GlueX DIRC Calibration (III)

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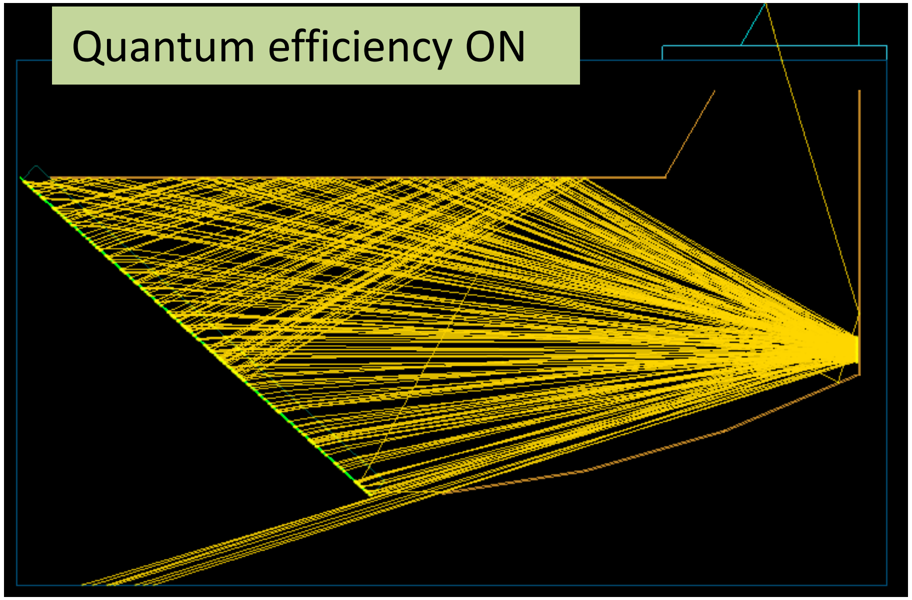
Outline

- Introduction
- Designed a fitting function
- Developed two methods to successfully determine t_0 and δ_{t_0} with good precision of <100ps per pixel
- Time delay between ports removes t_0 ambiguity.
- Conclusion/ Outlook

Introduction

- The goal of the study is calculating the t_0, and δ_{t_0} for an LED-based calibration system.
- Include quantum efficiency
- Simulation study was performed using one dataset which has 1000 simulated samples with different MC random seeds, each sample was generated by firing 200k events with 100 photons per event



Introduction

$$\sigma_t(\text{GlueX DIRC time precision}) = \sqrt{\sigma_{\text{TTS}}^2 + \sigma_{\text{DAQ}}^2 + \sigma_{t_0}^2}$$

Where:

$$\sigma_{\text{TTS}}(\text{transit time spread}) = 120\text{ps}$$

$$\sigma_{\text{DAC}}(\text{Data Acquisition}) = \frac{1000}{\sqrt{12}} \approx 285\text{ps, where DAQ binning} = 1\text{ns}$$

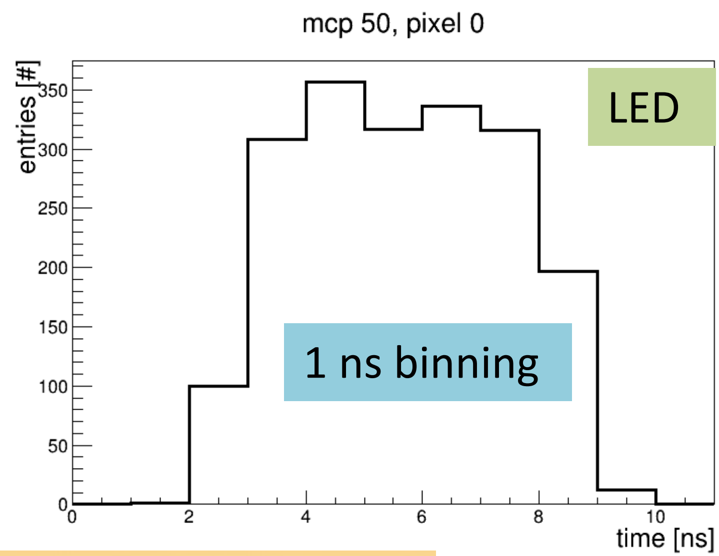
$$\sigma_t(\text{without } \sigma_{t0}\text{term}) = \sqrt{\sigma_{\text{TTS}}^2 + \sigma_{\text{DAQ}}^2} = \sqrt{120^2 + 285^2} \approx 310\text{ps}$$

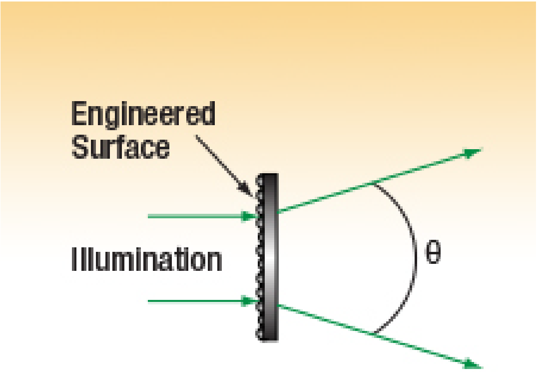
$$\sigma_{t_0} = ?\text{ ps}$$

$$\sigma_t = \sqrt{\sigma_{\text{TTS}}^2 + \sigma_{\text{DAQ}}^2 + \sigma_{t_0}^2} = \sqrt{120^2 + 285^2 + ?} \approx ?\text{ ps}$$

Introduction

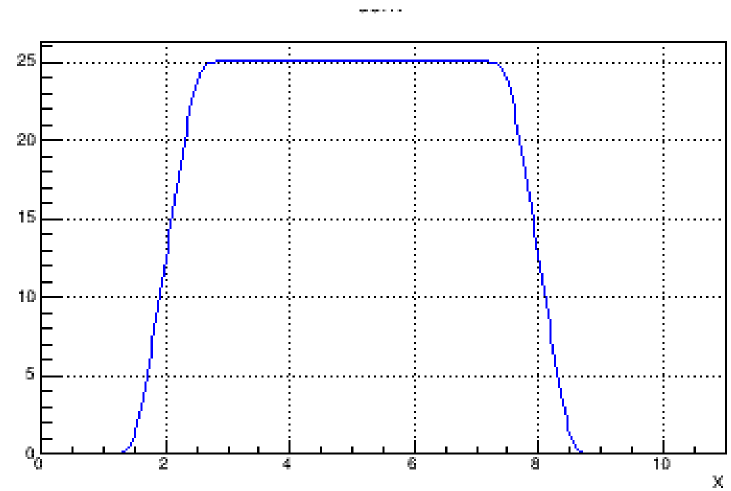
- Consider the PMT H12700 transit time spread contribution as a Gaussian distribution with sigma ~120 ps.
- Simulate LED time profile as suggested by Fernando
- Add dark noise as 1kHz per pixel
- Photon time distribution for an example channel, after implementation of quantum efficiency about 2000 photon are detected on this pixel from a total of 20M photons generated from the middle diffuser
- Simulations were carried out using a square diffuser with 50° Opening Angle



