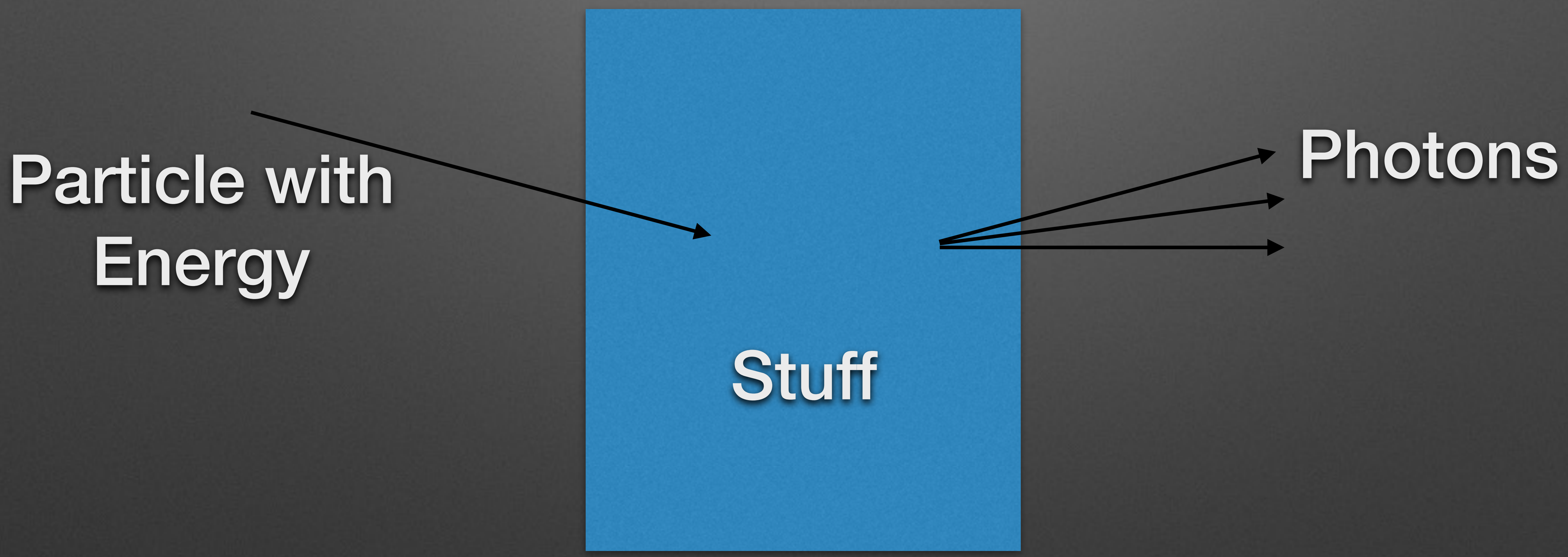
Oddities of light production in the noble elements

James Nikkel

Fun!!!!!
Good Morning
Redy to do Some phisics?!?
time to work on
^
e.g.

What is a scintillator?



What is a scintillator?

We would like:

$$N_{photons} = Y\, E_{incoming}$$

With ‘Y’ as large as possible

Monochromatic photons

What is a scintillator?

We would like:

$$N_{photons} = Y\, E_{incoming}$$

Monochromatic photons

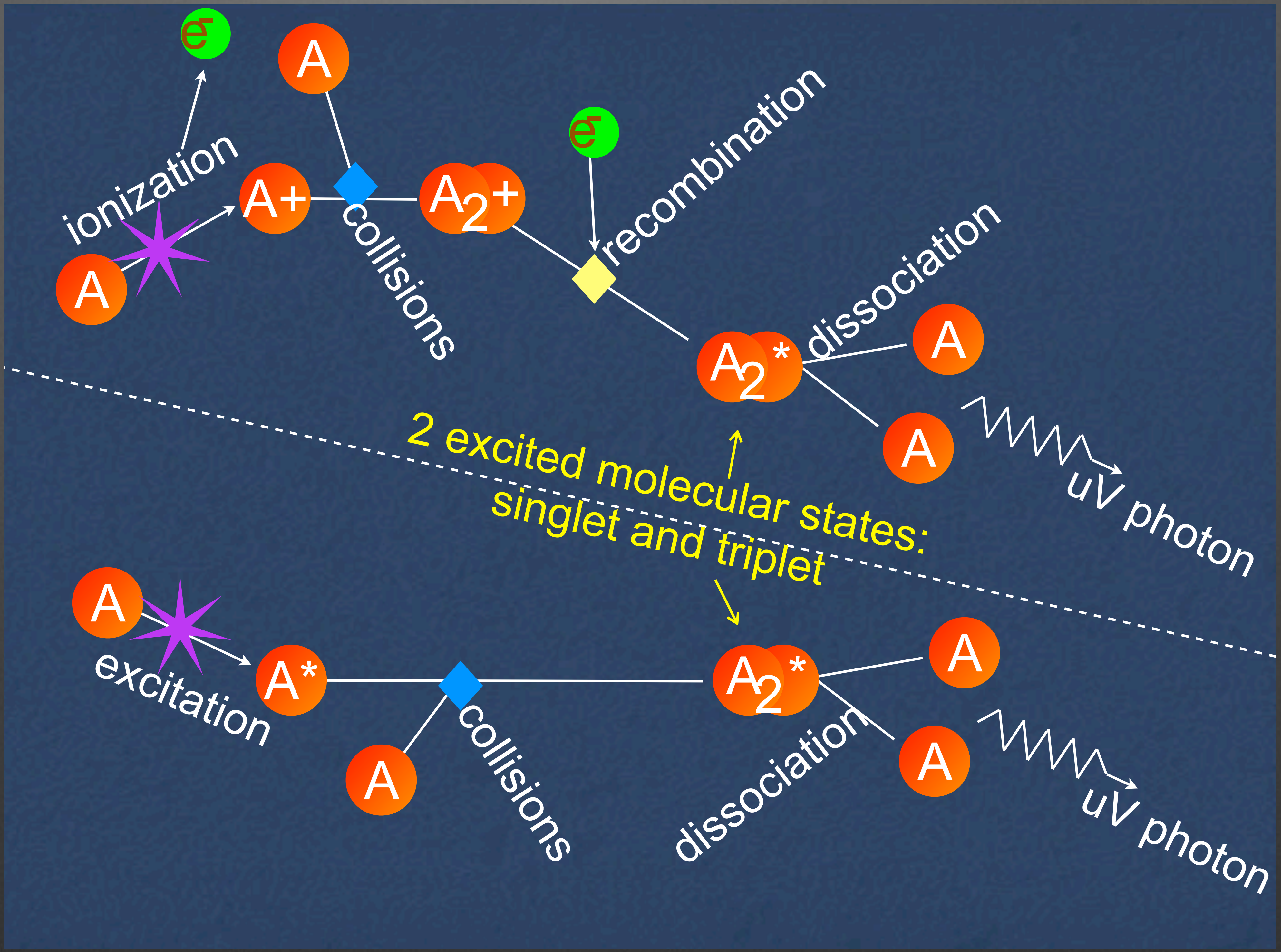
It would also be nice to get some particle identification information. This is typically from the timing profile of the emitted photons.

What is a scintillator?

The mechanism for producing light depends on the media:

- Organic liquid scintillators
- Organic crystal scintillators
- Inorganic crystal scintillators
- Molecular gases
- Noble liquids
- etc.

Scintillation in nobles



Scintillation in nobles

Element	Liquid density g/ml	Boiling point (K)	Electron yield (e^-/keV)	Photon yield (γ/keV)	Singlet decay time	Triplet decay time	Scintillation wavelength (nm)	Radioactive
$^{4}_{2}He$	0.13	4.2	39	22	10 (ns)	13 (s)	80	No
$^{20}_{10}Ne$	1.2	27.1	46	32	10 (ns)	15 (µs)	78	No
$^{40}_{18}Ar$	1.4	87.3	42	40	7 (ns)	1.5 (µs)	128	^{39}Ar 1 Bq/kg
$^{84}_{36}Kr$	2.4	119.9	49	25	7 (ns)	85 (ns)	148	^{85}Kr 1 MBq/kg
$^{132}_{54}Xe$	3.1	165.0	64	42	5 (ns)	27 (ns)	175	^{136}Xe <10 µBq/kg

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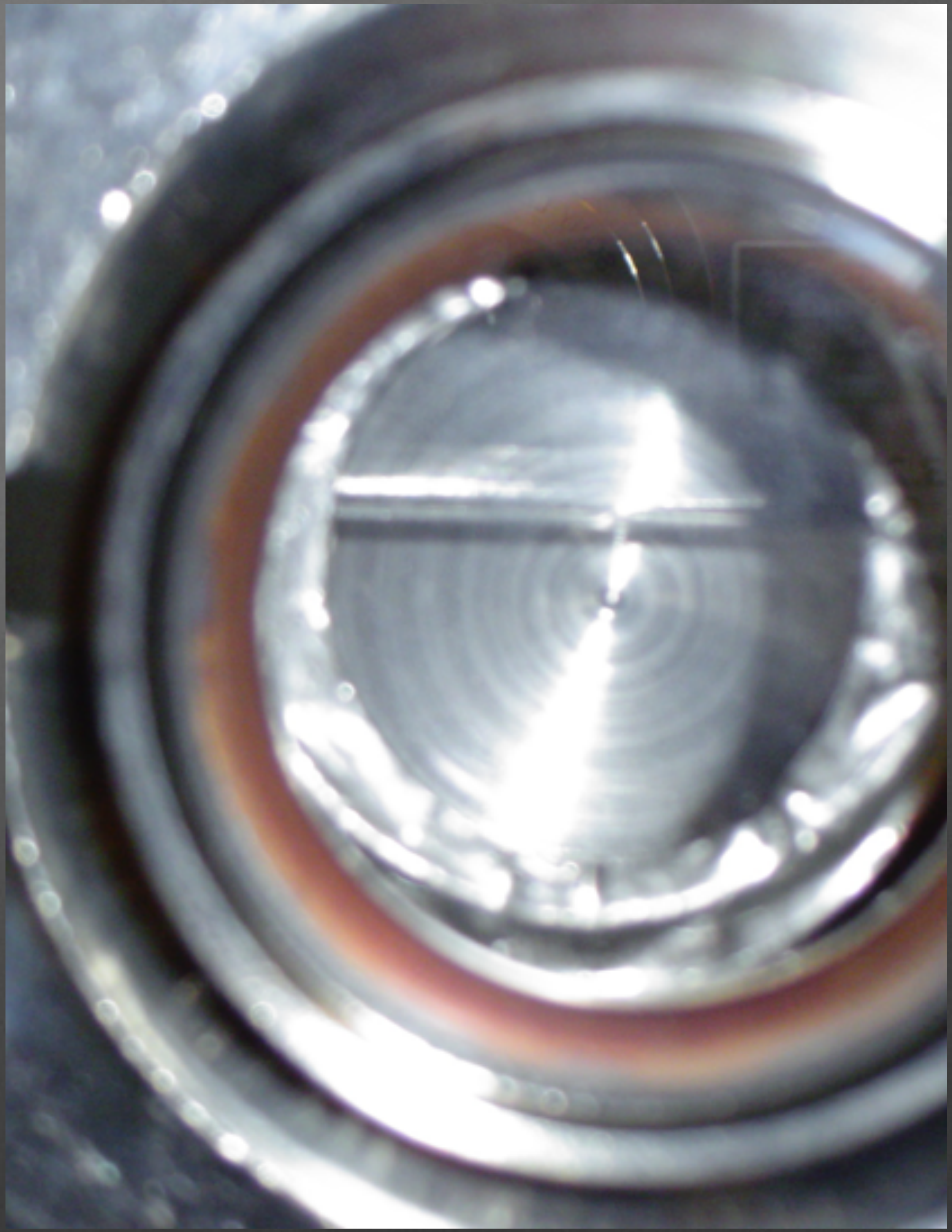
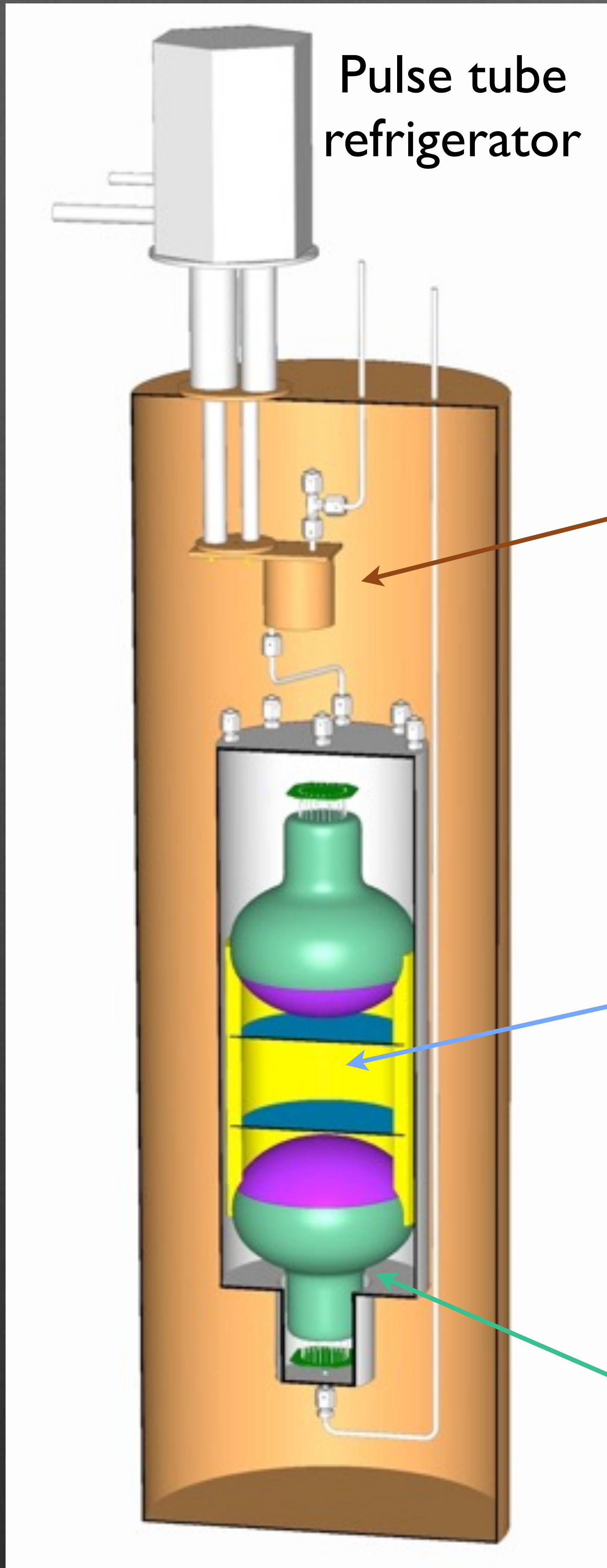
Liquid neon in nanoCLEAN

