Dual Readout: electronics option

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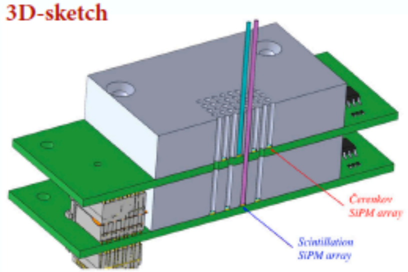
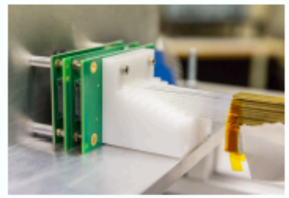
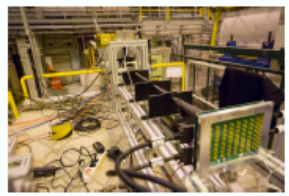
Test Beam 2017/18: SiPM readout

Two different tiers: Cherenkov upstream, scintillation downstream.

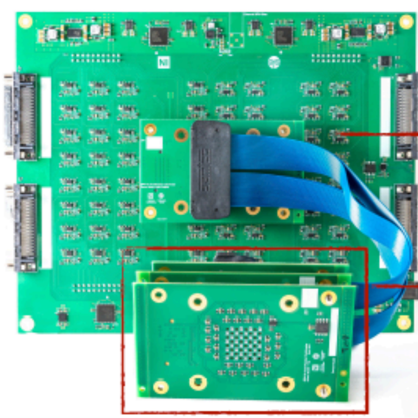
3D-sketch







HAMAMATSU S13615-1025	
Sensitive area	1×1 mm^2
Cell pitch	25 μm
No. of pixels	1584
Peak Photon Detection Efficiency	25%
Breakdown voltage V_{br}	53 V
Recommended operational voltage V_{op}	V_{br} + 5V
Gain at V_{op}	7×10^5
Dark Count Rate at V_{op}	50 kps
Optical Crosstalk at V_{op}	1%



Mother board:

64 DC-coupled amplifiers (with ~1μs shaping time).

Signals routing to the digitisation system.

2-tier daughter board with extension cable:

Individual bias voltage with fine adjustment (3V-range).

Temperature measurement for gain compensation.

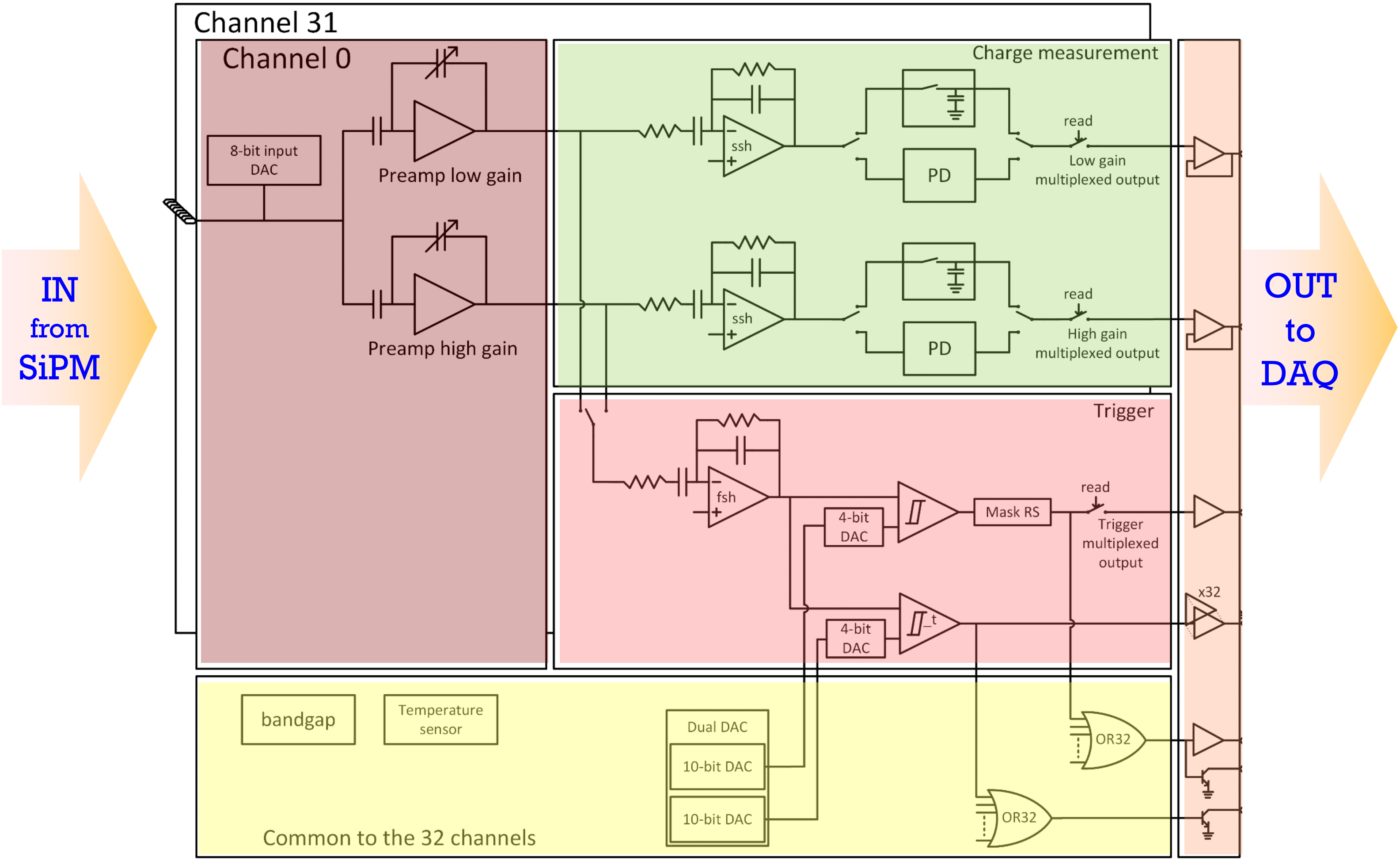
2 MADA Boards: a 32 channel digitizer with a sampling rate of 80MSpS/14-bit ADC and an FPGA based charge integration algorithm

