DARWIN observatory

– Ultimate Dark Matter detector and beyond

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on behalf of the DARWIN collaboration

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DARWIN

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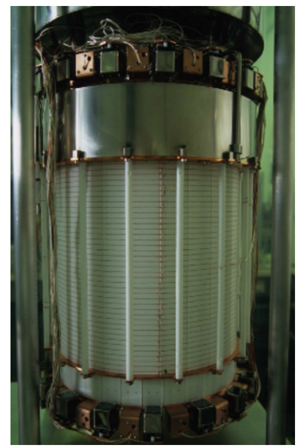
Continuation of the XENON program

- Consistent generational improvements
  - Mass, size, cleanlinesses, sensitivity...

Past

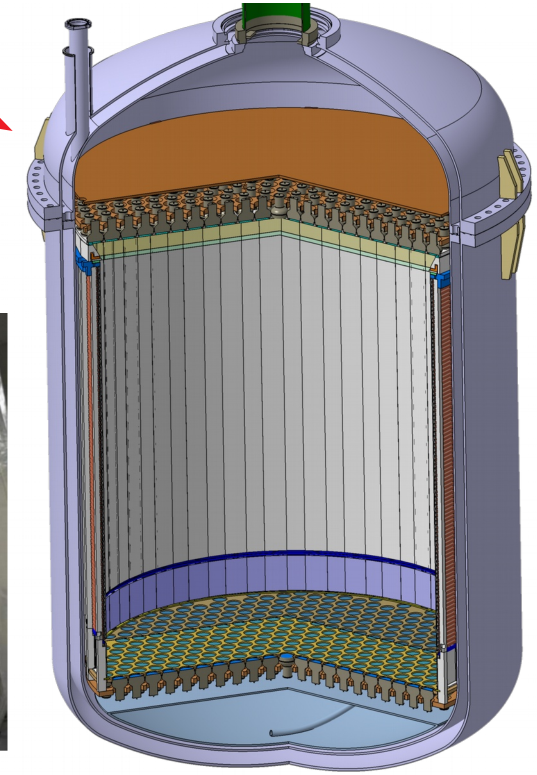
Past



Past

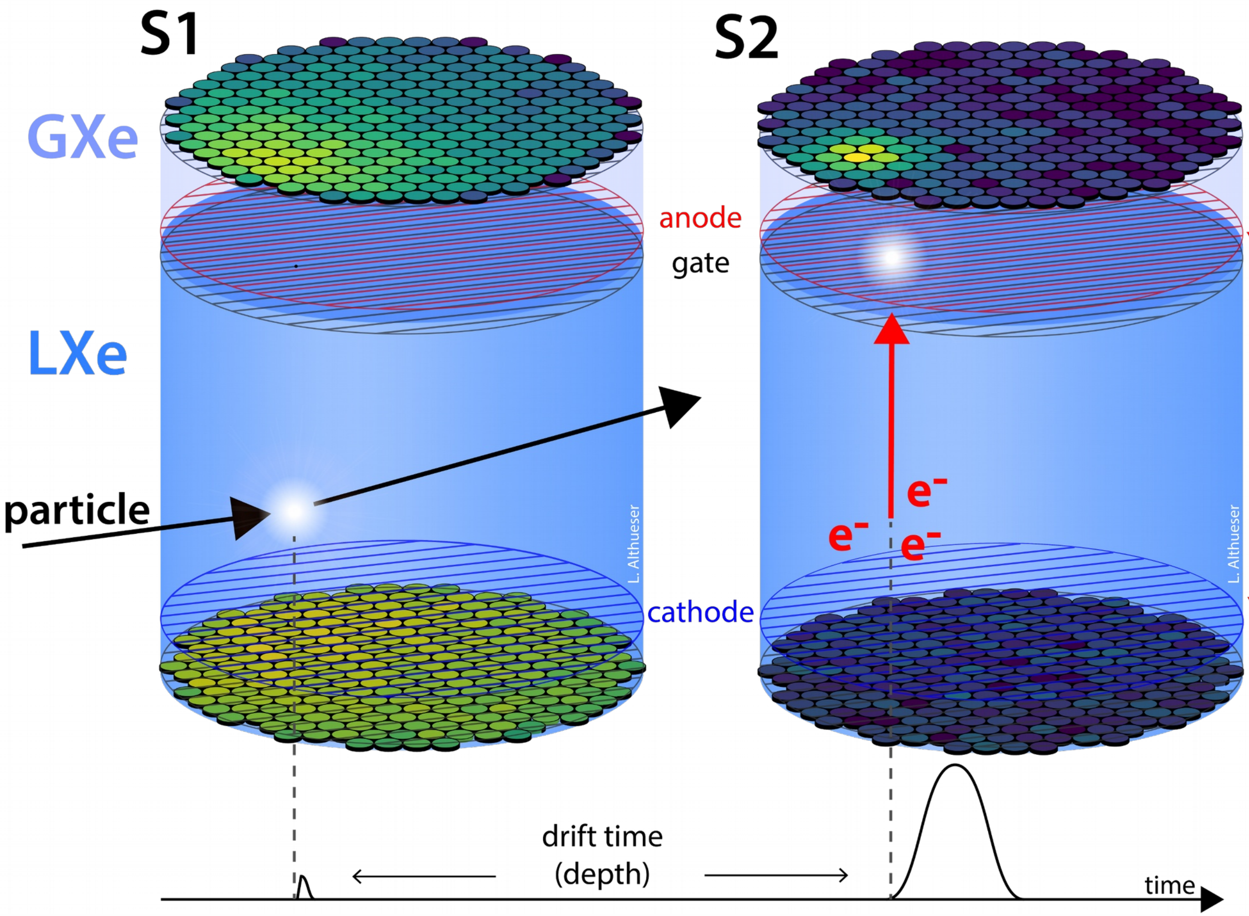
Present

Future

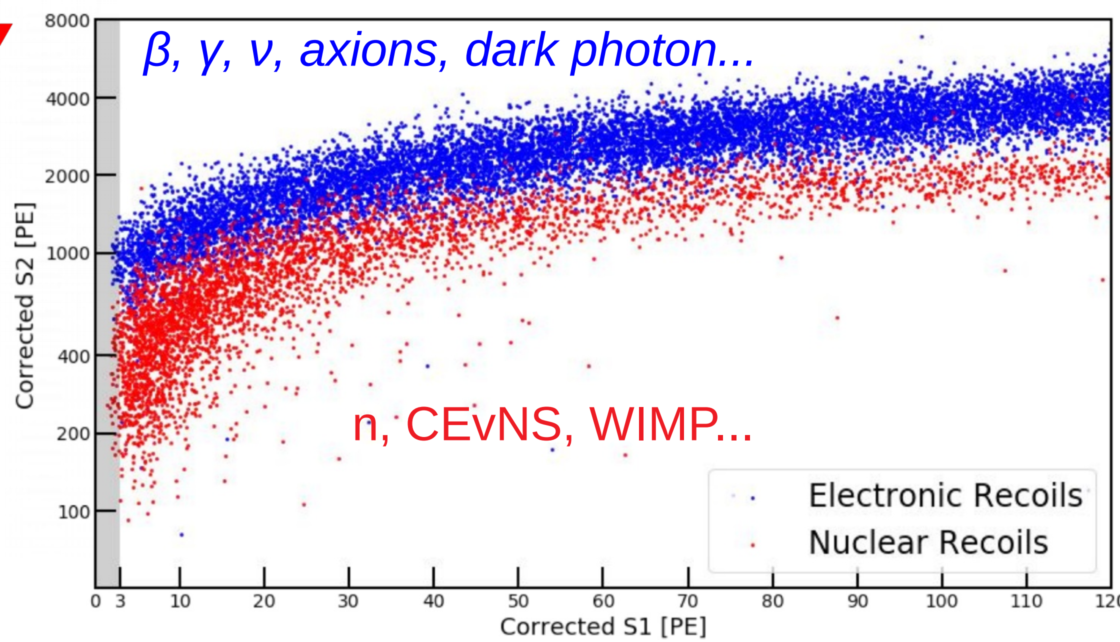


	XENON10	XENON100	XENON1T	XENONnT	DARWIN
