

Irradiation Test status

ISKRA VELKOVSKA, BRIGITA NOVAK, GREGOR KRAMBERGER, BOJAN HITI, BOR KOKOVNIK

JOZEF STEFAN INSTITUTE, LJUBLJANA

HGTD Week at CERN, October 2026

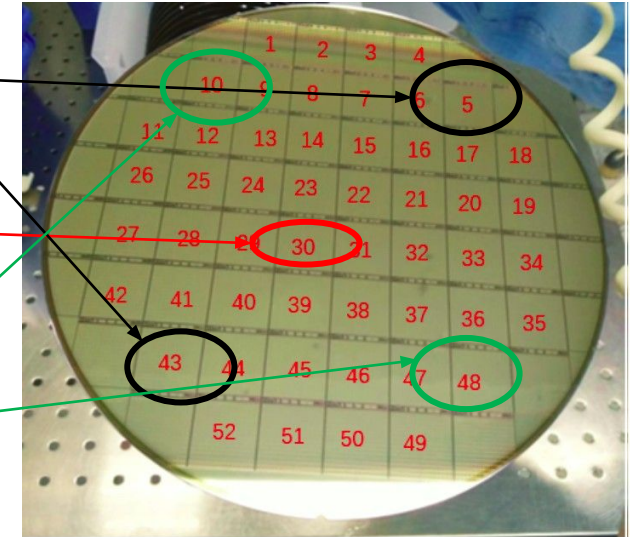
Irradiation tests – IT (a reminder)

- Upon reception we irradiate together 3 samples, from positions: 5,30,43
- We use Pos30 as the test device and other two as secondary devices to confirm the wafer acceptance
- We keep positions 10 and 48 for possible other studies (performance, charged hadrons irradiations...)

secondary QC-TSs from each wafer – Positions 5,43

primary QC-TS from each wafer – Position 30

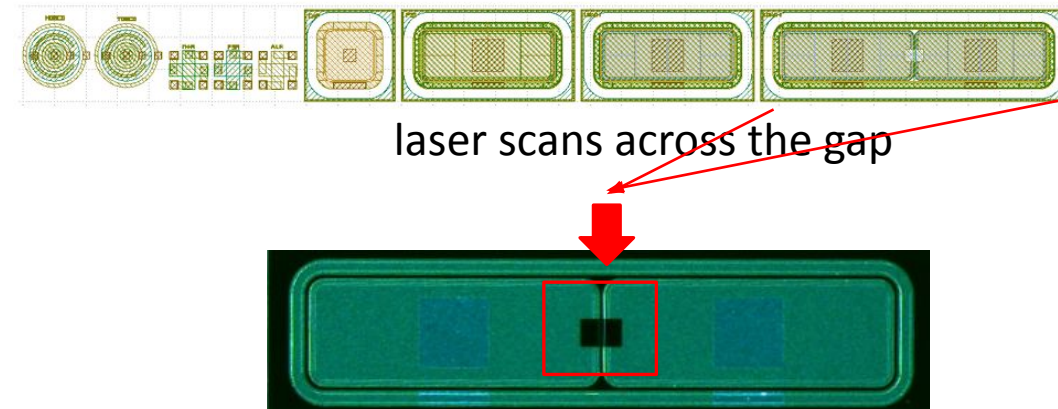
backup samples – performance studies 10,48



ATLAS-HGTD QC-TS

Measured IHEP QCTS

- QC-TS irradiated to $2.5 \times 10^{15} \text{ cm}^{-2}$ (nominal fluence)
- We decided to use **central channel** of the reactor for better uniformity – we are rechecking/performing additional calibration to make sure the dosimetry is spot on
- Samples measured after standard annealing and 2nd biasing – following the agreed procedures (described in the paper 10.48550/arXiv.2509.09187)

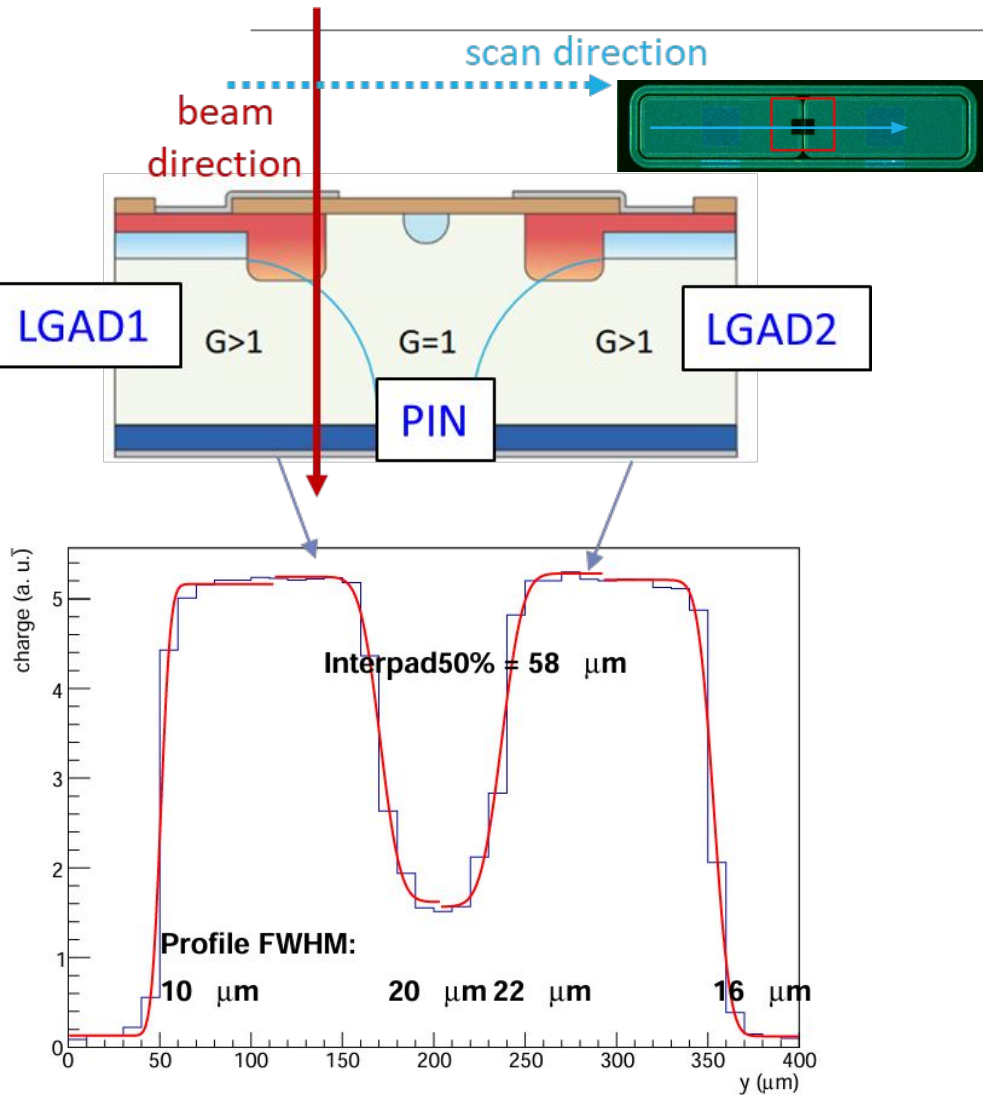


Procedure - reminder

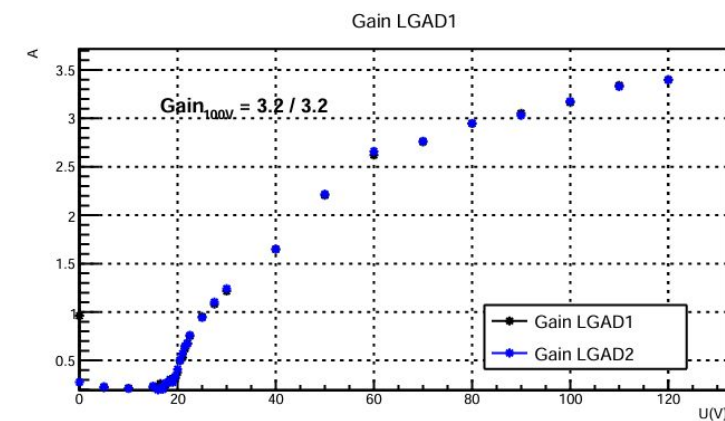
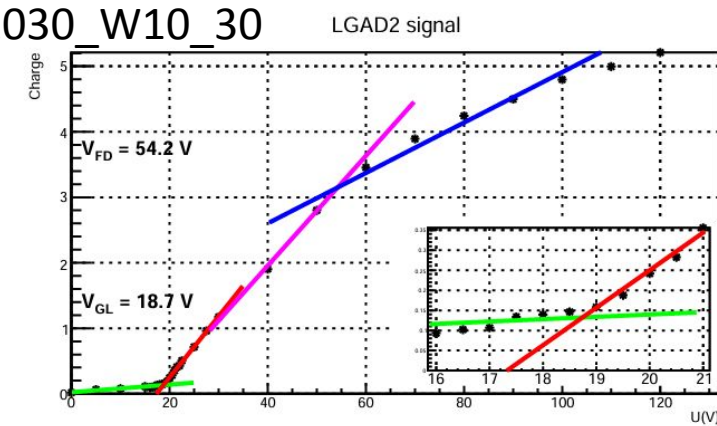
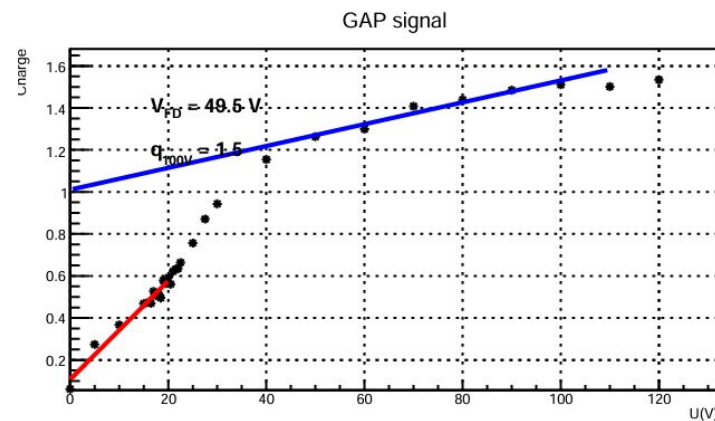
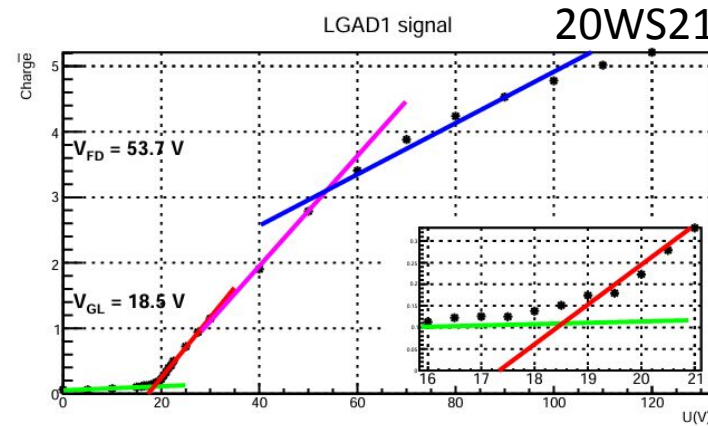
Acceptance:

- V_{gl} determined from TCT >16.7 V after $2.5e15$ n_{eq} cm^{-2}
- Gain at 100 V, 20°C with TCT Gain >2.7 after $2.5e15$ n_{eq} cm^{-2}

Monitoring parameters : Interpad gap, Vfd1,Vfd2



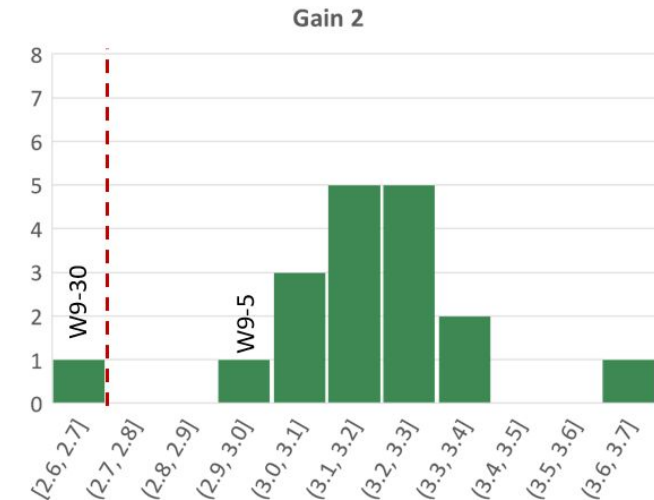
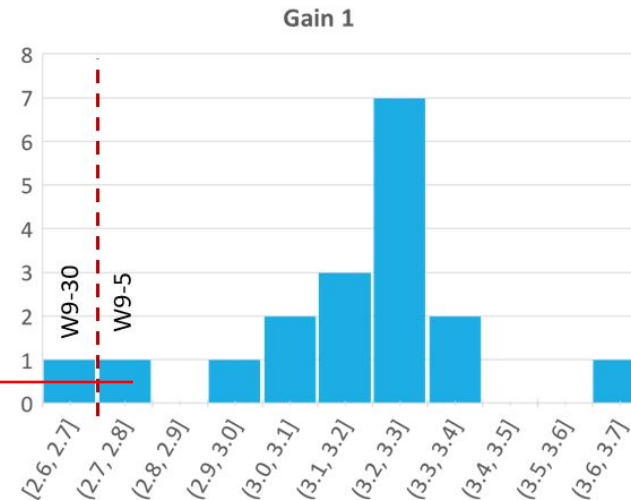
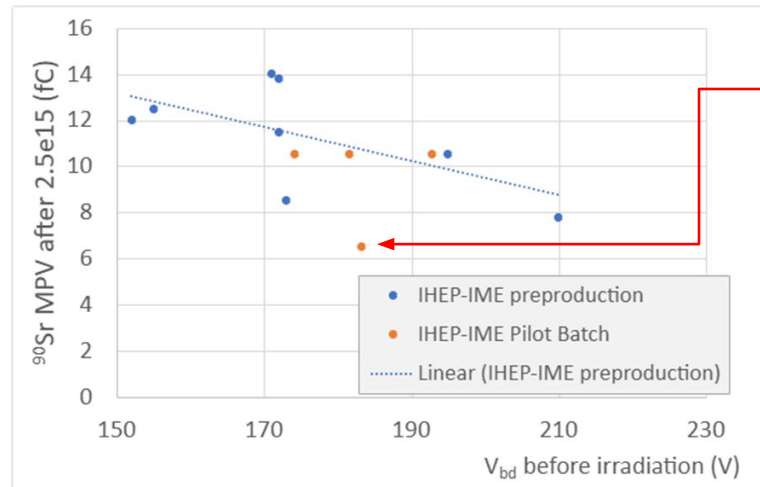
Batch1 - 20WS2106001030_W10_30



Pilot batch summary

Pilot batch	Time line
Wafers received	17
Wafers irradiated (two irr.)	17
Wafers tested	17
Wafers accepted	17
A retest was needed	1
Wafers rejected	0

- All wafers passed the acceptance
- We found one wafer that was on the limit and is an out layer with worse radiation hardness than the reset – verified by repeats, different QC-TS and Sr90.



