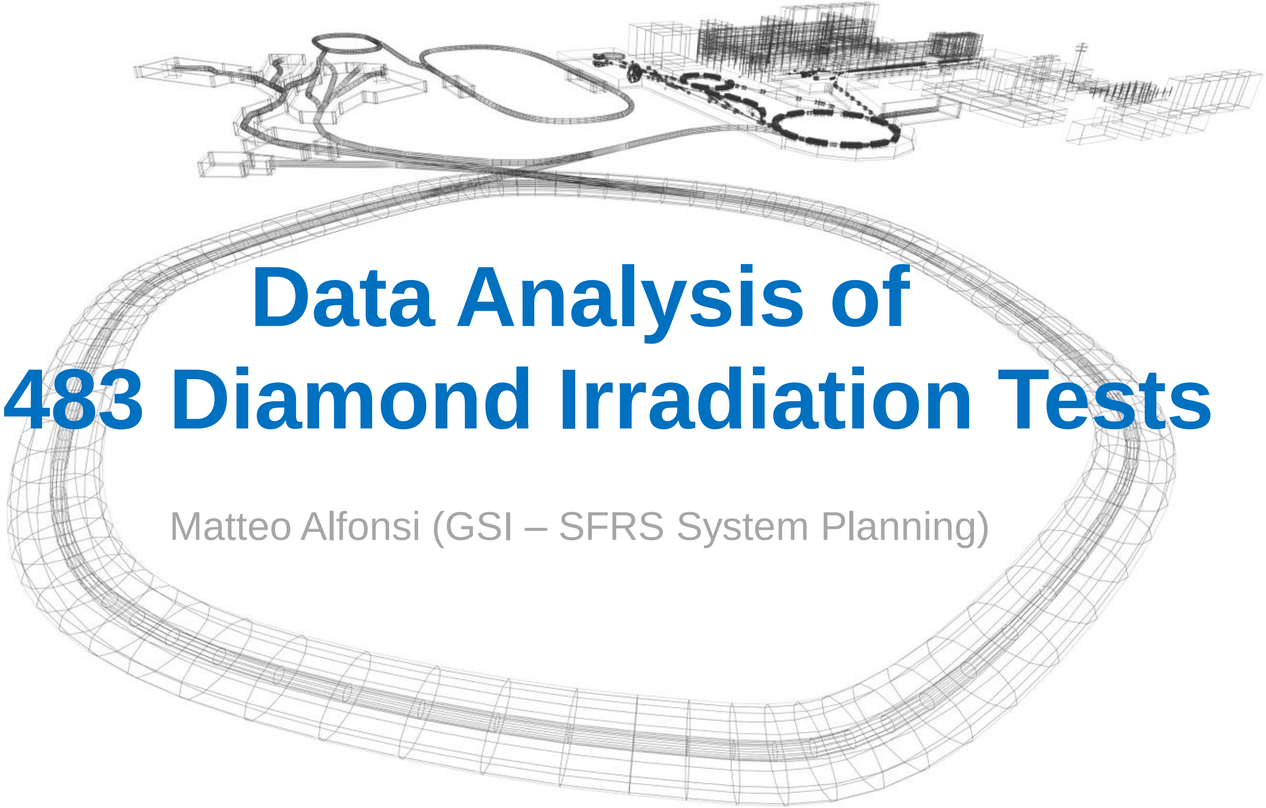
Data Analysis of S483 Diamond Irradiation Tests

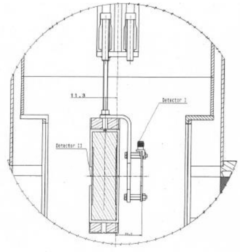


Matteo Alfonsi (GSI – SFRS System Planning)

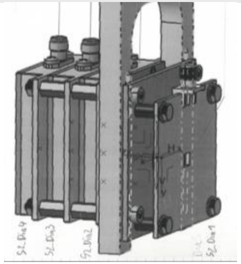
Irradiation Test Goal

- Diamond detectors @ SFRS should provide intensity information also during the maximum beam intensity, in case of specific measurements
- E.g. we expect to irradiate this detector with ~10^9 ions/mm^2 in a calibration for a cross-section measurement
- In Feb 2021 a polycrystalline Diamond (pcDIA) sample has been irradiated with Pb (1GeV/n) @ FRS S1. Comparable irradiation with U in Mar 2021.
- Periods of high intensity irradiation alternated with low rate periods in which the performance of the sample has been measured.
- Bunches of signal waveforms have been acquired with a high bandwidth oscilloscope, to check for degradation of signal properties

Irradiation Test Setup

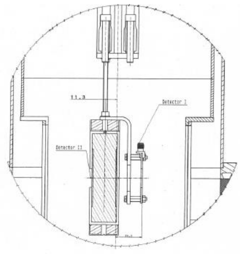


Ionization chamber (IC), Polycrystalline diamond (pcDIA) to be irradiated



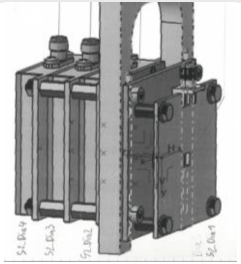
Stack of single-crystal diamond (scDIA) used as trigger

