Performance and Radiation Tolerance of the ATLAS CSC On-Chamber Electronics

Kurt Vetter
Brookhaven National Laboratory
http://www.inst.bnl.gov/~vetter/

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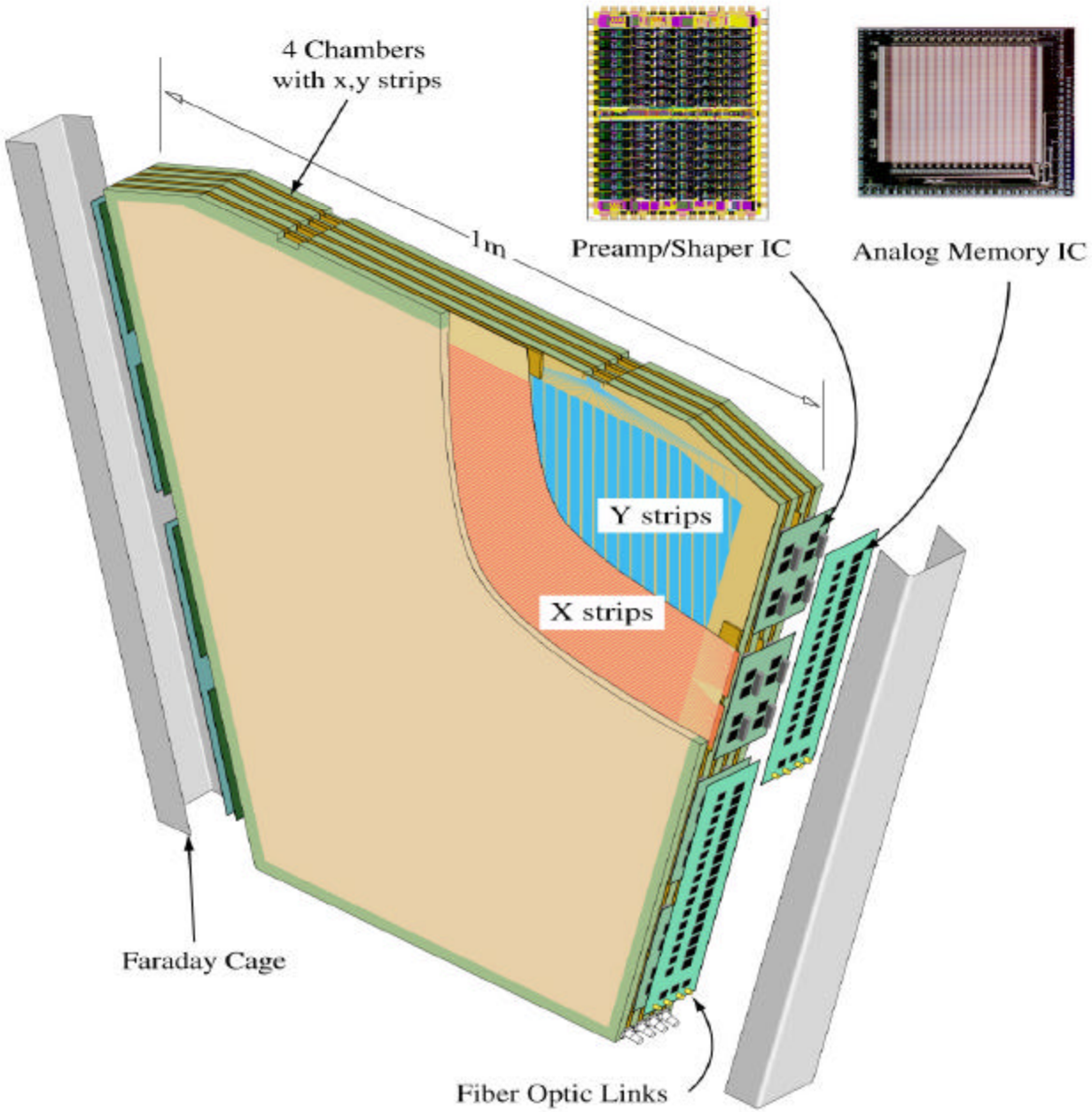
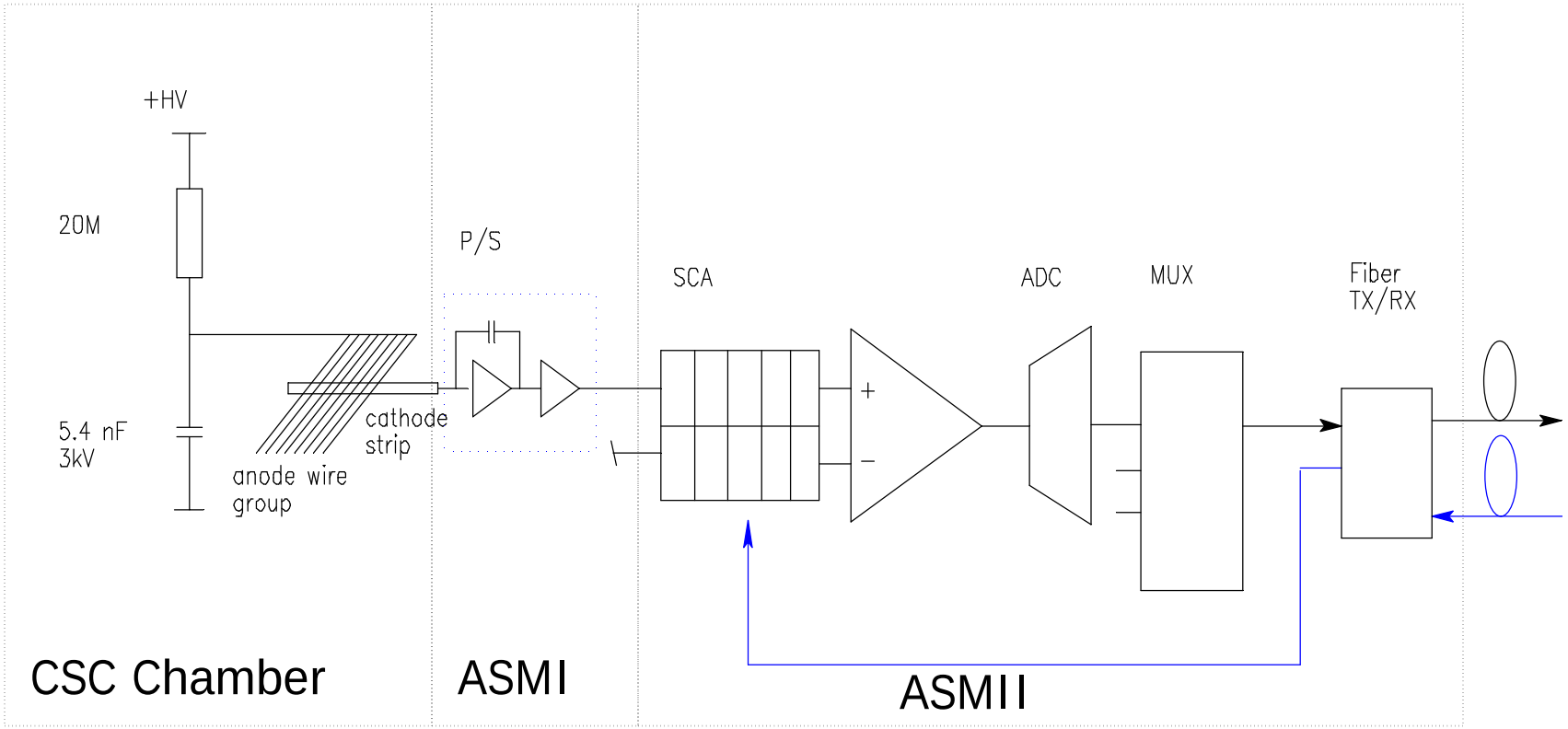
Outline

