Analysis Status of ZDC ECal

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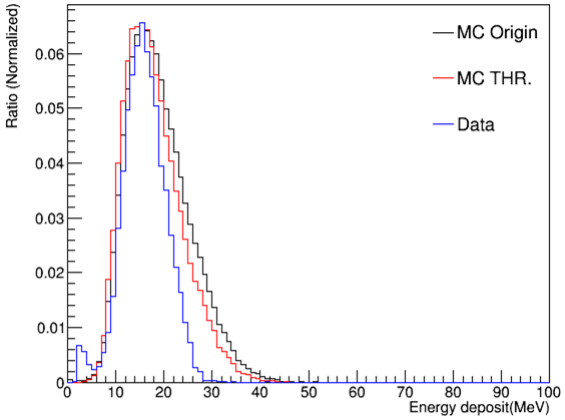
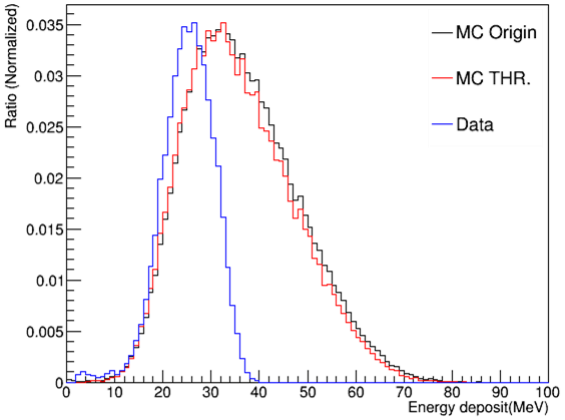
Inconsistency between Data and MC

