Analysis of S1 Triplet Component in Darkside-50 Dark Matter Experiment

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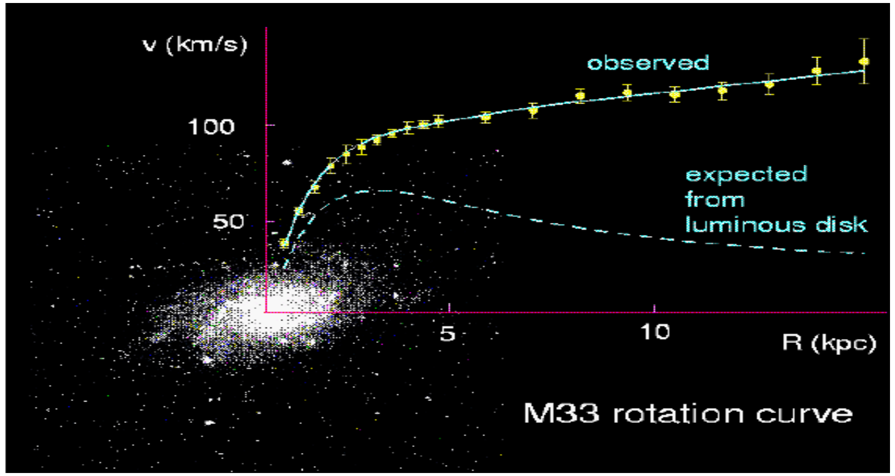
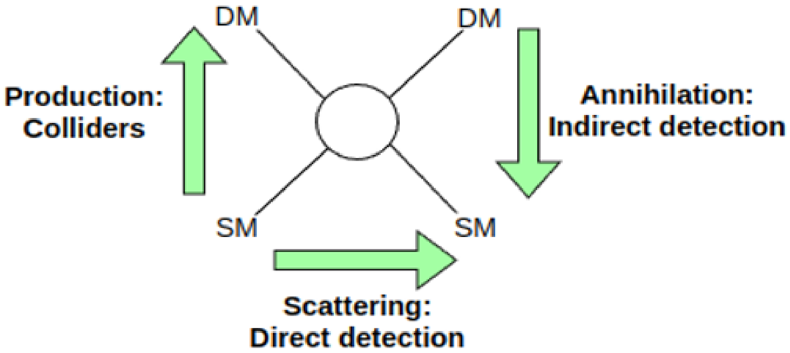
A search for WIMPs

- **Dark matter (DM)**: Cold, weakly-interacting, non-baryonic particle.
- Observational evidence: Galactic rotation curves, anisotropies in CMB radiation, bullet clusters, etc.
- Plethora of candidates: WIMPs, Axions, MACHOs, etc.
- **WIMPs** (**Weakly Interacting Massive Particles**) – A promising candidate well motivated by theories.
- WIMP search - Colliders, **Direct detection**, indirect detection.

