Template fit feasibility for Crilin SiPM timing: report on laser data

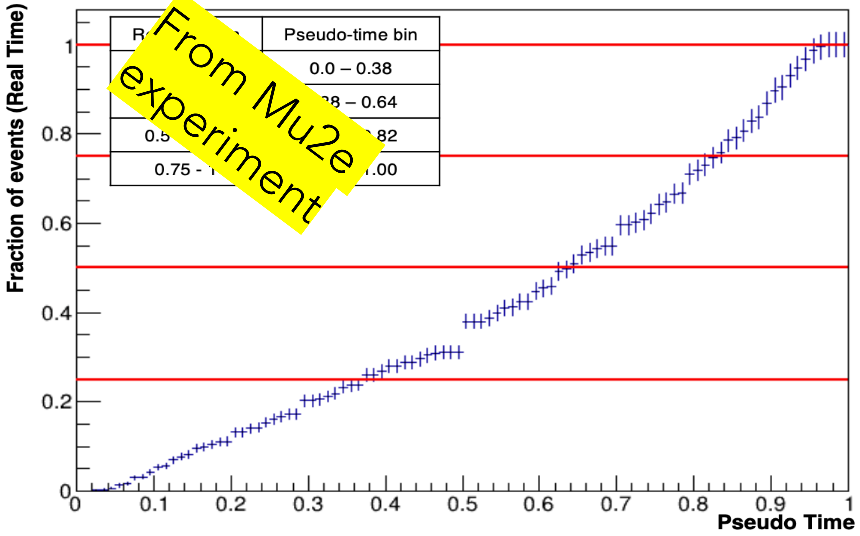
E. Diociaiuti, E. Di Meco, D.Paesani, I.Sarra

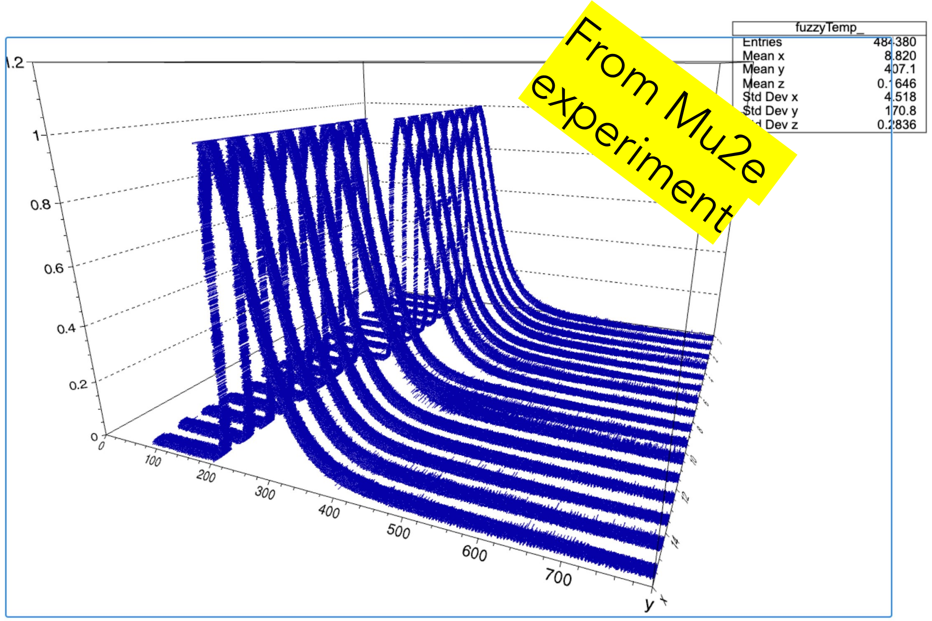
International
UON Collider
Collaboration

Template fit concept

- Individual SiPM pulse templates can be generated for each channel and for different particle types
- Templates are ROOT TSpline5 objects with fixed proportions
- For timing reconstruction a template object is fitted over each waveform using a 3 parameter optimization (scale, time, baseline)
- Low computational cost (good for online analysis)

- Template is generated by aligning and averaging a large dataset of SiPM pulses
- For alignment, a pseudo-time variable is used yielding an estimate of the real wave time position as a fraction of the sampled bin containing the true wave peak (or the true constant fraction threshold crossing)
- Pseudo-time and real-time cumulative distribution are correlated

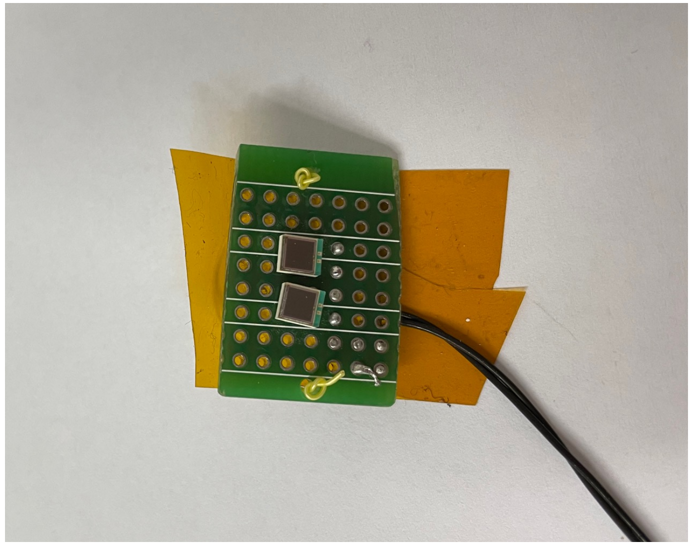


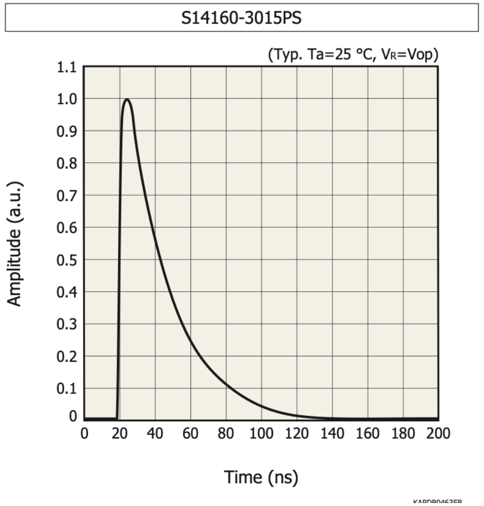


Setup and data

Crilin new front-end prototype

- Two Hamamatsu S14160-3015PS (15 um px size) in series
- SiPM readout and biasing via micro-coax lines
- Two stage amplifier (gain_tot = 7) w/ pole-zero cancellation
- Prototype validate, production in progress





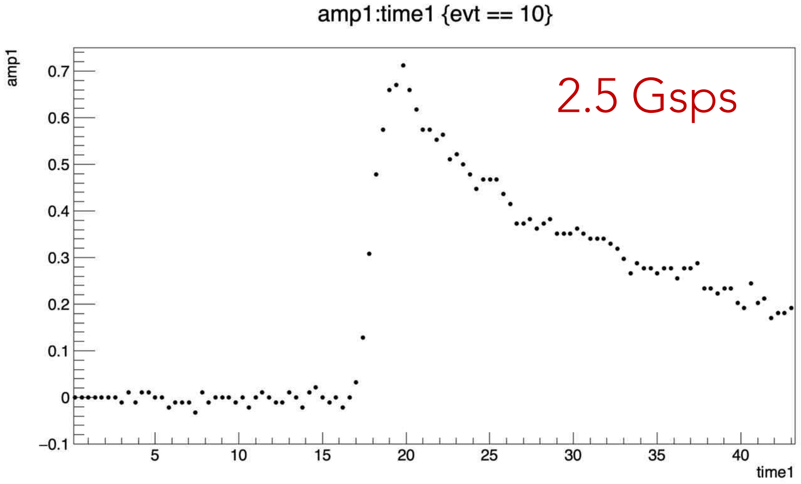
from datasheet

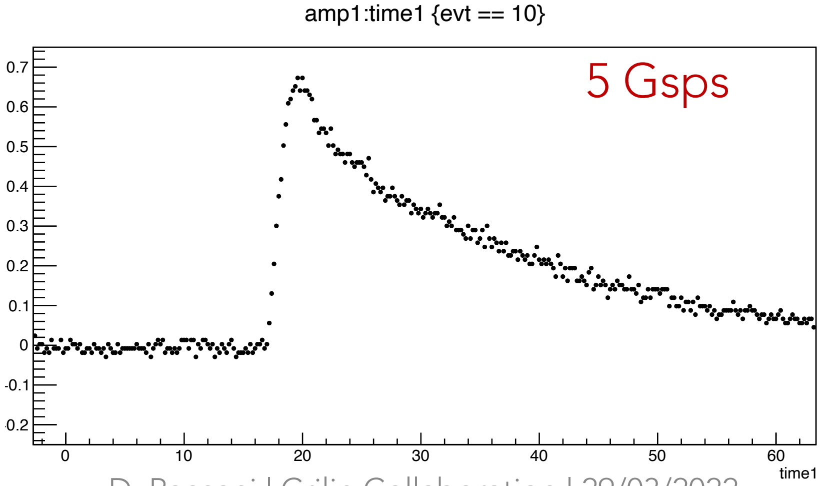
Setup

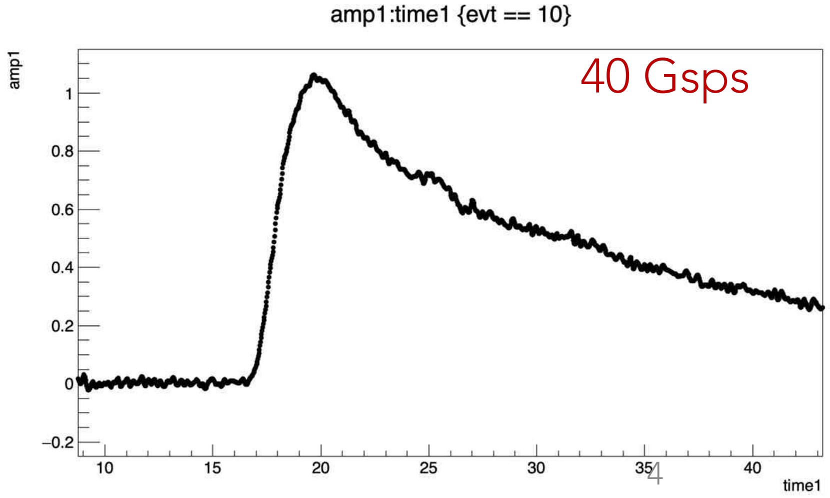
- Picosecond pulsed UV laser source w/ 100 kHz pulse repetition
- Digitisation via 40 Gsps oscilloscope

Data

1) Scan @ fixed laser amplitude and various sampling frequencies (run1)
2) Scan @ 40 Gsps and variable laser amplitude (run2)

