Study of the Use of Micro-twisted Pair Cable Links in the CMS Pixel System

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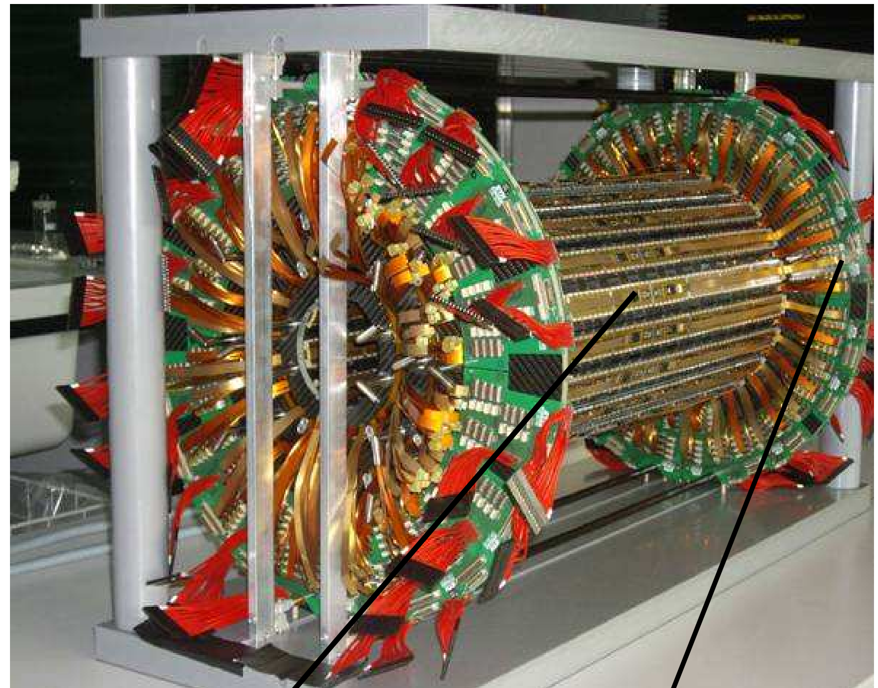
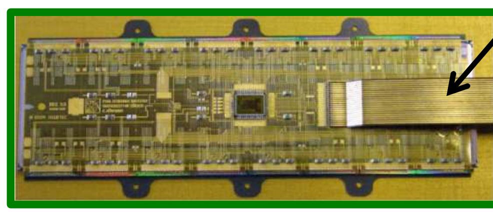
October 28, 2009
CMS Upgrade Workshop
Fermilab

Existing Use of Kapton Cables

- Connection to and from modules
- Located in the tracking volume.
- 21 Parallel lines per cable.
- Length limitation of 40cm.
- Can only bend in one direction – makes installation difficult.

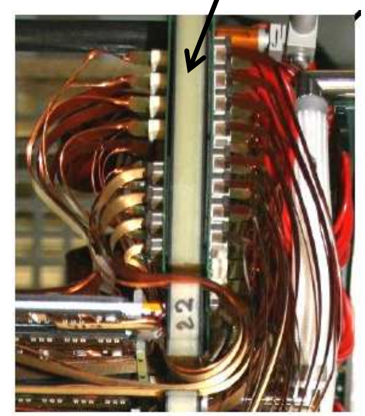
CMS pixel detector barrel





Module

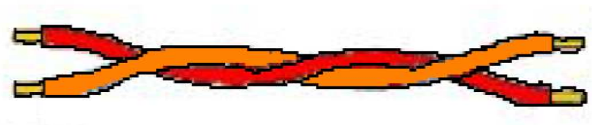
Kapton cable

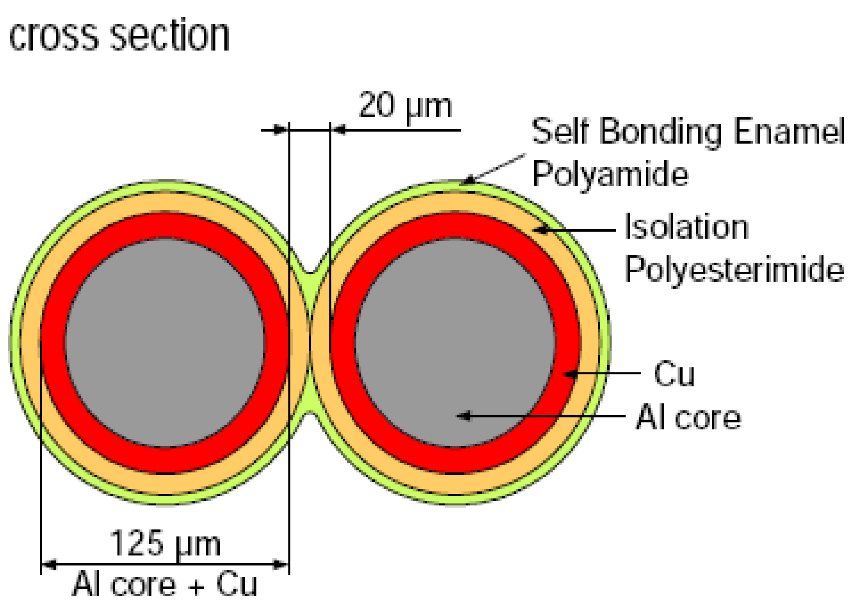


end-ring

What are Micro-twisted Pair Cables?

- 2x125µm of enameled Copper Cladded Aluminum (CCA) wires





From Elektrisola (CH)

Justifications for Replacing Kapton Cables

Reduce material budget – two ways

- In the cables themselves
- With longer cables can place connectors and optical links further out from the tracking region

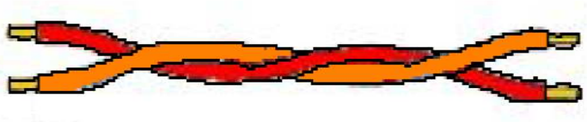
Kapton Cable

Easier installation

- More freedom in bending cables in all directions.

Cost

- Kapton cables are expensive.



Micro-Twisted pair

Advantages of Various Possible New Systems

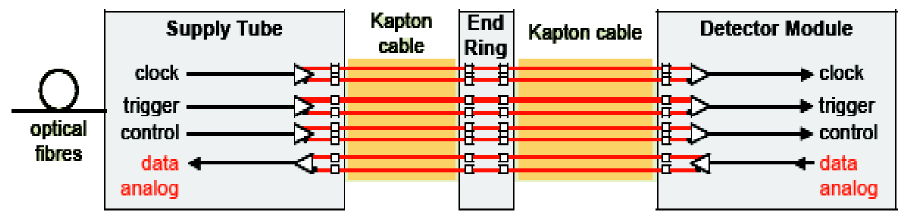
Material reduction

- Eliminate end ring connector
- Place optical links further out
- Reduction in cable itself – Two possibilities
  - Use same number of lines (Phase 1)
  - Replace 21 parallel lines with one or two digital pairs (shown) (Phase 2)

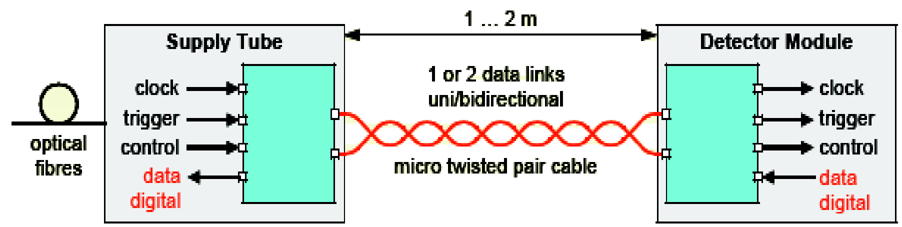
Power reduction

- Use a digital readout

•Existing System in CMS Pixel Detector



•New Concept



Multiline Micro-twisted Cable Bundling Machine

Cable sorting

Twist mechanics

Single Cables & Twisted pair cables on spools

This Study

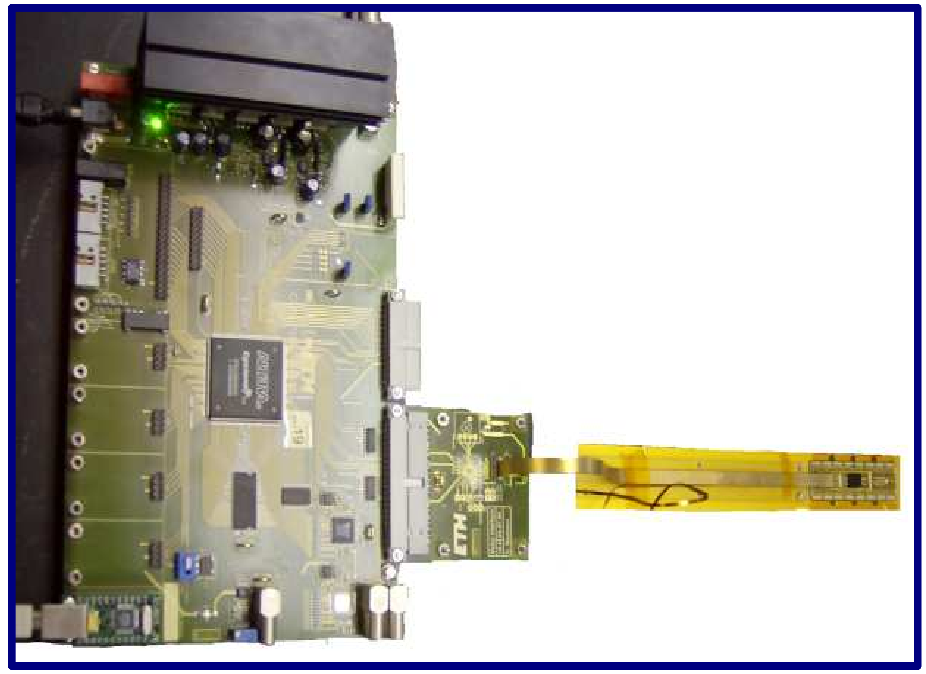
- Performance of the micro-twisted pair cables using the existing analog readout.

