# Xe doping analysis update

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# News & Analysis flow

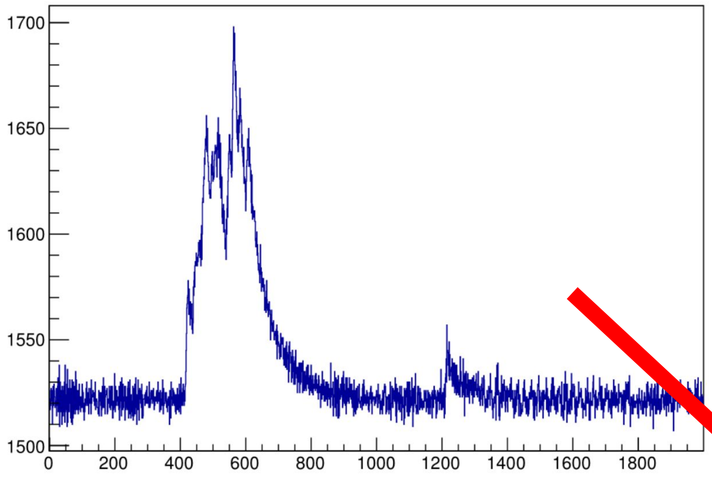
**Achieved: Calibration of deconvolved avg wfms in number of photons:**

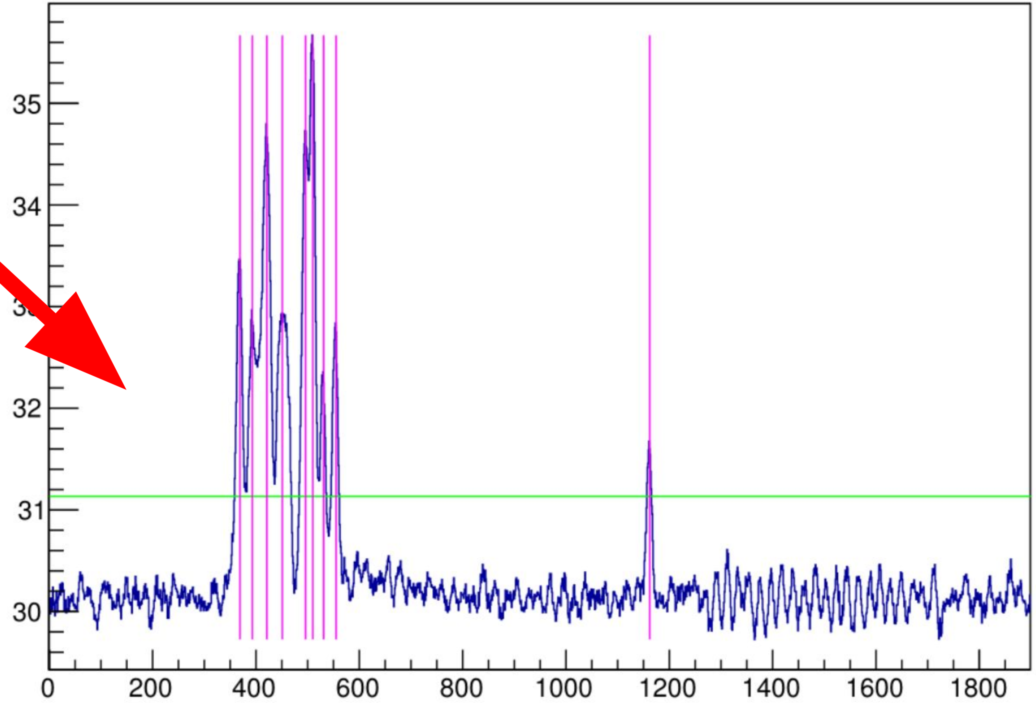
- simplified procedure to find onset: directly by a short FT (33 ns) FIR filter (dropped triangular)
- 1st approach: calibration through pulse height
- 2nd approach: calibration through pulse integral

**Determination and Survey of signal features (τ, LY) vs Xe doping profile**

- signal integral for Q & NQ  XArapuca
- integral ratio
- slow component for Q & NQ XArapuca

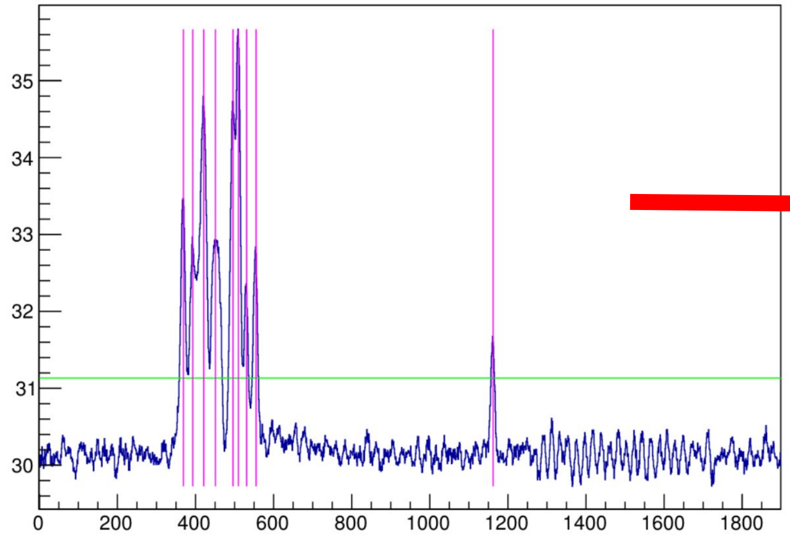
# P.H. calibration: Apply FIR filter and find pulse onsets



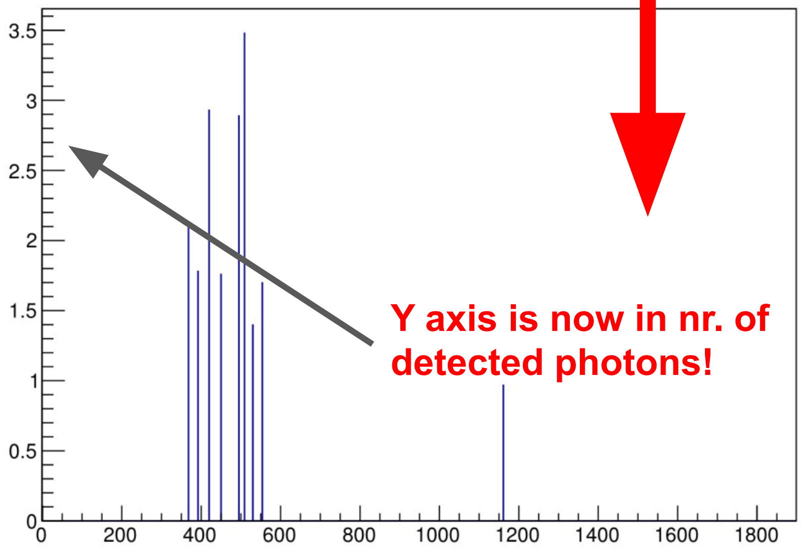

- FIR filter: cusp (33 ns flat top, 33 ns σ) convolved with RC decay of each channel (from <SPE>)
- **threshold** on filtered waveform ($BL + 10*\sigma_{BL}$) to find **onset** and height of each pulse

# FIR calibration: Turn pulses into deltas




- select proper pulses (on $\delta(t)$ basis) to populate SPE&DPE spectrum (as shown in past presentation)
- find in spectrum SPE & DPE structures
- determine SPE-PH

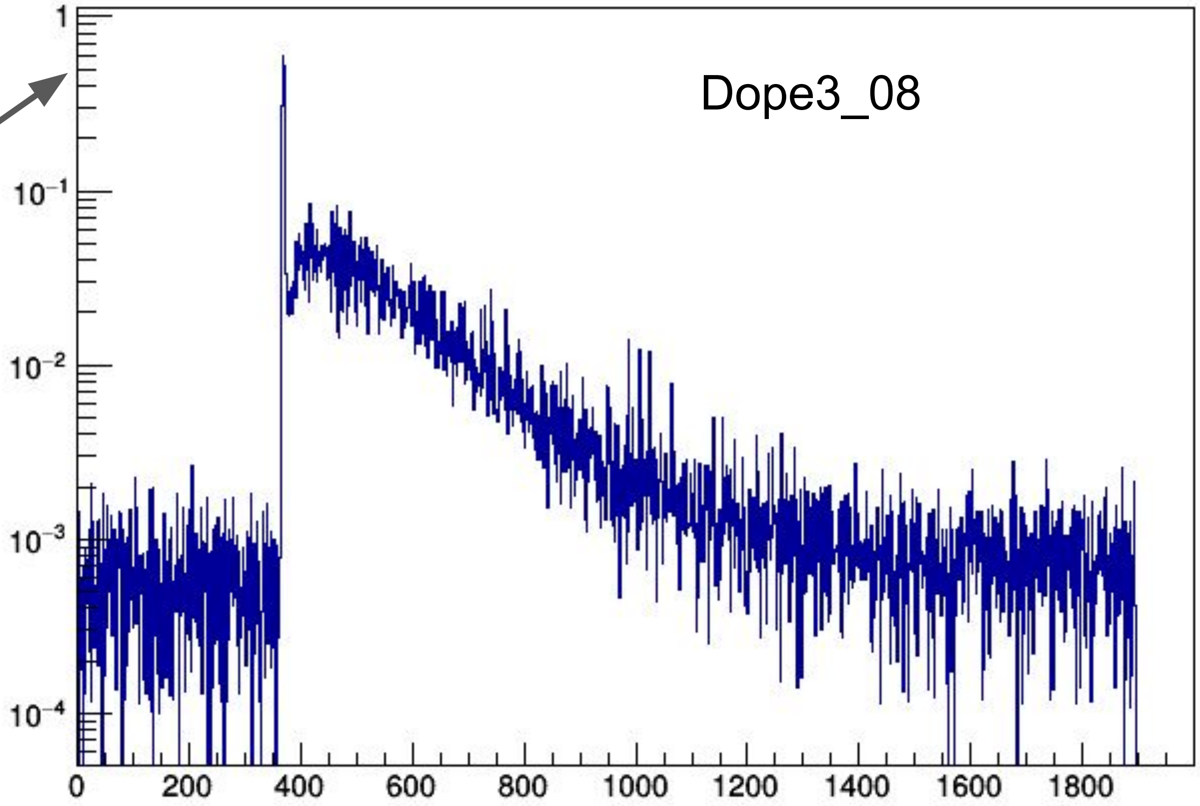
- each FIR-pulse is replaced by a delta w. calibrated Amplitude, and participate to build up the run <wfm>
  - t{$\delta$}=t{max FIR Pulse}
  - PH{$\delta$}= PH{FIR Pulse} / $PH_{SPE}$




