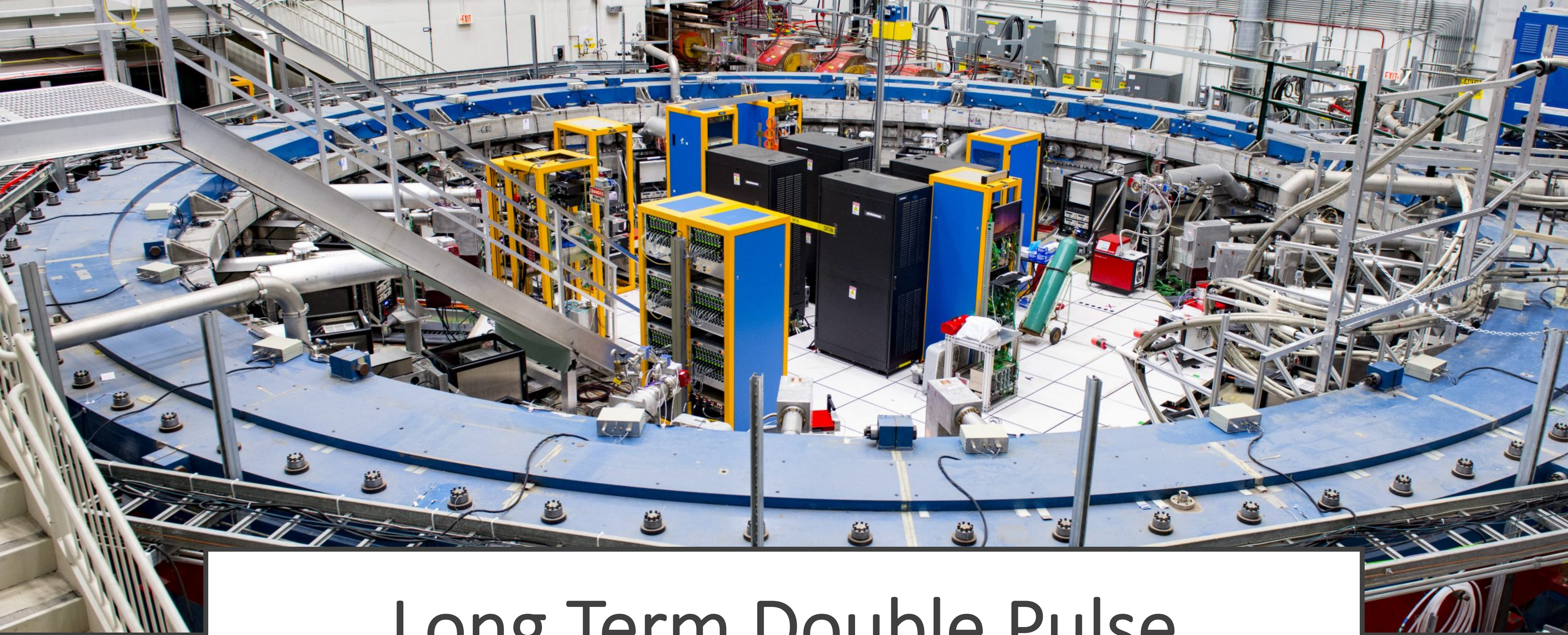


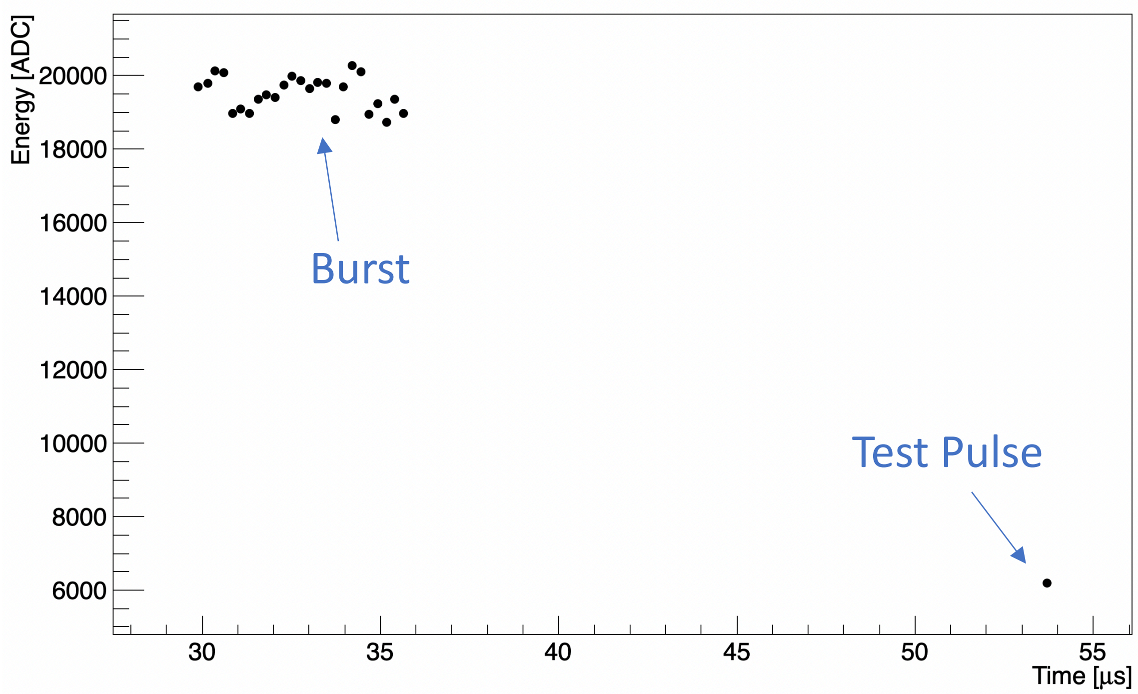
Long Term Double Pulse

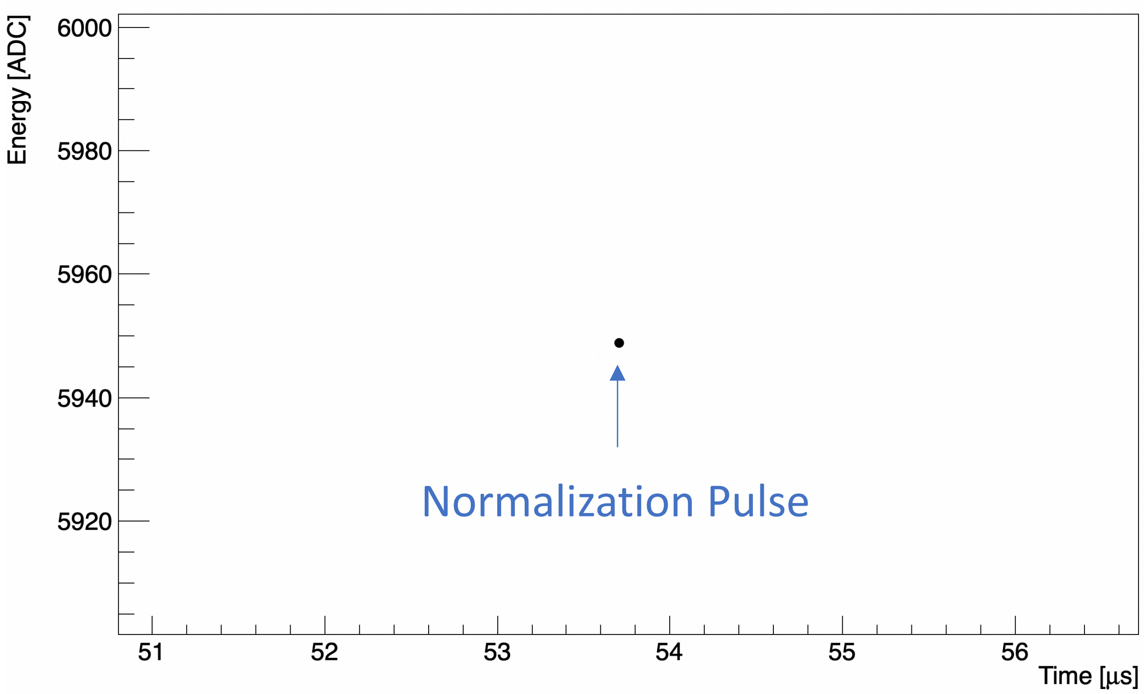
E.Bottalico

Muse General Meeting – 25 October 2019

LTDP Study

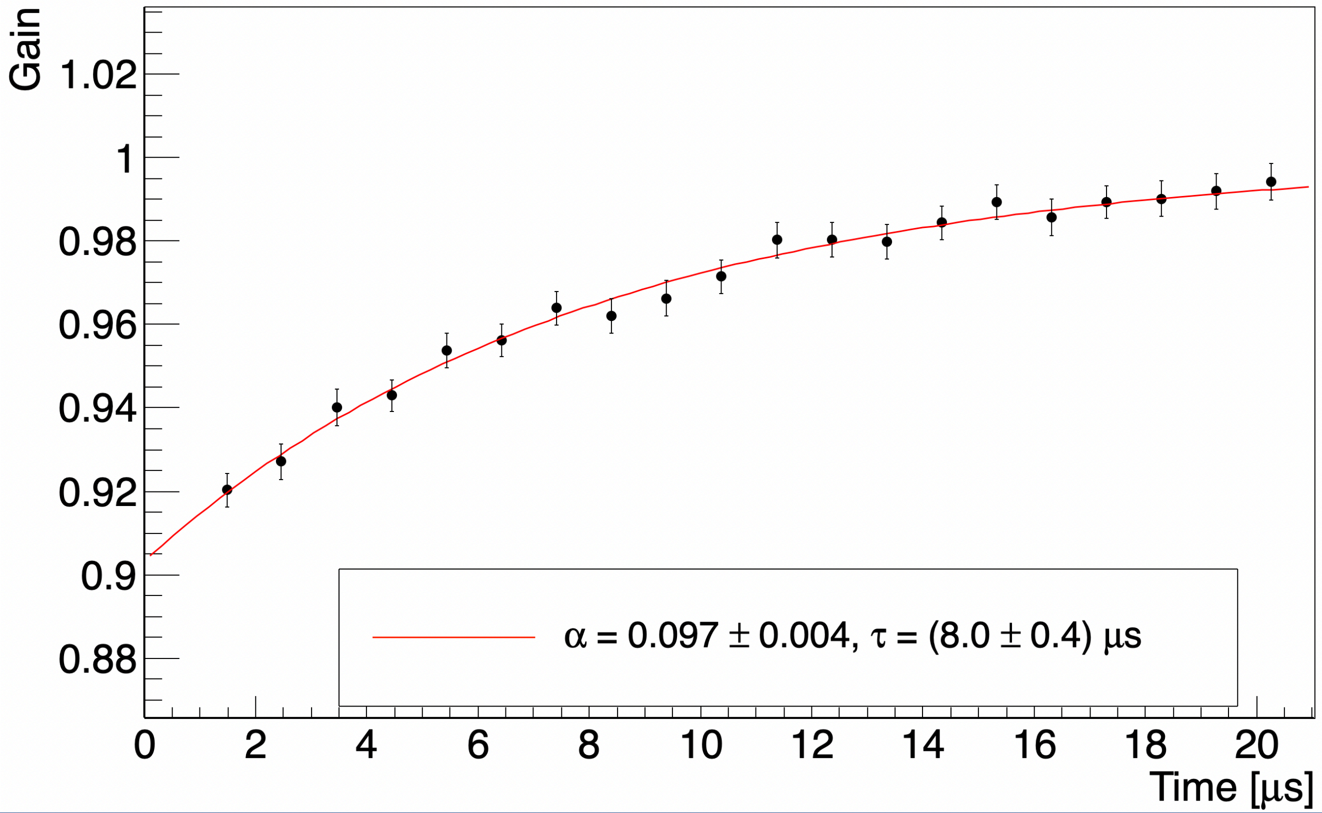
- Mimic the splash with laser in Burst mode.
- Measure the gain sag using a probe, Test Pulse (T), normalized to a Normalization Pulse (N).





