Detector R&D at KIPAC

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Detector R&D Overview

GLAST GeV Gamma-ray Observatory

- Si detector
- ASIC Integration

Next generation X-ray Observatory
- Compton camera (NeXT SGD)
- Scintillator polarimeter

Relativistic outflow
- Particle acceleration
- Dark matter

Multi-wavelength Observation

Next generation TeV gamma-ray Observatory
- Cherenkov camera (AGIS)

Other SLAC Activities

ASIC DAQ

photon detector
**Compton Camera Concept**

*Concept*
- Reconstruct incident photon direction, energy
  - Compton kinematics

*Applications*
- NeXT/SGD (Soft Gamma-ray Detector)
  - Next generation Japanese satellite
  - Soft gamma-ray spectrometer
    - 10 – 600 keV
  - Polarimeter
    - 3% 5σ sensitivity for 0.1 Crab @100ks
  - Complementary with GLAST
- Radiation detection technology
  - Localizing nuclear material

\[
\cos \theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}
\]
Science Driver for NeXT

* NeXT Science connection with DOE Science.
  - Precise measurement of dark matter density in 100s of galaxy clusters (complementary with LSST/SNAP).
    - Exquisite energy resolution (~6 eV) of X-ray calorimeter.
  - Observation of obscured AGNs (active galaxies).
    - Connection with GLAST AGN science.
    - Sensitive hard X-ray/soft gamma-ray spectral measurement by Hard X-ray Imager and SGD.
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 sensor assembly
    • 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 developed for low power, compact
  – On-chip sparse-data scan for faster readout
High Density Compact Assembly

* State-of-art compact assembly technique.
  – Minimize inactive material.
  – GLAST expertise
  – Simulation study to optimize performance.
Compton Camera Funding

* Funding sources
  - SLAC/DOE
    - Fabrication of engineering model (0.05 FTE, ~5 kUSD/year M&S)
  - Department of Homeland Security
    - 650 kUSD/2.5 year (0.6 FTE) since March/2007.
      - ASIC and silicon detector design/fabrication
      - High density assembly development
  - Pending
    - ISAS/JAXA (Japanese Space Agency)
      - Fabrication of mechanical engineering model, flight model of Compton camera for NeXT/SGD.
      - ~3M USD (~2M USD for M&S, ~1M USD for labor).
    - NASA MOO proposal to participate NeXT mission is approved.
      - Expect ~400 kUSD/year to support operation of SGD (2012-).
    - NASA proposal for solar polarization mission with UC Berkeley/SSL
      - Design/Fabrication of ASIC (~200 kUSD)
Scintillator Polarimeter

* 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
  - Engineering balloon flight supported by Swedish agency.
  - Applying for NASA funding.
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)

* Funding
  - AGIS R&D proposal to DOE/NSF.
  - KIPAC/Stanford funding (S. Funk).
Compact Camera Design with ASIC

* High integration in ASIC reduce external components.
  – Digitization in front-end.
  – Very small amount of cables from camera.
  – Lower cost.
  – ASIC is highly reliable.
    • Only one malfunctioning ASIC out of 15k at GLAST.
    • Dead channel fraction is 4E-4 and stable.
    • Majority of problem is in connection.

* ASIC specifications.
  – 4 µs trigger latency (4096 sampling @ 1GHz)
  – 9 bit Analog-to-Time converter.
  – Time-to-Digital conversion by FPGA.
  – Expected cost: ~$10/channel (including board/support)
ASIC Performance

* ASIC is designed and being tested @ Univ. of Hawaii.
New Photon Detector R&D

* SiPM (Silicon Photo-Multiplier)
  - Improved quantum efficiency by a factor of 2–3.
  - Cost implications
    • Photon collection power per cost is competitive with 8x8 multi-anode PMT.
  - In discussion with a vendor to fabricate 2x8 arrays.
  - HEP applications

PMT Q.E.

SiPM Q.E. (from catalog)

Not available

$450/PMT

$700/PMT

$450/PMT

$700/PMT
Summary

* KIPAC/SLAC is playing leading roles in
  – Development of readout electronics
    • Low power, low noise and highly integrated ASIC for Compton camera
    • Low power and 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 critical for future of KIPAC.
  – P5 recommendations on TeV astronomy.
    • Funding on R&D efforts.
    • Funding on the next generation TeV project in favorable budget situation.
  – Continuation of GLAST gamma-ray science into future.