The TORCH Detector
Beamtests & PID Performance

Thomas H. Hancock,
on behalf of the TORCH collaboration

9th April 2019

Outline

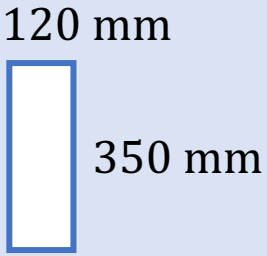
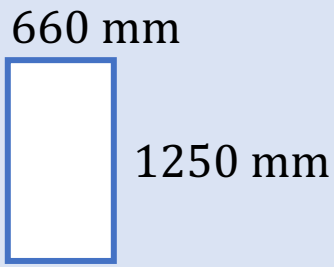
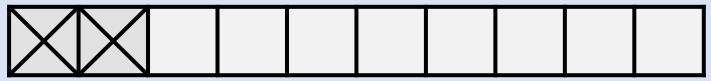
- What is TORCH?
- MCP-PMT development and testing
- Photon Yield

} Covered by Emmy Gabriel

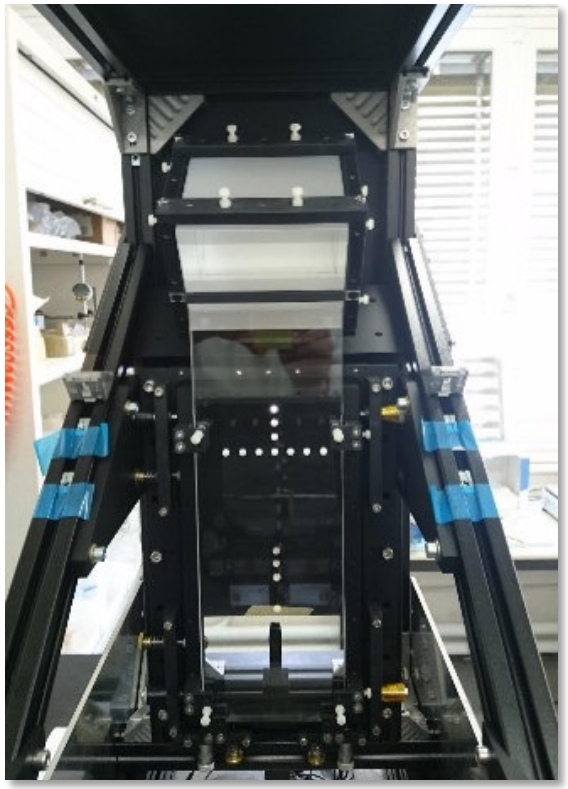
- Test Beam Campaigns
- Photon Timing Resolution
- PID Performance

} The focus of this talk

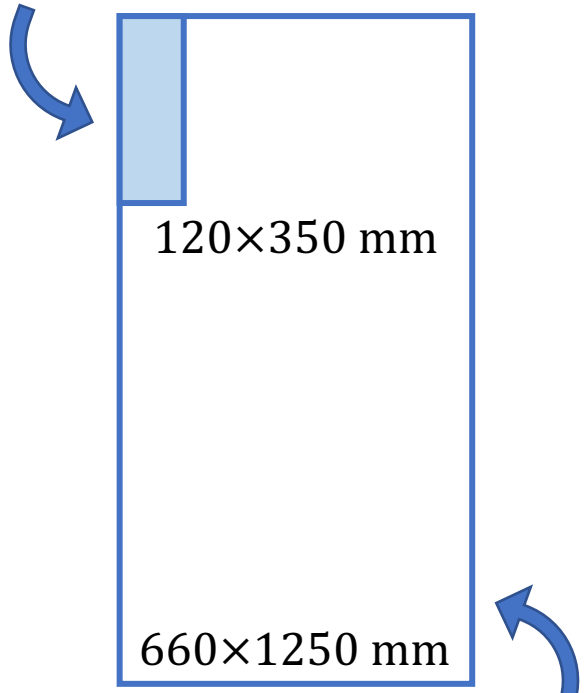
Test Beam Campaigns

1st – Nov' 17	2nd - Jun' 18	3rd - Oct' 18
Mini-TORCH 		Proto-TORCH 
Single 4×64 Phase III MCP 	Single 8×64 Phase III MCP 	Pair of 8×64 Phase III MCPs 
Measured: Single Photon Time Resolution **Photon Counting Efficiency** (see Emmy's talk)		**Preliminary Time Resolution Measurement Made** Photon Counting is in progress

