dRICH SiPM news

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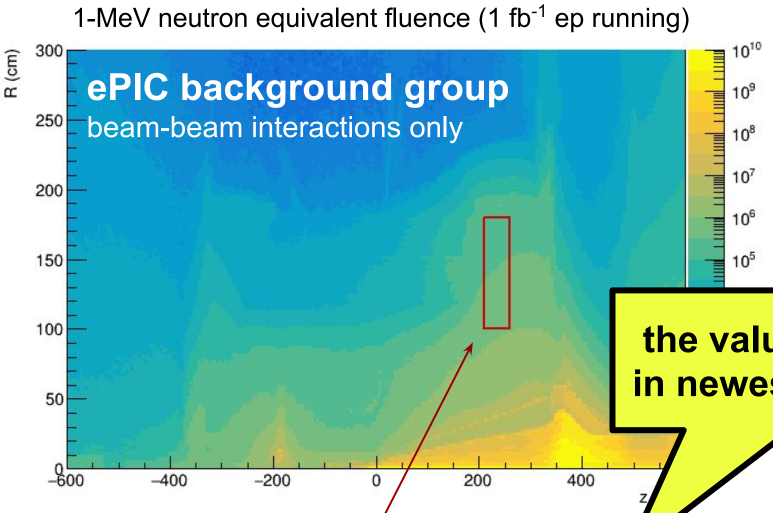
Neutron fluxes at the dRICH photosensor surface



the values increased in newest simulations

location of dRICH photosensors

mean fluence: 3.9 10^5 neq / cm^2 / fb^{-1}

max fluence: 9.2 10^5 neq / cm^2 / fb^{-1}

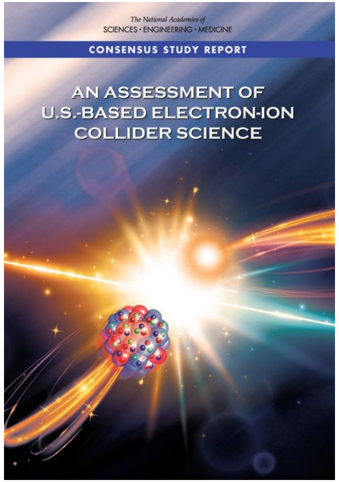
- radiation level is moderate

assume fluence: ~ 10^7neq / cm^2 / fb^{-1}

conservatively assume max fluence and <u>10x safety factor</u>

Most of the key Physics goals defined by the NAS require an integrated luminosity of 10 fb^{-1} per center of mass energy and polarization setting

The nucleon imaging programme is more … gry and **requires 100 fb^{-1}** … **s energy and polarization setting**



in 10-12 years the EIC will accumulate 1000 fb^{-1} integrated $\mathscr{L}$ corresponding to an integrated fluence of ~ 10^{10} n_{eq}/cm^2

study the SiPM usability for single-photon Cherenkov imaging applications in moderate radiation environment

→ radiation damage studied in steps of radiation load

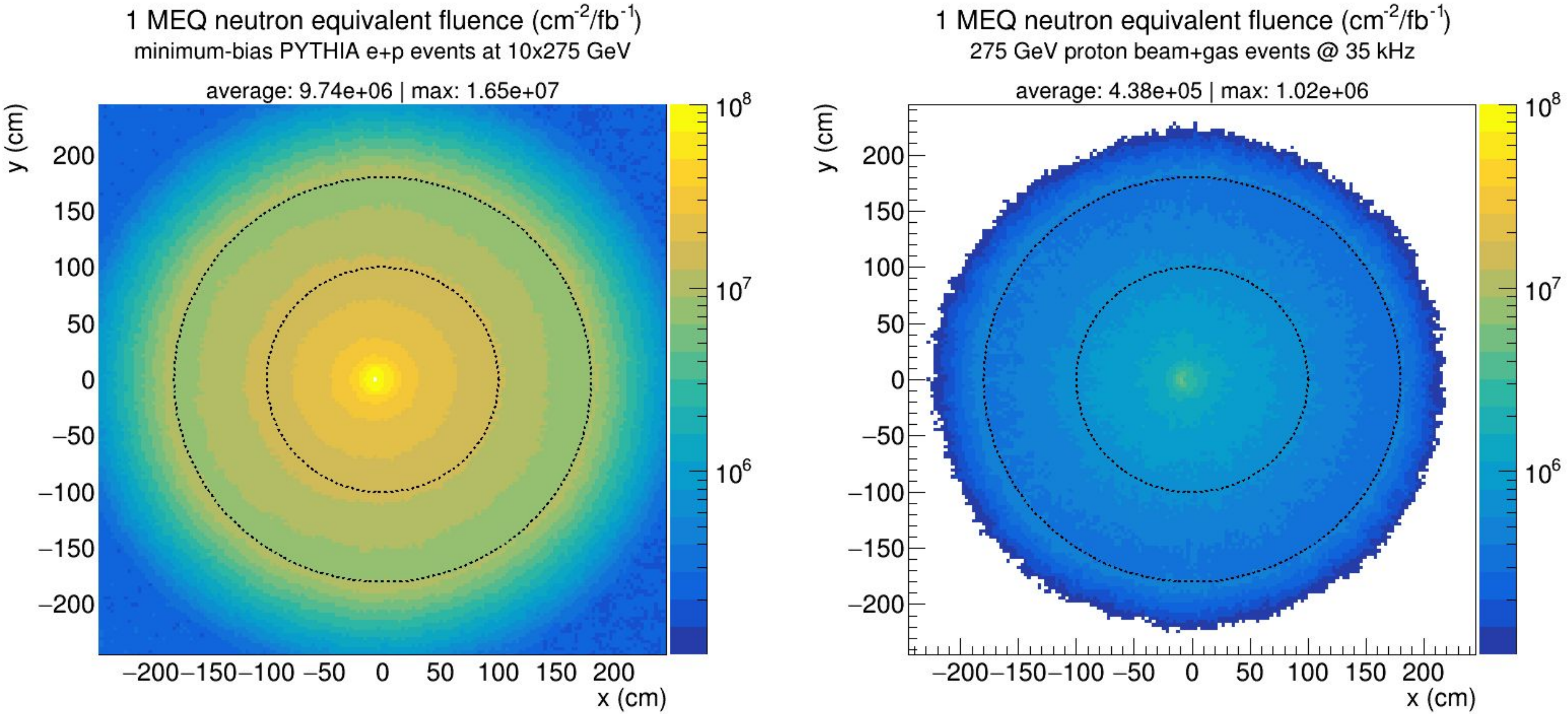
10^9 1-MeV n_{eq}/cm^2 *most of the key physics topics*

