PXD Background Study

Lu Cao

FSP workshop: slow pion tracking
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Background Sources

Overview

Touschek Scattering

particles within a bunch

$$\propto \frac{I^2}{\sigma_y n_b E_{beam}^3}$$

Beam-gas Scattering

elastic Coulomb scattering & Brems.

$$\propto P \times I$$

Synchrotron Radiation

$$\propto E_{particle}^2 B^2$$

Noise of Detector

Injection Background

Luminosity-dependent Bkg

Two-photon process

$$e^+e^- \to e^+e^-\gamma\gamma \to e^+e^-e^+e^-$$

Radiative Bhabha process

$$e^+e^- \to e^+e^-\gamma$$

PXD Limits

Overview

- $O_{PXD} < 3\%$
  - Occupancy: number of fired pixels per readout frame divided by the total number of pixels
  - To limit tracking performance degradation
  - Significant data loss because of bandwidth limitations
- **Dose rate < 2 Mrad/smy^2**
  - Dose: energy deposited by ionizing radiation per unit mass
  - Radiation damage
- **Non-ionizing energy loss (NIEL) fluence < 1 x 10^{14} /cm^{2}smy**
- **Instantaneous spike rates**
  - e.g. occupancy (data loss, can effect also later triggered events)

Dominant background at design luminosity

- Irreducible two-photon process, where the created pairs of low momentum electrons and positrons spiral through the detector

Other vulnerabilities

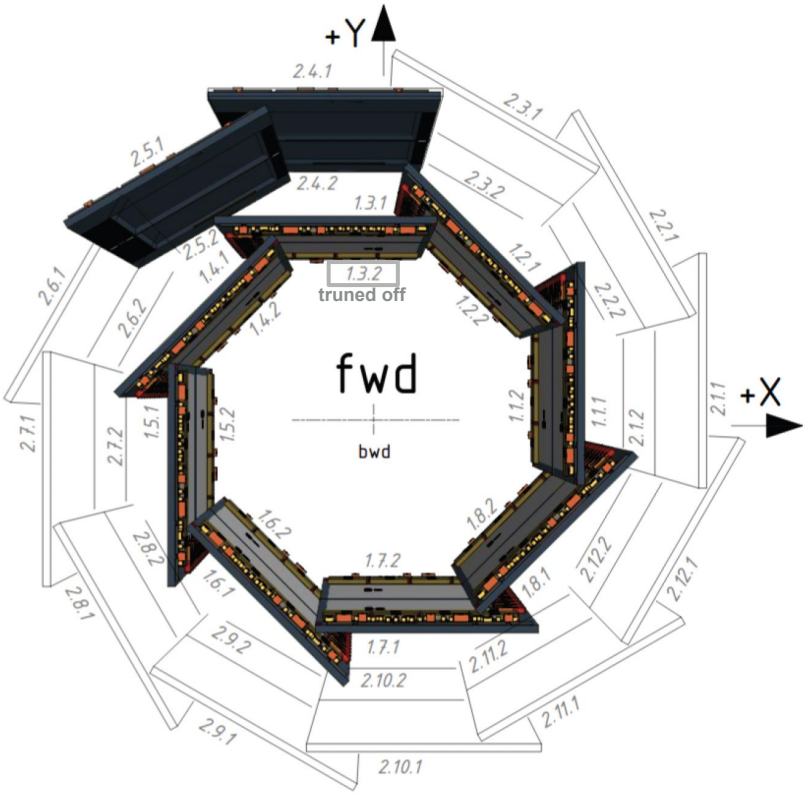
- Unexpected beam losses (damage the detector by creating dead switcher channels or inefficient regions but they could deposit significant dose shortening the detector's lifetime)
- Back-scatter of low-energy synchrotron radiation photons

** smy: snowmass year

Last Run (16-06-2021) Analysis

Dataset and analysis setup

Exp 18 Run 16-06-2021		#bunch	Current [mA]		Comments
LER	2349	393	250		Beam decay
	2350	1174	800		Beam decay
	2351	1174	400		Beam decay
HER	2353	393	250		Beam decay
	2355	1174	680		Beam decay
	2356	1174	400		Beam decay
Both	2358	1174	LER 740	HER 650	V-offset scan Lumi = [2.6, 2.1,1.0]×10^{34} $cm^{-2}s^{-1}$
	2359	1174	740	680	Beam decay
	2360	1174	740	680	Beam decay



Offline analysis:

- Release 5-02-06
- PXD beam background hit rates produced with Poisson random trigger (trigTypes=13)
- GT: data_reprocessing_prompt @ 08-10-2021 for hot & dead pixels masking and energy calibration

