STATUS OF THE LDR (LOW DOSE RATE) AND HDR (HIGH DOSE RATE) IRRADIATION CAMPAIGN IN ETH

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And all the ETH team, thanks for their support during the installation and operation!

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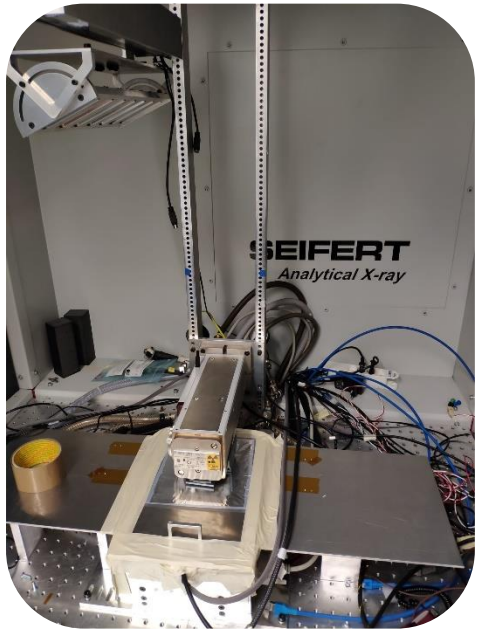
SETUP AT TEST DETAILS

- A high dose rate and low dose rate irradiation campaign has been carried out at ***ETH-Zurich*** starting in mid-October.

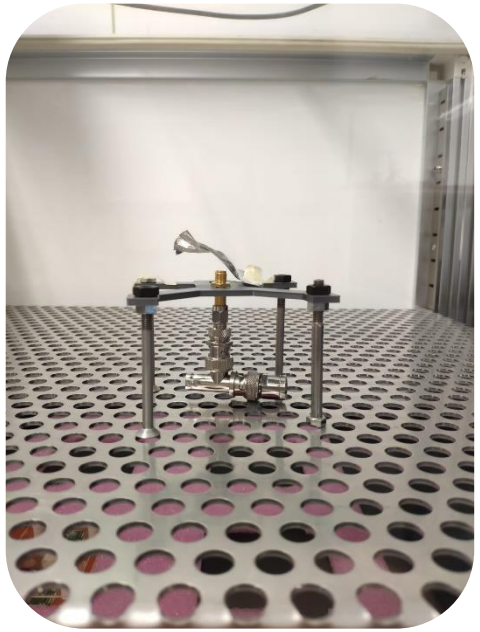
- **GOAL**: analyse the impact difference between High Dose Rate (HDR) irradiation and Low Dose Rate (LDR) irradiation in ***digital gates***, using the ***ring oscillators*** in RD53A.

- The campaign was divided in two phases:
  - 1st: ***HDR at -10°C*** up to 100Mrad, ***756krad/h***
    - ***Finished***, *kept at -10°C, powered and keeping ring oscillators working.*
  - 2nd: ***LDR at -10°C*** and 15C at ***100krad/h***
    - ***Ongoing***, already reached about 40Mrads.

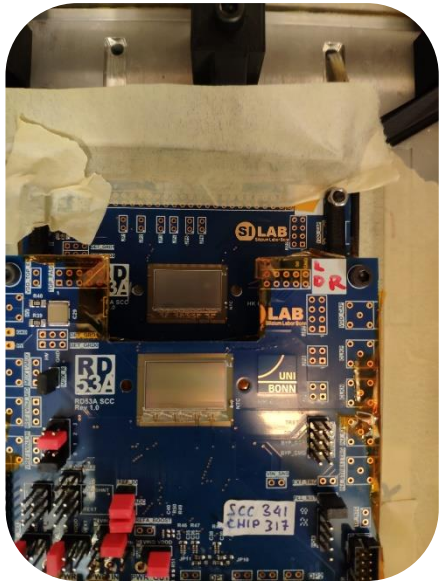
- LDR kept at 100krad/h after discussions with radiation experts at CERN who have seen similar LDR results when irradiating at 35krad/h and 100krad/h (optimizing testing time).

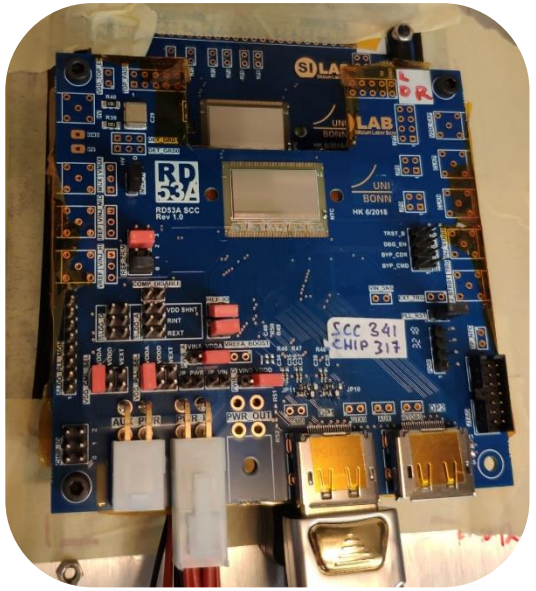


X-ray machine in ETH, HDR setup



Diode used for the calibration of the x-ray beam

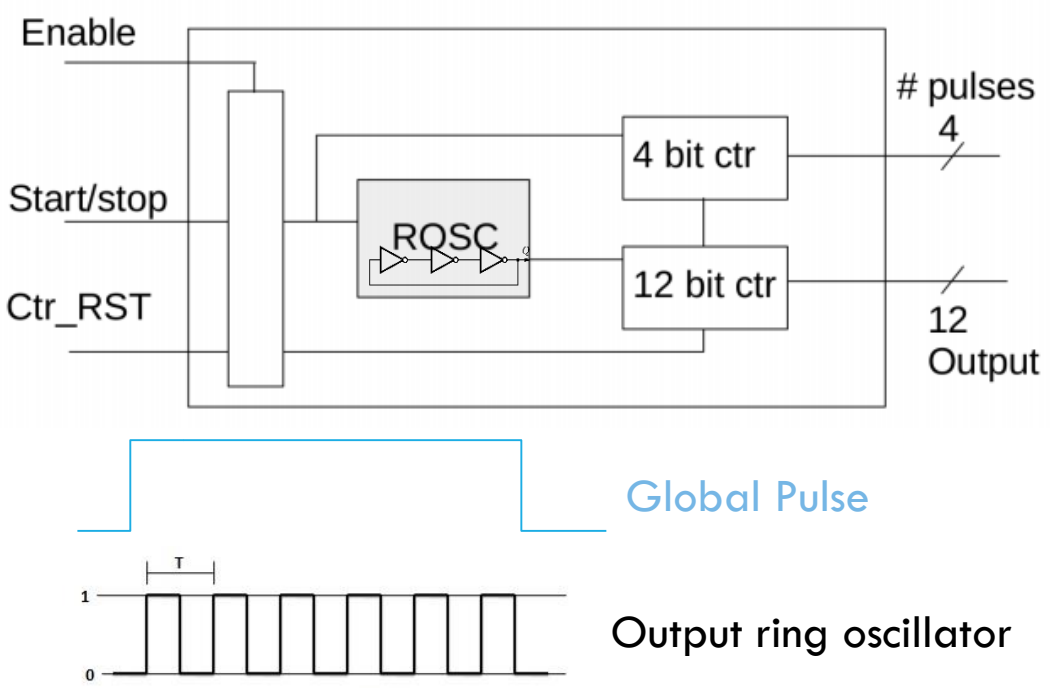




-10°C and 'warm' LDR setup

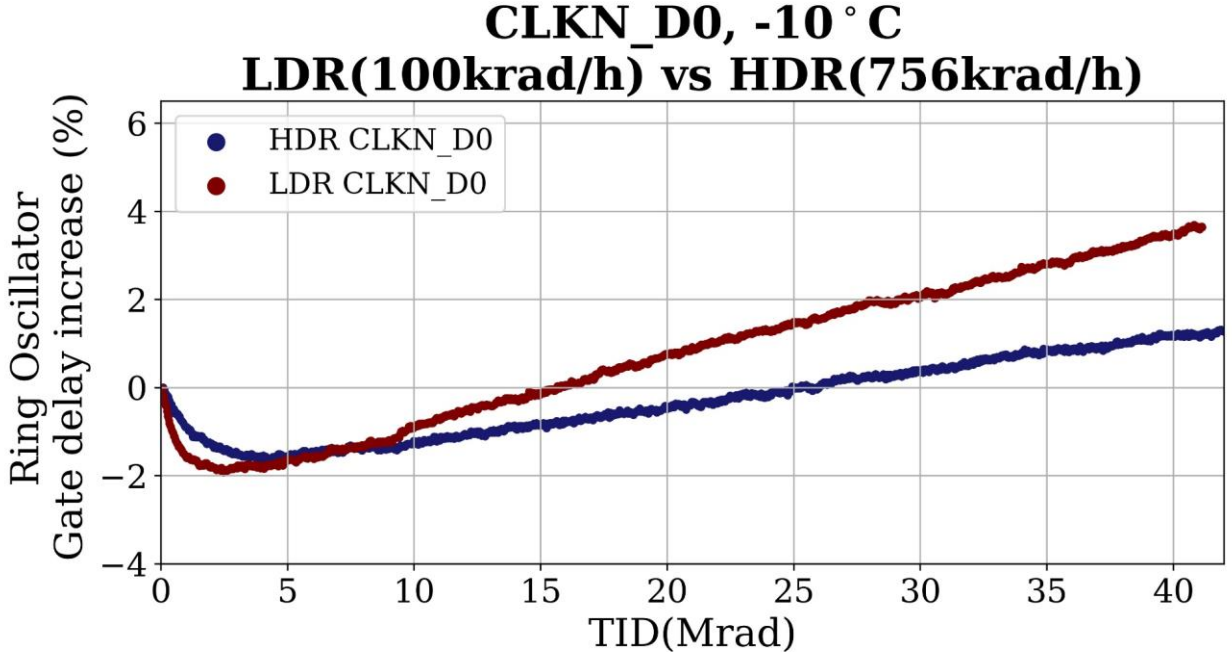
RESULTS:

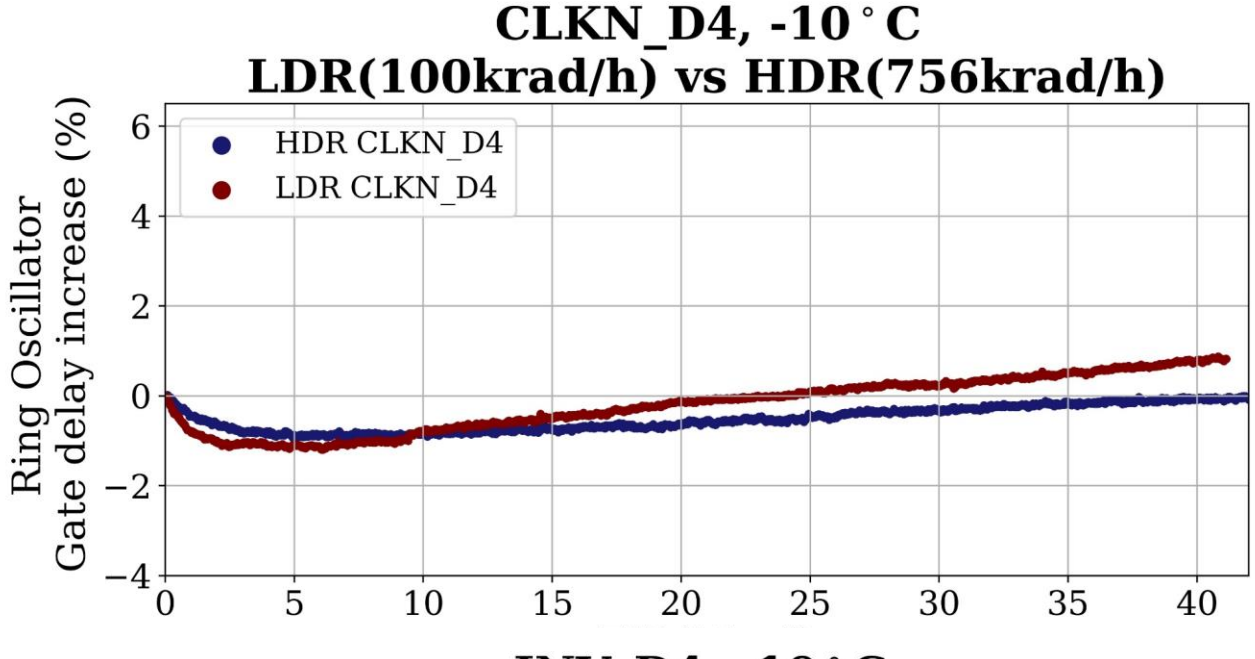
- ***Digital gate delay degradation with irradiation (TID, total ionizing dose)*** is shown in the following slides for both *HDR and LDR* tests in % of variation with respect to its value before irradiation at the same temperature.
- Direct powering mode was used during the campaign and sensing cables.
- Only ***PRELIMINARY*** results of the ***cold HDR and LDR*** tests are shown in this presentation
- ***Scale*** in all plots has been kept the ***same*** for the sake of comparison between gates.