~2004



microCLEAN

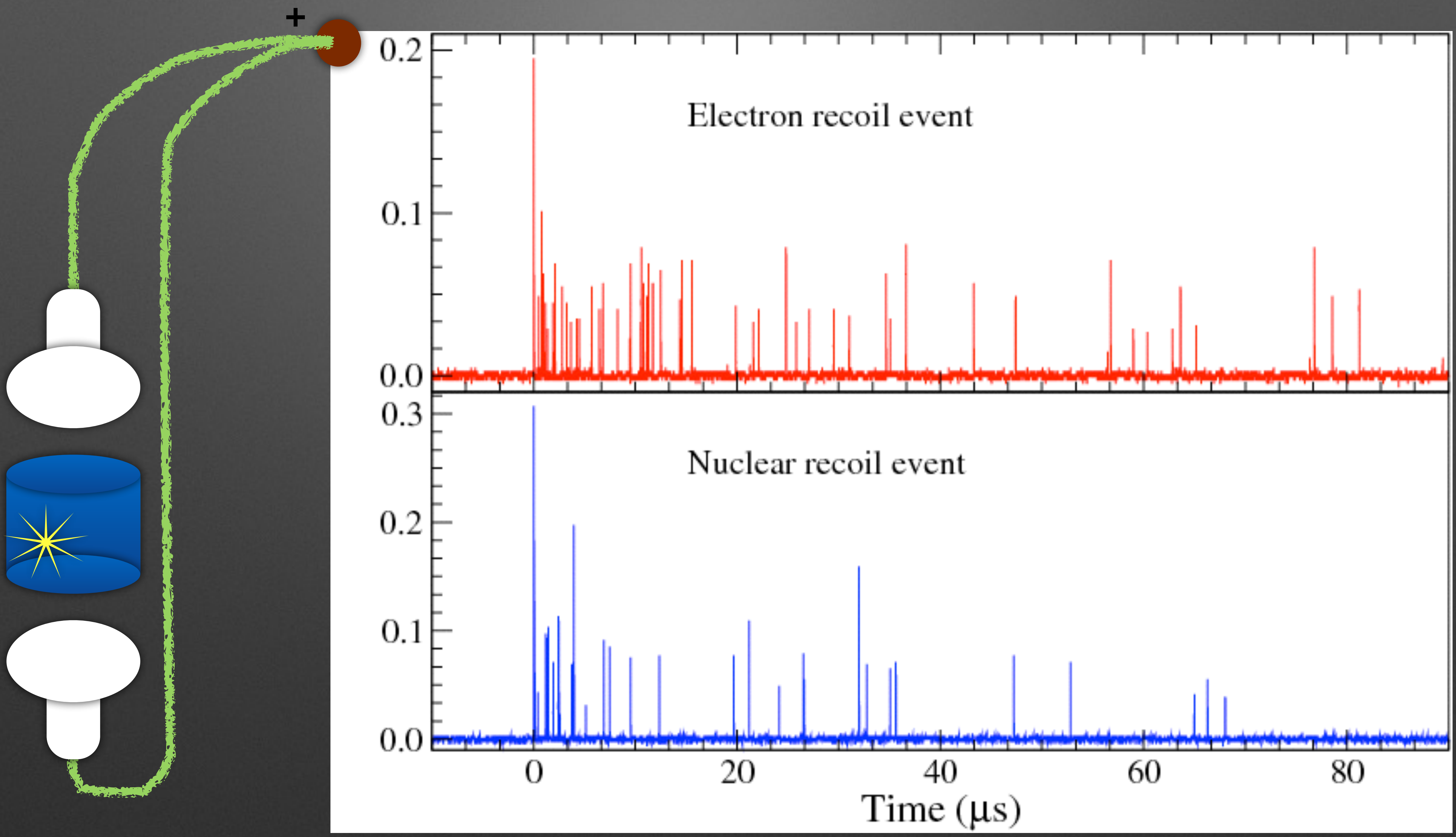


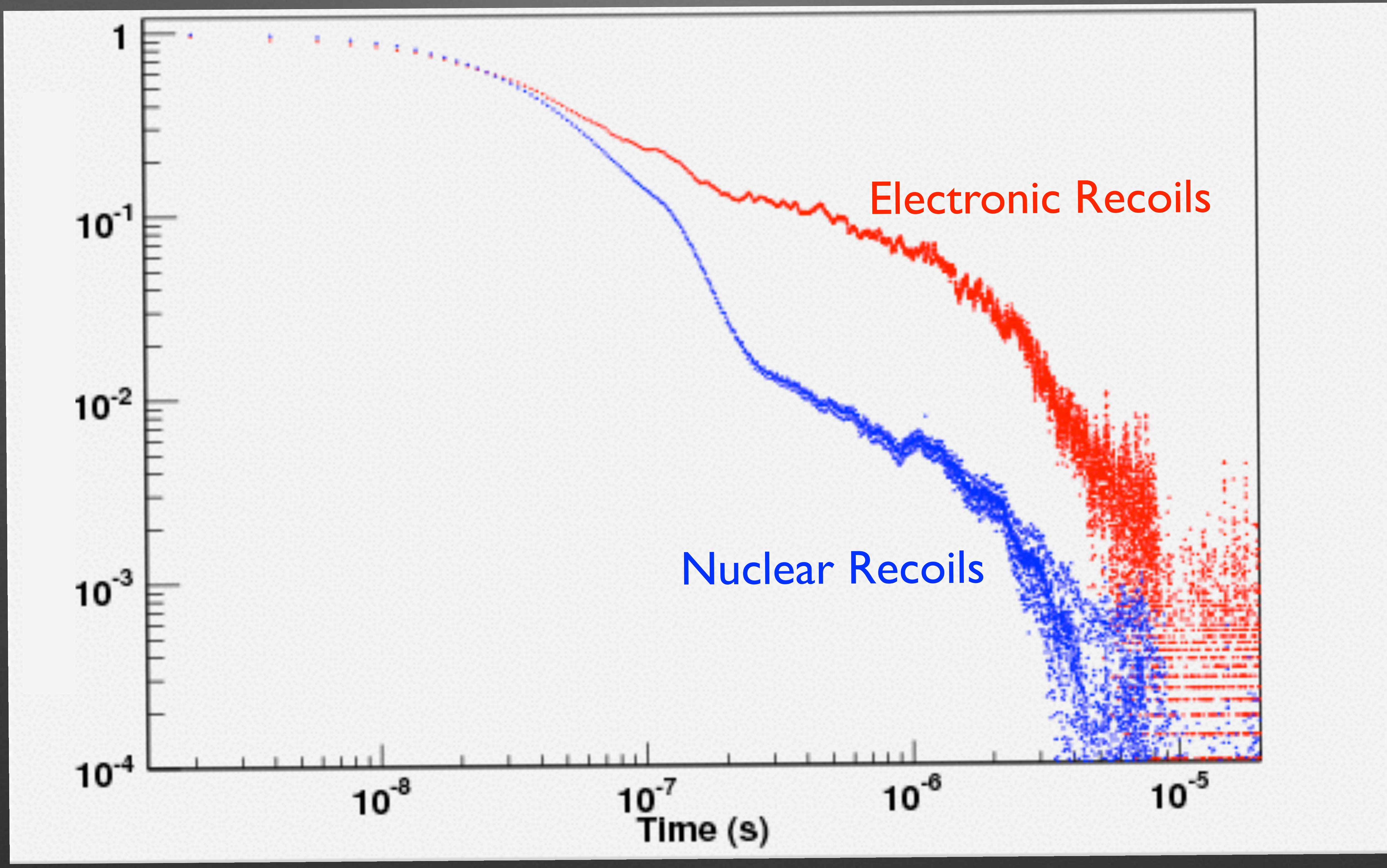
Copper liquifier

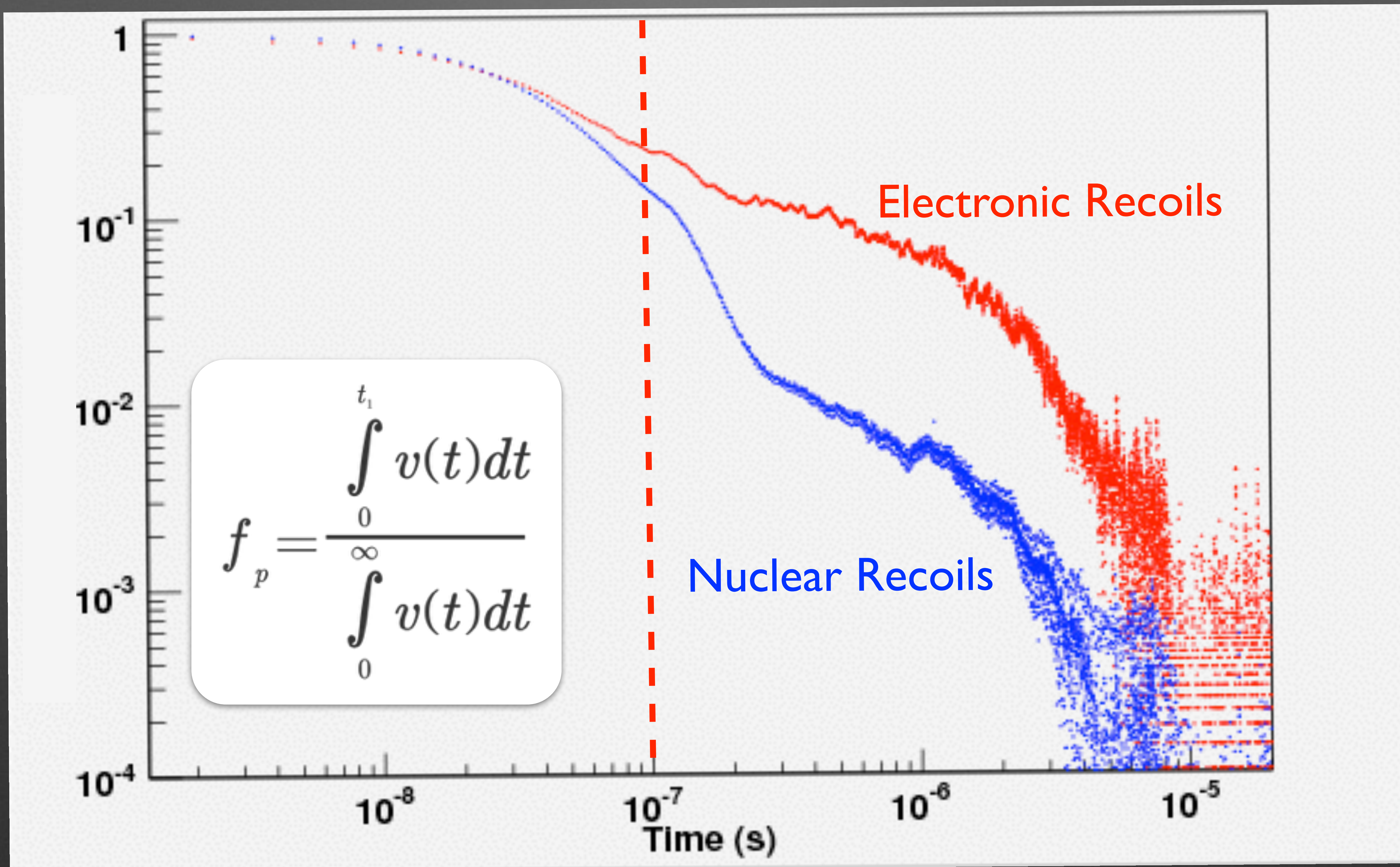
3.1 litre argon/neon target volume

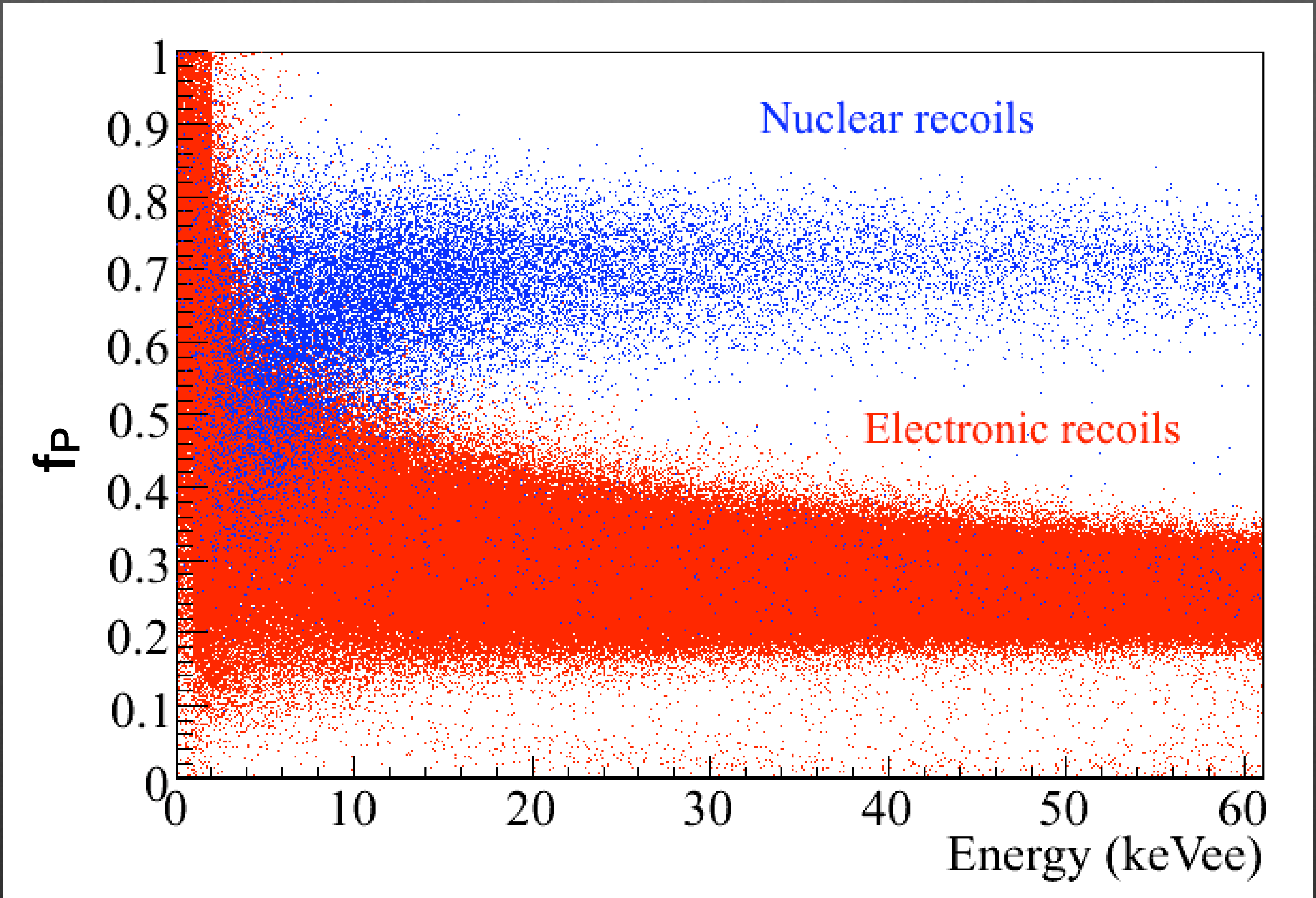
2x Hamamatsu R5912-02-MOD PMTs

Example of digitised PMT signals from 'tagged' sources

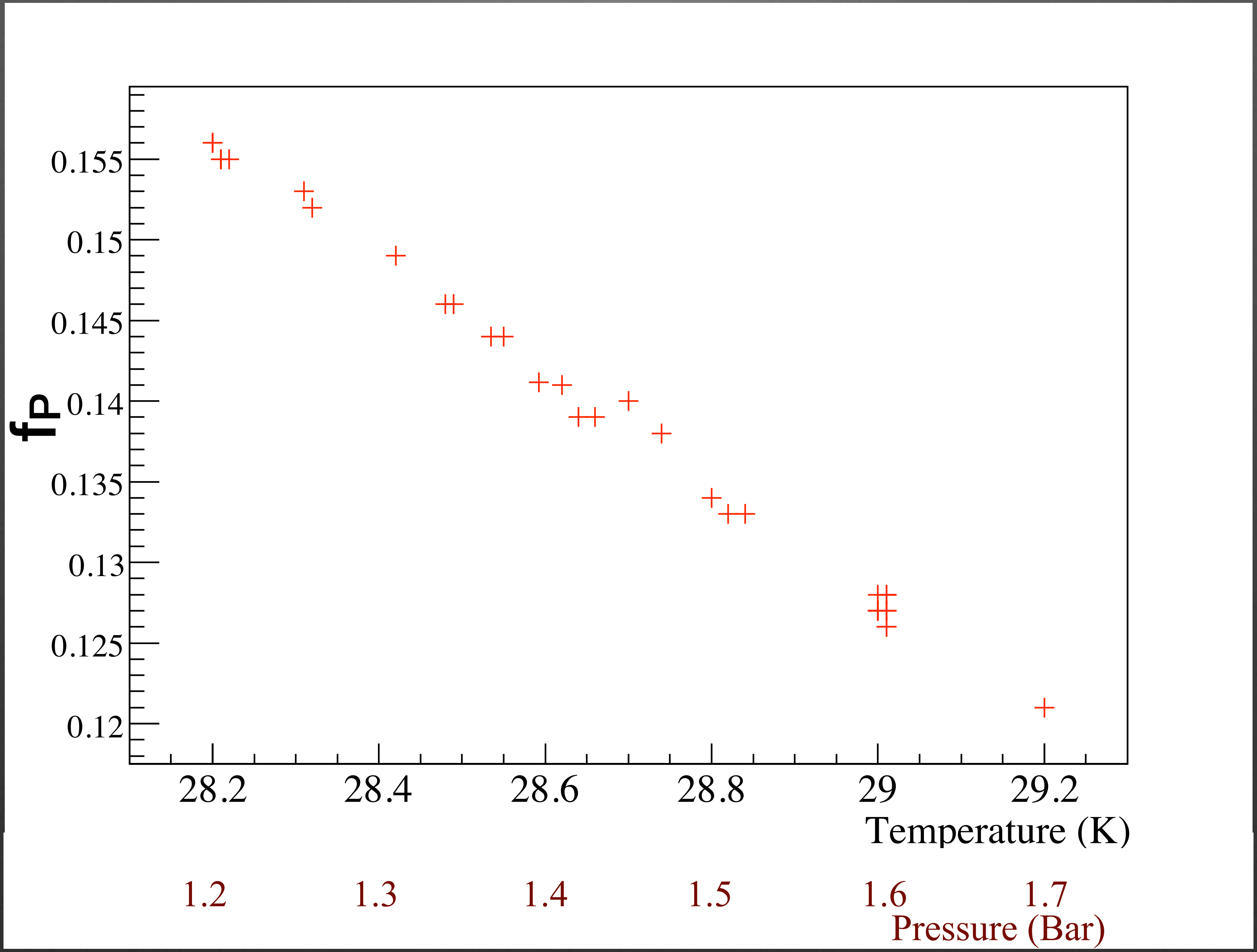



1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
Time (s)
Electronic Recoils
Nuclear Recoils

