SiPM irradiation 2022

update

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8 August 2022

This was the baseline plan as discussed in February 2022

2022 irradiation plan

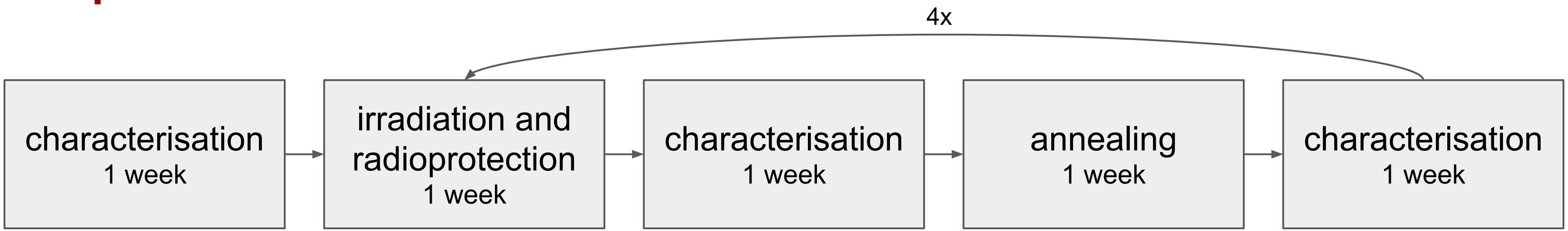
test SiPM performance and annealing with increasing integrated NIEL

simulate a more realistic experimental situation

irradiate full SiPM carrier boards with flat proton field

no collimators, this will make life much easier and very efficient use of beam

- **3 short accesses at TN protontherapy centre (TIFPA) in spring**
    - ideally 4 hours on Saturdays, should be sufficient time to setup and fire the beam
    - tentative dates: 23 April, 28 May and 2 July
    - one access every 4-6 weeks: allow time for radioprotection, characterisation and annealing
    - small NIEL integration steps, perhaps: $1\ 10^{9}$, $2\ 10^{9}$, $4\ 10^{9}$
- **plus 1 more access in fall**



some little changes down the way but mostly sticking to plan

2022 irradiation plan

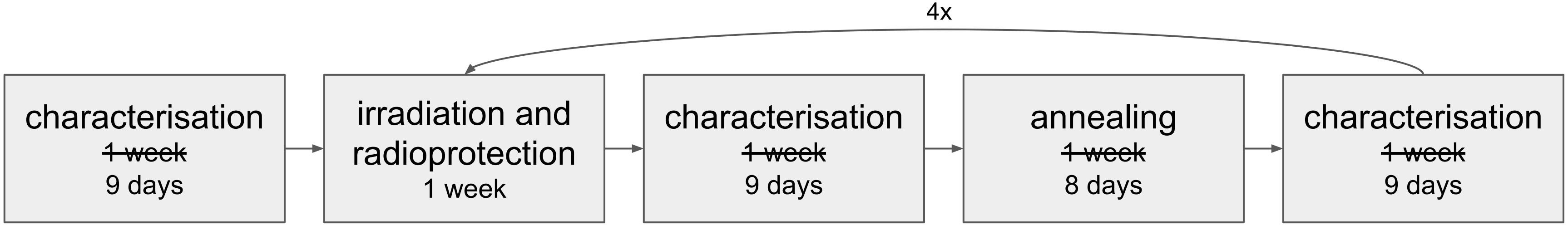
test SiPM performance and annealing with increasing integrated NIEL

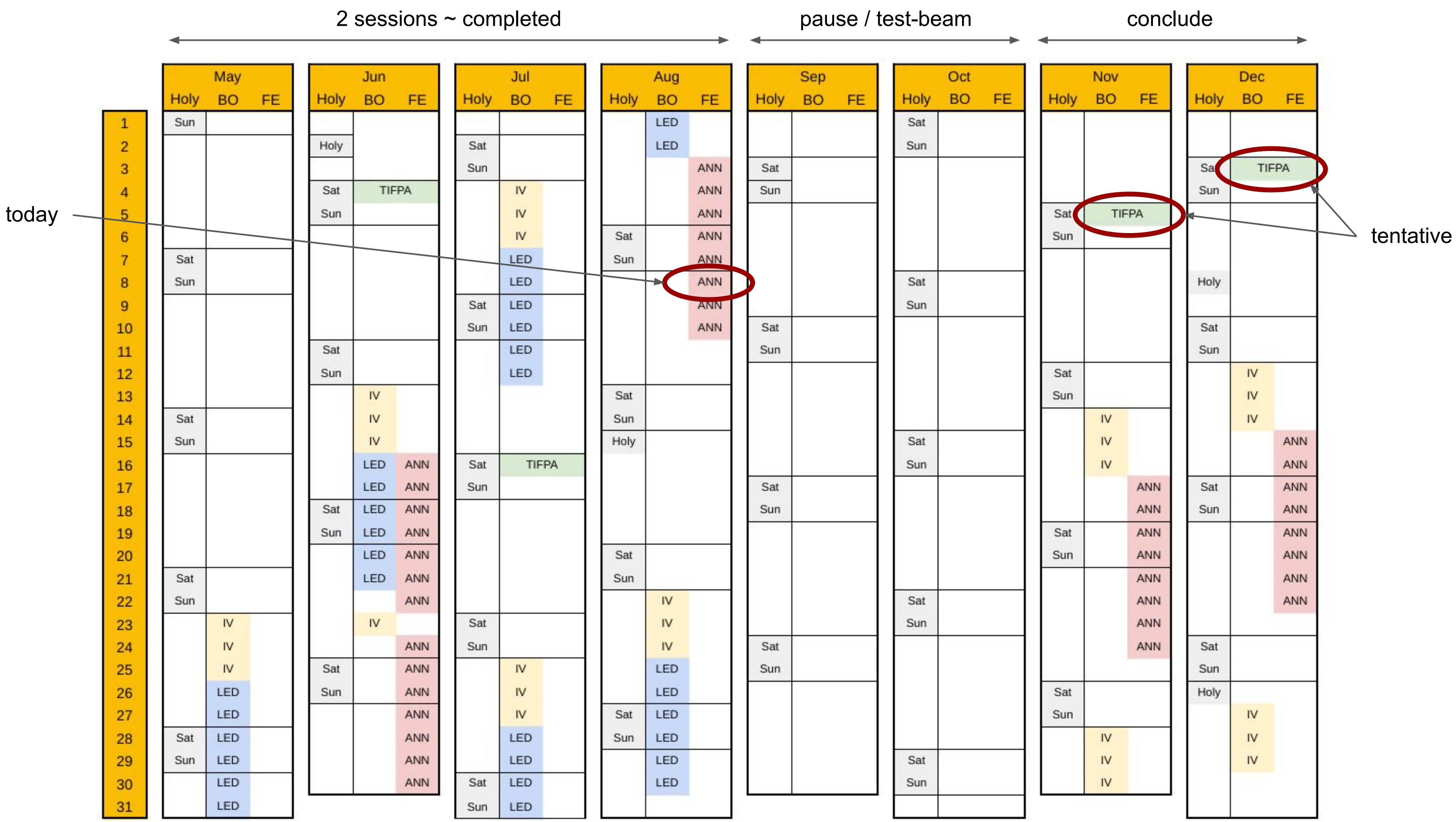
simulate a more realistic experimental situation

irradiate full SiPM carrier boards with flat proton field

no collimators, this will make life much easier and very efficient use of beam

- **~~3~~ 2 short accesses at TN protontherapy centre (TIFPA) in spring and summer**
  - ideally 4 hours on Saturdays, should be sufficient time to setup and fire the beam
  - ~~tentative dates: 23 April, 28 May and 2 July~~ actual dates: 4 June, 16 July
  - one access every 4-6 weeks: allow time for radioprotection, characterisation and annealing
  - small NIEL integration steps, perhaps: $1\ 10^9$, ~~$2\ 10^9$, $4\ 10^9$~~ $1\ 10^9$
- **plus ~~1~~ 2 more accesses in fall: perhaps 5 Nov ($1\ 10^9$) and 3 Dec ($2\ 10^9$)**





