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Noise and spurious pulses for Cherenkov light detection with 10-inch and 3-inch photomultipliers

S.Aiello, V.Giordano, E.Leonora

INFN-National Institute of Nuclear Physics
64, Via Santa Sofia, Catania
Italy
www.ct.infn.it

Valentina.Giordano@ct.infn.it

Summary

- ✓ PMT 10 inch and PMT 3inch in single photoelectron condition
 - Charge and Time distribution for pre and delayed pulses (spe)
 - Charge and Time distribution for afterpulses AP (type 1, type 2 and multiple AP2)

- ✓ PMT 3inch
 - Variation of transit time spread (TTS) and of fractions of spurious pulses in different conditions of response of PMT (from spe to 3 pe and 5 pe)

Spurious pulses

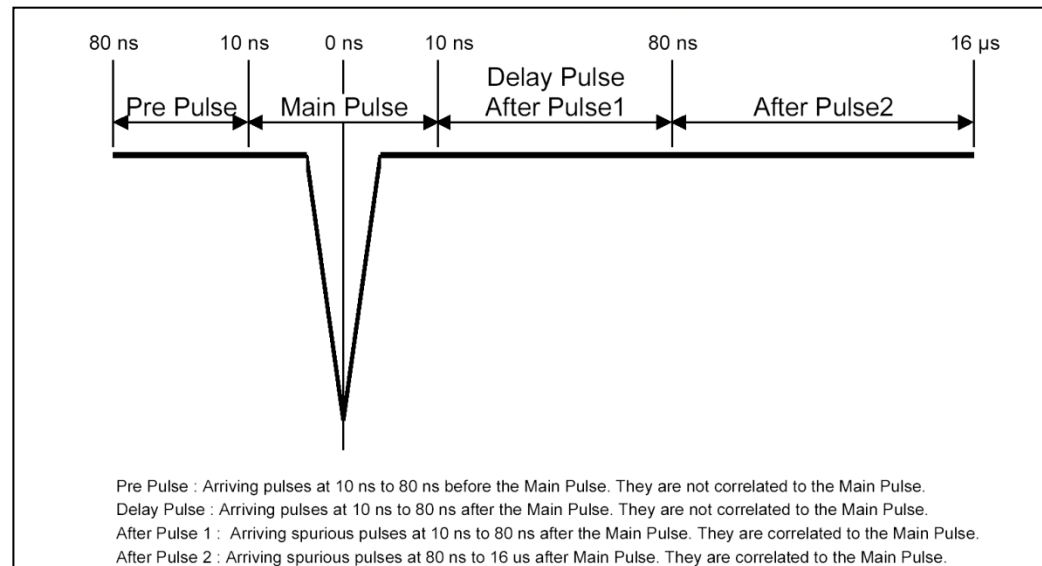
Spurious pulses not correlated with main pulse :

Pre-pulses : due to the direct photoelectron emission on the first dynode from the photons which passed the photocathode without interaction. The arrival time of pulse will be anticipated in confront of the main pulse.

Delayed: The primary photoelectron is reflected from the first dynode without a secondary electron emission, it turns towards the photocathode, makes a loop and only after it creates a cascade of electrons in the dynodes. The arrival time of the hit will be delayed in confront of the main pulse (delay 10ns-100ns).

Spurious pulses time-correlated with the main PMT response:

After pulses(type 1 , type 2, multiple after pulses): noise pulses that appear following the main PMT response to a detected light event. (100ns-16 μ s after Main pulse)



R7081 10-inch by Hamamatsu



Gain = $5 \cdot 10^7$

Laser PicoQuant wavelength 410nm

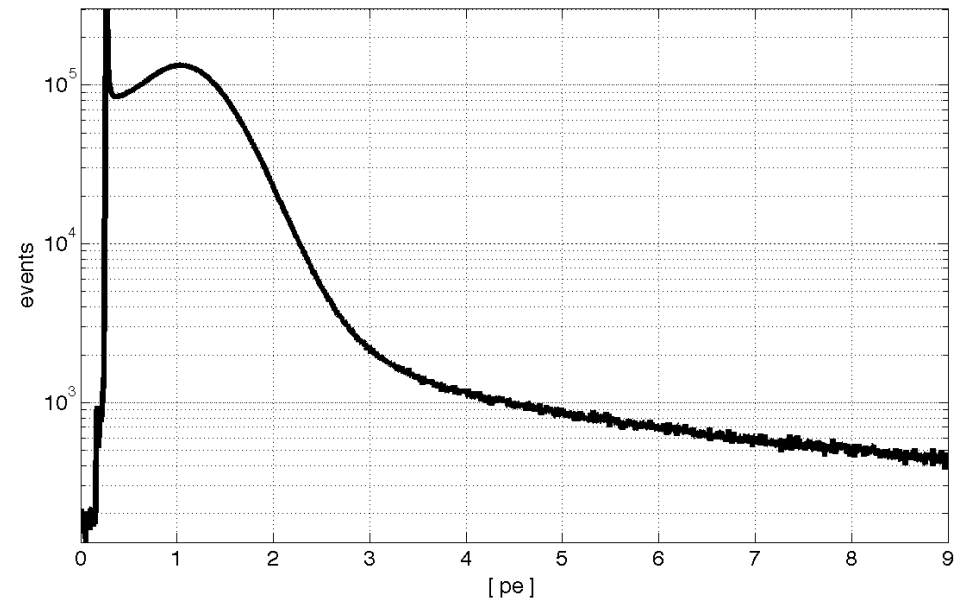
10kHz (external -trigger)

Large Are PMT Mushroom shape

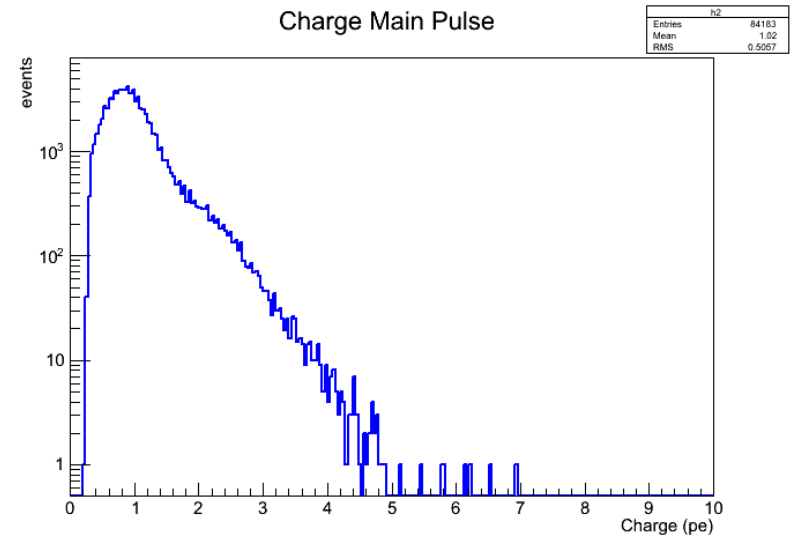
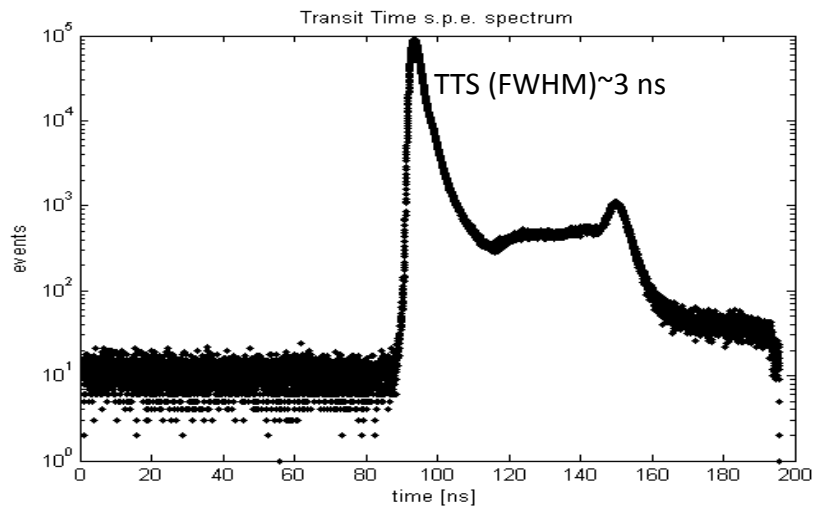
Bialkali photocathode

