Columbian College of Arts & Sciences

THE GEORGE WASHINGTON UNIVERSITY

DAQ / GEM Issues

MUSE Funding Review

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On behalf of the MUSE Collaboration

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THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

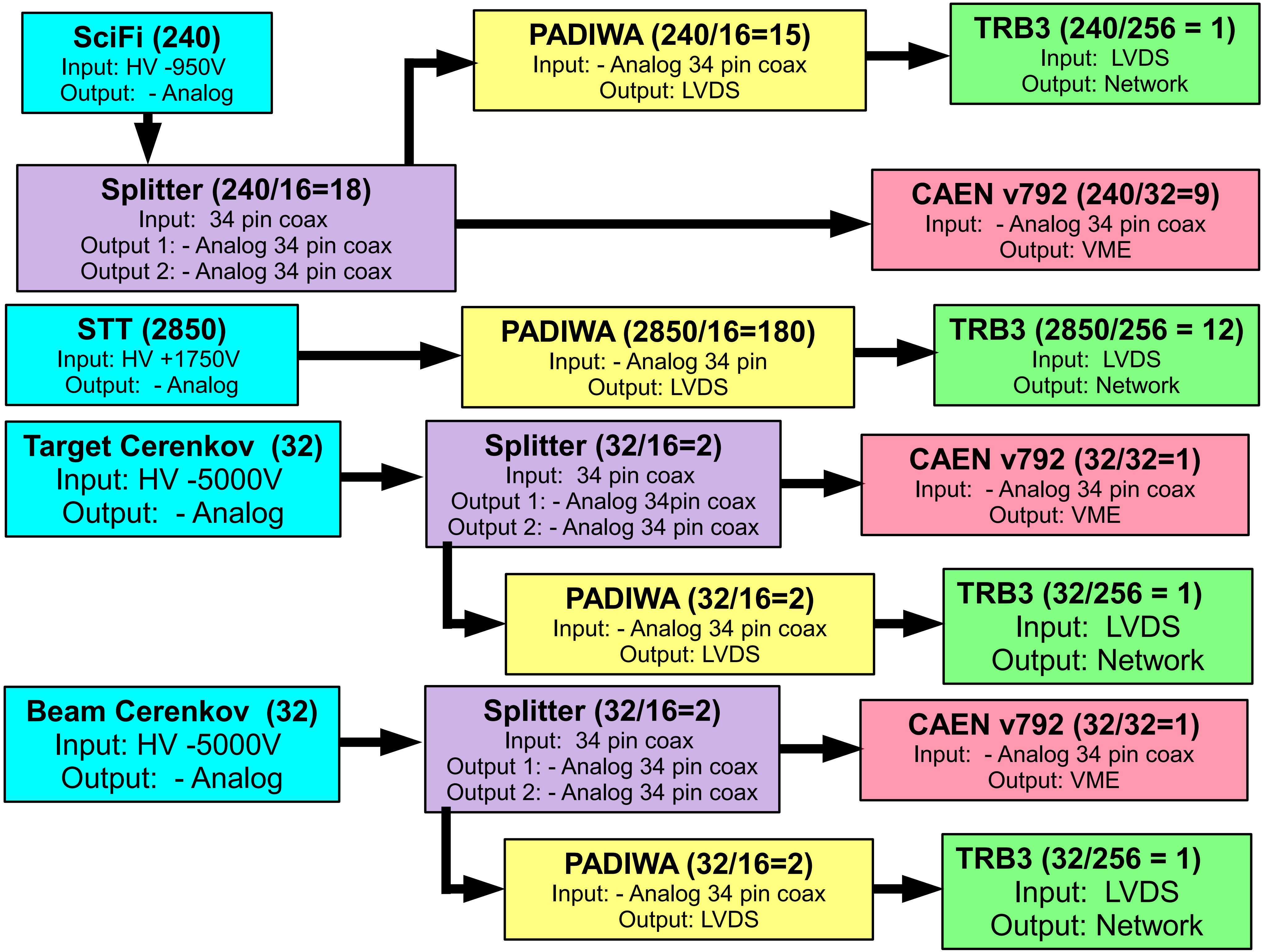
Outline

- Requirements
- Brief overview
- Charge measurement issues
- Timing, triggering and scaler issues
- Data creation & storage
- GEM issues
- Outlook