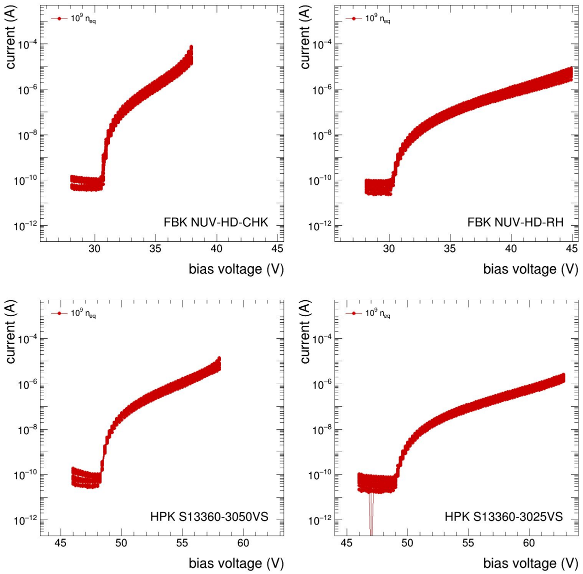
2 sessions ~ completed
pause / test-beam
conclude
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Holy
BO
FE
today
tentative
TIFPA
IV
LED
ANN
Sat
Sun

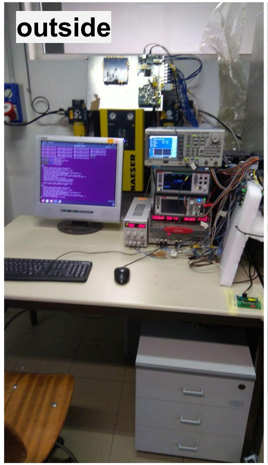
Irradiation (4 hours slots at TIFPA / CPT / Trento)

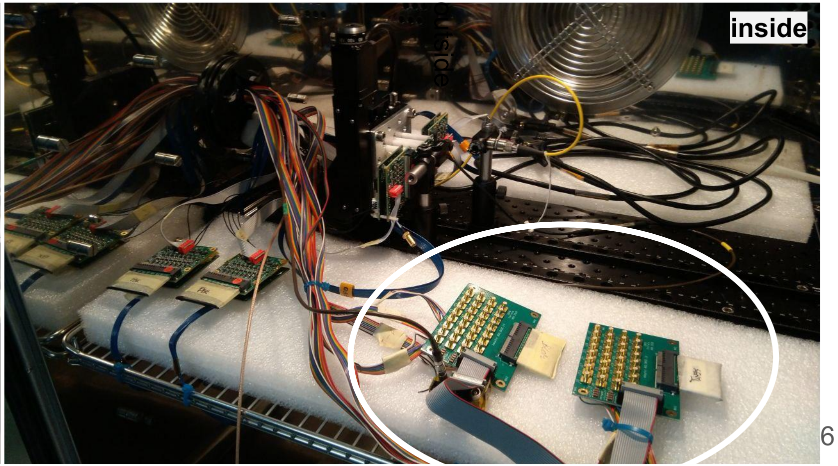
- **keep it simple**
  - large uniform irradiation field
    - no collimators
  - proton flux at location ~ 5.5 10^5 cm^{-2} s^{-1} nA^{-1}
    - typical irradiation: 14 nA for ~ 120 s
  - bare boards with poor-man supports
    - one board at a time
- **nominal irradiation campaign**
  - very fast beam setup thanks to experience of last year
  - several boards with one 10^9 neq shot completes in ~ 1 hour
  - rest of beam time utilised for “annealing by Joule effect with direct bias current” exploration
    - split total 10^9 in 5 equal shots of 2 10^8
    - interleaved with 30 minutes of annealing

Current measurements

- **climatic chamber**
  low-temperature operation
  all reported measurements at T = -30 °C
- **2x 40-channel multiplexers**
  automatic measurement of 2x SiPM boards (64 channels)
- **source meter**







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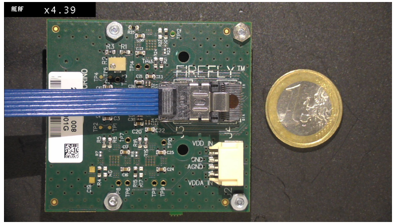
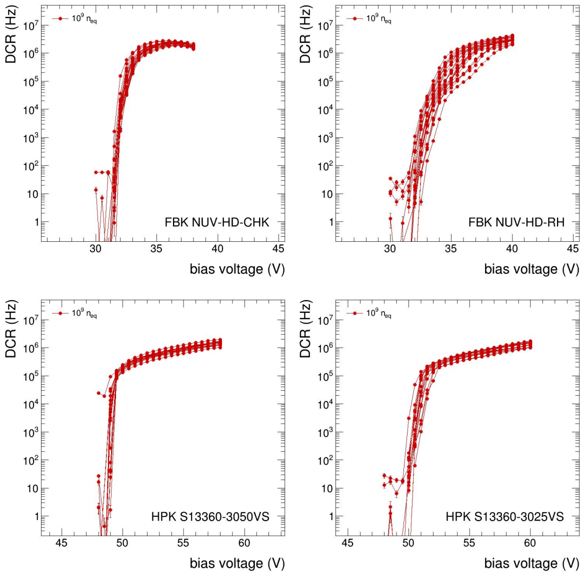
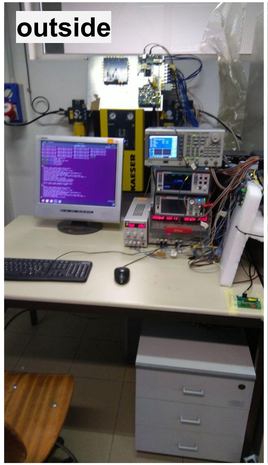
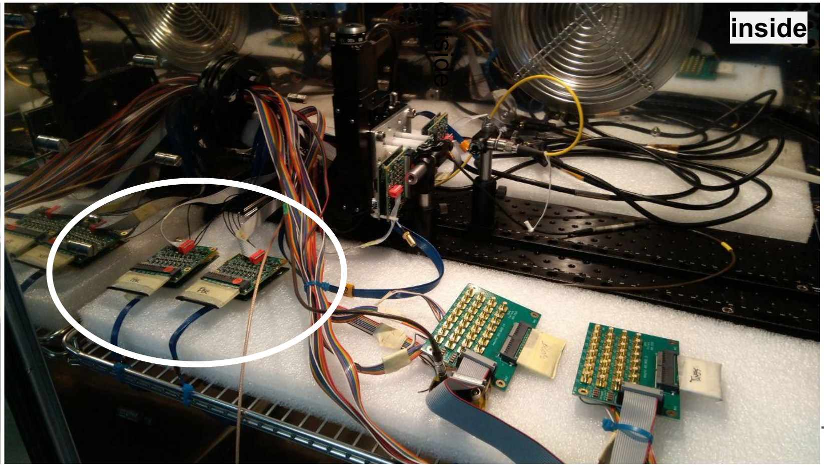
DCR measurements

