DarkSide: direct WIMP searches with two-phase argon TPCs

P. Meyers – Princeton

LNGS Scientific Committee Meeting – October 2013

DarkSide-50 TPC cryostat deployed in liquid scintillator neutron veto

The DarkSide Collaboration

IHEP

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IPHC, Université de Strasbourg

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Università degli Studi Milano
Università degli Studi Federico II Napoli
Università degli Studi Perugia
Università degli Studi Roma Tre

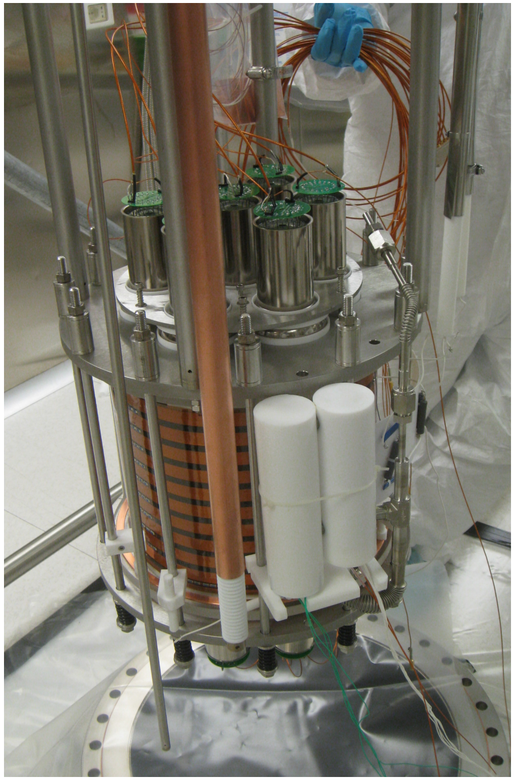
Jagiellonian University

KINR, NAS Ukraine

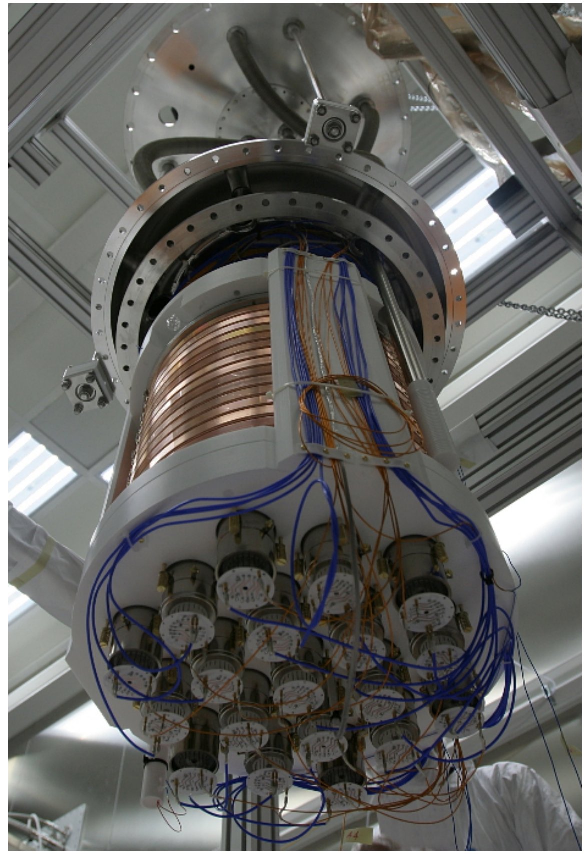
Joint Institute for Nuclear Research – Dubna
Lomonosov Moscow State University
Kurchatov Institute – Moscow
Saint Petersburg Nuclear Physics Institute

Augustana
Black Hills State
Fermilab
Princeton
SLAC
Temple University
University of Arkansas
UCLA
University of Chicago
University of Hawaii
University of Houston
University of Massachusetts
Virginia Tech

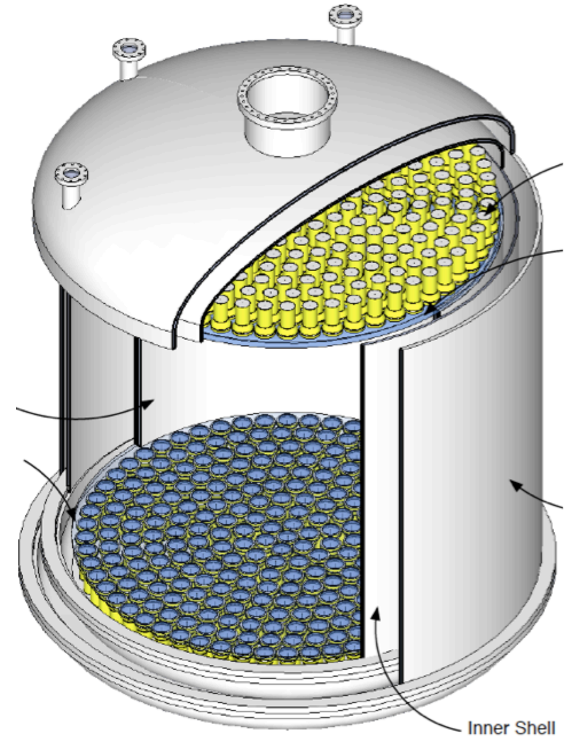
The DarkSide Program at Gran Sasso Lab, Italy