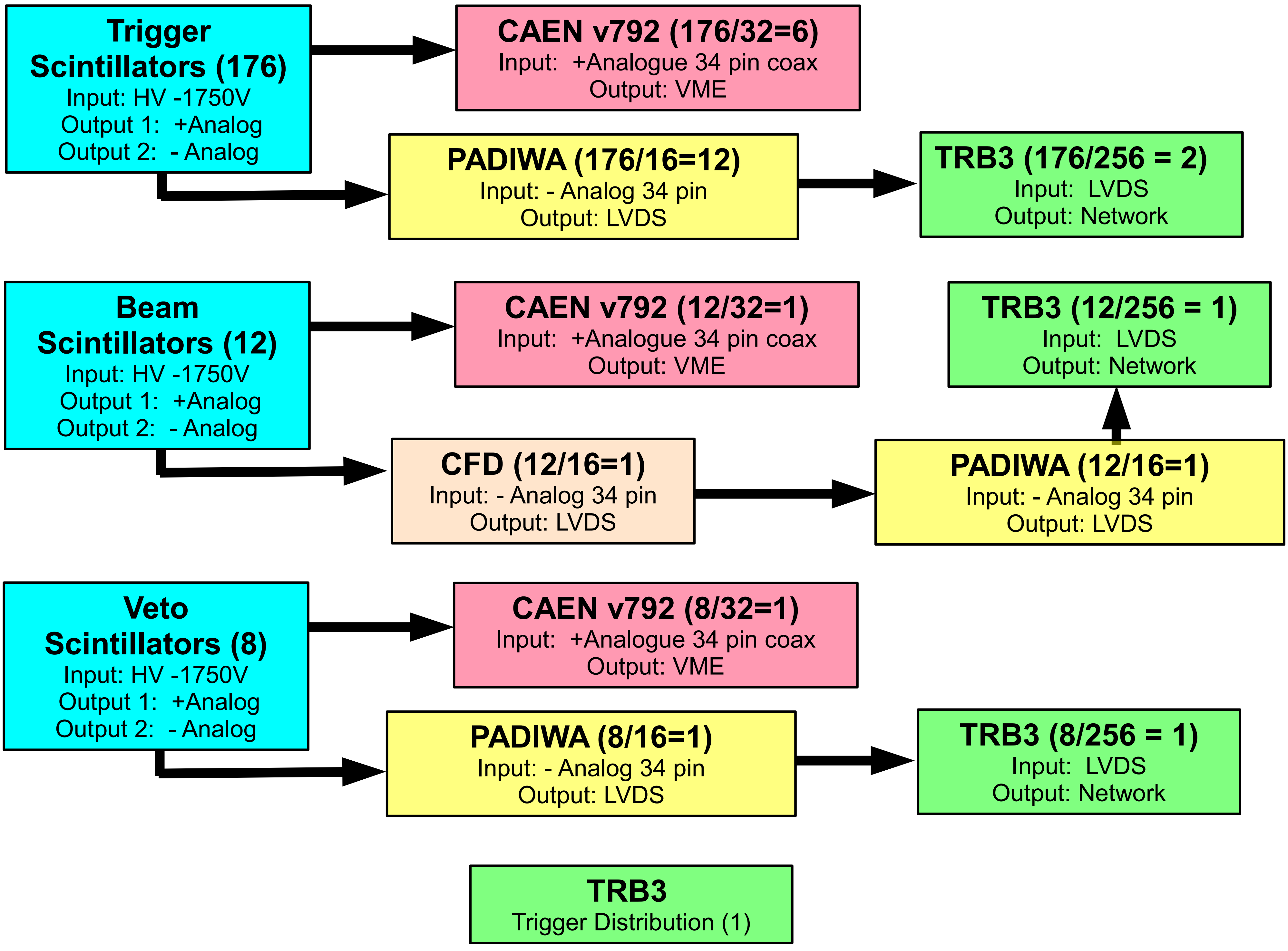
System Requirements

Detector	No. of Channels	Splitter	ADC	TDC	Trigger Input	Scaler
IFP Cerenkov	32	√	√	√	√	√
GEM	Existing Readout					
Scintillating Fibres	240	√	√	√	√	√
Target Cerenkov	32	√	√	√	√	√
Veto scintillators	8		√	√	√	√
Beam Monitor Scintillators	12		√	√		√
Straw Tube Tracker	2850			√		√
Scattered Particle Scintillators	176		√	√	√	√

- GEM readout pre-existing, needs to be faster
- Assumed largest number of Cerenkov channels, possibly only nine



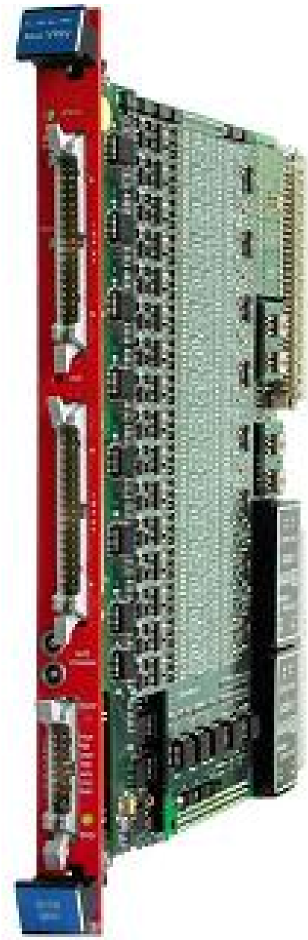
SciFi (240)
Input: HV -950V
Output: - Analog
Splitter (240/16=18)
Input: 34 pin coax
Output 1: - Analog 34 pin coax
Output 2: - Analog 34 pin coax
PADIWA (240/16=15)
Input: - Analog 34 pin coax
Output: LVDS
TRB3 (240/256 = 1)
Input: LVDS
Output: Network
CAEN v792 (240/32=9)
Input: - Analog 34 pin coax
Output: VME
STT (2850)
Input: HV +1750V
Output: - Analog
PADIWA (2850/16=180)
Input: - Analog 34 pin
Output: LVDS
TRB3 (2850/256 = 12)
Input: LVDS
Output: Network
Target Cerenkov (32)
Input: HV -5000V
Output: - Analog
Splitter (32/16=2)
Input: 34 pin coax
Output 1: - Analog 34pin coax
Output 2: - Analog 34 pin coax
CAEN v792 (32/32=1)
Input: - Analog 34 pin coax
Output: VME
PADIWA (32/16=2)
Input: - Analog 34 pin coax
Output: LVDS
TRB3 (32/256 = 1)
Input: LVDS
Output: Network
Beam Cerenkov (32)
Input: HV -5000V
Output: - Analog
Splitter (32/16=2)
Input: 34 pin coax
Output 1: - Analog 34 pin coax
Output 2: - Analog 34 pin coax
CAEN v792 (32/32=1)
Input: - Analog 34 pin coax
Output: VME
PADIWA (32/16=2)
Input: - Analog 34 pin coax
Output: LVDS
TRB3 (32/256 = 1)
Input: LVDS
Output: Network


