AGEING CHARACTERIZATION ON LARGE AREA PHOTOMULTIPLIERS

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Measurement motivation

- Characterization of the photomultiplier stability over long term operation
  - Gain
  - TT
  - TTS
  - Spurious pulses
- Modelling of the ageing mechanism

Ageing definition for this study

- Ageing: operative parameters variations of a photomultiplier with operating time
  - drift : instability over short time
  - life : instability over time longer than 1000 hours
- Photocathode fatigue is negligible
- Ageing mainly depends on variations of secondary emission ratio

Ageing model supposed

- Ageing is due to the progressive sputtering of caesium layer in dynodes due to secondary electrons hitting, followed by sputtering on dynode surface

- Caesium layer on dynode surfaces:
  - Reduce thermo-electrons emission (reduce noise)
  - Reduce secondary-electron emission (reduce noise)

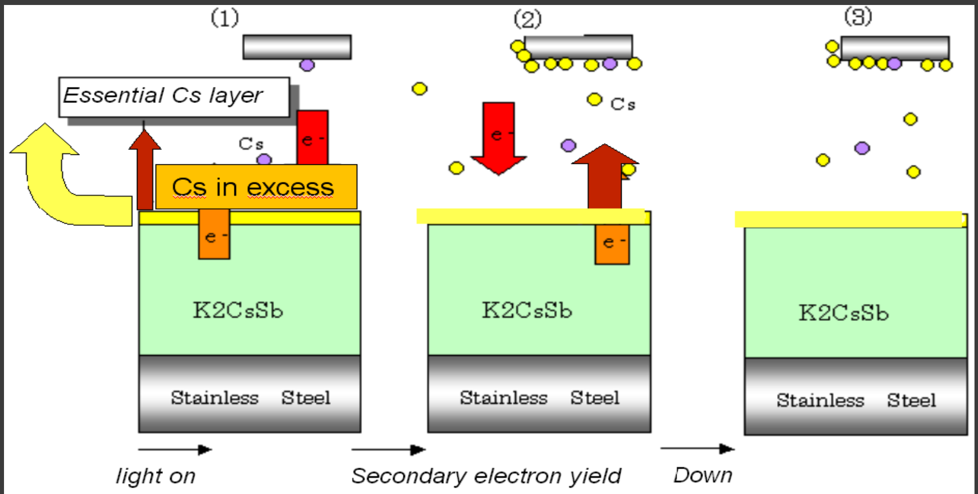
- Presence of excess layer of caesium is confirmed by Hamamatsu

- Caesium layer thickness dispersion is due to technology process (different behaviour on different PMTs)

- Ageing depends on the total accumulated charge

Ageing model : Up-drift and down-drift

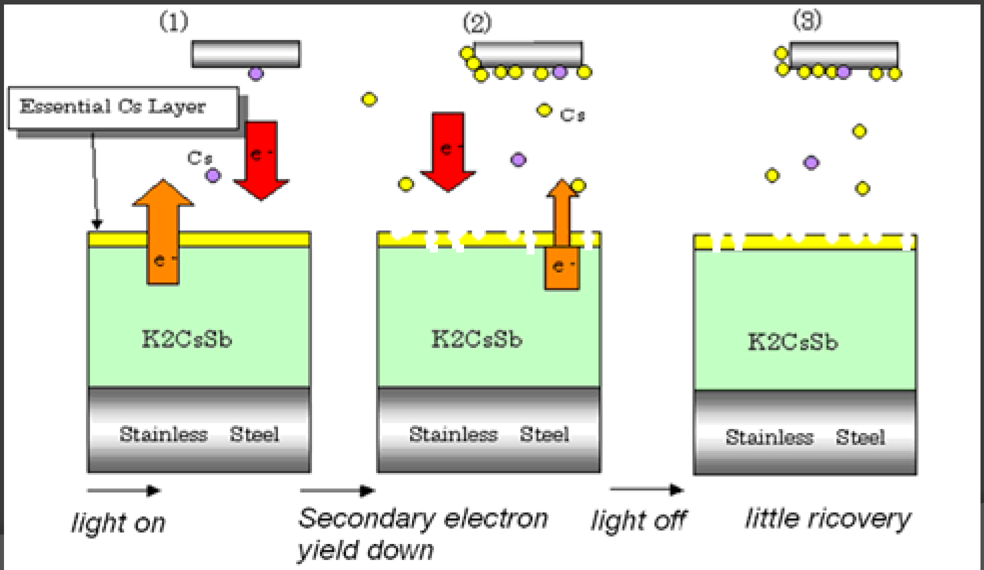
Up-drift



Progressive sputtering by secondary electrons of the excess caesium layer :

- Gain increase (decreasing the layer of Cs in excess)
- Evaporation of caesium ions in vacuum

