

Nuovo setup dell'apparato sperimentale PADME per la rivelazione dell'X17

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Per la collaborazione PADME

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PADME

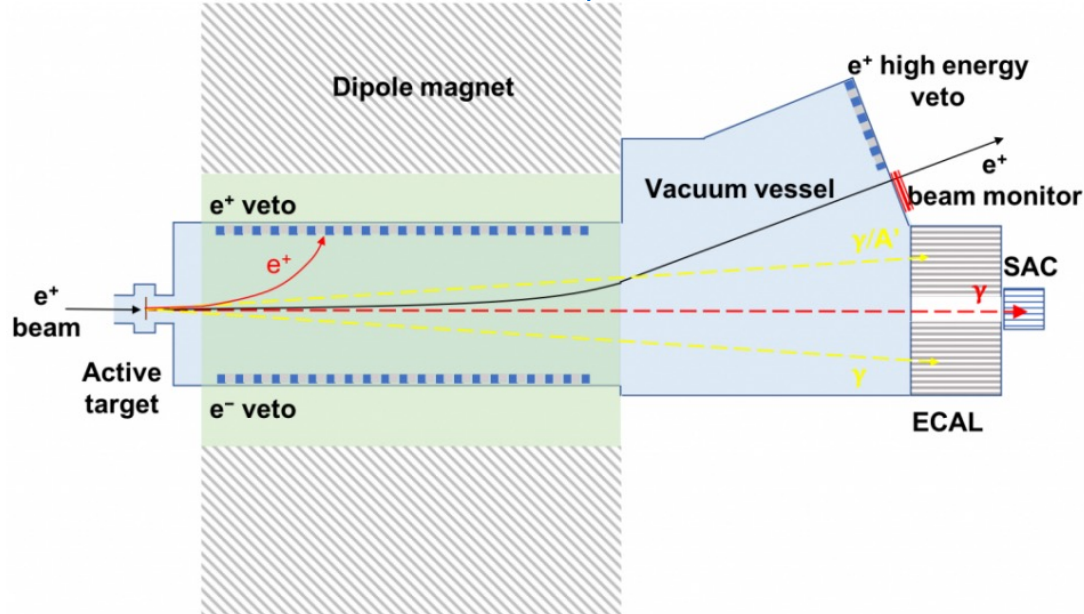
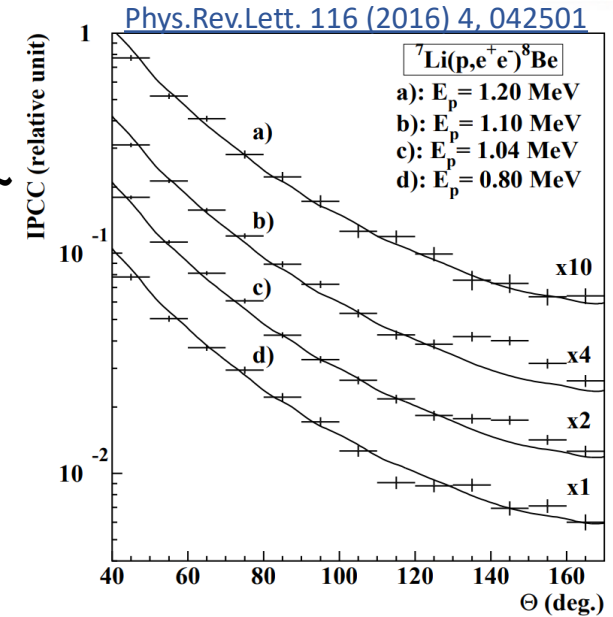


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- I recenti risultati della collaborazione ATOMKI hanno mostrato delle anomalie nelle misure dell'IPC per ⁴He, ⁸Be, ¹²C → compatibili con la produzione e successivo decadimento di un **nuovo mediatore di massa ~ 17 MeV, X₁₇**.
- PADME ha la possibilità di esplorare lo spazio dei parametri disponibile e porre limiti sia al modello vettoriale che pseudoscalare di questa particella.

Per approfondire: Talk di [C. Taruggi «Il bosone X17 nella ricerca italiana: Il caso di PADME e oltre»](#) e di [M. Mancini «Studio della produzione risonante del bosone X17 presso l'esperimento PADME»](#)



- Positron Annihilation into Dark Matter Experiment: $e^+e^- \rightarrow \gamma A'$ ai Laboratori Nazionali di Frascati (LNF).
- Fascio di e^+ ($E < 550$ MeV) su bersaglio attivo di $100 \mu\text{m}$ di diamante
- Misura di ΔM_{miss}^2 tramite il calorimetro elettromagnetico.

Può sfruttare la **produzione risonante** di X₁₇. Per fare ciò il \sqrt{s} deve essere molto prossimo alla massa attesa → è necessaria una procedura di scan fine: **PADME Run III**.

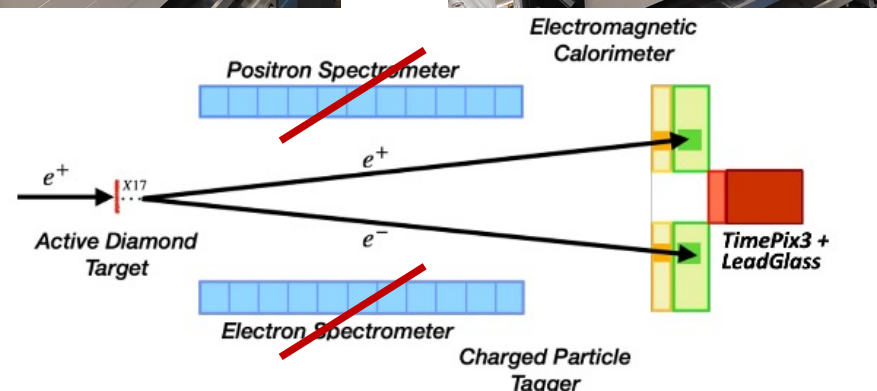
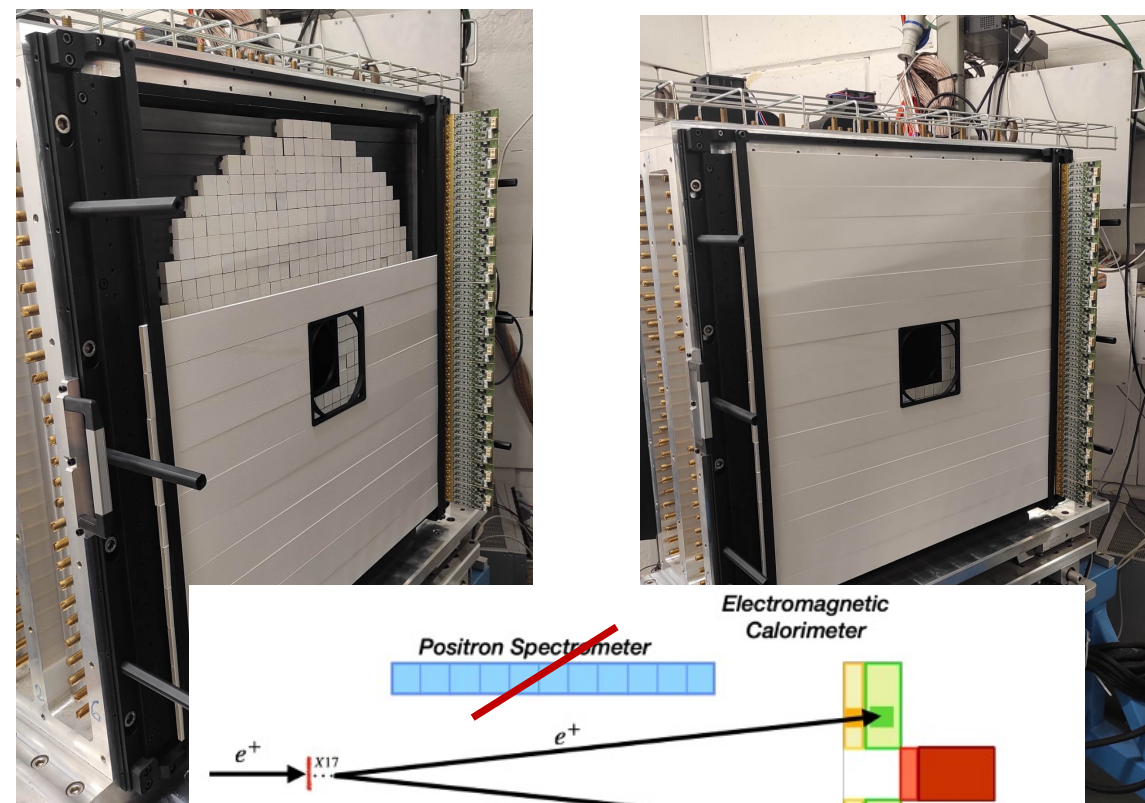
Per PADME Run III sono state apportate diverse modifiche al setup. Per l'identificazione del canale di decadimento $X_{17} \rightarrow e^+e^-$ in ECal, è stato sviluppato e installato un nuovo detector chiamato **ETag**.

ETag è un **tagger di particelle cariche** composto da sottili lastre di scintillatore plastico (BC408) lette da SiPM.

È composto da:

- 18 lastre verniciate con EJ-510 per ridurre la dispersione della luce.
- 120 canali di lettura forniti da SiPM Hamamatsu S13360-3050PE.
- Elettronica di front-end (FEE) adattata da PADME Veto.

Sono stati effettuati test per caratterizzare la risposta del nuovo rivelatore.



Obiettivo test: valutare l'efficienza e il light output in diverse posizioni su una lastra di ETag.

Singola slab di ETag letta ai lati da 4 SiPM da 50 μm di pixel size \rightarrow 8 canali di readout.

