Stereo Calorimetry at JUNO

Controlling Systematics by Measuring Scintillation Light with two Redundant PMT Systems

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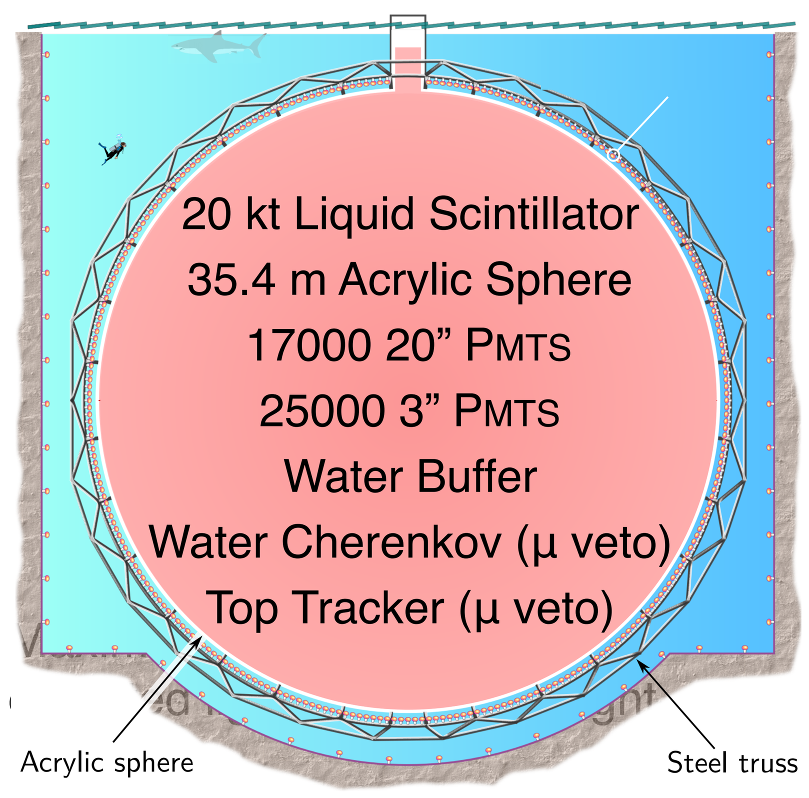
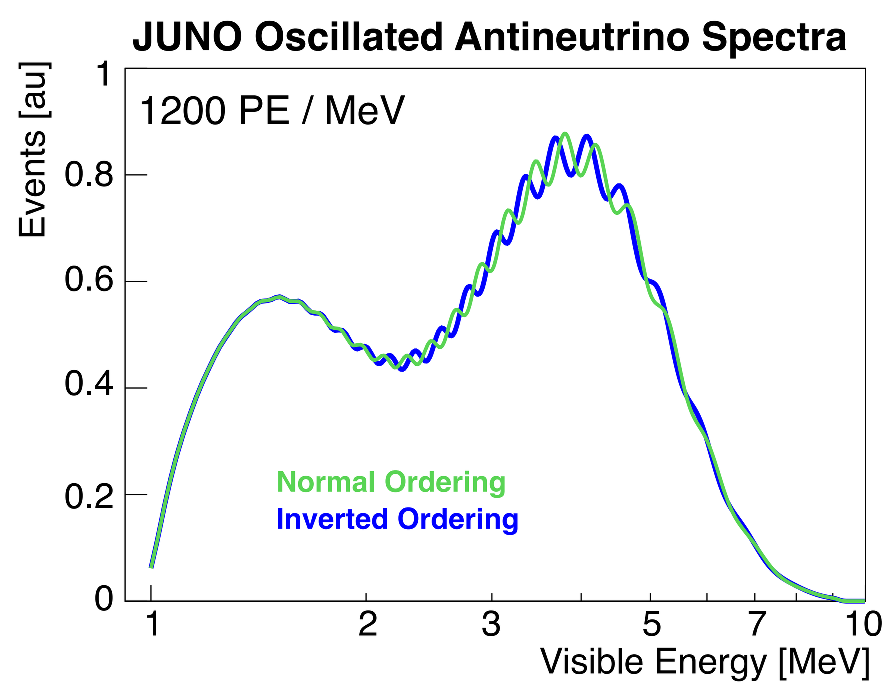
JUNO: an unprecedented Liquid Scintillator Detector