Trigger Scintillators (176)
Input: HV -1750V
Output 1: +Analog
Output 2: - Analog
CAEN v792 (176/32=6)
Input: +Analogue 34 pin coax
Output: VME
PADIWA (176/16=12)
Input: - Analog 34 pin
Output: LVDS
TRB3 (176/256 = 2)
Input: LVDS
Output: Network
Beam Scintillators (12)
Input: HV -1750V
Output 1: +Analog
Output 2: - Analog
CAEN v792 (12/32=1)
Input: +Analogue 34 pin coax
Output: VME
TRB3 (12/256 = 1)
Input: LVDS
Output: Network
CFD (12/16=1)
Input: - Analog 34 pin
Output: LVDS
PADIWA (12/16=1)
Input: - Analog 34 pin
Output: LVDS
Veto Scintillators (8)
Input: HV -1750V
Output 1: +Analog
Output 2: - Analog
CAEN v792 (8/32=1)
Input: +Analogue 34 pin coax
Output: VME
PADIWA (8/16=1)
Input: - Analog 34 pin
Output: LVDS
TRB3 (8/256 = 1)
Input: LVDS
Output: Network
TRB3
Trigger Distribution (1)

Hardware: Splitters

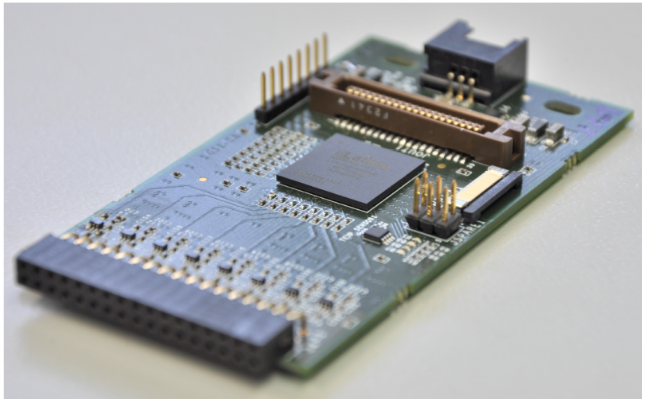
- SciFi splitters built into the bases of the PMTs
- Splitters for Cerenkov exist if we chose Photek PMT
- Need more channels for Photonis, splitter from PMT cost difference
- No splitters necessary for scintillators as they have two PMT outputs

