Light Collection in the Scintillation Bubble Chamber

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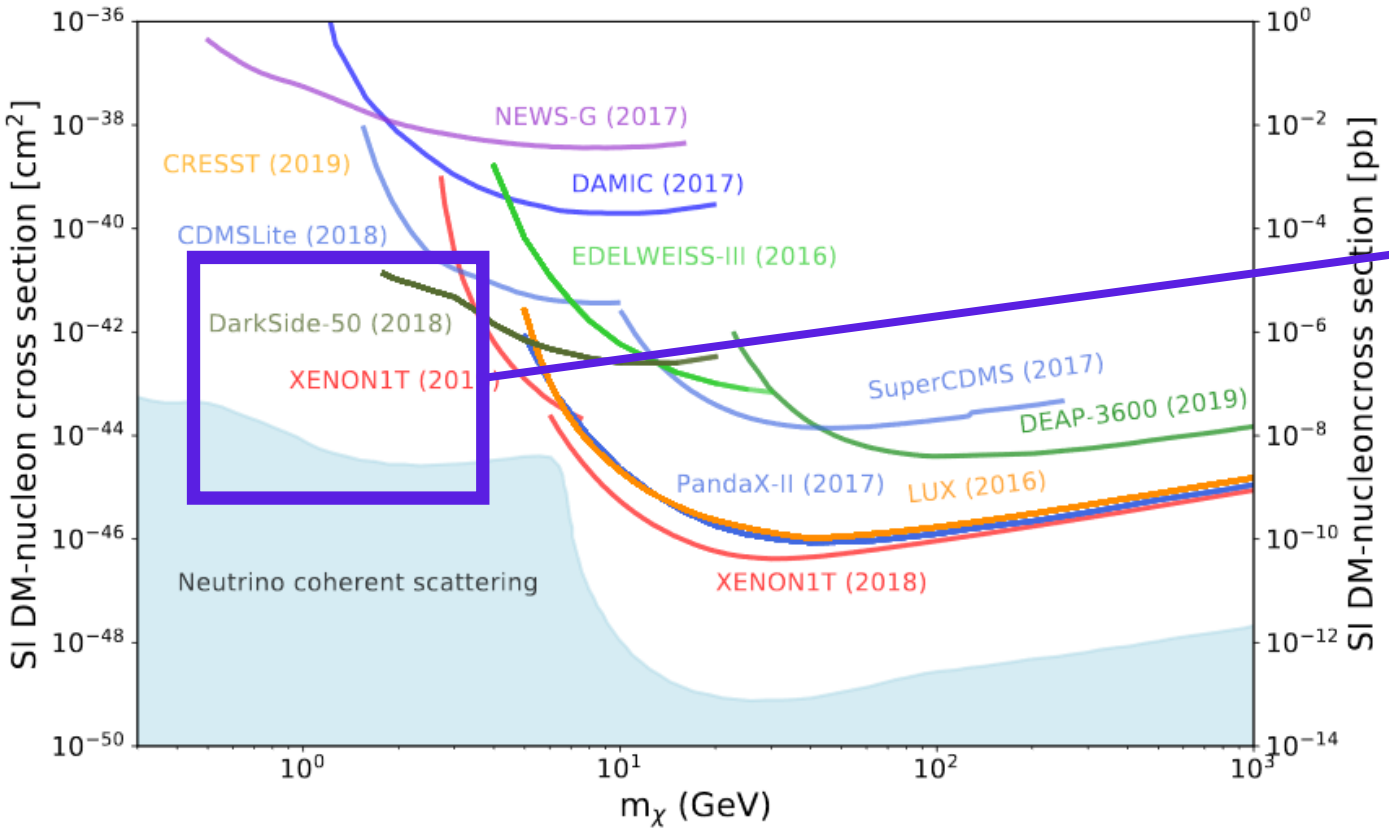
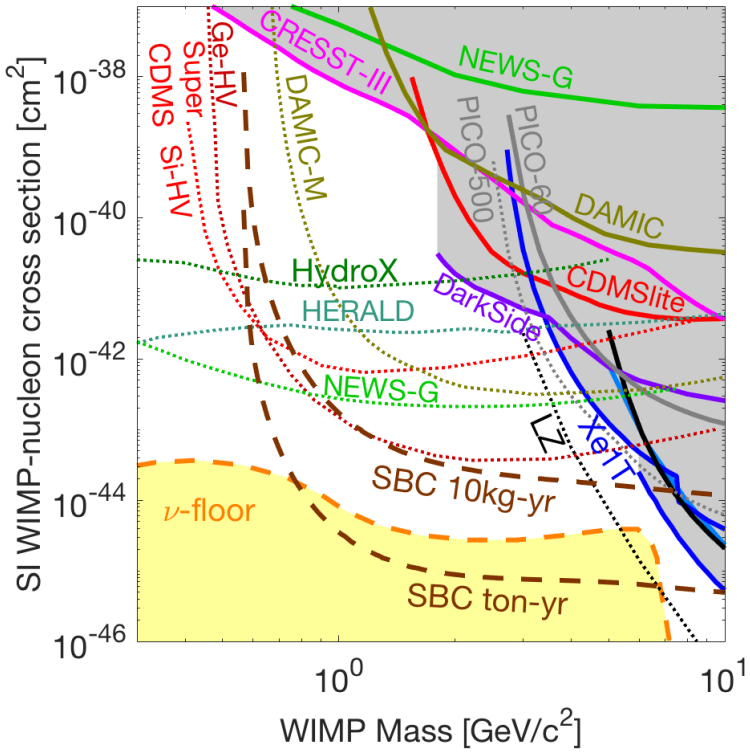
Dark Matter remains mysterious and eludes us….



