Detector R&D in KAPAC

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Outline
❖ Compton Camera
❖ SOI detector
❖ Scintillator Polarimeter
❖ Cherenkov Camera

Limited science discussion
Compton Camera Concept

❖ **Concept**
❖ **Reconstruct incident photon direction, energy**
  ✦ Compton kinematics
  \[ \cos \theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2} \]

❖ **Applications**
❖ **NeXT/SGD (Soft gamma-ray Detector)**
  ✦ Next generation Japanese satellite
  ✦ Soft gamma-ray spectrometer
    • 10 – 300 keV
  ✦ Polarimeter
    • 3% 5\(\sigma\) sensitivity for 0.1 Crab @100ks
  ✦ Complementary with GLAST
❖ **Radiation detection technology**
  ✦ Localizing nuclear material

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Compton Camera Development

- **Required technologies**
  - **Front-end ASIC**
    - Low noise for fine energy and angular resolution
      - Event selection with Compton kinematics
    - Low power for space application, portable device
  - **High density silicon detector stack**
    - Fabrication technique from HEP and GLAST
  - **High quality high-Z semiconductor detector**
    - CdTe/CdZnTe detectors being developed by collaborators
      - CdTe: ISAS for NeXT/SGD
      - CZT: CalTech for radiation detection technology R&D
Low Noise Low Power ASIC

❖ VATA-series low noise and low power ASIC
  ❖ Originated from VA1TA for KEK HEP experiment
  ❖ Noise optimized for expected capacitance load
  ❖ SEU (single-event upset) tolerant design
  ❖ On-chip ADC in progress for lower power
  ❖ On-chip sparse-data scan for faster readout (next phase)

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High Density Silicon Detector Stack

- **Detector optimization**
  - **Effect of inactive material**
    - FPC (flexible printed circuit)
    - Mechanical support
    - GLAST expertise
  - **Simulation study**

![Diagram of detector stack](image)

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<th>Energy (MeV)</th>
<th>Efficiency (%)</th>
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<tr>
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<td>10</td>
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Compton Camera Funding

- **Funding sources**
  - **SLAC/DOE**
    - Design of ASIC (0.1 FTE, ~10 kUSD/year M&S)
  - **Department of Homeland Security**
    - 650 kUSD/2.5 year (0.3 FTE) starting March/2007.
      - ASIC and silicon detector design/fabrication
      - High density assembly development
  - **ISAS/JAXA (Japanese Space Agency)**
    - Fabrication of ASIC for NeXT/SGD
  - **Pending**
    - NASA proposal for solar polarization mission with UC Berkeley/SSL (Space Science Laboratory)
      - Design/Fabrication of ASIC (0.1 FTE, ~200 kUSD)
- **Silicon-On-Insulator**
  - Complex electric circuits realized by 0.15 µm CMOS process
    - Self-trigger X-ray imager
    - Fast sparse-data readout
  - Detector using high-R substrate
    - Independent of low-R silicon for MOS
    - Thick detector possible up to 600 µm
      - Good for hard X-ray and near IR imaging
- **KIPAC is leading Astrophysics application**
- **Fabrication is funded by KEK**
- **Fabrication complete**
PoGO Concept

- Well-type phoswich detector
  - BGO, slow scintillator to veto BG
    - Narrow FOV, low background
  - Pulse shape discrimination to identify hits in fast scintillators
- 217 array of phoswich detectors
  - Large effective area
  - Azimuth angle distribution of Compton scattering

Funding

- KIPAC/Stanford Enterprise fund for M&S
- SLAC/DOE for ~0.3 FTE

Differentiate Crab pulsar models in a 6-hour balloon flight
SpaceWire based Electronics/DAQ

- SpaceWire interconnect standard
  - 200 Mbps, simple network protocol
  - Adopted by NASA, ESA, ISAS/JAXA
- Circuit design at KIPAC, fabricated by ISAS
  - Satisfactory performance at KEK synchrotron beam test
Cherenkov Camera

- Cherenkov camera with large # of pixel
  - Important for future TeV gamma-ray IACTs
    (Imaging Cherenkov Atmospheric Telescopes)
    - Large FOV (field-of-view)
    - Better angular resolution
    - Complementary to GLAST GeV gamma-ray science
  - ~1k ch. ⇒ 10k–100k ch. (x 50–100 telescopes)
    - Cost, power reduction and better reliability
- Leadership role expected in photon detector/electronics R&D (SLAC has long history in Cherenkov imaging with BaBar/DIRC)
- Low cost, low power multi-ch readout ASIC
  - Start from LABRADOR chip developed for ANITA by Univ. Hawaii
New Photon Detector R&D

- SiPM (Silicon Photo-Multiplier)
  - Improved quantum efficiency by a factor of 2–3.
  - Cost implications
    - Improve Q.E. by 2 → reduce telescope diameter by \( \sqrt{2} \) → reduce telescope cost by 2.5 (\( \propto d^{2.7} \)).
  - SiPM costs ~$20/ch.
- In discussion with a vendor to fabricate 8x8 array
- HEP applications

- PMT Q.E.
  - Bi-alkali
  - Super Bi-Al
  - Ultra Bi-Al
  - Not available
  - $700/PMT
  - $450/PMT

- SiPM Q.E. (from catalog)
  - $700/PMT
  - $450/PMT

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Conclusions

❖ KIPAC/SLAC is playing leading roles in
   ✦ development of readout electronics
     ✦ Low power, low noise ASIC for Compton camera
     ✦ Low power, low cost ASIC for Cherenkov camera
     ✦ SpaceWire electronics for PoGO
   ✦ development of detector technologies
     ✦ High density silicon detector assembly
     ✦ High Q.E. silicon photo-multiplier array
   ✦ Taking advantage of GLAST/HEP experiences

❖ Cherenkov camera R&D is getting started
   ✦ KIPAC/SLAC can play leading roles in
cdevelopment of future IACTs
   ✦ Beneficial for R&D of HEP Cherenkov detectors