A Novel Design of a High-Resolution Hodoscope for the Hall D Tagger Based on Scintillating Fibers

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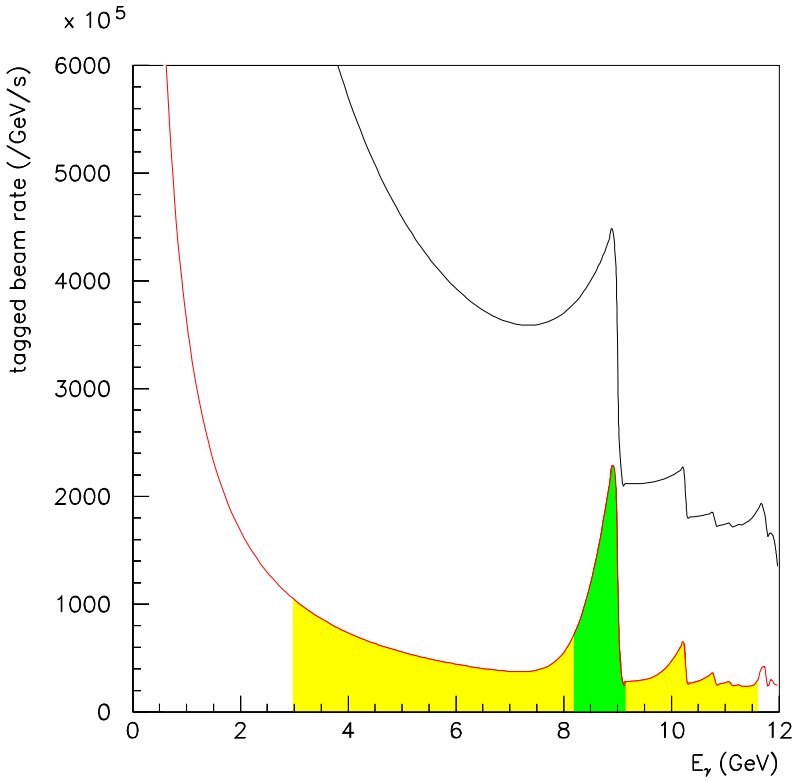
GlueX Photon Spectrum

Bremsstrahlung in diamond crystal:

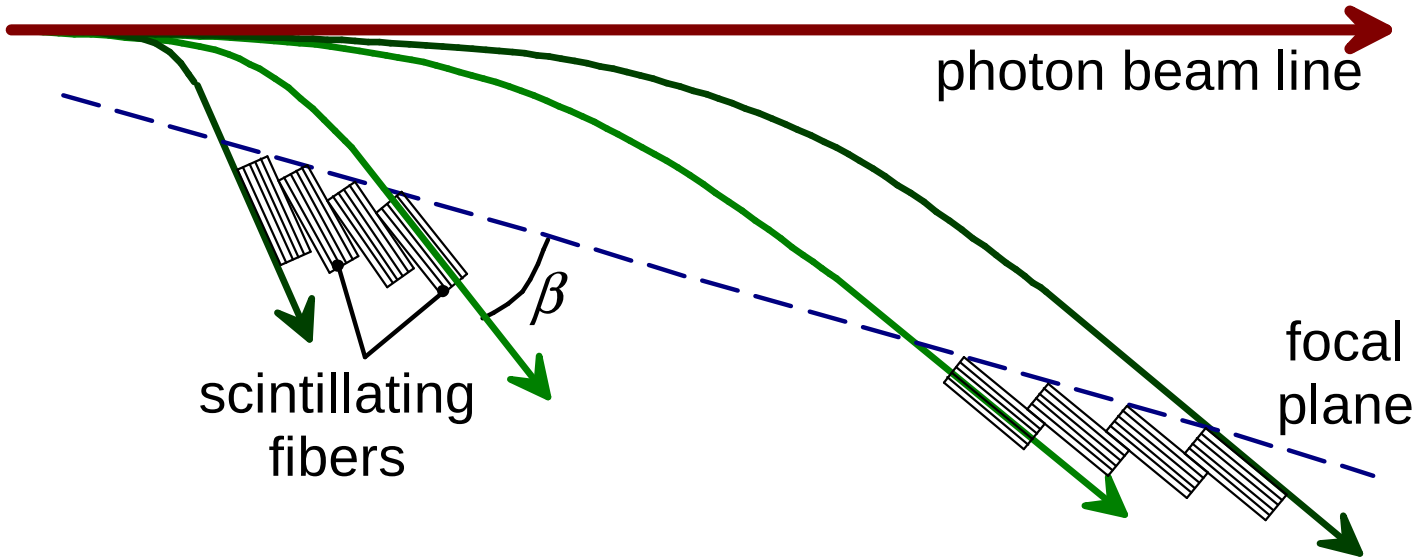
- coherent edges - *peaked in the forward direction*
- incoherent background - *extends under coherent peak*

