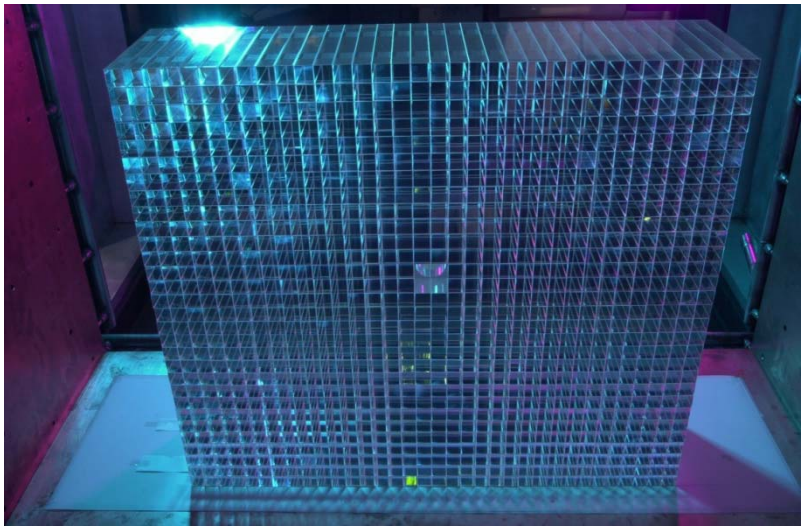
Using Solid State Photomultipliers with HYCAL

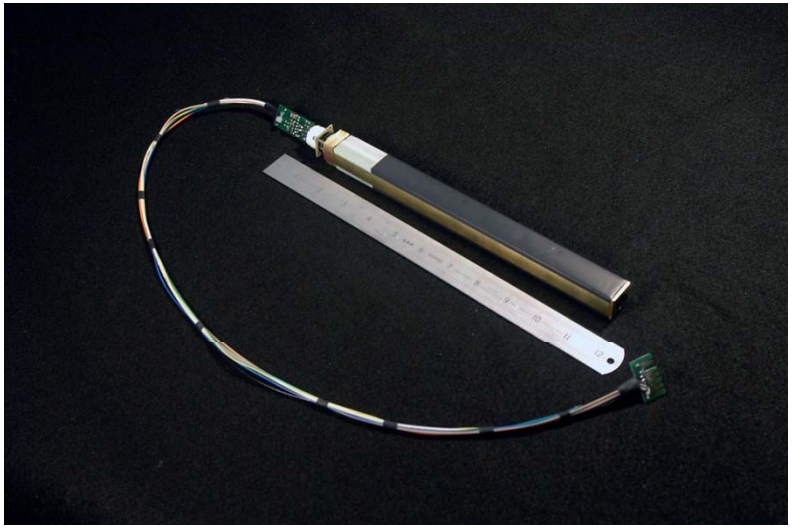
- Results from Simulation Studies
- Readout and triggering
- Funding opportunities for this technology

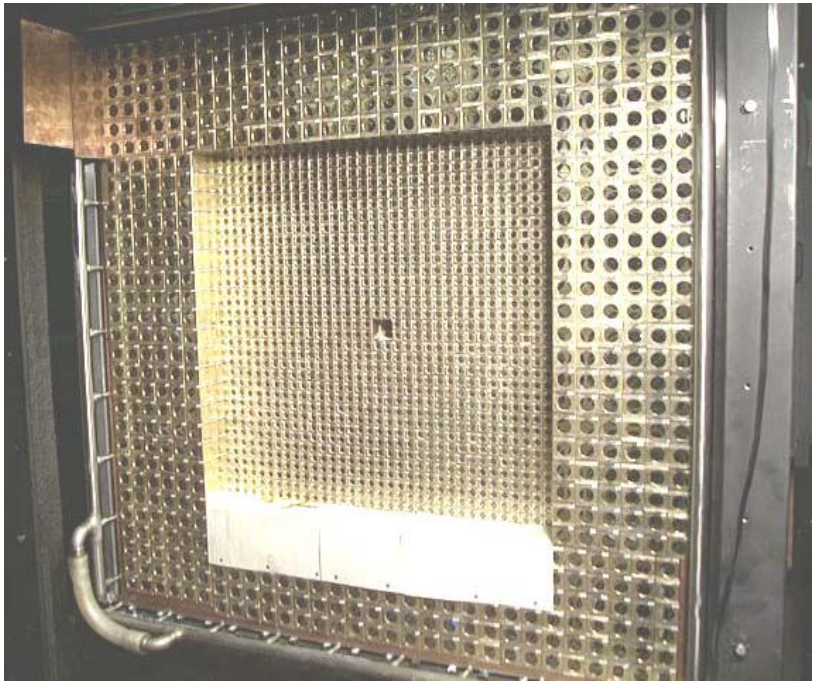
PrimEx Hybrid Calorimeter - HYCAL

A highly segmented hybrid calorimeter

- 576 lead-glass detectors ($4.00 \times 4.00 \times 40$ cm^3)
- 1152 lead-tungstate detectors ($2.125 \times 2.125 \times 21.5$ cm^3)
- energy resolution 1.3%
- position resolution 1.3 mm



