On the relationship between Vbias and S1 resolution

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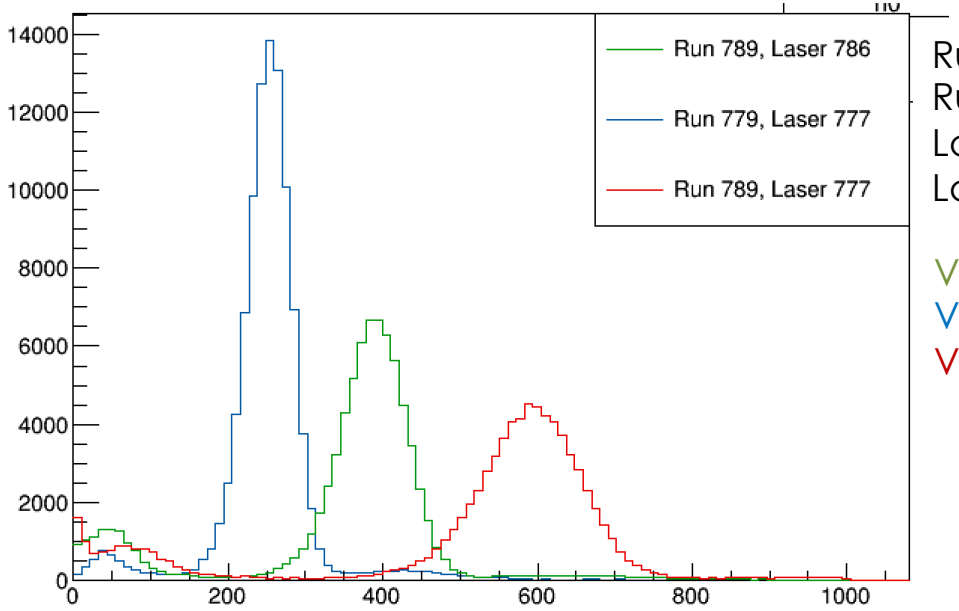
The Basic Facts

Basic information:

- Changing Vbias, SERs change

- Increasing Vbias, ^{241}Am peak in photoelectrons increases:
  - **evidence of extra instrumental component (AP/CT)**

- Reconstructing two source runs, with different Vbias, with the same SERs, the 241Am peak position is not recovered:
  - **no mistakes in data taking**

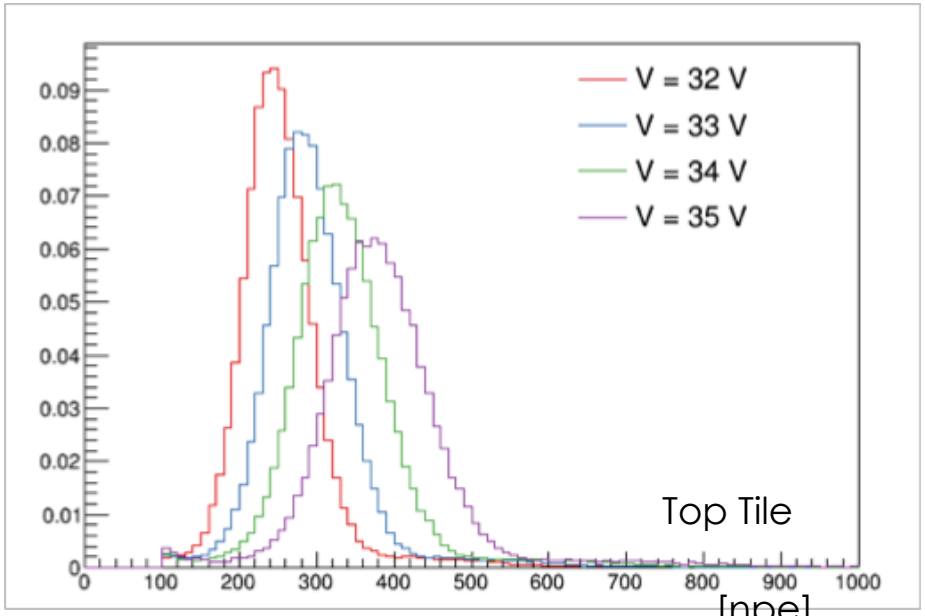


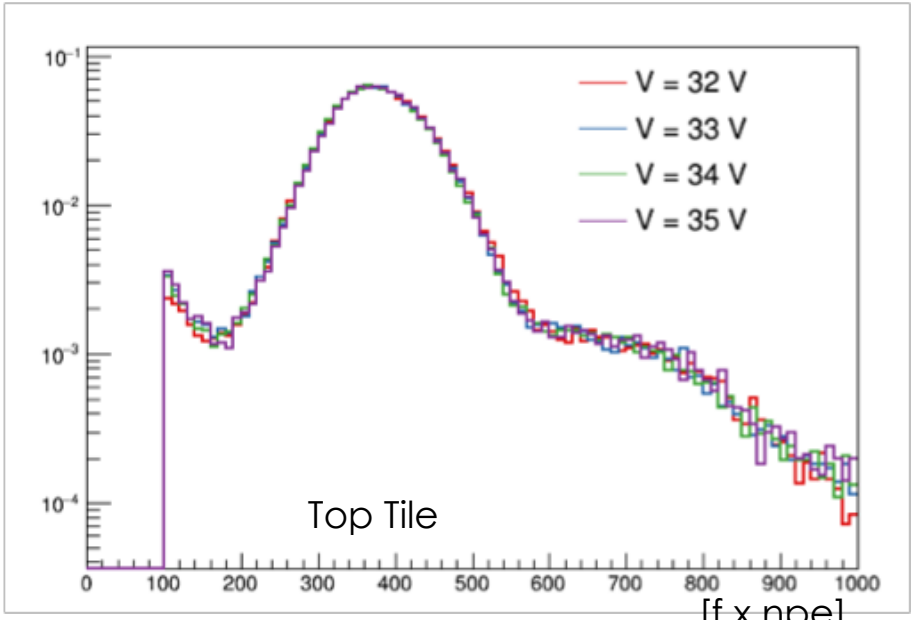
Run 789: Vbias = 35/70
Run 779: Vbias = 32/64
Laser 786: Vbias = 35/70
Laser 777: Vbias = 32/64

Vbias run = 35/70 – Vbias laser = 35/70
Vbias run = 32/64 – Vbias laser = 35/70
Vbias run = 35/70 – Vbias laser = 32/64

Vbias vs Resolution

We apply a scaling factor in npe for 241Am spectra taken with different Vbias, and reconstructed with associated SERs: spectral shapes are recovered



