Development of TRBv3 & *FIRST* Results of *FIRST* Test Beam

Cahit Uğur

Helmholtz-Institut Mainz

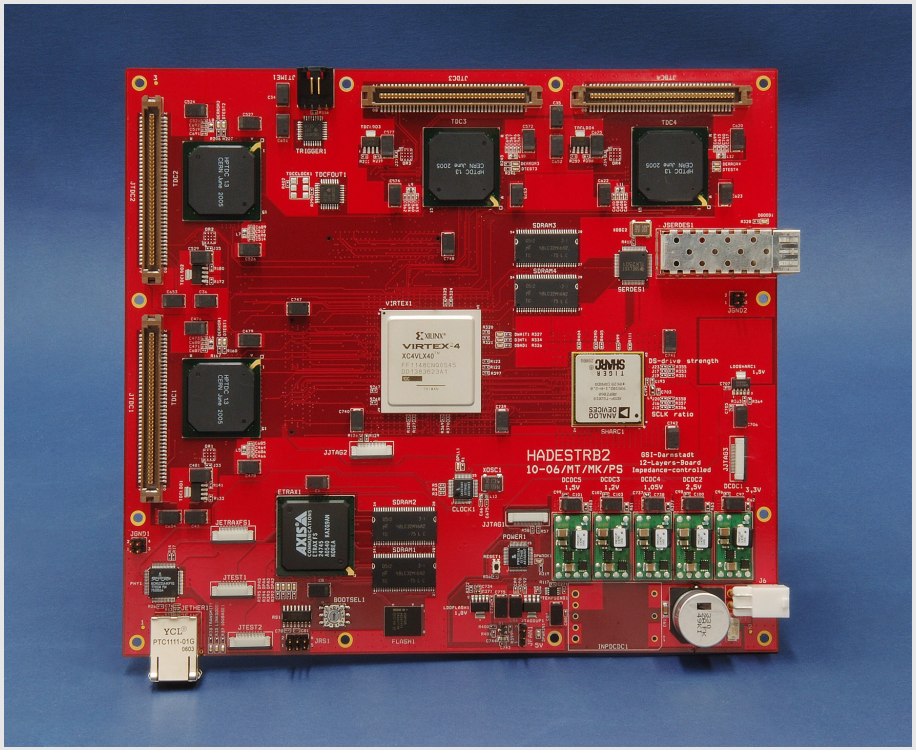
XL. PANDA Collaboration Meeting
5 March 2012, GSI Darmstadt, Germany

Outline

- Motivation
- TDC in FPGA
- Laboratory test results
- DIRC Prototype test beam setup and first results
- Conclusion & Outlook

Motivation

- to have high resolution, high channel density, low cost
- to replace ASIC-HPTDCs from CERN
- to provide solutions for different requirements e.g. higher resolution, zero dead time
- to provide different measurement capabilities, e.g. ToF, Charge
- to use in different detectors for different experiments



TDC Readout Board v2

Photo by Gaby Otto, GSI Darmstadt, 22.12.2006.

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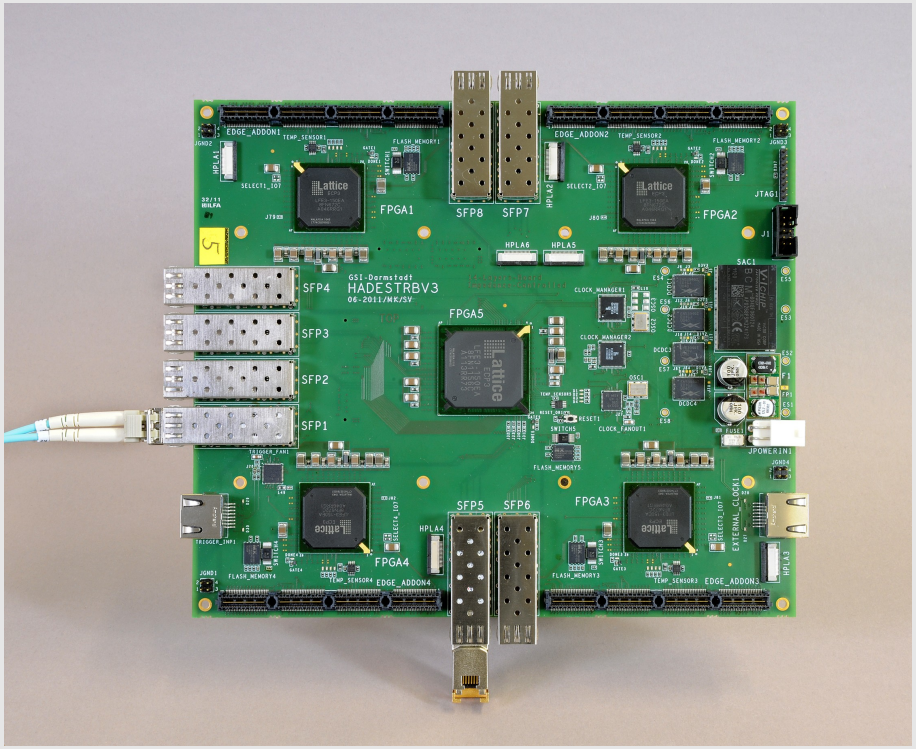

TDC Readout Board v3

Photo by Gaby Otto, GSI Darmstadt, 22.12.2006.

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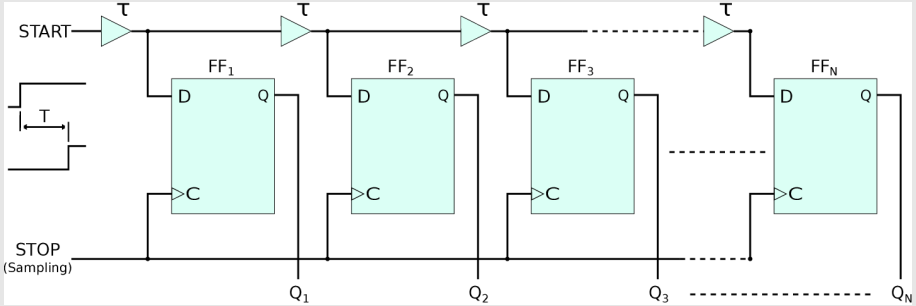
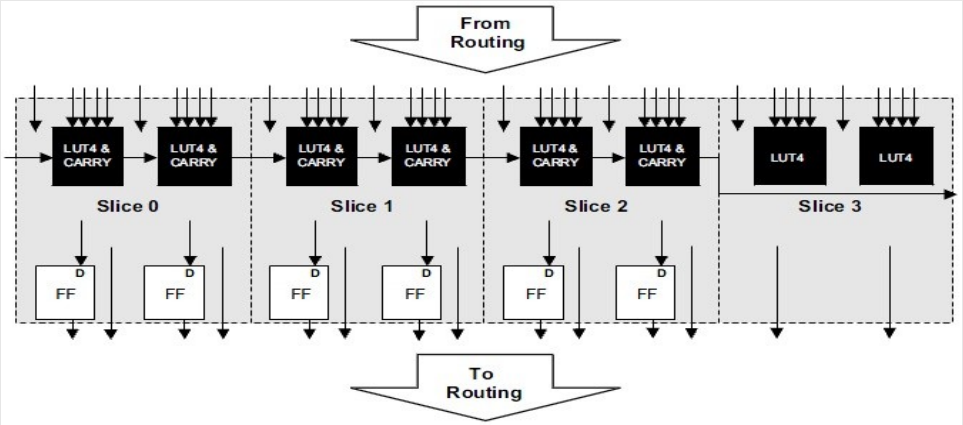
TDC in FPGA
Tapped Delay Line Method

- Tapped delay line is used for fine time measurements – suits well with the FPGA architecture
- Delay elements are realised by LUTs
- Fast carry chain structure forms the delay line
- Registers are used to sample the delay line



Tapped Delay Line Method [1]



PFU Diagramm [2]

