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Standalone Arapuca Analysis

30.10.2020

Reminder

Shifting and Scintillation

1) ArAr*

$$\frac{dAA}{dt} = -\frac{AA}{\tau_{128}} - \frac{AA}{\tau_{N2}} - \frac{AA}{\tau_{AX}} = -\frac{AA}{\tau_{TA}} \quad \rightarrow \quad \frac{1}{\tau_{TA}} = \frac{1}{\tau_{128}} + \frac{1}{\tau_{N2}} + \frac{1}{\tau_{AX}}$$

2) ArXe*

$$\frac{dAX}{dt} = +\frac{AA}{\tau_{AX}} - \frac{AX}{\tau_{150}} - \frac{AX}{\tau_{N2}} - \frac{AX}{\tau_{XX}} = +\frac{AA}{\tau_{AX}} - \frac{AX}{\tau_{TX}} \quad \rightarrow \quad \frac{1}{\tau_{TX}} = \frac{1}{\tau_{150}} + \frac{1}{\tau_{N2}} + \frac{1}{\tau_{XX}}$$

3) XeXe*

$$\frac{dXX}{dt} = +\frac{AX}{\tau_{XX}} - \frac{XX}{\tau_{175}}$$

Reminder

$$\frac{dAA}{dt}(scint@128nm) = K\frac{\tau_{TA}}{\tau_{128}}\frac{e^{-t/\tau_{TA}}}{\tau_{TA}}$$

$$\frac{dAX}{dt}(scint@150nm) = K\frac{\tau_{TA}}{\tau_{150}}\frac{\tau_{TX}}{\tau_{AX}}\frac{(e^{-t/\tau_{TA}} - e^{-t/\tau_{TX}})}{(\tau_{TA} - \tau_{TX})}$$

$$\frac{dXX}{dt}(scint@175nm) = K\frac{\tau_{TA}}{\tau_{XX}}\frac{\tau_{TX}}{\tau_{AX}}\frac{(e^{-t/\tau_{TA}} - e^{-t/\tau_{TX}})}{(\tau_{TA} - \tau_{TX})}$$

```
def mod1(t,a,b,c,d,e,f,t1,t2,t3): # not all pa
    return  (a*(np.exp(-(t - t0)/t1)) +
             b*(np.exp(-(t - t0)/t2)) +
             c*(np.exp(-(t - t0)/t3)))

def mod2(t,a,b,c,d,e,f,t1,t2,t3): # not all pa
    return  (d*(np.exp(-(t - t0)/t1)) +
             e*(np.exp(-(t - t0)/t2)) +
             f*(np.exp(-(t - t0)/t3)))
```

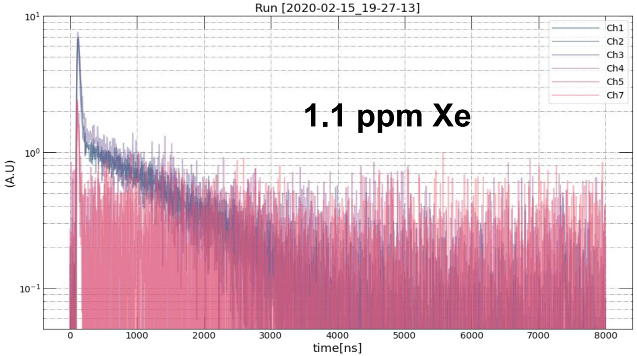
$$\frac{dXN}{dt}(scint@128nm + 150nm + 178nm) = K\left(\frac{\tau_{TA}}{\tau_{128}}\frac{e^{-t/\tau_{TA}}}{\tau_{TA}} + \frac{\tau_{TA}}{\tau_{AX}}\frac{(e^{-t/\tau_{TA}} - e^{-t/\tau_{TX}})}{(\tau_{TA} - \tau_{TX})}\right)$$

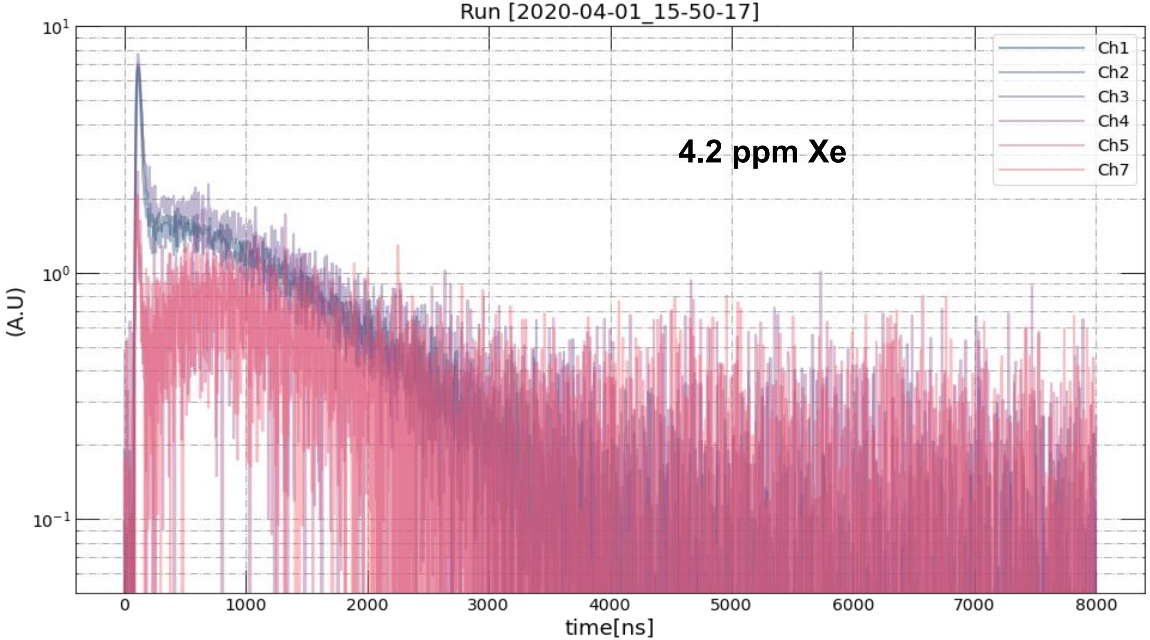
$$\frac{dXQ}{dt}(scint@178nm) = (1-\varepsilon)K\frac{\tau_{150}}{\tau_{XX} + \tau_{150}}\frac{\tau_{TA}}{\tau_{AX}}\frac{(e^{-t/\tau_{TA}} - e^{-t/\tau_{TX}})}{(\tau_{TA} - \tau_{TX})}$$

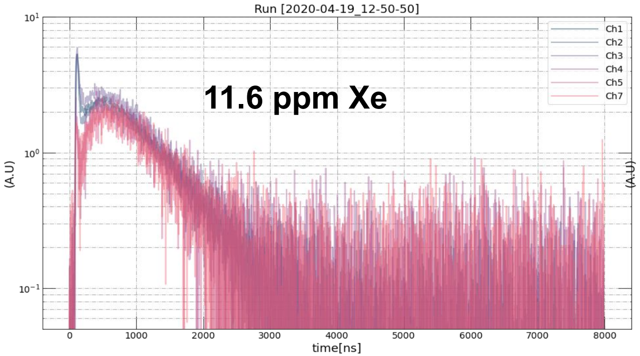
Run examples for each injection and channels

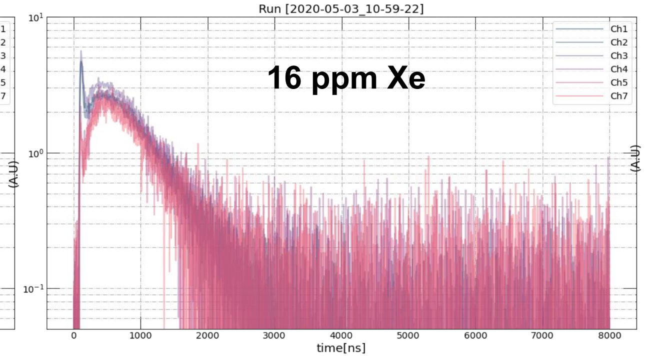
No Quartz = Ch1, Ch2, Ch3

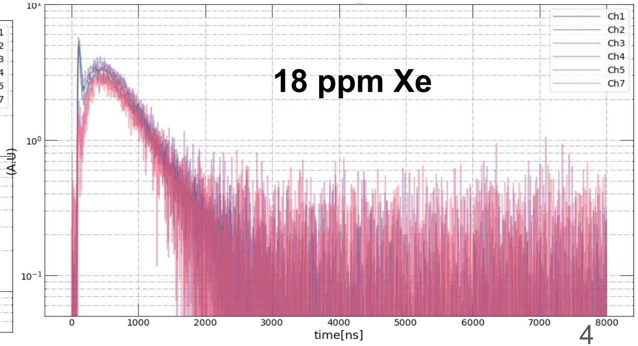
Quartz = Ch4, Ch5, Ch7

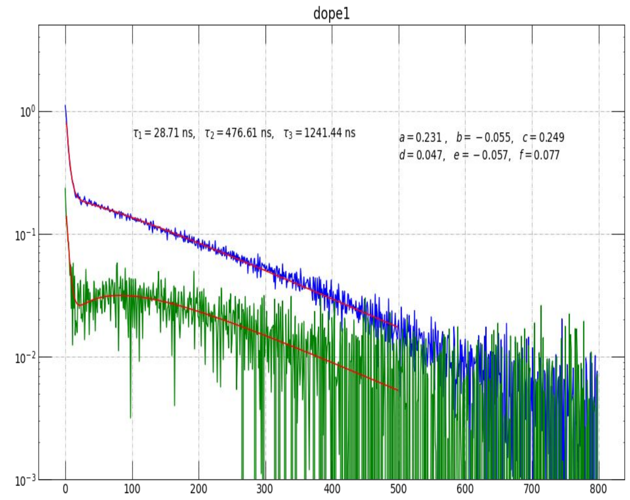


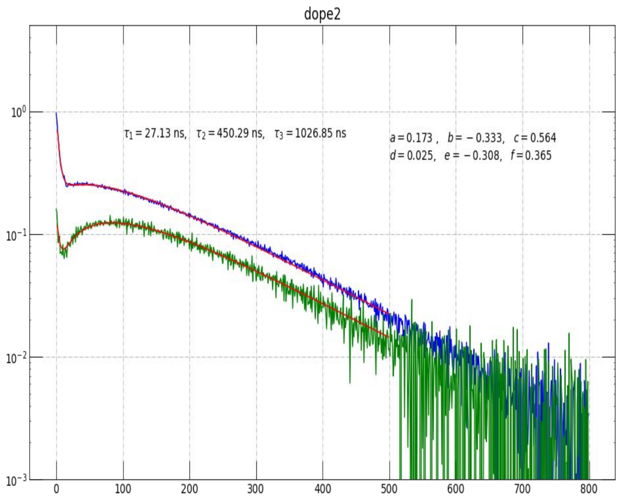


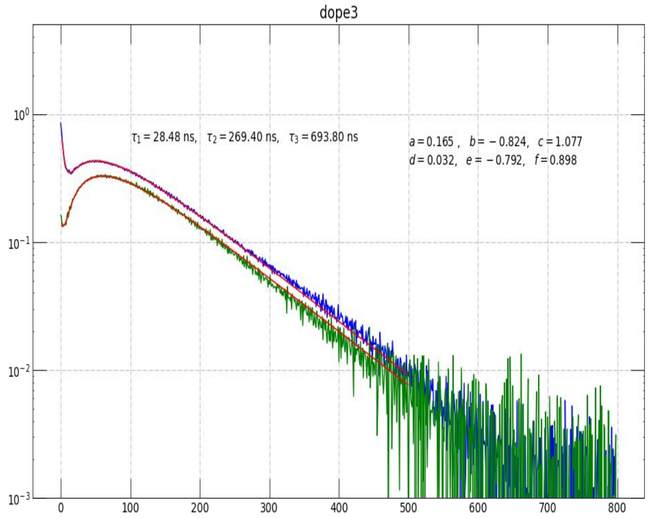


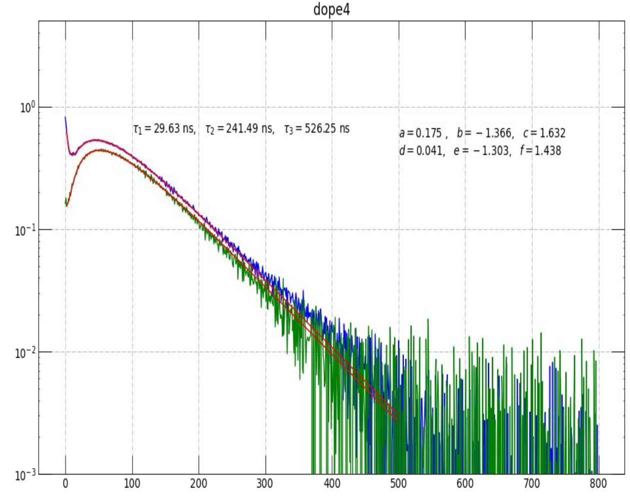


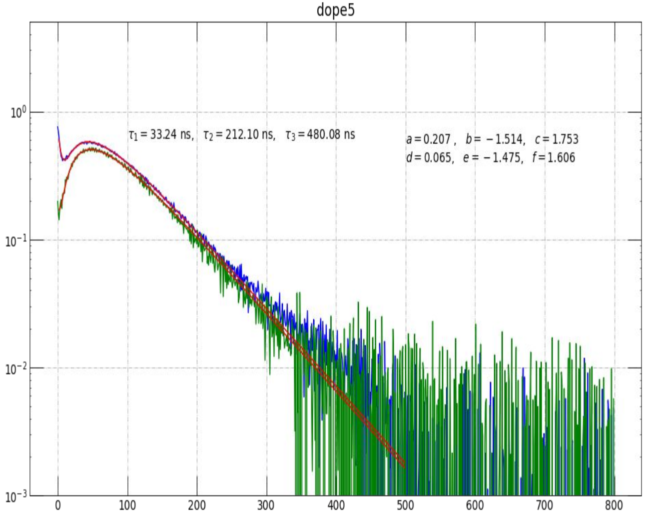












For each Dope simultaneous fit of the NQ / WQ

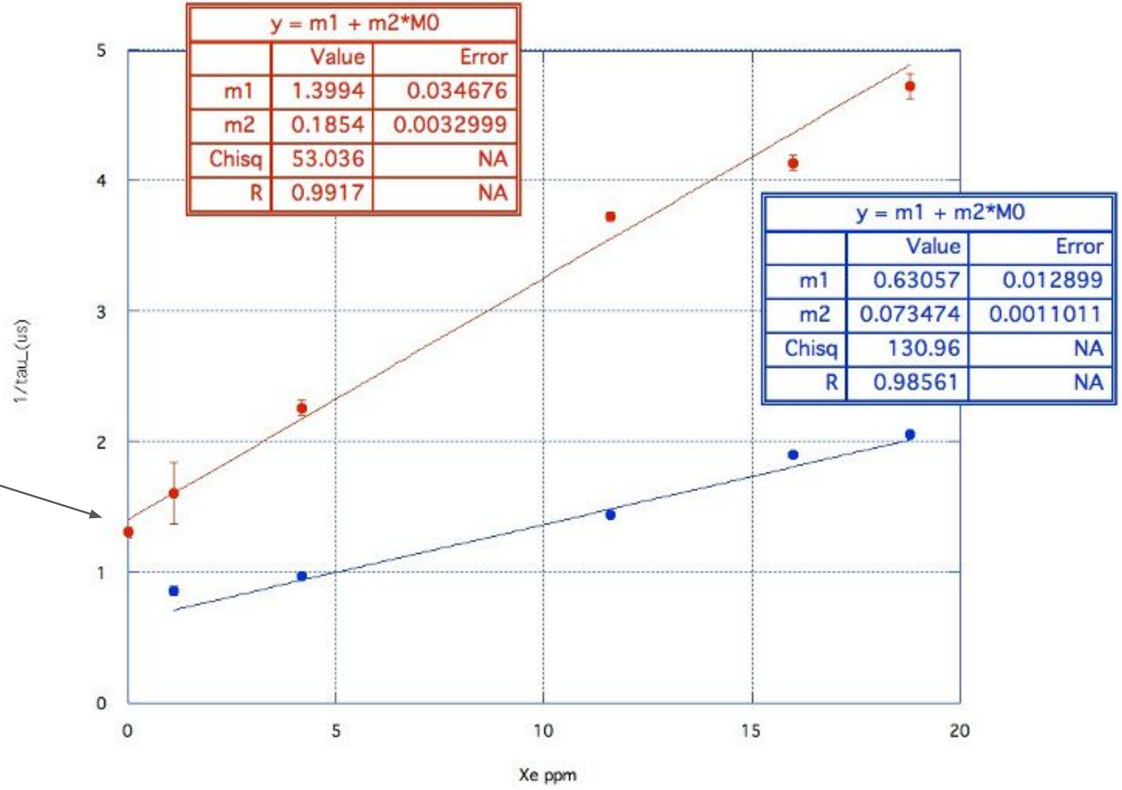
Xe ppm	tauTA (ns)	tauTA_err	tauTX (ns)	tauTX_err	P2_NQ	P2_NQ_err	P3_NQ	P3_NQ_err	P2_WQ	P2_WQ_err	P3_WQ	P3_WQ_err
1.10E+00	6.23E+02	9.13E+01	1.17E+03	4.94E+01	-9.66E-02	3.88E-02	2.91E-01	3.90E-02	-7.60E-02	1.93E-02	9.90E-02	2.03E-02
4.20E+00	4.43E+02	1.12E+01	1.03E+03	1.10E+01	-3.23E-01	1.44E-02	5.54E-01	1.48E-02	-3.08E-01	1.08E-02	3.61E-01	1.15E-02
1.16E+01	2.69E+02	2.53E+00	6.94E+02	2.98E+00	-8.23E-01	1.01E-02	1.08E+00	1.09E-02	-8.12E-01	9.19E-03	9.06E-01	9.99E-03
1.60E+01	2.42E+02	3.11E+00	5.26E+02	3.53E+00	-1.37E+00	2.99E-02	1.63E+00	3.19E-02	-1.34E+00	2.84E-02	1.46E+00	3.01E-02
1.88E+01	2.12E+02	4.18E+00	4.87E+02	4.67E+00	-1.45E+00	4.04E-02	1.69E+00	4.48E-02	-1.46E+00	4.00E-02	1.56E+00	4.38E-02

Table1: Results of the simultaneous fit of the XQ and XN average signal shapes (only the slow component parameters are reported).

-The fitting functions is **P1 exp(-t/tauF) + P2 exp(-t/tauTA) + P3 exp (-t/tauTX)**; the first term describes the fast component.

-The all decay times are forced to be the same for the XQ an XN X-Arapucas.

1.304 ± 0.04



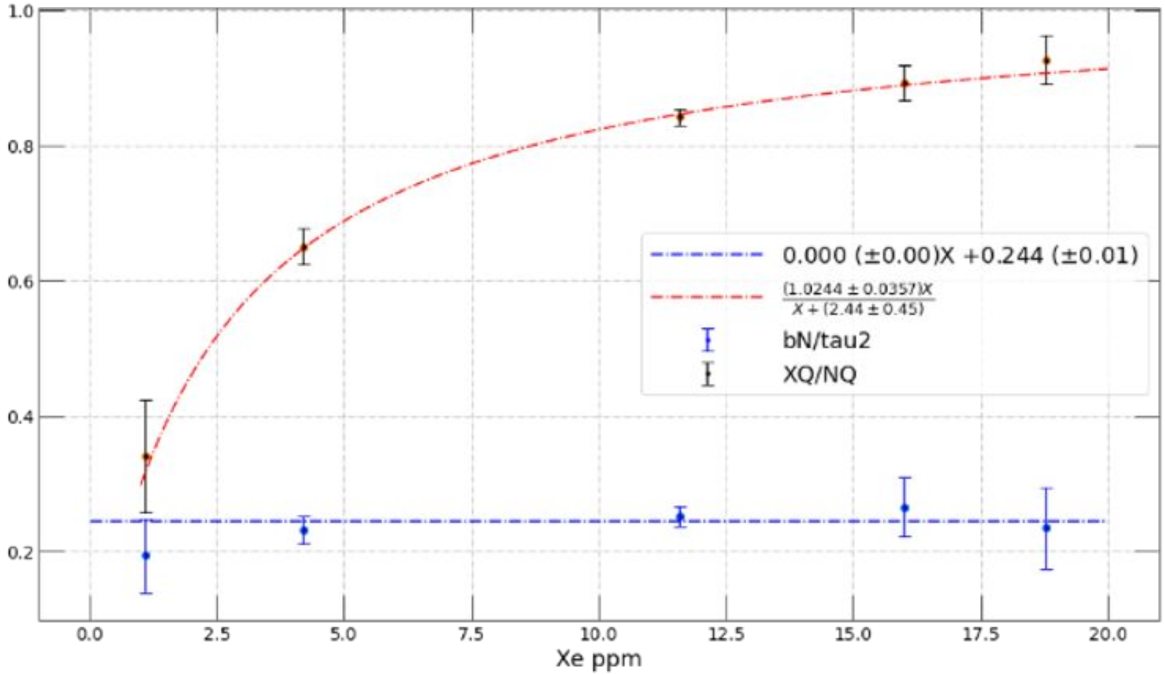
Values of **1/tauTA (red)** and **1/tauTX (blue)** from Table 1 as a function of the xenon concentration; the value at 0 ppm is the one measured before the doping with the Arapucas on the APA's; the linear fit of the data is also shown.

Xe ppm	B_NQ	B_NQ_err	B_WQ	B_WQ_err	C_NQ	C_NQ_err	C_WQ	C_WQ_err
1.10E+00	1.21E+02	3.86E+01	1.44E+01	1.76E+01	1.60E+02	3.71E+01	5.46E+01	1.52E+01
4.20E+00	1.02E+02	9.49E+00	2.36E+01	6.08E+00	3.27E+02	1.23E+01	2.13E+02	8.82E+00
1.16E+01	6.80E+01	4.05E+00	2.53E+01	3.96E+00	4.57E+02	6.26E+00	3.85E+02	5.53E+00
1.60E+01	6.43E+01	1.06E+01	2.84E+01	7.61E+00	4.65E+02	1.19E+01	4.15E+02	1.10E+01
1.88E+01	4.98E+01	1.28E+01	2.28E+01	1.11E+01	4.64E+02	1.62E+01	4.30E+02	1.55E+01

Table 2: Same results as in Table 1, but recomputed as;

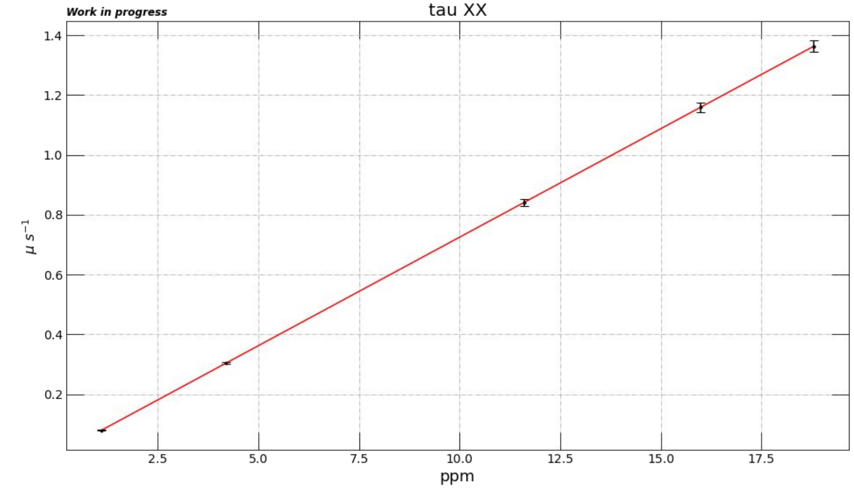
A exp(-t/tauF)/tauF + B exp(-t/tauTA)/tauTA + C (exp(-t/tauTA) - exp (-t/tauTX))/(tauTA – tauTX)

Again, only the slow component parameters are reported.



Plot of C_WQ/C_NQ (red) and B_NQ*TauTA (blue) as a function of the xenon concentration; for the first the fit is done with the function K1/(1+K2/ppm) to allow extracting the relation $(\frac{eta}{1+\tau_{XX}/(1+\varepsilon)\tau_{150}})$;

The second should be proportional to 1/tau_128, hence it should be constant.



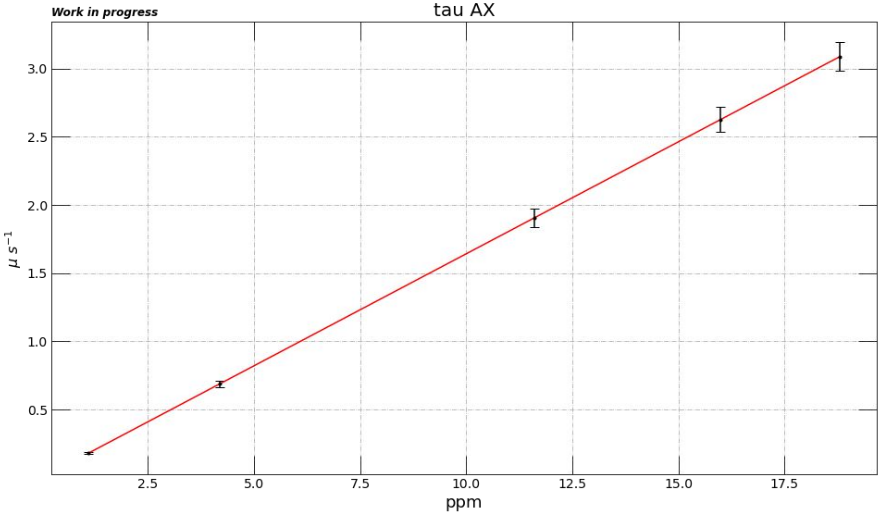
From the linear fit of $\frac{1}{\tau_{TX}}$ (blue line in plot 1) we get:

$$\frac{1}{\tau_{TX}} = \frac{1}{\tau_{150}} + \frac{1}{\tau_{N2}} + \frac{1}{\tau_{XX}} = (0.631 \pm 0.012) + (0.073 \pm 0.001)\ Xe[ppm]\ \mu s^{-1}$$

$$\boldsymbol{\tau_{XX} = \frac{(13.7 \pm 0.2)}{Xe[ppm]}\ \mu s}$$

Since, in addition, from the trend of the coefficients of the WQ/NQ double exponential fit formula (obtained from the fit of the data in plot 2) we have that:

$$\tau_{XX} = \frac{2.44 \pm 0.45}{Xe[ppm]} \tau_{150} (1 + \varepsilon)$$



From the linear fit of $\frac{1}{\tau_{TA}}$ (red line in plot 1) we get:

$$\frac{1}{\tau_{TA}} = \frac{1}{\tau_{128}} + \frac{1}{\tau_{N2}} + \frac{1}{\tau_{AX}} = ((1.4 \pm 0.04) + (0.185 \pm 0.01)\ Xe[ppm])\mu s^{-1}$$

hence:

$$\frac{1}{\tau_{128}} + \frac{1}{\tau_{N2}} = (1.4 \pm 0.04)\ \mu s^{-1}$$

$$\frac{1}{\tau_{N2}} = ((1.4 \pm 0.04) - \frac{1}{1.4 \pm 0.1})\ \mu s^{-1} = ((1.4 \pm 0.04) - (0.71 \pm 0.05))\ \mu s^{-1}$$
$$= (0.69 \pm 0.065)\ \mu s^{-1}$$

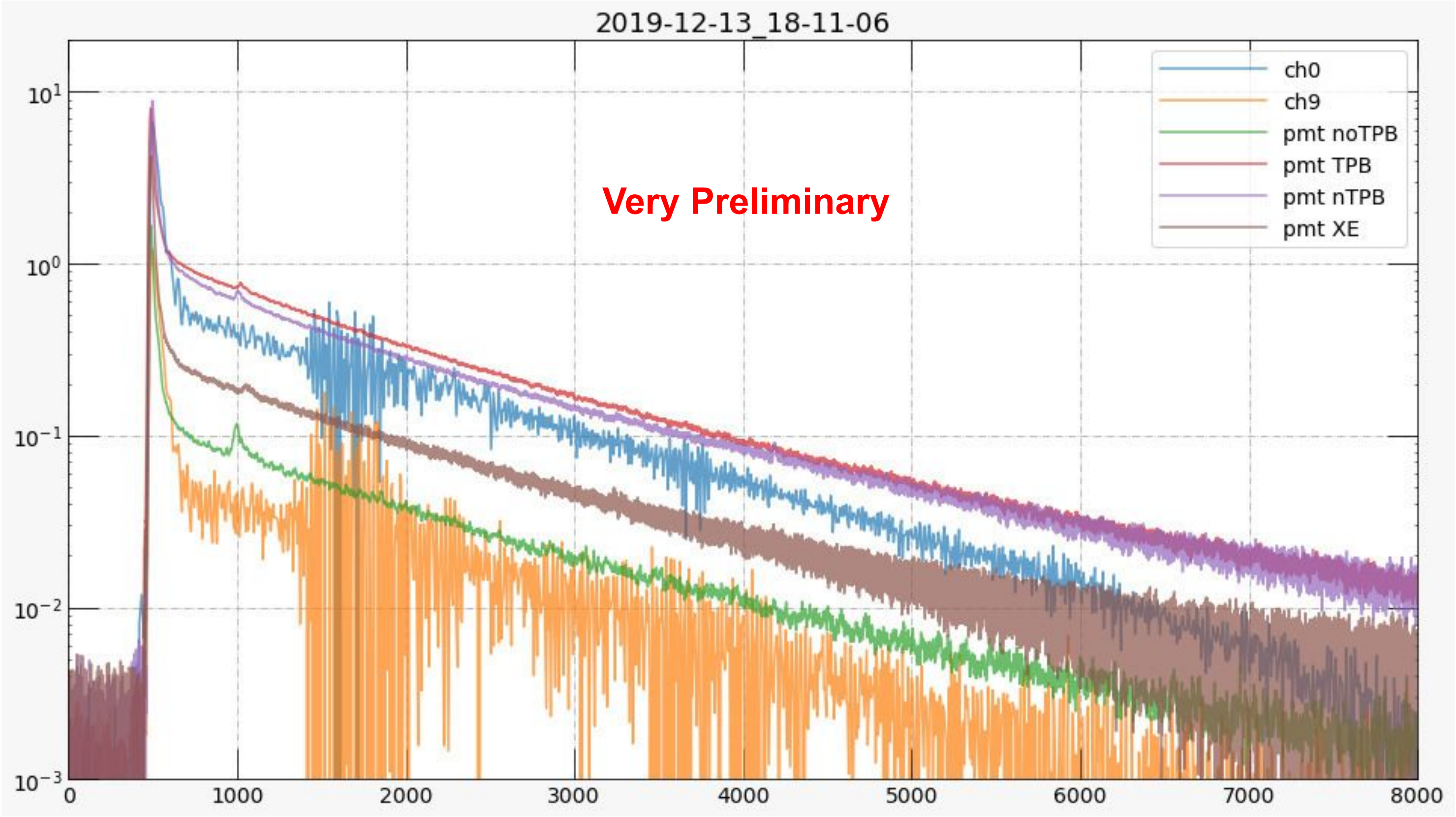
In the latter, we assume that the time constant of the Ar scintillation at 128 nm is $(1.4 \pm 0.1)\ \mu s$

$$\boldsymbol{\tau_{N2}(on\ ArAr*) = 1.45\ \pm 0.014\ \mu s}$$

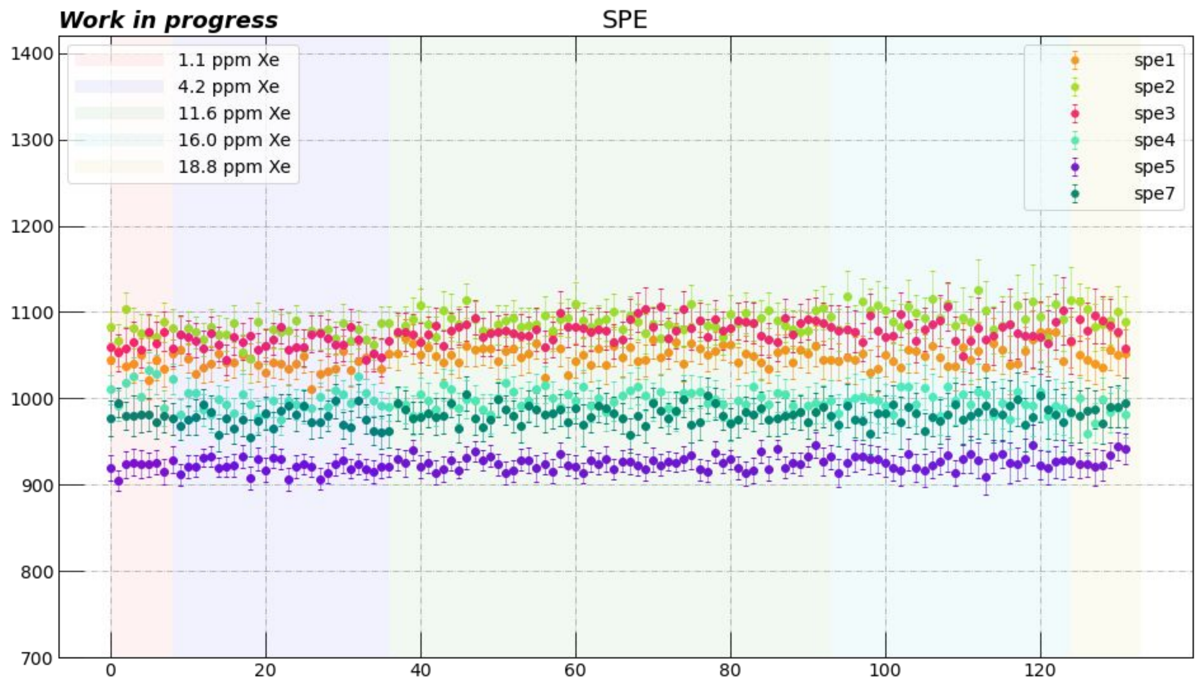
$$\frac{1}{\tau_{AX}} = (0.185 \pm 0.01)\ Xe[ppm]\ \mu s^{-1}$$

$$\boldsymbol{\tau_{AX} = \frac{5.4 \pm 0.3}{Xe[ppm]}\ \mu s}$$

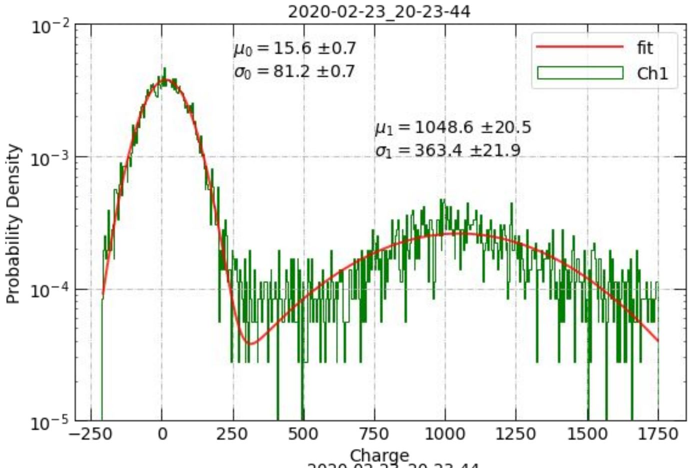
50L IC Results

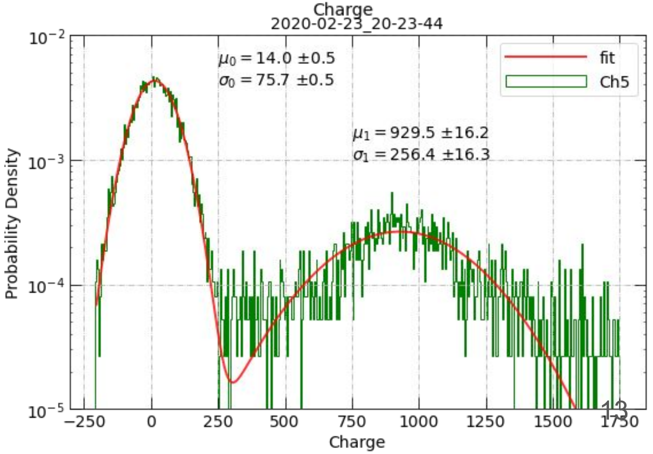


backup



SPE





ch1: 1048.4 +/- 11.6 (SYS 2.4)

ch2: 1087.8 +/- 13.6 (SYS 2.5)

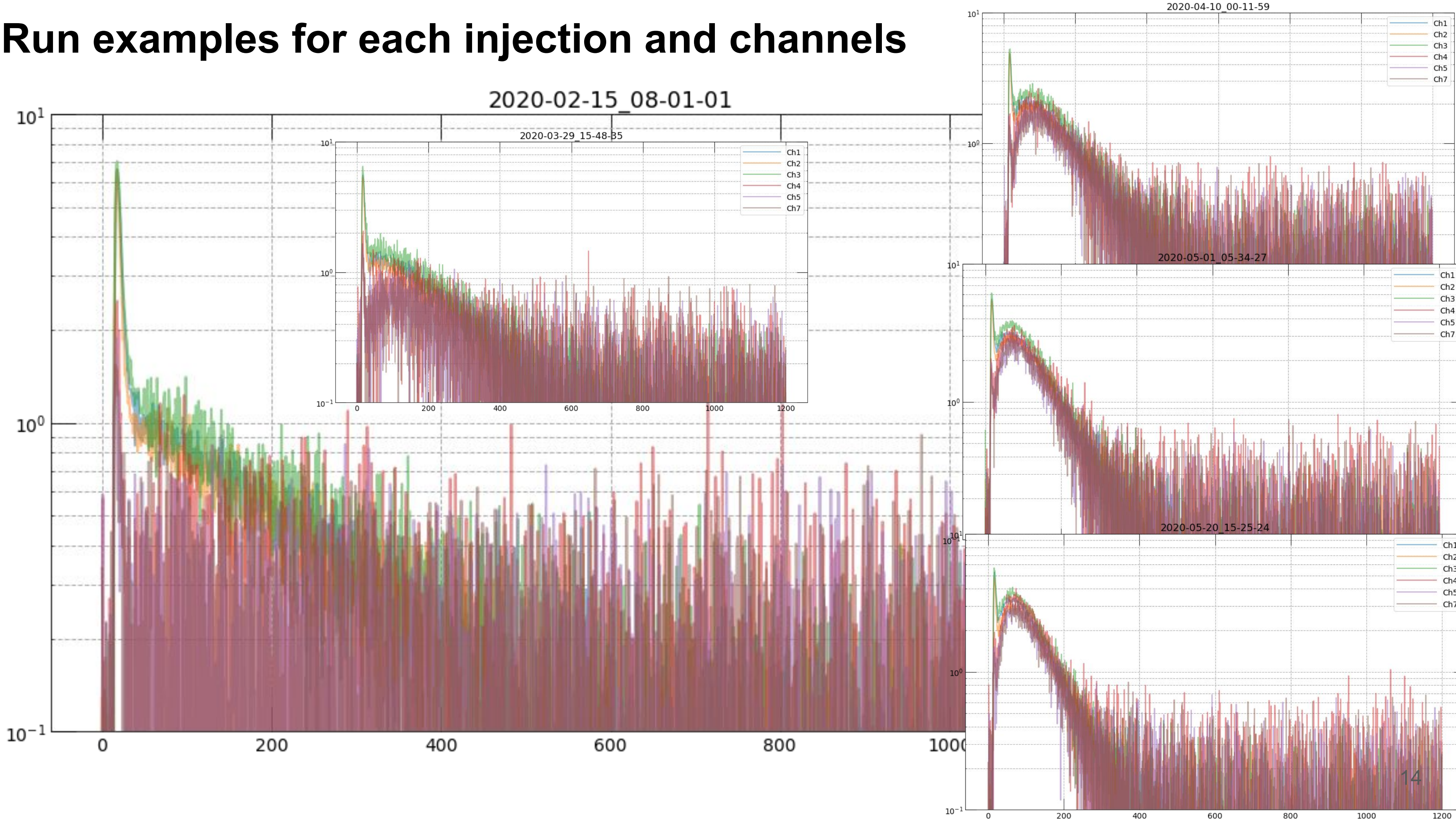
ch3: 1075.8 +/- 12.9 (SYS 3.1)

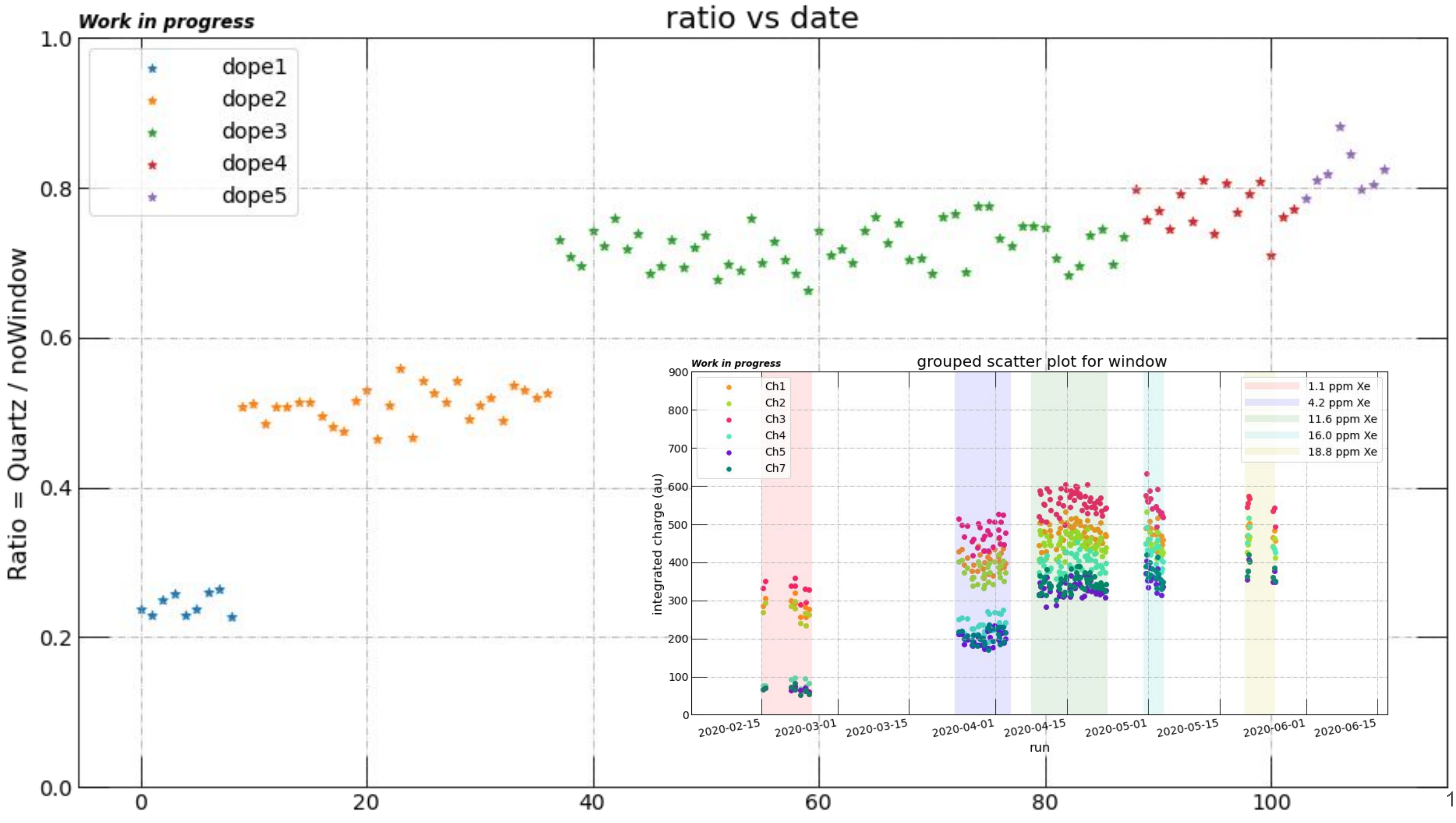
ch4: 997.41 +/- 12.0 (SYS 2.3)

ch5: 924.99 +/- 8.0 (SYS 0.16)

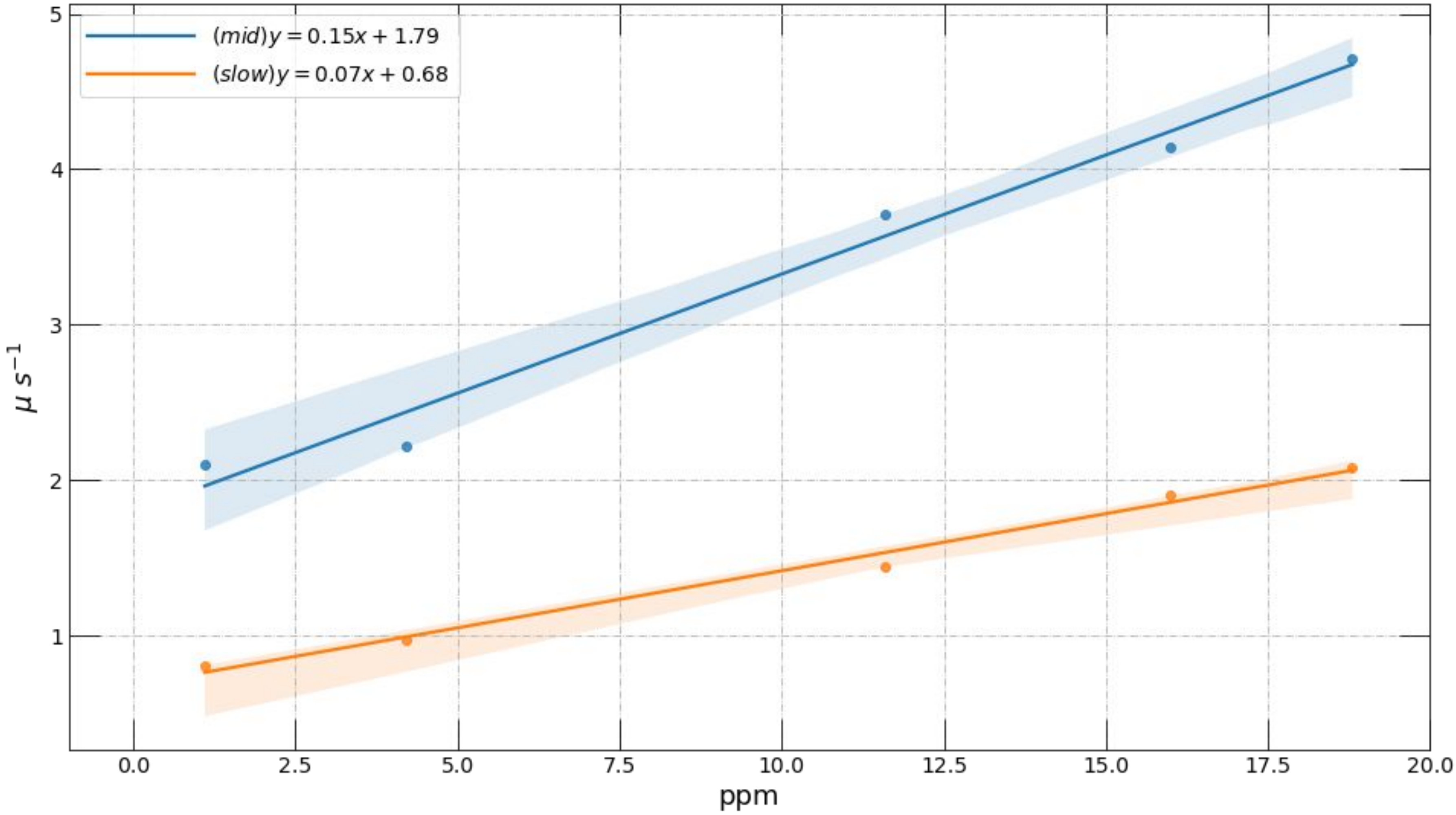
ch7: 980.68 +/- 10.3 (SYS 1.6)

Run examples for each injection and channels

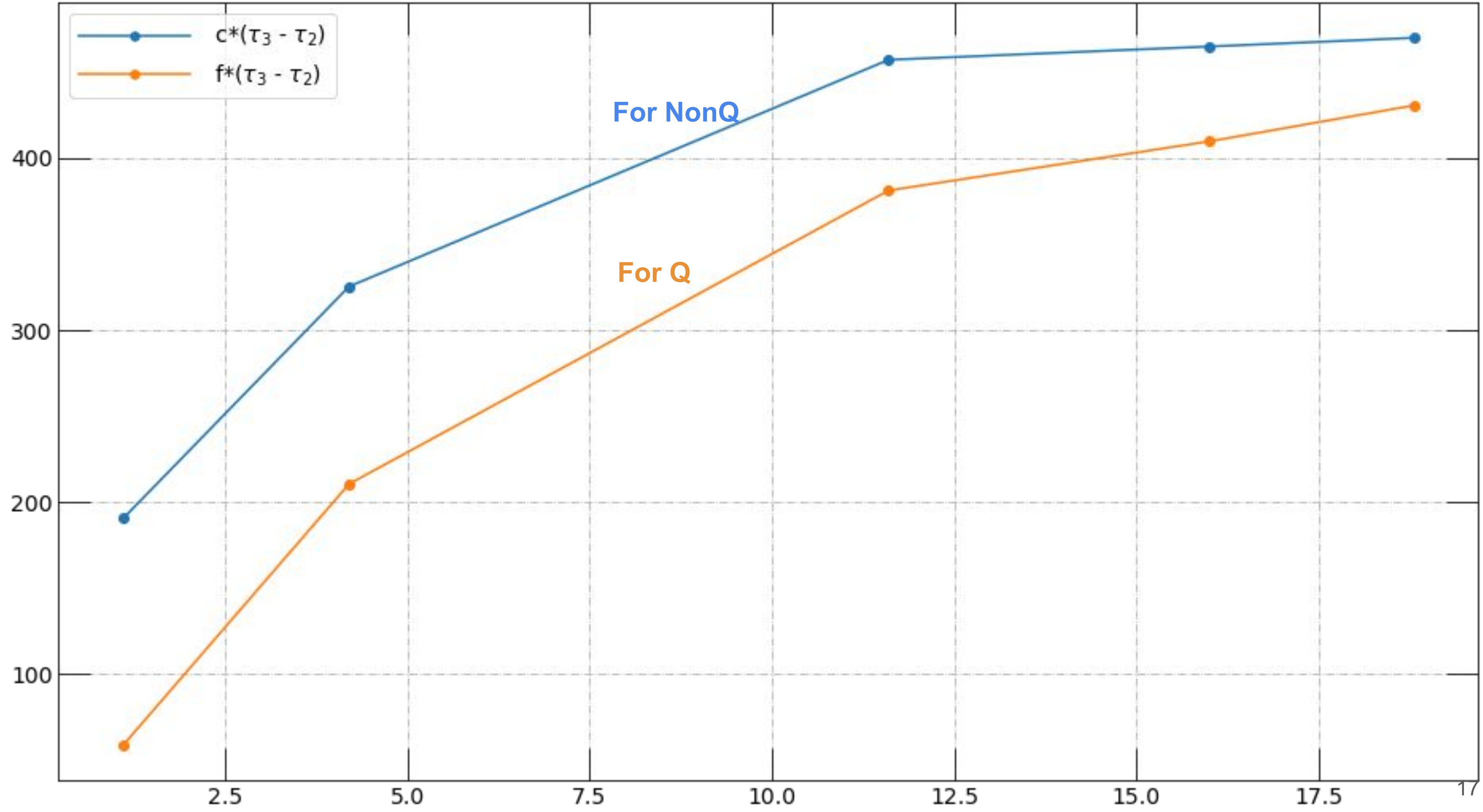




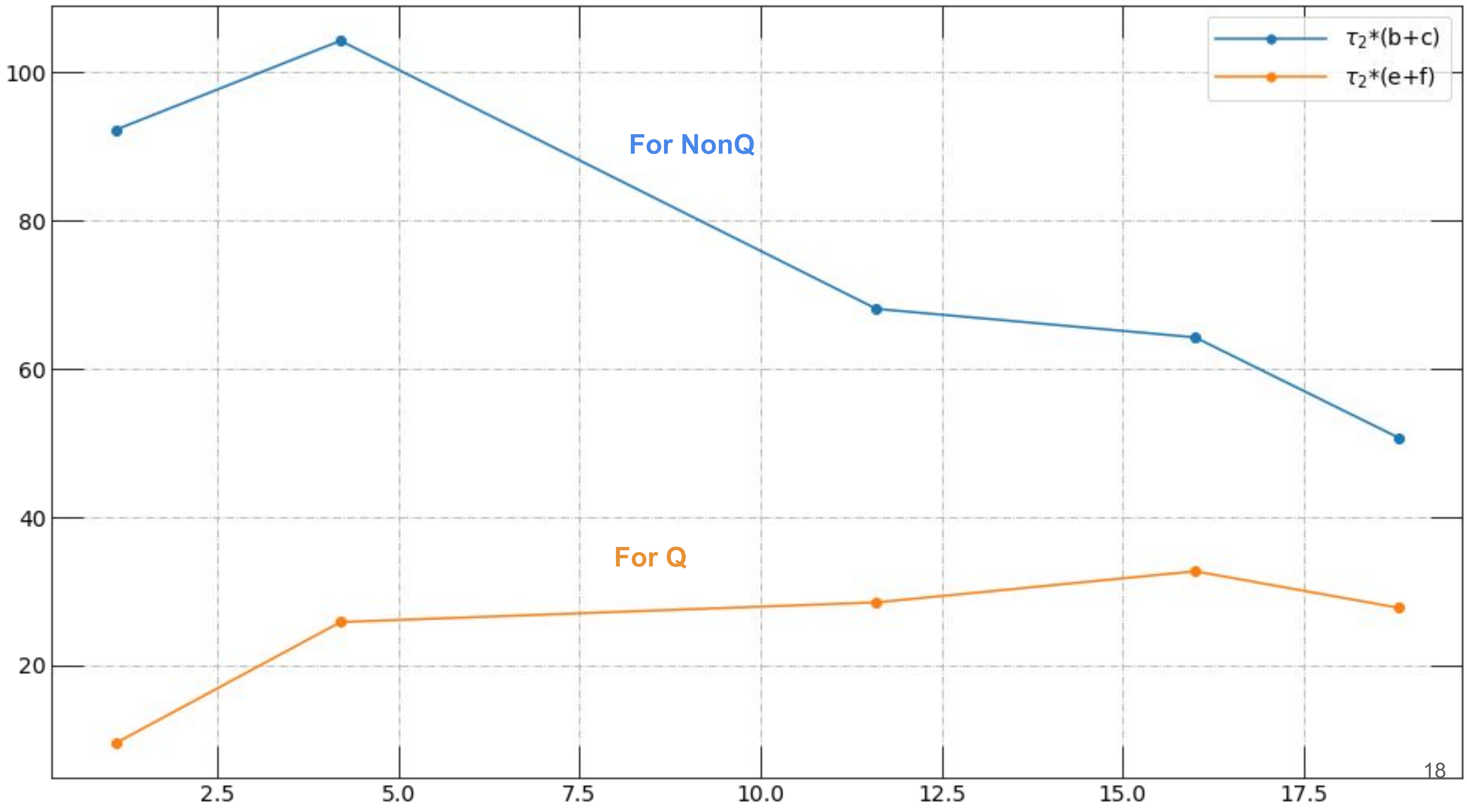
Work in progress
ratio vs date
dope1
dope2
dope3
dope4
dope5
Ratio = Quartz / noWindow
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100
Work in progress
grouped scatter plot for window
Ch1
Ch2
Ch3
Ch4
Ch5
Ch7
1.1 ppm Xe
4.2 ppm Xe
11.6 ppm Xe
16.0 ppm Xe
18.8 ppm Xe
integrated charge (au)
0
100
200
300
400
500
600
700
800
900
2020-02-15
2020-03-01
2020-03-15
2020-04-01
2020-04-15
2020-05-01
2020-05-15
2020-06-01
2020-06-15
run



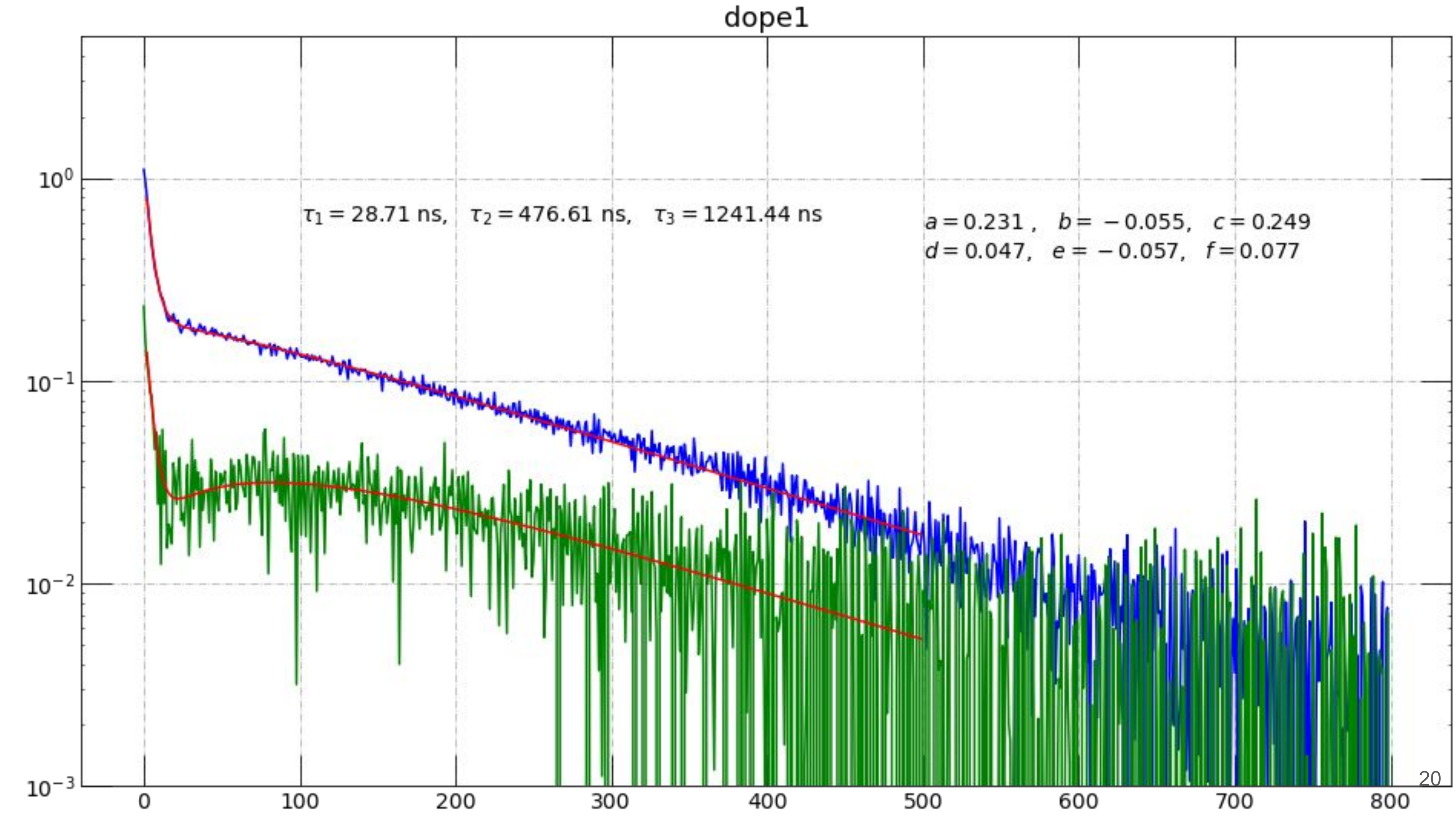
(mid) y = 0.15x + 1.79
(slow) y = 0.07x + 0.68
5
4
3
2
1
μ s⁻¹
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
ppm

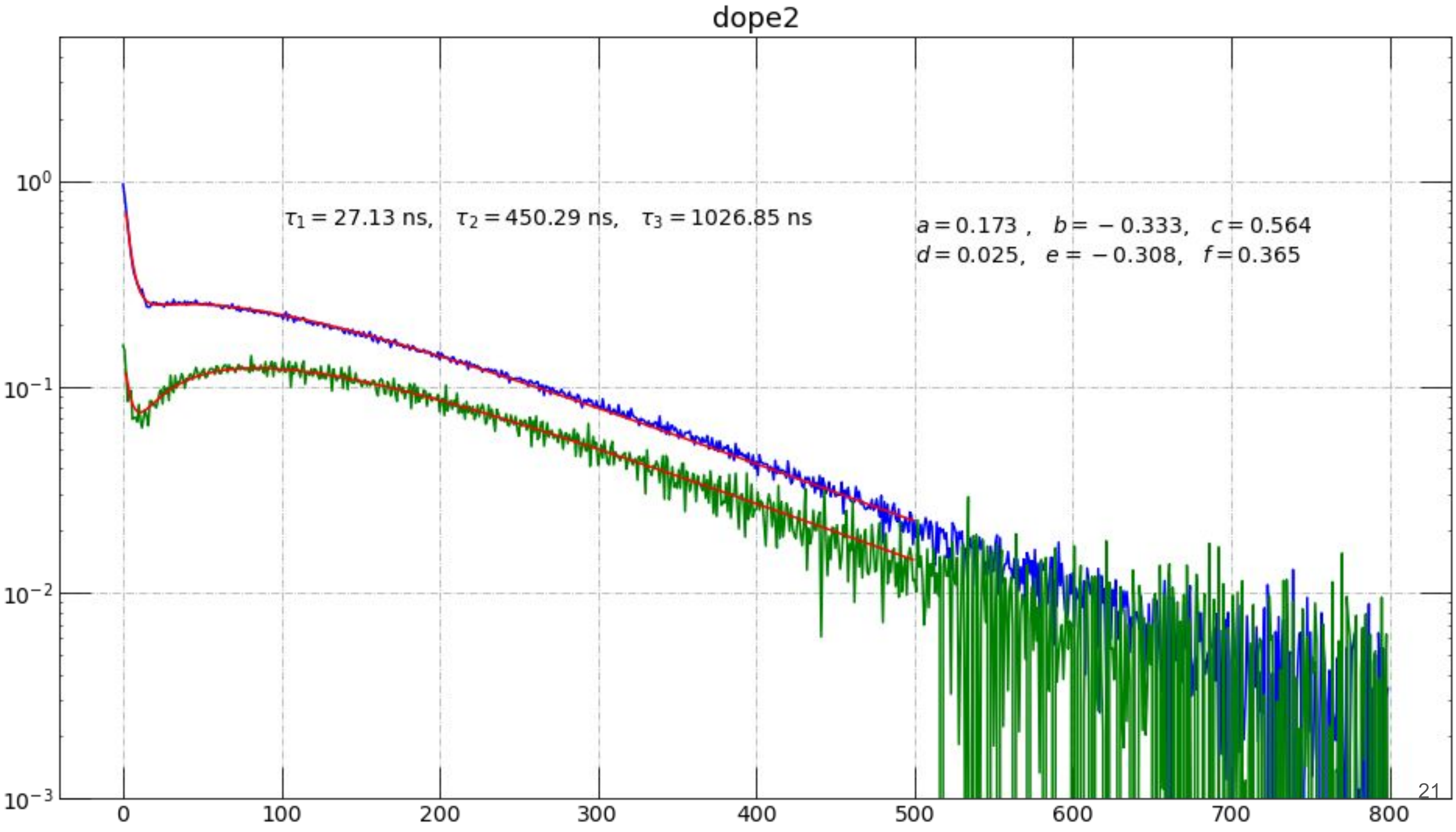


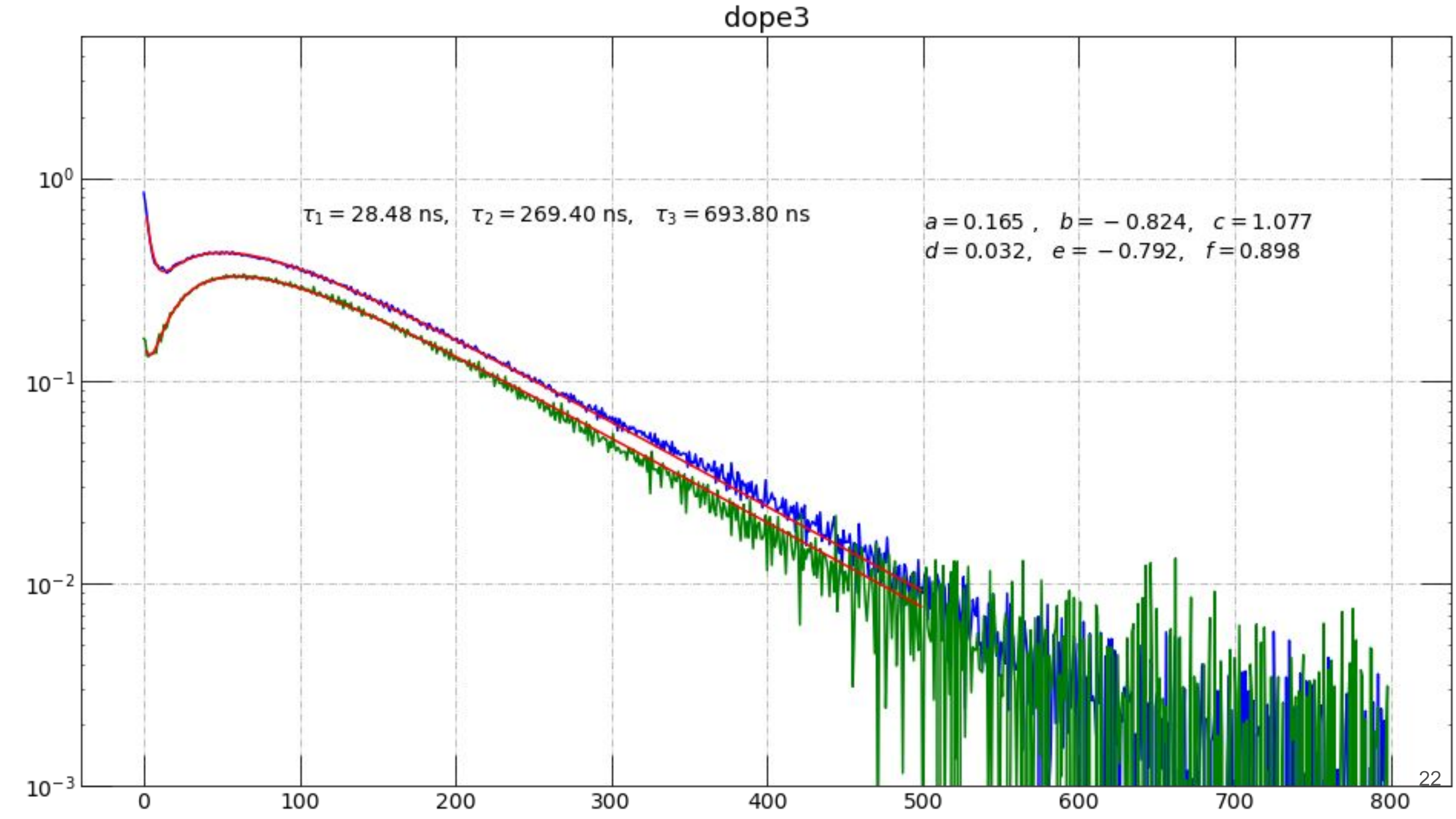
c*(τ3 - τ2)
f*(τ3 - τ2)
For NonQ
For Q
400
300
200
100
2.5
5.0
7.5
10.0
12.5
15.0
17.5

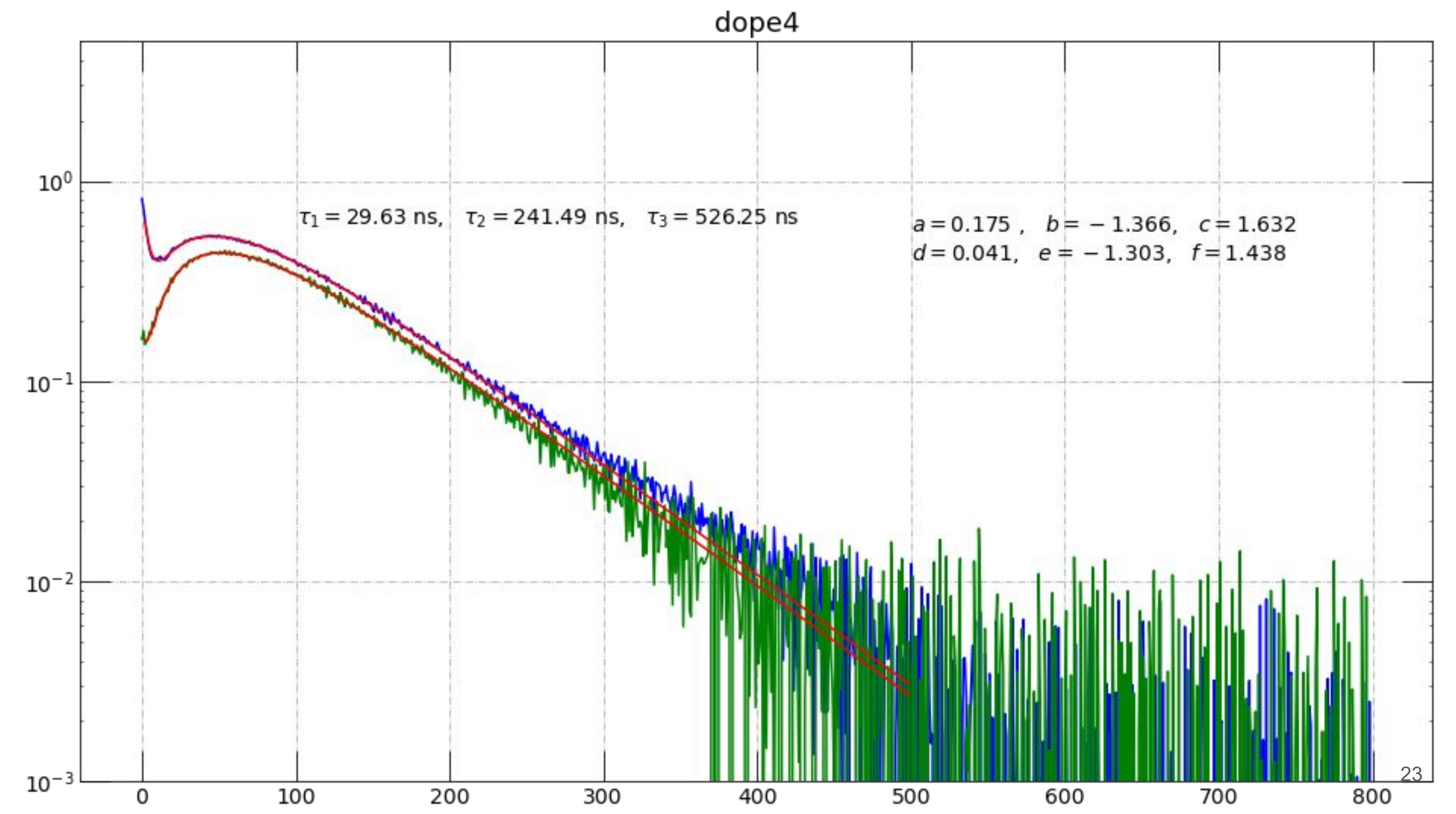

τ2*(b+c)
τ2*(e+f)
For NonQ
For Q
100
80
60
40
20
2.5
5.0
7.5
10.0
12.5
15.0
17.5

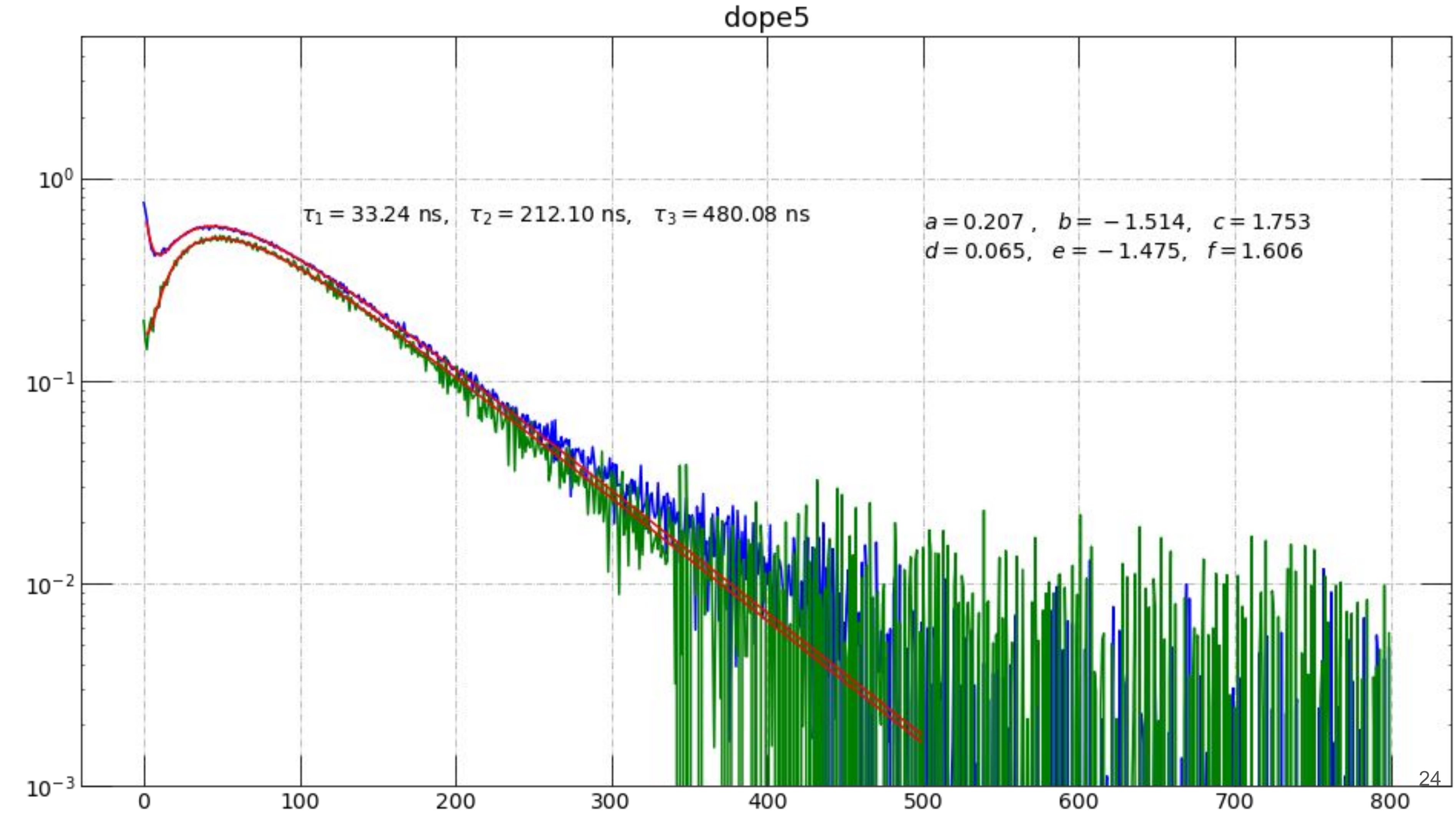
backup


dope1
$\tau_1 = 28.71$ ns, $\tau_2 = 476.61$ ns, $\tau_3 = 1241.44$ ns
$a = 0.231$, $b = -0.055$, $c = 0.249$
$d = 0.047$, $e = -0.057$, $f = 0.077$
10^0
10^{-1}
10^{-2}
10^{-3}
0
100
200
300
400
500
600
700
800

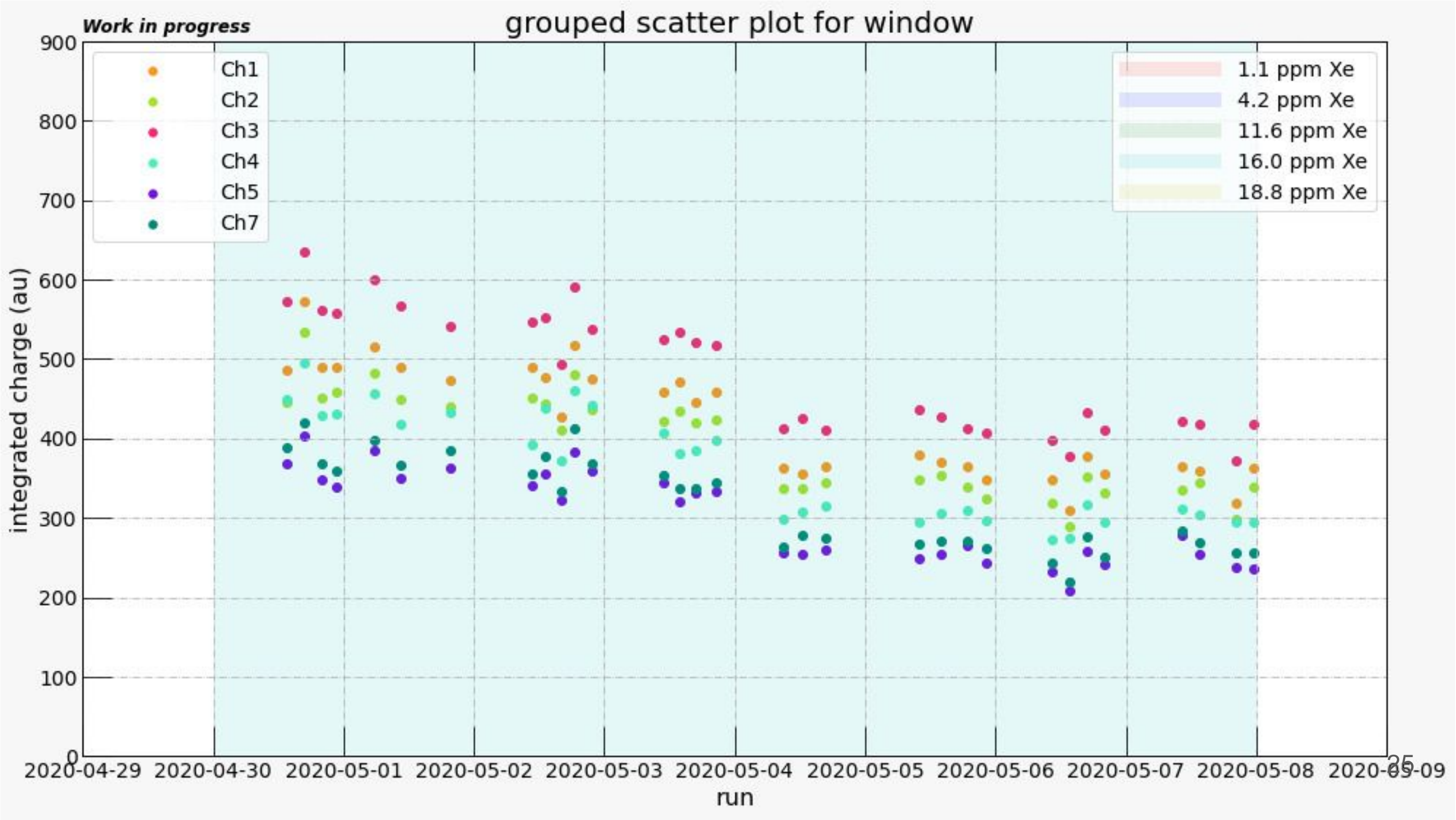

dope2
τ1 = 27.13 ns,   τ2 = 450.29 ns,   τ3 = 1026.85 ns
a = 0.173 ,   b = −0.333,   c = 0.564
d = 0.025,   e = −0.308,   f = 0.365
10^0
10^-1
10^-2
10^-3
0
100
200
300
400
500
600
700
800


dope3
τ1 = 28.48 ns,   τ2 = 269.40 ns,   τ3 = 693.80 ns
a = 0.165 ,   b = −0.824,   c = 1.077
d = 0.032,   e = −0.792,   f = 0.898
10^0
10^-1
10^-2
10^-3
0
100
200
300
400
500
600
700
800


dope4
τ1 = 29.63 ns,   τ2 = 241.49 ns,   τ3 = 526.25 ns
a = 0.175 ,   b = −1.366,   c = 1.632
d = 0.041,   e = −1.303,   f = 1.438
10^0
10^-1
10^-2
10^-3
0
100
200
300
400
500
600
700
800


dope5
τ1 = 33.24 ns, τ2 = 212.10 ns, τ3 = 480.08 ns
a = 0.207 , b = −1.514, c = 1.753
d = 0.065, e = −1.475, f = 1.606
10^0
10^−1
10^−2
10^−3
0
100
200
300
400
500
600
700
800

Dope4 after 2020-05-04(E180)



The X-Arapuca without Quartz window (XN) will see the sum of the three spectra, with the assumption that the three wavelengths are shifted with similar quantum efficiency.

$$\frac{dXN}{dt}(scint@128nm + 150nm + 178nm)$$
$$= K\left(\frac{\tau_{TA}}{\tau_{128}}\frac{e^{-\frac{t}{\tau_{TA}}}}{\tau_{TA}} + \frac{\tau_{TA}}{\tau_{AX}}\frac{(e^{-t/\tau_{TA}} - e^{-t/\tau_{TX}})}{(\tau_{TA} - \tau_{TX})}\right)$$

The X-Arapuca with the Quartz window (XQ) will only be sensitive to the third spectrum (the one from XeXe*)

$$\frac{dXQ}{dt}(scint@178nm) = (1-\varepsilon)K\frac{\tau_{150}}{\tau_{XX} + \tau_{150}}\frac{\tau_{TA}}{\tau_{AX}}\frac{(e^{-t/\tau_{TA}} - e^{-t/\tau_{TX}})}{(\tau_{TA} - \tau_{TX})}$$

The XN and XQ spectra at the different Xe concentrations can be fitted 'simultaneously' with the $\frac{dXN}{dt}$ *and* $\frac{dXQ}{dt}$ functions to extract the common value of τ_{TA} *and* τ_{TX}.

A linear fit of $\frac{1}{\tau_{TA}}$ *and* $\frac{1}{\tau_{TX}}$ as a function of the Xenon concentration could allow to estimate estimate of τ_{AX} *and* τ_{XX} :

$$\frac{1}{\tau_{TA}} = \frac{1}{\tau_{128}} + \frac{1}{\tau_{N2}} + \frac{1}{\tau_{AX}} = (a + b\ Xe[ppm])\mu s^{-1}$$

$$\frac{1}{\tau_{128}} + \frac{1}{\tau_{N2}} = a\ \mu s^{-1}$$

$$\frac{1}{\tau_{N2}} = (a - \frac{1}{1.6})\ \mu s^{-1}$$

$$\tau_{N2} = 1/(a - \frac{1}{1.6})\ \ \mu s$$

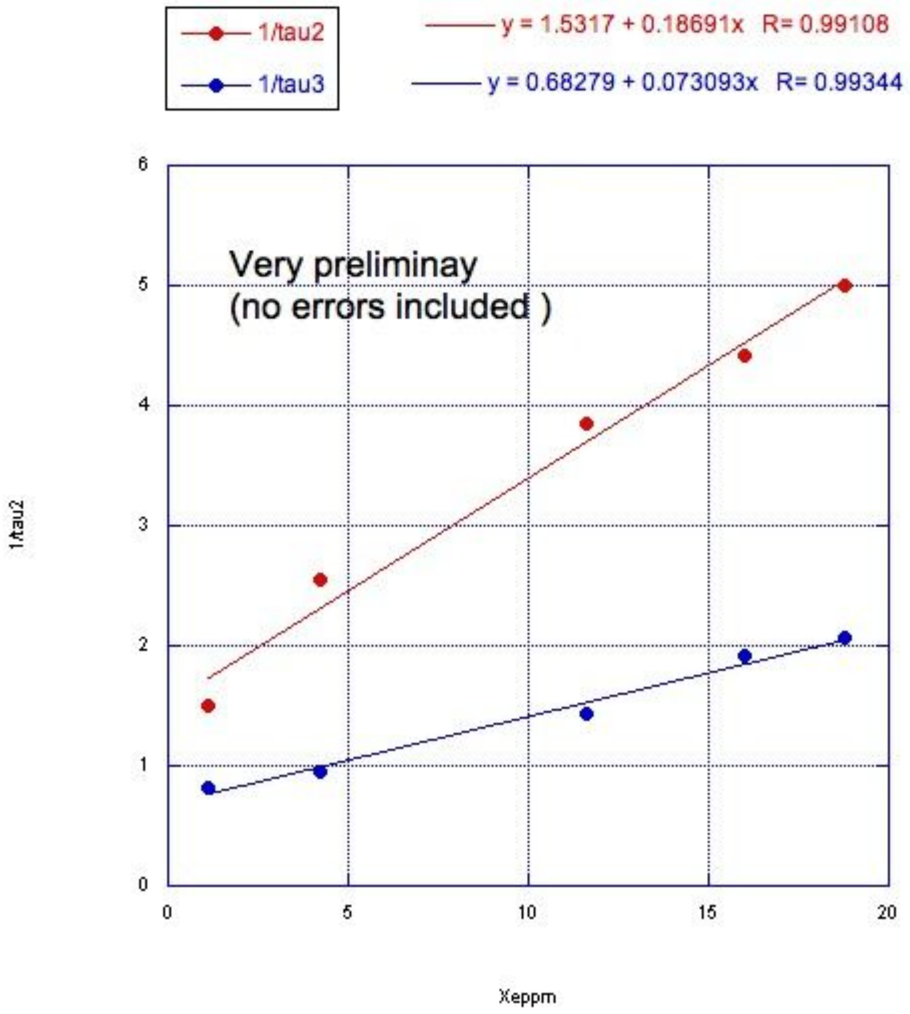
$$\frac{1}{\tau_{AX}} = b\ Xe[ppm]\ \mu s^{-1}$$

$$\tau_{AX} = \frac{1/b}{Xe[ppm]}\ \mu s$$

$$\frac{1}{\tau_{TX}} = \frac{1}{\tau_{150}} + \frac{1}{\tau_{XX}} = c + d\ Xe[ppm]\ \mu s^{-1}$$

$$\tau_{150} = \frac{1}{c}\ \mu s$$

$$\tau_{XX} = \frac{\frac{1}{d}}{Xe[ppm]}\ \mu s$$


1/tau2
1/tau3
y = 1.5317 + 0.18691x R= 0.99108
y = 0.68279 + 0.073093x R= 0.99344
Very preliminay
(no errors included)
1/tau2
Xeppm
0
1
2
3
4
5
6
0
5
10
15
20