Charge Measurement Issues

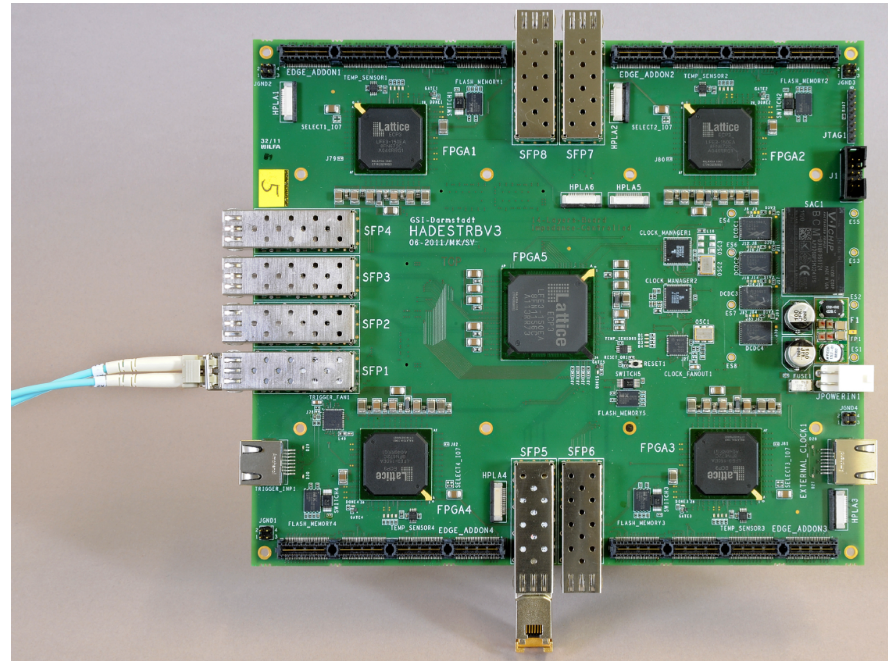


- Scintillator signals positive polarity, others negative
- Planned ADC: CAEN v792
- CAEN quoted for both positive & negative ADCs
- V792 only negative: CAEN offering convertor board
- Alternate possibility: Mesytec MQDC-32
  - ➔ Mesytec both +ve & -ve in same module
  - ➔ Mesytek 40% more expensive
- CAEN v792 already implemented in MIDAS
- Borrowed Mesytec MQDC-32 being read out in MIDAS
- Planned parallel readout in four five-ADC groups
- Crate power load may be an issue
- Power load and positive readout both under testing by CAEN

Triggering, Timing & Scalers: TRB3 & PADIWA System

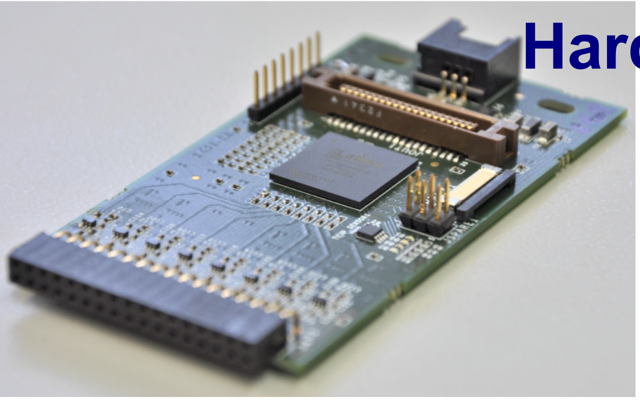


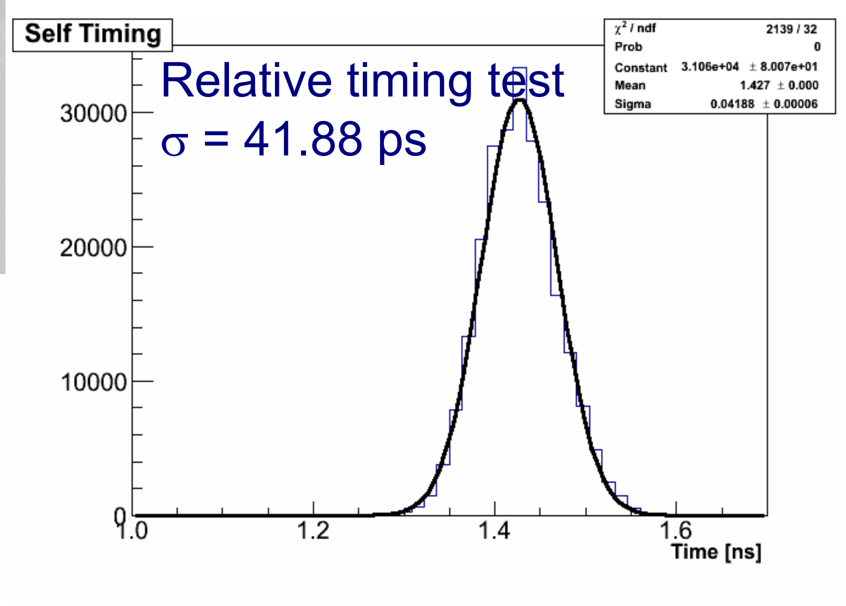
- PADIWA – discriminator card
- Will be used for all timing detectors
- 16 channels
- Produces LVDS signal for TRB3
- Cost-effective, 5V power supply
- Can be deployed directly at detector
- Produced by GSI

