Detailed look at PMTs DOM testing data

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on behalf of the Nikhef DOM integration team
DOM integration meeting - 11/11/2020

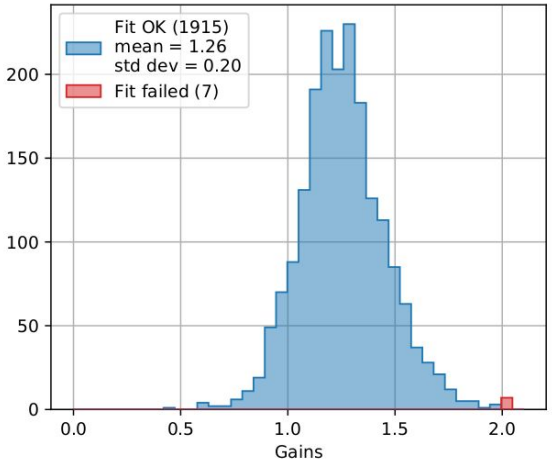
Overview

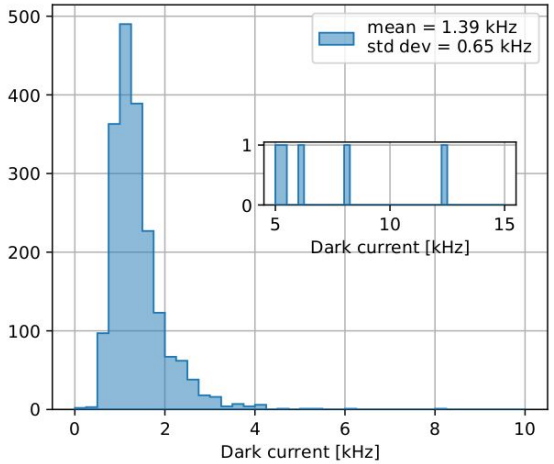
Based on a 62 DOM acceptance tests results

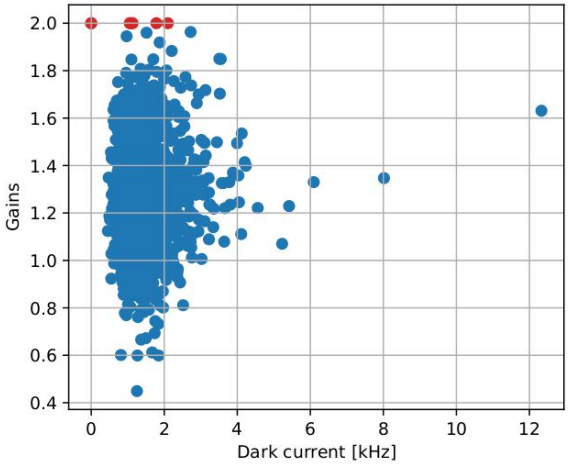
- From July to now
- Same computer, white rabbit switch
- 2 different dark boxes, 4 DOMs each

1. **Overview of PMTs gain and DCR distribution**
2. **Channels with systematic higher rate**
3. **Spark-like events**

Gain and DCR distributions



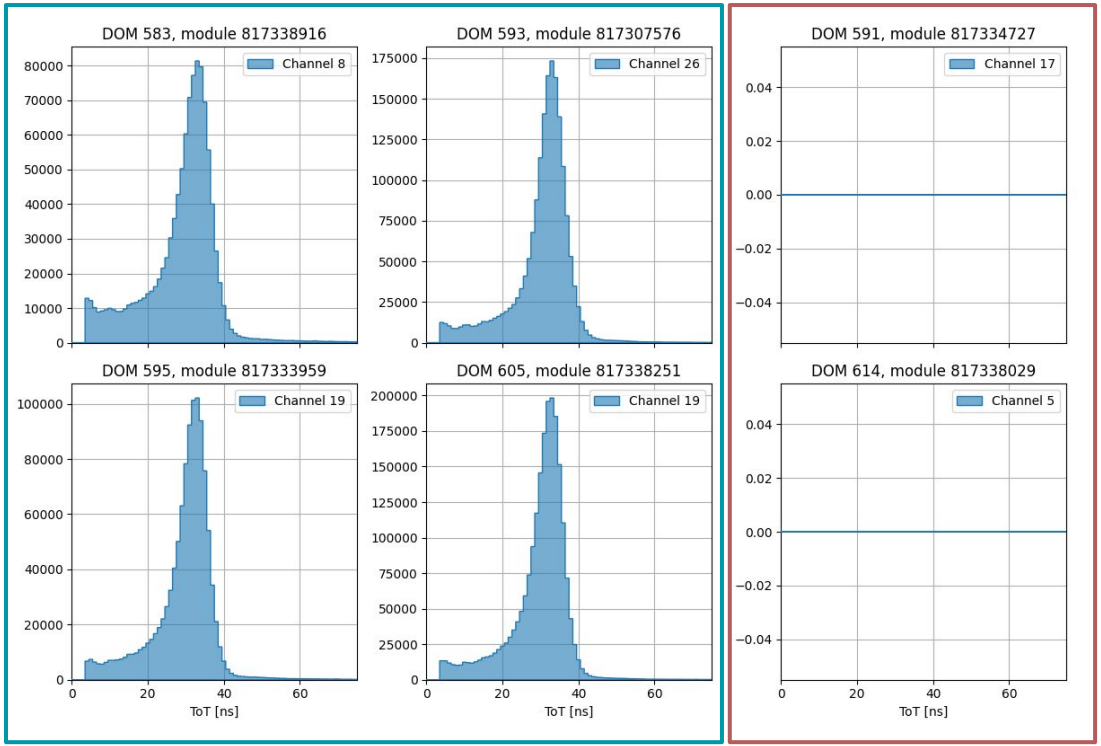




7 fit failed	0.3%	2 DCR < 0.25 kHz	< 0.1%
45 gain > 1.7	2.3%	1 DCR > 10 kHz	> 99.8%
1870 gain ok	97.4%	1919 DCR ok	~ 0.1%

So far, results are totally fulfilling requirements !