Citiroc1A

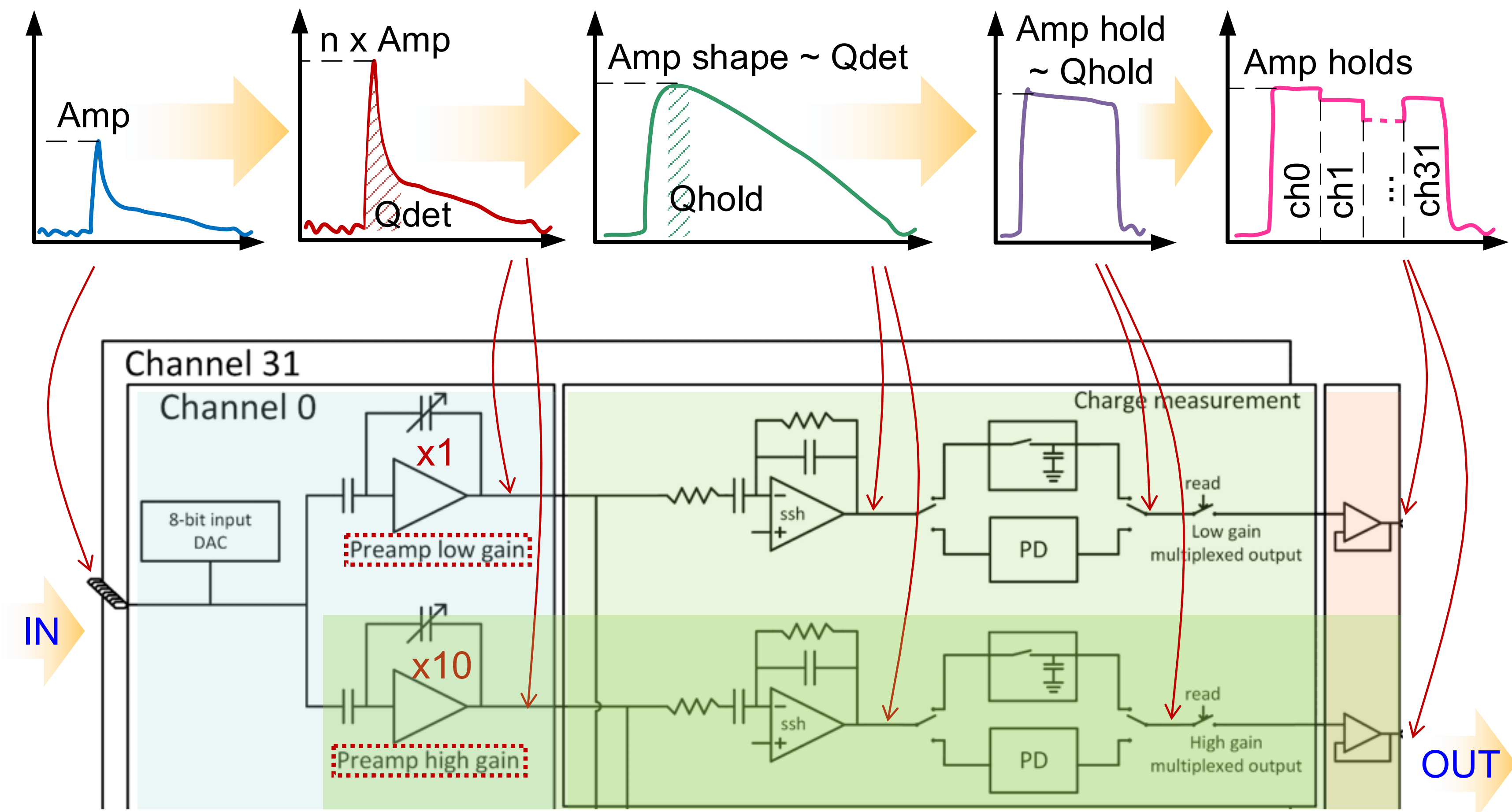
weeroc

Detector Read-Out	SiPM, SiPM array
Number of Channels	**32**
Signal Polarity	Positive
Sensitivity	Trigger on **1/3 of photo-electron**
Timing Resolution	Better than **100 ps RMS** on single photo-electron
Dynamic Range	0-400 pC i.e. 2500 photo-electrons @ 10^6 SIPM gain
Packaging & Dimension	TQFP160-TFBGA353
Power Consumption	225mW - Supply voltage: 3.3V
Inputs	32 voltage **inputs with independent SiPM HV adjustments**
Outputs	**32 digital outputs (for timing)** **2** multiplexed **charge output, 1** multiplexed **hit register and 2 trigger outputs**
Internal Program. Features	32 HV adjustment for SiPM (32x8bits), Trigger Threshold Adjustment, channel by channel gain tuning, 32 Trigger Masks, Trigger Latch, internal temperature sensor

