DARWIN :
an astroparticle physics observatory

@ KIT & Subatech

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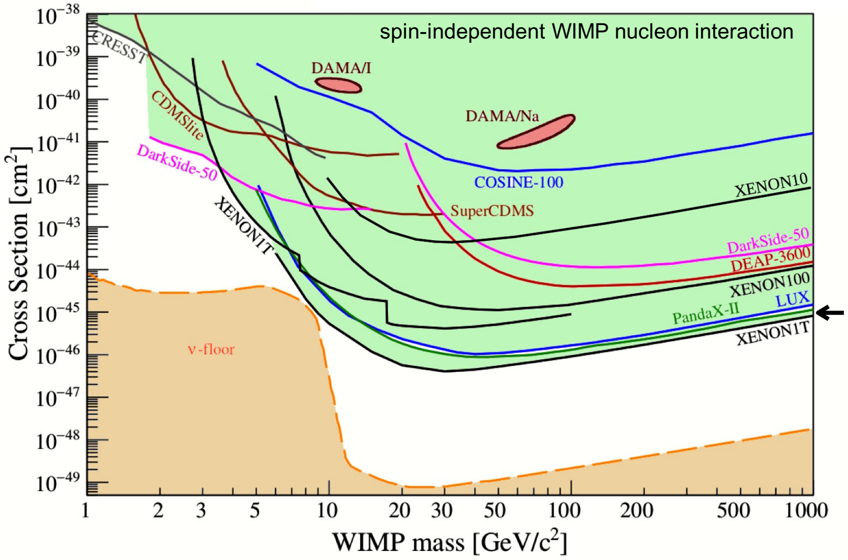
WIMP Detection landscape today

- The highest sensitivity above 2 GeV/c^2 comes from experiments using liquid noble gases as target (Xe, Ar). (heavy target and easy scalability)
- **DARWIN**, the ultimate LXe WIMP detector, with **50t of total mass**, plans to increase 100-fold the current sensitivity.



Current Limit (1 t×y)

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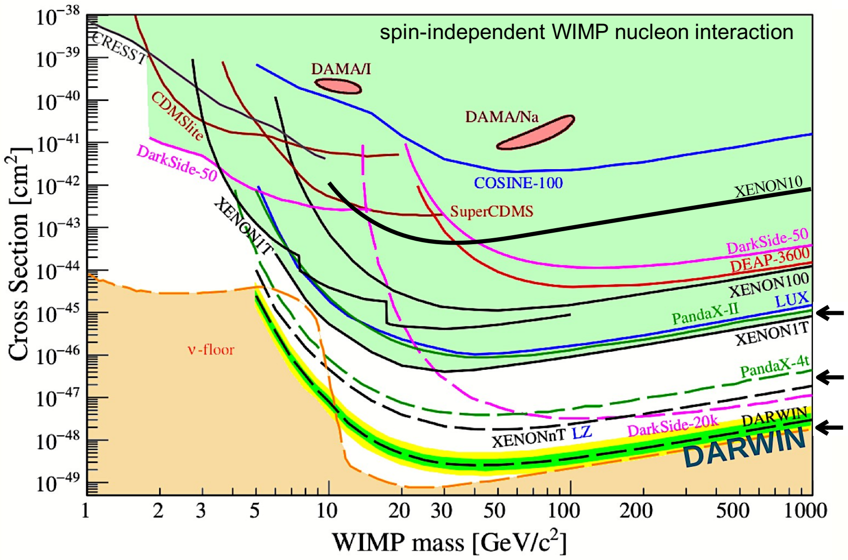


Current Limit (1 t×y)

Near Future Sensitivity

DARWIN

sensitivity limited by he neutrino floor (200 t×y)

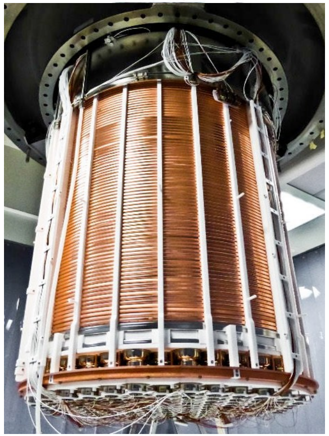
Phases of the XENON Program

XENON10
2005 – 2007
15 cm drift TPC
Total: 25 kg
Target: **14** kg
Fiducial: 5.4 kg

Achieved (2007)
$\sigma_{SI} = 8.8 \cdot 10^{-44}$ cm^2
@ 100 GeV/c^2

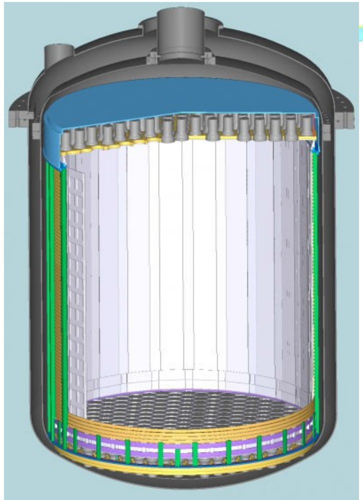
XENON100
2008 – 2016
30 cm drift TPC
Total: 161 kg
Target: **62** kg
Fiducial: 34/48 kg