Look at gain failed fit



4 channels with “normal” ToT distribution and high gain (above 2)

- Expected to fail

2 “dead” channels, discover during Acceptance tests

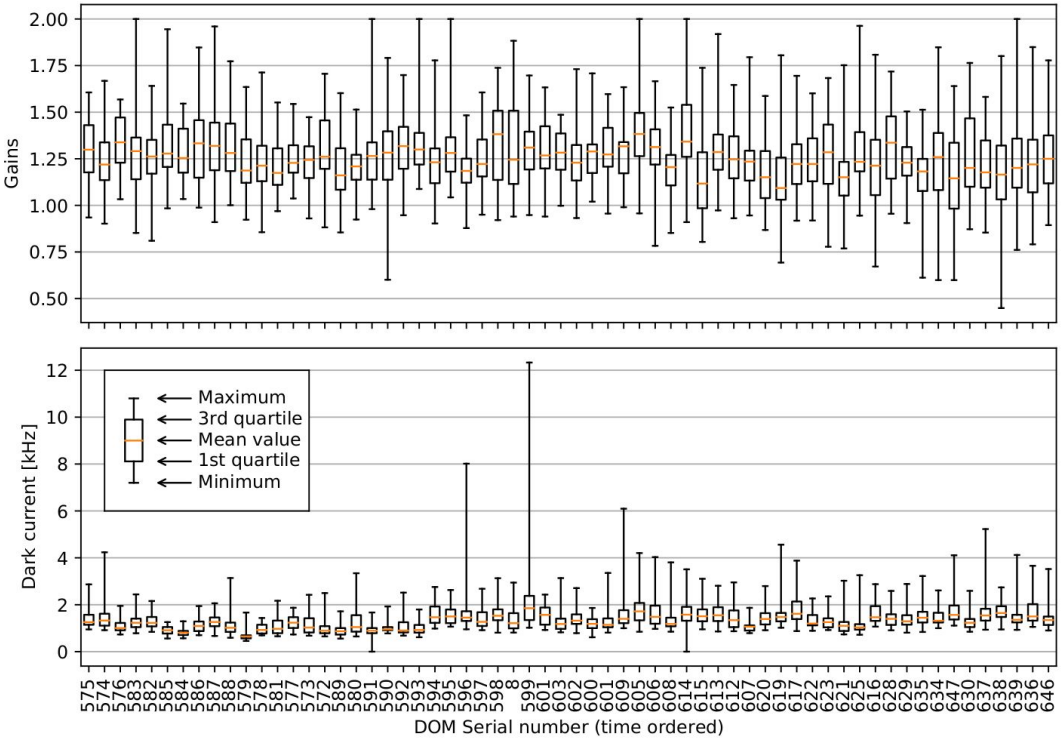
- Expected to fail

No time to look at the 7th

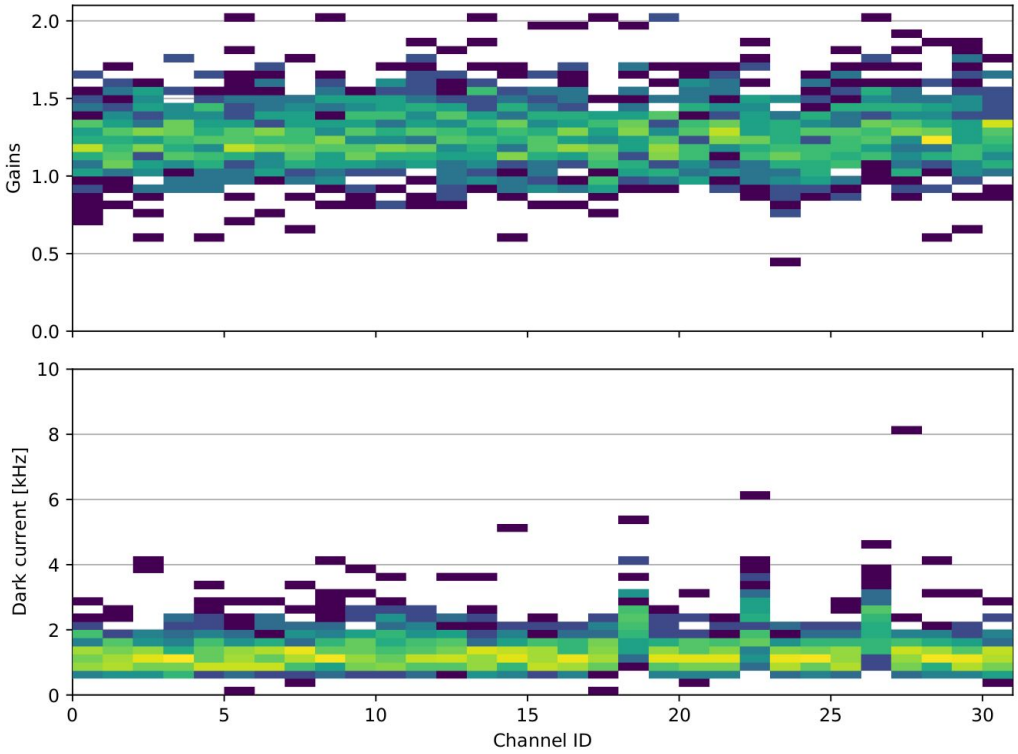
No surprise behind these cases. Problem for later HV tuning ?