- **Sorgente:** raggi cosmici
- **Trigger:** AND di due finger di BGO posizionati sopra e sotto il DUT e incrociati
- **DAQ:** CAEN V1742 ADCs a sampling, digitalizzati a 2.5 Gbps
- **Scan di 7 posizioni** \rightarrow ognuna con un run corrispondente

SiPMs card di destra \rightarrow



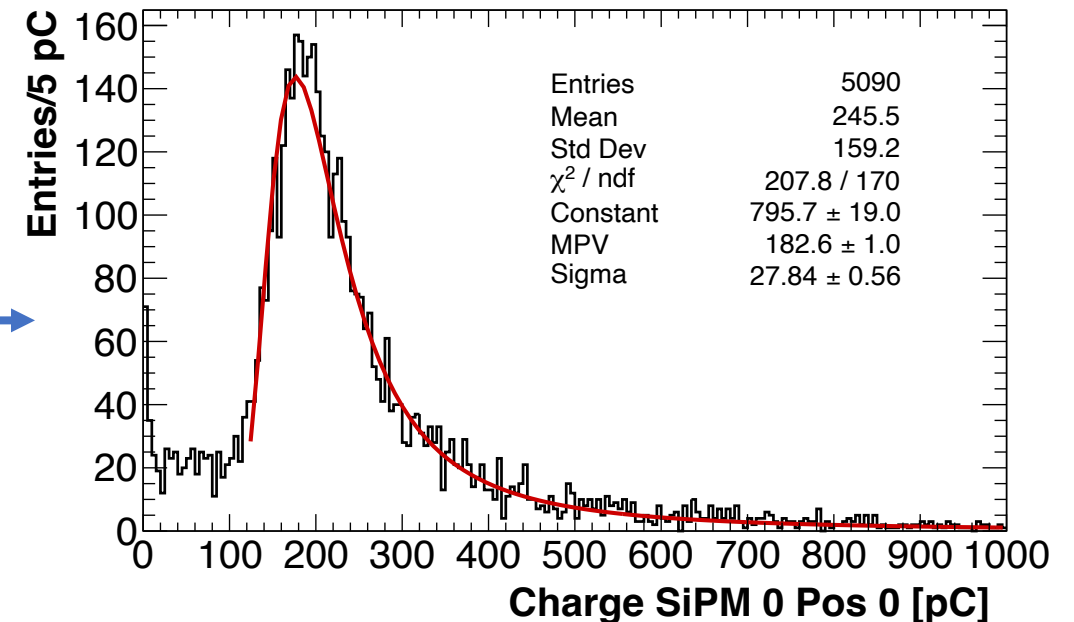
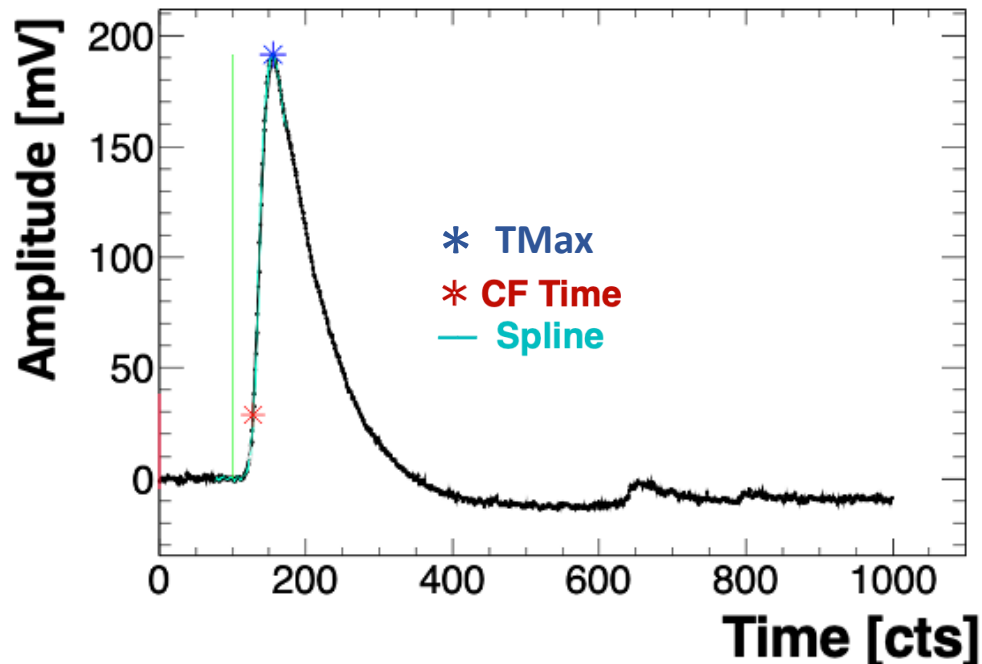
\leftarrow SiPMs card di sinistra

ETag slab

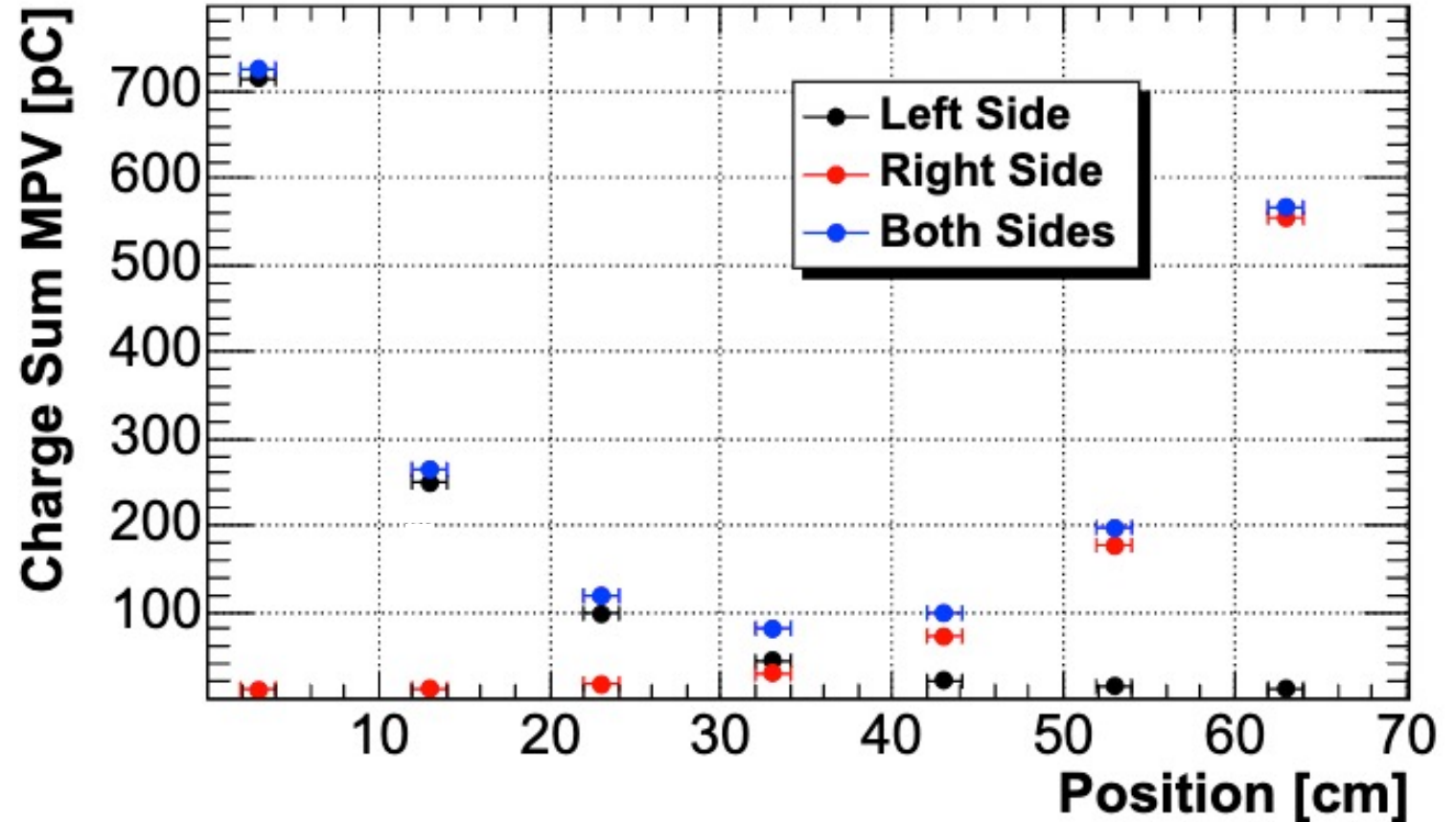


Finger BGO

- Nuovo **metodo di timing** applicato ai SiPMs → CF su un'interpolazione spline del fronte di salita dell'onda.
- Valore **Constant Fraction**: 12%.
- Finestra d'integrazione della carica: TMax-20ns, TMax+80ns.
- Eventi con TMax inferiori a 25 ns (65 cts) vengono scartati (carica sottostimata)
- Provate diverse combinazioni: Single SiPM, 4 SiPMs, 8 SiPMs.