LTDP Study

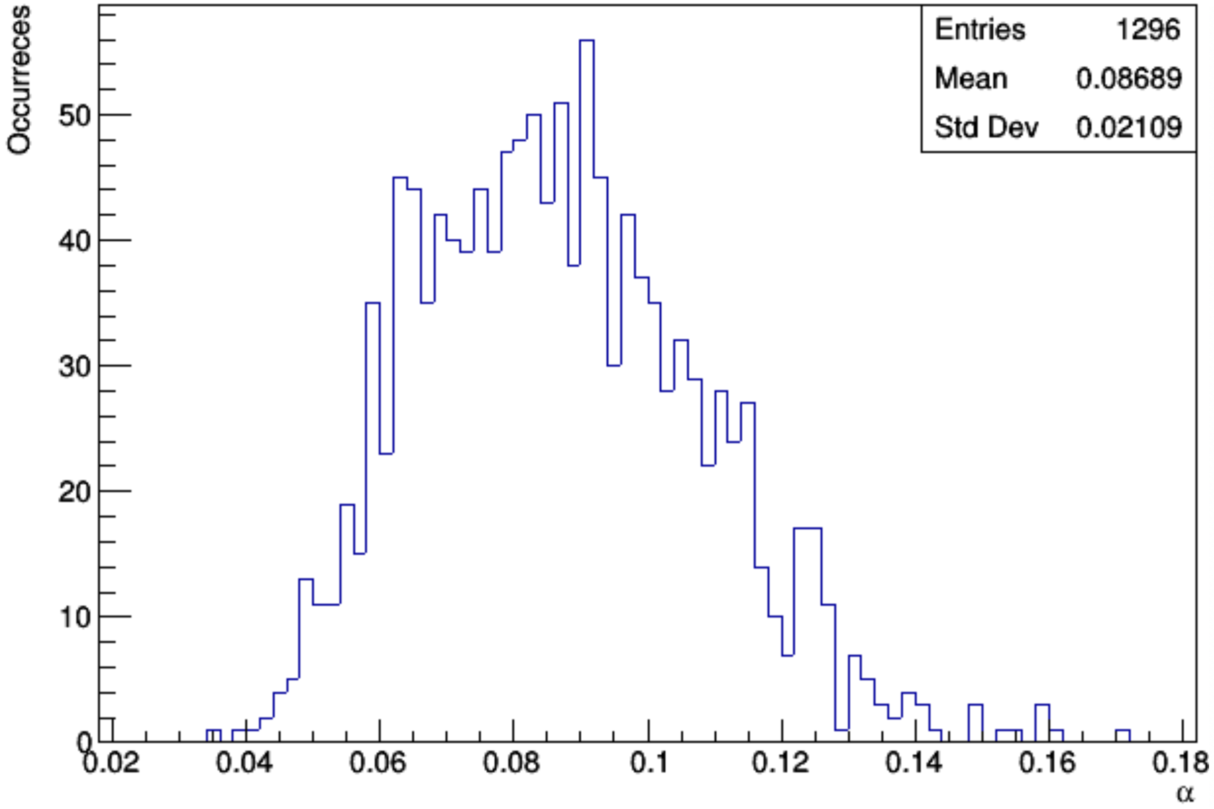
- We built the gain function computing for each point $G(t) = \frac{\langle T \rangle}{\langle N \rangle}$ where t is the delay between the last pulse in the burst and the Test pulse.
- The fit function is an exponential: $G(\mathrm{t}) = 1 - \alpha e^{-\frac{t}{\tau}}$