Active base by ISEG

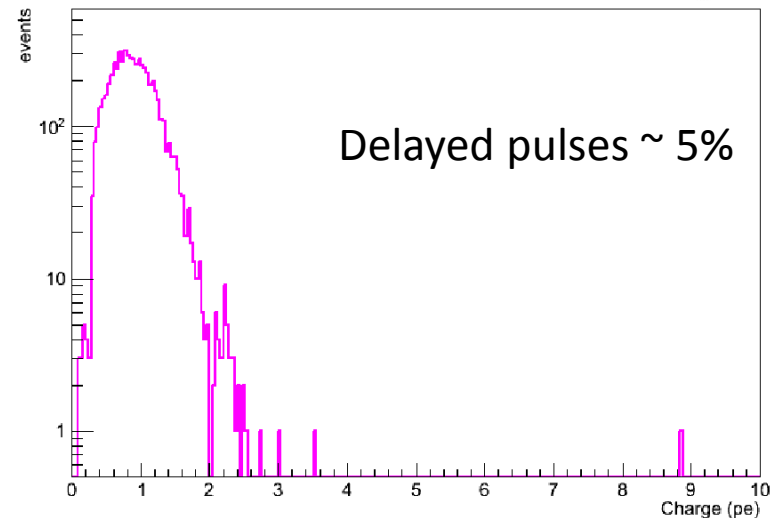
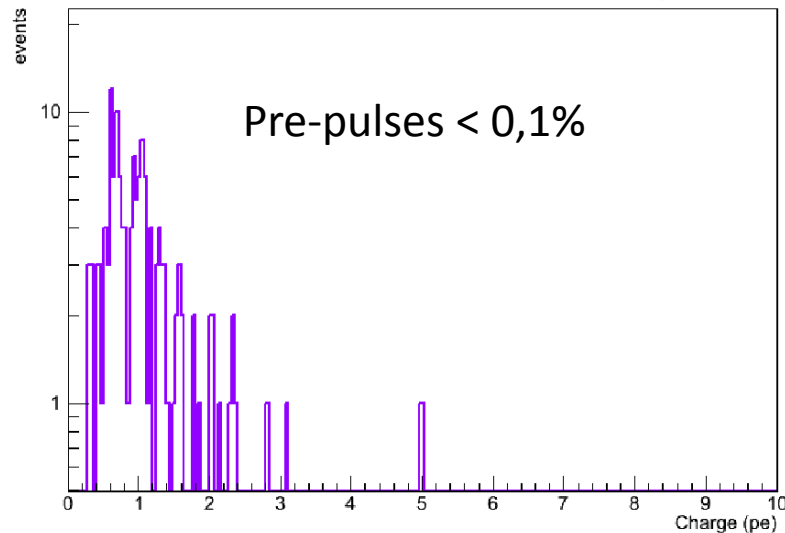
Charge distribution of dark pulses



10-inch Spurious Pulses (spe)



Both pre and delayed pulses have a charge distribution mainly of 1 spe



Measurements Setup for After pulses

Oscilloscope LeCroy

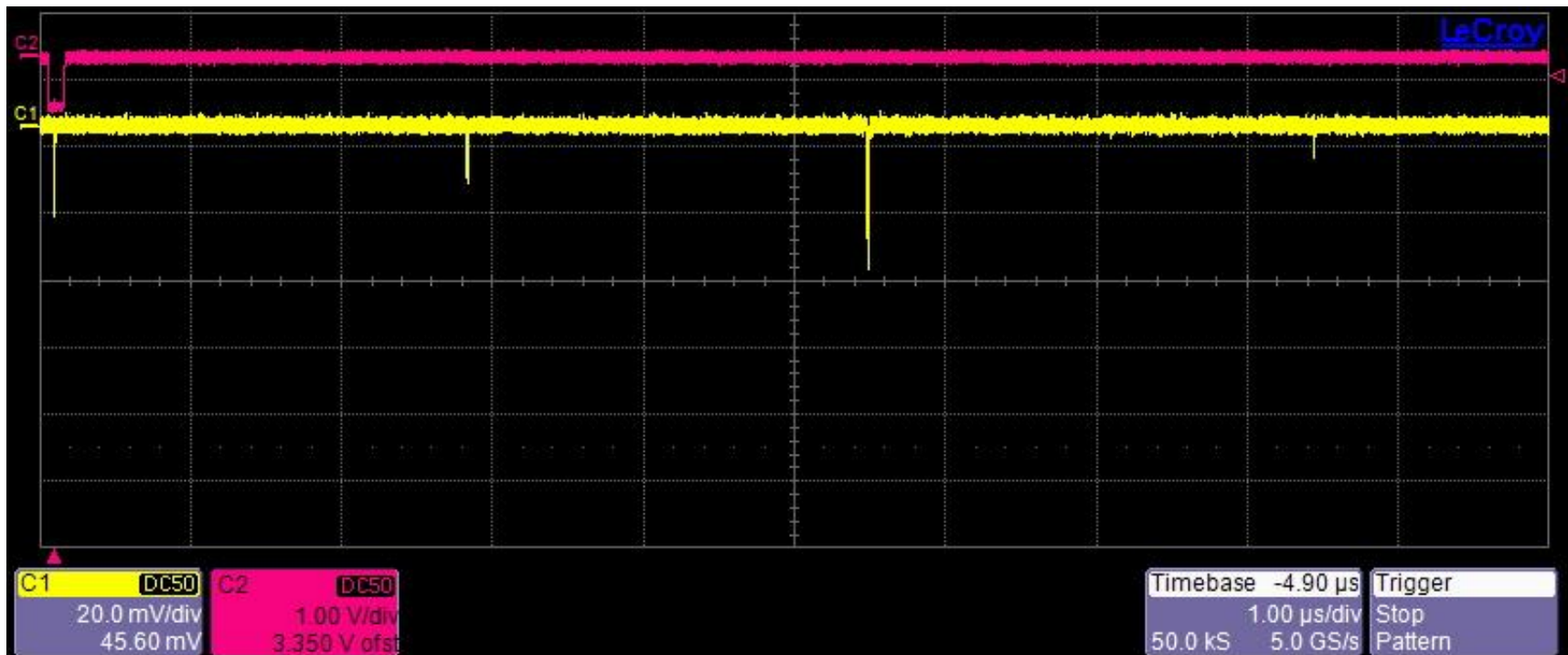
Trigger : Laser and PMT Main signal coincidence

Acquisition for $20\mu\text{s}$

5.0 GS/s

Offline analysis

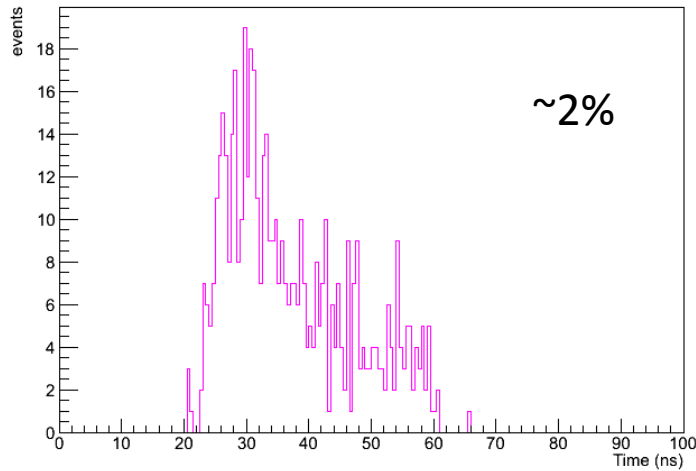
**Spurious pulses taken in
single photoelectron conditions**



