Xenon doping analysis in pDUNE

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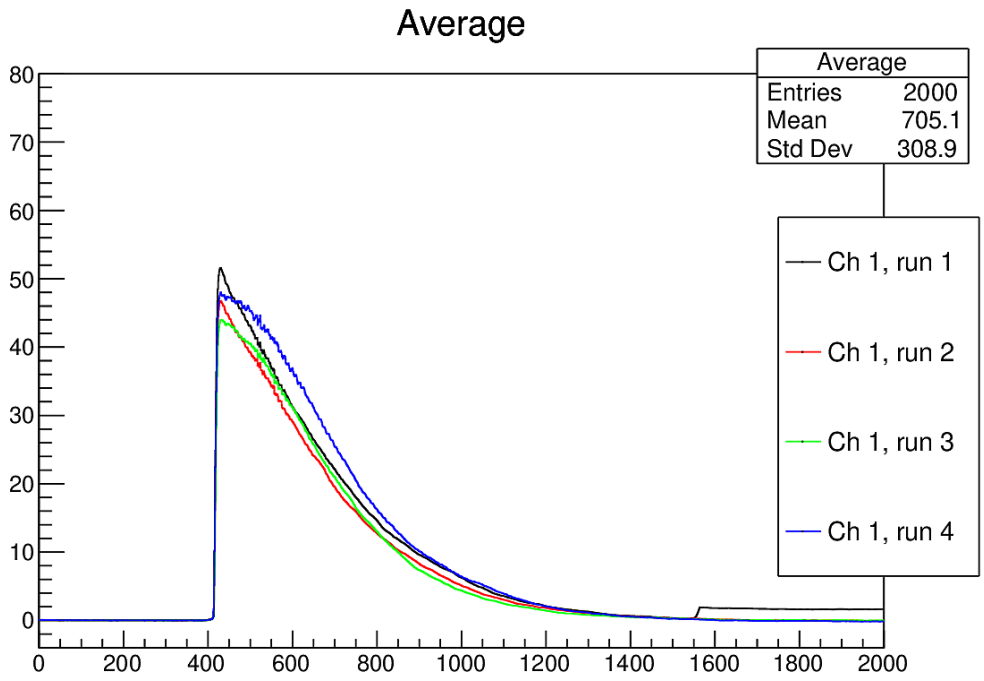
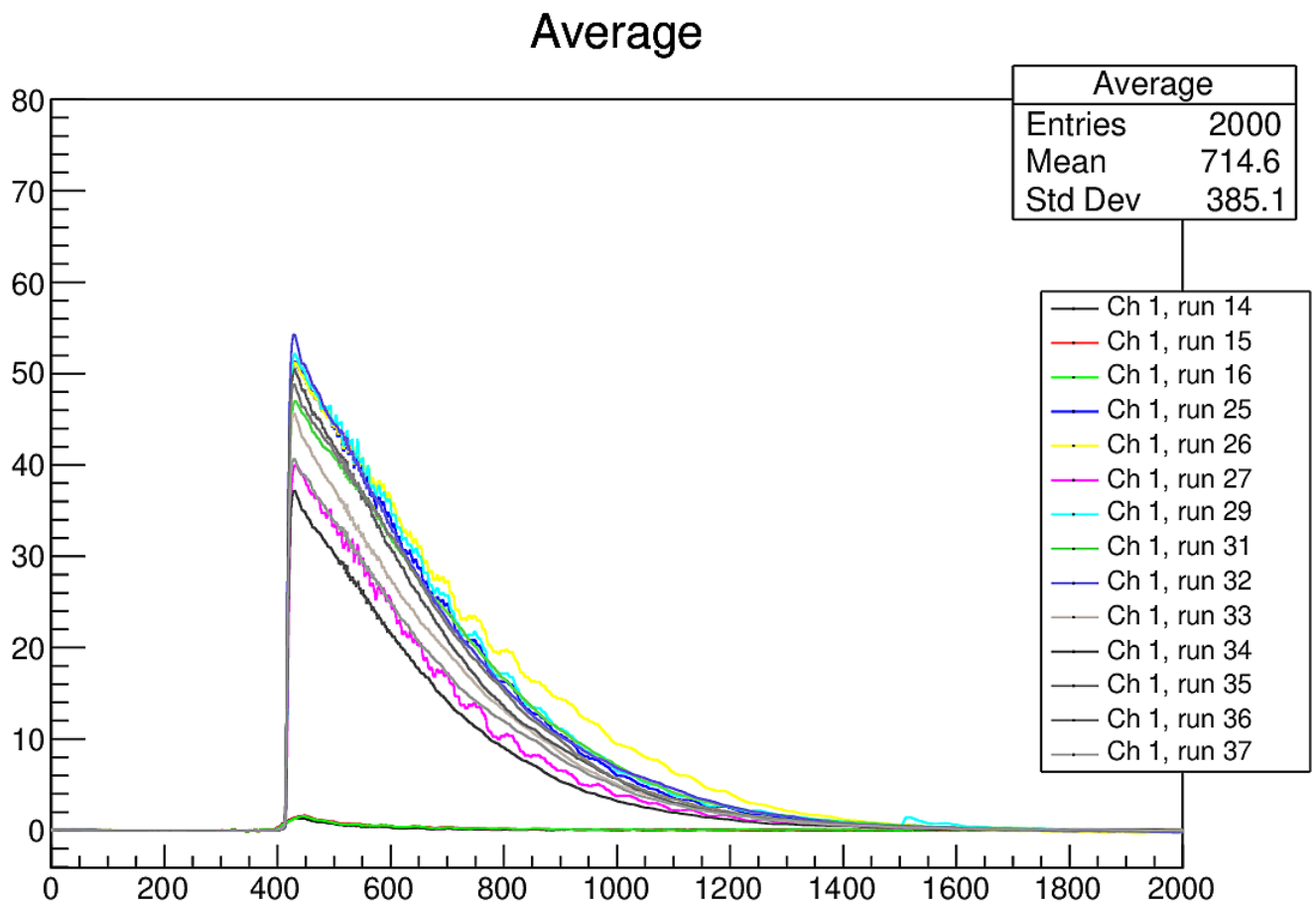
Average waveforms

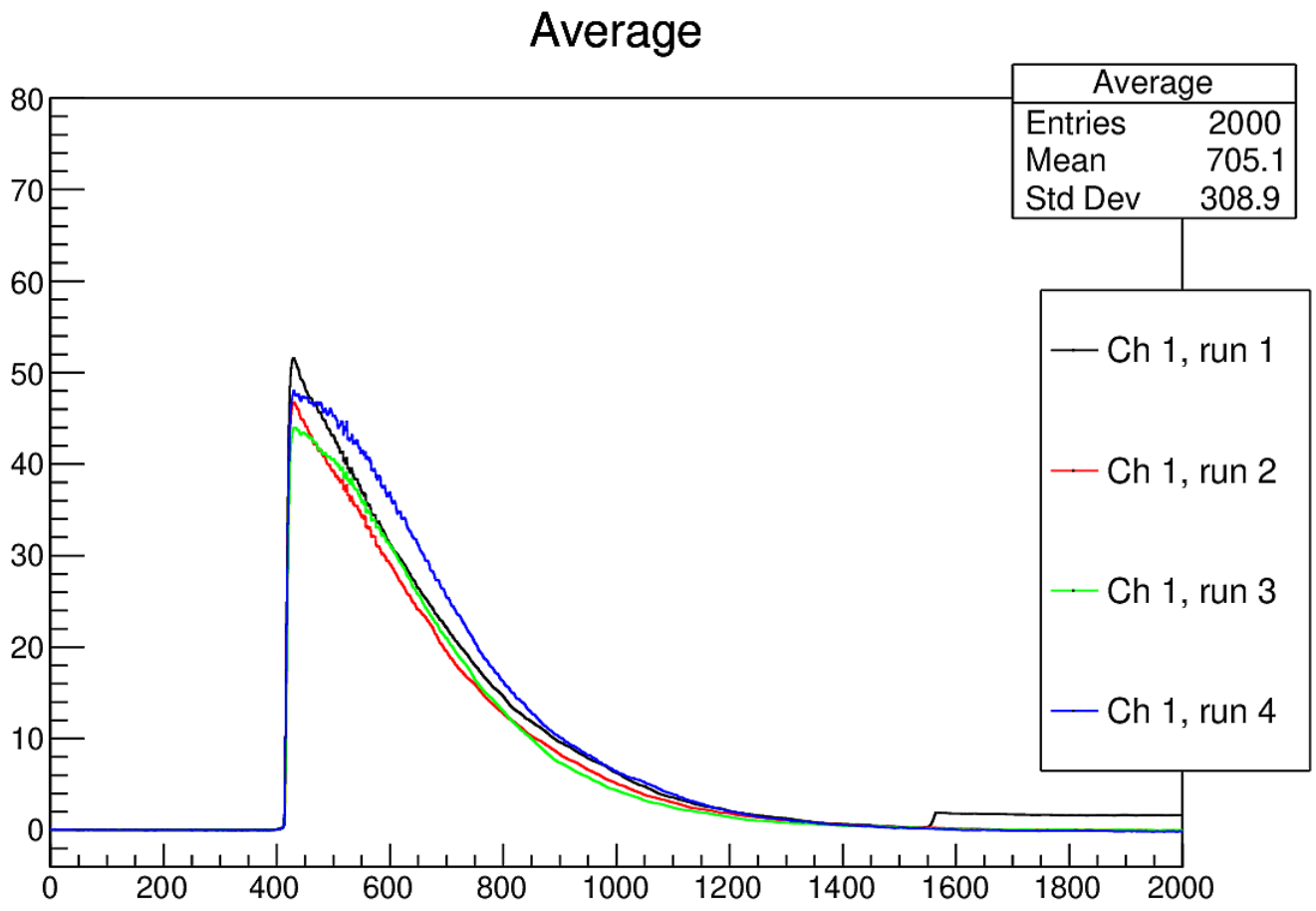
- External triggers analysis
- Select events with signals in the trigger area
- Select events with no events in the pre-trigger area



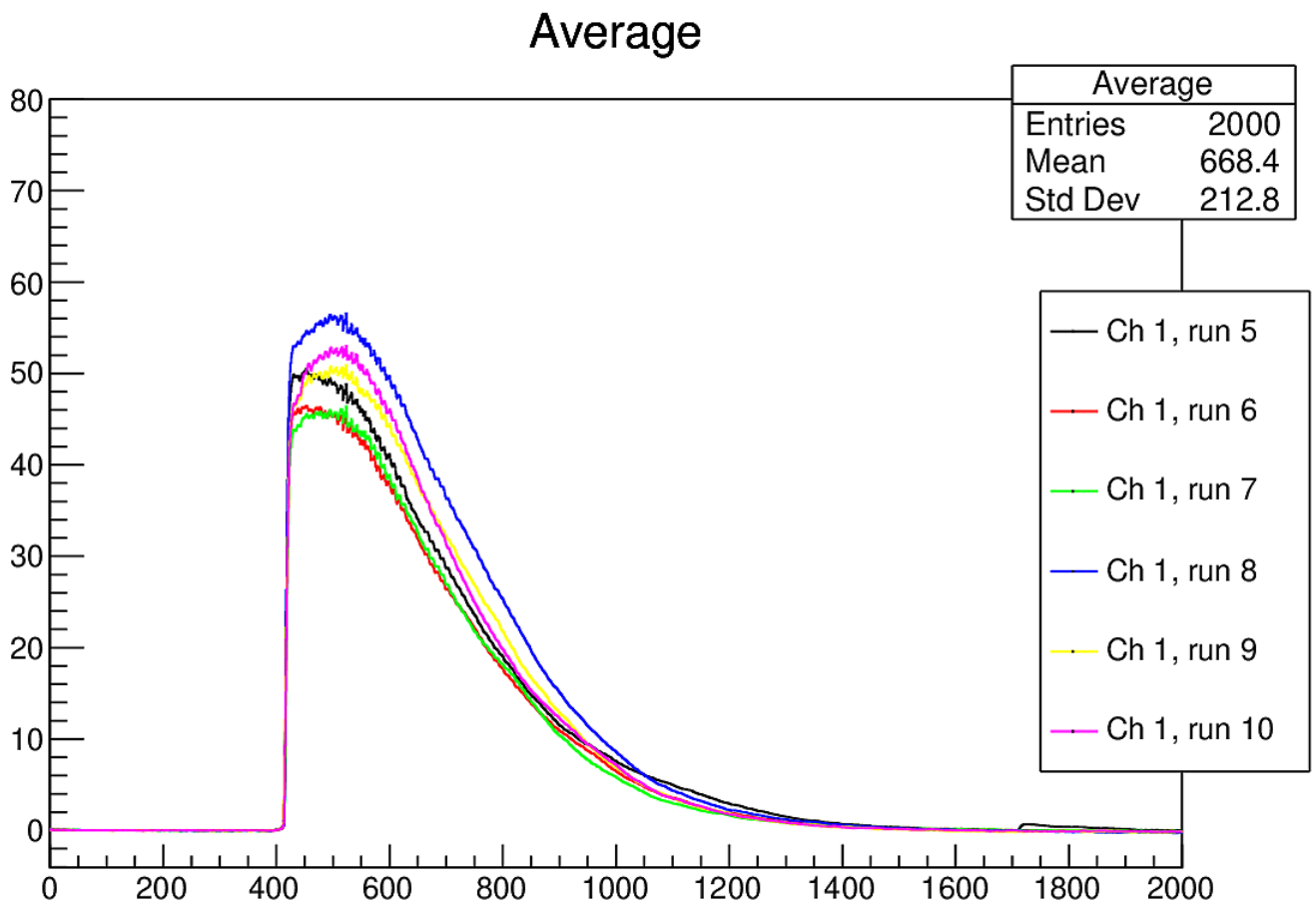
Average waveforms (Doping 1 E=0)



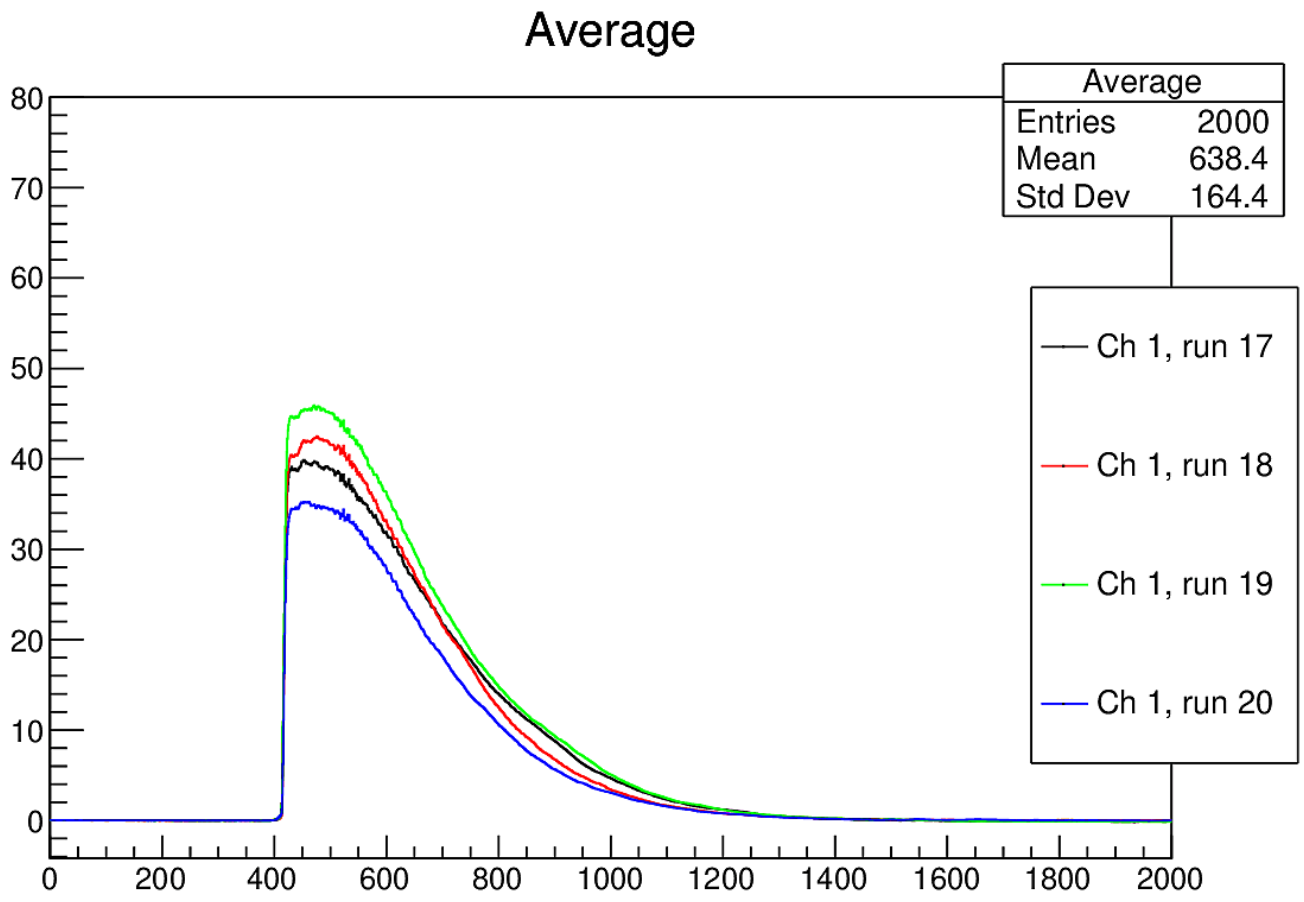
Average waveforms (Doping 2 E=100)