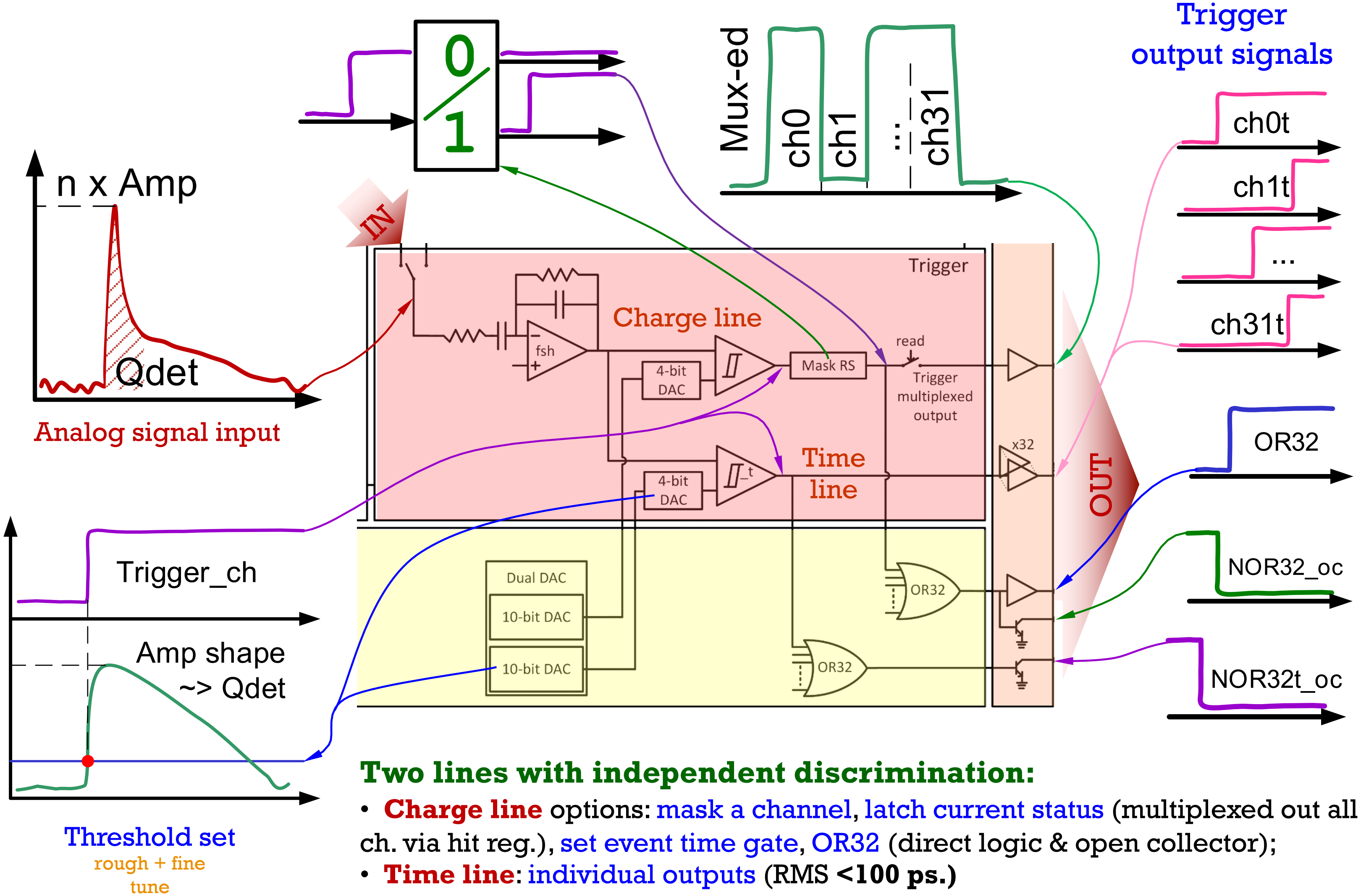
Citiroc1A: block scheme



Citiroc1A: charge measurements



Citiroc1A: trigger and timing

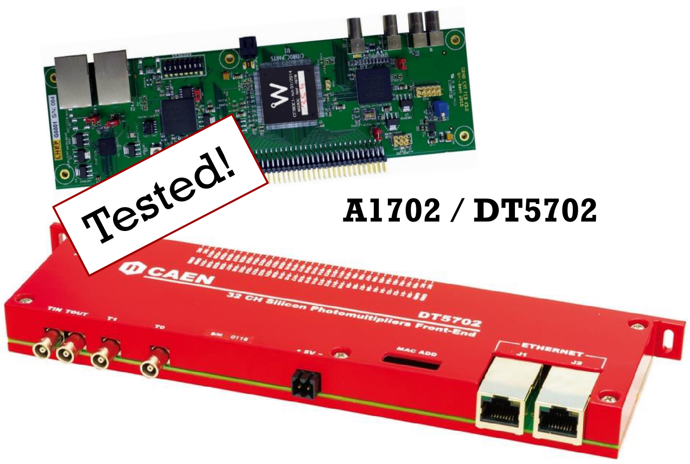


Two lines with independent discrimination:

- **Charge line** options: mask a channel, latch current status (multiplexed out all ch. via hit reg.), set event time gate, OR32 (direct logic & open collector);
- **Time line**: individual outputs (RMS **<100 ps.)**

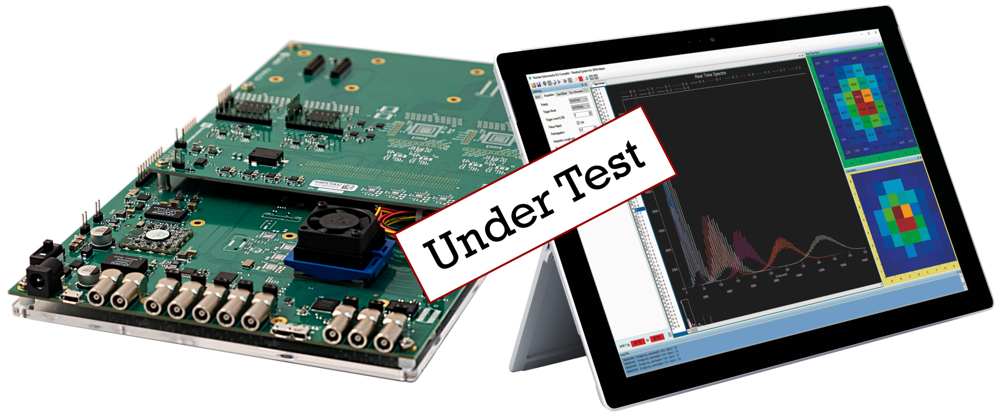
The evaluation boards

CAEN
Tools for Discovery



A1702 / DT5702

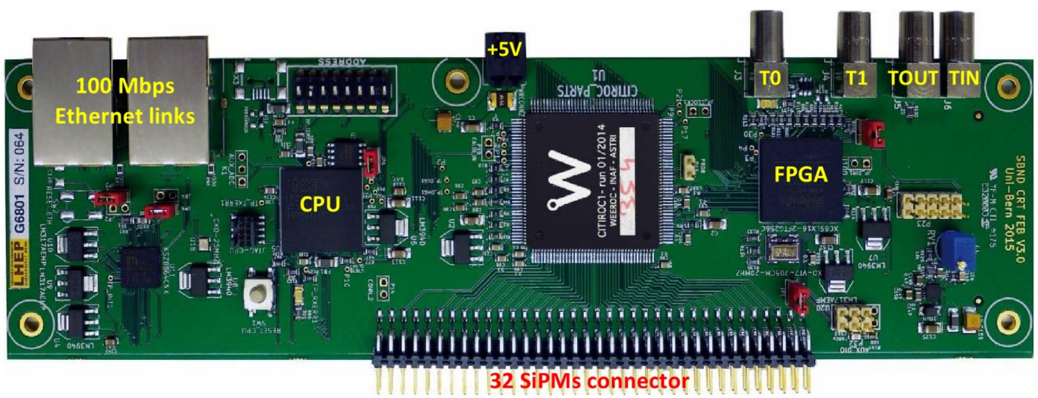
DT5550W



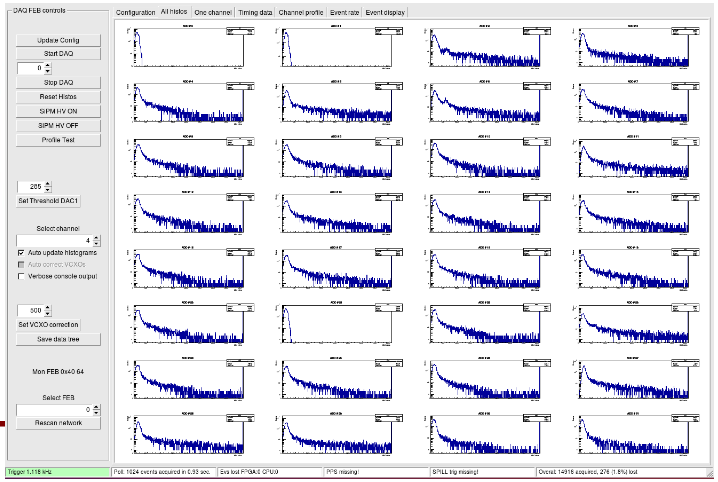
FERS - Unit

DT5702: general description

- Provides the bias voltage in the range of 20-90 V. The HV fine adjustment is performed by the ASIC (0.5-4.5V)
- Allows to probe the analogue signal for debug purpose (1ch at the time)
- The timestamp is measured in the FPGA with a resolution of 1ns
- Trigger logic (coincidence of adjacent channels, OR –logic among selected channels) doesn't allow the use of an external trigger
- Daisy chain of up to 256 boards into one network interface