Upper limits of the spin-independent dark matter parameter space

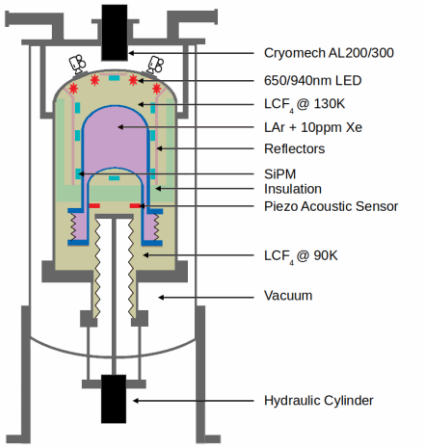
M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018) and 2019 update



SBC goals:

- Reach a 100eV threshold
- 10 kg-year / 1 ton-year exposure
- Backgrounds being neutrons and CEvNS

Scintillation Bubble Chamber (SBC) is a solution that combines…

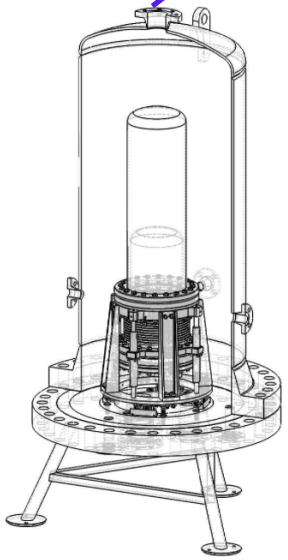


SBC

