EoC Full Chain T0 Performance Measurements

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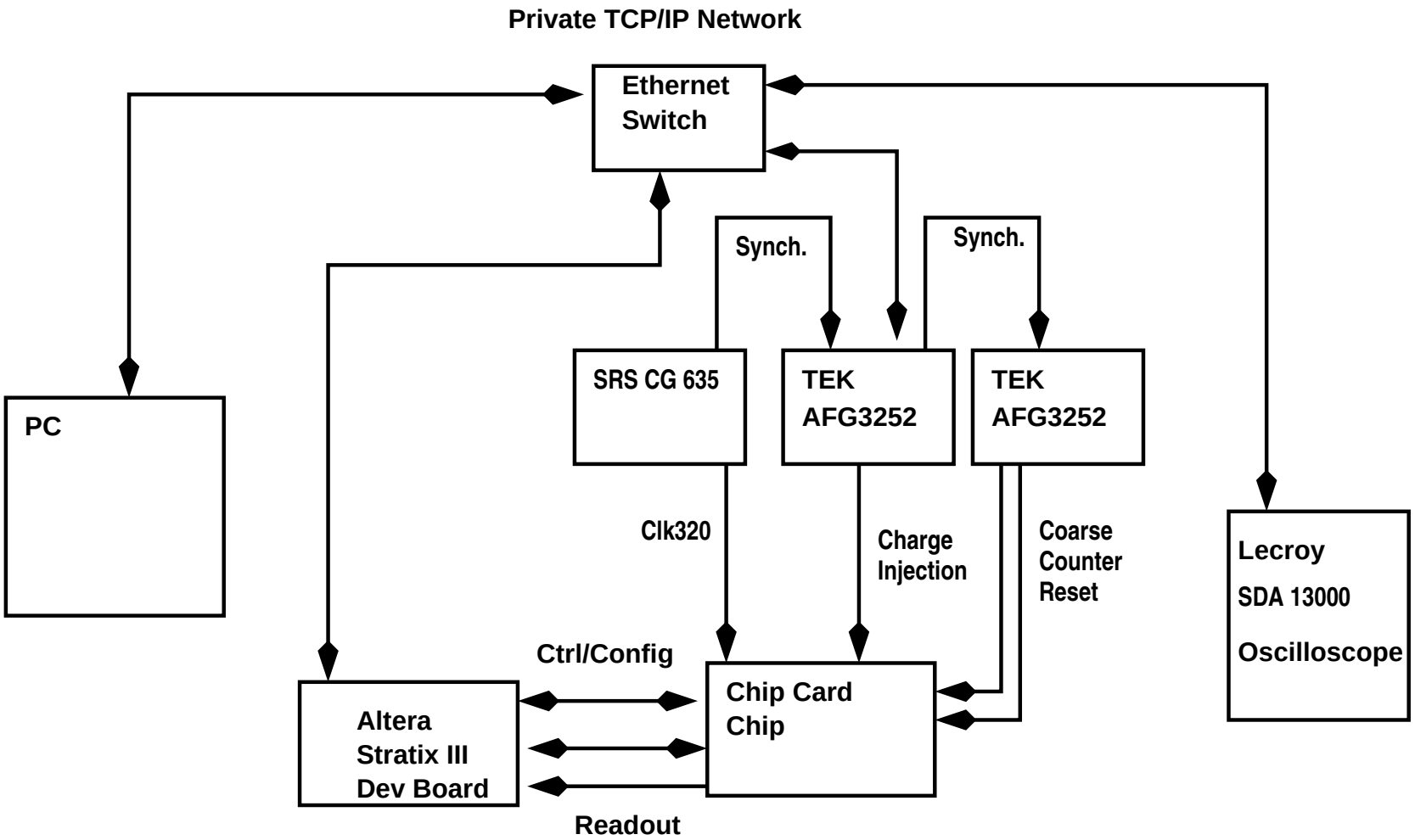
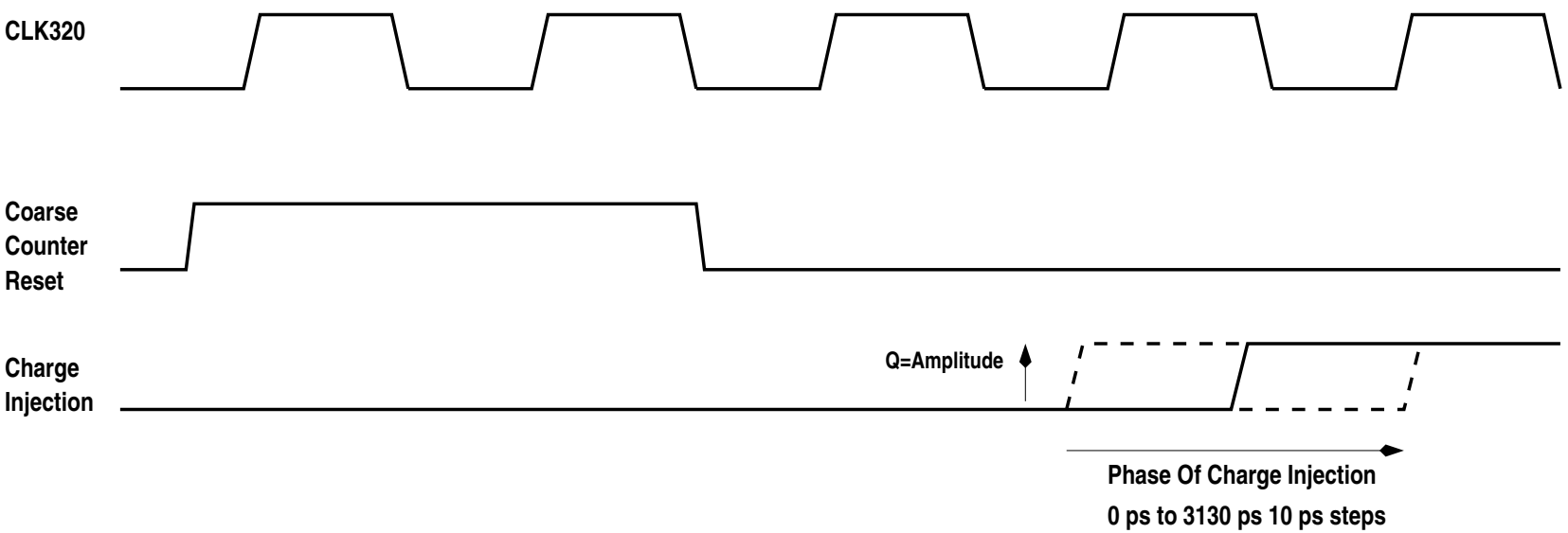
Digital Measurement Set Up



