HB/HE Front-End Strawman Proposal

- Understanding the many potential improvements that come from SiPMs
  - There are many
- Confronting existing front-end constraints
  - There are many
- Strawman proposal for HB/HE
  - Mechanics of SiPM interface, Readout Segmentation, Timing, ADC and TDC specs, Front-end FPGA, Digital Bandwidth, Power Consumption

SiPM Upgrade

- Basic performance improvements
  - High Quantum Efficiency (13% → 34%)
  - Higher Gain ($2x10^3$ → $5x10^5$)
- Potential performance limitations
  - Linearity limited to SiPM pixel count
    - 40,000 pixel devices will be linear over the same range as existing HPD+QIE readout
  - Deadtime of fired pixels
    - Average quantum inefficiency from fired pixels needs to be limited to ~1-2% at high luminosity
  - Radiation induced leakage current
    - Services and readout need to operate at the highest leakage currents foreseen from high integrated luminosity
- Mechanical differences
  - Channel density within a readout module is no longer limited by the photodetector size
    - No optical addition is required

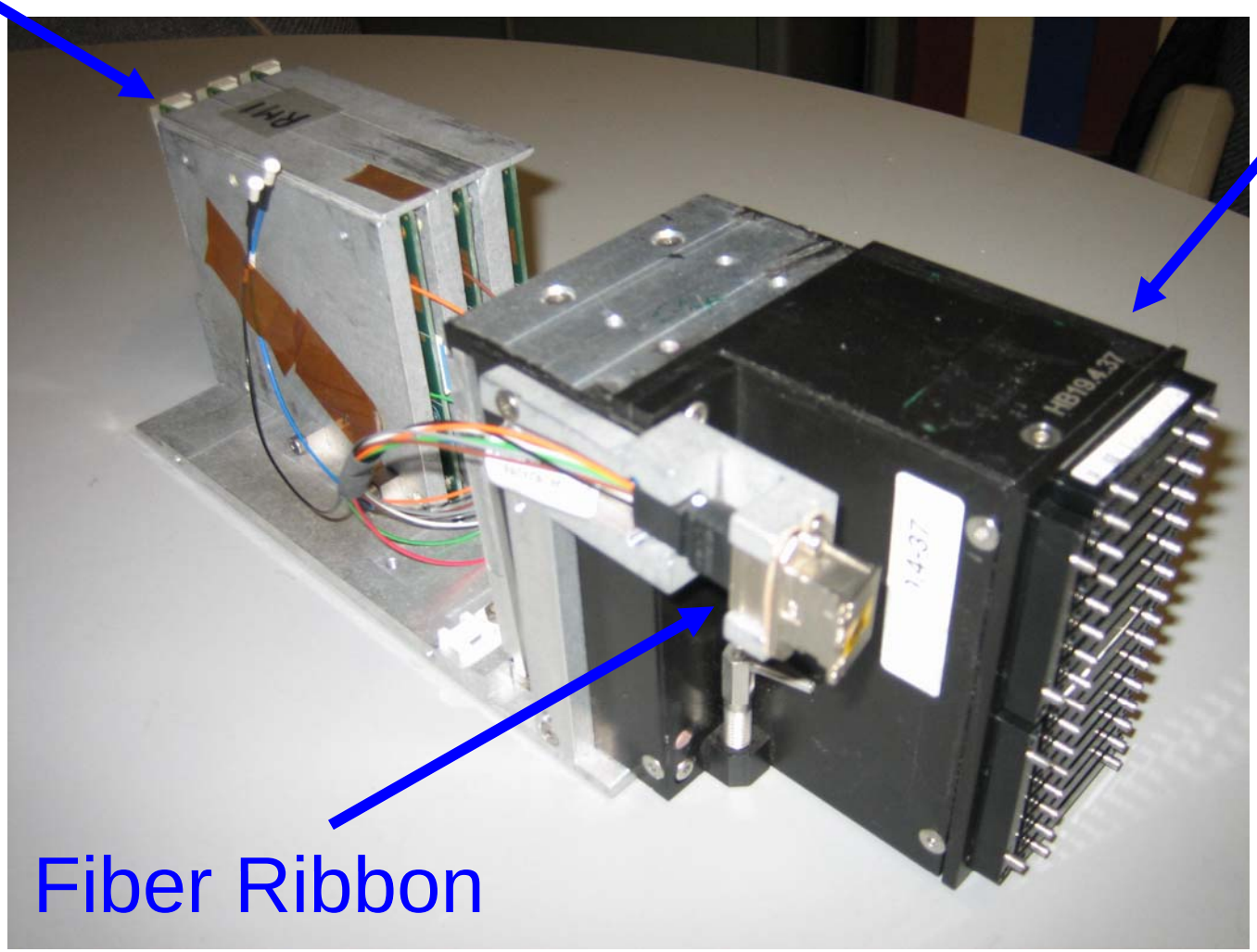
Potential Improvements

- Increased readout segmentation
  - Currently, 17 scintillation layers are added together for |eta|=1-14 in the barrel, no longitudinal segmentation exists except for the ECAL and outer HCAL readout
  - Compact SiPM footprint means that any combination of the 17 layers can be added together
- Response weighting (proposed by J. Freeman)
  - Sampling layers with front-plate (steel 40mm), absorbers 1-8 (brass 50.5mm), 9-14 (brass 56.5mm), back plate (steel 75mm) can be added with uniform response
  - Can be done with passive components in the analog addition
- Introduction of a timing measurement
  - Currently, the time-of-flight measurement from HCAL is based on an offline fit to the pulse shape in the limit of no pileup (low lumi)
  - Large SiPM signal means that the pulse can be split to perform a concurrent TDC measurement

Existing Constraints

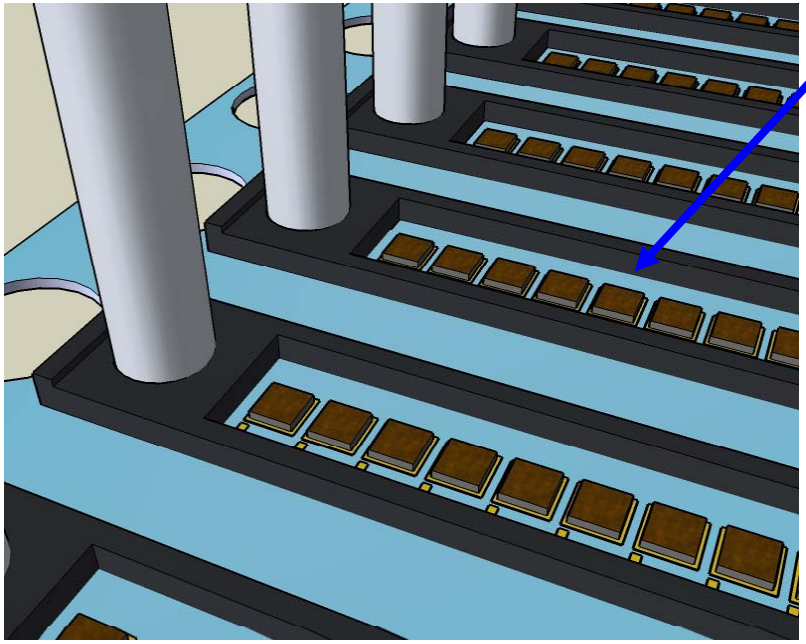
- Existing readout modules dissipate roughly 25 Watts (2.6A@5.5 V and 1.6A@6.5V)
  - Cooling runs at lowest inlet water temperature (14 C) with the QIE pack thermalizing at 22 C
  - Can RBX cooling power be increased to 300 W?
- Existing fiber plant/digital readout bandwidth
  - 8 multimode fibers per RM capable of running up to 5.0 GHz, currently operated at 1.6 GHz
  - Can current GOL operate up to 3.2 GHz?
  - Can the GBT operate at 4.0 GHz?