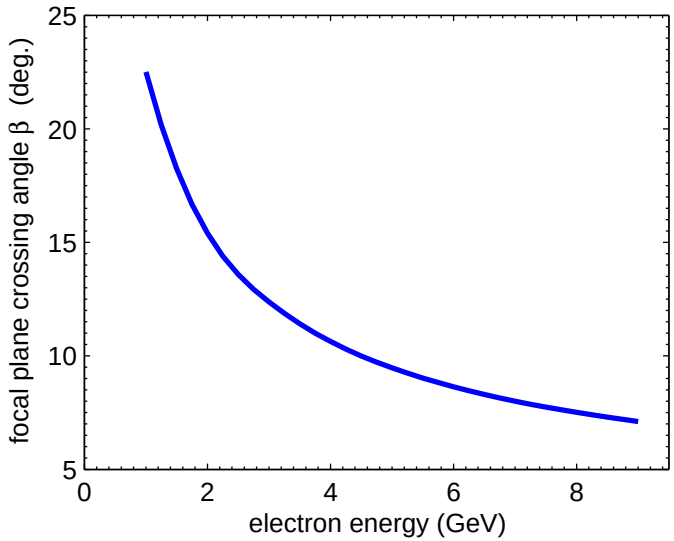
Beam collimation strongly reduces this background.



— full spectrum
— collimated beam
■ total coverage by broad-band hodoscope
■ range of interest to GlueX - instrumented with a tagger "microscope"

Focal Plane Geometry



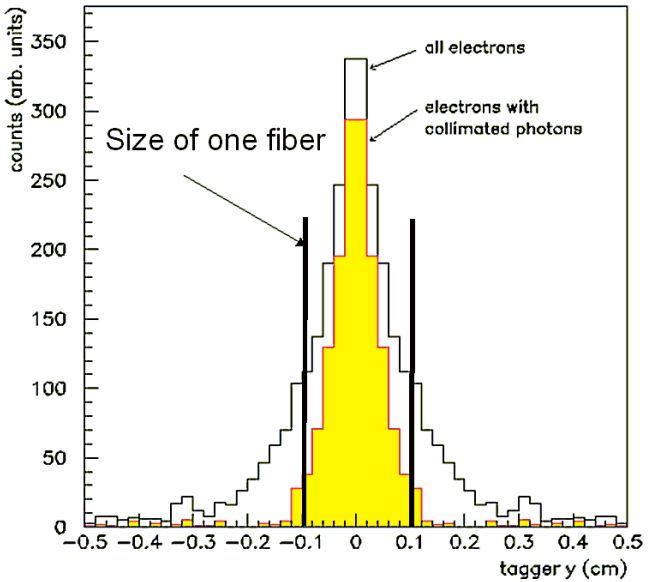


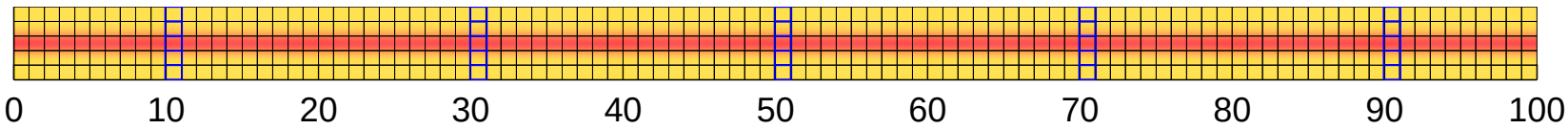
- Scintillating fiber detectors occupy the e^- focal plane.
- Fibers 2 cm-long, coaxial with e^- trajectories
- β varies with energy (steep dependence at the low E_{e^-} limit.)

