Get ToT-photon number distribution of PMT using parameters from MCMC fitting

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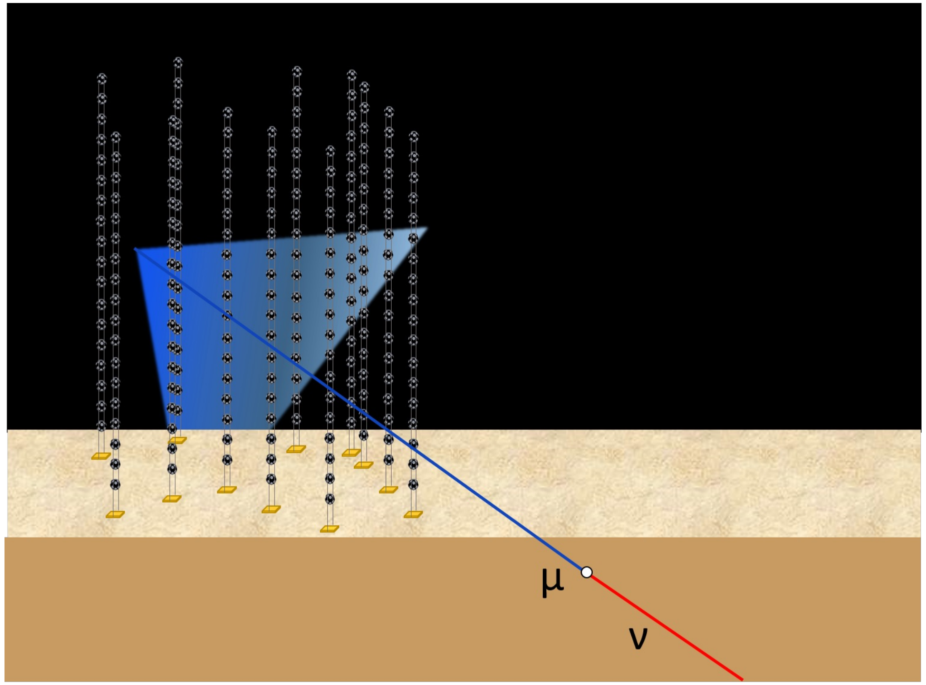
Background

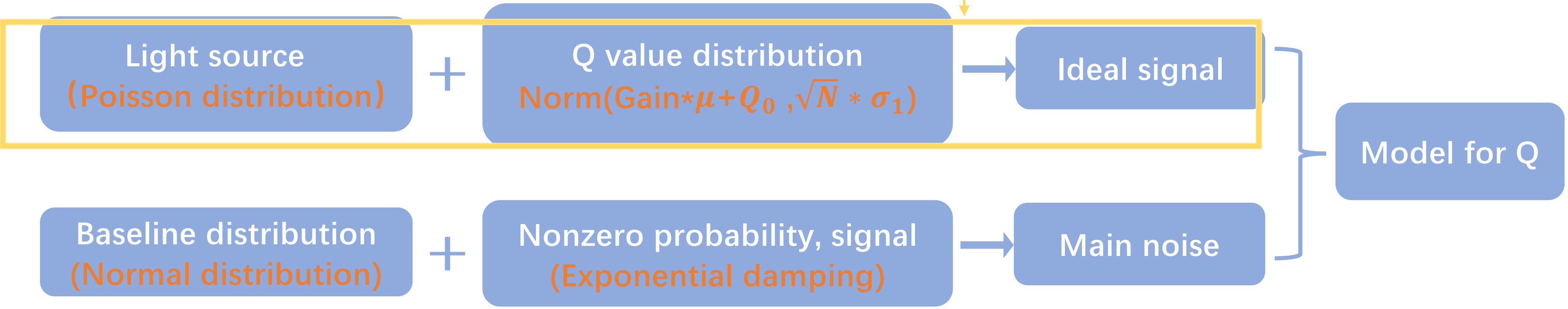
- Get Cherenkov light from secondary muon
- Need extremely sensitive light detectors(PMTs)
- Distinguish the number of photonelectron from limited information(ToT)



Q model of PMT(Photomultiplier Tubes)

