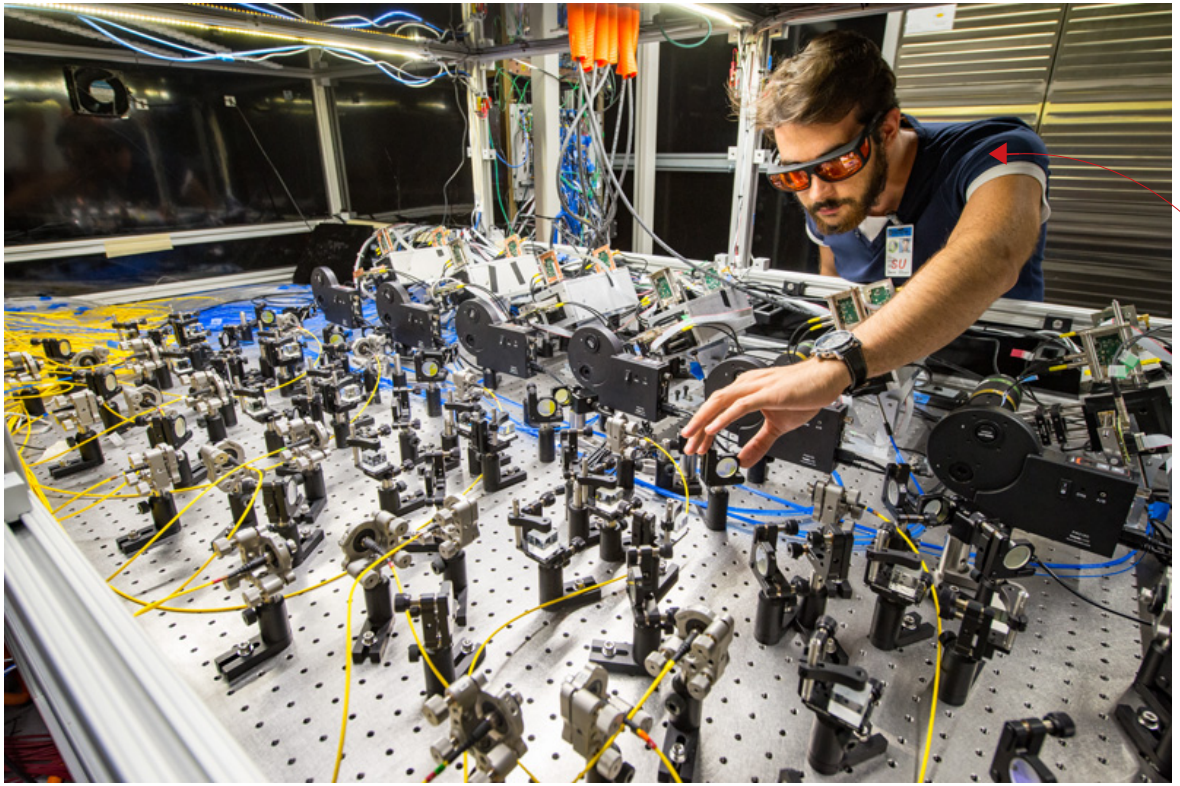
Fermilab



Short Term Double Pulse

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MUSE General Meeting – 25 Oct 2019

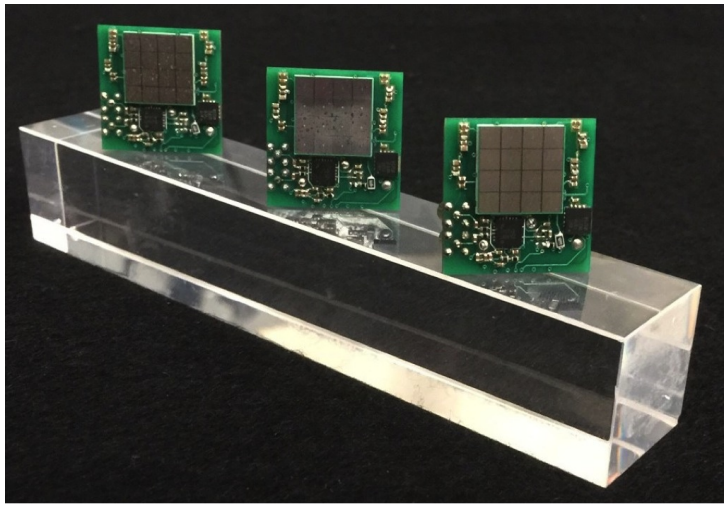
INFN
Istituto Nazionale di Fisica Nucleare

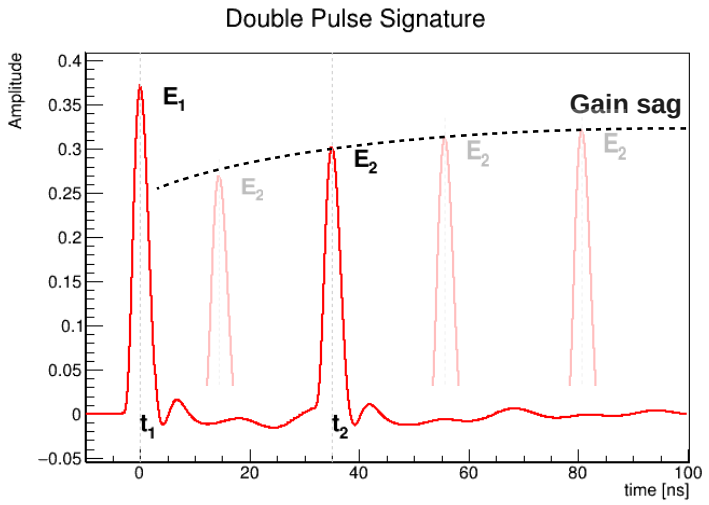
MUSE

Short Term Double Pulse (STDP)

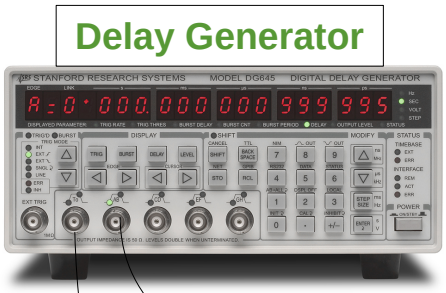
What it is:

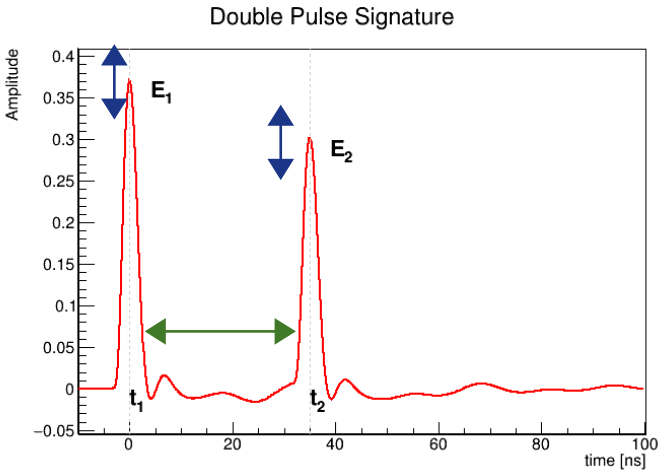
- It's a gain calibration for the very small time scale of 0-100 ns.
- Each SiPM of the calorimeters is composed by 57344 geiger-like pixels.
- When a positron hits, some of the pixels are fired, and they recover with a lifetime of roughly 15 ns.
- If another positron hits before the SiPM has fully recovered, fewer pixels are available and its energy would be measured lower than reality.

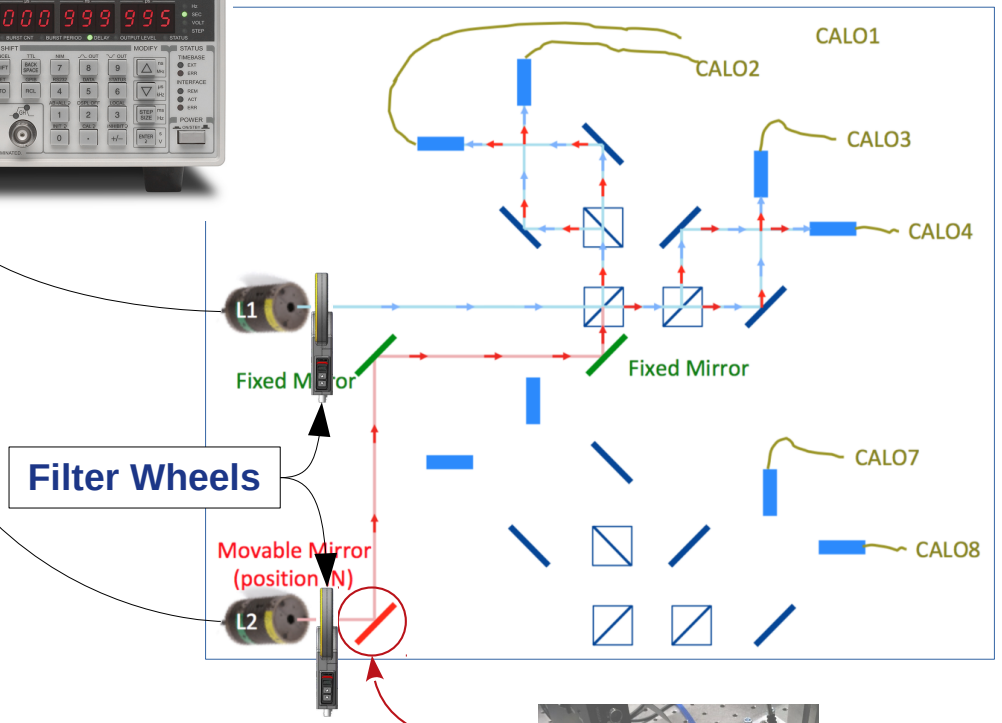




The Laser System







Dedicated *Double Pulse* laser setup:

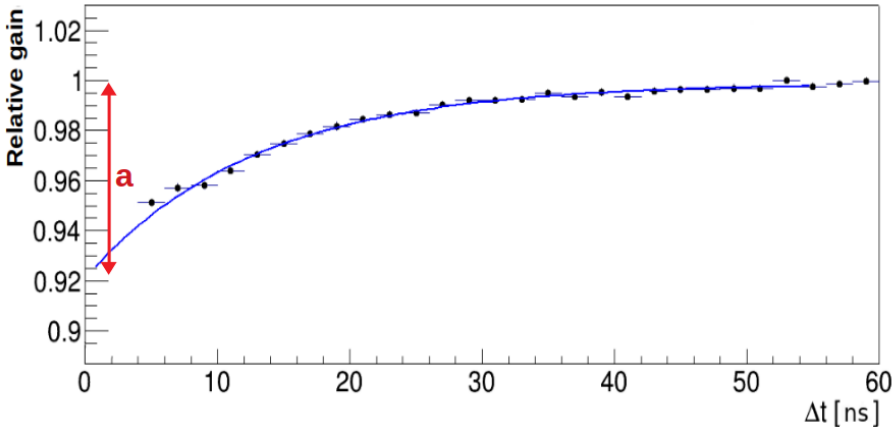
- A delay generator to generate pulses 0-100 ns apart
- Filter wheels to change intensities

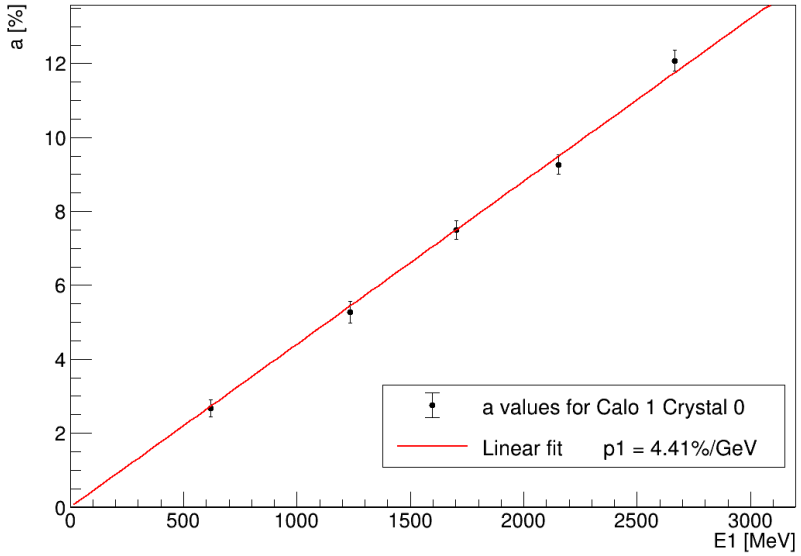
The results

- Exponential gain functions of the form

$$g(\Delta t) = 1 - a \cdot e^{-\frac{\Delta t}{\tau}}$$

are fitted for all the crystals.

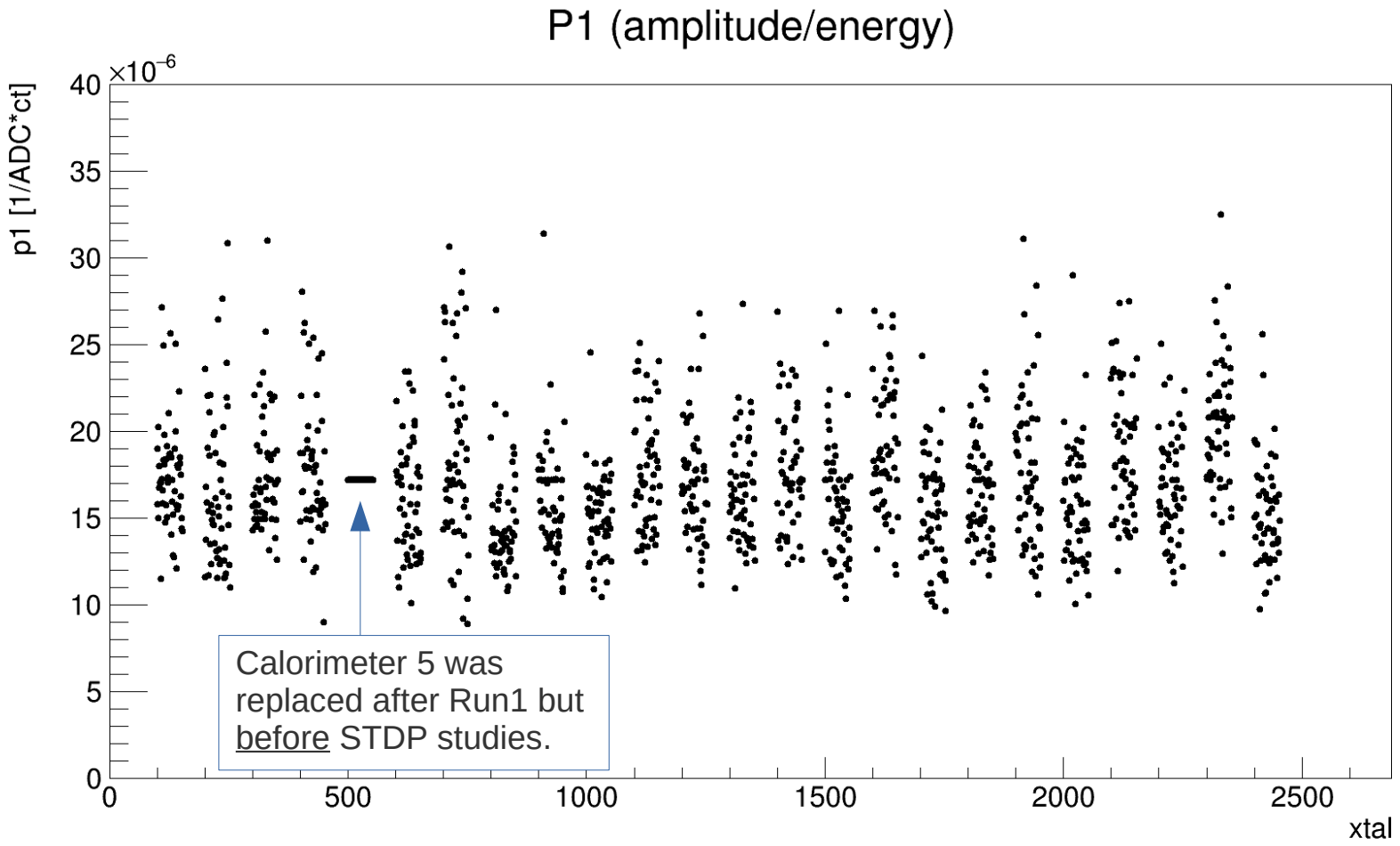




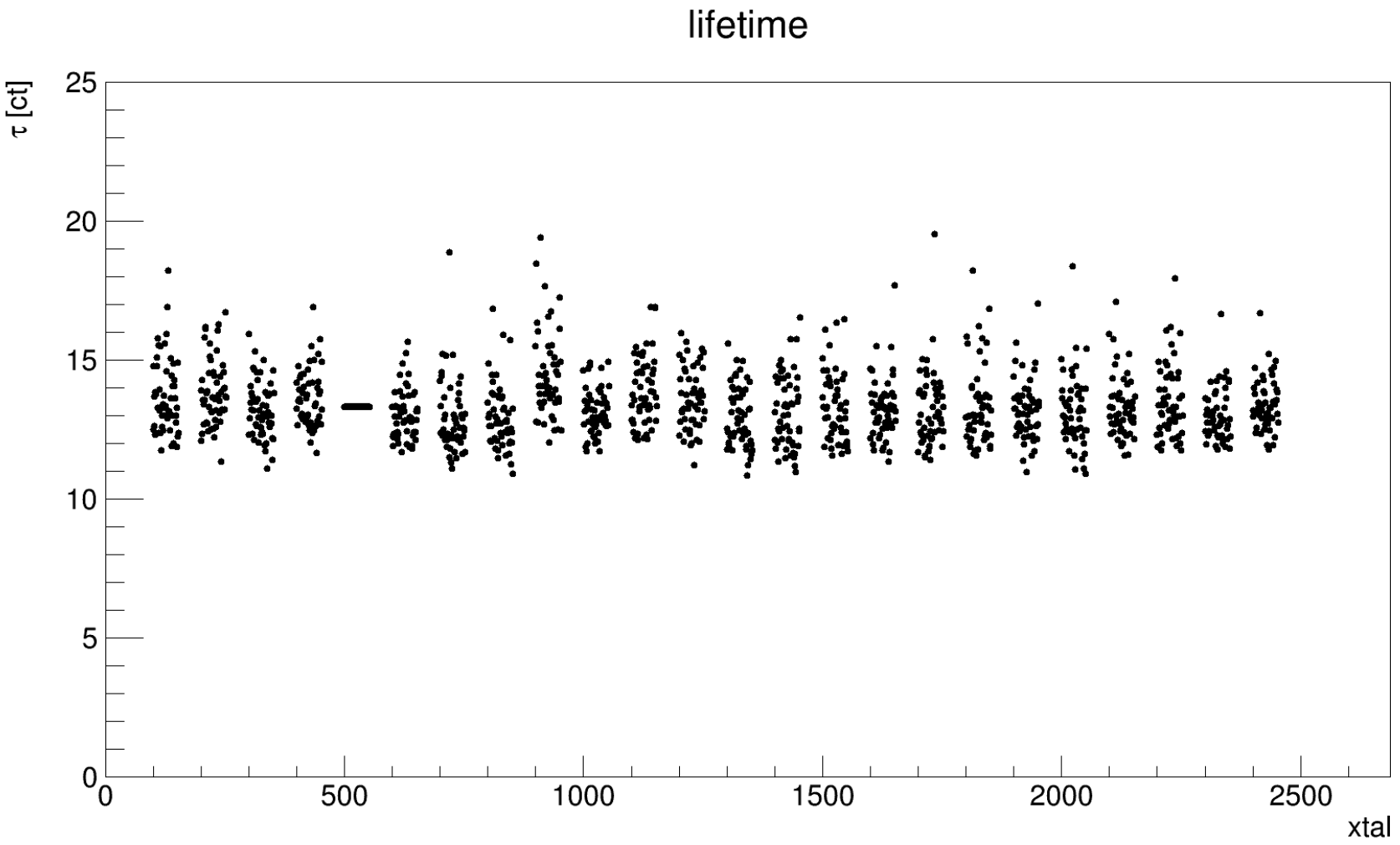
- The amplitude of the gain sag is strongly linear with the Energy of the first pulse, with a slope p1 ~5%/GeV.

- Each xtal is parameterized by p1 and τ.

Distributions (p1)

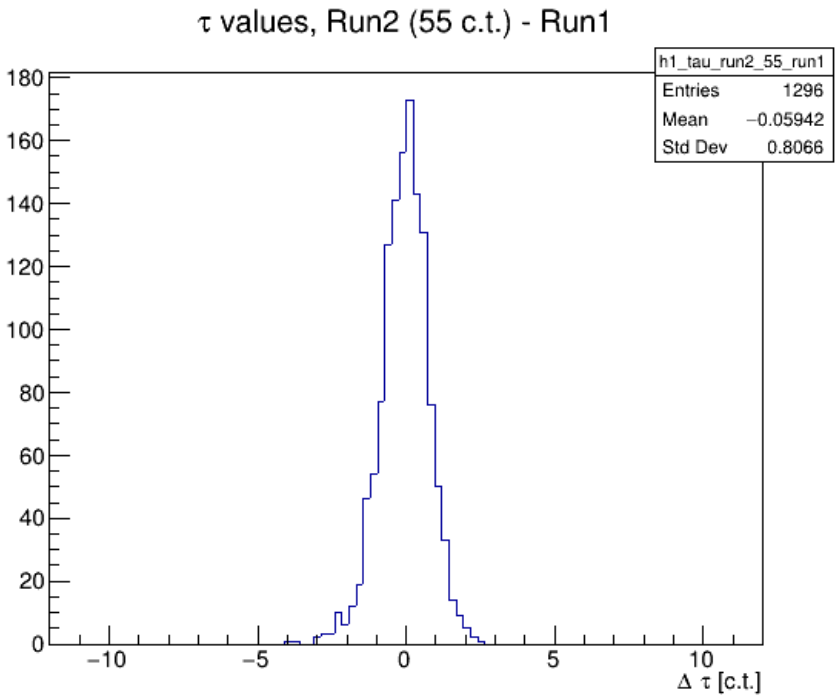


Distributions (tau)

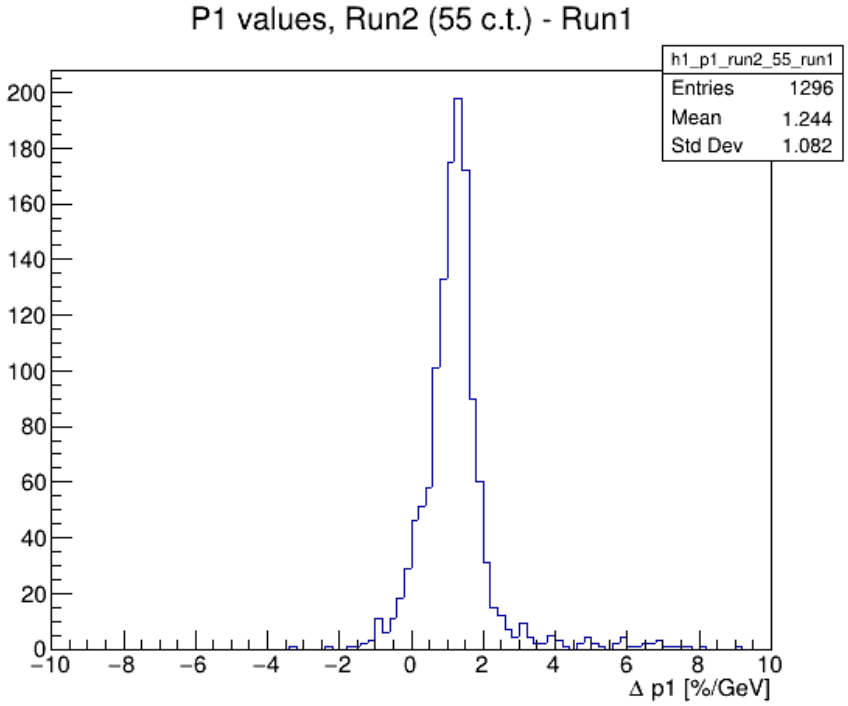


Run2 results

STDP analysis has been performed again for Run2.



Tau parameters are **stable** to the 0.1 c.t. level. (-0.5%)



P1 parameters show a systematic **shift:** +1.2%/GeV (+28%)

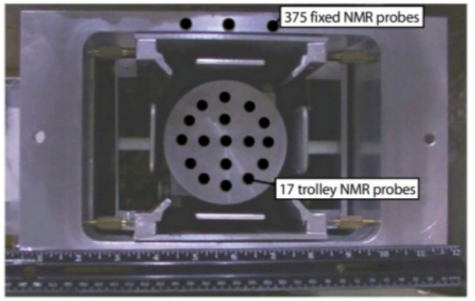
Both tau and p1 are estimated with a mean error of 2% (sigma = 0.8%)

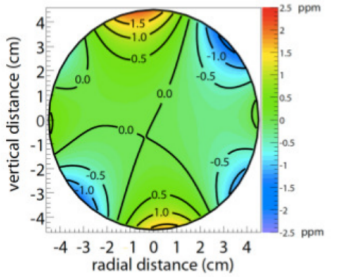
Trolley runs

- During Run2, sequences of STDP runs have been acquired during *trolley* runs.

- The trolley is a field-measuring device that runs around the ring with no beam → perfect time to perform laser studies!

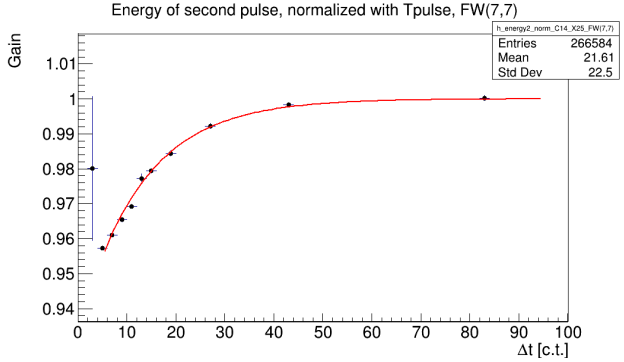
- Only one FW combination, scan of few Δt → high errors on parameters. But important results!



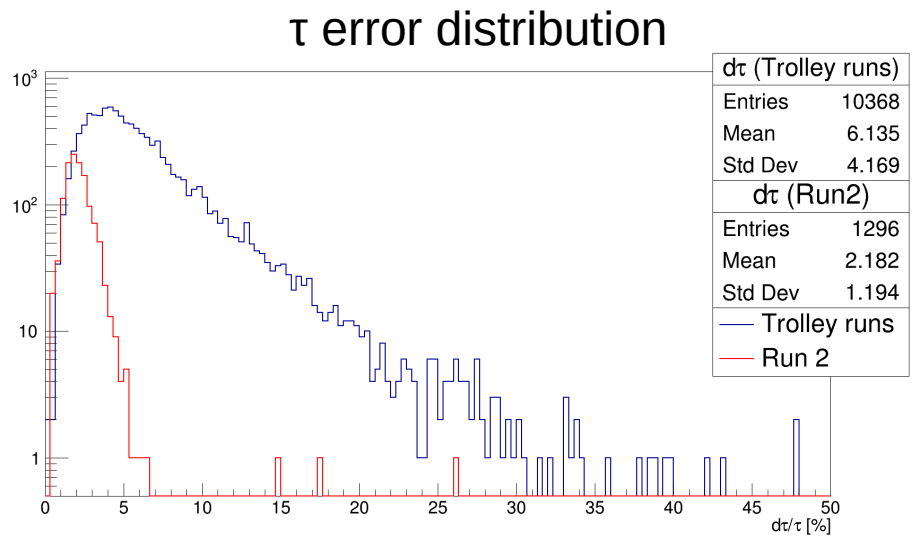


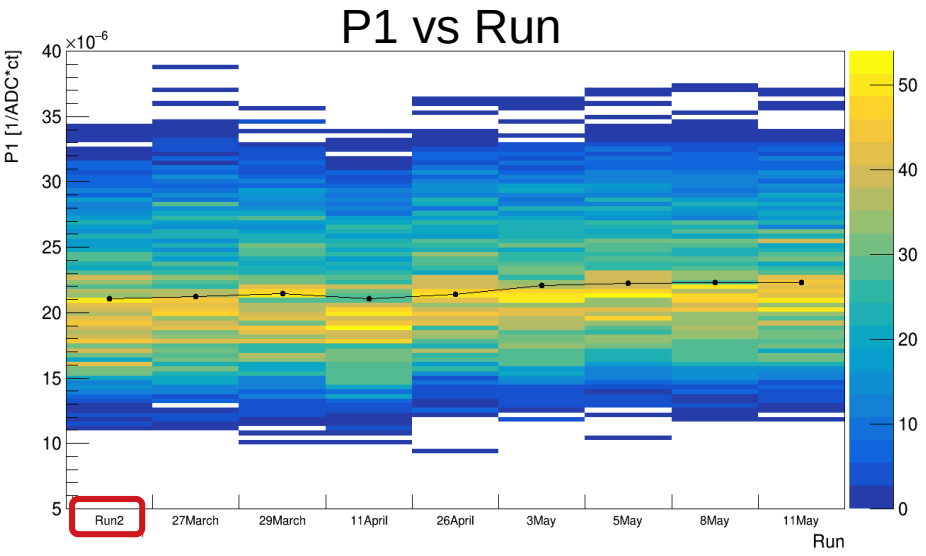
27 March 10:45 PM	24409 - 24432
29 March 3:30 PM	24475 - 24498
11 April 2:30 AM	24649 - 24682
26 April 5:30 PM	25864 - 25887
3 May 11:30 AM	26025 - 26049
5 May 11:00 AM	26112 - 26135
8 May 6:15 AM	26227 - 26262
11 May 9:00 AM	26393 - 26416
22 May 5:00 PM	26535 - 26558
6 June 8:45 AM	26729 - 26752
17 June 4:45 AM	26962 - 26985
19 June 6:40 AM	27050 - 27073
20 June 9:45 PM	27138 - 27161
22 June 9:00 PM	27223 - 27257
1 July 6:00 AM	27383 - 27406

Runs used for now



Parameters





- Fewer points on the gain sag resulted in high errors on taus

  → the tau values are fixed to the results found for Run2.

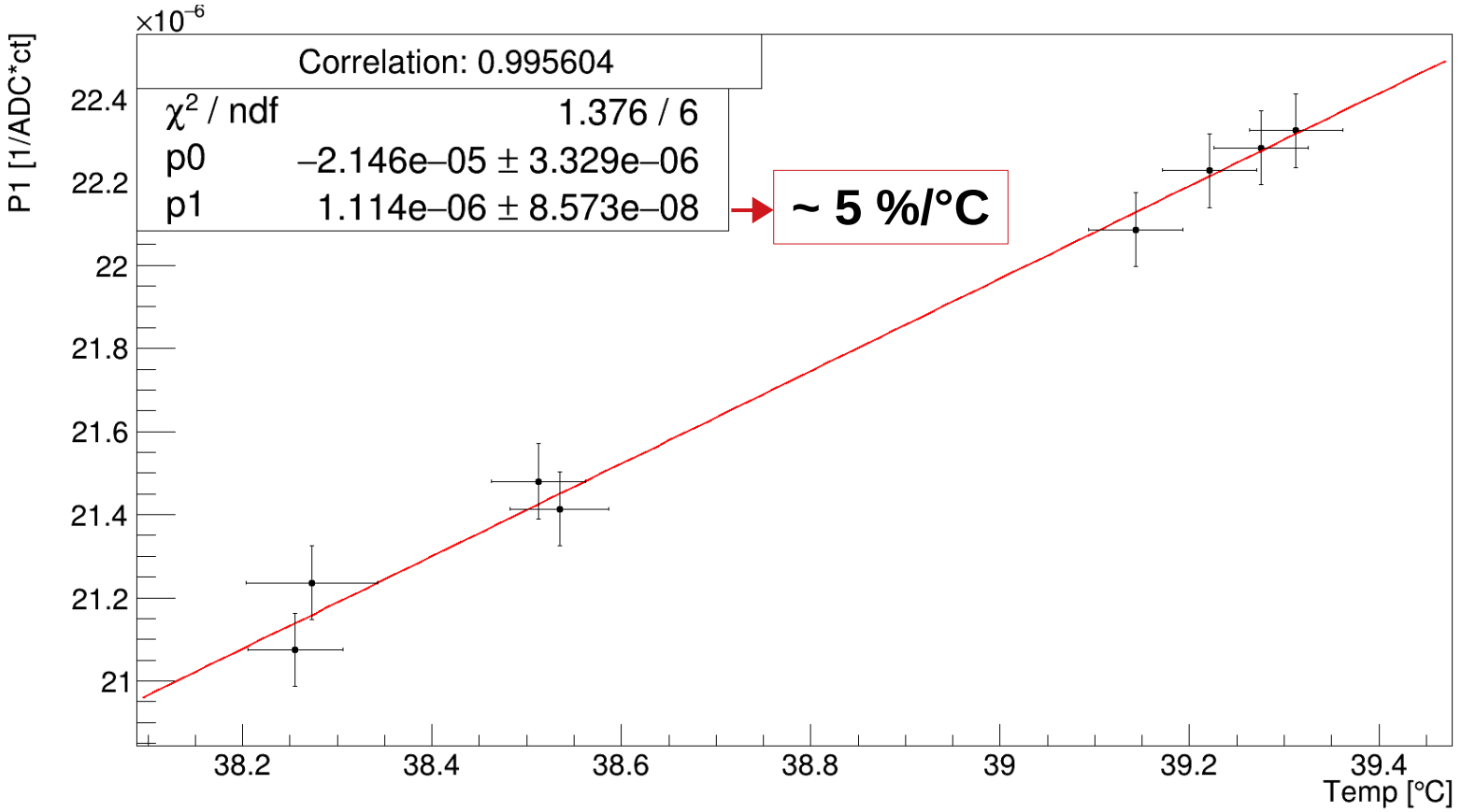
- Only one FW combination means only one amplitude per crystal

  → P1 = a/E1 given the strong linearity

- Results on P1 consistent with previous STDP analyses

Temperature dependence

Trolley runs are useful to study long-term drifts.



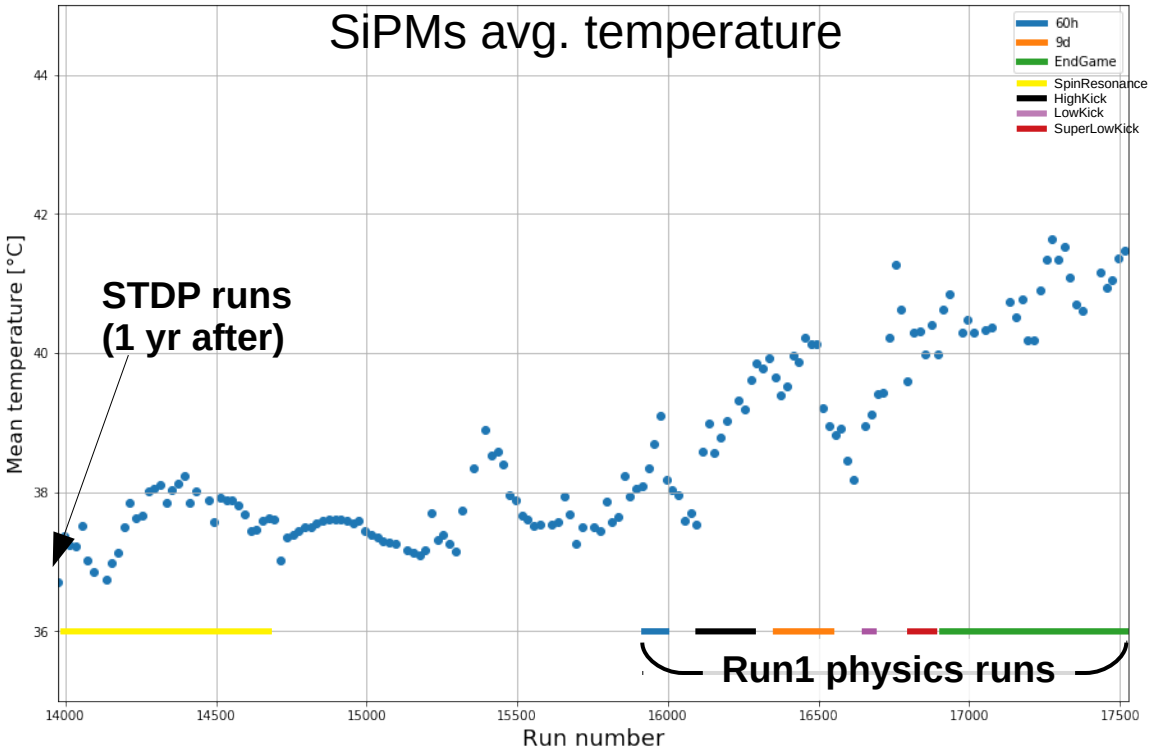
Strong correlation between temperature and p1

Systematic effect on Run1

Run1 physics runs: from end of March to end of June (37-41 °C)

Run1 STDP runs: end of December (36.3 °C)

Current status: Run1 has been processed with non-corrected STDP → assess the difference as systematic error. Predicted to be ~ 1 ppb.

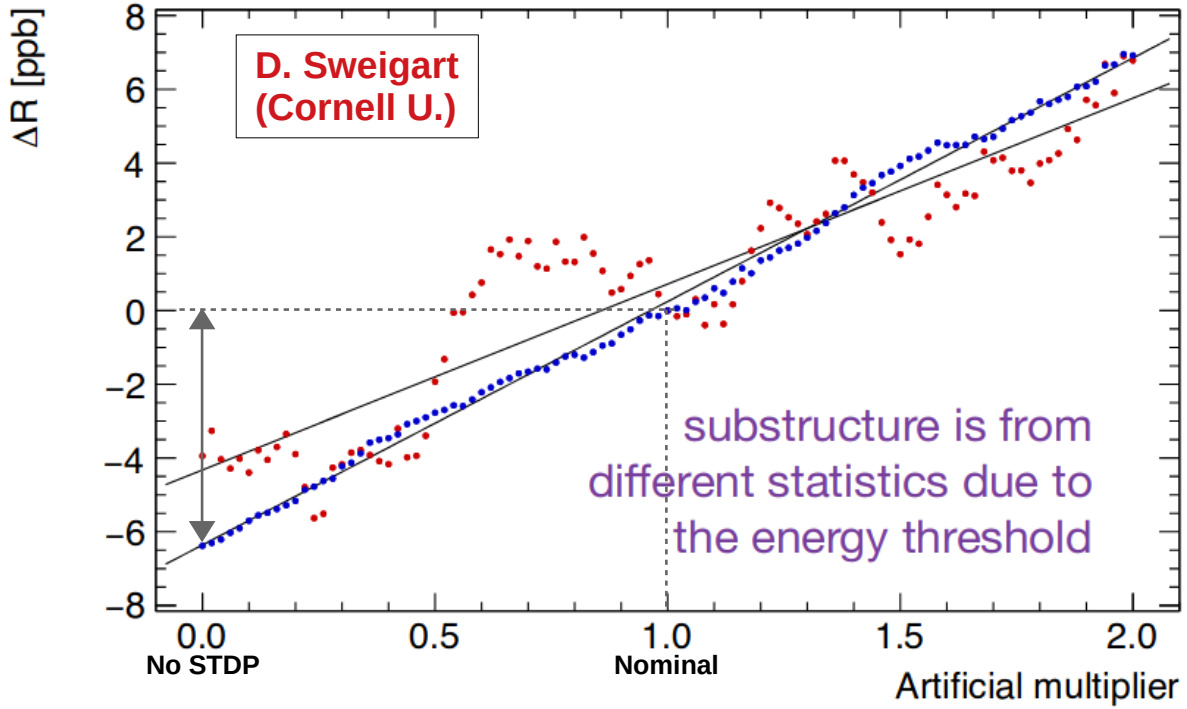


Dataset	Avg temp [°C]	Correction factor
STDP	36,3	1,000
60h	38,66	1,118
HighKick	38,87	1,129
9d	39,70	1,170
LowKick	39,37	1,154
SuperLowKick	40,46	1,208
EndGame	40,72	1,221
Full Run1	40,03	1,187

STDP effect on ω_a

The effect of STDP (without temperature correction) has been studied on the 9d dataset of Run1 by David Sweigart (Cornell).

Effect on R (blinded ω_a) investigated by scaling the **P1** parameter from 0 to 2x and performing the full ω_a fit procedure.



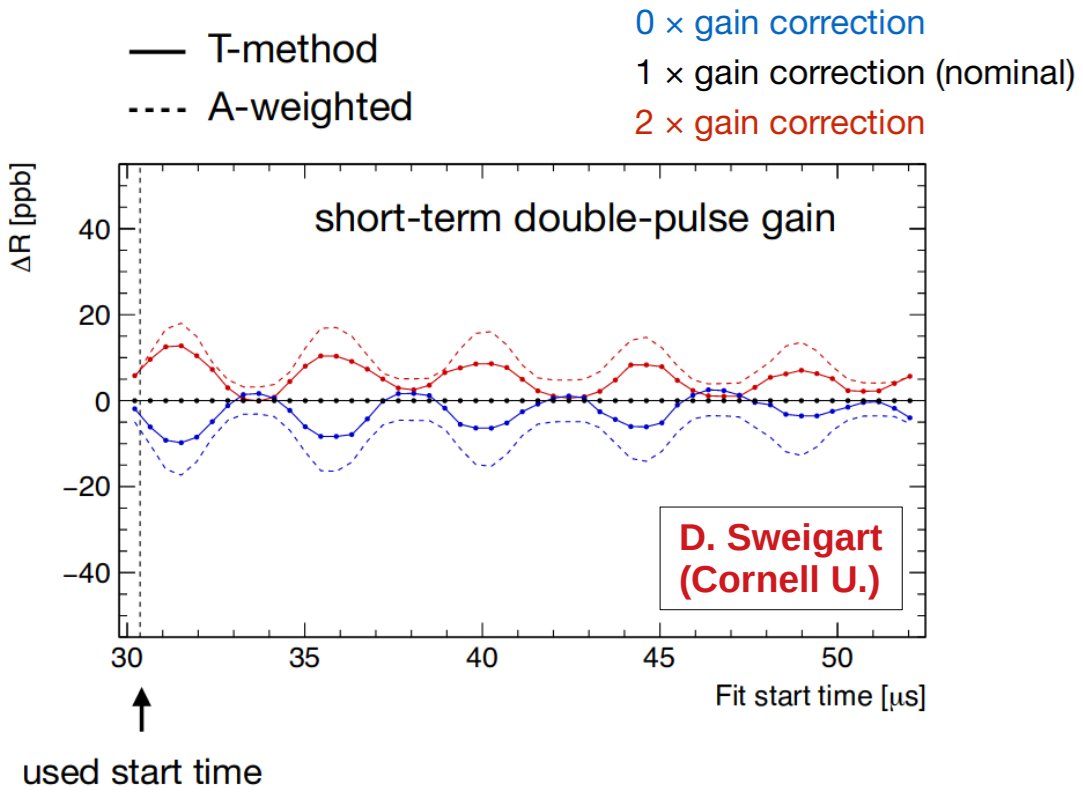
Red: T-Method (energy threshold of 1.7 GeV)

Blue: A-Method (Asymmetry weigthed)

Shift by applying STDP: 6 ppb.

STDP effect on ω_a

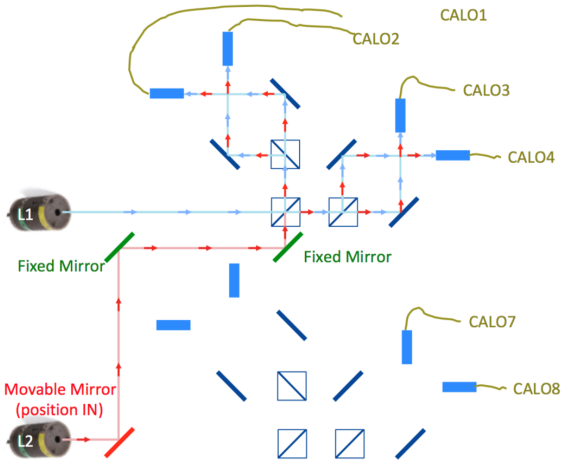
The effect on R oscillates with the start time of the full omega_a fit.



Shift caused by STDP (A-weighted): 5-16 ppb.

Conclusions

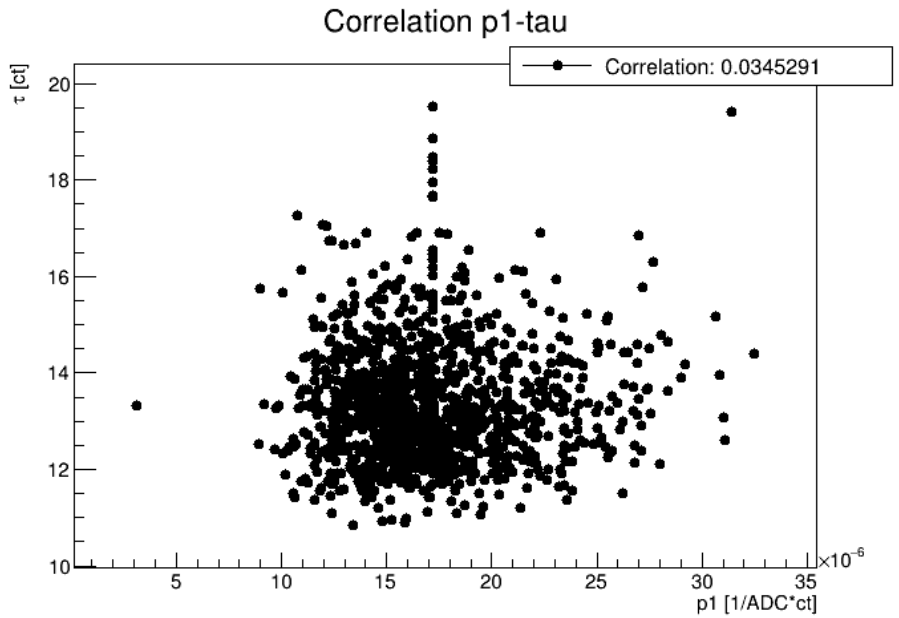
- The Short Term Double Pulse analysis is a well established procedure that investigates the SiPM recovery in the 100 ns time scale.
- Periodic data taking during trolley runs allows to address the systematic effect due to temperature.
- Correction applied to Run2 will be more precise.

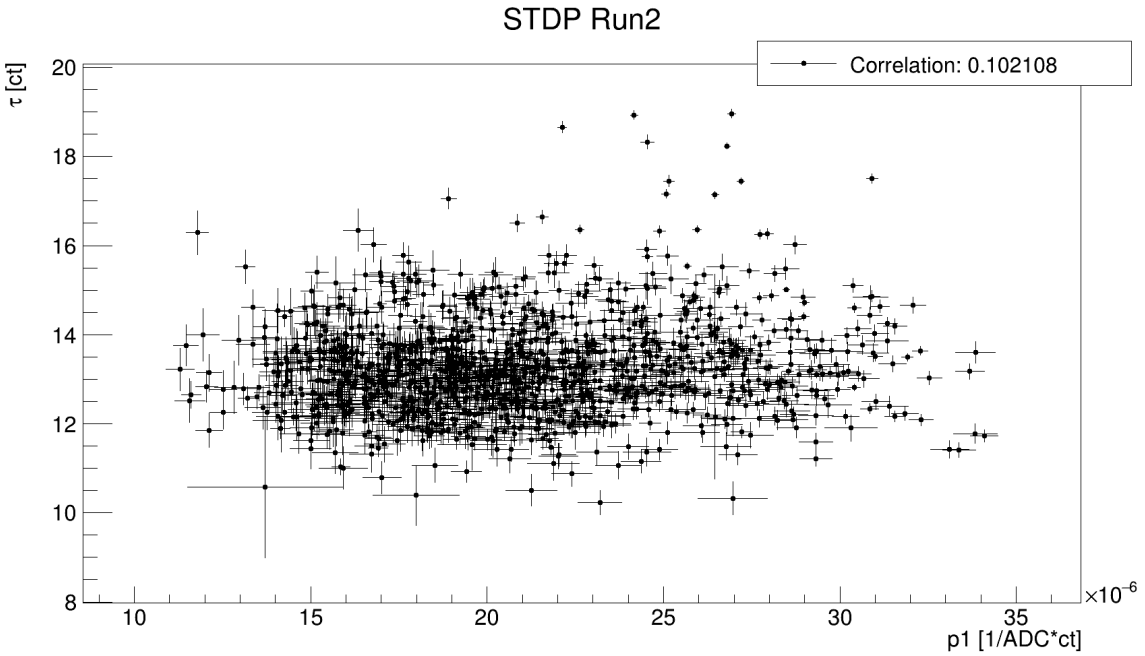


Error	E821 [ppb]	E989 goal [ppb]
Gain changes	120	20
Lost muons	90	20
Pileup	80	40
CBO	70	40
E and pitch	50	30
Total	180	70

The effect on ω_a is small, but at the end the overall gain systematic has to be less than **20** ppb!

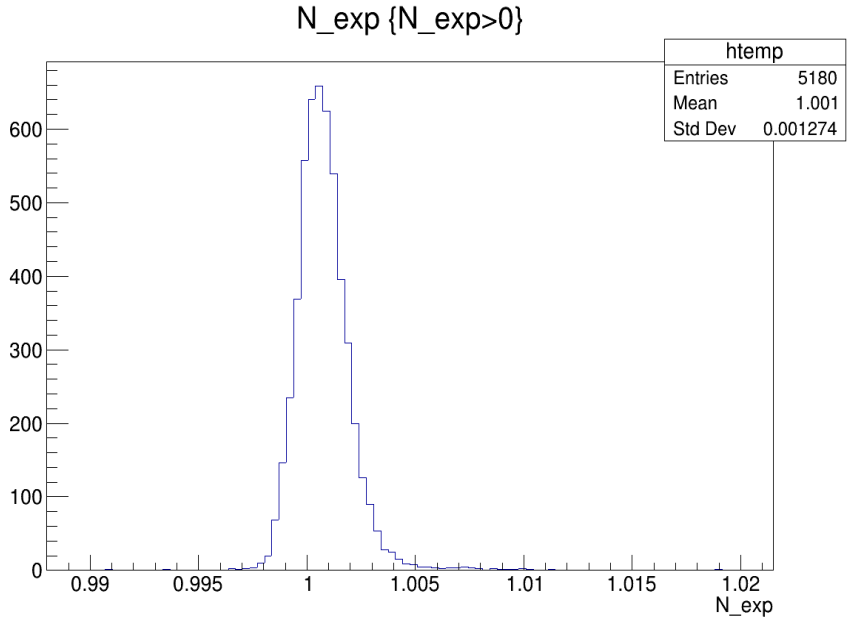
Backup

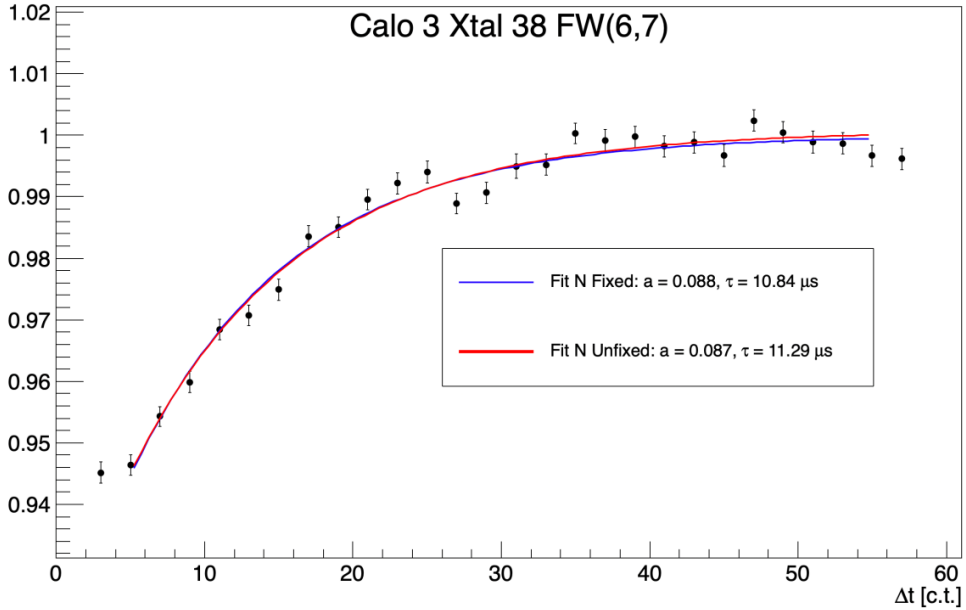

Correlation p1-tau
Correlation: 0.0345291
τ [ct]
20
18
16
14
12
10
5
10
15
20
25
30
35
×10⁻⁶
p1 [1/ADC*ct]


STDP Run2
Correlation: 0.102108
τ [ct]
20
18
16
14
12
10
8
10
15
20
25
30
35
×10⁻⁶
p1 [1/ADC*ct]

Backup

Gain shapes are fitted with the function g = N*(1 – a*exp(-x/tau)).
Currently N is fixed to 1.0.



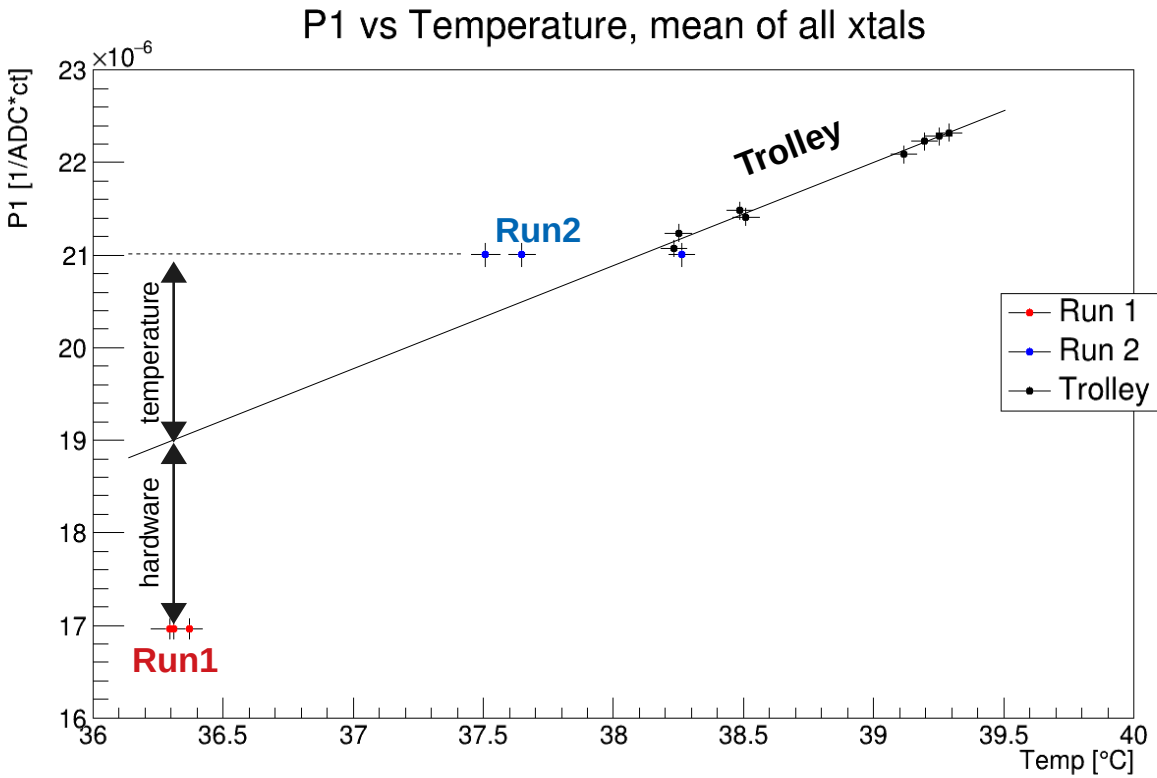


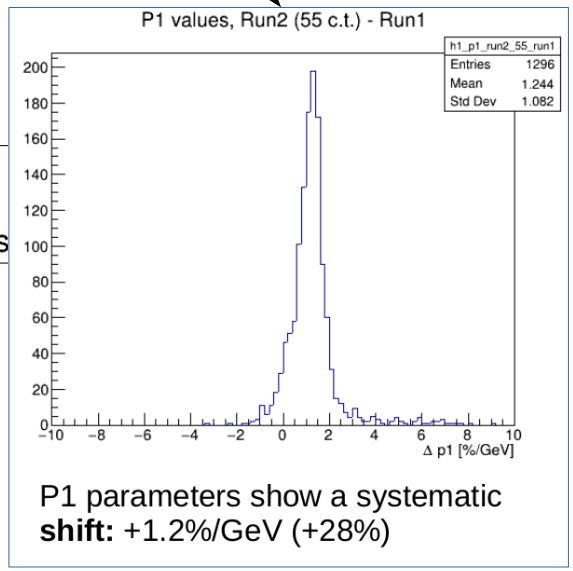
No difference on p1 parameters, little systematic shift on tau (~0.5 c.t.)

Backup

The full STDP sequences for Run1 (December) and Run2 (April) agree with the temperature dependence.

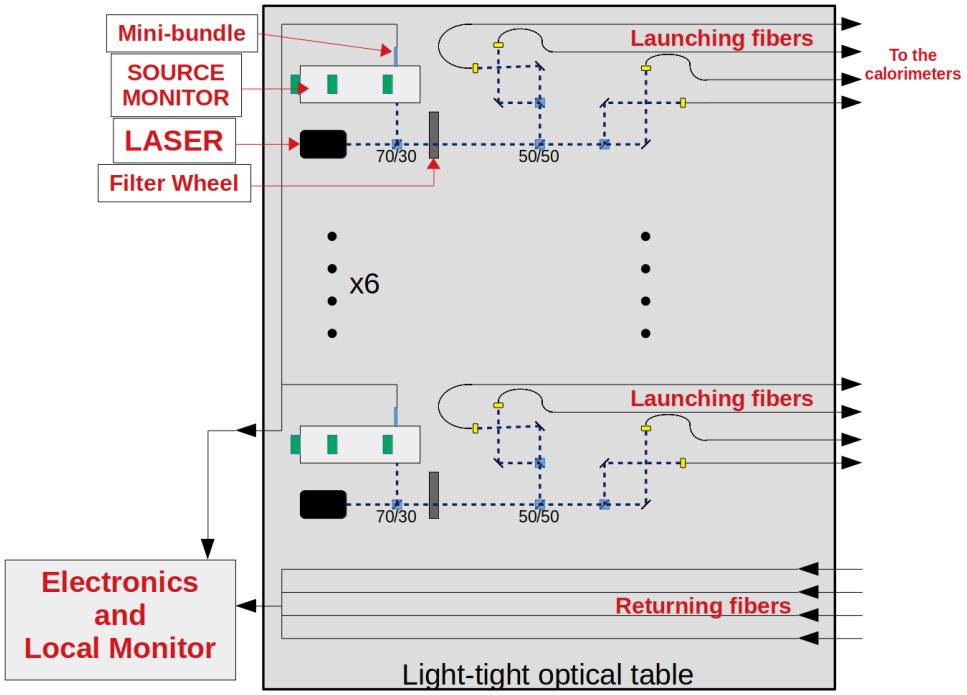
→ Some of the shift in P1 observed between Run1 and Run2 is due to the temperature effect.

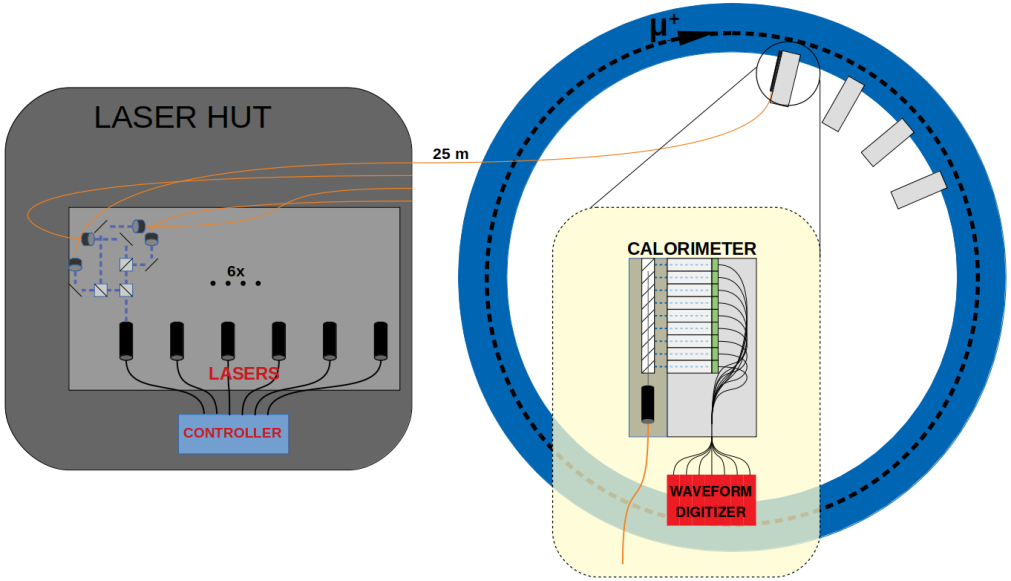




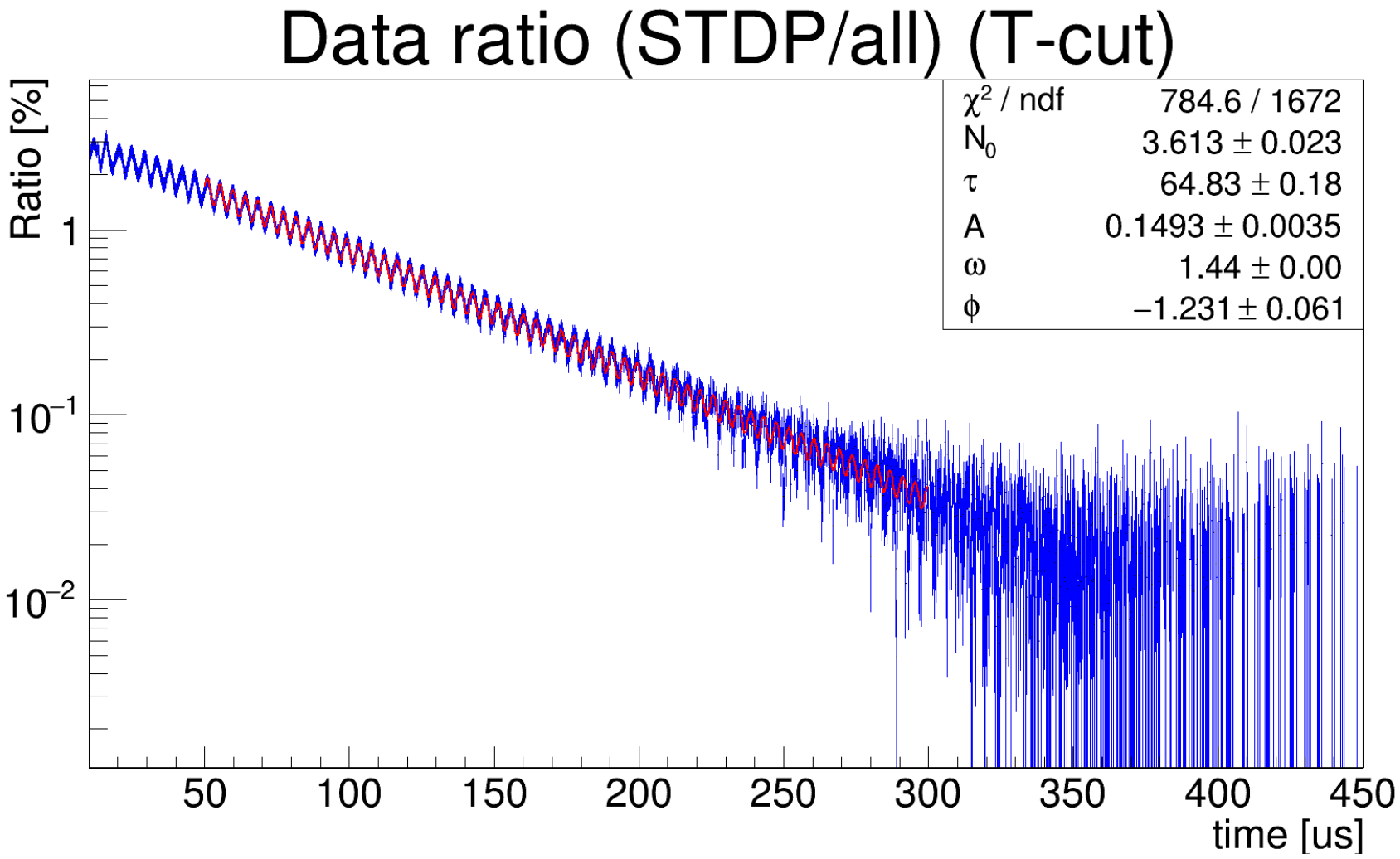
P1 parameters show a systematic **shift:** +1.2%/GeV (+28%)

Backup


Mini-bundle
SOURCE MONITOR
LASER
Filter Wheel
Launching fibers
To the calorimeters
70/30
50/50
x6
Launching fibers
70/30
50/50
Electronics and Local Monitor
Returning fibers
Light-tight optical table


LASER HUT
25 m
6x
LASERS
CONTROLLER
μ+
CALORIMETER
WAVEFORM DIGITIZER

Backup


Data ratio (STDP/all) (T-cut)
Ratio [%]
1
10^{-1}
10^{-2}
50
100
150
200
250
300
350
400
450
time [us]
χ^2 / ndf 784.6 / 1672
N_0 3.613 ± 0.023
τ 64.83 ± 0.18
A 0.1493 ± 0.0035
ω 1.44 ± 0.00
ϕ −1.231 ± 0.061