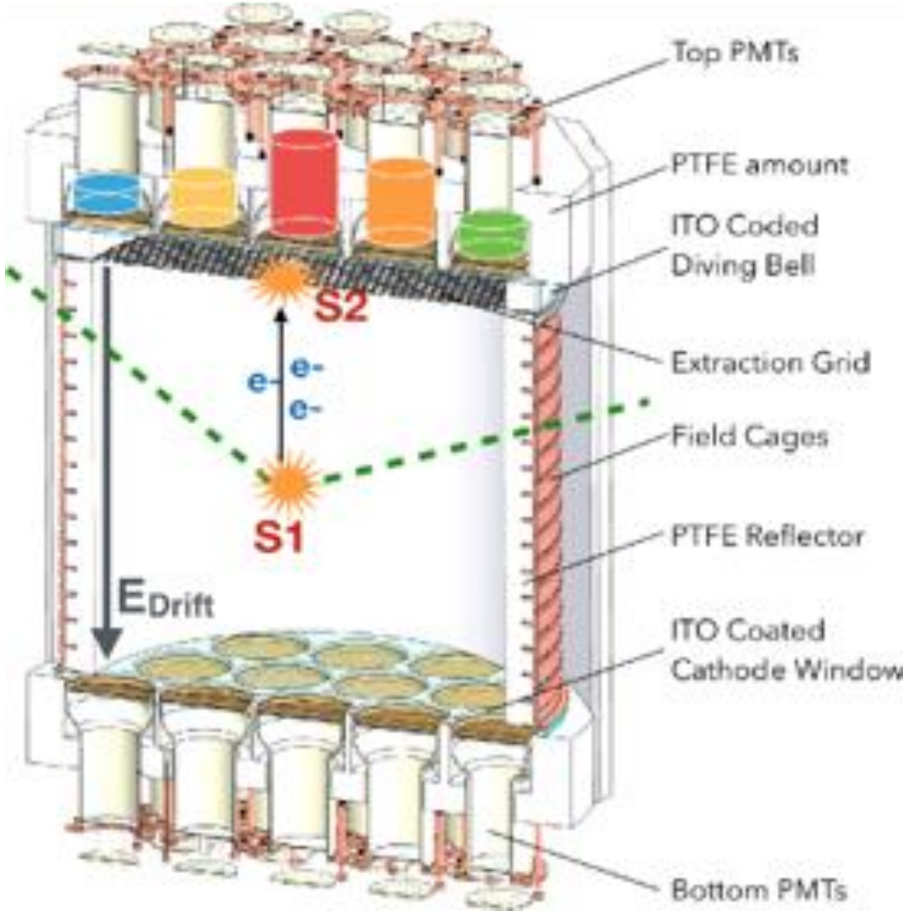


https://www.researchgate.net/figure/The-observed-rotation-curve-of-the-dwarf-spiral-galaxy-M33-extends-considerably-beyond_fig1_1797711



