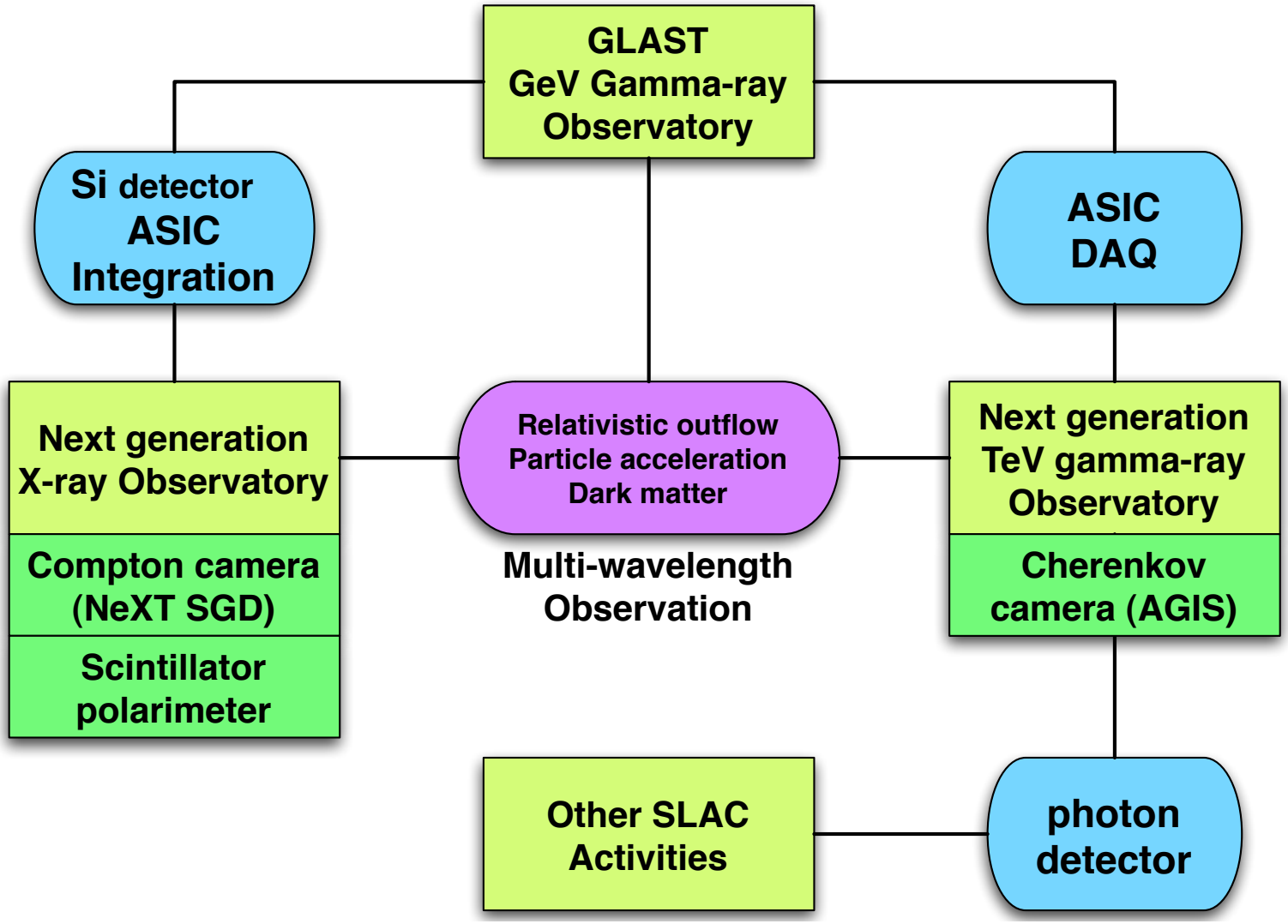
Detector R&D at KIPAC

Hiro Tajima

Kavli Institute for Particle Astrophysics and Cosmology

Detector R&D Overview

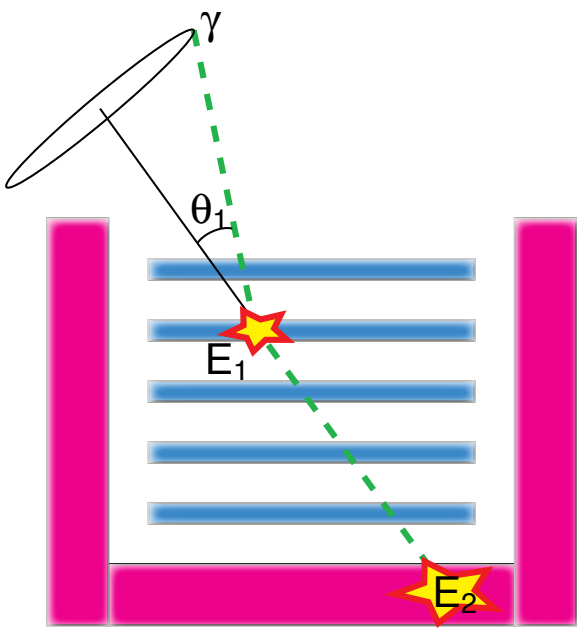


Compton Camera Concept

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

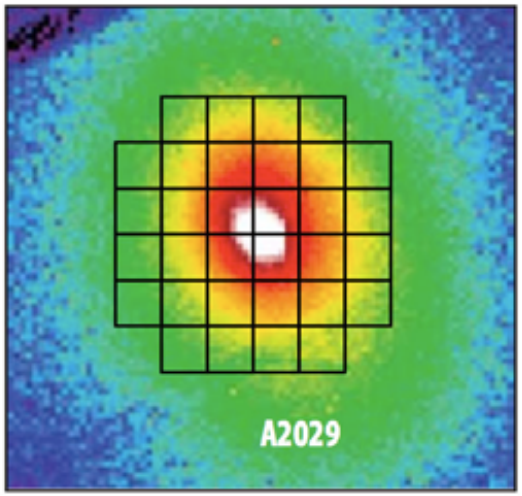
$$\cos\theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}$$

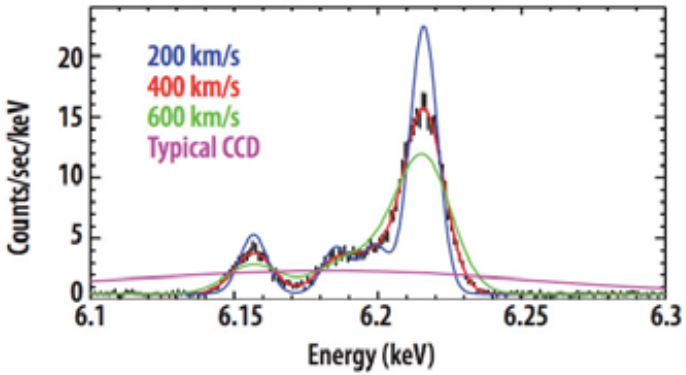
* Applications
  - NeXT/SGD (Soft Gamma-ray Detector)
    - Next generation Japanese satellite
    - Soft gamma-ray spectrometer
      - 10 – 600 keV
    - Polarimeter
      - 3% 5σ sensitivity for 0.1 Crab @100ks
    - Complementary with GLAST
  - Radiation detection technology
    - Localizing nuclear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



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.





A portion of a simulated spectrum (black) from the cluster A2029, assuming 400 km/s turbulence, and models assuming 200, 400, and 600 km/s, clearly showing the capability of SXS to measure cluster dynamics.

