In Ice PMT Non Linearity Calibration

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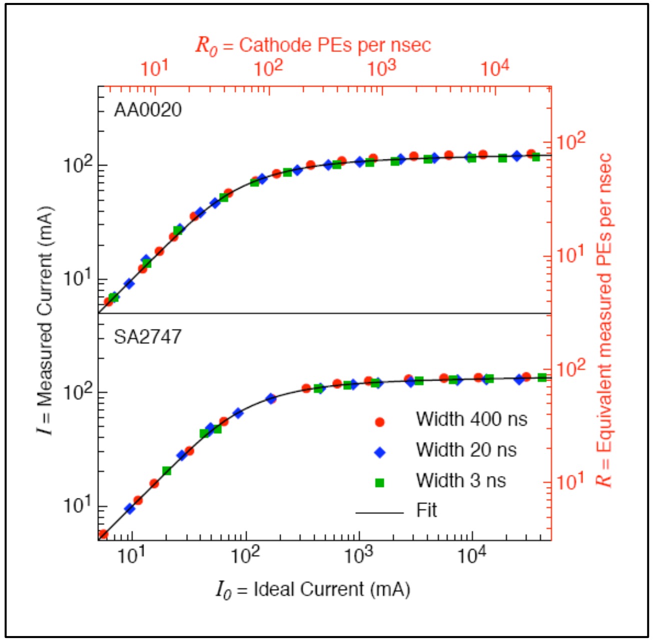
Introduction

- We know that the PMTs saturate for large input signals.
- For large signals understanding the saturation behaviour is necessary for interpreting data.
- We want to calibrate the saturation behaviour in ice.
- The flashers in ice are brighter than those available in the lab.
- In ice calibration gives the saturation behaviour in the environment in which data is taken.
- In ice calibration can be repeated over time to check to see if the behaviour changes.

- PMT saturation has been studied in the lab (below)by Chris W, see his Baton Rouge talk.

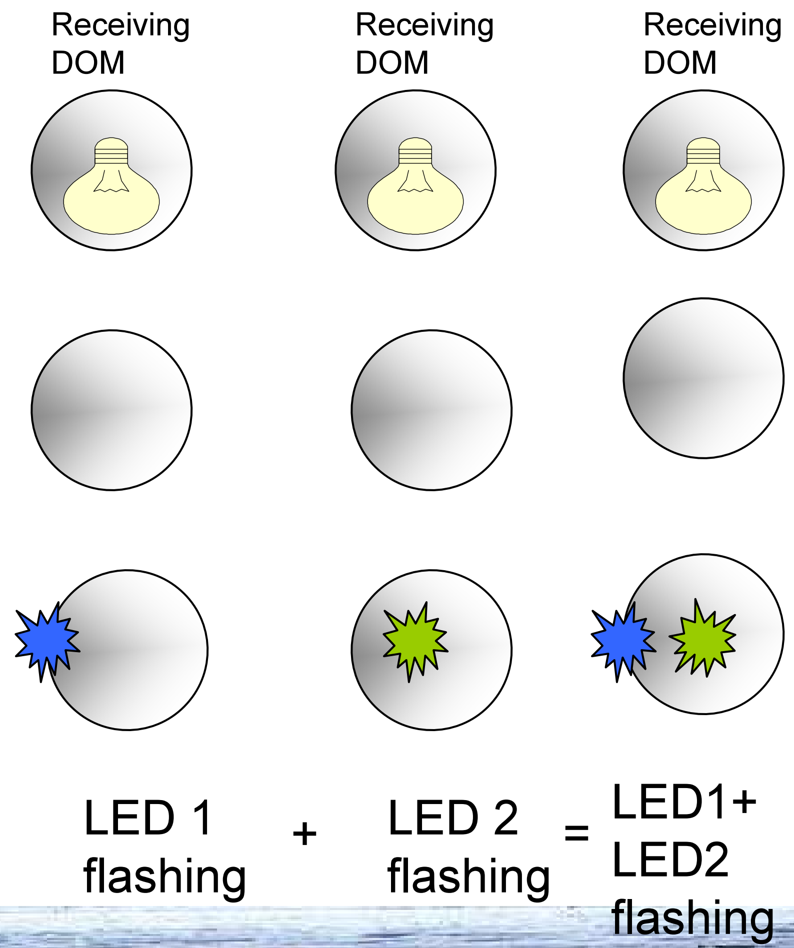


Since Gent …

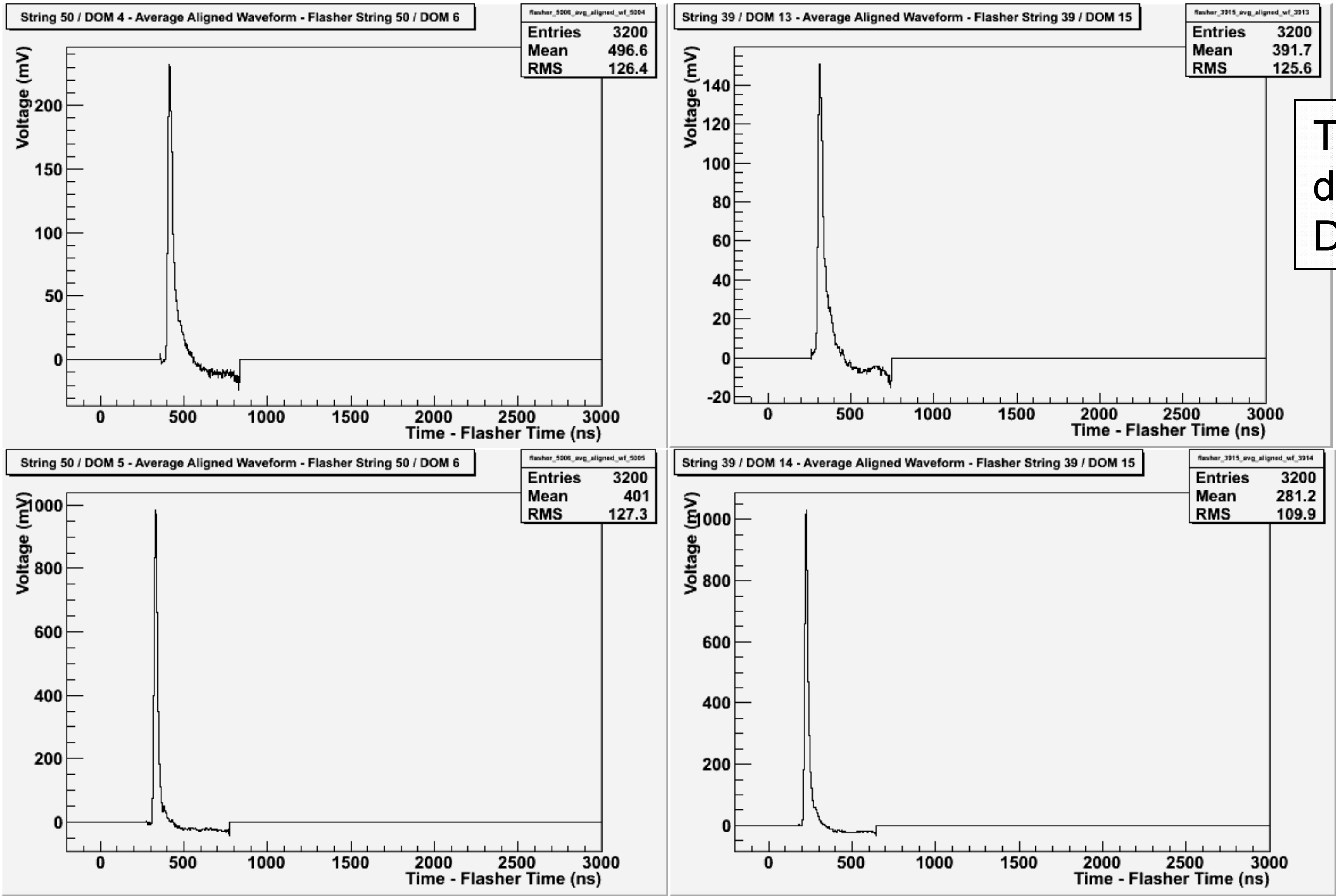
- The focus since the Gent meeting has been on trying to understand why the saturation curves had discontinuities and “wiggles”.
- New data were taken in January 08 using flashers with pDAQ. The data are good except for some dropped subruns which can be accommodated at this stage of the analysis.
- The new pDAQ data were taken with the flashers running with a bigger width.
- We also looked at an offset between ATWD channels 1 and 2 as a possible source of the discontinuity.