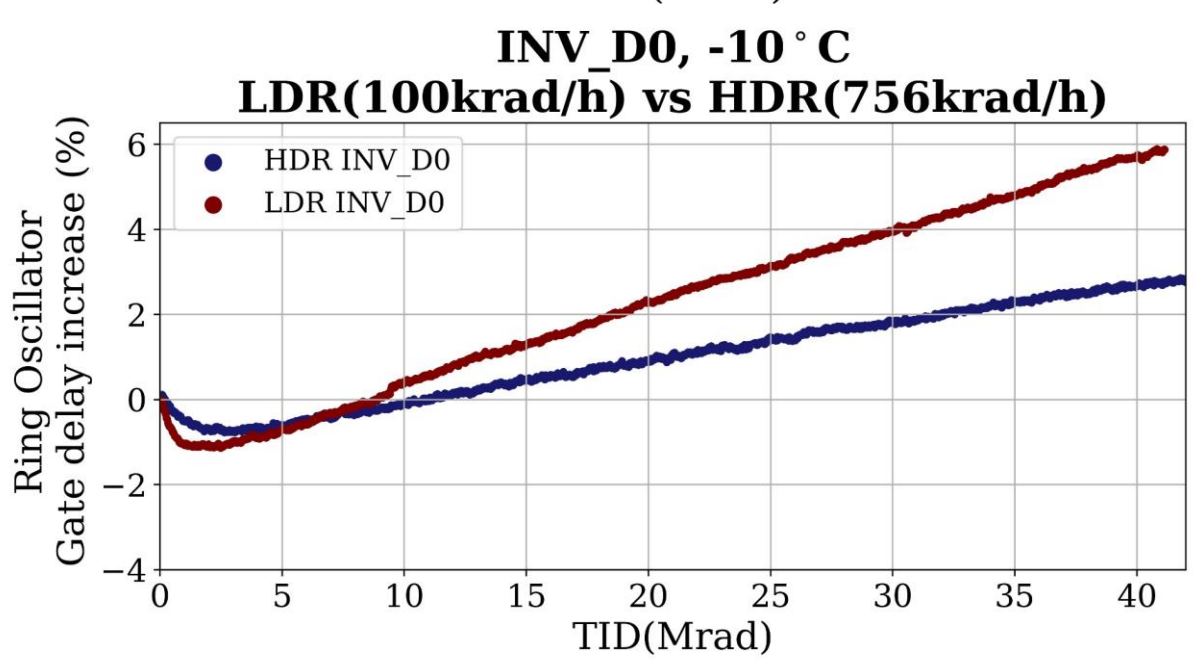


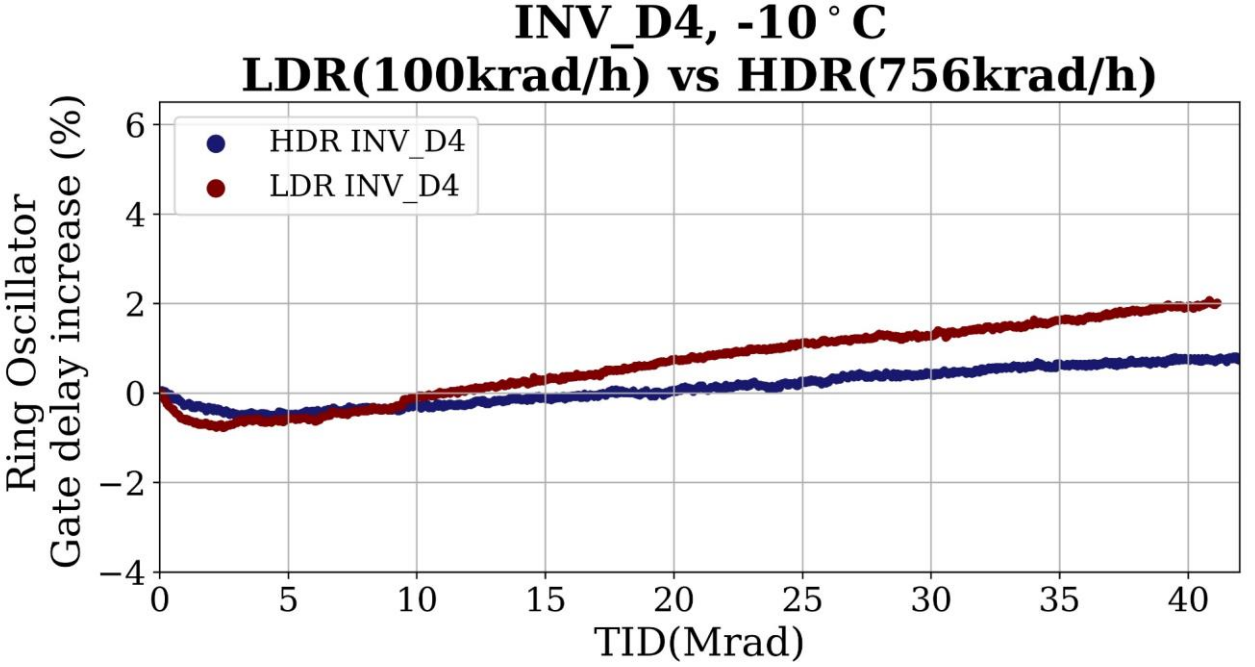
$$Td \sim \frac{1}{N * Frequency}$$

RESULTS: LDR VS HDR









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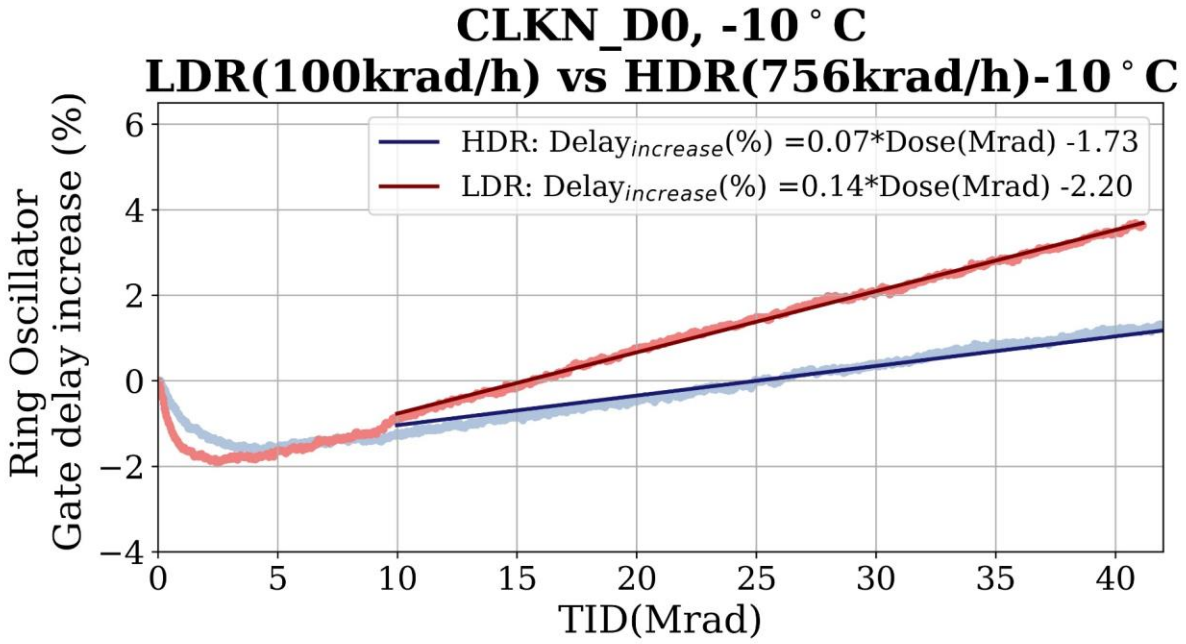