DarkSide-10
prototype
10 kg active
200 days Princeton
500 days LNGS



DarkSide-50
50/33 kg active/fiducial
Sensitivity~10^{-45} cm^2
in 3-year run



DarkSide-G2
3.3/2.8 T active/fiducial
Sensitivity~10^{-47} cm^2
in 5-year run

Goal: Multi-year, background-free data runs

Signal: **nuclear recoil** of Ar atom from elastic WIMP scatter

Major backgrounds:

- electron recoil from β decay or γ interaction
  - external/internal
- neutron-induced **nuclear recoil**
  - cosmogenic/radiogenic-internal

DarkSide-50 Infrastructure

LNGS:

- 3400 m.w.e overburden
- Cosmic μ reduced by 10^6
- Drive-in access

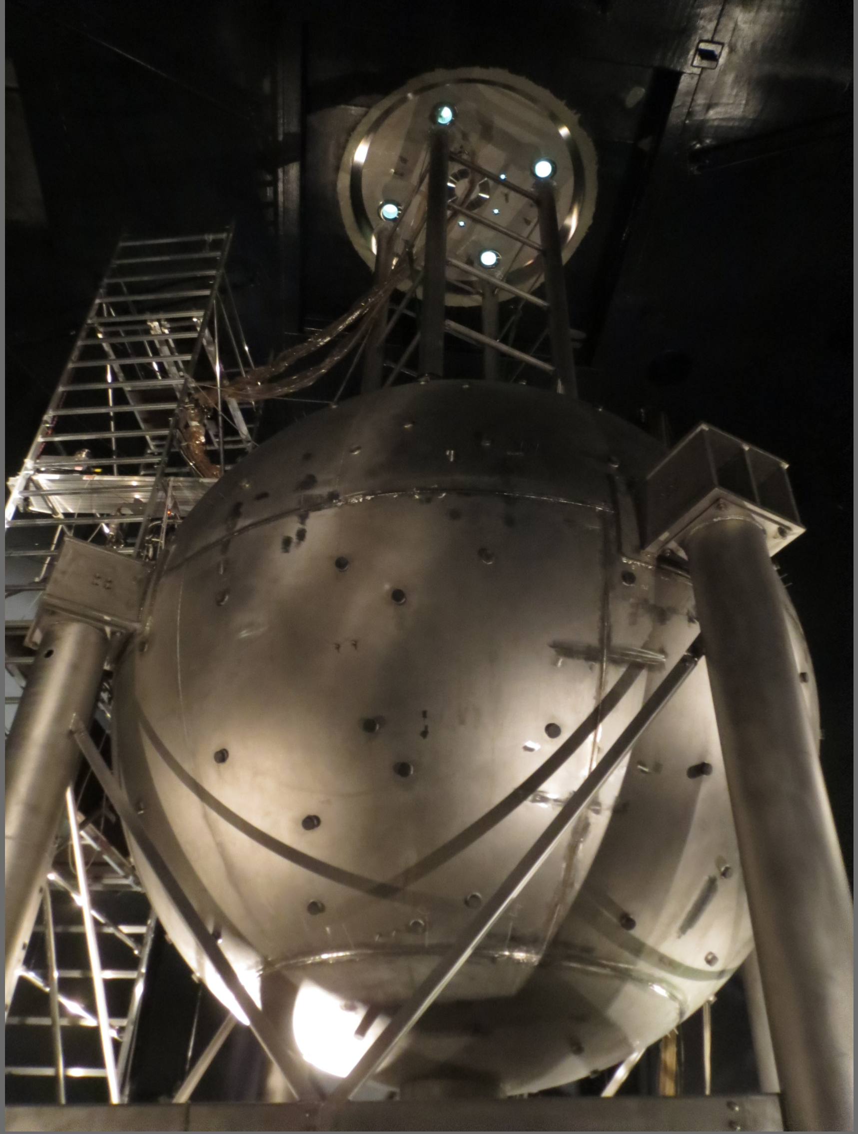
Assembly/deployment Cleanroom

- Class 10-100
- Rn suppression to 5-50 mBq/m^3

Water Cherenkov muon veto (CTF)

- 11 m ϕ × 10 m high
- 80 8” PMTs

Both sized for DS-G2



Liquid Scintillator Neutron Veto

- 4-m sphere
- Boron-loaded scintillator – fast capture gives charged particles
- 110 8” PMTs
- Efficiency ≥ 99% for radiogenic neutrons from detector components