Bubble Chambers

Pros:
- Great ER rejection
- Scalable demonstrated by PICO

Cons:
- No event-by-event energy information

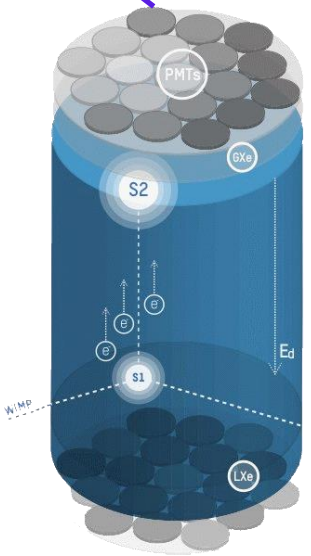


Pic: PICO-40L

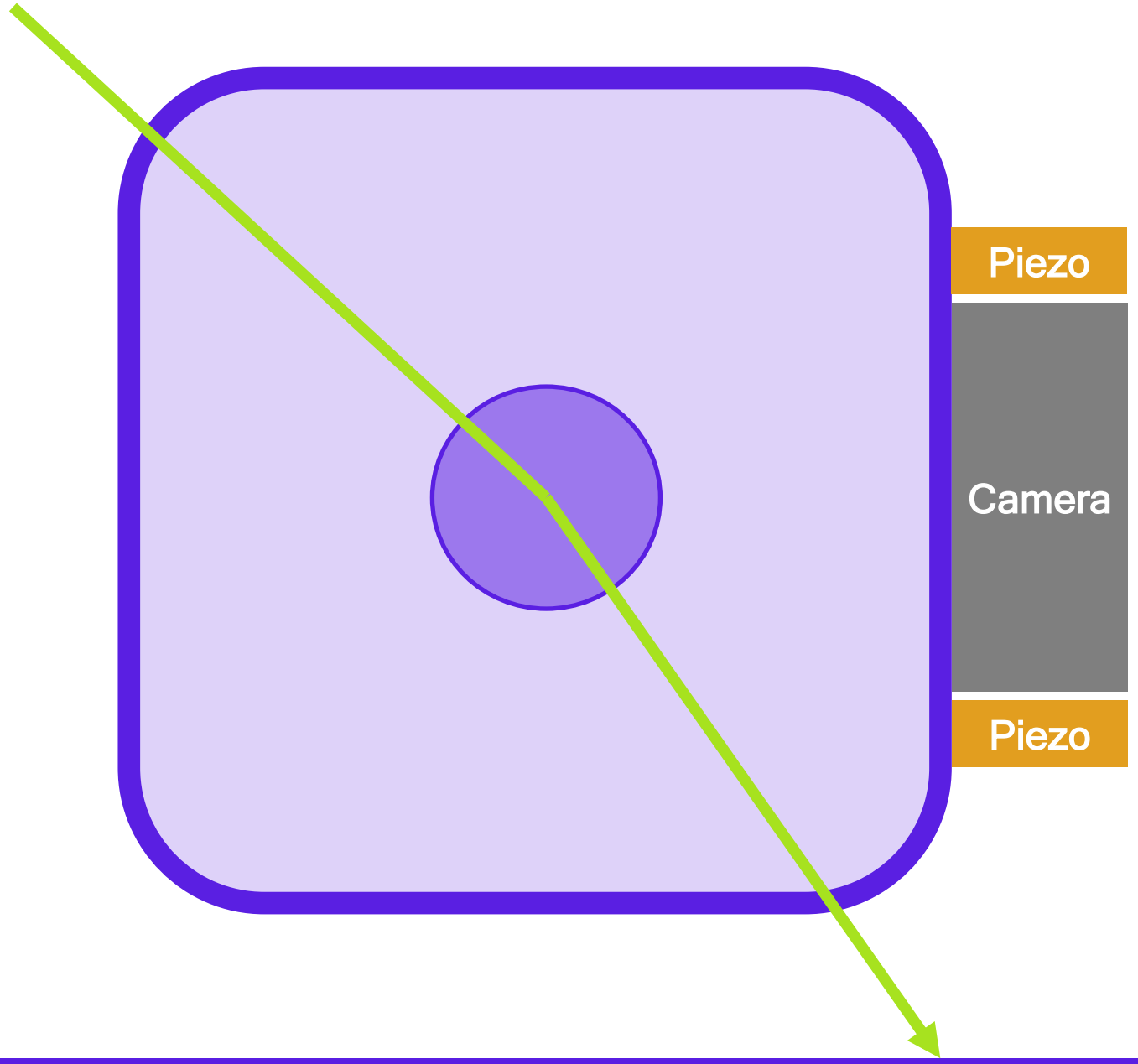
Liquid Noble gases experiments

Pros:
- Good timing information
- Good energy resolution

Cons:
- Weak ER discrimination



Pic: XENON



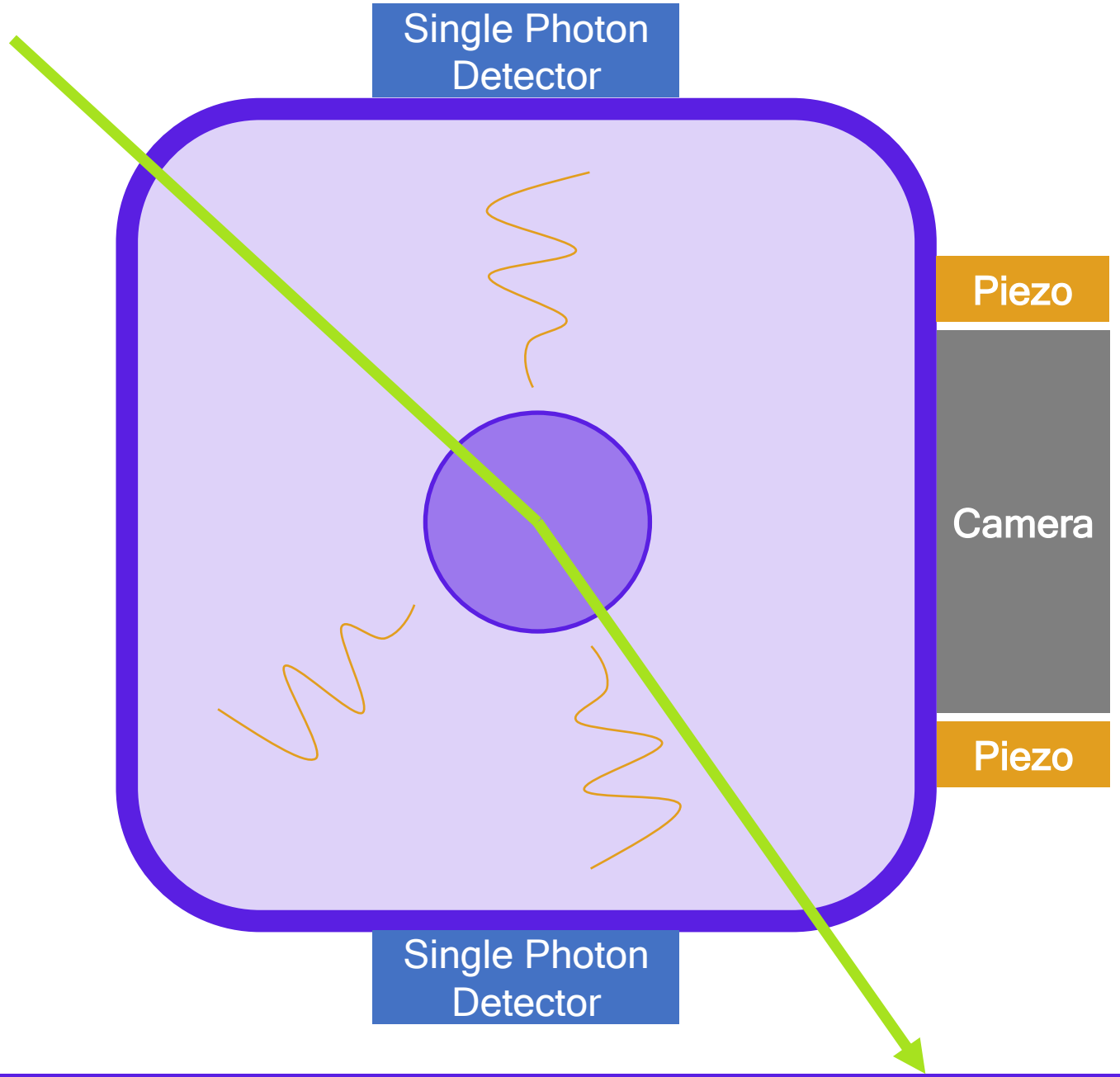
In bubble chambers….

