in 10 Minutes

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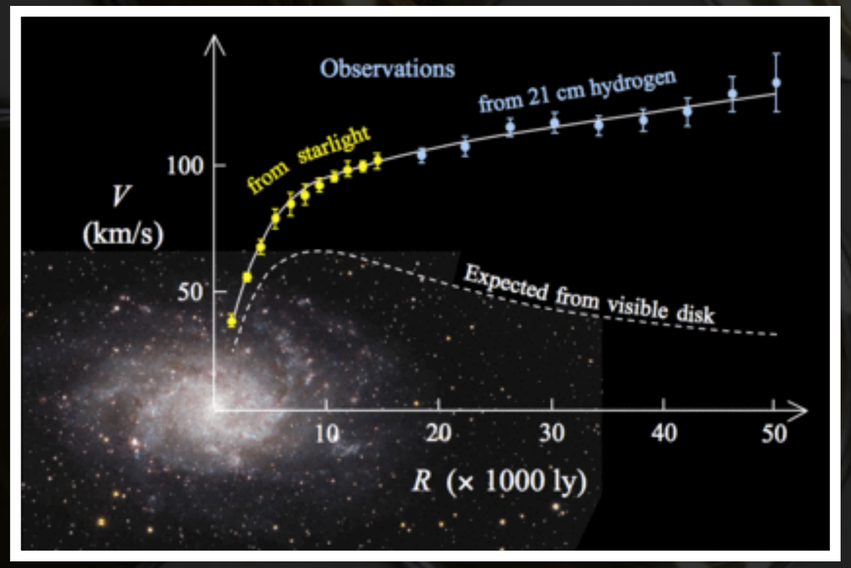
Temple University | 14 June 2016

http://darkside.lngs.infn.it/

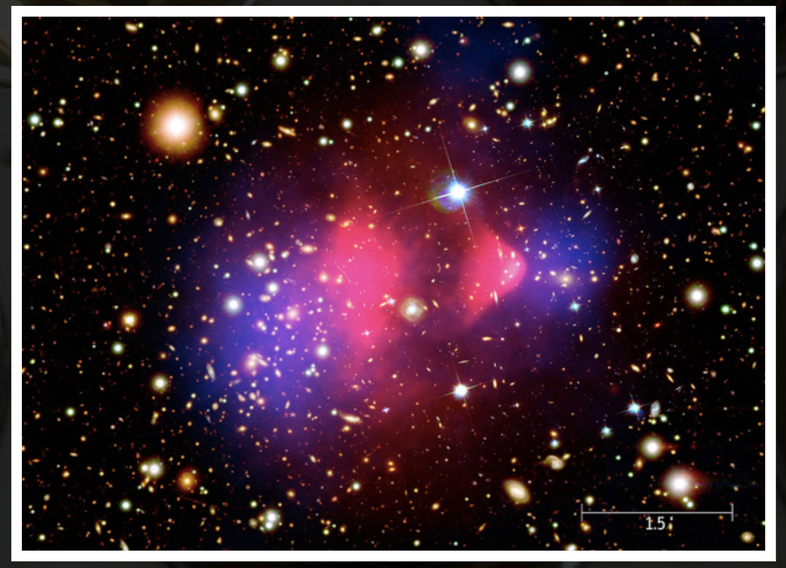
- What is dark matter?
  - Evidence for dark matter
  - Proposed components of dark matter
  - Properties of particulate dark matter
- What is DarkSide?
  - The Collaboration
  - Shielding and detector structure
  - Working principles
- What results do we have?
  - UAr vs. AAr & exclusion curves
- What are our future plans?
  - DS-20k and Argo

What is dark matter?

Evidence for Dark Matter

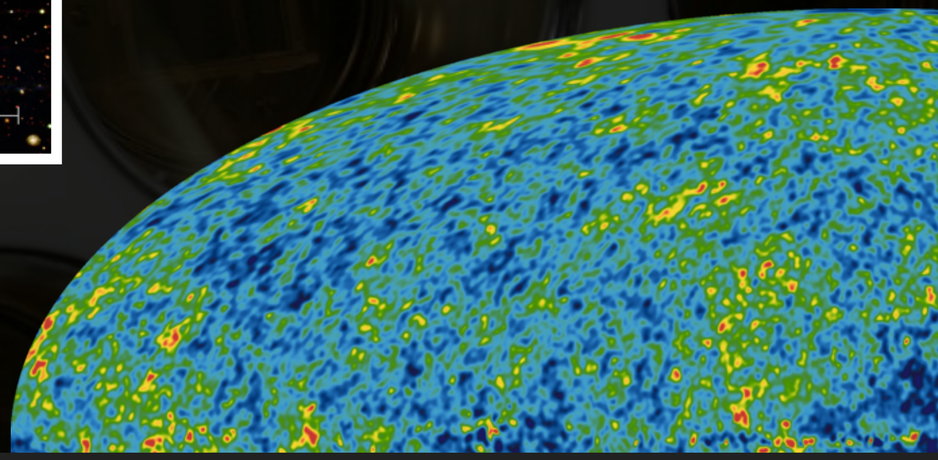


Rotation Curves of Spiral Galaxies /
Velocity Dispersions of Elliptical Galaxies
[non-Keplerian dynamics / virial theorem]



Gravitational lensing

Large structures aren't
behaving the way they "should"
— we're missing something!



Power spectrum of
CMB anisotropies

What is dark matter?

"Orthodox" dark matter candidates:

MACHOs
("Massive Compact Halo Objects": black holes, brown dwarfs, etc.)
Neutrinos

Dark Matter **must**…

…be massive
(~100GeV/c^2 = "cold" at decoupling)

…be particulate
(but non-Standard Model)

…be largely non-baryonic
(except for MACHOs, black holes, etc.)