- **climatic chamber**
  low-temperature operation
  all reported measurements at T = -30 °C
- **2x ALCOR-based front-end chain**
  automatic measurement of 2x SiPM boards (64 channels)
- **FPGA (Xilinx) readout**



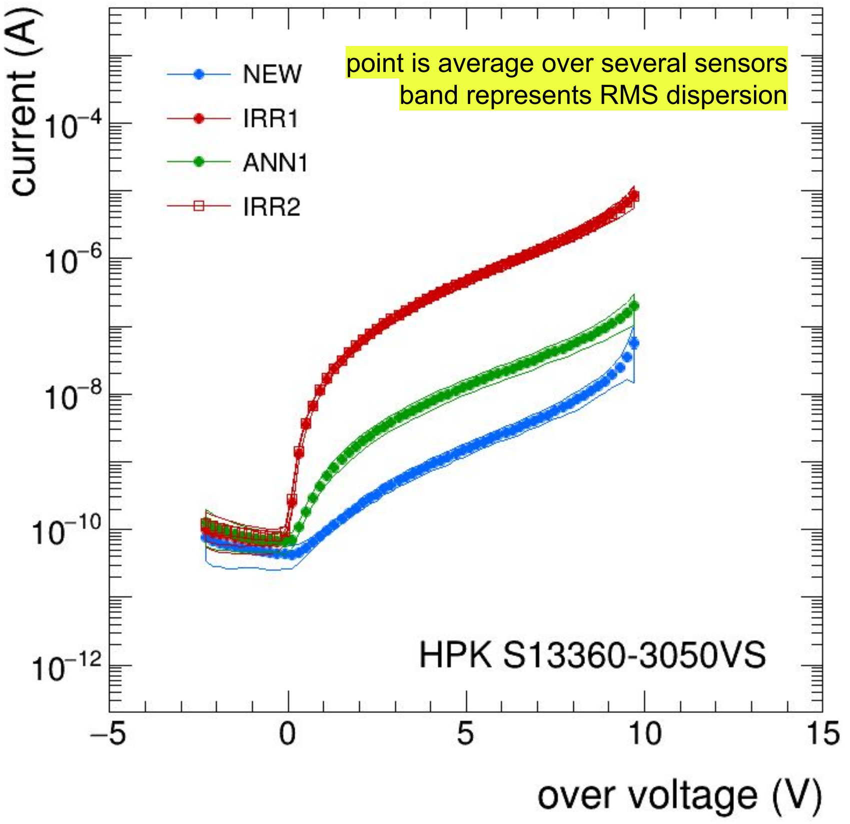


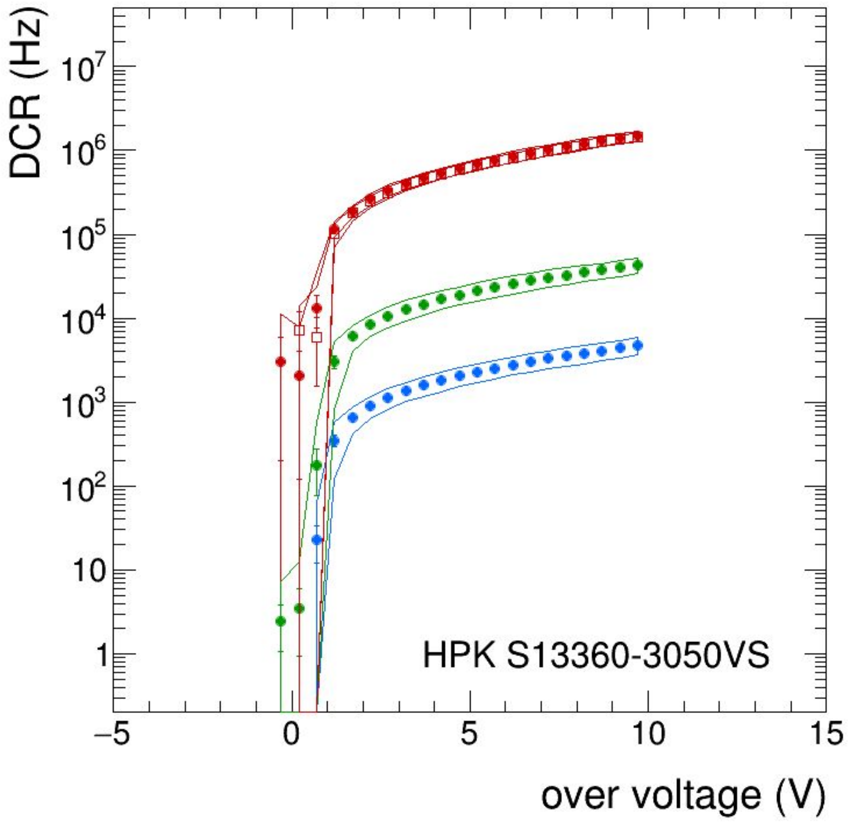




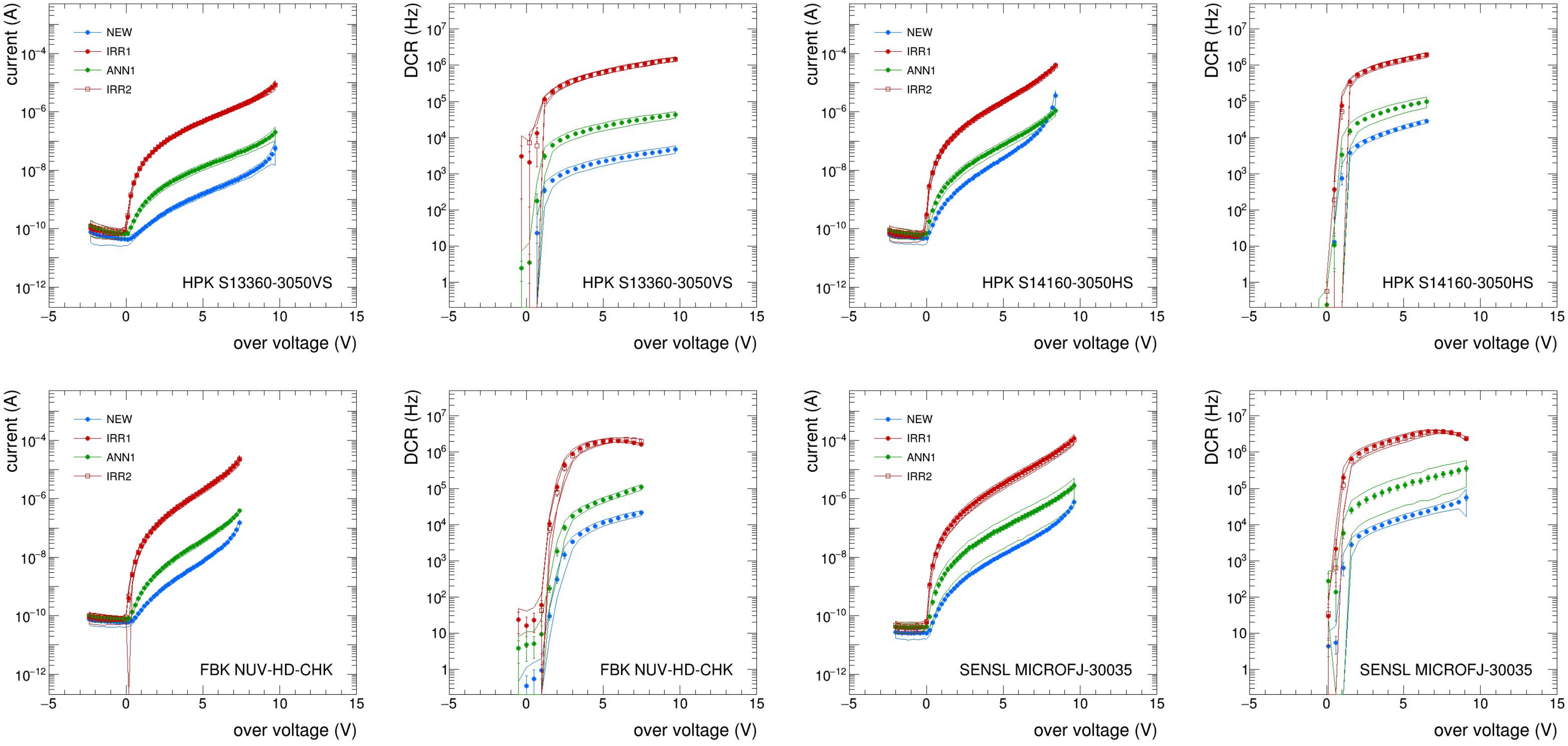
Annealing (in the oven @ Ferrara)

- **numbers**
  - Temperature = 150 C
  - Time = 150 hours
- **procedure**
  - insert all boards when the oven is hot
  - keep for 150 hours
  - switch off and let cool down for ~ 24 hours