- PMTs can distinguish single photon signal and be used for **Weak Light Signals**
- Integral for voltage-time signal and get **Q(quantity of electric charge) distribution**
- $\boldsymbol{Q} \propto \boldsymbol{\mu}$,ideally （μ is the mean number of photonelectrons collected by PMT）

$$S_{\mathrm{real}}(x) \approx \{(1-w) * Norm(Q_0, \sigma_0) + x\theta(x-Q_0) \times \exp[-\alpha(x-Q_0)]\}e^{-\mu}$$
$$+Possion(\mu) \times Norm(Q_0 + Q_{sh} + nQ_1, \sigma_1\sqrt{n})$$



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Light source
(Poisson distribution)

+

Q value distribution
Norm(Gain$*\mu+Q_0$,$\sqrt{N} * \sigma_1$)

→ Ideal signal

Baseline distribution
(Normal distribution)

+

Nonzero probability, signal
(Exponential damping)

→ Main noise

Model for Q

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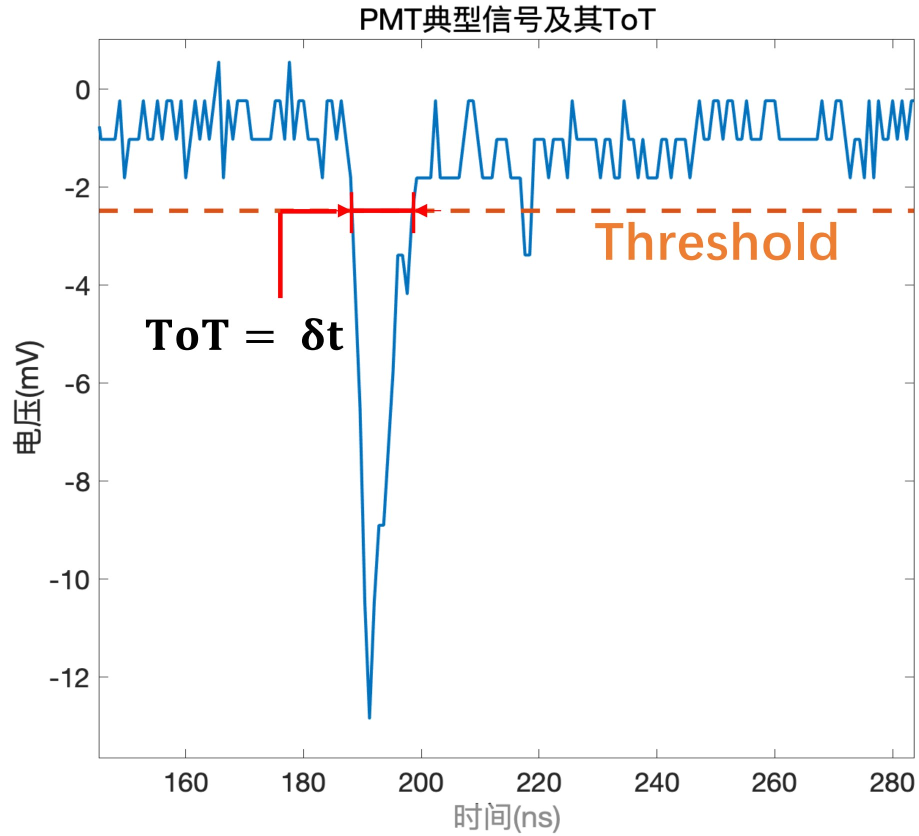
Light source (Poisson distribution) + Q value distribution Norm(Gain$*\mu+Q_0$,$\sqrt{N}*\sigma_1$) → Ideal signal

Baseline distribution (Normal distribution) + Nonzero probability, signal (Exponential damping) → Main noise

Ideal signal + Main noise → Model for Q

ToT of PMTs

- ToT is Time over threshold
- Use statistical information of multi-signal (1e5 groups)



ToT of PMTs

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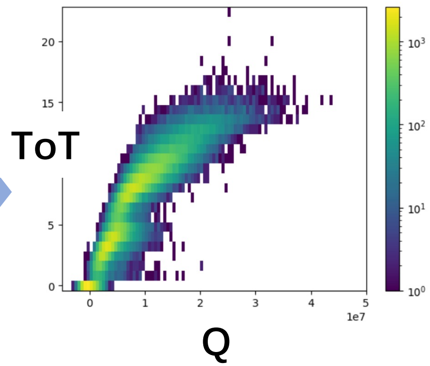
ToT