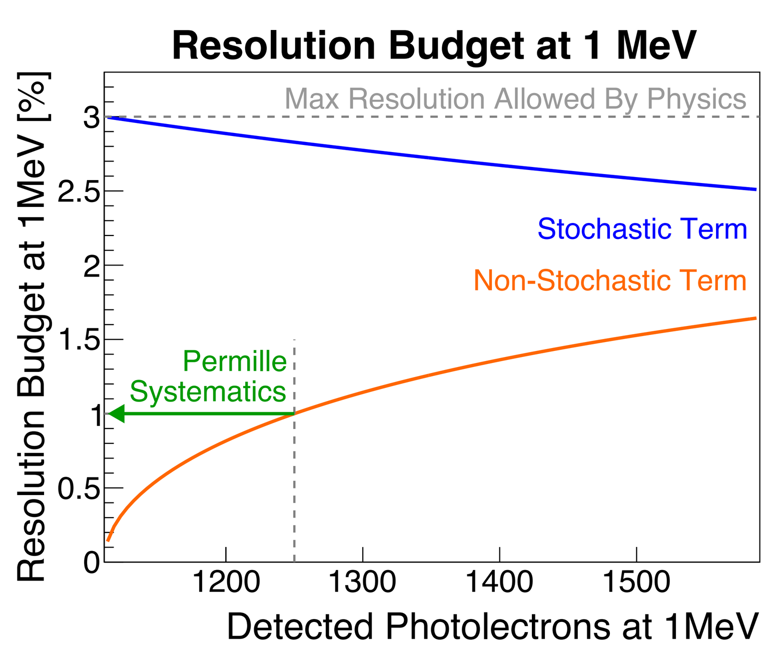


	DETECTOR TARGET MASS	ENERGY RESOLUTION
KamLAND	1000 t	6%/√E
Daya Bay	8+22 t	8%/√E
Reno	16 t	
Daya Bay	20 t	
Borexino	300t	5%/√E
JUNO	**20000 t**	**3%/√E**

Detect $\bar{\nu}_e$ from Nuclear Reactor

Goal: **Determine Neutrino Mass Ordering** by performing a precision measurement of the oscillated antineutrino energy spectrum at 53 km baseline





Energy Resolution $$\frac{\sigma(E)}{E} = \sqrt{\left[\frac{a}{\sqrt{E}}\right]^2 + [b(E)]^2}$$

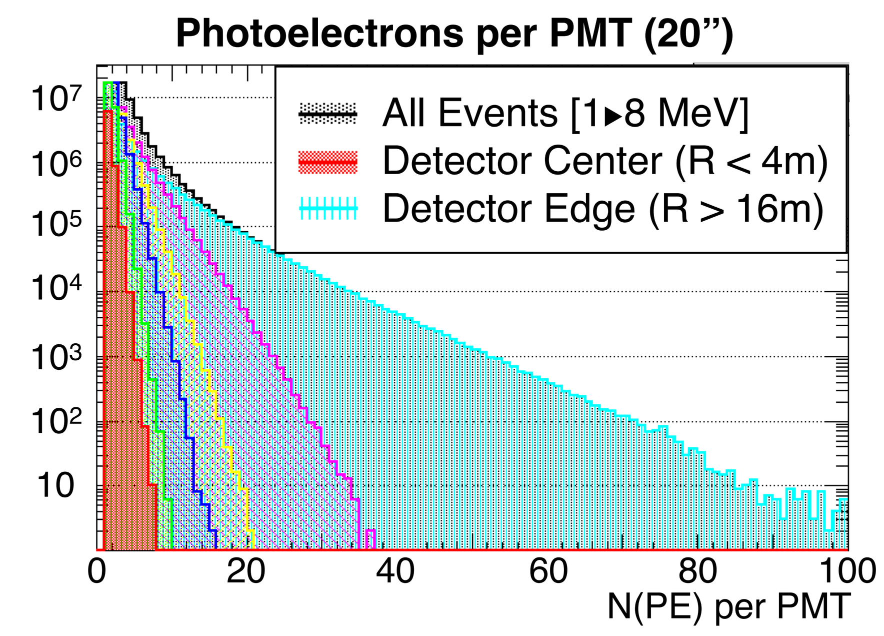
a: stochastic term
➤ Maximize detected light
[Photocoverage + LS Transparency + QE]

