Dark matter searches with low-noise ionization Ge detectors

Michael Marino
for the CoGeNT, MAJORANA collaborations

CENPA - University of Washington
Germanium Workshop, Berkeley, California
18 May 2010
Point-Contact Detectors

- P-type Point-Contact (PPC)
- Geometry: low-capacitance, noise; long-charge drift times

Figure adapted from Luke et al., IEEE trans. Nucl. Sci. 36, 926(1989).
Point-Contact Detectors

- P-type Point-Contact (PPC)
- Geometry: low-capacitance, noise; long-charge drift times
Low-energy performance

- Low noise, low threshold (< 1keV)
- Low-energy physics

Figure adapted from Aalseth, et al., PRL 101, 251301 (2008)
P-PC Detectors for WIMP searches

WIMP (ionization) spectra in Ge

- WIMP Mass: 5 GeV
- WIMP Mass: 10 GeV
- WIMP Mass: 40 GeV
WIMP Dark Matter Limits

90% CL exclusions

CDMS II, 612 kg-d

CoGeNT, 8.4 kg-d

DAMA, 3σ allowed region

CDMS Collaboration, arXiv:0912.3592;
Aalseth, et al., PRL 101, 251301 (2008);
DAMA Collaboration, EPJ C56 (2008), 333,
arXiv:0804.2741

DAMA, 3σ allowed region

Plot generated using DMTools, http://dmtools.brown.edu

M. G. Marino

Ge Workshop, UCB 18 May 2010
More exotic DM interactions: axioelectric effect

Red, solid = NaI (DAMA) resolution
Blue, dashed = PPC resolution
Normalized to 1 count/day/kg in NaI

CoGeNT

- Coherent Germanium Neutrino Technology
- Now looking for low-mass WIMPs (<10 GeV) with PPCs
- 1 group, many detectors
  - Several R&D detectors, (U Chicago, PNNL, UNC)
  - Currently 1 production detector (Soudan, MN)
- Current results: arXiv:1002.4703v2
Soudan characteristics

- Canberra custom Broad-Energy Ge (BEGe) detector
  - development spearheaded by O. Tench, K. M. Yocum at Canberra; J. Collar at U Chicago
- 0.44 kg detector, ~165 eV FWHM noise
- 2 in. ancient Pb inner shield, 8 in. Pb outer shield
- Radon exclusion box
- Neutron moderator
BEGe underground at Soudan
## DAQ

- NI, 20 MHz digitizer, trace length 400 µs

<table>
<thead>
<tr>
<th>Channel</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>High-gain (0-3.5 keV), 6µs shaping</td>
</tr>
<tr>
<td>1</td>
<td>High-gain (0-3.5 keV), 10µs shaping, triggering</td>
</tr>
<tr>
<td>2</td>
<td>Low-gain (0-14 keV), 10µs shaping</td>
</tr>
<tr>
<td>3</td>
<td>Muon-veto</td>
</tr>
<tr>
<td>4</td>
<td>High-gain, AC-coupled preamp trace (unshaped)</td>
</tr>
<tr>
<td>5</td>
<td>Low-gain, AC-coupled preamp trace (unshaped)</td>
</tr>
</tbody>
</table>
Triggering efficiency

Production Detector

~80% at 460 eV
Background reduction

- Microphonics cuts - analyze ratios of shaped channels (Morales, et al., NIM A 321 (1992) 410)

- Rise-time cuts - Previous results from R&D detectors indicated slow-pulse ‘contamination’
Rise-time vs. Energy (R&D detector PNNL)
Fast pulses vs. Slow pulses

Energy: 8.777280 (keV)

Energy: 9.582074 (keV)

R&D Detector PNNL

M. G. Marino
Slow pulse interpretation

• Incomplete charge collection in crystal dead layers

• Strauss and Larsen, NIM 56 (1967) p. 80


• Plus anything else?
Source studies (R&D detector UC)

Figure adapted from: arXiv:1002.4703v2 [astro-ph]
Rise-time summary

• Slow-pulse distribution suggests: *fiducial volume cut*

• Additional quantitative bench studies underway

• Other contributions to these slow pulses?
DM Limits

- Production detector at Soudan
- 56 days of live-time, beginning 4 Dec 2009
- With rise-time cuts: ~2 mm outer dead layer (0.33 kg effective mass)
- Following plots adapted from: arXiv:1002.4703v2
Rise-time cuts

\[ \text{ionization energy (keVee)} \]

- $^{68}\text{Ge} (L) + ^{65}\text{Zn} (L)$
- $^{65}\text{Zn} (K)$
- $^{68}\text{Ge} (K)$
Final spectrum

Example WIMP spectra:
\( \sigma = 10^{-4} \text{ pb} \),
\( M_W = 7, 10 \text{ GeV} \)

\(^{65}\text{Zn}, \ ^{68}\text{Ge} \)
WIMP Limits

CoGeNT 2008

CoGeNT 2010

M. G. Marino

Ge Workshop, UCB 18 May 2010
Axion limits

![Graph showing axion limits with various datasets and constraints.](image)
Closing

• Data taking still underway

• Quantitative investigations into understanding slow-pulses continuing

• Studying spectrum near threshold
CoGeNT collaboration

C.E. Aalseth, 1 P.S. Barbeau, 2 N.S. Bowden, 3 B. Cabrera-Palmer, 4 J. Colaresi, 5 J.I. Collar*, 2 S. Dazeley, 3 P. de Lurgio, 6 G. Drake, 6 J.E. Fast, 1 N. Fields, 2 C.H. Greenberg, 2 T.W. Hossbach, 1, 2 M.E. Keillor, 1 J.D. Kephart, 1 M.G. Marino, 7 H.S. Miley, 1 M.L. Miller, 7 J.L. Orrell, 1 D.C. Radford, 8 D. Reyna, 4 R.G.H. Robertson, 7 R.L. Talaga, 6 O. Tench, 5 T.D. Van Wechel, 7 J.F. Wilkerson, 7, 9 and K.M. Yocum 5
(CoGeNT Collaboration)

1 Pacific Northwest National Laboratory, Richland, WA 99352, USA
2 Kavli Institute for Cosmological Physics and Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA
3 Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
4 Sandia National Laboratories, Livermore, CA 94550, USA
5 CANBERRA Industries, Meriden, CT 06450, USA
6 Argonne National Laboratory, Argonne, IL 60439, USA
7 Center for Experimental Nuclear Physics and Astrophysics and Department of Physics, University of Washington, Seattle, WA 98195, USA
8 Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
9 Department of Physics and Astronomy, University of North Carolina, NC 27599, USA