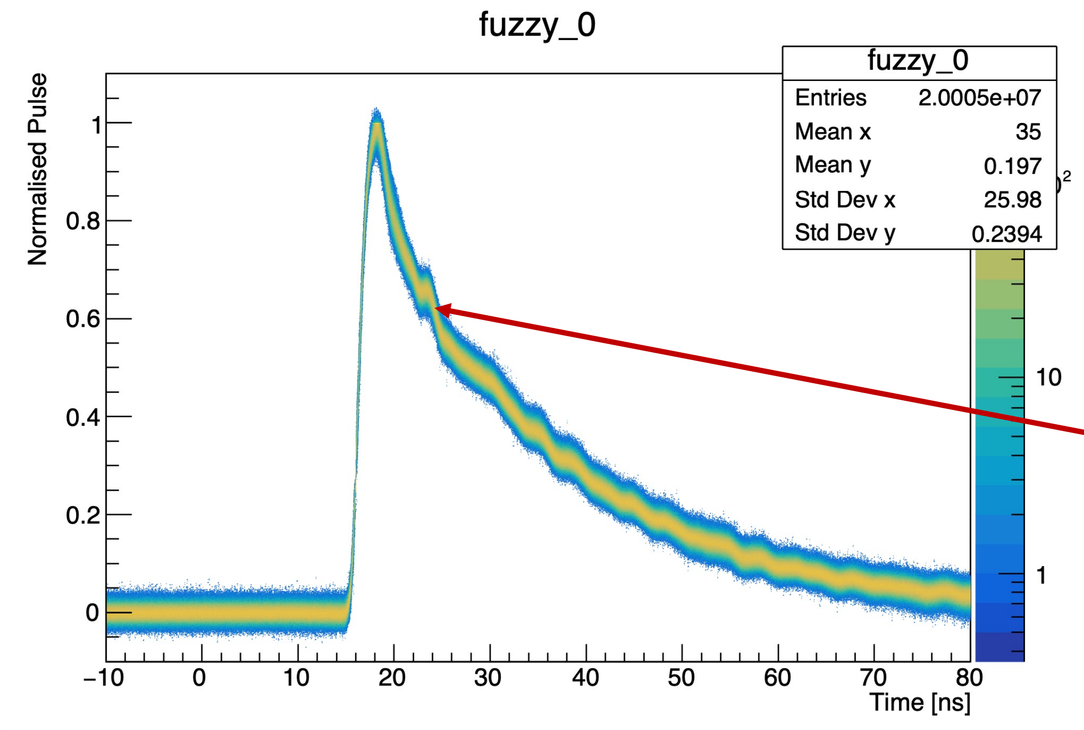


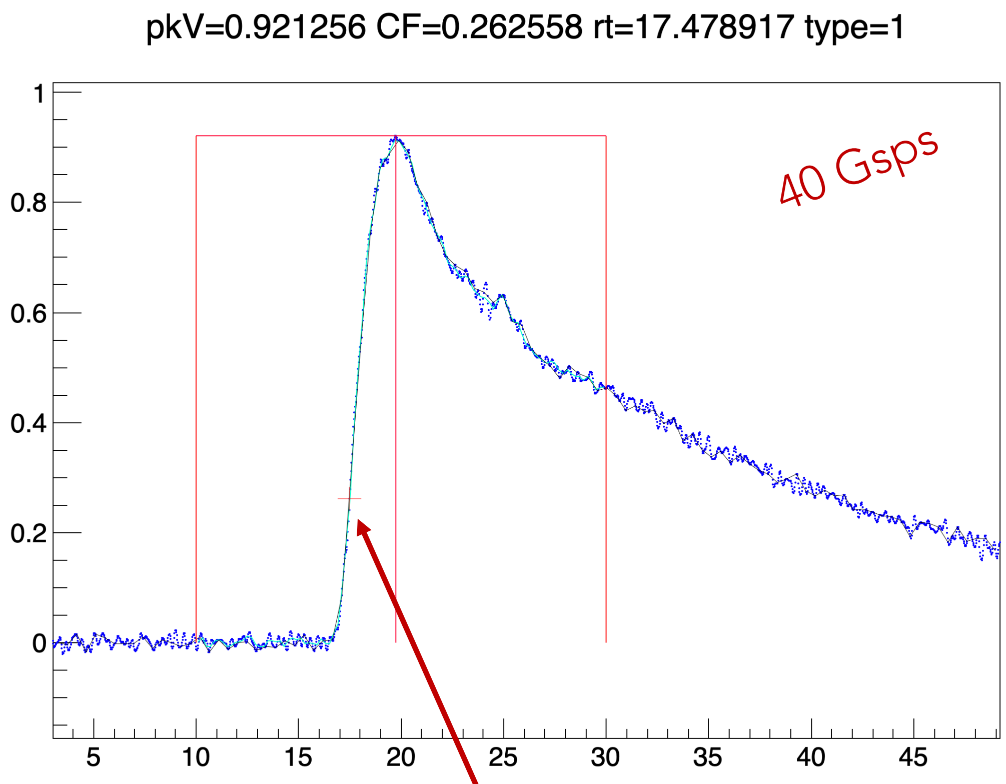




Template generation: pseudotime

- Pseudo-time generation
  - Wave interpolation
  - Pseudo-time using constant fraction
  - wave normalisation by fitting wave peak (w/ gaus)
- Template generation as a TProfile of the waveform dataset

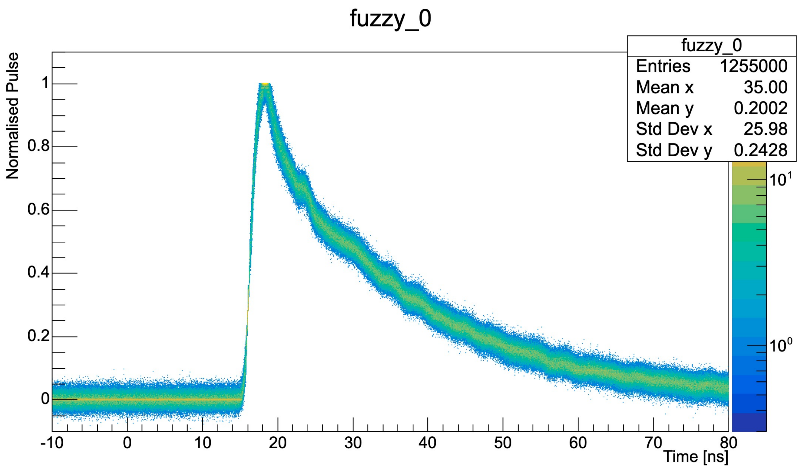


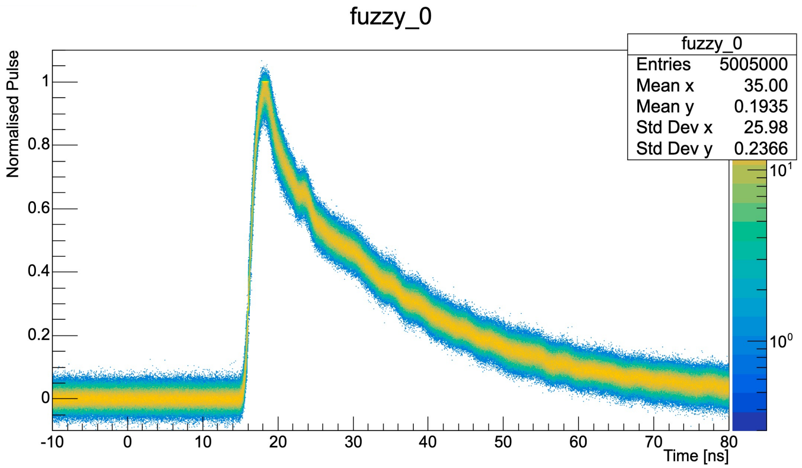


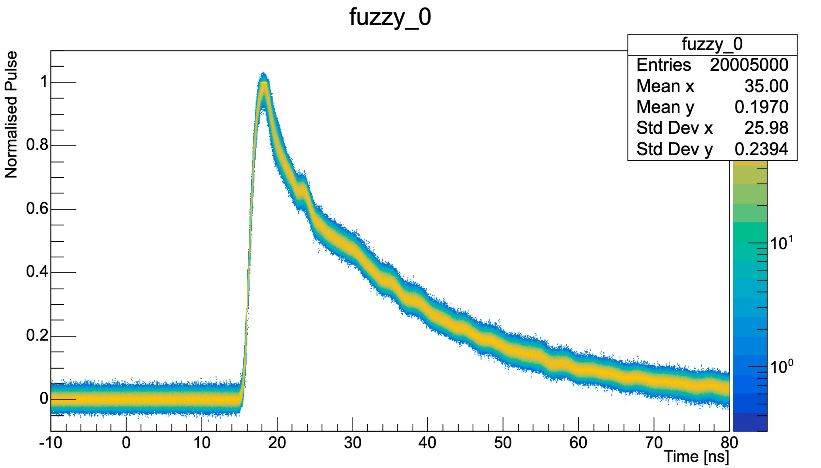
reconstructed time

Bump and oscillations visible in the WFs due to parasitic inductances in the FEE proto

Template generation: profiles (1 V @ 2.5, 5, 10, 20, 40 Gsps)