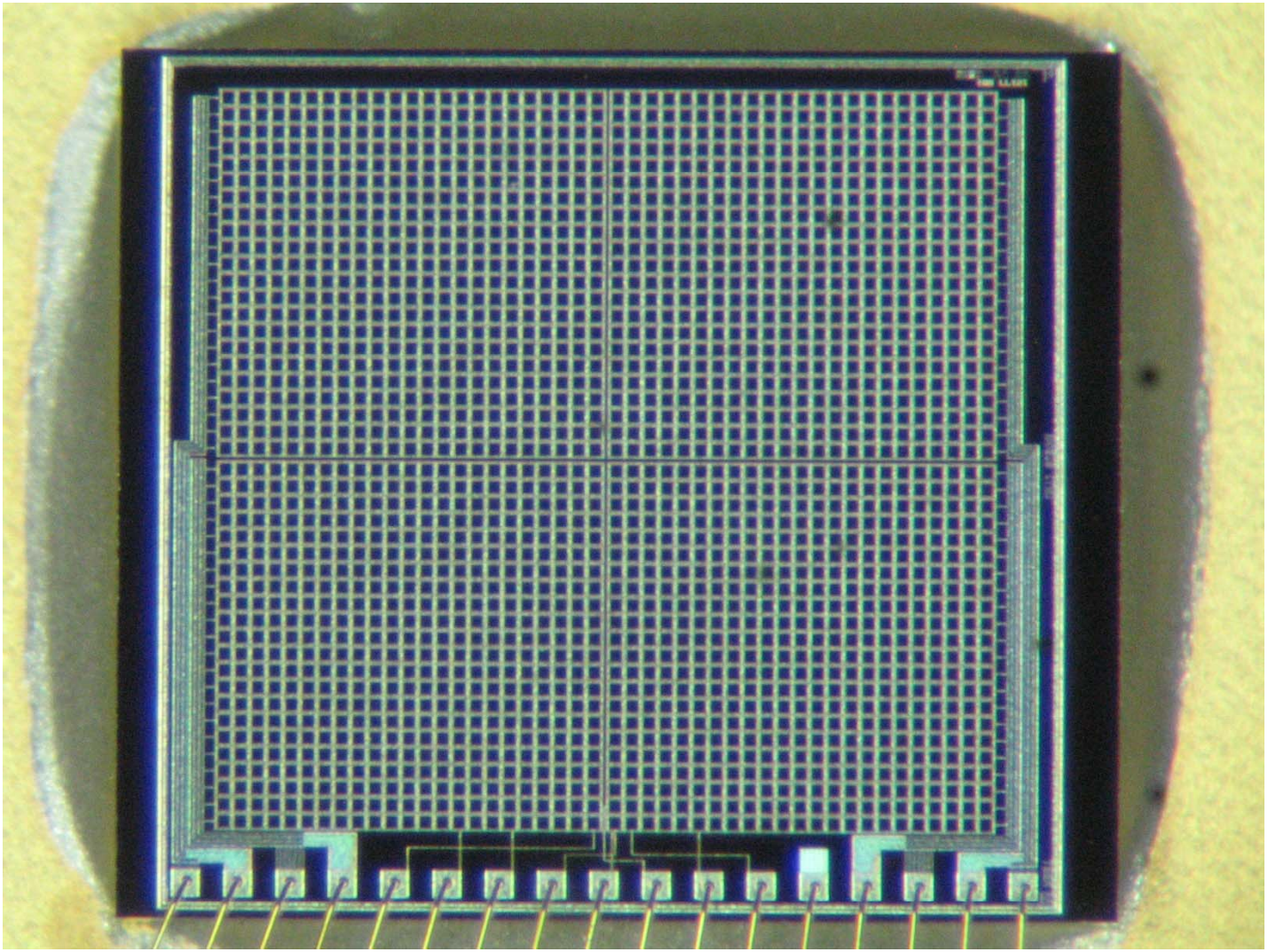




The proposal:

1. Replace the lead glass blocks with PbWO crystals
2. Replace the PMTs on HYCAL with an integrated SSPM-ADC detector. The ADC should be 12-bits, running at 250 mega-samples/s. This gives digitization every 4 ns.

SSPM Detector



Collaboration to Develop *Solid-State Photomultipliers* for Nuclear and Particle Physics Experiments

J. Christian †, E. Johnson, and C. Staples
Radiation Monitoring Devices
Watertown, MA

D. von Maluski, P. Martel, R. Miskimen, P-N. Seyo, and A. Teymurazyan
UMass

† Principle investigator

Supported by the D.O.E. Small Business Industrial Research program (SBIR)

i. SBIR phase I grant, *Solid State Photomulitplier for Polarized Scintillation Materials at Cryogenic Temperatures,* $100,000 awarded.
ii. SBIR phase I grant, *Optical Detector with Integrated ADC for Digital Readout*, $100,000 awarded *(this is the PRIMEX SBIR)*
iii. SBIR phase II grant, *SSPM for Polarized Target Scintillator Readout*, $750,000 approved.

Simple Monte Carlo study of multi-GeV photons incident on PbWO crystal coupled to SSPM photo-detector

Use simulation to study the effect on resolution from:

i. dark counts

ii. after pulsing

iii. cross talk

as a function of:

i. bias voltage

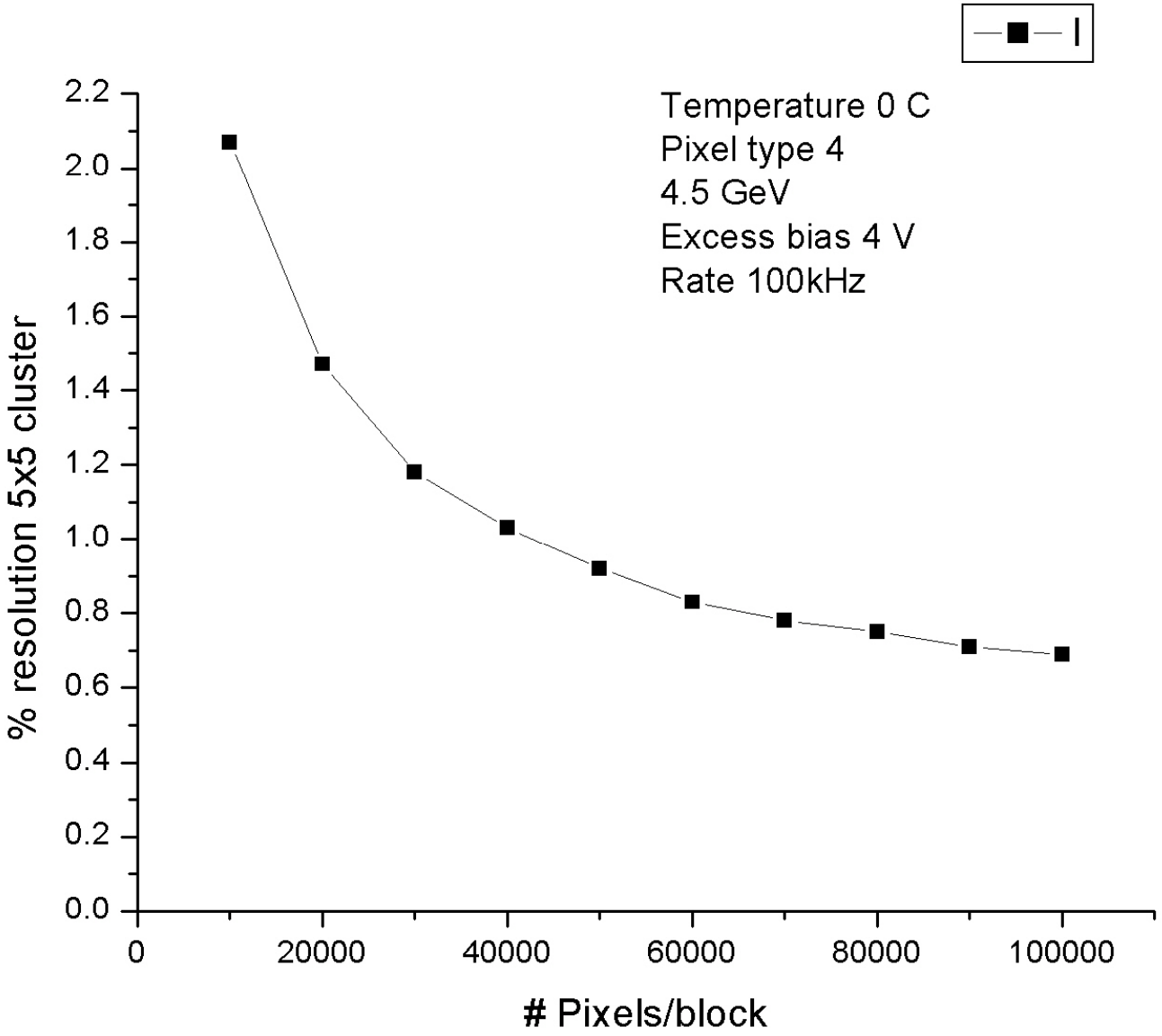
ii. average event rate

iii. number of pixels in array

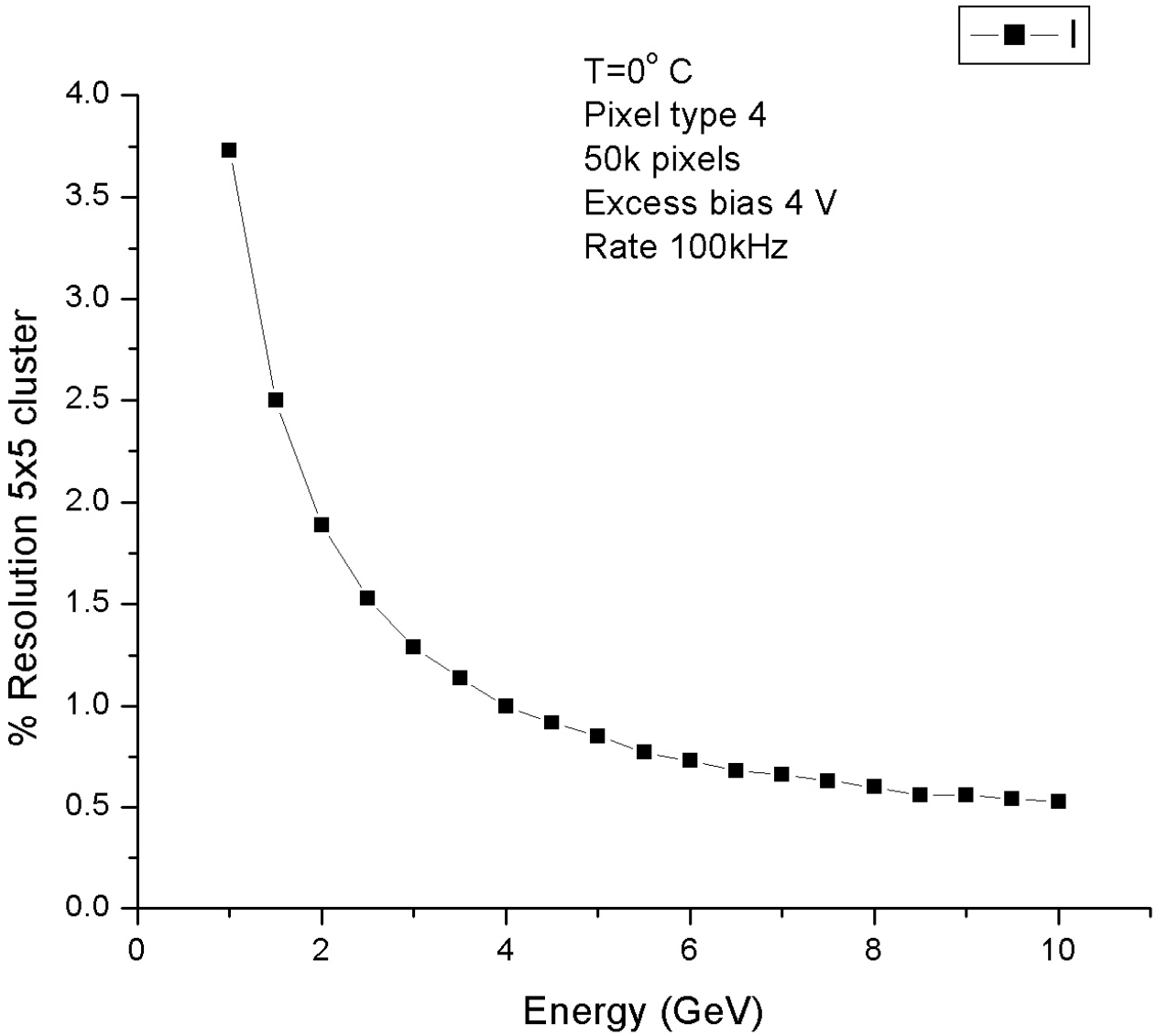
iv. beam energy

v. Temperature of the SSPM and PbWO crystal