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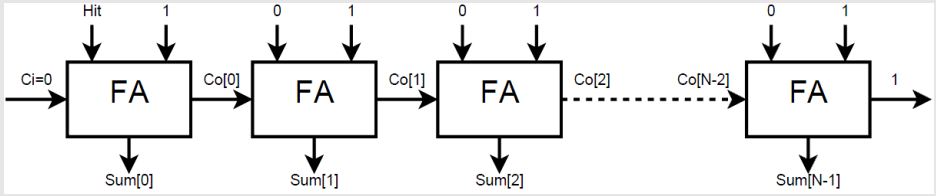
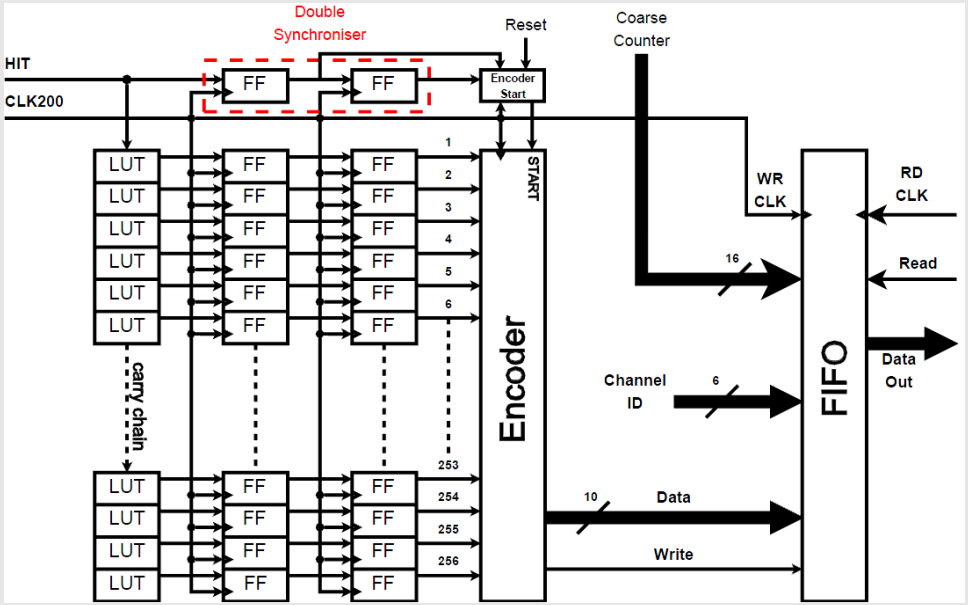
TDC in FPGA

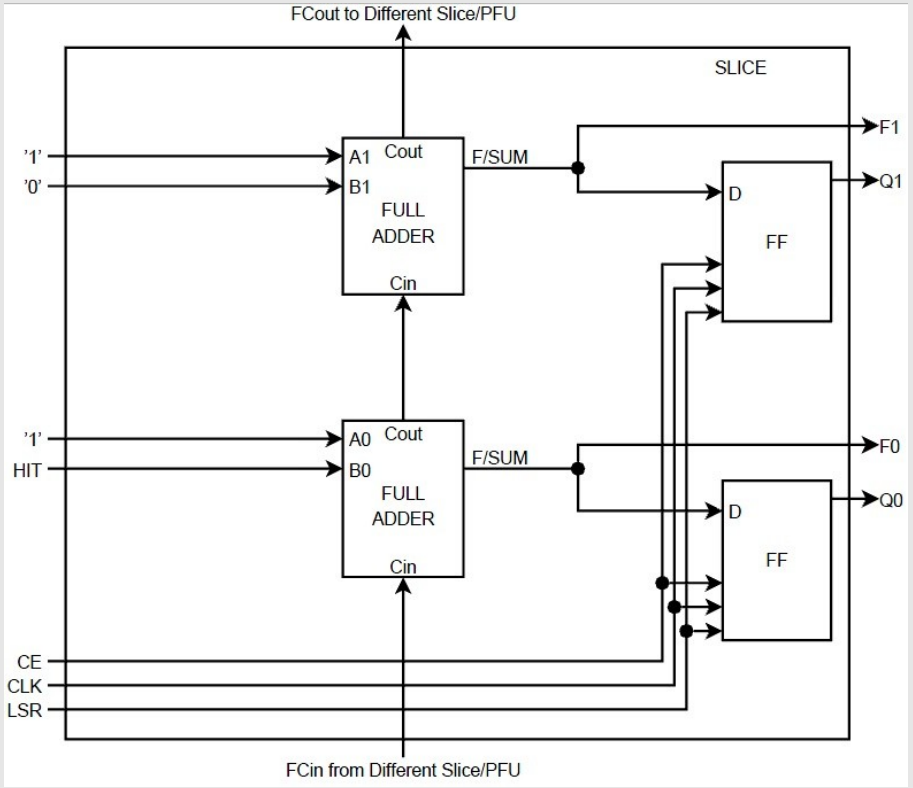
Architecture of the TDC



Delay line is realised with Full Adders [3]



TDC Architecture



Slice diagram with LUTs
programmed as Full Adders

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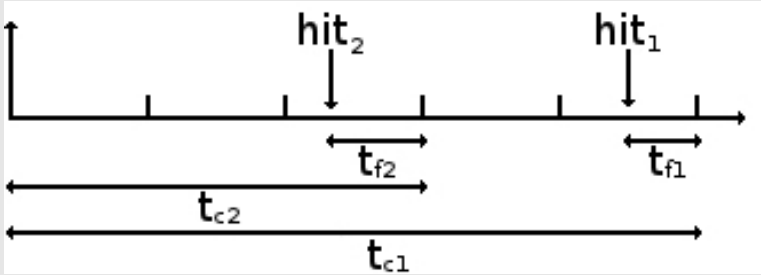
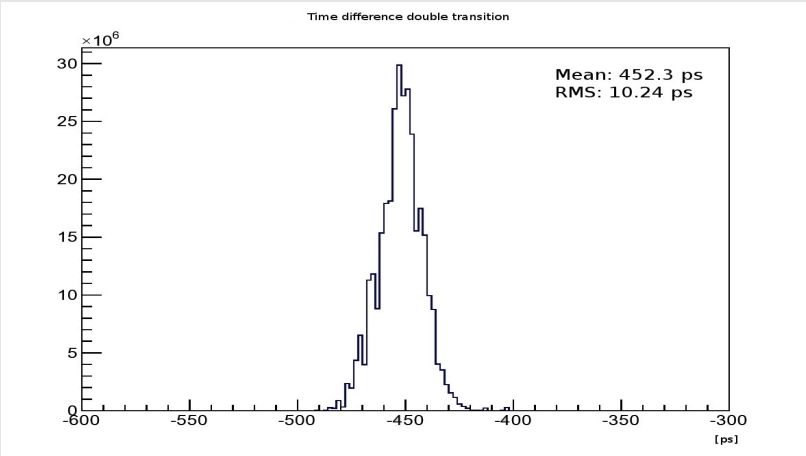
Laboratory Test Results

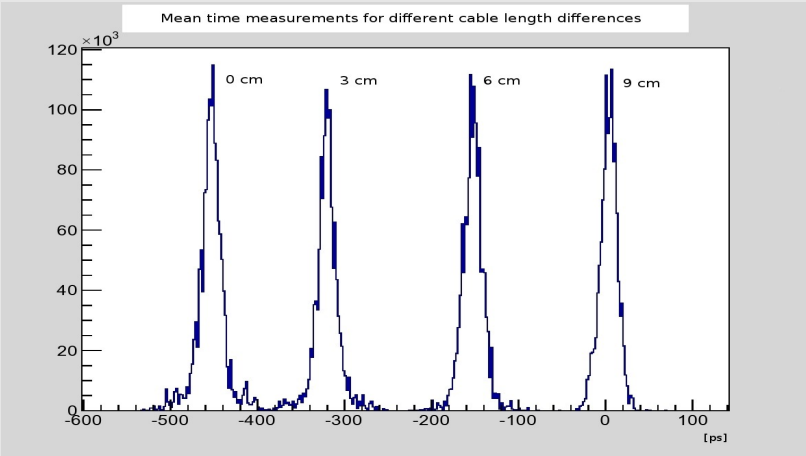
- Time difference measured between 2 channels
- $\Delta t = (t_{coarse1} - t_{coarse2}) - (t_{fine1} - t_{fine2})$
- RMS measured: 10.34 ps against the same clock
- Resolution: 10.34 ps / √2 = 7.3 ps RMS



