# PXD Backgrounds

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

# Background Sources

Background sources at Belle II in general are:

> **Collision-induced**: non-interesting physics processes originating from electron-positron collisions

> **Beam-induced**: physics processes originating from collisions of particles with beam pipe, magnets or with other particles in a bunch) $\rightarrow$ shown in this presentation

# Beam-Induced Backgrounds

Origin of the backgrounds can be traced with single-beam (HER or LER) SuperKEKB runs:

> **Touschek scattering** $\rightarrow$ Scattering of particles within a bunch
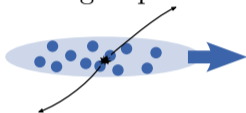


> **Beam-gas scattering**: Coulomb scattering and Bremsstrahlung $\rightarrow$ scattering of the gas molecules



> **Beam-Gas Rate\*** $\propto N_{gas\ molecules} \times N_{particles} \rightarrow \mathbf{P} \times \mathbf{I} \times \mathbf{Z_{eff}^2}$
> **Touschek Rate\*** $\propto N_{particles} \times \rho \rightarrow \mathbf{I} \times \frac{\mathbf{I}}{\sigma_\mathbf{y} \mathbf{n_b}}$

\*Rate=online PXD occupancy

# Heuristic Equation

> Total rate:

$$\mathbf{Rate_{PXD}} = \mathbf{T}\frac{\mathbf{I^2}}{\sigma_y \mathbf{n_b}} + \mathbf{BZ_{eff}^2 IP},$$

with $\mathbf{T}$ : **Touschek contribution**
$\mathbf{B}$ : **Beam − gas contribution**

> Divide through by $\mathbf{Z_{eff}^2 IP}$



FIGURE: arxiv:1802.01366. Shapes=currents, colors=beam size settings.

$$\frac{\mathbf{Rate_{PXD}}}{\mathbf{Z_{eff}^2 IP}} = \mathbf{B} + \mathbf{T} \times \frac{\mathbf{I}}{\sigma_y \mathbf{n_b Z_{eff} P}}$$

> Straight-line fit with $\mathbf{T}$ (slope of the straight line) and $\mathbf{B}$ (y-intercept of the straight line)

# Data

> LER single beam data : 11.05.2019, 14.05.2019 (narrower collimator settings)

> HER single beam data : 12.05.2019

> Data source: EPICS $n_b, \sigma_y, I, Rate_{PXD}$

> $Z_{eff} = 1.0, 7.0$

> $P_G$ = average of gauge pressures

> $P_{cal} = c \times P_G - (c-1)P_{base}$, where $c = 1.7$ and $P_{base} = 1.0e-9$

> Only matching timestamp data is shown

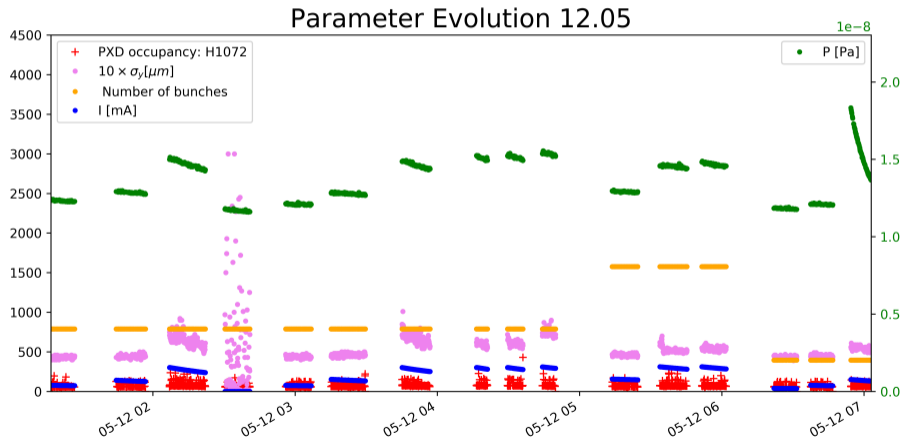> **Future plan**: cross-check with globally produced calibrated data