How to track wafers/sensors within acceptance, but somewhat smaller radiation hardness?

Overview IHEP-IME batch 1

	New status	Batch 1.1	Batch 1.2
Wafers received	100	50	50
Wafers irradiated	100	50	50
Wafers tested	100	50	50
Wafers accepted	100	50	50
A retest was needed	0	2	4
Wafers rejected	0	0	0

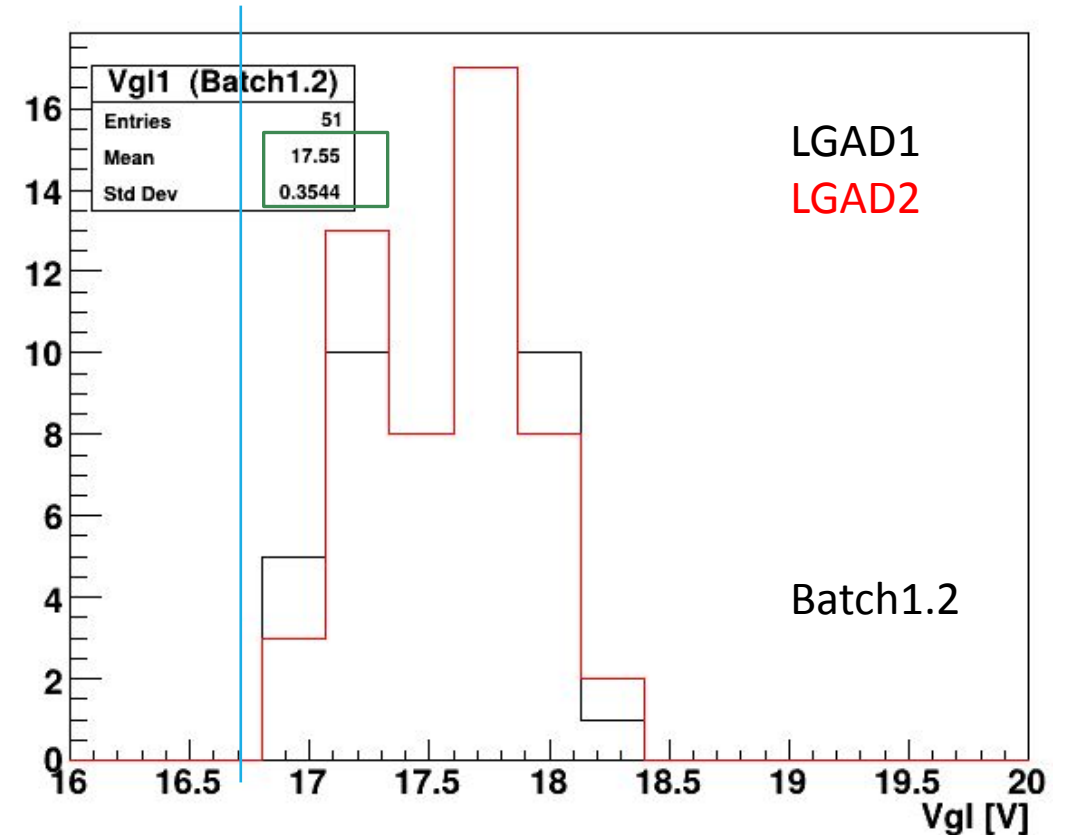
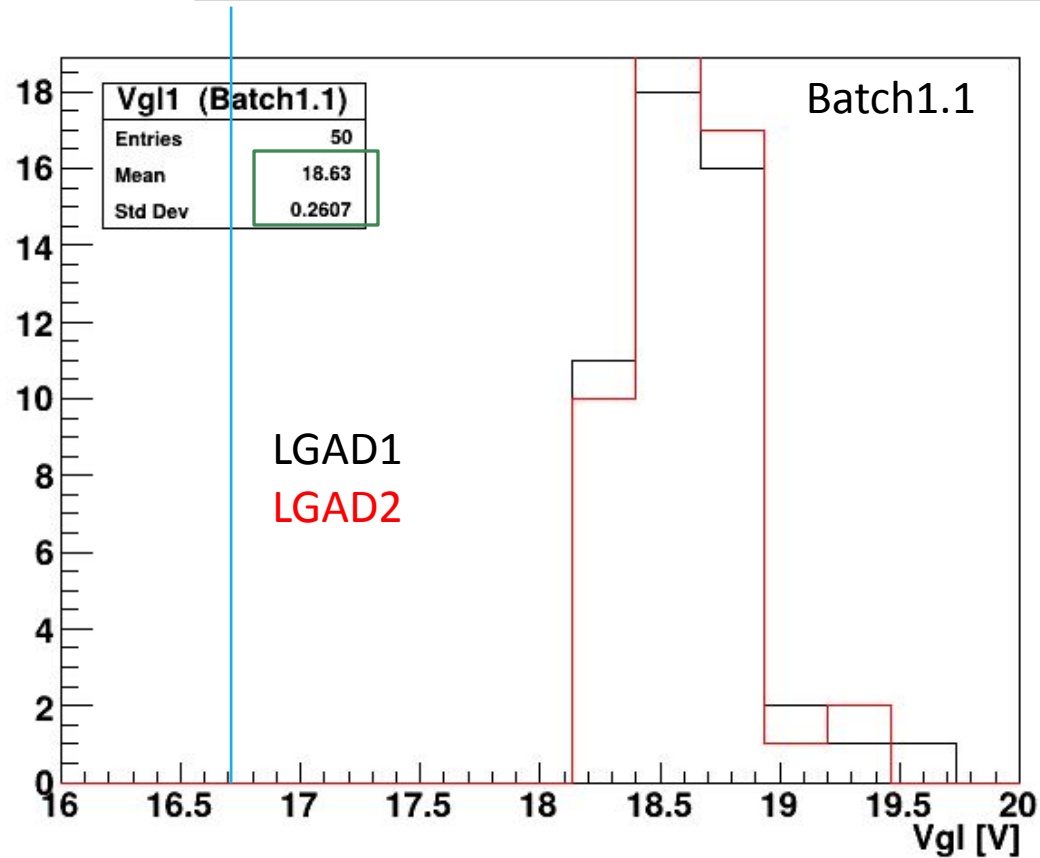
- Received more IHEP QCTS from 1st batch
 - Batches no 18 and 21
- Measured 50 samples, 48 of them on position 30
 - 2 samples (W19 & W23) from batch 18 had too high current and broke down by 10V so we measured position 5 instead. The 2 samples used the same measuring box
 - 1 sample had borderline Vgl, Sr90 results were good

Irradiations from Batch 1 on

- We use the “central channel” of the reactor where homogeneity of irradiation is better than for F19 channel which we used in the past. That makes irradiation campaigns much easier as we can have more samples in the irradiation container.
- The required power to deliver the same flux is 60kW (250 kW for F19) to have the same irradiation times i.e. same history (carefully calibrated!)
- We noted that the leakage current in PIN measured for Batch 1.1 was slightly less than for Pilot batch irradiated in F19.
- We overcorrected (using 66 kW) and the fluence delivered to the Batch 1.2 is in fact somewhat more than for Batch 1.1.
- **Still as you will see they meet the acceptance criteria, but as expected the average values of charge and V_{gl} as somewhat lower – very good sensitivity!**

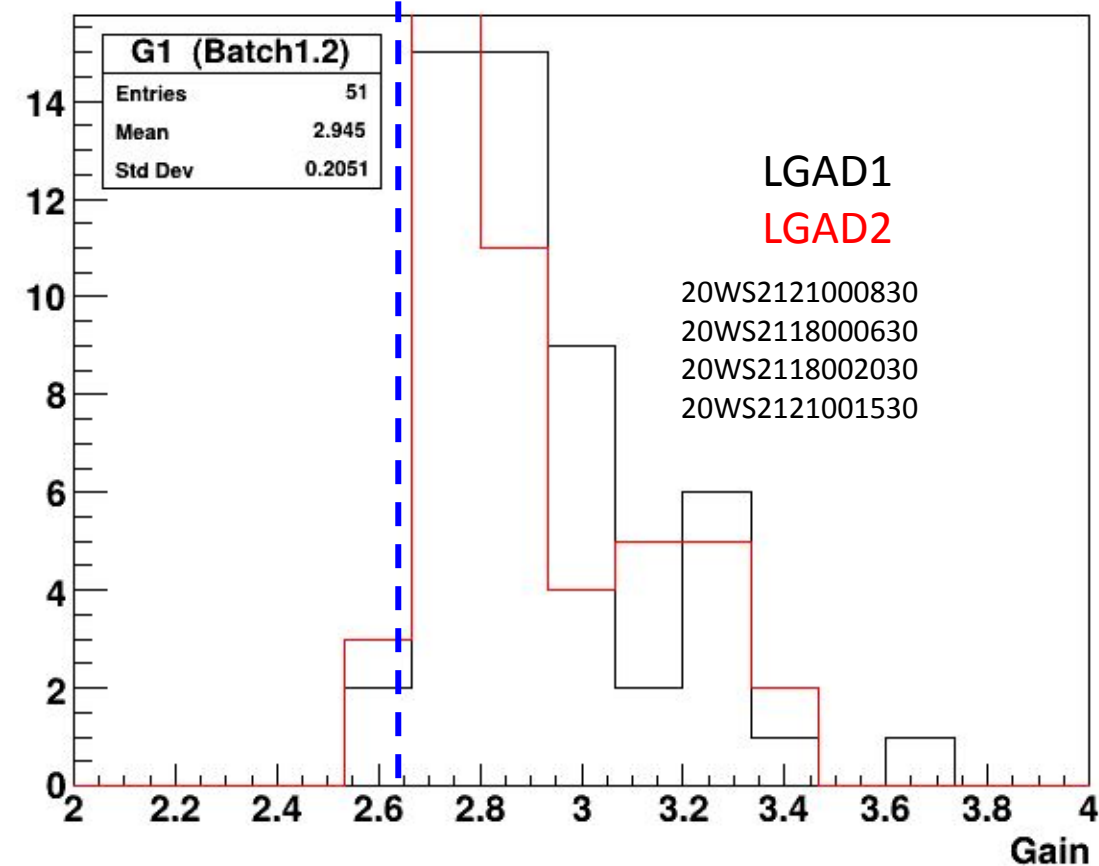
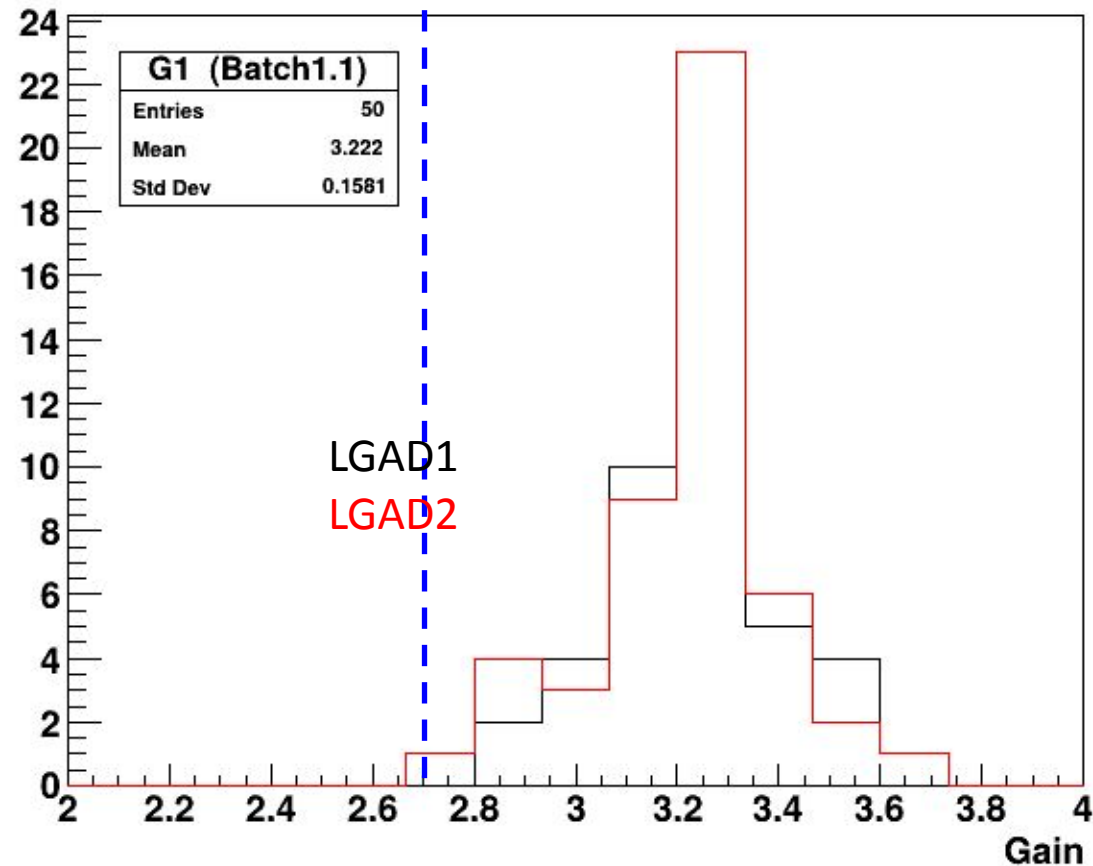


