Outline

• DarkSide program (DS-10, DS-50 and DS-G2)
• Dark matter detection in DarkSide
• Backgrounds
• Scaling to ton-size liquid argon TPC for WIMP detection
  – Depleted argon
  – Active background subtraction with veto detectors
  – Material selection
  – Calibration
• Schedule and sensitivity
DarkSide Program

- DarkSide utilizes liquid argon TPC to search for WIMP detection.
- Three stage program:
  - DarkSide-10, a prototype detector – 10 kg of liquid Ar
    - operating now underground at LNGS
    - demonstrated sufficient light yield in the liquid argon TPC at level of 9 p.e./keVee [reference]
  - DarkSide-50, a low background, 50 kg detector
    - DarkSide’s first WIMP search (sensitivity at the level of $\sim 2 \times 10^{-45}$ cm$^2$ for 100 GeV WIMPs at 90% C.L.);
    - currently under construction;
  - DarkSide-G2 (second generation), a multi-ton detector with an active mass of 3.3 tons,
    - WIMP sensitivity at the level of $2 \times 10^{-47}$ cm$^2$;
    - currently in the R&D phase with goal of producing a detector capable of 5 years zero background running.

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WIMPs elastically scatter from the nucleus that recoils (E < 100 keV)

For standard WIMPs (~100 GeV WIMPs interaction c-s $\sim 10^{-44} - 10^{-55}$ cm$^2$ per nucleon)

Results in $\sim$10-100 events/ton/yr
DarkSide detector - 2-phase argon TPC

Anode

Gas Layer

Extraction Grid

Field Cage

Liquid

Cathode

Photodetectors

Extraction Field (~3kV/cm)

Drift Field (~1kV/cm)

Wavelength shifter
Dark matter signal in DarkSide

Electro-luminescence
“S2” Light

“S1” Scintillation Light

Drift Charge

- Excellent signal to background discrimination power $>10^8$ based on nuclear recoil identification using scintillation shape discrimination [?];

Pattern of S2 light gives x-y position (~1cm resolution)

Time difference between S1 and S2 gives z position (few mm resolution)

- The precise determination of event positions in all three dimensions in TPCs
Argon as a target for dark matter detection

- Excellent scintillator: ~40,000 photons/MeV and very transparent to its own scintillation light
- Relatively abundant (1% in atmosphere) and easy to purify
- Possible scaling to multi-ton detectors: need to suppress $^{39}$Ar
  - Underground argon < 0.65% of $^{39}$Ar compared to atmospheric argon
  - DarkSide collaboration successfully demonstrated purity and extraction capability of underground argon
- Very powerful rejection capability for electron recoil background
Background sources and suppression

- **Internal Radioactivity**
  \(^{238}\text{U}, \, ^{232}\text{Th}, \) etc.
- **Gamma Rays**
  external and from shielding
- **Cosmic Muons**
- **Radiogenic Neutrons**
  from spontaneous fission and \((\alpha,n)\), externally and in shielding
- **Fast Neutrons**
  from muons in the shield and beyond

→ **Radiopure materials**
  *(radioassay insitu, active background discrimination and calibration)*
Active Veto Detectors

- Deploy DarkSide in the CTF in Gran Sasso
- Cryostat is surrounded with active neutron veto detector to identify neutrons from cosmic ray muons
- Neutron veto is filled with boronated liquid scintillator (Boron reduces capture time from 250 µs to 2µs)
- Water filled CTF, instrumented with PMTs successfully tags passing cosmic ray muons and act as passive neutron shield
- CTF tank + neutron veto reduce cosmogenic backgrounds by $\gg 10^3$

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Calibration

- The target and neutron veto will be actively calibrated using a combination of internal distributed ($^{83\text{m}}\text{Kr}$), external point sources (neutron and gamma sources) and neutron gun deployed in the neutron veto region.
- Point sources and neutron gun will be deployed using calibration insertion system.
- 6-axis articulated arm system for 360° coverage
Sensitivity and Timeline

- DarkSide-10 continues to operate - valuable experience with 2-phase operation, background level measurements
- DarkSide-50 to be deployed by the end of 2012
  - Reach $10^{-45}$ cm$^2$ in 3 years background free operation
- DarkSide-G2 ($\sim 3.3$ ton)
  - up to $10^{-47}$ cm$^2$ and will utilize the same active shielding as DarkSide-50
  - R&D to reach 5 years of background free running