Trade Studies of of Different Camera Approaches

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Outline

- Photon detectors
- Cost estimation method
- Cost comparisons.

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Toward the Future of Very High Energy Gamma-ray Astronomy

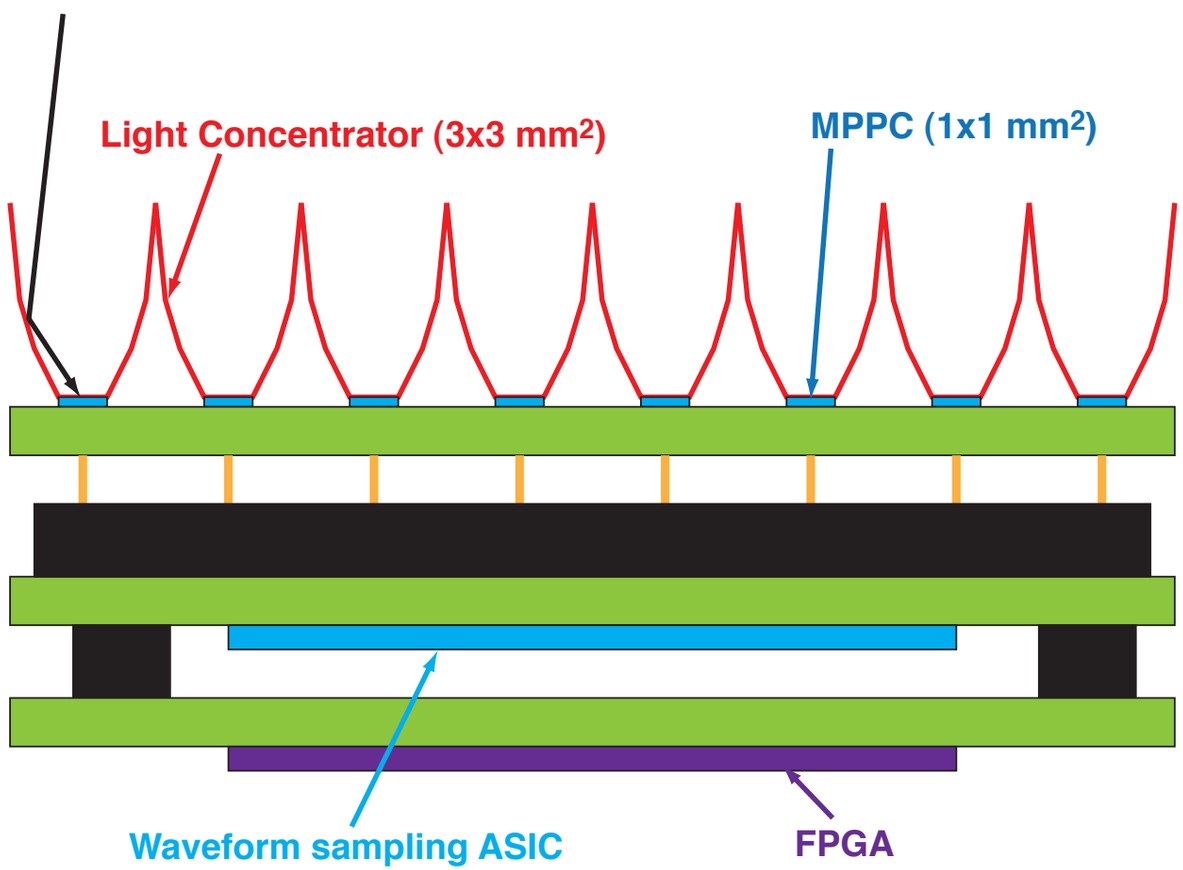
Photon Detectors in This Study

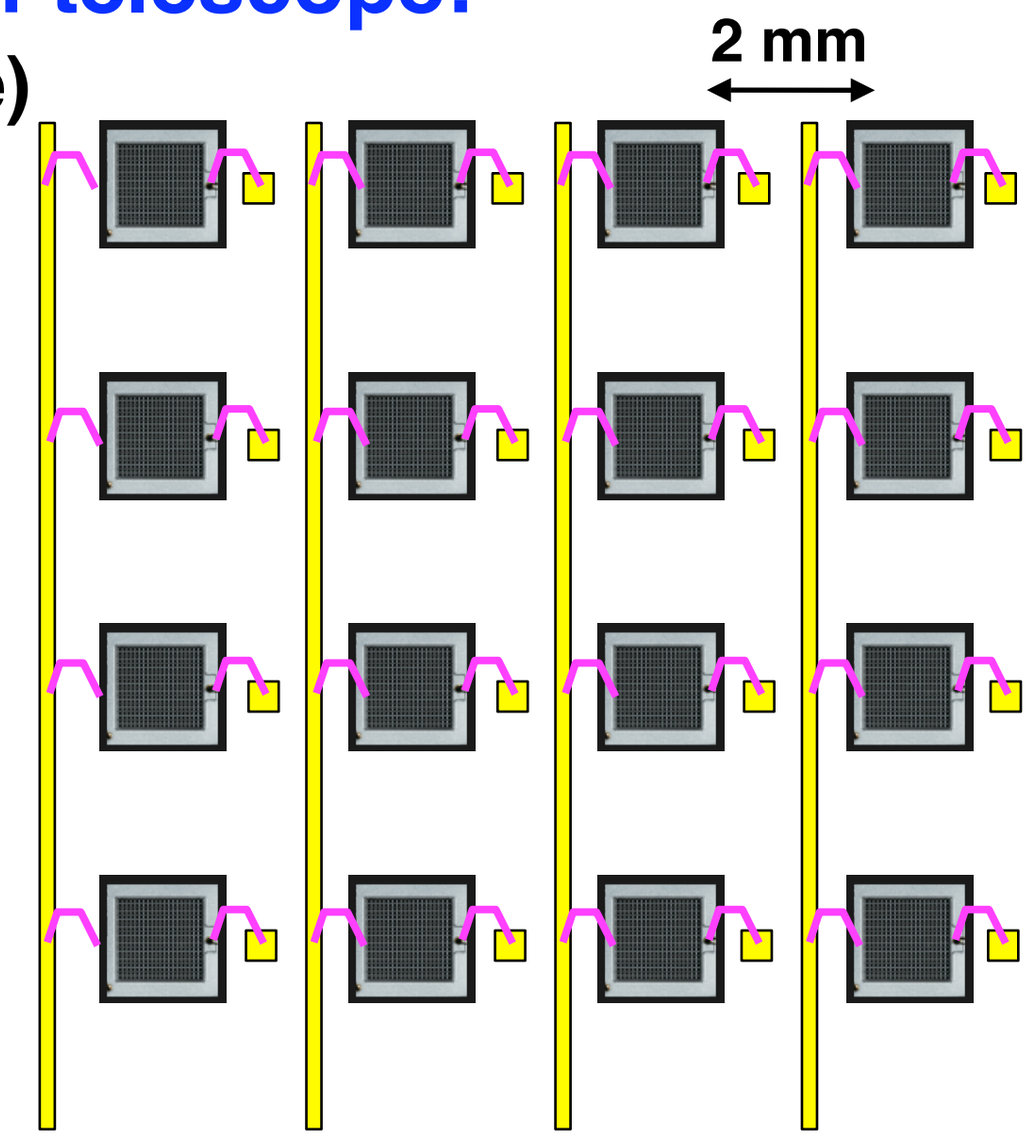
- **Multi-anode PMTs.**
  - **2”-64 channel with Bialkali photo-cathode.**
    - **89% fill factor.**
    - **Projected cost: $1500 ($23/ch) with large quantity.**
  - **1”-16 channel.**
    - **80% fill factor.**
    - **Projected cost with large quantity.**
      - **Bialkali photo-cathode: $800 ($50/ch).**
      - **Ultra-bialkali photo-cathode: $1200 ($75/ch).**
- **Multi-pixel Geiger-mode Avalanche Photo-Diode.**
  - **Projected cost with large quantity.**
    - **2x2 mm^2: $25/ch.**
    - **3x3 mm^2: $49/ch.**
    - **4x4 mm^2: $81/ch.**

Projected cost is confidential.

MG-APD Array

- **Buttable, modular design**
  - **Minimum light loss between modules.**
  - **Minimum distance between active area: 2 mm.**
  - **Light concentrator limit F/# of telescope:**
    - **$\sin\theta_{max}$ = (spacing)/(active size)**
  - **Assume collection eff: 80%.**