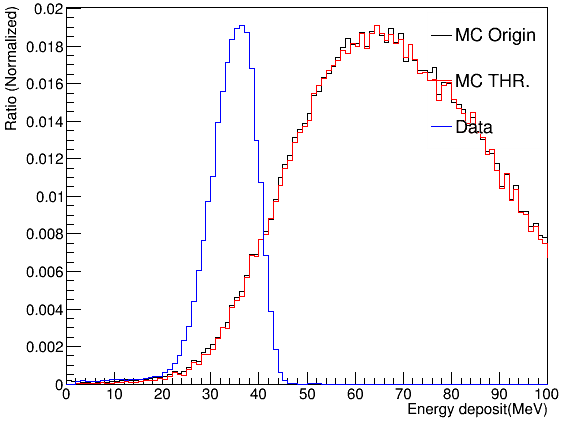
47MeV

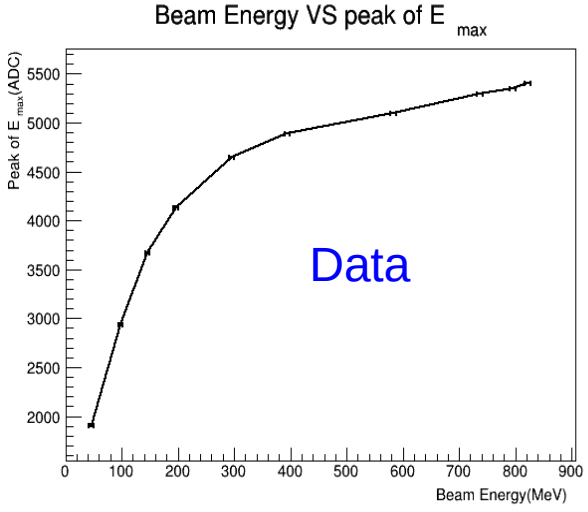


98MeV



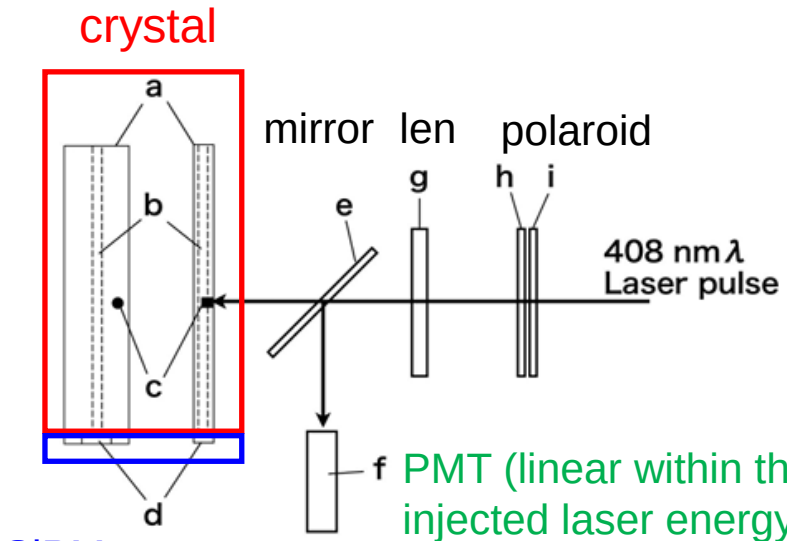
198MeV

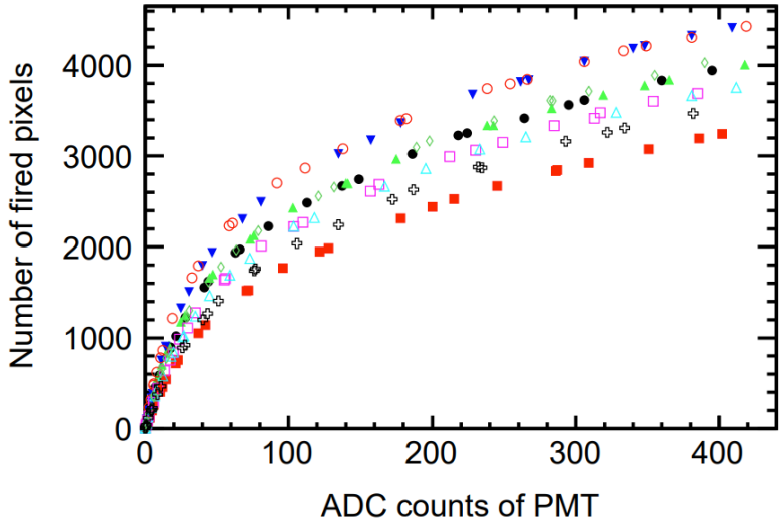




- Threshold has implemented in MC, but still can't find the consistency between data and MC. Only features of LYSO crystal are implemented in MC but not.
- How to describe SiPM behavior and input into MC?

Description of SiPM Behavior



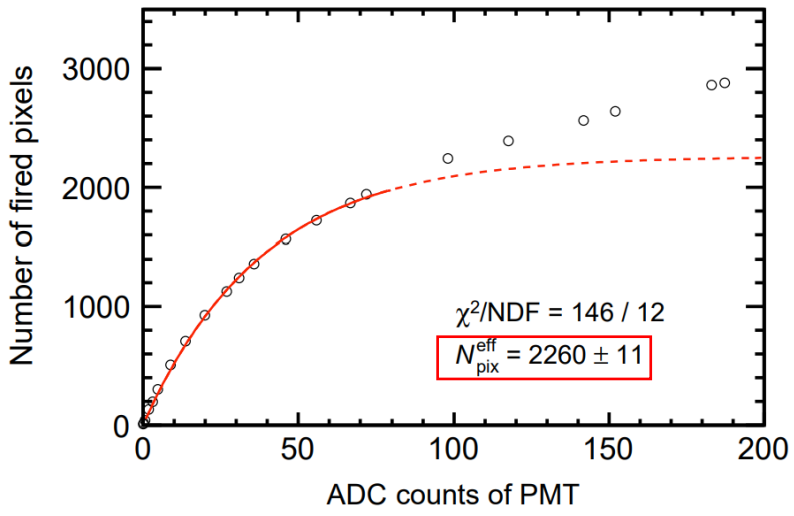


https://arxiv.org/abs/1510.01102

Correlation between laser intensity and number of fired pixel of SiPM
X : ADC count of PMT ➔ intensity of incident laser
Y : Number of fired pixel ➔ ADC of SiPM output devided by ADC of single pixel SiPM output