Timing Diagram



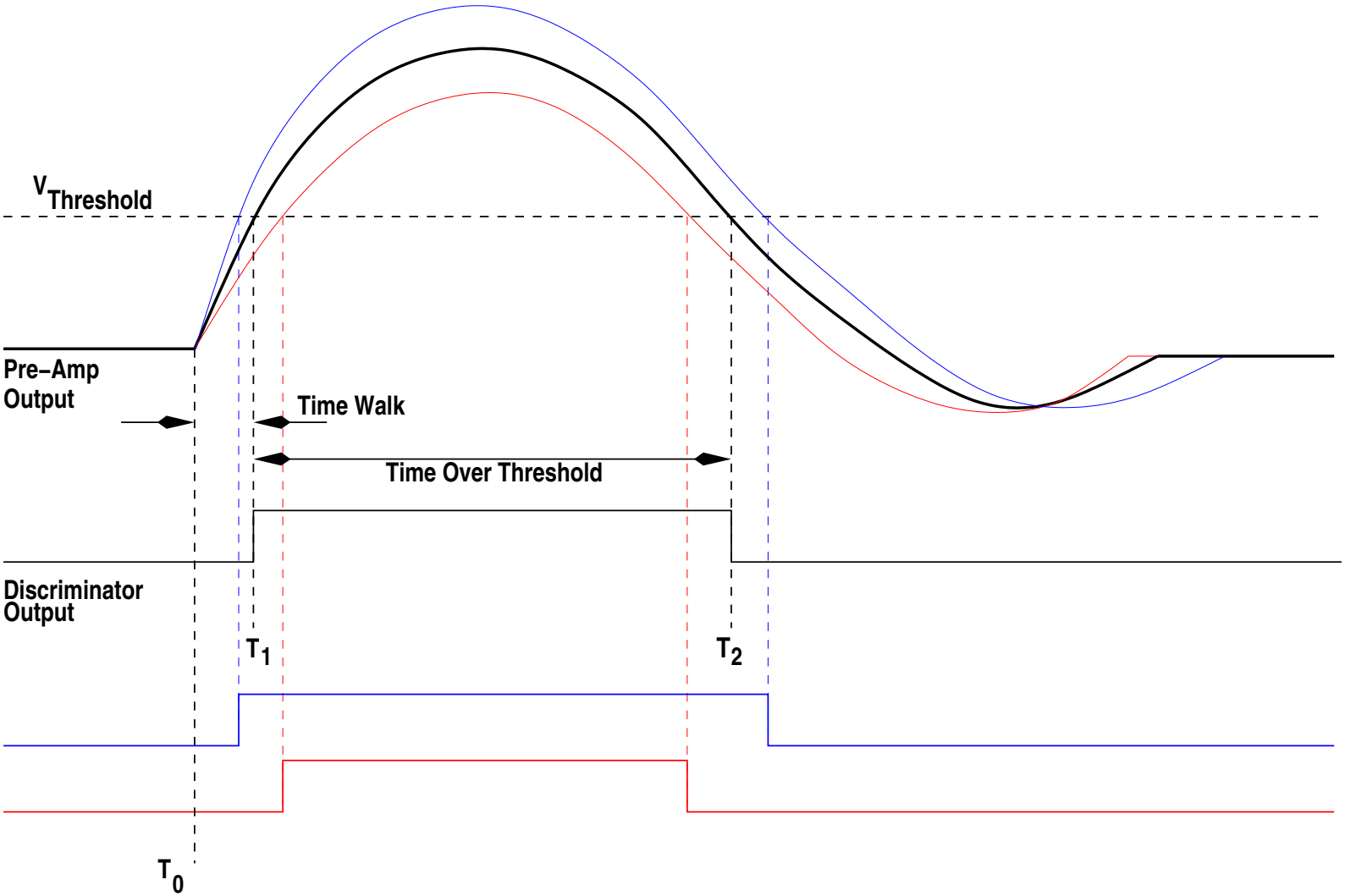
Parameter Space and Data Treatment

- Threshold set to 0.7 fC
- Charge Injection Duration set to 2.5 ns
- Charge injected 1.0fC, 1.2fC. . . 2.0fC, 3.0fC. . . 10.0fC
- Phase of injection swept from 0ps $\rightarrow$ 3130 ps
  - 314 settings
- repetition rate 10kHz
- coarse counter reset synchronously
- $\sim$20000 time stamps per point
  - first 10000 used for calibration
  - second 10000 used for measurement
- results for a single main array pixel presented
- TDC nonlinearity correction used for T1 and T2
  - Fine time = N * ($T_{clk}/32$) replaced with LUT with bin centres