Time difference between two measurements



Time resolution test



Mean measurement test

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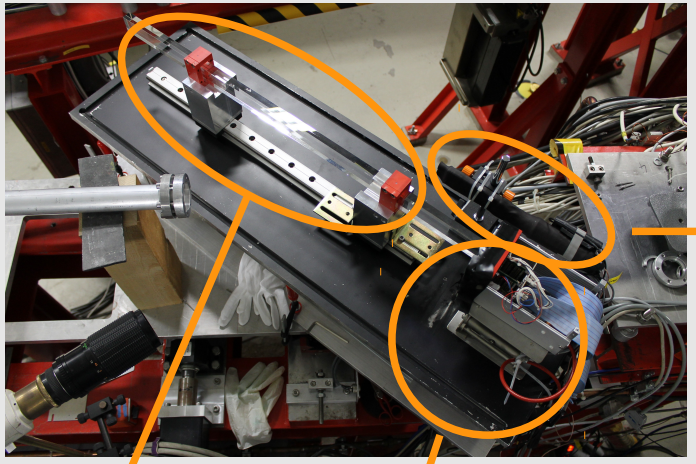
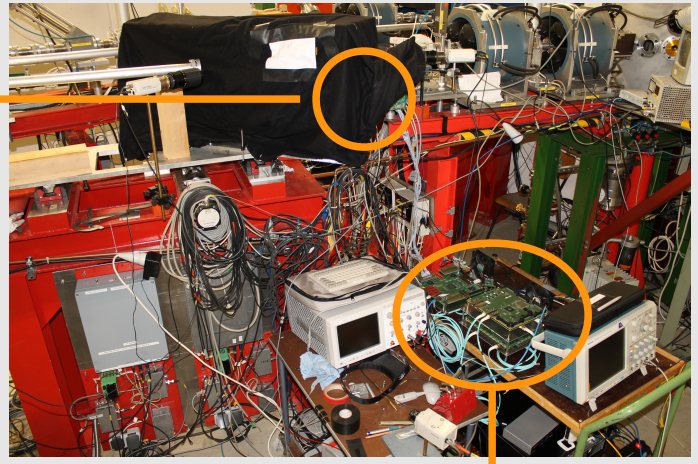
DIRC Prototype Test Beam @ MAMI

25 February 2012



Discriminator

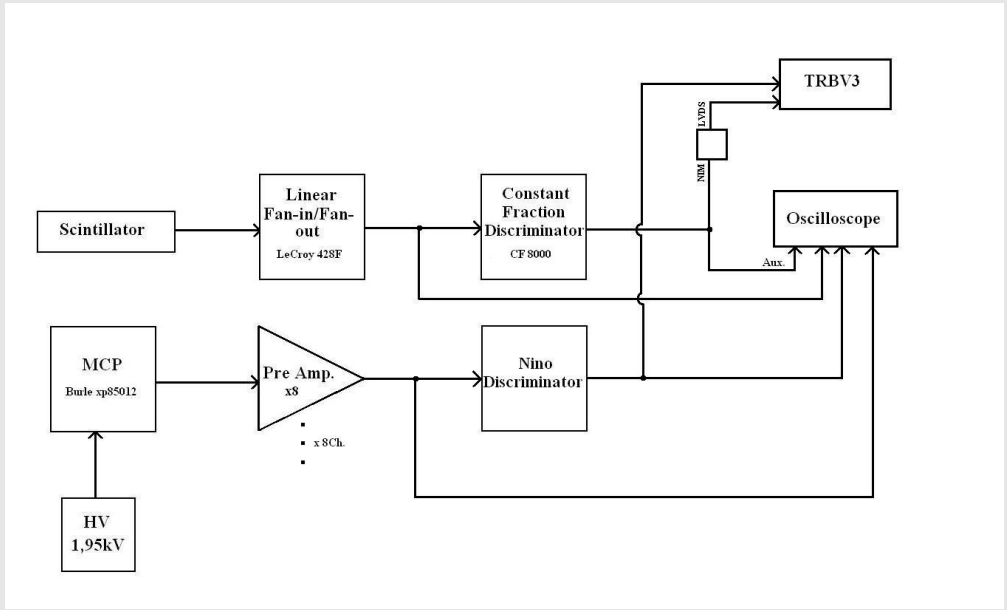
Scintillator



Quarz bar

MCP
&
Pre-amplifier

TRB3
&
Readout
Electronics



Triggerless!

Electron beam
Beam energy: 855 MeV
Beam spread: 0,3°

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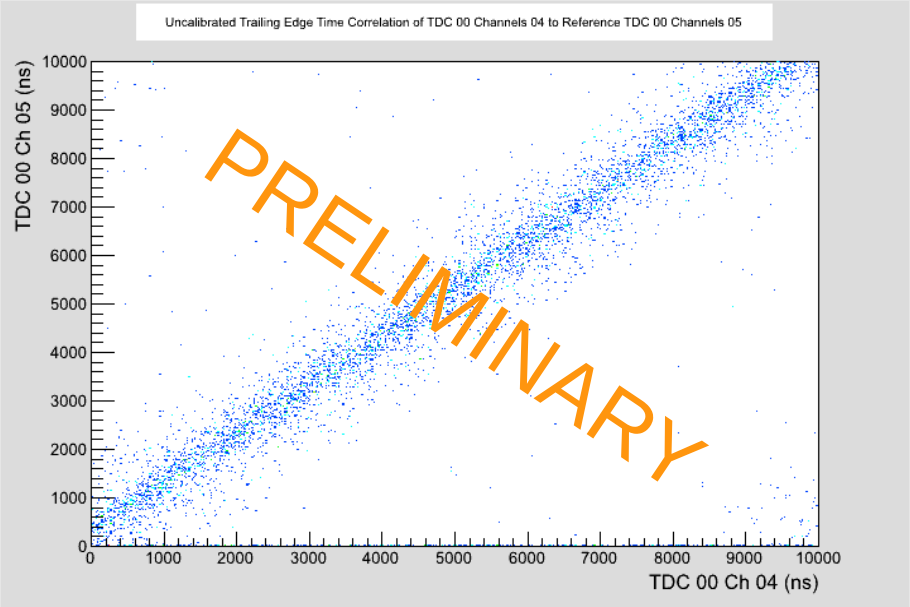
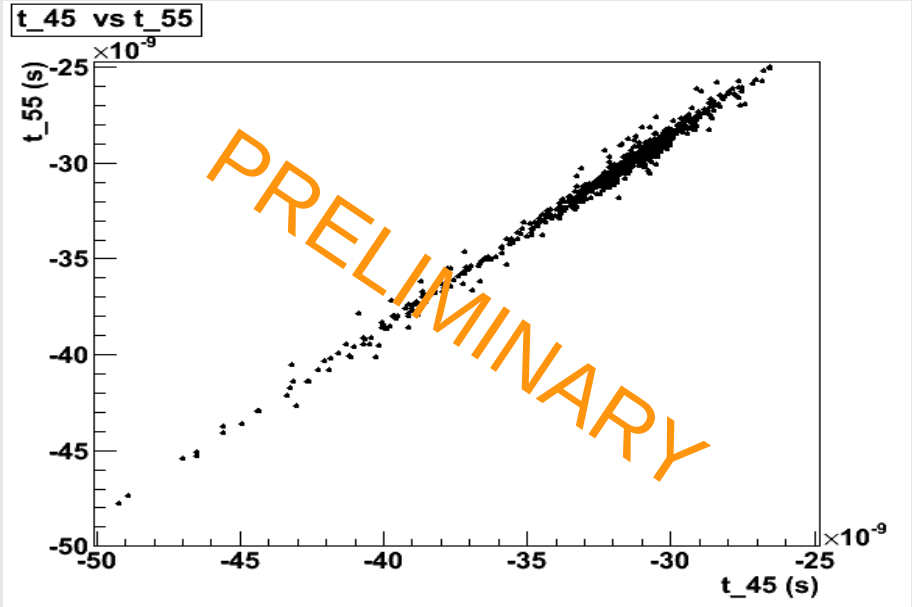
FIRST Results from the *FIRST* Beam