Sized for DS-G2

TPC Parts-preparation Cleanroom

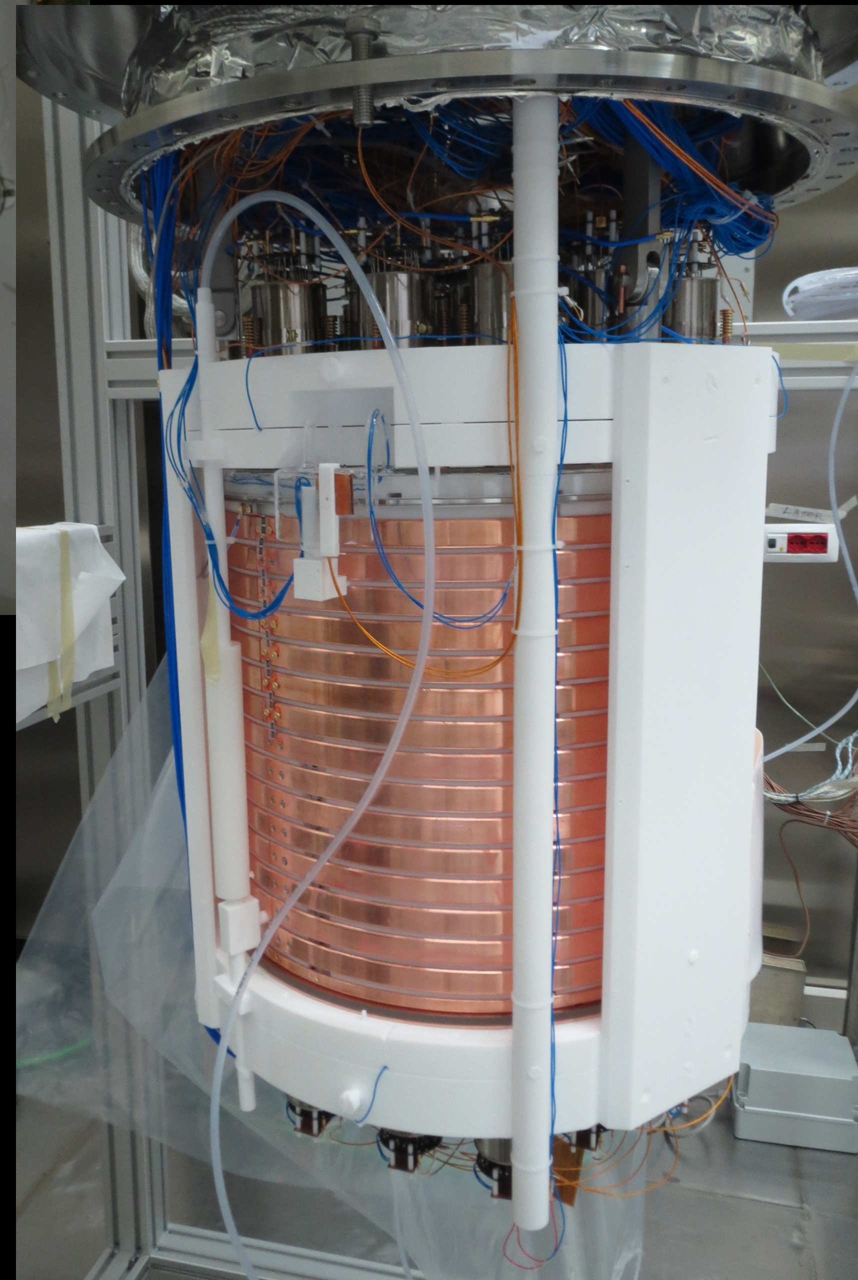
- Class 10-100
- Rn suppression to 5-50 mBq/m^3
- Evaporator for wavelength shifter

Stainless-steel Cryostat

- All-cold design
- Cooled by externally-liquefied Ar in continuous recirculation/purification

DS-50 TPC

- 38 3” R11065 PMTs
- 36 cm $\phi \times$ 36 cm high
- Ionization detection via electro-luminescence in 1 cm gas pocket