Focal Plane Segmentation

Microscope's high rate, high resolution, high tagging efficiency in the range of primary peak of 8.4 - 9 GeV is enabled by:

- $2 \times 2\,\mathrm{mm}^2$ cross-section SciFi array
  - small acceptance to mitigate rate
  - resulting $\sim 8\,\mathrm{MeV}$ resolution more than satisfies GlueX requirement
- vertical segmentation allows matching collimator acceptance
- limiting tags to the central row improves tagging efficiency with collimator

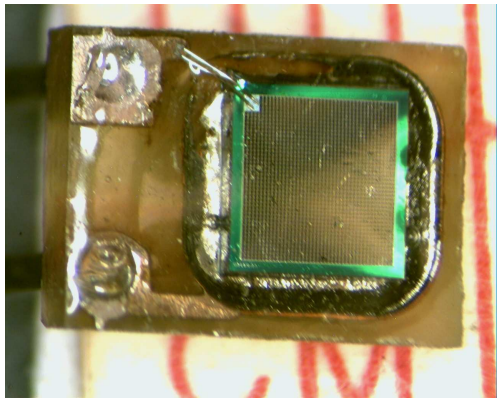




Choice of Scintillation Detector

Photo-detector technology chosen:
Silicon Photomultipliers (SiPMs)

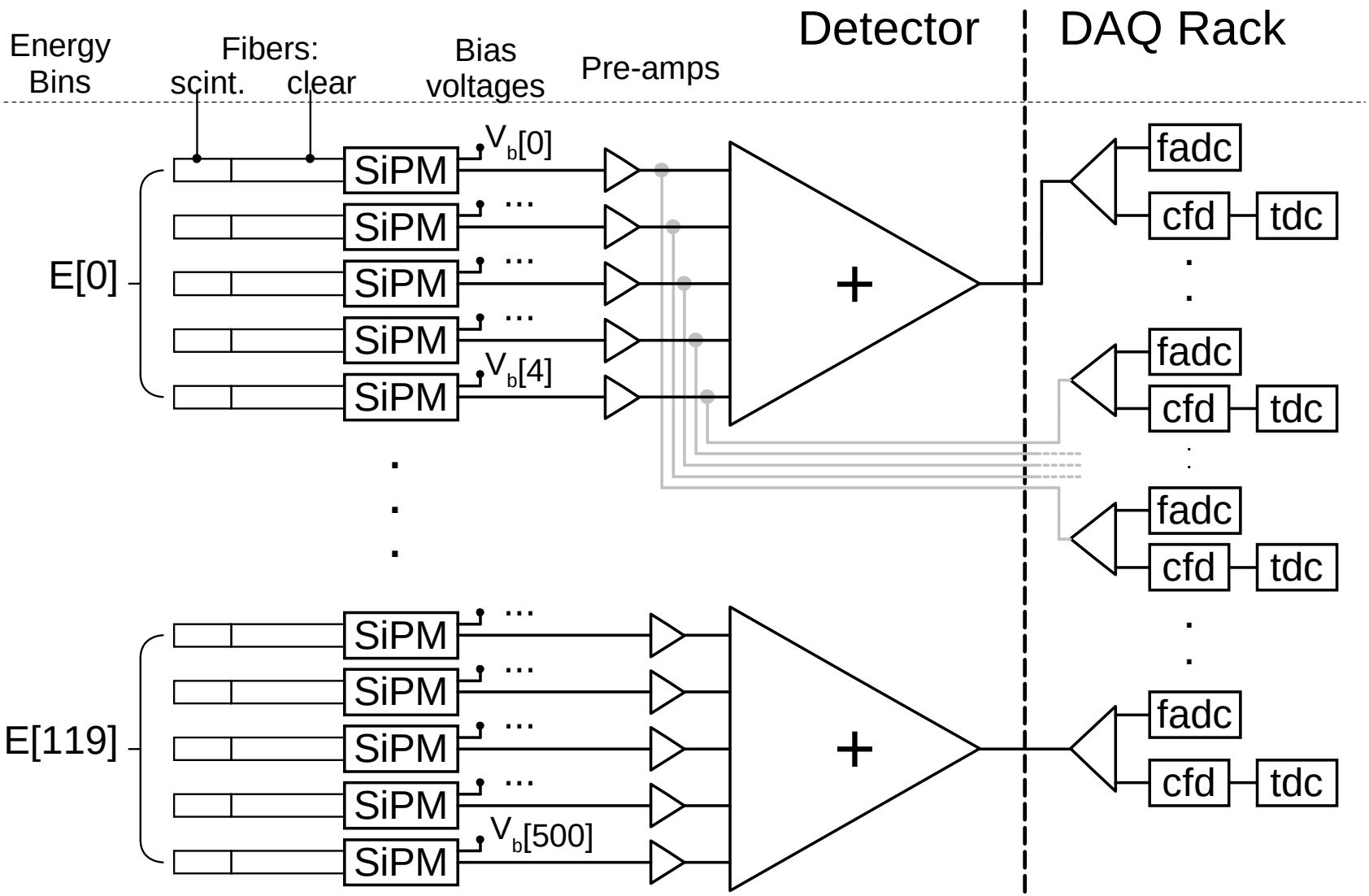
- comparable in speed and gain to PMTs
- high voltage not required ($V_{bias} < 100\,\mathrm{V}$)
- size of order $1\,\mathrm{mm}$ - matches fiber cross-section