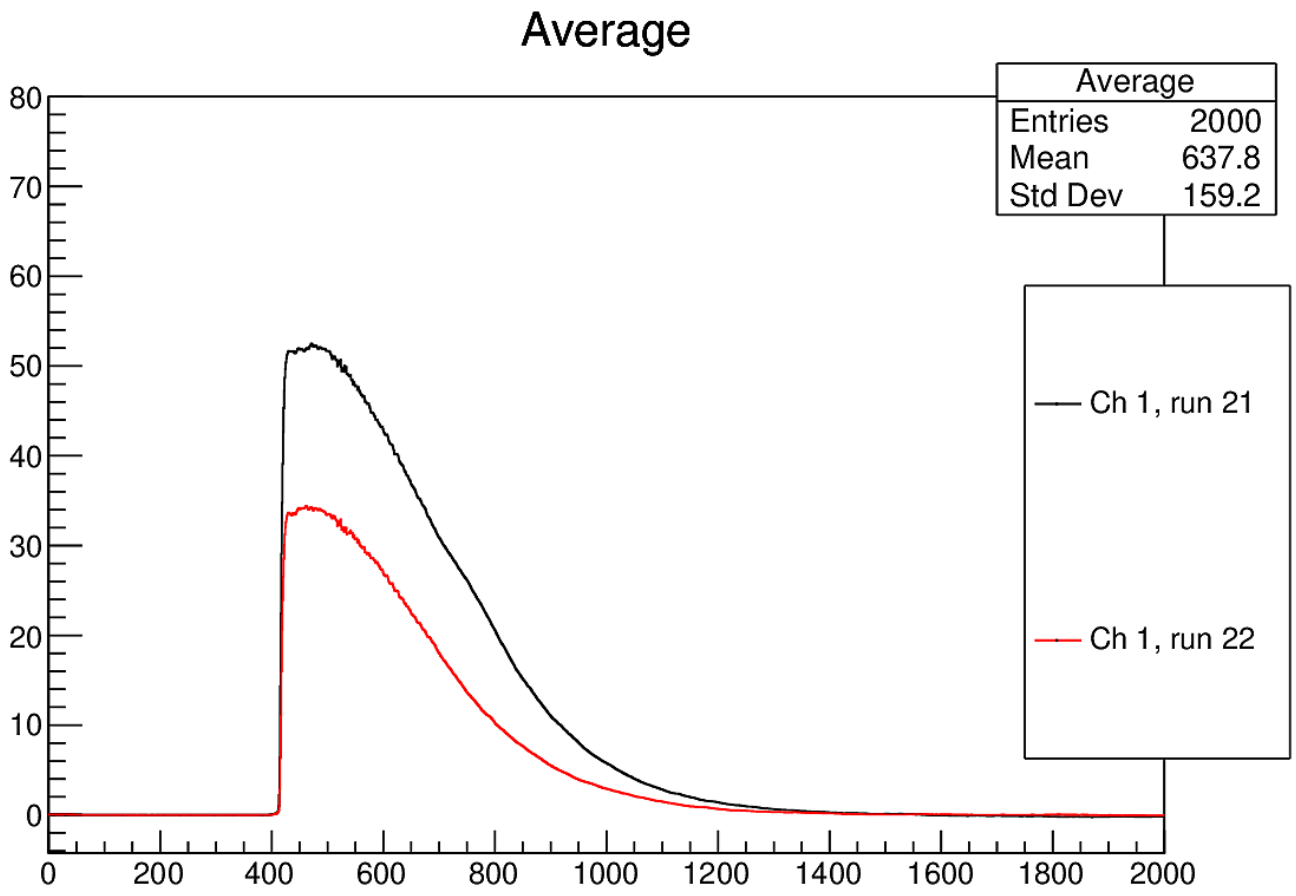
Average waveforms (Doping 2 E=0)



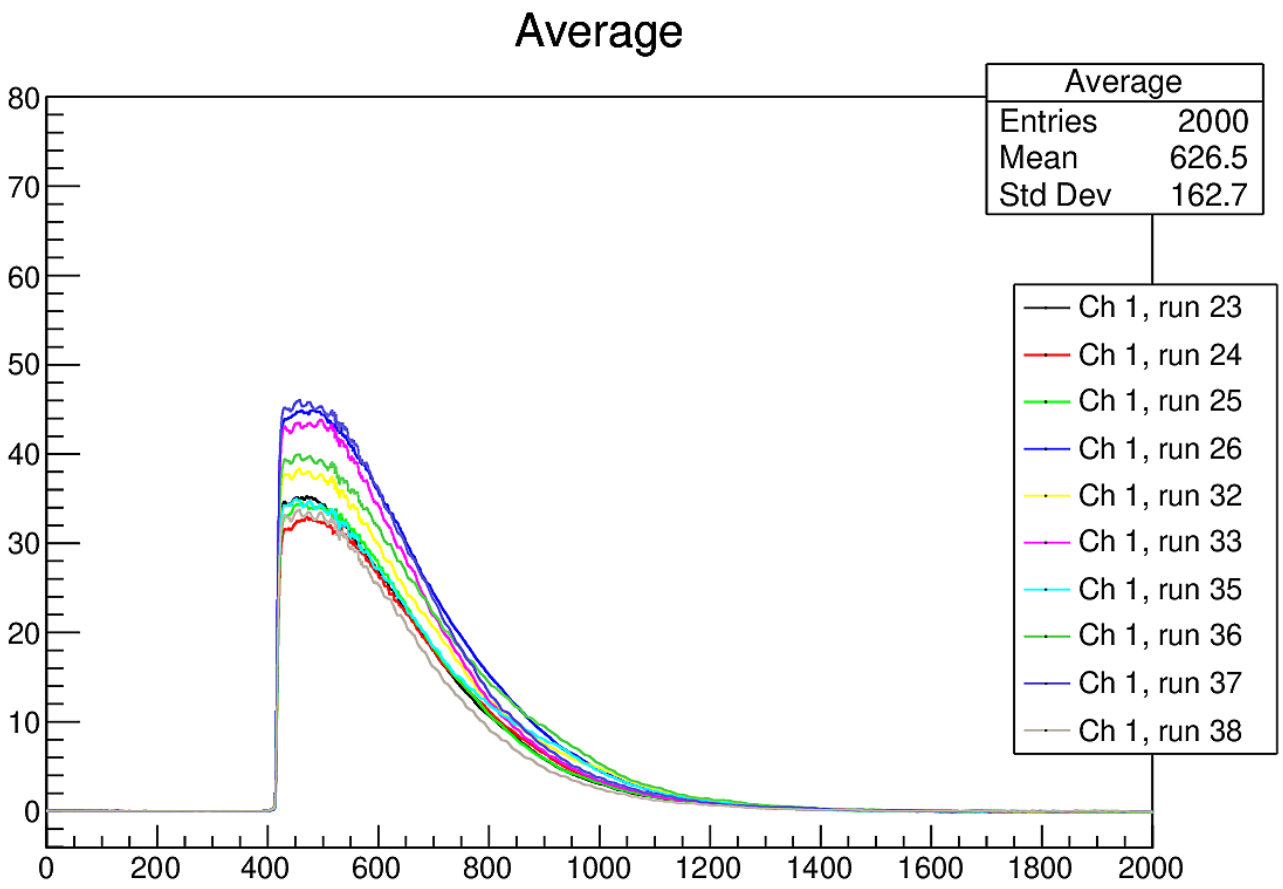
Average waveforms (Doping 2 E=300)



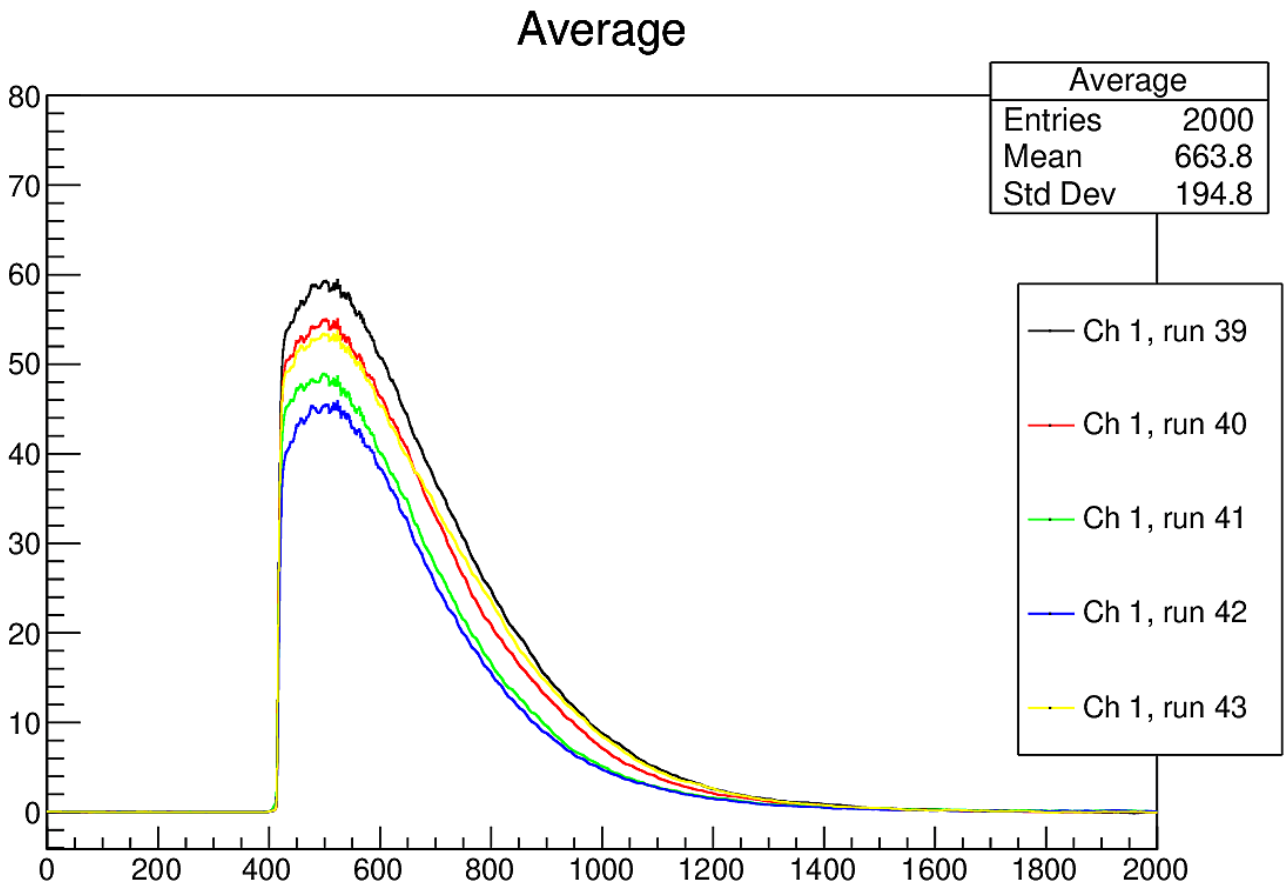
Average waveforms (Doping 2 E=400)



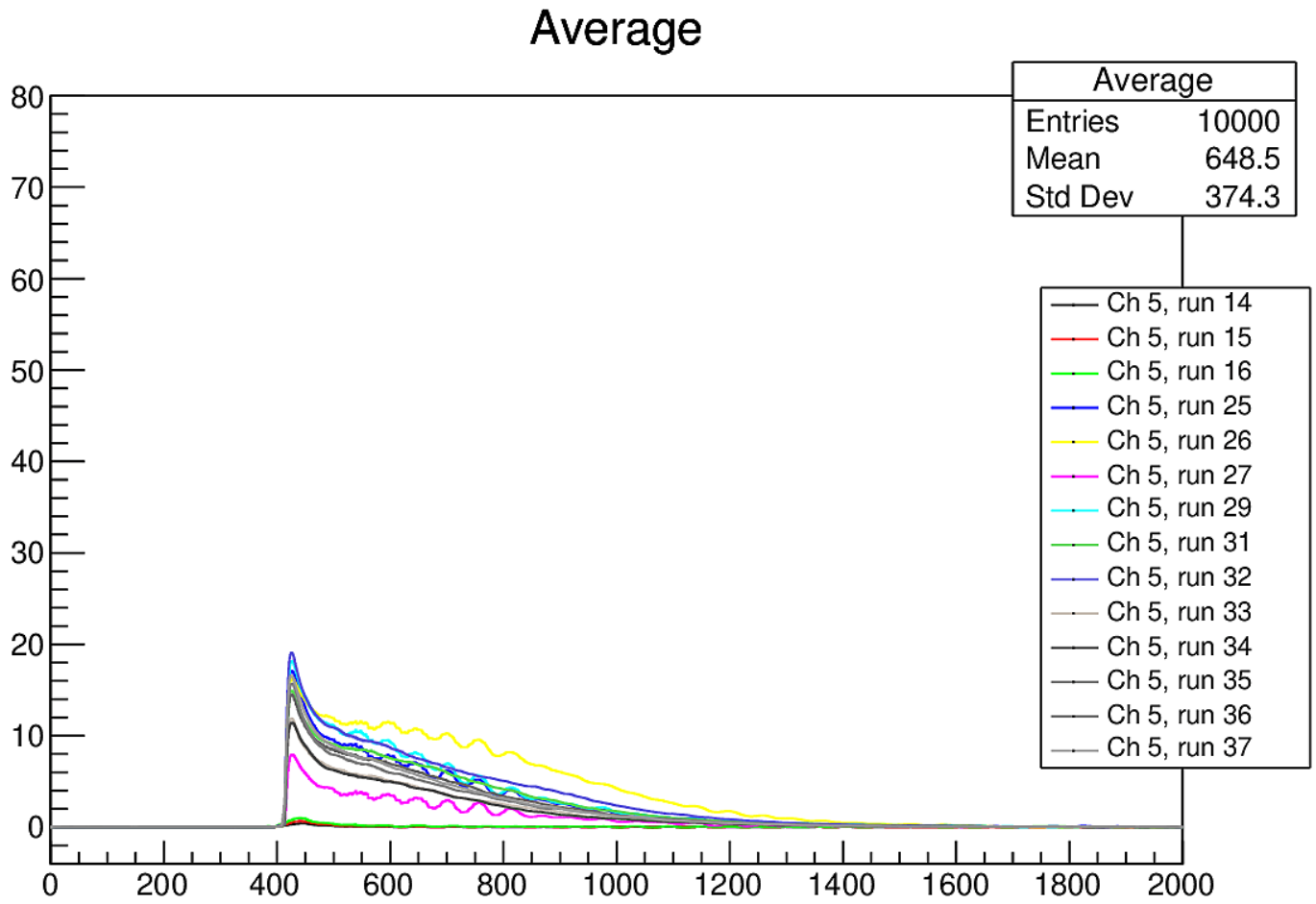
Average waveforms (Doping 2 E=500)



