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DarkSide-G2 Materials Assay

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On behalf of the DarkSide Collaboration

AARM Meeting – March 2014

Outline

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- DarkSide-G2 science goals
- Background strategy
- Progressive development from DarkSide-50
- DarkSide-G2 material list
- Materials of concern for the DarkSide-G2 scale-up
- Assay methods

DarkSide-G2 science goals

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- For a 100 GeV/c^2 WIMP-like dark matter particle:
  - 5 year run
  - Background free
  - 2 x 10^{-47} cm^2 spin-independent WIMP-nucleon cross section sensitivity

- Experimental specifications
  - 3.8 tonnes active mass of liquid argon (LAr)
    - Employ underground-sourced argon depleted of radioactive ^{39}Ar
  - Operated as a LAr time projection chamber (TPC)
  - Shielded by dual vetos:
    - Liquid scintillator veto (LSV) neutron and internal γ-ray veto surrounds TPC
    - Water Cerenkov anti-cosmic ray exterior shield: Counting test facility (CTF)
  - Located at Gran Sasso underground laboratory (LNGS)

SNOWMASS Spin-Independent Limit Plot

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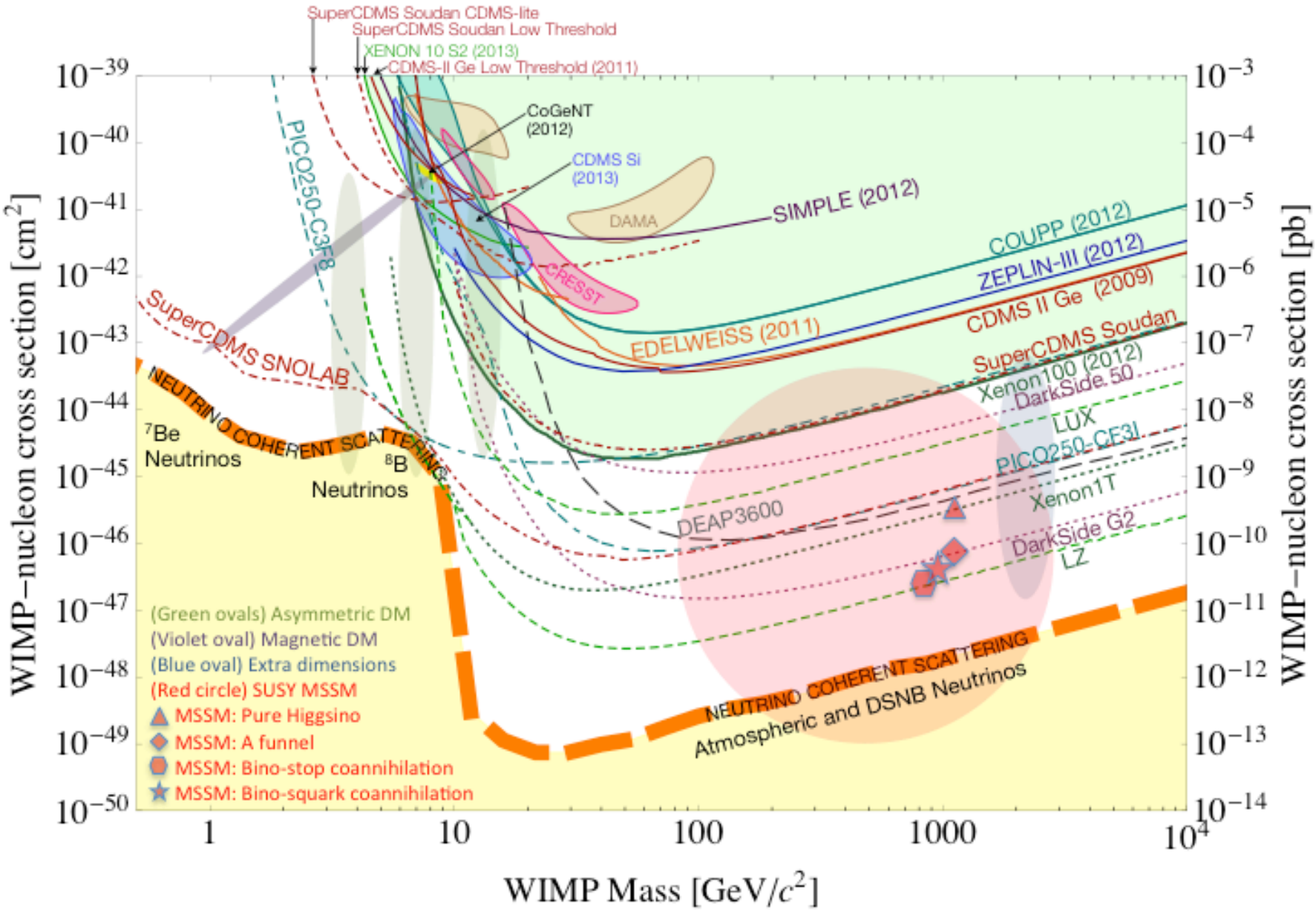