How the data are used

- Good data for this study was taken in Dec ’06 using TestDAQ and again in Jan 08 using pDAQ with different settings.
- The data set consists of different runs where the masks, brightness and widths of flashers were varied.
- Combination of different runs can be added to get the expected brightness from a different run.
- For example, for a particular DOM, LED 1 is flashed followed by LED 2. Then LED 1+2 are flashed together.
- The nearest neighbour and next to nearest neighbour above receive a signal and waveforms are collected.
- We use the average waveforms from the receiving DOM to make the saturation curve for that DOM.



Typical Average Waveforms for nearest and next to nearest neighbour receiving



TestDAQ data from Dec 06

Combining data from different runs

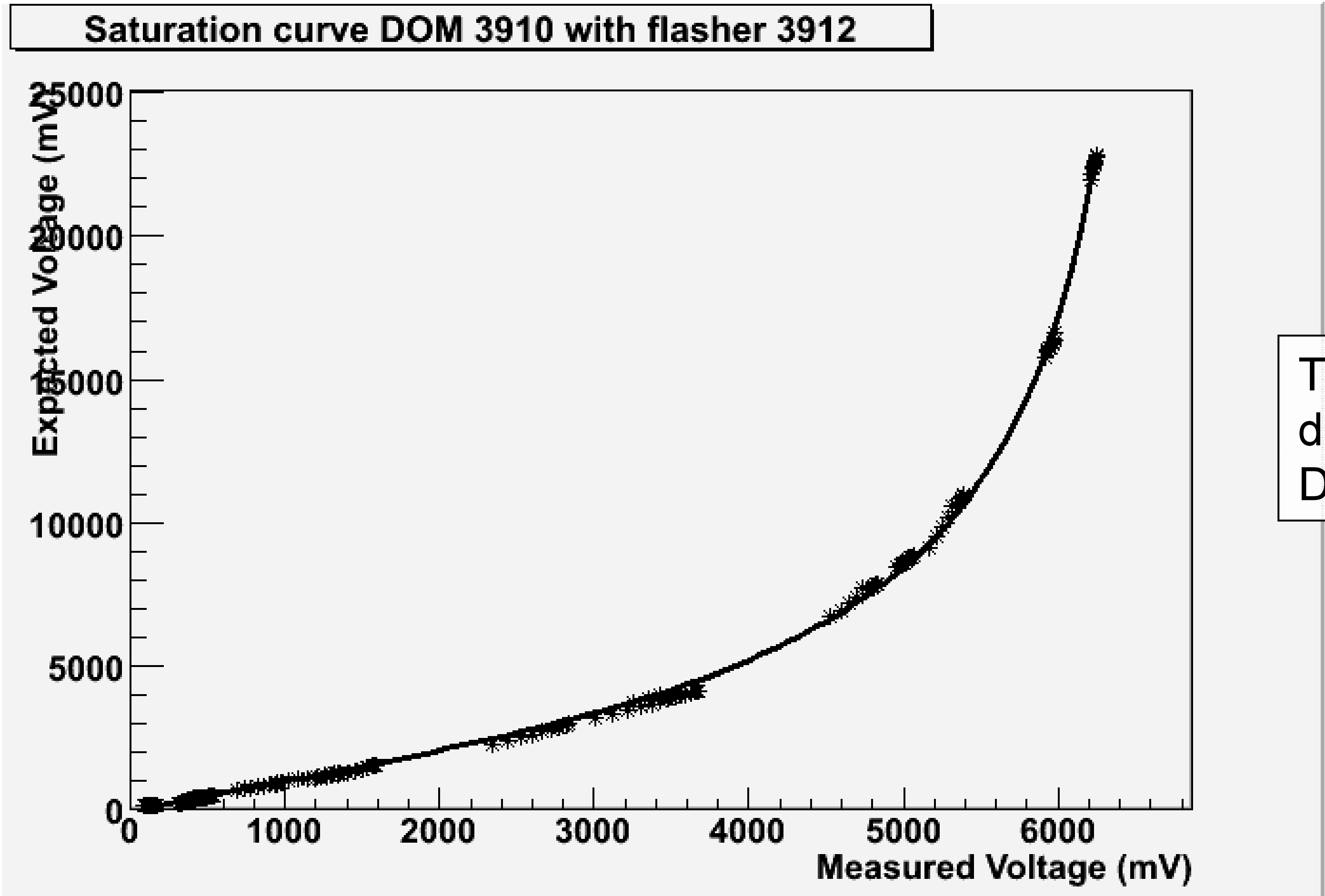
- We can combine runs with the following masks as follows→

- 001 =1
- 002 = 2
- 003 = 1+2
- 00C = 3+4
- 00F = 1+2+3+4
- 030 = 5+6
- 03F = 1+2+3+4+5+6

- For brighter runs the combinations of “sub”runs 1 and 2 for example, do not give the same response as the run 1+2

- This is the region where saturation begins, the *expected* voltage read from the waveforms by adding runs 1 and 2 is more than the *measured* voltage from the 1+2 run.

We then get a saturation curve for DOM 3910, for example



TestDAQ data from Dec 06

Fit function suggested by Chris Wendt

For this analysis to be useful elsewhere, we need a parameterization for the saturation curves.