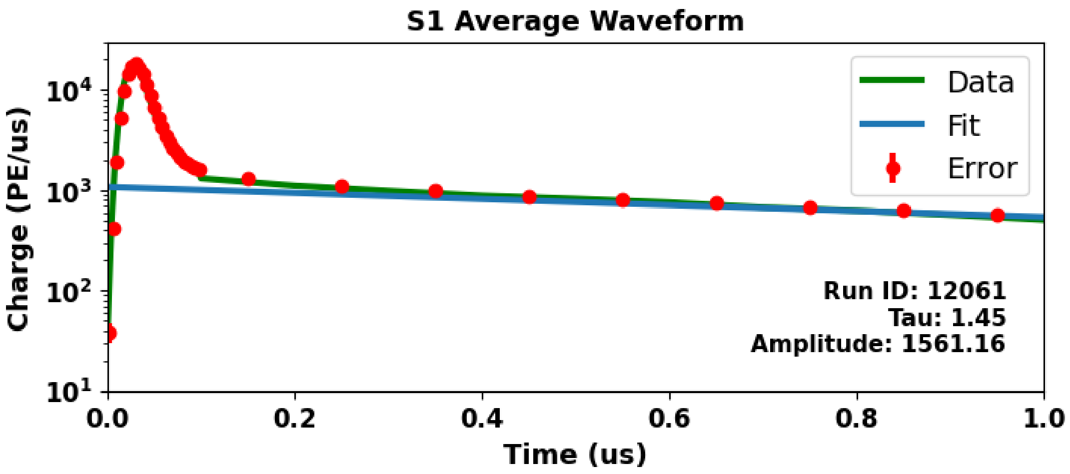
The darkside-50 experiment

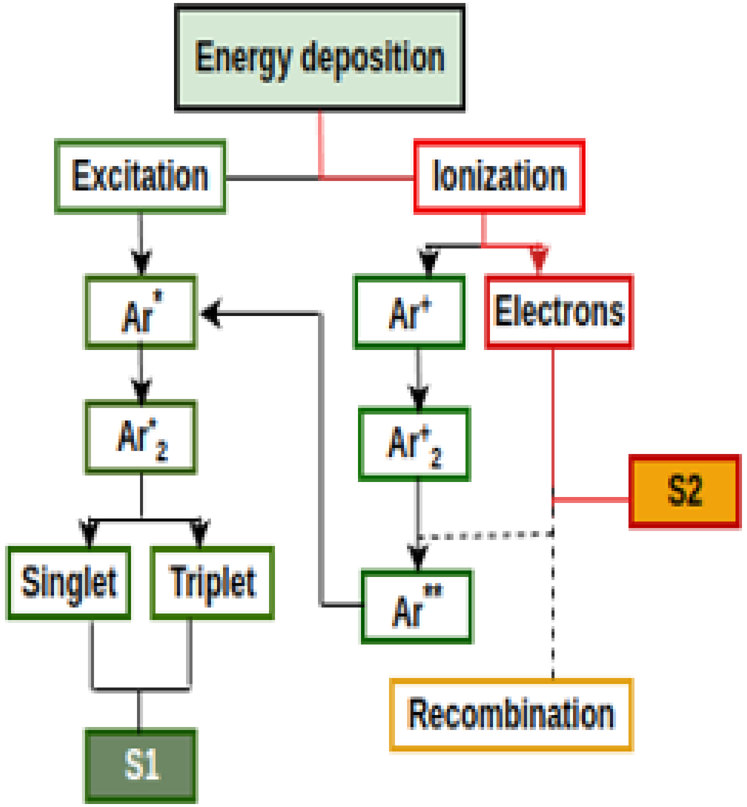
- LAr dual-phase time projection chamber (LAr TPC) at LNGS.
- 46.4 ± 0.7 kg active target of UAr.
- Readout from 19×2 PMTs.
- Outer cosmic and neutron veto chambers.
- UAr data collected from 2015 to 2018.
- DM + Ar ⇨ Nuclear Recoils (NR)
- Pulse Shape Discrimination (PSD) for ER (background) and NR differentiation.



Event signatures and S1 signal

- Primary scintillation signal ➡ **S1**
- Secondary scintillation signal ➡ S2 (electroluminescence light)
- S1 light yield in DS-50 ➡ 7.9 PE/keV
- S1 ➡ Singlet (~ 6 ns), **triplet (~ 1.6 μs)** components.