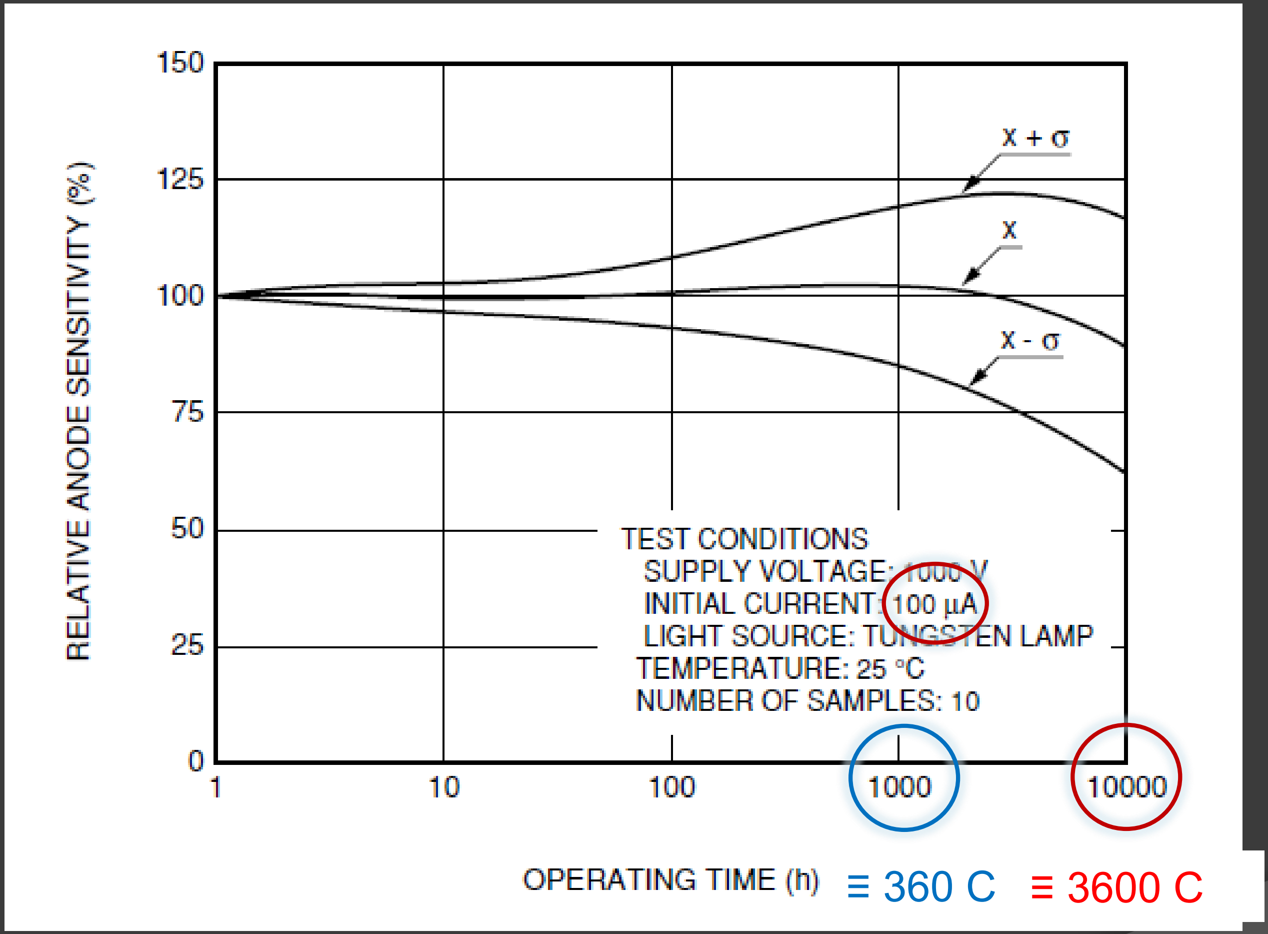
Down-drift



Once the excess caesium layer is removed, sputtering continues on the essential layer of Cs and on the dynode surface:

- Gain decrease
- Evaporation of caesium ions in vacuum

Up-drift and down-drift model



Typical time stability of photomultipliers tube
(from Hamamatsu Hand book. " PMT, principle and application "

Devices Under Test

- 2 Hamamatsu R7081 10” photomultiplier:
  - Standard Bi-alkali photocathode (STD)
  - Super-bialkali photocathode (SBA)
  - 10 stages
- The two PMTs differ only for the photocathode
- PMTs at the same start gain condition
  - $G \approx 5$ E 7
- The PMT bases for voltage supply were identical, passive

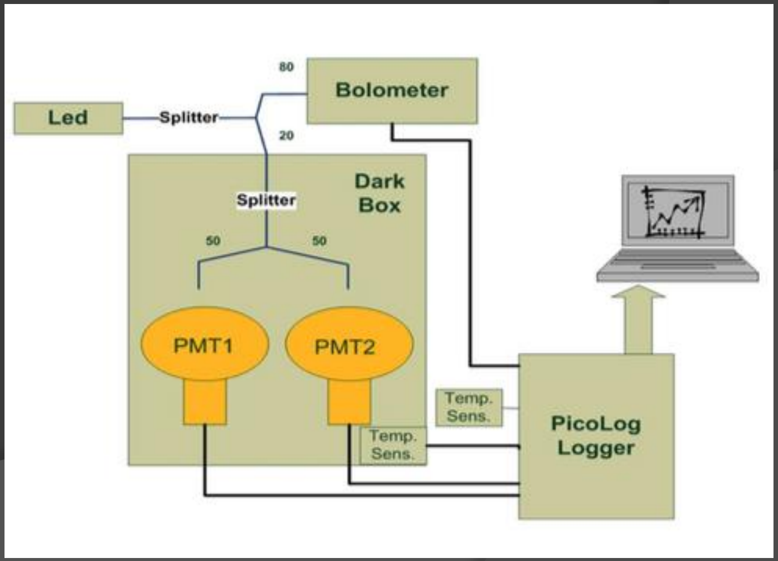
Characterization procedure

- Two alternate phases:
  - Ageing (continuosly pulsed light)
    - LED ON (about 3pe @ 1 MHz. High frequency to accelerate the aging process)
    - PicoLog recording of the anode DC current for each PMT
  - Measurements of PMT parameters (once a week)
    - LED OFF
    - Pulsed Laser at s.p.e. condition
    - s.p.e. charge spectrum
    - s.p.e. Transit Time spectrum
    - Spurious pulses
- Measurements time : from 28/5/2008 to 8/10/2011

≈ 3 years (considering Holidays)

Experimental set-up

- A light-tight dark box (65 x 65 x 110) cm. Thickness 2 cm
- A 400 nm LED (switched 50/50) to illuminate the PMTs uniformily
- A pulsed LASER set in s.p.e. condition (Picoquant PDL-800) (410 nm, 60 ps width, 10 KHz)
- NIM electronics for timing and charge acquisition
- A bolometer as monitor for the LED light stability
- A PicoScope logger to record (simultaneously, Tc = 1 sec)
  - the anodes current
  - internal and external temperature in the box
  - the bolometer output