Height	15 cm	30 cm	96 cm	148 cm	**2.6 m**
Diameter	20 cm	30 cm	97 cm	133 cm	**2.6 m**
Total mass	25 kg	161 kg	3.2 tons	8.3 tons	**50 tons**
Active mass	14 kg	62 kg	2.0 tons	5.9 tons	**40 tons**

Dual phase time projection chamber (TPC)



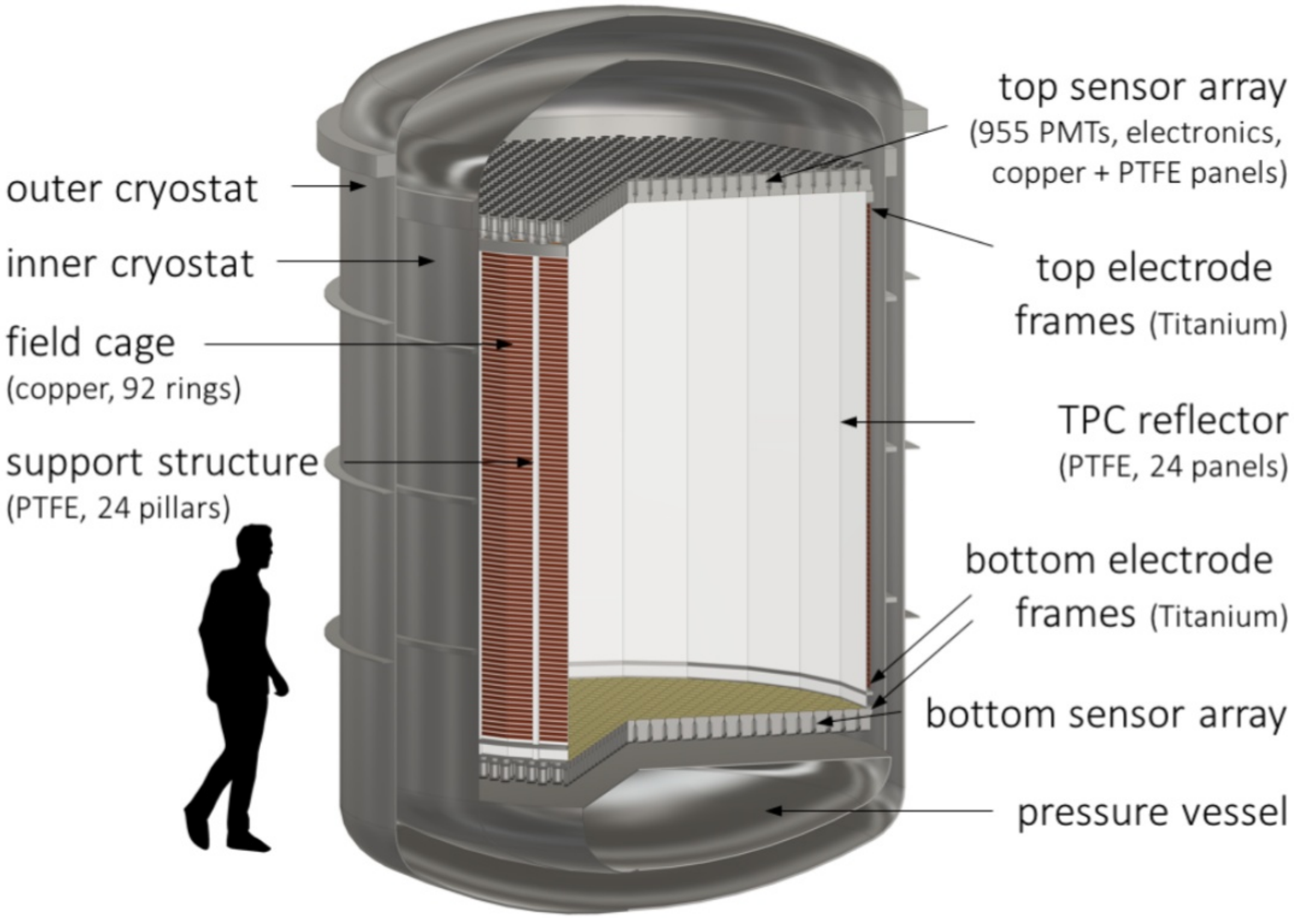
- Two distinct signals:
  - primary scintillation light → **S1**
  - delayed scintillation of electrons in gas after drift → **S2**
- Full 3D reconstruction:
  - S2 pattern → XY position
  - time between S2 and S1 → Z position



- S1 + S2 combination → improved energy resolution
- S2/S1 ratio for interaction type identification