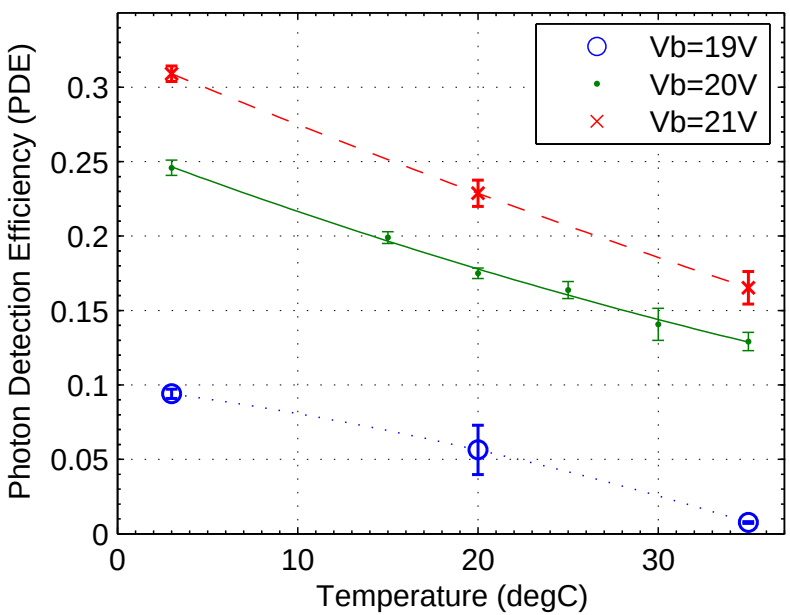
Best unit found: Photonique SSPM-0606BG4