Irradiation Test Setup



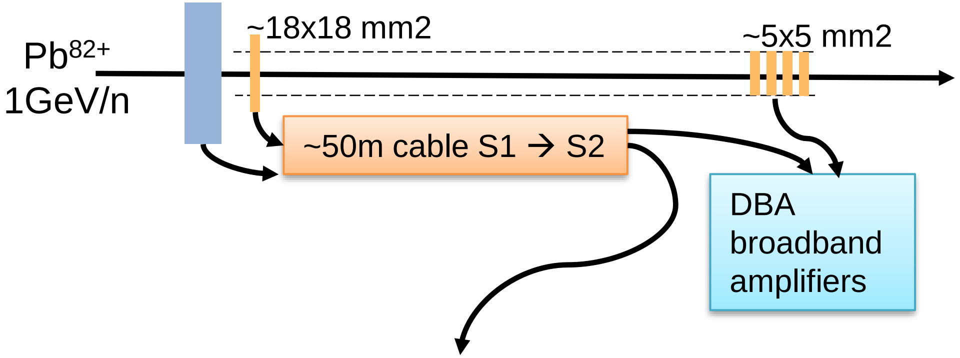
Ionization chamber (IC), Polycrystalline diamond (pcDIA)

S1 focal plane



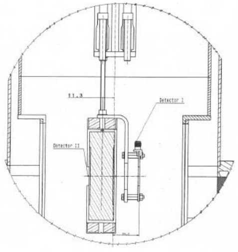
Stack of single-crystal diamond (scDIA), used as trigger

S2 focal plane

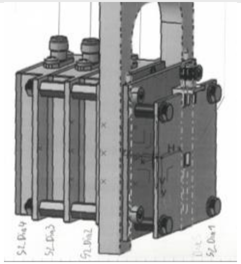


- Electronics at S2, amplifier only after long cable

Irradiation Test Setup



Ionization chamber (IC), Polycrystalline diamond (pcDIA)



Stack of single-crystal diamond (scDIA), used as trigger

- Electronics at S2, amplifier only after long cable
- Both MBS DAQ & waveform saving

