Optimizing a Thomson scattering diagnostic for fast dynamics and high background

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MST has unique parameter space:
- low density (~1e19 m⁻³)
- high background
- large dynamic range (core Te from 100 eV to >2 keV)
- non-changing events (δ change in Te, background in <100 µs)
- rapid discharge repetition rate (1.5 minutes)
- fast-changing events (x3 change in Tₑ, background in <100 µs)
- large dynamic range (core Tₑ from 100 eV to >2 keV)
- low density (~1e19 m⁻³)

MST has unique parameter space:
- Ruby-based system, LeCroy 2249-based digitizer
- 0.5 ms resolution, but no data during the crucial sawtooth period

Previous results
- 53 ns resolution, but no data during the crucial sawtooth period
- Ruby-based system, LeCroy 2249-based digitizer

New digitizers
- Brion: 1 GHz, 300 MHz bandwidth, 128 LS memory
- compact PCI with linux drivers
- PCI-5 interface connects remote crates to PC
- ~100 m pulse gives higher effective vertical resolution
- limit of ~200 pulses per discharge

High Background:
- for example in this figure, background is 10x signal.

Goal:
- measure the scattered photon distribution
- measure the background contribution - in particular quantifying the effect of the background fluctuations on the uncertainty of the scattered signal!

Fitting the raw voltage signal:
- Background 100 ns before and after is fit using 2nd order polynomial (R)
- the measured response-function (R) of the APD is used to fit the scattered signal (V)
- a fixed time is used for all APD channels of a single polychromator
- this provides channels with small signal backlash onto background fluctuations, or electrical noise.

Quantification of the background coupling:
- Measurement of scattered signal is no longer a fixed-time integral
- the response function adds information, reducing uncertainty
- In integral case, the background contribution is based on the background flux times the integral duration
- With response function R, the contribution is constrained to be co-incident with the scattered signal
- A Monte-Carlo code was used to quantify the new coupling:
- for a known scattered pulse and known background level
- many trials of random background fluctuations are evaluated
- background fluctuations scale with the rms of the scattered signal

Conventional Levenberg-Marquardt χ² minimization
- goal: find maximum likelihood temperature, and it’s uncertainty
- different algorithms were tested: amoeba, SVDfit but based on speed and accuracy Levenberg-Marquardt was selected
- to get uncertainty, photon distribution is randomized based on its uncertainty

Bayesian Probability theory method:
- goal: find maximum likelihood temperature but retain the full probability distribution
- normally the probability distribution is approximated by the mean and standard deviation
- this information is written with fitted data, so any result can be reproduced.

Computational Setup
- system is setup on sgrid cluster which processes data in parallel
- processing time for 50 points is ~1 minute
- MST shot cycle time has minimum of 1.5 minutes
- most of the minute is overhead from sgrid, so doubling the computation only adds seconds.

Long Term Support
- changes to code, calibration could change temperature, density
- we used MOU which uniquely identifies calibration data (P/QE, gain, transmission...)
- code version
- this information is written with fitted data, so any result can be reproduced.

More results and Conclusions:
- raw digitizer and fitting algorithms working well
- ~100 eV standard plasma conditions to 2 keV improved confinement regimes
- can now fit through sawtooth cycle for first time
- fitting between discharges, despite 1.5 cycle time
- response-function fit to scattered signal reduces background contribution by factor of 2.

Code version
- this work is supported by U.S. D.O.E.

Goal:
- measure the background contribution
- robust - must handle large dynamic range
- rapid discharge repetition rate (1.5 minutes)
- fast-changing events (x3 change in Tₑ, background in <100 µs)
- large dynamic range (core Tₑ from 100 eV to >2 keV)
- low density (~1e19 m⁻³)

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