TOP summary

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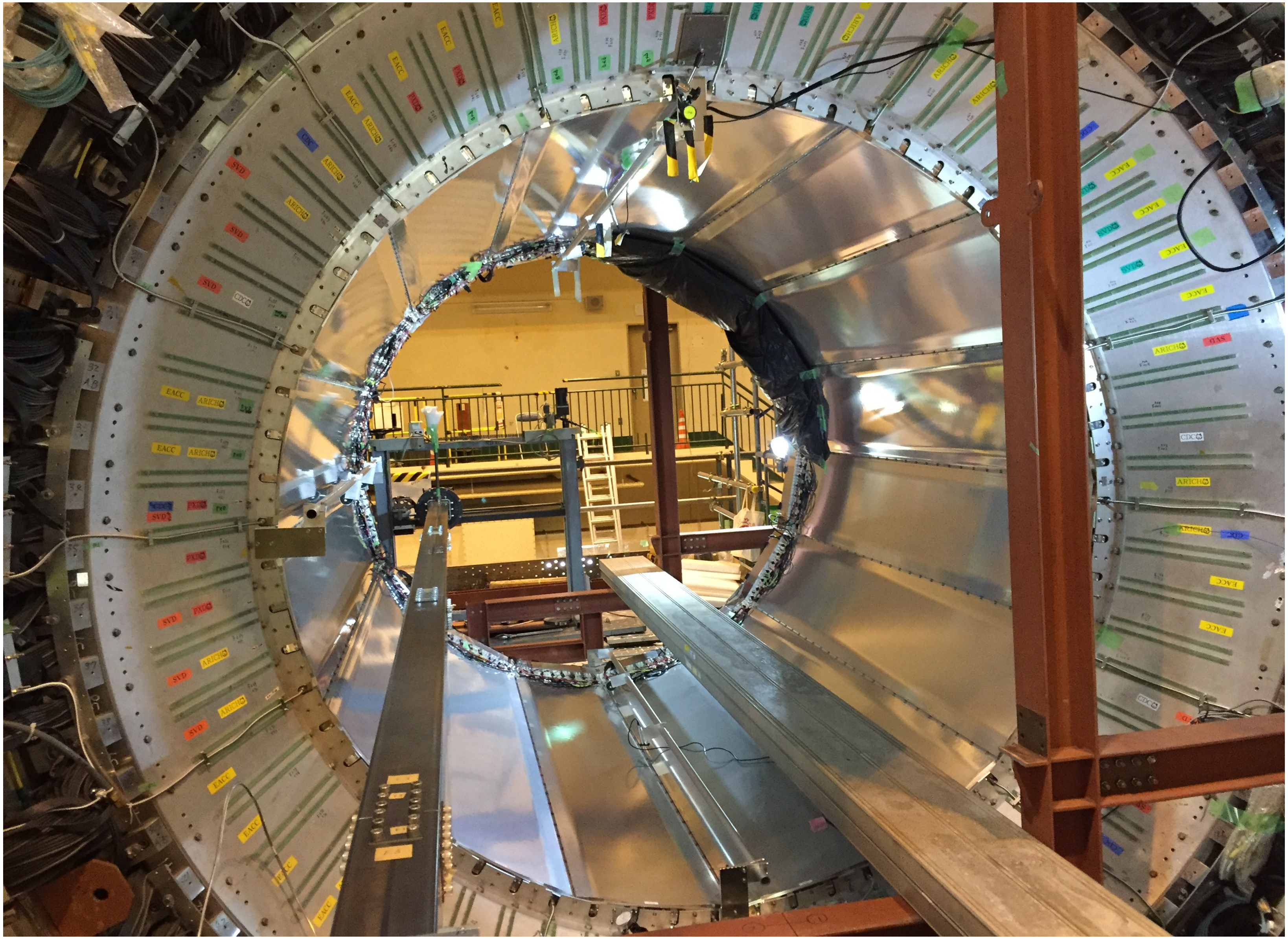
BelleII Italian meeting
Padova, May 31st, 2016

The TOP on BelleII

Good news first: the TOP installation is done

Four months-long effort by 20+ people shifting at KEK (~10 people constantly on the field)



Testing workflow

Pre-installation test

Run coordinator: B. Fulsom (PNNL)

Fuji staging area

→ First power-up
→ electronics and data fibers tests
→ light tightening
→ 24+ hrs of cosmics

Tsukuba Staging area

→ 20 hrs of cosmics
→ 4+ hrs of laser

In situ test

Run coordinator: U.T. (Torino)

→ **Detector commissioning**
  → Cabling test
  → 24+ hrs of laser
  → 3+ days Cosmic with custom scintillator trigger
→ laser system commissioning

Developments

→ FW upgrade tests
→ simultaneous readout
→ real-life operations

Commissioning status

Laser runs

→ Timing well understood
→ High rate

Cosmic rays

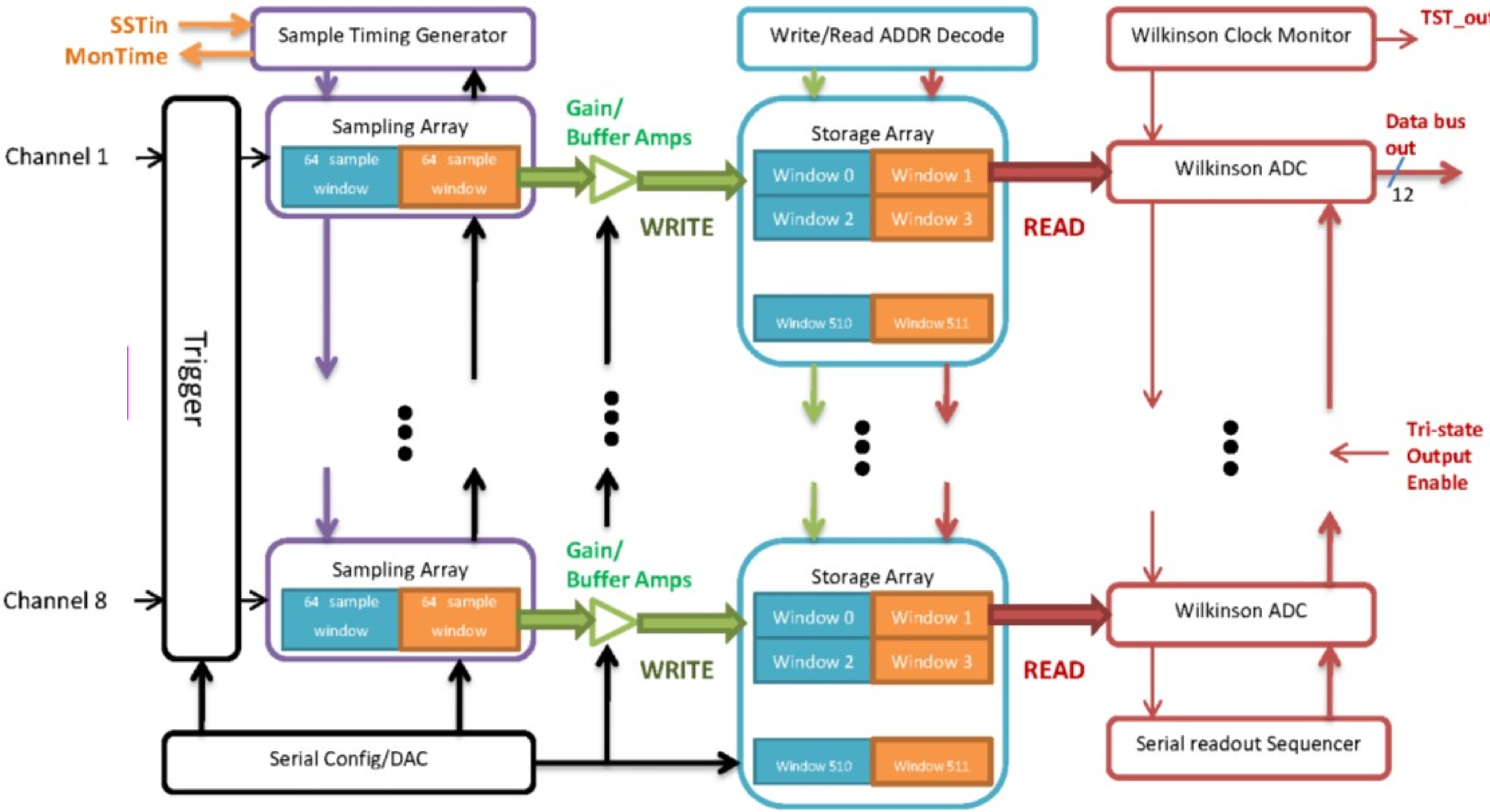
→ Very good illumination
→ miserable rate

Goals

Goals	
→ Mechanical integrity of all the modules → Cabling checks (HV, fibers, triggers...)	**Done / almost done**
→ Time calibration → Fast, online feature extraction → SW interlock	**Ongoing**
→ DAQ stability and reliability → Trigger capabilities → Event building	**On the critical path**

Many items: this talk will be Italy-biased...

TOP FEE: a scope on a chip



TOP readout modes

IRS3X is basically an 8-ch, miniaturized scope controlled by a FPGA

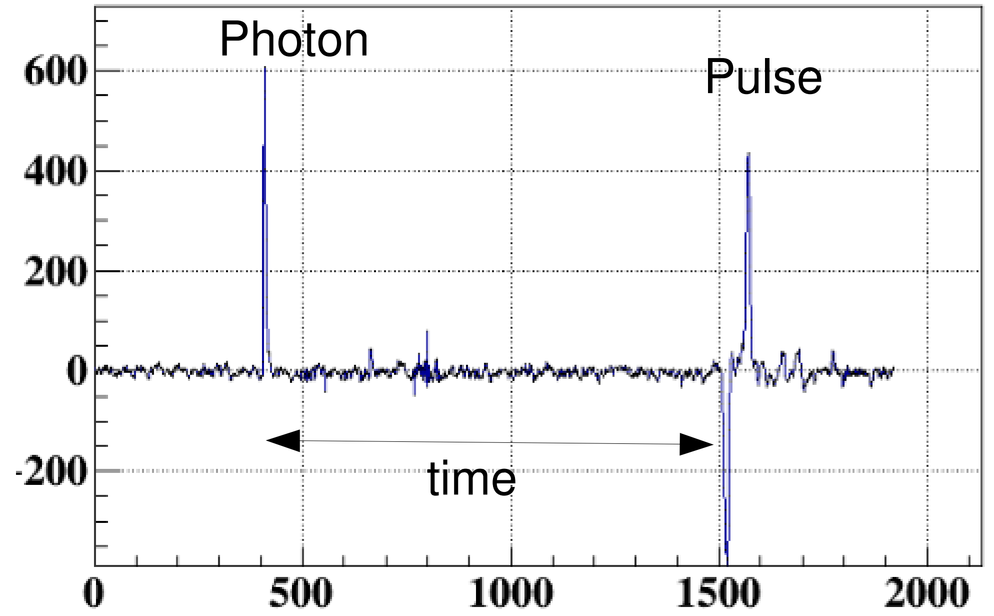
1) Full waveform mode: acquire a fixed number of samples after the trigger
→ For debugging. Insane data packet size

2) Feature-extraction mode: analyze the traces on the FPGA and same only the hit informations
→ target operation mode, still under development

How to make timing

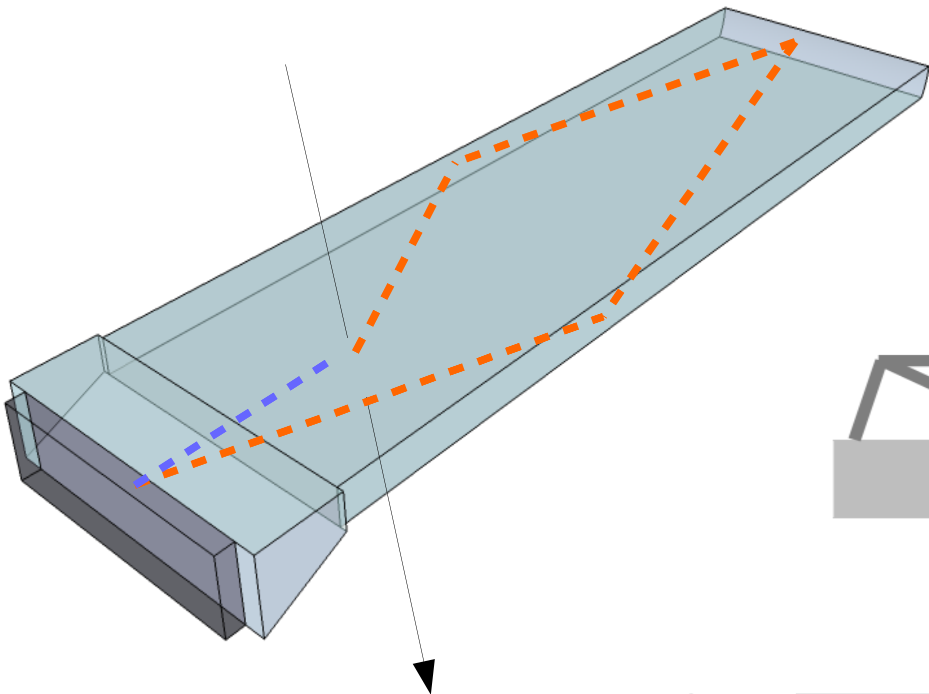
1) Final operation mode: RF clock

2) Commissioning:
→ When a trigger comes, inject a pulse on one asic channel
→ record both the PMT signal and the pulse
→ use the pulse timing as reference