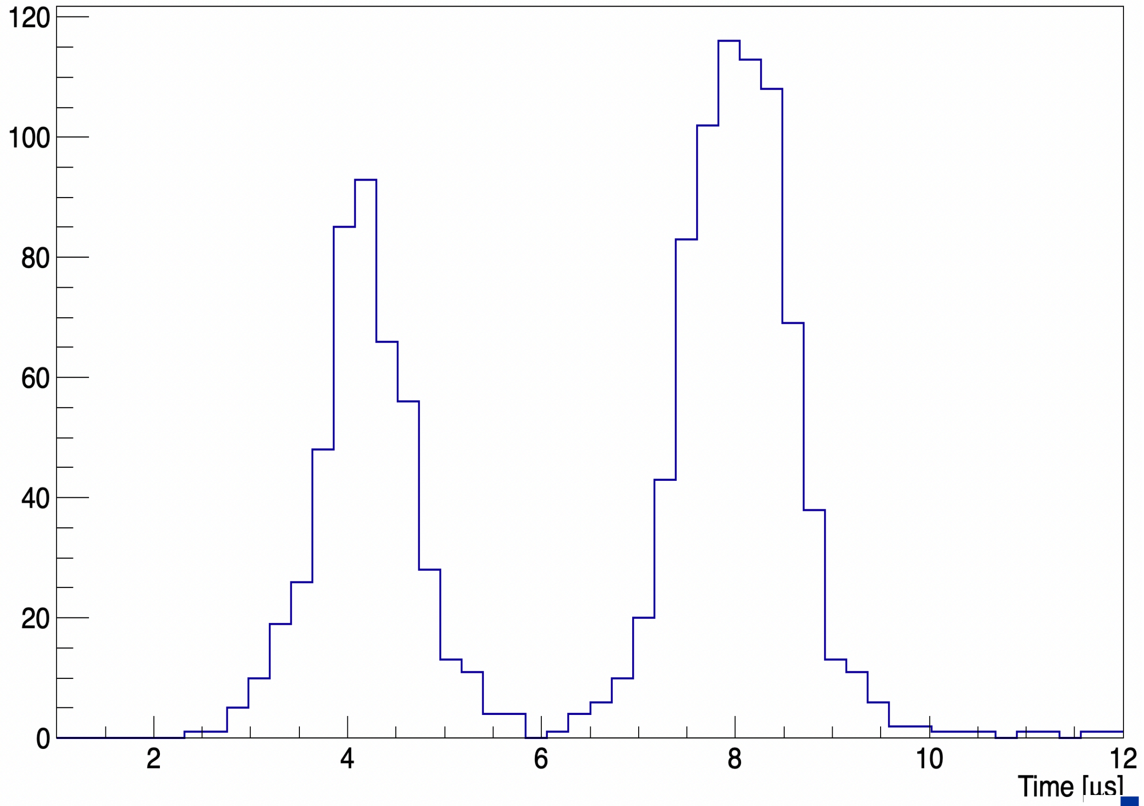
LTDP Study

- Distribution of the τ and α parameters for each crystal.

α distribution

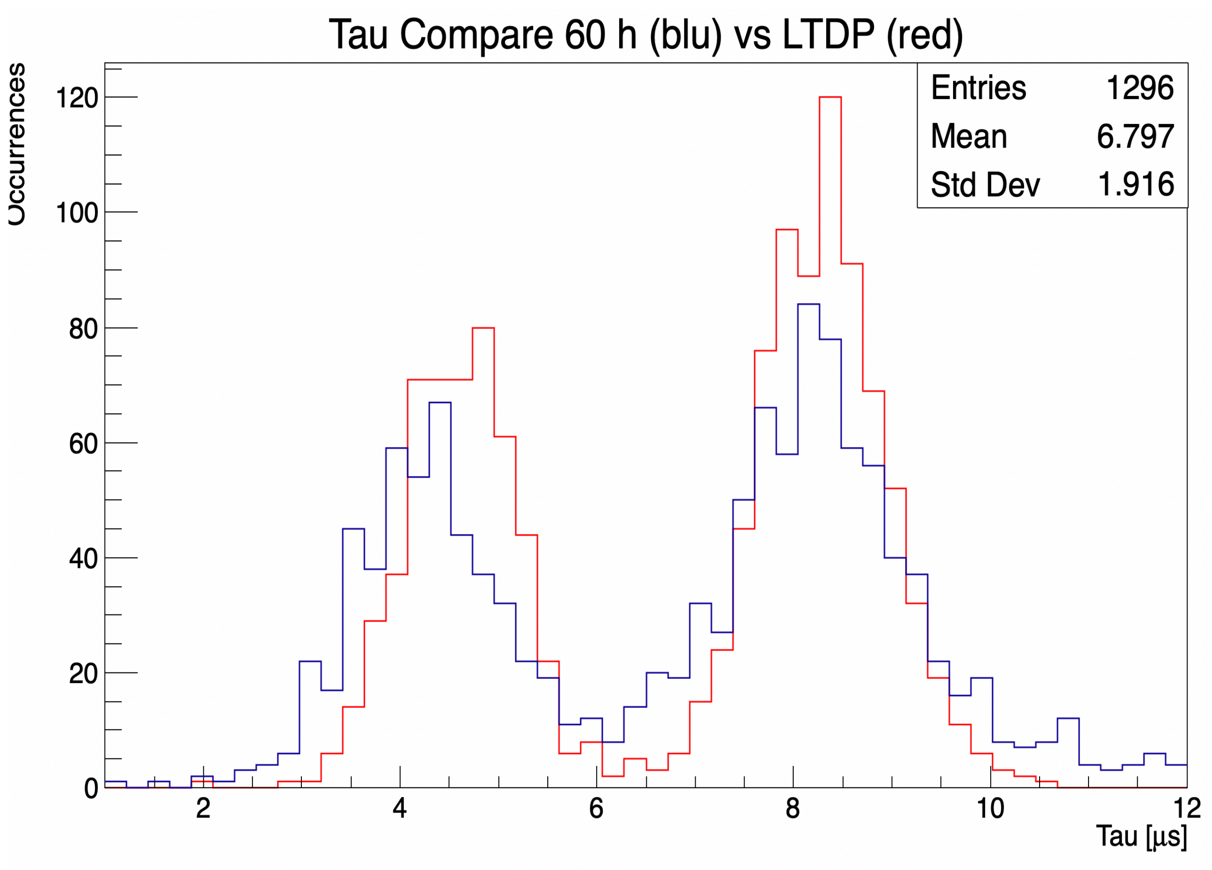


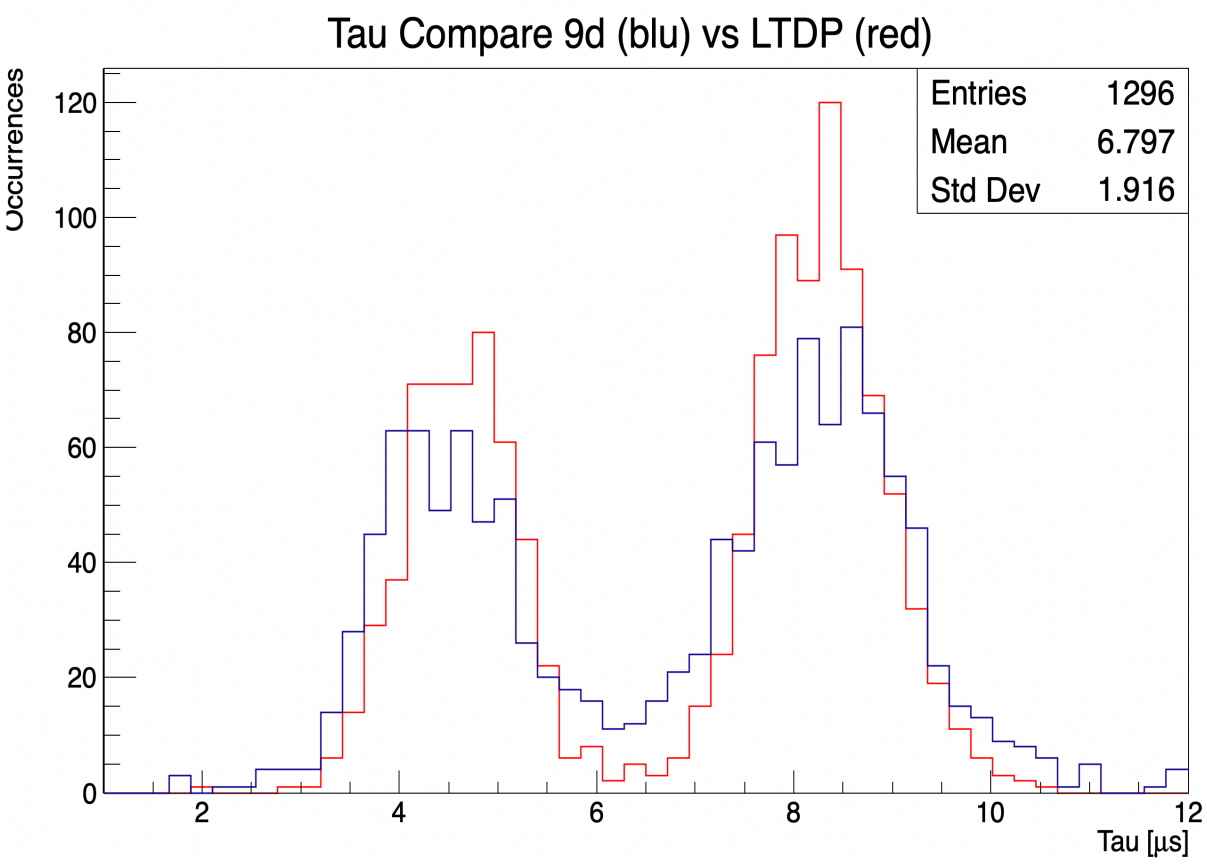
τ distribution



IFG Comparison

These are the comparison between the τ distributions obtained by LTDP and the 3 datasets (60h, 9d and Endgame).