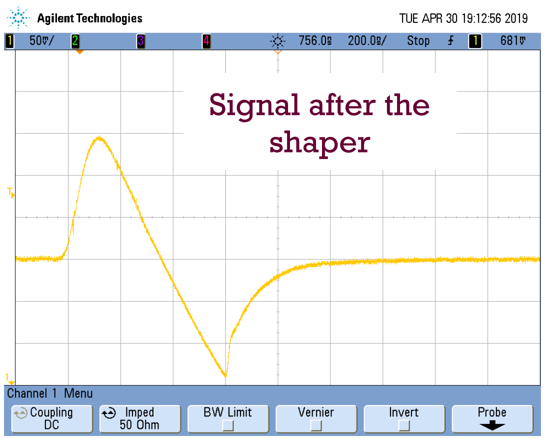


DaQ based on Root script



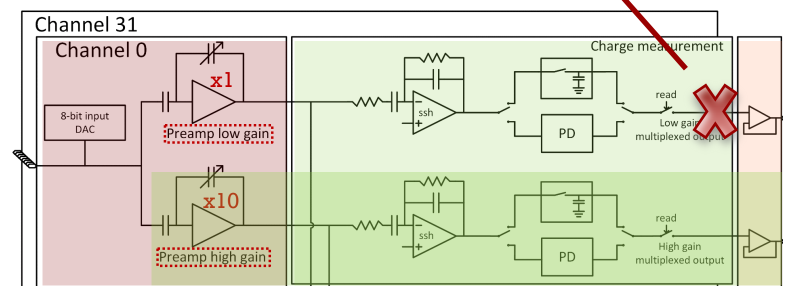
DT5702: Signal qualification

Typical response to a fast LED

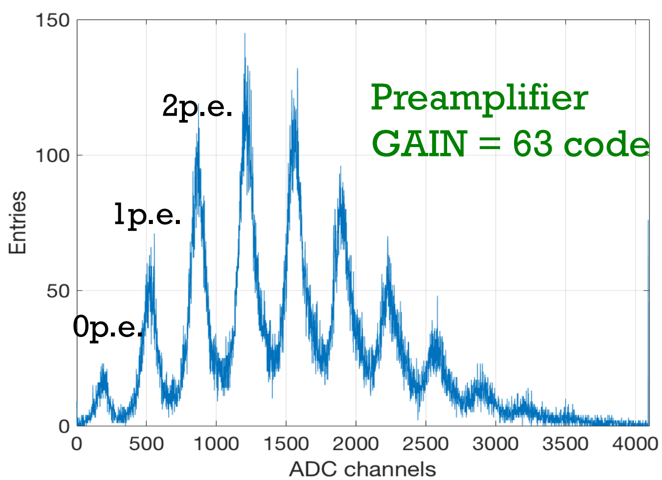


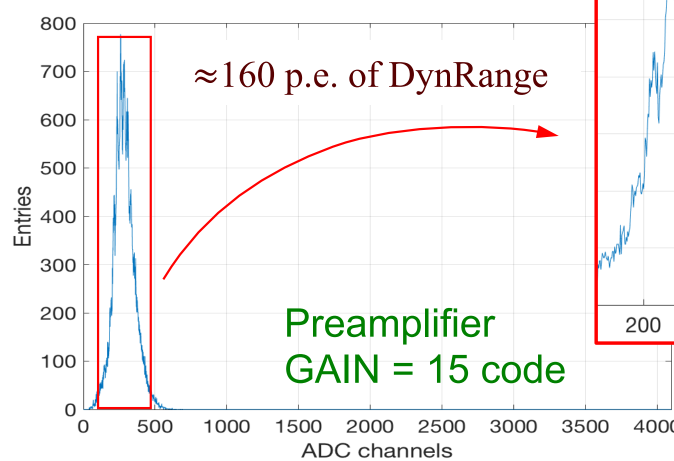
Hmamatsu SiPM:
1.3 x 1.3 mm²
50mu cell size

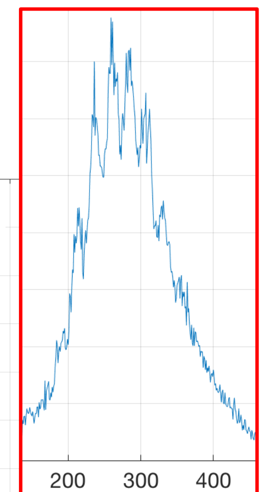
The branch low gain is not readout



Multiphoton spectra with two different preamplifier settings







Alcune considerazioni

La DT5702 ci ha permesso di sondare le potenzialità del Citiroc1A (si è ottenuto un buon multiphoton), ma abbiamo anche osservato alcune limitazione per la nostra applicazione:

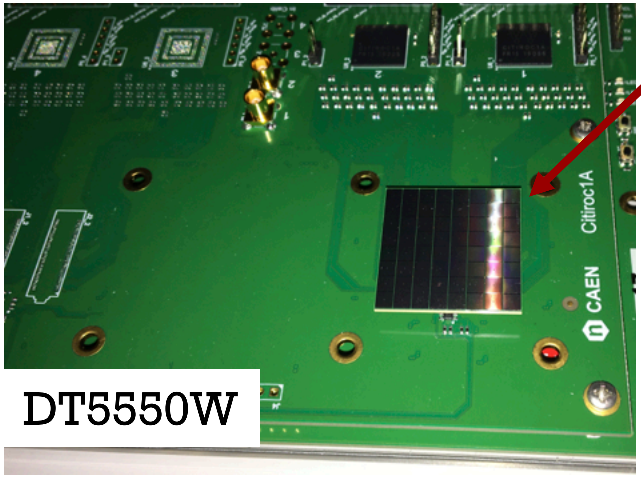
- Non abbiamo potuto studiare l'overlap nelle due linee analogiche (alto / basso guadagno)
- Vorremmo una risoluzione temporale dei segnali più spinta
- Vorremmo poter lavorare con trigger esterno

La DT5550W è il passo successivo:

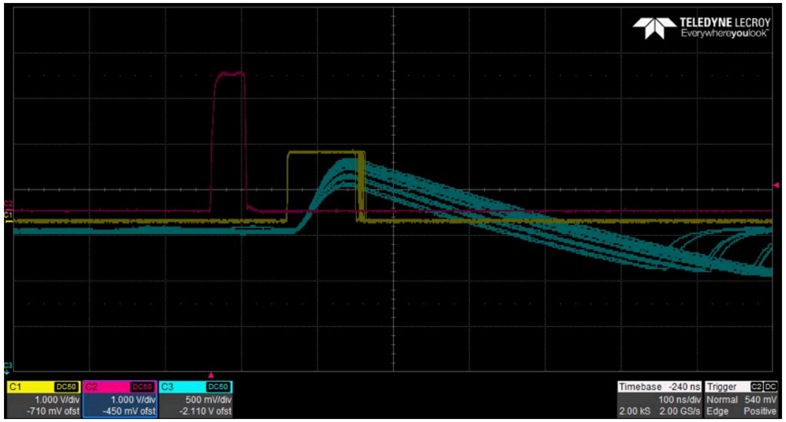
- Ci dovrebbe permettere di studiare i punti lasciati in sospeso con la board precedente
- Essendo la base di sviluppo della FERS, ci dovrebbe permettere di avere un ruolo chiave nella finalizzazione delle caratteristiche delle nuove board

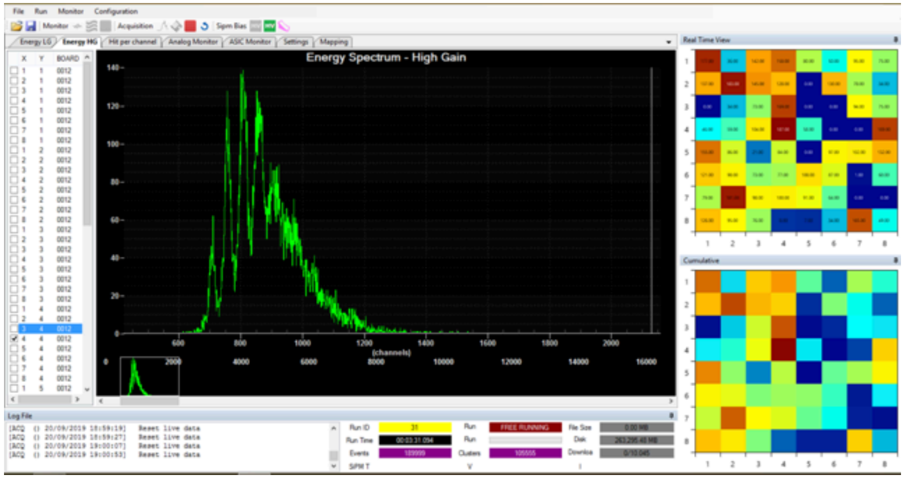
DT5550W

DT5550W: qualification (I)



Sensore utilizzato per la qualifica: matrice Hamamatsu di 64 SiPM 3x3 mm^2 con singola cella di 50μm