10^{10} 1-MeV n_{eq}/cm^2 *should cover most demanding measurements*

10^{11} 1-MeV n_{eq}/cm^2 *might never be reached*

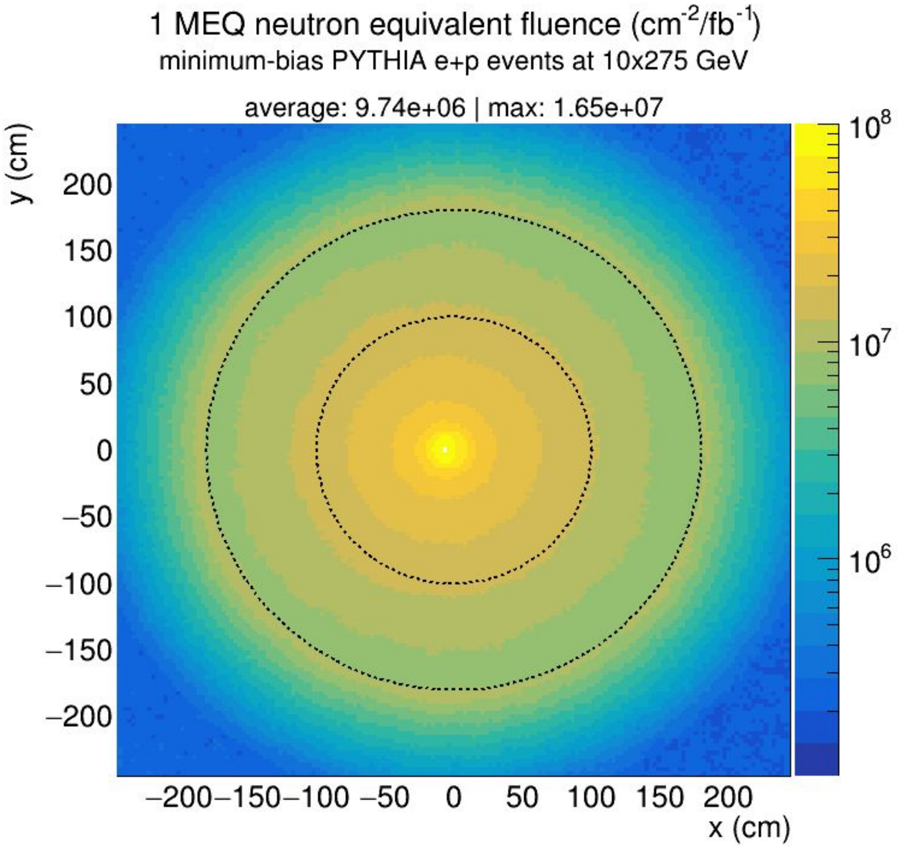
updated radiation simulations

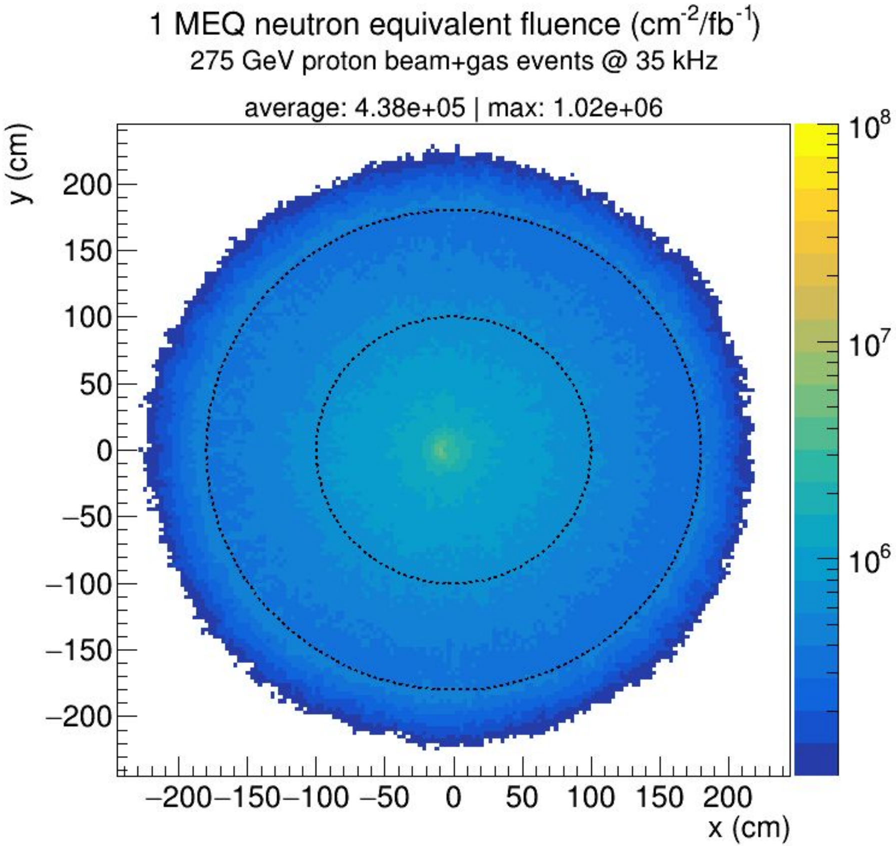
New radiation damage estimates



xy projections in 210 < z < 260 cm region, average and max values reported for 100 < R < 180 cm region