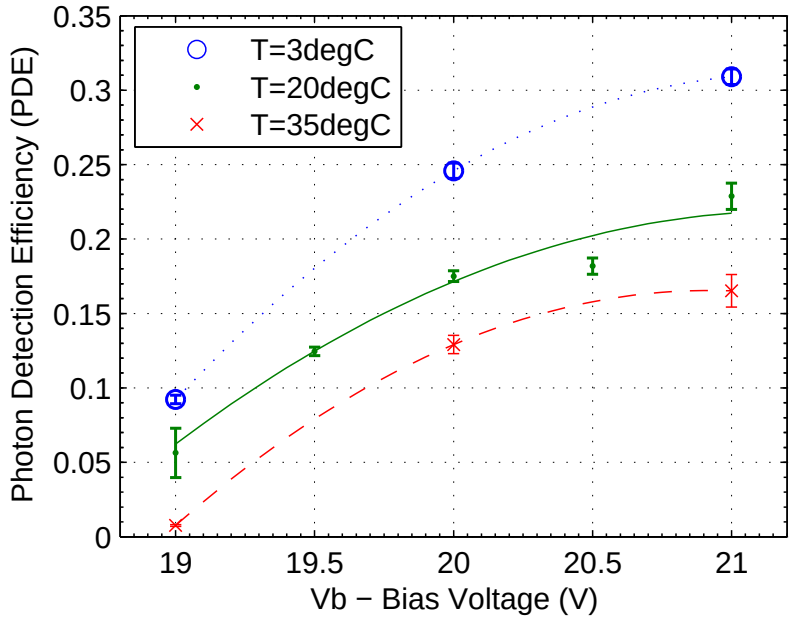
Active window	$(2.1\,\mathrm{mm})^2$	matches $2\,\mathrm{mm}$ square fibers
Pixel number	1700	good dynamic range for $200\,\mathrm{ps}$ res.
PDE	$\sim 20\%$	sufficient for expected pulses
Gain	$\sim 2 \times 10^5$	
Rise/recovery time	$3\,\mathrm{ns}/15\,\mathrm{ns}$	$\sim$95% detection eff. @ $2\,\mathrm{MHz}$ rate