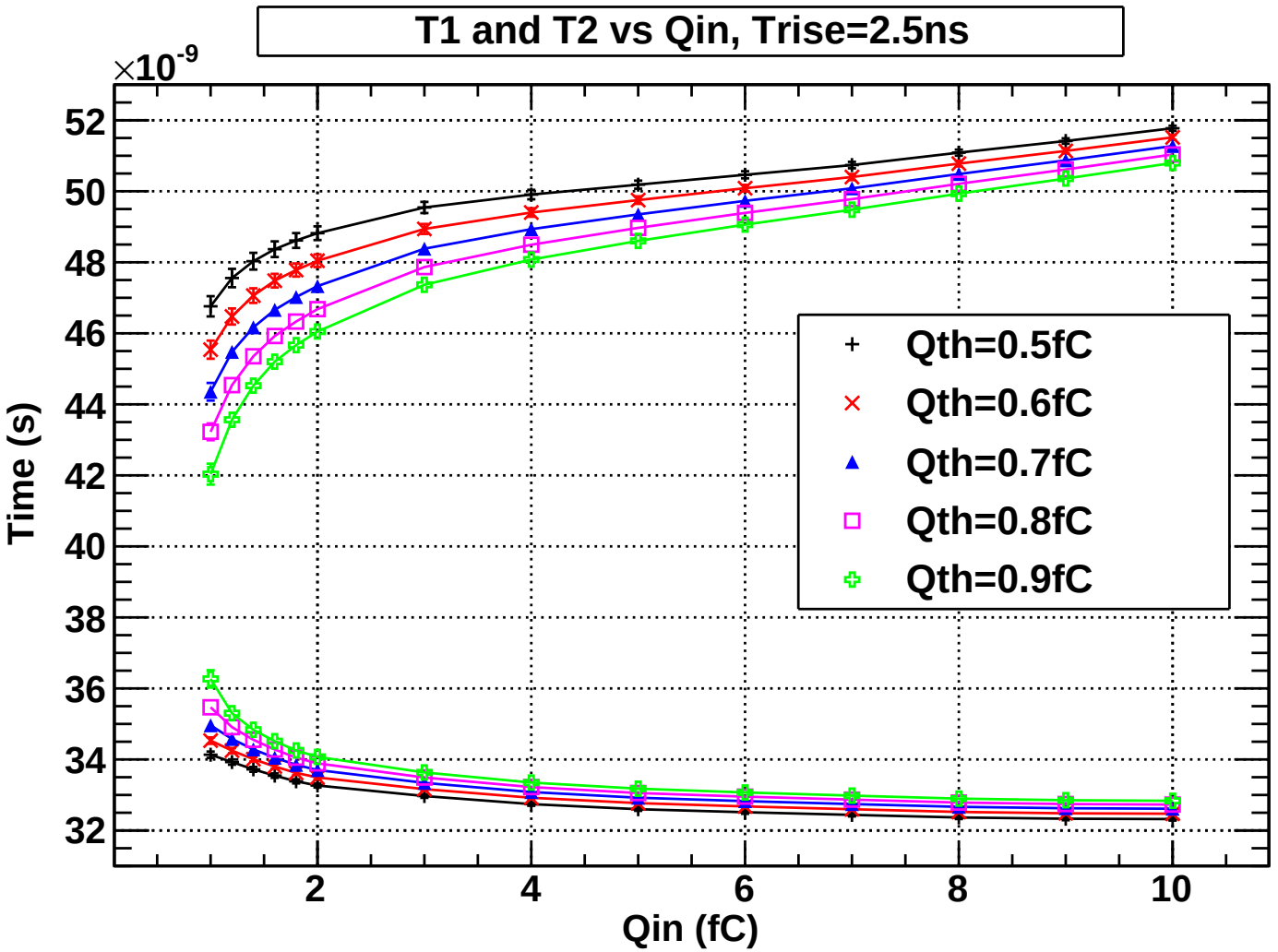
Working Point

- Digital VDD Set to 1.5V
- DLL Clock at 320 MHz
- Readout Clock at 320 MHz
  - Both are always present
- RxClkBias $\sim$300 μA
- Temperature:
  - Lab ambient temperature $\sim$22 °C

Time Over Threshold Time Walk Correction



T1 and T2 Timewalk: Test pixel measurements



Correction Methodology

- Necessary to define a pixel dependent, Q – *invariant* quantity
- Absolute calibration step still required
  - e.g. transmission line propagation delay

$$T_0 = T_0' - T_{ac} \tag{1}$$

- Where T_{ac} is the absolute calibration step and depends on pixel location
- T_{ac} may be determined to arbitrary precision.

Correction Methodology

Define T_0' as:

$$T_0' = T_1 - k(TOT) * (T_2 - T_1) \tag{2}$$

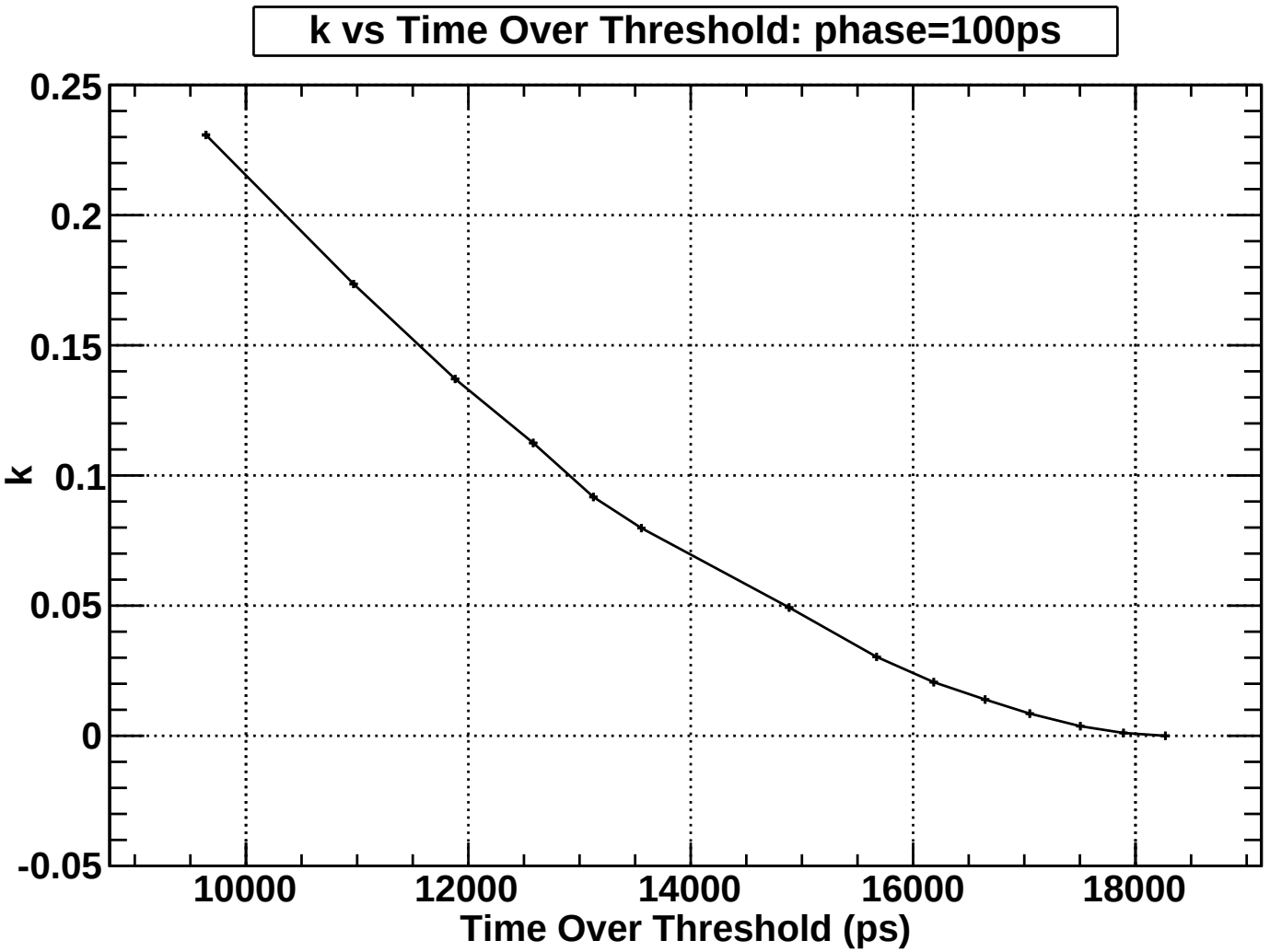
the k are functions of time over threshold. In practice a spline parameterisation is used to provide a continuous implementation of the discrete measurement points
k can be calculated:

$$k = \frac{T_1 - T_0'}{T_2 - T_1} \tag{3}$$

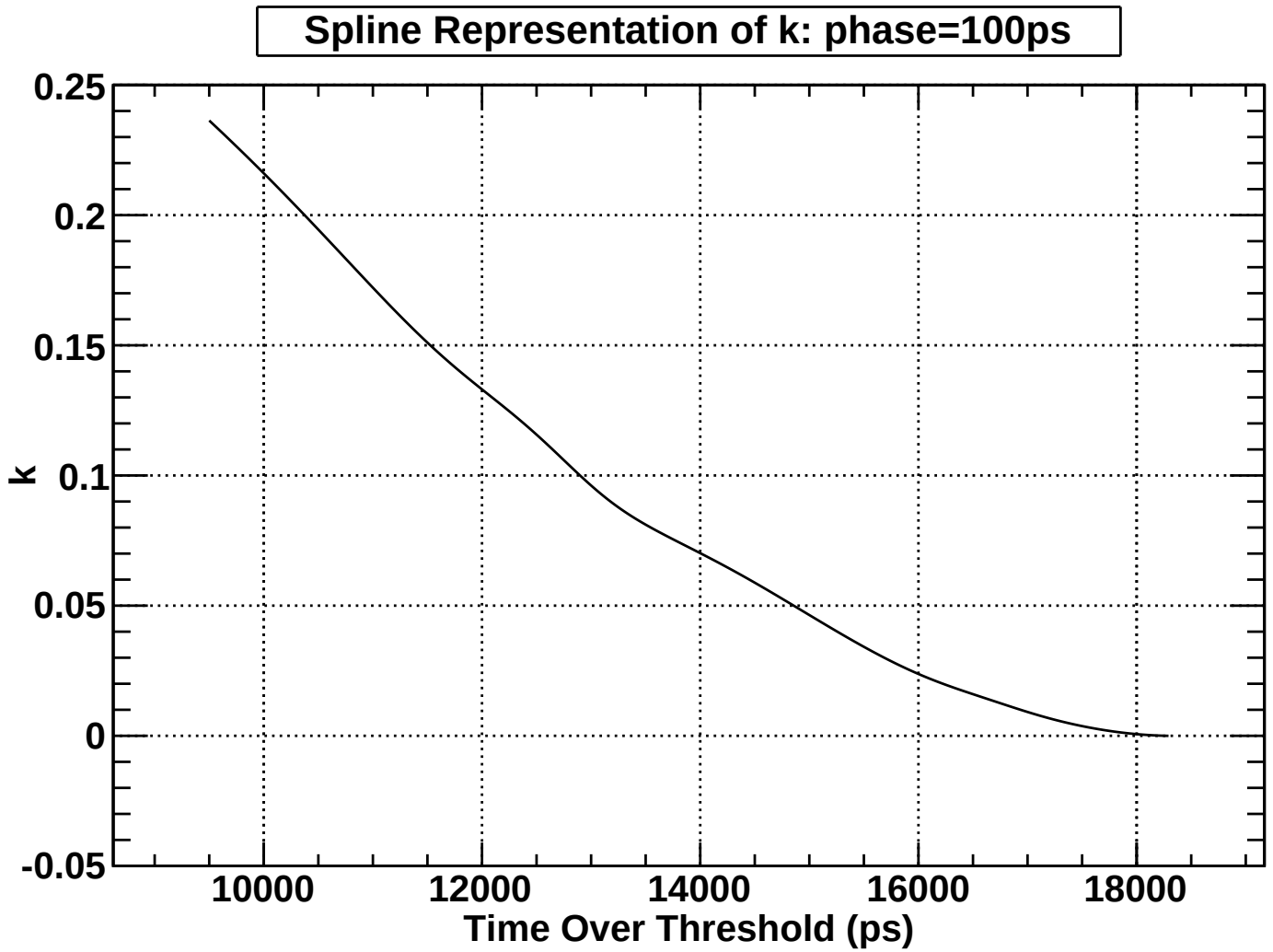
for Q, Q_{th}, Pixel and T_{rise} and Phase.