Single-Beam Analysis: LER

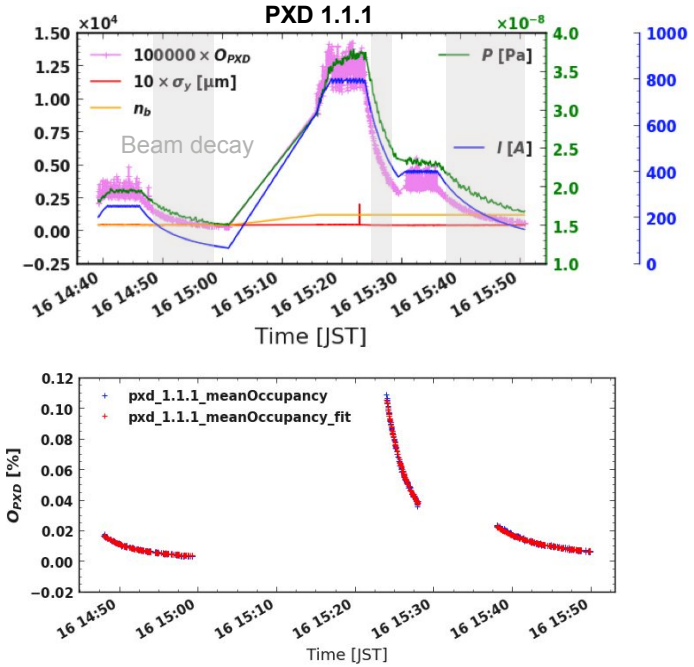
Background source decomposition in beam decay

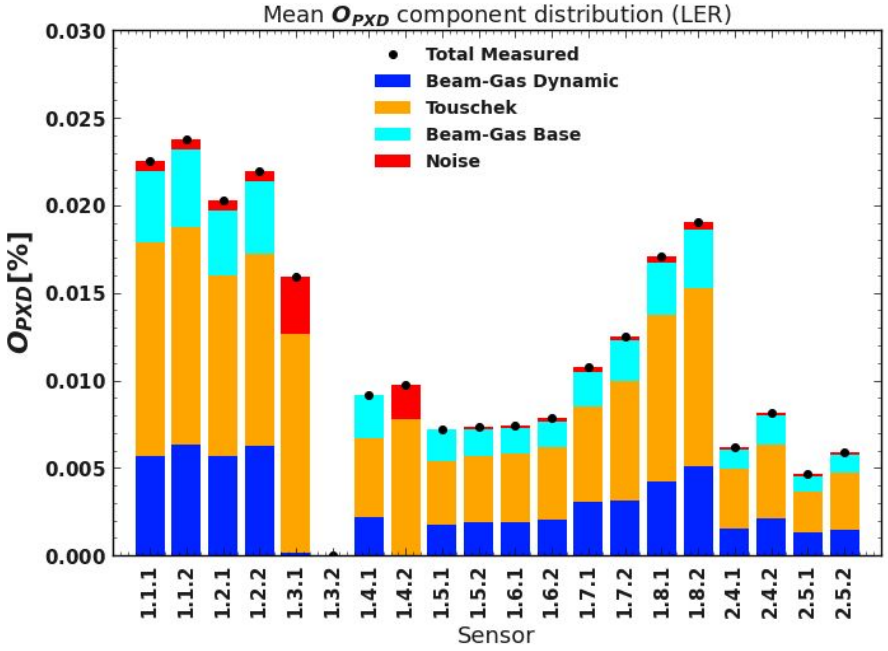
Single-beam background in LER:

- **Beam-gas scatting (base & dynamic)**
- **Touschek scattering**
- **Noise**

$$\mathcal{O}_{PXD}^{LER} = B_0 I + B_1 I^2 + \frac{T I^2}{\sigma_y n_b} + N$$

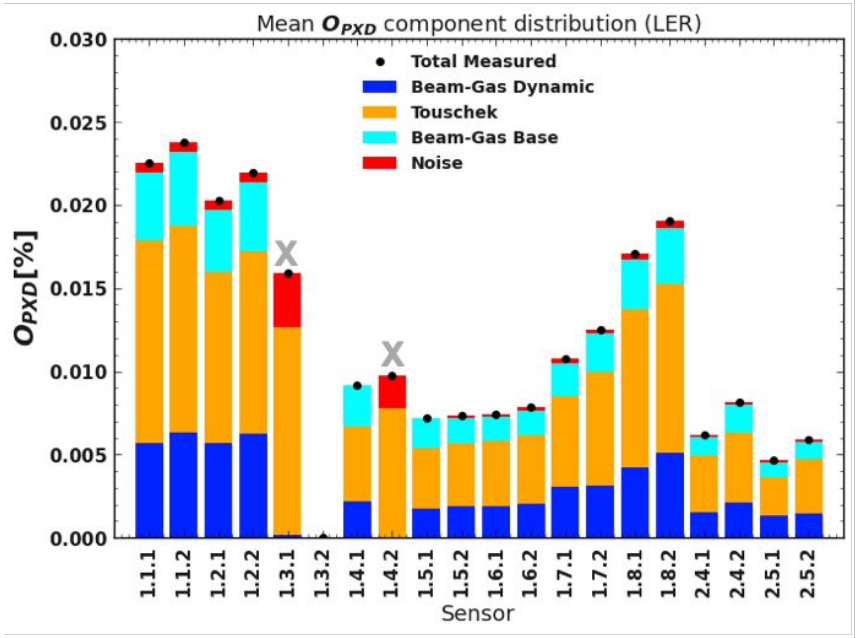
Apply fit on occupancy to extract the sensitivites of each source.