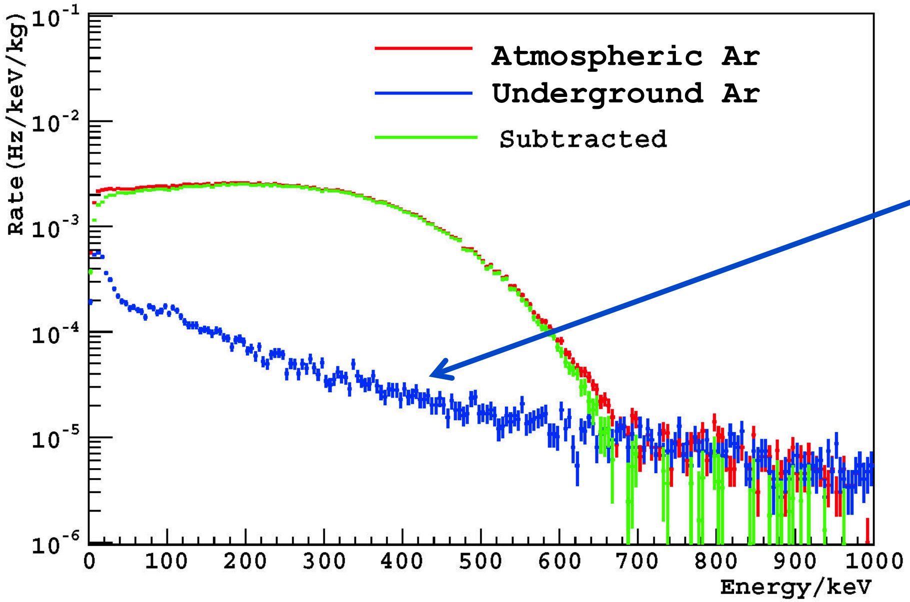


Goal: Multi-year, background-free data run

Signal: **nuclear recoil** of Ar atom from elastic WIMP scatter

Background: electron recoil from β decay or γ interaction

- Initially the dominant background by far
- In turn dominated by ^{39}Ar β decays, 1 Bq/kg in atmospheric argon
- Argon from underground sources can have very low ^{39}Ar

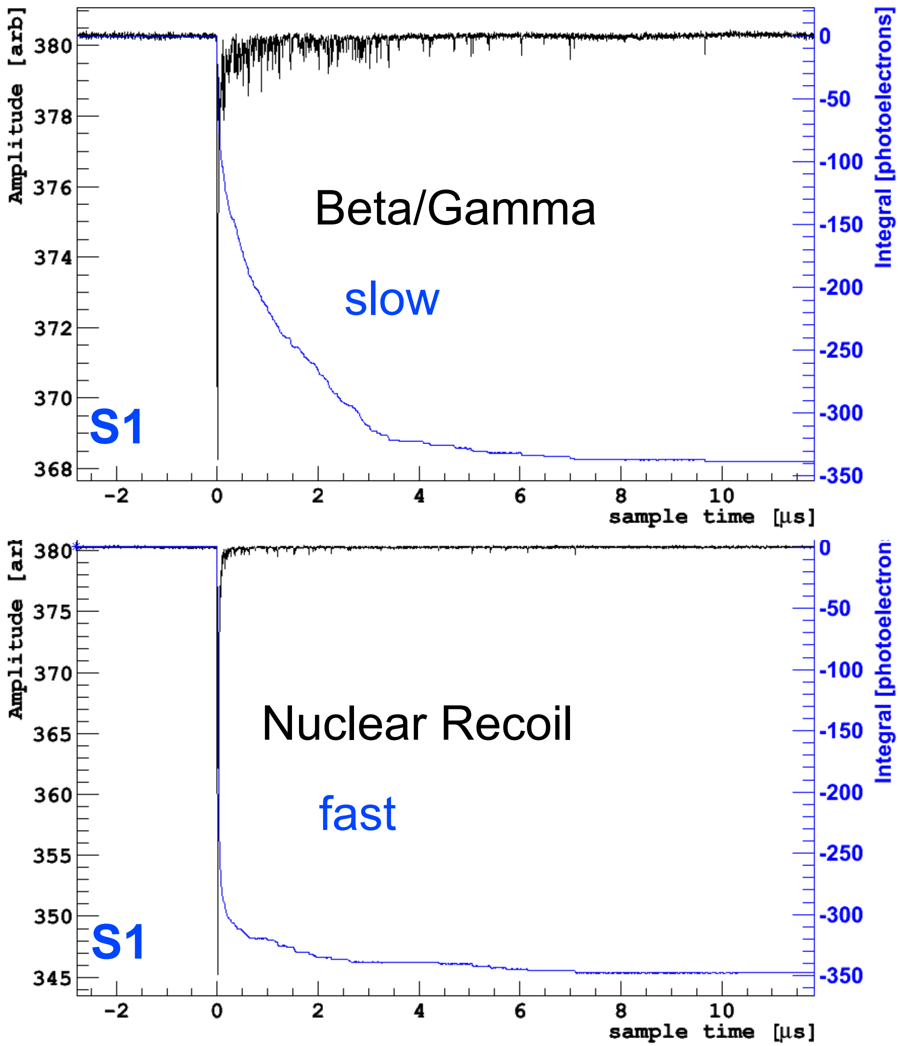


- Our measurements give an **upper limit** of 6.5 mBq/kg, a factor of >150 reduction.
- At this limit, ^{39}Ar still the dominant β/γ background, but not by much.

