ArDM - The only Dual-Phase tonne-scale Liquid **Ar**gon **D**ark **M**atter Detector

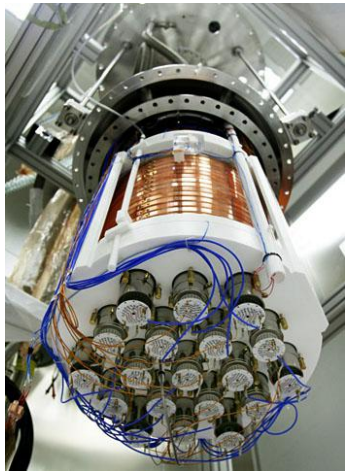
SPS and ÖPG Joint Annual Meeting

September 2, 2021

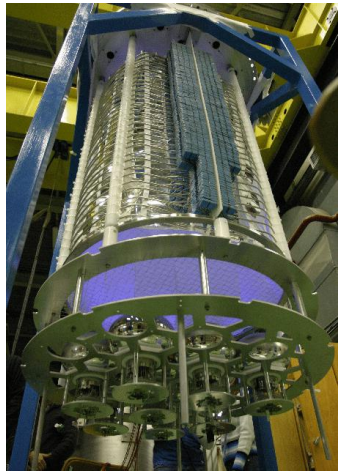
Global Argon Dark Matter Collaboration (GADMC)

Multi-national collaboration of >500 people from >80 institutions with a two-step program
Joint expertise of several argon dark matter experiments

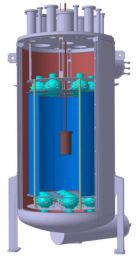
DarkSide-50



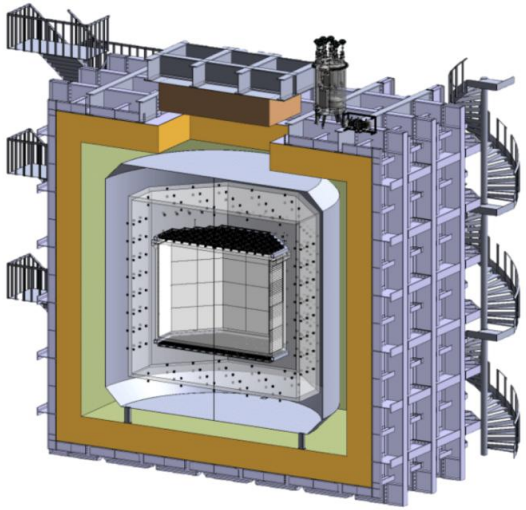
ArDM



DArT



DarkSide-20k



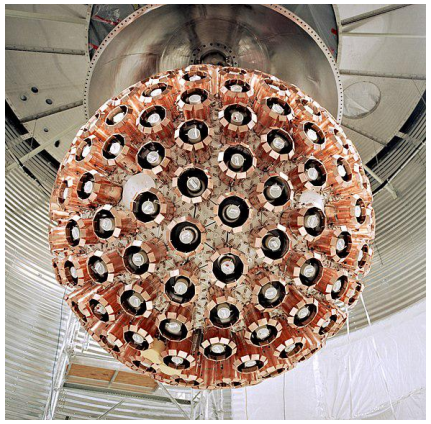
at LNGS

ARGO

~300t TPC

at Snowlab

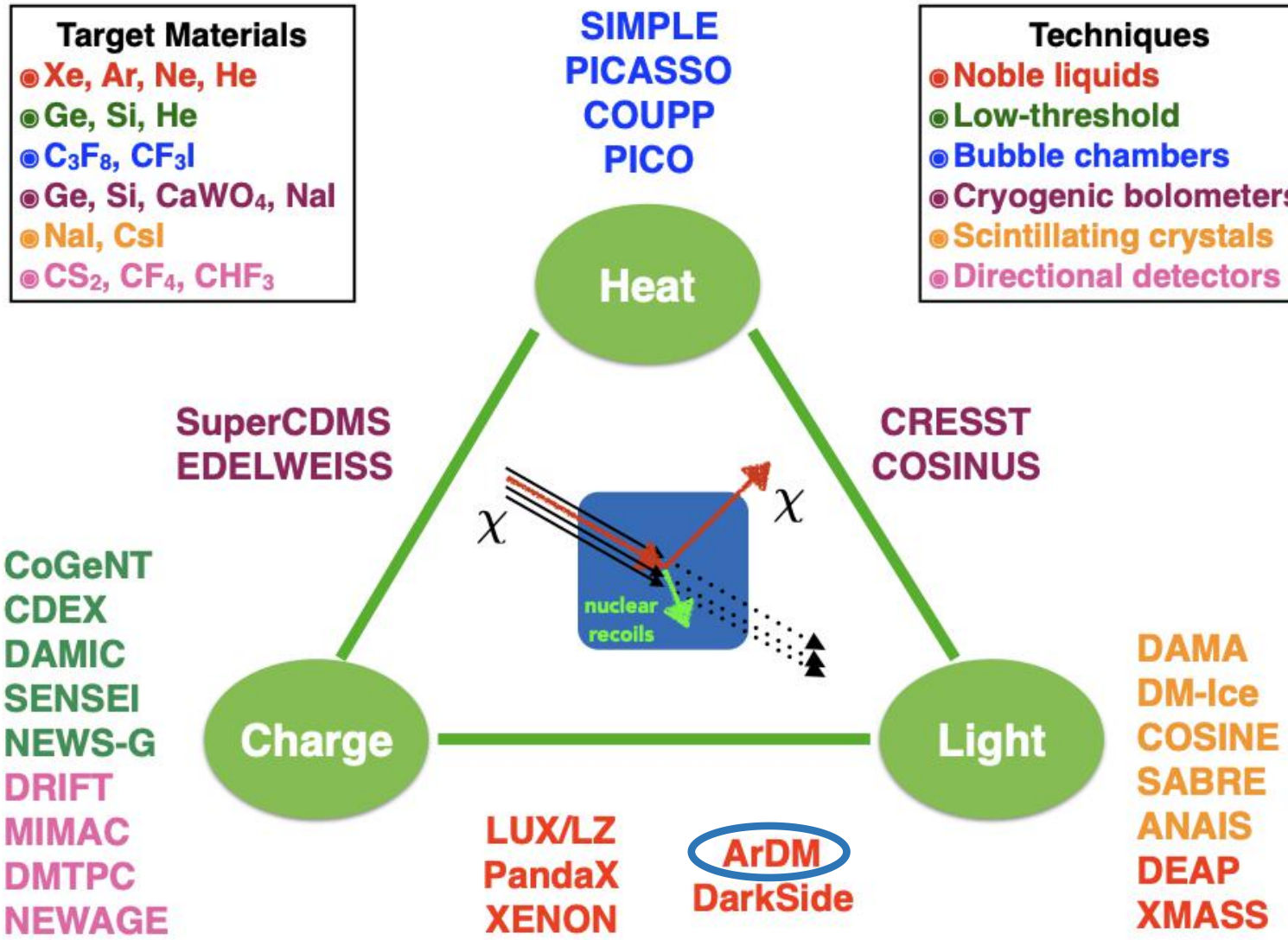
MiniCLEAN

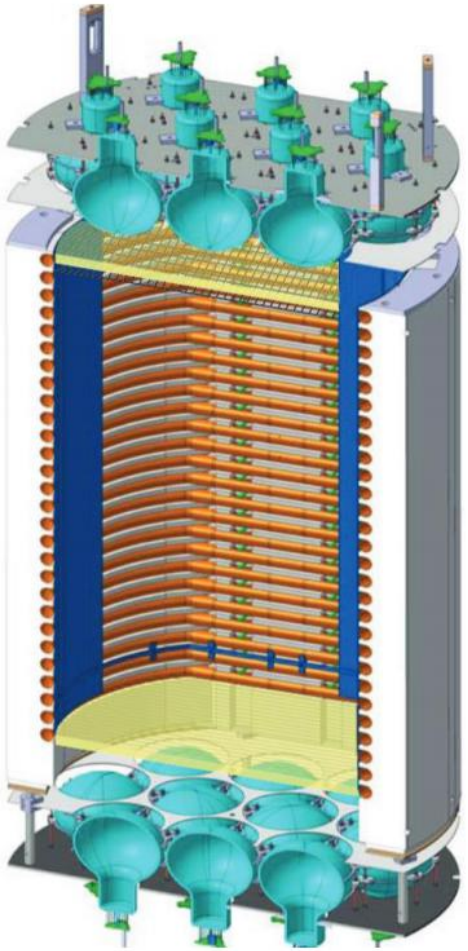


DEAP-3600

A 50t depleted argon (DAr) Dual-phase TPC
inside a 700t atmospheric argon (AAr) cryostat
➡ Projected sensitivity of 1.2×10^{-47} cm^2 at a WIMP mass of 1TeV/c^2
(with a 100 tonne·year exposure and a 20t fiducial mass)

Direct Dark Matter Detection (WIMPs)