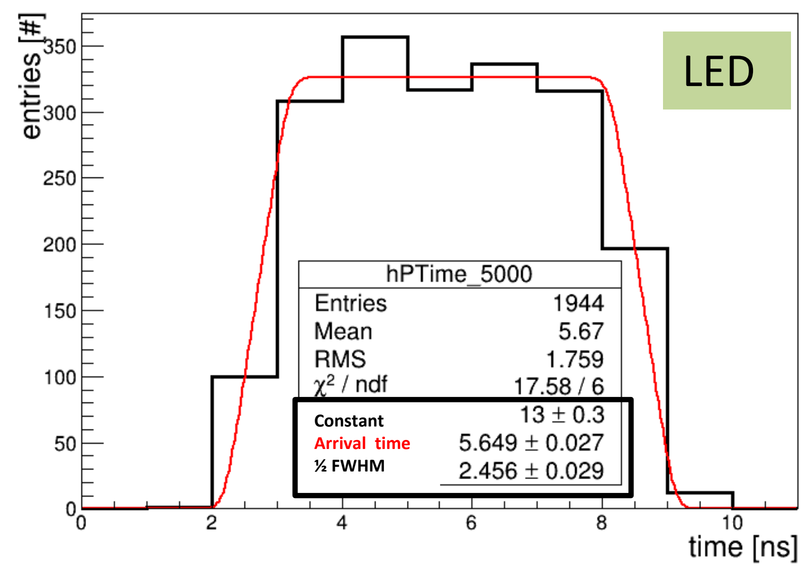


Designed Fitting Function

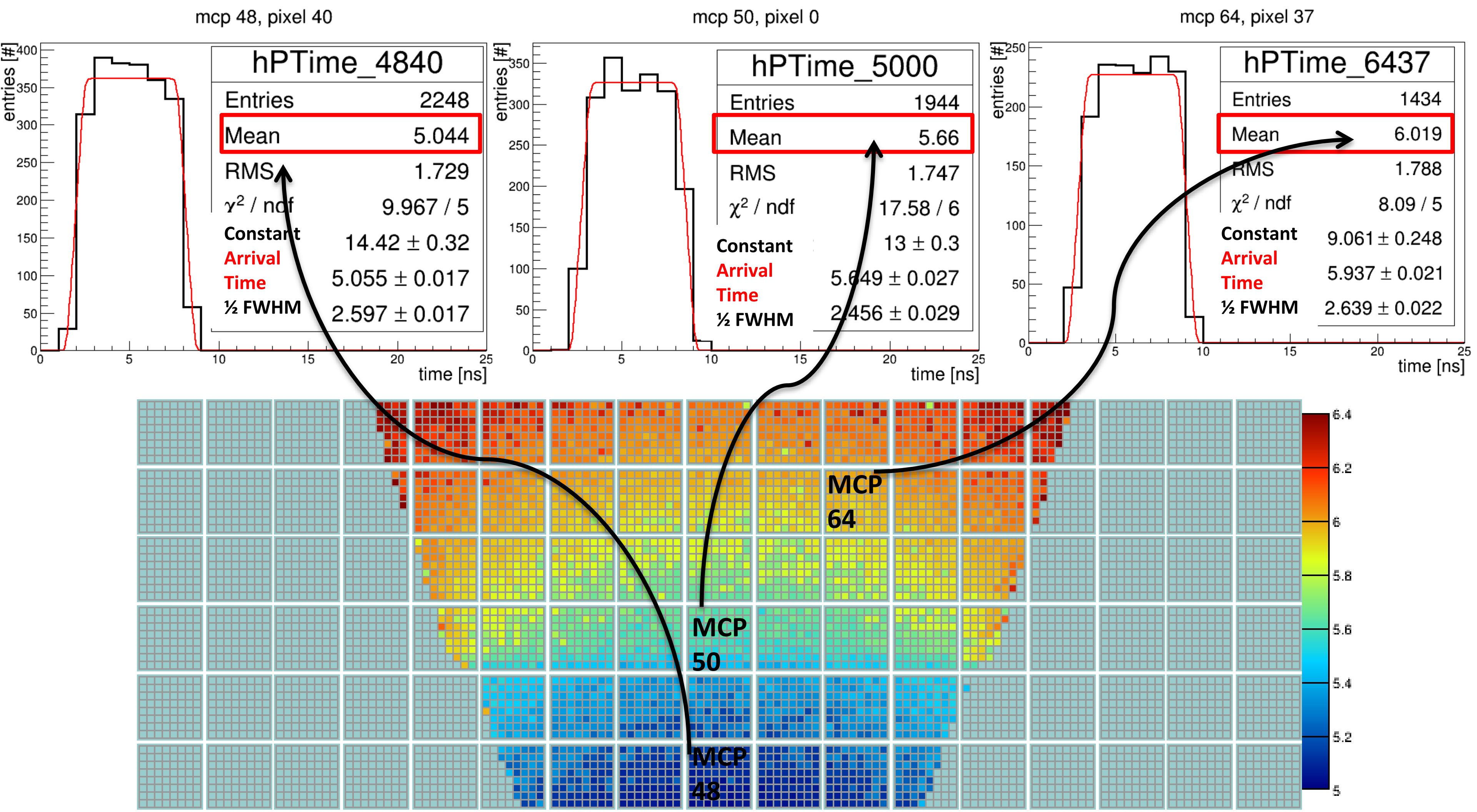
- Designing fitting function as a convolution of two functions: the PMT gauss smearing with sigma ~120 ps and the time profile of the LED



- The fitting function used for extracting the LED t_0 and δ_{t_0}.

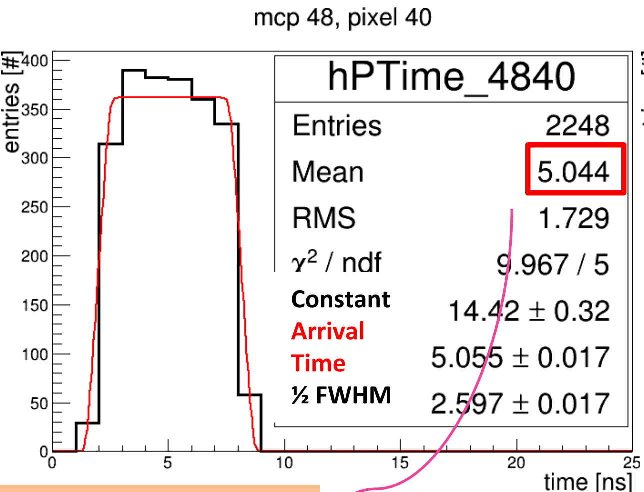


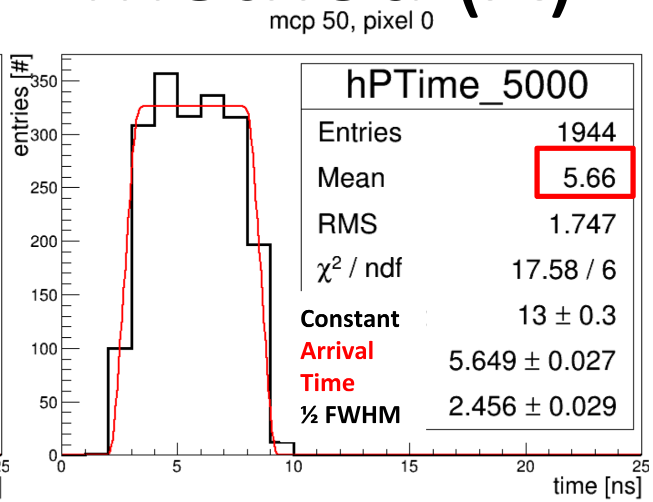
Photon Time Distribution Pixel by Pixel

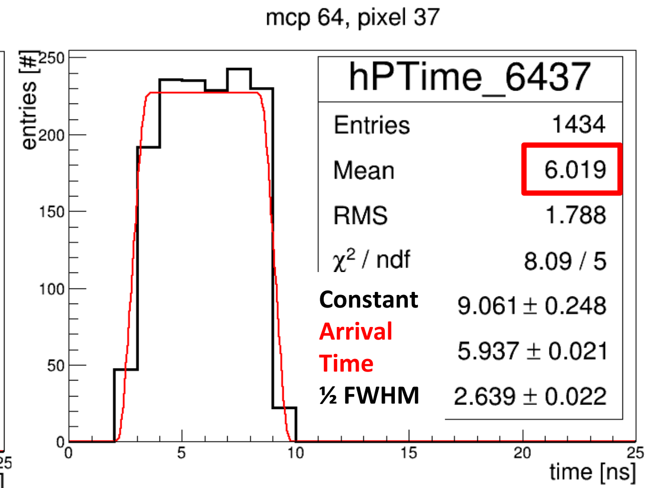


Photon time distribution pixel by pixel using one sample

Photon Time Distribution Pixel by Pixel Method (A)