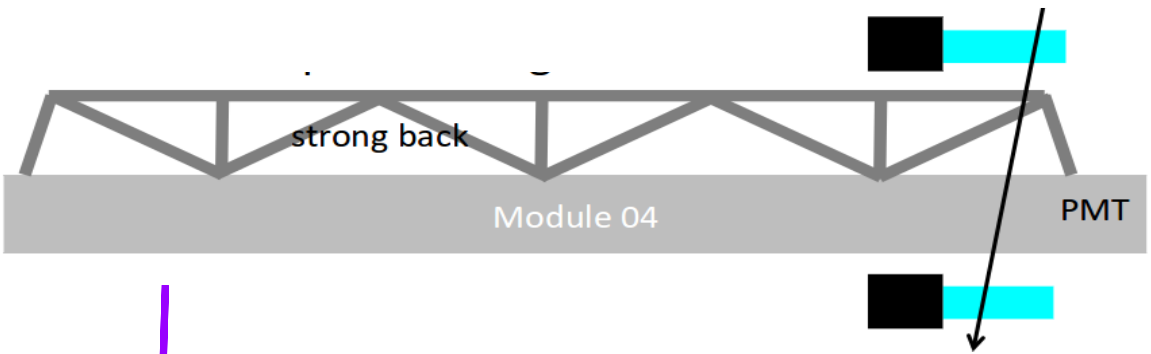


CRT commissioning

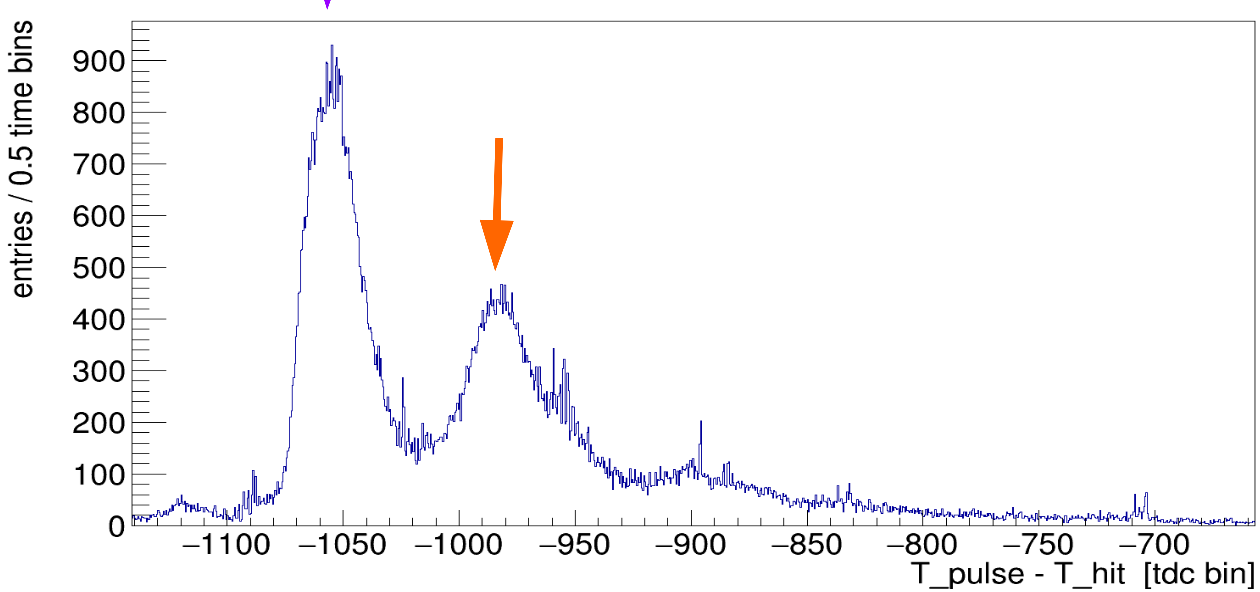
In the staging areas



Trigger provided by two Belle TOF scintillators
~ 30 x 20 cm



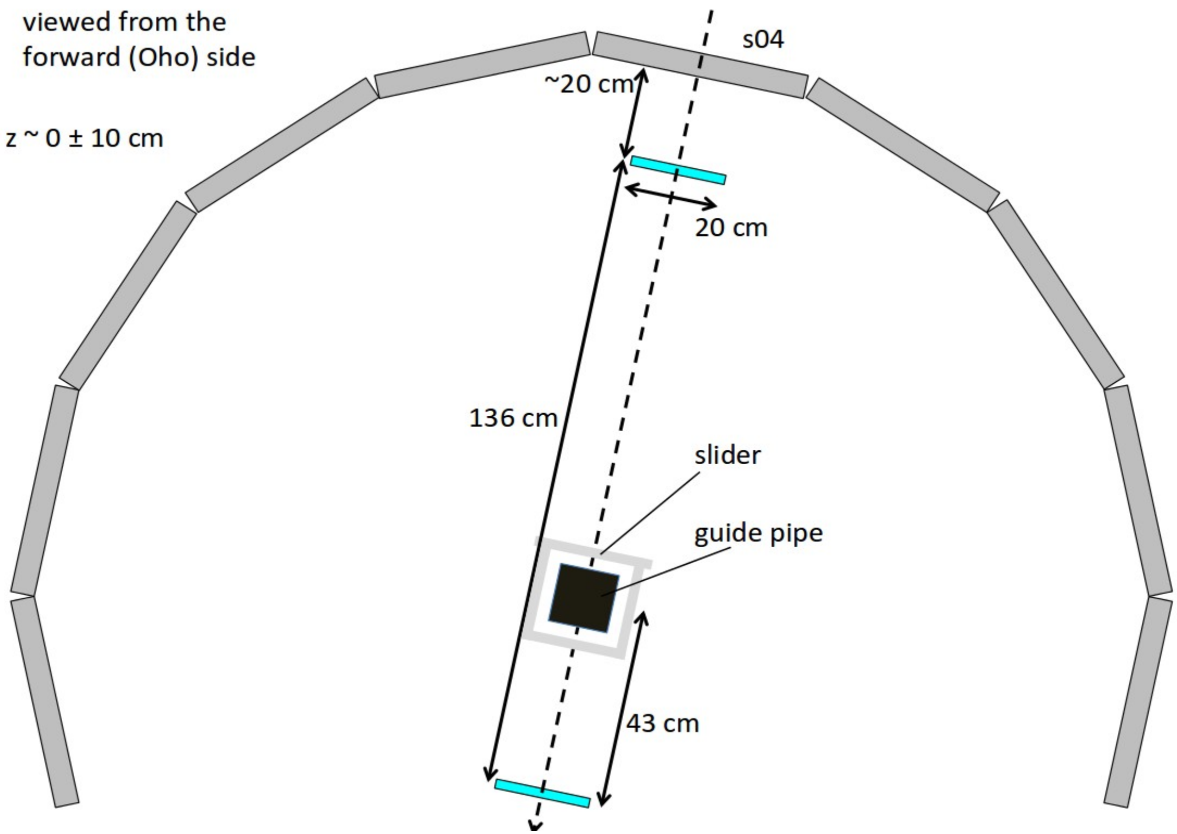
Large direct and reflected light yield, but poor timing



CRT commissioning

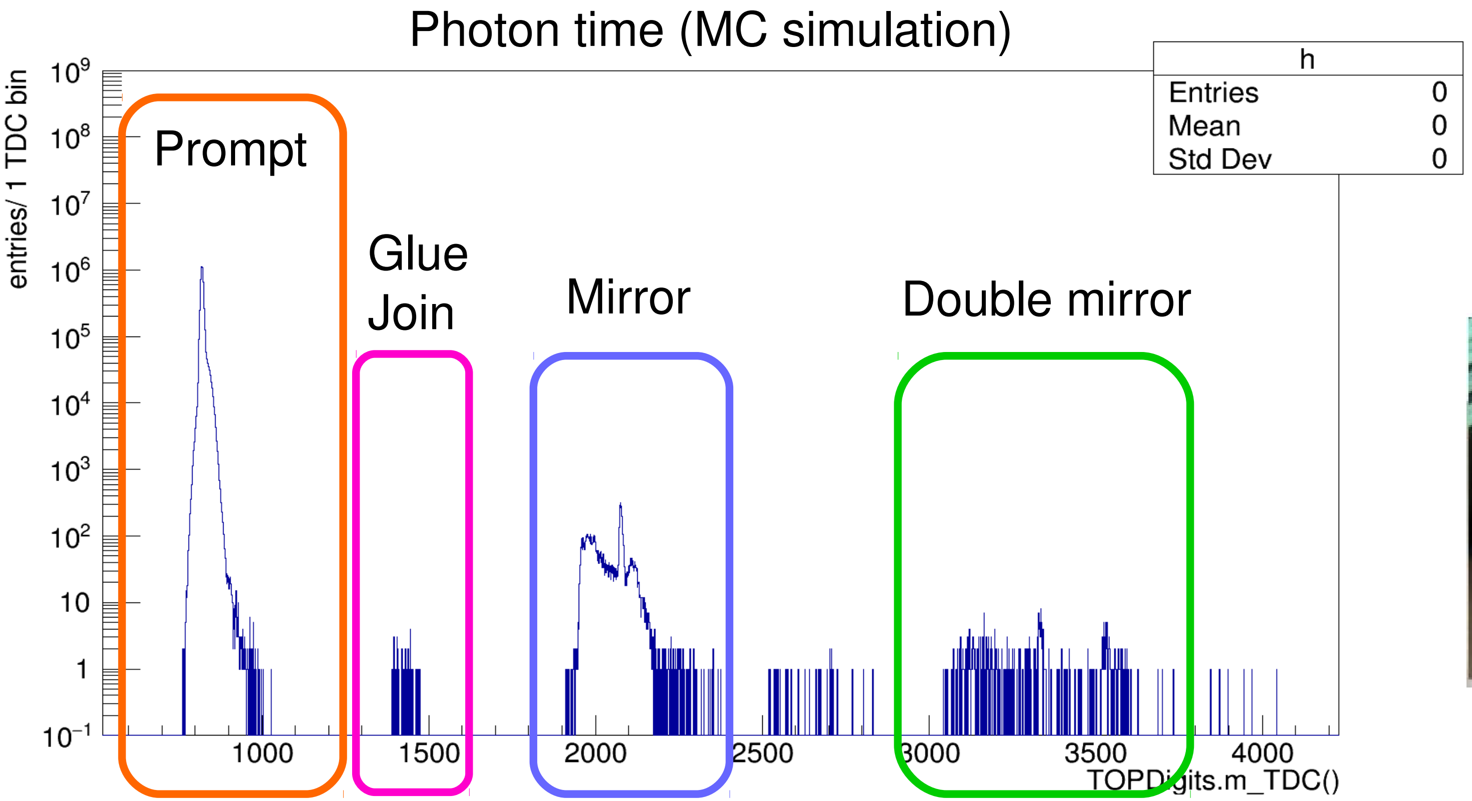
On the detector

KLM trigger was asked long ago, but it is not ready yet
→ home-made scintillator trigger (Nagoya)
→ this is a very serious issue for us

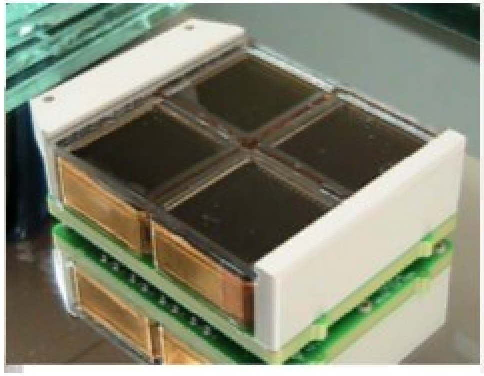


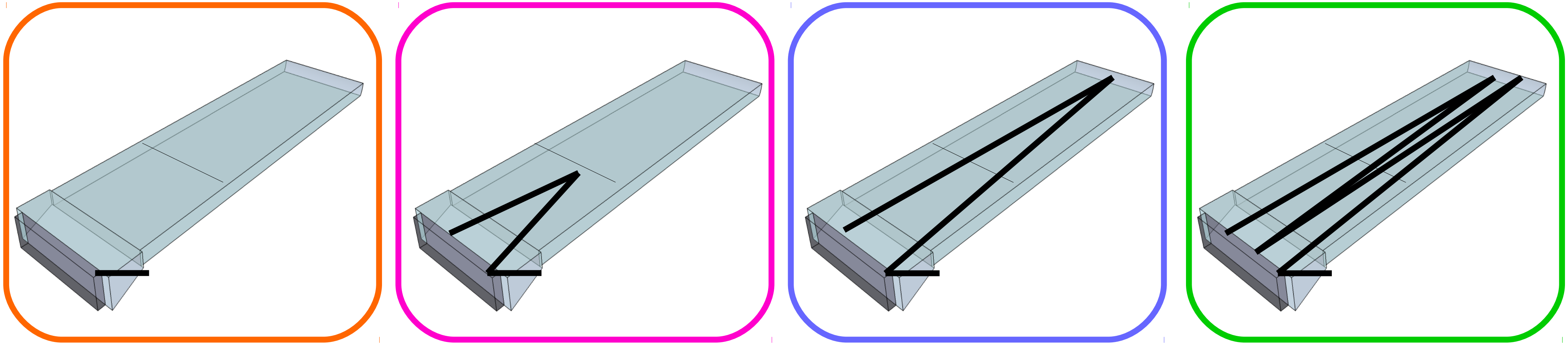
Two modules (back-to-back) at once
→ 0.15 – 0.05 Hz, $\beta \sim 1$

TOP tomography with time



PMTs are quite reflective...

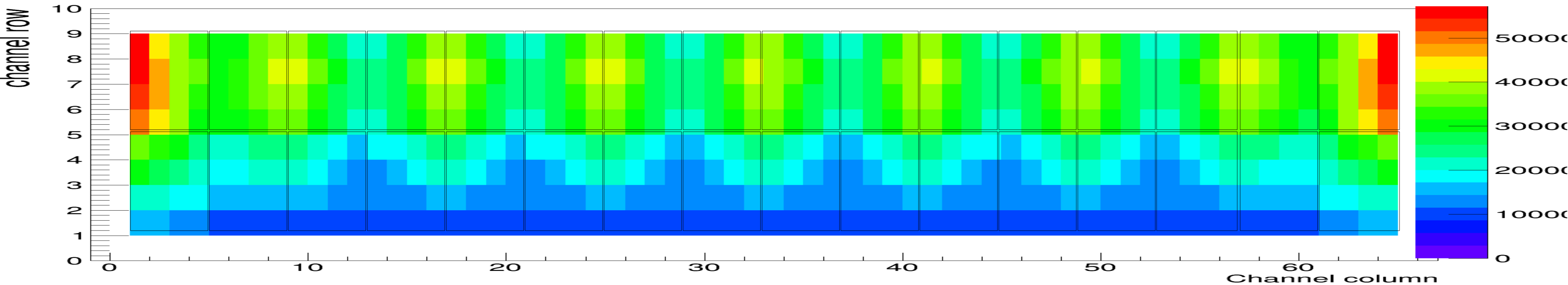




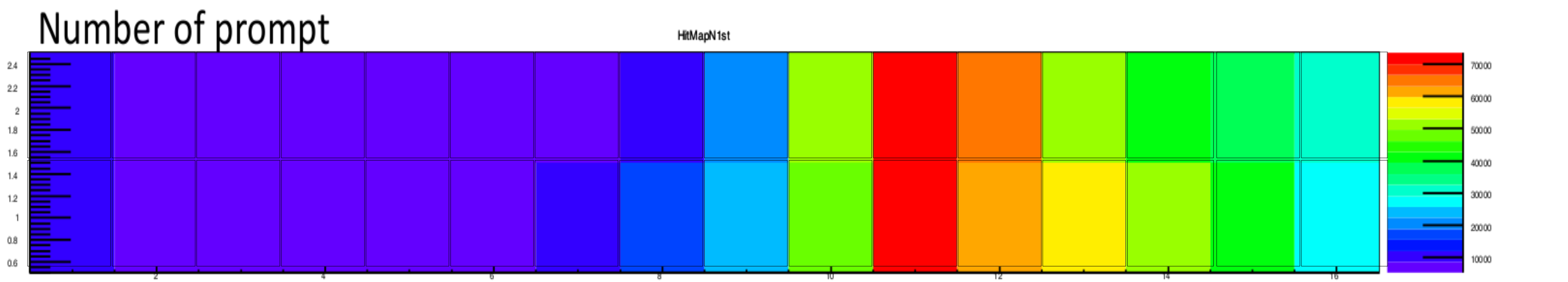
Commissioning with laser

Reminder:
→ one bundle (9 light sources) per module
→ flashing in front of the PMTs

Occupancy from MC simulation....



Reality of the very first laser run...

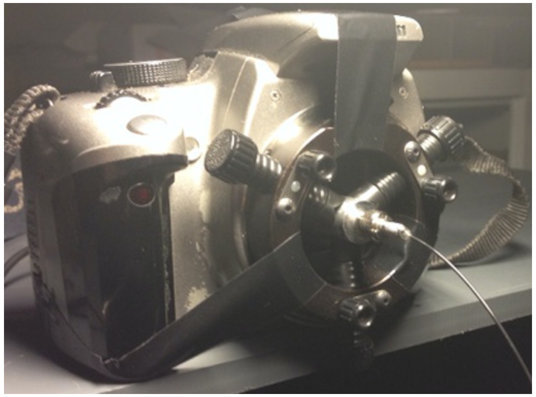


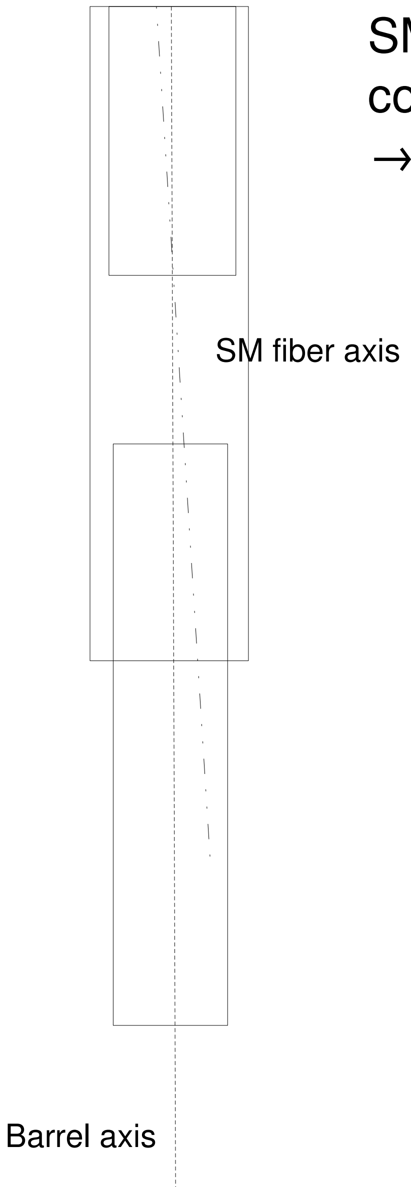
Very first laser run
→ why such large inhomogeneities?