**Y axis is now in nr. of detected photons!**

# Calibrated Run-averaged wfm (<wfm>)

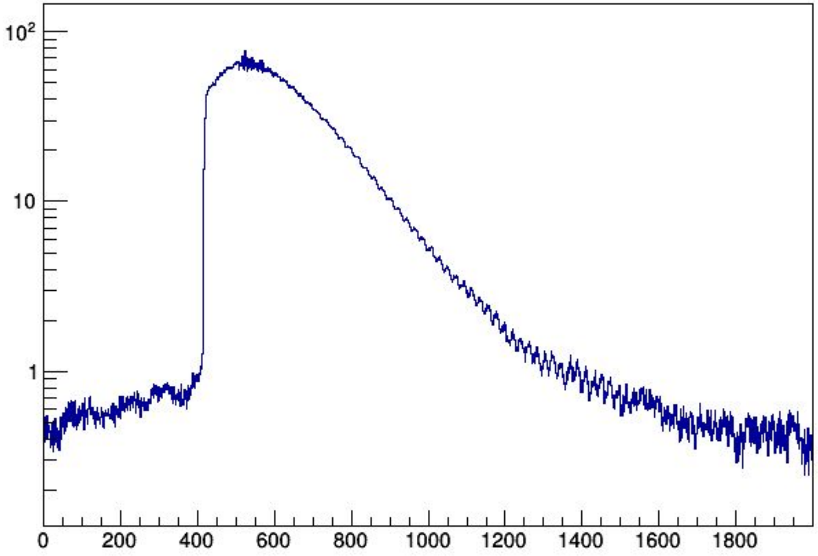
**Y axis is now in nr. of detected photons!**



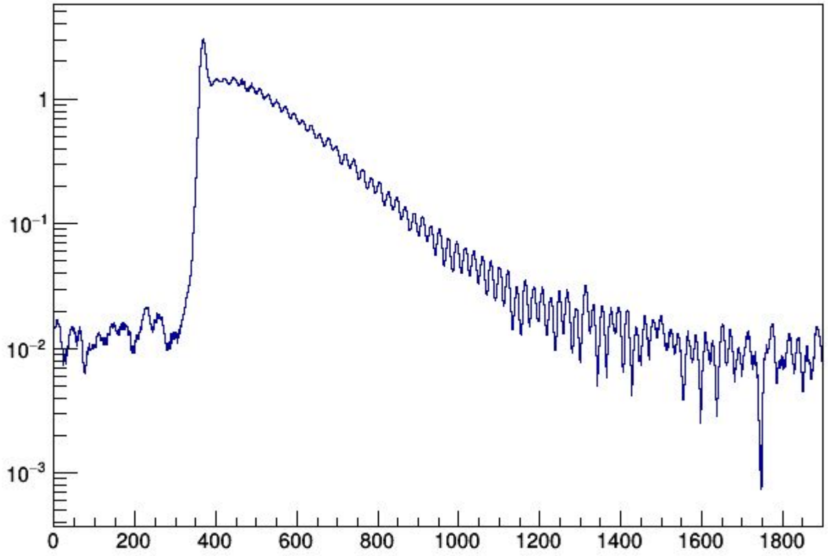

- improved timing (fast component not smeared), at the price of worsening SNR

# P.I. calibration: 1. Apply the FIR to raw averaged wfms

Raw <wfm> (Dope3_08)




Uncalibrated filtered <wfm> - 33 ns FT

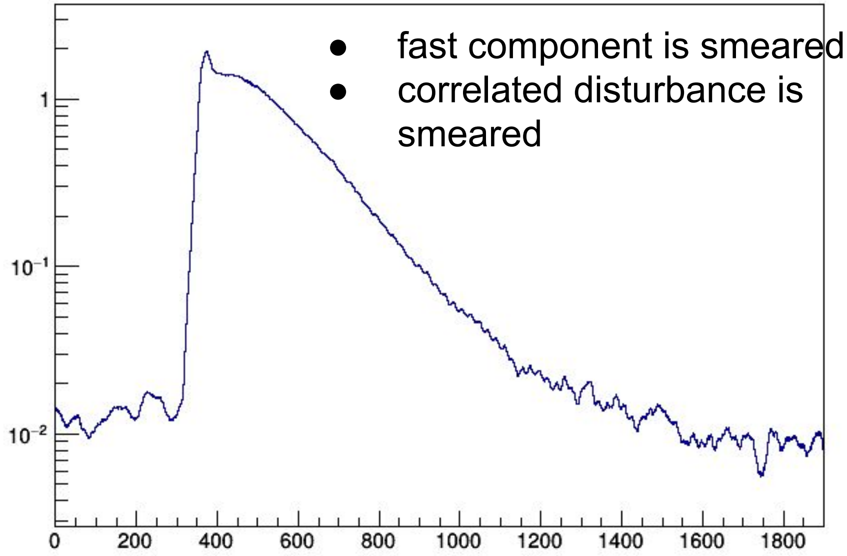



- For each run, the average raw wfm (<wfm>) is built discarding events with NO pulses (signal avg < B.L. + $3*\sigma_{BL}$ )
- FIR filter is applied to raw <wfm>: cusp (33 ns flat top, 33 ns σ) convolved with RC decay of each channel (from <SPE>)
- Moved from 99 ns→ 33 ns flat top filter to improve photon timing so skip triang filter (price to pay: <wfm> more noisy)

# 33 ns vs 99 ns FT filter

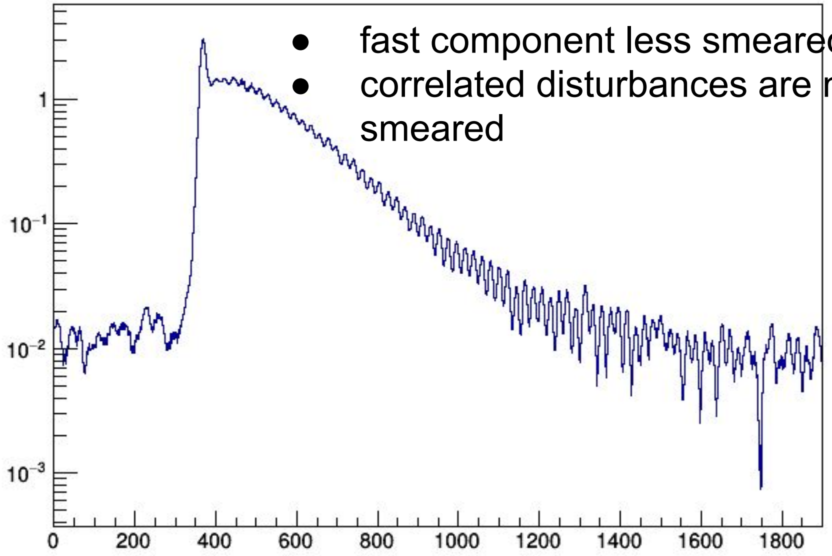
## Uncalibrated filtered <wfm> - 99 ns FT

