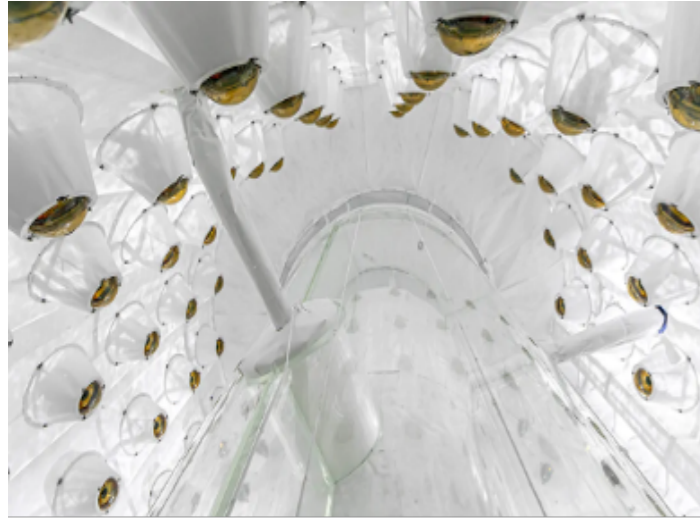
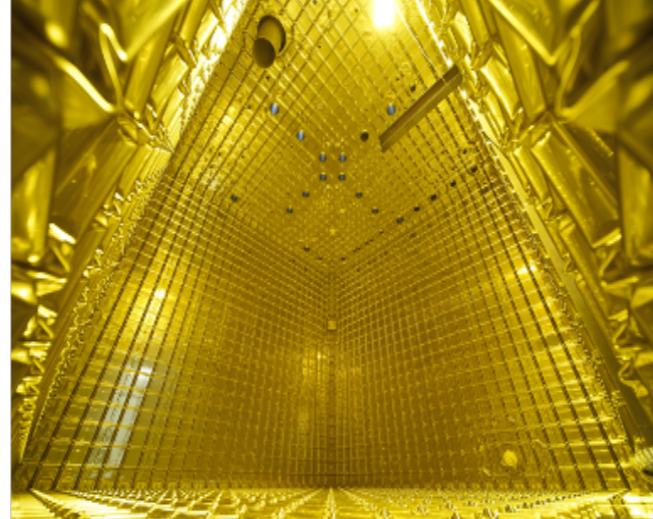