Achieved (2016)
$\sigma_{SI} = 1.1 \cdot 10^{-45}$ cm^2
@ 55 GeV/c^2



XENON1T
2011 – 2018
100 cm drift TPC
Total: 3 200 kg
Target: **2 000** kg
Fiducial: 1 300 kg

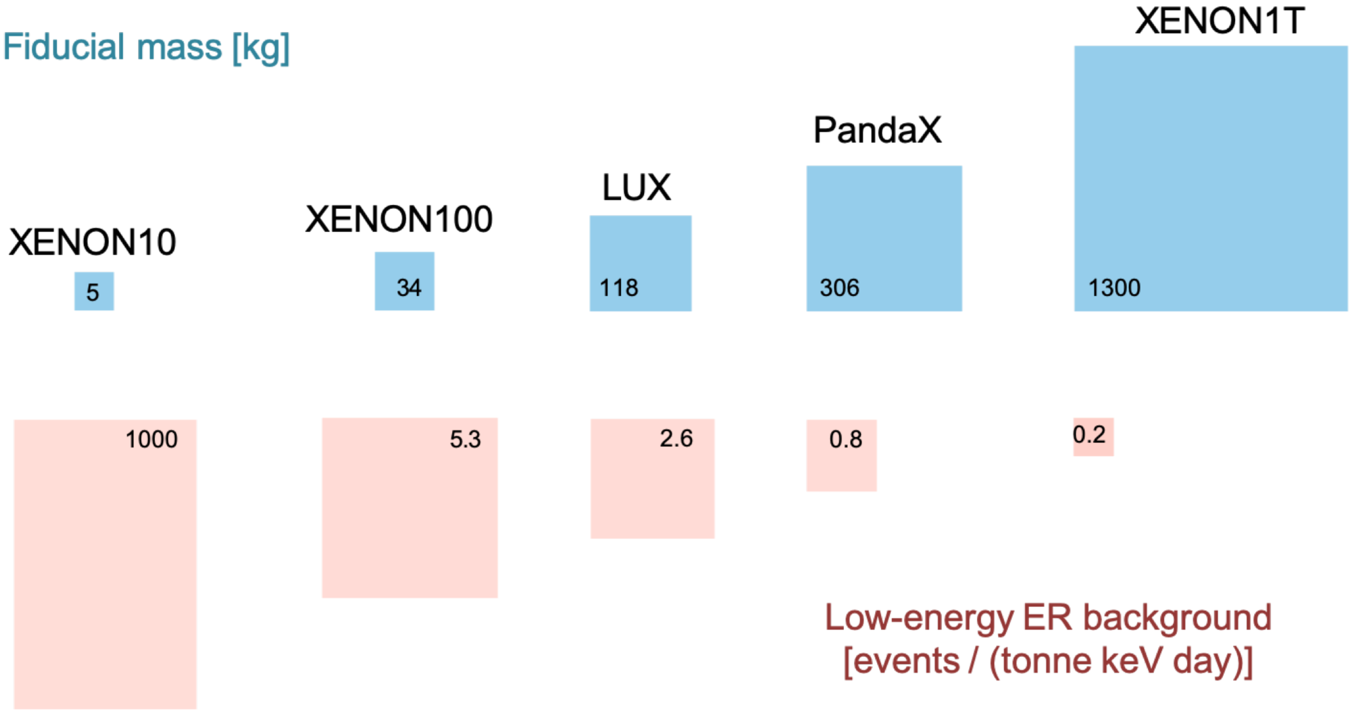
Achieved (2018)
$\sigma_{SI} = 4.1 \cdot 10^{-47}$ cm^2
@ 30 GeV/c^2



XENONnT
2019 – 2025
150 cm drift TPC
Total: 8 400 kg
Target: **5 900** kg
Fiducial: ~ 4 000 kg