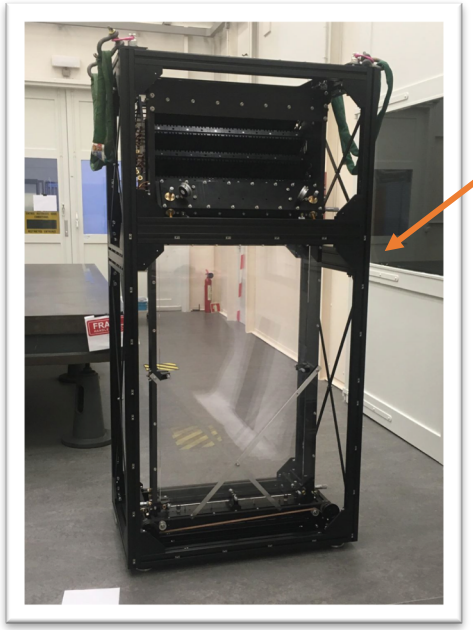
Mini-TORCH and Proto-TORCH



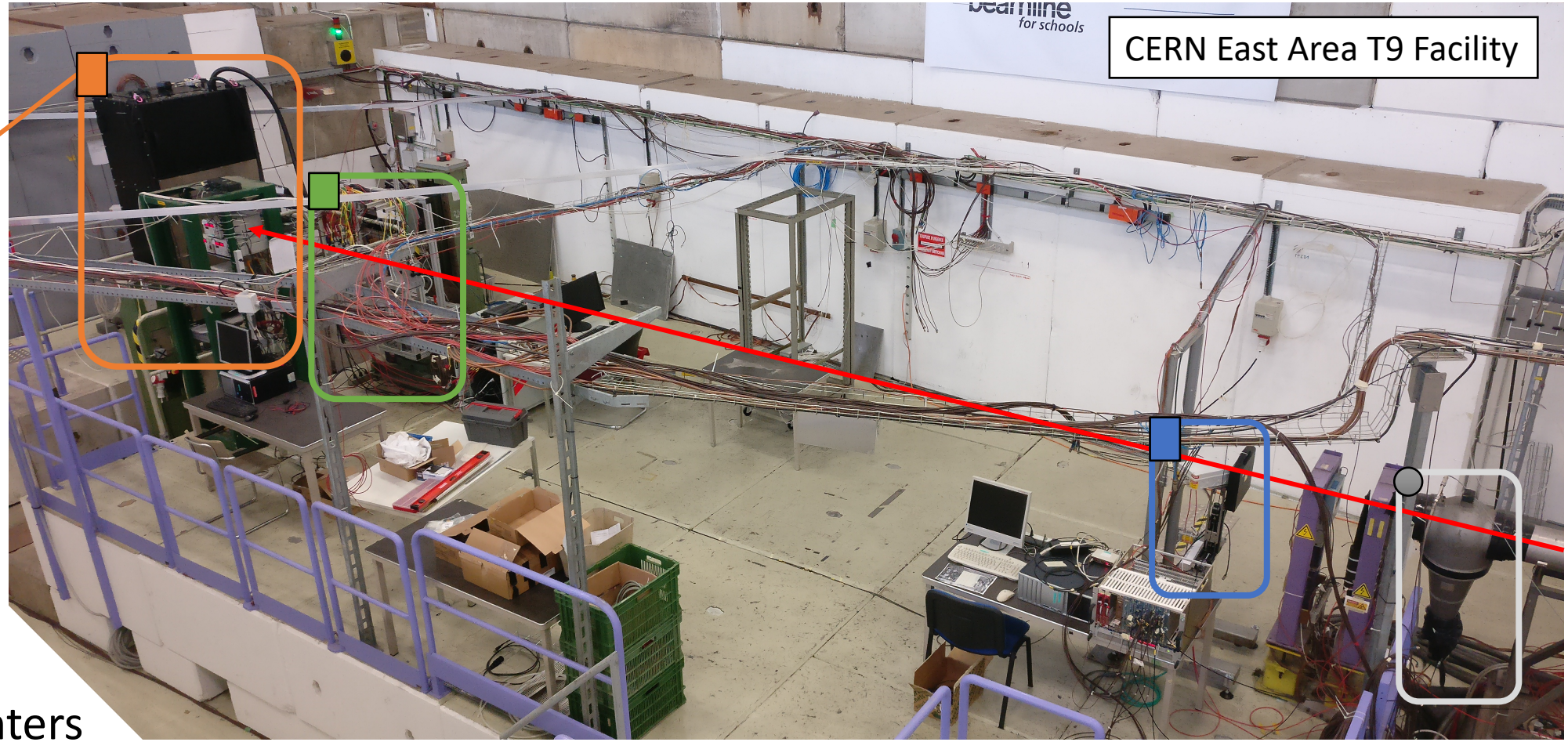
Mini-TORCH



Proto-TORCH

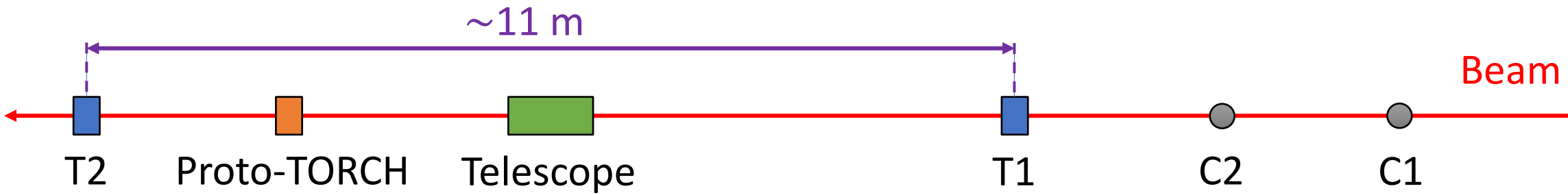


Proto-TORCH
Full-width, half-height



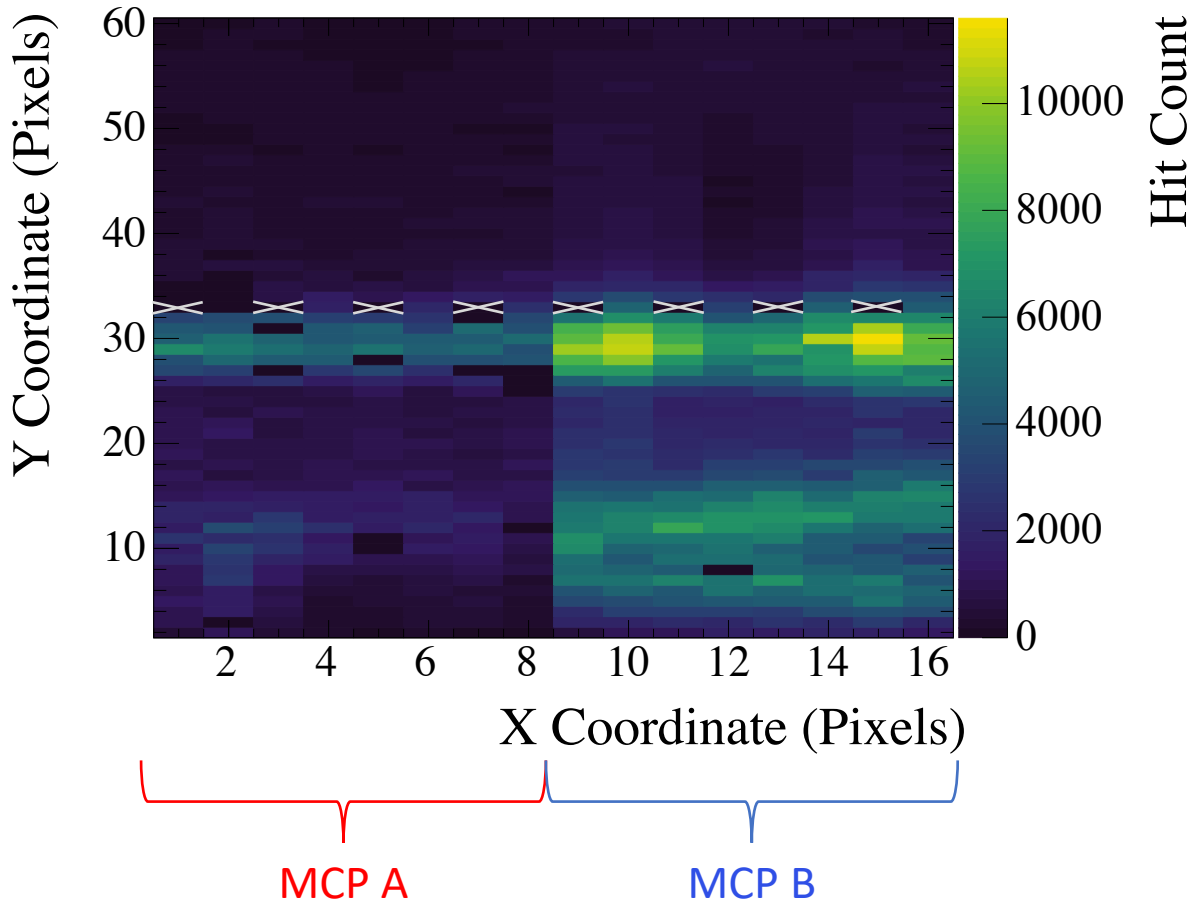
Timing Stations

Cherenkov Counters

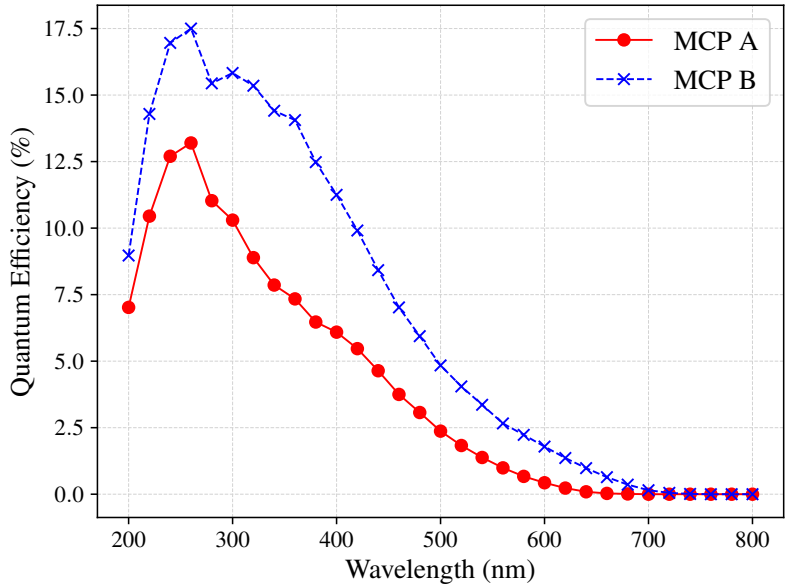


Initial look at Proto-TORCH data

Proto-TORCH Raw Hit Map



Difference in efficiency is due to Quantum Efficiency difference between tubes



Missing pixels are attributed to wire bonding issues

Crossed out channels are time reference channels

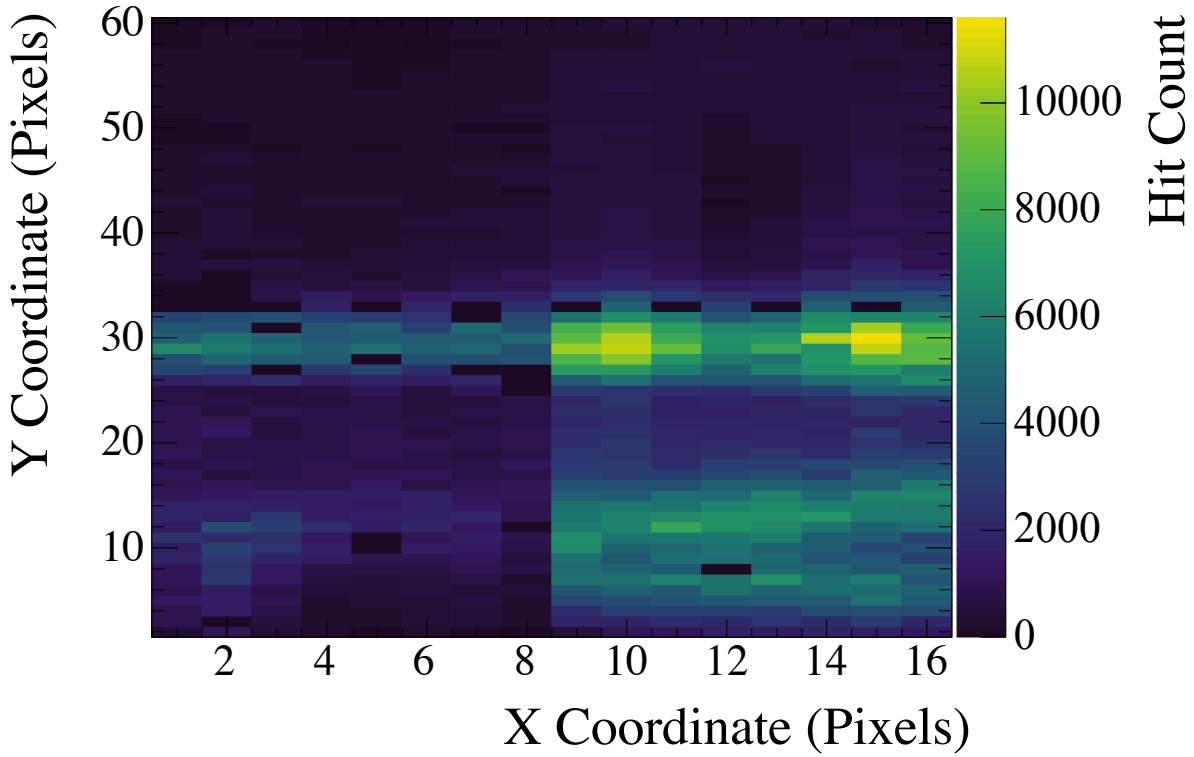
Time Resolution Analysis

Goal:

To measure the single photon timing resolution of Proto-TORCH

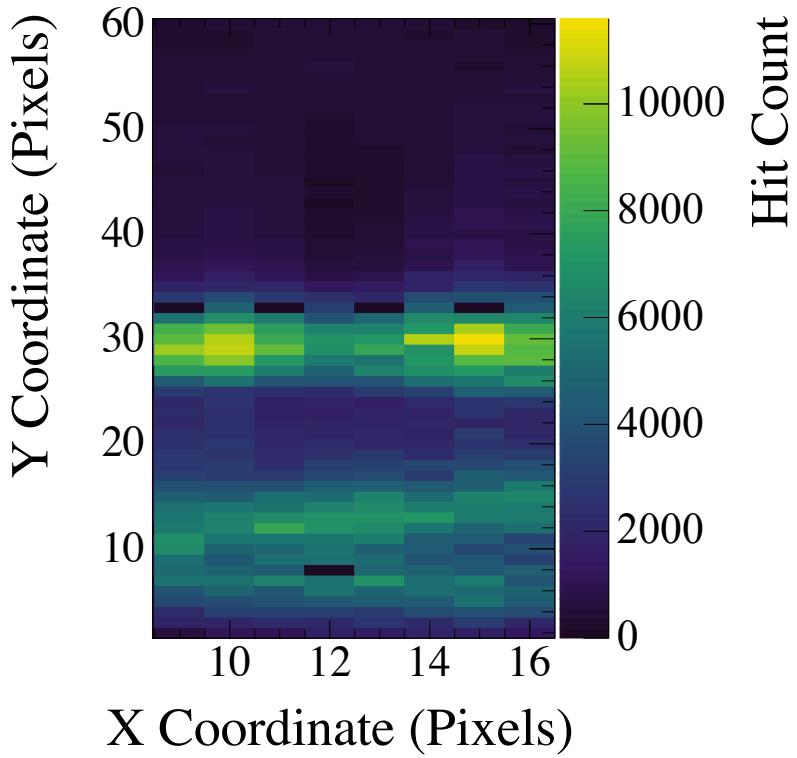
(Reminder: aiming for 70 ps)

Visualising Time Spread

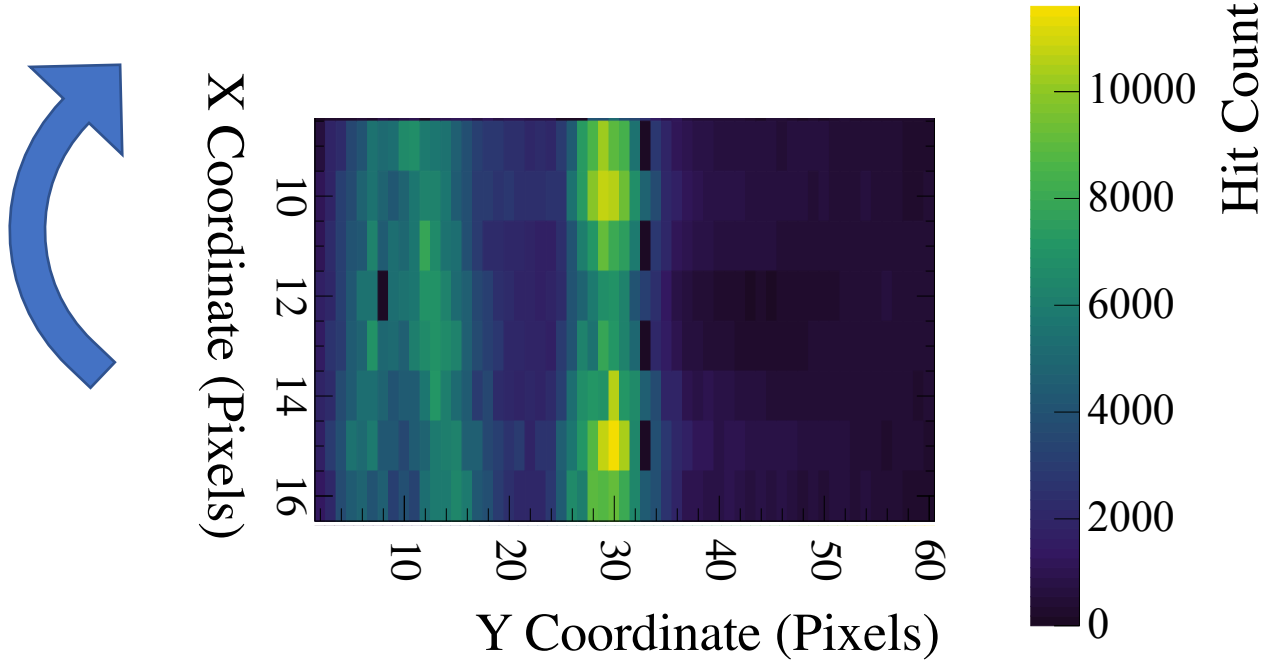


Visualising Time Spread

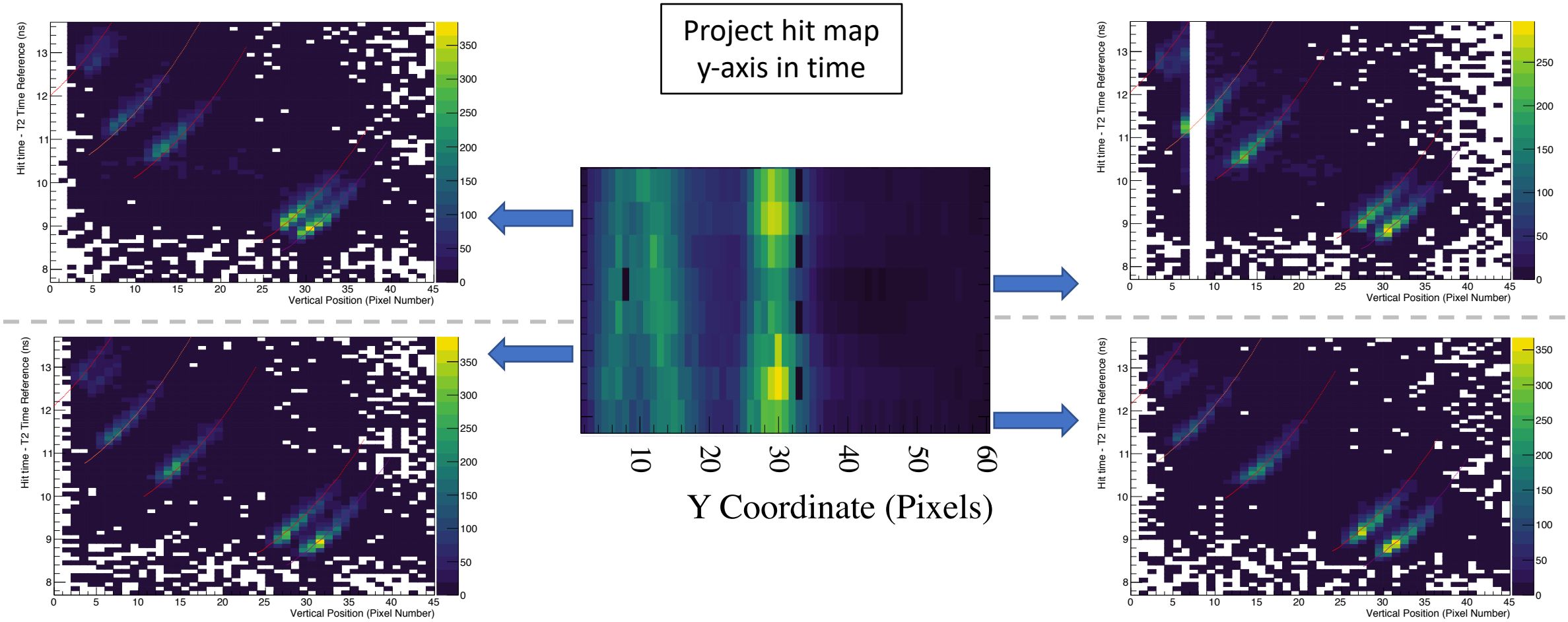
Focus analysis on more efficient MCP without dead channels



