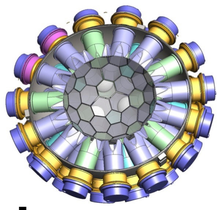
Brandeis University



Triplet lifetime measurement using MiniCLEAN Detector

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Brandeis University

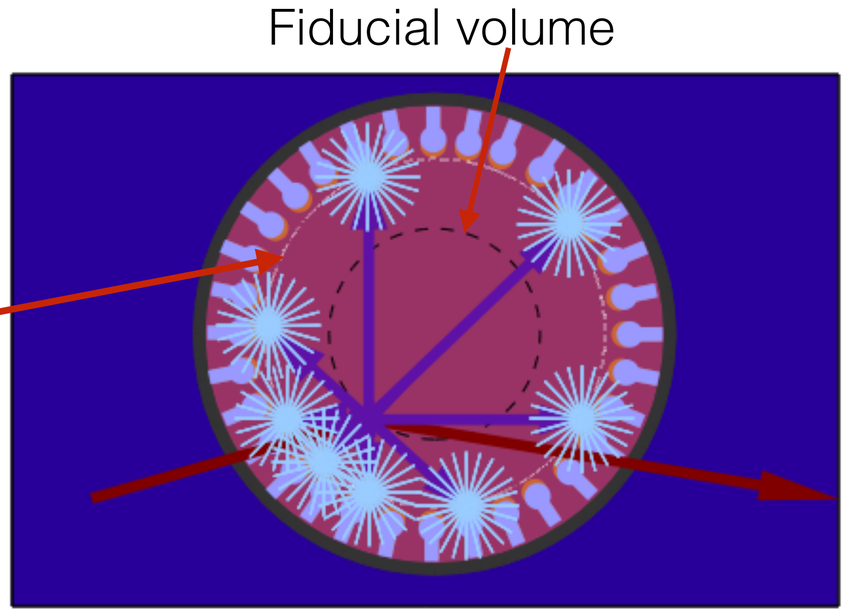
For the MiniCLEAN Collaboration

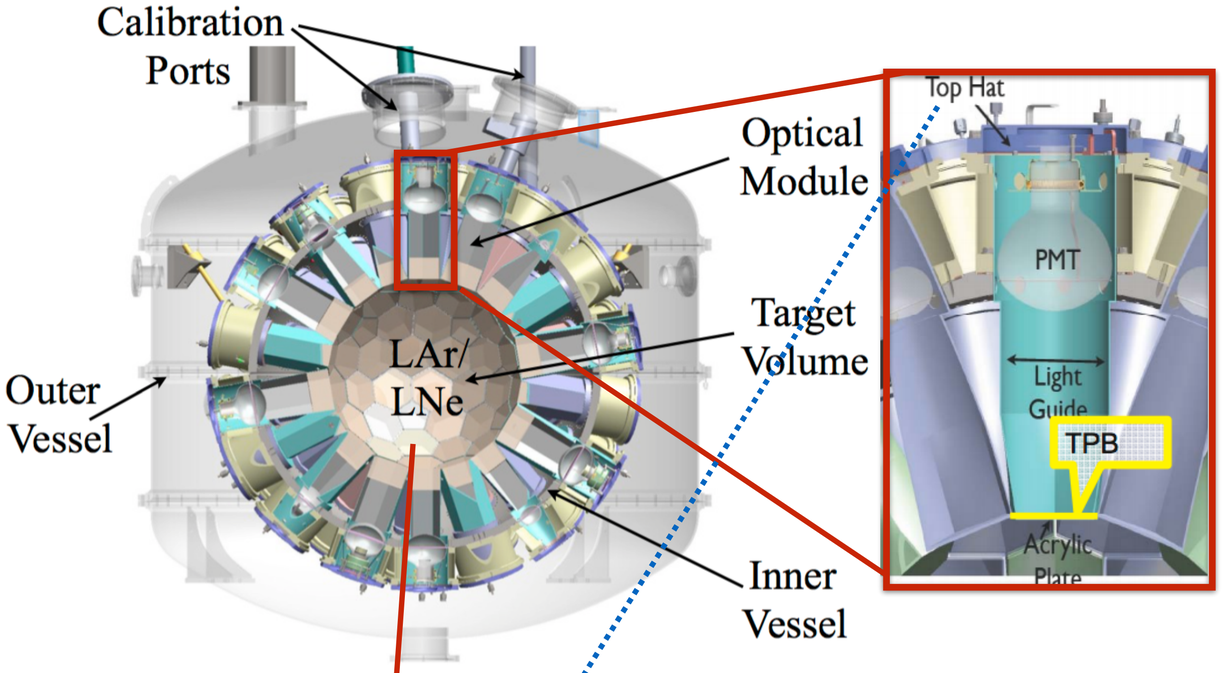
Presented results done at University of New Mexico