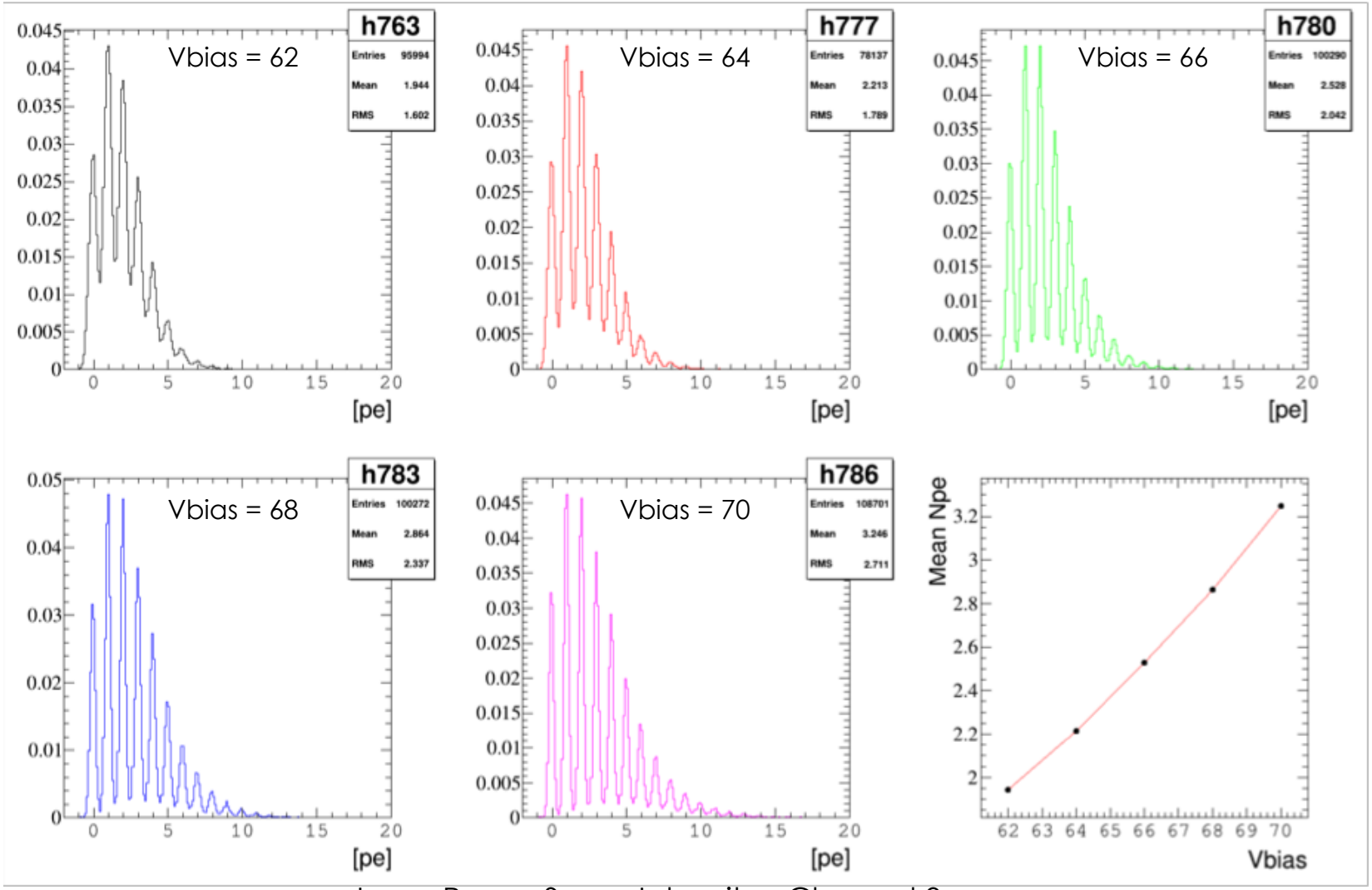


Applying a scaling factor on npe

Vbias has no impact on the shape

Laser: mean NPE vs Vbias

We observe a variation in the mean number of pe in laser runs taken with the same intensity but different Vbias

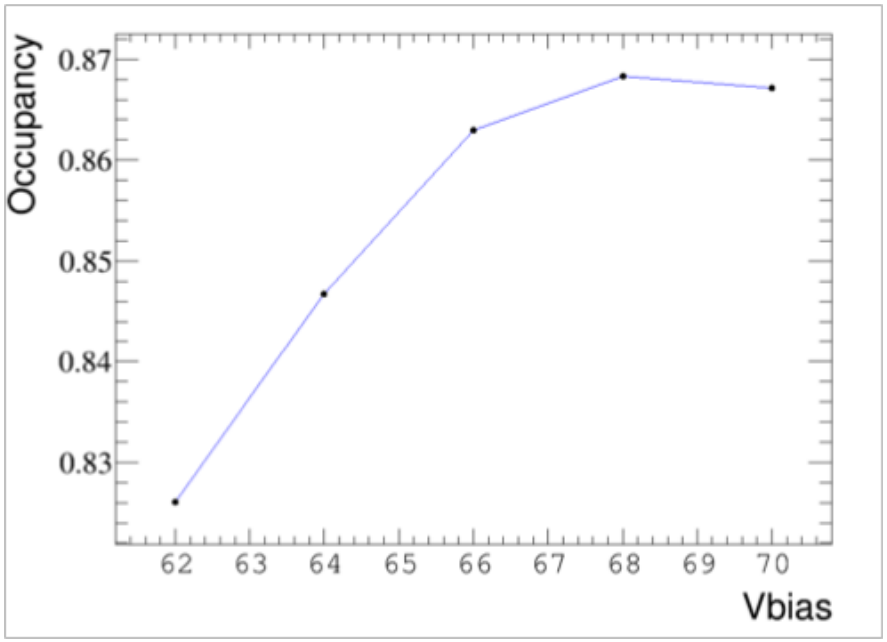


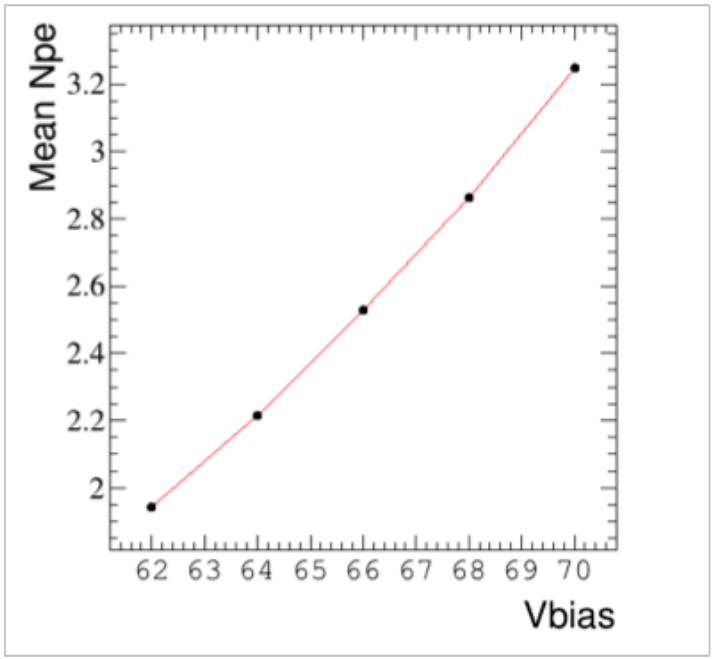
Laser Runs – Same Intensity - Channel 0

Laser: mean NPE vs Vbias

~~We evaluate the PDE by looking at the occupancy, id est 1 minus the fraction of events in the pedestal. This slightly increases with Vbias, up to the saturation at Vbias = 68~~.