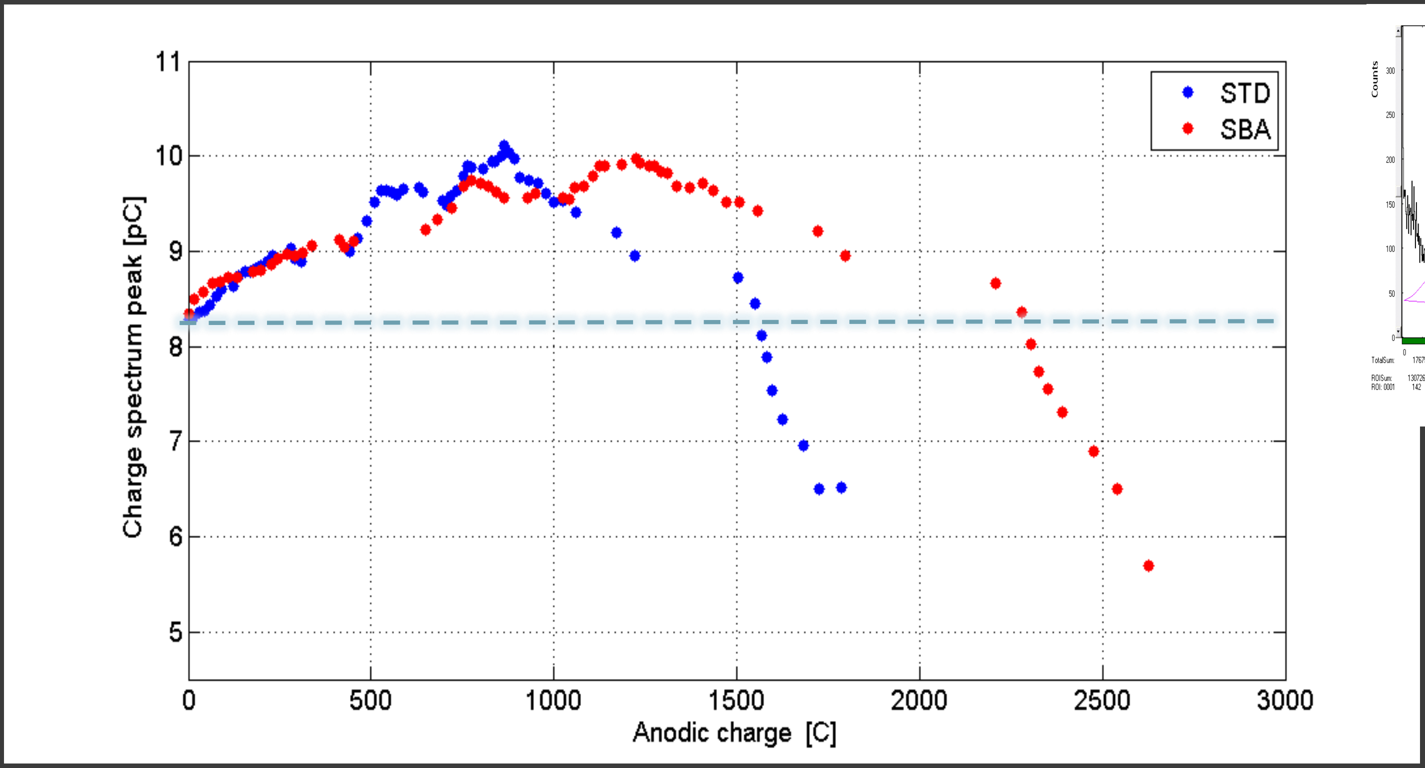


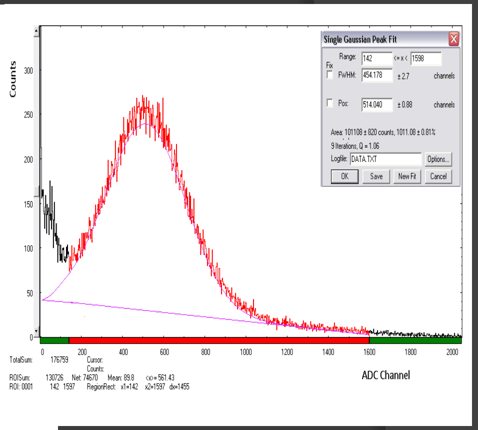
Results : premises

- In the following plots, the x-axes is the anodic charge measured by the PicoLog.
- The plots refers to the same operating time
- The SBA anodic current collected during the ageing phase is higher than the STD one (higher detection efficiency)
- The ageing process was stopped when the total charge arrived up to about 1800 C for the STD PMT and 2600 C for the SBA PMT
- LED light of about 3pe @ 1 MHz is equivalent to 15 times a source of 1 pe @ 200 KHz
  → the ageing operating time of 3 years is equivalent to about 45 years of operative life of 1 pe @ 200 KHz

Results: Gain

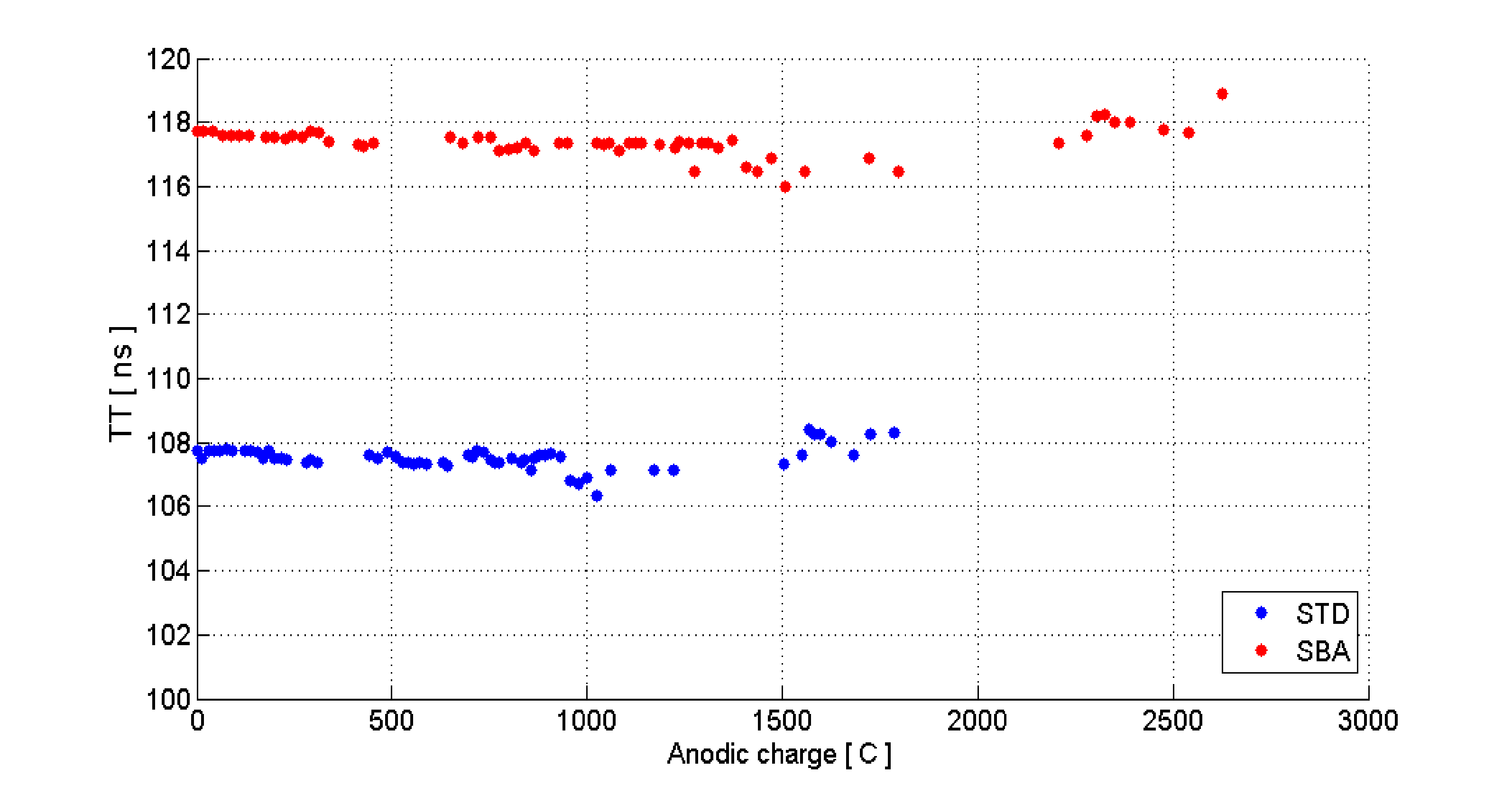
Measured studying the peak position of the Charge spectrum acquired in s.p.e. condition