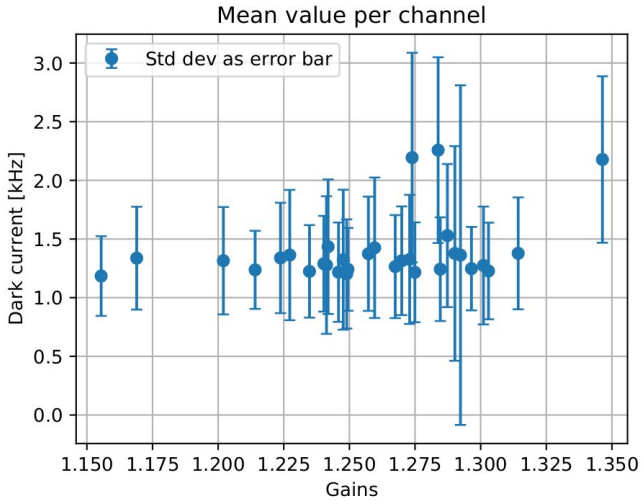
Gain and DCR per DOM

Stable production, except maximum DCR value which increase in the last DOMs



Gain and DCR per channel

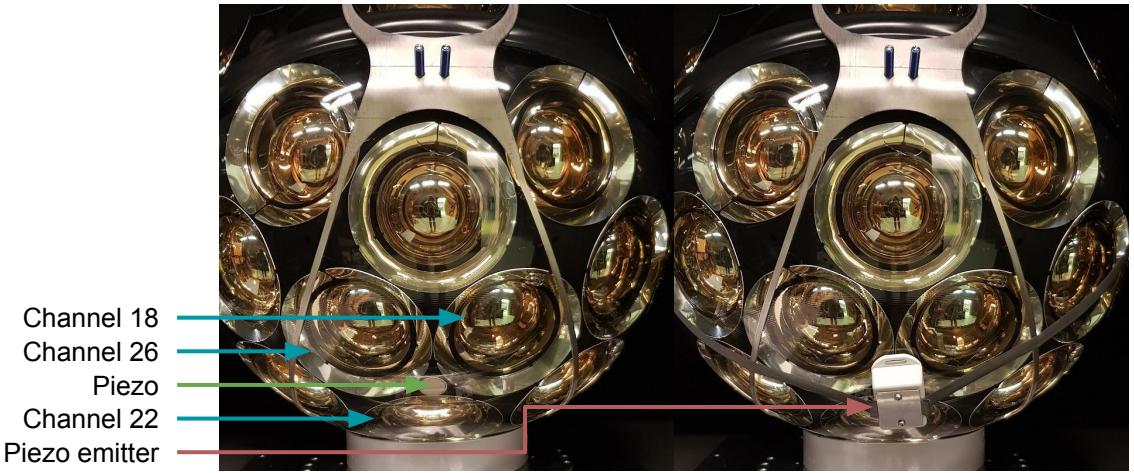


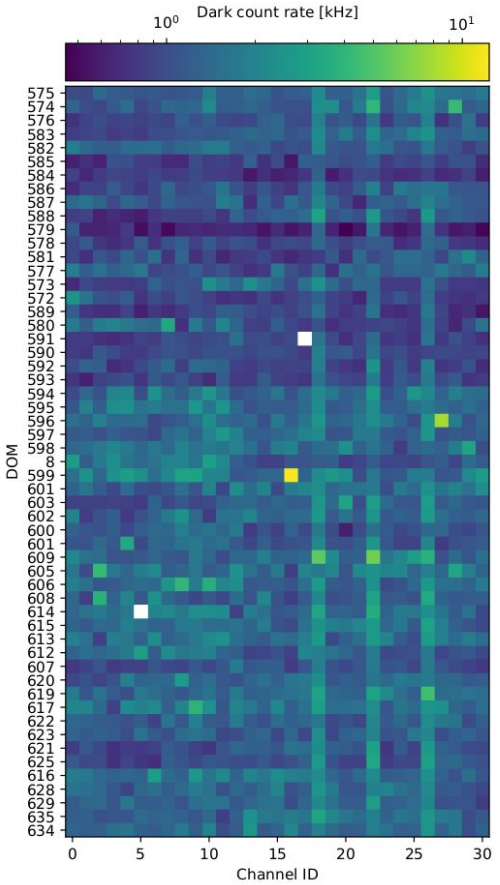


Channels 18, 22 and 26 are showing systematically higher rates than other channels. [2:2.5]kHz vs [1:1.5]kHz.

Nothing obviously suspicious on gain distribution. See elog-971

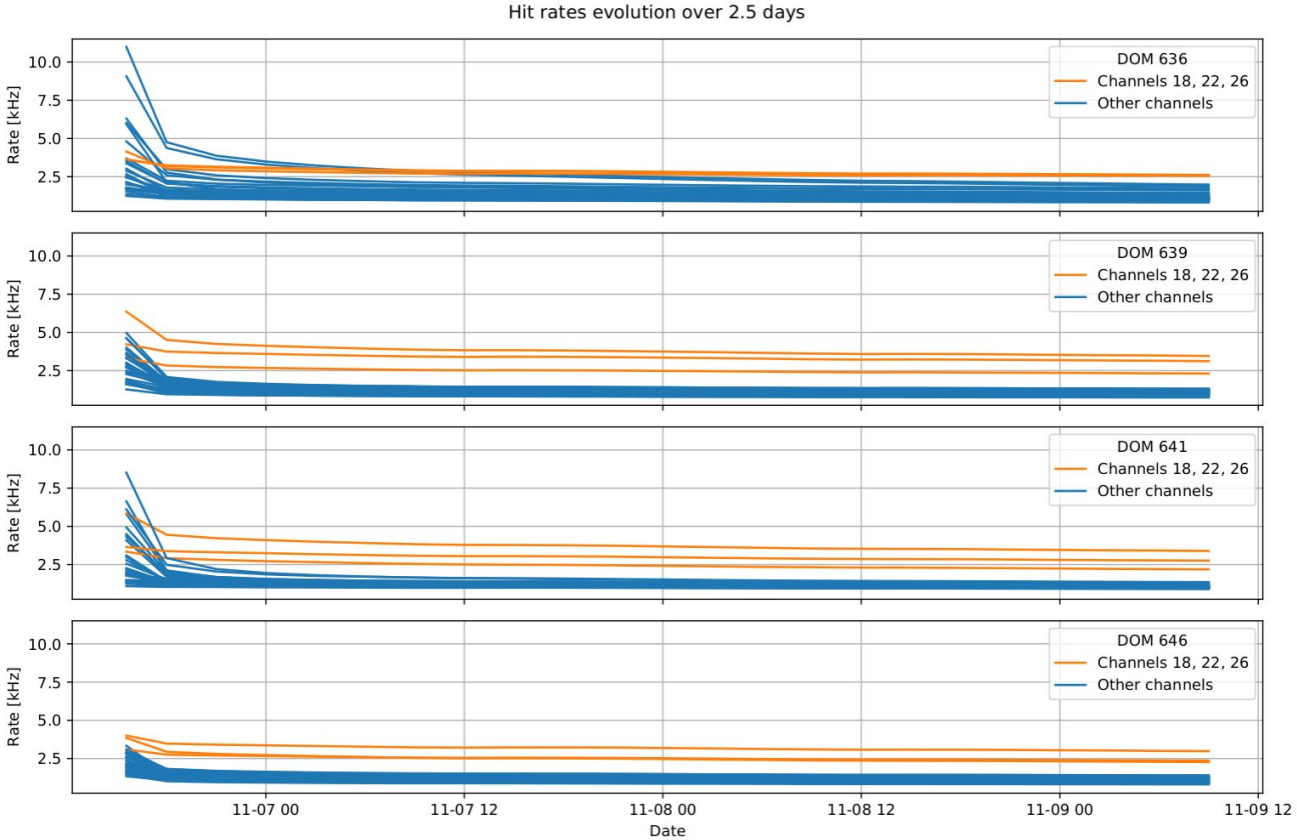
Current investigations





Additional (EM or radio)activity induced by In-DOM piezo sensor or DOM testing piezo emitter ?

Current investigations



Results for long term running, with piezo emitter put on the other side of the hemisphere

Channels 18, 22 and 26 stays the ones with largest DCR

Internal source (radioactivity/EM noise ?) (piezo material/glue ?)