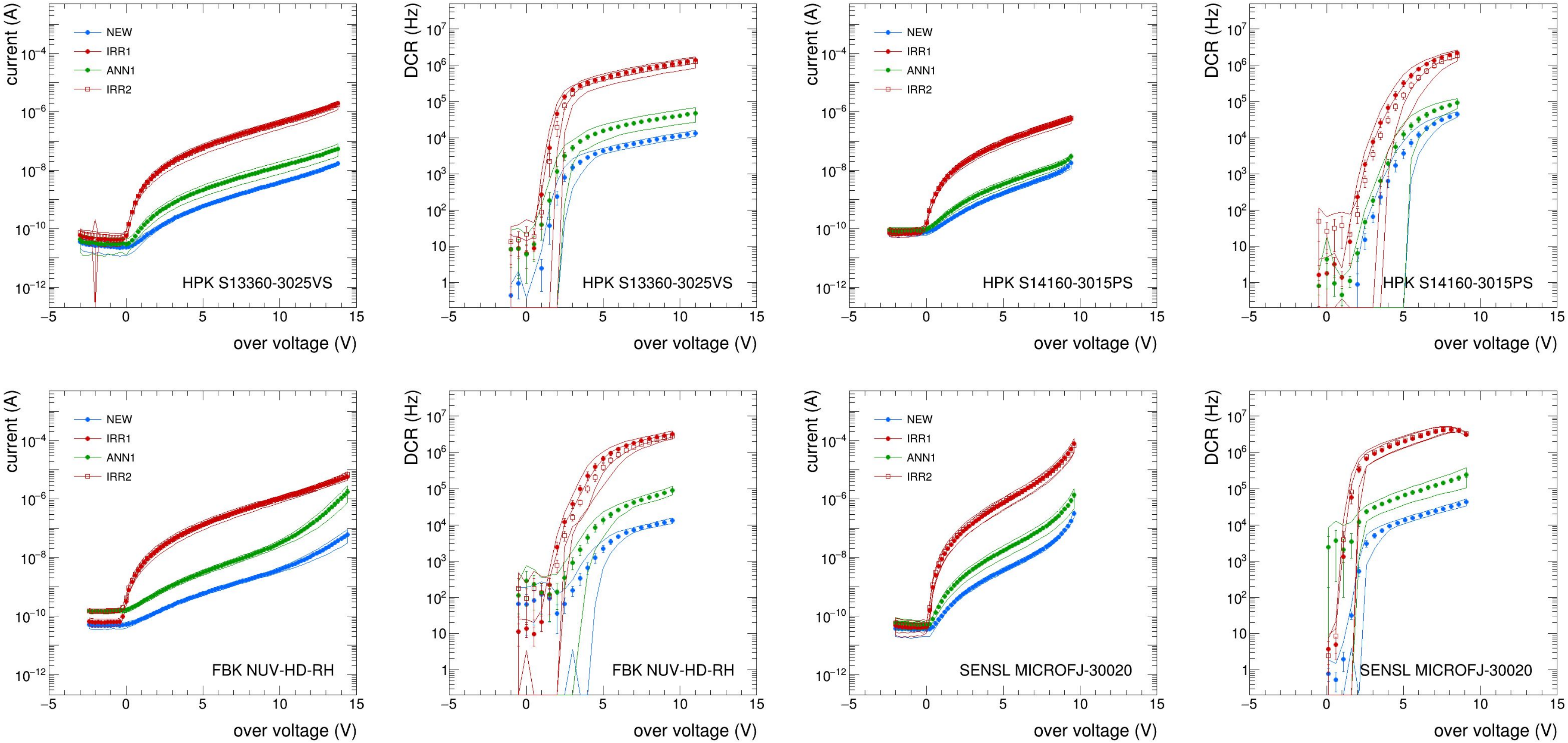




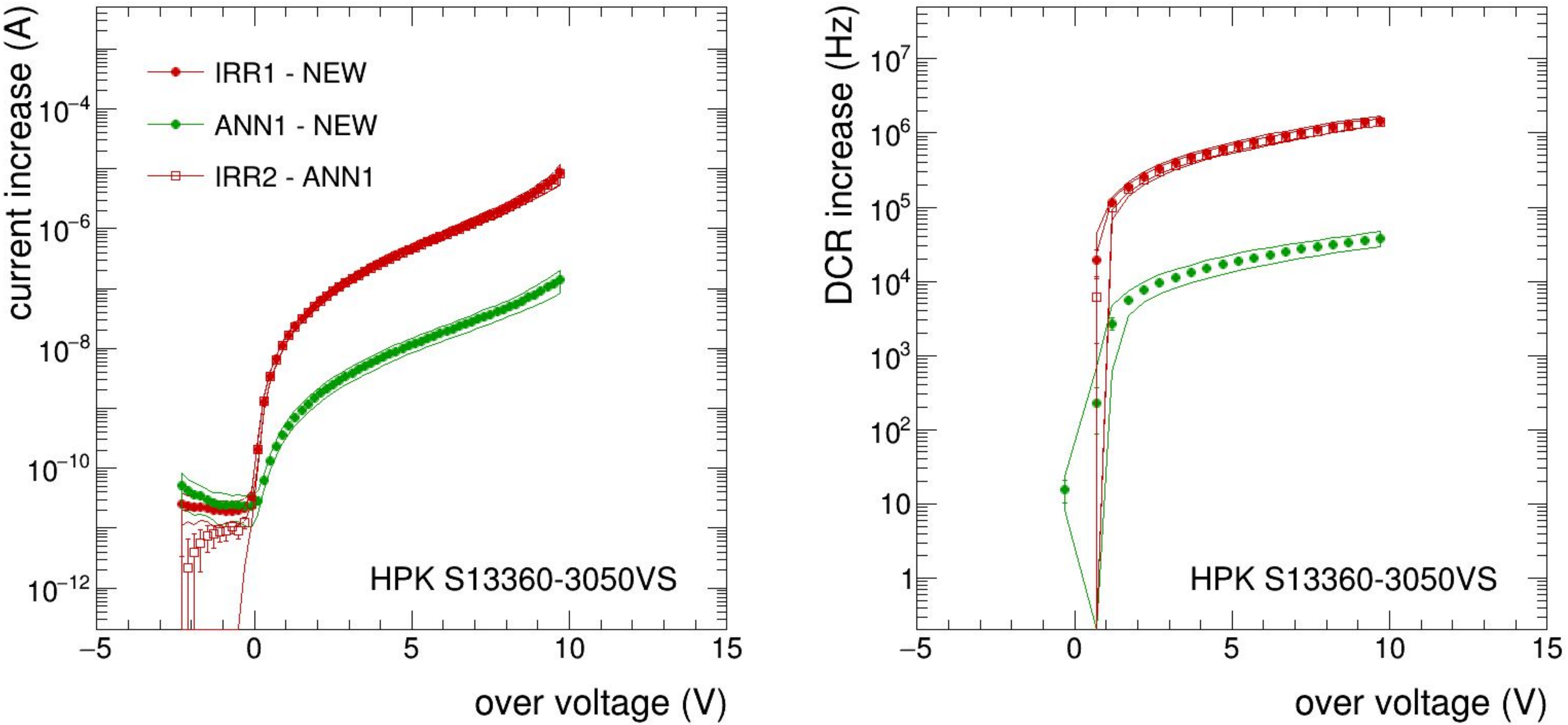
2nd irradiation shot brings currents / DCR at same level measured after 1st irradiation shot



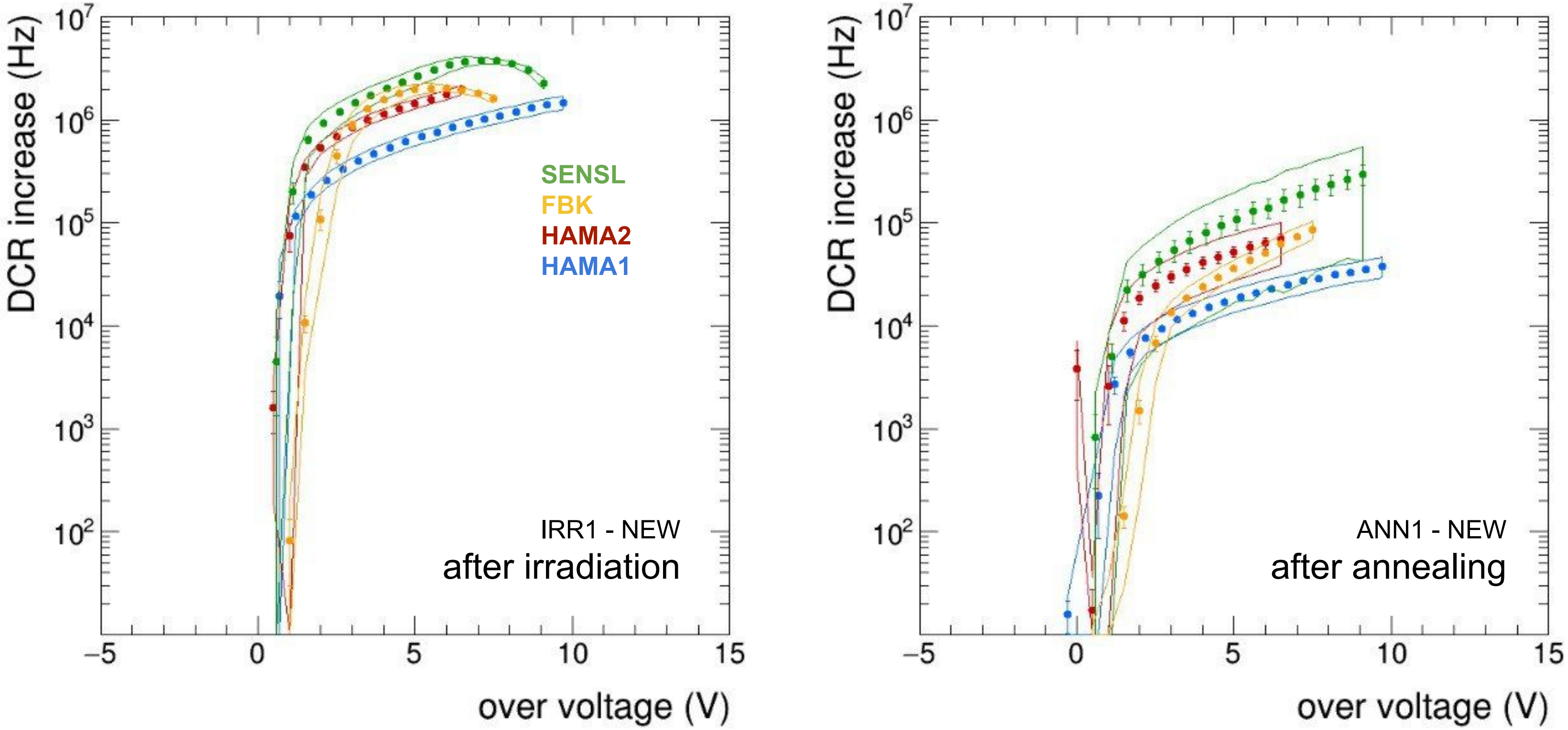
true for all sensors