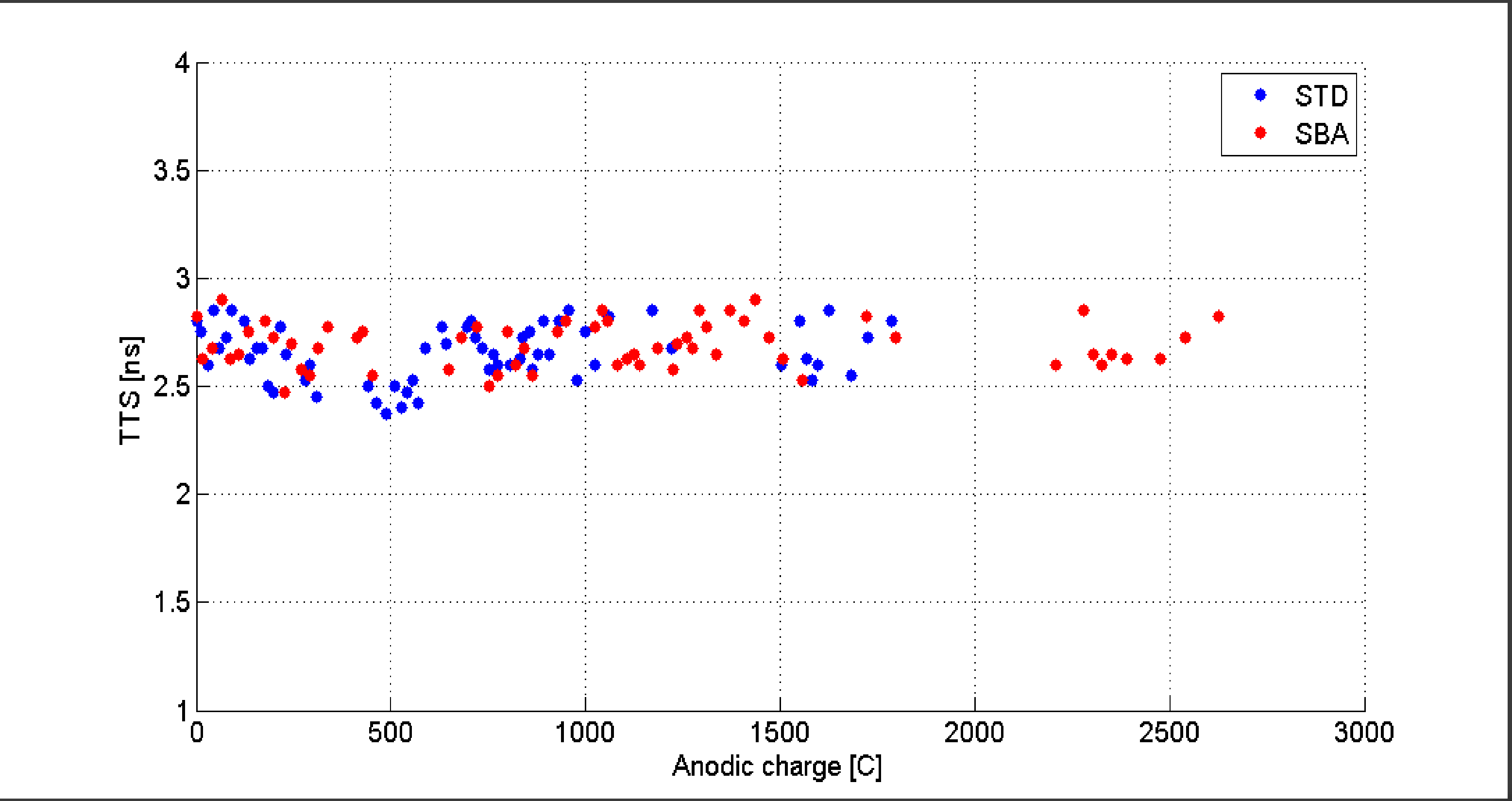
- **the up and down drift model was confirmed by measurements**
- **a first phase of up-drift with an increase of about 20 %**
- **a final phase of down drift with a diminuition up to 40% from the max value**

Results : Transit Time (relative)