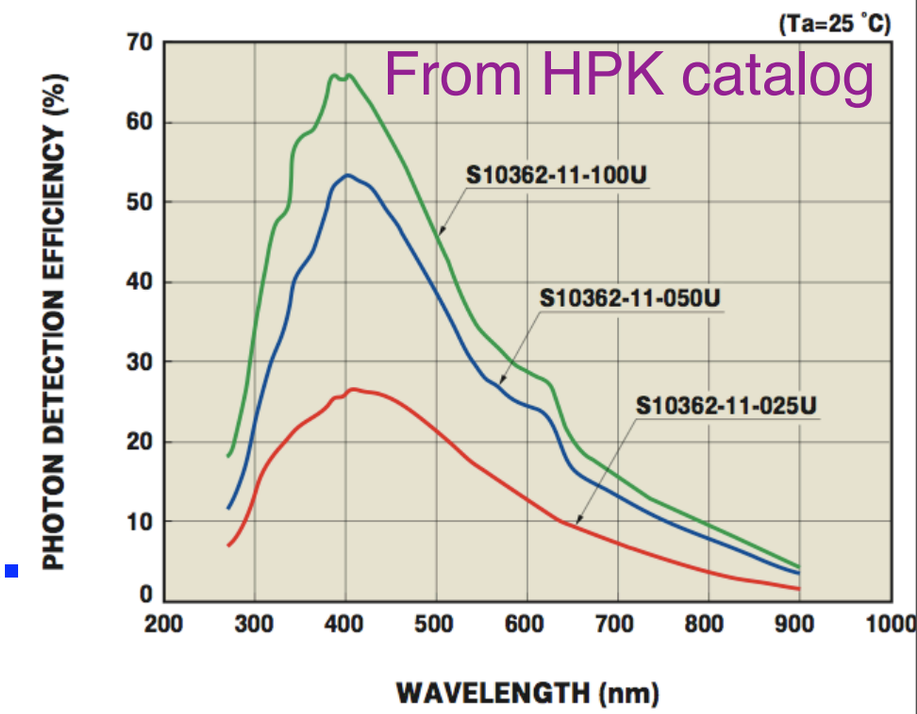


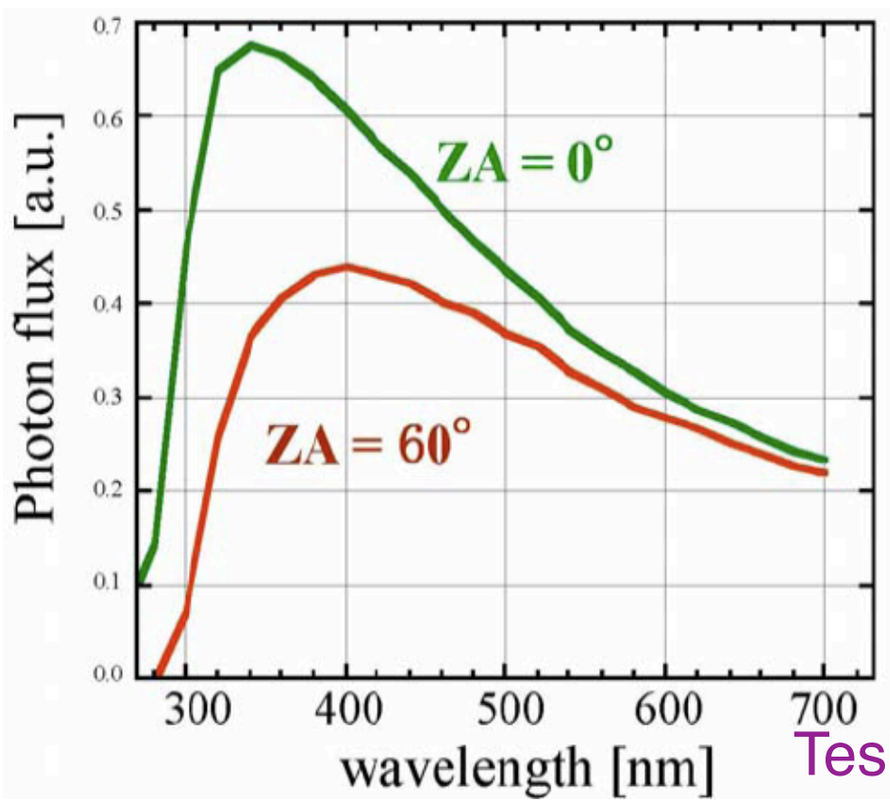


AGIS Electronics R&D,
H. Tajima, Future TeV Gamma-ray Astronomy, NOV 9, 2007

Effective P.E.D.

- Average P.D.E. weighted by photon yield.
  - Include fill factor for MG-APD.
    - 100 μm pixel for 2x2 mm^2 device.
    - 150 μm pixel for 3x3 mm^2 device.
    - 160 μm pixel for 4x4 mm^2 device.
  - Account for overestimate of MG-APD P.D.E. due to cross-talk.





