Off-Axis Liquid Scintillator Detector

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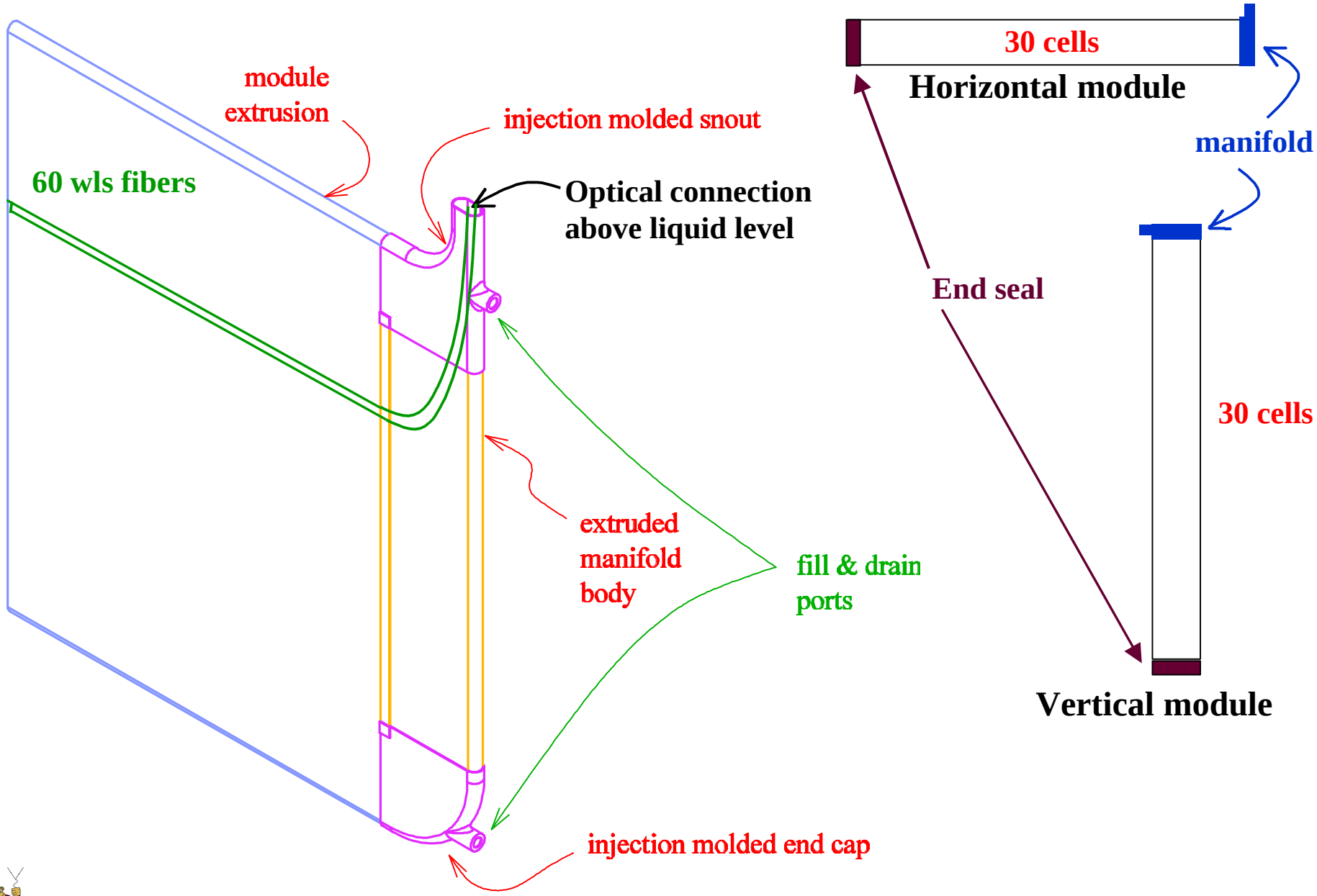
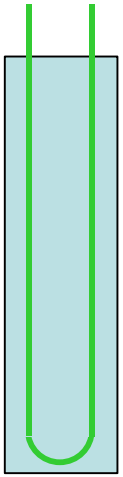
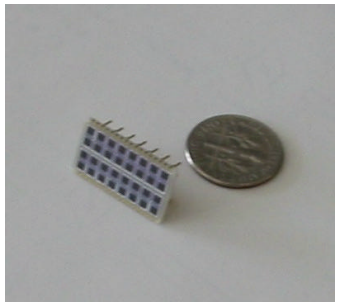
Module Manifold



Scintillator and Wavelength Shifting Fiber

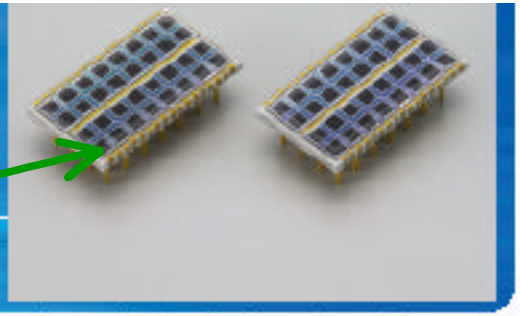
- **Scintillator Element Length 48 ft** **(2 x MINOS)**
  - **Sufficient light output with single ended readout (U loop)**
  - **Good shipping length**
  - **Good event containment**
  - **Good assembly unit**
- **Scintillator Material** **400,000 m^2 (16 x MINOS)**
  - **Liquid**
    - **Bicron 517 L 4 cm x 3 cm**
- **WLS Fiber**
  - **Kuraray 0.8 mm diameter**
  - **U loop**
- **Photodetector** **600,000 channels (30 x MINOS)**
  - **APD**





Si APD array
S8550

4 x 8 element APD array with low noise and enhanced short-wavelength sensitivity



S8550 is an APD (avalanche photodiode) array designed for short wavelength detection, featuring low noise and low terminal capacitance. S8550 also offers uniform gain and small cross-talk between each element.

Features

- High sensitivity and low noise in short wavelength region
- Low terminal capacitance
- Optimized for blue light detection
- Uniform gain and low cross-talk variation between each element

Applications

- Low-light-level photometry in the visible range
- Detector systems combined with scintillator

HAMAMATSU

Parameter	Rating	Unit
Element size	1.6 × 1.6 (× 32 elements)	mm
Element pitch	2.3	mm
Package	Ceramic	-
Window material	Epoxy resin	-