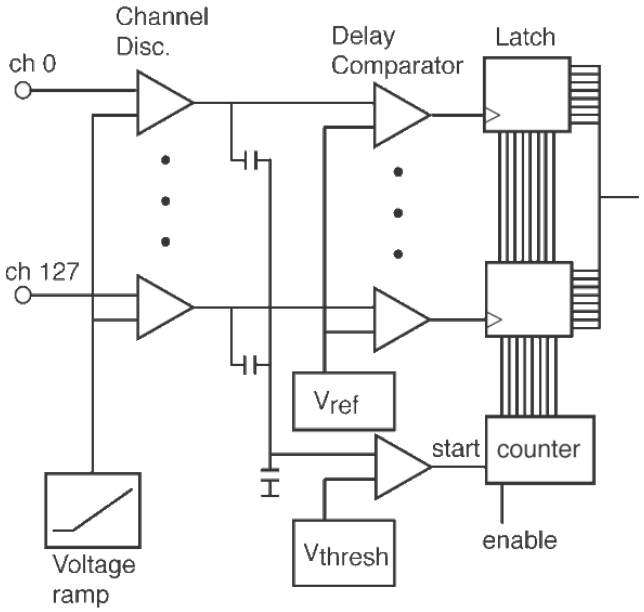
  - Observation of obscured AGNs (active galaxies).
    - Connection with GLAST AGN science.
    - Sensitive hard X-ray/soft gamma-ray spectral measurement by Hard X-ray Imager and SGD.

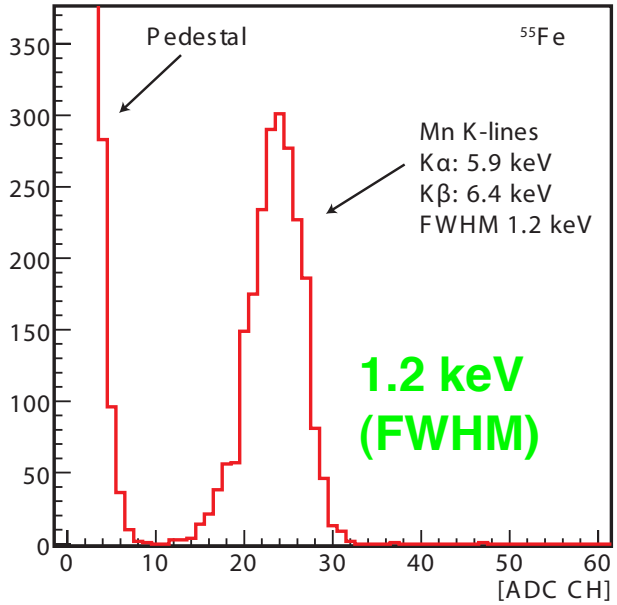
Compton Camera Development

* 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

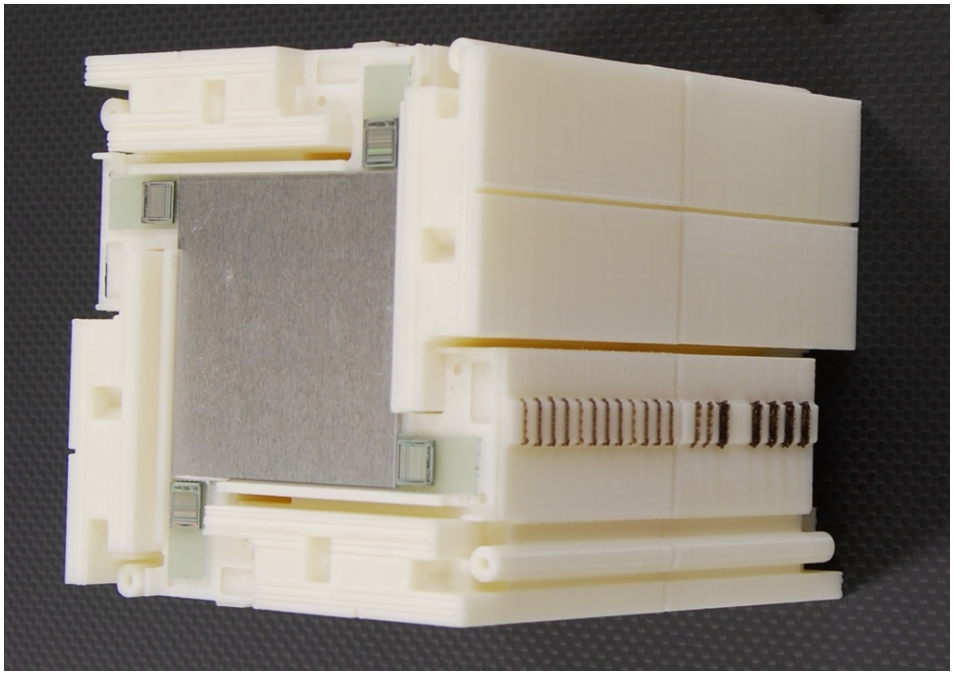
* VATA-series low noise and low power ASIC
  - Originated from VA1TA for KEK HEP experiment
  - Noise optimized for expected capacitance load
  - SEU (single-event upset) tolerant design
  - On-chip ADC developed for low power, compact
  - On-chip sparse-data scan for faster readout