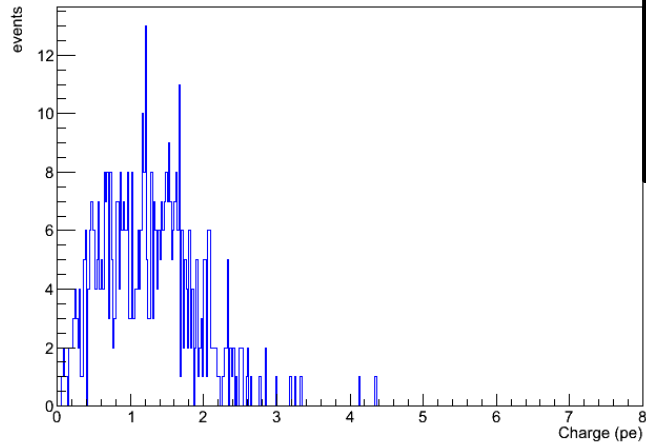
10-inch After pulses (spe)

Type 1: (10 ns - 100 ns) : due to
luminous reaction on the electrodes.

Time Distribution After Pulses type 1



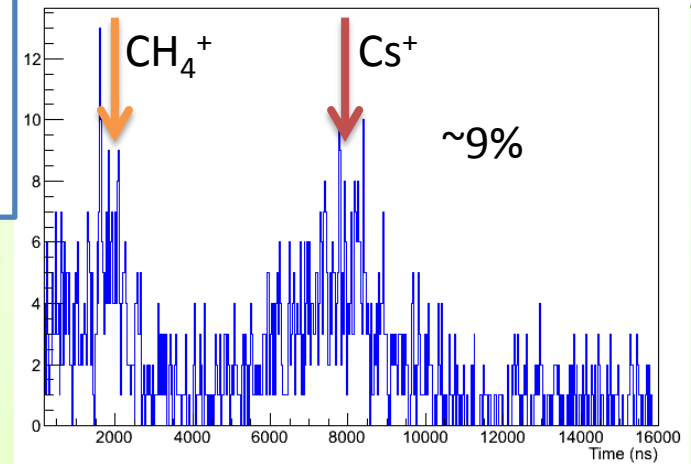
Charge Distribution After Pulses type 1



AP1
mainly
of 1 pe.

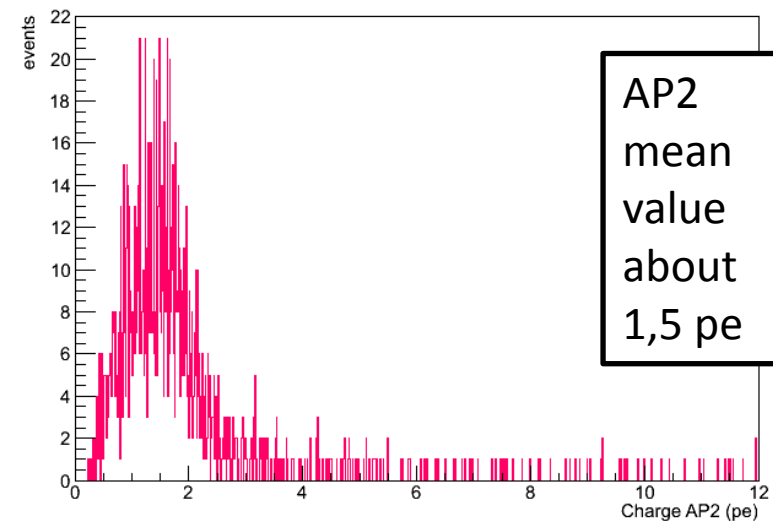
Type 2: AP (100 ns - 16μs) :
due to the ionization of the residual gas in
the PMT.

Time distribution After Pulses type 2



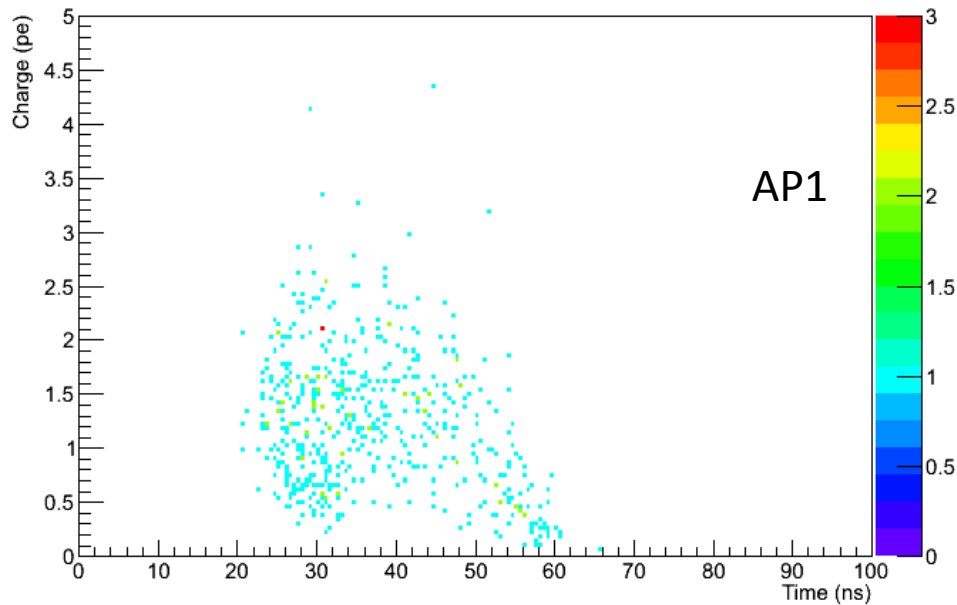
2 peaks
(ion
contributi
ons)

Charge distribution AP2



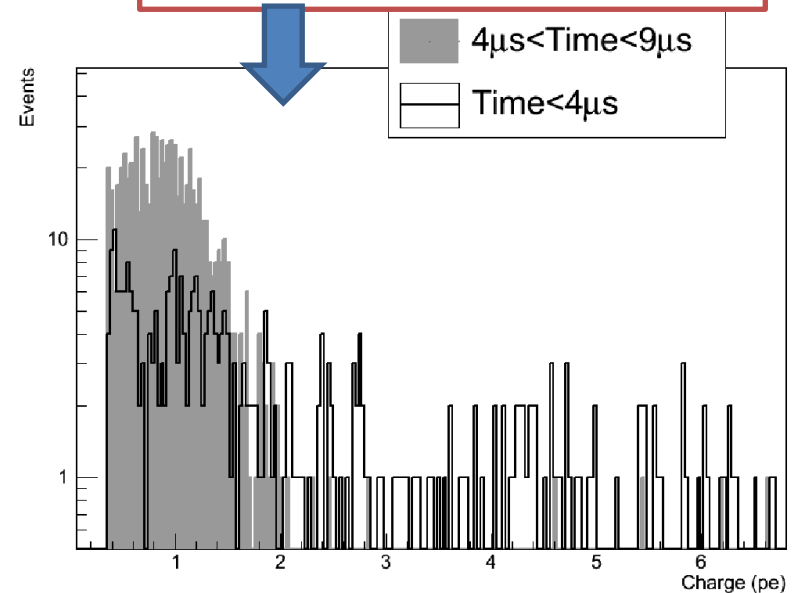
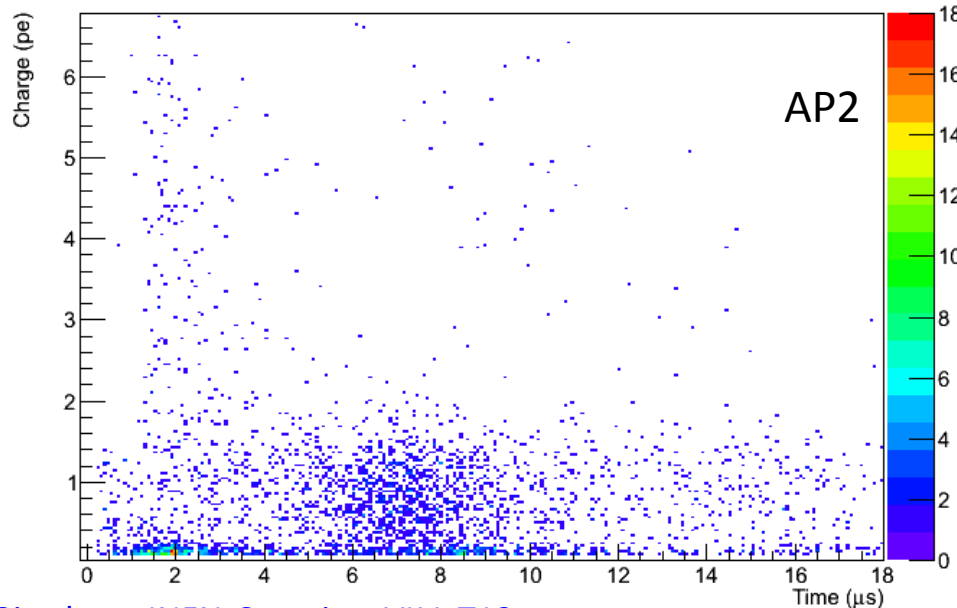
AP2
mean
value
about
1,5 pe