■ Absolute maximum ratings

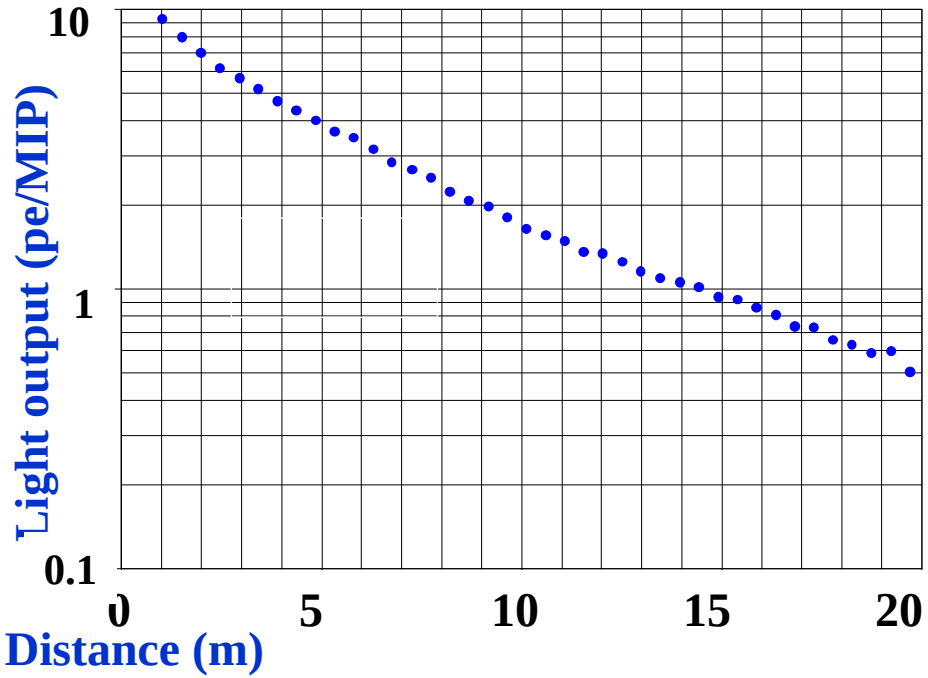
Parameter	Symbol	Value	Unit
Operating temperature	Topr	-20 to +60	°C
Storage temperature	Tstg	-20 to +80	°C

■ Electrical and optical characteristics (Ta=25 °C)

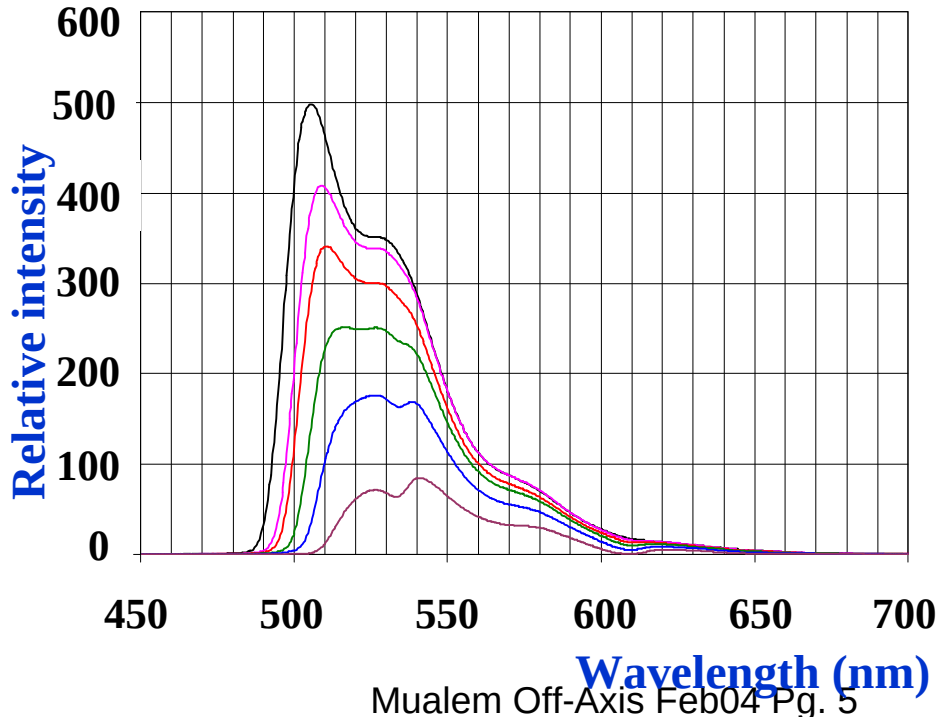
Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Spectral response range	λ		-	320 to 1000	-	nm
Peak sensitivity wavelength	λp	M=50	-	600	-	nm
Quantum efficiency	QE	λ=420 nm	60	70	-	%
Breakdown voltage	VBR		-	400	500	V
Dark current	ID	per 1 element, M=50	-	10	50	nA
Terminal capacitance	Ct	per 1 element, M=50, f=10 kHz	-	10	-	pF
Gain	M		-	50	-	

Measurement of Long Fiber Light Transmission

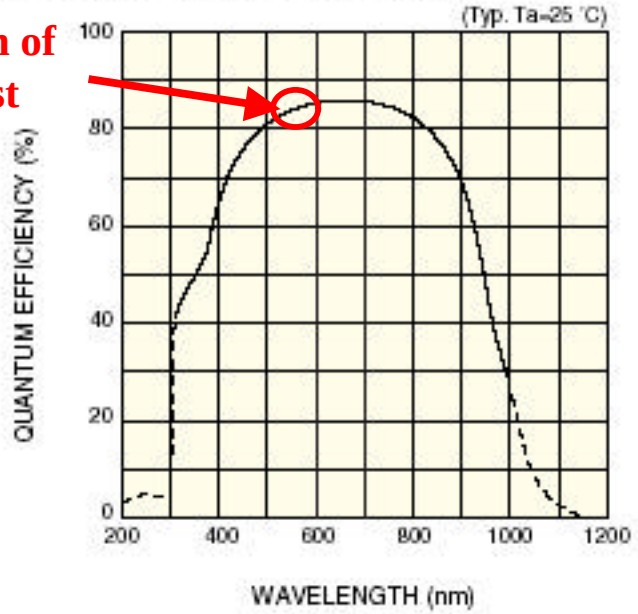
Attenuation in 1.2 mm WLS fiber (bialkali photocathode)