…interact **only** via the weak force and gravity
(**no** EM charge)

…account for 26.8% of universal mass-energy
(84.5% of total universal mass)

ΛCDM Model

Λ = "dark energy"
CDM = "cold dark matter"

Leading Candidate: **WIMPs**
Weakly Interacting Massive Particles

The DarkSide Collaboration: 48 Universities, Laboratories and Organizations from 12 countries

Timeline:

2011 - 2013
Prototype 10kg detector "DS-10"

2013 - Present
50kg active volume detector "DS-50"

2020 - ?
20Mg active volume detector "DS-20k"

202_ - ?
200Mg active volume detector "ARGO"

APC, Université Paris Diderot, CNRS/IN2P3 | Gran Sasso Science Institute (GSSI) | Laboratori Nazionali del Gran Sasso (LNGS) | Augustana University | Belgorod National Research University | Black Hills State University | Budker Institute of Nuclear Physics | Instituto Nazionale di Fisica Nucleare (INFN) | Universidade Estadual de Campinas | Università degli Studi | Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) | I(NCD)TIM | University of California | Joint Institute for Nuclear Research (JINR) | ETHZ, Swiss Federal Institute of Technology | Fondazione Bruno Kessler (FBK) | **Fermi National Accelerator Laboratory (FNAL)** | Fort Lewis College | University of Hawai'i | Institute of High Energy Physics (IHEP) | IPHC, Université de Strasbourg, CNRS/IN2P3 | Institute for Nuclear Research, National Academy of Sciences of Ukraine | Smoluchowski Institute of Physics, Jagiellonian University | National Research Centre Kurchatov Institute | Lawrence Livermore National Laboratory (LLNL) | LPNHE Paris, Université Pierre et Marie Curie, Université Paris Diderot | Laboratorio Subterráneo de Canfranc | National Research Nuclear University MEPhI | Politecnico di Milano | Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University | Novosibirsk State University | St. Petersburg Nuclear Physics Institute, NRC Kurchatov Institute | Università di Pisa | Pacific Northwest National Laboratory (PNNL) | Princeton University | Università di Roma (Roma Uno) | SLAC National Accelerator Laboratory | Temple University | TIFPA, Trento Institute for Fundamental Physics and Applications | Amherst Center for Fundamental Interactions, University of Massachusetts | University of Crete | Instituto de Física, Universidade de São Paulo | Virginia Tech

Direct dark matter detection is primarily an exercise in background-reduction.

Weakly
Interacting
Massive
Particles

→ Only interact (very rarely) with "normal" matter via the **gravitational** and the **weak** force (or a new force at the weak scale) → Look for a collision between a WIMP and an argon nucleus

Other particles:
electrons,
alphas,
neutrons, etc.

→ Interact via the gravitational and weak forces, but also the **EM force** → Add background to our data — remove as many as possible!

DarkSide Structure — Vetos

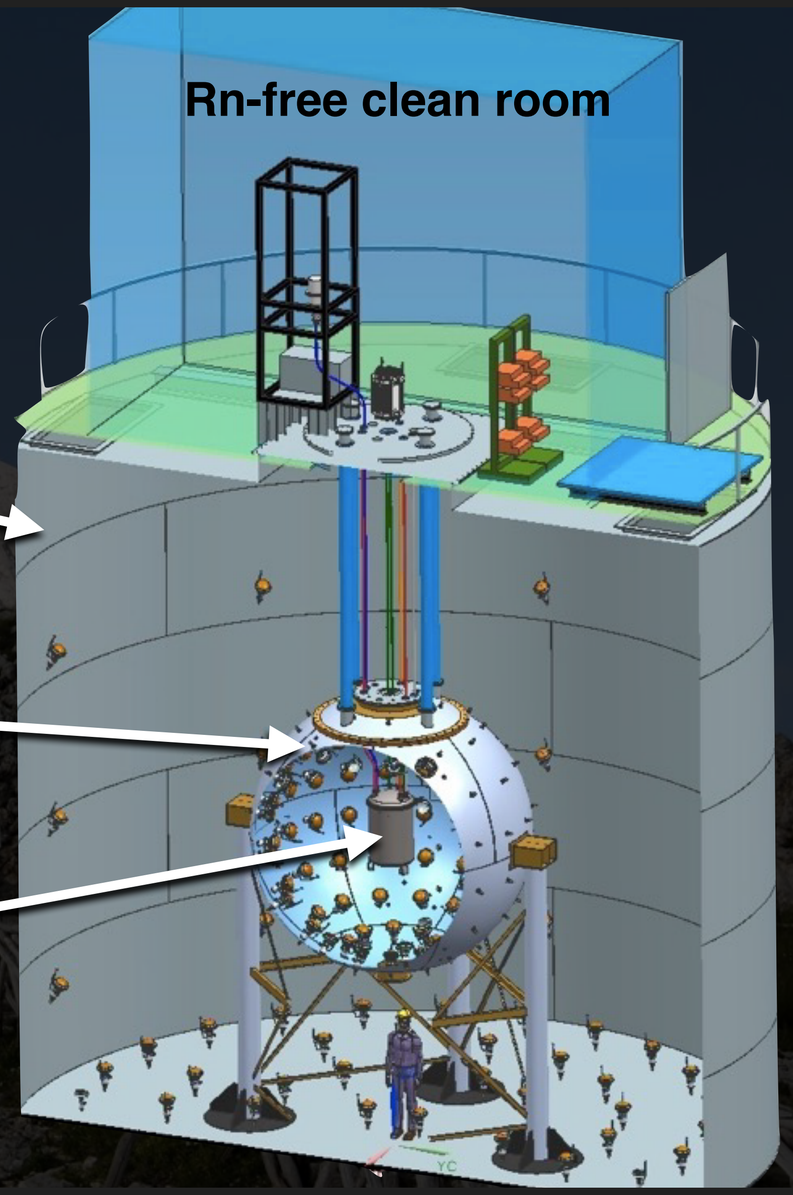
Gran Sasso* (pictured) provides 3800 m.w.e. passive shielding against cosmic rays