S1 focal plane

S2 focal plane

Pb^{82+} 1GeV/n

~18x18 mm2

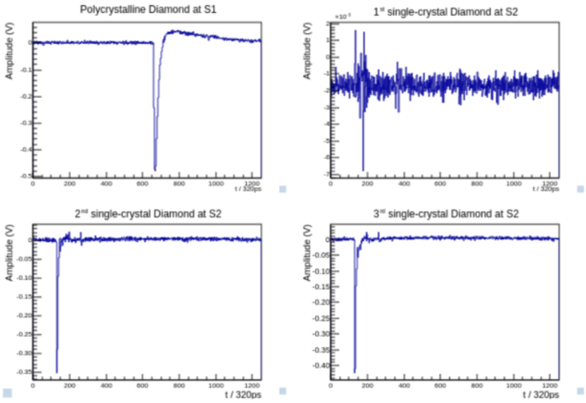
~5x5 mm2

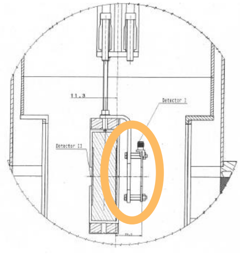
~50m cable S1 → S2

DBA broadband amplifiers

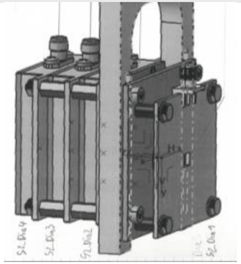
MBS DAQ

Go4 analysis
- Calculate integrated irradiation



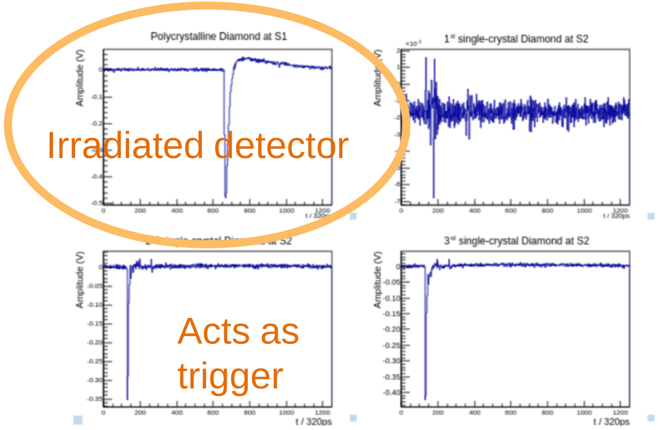


Ionization chamber (IC), Polycrystalline diamond (pcDIA)
HV -300V

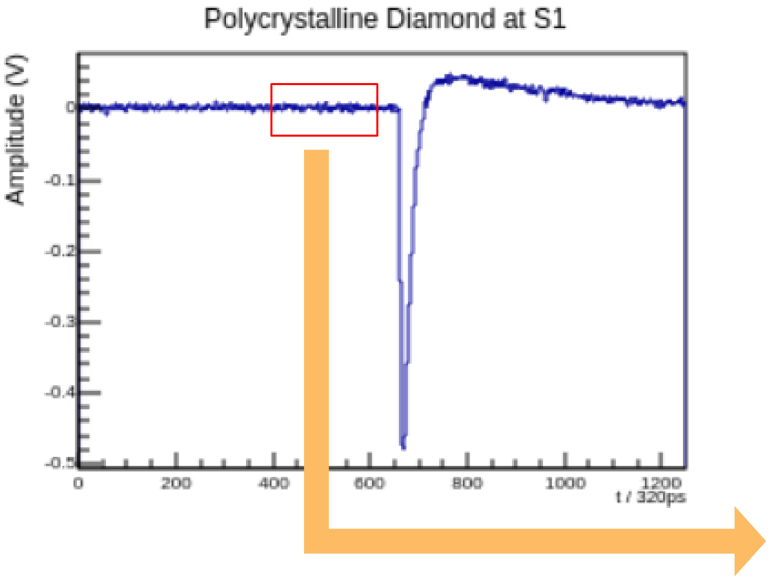


Stack of single-crystal diamond (scDIA), 2nd of the stack as trigger

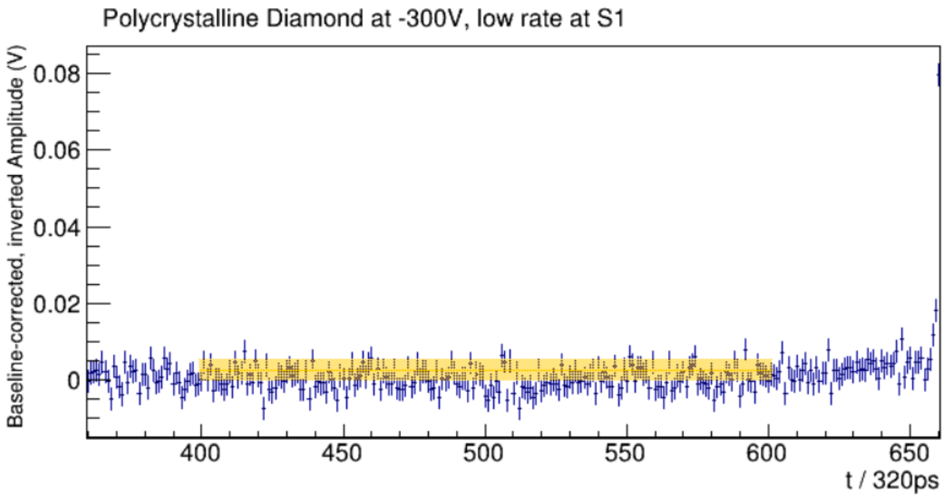
Waveform processing tools development with first low rate dataset



Waveform processing



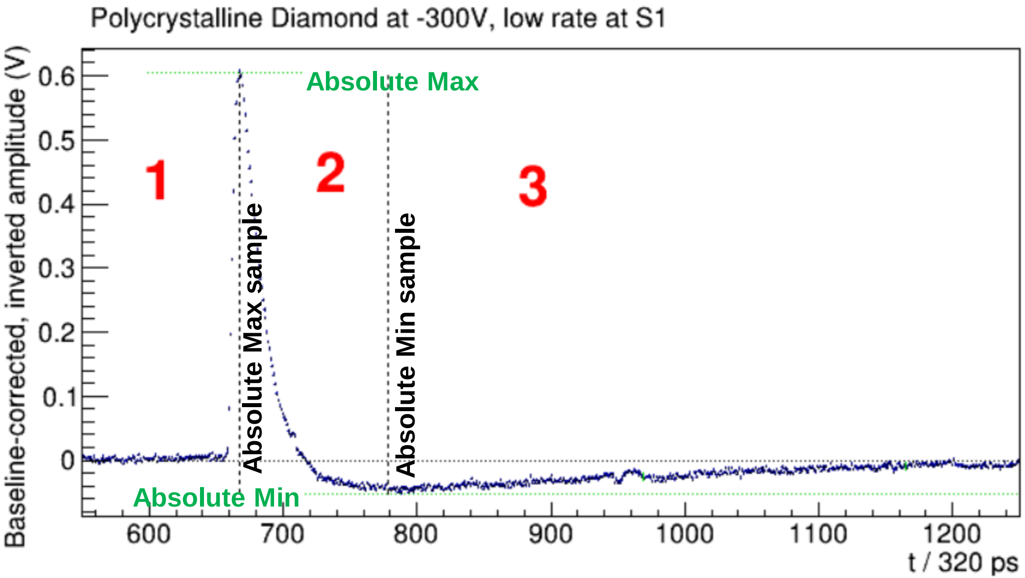
- Baseline calculated just before the signal
- Baseline-corrected signal inverted