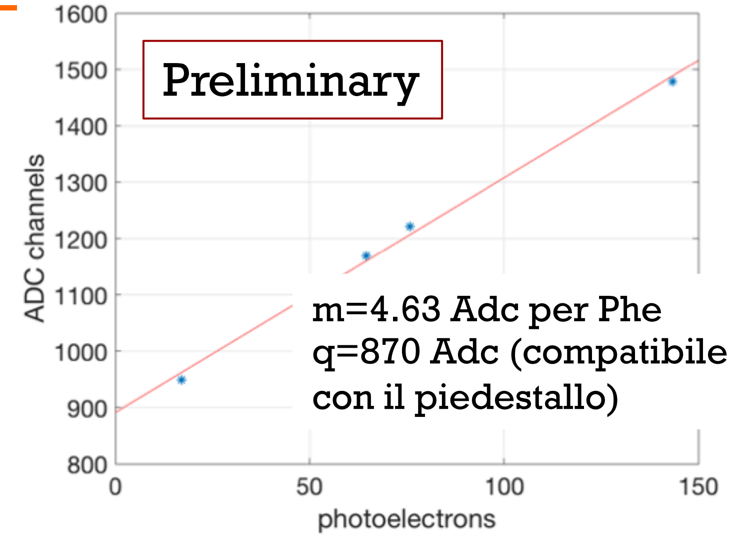


Multiphoton ottenuto impulsando il sensore con LED e acquisendo i dati con trigger esterno.
High-Gain con guadagno 30 a.u.

DT5550W: qualification (II)

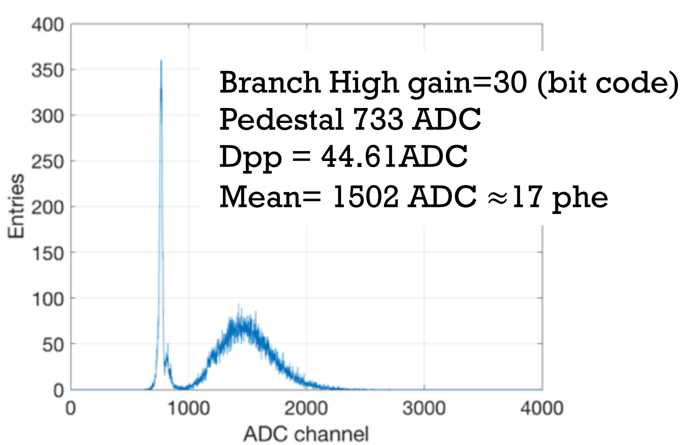
Abbiamo una misura preliminare del range dinamico in Ph-e:

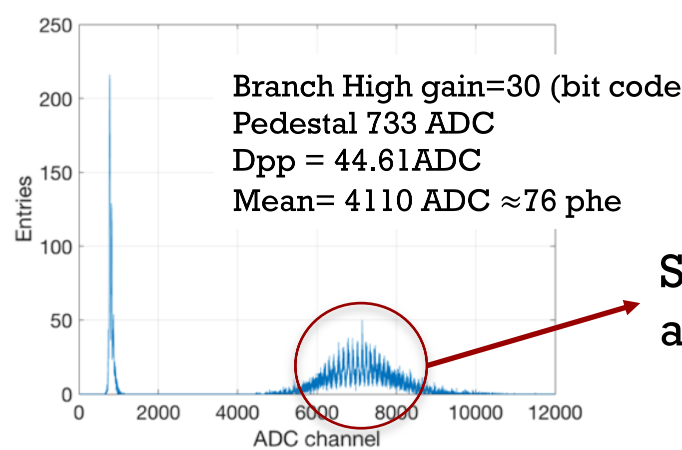
- Abbiamo misurato il Dpp sul Branch High Gain (setting 30 a.u.)
- Abbiamo acquisito spettri con intensità di luce crescente fino a mostrare contemporaneamente i segnali sul High-Gain and Low-Gain (setting 20 a.u.)
- Range dinamico stimato ≈2500 phe (la linearità è ancora da studiare)



Purtroppo abbiamo anche riscontrato qualche inconveniente!

L'azienda darà tutto il supporto necessario

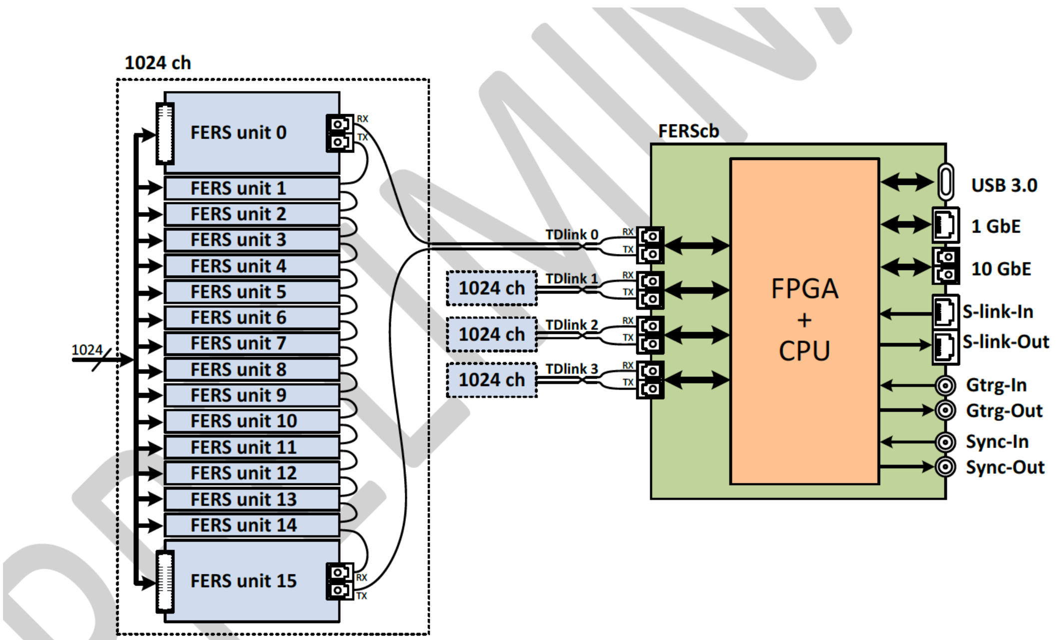




Struttura a picchi anomala

How to handle a “medium-size” calorimeter?