- For this study, $T0'$ was taken as $< T_1(10fC) >$

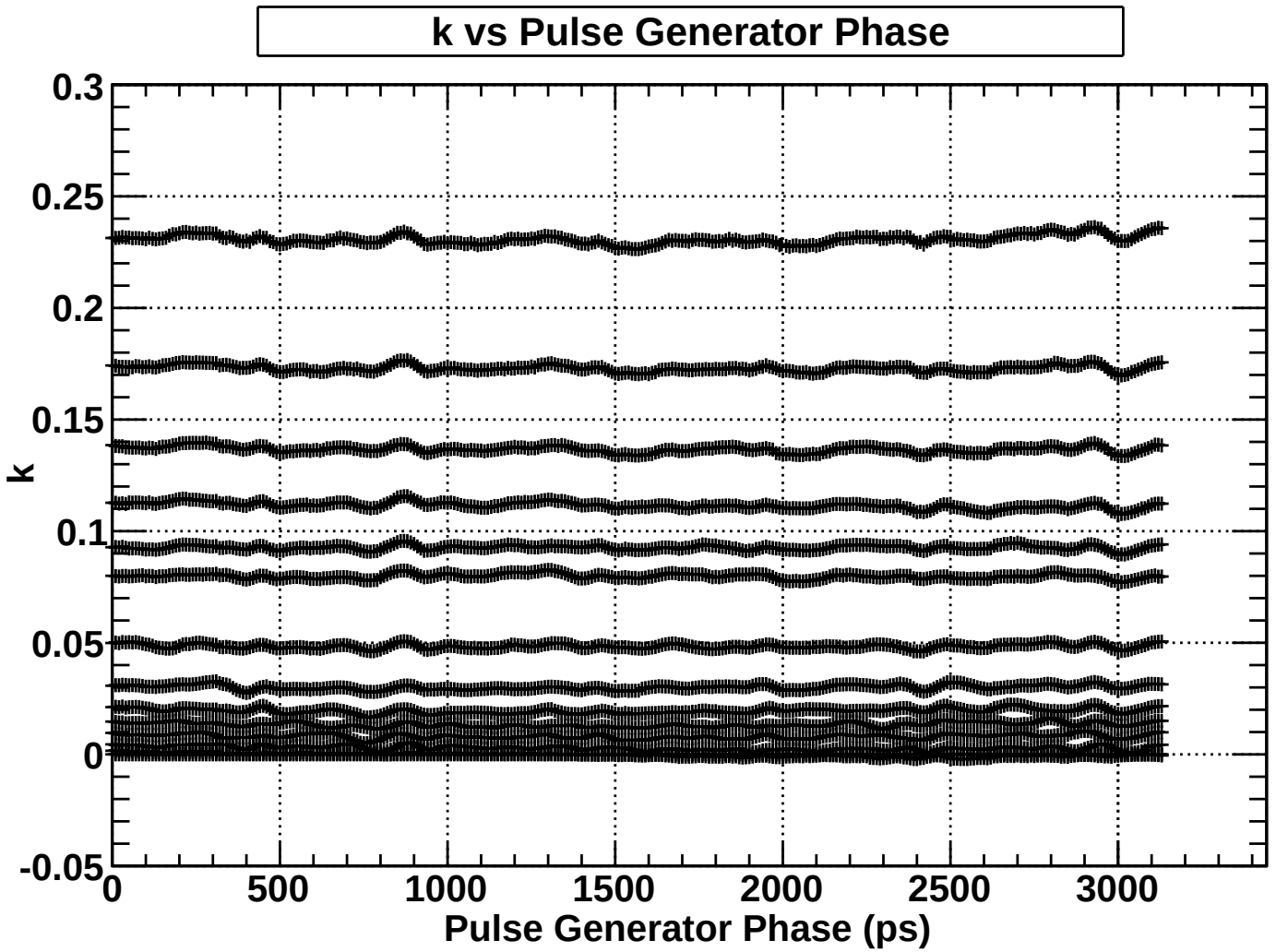
Typical k


k vs Time Over Threshold: phase=100ps
0.25
0.2
0.15
0.1
0.05
0
-0.05
k
10000
12000
14000
16000
18000
Time Over Threshold (ps)