Description of SiPM Behavior

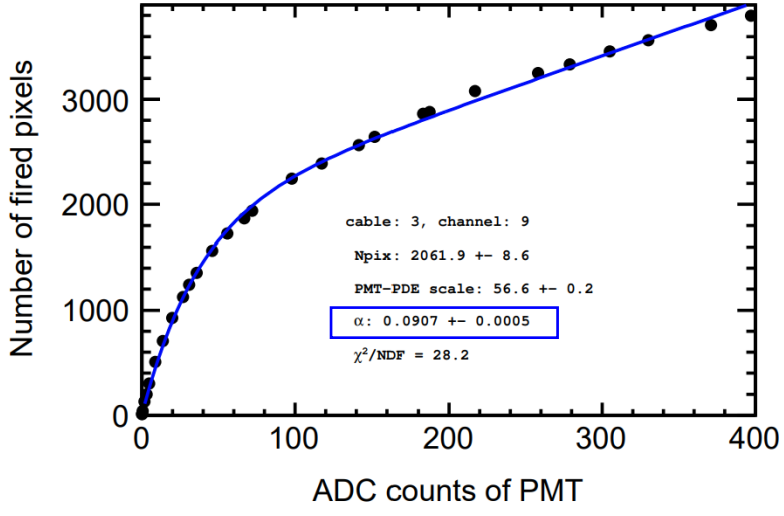
LO ➔ ϵ, N_{pix}



$$N_{fire}^{LO} = N_{pix}\left[1 - \exp\left(-\frac{\epsilon N_{in}}{N_{pix}}\right)\right]$$

- N_{fire}^{LO} = Num. of fired pixcel of SiPM
- N_{pix} = Num of pixcel of SiPM
- ϵ = photon detection efficiency of SiPM

NLO ➔ α



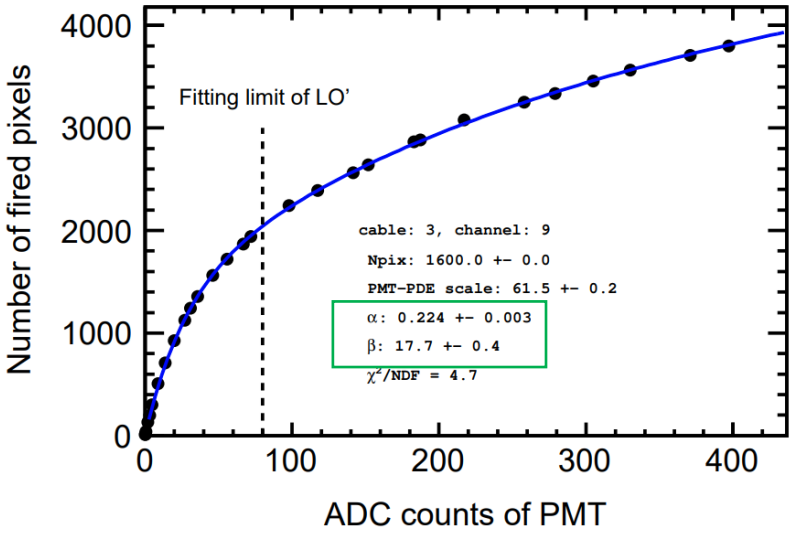
$$N_{\mathrm{R}} = \epsilon N_{\mathrm{in}} - N_{\mathrm{fire}}^{\mathrm{LO}}$$

$$N_{\mathrm{fire}}^{\mathrm{NLO}} = N_{\mathrm{fire}}^{\mathrm{LO}} + \alpha N_{\mathrm{R}}$$

- N_R = rest of photons do not detected by SiPM at the first time.
- α = average contribution of remaining photons.

Description of SiPM Behavior

NLO' ➔ β



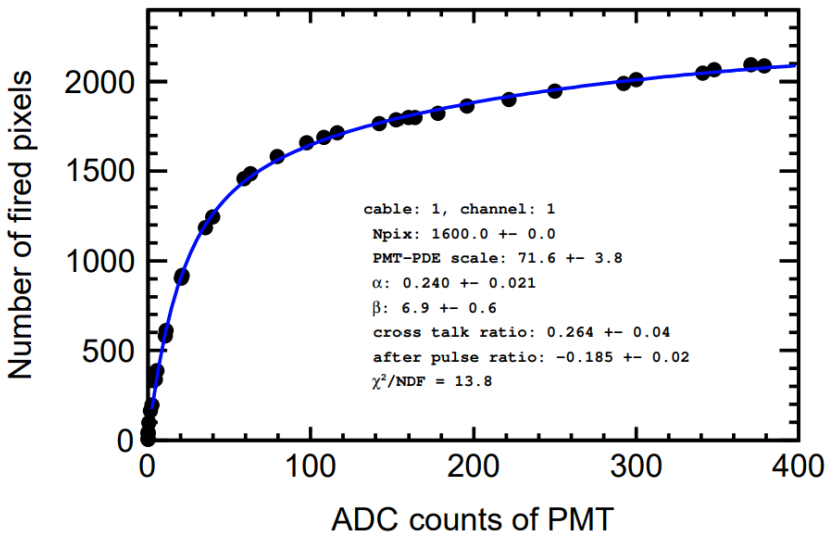
$$N_{\text{fire}}^{\text{NLO}'} = N_{\text{fire}}^{\text{NLO}} \frac{\beta + 1}{\beta + \epsilon N_{\text{in}}/\text{LO}}.$$