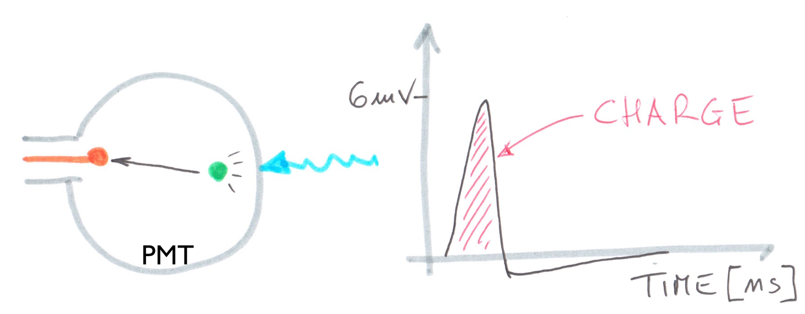
b: non-stochastic term
➤ Control systematic uncertainties

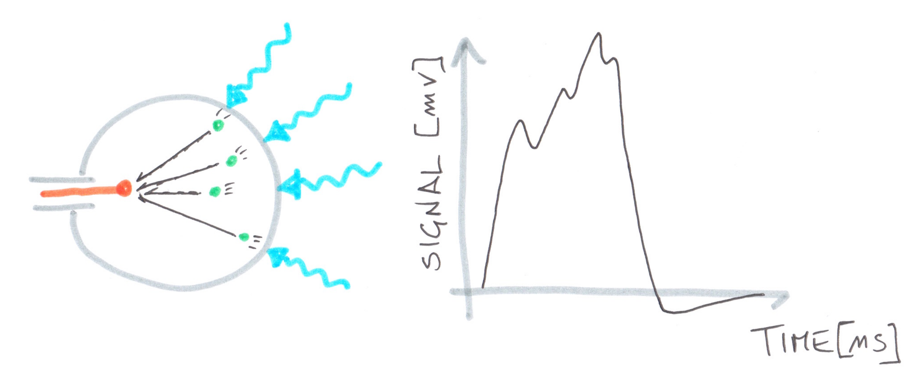
Charge Reconstruction and Energy Accuracy

Large Liquid Scintillator (LS) volume and large PMT surface (20" diameter) imply unprecedented PMT dynamic range making **charge reconstruction** challenging