Vgl – Batch 1 (100 wafers tested)



- All wafers are comfortably within the threshold
- Note we have changed the fluence by 10% - we are now using central channel which is more uniform irradiations
- Batch1.1 has higher Vgl than Batch1.2 due to 10% larger fluence

Gain – Batch 1 (100 wafers tested)



- Similar observation than for Vgl measurements - all wafers inside the threshold for Batch1.1
- For Batch1.2 we had four samples at the border (note 10% higher than nominal fluence)

Batch 1.1 tests

- 48 wafers with no issues
- 20WS2107001830 – passes the necessary thresholds (accepted), but **Vgl** and **charge gain** indicate somewhat smaller radiation hardness. To be looked at.
- 20WS2106000430 – has only problematic gain measurement in LGAD2, Vgl and gain in LGAD1 are all fine – very likely dust obstructing the light, not likely a wafer problem.
- The problems not linked to the B6-W2 and B6-W8 – the two wafers showing different behaviour in PQC tests.

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2107000130	7	1	30	18.6	18.7	3.4	3.4
20WS2107000230	7	2	30	19.0	18.8	3.2	3.2
20WS2107000330	7	3	30	18.8	18.7	3.2	3.2
20WS2107000430	7	4	30	18.6	18.5	3.1	3.1
20WS2107000530	7	5	30	18.5	18.5	3.2	3.2
20WS2107000630	7	6	30	18.5	18.9	3.5	3.5
20WS2107000730	7	7	30	18.7	18.5	3.2	3.2
20WS2107000830	7	8	30	18.6	18.6	3.3	3.3
20WS2107000930	7	9	30	18.9	18.7	3.4	3.4
20WS2107001030	7	10	30	18.7	18.4	3.3	3.3
20WS2107001130	7	11	30	18.7	18.6	3.3	3.3
20WS2107001230	7	12	30	18.6	18.5	3.3	3.3
20WS2107001330	7	13	30	18.4	18.5	3.3	3.3
20WS2107001430	7	14	30	18.4	18.7	3.3	3.2
20WS2107001530	7	15	30	18.7	18.5	3.3	3.3
20WS2107001630	7	16	30	18.4	18.4	3.3	3.3
20WS2107001730	7	17	30	18.4	18.6	3.5	3.3
20WS2107001830	7	18	30	17.4	17.6	2.8	2.8
20WS2107001930	7	19	30	18.6	18.4	3.2	3.2
20WS2107002030	7	20	30	18.8	18.6	3.6	3.6
20WS2107002130	7	21	30	18.5	18.7	3.4	3.4
20WS2107002230	7	22	30	18.5	18.5	3.2	3.2
20WS2107002330	7	23	30	18.6	18.5	3.3	3.3
20WS2107002430	7	24	30	18.7	18.3	3.5	3.4
20WS2107002530	7	25	30	18.8	18.5	3.1	3.1
20WS2106000130	6	1	30	18.6	18.7	3.2	2.9
20WS2106000230	6	2	30	19.0	19.2	3.0	3.0
20WS2106000430	6	4	30	18.9	18.8	3.5	2.6
20WS2106000530	6	5	30	18.2	18.5	3.1	2.8
20WS2106000630	6	6	30	18.5	18.6	2.9	2.9
20WS2106000830	6	8	30	19.3	19.4	3.4	3.4
20WS2106000930	6	9	30	19.7	19.3	3.2	3.2
20WS2106001030	6	10	30	18.5	18.7	3.2	3.2
20WS2106001130	6	11	30	18.5	18.7	3.0	2.9
20WS2106001230	6	12	30	18.9	18.7	3.0	3.0
20WS2106001330	6	13	30	18.9	18.6	3.2	3.2
20WS2106001430	6	14	30	18.7	18.5	3.5	3.5
20WS2106001530	6	15	30	18.7	18.4	3.1	3.1
20WS2106001630	6	16	30	18.6	18.7	3.2	3.2
20WS2106001830	6	18	30	18.6	18.9	3.0	3.0
20WS2106001930	6	19	30	18.7	18.7	3.1	3.1
20WS2106002130	6	21	30	18.4	18.2	3.1	3.1
20WS2106002230	6	22	30	18.9	18.9	3.1	3.1
20WS2106002530	6	25	30	18.3	18.7	3.1	3.1
20WS2115000430	15	4	30	18.3	18.3	3.2	3.2
20WS2115000630	15	6	30	18.5	18.4	3.2	3.2
20WS2115000730	15	7	30	18.3	18.4	2.9	2.9
20WS2115001130	15	11	30	18.4	18.3	3.1	3.1
20WS2115001430	15	14	30	18.4	18.5	3.2	3.2
20WS2115002530	15	25	30	18.1	18.3	3.0	3.0

Batch 1.2 tests (10% larger fluence)

20WS2118000130	18	1	30	17.7	17.7	2.8	2.8
20WS2118000230	18	2	30	17.6	17.7	2.9	2.9
20WS2118000330	18	3	30	17.8	18	3	3
20WS2118000430	18	4	30	17.7	17.6	3	3.1
20WS2118000530	18	5	30	17.1	17	3.1	3.1
20WS2118000630	18	6	30	17.4	17.4	2.9	2.6
20WS2118000730	18	7	30	18	17.1	2.8	2.8
20WS2118000830	18	8	30	17.6	17.2	2.8	2.8
20WS2118000930	18	9	30	17	17.3	3	2.8
20WS2118001030	18	10	30	17.9	17.9	3	3
20WS2118001130	18	11	30	17.9	17.4	2.9	2.9
20WS2118001230	18	12	30	16.9	17.2	2.8	2.8
20WS2118001330	18	13	30	16.8	16.9	3	3.1
20WS2118001430	18	14	30	16.9	17	3.3	2.7
20WS2118001530	18	15	30	17.4	17.3	2.9	2.9
20WS2118001630	18	16	30	17.8	17.8	2.8	2.8
20WS2118001730	18	17	30	17.9	17.6	2.8	2.8
20WS2118001830	18	18	30	17.8	17.9	3.3	3.3
20WS2118001905	18	19	5	17.7	17.9	3.3	3.3
20WS2118002030	18	20	30	17.3	17.4	2.7	2.6
20WS2118002130	18	21	30	17.6	17.8	3	3
20WS2118002230	18	22	30	17.6	17.7	2.9	2.9
20WS2118002305	18	23	5	18.1	17.9	2.8	3.4
20WS2118002430	18	24	30	17.9	18.1	3	3.1
20WS2118002530	18	25	30	17	17.2	2.7	2.7

90Sr
retest

20WS2121000130	21	1	30	17.5	17.4	2.9	2.9
20WS2121000230	21	2	30	17.1	17.2	2.9	2.9
20WS2121000330	21	3	30	17.7	17.7	2.9	2.9
20WS2121000430	21	4	30	17.7	17.7	2.9	2.9
20WS2121000530	21	5	30	17.1	17.1	3.1	3.1
20WS2121000630	21	6	30	17.8	17.8	2.9	2.8
20WS2121000730	21	7	30	17.7	17.7	2.9	2.8
20WS2121000830	21	8	30	17.2	17.1	2.6	2.6
20WS2121000930	21	9	30	17.8	17.7	2.9	2.8
20WS2121001030	21	10	30	17.8	17.7	2.9	2.9
20WS2121001130	21	11	30	17.4	17.4	2.9	2.9
20WS2121001230	21	12	30	17.2	17.8	3.3	3.2
20WS2121001330	21	13	30	18.1	17.5	3.3	3.2
20WS2121001430	21	14	30	17.3	17.3	2.8	2.8
20WS2121001530	21	15	30	17.1	17.1	2.6	2.7
20WS2121001630	21	16	30	17.4	17.3	2.7	2.7
20WS2121001730	21	17	30	17.3	17.2	2.7	2.7
20WS2121001830	21	18	30	18	18.1	2.9	2.9
20WS2121001930	21	19	30	17.5	17.7	3.6	2.8
20WS2121002030	21	20	30	17.3	17.4	2.8	2.8
20WS2121002130	21	21	30	18.2	18.2	3.2	3.2
20WS2121002230	21	22	30	18	17.9	3.4	3.4
20WS2121002330	21	23	30	17.7	17.8	2.8	2.8
20WS2121002430	21	24	30	17.4	17.4	3	2.8
20WS2121002530	21	25	30	17.5	17.6	2.8	2.7

1st test

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2121001530	21	15	30	17.1	17.1	2.6	2.7
20WS2118000630	18	6	30	17.4	17.4	2.9	2.6
20WS2118002030	18	20	30	17.3	17.4	2.7	2.6
20WS2121000830	21	8	30	17.2	17.1	2.6	2.6

RETEST

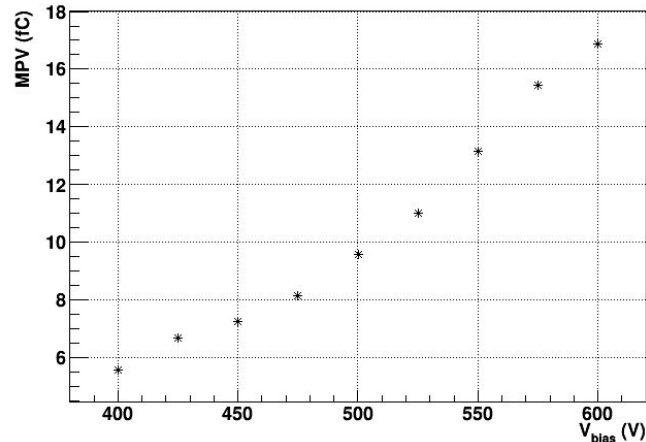
ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2121001530	21	15	30	17.5	17.4	2.8	2.8
20WS2118000630	18	6	30	17.4	17.5	2.8	2.8
20WS2118000605	18	6	5	17.5	17.6	2.7	2.9
20WS2118002030	18	20	30	17.4	17.5	2.9	2.9
20WS2121000805	21	8	5	17.6	17.7	3	3

All wafers passed
after retest of also
other positions!

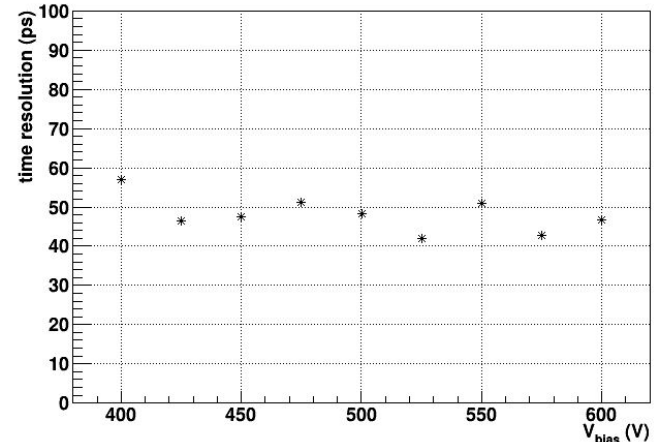


Sr90 results with B18-13-30 (low Vgl)

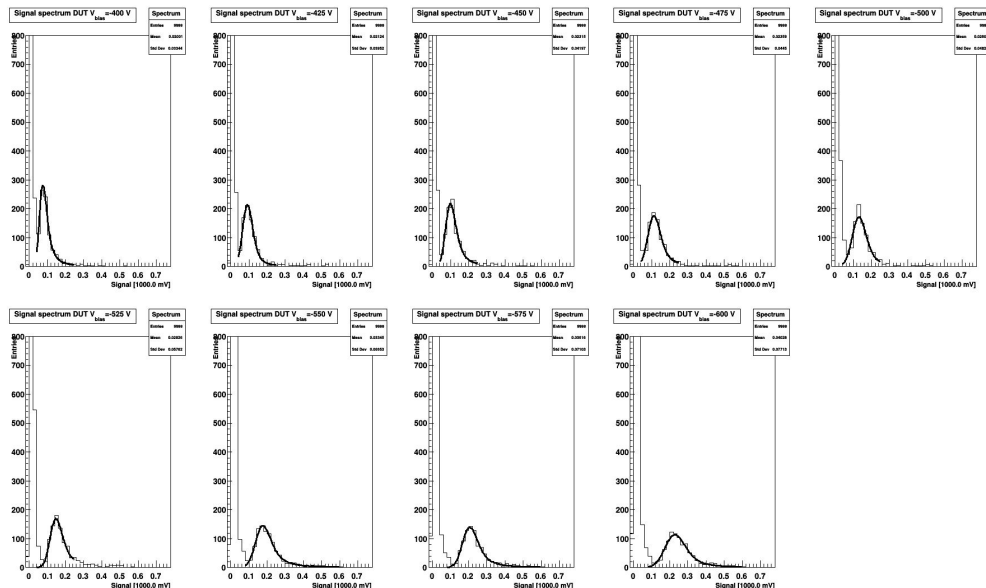
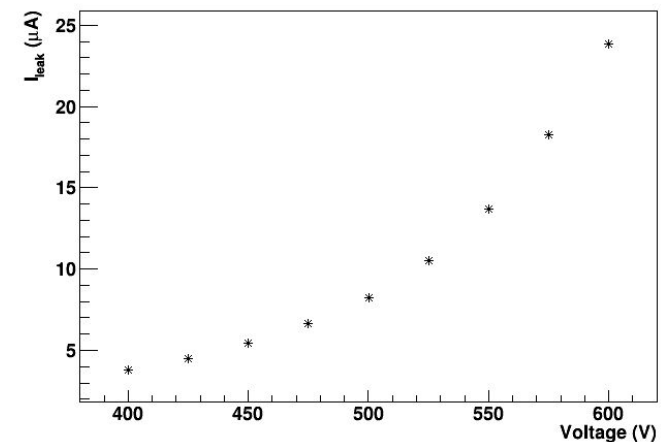
Teledyne_UKRI_IHEP_B18_13_30_2.SE1S