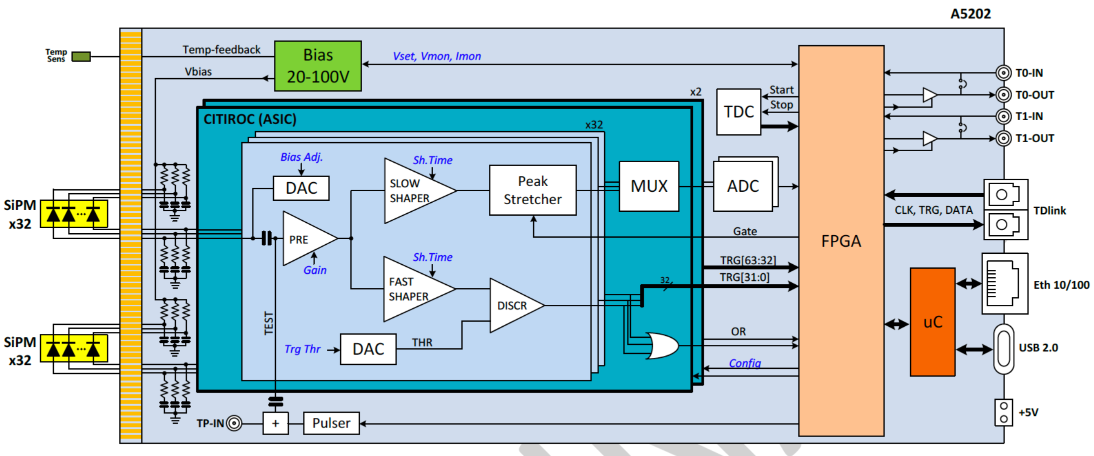
If the Citirorc1A qualification will fulfil our requirements we still need a compact and scalable solution for a test beam



The basic principle

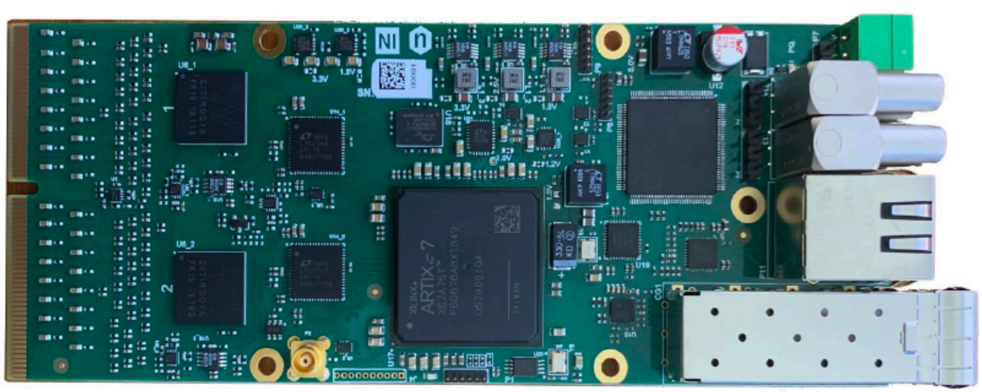
- FERS-unit can be used in standalone or connected to the system
- Up to 16 FERS-unit can be connected in daisy-chain (FERSnet)
- The FERSnet data throughput is up to 200 MB/s
- The FERScb is a data collector housing 4 high speed optical link (TDLink)
- The connection to the host PC is performed with a 10 Gbit ethernet
- The FERScb has an embedded ARM processor (Quad Core) running Linux for data processing / data compression

FERS unit - Citirorc: block scheme



The basic principle

- 2 Citiroc1A (64 ch)
- Timing with a TDC implemented into the FPGA (≈ 0.5 ns)
- 2 ADC to measure the charge
- 1 HV power supply (20 – 100V) with temperature compensation
- Interface for readout



60 mm

150 mm

In conclusione

- Il Citiroc1A sembrerebbe ancora poter fare al caso nostro, ma bisogna completare la qualifica

- La scheda DT5550W è stata consegnata agli inizi di Settembre ed è in fase di commissioning. Anche se già abbiamo riscontrato delle anomalie, Andrea Abba ha garantito il pieno supporto per risolvere i problemi riscontrati

- Il debug della DT5550W sarà un'attività cruciale per evitare problemi sulla FERS, l'evoluzione compatta che vorremmo utilizzare per il test beam

- La FERS non è ancora in commercio anche se CAEN ha prodotto qualche prototipo per il debug/commissioning.

- In parallelo abbiamo ordinato qualche SiPM di Hamamatsu con cell size di 10 μm e 15 μm per studiare anche il problema dell'estensione dinamica del sensore. I sensori sono stati consegnati, le board di lettura sono state modificate e tra qualche settimana dovremmo ricevere gli assembly per poter cominciare con i test

Backup

IDEA: Dual Readout calorimeter

- Preparazione prototipo 10 cm x 10 cm x 100 cm (totale = 58.5 + 8 SJ)
  - Full containment EM
  - Studio meccanica con capillary metallic e elettronica CAEN
  - Previsto test beam a DESY in autunno
  - Potenziale call di CSN5 per full containment hadronic calorimeter
    - Vedi talks Ferrari/Santoro
- Catania: test SiPM 5 kE
- Pavia:
  - Meccanica capillari metallici 4 kE, fibre (forse UK) 5 kE SJ
  - Consumi test beam 3 kE SJ
- Milano:
  - Schede interfaccia SiPM 15 kE
  - Meccanica interfaccia SiPM 3 kE
  - SiPM 4.5 kE
  - DAQ board con citiroc 25 kE ?

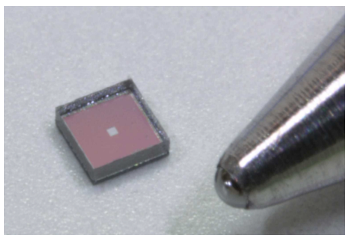
Collaborazioni:

RBI (Croazia)

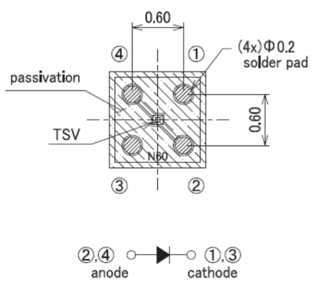
U. Sussex (UK)

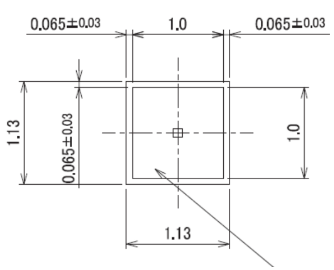
The chosen SiPM

The sensor in use has 25 μm cell pitch (S13615-1025)



Parameters	S13615 -1025	S13615 -1050	Unit
Effective photosensitive area	1.0x1.0		mm^2
Pixel pitch	25	50	μm
Number of pixels / channel	1584	396	-
Geometrical fill factor	47	74	%





Parameters		Symbol	S13615 -1025	S13615 -1050	Unit
Spectral response range		λ	320 to 900		nm
Peak sensitivity wavelength		λp	450		nm
Photon detection efficiency at λp*3		PDE	25	40	%
Breakdown voltage		V_{BR}	53 ±5		V
Recommended operating voltage*4		V_{op}	V_{BR} + 5	V_{BR} + 3	V
Dark Count	Typ.	-	50		kcps
	Max.		150		
Crosstalk probability	Typ.	-	1	3	%
Terminal capacitance		Ct	40		pF
Gain*5		M	7.0×10^5	1.7×10^6	-