Not considerable variations in Transit Time during operating time

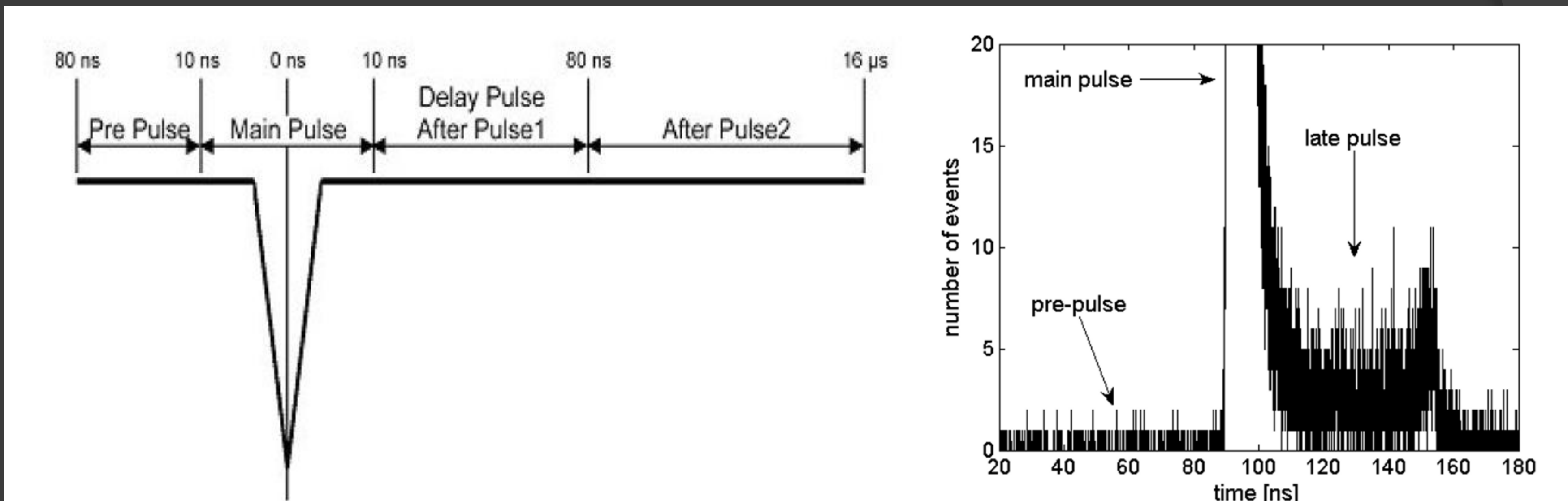
Results: Transit Time Spread (FWHM)