- fast component is smeared
- correlated disturbance is smeared



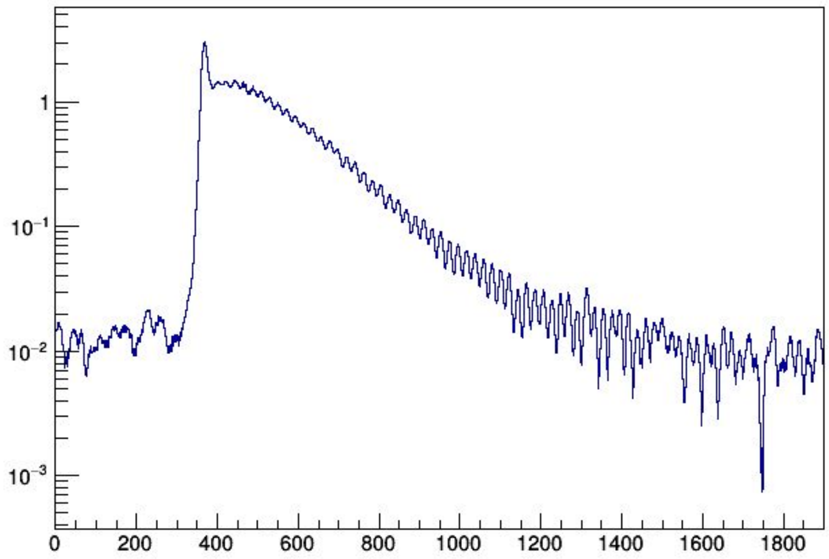

## Uncalibrated filtered <wfm> - 33 ns FT

- fast component less smeared
- correlated disturbances are not smeared

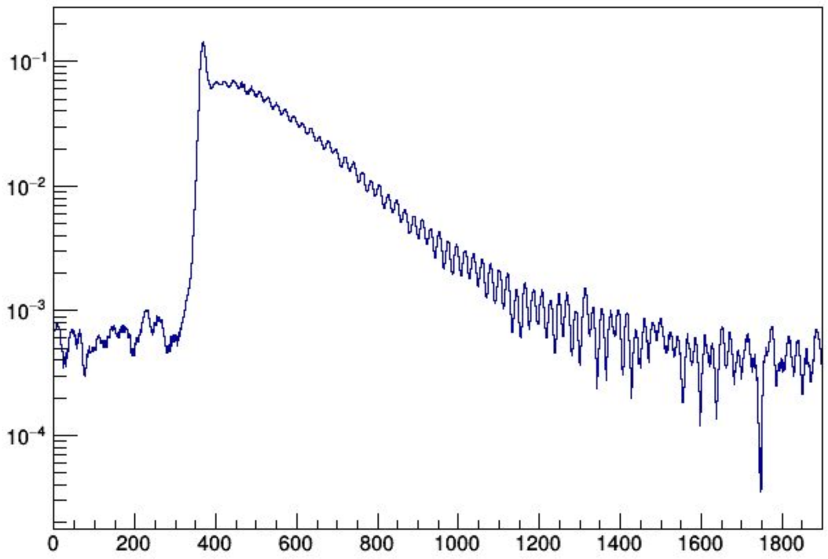


# P.I. calibration: 2) Absolute calibration of filtered <wfm>

Uncalibrated filtered <wfm>

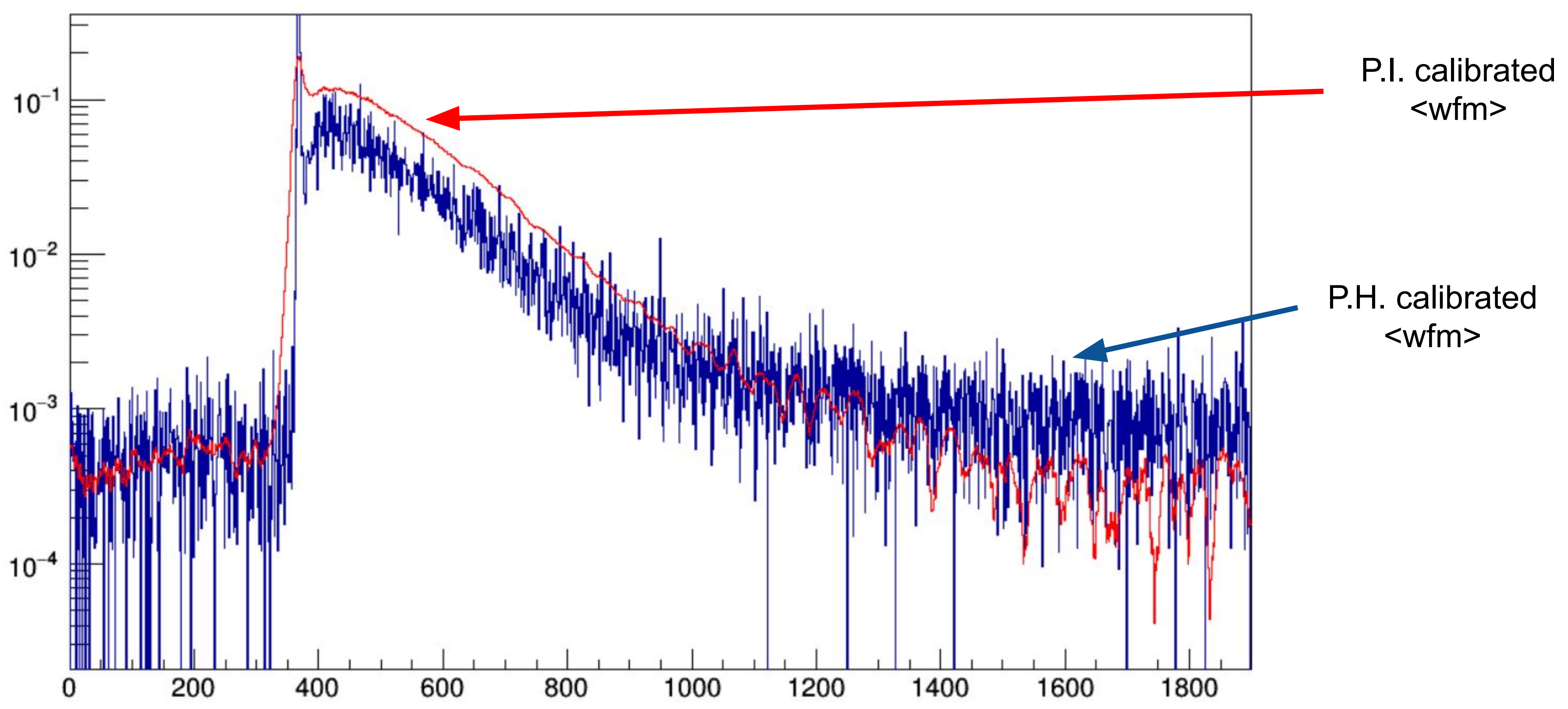



Calibrated filtered <wfm>



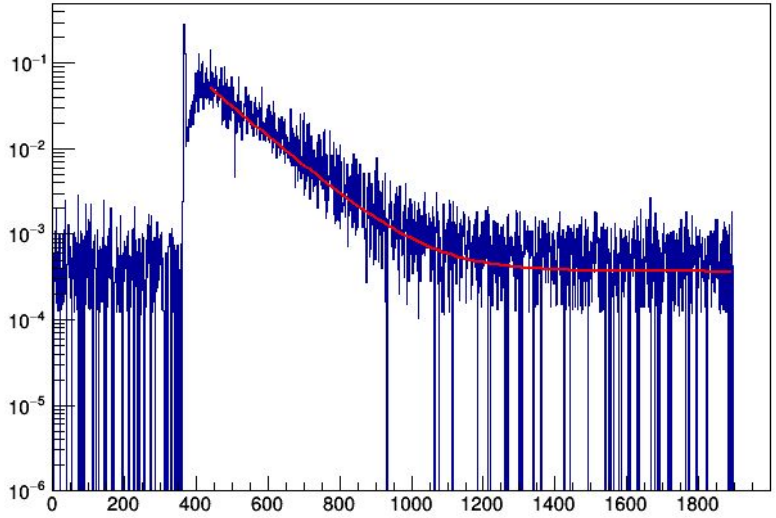

- find the integral of a filtered SPE pulse
- calibrate in nr. of photons by re-scaling the y axis in the filtered <wfm>

# Comparison of P.I. vs P.H. calibration

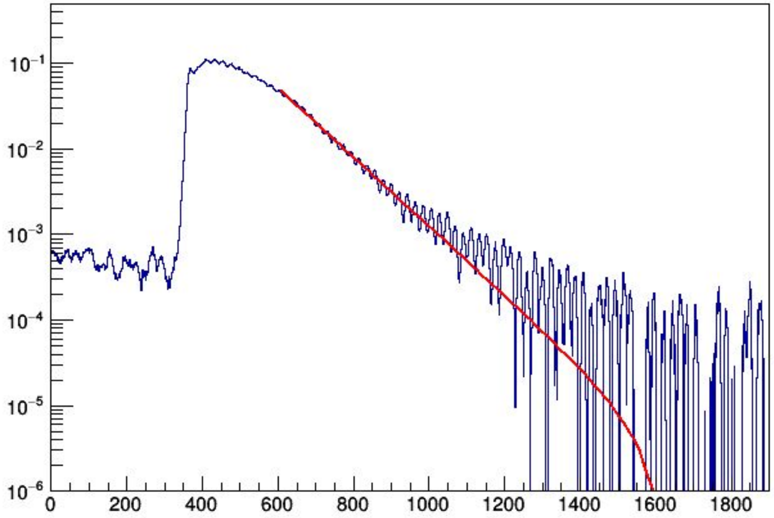


# P.I. vs P.H. calibration: fitting the slow component

P.H. calibrated <wfm>



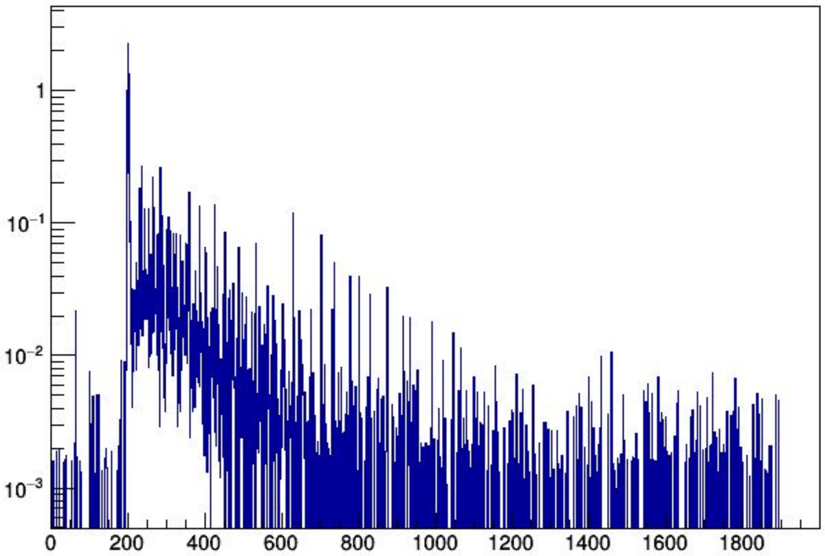

P.I. calibrated <wfm>



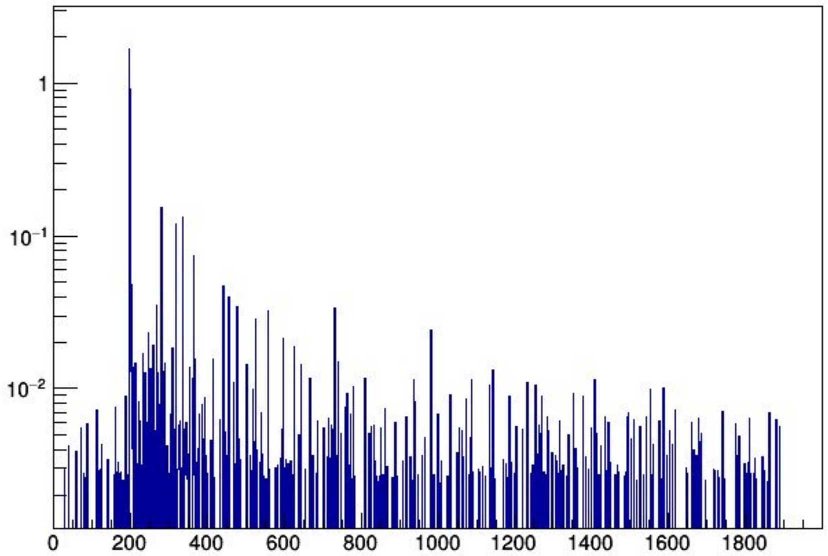

- In the P.H. calibrated <wfm>, the whole decay (from the maximum onward) can be well fitted → **from now on we select FIR filter PH method**
- **small differences between the fitted $\tau_s$**
- In the P.I. calibrated <wfm>, the fit results may change based on the fit range (due to residual pile-up from finite pulse width)
- fit function: p0+exp(p1+p2*x)