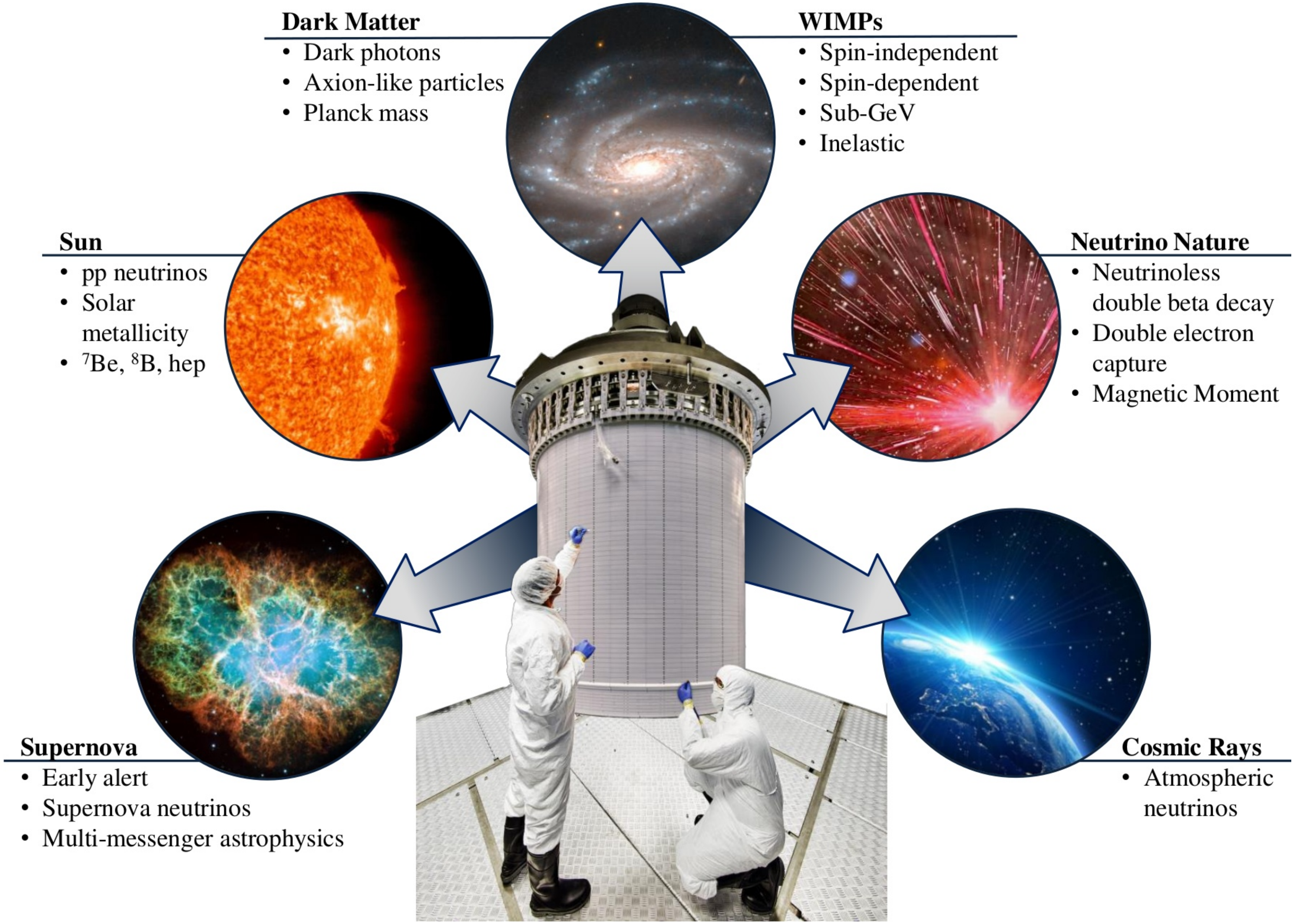
DARWIN “baseline” design

- Time-projection chamber
  - 40 “active” tons of LXe
  - 2.6 m in diameter and height
  - Baseline: 955+955 3” PMTs
  - PTFE reflectors for better light collection
- Goal – low background
  - Deep underground (3500 m.w.e @ LNGS, other labs in consideration)
  - Ultra-low background cryostat
  - Active and passive Rn mitigation
  - Outer neutron and muon veto

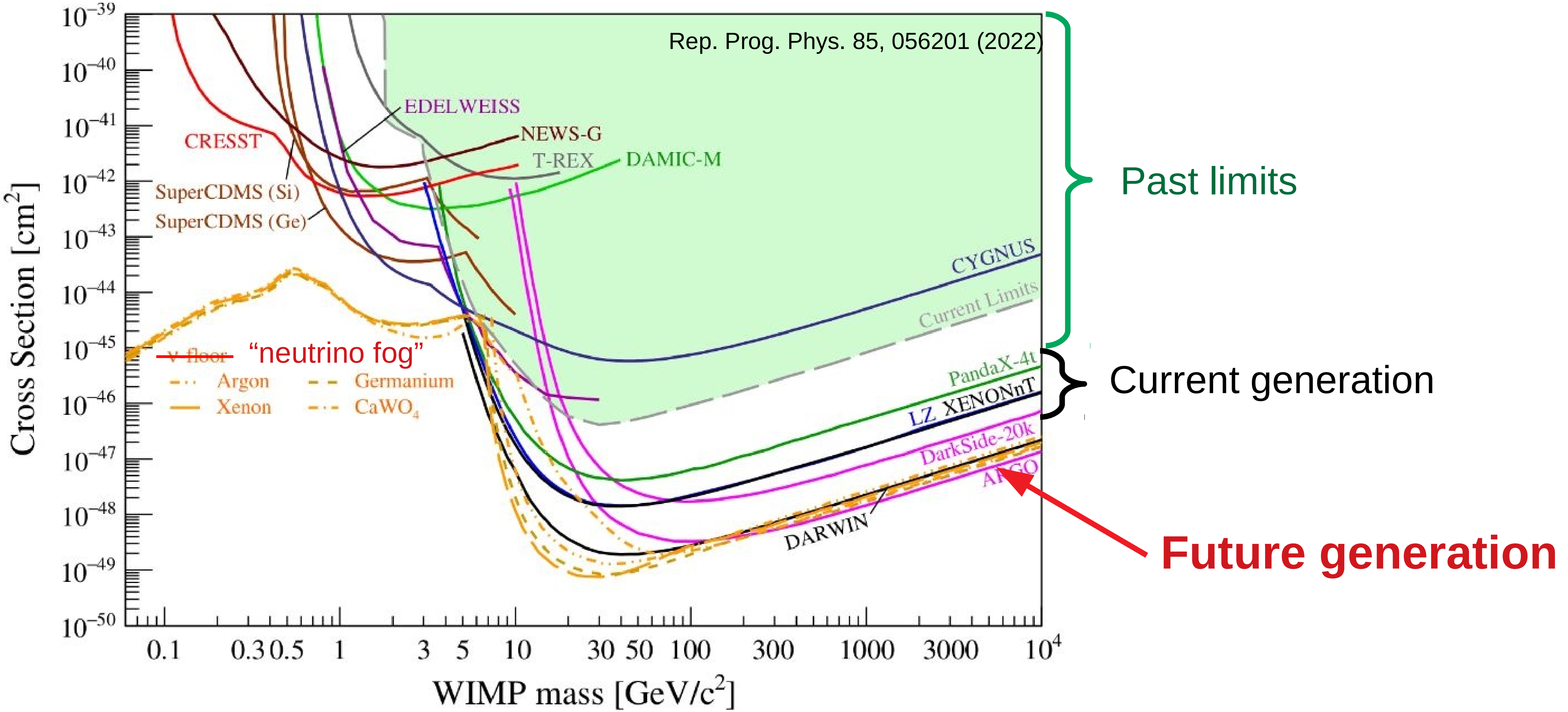


- Truly multi-purpose rare-event search experiment!