HB Readout Module



Electrical Decoding Unit Concept

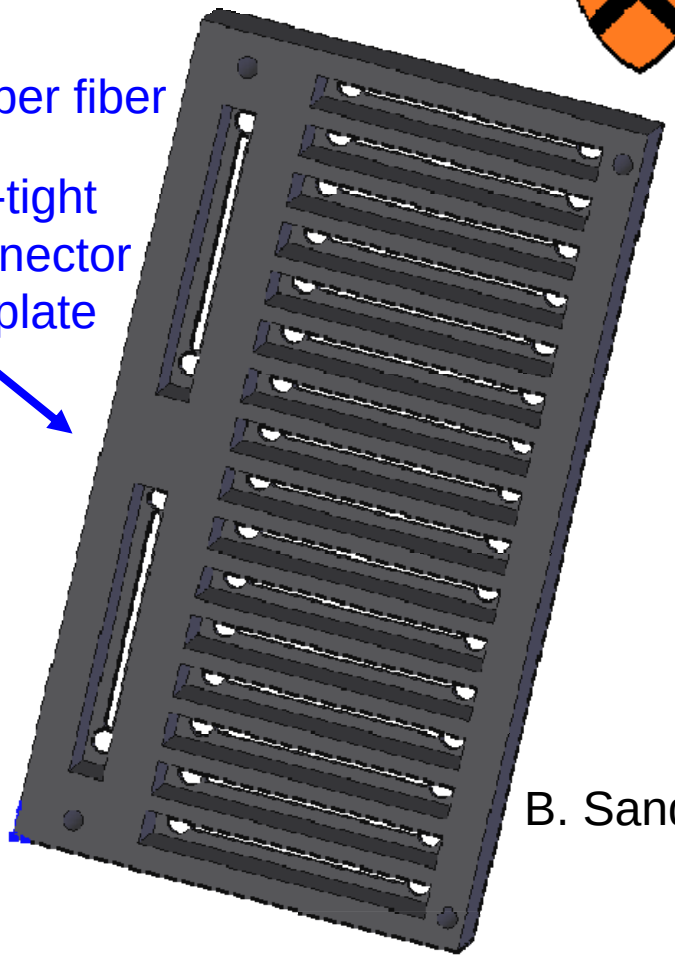
Proposed by Arjan Heering and Sergey Los