true for all sensors

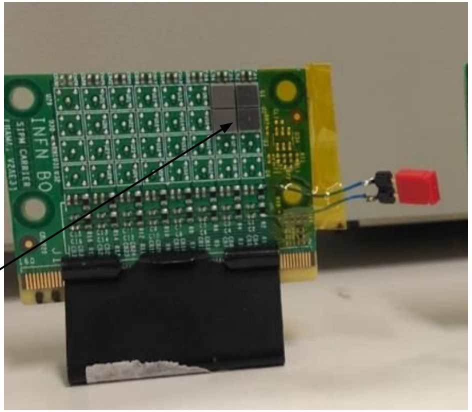


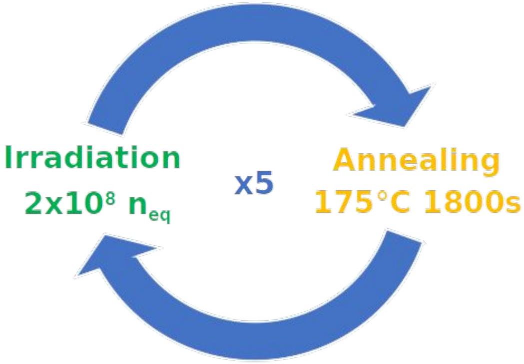
DCR (@ Vover = 3 V) increases by ~ 350 kHz after each 10^9 neq shot
residual DCR excess (@ Vover = 3 V) of ~ 10 kHz after annealing