Origin of the inhomogeneities

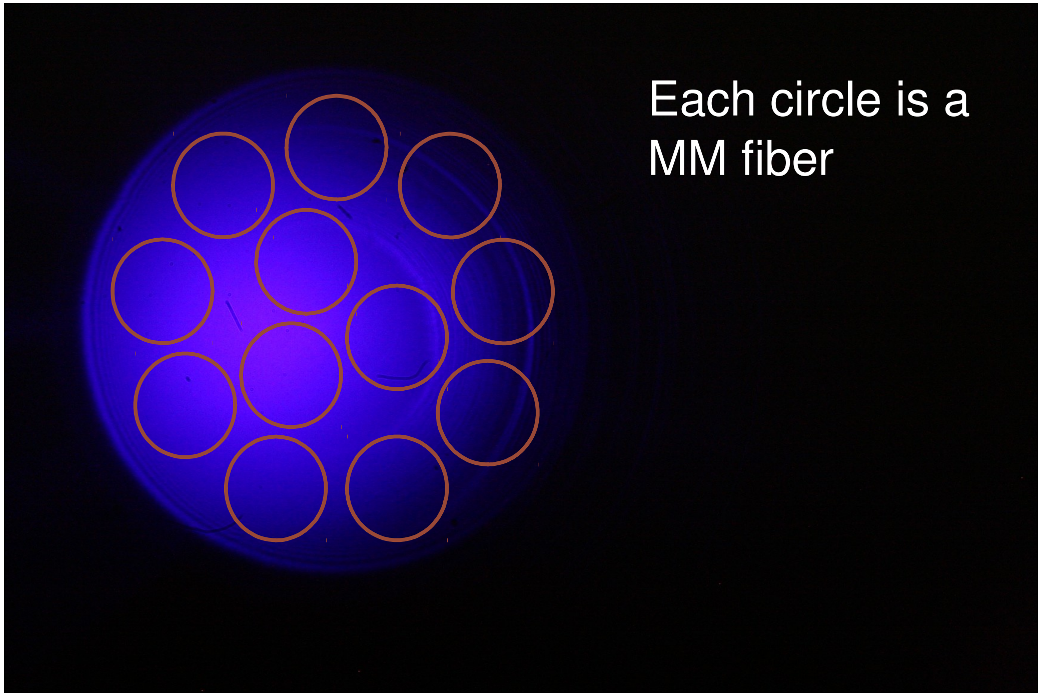
The light is flashed over the final MM bundle form few mm distance in a cilindrical connector

High-tech beam profiler in Torino

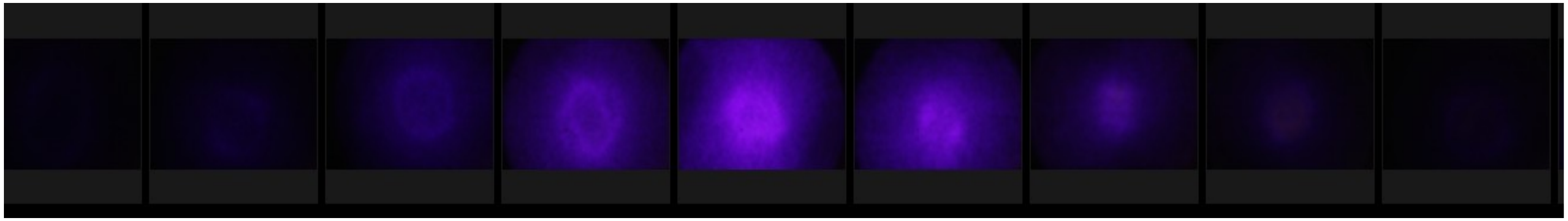




SM fiber not aligned with the connector axis
→ Not homogeneous light distribution!

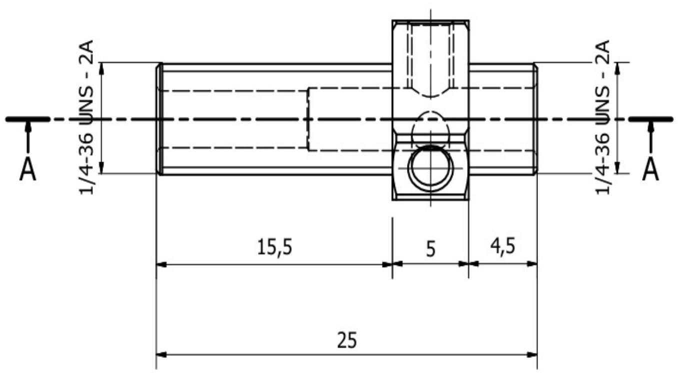


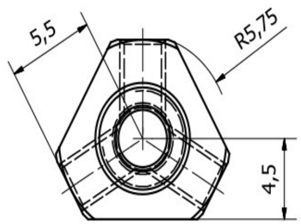
Light modulation on a MM bundle

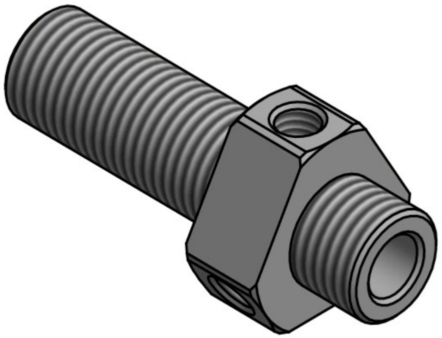


Flat-fielders

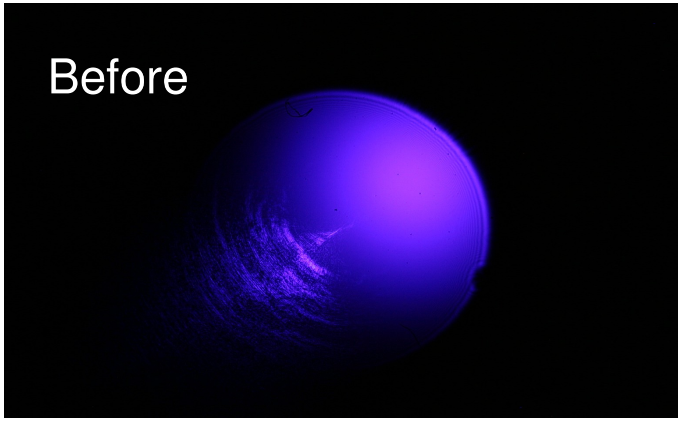
Flat fielder from Padova

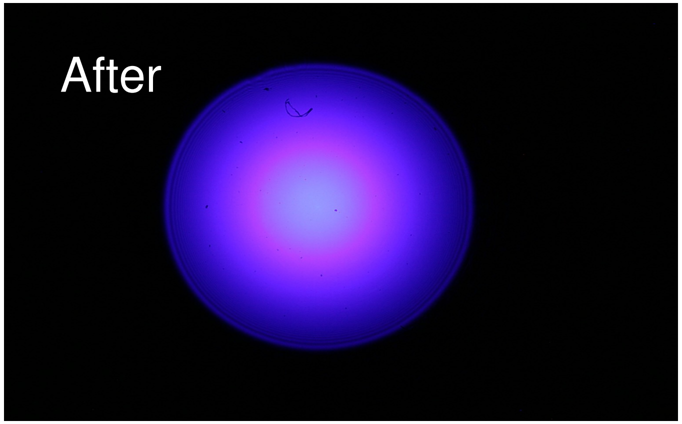




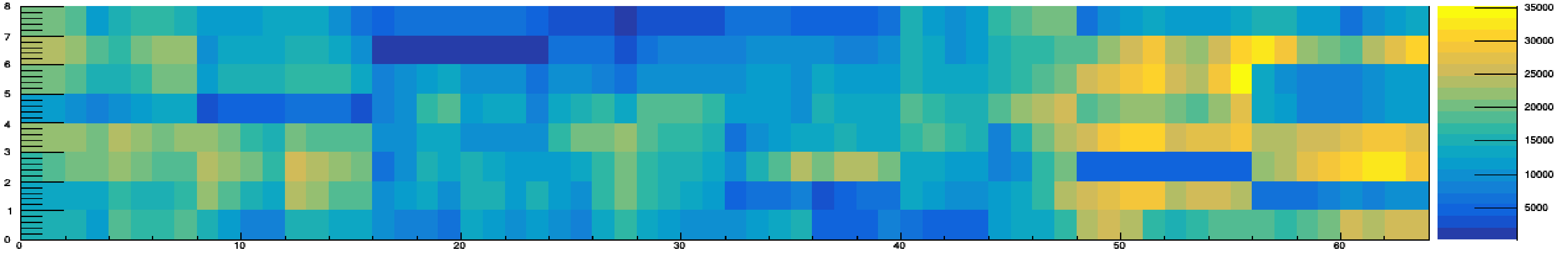


A quite dramatic example (and proof of Ezio's alignment skills)



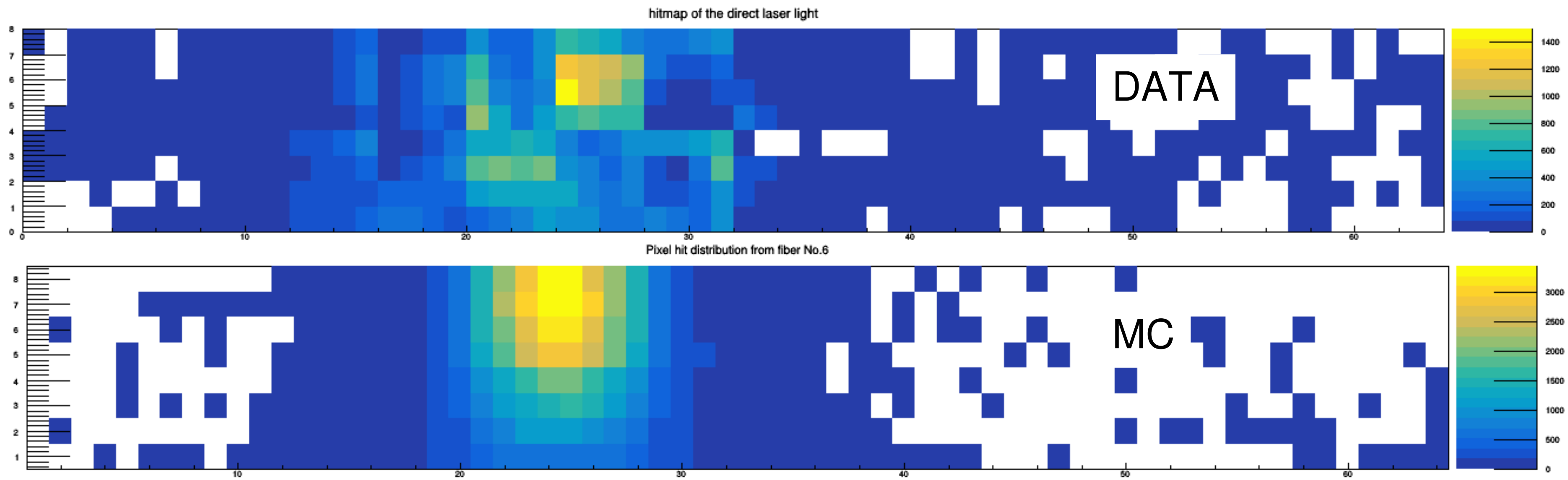


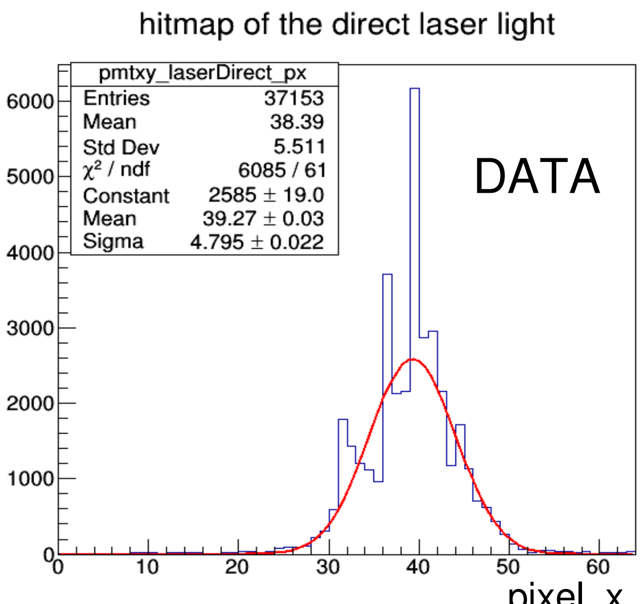
Residual inhomogeneities reduced by a factor of 10

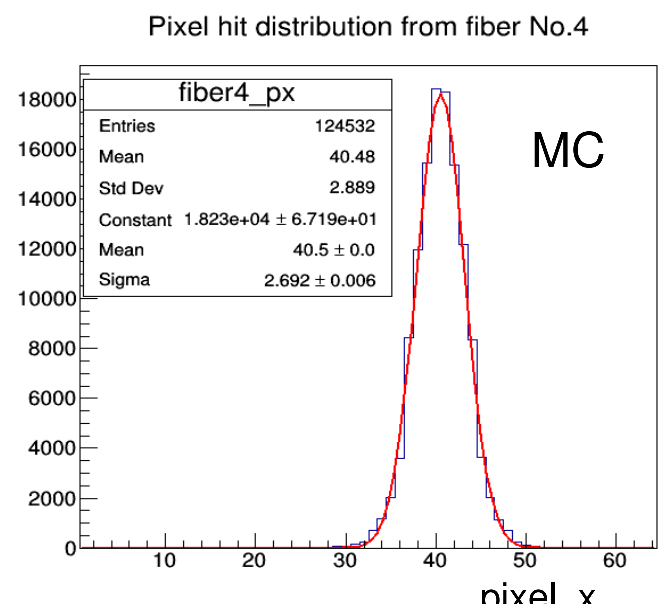


Data-MC comparison

We have a set of single-spot laser data taken on module 07 to make data-MC comparison