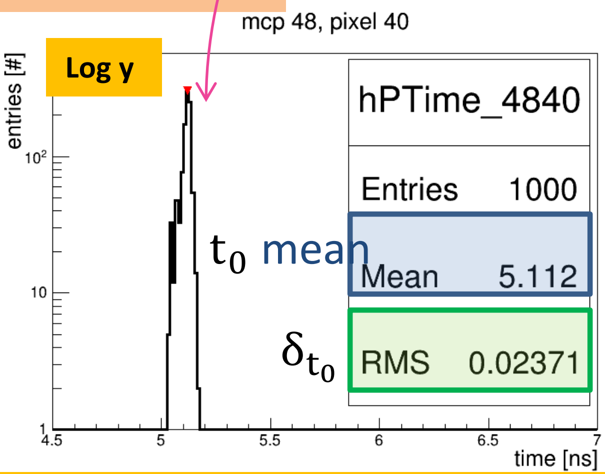


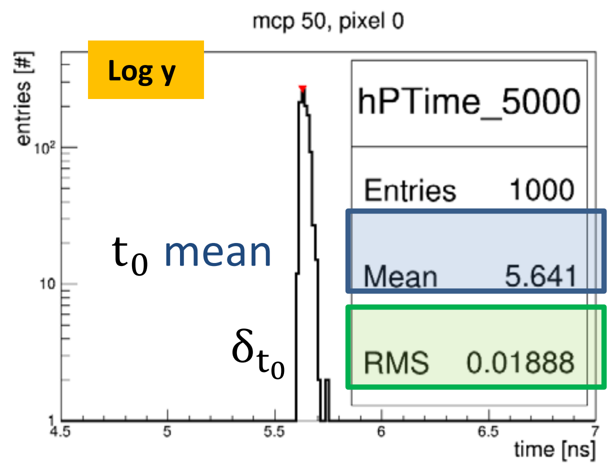


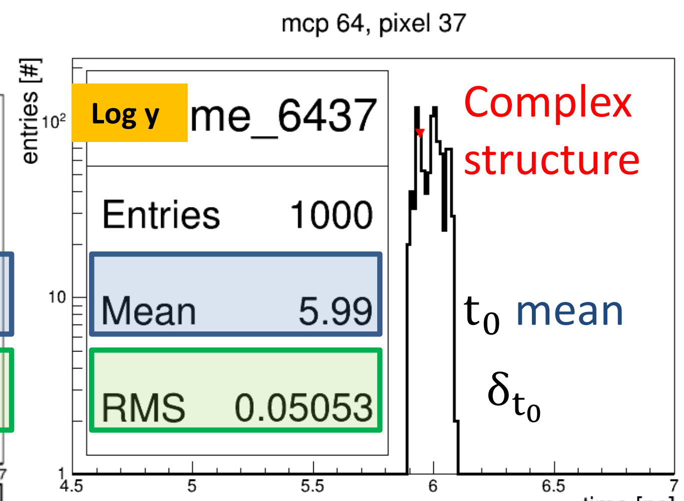


" fill with the mean of the histogram"