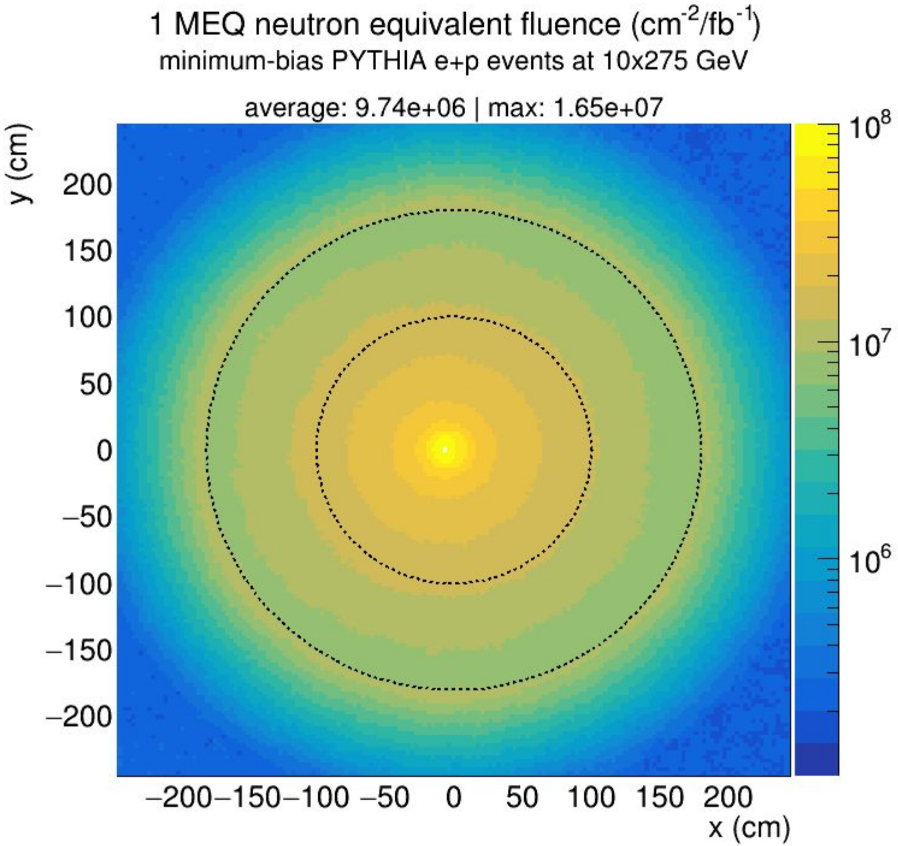
New radiation damage estimates

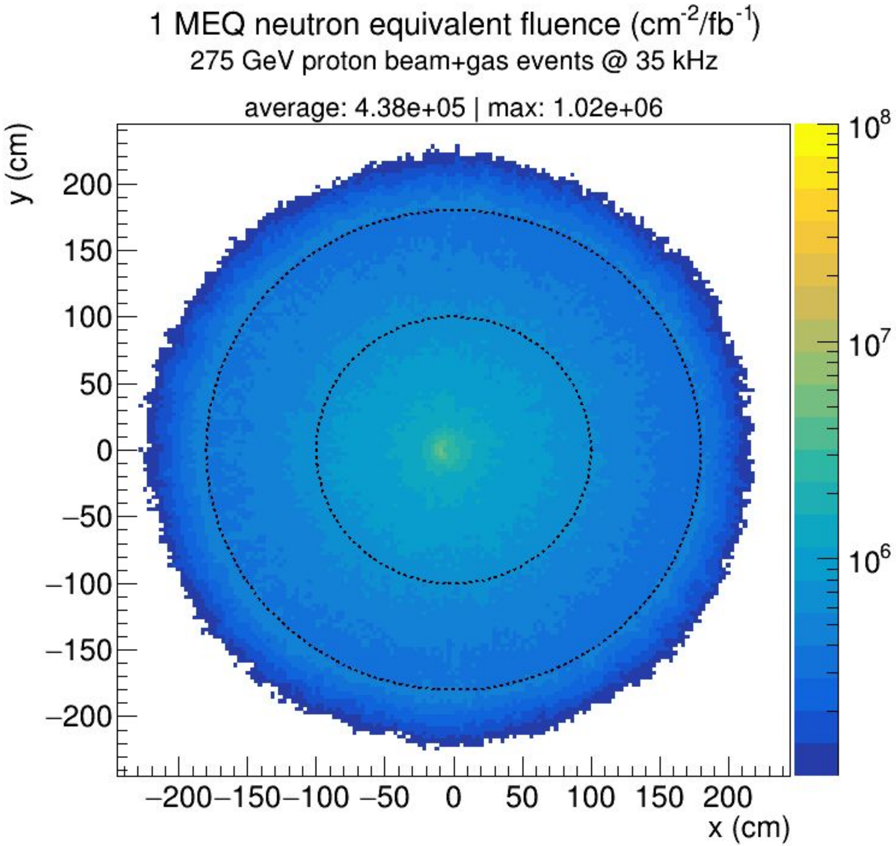




before: max fluence = 9.2 10^5 neq/fb^{-1} | now: max fluence = 1.75 10^7 neq/fb^{-1} ⇒ new estimates are ~20x larger

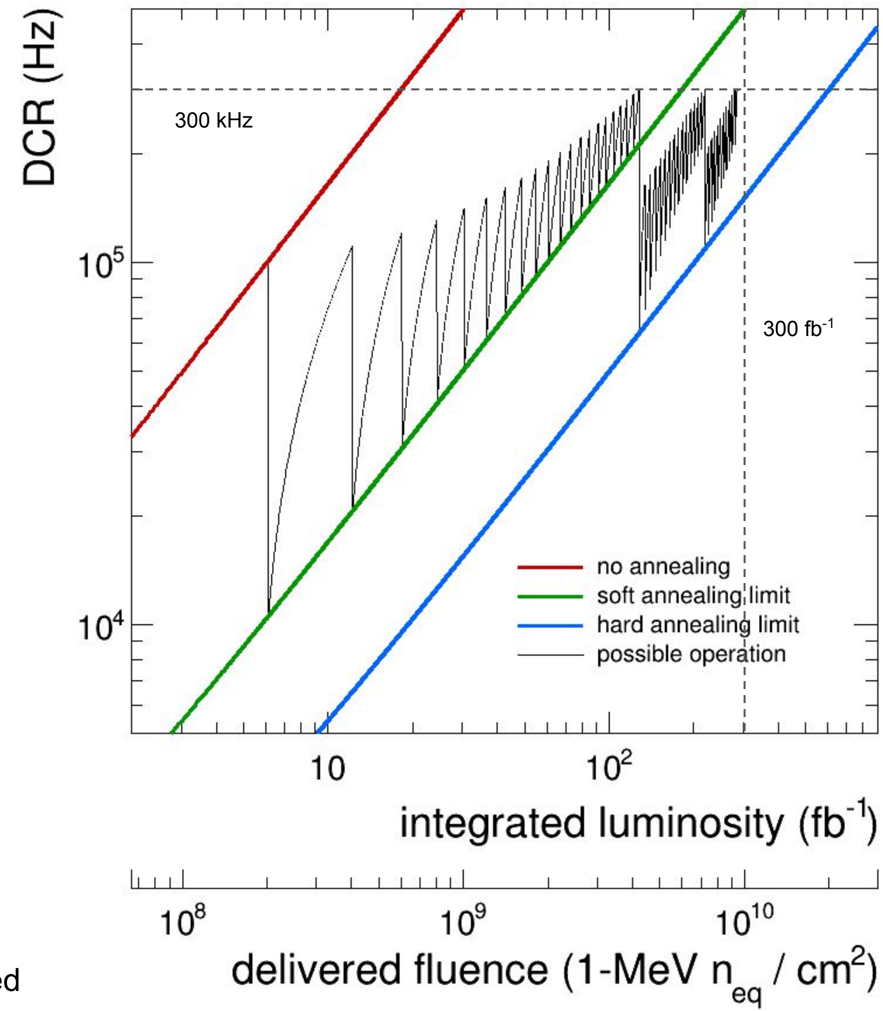
New radiation damage estimates





new estimates are ~20x larger, but we had a 10x safety factor ⇒ we got the safety factor eaten and a 2x faster ageing

Updated ageing model



model input from R&D measurements (up to 2022)

- DCR increase: 500 kHz/10^9 n_{eq}
- residual DCR (online annealing): 50 kHz/10^9 n_{eq}
- residual DCR (oven annealing): 15 kHz/10^9 n_{eq}