Not major, but will be investigated

“Sparks” like events

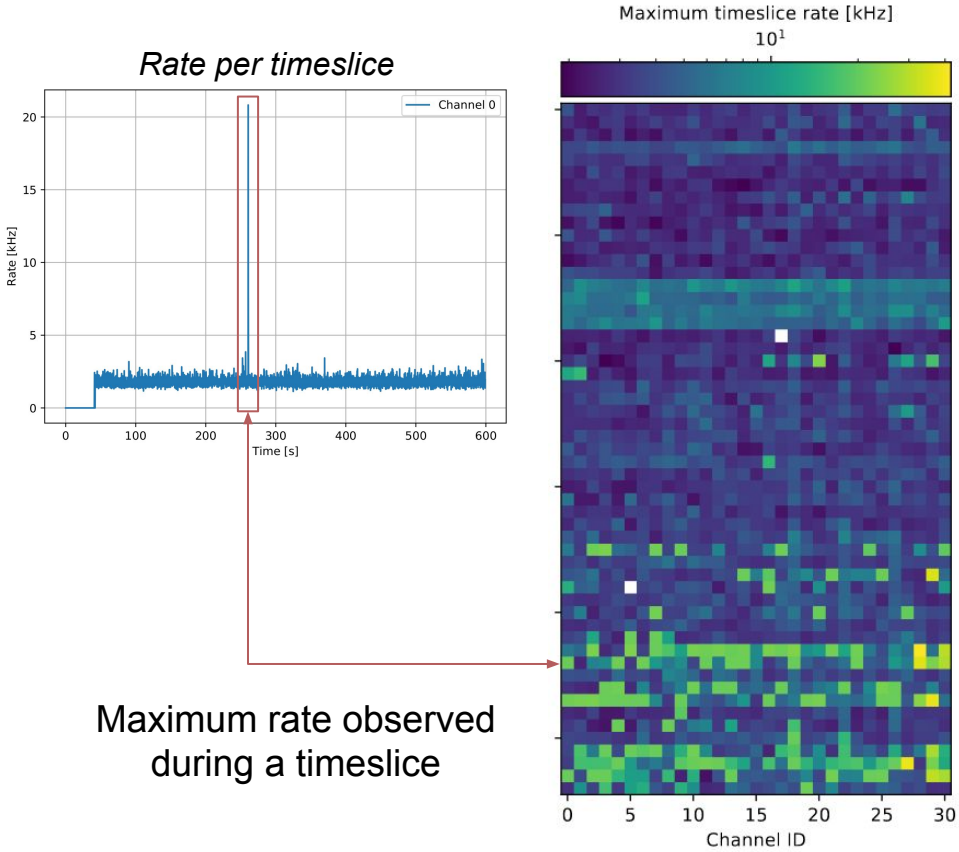
See elog-973.

Looking at rate in function of time :

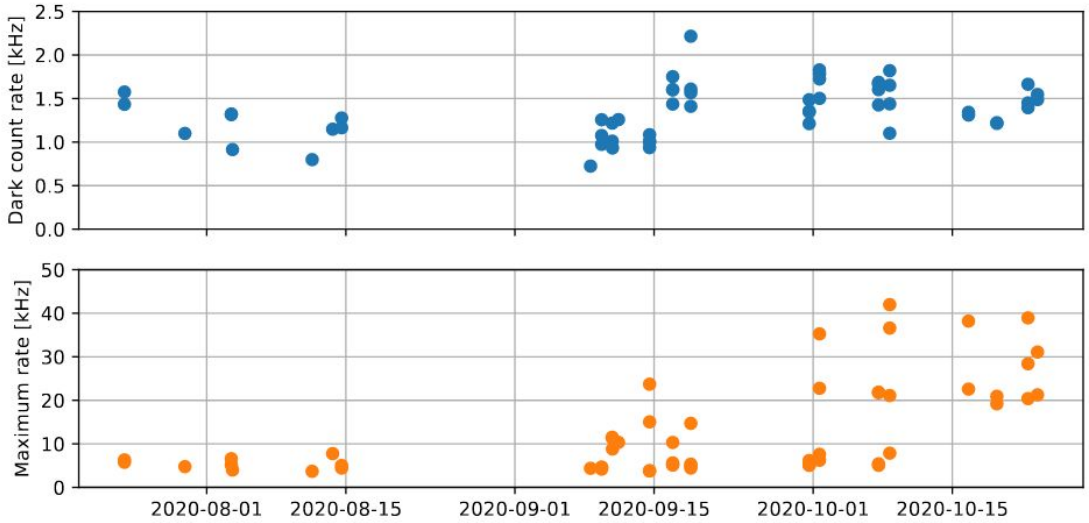
- Clear outliers, timeslice with really high rates

By selecting the maximum / channel

- Clearly more and more common phenomena
- Not impacting significantly the DCR mean value



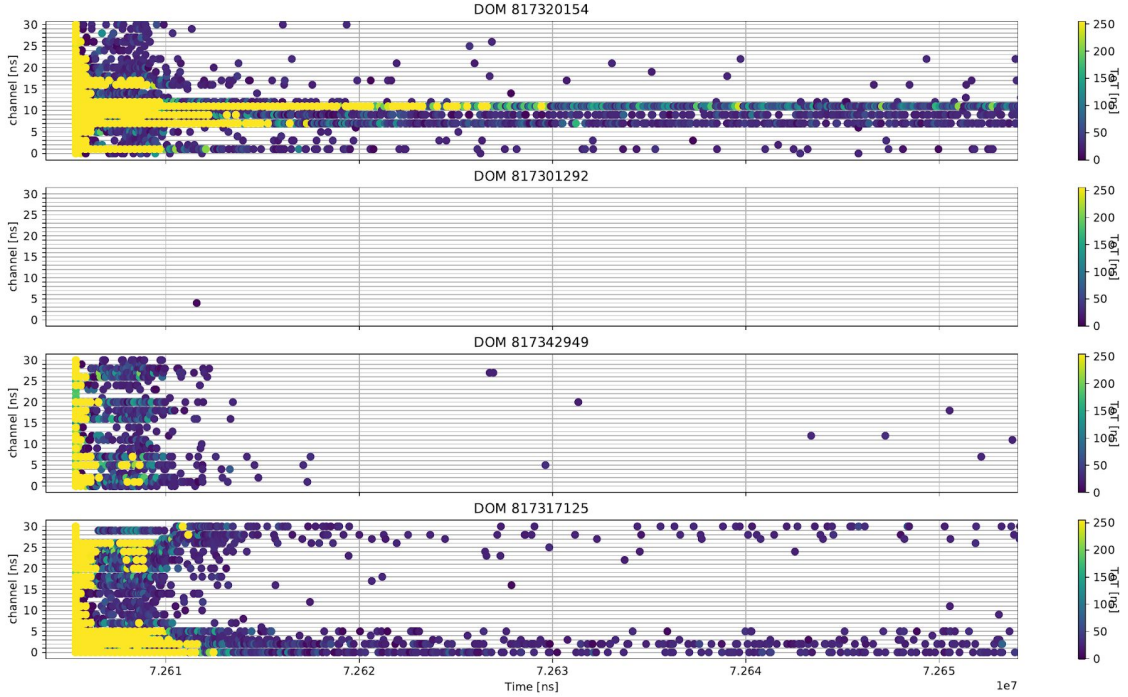
High rate timeslices : evolution



Smalle effect on measured DCRs

Effect seems appears around mid September. In the same period, new batch of PMTs start to be integrated.

“Sparks” ?