- Main aspects studied
  - Transmission of the analog address levels
  - Attenuation of the analog pulse height signal
  - Verification of performance – standard pixel system tests

Experimental Setup

- All tests were done using the standard PSI test board and software.

- Signals from one module were studied. This requires the standard "adapter" between the test board and the cable links.

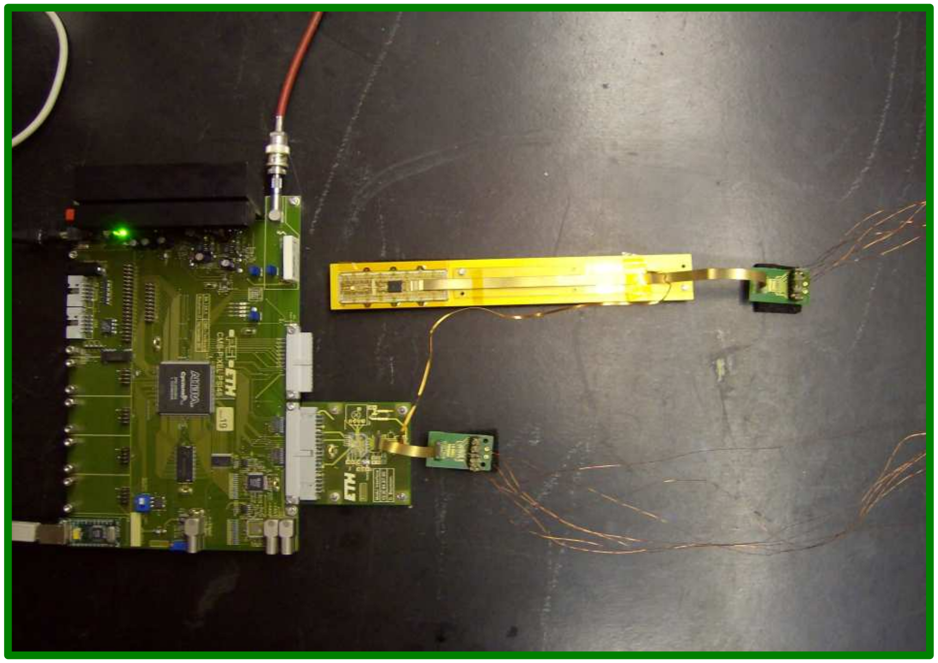


Standard Connection
Used only a short Kapton cable
No μ-twisted pair cable

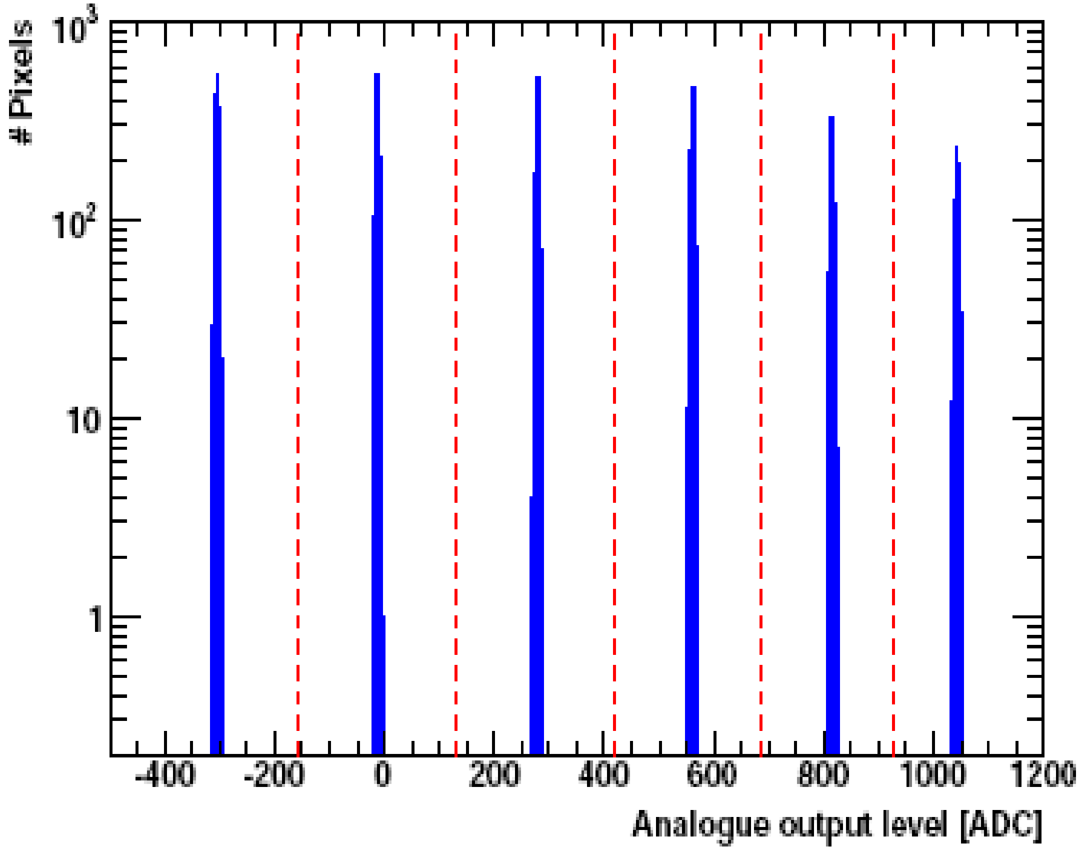
Experimental Setup, continued

- The micro-twisted pair cables were added to the usual setup, inserted just before the connection to the adapter board

- Different lengths of micro-twisted pair cable were tested.



Analog Address Levels



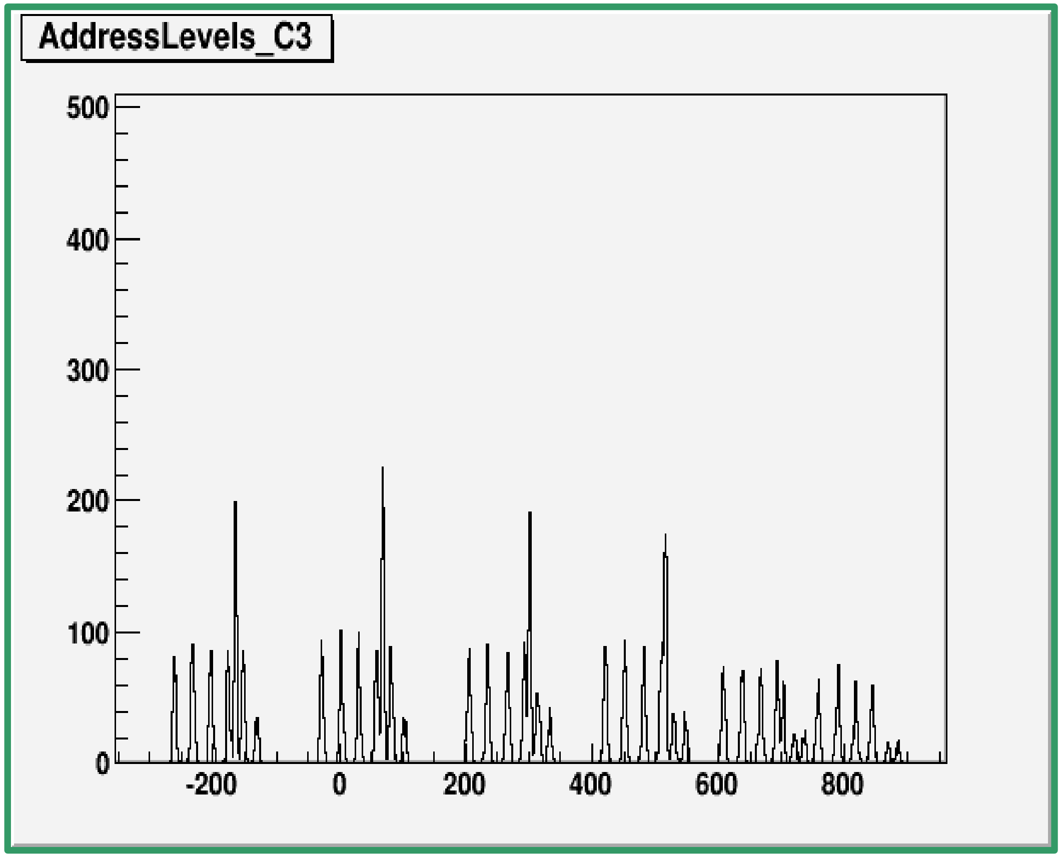
✓Each address clock cycle can take one of six different levels.