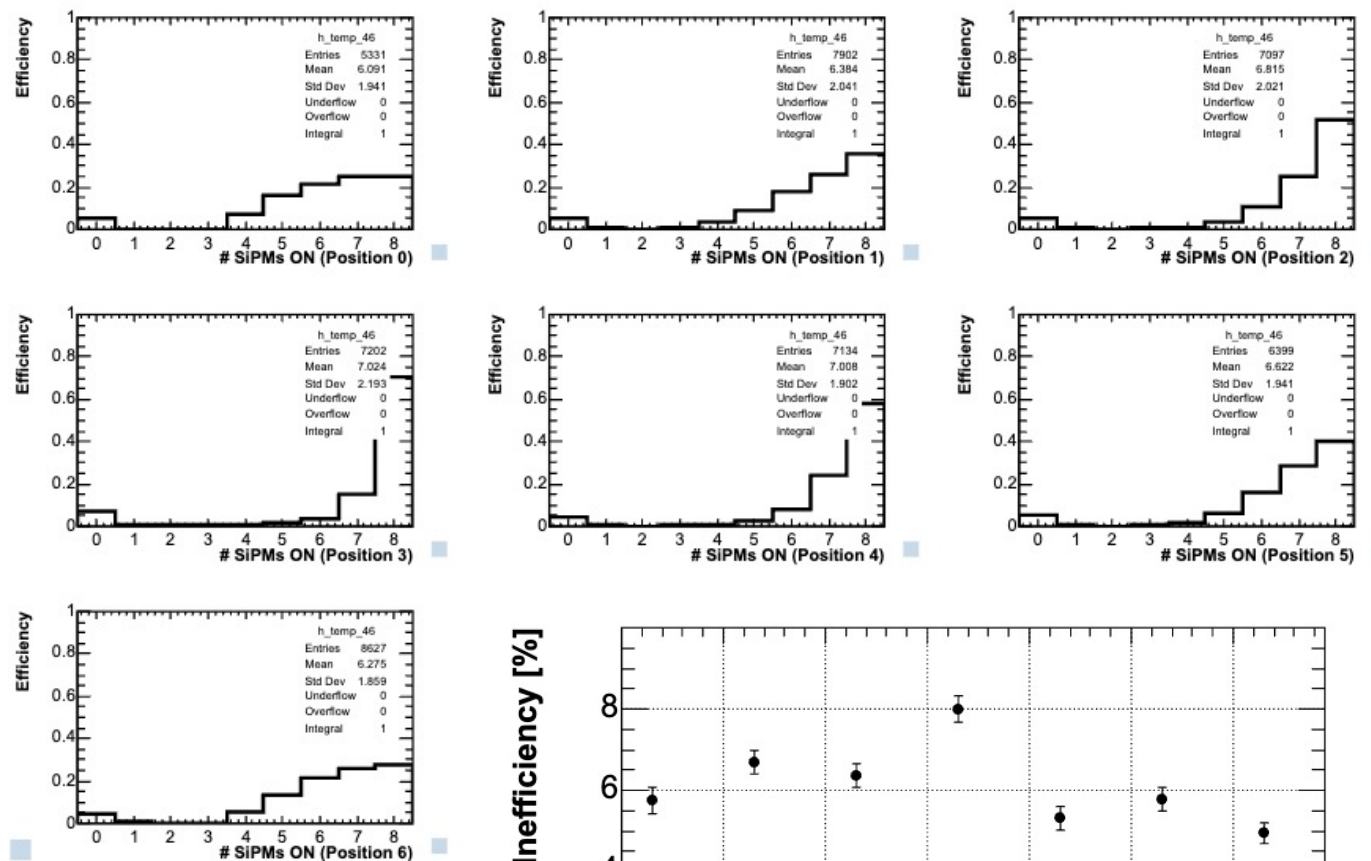
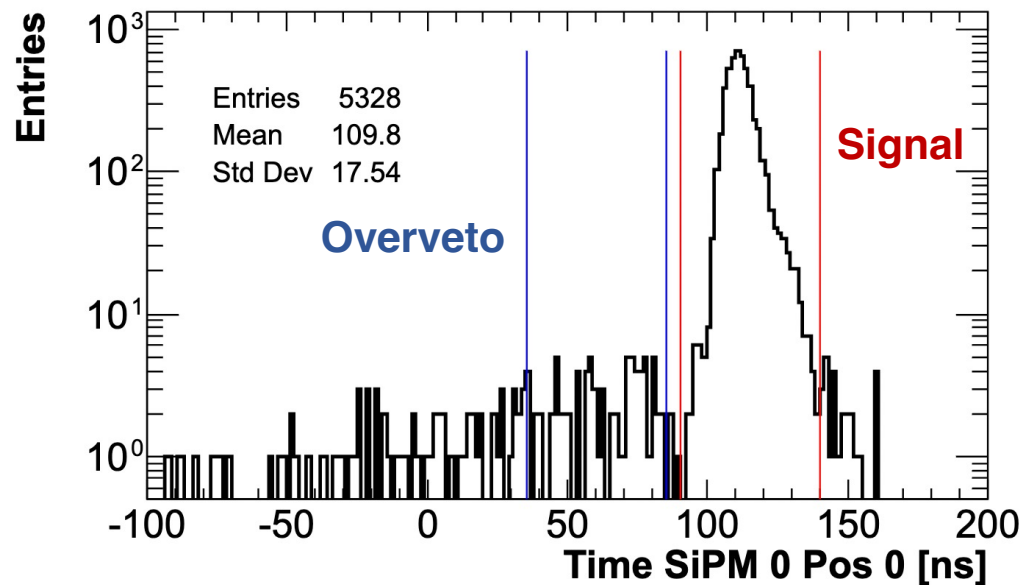
- **MPV dai fit Landau** applicati sulle somme in carica (left, right, both SiPMs card) in funzione della posizione:
 - Le ampiezze dei segnali non sono equalizzate
 - **I segnali sono sensibilmente attenuati** muovendosi verso il lato opposto della barra
 - Può essere risolto utilizzando la **somma in carica dei due lati**



Requisiti:

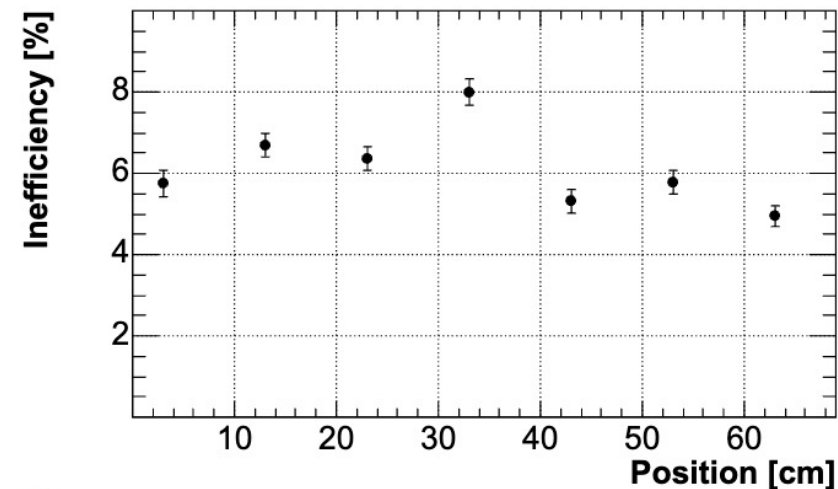
- SiPM al di sopra di una soglia in carica (2 pC, dal piedistallo) → ON
- Segnale in tempo con i BGO di trigger (finestra di 50 ns **regione rossa**)

Inefficienza: meno di 2 SiPM ON e in tempo



Tagli:

- $|\Delta T \text{ BGO}| < 5 \text{ ns}$
- $T_{\text{Max}} > 25 \text{ ns}$

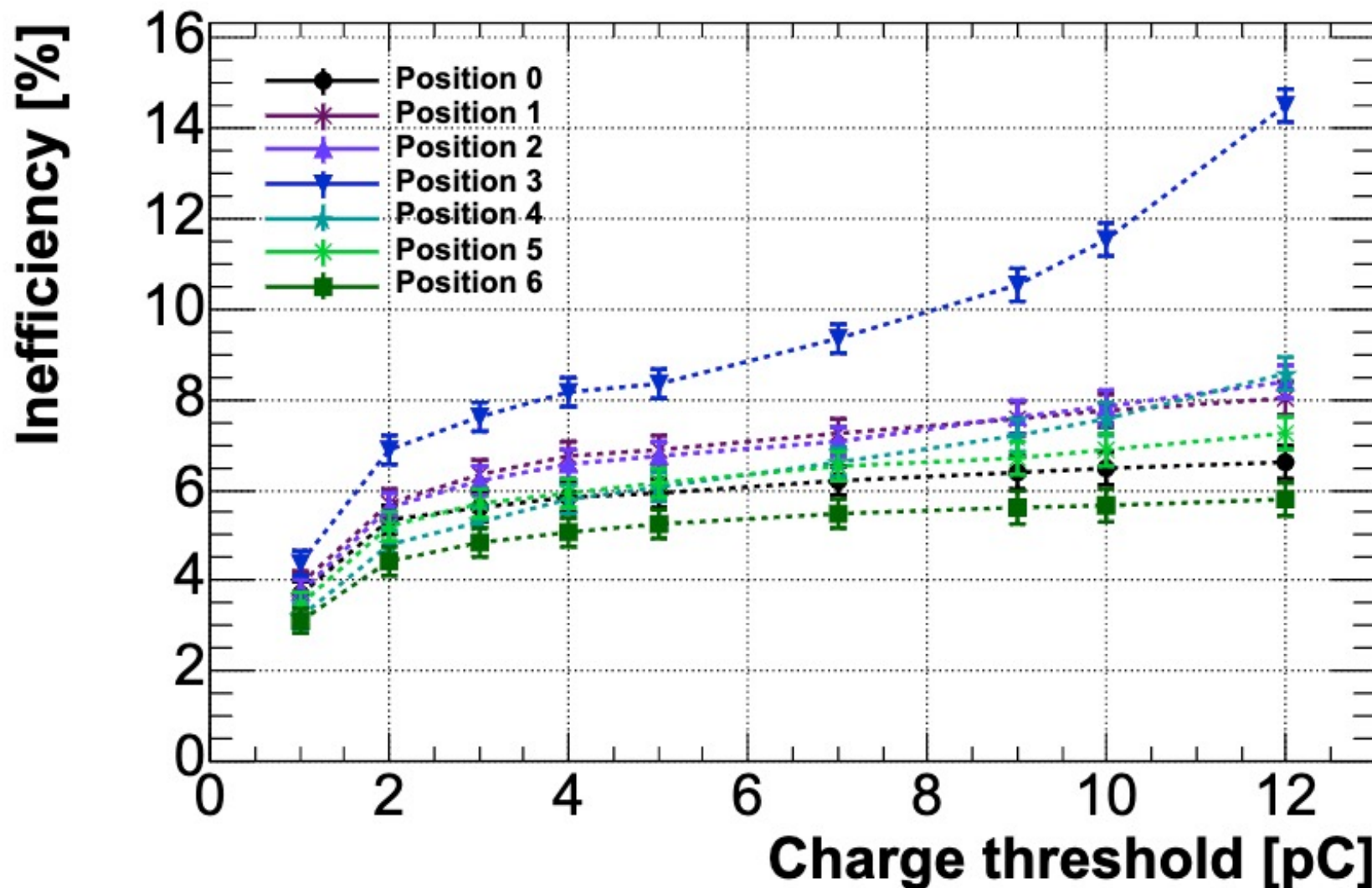


Inefficienza: meno di 2 SiPM ON e in tempo

- Quasi stabile al di sotto del 8%
- Le performance al centro della barra sono peggiorate dall'attenuazione