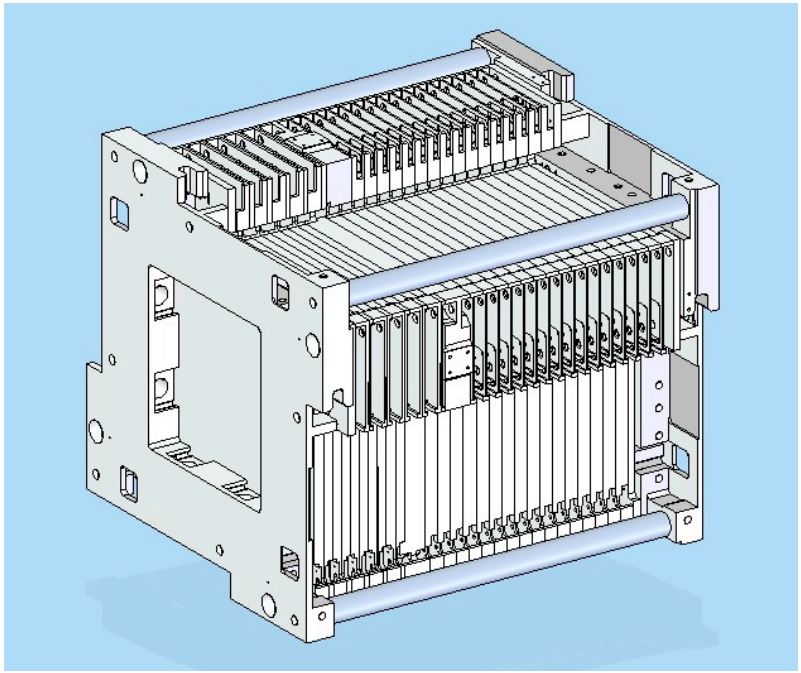




High Density Compact Assembly

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



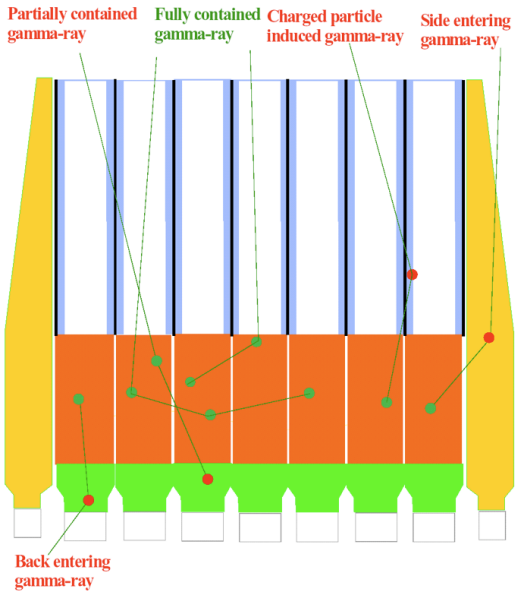


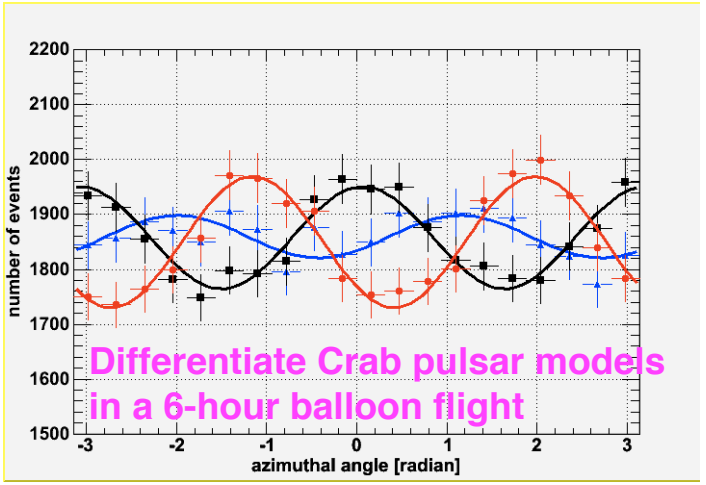
Compton Camera Funding

* 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

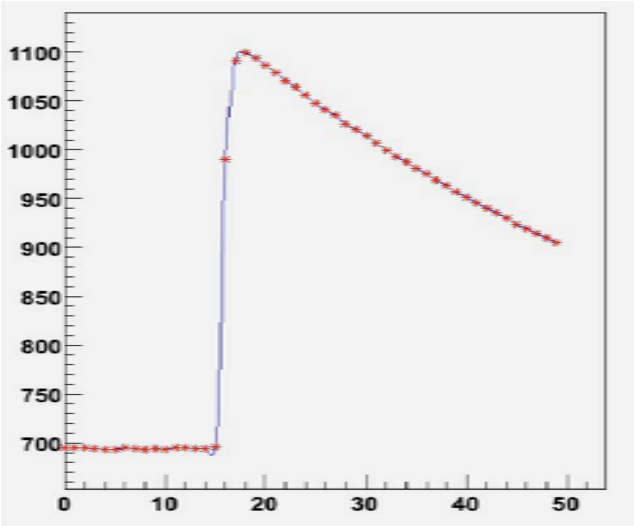
* PoGO Concept
  - Well-type phoswich detector
    - BGO, slow scintillator to veto BG
      - Narrow FOV, low background
    - Pulse shape discrimination to identify hits in fast scintillators
  - 217 array of phoswich detectors
    - Large effective area
    - Azimuth angle distribution of Compton scatting
* Funding
  - Engineering balloon flight supported by Swedish agency.
  - KIPAC/Stanford Enterprise fund for M&S (T. Kamae).
  - Applying for NASA funding.