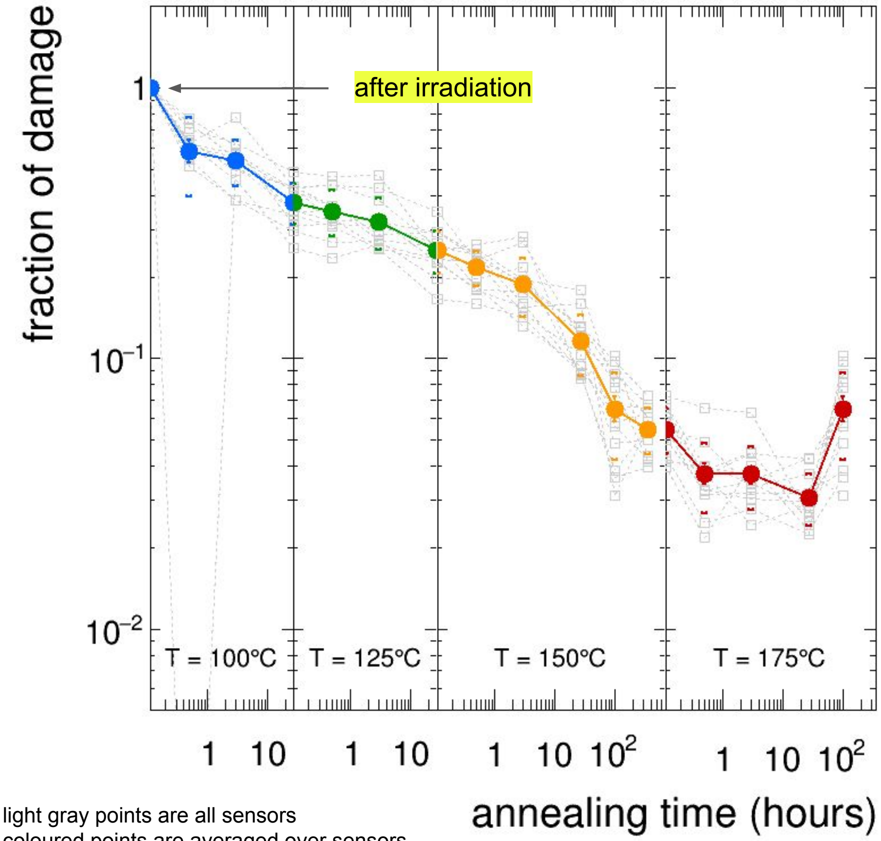
1-MeV neq fluence from background group

- 1.75 10^7 n_{eq} / fb^{-1}
- includes 2x safety factor

all parameters are the same used for the previous model
only neq/fb^{-1} is updated to new estimate, with 2x safety factor
which corresponds to a 4x faster ageing than previously reported

Detailed studies of SiPM online self-annealing

online self-annealing with reverse bias



light gray points are all sensors
coloured points are averaged over sensors
coloured brackets is the RMS

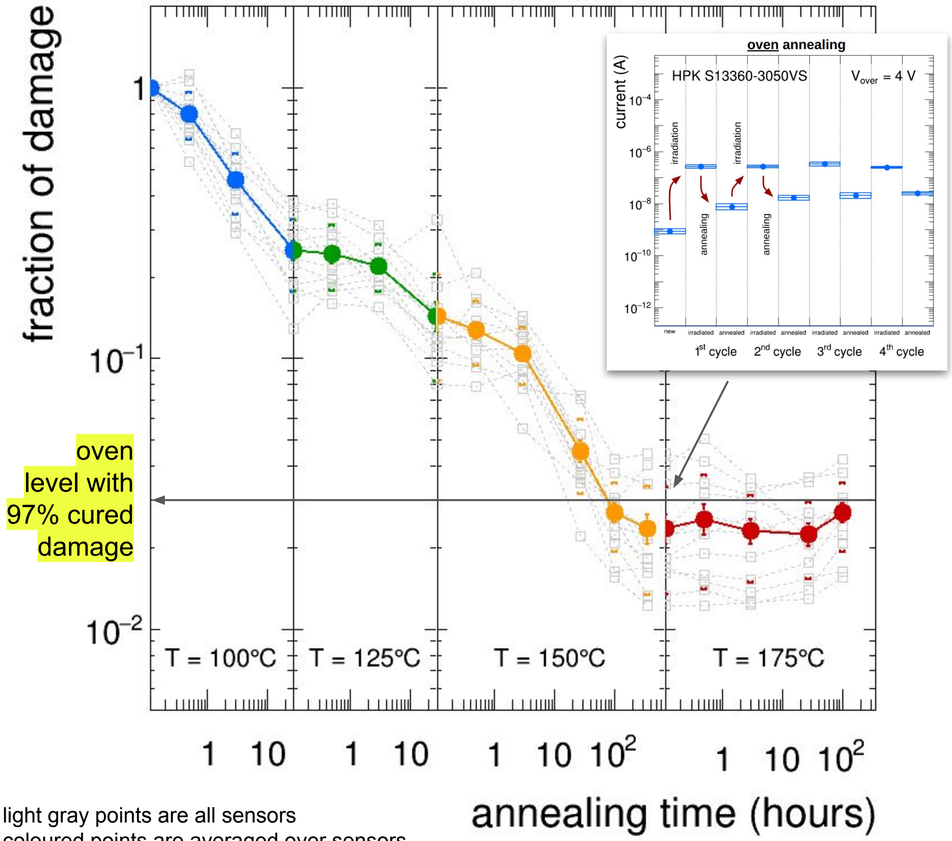
test on a large number of proton irradiated sensors how much damage is cured as a function of temperature and time

in this study, the same sensors have undergone self-annealing in increasing temperature steps and increasing integrated time steps

- started with T = 100 C annealing
  - performed 4 steps up to 30 hours integrated
- followed by T = 125, 150 and 175 C