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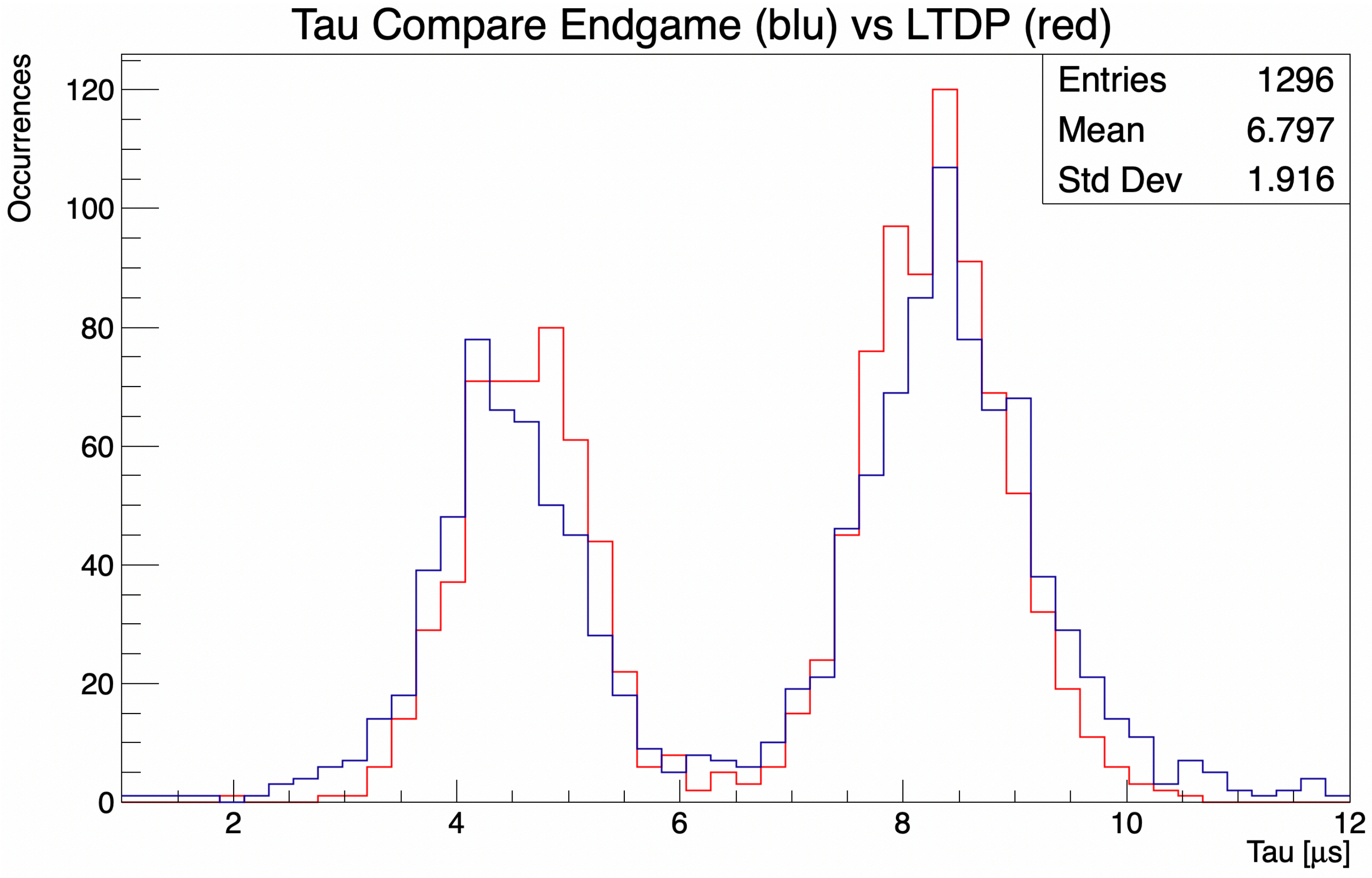
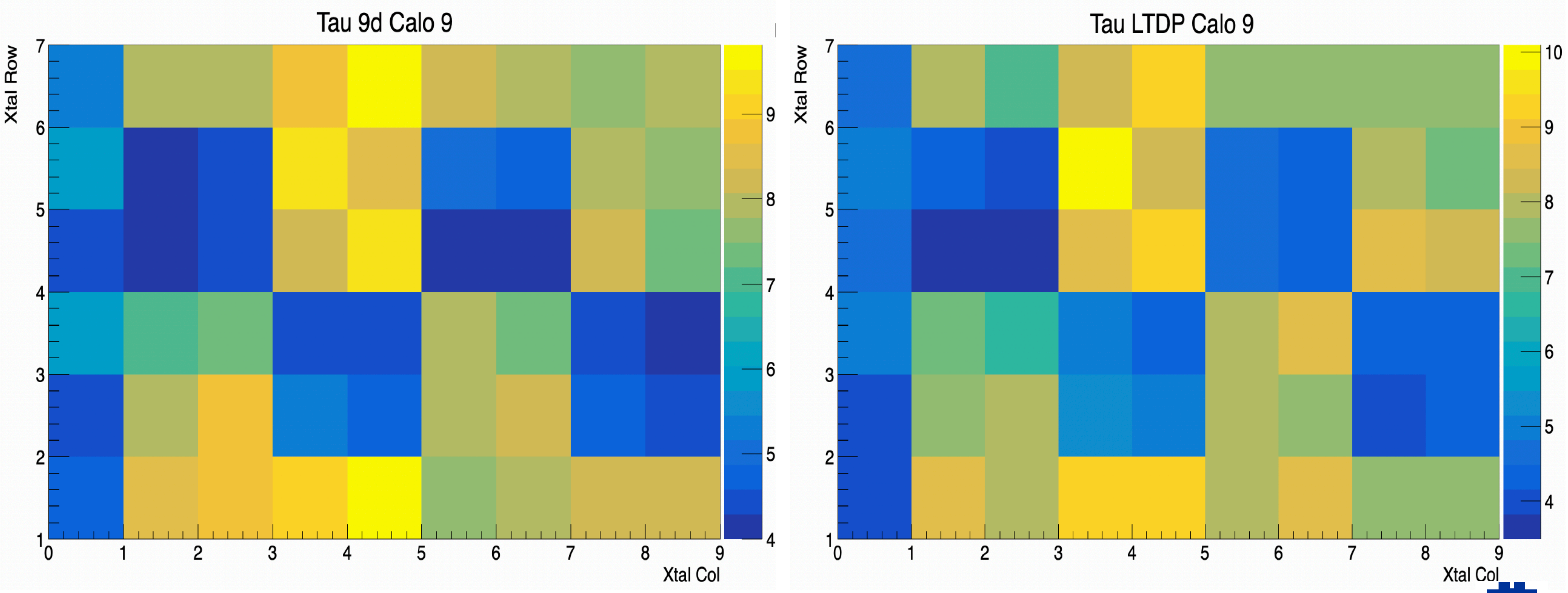