Jingke Xu Ph.D. thesis, 2013

Background: electron recoil from β decay or γ interaction

- Pulse shape discrimination in argon



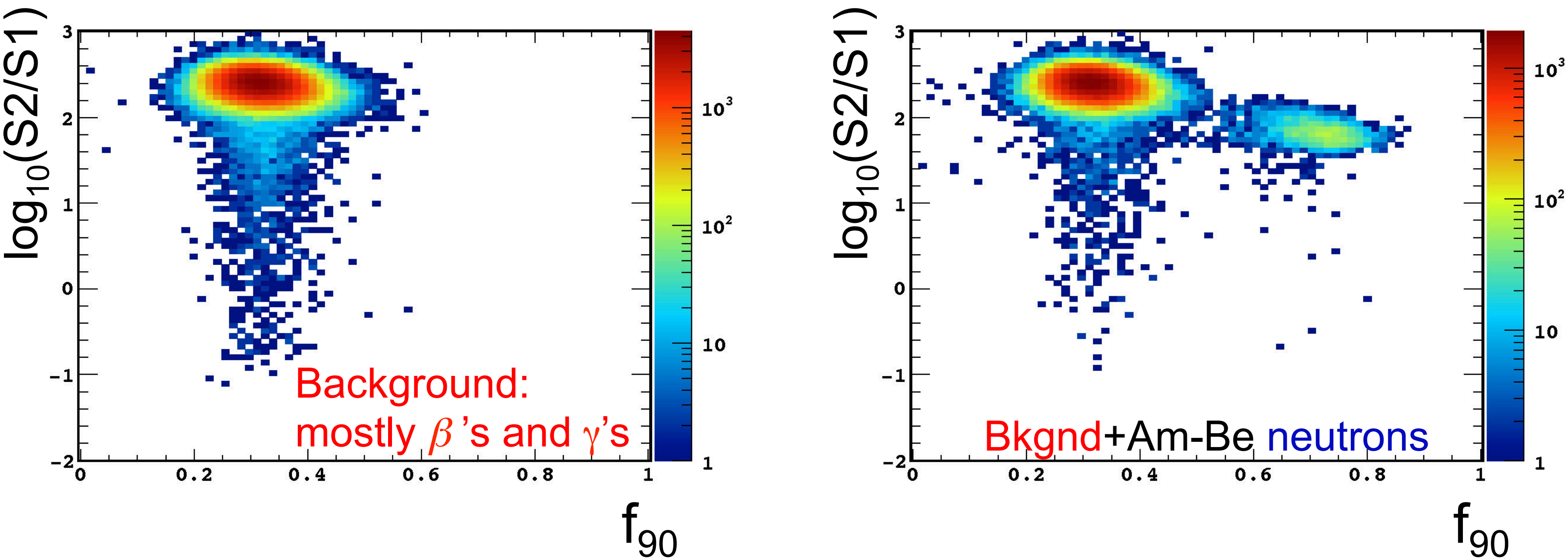
Two events with ~the same integrated scintillation signal from DS-10.

Simple discriminant: f_{90} = fraction of scint in first 90 ns.

- $f_{90} \approx 0.75$ for nuclear recoils
- $f_{90} \approx 0.3$ for electron recoils
- Electron rejection as high as 10^8 with sufficient p.e. statistics

Background: electron recoil from β decay or γ interaction

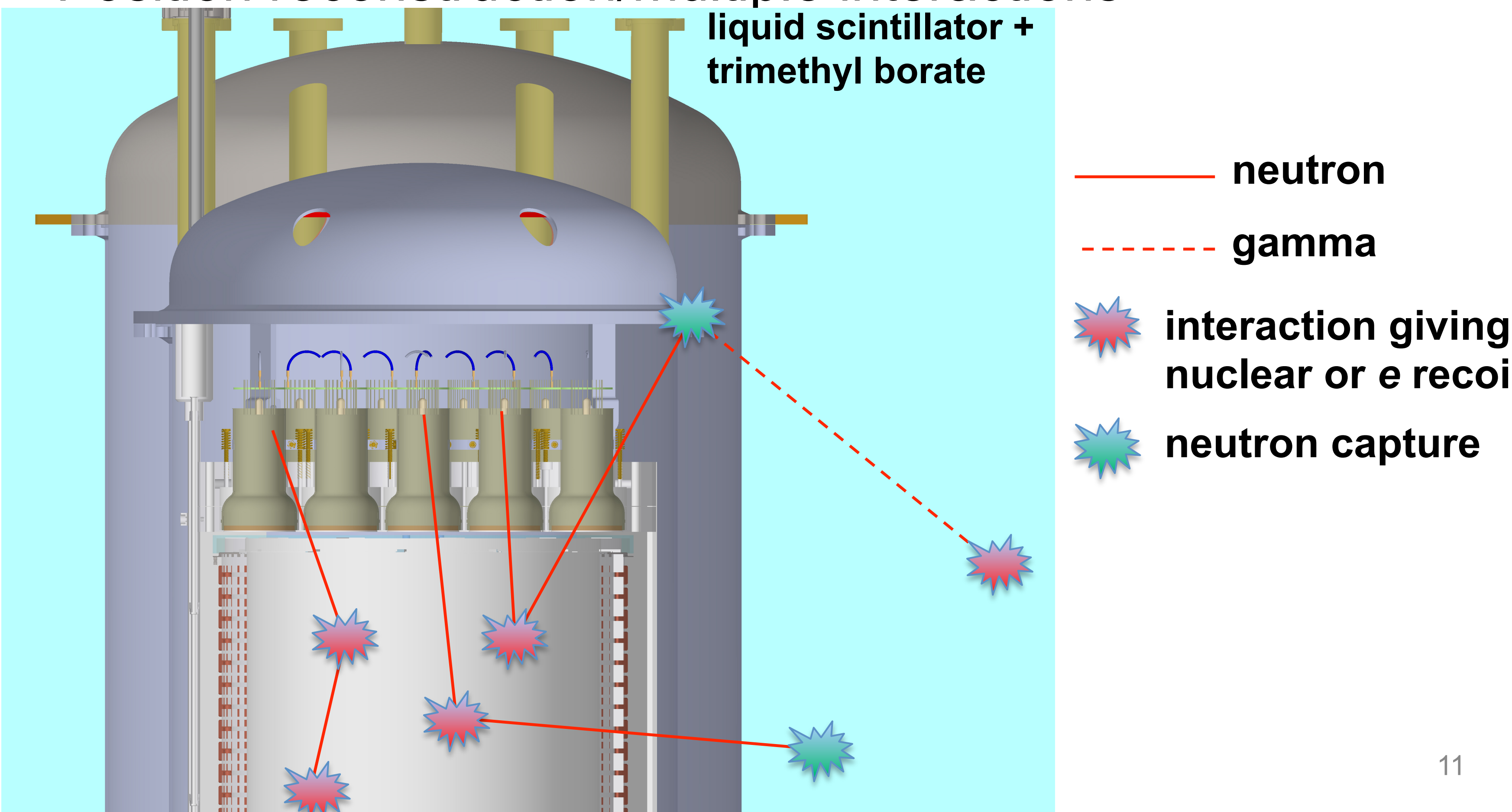
- Ionization/Scintillation ("S2/S1") – as in xenon, where electron rejection ~100
- S2/S1 appears ~independent of f_{90}
- Indications that rejection in argon weakens at low energy