10-inch After pulses (spe)



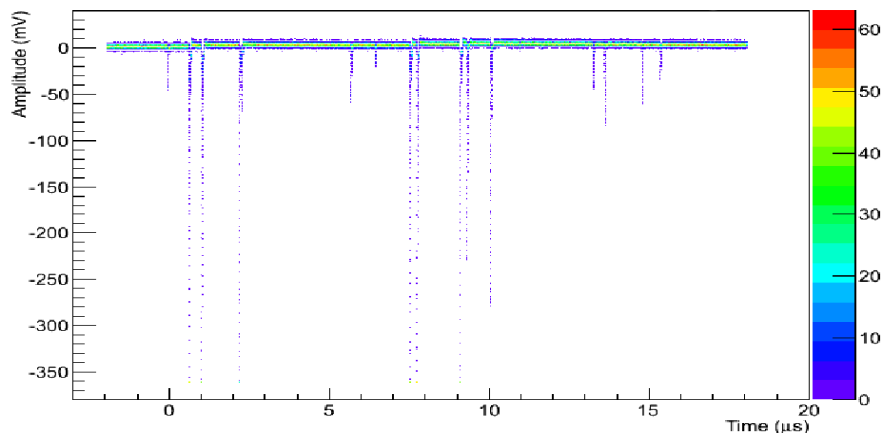
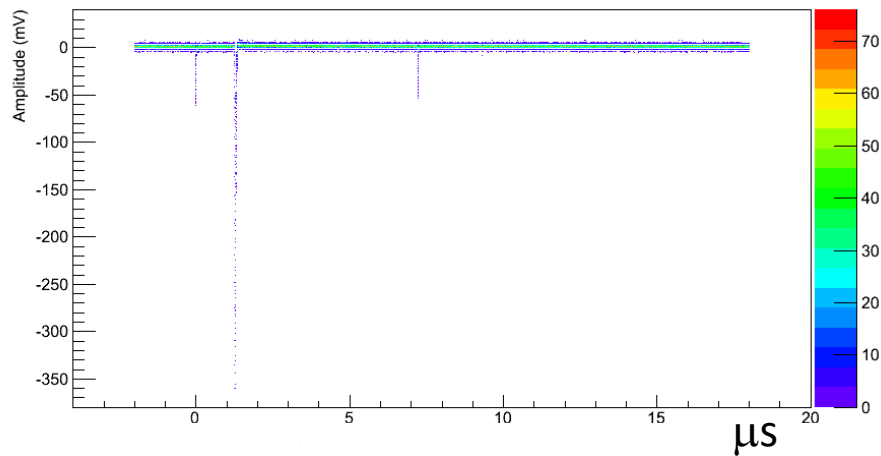
Charge Vs Arrival Time for After pulses:
 AP1 are mainly of spe
 AP2 have more high charged events

Charge distribution of AP2 in different time ranges.
 In black there is the peak corresponding to CH_4^+ while in gray there is the Cs^+ peak.
 High charged AP2 are due mainly to CH_4^+



10 inch Multiple After pulses (spe)

Multiple AP2 events are present in PMTs.
For only one AP2 the mean charge is about 1,2 pe but charge per pulse increases up to 3 pe with the increasing of number of AP2

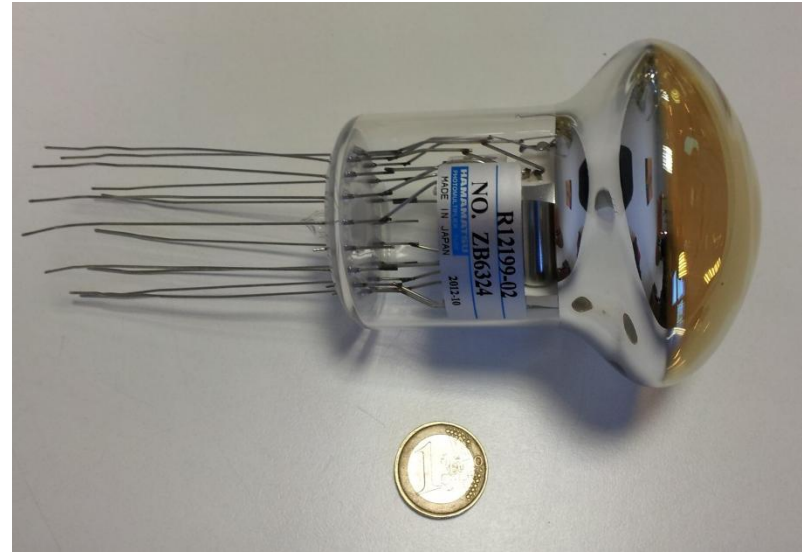


N° AP2	Fraction (%)	Mean Charge (pe)
1	8,27	1,2
2	2,59	1,3
3	0,87	1,9
4	0,46	2,9
5	0,21	2,5
6	0,15	2,5
7	0,10	2,6
8	0,08	2,6
9	0,03	2,3
10	0,05	2,3
11	0,03	2,9

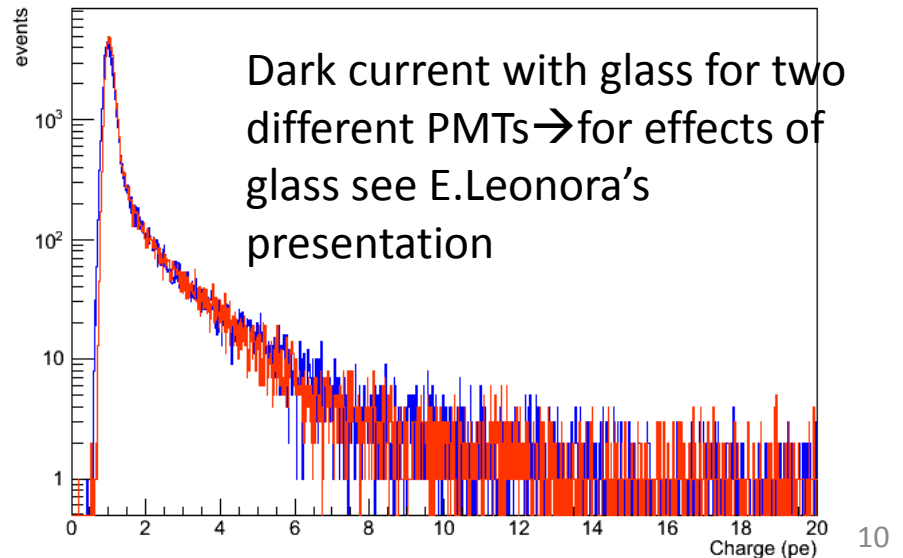
R12199-02 PMT 3-inch by Hamamatsu

- Gain = $5 \cdot 10^6$
- Laser PicoQuant wavelength 410nm, 10kHz (ext-trigger)
- Mushroom shape
- Bialkali photocathode
- Passive base made by Erlangen group