Hamamatsu S13360-3050 (HAMA1) is always the best with
lowest DCR when new, increase with NIEL, residual after annealing

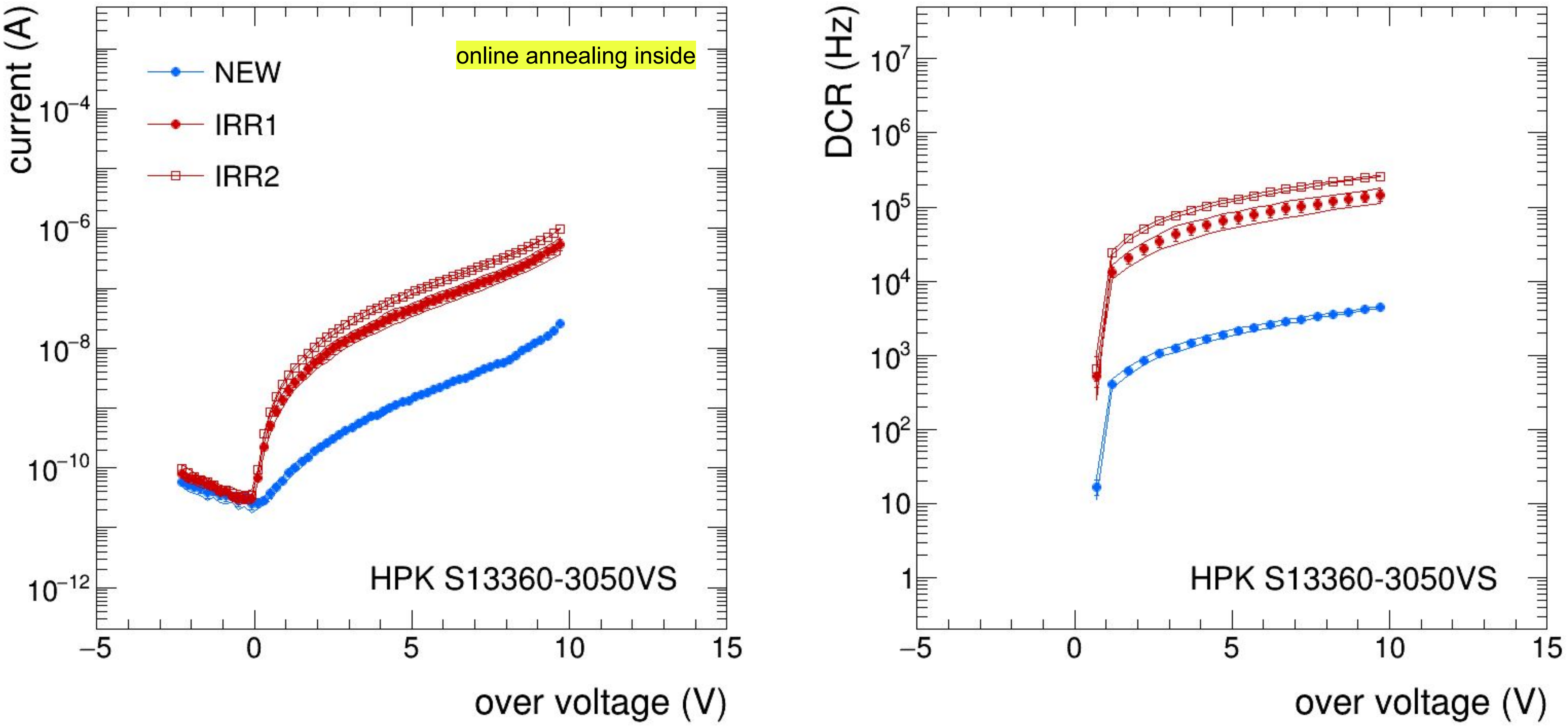
Online annealing



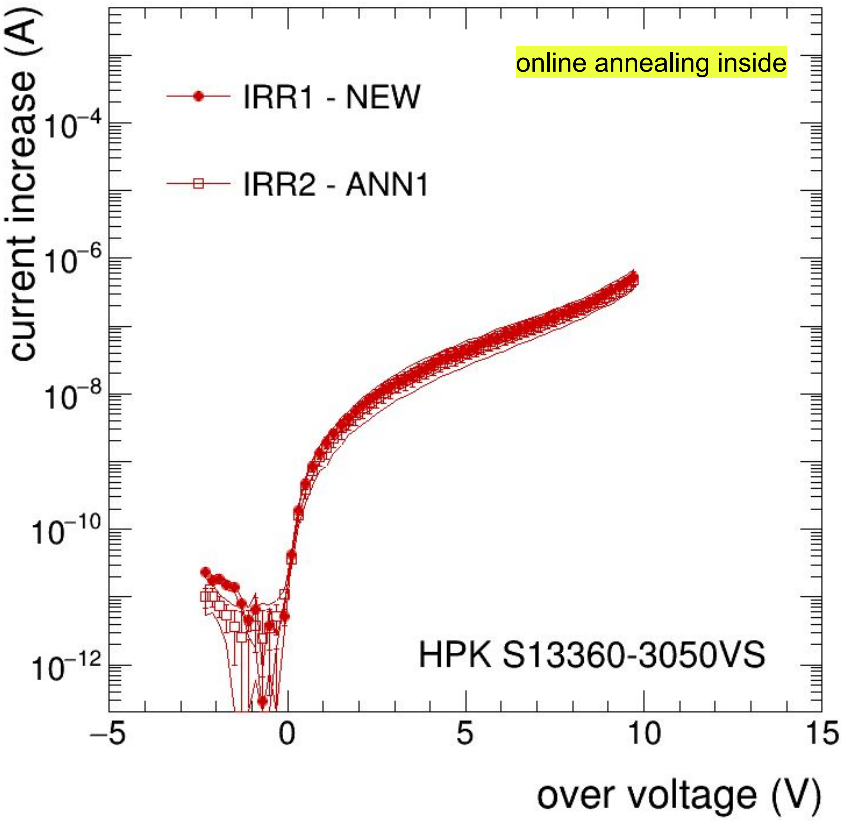


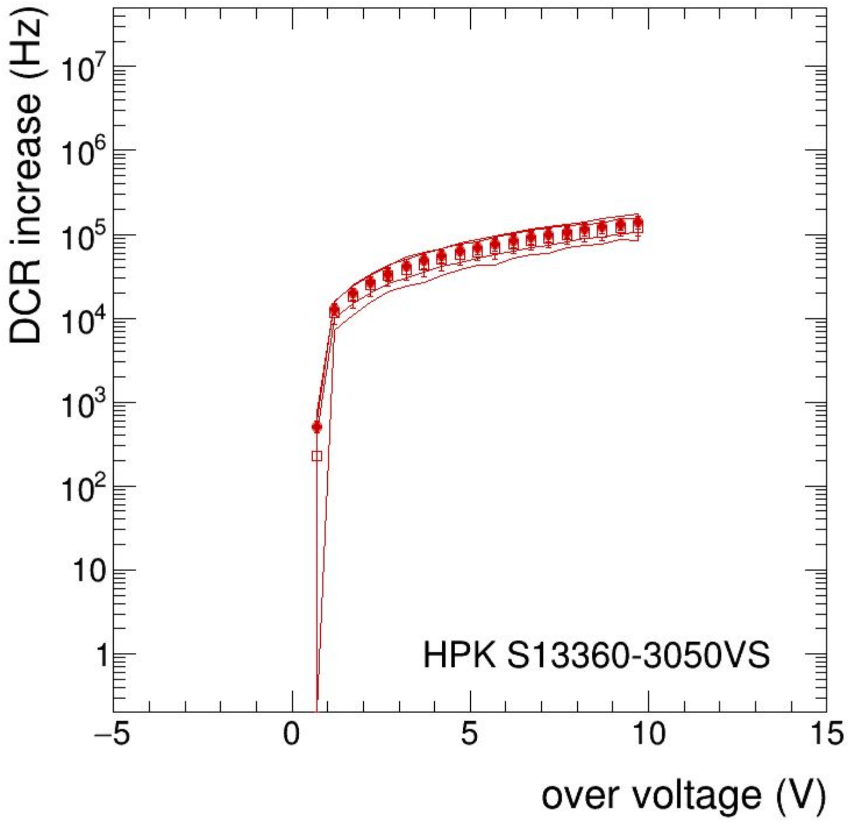
explore solutions for in-situ annealing

- total fluence of 10^9 n_{eq}
  - delivered in 5 chunks
  - each of 2 10^8 n_{eq}
- interleave by annealing
  - forward bias, ~ 1 W / sensor
  - T = 175 °C, thermal camera
  - 30 minutes
- preliminary tests
  - Hamamatsu S13360-3050



2nd irradiation shot brings currents / DCR at higher level than measured after 1st irradiation shot