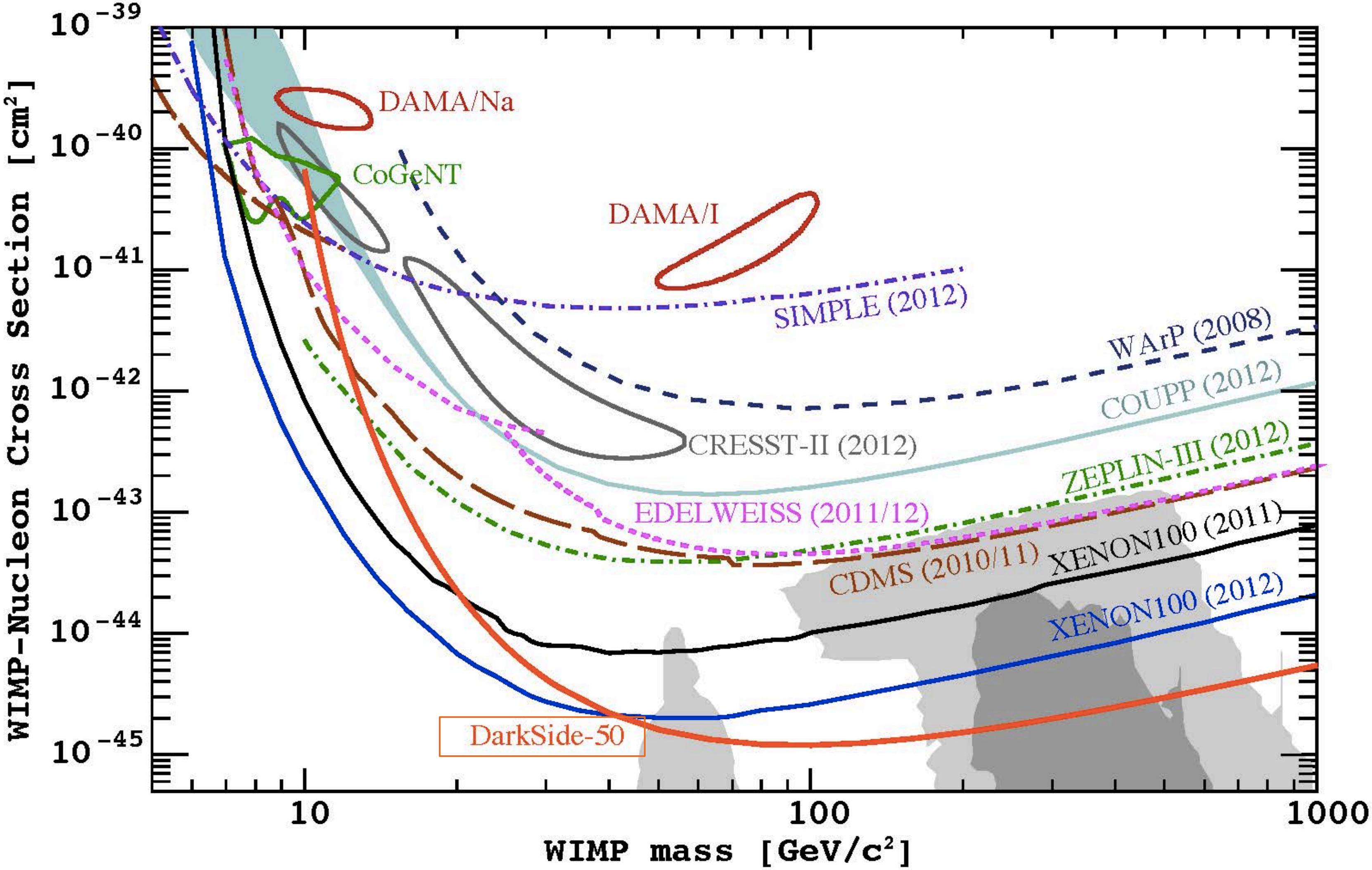
DarkSide-10 data: events with 100-200 scintillation p.e.
(≈57-114 keV_r in DS-10, somewhat lower in DS-50)