3-inch PMTs into a
multiPMT optical
module



Charge pe

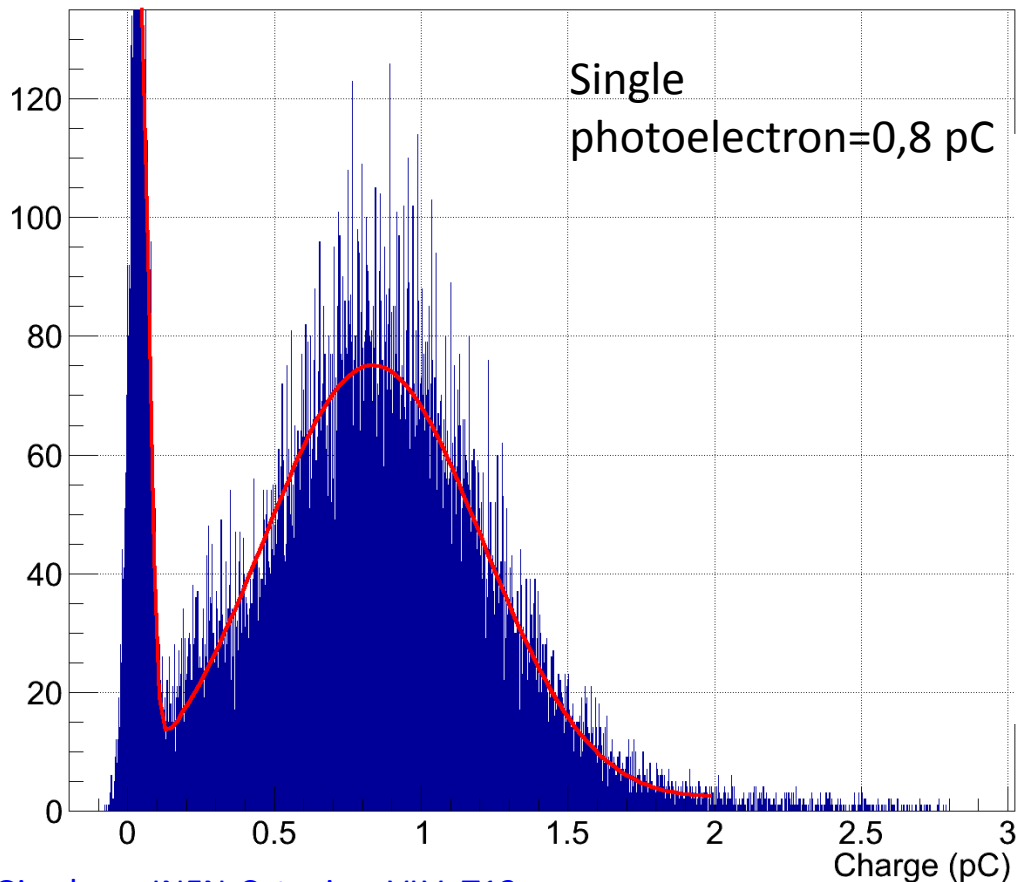


3 inch characterization in spe conditions

Peak to valley ratio:

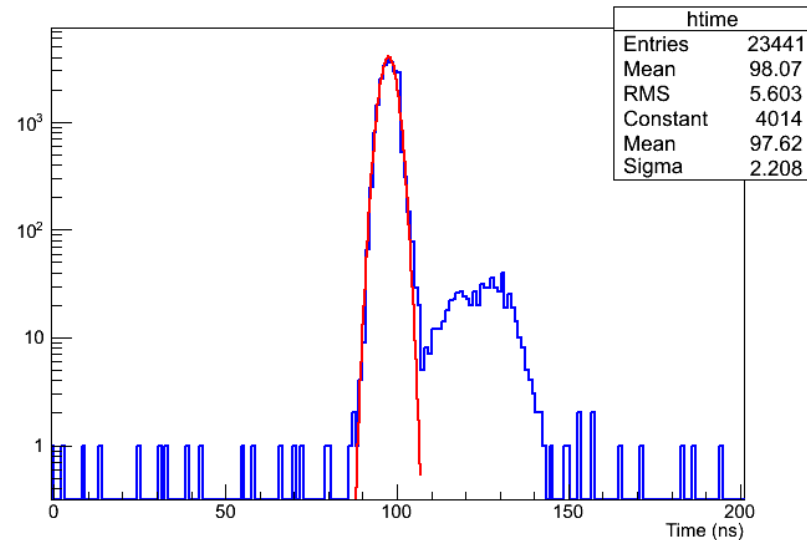
Fit expo+gaus

Charge Spectrum spe



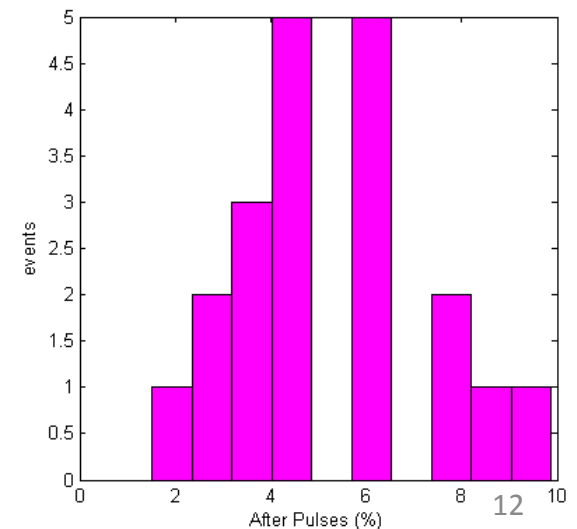
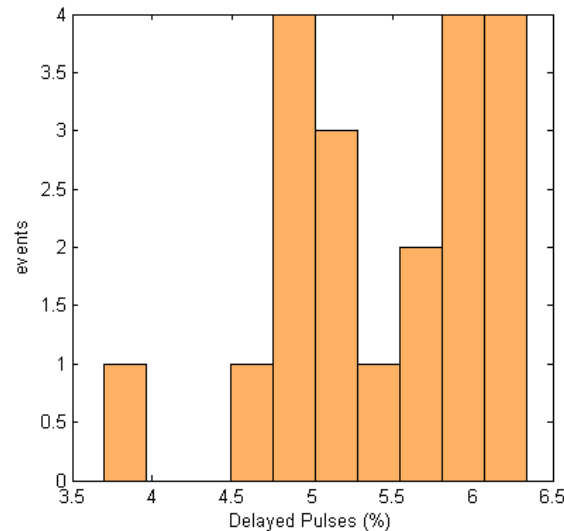
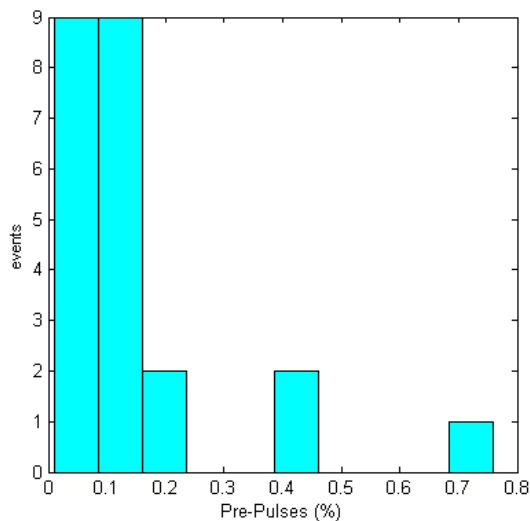
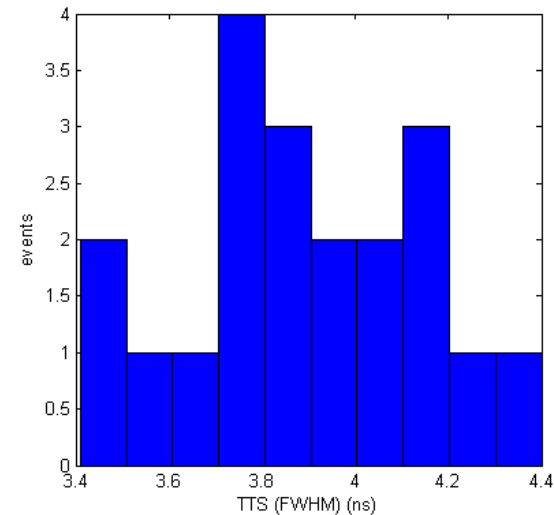
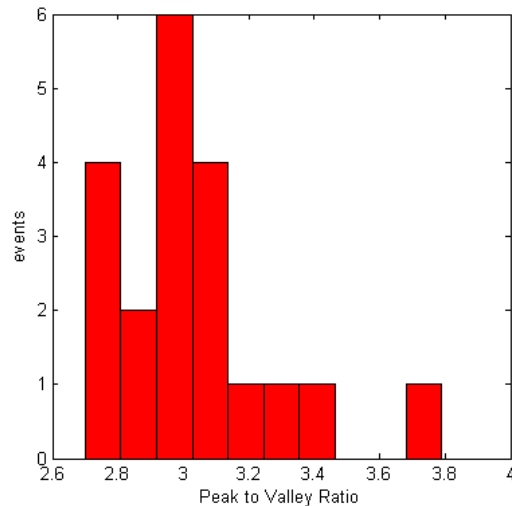
TTS ~ 4 ns