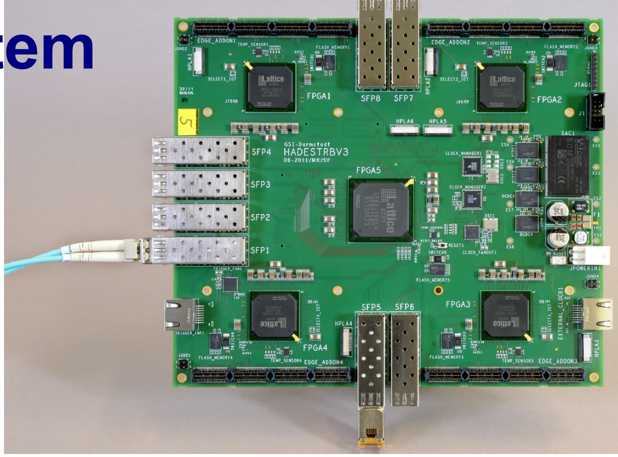


- TRB3 FPGA-based readout
- Designed by GSI as complete readout solution
- Hosts: TDC, Scaler, Trigger
- “Stand alone” module
- Simple 48V power supply
- Read out via Gigabit ethernet
- Rates of ***O***(100 kHz) possible

Hardware: TRB3 & PADIWA System

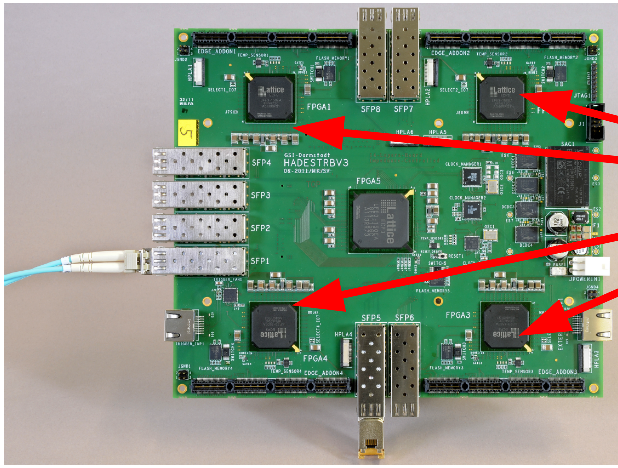






- Precise, cost-effective, high channel density (256 channels / board)
- PADIWA customizable for each detector if necessary
- TRB3 & single PADIWA already being read into MIDAS data stream
- Used as TDC ~40 ps timing resolution in initial **rough** readout test at PSI
- 11 ps resolution, demonstrated in bench tests, better than needed
- Scaler functionality programmed on board, readout to be tested
- Excellent support from Michael Traxler (GSI)
- Agreement with Mainz to test PADIWA / Mainz board readout

Triggering: TRB3 as Trigger



Each peripheral FPGA manages 1 interface board
Each interface board manages 4 PADIWAS

- TRB3 has five FPGAs
- Peripheral FPGAs manage PADIWAS, have most TDC / Scaler logic
- Central FPGA manages interactions and has space for trigger logic
- There are several direct lines for trigger signaling between boards
- A single trigger-equipped FPGA will do final logic and distribution
- Trigger decision in 80 ns
- GSI loaned us a third TRB3 & PADIWA group for trigger development
- Rutgers will investigate, work on adding code
- Use of TRB3 removes need for CAEN V1495 & reduces splitter needs

General Trigger Procedure

TABLE VIII. Probability of identifying a particle as a given type from RF times measured by the three SciFi planes. Geometric efficiency and cut efficiency with a simple algorithm are included. See text for details.