ArDM

Total volume: 1.5t of LAr
Active Dual-phase TPC target volume: 650kg of LAr
Located at: Laboratorio Subterráneo Canfranc (LSC), Spain
850m below the surface

Installation at LSC: 2012-2013
First Single-phase (SP) data-taking (Start of Run I): February 2015
Final Single-phase commissioning: July 2015
Upgrade to Dual-phase (DP): June 2016
First Dual-phase data-taking (Start of Run II): December 2017
Continuous upgrades and optimizations until late 2018
Dual-phase data-taking period: Summer 2019
Stopped operating in 2020
➡ new phase: DArT

Total raw data of Run I: 3.3 billion SP events
Total raw data of Run II: 3.5 billion DP events;
(thereof 334 million events
with a neutron calibration source)

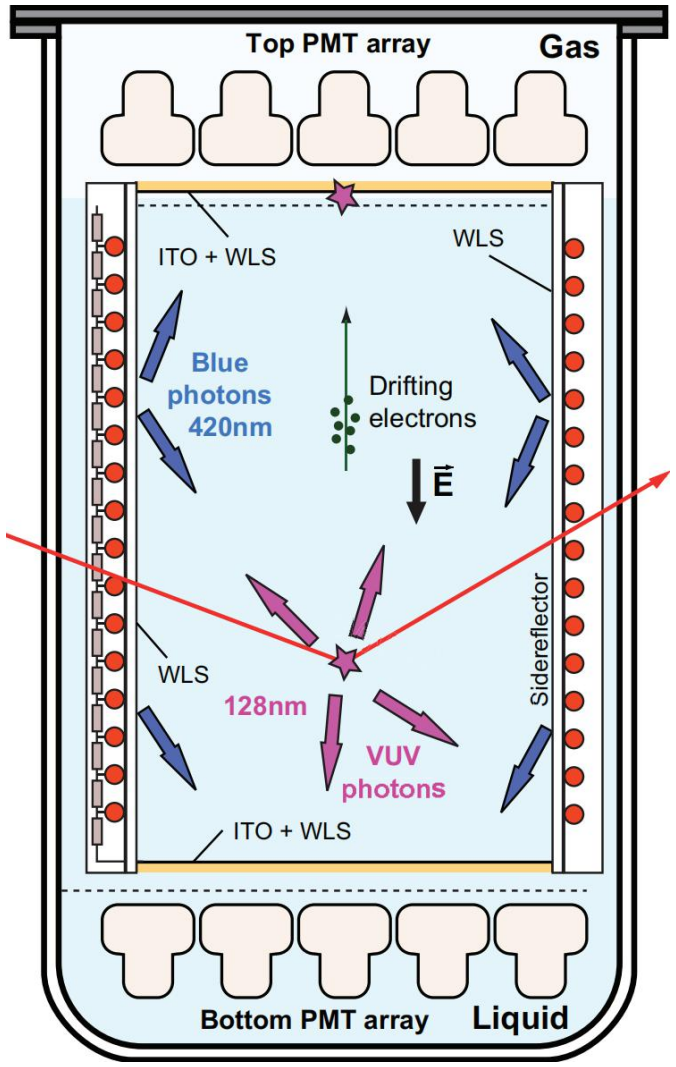
LSC
Laboratorio Subterráneo Canfranc

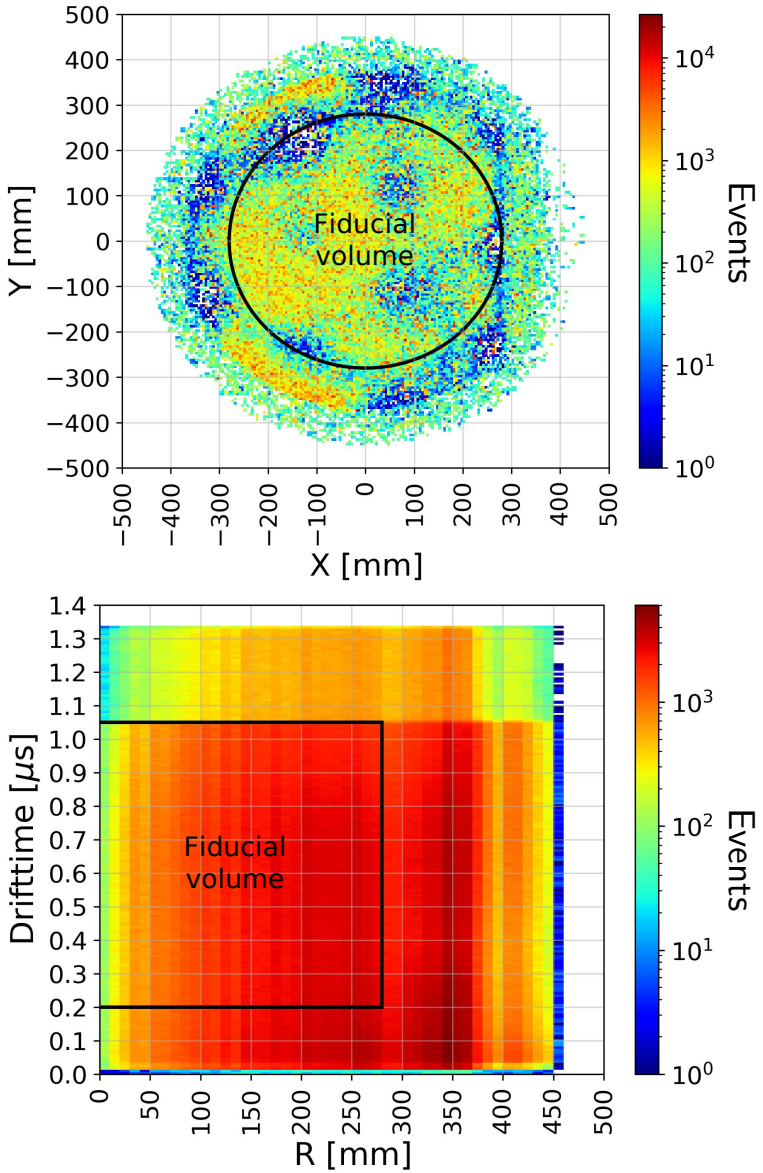
Backgrounds and pulse shape discrimination in the ArDM liquid argon TPC
ArDM Collaboration • J. Calvo (Zurich, ETH) et al. (Dec 2, 2017)
Published in: *JCAP* 12 (2018) 011 • e-Print: 1712.01932 [physics.ins-det]

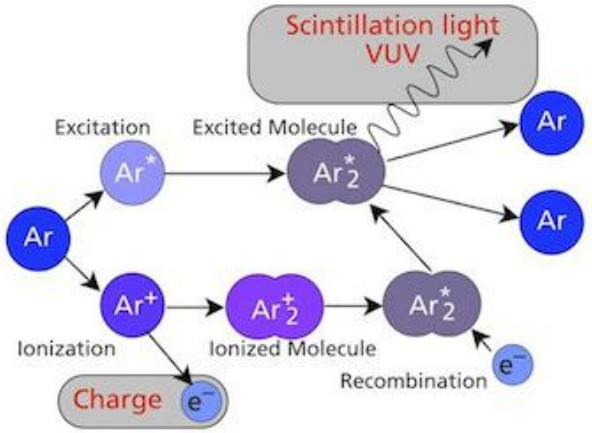
Measurement of the attenuation length of argon scintillation light in the ArDM LAr TPC
ArDM Collaboration • J. Calvo (Zurich, ETH) et al. (Nov 8, 2016)
Published in: *Astropart.Phys.* 97 (2018) 186-196 • e-Print: 1611.02481 [astro-ph.IM]

Commissioning of the ArDM experiment at the Canfranc underground laboratory: first steps towards a tonne-scale liquid argon time projection chamber for Dark Matter searches
ArDM Collaboration • J. Calvo (Zurich, ETH) et al. (Dec 19, 2016)
Published in: *JCAP* 03 (2017) 003 • e-Print: 1612.06375 [physics.ins-det]

Dual-Phase LAr Time-Projection Chamber (TPC)