Rich physics reach



Ultimate WIMP sensitivity

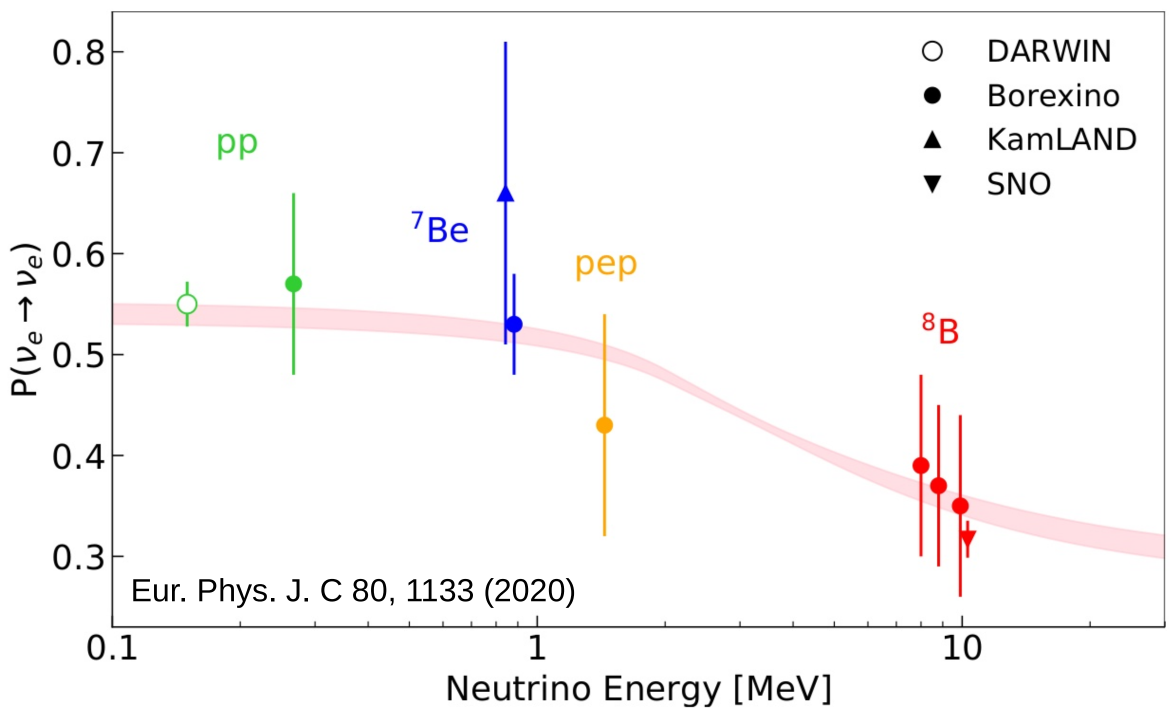


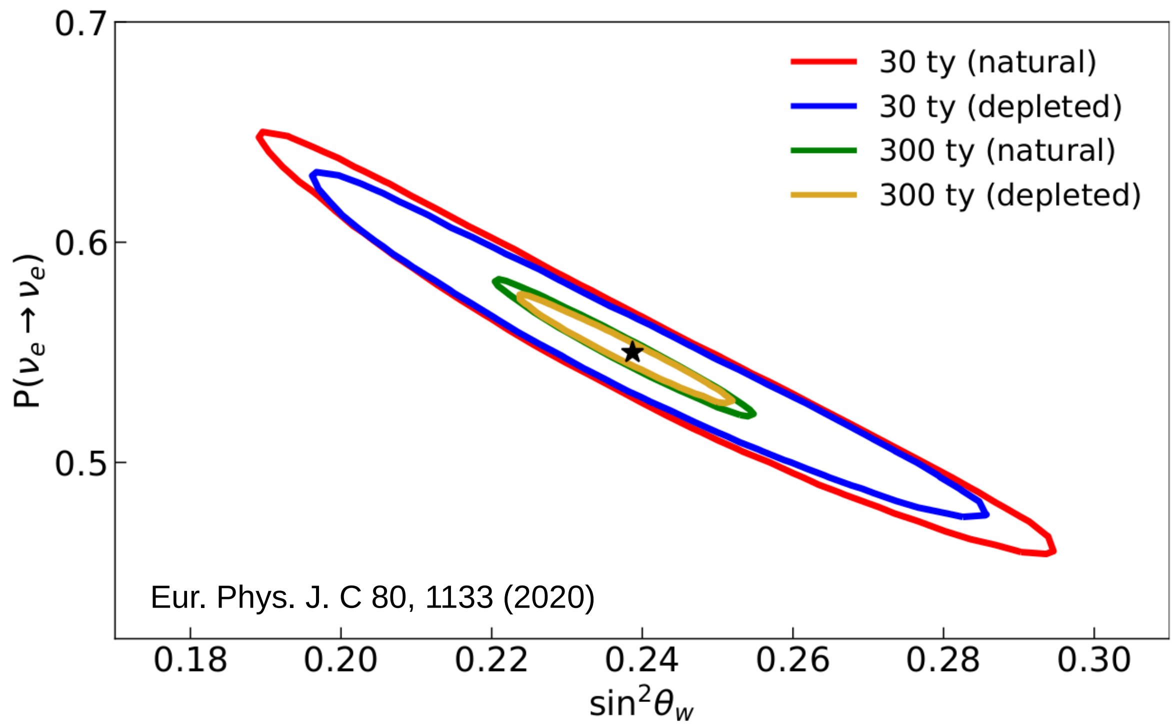
> Achieve "neutrino fog" with the next generation

> Ultimate sensitivity dominated by neutrino interactions

Solar neutrinos

- WIMP detectors → great tool for solar neutrino studies
- Detection via elastic electron-neutrino scattering
- Reach 0.15% with 300 ty exposure
- Measurement of electron neutrino survival probability and weak mixing angle