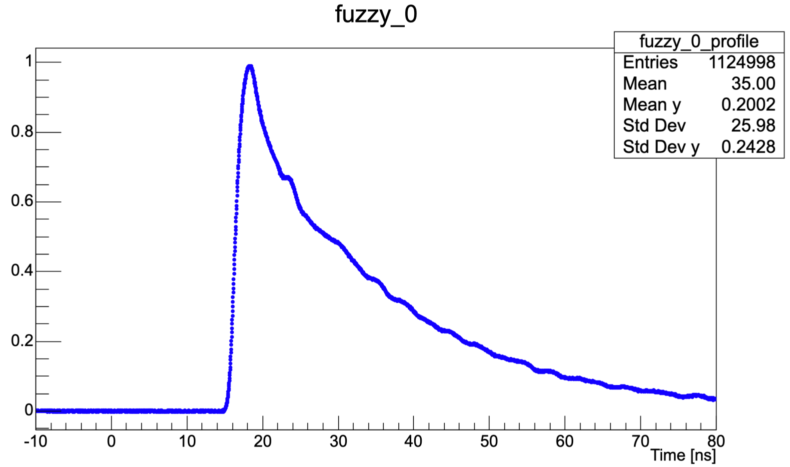


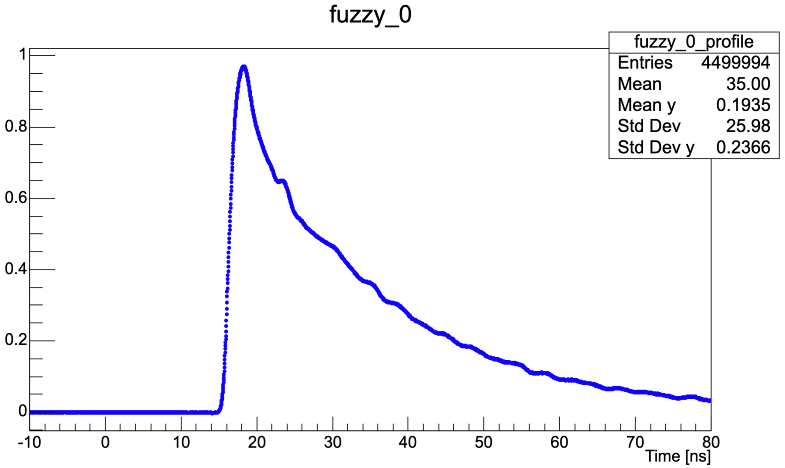


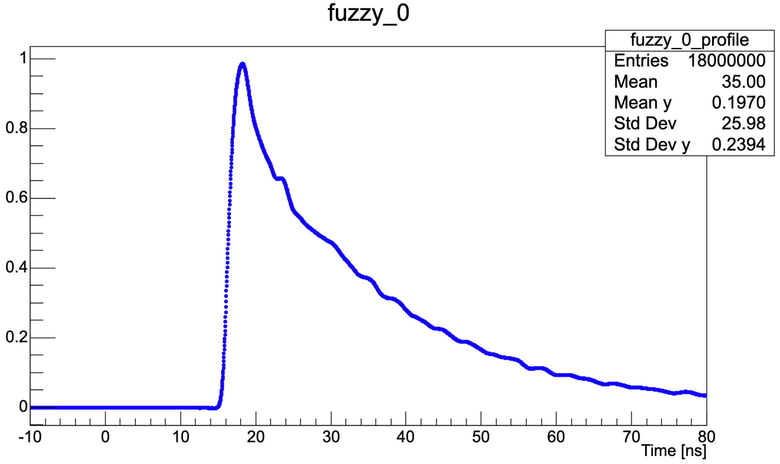
2.5 Gsps

10 Gsps

40 Gsps





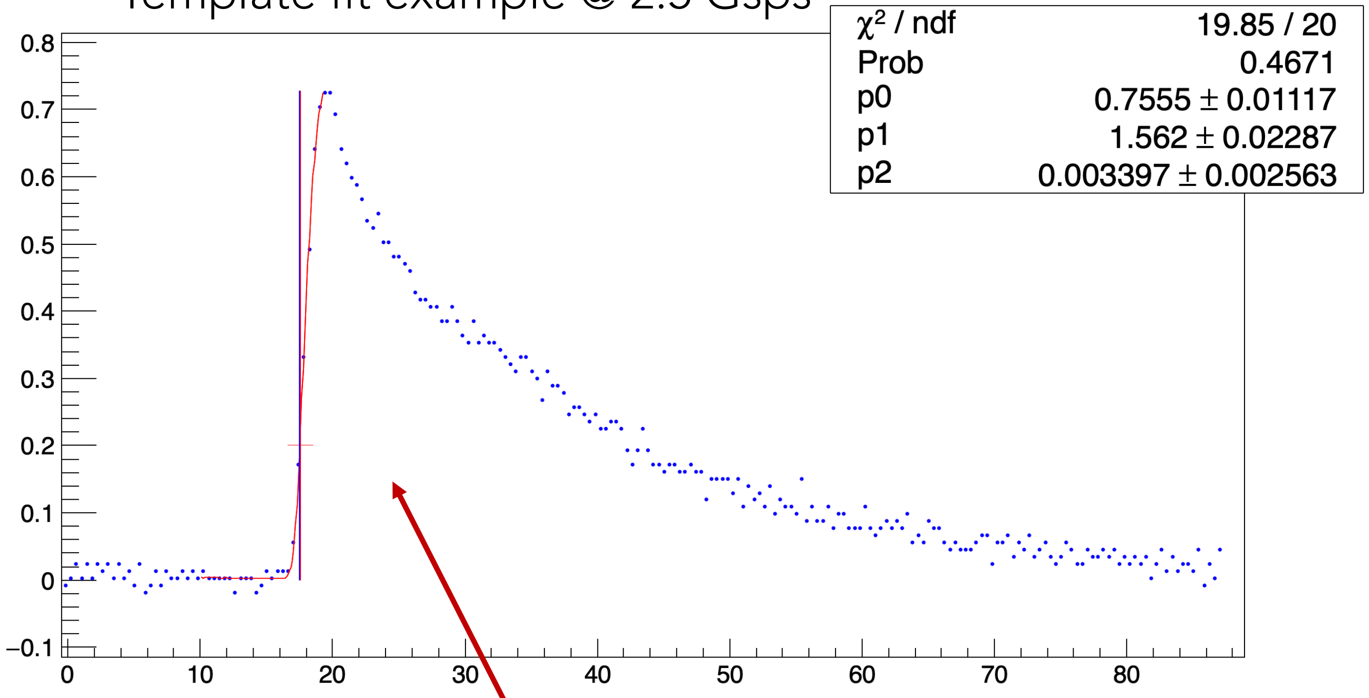


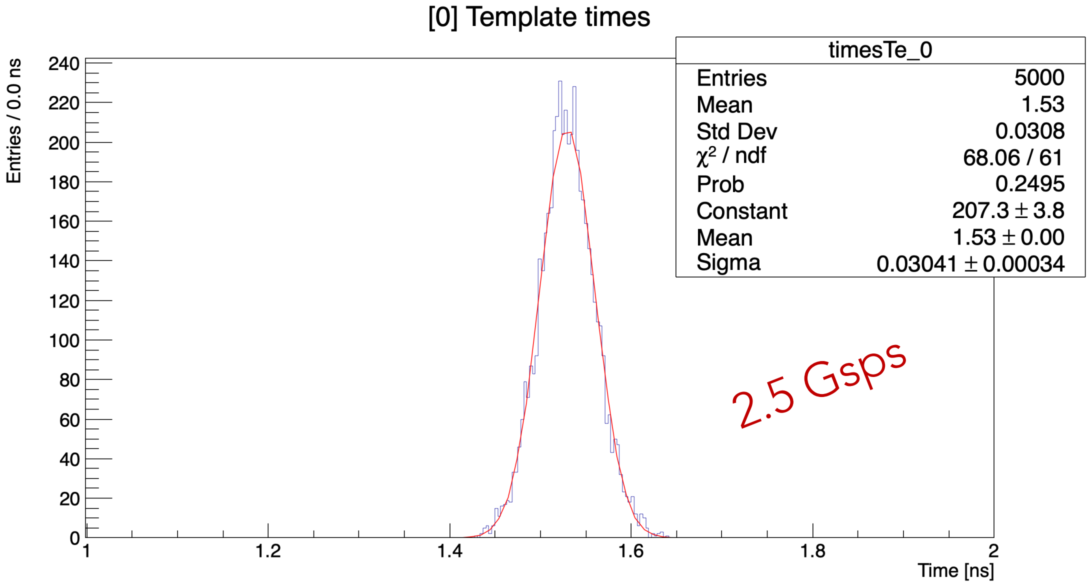
Template fit

- Waveform errors:
  - ex = time_bin/sqrt(12)
  - ey = ADC_lsb/sqrt(12) $\oplus$ baseline_RMS

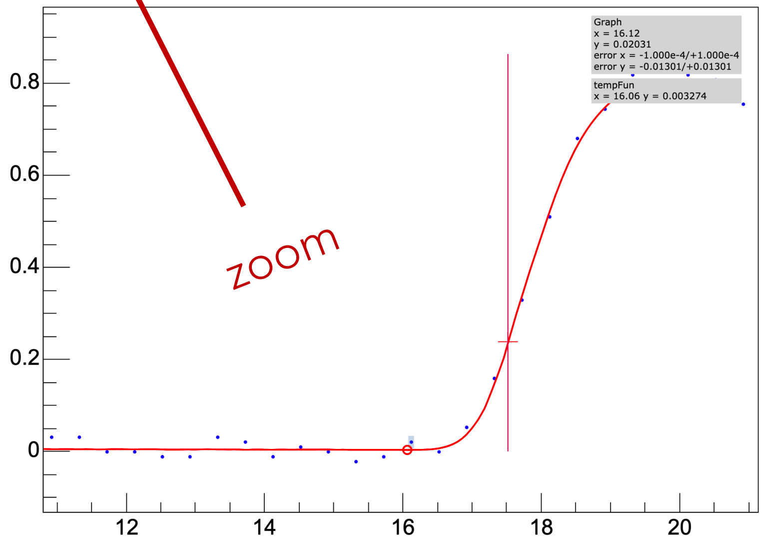
- Fit efficiency is 100 % for these runs