Photon time distribution pixel by pixel using one sample

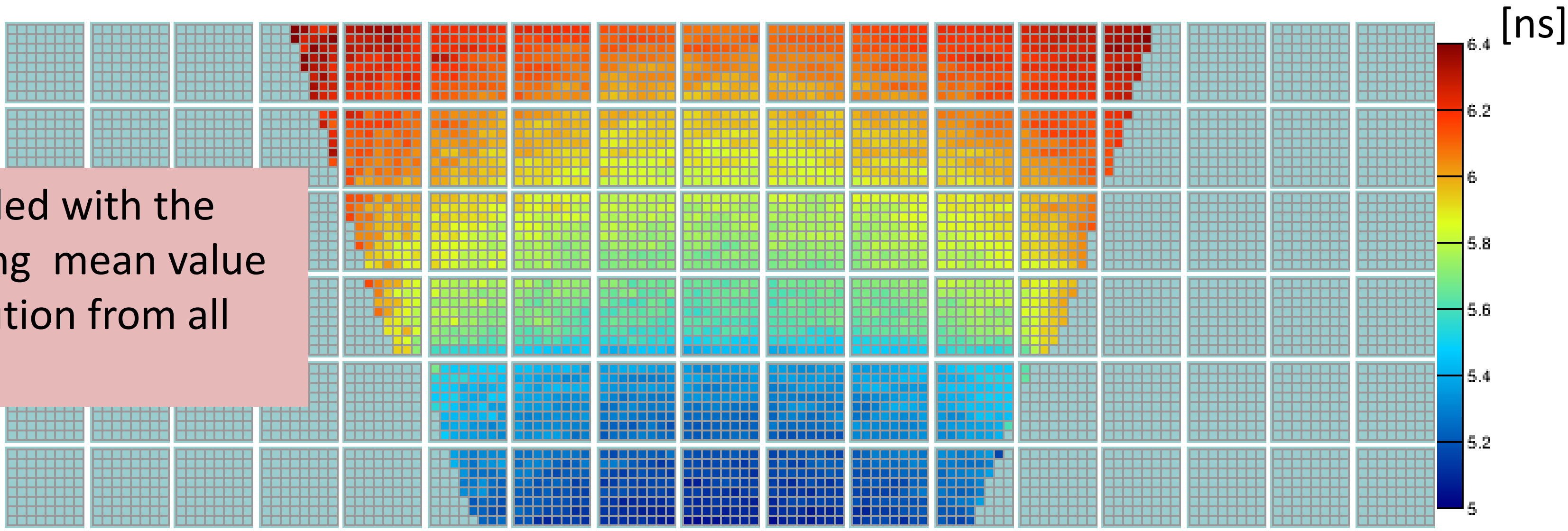




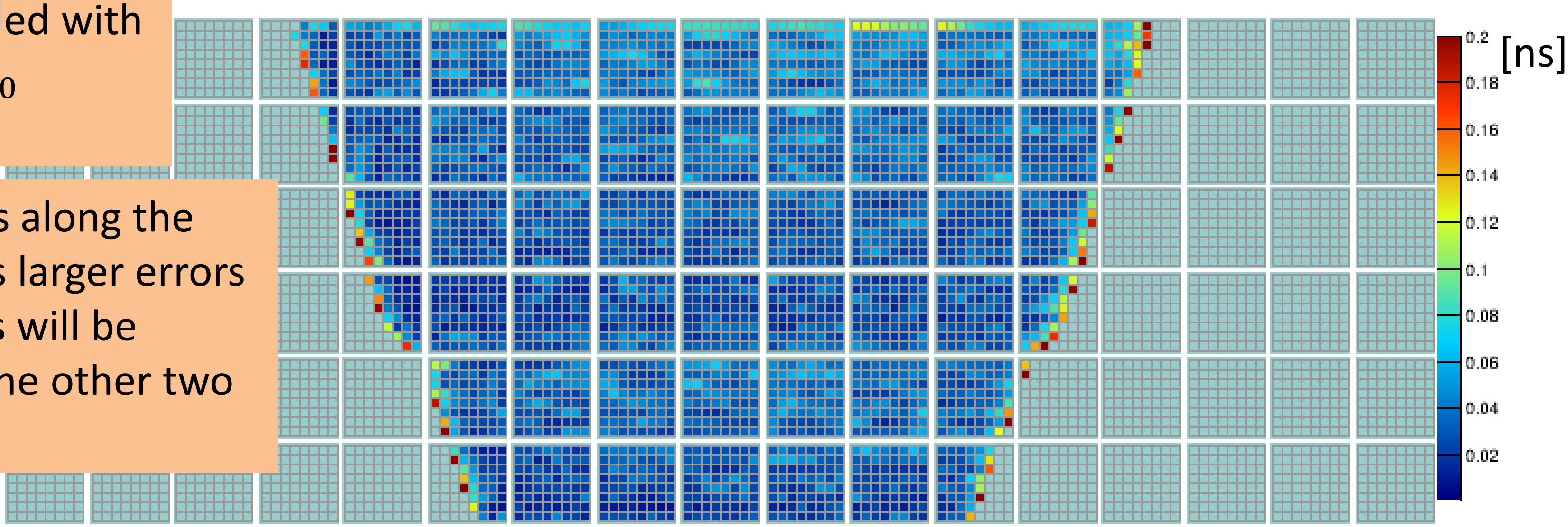


Corresponding t_0 distribution pixel by pixel using all samples

One Port t_0 and δ_{t_0} Maps (Method A)



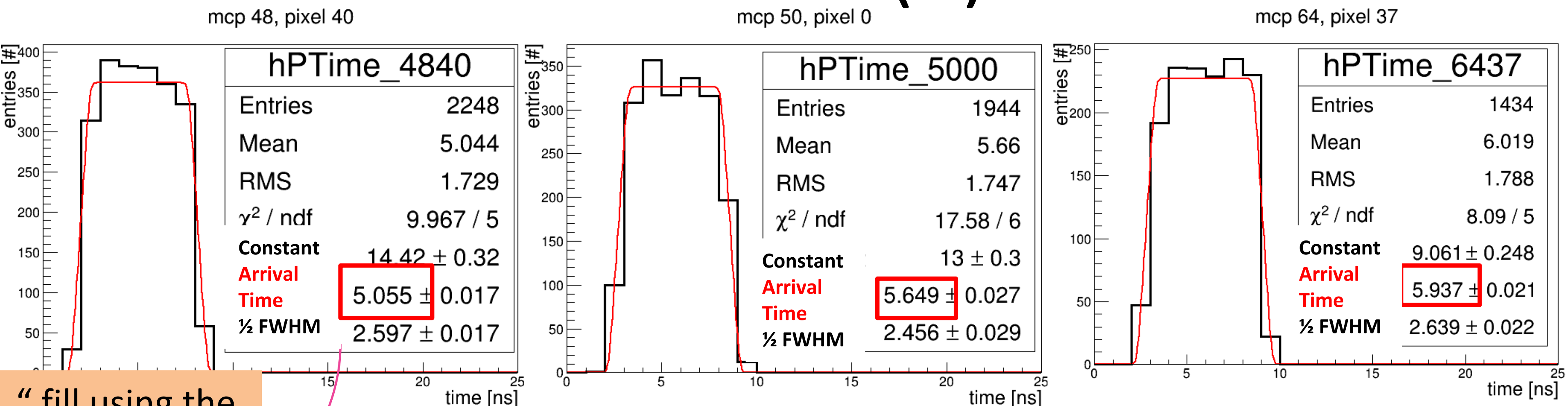
Each pixel filled with the corresponding mean value of t_0 distribution from all samples.



Each pixel filled with the RMS of t_0 distribution.

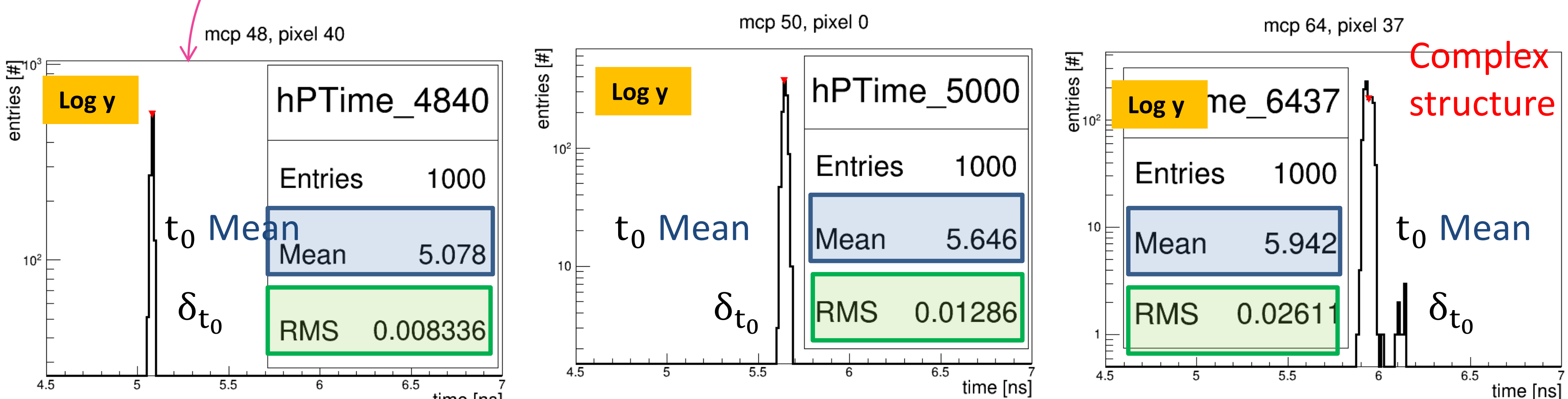
Low statistics along the edges causes larger errors - these pixels will be covered by the other two ports.

Photon Time Distribution Pixel by Pixel Method (B)



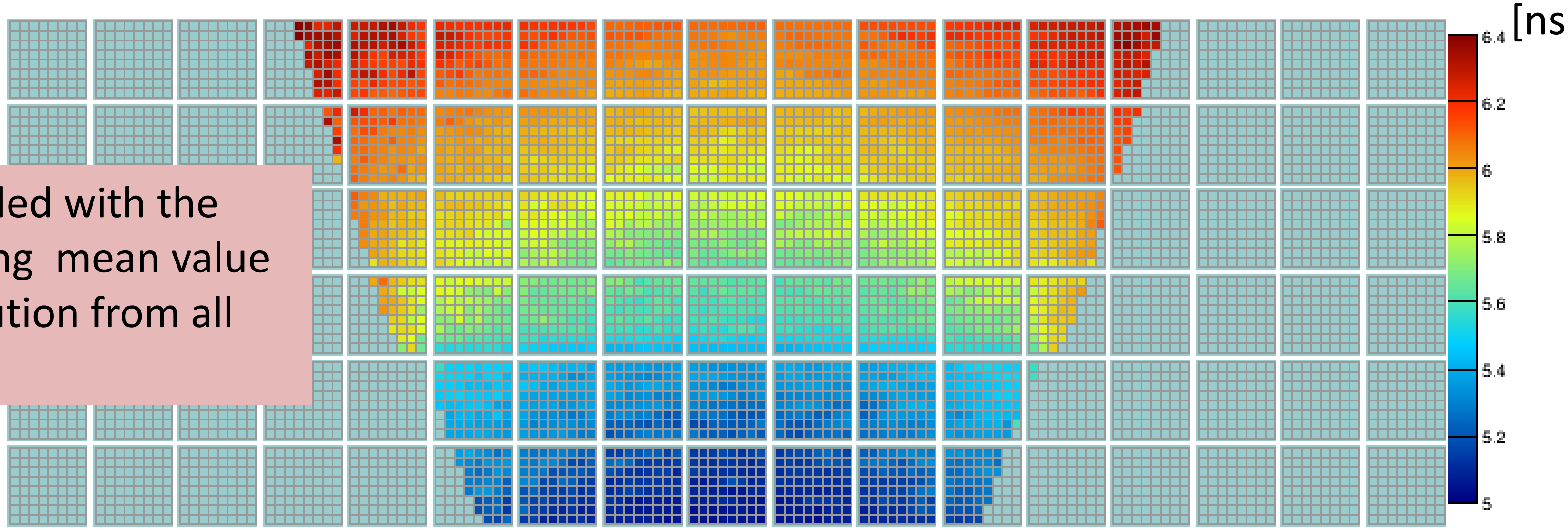
" fill using the designed fit function"

