The R&D of DS-20k Detector

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On behalf of the DarkSide Collaboration

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Global Argon Dark Matter Collaboration

DEAP-3600 (running)
DarkSide-50 (running)
miniCLEAN
ArDM

DarkSide-20k 2022~

~300 tonnes

ARGO 2029~
Projected Sensitivity
DarkSide-20k Detector

- Inner detector: Sealed acrylic dual phase TPC filled with ~50 tonnes Underground Argon (UAr);
- Membrane cryostat filled with ~700 tonnes Atmospheric Argon (AAr);
- Veto detector: 2% Gd doped acrylic panels as neutron veto;
- Copper Faraday cage;
- SiPMs as photosensors: 8280 channels for TPC, ~3000 channels for Veto.
Liquid Argon TPC

- Anode (Clevios+TPB)
- Wire Grid (SS)
- Field Cage (Clevios)
- Reflector (ESR+TPB)
- Cathode (Clevios+TPB)
- GAr
- Acrylic Vessel
- LAr
Conductive Polymer: Clevios

- Blue aqueous dispersion
- Radio-pure; Rn emanation measured after coating: no $^{222}\text{Rn}$ is observed
- Coating methods: Wire Wound Rod (small, flat substrate) and Painting (large substrate) with brush or spray gun
- High transparency for 420 nm light
R&D for TPC Parts

Acrylic plate with 5μm Clevios and TPB coated. Tested in LAr

Stainless steel wire grid. Will be tested in Proto_0 TPC

Enhanced Specular Reflector (ESR) with TPB coated. Tested in LAr
Proto_0: A TPC Demonstrator

- Integrated test of the new techniques: Clevios, ESR, wire grid...
- S2 related study: S2 pulse shape, XY resolution
- Online adjustable gas pocket to optimize the gas pocket configuration
- First Commissioning in Q4 of 2019
Proto_1ton

• A scaled down version of DS-20k TPC by using totally ~1 tonne liquid argon;

• Acrylic bonding is under development at University of Alberta;

• 370 readout channels;

• Will be assembled in the summer of 2020.
Neutron Veto

- Capture neutron by Gadolinium
- Gd doped acrylic panels, 2% Gd by weight is required
- Use ESR as reflector (same as TPC)
- WLS candidates: TPB and PEN
- ~3000 channels SiPMs for photon detection
Gd Doped Acrylic Panel

- Ultimate goal: 2% Gd doped in 5 cm thick acrylic panel

- Mix MMA and Gd salts before polymerization.

- Gd salt candidates:
  Gadolinium Oxide, Gd$_2$O$_3$
  (Nano particles with grain diameter between 80 nm and 100 nm)
  Gadolinium Sulfate, Gd$_2$(SO$_4$)$_3$

- First doping test: 1% Gd doped in 3mm acrylic panels by Donchamp Acrylic CO.
Reflectors in Veto Detector

- PEN as an alternative wave length shifter in the veto detector
- Efficiency increases at lower temperatures and shorter wavelengths
- PEN has efficiency comparable to TPB in LAr
- PEN has also been considered by ProtoDUNE DP

<table>
<thead>
<tr>
<th>Sample</th>
<th>250 nm</th>
<th>128 nm</th>
<th>128 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPB+PMMA</td>
<td>0.59(7)</td>
<td>0.43(7)</td>
<td>0.52(10)</td>
</tr>
<tr>
<td>PEN+PMMA</td>
<td>0.15(2)</td>
<td>0.24(4)</td>
<td>0.40(7)</td>
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<tr>
<td>PEN</td>
<td>0.16(4)</td>
<td>0.25(5)</td>
<td>0.42(8)</td>
</tr>
<tr>
<td>PEN (glass)</td>
<td>0.15(3)</td>
<td>0.12(3)</td>
<td>0.20(6)</td>
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<tr>
<td>PEN+PMMA</td>
<td>0.25(5)*</td>
<td>0.56(13)</td>
<td>0.77(20)</td>
</tr>
<tr>
<td>TPB+PMMA</td>
<td>0.27(8)*</td>
<td>0.58(15)</td>
<td>0.80(23)</td>
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<tr>
<td>PEN</td>
<td>0.26(4)*</td>
<td>0.28(4)*</td>
<td>0.38(7)</td>
</tr>
<tr>
<td>VM2000</td>
<td>0.09</td>
<td></td>
<td>0.317(16)</td>
</tr>
<tr>
<td>TPB+TTX</td>
<td></td>
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</tbody>
</table>

PEN
polyethylenenaphthalate
Cryostat

- A ProtoDUNE like membrane cryostat will be used for DS-20k
- The cryostat is tested and currently being used in ProtoDUNE detectors
Cryogenics

- Cryogenics loop for UAr:
  Cooling power ~8kW for latent heat only
  Maximum circulation speed: 1000 stdL/min

- The condenser box is welded this summer; and the system will be tested in Q4 of 2019.
SiPMs as the Photosensors

- Photon Detection Efficiency (PDE) ~50%;
- Good performance at LAr temperatures;
- SiPM customization for cryogenic temperatures (by FBK);
- One Photo Detector Module (PDM) as one readout channel, 25 PDMs as one installation unit (Motherboard, MB);
- The first MB, MB1, has just been tested in LAr at CERN in this July.
**PE counting**

![Graph of PE counting](image)

**Average Waveform**

![Average Waveform Graph](image)
UAr Purification

- ARIA project
- Big cryogenic distillation columns in Seruci, Sardinia, Italy, for final chemical purification of the UAr
- Prototype Seruci-0 is assembled and a functionality test is done with nitrogen.
- Final test in this September by using oxygen doped argon
Conclusions

- DarkSide-20k is the next generation LAr detector for WIMP searches

- TPC related techniques are under R&D:
  - Clevios, ESR, wire grid and acrylic bonding

- Veto related techniques are under R&D:
  - Gd doped acrylic and PEN

- R&D for the other significant technologies is on-going:
  - SiPMs, cryostat, cryogenics and UAr purification