- "noise around baseline" crucial role for next steps

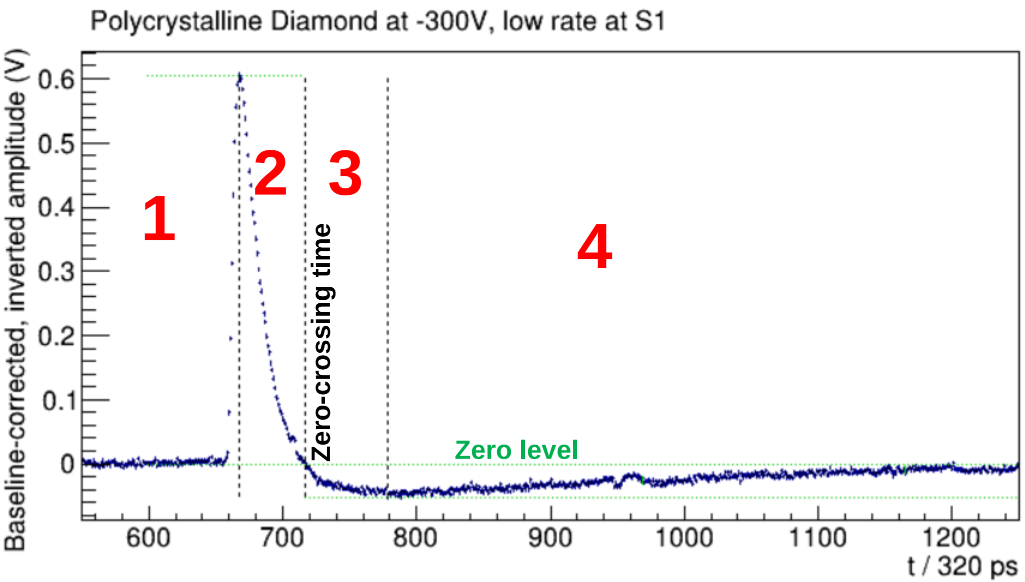
Signal shape descriptors (I)

- Absolute Min & Max searched
- Corresponding samples divide the waveform in three regions



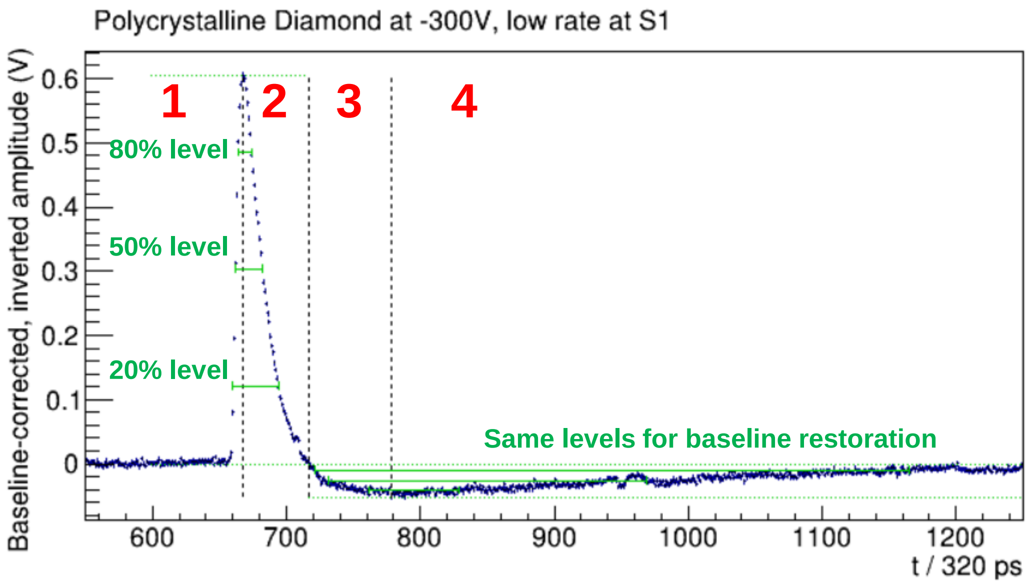
Signal shape descriptors (II)

- Between Min and Max, Zero-crossing time as weighed-average time
- Weigh is function of the distance to zero level, normalized to signal noise



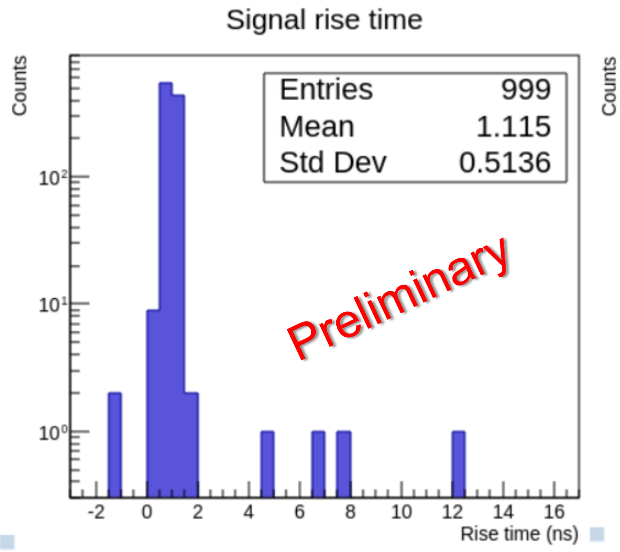
Signal shape descriptors (III)

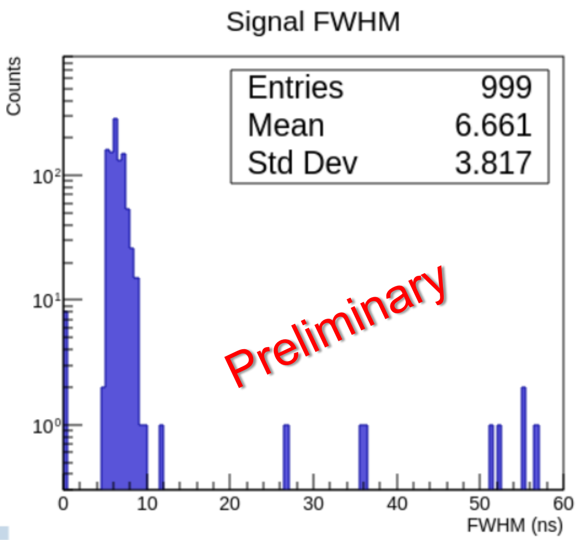
- Each region searched for the crossing-time of the 20%-, 50%- and 80%-level of the Max and the Min (for the baseline restoration)
- The same weighed average approach is used
- Quantities such as Rising Time, FWHW, etc., are built