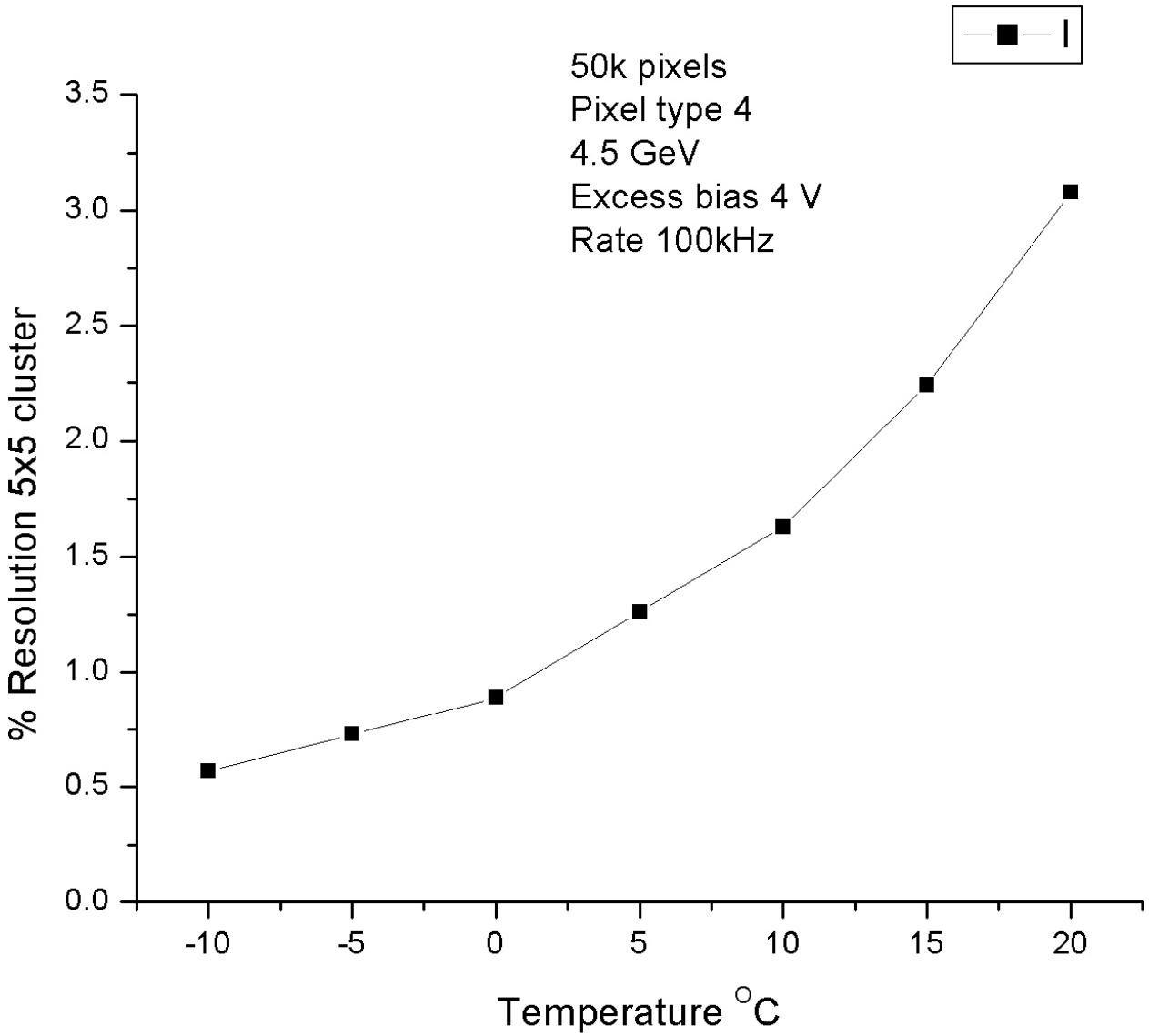
Simulation: Energy Resolution versus Number of Pixels



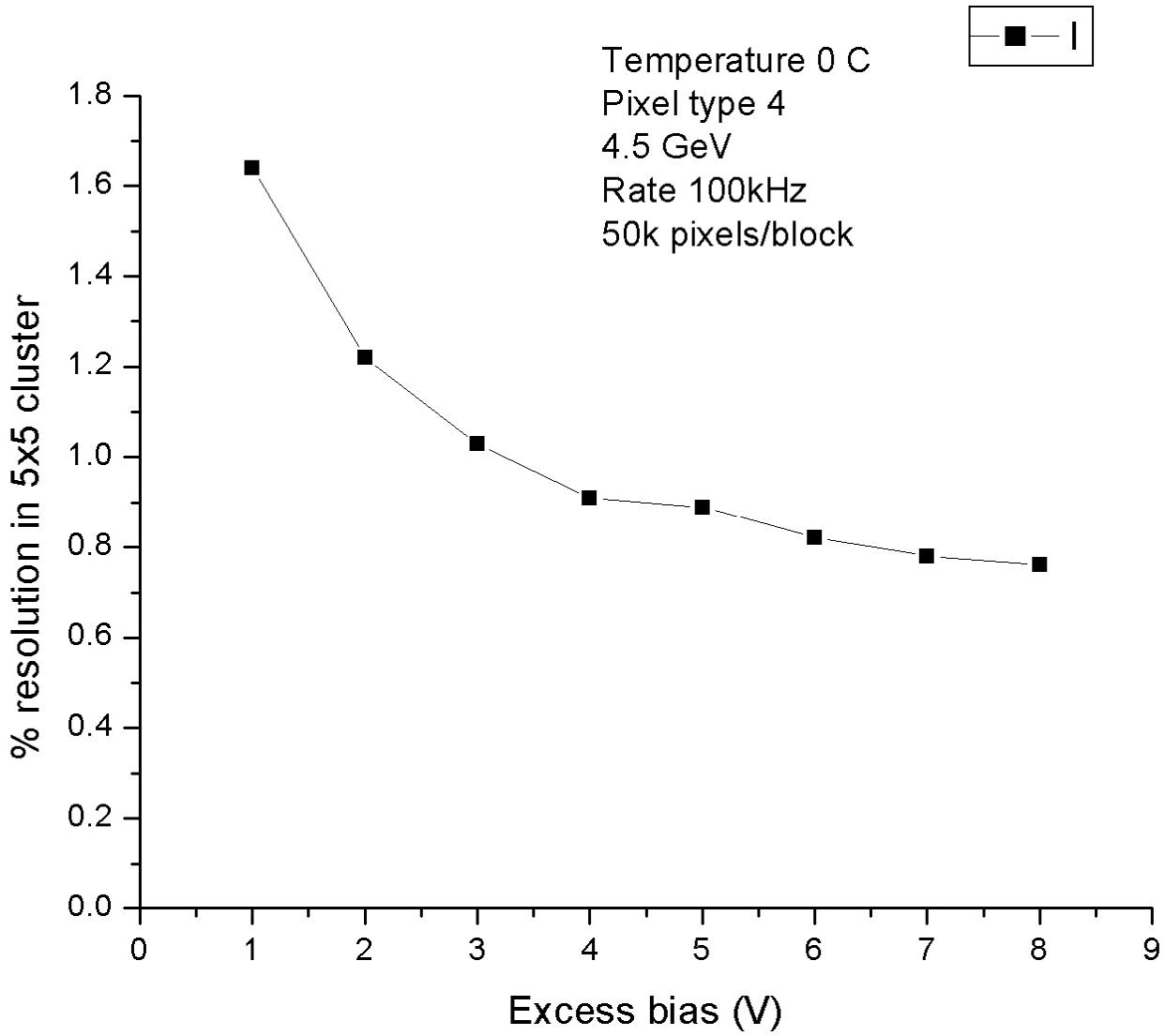
Simulation: Energy Resolution versus Photon Energy