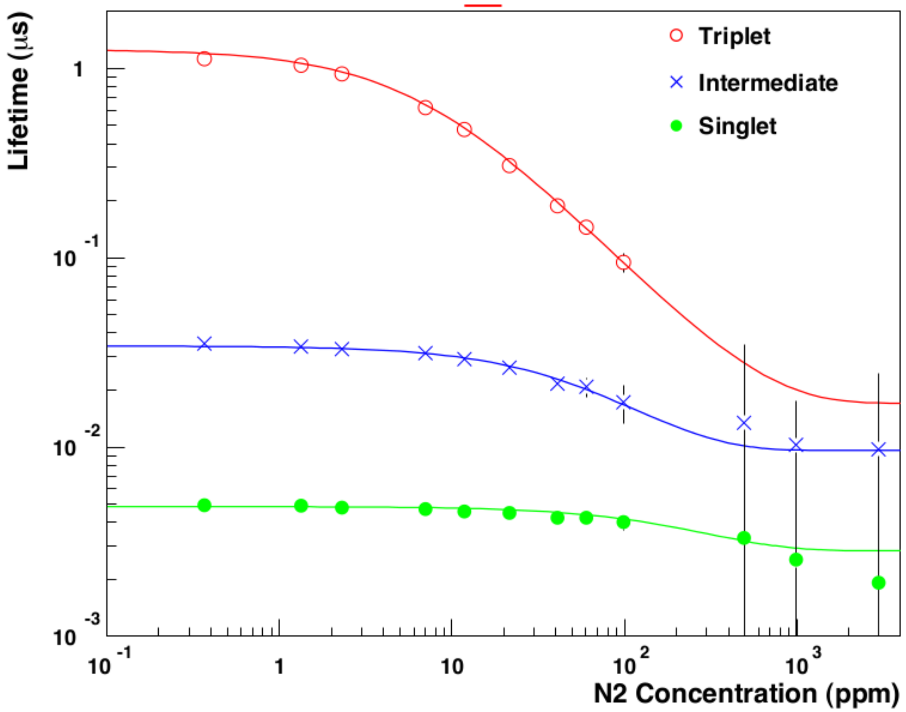


Impurities in DS-50 and its effects on S1 signal

- Argon is purified in gas phase using a hot getter.
- For maintenance purposes, the inline getter was bypassed for about 5 days (120 hours).
- Impurities in DS-50 ⇨ N_2, O_2, H_2O, etc.
- Impurities, especially N_2, at the ppm level causes **reduction of scintillation** (see arXiv:0804.1217v1 [nucl-ex] 8 Apr 2008).
- Quenching of light yield in N_2 - contaminated LAr is expected.

$$Ar_2^* + N_2 \Rightarrow 2Ar + N_2$$

- N_2 contamination in LAr ⇨ Suppression of triplet component.