# 11.05.2019 LER single-beam background

> vary $I, n_b$, test emittance knob YaECK varying $\sigma_y$



Parameter Evolution 11.05

Legend:
- PXD occupancy: H1072 (red +)
- $10 \times \sigma_y [\mu m]$ (pink)
- Number of bunches (orange)
- $I$ [mA] (blue)
- $P$ [Pa] (green)
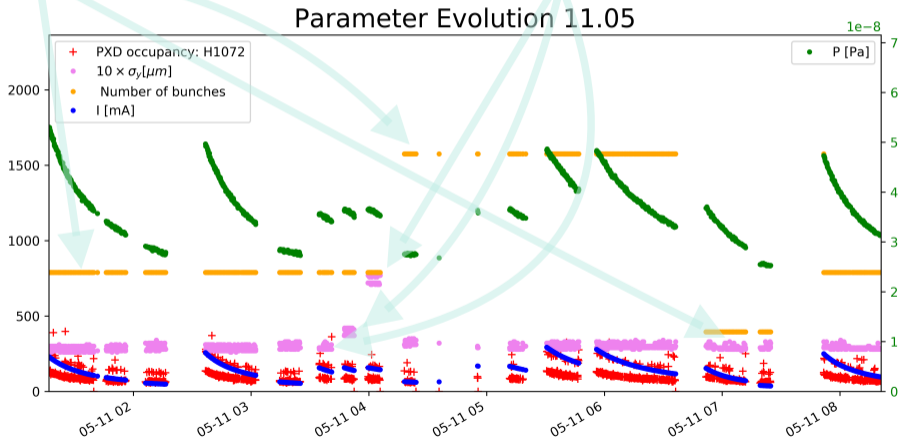
# 12.05.2019 HER single-beam background

> vary $I, n_b$, test ECK varying $\sigma_y$



Parameter Evolution 12.05

Legend:
- PXD occupancy: H1072 (red +)
- $10 \times \sigma_y[\mu m]$ (pink)
- Number of bunches (orange)
- I [mA] (blue)
- P [Pa] (green)

# 14.05.2019 LER single-beam background (narrower collimator)

> vary $I, n_b$, test ECK varying $\sigma_y$



Parameter Evolution 14.05
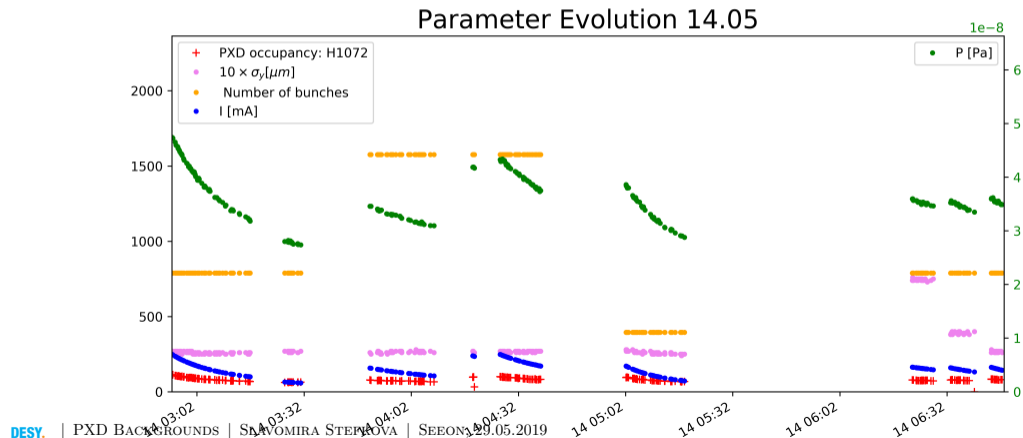
# Narrower D02V1 collimator: 11.05.2019