Statistical relationship

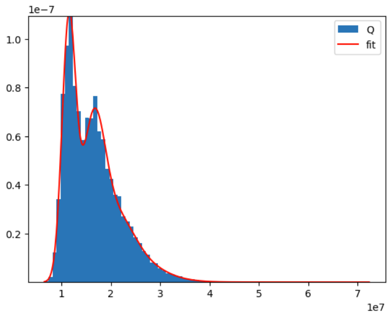
with Q value

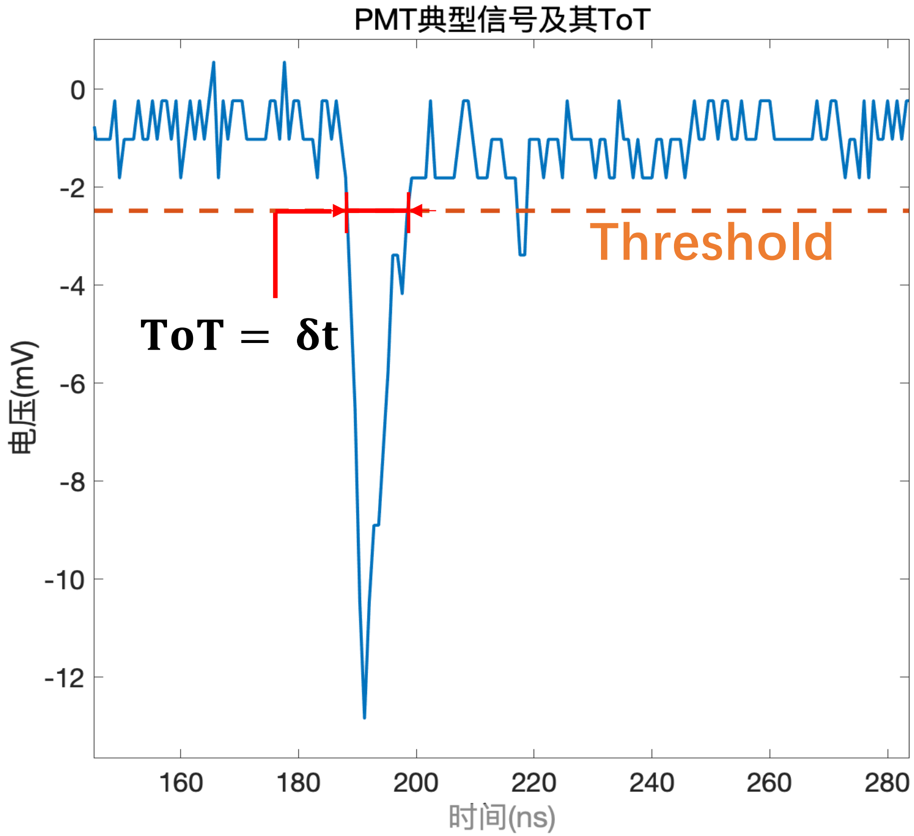


Q model

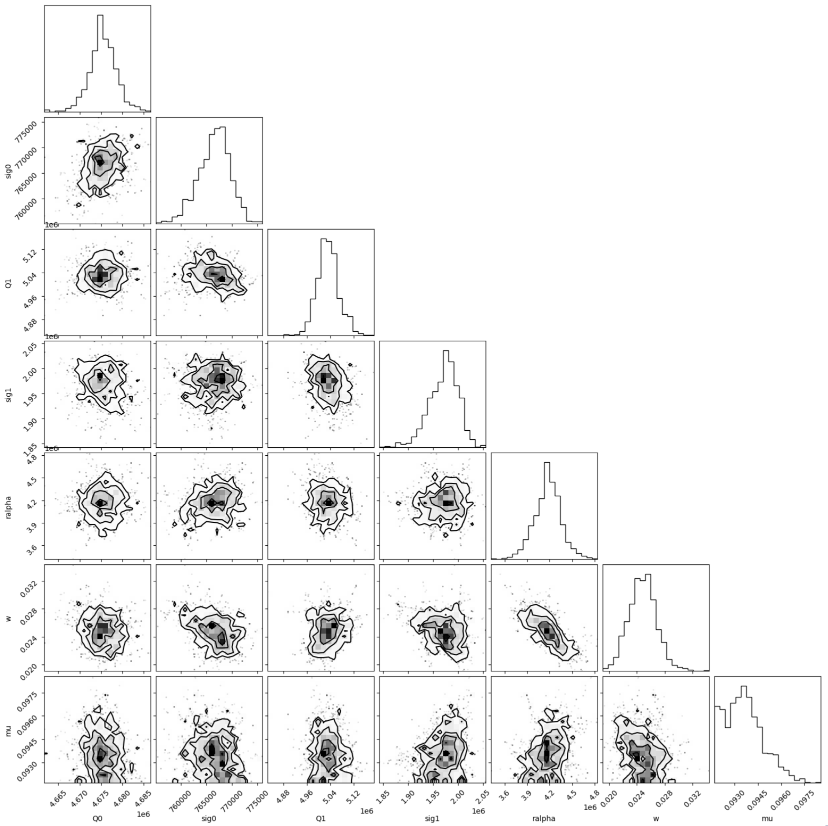
Fitting 8 parameters

with Q value

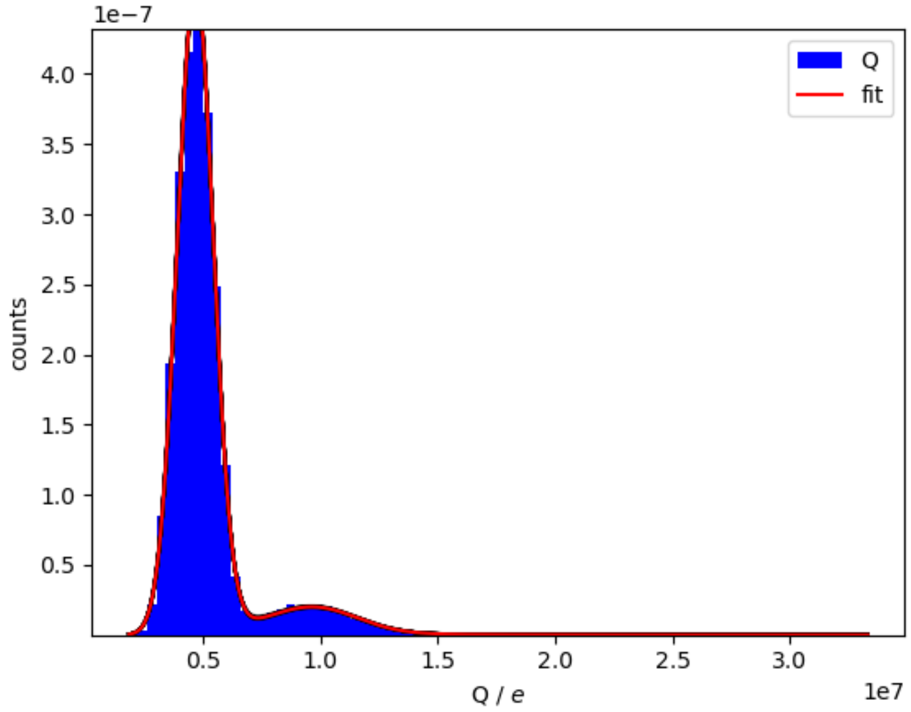