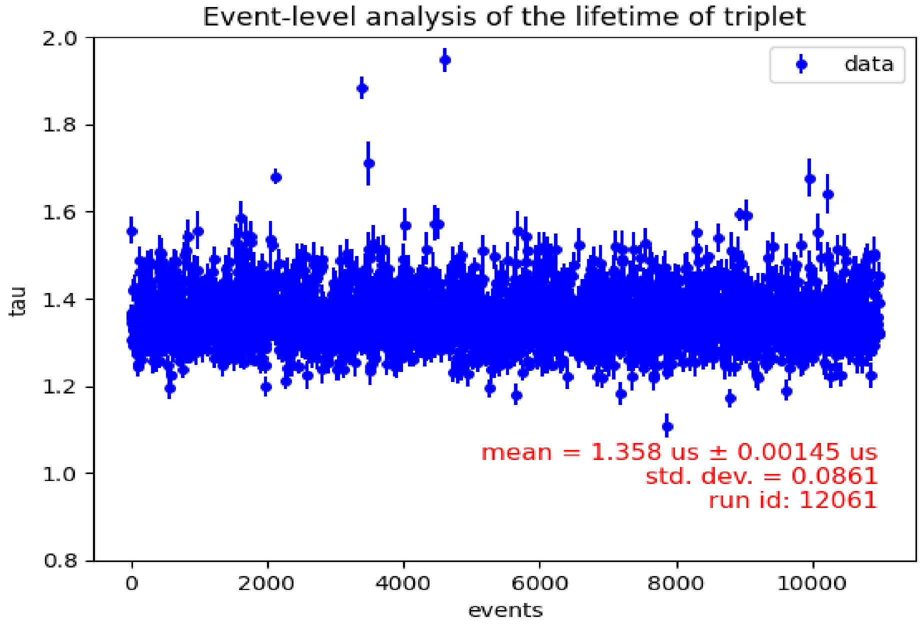
arXiv:0804.1217v1 [nucl-ex] 8 Apr 2008

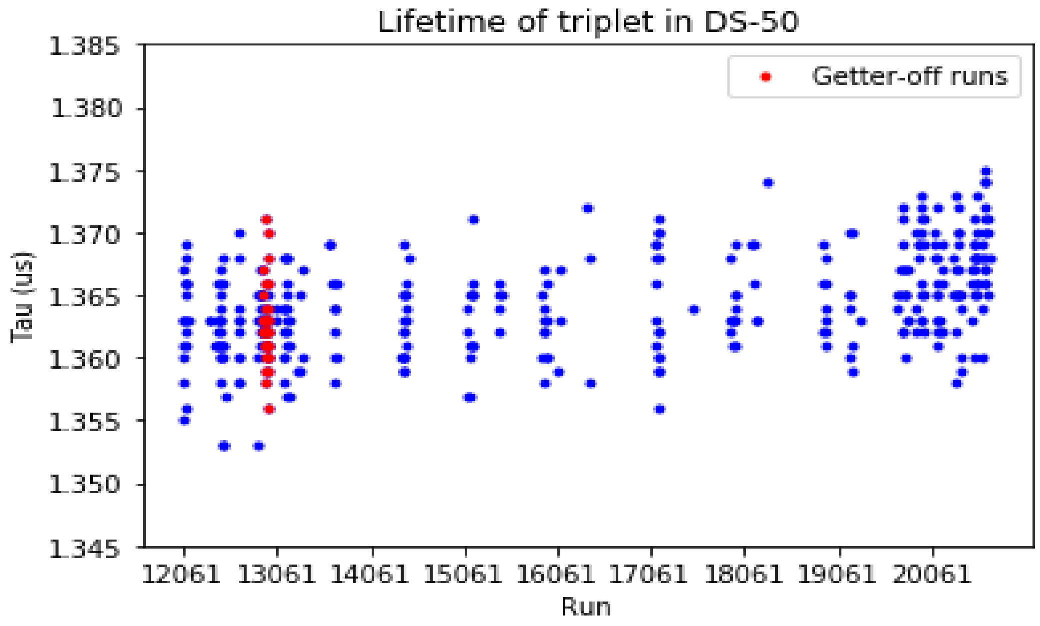
Effect of impurities on triplet lifetime

Checking the effect on lifetime of the S1 triplet component event-wise and run-wise using the 3-year data taken from DS-50.

Selection cuts applied:

- $\Delta t > 20\times10^{-3}$
- $0.15 < s1\_f90 < 0.5$
- $s2 > 0$
- tdrift >10
- $s1 > 1000$
- $0 < s1\_fwhm < 0.04$





- Getter-off runs – **12911-12977**
- Gradual increase of tau after the getter was turned back on.
- **No significant decrease of tau** during getter-off period.

Summary

- Impurities can quench scintillation.
- The probability of hitting a N_2 molecule is proportional to the lifetime of the excimer.
- With low concentration below 0.5 ppm of N2, no reduction of triplet decay constant is expected.
- But from our analysis, no such degradation was observed, which may indicate that **the concentration of N_2 is very low (<ppm) in DS-50.**
- Using this value as a reference for purity level in the DArT experiment, which is specifically designed for the impurity check of underground argon.

References:

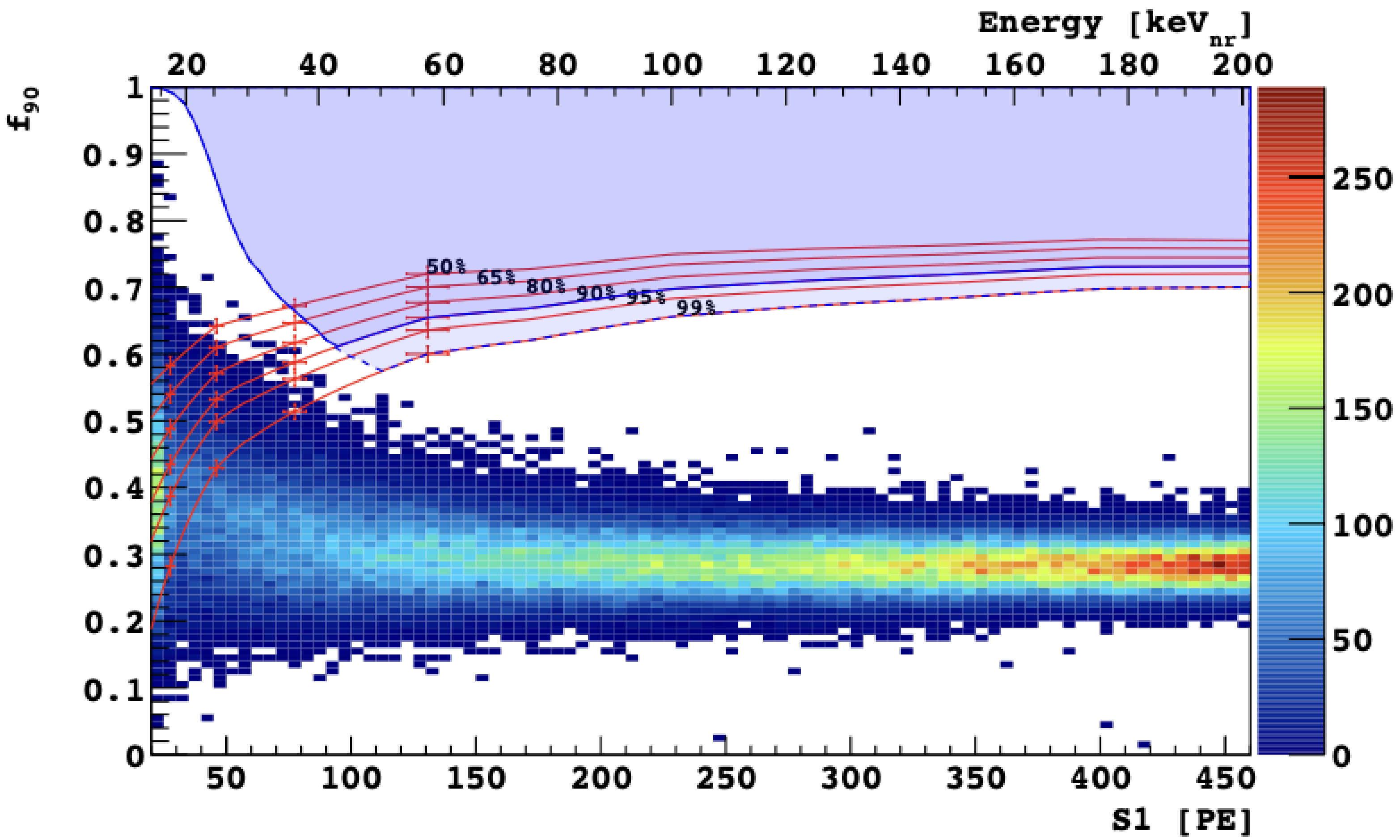
1. P. Agnes et al. (The DarkSide Collaboration), JINST, 12, P12011 (2017).