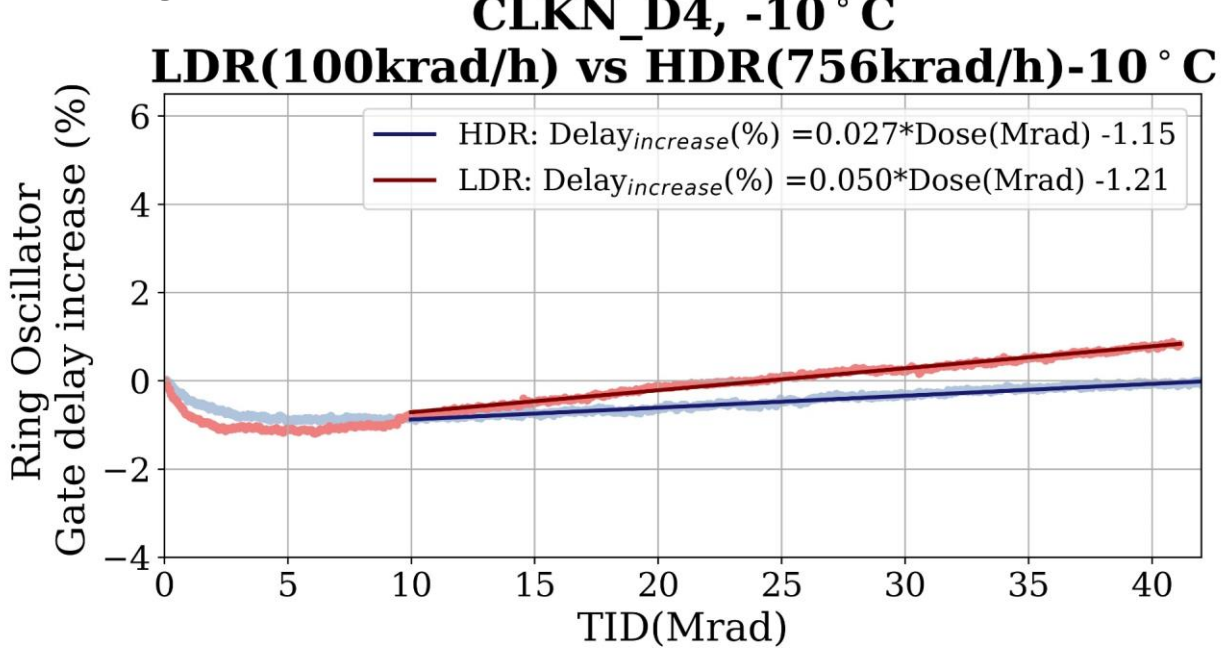

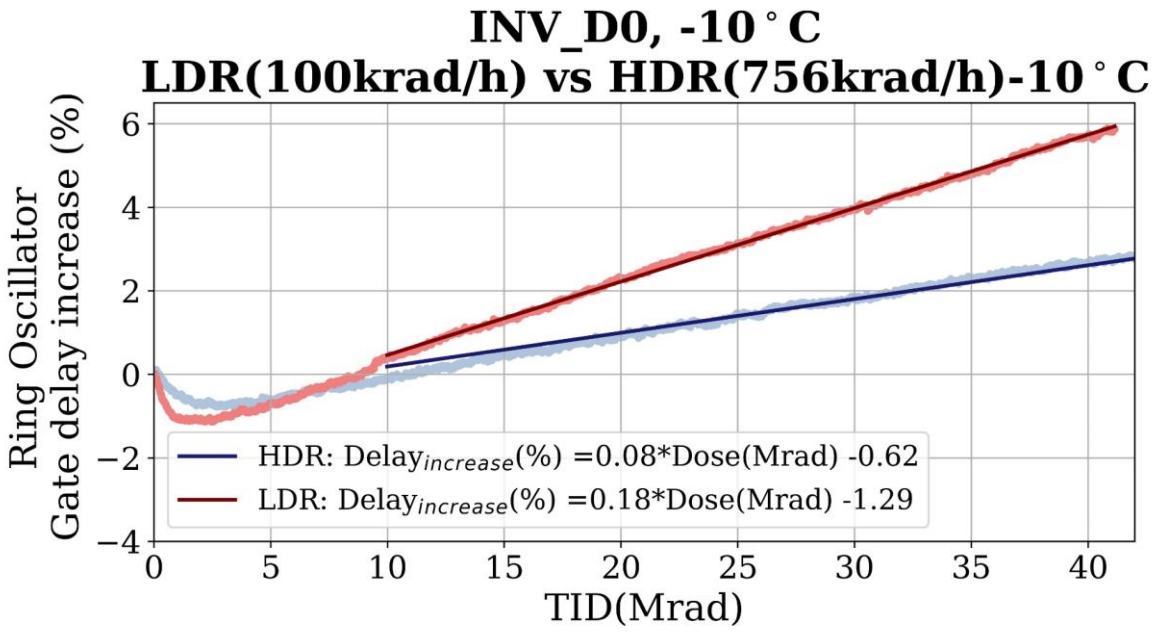

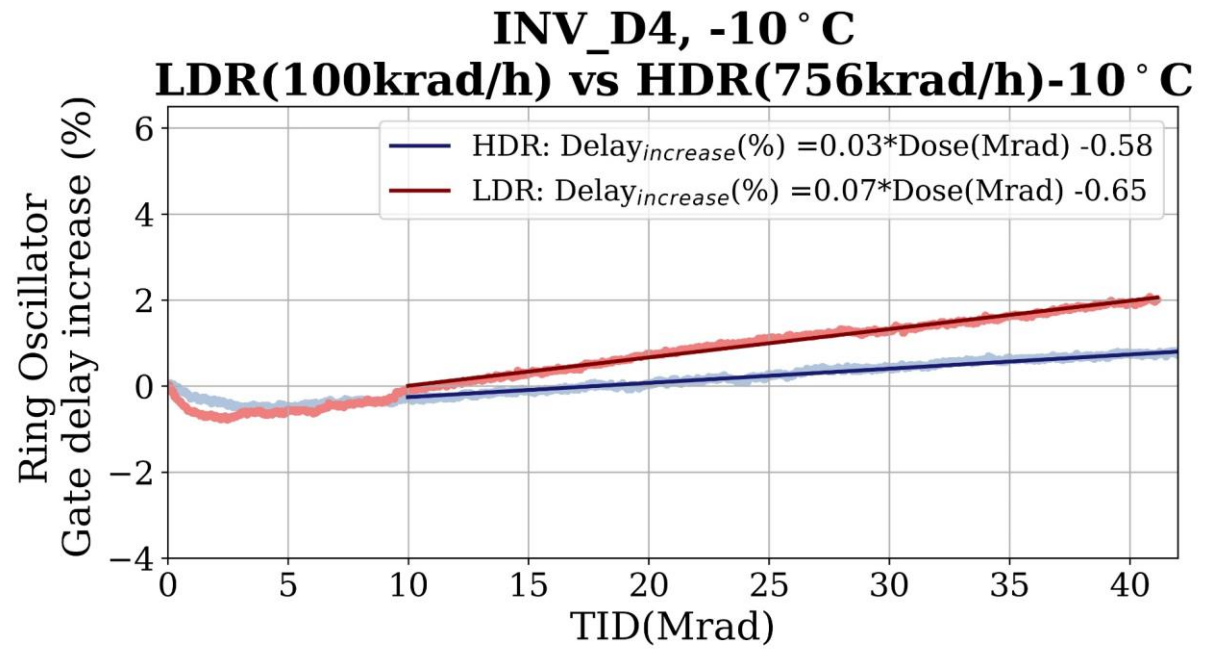

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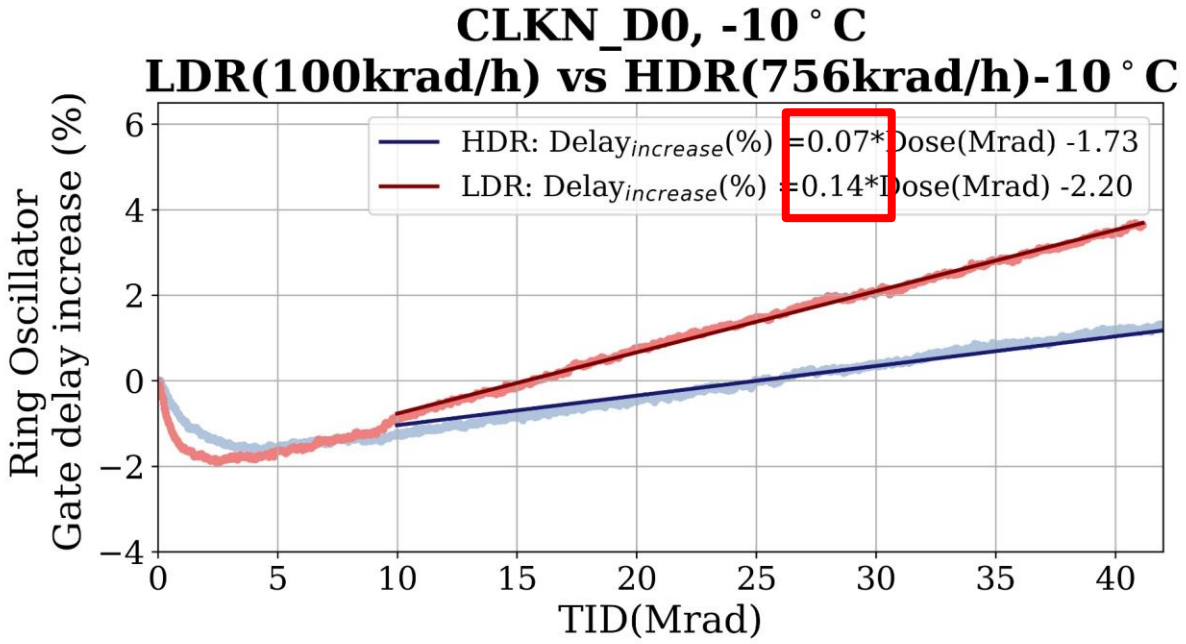

