CBC2:

X-ray Irradiation Results

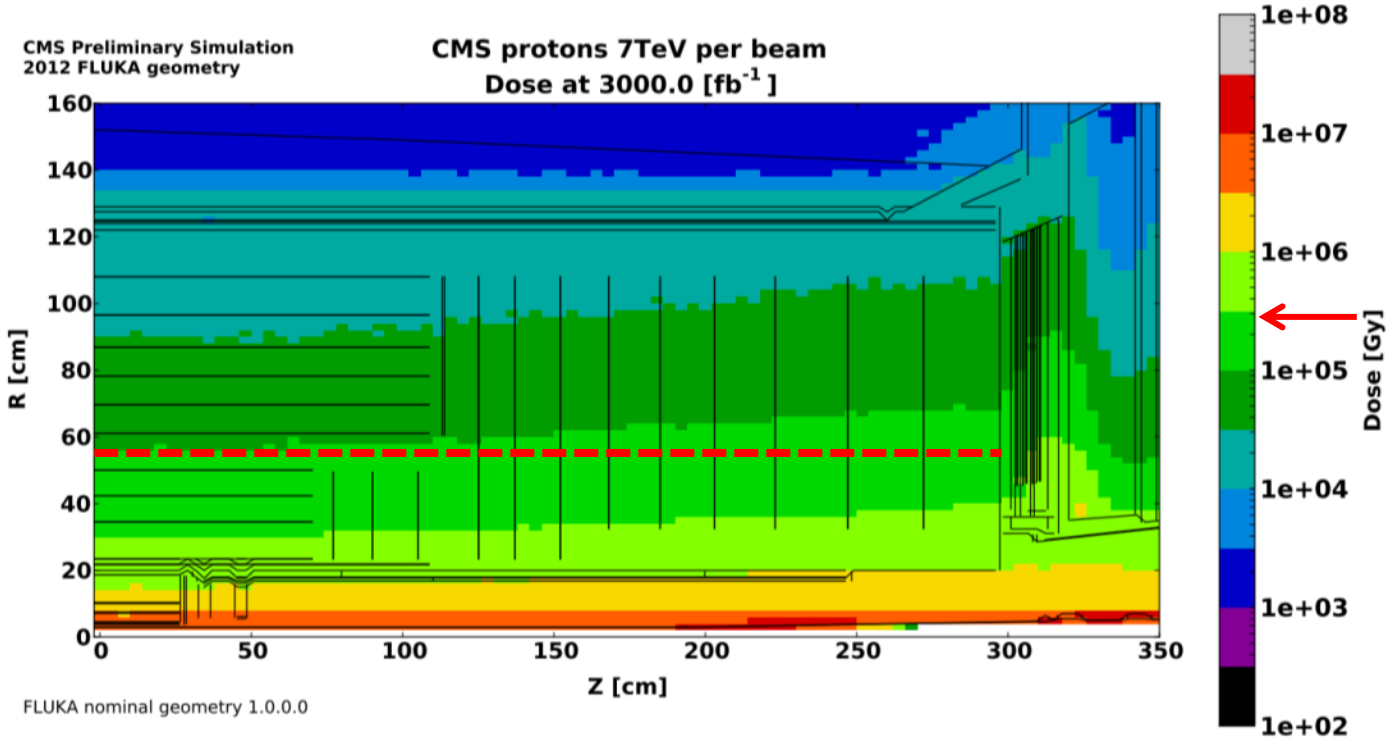
Davide Braga, Mark Raymond

06 November 2014

Imperial College London

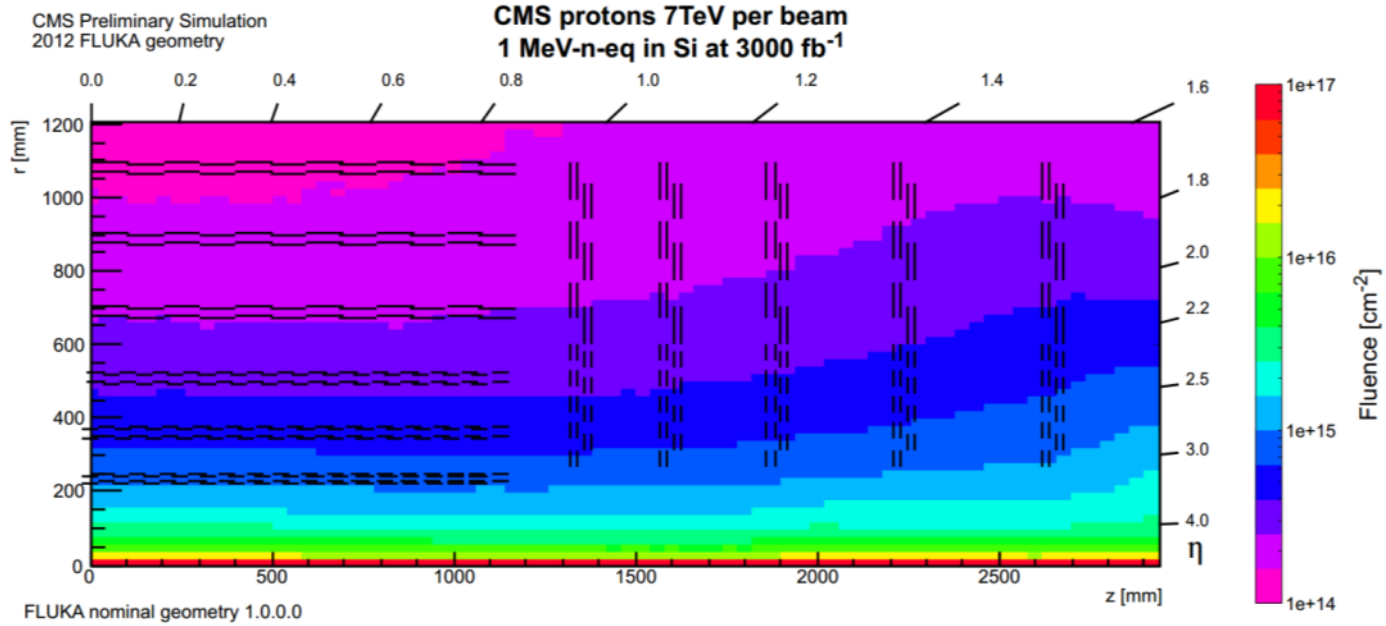
Science & Technology Facilities Council

HL-LHC dose for CBC2



< 3e+05 Gy = 30 Mrad

→ With x2 safety margin expect to be radHard to >60Mrad

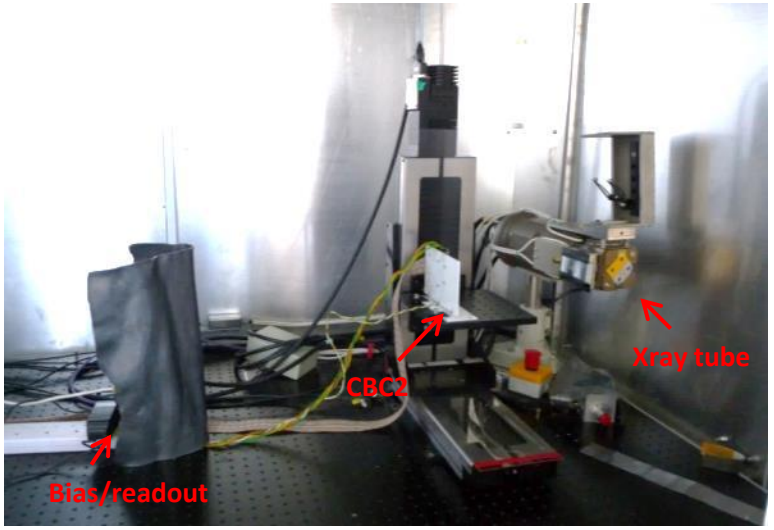