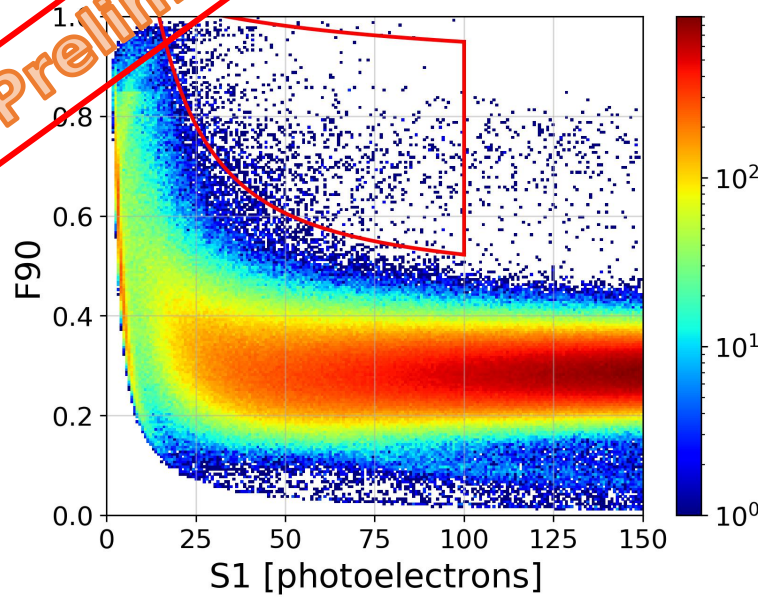


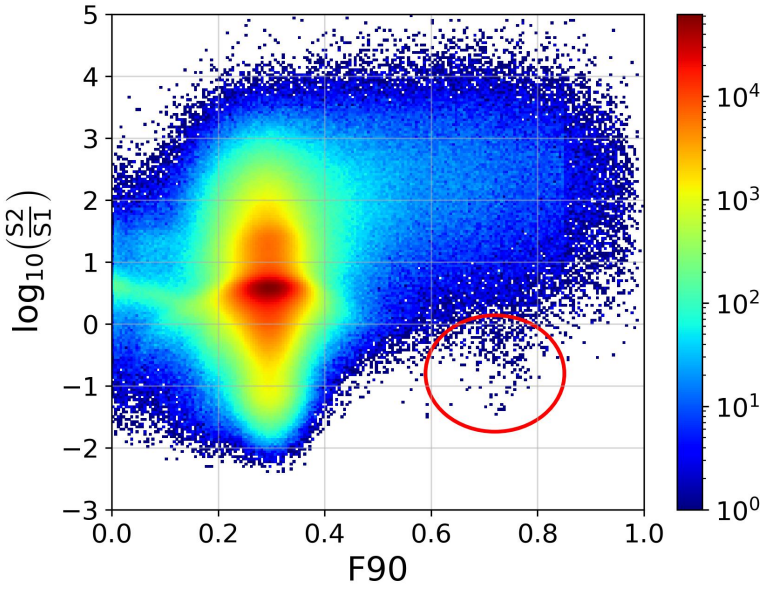
Two signals in LAr/GAr:
S1 ➡ Scintillation in the liquid
(provides pulse-shape discrimination ➡ F90)
S2 ➡ Electroluminescence (scintillation in the gaseous phase proportional to the extracted ionization charge;
provides charge-to-light ratio ➡ S2/S1)

Event vertex reconstruction in **3D**
XY: S2 light pattern on top PMTs
Z: Time difference between S1 and S2
➡ precise fiducialization

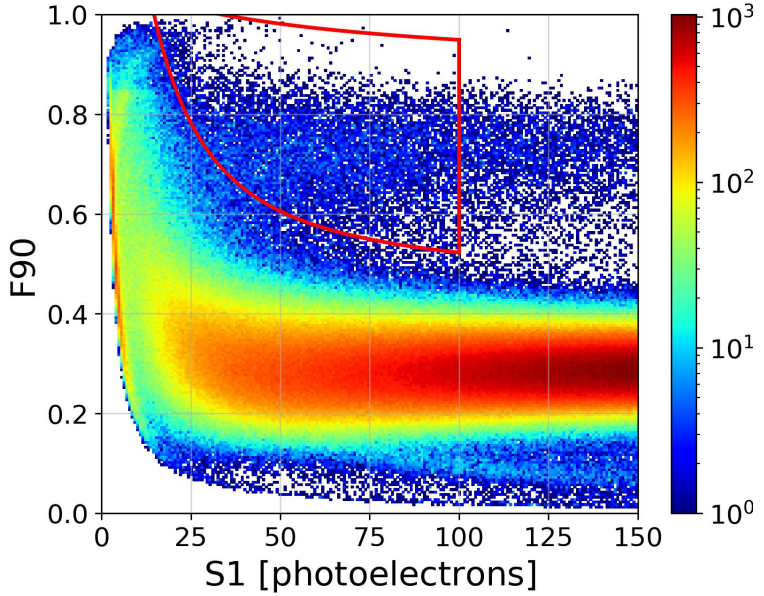
Background Discrimination

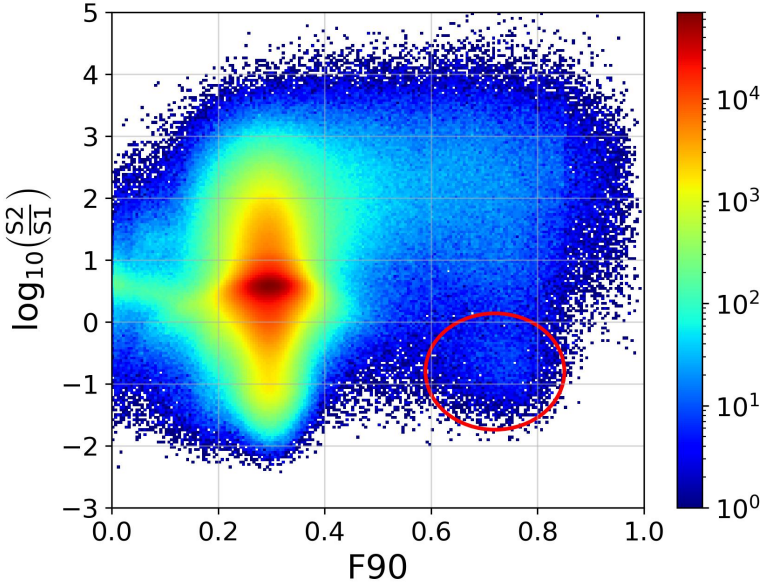
Preliminary



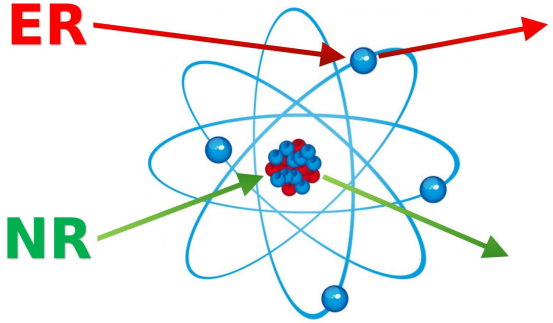


ArDM DP data





ArDM DP data + Neutron source



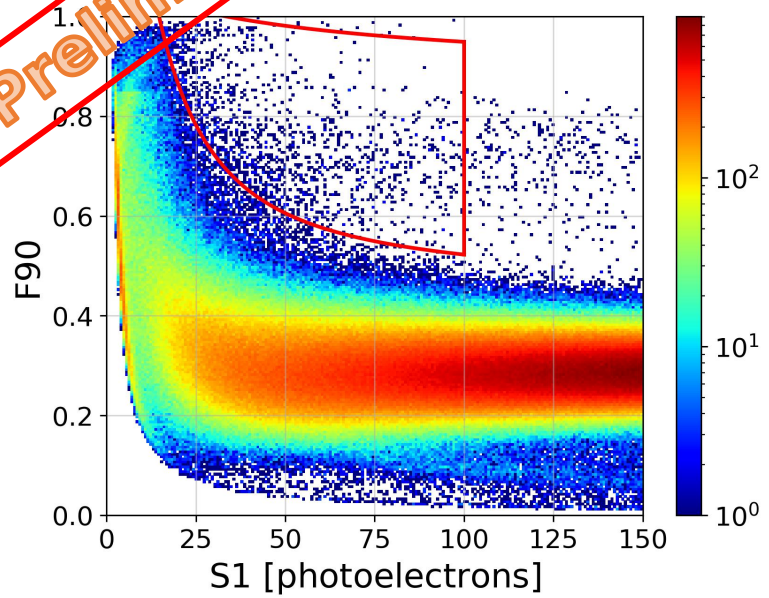
Two types of recoils
ER: Electrons and photons
NR: Neutrons and WIMPs

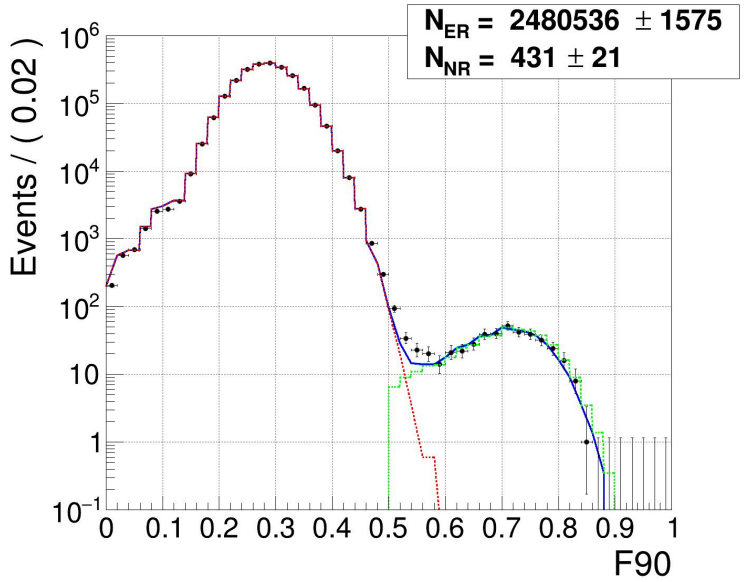
Two discrimination variables in Ar:
F90 (pulse-shape)
S2/S1 (charge-to-light ratio)

