

ProtoDUNE Dual Phase light data analysis

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-
- ◆ PMT calibration status
 - ◆ Alternative LCS
 - ◆ S1 characterization

PMT calibration status

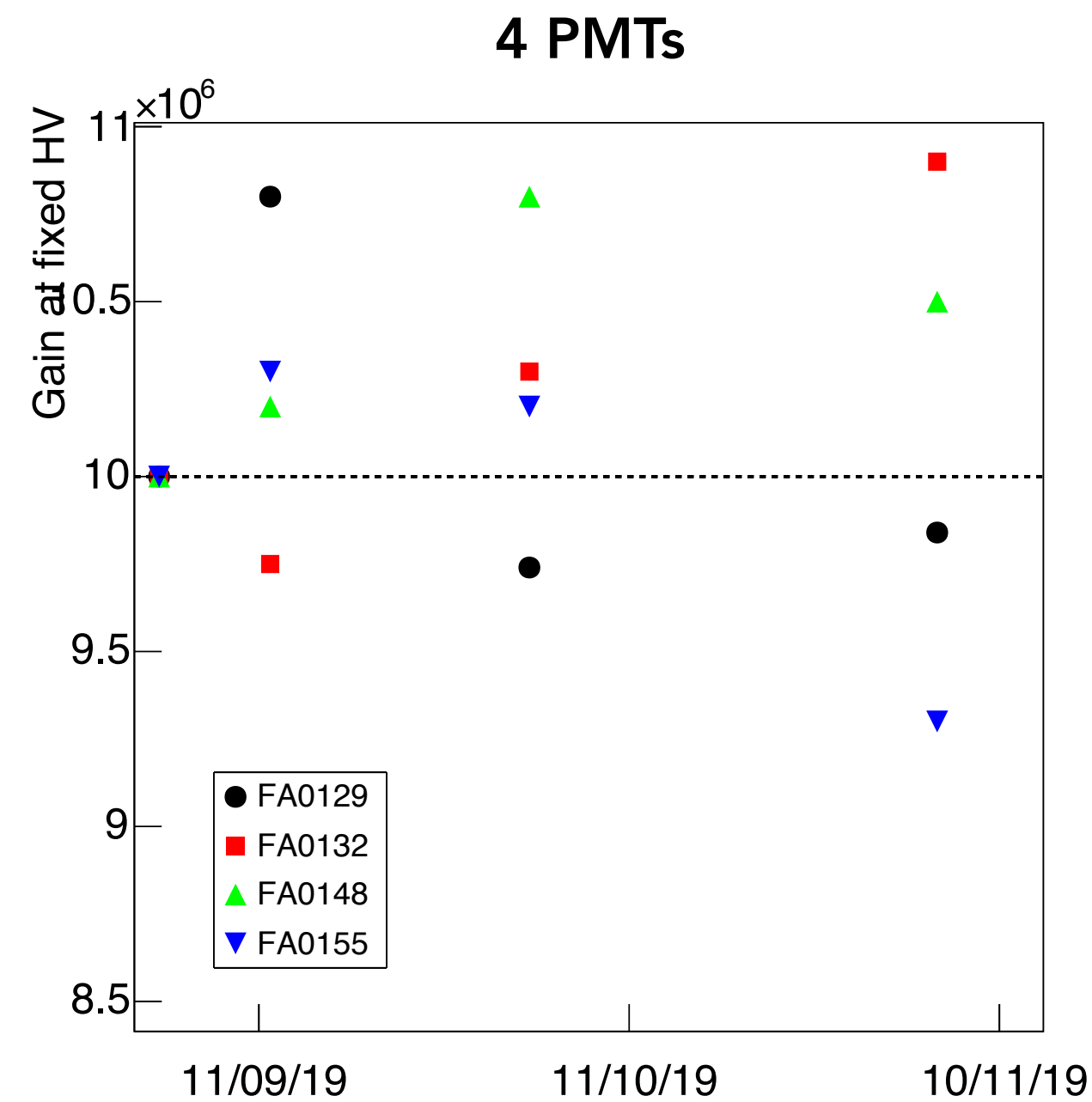
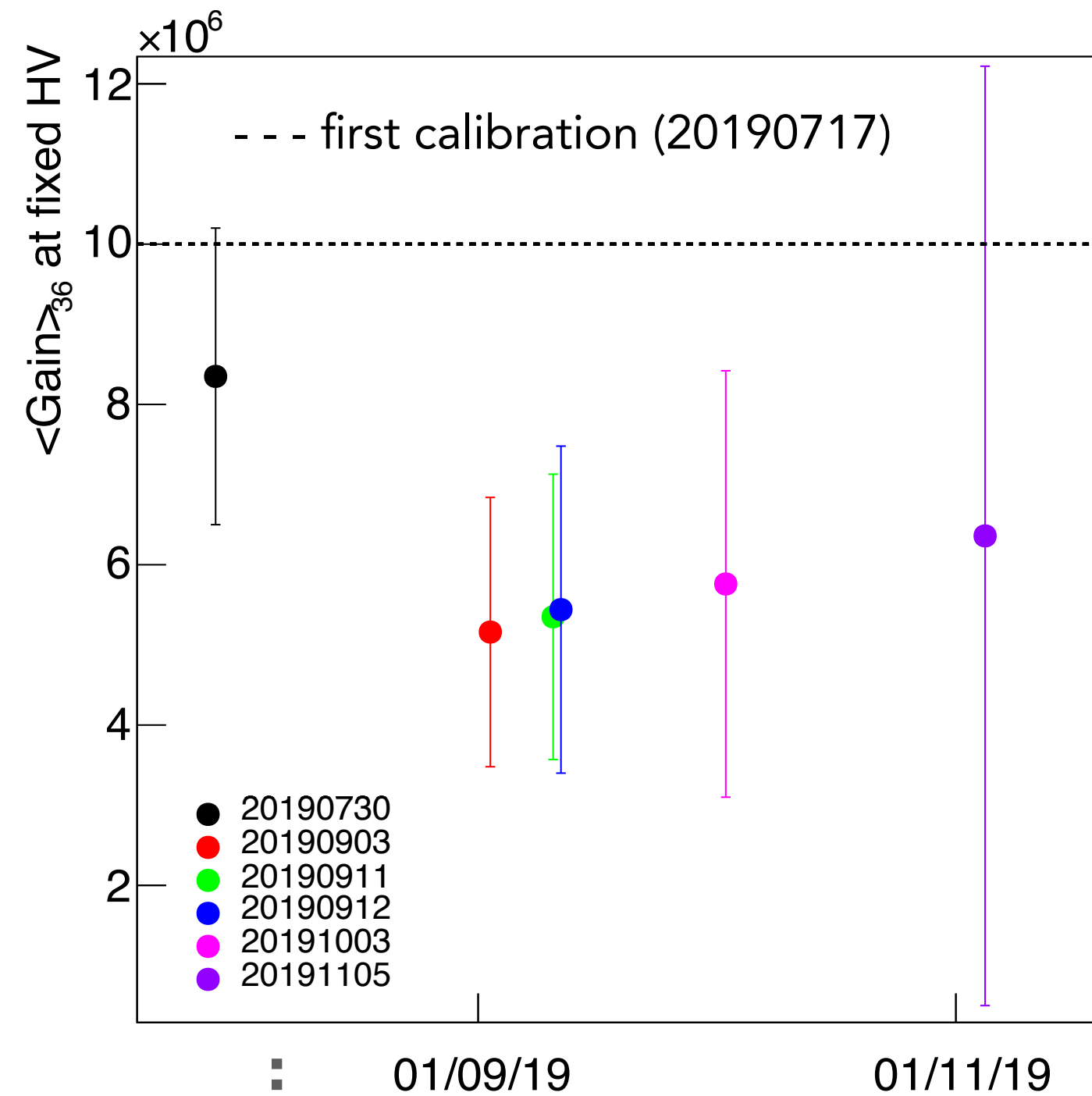


Gain vs High Voltage

- * Black: done
- * Red: to do
- * Orange: ongoing

#	Runs	Date	Person/people taking data	#Ev	LEDs	LED connected to top fibers?	#PMTs	HV range	Crosstalks?	W (us)
1	510-533	30/07/2019	Ana	20k	1-6 (separate)	NO	36	Customized	NO	1.2
2	862-897	03/09/2019	Daniel	20k	1-6 (separate)	NO	36	1100-1500 V (75 V steps)	NO	1.2
3	950-956	11/09/2019	Antonio/Inés	20k	1-6 (same time)	NO	36	1500-1700 V (50 V steps)	NO	1.2
4	1006-1013	12/09/2019	Antonio/Inés	20k	1-6 (same time)	NO	36	1500-1750 V (50 V steps)	NO	1.2
5	1284-1291	03/10/2019	Carmen/Diana	20k	2,3,4,5 (same time)	YES	24	1400-1750 V (50 V steps)	NO	1
07/10/2019 —> Change of the trigger inputs (black box from trigger-in to ADC channel #53)										
6	1367-1373	08/10/2019	Daniel/Ana	20k	2,3,4,5 (same time)	YES	24	1450-1750V (50 V steps)	YES	1
7	1637-1644	21/10/2019	Diana	20k	1-6 (same time)	NO	32	1450-1750V (50 V steps)	YES	1
8	1669-1676	29/10/2019	Ana	50k	1-6 (same time)	NO	32	1450-1750V (50 V steps)	YES	1
30/10/2019 —> LCS trigger done with SiPM (ch#55) & black box is disconnected										
9	1700-1707	30/10/2019	Diana/Ana	20k	1-6 (same time)	NO	32	1450-1750V (50 V steps)	~NO	1
10	1779-1786	05/11/2019	Daniel	20k	1-6 (same time)	NO	32	1450-1750V (50 V steps)	~NO	1

Gain stability (from G vs HV measurements)



◆ Comments:

- Plan: recover the previous trigger configuration (black box)
- Attenuate the trigger signal (hardware) to mitigate/eliminate the crosstalks
- The PMT HVs have been tuned several times to keep the gain constant:
 - Initial values (CIEMAT)
 - 17/07 (v1720, first calibration at CT)
 - 30/07 (first calibration w/ v1740)
 - 12/09
 - 05/11 (>20% of G variation)

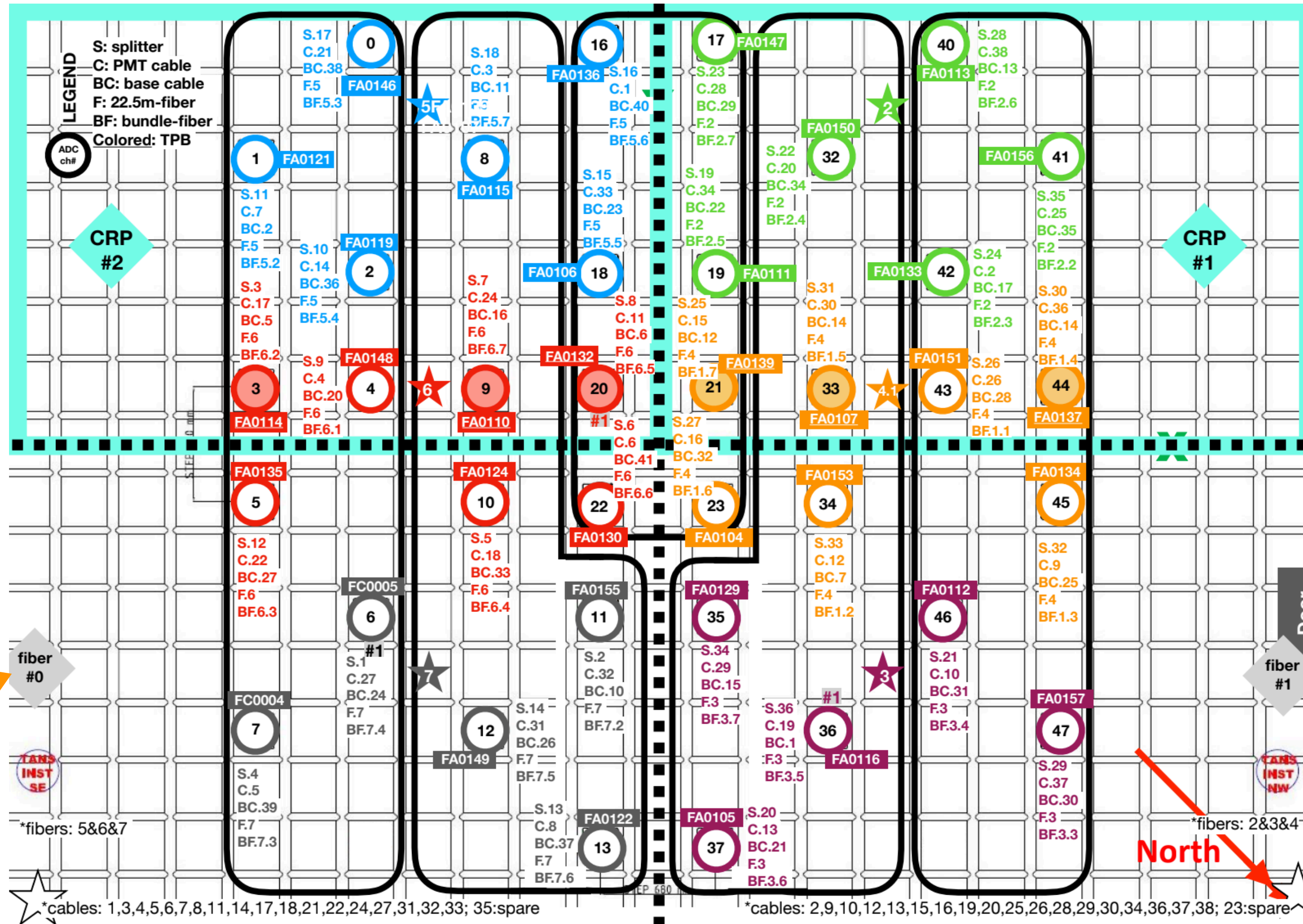
Find a better way of showing these results!

- ◆ Average gain ~36 PMTs at the HV for $1e7$ obtained in first calibration in LAr (20190717)
- ◆ There is a big dispersion among PMTs! (large error bars)

Alternative LCS



Alternative LCS layout



Alternative LCS:

- Goal: calibration with diffuse light from the top of the detector
- System based on 2 optical fibers at the top
- This option reduces the number of fibers

PMT calibration with top fibers

Crosstalks since
07/10!

8

#Run	Date	Measurement	LED	LED voltage (V)	Target PMT gain (20190912)
1382	09/10	Gain stability	1 (top left)	19.5	1E+08
1383	09/10	Gain stability	4 (top right)	19.5	1E+08
1384	09/10	Gain stability	1 & 4 (top both sides)	19.5	1E+08

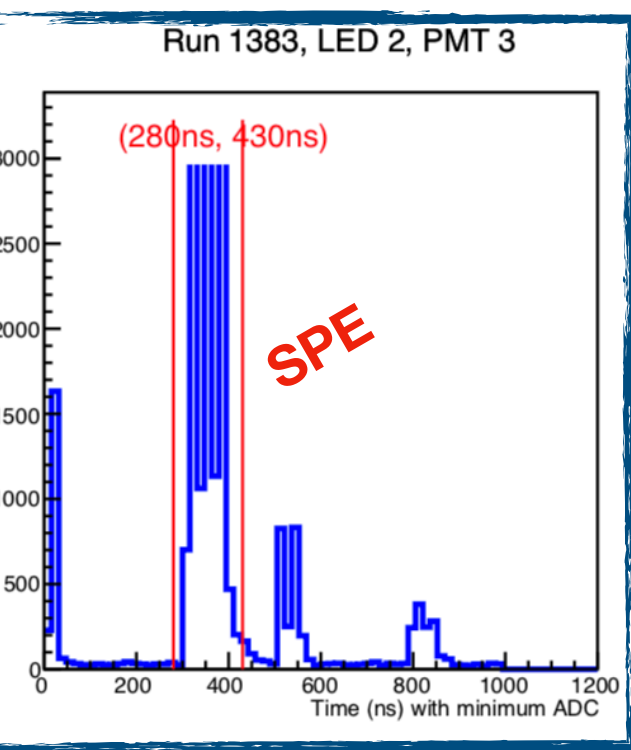
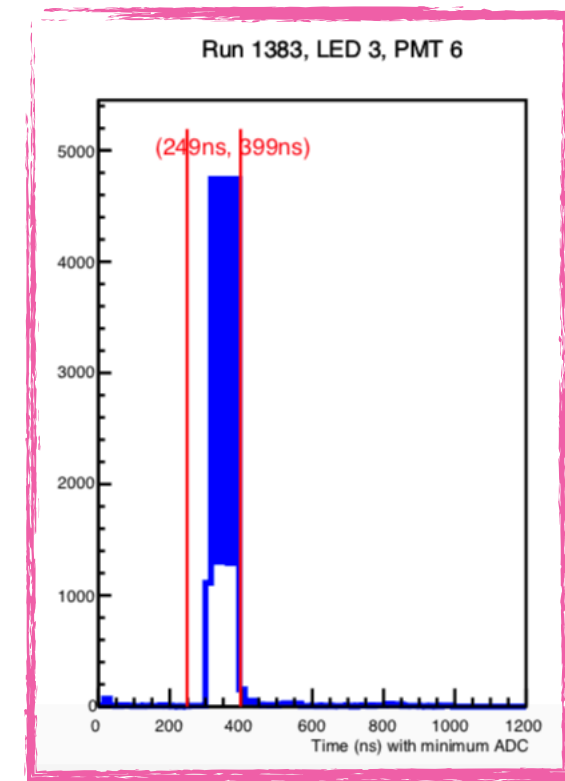
- ◆ **Other runs** were taken before but they were not “good ones”: PMT gain was too low, time window was too long, waveforms were too affected by crosstalks... we learnt from them!
- ◆ **Runs #1382-1384** give us an idea of the performance of the system
- ◆ Results from run #1383 (next slide) show that **29/32 PMTs** can be calibrated ($\Delta G = -12 \pm 11\%$) using the alternative LCS with LEDs at maximum power (19.5 V)

SN	Expected gain	Obtained gain	ΔG (%)
FA0104	9.16E+07	8.21E+07	-10
FA0105	8.91E+07	6.67E+07	-25
FA0107	1.02E+08	9.41E+07	-8
FA0110	1.02E+08	8.93E+07	-12
FA0112	1.01E+08	9.05E+07	-11
FA0114	1.01E+08	8.67E+07	-14
FA0116	9.36E+07	7.9E+07	-16
FA0122	1.01E+08	8.79E+07	-13
FA0124	7.82E+07	8.84E+07	13
FA0129	1.00E+08	8.37E+07	-16
FA0130	1.03E+08	8.95E+07	-13
FA0132	1.03E+08	8.44E+07	-18
FA0135	1.02E+08	7.62E+07	-25
FA0139	9.91E+07	9.51E+07	-4
FA0148	9.68E+07	8.84E+07	-9
FA0149	9.3E+07	7.89E+07	-15
FA0151	9.88E+07	1.04E+08	6
FA0153	9.77E+07	1.02E+08	4
FA0155	9.65E+07	8.19E+07	-15
FC0004	1.01E+08	8.43E+07	-16
FC0005	1.05E+08	6.65E+07	-37

* Comparison with regular PMT calibration (03/10/2019) —> table!

Run #1383, Oct 9, grids @ 6.5 kV

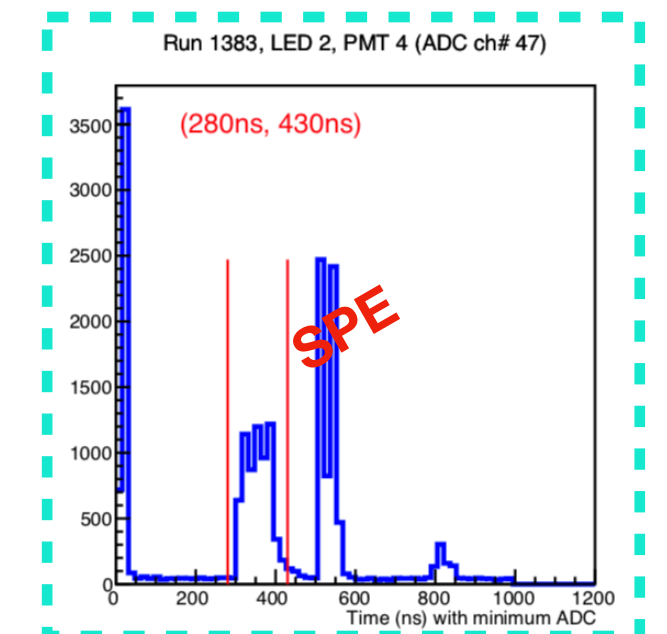
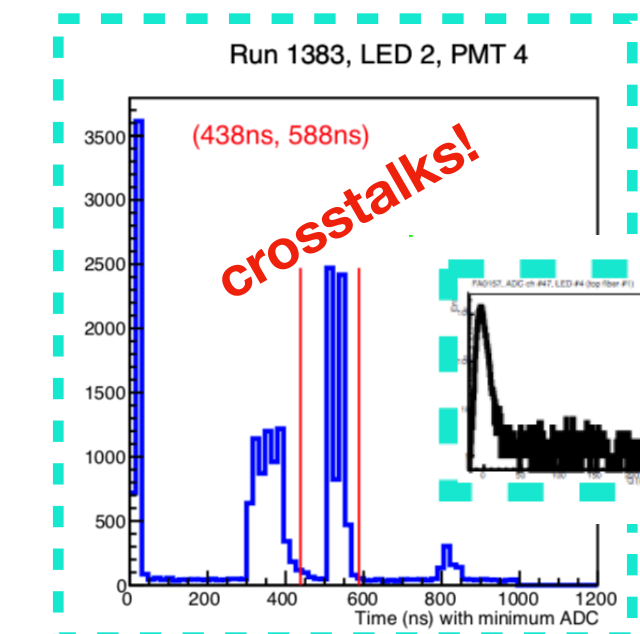
* Oscilloscope PMTs



- ◆ LED #4 (fiber #1)
- ◆ 19.5 V
- ◆ PMTs @ 1e8

◆ 29/32 PMTs ✓
 ◆ 3/32 PMTs ✗

best result



◆ Best result:

- Run #1383
- LED #4 (fiber #1) @ 19.5 V
- PMTs @ 1e8
- **29 / 32 PMTs can be calibrated**
- 3 PMTs see too much light —> lower LED voltage next time

◆ Plan (36 PMTs):

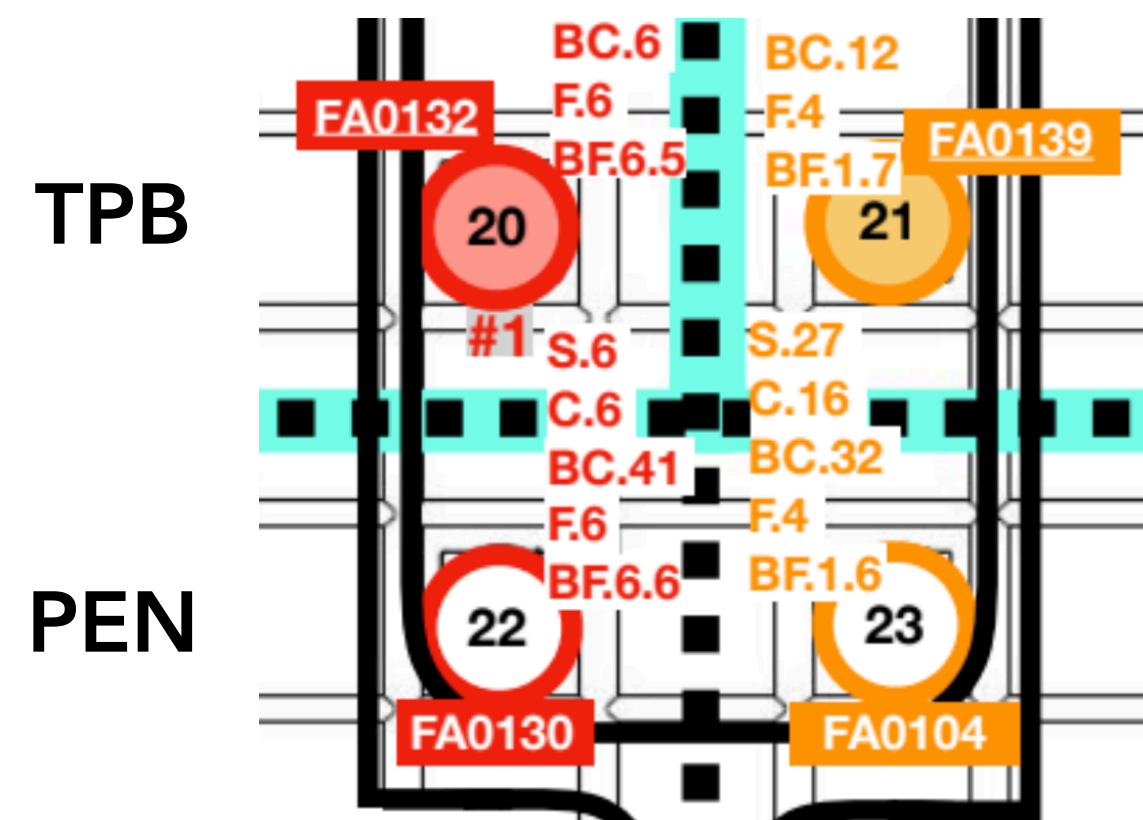
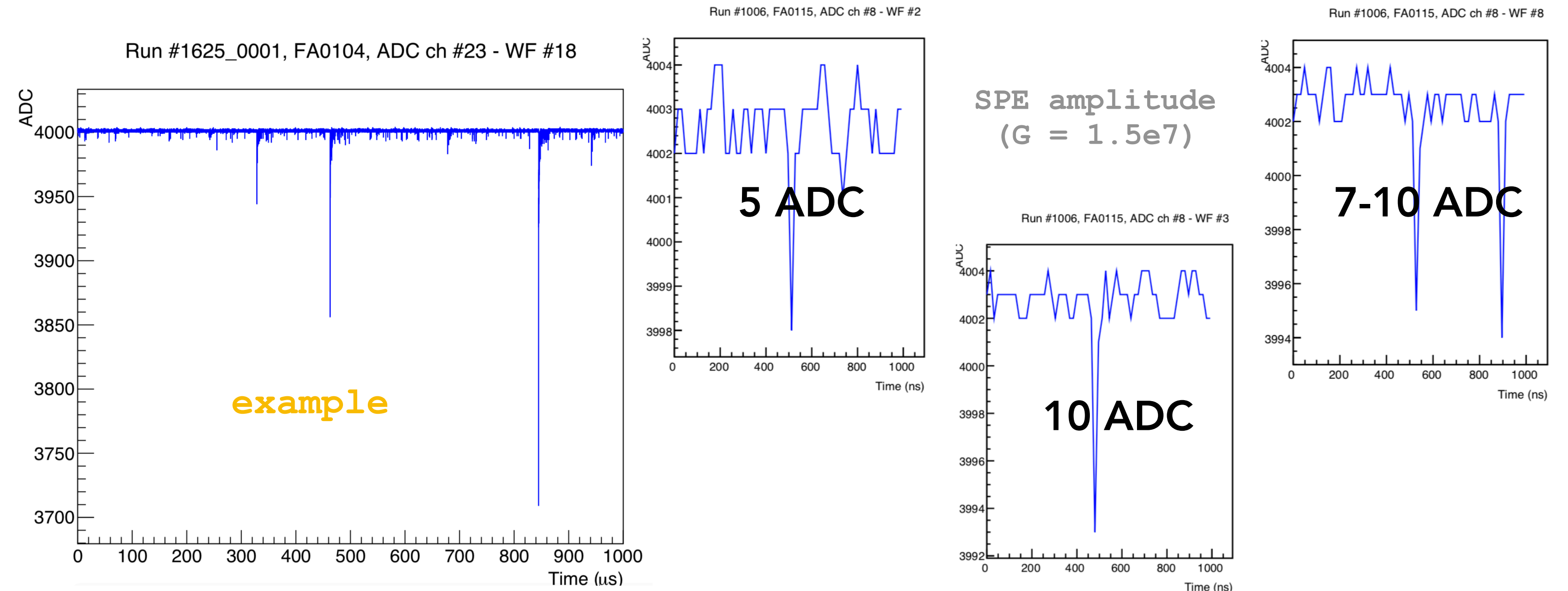
- Reconnect the 4 oscilloscope PMTs to ADC
- Connect one LED to the top fiber #1 (right one) and calibrate in the previous conditions
- Do a scan on the LED voltage to calibrate **all the PMTs**
- Recover the baseline configuration and perform regular calibration right after to compare
- Take also G vs HV curves

S1 characterization

S1 signal: peak counting

◆ Run 1625 (18/10/2019)

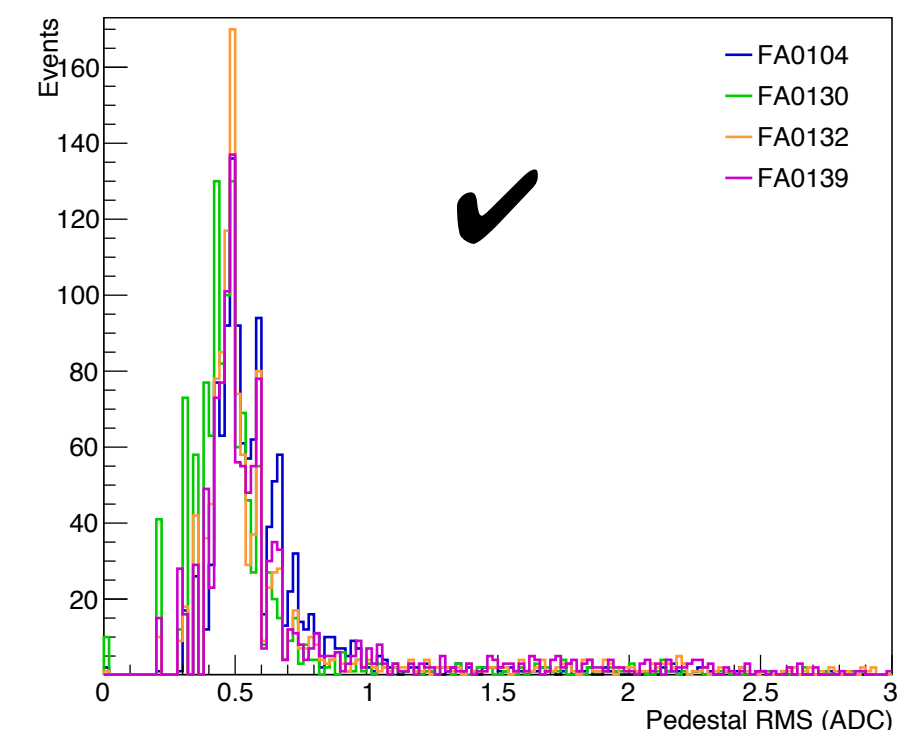
- Random trigger
- 30k events (250 subruns)
- **Only 1.3k events processed!**
- Fields off
- Time window: 1 ms
- Sampling: 16 ns
- PMTs at $G=1e7$ (20190912)



Event 18 --> S1 signal! Time: 328.448 us; Amplitude: 47.25 ADC; Charge: 1.74099e+08 (e)
 Event 18 --> S1 signal! Time: 462.72 us; Amplitude: 145.25 ADC; Charge: 4.63776e+08 (e)
 Event 18 --> S1 signal! Time: 844.976 us; Amplitude: 292.25 ADC; Charge: 1.05483e+09 (e)
 Event 18 --> S1 signal! Time: 941.696 us; Amplitude: 27.25 ADC; Charge: 7.65645e+07 (e)

◆ S1 identification algorithm:

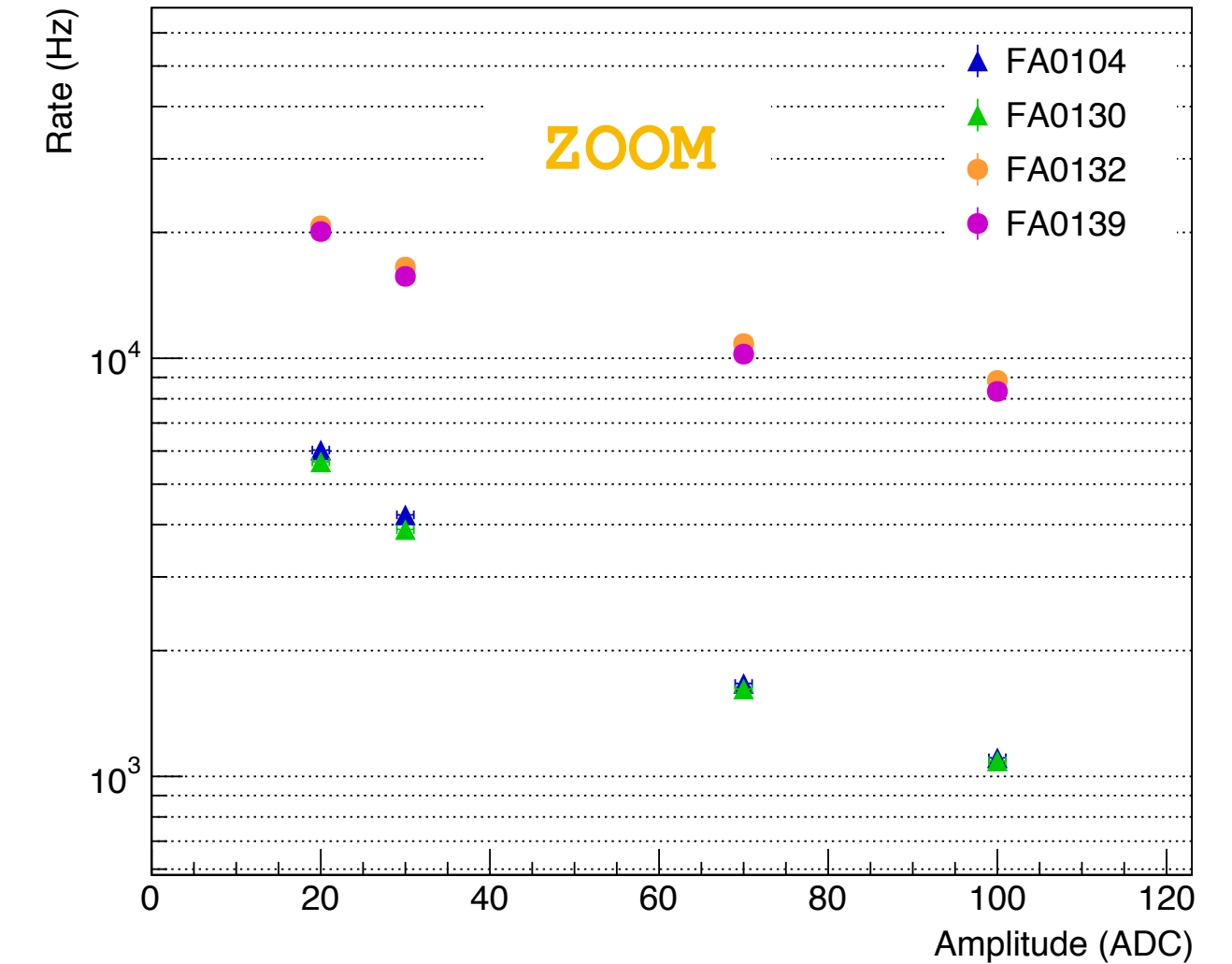
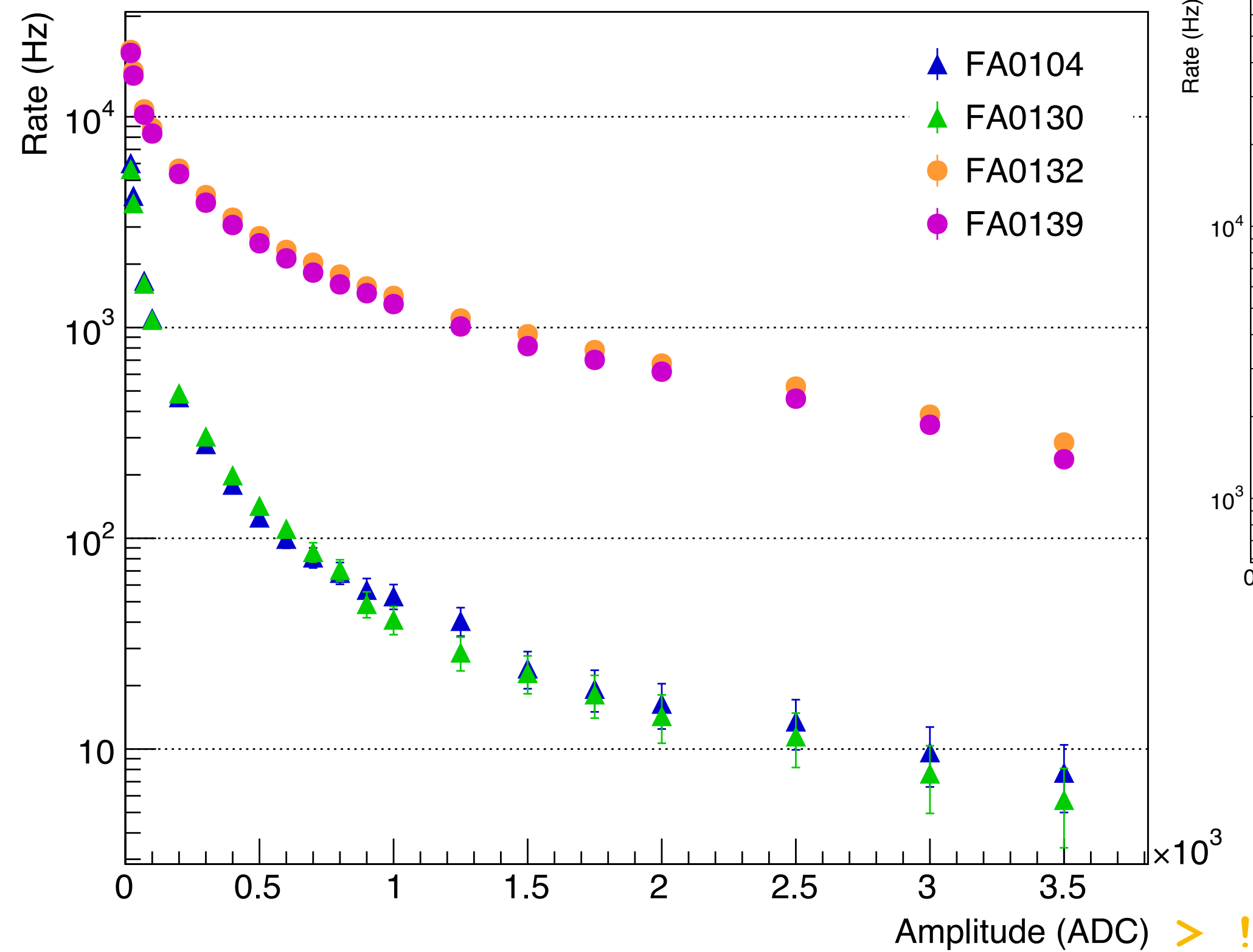
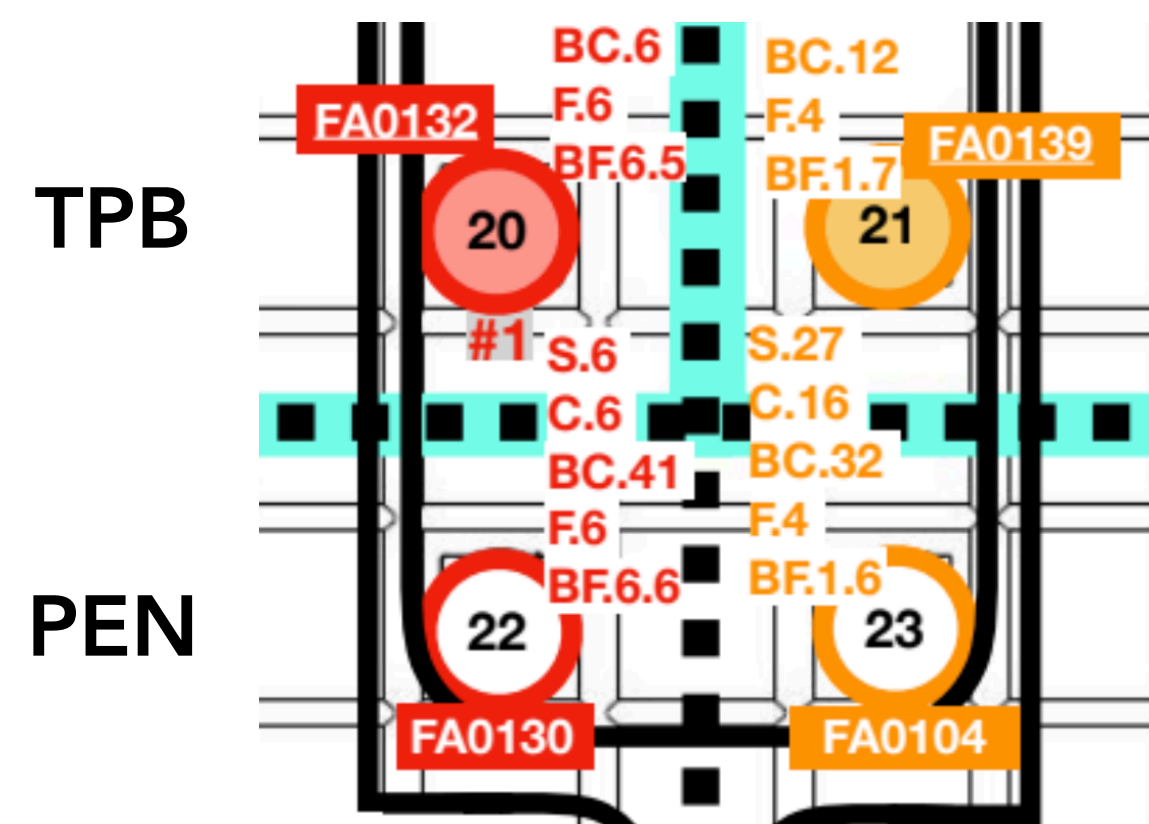
- pedestal = 20 first samples with ped_RMS < 3 ADC
- amplitude = pedestal - minimum
- S1 signal if amplitude > 20 ADC
- If S1 is found, the 16 us window after it is ignored!



S1 signal: rate vs amplitude

◆ Run 1625 (18/10/2019)

- Random trigger
- 30k events (250 subruns)
- **Only 1.3k events processed!**
- Fields off
- Time window: 1 ms
- Sampling: 16 ns
- PMTs at G=1e7 (20190912)



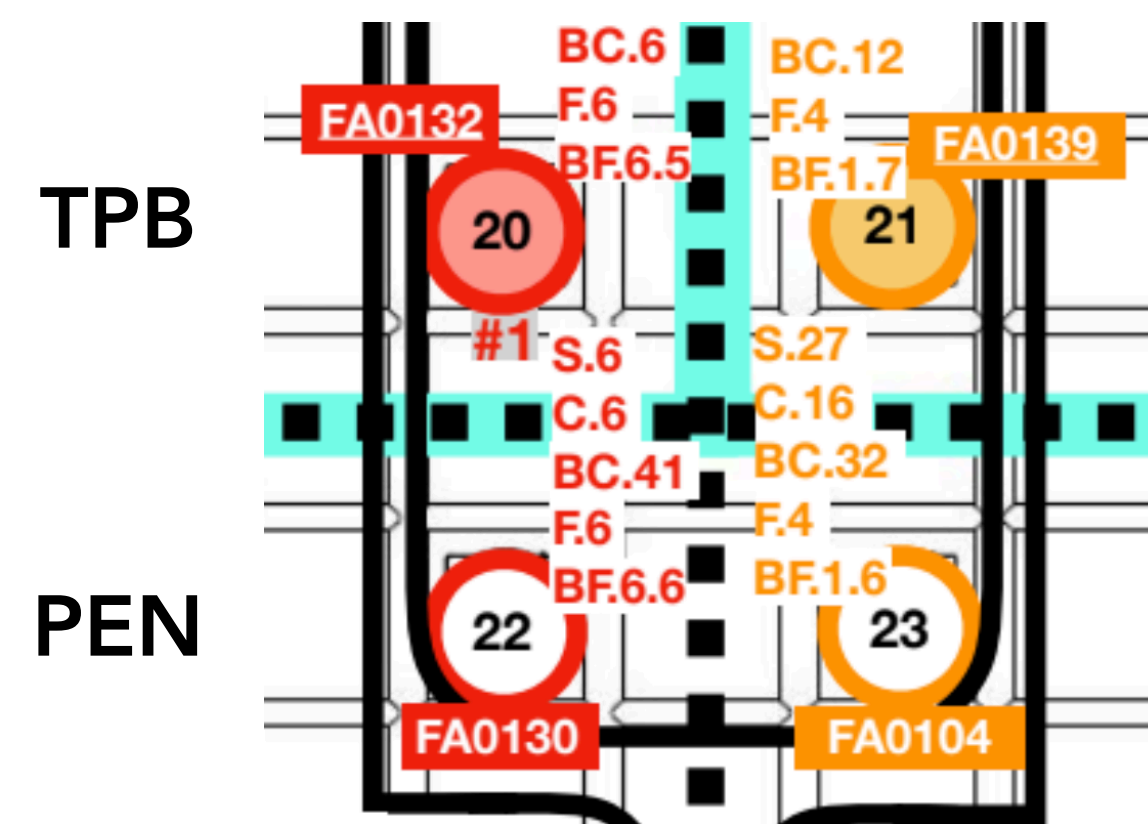
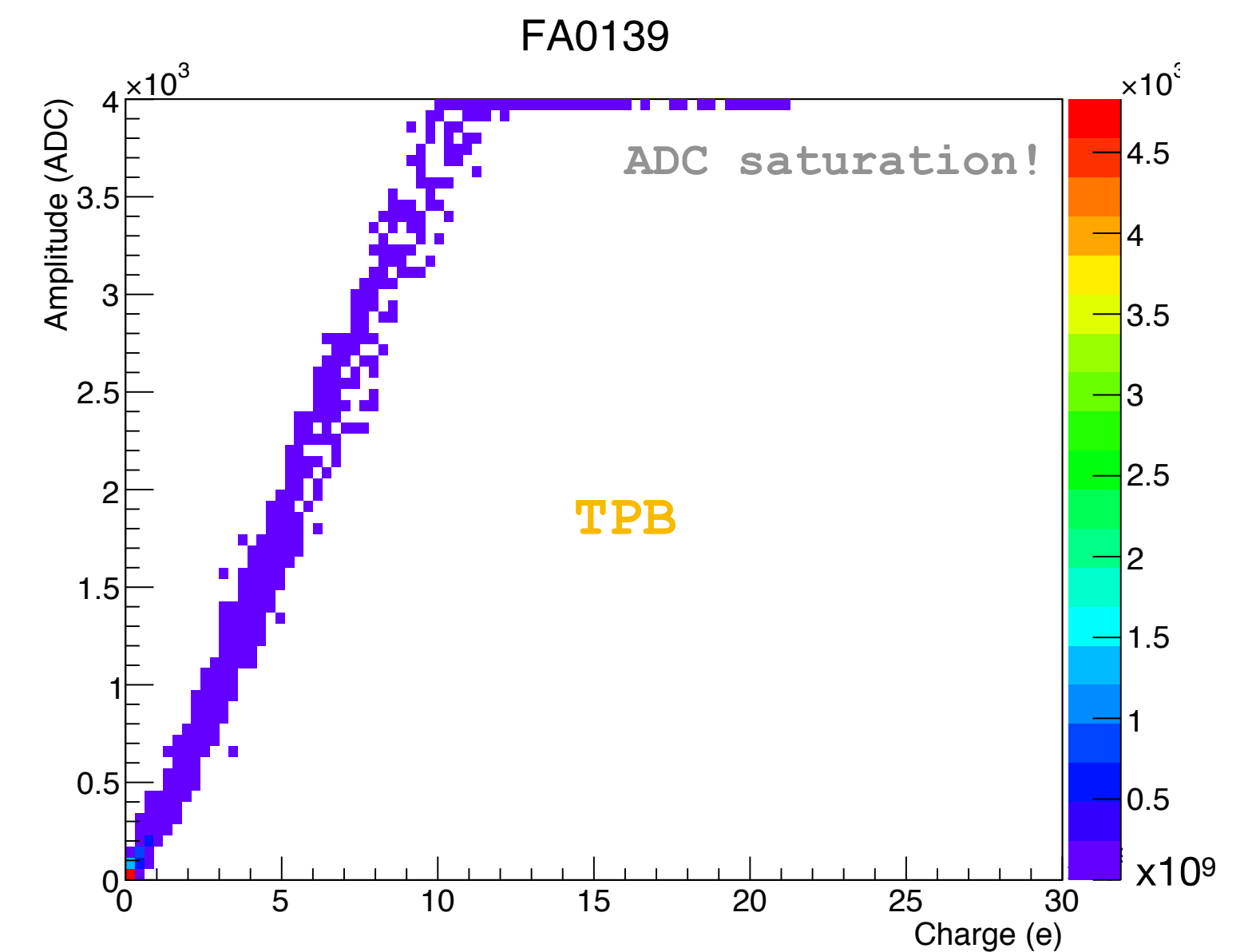
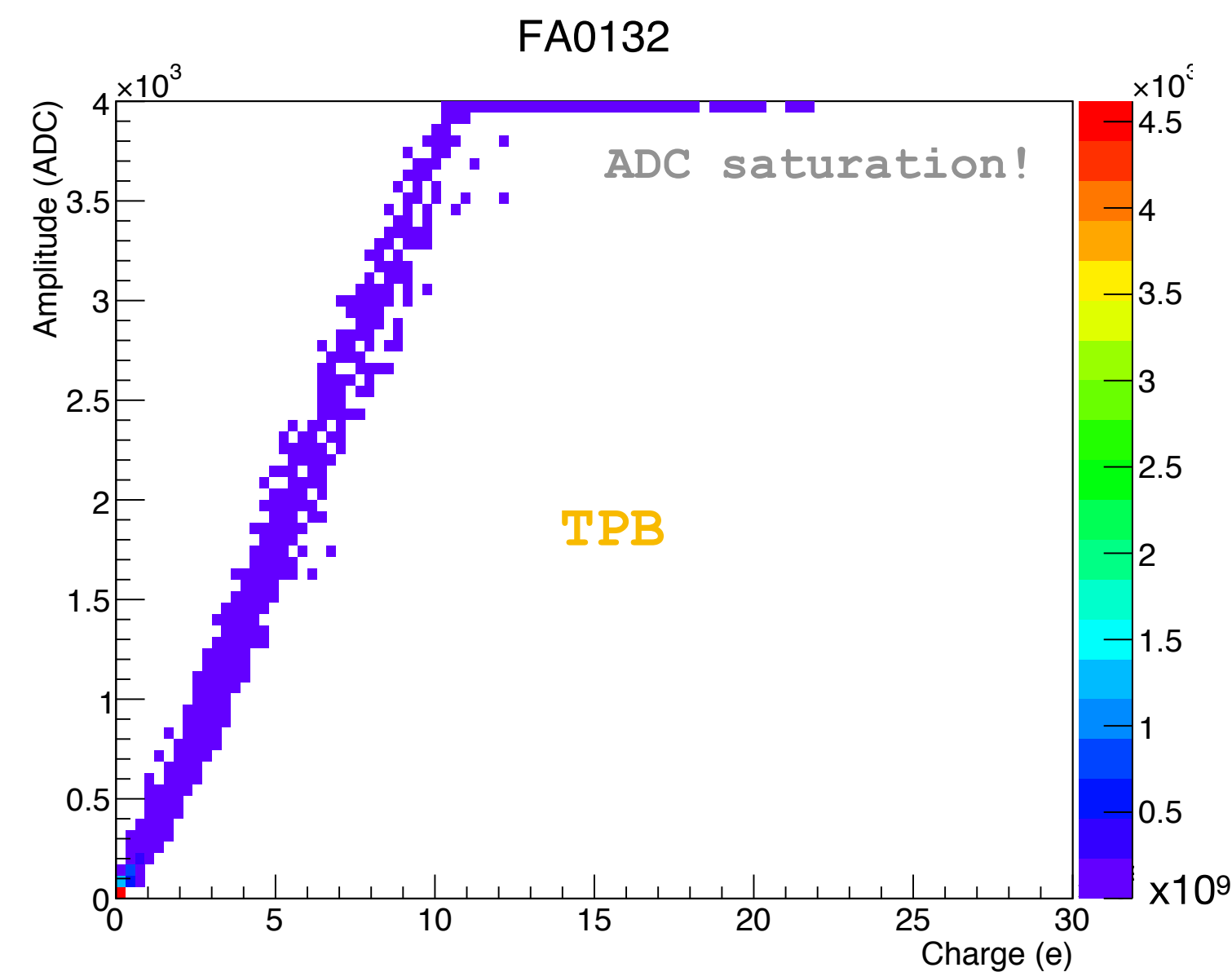
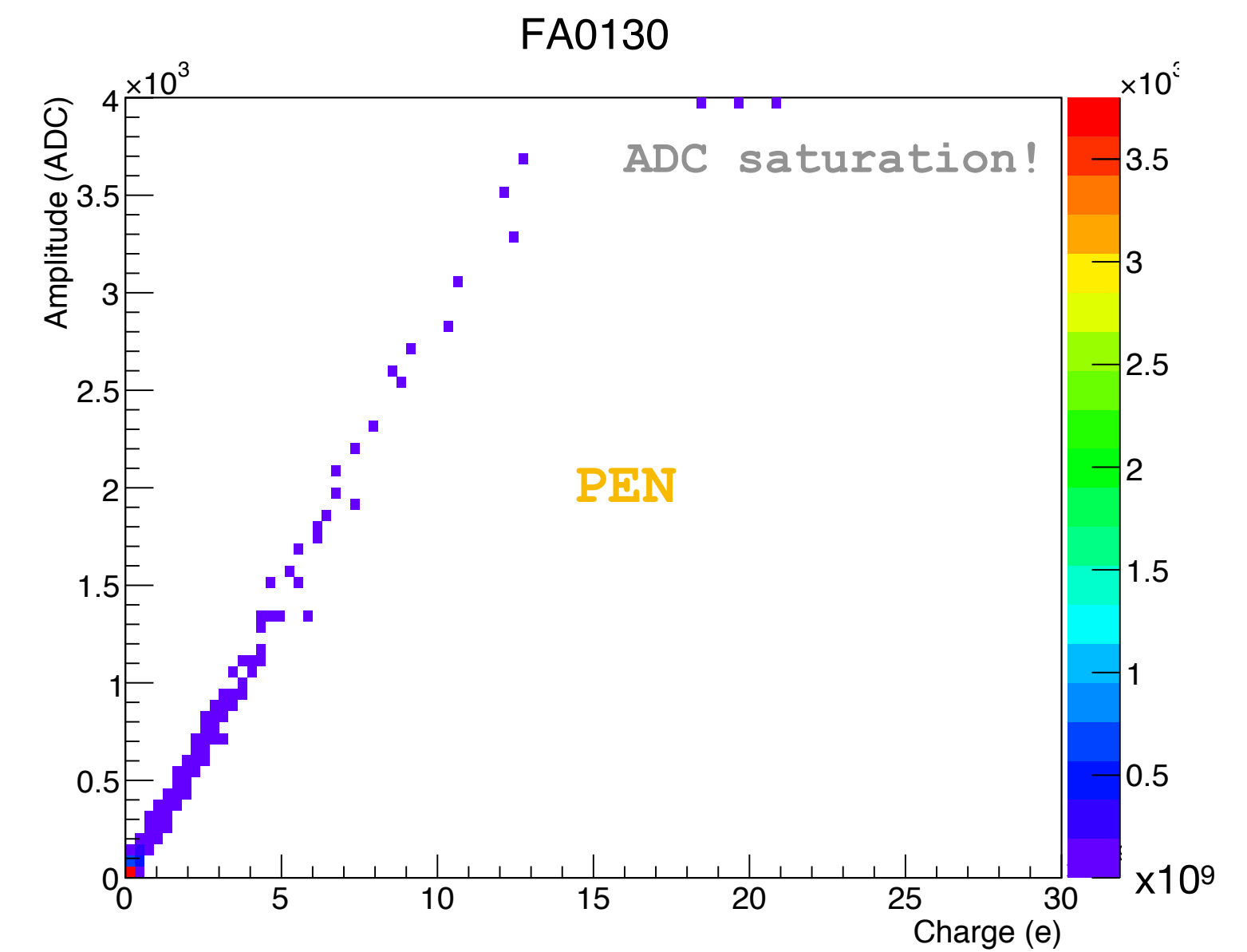
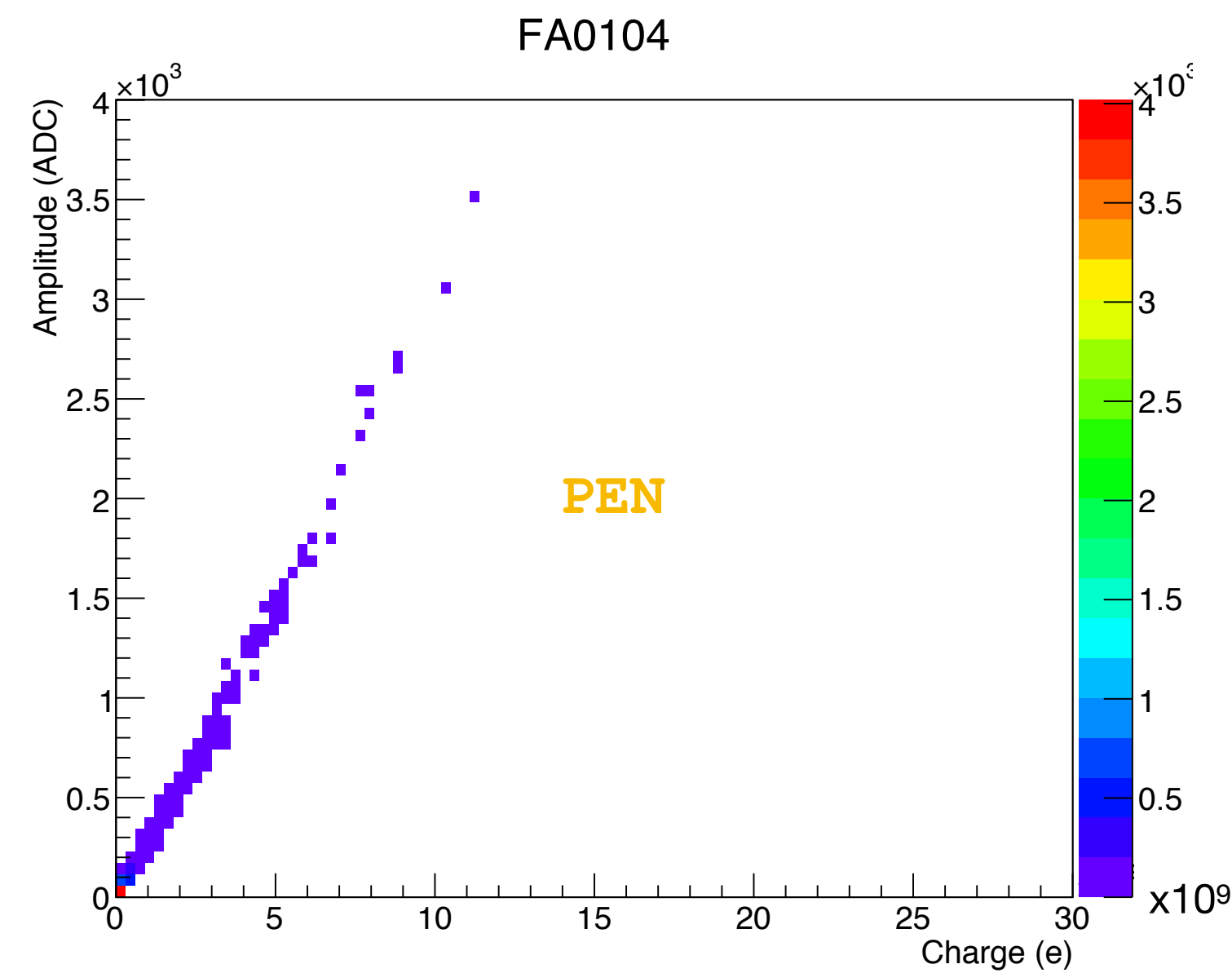
- ◆ S1 rate = #S1 signals / effective time
- ◆ effective time = (time window x #events) - (#S1 signals x 16 us)
- ◆ **Results:**
 - TPB PMT: S1 rate ~ 15-20 kHz
 - PEN PMT: S1 rate ~ 4-6 kHz

S1 signal: amplitude vs charge

Integration window: 96 ns
 (-2bins,+4bins) = (-32ns,+64ns)

◆ Run 1625 (18/10/2019)

- Random trigger
- 30k events (250 subruns)
- **Only 1.3k events processed!**
- Fields off
- Time window: 1 ms
- Sampling: 16 ns
- PMTs at G=1e7 (20190912)



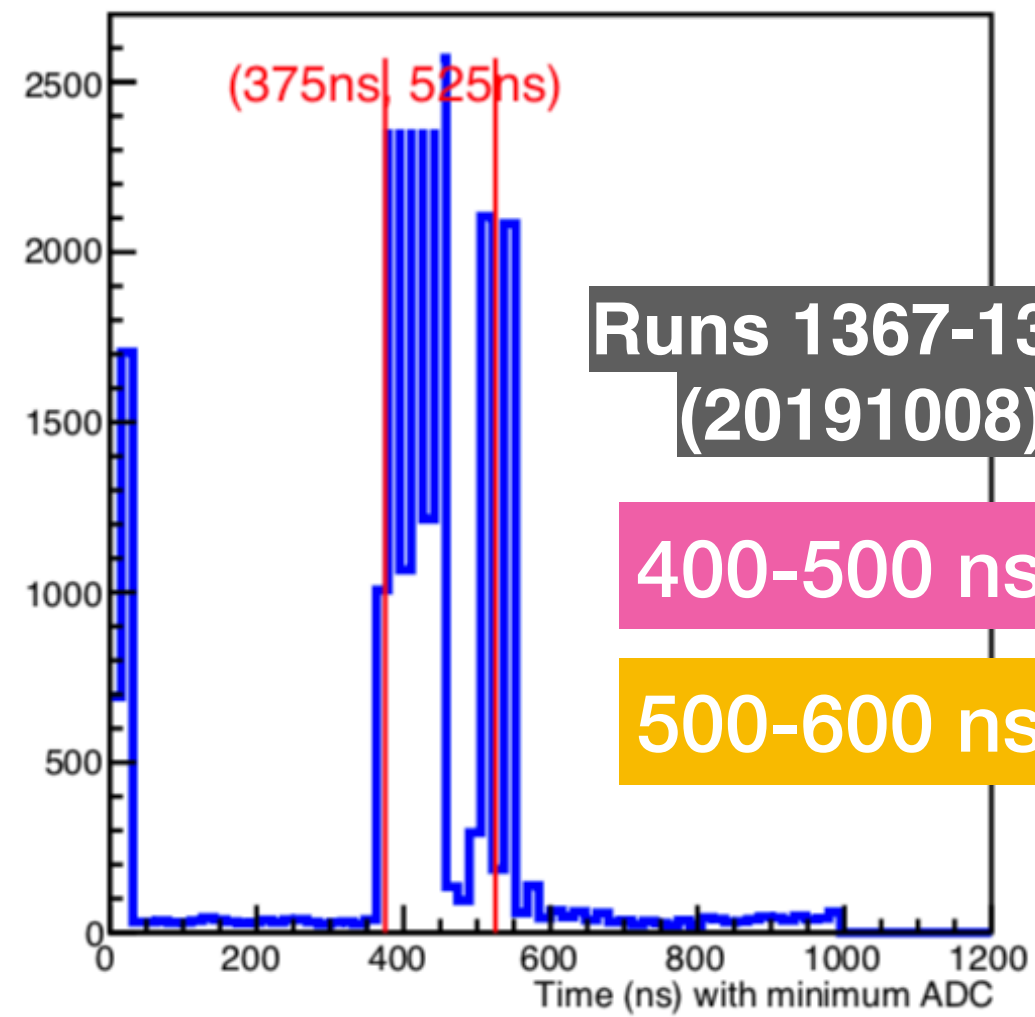
S1 signal: next steps

- ◆ Obtain same results with more statistics (30k vs 1.3k)
- ◆ Analyze other runs (PMT gain = $1e6$ to avoid ADC saturation? TPB & PEN equalized in gain?)
- ◆ Study more PMTs and look for position dependencies (not-centered? corners?)
- ◆ Characterize the SPE amplitude vs PMT gain in order to define the threshold

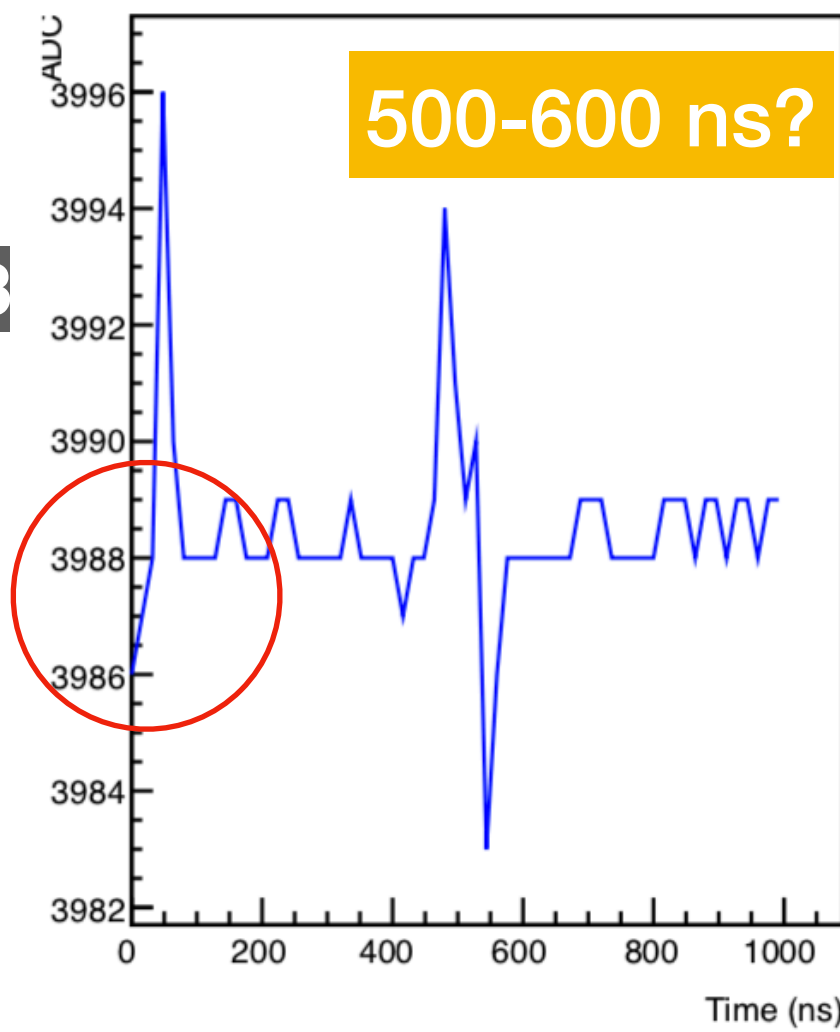
Backup



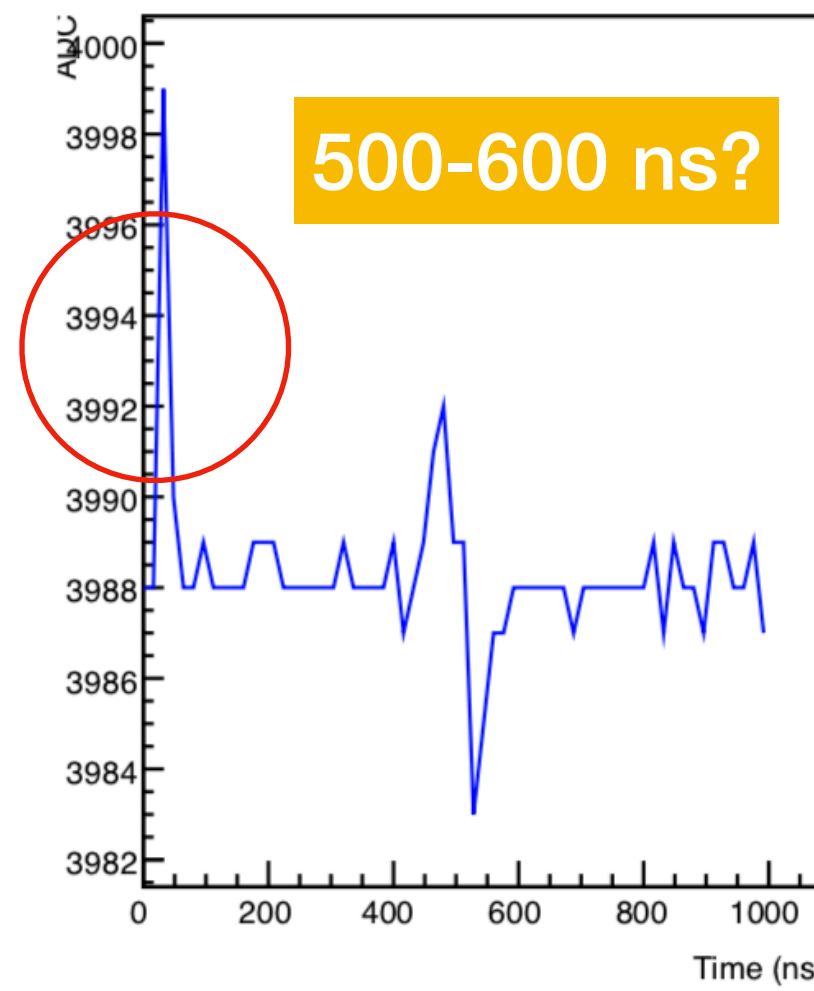
Run 1369, LED 2, PMT 4



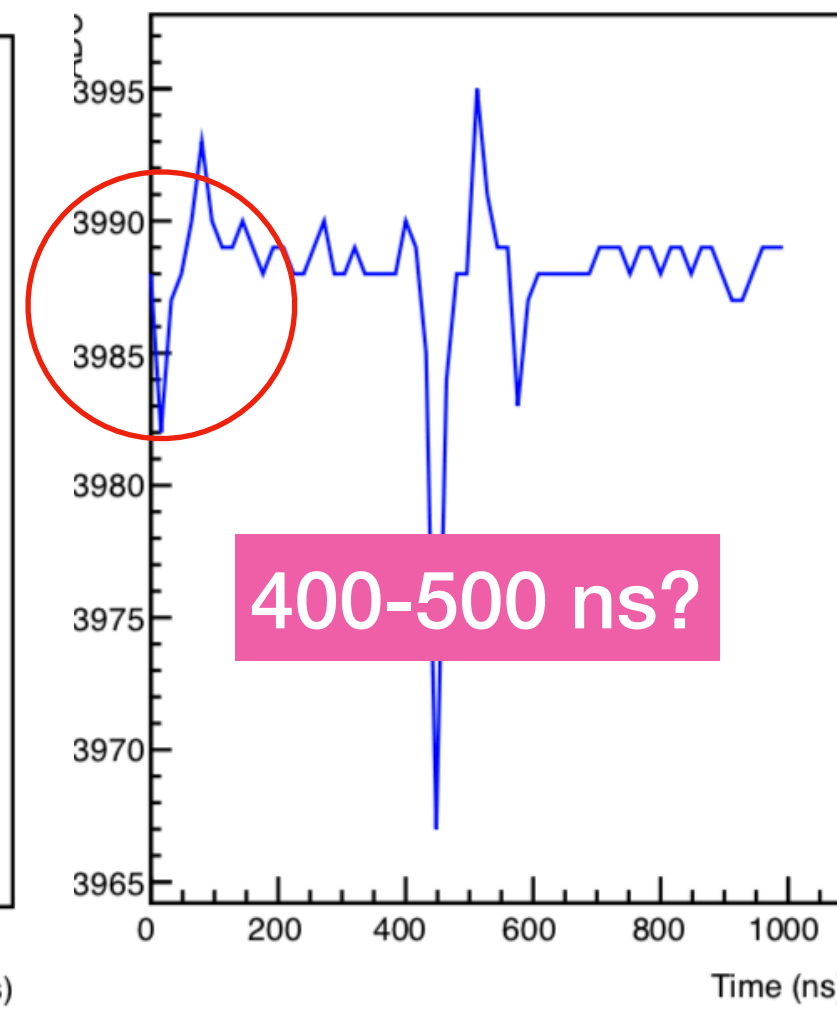
Run #1369, FA0157, ADC ch #47 - WF #30



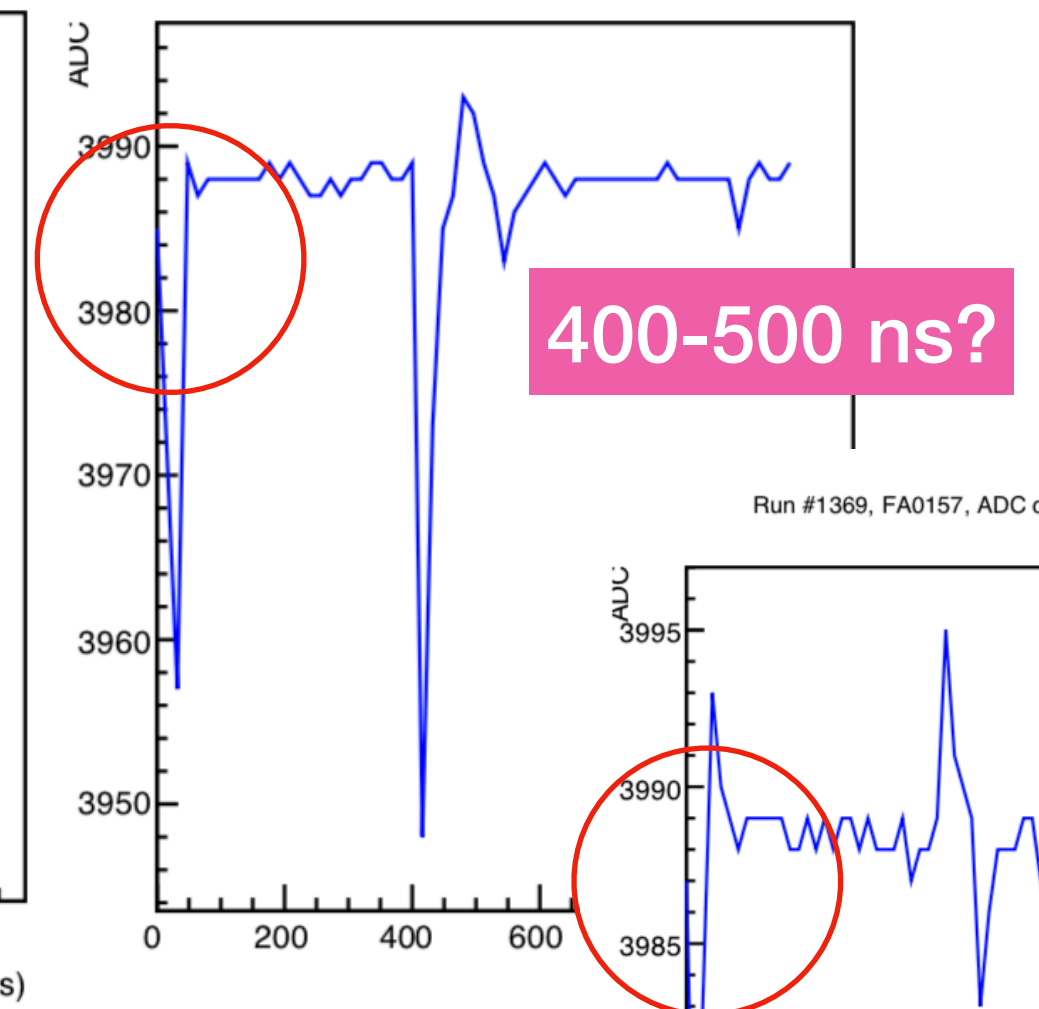
Run #1369, FA0157, ADC ch #47 - WF #9



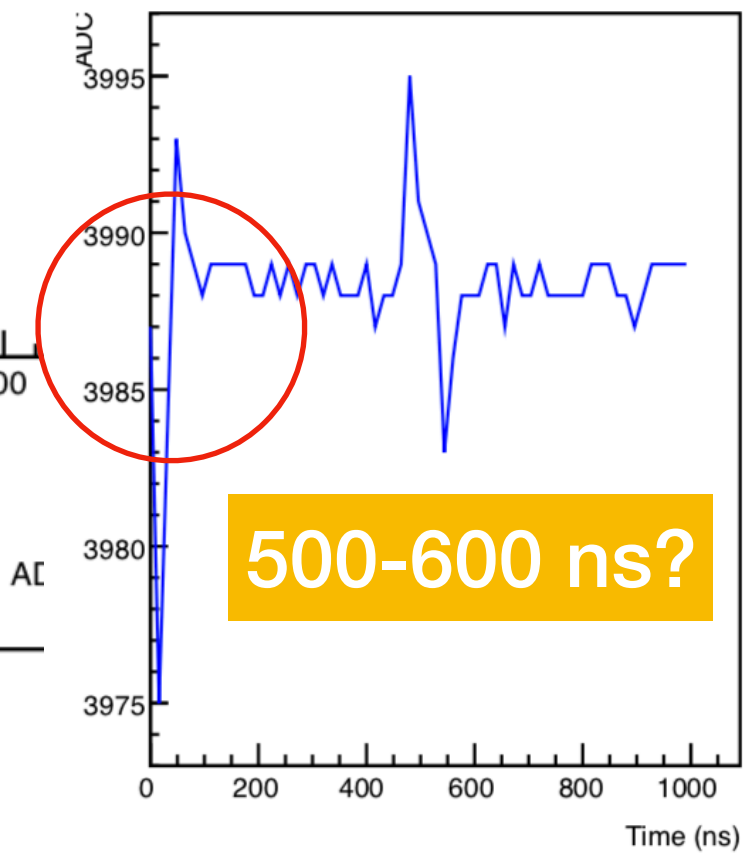
Run #1369, FA0157, ADC ch #47 - WF #4



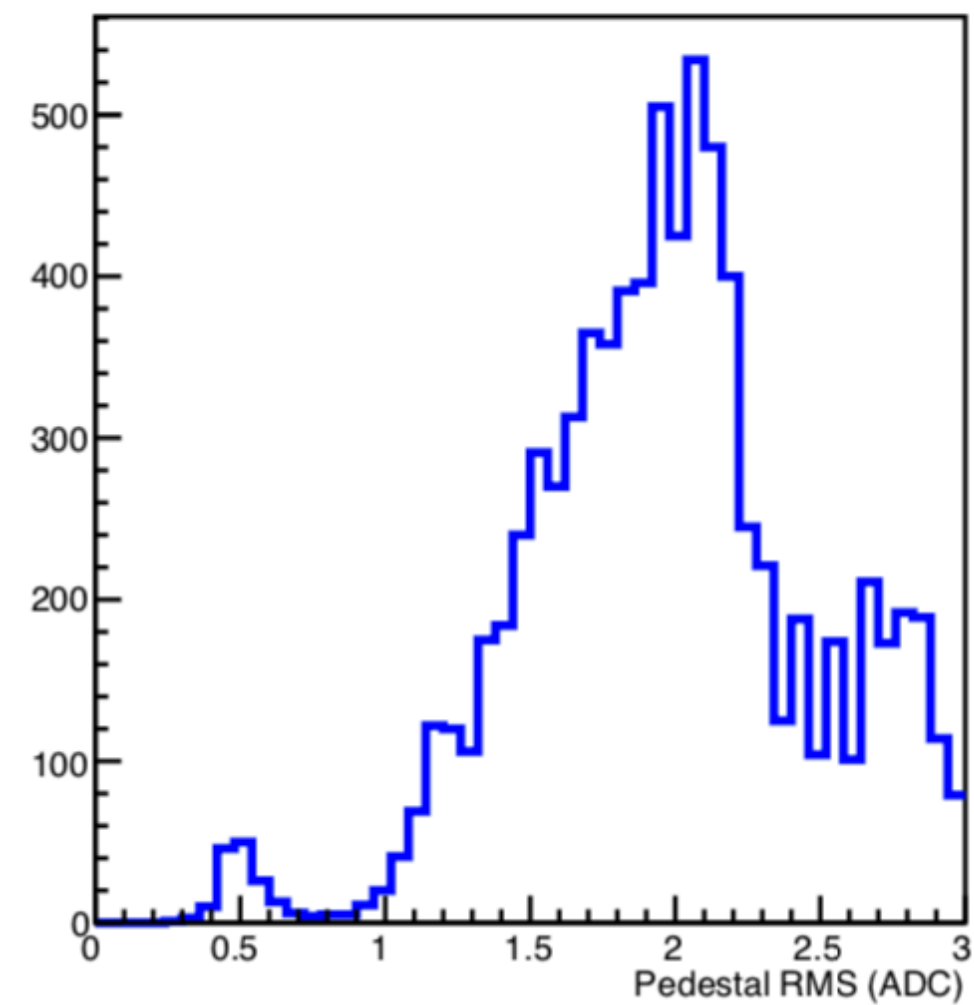
Run #1369, FA0157, ADC ch #47 - WF #46



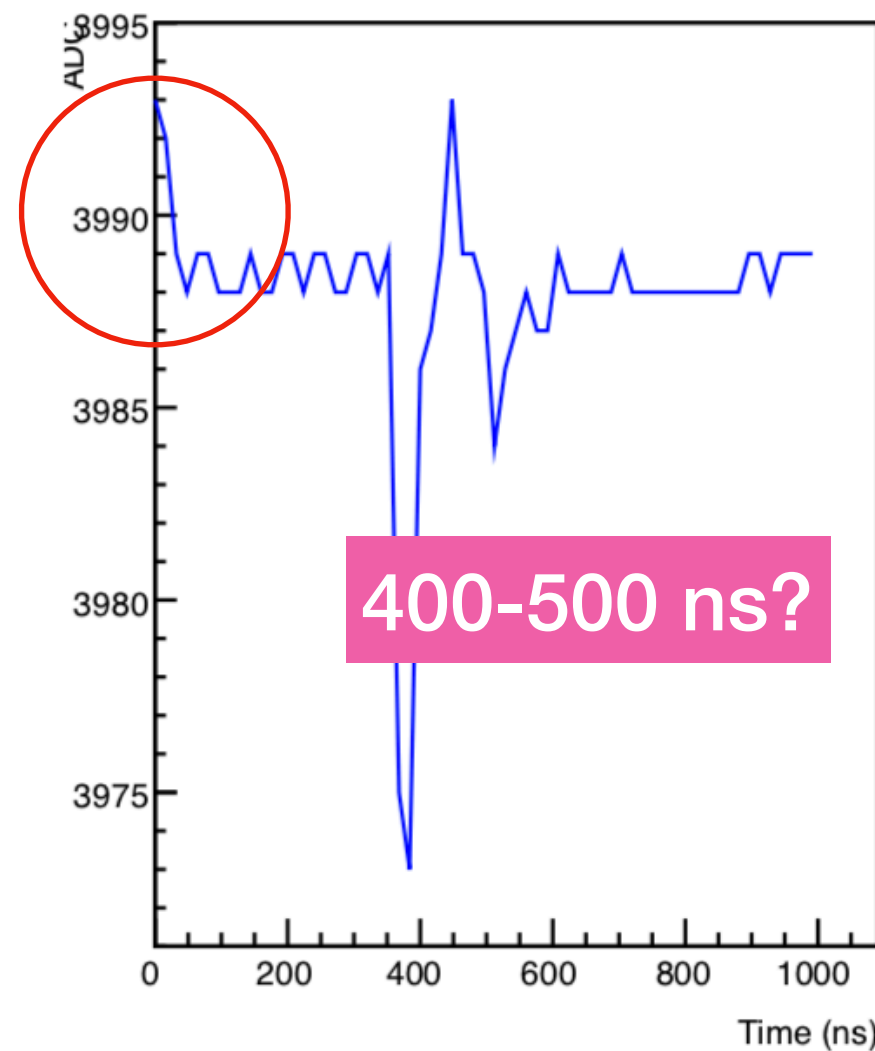
Run #1369, FA0157, ADC ch #47 - WF #35



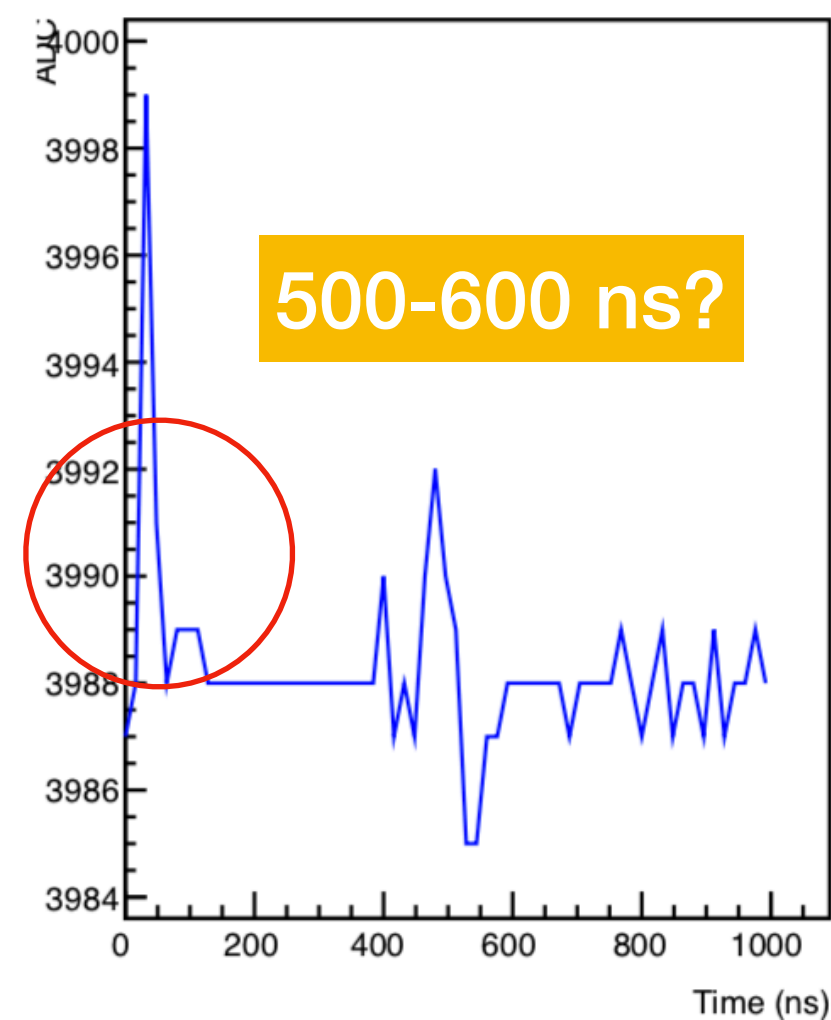
Run 1369, LED 2, PMT 4



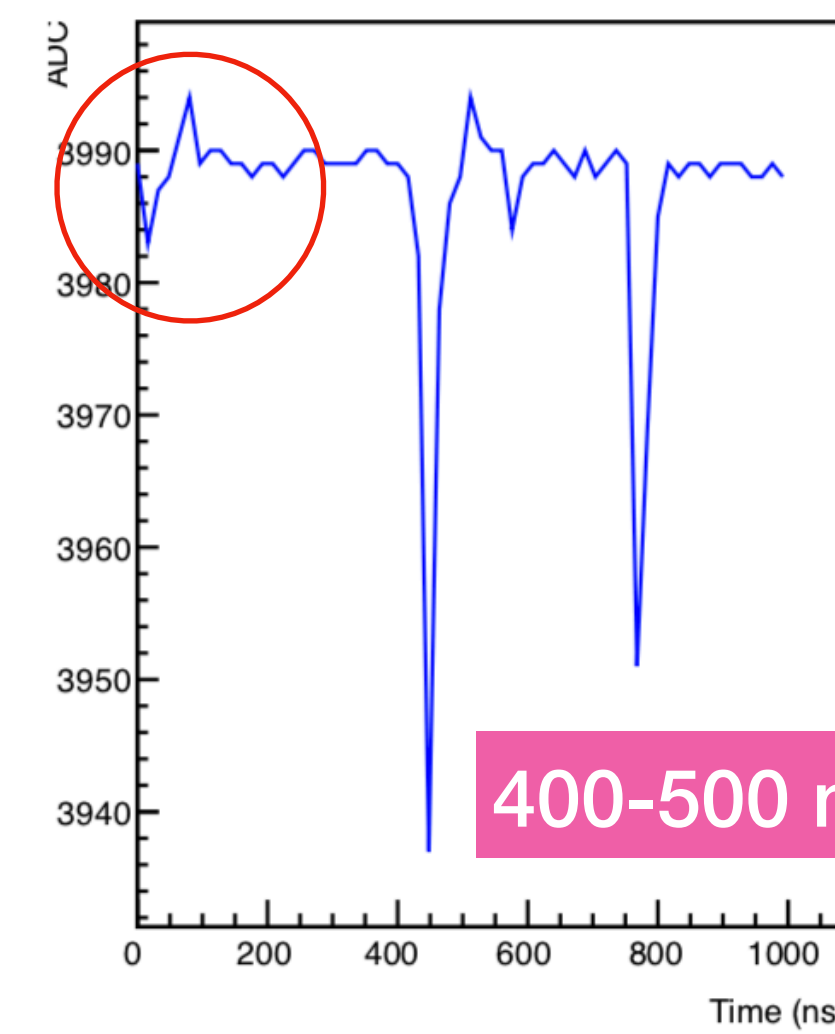
Run #1369, FA0157, ADC ch #47 - WF #1



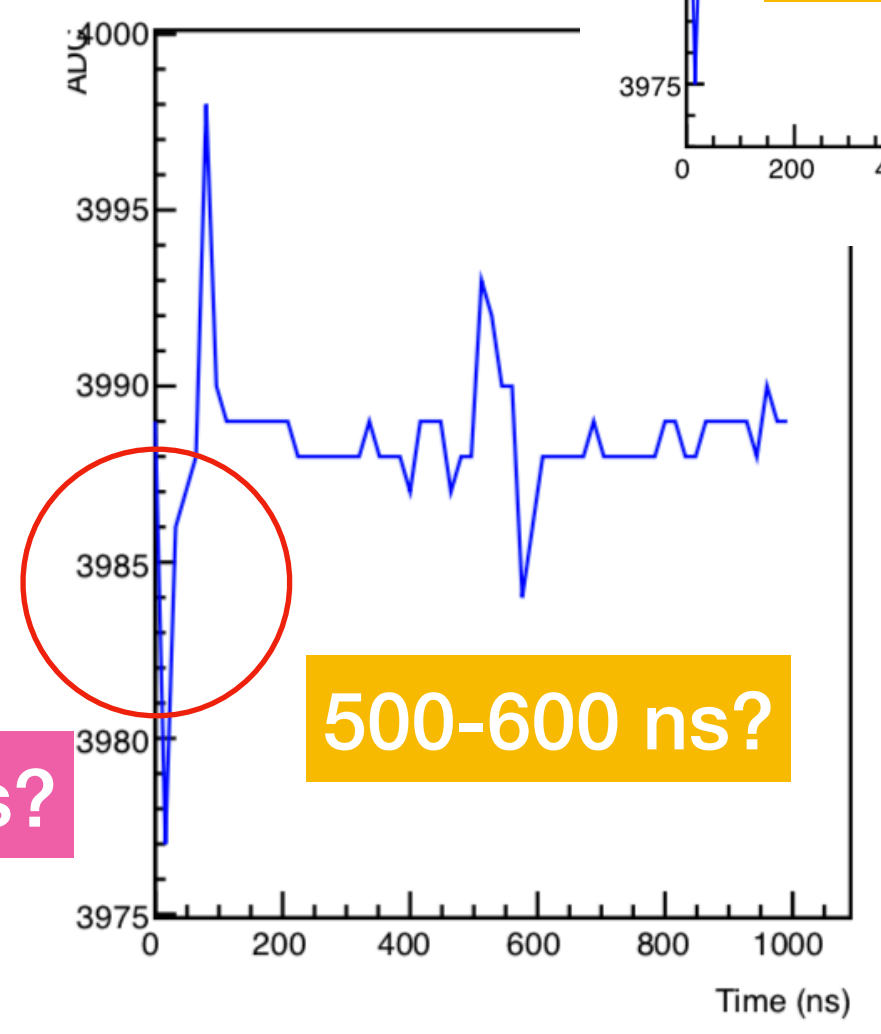
Run #1369, FA0157, ADC ch #47 - WF #7



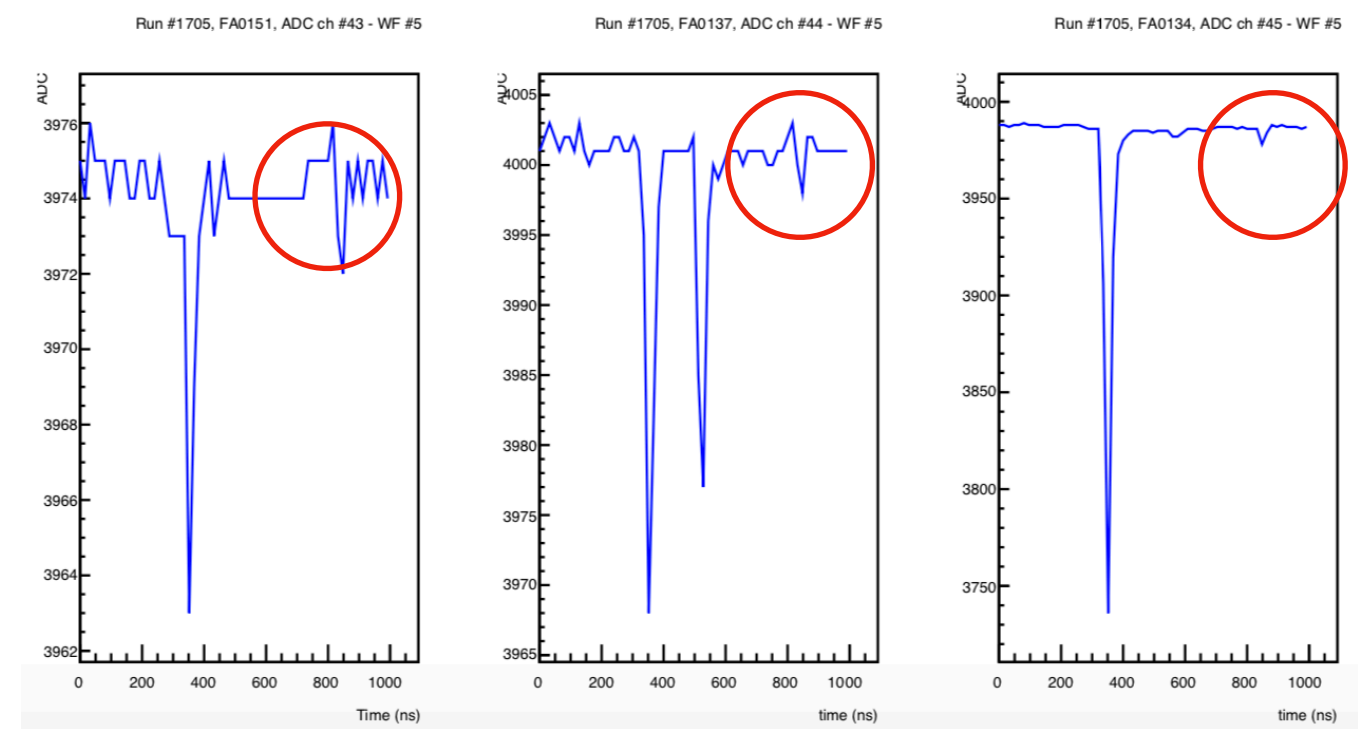
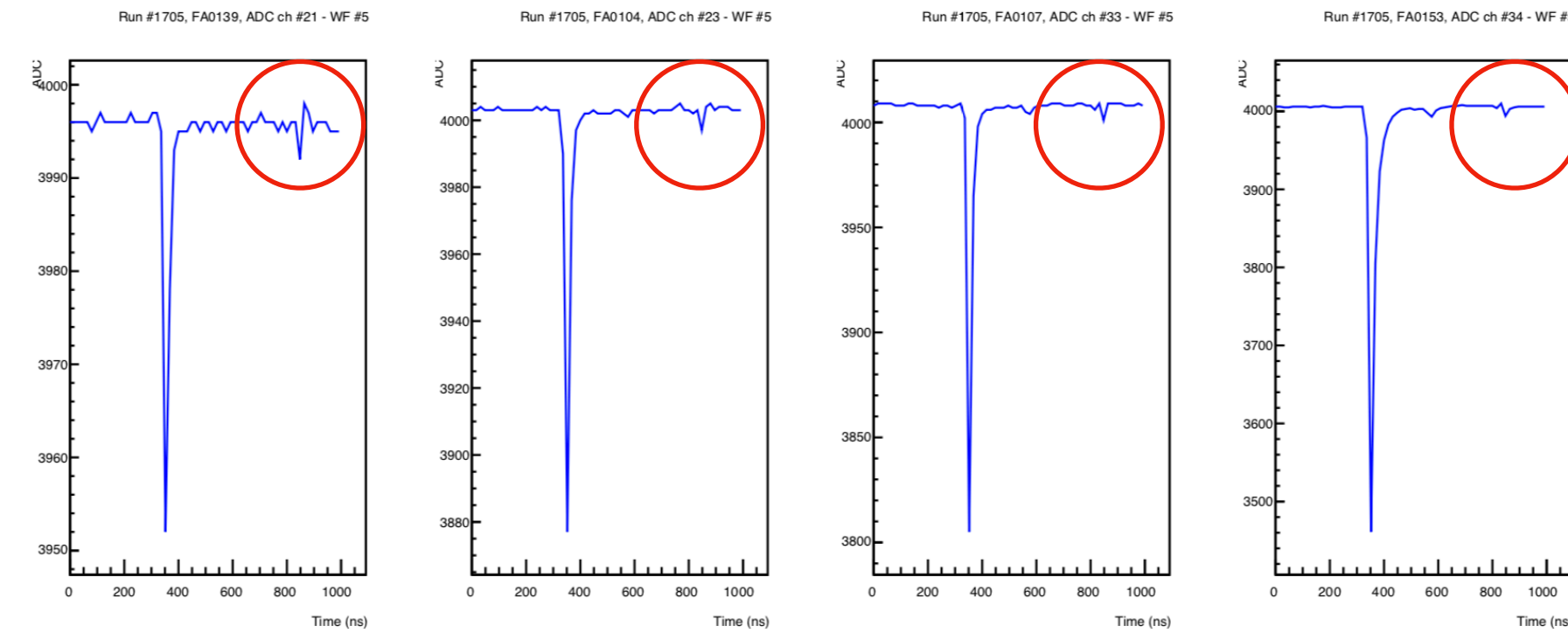
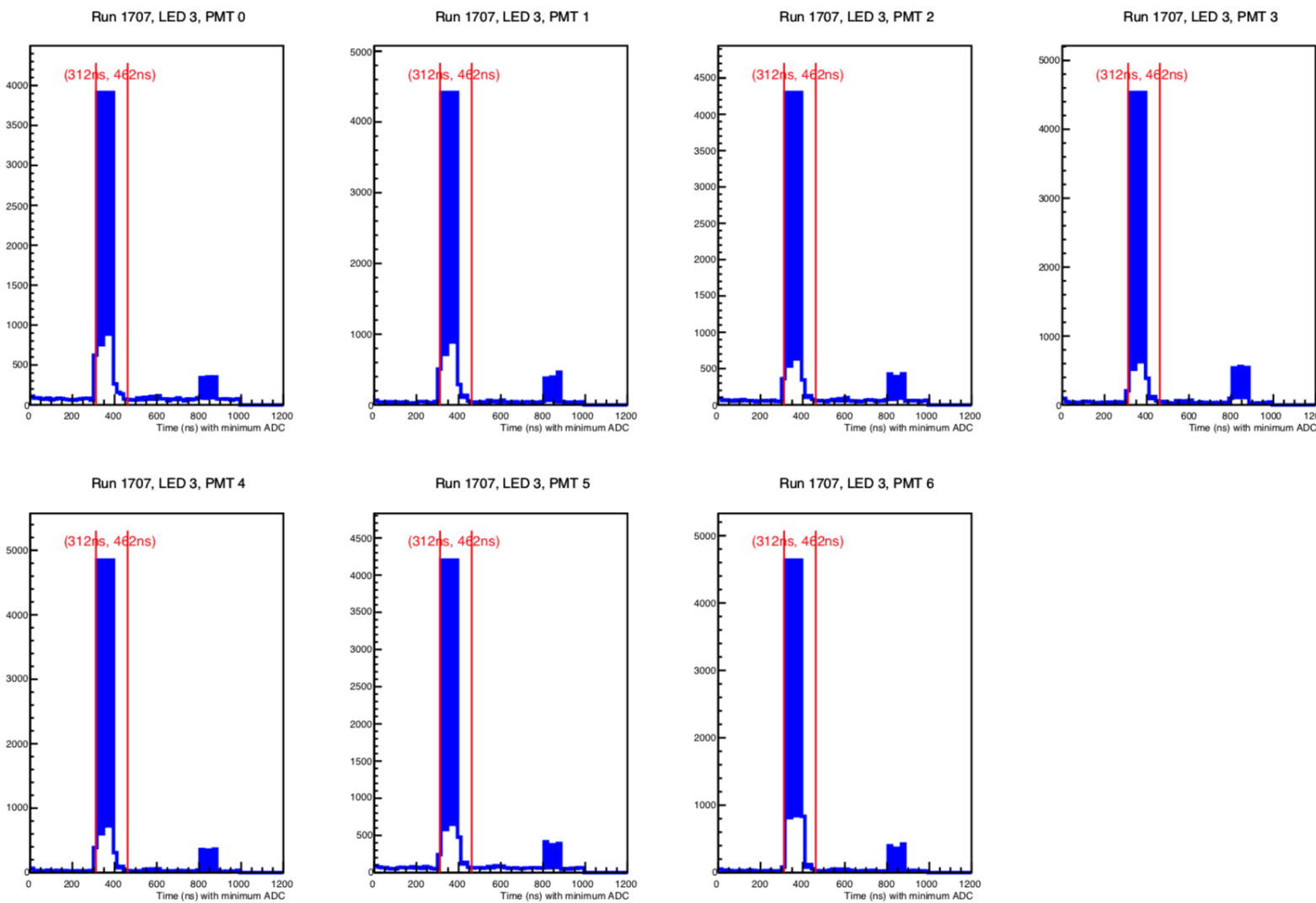
Run #1369, FA0157, ADC ch #47 - WF #5



Run #1369, FA0157, AI



Runs 1700-1707: new configuration



Example!
PRELIMINARY