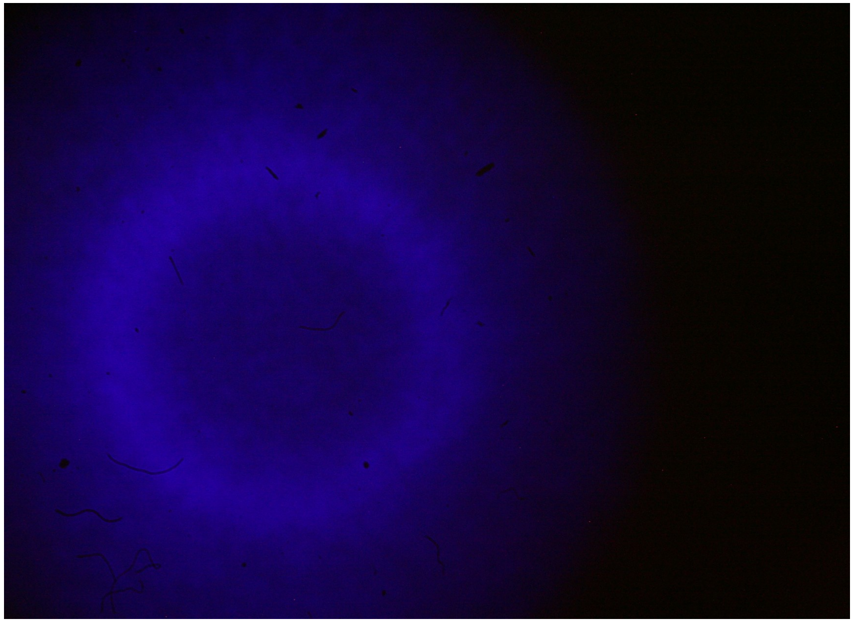
Quite different light spot Shape

→ no Q.E. correction
→ no gain correction

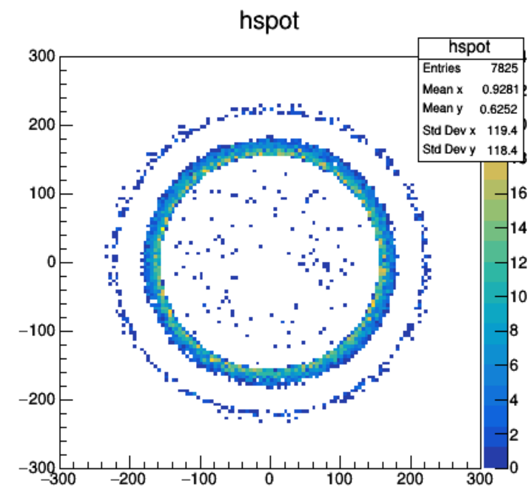
Ring-like structures

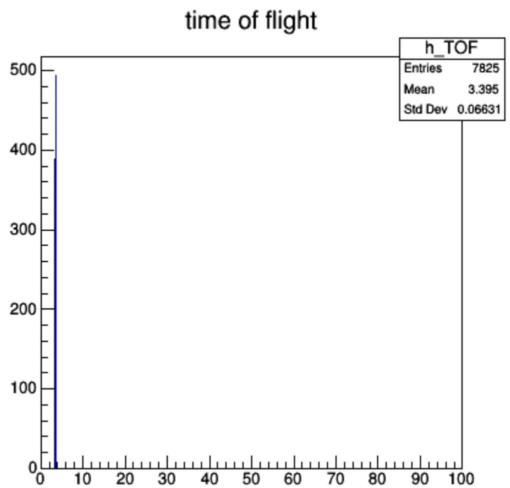
MC: Gaussian spot

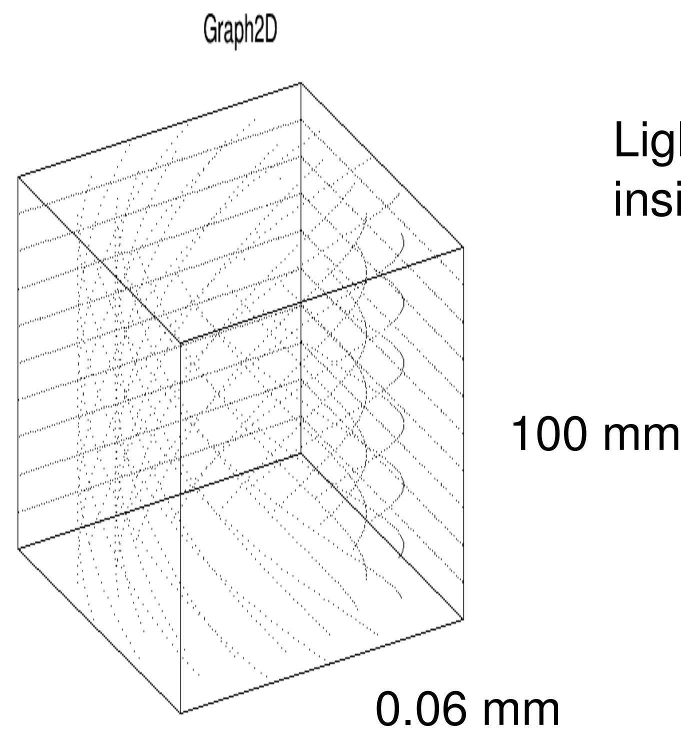
Data: Not gaussian at all!



Simulation (UT's private code, to be released)







Light trajectory inside the fiber

The light is entering the MM fiber from a narrow, non-zero angle

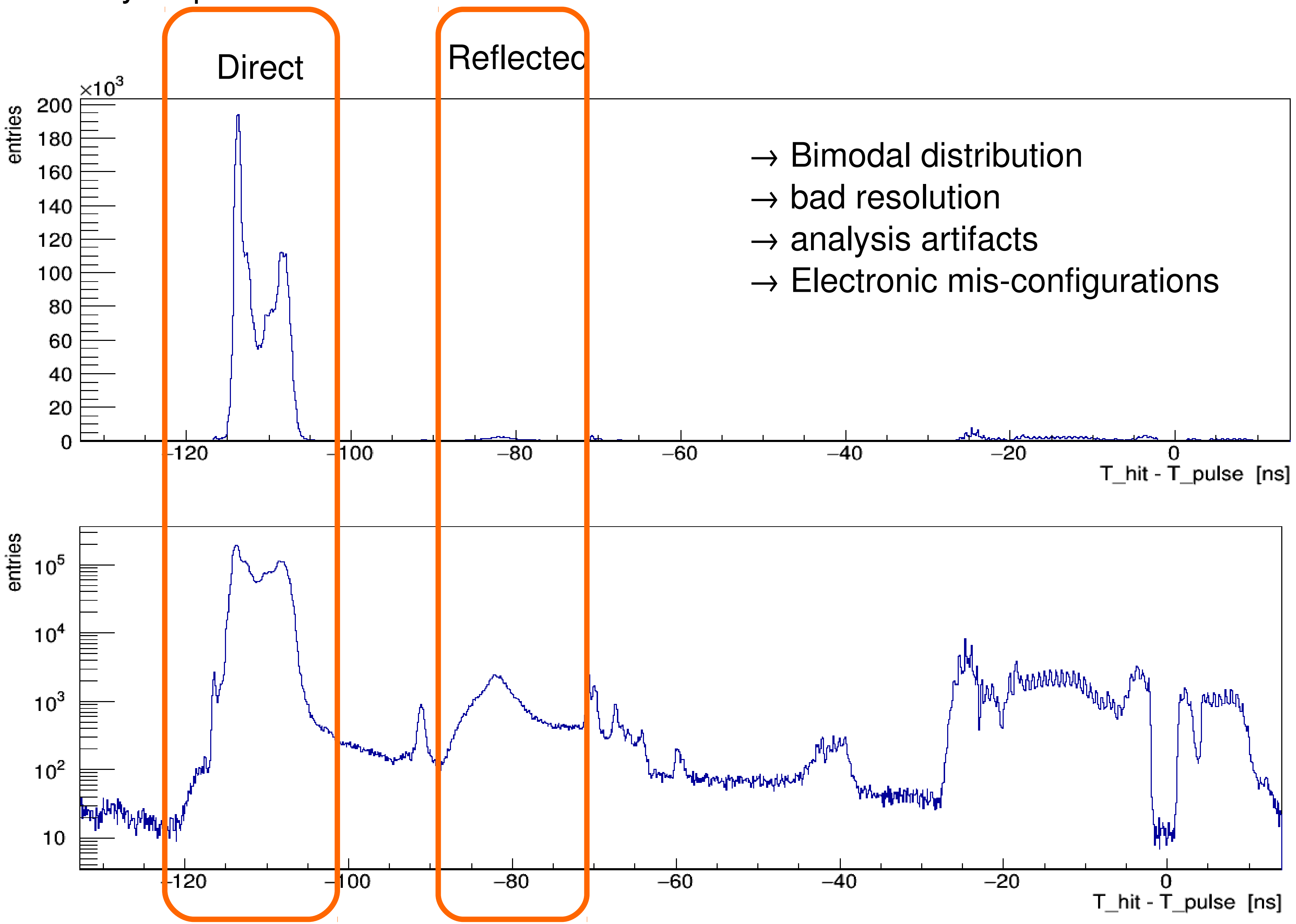
→ helicoidal propagation

→ ring-like spot

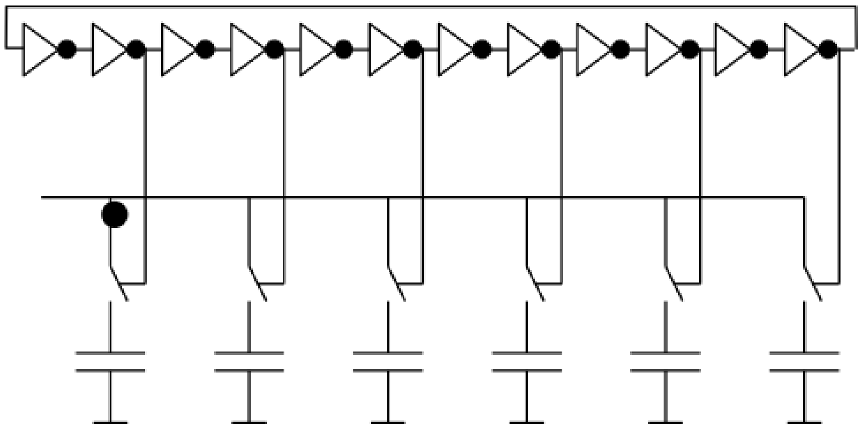
Still to be included in the simulation

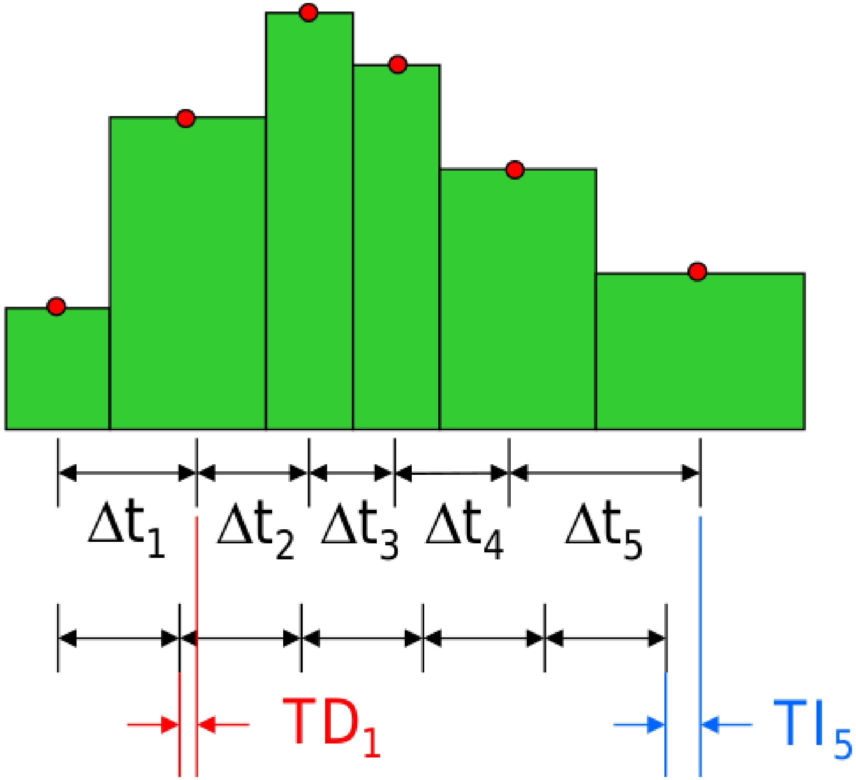
TOP tomography: real data

Reality is quite different from the ideal MC



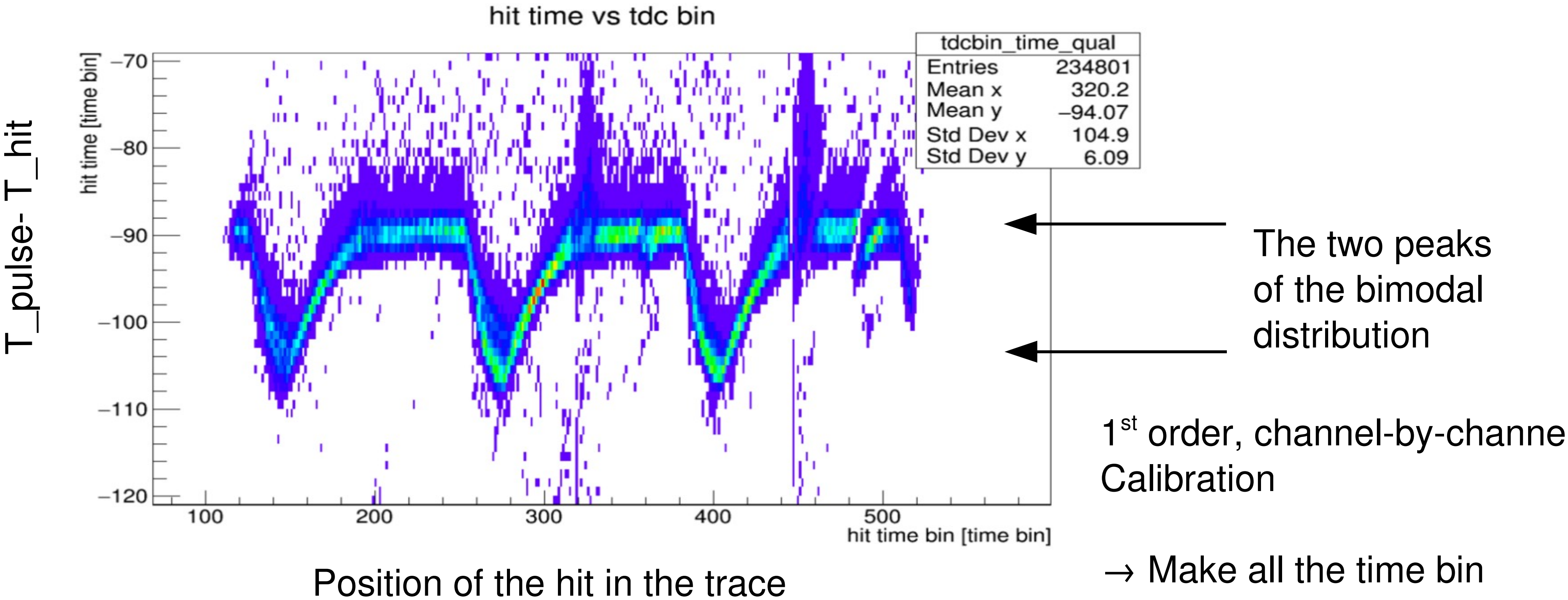
TOP readout: Time base calibration





- Inverter chain has transistor variations
  $\rightarrow$ Δt_i between samples differ
  $\rightarrow$ "Fixed pattern aperture jitter"
- "Differential temporal nonlinearity"
  $TD_i = \Delta t_i - \Delta t_{nominal}$
- "Integral temporal nonlinearity"
  $TI_i = \Sigma \Delta t_i - i \cdot \Delta t_{nominal}$
- "Random aperture jitter" = variation of Δt_i between measurements

Time base calibration from laser



1[st] order, channel-by-channel Calibration

→ Make all the time bin equally spaced

After the channel-by-channel time bin correction:

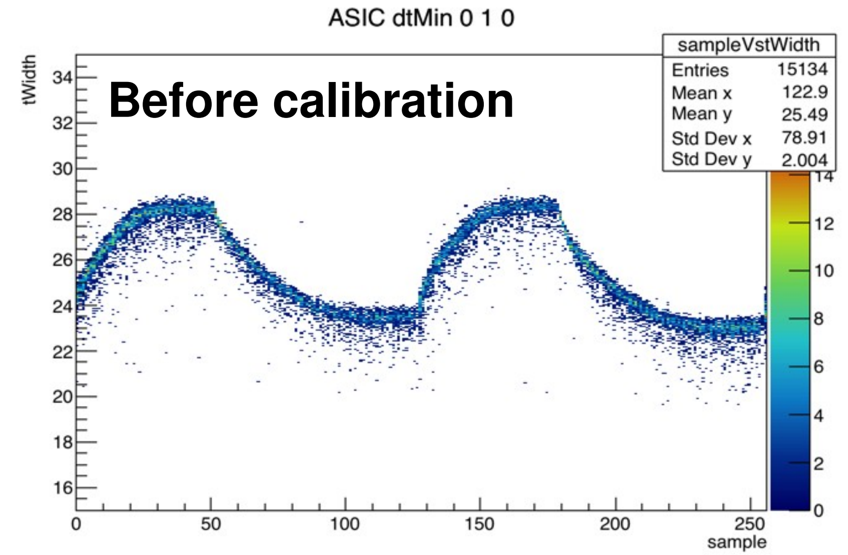
→ channel intercalibration (time alignment)
→ module intercalibration (time alignment)

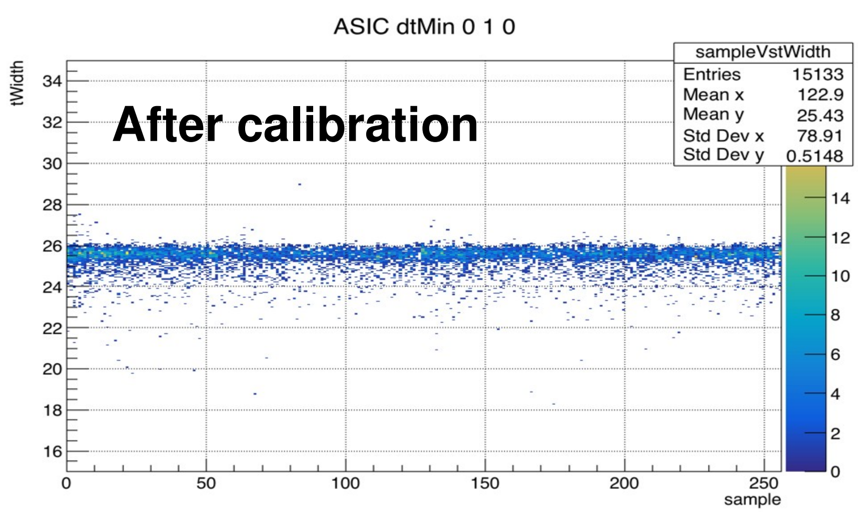
Time base calibration from laser

The laser is the primary system for the time-base calibration

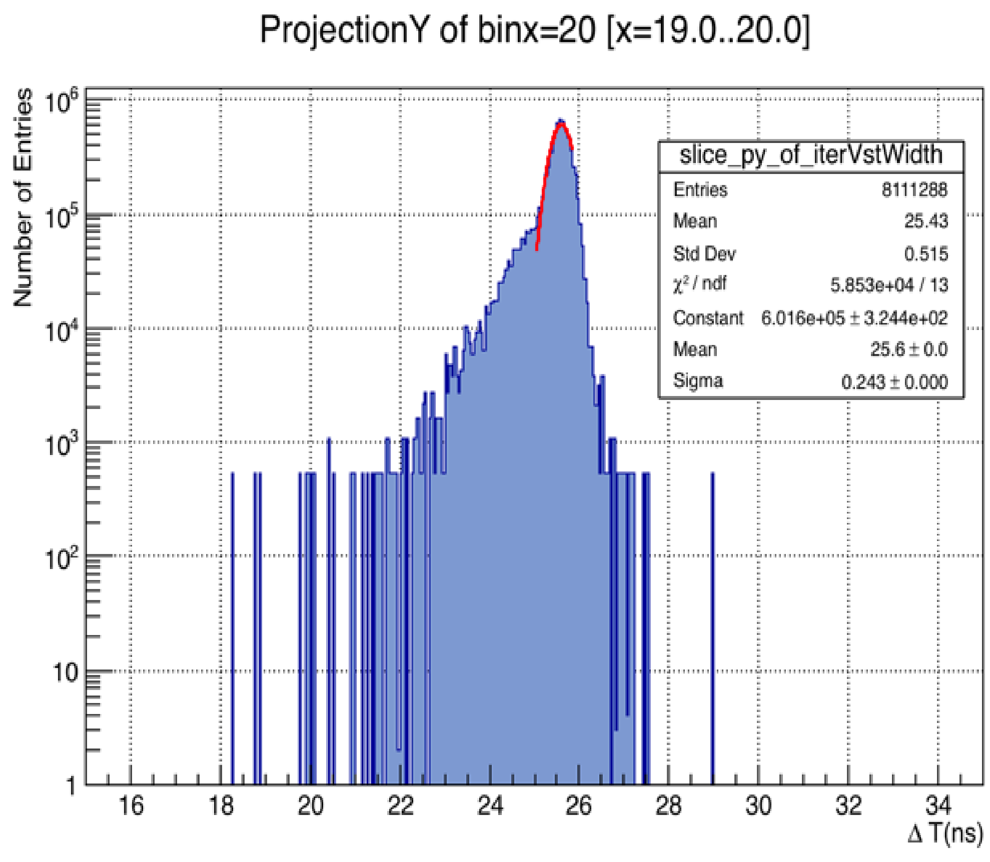
Minimization is not trivial
- → clean hit selection
- → fast hit finding
- → iterative method: must converge in the right place

Hawaii – Torino – Wayne State joined effort

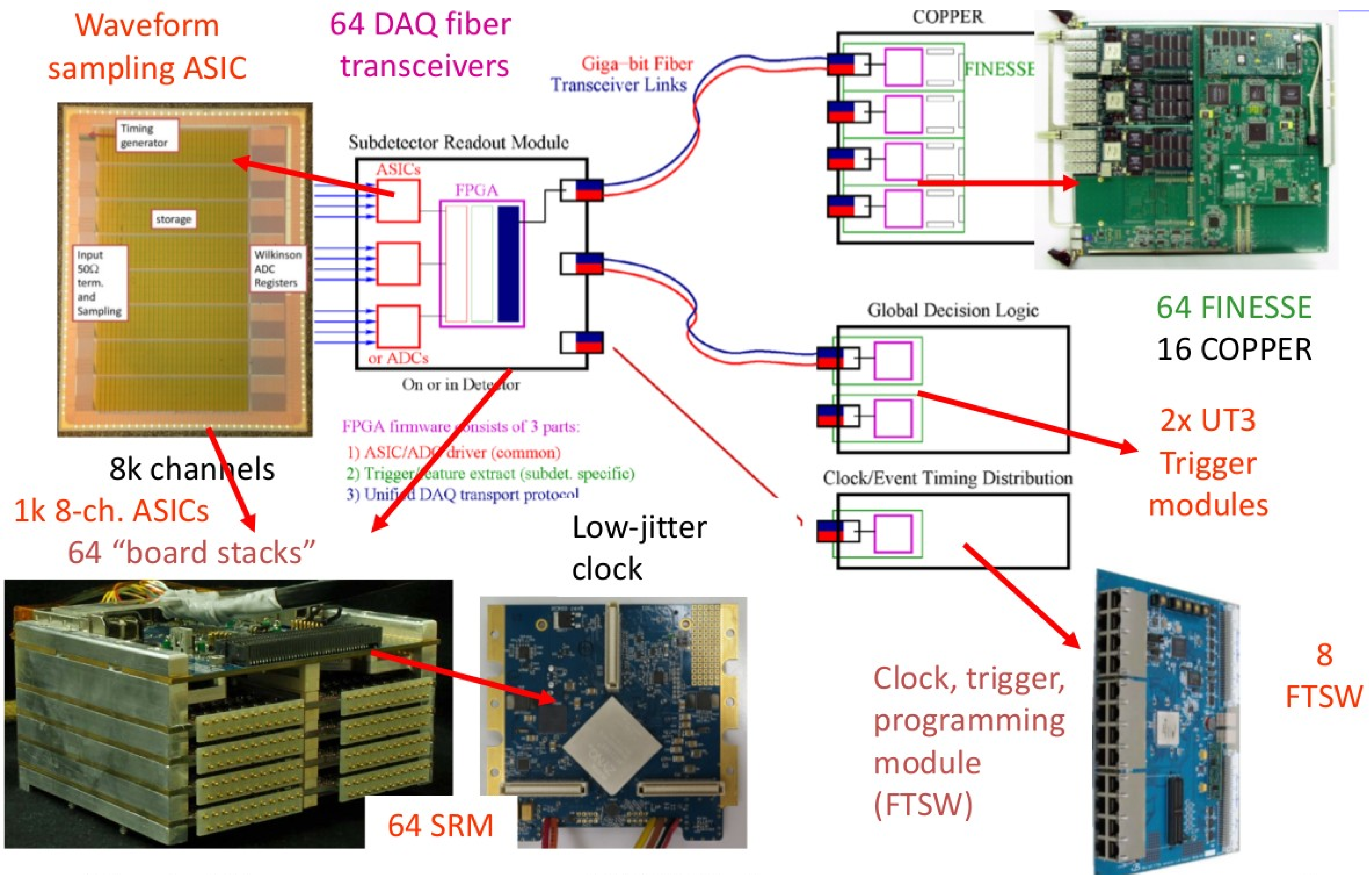




1 ns → 250 ps   (goal: < 80 ps)



TOP DAQ



Waveform sampling ASIC
64 DAQ fiber transceivers
Giga-bit Fiber Transceiver Links
COPPER
FINESSE
Timing generator
storage
Input 50Ω term. and Sampling
Wilkinson ADC Registers
Subdetector Readout Module
ASICs
FPGA
or ADCs
On or in Detector
FPGA firmware consists of 3 parts:
1) ASIC/ADC driver (common)
2) Trigger/feature extract (subdet. specific)
3) Unified DAQ transport protocol
8k channels
1k 8-ch. ASICs
64 "board stacks"
Low-jitter clock
Global Decision Logic
Clock/Event Timing Distribution
64 FINESSE
16 COPPER
2x UT3 Trigger modules
Clock, trigger, programming module (FTSW)
8 FTSW
64 SRM

Firmware development

Main issues

→ **Manpower**

1 (2) person is working on this from PNNL (Hawaii)

→ **Feature extraction   (Hawaii - PNNL)**

Full waveform → hits

64x15x 512 words / event → ~8x50 words / event

10 Hz → 10 kHz

→ **Soft reboot (Hawaii - PNNL)**

A large fraction of problems is now solved with <u>hard reboot</u>

→ long operation time

→ not really a solution

→ **DAQ integration (Hawaii – PNNL - KEK)**

→ We cannot run the copper at its full speed

→ We experience tranfser rate slowing down during data taking

What can be done in Italy

→ **A full FE boardstack is in Torino**

→ no way to get a copper / FTSW

→ FW development is still possible

Software development

Two different frameworks, sometimes overlapping

top (M. Staric)
→ Intended for final data analysis
→ MC simulation is analyzed with it
→ Coherent, simple, but unsuitable for debugging

topcaf (M. Barret, J Strube, U.T.)
→ Intended for full waveform analysis
→ Developed at PNNL, changed at least 3 generations of mantainers
→ Large overlappings with top
→ **Needs to be improved!**

Some examples:
→ New dT calibrator (Hawaii - Torino – Wayne state) : **1 hr/run → 5 mins / run**
→ New hit finder (Torino) : **3 hrs/run → 10 mins / run**
→ Improved calibration pulse selection (Torino – PNNL): **efficiency +100%**

Conclusions

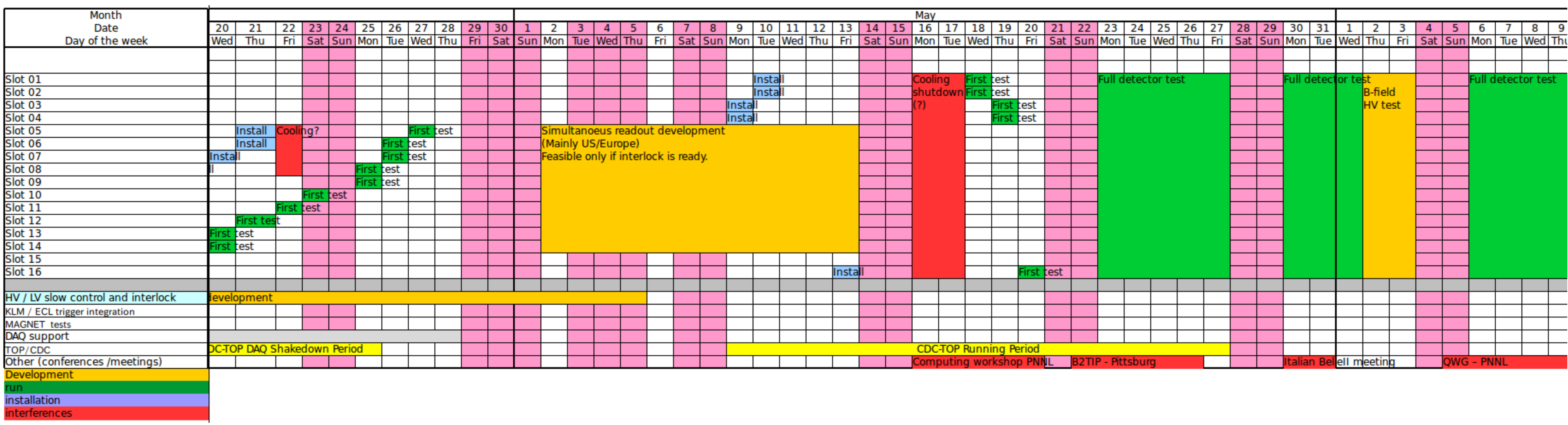
TOP commissioning is going well
→ No dead channels
→ all modules have comparable performances

Some items are on the critical path
→ feature extraction
→ time calibration
→ KLM cosmic trigger
→ Software

B-field test form June 15th
→ No access to the detector

CDC goes in in August
→ No more room for HW replacing and Recabling

HW must be commissioned within the next 2 weeks

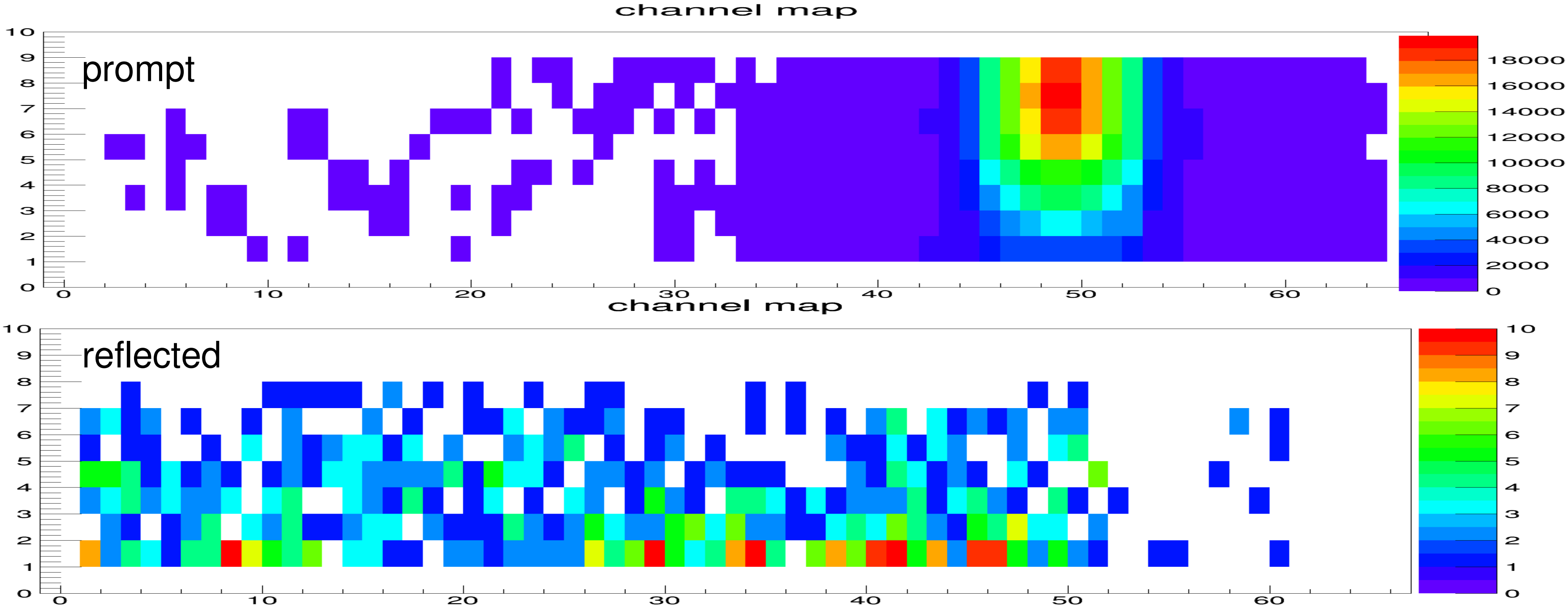


Testing schedule won't fit any slide...
https://belle2.cc.kek.jp/~twiki/bin/view/Detector/TOP/WebHome