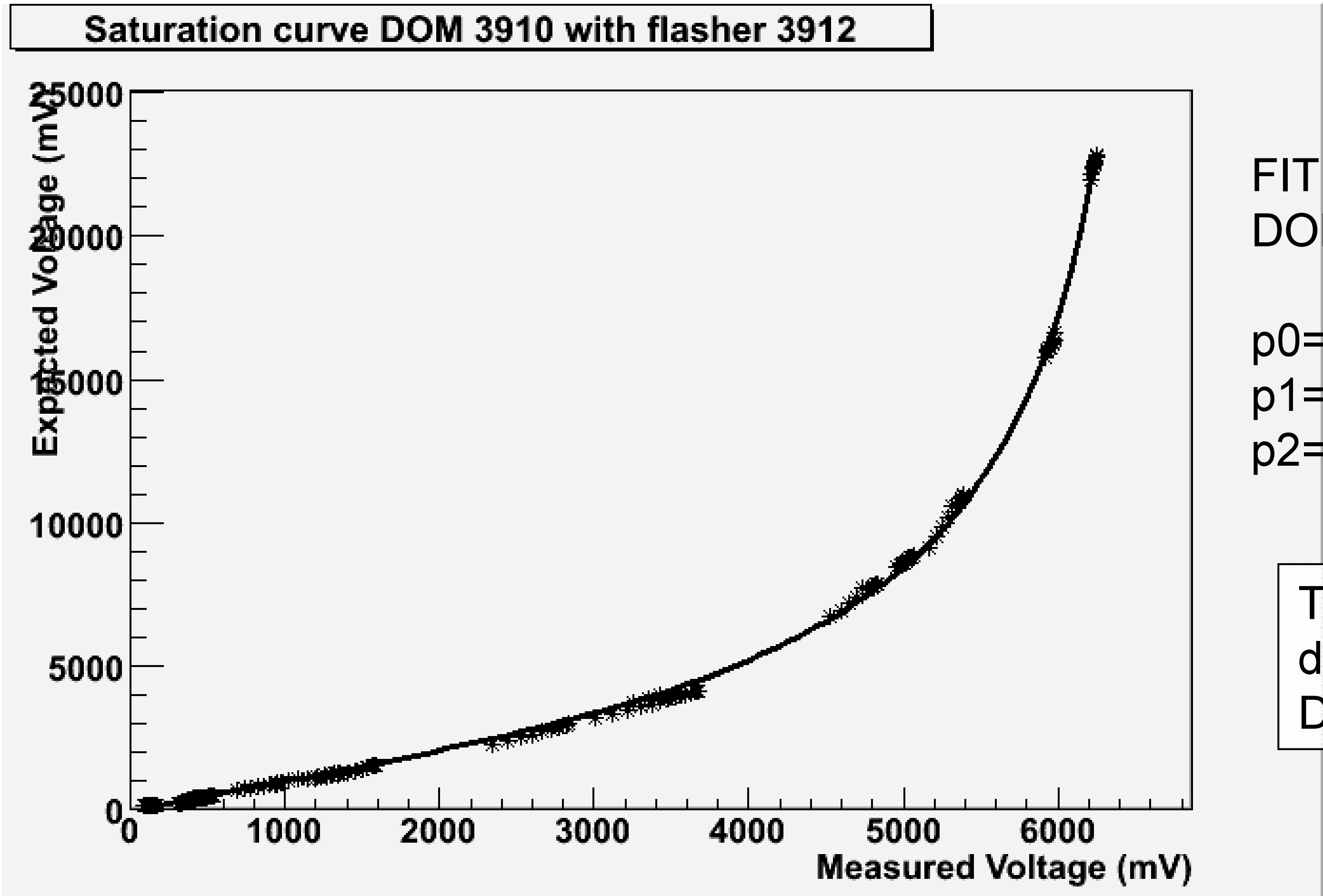
$$V_{expected} = V \exp\left(p0(V/p1)p2\right) / (1 - V/p_1)^{0.25}$$

V= measured voltage (after waveforms are calibrated).

p_0, p_1 and p_2 are parameters which have no physical meaning.

This fit was proposed by Chris Wendt via private communication.
It works well for all saturation curves fitted so far.

Saturation Curve with Chris' fit and parameter values



FIT PARAMETERS
DOM 3910

p0=7.84428e-01
p1= 6.69371e+03
p2= 2.53413

TestDAQ data from Dec 06

Up to this point …

- Prior to, and just after, the Gent meeting the curves were made with Dec 06 data where:

- There are some “wiggles” in the curves and the different width and brightness runs sometimes appear not to line up on what would be a smooth saturation curve

- Also we found that before ATWD channel 1 saturates the average waveforms from it does not match the same average waveforms made using ATWD channel 2.

- This channel offset could propagate up the saturation curve if it is not accounted for.

More data taken in January 08

- More data was taken for DOMs on strings 39 and 50 using flashers in pDAQ.
- The bright and width combinations were changed to see if the wiggles in the saturation curves will go away.
- Horizontal LEDs were also used this time.
- Note this was the first time pDAQ was used to take this data and it worked well, apart form some “skipped” subruns

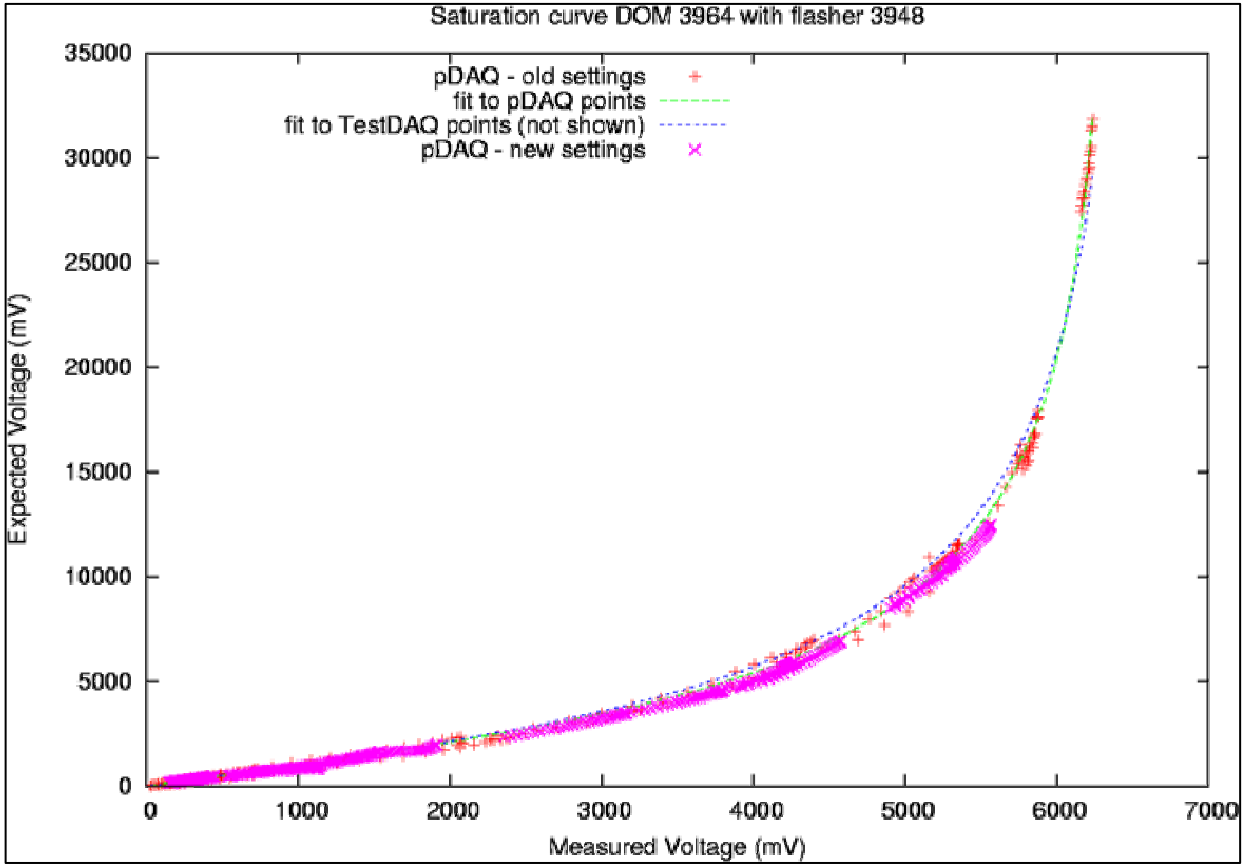
- B W Mask Rate(Hz) LED Number
- 0 127 040 10 7
- 0 127 080 10 8
- 0 127 0C0 10 7+8
- 0 127 300 10 9+10
- 0 127 3C0 10 7+8+9+10
- 0 127 C00 10 11+12
- 0 127 FC0 10 7+8+9+10+11+13
- …
- 127 127 001 5 1
- 127 127 002 5 2
- 127 127 003 5 1+2 127 127 004 5 3
- 127 127 008 5 4
- 127 127 00C 5 3+4
- 127 127 00F 5 1+2+3+4
- 127 127 010 5 5
- 127 127 020 5 6
- 127 127 030 5 5+6
- 127 127 03F 5 1+2+3+4+5+6

