PXD TID measurement

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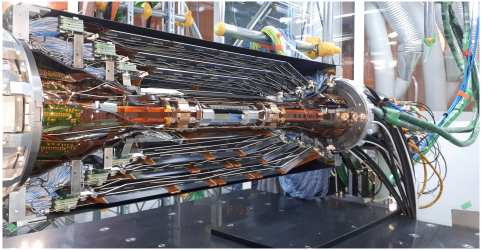
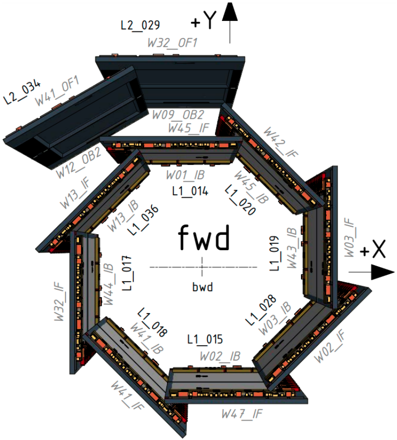
Overview

- Design inst. luminosity at $8 \times 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Expect ionizing dose rate of about $20\,\mathrm{kGy\,yr}^{-1}$ at design lumi
- Currently running well below design lumi and dose rate





Overview

Goals:

- Estimate the PXD total ionizing dose (TID) as time series per module
- Find method that applies since the start of Phase 3 to today and beyond
- Using 1 Hz EPICs online PVs and create a robust and lightweight approach

Method:

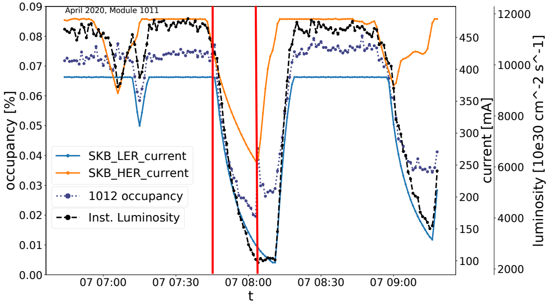
- Exploit beam decays to obtain constant noise floor and correct occupancy time series
- Apply fit to the corrected occupancy that is dependent on accelerator PVs (currents)
- Get model for noise corrected occupancy
- Propagate model by interpolating coefficients
- Outlier correction using geometric relations, defined by offline analysis template
- The modeled PXD occupancy is then converted to a dose rate and summed

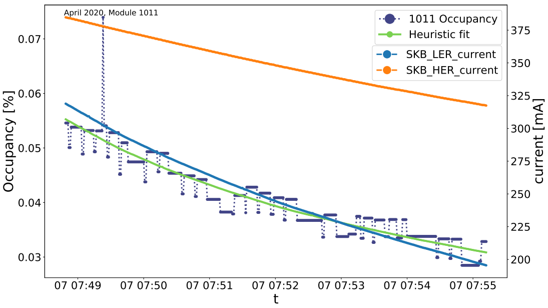
Challenges:

- The major challenge is to correct for noise hits contributing to the PXD occupancy online PV

Noise floor correction

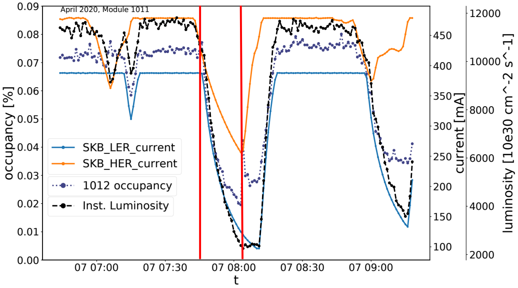
- PXD occupancy PV contains a floor from noisy pixels firing in triggered events
- The noise floor is assumed constant during a physics run but can change from run to run
- The noise floor is usually observed to be non-negligible ($> 10\,\%$ of occupancy)
- Fit heuristic function to 1Hz occupancy during a beam decay with a constant term for noise
- Subtract the determined noise floor from the occupancy of the physics run