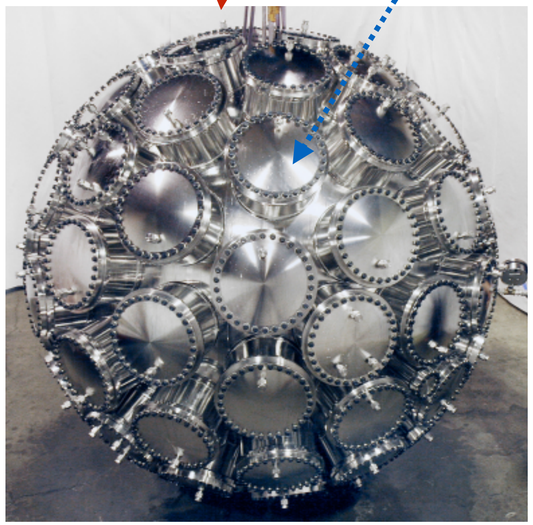
2/23/2018
UCLA Dark Matter
Los Angeles, CA

THE UNIVERSITY of NEW MEXICO

MiniCLEAN Detector Design



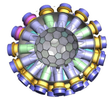




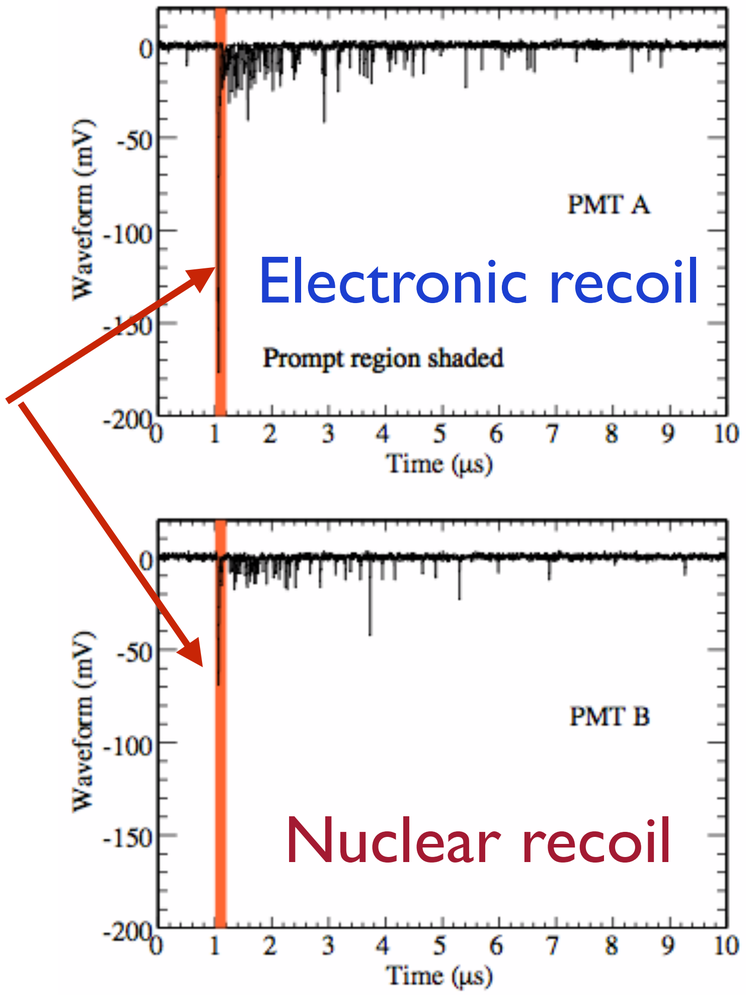
- Single Phase liquid argon detector.
- With 500 kg (150 kg fiducial) of LAr.
- Cryogenic PMTs.
- Exchange target volume (Ar/Ne).
- Fiducialization provides self-shielding.

MiniCLEAN Goals

- With our detector :
  - Unique 4π PMT coverage.
  - Water tank provides extra shielding from external gamma and neutron.
  - Test novel analysis and background rejection techniques.
- At our light yield (6 P.E./keV):
  - High statistic measurement (^{39}Ar Spike run) of the background discrimination of beta-decay.
  - PSD discrimination expected at ~ 10^{-10} level.
  - Informative for next generation (~ 200T) single phase LAr detector.
- Currently the detector is filling.