P. Rubinov

1 SiPM per fiber

Light-tight
18-connector
Faceplate

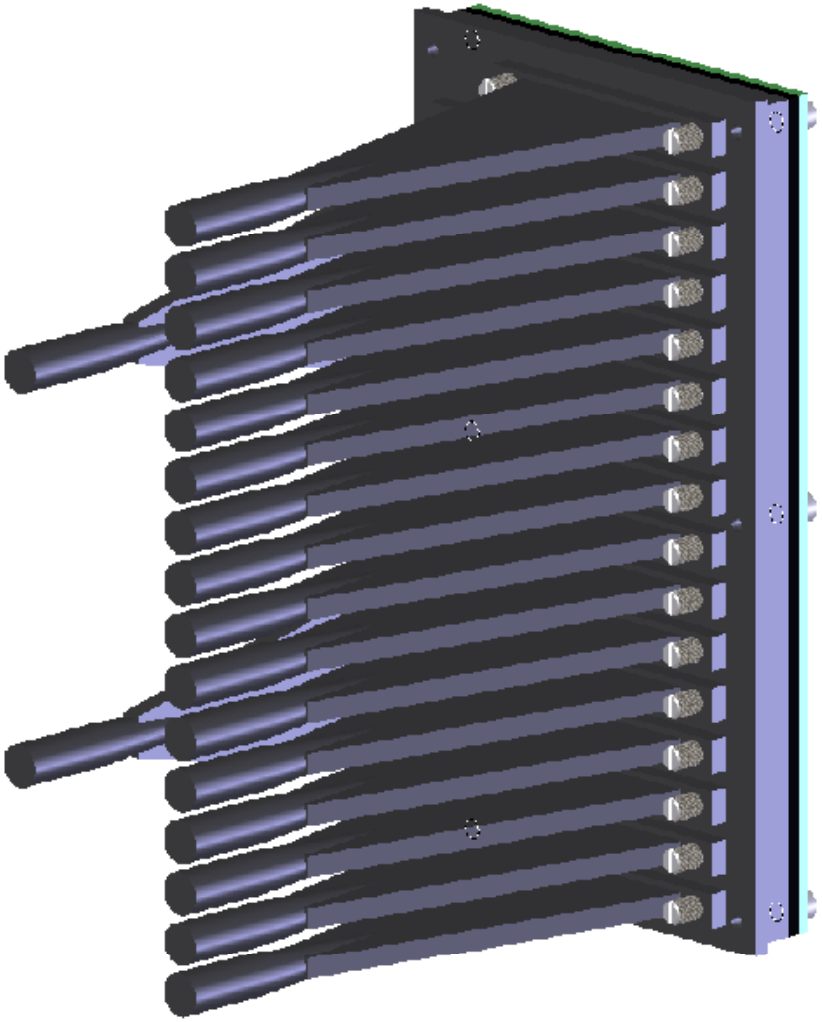


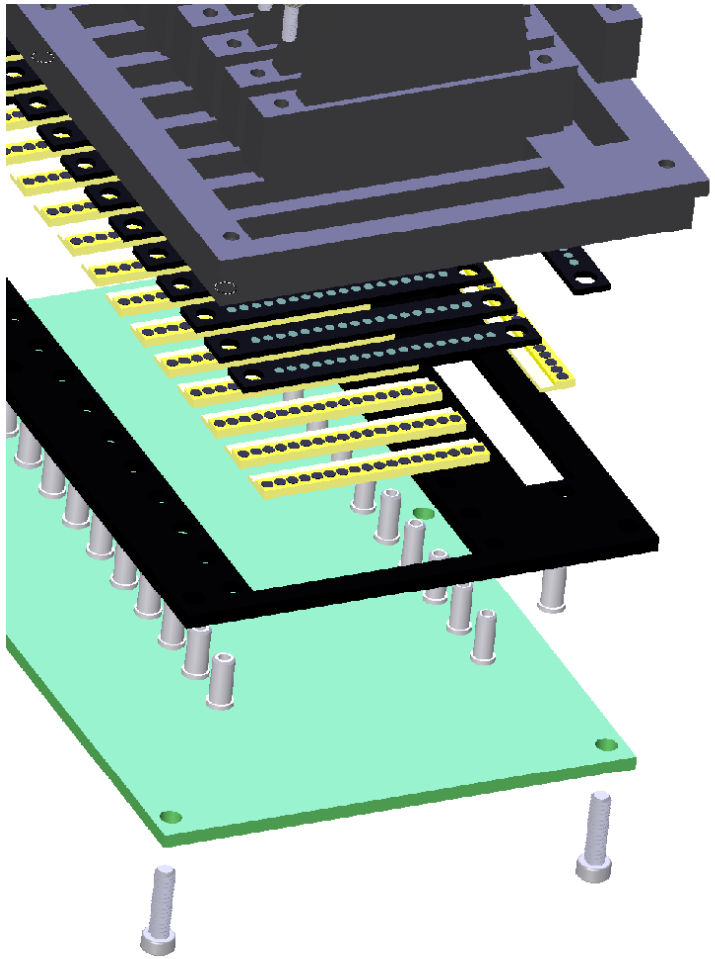
B. Sands

Basic Concept

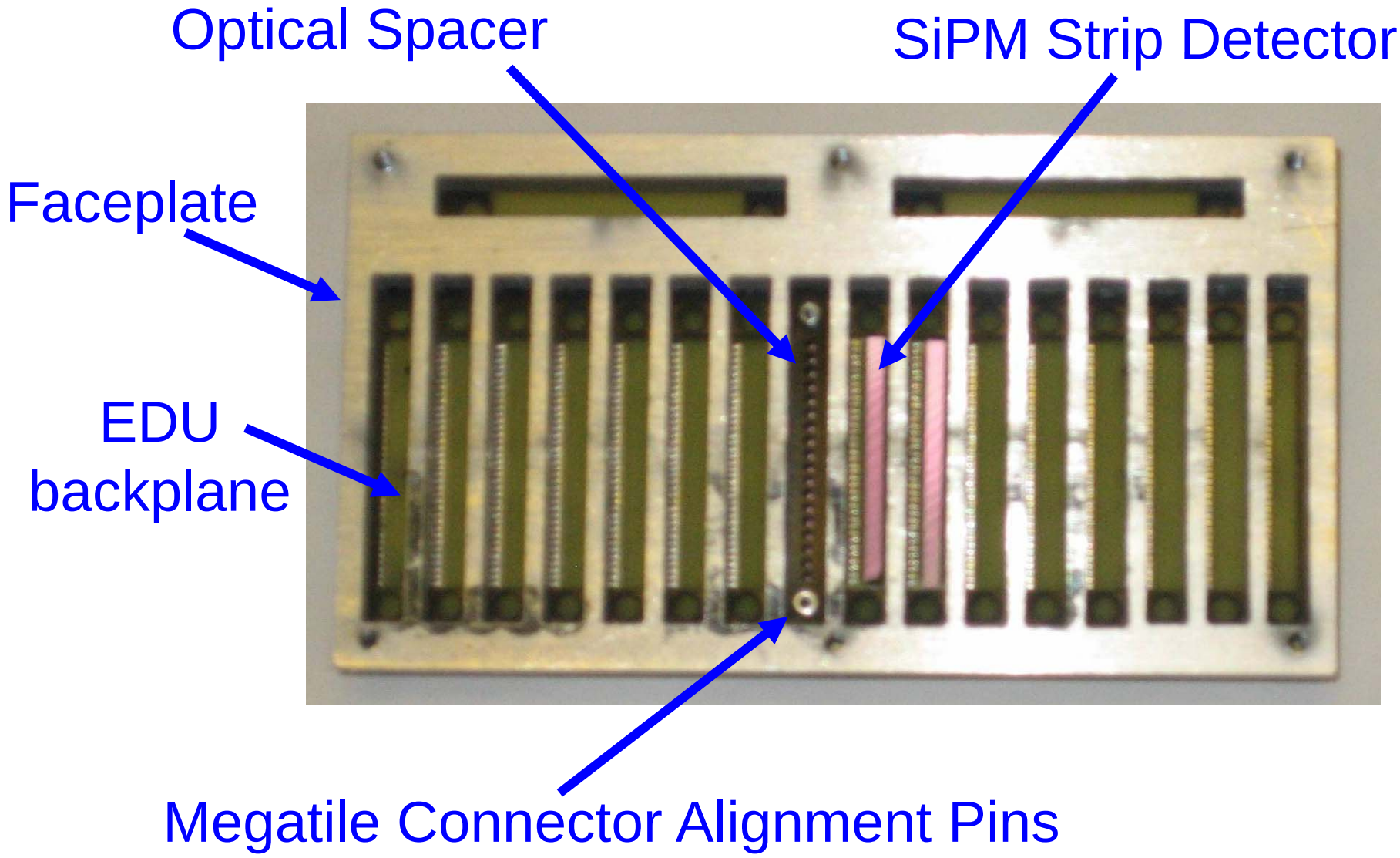
- **Do Optical/Electrical Conversion at the Megatile Connector**
- **1 SiPMs (1mm^2) per fiber**
- **Perform Analog Addition to form (segmented) towers**