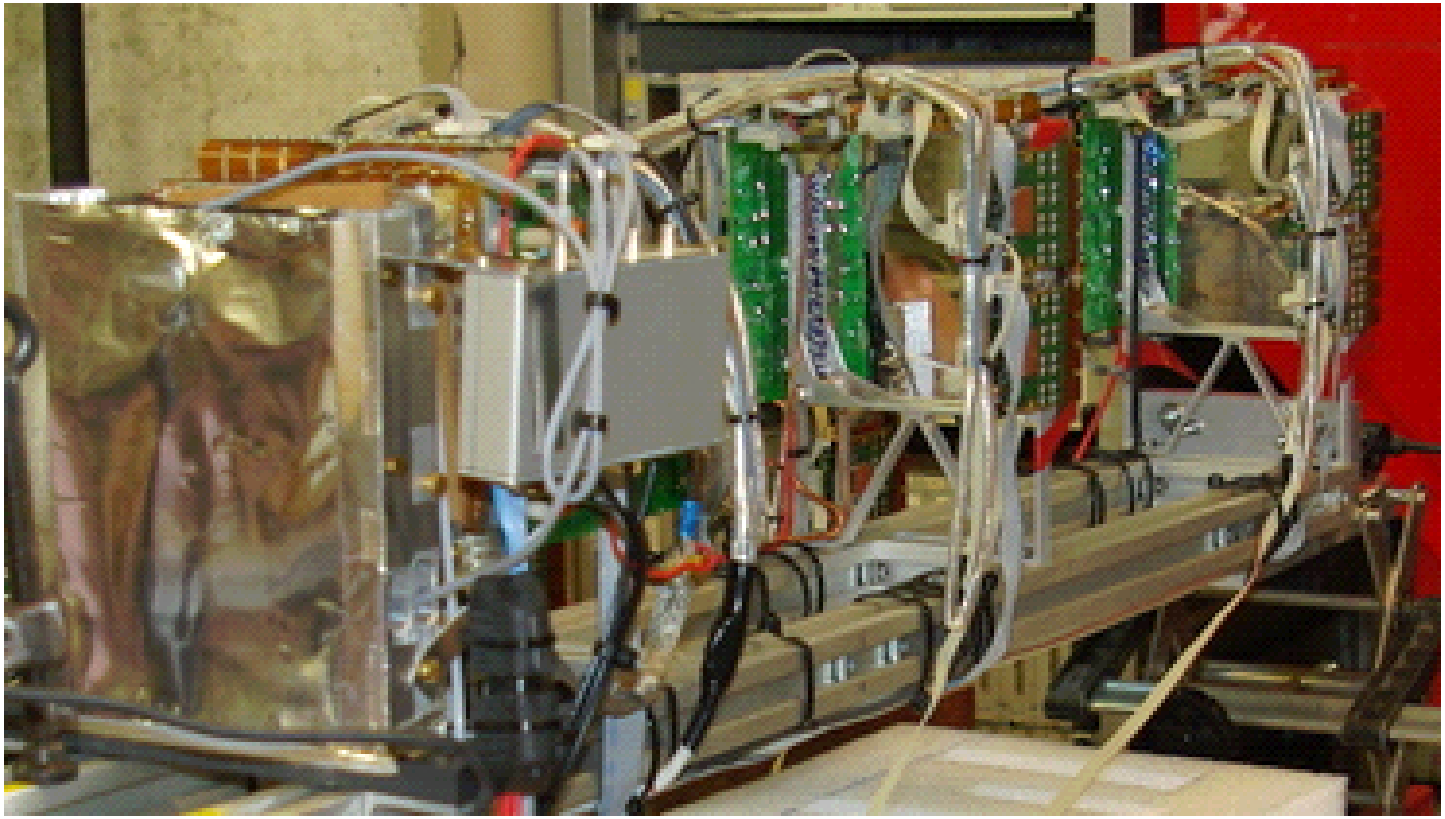
Momentum (MeV/c)	Detector	Particle Type	Fraction e ID	Fraction μID	Fraction π ID
115	Target SciFi	e	0.9920	0.0000	0.0000
115	Target SciFi	μ	0.0000	0.9714	0.0198
115	Target SciFi	π	0.0000	0.0000	0.9918
153	Target SciFi	e	0.9920	0.0105	0.0000
153	Target SciFi	μ	0.0000	0.9999	0.0000
153	Target SciFi	π	0.0000	0.0070	0.9903
210	Target SciFi	e	0.9920	0.0000	0.0080
210	Target SciFi	μ	0.0000	0.9924	0.0072
210	Target SciFi	π	0.0001	0.0000	0.9998