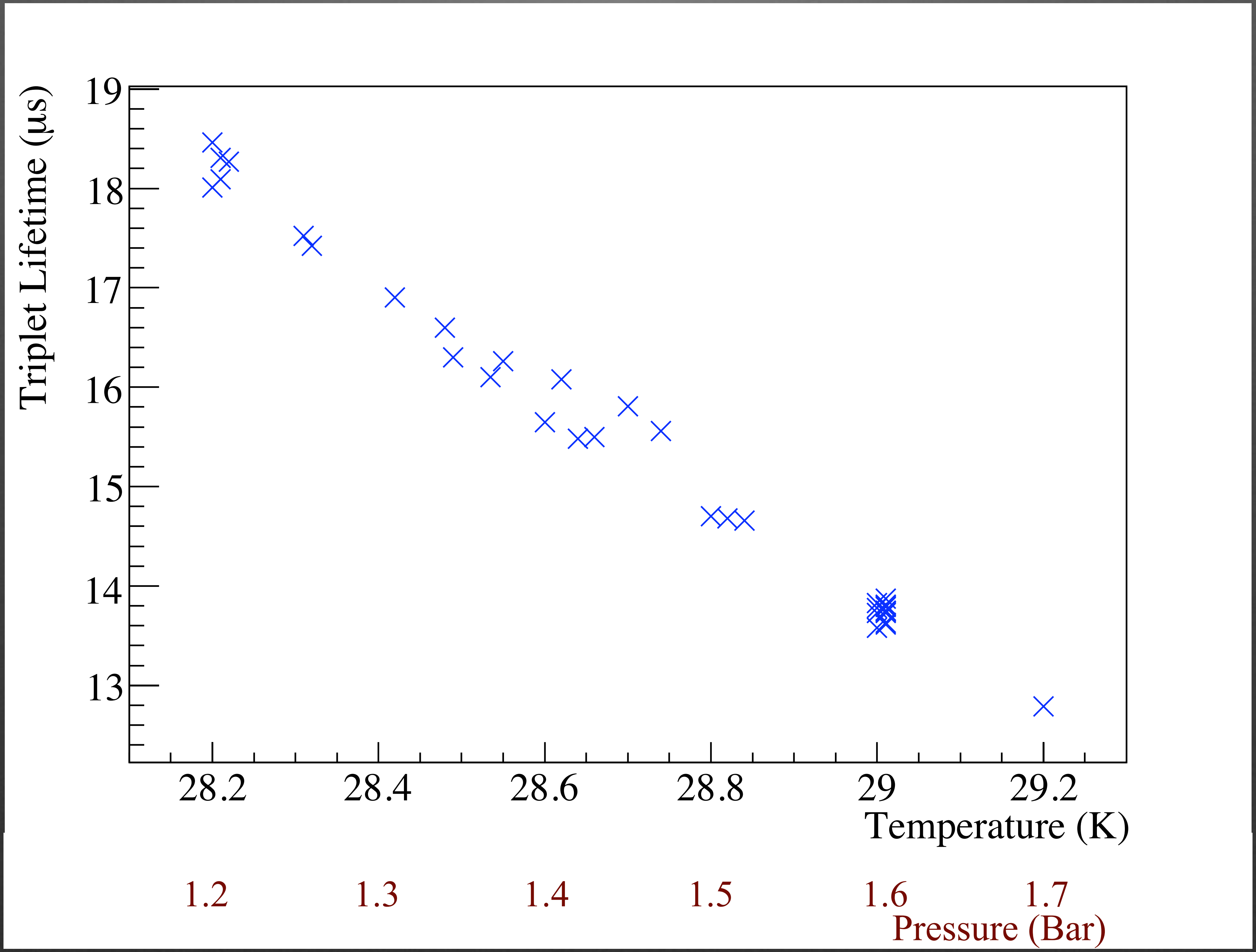

1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
Time (s)
Electronic Recoils
Nuclear Recoils
$$f_p = \frac{\int_0^{t_1} v(t)dt}{\int_0^{\infty} v(t)dt}$$


Nuclear recoils
Electronic recoils
f_P
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
Energy (keVee)

We observed an unexpected temperature/pressure dependance



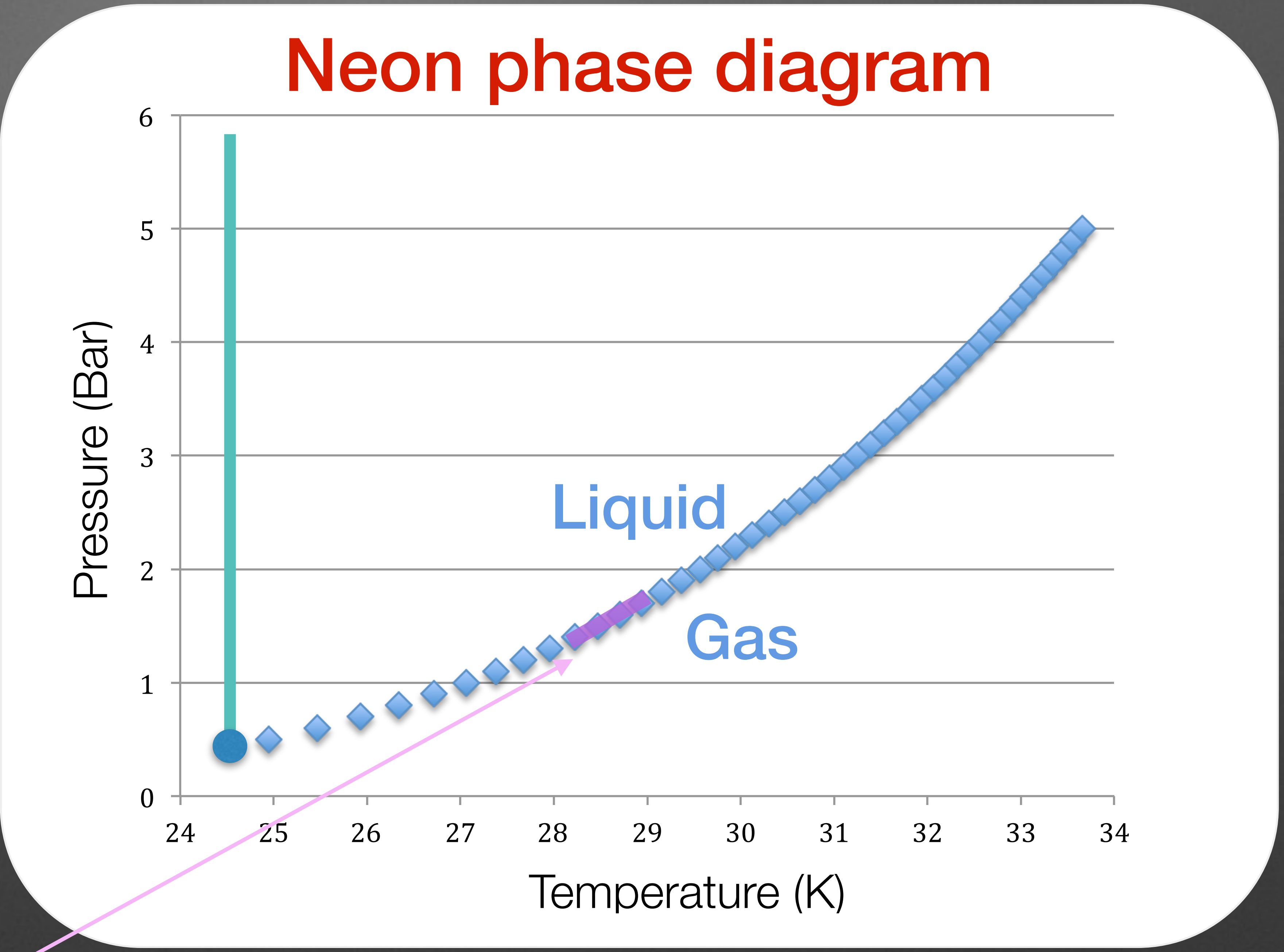
We observed an unexpected temperature/pressure dependance