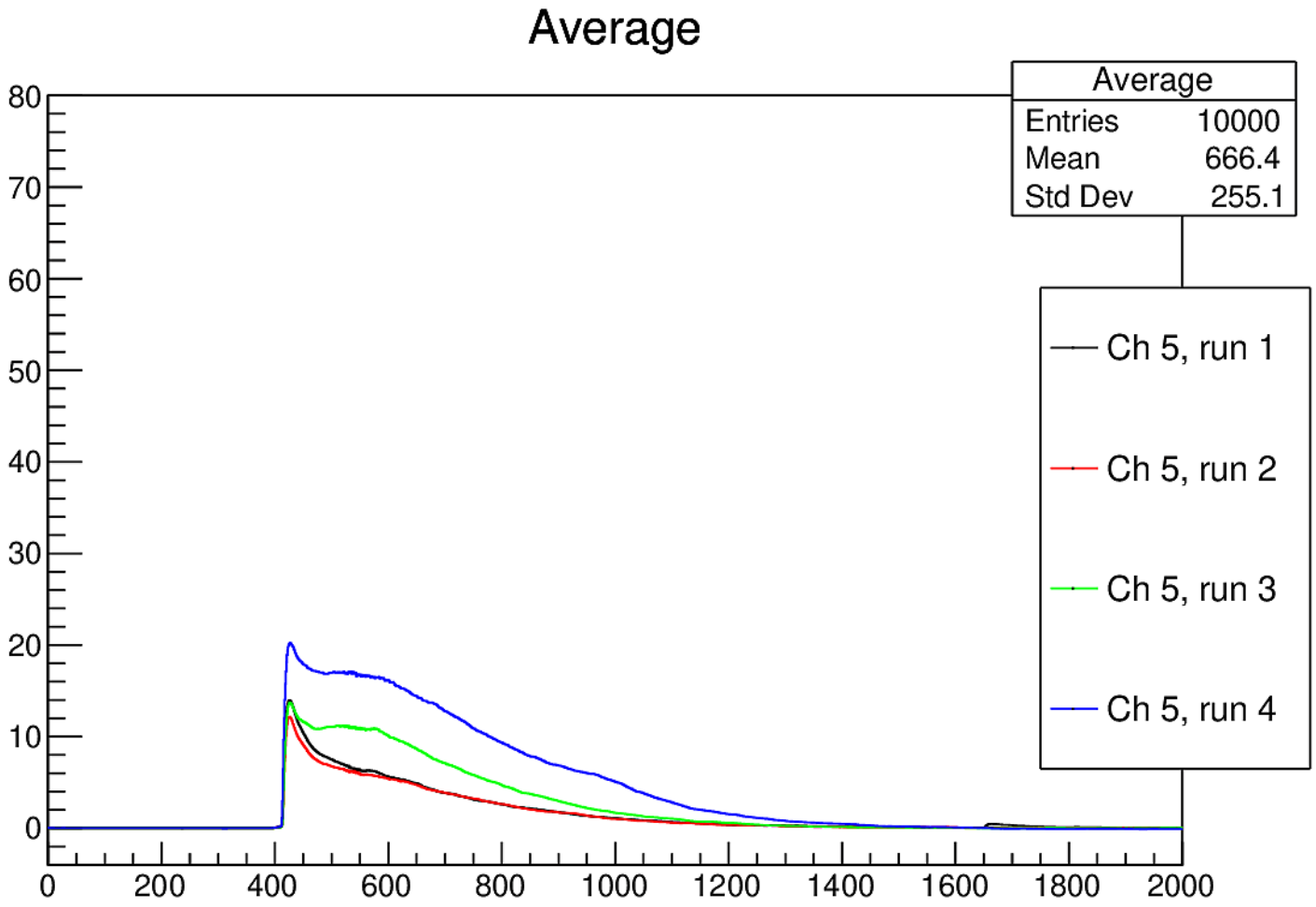
Average waveforms (Doping 2 E=0)



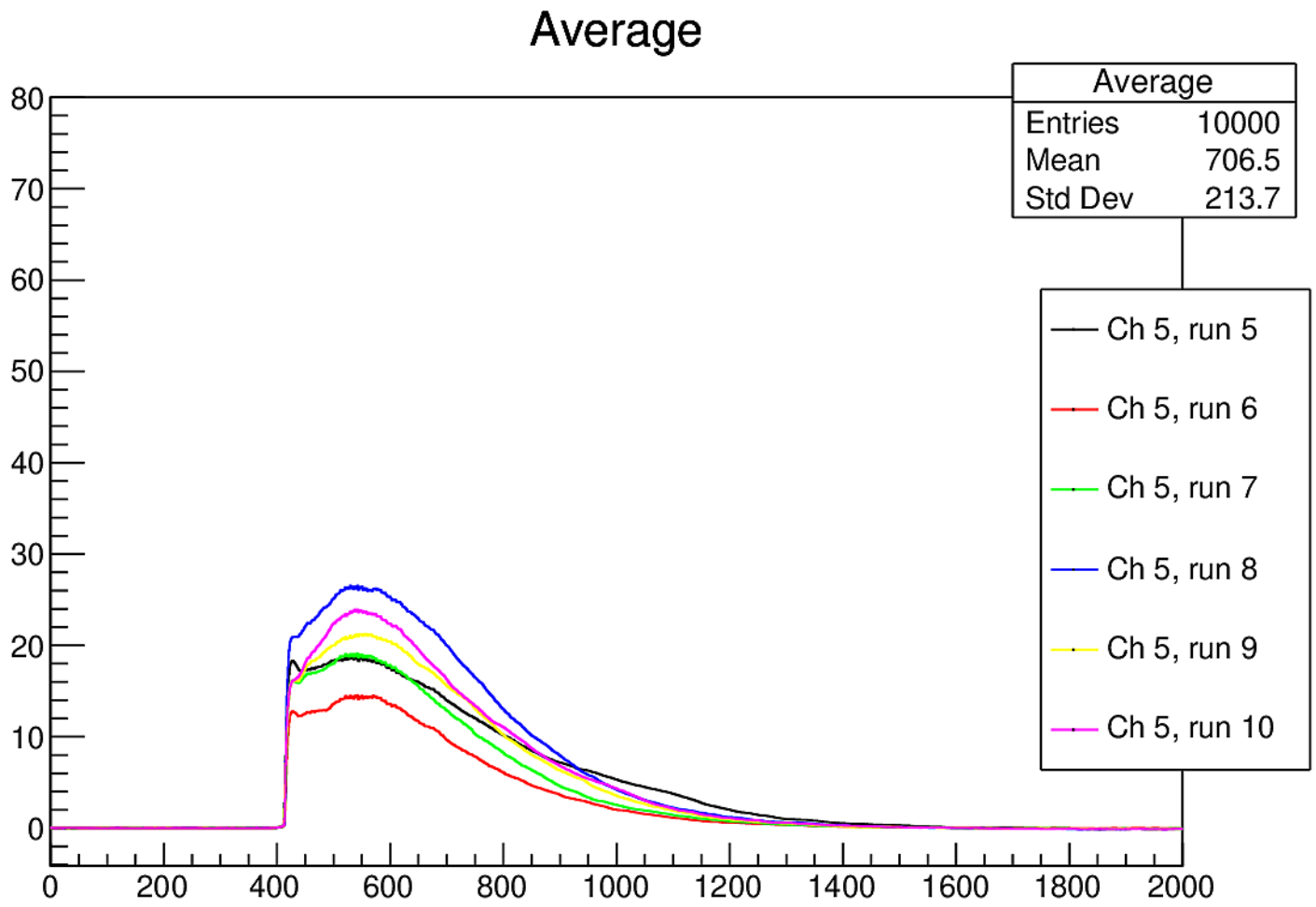
Average waveforms (Doping 1 E=0)



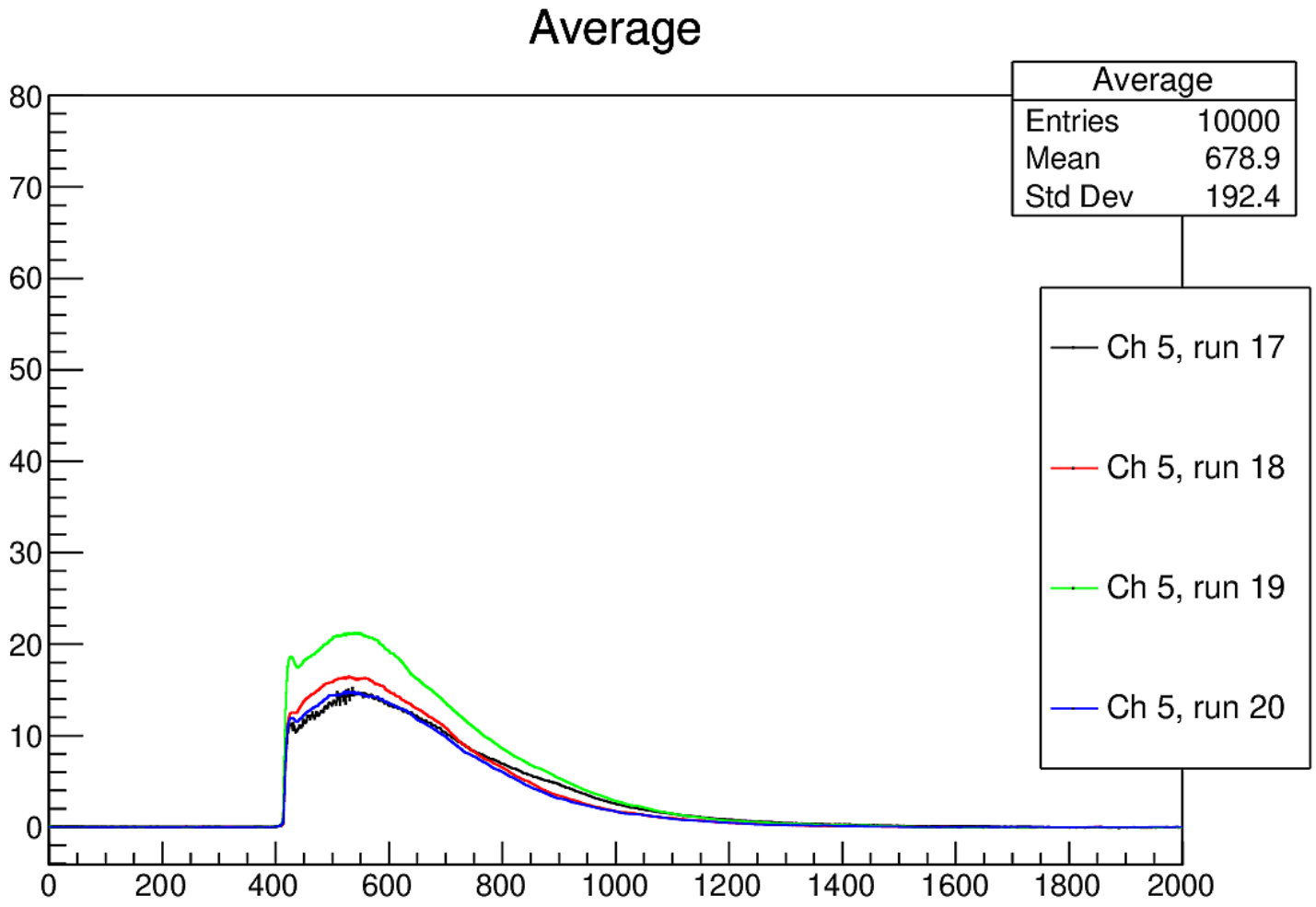
Average waveforms (Doping 2 E=100)



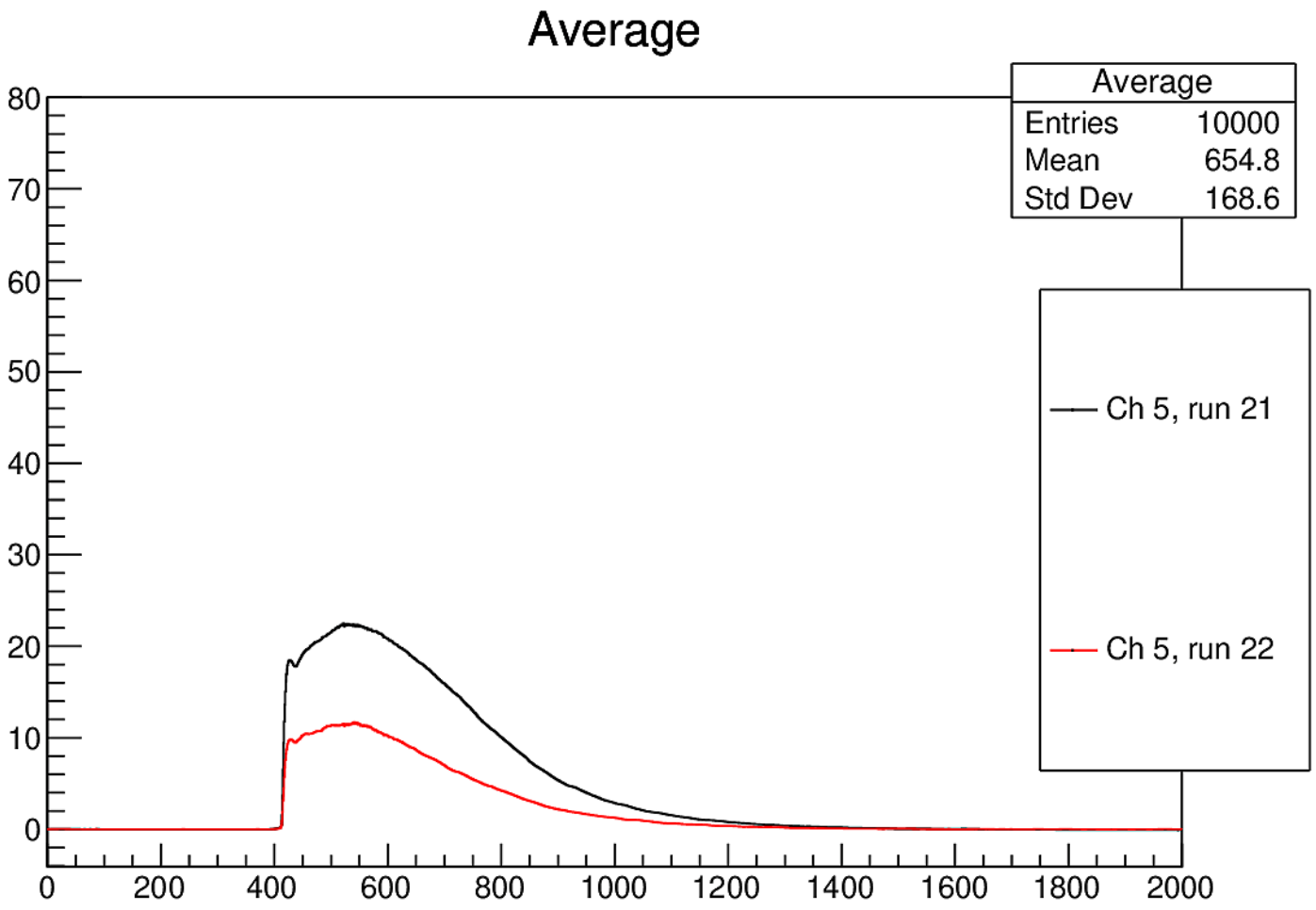
Average waveforms (Doping 2 E=0)



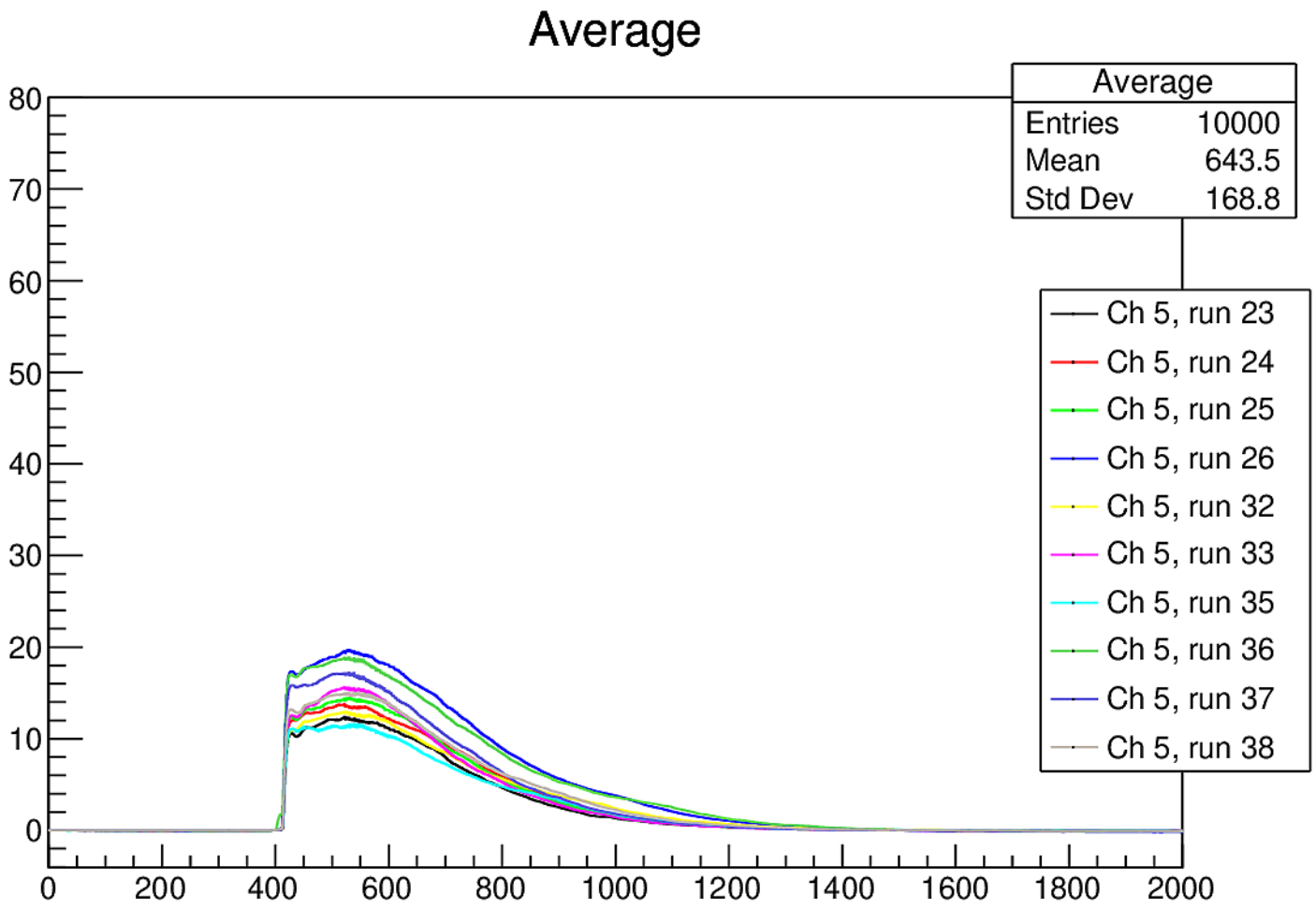
Average waveforms (Doping 2 E=300)