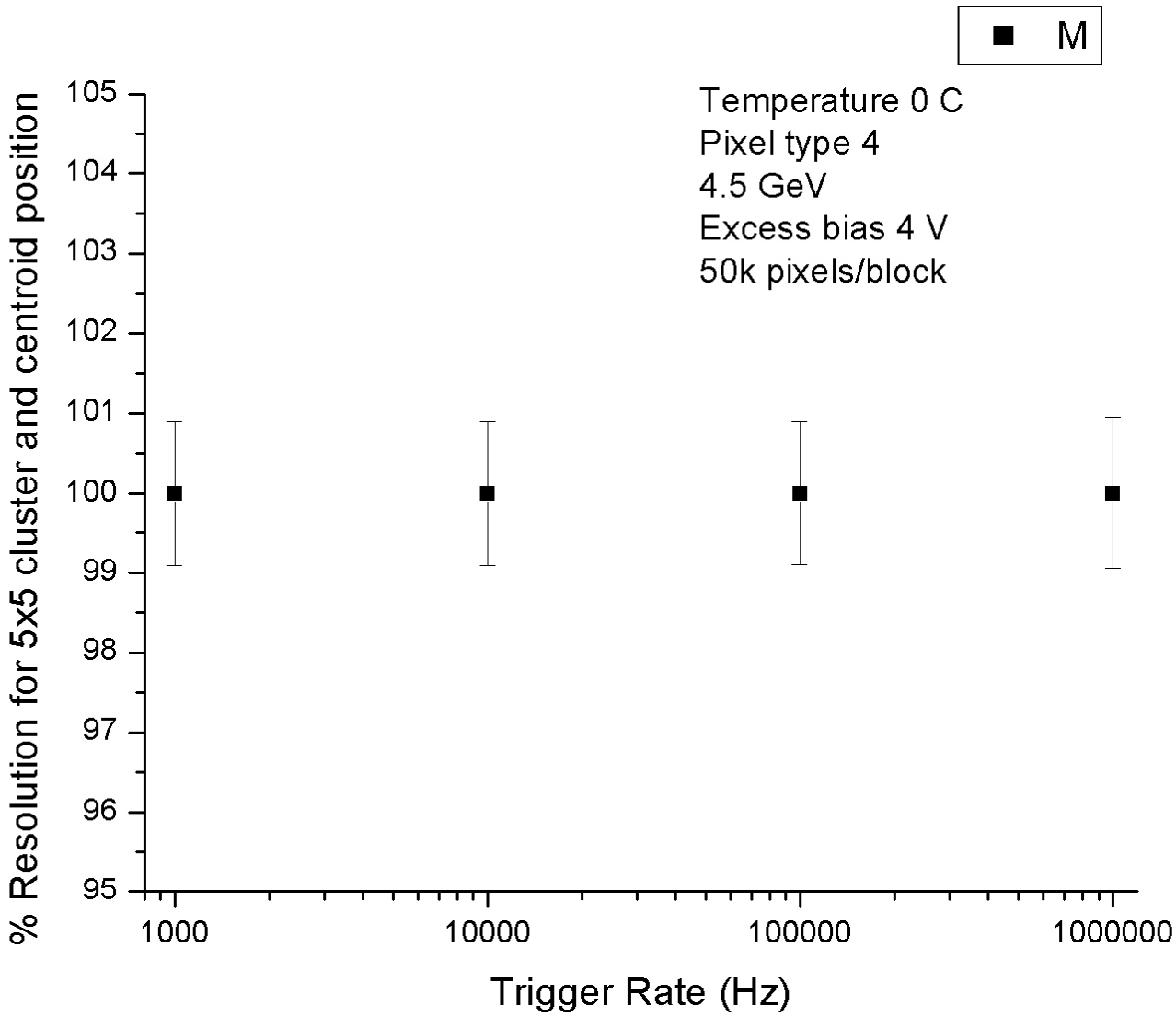
Simulation: Energy Resolution versus Temperature



Simulation: Energy Resolution versus Detector Bias



Simulation: Energy Resolution versus Average Event Rate



How does the experiment benefit?

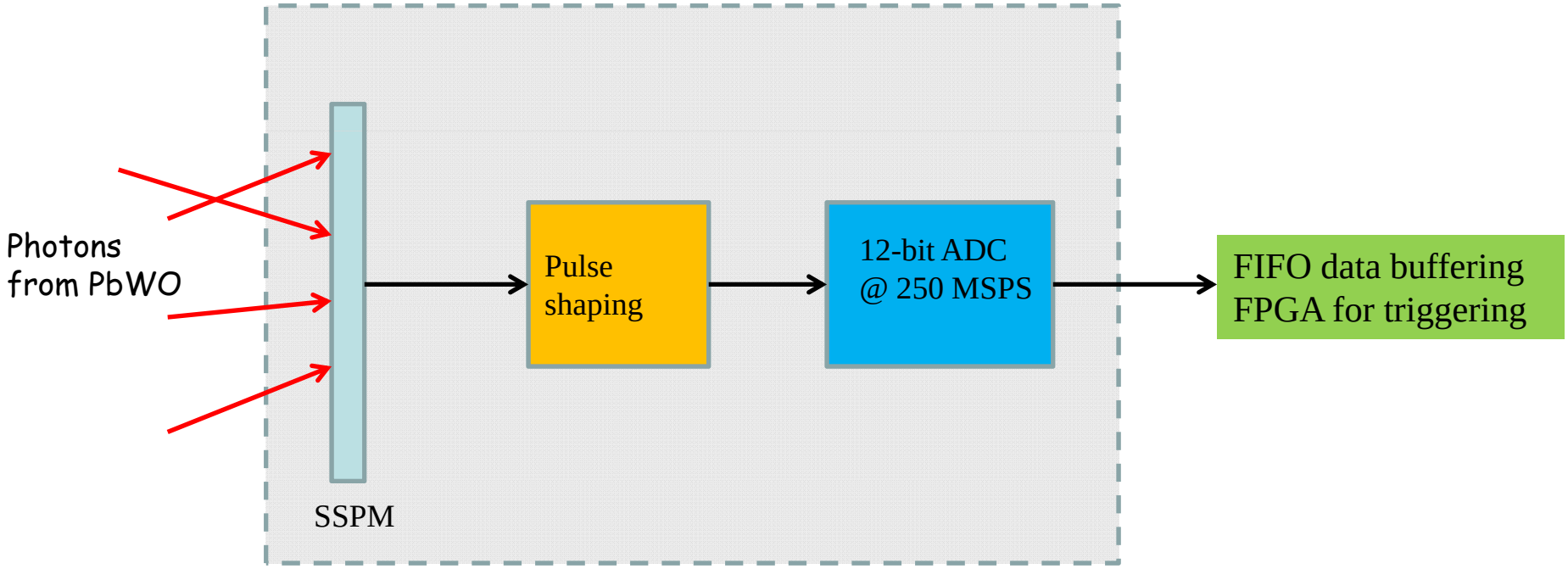
- SSPM's have no sensitivity to helium gas or fringe magnetic fields.
- SSPM's are biased at ≈ 30 V. Expensive and complicated high voltage supplies, requiring thousands of independently controllable voltage channels, are not required.
- Kilometers of analog delay cable are not required for timing analog signals into gated ADC's.
- FASTBUS or VME ADC's are not required.