DarkSide-G2 background strategy

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- Signal-based methods
  - Native (S1) LAr scintillation pulse shape discrimination
  - Fiducialization from drift-delayed secondary scintillation (S2)
  - S1/S2 scintillation ratio discrimination of electron and nuclear recoils
- Veto methods
  - Multiple interaction site event rejection
  - High-efficiency, liquid scintillator-based external veto
  - Dual cosmic-ray water Cerenkov outer veto and liquid scintillator veto
- Material selection and screening
  - Underground-sourced Argon (Uar) reduces ^{39}Ar decay concerns
  - *In situ* self-assay of internal backgrounds with vetos and non-fiducial LAr
  - Assembly and preparation in radon suppressed clean rooms
  - Material screening for U/Th/K – Limit and quantify backgrounds
    - (α,n) reaction neutrons (greatest concern)
    - Gamma-ray background (moderate concern)
    - Spontaneous fission neutrons (less concern)

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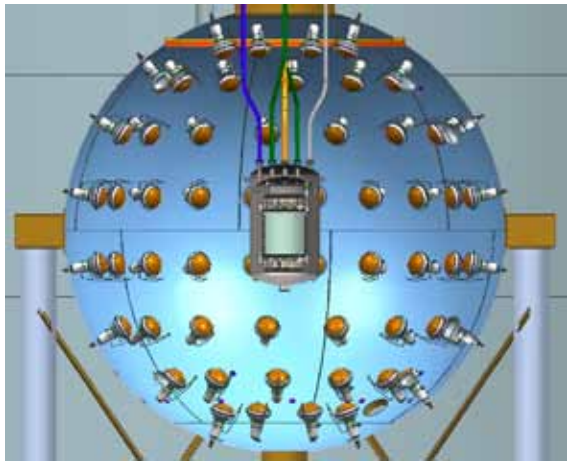
This presentation's focus

DarkSide-50 – Basis for evolution to G2



- Well developed background budget
- Most materials assayed to target values
  - Predominately HPGe counting at LNGS
- DarkSide-50 will give valuable feed-back on this assay program

Source	Quantity	^{238}U, ^{232}Th [mBq/kg]	Cosmogenic n Recoil Bkgs. [(0.1 ton·yr)$^{-1}$]	Radiogenic n Recoil Bkgs. [(0.1 ton·yr)$^{-1}$]	β/γ before cuts [counts/(kg·keV·d)]
Scintillator [42]	11.8 T	$<7.4\times10^{-5}$,$<4.1\times10^{-6}$	~0.12	$<1.5\times10^{-4}$	$<2.2\times10^{-5}$
Veto PMTs [43]	50	~360*,~200*	–	<0.07	<0.27
Steel [44, 45]	64.2 T	<0.74, <1.1	~0.24	<0.024	<0.011
Lead [46]	119.9 T	<0.01, <0.004	~0.72	$<2.2\times10^{-4}$	<0.001
Mine Rock [47, 48]	–	~116,000, ~12,000	~0.51	<0.01	<0.003
Source	Quantity	^{238}U, ^{232}Th [mBq/kg]	Total n production [n/yr]	Total n Recoil Bkgs. [(0.1 ton·yr)$^{-1}$]	β/γ before cuts [ev/(kg·keV·d)]
Acrylic Vessel [46, 49]	18 kg	<0.013, <0.0045	<0.044	<0.005	<0.001
Titanium Dewar [37]	73.9 kg	<0.2, <0.2	<4.9	<0.15	<0.22
DAr	50 kg	–	–	–	≤10
3" QUPIDs	38	<0.49**, <0.40**	<1.8	<0.07	<0.15
Cu Internal Parts [35, 46]	27.7 kg	<0.036, <0.0098	<0.23	<0.036	<0.005
PTFE Internal Parts [46]	7.3 kg	<0.0096, <0.0011	<0.20	<0.02	$<1.5\times10^{-4}$