Spectra from 1.2 mm WLS fiber at 0.5, 1, 2 ,4, 8, 16 m

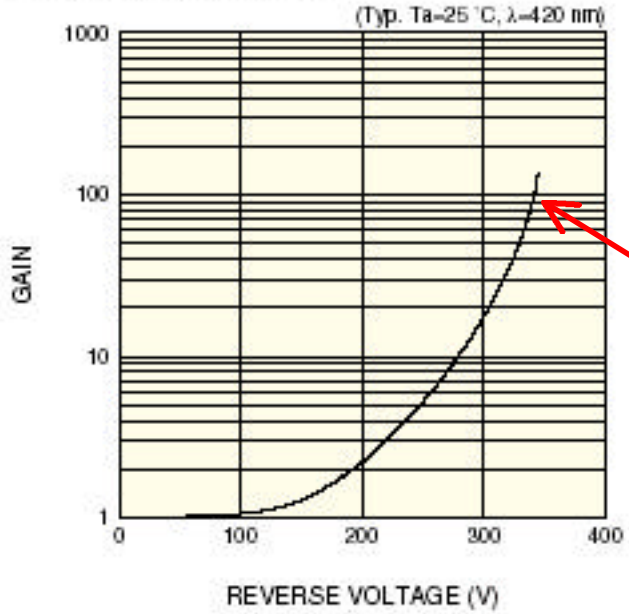


■ Quantum efficiency vs. wavelength

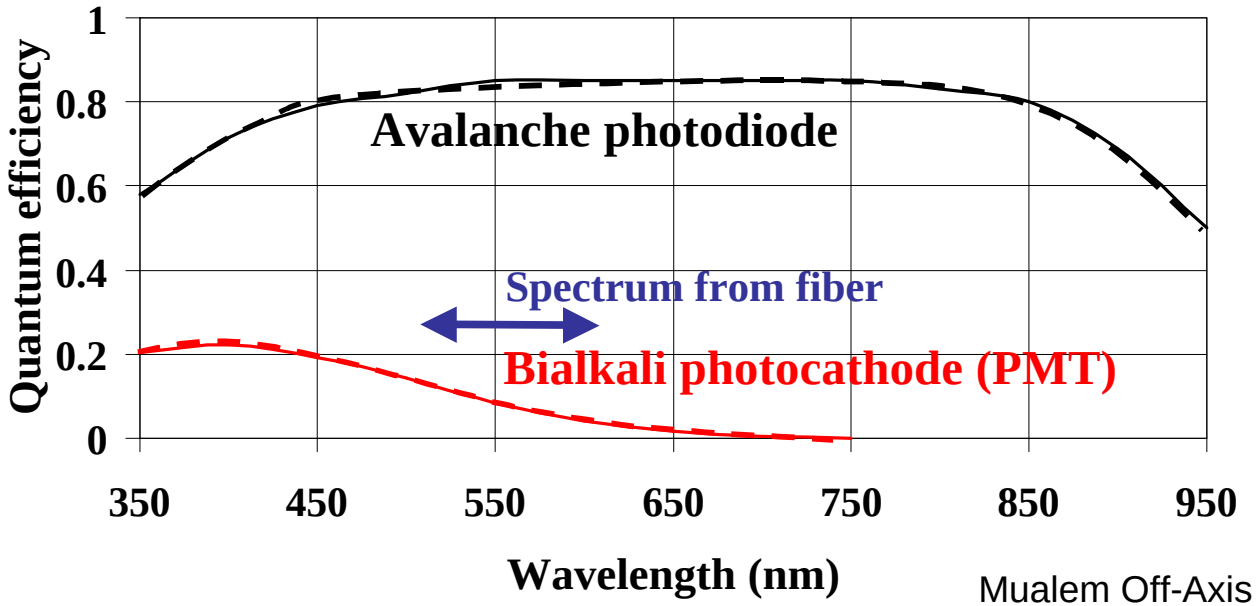


Region of interest

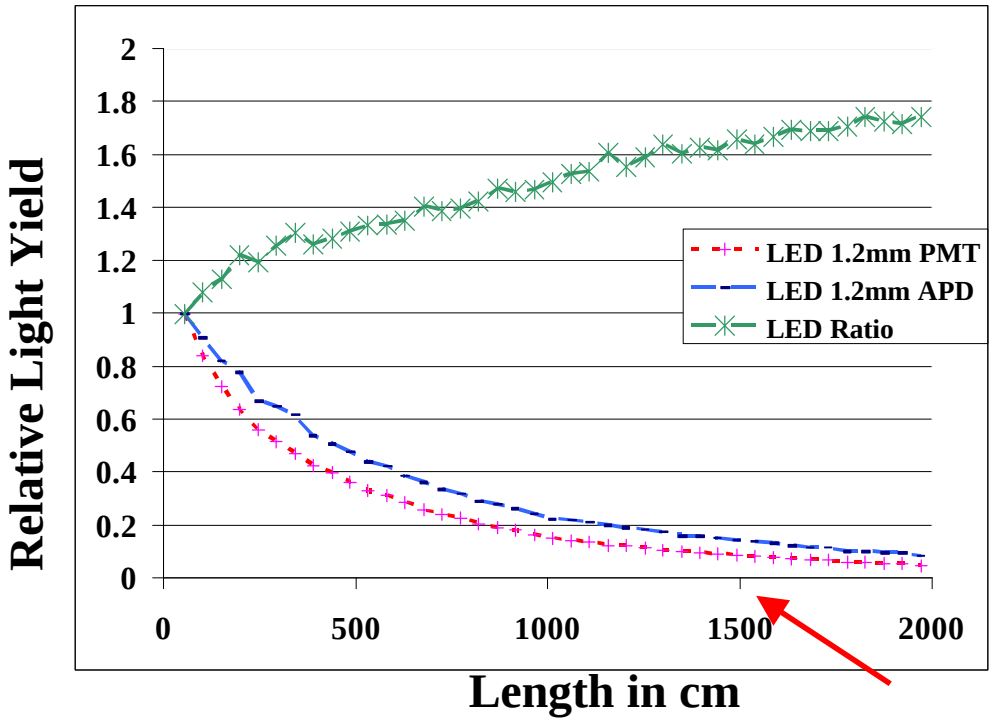
■ Gain vs. reverse voltage



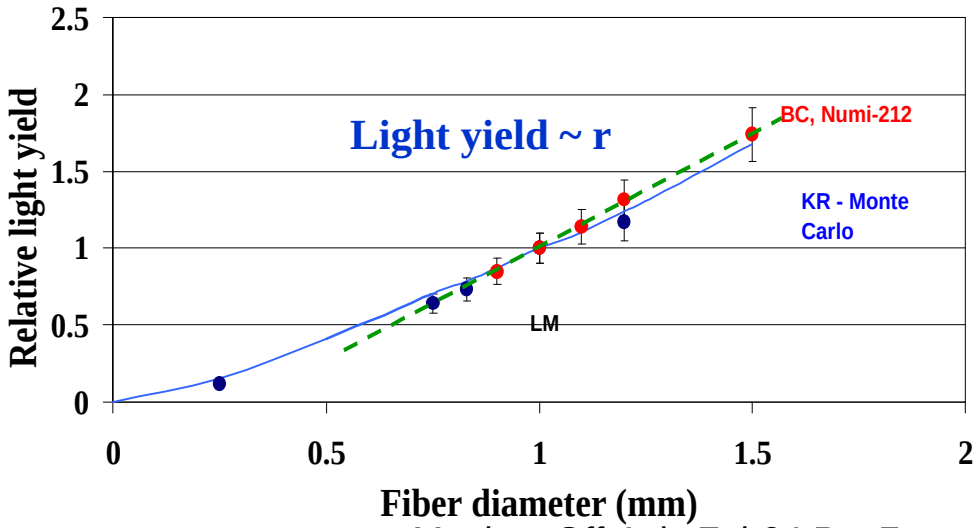
gain = 100



WLS Fiber Attenuation – APD vs PMT



WLS Fiber Diameter

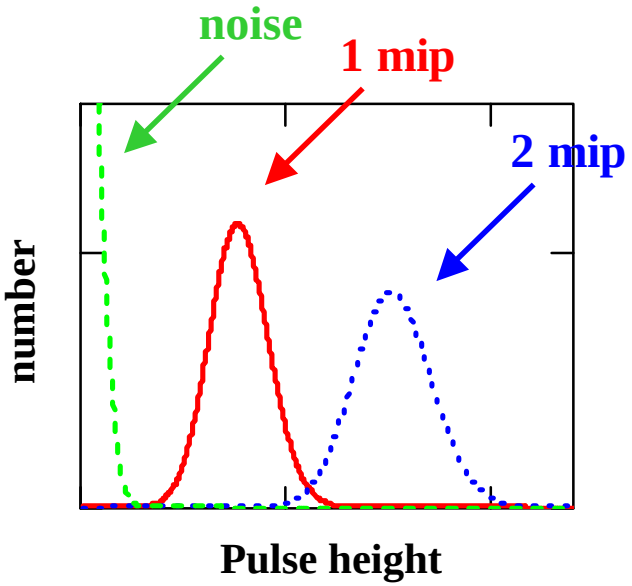


Photon Economics Based on Measurements

- **.95 pe/mip @ 15 m with 1.2 mm fiber with MINOS scintillator (1 cm) and pmt**
- **10.6 pe @ 15 m with 1.2 mm fiber with MINOS scintillator and APD (1.4x spectrum, 8x QE at peak)**
- **42.5 pe @ 15 m with 1.2 mm fiber U loop, APD with MINOS scintillator**
- **28 pe @ 15 m with 0.8 mm fiber U, APD with MINOS scintillator**
- **42 pe @ 15 m with 0.8 mm fiber U, APD with liquid scintillator (3 cm x 4 cm cell gives photons produced, 1.5x geometry)**

Photon Statistics

Solid Scintillator Response Calculation at 48 ft.



APD cooled to 0°C
MASDA chip

Solid

MIP

28 pe x 100 gain = 2800 electrons

Noise

350 electrons (amplifier)

100 electrons (APD)

S/N = 7.7

Liquid

MIP

42 pe x 100 gain = 4200 electrons

Noise

350 electrons (amplifier)

100 electrons (APD)