Unfortunately, microCLEAN was constrained by the phase boundary

We could not separate out temperature from pressure effects

The detector also had a limited range of operation



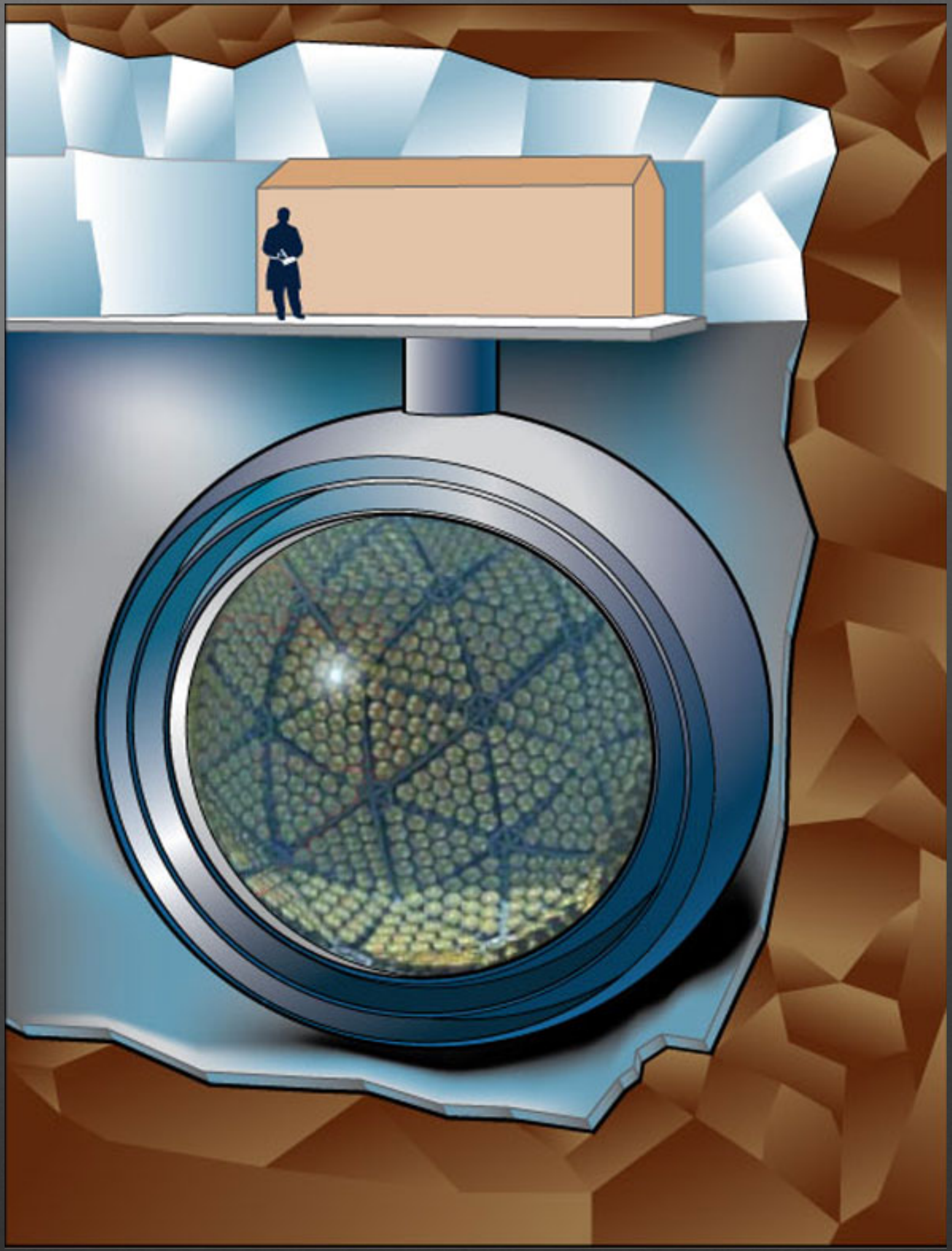
Triple Point: 24.556 K, 0.4337 bar

Why do we care?

Liquid neon has a density of
1.2 g/cm^3

The pressure increases 120 mBar per metre of depth

A 5 metre tall detector (~100 tonne)
will have an excess pressure of 0.6 bar at the bottom

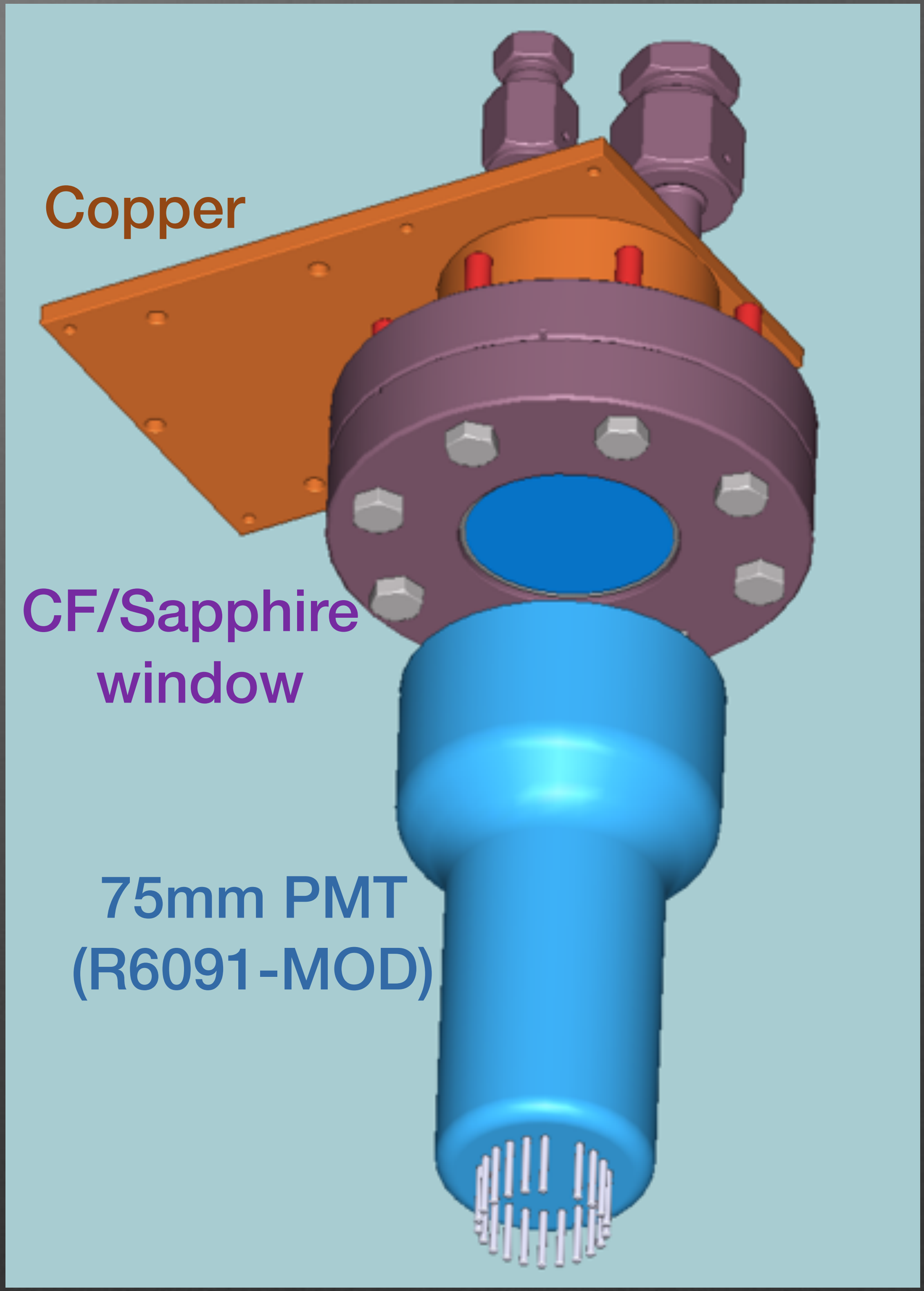


LEELA

In LEELA, the temperature and pressure can be set independently, and over a much wider range

A single pmt detects the scintillation light collected from a PTFE cavity

Target volume ~50ml



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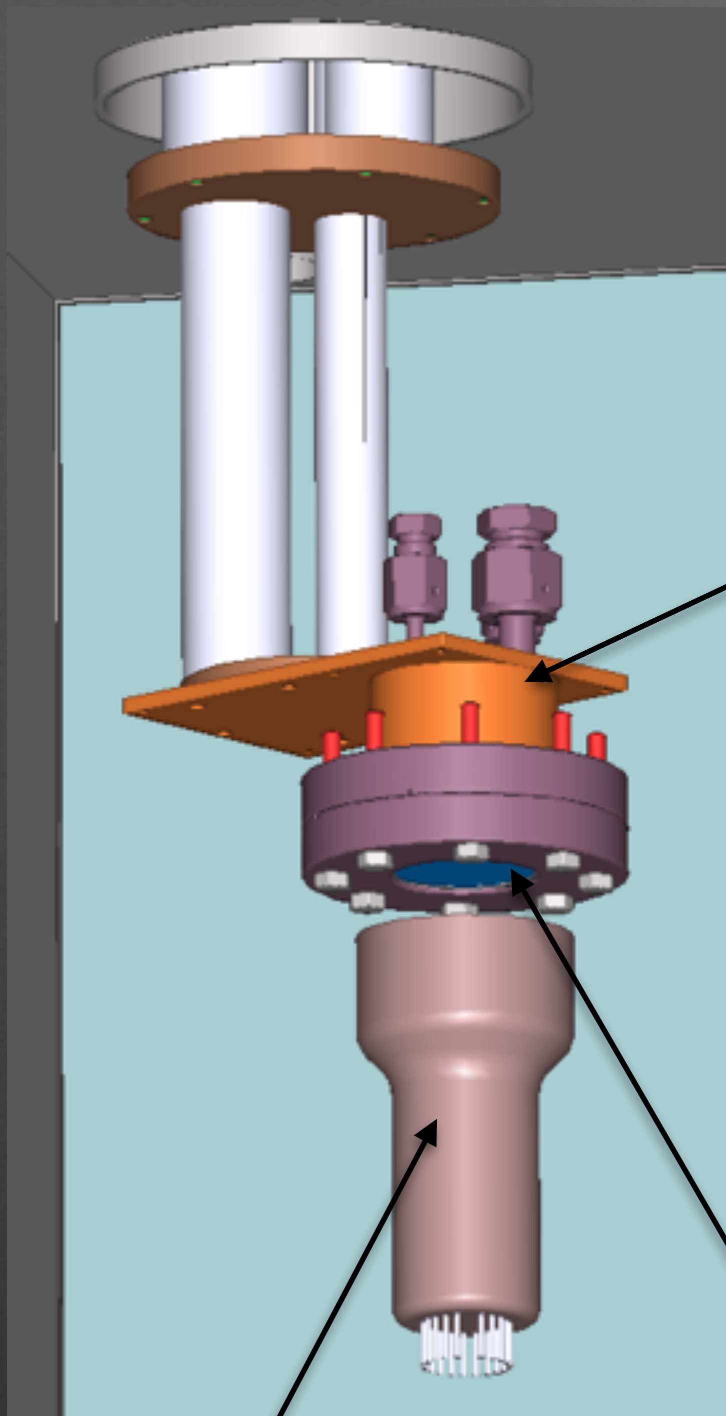
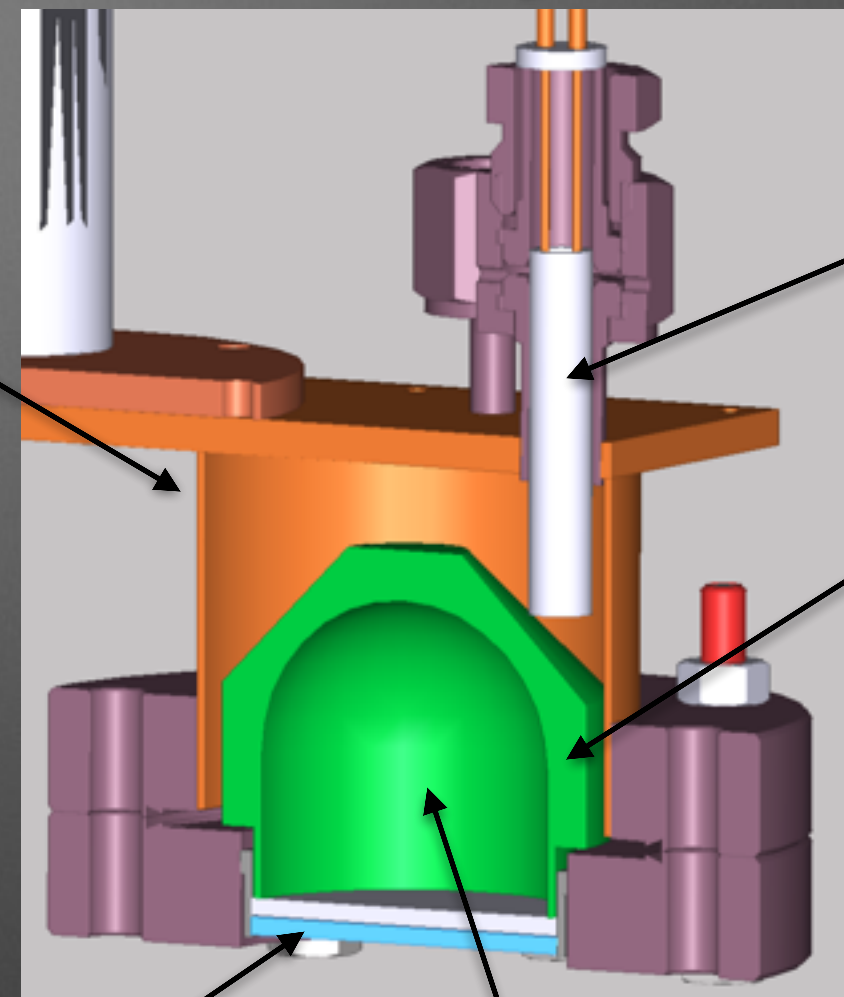
Cut-away view