Preliminary HB EDU Design



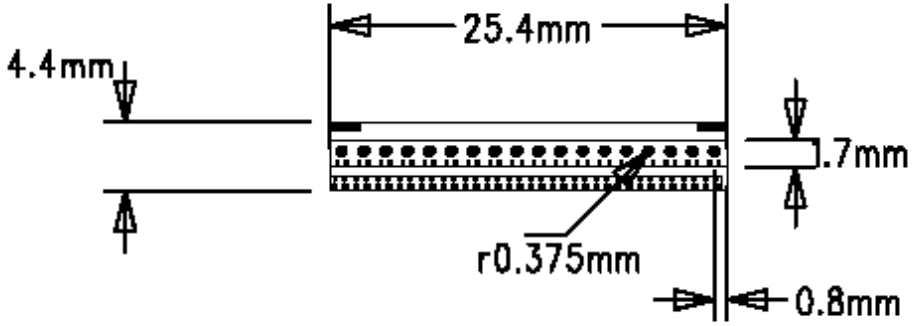


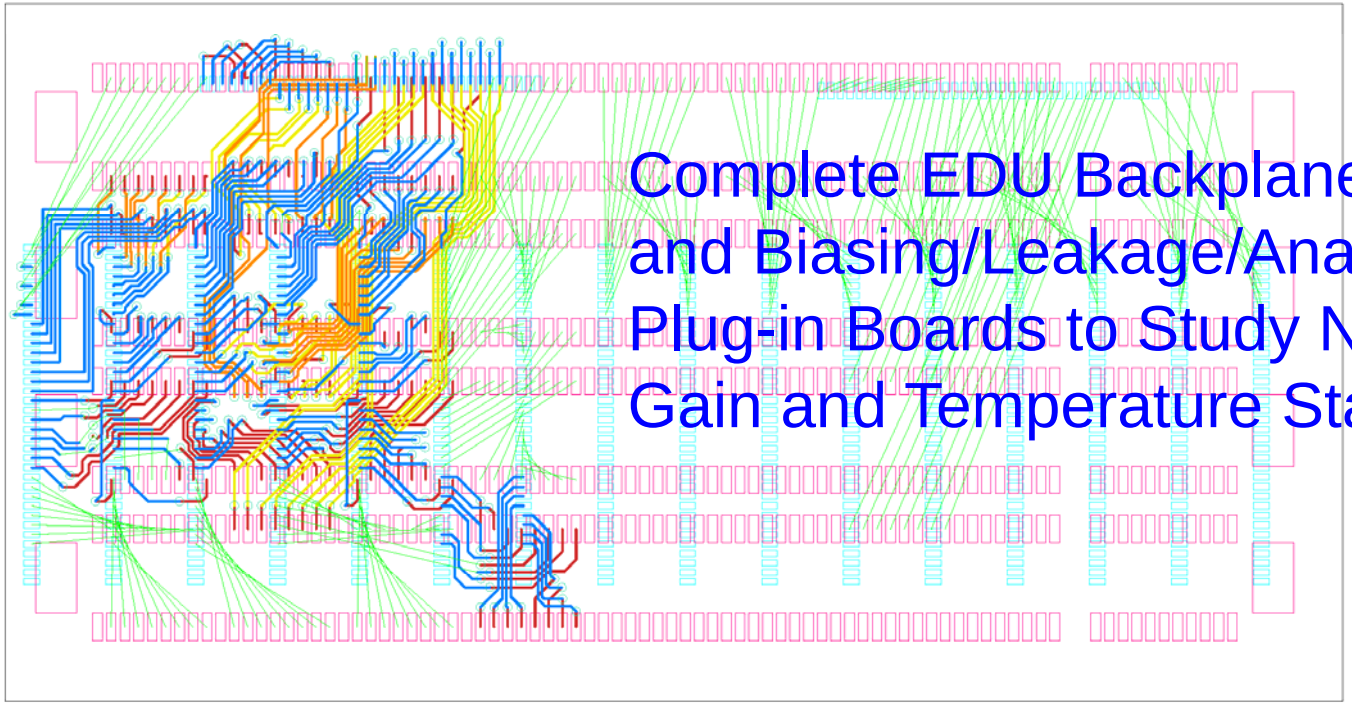
EDU Mechanical Prototype



Next Steps for EDU

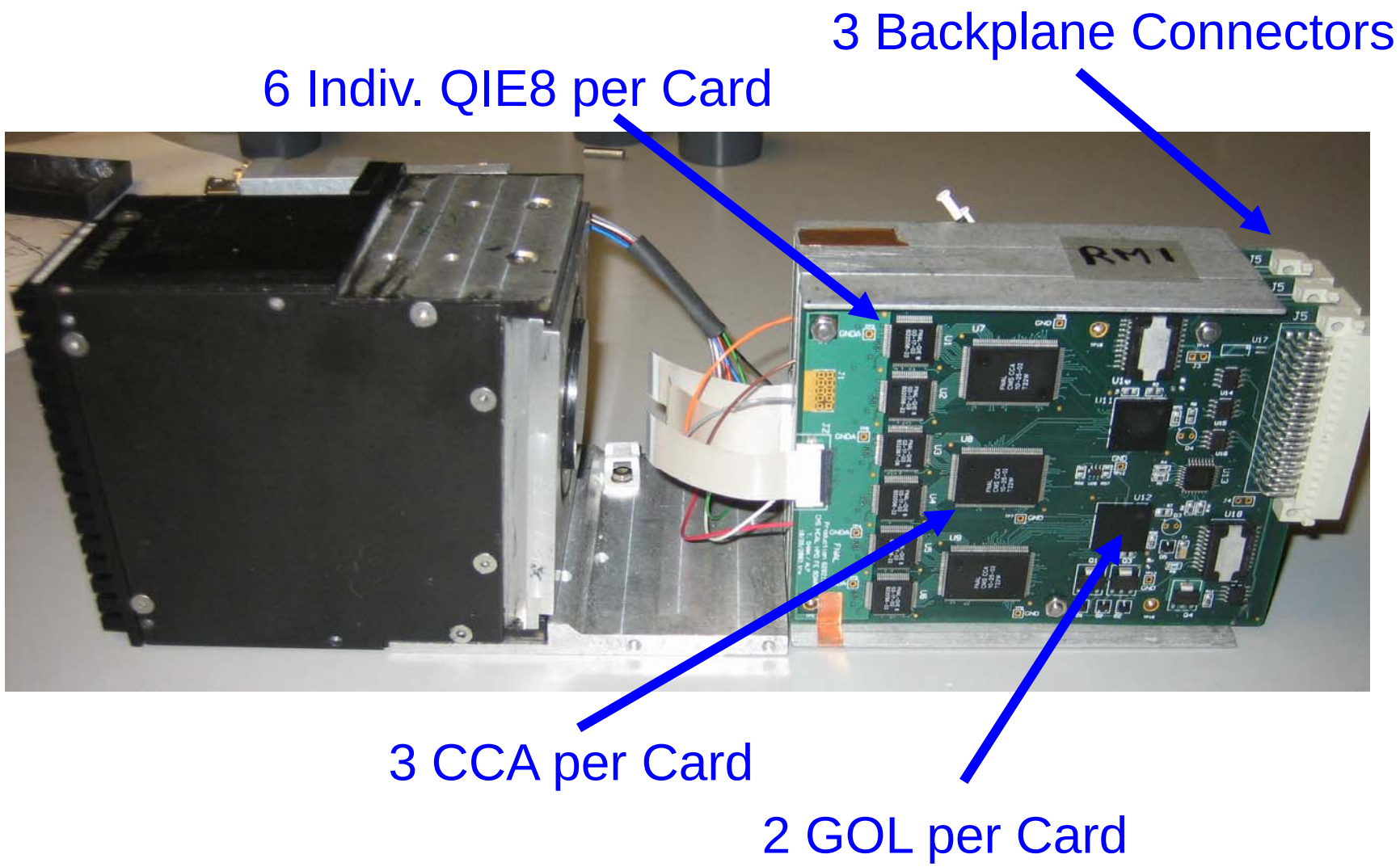
Submit SiPM Strip Detector Geometry to Manufacturers





Complete EDU Backplane Layout and Biasing/Leakage/Analog Addition Plug-in Boards to Study Noise/Crosstalk, Gain and Temperature Stability

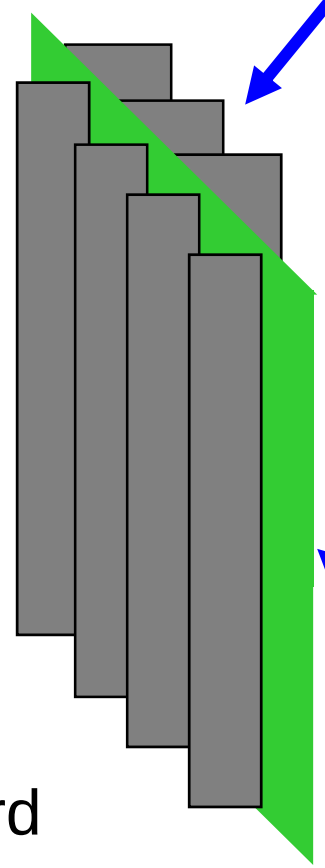
RM QIE Readout Pack



Backplane Adaptor

3 Backplane Connectors

4 Plug-in QIE Readout Cards
(2 GOL Connections per Board)



4 Plug-in Boards:

- Naturally extends to 8-fibers per RM (2 per Board)
- Uses available “HV cable space” for larger channel capacity
- Adapts to the EDU 4 Plug-in board analog addition simplifying cabling within the RM

Backplane can be used for clock cleanup and distribution

HB Digital Readout Bandwidth

Current Readout (1.6 GHz) Format

	D(31:30)	D(29:25)	D(24)	D(23:22)	D(21:17)	D(16)	D(15:14)	D(13:9)	D(8:7)	D(6:5)	D(4:3)	D(2)	D(1)	D(0)
Optical Cable 1	QIE 0 Exp (1:0)	QIE 0 Mant (4:0)	QIE_Reset (abort gap marker?)	QIE 1 Exp (1:0)	QIE 1 Mant (4:0)	"0"	QIE 2 Exp (1:0)	QIE 2 Mant (4:0)	QIE 0 CapID(1:0)	QIE 1 CapID(1:0)	QIE 2 CapID(1:0)	Control Flag=0	Data Flag=1	"1"
Optical Cable 2	QIE 4 Exp (1:0)	QIE 4 Mant (4:0)	QIE_Reset (abort gap marker?)	QIE 5 Exp (1:0)	QIE 5 Mant (4:0)	"0"	QIE 3 Exp (1:0)	QIE 3 Mant (4:0)	QIE 4 CapID(1:0)	QIE 5 CapID(1:0)	QIE 3 CapID(1:0)	Control Flag=0	Data Flag=1	"1"

FE DATA FORMAT

Possible HB Readout (3.2 GHz) Format with GOL

QIE0 8-bit	QIE1 8-bit	QIE2 8-bit	QIE3 8-bit	QIE4 8-bit	QIE5 8-bit	TDC0 5-bit	CapID(0-3) 2-bit	ErrBit 1-bit	TDC3 5-bit	CapID(4-5) 2-bit	ErrBit 1-bit

Optical Cable 1

QIE6 8-bit	QIE7 8-bit	QIE8 8-bit	QIE9 8-bit	QIE10 8-bit	QIE11 8-bit	TDC6 5-bit	CapID(6-7) 2-bit	ErrBit 1-bit	TDC9 5-bit	CapID(8-11) 2-bit	ErrBit 1-bit