Template fit example @ 2.5 Gsps



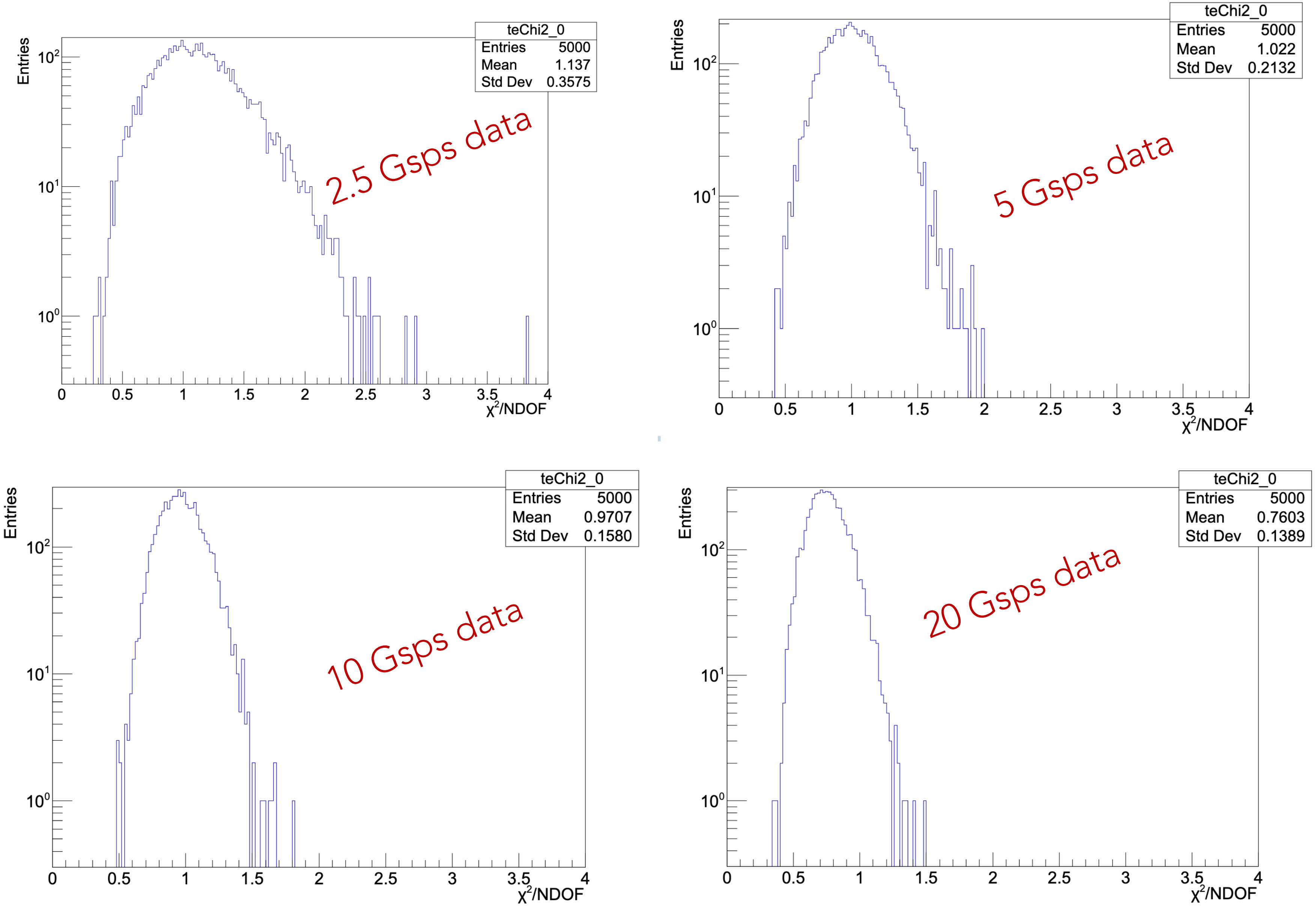


zoom



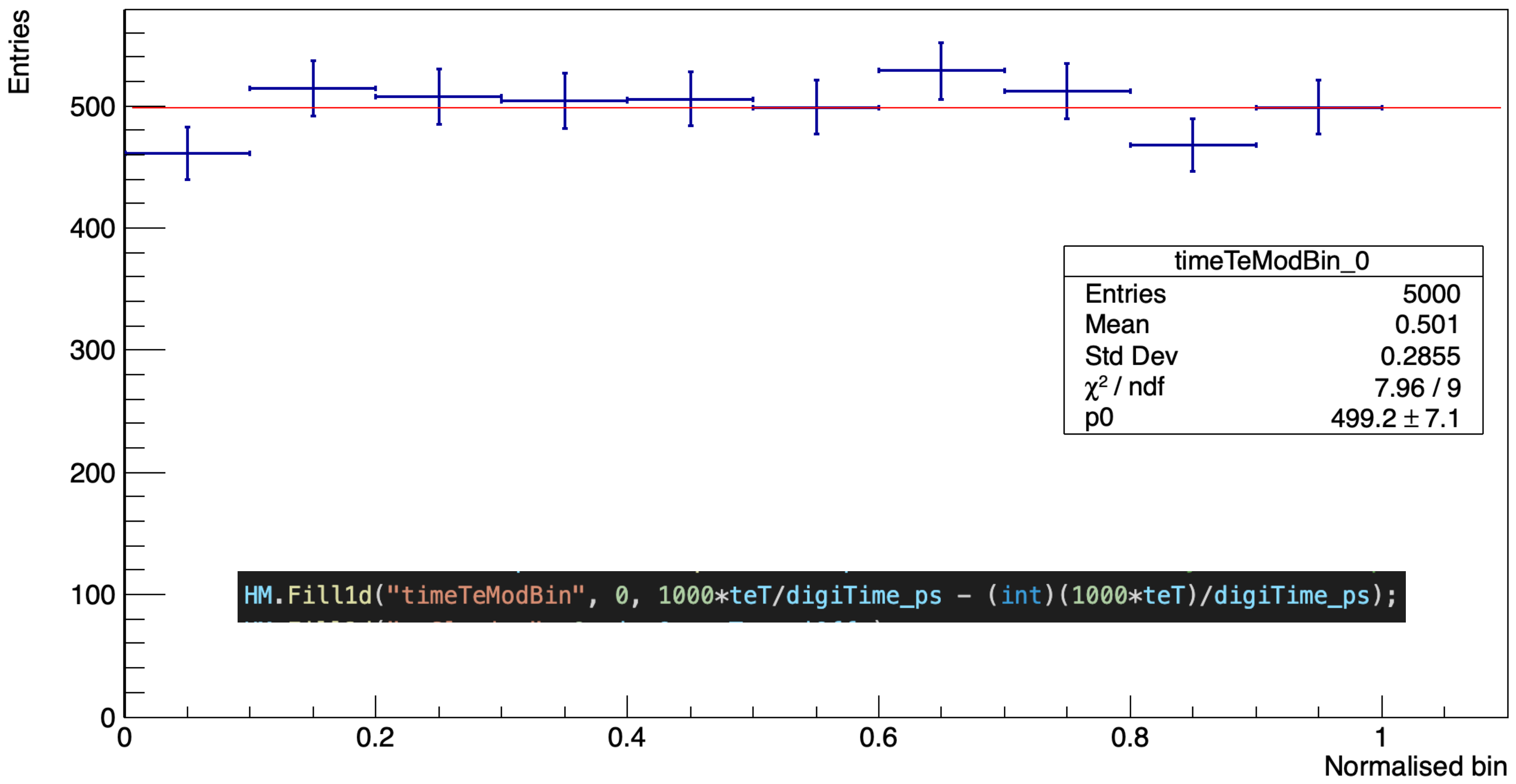
Template fit X^2_{red} check

- Splines generated @ 40 Gsps
- Data sampled at different frequencies used for timing reconstruction
- Fit range is fixed
- Higher NDOF w/ higher sampling rates