Sono necessari:

- Una simulazione Geant4 del setup per valutare i fattori geometrici
- Un algoritmo multi-hit per escludere i dark count dei SiPM

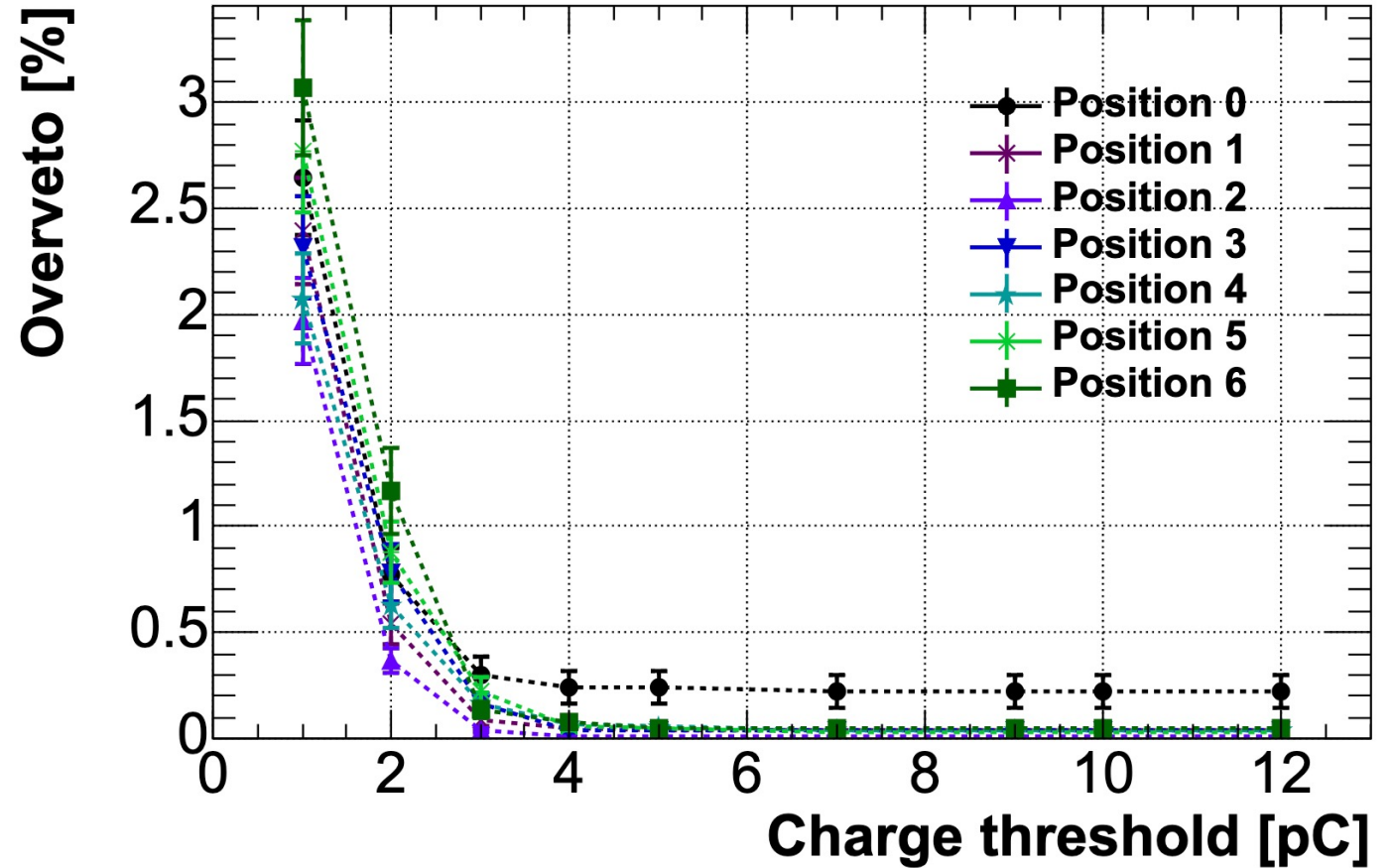
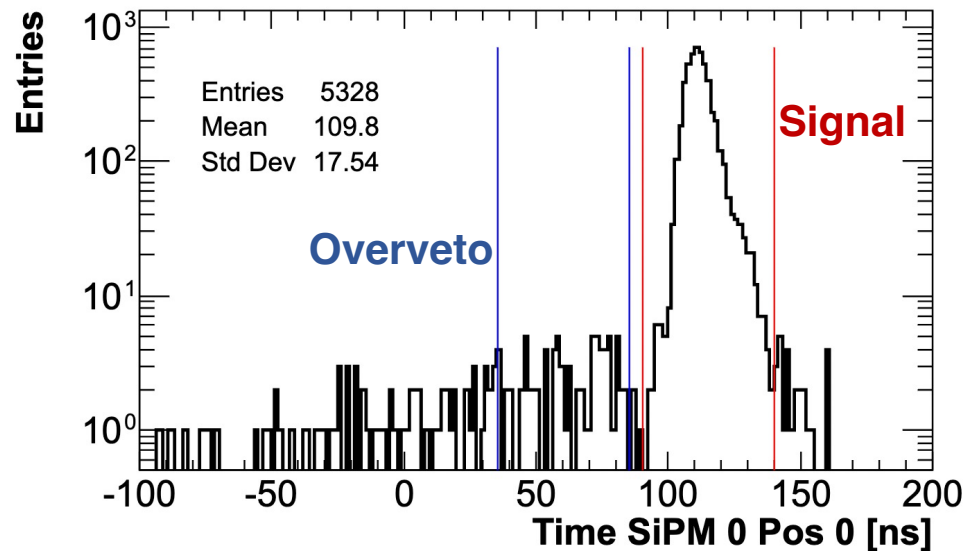


Overveto: almeno due SiPM ON e fuori tempo (**regione blu**)

- Quasi rimosso con un piccolo taglio in carica

Sono necessari:

- Algoritmo multi-hit per identificare i contributi dei dark count dei SiPM



I risultati ottenuti finora con questi test sembrano promettenti:

- I segnali al centro della lastra hanno una bassa carica ma sono sufficienti per essere rilevati su entrambi i lati.
- Richiedendo segnali in tempo e una carica superiore a 2 pC, l'inefficienza è inferiore all'8% in tutte le posizioni, ma mai pari a zero.
- Le soglie finali saranno un compromesso tra inefficienza e overveto.
- Abbiamo iniziato a testare un nuovo algoritmo di ricostruzione per carica e tempi che verrà implementato nel framework di analisi.

Next steps:

- Sviluppo di un algoritmo multi-hit per identificare i contributi dei dark count dei SiPM.
- Simulazione Geant4 del setup per capire quanti trigger non attraversano la barra.

A nighttime aerial photograph of a city harbor. In the foreground, a large container yard is filled with stacks of colorful shipping containers. The harbor is filled with boats and ships, and the city lights are visible in the background. A Ferris wheel is prominent on the right side of the harbor. The text "Backup slides" is overlaid in the center of the image.

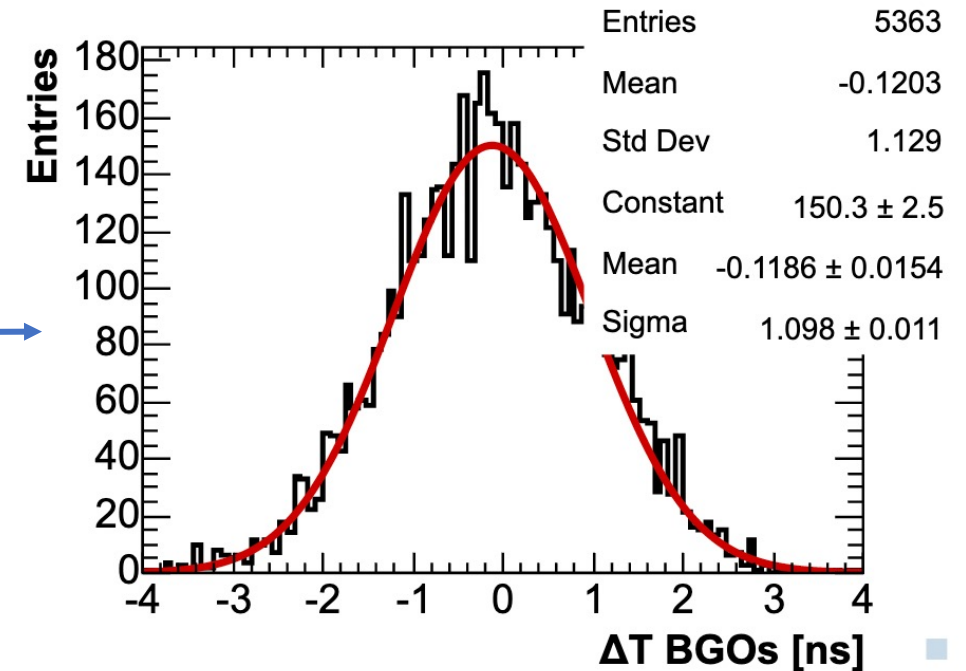
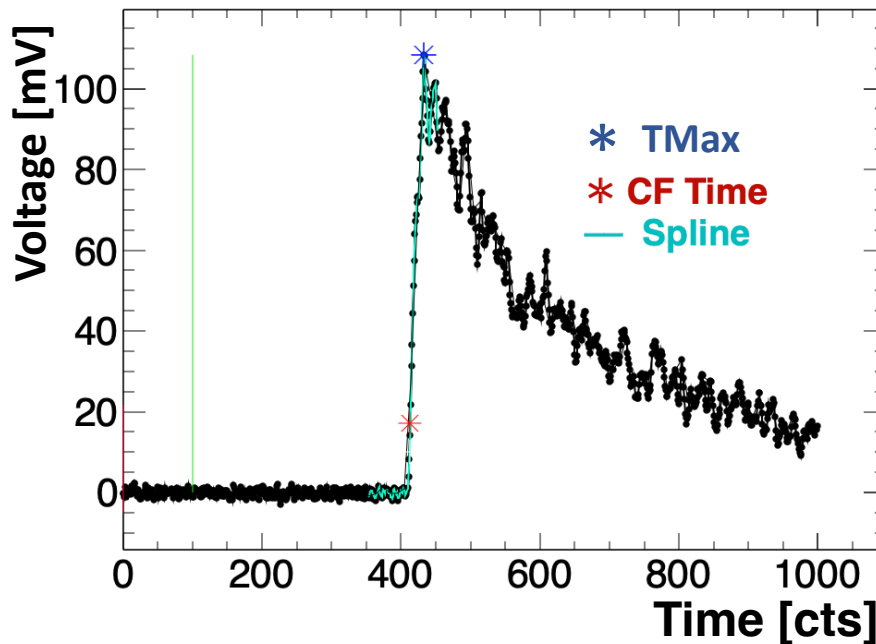
Backup slides