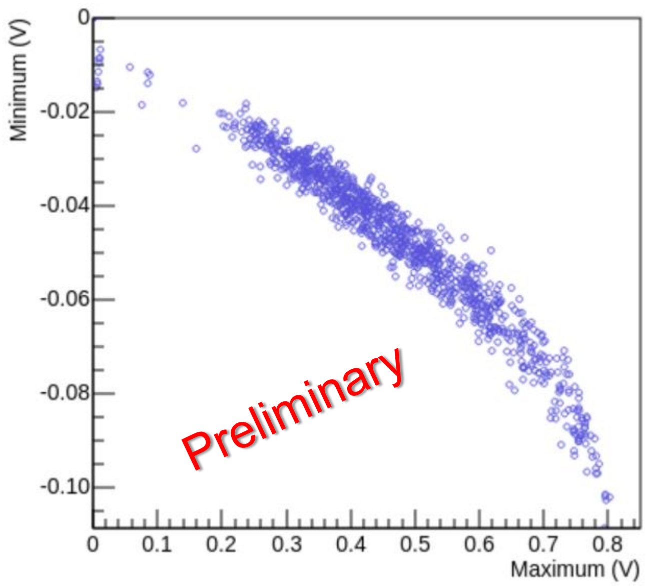
First low rate dataset

- Timing characteristics (expected and needed fast signals)



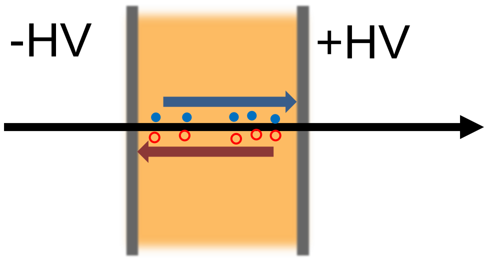


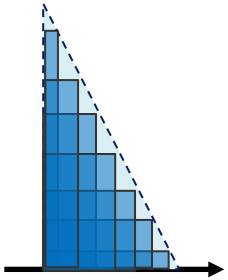
- Maximum and minimum correlated



Signal model

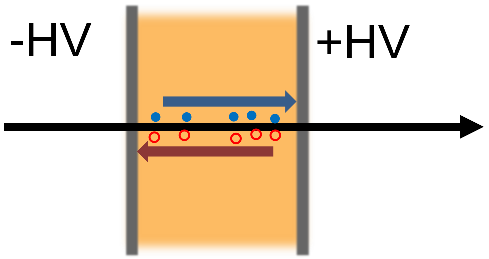
- Ions cross diamond volume in the same direction of drifting charges

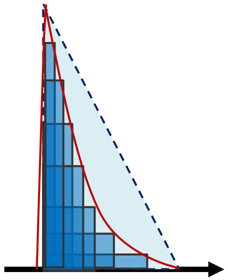




Signal model

- Ions cross diamond volume in the same direction of drifting charges



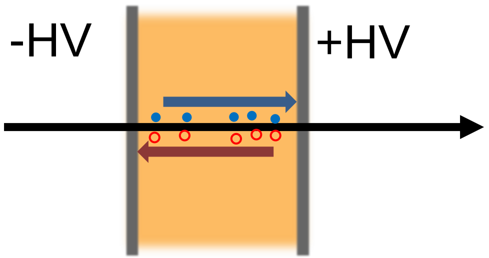


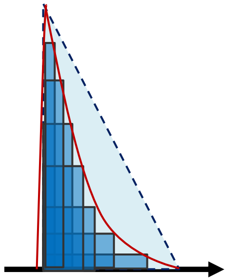
Defects in pcDIA traps especially charges that have to drift the longest

Signal model

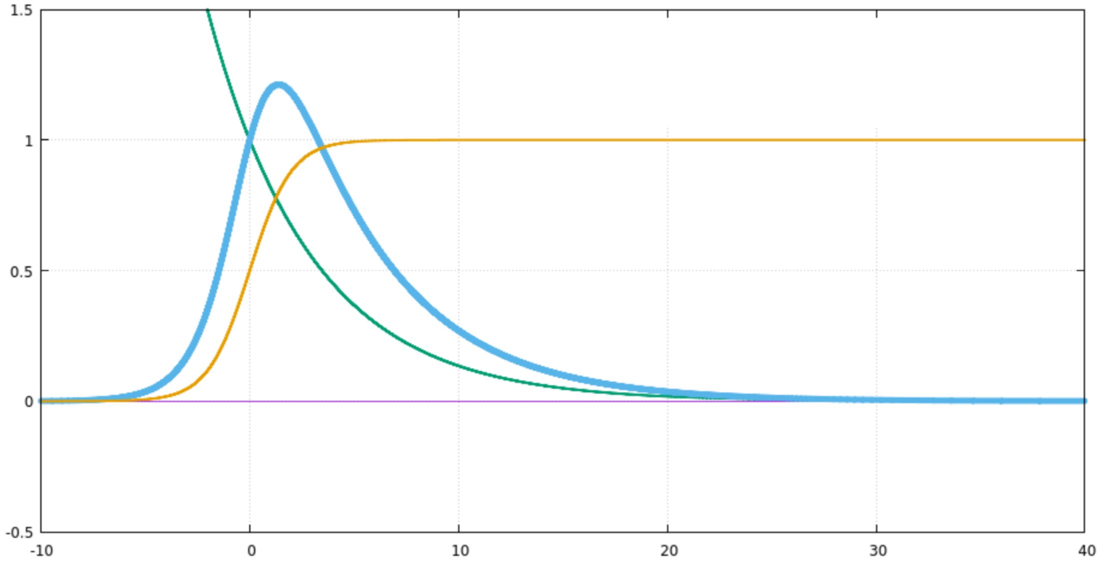
- Ions cross diamond volume in the same direction of drifting charges