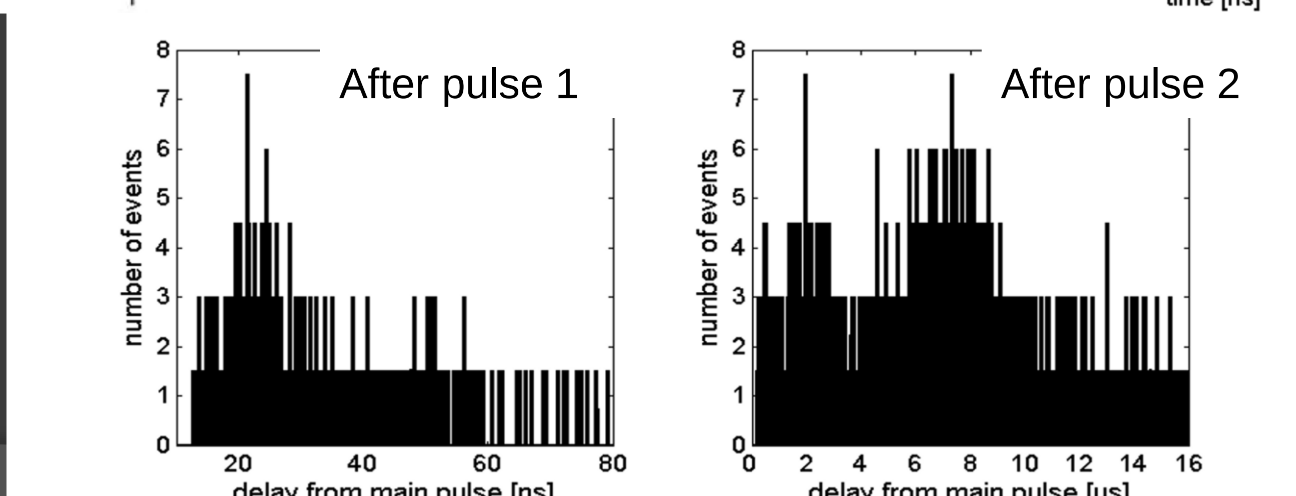


Not considerable variations in Transit Time Spread

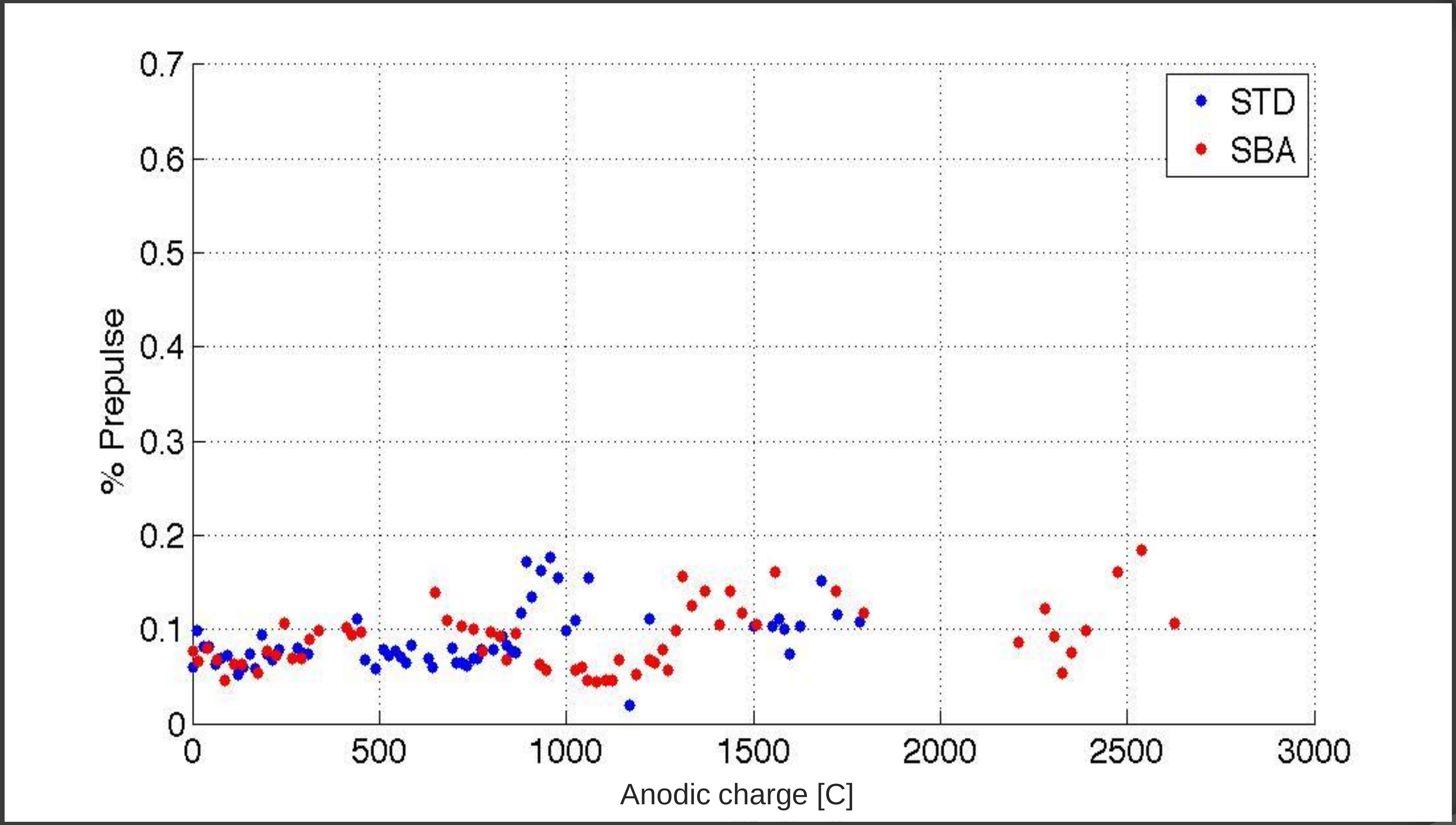
Spurious pulses

For each group the ratio of spurious events on main pulses events were calculated