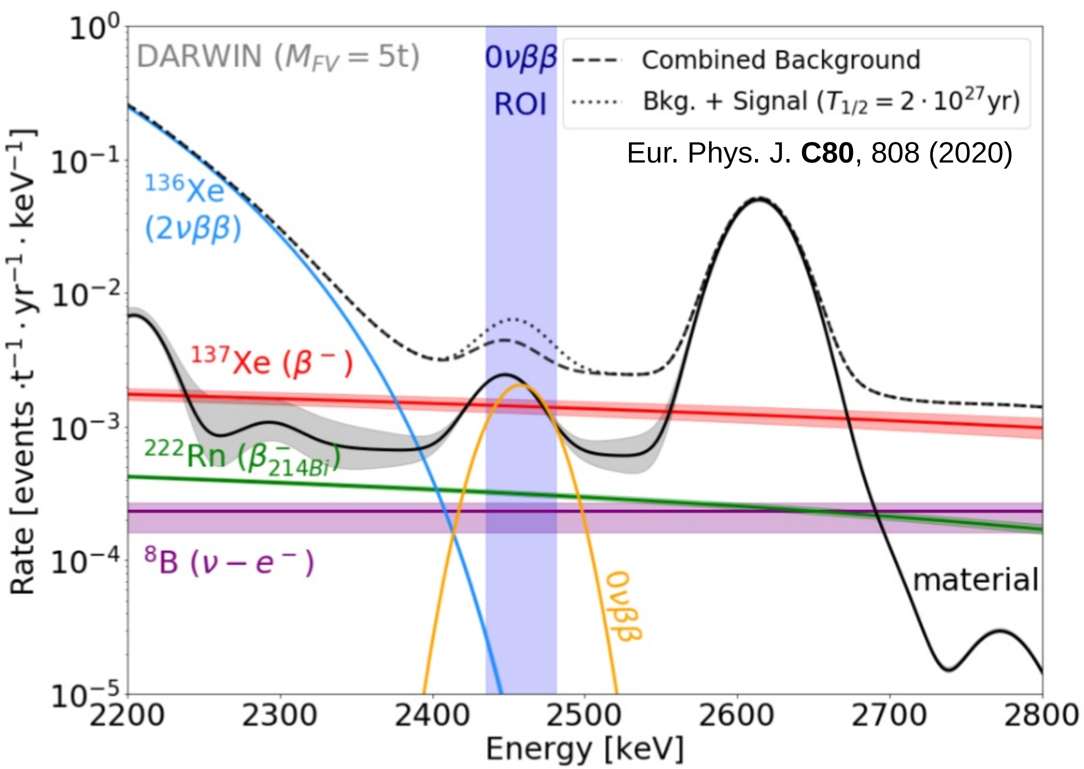


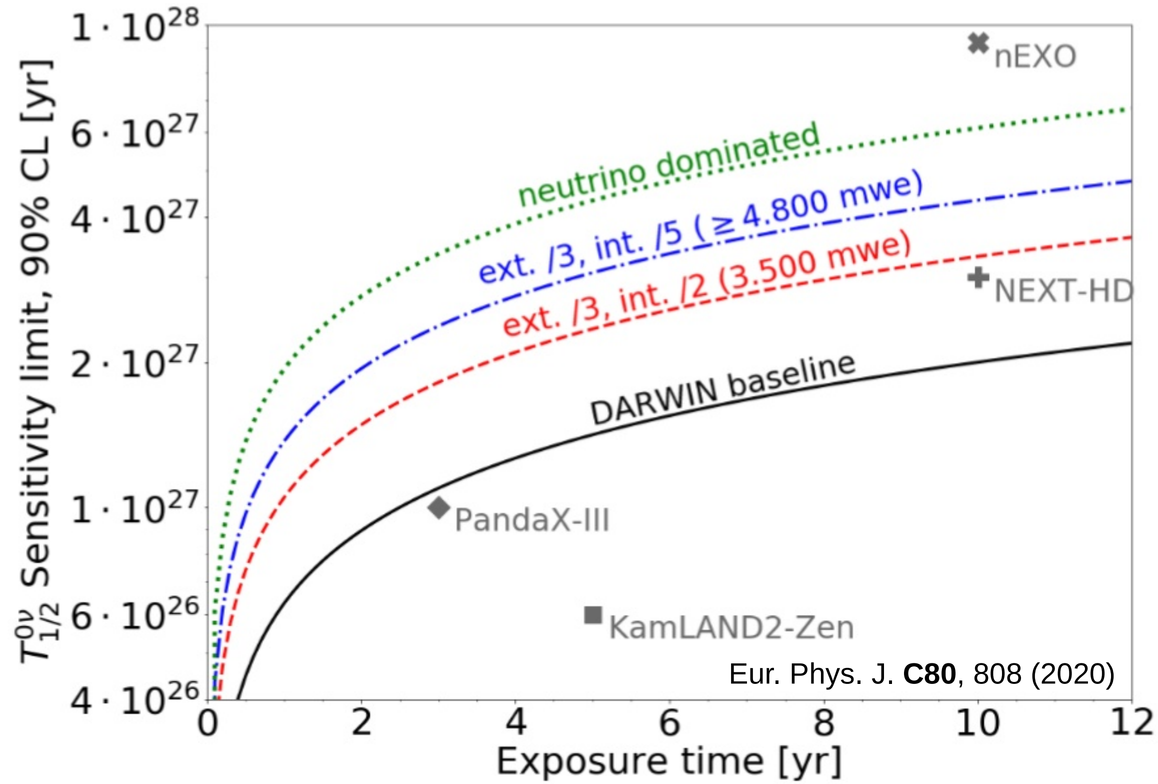
Neutrinoless double beta decay

- 8.9% of ^{136}Xe in natural xenon → 3.5 tonnes inside the TPC
- Projected sensitivity after 10 years:

$$T_{1/2} = 2.4 \cdot 10^{27} \text{ years (90 \% C.L.)}$$

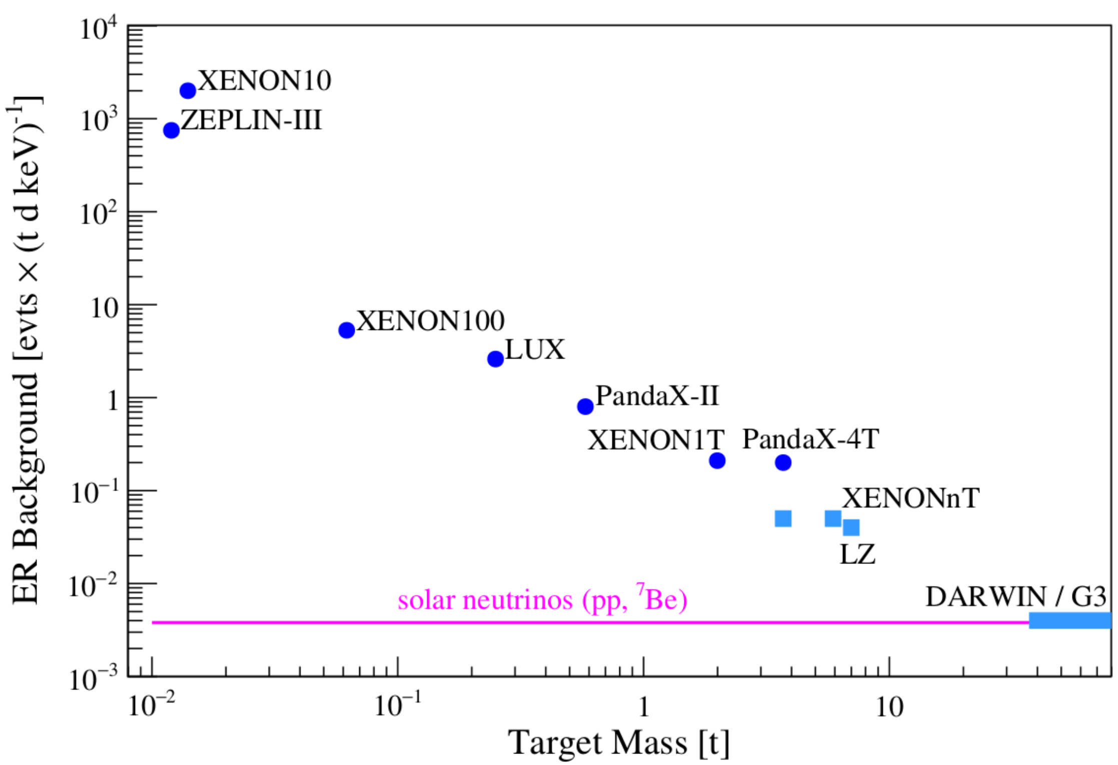
- Even better sensitivity if better background levels are achieved