S/N = 10

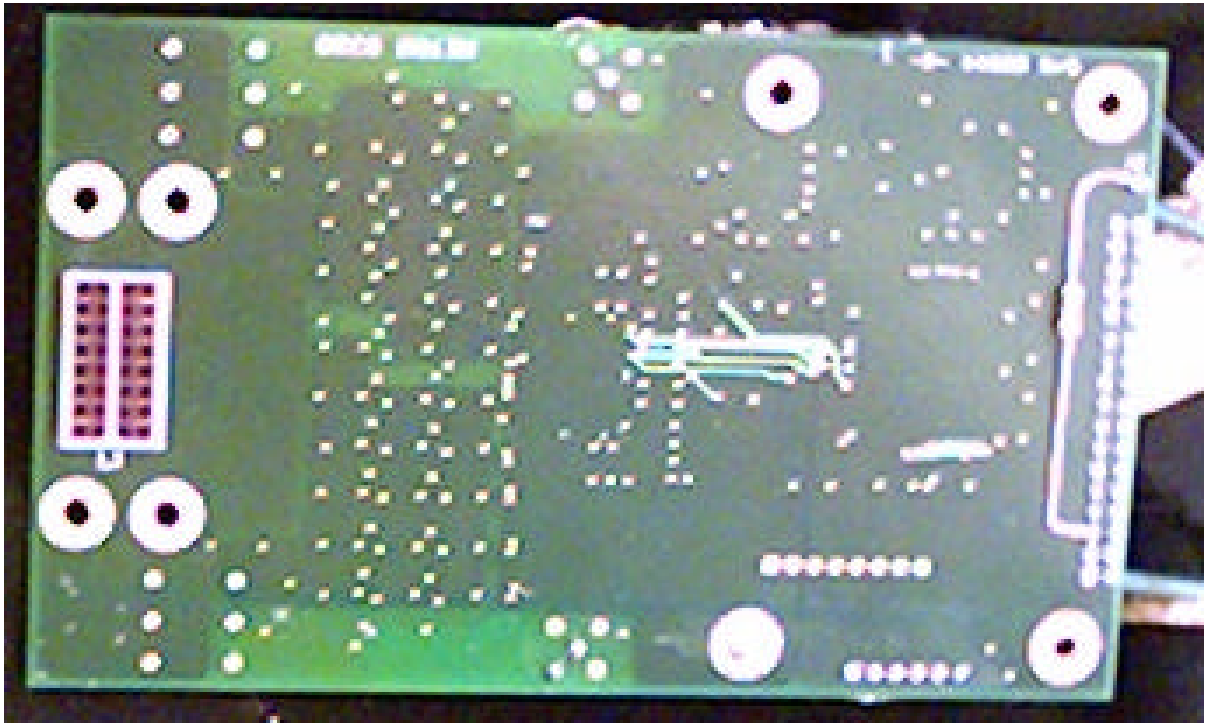
Prototype Board

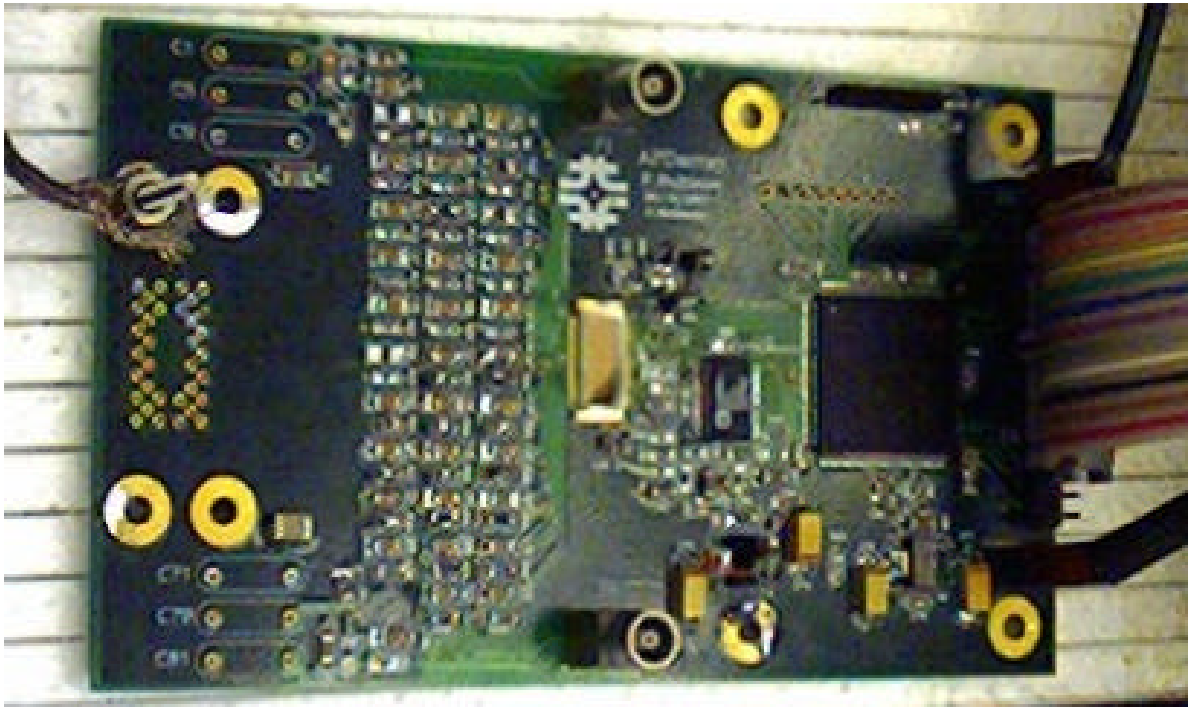
32 Ch. APD Array