Copper vessel

Sapphire window

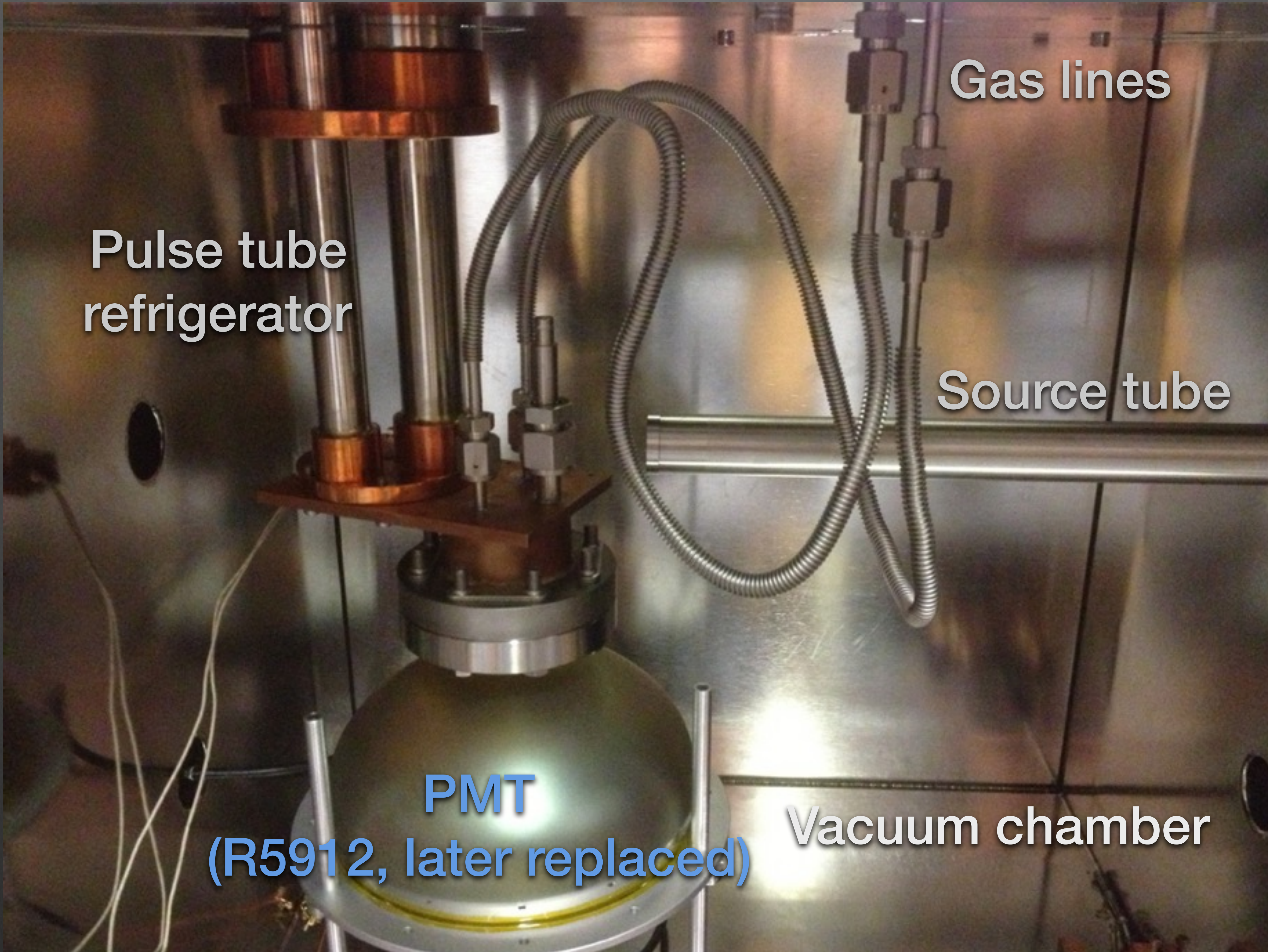
75mm PMT
(R6091-MOD)



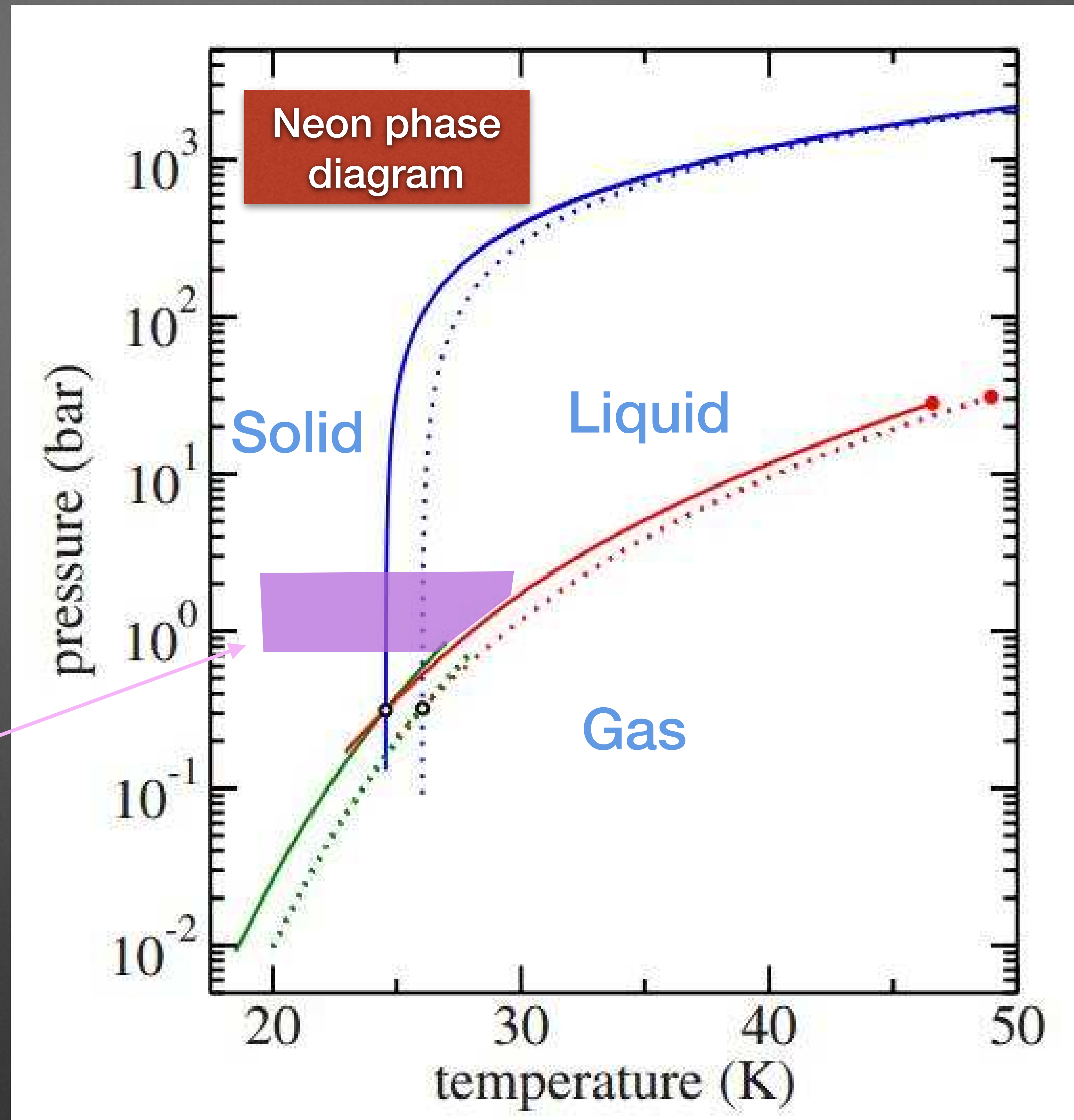
Level sensor

PTFE

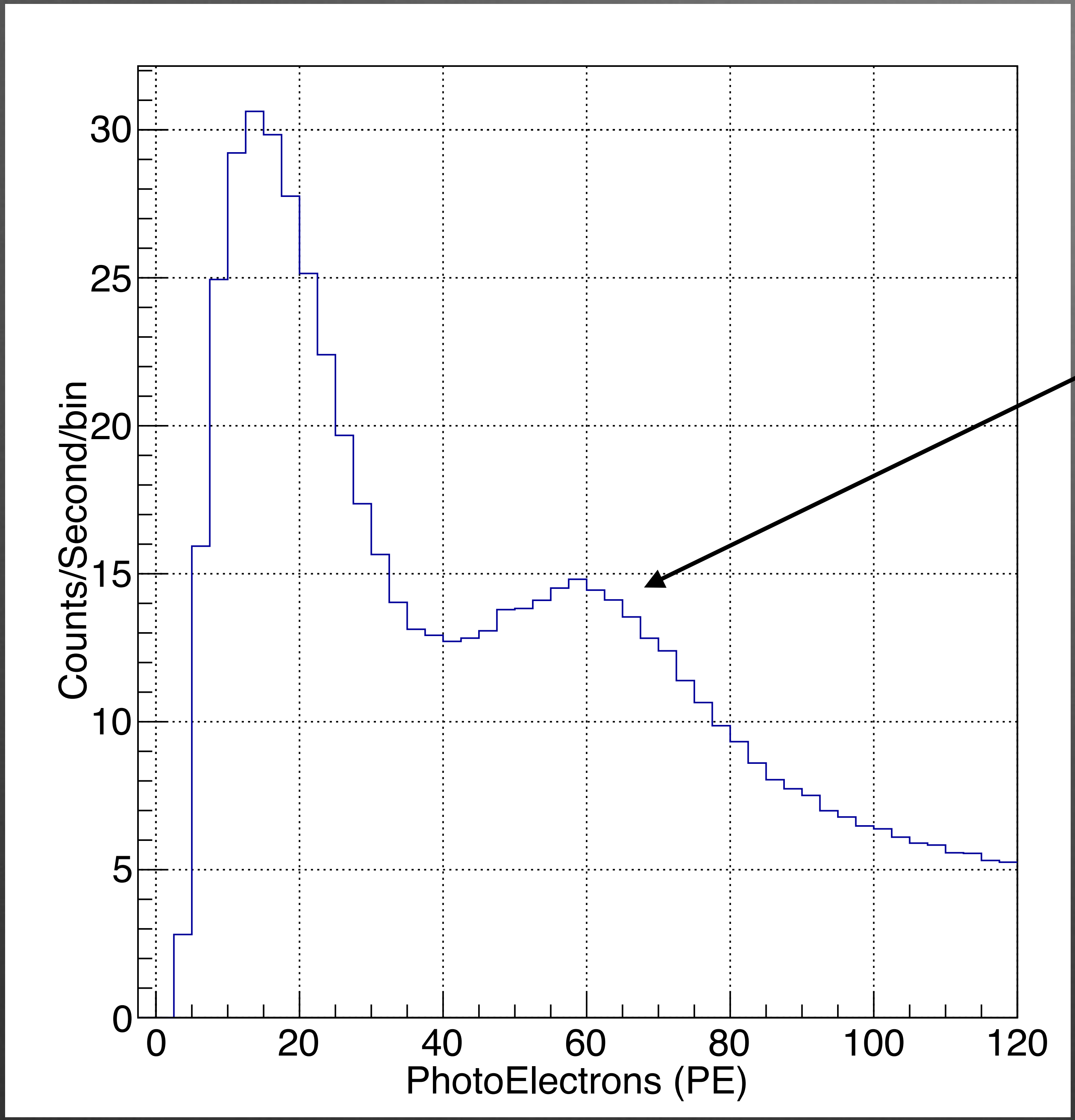
Inner volume (50 ml) coated with wavelength shifter


Gas lines
Pulse tube refrigerator
Source tube
PMT
(R5912, later replaced)
Vacuum chamber