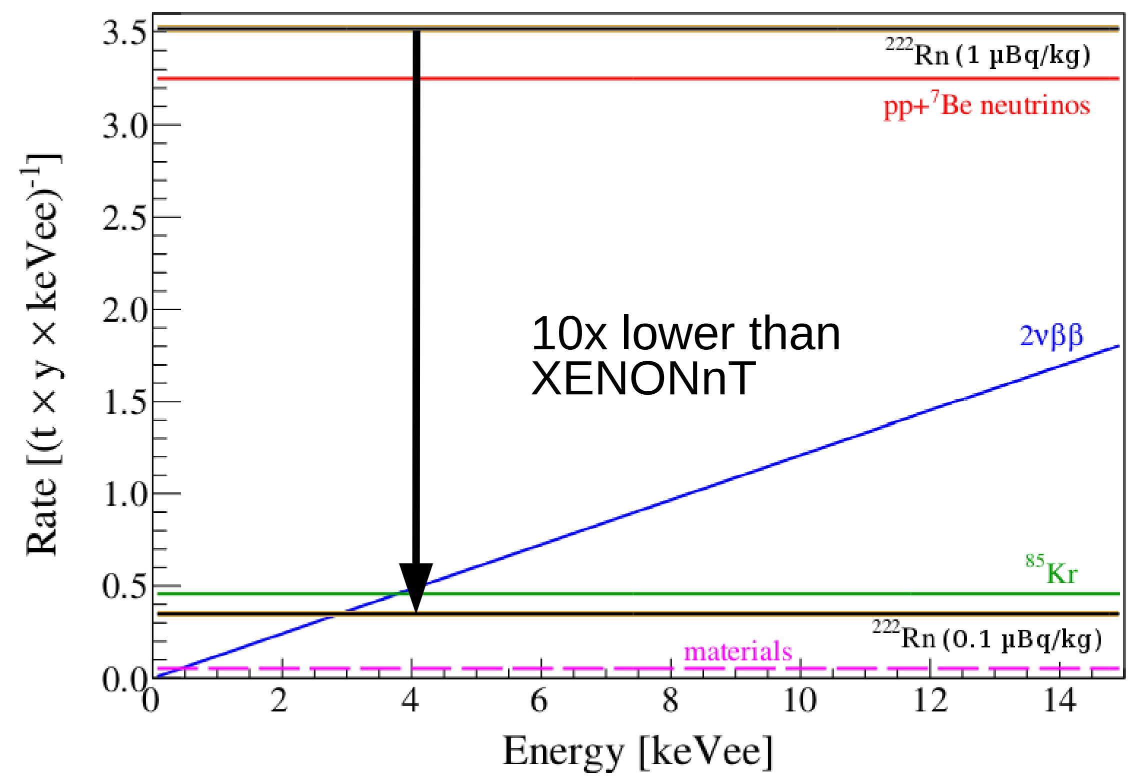




Radon background mitigation

- Radon – historically main background for Dark Matter searches
- DARWIN target: ER background dominated by neutrinos
  - Goal – 0.1 µBq/kg
  - Level below 1 µBq/kg achieved XENONnT
  - 10x improvement w.r.t. XENONnT

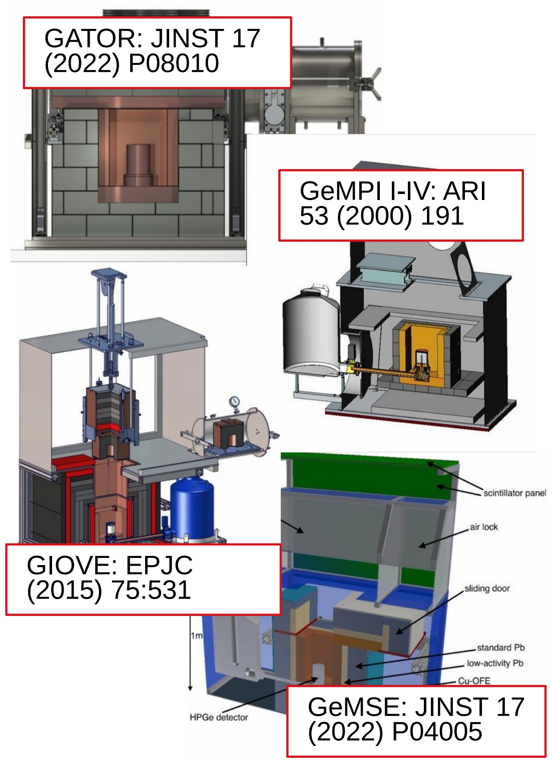




Radon mitigation strategy

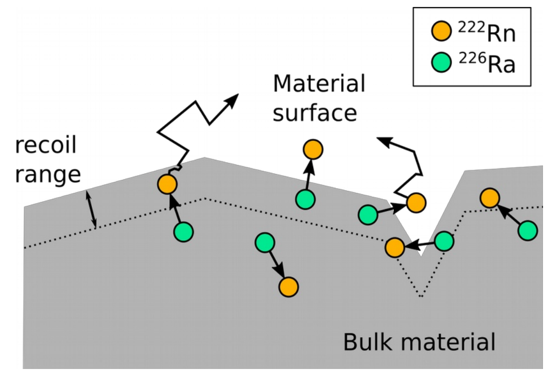
Material screening and selection

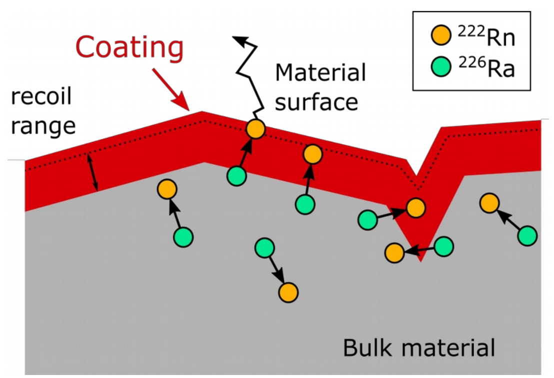
- avoid Rn at the first place
- multiple screening facilities available to DARWIN groups