We observe an increase of the occupancy (1 = fraction of zeros) up to 68 and than a saturation. However, the mean number of PE still increases at Vbias 70

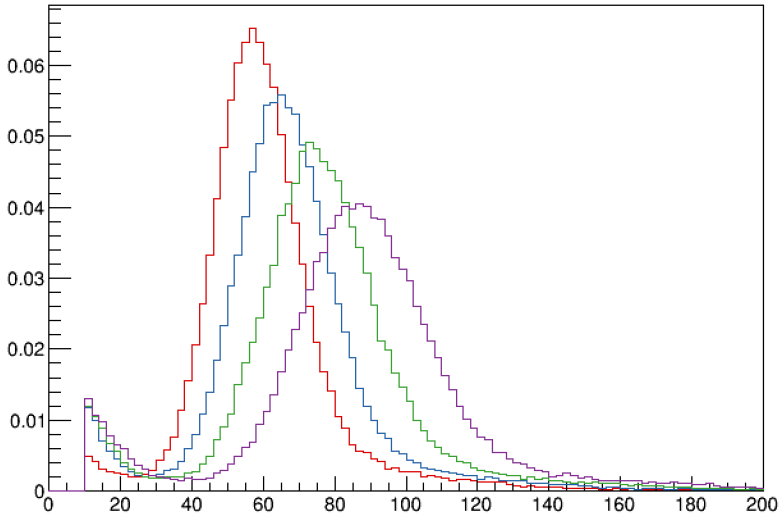


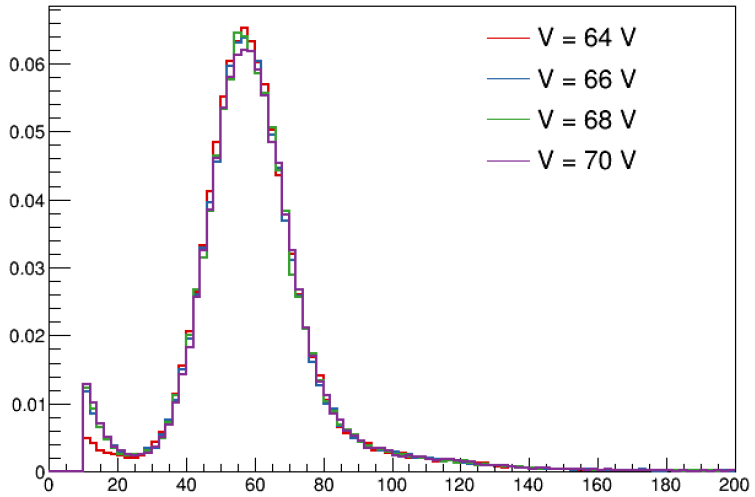


Laser Runs – Same Intensity - Channel 0

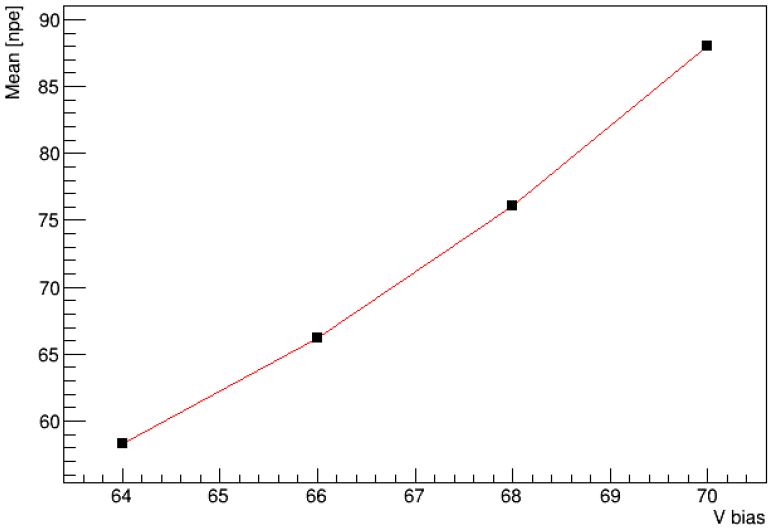
Physics: scaling factor vs Vbias

Physics Runs – ^{241}Am - Channel 0



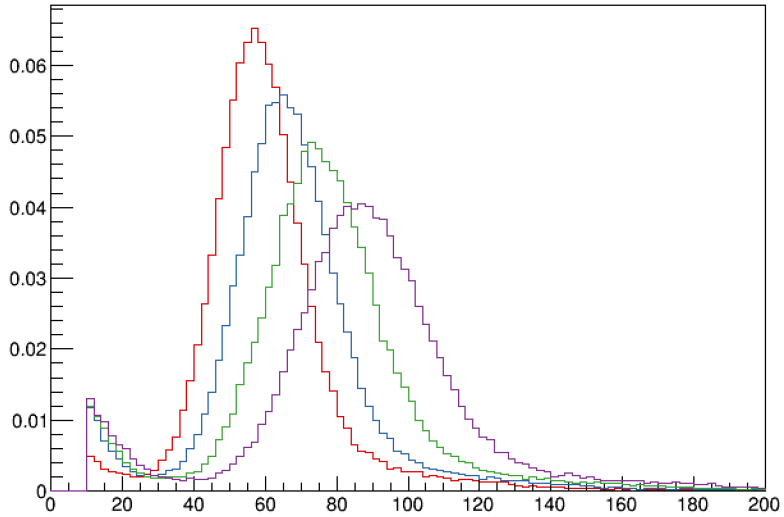


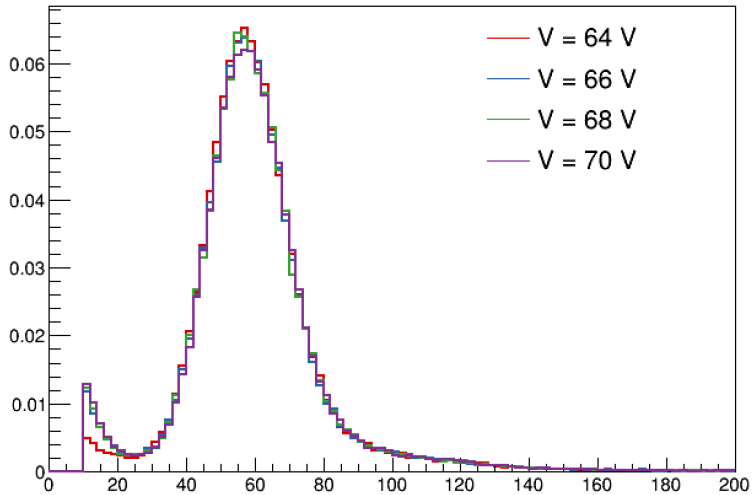
Using the same channel of the previous slide, we extract the 241Am peak position for different Vbias



Physics: scaling factor vs Vbias

Physics Runs – ^{241}Am - Channel 0





Two cases:

- PDE increases: hence, we should observe an improvement in resolution
- CT/AP increases: hence, resolution should worsen

There is not an evident change in resolution: mixing of the two effects or something else?