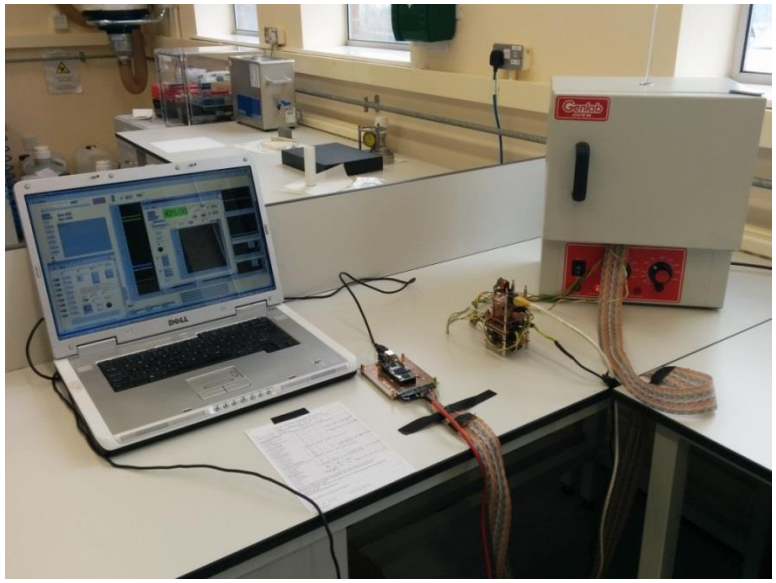
NB: calculated for 3000 fb^{-1} but with present Tracker

https://twiki.cern.ch/twiki/bin/view/CMSPublic/BRILRadiationSimulation

Total Ionizing Dose test at Diamond X-ray facility

- Molybdenum tube
- Wire-bonded CBC2 (“face-up”)
- CBC2 always biased and operational during irradiation and annealing