Trigger the need of a proper spark-like events reconstruction and a systematic study

Coincidences creation

Only L0 hits available, home-made coincidence reconstruction. General comments :

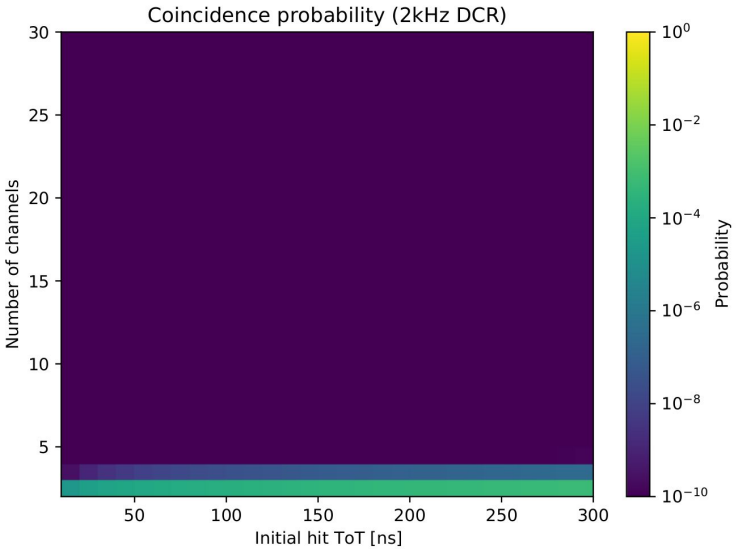
- Merge following hits (i.e. ToT can go above 255)
- Sort hits in time (not only per channels)

Procedure :

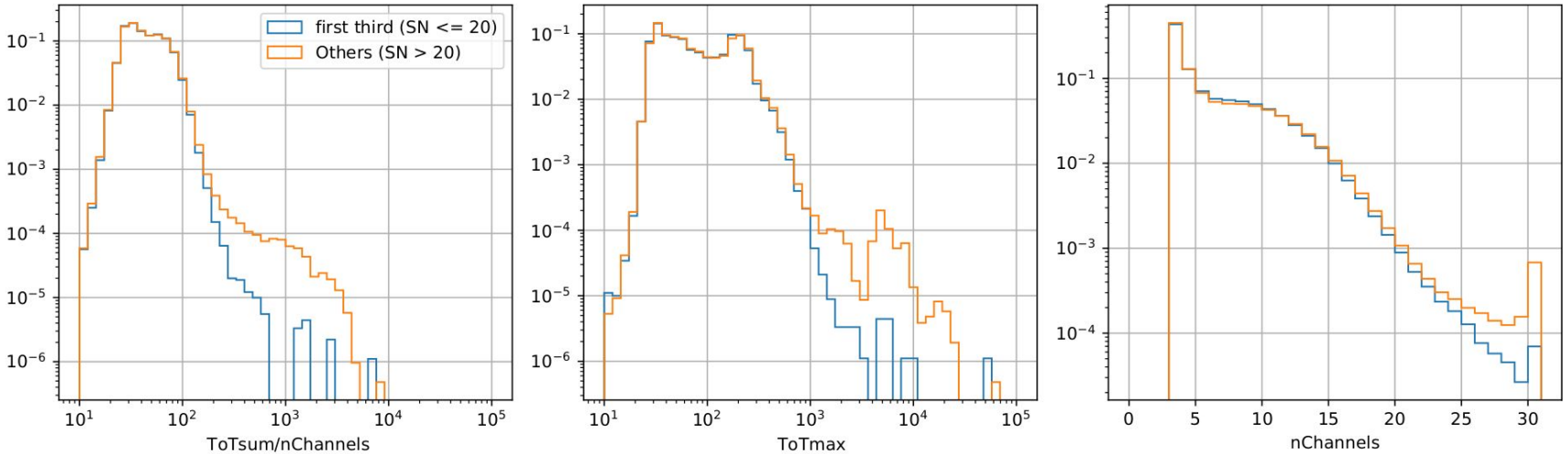
- Take a hit. Coincidence window [t_{hit}, t_{hit} +ToT].
- Next hit :
  - If inside, append to coincidence, update [t_{hit}, t_{hit} +ToT]
  - If outside, close previous coincidence, open new one.

Throw away coincidence nChannels == 2 :

- Almost no coincidences on DCR



Identify spark-like events

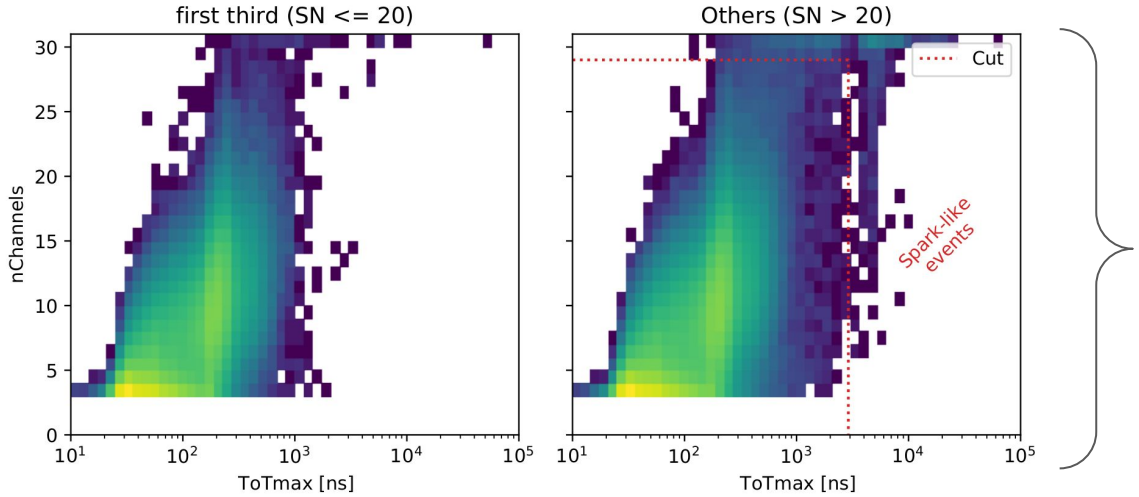


Separate the production in two, and normalize in the [0:100] ns window

- 20 firsts DOMs (~first third) used as reference, no obvious sparks
- 42 latest DOMs which contains sparks

Clear contribution of sparks !