11m-diameter, 10m-tall Water Čerenkov Detector (WCD) provides active shielding against γ's, n's, μ's

4m-diameter borated Liquid Scintillator Veto (LSV) provides additional active shielding against γ's and n's

…these all surround the inner detector Time Projection Chamber (TPC)

*the highest peak in the Apennines



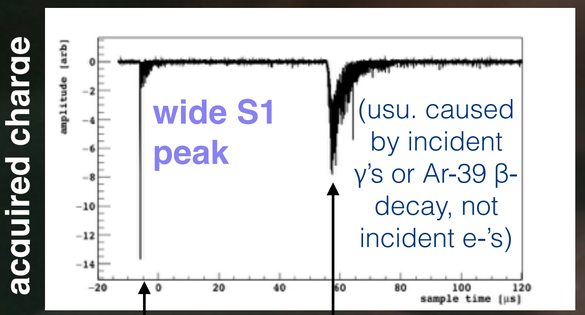
DarkSide Structure — TPC

Two-phase (gaseous/liquid) argon TPC

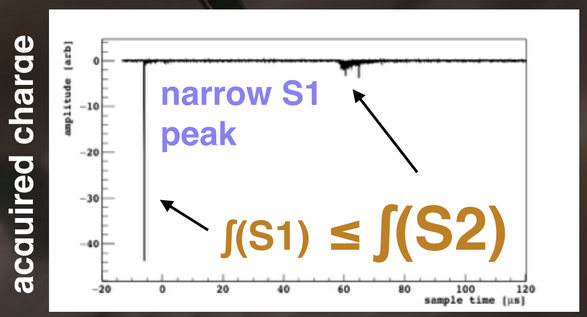
Primary (S1) and secondary (S2) scintillation signals allow for particle identification via Pulse Shape Discrimination (PSD) and 3D event position reconstruction

def: f90 fraction of light seen in the first 90ns of the S1 pulse (which can be several μs long)

ER (electron recoil)

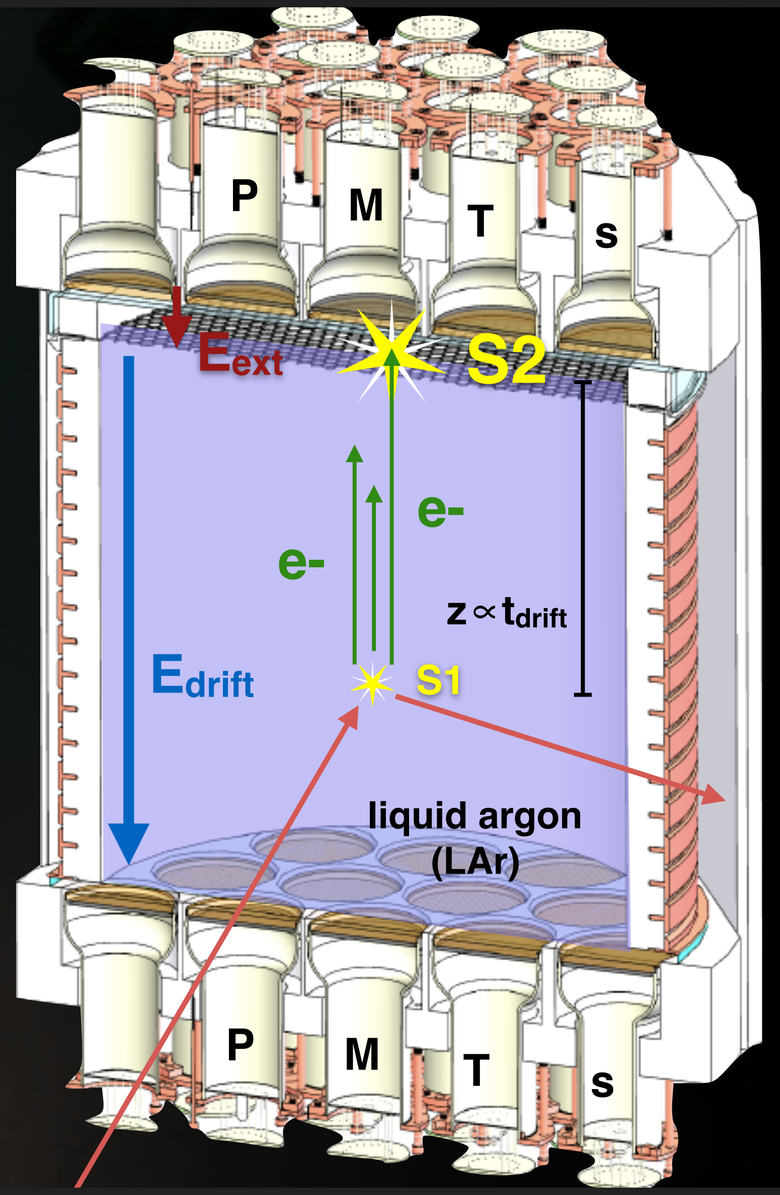


NR (nuclear recoil)