Overall Detector Schematic



Case for Individual Bias Control

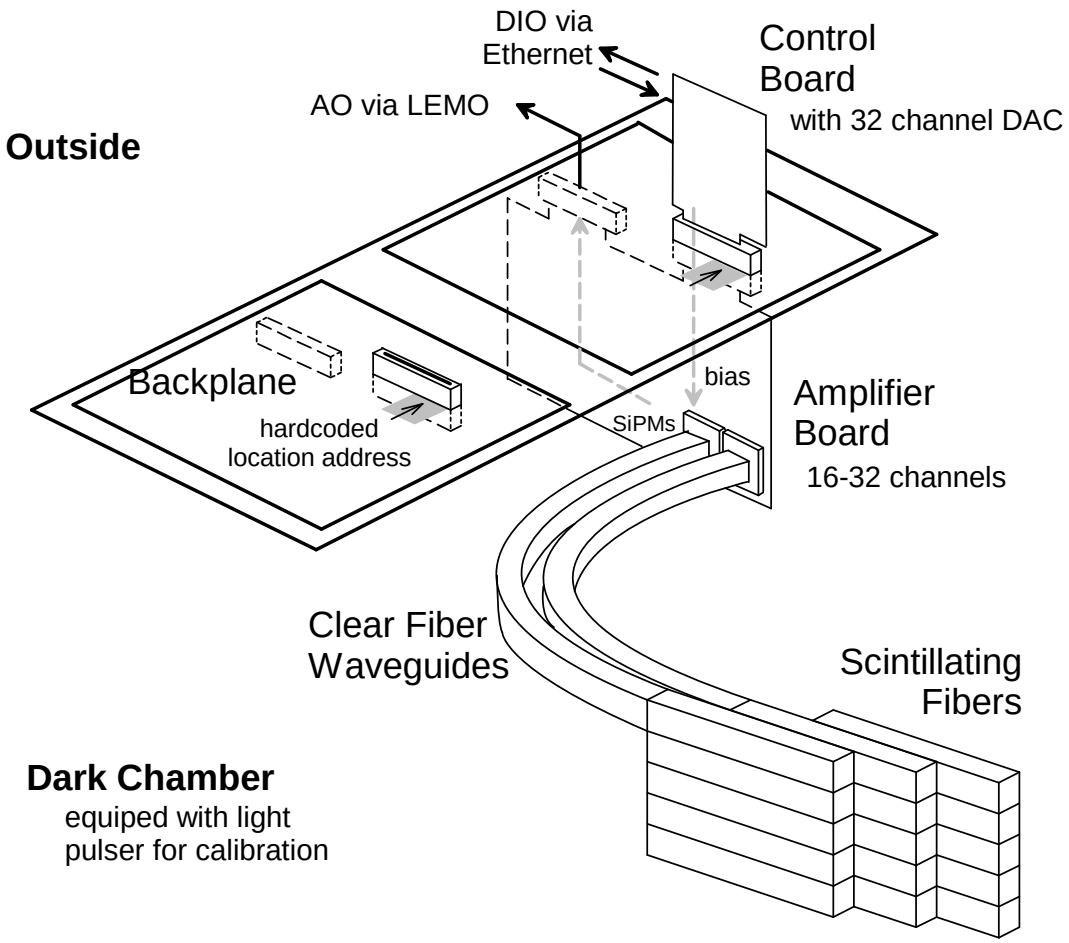




Sensitivity to ambient temperature ($\sim 2\%/^{\circ}\mathrm{C}$) and performance variability from one unit to the next demands individual bias voltage control. ($\sim 40\%/\mathrm{V}$) Compensation for shortcomings in optics is also convenient.

Readout/Control Scheme

- digital and analog electronics on different boards
- full microscope: 20 pairs of boards
- maintenance on electronics and optics decoupled



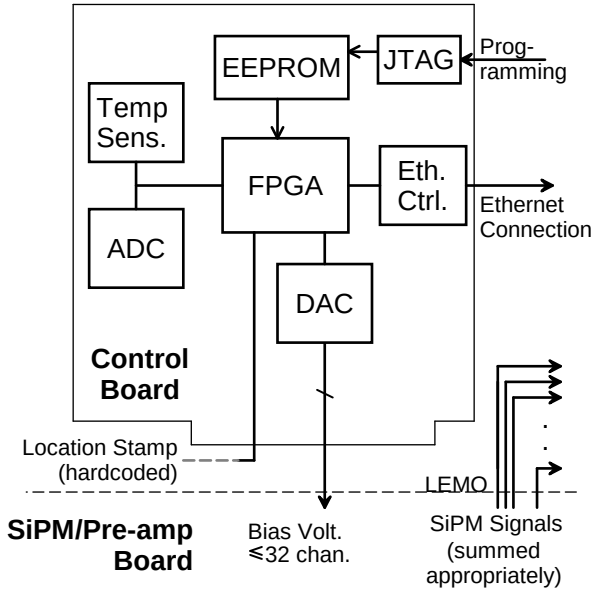
Electronics Overview

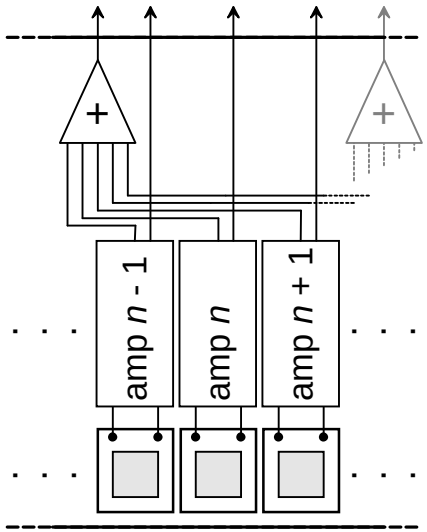
Control board:

- FPGA-centered design
- control through ubiquitous, robust, address-aware Ethernet
- V_{bias} via DAC: 32-chan., 14 bit, $\lesssim 200\,\mathrm{V}$
- on-board health sensors (Temp., ADC)