Scaling factors: physics and laser runs

We observe that the variation in the mean number of laser runs is equal to the variation in the peak position of 241Am spectra

With respect to Vbias = 64 →

Vbias	Laser: Mean Npe	Physics: Scaling Factor
62	0.88	NA
64	1.00	1.00
66	1.14	1.14
68	1.29	1.30
70	1.47	1.50

Hard to think that PDE increases by more than 50%. Likely, we are observing a strong increase of AP/CT. But why resolution is unchanged?

Scaling factors: physics and laser runs

Fluctuations of AP and CT seem negligible with respect to the photon statistics

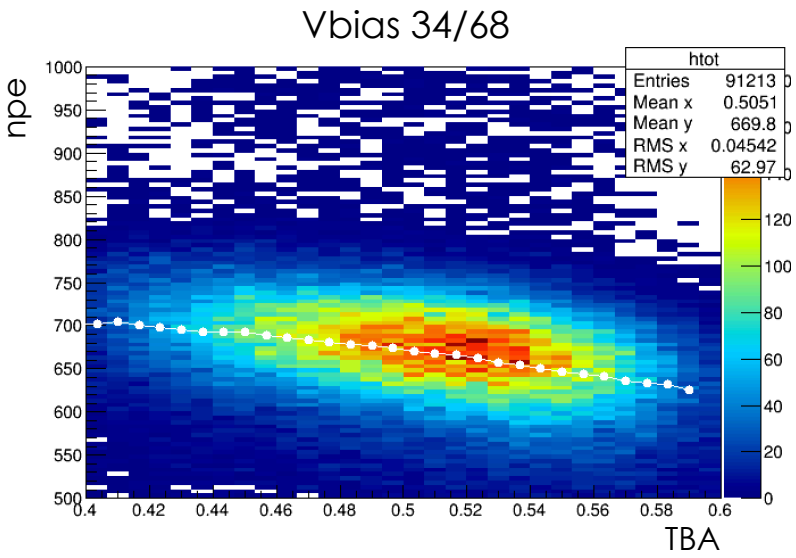
As a consequence, we can evaluate the true LY (LY_{true}) from the observed LY(LY_{obs}) obtained from the energy scale corrected by the Fano as following

Sigma/mean = sqrt(Fano / (LY_{obs} x E_{Am})) = sqrt(1 / (LY_{true} x E_{Am}))

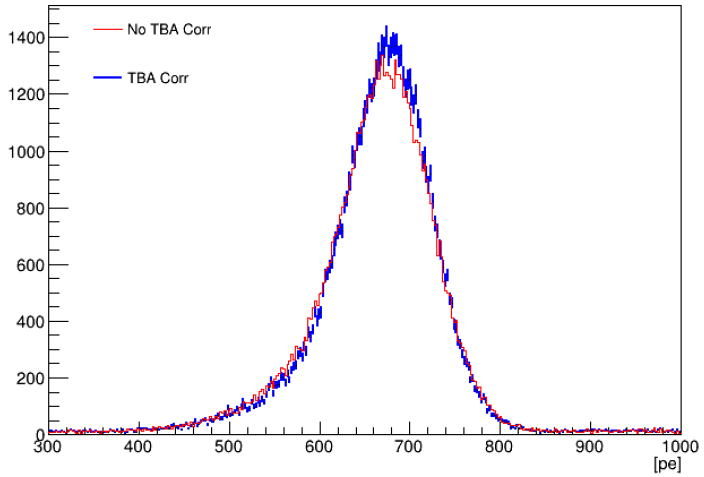
LY_{true} = LY_{obs} / Fano

But first we have to correct by the top/bottom asymmetry

Top/Bottom Asymmetry (TBA)



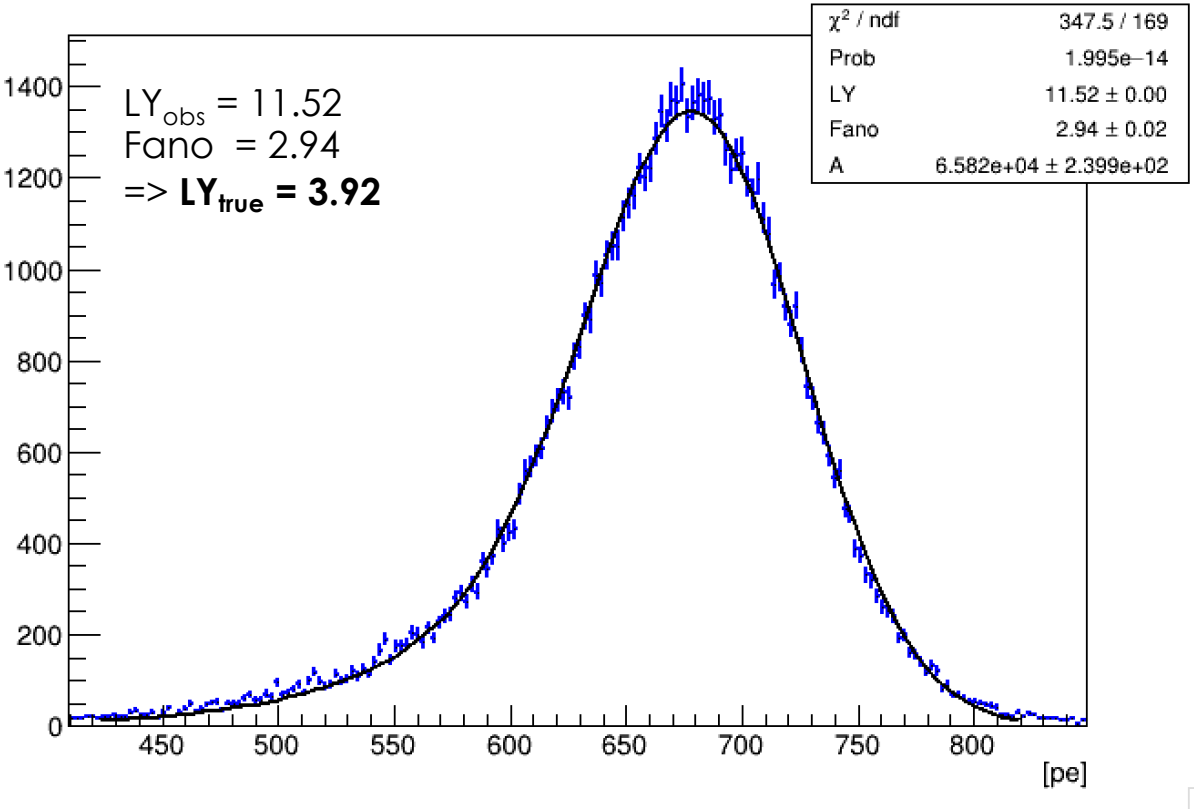
Peak of Am241 evaluated from each slice of TBA