MASDA Integrator

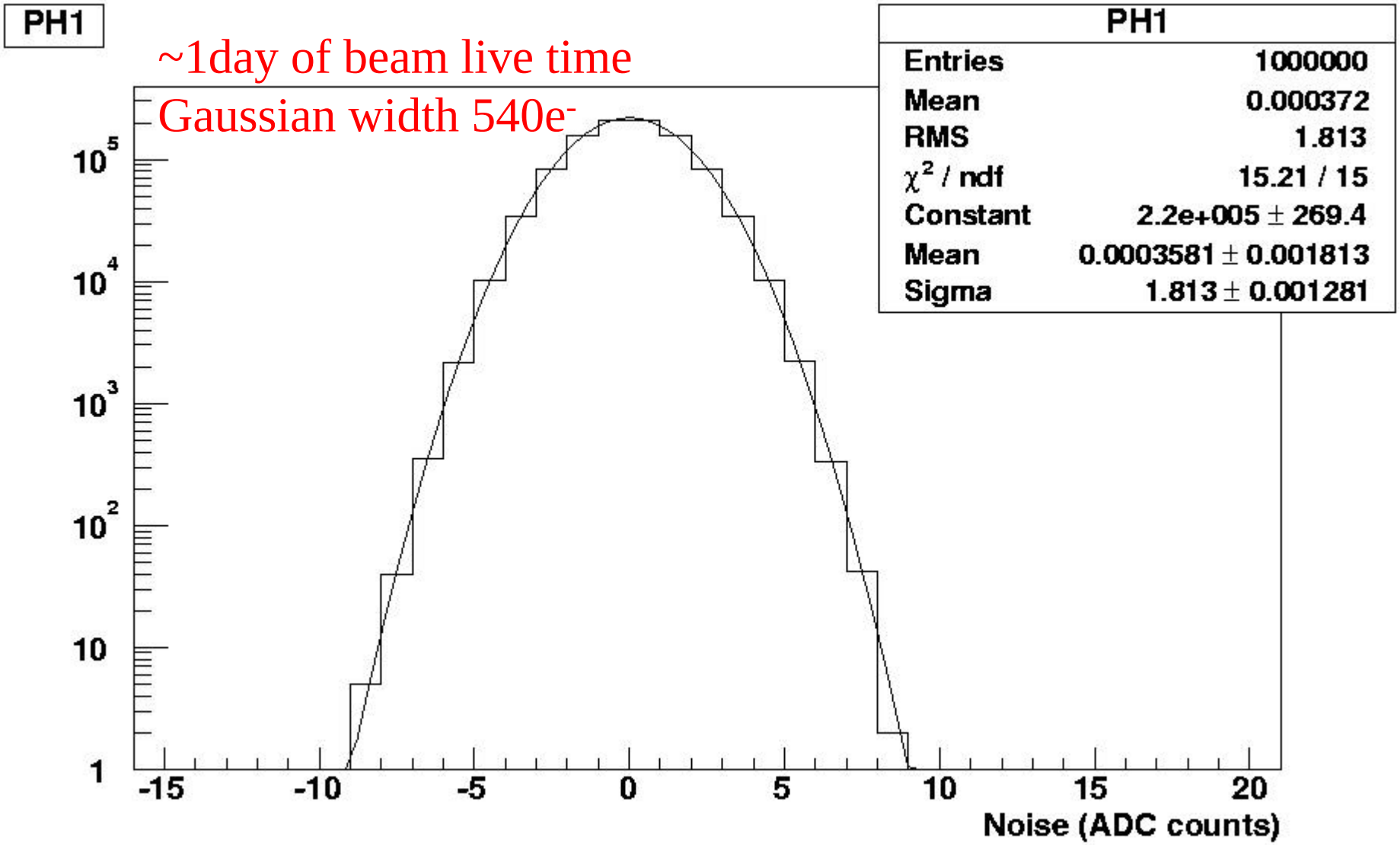
ADC

CPLD clock/readout

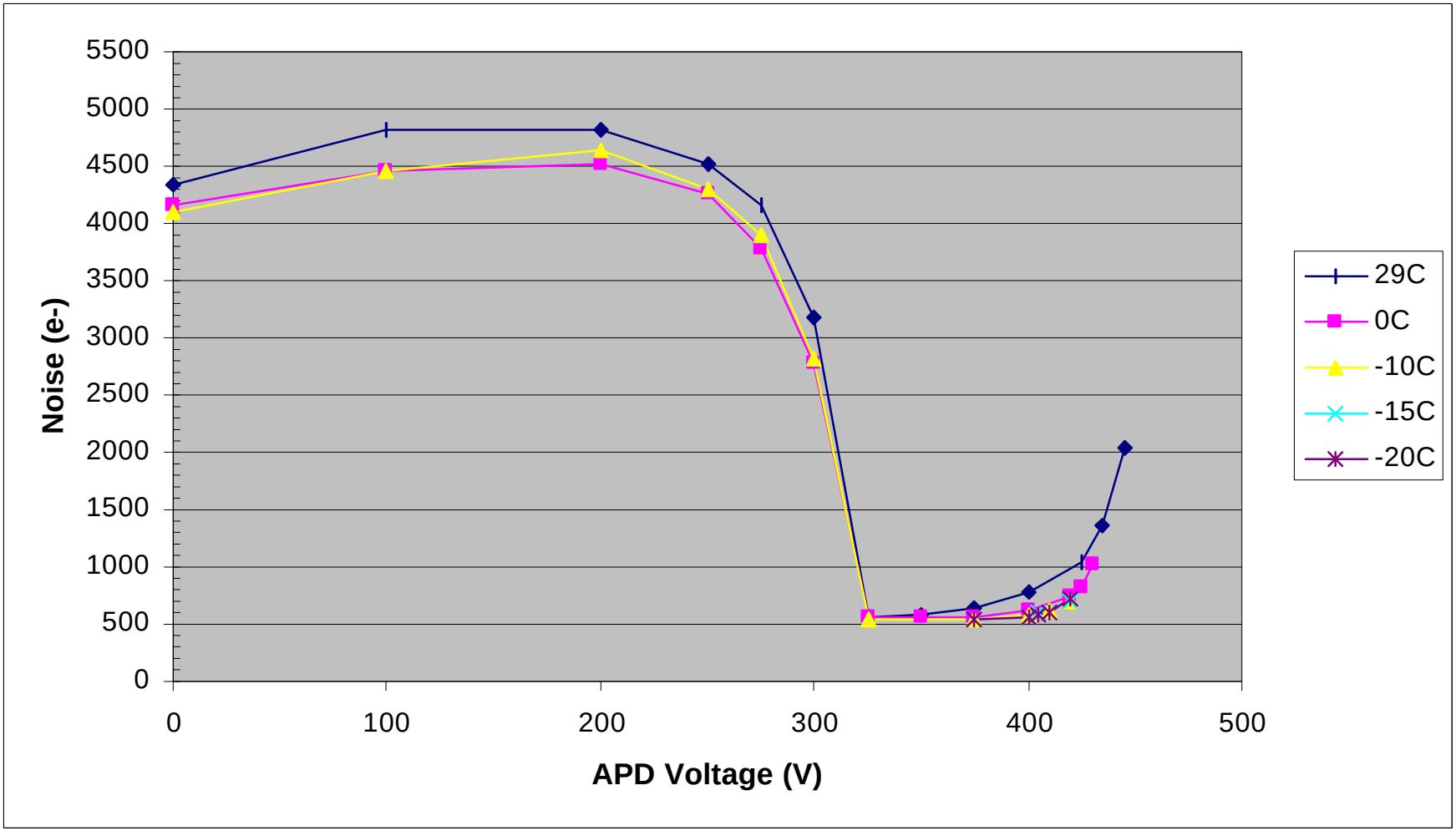