Optical Cable 2

HB Digital Readout Bandwidth

Possible HB Readout (4.0 GHz) Format with GBT

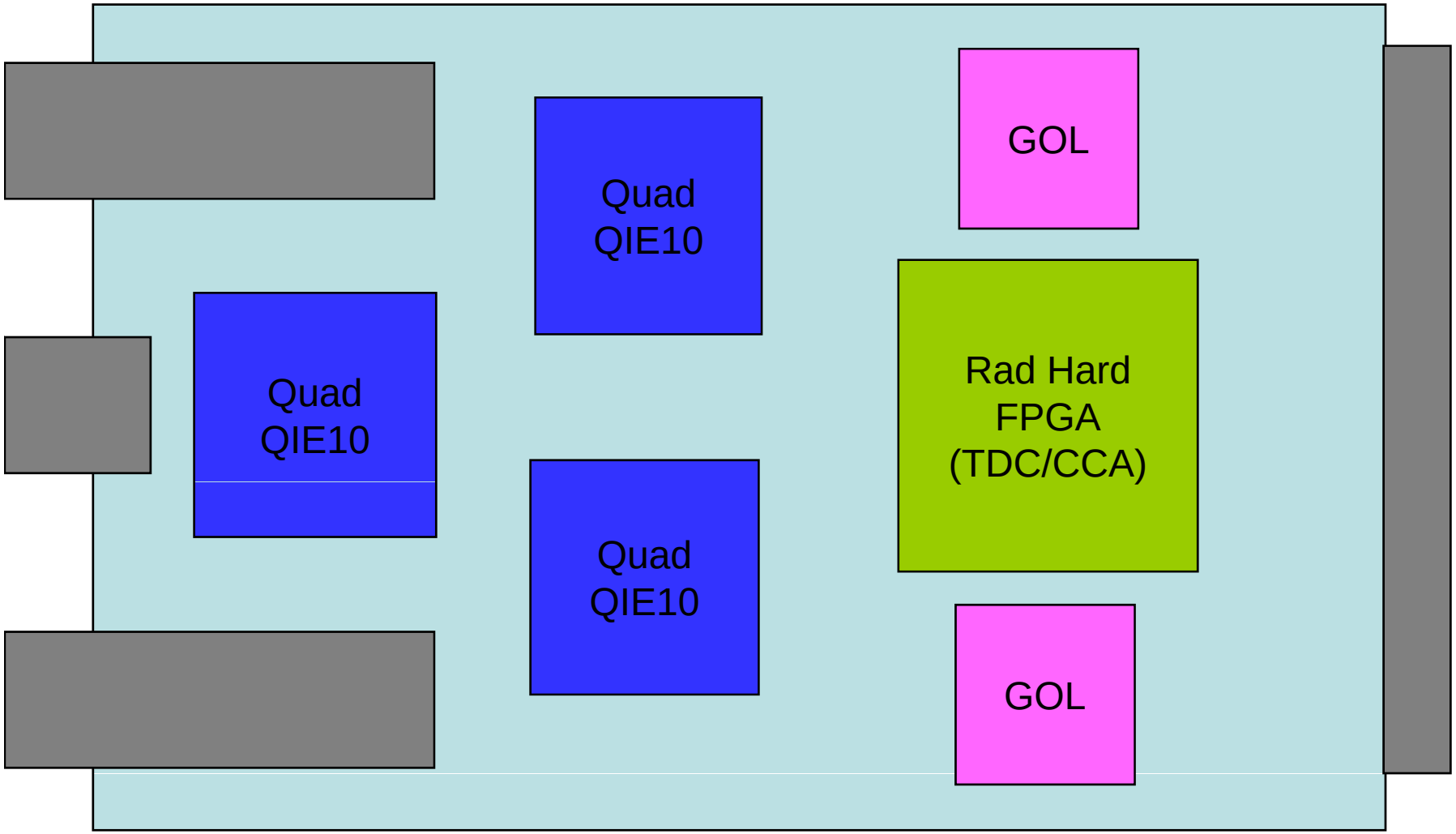
QIE0 8-bit	QIE1 8-bit	QIE2 8-bit	QIE3 8-bit	QIE4 8-bit	QIE5 8-bit
TDC0 5-bit	TDC1 4-bit	TDC2 4-bit	CapID(0-3) 2-bit	ErrBit 1-bit	
TDC3 5-bit	TDC4 4-bit	TDC5 4-bit	CapID(4-5) 2-bit	ErrBit 1-bit	

Optical Cable 1

QIE6 8-bit	QIE7 8-bit	QIE8 8-bit	QIE9 8-bit	QIE10 8-bit	QIE11 8-bit
TDC6 5-bit	TDC7 4-bit	TDC8 4-bit	CapID(6-7) 2-bit	ErrBit 1-bit	
TDC9 5-bit	TDC10 4-bit	TDC11 4-bit	CapID(8-11) 2-bit	ErrBit 1-bit	