Accelerated annealing

Irradiation cabinet

1st room-temp irradiation

1 chip irradiated to ~12 Mrads

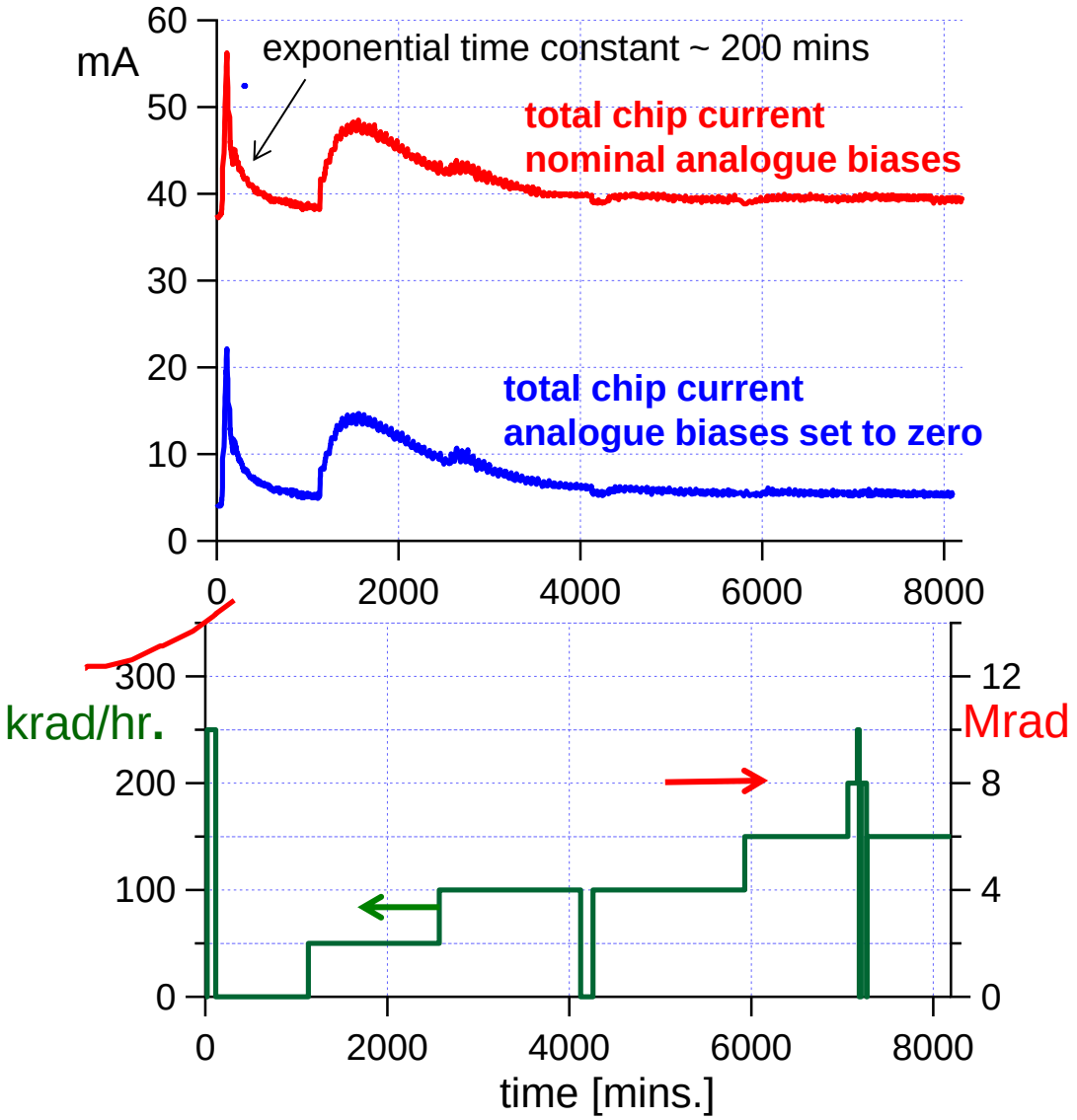
no significant change to behaviour apart from:

current increase during early stages
of irradiation ~ 1 Mrad
decays away if stop irradiation
effect disappears at higher dose levels

so not necessarily a problem, but

chips in HL-LHC will be cold
- does that affect the behaviour?
(the rate current decays away)

not clear what is going on and in
what part of the chip
(no separation between
analogue/digital supplies)



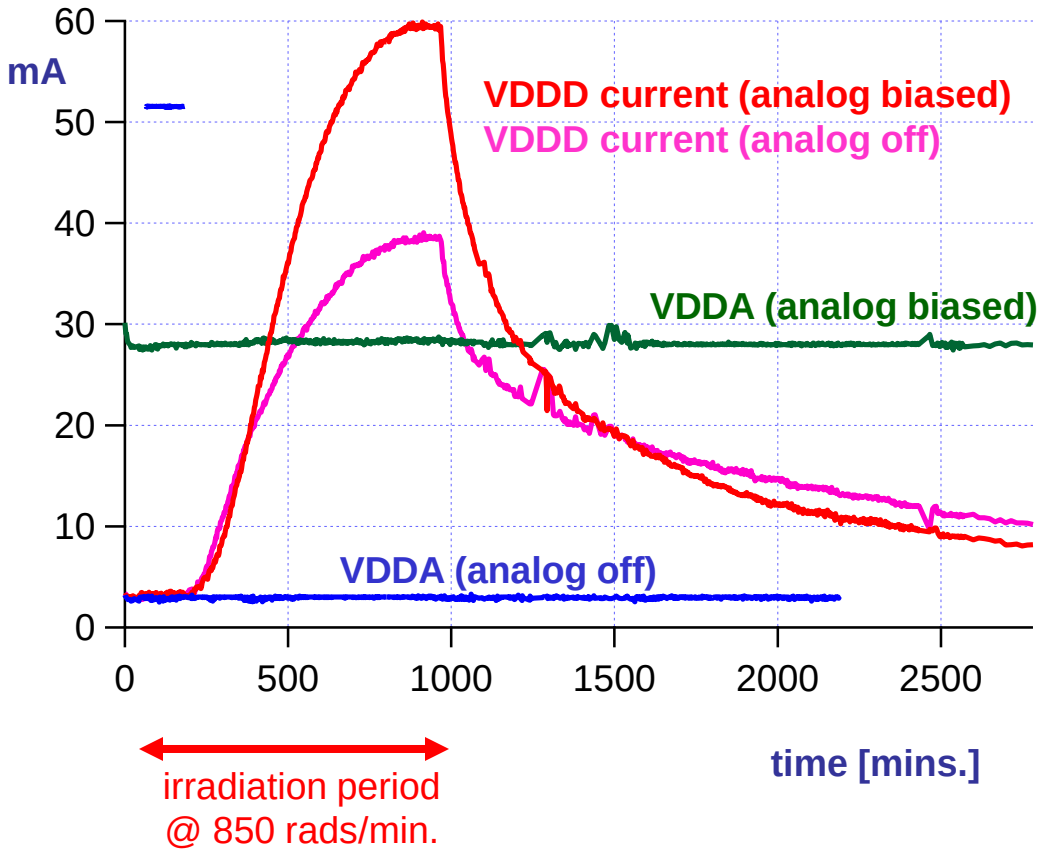
*https://indico.cern.ch/event/312869/session/1/contribution/7/material/slides/0.pdf