- Primary trigger: (beam e / μ) + (scattered particle in scintillators) + NOT(Veto)
- Beam particle determined from RF time in SciFi + RF time in Target Cerenkov + Time in IFP Cerenkov (when used)
- Scattered particle requires hits in BOTH scintillator plane, with loose directional cut

Data Storage

- 2kHz design trigger rate, data rate of 0.6 MB/s without GEMS
- Assuming pedestal suppression and no noise, one extra beam particle
- Total experimental data = 16TB, before adding GEM data
- Including GEMS increases data rate by ~factor of 6
- Looking into reducing GEM data production
- Anticipate purchase of 90TB RAID array
- Raw data duplicated at GW
- Reduced data stored at all institutions analysing MUSE data

Status: GEM Chambers



- Electronics pre-existing
- Currently being read into MIDAS
- Need work to speed up readout algorithm
- Produce large data volume

Action Plan: GEM Chambers

- Presently <400 Hz (1.8ms deadtime / event) with 2 telescopes
- Goal = 2-2.5 kHz @ <20% deadtime (100us dead time per event)

Immediate actions (low risk)

- Only read one GEM telescope (x2 speed - 900us)
- Implement block transfer (x2 speed - 450us)
- Use 3 VME crates (one per GEM element), requires change of cabling (x3 speed – 150us)

Further Actions (requiring R & D, some risk)

- Occupancy and zero suppression (exists in firmware, not tested)
  - ➔ Occupancy @ 50kHz: 1 cluster/ev. x (3+3) strips/cluster <= 2%
  - ➔ Occupancy @ 5MHz: 2-4 clusters + noise → 10-15%
- Fast-RAM for buffering digitized APV data (firmware is developed)

- Moved one GEM telescope with readout back to HU to investigate

GEM Feasibility

- GEMS are the “bottleneck”
- Low risk actions should bring 150us GEM readout (30% deadtime @ 2kHz)
- R&D could possibly bring much more: will be investigated in parallel
- Note: UVa (N. Liyanage) expect / have achieved much better GEM readout performance, this should be do-able!
  - ➔ UVa: Planning 10 kHz for SBS (50,000 channels).
  - ➔ MPD: Achieved 1-2 kHz for 2,048 channels, no zero suppression
  - ➔ SRS: 2 kHz with 2,048 channels, 6 time samples, no zero suppression
  - ➔ Achieved 600 Hz with SRS and 9k channels (equivalent to 3.6kHz with MUSE)

Overall Feasibility

- TRB TDC readout nearly dead time free
- Tests of block transfer on v792 indicate 100us readout time for 5 in chain-block transfer mode safely achievable
- GEMS are the “bottleneck”
- Conservative improvements should bring 150us GEM readout (30% deadtime @ 2kHz)
- R & D, less certain, investigations in parallel, could speed things up further
- Should we be stuck at 150 to 200us, (30 – 40% deadtime @2kHz), have other options to achieve necessary statistics & manageable event rate:
  - ➔ Pre-scale electron triggers
  - ➔ Pre-scale forward-angle triggers
  - ➔ Alter time balance between settings: measure longer in higher-dead time configurations

Status: General Overview

- Reading out into MIDAS:
  - ➔CAEN v792 ADC
  - ➔TRB3 & PADIWA TDC
  - ➔GEM chambers
  - ➔CAEN v272 I/O register

- Modules on loan for development
  - ➔Mesytec MQDC-32 ADC
  - ➔Extra TRB3 & PADIWA for trigger development

- Need input registers for VME crates to save event numbers

- All necessary modules can be delivered within four months of ordering

Conclusion

- Well developed solution planned
- Few potential cost / hardware improvements to be decided
- Test modules on loan for all outstanding questions
- GEM readout improvement underway at Hampton
- Should be ready to order modules as soon as funding decision received