Teledyne_UKRI_IHEP_B18_13_30_2.SE1S



Leakage current T = 0 C



- Charge at 550 V is above 12 fC (Sr90 requirement is 5 fC) --> device performance excellent
- It looks like preproduction acceptance criteria are too strict
- Sr90 on additional IT devices planned

Overview IHEP-IME

	Previous status	Change (Batch2)	New status
Wafers received	117	95	213
Wafers irradiated	117	95	213
Wafers tested	117	95	213
Wafers accepted	117	93	211
Need more tests	0	2	0
Wafers rejected	0	0	0

- Received IHEP QCTS from 2nd batch
 - Batches no 23, 31, 33 & 36
- Measured 95 samples
 - 1 sample (B23 W4) had too high current and broke down by 10V so I measured it on position 5 instead
 - 6 samples in B36 measured on position 30 had gain under acceptance criteria so I also measured position 5 too
 - 4 samples on position 5 were good, 2 need more tests

Batch 2 results – batch 23

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2123000130	23	1	30	18.2	18.4	3	3.1
20WS2123000230	23	2	30	18.4	18.3	2.9	2.9
20WS2123000330	23	3	30	18.6	18.5	3	3.1
20WS2123000430	23	4	5	18.1	18.2	3.3	3.3
20WS2123000530	23	5	30	18.1	18	2.9	3
20WS2123000630	23	6	30	18.2	18.2	3.1	3
20WS2123000730	23	7	30	18.3	18.4	3	3
20WS2123000830	23	8	30	18.5	18.5	3	3
20WS2123000930	23	9	30	18.4	18.4	3.1	3.1
20WS2123001030	23	10	30	18.4	18.4	3.2	3.2
20WS2123001130	23	11	30	18.2	18.2	3	3
20WS2123001230	23	12	30	18.2	18.1	3	2.9
20WS2123001330	23	13	30	18.2	18.3	3	3
20WS2123001430	23	14	30	18.2	18.1	2.9	2.9
20WS2123001530	23	15	30	18.2	18.2	2.8	2.8
20WS2123001630	23	16	30	18.5	18.4	2.8	2.8
20WS2123001730	23	17	30	18.3	18.3	3	2.9
20WS2123001830	23	18	30	18.4	18.5	2.8	2.8
20WS2123001930	23	19	30	18.2	18.3	3	2.9
20WS2123002030	23	20	30	18.6	18.3	2.8	2.8
20WS2123002130	23	21	30	18.4	18.3	3	3
20WS2123002230	23	22	30	18.4	18.5	2.9	2.9
20WS2123002330	23	23	30	18.5	18.5	2.9	2.9
20WS2123002430	23	24	30	18.4	18.3	3	3
20WS2123002530	23	25	30	18.4	18.3	2.8	2.8



Batch 2 results – batch 31

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2131000130	31	1	30	18.1	17.9	3.3	3.4
20WS2131000230	31	2	30	18.4	18.4	3.6	3.6
20WS2131000430	31	4	30	18.3	18.3	3.5	3.5
20WS2131000530	31	5	30	18.3	18.1	3.4	3.3
20WS2131000630	31	6	30	18.2	18.4	3.5	3.5
20WS2131000730	31	7	30	18.4	18.4	3.7	3.6
20WS2131000830	31	8	30	18.4	18.4	3.5	3.5
20WS2131000930	31	9	30	18.2	18.1	3.5	3.5
20WS2131001030	31	10	30	18.1	18.2	3.4	3.4
20WS2131001130	31	11	30	18.3	18.4	3.4	3.4
20WS2131001230	31	12	30	18.6	18.4	3.4	3.4
20WS2131001330	31	13	30	18.2	18.4	3.6	3.6
20WS2131001430	31	14	30	18.3	18.4	3.4	3.4
20WS2131001530	31	15	30	18.4	18.2	3.4	3.4
20WS2131001630	31	16	30	18.3	18.5	3.4	3.4
20WS2131001730	31	17	30	18.2	18.1	3.5	3.5
20WS2131001830	31	18	30	18.3	18.1	3.4	3.4
20WS2131001930	31	19	30	18.4	18.3	3.3	3.3
20WS2131002030	31	20	30	18.4	18.5	3.2	3.2
20WS2131002130	31	21	30	18.3	18.3	3.5	3.5
20WS2131002230	31	22	30	18.5	18	3.1	3.1
20WS2131002330	31	23	30	18.4	18.4	3.4	3.4
20WS2131002430	31	24	30	18.4	18.5	3.6	3.6
20WS2131002530	31	25	30	18	18.1	3.3	3.3



Batch 2 results – batch 33

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2133000130	33	1	30	18.8	18.6	3	3
20WS2133000230	33	2	30	18.5	18.4	3.4	3.4
20WS2133000330	33	3	30	18.4	18.4	3.3	3.3
20WS2133000430	33	4	30	18.6	18.6	3.4	3.3
20WS2133000530	33	5	30	18.6	18.6	3.4	3.4
20WS2133000630	33	6	30	18.4	18.4	3.1	3.1
20WS2133000730	33	7	30	18.5	18.4	3.6	3.6
20WS2133000830	33	8	30	18.5	18.4	3.1	3.1
20WS2133000930	33	9	30	18.4	18.4	3.5	3.5
20WS2133001030	33	10	30	18.1	18.1	3.4	3.4
20WS2133001130	33	11	30	18	18.1	3.3	3.3
20WS2133001230	33	12	30	18.5	18.4	3.6	3.6
20WS2133001330	33	13	30	18.5	18.5	3.3	3.3
20WS2133001430	33	14	30	18.4	18.5	3.2	3.2
20WS2133001530	33	15	30	18.6	18.5	3.4	3.4
20WS2133001630	33	16	30	18.5	18.5	3	3
20WS2133001730	33	17	30	18.6	18.6	3.2	3.2
20WS2133001830	33	18	30	18.5	18.5	3.3	3.2
20WS2133001930	33	19	30	18.5	18.6	3.2	3.2
20WS2133002030	33	20	30	18.3	18.3	3.1	3.1
20WS2133002130	33	21	30	18.2	18.2	3.1	3.1
20WS2133002230	33	22	30	18.6	18.7	3.5	3.5
20WS2133002330	33	23	30	18.6	18.5	3.1	3.1
20WS2133002430	33	24	30	18.3	18.6	3.3	3.3
20WS2133002530	33	25	30	18.3	18.5	3.4	3.4



Batch 2 results – batch 36

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2136000130	36	1	30	18.2	18.2	3	3
20WS2136000230	36	2	30	18.5	18.2	2.8	2.8
20WS2136000330	36	3	30	18.5	18.7	2.8	2.8
20WS2136000430	36	4	30	18.4	18.4	2.8	2.8
20WS2136000630	36	6	30	18.4	18.4	2.8	2.8
20WS2136000730	36	7	30	18.3	18.4	2.4	2.4
20WS2136000830	36	8	30	18.3	18.4	2.7	2.7
20WS2136000930	36	9	30	18.5	18.5	2.7	2.6
20WS2136001030	36	10	30	18.2	18.3	2.8	2.8
20WS2136001130	36	11	30	18	18.1	2.6	2.6
20WS2136001230	36	12	30	18.4	18.4	3	2.9
20WS2136001330	36	13	30	18.3	18.5	2.6	2.6
20WS2136001430	36	14	30	18.3	18.3	3.9	3.9
20WS2136001530	36	15	30	18.5	18.4	2.8	2.8
20WS2136001630	36	16	30	18.5	18.5	2.9	2.9
20WS2136001730	36	17	30	18.5	18.6	2.9	2.9
20WS2136001830	36	18	30	18.5	18.6	2.7	2.8
20WS2136002030	36	20	30	18.5	18.5	3	2.9
20WS2136002130	36	21	30	18.6	18.6	2.9	2.9
20WS2136002230	36	22	30	18.6	18.6	2.9	2.9
20WS2136002430	36	24	30	18.1	18.4	3	3

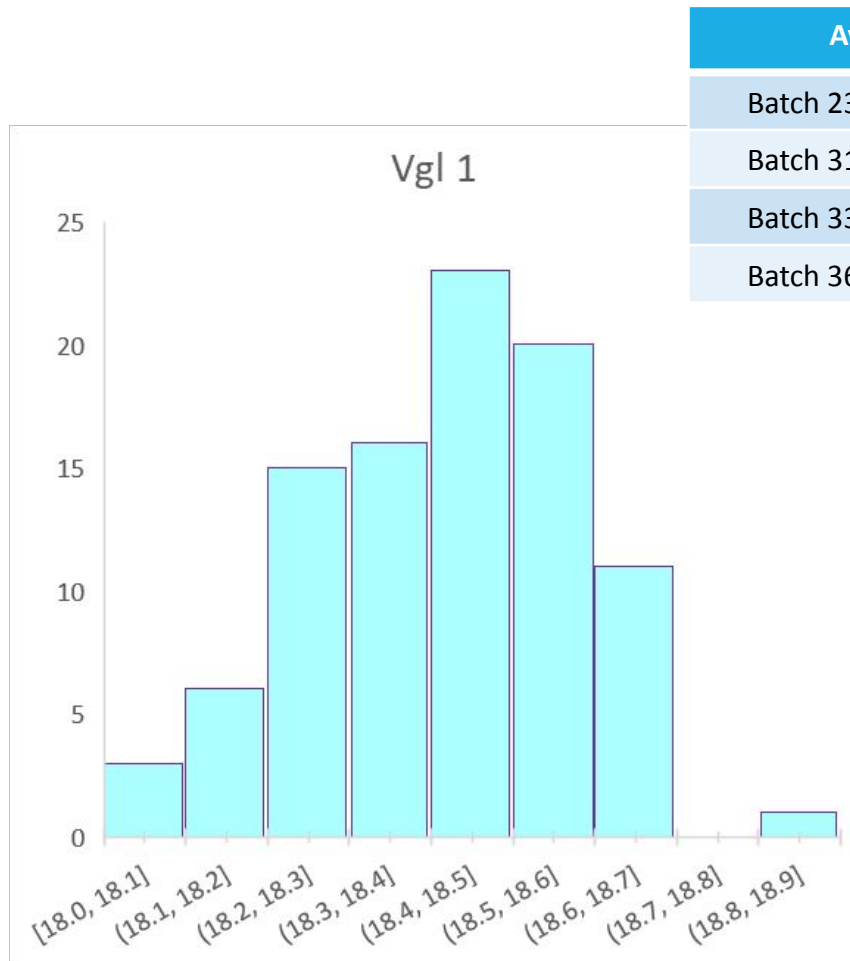


Batch 2 results – batch 36 position 5

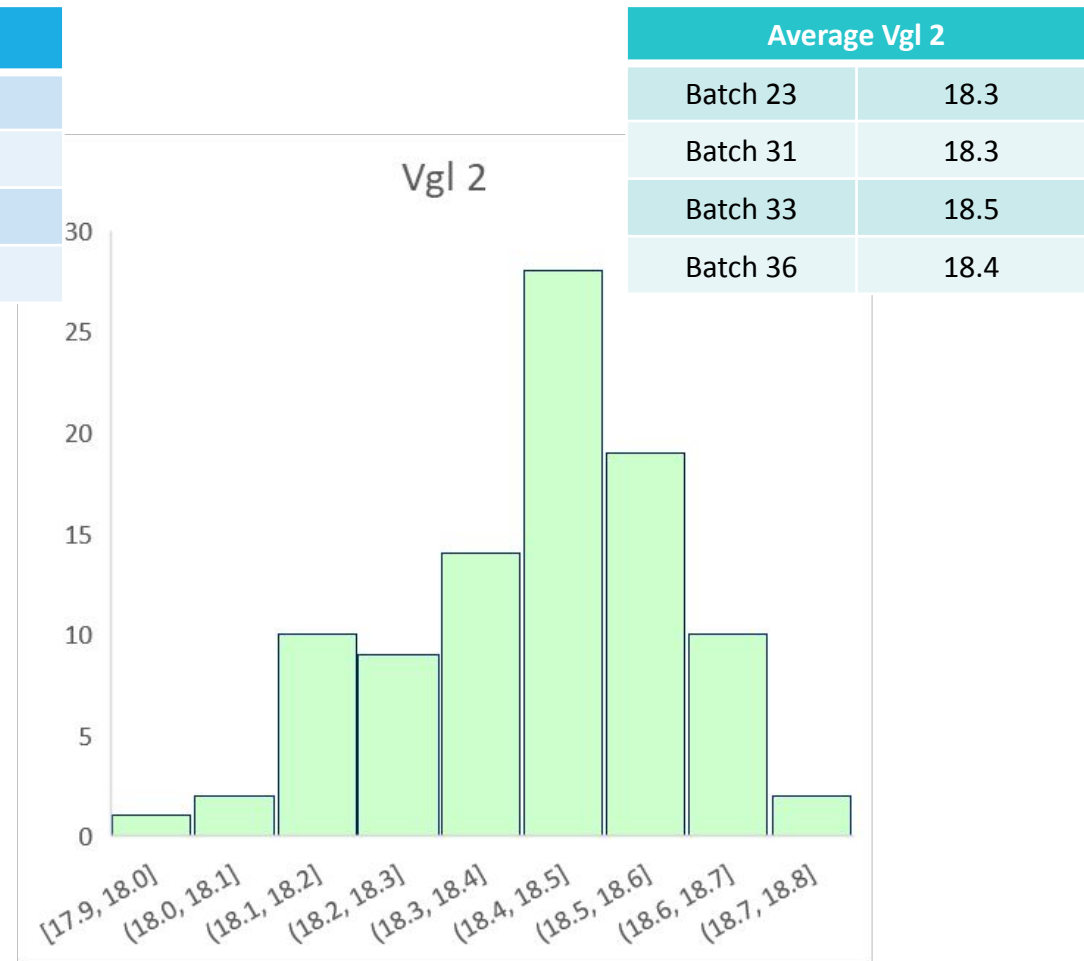
Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2136000705	36	7	5	18.5	18.5	2.6	2.6
20WS2136000805	36	8	5	18.3	18.3	3.1	3.1
20WS2136000905	36	9	5	18.6	18.4	2.9	2.9
20WS2136001105	36	11	5	18	17.9	2.5	2.4
20WS2136001305	36	13	5	18.3	18.3	2.8	2.8
20WS2136001805	36	18	5	18.6	18.5	2.9	2.9