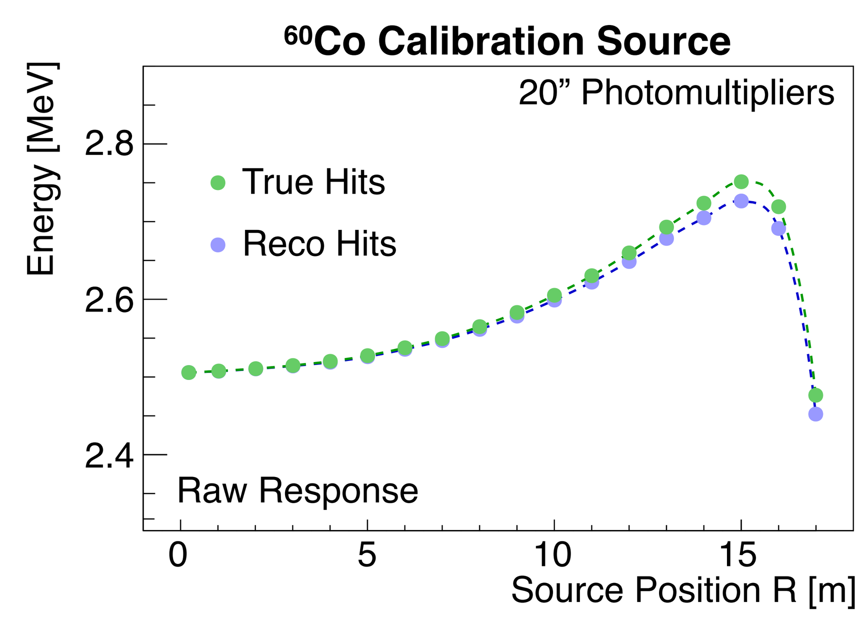
Noise and overshoot can easily introduce **charge non-linearities** when many photoelectrons pile-up at the PMT anode