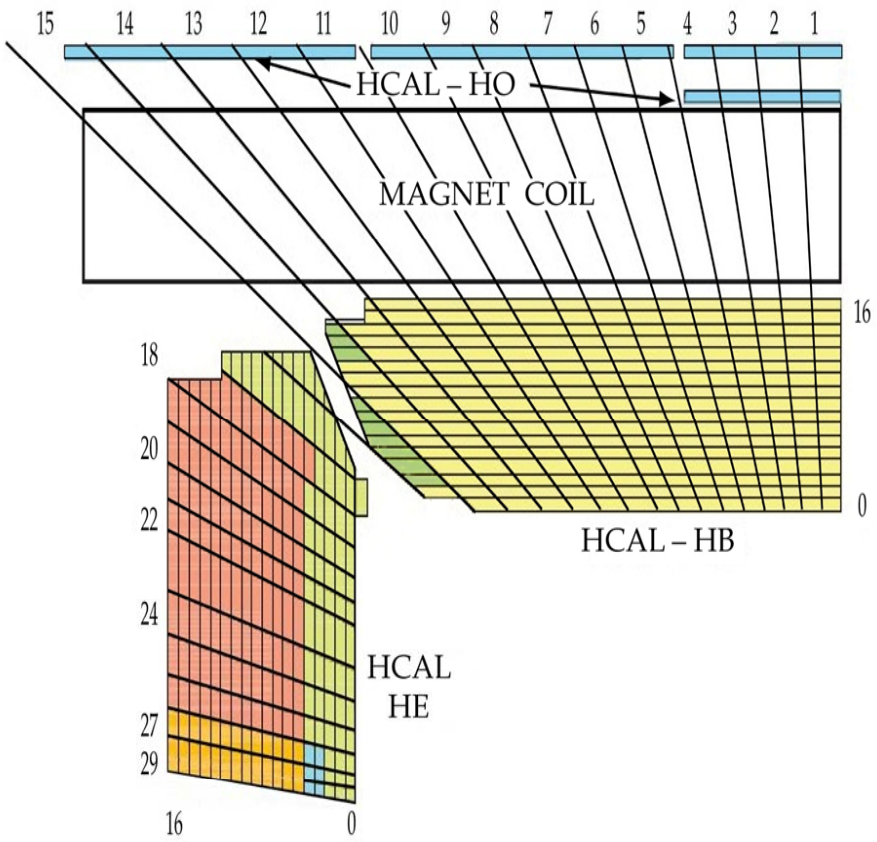
Optical Cable 2

QIE10 12-Channel Cards

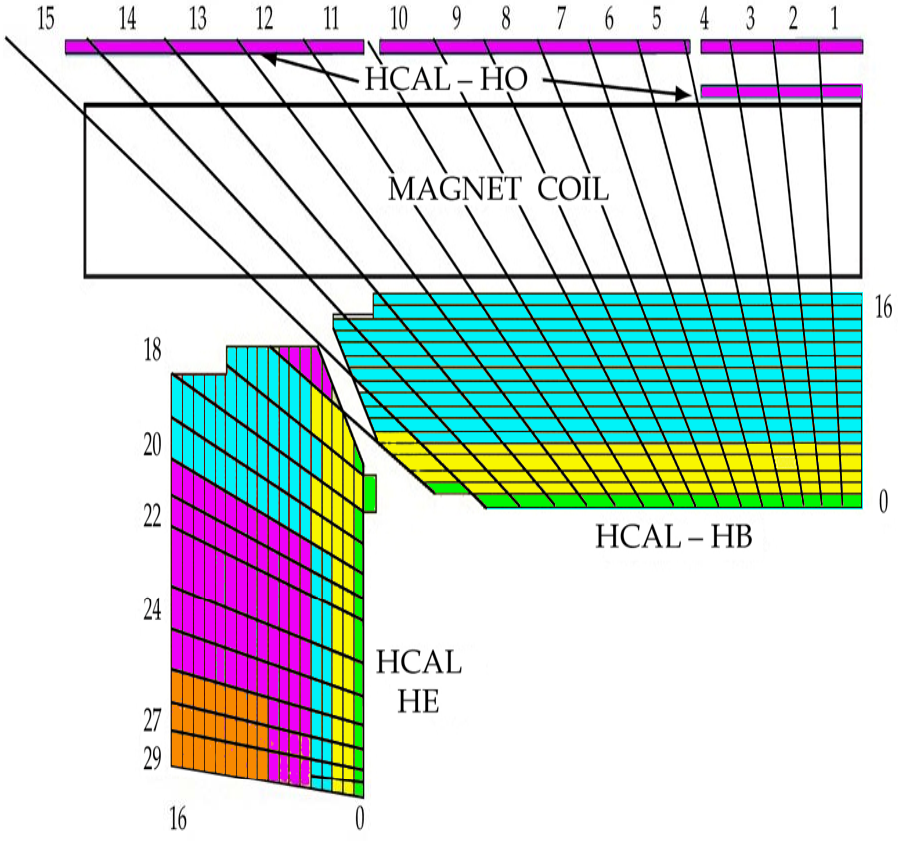


HB Long. Segmentation

18 Channel RMs

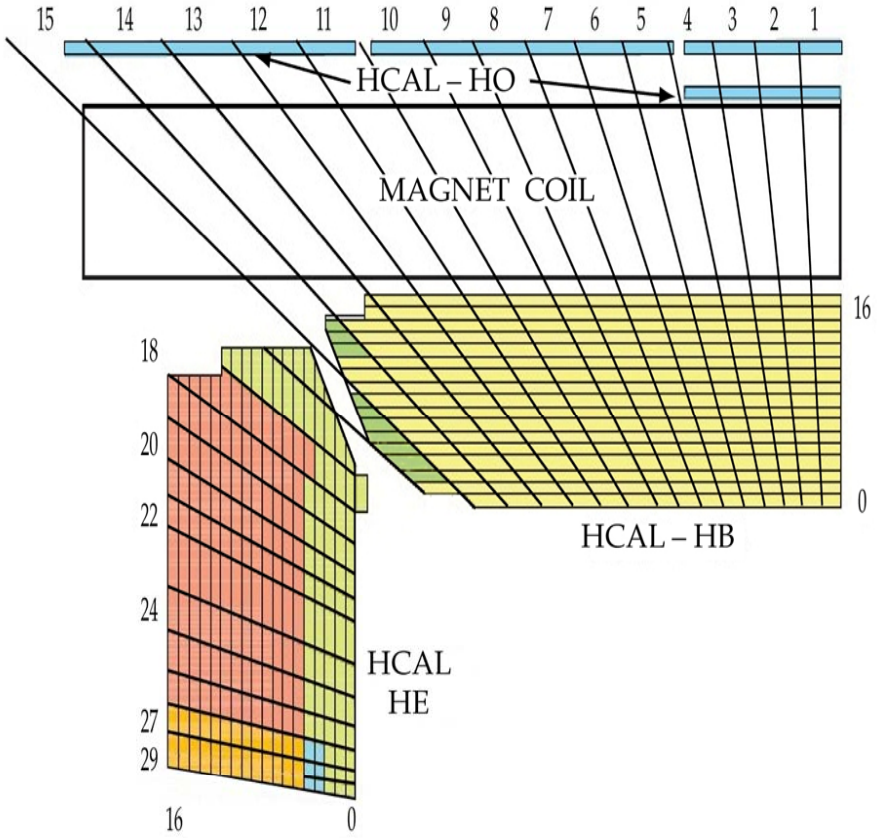


48 Channel HB RMs
32 Channel HE RMs

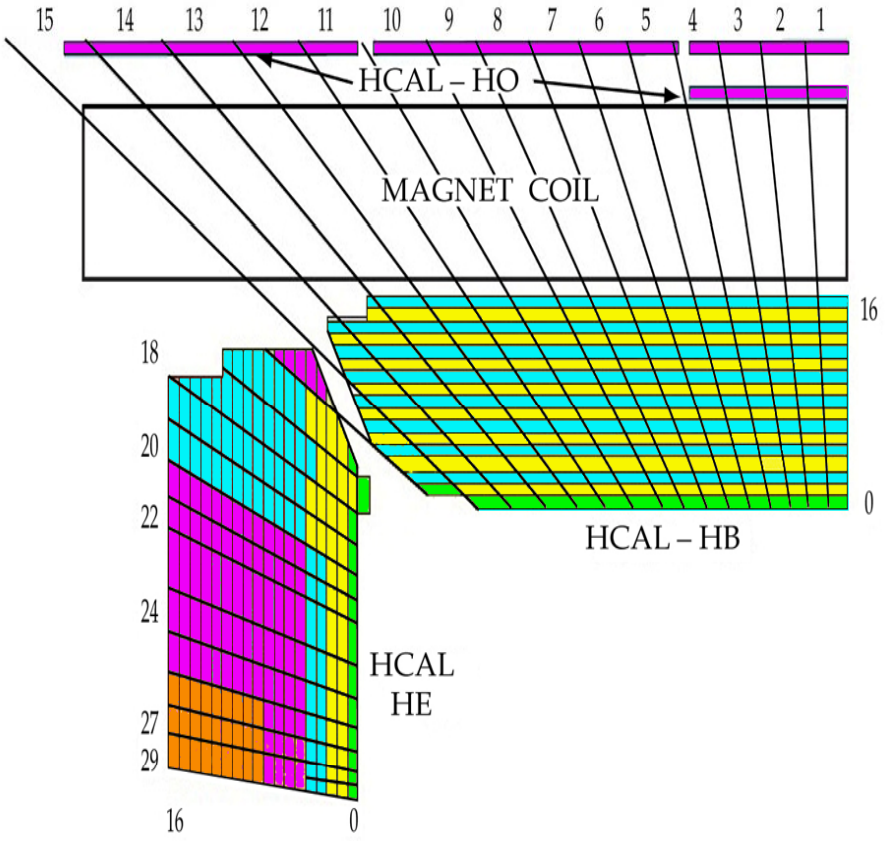


HB Long. Segmentation

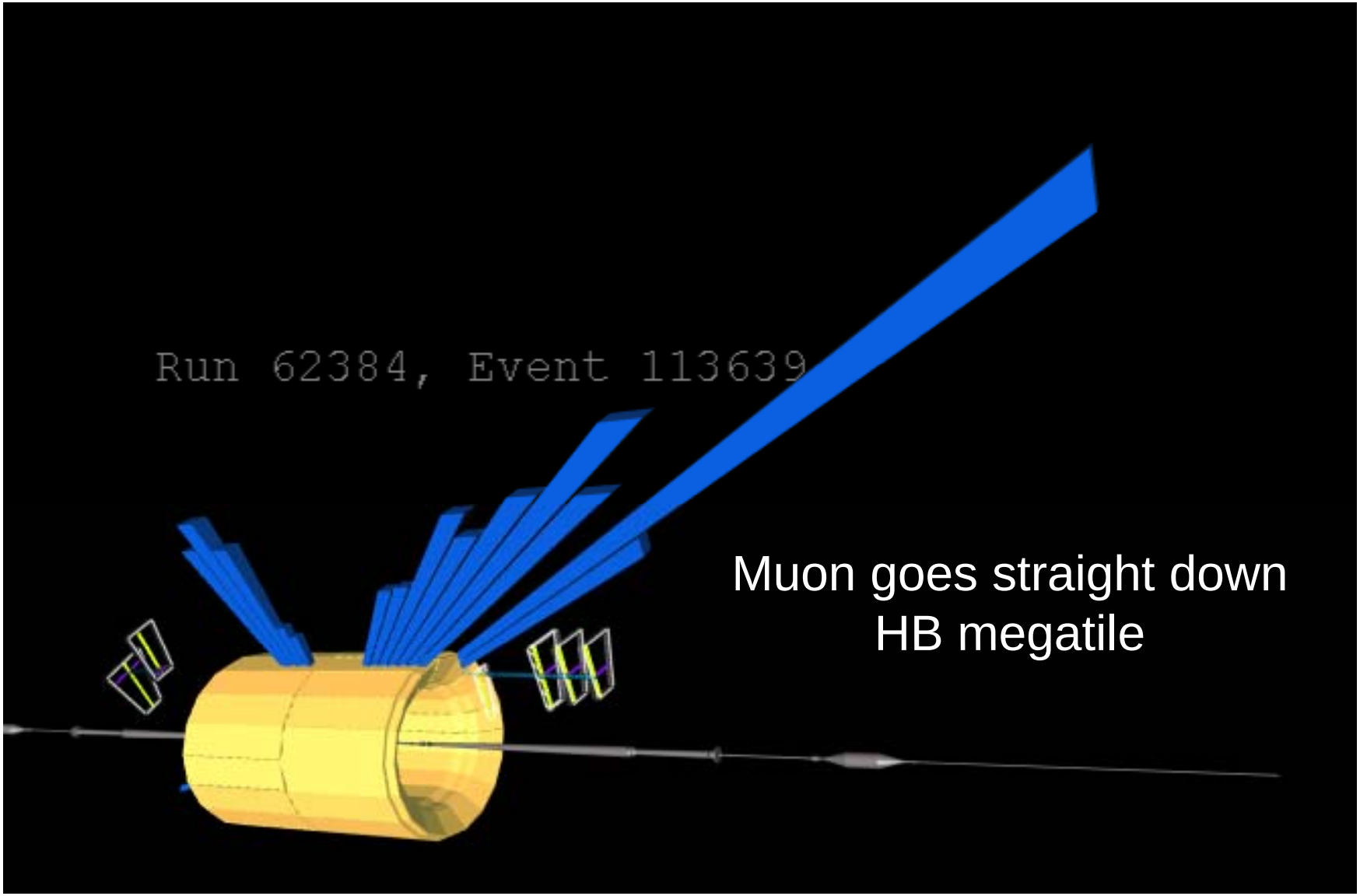
18 Channel RMs



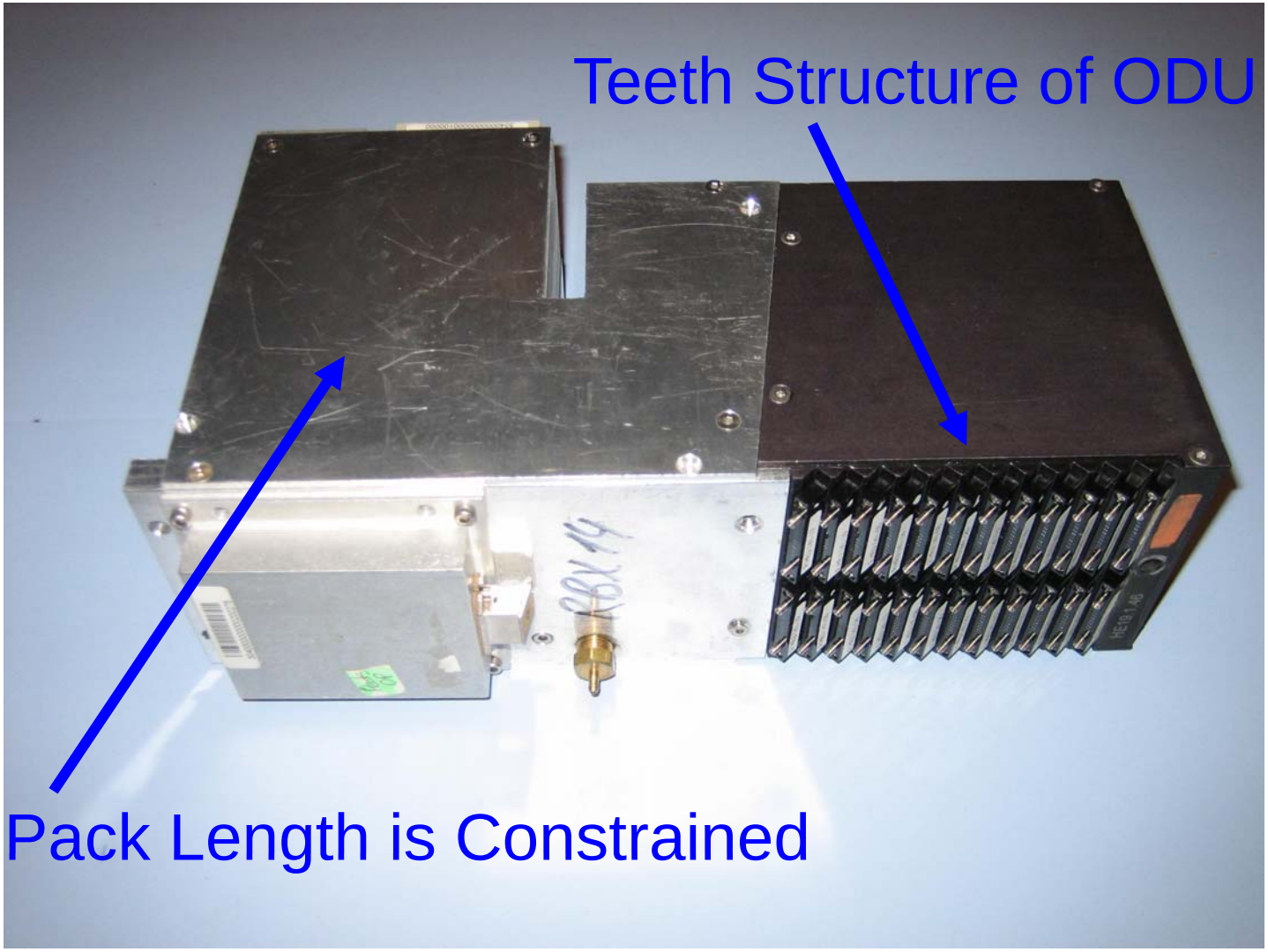
48 Channel HB RMs
32 Channel HE RMs