Projected
$\sigma_{SI} = 1.6 \times 10^{-48}$ cm^2
@ 50 GeV/c^2

Evolution of LXe TPC as WiMP detectors



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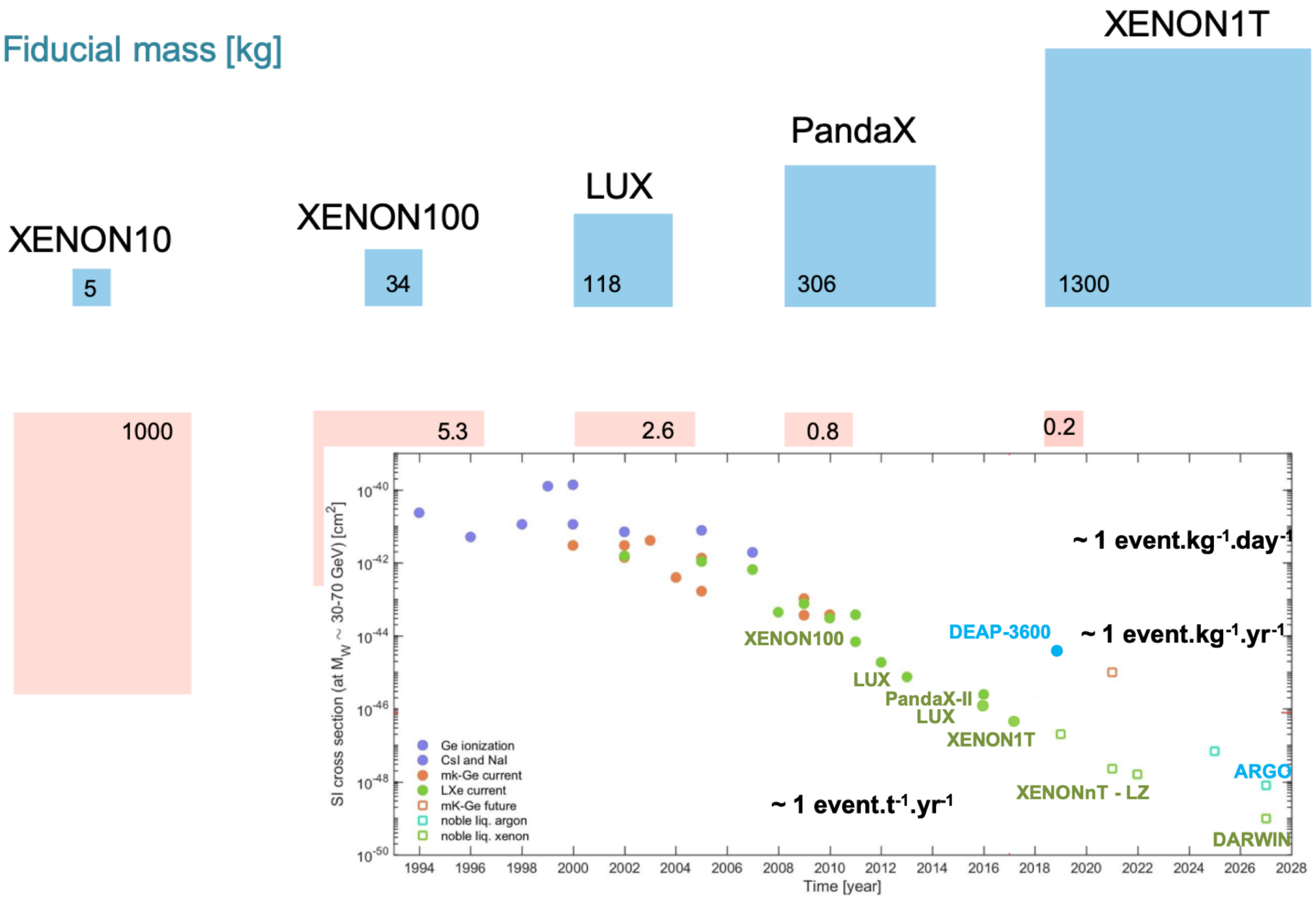
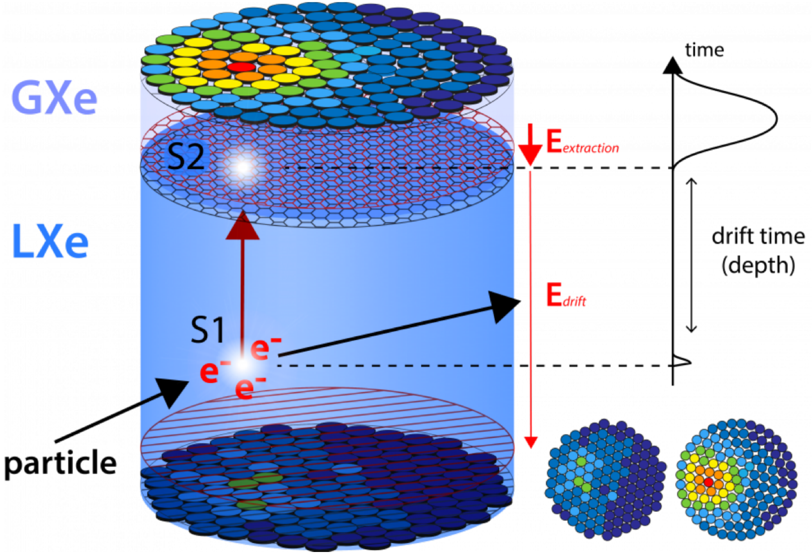


Dual phase TPC: principle

TPC = Time Projection Chamber

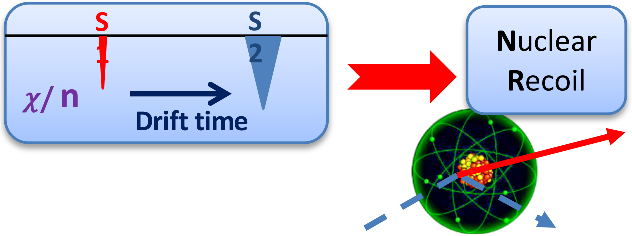


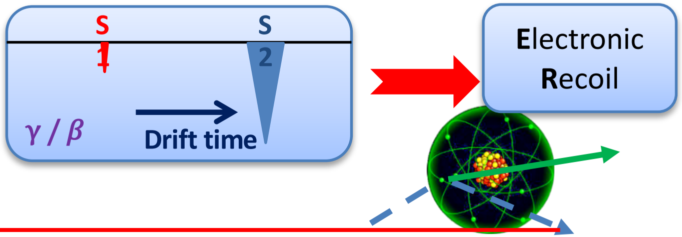
S1:
→ Photon (λ = 178 nm) from Scintillation process

S2:
→ Electrons drift
→ Extraction in gaseous phase
→ Proportional scintillation light