Visualising Time Spread

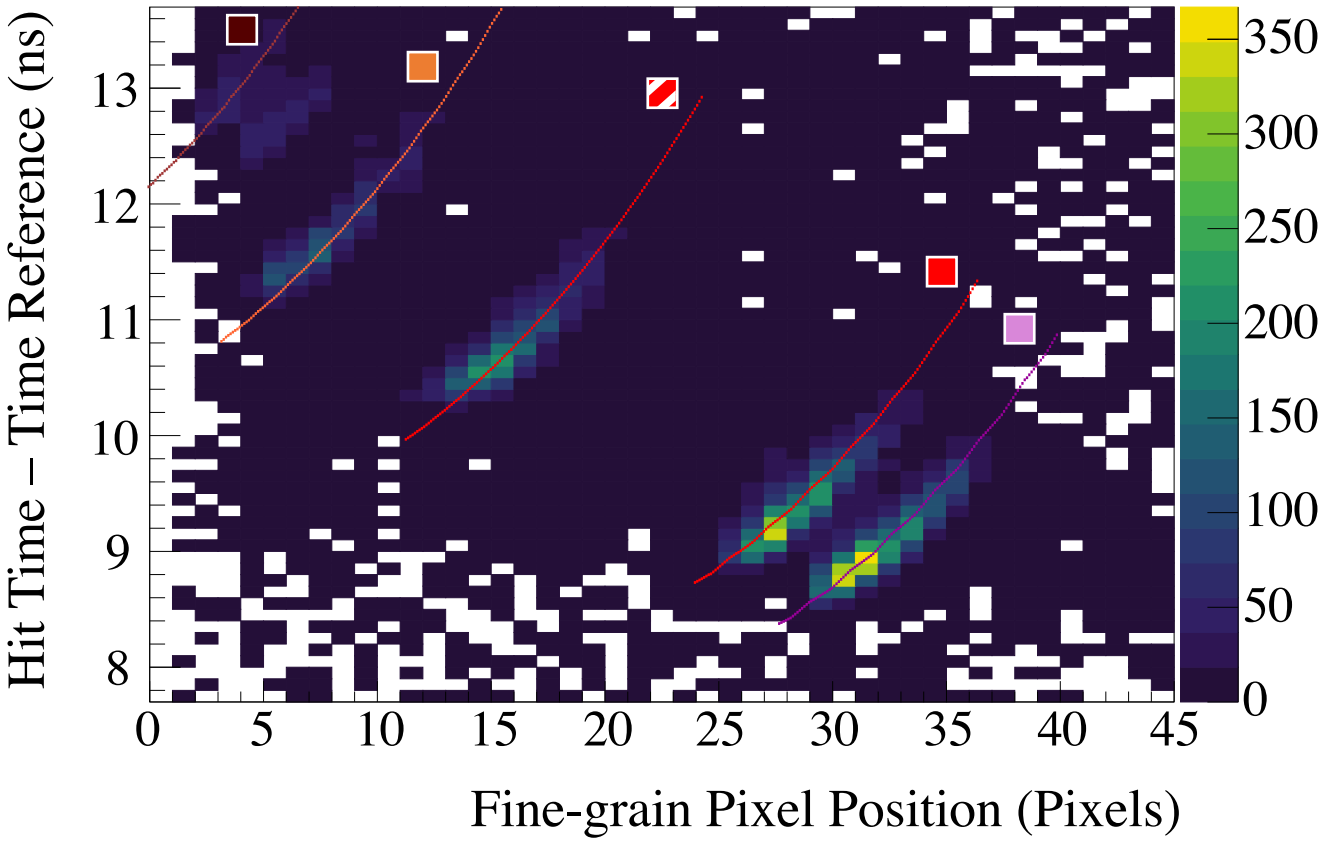


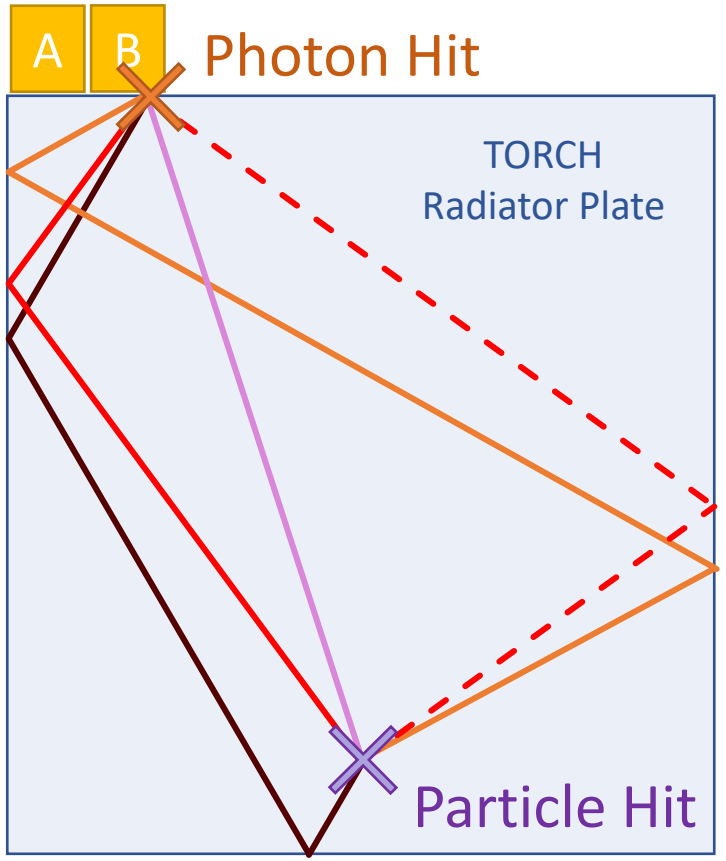
Visualising Time Spread



Separating Reflections

Example Time Projection Plot for single MCP column





Residual Distribution Widths

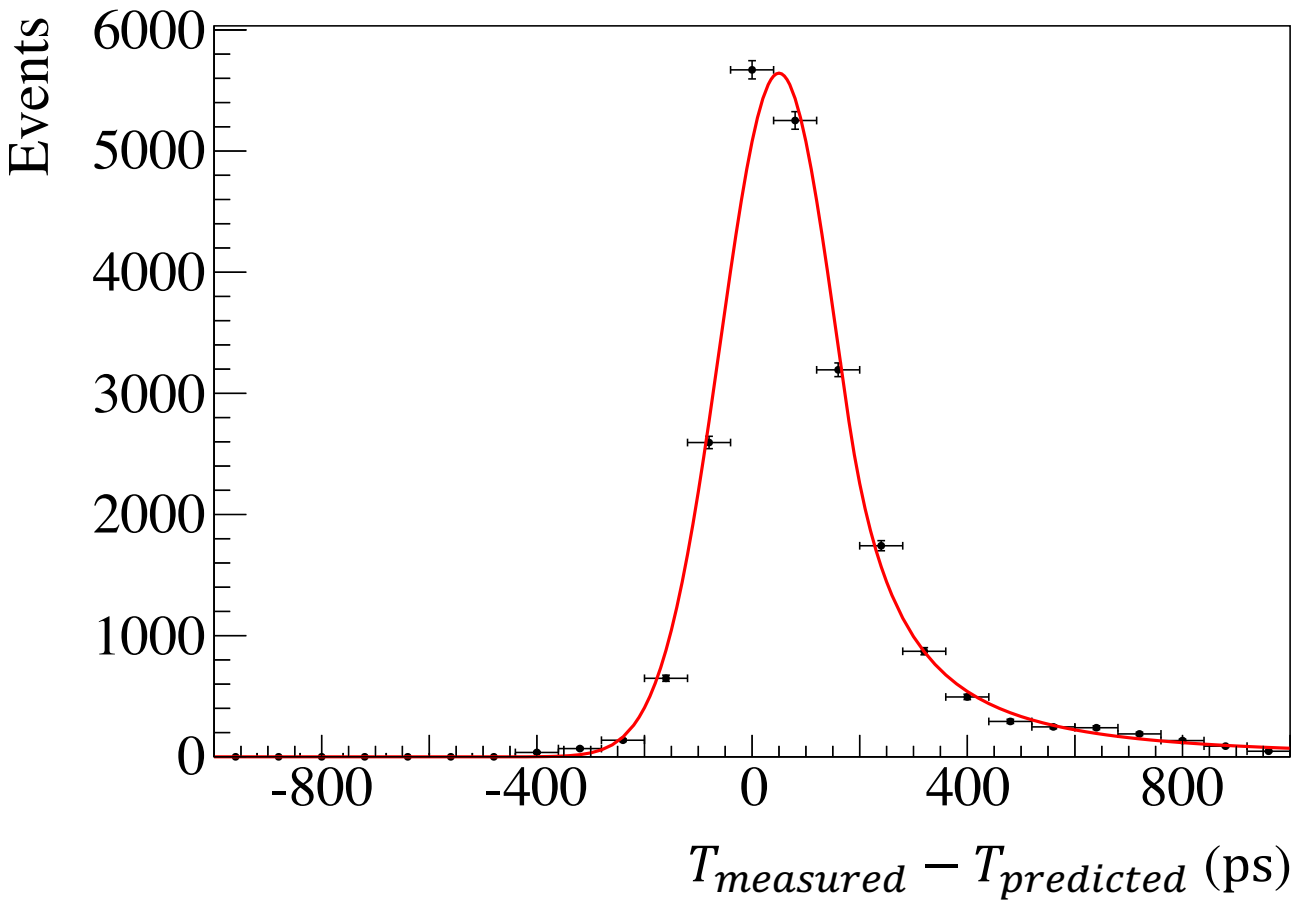
- $T_{measured} - T_{predicted}$ gives residual distribution

- Fit with Crystal Ball function

➢ Gaussian spliced with a exponential tail

➢ Width of Gaussian component gives timing resolution, almost…

Example residual distribution



Disentangling TORCH Time Resolution

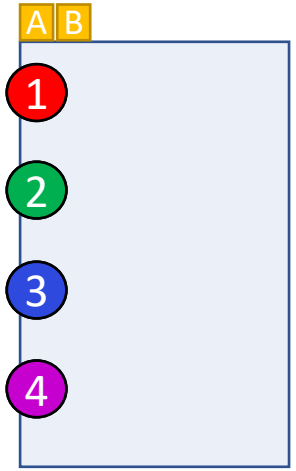
$$\sigma^2_{TORCH} = \sigma^2_{measured} - \sigma^2_{beam} - \sigma^2_{timeref}$$

- σ_{beam} is the time spread due to the beam profile
  - ➢ Measured using beam profile measurement and TORCH simulation
  - ➢ Varies between ~ 12 ps and ~ 32 ps depending on beam position

- $\sigma_{timeref}$ is the resolution of the time reference station
  - ➢ Independently measured to be 42 ± 3 ps