Region of interest for WIMPs/Neutrons

Background Discrimination

Preliminary





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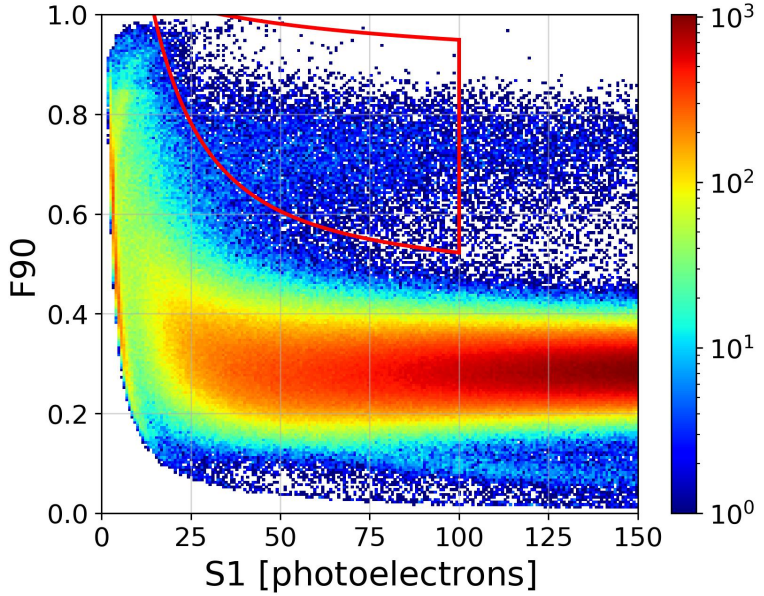

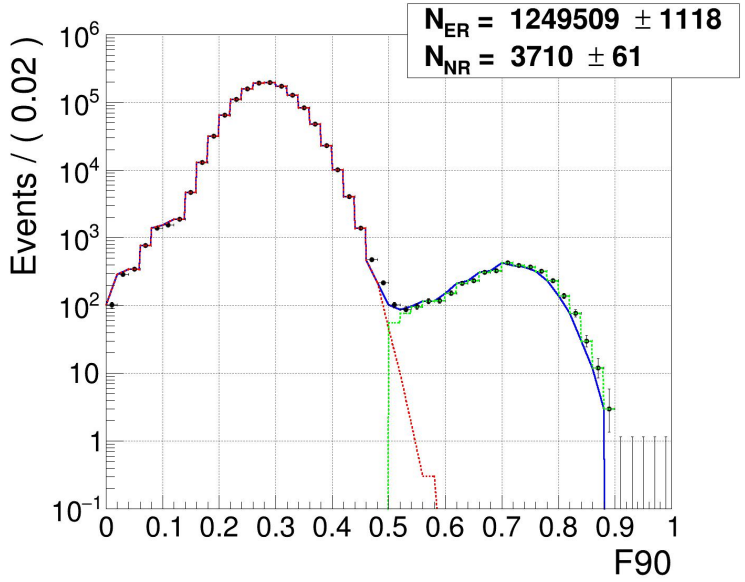

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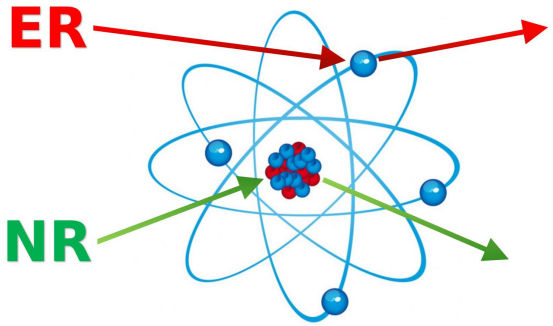

Two types of recoils
ER: Electrons and photons
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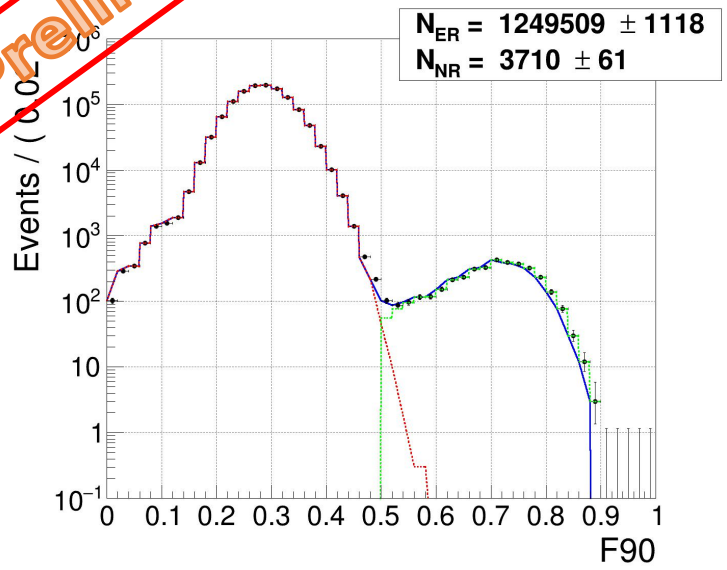
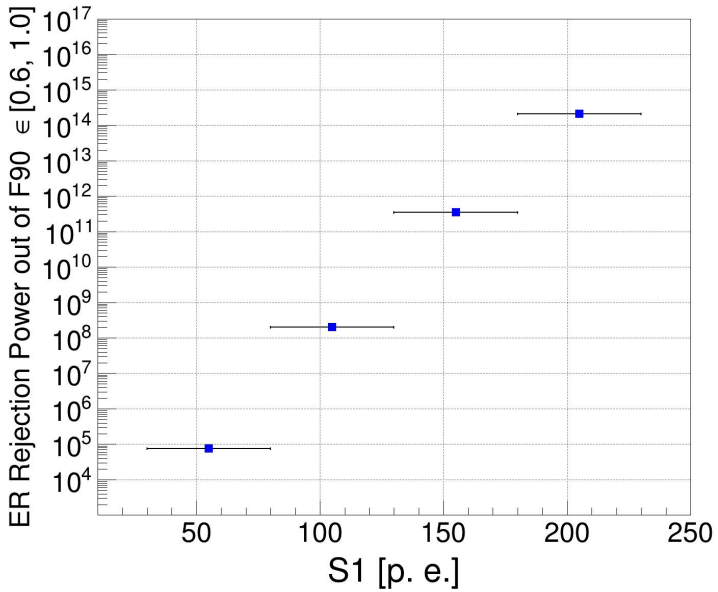
Two discrimination variables in Ar:
F90 (pulse-shape)
S2/S1 (charge-to-light ratio)

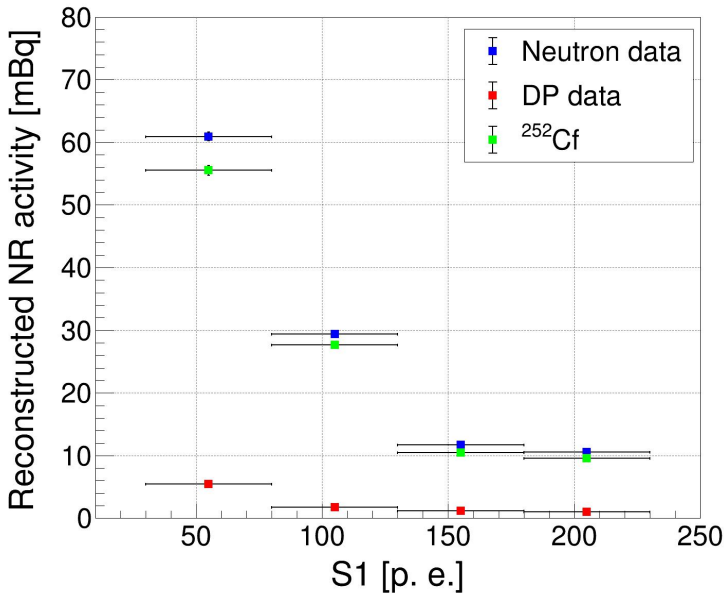
Region of interest for WIMPs/Neutrons

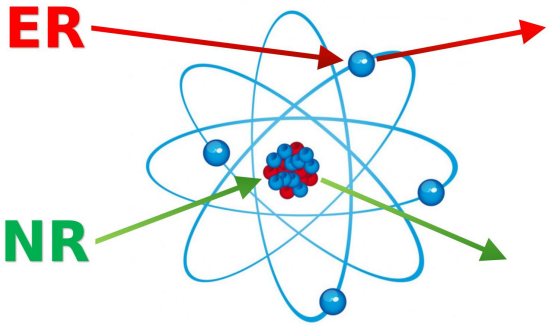
Pulse-Shape Discrimination (F90)