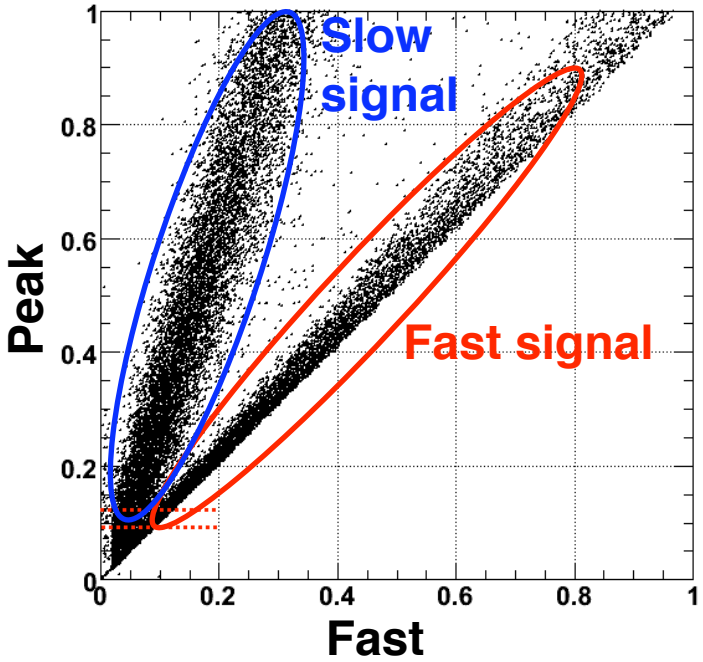


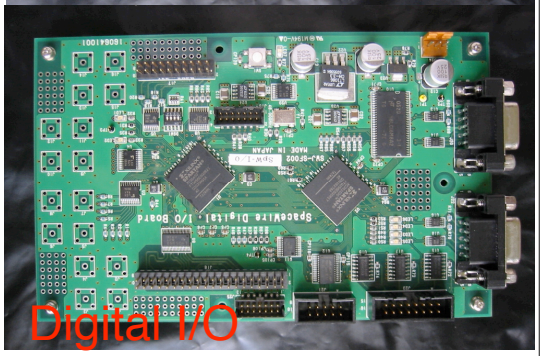


SpaceWire based Electronics/DAQ

* 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





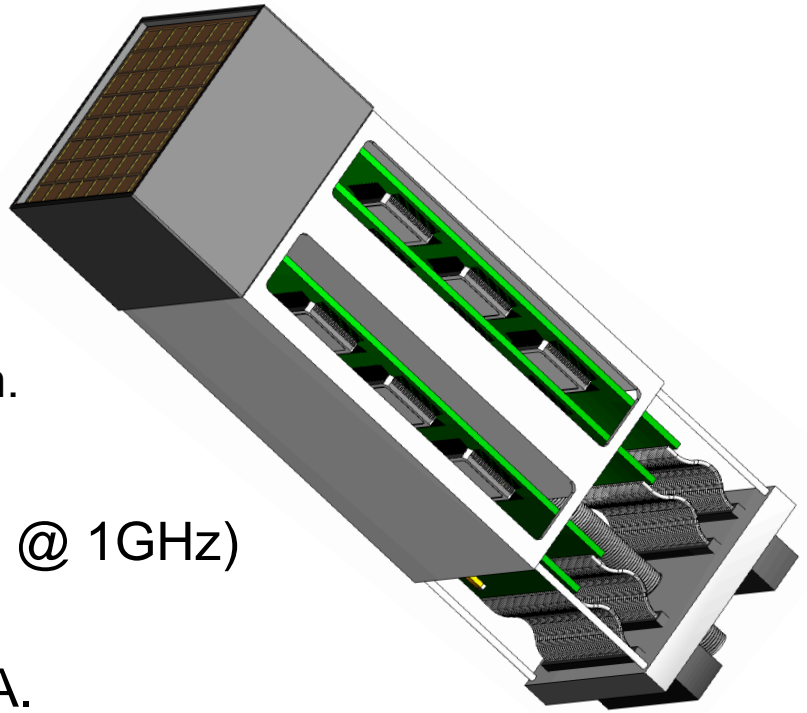


Cherenkov Camera

* 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

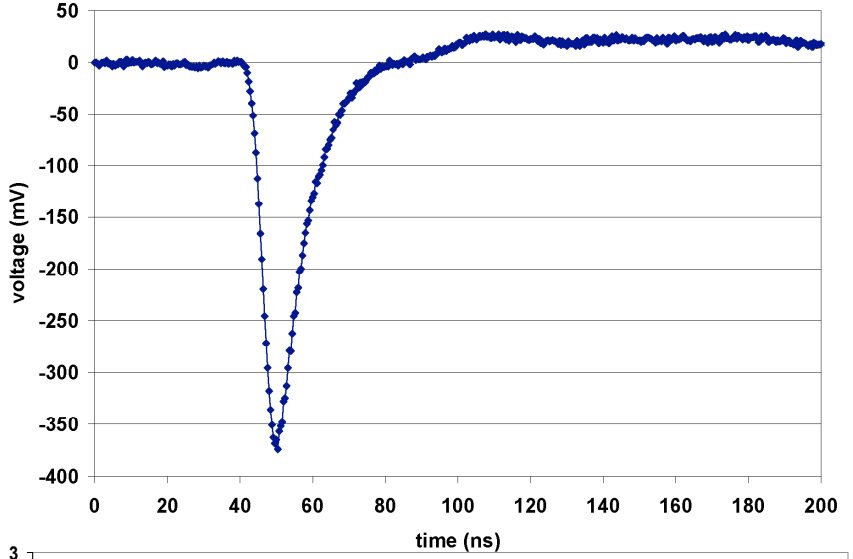
* High integration in ASIC reduce external components.
  - Digitization in front-end.
  - Very small amount of cables from camera.
  - Lower cost.
  - ASIC is highly reliable.
    - Only one malfunctioning ASIC out of 15k at GLAST.
    - Dead channel fraction is 4E-4 and stable.
    - Majority of problem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