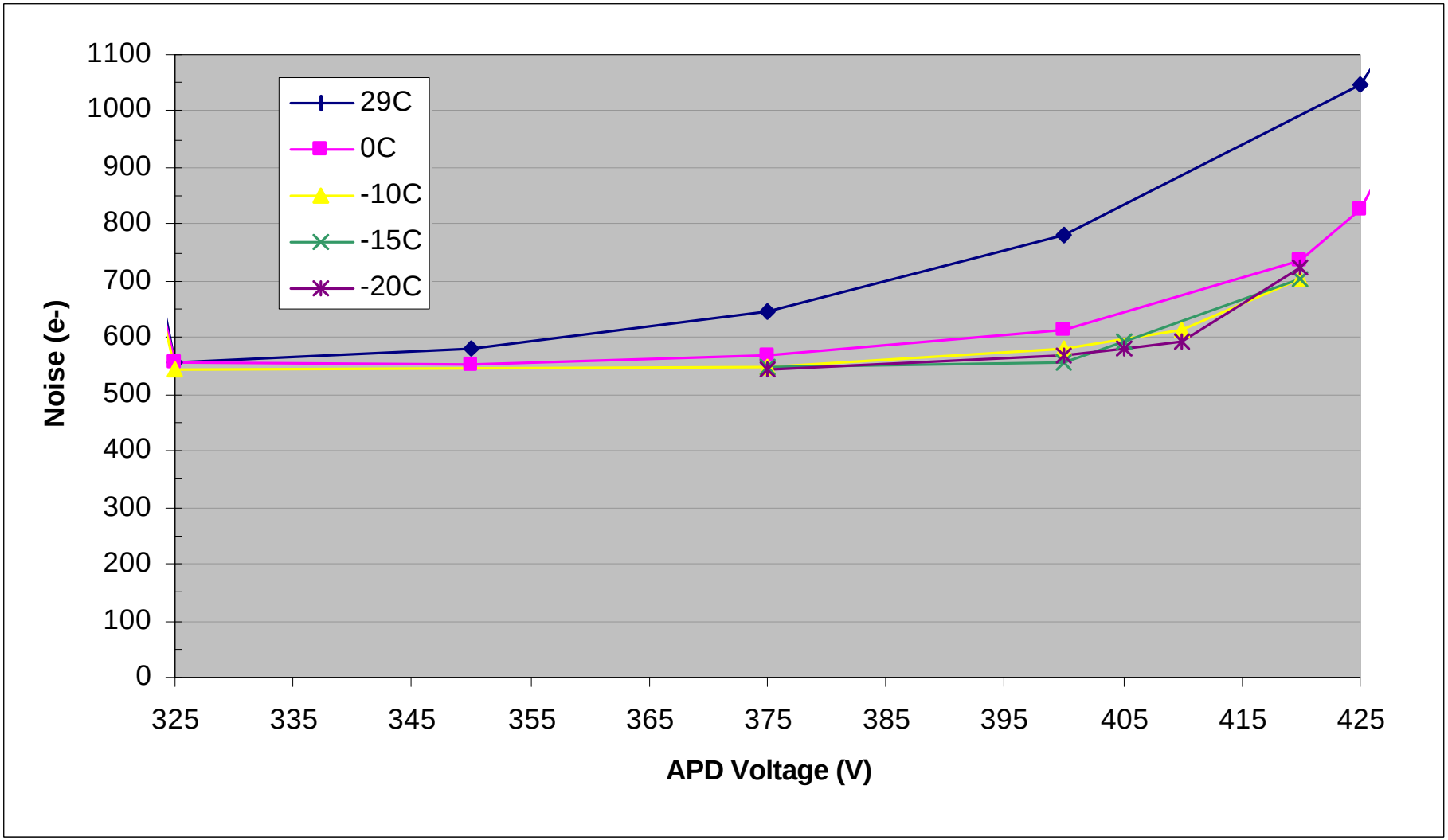
Fit to noise showing Tails…



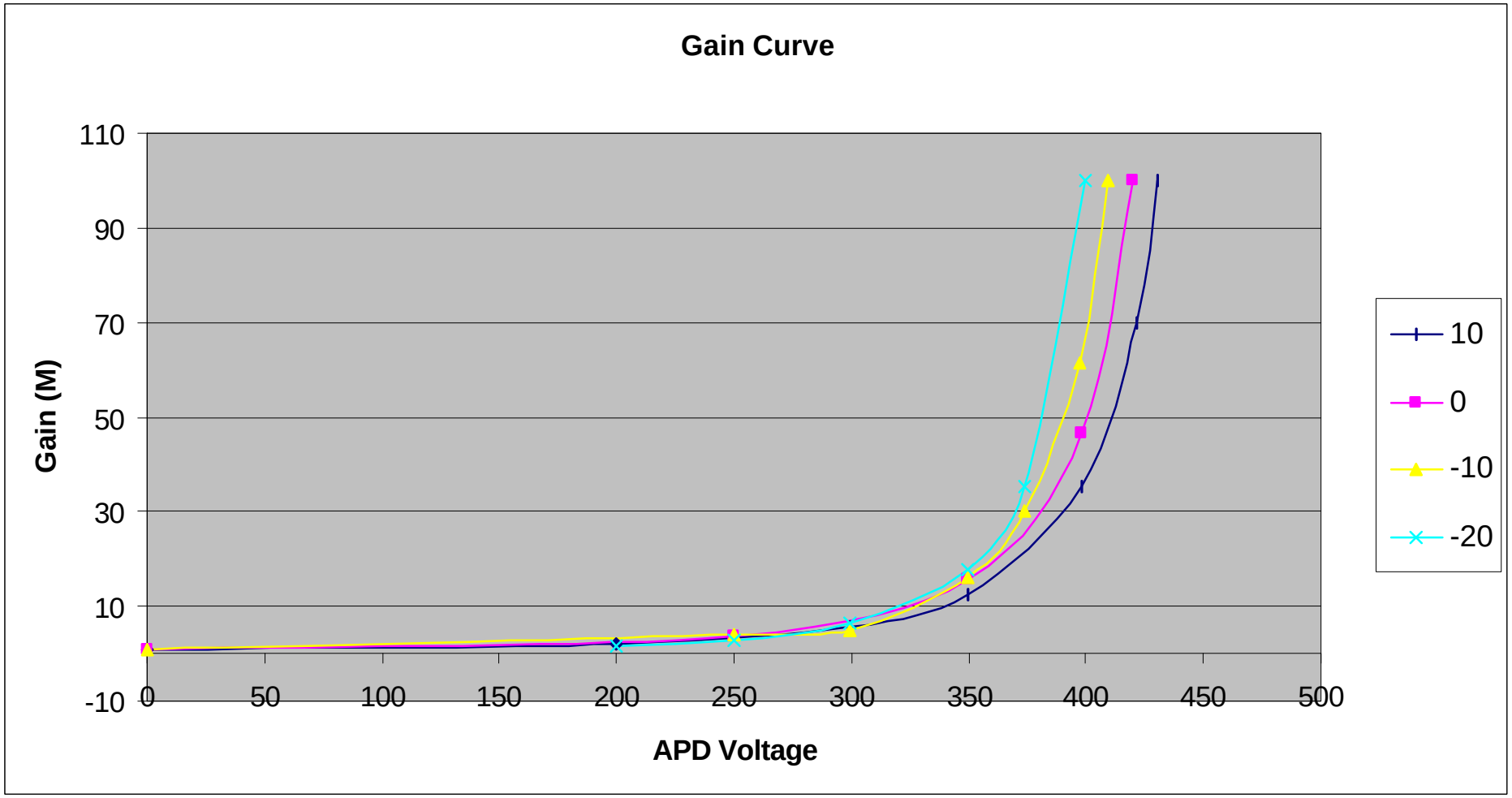
