{77m\text{Ge}}$  →  $^{77m}\text{Ge}$  background
- $\text{BI}^{\text{other}}$  → External background
- $\epsilon_{77m\text{Ge}}$  → Chance of a  $^{77m}\text{Ge}$  background event remaining unvetoes (1 - recall)

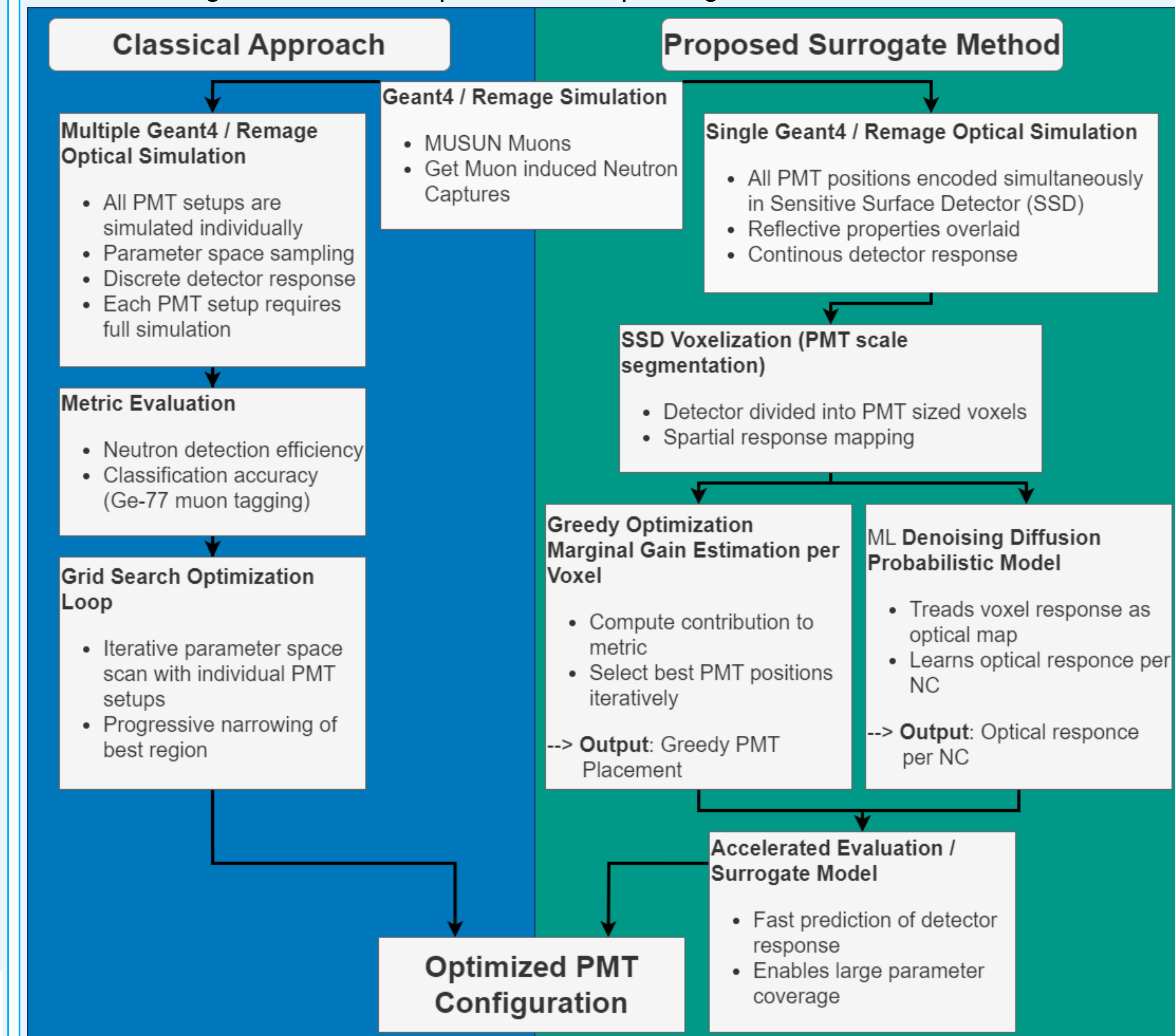
Ge Survival is defined as the Chance a  $^{77m}\text{Ge}$  production remains unvetoes, signal survival is defined as the fraction of uncorrelated  $0\nu\beta\beta$  signals surviving the cut. FOM normalized to an idealized reference point (0% Ge survival, 100% signal survival).

Negative FOM values indicate worse sensitivity than not building the system. Current best case marked with a blue star.