IFG Comparison

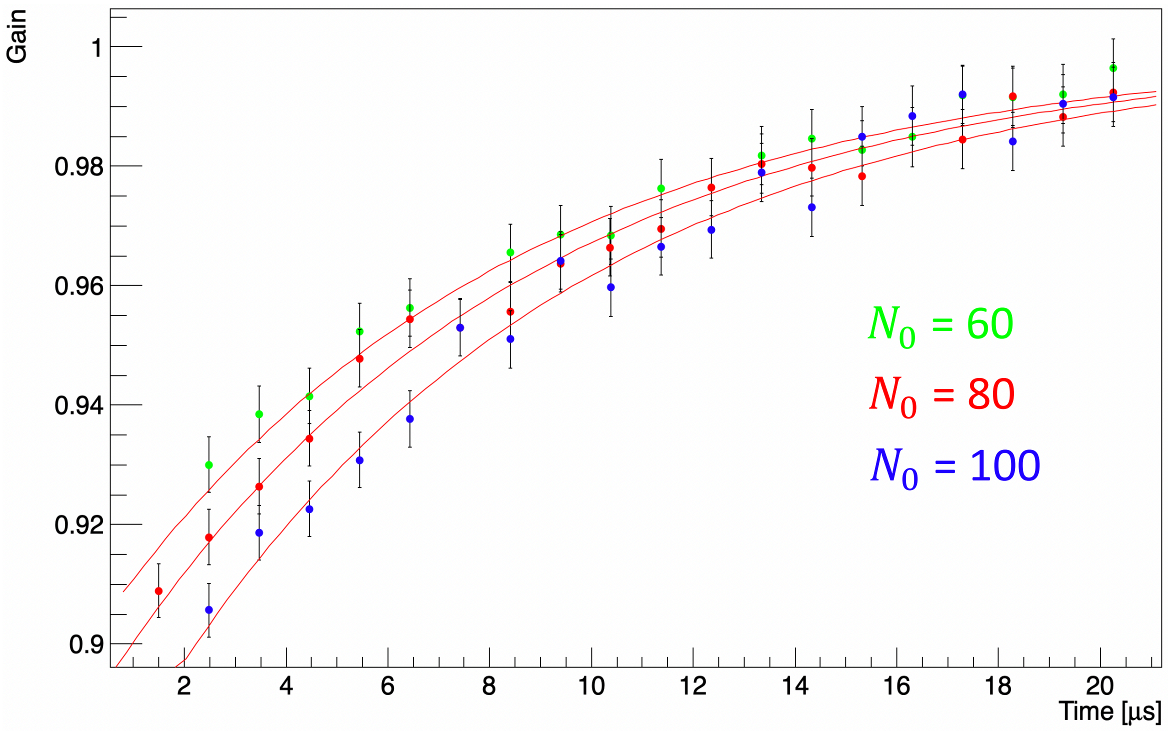
The distributions of the τ parameters have the same pattern in the calorimeter for the IFG and LTDP data.



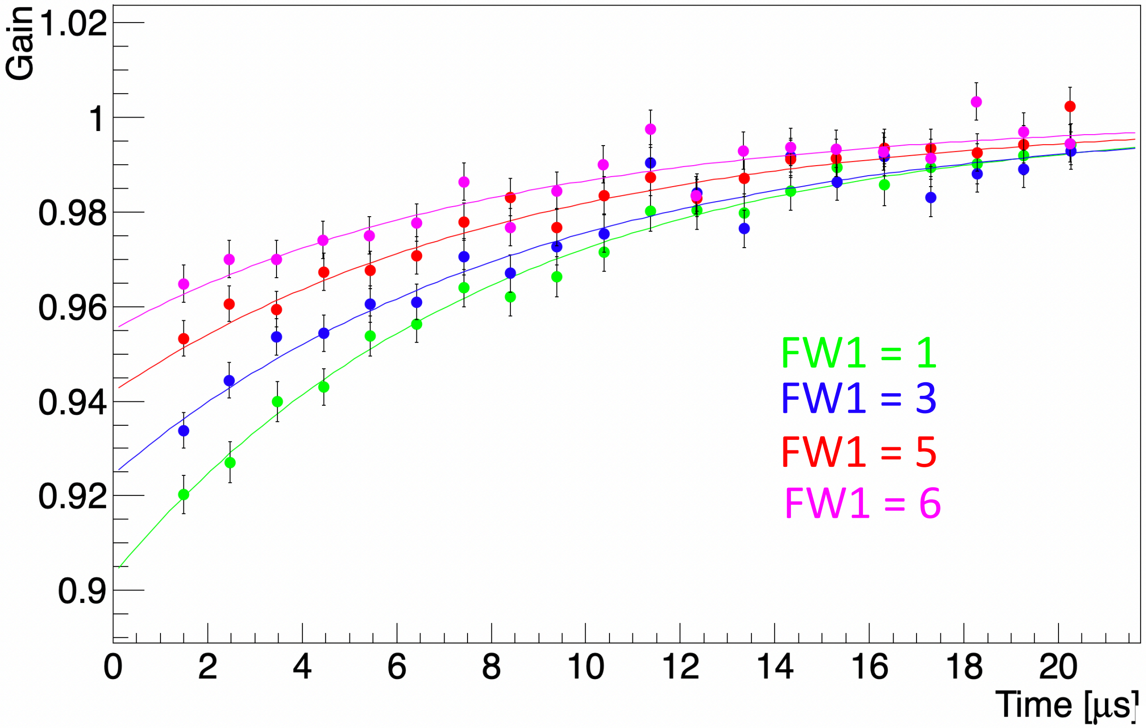
Energy Study

- To study the energy dependence of α we change the number of pulses in the Burst (N_0) and the energy of the single pulse in the burst (E_0), by varying the Filter Wheel (FW) position. In the following plots are shown different gain function for different combination N_0 and E_0, fitted with the same exponential function:

Scan N_0



Scan E_0



Energy Study

We compute an analytical function to describe the gain sag due to the Burst mode:

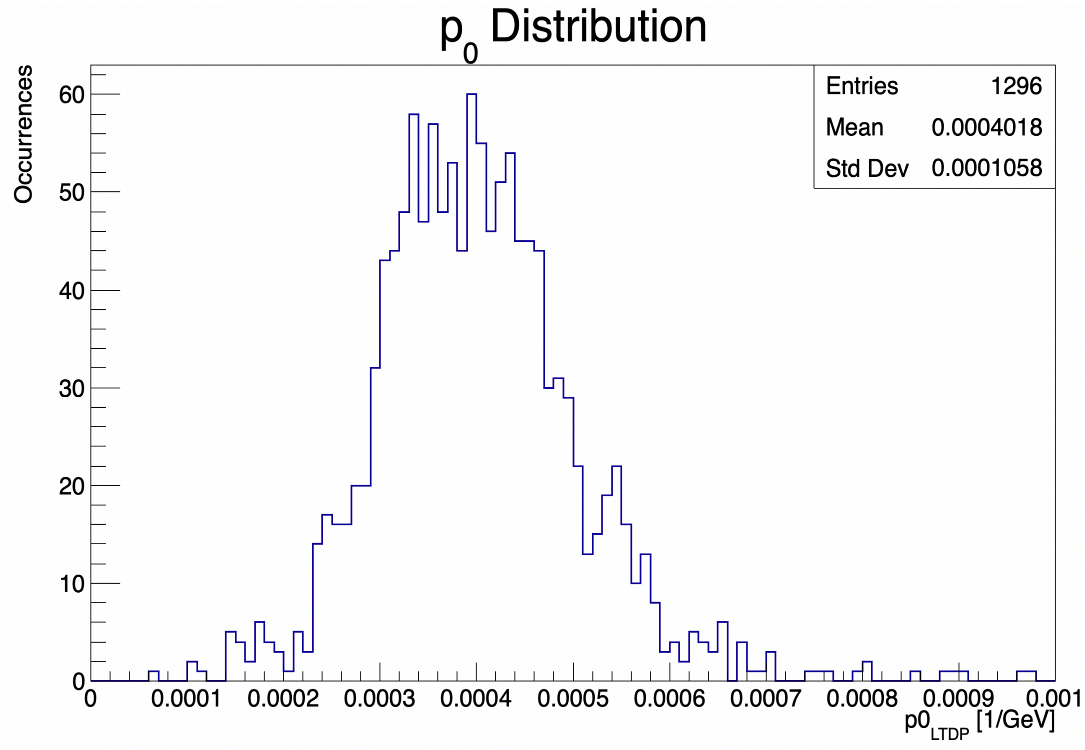
$$G(t) = 1 - (1 - e^{-p_0 E_0}) \frac{1 - e^{-\frac{N_0 \delta}{\tau}}}{1 - e^{-\frac{\delta}{\tau}}} e^{-\frac{t}{\tau}}$$