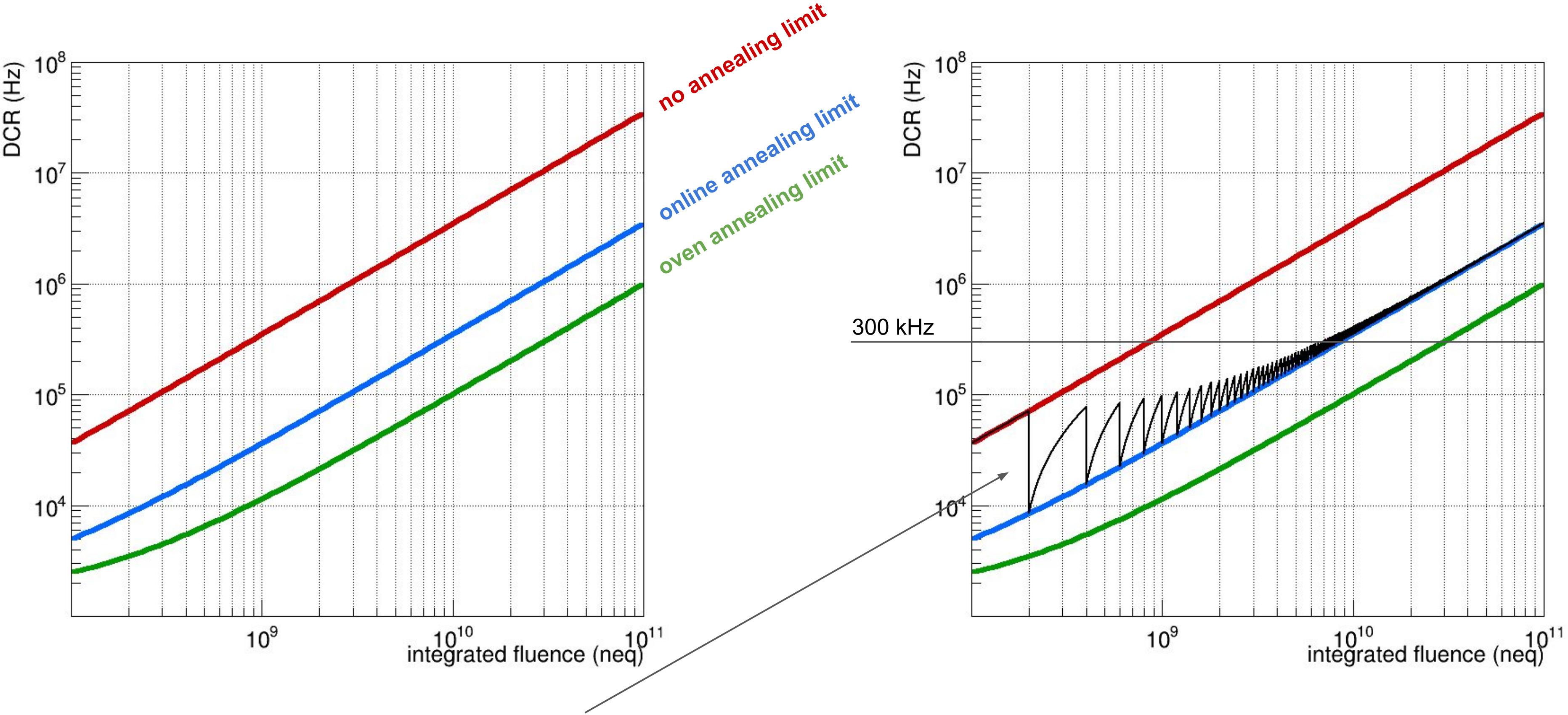




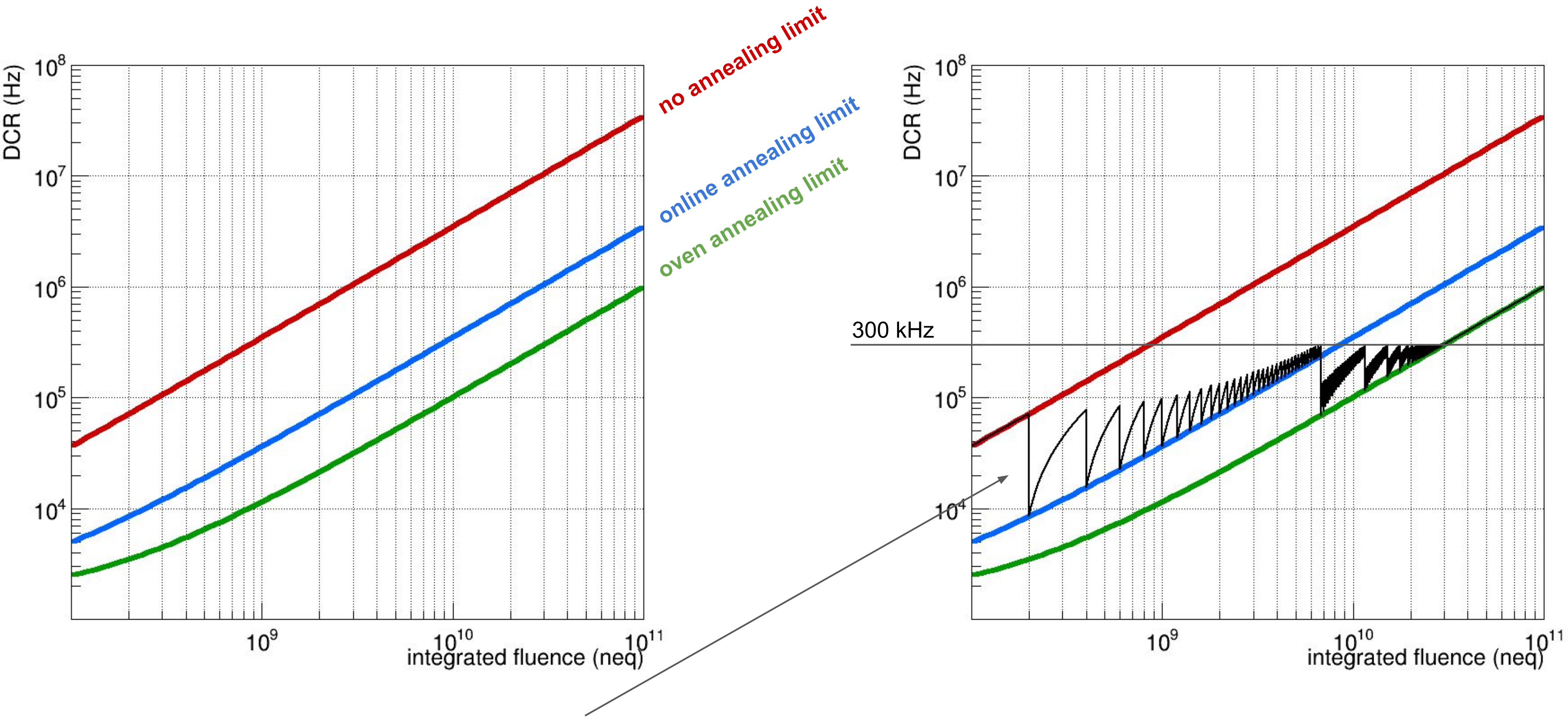
DCR (@ Vover = 3 V) increases by ~ 35 kHz after each 10^9 neq shot
memo: it was 350 kHz without online annealing

Radiation damage model (HPK S13360-3050 @ Vover = 3 V)

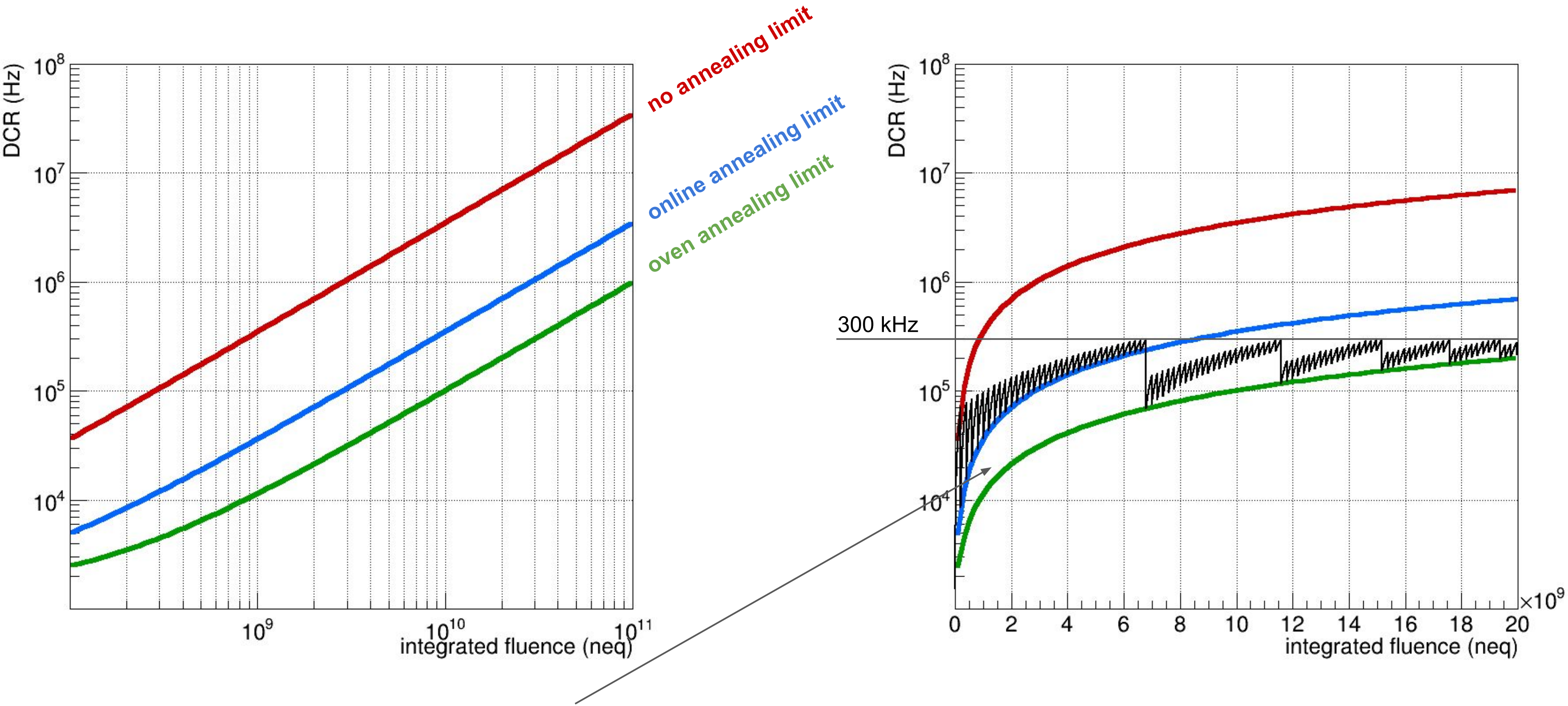
- **reasonable assumptions**
  - radiation damage is additive
  - does not know and care of the past damage
  - annealing heals up to a certain fraction of damage, not more than that
- **numbers**
  - DCR when new = 1.5 kHz
  - DCR increase with radiation damage = 350 kHz / 10^9 neq
  - DCR increase with online annealing = 35 kHz / 10^9 neq
  - DCR residual after oven annealing = 3%
- **how it works?**
  - start with DCR as new → NEW
  - add DCR with increasing radiation → NEW + NIEL1
  - heal with annealing → NEW + x NIEL1
  - add DCR with increasing radiation → NEW + x NIEL1 + NIEL2
  - heal with annealing → NEW + x (NIEL1 + NIEL2)



online annealing every 2 10^8 neq (500 times)



online annealing every 2 10^8 neq (500 times)
oven annealing when DCR > 300 kHz



online annealing every 2 10^8 neq (500 times)
oven annealing when DCR > 300 kHz