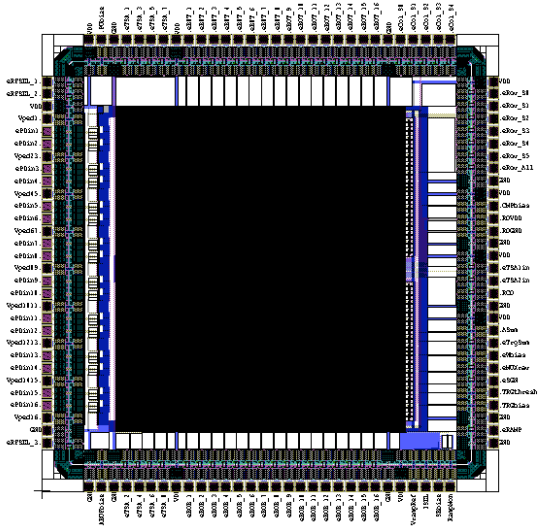


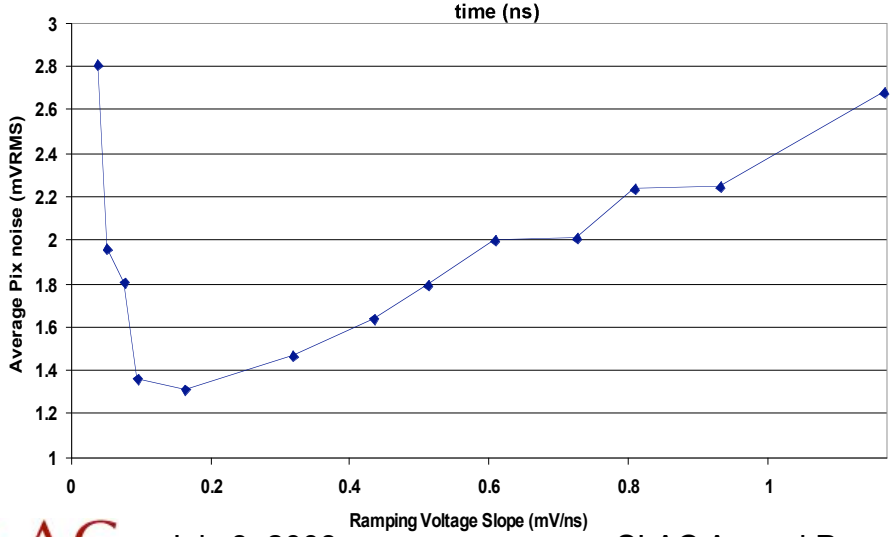
* ASIC specifications.
  - 4 μs trigger latency (4096 sampling @ 1GHz)
  - 9 bit Analog-to-Time converter.
  - Time-to-Digital conversion by FPGA.
  - Expected cost: ~$10/channel (including board/support)

