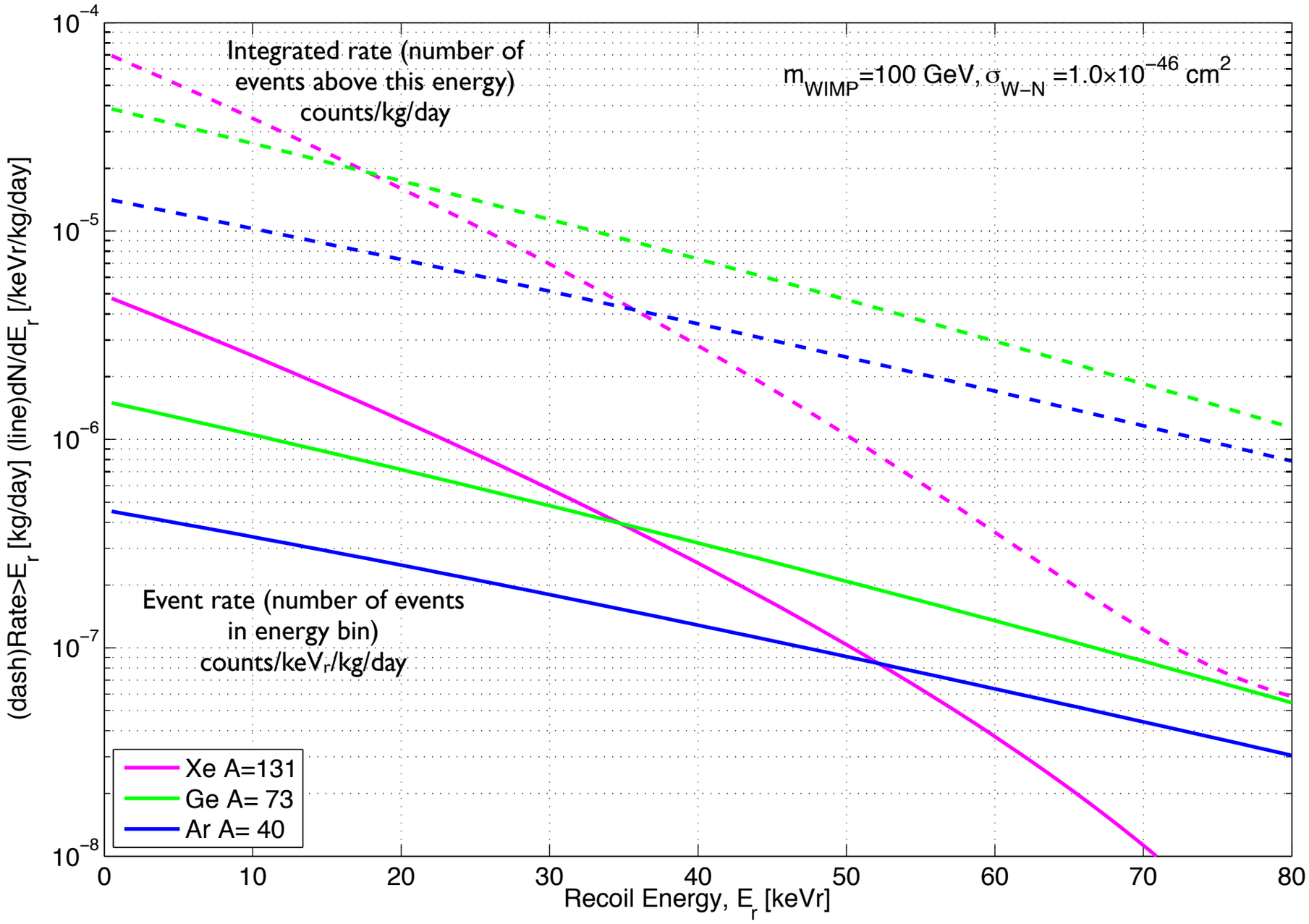
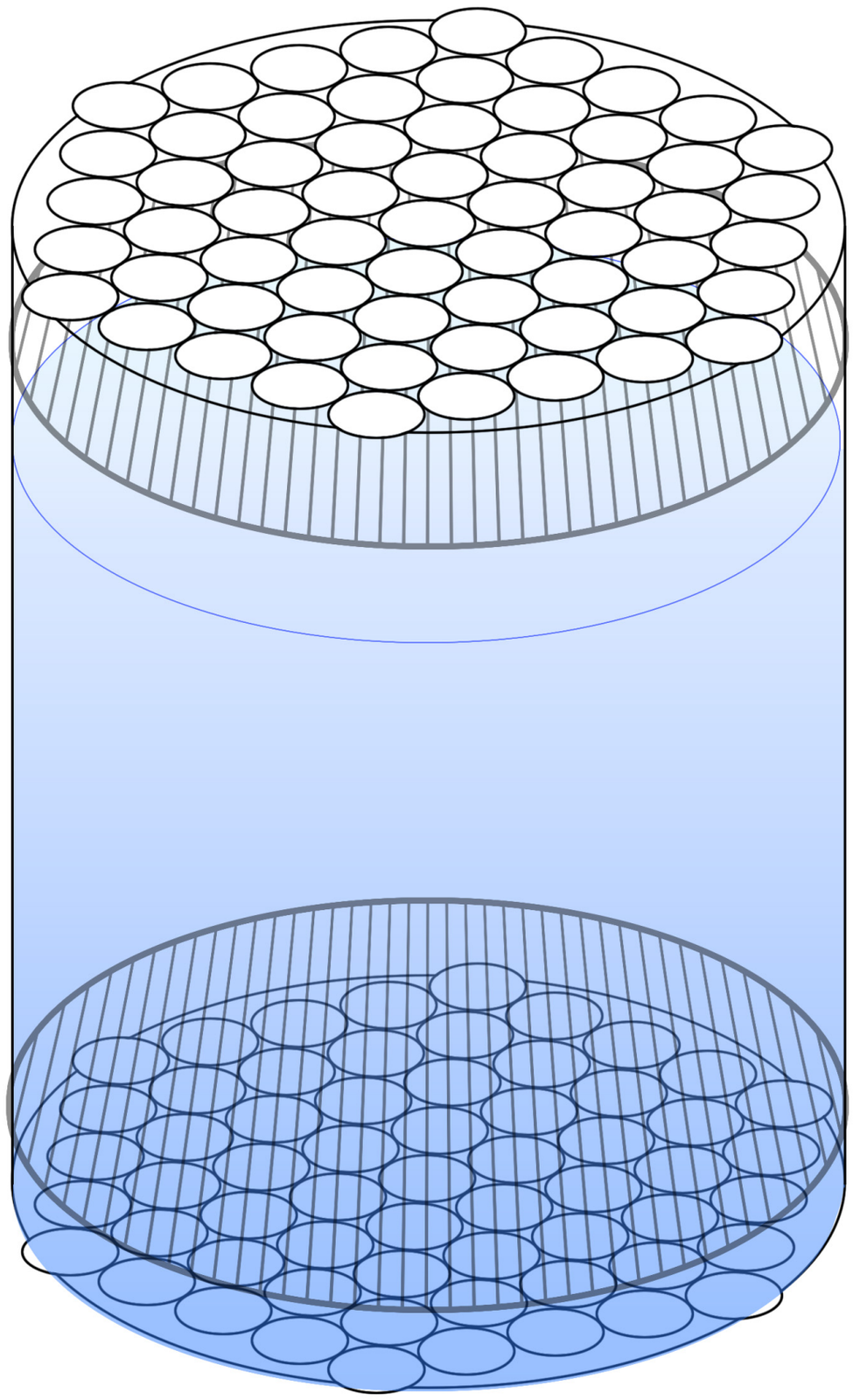
Time Projection Chamber