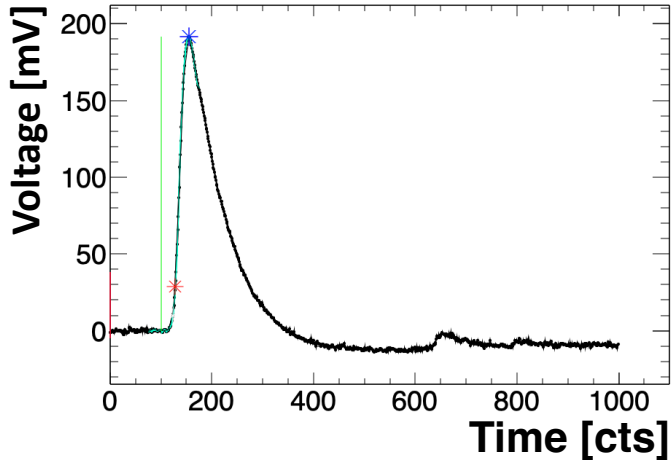
New timing method (also applied on the SiPMs):

- Spline interpolation on the rising edge
- Constant fraction method applied on the Spline
- CF fixed at 12% but should be optimized.

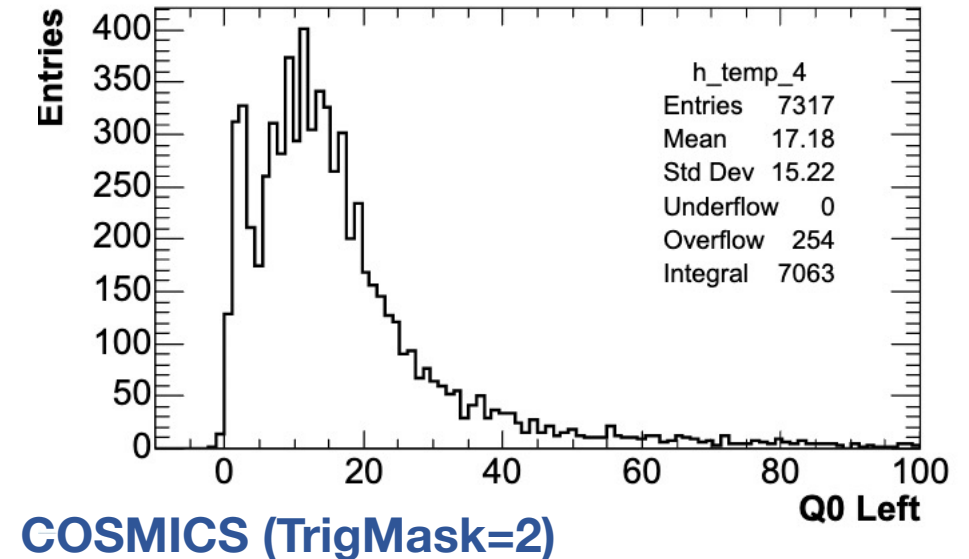
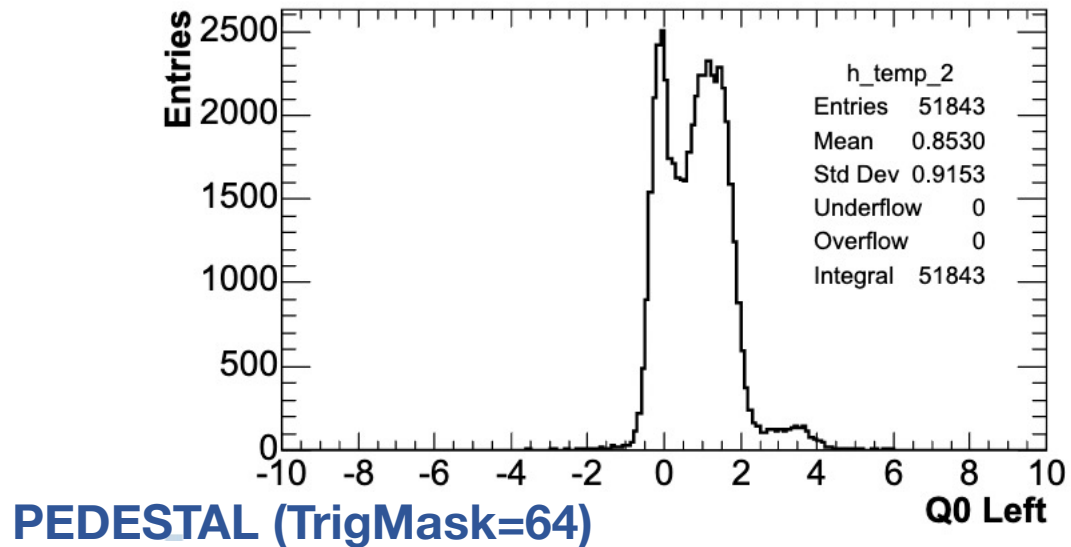
Resolution of the time difference between the two BGOs powered on $O(500 \text{ ps})$

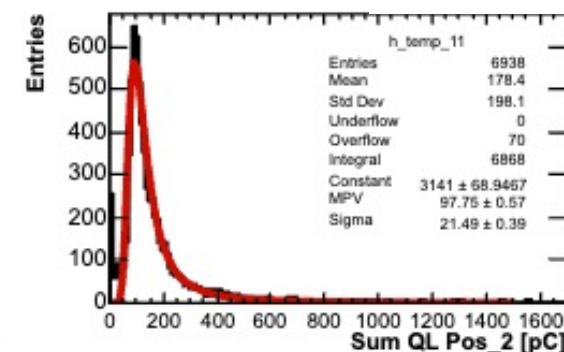
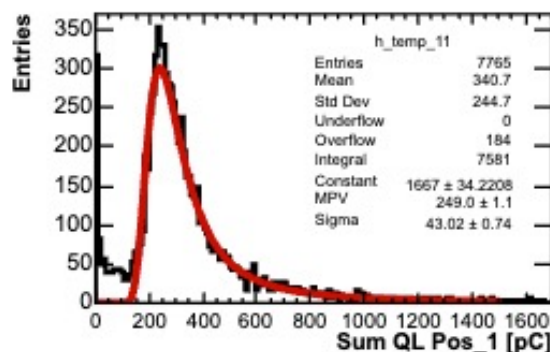
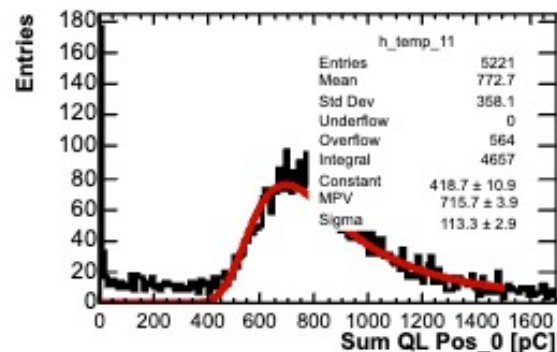
```
TSpline5 waveSp = TSpline5("wsp", &waveGra);
auto waveSpFun = [&waveSp](double *x, double *){ return waveSp.Eval(x[0]); };
TF1 waveFitFun = TF1("fitf", waveSpFun, tmin, tmax, 0);
peakTmp = waveFitFun.GetMaximum(tmin, tmax);
peakTimeTmp = waveFitFun.GetMaximumX(tmin, tmax);
thr = peakTmp * thisPar->cf;
timeTmp = waveFitFun.GetX(thr);
```



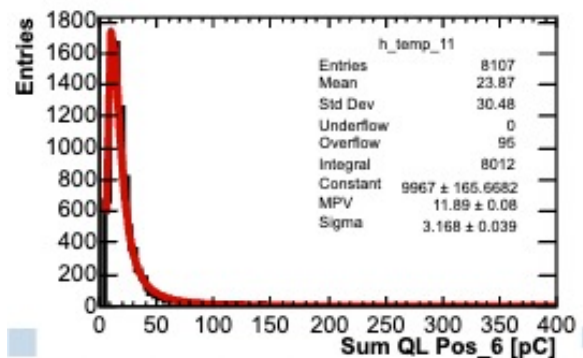
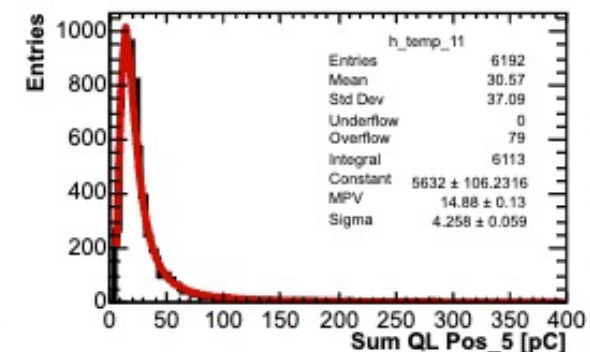
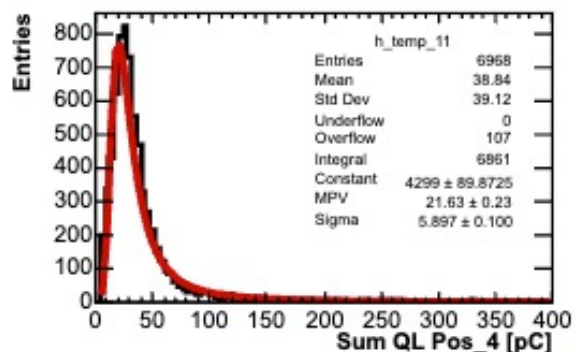
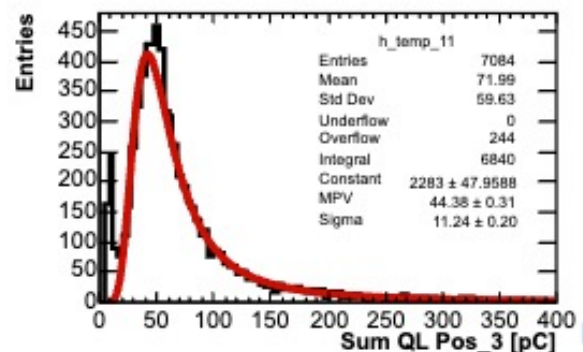


- Same timing method applied for the SiPMs
- Charge time integration window: $T_{max}-20ns$, $T_{max}+80ns$.
- Events with a T_{Max} below 25 ns are thrown out (charge underestimated)
- Different combination tried: Single SiPM, 4 SiPMs, 8 SiPMs.