# Example - start of doping 1

Ch 1 - no quartz

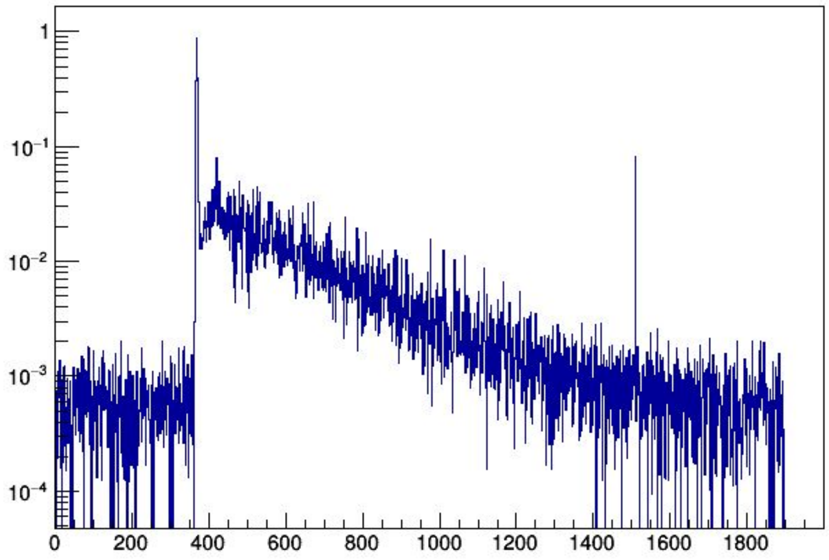



Ch5 - quartz

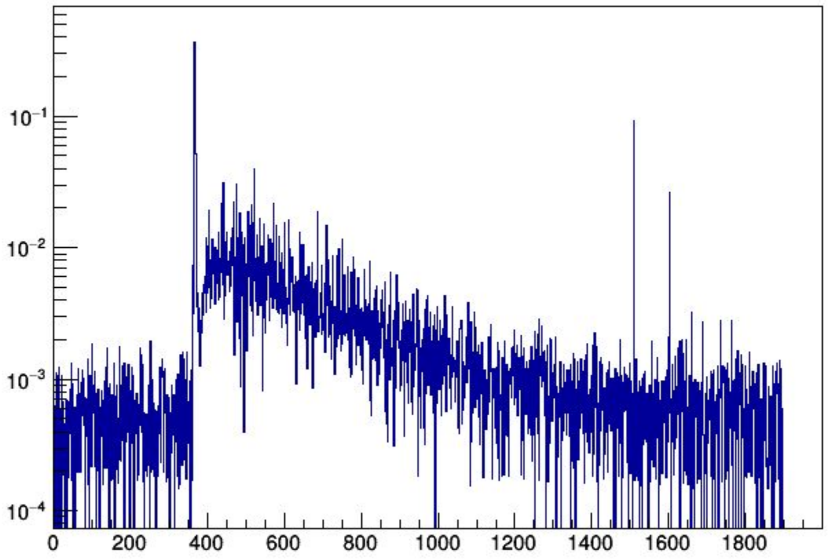


# Example - start of doping 2

Ch 1 - no quartz

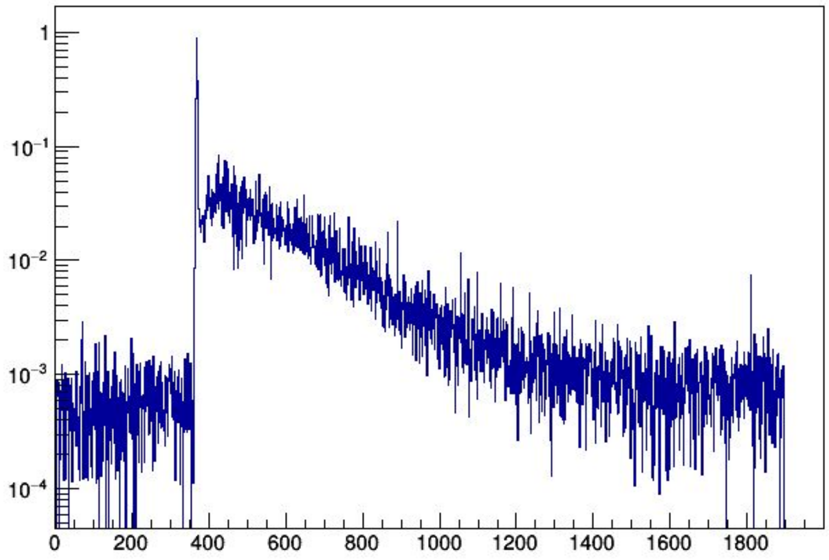



Ch5 - quartz

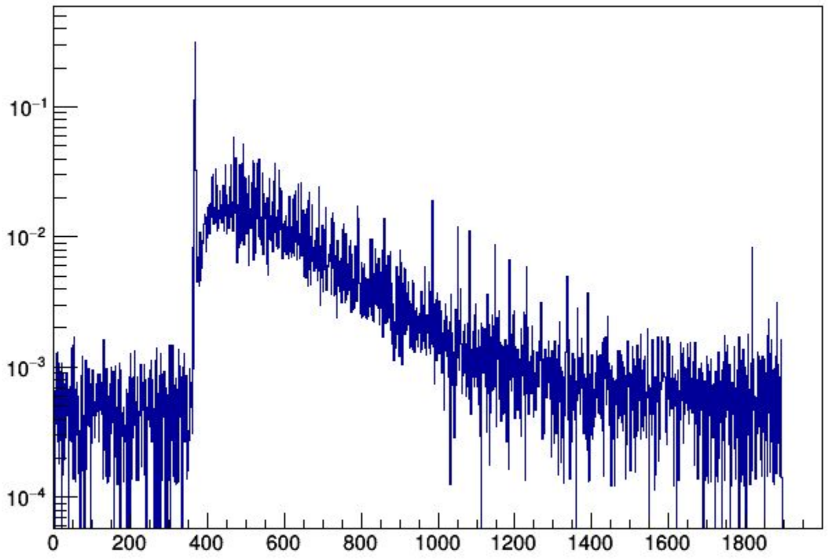


# Example - start of doping 3

Ch 1 - no quartz

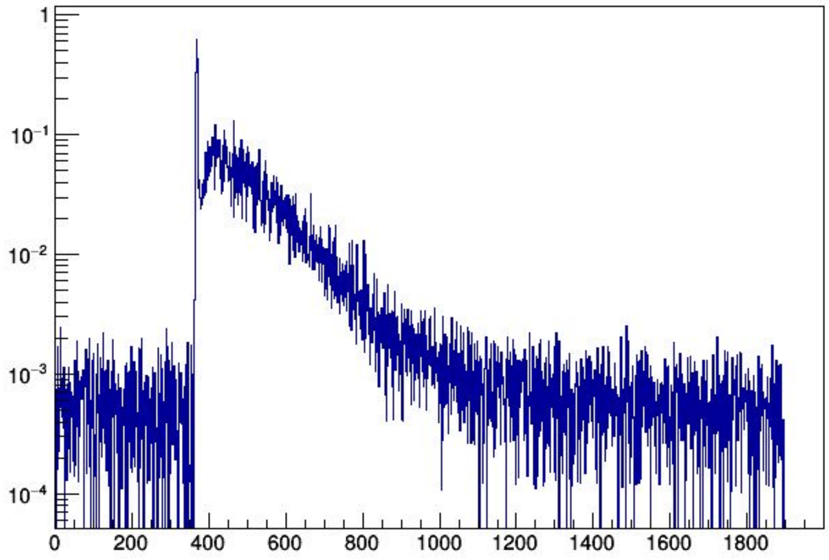



Ch5 - quartz

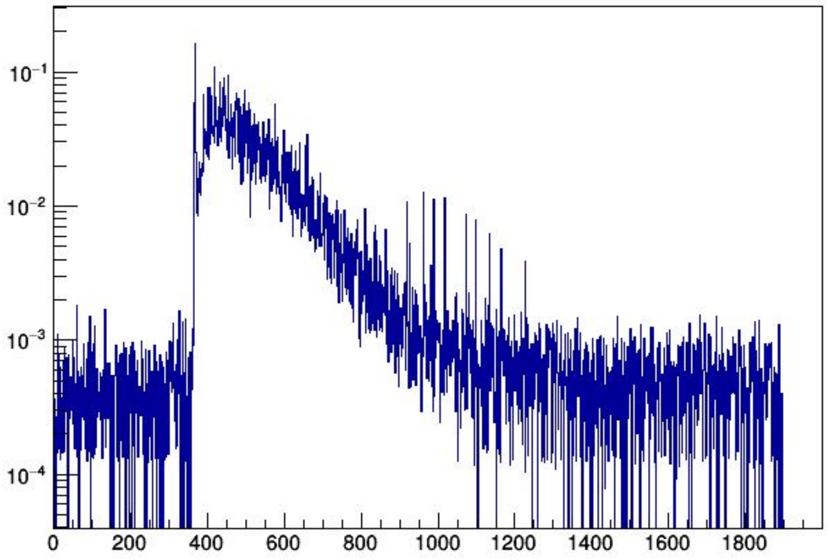


# Example - start of doping 4

Ch 1 - no quartz

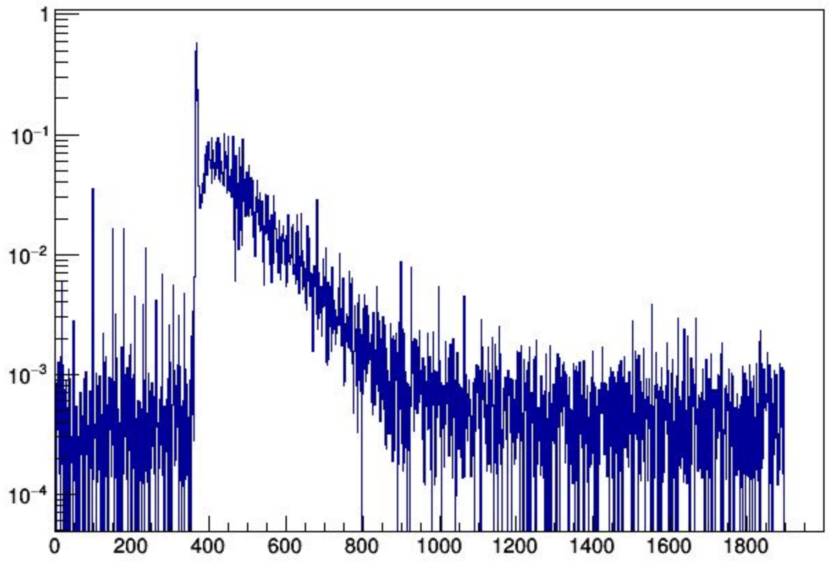



Ch5 - quartz

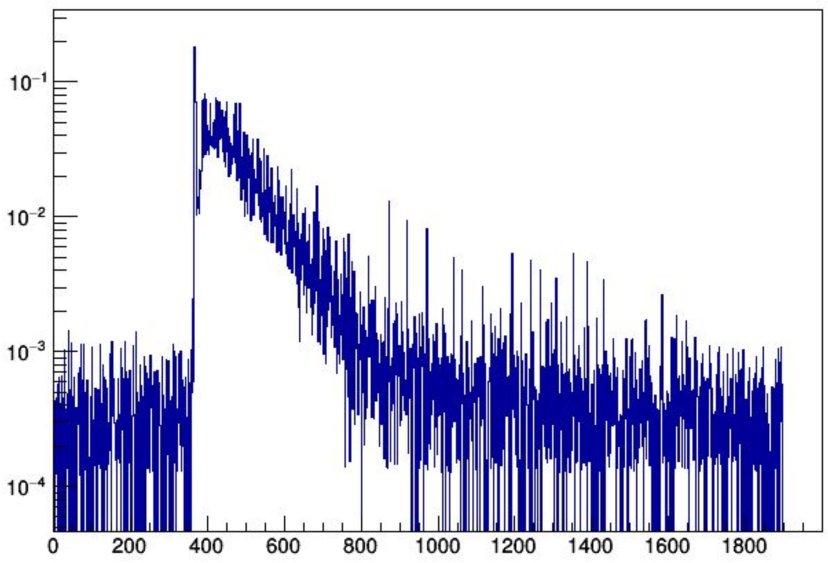