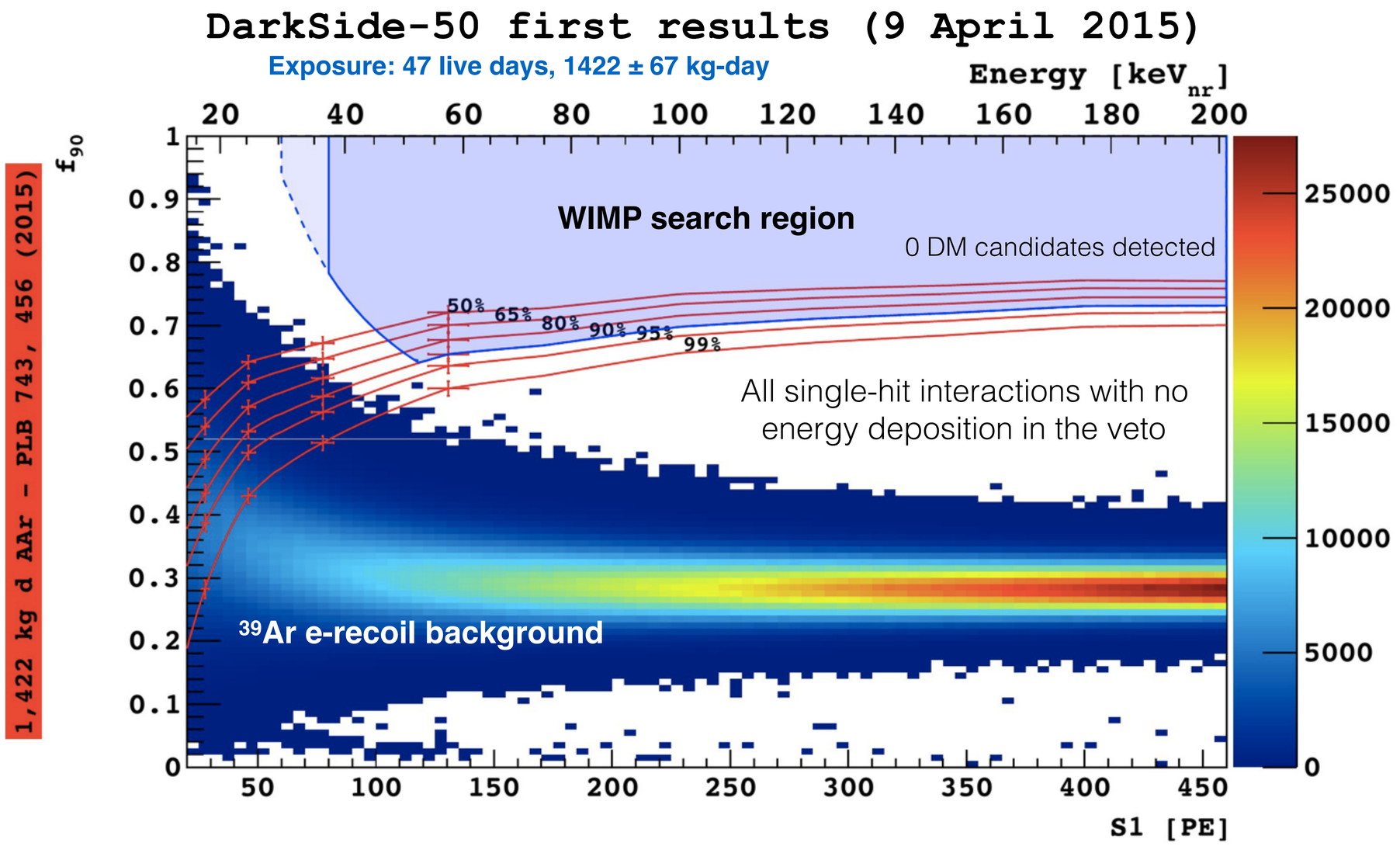
S2/S1 ratio and Pulse Shape Discrimination (PSD)

(WIMPs interactions are NRs)



First results used atmospheric argon (AAr), which contains ^{39}Ar — a cosmogenic isotope of argon (τ = 269y) in trace amounts.