Detailed studies of SiPM online self-annealing

online self-annealing with forward bias



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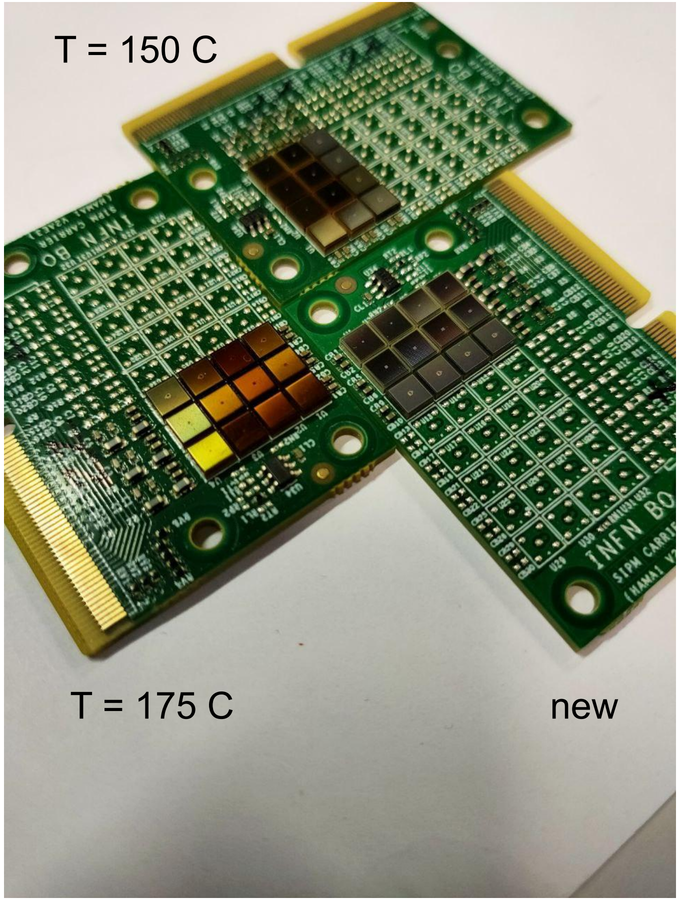
fraction of residual damage seems to saturate at 2-3%
after ~ 300 hours at T = 150 C

continuing at higher T = 175 C seems not to cure more than that

Detailed studies of SiPM online self-annealing



but, after many hours of online annealing

we noticed alterations on the SiPM windows
in particular in one board that underwent

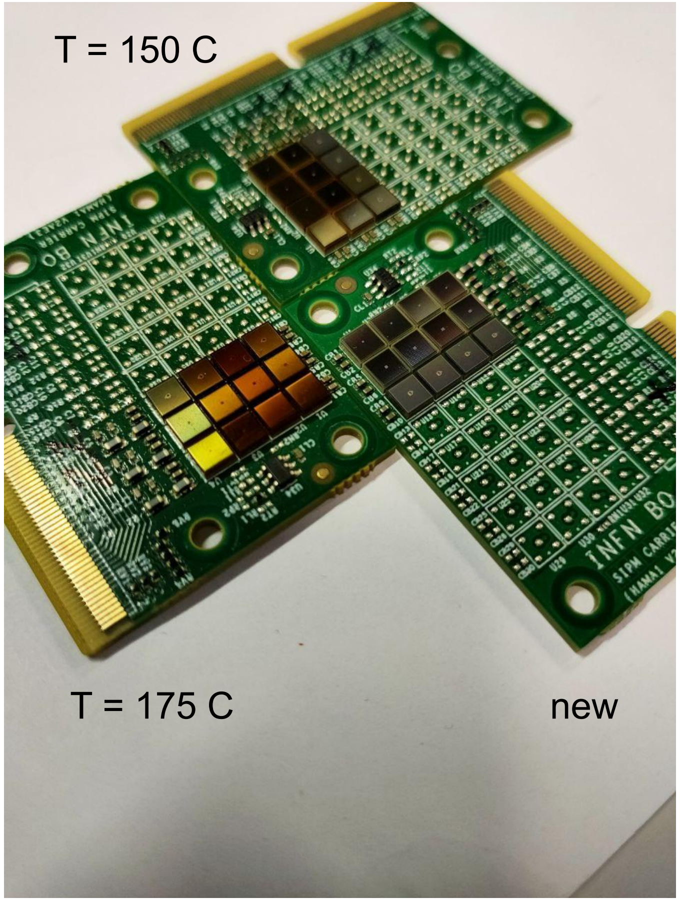
500 hours of online annealing at T = 175 C

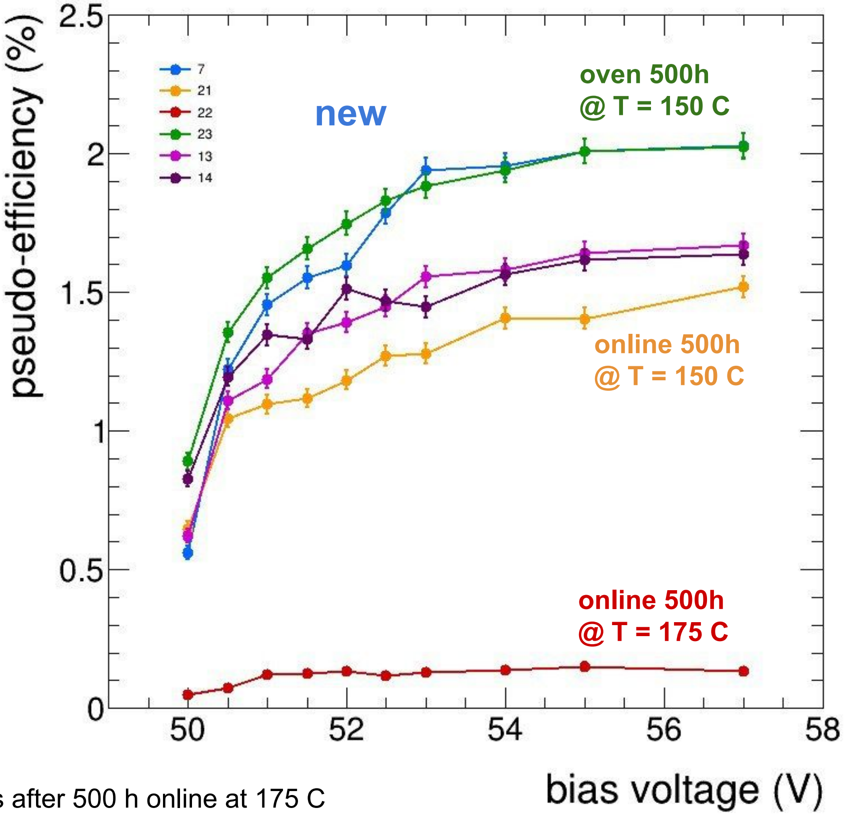
the sensors appear "yellowish" when compared to new

less "yellowish" but still a bit "yellowish" the sensors
in a board that underwent 500 hours at T = 150 C