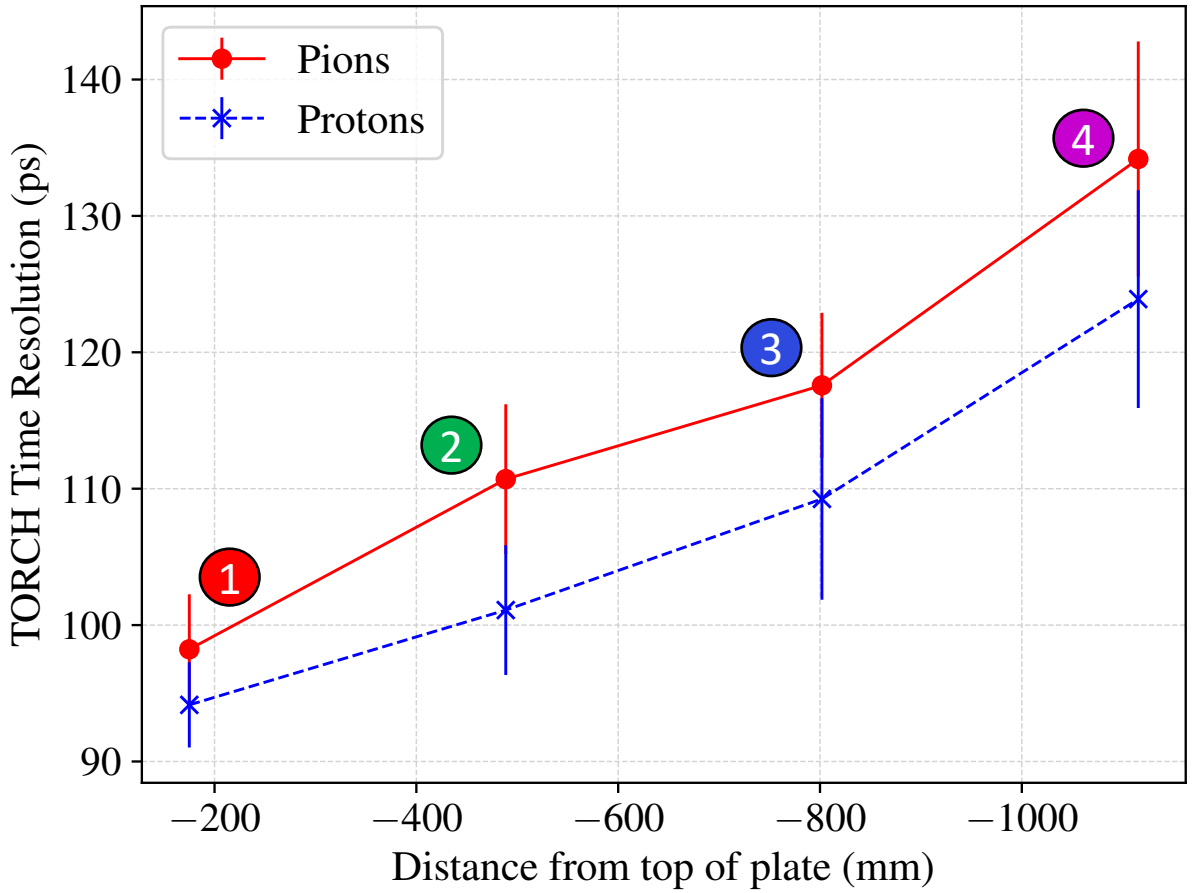
Preliminary Time Resolution Results

- Measure for each pixel column
  - ➢ Best achieved is 89.1 ± 1.3 ps
- Average individual column resolutions for beam positions down the plate



- Results still missing calibration of MCP charge per pixel

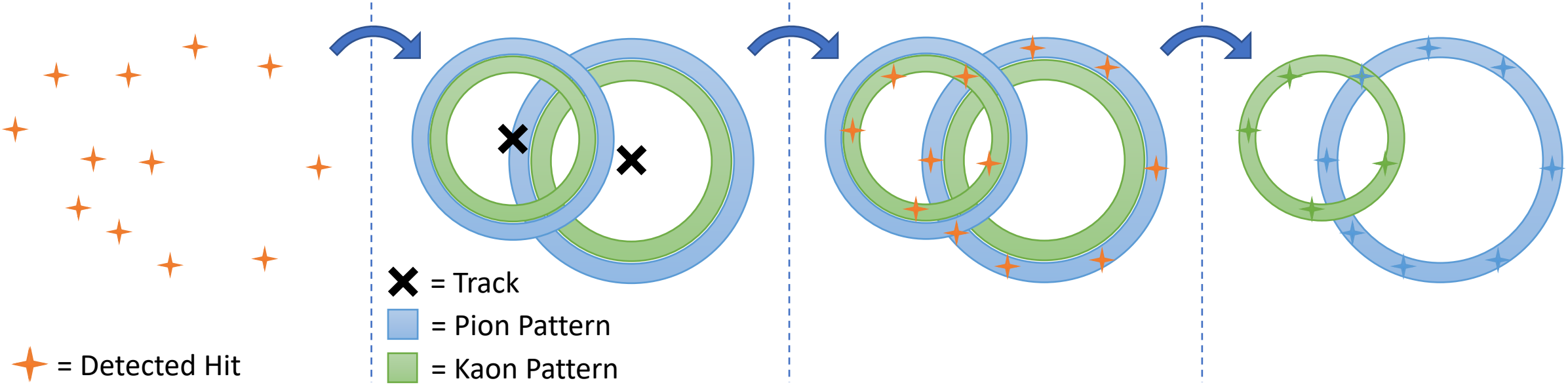
Average of individual resolutions measured for each position