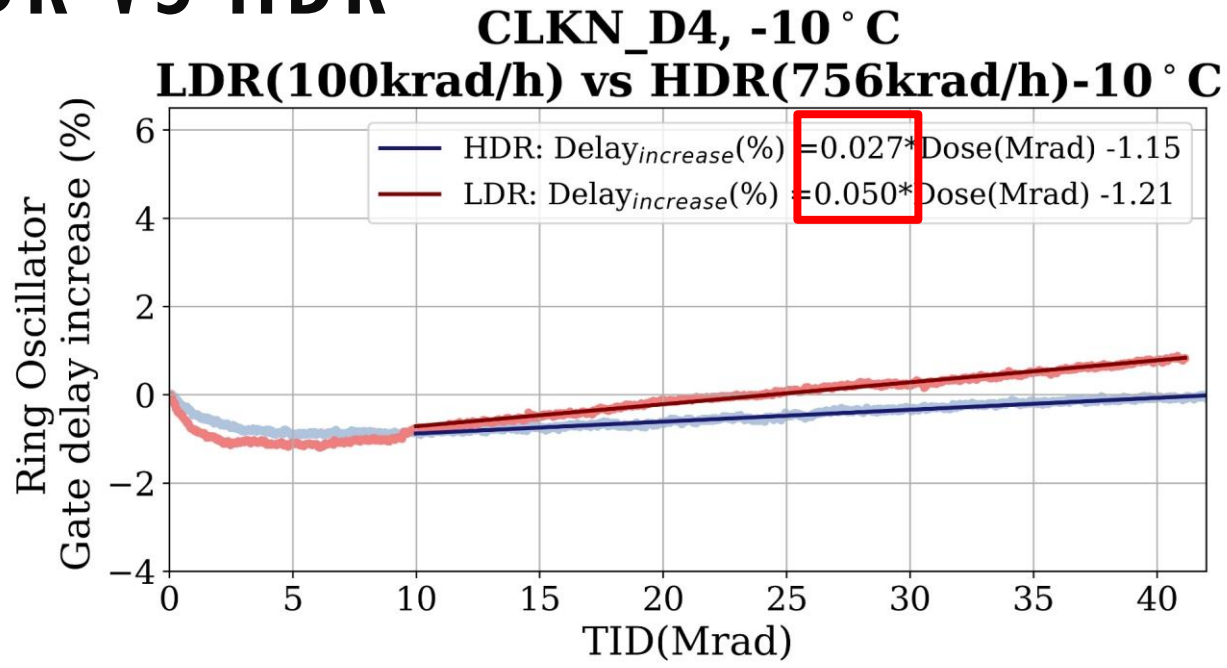

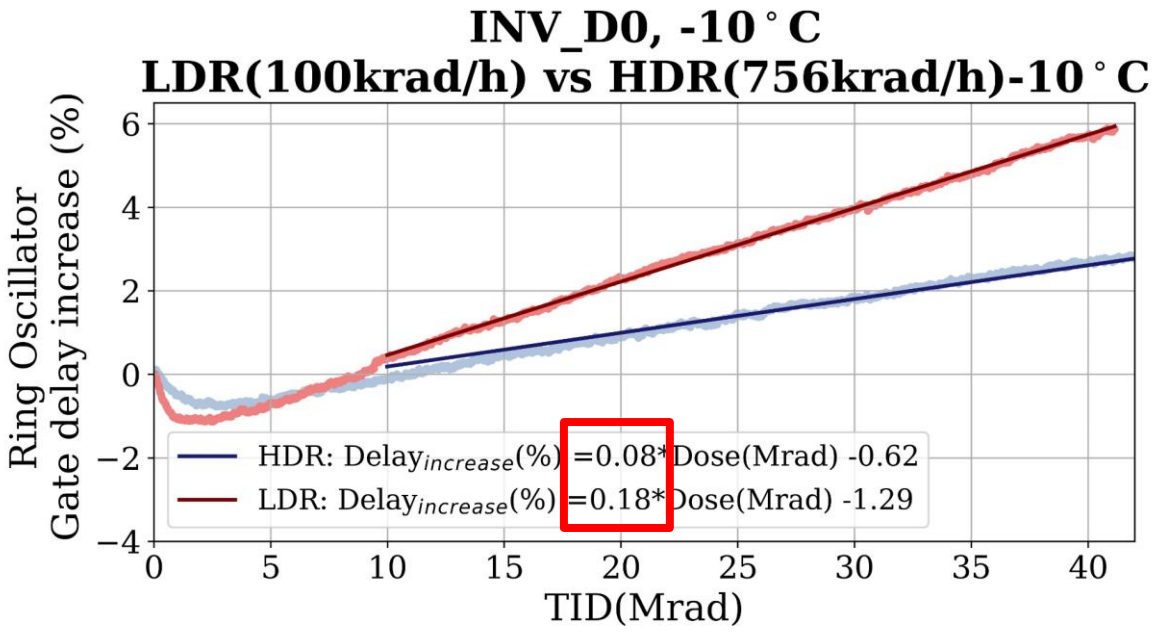

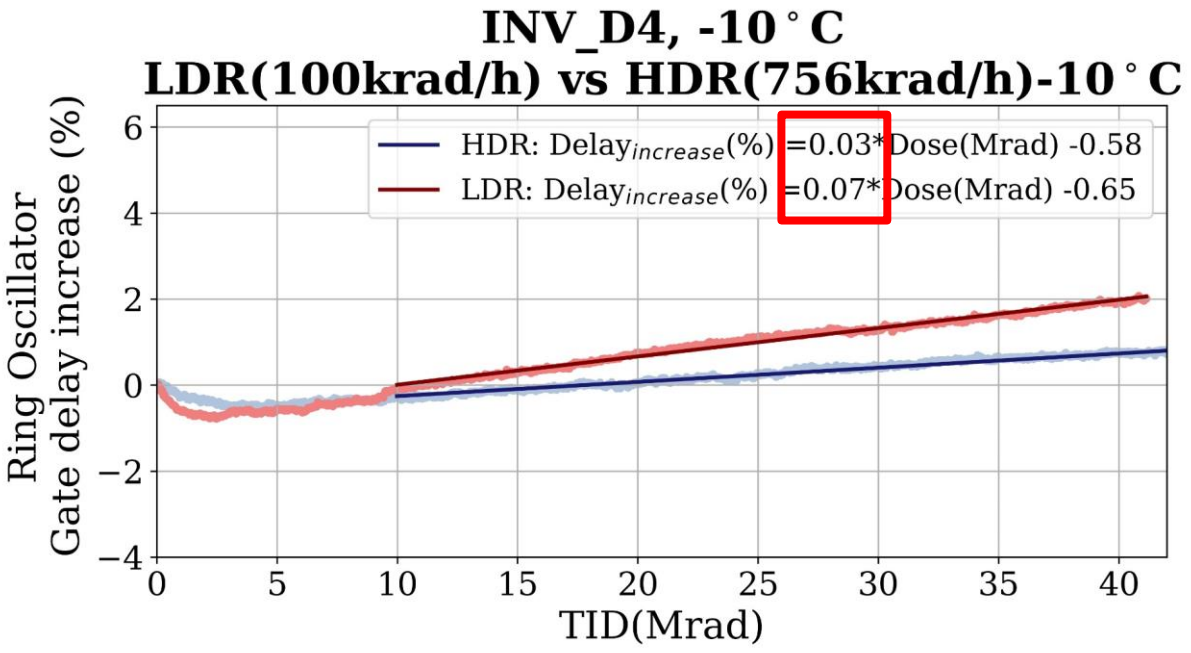

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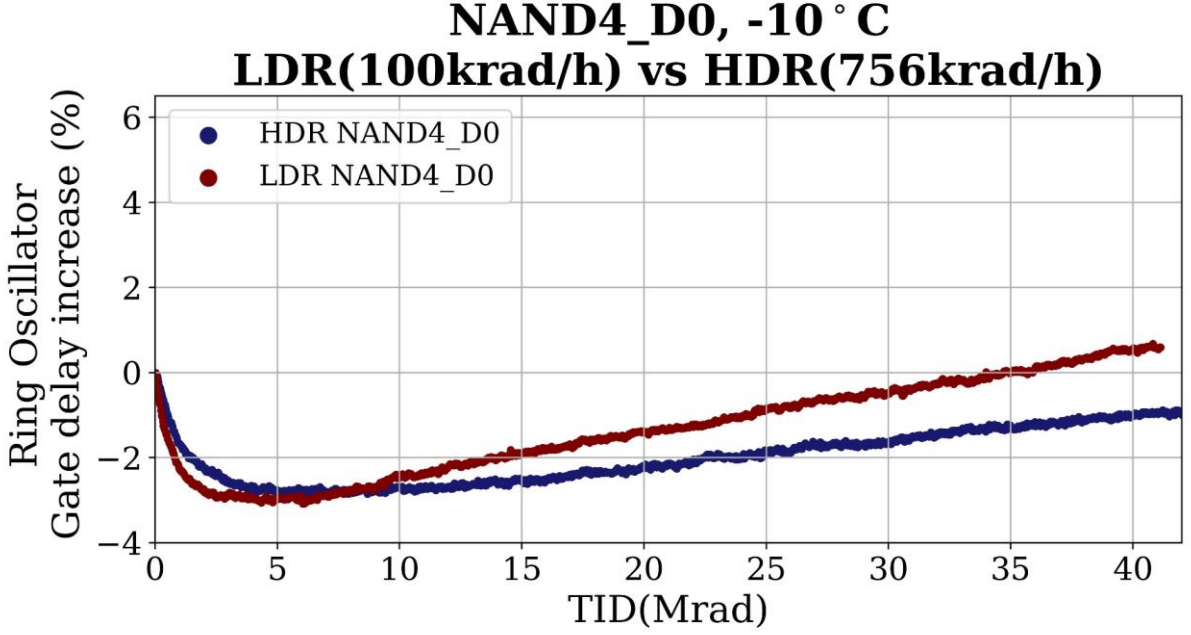
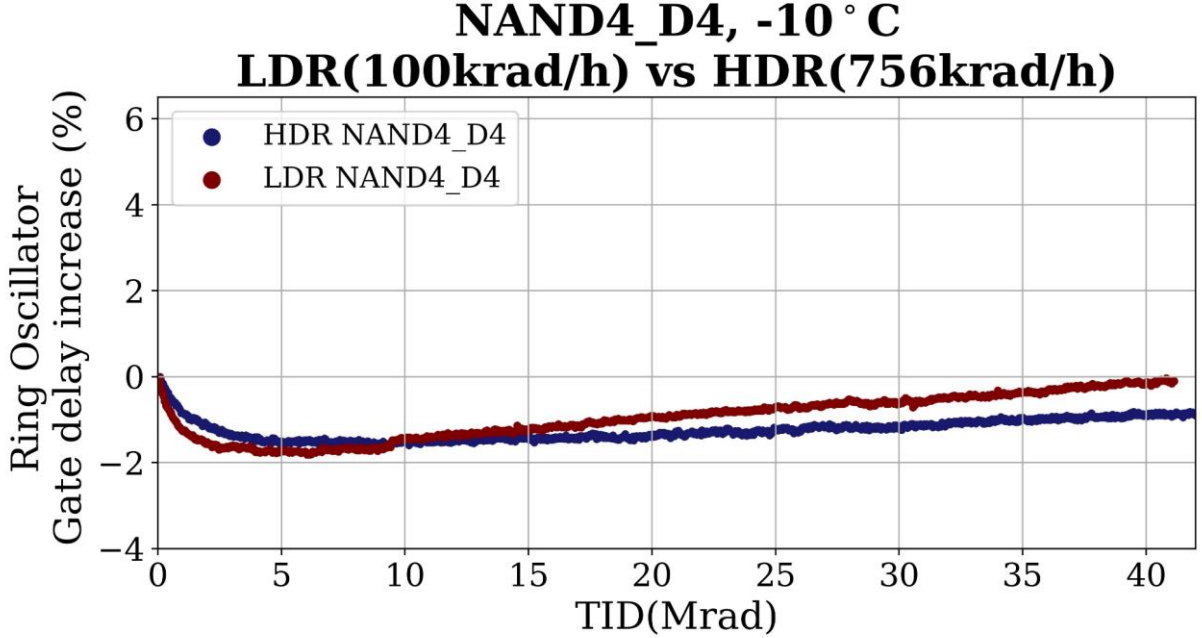
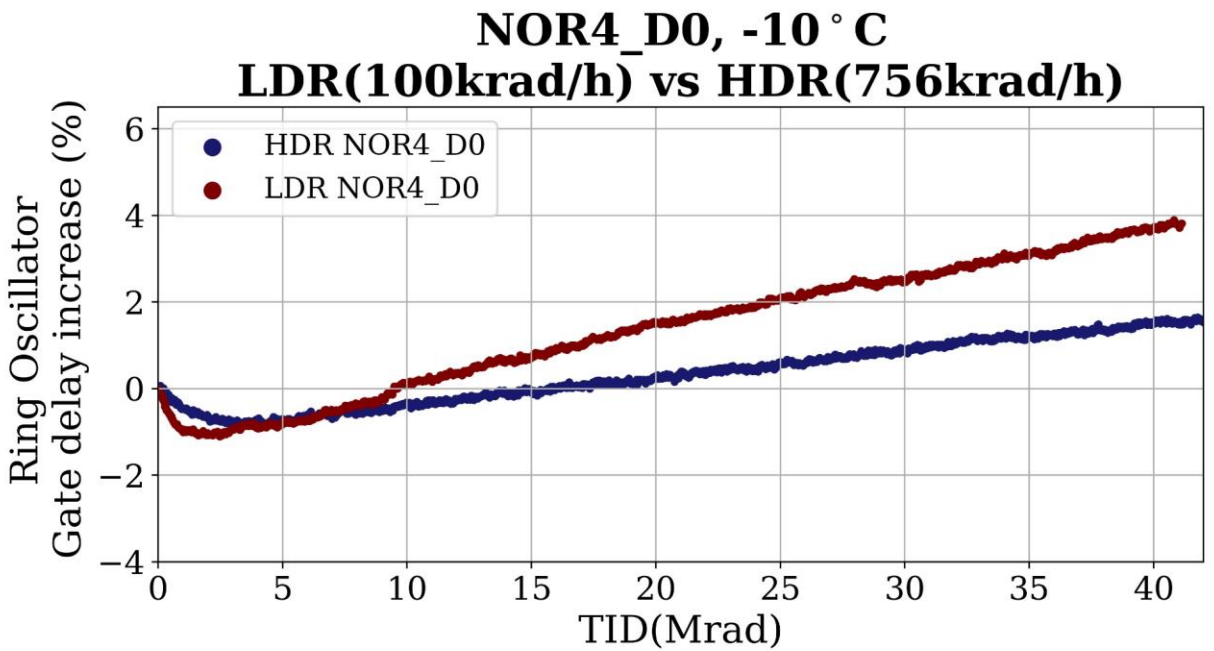
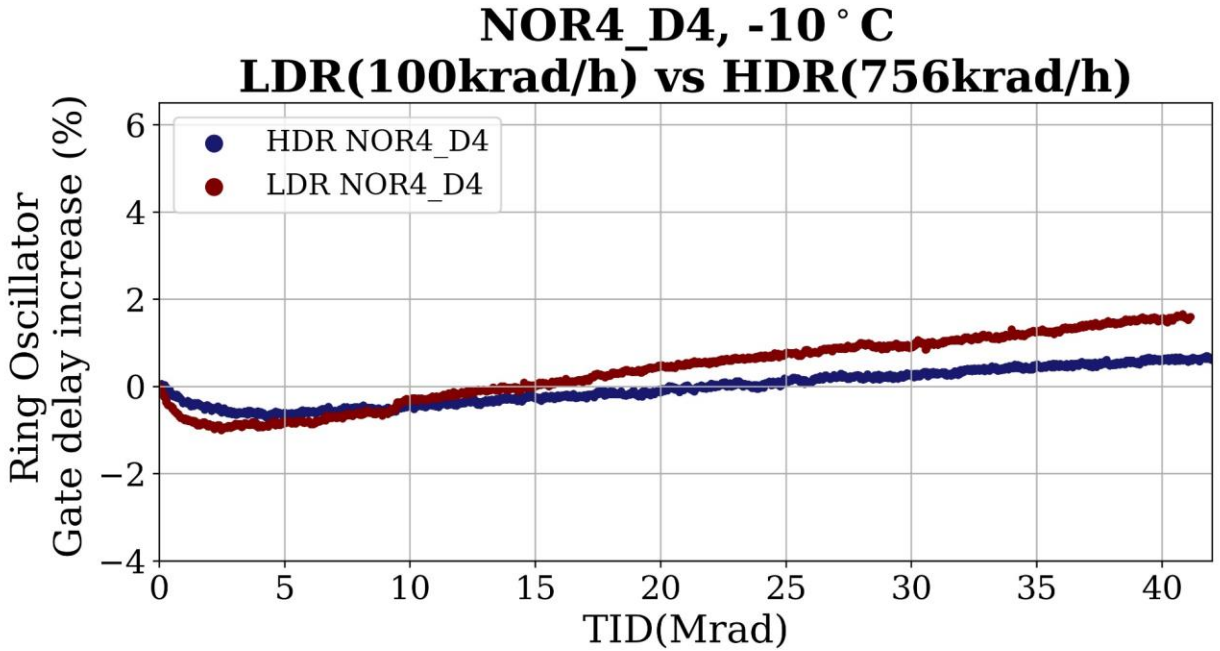
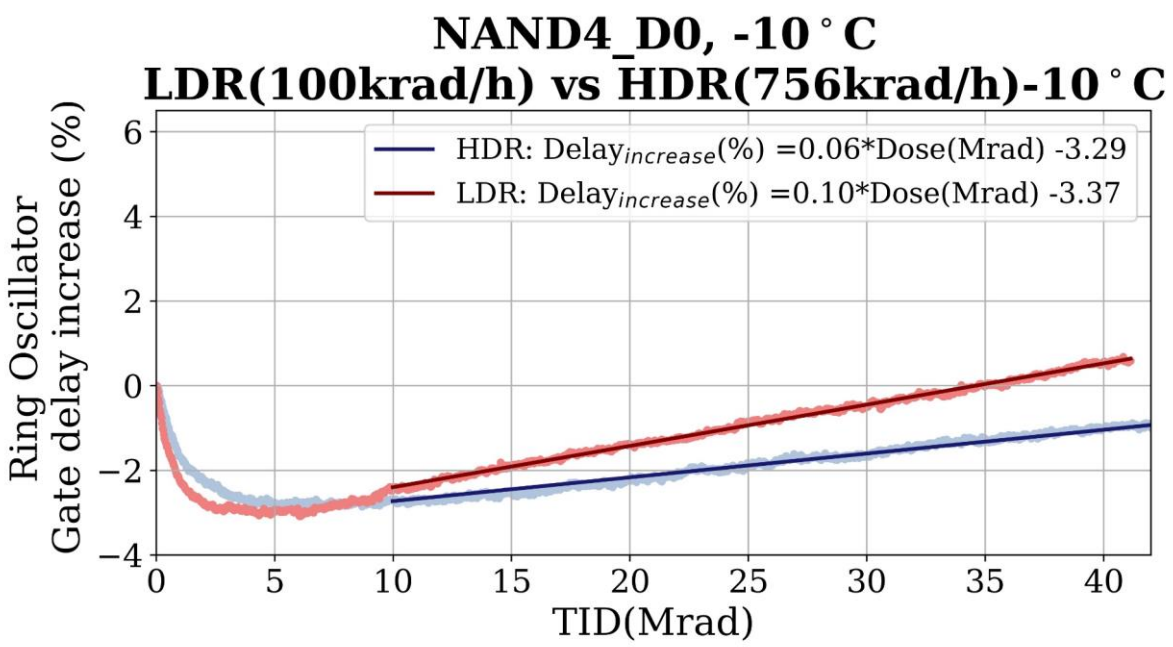