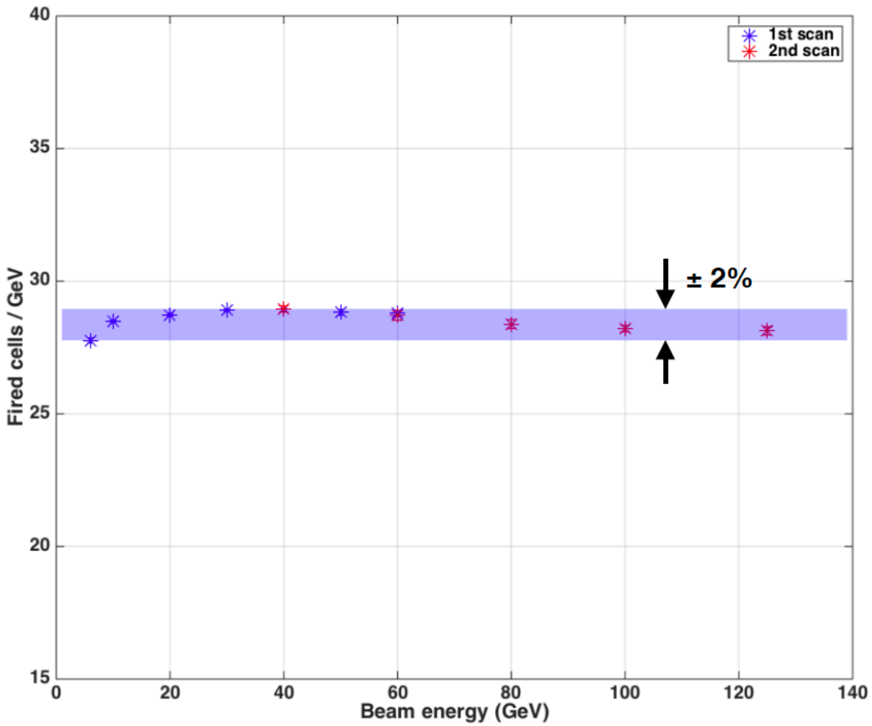
Summary plot from 2017

Cherenkov light yield:

$V_{Bias} = 5.5\ V_{ov}$ (57.5 V) and ***PDE ~ 25%.***

~ 28.6 Cpe/GeV, 2% linear from 6 to 125 GeV.

Correcting for 36% e.m. energy containment: ~ ***69 ± 5 Cpe/GeV.***



More than ***2 times larger*** than what measured with the previous* PMT-based modules.

Example:

Stochastic term of RD-52 e.m. resolution could be improved from ~14%/√E up to ~***12.5%/√E***.

(sampling fluctuations: ~ 9%/√E).

M. Antonello, VCI2019 conference

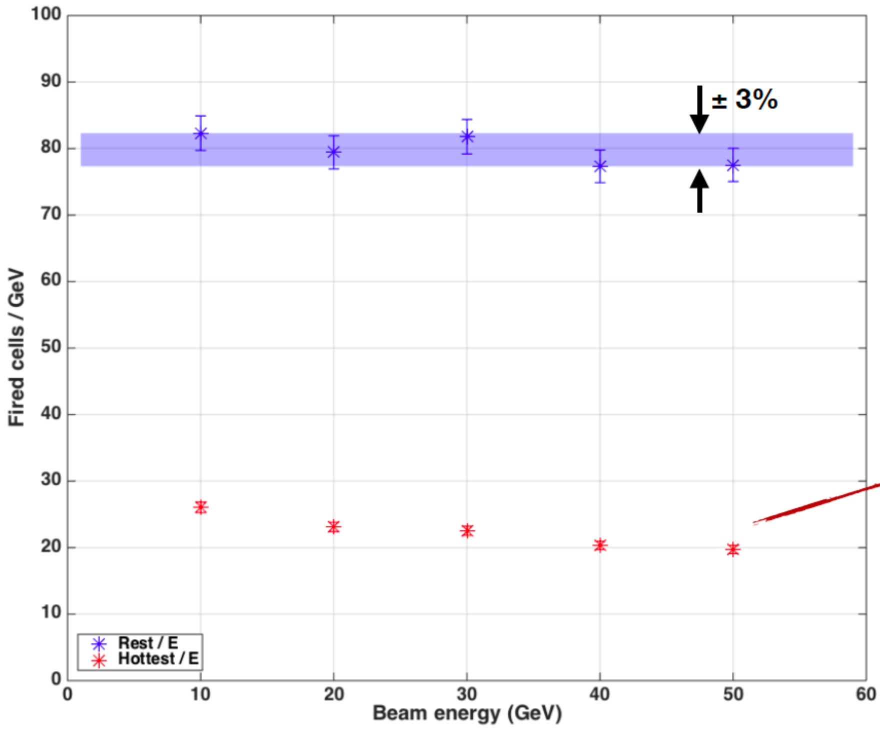
Summary plot from 2017

Scintillation light yield:

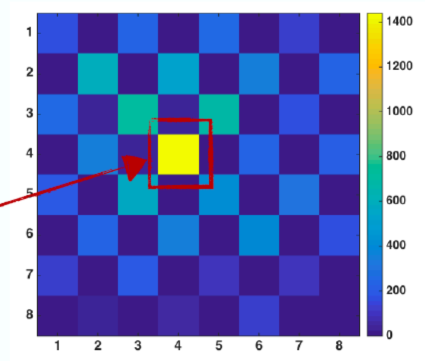
$V_{Bias} = 0.5\ V_{ov}$ (52.5 V) and ***PDE ~ 2%.***

@ **10 GeV** (corrected for non-linearity response): ~ ***108.4*** fired cells/GeV.

Correcting for 45% e.m. energy containment and occupancy effects: ***~3200 ± 200 Spe/GeV.***



Scintillation signal is more than ***50 times greater*** than the Cherenkov one.



Attenuation needed!!!

M. Antonello, VCI2019 conference

Summary plot from 2018

Scintillation light yield:

V_{Bias} = ***0.5 V_{ov}*** (52.5 V) and ***PDE ~ 2%.***

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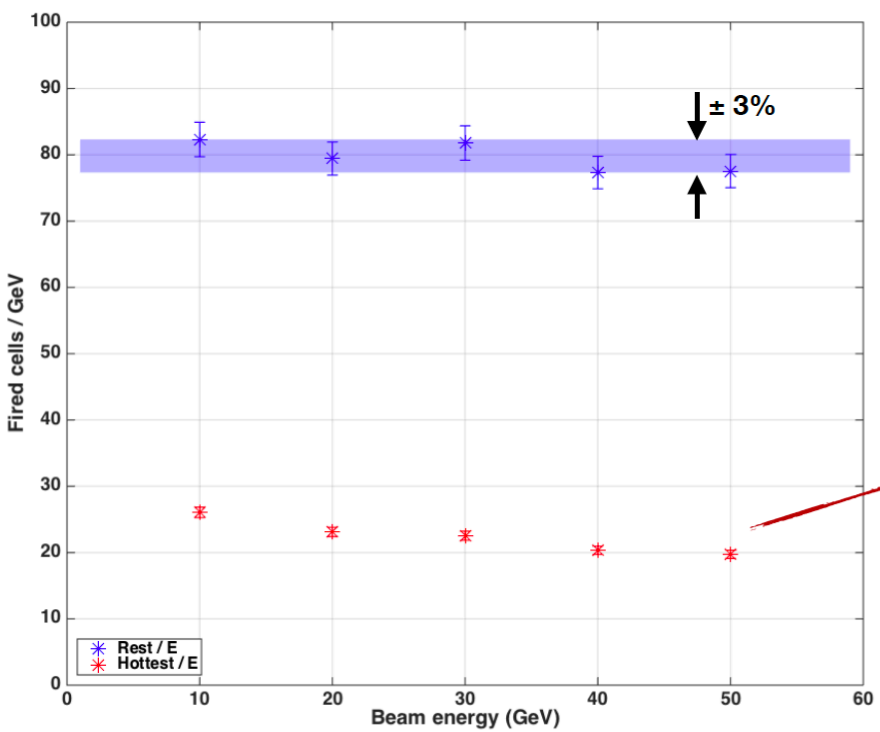

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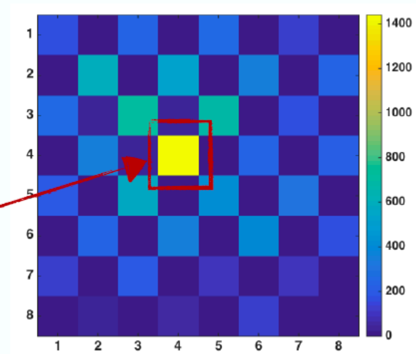
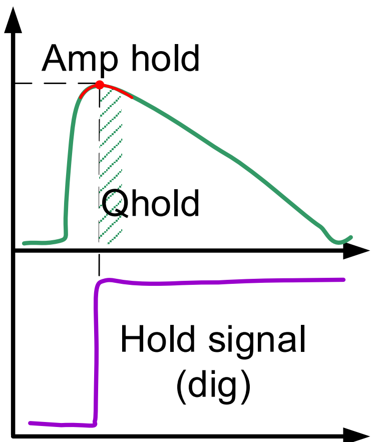


Attenuation needed!!!