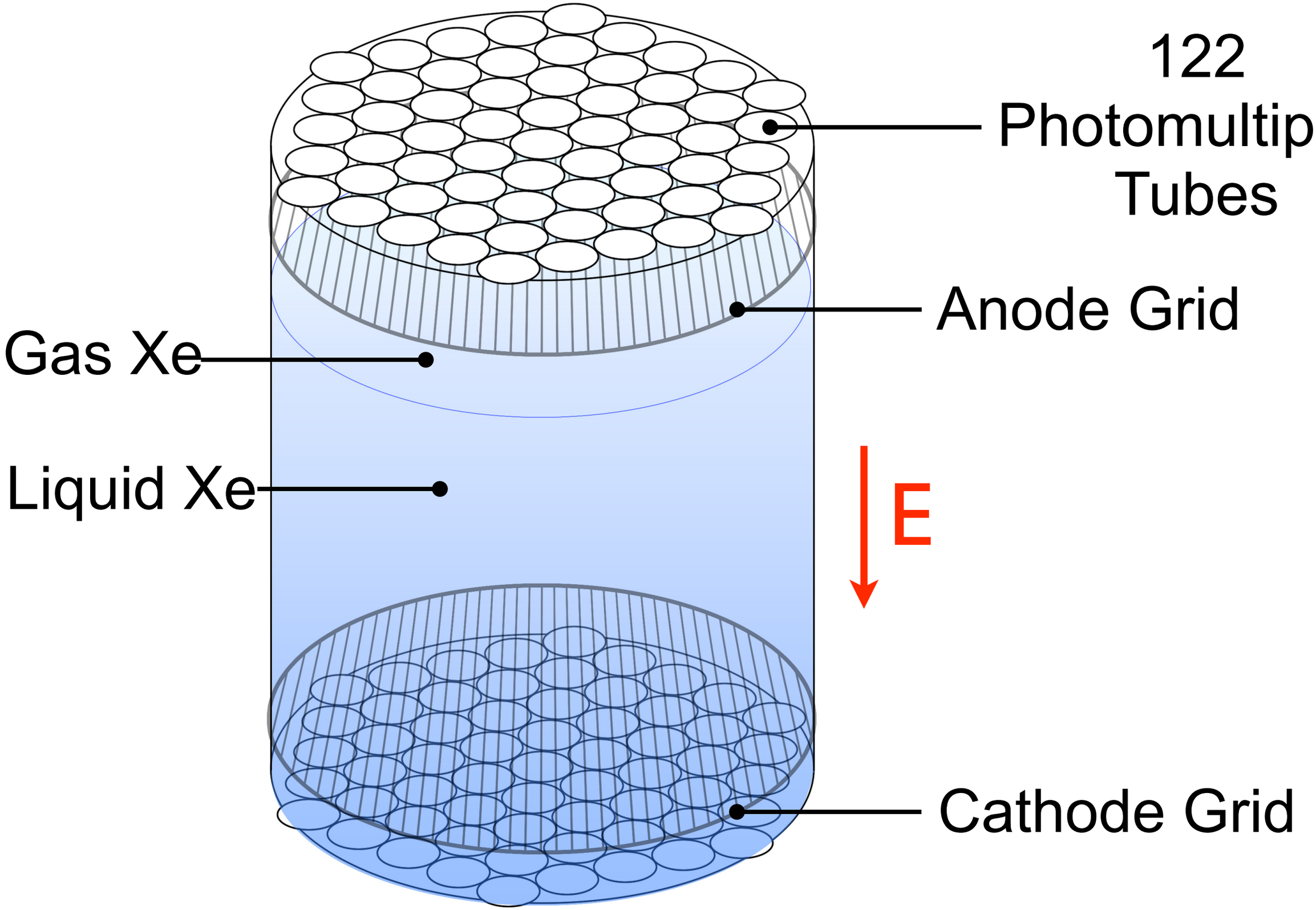
Jeremy Chapman

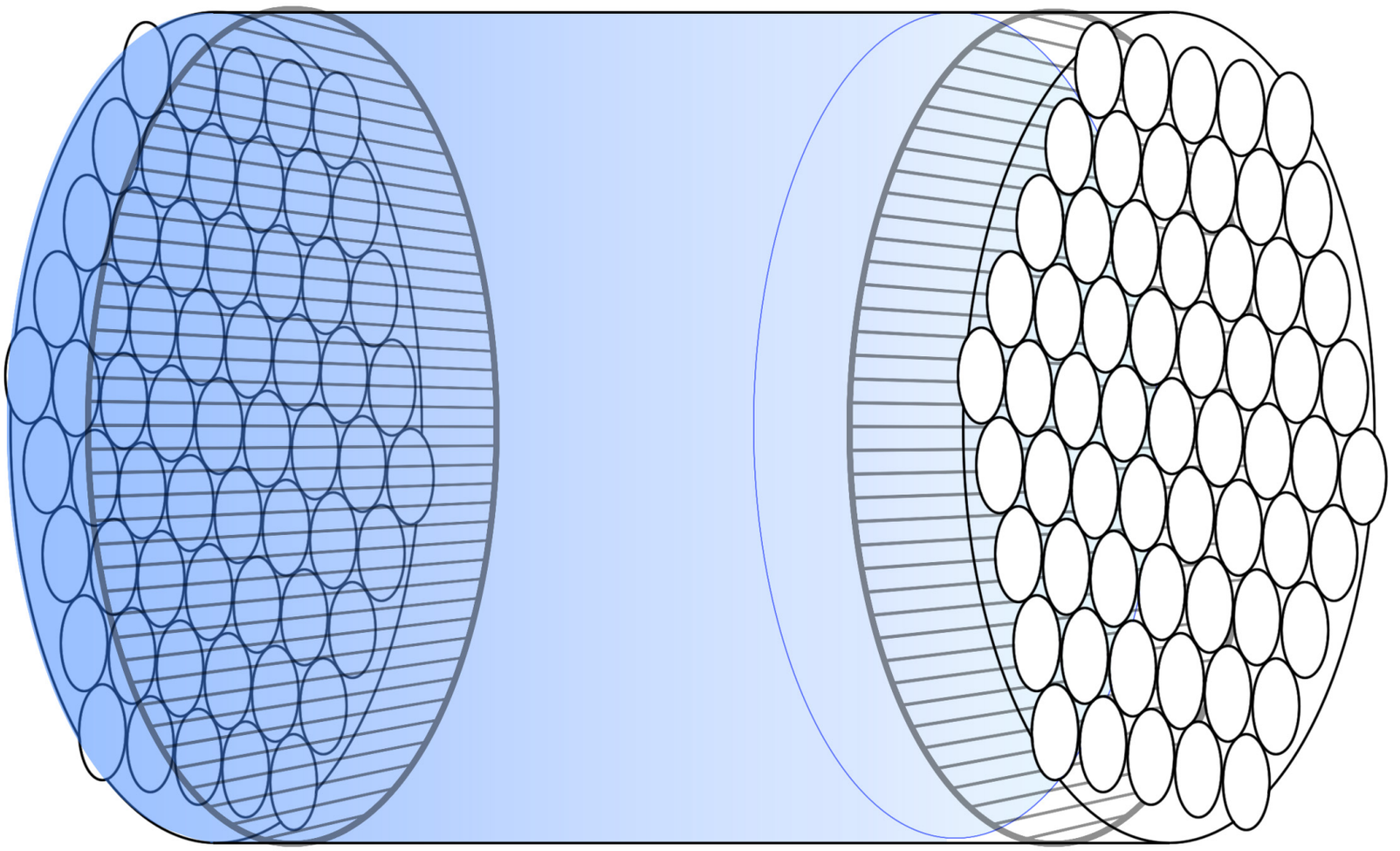
on behalf of the LUX collaboration

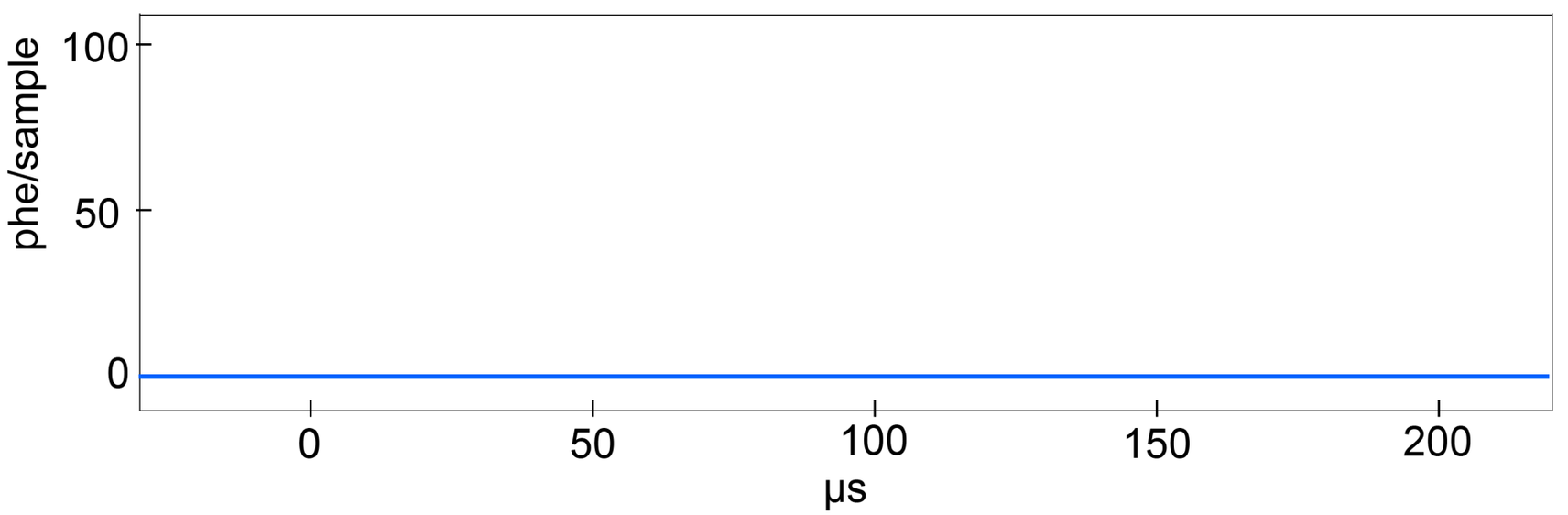
Liquid Xenon





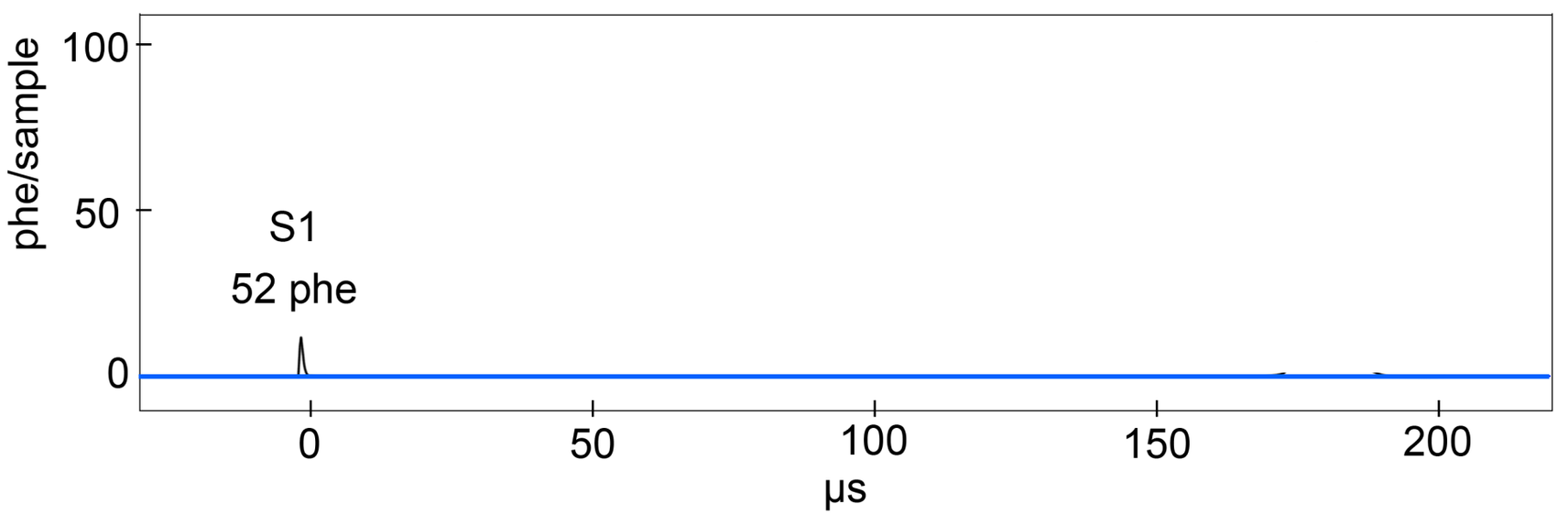

122
Photomultiplier
Tubes
Anode Grid
Gas Xe
Liquid Xe
E
Cathode Grid

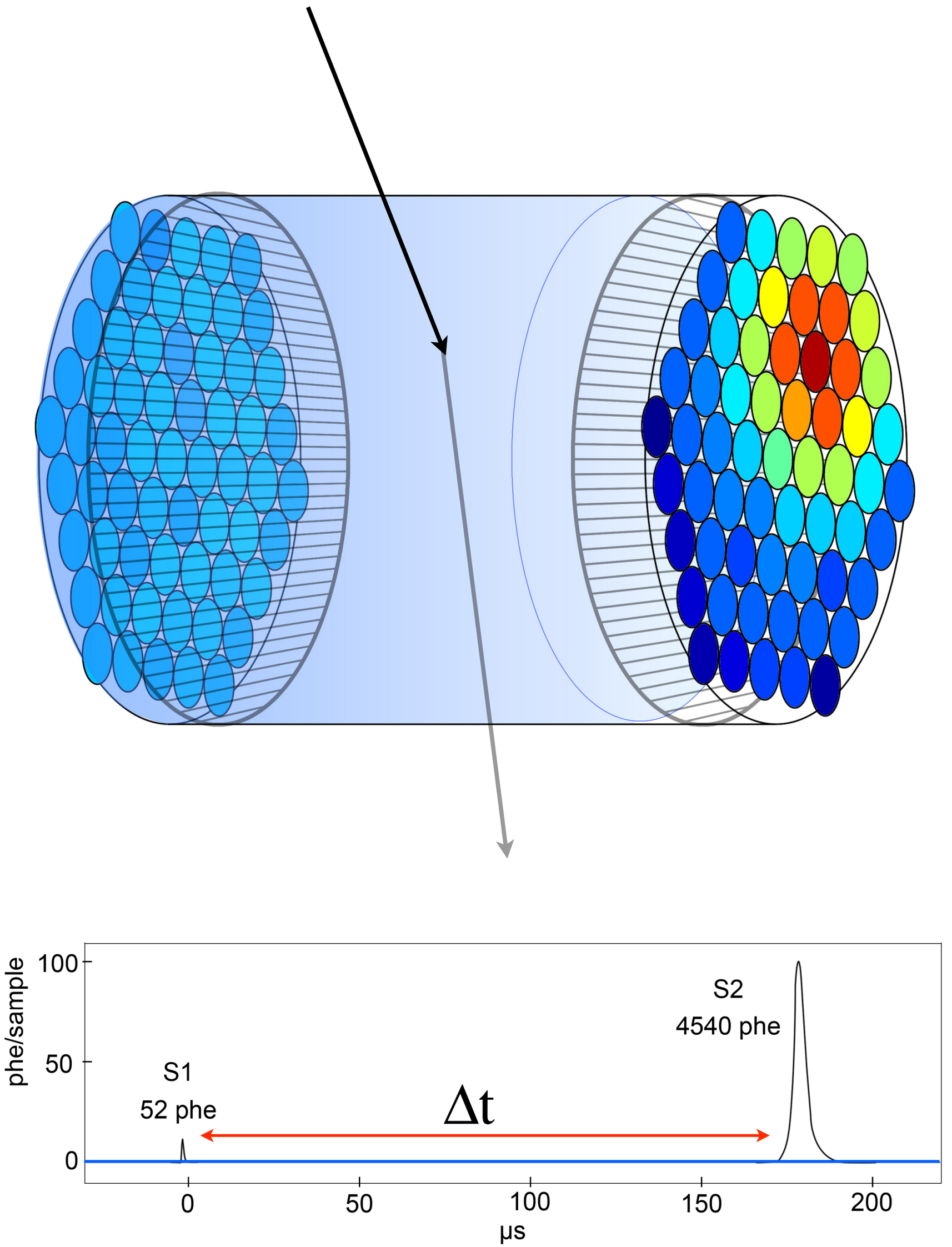



phe/sample
100
50
0
0
50
100
150
200
μs

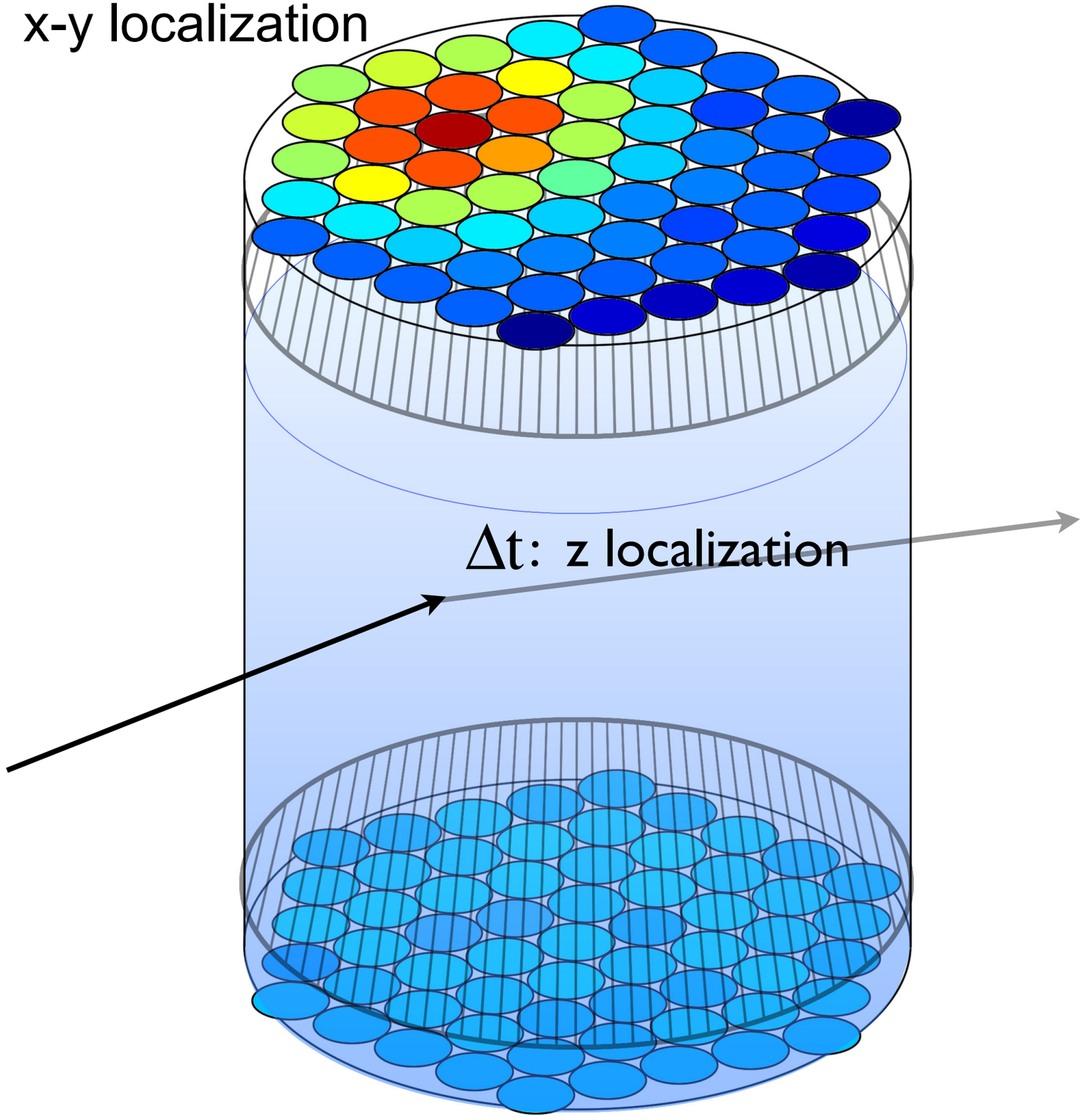
S1

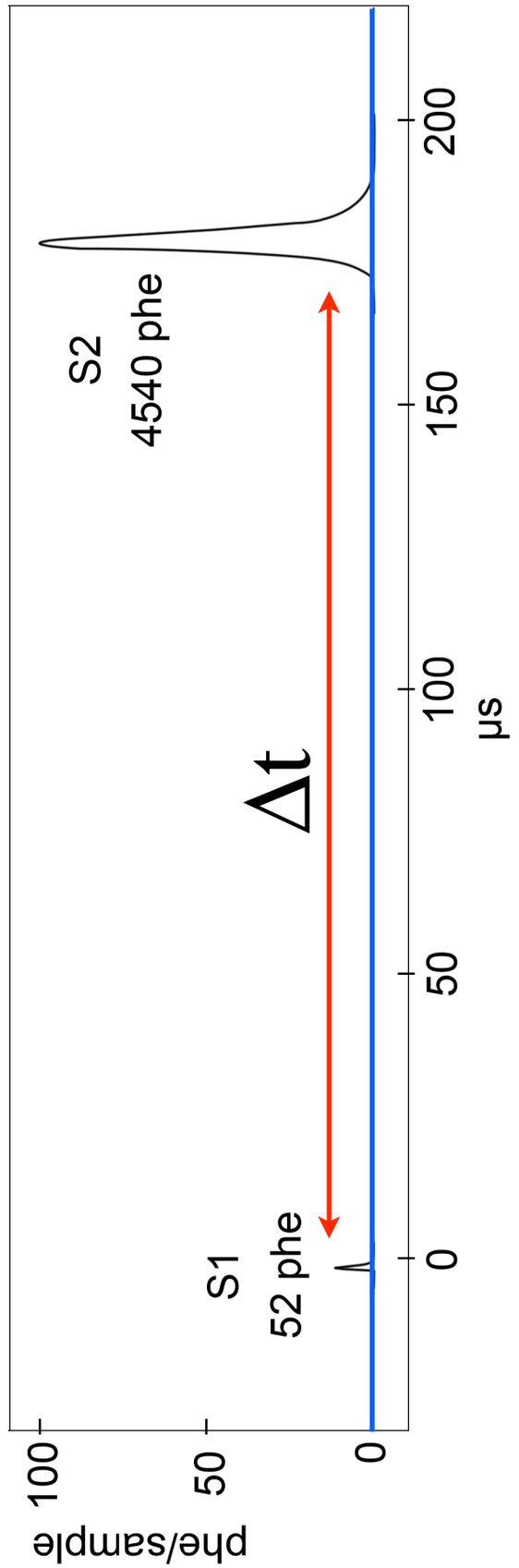
e-
e-
e-
e-
e-