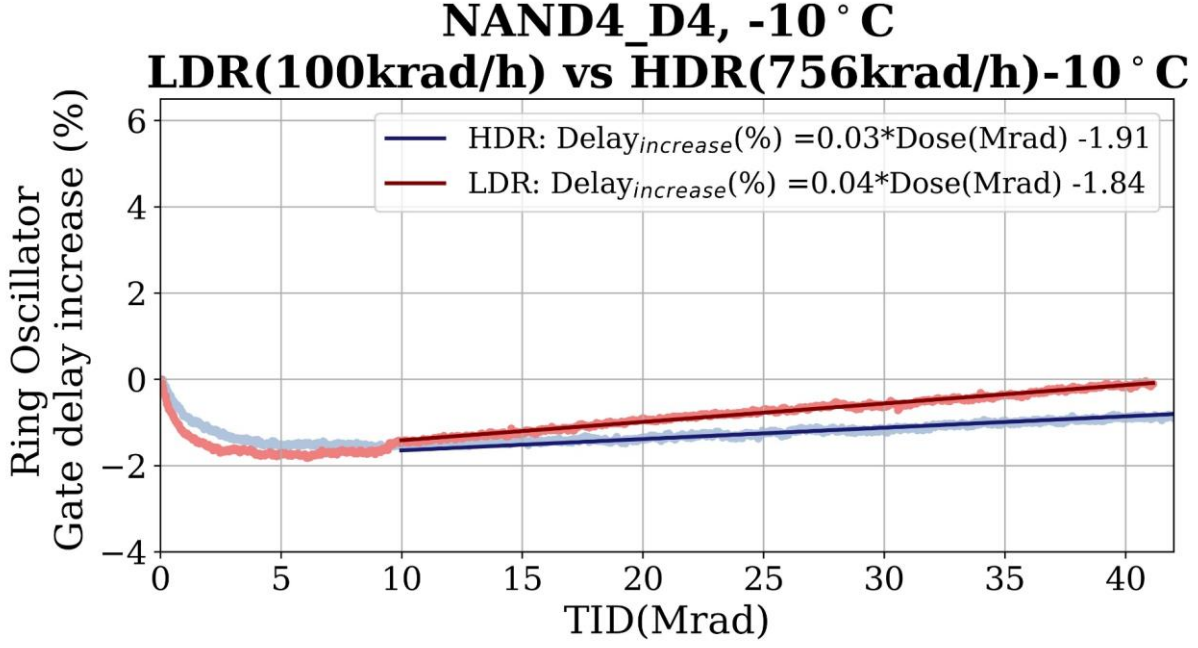


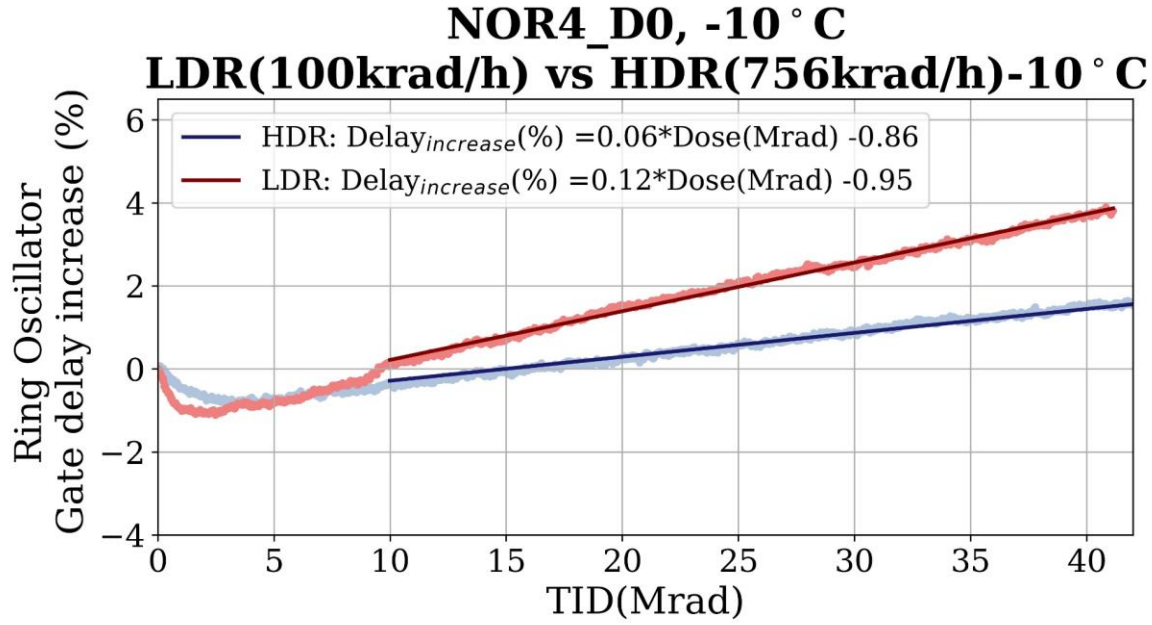


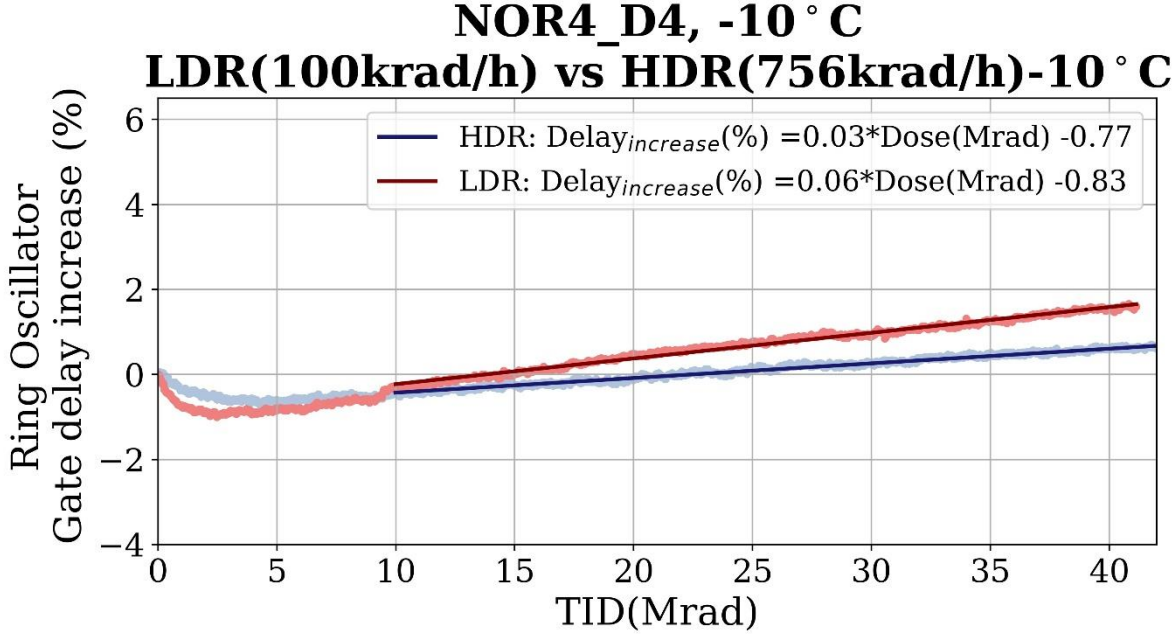


RESULTS: LINEAR FITS:



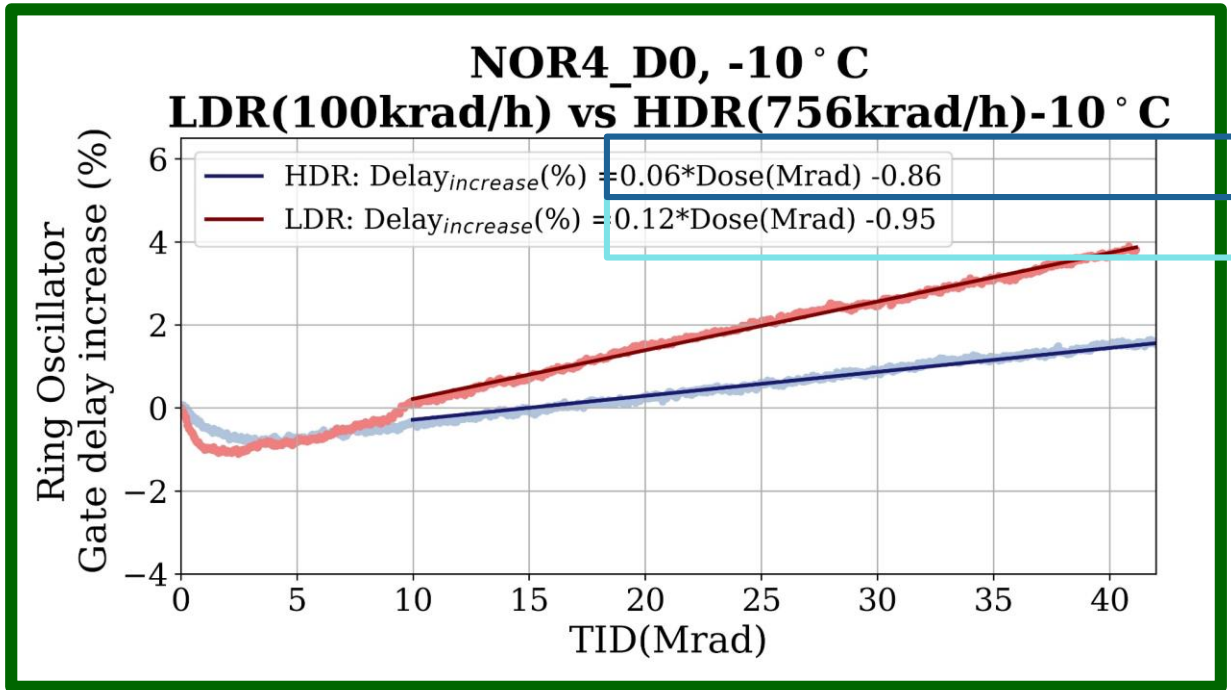


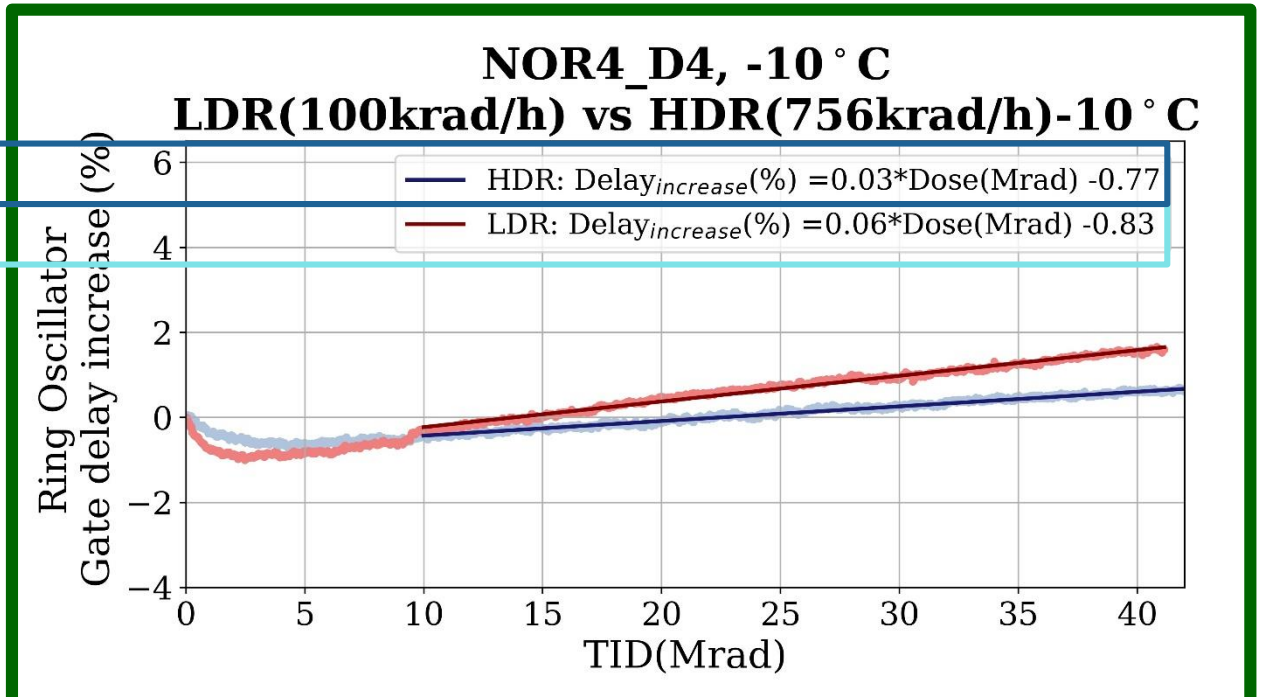




RESULTS: LINEAR FITS:

- **Gates with driving strength 0 and 4, same rate:**
  - **D0 degrades ~twice faster than D4 (depending also on the gate)**
- Gates with same driving strength irradiated at different rates:
  - LDR seems ~twice worse than HDR