let's compare them under the laser light

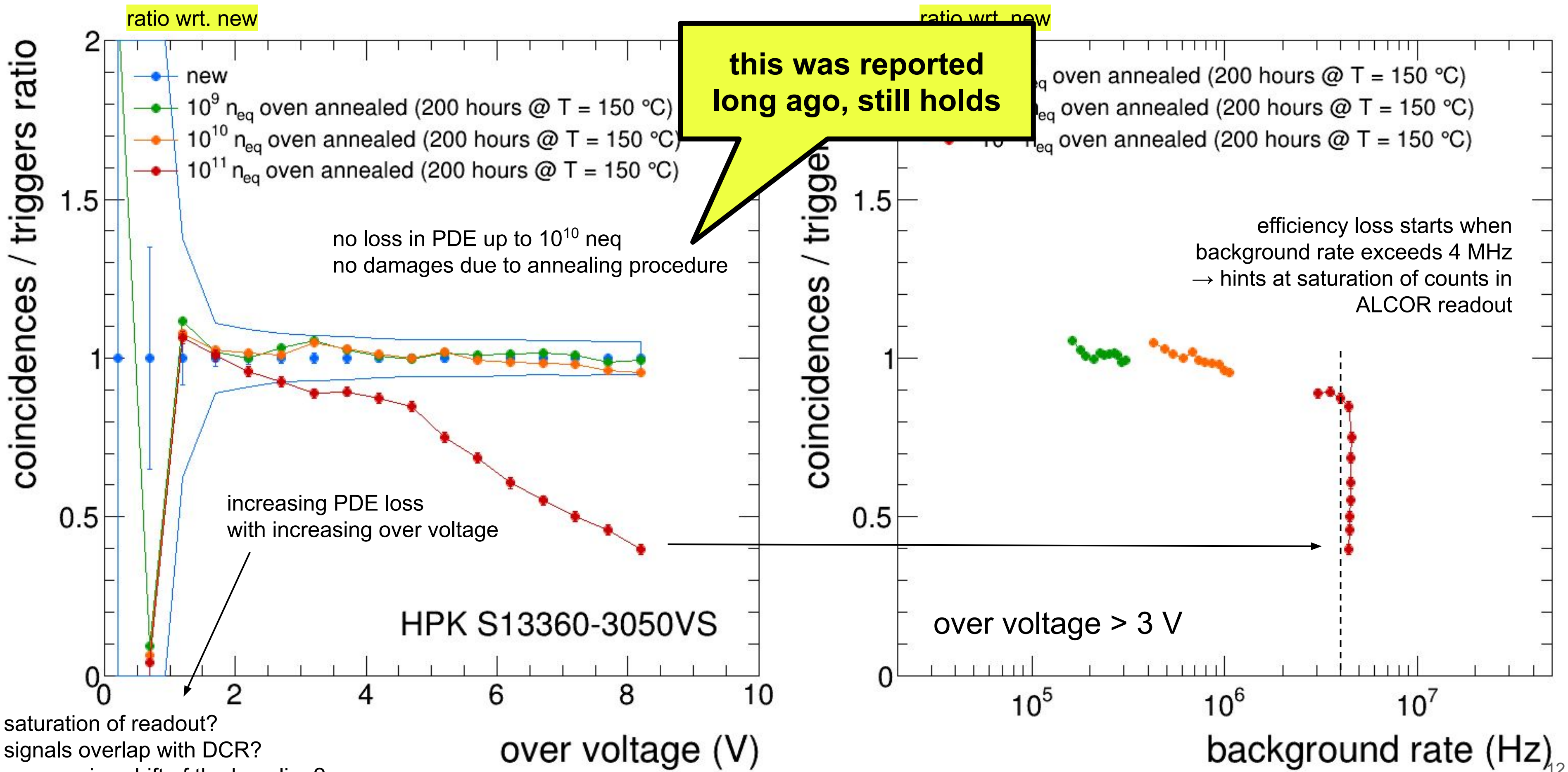
Detailed studies of SiPM online self-annealing





serious efficiency loss after 500 h online at 175 C
25% efficiency loss after 500 h online at 150 C
no efficiency loss after 500 h oven at 150 C
not clear why oven annealing is less critical on window, but in line with previously-reported "no damages due to annealing procedure" for 200 h in oven at T = 150 C

Light response after irradiation and annealing



saturation of readout?
signals overlap with DCR?
progressive shift of the baseline?

window damage studies

Detailed studies of SiPM window damage

measurements are ongoing
4 SiPM under study
each undergoing online annealing

- at forward bias
- at different temperature
- following the same annealing protocol
- same integrated annealing time and cycles

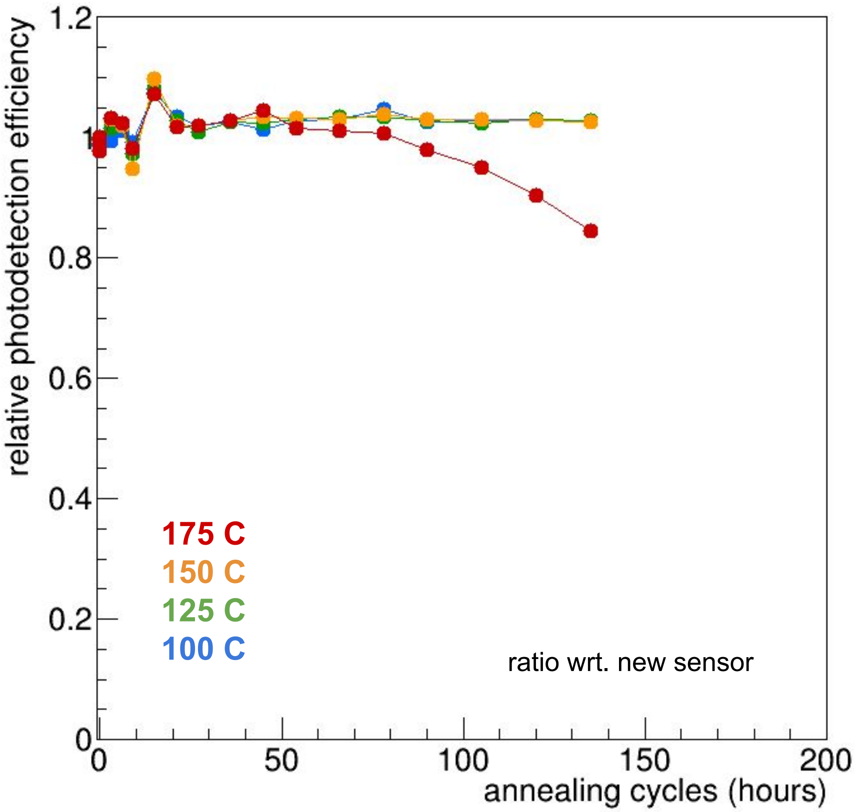
measurements are performed with the upgraded laser setup

the plot reports the variation of the PDE wrt. the sensors measured before the beginning of the annealing cycles (new)

measurements are still ongoing
so far, after ~135 hours (135 1-hour cycles)

observation of beginning of efficiency loss at 175 C
lower temperatures are unaffected

