Imperial College London

Experimental study of electron emission from cathodic wires in xenon detectors

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LUX-ZEPLIN collaboration

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Motivation

Spurious emission of electrons from cathodic grids (eventually breakdown)

- Limits the drift field of the TPC ↔ key parameter in NR/ER discrimination.
  →Impact on experiment background.

- Limits the field on the wire surface (~50 kV/cm from previous experiments)
  ↔ Constrains the design of the grids (wire diameter, pitch, materials)
  → Impact on the light yield (S1 threshold).

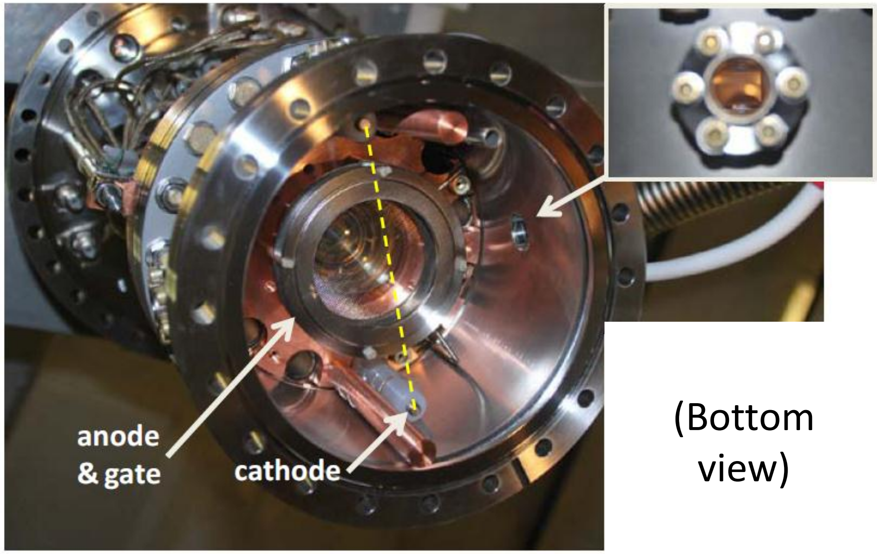
- Can limit the energy threshold of ionisation channel ("S2-only" searches).
  → Impact on sensitivity for light WIMP searches.

→ **Impacts WIMP search sensitivity.**

Grid design requirements are even more demanding for the multi-tonne experiments. Basic understanding of this phenomenon is critical.

A test chamber with single electron sensitivity is needed for a systematic study.

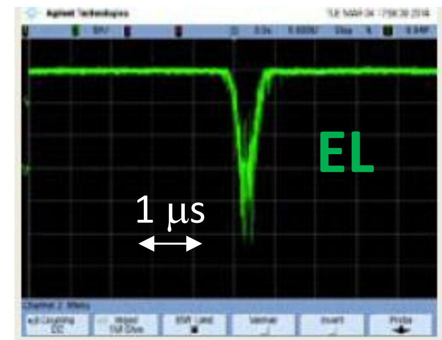
Imperial College wire test chamber



(Bottom view)

- **A single wire as cathode**
  High field on wire surface at reasonably low voltage

- 4.3 kg of LXe; -101°C.
- 1 PMT viewing down from gas.
- ZEPLIN-III gas system and DAQ.