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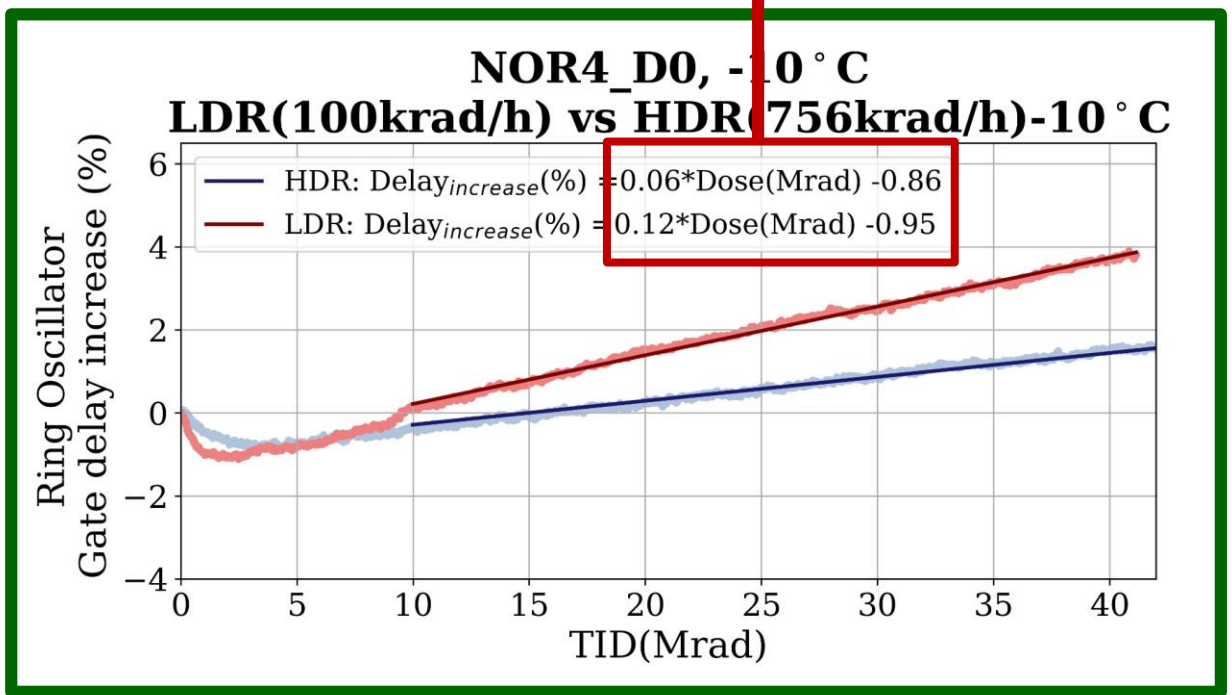
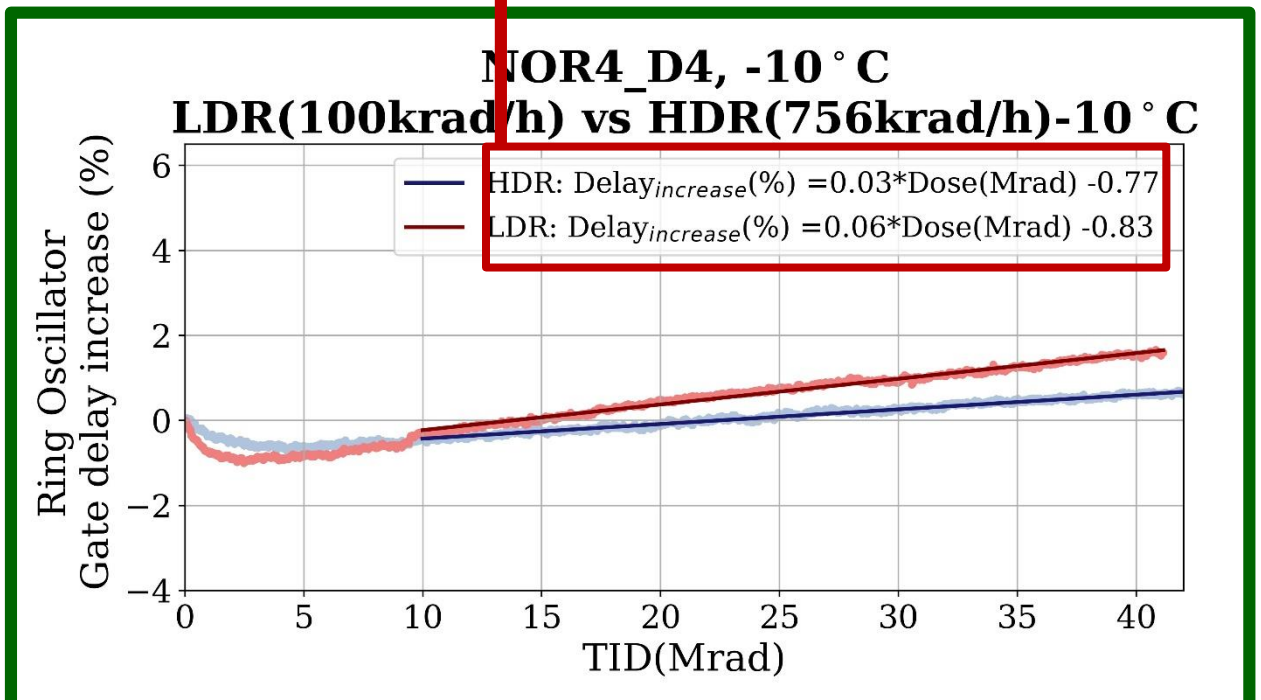




CONCLUSIONS:

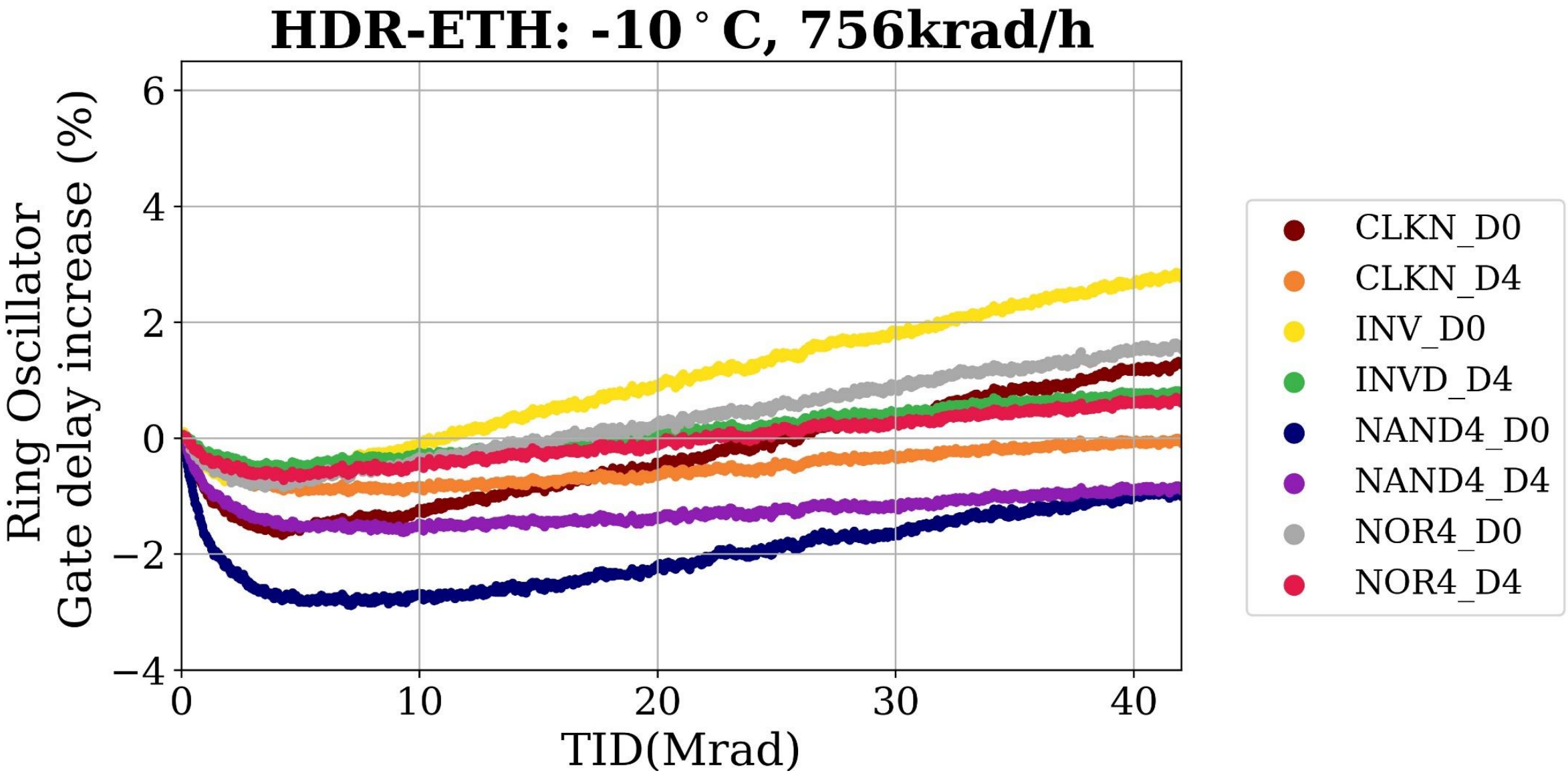
- Indications of a low dose rate effect have been seen during the first Mrads of a LDR irradiation campaign compared with a HDR test.

- Further analysis is needed:
  - Extrapolation of LDR fits to 500Mrads and 1Grad to have an estimate of final degradation at LDR
  - Comparison with other HDR and LDR campaigns

Thank you!