3D reconstruction :
→ X,Y from top array
→ Z from Drift time

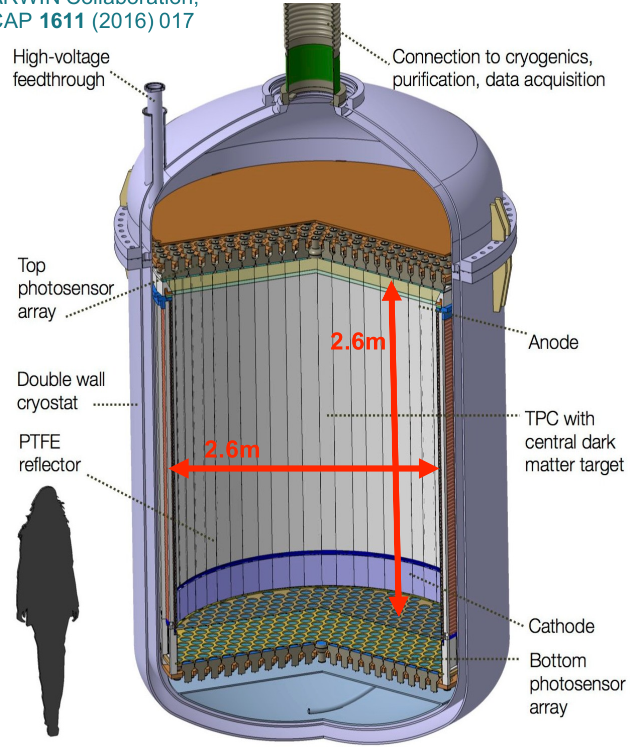
$$(S2/S1)_{WIMP,n} < (S2/S1)_{\gamma,\beta}$$





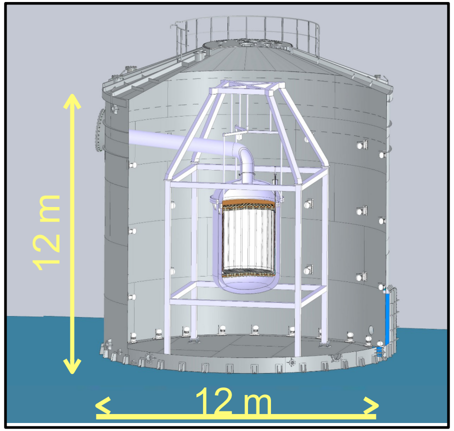
DARWIN Baseline design

DARWIN Collaboration,
JCAP **1611** (2016) 017



baseline design with PMTs but several alternatives under consideration

- Dual-phase Time Projection Chamber (TPC).
- 50t total (**40t active**) of liquid xenon (LXe).
- Dimensions: **2.6 m diameter and 2.6 m height.**
- Two arrays of photosensors (top and
- bottom). 1910 PMTs of 3” diameter.
- Low-background double-wall cryostat.
- PTFE reflector panels & copper shaping
- rings. Outer shield filled with water (12 m diameter).



Possible realization of DARWIN inside the water tank

WIMP Detection landscape today

Ultra-low Background —— Large Target (40t) —— Low Energy Threshold

DIRECT DETECTION OF DARK MATTER

DARWIN

much more than a dark matter detector

SOLAR AXIONS

NEUTRINOLESS DOUBLE-BETA DECAY ^{136}Xe

GALACTIC AXION-LIKE PARTICLES

LOW-ENERGY SOLAR NEUTRINOS

BOSONIC SUPERWIMPs

GALACTIC SUPERNOVA NEUTRINOS

CNNS

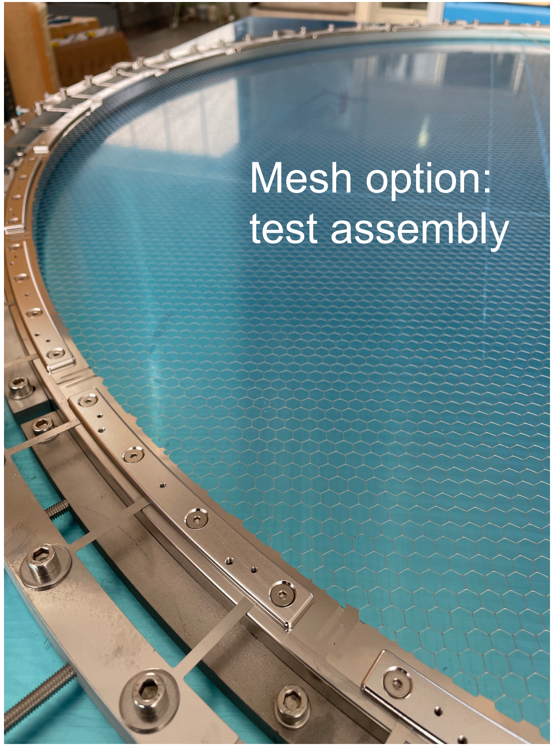
DMLab Current Work

Taken from DMLab White paper

Work in progress

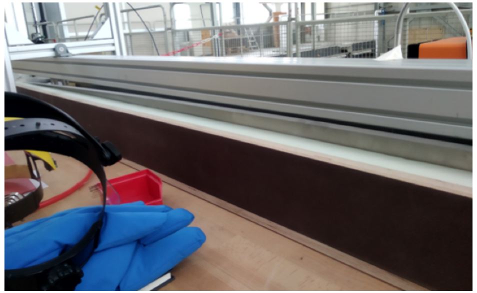
- design of the large-scale TPC including high-voltage electrode systems, the PTFE frame of the TPC body, and material characterisation (involved teams in the IRL: IJCLab and KIT);
- technology development for the high-performance cryogenics (storage & recovery) and purification systems of the 50-ton volume of liquid xenon (involved teams in the IRL: Subatech, LPNHE and KIT);
- sensitivity and analysis studies for DARWIN on dark matter and neutrino physics (involved teams in the IRL: IJCLab, KIT, LPNHE, and Subatech).