Saturation curve for 3946

(note typo in title of graph)

using old and new data

- Shown here are:
- The fit to the old TestDAQ curve (Dec 06 data).
- The pDAQ curve made with the old settings (some new pDAQ data, Jan 08, were taken with the old settings).
- pDAQ curve with new settings
- Fit to new pDAQ points.
- We use the peak as points along the leading edges of the waveforms
- The aim was to see if the data, taken with the same settings but with pDAQ, give the same curve as with TestDAQ.



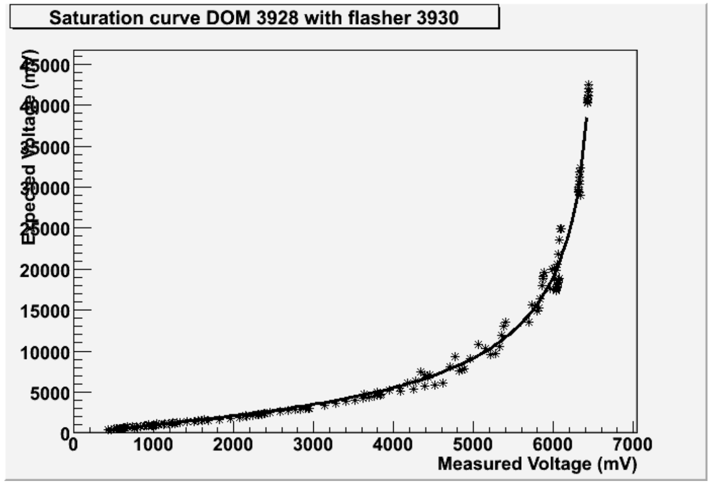
Wiggles in saturation curve for 3928 using old TestDAQ and new pDAQ

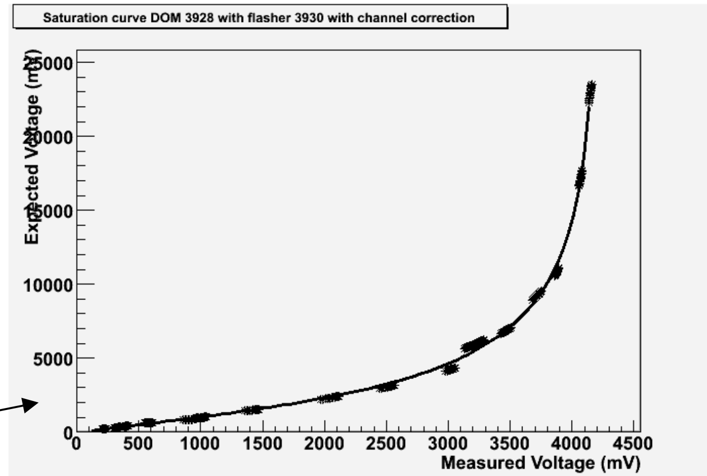
- The main reason for using the new settings with bigger width was to see if the "wiggles" and discontinuities in the saturation curve will go away. We wanted avoid using waveforms with sharp rising edges.

- The top curve is made using old TestDAQ data.

- The bottom curve is made with pDAQ curve with new settings, which have bigger widths. This has the channel correction included.

- With the new settings the wiggles are no longer there although there is still a set of points which seem off.