Fitting result with MCMC – single photonelectron

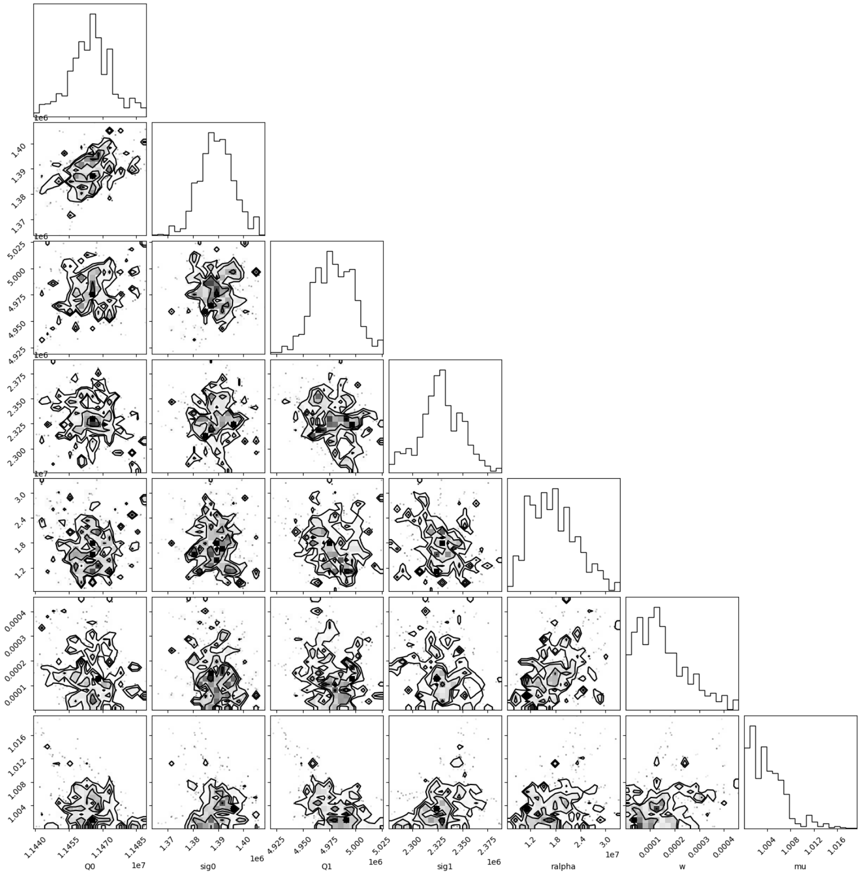


Count



Q

Fitting result with MCMC – Multi-photonelectron



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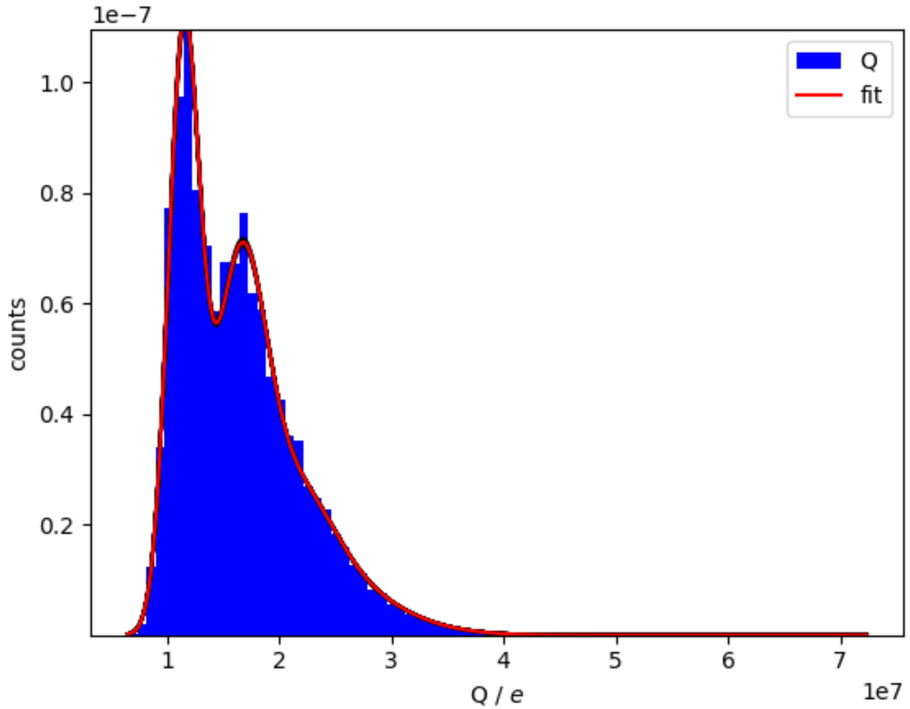
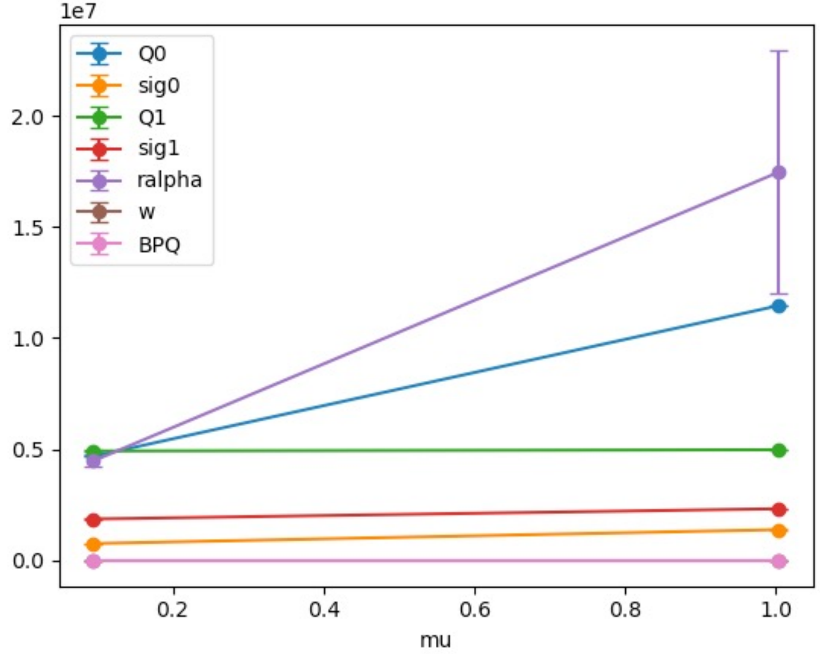