Cooled setup results

VDDD and VDDA now supplied separately

current increase clearly confined to the digital rail (VDDD current)

but magnitude depends on whether analog stages biased or not



current saturates at around 800 krads
stopped irradiation at this point

current still decays away with time constant ~1000 minutes, even at this cold temperature
(c.f. ~200 minutes at ~30^{o})

NB: 850 rads/min is ~ 85x the worst case doserate at HL-LHC

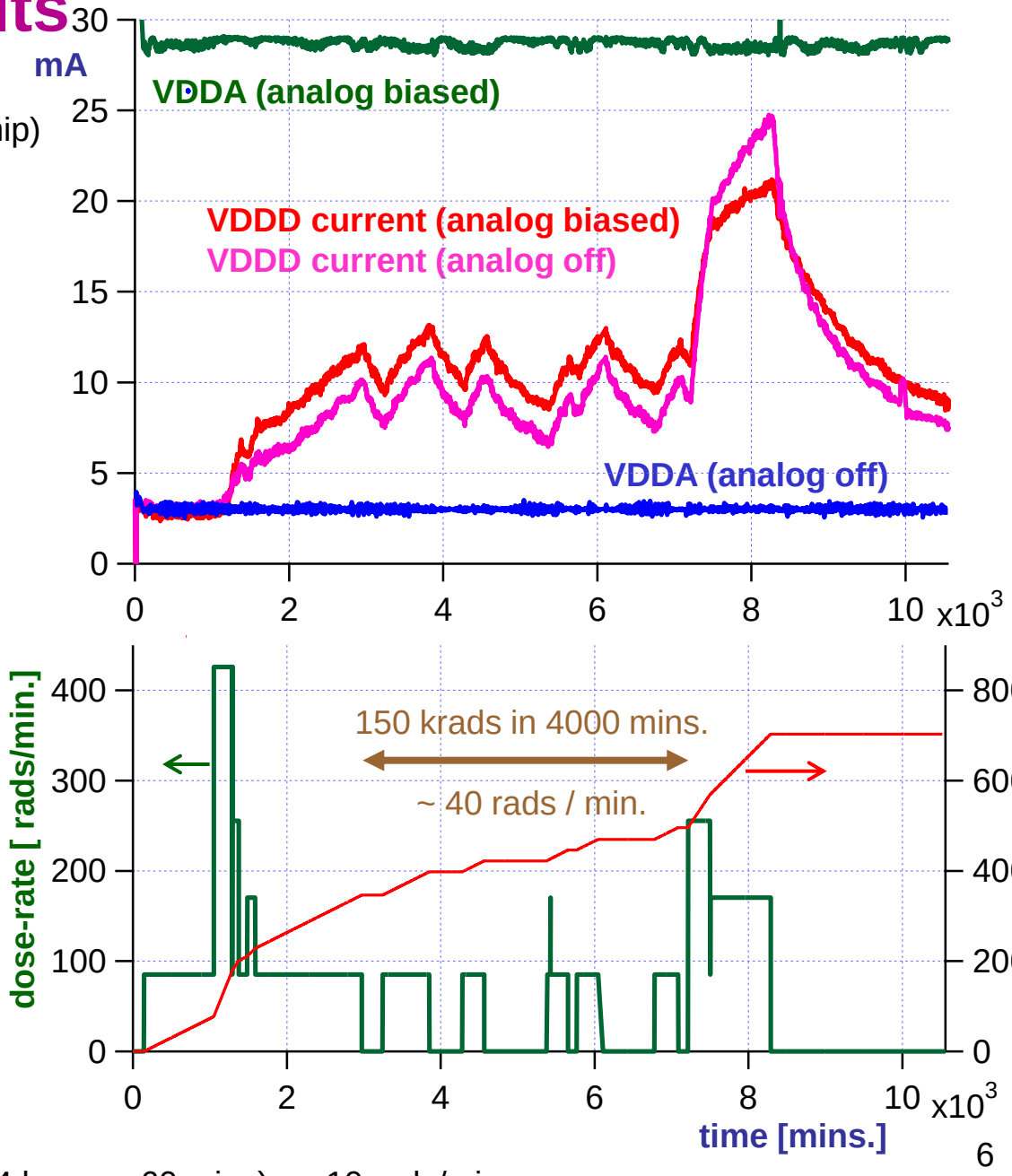
More details in:
https://indico.cern.ch/event/332678/session/1/contribution/4/material/slides/0.pdf

Cooled setup results

try a low dose-rate irradiation (new chip)

couldn't get continuous dose-rate low enough as that at HL-LHC*

but current plateaus at
~ 40 rads / min.