1. **System Overview**
   - Chamber Configuration
   - Signal Flow
   - Signals and Noise
   - High Rate Performance
   - Pre-Amp/Shaper
   - Sampling
2. **ASMII**
   - Functionality
   - Optical Links
   - Data Transmission
3. **Radiation**
   - Requirements
   - Component Testing
   - Test Plans
4. **Summary**

ATLAS CSC with Electronics



Signal Processing Chain



Signals and Noise

1. Chamber electrode Configuration
   - 4 gas gaps
   - 192 precision strips
     - Readout pitch = 5.547mm
     - Cstrip 20-50pf
   - 48 Transverse strips (no interpolation)

2. Signal Size
   - Muon generates 75 electron-ion pairs (Landau peak)
   - gas gain ~ 10^5
   - 12% of charge is collected by the precision cathode in 100ns
   - signal size ~ 900,000 e^- (144 fC) ? $Q_?$
   - central strip of cluster receives ~ ½ of charge => 72 fC ($Q_{?,cent}$)

3. Noise
   - Electronics noise shouldn't degrade position resolution

$$? _{x,elec} ? \frac{\sqrt{3}\,?d\,?ENC}{Q_?} ? 33?m$$

$ENC ? 0.5fC ? 3100e^? ?$ TOTAL input referred noise

Signals and Noise

4. Signal-to-noise

$$\text{Signal-to-noise (max. strip)} ? \frac{Q_{?,cent}}{ENC} ? \frac{72\,fC}{3100e^{?}} ? 145$$

5. Dynamic Range and Gain (for 98.5% efficiency)

$$\frac{Q_{FS}}{Q_{?}} ? 5$$

$$? \;\; Q_{FS} ? 5?Q_{?} ? 725?ENC ? 360\,fC$$

6. Quantization

$$\frac{Q_{FS}}{2^{Nbits}?\sqrt{12}} ?? \; ENC$$

$$2^{Nbits} ?? \frac{Q_{FS}}{\sqrt{12}\,?ENC} ? 209$$

$$Nbits ?? 7.7$$

$Nbits$? 10 (? $_{Q,quant}$? 20% ENC) or 12 (? $_{Q,quant}$? 5% ENC)

12-bits prefered to accommodate negative lobe, gain and offset variations

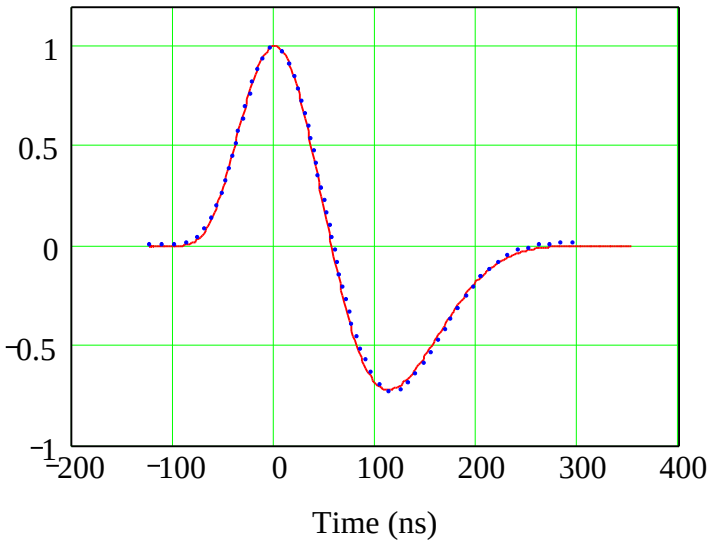
High Rate Performance

- Overall background rate 10^7 Hz per chamber
- 50% charged particles, 50% neutron and ?
- Charged particle background is rejected by
  - timing window around trigger (out of time)
  - or by pattern recognition of non-projective tracks
- Neutrals can deposit high charges:
  - 50% of neutrals above Q_{FS}
  - 1% of neutrals above 6?Q_{FS}
- Neutrals produce short-range electrons usually confined to 1-layer
- But a neutral hit anywhere in chamber induces charge on all strips by anode-cathode crosstalk:

$$Q_{cross} \; ? \; \frac{C_{ac}}{C_{filt}} \; ? Q_{anode} \; ? \; 10^{?4} Q_{anode}$$