> Poisson, 789 bunches, I = 240 → 100mA
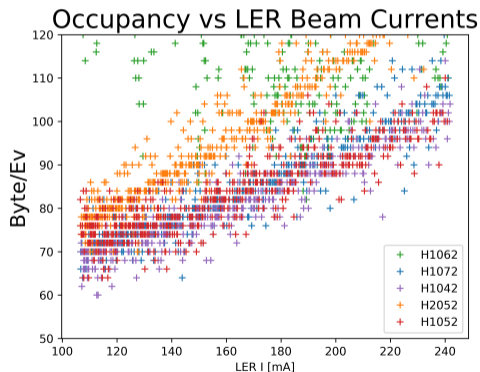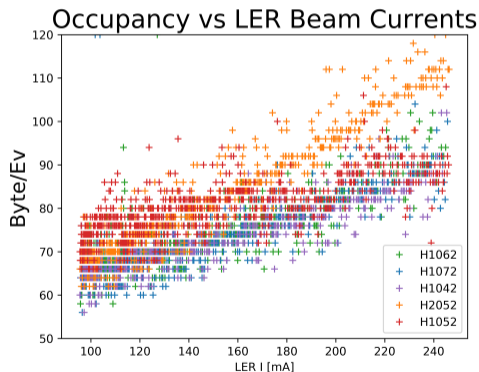


Run 138

Run 154

# Narrower collimators: 11.05.2019 and 14.05.2019

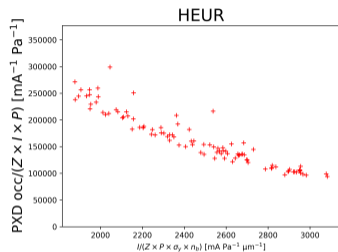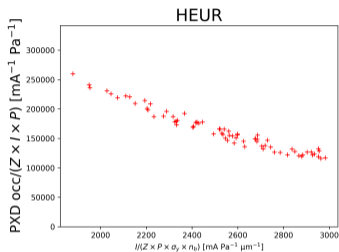> Poisson, 789 bunches, $I = 240 \to 100$mA
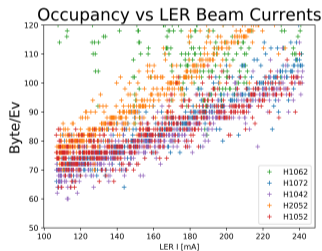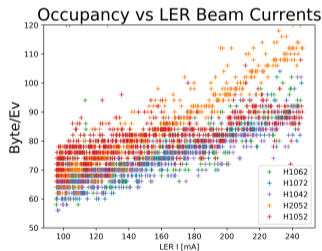


Run 138, 11.05　　　　　Run 154, 11.05　　　　　Run 307, 14.05
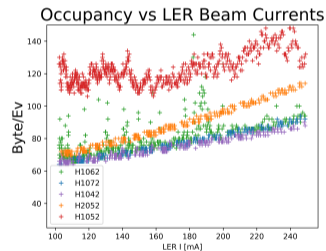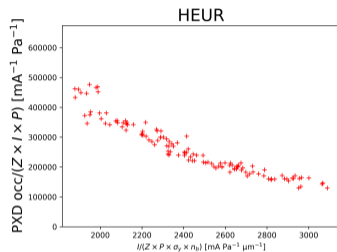
# Heuristic Decomposition - LER - Run 307
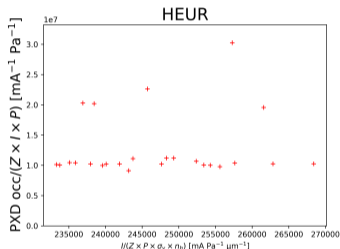


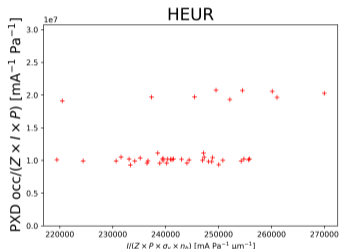Run 307, H1042          Run 307, H1052          Run 307, H2052