Preliminary









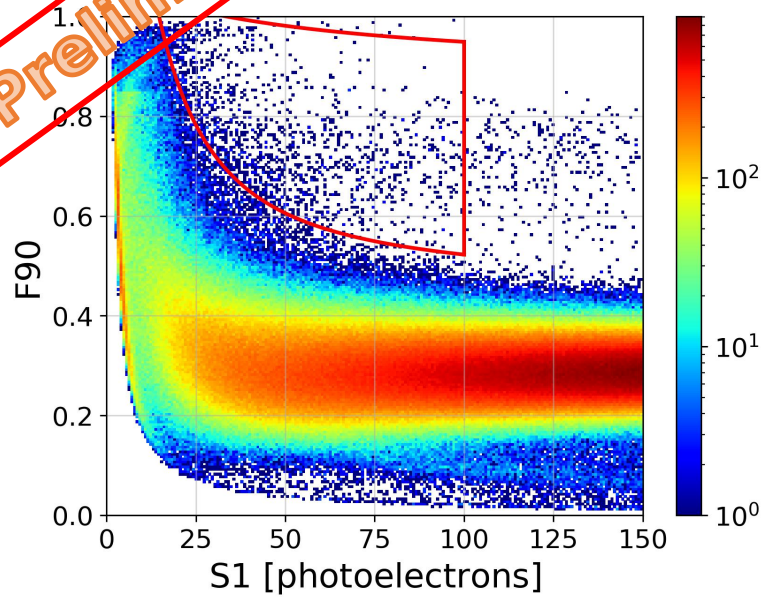
ER: Electrons and photons
NR: Neutrons and WIMPs

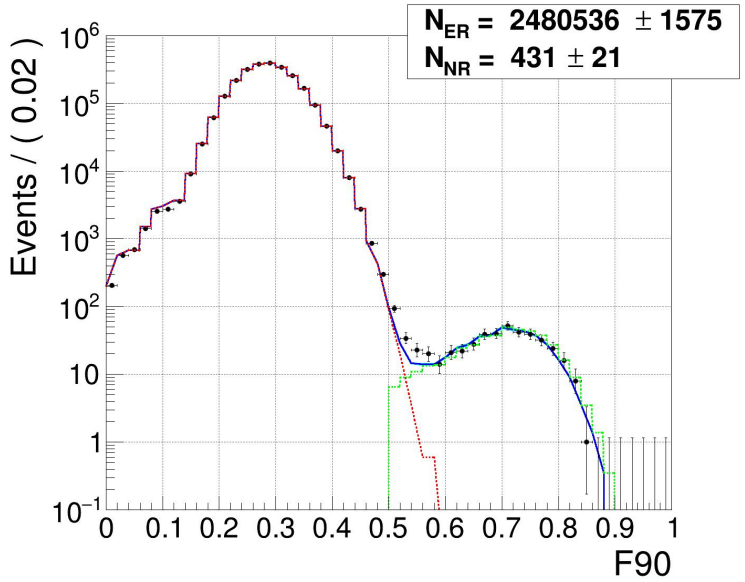
➡ Only 1 in ~10^5 ER events is not rejected by pulse-shape discrimination alone (strongly energy dependent; here the RoI is F90 ≥ 0.6)

S1 bin [p. e.]	ER Leakage into F90 ∈ [0.6, 1.0]	N_{NR} Neutron Data	N_{NR} DP Data	^{252}Cf NR events	^{252}Cf Activity [mBq]
30 to 80	1.34e-05 ± 2.03e-07	7684.8 ± 91.3	683.9 ± 21.2	7000.9 ± 93.7	55.51 ± 0.74
80 to 130	4.92e-09 ± 1.08e-10	3709.7 ± 61.2	217.3 ± 10.7	3492.4 ± 62.1	27.69 ± 0.49
130 to 180	2.88e-12 ± 8.06e-14	1478.5 ± 34.5	153.1 ± 8.9	1325.4 ± 35.6	10.51 ± 0.28
180 to 230	4.80e-15 ± 1.59e-16	1329.9 ± 36.5	124.6 ± 8.0	1205.3 ± 37.3	9.56 ± 0.30
Total:	———	14202.9 ± 120.8	1178.9 ± 26.6	13024.0 ± 123.7	103.26 ± 0.98