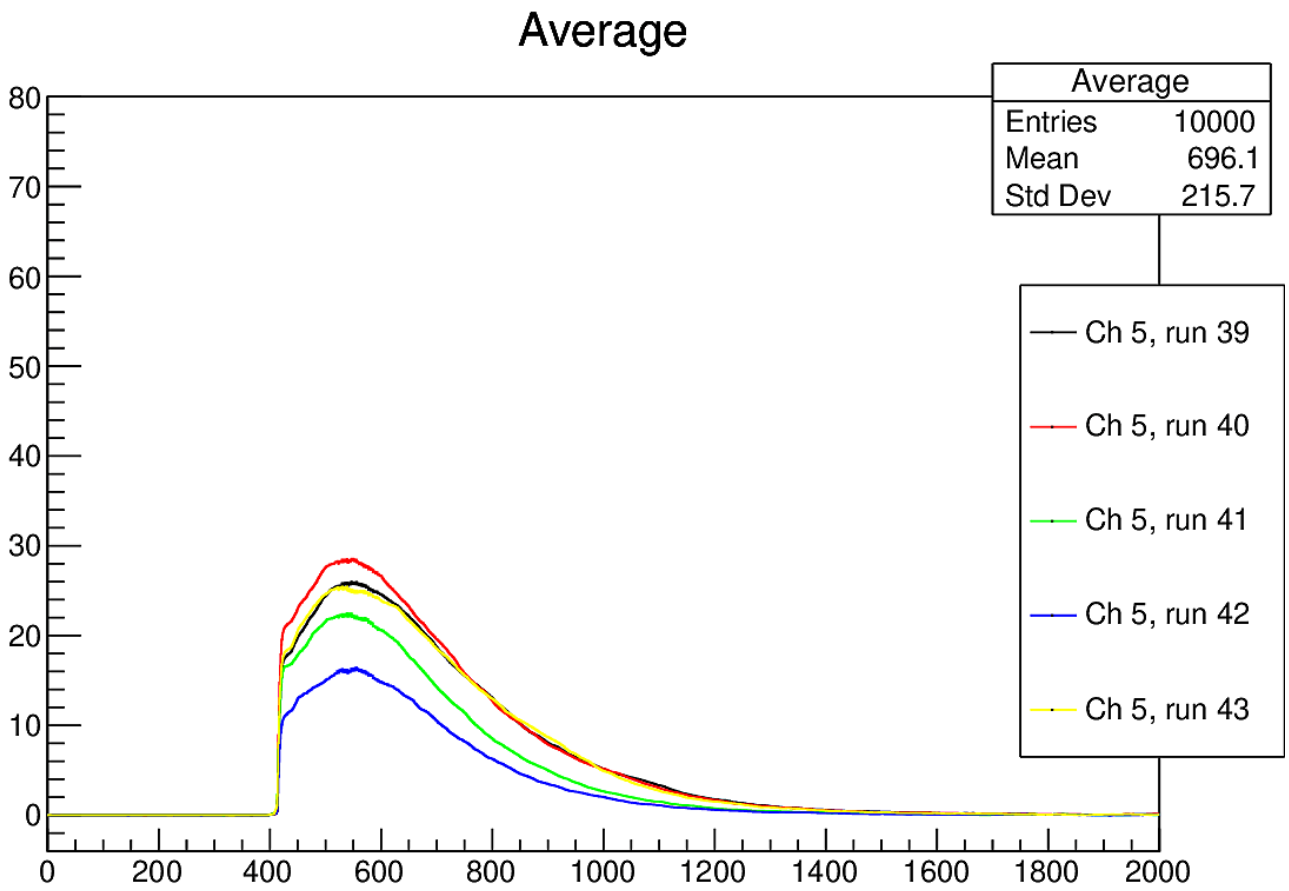
Average waveforms (Doping 2 E=400)



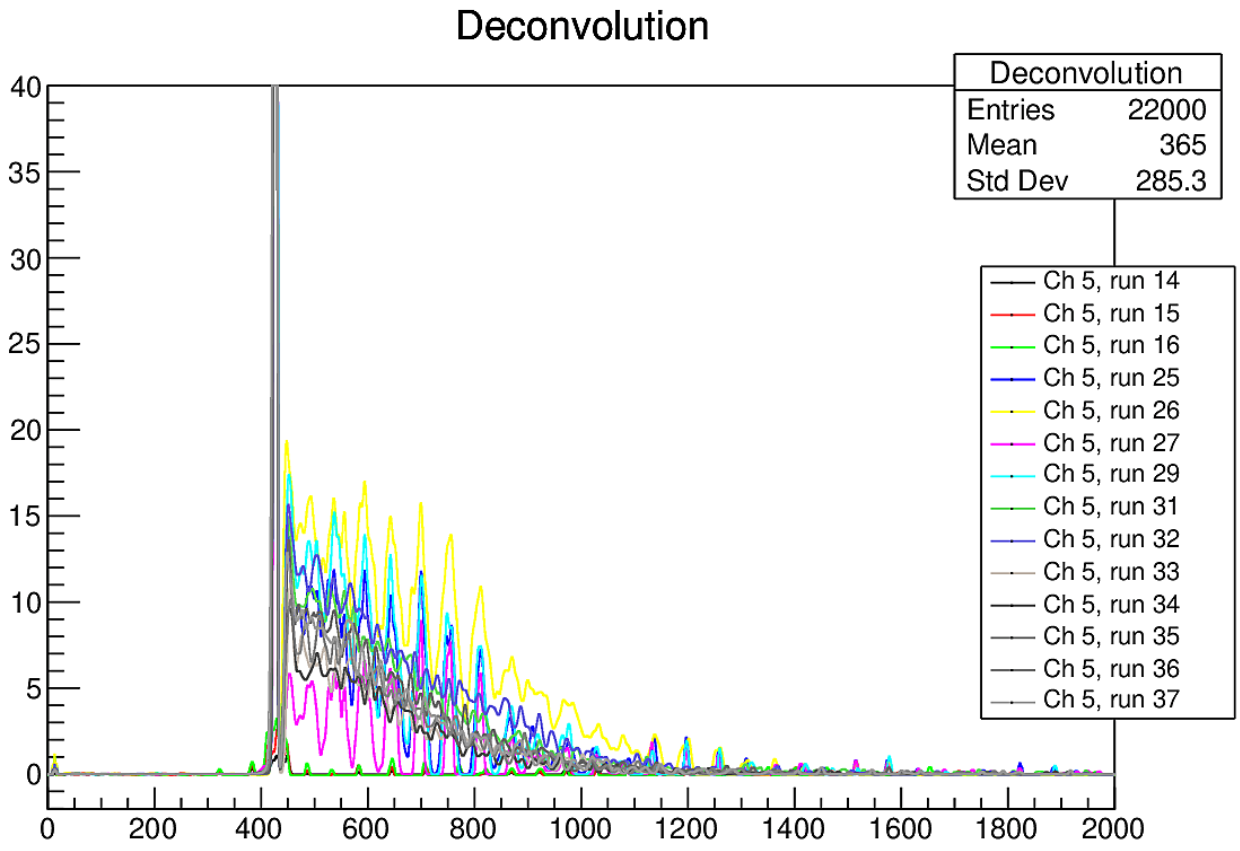
Average waveforms (Doping 2 E=500)



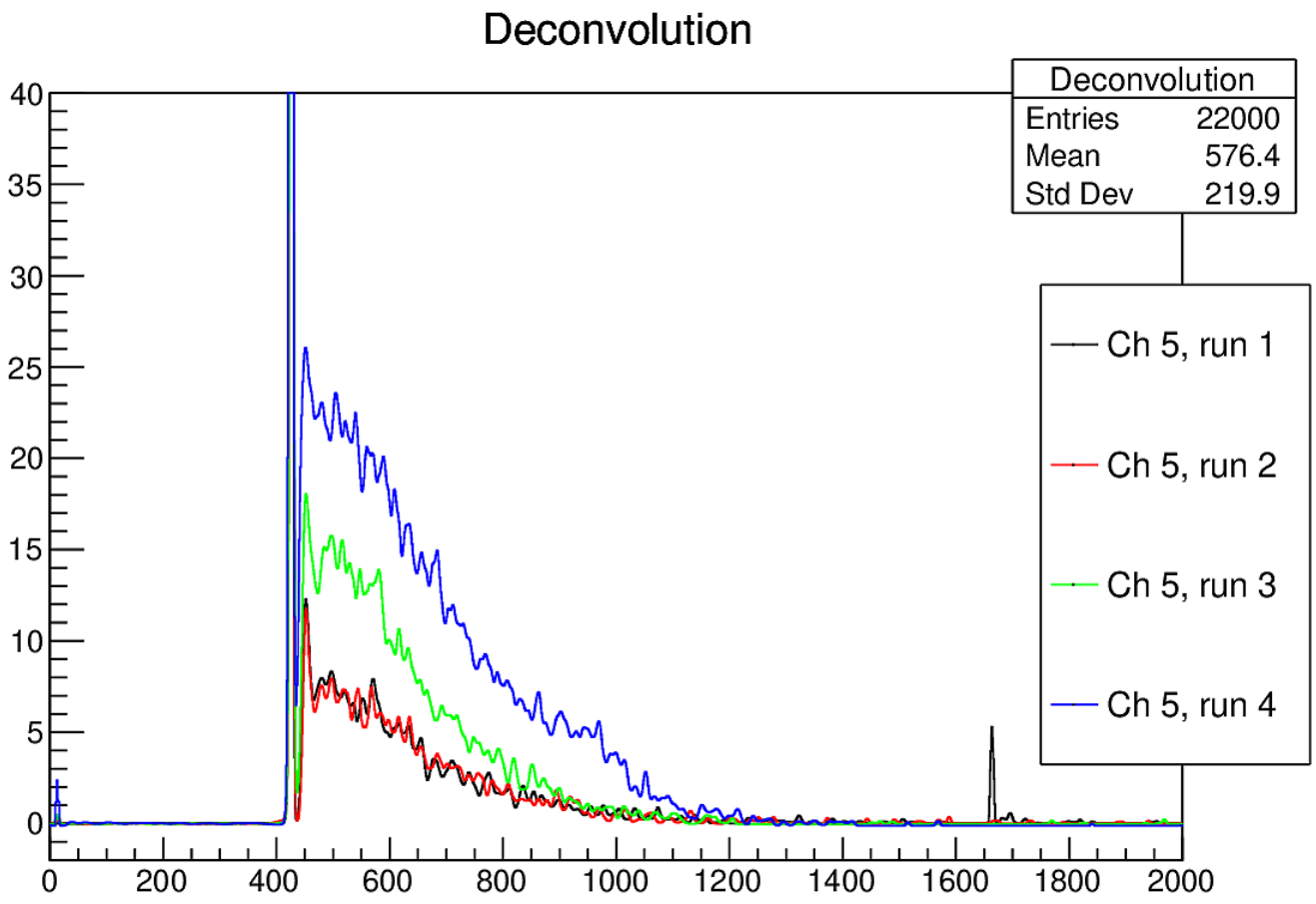
Average waveforms (Doping 2 E=0)



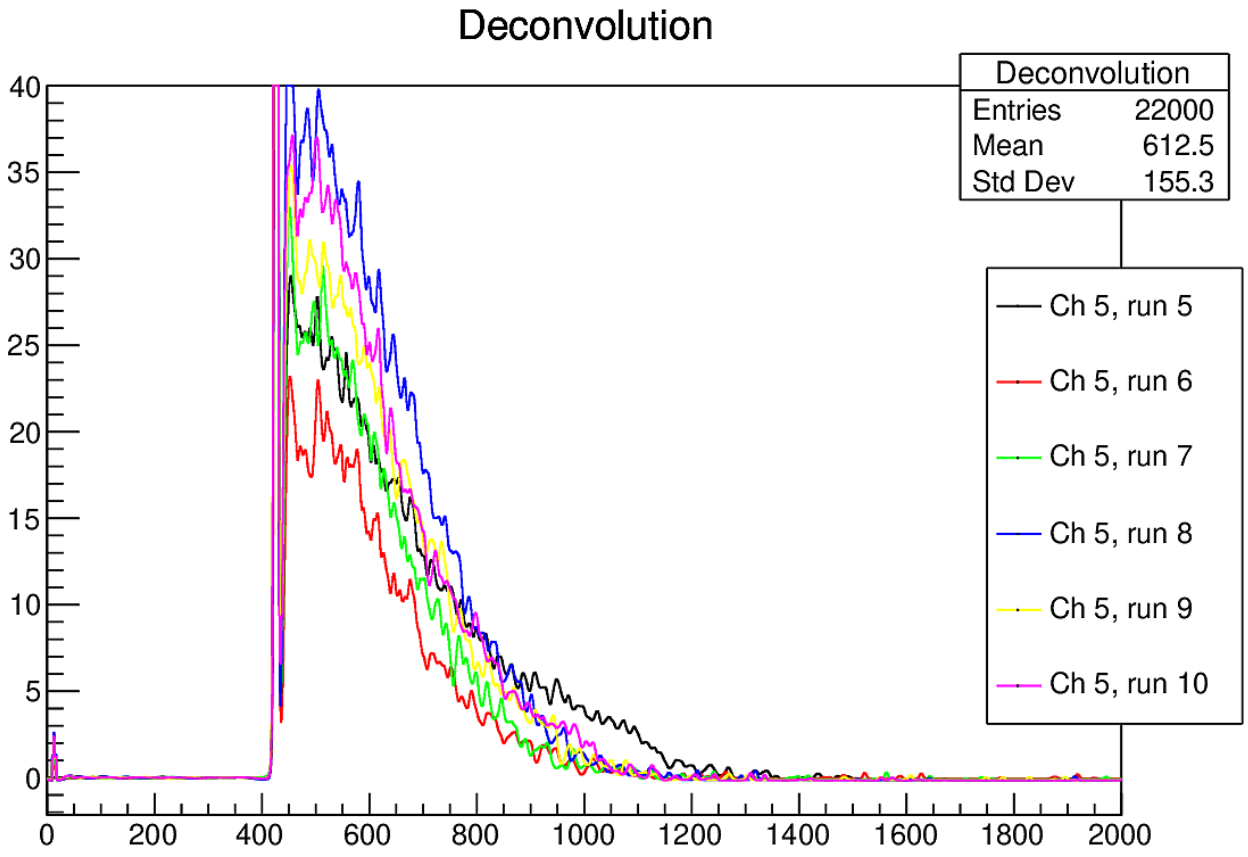
Deconvolved waveforms (Doping 1 E=0)