Summary table from DarkSide-50 proposal to DOE/NSF → Not current; acts as single basis for evaluation and evolution

DarkSide-G2 – Thinking about materials

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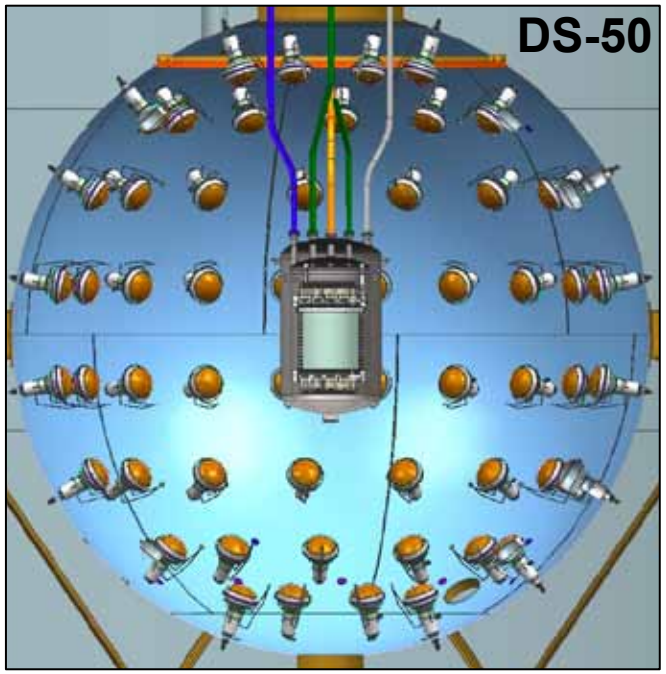
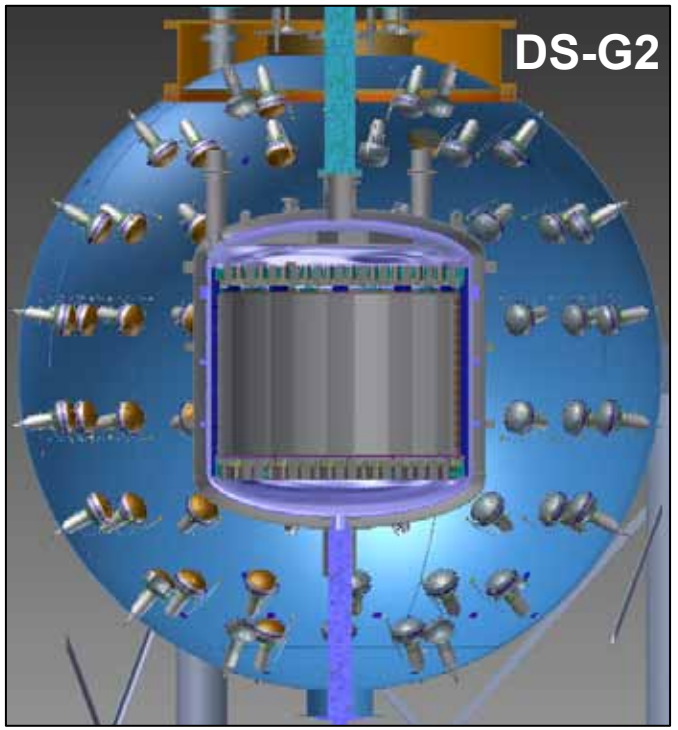
- "Scale-up"





- Yes, more target argon
- More PMTs
- More cryostat and other materials, but surface to volume should win