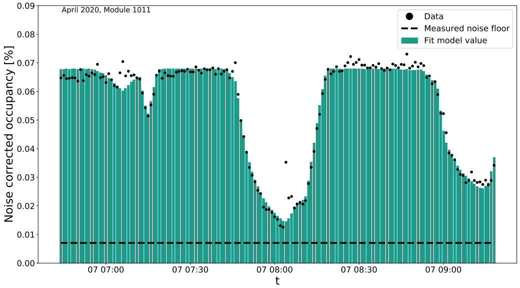




Fit model

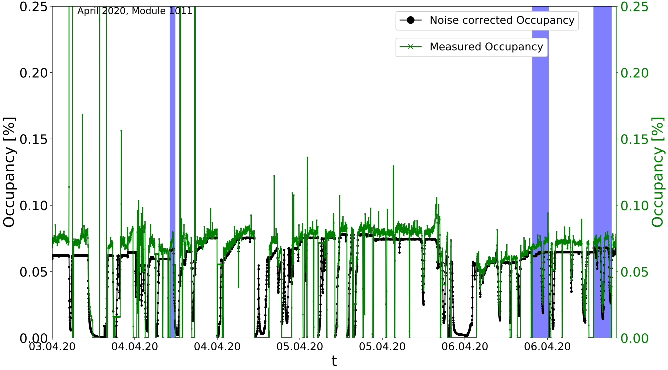
- The fit parameters describe the expected background (mostly) in dependence of the currents
- Should the beam conditions change drastically (25.Nov 2021) the model loses its validity





Modeled Occupancy

- The modeled occupancy is noise corrected, robust and available over entire time frame
- The impact of previously determined noise floor can be directly observed
- Iteratively increase the time frame that is fitted to improve statistic in fit



Estimate of dose rate from occupancy

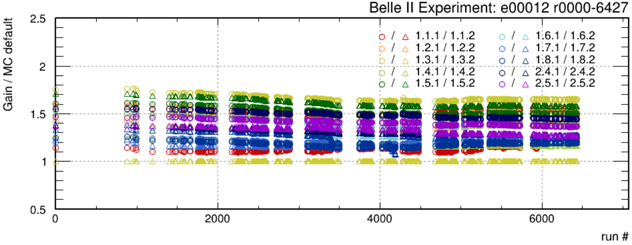
- Estimate the PXD module dose rate $\dot{R}_i$

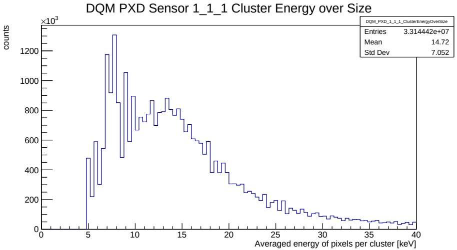
$$\dot{R}_i = \frac{f_{\text{dhh\_clock}}}{N_{\text{trg\_len}}} \cdot \frac{\overbrace{(O_i - O_{\text{noise},i})}^{\text{fit model prediction}}}{100} \cdot k \cdot \langle \frac{E}{A} \rangle_i \cdot \frac{1}{V_{\text{pixel}} \rho_{\text{Si}}}$$