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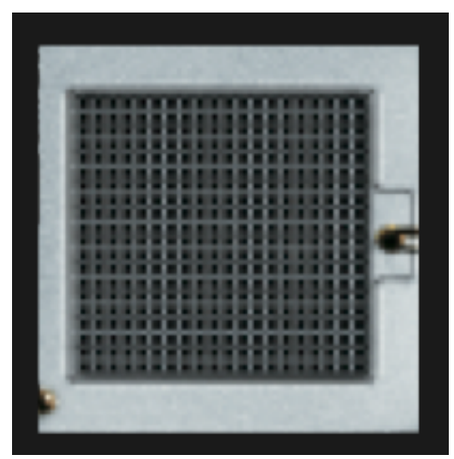

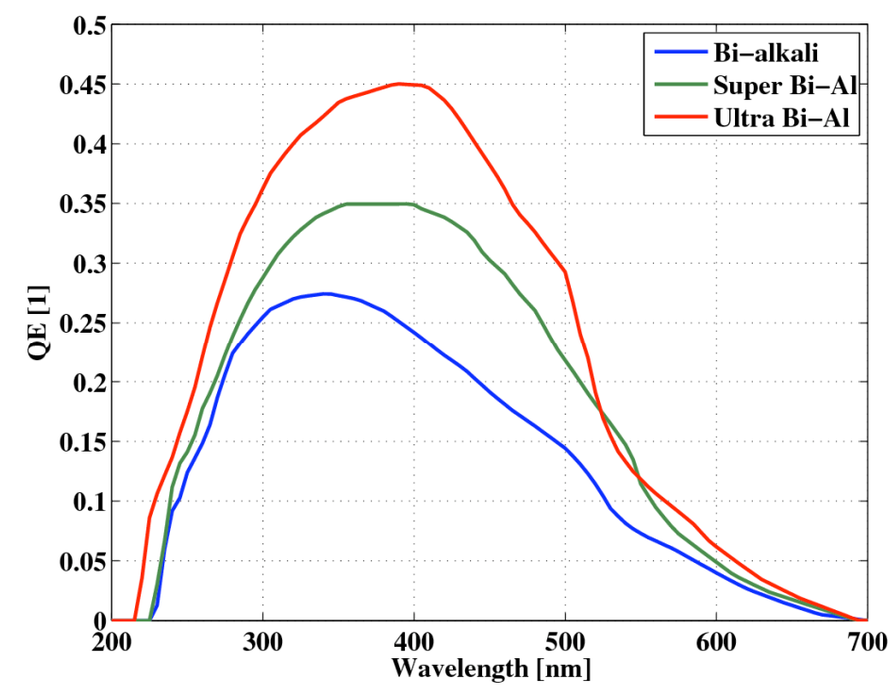

Camera Cost Calculation

- **Telescope parameters.**
  - Diameter: 8 m
  - FOV: 6°
  - F/#: > 0.6 (depends on θ_{max} of light concentrator)
  - Telescope cost is not considered.
- **Camera cost calculation.**
  - # of ch = (FOV/pixel size)^2.
  - Include $15/ch camera readout cost.
- **Figure of Merit (independent of mirror size).**
  - Camera cost / (ε * effective Q.E.* ϕ_{mirror}^2).
    ε = fill factor * light concentrator efficiency.
- **Not intended as comprehensive analysis.**
  - Get some feeling about R&D directions.

Camera Cost Comparison

	cost/ ch	effective P.D.E.	F/#	angular pixel size	# of ch/ camera	Camera cost	FOM
2 mm MG-APD	$40	36%	0.87	0.033°	33k	$1,320k	4.6
3 mm MG-APD	$64	40%	0.67	0.054°	13k	$800k	2.5
4 mm MG-APD	$96	40%	0.6	0.072°	7k	$670k	2.1
2”-64ch MAPMT	$39	17%	0.6	0.072°	7k	$270k	1.9
1”-16ch MAPMT	$65	17%	0.6	0.072°	7k	$460k	3.5
1”-16ch UBA MAPMT	$91	28%	0.6	0.072°	7k	$640k	2.8
1” UBA PMT	$315	28%	0.6	0.15°	1.6k	$510k	0.4*

*Mirror ϕ = 19 m

Summary

- Camera cost can be within $1M limit for 8 m, F=0.6, FOV=6° telescope.
- 2”-16ch MAPMT and 4 mm MG-APD seems to give best FOM.
  - At same angular pixel size: 0.072°
  - Probably good starting point.
    - 4 mm MG-APD not in fabrication plan of the vendor.
- 3 mm MG-APD gives smaller angular pixel size of 0.054° with slightly worse FOM.
- 1” MAPMT may not be cost effective even though better Q.E. with UBA option.
- Requires better knowledge of light concentrator efficiency, P.D.E. for photon detectors.