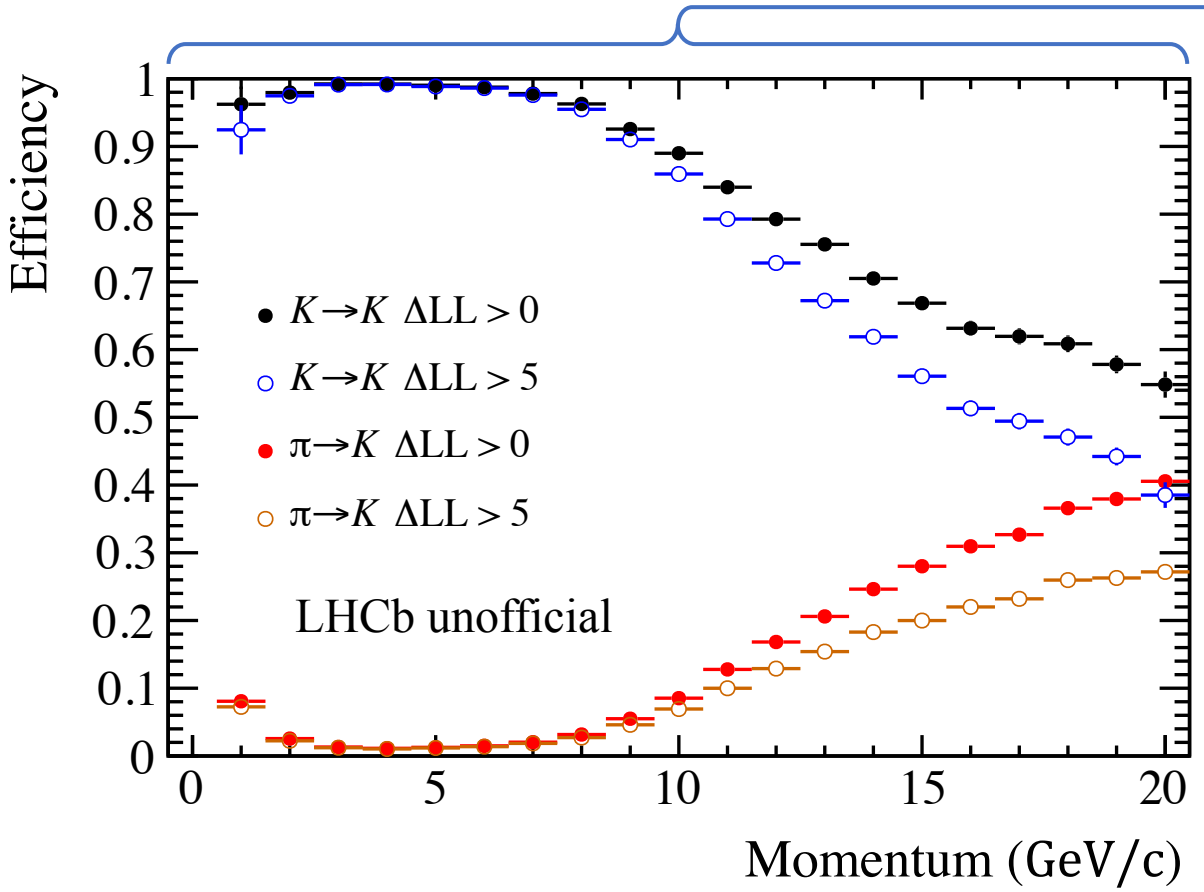
Simulating PID Performance in LHCb

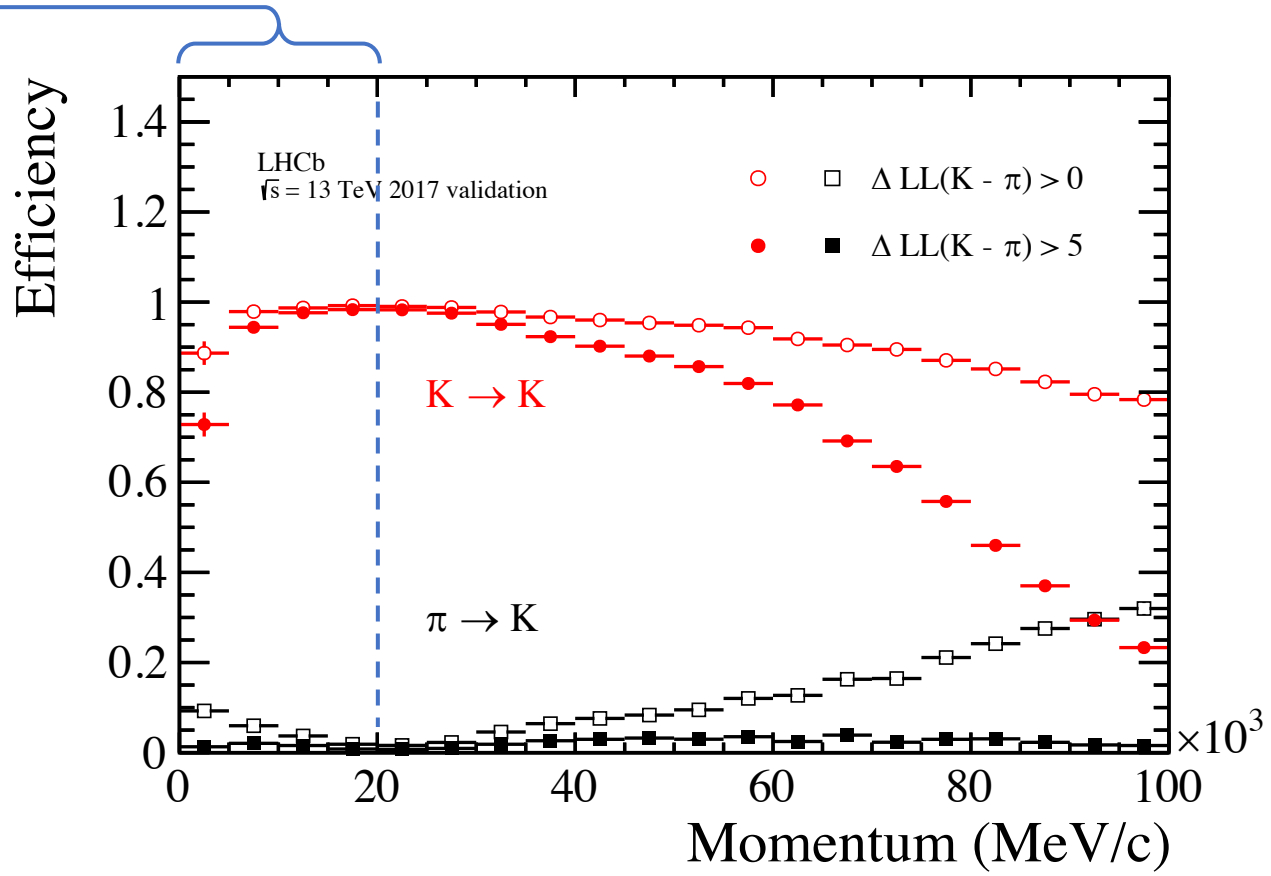
- TORCH integrated into full LHCb upgrade simulation

- Pattern recognition algorithm based on ΔLog-Likelihood (ΔLL) approach



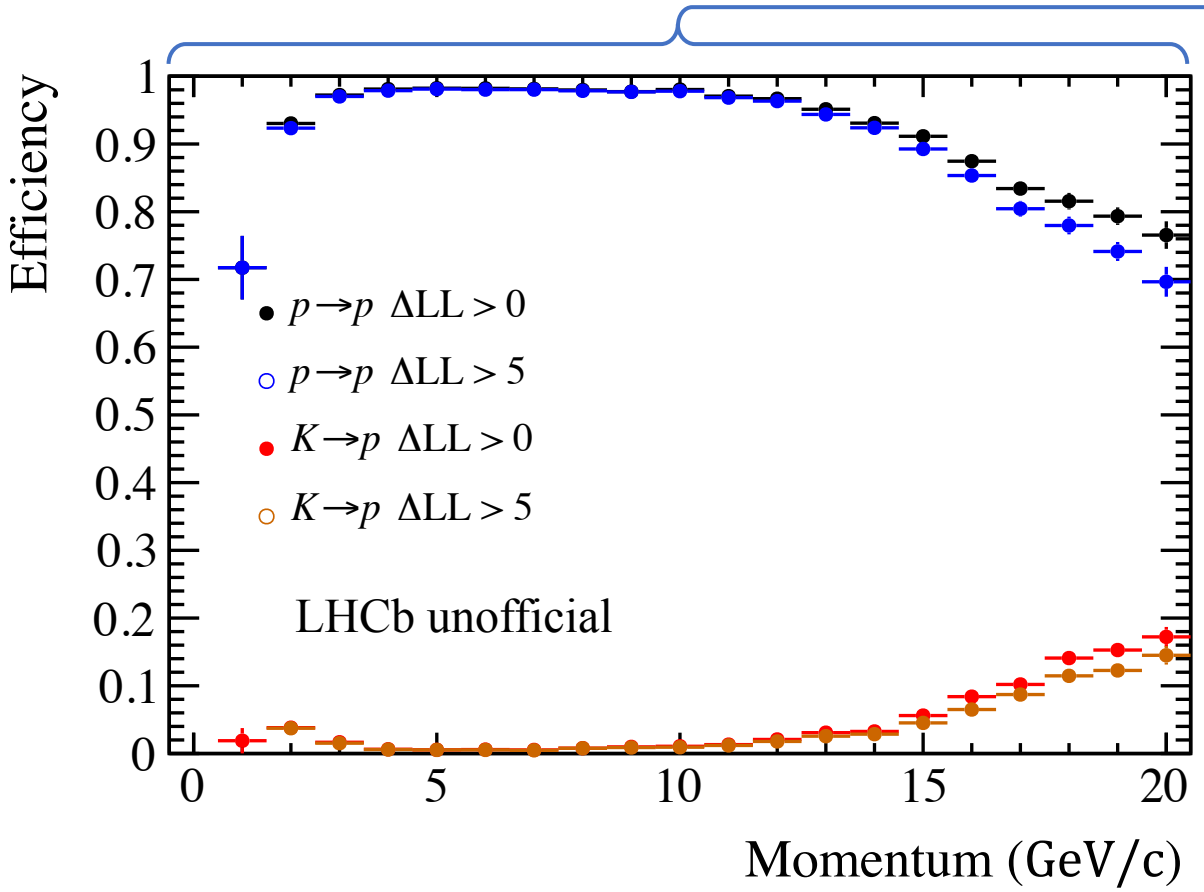
Preliminary PID Performance: $\pi - K$

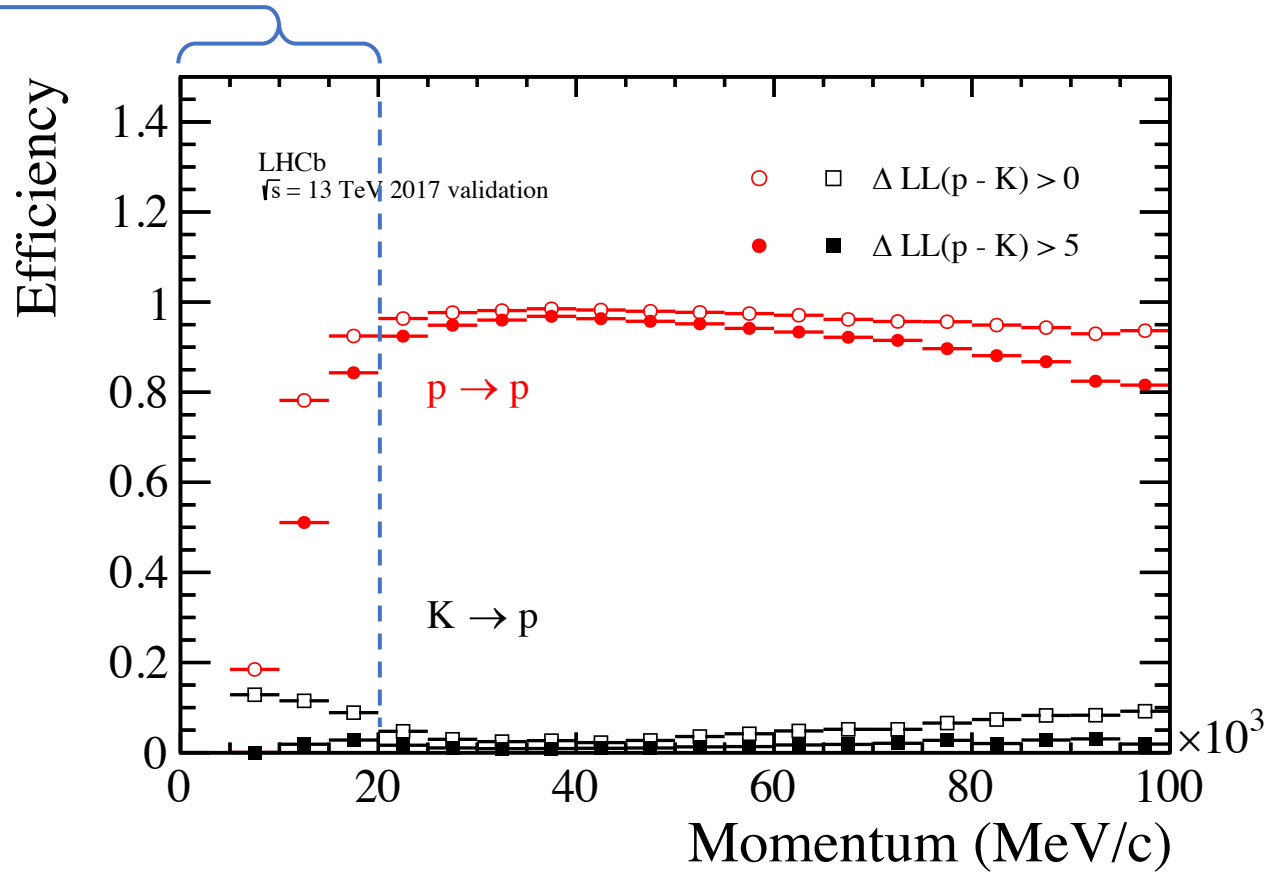




Inclusive B Events, $\mathcal{L} = 2{\times}10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Preliminary PID Performance: $\mathbf{K - p}$





Inclusive B Events, $\mathcal{L} = 2{\times}10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Conclusions

- TORCH has taken big step towards a full scale demonstrator

- Time resolution is approaching the desired 70 ps

➢ Current results indicate the need for further calibrations (in progress)