Background: **neutron-induced nuclear recoil**

- Radiogenic (α,n) from detector components dominates
- Screen and select materials for extremely high radiopurity
- PMTs largest source, then cryostat steel
- Highly efficient neutron veto rejection ≥100
- Position reconstruction/multiple interactions

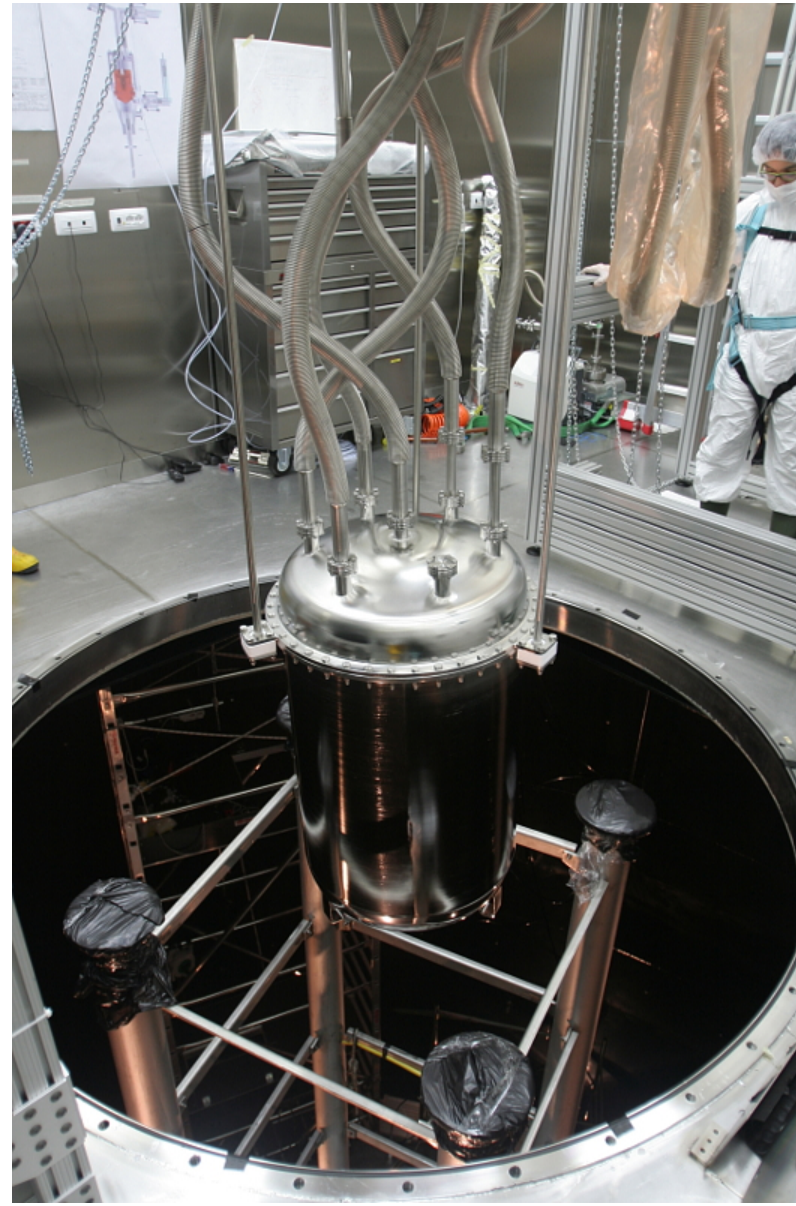


DarkSide-50 sensitivity



DarkSide-50 Status

- Water tank instrumented
- Neutron veto instrumented
- ~200 kg of Underground Ar collected (~150 kg needed for DS-50)
  - Still to be purified to ~5 ppm
- TPC test assembly and deployment
  - 38 PMTs – a mix of Hamamatsu R11065, -10, and -20
- Test run May 13 – June 27, 2013
- Stable running at 26 kV (0.5 kV/cm)
- R11065-20s do not work at LAr temperature!
  - Working with Hamamatsu on this – already much progress
- Neutron veto air run with calibration sources – July 2013