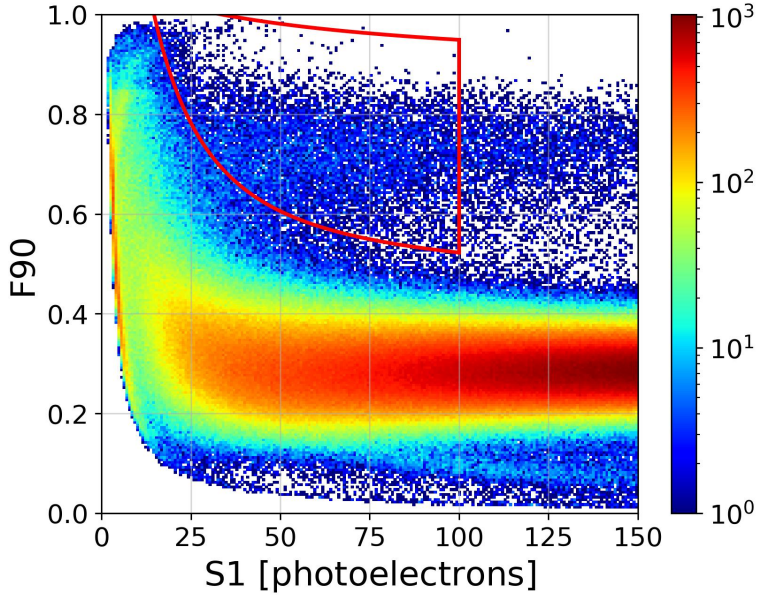
Background Discrimination

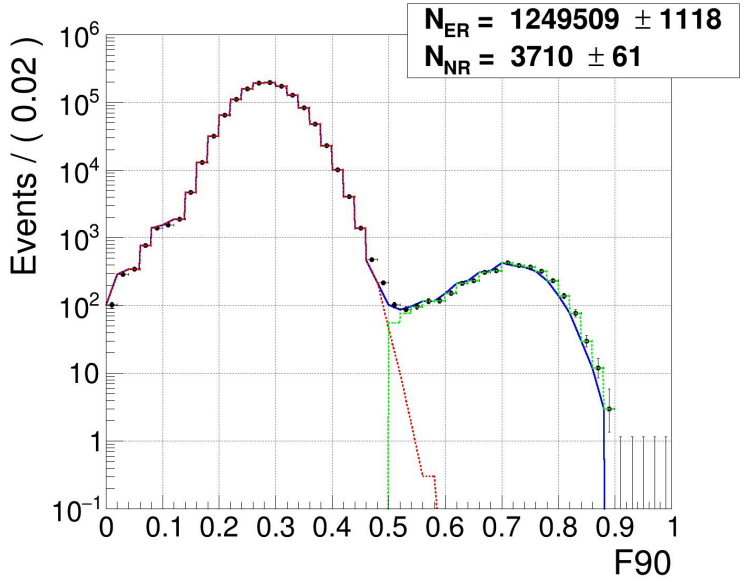
Preliminary



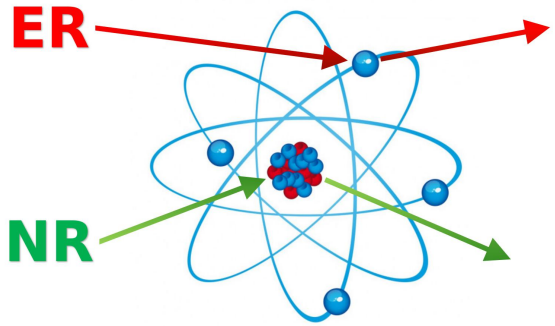


ArDM DP data





ArDM DP data + Neutron source



Two types of recoils
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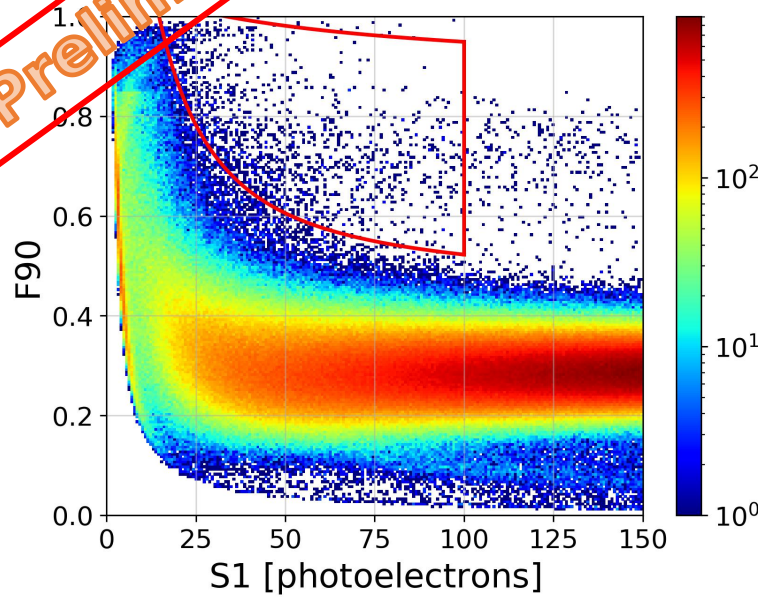
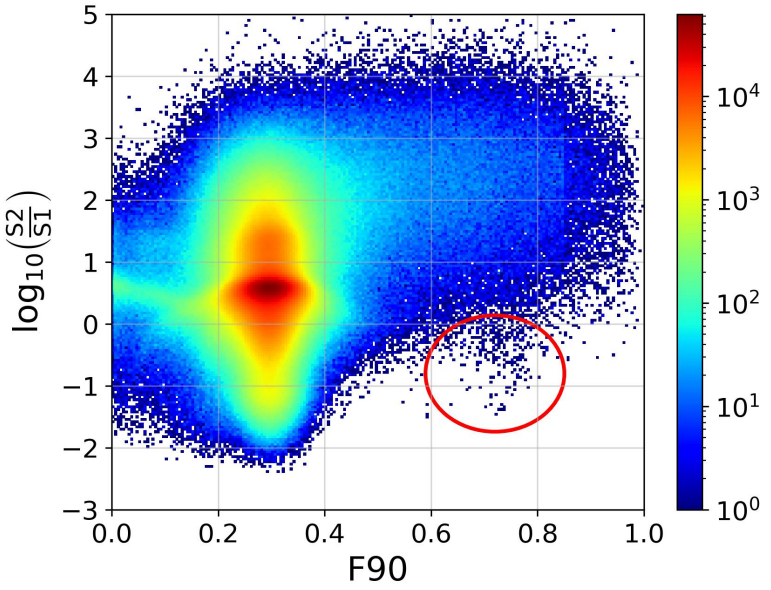
Discrimination via pulse shape (F90): ~10^5 (energy dependent)

Region of interest for WIMPs/Neutrons

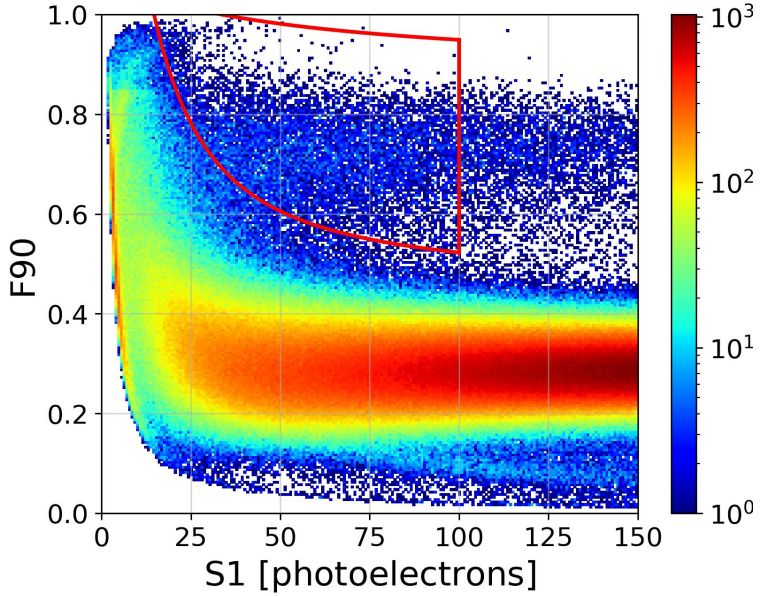
Background Discrimination

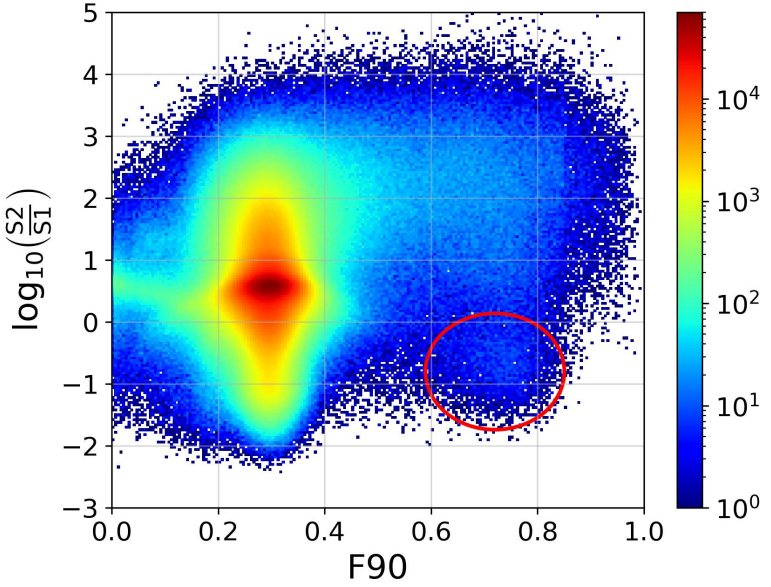
Preliminary





ArDM DP data





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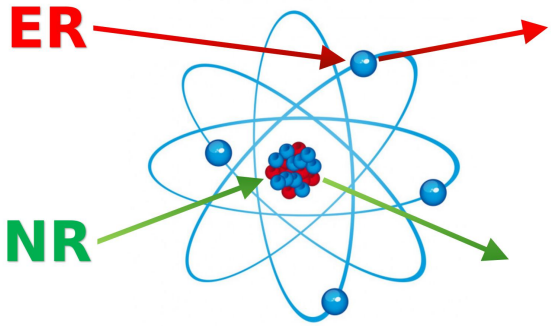

Two types of recoils
ER: Electrons and photons
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Discrimination via pulse shape (F90): ~10^5 (energy dependent)