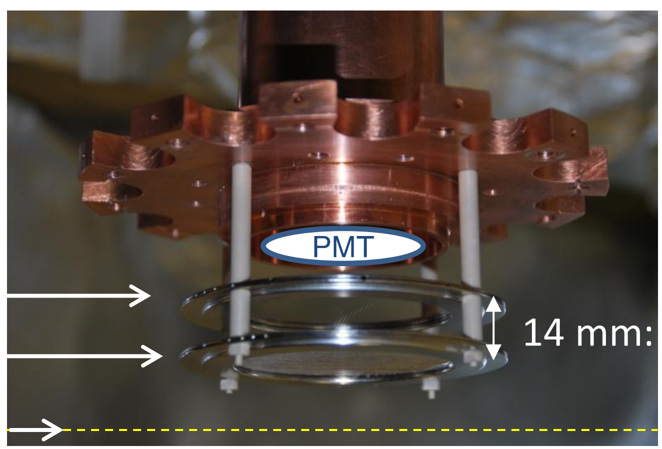
Electroluminescence region

↑

anode

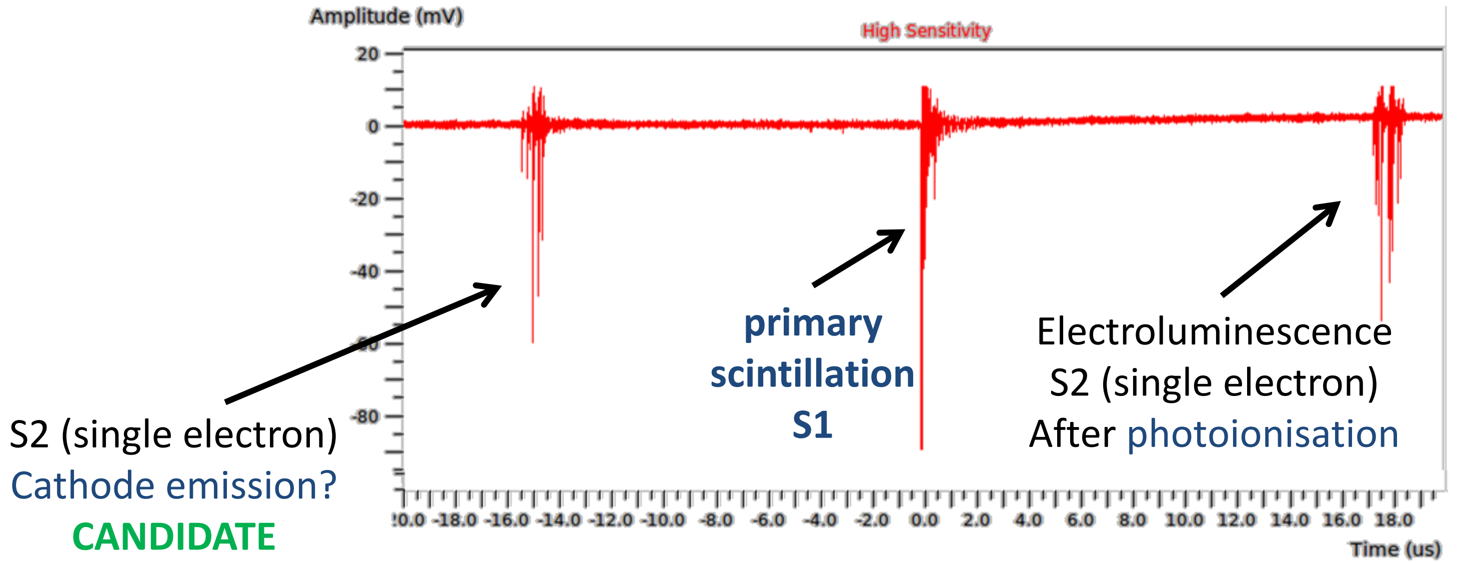
gate