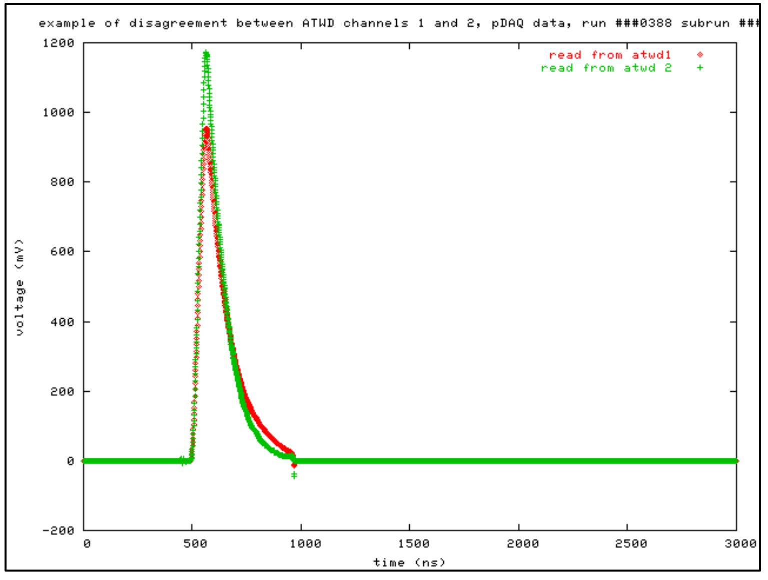




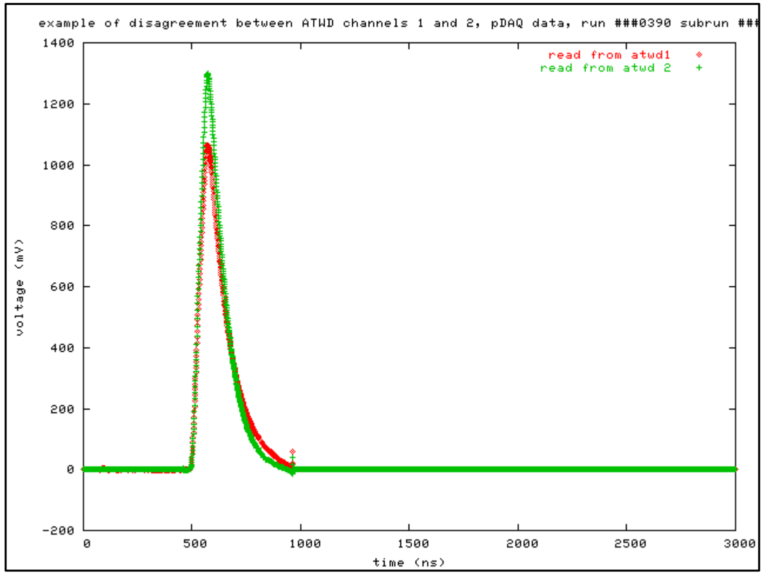
Note different scales and channel correction included here (more on this later in the talk)

ATWD channel 1 and channel 2 offset

We now turn to the offset between channels 1 and 2
Waveforms read from ATWD channel 1 and channel 2 are different (pDAQ).



run00110388 subrun 00000082



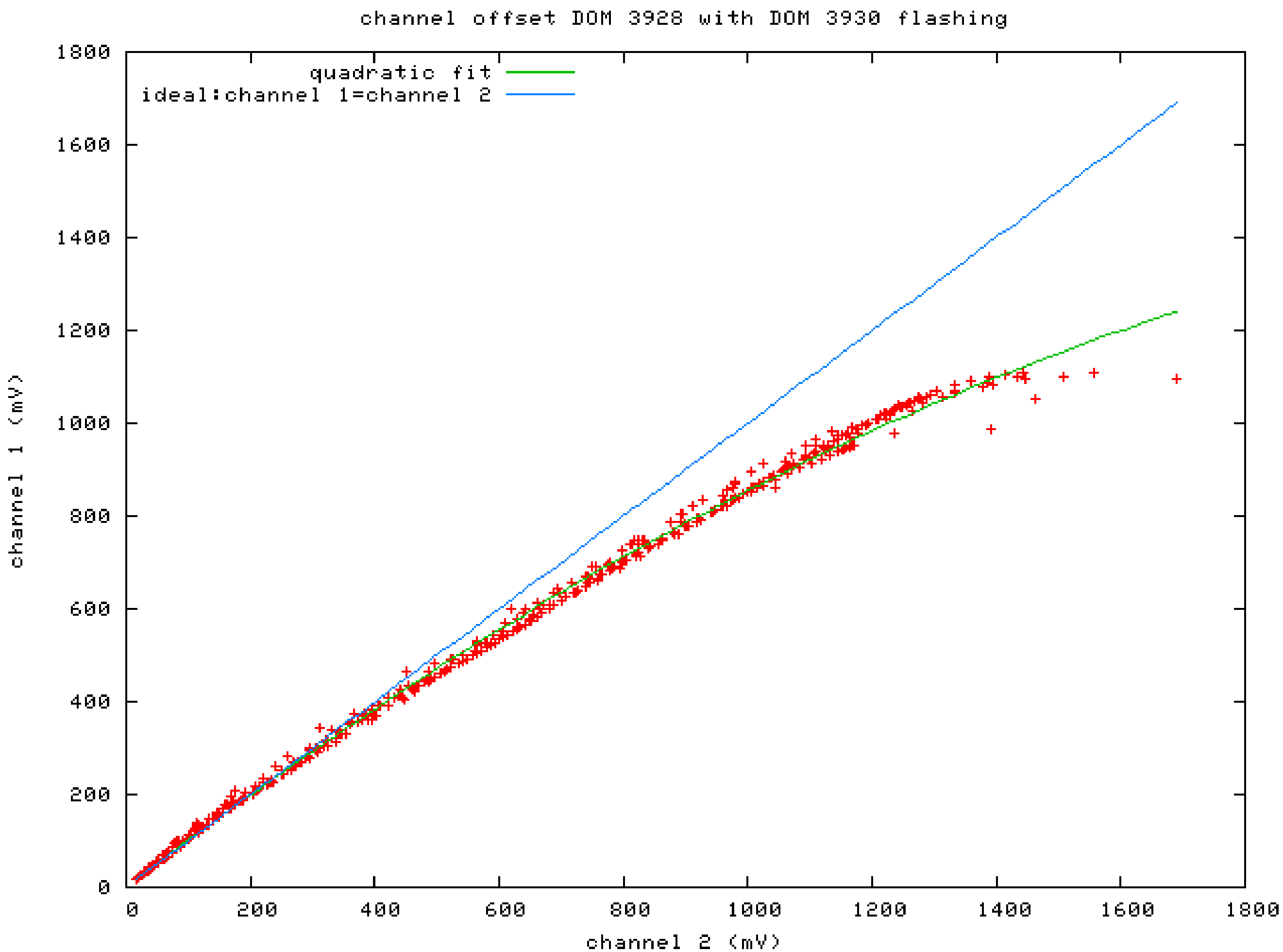
run 001100390 subrun 0000009

ATWD channel 1 and channel 2 offset

- As mentioned above we see an offset between ATWD channel 1 and channel 2, shown to the right.