Pulse Shape Discrimination



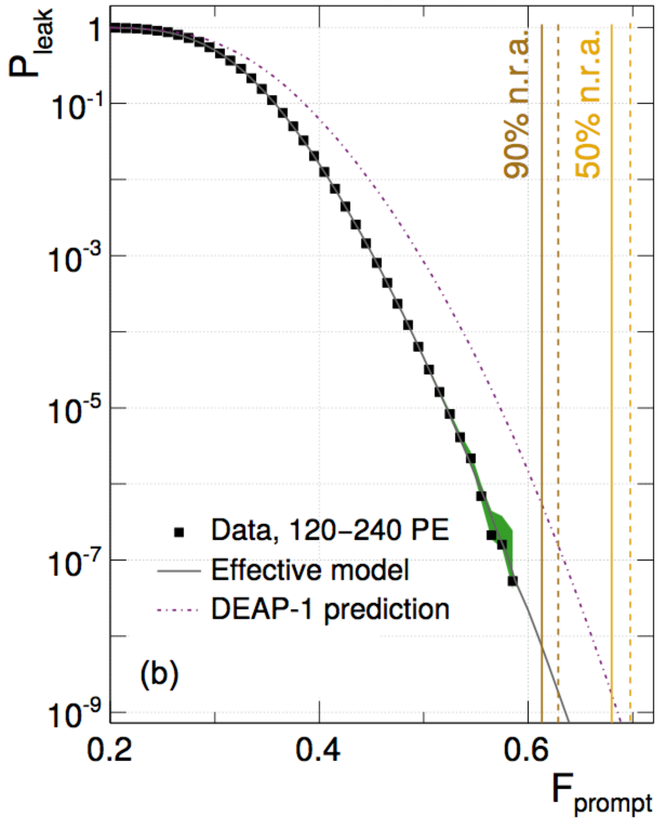
DEAP-1 result

$$F_{prompt} = \frac{Prompt\ photoelectrons}{Total\ photoelectrons}$$

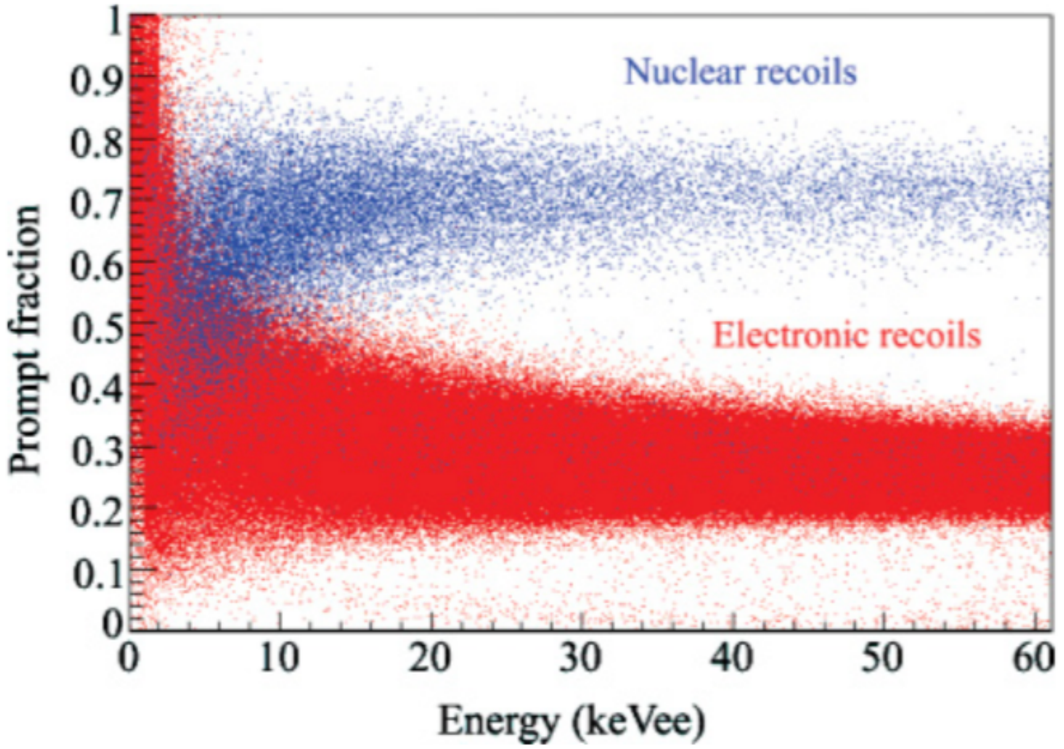
- Exploit the difference of singlet/triplet lifetime of the scintillation light.(singlet ~ 7 ns/triplet ~ 1.6 μs)
- The voltage waveform was integrated from 28 ns before the event trigger time and 80 ns after the trigger prompt peak.
- The late component is the integral from 80 ns after the trigger to the end of trigger window.