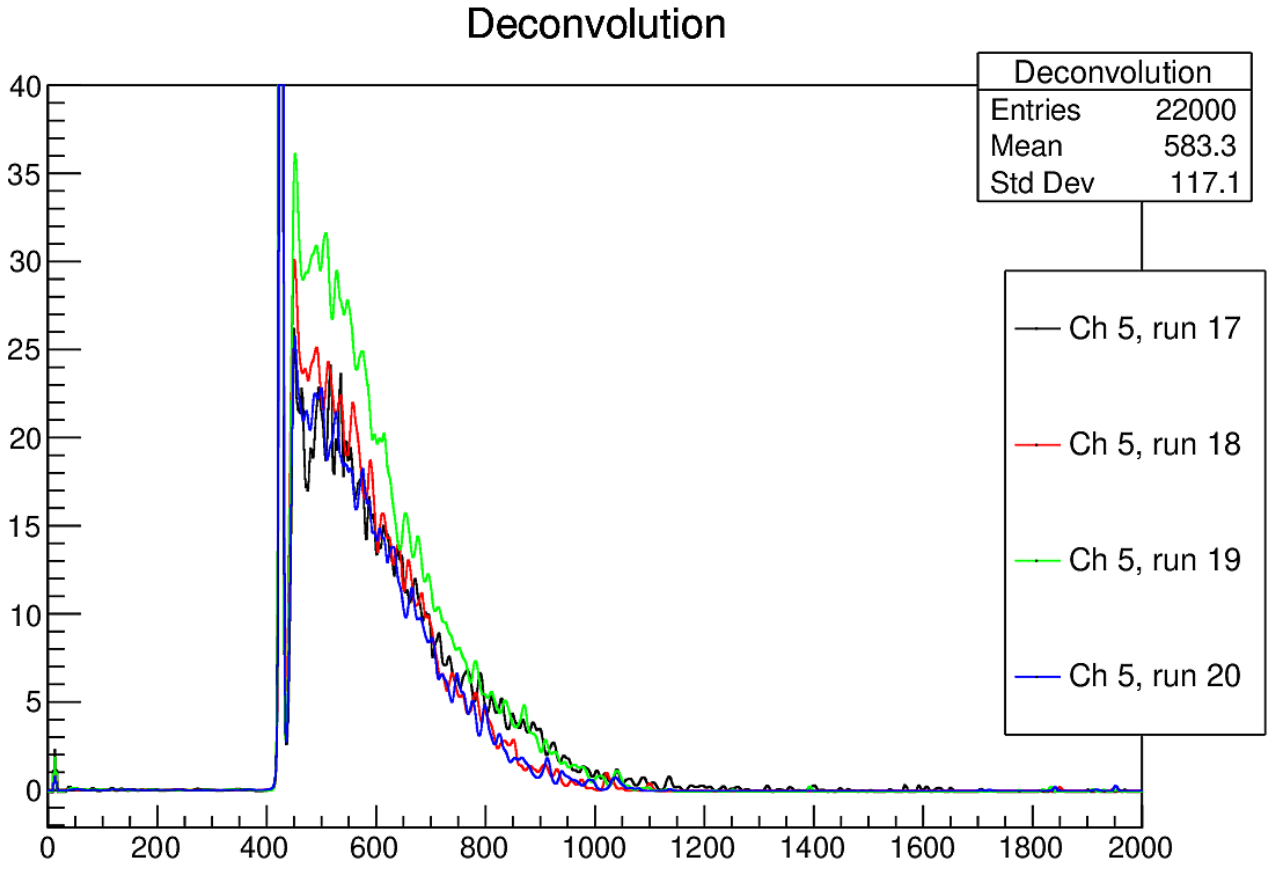
Deconvolved waveforms (Doping 2 E=100)



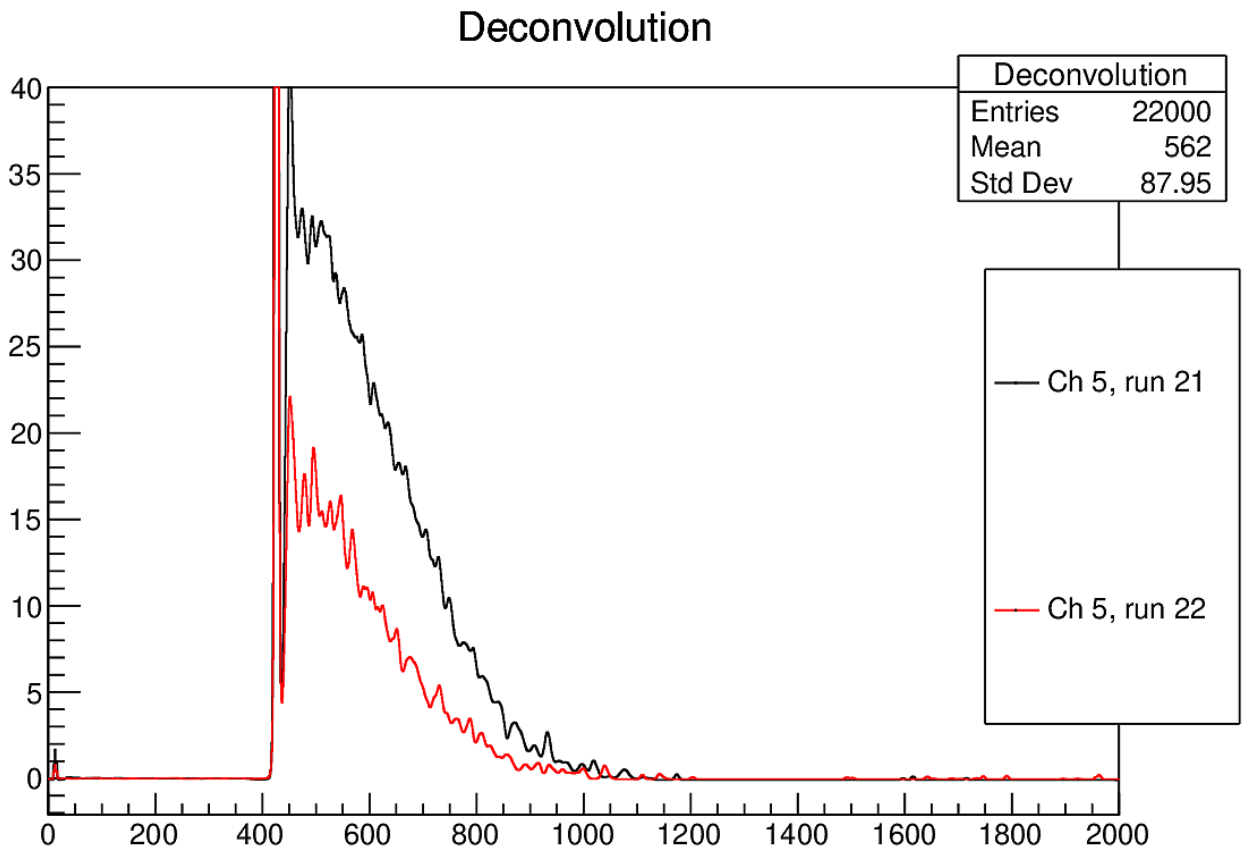
Deconvolved waveforms (Doping 2 E=0)



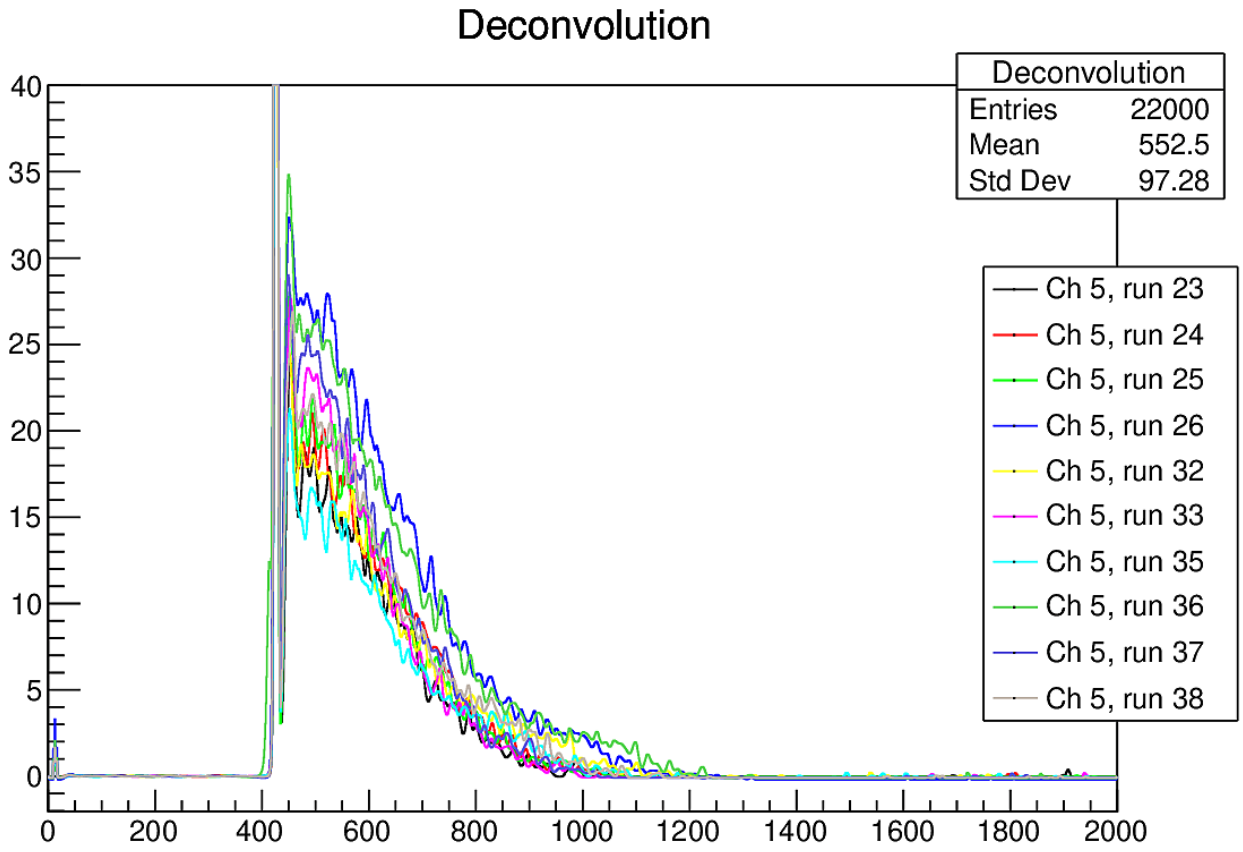
Deconvolved waveforms (Doping 2 E=300)



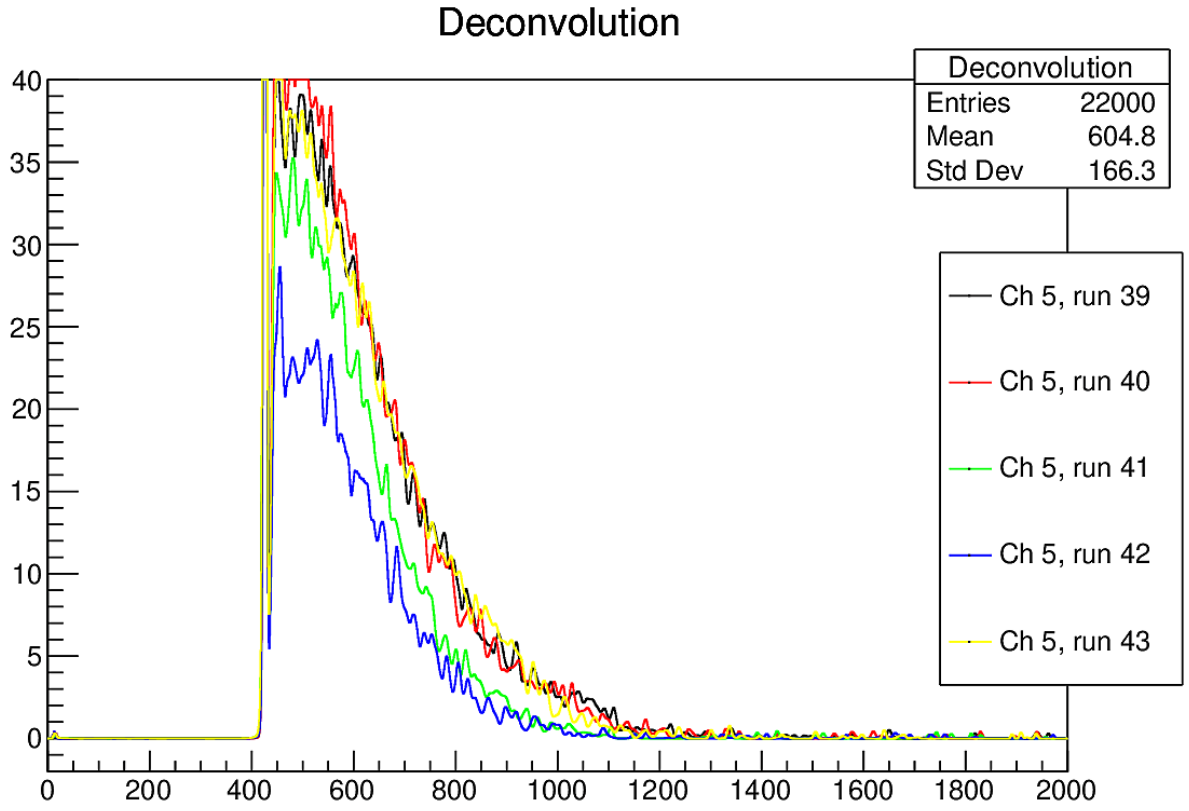
Deconvolved waveforms (Doping 2 E=400)



Average waveforms (Doping 2 E=500)

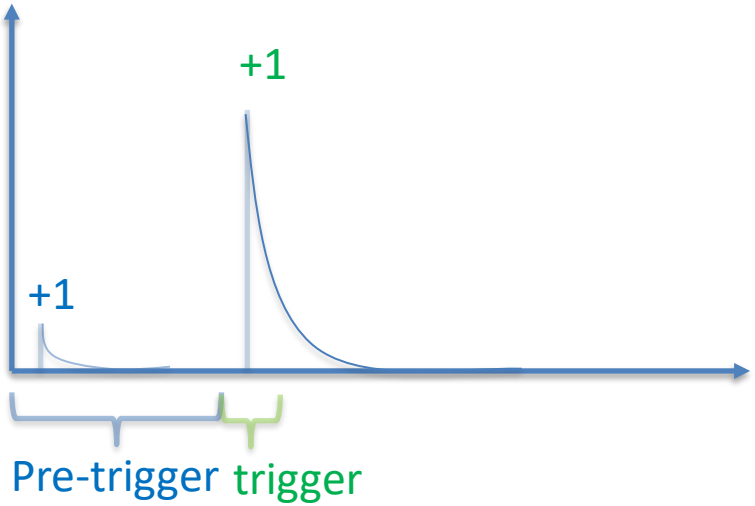


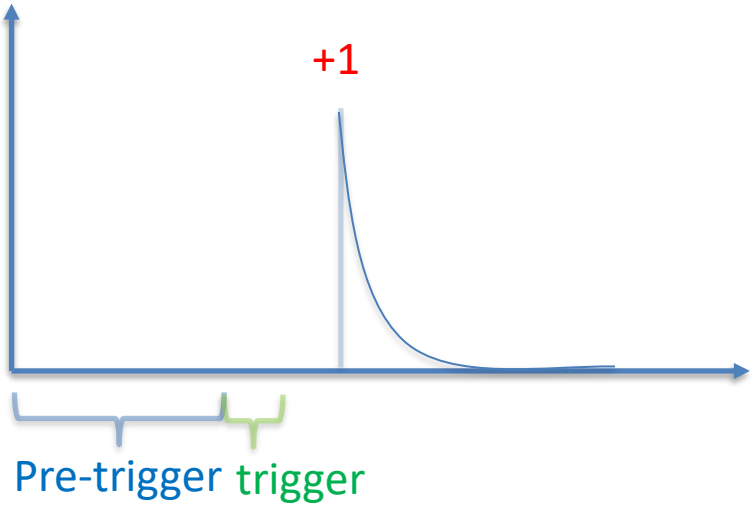
Average waveforms (Doping 2 E=0)



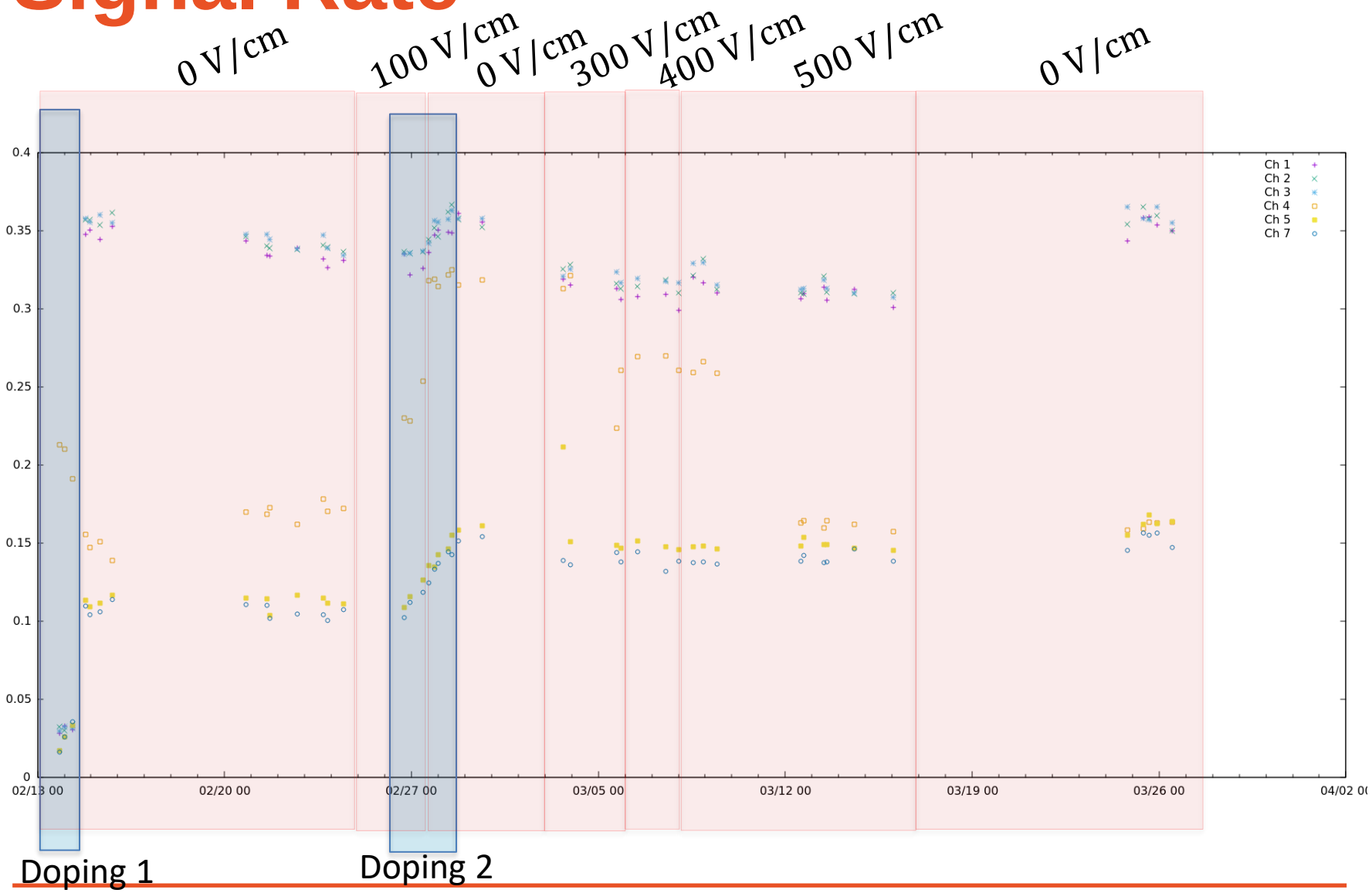
Rates definition

- Signal rate: number of waveform with signal in trigger region
- Zero rate: number of waveforms with no signal in trigger region
- Pre-trigger bkg rate: Number of waveforms with at least 1 photon in pre-trigger region

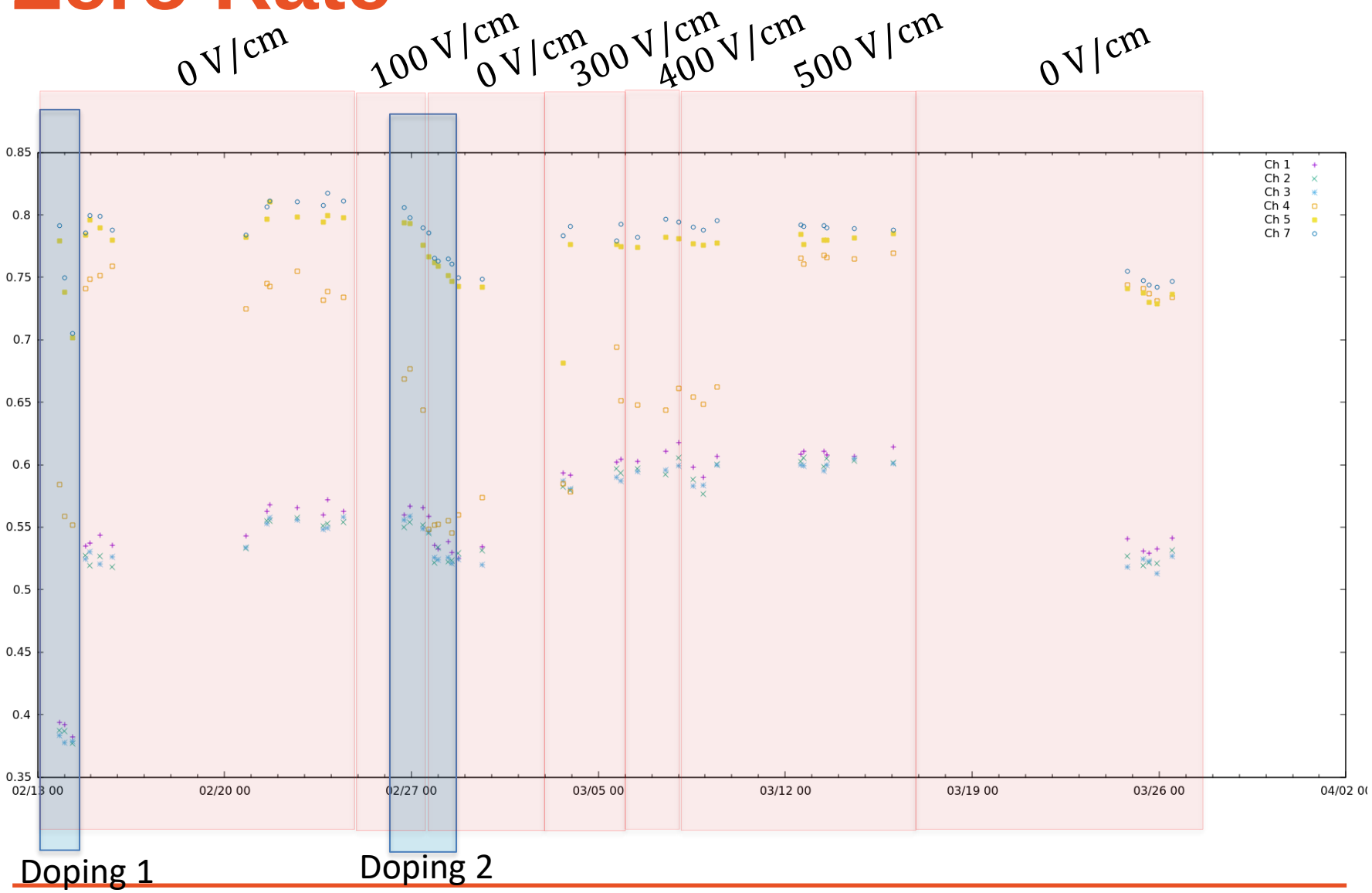




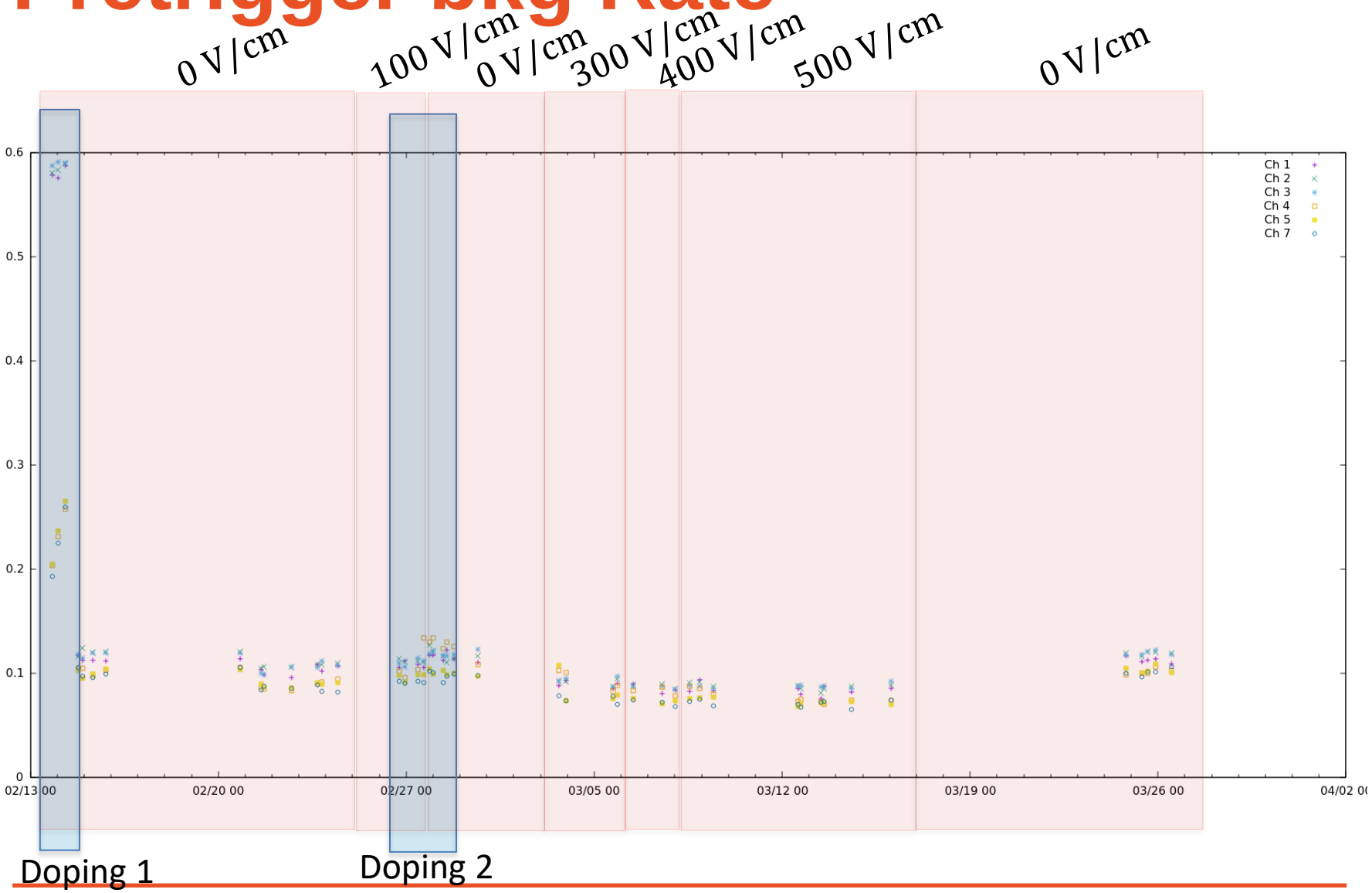
Signal Rate


0 V/cm
100 V/cm
0 V/cm
300 V/cm
400 V/cm
500 V/cm
0 V/cm
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 7
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
02/13 00
02/20 00
02/27 00
03/05 00
03/12 00
03/19 00
03/26 00
Doping 1
Doping 2

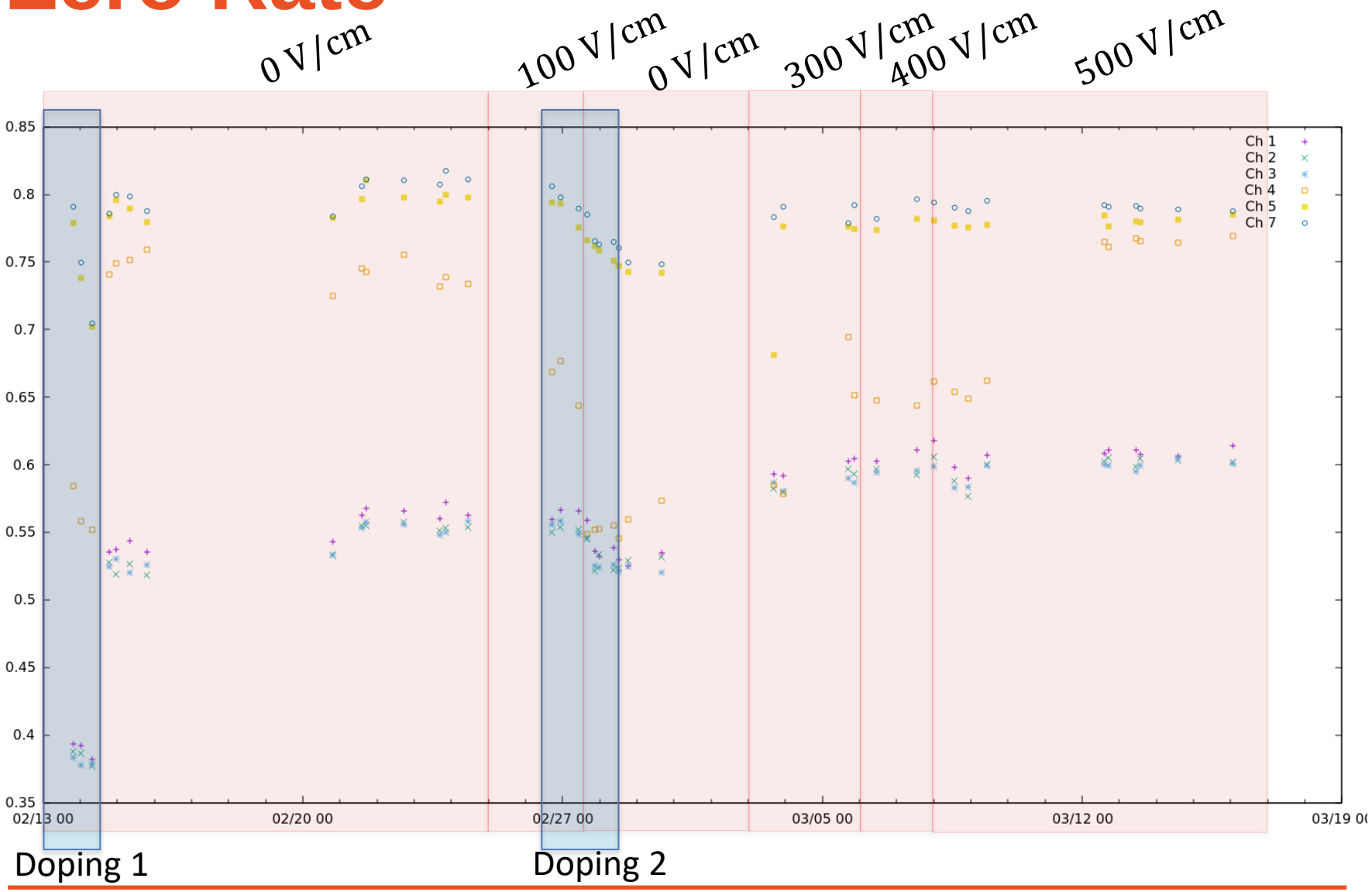
Zero Rate


0 V/cm
100 V/cm
0 V/cm
300 V/cm
400 V/cm
500 V/cm
0 V/cm
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
02/13 00
02/20 00
02/27 00
03/05 00
03/12 00
03/19 00
03/26 00
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 7
Doping 1
Doping 2

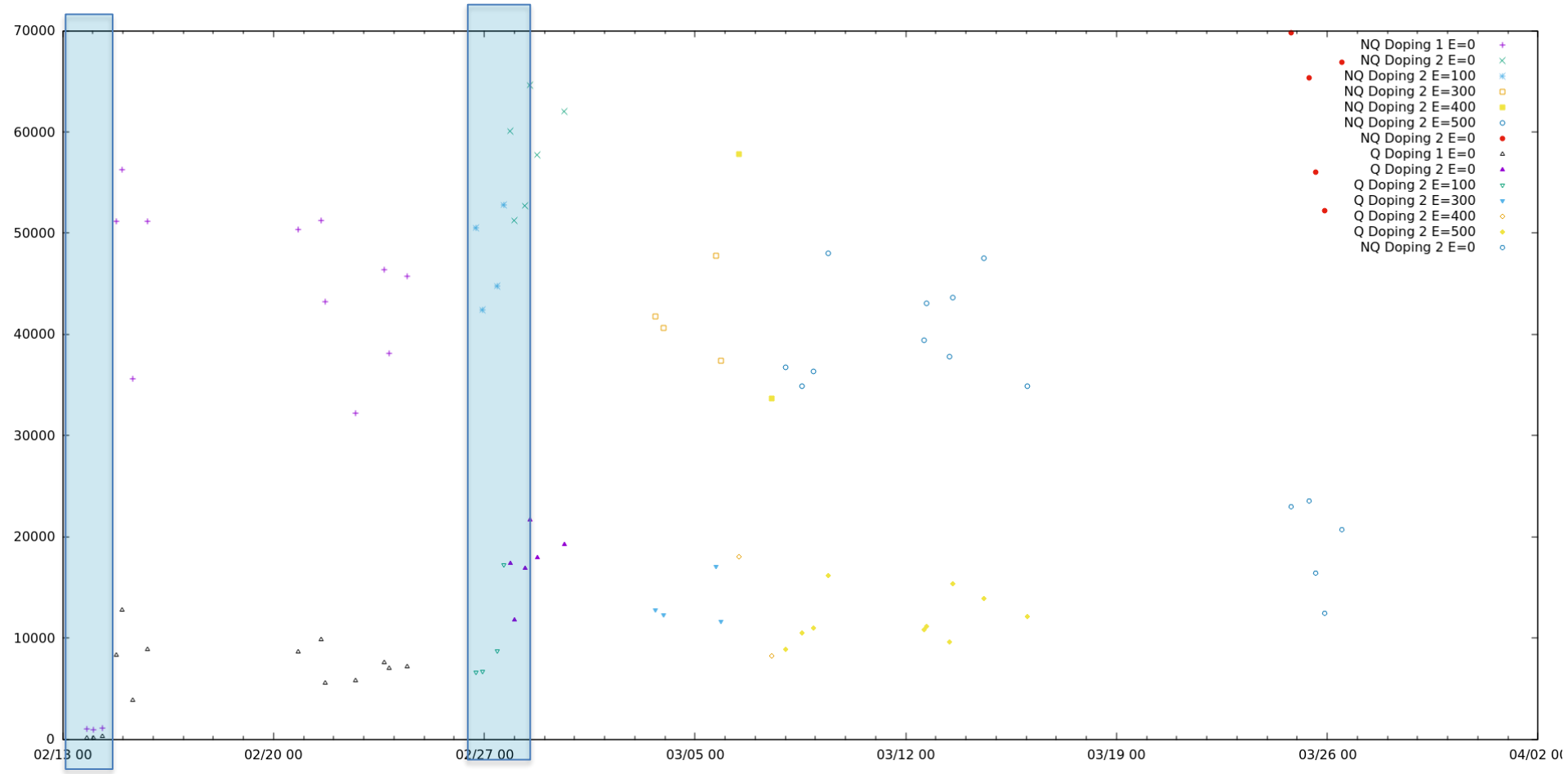
Pretrigger bkg Rate



Zero Rate


0 V/cm
100 V/cm
0 V/cm
300 V/cm
400 V/cm
500 V/cm
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
02/13 00
02/20 00
02/27 00
03/05 00
03/12 00
03/19 00
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 7
Doping 1
Doping 2

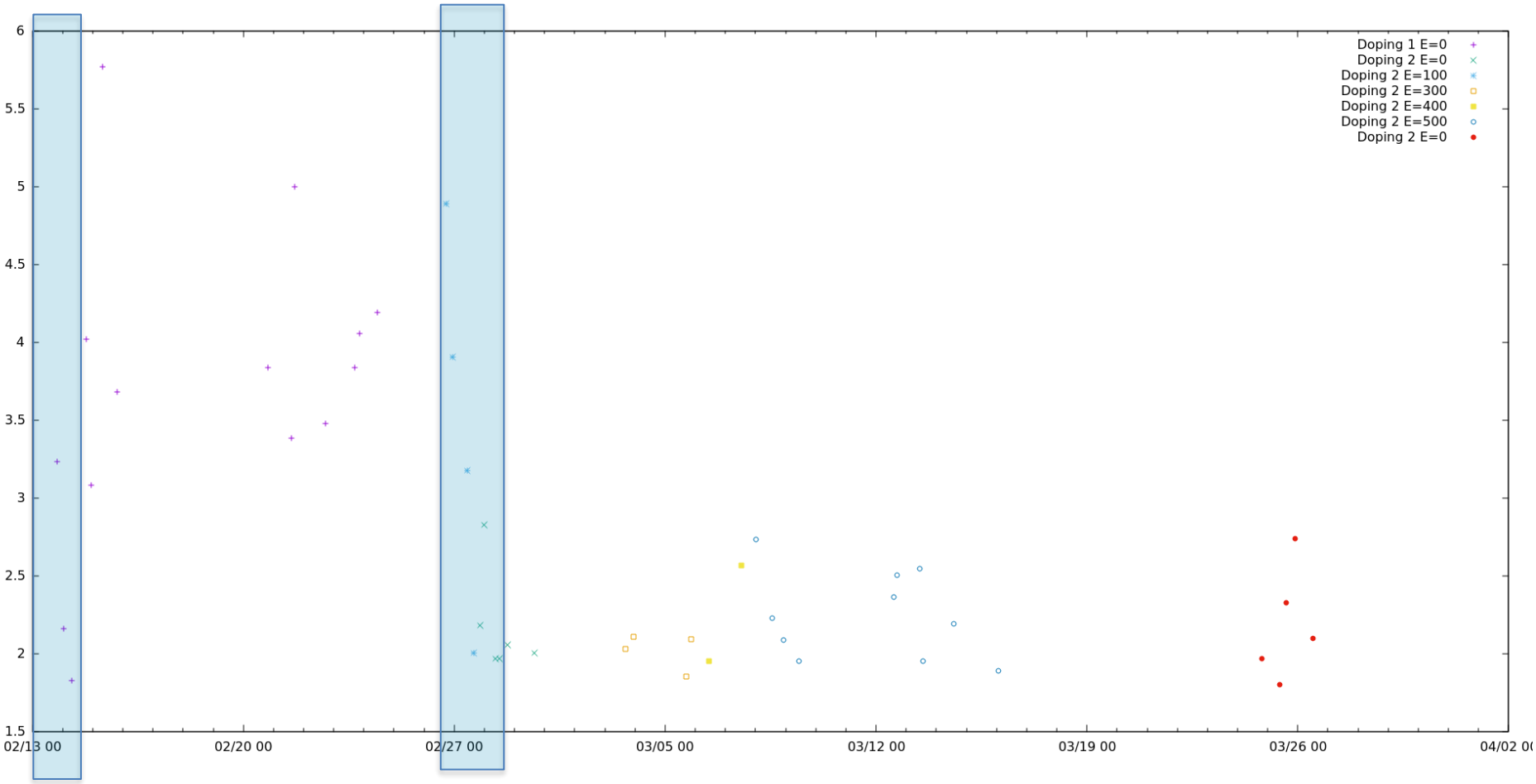
Integrals



Doping 1

Doping 2

Integrals ratio



Doping 1

Doping 2

Light emission model (Xe)

$$\frac{dN_{Ar,1}}{dt} = -\lambda_{Ar,1}N_{Ar,1} - \lambda_q N_{Ar,1} - \lambda_m N_{Ar,1}$$

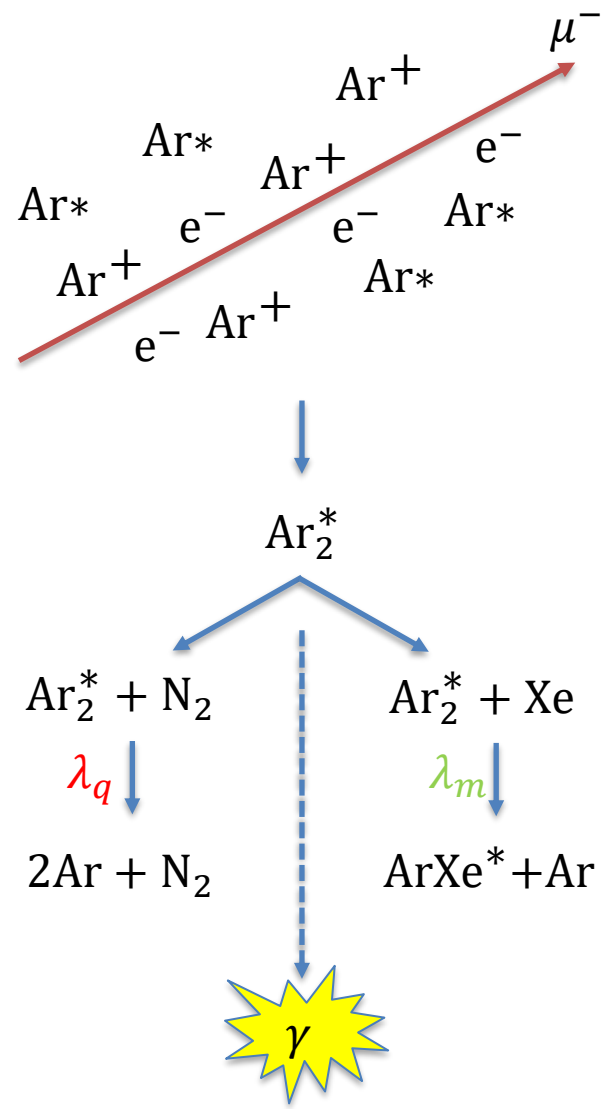
$$\frac{dN_{Ar,3}}{dt} = -\lambda_{Ar,3}N_{Ar,3} - \lambda_q N_{Ar,3} - \lambda_m N_{Ar,3}$$

$$\lambda_{1m} = \lambda_{Ar,1} + \lambda_q + \lambda_m$$

$$\lambda_{3m} = \lambda_{Ar,3} + \lambda_q + \lambda_m$$

$$\frac{dN_{\gamma,Ar}}{dt} = -\lambda_{Ar,1}N_{Ar,1} - \lambda_{Ar,3}N_{Ar,3}$$

$$r_{Ar} = q\, N_0\, \lambda_{Ar,1} e^{-\lambda_{1m}t} + (1-q) N_0\, \lambda_{Ar,3} e^{-\lambda_{3m}t}$$



q is the fraction of Ar_2^* singlet

Light emission model (Xe)

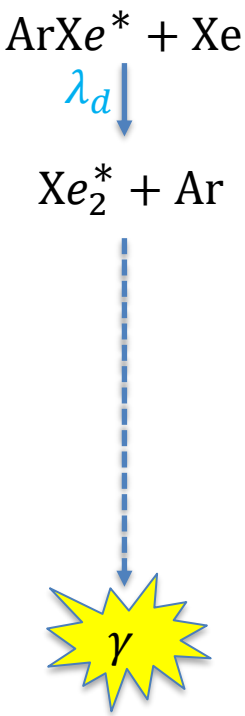
$$\frac{dN_{ArXe^*}}{dt} = +\lambda_m N_{Ar,1} + \lambda_m N_{Ar,3} - \lambda_d N_{ArXe^*}$$

$$\frac{dN_{Xe,1}}{dt} = +\lambda_d\, pN_{ArXe^*} - \lambda_{Xe,1} N_{Xe,1}$$

$$\frac{dN_{Xe,3}}{dt} == +\lambda_d\, (1-p) N_{ArXe^*} - \lambda_{Xe,3} N_{Xe,3}$$

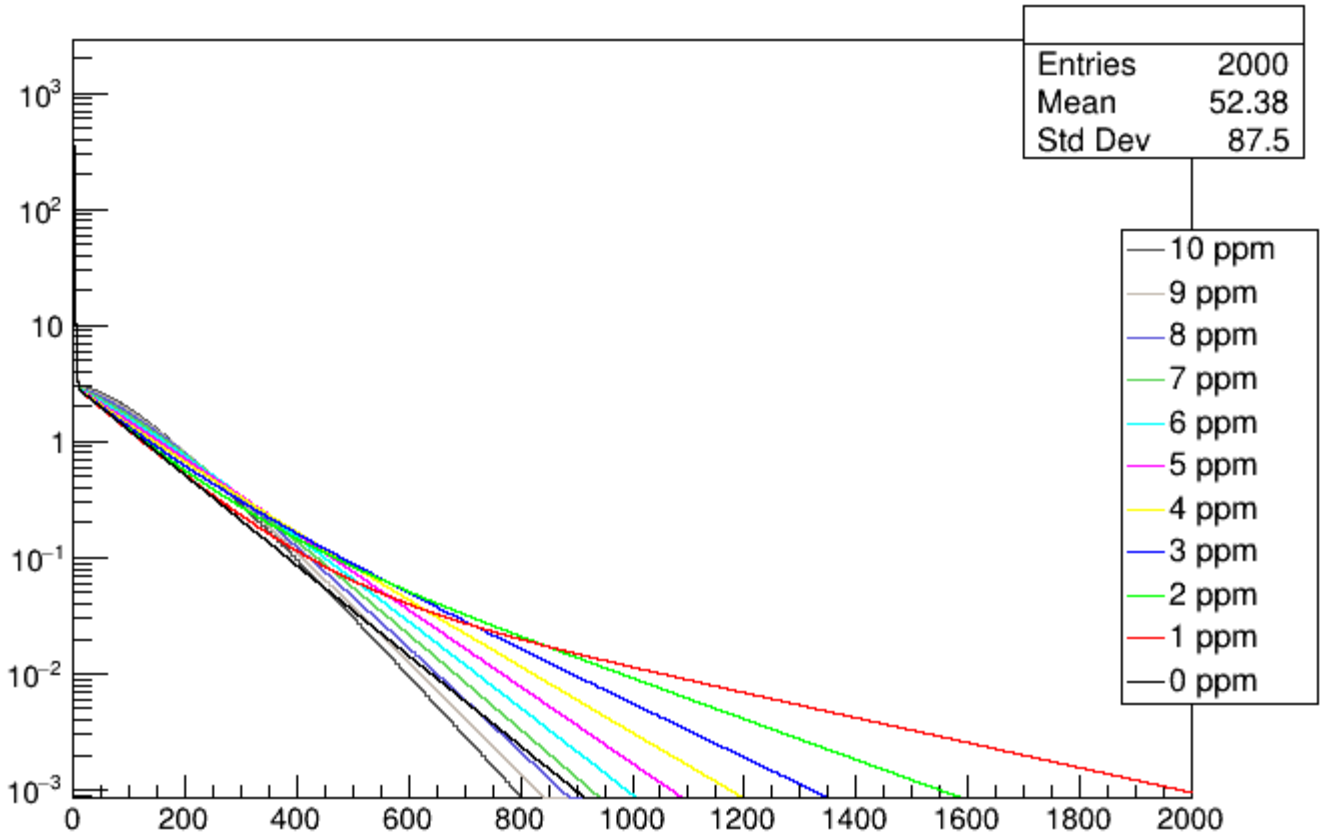
$$\frac{dN_{\gamma,Xe}}{dt} = -\lambda_{Xe,1} N_{Xe,1} - \lambda_{Xe,3} N_{Xe,3}$$

$$r_{Xe} = A_1 e^{-\lambda_{Xe,1} t} + A_2 e^{-\lambda_{Xe,3} t} + A_3 e^{-\lambda_d t} + \\ + A_4 e^{-\lambda_{1m} t} + A_5 e^{-\lambda_{2m} t}$$



p is the fraction of Xe_2^* singlet

Light distribution (low concentration)



$\lambda_{Ar,1}^{-1} = 7$ ns

$\lambda_{Xe,1}^{-1} = 4.3$ ns

$\lambda_q = 8 \times 10^{-5}\ [N_2](\text{ns ppm})^{-1}$

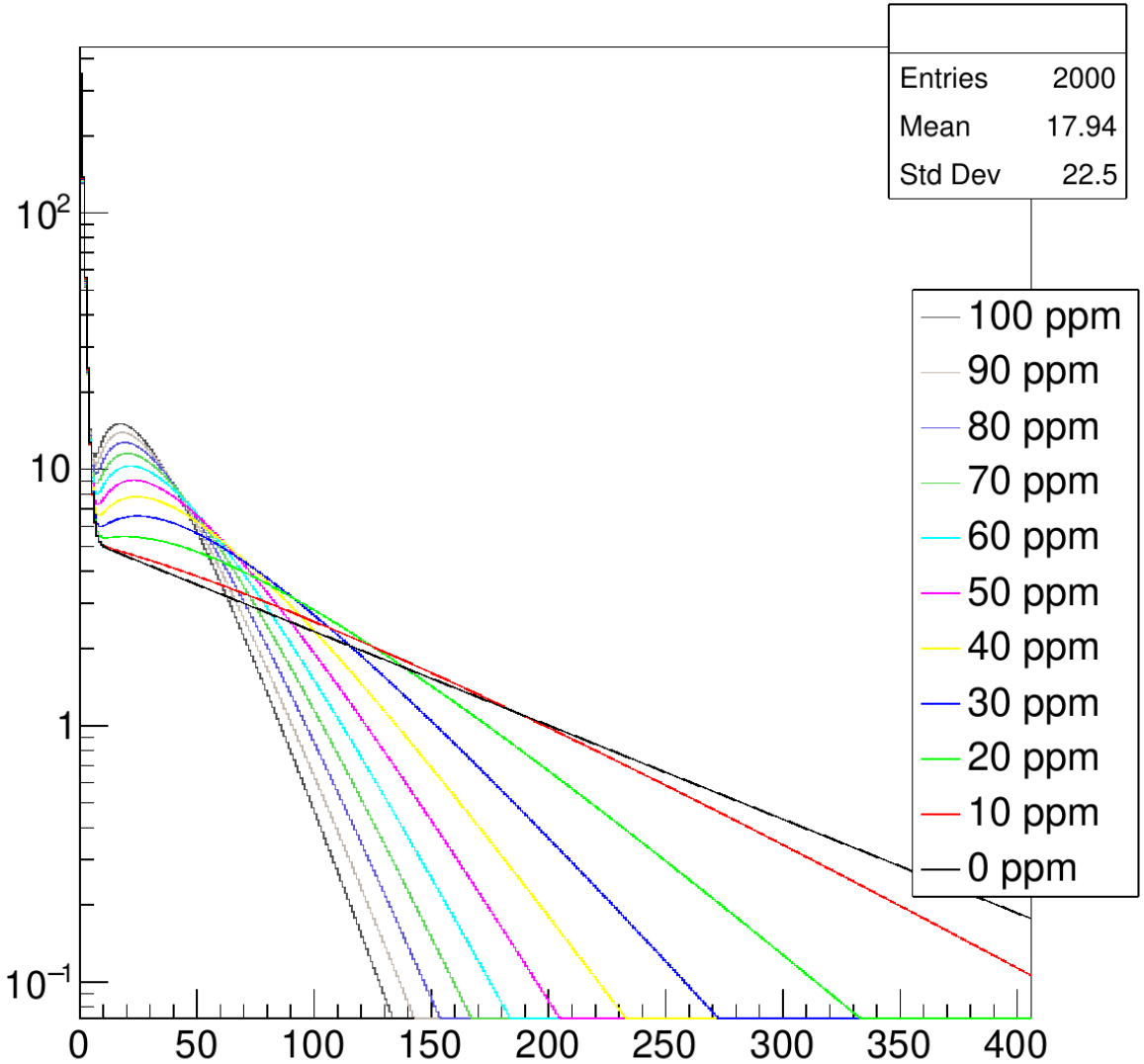
$\lambda_m = 8.8 \times 10^{-5}\ [Xe](\text{ns ppm})^{-1}$

$\lambda_{Ar,3}^{-1} = 1400$ ns

$\lambda_{Xe,3}^{-1} = 22$ ns

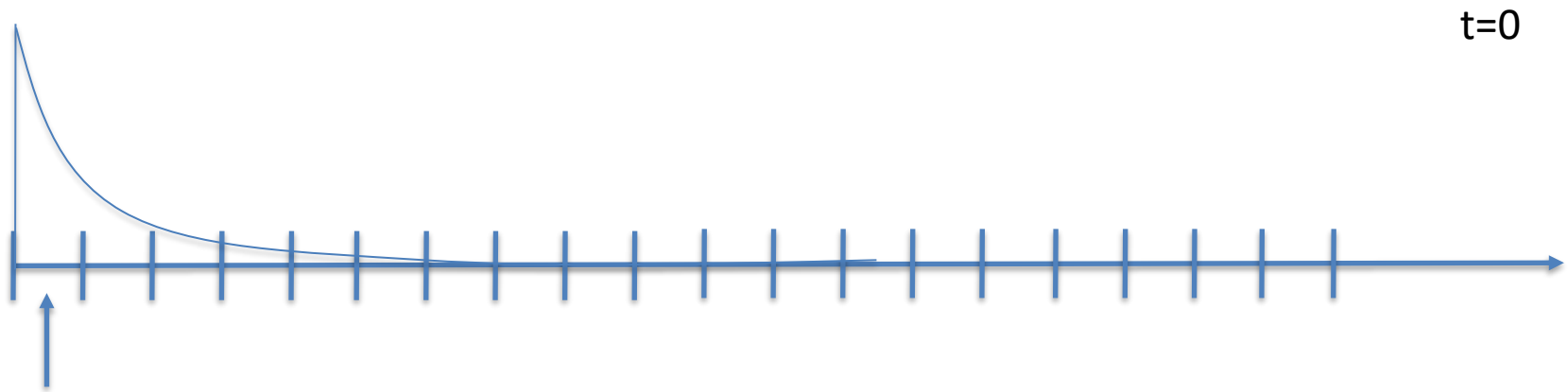
$\lambda_d = 2700\ [Xe]^{-0.7}\ \text{ns}^{-1}\text{ppm}^{-0.7}$

Light distribution (high concentration)



Simulation

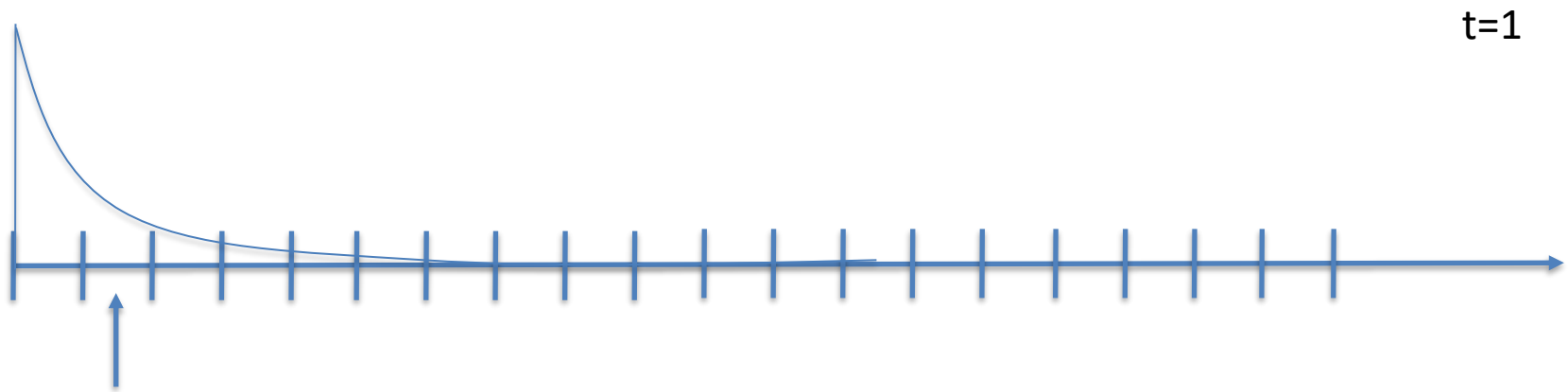
- For each time step (sampling period) n_{Ar} and n_{Xe} photons are generated according to the distribution.



$n_{Ar} = 10$
$n_{Xe} = 1$

Simulation

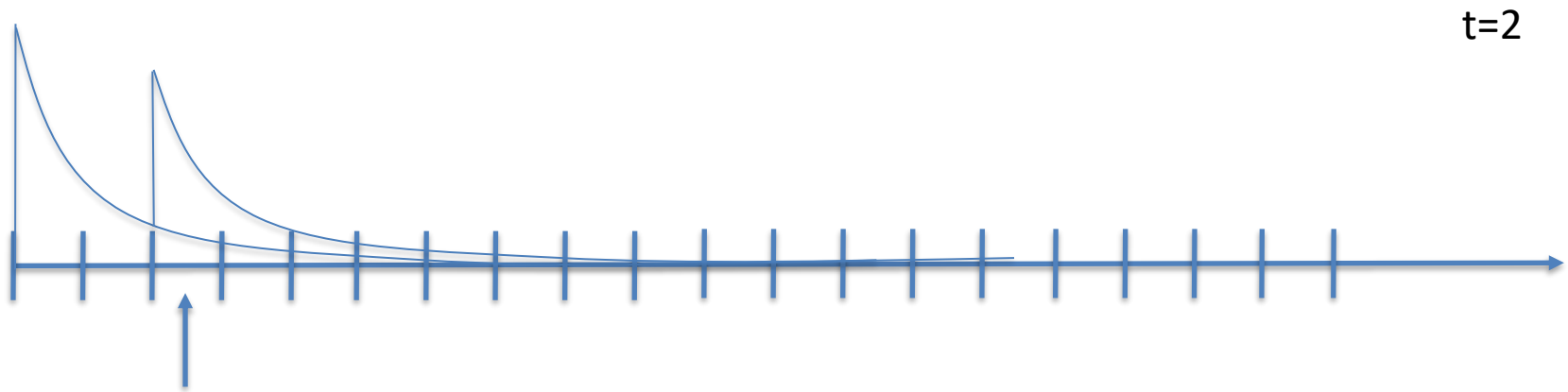
- For each time step (sampling period) n_{Ar} and n_{Xe} photons are generated according to the distribution.



$n_{Ar} = 0$
$n_{Xe} = 0$

Simulation

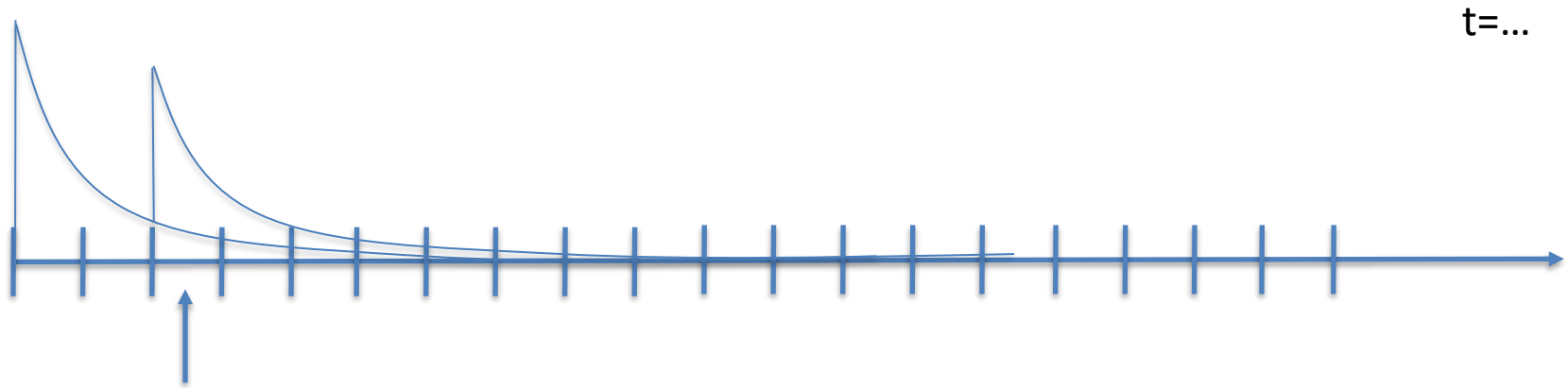
- For each time step (sampling period) n_{Ar} and n_{Xe} photons are generated according to the distribution.



$n_{Ar} = 4$
$n_{Xe} = 2$

Simulation

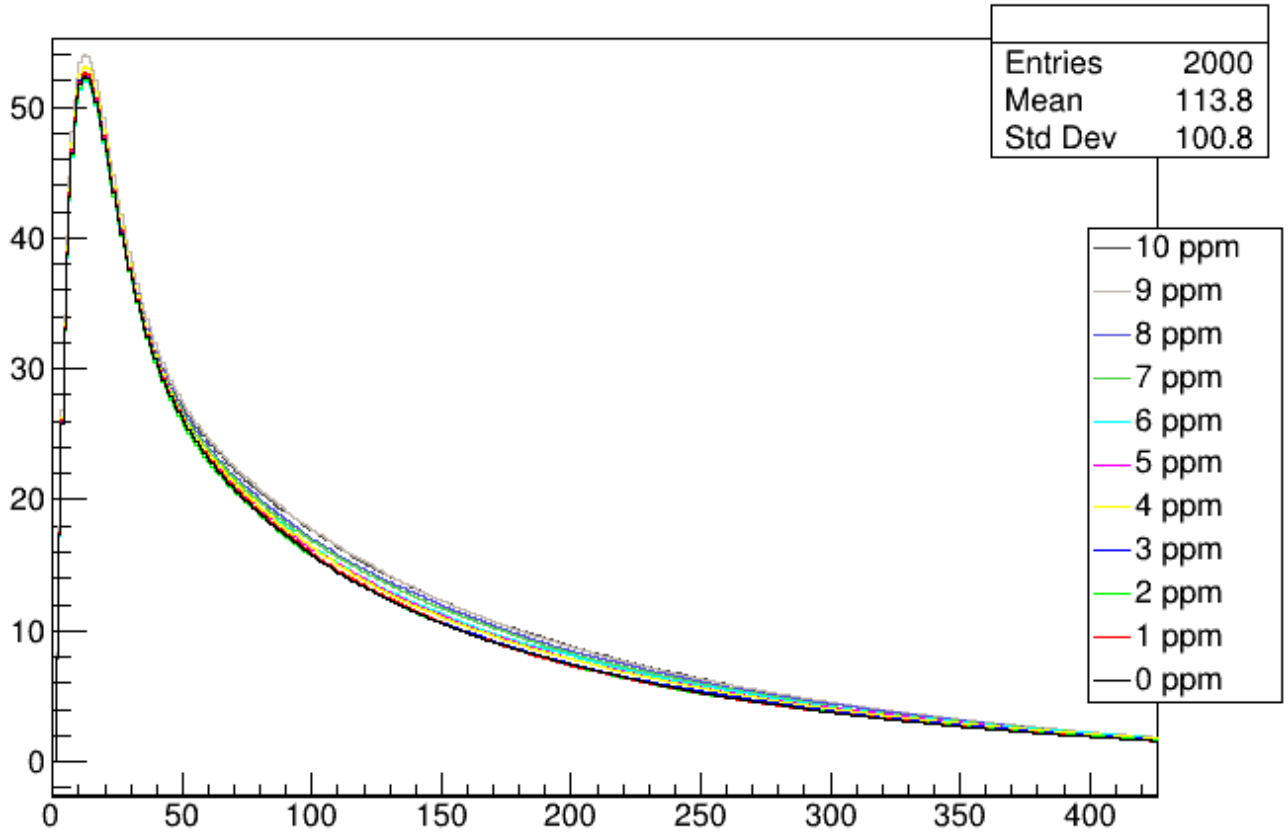
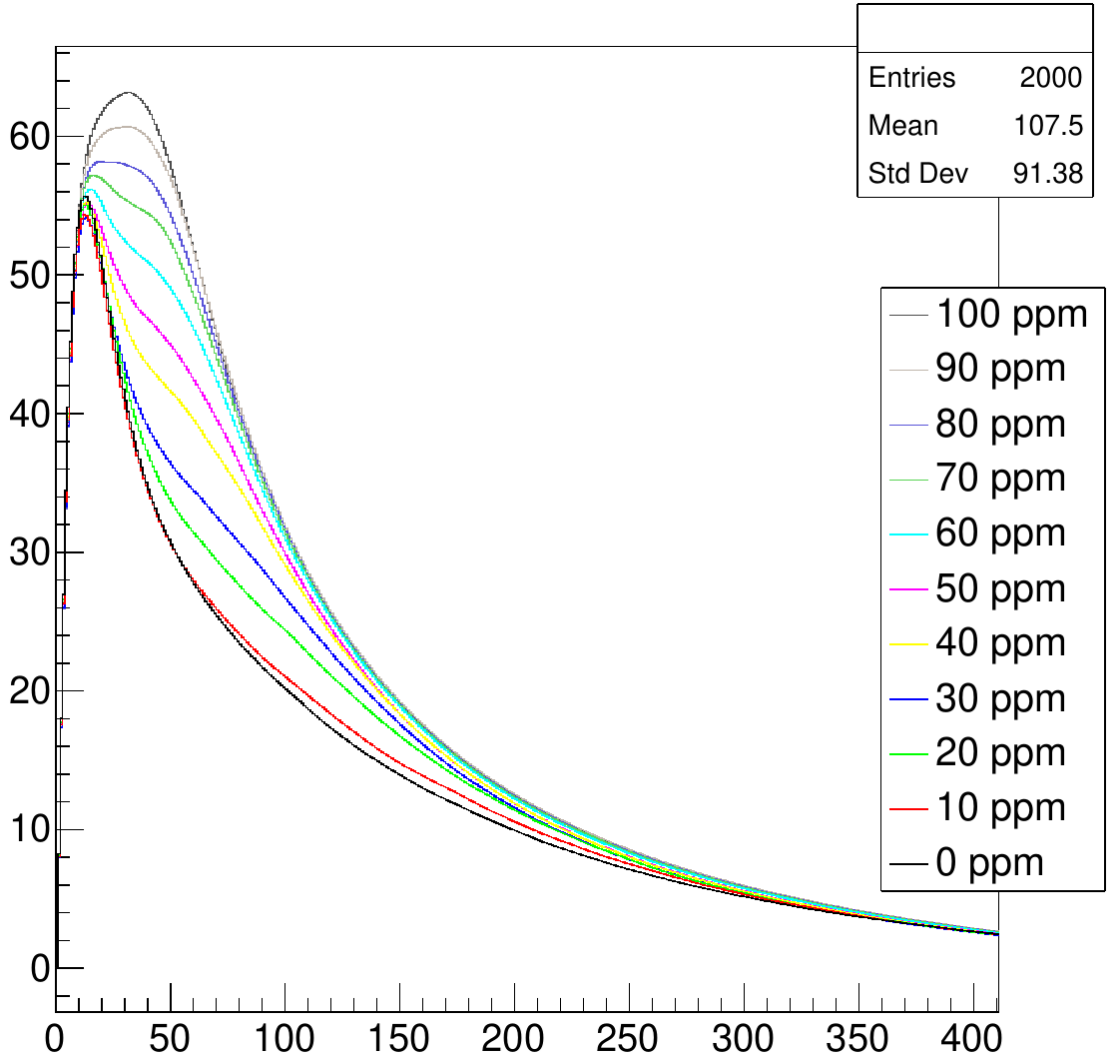
- For each time step (sampling period) n_{Ar} and n_{Xe} photons are generated according to the distribution.
- The final number of photons detected is computed considering efficiency for argon light and xenon light.



$n_{Ar} = 4$
$n_{Xe} = 2$

so on…

Waveform (low concentration)



Waveform (high concentration)