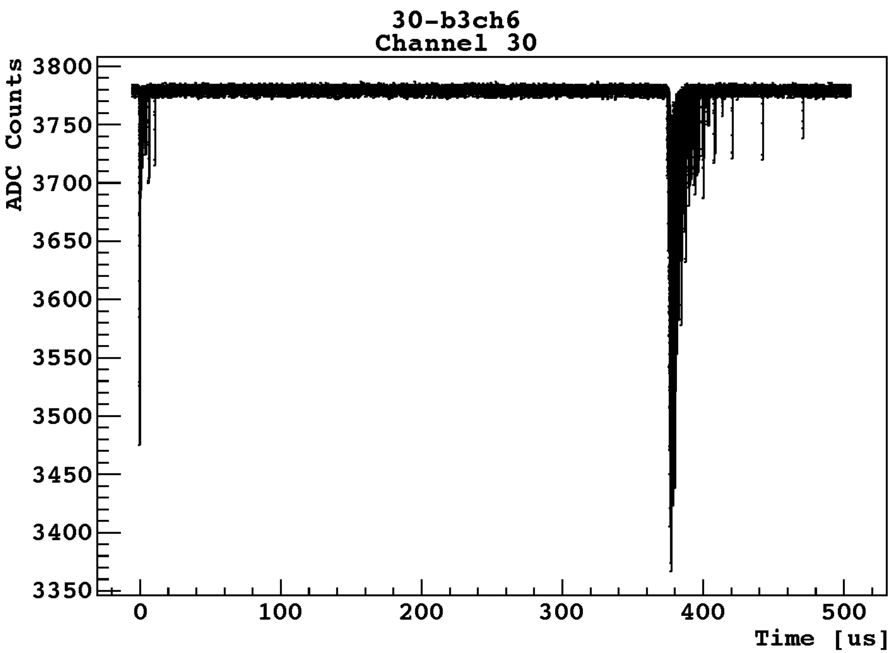


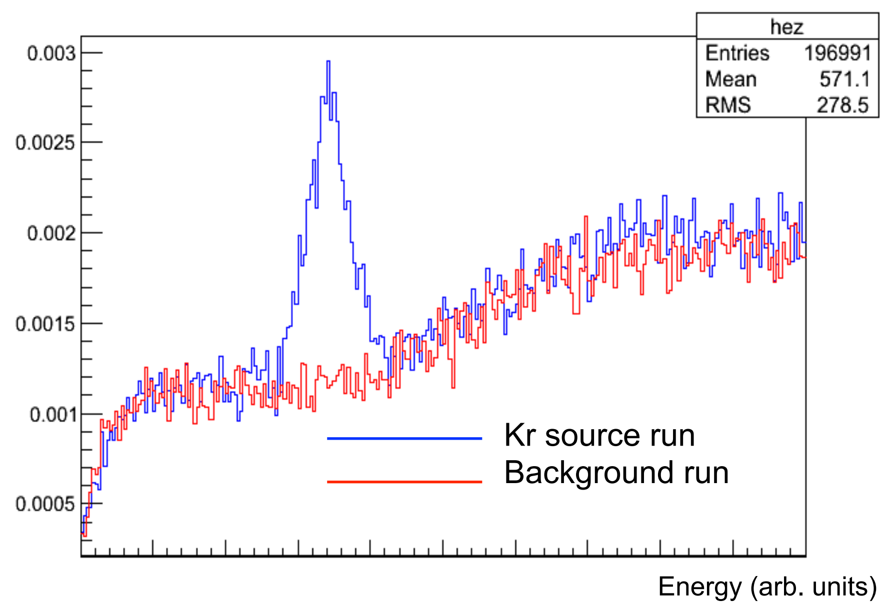
DarkSide-50 Status

- Neutron veto scintillator plant commissioned Aug. 26-30
- Liquid scintillator master solution distilled Sep. 9-13
- Final TPC assembly complete Aug. 31
  - Using R11065s
- TPC deployed in neutron veto tank Sep. 13
- TPC cryostat cool and fill Sep. 16-20
- TPC commissioning Sep. 20-now
- Neutron veto filled Sep. 30-Oct. 13
- CTF water fill started Oct. 2, est. full mid-Nov.

TPC Commissioning

- PMTs all working and calibrated
- TPC HV stable at $E_{drift}/E_{extract}$ = 2.8/0.2 kV/cm
- Two-phase operation established
- ^{85}Kr source commissioned
- Good light yield (final calibration soon)





Neutron Veto Commissioning

- All PMTs working
- 108/110 electronics channels working (spares to be installed)
- Waiting for water shielding to lower rates for calibration

CTF/Muon Veto Commissioning

- 77/80 PMTs working
- 79/80 electronics channels working (one noisy channel to be fixed)

Trigger/Data Acquisition Commissioning

- TPC/neutron veto/muon veto working individually
- Integration underway

DarkSide-50 Physics Run

- 2 weeks more of commissioning
- Background run with atmospheric argon (1 week ≈ 3 years of UAr background)
- Fill with underground argon for long data run

DarkSide neutron veto (before Tyvek wrap)
in CTF water tank