Surface treatment

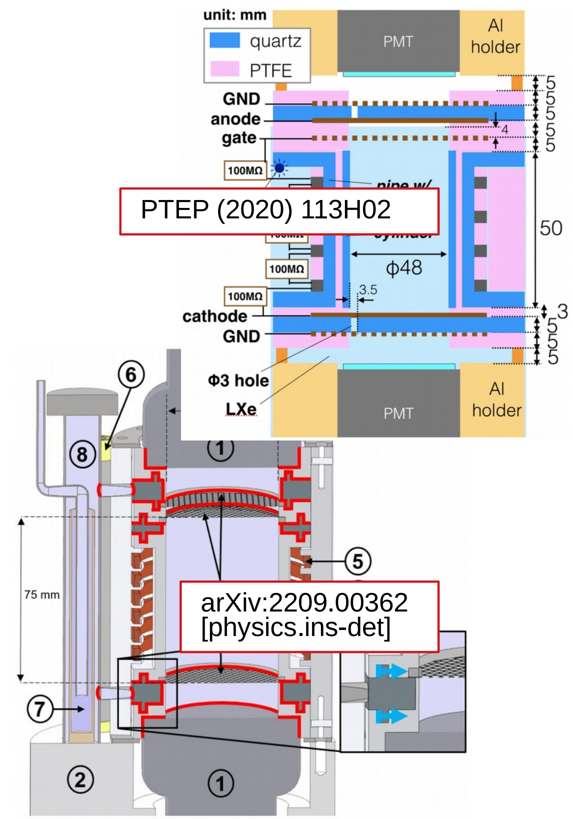
- "lock" Rn in materials
- active R&D for coating





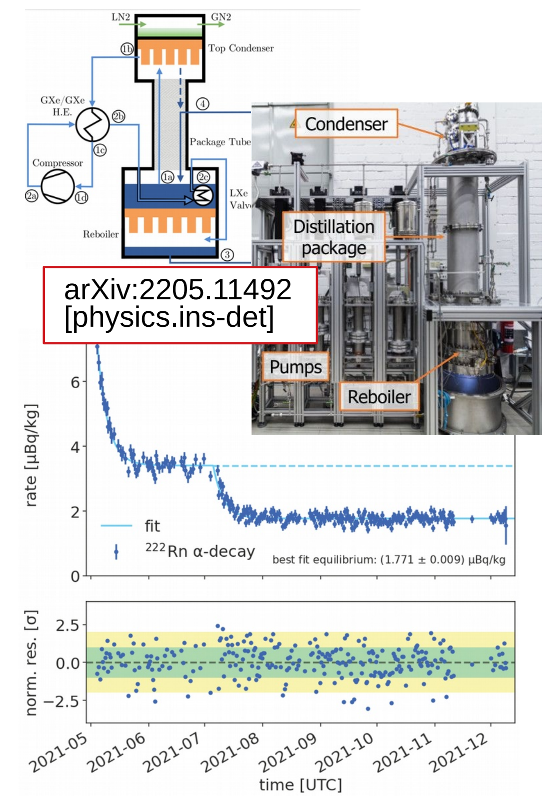
Detector design

- avoid Rn in active volume
- R&D for hermetic TPC



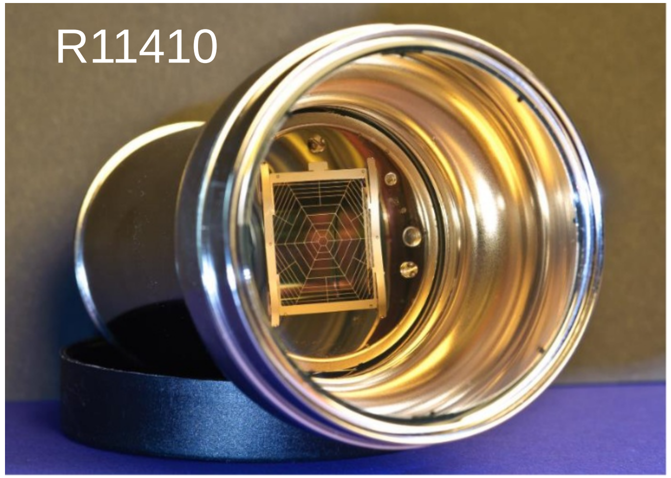
Radon removal

- remove Rn from the detector
- distillation column performs well in XENONnT



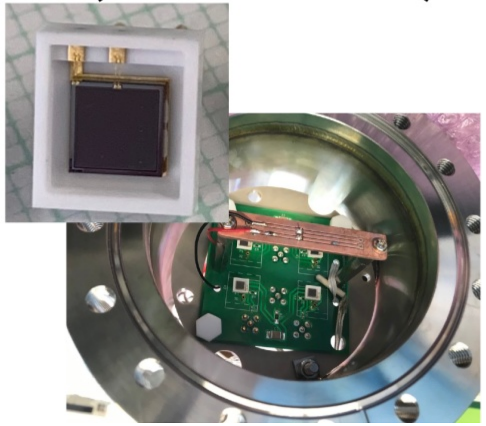
Light sensor R&D

> "Baseline" design with PMTs
  - 3" PMTs R11410 (XENONnT, LZ)
  - reliable well-tested solution
  - But: relatively "dirty"

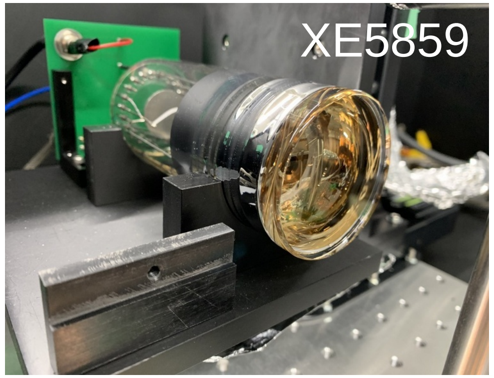


> Clean PMT alternative?

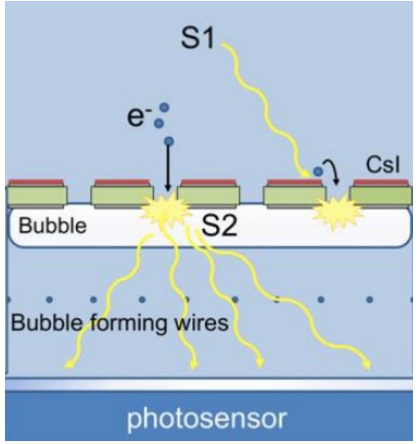
> Silicon PMs



> Hybrid sensors?