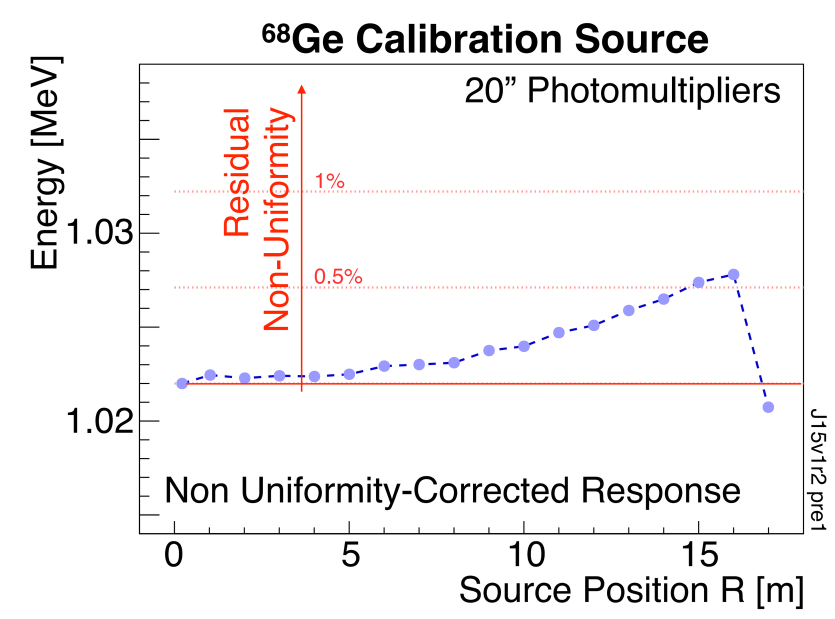






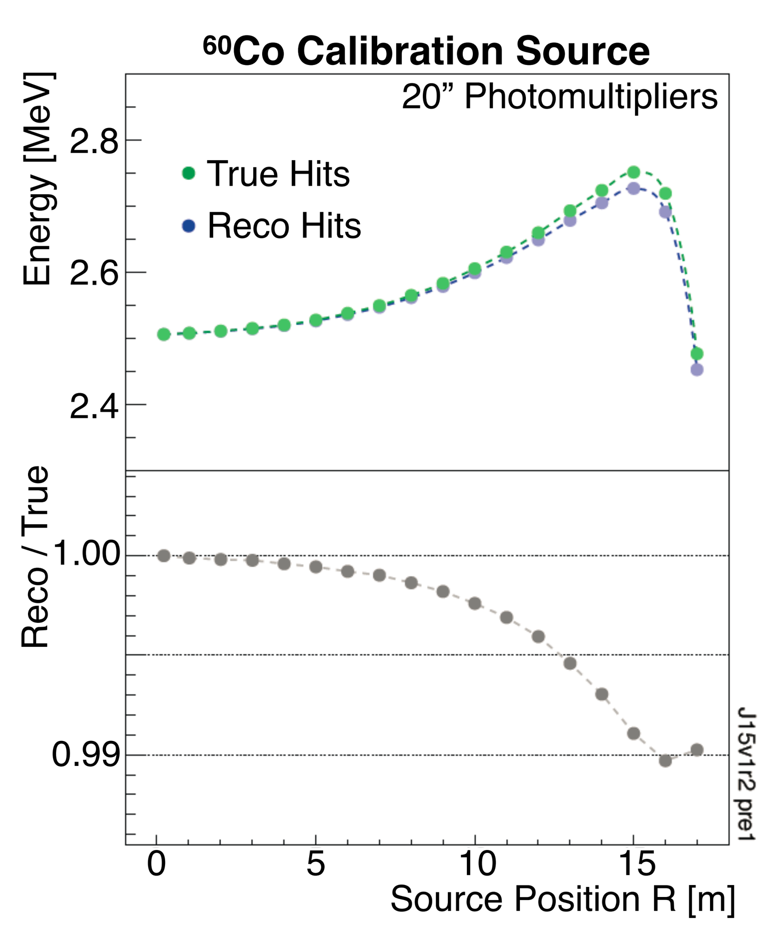
Detector response is nonuniform. Map it using calibration source (eg. ^{60}Co) ➤ Such map embeds charge non-linearities which are energy dependent ➤ When map is applied at different energy does not work properly