Pulse Shape Discrimination

DEAP-3600



https://arxiv.org/abs/1707.08042v2

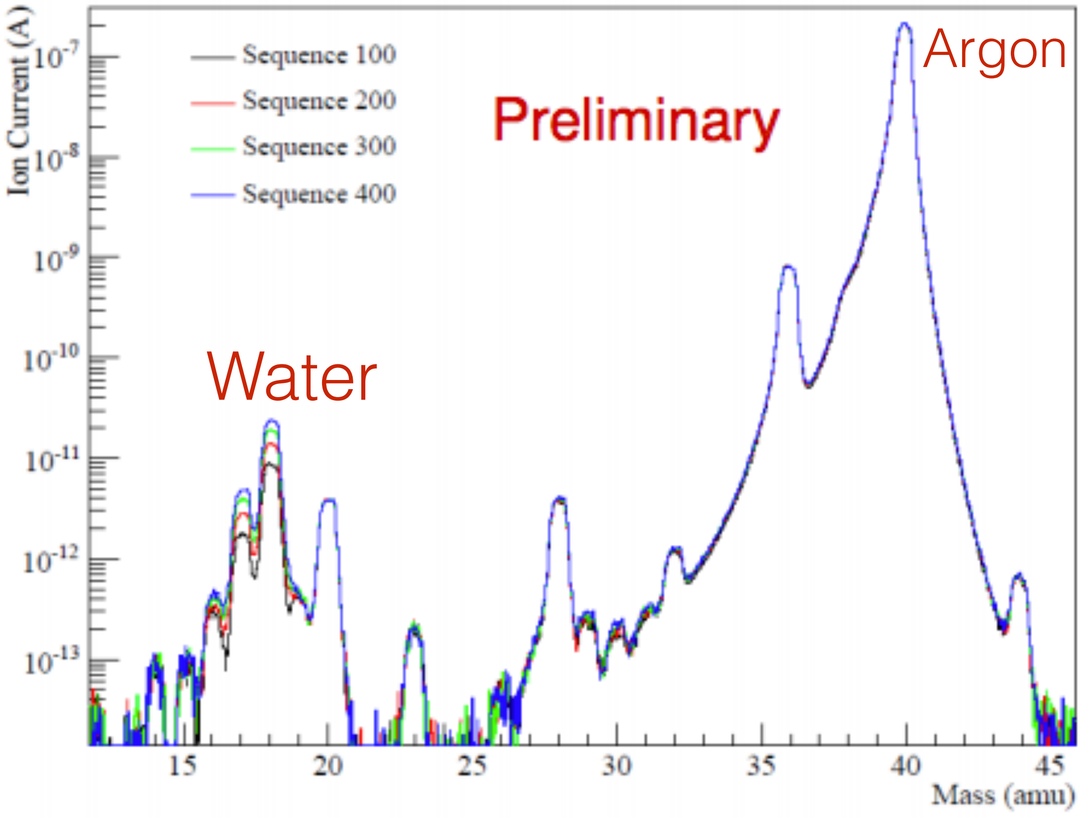


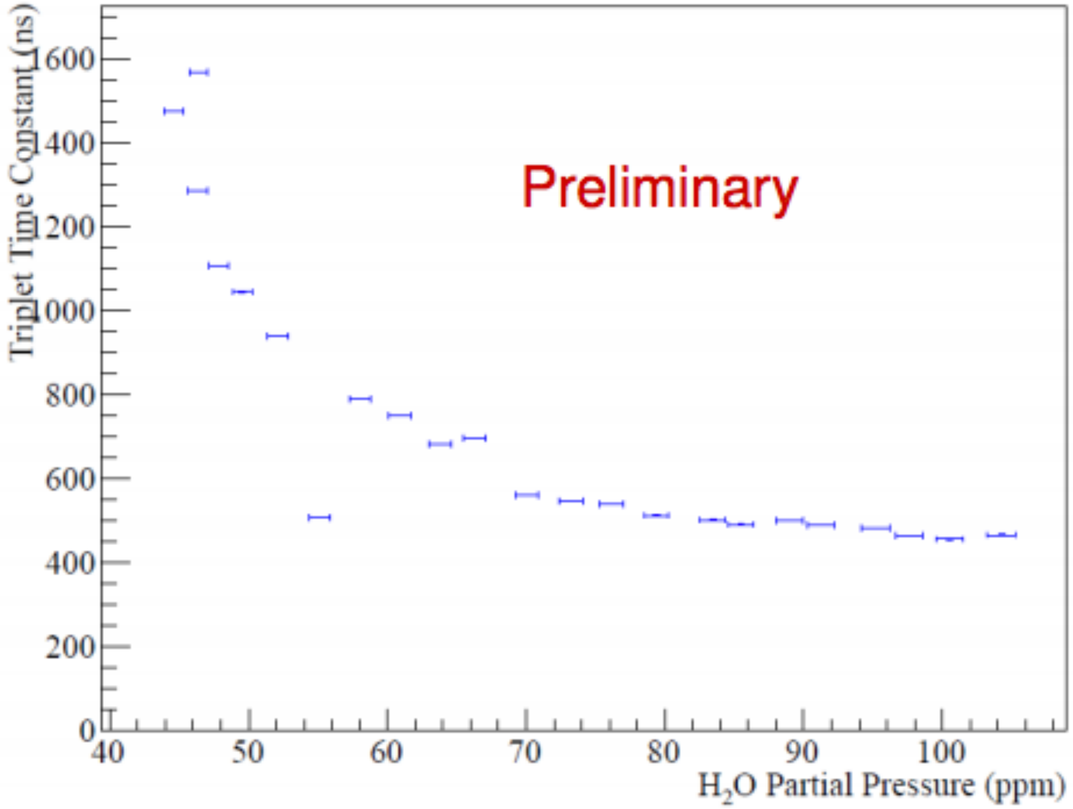
MicroCLEAN Phys. Rev. C78, 035801 (2008)