Batch 2 results - Vgl



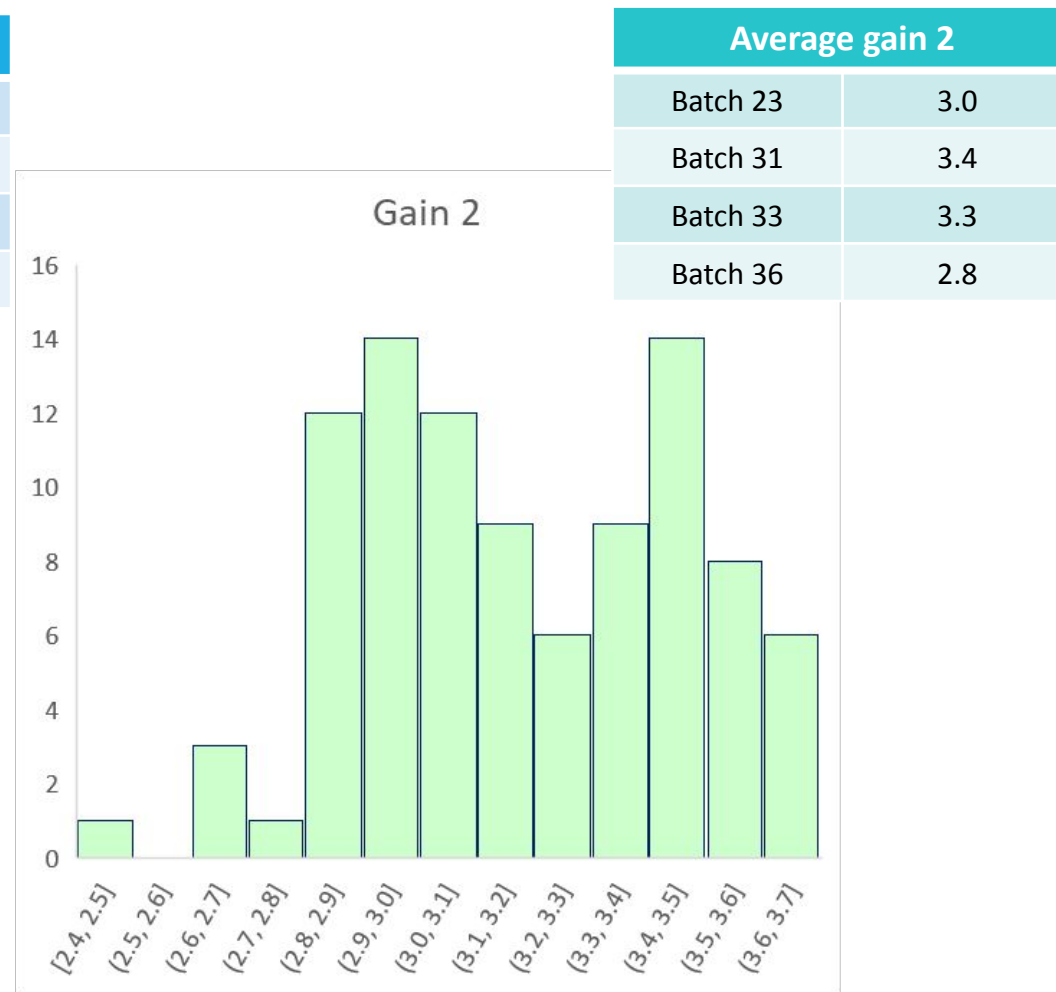
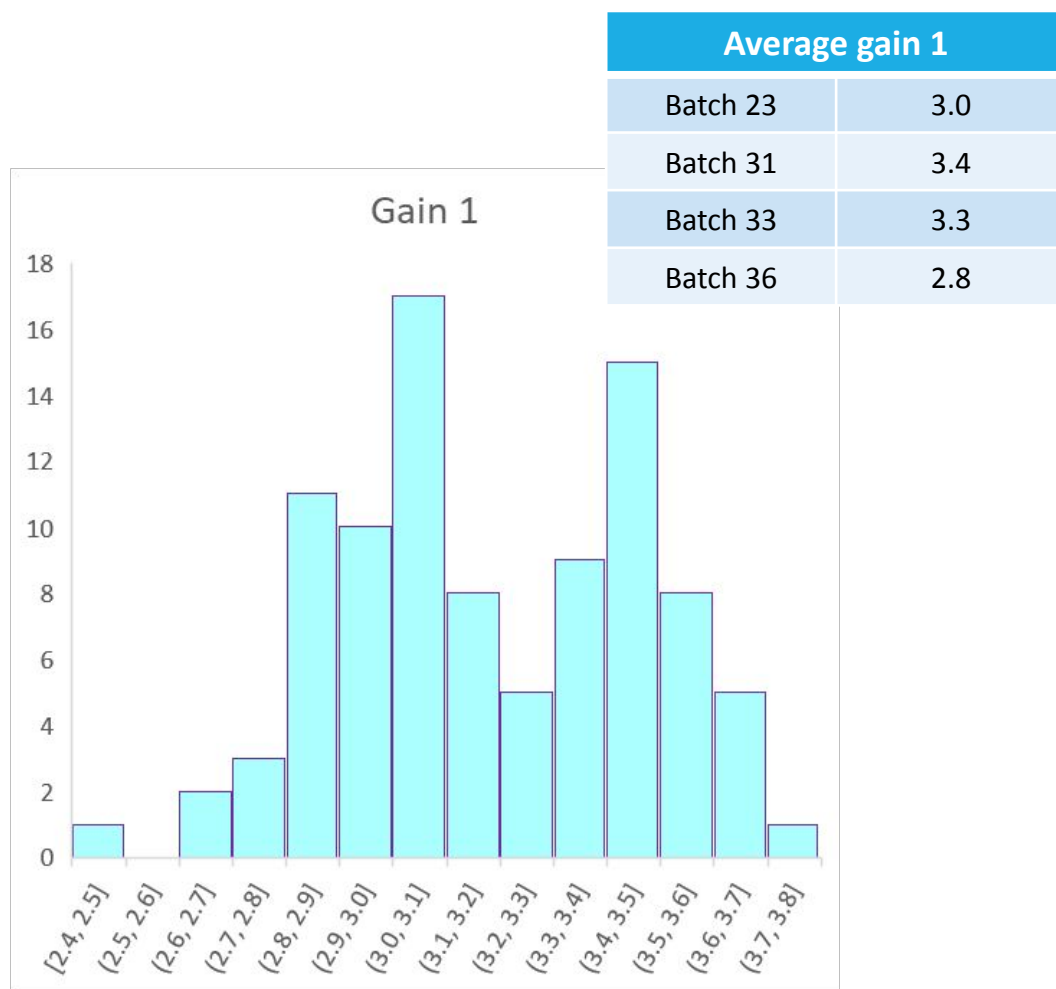
Average Vgl 1	
Batch 23	18.3
Batch 31	18.3
Batch 33	18.4
Batch 36	18.4



Average Vgl 2	
Batch 23	18.3
Batch 31	18.3
Batch 33	18.5
Batch 36	18.4

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

Batch 2 results



Preproduction acceptance criteria:

V_{gl} > 16.9 V

Gain > 2.7

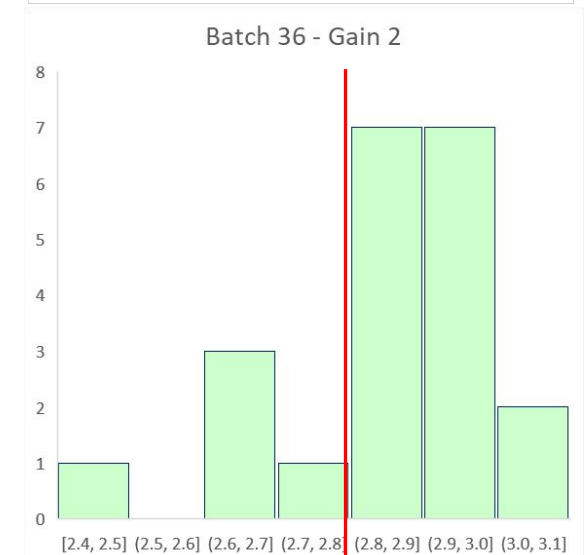
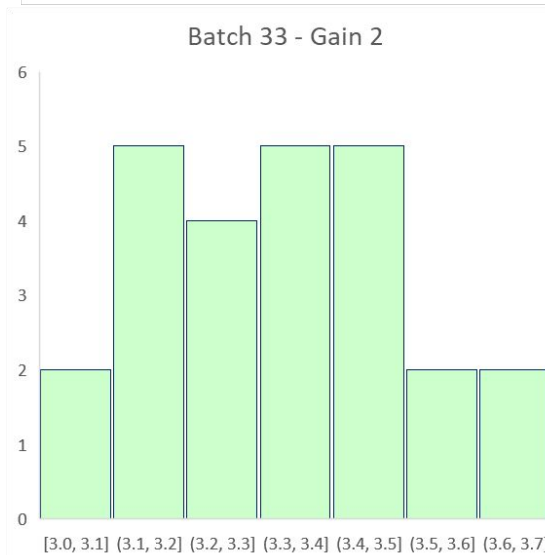
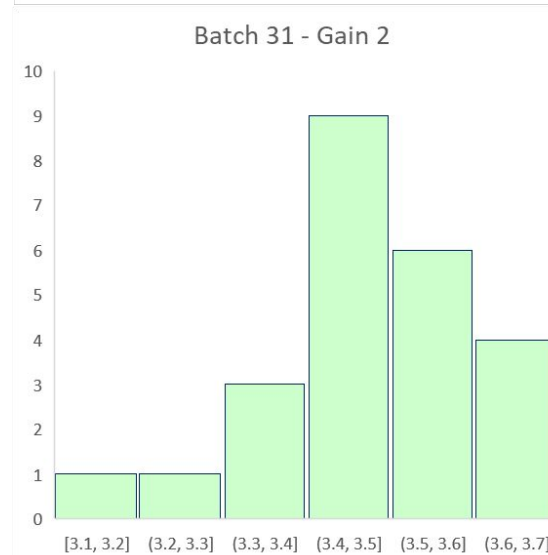
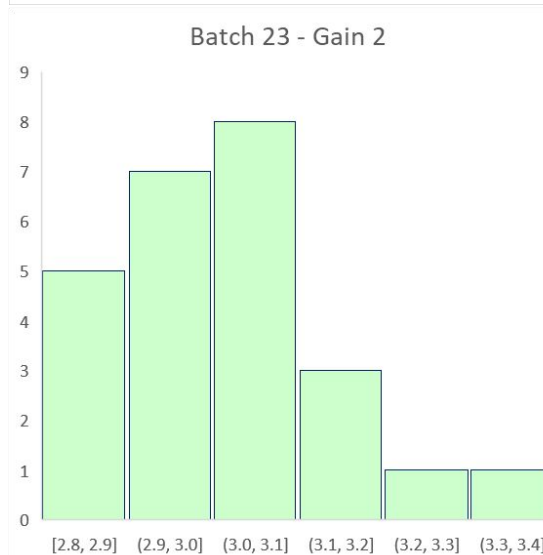
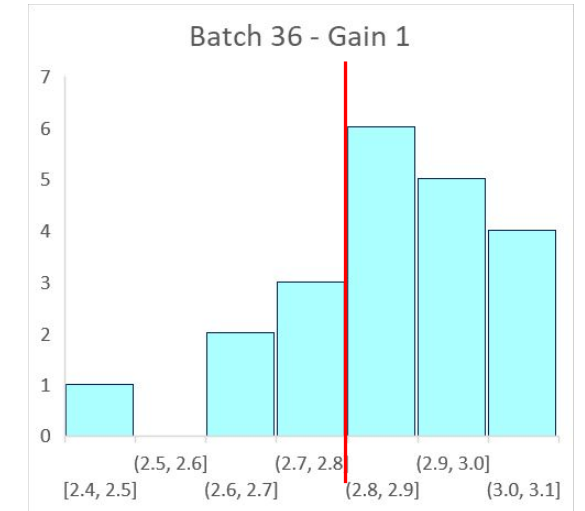
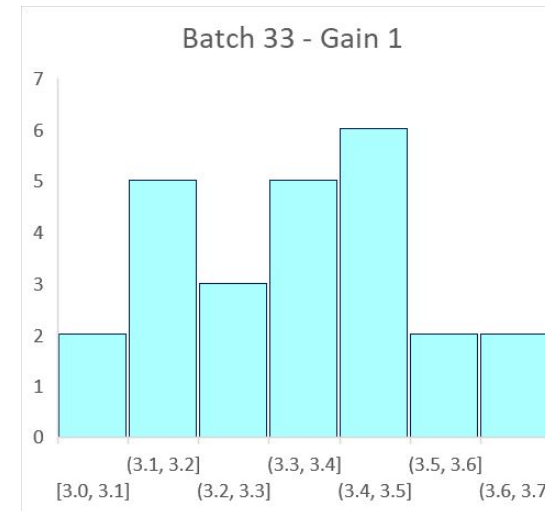
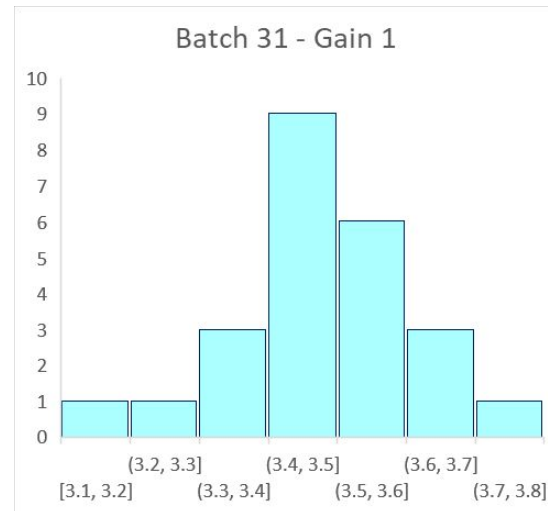
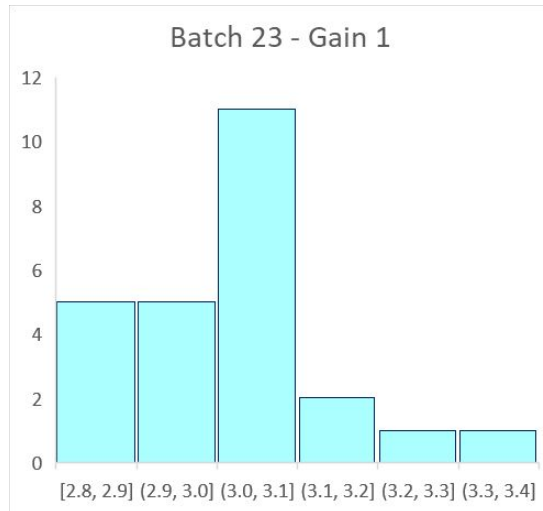