Mohawk Events



HE RM



HE Digital Readout Bandwidth

Possible HE Readout (2.8 GHz) Format with GOL

QIE0 8-bit	QIE1 8-bit	QIE2 8-bit	QIE3 8-bit

TDC0 5-bit	CapID(0-3) 2-bit	ErrBit 1-bit	TDC1 5-bit	TDC2 5-bit	TDC3 5-bit	ExtraBit 1-bit

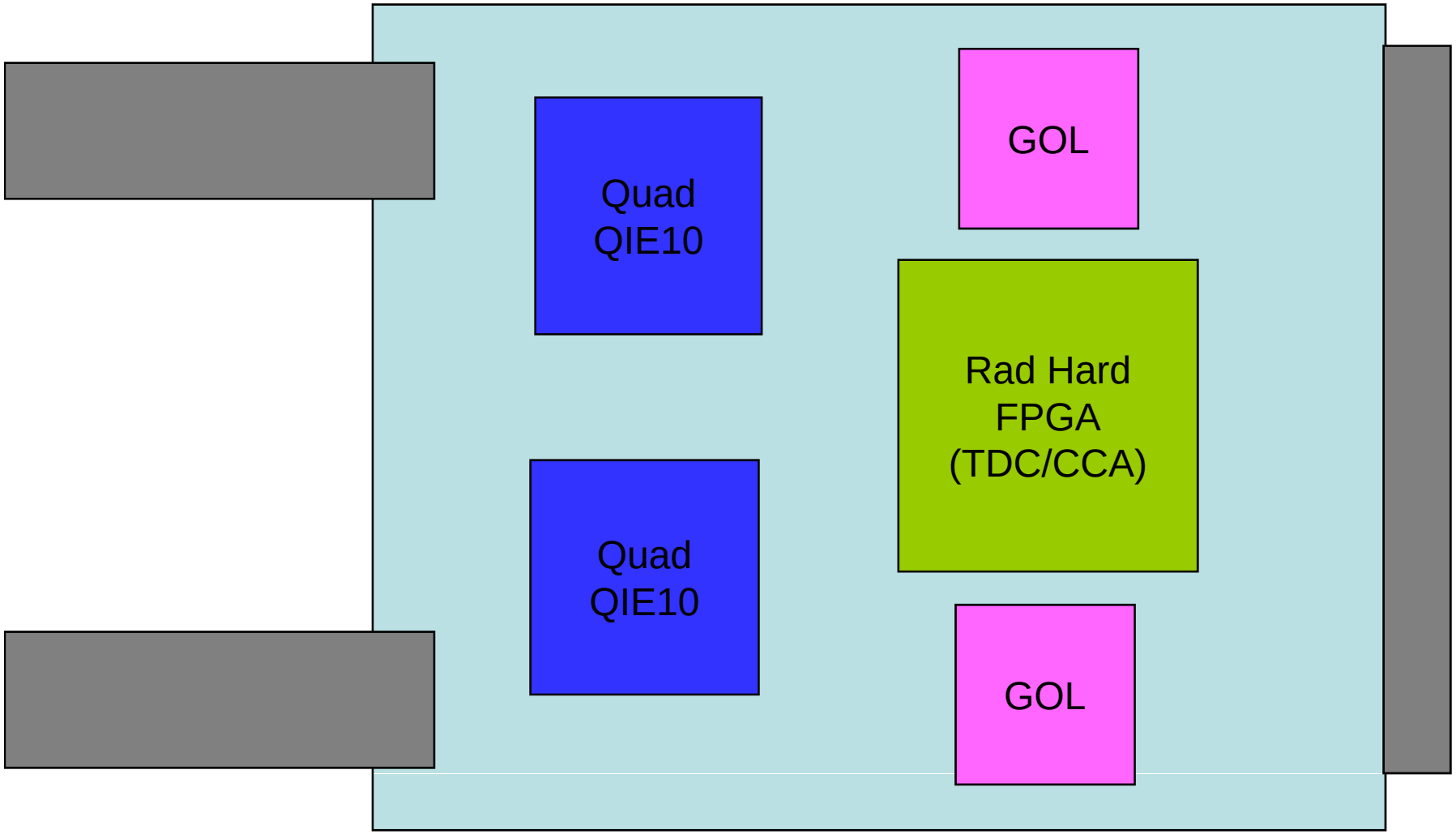
Optical Cable 1

QIE4 8-bit	QIE5 8-bit	QIE6 8-bit	QIE7 8-bit

TDC4 5-bit	CapID(4-7) 2-bit	ErrBit 1-bit	TDC5 5-bit	TDC6 5-bit	TDC7 5-bit	ExtraBit 1-bit