$$f(t|A,\sigma,t_0,\tau) = \frac{Ae^{-\frac{t-t_0}{\tau}}}{1+e^{-\frac{t-t_0}{\sigma}}}$$





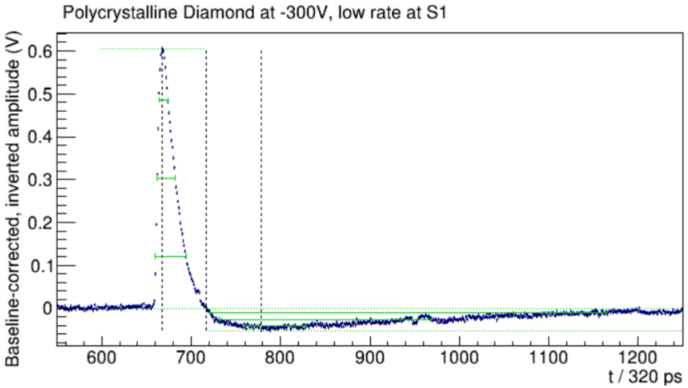
Defects in pcDIA traps especially charges that have to drift the longest

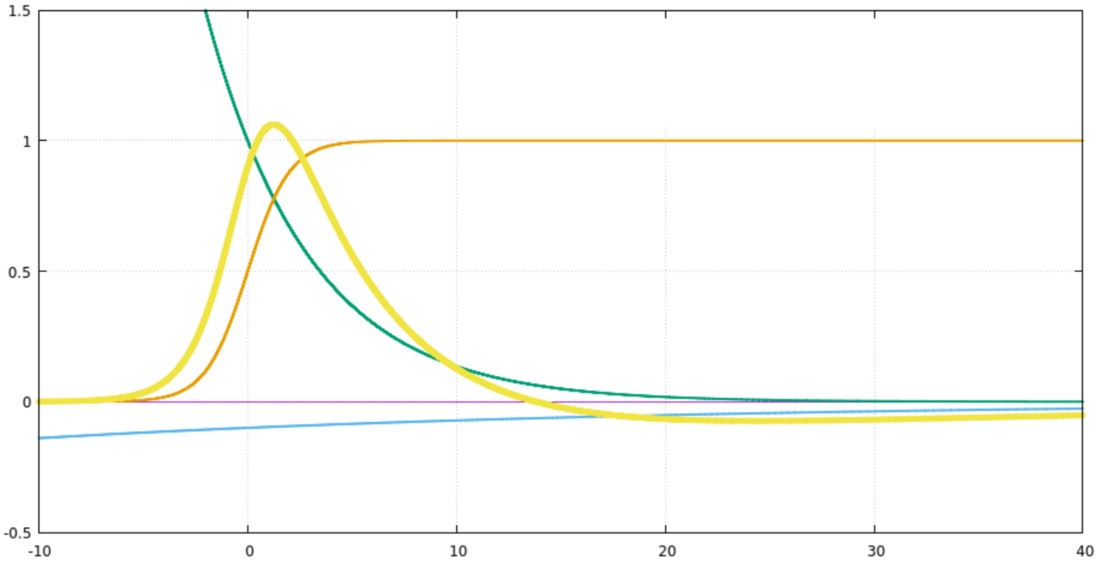


Signal model

However our signal is bipolar!
(very likely feature of the preamp, verification ongoing)

$$f(t|A,B,b_r,\sigma,t_0,\tau) = \frac{A\left(e^{-\frac{t-t_0}{\tau}} - Be^{-\frac{t-t_0}{\tau \cdot b_r}}\right)}{1+e^{-\frac{t-t_0}{\sigma}}}$$