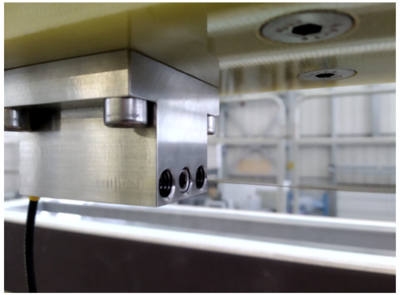
Development of large-scale electrodes: simulation and hardware



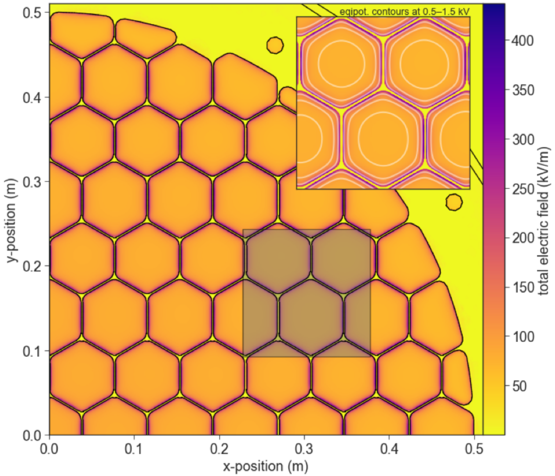
Mesh option:
test assembly

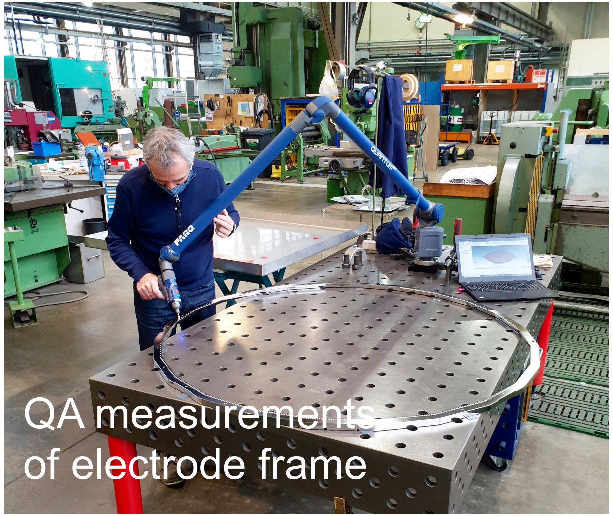
Wire option:
thermal stress test with
long LN_2 bathtub