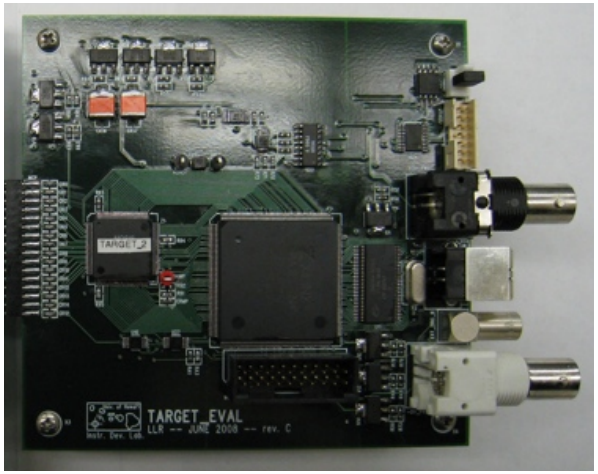
ASIC Performance

* ASIC is designed and being tested @ Univ. of Hawaii.



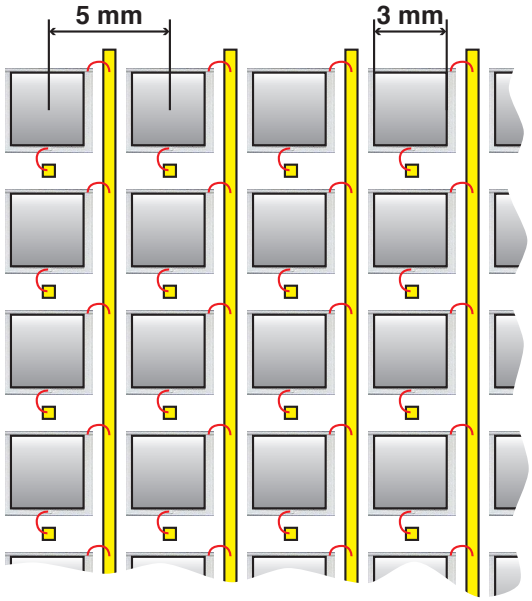


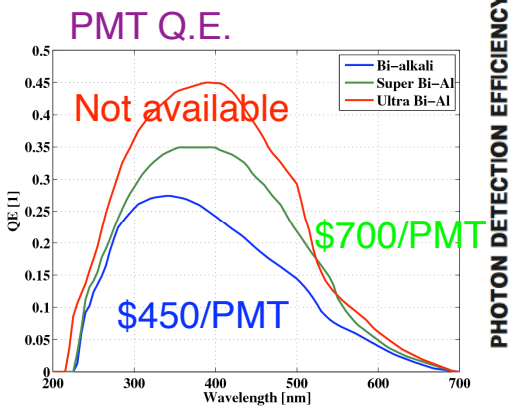


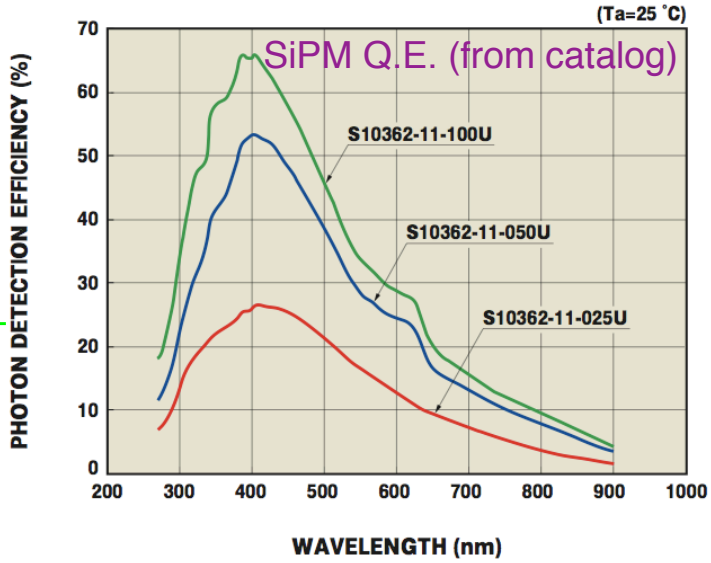


New Photon Detector R&D

* 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







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.