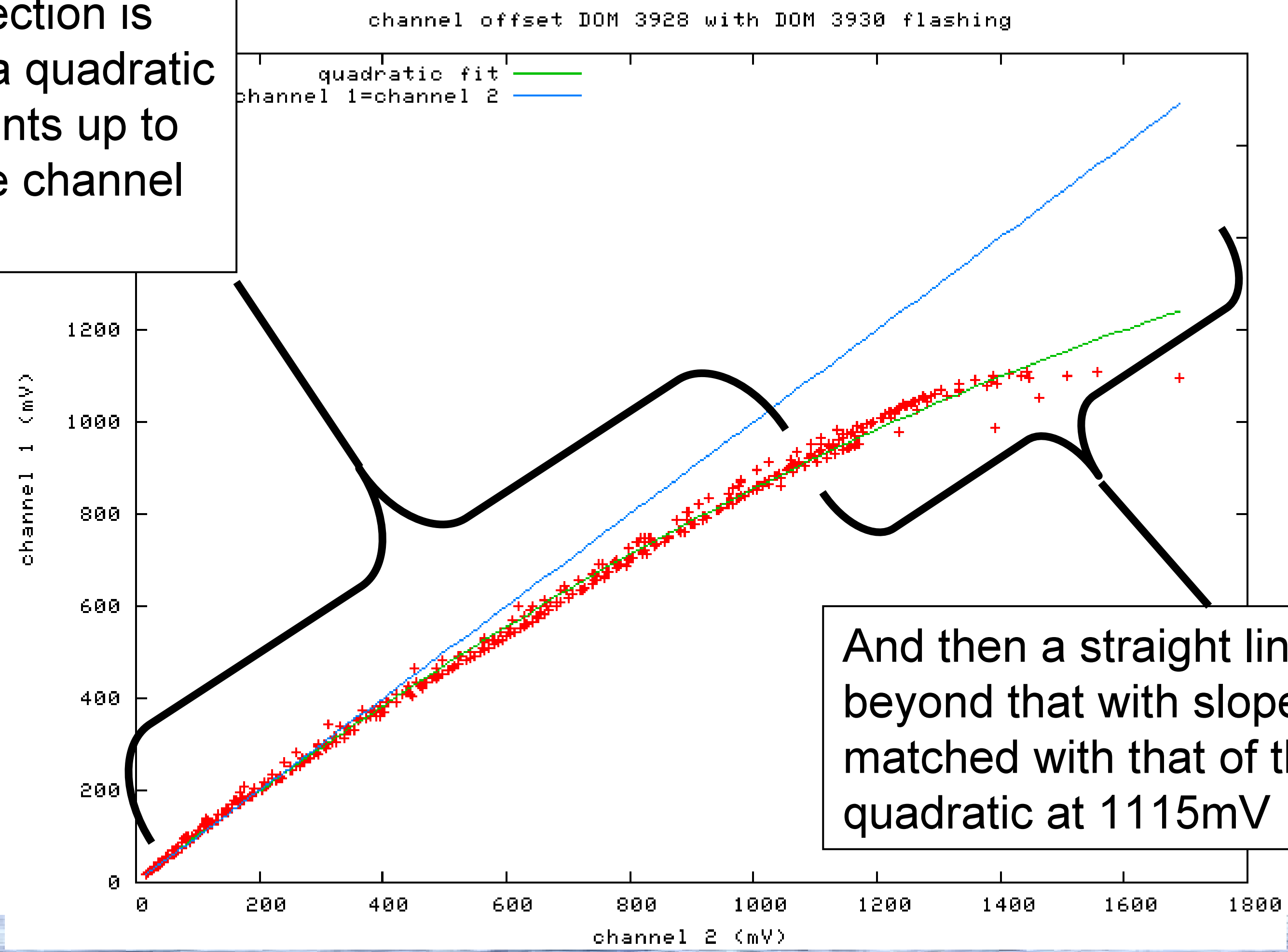
- With the data at hand we can study this offset up to the region were channel 1 saturates.

- We can see if this offset propagates through the saturation curve and may be responsible for some of the “jumps” in the curves.



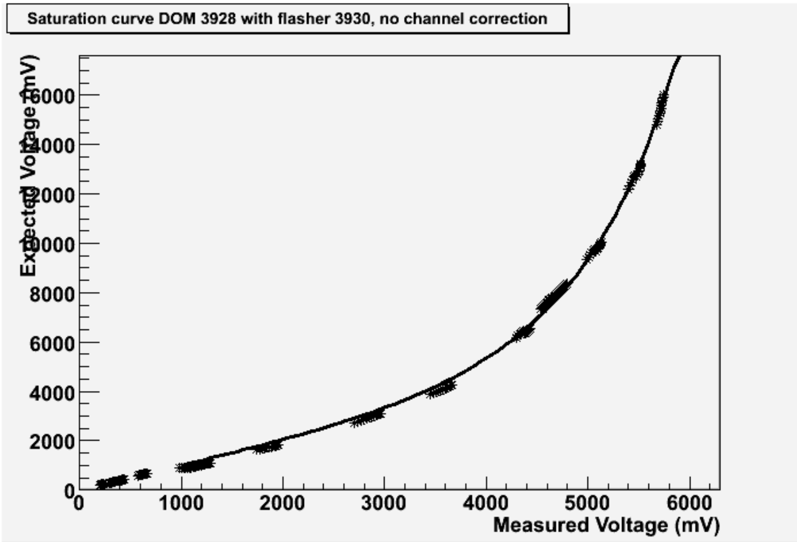
ATWD channel 1 and channel 2 offset

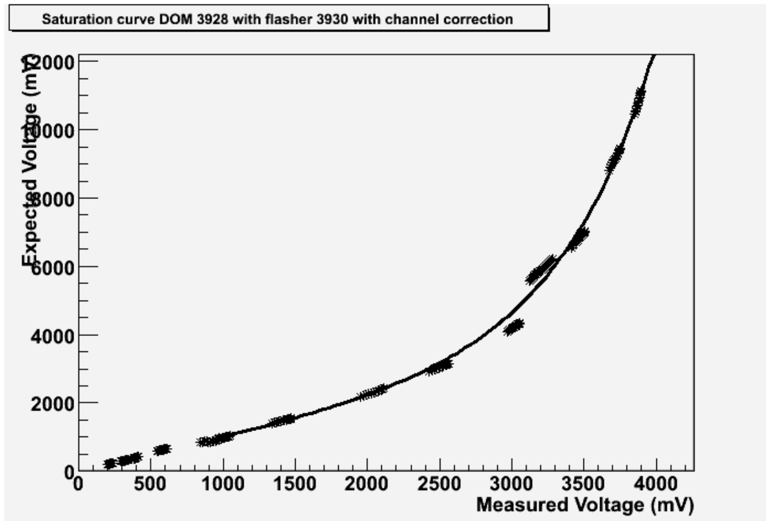
The offset correction is done by fitting a quadratic to the offset points up to 1115mV, where channel 1 saturates.



And then a straight line beyond that with slope matched with that of the quadratic at 1115mV