- Simulation studies show strong PID performance in LHCb

➢ Work ongoing to study TORCH performance in High Luminosity LHC regime

Back-up

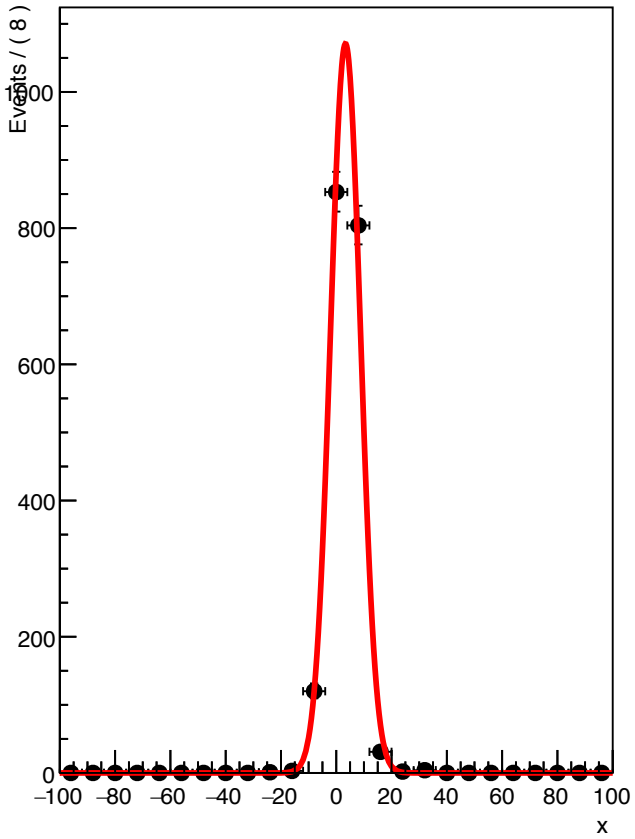
Spread from beam

- Measure spread from beam using simulation

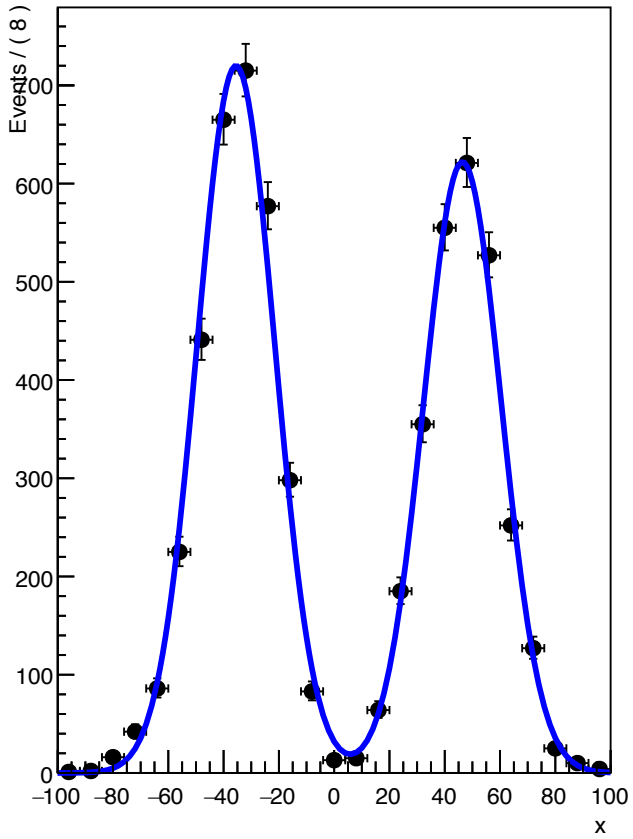
➢ Compare width of residual distribution with and without beam spread

- Red fit is a single gaussian
- Each blue peak is two convolved gaussians, one with its width fixed from the red fit

Pencil Beam
(σ_{ideal})