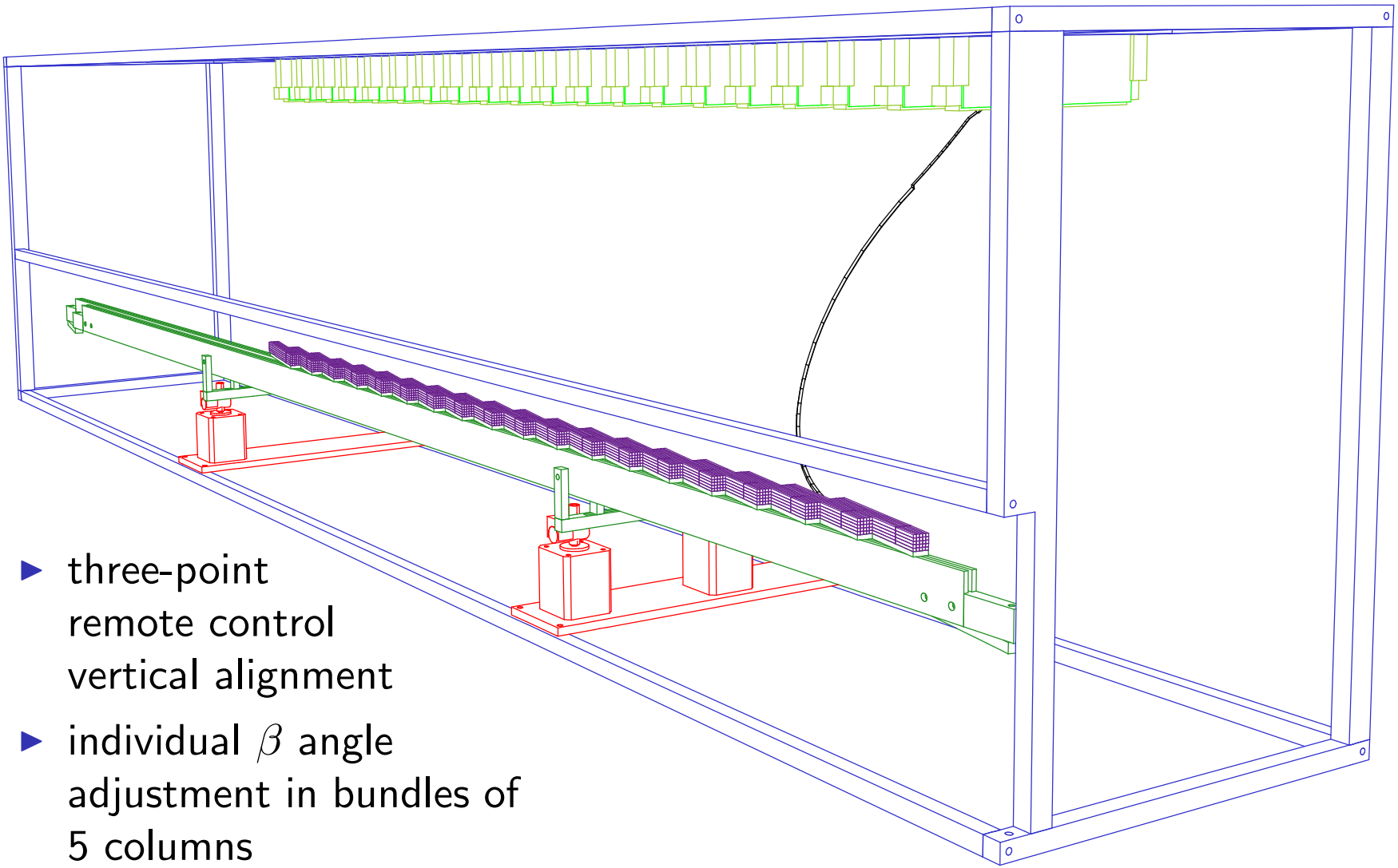
Amplifier boards contain:

- array of up to 32 SiPMs
- fast, two-stage transimpedence amplifiers
- summing circuitry
- board temperature sensor
- precision connectors for alignment with optics