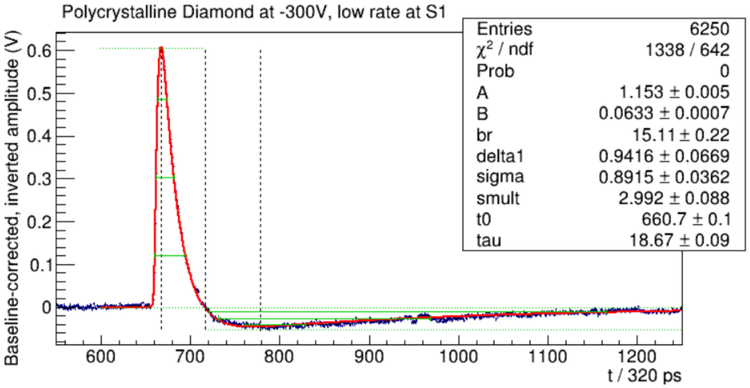


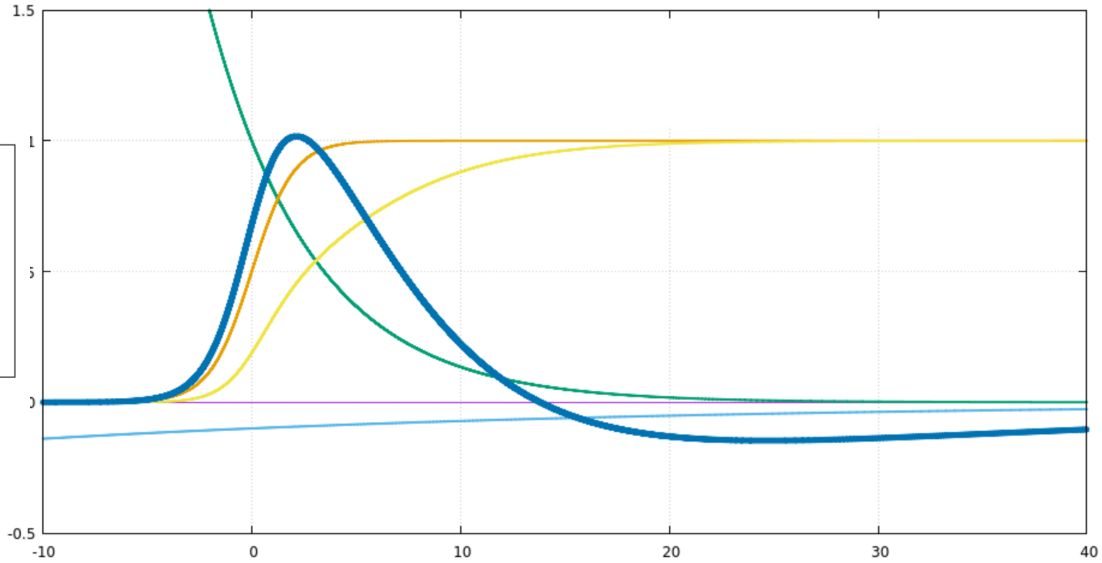


Signal model

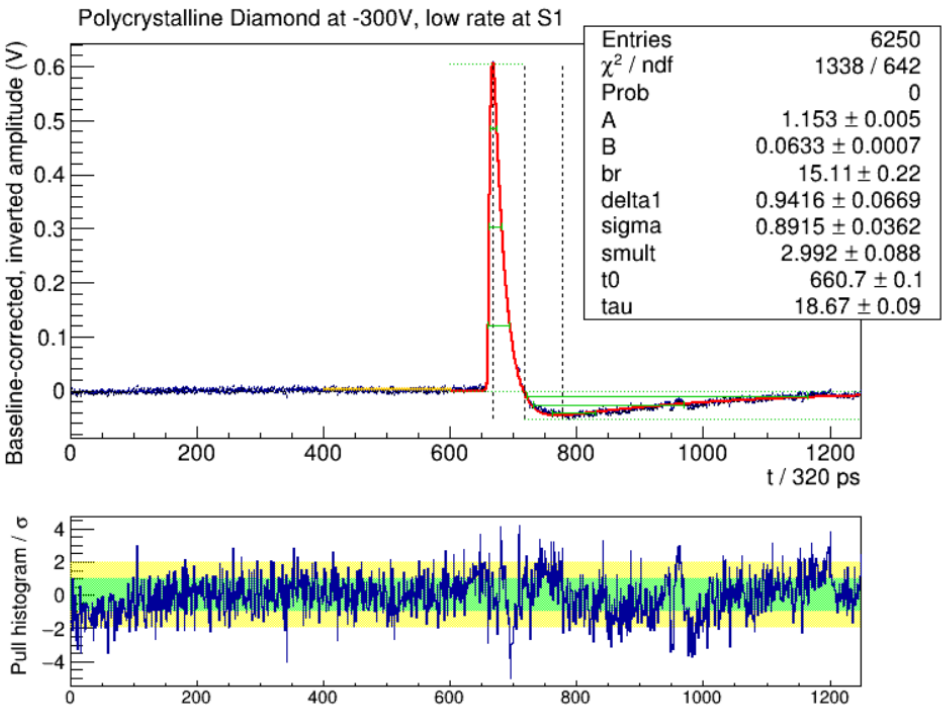
A further sigmoid term is needed to better fit the rising edge near the peak. No physics motivation ☹

$$f(t|A, B, b_r, \delta_1, \sigma, s_m, t_0, \tau) = \frac{A\left(e^{-\frac{t-t_0}{\tau}} - Be^{-\frac{t-t_0}{\tau \cdot b_r}}\right)}{\left(1 + e^{-\frac{t-t_0}{\sigma}}\right)\left(1 + e^{-\frac{t-t_0-\delta_1}{\sigma \cdot s_m}}\right)}$$