Backup

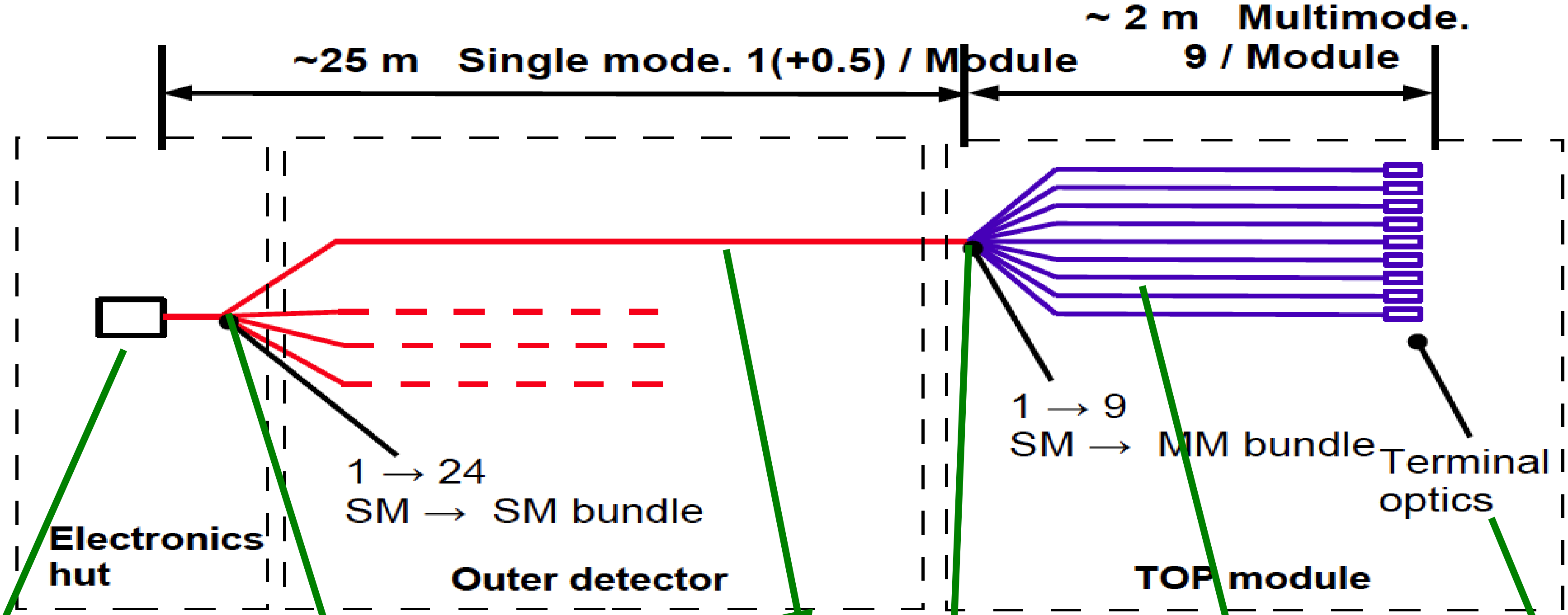
Tracking down the reflected spot

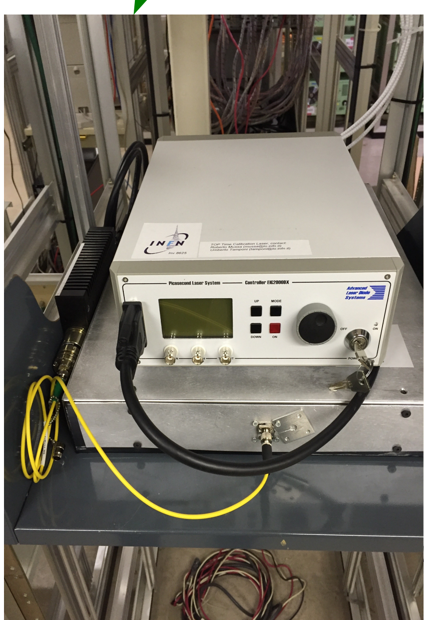
MC with one single source out of nine



Channel-by-channel ratio may not be the best observable
→ can we build a look-up table to predict the reflected pattern based on the direct one?

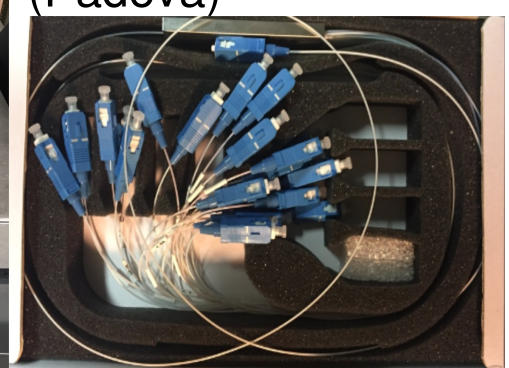
Laser calibration system



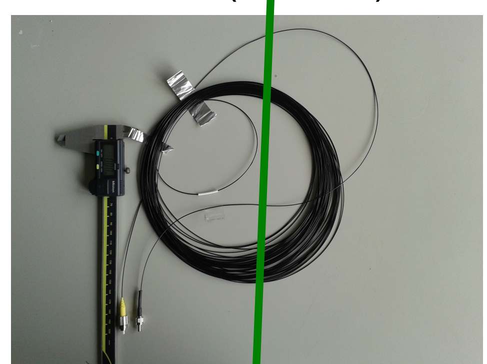


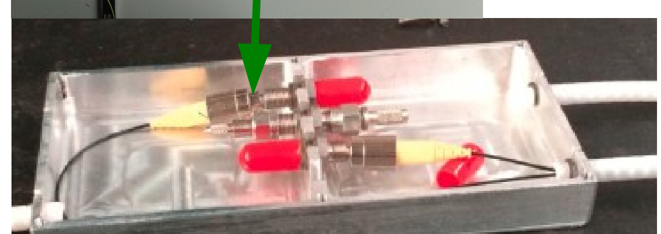
PiLas laser (Torino)

NEW: Splitter 1-24 via Planar Light Circuit (Padova)

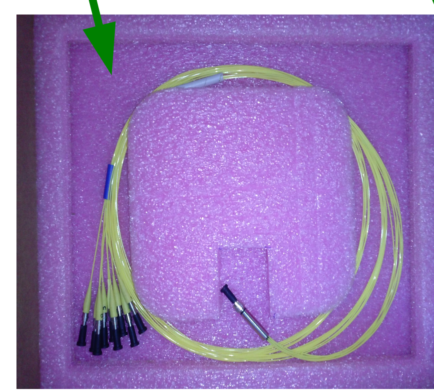


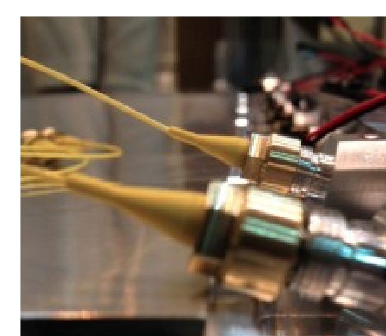
SM fiber (Torino)



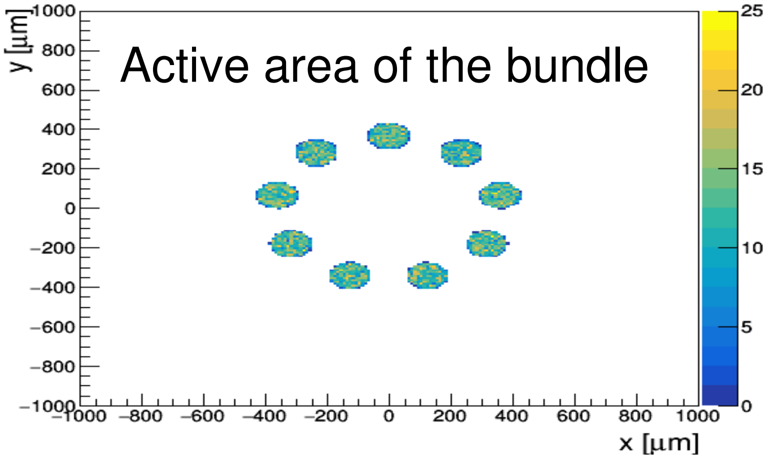


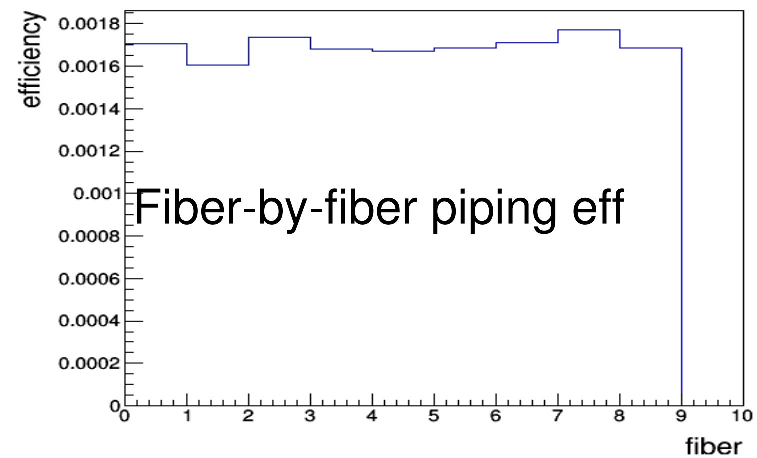
Connector SM-MM: (Torino)