Time distribution



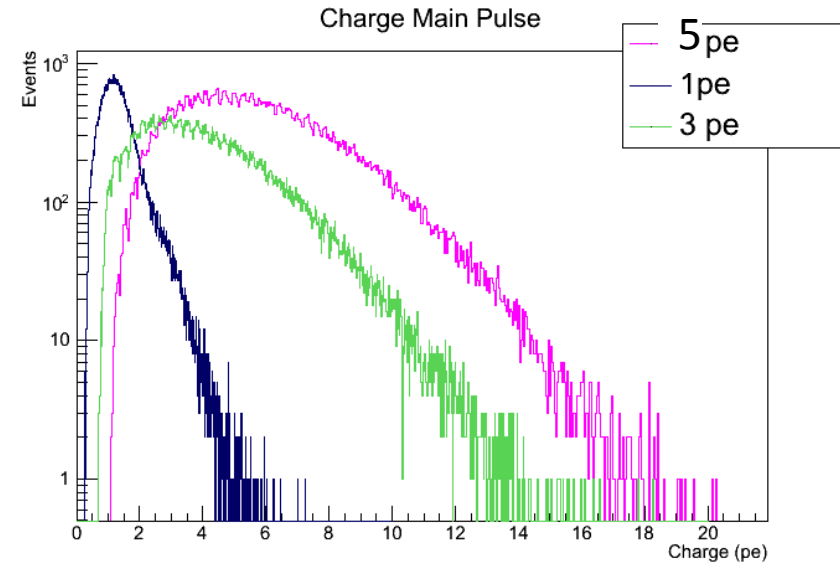
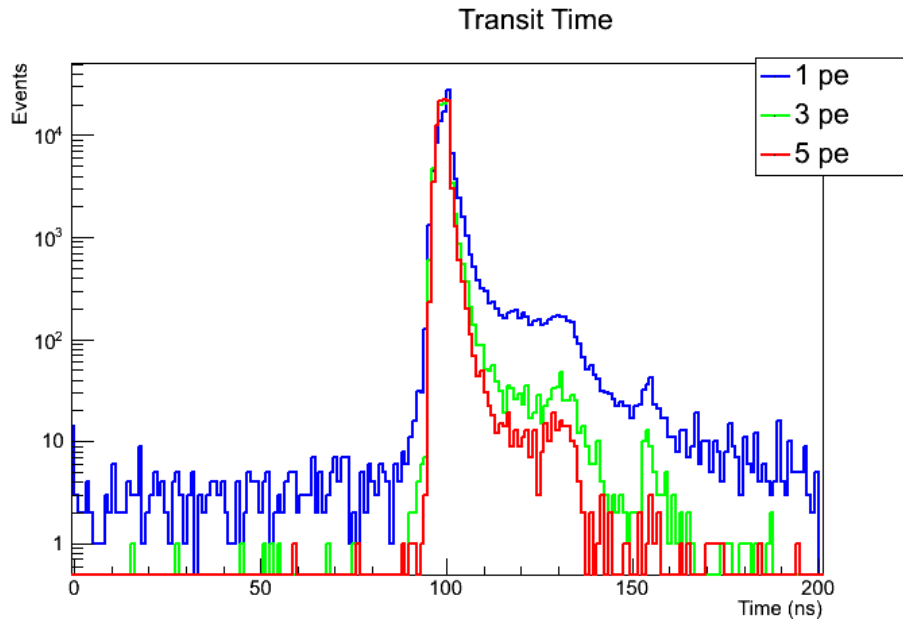
3-inch main properties

Set of 20 PMTs by HAMAMATSU 3-inch R12199-02 tested in INFN-Catania laboratory



3 inch Characterization (1, 3, 5 pe)

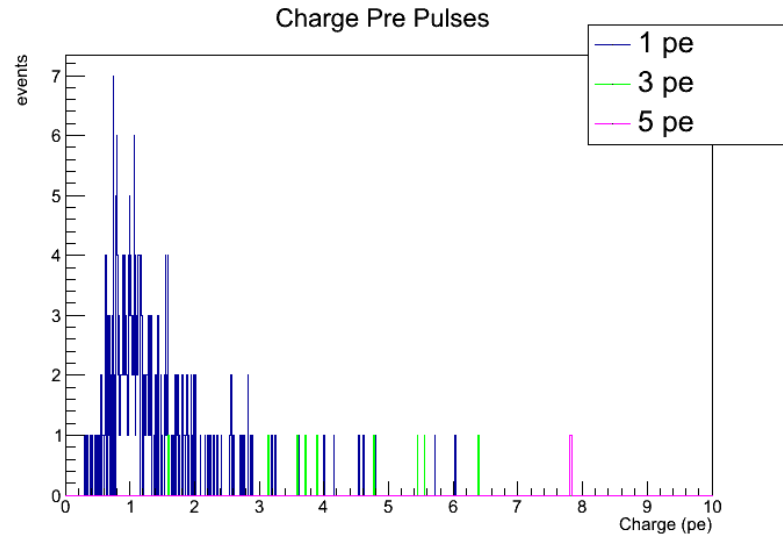
Mean charge PMT response of 1, 3 and 5 pe



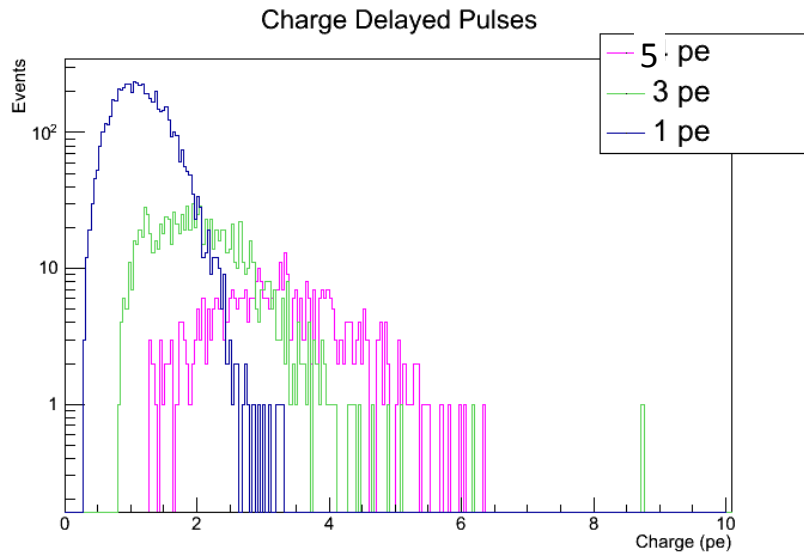
conditions	TTS FWHM (ns)
1 pe	4,0
3 pe	3,0
5 pe	2,8

Changing PMT conditions from 1 to 5 pe TTS is reduced .