Photon time distribution pixel by pixel using one sample from dataset _20M

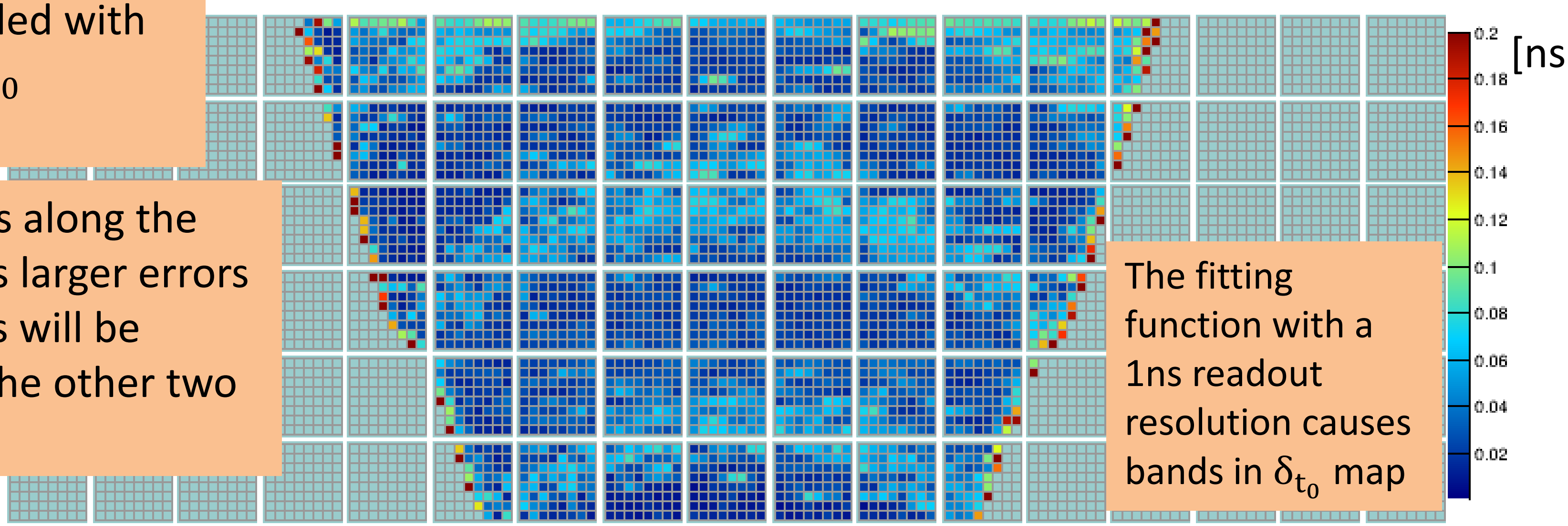


Corresponding t_0 distribution pixel by pixel using all samples

One Port t_0 and δ_{t_0} Maps (Method B)



Each pixel filled with the corresponding mean value of t_0 distribution from all samples.



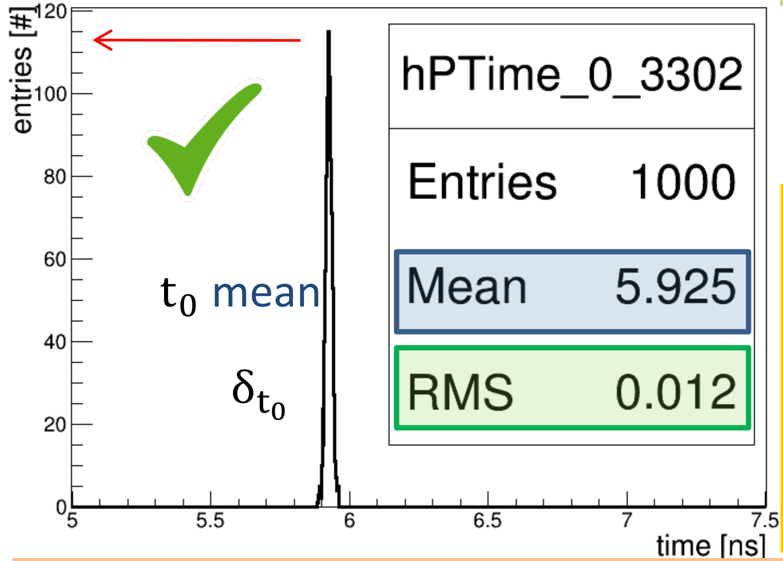
Each pixel filled with the RMS of t_0 distribution.

Low statistics along the edges causes larger errors - these pixels will be covered by the other two ports.

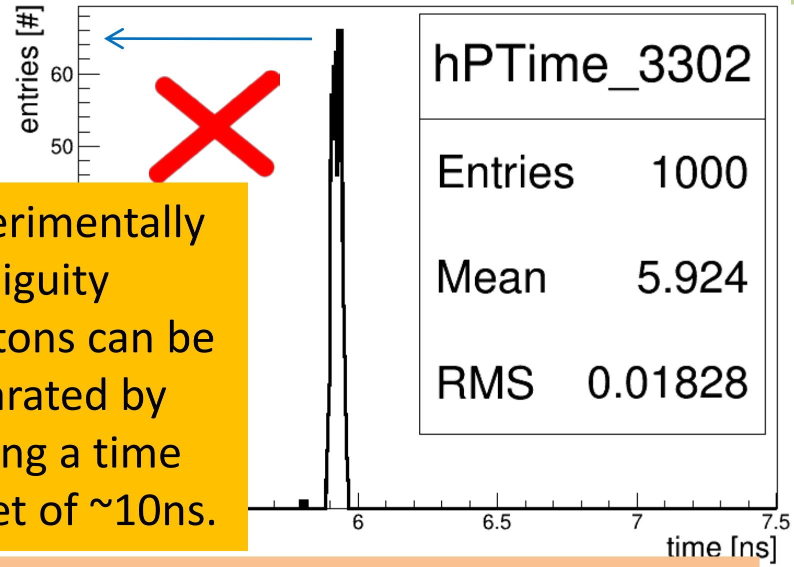
The fitting function with a 1ns readout resolution causes bands in δ_{t_0} map