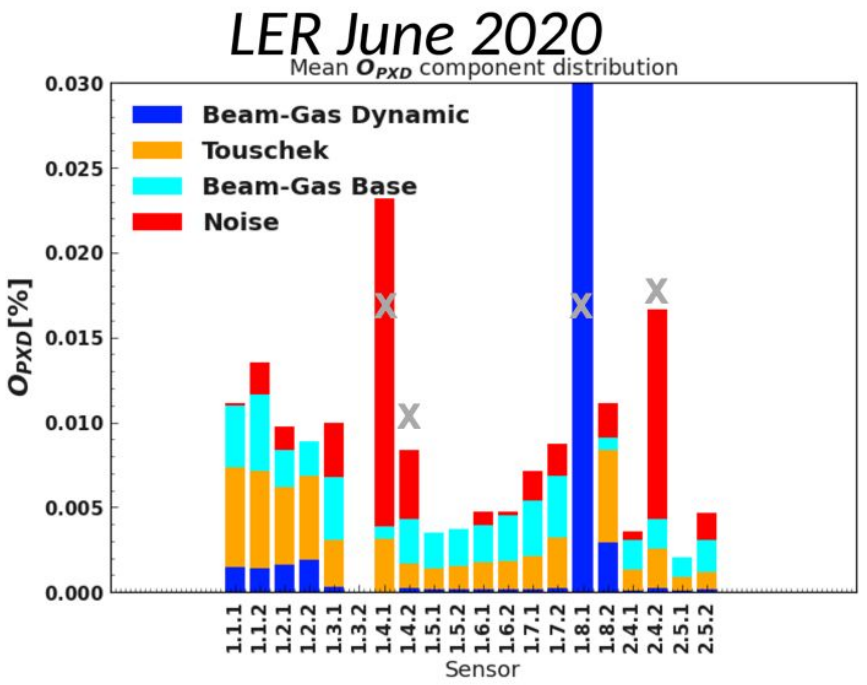




Single-Beam Analysis: LER

Comparison with 2020 June run





	June 2020		June 2021		Ratio (2021/2020)	
	L1	L2	L1	L2	L1	L2
B0 (*10^{-8})	13.2	7.7	10.1	4.4	**0.78**	**0.57**
B1 (*10^{-10})	1.9	0.3	3.5	1.5	**1.79**	**5.61**
T (*10^{-5})	2.7	0.8	2.9	1.3	**1.04**	**1.54**

X: noisy sensors are excluded in average for comparing

Single-Beam Analysis: HER

Background source decomposition in beam decay

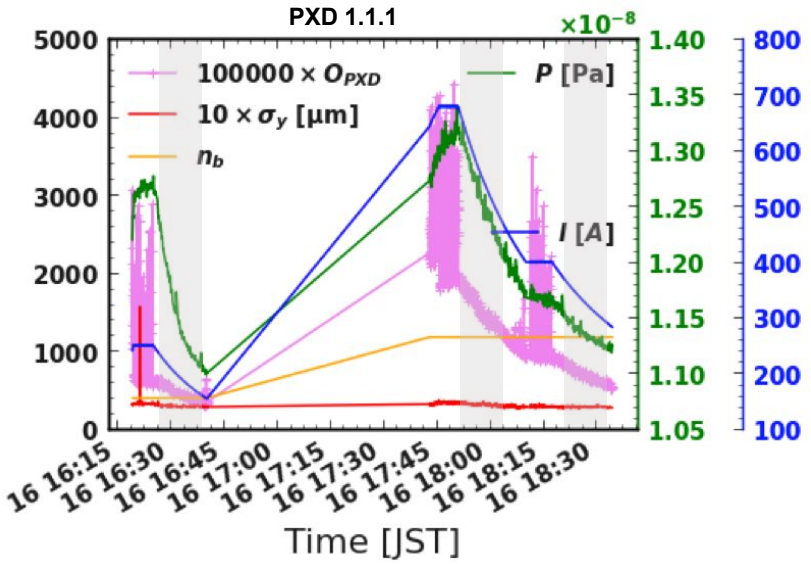
Single-beam background in HER:

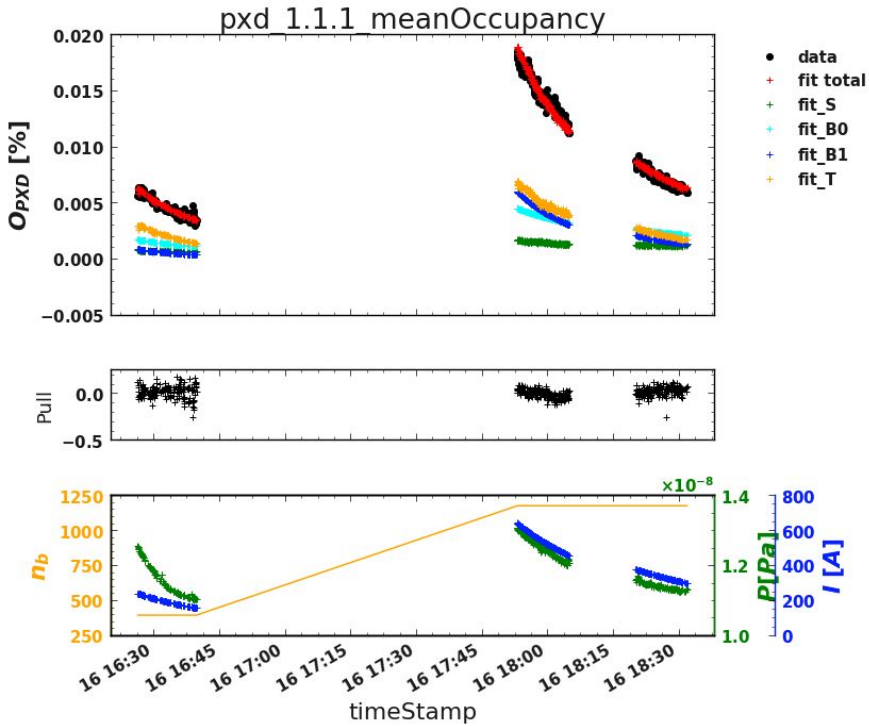
- **Beam-gas scatting (base & dynamic)**
- **Touschek scattering**
- **Synchrotron radiation**
- **Noise**

$$\mathcal{O}_{PXD}^{HER} = B_0 I + B_1 I^2 + \frac{TI^2}{\sigma_y n_b} + S \cdot (spf/cf) I + N$$

particle flux: the number of particles per unit time and unit area

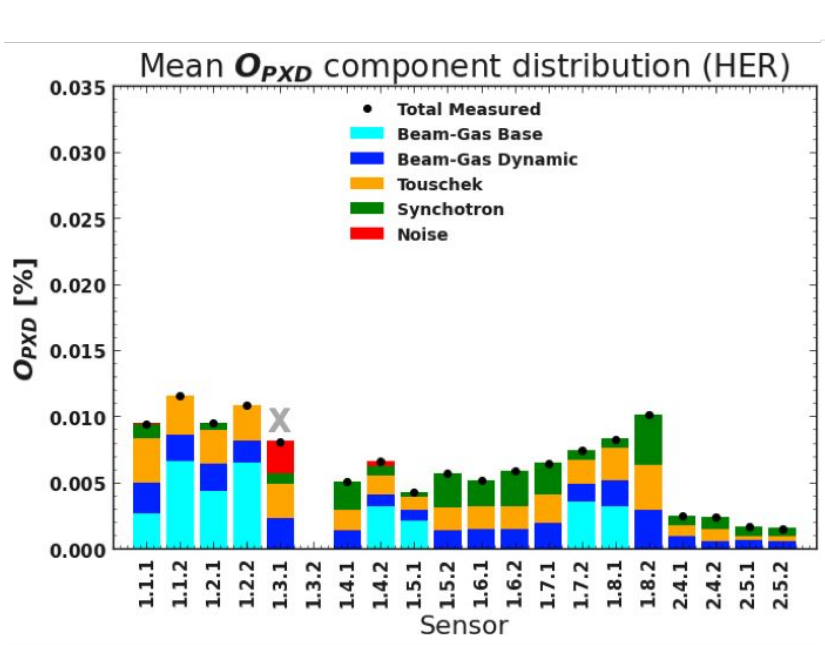
Apply fit on occupancy to extract the sensitivites of each source.