✓ In the existing system, the address level widths are small and the levels are well differentiated.

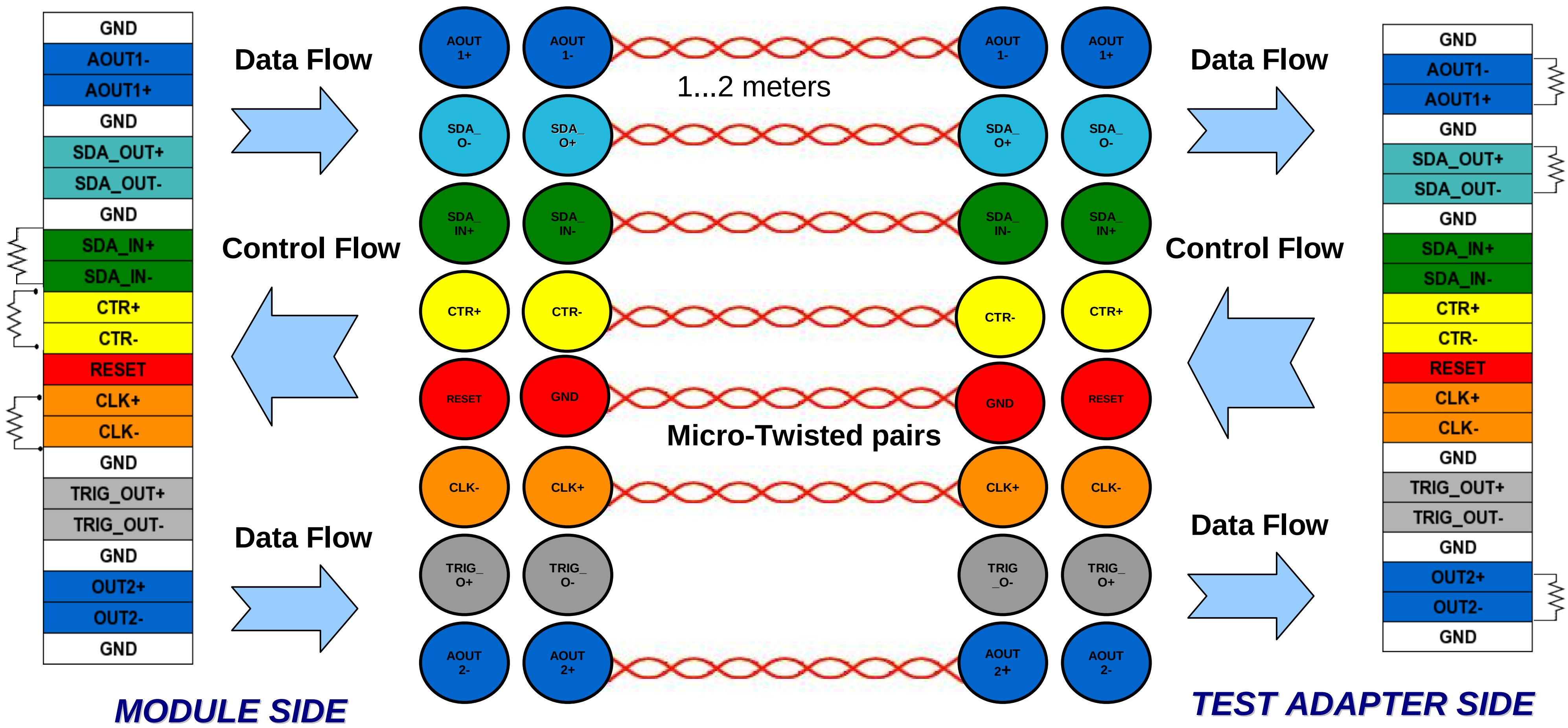
Address Level Problem

➢ Initial tests with μ-twisted cables showed deteriorated distributions. Separation between levels were smaller while widths were larger making level differentiation much more difficult.

➢ This problem will be shown to be solved by adjusting the termination resistors on the data lines.



Cable Lines and Termination Resistors

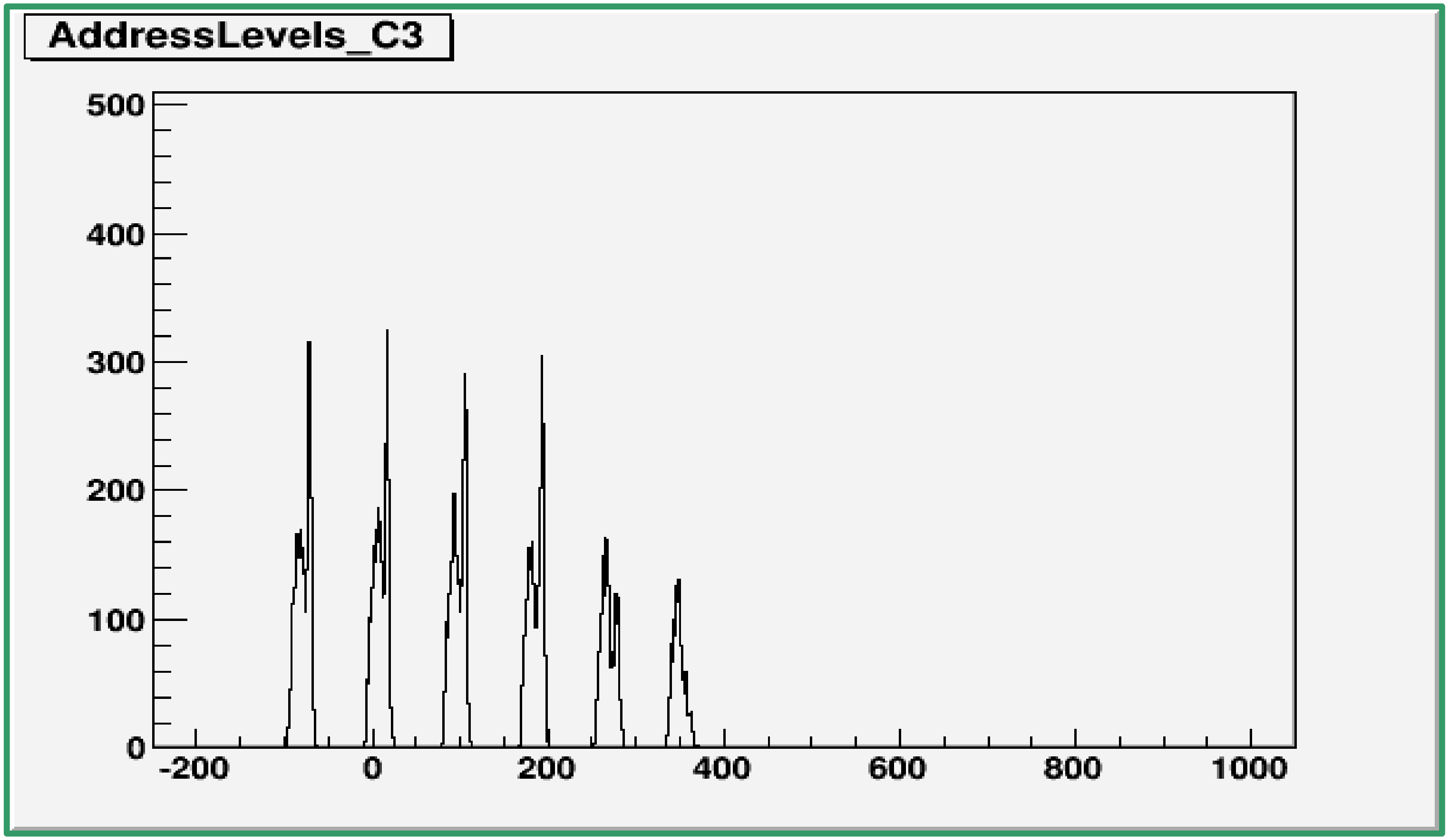


- Three differential data pairs terminated at adapter end (AOUT1, AOUT2, SDA_OUT).
- Three differential control pairs terminated at module end (CTR, CLK, SDA_IN).
- One reset pair.
- Trigger lines not connected.

Termination Resistors

- Data Lines
  - Resistor values were varied but were always set equal to each other on the three data pairs.
- Control Lines
  - Satisfactory performance was achieved by always using 180 Ω resistors.