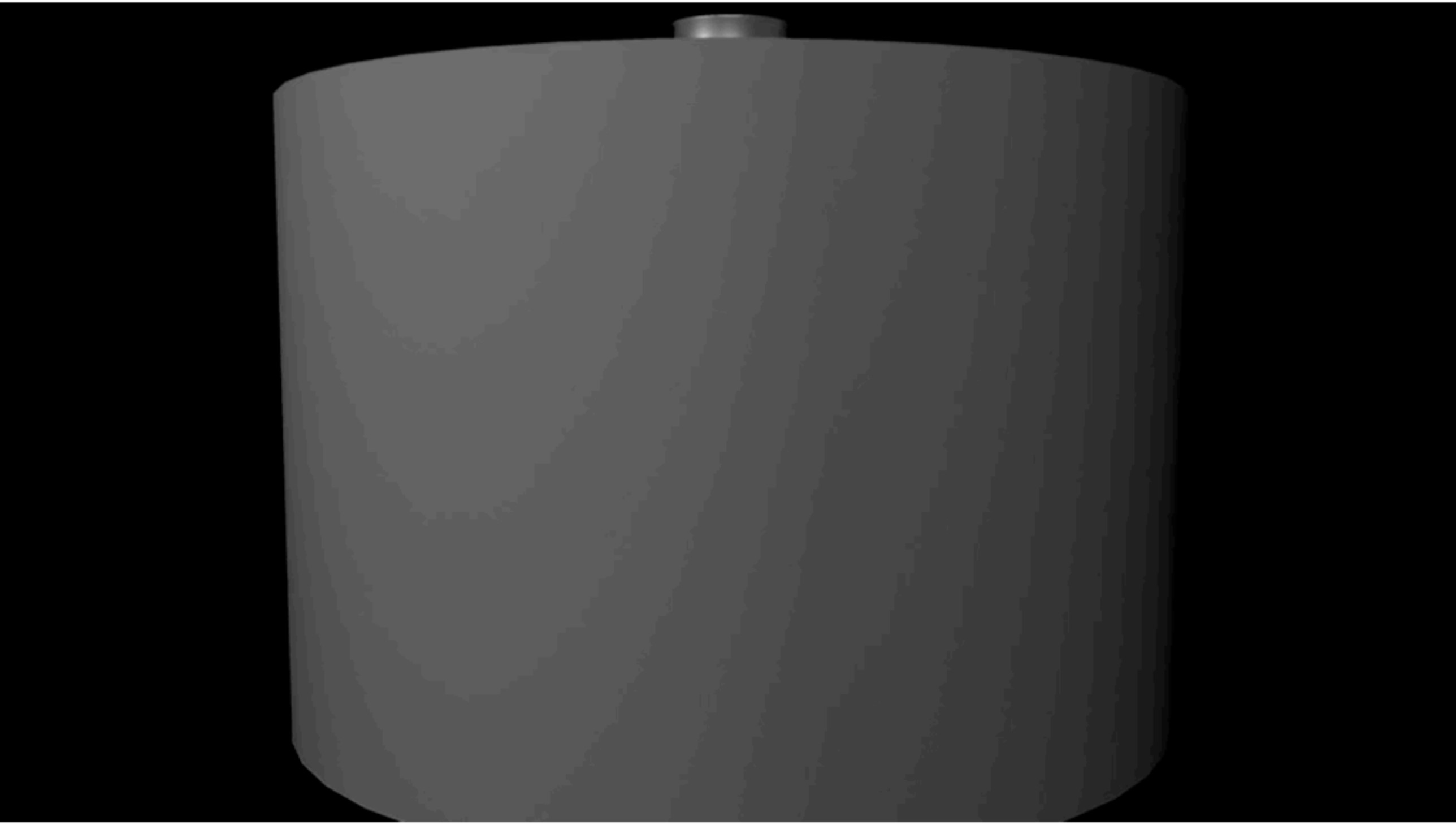



phe/sample
100
50
0
S1
52 phe
Δt
S2
4540 phe
0
50
100
150
200
μs

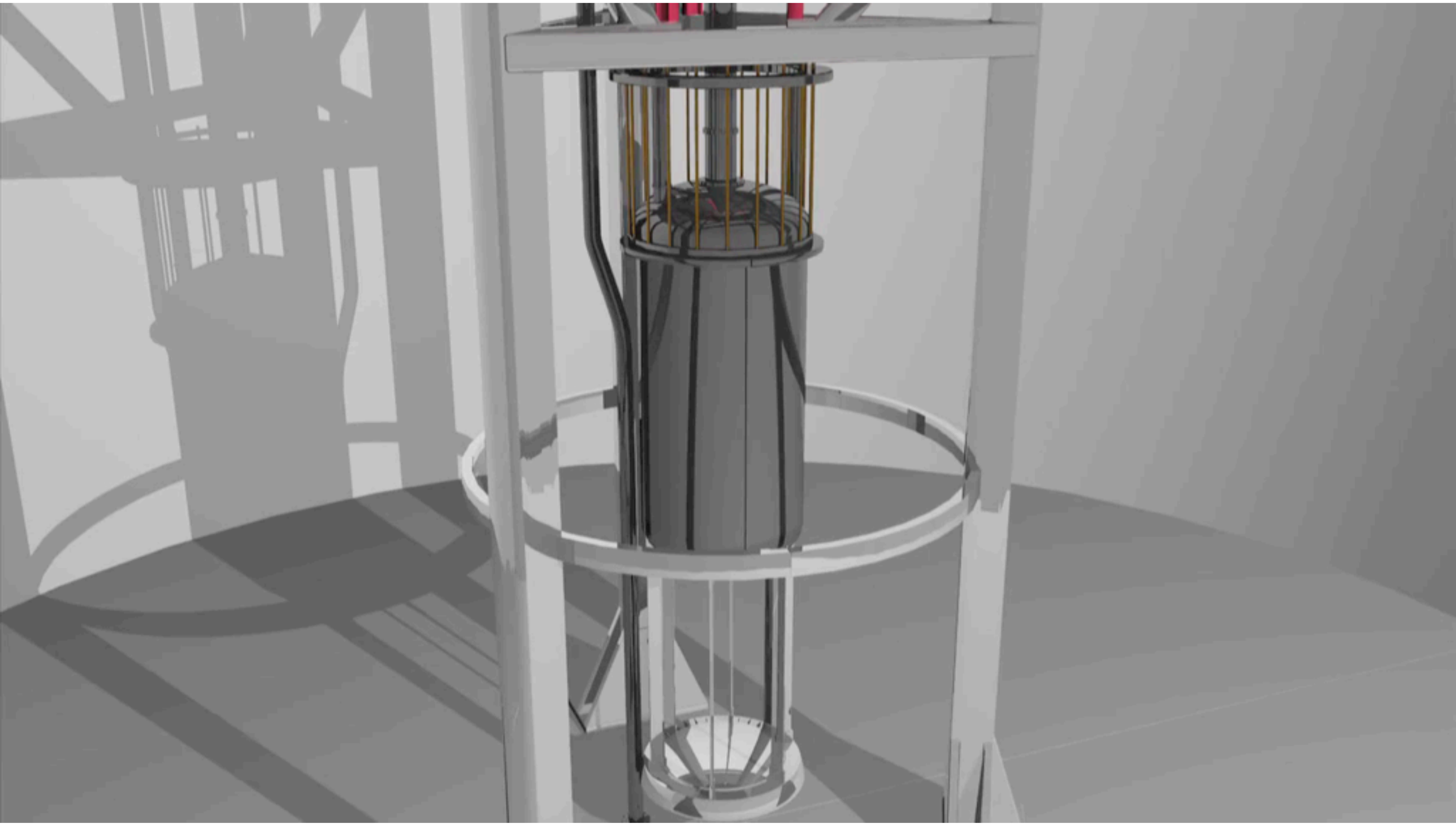
top hit pattern:
x-y localization





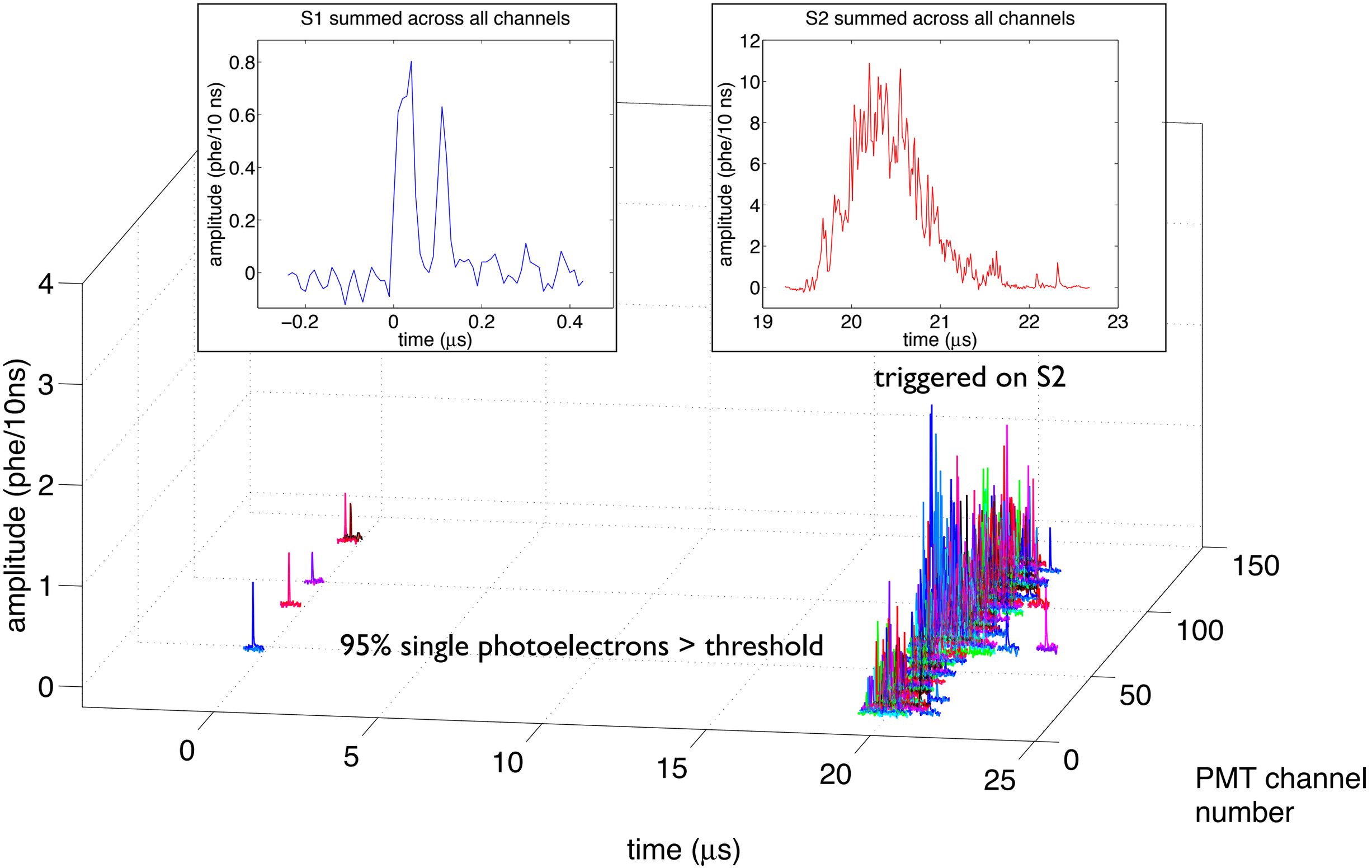


Animations: Harvard-Smithsonian Center for Astrophysics, Annenberg Media

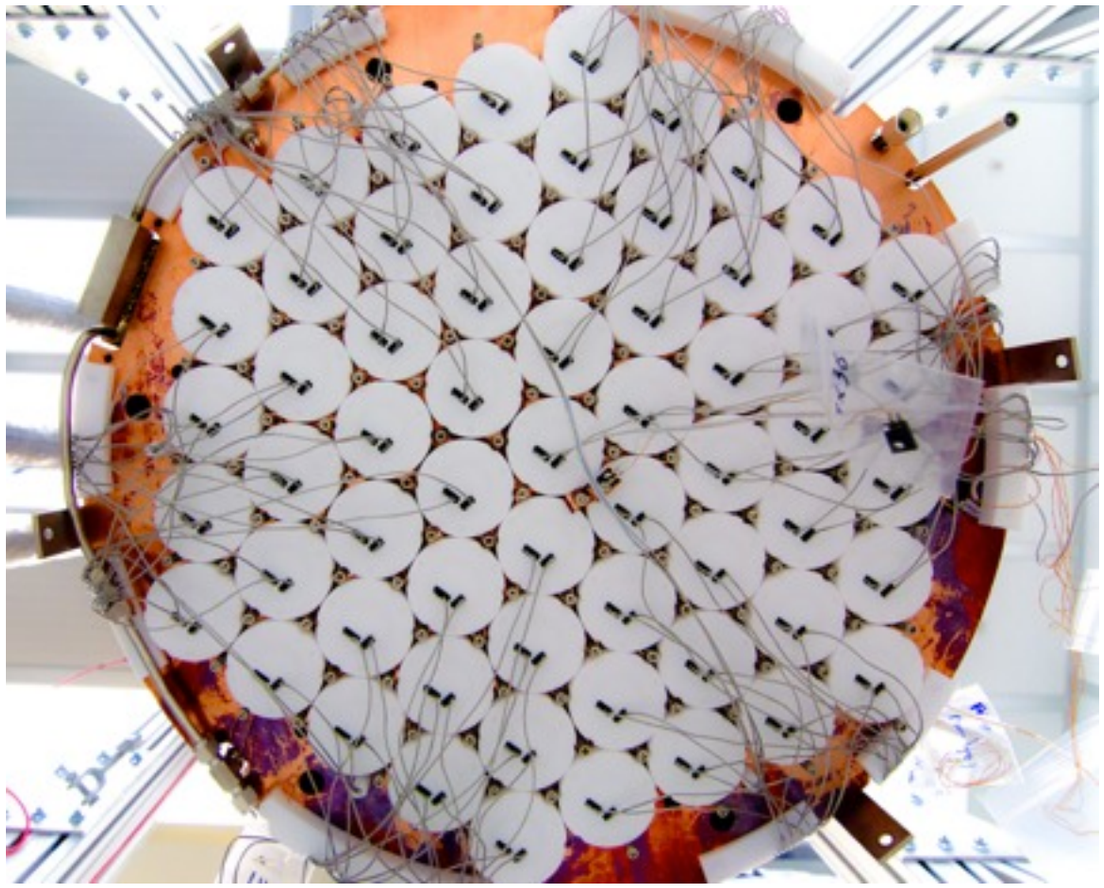


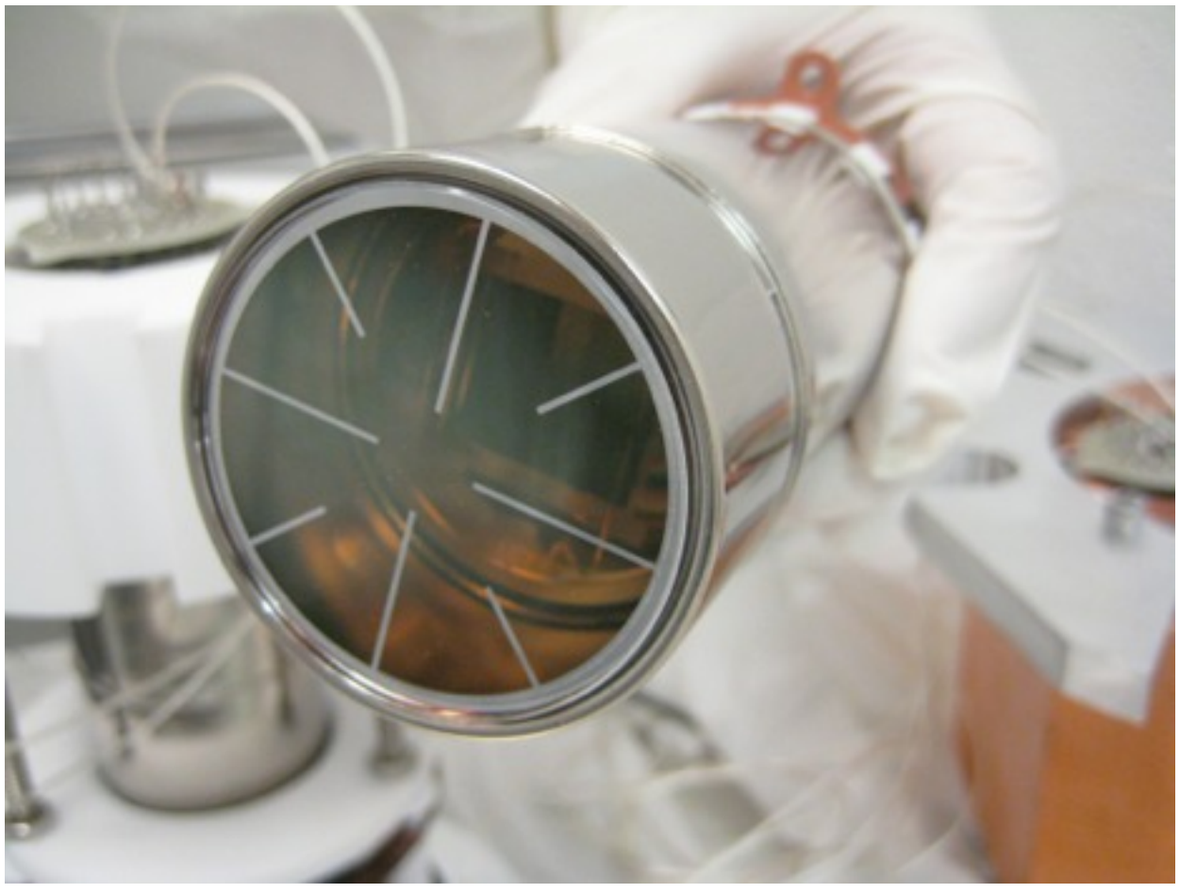
Animations: Harvard-Smithsonian Center for Astrophysics, Annenberg Media

1.5 keV$_{ee}$


S1 summed across all channels