*30 Mrads / (10 years x 200 days x 24 hours x 60 mins) = ~10 rads/min

Summary so far

Cooled irradiation setup shows:

current increase confined to **digital** supply rail (VDDD)

but magnitude affected by values in analog bias registers (nominal or zero)

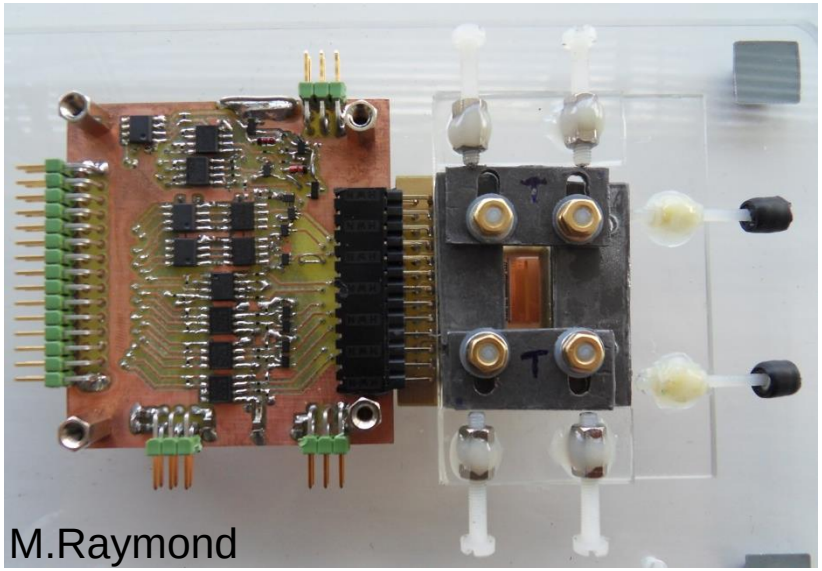
current is not “frozen in” by operation at low temperature

continuous annealing even at T= -15°C

→ should not be significant at HL-LHC dose-rates

Masked Irradiation

→ Demonstrated that increase in digital current is due to **static leakage in SRAM memory** at high-dose



Summary

- Excess static current due to drain-to-source leakage in pull-down nMOS of SRAM cell (non-ELT).
- Effect of analogue biasing on magnitude of the current explained by the biasing conditions during irradiation

→ Origin of excess leakage and failure mechanisms understood

→ Effect should only be a problem at high-rate: should not cause problems for outer tracker (<30 Mrads over 10 years) but could cause problems at lower radii if CBC were to be used there