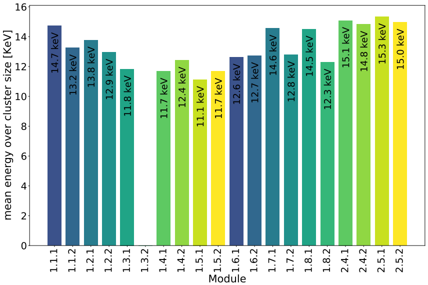
$\dot{R}_i$		module dose rate
i	Layer, ladder, sensor	module name
$f_{\text{dhh\_clock}}$	$76\,230\,000\,\text{Hz}$	DHH clock
$N_{\text{trg\_len}}$	PXD_HXXXX_trg_len_VALUE_set/default $= 1768$	Trigger length
O_i	PXD_O_HXXXX_AVG_OCC_cur	Occupancy of module
$O_{\text{noise},i}$	default $= 0$	Noise floor of module
k	$1/6.242 \times 10^{18}\,\text{eV J}^{-1}$	conversion eV to J
E	run and module specific	Energy dep. in cluster
A	run and module specific	Size of cluster
V_{pixel}	$\text{default}_{\text{inner}} = 219 \times 10^3\,\mu\text{m}^3$ $\text{default}_{\text{outer}} = 300 \times 10^3\,\mu\text{m}^3$	Mean volume of pixel
ρ_{Si}	$2.34 \times 10^{-3}\,\text{kg/cm}^3$	Density of silicon

Energy calibration $\langle \frac{E}{A} \rangle$

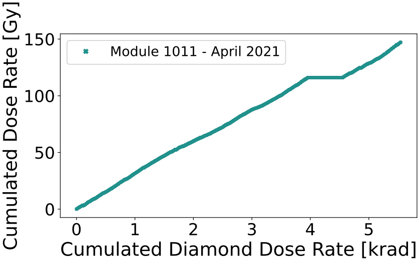
- $\langle \frac{E}{A} \rangle$ is the mean energy deposition per firing pixel
- The calibration is from Qingyuan's offline analysis
- Energy calibration ~ stable over time
- Example values for exp. 12 run 5934



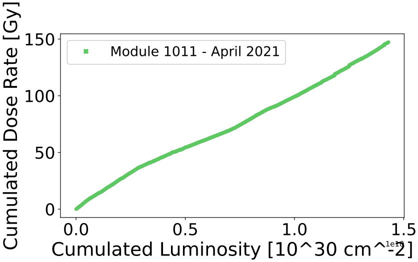




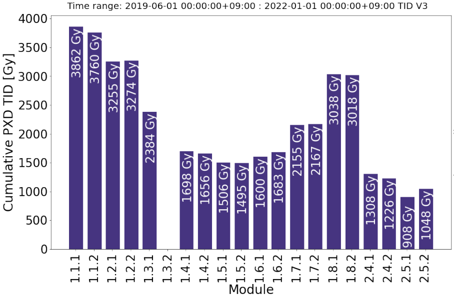
Result



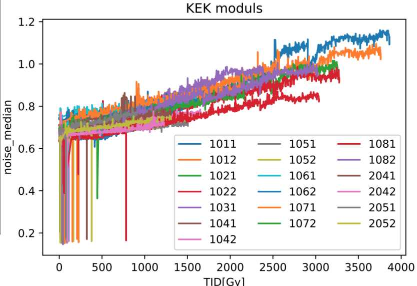
Module 1011 - April 2021
Cumulated Dose Rate [Gy]
Cumulated Diamond Dose Rate [krad]



Module 1011 - April 2021
Cumulated Dose Rate [Gy]
Cumulated Luminosity [10^30 cm^-2]
1e10



Time range: 2019-06-01 00:00:00+09:00 : 2022-01-01 00:00:00+09:00 TID V3
Cumulative PXD TID [Gy]
3862 Gy
3760 Gy
3255 Gy
3274 Gy
2384 Gy
1698 Gy
1656 Gy
1506 Gy
1495 Gy
1600 Gy
1683 Gy
2155 Gy
2167 Gy
3038 Gy
3018 Gy
1308 Gy
1226 Gy
908 Gy
1048 Gy
Module