What are the benefits? Continued

- ADC's running at 250 MSPS have time resolution of 4 ns. Waveform digitization at the crystal level provides "time digitization" for each crystal.

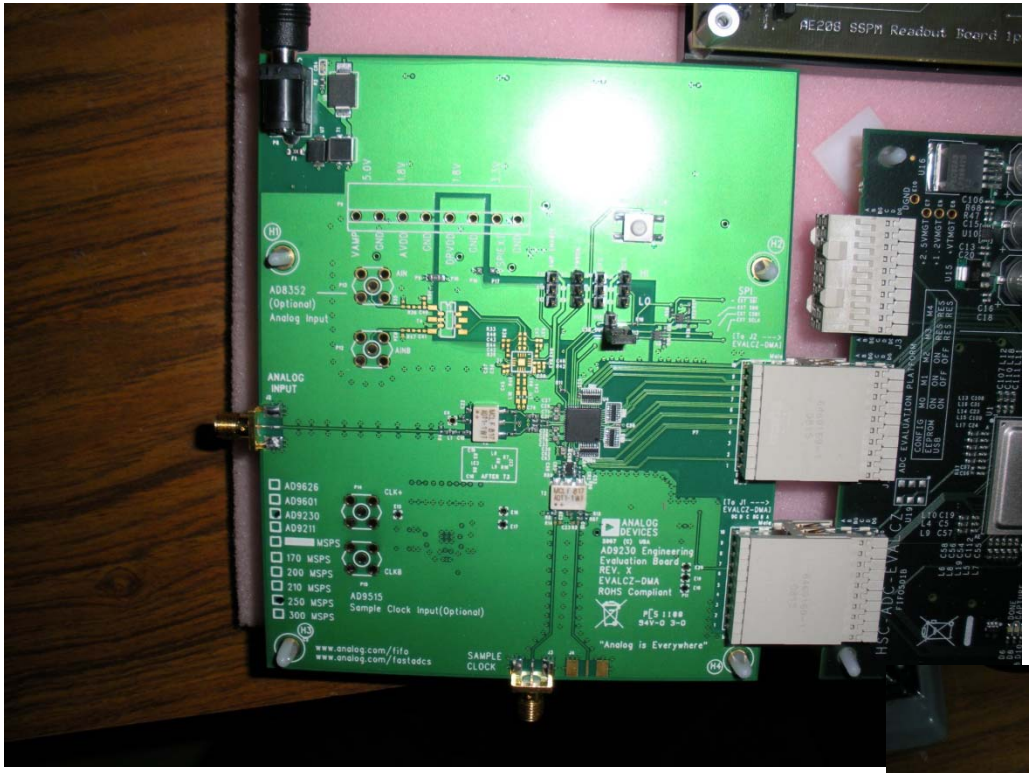
- Digitally sum energies over groups of n x n crystals ($n \leq 5$) using commercial *Field Programmable Gate Arrays* (FPGA). Trigger HYCAL on the presence of one or more energy clusters. The custom analog summing electronics is no longer needed.