Noise vs. Voltage by temp.



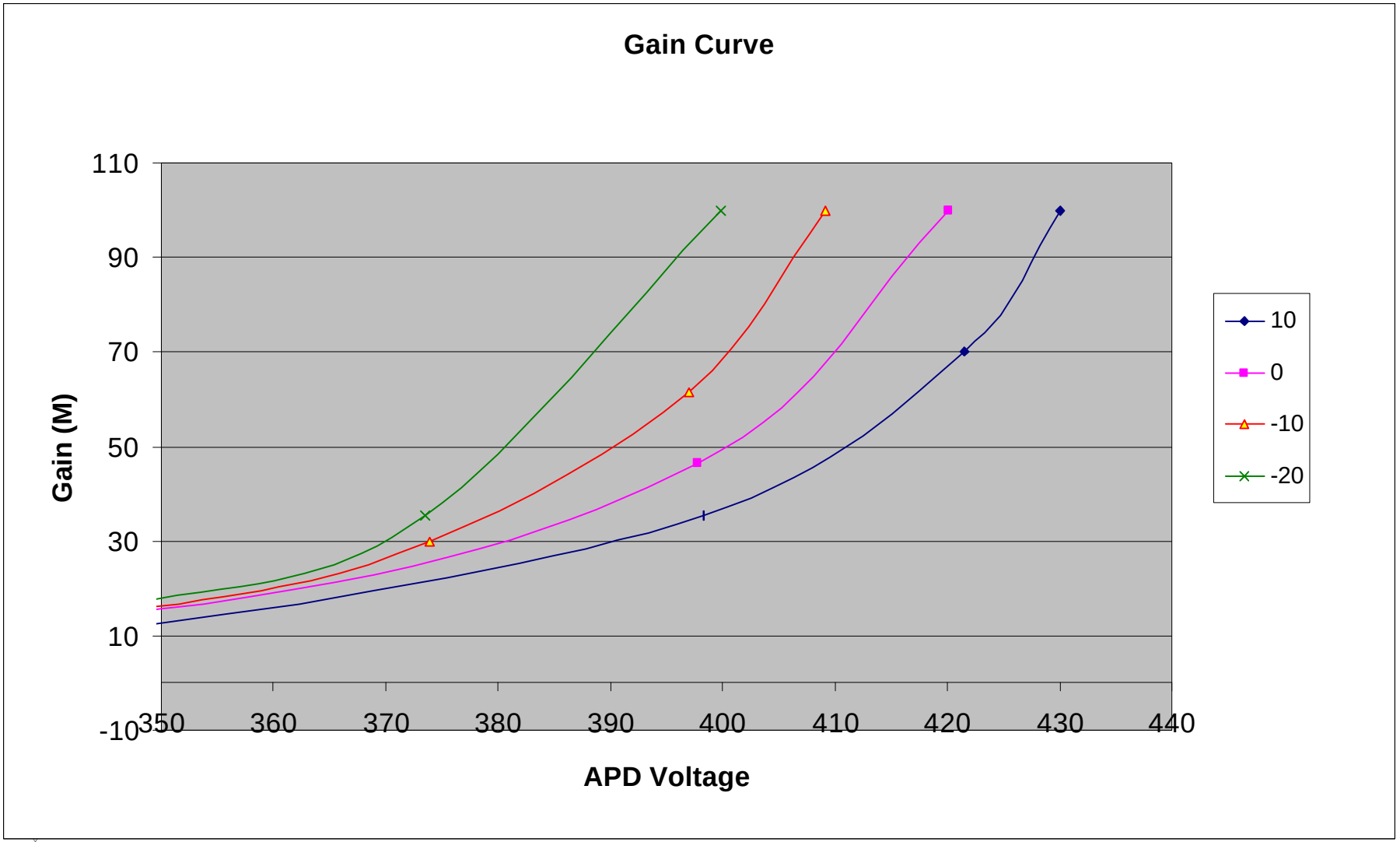
Noise vs. Voltage by temp. (zoomed)