Three Port t_0 Map calculations

Channel 3302 fired by left diffuser

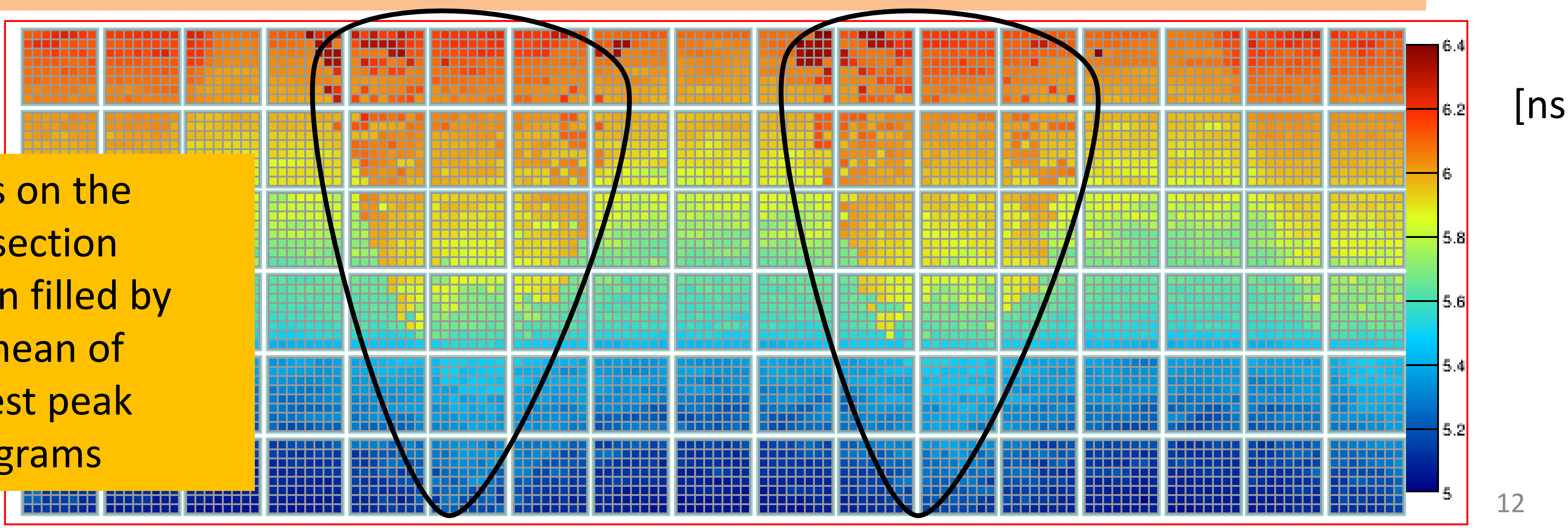


Channel 3302 fired by middle diffuser



Experimentally ambiguity photons can be separated by adding a time offset of ~10ns.

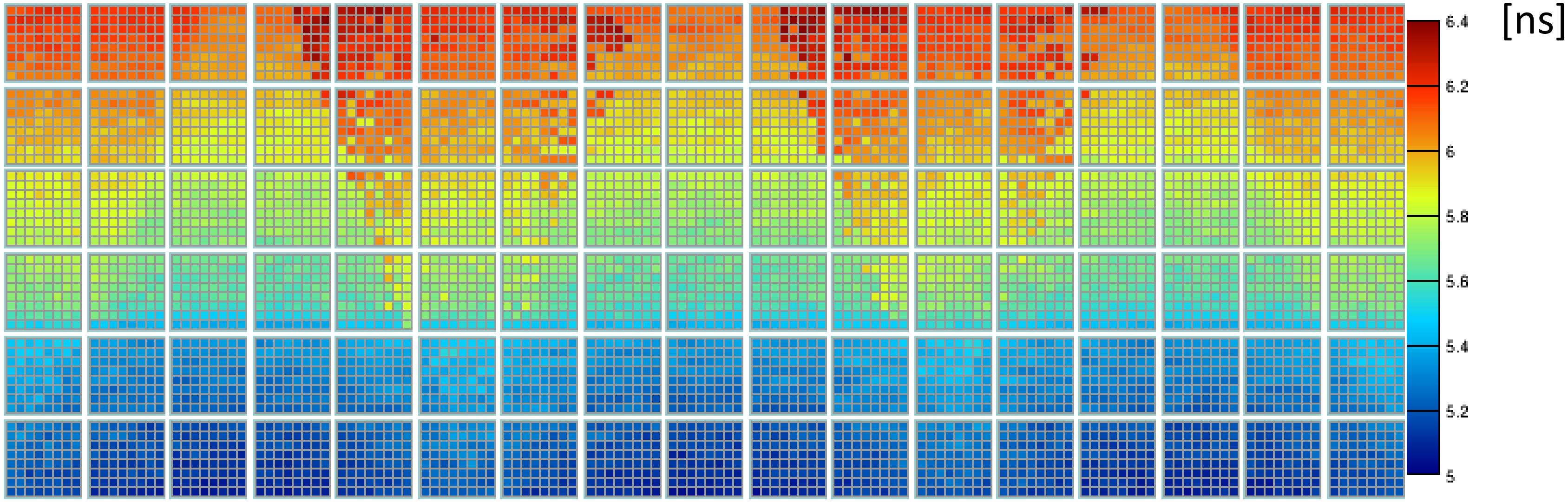
Certain channel fired by two optical diffusers sources



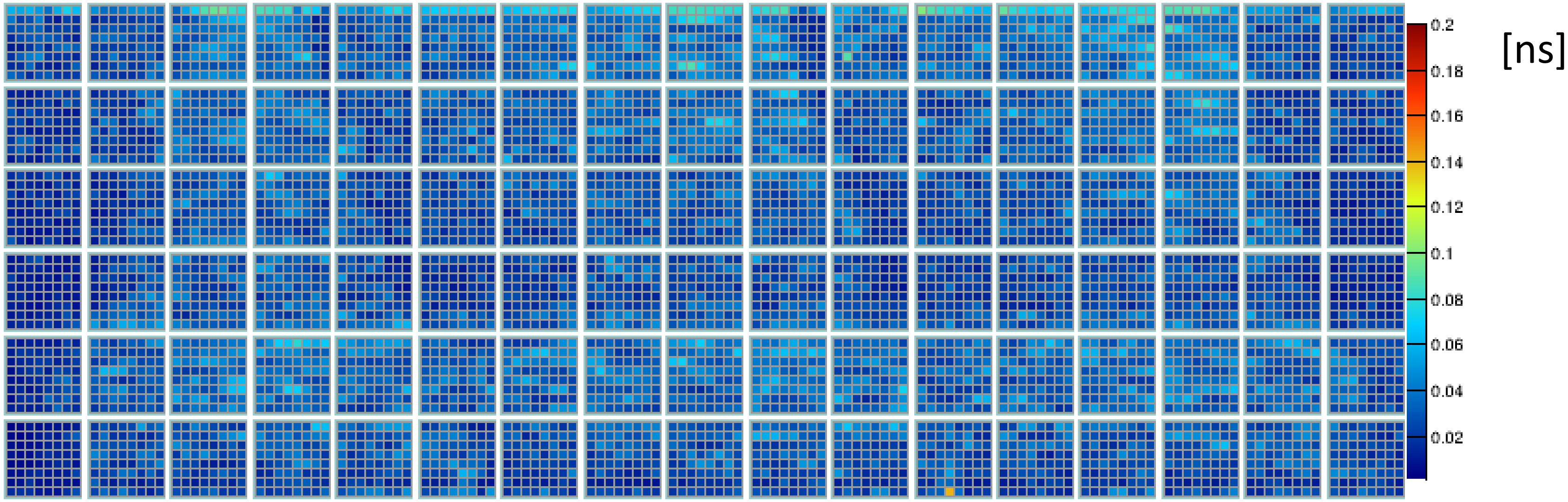
Pixels on the intersection region filled by the mean of highest peak histograms