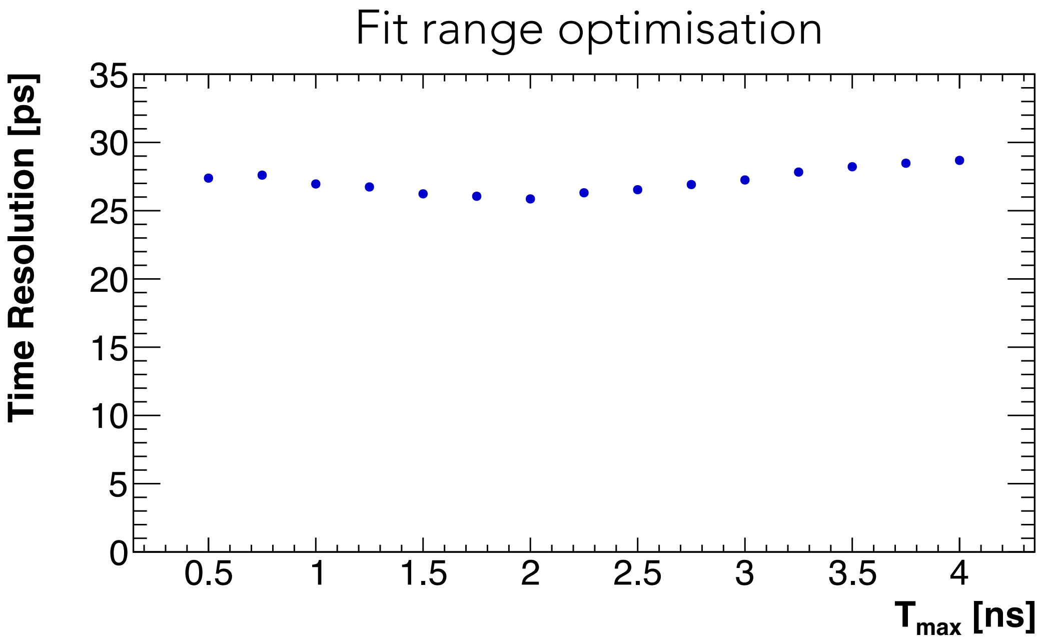
Digitiser time bias check

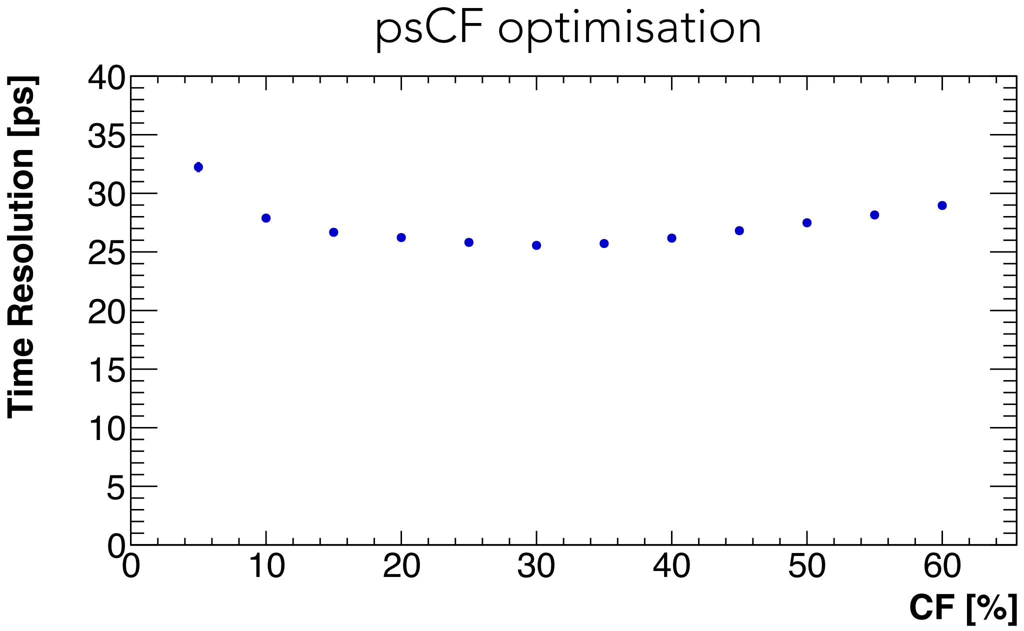
T_reco – T_bin @ 40 Gsps



Template fit optimisation

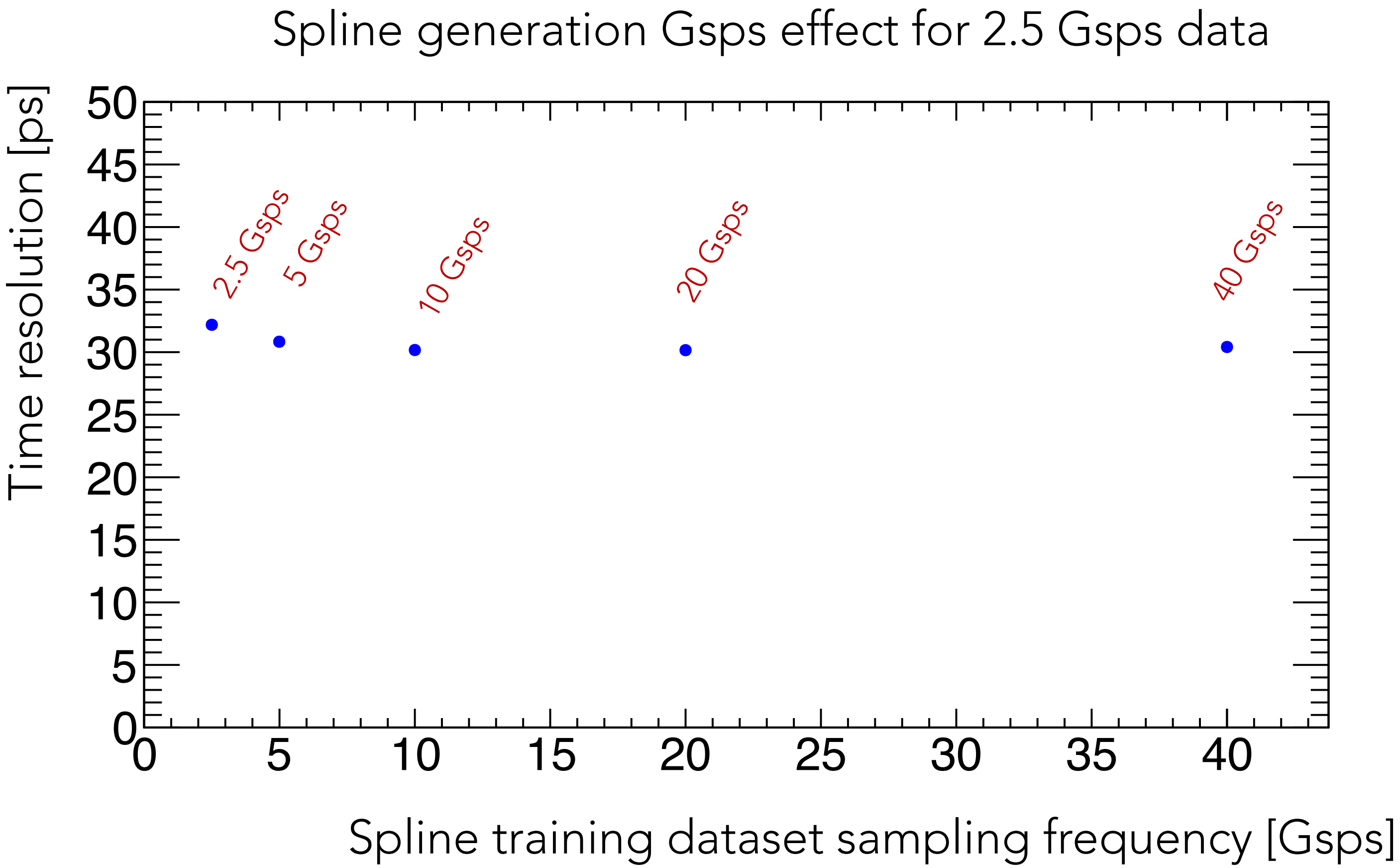
- Data used for optimisation (run1):
  - Spline generated @ 40 Gsps
  - Data sampled @ 5 Gsps
- Pseudotime constant fraction → optimum @ 30 %
- Fit range [psT – Tmin, psT + Tmax]
  - T_start fixed → Tmin = 7.5 ns
  - T_stop optimised → optimum @ Tmax = 1.8 ns
- Template spline bin width → optimum @ 20 ps/bin





Effect of spline training dataset sampling frequency on resolution

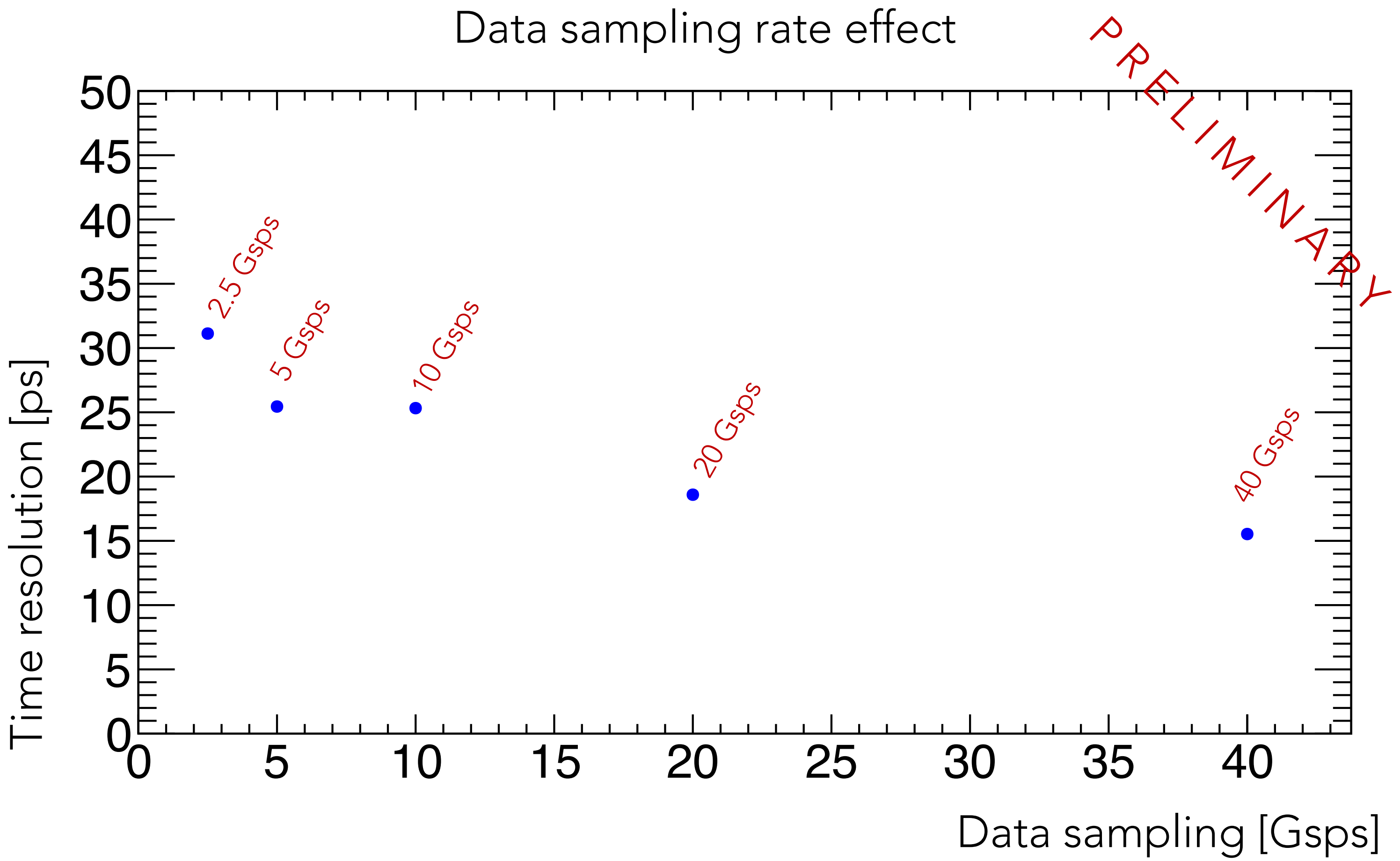
- Data used (run1):
  - Data sampled at 2.5 Gsps
  - Splines generated on data sampled at 5 different frequencies



Effect of fitted data sampling frequency

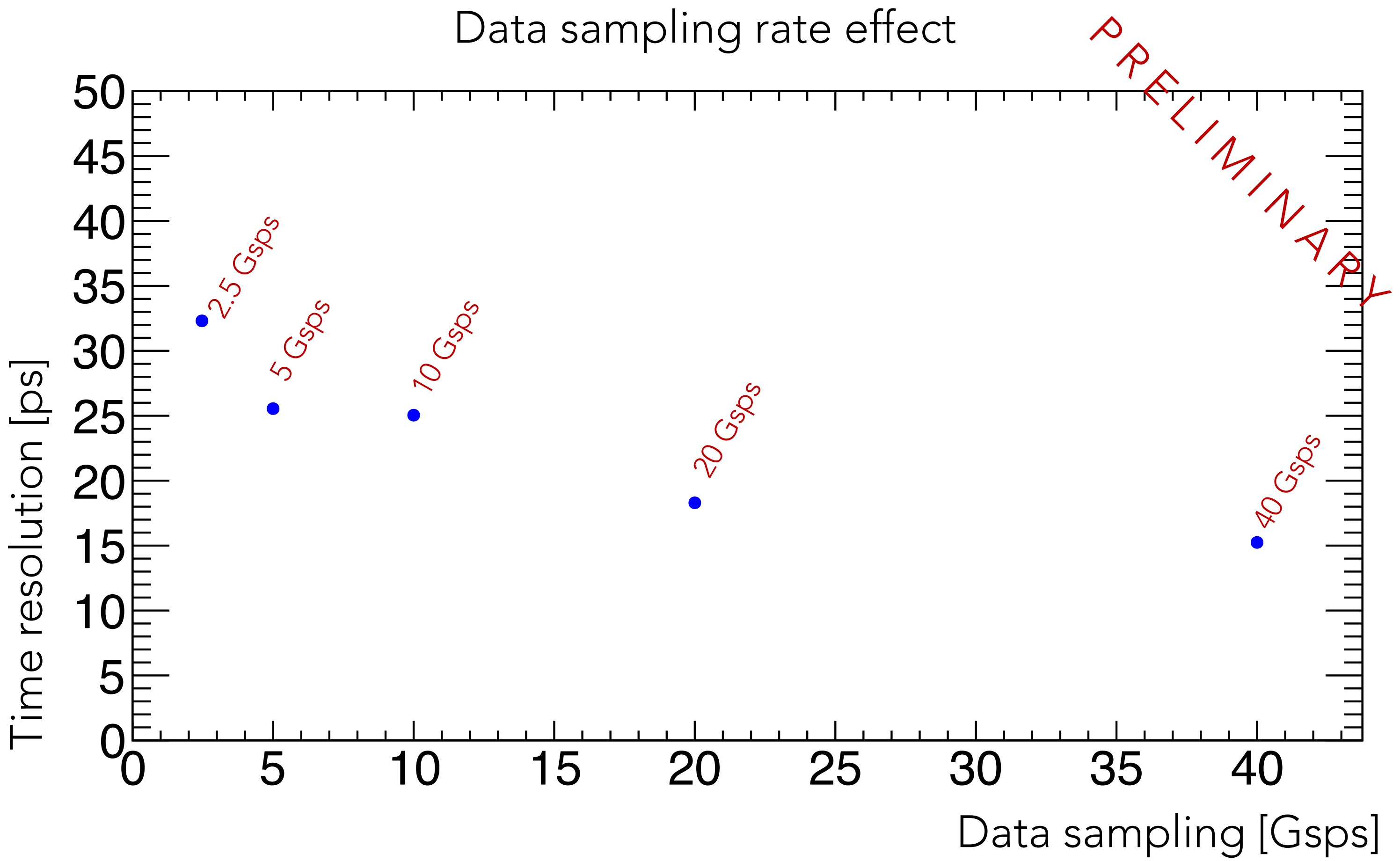
- Data used (run1):
    - Spline generated @ 40 Gsps
    - Data sampled at 5 different frequencies

- Further study needed by offline down sampling 40 Gsps data to remove systematic effects!!