Charge correction as a function of TBA

Fit of corrected spectra

Run 785 - Vbias 34/68



Note: this in the assumption that the entire resolution is due to photon statistics

Fit of corrected spectra

LYtrue as a function of Vbias

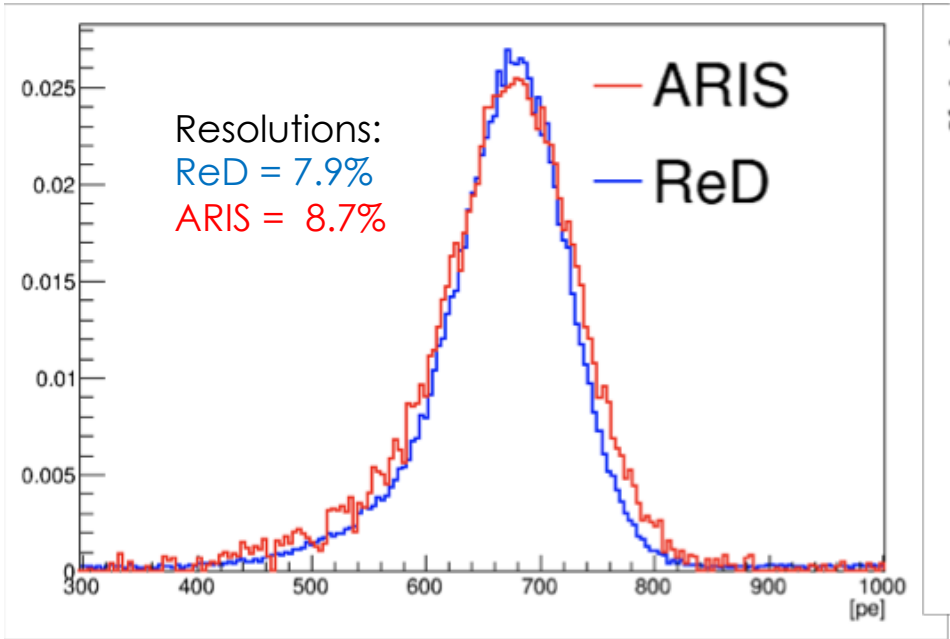
Vbias	LY_{obs} [pe/keV]	Fano	LY_{true} [pe/keV]
32/64	8.69	2.30	3.78
33/66	10.01	2.55	3.92
34/68	11.52	2.94	3.92
35/70	13.31	3.31	4.02

The slight increasing of LY_{true} is compatible with increasing of PDE observed in the occupancy of laser runs, shown before.

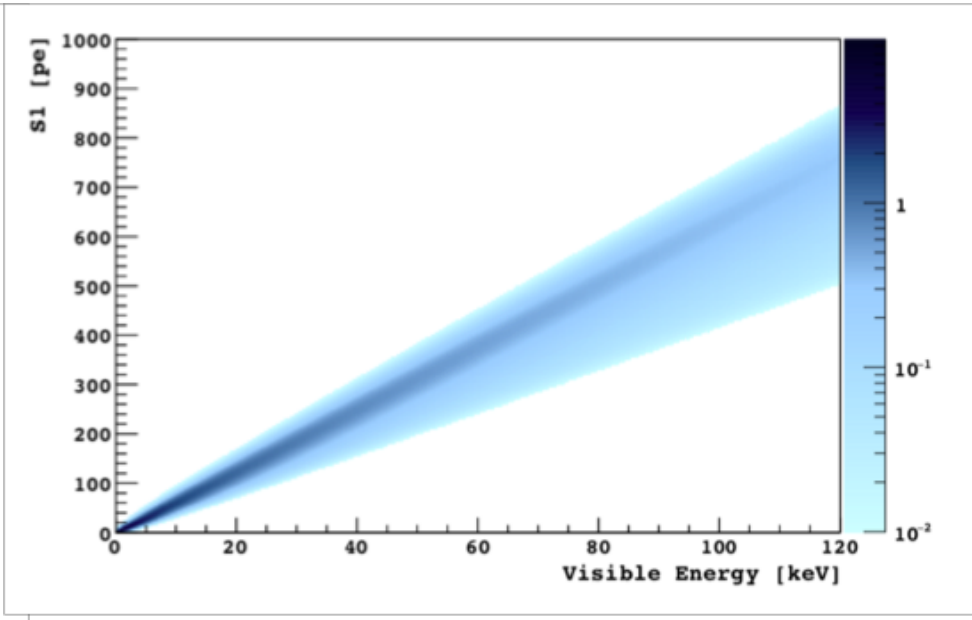
NOTE: here we are assuming that the entire resolution is due to photon statistics (F =1). This values has to be taken as lower limits

Comparison with ARIS

LY in ARIS is 6.2 pe/keV



ARIS response includes PMT SERs



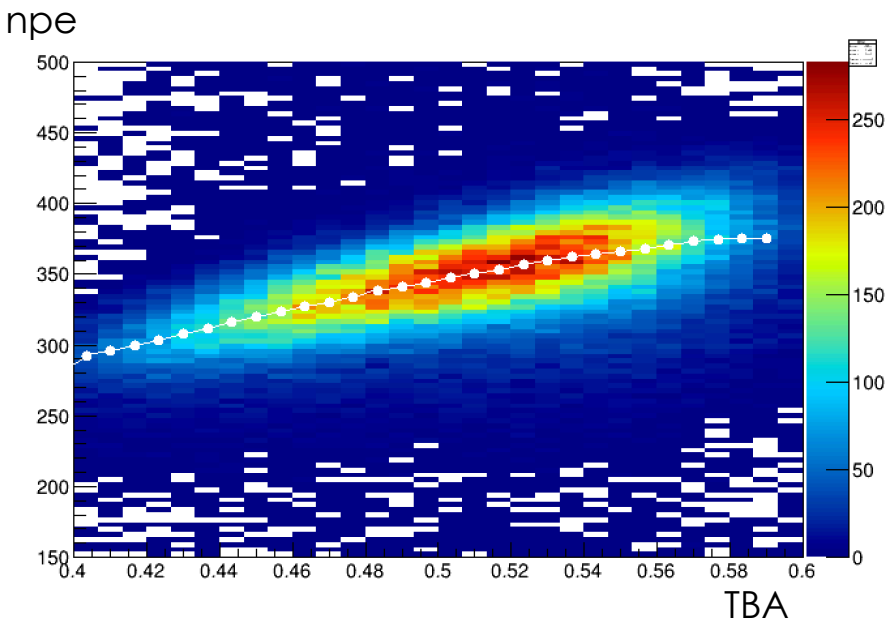
Questions:

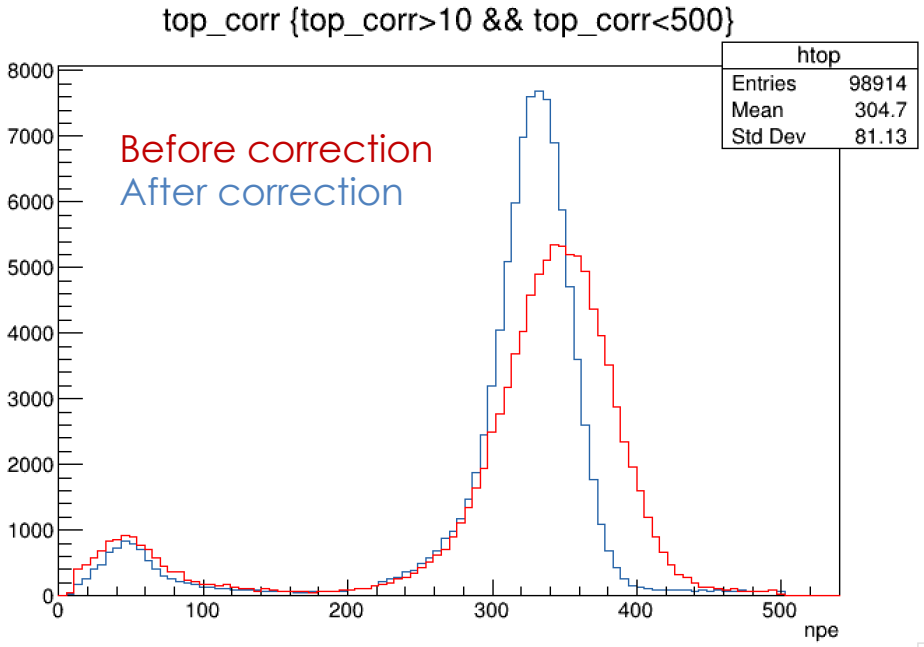
- **Higher LY in ReD or lower LY but better SERs?**
- Since the LY from energy scale with SiPM is not reliable, how can we calibrate DS20k?
- How to calibrate DS20k if a SiPM in a tile does not work?

Note about individual tiles

TBA can not be applied to top and bottom tiles, individually. This because top and bottom are fully anti-correlated and TBA entirely depends on top and bottom. As a consequence, correcting each tile response by TBA will inherit the resolution from the total charge (top+bottom).

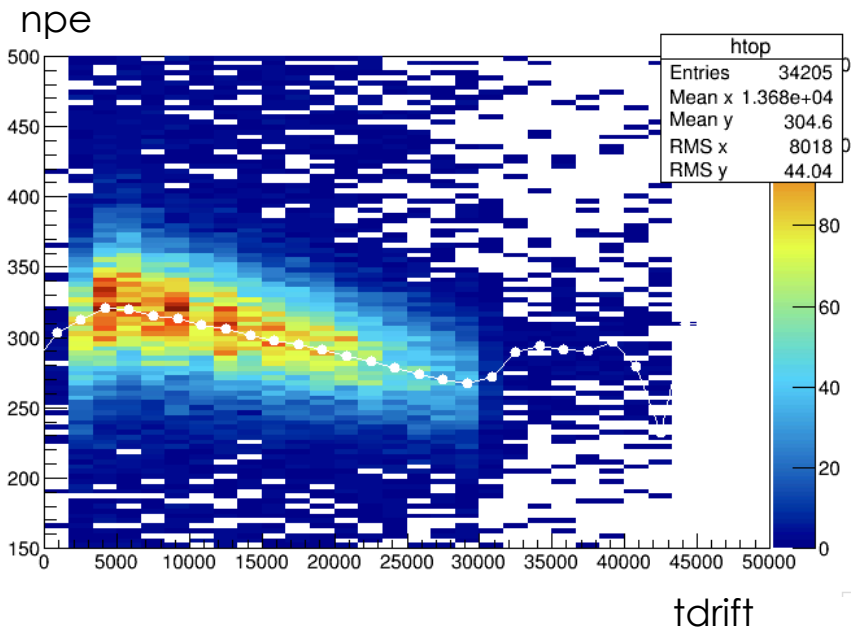
As an exercise, we apply the previous fitting procedure to the top charge only