Identify spark-like events



"Sparks" events :

- ToTmax > 2900 ns

Or

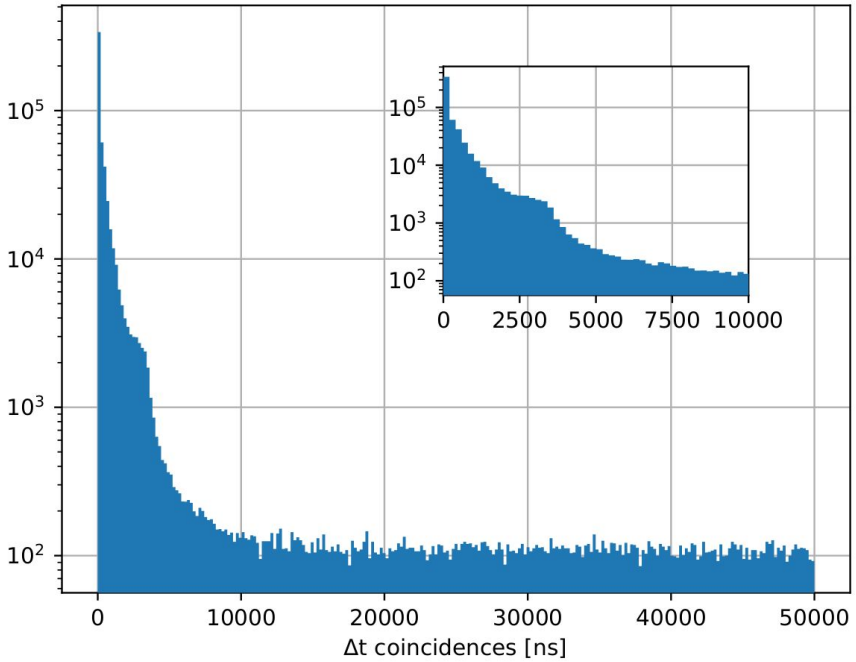
- nChannel >= 29

Quite empirical cuts, but clear contribution. Should work !

Selected contribution is not the only one appearing in the SN > 20 ...

Delta t distribution

T between following coincidences (no cut)

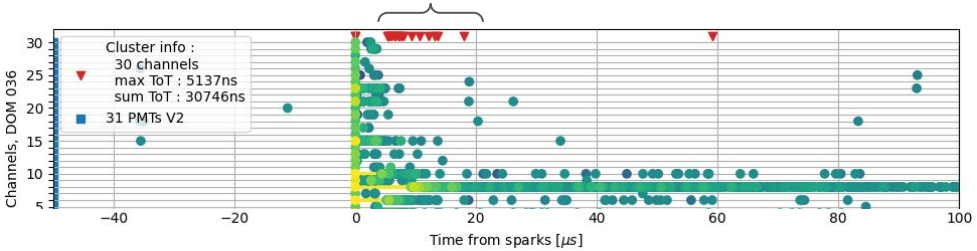


At dt < ~20us, a lot of bad “coincidences” :

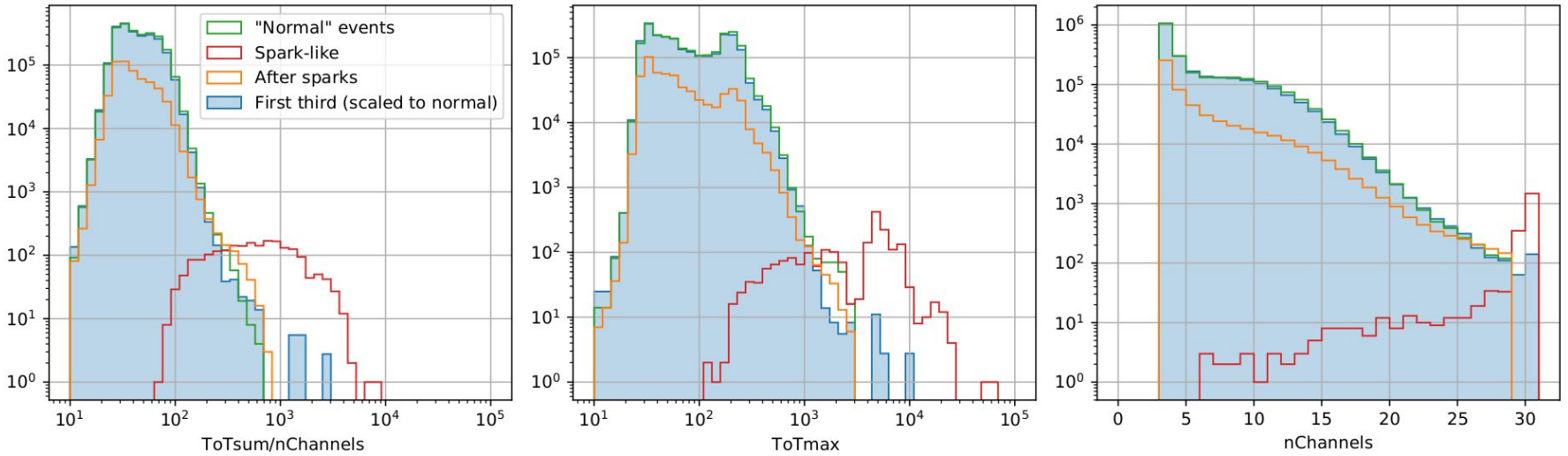
- Structure around 3us, clear afterpulses
- Exponential structure
  - Not sure, might be DCR related

Events with dt < 20us
partially induced by sparks

Cluster created on afterpulses and others ...



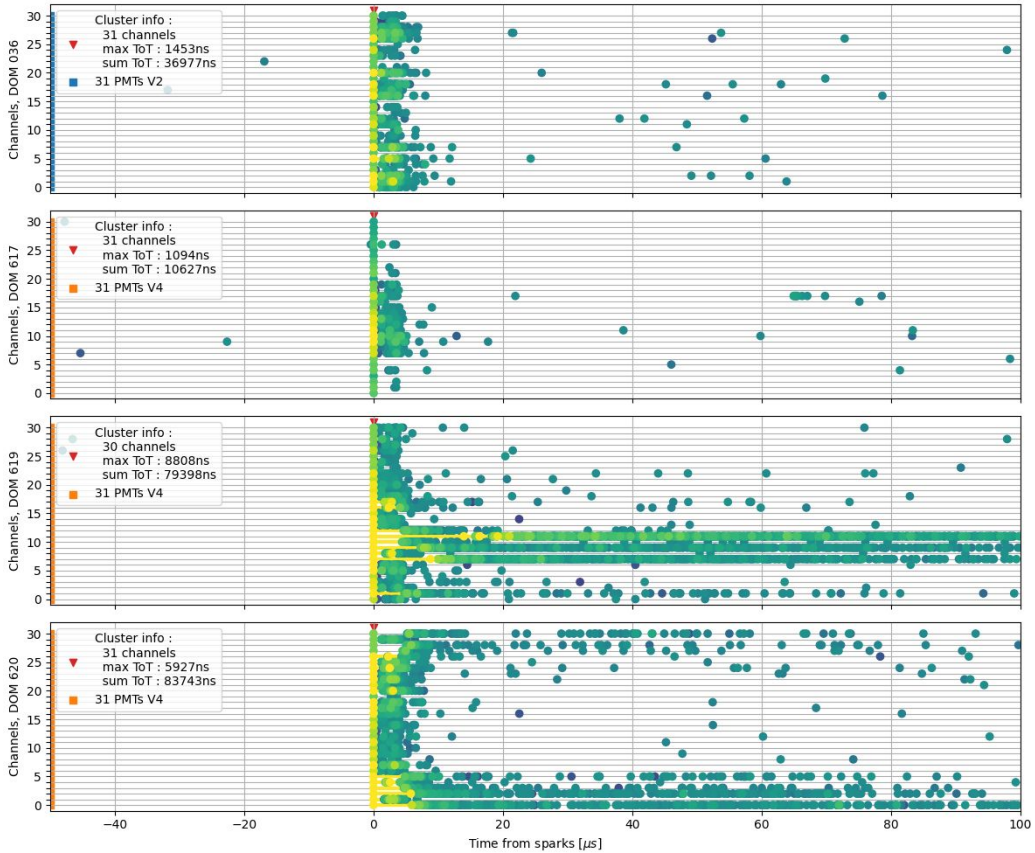
Identify spark-like events



- Spark-like: Above spark cuts
- After sparks: Not a sparks but dt < 20us
- “Normal”: Not a sparks and dt > 20us
- First third: First DOMs scaled to “Normal”

Clear separation between the 3 categories.
Good agreement between “Normal” and the distribution coming from first DOMs.