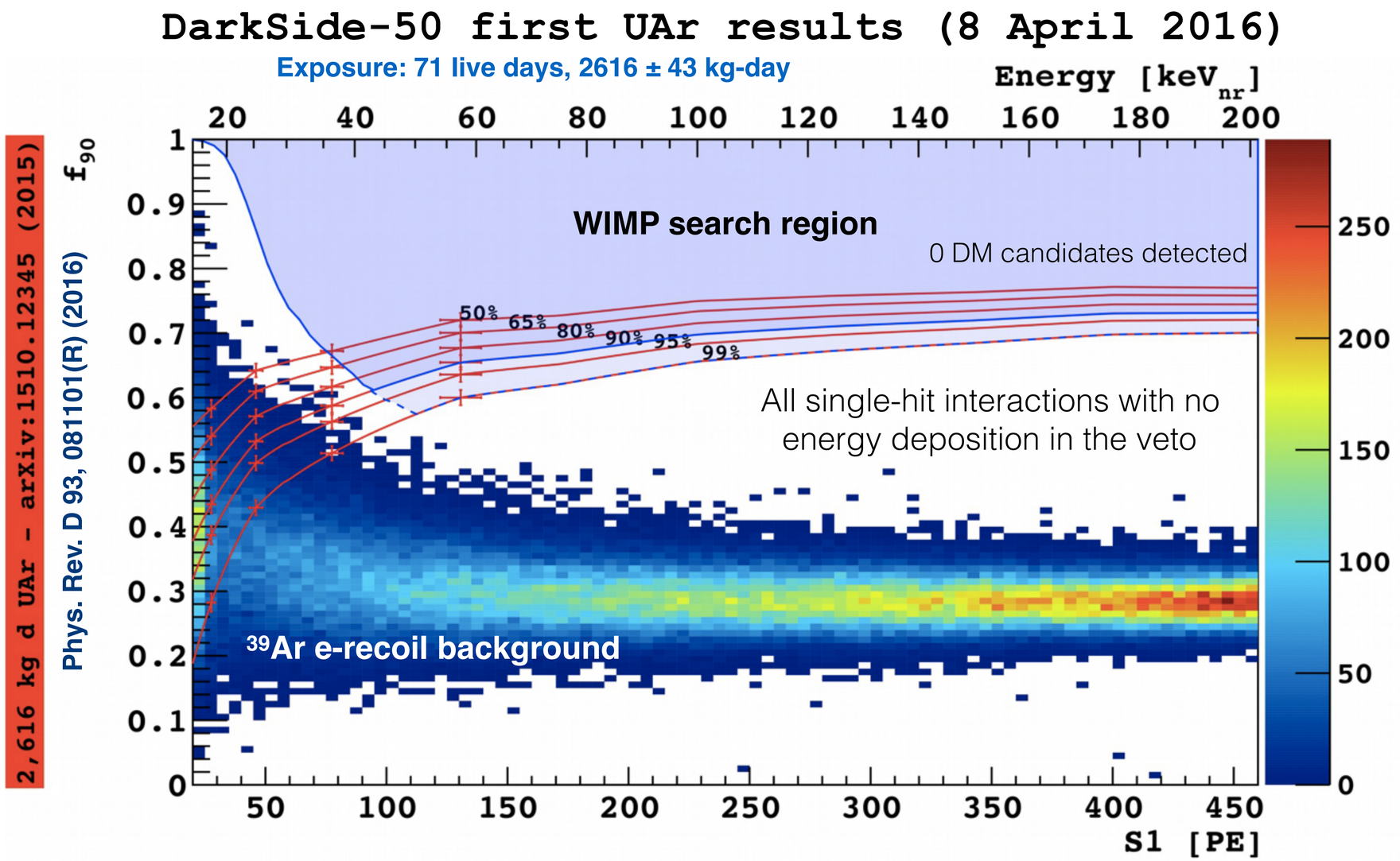
…more recent results use underground argon (UAr) extracted from the Kinder Morgan CO_2 source in Cortez, CO, USA.



Discrimination power of DarkSide-50: 15M e-recoil events in WIMP energy range… 0 NR events.