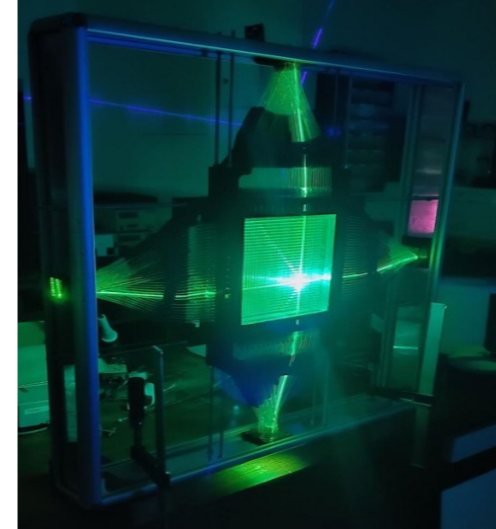
XENON detector



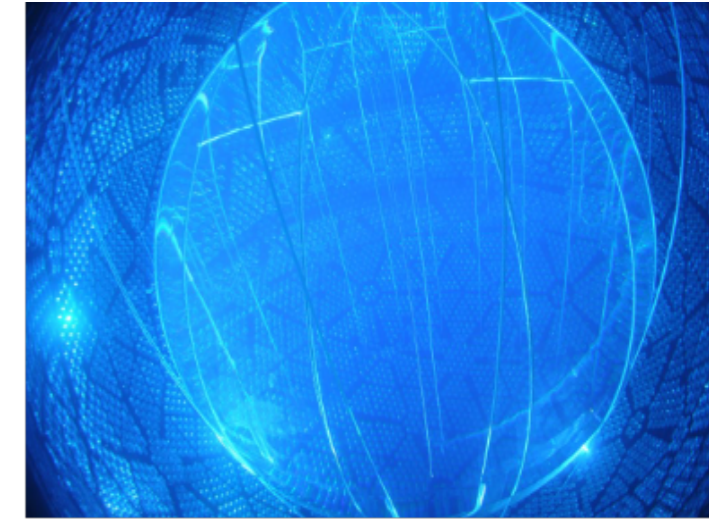
DUNE cryostat



LiquidO fibers



SNO+ detector



# Neutrino and dark matter liquid detectors [DRD2]

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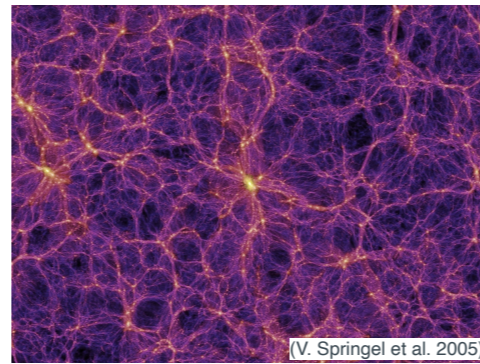
Roxanne Guenette



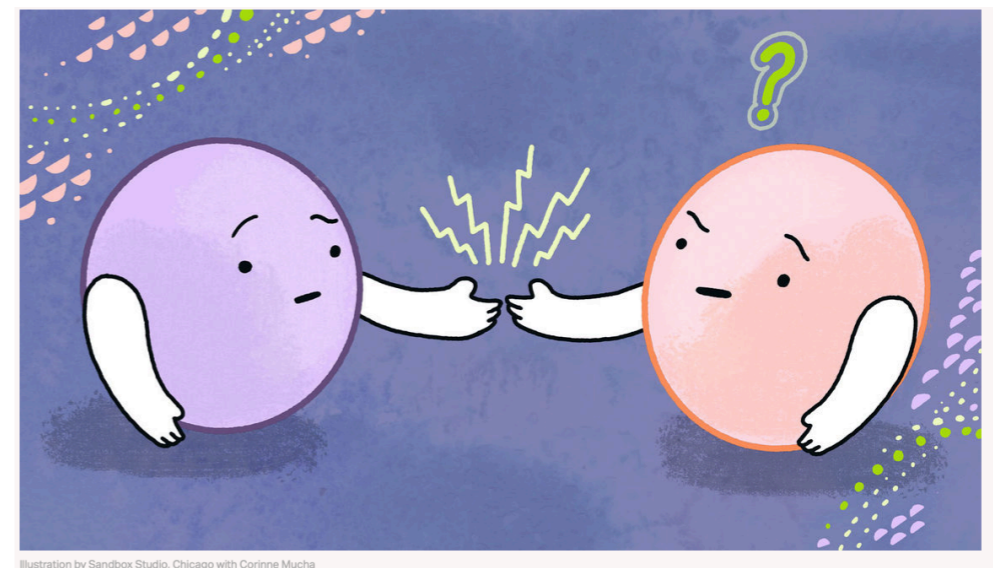
The University of Manchester

# Dark Matter and Neutrinos

- What is Dark Matter?



- What is the nature of neutrinos?