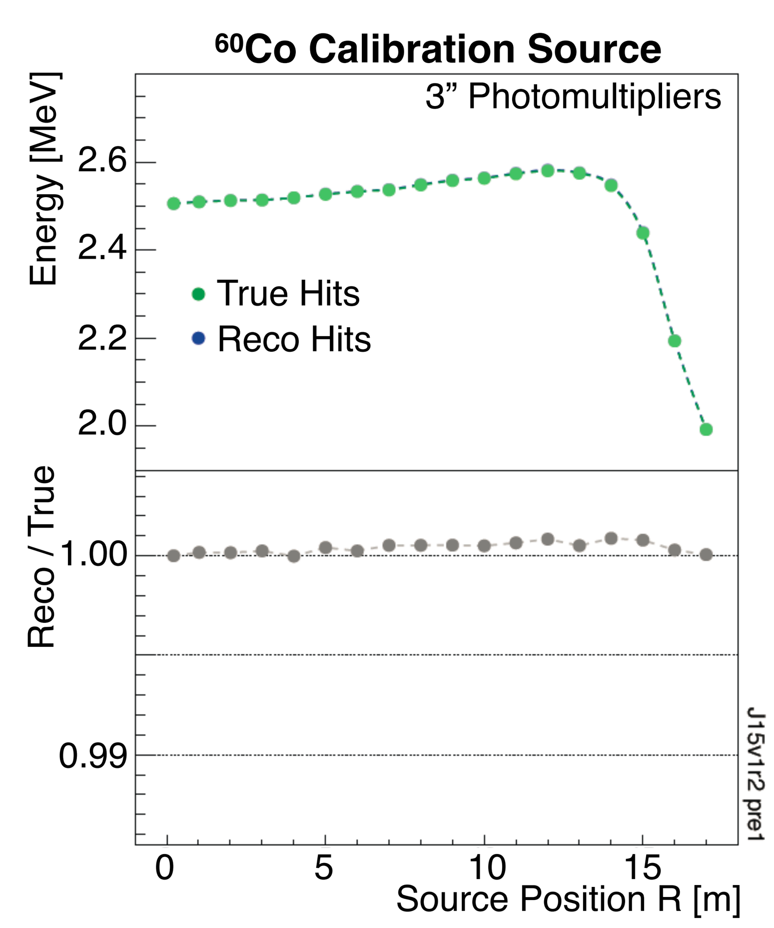




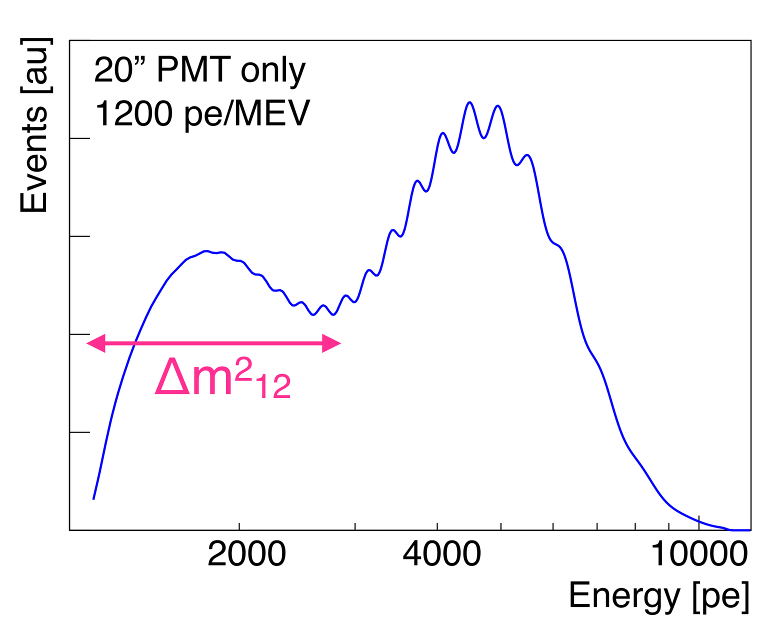
Stereo Calorimetry Concept: Calibration & Physics

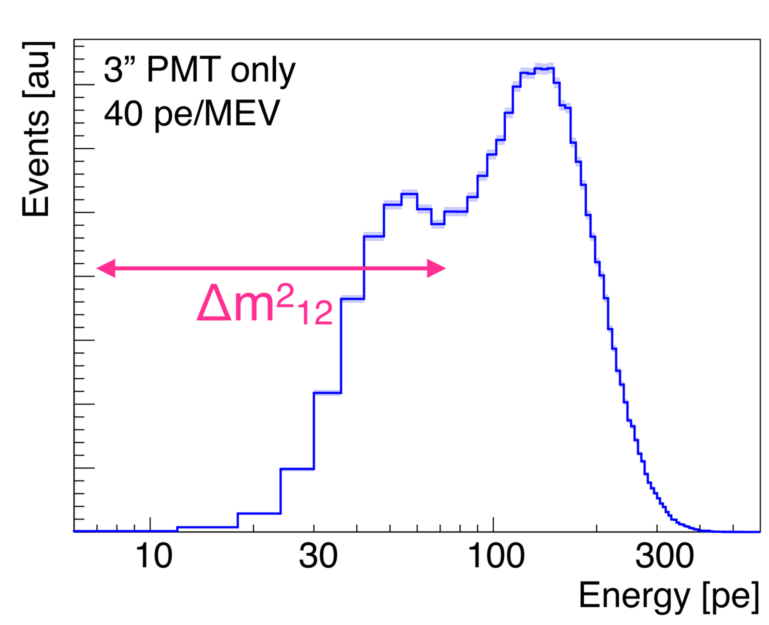
To **disentangle** charge non-linearities from other **response** effects (eg. non-linear LS light yield, non-uniform detector response) JUNO implements a system of **3" PMTs** whose mean illumination is low enough for them be always working in **single-PE (photon counting) regime**.