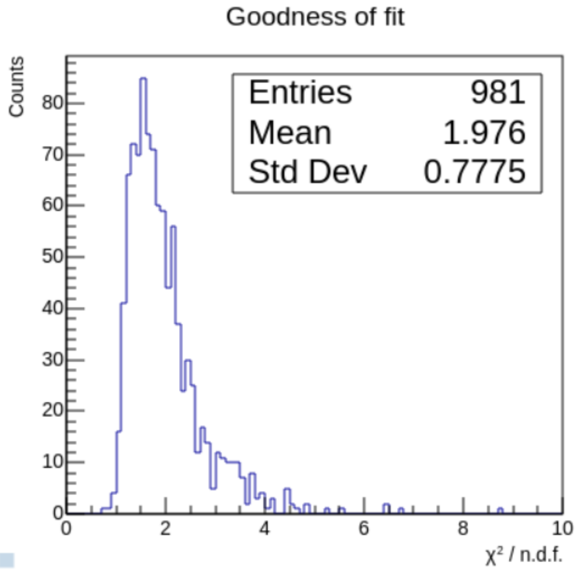




Signal model on first dataset

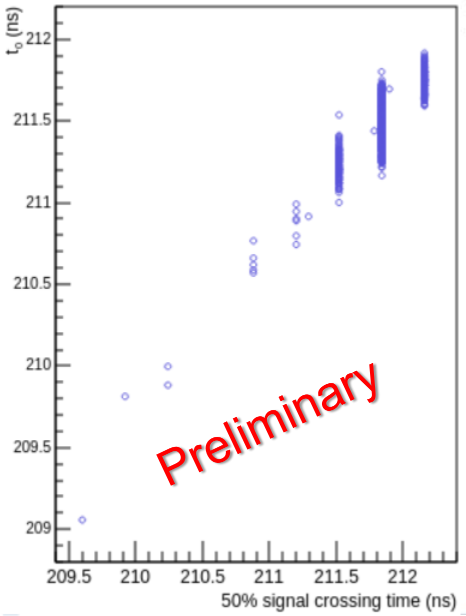


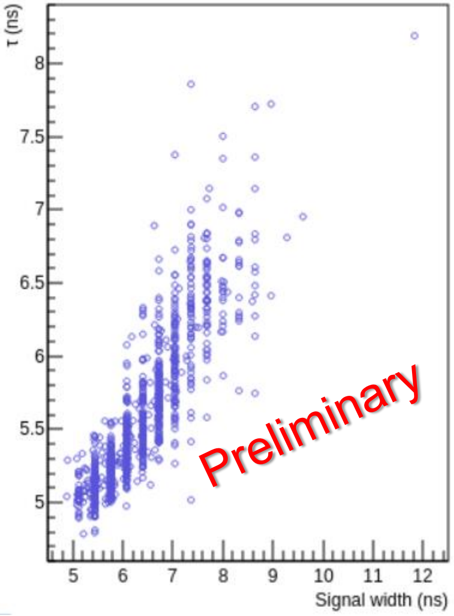
- Fit quite successful (98.2%) on the first bunch of waveform before high rate irradiation

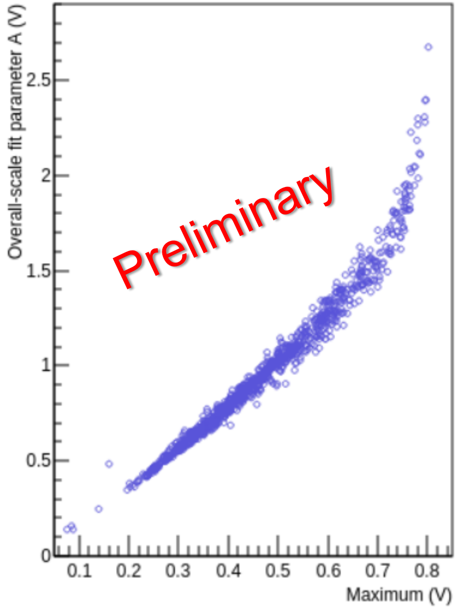


First low rate dataset analysis

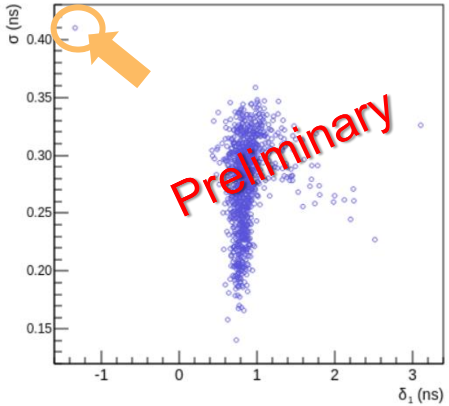
- Correlation between shape descriptors and fit parameters







- Correlation among fit parameters



$$\frac{A\left(e^{-\frac{t-t_0}{\tau}} - Be^{-\frac{t-t_0}{\tau \cdot b_r}}\right)}{\left(1+e^{-\frac{t-t_0}{\sigma}}\right)\left(1+e^{-\frac{t-t_0-\delta_1}{\sigma \cdot s_m}}\right)}$$

Prospects & next steps

- Process and analyze waveforms from another bunch with the same conditions (low rate, -300V HV, …), after the high rate irradiation period → ongoing

- Calculate the integrated ions after the high rate irradiation until this second bunch (right now rough estimate of $8 \cdot 10^9$ ions/mm^2 for the whole test)
  → next step

- Extend this analysis to the irradiation test in March, performed with U beam

Many thanks to Chiara, Michael, Mladen, Joshua, …

… and thanks for your attention!