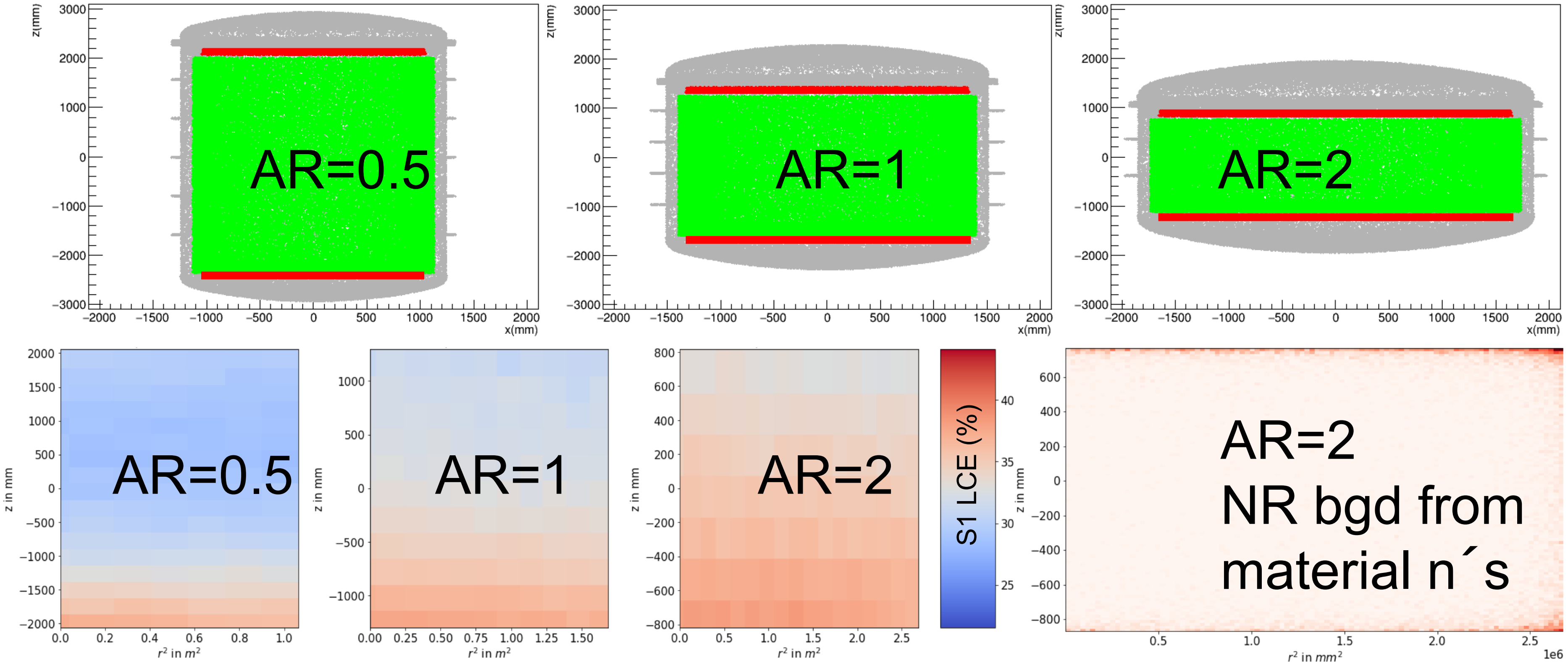
Mesh option:
simulation





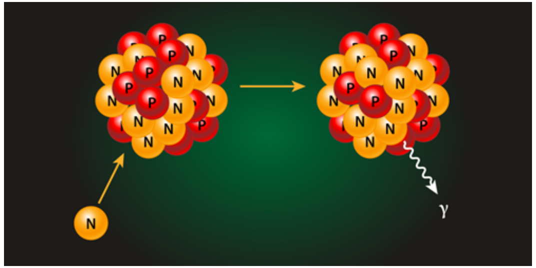
QA measurements
of electrode frame

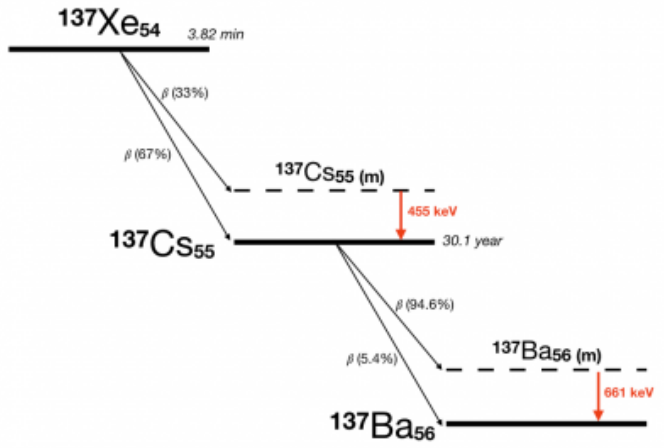
Optimisation of the TPC geometry (aspect ratio)



Neutron capture : ^{137}Xe

Eur. Phys. J. C 80, 808 (2020)