Three Port t_0 and δ_{t_0} Maps (Method A)

t_0

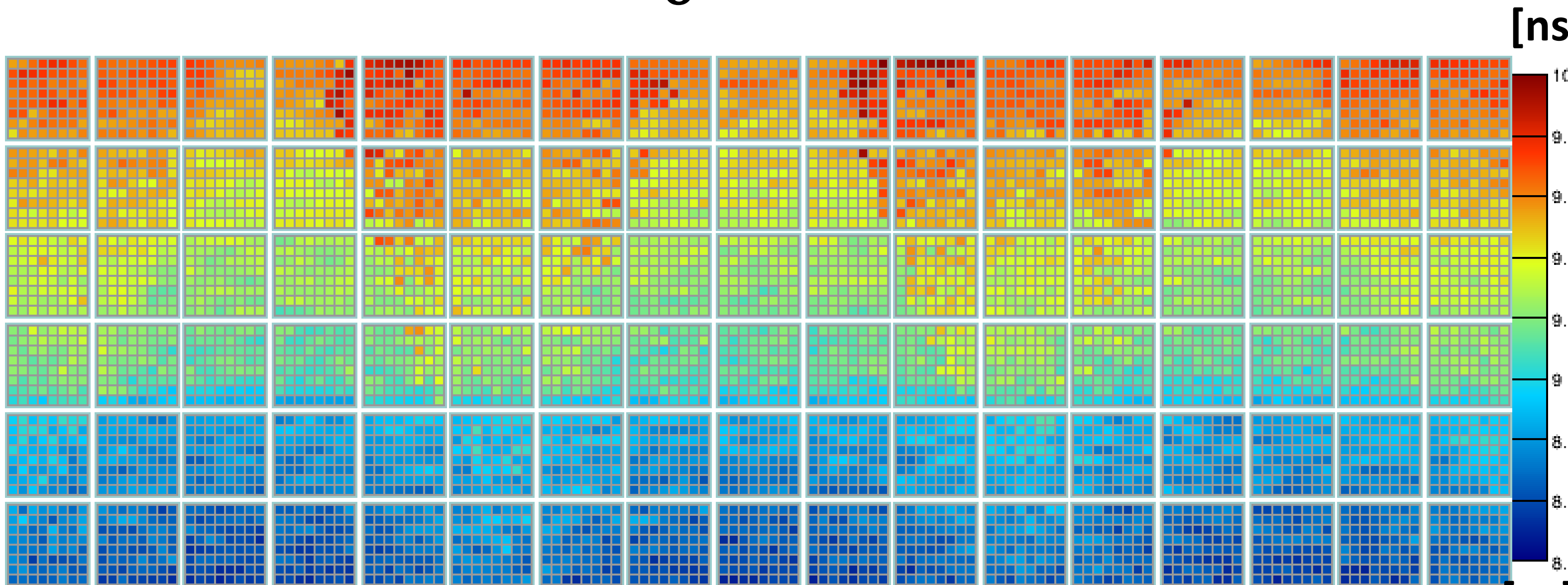


δ_{t_0}

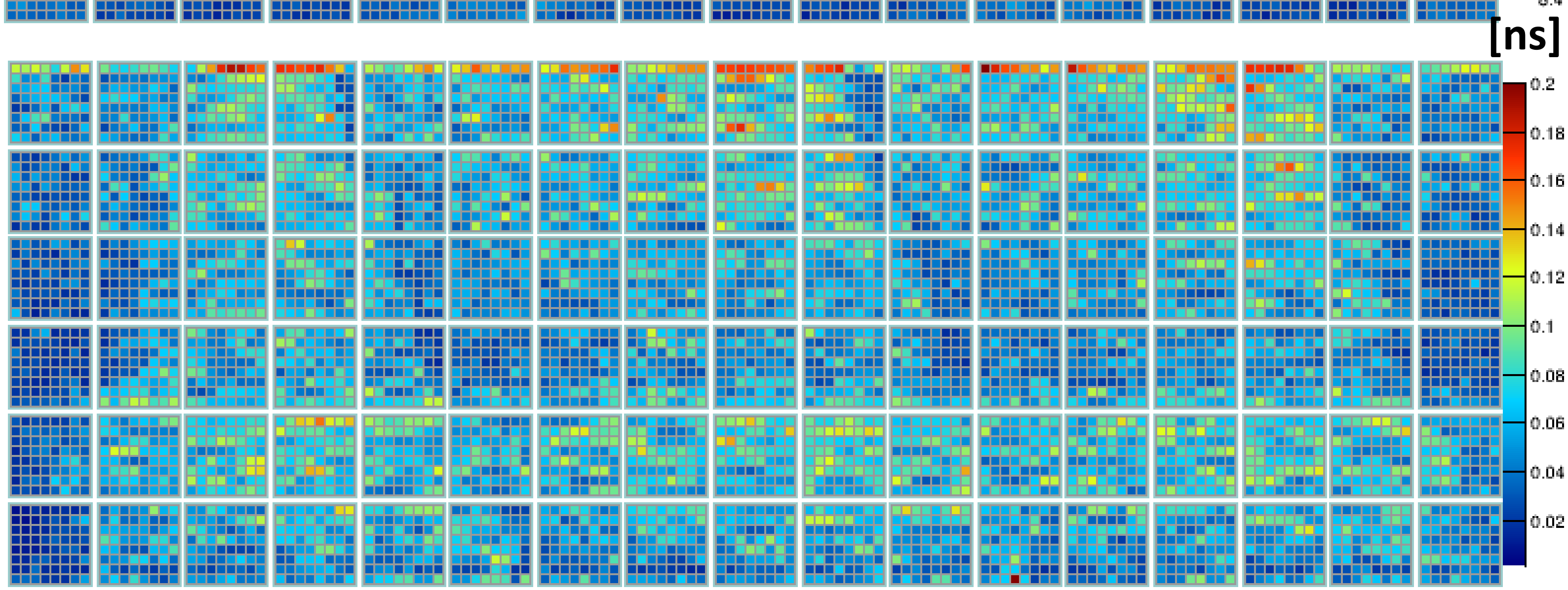


Three Port t_0 and δ_{t_0} Maps (Method A)

t_0



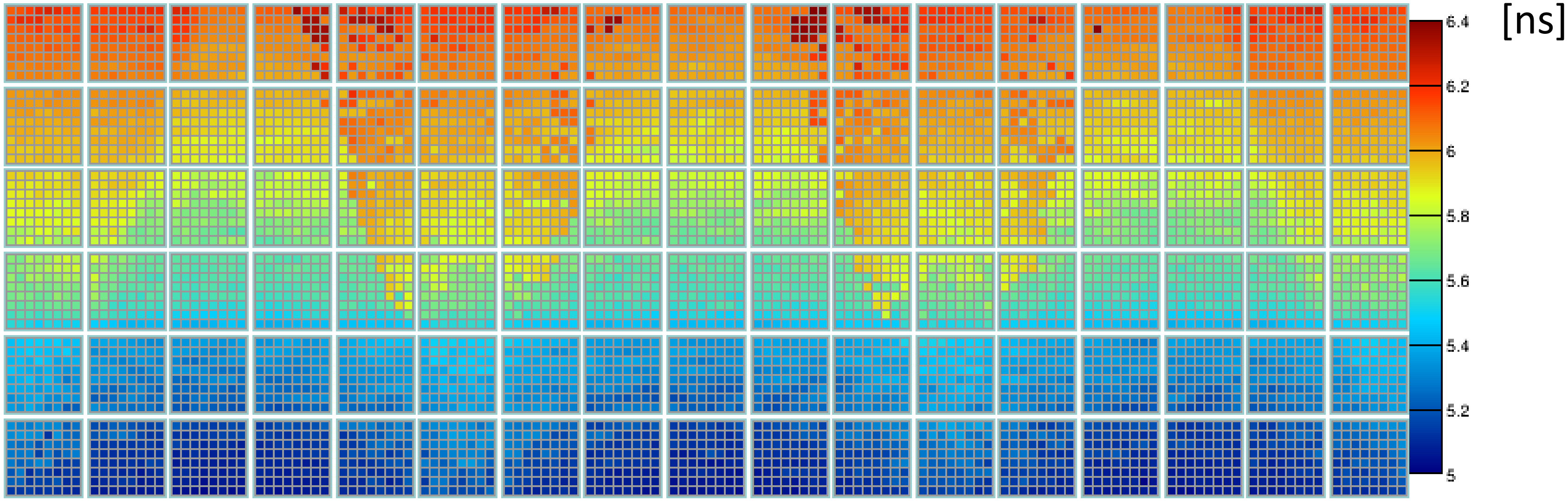
Relaxing the LED pulse characteristics by doubling the timing on the rise, fall times and width and adding additional timing jitter[20ps].