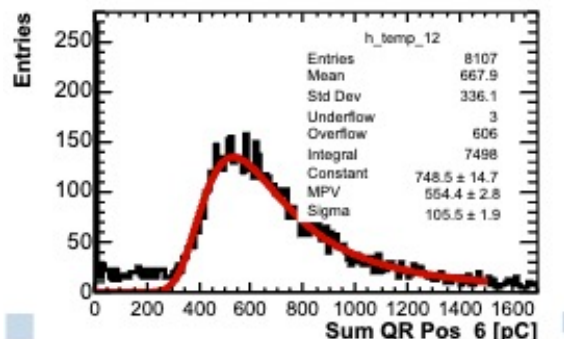
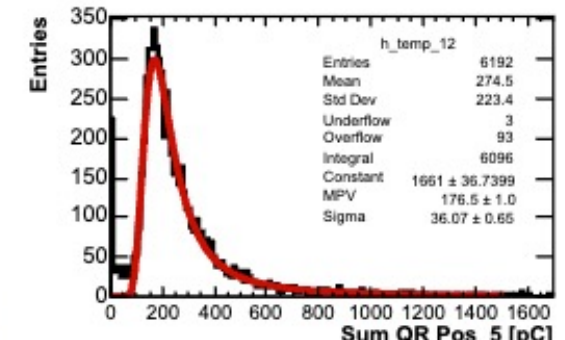
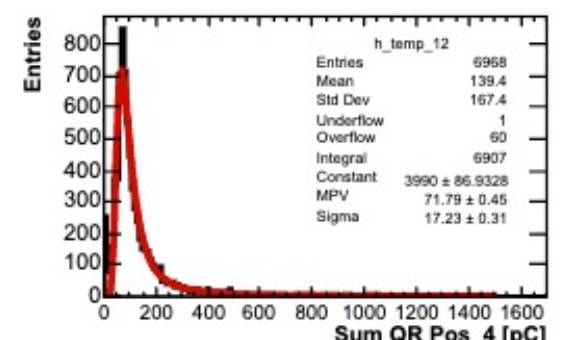
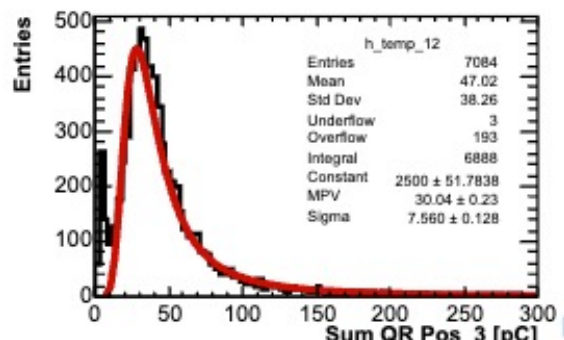
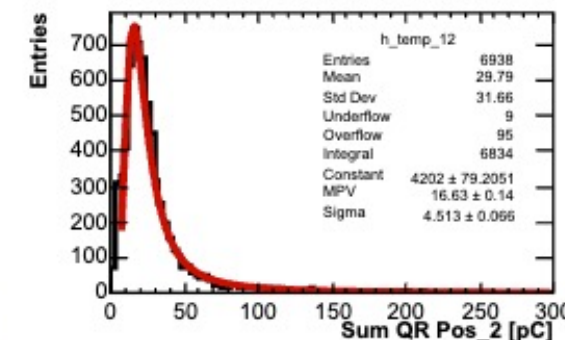
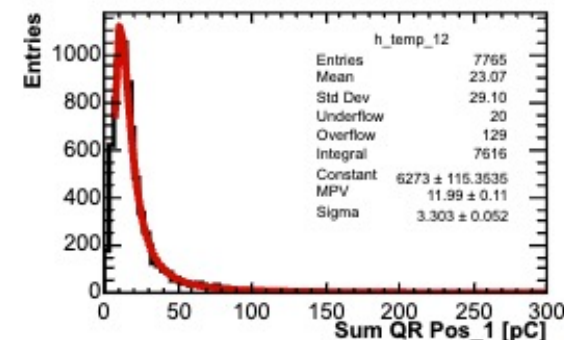
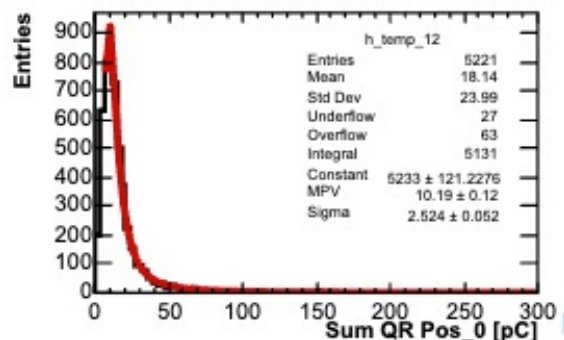


SiPMs cumulative charge for the left card in each position



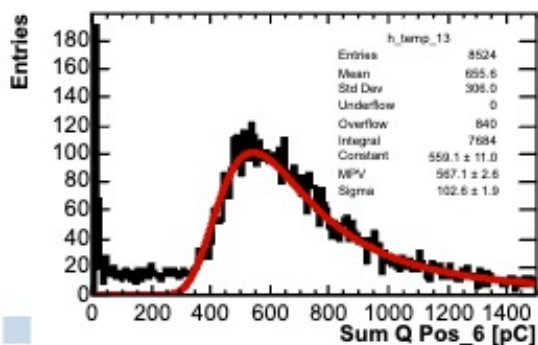
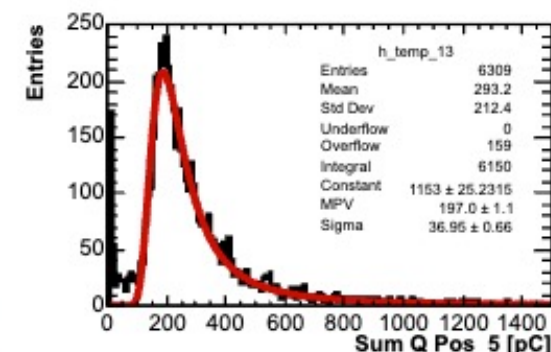
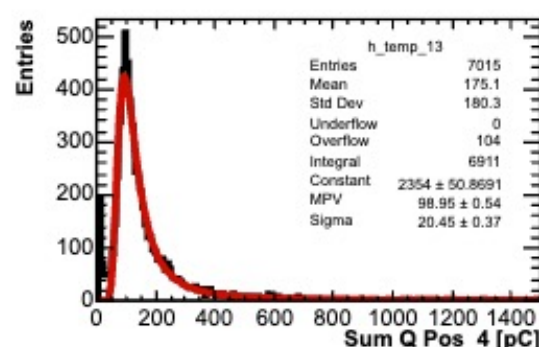
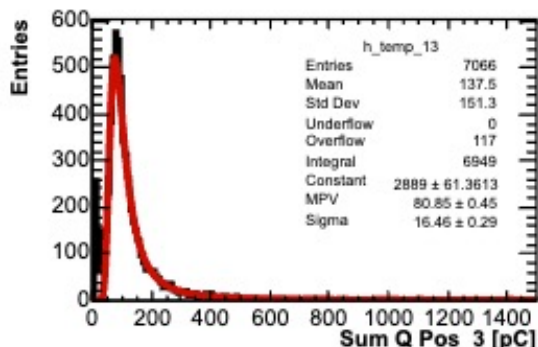
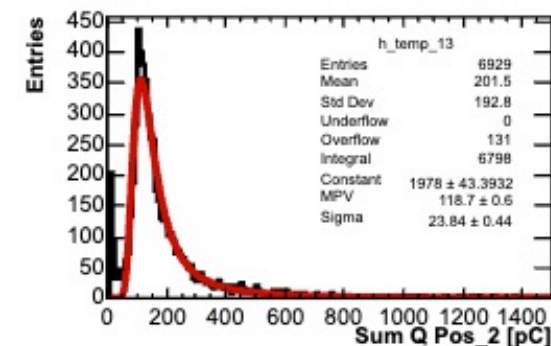
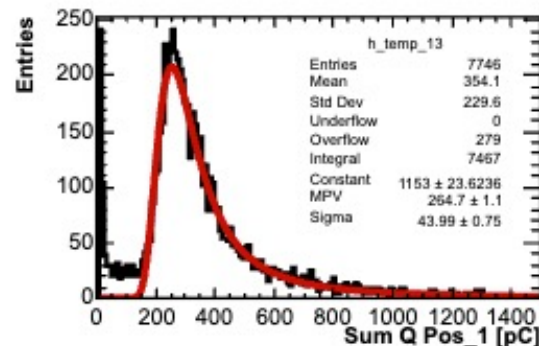
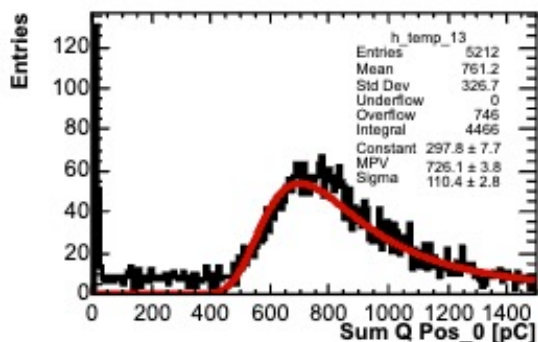
LEFT CARD (TrigMask=2)