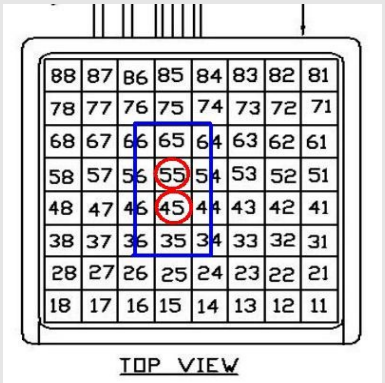
Time Correlation between pixel 45 & 55



TDC result



Oscilloscope result



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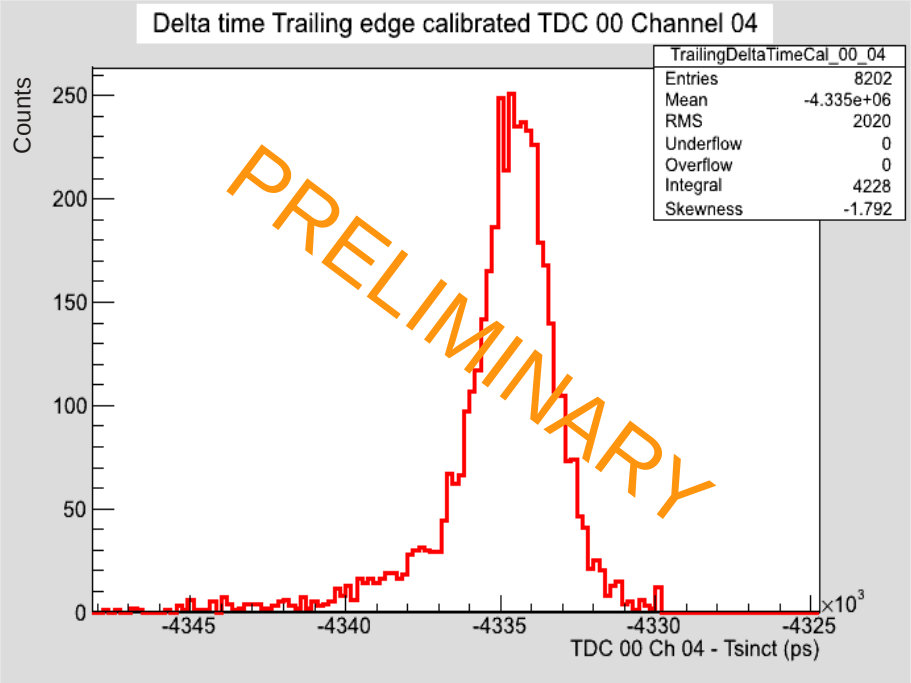
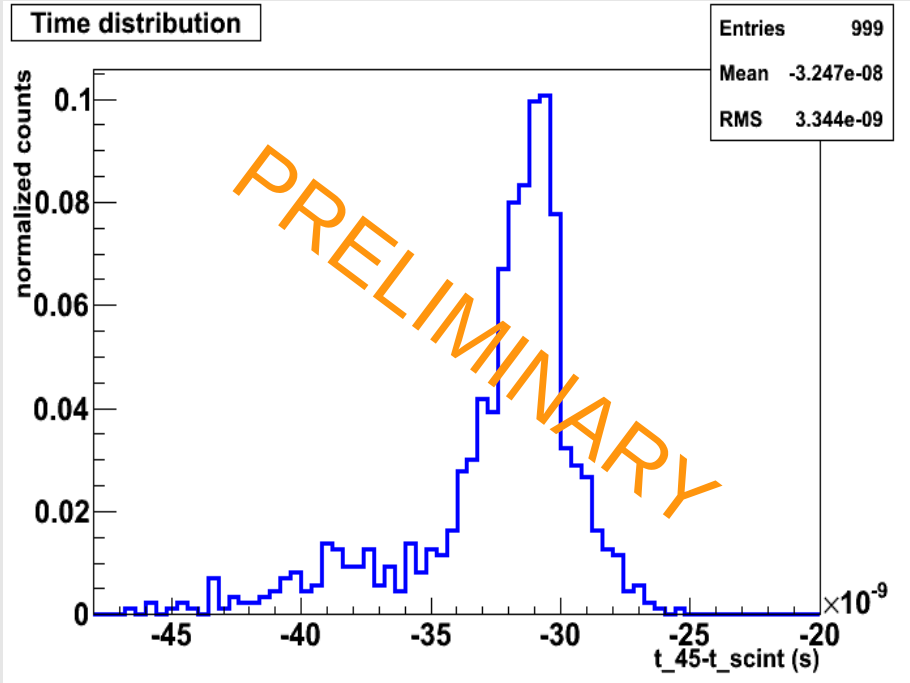
FIRST Results from the *FIRST* Beam

Measured time difference between the pixel 45 and scintillator



TDC result



Oscilloscope result

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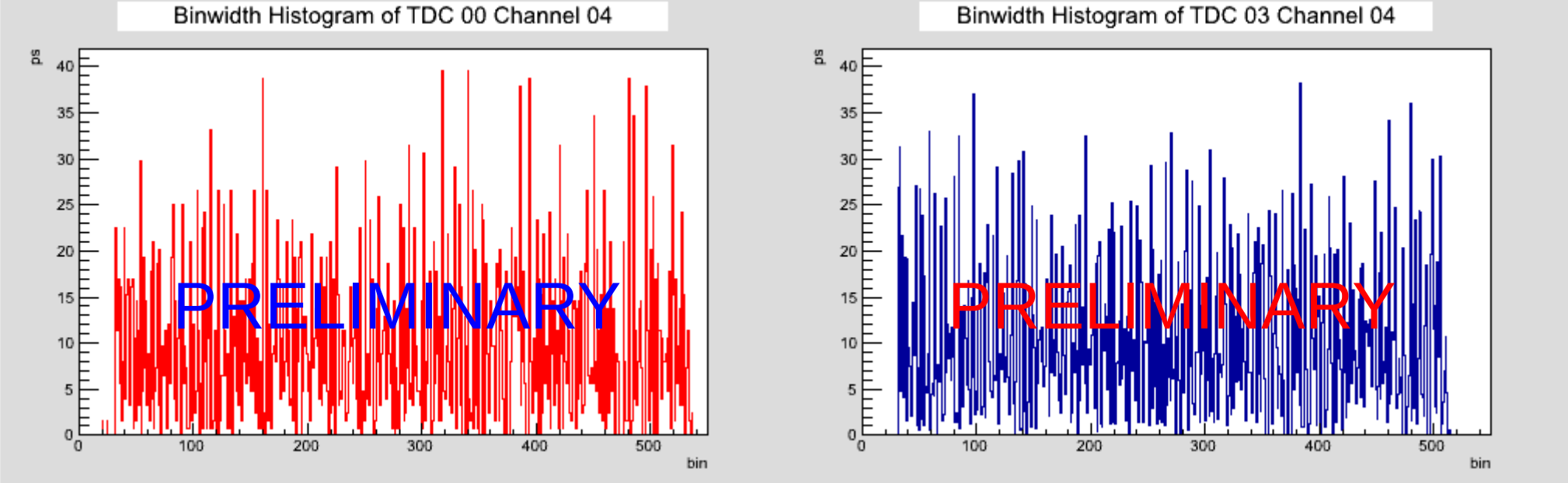
FIRST Results from the *FIRST* Beam

Bin width comparison of Beam results and Lab results



Beam result

Lab result

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Conclusion & Outlook

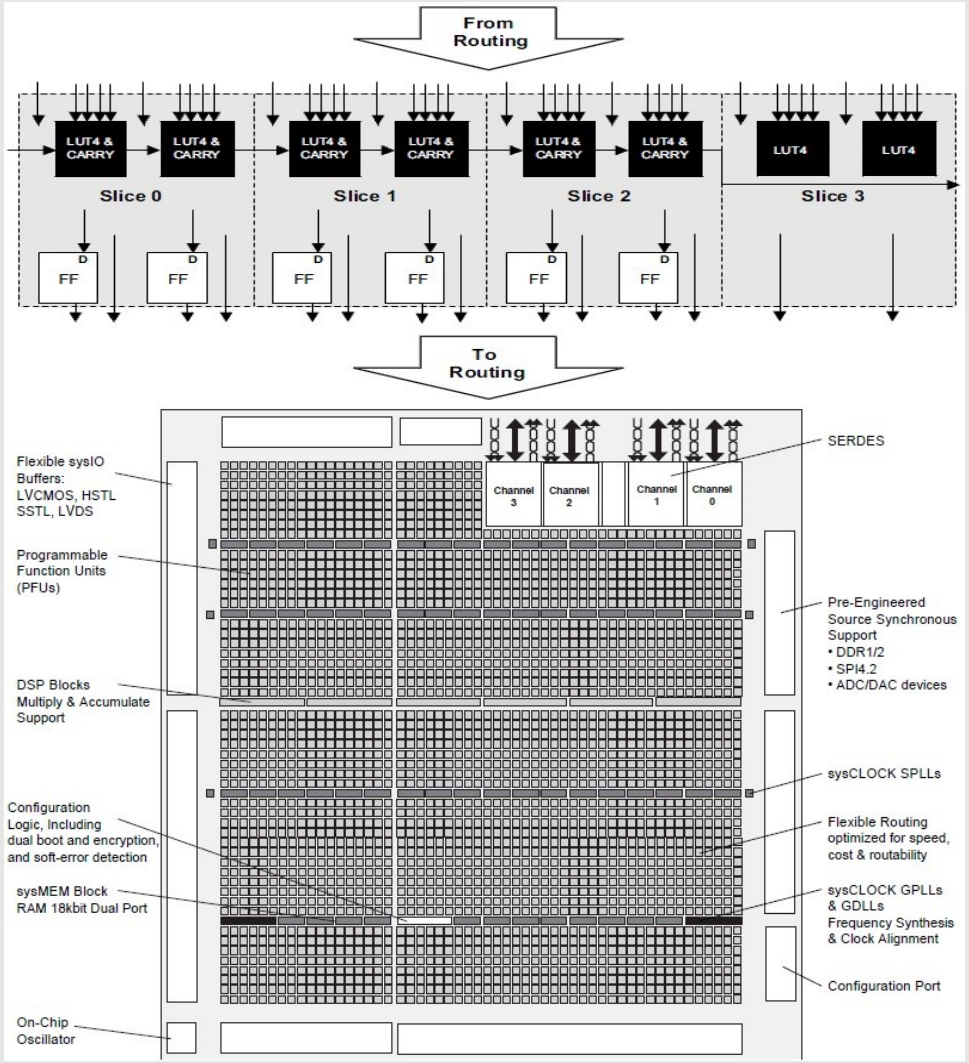
- Multi-Purpose TDC in FPGA chip has been developed
- The first board has been tested with real beam for the **FIRST** time!
- For test purposes 6 channels were used
- Time data was taken successfully with the electronics prototype
- Time distribution and correlation information of the pixels are consistent with the oscilloscope
- For more tests the TDC will be tested in the next Hades beam time during April and DIRC prototype beam time in May
- More time information will be collected (rising and falling edges – ToT – of the signals)
- More channels will be implemented