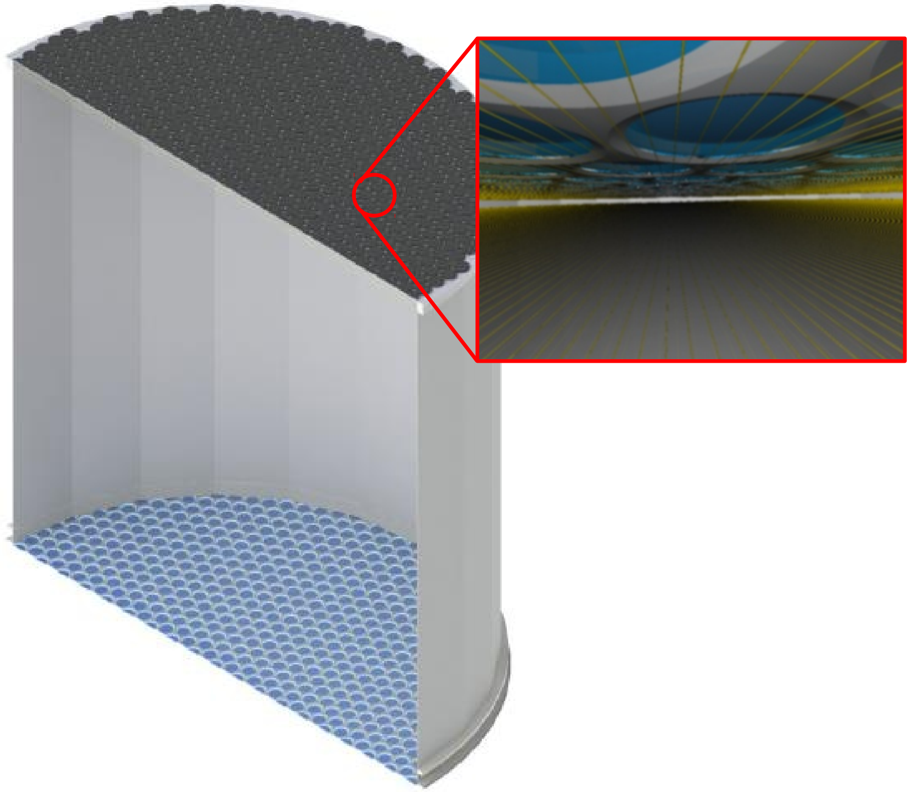
> Liquid hole multipliers?



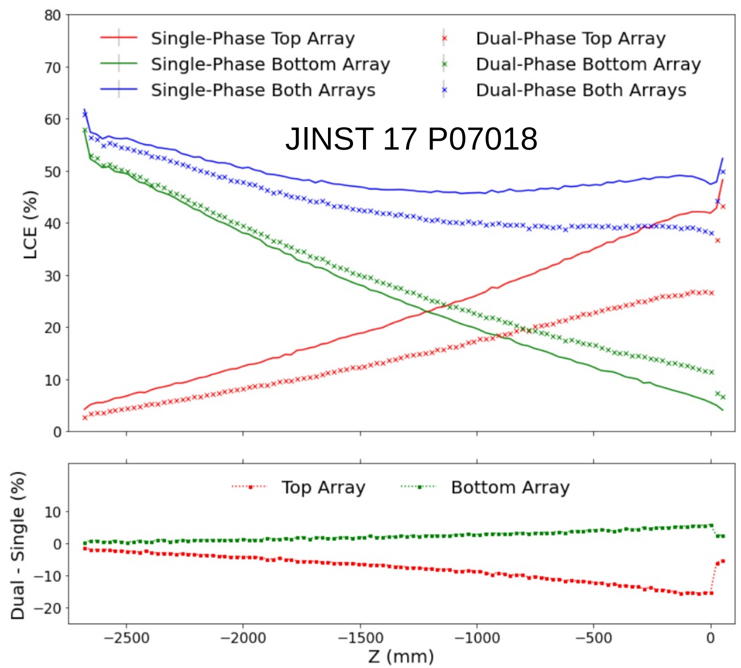
> Current R&D on quantum efficiency, dark count rates, radioactivity, operations…

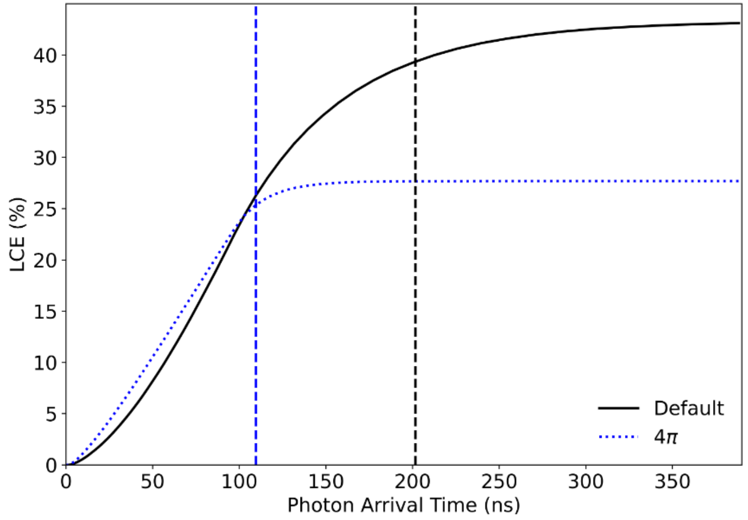
Simulation tools development

- Cross validation of CPU (Geant4) and GPU (Chroma) optical simulations to a percent level.



Component	Absorbed photons, %
LXe (L_{abs} = 50 m)	**22.7**
Electrodes	**18.0**
Gate	7.7
Cathode	3.1
Bottom screen	2.6
Anode	1.7
Top screen	1.6
Frames	1.3
PMTs	**9.0**
Bottom PMTs	6.3
Top PMTs	2.7
PTFE reflectors	**7.2**
Total	**56.9**





- Essential tool for detector design:
  - Sensor type/placing, coating, 4pi geometry, single/dual phase
  - Understanding limitations and improvement possibilitites

Addressing the scale

- PANCAKE test platform in Freiburg:
  - 2.7 m diameter, 5 cm LXe height
  - test horizontal components – real scale frames, electrodes etc.

- Xenoscope in Zurich:
  - 16 cm inner diameter, up to 2.6 m LXe height
  - Full scale electron drift demonstration – high voltage, drift field properties, purity etc

XENON+LZ+DARWIN = XLZD

- Future merger of collaborations for the next-generation LXe observatory
- Forming XLZD consortium
  - currently 104 group-leaders in 16 countries
  - joint “white paper” on physics reach
  - first in-person meeting at KIT in June 2022
- Follow us at: XLZD.org

XLZD consortium meeting
KIT, June 2022

Summary

- DARWIN – truly multi-purpose detector with extensive physics reach:
  - Dark Matter search
  - solar neutrinos
  - neutrinoless double beta decay
  - supernova neutrinos
  - axions, neutrino magnetic moment
- Active R&D and design phase
  - radiopurity mitigation
  - light sensor development
  - mechanical and engineering studies
  - simulation techniques
- New consortium for next generation LXe observatory XLZD (XENON+LZ+DARWIN)

A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics

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For more physics topics – community paper: arXiv:2203.02309 [physics.ins-det]