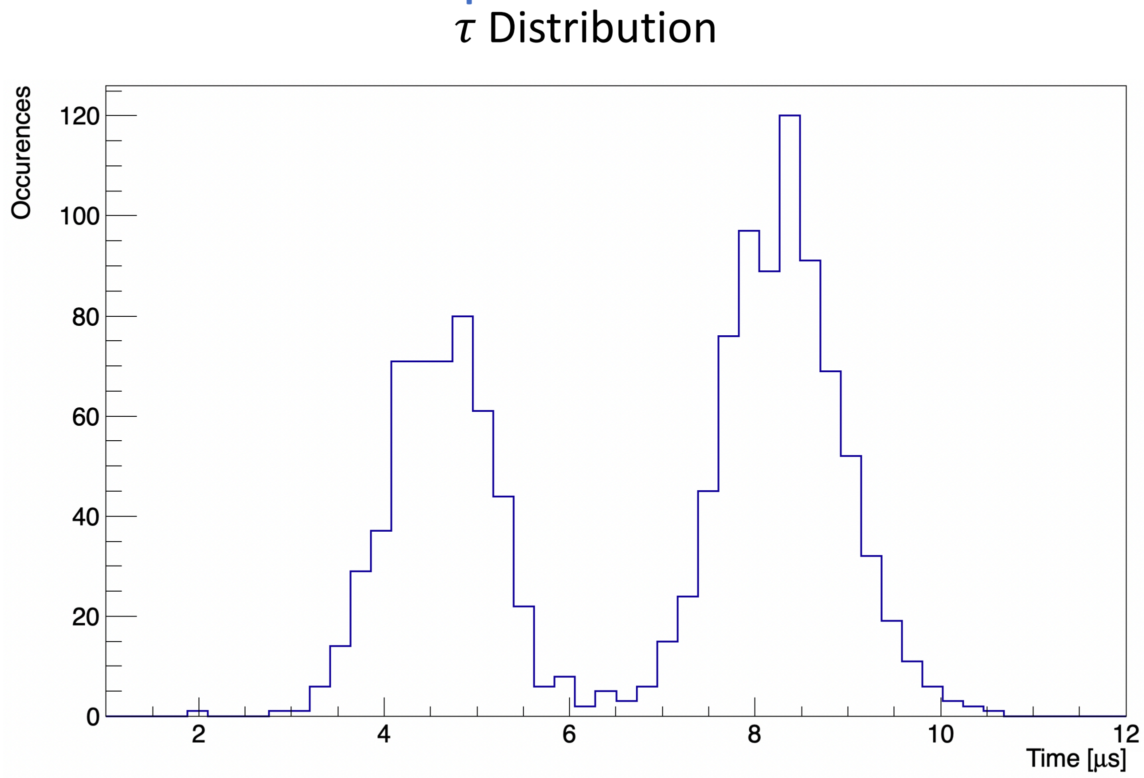
$\rightarrow F(\mathrm{N}_0, \delta, \tau)$

We put $(1 - e^{-p_0 E_0}) \cdot F(N_0, \delta, \tau)$ instead of α, where p_0 is the gain sag in function of energy and δ the distance between 2 pulses in the burst (120 ns). In this way we can characterize the gain sag in function of the parameters p_0 and τ.

Fit Mode

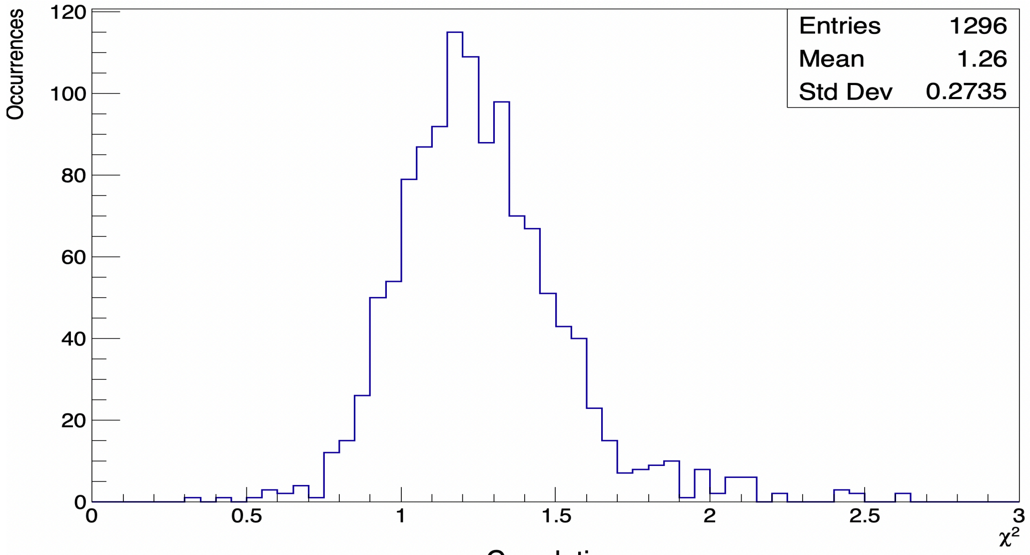
We perform a combined fit of the gain building a 3-dimensional histogram, for each SIPM, where each bin of coordinates (E_0, N_0, t) is weighted with the value of the gain in that bin. We perform the fit with the function of $G(t) = 1 - (1 - e^{-p_0 E_0})F(\delta, N_0, \tau)e^{-\frac{t}{\tau}}$ shown before, with free parameters τ and p_0. These are the distributions of the parameters:



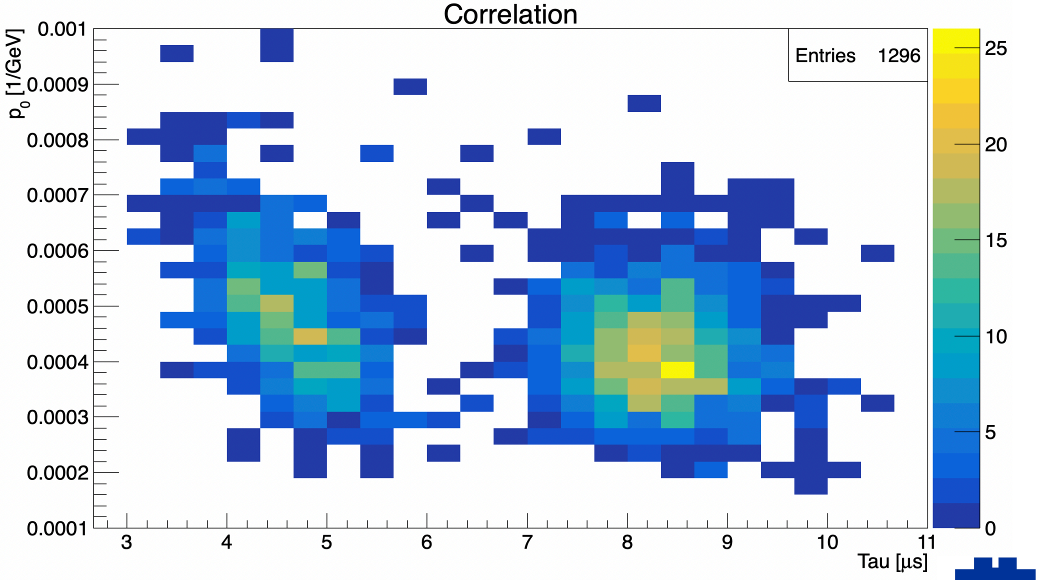


Fit Mode

Distribution of the χ^2 of the 1296 fits



Scatter plot p_0 - τ to show the correlation between the parameters (ρ=-0.36)



Definition α_{LTDP}

The IFG curves are fitted with $G_{IFG}(t) = 1 - \alpha_{IFG} e^{-t/\tau_{IFG}}$. To compare the α parameter, we define α_{LTDP} modeling the splash with a Gaussian. Convoluting the Gaussian distribution $E_0 \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{t^2}{\delta t^2}}$ (where δt is the time spread of the Splash) with the SiPM response $p_0 e^{-\frac{t}{\tau}}$ we obtain:

$$\frac{E_0(p_0)}{\sqrt{2}} e^{\frac{\delta t^2 - 4\tau \cdot t}{4\tau^2}}(t = 0) \rightarrow \frac{E_0(p_0)}{\sqrt{2}} e^{\frac{\delta t^2}{4\tau^2}}$$