Backup slides

RESULTS: HDR: GATE DELAY



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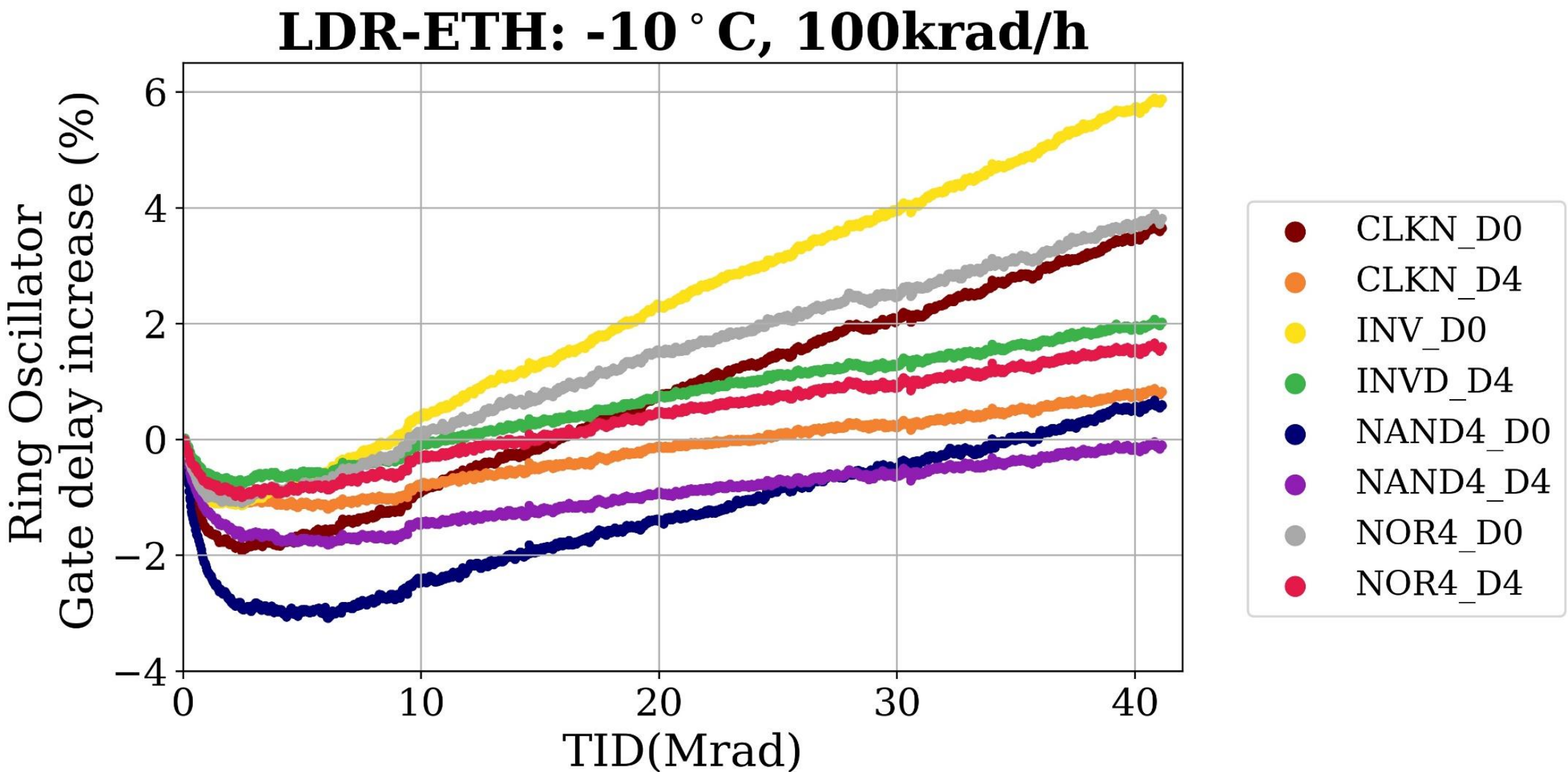
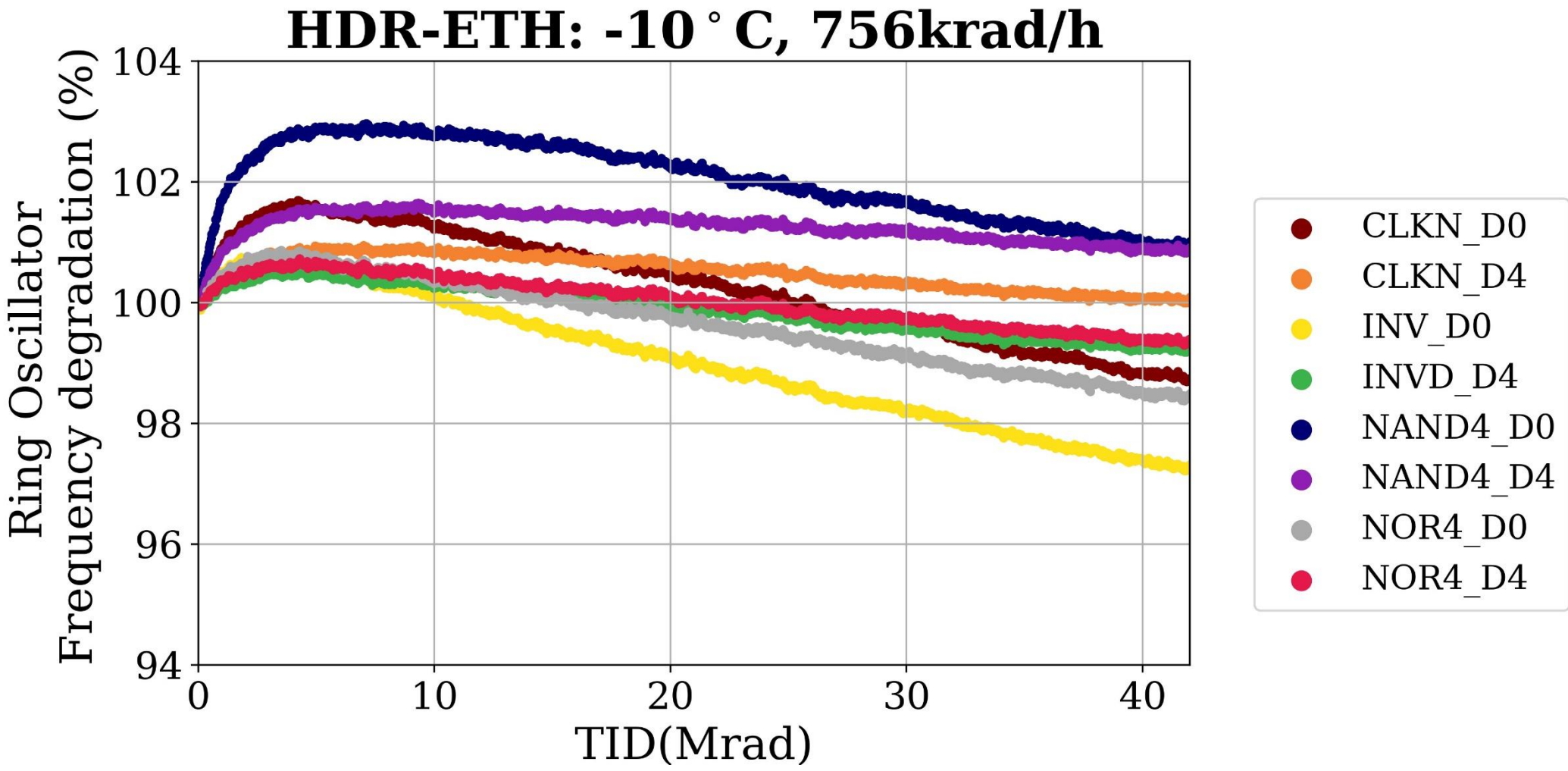


RESULTS: HDR: FREQUENCY OF RING OSCILLATORS



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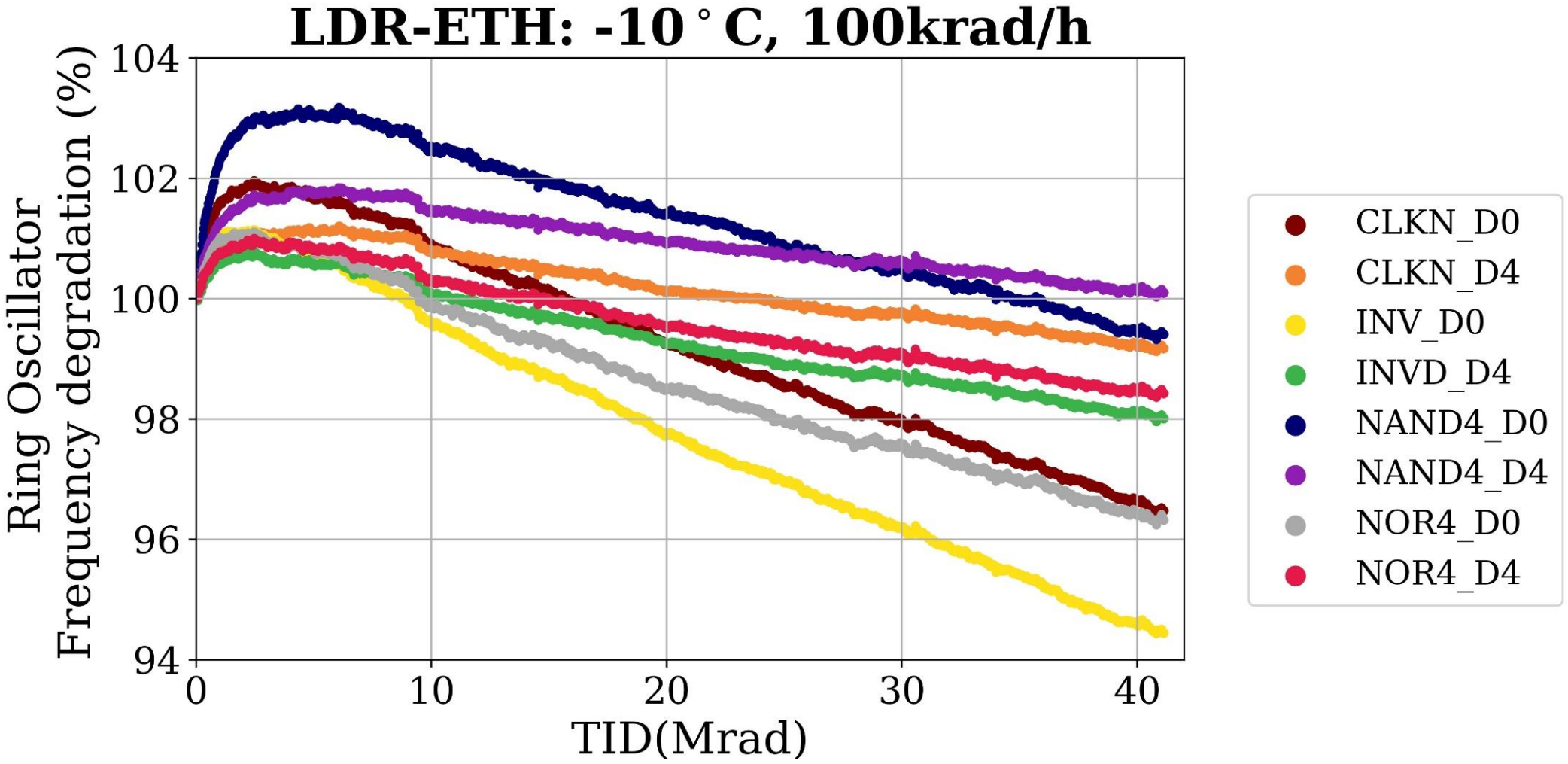
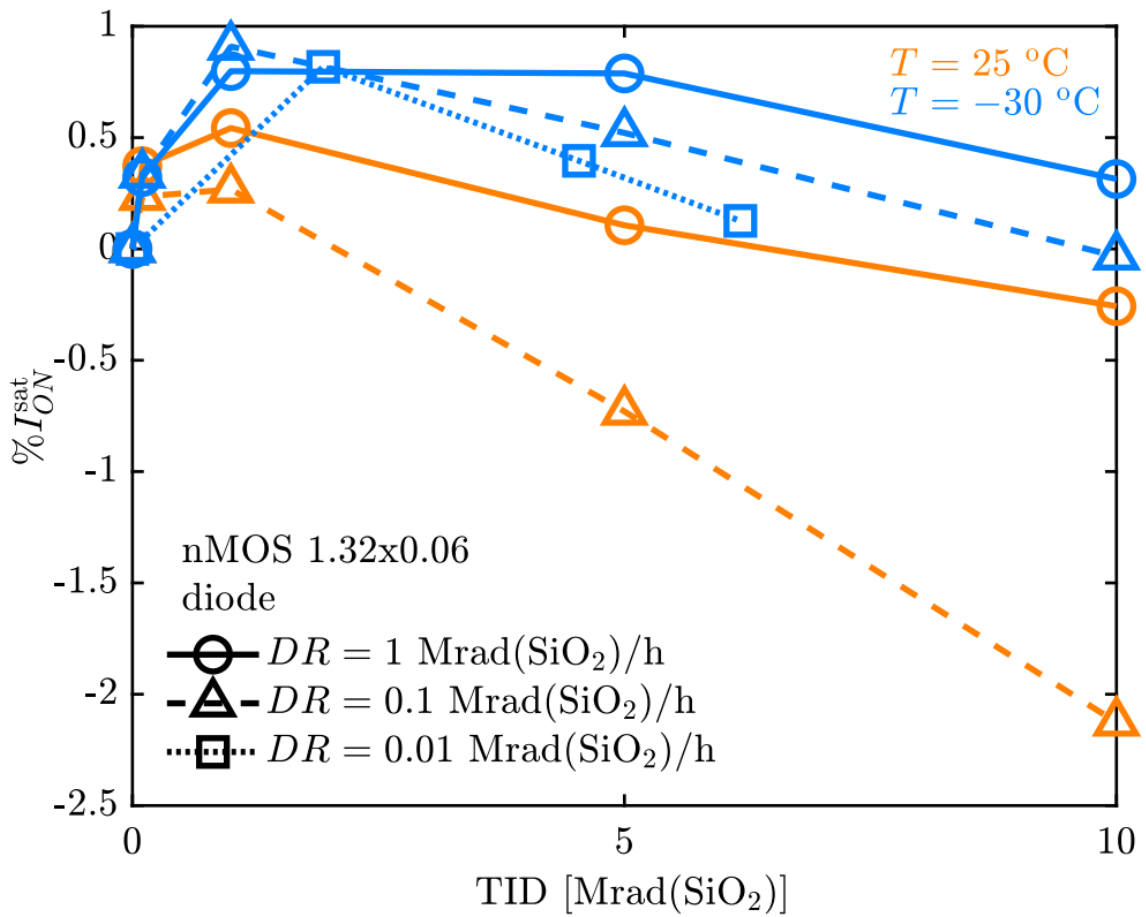
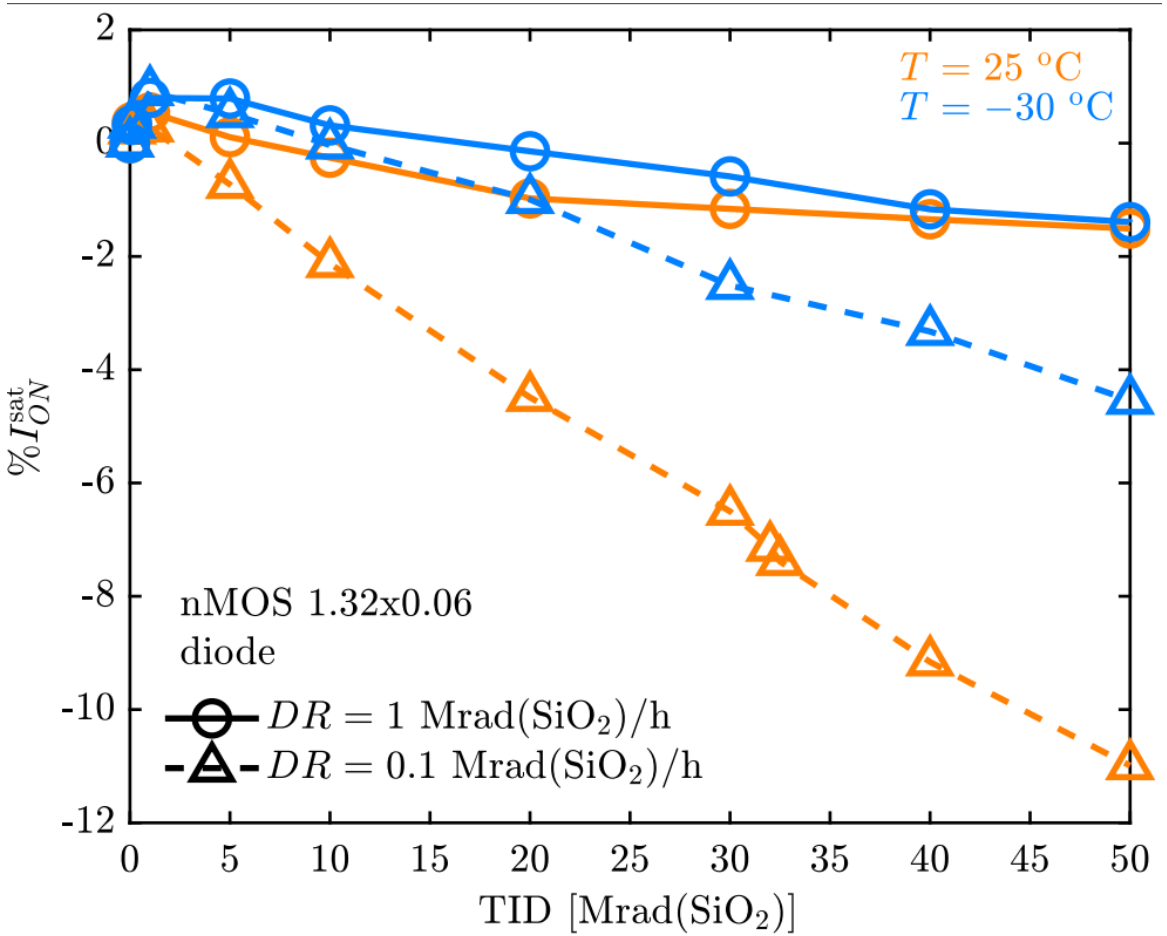