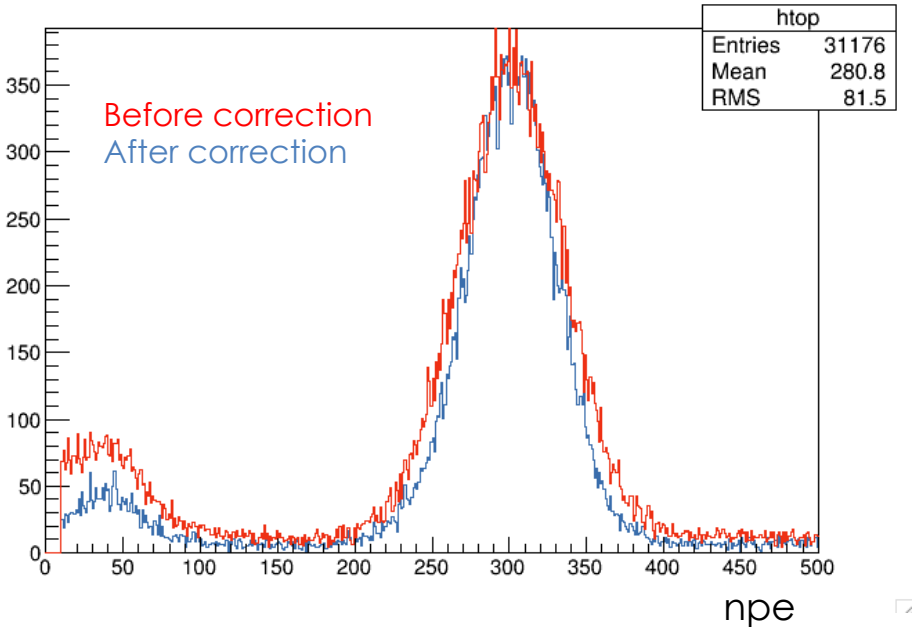




Correcting for tdrift

Correcting using tdrift, the situation changes…

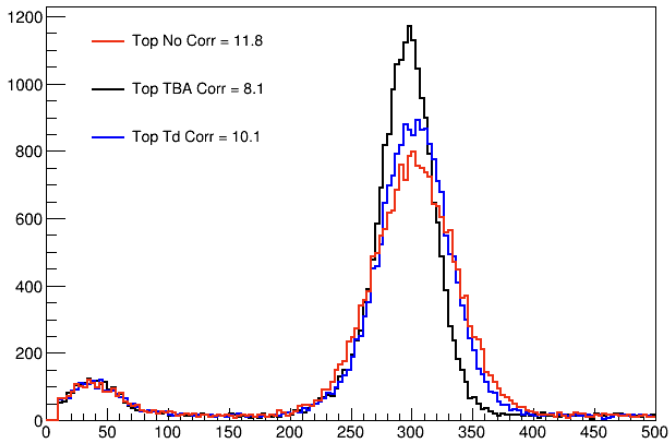


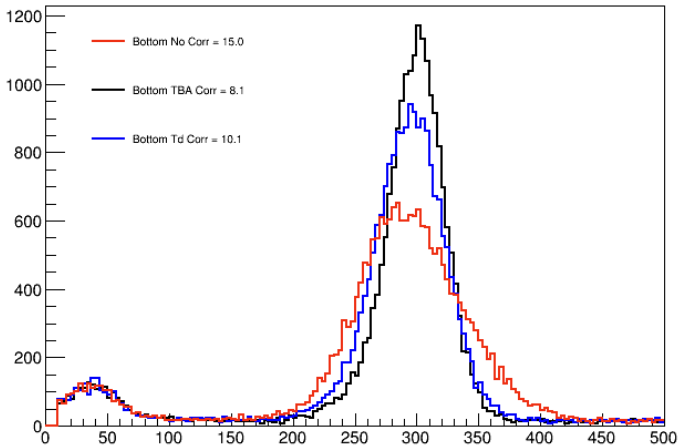


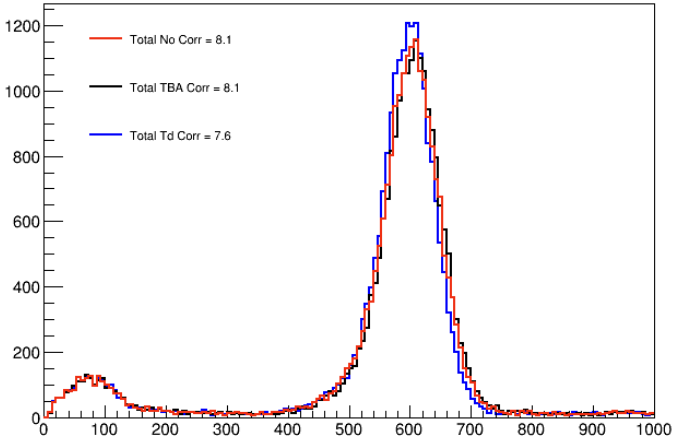
tdrift is independent on S1 top and bottom

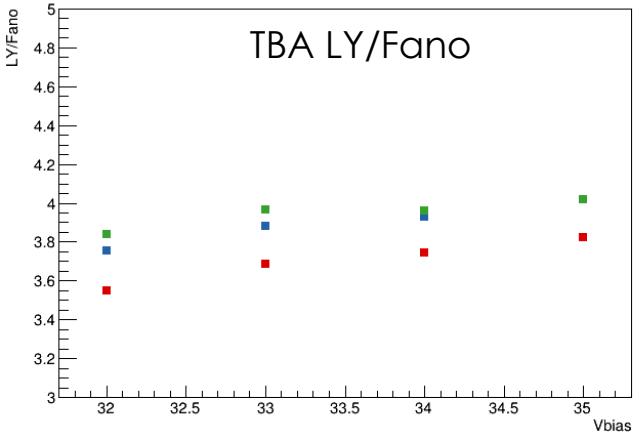
Correcting for tdrift/tba

RMS (sigma/mean*100) obtained with a simple gaussian fit









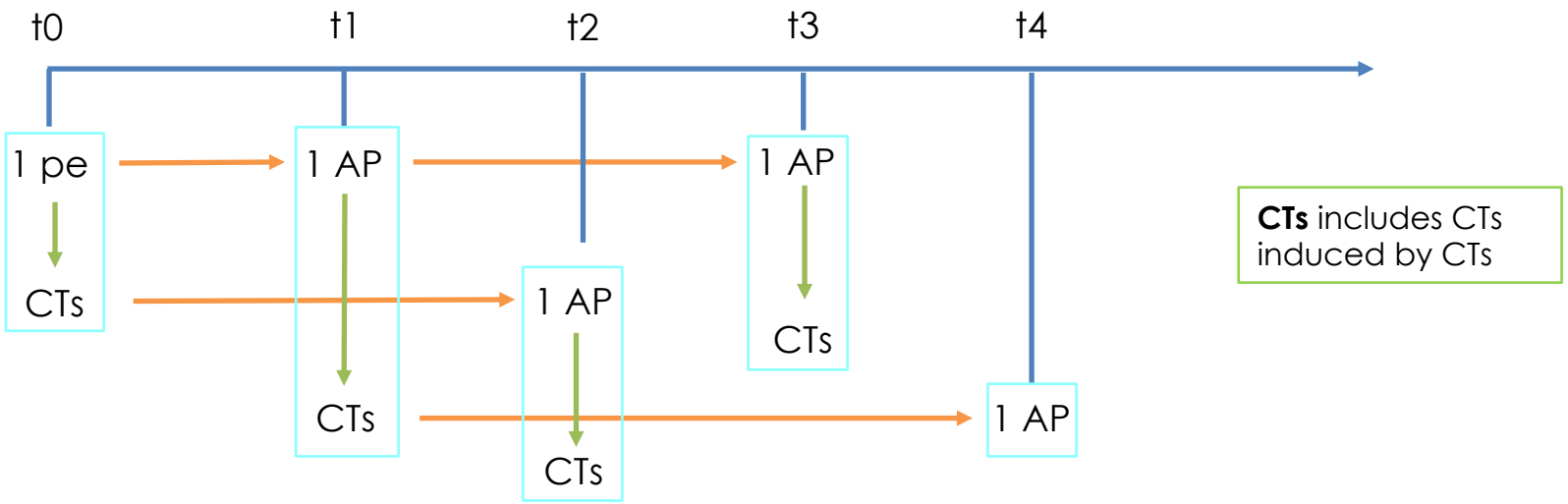
Note that TBA RMS never changes

Electronics Simulation & Vinogradov

1 PE at t0 can induce:
- Direct Cross Talks (DiCT): at t0 with mean number = mu
- {0,1} After Pulse (AP) at t1 + t0

DiCT and AP can induce in turn DiCT and AP

Since AP are delayed, we can study the statistics of all hits at t0 only, and then repeating the procedure for all hits at t1 + t0, and so on.