Particle needs to deposit a large amount of energy in a small length to initiate a bubble.

Electrons and gammas stopping power usually too low

Alphas background reduced by fiducial cuts and piezos

WIMPs and neutrons are left



In scintillation bubble chambers….

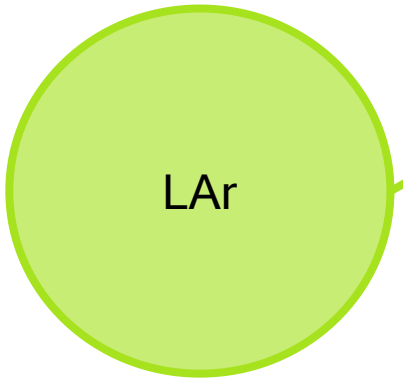
Every benefit from a bubble chambers PLUS

Energy discrimination from photon information

Further electron background reduction from timing information

Scintillation takes energy from bubble creation

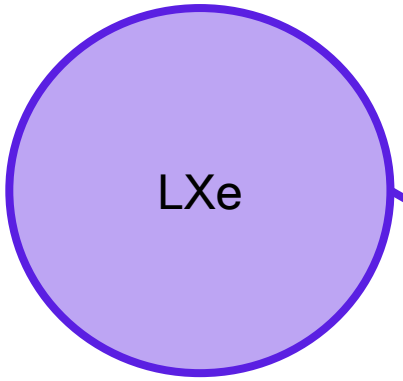
Liquid Argon or Liquid Xenon?
Why not both?



Pros:
- Cheap, ~2.5 USD/L
- Two excimers with two different distinguishable time constants that depend on the type of interaction. t1 = few ns, t2 = few us

Cons:
- Scintillation @ λmax = 128nm
- Boiling point @ 90K, 1 atm

Doping LAr with ppm of LXe waveshifts some of the photons to LXe wavelengths for a better light yield.



Pros:
- Higher density which translates to better exposure
- Scintillation @ λ = 175nm
- Boiling point @ 165K, 1 atm

Cons:
- Too expensive per kg

Pic: R6834

Pic: R5912

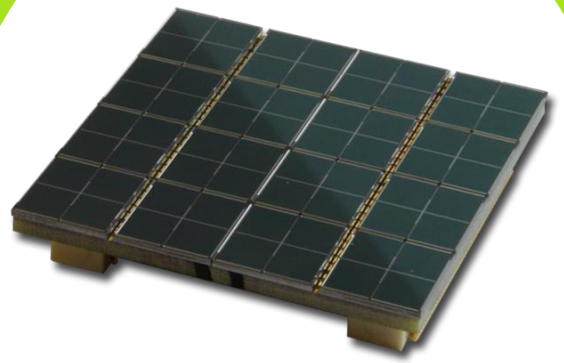
Single photon detector requirements:

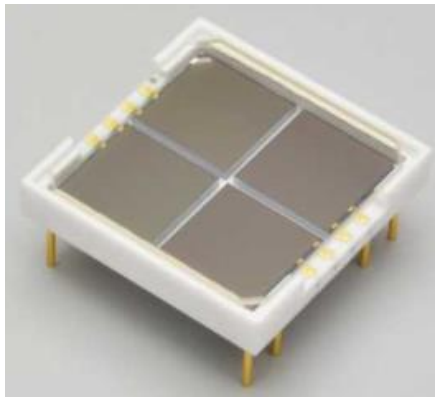
- High photon collection efficiency
- Tolerate liquid argon temperatures (~90K)