Example of event



Good way to count sparks !

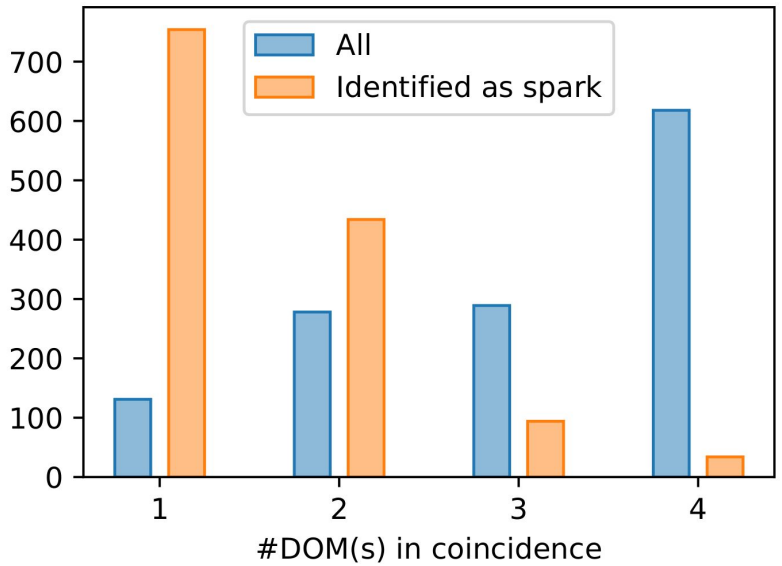
Anyway, sparks can be seen in multiple DOMs.

When sparks reconstructed in multiple DOMs :

- Attributed to the DOM seeing the largest ToT sum.

More here

Last : select sparking DOM



Look at coincidence between DOMs

- Cluster closer than 50ns

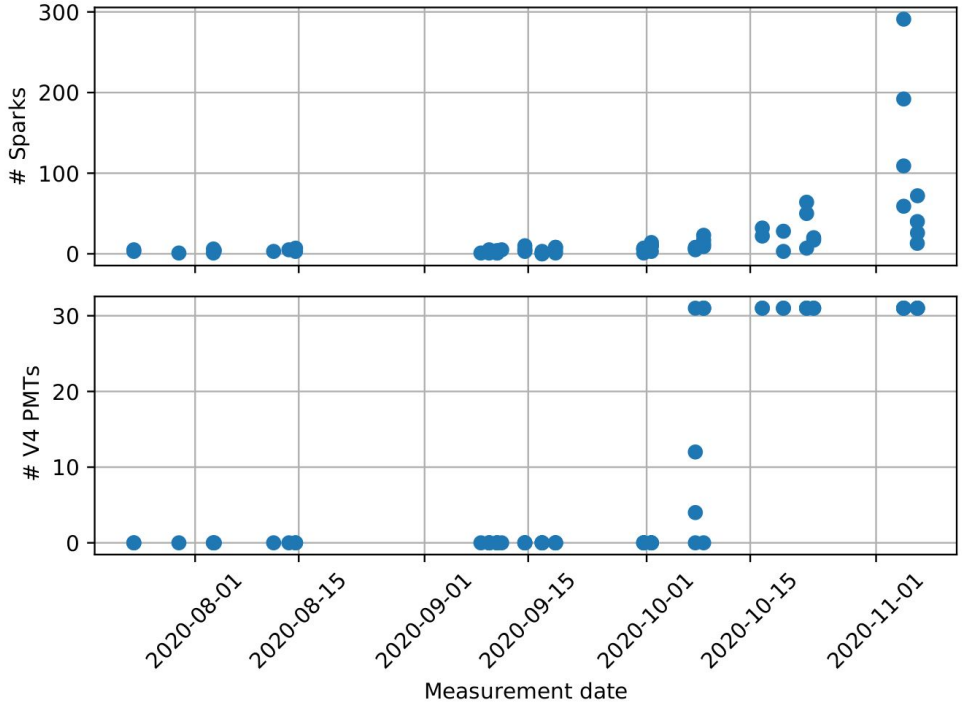
Number of DOMs seeing a signal in coincidence with the sparking DOM (including itself) : All

- Sparks visible by multiple DOMs most of the time

Identified as spark :

- Mostly only 1 or 2 DOMs reconstructing the event as spark
  - Pretty good result !