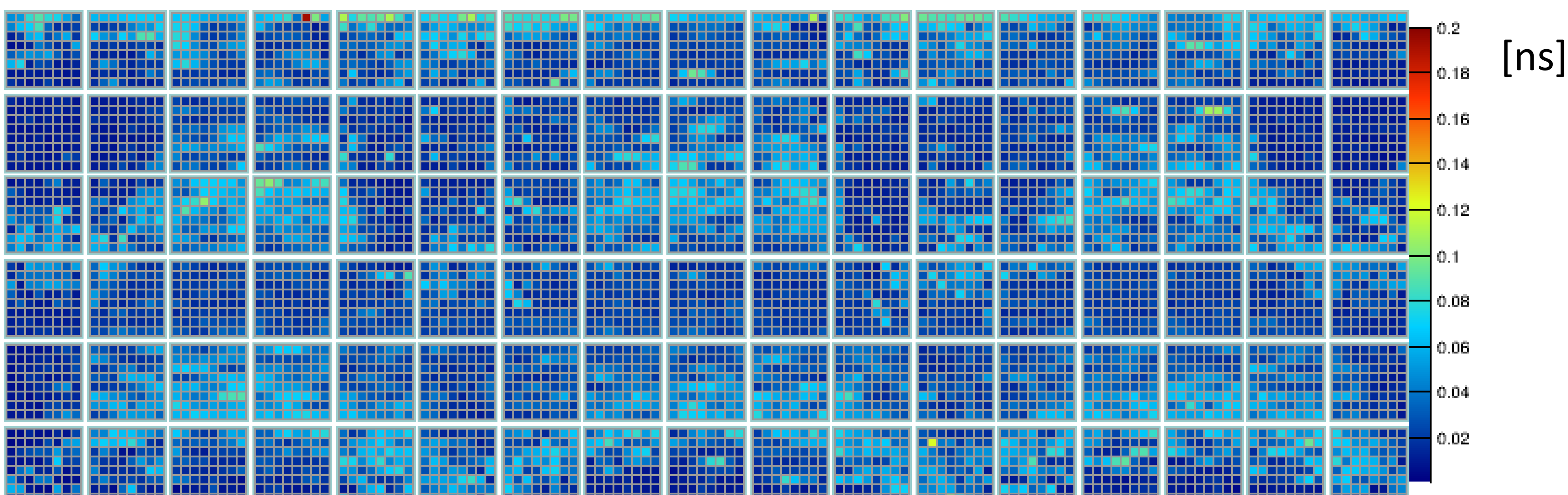
δ_{t_0}

Three Port t_0 and δ_{t_0} Maps (Method B)

t_0

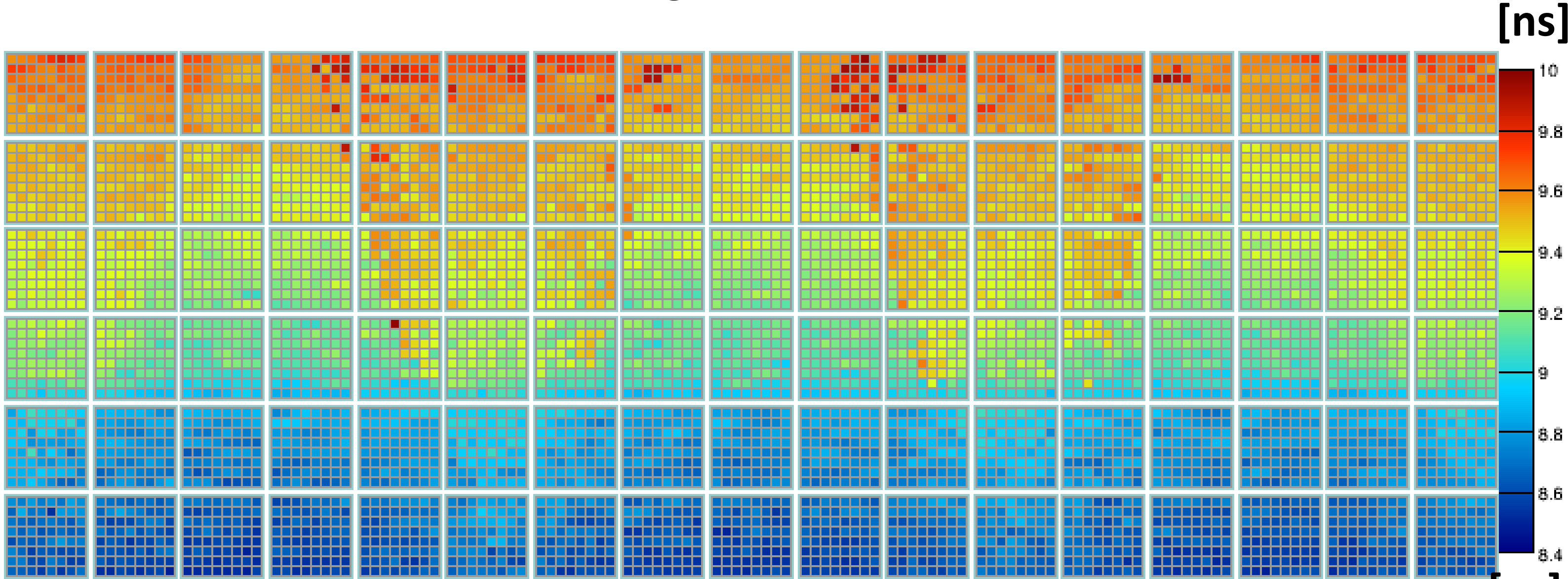


δ_{t_0}



Three Port t_0 and δ_{t_0} Maps (Method B)

t_0



Relaxing the LED pulse characteristics by doubling the timing on the rise, fall times and width and adding additional timing jitter[20ps].

δ_{t_0}

Conclusion/ Outlook

Simulation of LED-based calibration shows stable t_0 determination with an error of < 100ps

$$\sigma_t(\text{GlueX DIRC time precision}) = \sqrt{\sigma_{TTS}^2 + \sigma_{DAQ}^2 + \sigma_{t_0}^2}$$

Where:

$\sigma_{TTS}(\text{transit time spread}) = 120\text{ps}$

$\sigma_{DAC}(\text{Data Acquisition}) = \frac{1000}{\sqrt{12}} \approx 285\text{ps}$, where DAQ binning = 1ns

$\sigma_t(\text{without } \sigma_{t0} \text{term}) = \sqrt{120^2 + 285^2} \approx \boxed{310\text{ps}}$

$\sigma_{t_0} = 100 \text{ ps}$

$\sigma_t = \sqrt{120^2 + 285^2 + 100^2} \approx \boxed{325\text{ps}}$

Using an relaxed LED pulse timing characteristics

$\sigma_{t_0} = 200 \text{ ps}$

$\sigma_t = \sqrt{120^2 + 285^2 + 200^2} \approx \boxed{370\text{ps}}$

Thank You