NLO : α gives the **average charge contribution of remaining photon**.

NLO' : β gives **the charge contribution of remaining photon and it decreases as the number of photons on a pixel increases.**

Description of SiPM Behavior

NLO' + Cross talk and after pulse



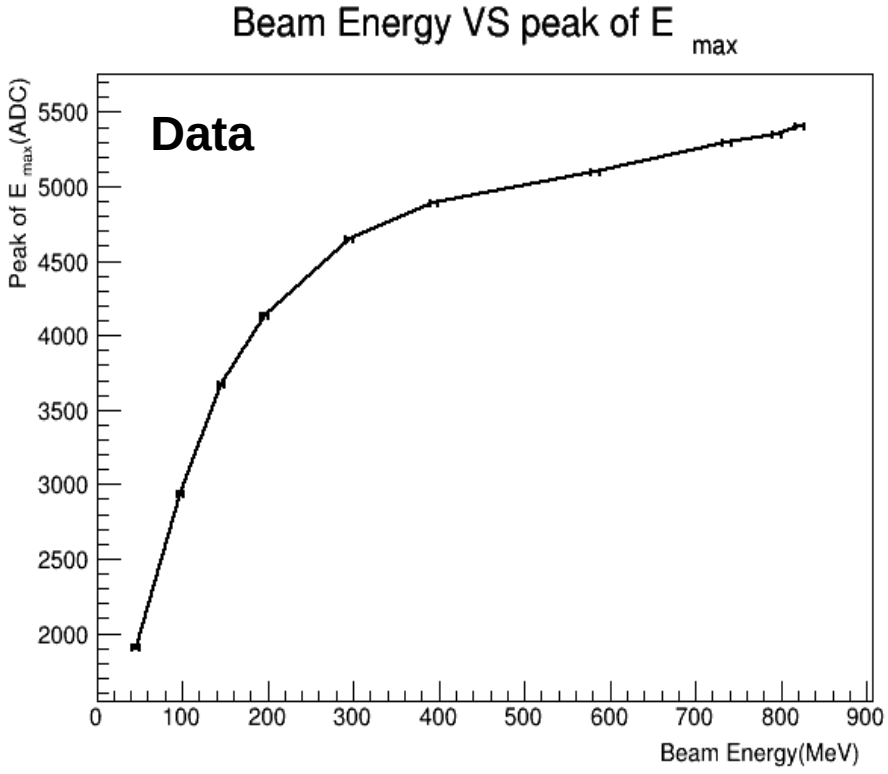
$$N_{\mathrm{fire}}^{\mathrm{NLO'_{C\cdot A}}} = N_{\mathrm{fire}}^{\mathrm{NLO'}}\left(1 + P_{\mathrm{cross}} \cdot \mathrm{e}^{-\epsilon N_{\mathrm{in}}/N_{\mathrm{pix}}}\right) \cdot (1 + P_{\mathrm{after}})$$

Crosstalk occurs when a photon, created by the primary avalanche, subsequently induces a second avalanche in a neighboring pixel.

An **after pulse** occurs when a second avalanche is seeded by the release of an electron trapped in a lattice defect of the depletion zone, or a hole defuses toward the depleted layer and, consequently, induces a second avalanche. The hole is created by a photon in the same mechanism as the crosstalk, and this diffusion delays the after pulses because the electric field of the bulk is weak.

Both results the increase in the average number of fired pixels.