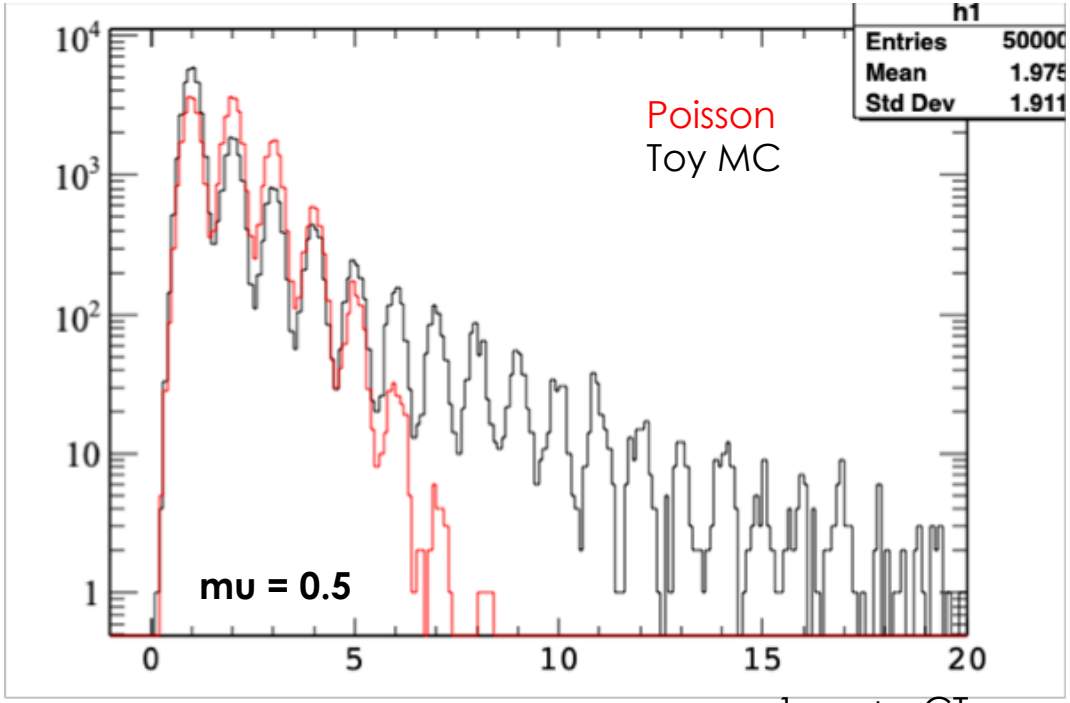
We can treat hits at different times as independent events

Electronics Simulation & Vinogradov

If the mean number of CTs for each PE is mu, we expect an **effective mean value** due to the CTs induced by CTs themselves as **mu_eff = mu / (1 - mu)**

Up to now, we have treated the statistics of CTs as **Poisson(mu/(1 - mu))**, but this is wrong.

We have tested it with a toy MC

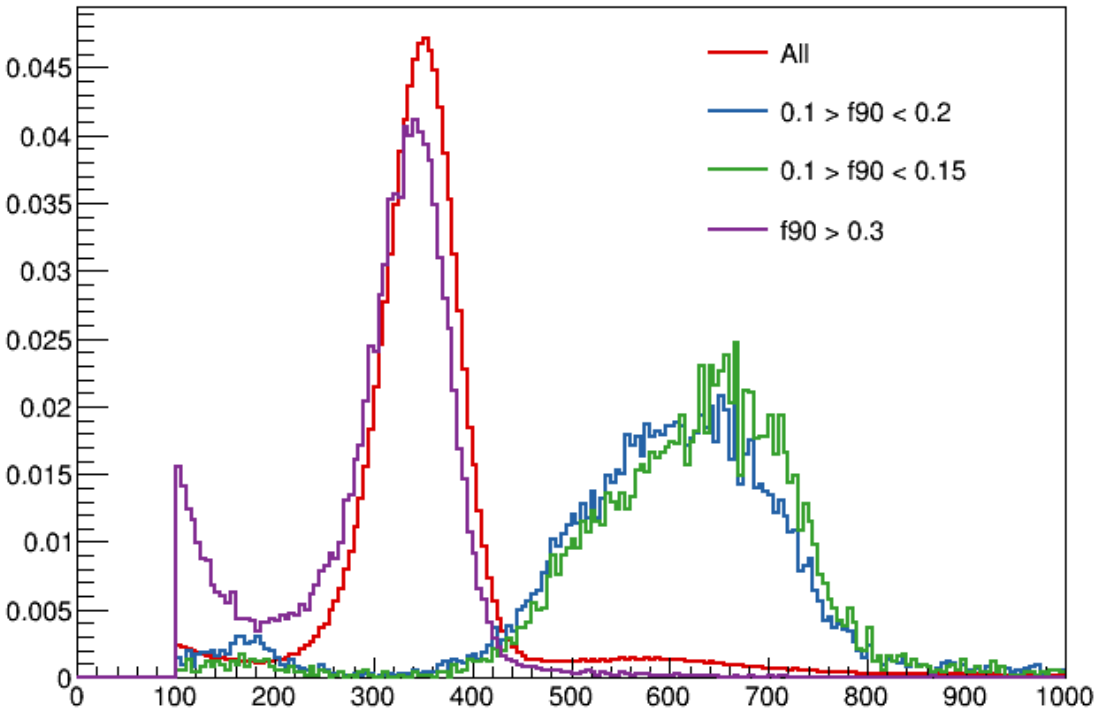


1 pe + nCTs

The mean number doesn't change but the RMS increases

Pile Up

Be careful that we are observing pile-up of Am241. They can be selected by looking at f90. We've estimated about 3% of events in pile-up, which means, assuming a gate of 10 us, an interaction rate of about 2 kHz. We strongly suggest to put the source a few centimeters far away from the source. This impact a bit on the resolution.



Final Considerations

The LY is not a so important parameter: the resolution is the key one

Resolution is composed by:
- Photon statistics
- SER (which should be negligible)
- AP/CT statistics

If we assume that AP/CT are not contributing to sigma, than ReD LY should be ~4 pe/keV. But ReD resolution is better than ARIS, where LY is well known (6.2 pe/keV)

⇒ **AP/CT induces an additional smearing**

However, increasing Vbias, we observe a clear amplification of the LY in the energy scale, but not on the resolution

⇒ **a possible explanation is that, increasing Vbias, PDE and AP/AC increase as well in a way that the total resolution is almost invariant**