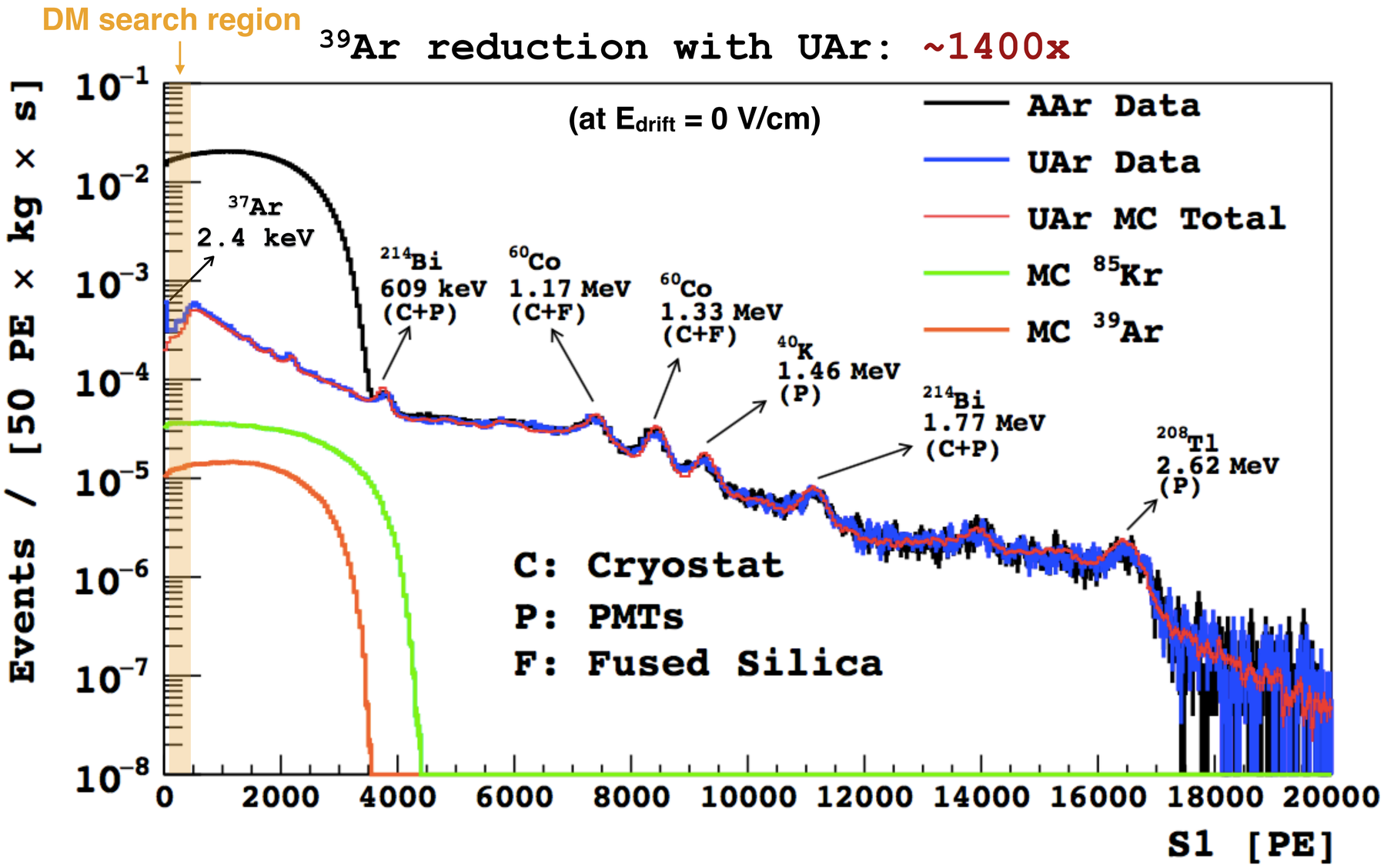
1 in 1.5e7 discrimination

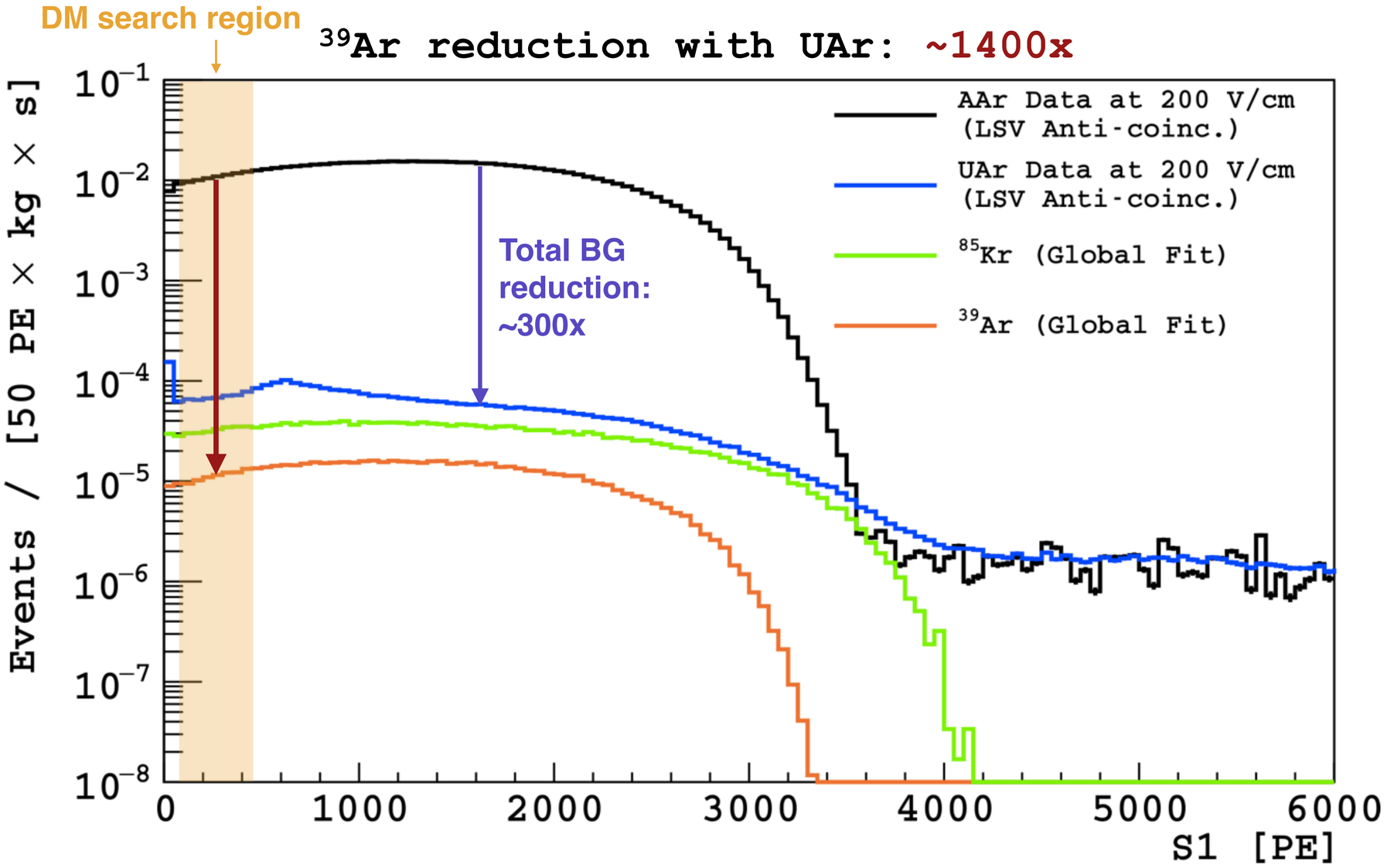
Underground argon reduces background even further…



47 days of AAr ^{39}Ar background is equivalent to 38.7 years' of UAr in DS50!