Temperature and pressure range covered



Triple Point: 24.556 K, 0.4337 bar



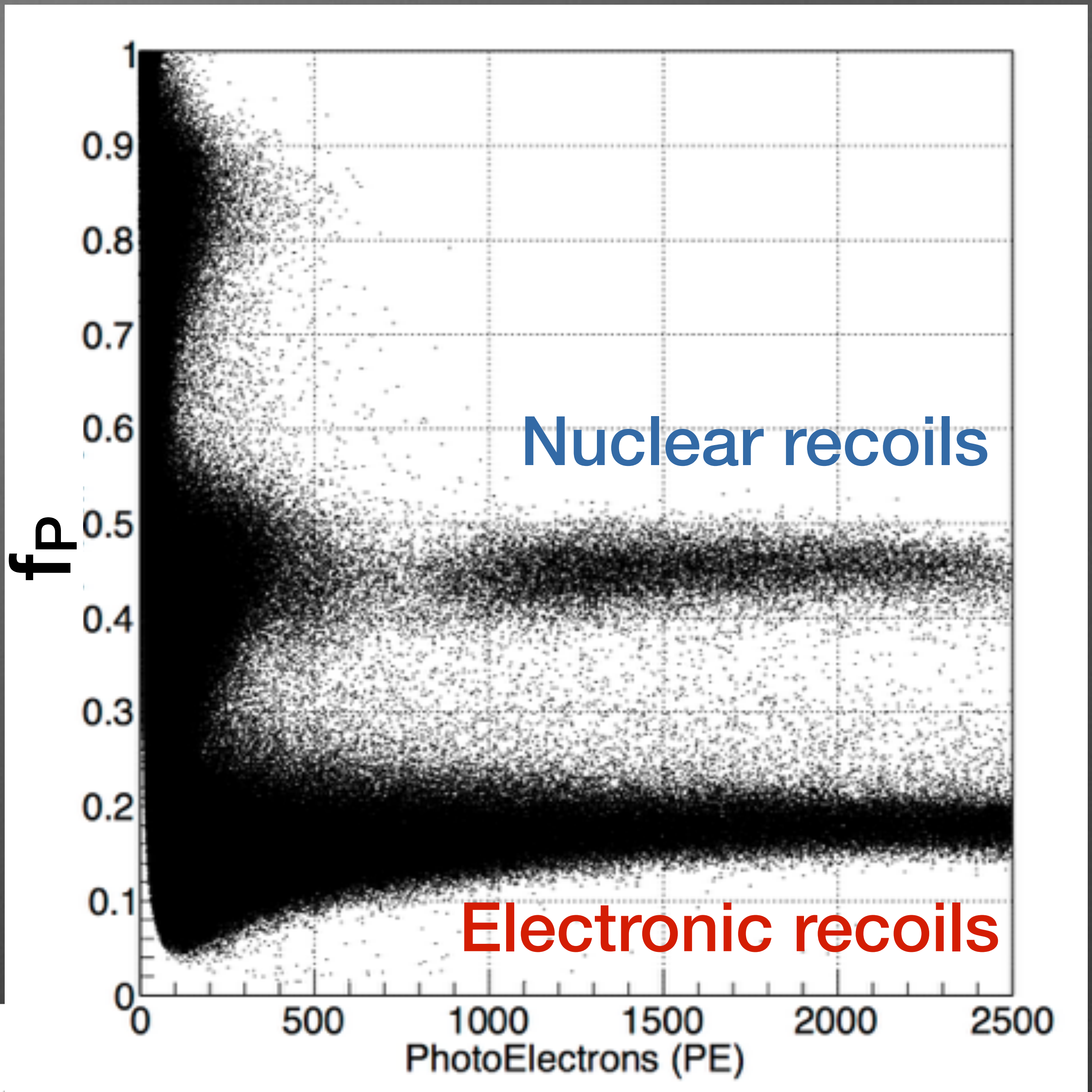
^{241}Am 60 keV line

Yield ~1 PE/keV

As the goal was to map out pressure and temperature, 2 sources were used simultaneously to generate nuclear and electronic recoils:

^{241}Am as a gamma source

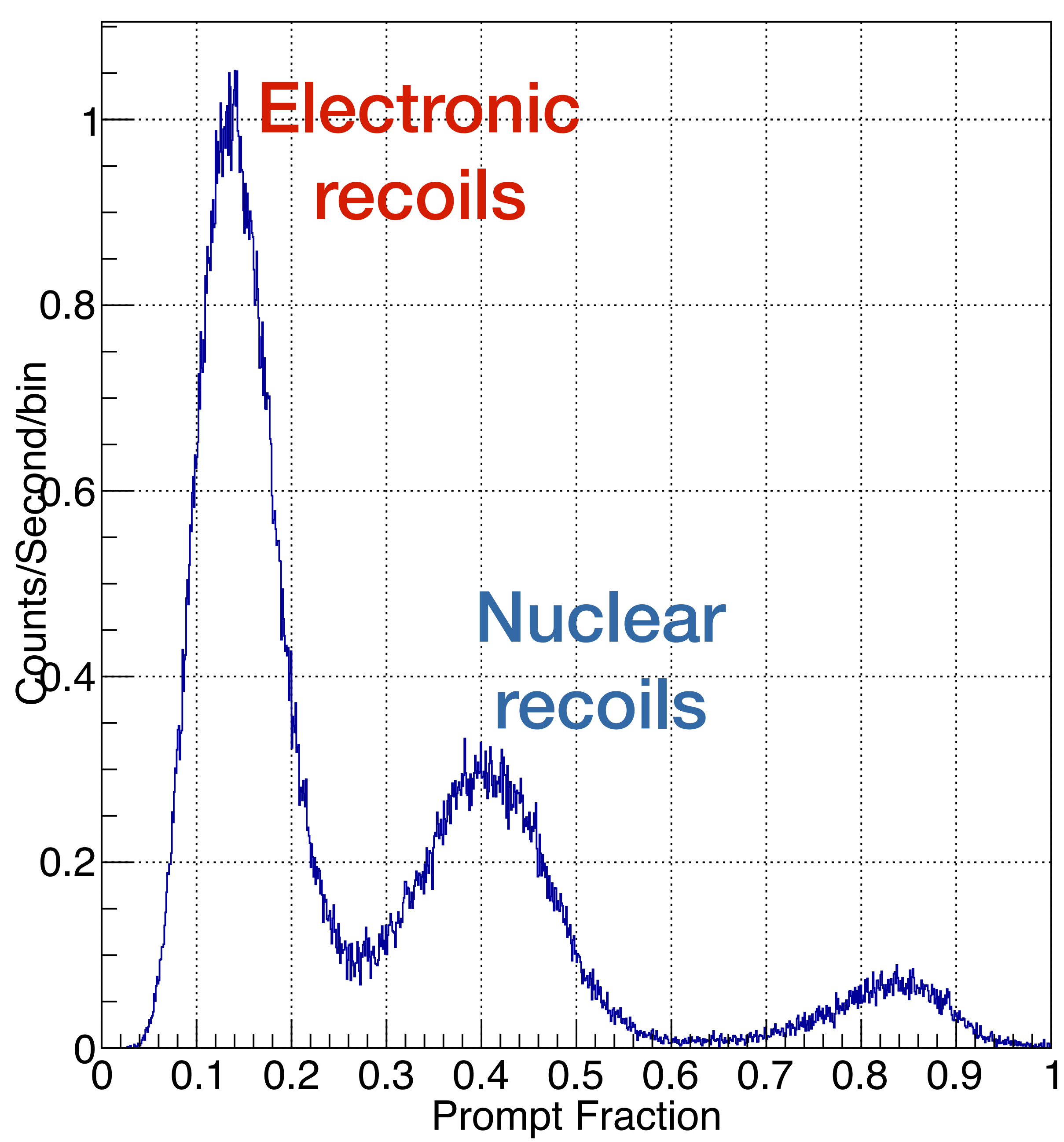
AmBe as a neutron source



$$f_p = \frac{\int_0^{t_1} v(t)dt}{\int_0^{\infty} v(t)dt}$$

The discrimination can be quantified by taking slices in energy or PE

Clear separation is seen between different types of interactions



100-200 PE events

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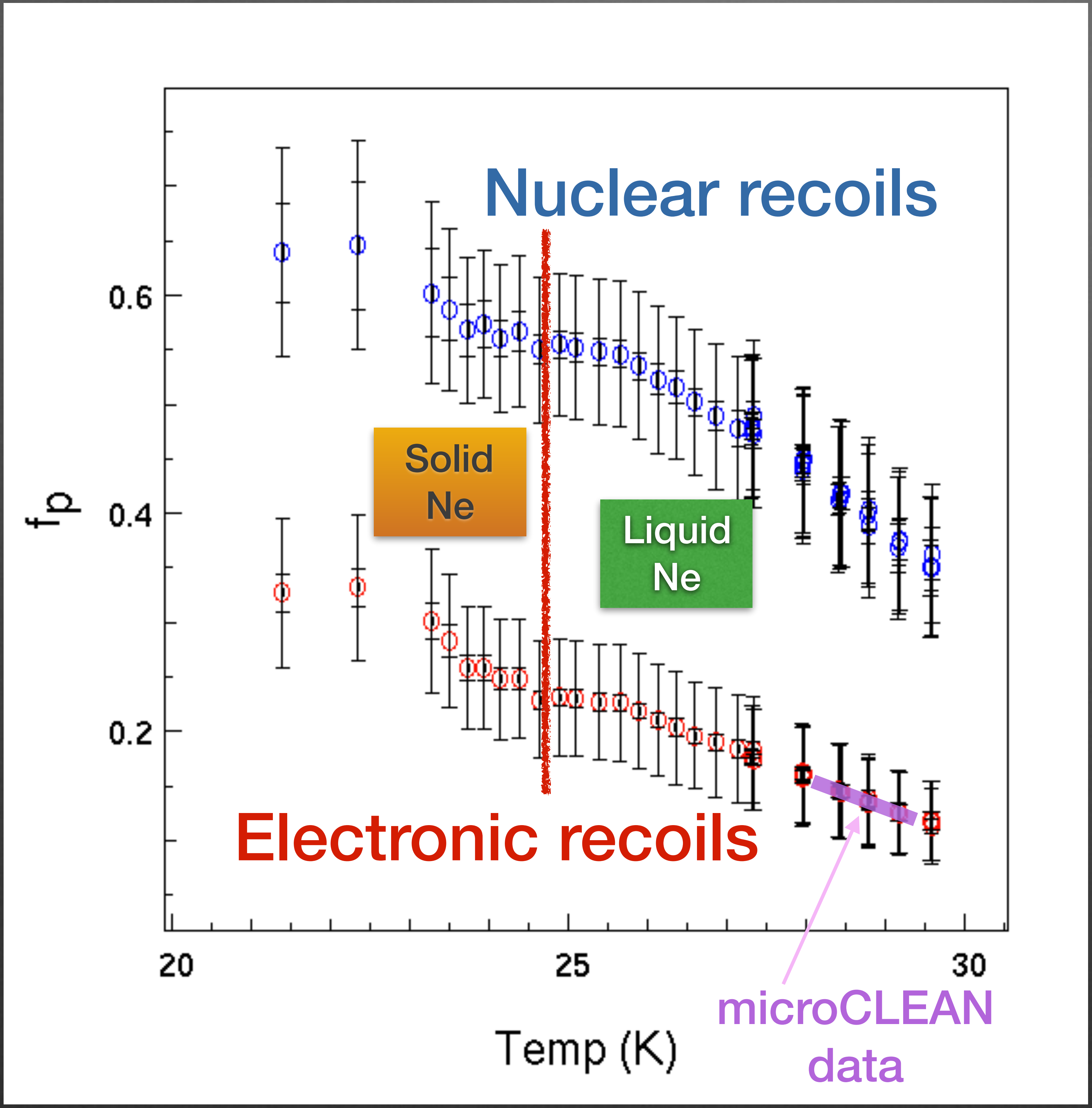
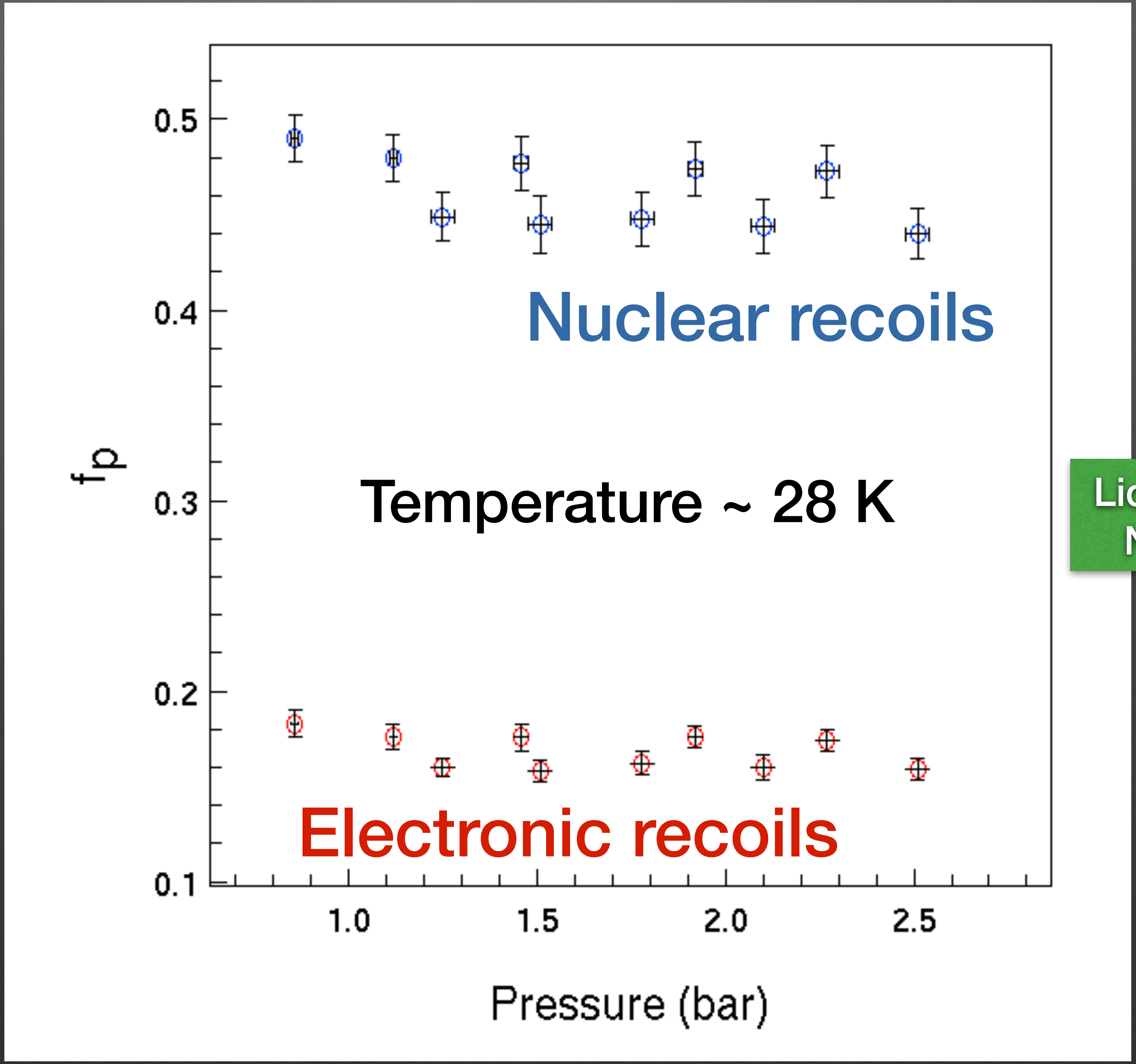