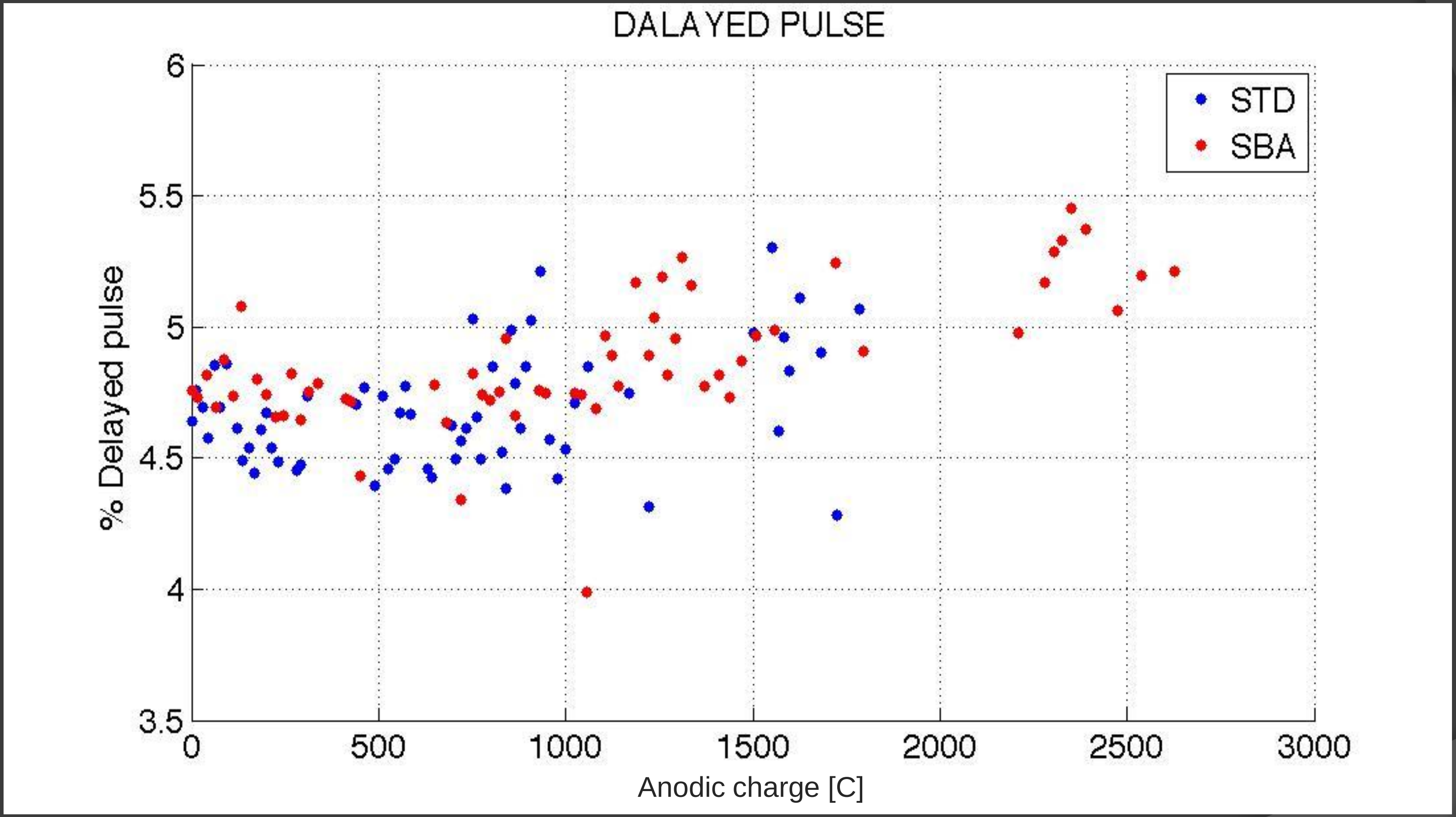


Results: fraction of pre-pulses



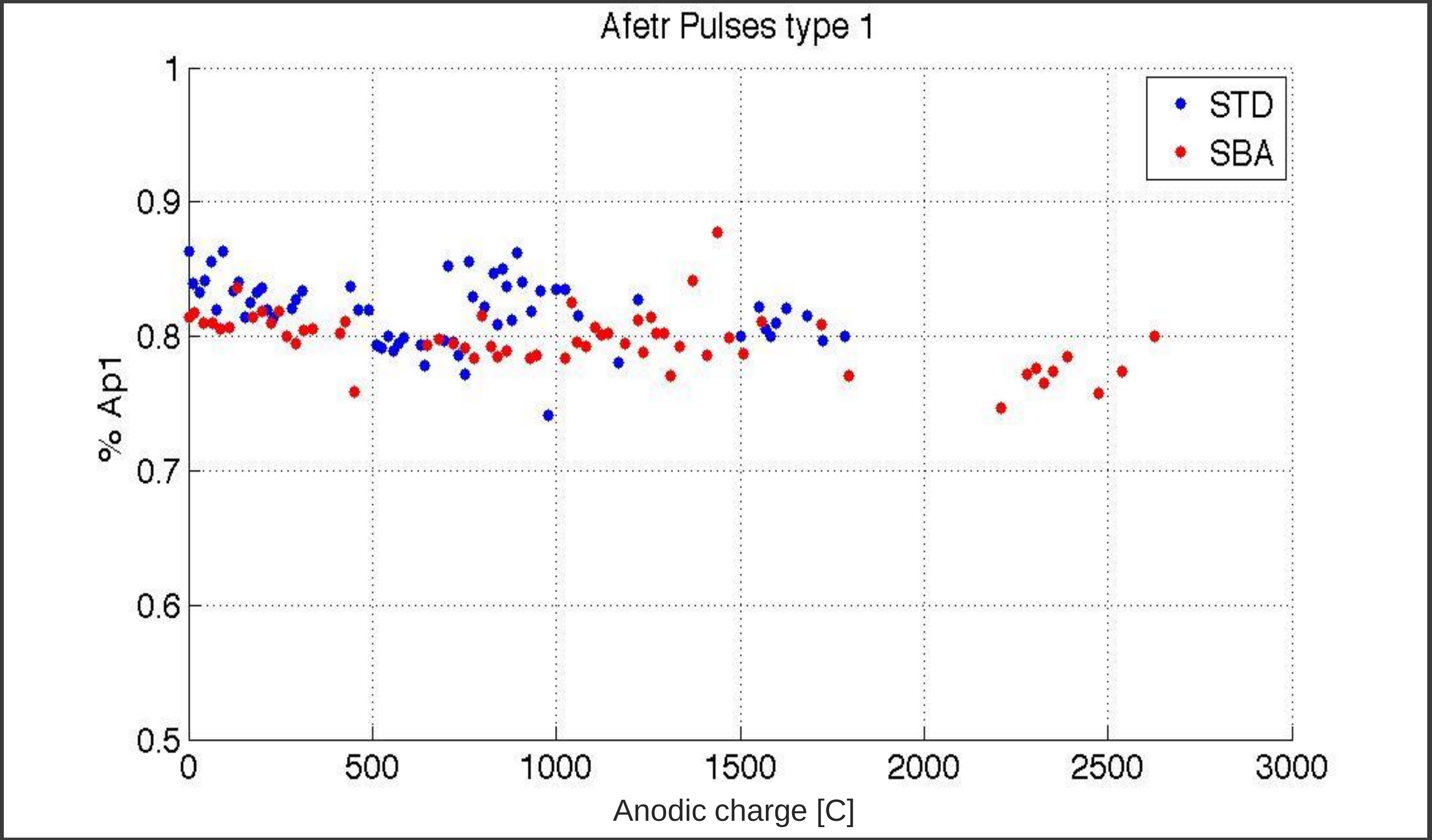
Not considerable variations during operating time

Results: fraction of delayed pulses



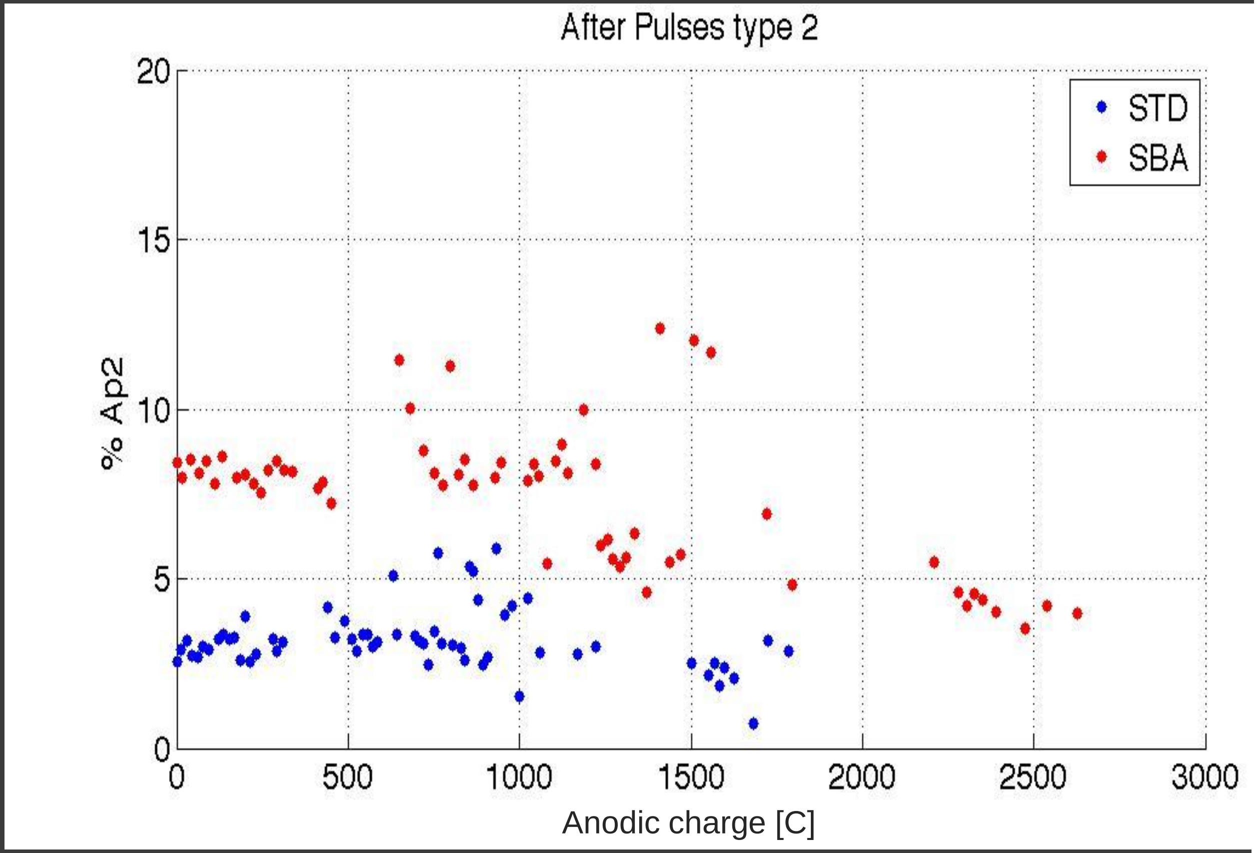
Not significative variations during operating time