Spline Parameterisation of k



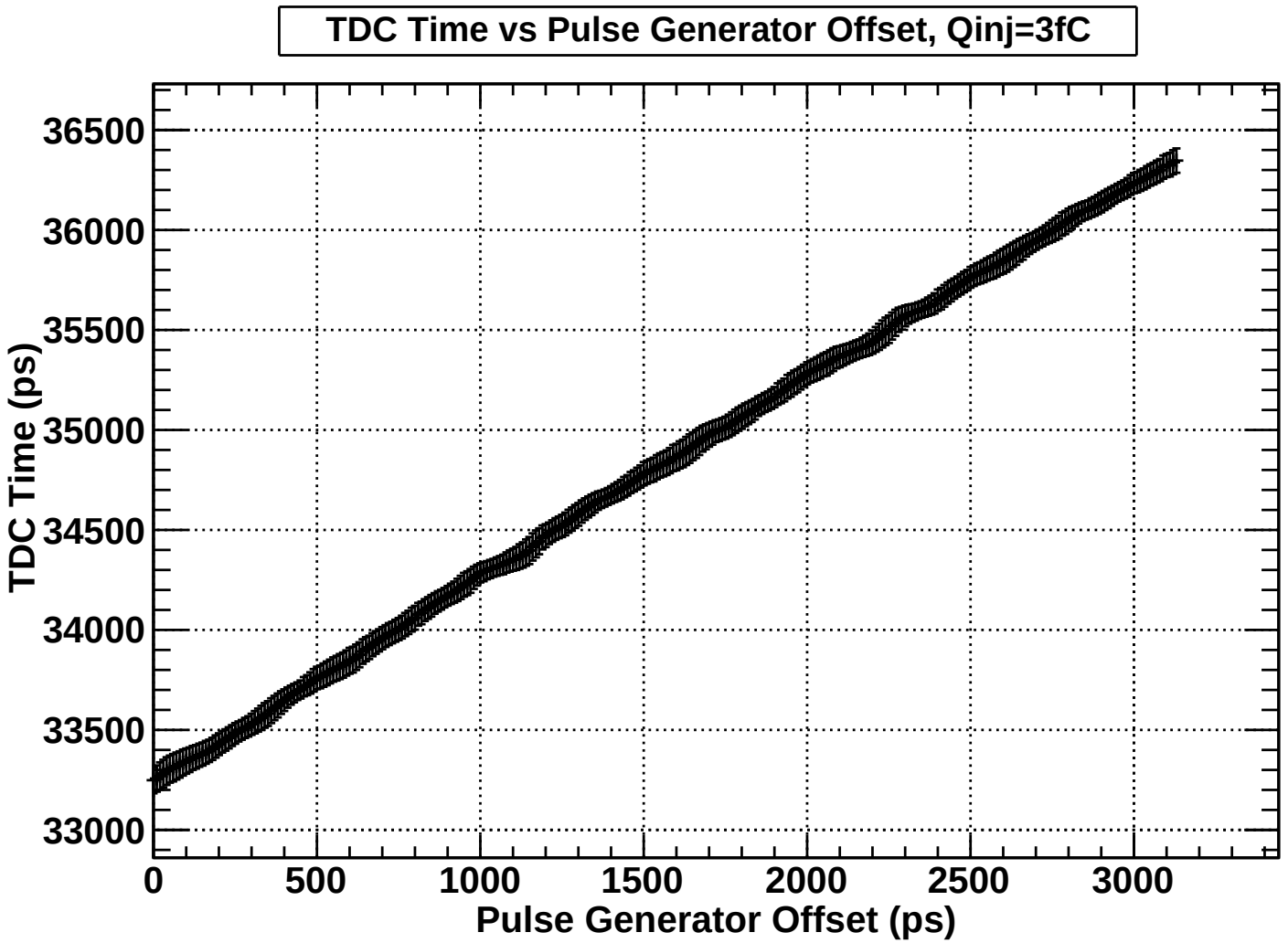
k vs Phase


k vs Pulse Generator Phase
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
k
0
500
1000
1500
2000
2500
3000
Pulse Generator Phase (ps)

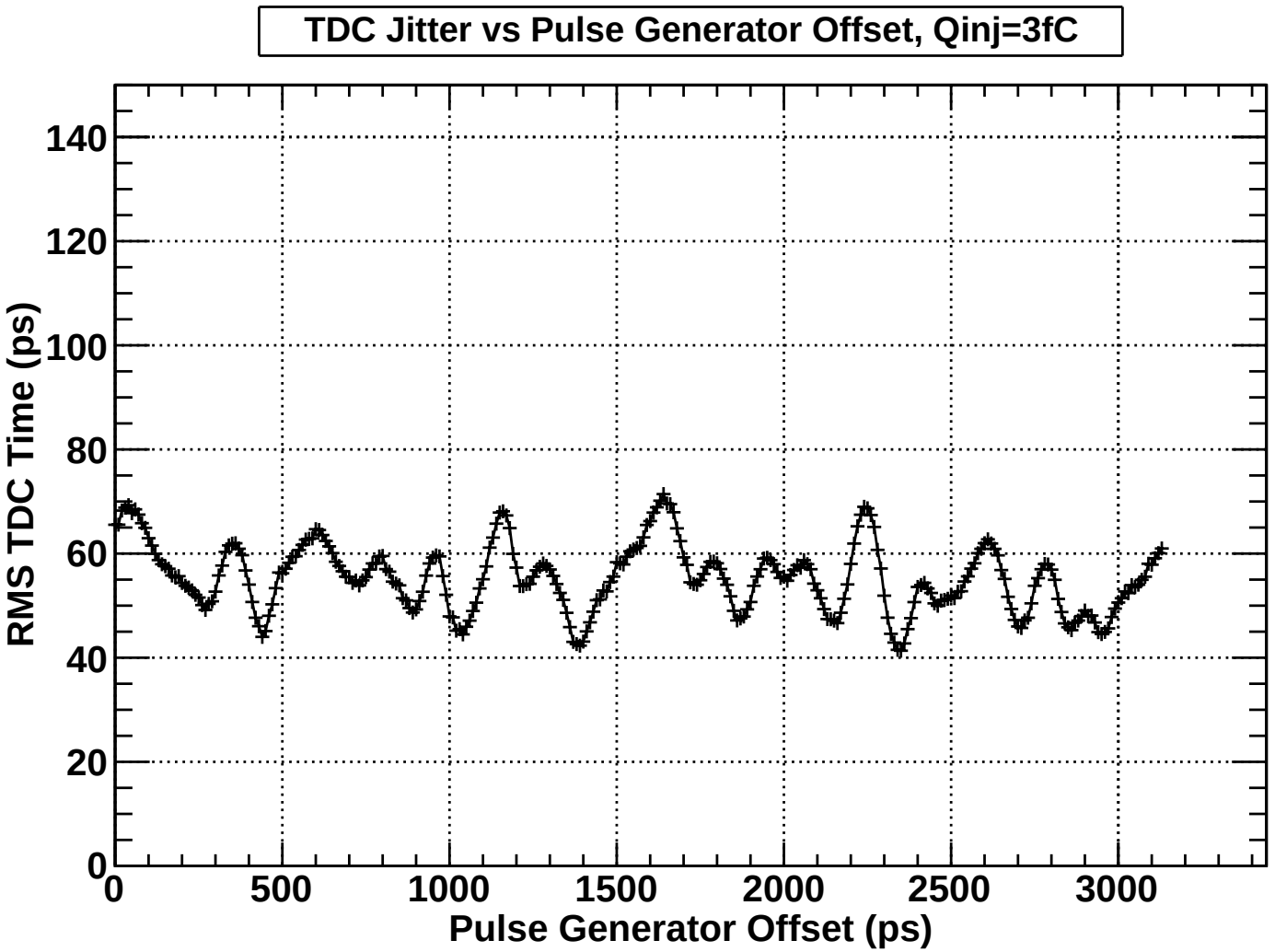
Correction Methodology

- non-flat k vs phase means that the correction depends on where the hit falls
- a 2 stage correction yields better T_0' reconstruction
  - correct with an initial (phase independent) estimate
  - use estimated phase to refine T_0' correction