The changes of f_{prompt} with temperature are consistent with the microCLEAN measurements, but over a wider range, including into solid phase

There appears to be little pressure dependence on f_{prompt}



Liquid Ne

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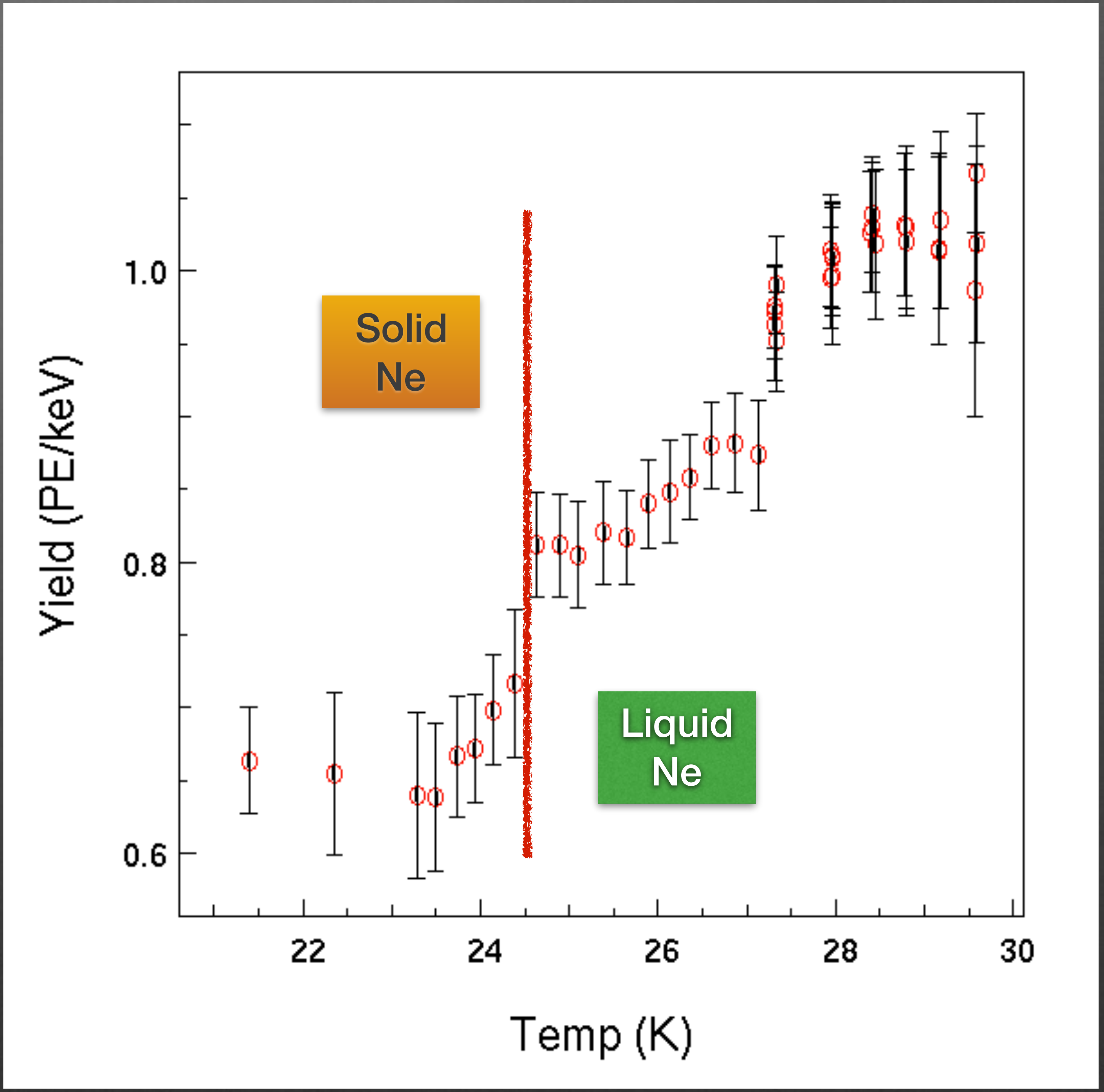
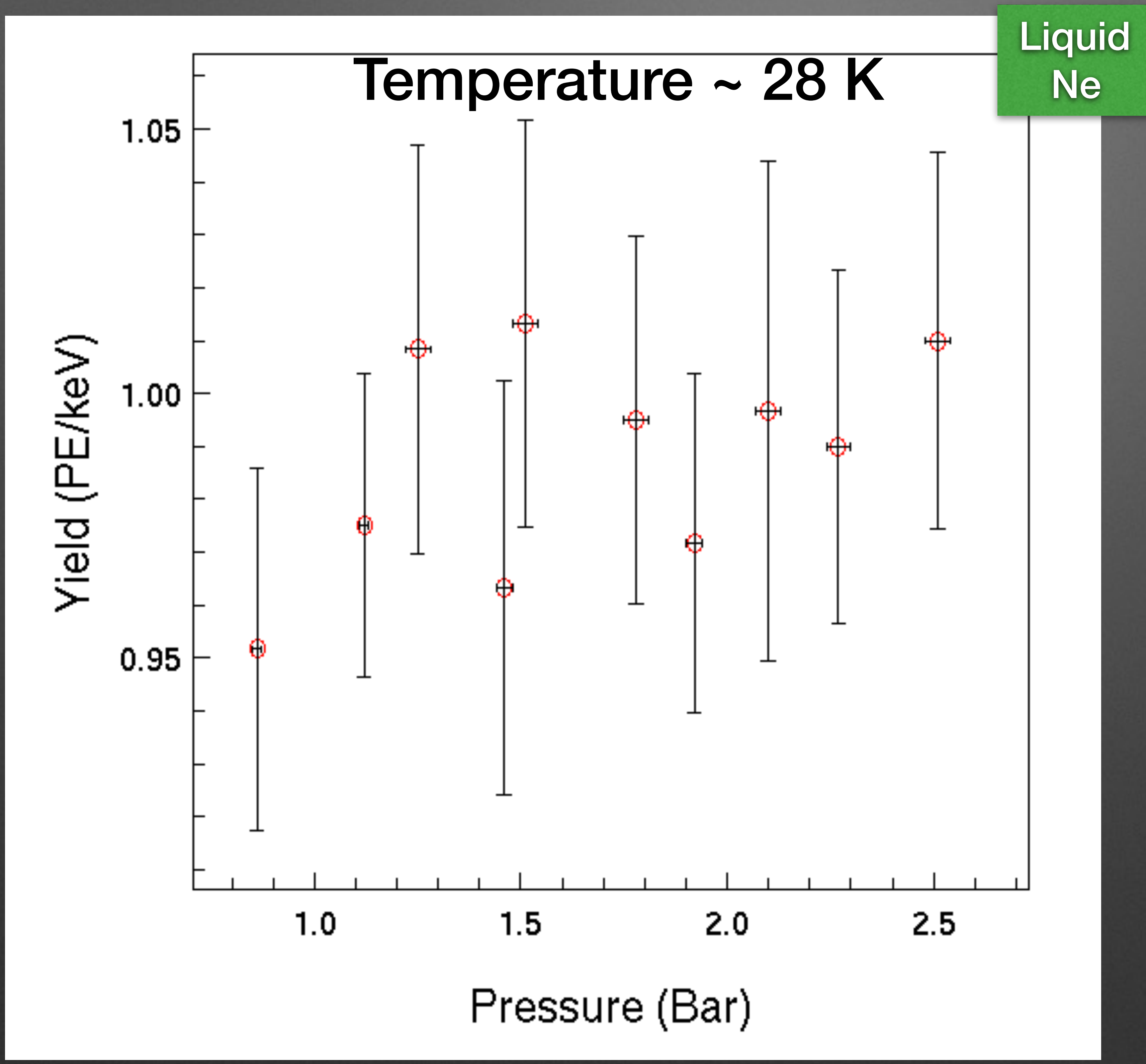
Some dependence of light yield is observed as a function of temperature

Yield is obtained from a 60 keV line source, however there may be some pushing of the peak due to the trigger as f_{prompt} changes

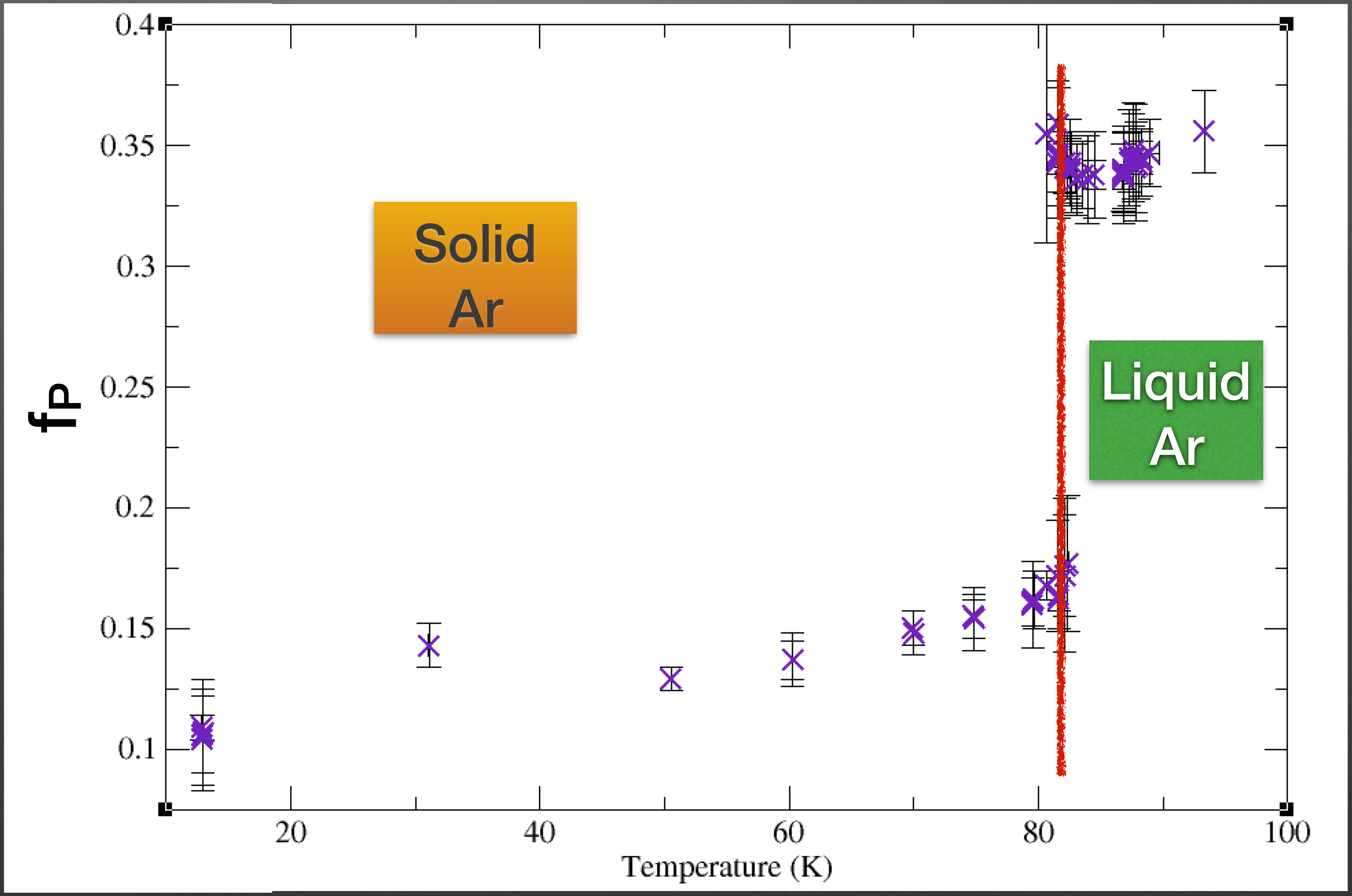




The pressure dependence of the yield appears to be small

LEELA filled with liquid argon

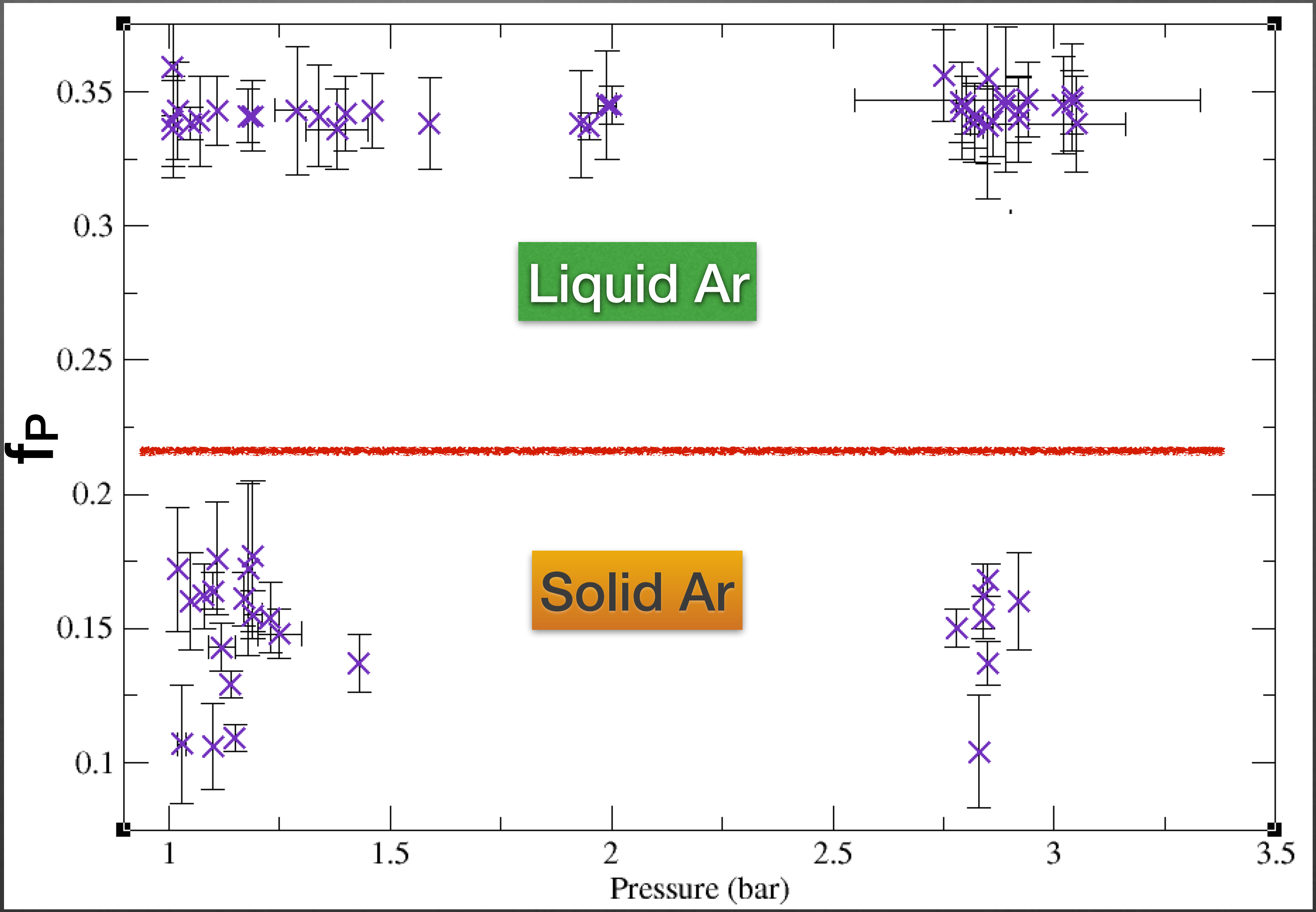
Measured prompt fractions for electronic recoils in argon as a function of temperature