> The heuristic decomposition does not describe the data
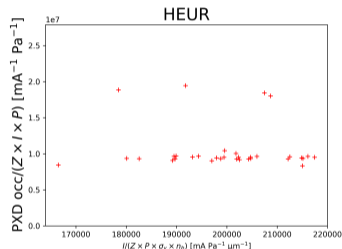
# Heuristic Decomposition - HER

> Varying the emmitance knob settings, H1072
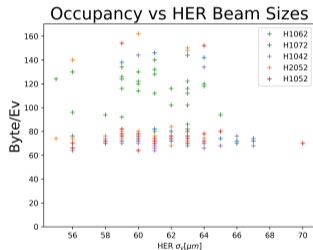


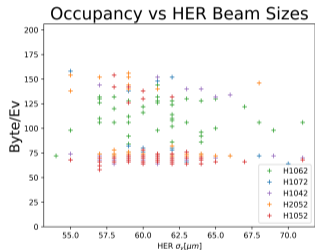Run 202,YaECK=0          Run 203, YaECK=+0.6          Run 204,YaECK=+1.2

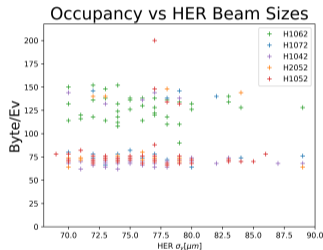> No slope → Beam-Gas contribution only

# Occupancy and Size of Beam

> Different beam sizes have no implication on occupancy $\rightarrow$ Beam-Gas contribution only



Run 202,YaECK=0          Run 203, YaECK=+0.6          Run 204,YaECK=+1.2

> The heuristic decomposition only points to beam-gas contribution

# Phase 3 results

> Average occupancy is well below the 3%
> Heuristic model does not fit the data with LER single beams (both 11.05.2015 nor 14.05.2019)
> HER 12.05.2019: Beam-gas contribution only
> The effect of vertical collimators on backgrounds is seen
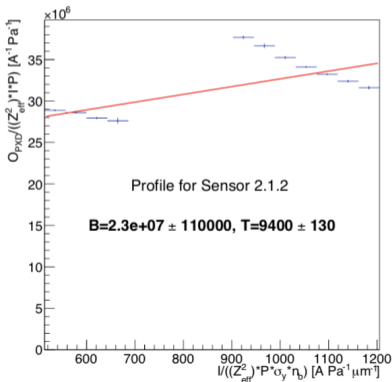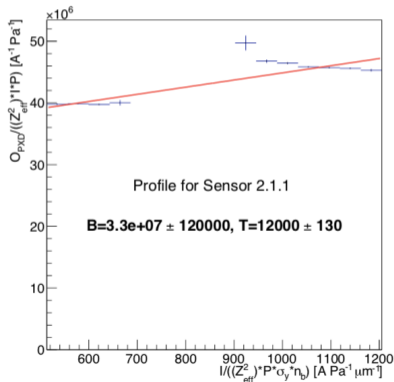> Investigate the negative behaviour of the slope

# Phase 2 results - Heuristic plots

> In Phase 2 the background composition has both Touschek and Beam-Gas contribution

> June 11 HER single beam data
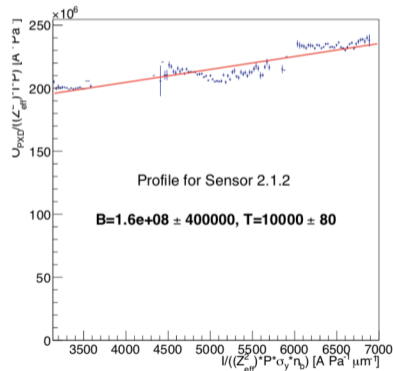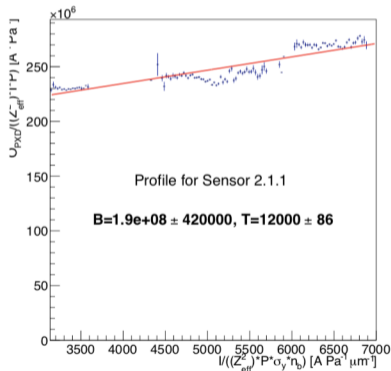
# Phase 2 results - Heuristic plots II