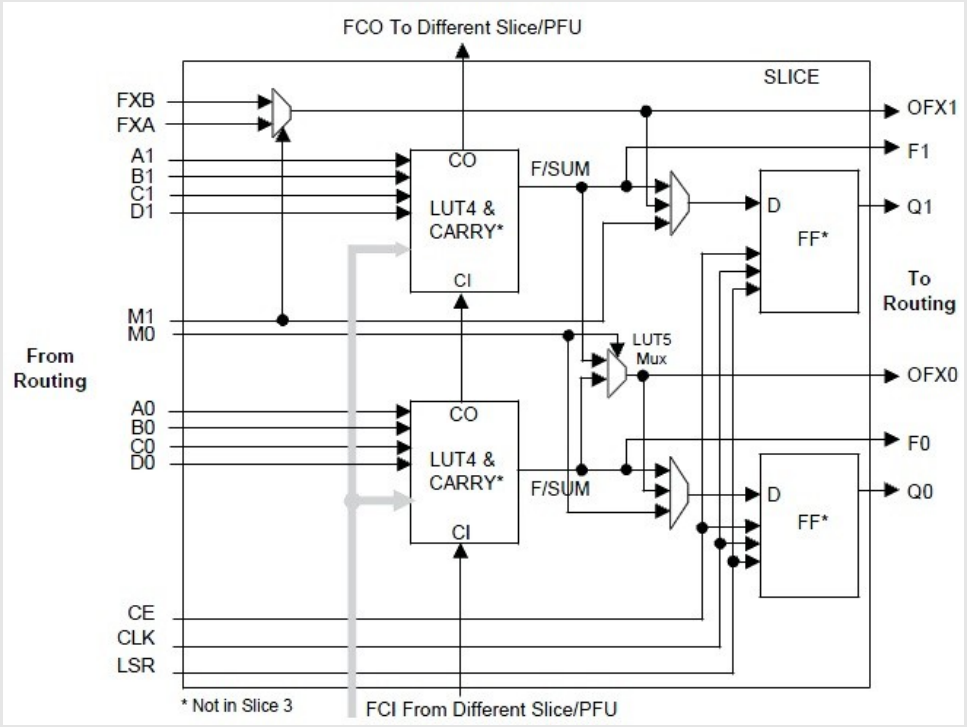
References

[1] J. Kalisz, Review of methods for time interval measurements with picosecond resolution, Metrologia, 2004.
[2] LatticeECP2/M Family Handbook, HB1003, Version 04.3, March 2009.
[3] J. Song et al., A high-resolution time-to-digital converter implemented in field-programmable-gate-arrays,IEEE TRANSACTIONS ON NUCLEAR SCIENCE, 2006.

Backup Slides

Architecture of Time-to-Digital Converter





Lattice ECP2M FPGA Slice Diagram, PFU Diagram and Floorplan

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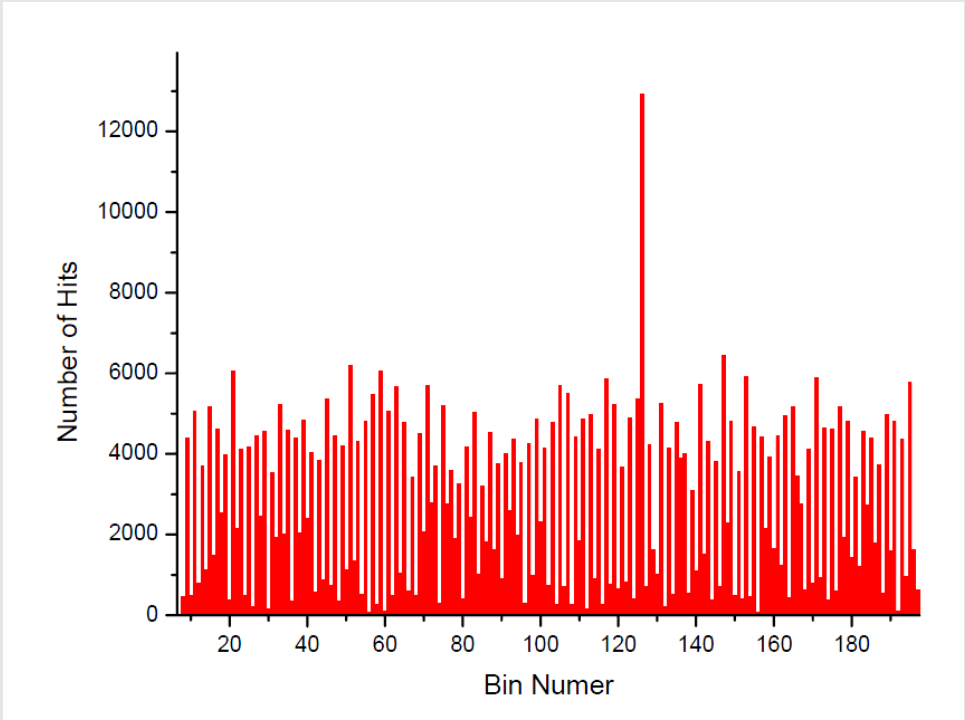
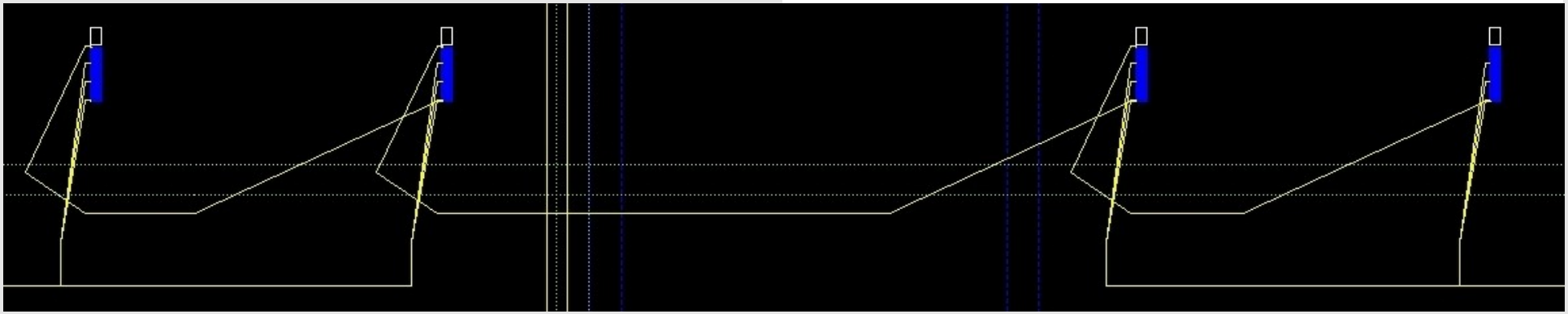
Architectural Effects of FPGA

- Effect of primary clock line in the FPGA
- Effect of longer inter-slice routings
- Effect of PFU architecture