SiPMs cumulative charge for the right card in each position



RIGHT CARD (TrigMask=2)

SiPMs cumulative charge for the left and right card in each position



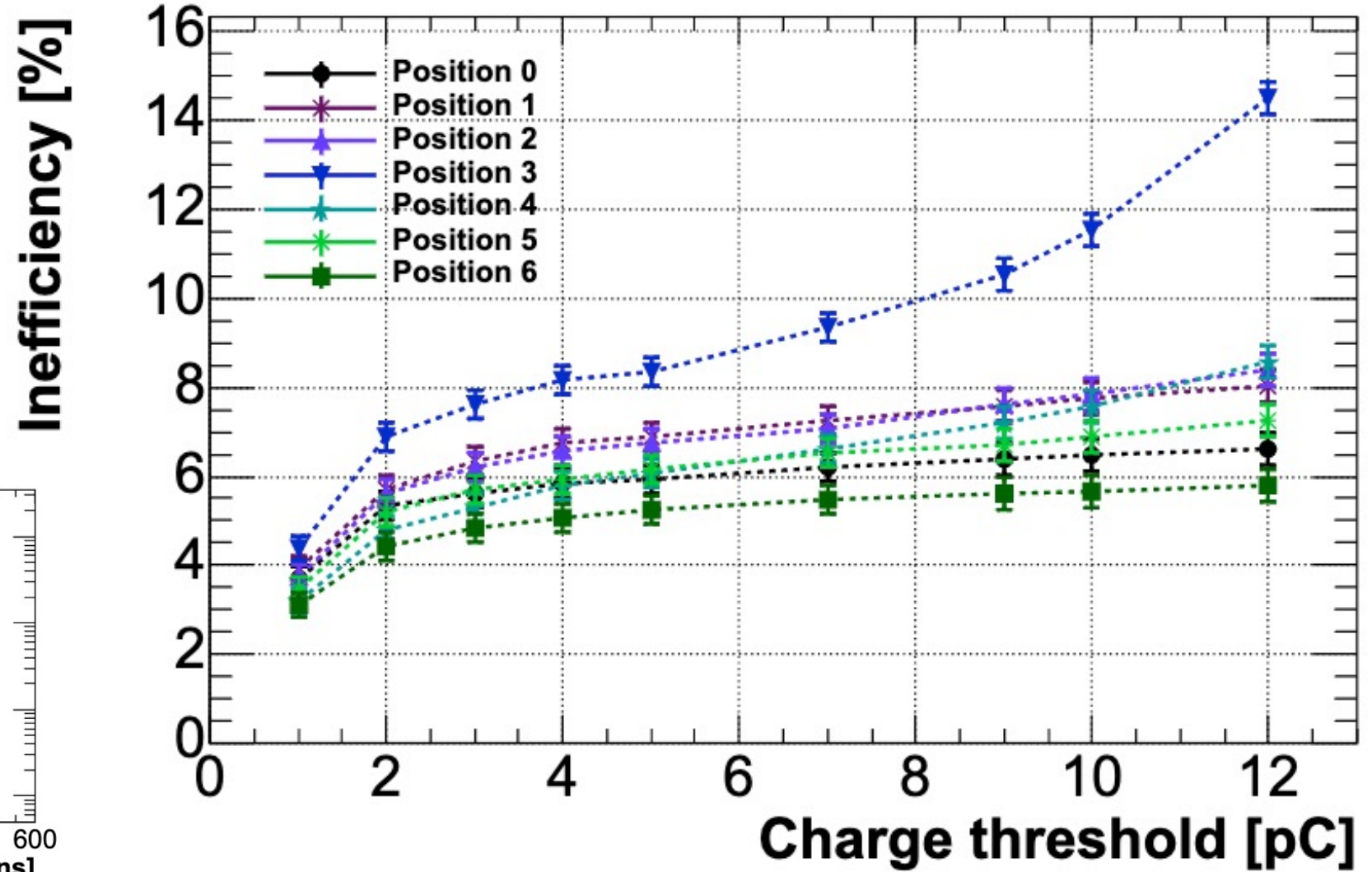
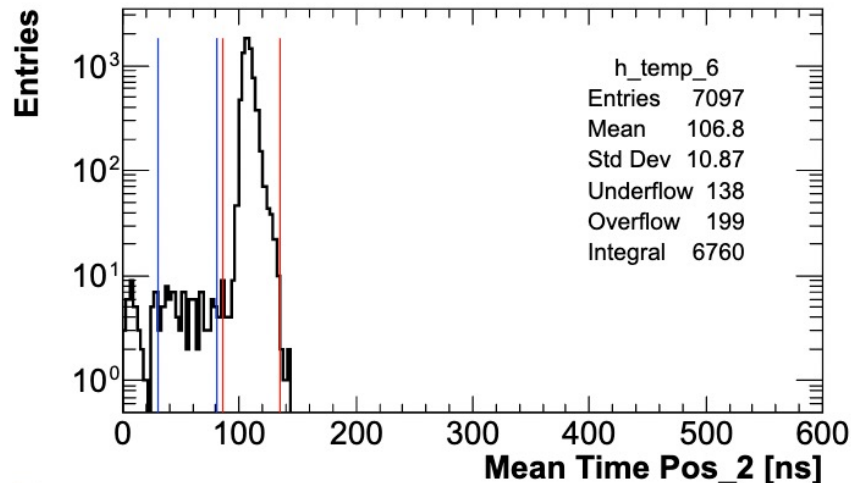
BOTH CARDS (TrigMask=2)

Requirements:

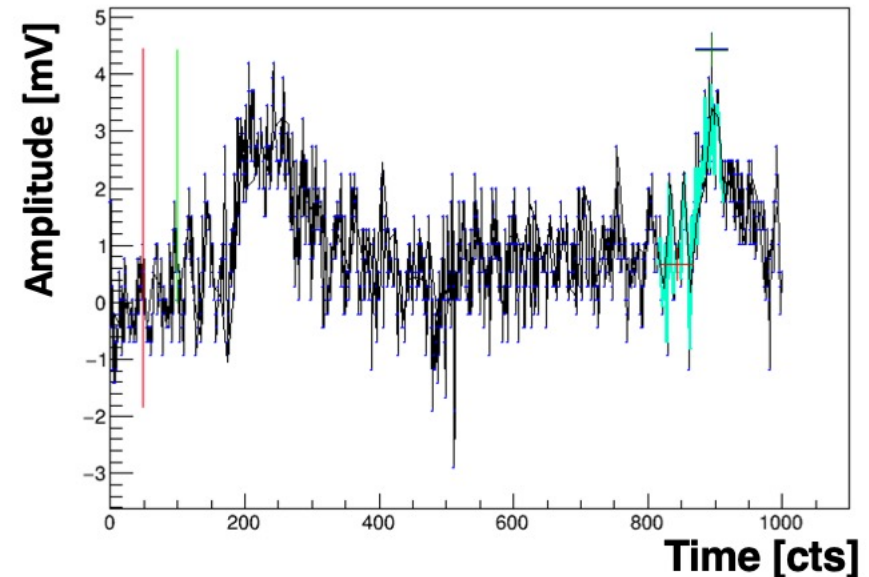
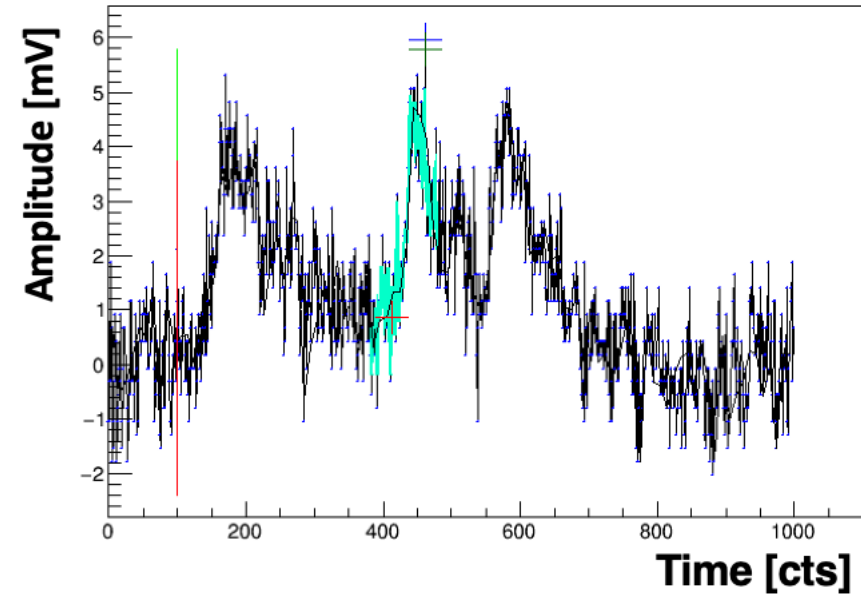
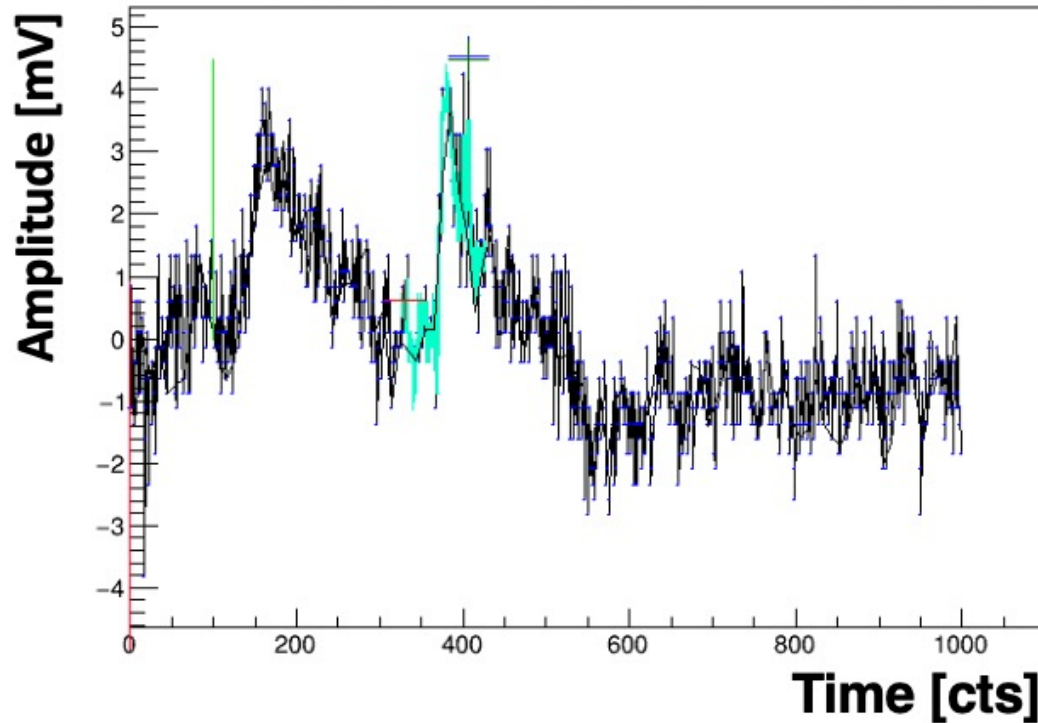
- SiPMs over a defined Q threshold
- Signals in time wrt the BGO (50 ns window)