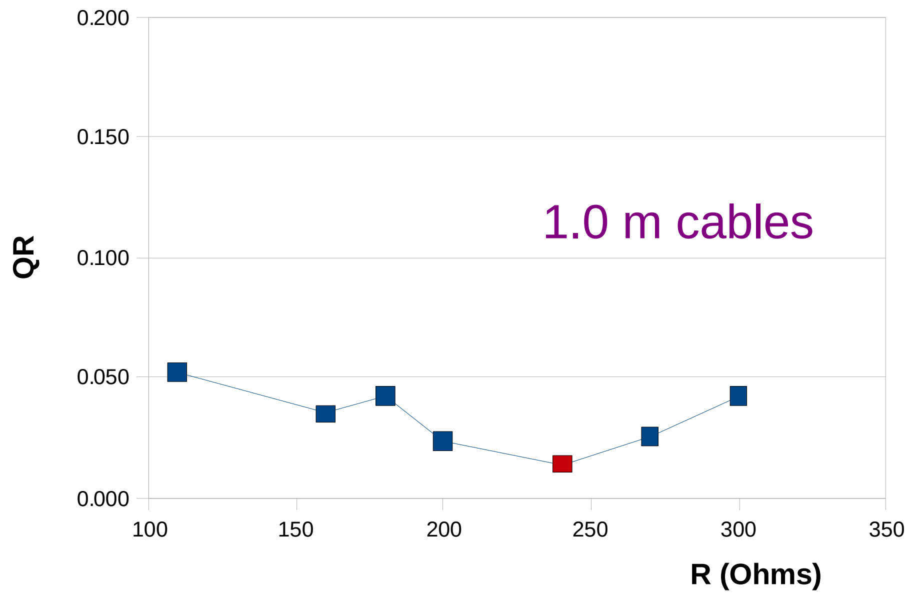
Quality ratio

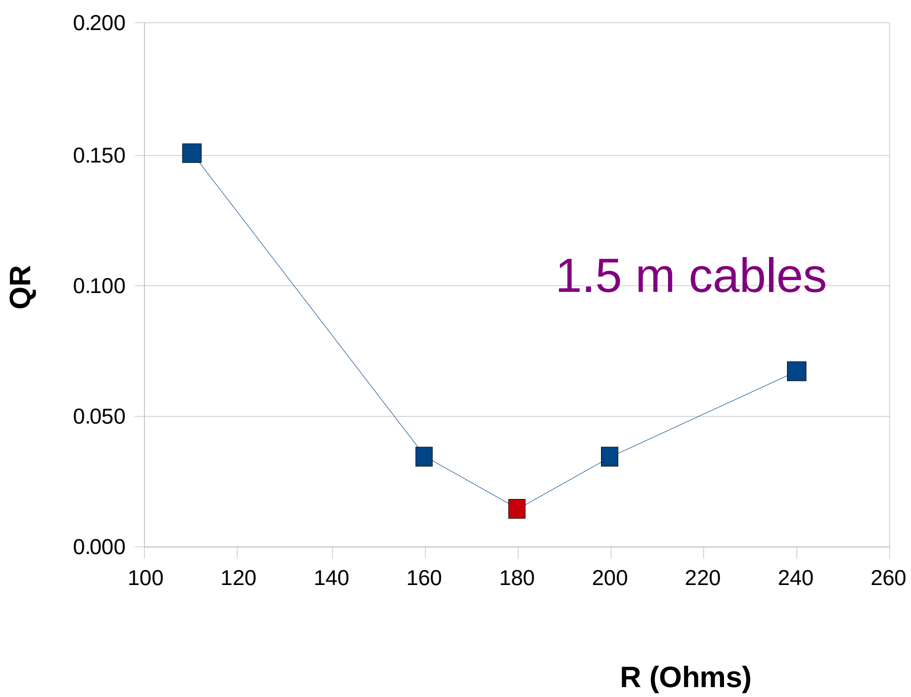


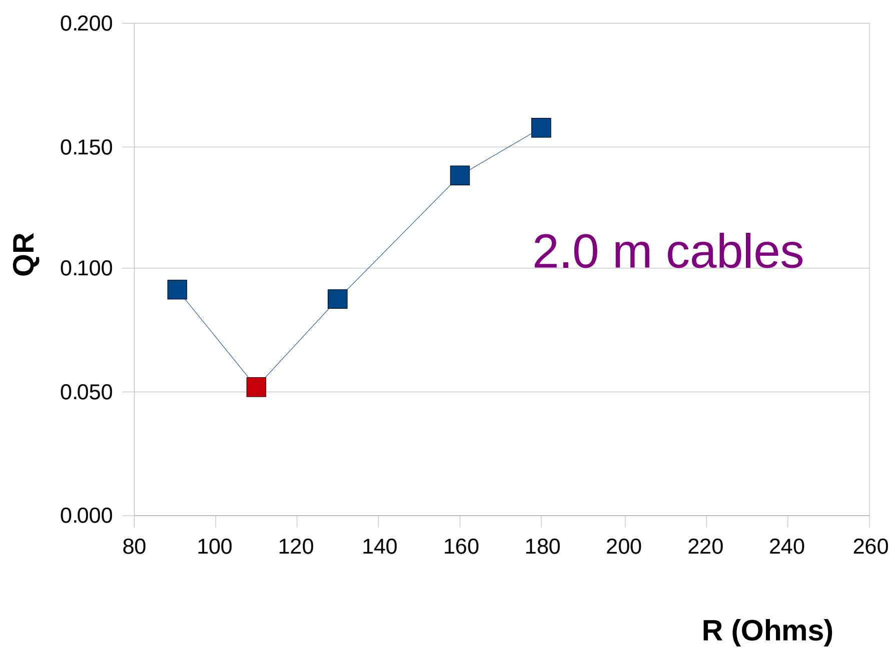
- To optimize performance, we defined a quality ratio, QR, as follows.
- QR = RMS / SEPARATION
- RMS is the rms for an address level averaged over all address levels.
- SEPARATION is the average separation between adjacent address levels.
- We want QR to be as small as possible.

Quality Ratio vs Termination Resistance

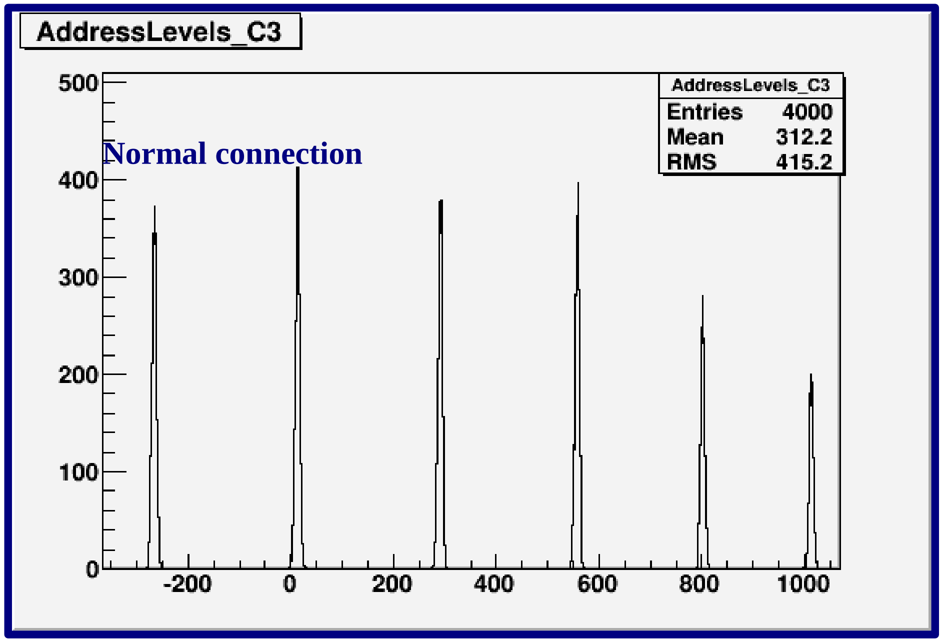
The optimum resistance was found to be different for each cable length.







At optimum resistance, level differentiation is very good.