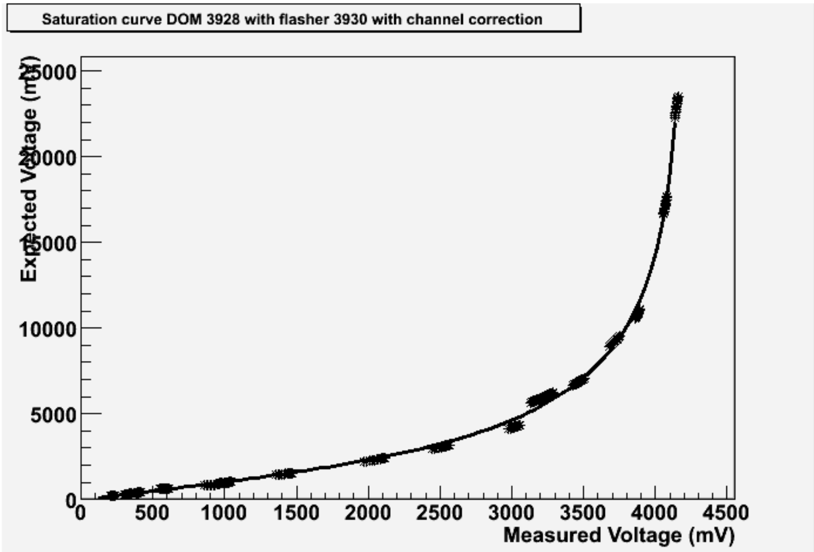
Channel offset corrected curve for 3928

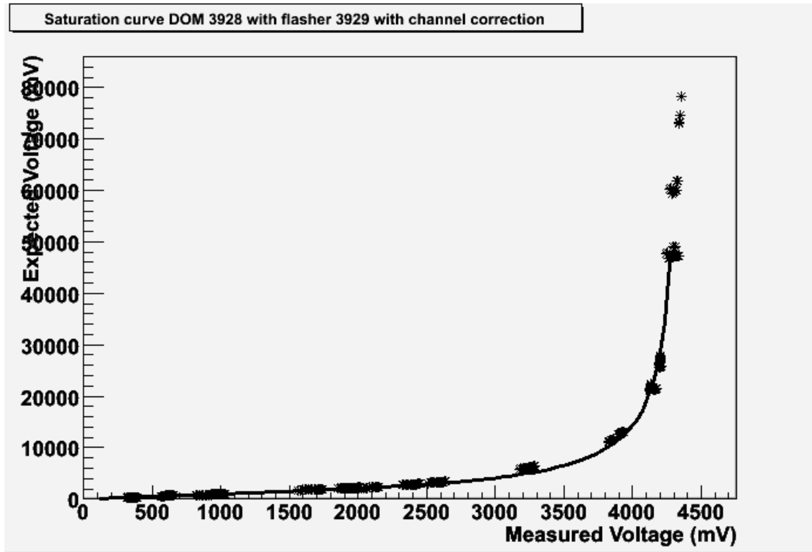




So this DOM now appears to saturate just beyond 4100mV
After the channel offset correction is included.

Fits to Saturation curve for 3928 using two flashing DOMS





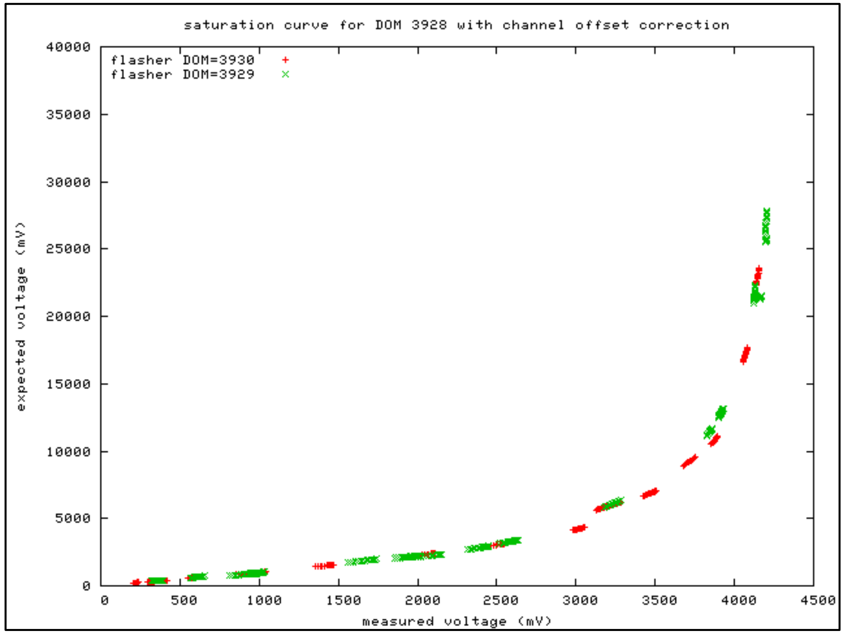
Two curves for 3928, one made with 3930 flashing (left) and the other with 3929 flashing (right). The parameters for the fits are:

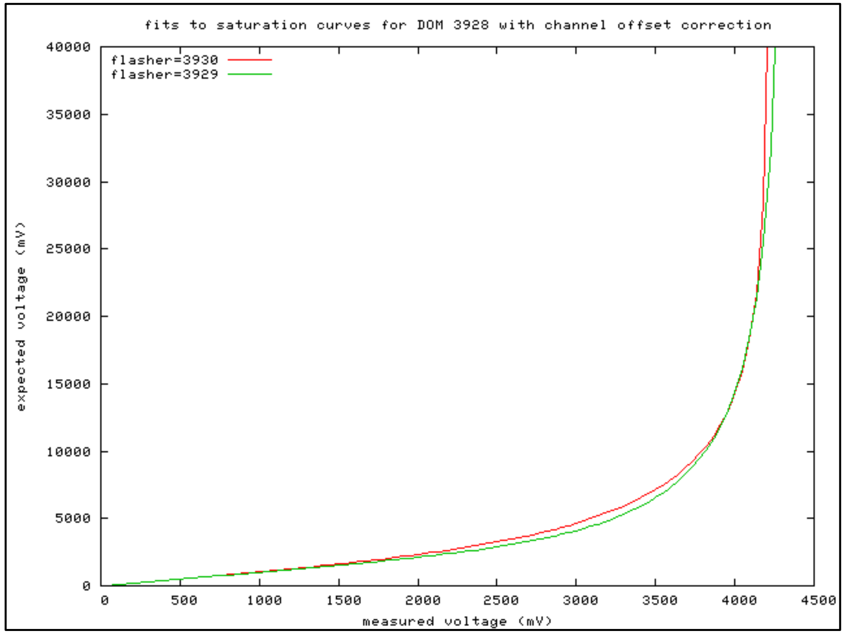
p0	7.27769e-01
p1	4.25667e+03
p2	2.32327e+00

The curve on the left is same as on pervious slides but with more points shown.

p0	9.42371e-01
p1	4.35517e+03
p2	3.73879e+00

Overlay of Saturation curve for 3928 using two flashing DOMS

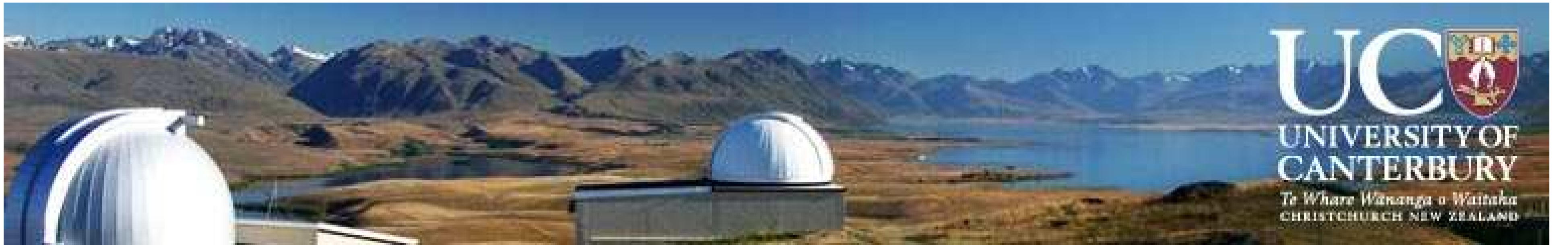




Left: Two curves for 3928 with 3930 flashing (red) and with 3929 flashing (green).
Right: Fits to the two curves for 3928, with 3930 flashing (red) and with 3929 flashing (green).