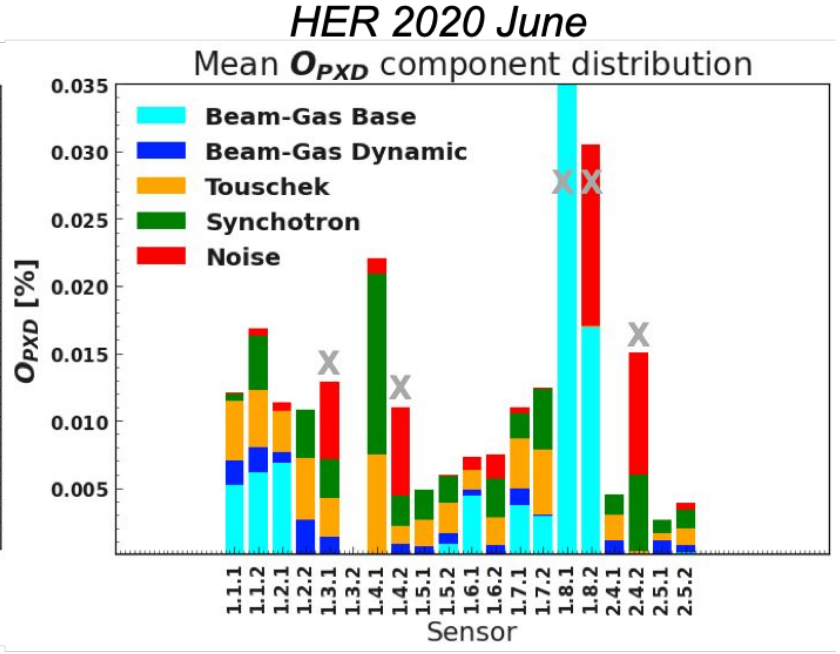




Single-Beam Analysis: HER

Comparison with 2020 June run





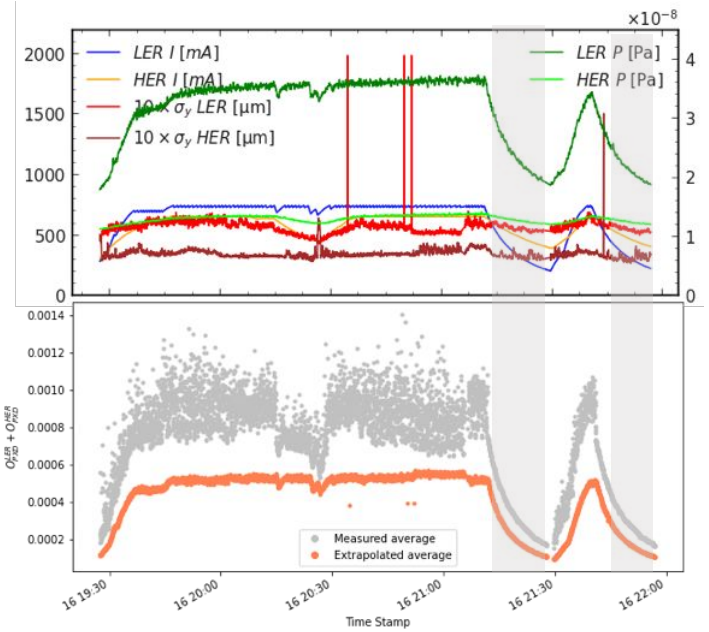
	June 2020		June 2021		Ratio (2021/2020)	
	L1	L2	L1	L2	L1	L2
B0 (*10^{-8})	9.4	0.3	6.1	0.008	**0.65**	**0.03**
B1 (*10^{-10})	1.0	0.8	1.0	0.4	**1.05**	**0.51**
T (*10^{-5})	0.7	0.3	0.4	0.1	**0.55**	**0.39**
S (*10^{-8})	3.7	5.2	1.1	1.9	**0.29**	**0.36**

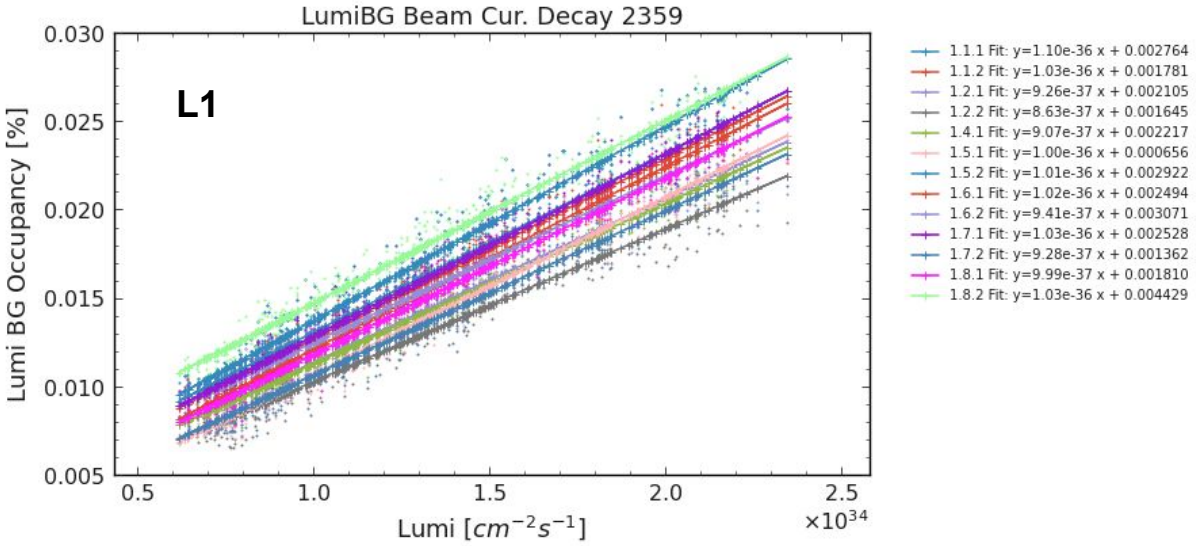
X: noisy sensors are excluded in average for comparing