R_{TERM}

Mod-side

SDA_IN: 180Ω

CTR: 180Ω

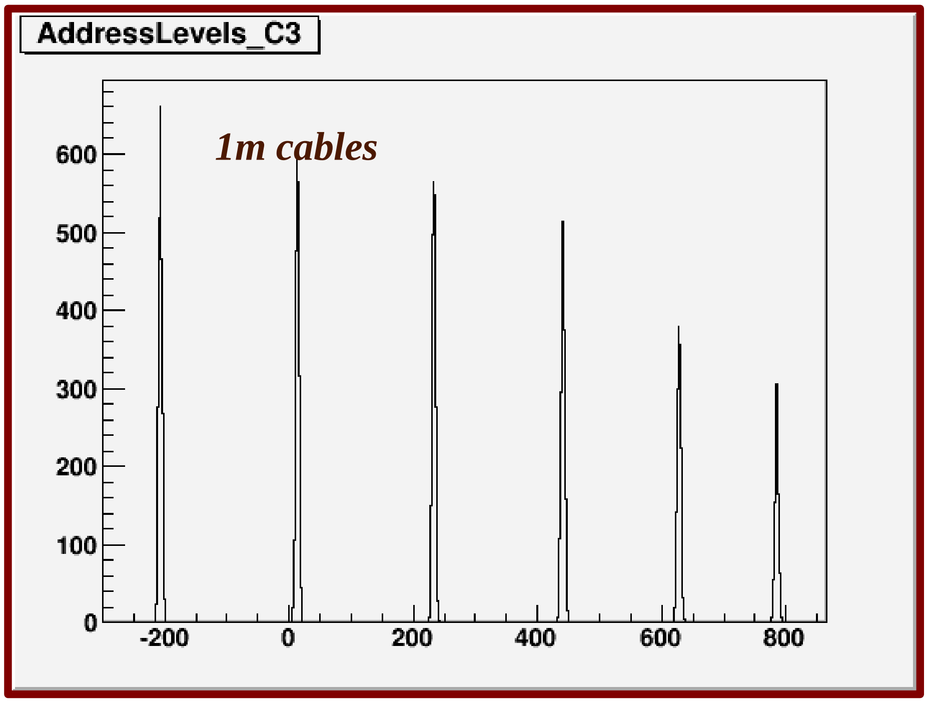
CLK: 180Ω

Adapter-side

SDA_O: 240Ω

AOUT1: 240Ω

AOUT2 : 240Ω



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Adapter-side

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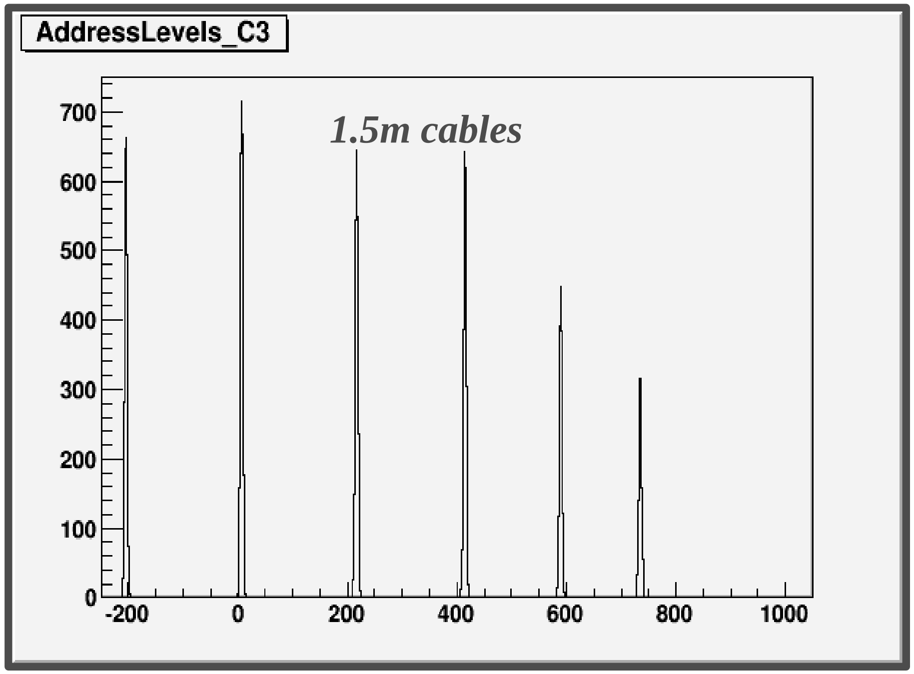


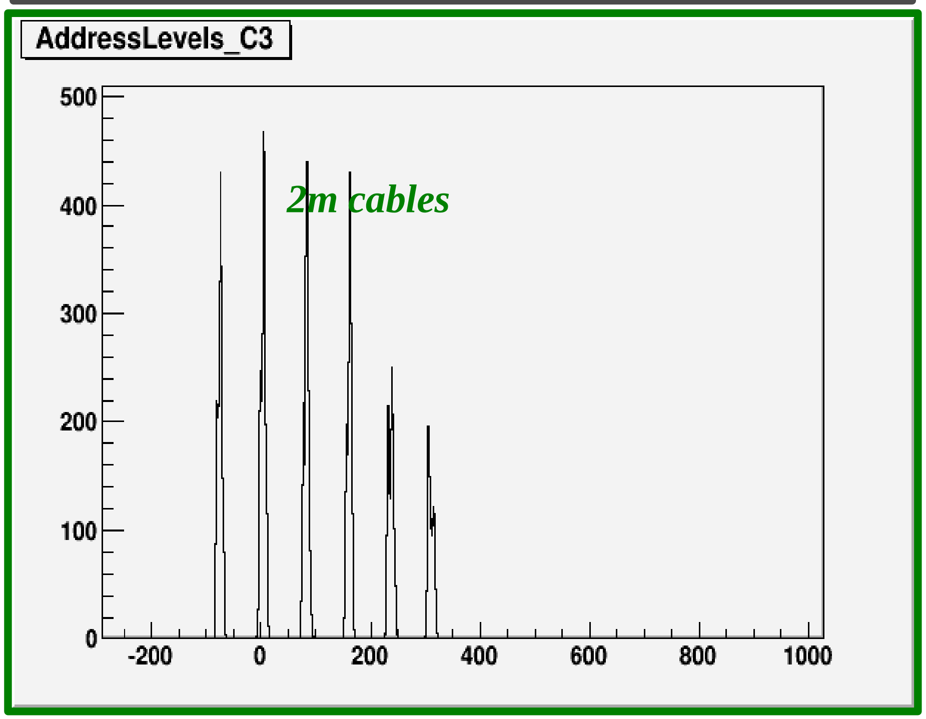
R_{TERM}

Mod-side

SDA_IN: 180Ω
CTR: 180Ω
CLK: 180Ω

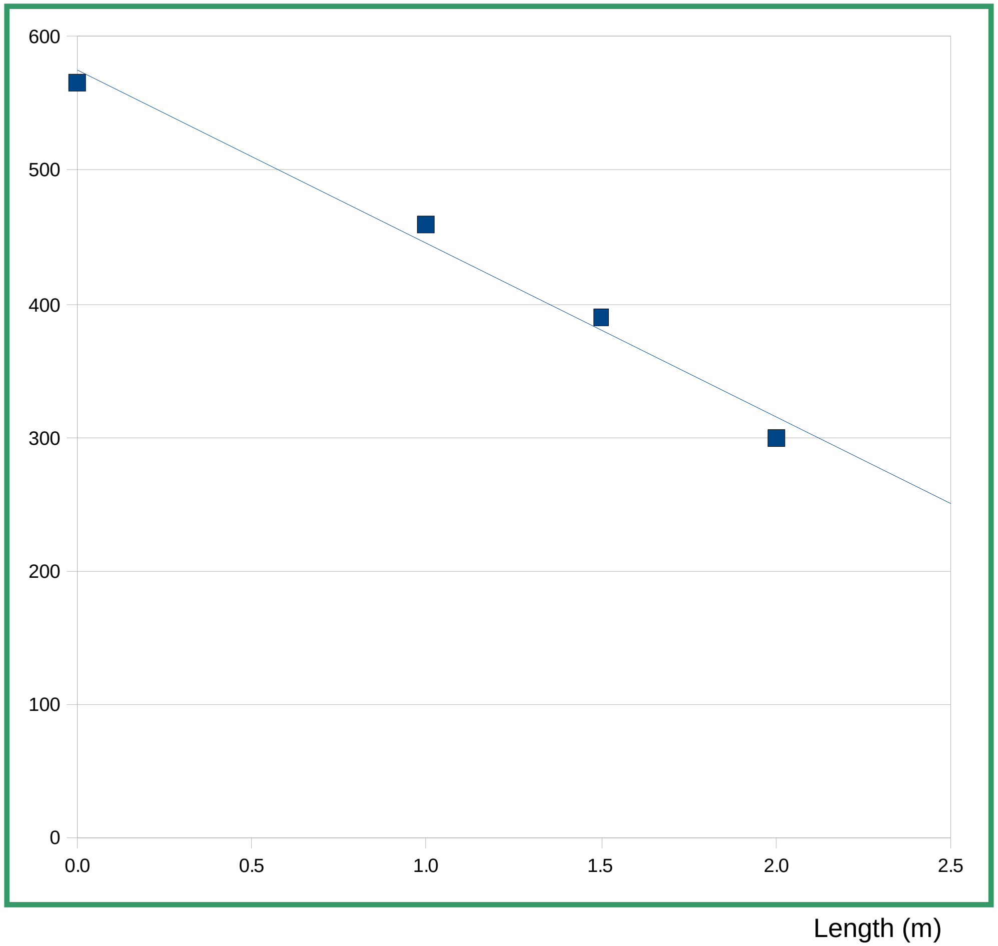
Adapter-side

SDA_O: 110Ω
AOUT1: 110Ω
AOUT2 : 110Ω



Signal Attenuation

Attenuation of the pulse height is within acceptable limits (47% at 2 meters).