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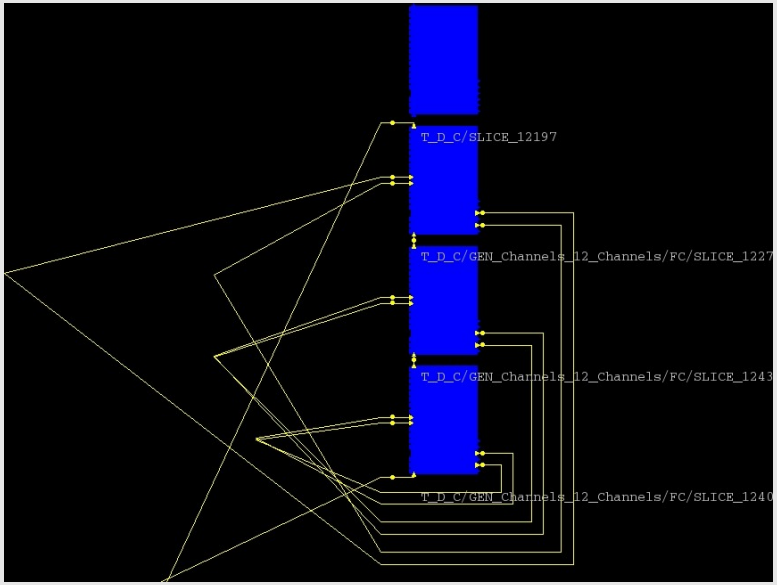

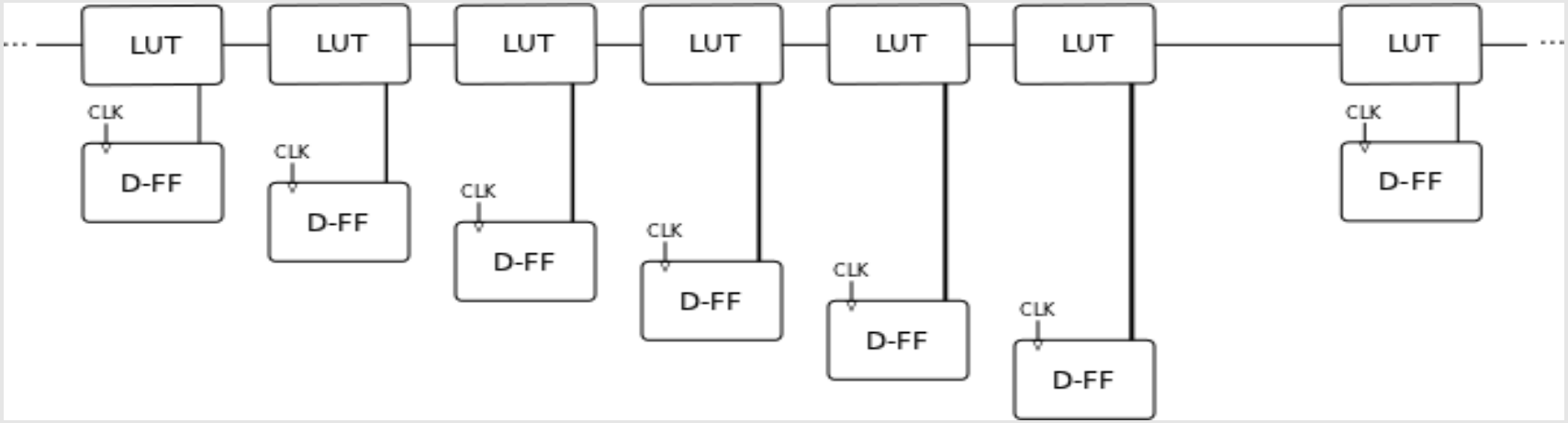

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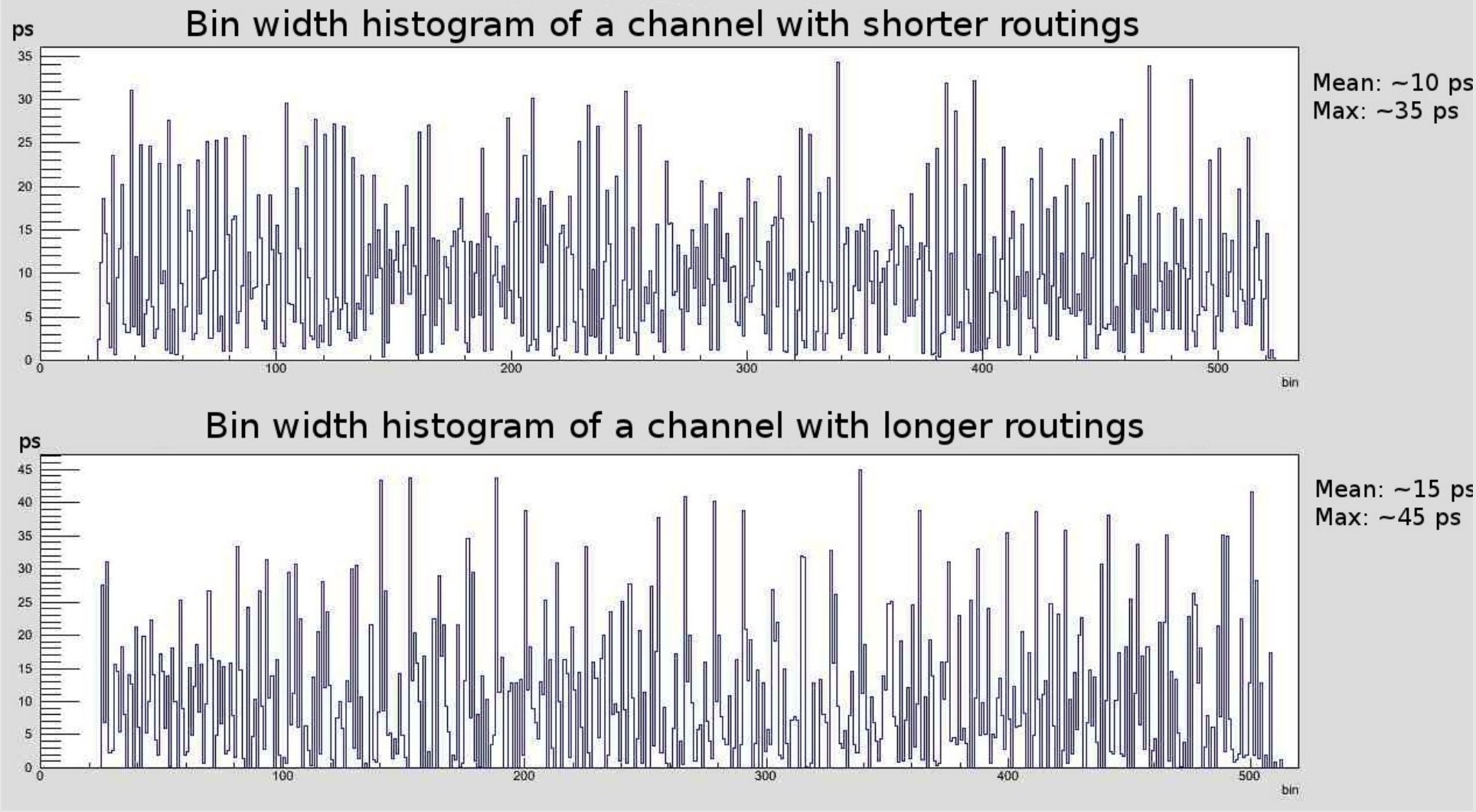

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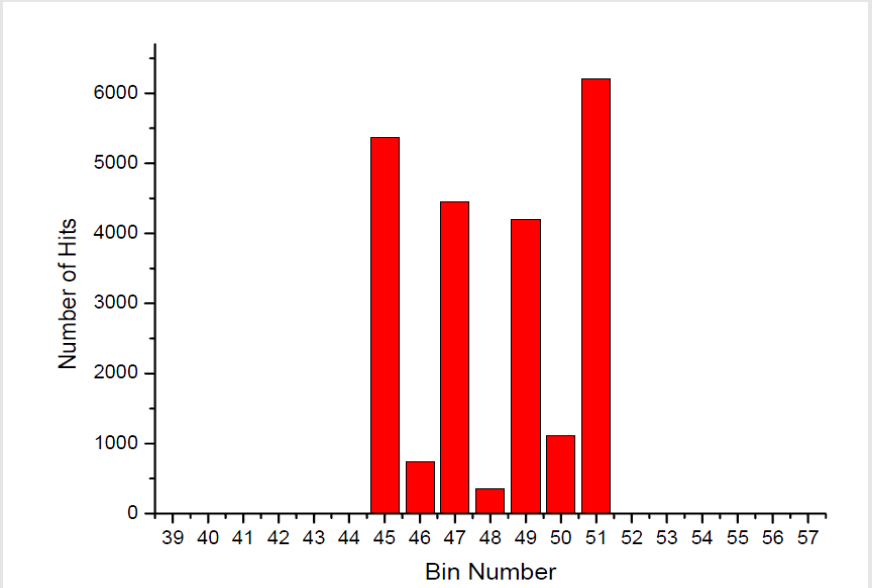