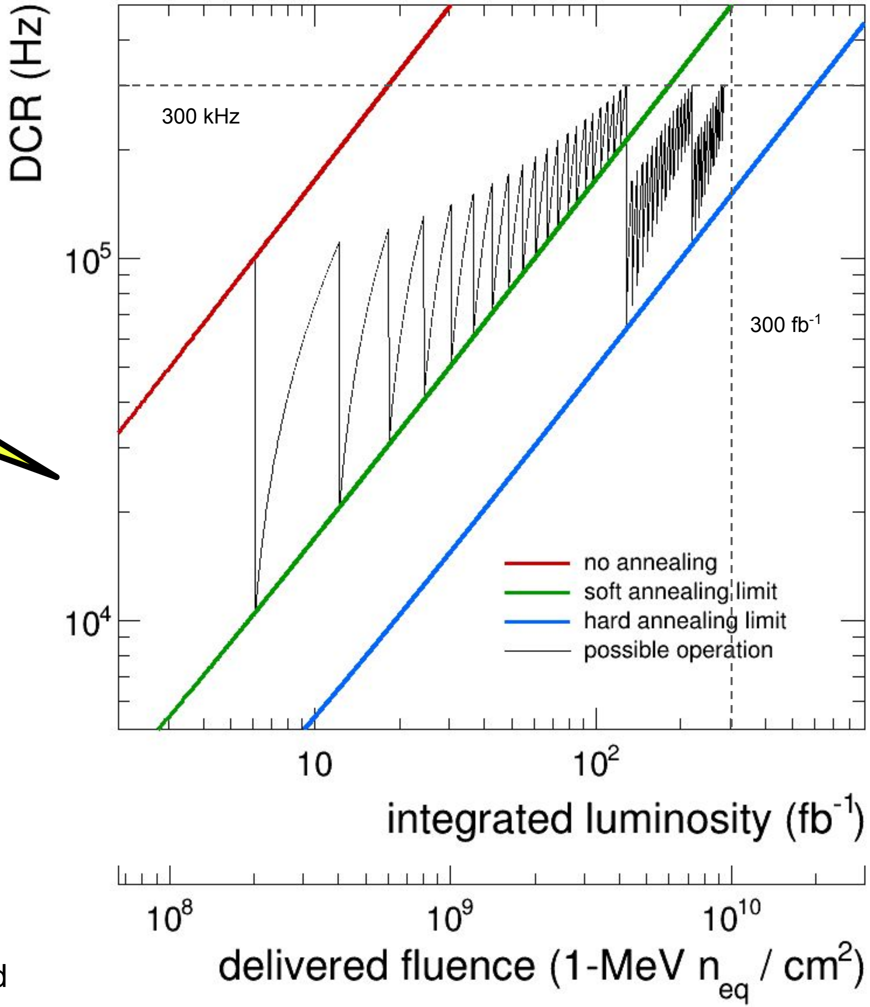
we will continue this study
this is already good news



Updated ageing model

Hamamatsu S13360-3050 @ Vover = 4 V, T = -30 C

the "possible operation" scenario shown here has 44 soft-annealing cycles and 3 hard-annealing cycles



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1-MeV neq fluence from background group (conservative)

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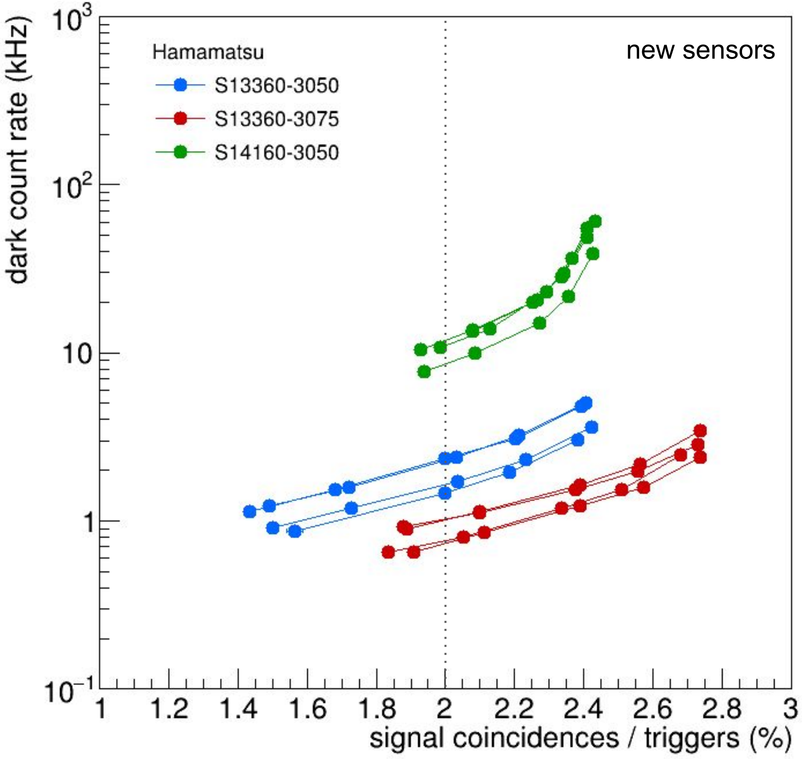
studies with laser

Comparison between sensors

3 Hamamatsu sensor types, 4 sensors each measured as NEW



proxy for photodetection efficiency

at the same level of detection efficiency

namely, the probability to detect light from laser pulse

different sensors have different DCR level

<u>best</u>: S13360-3075

most promising sensors, large pitch SPADs (75 μm)

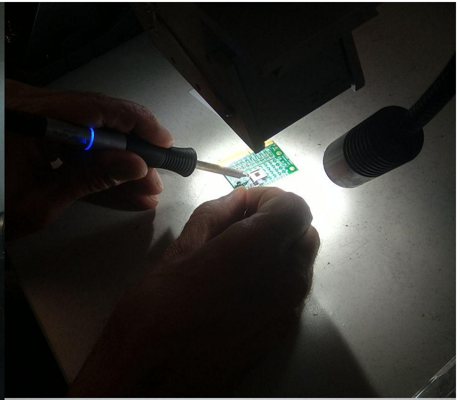
<u>second</u>: S13360-3050

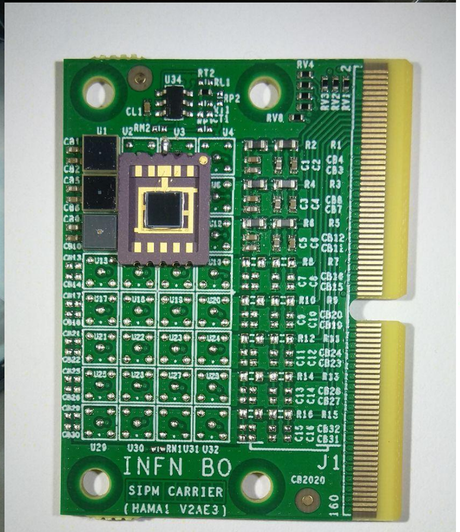
same technology, medium pitch SPADs (50 μm)

<u>worst</u>: S14160-3050

different technology, medium pitch SPADs (50 μm)