amplitude (phe/10 ns)
time (μs)
S2 summed across all channels
amplitude (phe/10 ns)
time (μs)
triggered on S2
95% single photoelectrons > threshold
amplitude (phe/10ns)
time (μs)
PMT channel number

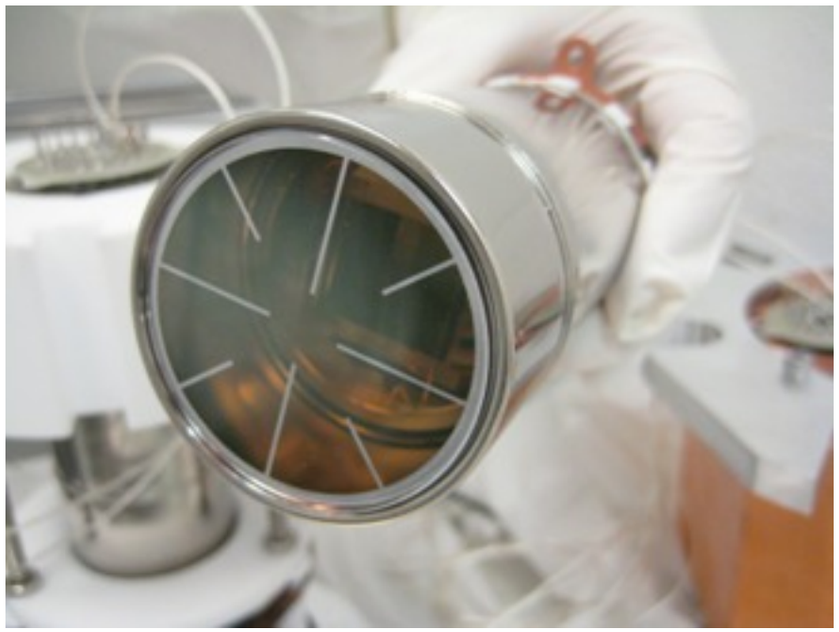
PMTs

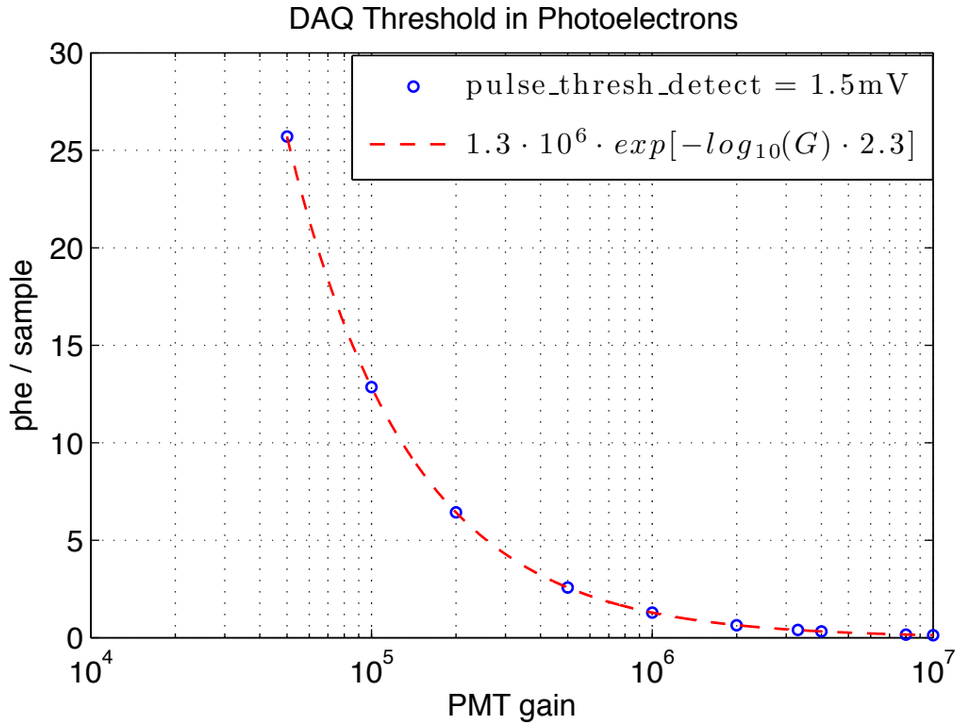


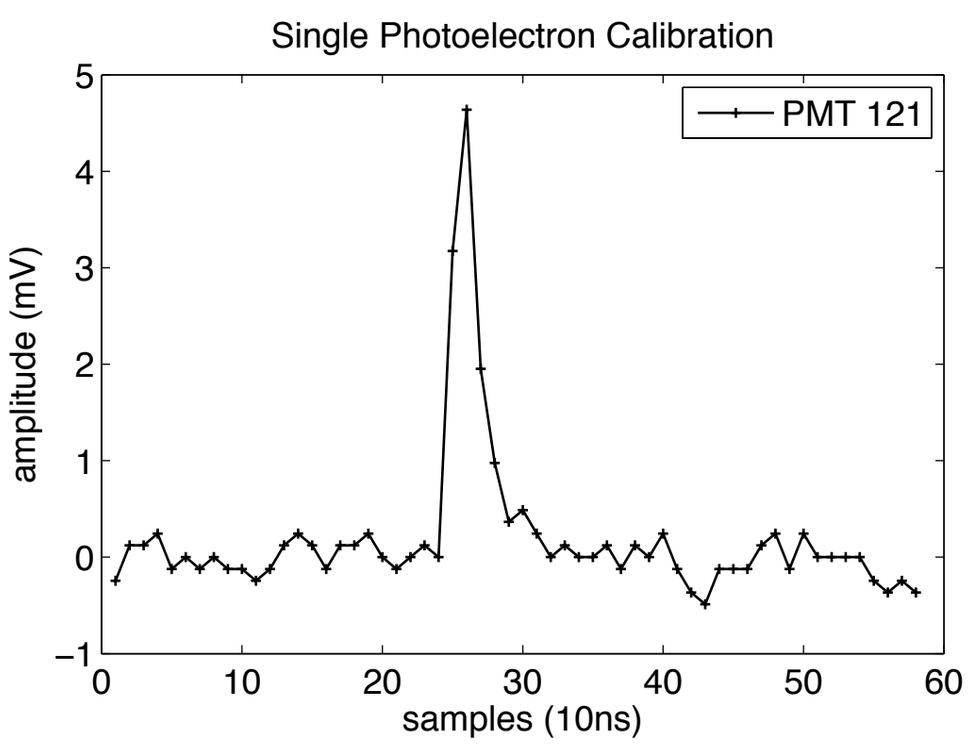


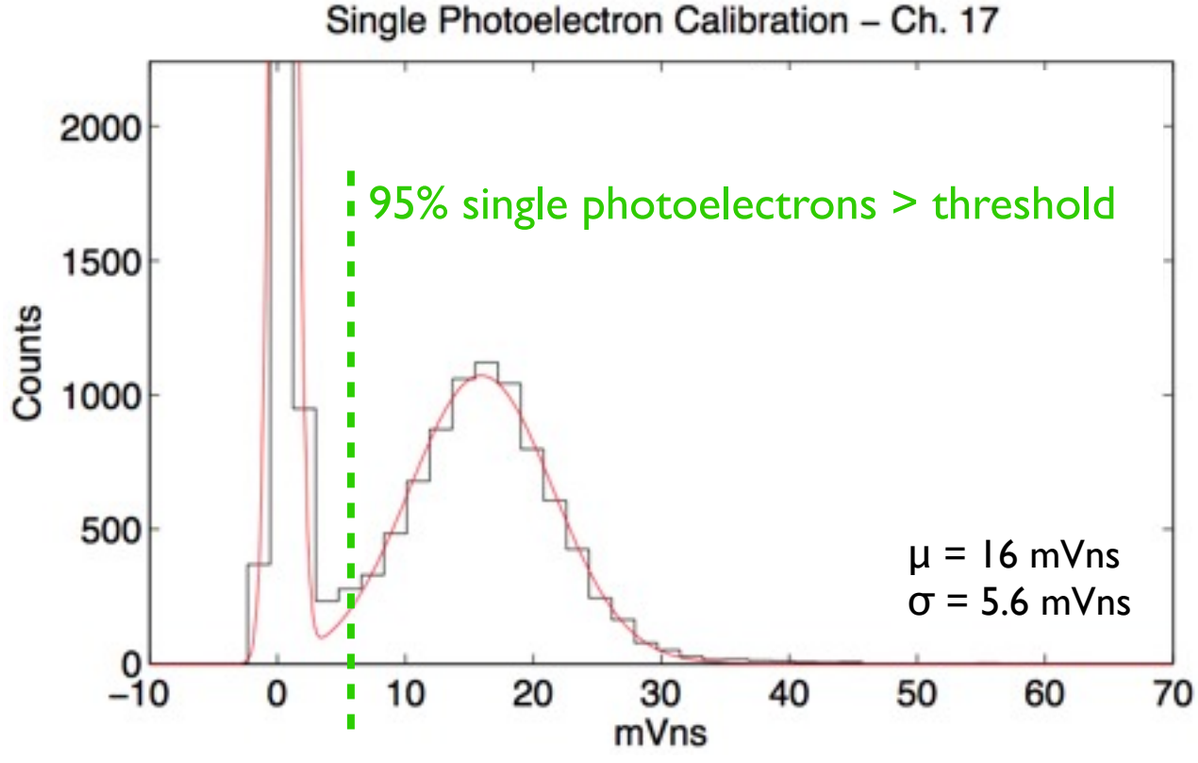
- Hammamatsu R8778
- 2 inch diameter
- Average QE of 33%
- Nominal gain of 4e6
- Ultra-low bg (12mBq/PMT)