Cuts:

- $|\Delta T \text{ BGO}| < 5 \text{ ns}$
- $T_{\text{Max}} > 25 \text{ ns}$



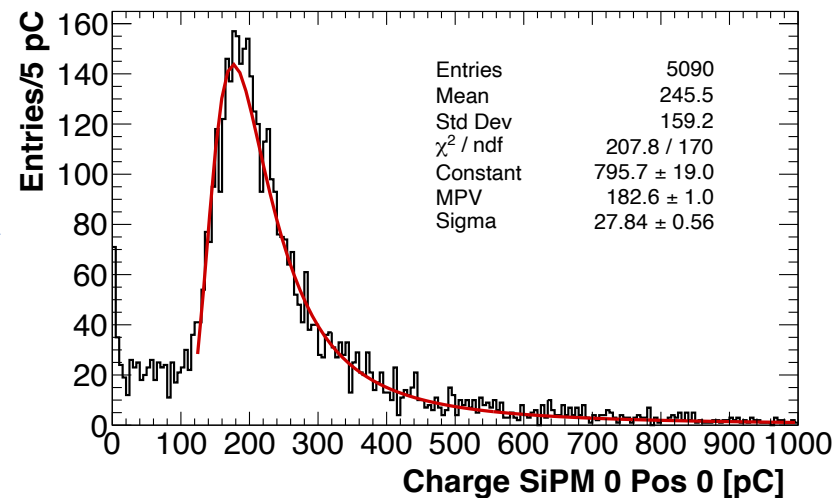
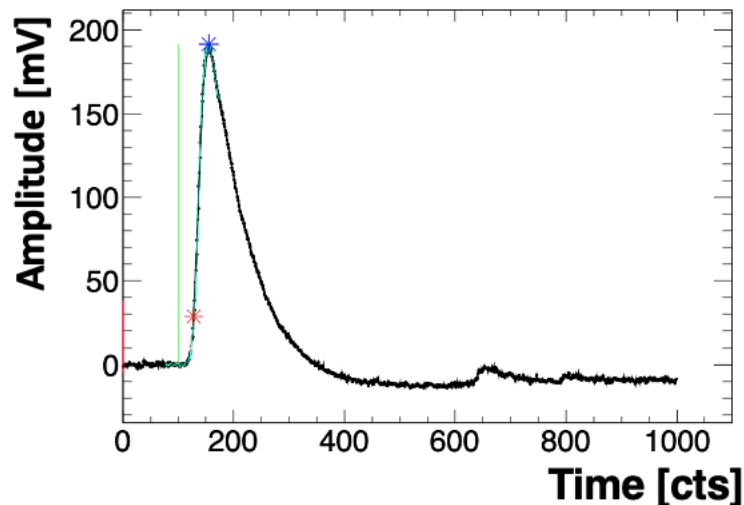
- Single hit algorithm based on max peak search
- If the single-photon emission of the SiPM is greater than the actual signal \rightarrow false Overveto
- Expected to be worse if the temperatures during the run were higher than 25 °C.



New detector installation: ETag → needed to discriminate charged leptons entering in ECal for the identification of the $X_{17} \rightarrow e^+e^-$ decay channel.

The aim was to evaluate the efficiency and the light output on different position of an ETag slab → necessary to tune the general MC of the experiment.

- Single ETag slab (BC408 – 0.5x4x66 cm³) readout on each side by four 50 μm SiPMs
- Source: cosmic rays
- Trigger: AND of two BGO fingers (ECal spares) placed over and under the DUT and crossed (discriminator thresholds 30 mV)
- Charge and timing evaluated on the digitized waveforms
- Different combination tried for charge considerations: single SiPM, 4 SiPMs, 8 SiPMs.

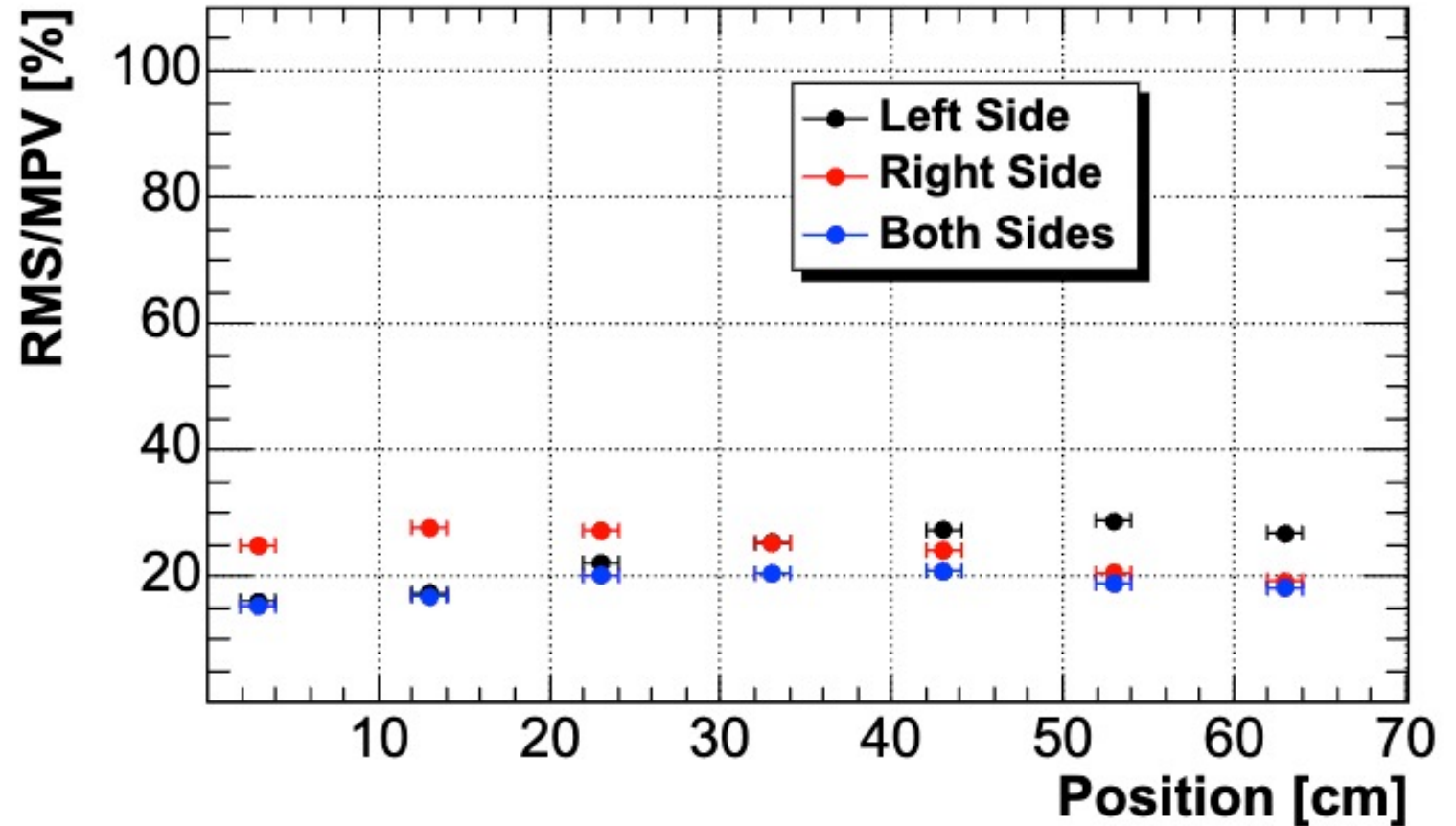


Left SiPMs card



Right SiPMs card

- Landau fits MPV/RMS wrt Position:
 - Quite stable
 - From the Poissonian distribution of the number of photo-electrons we got a preliminary estimation of the N p.e. ~ 25 .



- Quantities evaluated by requiring signals with $Q > Q_{thre}$ (ON) in a certain time region \rightarrow on single SiPM
- Inefficiency: not a single SiPM ON and in time (**red region**)
- Overveto: 2 SiPMs ON and out of time (**blue region**)

Next steps:

- MC simulation of the setup to understand if the remaining inefficiency is due to geometry.
- Multi-hit algorithm to remove the coincidence of signal and dark count emission.