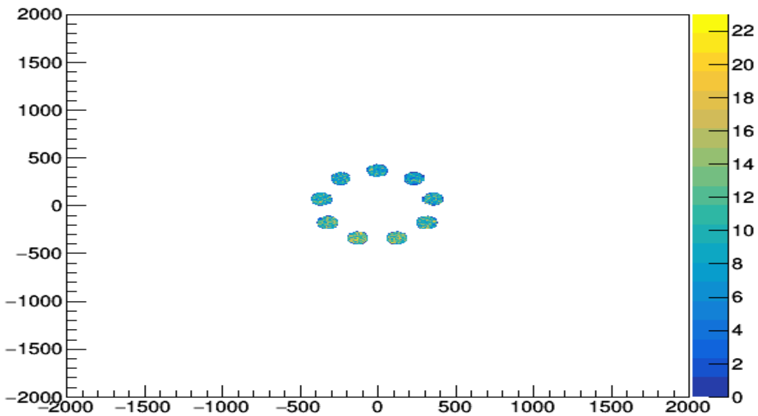


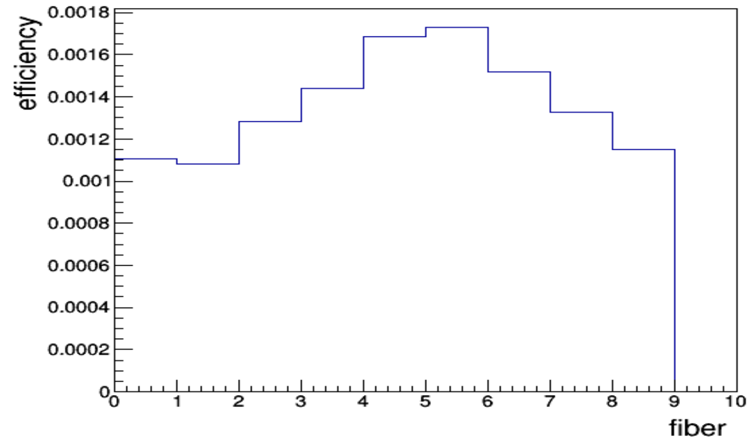
Origin of the inhomogeneities: toy MC



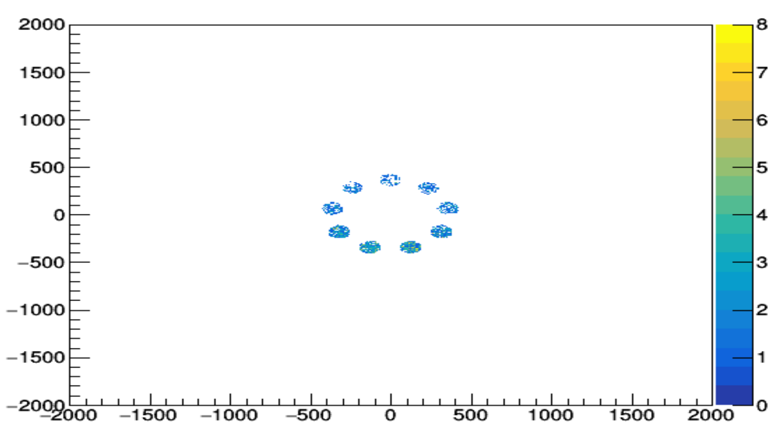


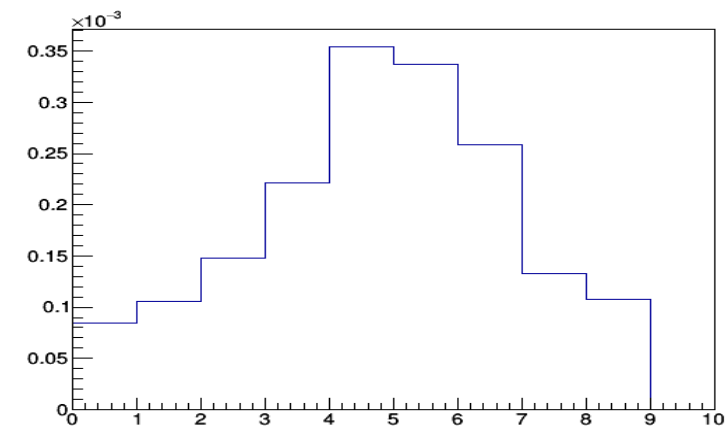
Tilt = 0°





Tilt = 5°





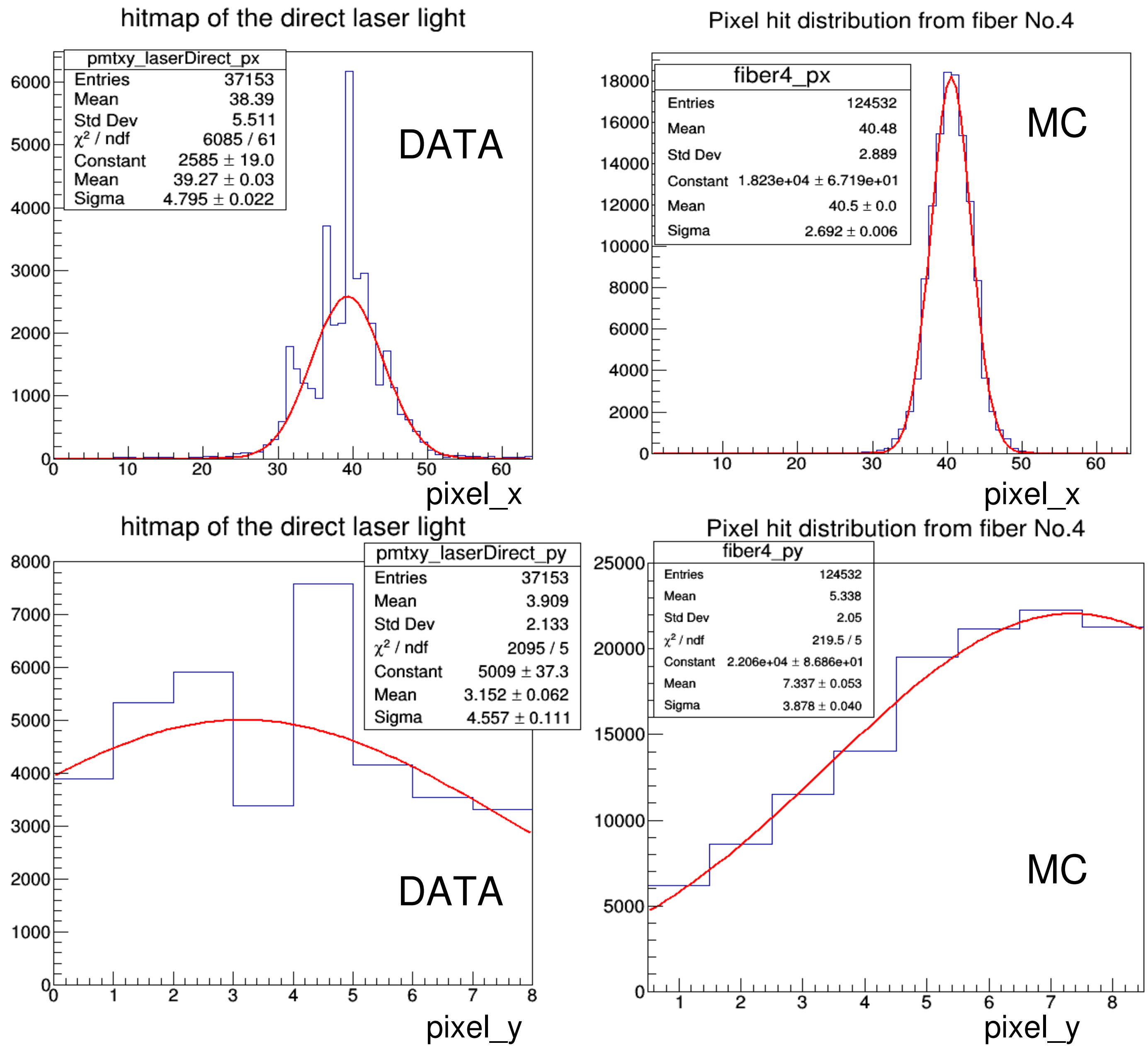
Tilt = 15°

Is it realistic?

Alignment survey

We compare the gaussian fit of the x and y projections of the hit maps

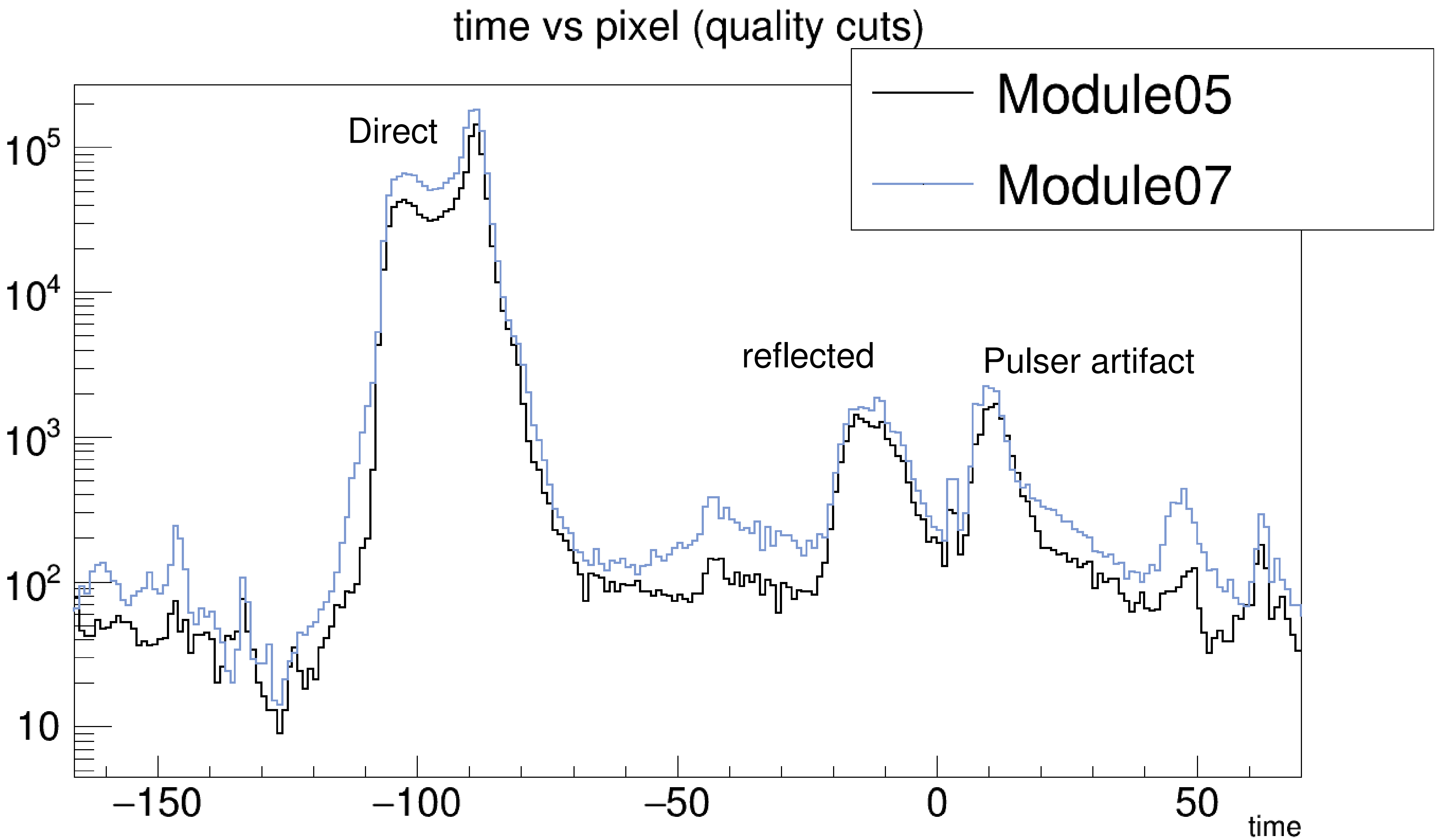
- → Maximum position
- → spot size (x only)



Projection x

Projection y

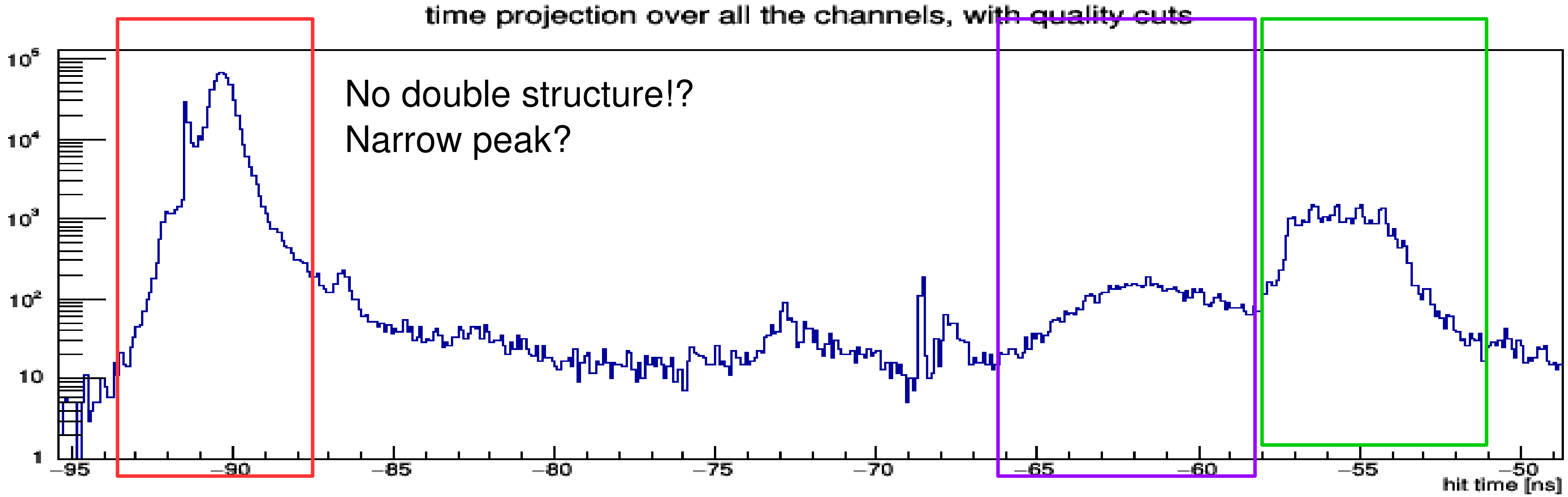
Timing

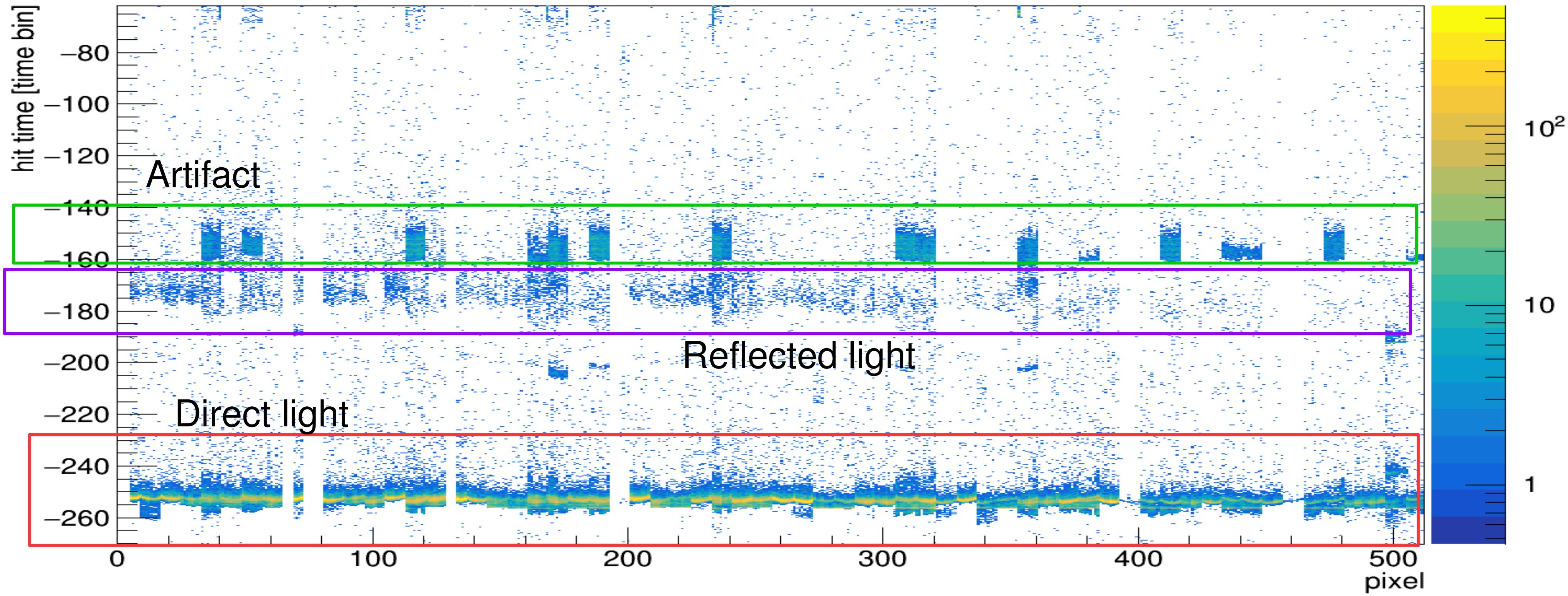


time vs pixel (quality cuts)
Module05
Module07
Direct
reflected
Pulser artifact
10^5
10^4
10^3
10^2
10
−150
−100
−50
0
50
time

Timing (II)