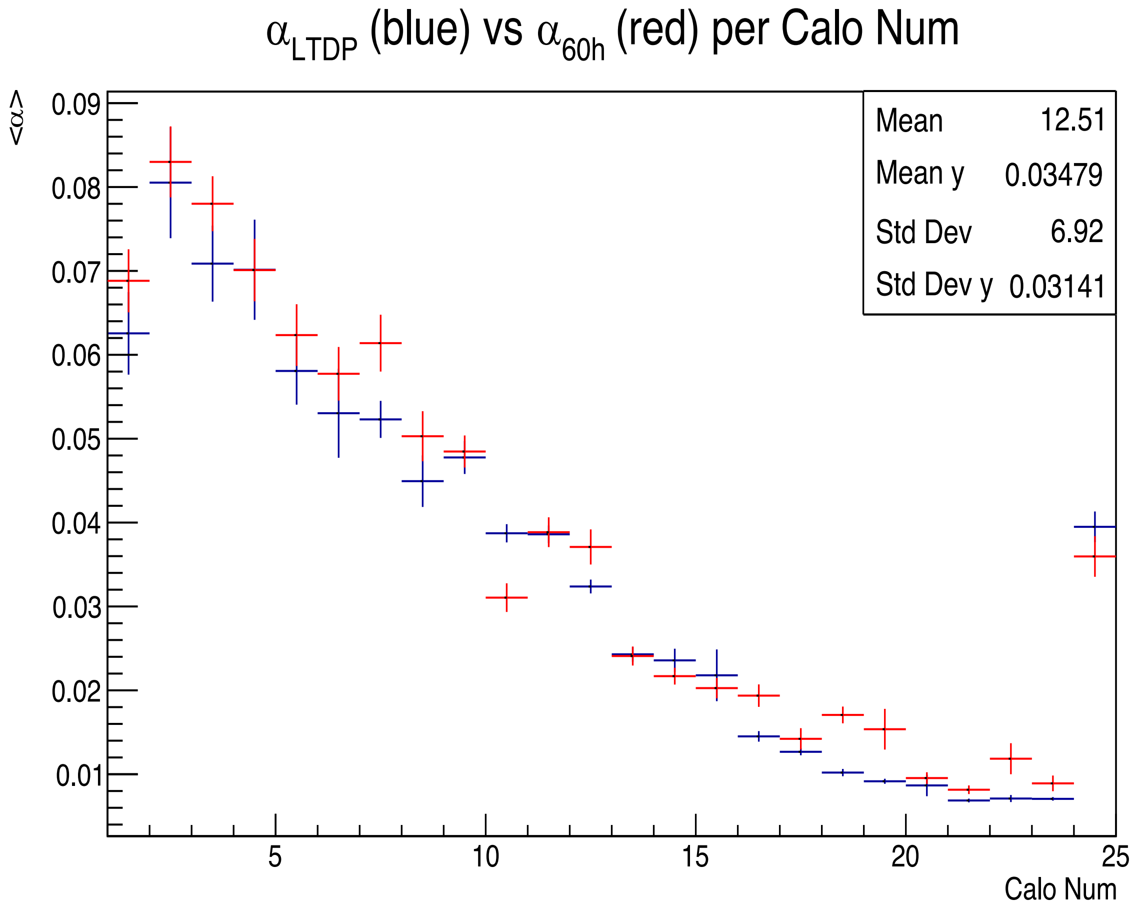
In such way we can approximate $G(t) = 1 - (1 - e^{-p_0 E_0}) F(\delta, N_0, \tau) e^{-\frac{t}{\tau}}$ as $G(t) \sim 1 - p_0 E_0 e^{-\frac{t}{\tau}}$ and assuming α_{LTDP} as:

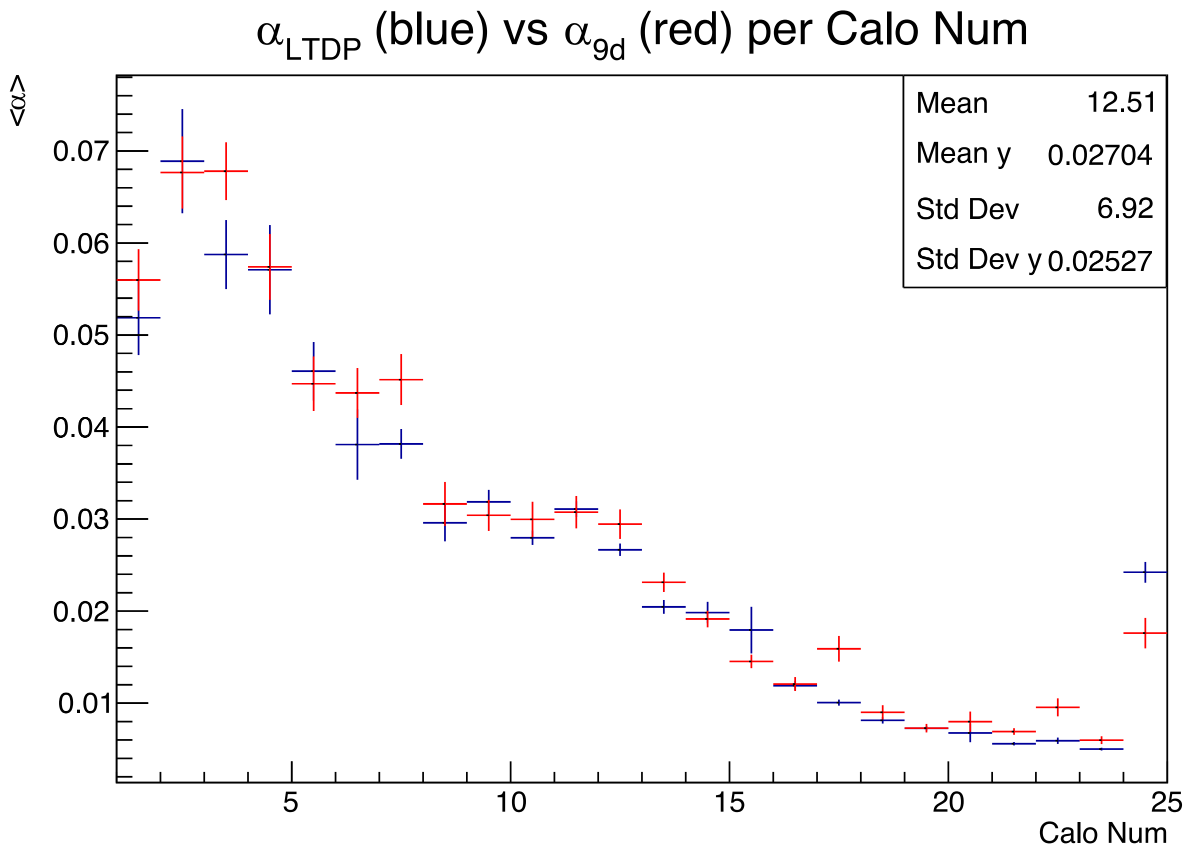
$$\alpha_{LTDP} = \frac{E_{splash} \cdot p_0}{\sqrt{2}} e^{\frac{\delta t^2}{4\tau^2}}$$

Where $\mathrm{E}_{\mathrm{splash\ meas}}$ is the splash energy measured.

IFG Comparison

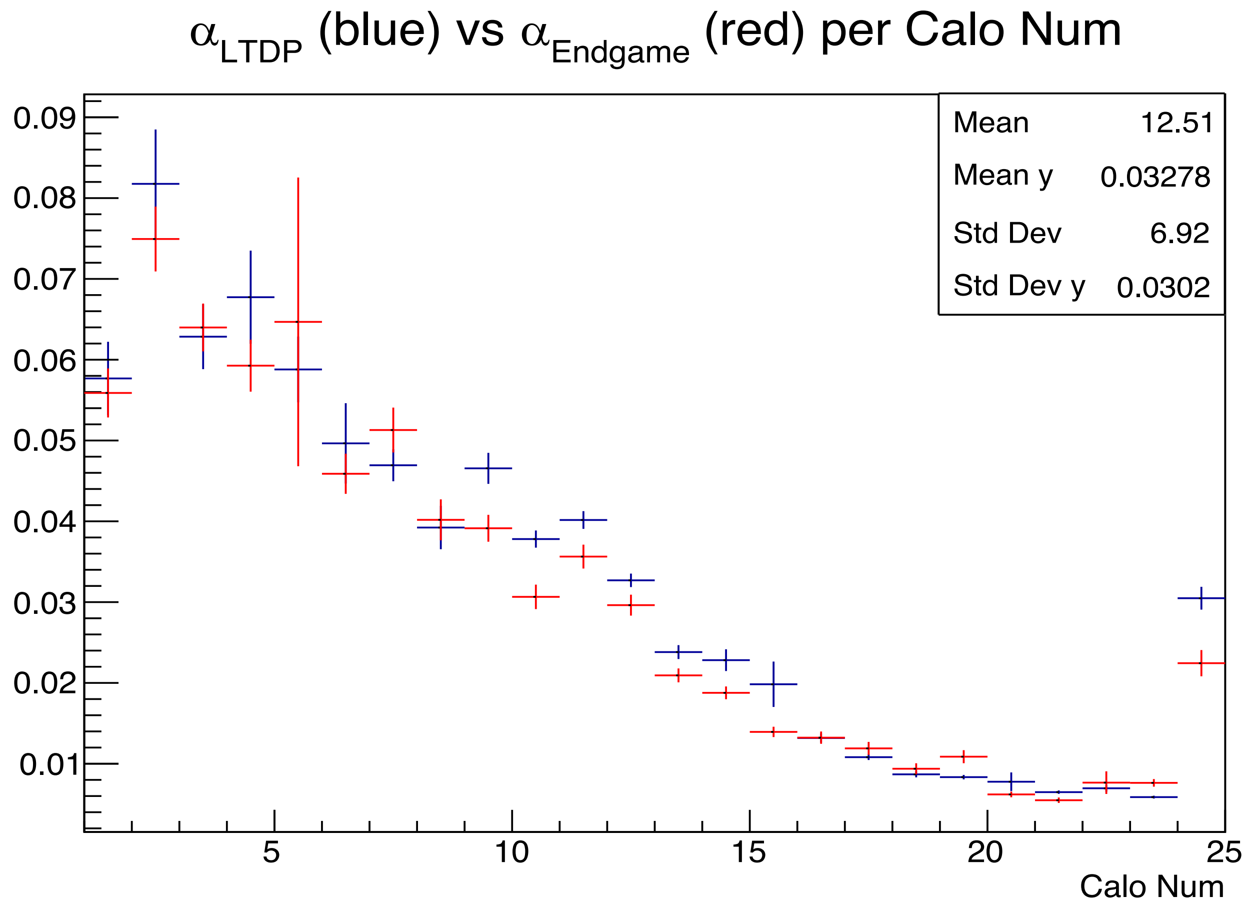
Comparison between α_{LTDP} and α_{IFG} for the 3 dataset (60h, 9d and Endgame):