# Example - end of doping 4

Ch 1 - no quartz



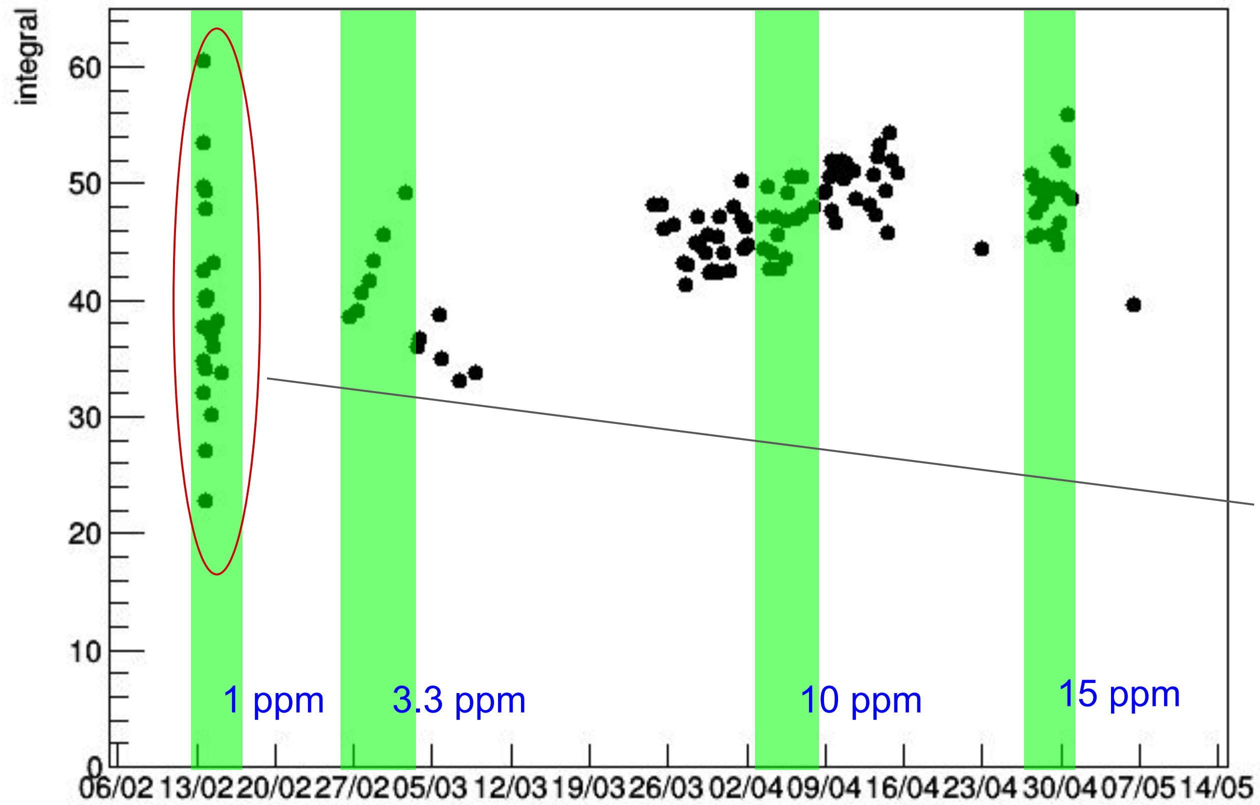

Ch5 - quartz



# Survey of the total light yield - no quartz XArapuca

Y axis is in nr. of photons!

Dots = average nr. of detected photons for each trigger in the run




***Def.:***

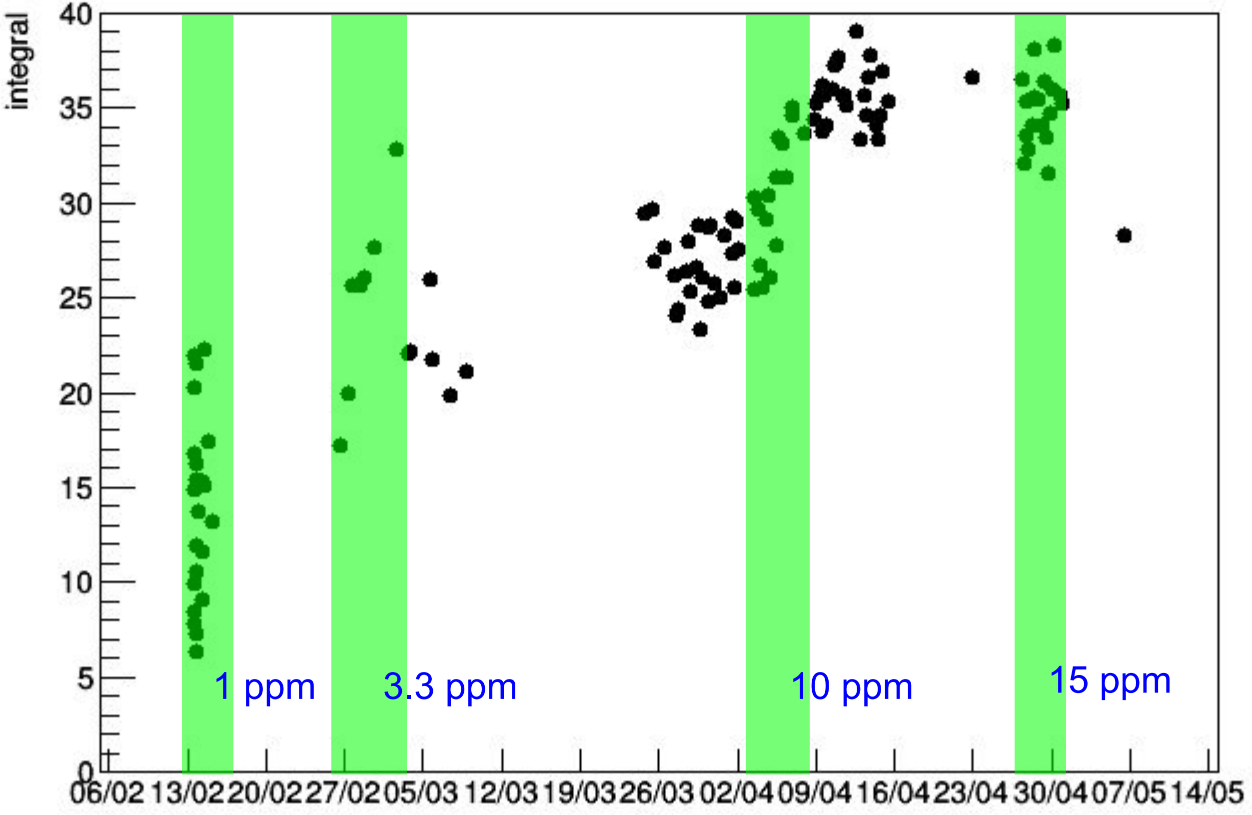
$\langle LY \rangle_{NQ} = \Sigma_{i=1,2,3}$ Integral$_i$

D1 scattering of values related to low light&low statistic runs

# Survey of the total light yield - quartz XArapuca

Y axis is in nr. of phtons!

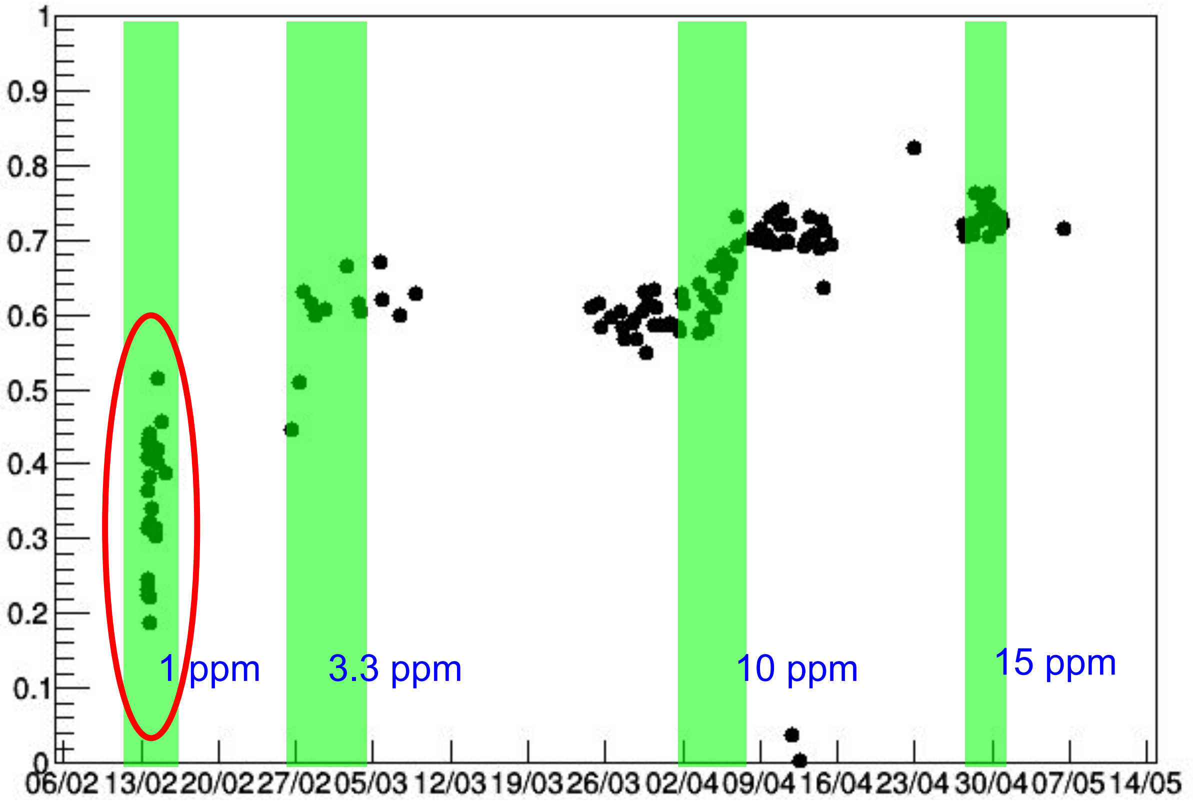
Dots = average nr. of detected photons for each trigger



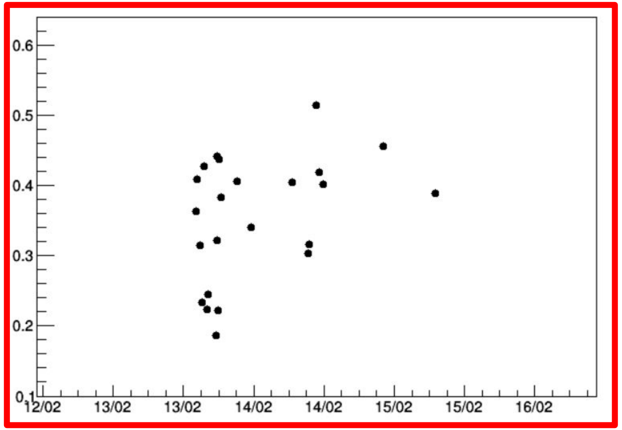

***Def.:***

$\langle LY \rangle_Q = \Sigma_{i=4,5,7} \text{Integral}_i$

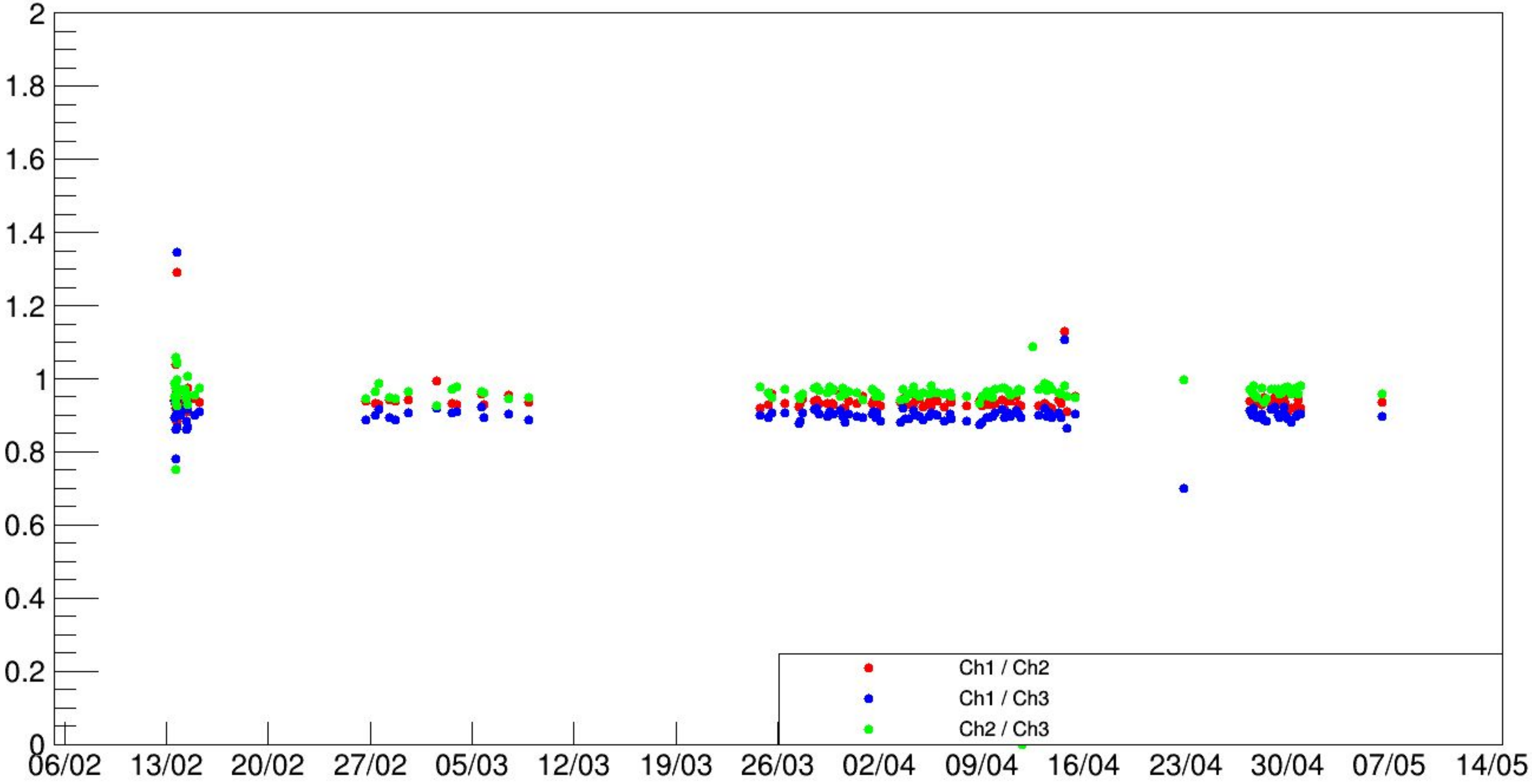
# Survey of the deconvolved Q/NQ light yield ratio



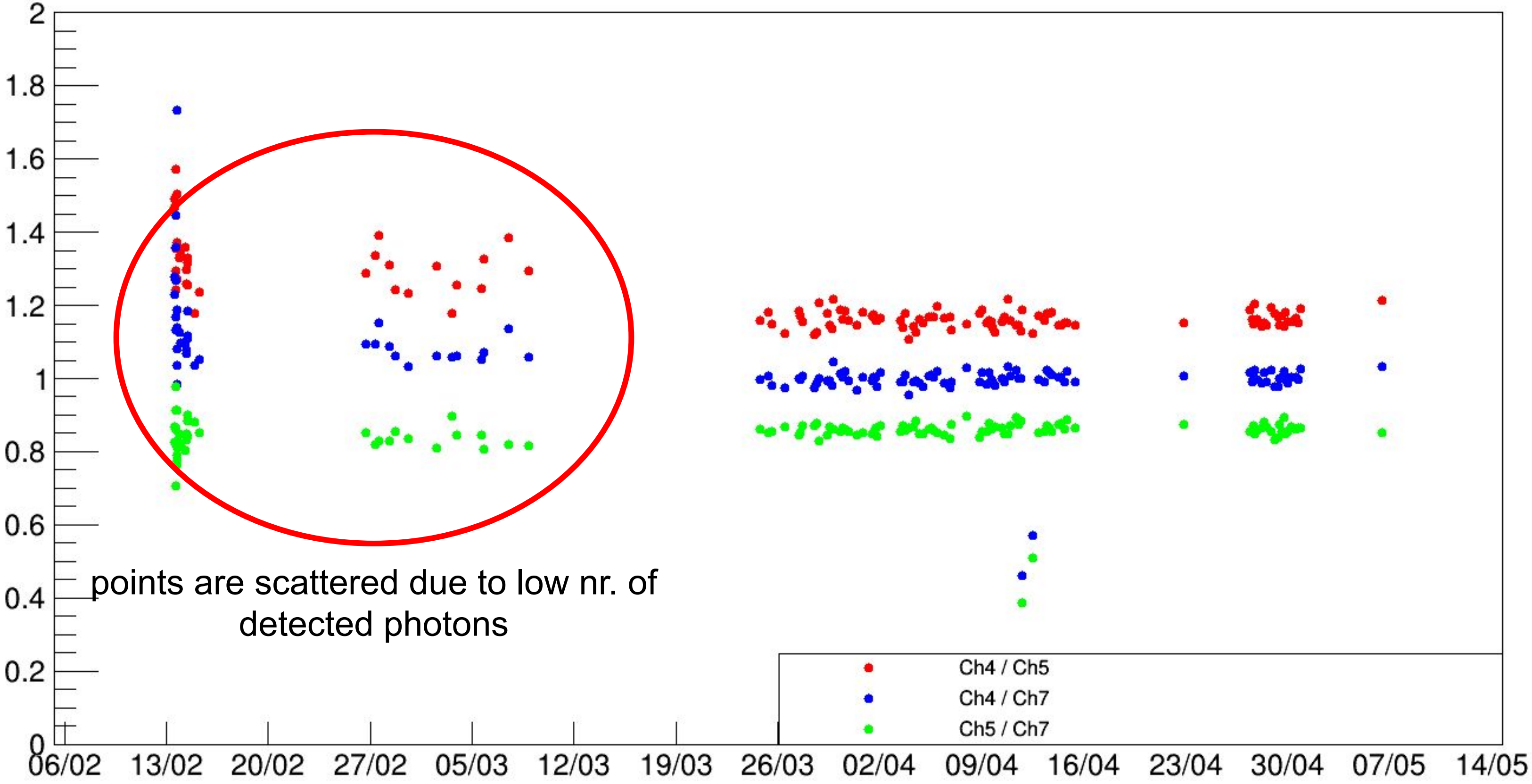

Zoom on D1



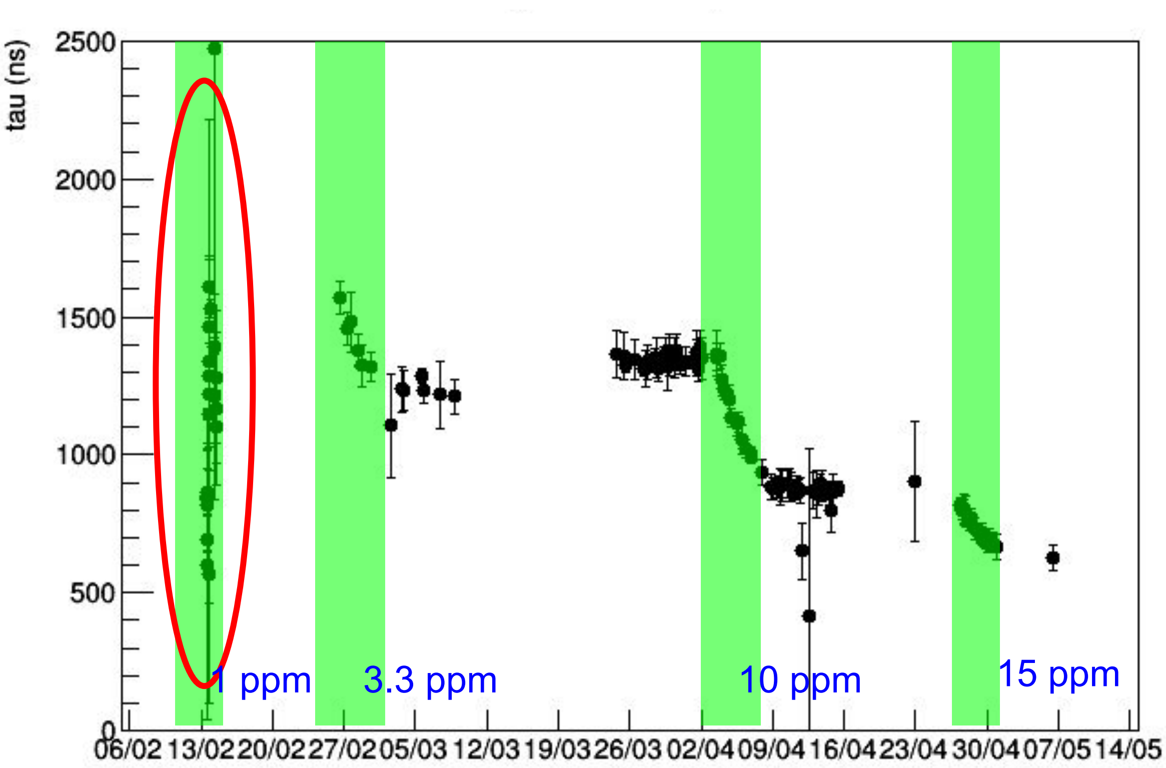
# Survey of the detected light ratio among Chs
# no quartz XArapuca



# Survey of the detected light ratio among Chs quartz XArapuca



# Survey of the avg slow component - no quartz XArapuca



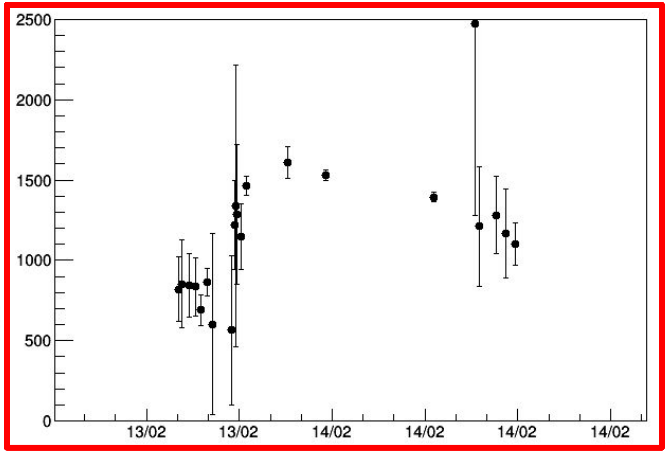

***Def.:***

$< \tau >_{NQ} = \Sigma_{i=1,2,3}\ \tau_i / 3$

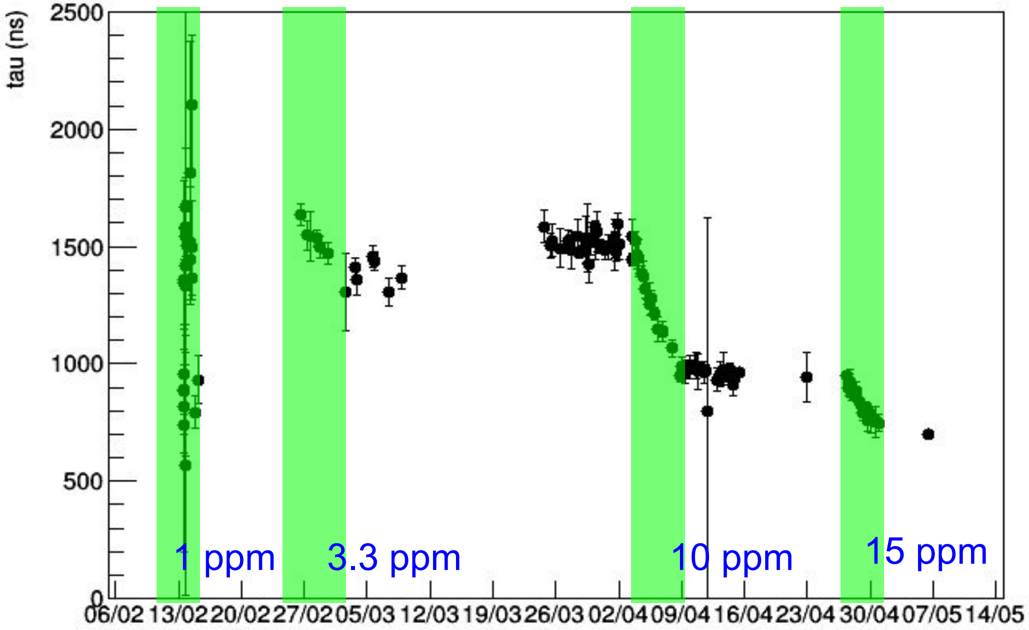
***Def.:***

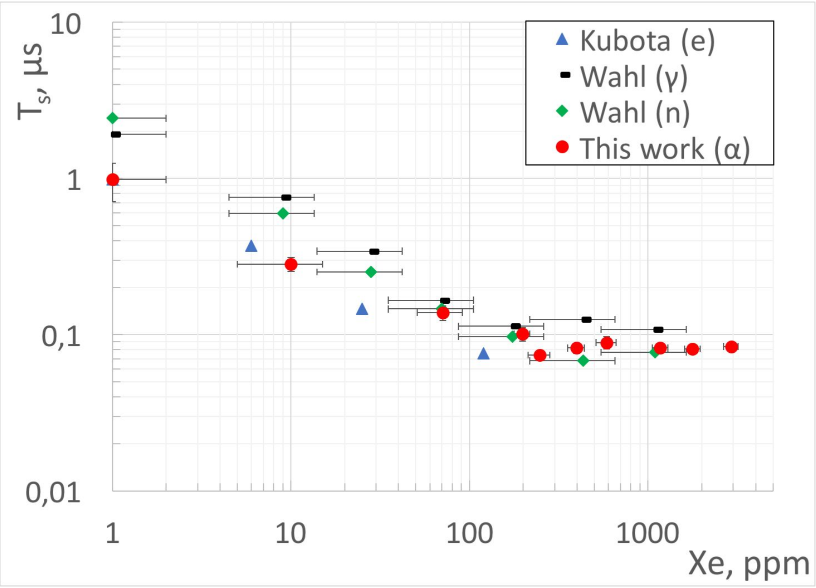
$\sigma <\tau>_{NQ} = \text{STDdev}(\ \tau_i\ )$

Zoom on D1:LY seems to increase in first D1 runs: Better to add couple of runs to compensate for low statistics



D. Akimov et al.arXiv:1906.00836v3

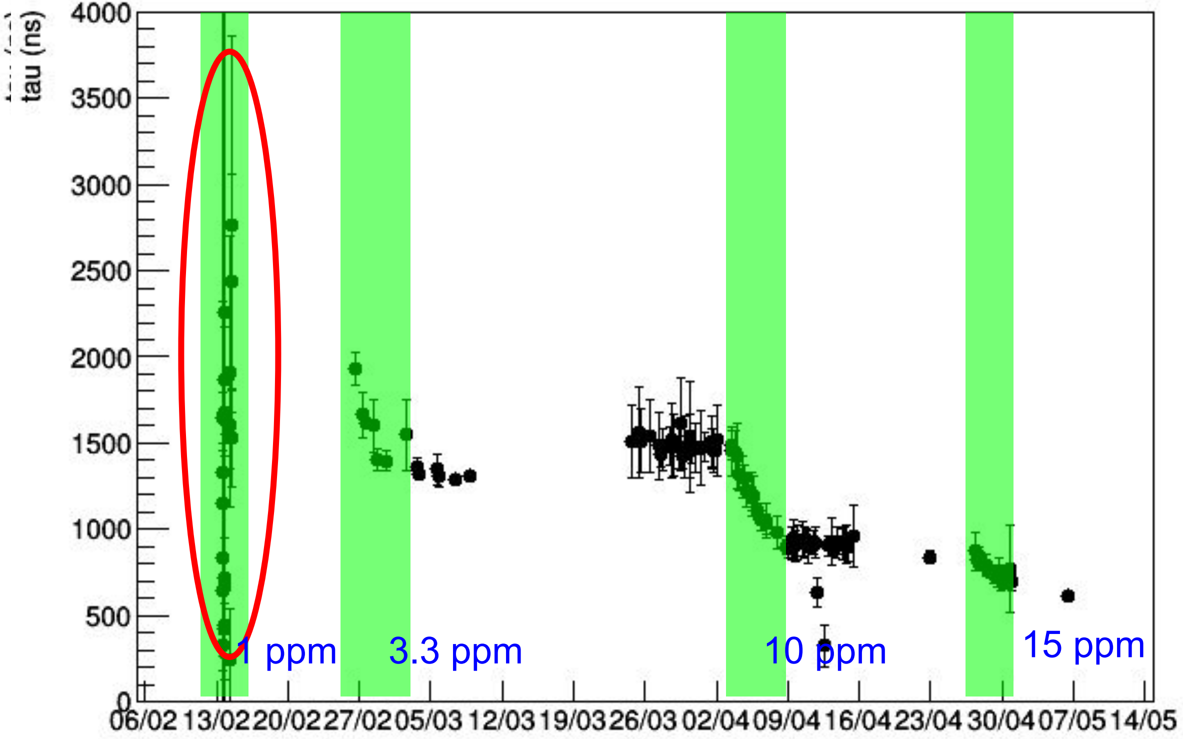



Start D2 (1ppm Xe)→ End D4 (15.2 ppm Xe ): $\tau$ reduction ~4

Akimov et al.: 1ppm → 15ppm: $\tau$ reduction factor ~3, but with **α**s

# Survey of the avg slow component - quartz XArapuca




***Def.:***

$< \tau >_Q = \sum_{i=1,2,3} \tau_i / 3$

***Def.:***

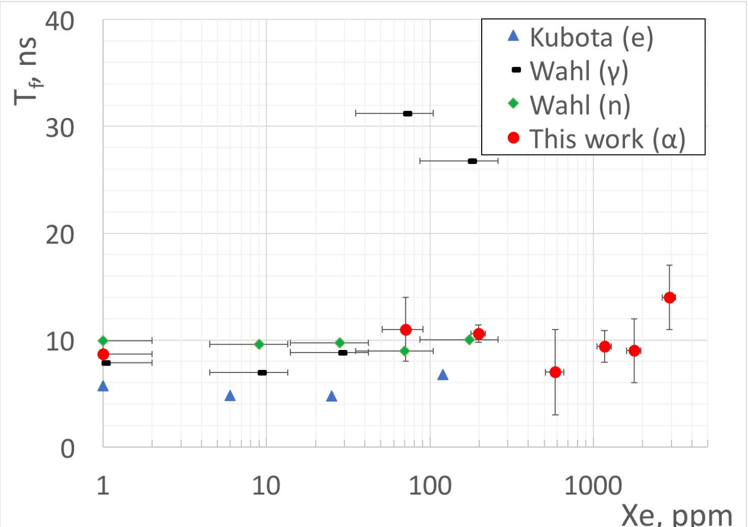
$\sigma <\tau>_Q = \text{STDdev}( \tau_i )$

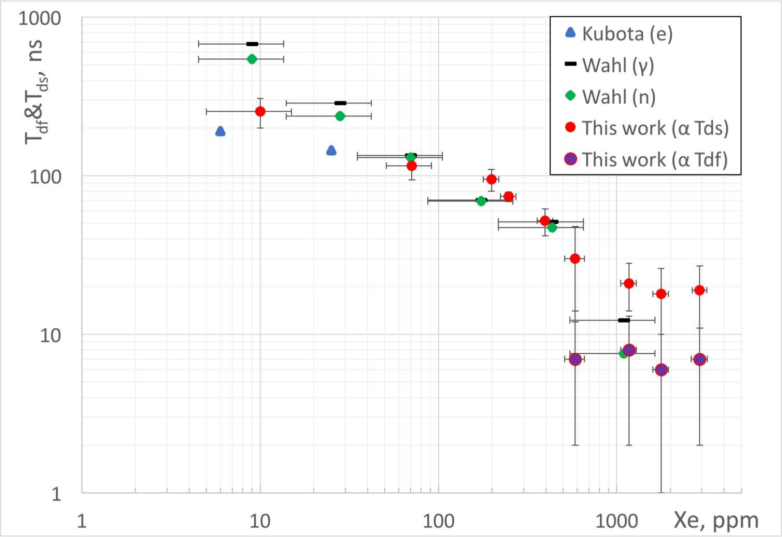
# Conclusions

- Calibration of Integral{<wfm>} to #Detected Photons Achieved:
  - NQ: Increase factor ~ 1.5 - 2.5 from D1 (<20-30> ph large scatter) to D4 (<45> ph)
  - Q: Increase of factor ~ 3 from D1 (~<12> ph large scatter) to D4 (<35-40> ph)
- Compared two methods to build <wfm> by FIR filtering the raw wfms
  - finally adopted methods providing better timing at the price of more noisy wfms
- Evolution of <wfm> shape w. [Xe] well coherent with expectations and literature values (so far only slow component studied)
  - in NQ observed $\tau_s$ decrease from 1600 (start D1) to ~ 600 (end D4)
  - in Q observed $\tau_s$ decrease from 1900(?) (start D1) to ~ 600 (end D4)
  - the whole slow component is fitted (no dependency of $\tau_s$ to fit range)

# To do:

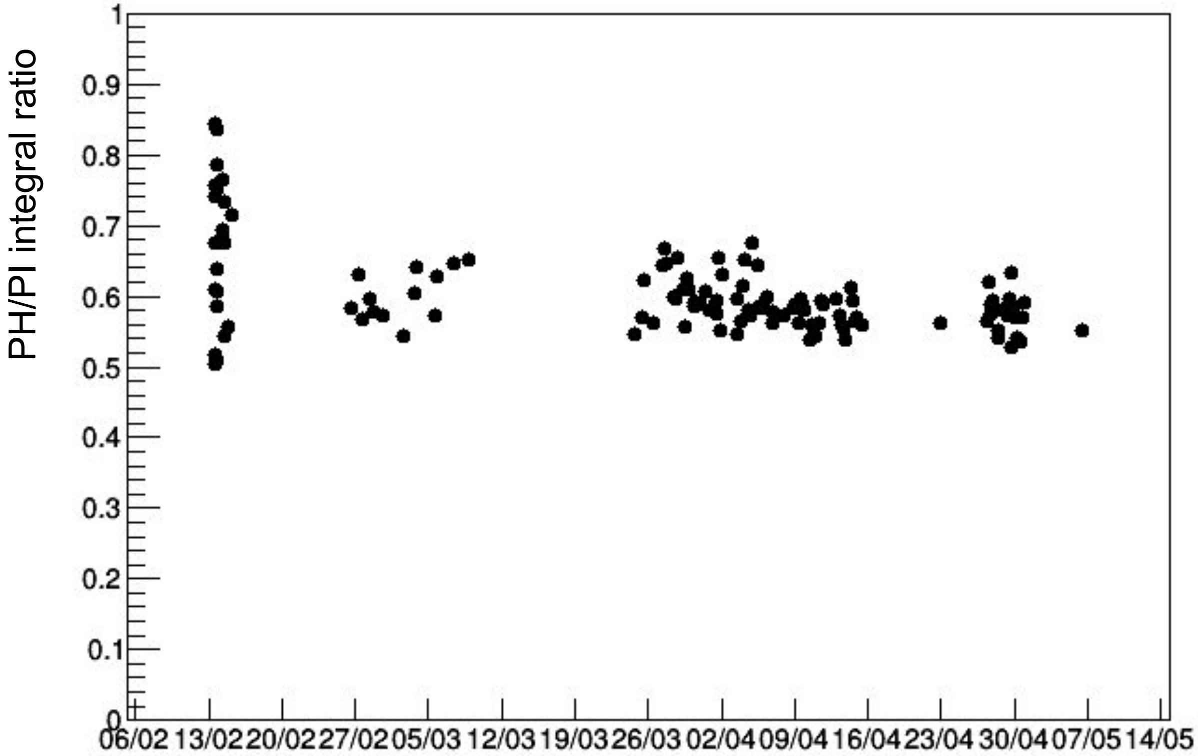
- Study the fast component (it seems Cerenkov in LAr/Quartz is relevant)
- Study characteristic Time transfer constants $T_{df}$ and $T_{ds}$ vs [Xe]
- workout systematics
- improve statistical errors on D1 by grouping runs
- fit $\boldsymbol{\tau}_s$ on $\boldsymbol{\Sigma}$(Ch_i) instead of averaging over the 3 ($\boldsymbol{\tau}_s$ )
- Analyse the Efield runs



# Extras

# P.I. vs P.H. calibration: <wfm> integral ratio (no quartz XArapuca)



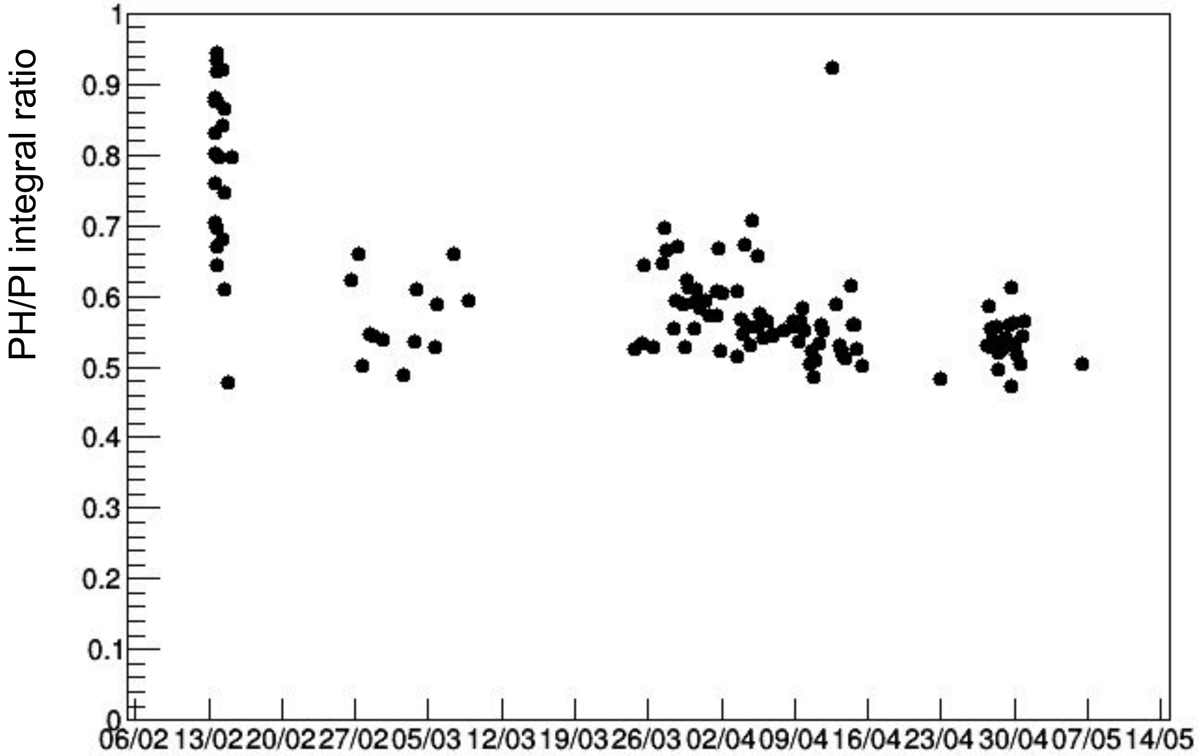

***Def.:***

$\text{ratio}^{\mathbf{NQ}}_{\mathbf{PH/PI}} =$

$(\sum_{i=1,2,3} \text{Integral}_{\mathbf{i}}^{\mathbf{PH}}) / (\sum_{i=1,2,3} \text{Integral}_{\mathbf{i}}^{\mathbf{PI}})$

- The ratio is not 1!
- as $\text{Integral}_{\mathbf{PH}}$ / $\text{Integral}_{\mathbf{PI}}$ decreases slightly over time, the P.I. - calibrated <wfm> might be affected more by pile-up

# P.I. vs P.H. calibration: integral ratio (quartz XArapuca)

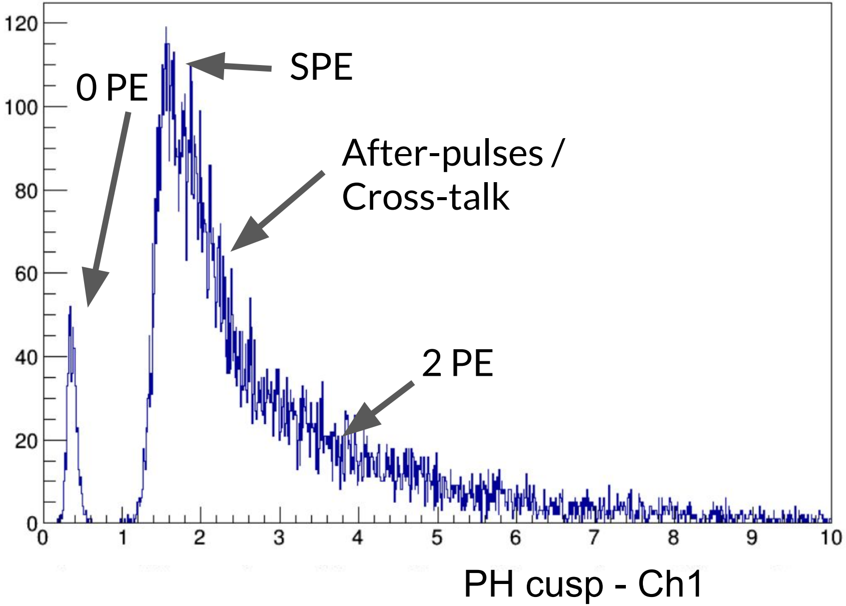



***Def.:***

$\text{ratio}^{Q}_{PH/PI}$ =

$(\sum_{i=4,5,7} \text{Integral}_{i}^{PH}) / (\sum_{i=4,5,7} \text{Integral}_{i}^{PI})$

# P.H. calibration: 3) Calibrate in nr. of photons




- from the pulse height spectrum find the p.h. corresponding to a SPE
- calibrate in nr. of photons

**Y axis is now in nr. of detected photons!**