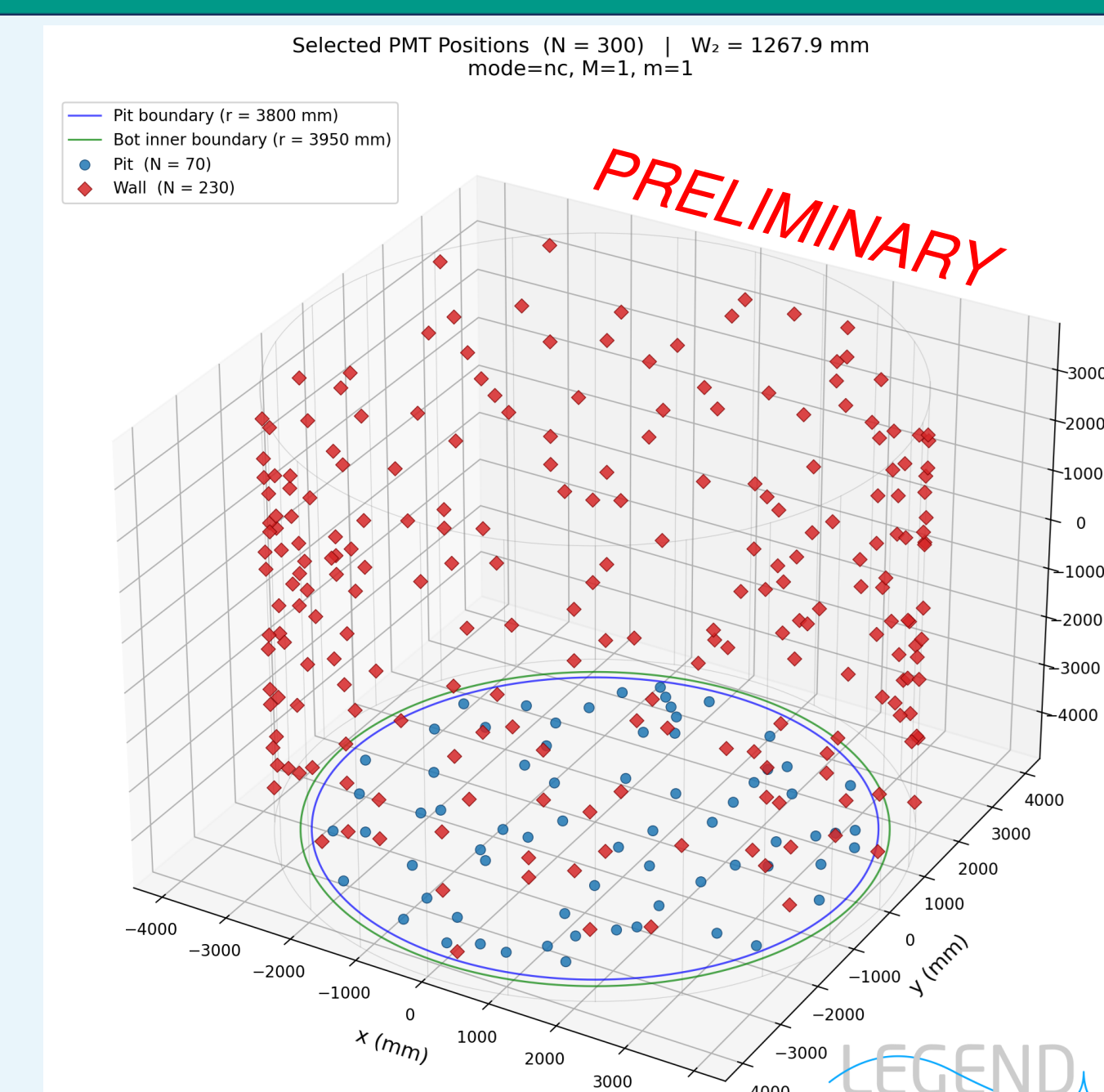


## Geometry Optimization

→ Use surrogate method to optimize PMT placing within the water tank



The favored PMT placement of the surrogate method is a homogeneous distribution of the tubes. PMTs in blue would be placed in the "pillbox" underneath the cryostat, whilst the PMTs in red would be installed in the outer volume on the PMT scaffold. This result would be implemented by means of an equispaced grid installed in the water tank and used to mount the PMTs.



## References:

- Cowan, G., Cranmer, K., Gross, E. *et al.* Asymptotic formulae for likelihood-based tests of new physics. *Eur. Phys. J. C* **71**, 1554 (2011). <https://doi.org/10.1140/epjc/s10052-011-1554-0>