Optical Cable 1

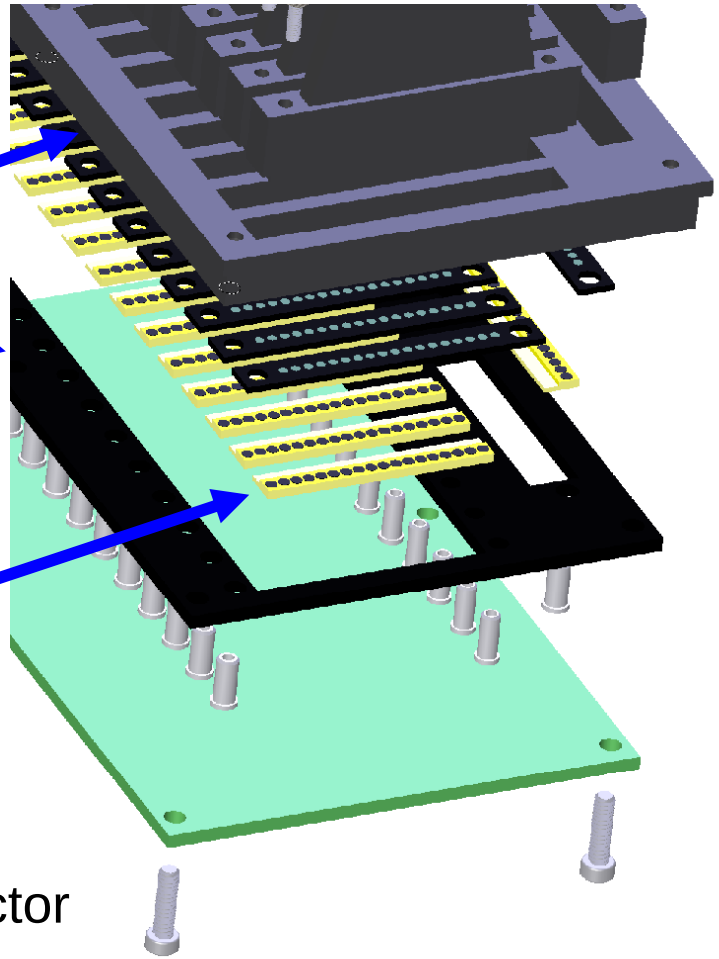
QIE10 8-Channel Cards



Preliminary HE EDU Design

Replace Flat Piece
and Faceplate
with Saw Tooth

Mount SiPM Strip Detectors
with Flexible Kapton Cables

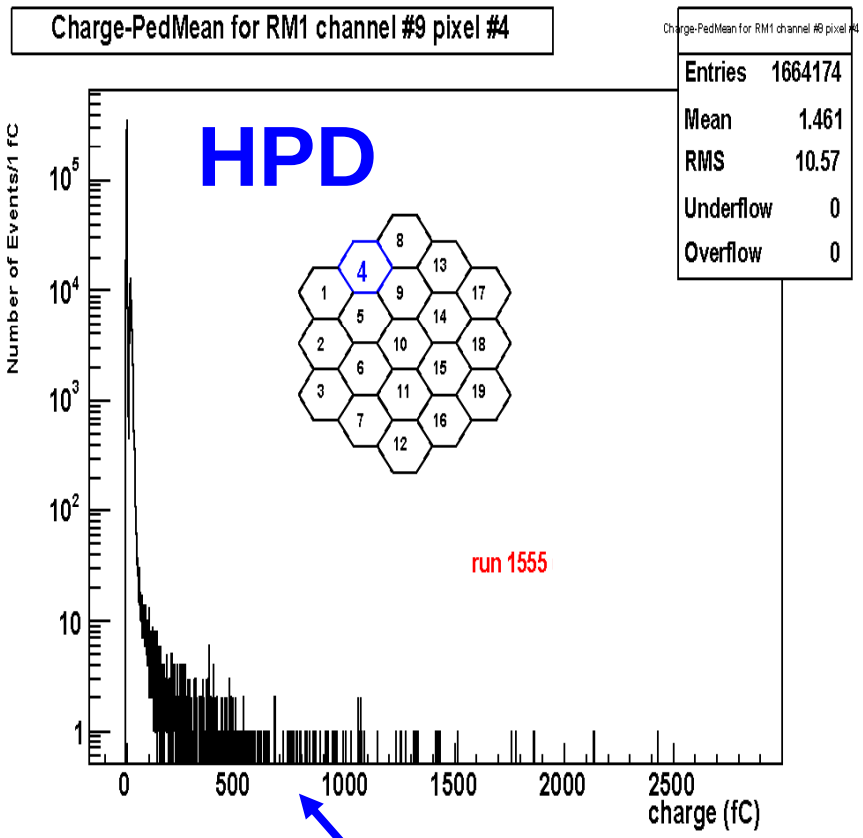


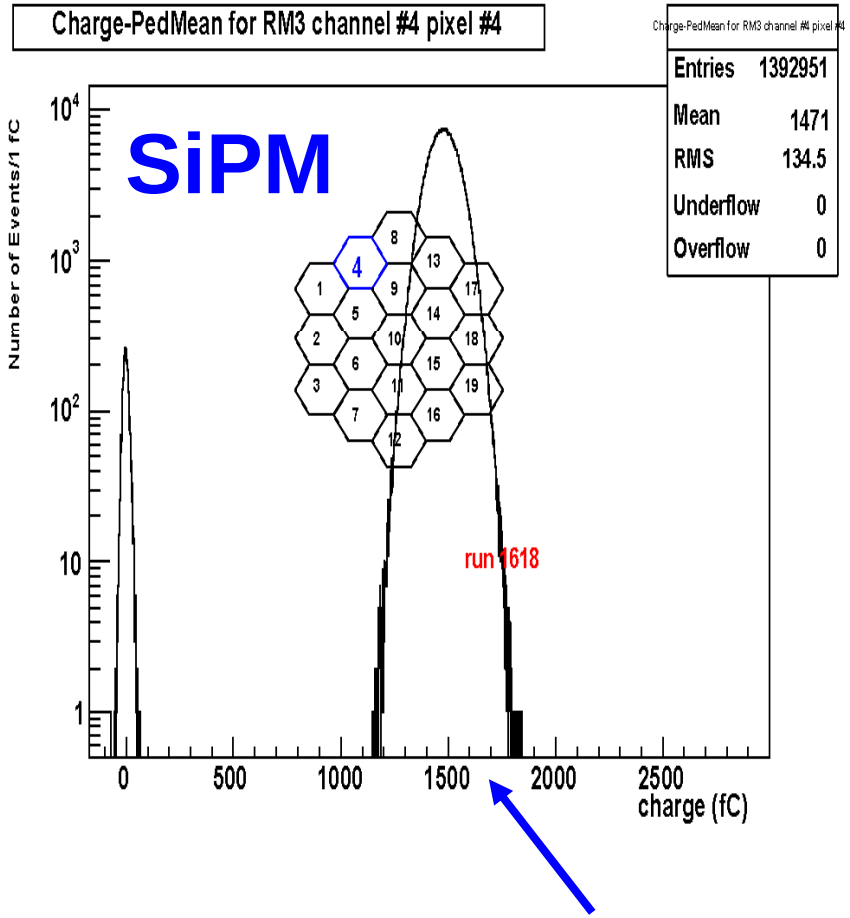
To Do: make the 12-fiber Megatile Connector
Mechanical Model

SiPM Testing in 4T Magnet

HPD vs. SiPM in 4T B Field

SiPMs are very quiet and operate at higher gain.





Overview of Supporting Talks

- SiPMs (Jim F., Jim R., Arjan, Aldo)
- QIE10 Specs (Julie)
- GOL/GBT (Julie)
- Rad Hard FPGA for TDC/CCA (Tullio, John)
- Cooling (Ianos)
- Simulation (Shuichi)