3 inch Spurious Pulses : Pre-Pulses and delayed (1, 3, 5 pe)



conditions	Pre-pulses	delayed
1 pe	0,3 %	6,40 %
3 pe	0,01 %	1,14 %
5 pe	0,002 %	0,47 %

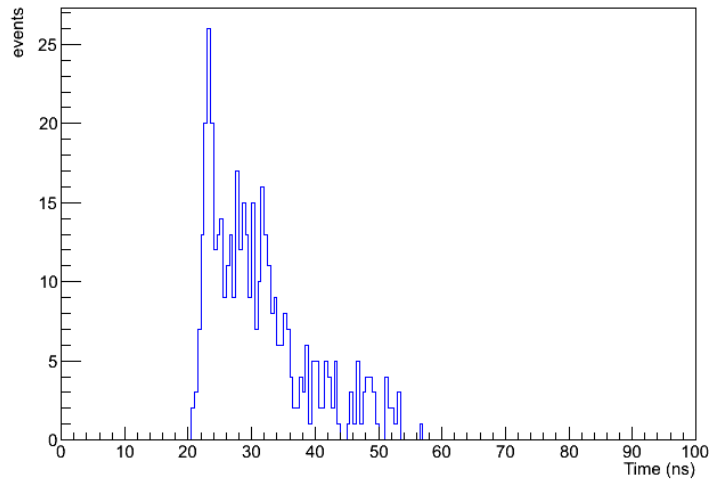


Pre pulses and delayed fractions became lower at conditions of 3 pe and 5 pe.

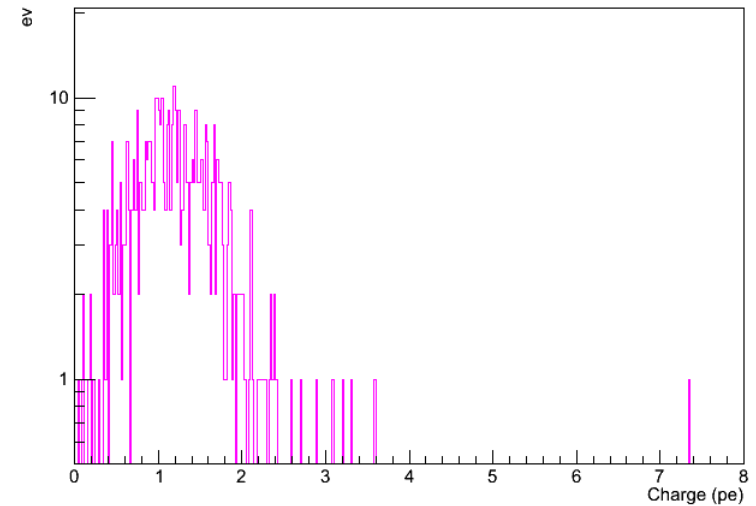
Pre pulses (very low statistic!) and delayed pulses increase in charge from 1 pe to 5 pe.

3 inch After pulses type 1 (spe)

Arrival Times AP1

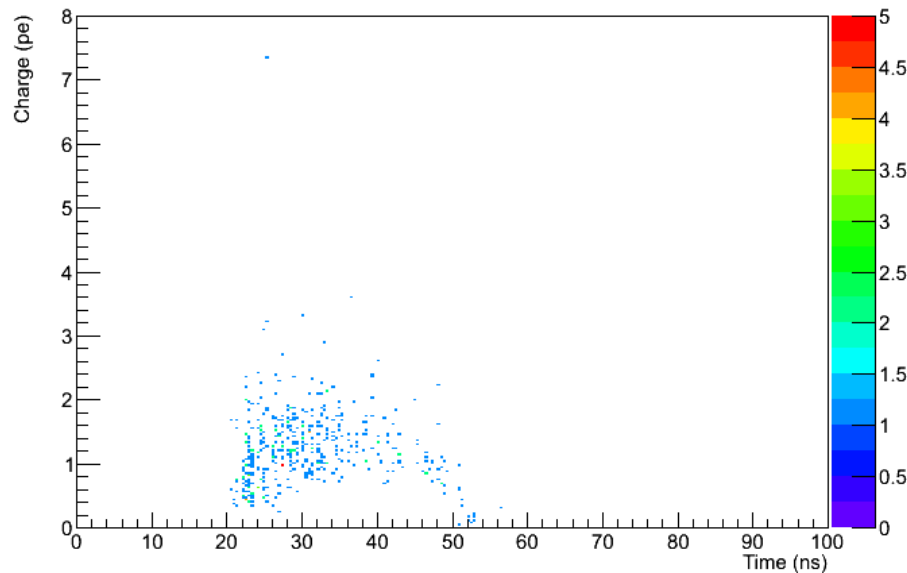


Charge AP1



AP1 = 0,11 %

Fraction of AP1
lower than that of
10inch



Behaviour of AP1
looks very similar to
10-inch PMT.