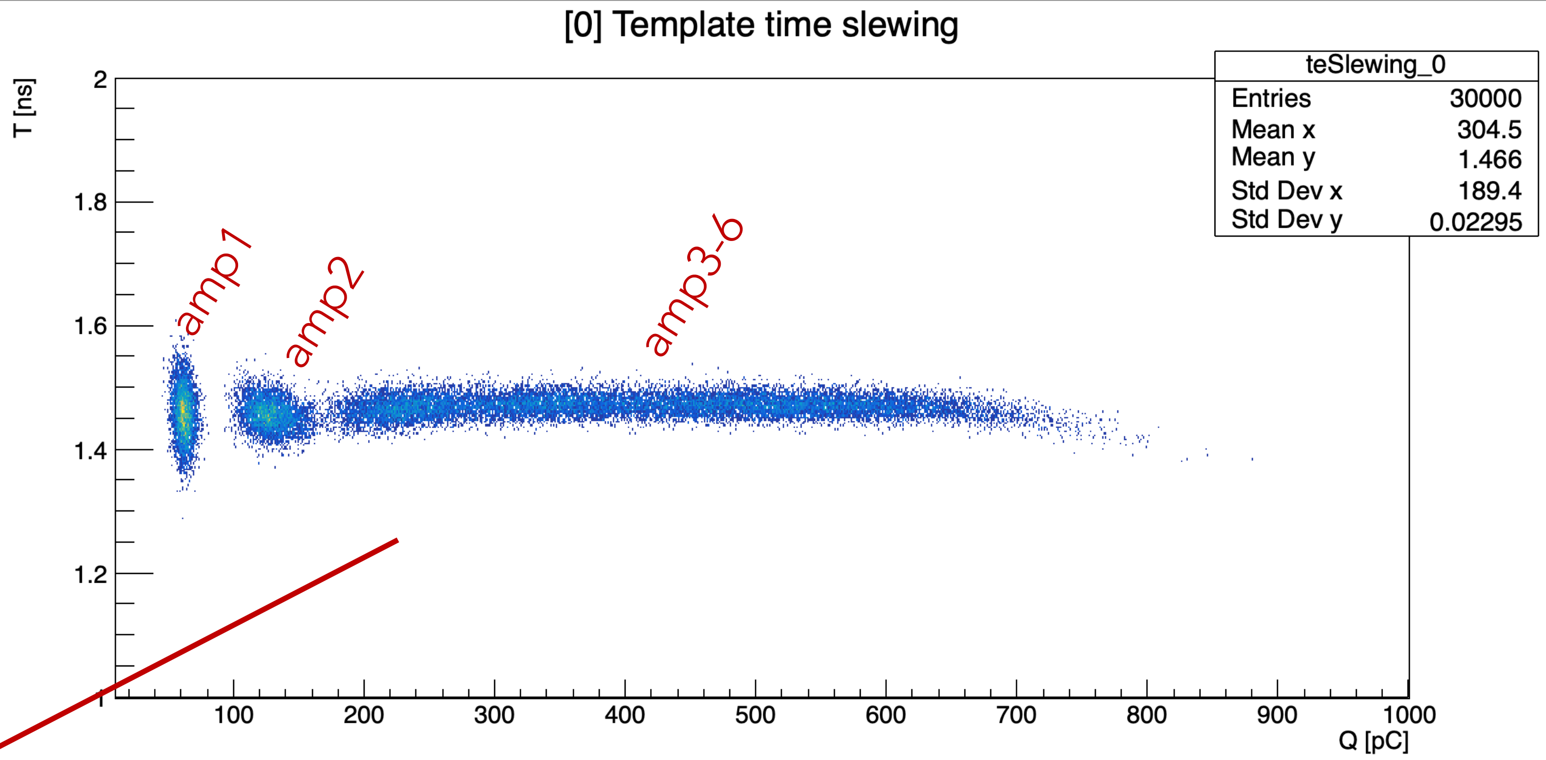
Combined effects

- Data used (run1):
  - Data taken at various sampling rates fitted with spline generated at same sampling rates
- This is the real case scenario for templates generation/adjustment (for each channel) during run time !
- Further study needed by offline down sampling 40 Gsps data!!

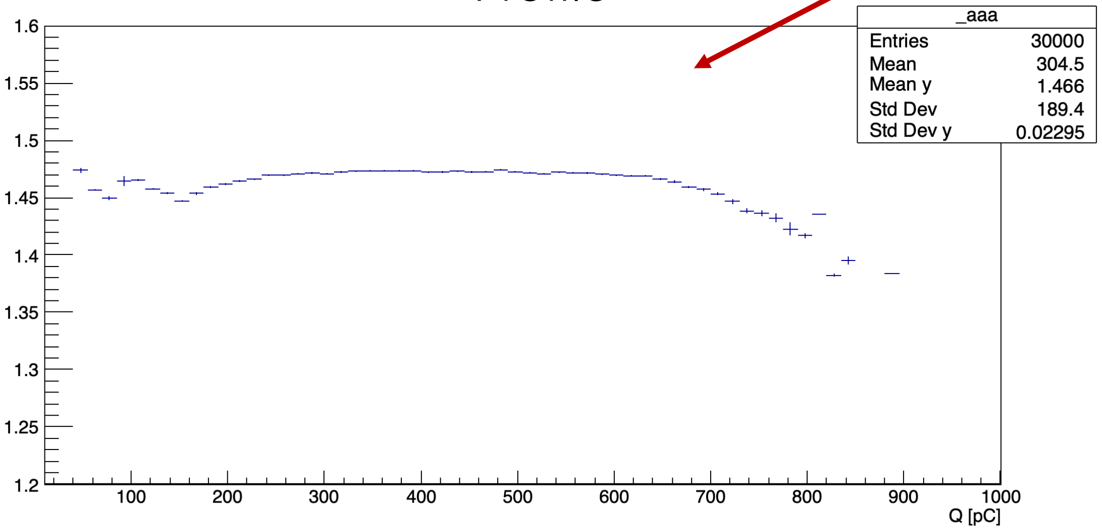


Laser run 2

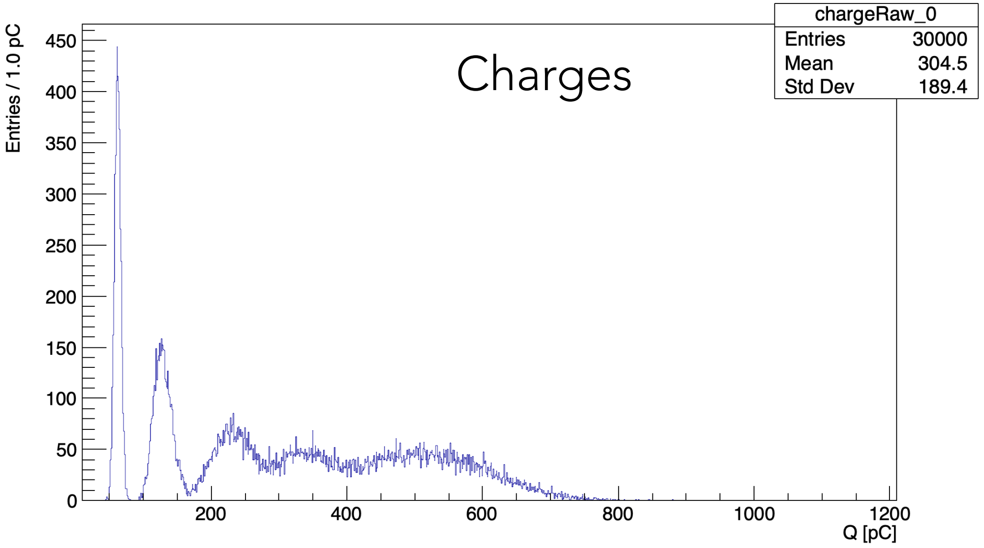
- Run2 data:
  - Spline generated @ 40 Gsps
  - Data sampled @ 40 Gsps
  - 6 laser amplitude increments
- No slewing correction was applied to fitted waveforms



Profile



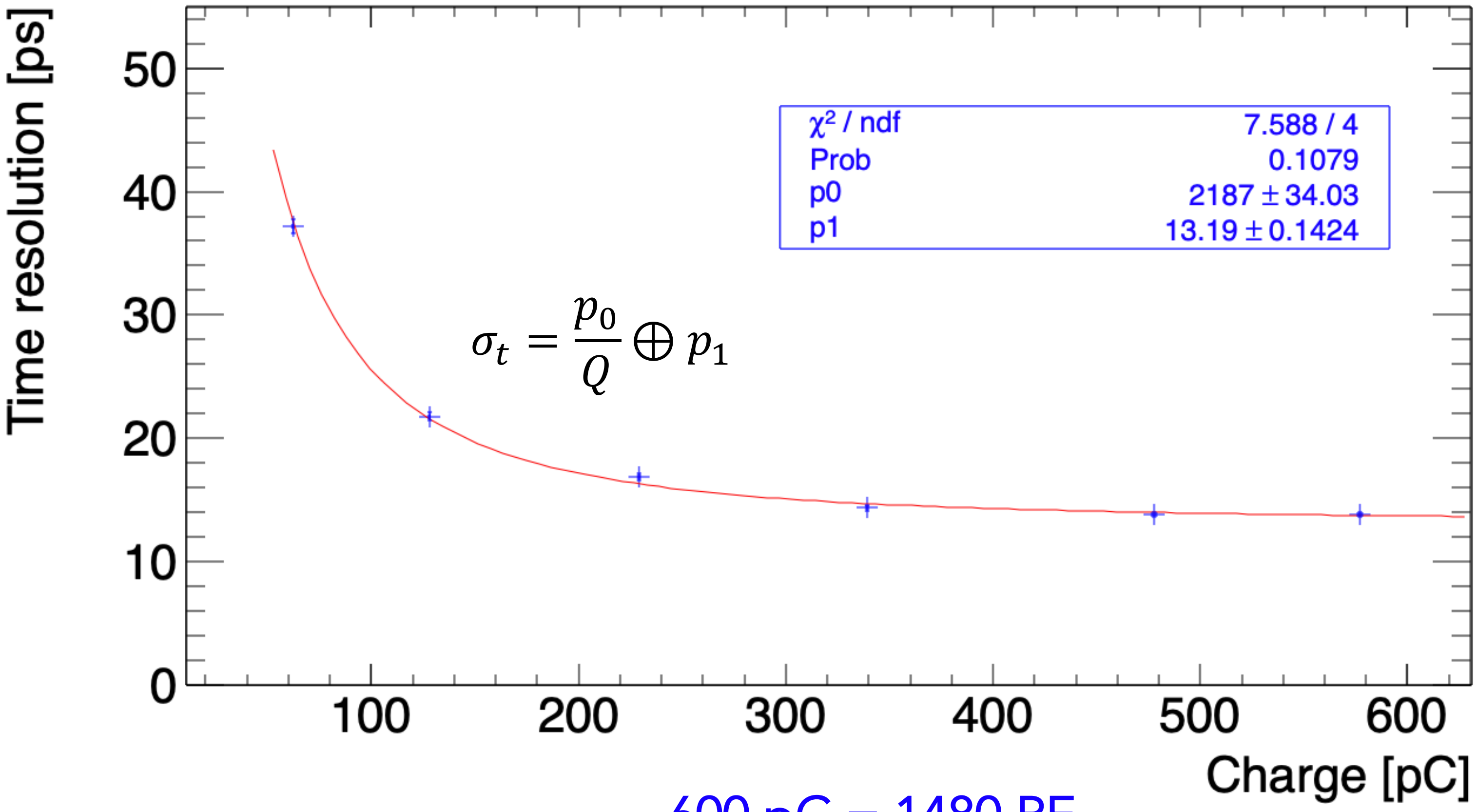
Charges



Time resolution vs charge

- Data used (run2):
  - Splines generated at 40 Gsps
  - Data sampled at 5 Gsps
  - 6 different laser amplitudes