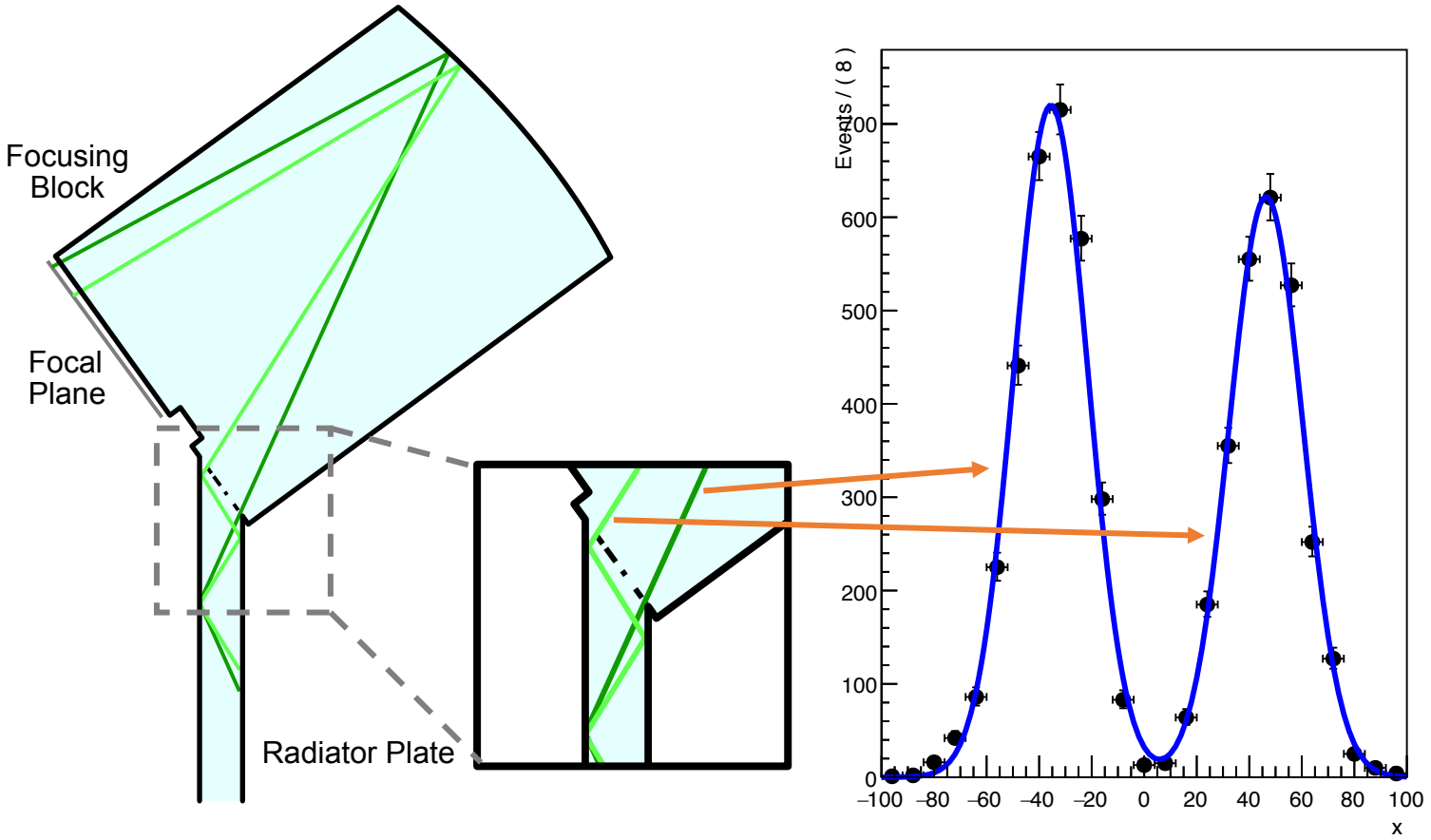


Beam profile from data
$\left(\sqrt{\sigma_{beam}^2 + \sigma_{ideal}^2}\right)$

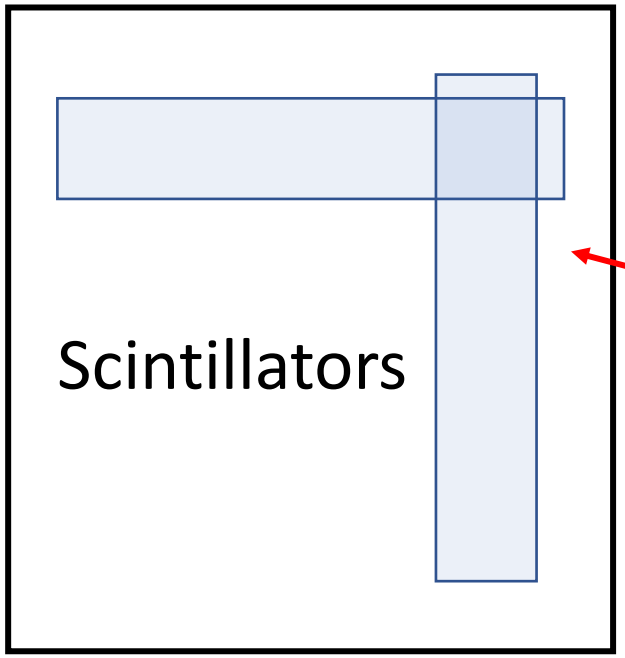


Explaining the double peak

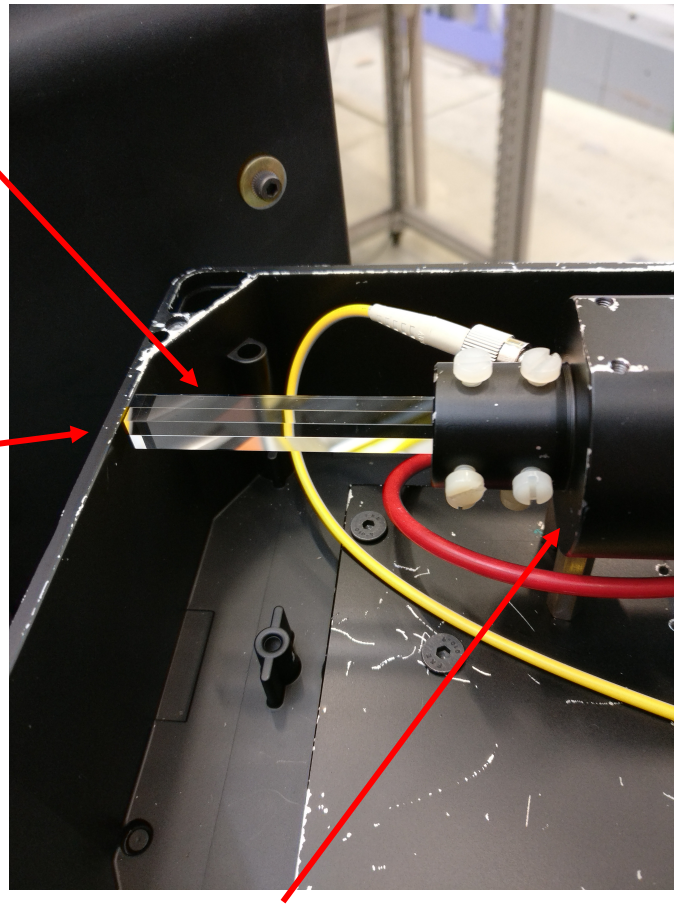
- Optics design results in a discontinuity in the photon path
- In data this cannot be resolved, but becomes apparent in simulation



The Testbeam Setup – Timing Stations



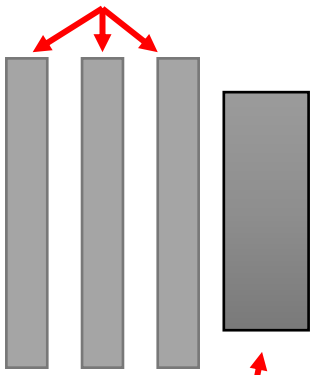
Borosilicate
"Timing Finger"



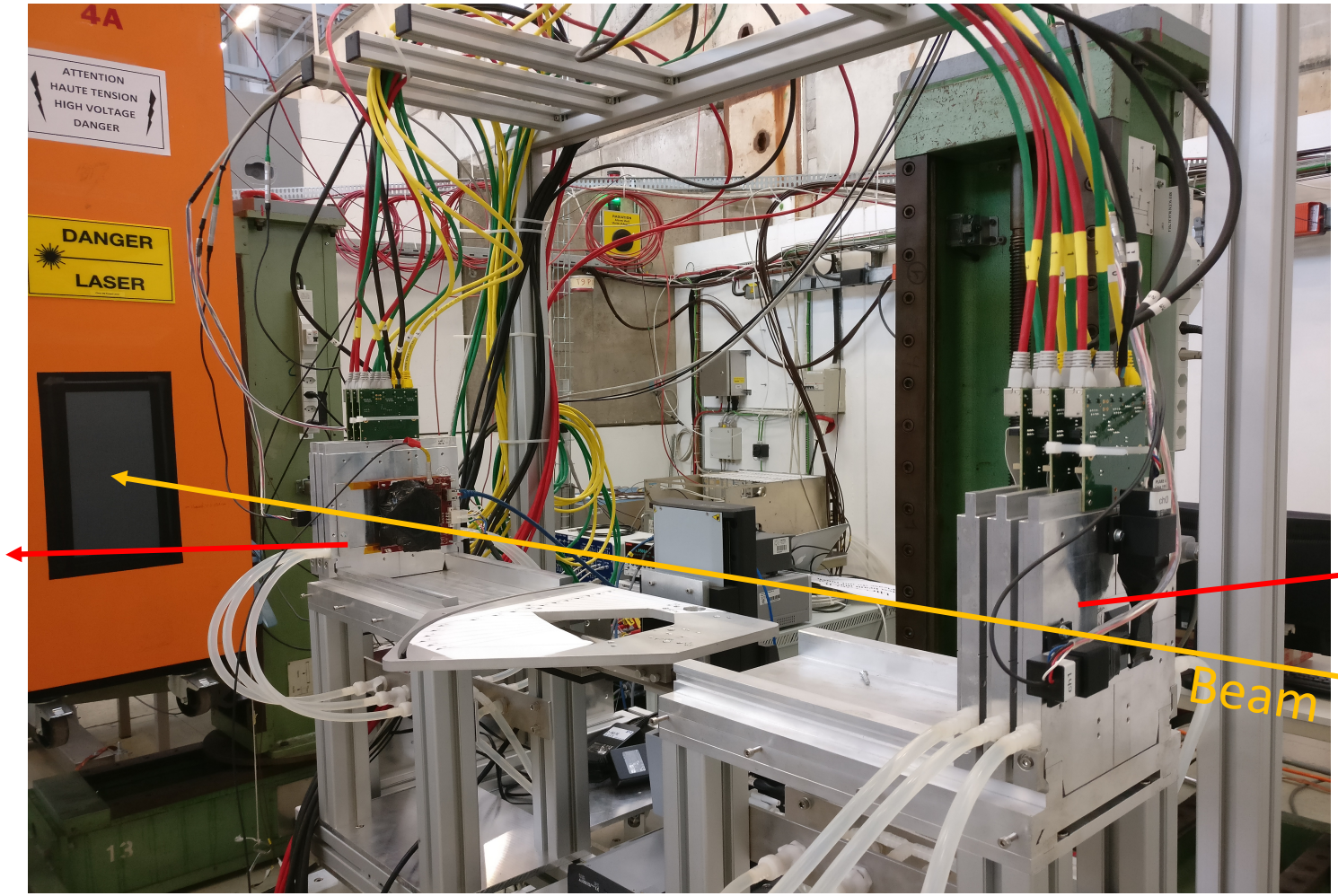
MCP-PMT

The Testbeam Setup – Beam Telescope

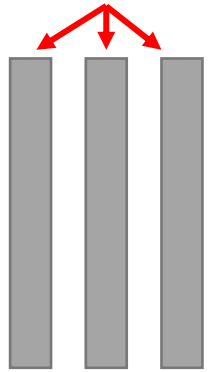
Pixel (MIMOSA) Planes



Timing Plane



Pixel (MIMOSA) Planes



Time walk Correction

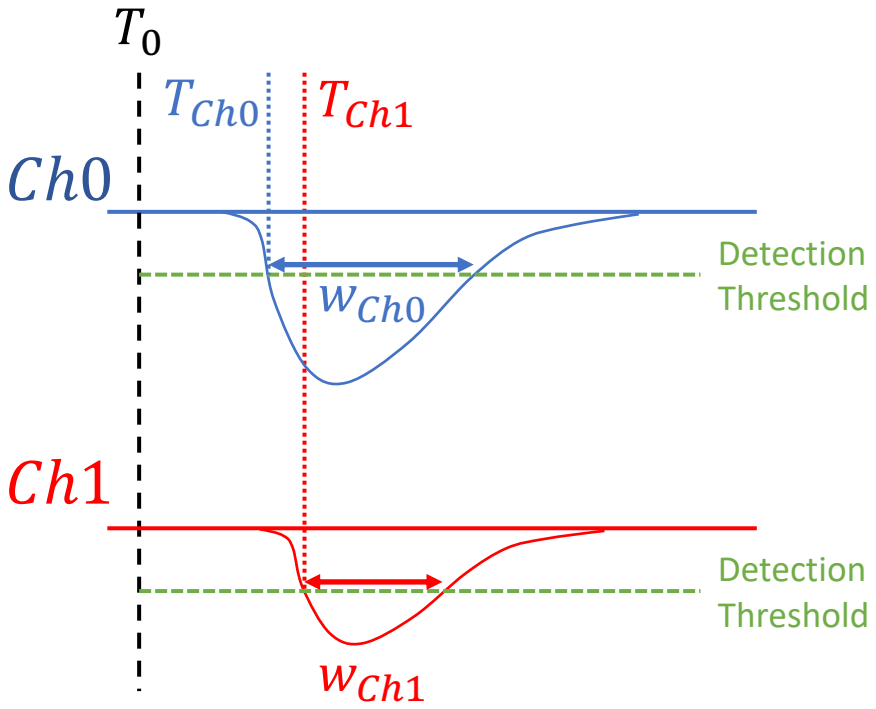
- Hits in TORCH are grouped into clusters

➢ 1 cluster = 1 incident photon

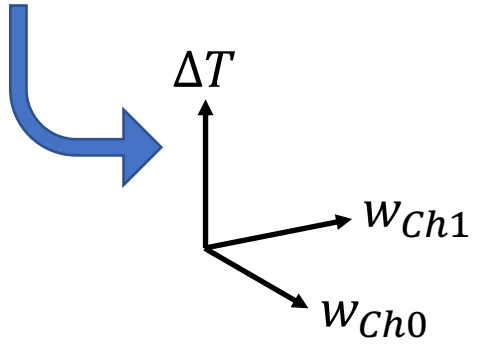
- Hits in a cluster should be simultaneous

➢ Time walk correction adjusts the relative time of all hits in a cluster to make this true

- Data driven approach utilises correlation between hit width (w_x) and leading edge time (T_x) to perform the correction



$$T_{Ch0} - T_{Ch1} = \Delta T(w_{Ch0}, w_{Ch1})$$



Fit to get time walk correction