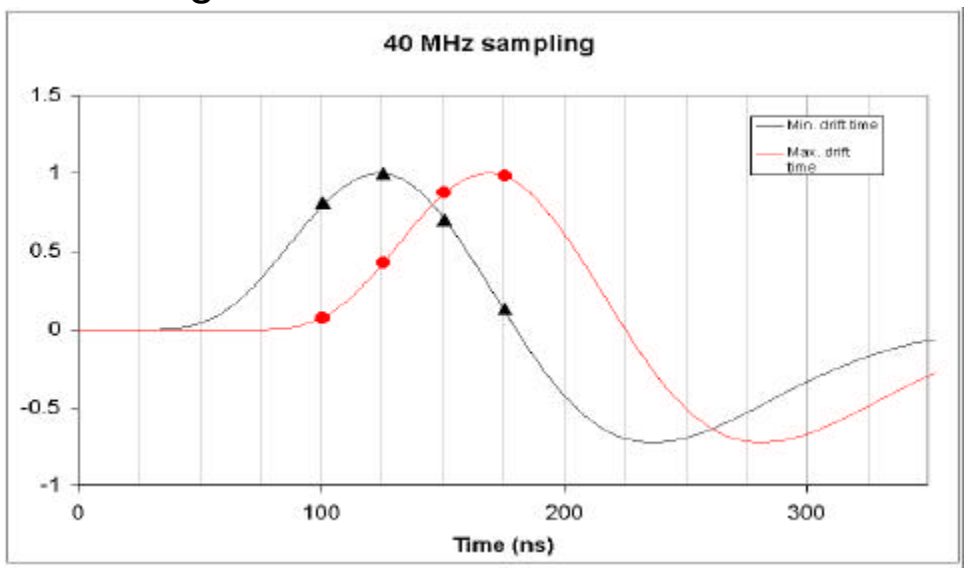
Pre-Amp Shaper

- Optimal pulse shaping is a compromise between noise, which degrades position resolution, and pileup which contributes to inefficiency.
- Bipolar pulse preferred in high-rate environment.
- From Monte Carlo study, peaking time should be ~ 100 ns and FW1%M < 430 ns
- Bipolar 7^{th}-order shaper using complex poles gives same return to baseline as 12^{th}-order CR^2-RC^n configuration
- Pulse Waveform

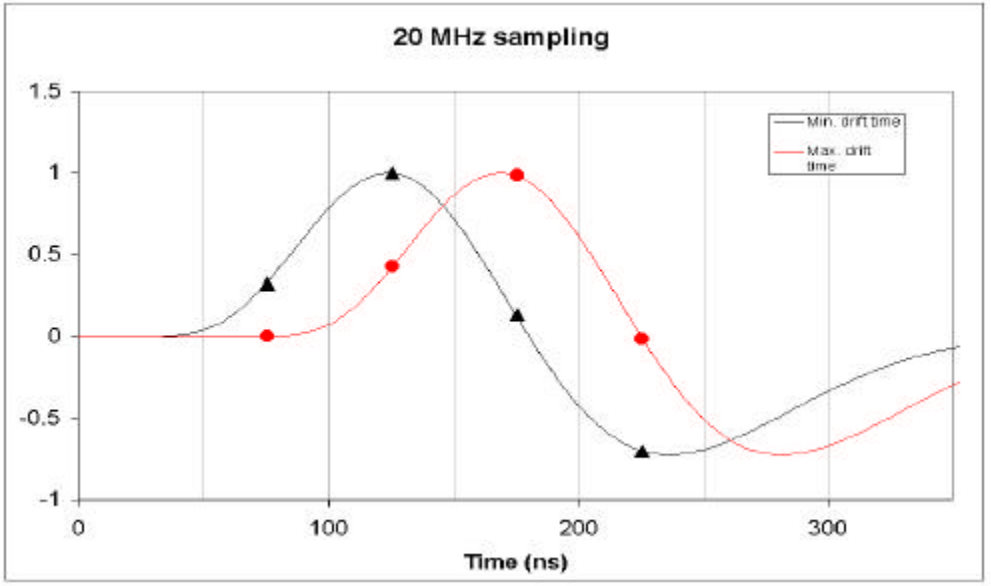


Sampling Rate

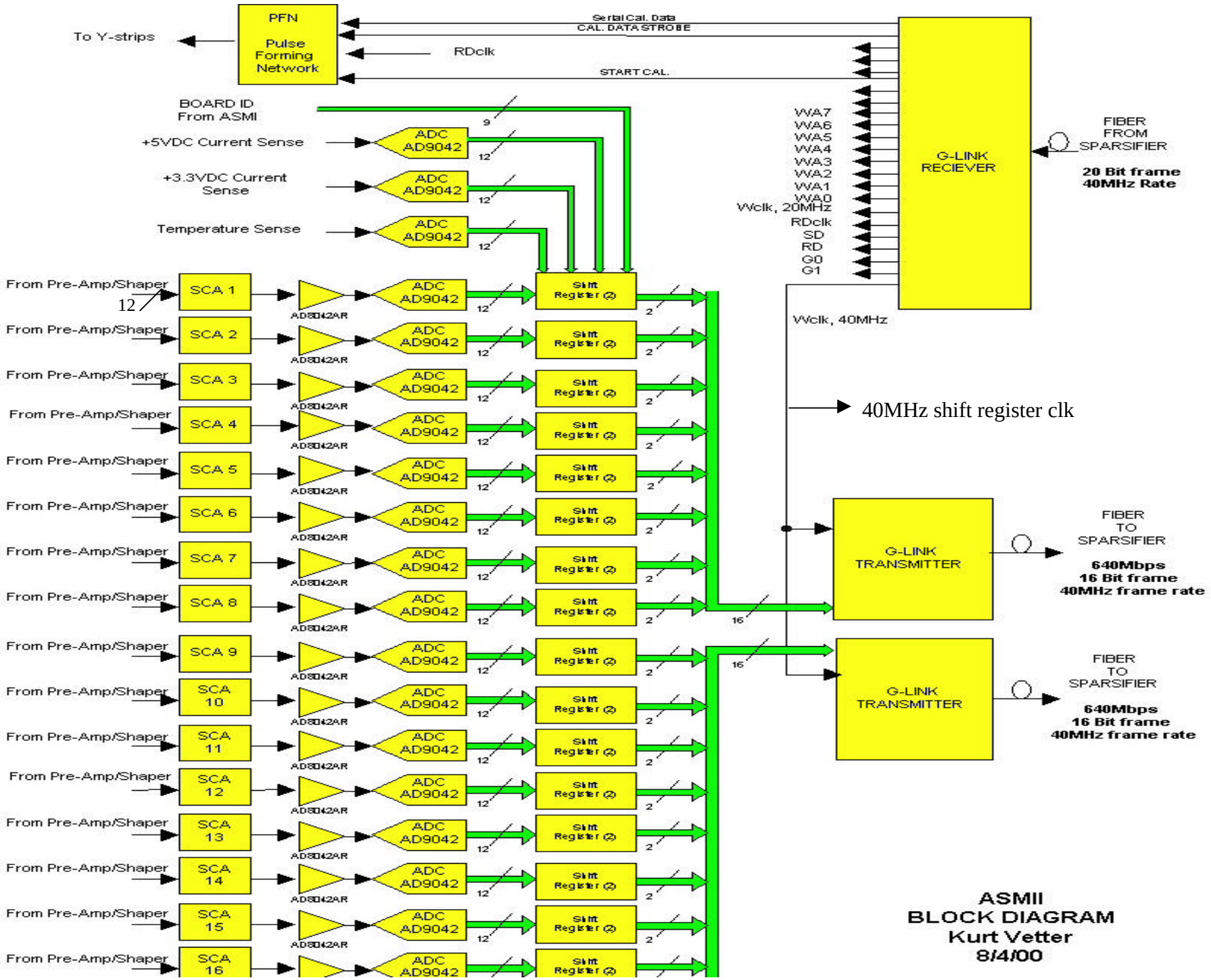
- With 40 MHz sampling and only 4 samples, we can't always get the peak and both neighbors



- 20 MHz sampling/4 samples gives a wider window and doesn't degrade the resolution or efficiency

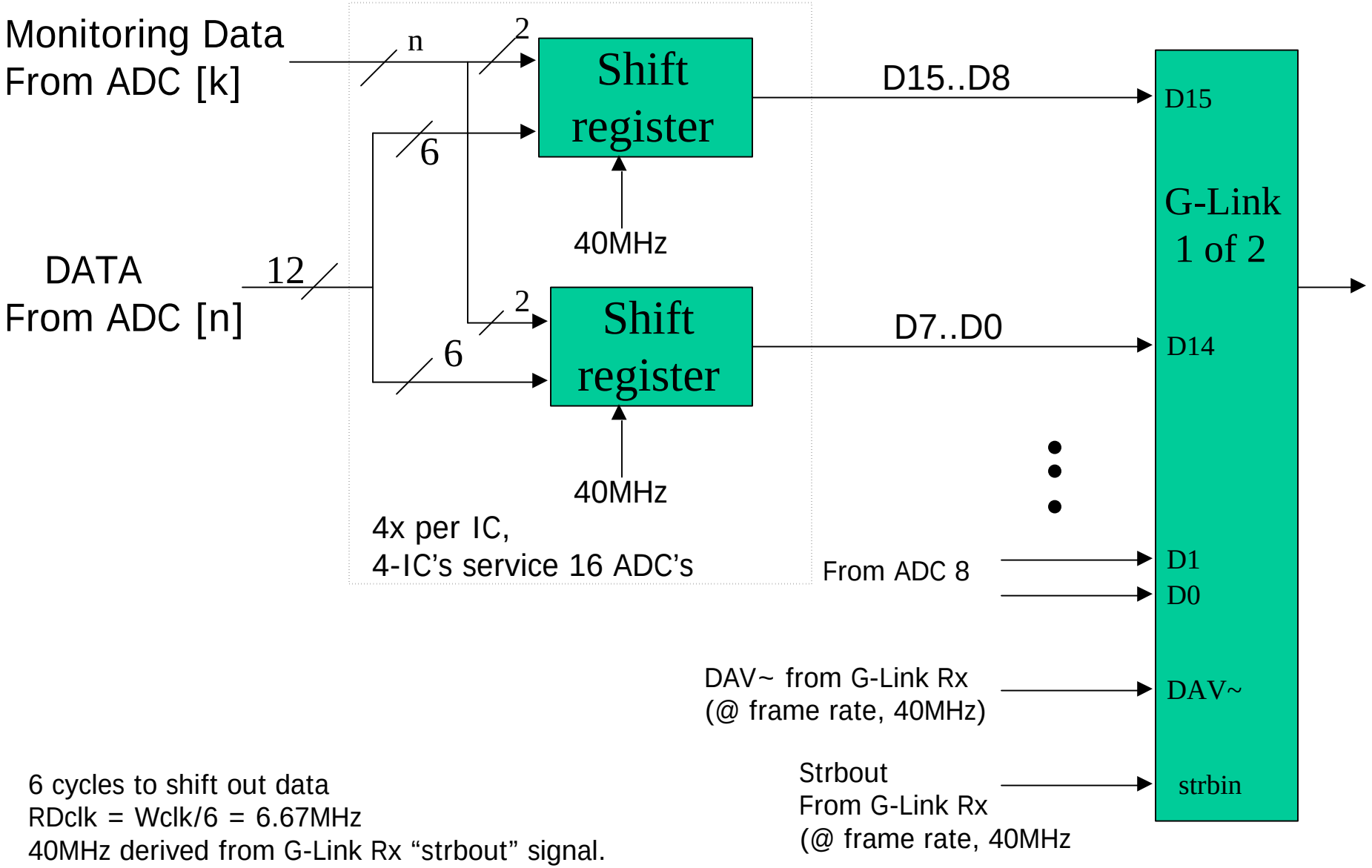


ASMII Block Diagram



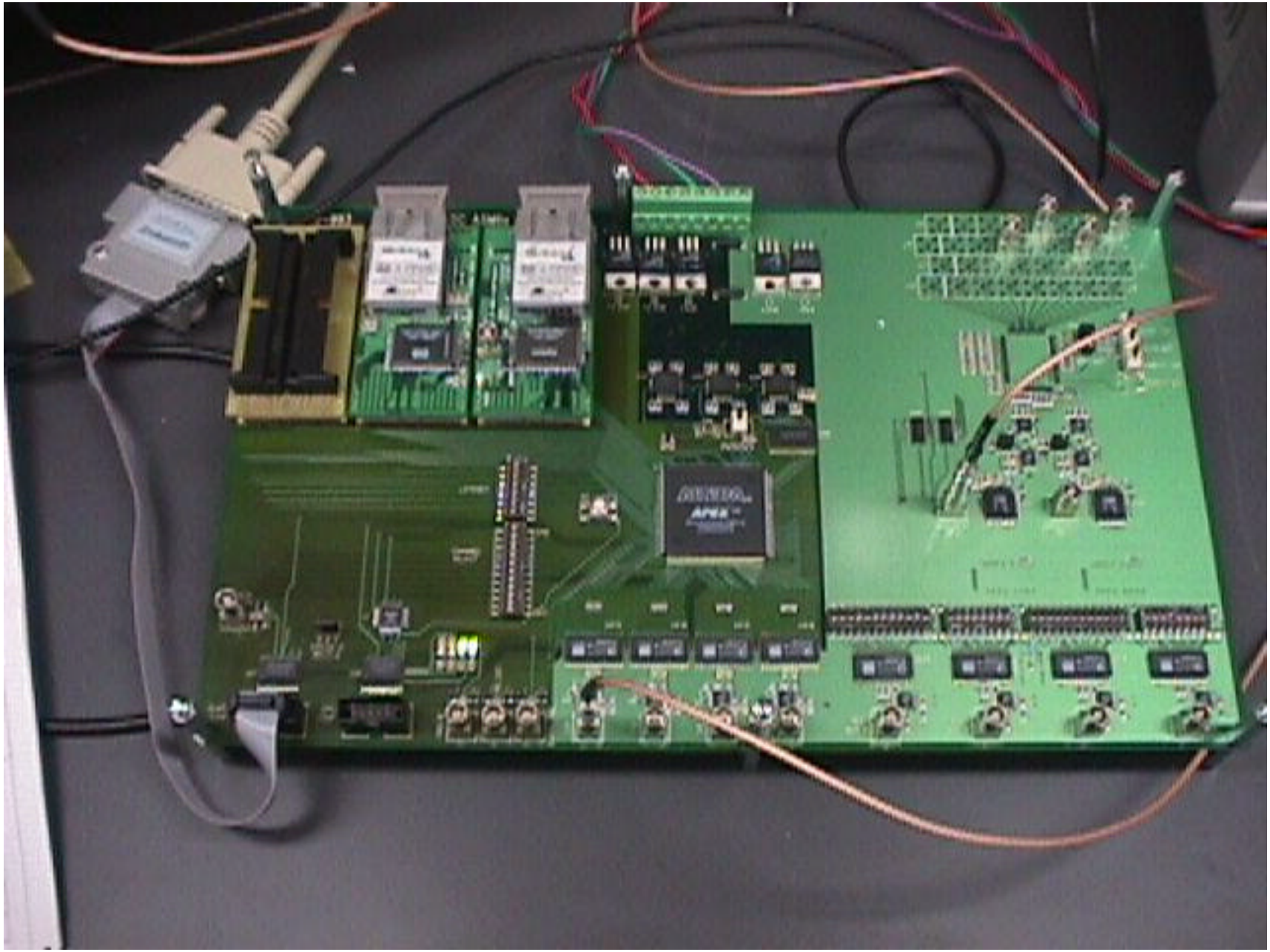
Readout Implementation

2-Bits per ADC, Single Frame Mode
(1 of 2 transmitter links shown)

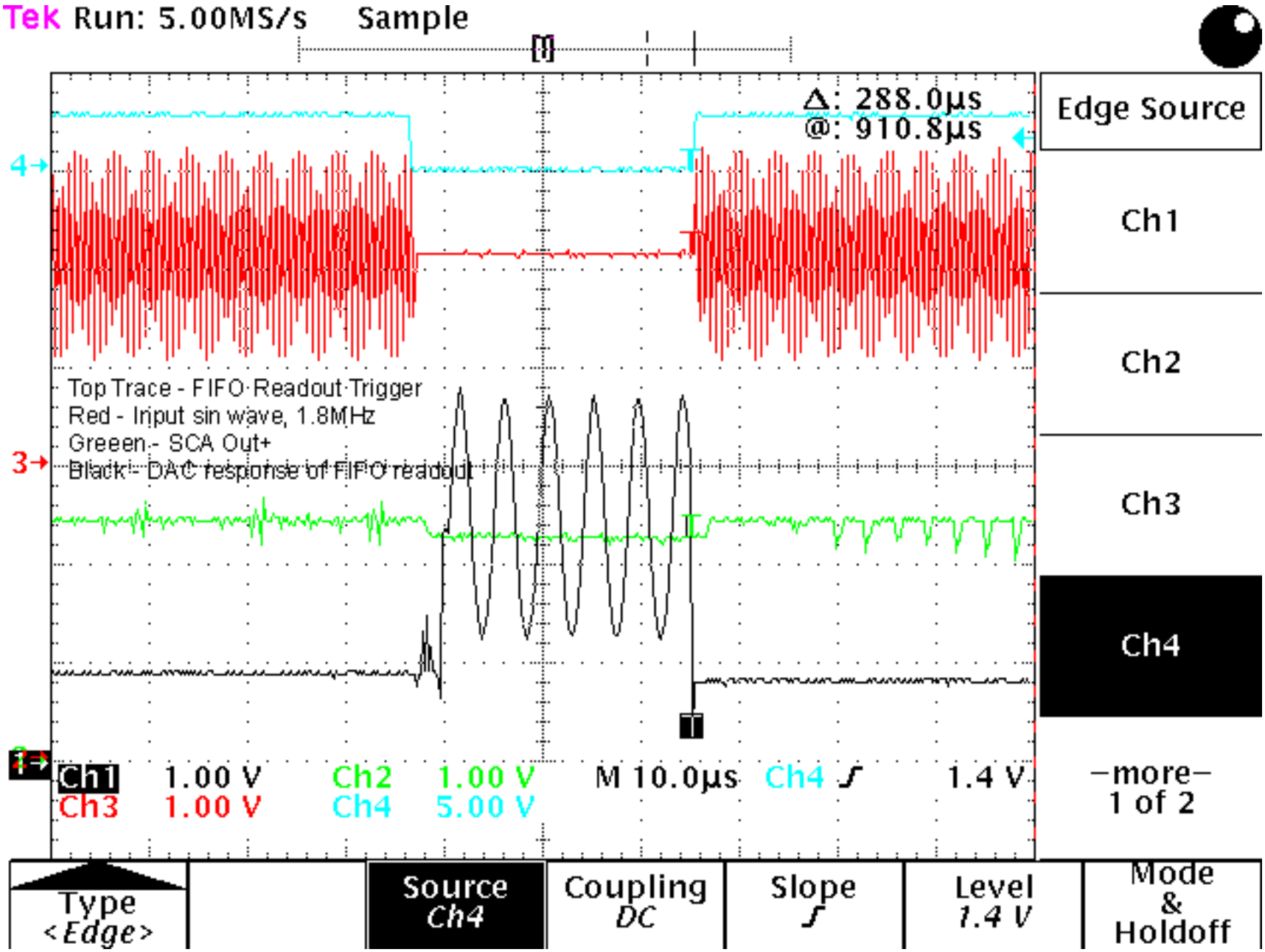


6 cycles to shift out data
RDclk = Wclk/6 = 6.67MHz
40MHz derived from G-Link Rx "strbout" signal.
Pipeline cannot accommodate higher readout rates.

ASMIIa Prototype



SCA Muon Mode Response



Optical Data and Control Links

- Two G-Link Transmitters
  - Transmit raw data quantized to 12-bits from SCA
  - 16 bit data field
  - 40MHz frame rate
- One G-Link Receiver
  - Provides SCA control
  - Provides Calibration data and control
  - 20 bit data field
  - 40MHz frame rate
  - 14 SCA control bits
  - Provides Frame Clock for G-Link Transmitters
- ADC Outputs Serialized into G-Link data field
  - Two serial lines per ADC, 6-bits deep
  - 40MHz serial data rate
  - 8 ADC’s serialized into one G-Link Tx

Data Transmission

- Buffer data for L1 latency in SCA (~2.5us, 50-cells at 20MHz)
- Transmit 4-time samples within L1 trigger rate of 100KHz
  - Must transmit 4-samples in less than 10us
  - One time sample corresponds to reading 12 SCA channels
  - 15 SCA READ CLK cycles required for one time sample
  - 4 time samples corresponds to 60 SCA READ CLK cycles
  - SCA READ CLK >= 6.67MHz (4-samples = 9us)
- Transmit On-Chamber current and temperature
  - Digitize current sense and temperature
  - Data fused into main data stream as serial bit stream
  - Readout controlled by sparsifier
- Transmit board identification (board ID).
  - Data fused into main data stream as serial bit stream.
  - ID set by on-board switches or links.

CSC Radiation Requirements and Tolerance

- REQUIREMENTS
  - Ionizing dose of 4.4krad/yr
  - Neutron flux of 7x10^12 n/cm^2/yr
  - Converts to 1.8x10^12 1-MeV equivilant n/cm^2/yr

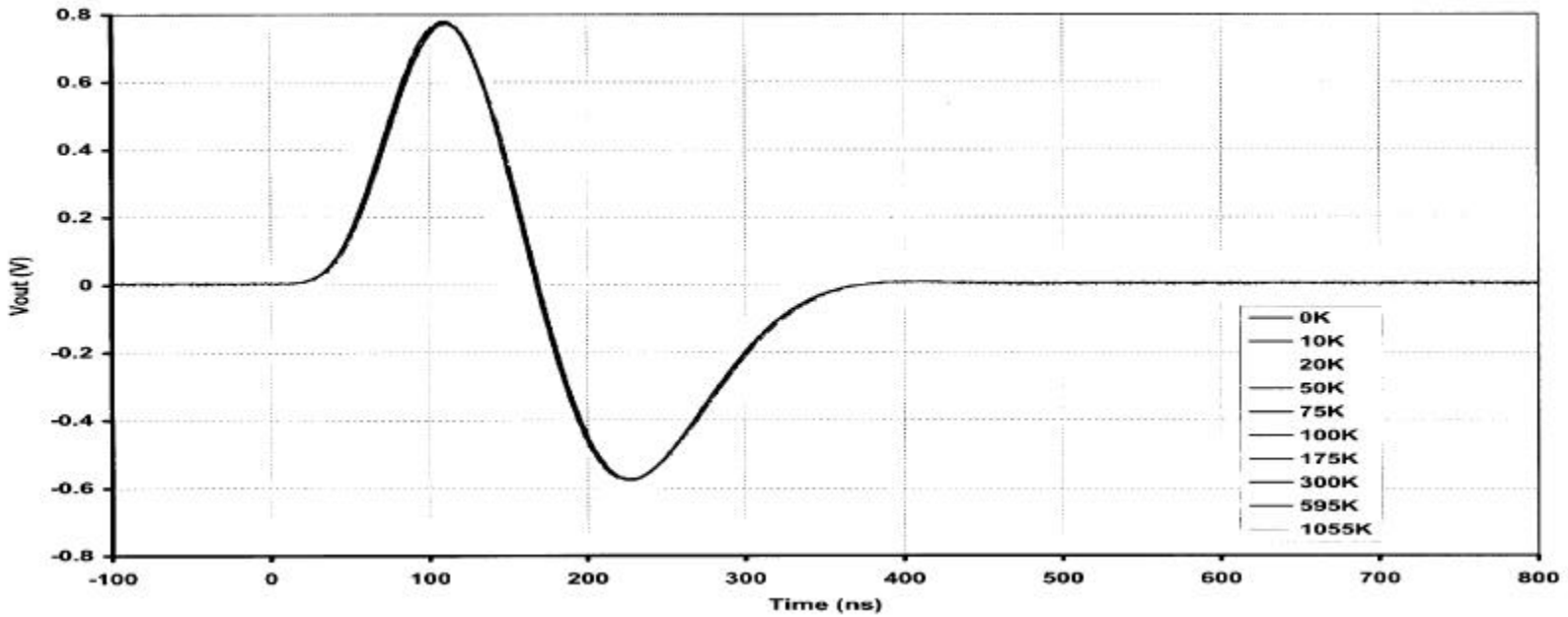
- Radiation Tolerance Criteria for SEU
  - In-efficiency = 0.1%
  - In-efficiency per G-Link = 0.78x10^-6
  - Link down time = 1ms
  - # of chips per link = 2
  - Data dropped after recovery = 8-triggers
  - Link down probability per SEU = 100%
  - Acceptable SEU rate = 1 SEU per 43 minutes per chip

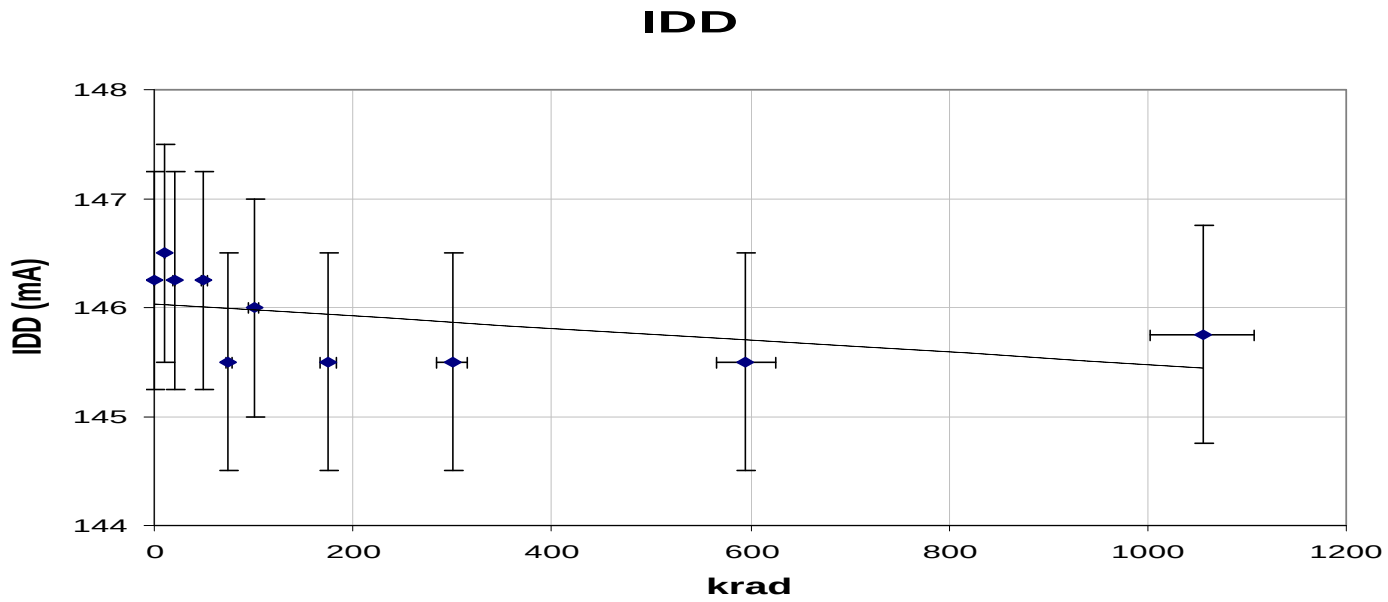
On-Chamber Components

COMPONENT	COMMENTS
HDMP 1022	Extensive testing has been performed. Plan to conduct our own test.
HDMP 1024	Developing test hardware at UCI
SCA	Testing to be completed by LAr.
AD9042 (ADC)	Used on LAr FEB. Extensive testing performed by Denes at Princeton.
AD8042 (op-amp)	Used on LAr FEB. Ionizing survival test done by Lar.
Level Translators MC10H116	No testing done to date.
DAC?	Trying to develop alternate solution for 0.5% required calibration pulse accuracy.
74ALS166	COTS Qualification
Pre-Amp/Shaper	Passed ionizing test.
ASMI/ASMII	Test final ASMII under Sparsifier control. *Does anything unexpected happen?*

Preamp Shaper Irradiation Results

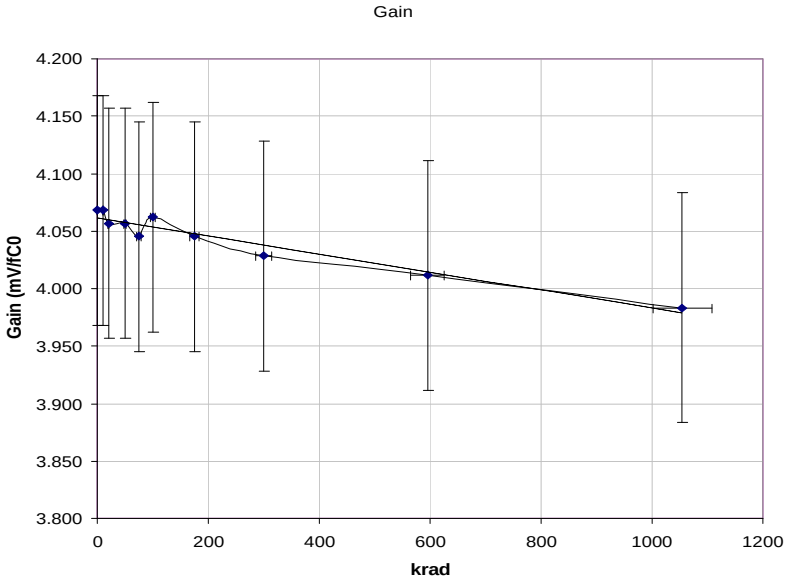
0.5um CMOS HP

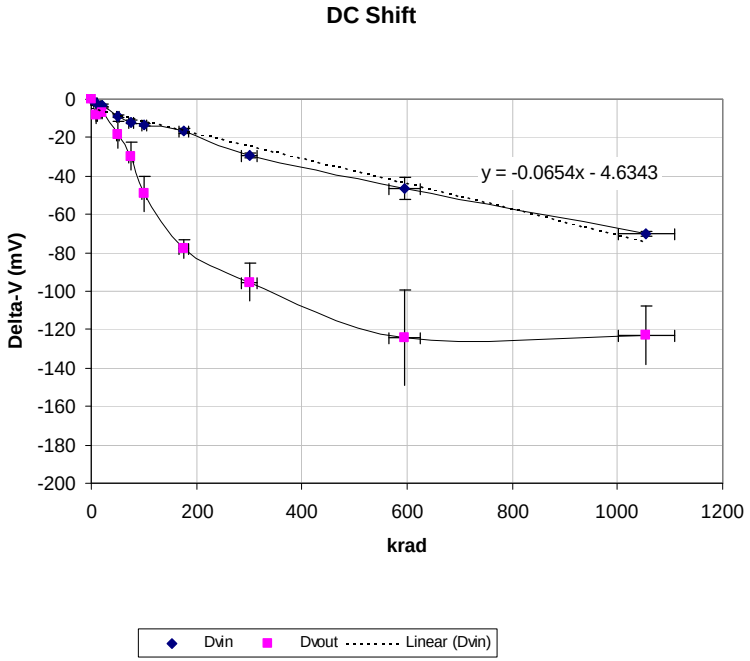


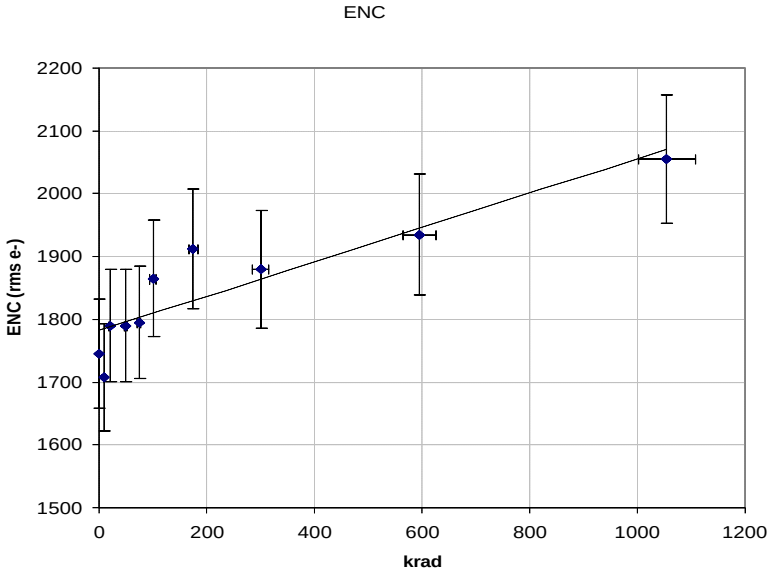


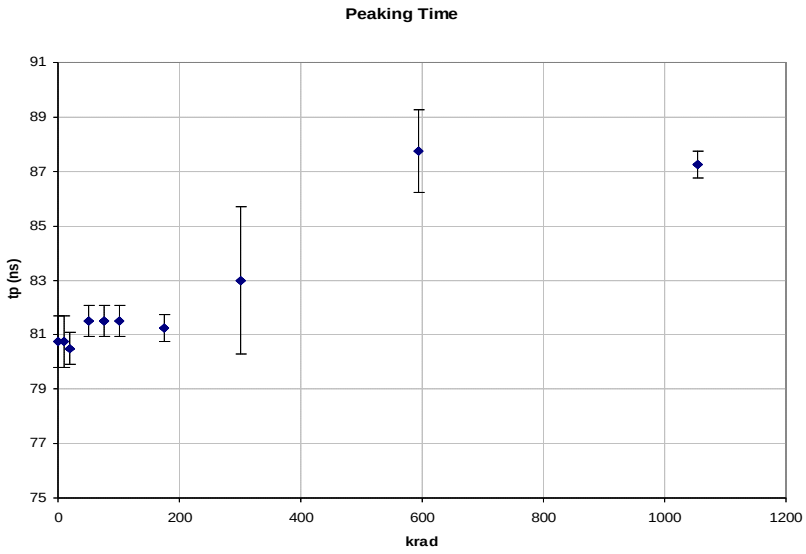
Preamp/Shaper Irradiation Results

0.5um CMOS HP

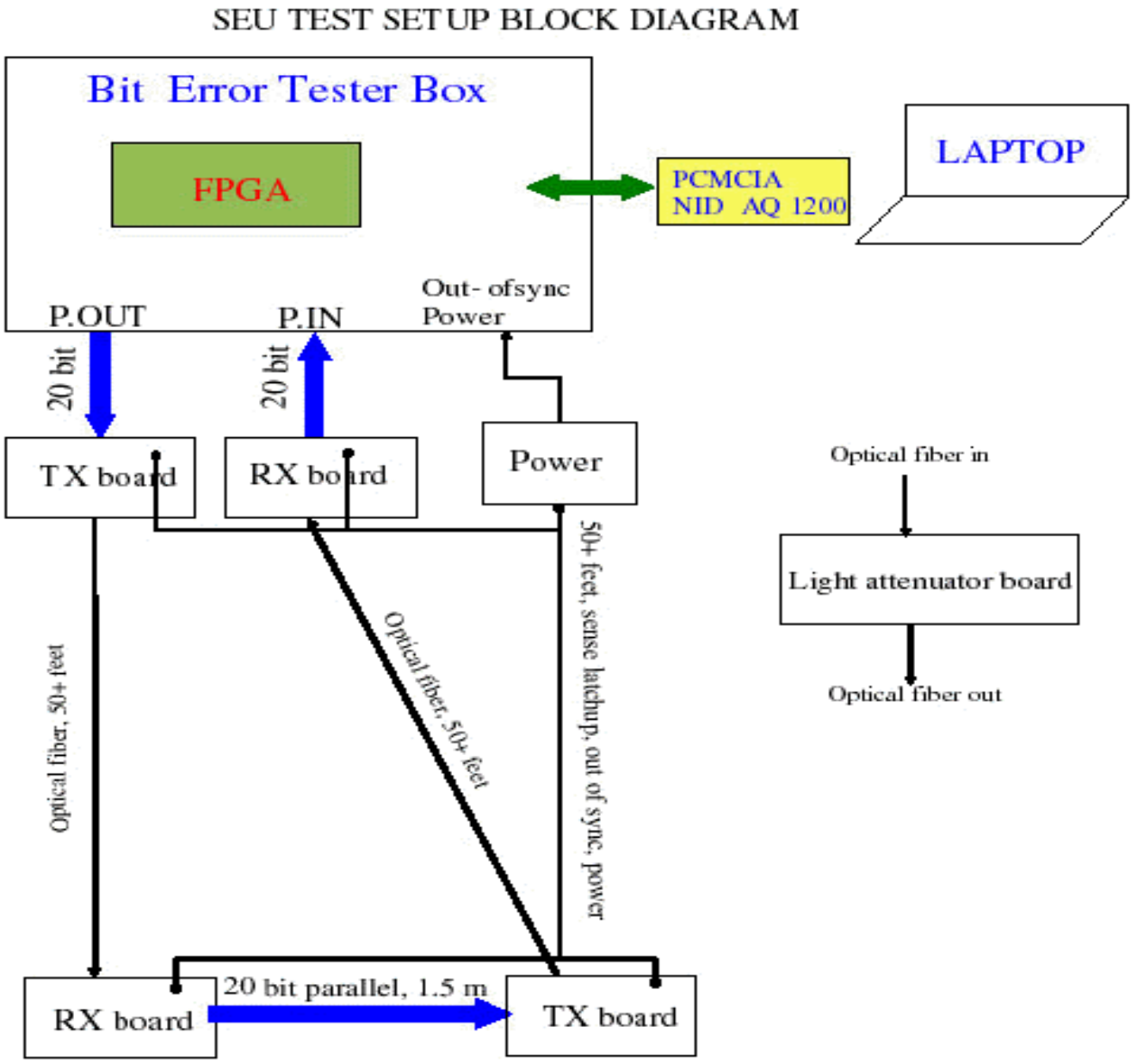








G-Link Receiver Test



Y. Li 8/10/2000

Summary and the Road Ahead

1. Minimize SEU problem by moving SCA control logic off-chamber
2. Developed 24-channel prototype ASMII to verify SCA Muon Mode
3. Beam test data verified performance of Preamp/Shaper and 20MHz sampling
4. Developed VME DAQ board to support beam test of front end electronics
5. Preamp/Shaper passed Ionizing radiation test to 1Mrad
6. G-Link Receiver and Transmitter boards have been built
7. Characterize G-Link Receiver for Ionizing and Neutron radiation by Dec. 2000
8. More detailed testing of SCA Muon mode required
9. Plan to develop full 192-channel ASMII within next few months
10. Beam test complete on-chamber electronics prototypes in spring of 2001
11. Evaluate cooling approach
12. Coordinate radiation test and qualification efforts with LAr and UCI