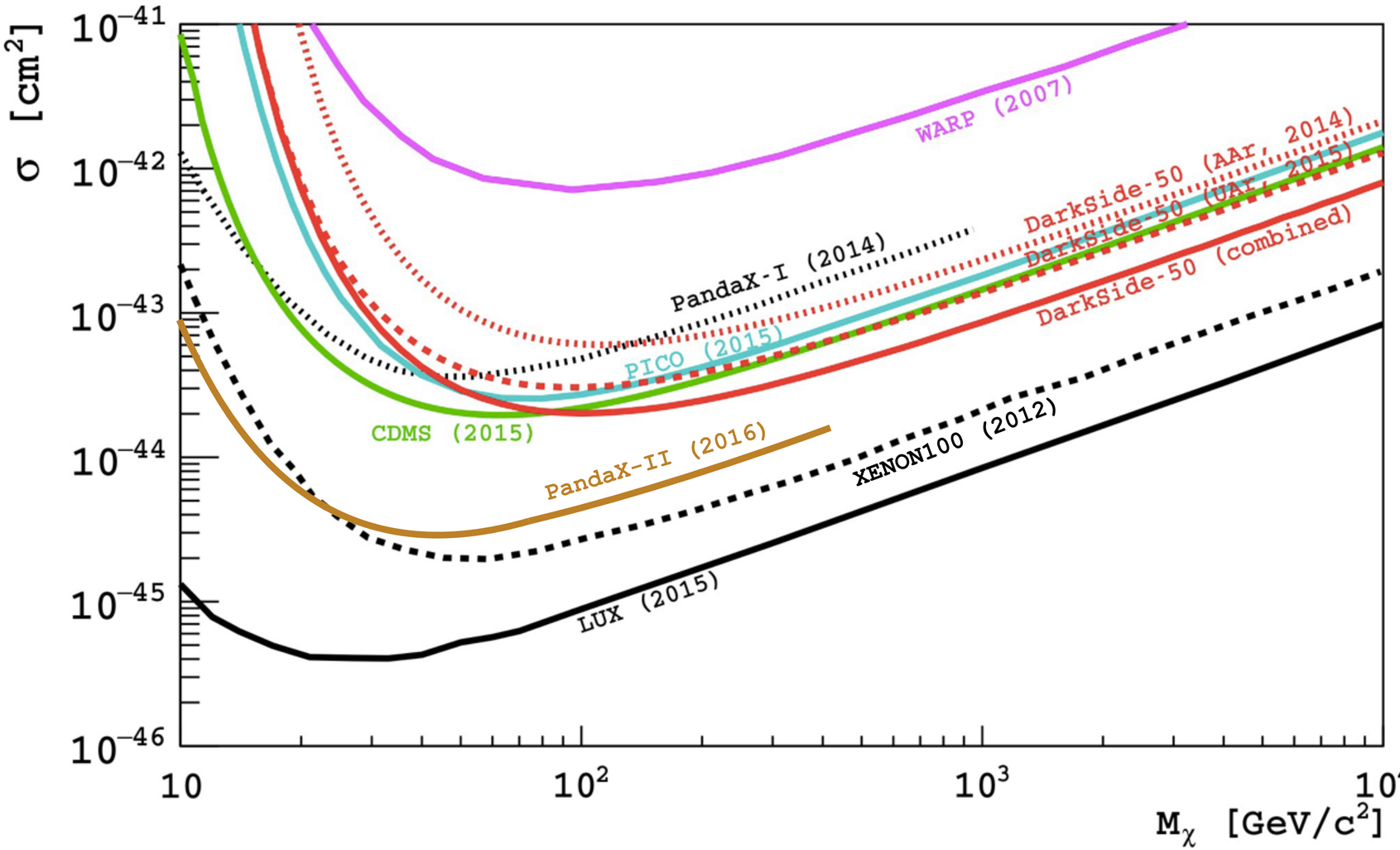
Discrimination power allows for an ^{39}Ar-free 5.5 ton-yr UAr exposure.


DM search region
^{39}Ar reduction with UAr: ~1400x
(at E_{drift} = 0 V/cm)
AAr Data
UAr Data
UAr MC Total
MC ^{85}Kr
MC ^{39}Ar
^{37}Ar
2.4 keV
^{214}Bi
609 keV
(C+P)
^{60}Co
1.17 MeV
(C+F)
^{60}Co
1.33 MeV
(C+F)
^{40}K
1.46 MeV
(P)
^{214}Bi
1.77 MeV
(C+P)
^{208}Tl
2.62 MeV
(P)
C: Cryostat
P: PMTs
F: Fused Silica
Events / [50 PE × kg × s]
S1 [PE]



Severely reduced BG with UAr means we can scale up!