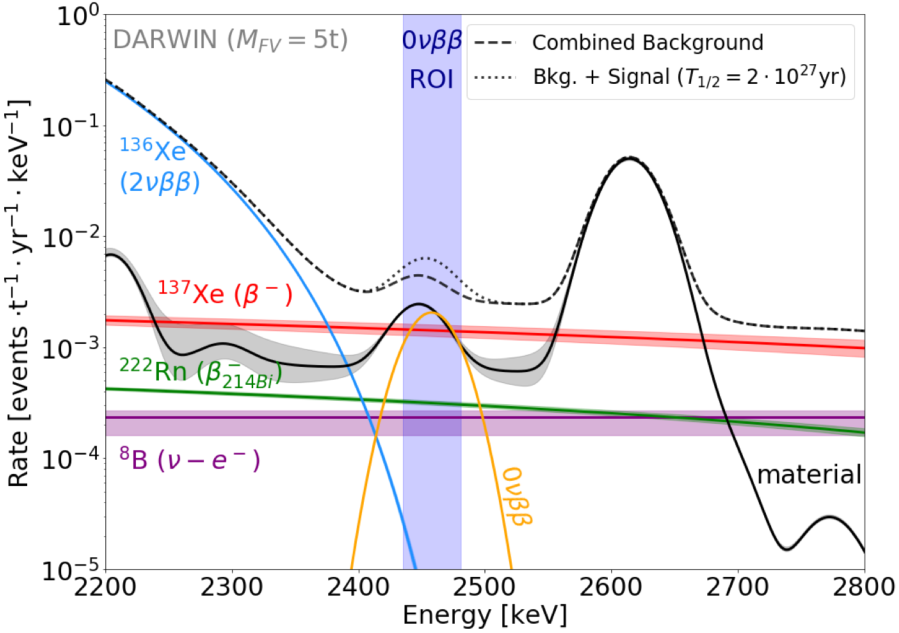
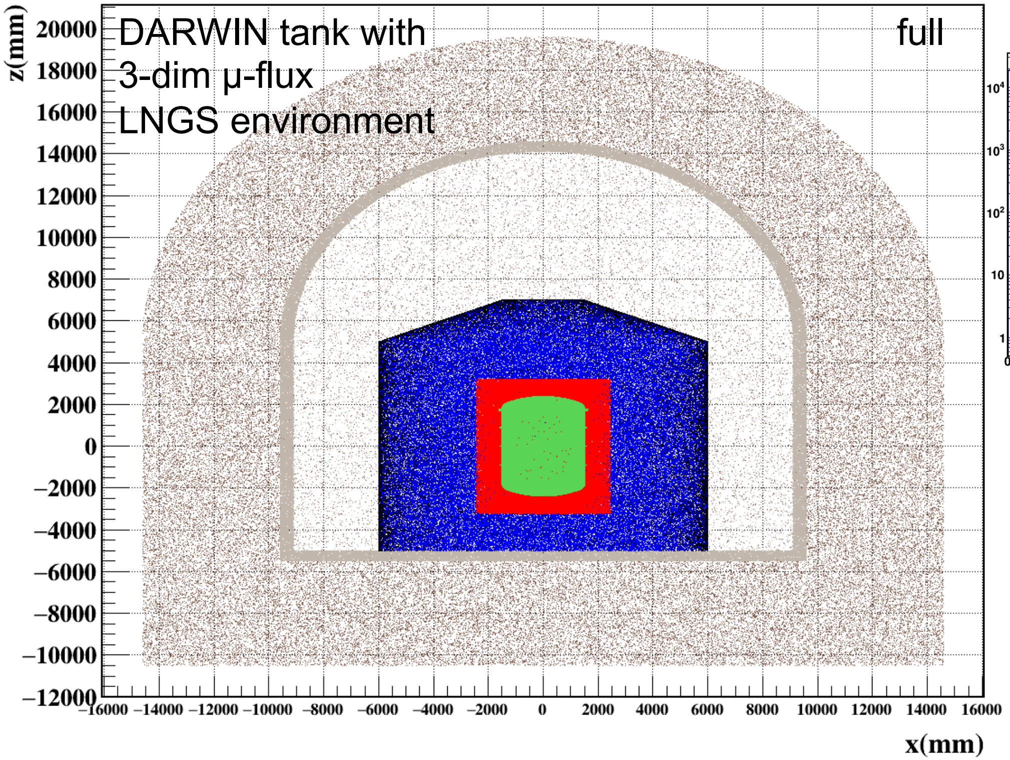
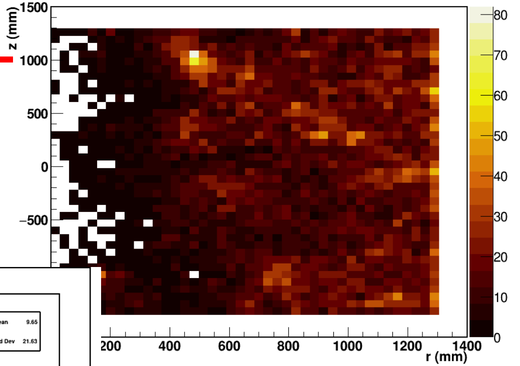


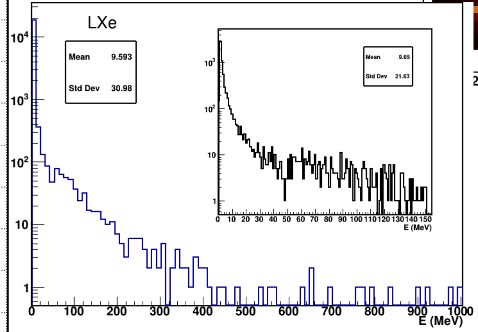
Fig. 7: Predicted background spectrum around the $0\nu\beta\beta$-ROI for the 5 t fiducial volume. A hypothetical signal of 0.5 counts per year corresponding to $T^{0\nu}_{1/2} \approx 2 \times 10^{27}$ yr is shown for comparison. Bands indicate $\pm 1\,\sigma$ uncertainties.