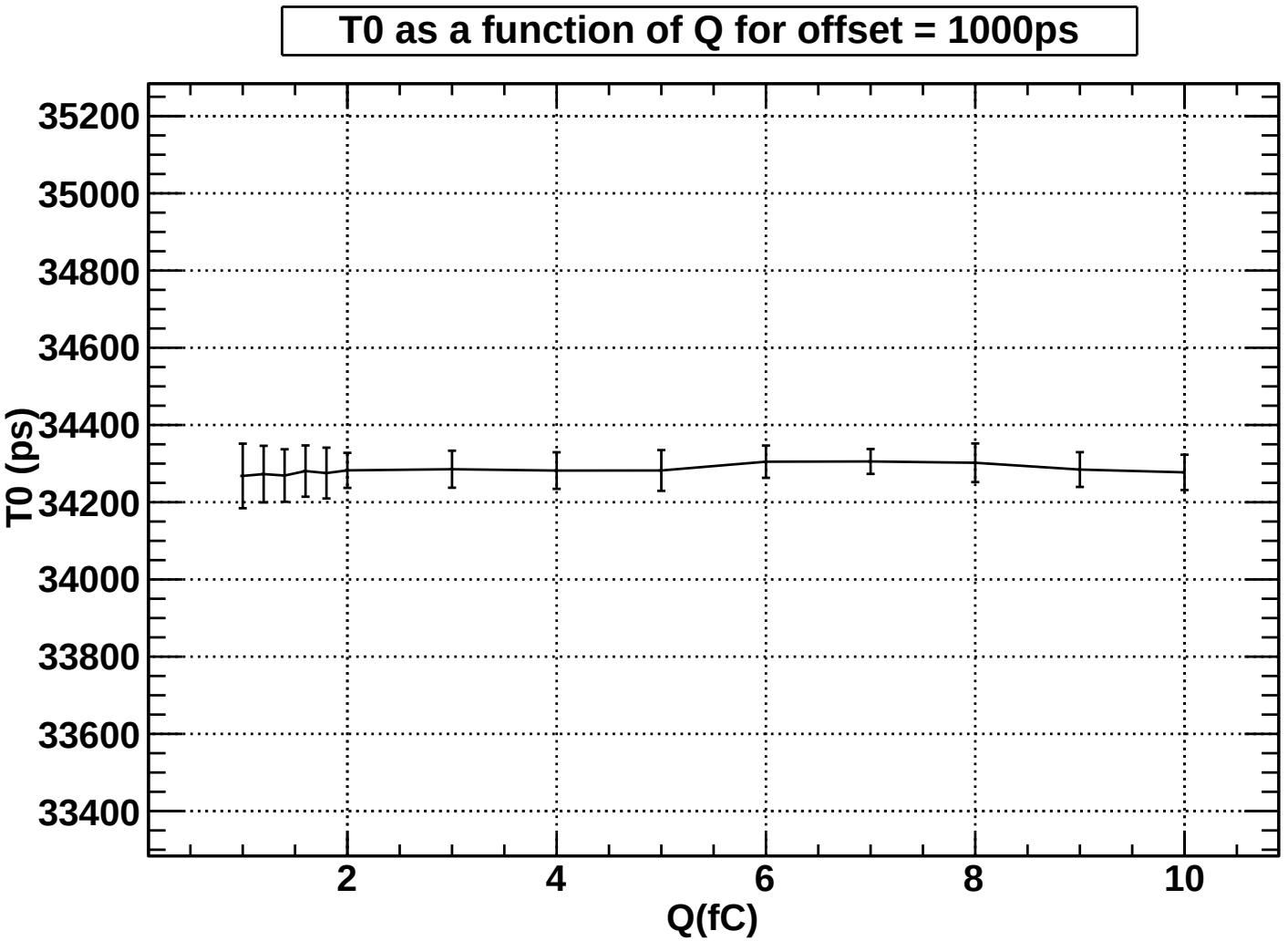
T_0' Transfer Curve



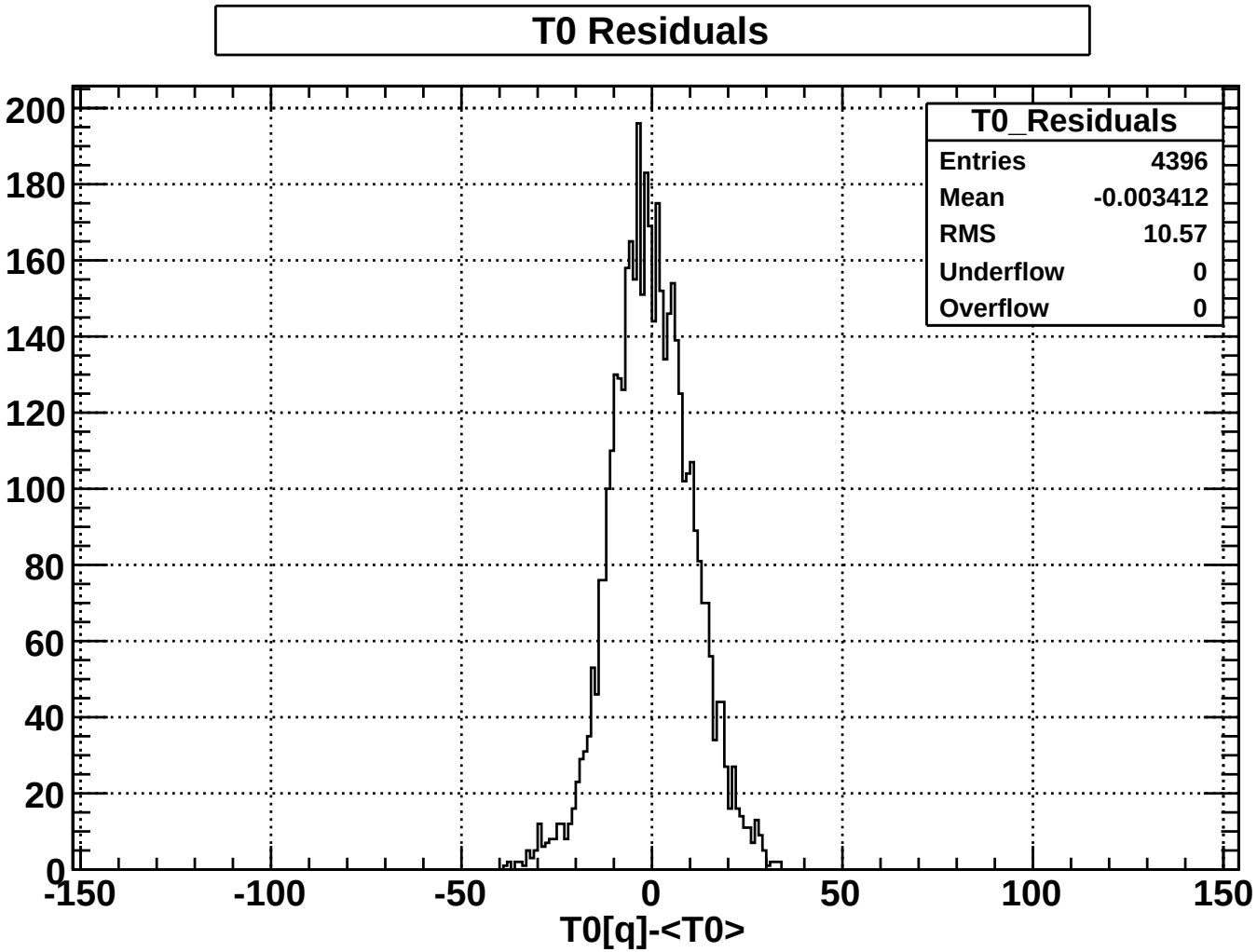
T_0' Jitter


TDC Jitter vs Pulse Generator Offset, Qinj=3fC
RMS TDC Time (ps)
Pulse Generator Offset (ps)
0
20
40
60
80
100
120
140
0
500
1000
1500
2000
2500
3000

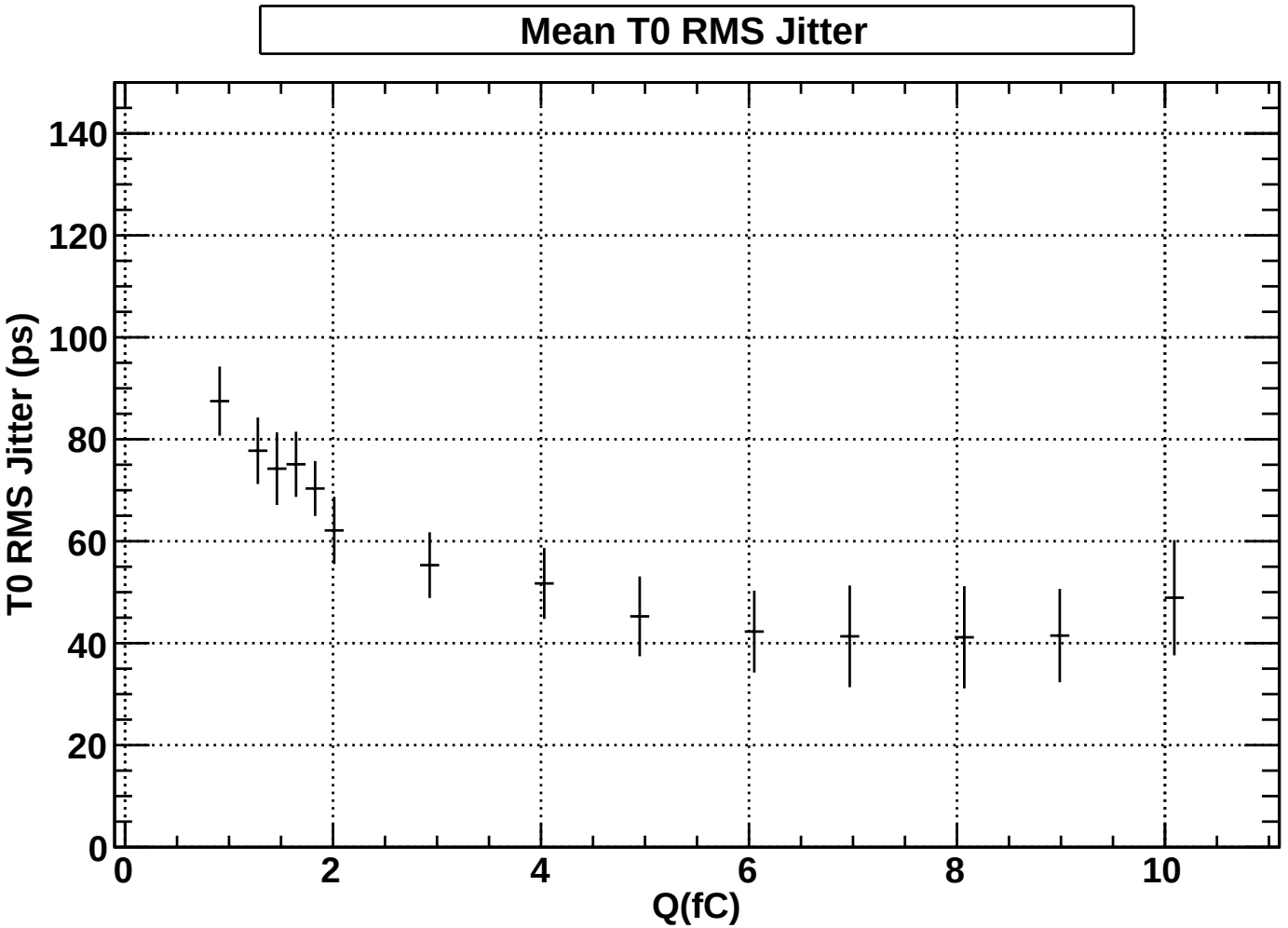
T_0' vs Q: Single Phase



T_0': Systematic Residuals: All Qs and phases



T_0': Average Random Jitter vs Q



Summary

- Synchronisation between clock generator and two pulse generators
  - reset and charge injection well defined relative to clock
  - phase of charge injection relative to clock investigated
    - steps of 10 ps
  - standard 1-10fC charge range used
- The Q-invariant quantity T_0' defined and measured
  - two sets of 10000 time stamps taken
  - statistical independence between calibration set and measurement set
  - two stage T_0' used
  - spline parameterisation of k used to give continuous mapping from discrete measurements
- T_0' vs Q shown with two contributions
  - residual systematic timewalk
    - distribution width estimated to be 10 ps RMS
  - random jitter
    - variation due to phase measured
    - expectation values and distribution widths shown
    - $\sim$ 60 ps at 2.4fC