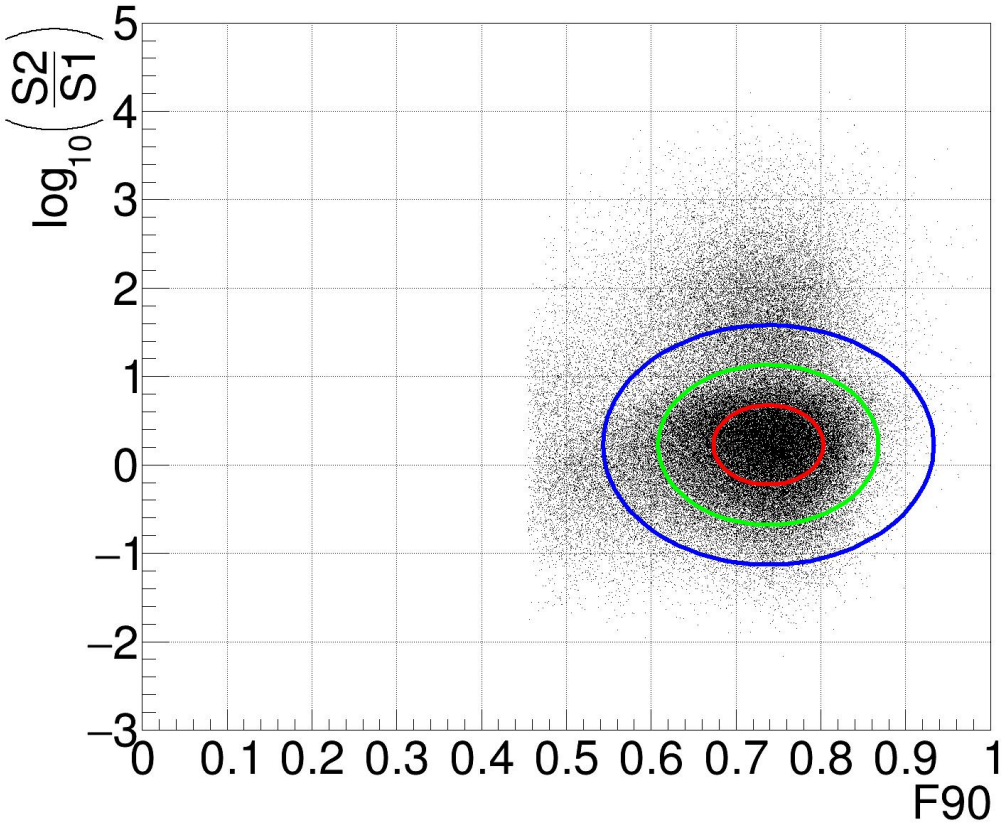
Region of interest for WIMPs/Neutrons

Background Discrimination

Preliminary

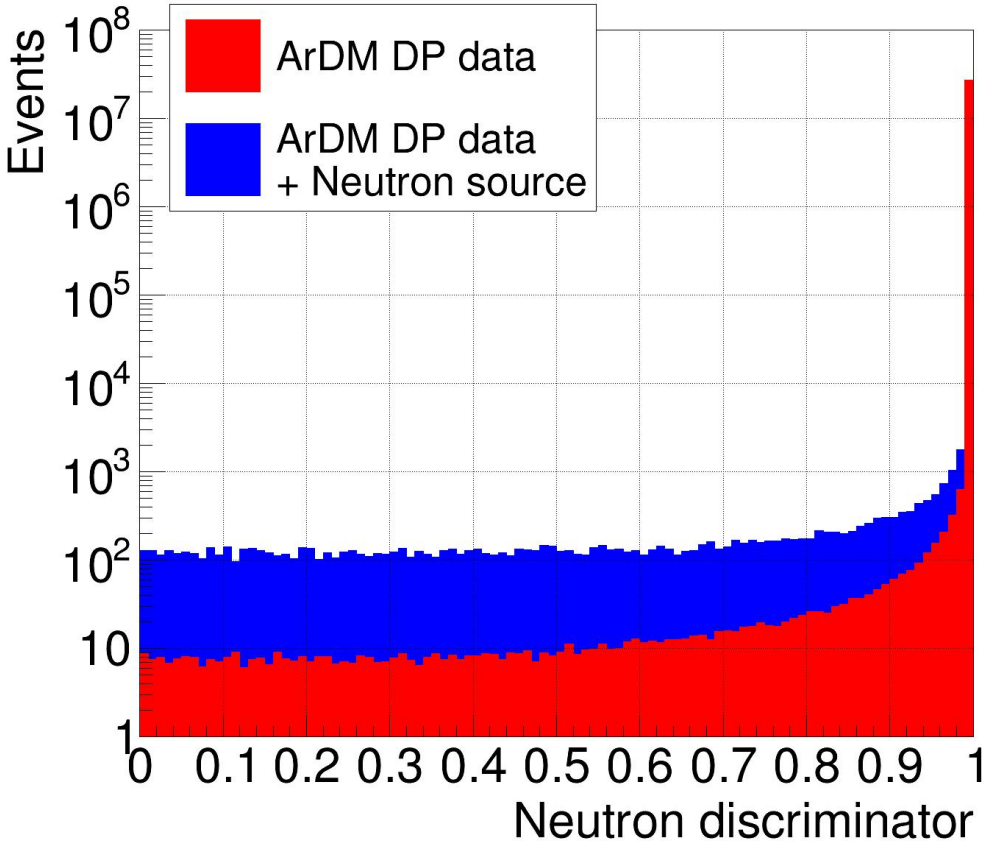
ArDM data with a neutron source allows the extraction of a new discriminator of ERs versus NRs

2D Gaussian fit of neutron-dominated data in the S2/S1 versus F90 plane



➡ New Neutron discriminator (the distance to the center of the 2D Gaussian in terms of its CDF)
0: Very NR-like
1: Very NR-unlike ↔ ER-like

➡ additional ER rejection power (work in progress)

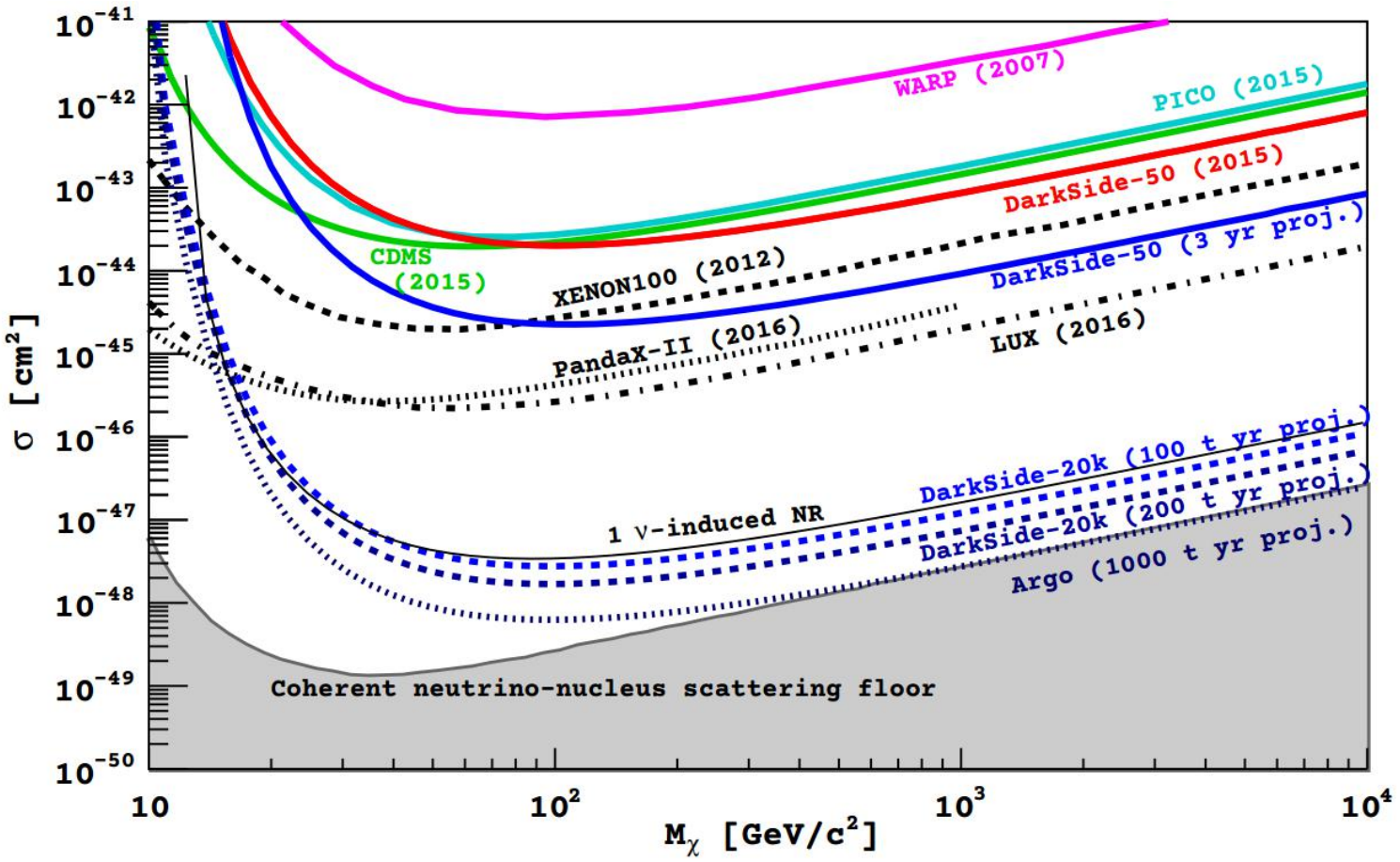


Outlook

ArDM:
~30 live days
650kg active AAr target

DArT:
Radio-purity test of DAr
inside the ArDM detector
with ArDM working as a veto

DarkSide-20k:
20t active DAr target



Taken from: DarkSide-20k: A 20 Tonne Two-Phase LAr TPC for Direct Dark Matter Detection at LNGS; DOI: 10.1140/epjp/i2018-11973-4

DArT: ^{39}Ar Depletion Factor Measurement Facility

Design and Construction of a New Detector to Measure Ultra-Low Radioactive-Isotope Contamination of Argon

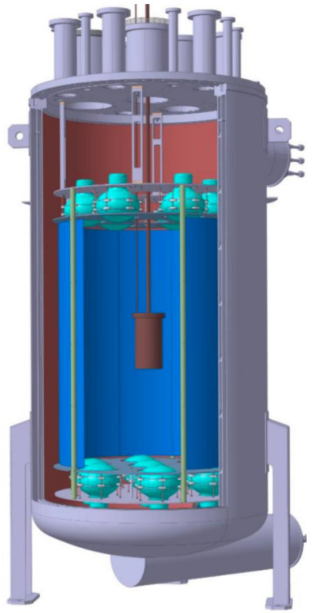
DarkSide-20k Collaboration • C.E. Aalseth (PNL, Richland) Show All(330)
Jan 22, 2020

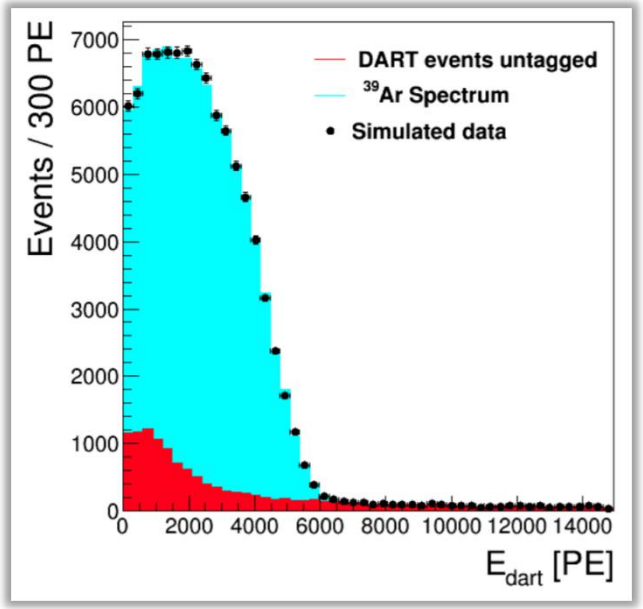
19 pages
Published in: *JINST* 15 (2020) 02, P02024
e-Print: 2001.08106 [astro-ph.IM]
DOI: 10.1088/1748-0221/15/02/P02024
Experiments: DARKSIDE