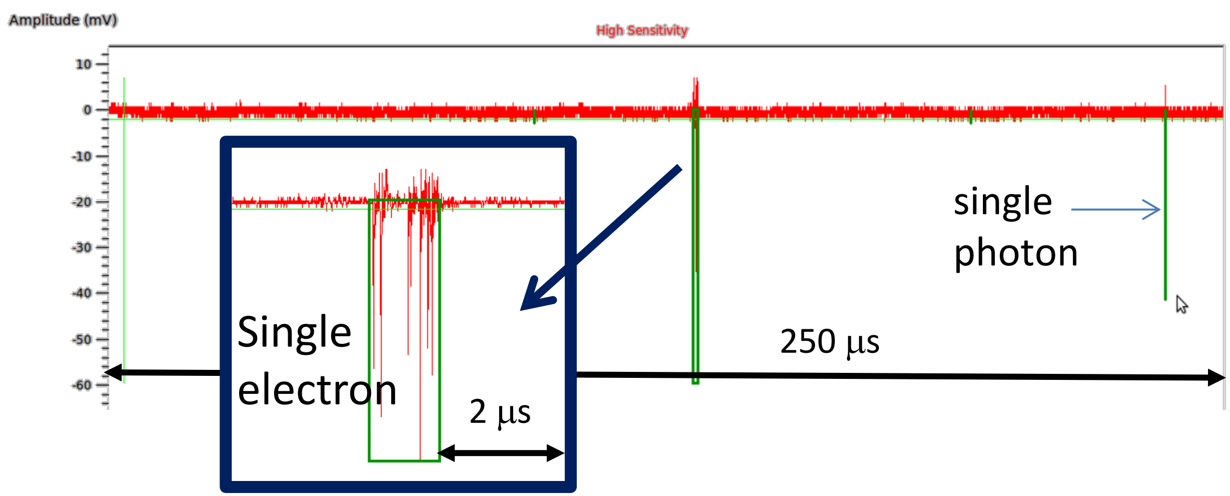
cathode



14 mm: ~10 mm LXe + ~ 4 mm GXe

Acquired waveforms. Candidates for emission events.