Photomultipler tubes (PMTs)

- Special PMTs can tolerate the temperatures with reduced gain and increased dark current
- Normal PMTs require thermal insulation that function as light guides. See DEAP3600 for example
- Require waveshifters
- Possible candidate but space can be an issue and collection efficiency is lost due to extra parts

Pic: FBK large SiPM tiles





Pic: Hamamatsu Quad VUV4 SiPMs

Single photon detector requirements:

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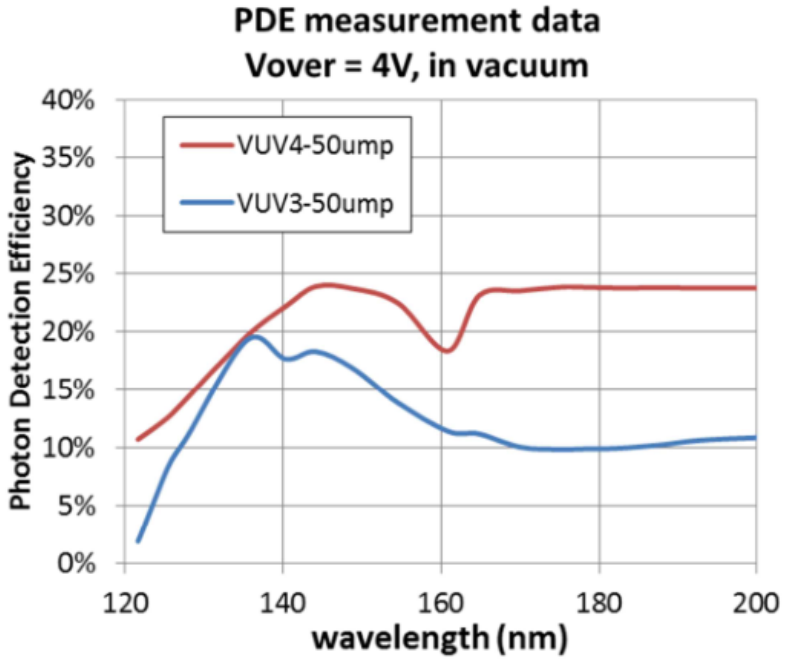
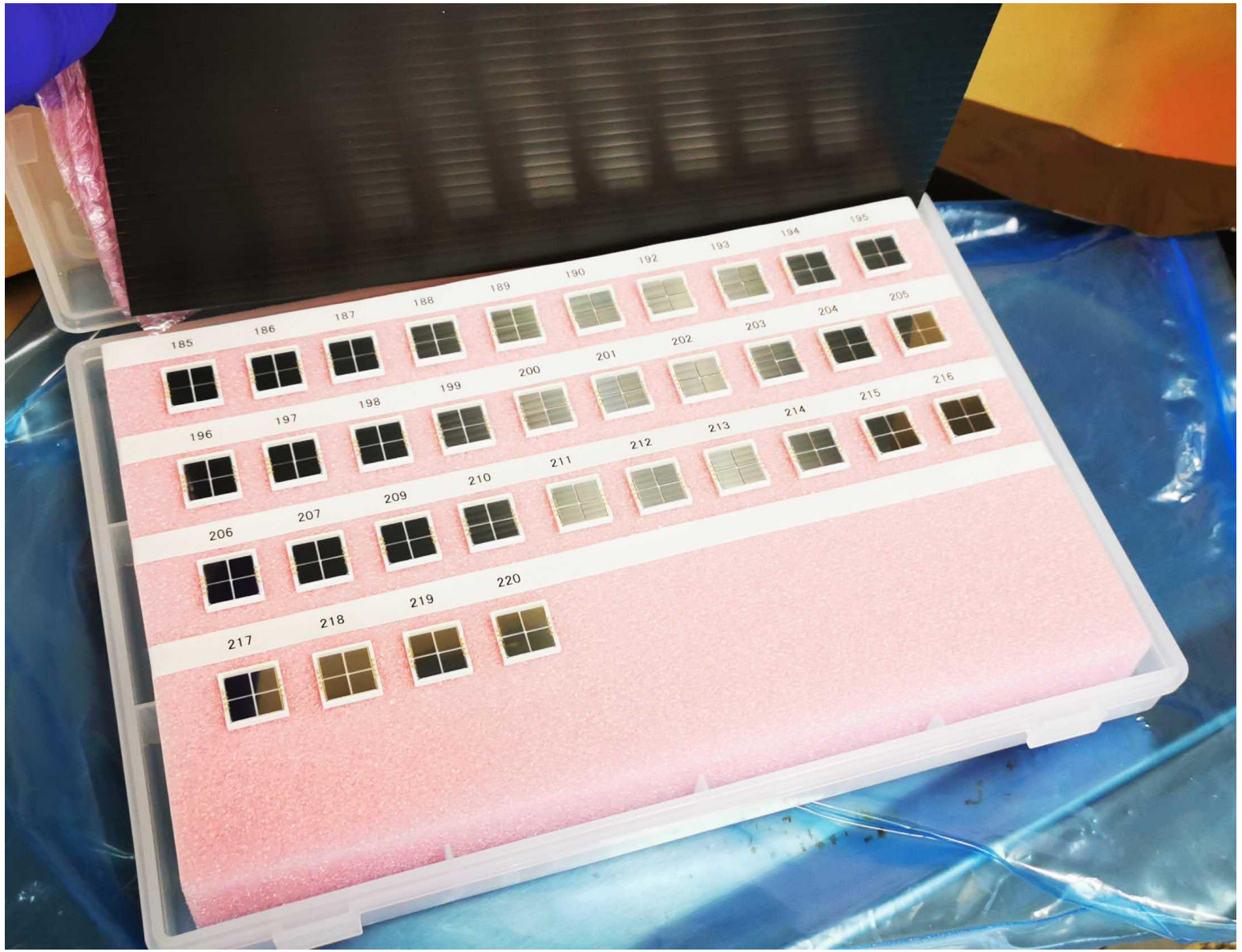