Threshold

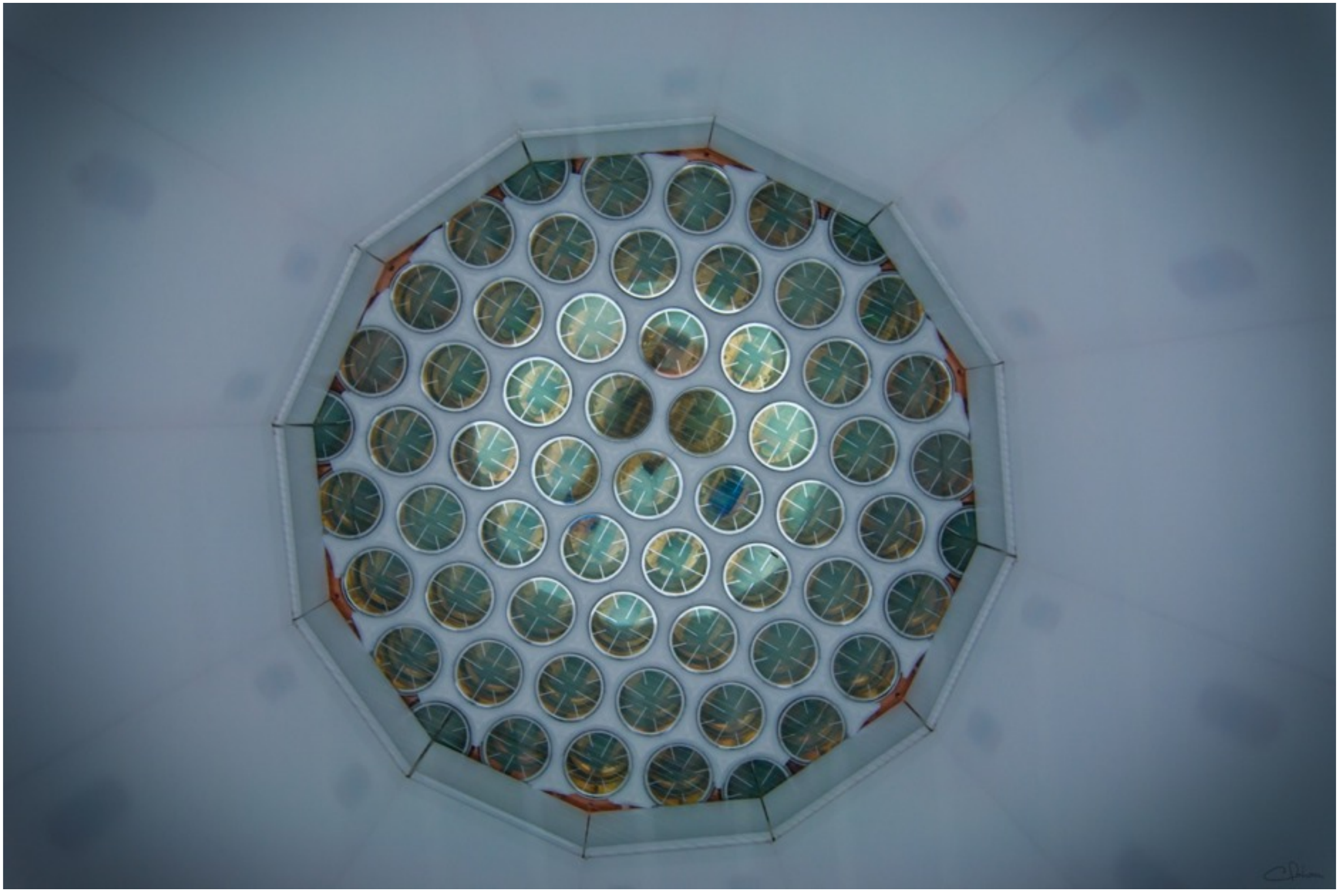



DAQ Threshold in Photoelectrons
pulse_thresh_detect = 1.5mV
$1.3 \cdot 10^6 \cdot exp[-log_{10}(G) \cdot 2.3]$
phe / sample
PMT gain
30
25
20
15
10
5
0
10^4
10^5
10^6
10^7

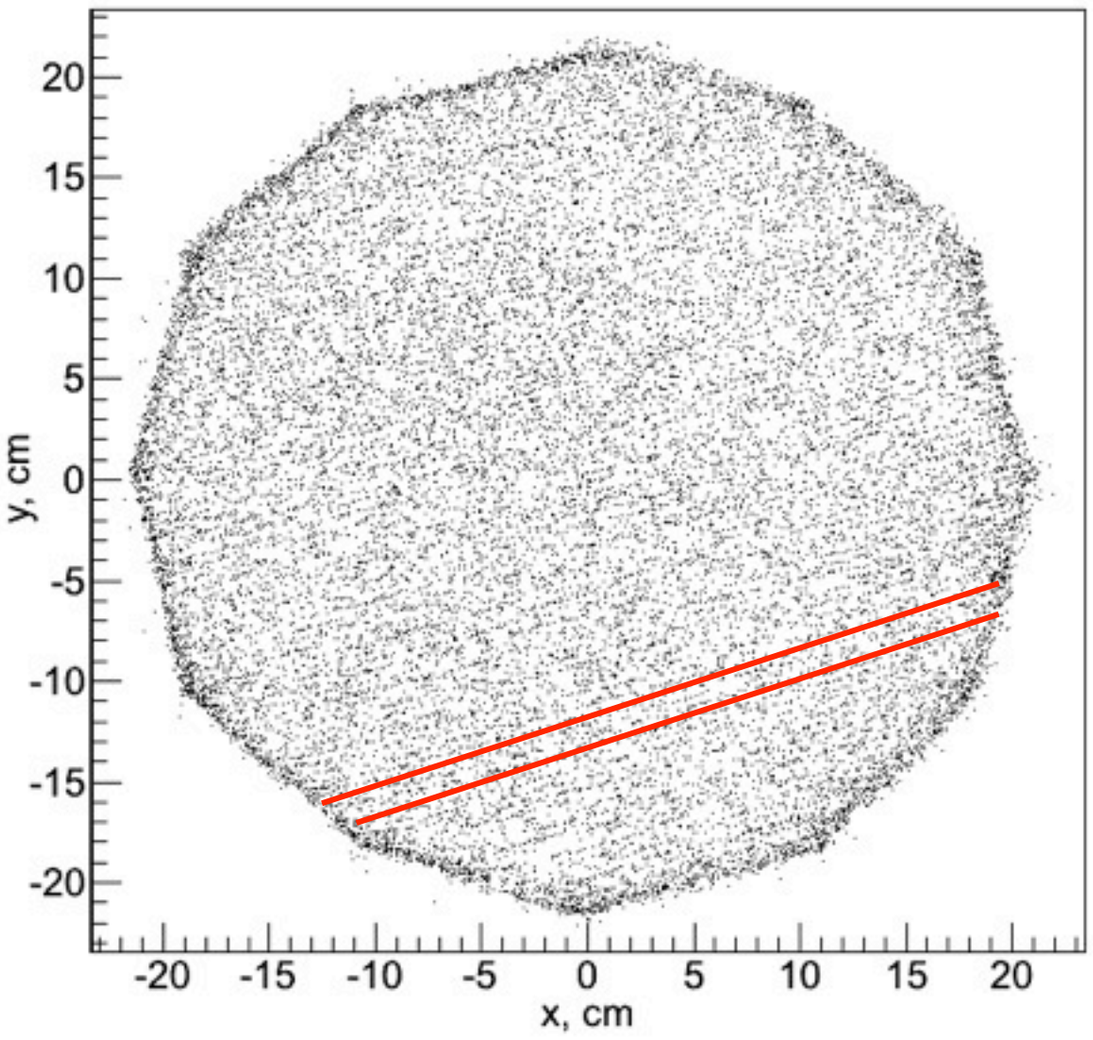

Single Photoelectron Calibration
PMT 121
amplitude (mV)
samples (10ns)
5
4
3
2
1
0
−1
0
10
20
30
40
50
60

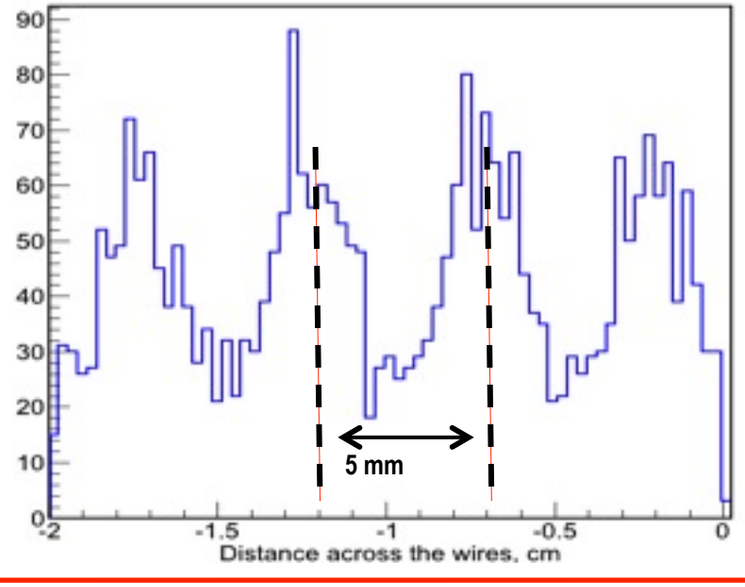

Single Photoelectron Calibration – Ch. 17
95% single photoelectrons > threshold
μ = 16 mVns
σ = 5.6 mVns
Counts
mVns
2000
1500
1000
500
0
−10
0
10
20
30
40
50
60
70

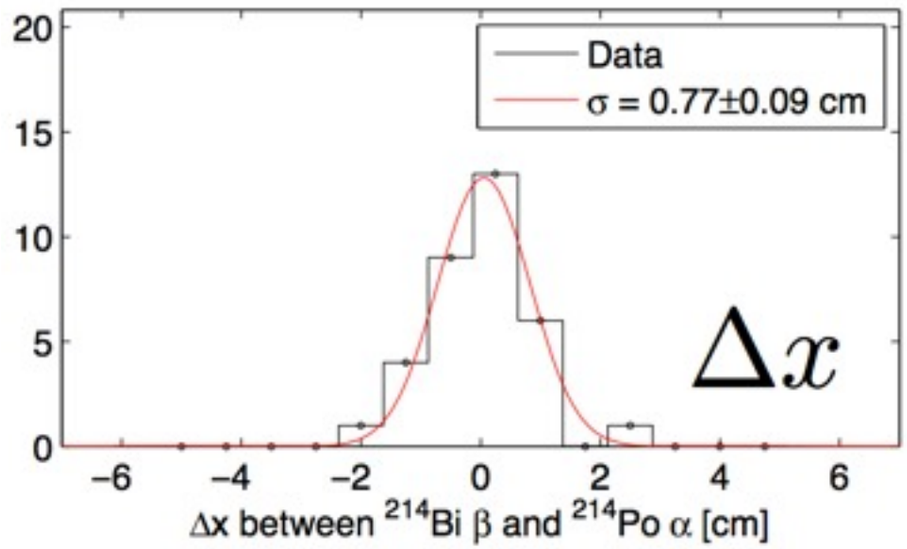
WIMP's eye view

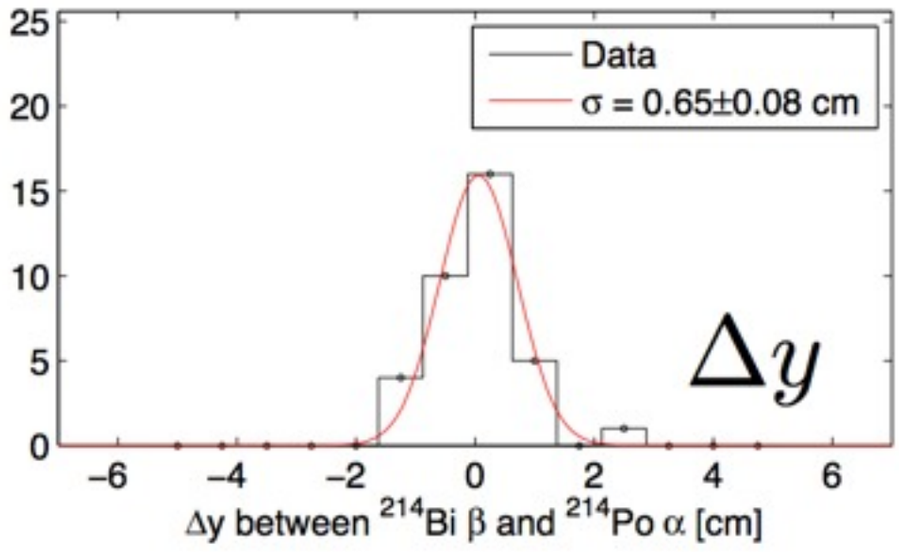


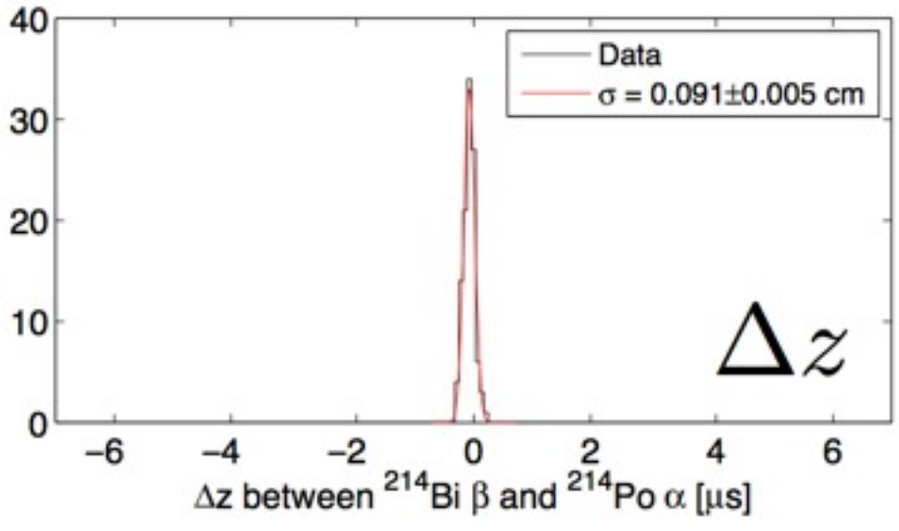
XYZ localization





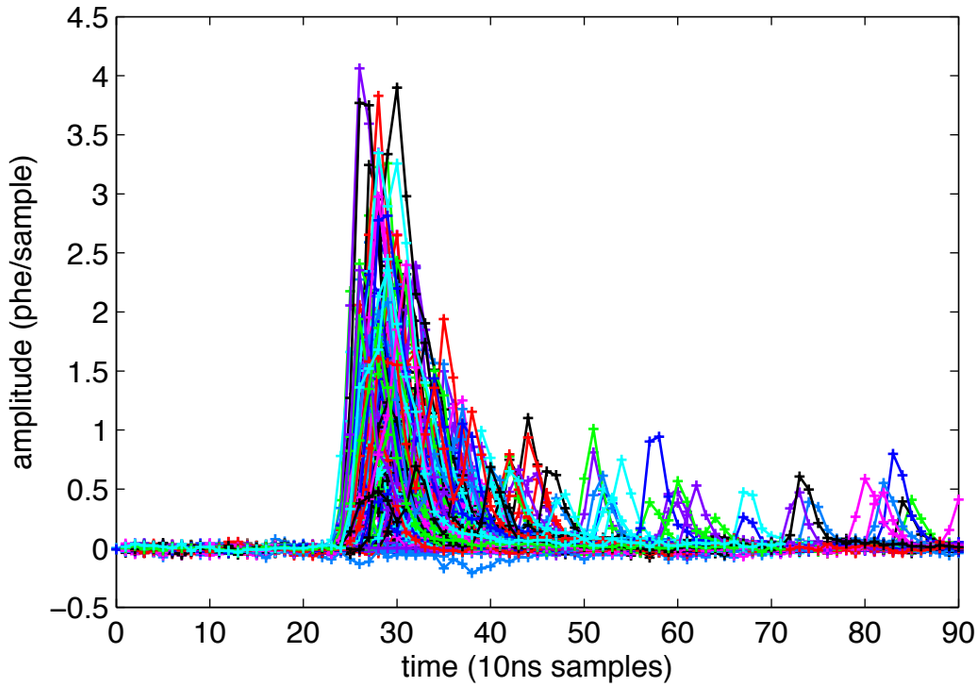


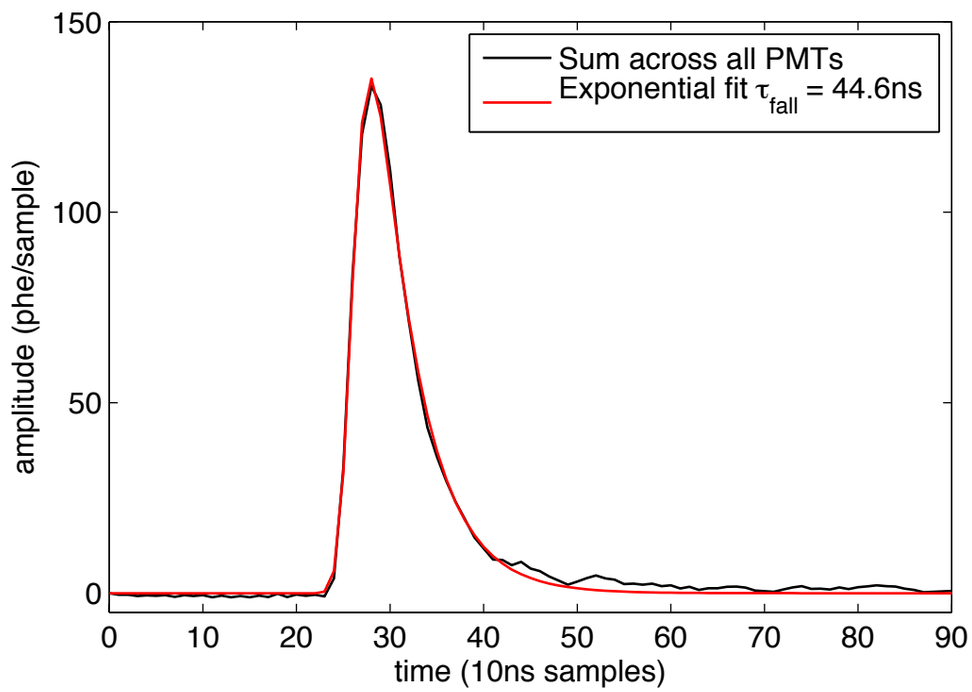




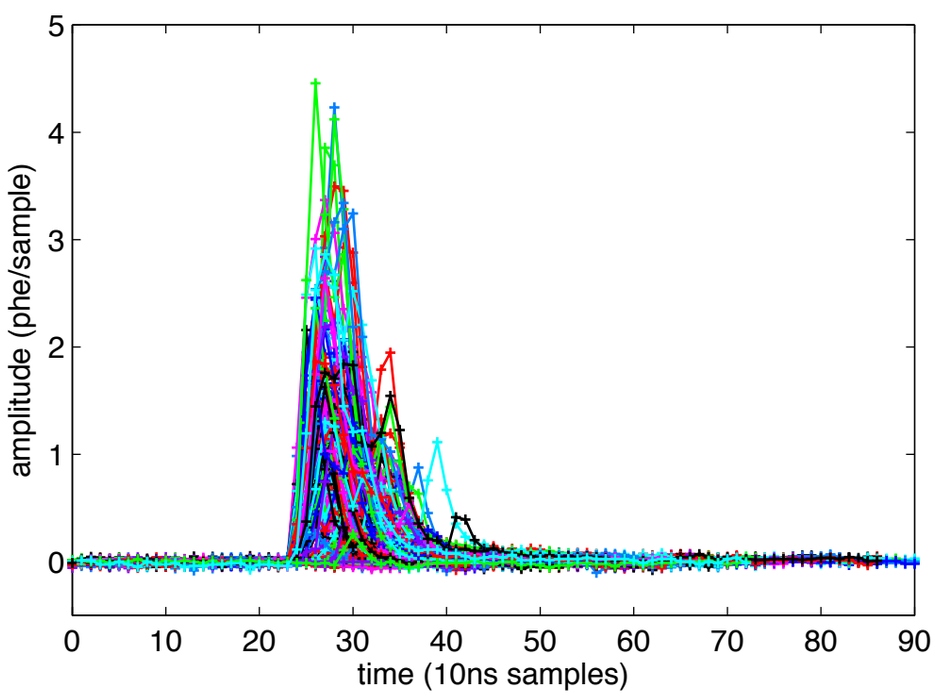
Primary Scintillation (S1)

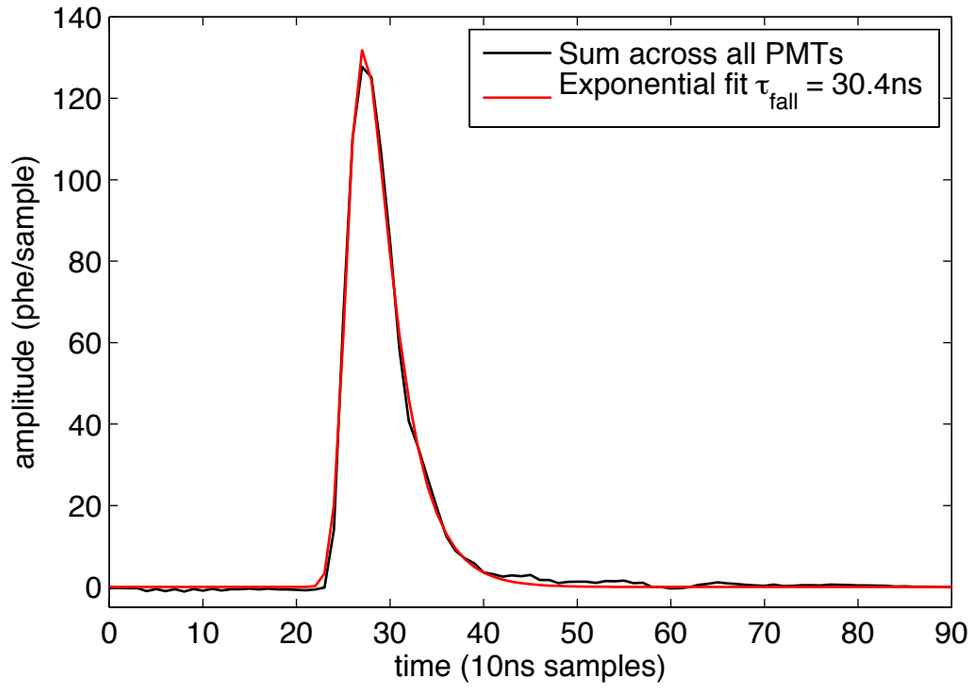
Zero field





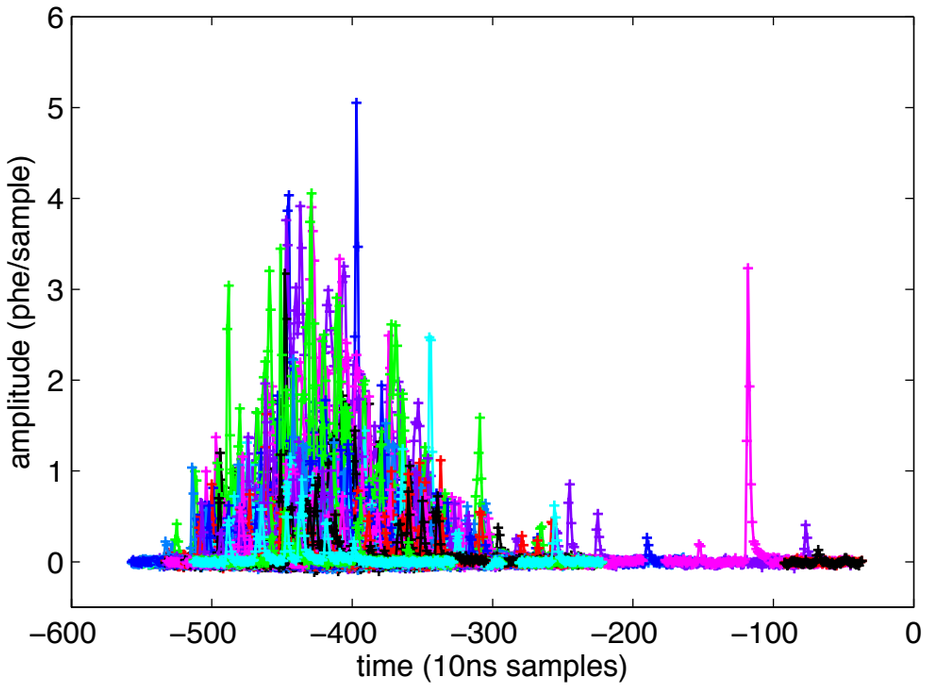
Field applied

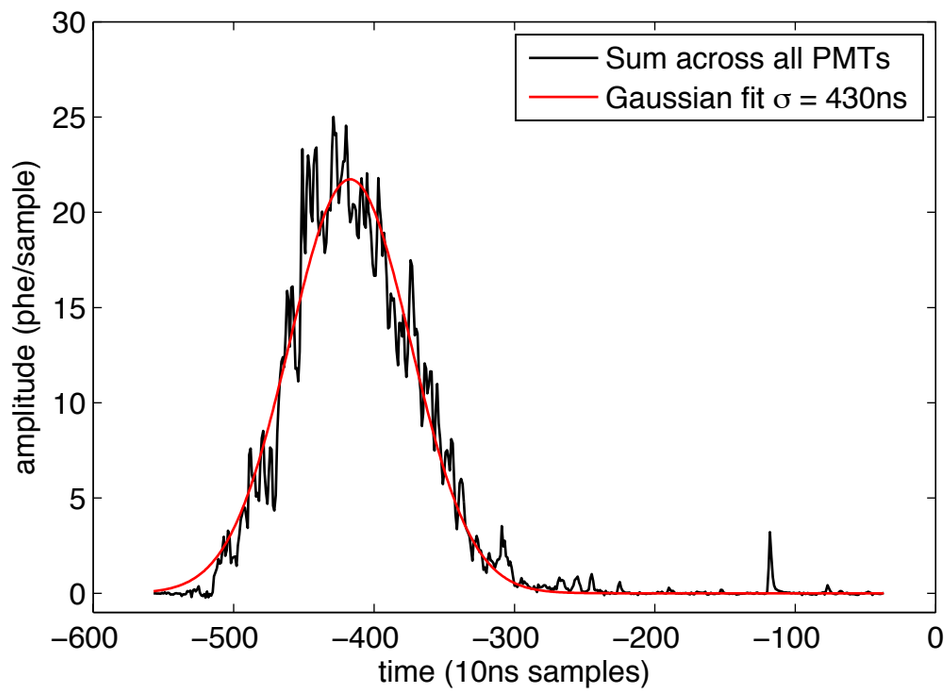




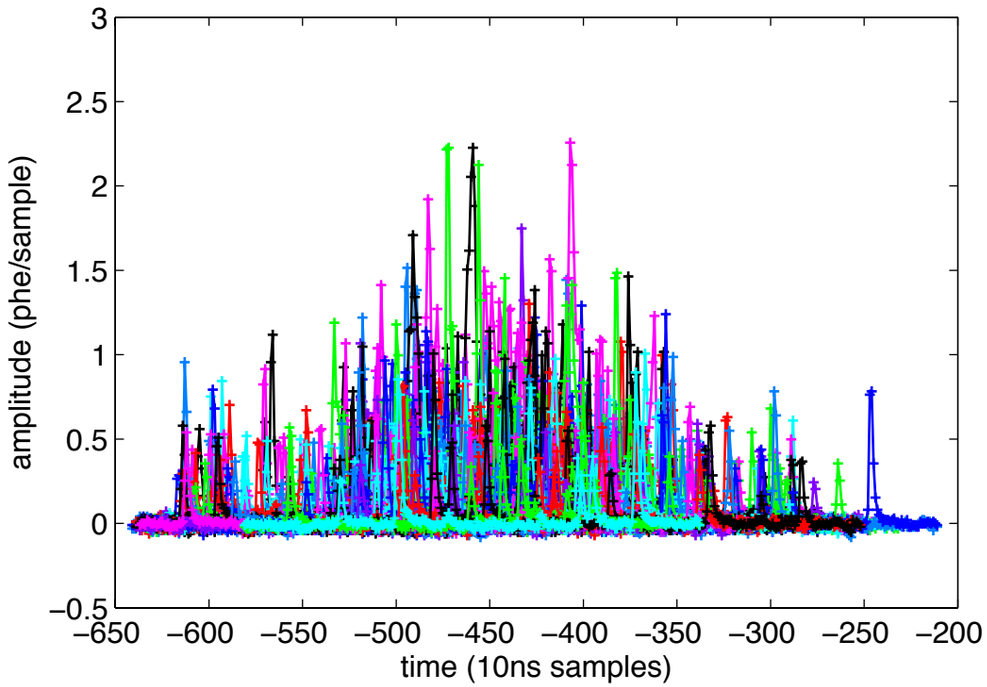
Secondary Scintillation (S2)