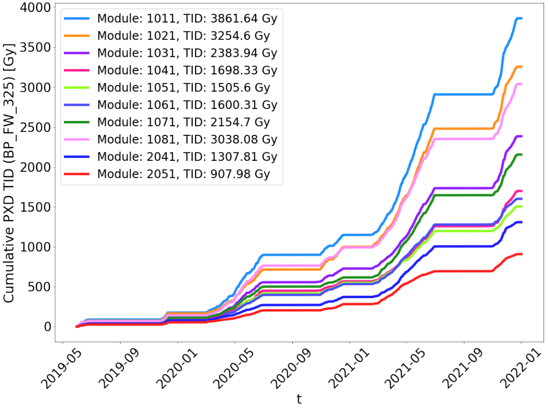
KEK moduls
noise_median
TID[Gy]
1011
1012
1021
1022
1031
1041
1042
1051
1052
1061
1062
1071
1072
1081
1082
2041
2042
2051
2052

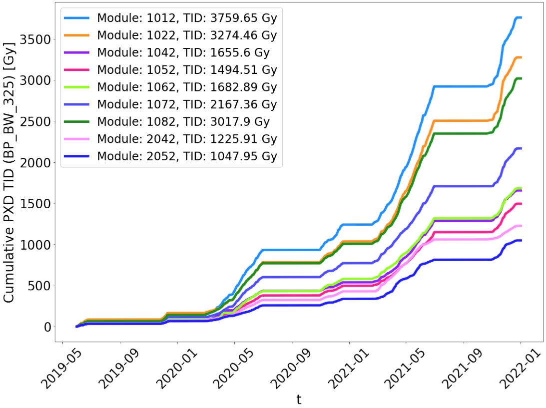
Summary

- Implemented method for PXD TID estimation using online PXD and Diamond PVs from EPICs
- Noise floor correction: focus on physics runs with beam decays in both rings and fit the noise floor for explicit correction
- Main focus was on the fit model to estimate a noise corrected PXD occupancy using heuristic scaling laws
- A most robust, reliable and fast measurement upon an unreliable data set that suffers from artifacts, archiver compression and missing calibration in an ever-changing environment
- Error of dose rate depends mostly on ecal $\sim 15\,\%$, then occupancy $< 5\,\%$
- The TID data set is uploaded here `https://drive.google.com/drive/folders/1X1ye5A1JU3T0KACwVgE94pac6teuEIha?usp=sharing`

Backup Result

- Evolution of TID for all modules over the frame of phase 3





Backup Heuristic Fit

- $O = B_H \cdot F_{B,H} + B_L \cdot F_{B,L} + D$, D identifies as noise, no injection (see backup)
- $O_{\text{corr}} = B_H \cdot F_{B,H} + B_L \cdot F_{B,L} + Inj$, already noise corrected (see backup)
- Heuristic background features, T_H, T_L, B_H, B_L, C_L and D are fit parameters
- Injection background is described by fit parameter times beam gate status

$$\underbrace{O}_{\text{Rate}} = \underbrace{T_H(x_1) \cdot F_{T,H} + B_H(x_2) \cdot F_{B,H}}_{\text{HER storage}} + \underbrace{T_L(x_3) \cdot F_{T,L} + B_L(x_4) \cdot F_{B,L}}_{\text{LER storage}} + \underbrace{C_L \cdot L}_{\text{Lumi}} + D + \underbrace{INJ_H(x_5) + INJ_L(x_6)}_{\text{Injections}}$$

$$F_{B,H} = 3 \cdot P_{1,H} \cdot I_H^2 + P_{0,H} \cdot I_H$$

HER beam-gas feature (physical scaling)

$$F_{T,H} = \frac{I_H^2}{\sigma_{X,H} \cdot \sigma_{Y,H} \cdot (\sigma_{Z,0,H} + \sigma_{Z,1,H} \cdot I_H/n_{b,H}) \cdot n_{b,H}}$$

HER Touschek feature

$$F_{B,L} = 3 \cdot P_{1,L} \cdot I_L^2 + P_{0,L} \cdot I_L$$

LER beam-gas feature

$$F_{T,L} = \frac{I_L^2}{\sigma_{X,L} \cdot \sigma_{Y,L} \cdot (\sigma_{Z,0,L} + \sigma_{Z,1,L} \cdot I_L/n_{b,L}) \cdot n_{b,L}}$$

LER Touschek feature