New Hamamatsu SiPM prototypes





S13360-3050UVE

newly-developed Hamamatsu SiPM sensors

based on S13360 series

few samples of 50 μm and 75 μm SPAD sensors

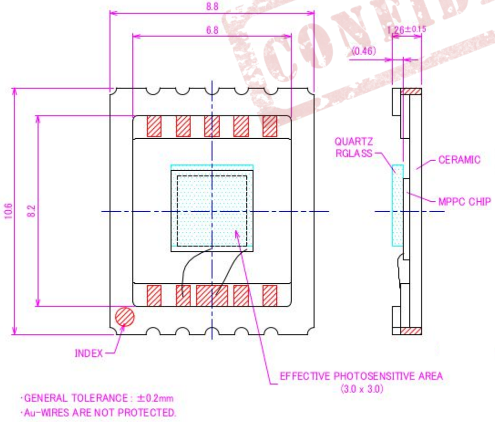
on paper they look VERY promising

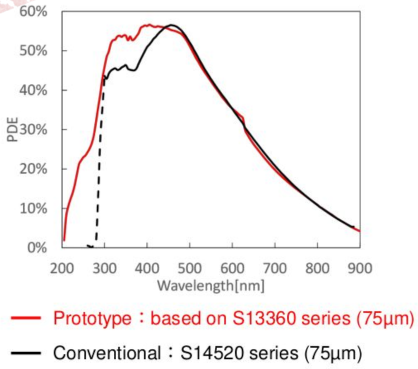
- improved NUV sensitivity
- improved signal shape
- improved recharge time

mounted on EIC SiPM test boards

we will characterise and test them in full

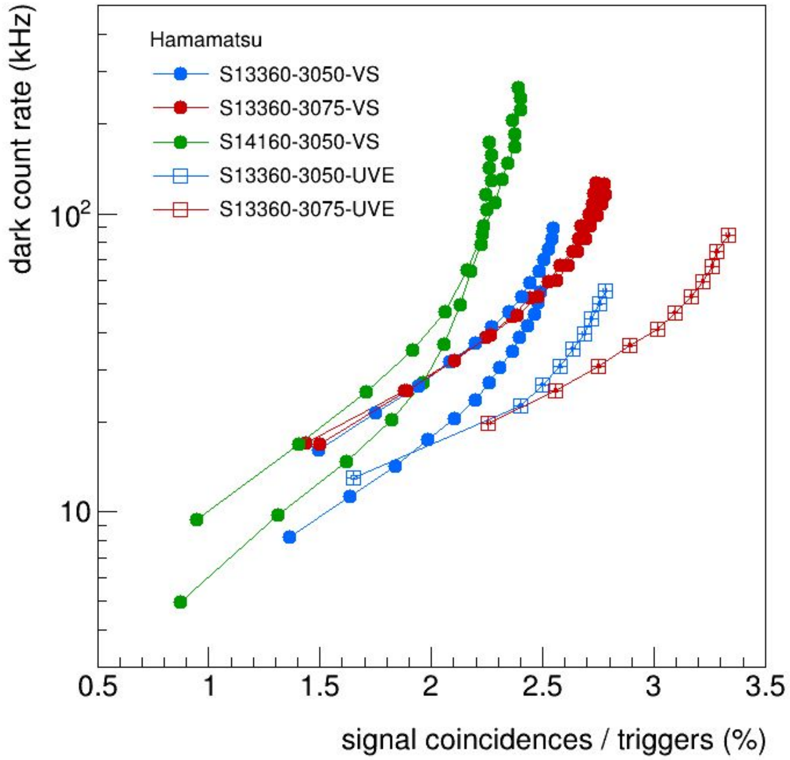
irradiation, annealing, laser, …

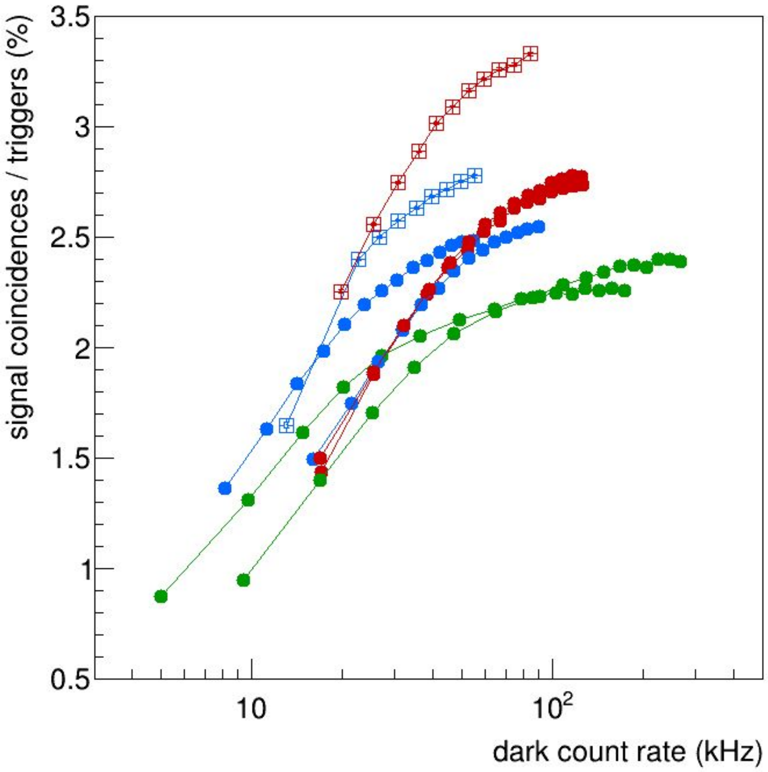




prototype Hamamatsu sensors (10^9 neq after oven annealing)

PRELIMINARY





prototype Hamamatsu UVE sensors have significantly higher efficiency than standard sensors
caveat: we only measure PDE at the fixed laser wavelength of ~400 nm, larger PDE expected because…
prototype sensors have a NUV-enhanced behaviour.
we will study them further, currently asking Hamamatsu status for production and quotation of this product

Summary

- **updated radiation simulations**
  - new radiation damage estimates at dRICH SiPM location
  - a factor 20x larger than what reported last year
  - dRICH used a 10x safety factor, the updated did no hurt too much
    - still this is not a good news, detector will age faster than expected so far
- **detailed studies of online "in-situ" annealing**
  - forward-bias annealing is better that reverse-bias (although current is higher)
  - long forward-bias annealing can reach oven-annealing level of recovery
    - this is a pretty a good news
  - but we observed degradation of efficiency / optical properties (likely the protective resin)
    - this sounds like a bad news, but
    - promising studies ongoing, T = 150 C annealing is effective and not destructive
- **Hamamatsu prototype SiPM sensors**
  - NUV and signal enhanced, very promising on paper
  - laser studies show that they are indeed promising
    - we will study more, queried Hamamatsu for production / costs
    - this is a good news