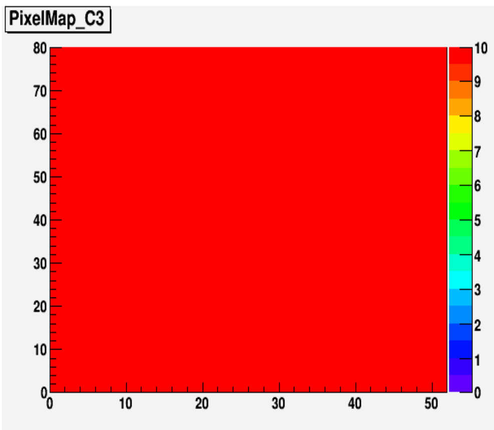
Pulse Height (ADC units) vs. Cable Length

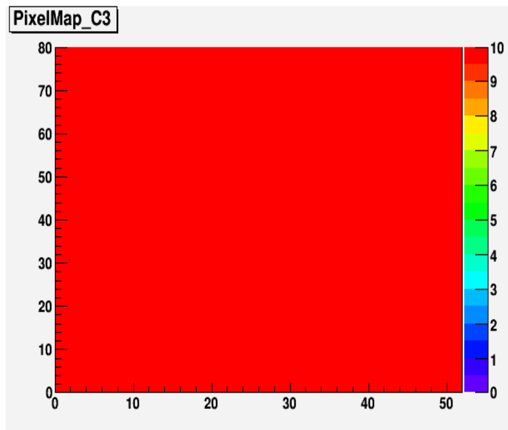
Pixel Alive and CalDel MAP

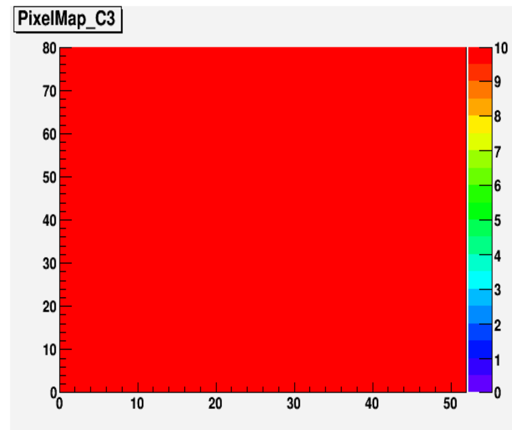
Standard connection

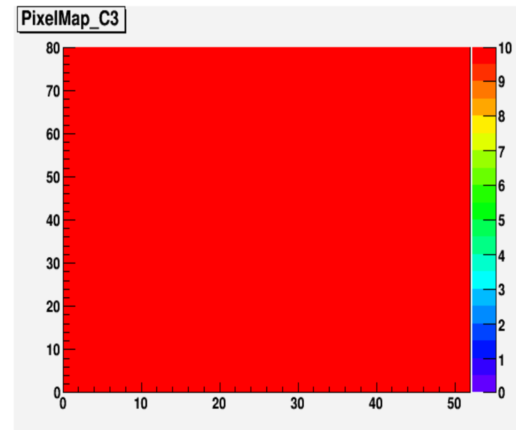
With micro-twisted pair cables connection

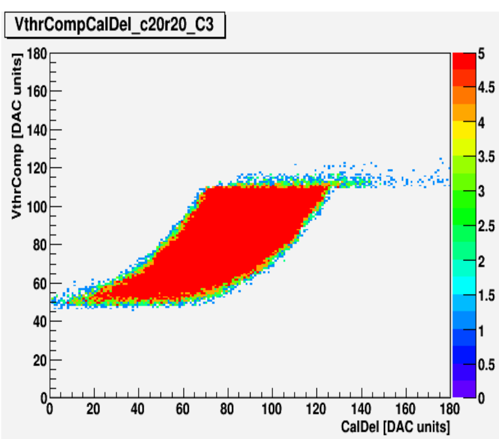
1.0 m cables | **1.5 m cables** | **2.0 m cables**

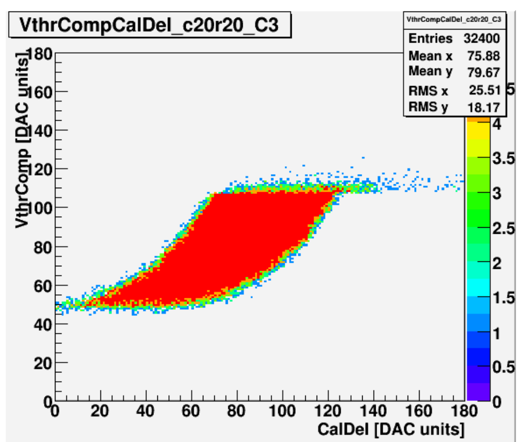


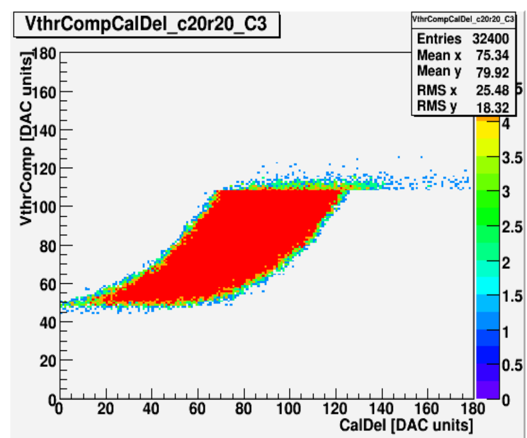


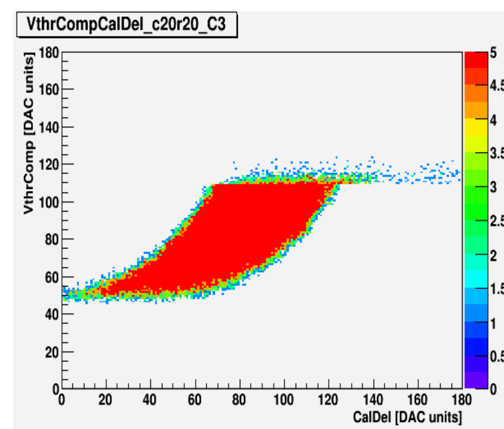






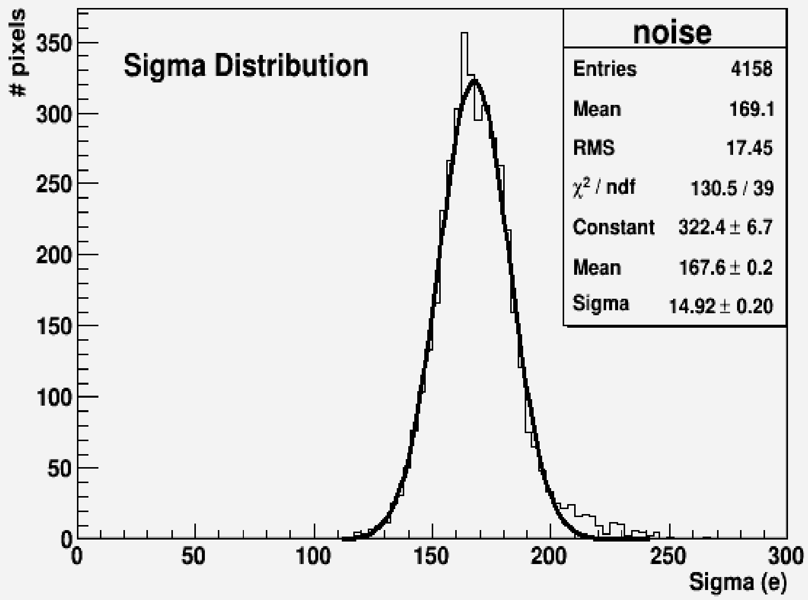




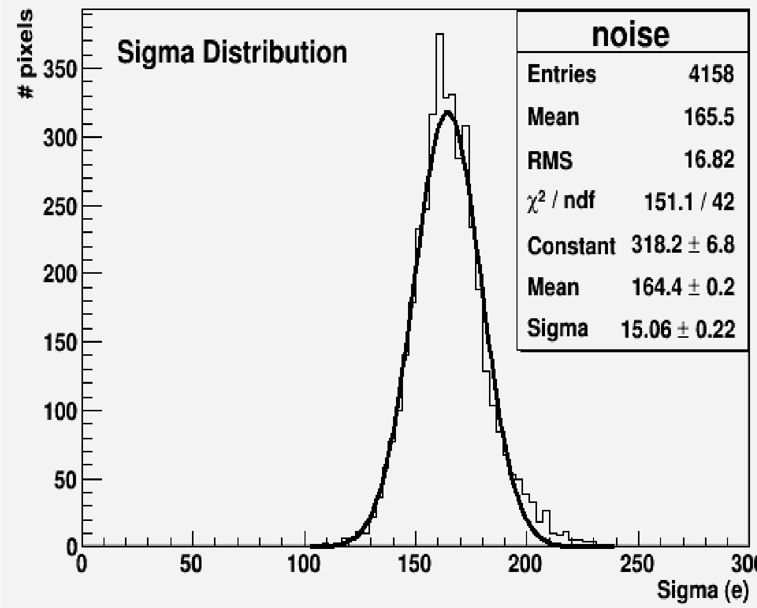


Noise Distributions (One ROC)