Comprehensive DarkSide-G2 material list

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Material	Short Name	Matrix
External		
Mine Rock	Mine Rock	Rock
LN (from Borexino N2 systems)	LN or N2	N2 gas
GAr and LAr *transfer lines* to/from LAr-TPC vessel	Transfer Lines	Stainless steel
DS Radon-Suppressed Clean Rooms	Low Rn Cleanrooms	N/A
Counting Test Facility (CTF)		
Counting Test Facility (Water tank / Muon veto)	CTF	Stainless Steel
CTF 8" PMTs	CTF PMTs	PMT
Muon veto water tank (H2O Plant)	H2O	H2O
Cleaning water (H2O Plant --> Cleaning Module)	H2O Cleaning	H2O
Liquid Scintillator Veto (LSV)		
Liquid scintillator vessel support structure	LSV Support	Stainless Steel
Stainless Steel of LSV	LSV	Stainless Steel
LSV 8" PMTs	LSV PMTs	PMT
Lumirror light reflector	Lumirror	Polyester
Scintillator 1:1 PseudoCumene (PC) and TriMethylBorate (TMB) (storage in Borexino tanks)	PC-TMB	Scintillator
Time Projection Chamber (TPC)		
Stainless steel of LAr-TPC cryostat vessels	TPC Cryostat	Stainless Steel
High voltage feed-through (low background UHMWPE + stainless steel rings)	HVFT	HDPE + Stainless Steel
All wiring and cables	Cables	Copper + plastics
Cryogenic preamps ("low background" - Discrete on Cirlex)	Cryo Preamps	Kapton + eletronics
PMT divider (considered part of the PMT spec)	TPC PMT Divider	Kapton + eletronics
Hamamatsu 4" R11065-40 PMTs (Bialkali-LT)	TPC PMTs	PMT
PTFE for TPC cage	TPC PTFE	PTFE
Copper field rings and parts	TPC Cage	Copper
Fused silica window	Fused silica	Fused silica
Wavelength shifter (Tetraphenyl butadiene)	TPB	TPB
Ar-39 Depleted Target (Underground Argon)	UAr	Argon
R&D Components		
Low background Titanium	Titanium	Ti
Optical link preamp to digitizers	Optical Link	Quartz
ASIC for cryo preamp	ASIC	Electronics
PMT to cage anode HV bypass capacitor	HV Capacitor	Electronics

DarkSide-G2 TPC materials

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- DS-50 TPC → replaced by → DS-G2 TPC
  - DarkSide-50 assay program and experimental results qualify:
    - Facility
    - Water Cerenkov veto: Counting Test Facility (CTF)
    - Liquid Scintillator Veto (LSV)
  - Focus on backgrounds from "new" DarkSide-G2 TPC components
    - "new" in the sense DS-G2 is obtaining new materials to build the G2 TPC etc.
- Assay limit requirements for DS-G2 based on background budget

Item	Matrix	^{238}U [mBq/kg]	^{232}Th [mBq/kg]
TPC Field Cage	Copper	<0.04	<0.01
Fused Silica	Fused silica	<0.001	<0.001
TPC PTFE	PTFE	<0.01	<0.001
R11065-G2 TPC PMT's	PMT	<0.08/unit	<0.08/unit
PMT base and preamp	PCB, components, connectors, solder	<0.02/unit	<0.02/unit
LAr-TPC cryostat	Stainless steel	<0.1	<0.1
HVFT	HDPE and Stainless steel	<1	<1

Summary table from DarkSide-G2 proposal to DOE/NSF

Assay Methods

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- HPGe Counting
  - Continued use of LGNS HPGe counting
    - Currently long counting queue
  - Target items that require non-destructive assay
    - PMTs
    - Cryogenic preamps (but also see destructive assay)
- Use mass spectrometry methods for items that can be sampled
  - Copper, Stainless steel
  - PTFE, HDPE
  - “Kapton”-based electronics components
  - Fused silica
- Desire development of methods for assaying surface contamination
  - Desirable QC check on the planned cleaning and handling processes
  - This is principally targeted at radon progeny on surfaces

Summary

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- DarkSide-50 is operating
  - Results from DarkSide-50 assay program and operation
    - Qualify and quantify the backgrounds associated with
      - Facility, counting test facility (CTF), liquid scintillator veto (LSV)
    - Provide basis for developing confidence for DarkSide-G2 background budget
  - For a complete summary of DS-50 status:
    - UCLA Dark Matter 2014: "*DarkSide-50: performance and results from the first atmospheric argon run"* Luca Grandi, University of Chicago
      - http://www.pa.ucla.edu/sites/default/files/webform/DM2014_forD.pdf
- DarkSide-G2 assay program
  - Mostly focused on "new" materials in and within scaled-up TPC
    - Stainless steel, copper
    - HDPE, PTFE
    - PMTs, preamps
    - Fused silica
  - Combination of assay methods to cover the requirements:
    - LNGS HPGe counting
    - Mass spectrometry techniques