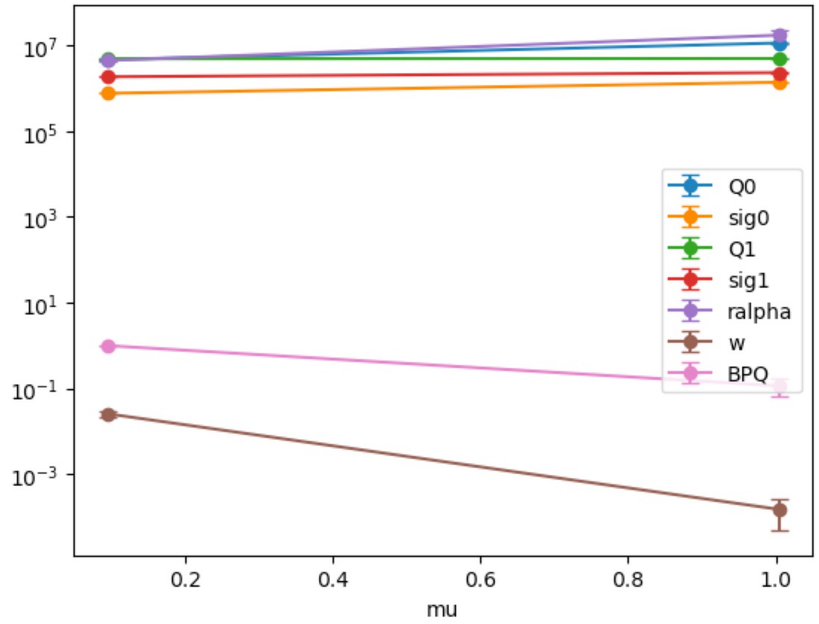


Q

Put fitting result of two different μ

$$P(Q) \approx \{(1-w) * Norm(Q, Q_0, \sigma_0) + x\theta(x-Q_0) \times \exp[-\alpha(x-Q_0)]\} e^{-n}$$
$$+Possion(Q, n) \times Norm(Q, Q_0 + Q_{sh} + nQ_1, \sigma_1\sqrt{n})$$





Put fitting result into probability distribution

$$P(Q) \approx \{(1-w) * Norm(Q, Q_0, \sigma_0) + x\theta(x-Q_0)\times \exp[-\alpha(x-Q_0)]\}e^{-n}$$
$$+Possion(Q,n)\times Norm(Q, Q_0 + Q_{sh} + nQ_1, \sigma_1\sqrt{n})$$

- Get probability with different n (photonelectron number)