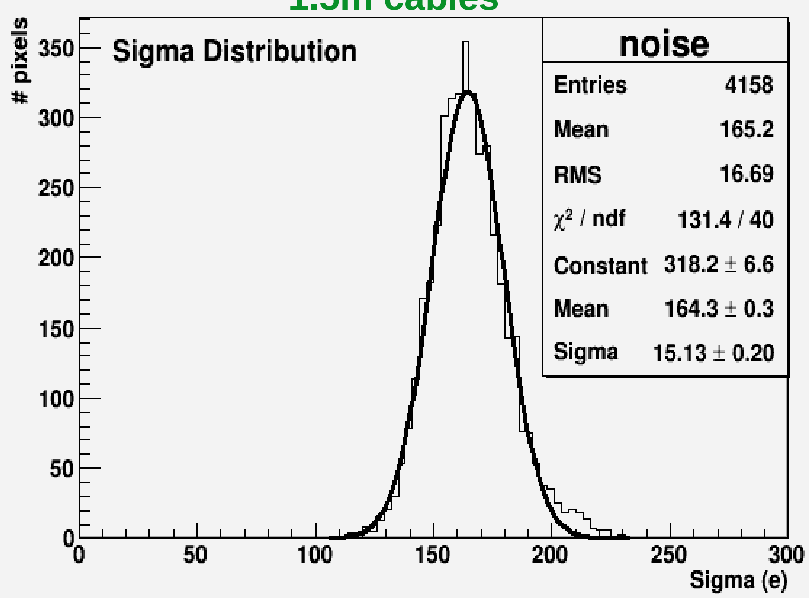
Normal connection



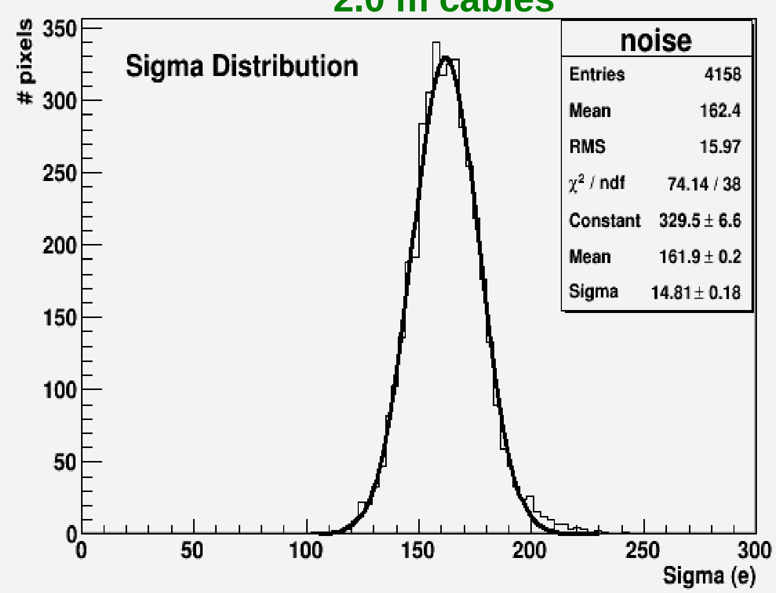
1.0 m cables



1.5m cables



2.0 m cables



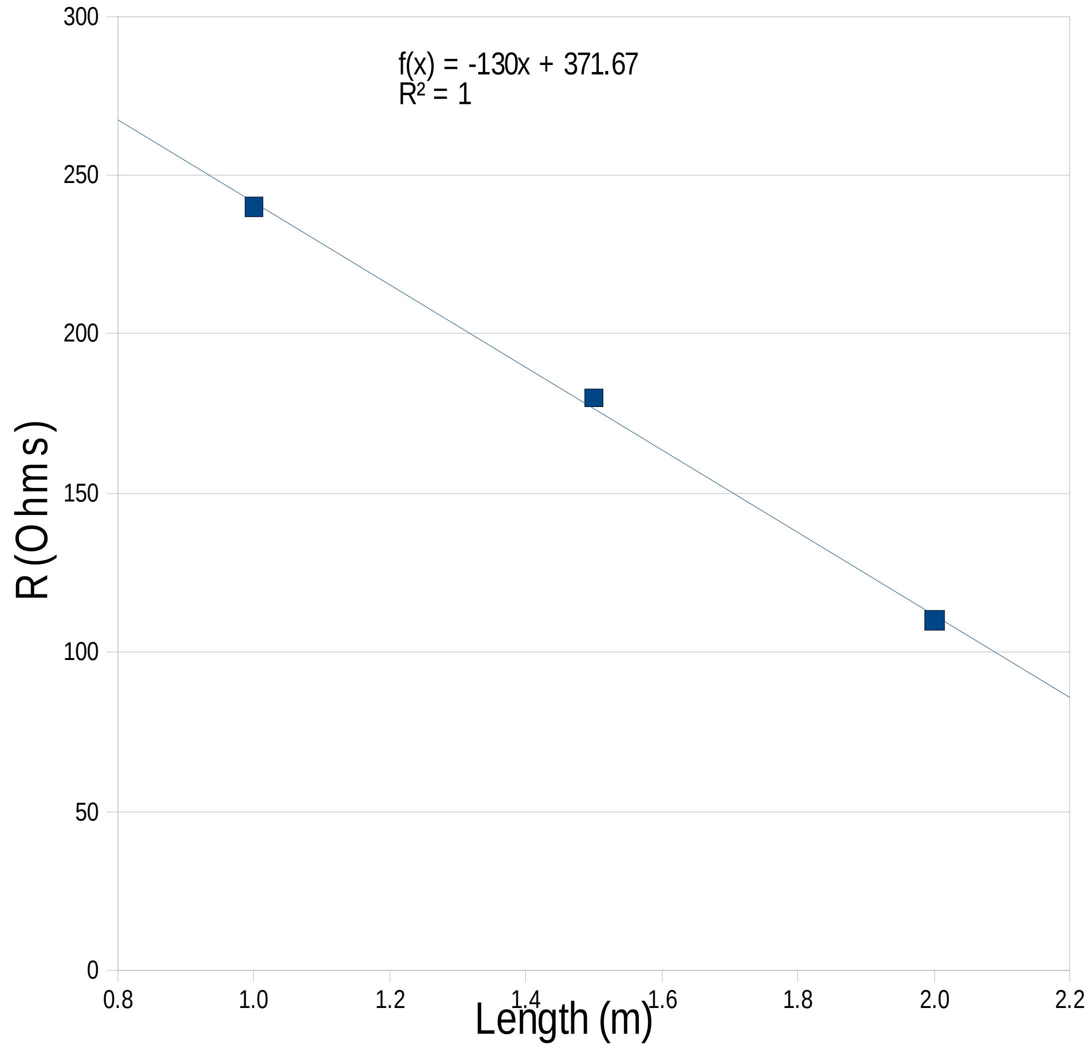
Conclusion

- We can obtain satisfactory performance for all lengths of micro-twisted pair cables up to 2 meters using the existing analog readout scheme.

Backup Slides

$R_{optimum}$ Vs Length

There seems to be a linear relation between optimum resistance and length but we have only measured three points.

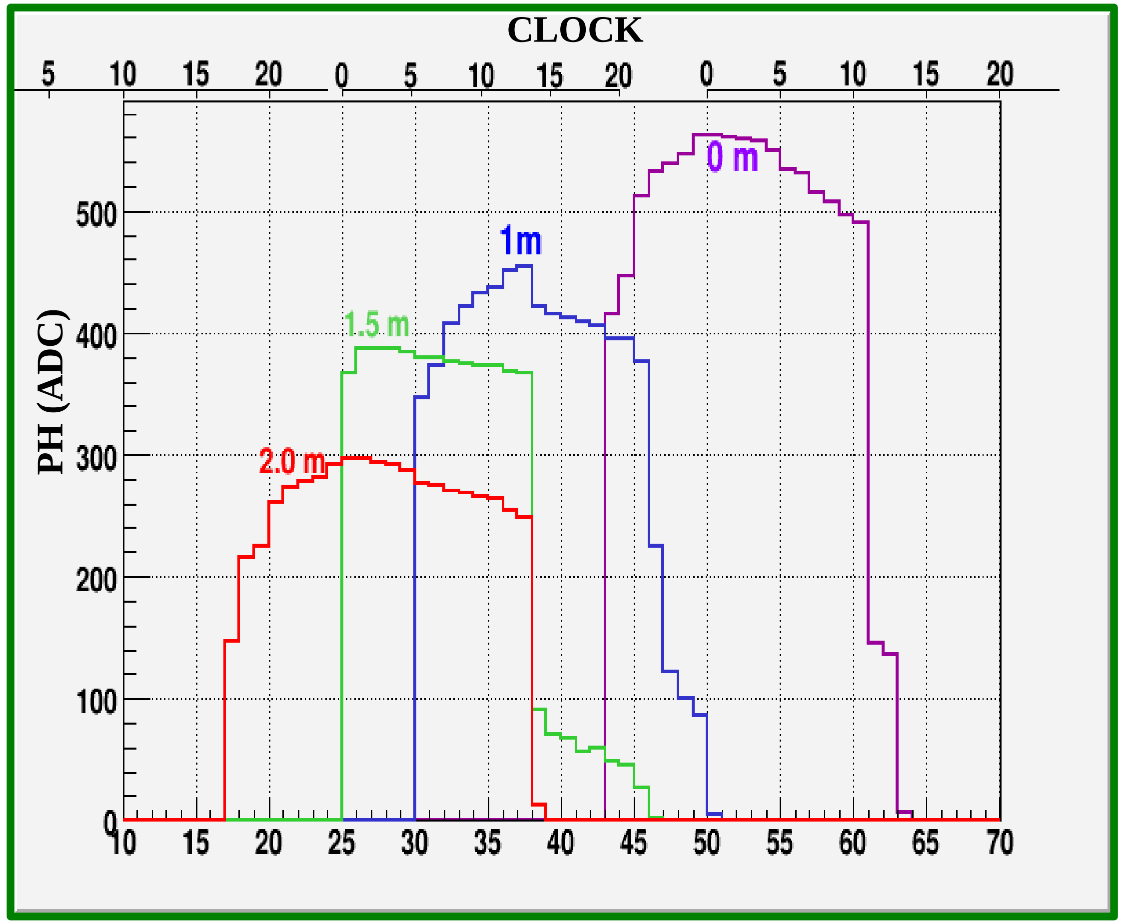


Timing and Pulse Height study

- These tests are done through the usual procedure of injecting a controlled amount of charge into the pixel readout system (VCAL DAC).

- The arrival time of the data signal is studied by varying the CLOCK parameter which controls the sampling time interval of the ADC on the test board. (Smaller values of the CLOCK parameter correspond to later sampling times.)

- A scan of the CLOCK delay (in 1 ns steps) is done in order to determine and set an optimum value (maximum pulse height).

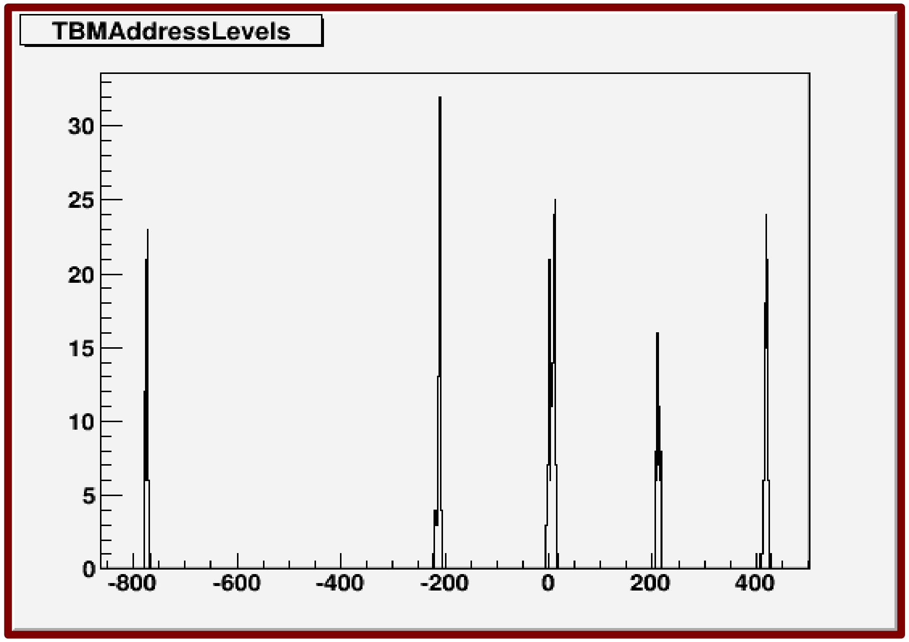


Pulse height as a function of data signal delay.

1.0 m cables

R_{TERM}

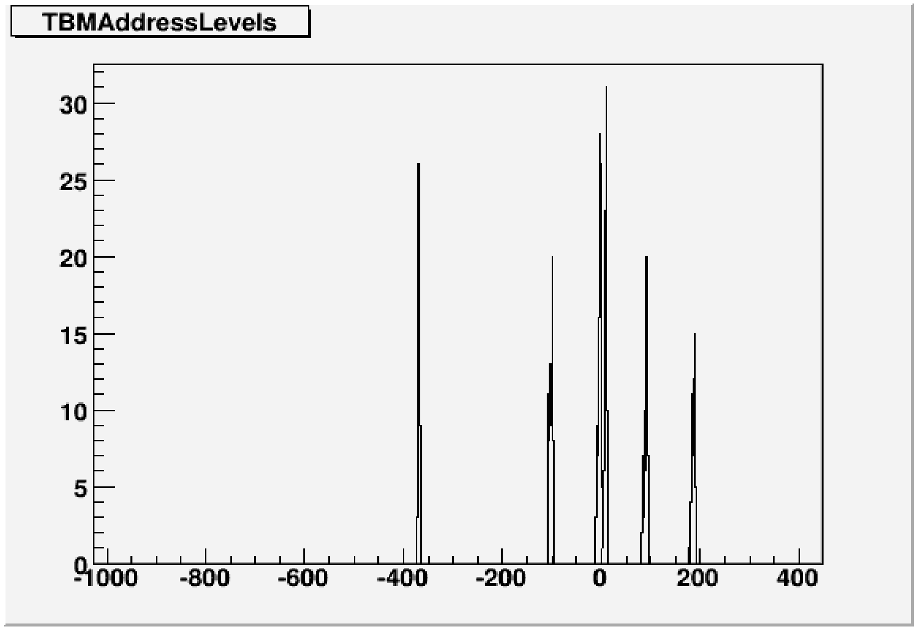
Mod-side
SDA_IN: 180Ω
CTR: 180Ω
CLK: 180Ω
Adapter-side
SDA_O: 240Ω
AOUT1: 240Ω
AOUT2 : 240Ω



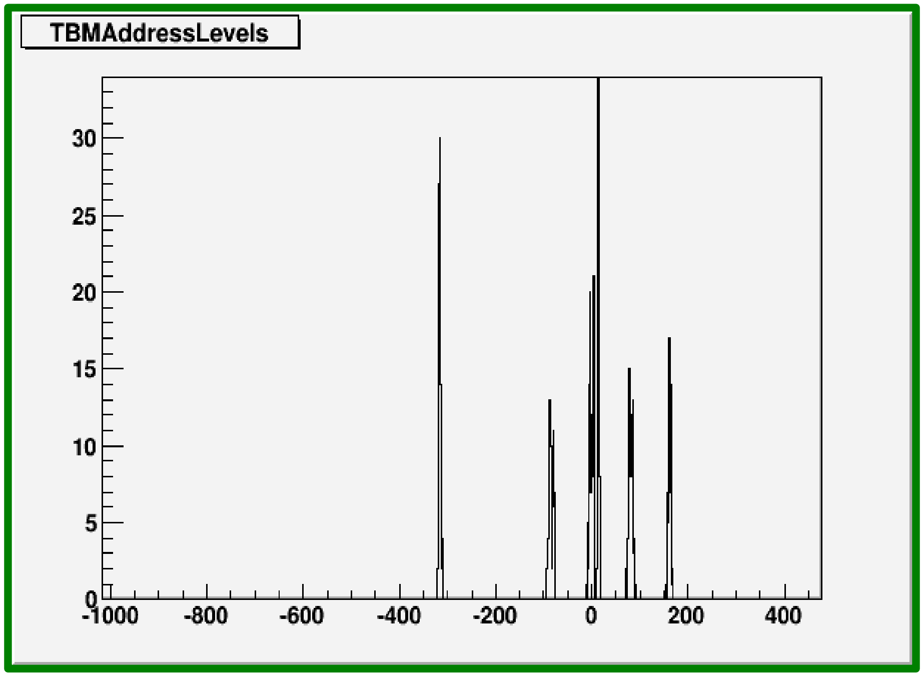
1.5 m cables

R_{TERM}

Mod-side
SDA_IN: 180Ω
CTR: 180Ω
CLK: 180Ω
Adapter-side
SDA_O: 180Ω
AOUT1: 180Ω
AOUT2 : 180Ω



2.0 m cables


TBMAddressLevels
30
25
20
15
10
5
0
-1000
-800
-600
-400
-200
0
200
400