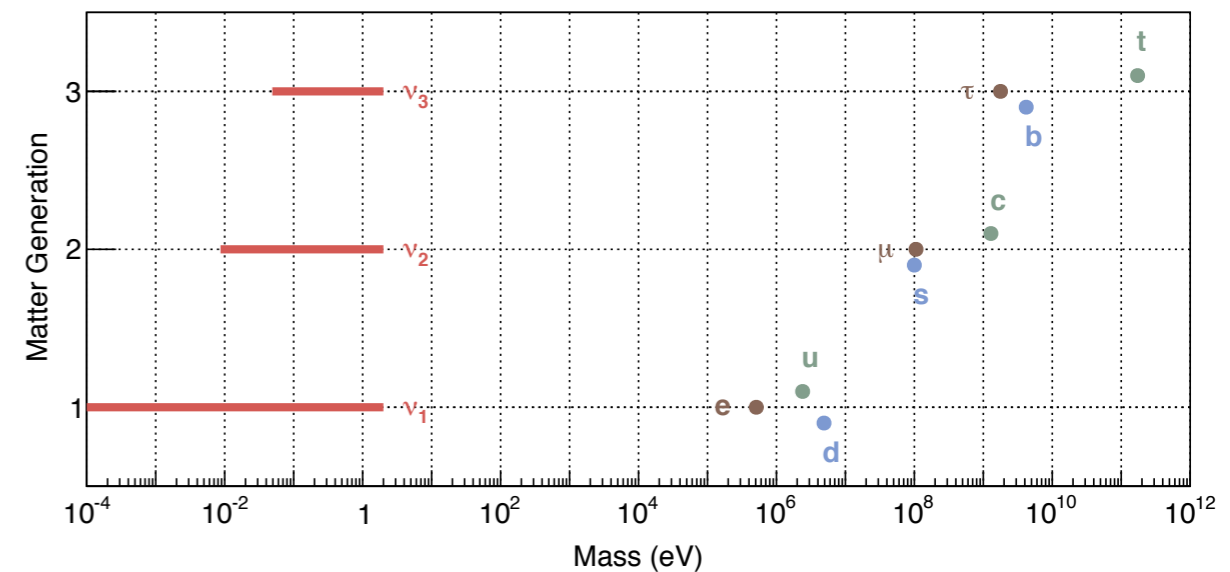


- What is the mass of neutrinos?

- What is the neutrino mass ordering?

- Do neutrinos violate CP?

- Are there sterile neutrinos?



# Dark Matter and Neutrinos

---

• What is Dark Matter?

**Direct searches**

• What is the nature of neutrinos?

**$0\nu\beta\beta$  searches**

• What is the mass of neutrinos?

**End point of  $\beta$  decays**

• What is the neutrino mass ordering?

• Do neutrinos violate CP?

• Are there sterile neutrinos?

**Neutrino oscillation**

# Dark Matter and Neutrinos

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• What is Dark Matter?

• What is the nature of neutrinos?

• What is the mass of neutrinos?

• What is the neutrino mass ordering?

• Do neutrinos violate CP?

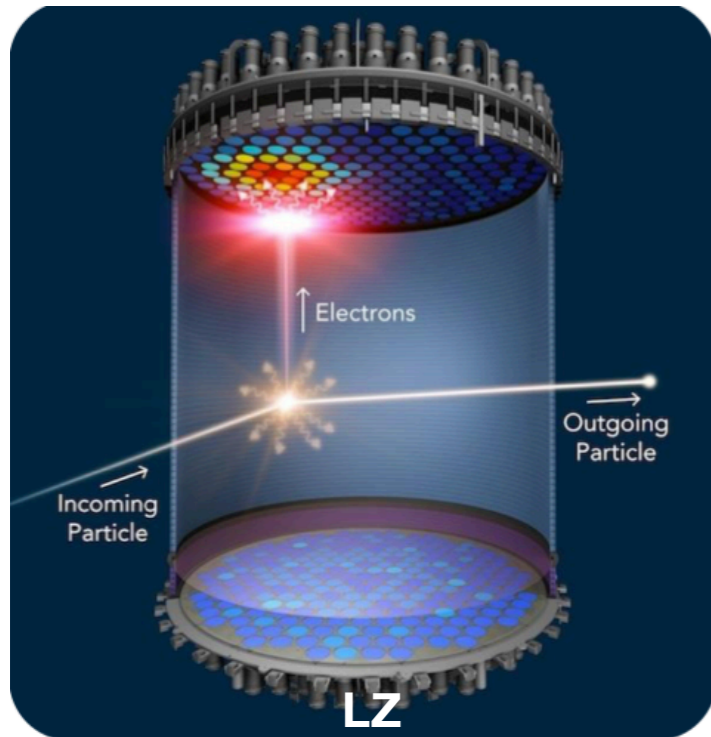
• Are there sterile neutrinos?