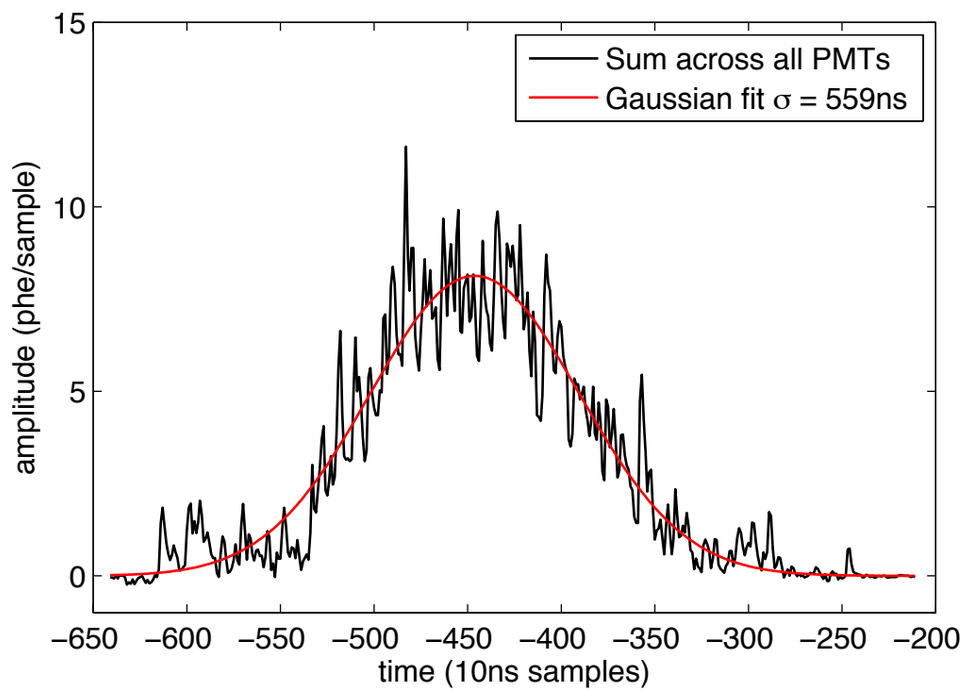
60 μs
drift time





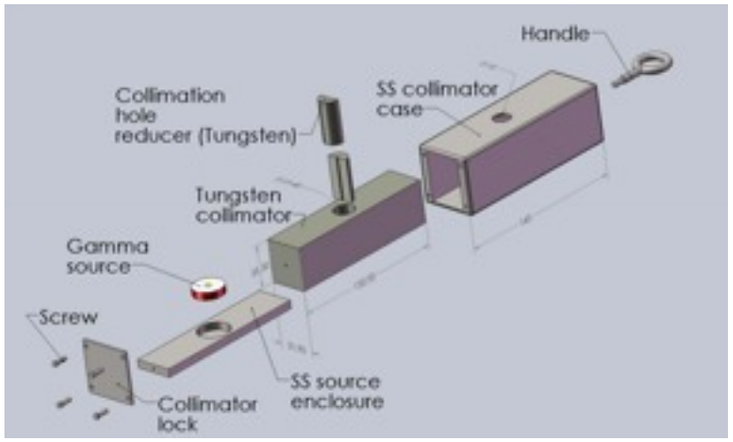
220 μs
drift time

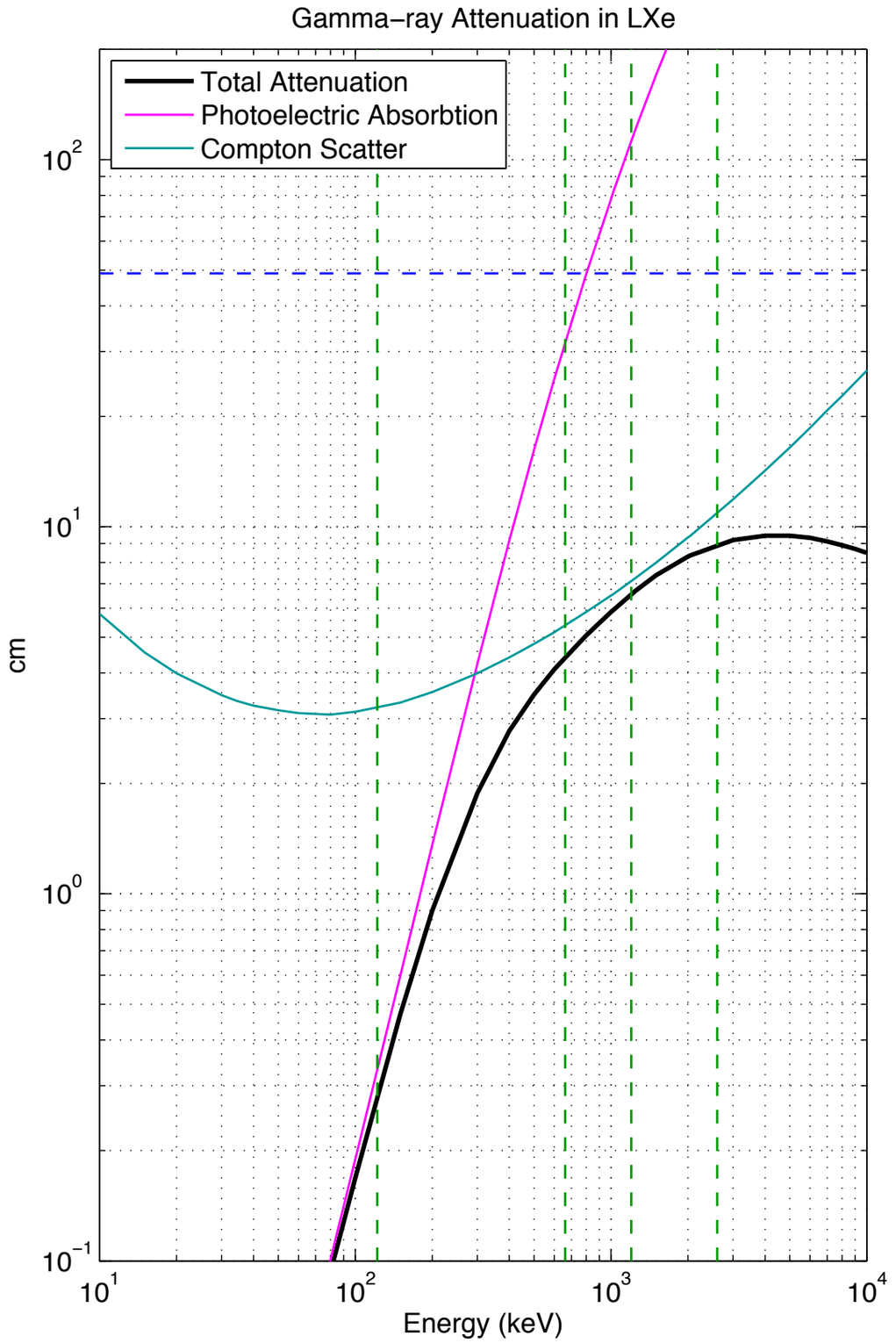




Calibrating LUX - from the outside

Challenge: Low-energy single scatter recoils in the center of the detector.





Calibrating LUX - from the inside

Internal Sources:

Activated xenon - 164, 236 keV

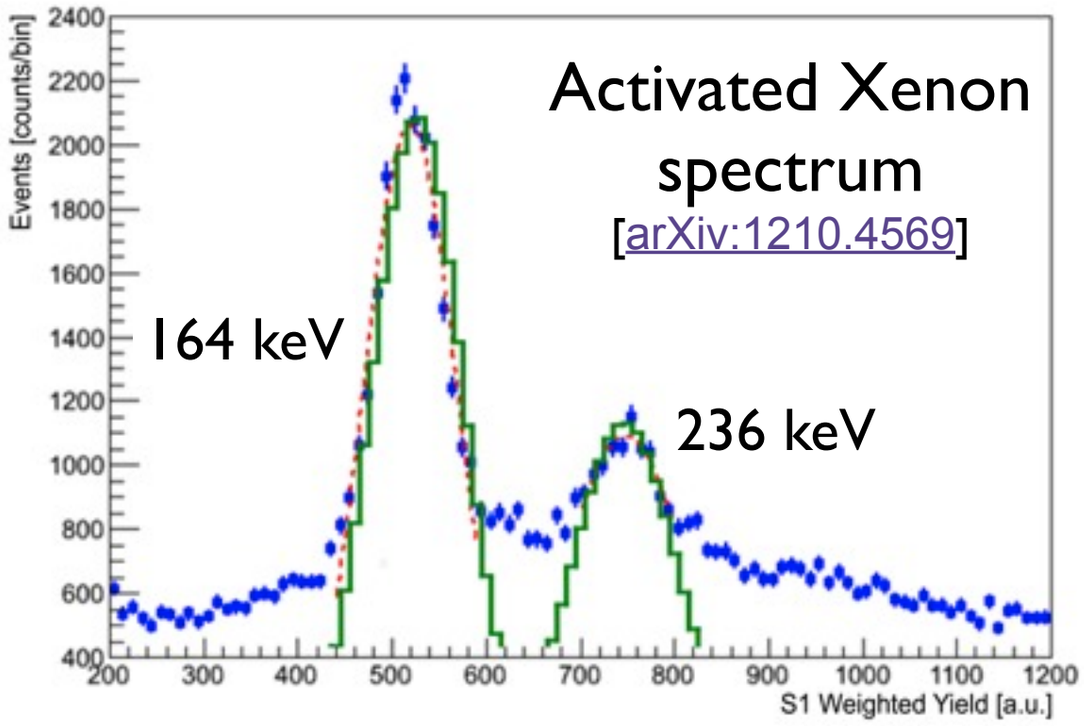
Kr-83m - 9+32 = 41 keV

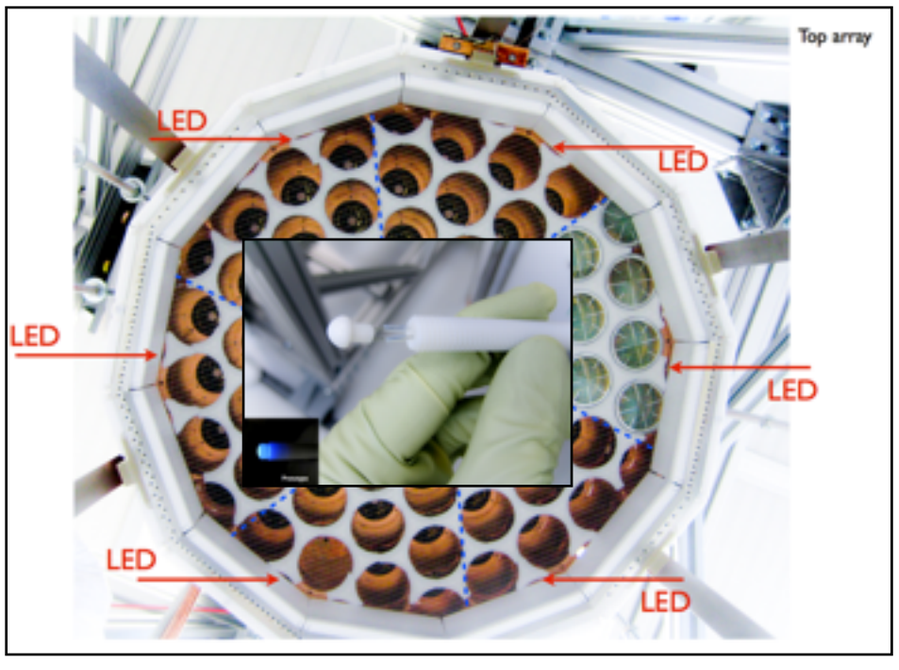
[arXiv:0912.2337, arXiv:0905.1766]

Rn-222 - 5.5, 6.0, 7.7 MeV alphas

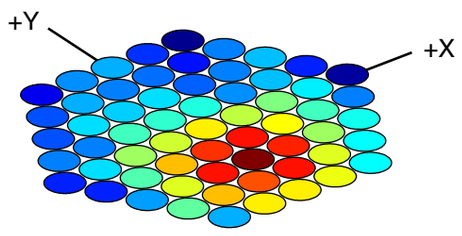
[arXiv:1210.4569]