- Use FPrompt to discriminate nuclear and electron recoil.
- 3×10^{-8} rejection by DEAP-1 in Argon, further improved by DEAP-3600.

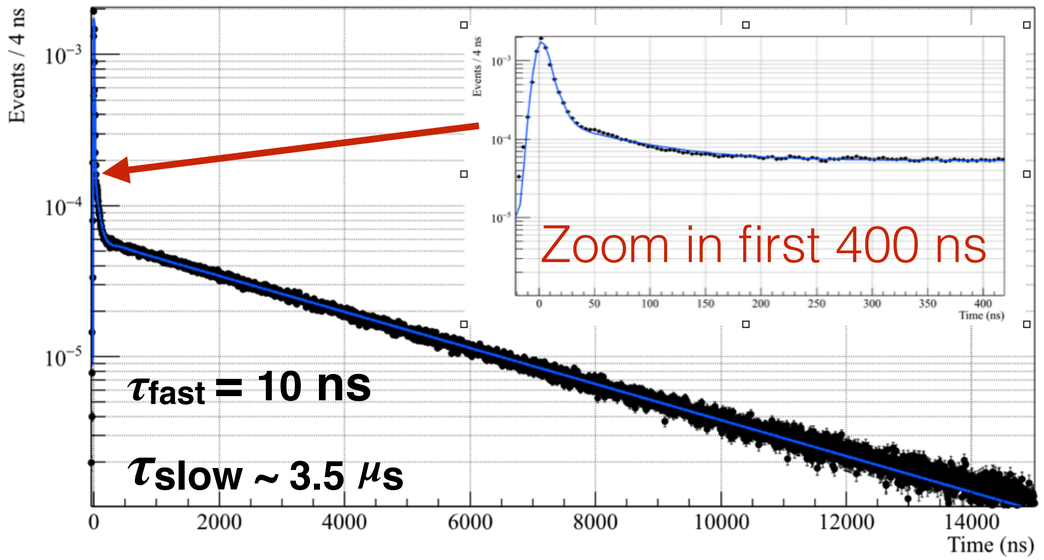
Triplet Lifetime in Warm Gas

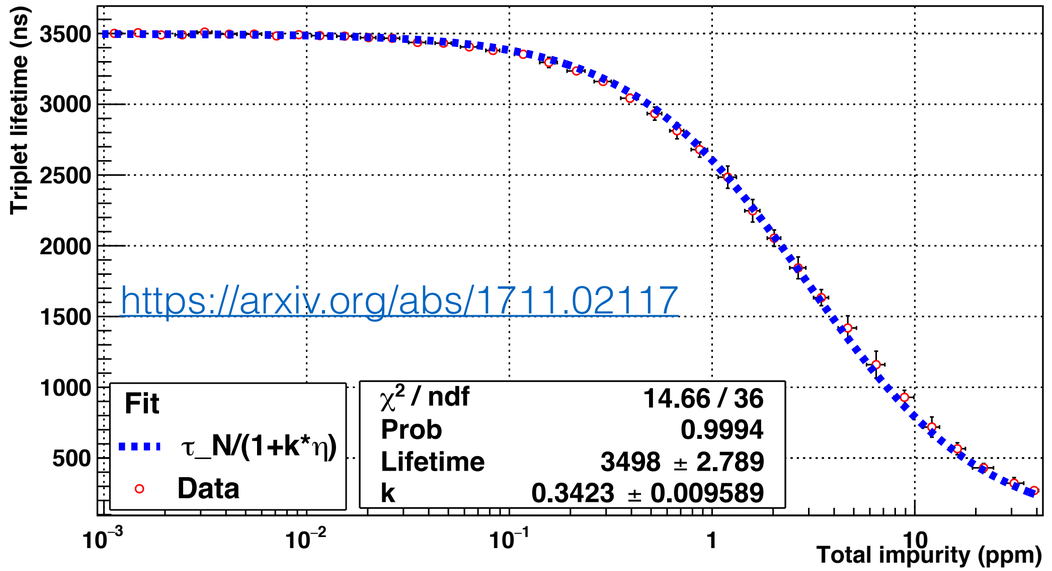
- In warm gas, triplet light is rapidly quenched as water vapor outgases from acrylic.
- Monitored with RGA (Residual Gas Analyzer) which shows water vapor peak rising over several hours.
- Triplet lifetime clearly decreased when the water partial pressure increased.