Combined AAr/UAr WIMP Exclusion Curve



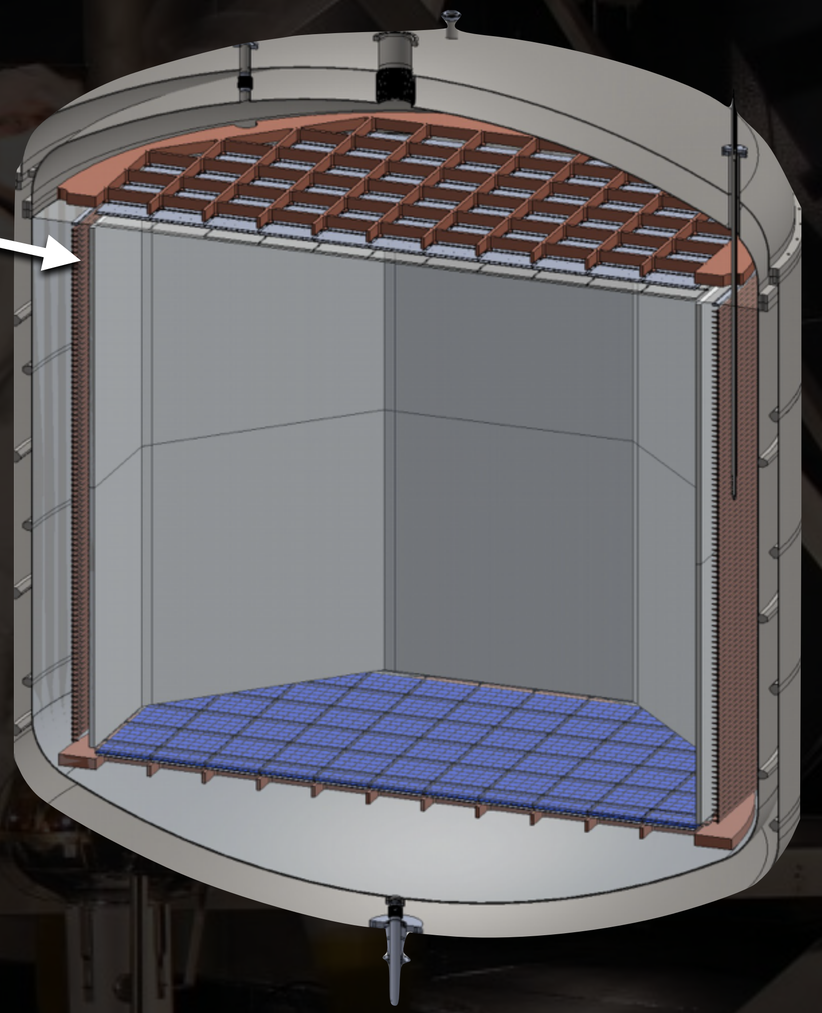
BEST limit with argon target

3rd best limit at high WIMP masses (≳ 250 GeV/c²)

(Exclusion curve *.txt file available here.)

DarkSide-20k

20Mg (20-ton) fiducial mass detector
Proposed to INFN/NSF in December 2015



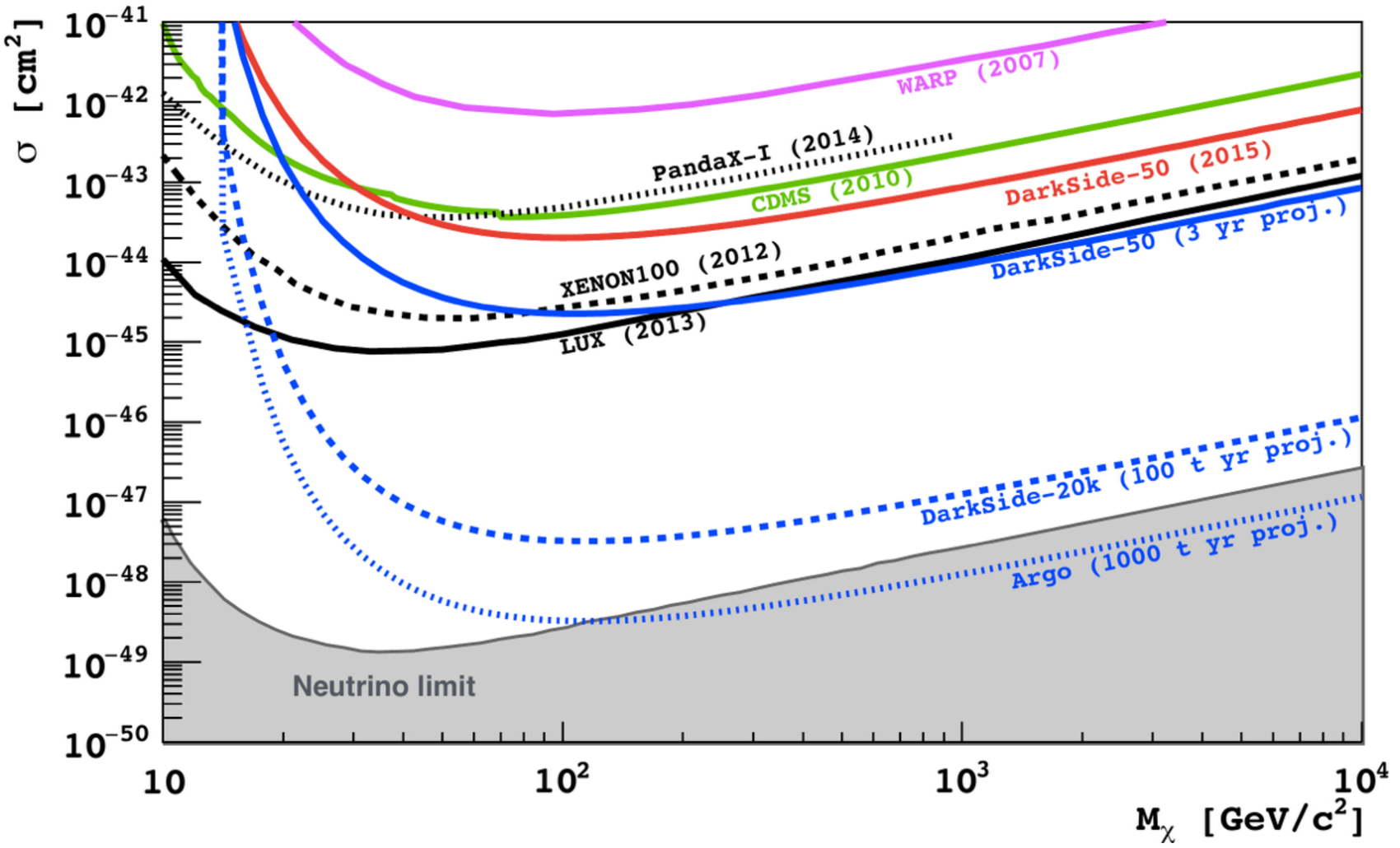
Goals:

100 ton-year background-free exposure
$\sigma < 10^{-47}$ cm^2 at 1 TeV/c^2

Argo:

200Mg (200-ton) fiducial mass detector
$\sigma < 10^{-48}$ cm^2 at 1 TeV/c^2

Projected Limits for DS-20k and Argo



Additional Future Plans

- Possible solar neutrino search?
- Increased production of UAr for ton-scale detectors

Prepared for submission to JCAP

Solar neutrino detection in a large volume double–phase liquid argon experiment

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Thank You!
in 10 Minutes

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