Summary

- We’ve made PMT saturation curves using TestDAQ data taken in Dec 06 and new pDAQ data taken in Jan 08.
- The curves for a few DOM were made and the curves with both sets of data seem similar.
- The curves with the new data appear to be smoother so the Jan 08 settings should be used when more data are taken.
- Channel 1 and 2 offset correction appears to be a big effect and should be included in the channel calibration. Chris Wendt will also look at this in the lab as we need to arrive at a correct method account for this offset
- The channel offset kicks in earlier that PMT saturation so one should be mindful of this even if one is working away from the region where the PMTs saturate.
- The three parameter fit suggested by Chris Wendt seem to fit all saturation curves well.
- This should add three parameters to the DOM calibration and we will work with DOM ‘*Calibrationists’* to see how best to include this analysis onto DOMCal.



- Backup slides

Even more on combining data from different runs

- At some brightness the 1+2 run may already be in the turnover region while the 1 and 2 runs are not yet there.
- So one starts to see a turnover in a curve of the measured vs expected voltages.
- At higher brightness however, the 1 and 2 runs, for example, may already be in the saturated region. That is, the measured voltage is already not what one expects.
- One has to correct this before calculating an expected voltage. This is done by interpolating the measured vs expected curve already made at a lower brightness, and correcting the current expected voltage.

More on combining data from different runs (table shown in Gent)

Run number	LEDmask	LEDs	Bright	Width
run0031618	001	000001	0	50
run0031619	002	000010	0	50
The above two runs should reproduce the 000011 run below				
run0031620	003	000011	0	50
run0031621	00C	001100	0	50
The above two runs should reproduce the 001111 run below				
run0031622	00F	001111	0	50
run0031623	030	110000	0	50
The above two runs should reproduce the 111111 run below				
run0031624	03F	111111	0	50
run0031625	001	000001	16	40
run0031626	002	000010	16	40
etc …				
run0031627	003	000011	16	40
run0031628	00C	001100	16	40

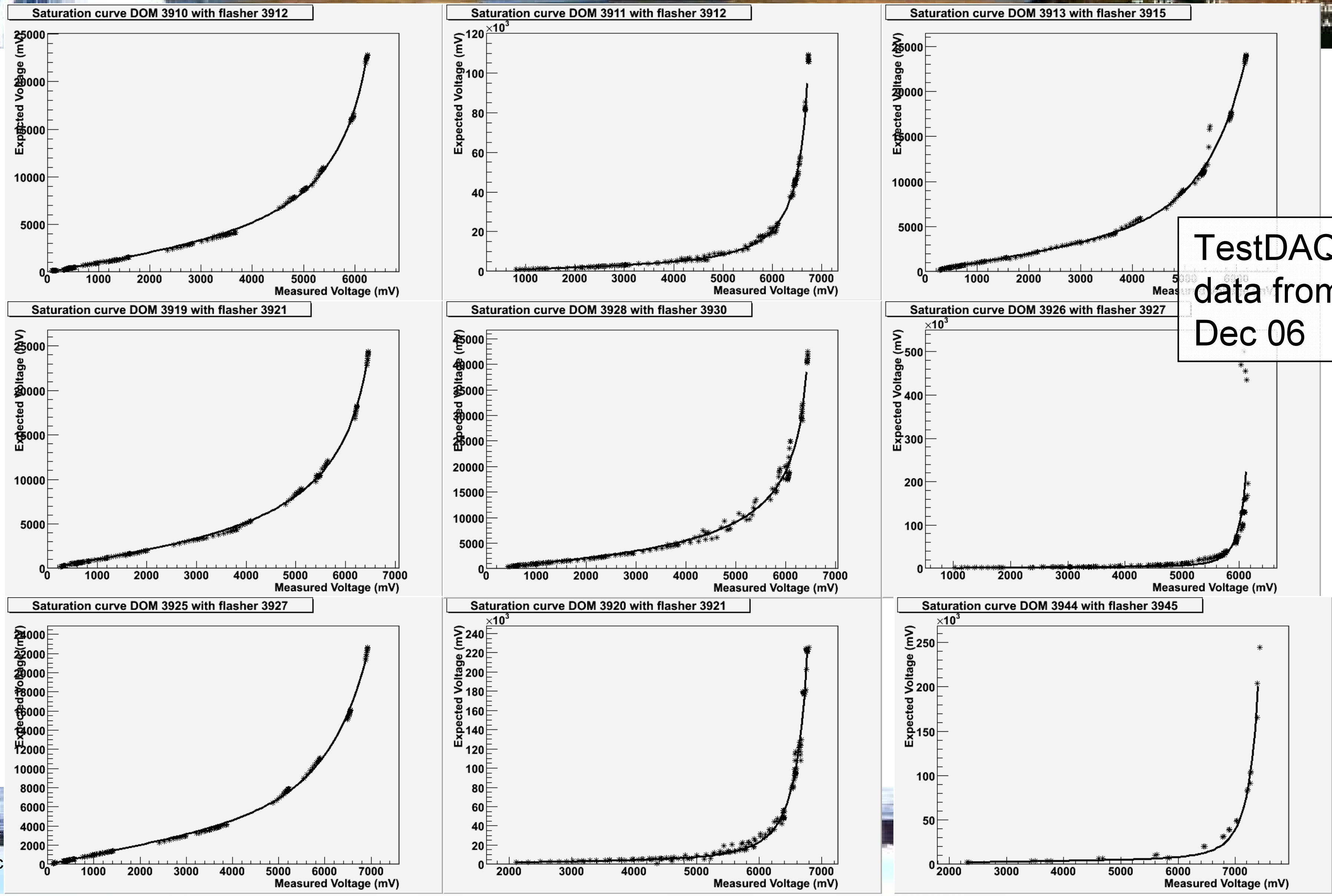
000001
+000010
000011

000011
+001100
001111

or

000001
000010
+001100
001111

Saturation Curves for a few different DOMs



TestDAQ data from Dec 06

Example of fit parameters (with old data TestDAQ)

DOM 3910

p0=7.84428e-01
p1= 6.69371e+03
p2= 2.53413e+00

DOM 3921

p0=7.24544e-01
p1= 6.83027e+03
p2= 2.32233e+00

DOM 3943

p0=6.30038e-01
p1= 6.65134e+03
p2= 1.87528e+00

DOM 3947

p0=2.15697e+00
p1= 8.56996e+03
p2= 4.17840e+00

DOM 3911

p0=1.29907e+00
p1= 6.94097e+03
p2= 3.70493e+00

DOM 3920

p0=2.32688e+00
p1= 7.16499e+03
p2= 5.59589e+00

DOM 3929

p0=7.44752e+00
p1= 8.36873e+03
p2= 7.11410e+00

DOM 3938

p0=1.49075e+00
p1= 8.01208e+03
p2= 4.67917e+00

DOM 3944

p0=6.67532e+00
p1= 8.35620e+03
p2= 1.02018e+01