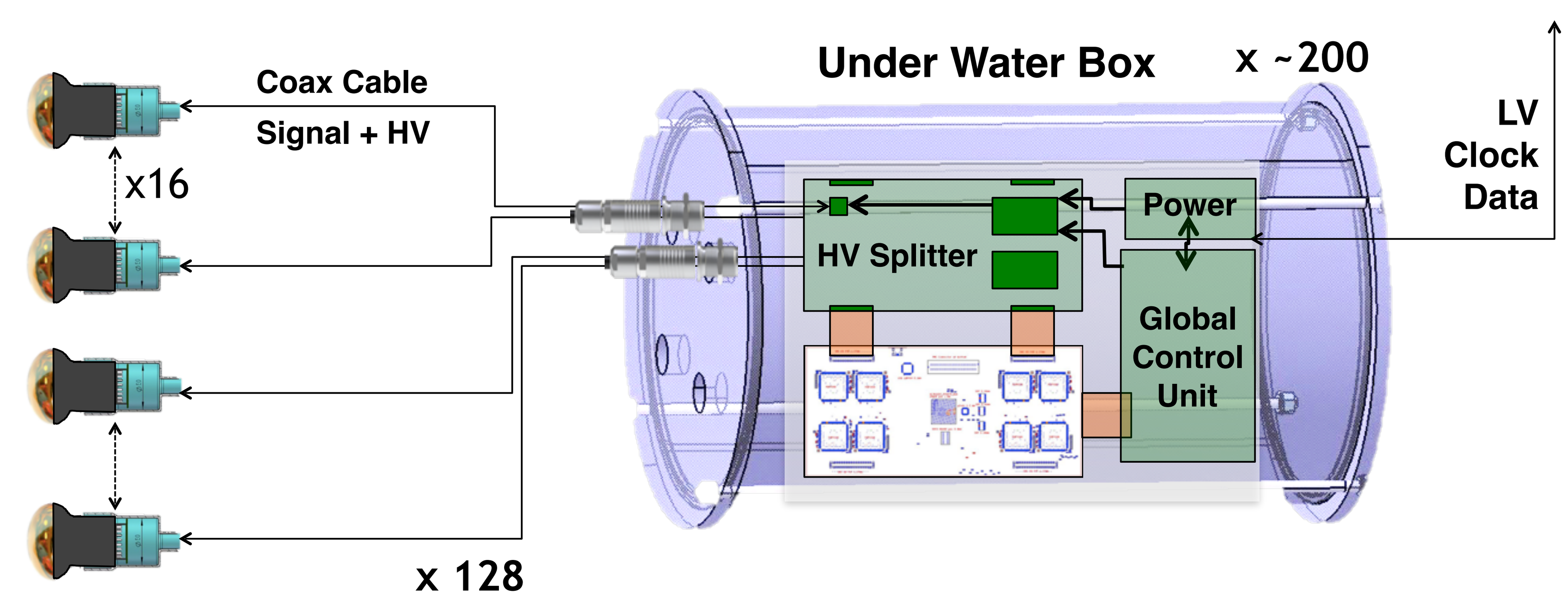


Cross-calibrate the response of the two systems to better control the systematic uncertainties associated to light detection and energy reconstruction. Use both **calibration sources** and **oscillation parameters** as standard candles.





Stereo Calorimetry Implementation



Underwater 3" PMTs

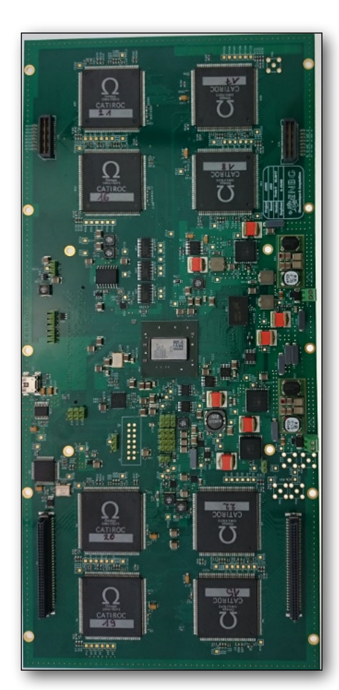
Charge Integration through CatiROC ASIC (Omega Lab)

16 channels / ASIC

128 channels / readout board

Custom-designed underwater box hosting power & readout

Low voltage / data / clock via connection to surface



HZC Photonics (XP72B22)
Production rate: 2000/month
Gain (at JUNO): 3 10^6
QE x CE (at 420nm): 24%
SPE Resolution: 35%
Dark Rate at 1/4 PE: 1kHz
Transit Time Spread: 5 ns