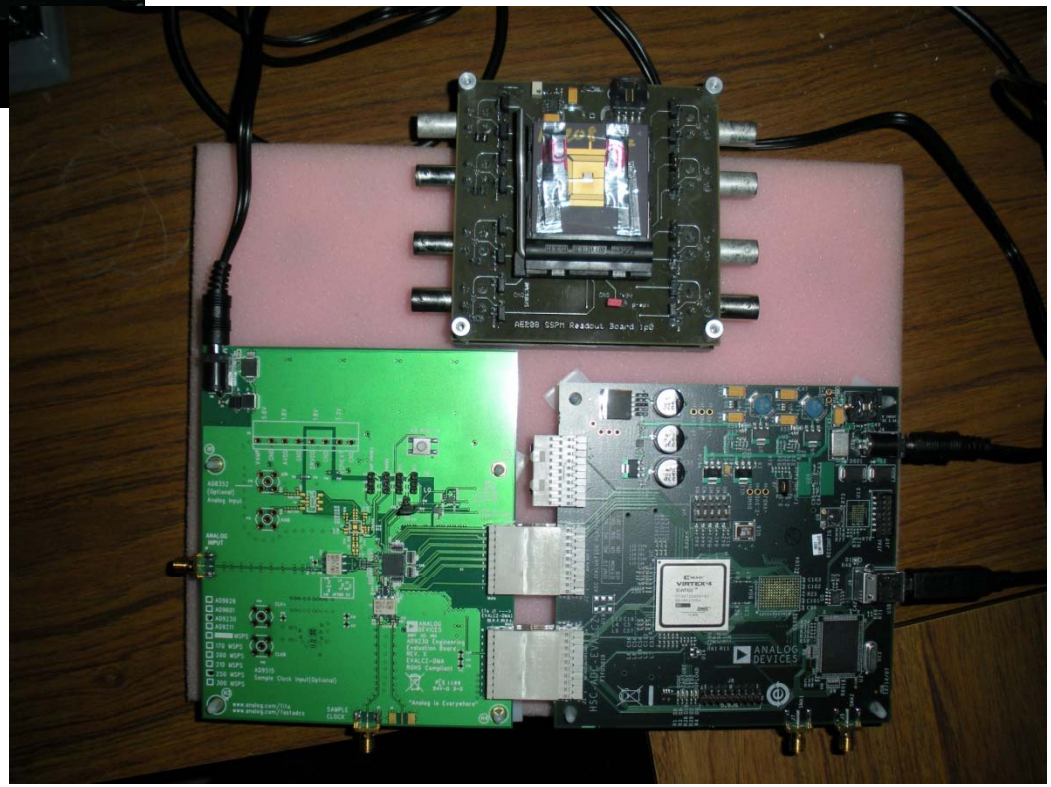
Working concept: waveform digitizer



SSPM-ADC board

ADC testing at UMass

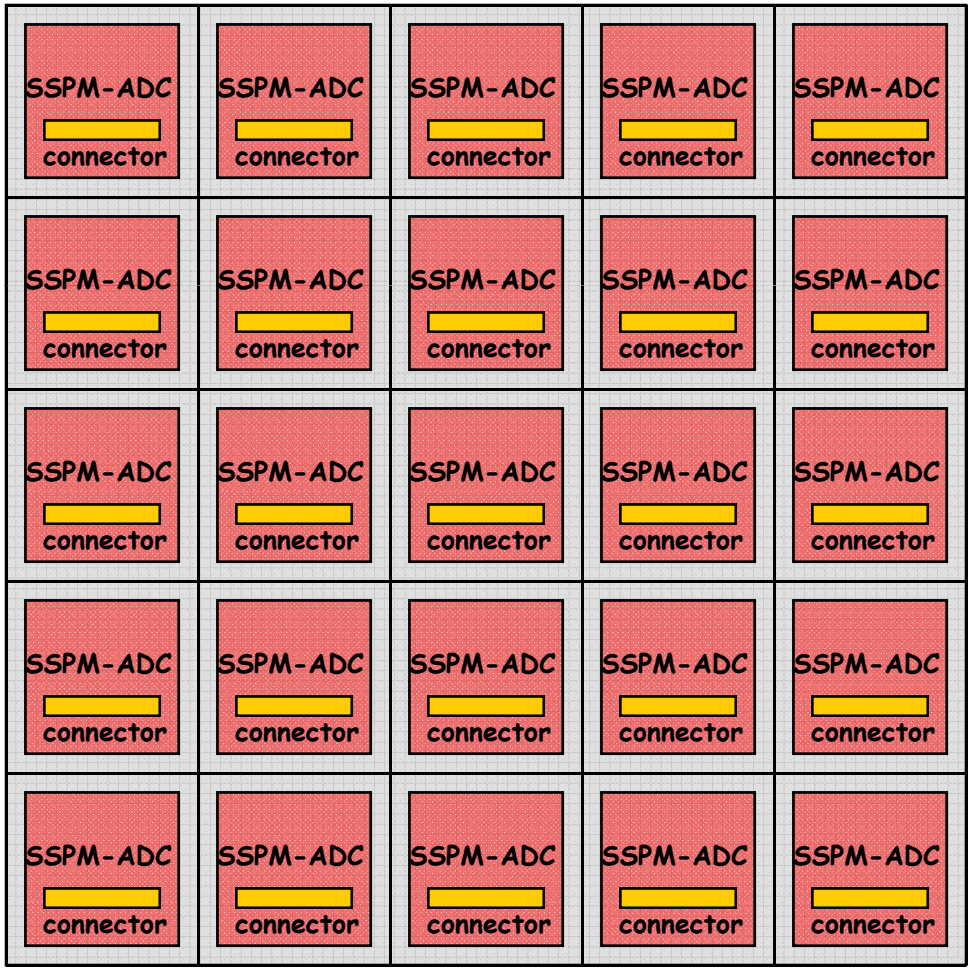




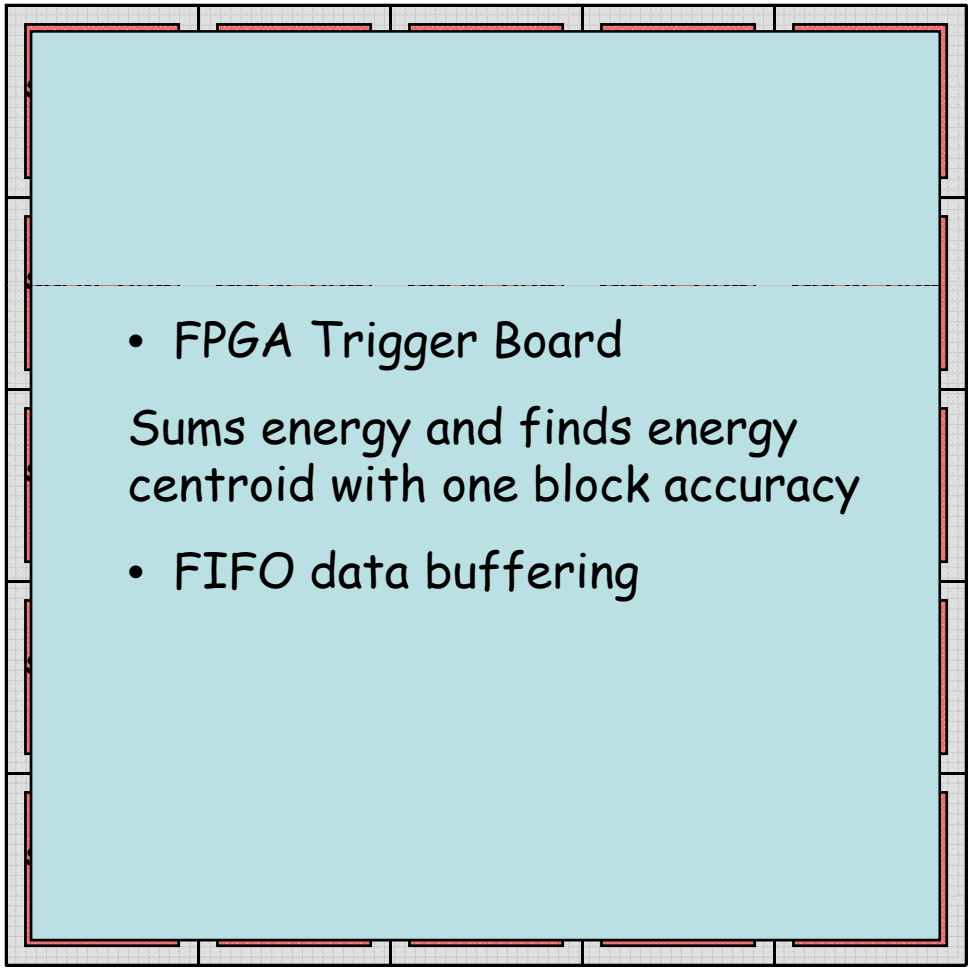
Installation onto back of HYCAL

PbWO	PbWO	PbWO	PbWO	PbWO
PbWO	PbWO	PbWO	PbWO	PbWO
PbWO	PbWO	PbWO	PbWO	PbWO
PbWO	PbWO	PbWO	PbWO	PbWO
PbWO	PbWO	PbWO	PbWO	PbWO

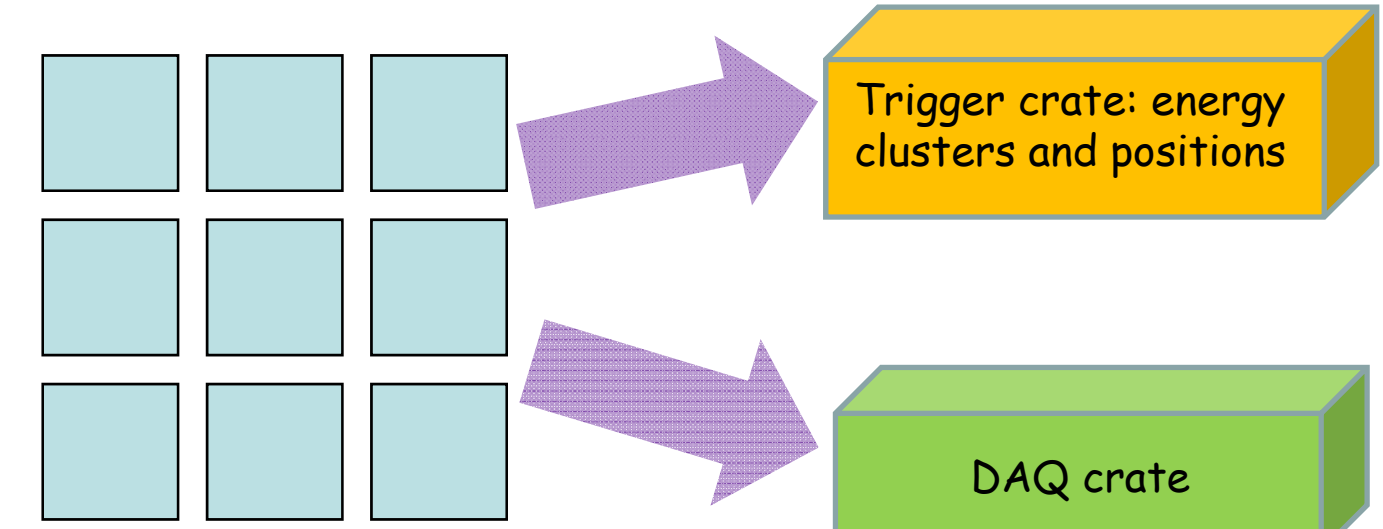
Installation onto back of HYCAL



Installation onto back of HYCAL



- Assume 60 x 60 array of PbWO blocks = 3596 channels
- Need 144 Trigger/FIFO boards covering 5 x 5 segment of blocks
- 144 fiber optic cables to connect Trigger/FIFO boards with trigger electronics in crate
- 144 fiber optic cables to connect Trigger/FIFO boards with DAQ readout crate



Summary

What electronics are no longer needed?

1. PMT's and tube bases
2. HV supplies
3. Analog delay cable
4. Fastbus/VME ADC's
5. The custom UVa analog energy summing electronics

What capabilities are added?

1. Waveform digitization for each crystal
2. Timing measurements for each crystal
3. Capability for triggering on a single energy cluster, or multiple clusters (i.e. a $\pi^0\pi^0$ trigger). A more restrictive trigger could allow us to run at higher luminosity.
4. No sensitivity to magnetic fields or helium

What do we have to develop ?

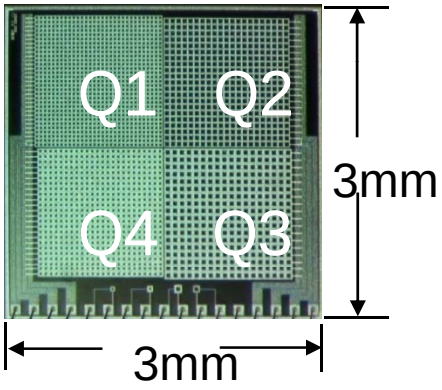