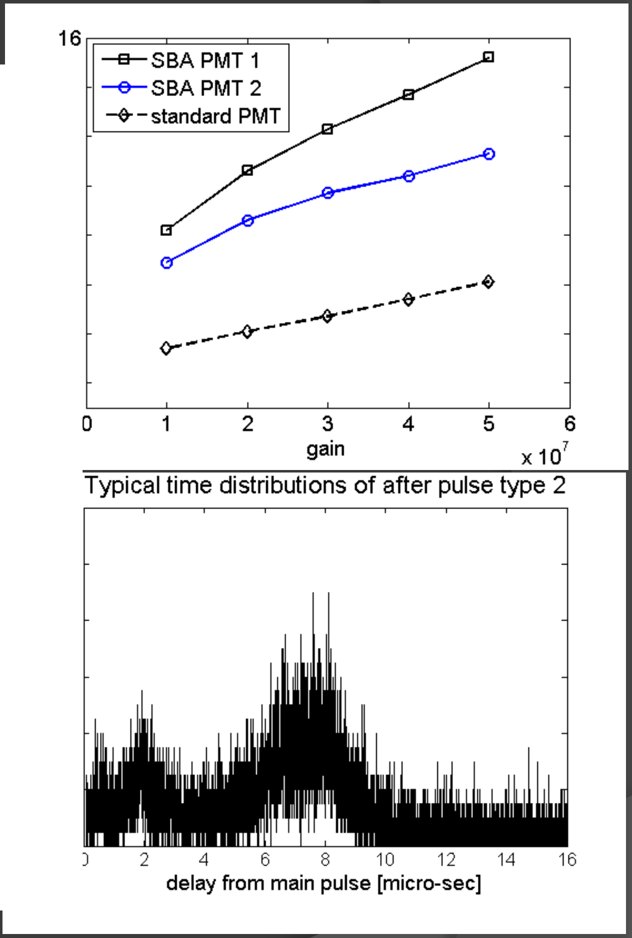
Results: Type 1 after pulse



Not considerable variations during operating time

Results: type 2 after pulse





- Not considerable variations for a lot of the operating time
- Significative decrease for SBA PMT, from the 8% to 5% , after 1700 C
- Study of the effects of ions Cs evaporated on fraction of after pulses 2

Conclusions

- Apart the Gain, all the measured parameter of the two PMTs are stable during ageing
- A first phase of Up-drift with a gain increase of about 20 % followed by a final phase of down-drift with an gain decrease of about the 40% from max value
- The ageing model of Up- and Down- drift has been demonstrated by the results
- The ageing process was stopped when the total charge arrived up to about 1800 C for STD PMT and 2600 C for SBA PMT
- The measuring time (3 years) is equivalent to an operating time of about 45 years @ 1 pe @ 200 KHz
- The final values of the Gain for both PMTs is still suitable for their use

Work in progress

- An accurate study of the dynode surfaces after ageing by microscope is being carried in the next months

Thanks for the attention

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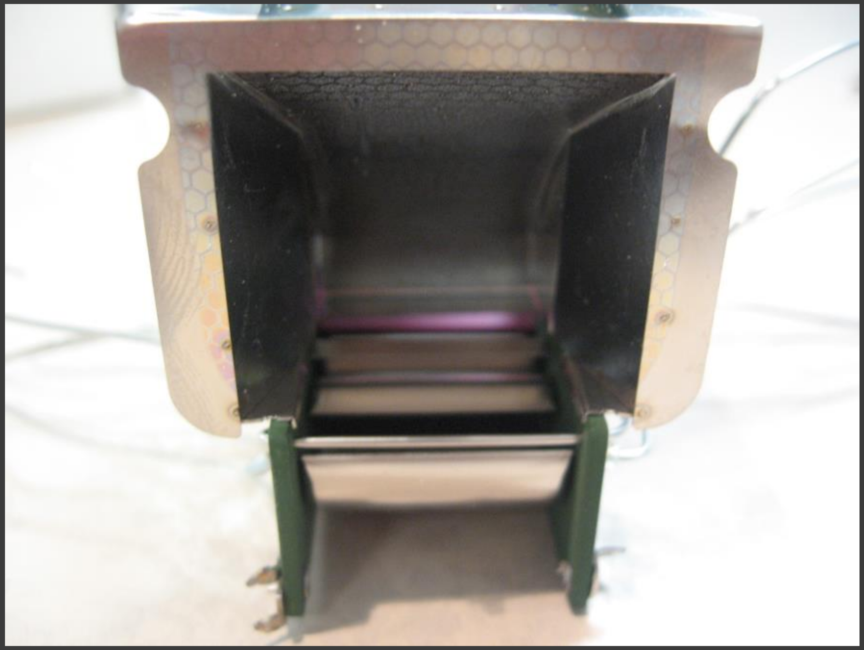
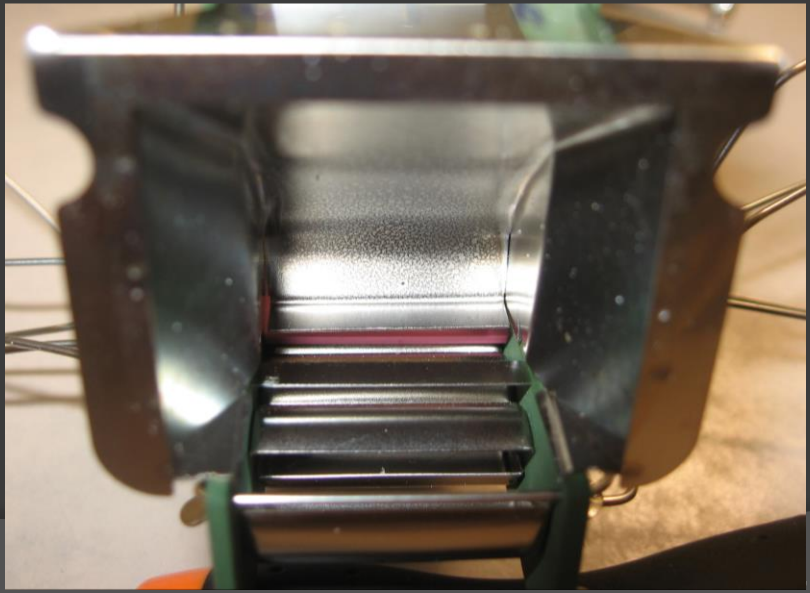
Pictures of sputtered dynodes



Last Dynode



First Dynode