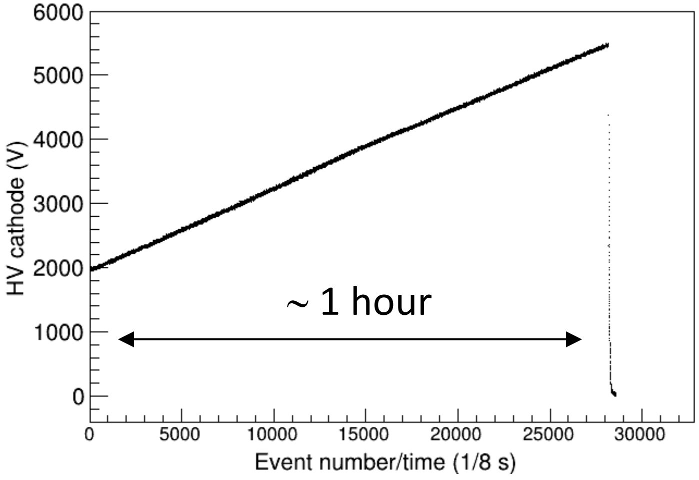




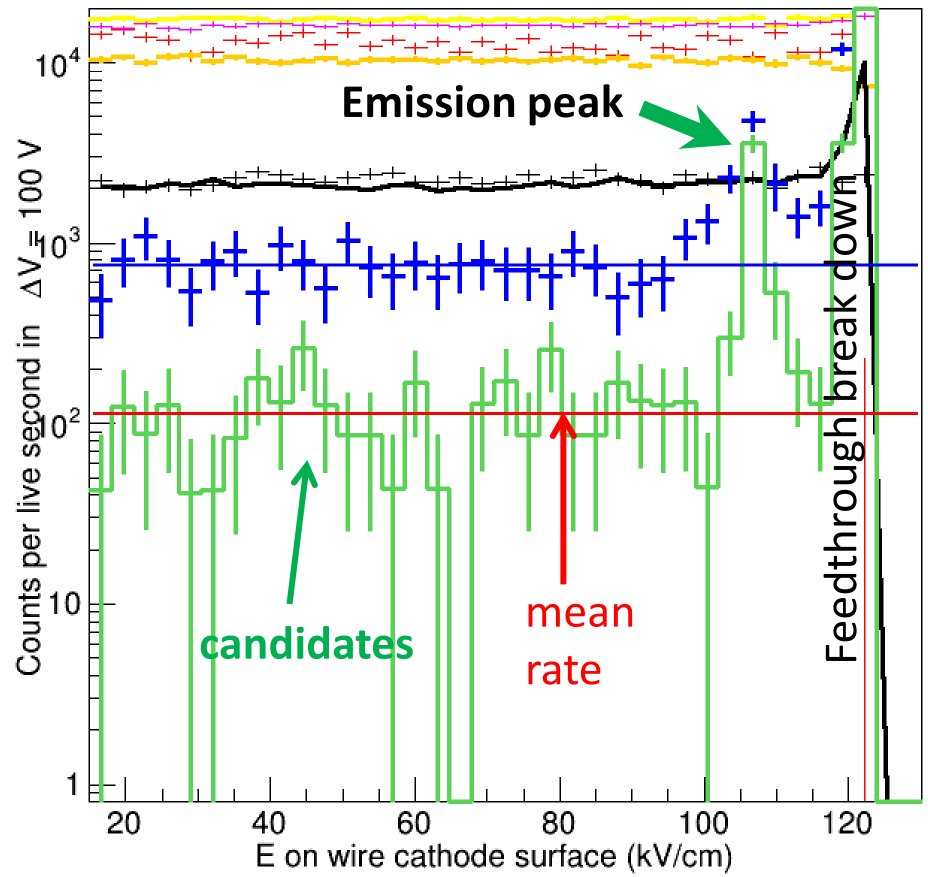
Wire test

Slow ramp up of cathode voltage while acquiring at constant rate (8 Hz).

Maximum voltage/field determined by cathode feedthrough limit (~5.5 kV). Wires did not break down themselves.



Run#12: LUX gate wire, SS304 100 μm



Test Summary

Preliminary DAQ settings

Optimised DAQ settings

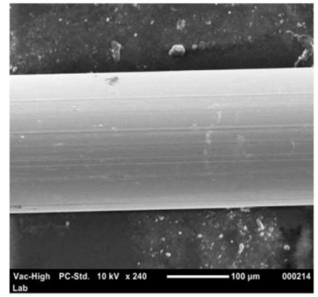
Wire	Diameter	Material	Run	Max E_w*	Min E_w Emission Peak
ZEPLIN-III	**100 μm**	SS316L	#8	150 kV/cm	Not seen
			#9	163 kV/cm	Not seen
			#17	131 kV/cm	111 kV/cm
XED/CWRU	**40 μm**	BeCu	#10	310 kV/cm	Not seen
RS (COARSE)	**500 μm**	Cu(Sn)	#11	46 kV/cm	Not seen
LUX GATE	**100 μm**	SS304	#12	123 kV/cm	105 kV/cm
			#13	122 kV/cm	112 kV/cm
			#14	124 kV/cm	20 kV/cm
LUX CATHODE	**200 μm**	SS302	#15	70 kV/cm	10 kV/cm
			#16	69 kV/cm	57 kV/cm
(ELECTROPOLISHED)			#19	66 kV/cm	Not seen

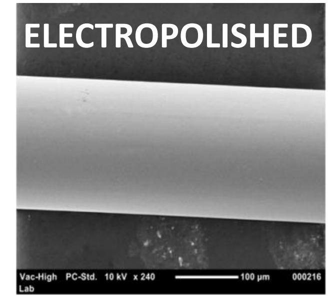
* Always defined by the cathode feedthrough voltage limitation.