Gain per batch

Preproduction acceptance criteria:

$V_{gl} > 16.9 \text{ V}$

Gain > 2.7



Overview IHEP-IME

	Previous status	Change (Delivery 3)	New status
Wafers received	213	112	325
Wafers irradiated	213	112	325
Wafers tested	213	112	325
Wafers accepted	211	112	325
Need more tests	2	0	0
Wafers rejected	0	0	0

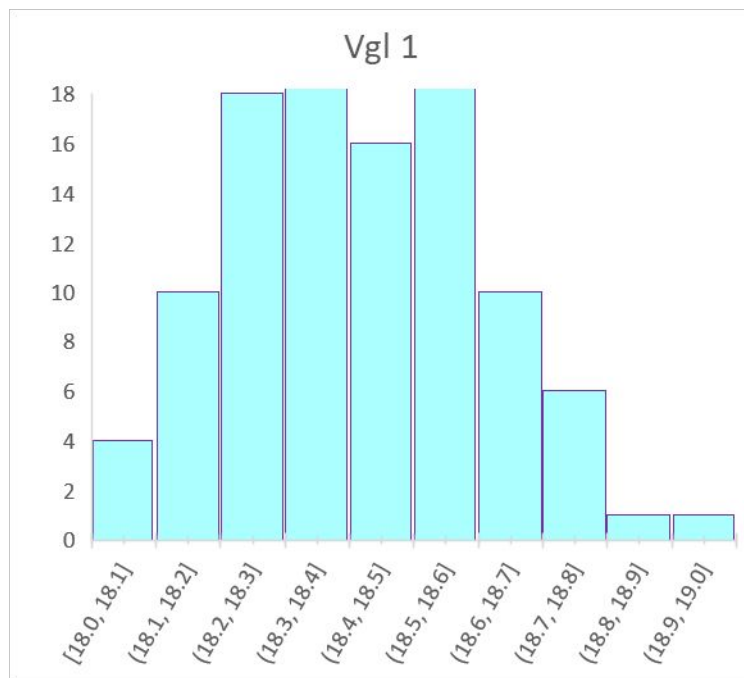
- Received IHEP QCTS from 3rd delivery
 - Batches no 10, 15, 27, 28, 30, 34 & 35
- We only irradiated positions 5 and 30
- Measured all 112 samples, 110 of them on position 30, 2 on position 5
 - Batch 10 W14 & batch 28 W22 broke down early on position 30 so I measured position 5 instead

Delivery 3 results - Vgl

Preproduction acceptance criteria:

Vgl > 16.9 V

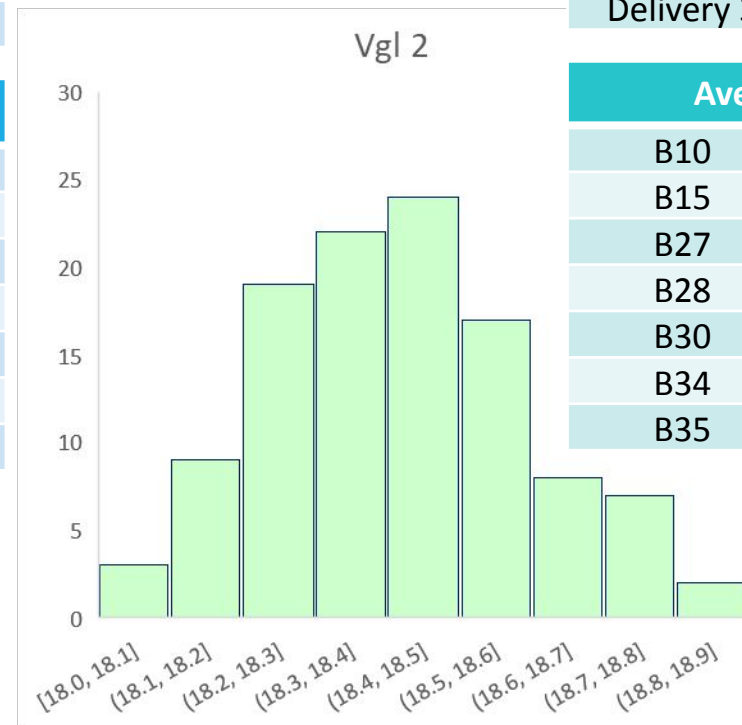
Gain > 2.7



Average Vgl 1	
Delivery 1	18.08
Delivery 2	18.27
Delivery 3	18.37

Average Vgl 1	
B10	18.4
B15	18.2
B27	18.3
B28	18.4
B30	18.4
B34	18.4
B35	18.2

Average Vgl 2	
Delivery 1	18.07
Delivery 2	18.24
Delivery 3	18.39



Average Vgl 2	
B10	18.4
B15	18.2
B27	18.4
B28	18.4
B30	18.4
B34	18.2
B35	18.1

Preproduction acceptance criteria:

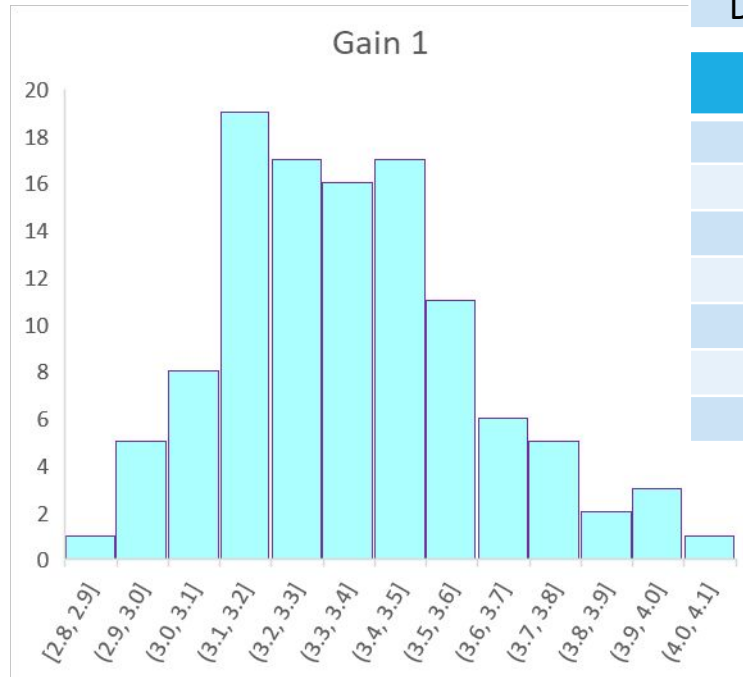
Vgl > 16.9 V

Gain > 2.7



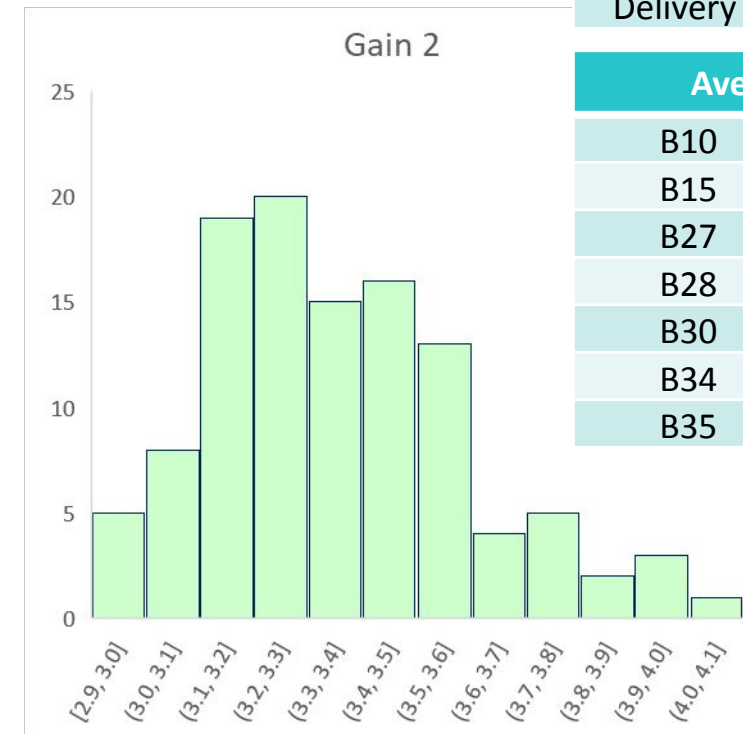
Delivery 3 results - gain

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7



Average gain 1	
Delivery 1	3.08
Delivery 2	3.02
Delivery 3	3.29

Average gain 1	
B10	3.5
B15	3.3
B27	3.2
B28	3.3
B30	3.1
B34	3.4
B35	3.8



Average gain 2	
Delivery 1	3.05
Delivery 2	3.03
Delivery 3	3.28

Average gain 2	
B10	3.5
B15	3.3
B27	3.2
B28	3.3
B30	3.1
B34	3.4
B35	3.8

Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

Delivery 3 – Batch 10

Preproduction acceptance criteria:

Vgl > 16.9 V

Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2110000130	10	1	30	18.9	18.8	3.7	3.7
20WS2110000230	10	2	30	18.7	18.5	3.5	3.5
20WS2110000330	10	3	30	18.5	18.6	3.7	3.7
20WS2110000430	10	4	30	18.7	18.6	3.5	3.5
20WS2110000530	10	5	30	18.5	18.6	3.8	3.7
20WS2110000630	10	6	30	18.4	18.4	3.8	3.8
20WS2110000730	10	7	30	18.5	18.5	3.9	3.9
20WS2110000830	10	8	30	18.5	18.5	3.4	3.4
20WS2110000930	10	9	30	18.5	18.5	3.6	3.6
20WS2110001030	10	10	30	18.5	18.4	3.6	3.6
20WS2110001130	10	11	30	18.4	18.6	3.5	3.5
20WS2110001230	10	12	30	18.6	18.5	3.4	3.4
20WS2110001330	10	13	30	18.3	18.4	3.3	3.3
20WS2110001430	10	14	5	18.5	18.3	3.1	3.2
20WS2110001630	10	16	30	18.3	18.3	3.4	3.4
20WS2110001730	10	17	30	18.3	18.3	3.4	3.4
20WS2110001830	10	18	30	18.4	18.3	3.5	3.5
20WS2110001930	10	19	30	18.2	18.2	3.4	3.4
20WS2110002030	10	20	30	18.2	18.2	3.4	3.4
20WS2110002130	10	21	30	18.3	18.4	3.5	3.5
20WS2110002230	10	22	30	18.3	18.3	3.3	3.3
20WS2110002330	10	23	30	18.3	18.3	3.6	3.5
20WS2110002430	10	24	30	18.3	18.1	3.4	3.4
20WS2110002530	10	25	30	18.4	18.4	3.5	3.5