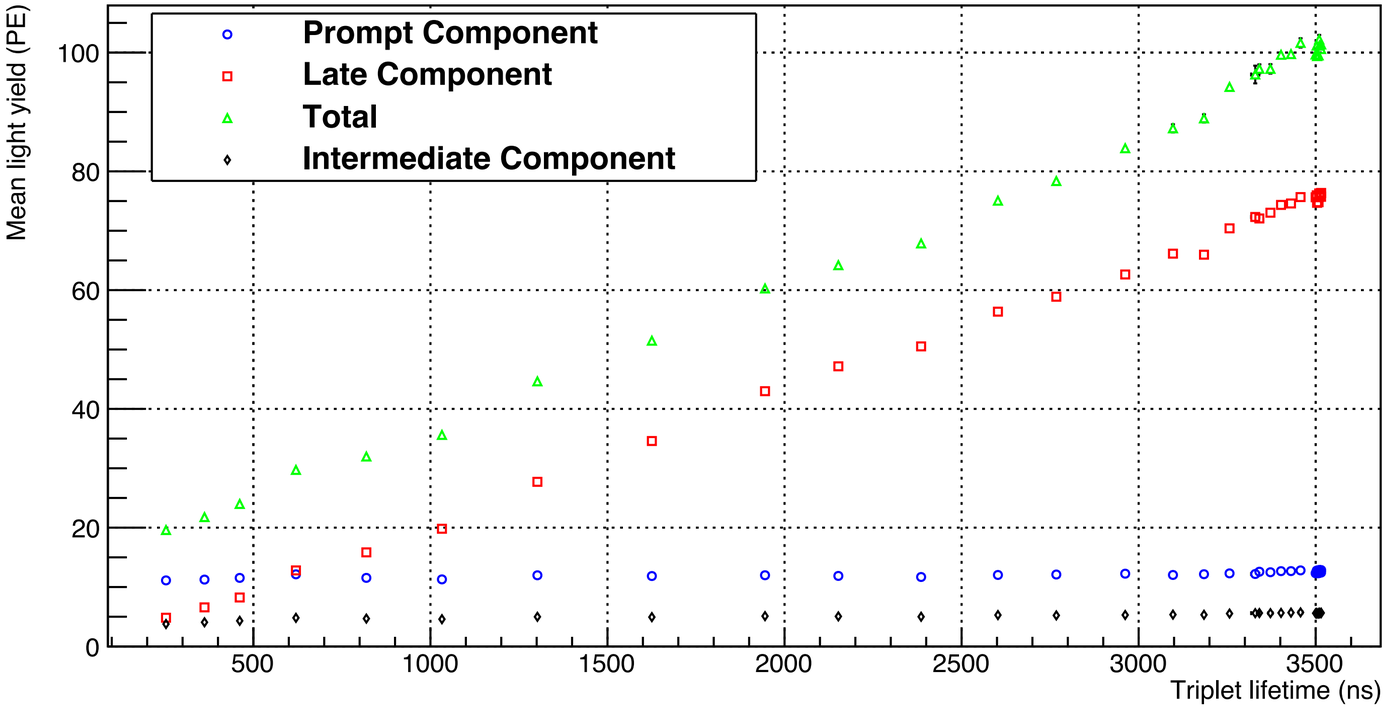
Triplet Lifetime in Cold Gas





- In this work, the longest triplet lifetime in gaseous argon has been measured by MiniCLEAN.
- Triplet lifetime is very sensitive to the purity of argon, thus can be used to monitor the detector health.
- Stable long time constant indicates the impurity level is controlled during data taking.
- Impurity molecules (Oxygen, Nitrogen, etc.) quenching triplet state result in reduction of triplet lifetime and light yield.
- Triplet lifetime reaches maximum when the impurity level below 10 ppb.