> June 12 LER single beam data
> However, negative slope is not something that have not been seen before
> Valid for Layer 1 and 2

# Data-MC agreements for Phase 2

> Dedicated MC samples produced to make comparative studies
> For LER single beam runs (June 12, July 16): good agreement

| Sensor | B Data/B MC | T Data/T MC |
|--------|-------------|-------------|
| 1.1.1 | 7.55±0.020±0.23 | 1.36±0.013±0.83 |
| 1.1.2 | 7.06±0.019±0.079 | 1.39±0.014±0.61 |
| 2.1.1 | 7.00±0.025±0.12 | 1.29±0.015±0.82 |
| 2.1.2 | 4.86±0.023±0.33 | 1.07±0.014±0.72 |

| Sensor | B Data/B MC | T Data/T MC |
|--------|-------------|-------------|
| 1.1.1 | 17.95±0.019±0.047 | 2.39±0.0076±0.42 |
| 1.1.2 | 17.04±0.018±2.60 | 2.37±0.0077±14.00 |
| 2.1.1 | 16.57±0.021±0.14 | 1.91±0.0075±0.43 |
| 2.1.2 | 16.19±0.021±2.60 | 2.00±0.0074±13.00 |

> For HER single beam runs (June 11): not such a good agreement (wrong MC suspected)

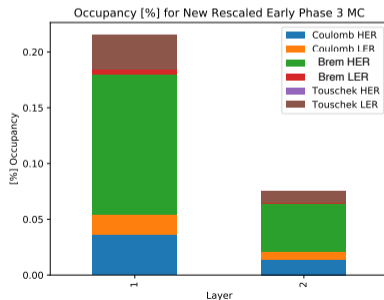| Sensor | B Data/B MC | T Data/T MC |
|--------|-------------|-------------|
| 1.1.1 | 82.54±0.16±19 | 47.97±0.31±33 |
| 1.1.2 | 85.42±0.17±0.31 | 52.58±0.35±0.67 |
| 2.1.1 | 78.88±0.18±0.043 | 45.41±0.32±0.48 |
| 2.1.2 | 79.65±0.19±0.0069 | 45.59±0.36±0.55 |

# Projections

> Use June LER/HER Data/MC ratios to scale for early Phase 3
> For both layers: average Data/MC from 2 sensors from June samples
> For final Phase 3: both currents$\times 3 \to$ single beam bkg $= 2\%$
> + Other backgrounds: two-photon, synchotron



Occupancy [%] for New Early MC Phase 3
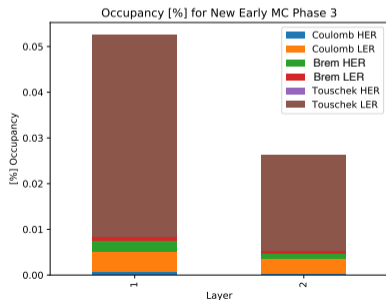
| Scales | BG | T |
|--------|-----|-----|
| LER L1 | 4.2 | 0.7 |
| HER L1 | 50 | 28 |
| LER L2 | 2.3 | 0.5 |
| HER L2 | 35 | 18 |



Occupancy [%] for New Rescaled Early Phase 3 MC

# Conclusions

> First look at Phase 3 single-beam runs
> Dominated by beam-gas scattering processes
> Negative slope in LER is not understood $\rightarrow$ needs investigation
> Look at whether these contributions come from single cluster data or not
> Systematic effects are being evaluated
> Phase 2 results are being finalised $\rightarrow$ data is in rather a good agreement with simulation
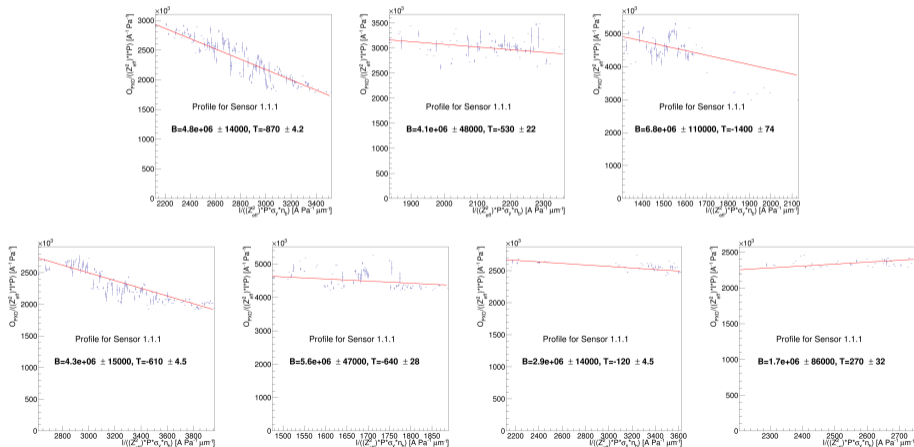> Assuming phase 2 Data/MC agreement, extrapolation to Phase 3 seems safe

# Backup

# Global Picture

> The global picture: run 138-153 for the decomposition does not confirm that the
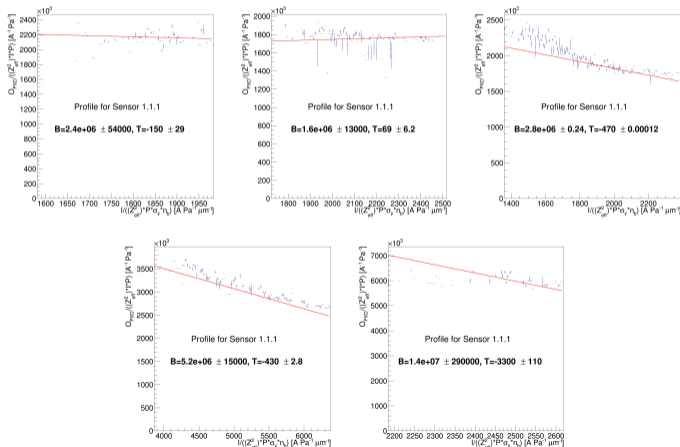> model works
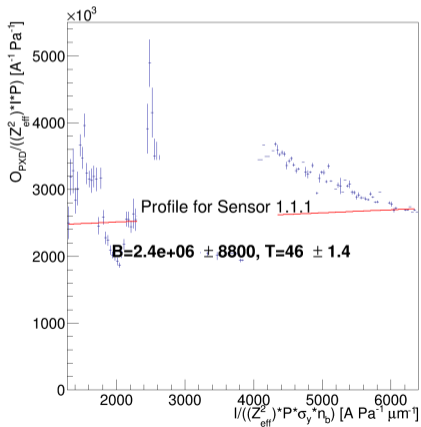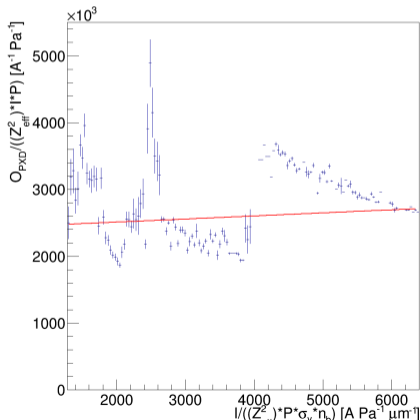
# Individual Runs I