Sparks increase

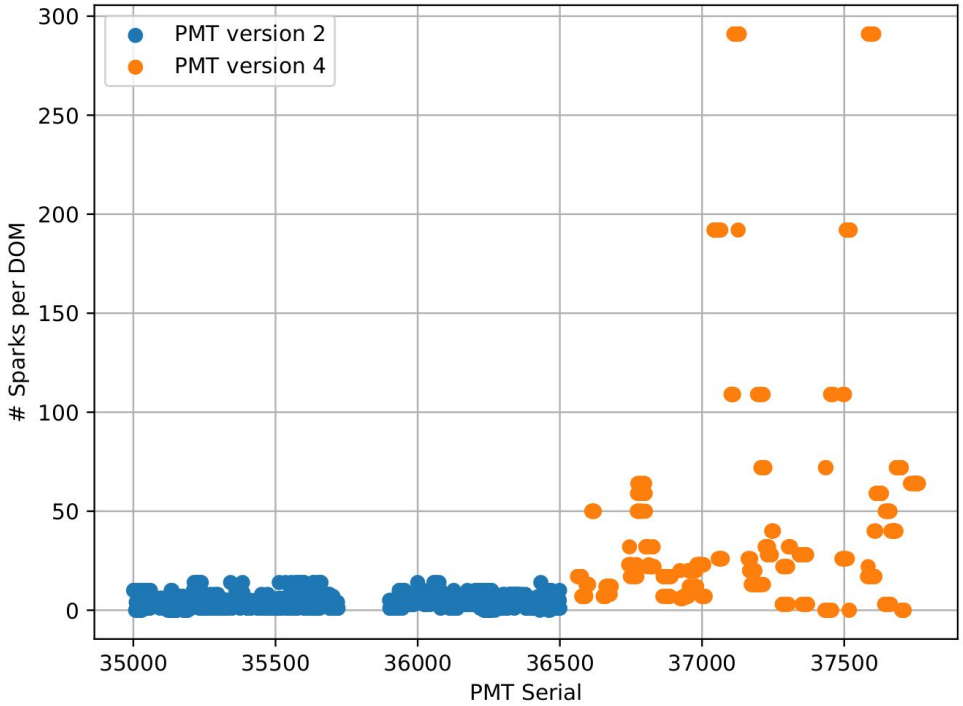


Few sparks in the early production

Clear increase in October

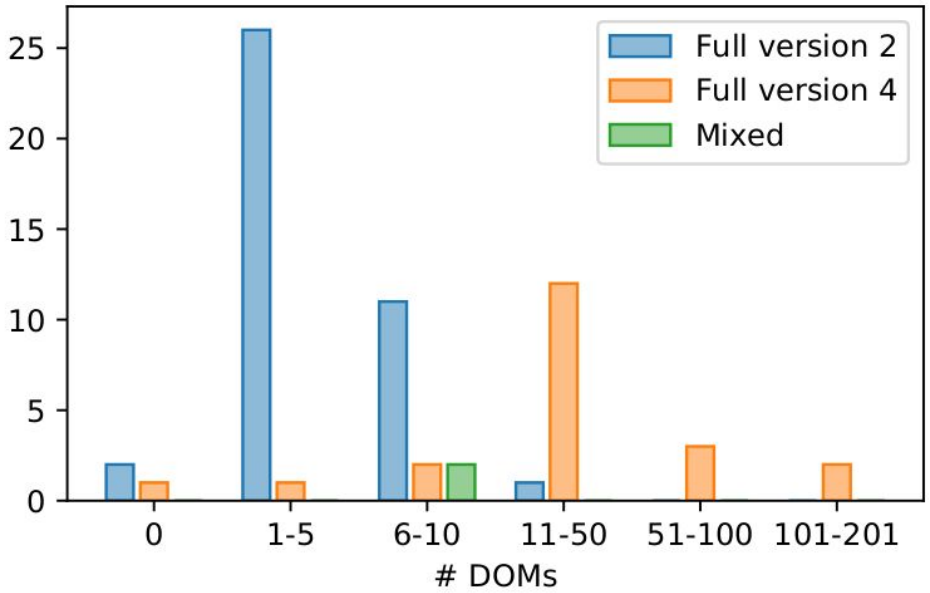
Correspond to integration of V4 PMTs

Sparks increase



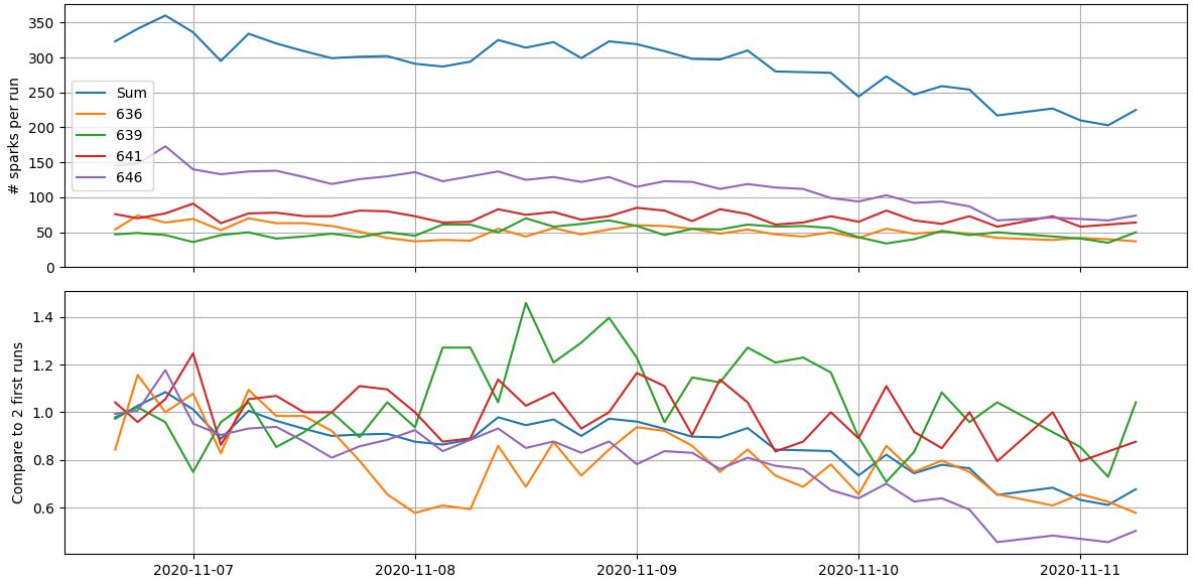
Clear relation with PMT version !

Anyway, not all V4 PMTs are generating a lot of sparks.



Serial number	UPI	nV4	nSparks
614	3.4/CP:8a77bd45/1.614	12.0	6.0
615	3.4/TSFP/1.615	31.0	7.0
42	3.4/TSFP/1.613	4.0	8.0
617	3.4/TSFP/1.617	31.0	12.0
616	3.4/TSFP/1.616	31.0	7.0
619	3.4/TSFP/1.619	31.0	17.0
620	3.4/TSFP/1.620	31.0	23.0
623	3.4/TSFP/1.623	31.0	22.0
622	3.4/TSFP/1.622	31.0	32.0
621	3.4/TSFP/1.621	31.0	3.0
625	3.4/TSFP/1.625	31.0	28.0
630	3.4/CP:c5d0d39e/1.630	31.0	59.0
628	3.4/TSFP/1.628	31.0	50.0
629	3.4/TSFP/1.629	31.0	64.0
634	3.4/TSFP/1.634	31.0	17.0
635	3.4/TSFP/1.635	31.0	20.0
646	3.4/CP:f9cab99e/1.646	31.0	72.0
647	3.4/CP:7d2772c9/1.647	31.0	109.0
637	3.4/CP:58f55a9c/1.637	31.0	192.0
638	3.4/CP:31de75e7/1.638	31.0	291.0
639	3.4/CP:5d3931ed/1.639	31.0	13.0
636	3.4/CP:a760244a/1.636	31.0	26.0
641	3.4/CP:c5e59007/1.641	31.0	40.0

Long runs



4 DOMs running since Friday afternoon. 20 minutes run every 3 hours.
Monitor the number of sparks (following previously described method).
~30% reduction in ~5 days.

Conclusion

Spark-like events are observed in Nikhef test setup

- Probably occurring since the beginning, but drastically increased start of October
- Strong correlation with new PMT (Version 4) introduction

Rate decreasing with time, but very slowly ...

More investigation planned

- External camera inside the box, to localize accurately where sparks happen
- Based on Serial number, comparison between “good” and “bad” version 4 PMTs

And maybe some improvement on the analysis method …

- Check ambiguity solving : is the sparks attributed to the proper DOM
- Look at channel level systematic effects