IFG Comparison

Comparison between α_{LTDP} and α_{IFG} for the 3 dataset (60h, 9d and Endgame):

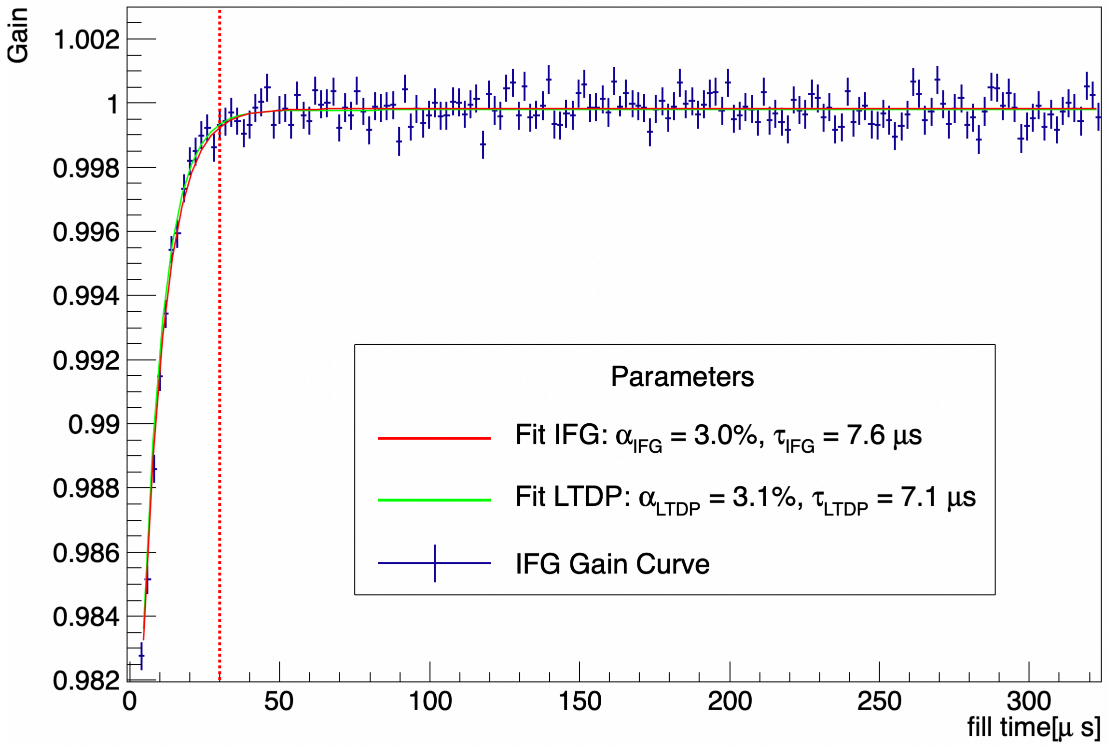


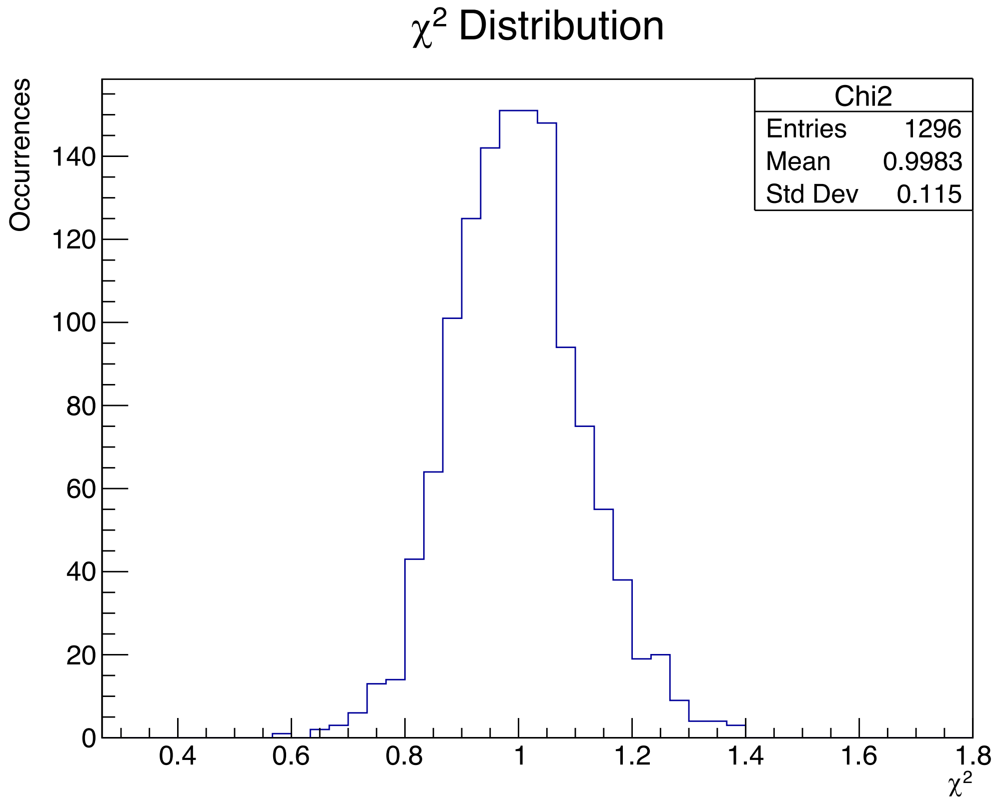
IFG Comparison

The next step is to build the LTDP correction functions to compare them with the IFG functions. In these plots are shown the IFG gain curves (blue dots), the IFG fit with $G_{IFG}(t)$ (red curve) and the LTDP correction function (green curve) define in this way:

$$G_{LTDP}(t) = N\left(1 - \alpha_{LTDP} \cdot e^{-\frac{t}{\tau_{LTDP}}}\right)$$

Where N is the only free parameter.





IFG Comparison

Finally to study quantitatively the goodness of the LTDP corrections we apply the G_{LTDP} function (for the 60h dataset) instead of G_{IFG} to correct positron energy E_p.

$$E'_p = \frac{E_p}{G_{LTDP}(\Delta t)}$$

The fit result are:

- LTDP Correction: $\frac{\chi^2}{NDF}$: 0.954134 with prob 0.973296 R: -42.707$\pm$ 1.33528
- IFG Correction: $\frac{\chi^2}{NDF}$: 0.954346 with prob 0.972728 R: -42.6989 $\pm$ 1.3354

$$\delta R = 8.1 \text{ ppb}$$

Conclusion

- Using the Long Term Double Pulse we can describe the gain sag of the SIPM as a function of energy by 2 parameters (p_0, τ).
- By assuming a convolution model for the splash we can compute the gain sag as $G_{LTDP}(t) = N\left(1 - \alpha_{LTDP} \cdot e^{-\frac{t}{\tau_{LTDP}}}\right)$ and find a good agreement with the IFG.
- The effect of these corrections are inside the 20 ppb final score for gain corrections.
- This is a perfect indipendet check for the IFG corrections.