Silicon Photomultipliers (SiPMs)

- Array of avalanche photodiodes
- Great single PE resolution
- Can tolerate LAr temperatures
- Specially fabricated SiPMs can detect Argon and Xenon scintillation without waveshifters
- Winner-winner chicken dinner



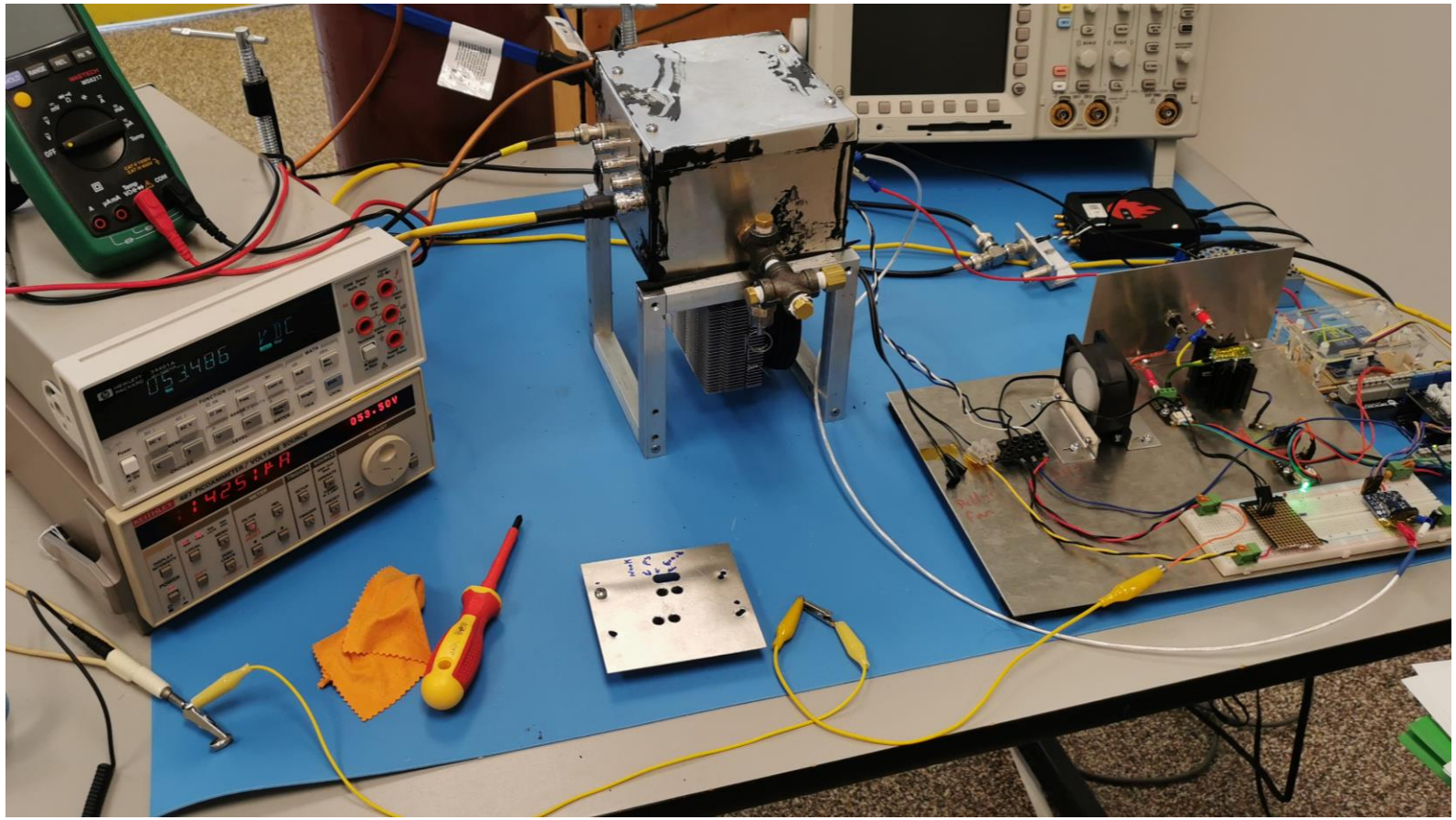
SBC acquired 34 SiPMs back in 2019

My Objective:

- Quantify the SiPM uniformity by measuring the breakdown voltage distribution…

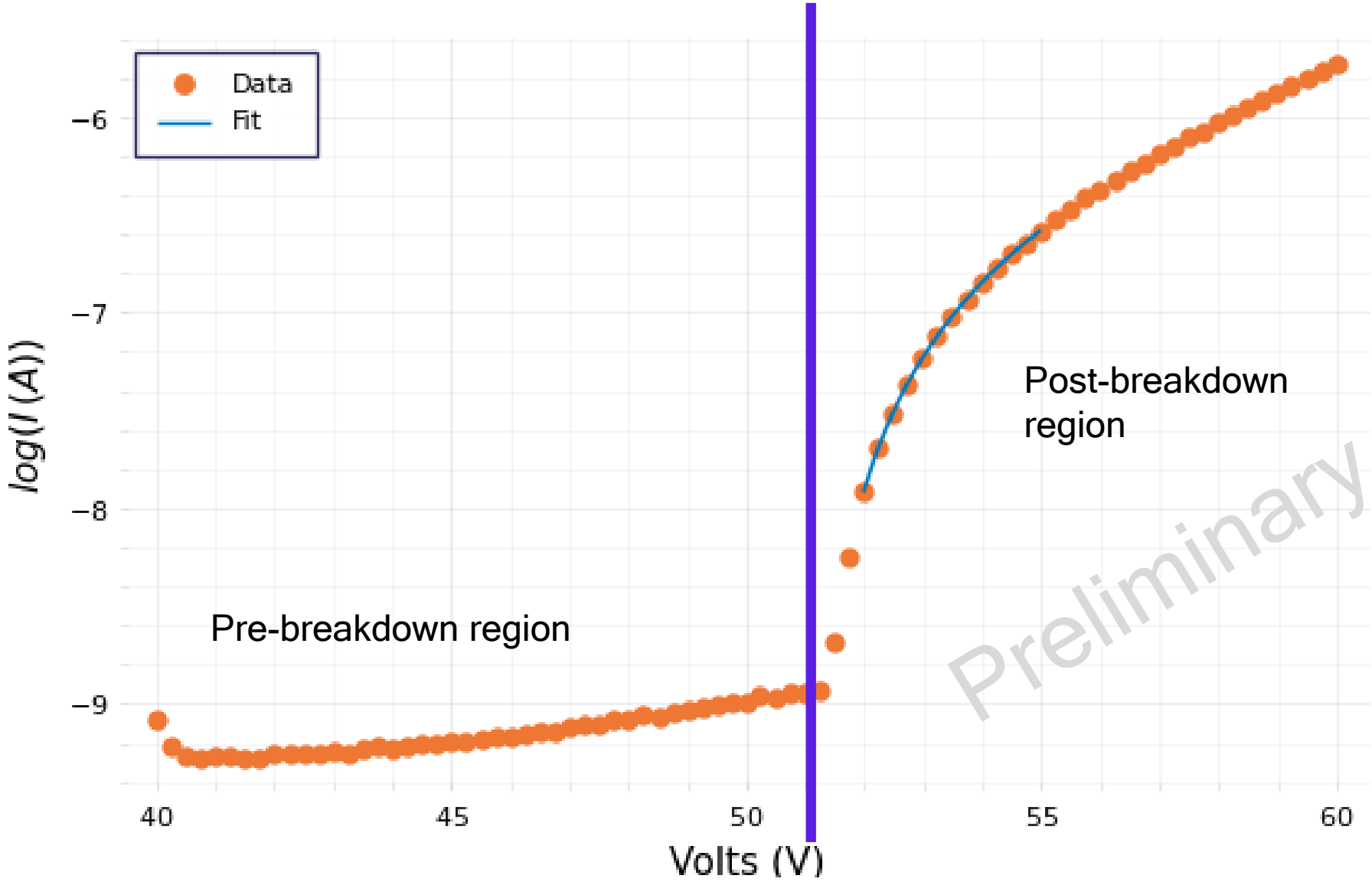
SiPM Breakdown Voltage is the start of the avalanche breakdown

