

# A method for pile-up events removal

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#### **Beam rate**

- The beam flux must match with the subdetector with lower beam rate
- It is the SC which operates at very low rates, i.e. ~ 10 kHz
- What it was seen in the last data taking (GSI CNAO 2021) is that the **beam flux is not constant**

Example: CNAO 2021 – 3 nights data taking



10<sup>6</sup> events Mean beam rate: **16 kHz** 

Credits to Marco Bon - FOOT meeting 2 March 2022



#### **Start Counter Pile Up**

→ there is the possibility of **pile up events**, which are visible in the **SC signal** 

**Pile up** is the superimposition of more than a projectile in the SC time window, which is ~ **350 ns.** It means that the signal from the SC could have more than one peak in pile up cases:



It is fundamental to filter out pile up events because they worsen the overall analysis. One method to discriminate pile up events is the **derivative method**, implemented on SHOE



# **Derivative method, 1**

At first, the derivative is made by an algorithm which iterates on every point of the SC signal. The derivative range is of 5 points.



- From every peak of the signal, we obtain two peaks in the derivative, whose height depends on the steepness of the primitive signal
- Baseline noise and overshoot are negligible with this method using 5 consecutive points in the elaboration of the derivative.

# **Derivative method, 2**

Then a **threshold** is defined as the 50% of the positive peak height.



- The symmetric value is used for the negative threshold.
- 50% is chosen to have a good distance between baseline and so for a good discrimination



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# **Derivative method, 3**

A single signal intersects the threshold lines **4 times**: two for the positive and two for the negative ones. For a **pileup** signal the intersections are **more than 4**.

• This is at the basis of the constant threshold discrimination method.





The method was tested on real **data taken at GSI** of beam of **O**<sup>16</sup> of 400 MeV/n against a target of C (*DataGSI2021/data\_test.00004310.physics\_foot.daq.RAW.\_lb0000.\_FOOT-RCD.\_0001.data*)



stTotChargevsTotTime

In the graph time vs charge of all the events, the 2 "columns" are due to *minimum bias trigger* and *trigger fragmentation,* which have 2 different response times.

• Column width are due to the SC resolution of 12 ns.

Before and after the "columns", it is possible to find two different types of events:



n.b: they can be even in the trigger columns

• Applying the **derivative method**, pile up events are filtered out, as it is visible mainly after the "columns":



#### stTotChargevsTotTime-NOPILEUP-DerivativeMode

With a removal of 0.8% of the total events



• The method is also able to filter out pile up events in the trigger "columns":



events with 50 ns < t < 120 ns: 395577



*With pile up filter, events with 50 ns < t < 120 ns: 393778* 

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with a **removal in** 50 ns < t < 120 ns **of~ 0.5 %** 

• This method is more powerful than just a time cut.



#### "hidden" pile up events

One of the two peaks is outside the SC time window. Instead, seeing the signal of the same event on the channel of the **TW**, **all peaks** can be found.



Credits to Roberto Zarrella

- To disentangle this pileup, an algorithm which also includes the signal in the TW can be introduced.
- However, in first analysis, just a temporal cut on SC with t<50 ns could be enough because they
  represents little % of all the events.</li>



• In first analysis, it is possible to filter out hidden pileup applying a cut of t<50ns



stTotChargevsTotTime-NOPILEUP-DerivativeMode - time cut

with a removal (derivative + cut) of~ 1.1 % of the total events



#### **Comments**, 1

Pile up events which are temporary very close are successfully discriminated.



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More than 4 crosses: pile up event



# **Comments**, 2

Some pile up events are not well discriminated when one peak is between the end of the SC time window. The derivative is bad reconstructed and the threshold is too high to have intersections with the signal.



Only **4 crosses**: recognized as single event

- The solution could be to decrease the value of the threshold.
- However, the presence of this events is very low, ~ 0.004% of the total

![](_page_13_Picture_6.jpeg)

# Upgrades

- Two separate thresholds for positive and negative peaks
- Threshold at 45 % of peak height

![](_page_14_Figure_3.jpeg)

More than 4 crosses: pile-up

 $<sup>\</sup>rightarrow$  able to discriminate even "particular" cases

# Conclusions

The derivative method revelead as valid for pile up discrimination, with a removal of ~ 1 % of total events

- Applying this method on SC, we prevent a bad propagation on further detectors, such as TW
- It is fast, so it does not worsen monitoring capacity during data taking
- Improvements on the algoritm could increase the performace, such as
  - new threshold values
  - "on-line" pileup counting

#### **Backup slides**

![](_page_17_Picture_1.jpeg)

![](_page_17_Picture_2.jpeg)

# example

DataGSI2021/data\_test.00004310.physics\_foot.daq.RAW.\_lb0000.\_FOOT-RCD.\_0001.data • Both *minimum bias trigger* and *trigger fragmentation* 

![](_page_18_Figure_2.jpeg)

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## Implementation

The method was developed in SHOE in the branch "pileUpStudy"

In particular, the following function was introduced

Bool\_t TASTrawHit::CheckForPileUp(std::vector<double>\* w\_ptr, std::vector<double>\* t\_ptr, Int\_t event)

which modifies the private attribute bool pileup of the classes

TASTrawhit (class of the single waveform signal from SC)

TASTntuRaw (class of vector of waveform signals and "SuperHit" which is the sum of the 8 channel ones)

TASThit (class of the object hit, which takes physical information from "SuperHit" waveform, such as time, charge ...)

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TASTntuHit (class of vectors of hits)

![](_page_19_Picture_9.jpeg)

# **Charge method**, 1

Another method to discriminate pile up is the integral method.

- Integrating the signal of the SC, it is possible to obtain the value of the **charge** of the crossing particle, from which discriminating single and pile up events.
- The signal integral is computed excluding the samples with *amplitude > baseline + 2 st.dev*

![](_page_20_Figure_4.jpeg)

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• In this way we remove the positive **overshoot**, a positive peak of the signal due to electronics which is different from event to event.

![](_page_20_Picture_6.jpeg)

# **Charge method, 2**

Removing overshooting, it is possible to distinguish charges of single events and pileup ones as separate peaks in the histogram of charges.

![](_page_21_Figure_2.jpeg)

To filter out pileup events, a cut can be introduced in the value of charge. In this case as c < 0.2 nC.

This method is developed by Giacomo Traini et al. And under implementation on Shoe

![](_page_21_Picture_5.jpeg)

![](_page_21_Picture_6.jpeg)