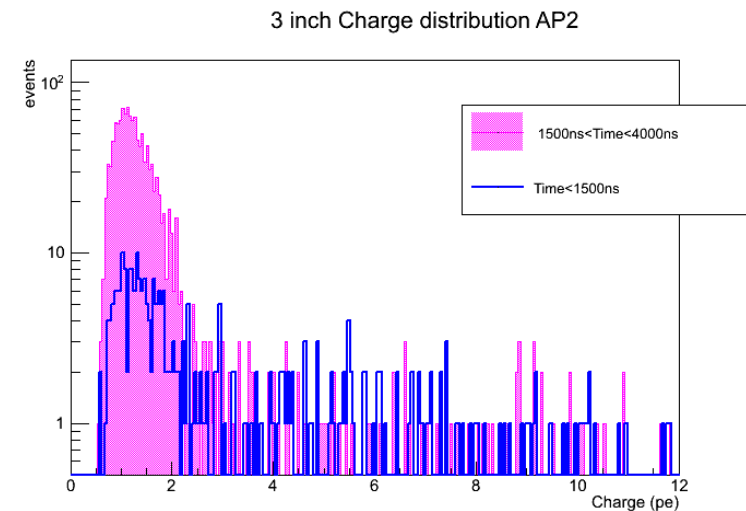
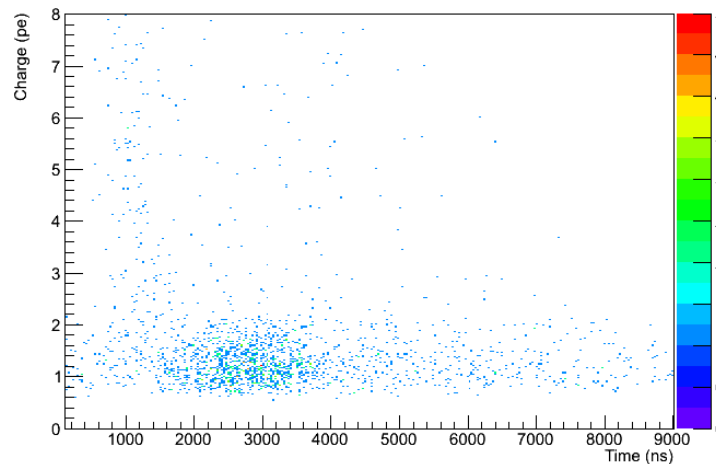
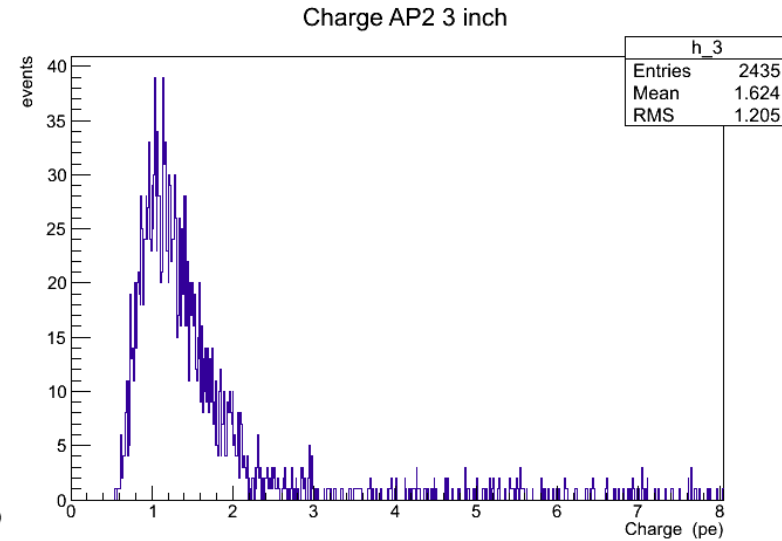
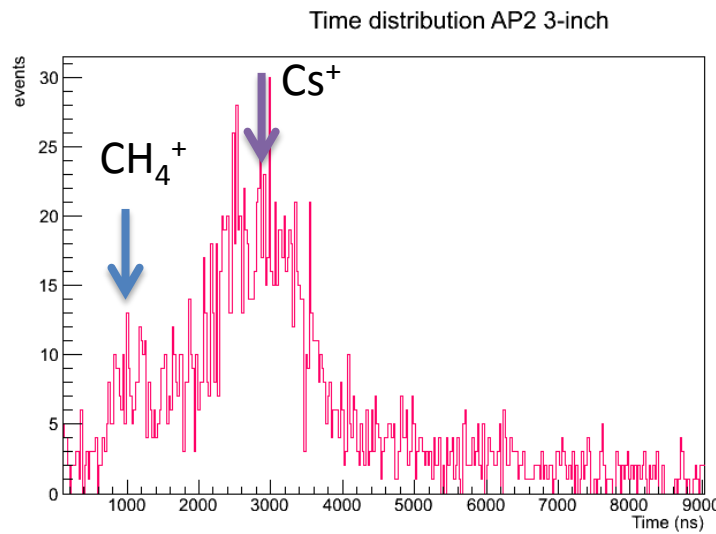
3 inch After pulses type 2 (spe)

Fraction of AP2 lower than that of 10inch **AP2 = 4,15 %**

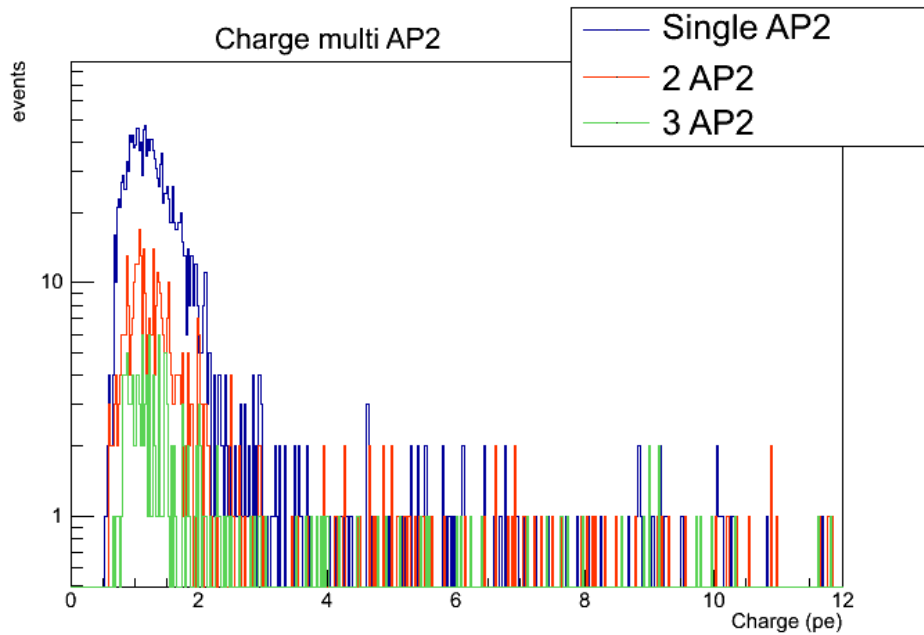
Two peaks like 10-inch at $\sim 1\mu\text{s}$ and $\sim 3\mu\text{s}$ for the two ions Cs^+ and CH_4^+ (time difference with 10-inch due to the geometry).

Higher mean charge for AP2 than AP1.

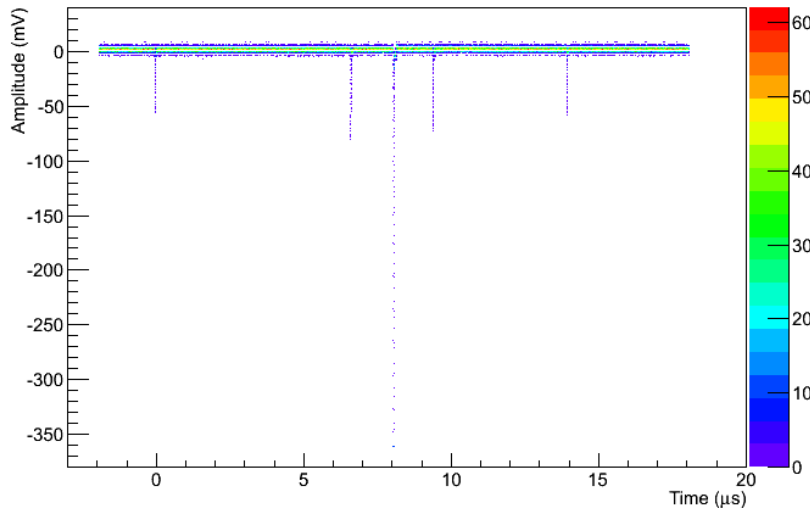
Time-Charge correlation has a behaviour similar to that of 10-inch with an higher charge component for the CH_4^+ peak.



3 inch Multiple Afterpulse (spe)



Number of AP type 2	Events (%)	Mean Charge (pe)
1	3,81%	1,20
2	0,25%	1,21
3	0,07%	1,18
4	0,025%	1,22



Differently to 10-inch PMT , in 3 inch PMT multiple AP2 have a charge mainly of spe.
Multiple AP2 show lower fractions in confront of 10-inch PMT

Conclusions

10 inch (spe conditions)	3 inch (spe conditions)
TTS (FWHM) ~ 3 ns	TTS (FWHM) ~ 4 ns (in 3 pe and 5 pe conditions it becomes lower)
Pre-pulses and delayed are of spe charge	Pre-pulses and delayed are of spe charge (in 3 pe and 5 pe, fractions are lower and charge increases)
AP1 mainly of spe,temporal peak at around 30 ns	AP1 mainly of spe,temporal peak at about 20 ns
AP2 mainly of 1,5 pe ,temporal peaks at around $2\mu\text{s}$ and $8\mu\text{s}$ (Cs and CH_4^+). First peak with an higher charge contribution in confront of the second	AP2 mainly of 1,6 pe ,temporal peaks at around $1\mu\text{s}$ and $3\mu\text{s}$ (Cs and CH_4^+). First peak with an higher charge contribution in confront of the second
Single AP2 with mean charge of 1,2 pe	Single AP2 have a mean charge mainly of 1,2 pe
Multiple AP2(>1) with a mean charge $>1,5$ pe	Multiple AP2 (>1) with a lower statistic than 10-inch and mean charge of about 1,2 pe



Thank you for your attention