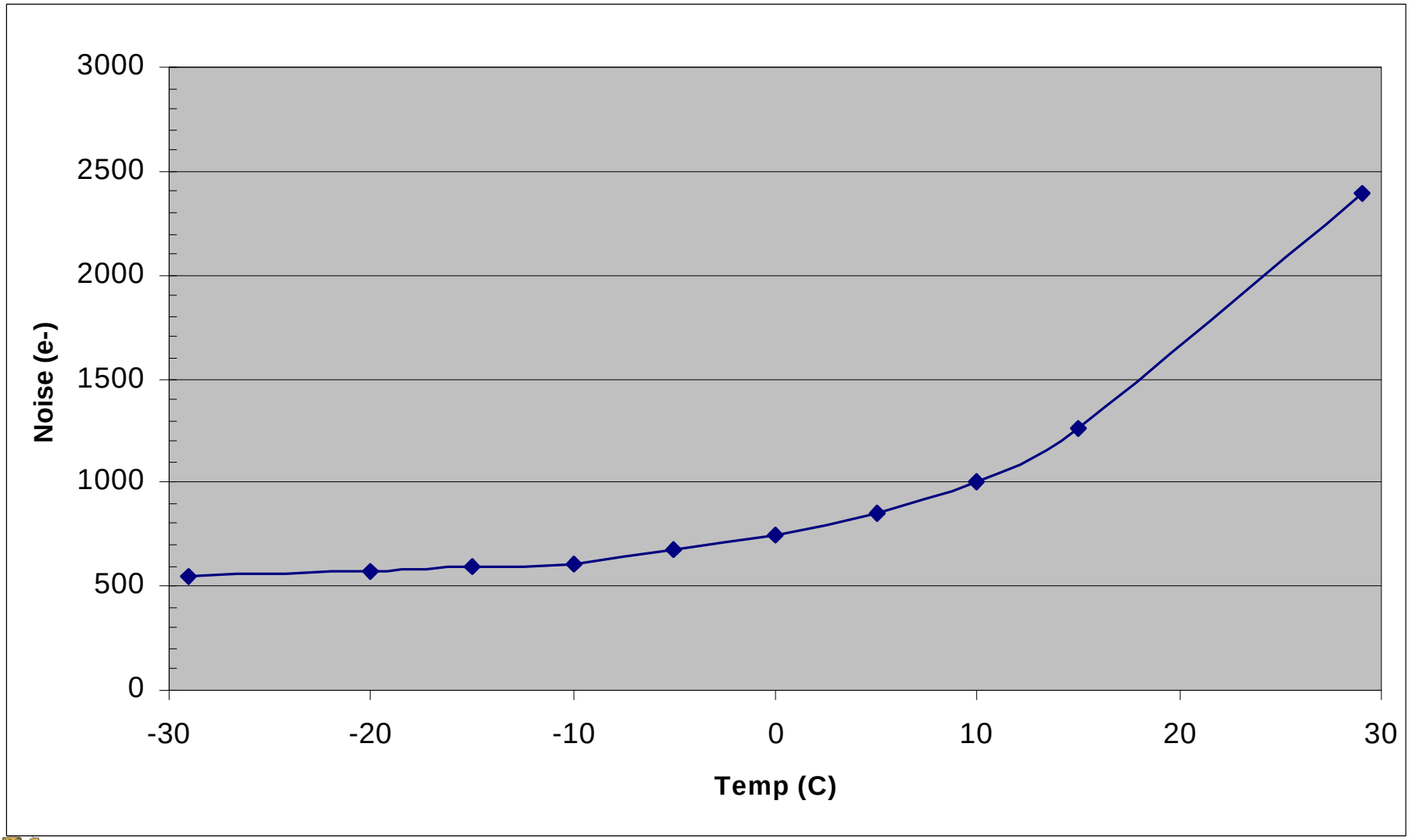
Gain vs. Voltage by temp.



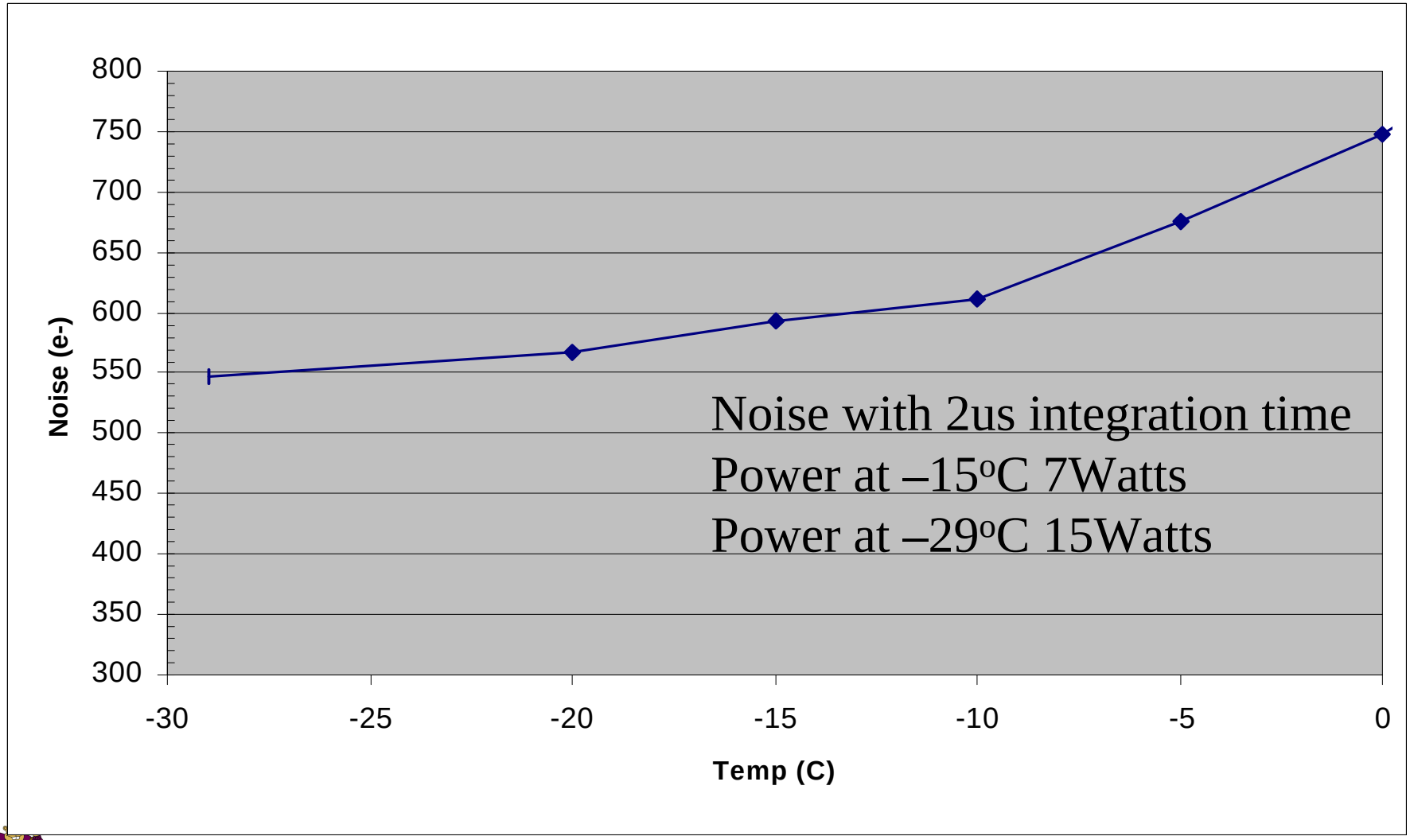
Gain vs. Voltage by temp. (zoomed)



Noise vs. Temp (M=100)



Noise vs. Temp (M=100) (zoomed)



Results

- **APD/Electronics tests show system can be sufficiently quiet. Improvement expected by simply reducing amplifier input capacitance.**
- **Test system achieves ~600e^- noise at M=100 and T=-10^{o}C**
- **Expected light yield for 14.4m modules with 0.8mm fiber 4200 electrons.**