HpGeDSSD Tracking R&D and the X-Array

DOE Germantown 13th Nov 2002
C.J. Lister Argonne National Laboratory

Strategy
Detectors Status
Current R&D Projects
Future Procurement Plan
Current Effort Level
Plan for FY2003
Longer Term Plans
Resources Needed
Strategic Approach to $\gamma$-Ray Tracking using Planar HpGeDSSD’s

4-Pronged Approach:

1) Develop Planar Germanium Detector Technology
2) Develop Digital Tracking Technologies
3) Demonstrate Scientific Usefulness of Devices for many Applications
4) Develop an Efficient Focal Plane Array for the FMA, The X-Array

Note: We co-ordinate our R&D with the detector development group at the Naval Research Laboratory, (Dr. R. Kroeger, Dr. B. Phlips) who pioneered work with HpGeDSSD’s for space science and national security.
Planar Germanium Detector Status
Manufactured by Ortec, Oak Ridge, TN

“Mark 3”
Traditional p-type bulk material with Boron/ Lithium Construction….. a “LEPS”
92 x 92 x 20 mm Wafers
16 x 16 Orthogonal 5mm strips
3 mm guard ring
All Warm FET preamp
Bulky Test Cryostat
By far the best to date: 1.5 keV FWHM (Li) 16 strips
2.1 KeV FWHM (B) 15 strips

“Mark 4” (December 2002)
All Cold FET preamps
Guard ring-less ?? (or 14 x 14 fallback)
Same Mechanical Package as “Mark 3”
Current R&D Projects

Technical

Digital Pulse Processing
(J. Amann)

Analysis of Resolution, “Addback” and “Event-loss”
(S. Freeman)

Monte Carlo Simulations
(E.F. Moore)

Two Detector (64-Channel) Analog Data. Acq.
(K. Teh)

VME Capability for Analog and Digital System.
(K. Teh)

Applications

Doppler Correction “Inbeam”
(S. Fischer)

Polarization of γ-rays from α-decay sources
(N. Hammond)

SBIR project “Hunting for Fossils on Mars”
(D. Nisius)

ANL Technology Division “Compton Camera”
(F. Kondev)

The “X-Array”, a FMA Focal Plane Detector
(E.F. Moore / Teng Lek Khoo)
HpGeDSSD Position Sensitivity Tests
J. Amann, DePaul University

$^{60}$Co Interaction
Real & Induced charge

Collimated source tests:
Position across single strip
Determined from difference in size of induced signal in adjacent strips
Testing HpGeDSSD Resolution and Efficiency  
Dr. S.J. Freeman (U. of Manchester UK / ANL sabbatical visitor)

Matching expectation and reality reveals a great deal about how the detector works.

* Resolution, and gain-shifts, measures capacitive coupling.
* Front-Back charge consistency quantifies collection loss
* Surface-Maps quantify edge-losses
* Absolute Efficiency becomes a matter of definition
First In-Beam Test of “Mark 2” HpGeDSSD Detector

Fast Moving Ions ($v/c=0.08$)

Pixel-by-pixel correction

Ten-fold improvement in FWHM

Mark 3 detector has better intrinsic energy resolution and better pixel definition: Test in August 2002
“Mark 3” HpGeDSSD In-beam Experiment at ATLAS
Test of Doppler-shift correction capability
(October 2002)
Single Pixel Events Reconstructed
( ~20% of events)
HpGeDSSD Imaging Test

BIR sample holder

Collimated 15 mCi $^{109}$Cd source

Quartz sample with 1 mm drilled holes
  • Paraffin
  • Graphite

Information on position from strip hits only

P.I. Dr. D. Nisius,
BioImaging Research Corp.
Future HpGeDSSD Detector Procurement Plan

1) Streamlined Mechanical Envelope

Construct a practical compact cryostat for Array deployment
Thin-Contact Technology
(First Unit ~ $125K, four for $500K)

2) “Full Detector Stack”

To Construct a full tracking unit, with 4 layers of germanium

A) Phase 1 would be a test cryostat loaded with 2 wafers
B) Phase 2 would reload cryostat with 2 more wafers
( Total Estimated Prototype ~ $500K )
**X-Array Physics Applications**

- $\alpha - \gamma$: Fine structure spectroscopy
- $p - \gamma$: Fine structure spectroscopy
- $\beta - \gamma$: Decay studies
- $e - \gamma$: Conversion electron spectroscopy

**Isomer Studies**

**Low Energy Coulomb Excitation**

**Design Optimization For:**

High Efficiency, Good Energy Resolution, High Count rate Capability, Considerable Segmentation, Mechanical Flexibility, Compatibility with existing silicon arrays and is ideal for RIA in the future.
X-Array MCNP Geometry