Scintillation light in gaseous argon



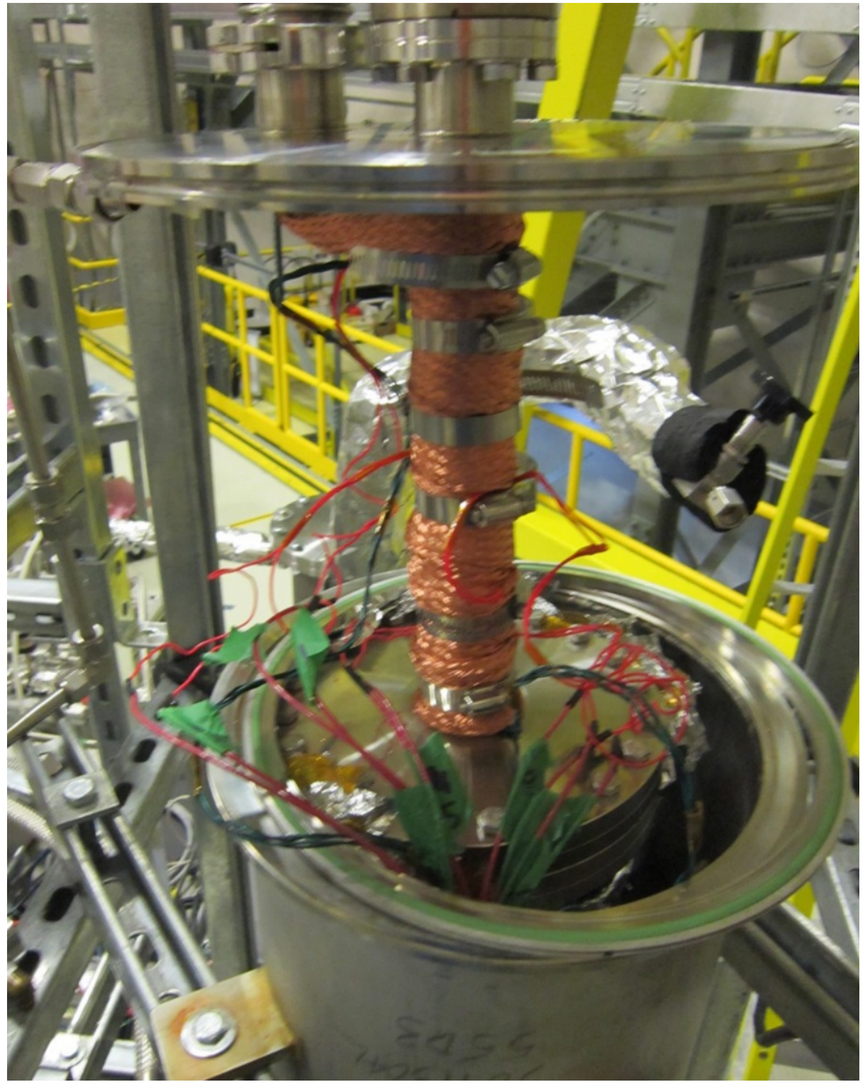
τ (μs)	Ref.	Number density ($10^{20} cm^{-3}$)	Estimate impurities level	Induced particle type
2.8	Thonnard *et al.*[7]	0.19	< 2 ppm	β
2.84±0.02	Gleason *et al.*[8]	4	< 1 ppm	β
2.86	P. Millet *et al.*[9]	0.1- 0.26	< 1 ppm	α
2.88±0.08	K. Mavrokoridis *et al.*[2]	0.24	< 1ppb	α
2.9	Carvalho *et al.*[10]	3	not reported	β
3.0±0.05	Suemoto *et al.*[11]	2.2	< 10 ppm	β
3.14 ±0.067	C. Amsler *et al.*[6]	0.32	< 9 ppb	α
3.15±0.05	P. Moutard *et al.*[3]	0	< 1 ppm	γ
3.2 ± 0.3	Keto *et al.*[12]	2.6	< 2 ppm	β
3.22±0.042	Oka *et al.*[13]	0.32	< 5 ppm	β
3.24±0.05	F. Marchal *et al.*[14]	0.2	<1 ppm	γ
2.524 ± 0.005	this work	0.85	~1 ppm	β, γ
3.48 ± 0.01	this work	0.85	< 1 ppb	β, γ

https://arxiv.org/abs/1711.02117

- Prompt component from third continuum (190 nm - 250 nm).
- Late component from triplet states of second continuum (peak at 128 nm).
- Intermediate components from singlet states of second continuum (peak at 128 nm)
- Study of the triplet lifetime and light yield as a function of impurity level.
- Results to be submitted to Physical Review C.