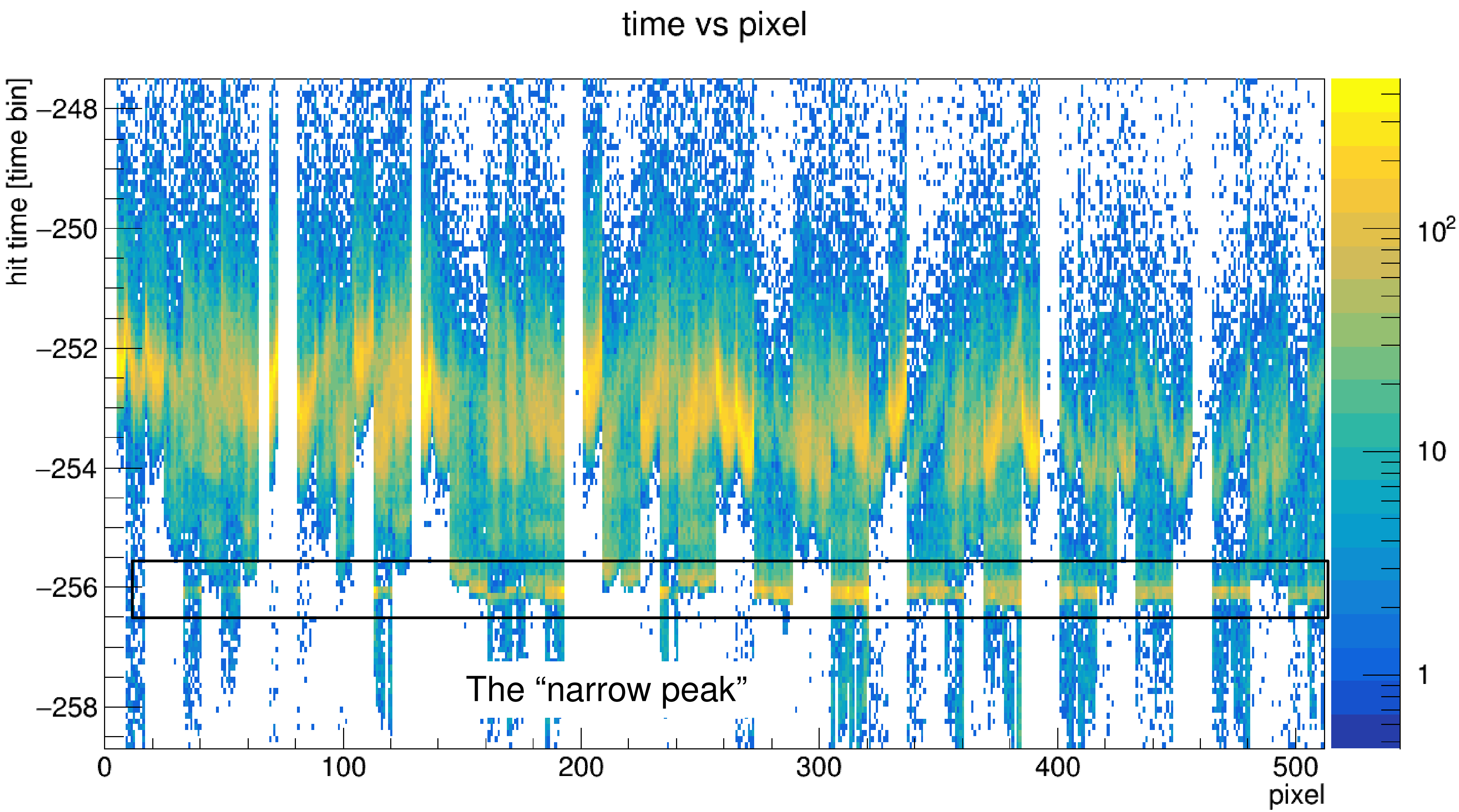
Zoom in the laser light region





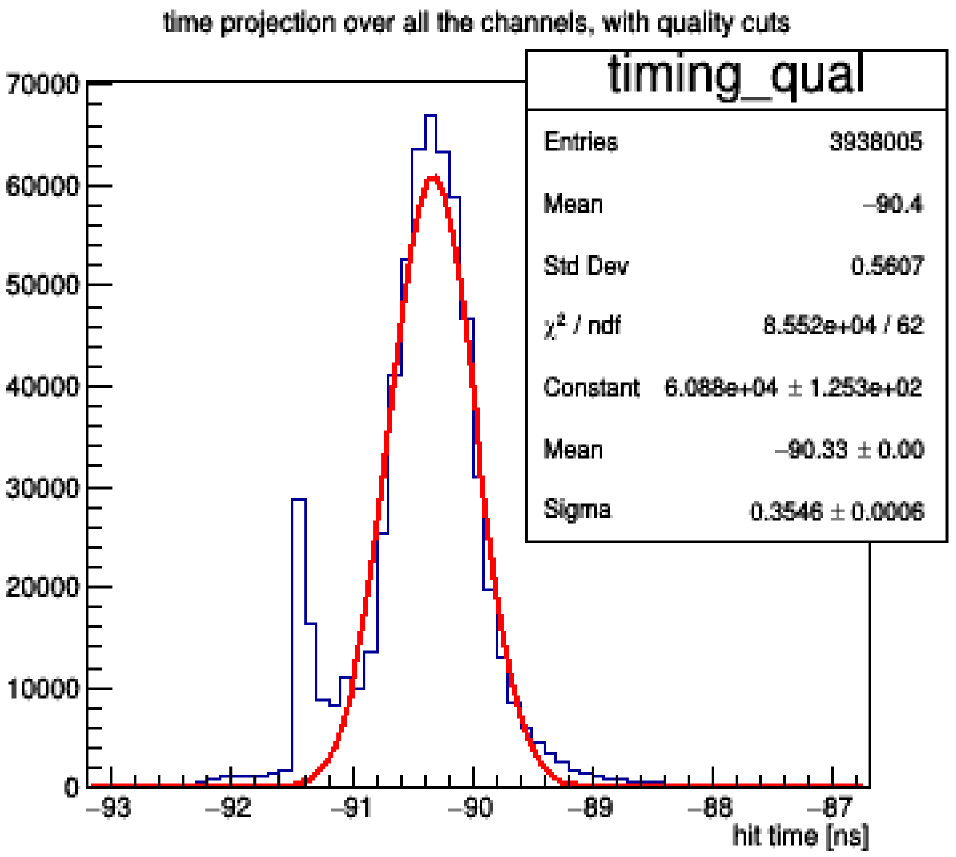
Timing (III)

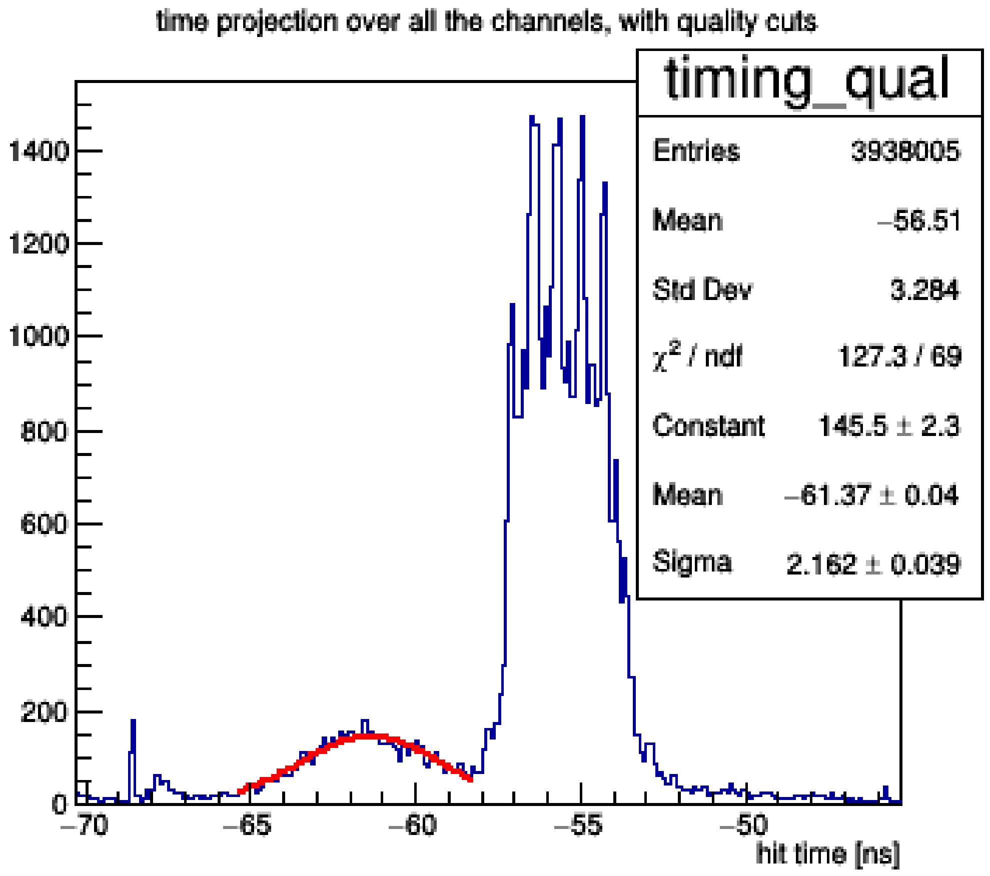
Even finer zoom: direct laser light only



Timing: all channels

Integrating over all the channels (assuming 1 time bin = 0.357 ns, which is not correct probably)

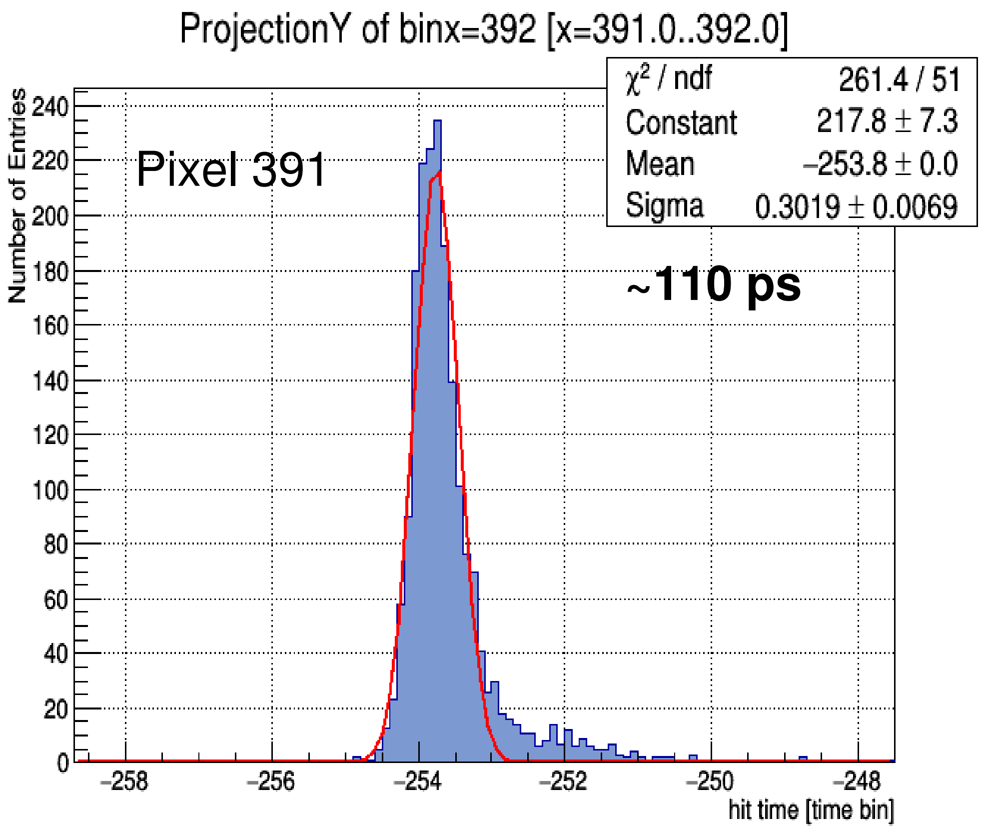


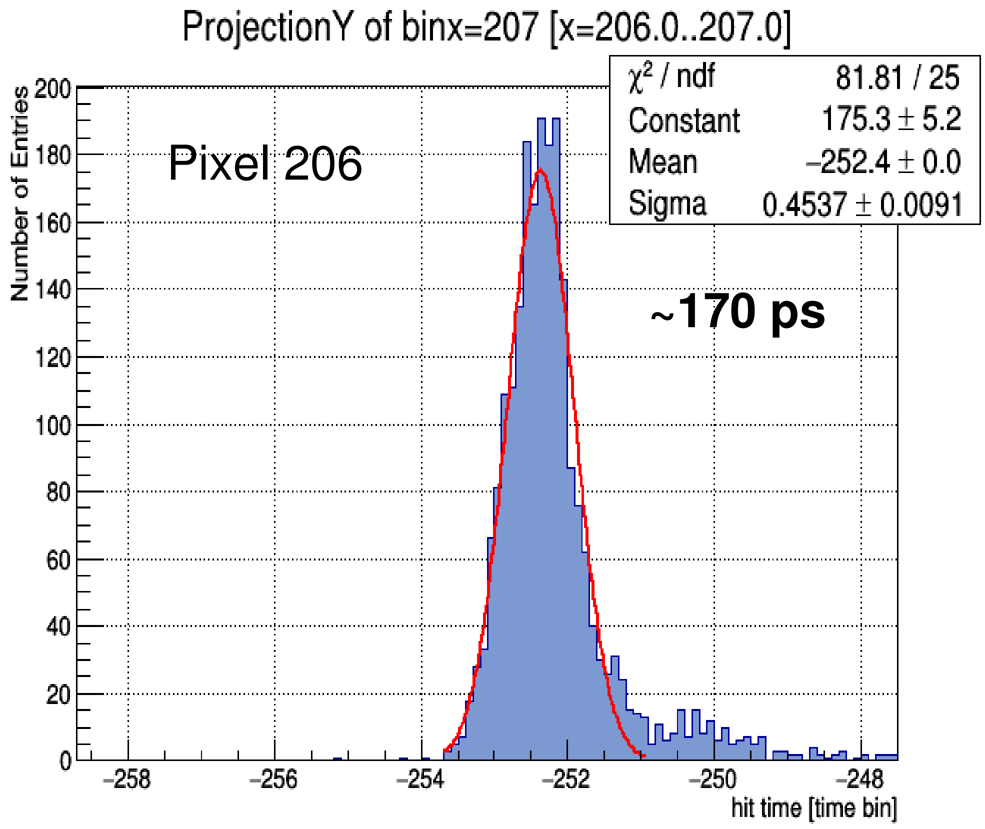


Direct light resolution: ~350 ps (360 assuming time bin = 0.370 ns)

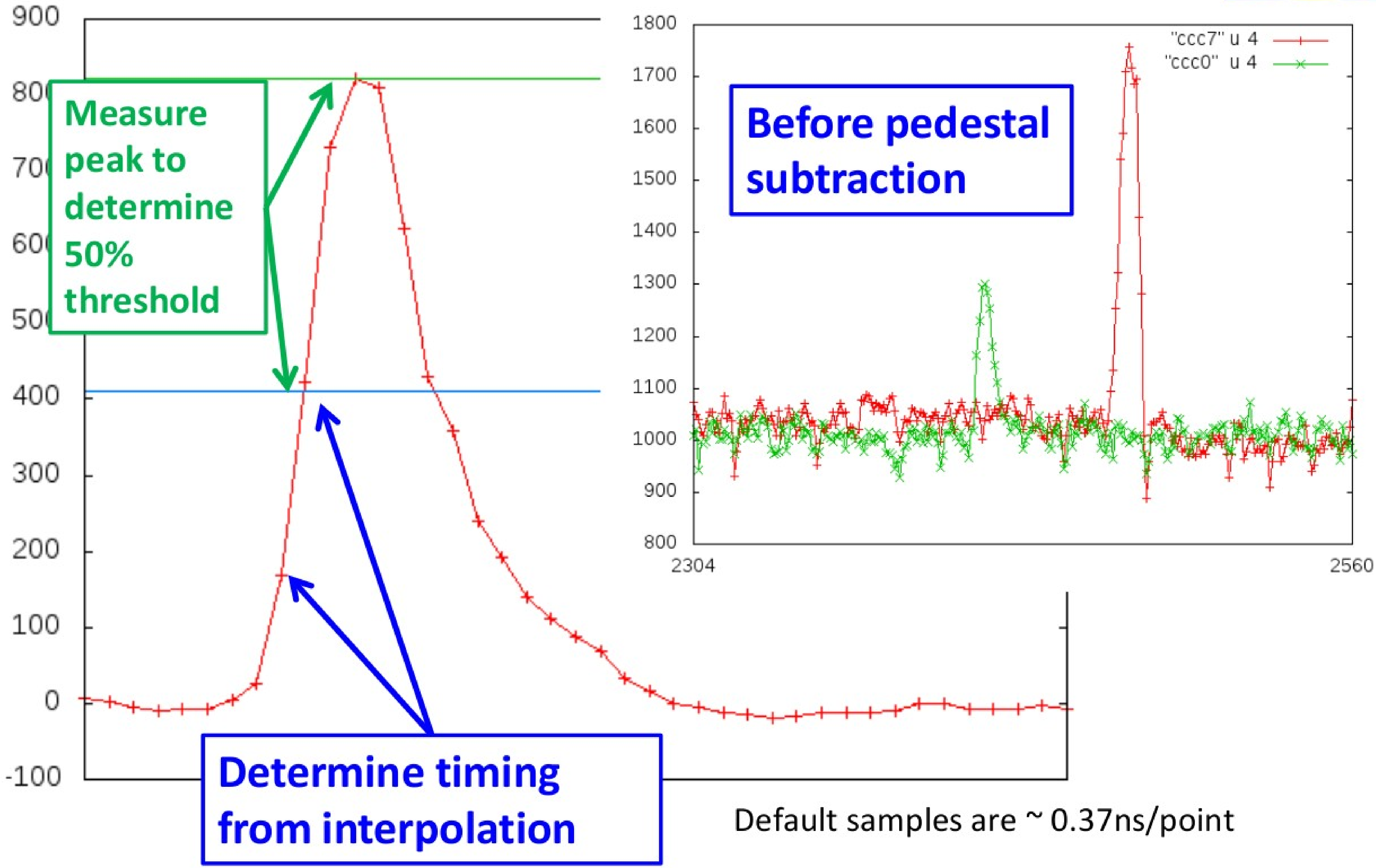
Timing: single channel

Some single channel time distributions





1. Ped subtract & 50% CFD



Default samples are ~ 0.37ns/point

Example laser timing Residual