Vertical cross section

Horizontal cross section
MCNP Results

Photopeak efficiency

Peak to Total (E > 30 keV)
“Mark 3” Planar Module delivered 18th February 2002
“Mark 4” expected December 2002

Detailed Design of Focal Plane Vacuum Envelope

Simulations for different back detector sizes / geometries

Extensive Discussions with detector manufacturers concerning size and segmentation vs. cost
## Proposed Preliminary X-Array Budget

*November 2002*

<table>
<thead>
<tr>
<th>Item</th>
<th>$K (X-Array)</th>
<th>$(Tracking)</th>
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<tr>
<td>5 Big “Back” detectors</td>
<td>5 x 125</td>
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<tr>
<td>4 Streamlined Planars (First counted in GARBO R&amp;D)</td>
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<td>Clover high resolution Amps, ADC’s, TDCs and logic (25channels)</td>
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<td>Planar high resolution Amps, ADC’s, TDCs and logic (160channels)</td>
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<td>High Power NiM, CAMAC and VME Crates, High Voltage</td>
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<td>Laboratory Tax (11%)</td>
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<td>73</td>
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<td><strong>TOTAL</strong></td>
<td><strong>$938K</strong></td>
<td><strong>$744K</strong></td>
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## Current (CY2002) Effort Level

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<th>NAME</th>
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<tr>
<td>C.J. Lister</td>
<td>ANL (Physics)</td>
<td>(1.75 FTE)</td>
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<td>M. P. Carpenter</td>
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<td>N. Hammond</td>
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<td>RVF Janssens</td>
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<td>E.F. Moore</td>
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<td>T.L. Khoo</td>
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<td>K. Teh</td>
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<td>F. Kondev</td>
<td>ANL (Technology)</td>
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<td>Prof. S. Freeman</td>
<td>U. Manchester U.K.</td>
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<td>Prof. S. Fischer</td>
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<tr>
<td>Dr D. Nisius</td>
<td>BioImaging Research Inc.</td>
<td>(0.25 FTE)</td>
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~ 3.0 FTE
Plans For FY2003

1) Test and Evaluate “Mark 4”

2) Build Compton Camera.

3) Build PET scanner and start Medical Collaboration with U. Chicago Medical Center Radiology Group (Prof. R. Beck).

4) Procure “Mark 5” Streamlined Detector with thin contact technology.

5) Design / Specification of Detector Stack

6) Polarization Physics at ANL

7) “Fast Ion” physics of odd-A nuclei at MSU

8) Procurement of 2 large backing detectors; “2-sided” box evaluation of X-Array performance.
Longer Term Plans (2003-5)

1) Procure and evaluate a HpGeDSSD “4 stack”
2) Develop Signal Processing and software for Tracking
3) Build full X-Array by 2005

Resources Needed for Plan (2003-5)

1) Planar Detectors and Tracking Technologies $1466K
   ( Inc. Wafers for X-Array and “4-Stack” )
2) X-Array Infrastructure and Backing Detectors $938K
60Co “Deep” Interaction

TRIGGER SETUP

Edge SMART

Trigger on
1 2 3 4 Ext
Ext10 Line

cplg Ext
DC AC LFREJ
HFREJ HF

slope Ext
Pos Neg

External
Atten x1
DC58k DC1MΩ

Holdoff
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Off Time Events

500 NS/s

□ STOPPED
60Co “Shallow” Interaction
137Cs “Shallow, 2 Interactions” Interaction
57Co “Deep, Center” Interaction
MCNP Results

GARBO MCNP efficiency vs. Clover size in cm

Energy (keV)

Absolute efficiency

14x14x7
12x12x6
10x10x5
12x12x9
# Post Meeting Budget Revision

Revised Budget Numbers November 14th 2002 following DOE visit.

<table>
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<tr>
<th>YEAR</th>
<th>“TRACKING R&amp;D” (GRTCC Report)</th>
<th>“X-ARRAY” (FMA Specific)</th>
<th>(Tracking Related*)</th>
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<td>Tax (11%)</td>
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<tr>
<td></td>
<td>$722K</td>
<td>$938K</td>
<td>$744K</td>
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* The “tracking related” component of the X-Array is the inner box of planars and their associated electronics. These detectors form a key component of the X-Array, as they provide the X-ray and polarization sensitivity which makes the instrument unique. The detectors can also be used separately from the array for use as a PET scanner, Compton camera, or in many other “Tracking” applications.

a) This component is $125K for a “streamlined, thin contact HpGeDSSD” plus $25K for digital pulse processing boards for our data acquisition system.

b) Estimated cost of a “4-Stack” of planars in a single cryostat.