$T = 25$ °C
$T = -30$ °C
nMOS 1.32x0.06
diode
$DR = 1$ Mrad(SiO$_2$)/h
$DR = 0.1$ Mrad(SiO$_2$)/h
$DR = 0.01$ Mrad(SiO$_2$)/h
$\%I_{ON}^{sat}$
TID [Mrad(SiO$_2$)]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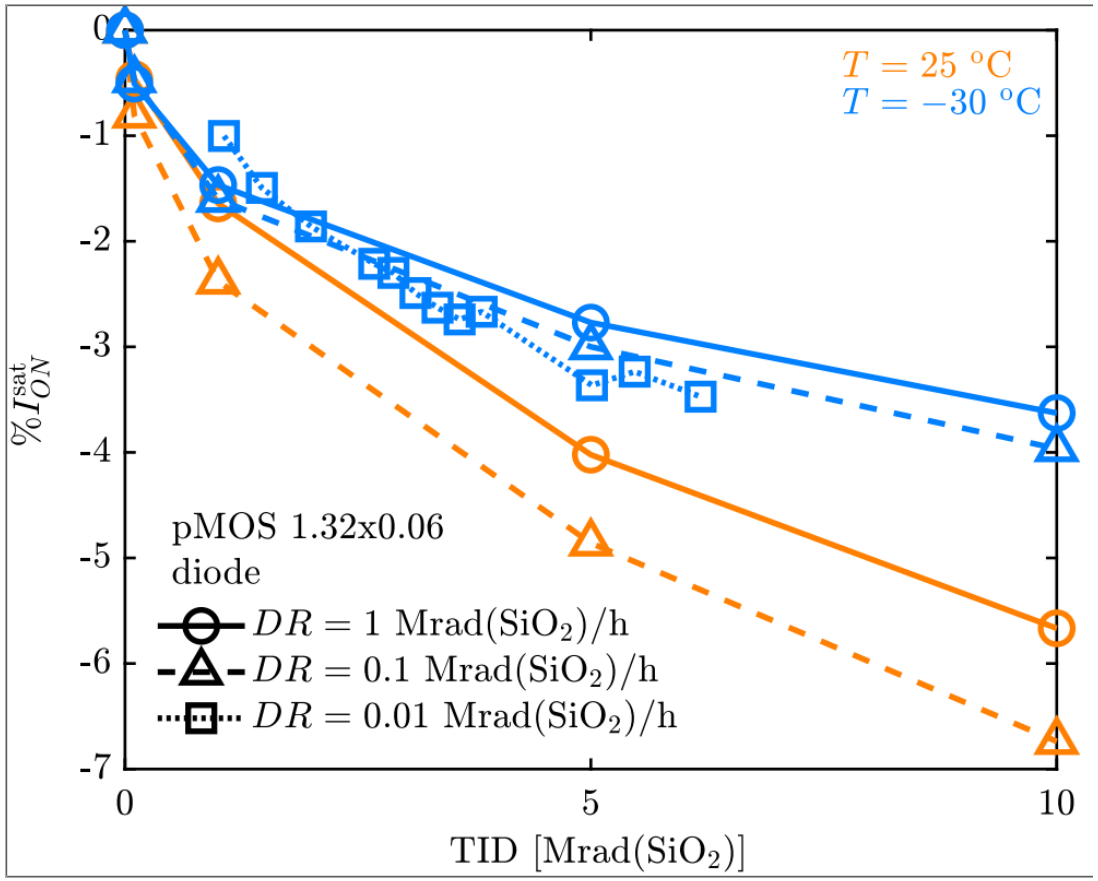
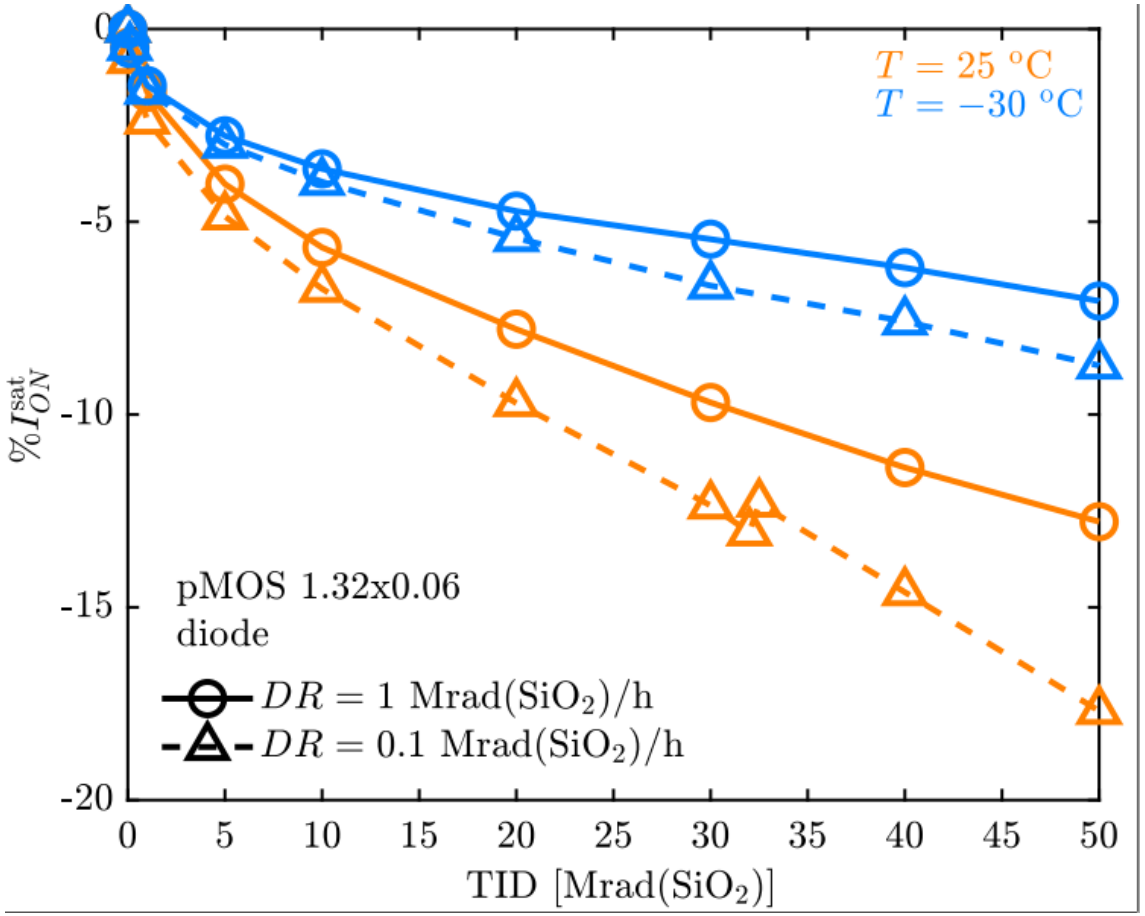

$T = 25$ °C
$T = -30$ °C
pMOS 1.32x0.06
diode
$DR = 1$ Mrad(SiO$_2$)/h
$DR = 0.1$ Mrad(SiO$_2$)/h
$DR = 0.01$ Mrad(SiO$_2$)/h
$\%I_{ON}^{sat}$
TID [Mrad(SiO$_2$)]
0
-1
-2
-3
-4
-5
-6
-7
0
5
10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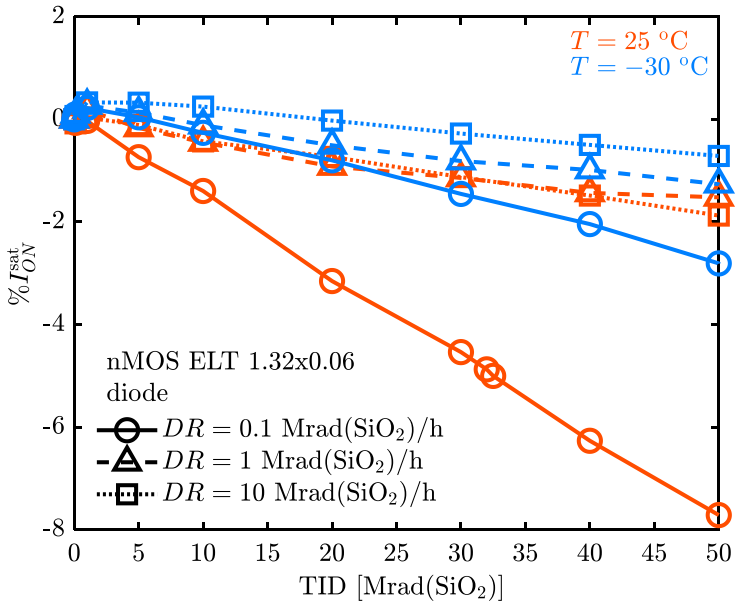
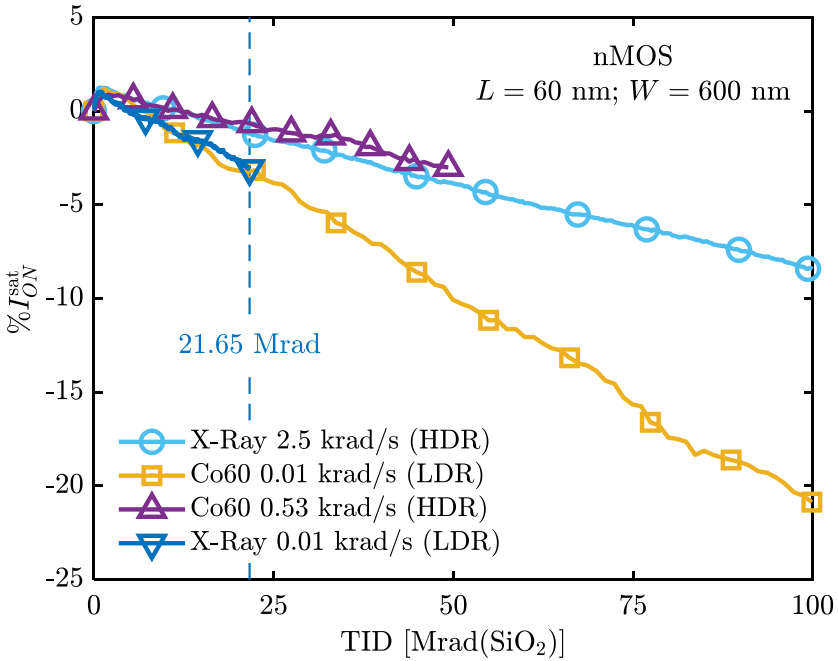
diode
$DR = 1$ Mrad(SiO$_2$)/h
$DR = 0.1$ Mrad(SiO$_2$)/h
$\%I_{ON}^{sat}$
TID [Mrad(SiO$_2$)]
0
-5
-10
-15
-20
0
5
10
15
20
25
30
35
40
45
50

ELT L=0.06 µm ↓

nMOS→





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