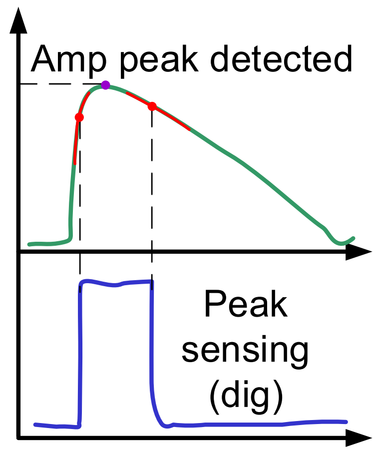
M. Antonello, VCI2019 conference

Citiroc1A: charge measurements (II)

Two techniques implemented to measure the amplitude:
Track & Hold and Peak Detector

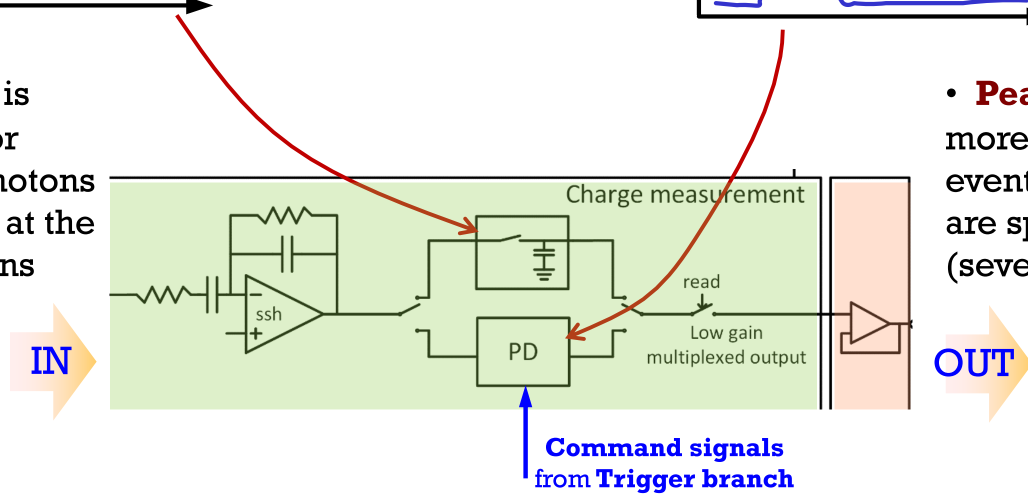


The choice of the **best peak sampling** solution depends on the final application.



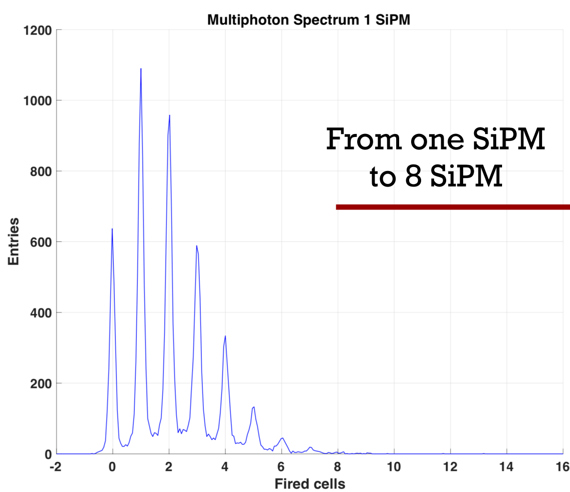
- **Track & hold** is more suitable for events where photons are all detected at the same time (few ns spread)

- **Peak detector** is more suitable for events where photons are spread in time (several 10 or 100ns)

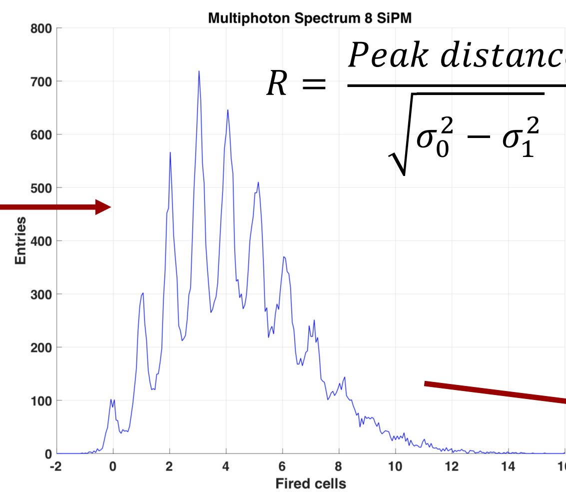


Signal Grouping

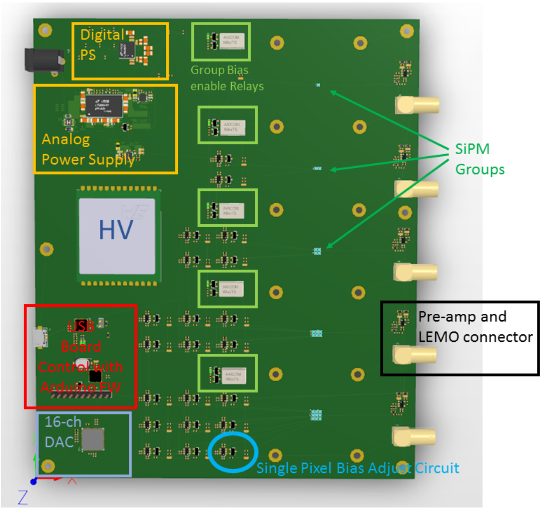
- This board allows to investigate the SiPM performances when the signals are grouped analogically (from 1 to 9 SiPMs)
- Each SiPM is individually biased
- Same FEE used in the test beam

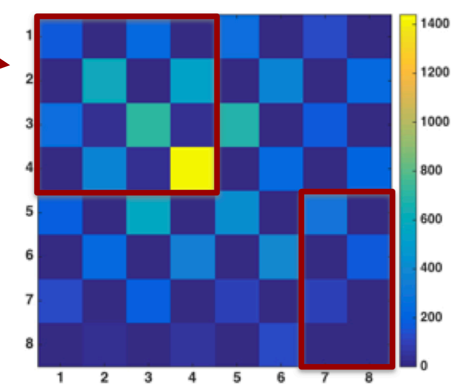


From one SiPM
to 8 SiPM



$$R = \frac{Peak\ distance}{\sqrt{\sigma_0^2 - \sigma_1^2}}$$





	1 SiPM	4 SiPM	8 SiPM
R = resolving power (ph-e)	24.5	16.6	10.0
Space granularity (mm^2)	≈4.5	≈18	≈36