Access the Behavior of SiPM from Data (1)



LO ➔ ϵ, N_{pix}

$$N_{fire}^{LO} = N_{pix}\left[1 - \exp\left(-\frac{\epsilon N_{in}}{N_{pix}}\right)\right]$$

NLO ➔ α

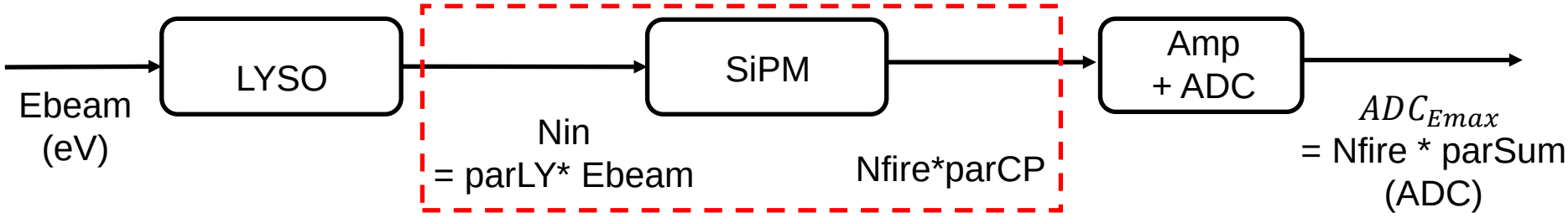
$$N_{\mathrm{R}} = \epsilon N_{\mathrm{in}} - N_{\mathrm{fire}}^{\mathrm{LO}}$$
$$N_{\mathrm{fire}}^{\mathrm{NLO}} = N_{\mathrm{fire}}^{\mathrm{LO}} + \alpha N_{\mathrm{R}}$$

NLO' ➔ β

$$N_{\mathrm{fire}}^{\mathrm{NLO}'} = N_{\mathrm{fire}}^{\mathrm{NLO}} \frac{\beta + 1}{\beta + \epsilon N_{\mathrm{in}}/\mathrm{LO}}.$$

Can our data adopt to the fit?

Access the Behavior of SiPM from Data (2)



Paper describes the relation between Nin and Nfire

In LYSO :

① Ebeam ➔ Nphoton/eV (Photon Detection Efficiency)➔ Birk's low (light yield saturation effect)

② **Nin** = [(Nphoton/eV)*Birk] *Ebeam = **parLY * Ebeam**

③ **parLY includes the effect of PDE and Birk's law**

In SiPM :

① Effect : **photon detection eff, correction of charge for "rest photon", cross talk, after pulse**

② Relation between Nfire and Nin : N_{fire}^{LO}, N_{fire}^{NLO}, $N_{fire}^{NLO'}$, $N_{fire}^{NLO'(CA)}$

③ Convert Nfire to charge, **Nfire* parCP**

In Amp + ADC :