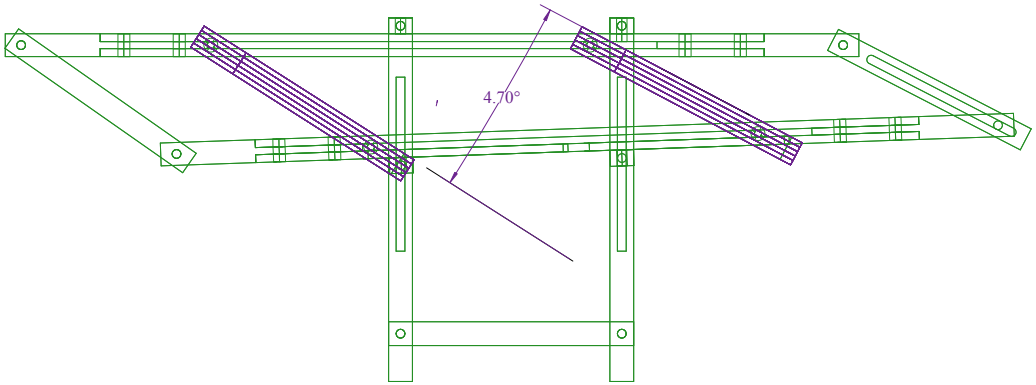


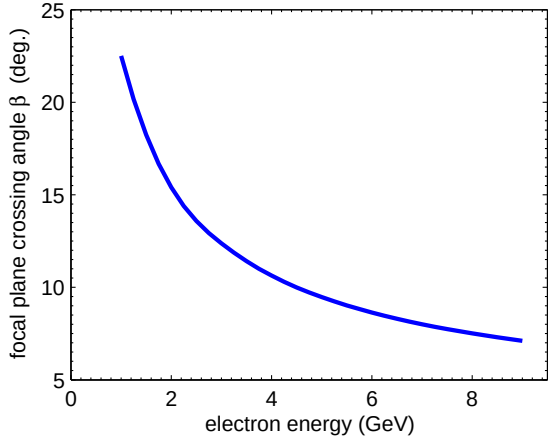
Mechanical Structure



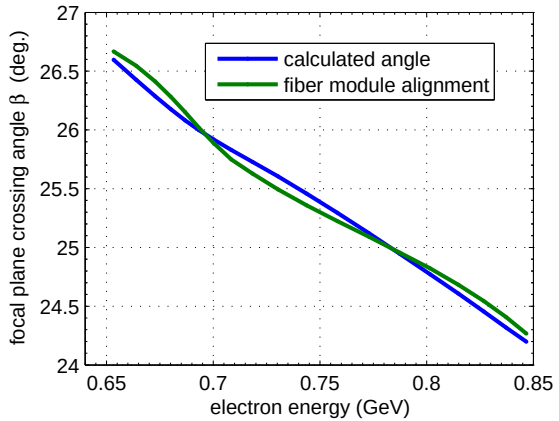
- three-point remote control vertical alignment
- individual β angle adjustment in bundles of 5 columns

Alignment of Fiber Modules





Support frame for fiber modules designed to allow alignment with all crossing angles[a] for the useful energy range.



[a] within alignment errors (due to geometric constraints) that are an order of magnitude smaller than the acceptance angle of a scintillating fiber

Summary and Outlook

- The GlueX tagger microscope represents a novel design with vertical segmentation of the focal plane as well as high energy resolution capability.
- Fully general electronics for fast SiPM readout with bias control and monitoring via Ethernet.
- Flexible mechanical design allows mobility of the device along a wide energy range.

Outlook:

- A prototype with 5% of full channel count is nearing completion:
  - Electronics boards are laid out and submitted for fabrication
  - Mechanical design is complete.
  - A fiber bundle is finished and ready for coupling to SiPMs.
- Beam test of the prototype is planned.
- Full tagger microscope construction planned for 2011.

Distribution of Bremsstrahlung Photons

Distribution of bremsstrahlung γ's in angle and energy

- coherent
- incoherent