Delivery 3 – Batch 27

Preproduction acceptance criteria:

Vgl > 16.9 V

Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2127000130	27	1	30	18.3	18.4	2.8	2.9
20WS2127000230	27	2	30	18.3	18.2	3.1	3.1
20WS2127000330	27	3	30	18	18.2	3.3	3.3
20WS2127000430	27	4	30	18	18.1	3.2	3.2
20WS2127000530	27	5	30	18.1	18	3	3
20WS2127000630	27	6	30	18.2	18.2	2.9	3
20WS2127000730	27	7	30	18.4	18.4	3.1	3.1
20WS2127000830	27	8	30	18.5	18.5	3.2	3.2
20WS2127000930	27	9	30	18.3	18.1	3.3	3.3
20WS2127001130	27	11	30	18.2	18.3	3.2	3.2
20WS2127001230	27	12	30	18.1	18.2	3	3
20WS2127001330	27	13	30	18.1	18.4	2.9	2.9
20WS2127001430	27	14	30	18.5	18.4	3	3
20WS2127001530	27	15	30	18.1	18.3	3.2	3.2
20WS2127001630	27	16	30	18.6	18.5	3.1	3.1
20WS2127001730	27	17	30	18.4	18.5	3.2	3.2
20WS2127001830	27	18	30	18.2	18.4	3.1	3.1
20WS2127001930	27	19	30	18.3	18.4	3.4	3.4
20WS2127002030	27	20	30	18.2	18.2	3.4	3.4
20WS2127002130	27	21	30	18.4	18.5	3.3	3.3
20WS2127002230	27	22	30	18.7	18.7	3.3	3.3
20WS2127002330	27	23	30	18.4	18.7	3.4	3.4
20WS2127002430	27	24	30	18.5	18.7	3.1	3.1
20WS2127002530	27	25	30	18.6	18.4	3.3	3.3



Delivery 3 – Batch 28

Preproduction acceptance criteria:

Vgl > 16.9 V

Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2128000130	28	1	30	18.4	18.4	3.4	3.4
20WS2128000230	28	2	30	18	18.2	3.2	3.2
20WS2128000330	28	3	30	18.2	18.2	3.2	3.2
20WS2128000430	28	4	30	18.3	18.5	3.5	3.5
20WS2128000530	28	5	30	18.5	18.3	3.2	3.2
20WS2128000630	28	6	30	18.1	18.2	3.3	3.3
20WS2128000730	28	7	30	18.3	18.2	3.4	3.3
20WS2128000830	28	8	30	18.4	18.3	3.4	3.4
20WS2128000930	28	9	30	18.3	18.2	3.3	3.3
20WS2128001130	28	11	30	18.2	18.1	3.2	3.2
20WS2128001230	28	12	30	18.5	18.3	3.3	3.2
20WS2128001330	28	13	30	18.3	18.3	3.3	3.3
20WS2128001430	28	14	30	18.5	18.6	2.9	2.9
20WS2128001530	28	15	30	18.6	18.7	3.3	3.2
20WS2128001630	28	16	30	18.4	18.5	3.4	3.4
20WS2128001830	28	18	30	18.3	18.5	3.5	3.5
20WS2128001930	28	19	30	18.5	18.5	3.4	3.4
20WS2128002030	28	20	30	18.6	18.5	3.6	3.5
20WS2128002130	28	21	30	18.5	18.4	3	3.1
20WS2128002205	28	22	5	18.1	18.3	3.7	3.7
20WS2128002330	28	23	30	18.8	18.6	3.1	3.1
20WS2128002430	28	24	30	18.5	18.4	3.3	3.3
20WS2128002530	28	25	30	18.1	18.4	3.5	3.5



Delivery 3 – Batch 30

Preproduction acceptance criteria:

Vgl > 16.9 V

Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2130000130	30	1	30	18.4	18.7	3.1	3.1
20WS2130000230	30	2	30	18.2	18.4	2.9	2.9
20WS2130000330	30	3	30	18.6	18.5	3.1	3.1
20WS2130000430	30	4	30	18.7	18.8	3	3
20WS2130000530	30	5	30	18.5	18.5	3.3	3.3
20WS2130000630	30	6	30	18.6	18.7	3.2	3.2
20WS2130000730	30	7	30	18.5	18.7	3.2	3.2
20WS2130000830	30	8	30	18.6	18.6	3.1	3.1
20WS2130000930	30	9	30	18.3	18.3	3.2	3.2
20WS2130001030	30	10	30	18.4	18.4	3.3	3.3
20WS2130001230	30	12	30	18.4	18.6	3.3	3.3
20WS2130001330	30	13	30	18.3	18.3	3.1	3.1
20WS2130001430	30	14	30	18.1	18.2	2.9	2.9
20WS2130001530	30	15	30	18.2	18.2	3.2	3.2
20WS2130001630	30	16	30	18.5	18.3	3.1	3.1
20WS2130001730	30	17	30	18.3	18.4	3.1	3.1
20WS2130001830	30	18	30	18.3	18.3	3.1	3.1
20WS2130001930	30	19	30	18.4	18.4	3.1	3.1
20WS2130002030	30	20	30	18.6	18.3	3.1	3.1
20WS2130002130	30	21	30	18.3	18.3	3	3
20WS2130002230	30	22	30	18.1	18.3	3	3
20WS2130002330	30	23	30	18.2	18	3.1	3.1
20WS2130002430	30	24	30	18.6	18.5	3	3



Delivery 3 – Batch 15, 34 & 35

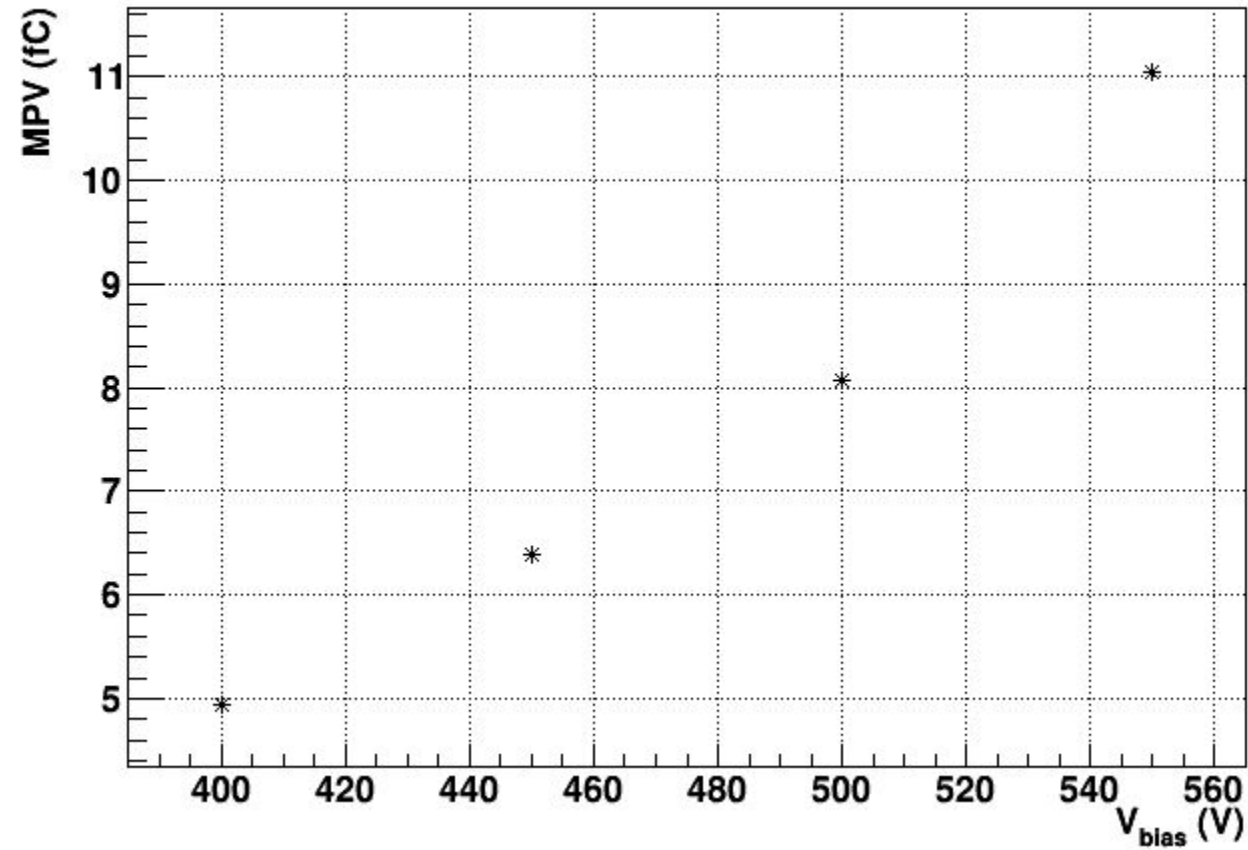
Preproduction acceptance criteria:
Vgl > 16.9 V
Gain > 2.7

ATLAS ID	Batch	Wafer	Position	Vgl 1	Vgl 2	Gain 1	Gain 2
20WS2115001830	15	18	30	18.2	18.2	3.3	3.3
20WS2134000230	34	2	30	18.5	18.3	3.4	3.4
20WS2134000330	34	3	30	18.4	18.2	3.4	3.4
20WS2134000430	34	4	30	18.2	18.2	3.1	3.1
20WS2134000530	34	5	30	18.2	18.4	4	4
20WS2134000630	34	6	30	18	18.2	3.5	3.5
20WS2134000730	34	7	30	18.3	18.4	3.2	3.2
20WS2134000830	34	8	30	18.3	18.2	3.2	3.2
20WS2134000930	34	9	30	18.2	18.1	3.5	3.5
20WS2134001030	34	10	30	18.3	18.4	3.2	3.2
20WS2134001130	34	11	30	18.5	18.4	3.2	3.2
20WS2134001230	34	12	30	18.7	18.3	3.1	3.1
20WS2134001330	34	13	30	18.7	18	3.6	3.6
20WS2135000130	35	1	30	18.1	18.1	3.9	3.9
20WS2135000230	35	2	30	18.2	18.1	3.7	3.7
20WS2135000330	35	3	30	18.2	18.1	3.7	3.8
20WS2135000430	35	4	30	18.2	18.2	3.6	3.6
20WS2135000530	35	5	30	18.2	18.1	3.9	3.9



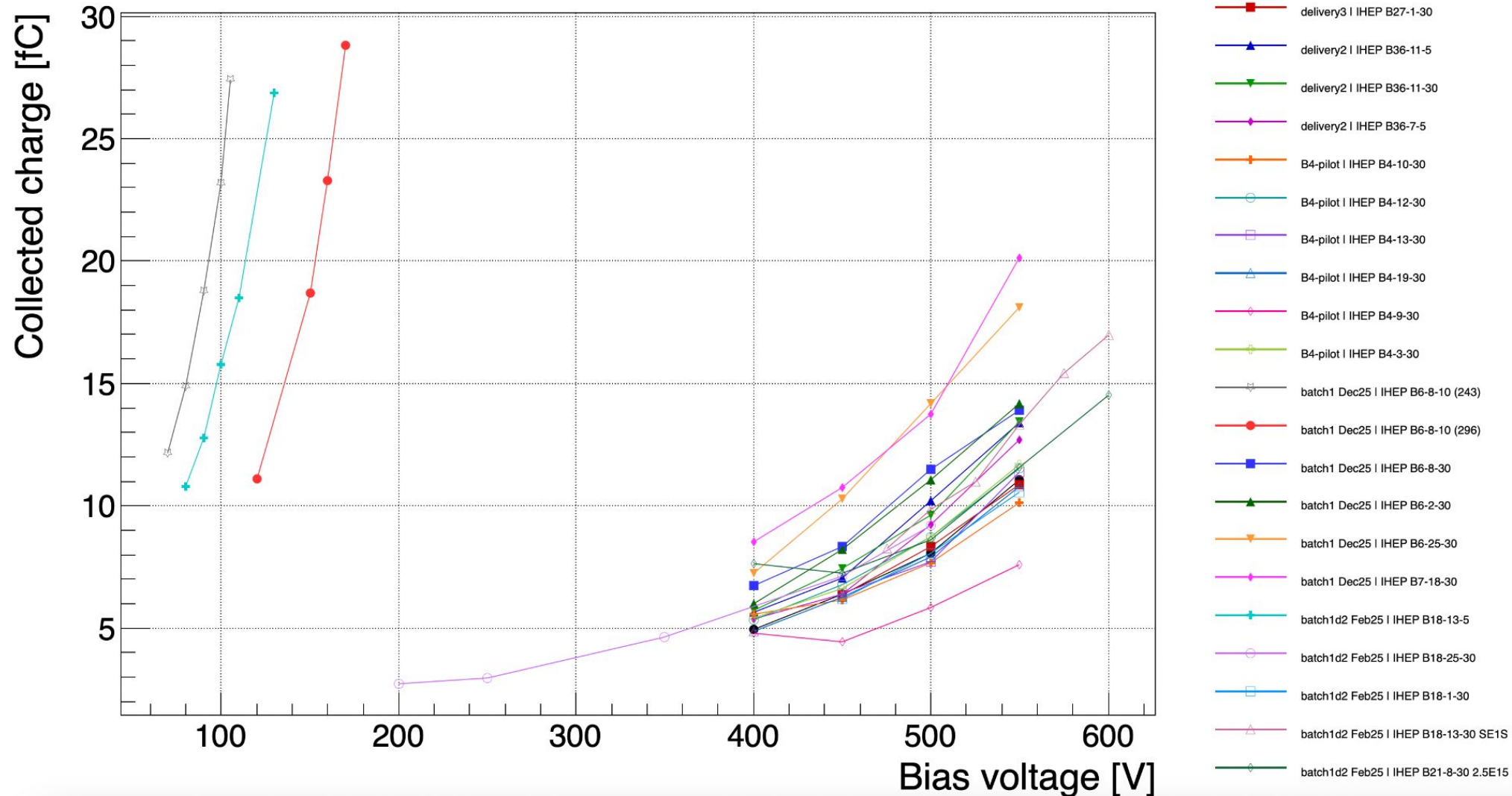
Sr90 measurement for B34 W12

IHEP_B34-12-30_25e14



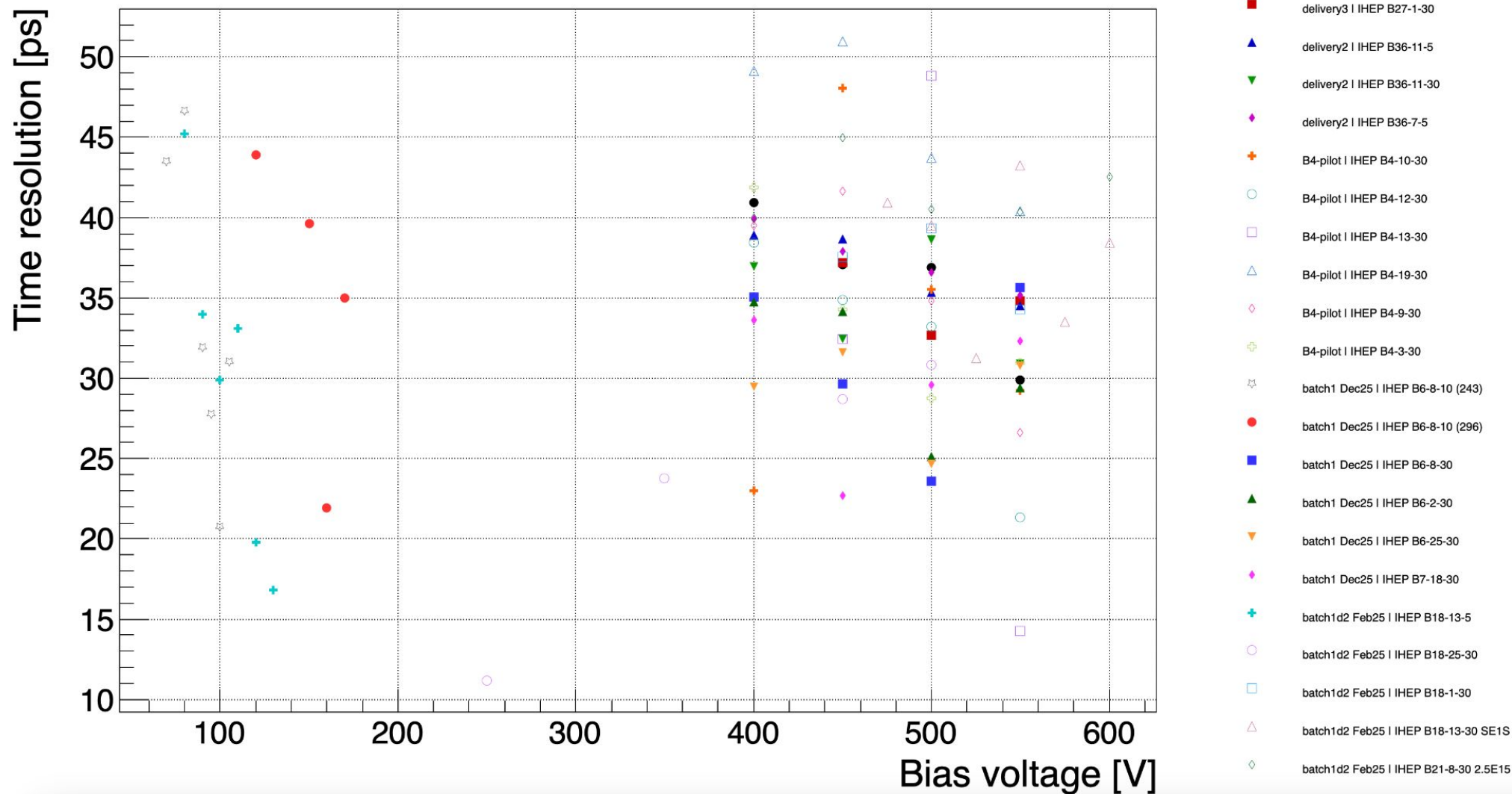
CC and TR summary

Collected charge vs bias voltage



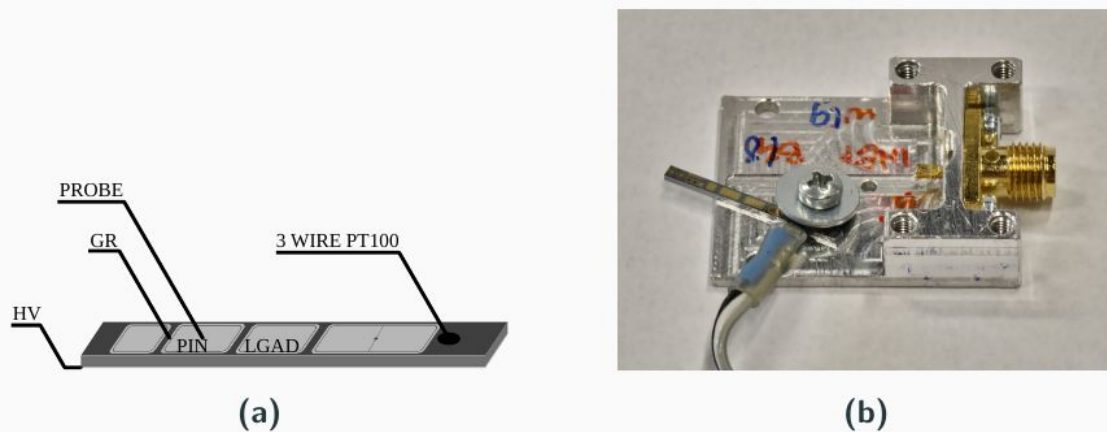
TR

Time resolution vs bias voltage



Temperature Dependence of Gain in Production Sensors

Measurement setup



Goal of the scan

- Measure LGAD/PIN IV curves versus temperature
- Extract gain after surface-current subtraction
- Determine $I_{\text{gen}}(T)$, effective E_g , and $V_{\text{BD}}(T)$ scaling

Measurement details

- Probe station scans from 0 to 550 V
- Temperatures from about -20 °C to 25 °C
- PT100 mounted directly on sample face
- Three repeated measurements averaged

$$G = (I_{\text{LGAD}} - I_{\text{surface}}) / (I_{\text{PIN}} - I_{\text{surface}})$$

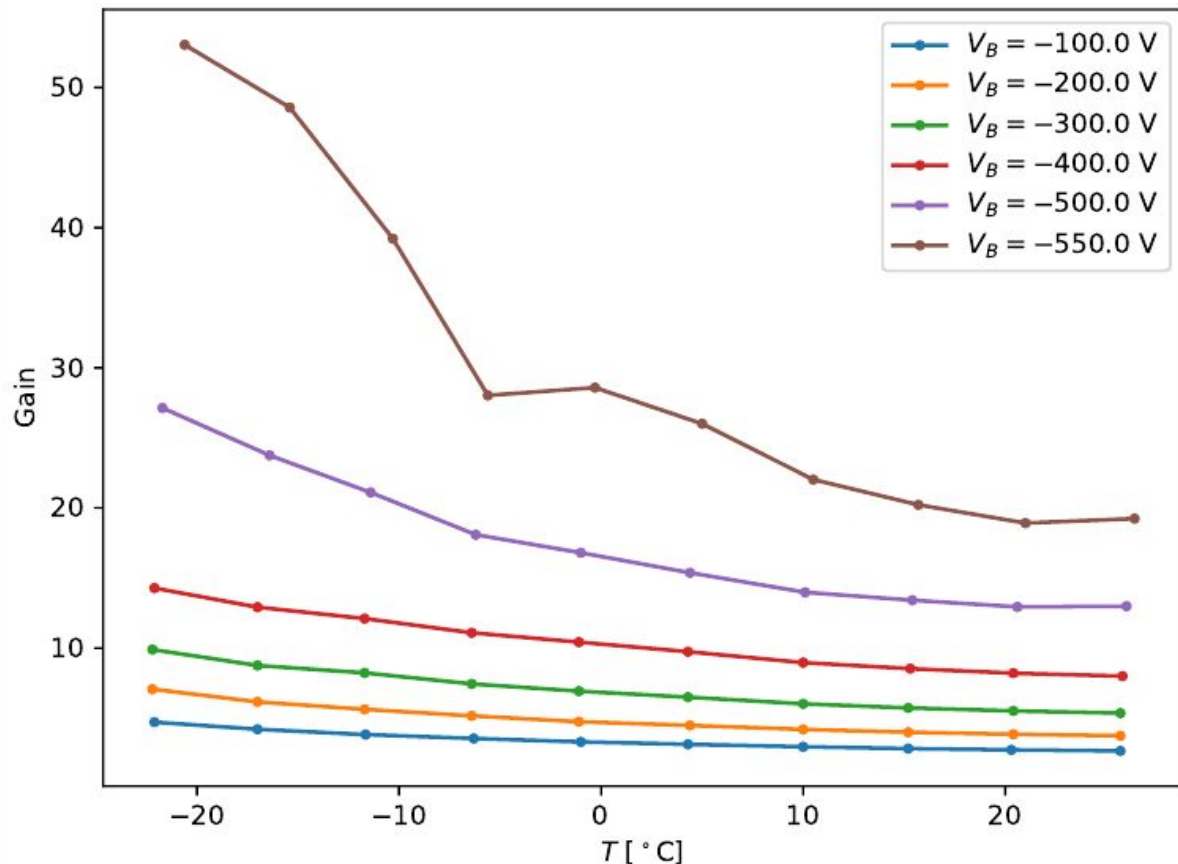
Surface current is estimated from linear fits to the PIN diode IV curves, then subtracted before forming the LGAD/PIN ratio.

The effective energy gap:

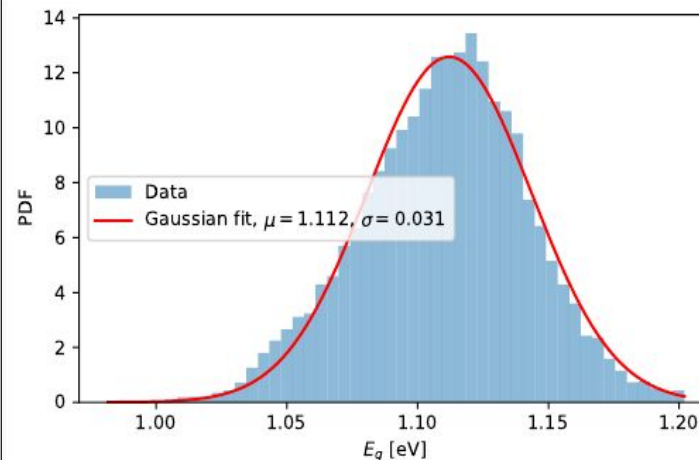
$$E_g = -2k_B \frac{T_1 T_2}{T_2 - T_1} \log \frac{I(T_1) T_2^2}{I(T_2) T_1^2}$$

Key results: cold operation increases gain, V_{BD} shifts with T

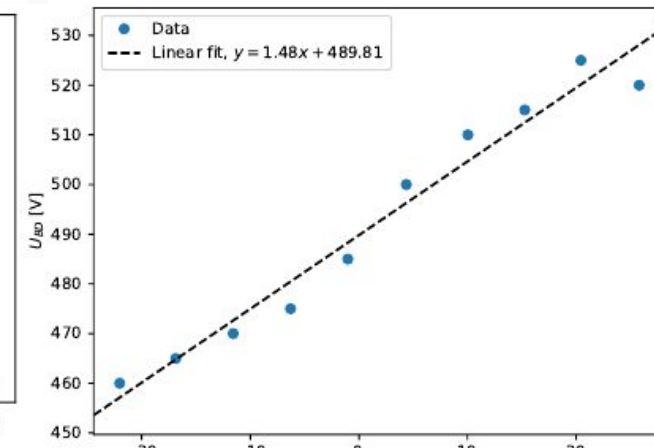
Gain vs temperature at fixed bias



I_{gen} scaling



$V_{BD}(T)$



- At fixed bias, gain is higher at lower temperature, especially near 500-550 V.
- Effective energy gap: $E_g = 1.11 \pm 0.03\text{ eV}$.
- Breakdown knee appears above $\sim 450\text{ V}$;
- V_{BD} increases by 1.48 V/K .



Conclusions

- We have so far tested QC-TS from 117 wafers (17 Pilot, 100 Batch1)
- All the wafers passed irradiation hardness acceptance test
- Wafers needed a retests:
 - Wafer 9 from Pilot batch – which **although passed acceptance has a lower radiation hardness**
 - Wafers Batch1/B1-W4 and Batch1/B7-W18 needed a retest and were found ok – radiation hardness in line with the rest. Possible dust/residuals obstructed the light?
 - Four wafers from Batch1.2 are at the limit, but received 10% more fluence – retest successful
- **We need to pay attention to those wafers that are close to the limit in all parameters even though they passed acceptance**
 - Keep track of the modules using these sensors and possibly place them in less harsh positions
 - We can put a comment in the Wafer database entry.
- We now use central irradiation channel in the reactor core which removes fluence uncertainty .
- SQC - irradiation tests show :
 - Very good and expected performance of sensors
 - No difference between different classes (defined at CQC)