Luminosity Background

Exp 18 lumi-run: 2358-2360

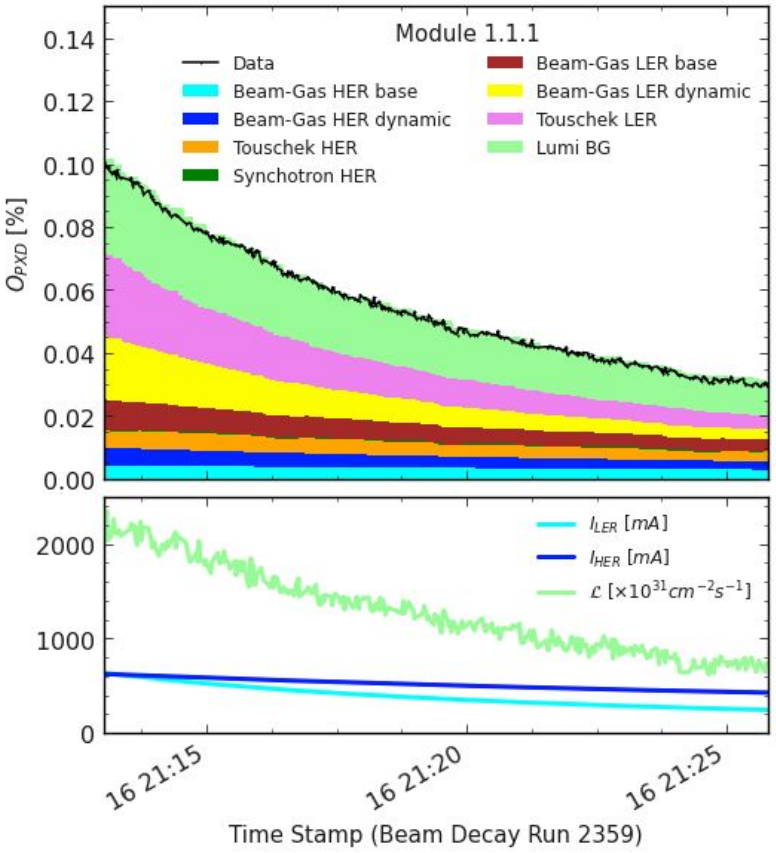
- Extrapolate single-beam bkg to lumi run beam conditions
  - Same parameterization as used for decomposition
  - Based on fitted sensitivities
  - Skip noisy sensors 1.3.1, 1.4.2
- Subtract extrapolated single-beam bkg (LER+HER) from total measured data in lumi-run
- In beam decay, apply linear fit on residual component (lumi bkg) to get its dependency information on luminosity





Background Decomposition in Lumi-Run

- Utilize obtained single-beam **sensitivities** and **lumi-dependency** to calculate each bkg source
- Stacked compositions show a good agreement of total measured data
- Ongoing: extracting data/MC correction factors for BG19c samples, estimate background level @ design opics



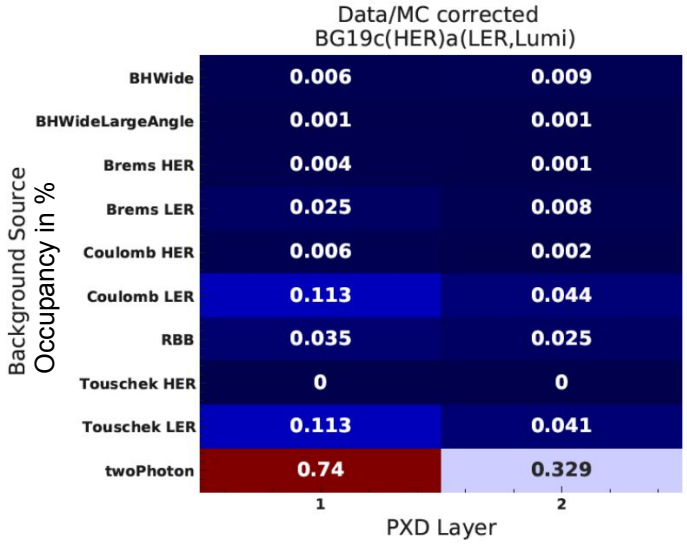
Current Margin wrt Nominal

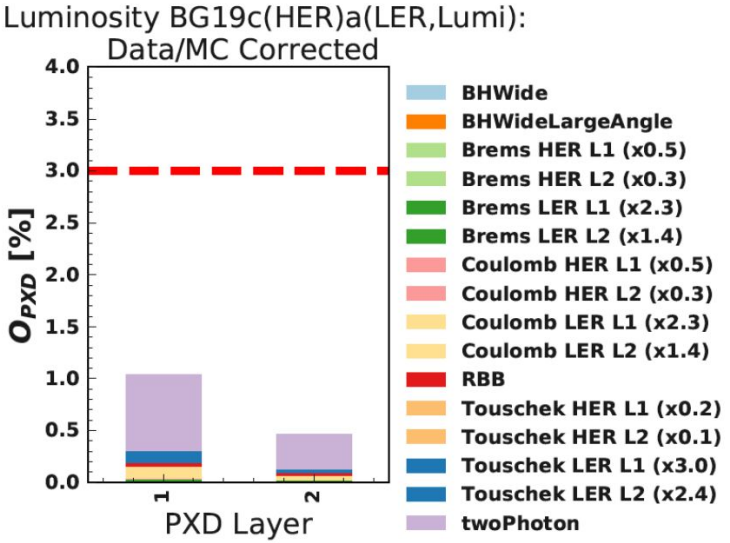
Based on June 2020 run result

taken from Sally's talk

- Use data/MC 27.06.2020 bugfix2 ratios to correct the BG19c sample
- Two-photon background will be **dominant**
- Two caveats: extrapolation missing injection and SR backgrounds, attainability of simulated collimator settings
- **Conclusion:** With our current understanding, $\mathcal{O}_{PXD} < 3\%$ at original design luminosity optics