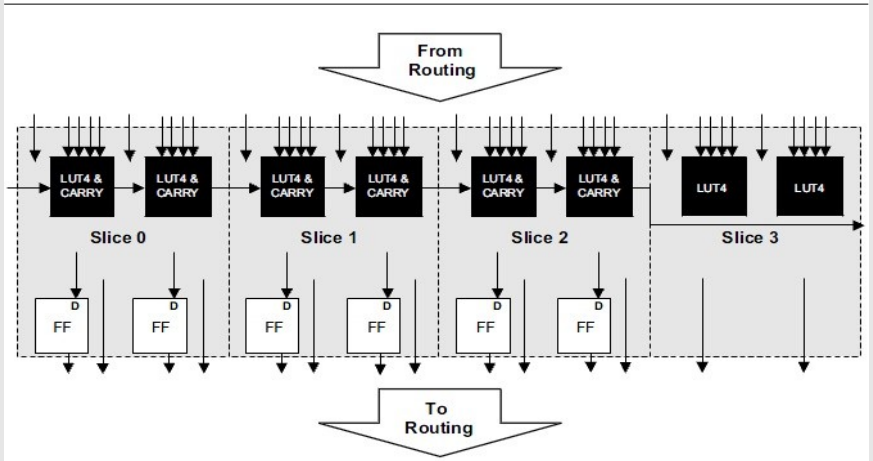

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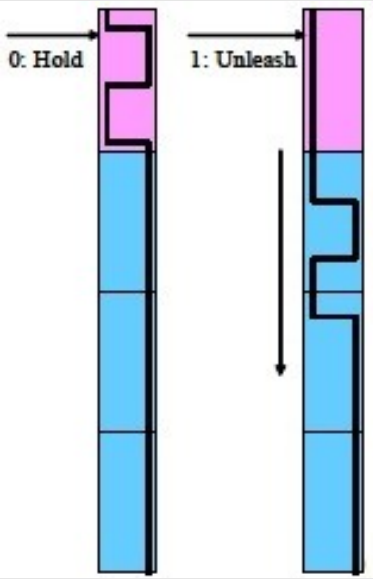
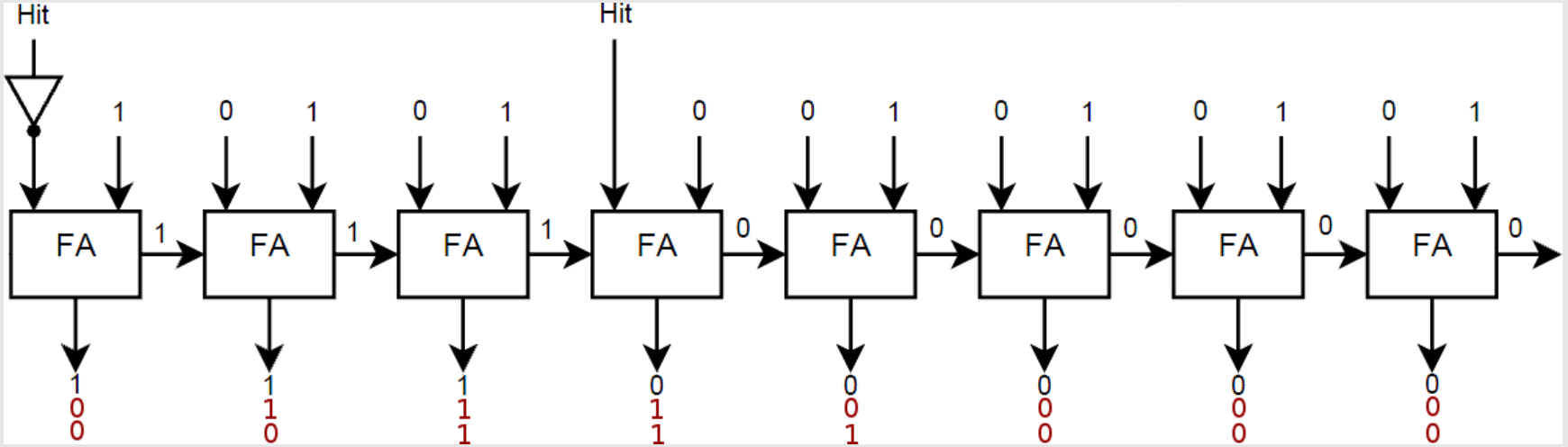
Wave Union Launcher

- More than one delay line is necessary in order to reduce the effect of wide bins
- Wave union launcher is implemented
- Bin widths & non-linearities are reduced





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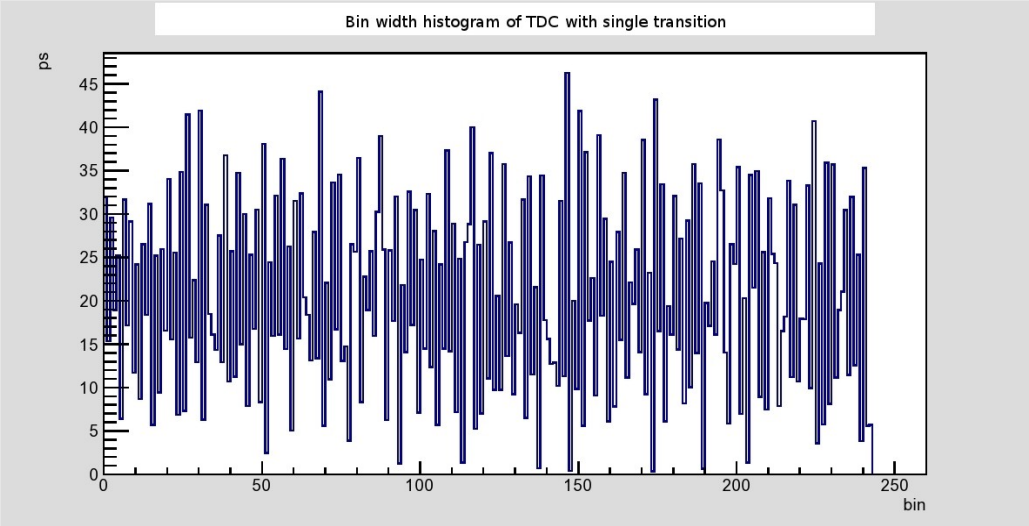
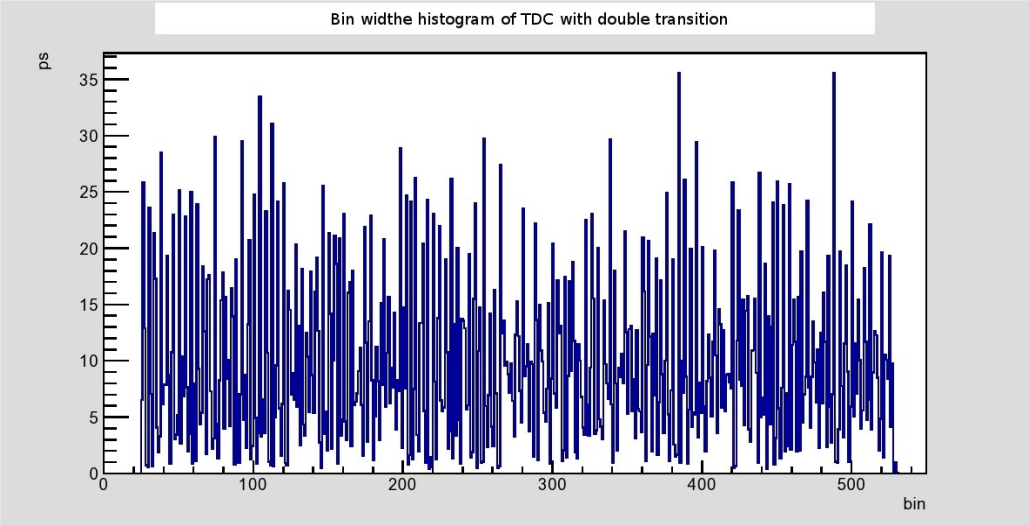
Wave Union Launcher