**Large Liquid Detectors!**

# Liquid Detectors

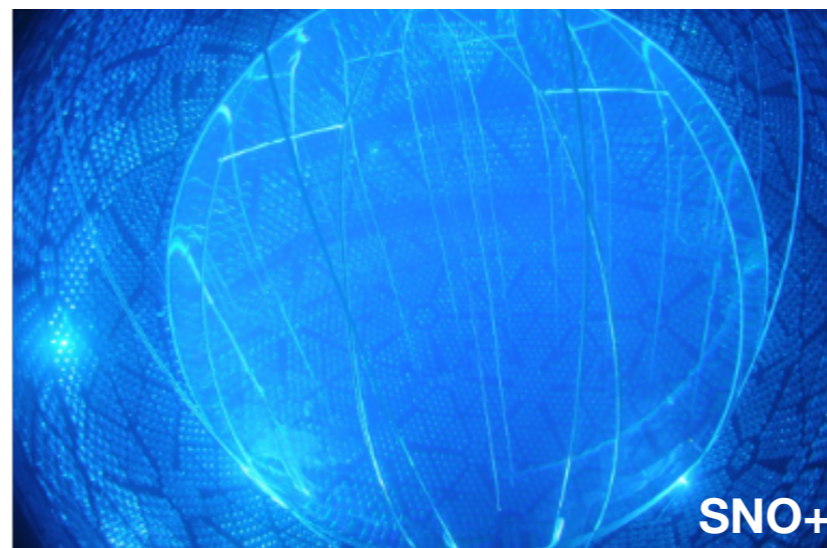
## Noble Elements

- Argon & Xenon
- Ionization charge (+ amplification)
- Scintillation light (Ar:128nm & Xe:175nm)



## Liquid Scintillators

- Scintillation light
- Isotope loading
- Water-based LS
- Opaque scintillator



## Water Cherenkov

- Cherenkov light
- Loading for n capture



# Liquid detectors physics needs (high level overview)

---

## Neutrinos

- **Push Energy thresholds down** to  $\sim 1$  MeV to enhance oscillation physics, supernovae  $\nu$ s study, to enable solar  $\nu$ s ...
- **Unambiguous readout**
- **Scalability**

## Dark Matter

- **Push Energy thresholds down** to 1 meV/10 eV/1 keV to enable low mass DM/1 GeV DM/WIMPs.
- **Reduce background rates**
- **Scalability**

## $0\nu\beta\beta$

- **Improve Energy Resolution** to sub-% FWHM
- **Reduce background rates**
- **Scalability**

# Future targeted *projects*

## Liquid Nobles (Argon/Xenon)

- Dark Matter (Xe): XLZD  
(Few R&D needs from inputs)
- Dark Matter (Ar): Argo/  
GADMC
- Neutrinos: DUNE LAr  
3<sup>rd</sup>/4<sup>th</sup> modules
- $0\nu\beta\beta$ : nEXO
- Future Kilotonne-scale  
Xenon detectors:

<https://indico.slac.stanford.edu/event/8015>

## Liquid Scintillator

- THEIA (WbLS)
- LS  $0\nu\beta\beta$ : SN0+ high Te  
doping, KL-Z+
- Opaque LS: LiquidO

## Water Cherenkov

- HyperK  
(Few R&D needs from inputs)
- Future neutrino  
telescopes

# DRD2 Goals and Organisation

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- Work Packages: (based on the 2021 ECFA Detector R&D Roadmap)

**Charge Readout**

**Convener: Elena  
Gramellini (Manchester)**

**Light Readout**

**Target Properties**

**Scaling-up Challenges**



# DRD2 Organisation

- Work Packages:

Applies to Noble Element Detectors only

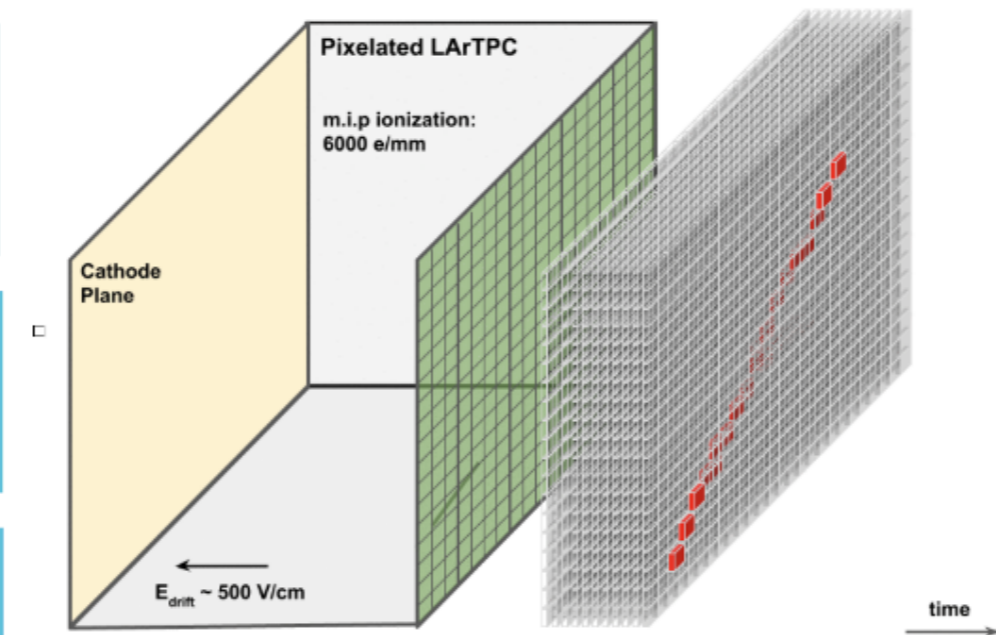
**Charge Readout**

**Pixels & charge+light**  
Co-Lead: E. Gramellini (Manchester)

**Charge-to-light, electroluminescence & amplification**  
Co-Lead: K. Mavrokoridis (Liverpool)

**Ion detection**

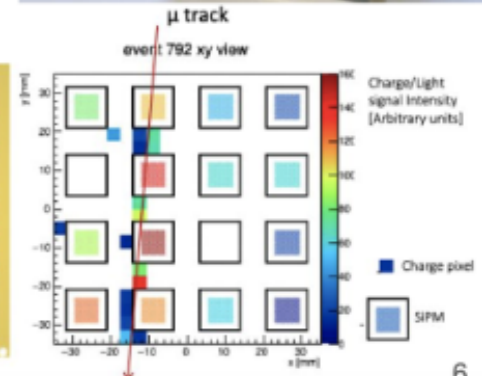
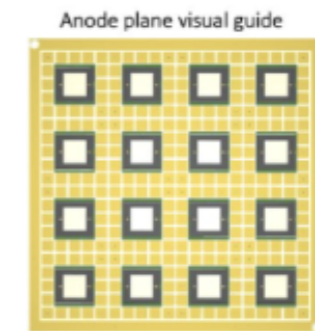
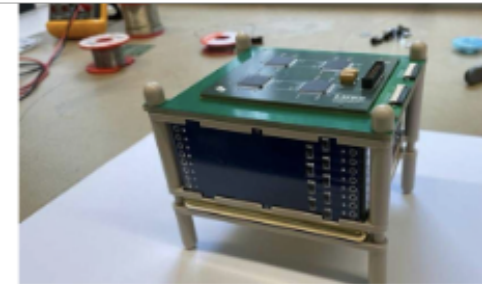
## QPix



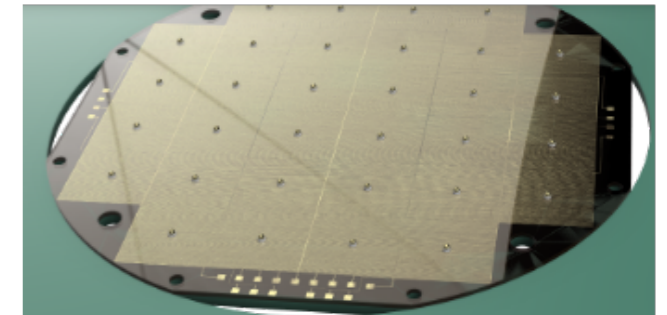
[arXiv:2406.14121](https://arxiv.org/abs/2406.14121)

## SoLAr

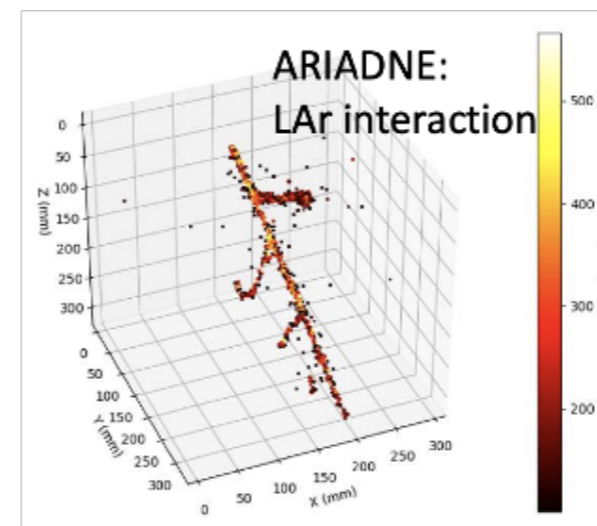
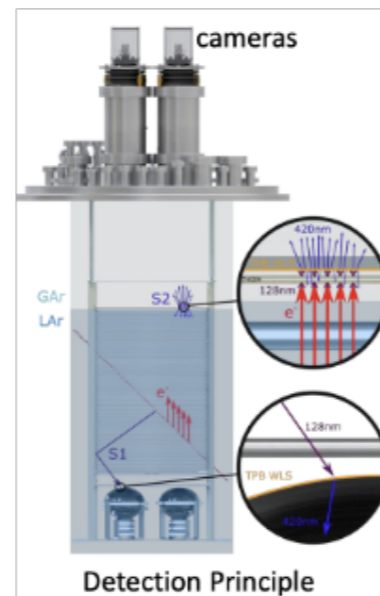
First track with integrated Q+L readout



## LiLAr



## ARIADNE



# DRD2 Organisation

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- Work Packages:

Applies to Noble Element Detectors mostly as visible photon detection is covered in DRD4

**Light Readout**

**Increased sensor  
quantum efficiency**

**Co-Lead: M. Garcia Peris (Manchester)**

**Higher efficiency  
WLS and collection**

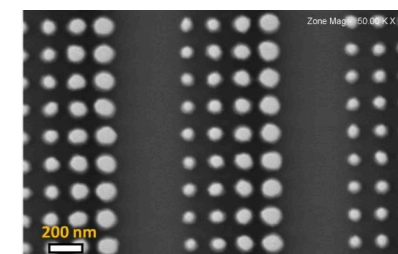
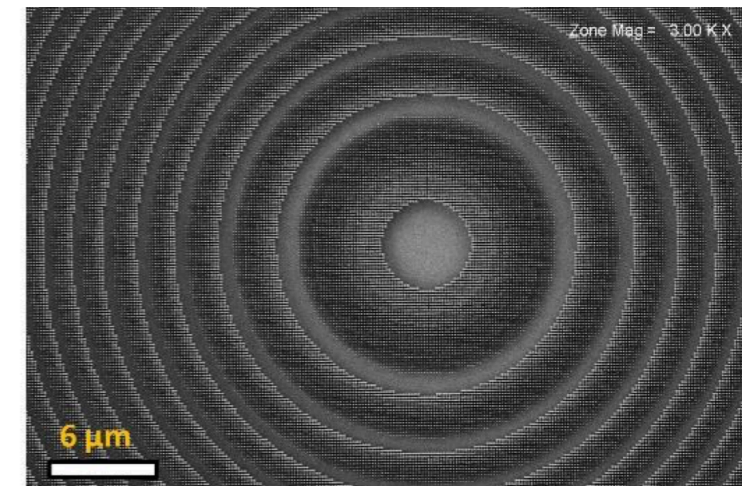
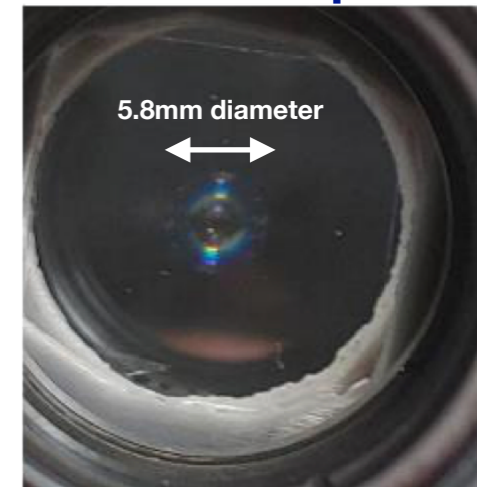
**Improved sensors  
for LS & WC**

# DRD2 Organisation

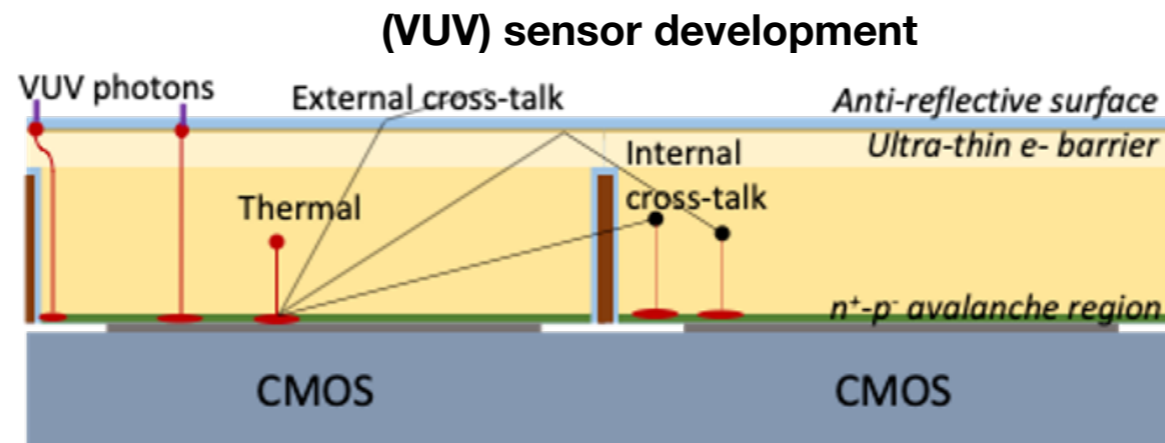
- Work Packages:

Applies to Noble Element Detectors mostly as visible photon detection is covered in DRD4

## VUV metaoptics



[arXiv:2401.11315](https://arxiv.org/abs/2401.11315)



*J. Monroe, 2<sup>nd</sup> Liquid Detectors Community Meeting*

Wavelength Shifter	$\lambda_{em}$ [nm]
TPB	430
p-Terphenyl	350
bis-MSB	440
pyrene	470
PEN	420

*Instruments 2021, 5(1), 4*

Light Readout

Increased sensor quantum efficiency

Co-Lead: M. Garcia Peris (Manchester)

Higher efficiency WLS and collection

Improved sensors for LS & WC

Edinburgh, Manchester, Liverpool, Open Uni., RAL/STFC, RAL PPD, Royal Holloway, Royce Institute, Sussex, York

# DRD2 Organisation

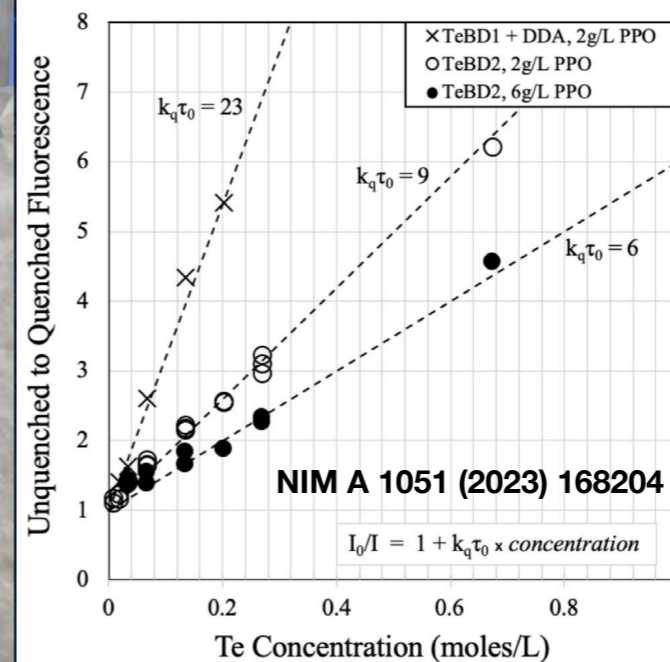
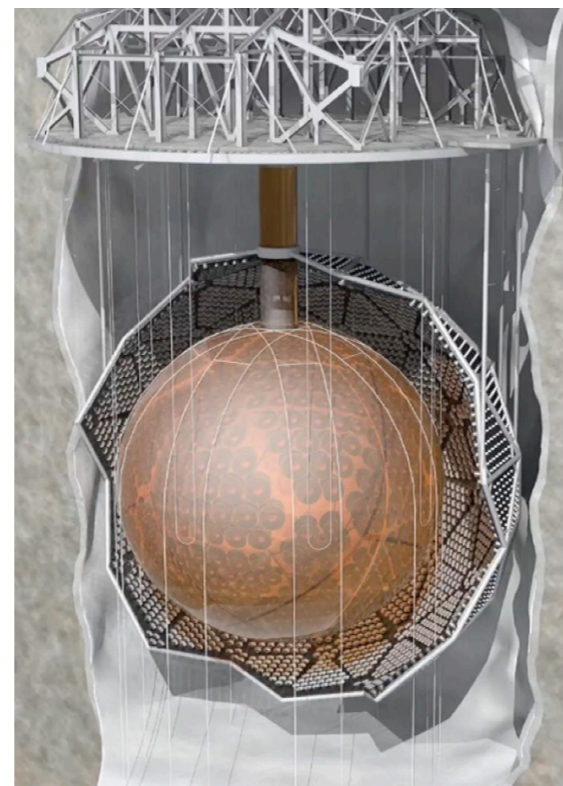
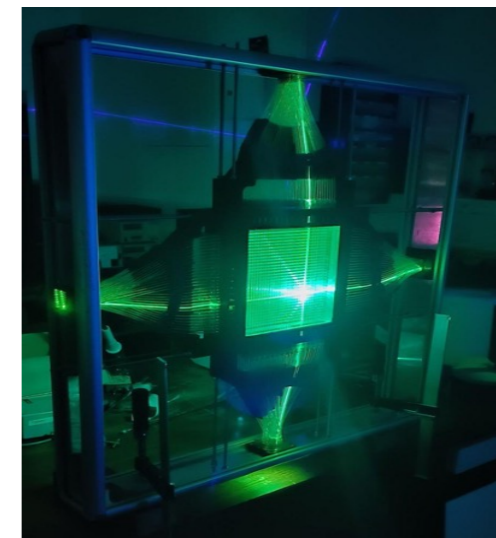
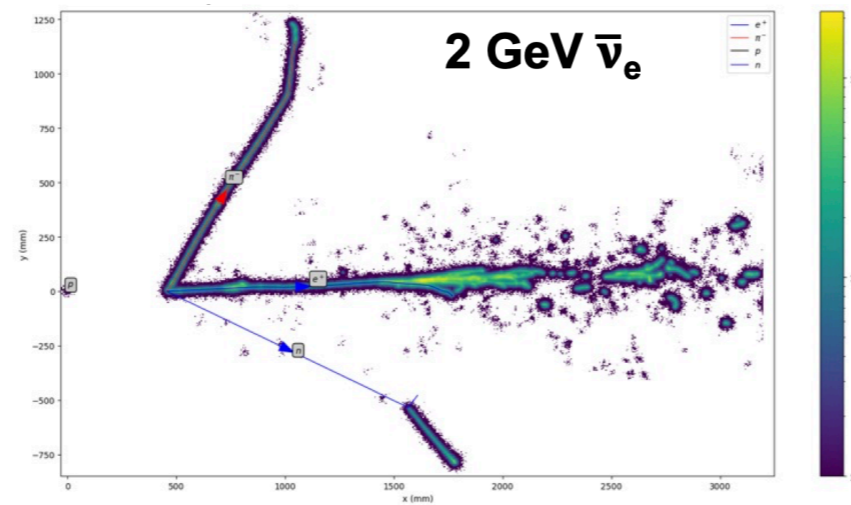
- Work Packages:

Target Properties

Target properties and isotope loading of LS & WC

Target properties and isotope loading of noble elements

LiquidO (opaque scintillator)



Te loading development

# DRD2 Organisation

- Work Packages:

**Scaling-up Challenges**

**Radiopurity & background mitigation**

Co-Lead: P. Scovell (Boulby)

**Detector and target procurement/production & purification**

**Large-area readouts**

**Material properties**



**UAr @ Aria**



# Summary of UK activities



- Activities in almost all the Tasks (UK Task Leaders for 1.1, 1.2, 2.1 and 4.1)
- Synergies across topics via “Light detection and background reduction”
- Coordination across sub-topics remains beneficial for strategic R&D

# Summary

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- DRD2 was recently launched to cover R&D for Liquid Detectors targeted mostly at rare event searches (neutrinos & dark matter)
- Collaboration in the process of establishing the MOUs
- Several UK leadership (**make sure you will sign the MOUs!**)
- Wide effort to coordinate and leverage activities across DRD2 (and across UK)