Time resolution vs charge for 5 Gsps data



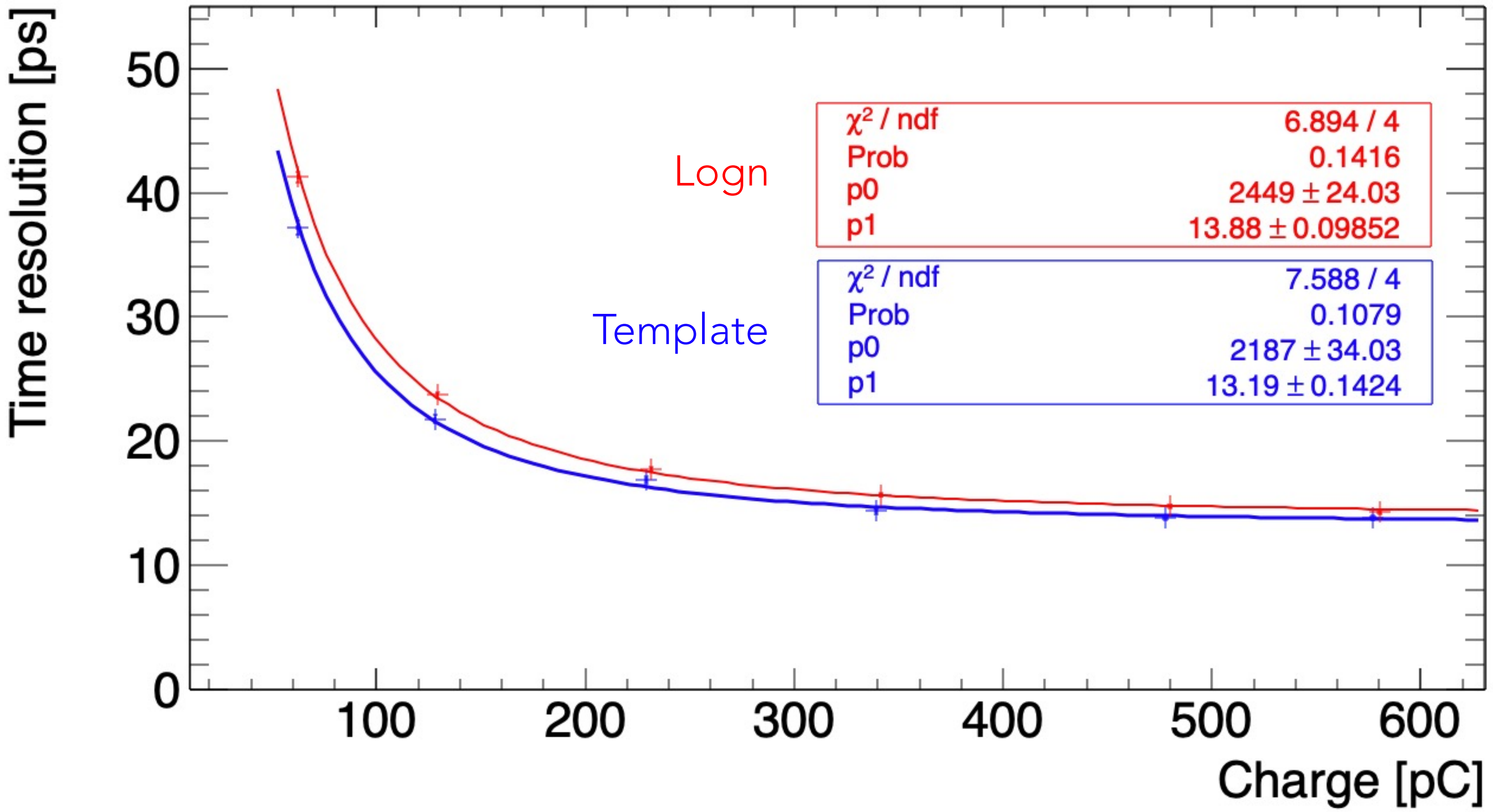
$$\sigma_t = \frac{p_0}{Q} \oplus p_1$$

600 pC = 1480 PE

Template vs logn

- Results are consistent
- Template fit has slightly superior timing resolution
- Template fit is computationally less expensive (3 vs 5 parameters optimisation)

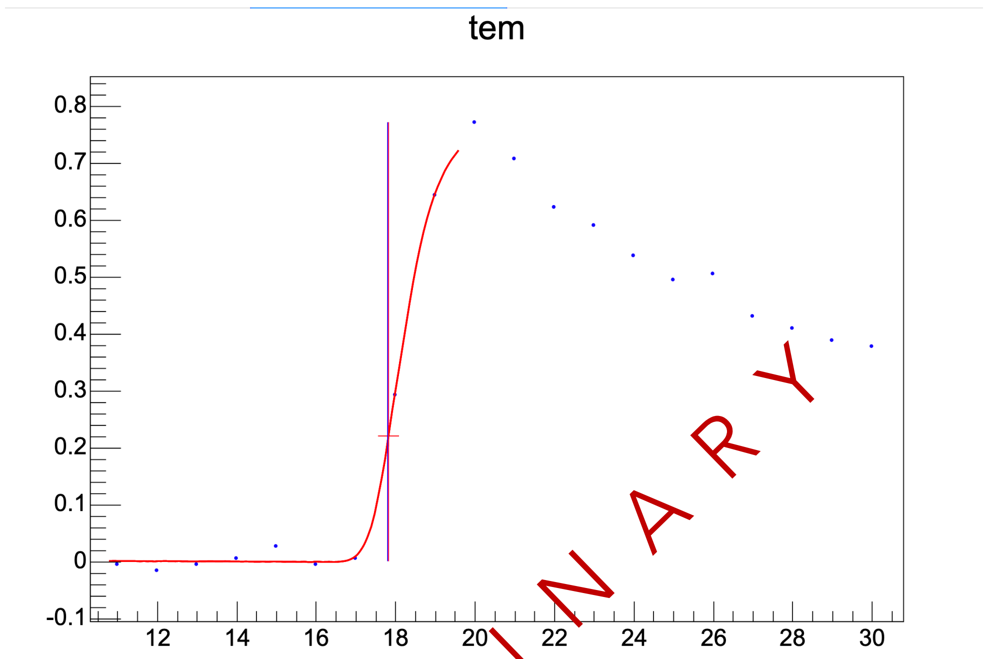
$$\sigma_t = \frac{p_0}{Q} \oplus p_1$$

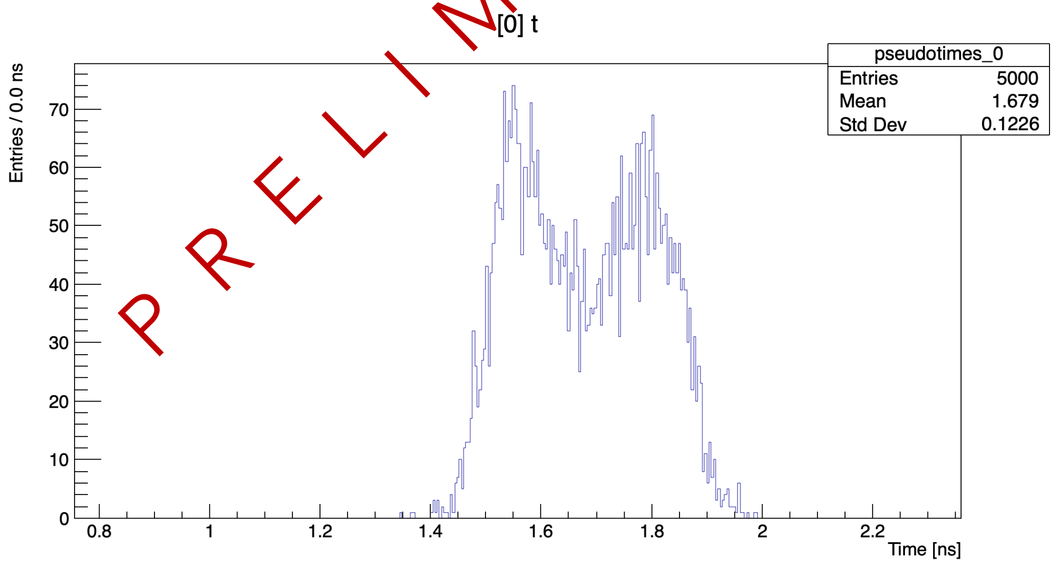


Data sampled at 1 Gsps

- Some runs were performed w/ 1 Gsps sampling
- For these runs, timing reconstruction is problematic
- The same procedure as before results in O(120 ps) resolution
- There are too few points (1 or 2) on the rising edge to correctly perform the waveform reconstruction

- Further investigation needed!!!