Simulation of muon-induced background

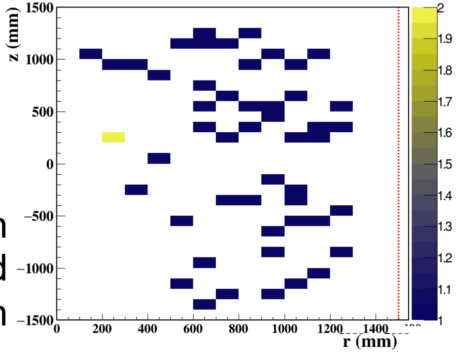




position of μ-induced n´s entering the TPC

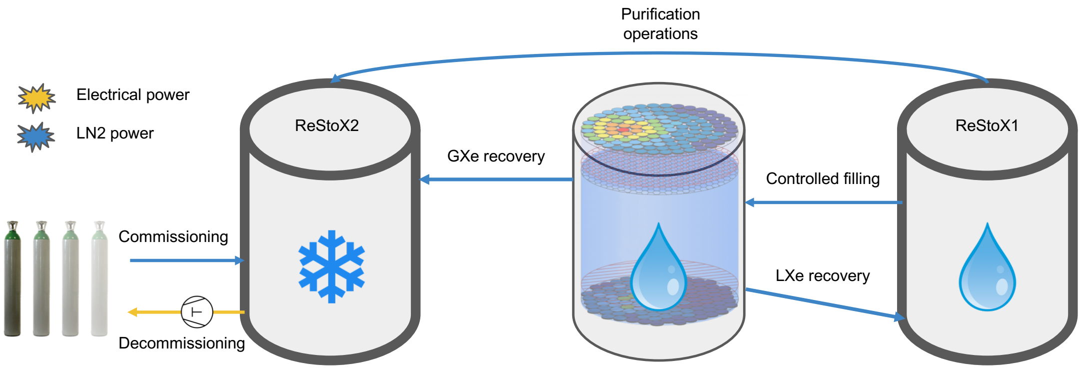


energy of μ-induced n´s produced/entering the TPC



^{137}Xe production through μ-induced spallation

Storage & recovery



Bottles
- O(200) bottles
- Low purity

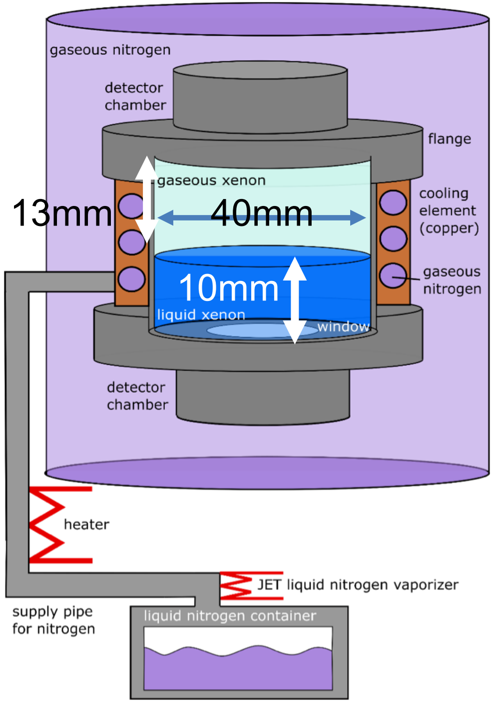
Warm/freeze storage
- Cold on demand
- Fast gas recovery (>1 ton/h)
- Cryo-pumping

Cryostat
- Stable data taking
- 8 ton LXe
- Overpressure hazard

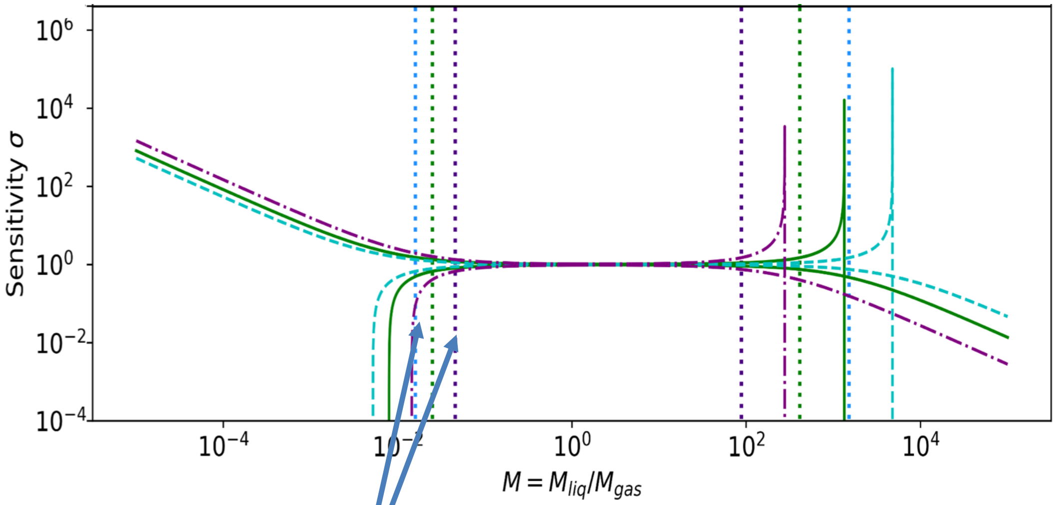
Cold storage
- Always cold
- Stable PT conditions
- Gravity liquid recovery (>>1 ton/h)

ReStoX 2

Conceptual design to determine the solubility of tritiated molecules in liquid Xe



β-induced X-ray spectrometry (*BIXS*) via Si pixel det. vs. **PMT readout**

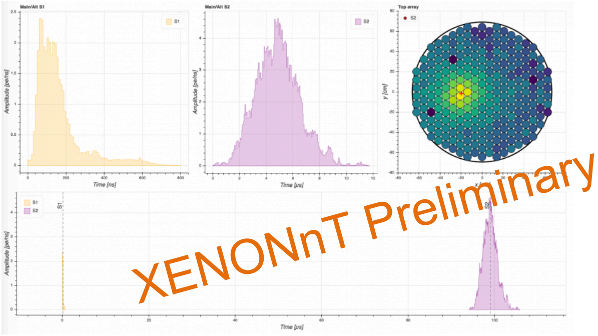


100% stat. uncertainty for various design geometries (aperture, reflectivity)

Summary and outlook

- Xenon based Dual-Phase Time Projection Chamber has proven to be the **leading technology** in the field of direct Dark Matter searches.

- XENONnT **started its physics program**, and aims to improve the results of its predecessor and answer to the Low-ER excess question.



- DARWIN will be **much more than the ultimate LXe-based dark matter detector**

  ➔ large detector with ultra-low backgrounds, very good energy resolution, low energy threshold

- There are a lot of connexions which we can exploit and we hope that **DARWIN can profit from DMLab**, and **DMLab can profit from DARWIN** and its connexions and the already existing work which we want to intensify