- More virtual bins
- Narrower bins
- Homogeneous bin distribution



Bins: ~240
Mean: ~20 ps
Max: ~45 ps



Bins: ~520
Mean: ~10 ps
Max: ~35 ps

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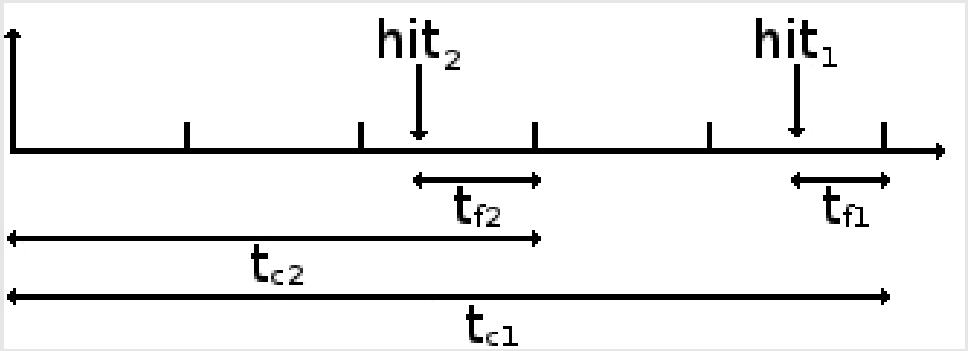
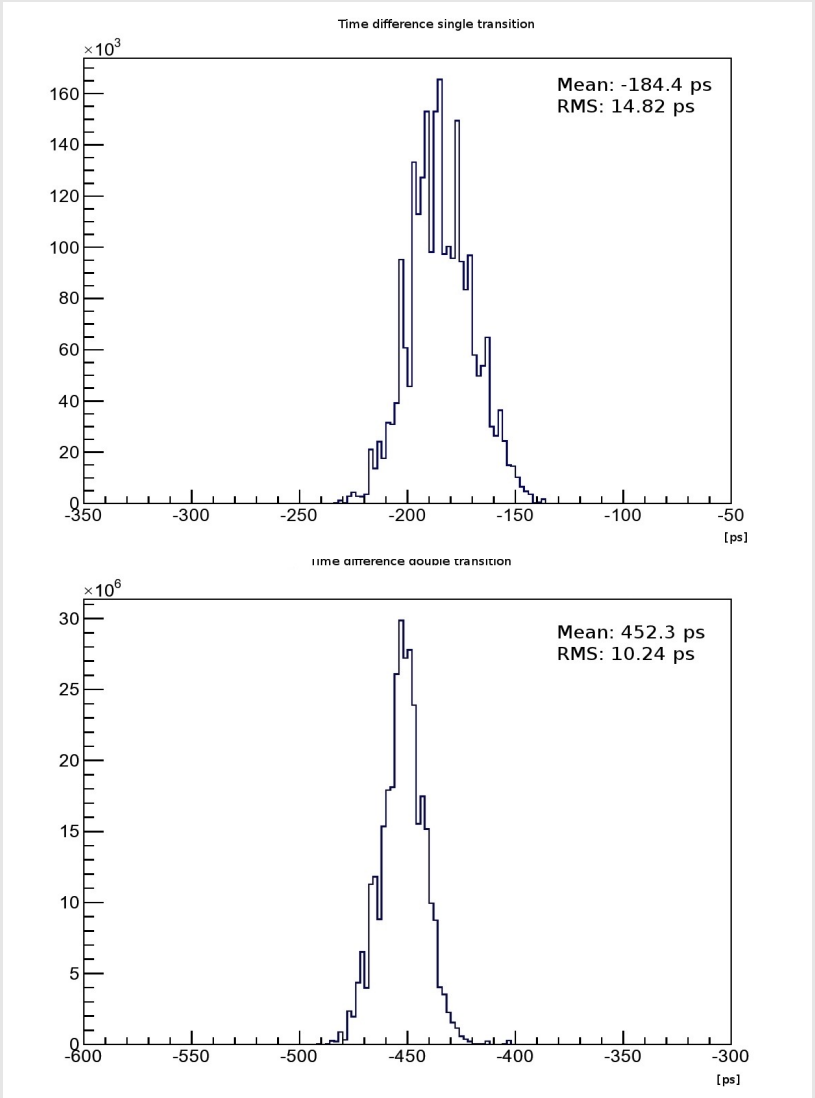
Statistical Error & Resolution

- Time difference measured between 2 channels
- $\Delta t = (t_{coarse1} - t_{coarse2}) - (t_{fine1} - t_{fine2})$
- RMS measured: 10.34 ps

  against same clock
- Resolution: 10.34 ps / √2 = 7.3 ps
- Effect of 2 transitions:

  14.82 ps / 10.34 ps = 1.43 factor





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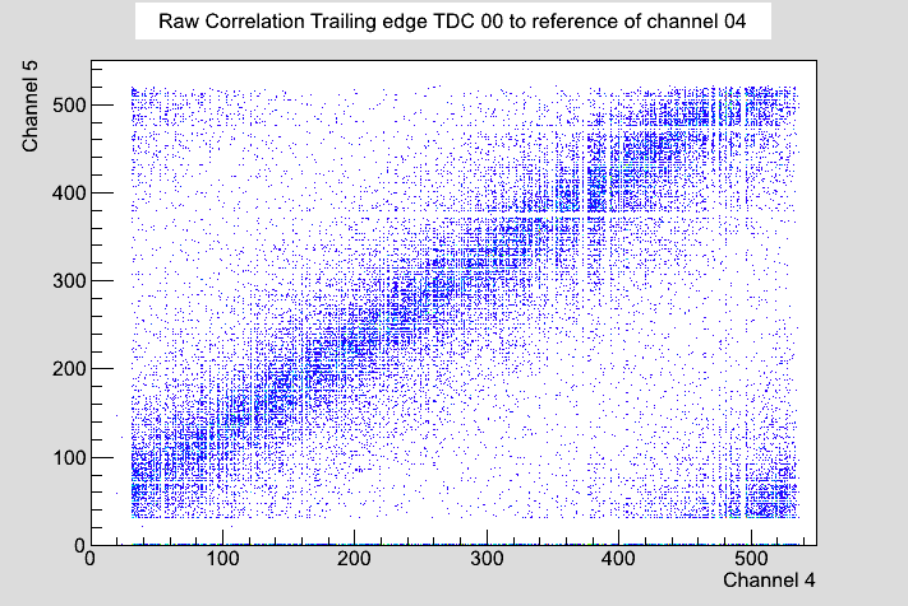
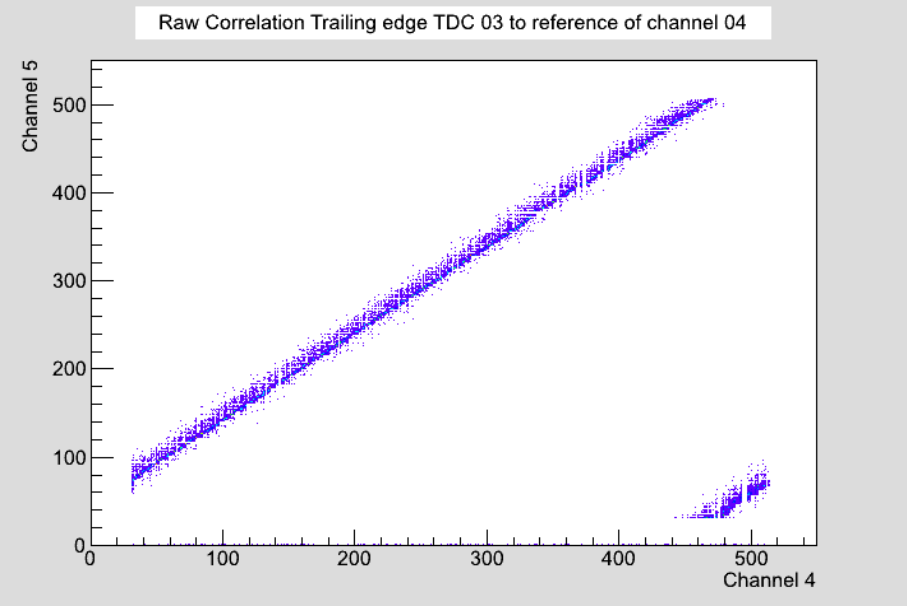
Fine Time Correlation



Beam result



Lab result