Parameters @ Original Design Optics	LER	HER
Beam current [A]	3.6	2.6
N. of bunches	2500	2500
Vertical beam size [um]	24	10
β_x^*/β_y^* at IP [mm]	32/0.27	25/0.30
Pressure [nTorr]	1	1





Summary

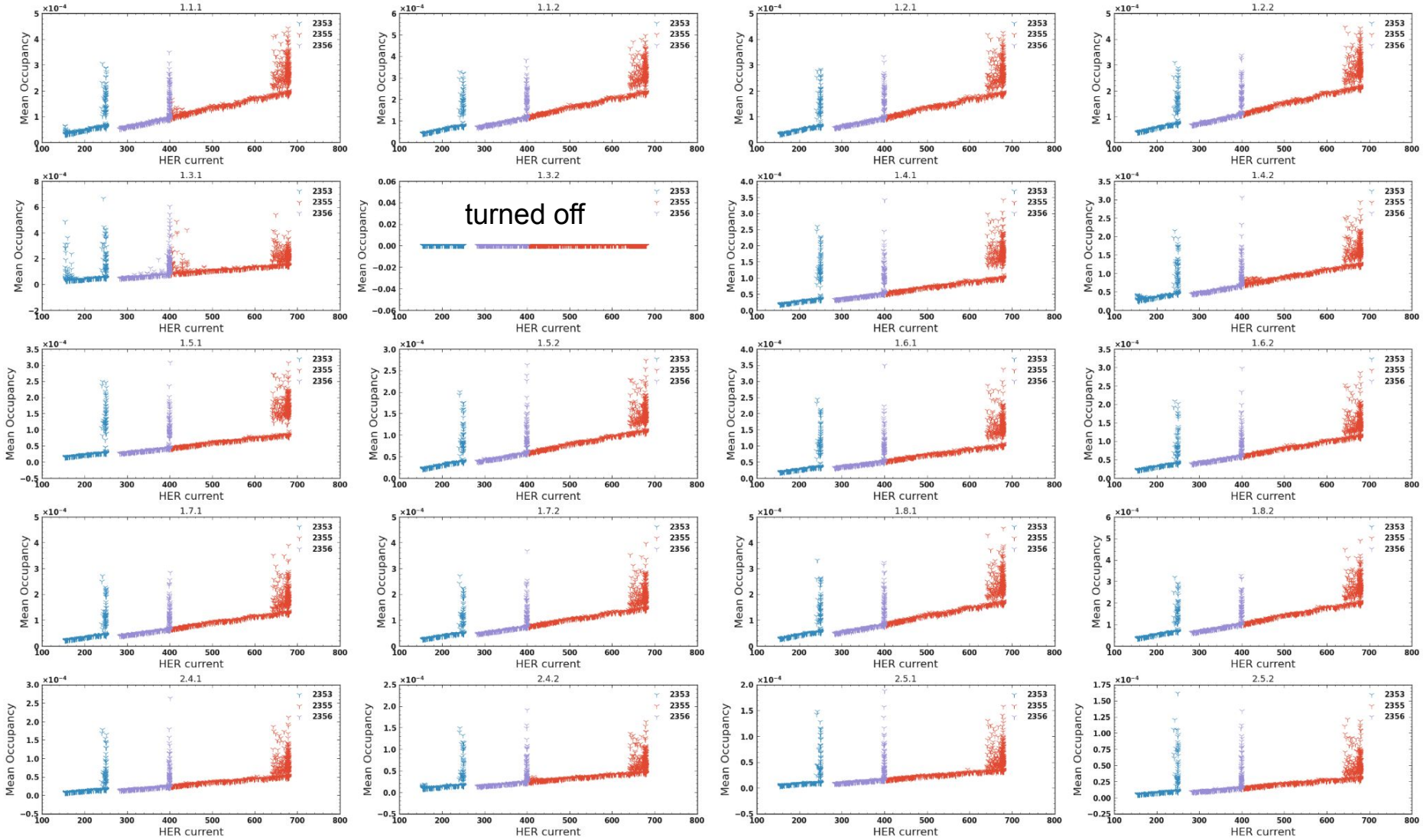
- Analysis on last run data taken in June 2021 is partially done
- Update of background level expectation is ongoing
- June 2020 result implies a safe margin for PXD @ original design optics
- Further study on injection background (outside of veto) is needed

Thank you!