Conclusions

- A preliminary attempt at demonstrating a template fit procedure for Crilin timing was demonstrated with laser data
- Minor effects relative to the spline generation dataset sampling frequency were shown
- First characterisation of digitisation rate effect on timing resolution in the range 1 Gsps → 40 Gsps
- Expectations with template fit procedures: from O(30 ps) @ 2.5 Gsps to O(15 ps) @ 40 Gsps for amplitudes @ ½ Crilin FEE dynamic range (IF we chose to digitise our signals)
- Sampling rates around 2 Gsps seems a good compromise for digitisation (at least 4 points required on the rising edge)

Caveats

- Laser data will need a comparison with actual particle hits
- Waveforms were really noisy due to the prototypal nature of the demonstrated FEE → better SNR and lower distortions in the final prototype will yield better results
- Trigger jitter was ignored

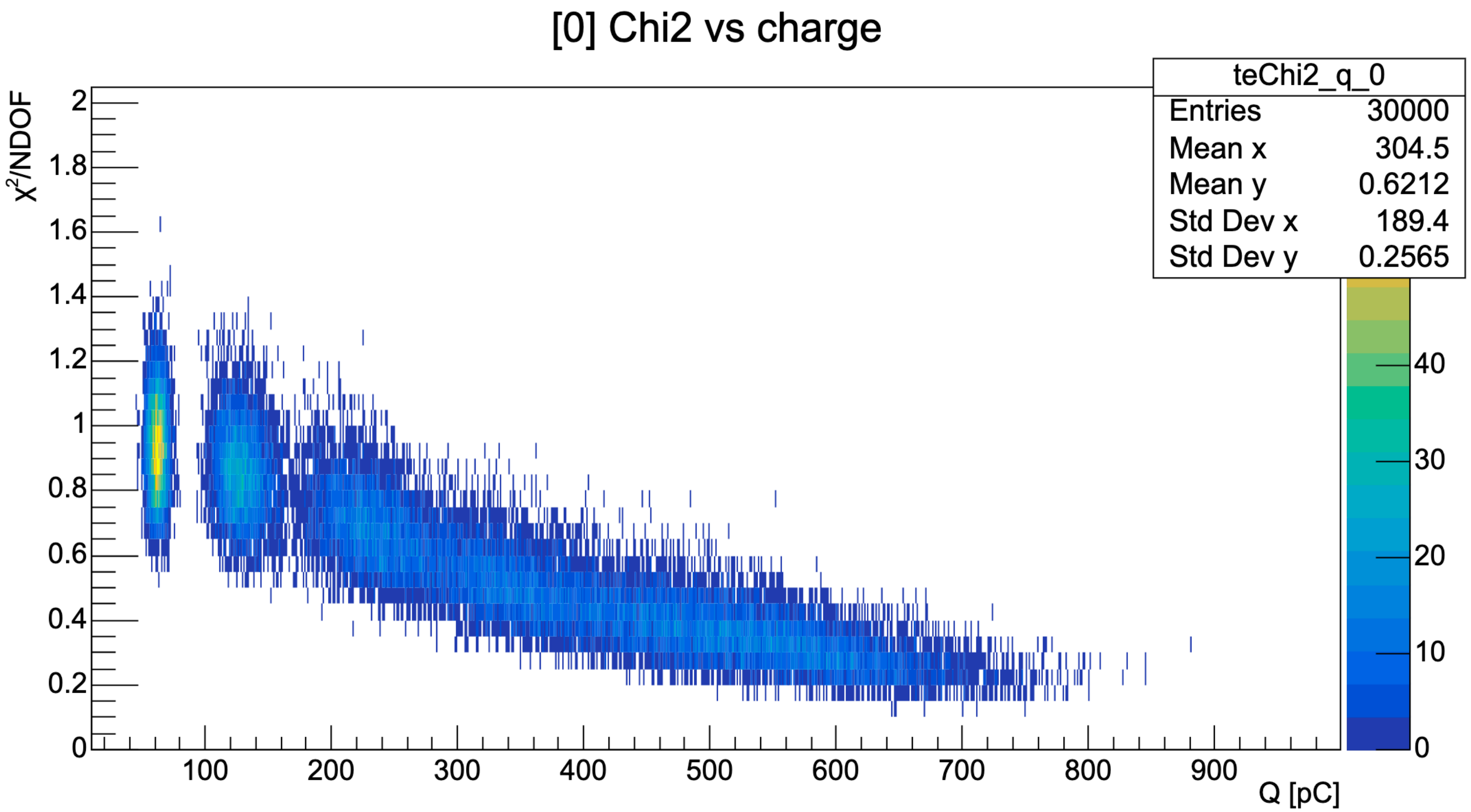
Improvements and next steps

- Check waveform deterioration after TNID irradiation
- The test spanned a signal range up to ~ 1500 PE → conversion from charge to energy scale is due (w/ test beam @ LNF-BTF)
- Approx. 1000 PE / 1 GeV deposit are expected from last TB
- An overall 1/sqrt(2) improvement on timing resolution to be expected due to Crilin’s dual crystal readout

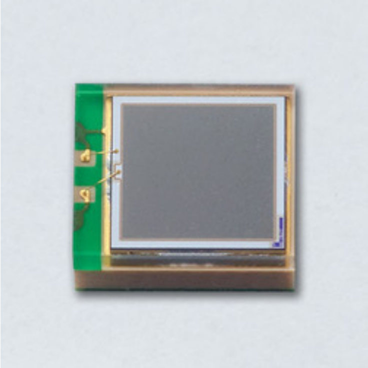
BACKUP

Chi2 vs charge

- Data used (run2):
  - Spline generated @ 40 Gsps
  - Data sampled @ 40 Gsps
  - 6 laser amplitude increments

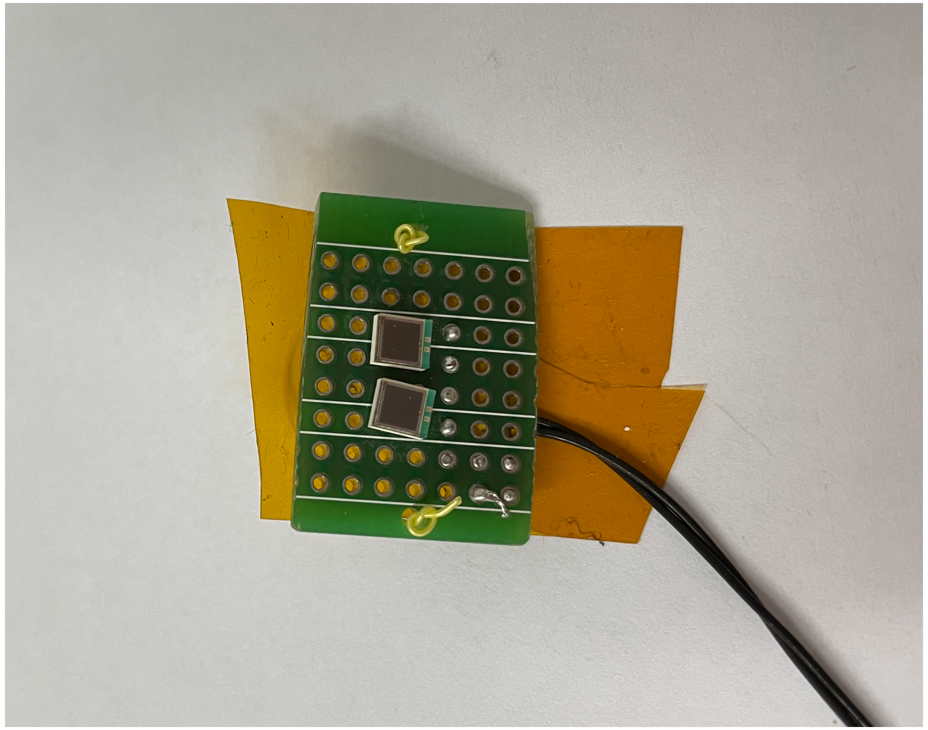


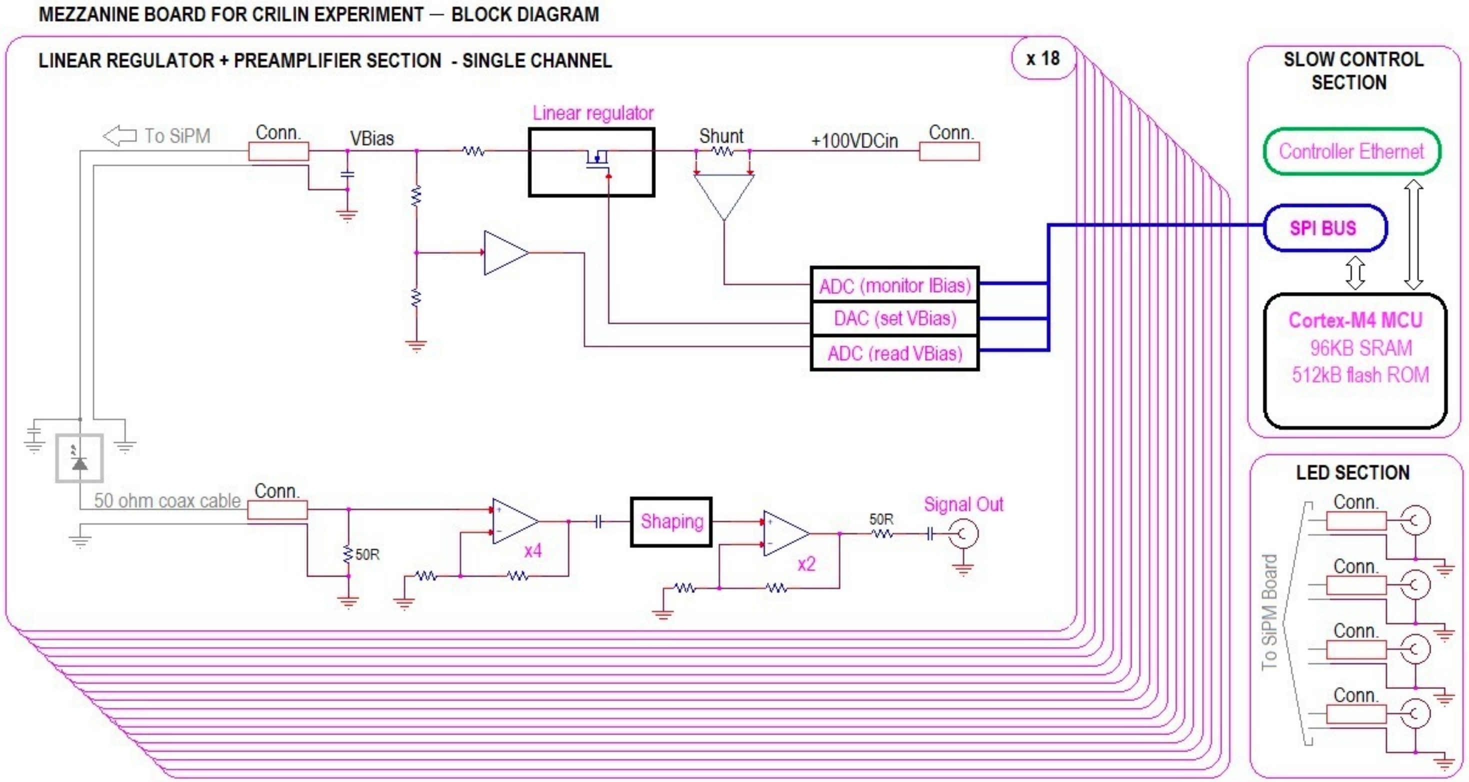
Crilin new front-end prototype



Crilin new front-end prototype

- Two Hamamatsu S14160-3015PS (15 um px size) in series
- SiPM readout and biasing via micro-coax lines
- Two stage amplifier w/ pole-zero cancellation
- Prototype validate, production in progress





Trigger

- Acquisition was triggered using Laser's trigger out
- All times were referred to to Laser's trigger out