1. Integrated SSPM-ADC card with approximately 50k pixels of 30 μm size. The SBIR phase I and II proposals can provide us with a detector, if funded.
2. FPGA triggering and readout board
3. HYCAL will need to operate at a reduced temperature, ideally at 0° C.

Proposed funding and construction timeline

Date	Task	Status
Spring 2008	Phase I SBIR approved for HYCAL	Done
Dec. 2008	JLab PAC proposal submitted. In our proposals the SSPM is presented as one option.	
2008 and winter 2009	Demonstrate waveform capture with 250 MSPS ADC; measure resolution of SSPM coupled to PbWO in beam test at JLab; develop GEANT simulation.	Started
March 2009	SBIR Phase I report and Phase II proposal submitted to DOE	
Summer 2009	DOE reports back on Phase II proposal	
Fall 2009	NSF MRI proposal submitted with best cost estimates for the SSPM option.	
Spring 2010	MRI approved	
2010-2011	Beam tests with crystals and SSPM-ADC modules. Develop trigger and readout electronics with JLab support.	
Fall 2011	SBIR sponsored R&D completed. Procure detectors and readout electronics.	

Planned Effort

- GEANT simulation of light production in PbWO block from high energy gamma's, and collection onto an array of pixels.
- Test the 250 MSPS 12-bit ADC with the RMD SSPM



- Optically couple SSPM to PbWO block. Test with GeV photon beam @ Jlab.

➡ Test predictions of simulation studies.

- Submit phase II SBIR proposal. *We will need the support of this collaboration for a successful proposal.*