① Amplification : parAmp

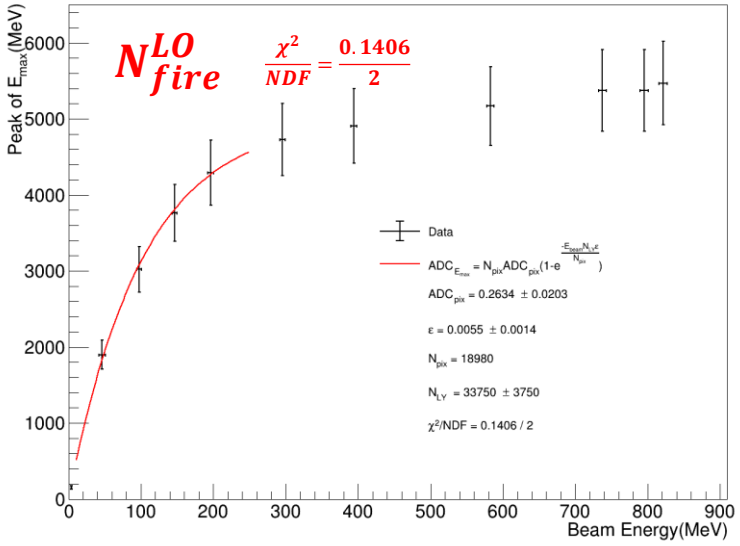
② Voltage to digit : parADC

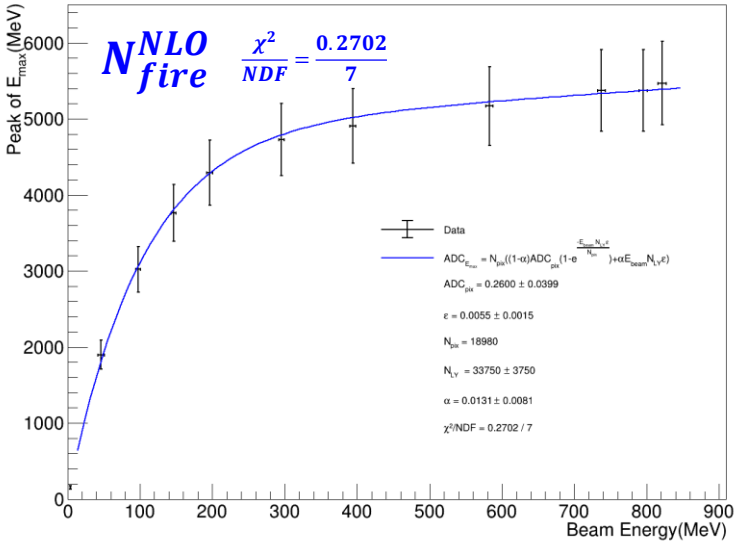
③ Final output from electronic **=** Nfire * parCP* parAmp * parADC = **Nfire * parSum =** ADC_{Emax}

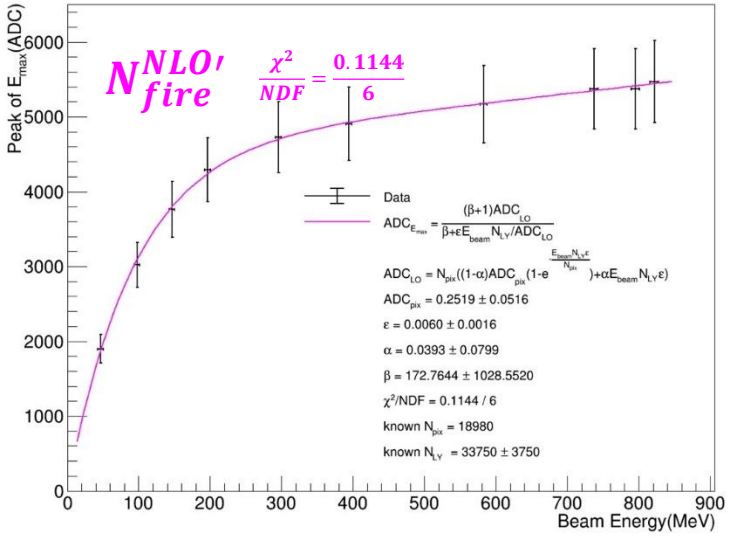
④ Where Nfire, one can describe by the formula explained earlier

Use LO as example : $ADC_{Emax} = N_{fire} * parSum = N_{pix}\left[1 - \exp\left(-\frac{(\epsilon * parLY) * Ebeam)}{N_{pix}}\right)\right] * parSum$

Access the Behavior of SiPM from Data (3)







- 10% uncertainty added to data points after considering the energy convergent factor and fitting quality of peak energy.
- Fitting quality looks nice. Better chi2/ndf after considering higher order.
- All the parameters looks reasonable, except for β.

Access the Behavior of SiPM from Data (4)

	Parameters			Note.
N_{fire}^{LO}	$\epsilon * N_{LY}$	Light yield of SiPM	(0.0055±0.0014)*(33750±3750)	Fit
	N_{pix}	Num. of pixel of SiPM	18980	Fixed, from manual
N_{fire}^{NLO}	α	average charge contribution of one rest photon	0.00393 ± 0.0799	Fit
	N_{pix}	Num. of pixel of SiPM		Fixed, from manual
	$\epsilon * N_{LY}$	Light yield of SiPM		Fixed, from LO fit
$N_{fire}^{NLO'}$	β	charge contribution of one photon decreases as the number of photons on a pixel increases	**172.7644 ± 1028.5520**	Fit **Why large uncertainty?**
	$\epsilon * N_{LY}$	Light yield of SiPM	**(0.0060±0.0016)*(**33750±3750)	Fit
	N_{pix}	Num. of pixel of SiPM		Fixed, from manual
	α	average charge contribution of one rest photon		Fixed, from NLO fit

- We will investigate fitting of $N_{fire}^{NLO'}$.
- We could already implement SiPM behavior in MC with N_{fire}^{NLO} fitting results.

Summary

- We try to implement SiPM behavior into MC to have better agreement. The first step, obtain the parameters of SiPM description, is done. We will see the outcome of MC with it in the near future.