Triple Point: 83.78 K, 0.6875 bar

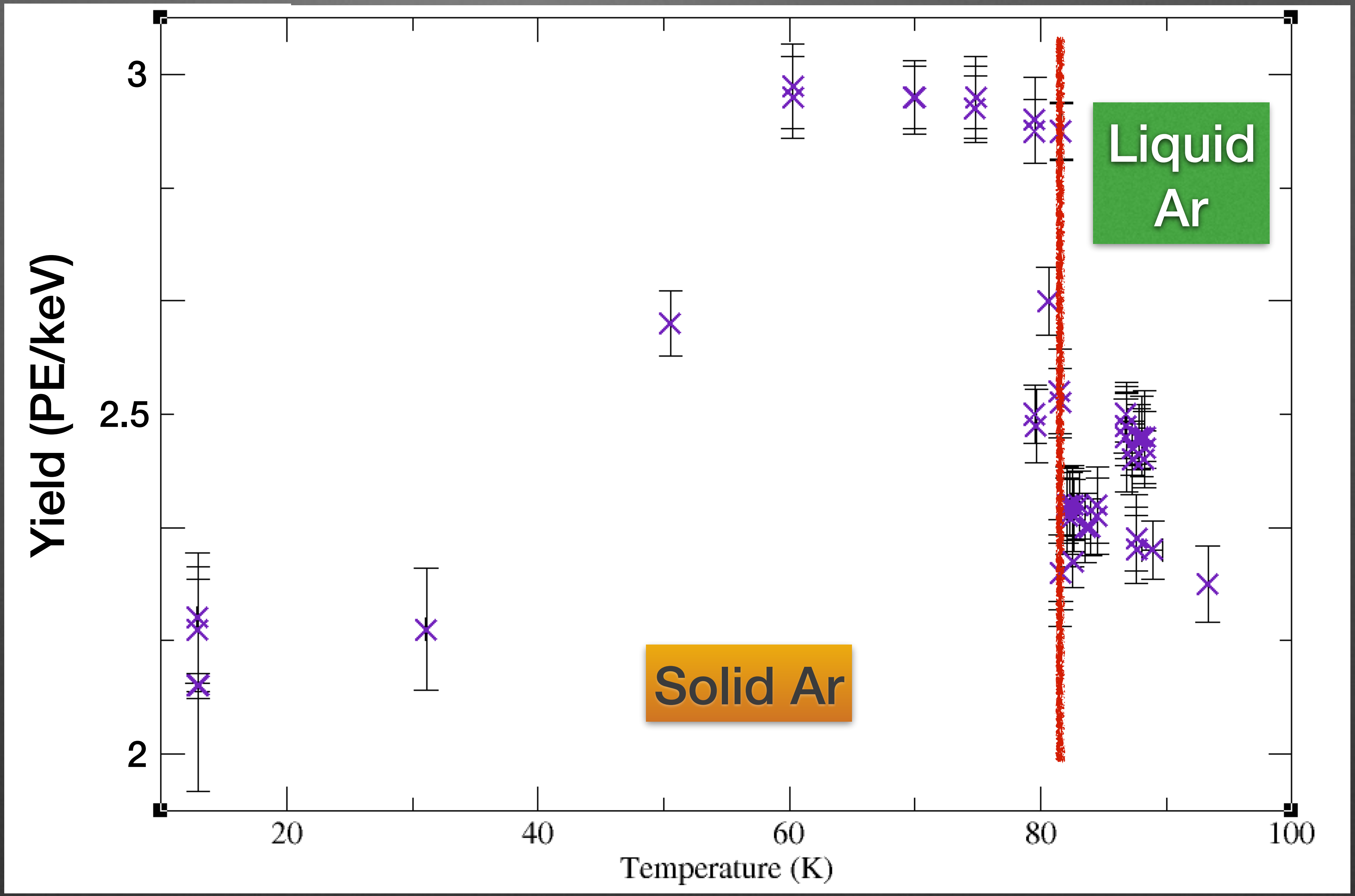
LEELA filled with liquid argon

Measured prompt fractions for electronic recoils in argon as a function of pressure



LEELA filled with liquid argon

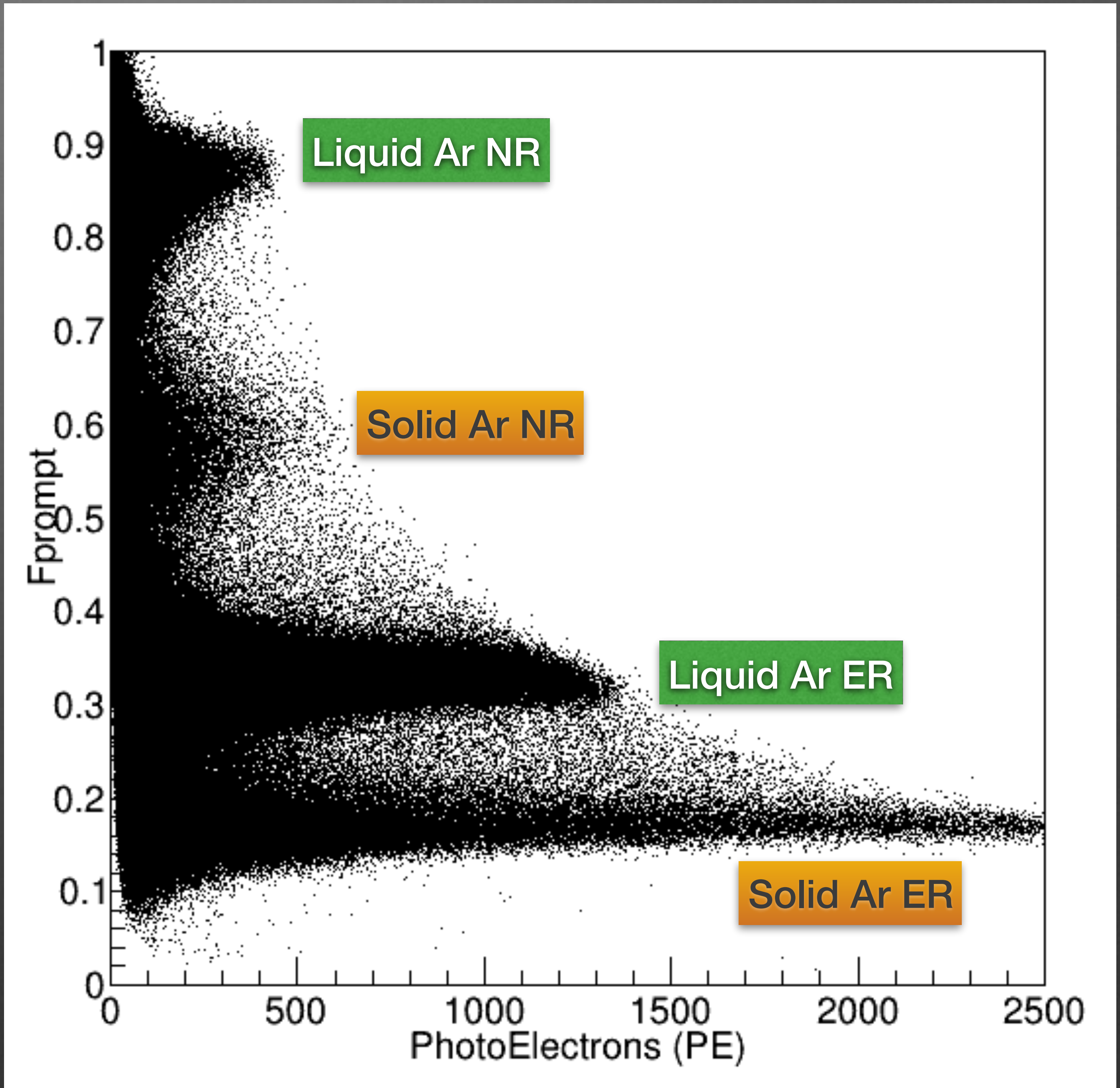
Measured yield for electronic recoils in argon as a function of pressure



LEELA filled with liquid argon

As there appears to be an abrupt transition,
both phases are present in some data sets

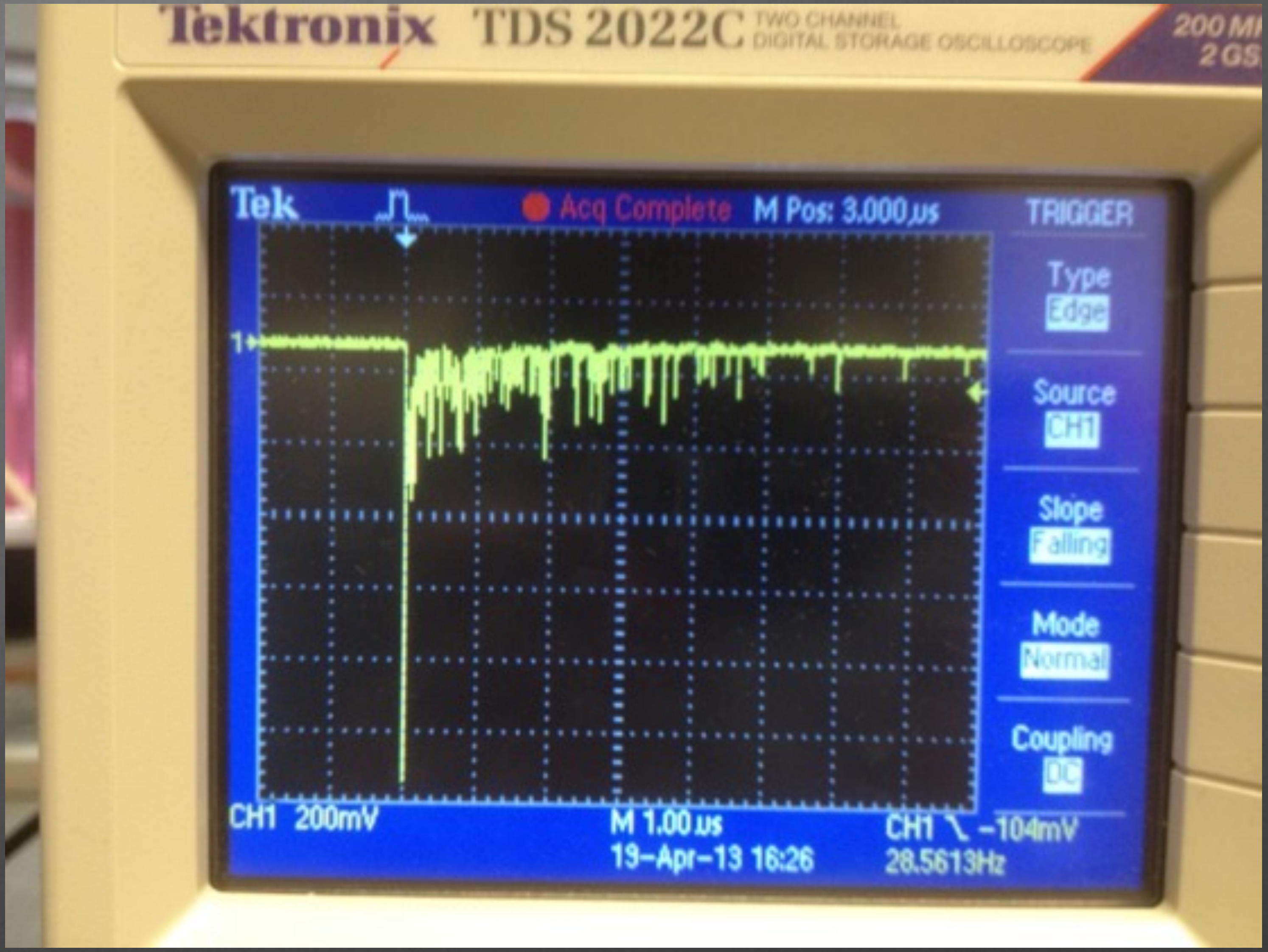
As argon detectors use f_p to reduce backgrounds, one must be vigilant to keep parts of the detector from freezing



T = 82.3 K

Thank you for your time

I hope that was enjoyable and I welcome any questions



LEELA’s first light