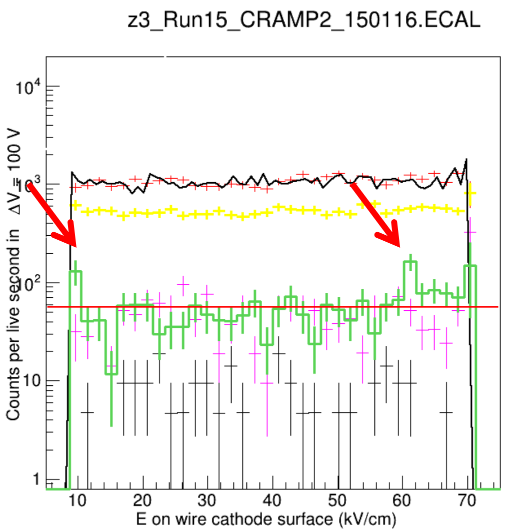
ELECTROPOLISHING

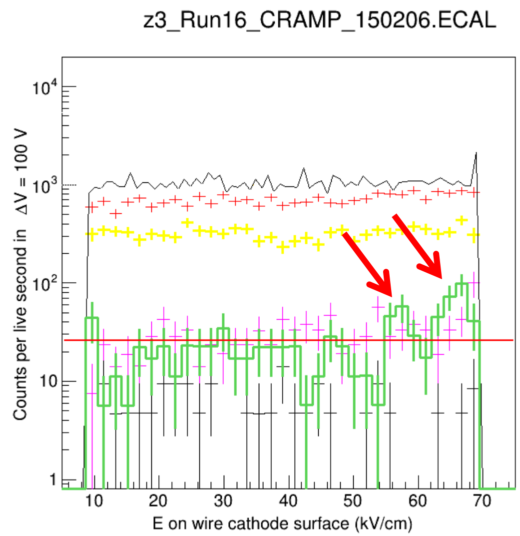
TESTS with the LUX CATHODE WIRE

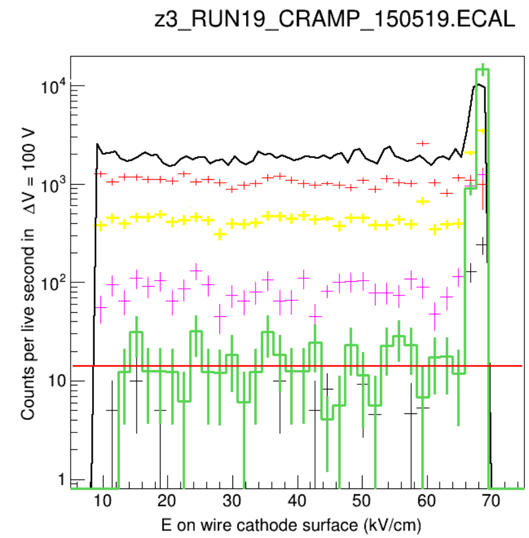
SS 302 200 μm

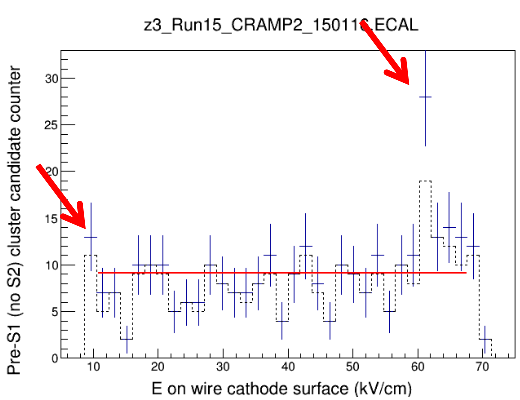


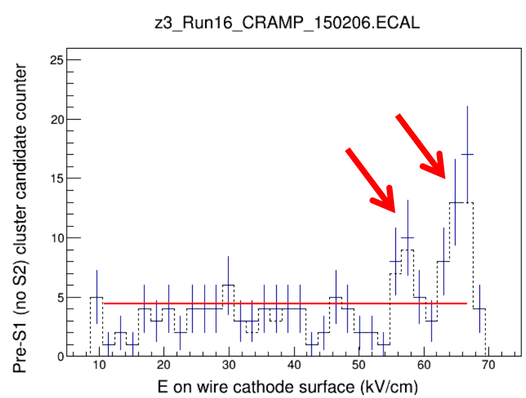


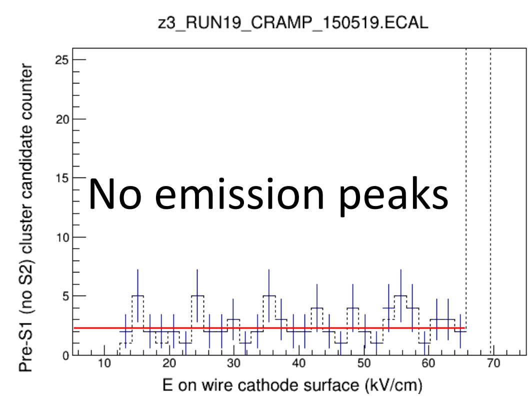












Conclusions

Understanding spurious electron emission is key to designing electrically-resilient electrode grids for the new LXe DM detectors.

Electron emission has been observed for different kinds of wires in the Imperial College test chamber with sensitivity for ~100 e-/s emitters:

- Some differences in behaviour can be established between them.
- Evidence of improvement after electropolishing.

Although questions remain regarding the fundamental process(es) behind the emission, there are signs of the importance of the surface quality and conditions (e.g. local electric field enhancement due to micro-defects, intrusion particles…).

Remaining tests: contrast wires with different finishes and explore further the effect of the metal work function.

Larger setups within LZ R&D will test grids of various sizes.