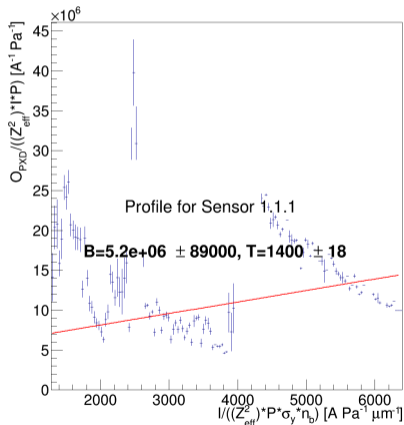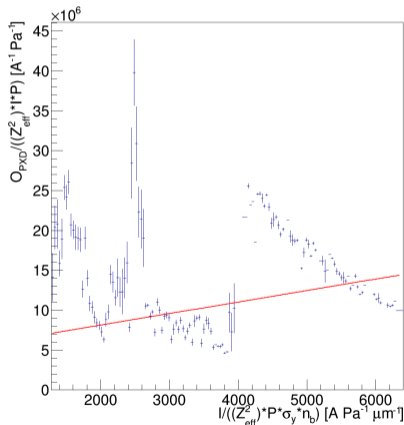> This is confirmed in individual runs (138-144):

# Individual Runs II

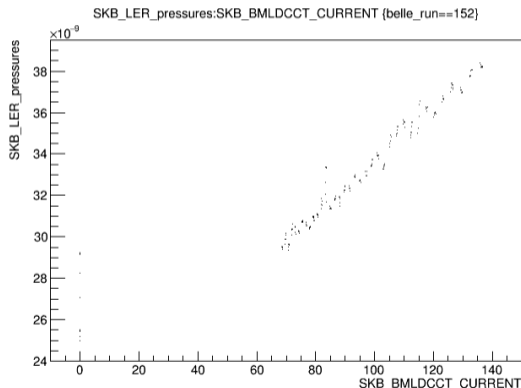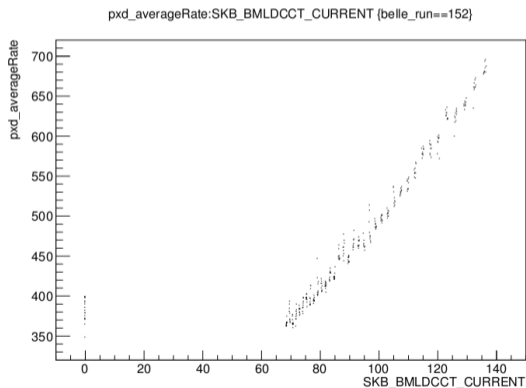> This is confirmed in individual runs (149-153):

# Global Picture for SVD is the same

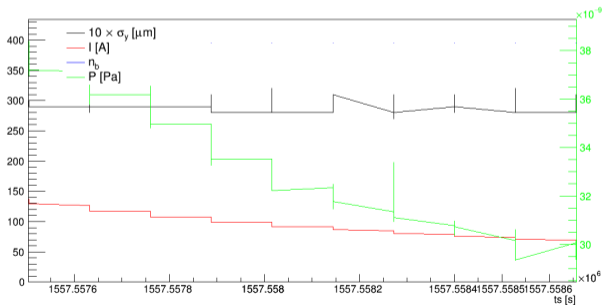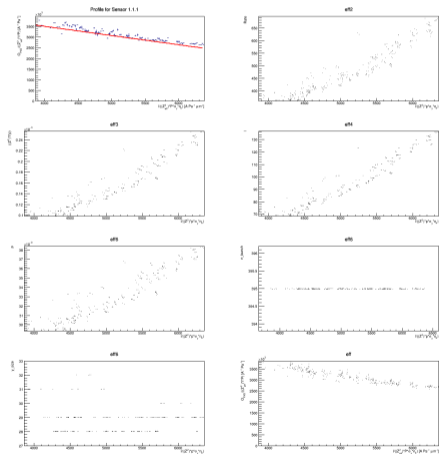> Similar behaviour observed for SVD

# Detailed Look at Run 152

> The dependency of pressure and the rate on current seems reasonable

# Detailed Look at Run 152

# Collimators