LEDs - 12, 400nm

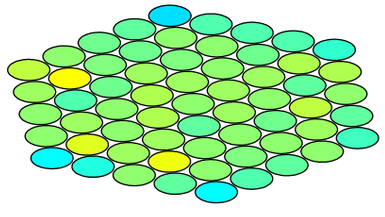




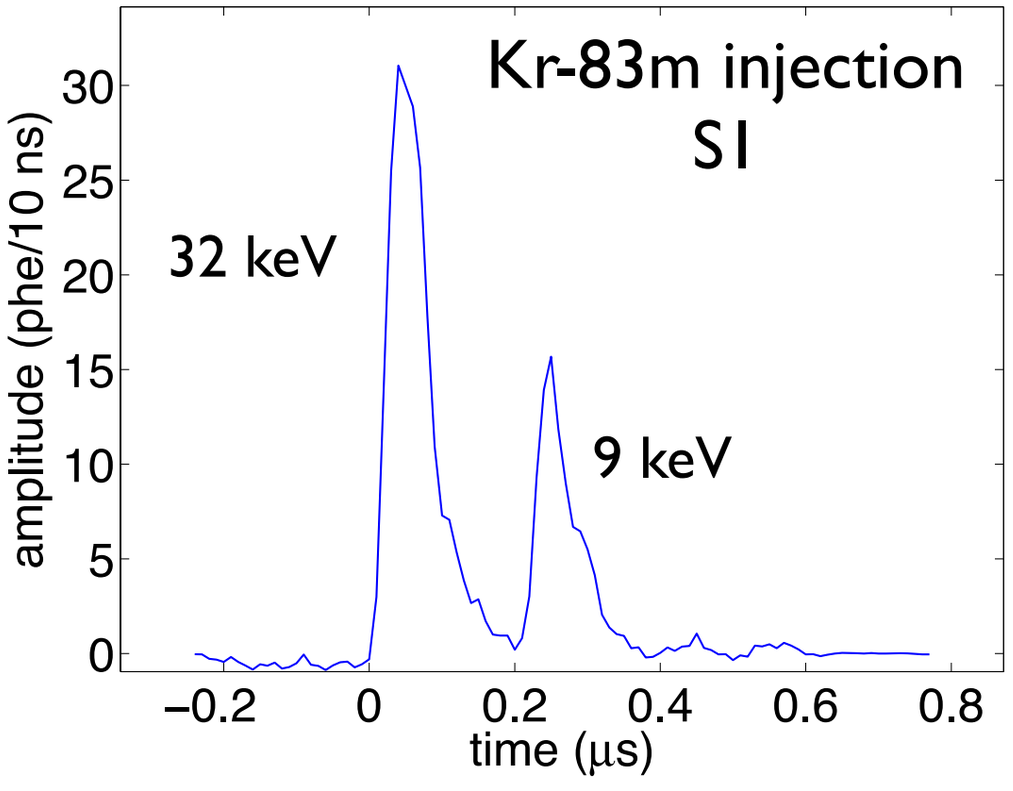
PMT Hit Pattern



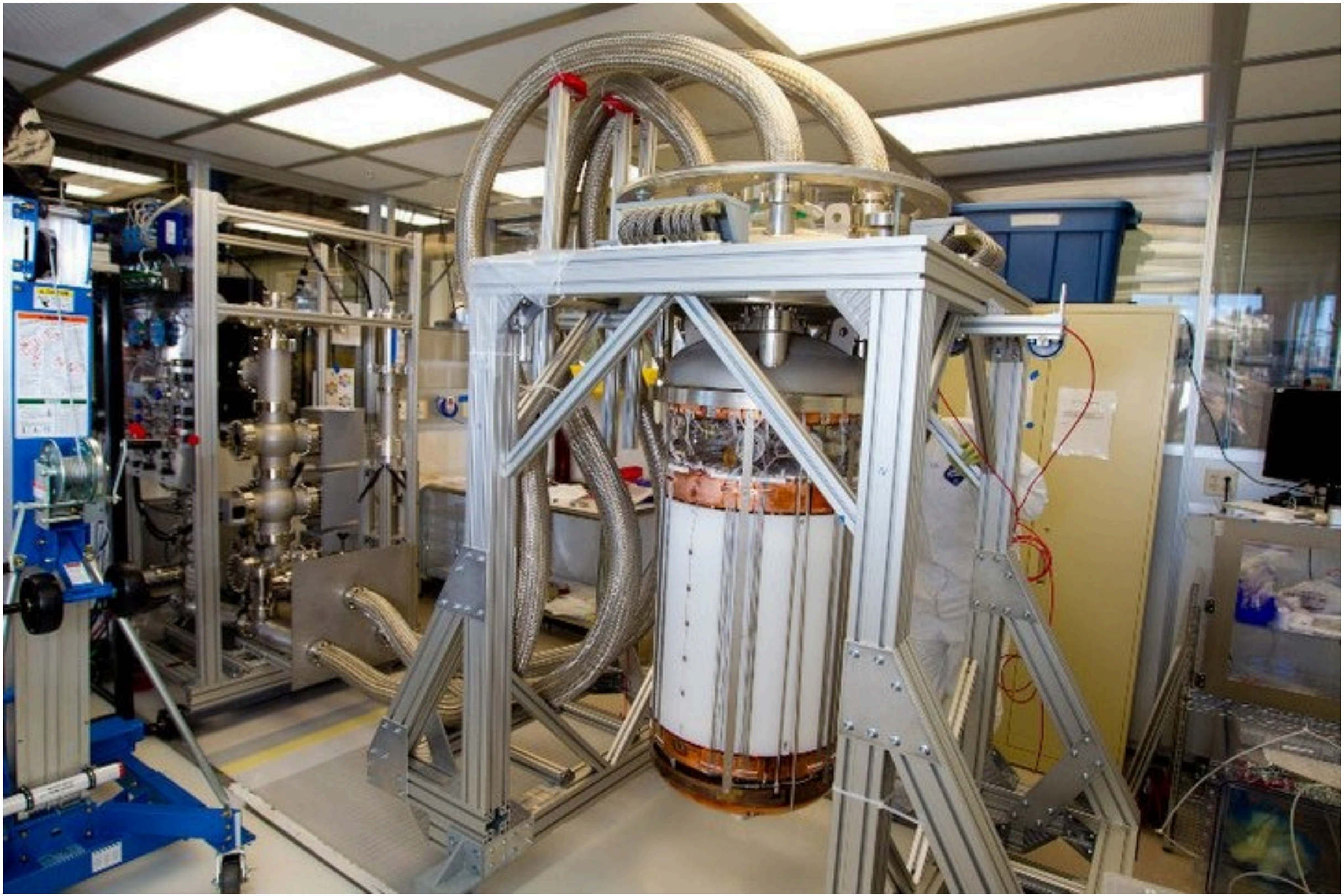
Kr-83m injection
S2 hit pattern



S1 summed across all channels



LUX Detector Construction



LUX Underground

LUX Underground

Current Status

- Detector cool-down completed in early February
  - after extensive gas phase testing
  - ~2 weeks to reach 180K

- Total xenon volume (~350kg) condensed by mid February
  - completed in 3 days

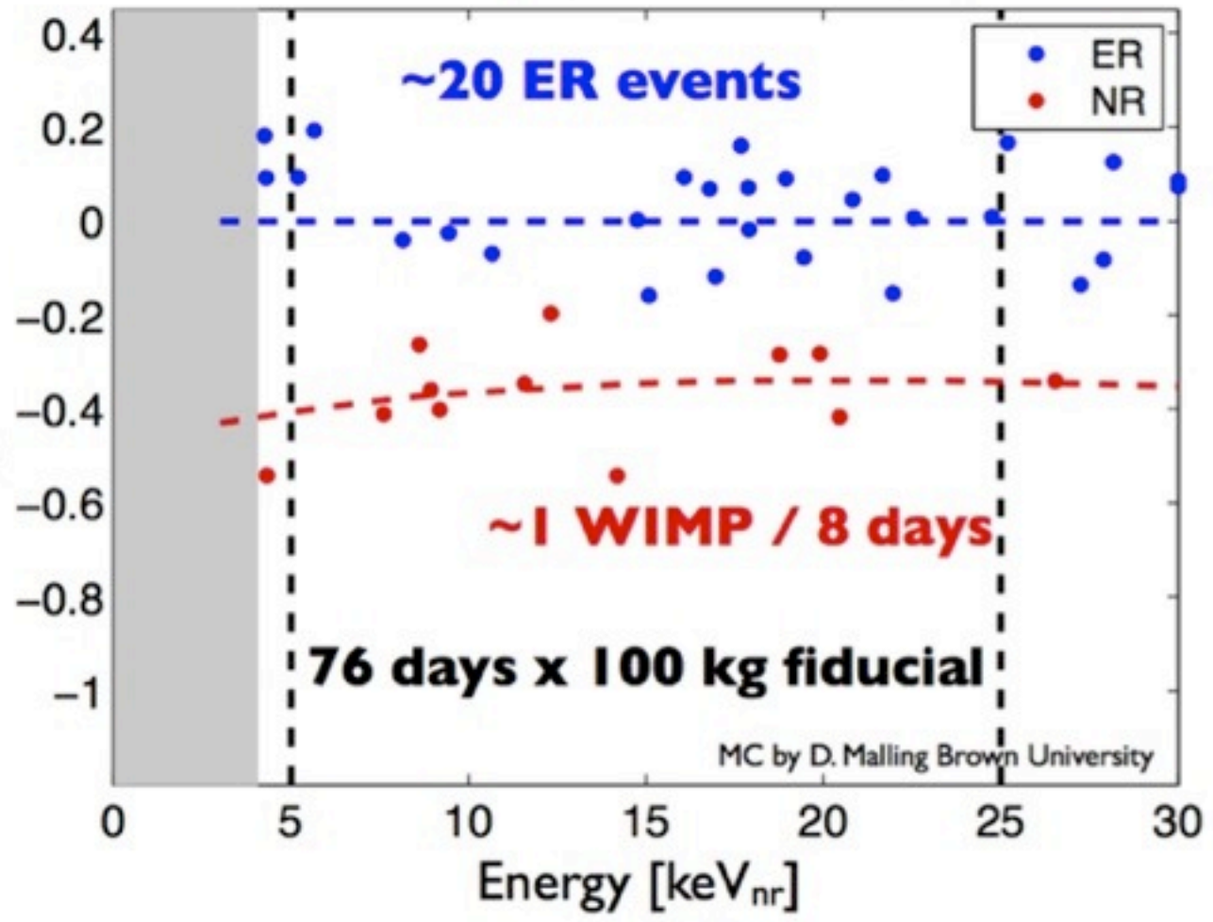
- Detector commissioning and optimization currently underway
  - xenon purification (currently >90cm e- mean free path)
  - calibration
  - sub-system verification

- Short (~60 day) WIMP search run results by end of 2013
- Long (~300 day) WIMP search run beginning in 2014

LUX Sensitivity

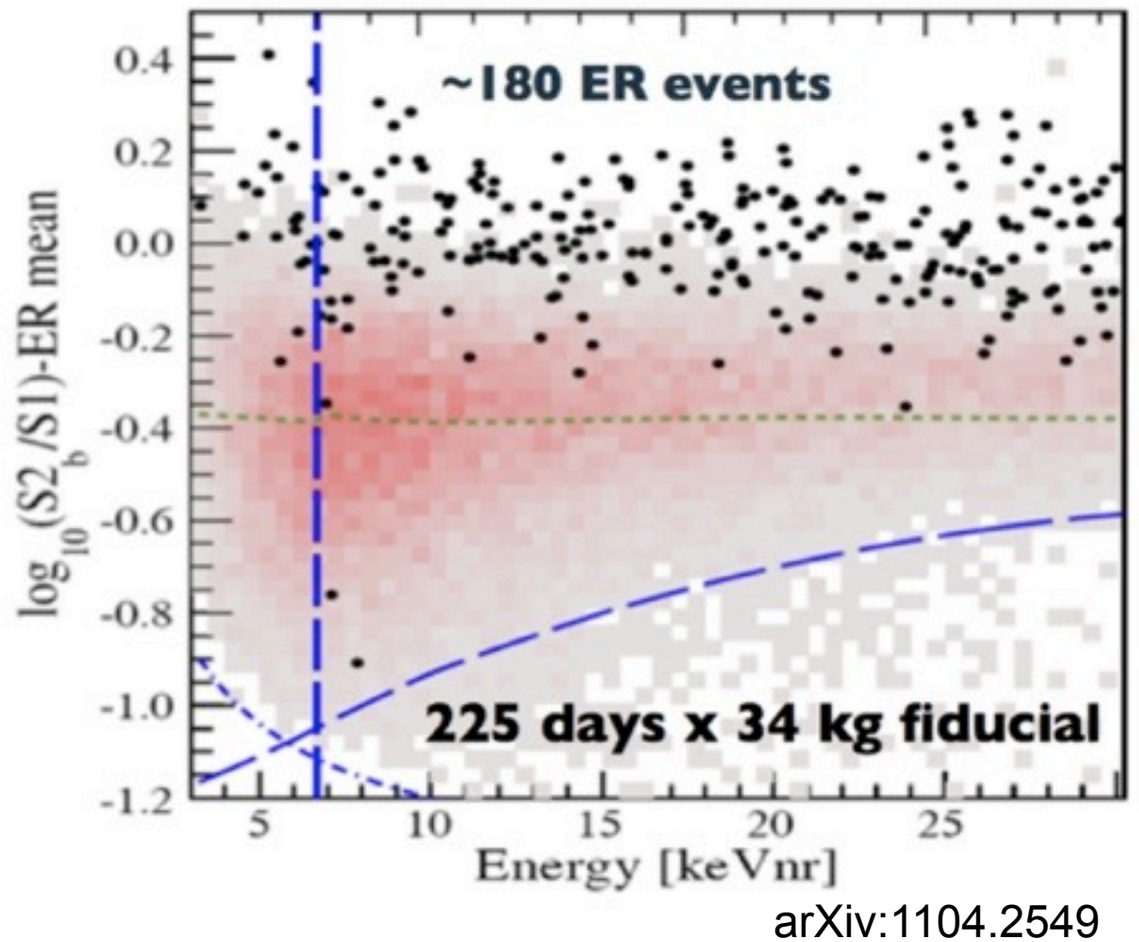
Comparing nominally equivalent kg-days for 100 kg LUX fiducial versus 34 kg XENON fiducial but LUX has much greater sensitivity/kg-day because of cleaner signal/fewer BG events

LUX (Monte Carlo)



LUX signal and background expectation for 7,600 kg-days net exposure. WIMP events assume m = 100 GeV, σ = 3×10^{-45} cm^2. Assumes 100 kg fiducial. Given very low ER rate, can significantly increase fiducial in early running.

XENON100



arXiv:1104.2549

XENON100 7,600 kg-days result for comparison. Note higher ER rate - ~180 events primarily due to Compton scattering of external gamma background.

LUX WIMP Sensitivity