Single-phase inner detector for 1.6 L of LAr inside 1t ArDM detector acting as an active veto for background radiation (at LSC)

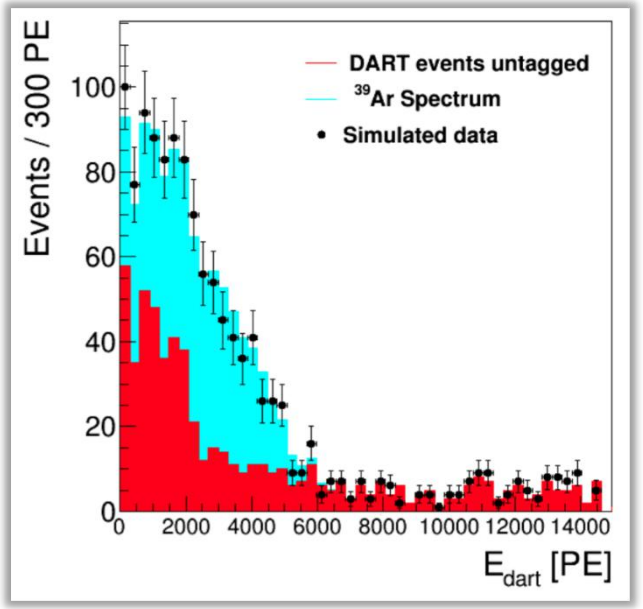
➡ Measure DAr-to-AAr ^{39}Ar depletion factor (DF) of the order of 1000 with 10% precision in a one week run

Status: the PMTs have been tested in LN_2 at ETH Zürich and are currently being coated at LNGS; Integration of DArT into ArDM in the coming months





DF = 10, precision of 1%



DF = 1400, precision of 7%

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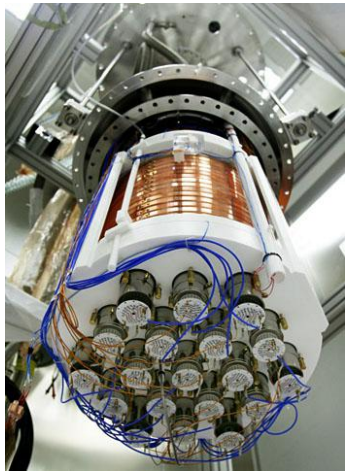
Joint expertise of several argon dark matter experiments

DarkSide-50



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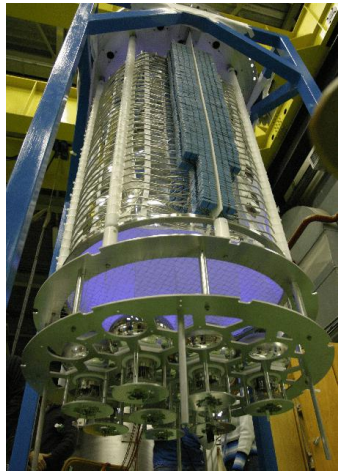

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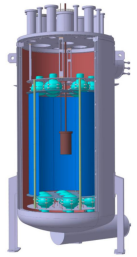

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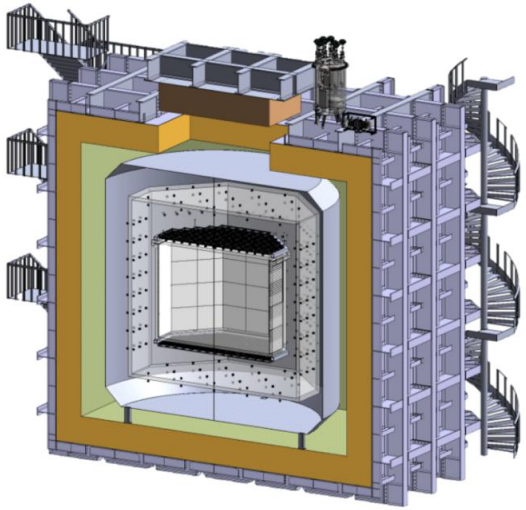

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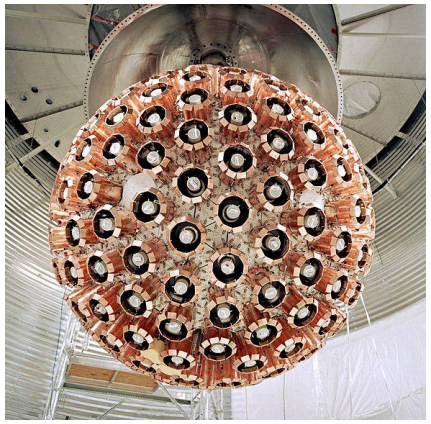


DEAP-3600

A 50t depleted argon (DAr) Dual-phase TPC
inside a 700t atmospheric argon (AAr) cryostat
➡ Projected sensitivity of 1.2×10^{-47} cm^2 at a WIMP mass of 1TeV/c^2
(with a 100 tonne·year exposure and a 20t fiducial mass)

Questions?

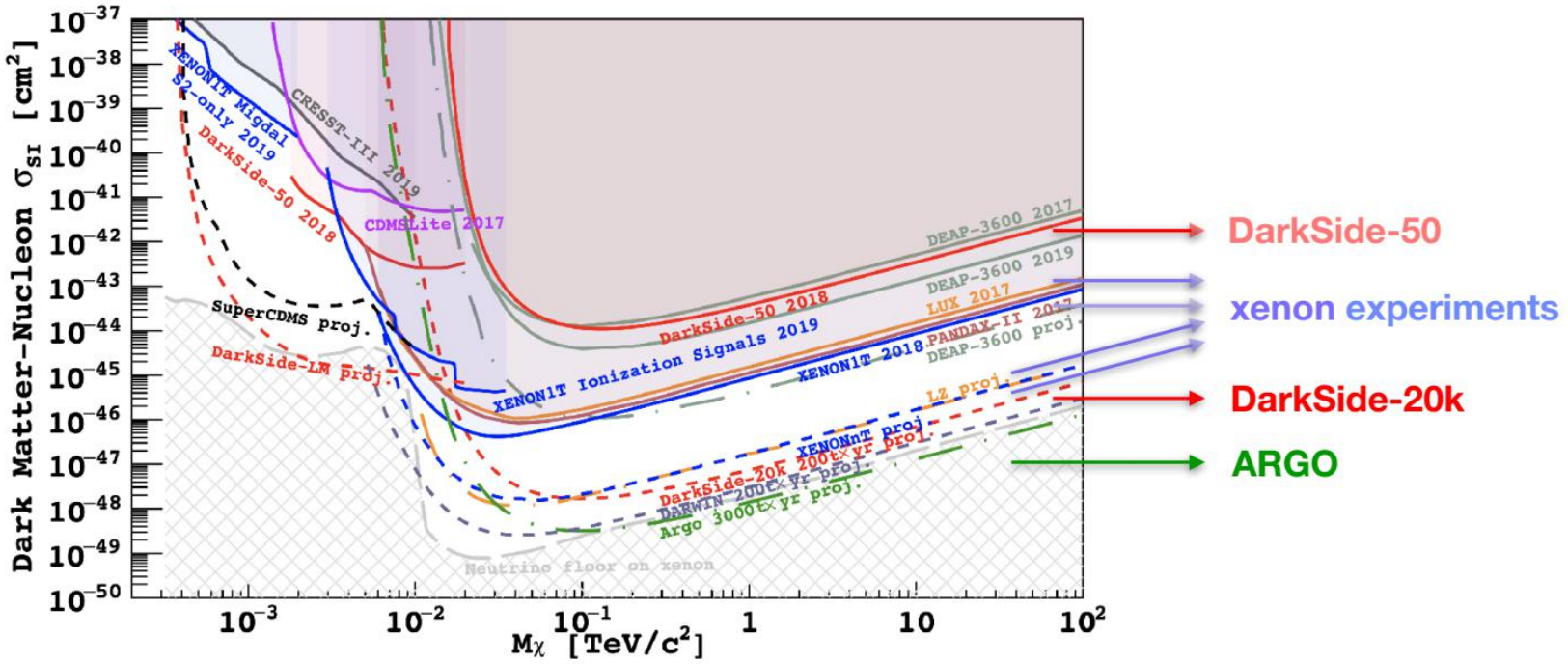
Backup slides

DArT - Planned Schedule

Projected Sensitivity

DarkSide-20k goal:

increase exposure by 3-4 orders of magnitude
total number of background events in full exposure <0.1 (as in DarkSide-50)



Taken from: CERN Detector Seminar from May 28, 2021 by Alexander Kish;
The DarkSide-20k dual-phase argon TPC for particle dark matter detection
Indico: https://indico.cern.ch/event/1041835/