→ Currently considering improved and alternative SRAM designs anyway

Higher dose rates

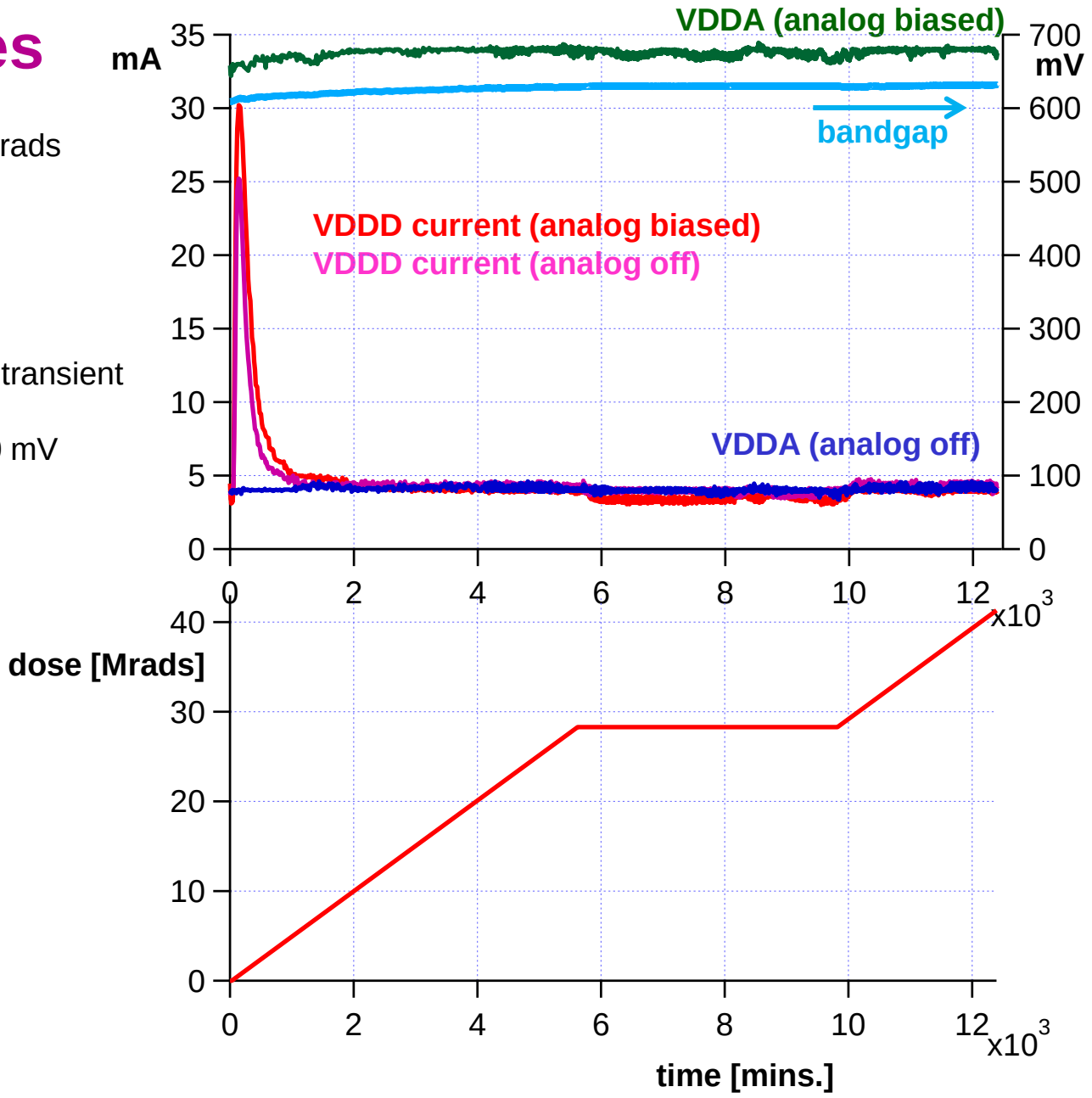
have now taken 1 chip to ~40 Mrads

~300 krad/hour

room temperature irradiation

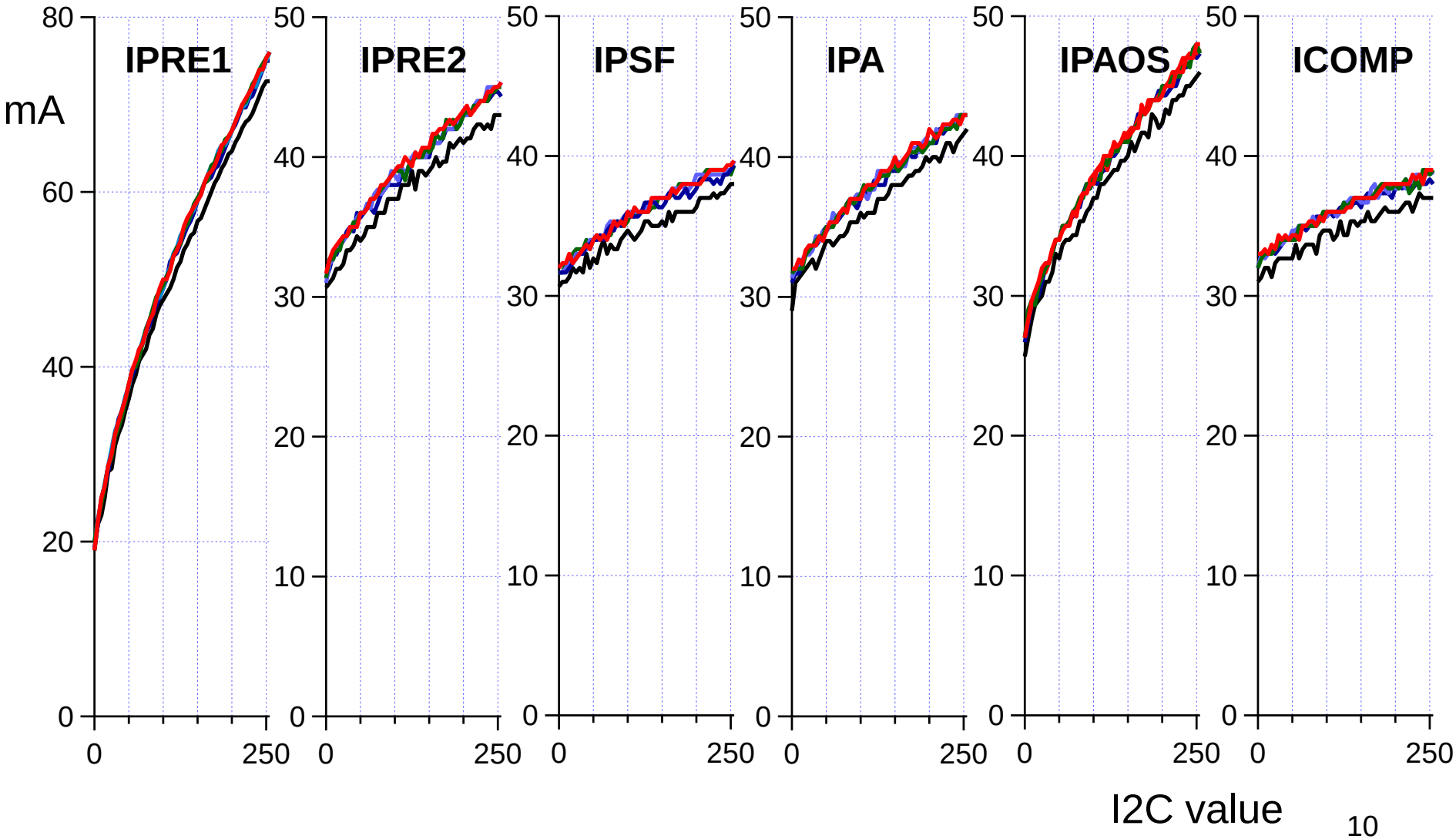
power ~ static after initial digital transient