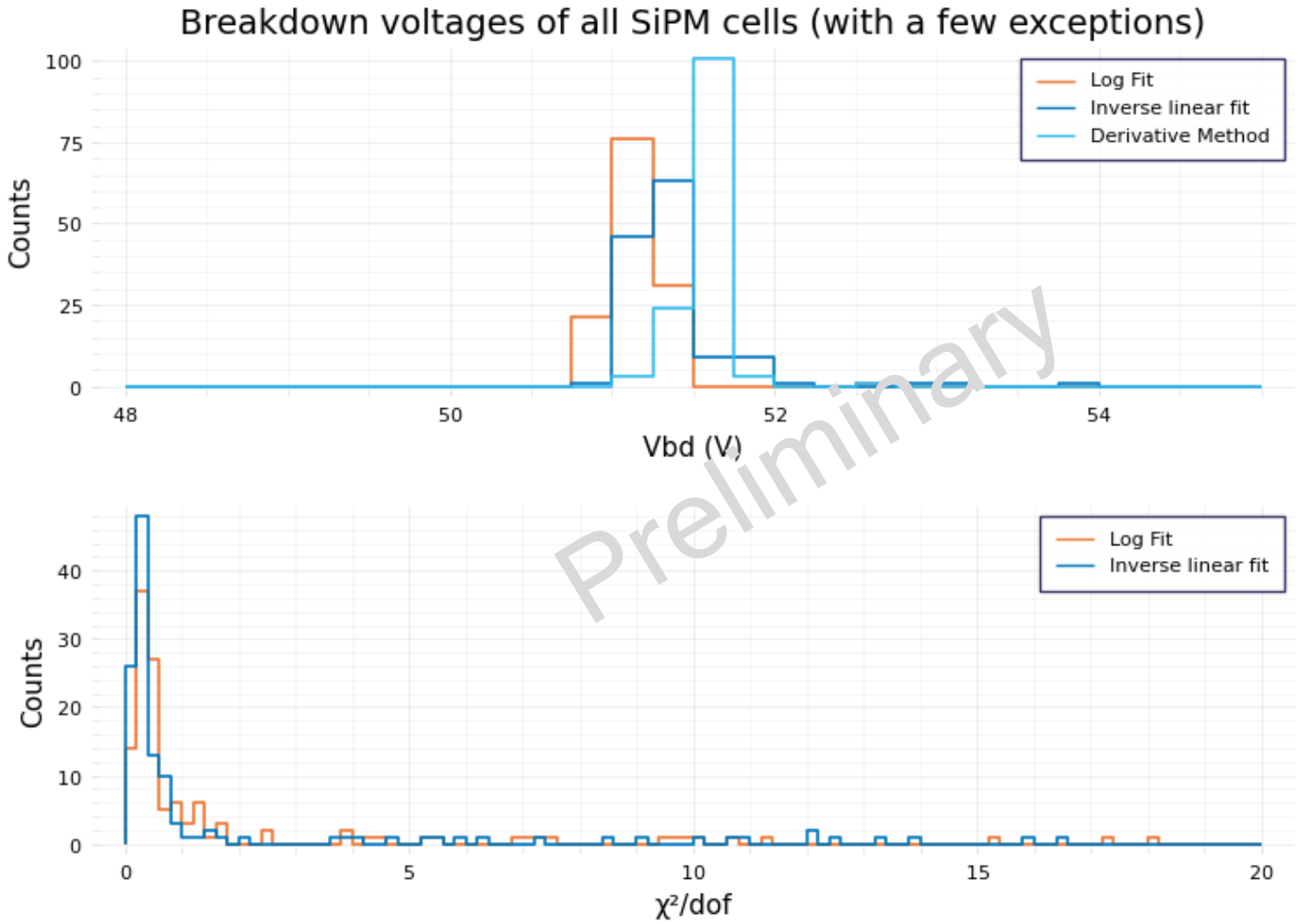
Most important characteristic to measure



Measured current vs voltage of 136 SiPMs cells @ Queen's University

- From 40V to 60V
- Peltier cooling system to maintain a constant temperature of **0°C**
- Nitrogen gas purge to minimize exposure to humidity


Data
Fit
−6
−7
−8
−9
log(I (A))
40
45
50
55
60
Volts (V)
Pre-breakdown region
Post-breakdown region
Preliminary



Log Fit

$$\log(I) = n\log(V - V_{BD}) + \alpha$$

Inverse Linear Fit

$$\left(\frac{d\log I}{dV}\right)^{-1} = \frac{(V - V_{BD})}{n}$$

Derivative Method

$$V_{BD} = \max\left(\frac{d\log I}{dV}\right)$$


Rocco Coppejans
Matt Bressler
Pietro Giampa
Eric Poulin
Stephen Windle
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Austin de St. Croix
C Eric Dahl
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