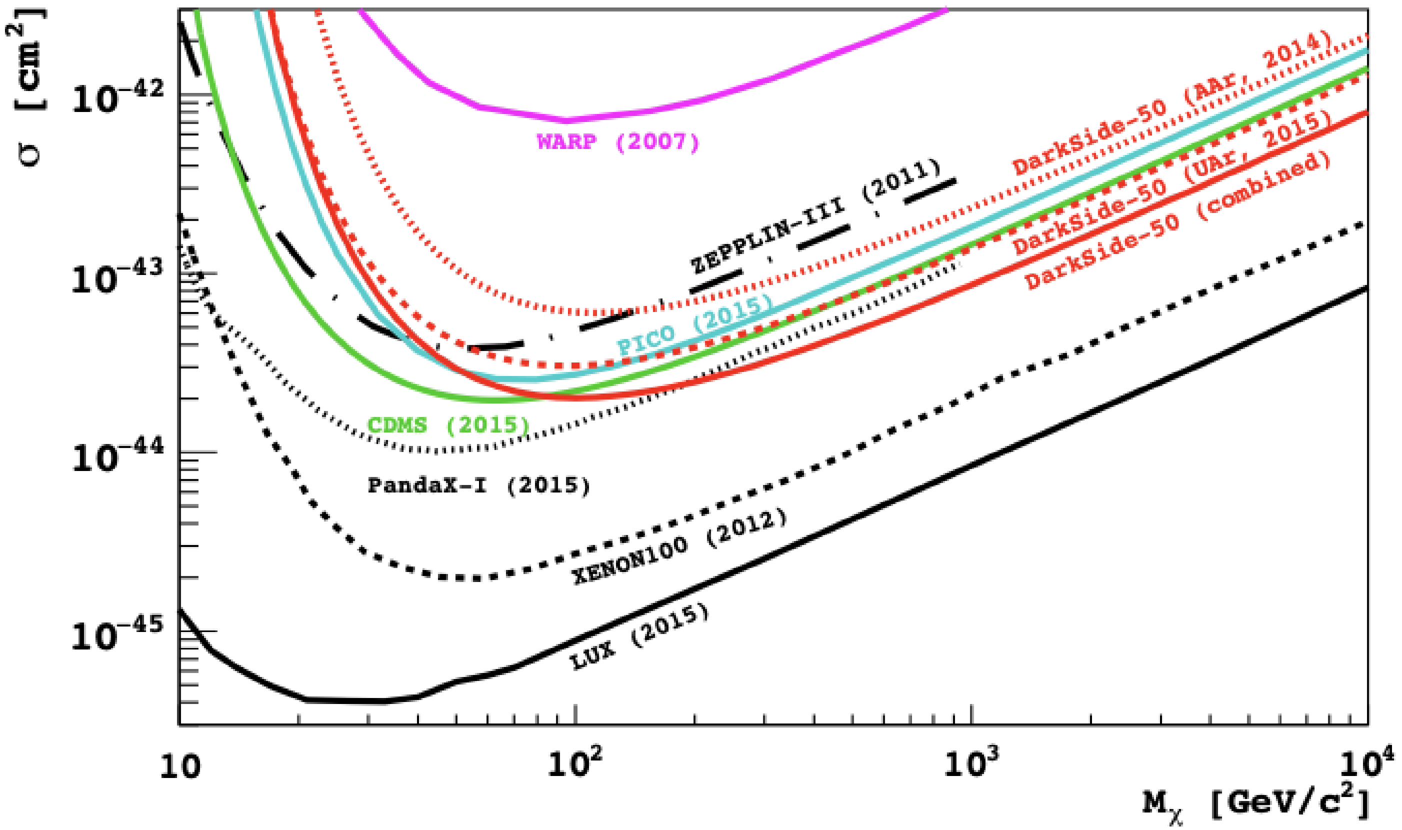
2. WArP Collaboration, Effects of Nitrogen contamination in liquid Argon, arXiv:0804.1217v1 [nucl-ex] 8 Apr 2008.

3. E. Sanchez Garcia (The DarkSide Collaboration), DArT, a detector for measuring the 39Ar depletion factor, arXiv:2001.08077v1 [physics.ins-det] 22 Jan 2020.

Thank you for your attention!

Backup


Energy [keV$_{nr}$]
20
40
60
80
100
120
140
160
180
200
f_{90}
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50%
65%
80%
90%
95%
99%
50
100
150
200
250
300
350
400
450
S1 [PE]
250
200
150
100
50
0


σ [cm²]
10⁻⁴²
10⁻⁴³
10⁻⁴⁴
10⁻⁴⁵
10
10²
10³
10⁴
M_χ [GeV/c²]
WARP (2007)
ZEPPLIN-III (2011)
DarkSide-50 (AAr, 2014)
DarkSide-50 (UAr, 2015)
DarkSide-50 (combined)
PICO (2015)
CDMS (2015)
PandaX-I (2015)
XENON100 (2012)
LUX (2015)