small shift in bandgap ~20 mV

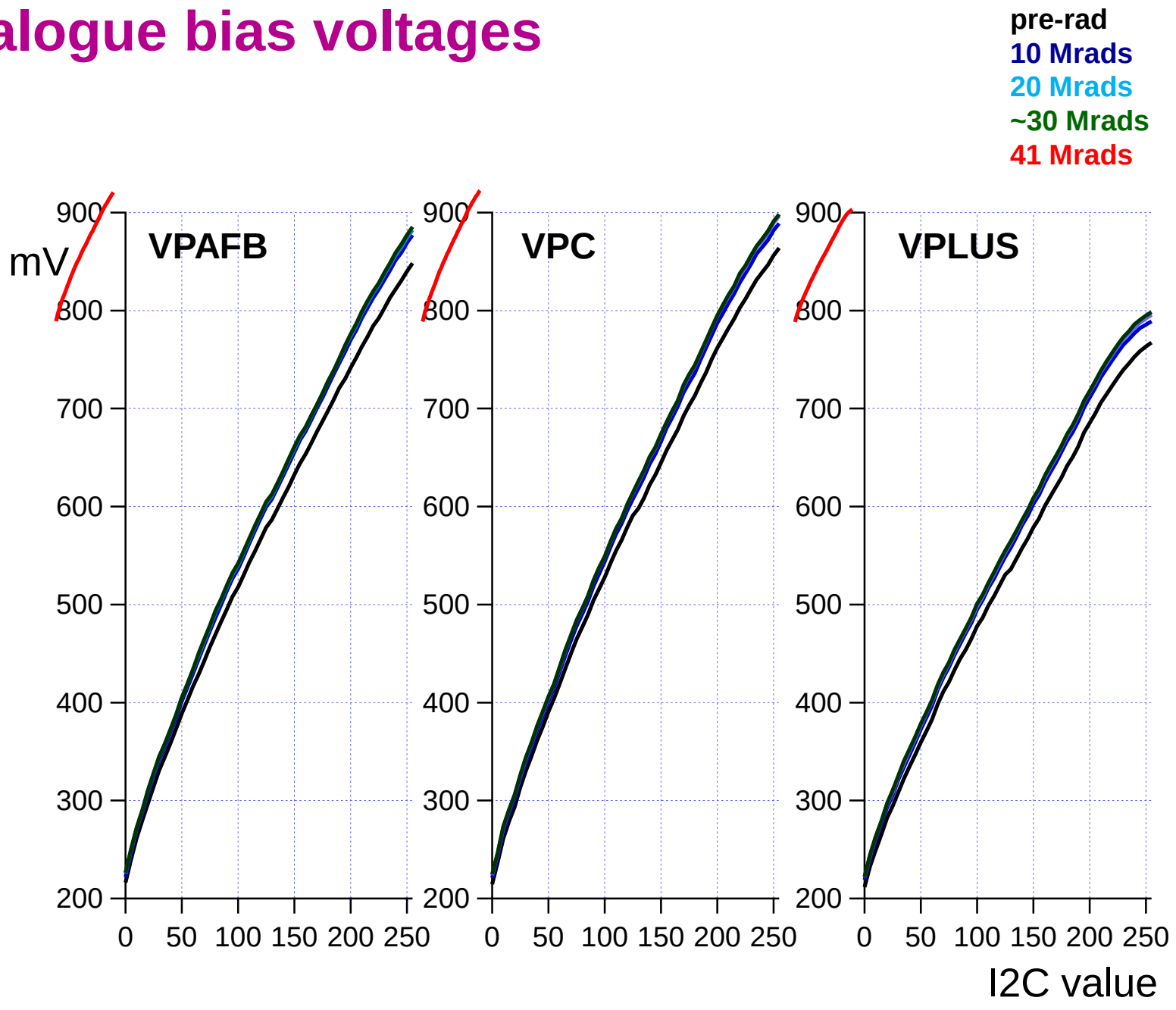


Analogue bias currents

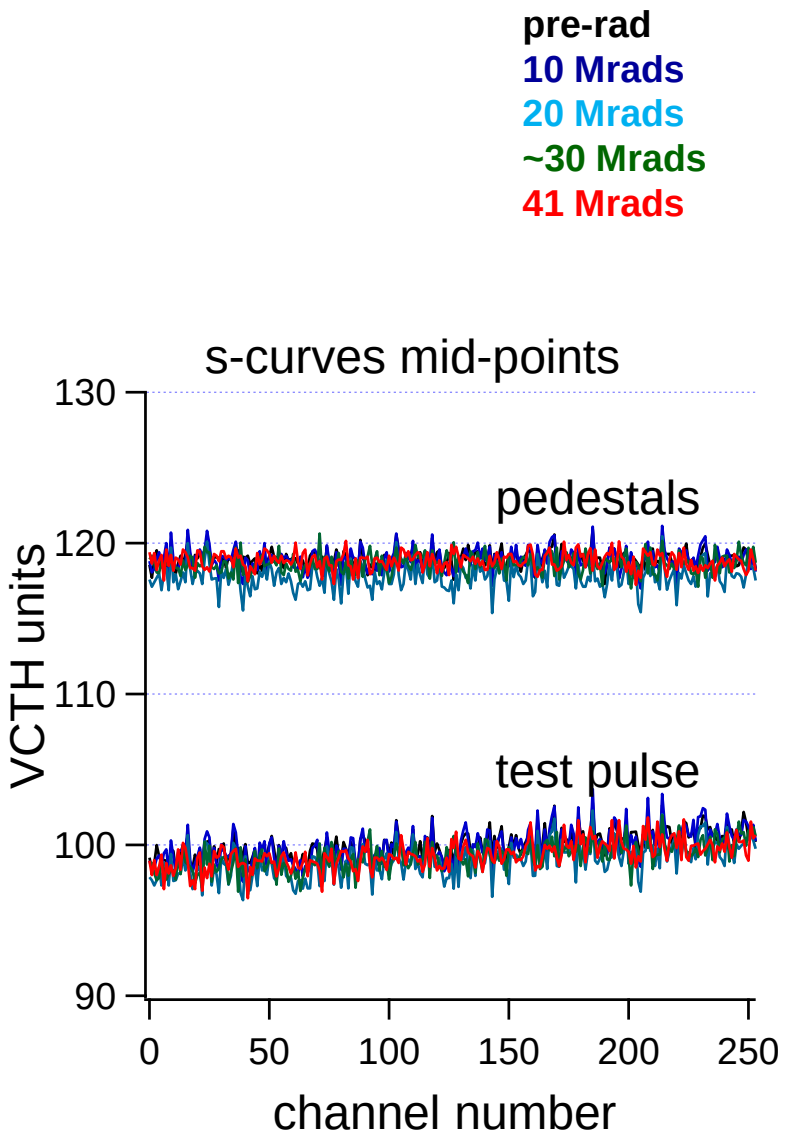
pre-rad
10 Mrads
20 Mrads
~30 Mrads
41 Mrads

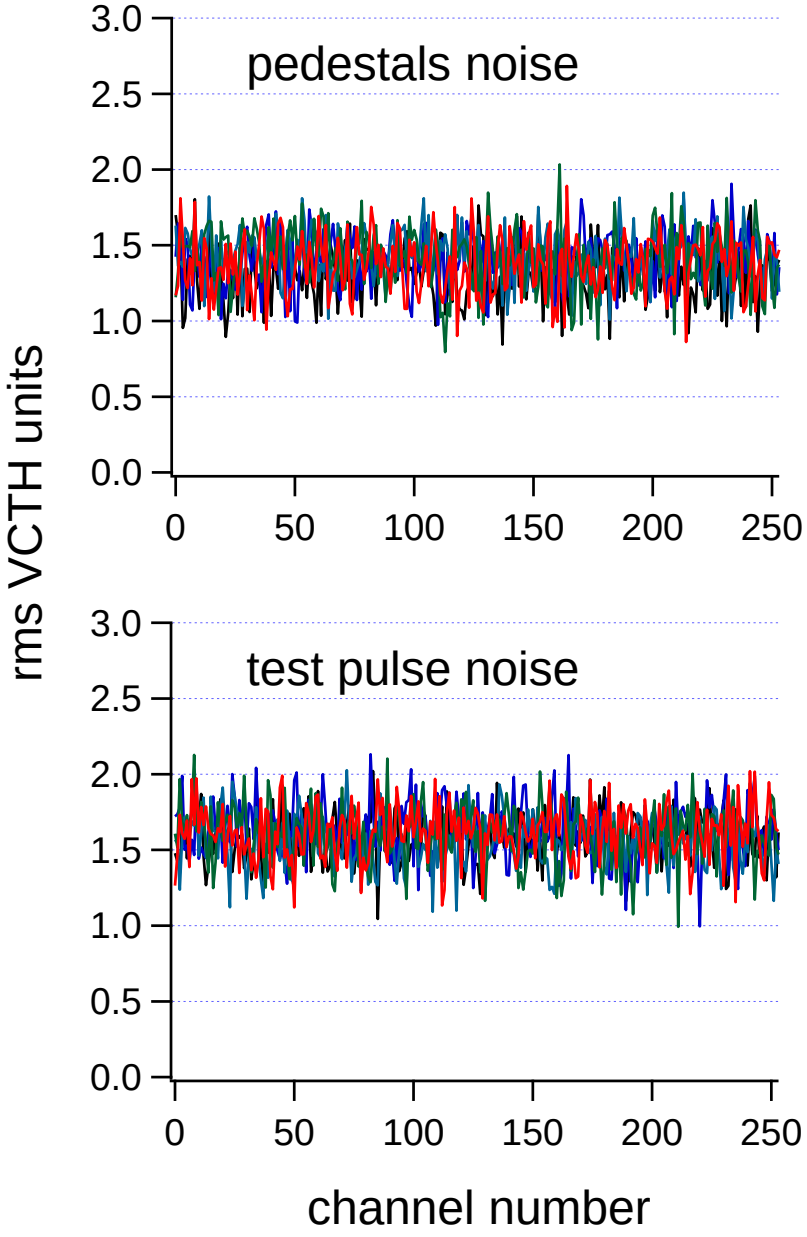


Analogue bias voltages



S-curves


pre-rad
10 Mrads
20 Mrads
~30 Mrads
41 Mrads
s-curves mid-points
pedestals
test pulse
VCTH units
channel number
130
120
110
100
90
0
50
100
150
200
250


pedestals noise
test pulse noise
rms VCTH units
channel number
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250

Conclusions

- CBC2 shows **expected radiation insensitivity** to ~ 40 Mrads

  (40 Mrad limit dictated by availability of source)

- Irradiation to 40Mrad showed only a **short-term increase in current** which **recovers completely even at T=-15°C** annealing after a few hours

- **Modules** instrumented with CBC2s **can be safely irradiated**, at low dose it might be necessary to wait for a few hours before running the chips, at high-dose it should make no difference.