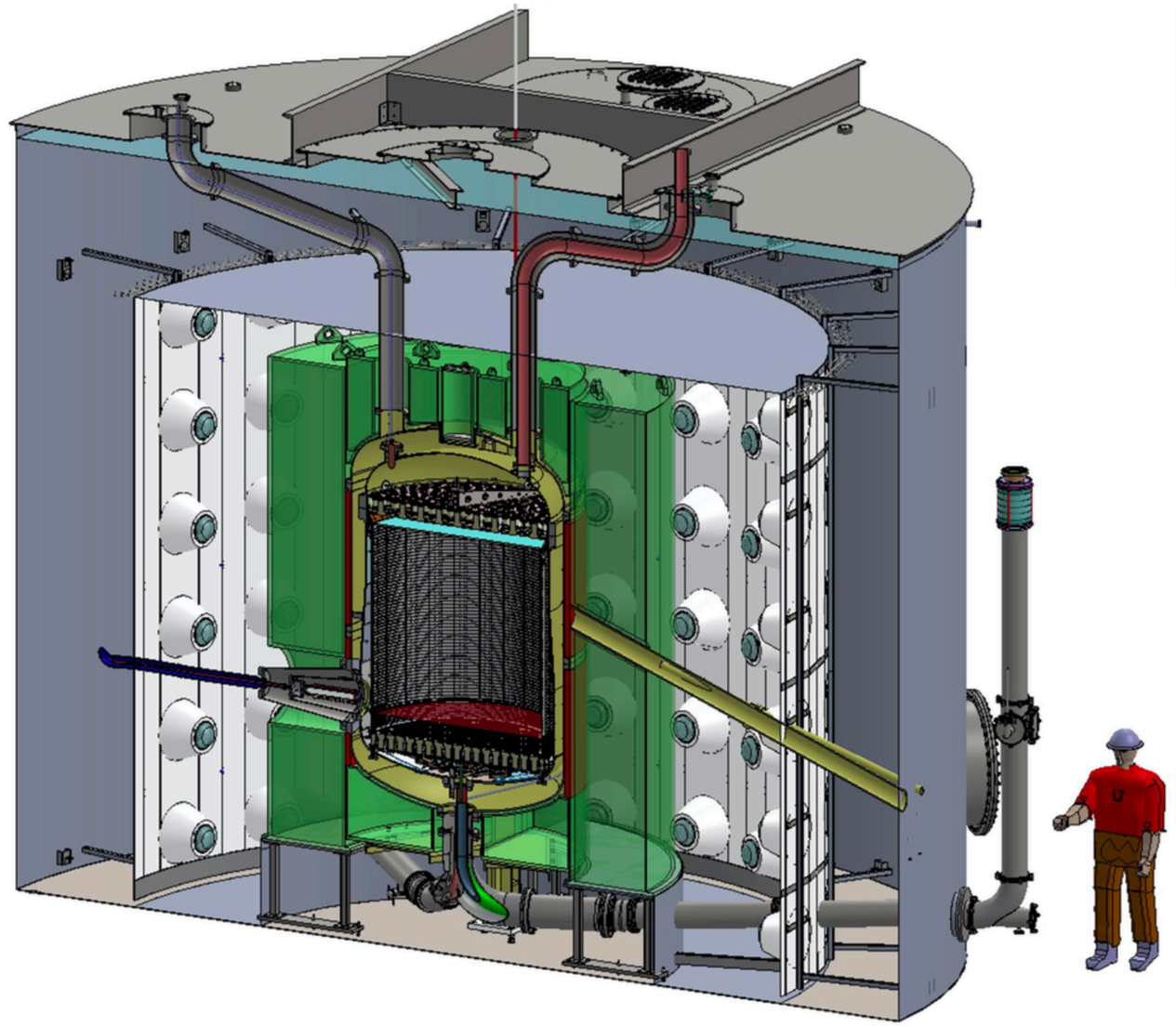
MiniCLEAN Status

- Colling and Filling
  - MiniCLEAN is commissioning a cooling upgrade on the condenser.
  - Couple a 500W cryocooler to re-liquify LN2. This will reduce LN2 usage and increase run time.
  - Using triplet lifetime to closely monitor the quality of the gas.
- Schedule :
  - Finish filling by the end of April.
  - Calibration/Commissioning - May.
  - Natural argon data run - July.
  - ^{39}Ar Spike run - Sep.
  - Decommissioning - Oct. and onwards.



From single phase to dual phase

- Experience from MiniCLEAN
  - Physics of liquid noble gas.
  - Simulation of detector performance.
  - Detection technique of dark matter search.
  - ~ 2 yrs working experience at SNOLAB.
- Join LZ experiment (Hugh Lippincott)
  - Working on improving collaboration simulation package.
  - Testing components of outer detector (Sally Shaw)
  - Properties of Liquid Scintillator (BNL)
  - Projected sensitivity talk (Jim Dobson)



Conclusions

- Triplet lifetime time can be used to monitor detector health during the cooling and filling.
- Long triplet lifetime improves PSD in gaseous argon dark matter detector.
- Pulse shape discrimination expected at 10^{-10} level.
- Filling of MiniCLEAN detector is underway.

Thanks for the support from our funders:

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U.S. DEPARTMENT OF ENERGY | Office of Science

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