Backup

Single-Beam Analysis: HER

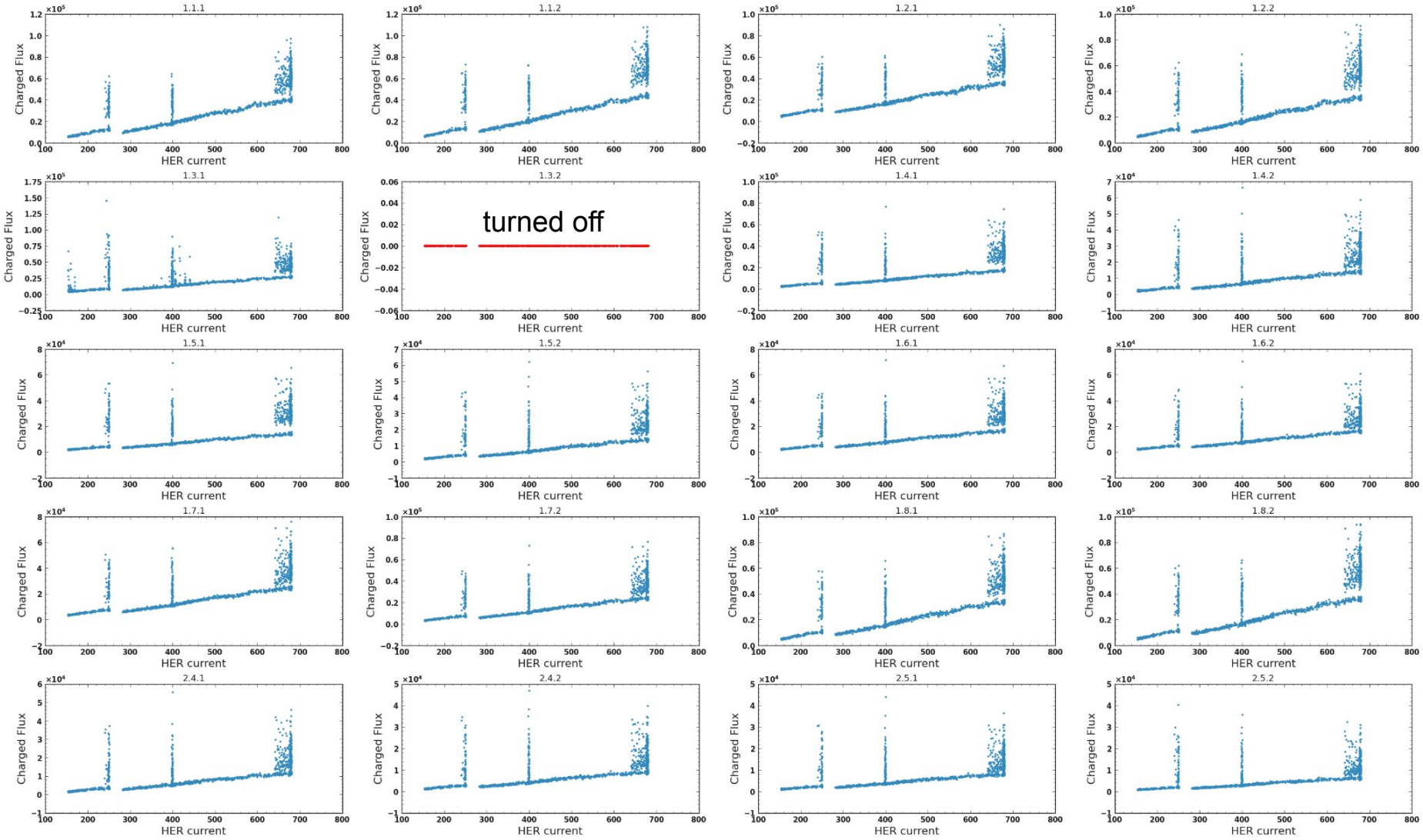
Mean occupancy vs. current



Single-Beam Analysis: HER

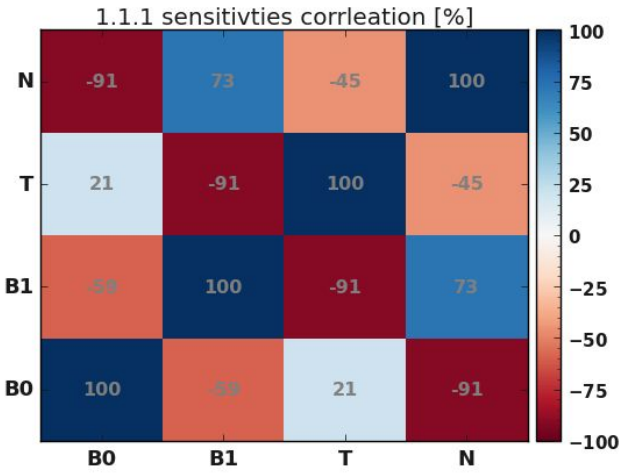
Charged flux

Category	Energy	Cluster Size
spf: Soft Photon Flux	6 < E < 10 KeV	1
cf: Charged Flux	E > 10 KeV	> 1



Correlations of Extracted Sensitivities

LER:



HER: