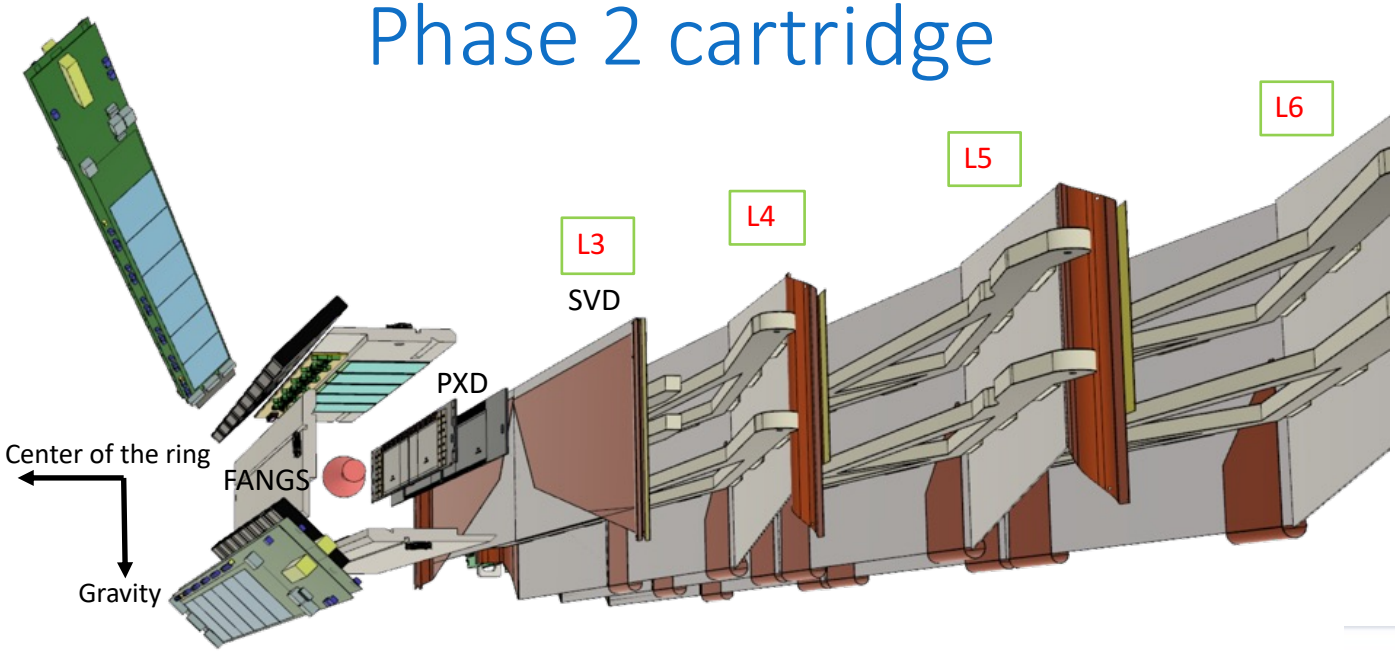
SVD Beam Background
&
Belle II Background summary

G. Rizzo – Belle2 Italia – 23-24 Maggio - Torino

Phase 2 cartridge



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- PXD + SVD sector in the horizontal plane
- BEAST II Detectors tuned for background studies
  - FANGS (Atlas pixels) SR
  - PLUME (CMOS pixel) spatial info
  - CLAWS (Plastic scintillators SiPM redout) time evolution injection back.

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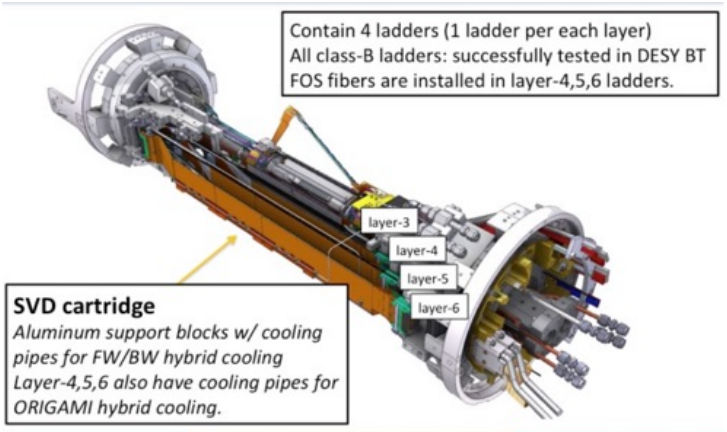


SVD background & comparison with simulation

- One important goal of phase 2 for SVD (PXD/BEAST) is to measure background & understand if conditions are safe for installation of the entire VXD for phase 3.
- Comparison **phase 2 data** vs **simulation** fundamental to extrapolate background to phase 3 and compare with **detector limits** to decide if it's safe to start transition from phase 2 to phase 3.
- Decision needed by B2GM in June.

SVD Detector Limits

Safety Factor= Detector Limit /Phase 3 Sim

- Occupancy: 2% in L3 (limit from tracking group, before time cut)
  - Need measurement of occupancy in phase 2 with collision at final Lumi
  - Ratio among occupancy in phase 3 vs phase 2 in simulation, with no time cut, is 8.
  - Phase 3 simulation gives 1.4% → only 1.4 safety margin w.r.t simulation (=2%/1.4%)
  - Occupancy only affect performance and not safety, some excess w.r.t 2% can be tolerated, still improvement in background can be pursued at the beginning of phase 3
- TID: 10 Mrad (in 10 yr) → 100 mrad/s including injection!
  - Phase 3 Sim = 100 krad/yr , Phase 2 Sim = 20 krad/yr
  - Extrapolation ratio = Phase 3 Sim/Phase 2 Sim = 5
  - need to know injection dose vs normal running dose
  - --> safety factor 10 but if huge discrepancy is seen among occupancy data and simulation, this also increase the expected dose in SVD
- Bulk damage (NIEL): ~ 10^13 neq/cm2 (TBC)
  - Phase 3 simulation ~ 2*10^11 neq/cm2/yr → safety factor ~ 5

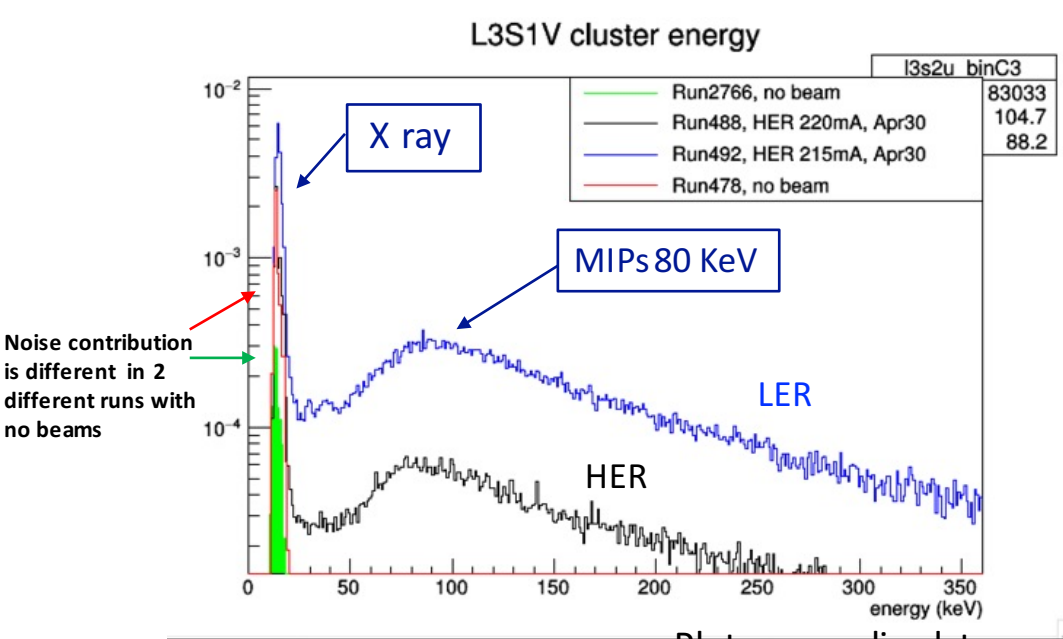
SVD background study summary

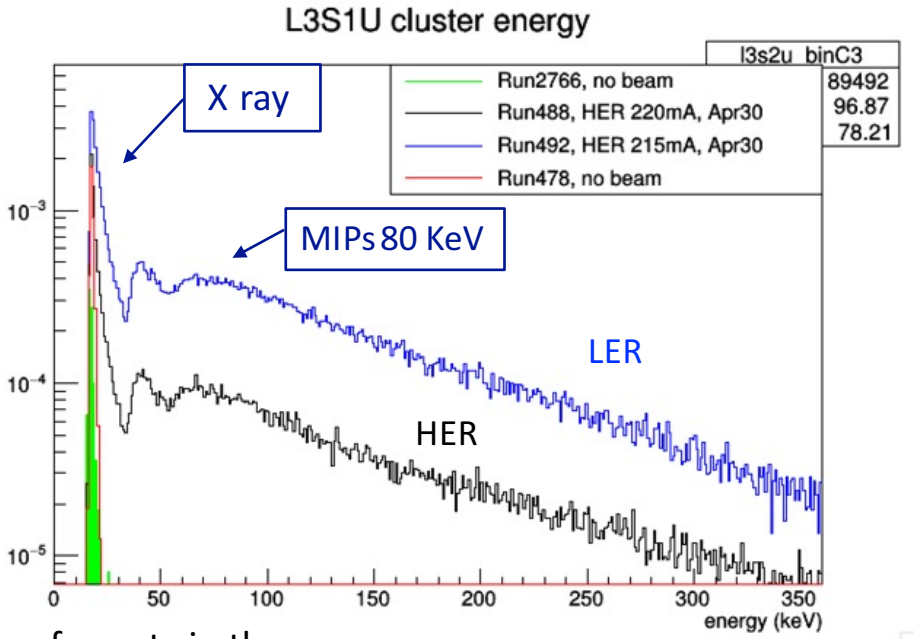
- Several test performed with SVD ON during stable beams, from first days, with different combinations of HER/LER currents.

1. Studied occupancy vs currents to compare with Phase 2 simulation (need to make extrapolation to phase 3…)
   - **Occupancy** measured is higher than expected from Phase 2 simulation by ~ one order of magnitude (using data from Apr. 30 test, single beams)
     - even after the improvements seen from the beginning of Phase 2
     - Hints of additional source not present in simulation
2. Studied cluster energy spectra to understand background composition
   - **Cluster Energy** spectrum from background contains a contribution from low energy component (10-40keV) from photons, and a contribution from MIPs at ~ 80 keV .

SVD L3 energy spectra – Beam & no Beam runs

- Low energy component can be a hint of SR, as seen in other detectors (PXD/FANGS),
  - … SVD cannot be very predictive in the range 10-20 keV since it's also populated by noise hits and variation is observed in noise contribution
- Noise contribution is anyway not affecting the total background estimation since it's always 1-2 order of magnitude lower than beam background over the whole energy range





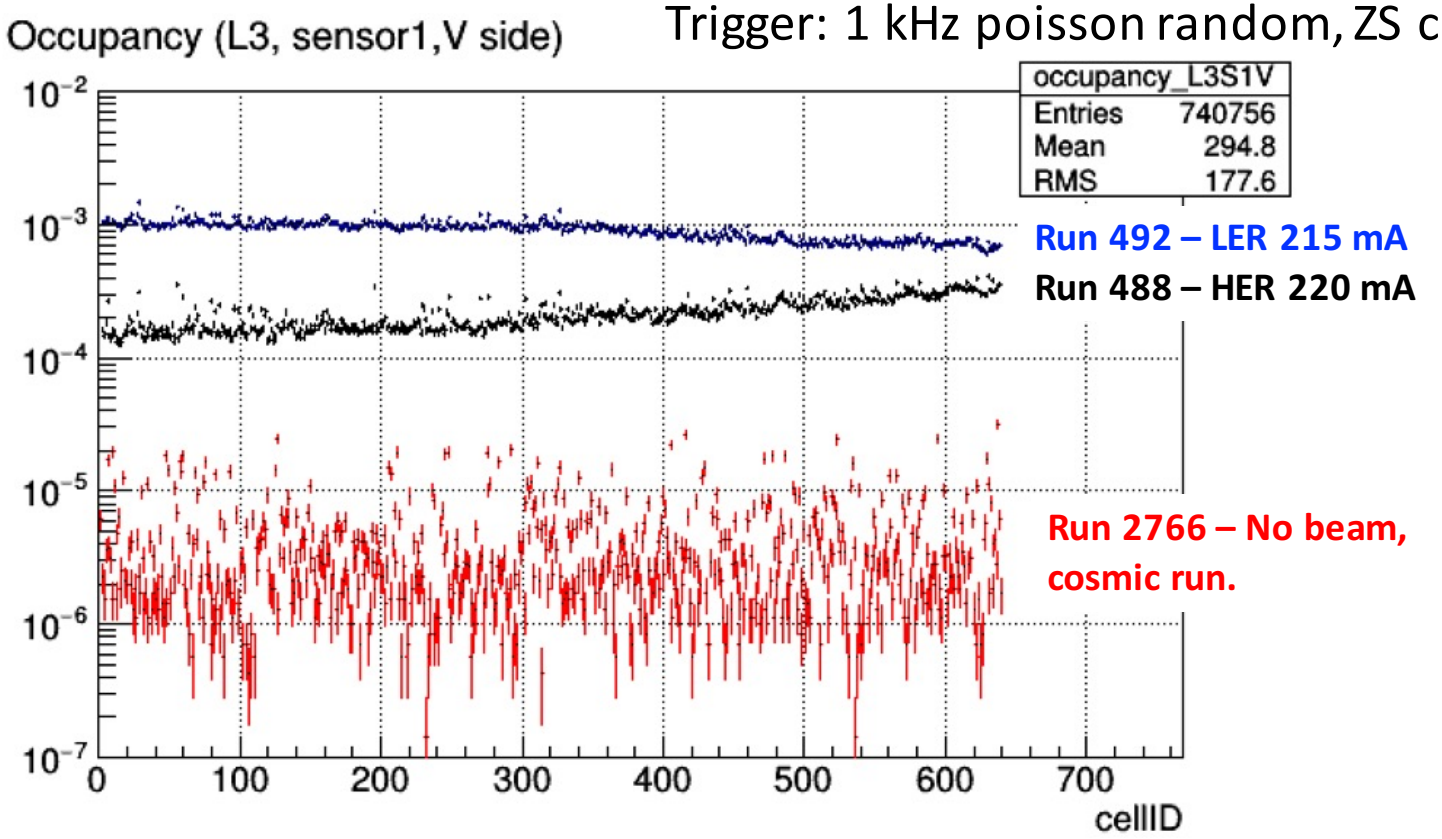
Plots normalized to number of events in the run

SVD L3 Occupancy – Beam & no Beam runs

SVD L3 Occupancy with 2 different beam runs ~ 10^{-3} 10^{-4}

SVD Noise Occupancy with ZS cut=5 is very small ~ 2 order of magnitude lower than beam background, varying a bit in range $5\ 10^{-6} – 2\ 10^{-5}$

Trigger: 1 kHz poisson random, ZS cut=5



Other subdetectors have a clear hints of SR

Layer 1 Backward PXD Backgrounds

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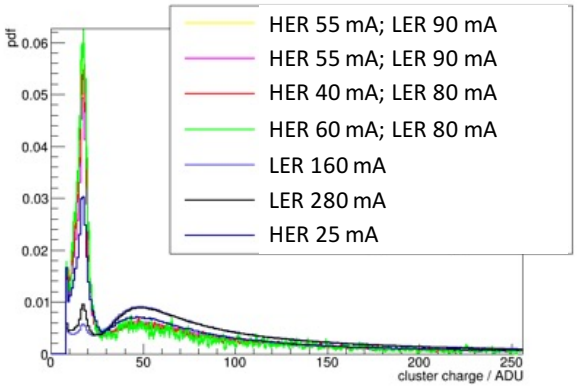
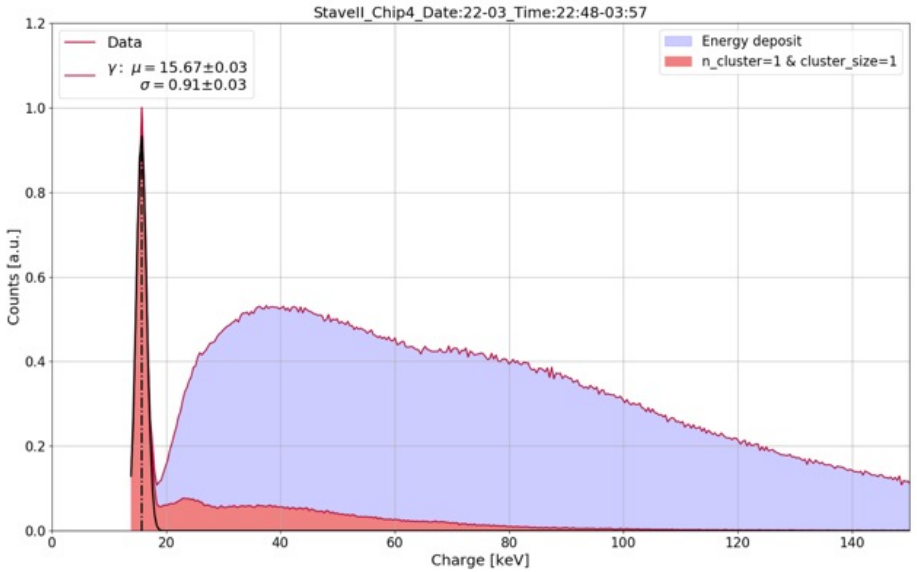


- Largest SR from HER
- LER contribution non negligible still
- Occupancies larger than desired

Synchrotron Radiation (FANGS)



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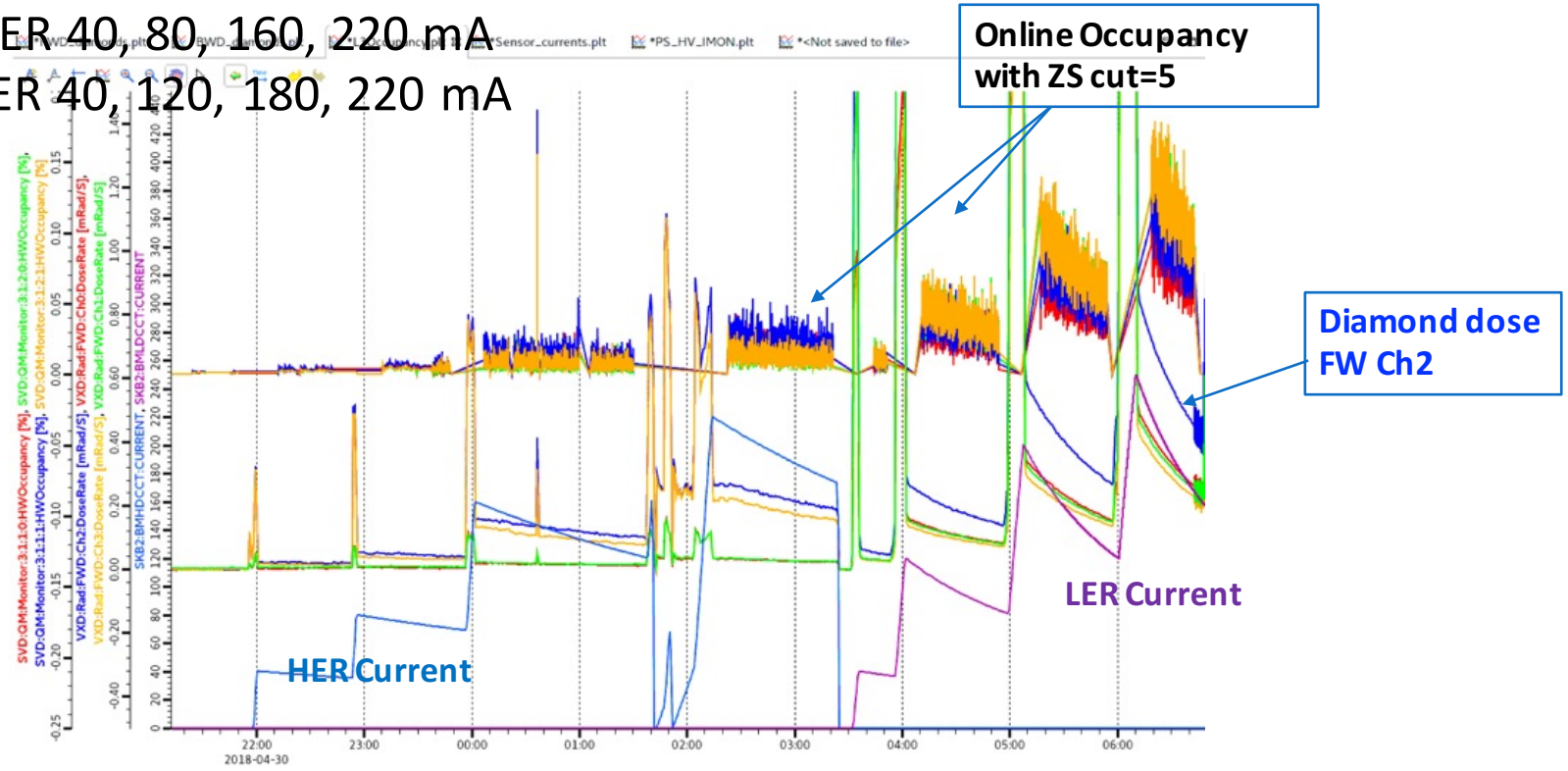
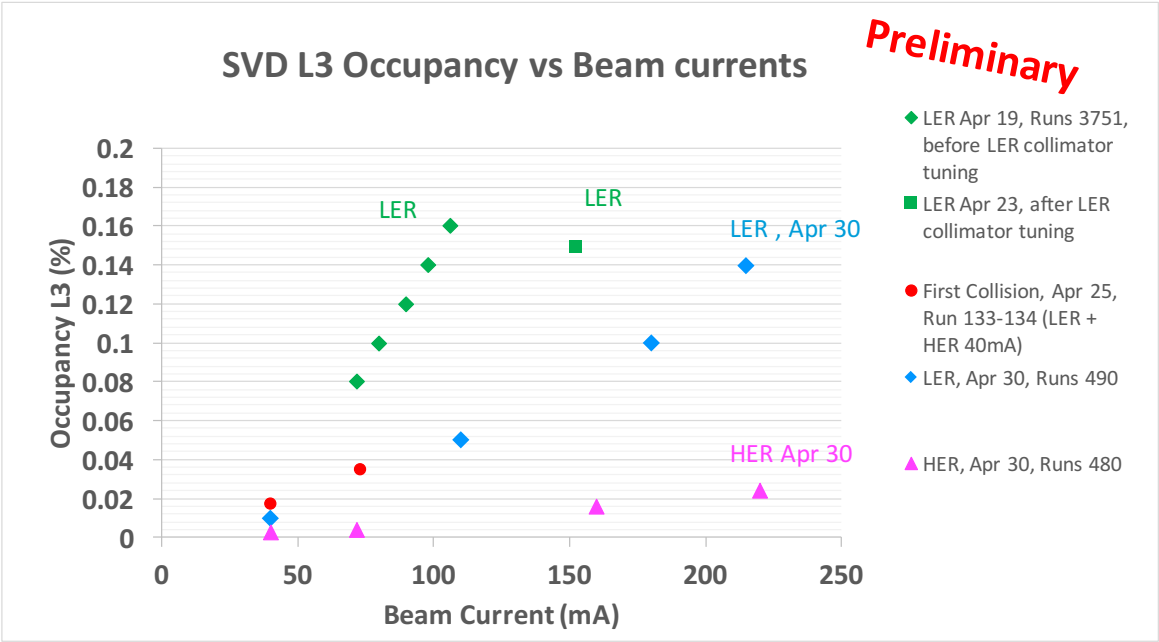
An example of single beam background study Apr 30th : Occupancy, Dose, Beam Current

- Beam conditions: HER/LER single beams in steps:
  - HER 40, 80, 160, 220 mA
  - LER 40, 120, 180, 220 mA



SVD L3 background occupancy improved with time

- From first LER beam data (Apr 19) background improved
  - collimator tuning on Apr 23
- During First Collision runs on Apr 25 improvement from LER confirmed
  - Red points,
  - HER contribution very small during collision runs.
- Further improvement also observed in LER during test done Apr 30.
  - **Green to Blue LER data points**
- Background dependence from beam current can give hints on their origin
  - Linear dependence before Apr 23
- Now quadratic term is visible…



Touschek scattering $\propto \frac{I^2}{\sigma \cdot E^3}$

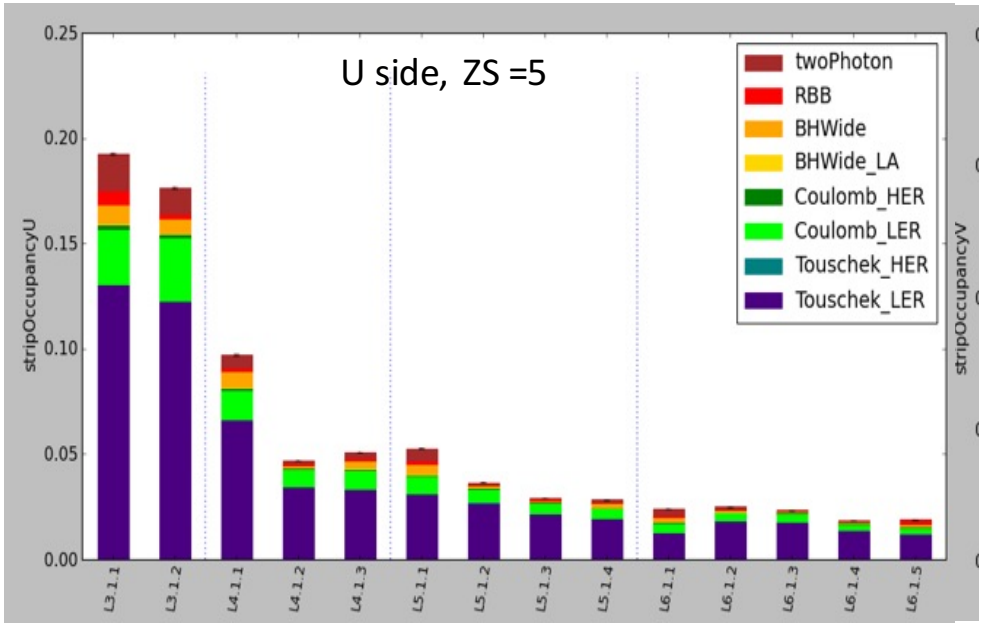
Coulomb scattering $\propto I \cdot P = I \cdot (P_0 + P'\ I) = P_0 I + P' I^2$

SR $\propto I$, NOT expected IN SIMULATION

Phase 2 simulation

- Luminosity term still very small in first collisions
- In phase 2 background from single beam contributions expected to dominate
  1. Touschek LER
  2. Coulomb LER

H. Tanigawa



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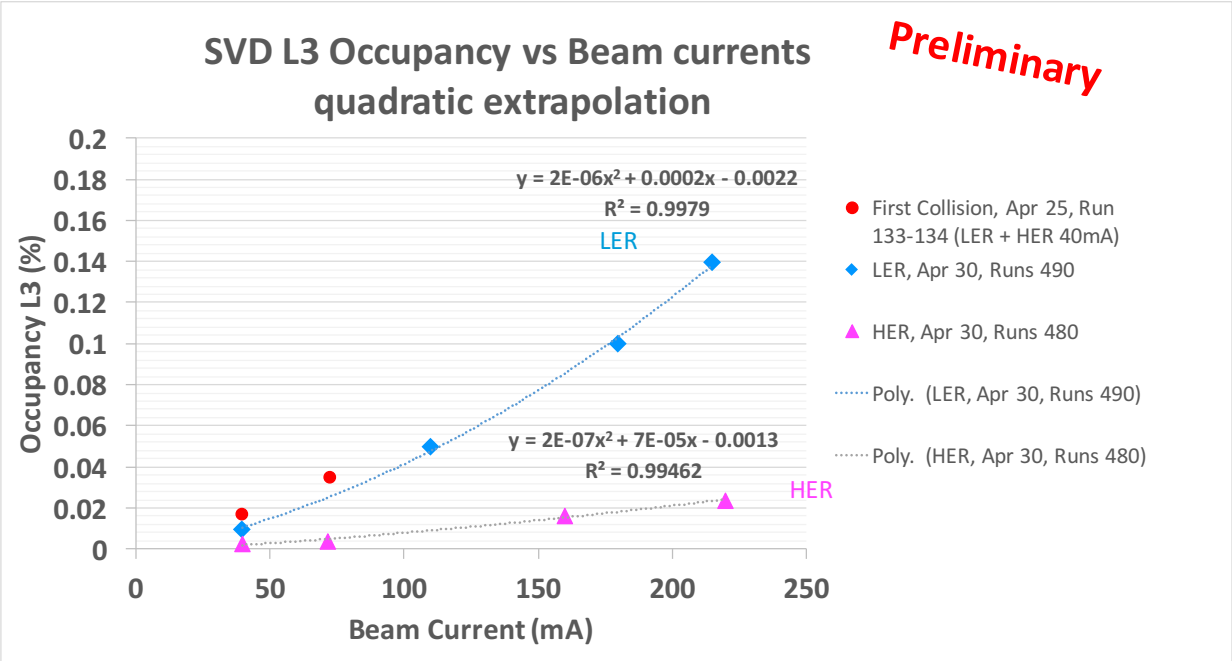
$$\text{Coulomb scattering} \propto I \cdot P = I \cdot (P_0 + P'\ I) = P_0 I + P' I^2$$

SR $\propto I$, not expected in SIMULATION

L3 Occupancy extrapolation with quadratic fit

- Fitting with quadratic terms, both LER and HER contribution, shows background is a factor 15 (2.4%/0.15%) higher than expected from Phase 2 simulation.
- Data extrapolation (quadratic) from single beams @ nominal Phase 2 currents:
- TOT single beam L3 Occu = 2.4%
  - LER 1 A → L3 Occu =2.2%
  - HER 0.8 A → L3 Occu =0.18%
- Phase 2 Simulation from single beams:
- TOT single beam L3 Occu = 0.15%
  - LER Simulation → 0.15%
  - HER Simulation → <0.005% ?



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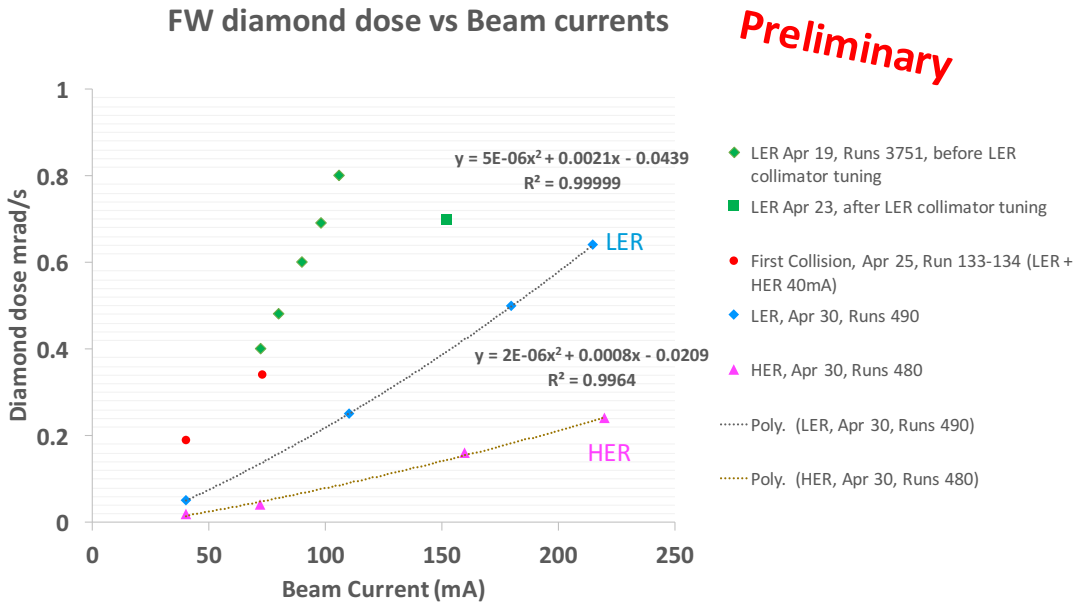
$$\text{Coulomb scattering} \propto I \cdot P = I \cdot (P_0 + P'\ I) = P_0 I + P' I^2$$

SR $\propto I$, NOT IN SIMULATION

Diamond dose extrapolation with quadratic fit

- Same extrapolation (with quadratic fit for both LER and HER contribution) shows diamond dose is only a factor ~2 higher than expected from Phase 2 simulation.
- Data extrapolation (quadratic) from single beams @ nominal Phase 2 currents:
- TOT single beam FW dose = 9 mrad/s
  - LER 1 A → FW dose =7 mrad/s
  - HER 0.8 A → FW dose =2 mrad/s
- Phase 2 Simulation from single beams:
- TOT single beam L3 Occu = 4.5 mrad/s
  - LER Simulation → 4 mrad/s
  - HER Simulation → 0.5 mrad/s



- Diamonds don't see the huge discrepancy seen by SVD.

Preliminary conclusions by the SVD side

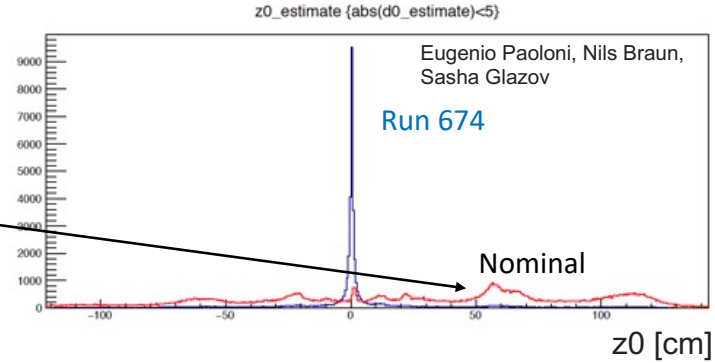
- Beam background in SVD (Apr 30 data) is higher by a factor ~ 15 w.r.t phase 2 simulation
  - Very bad since we have Occupancy limit (2%)/phase 3 simulation = 1.4!
- Diamonds don't see the huge discrepancy data simulation seen by SVD
- Possible explanation → one background component is missing in simulation, that is not affecting the diamonds while is affecting SVD, and also in PXD , can be SR and/or "beam scraping" background
  - Not affecting diamonds either because diamonds are in a different location or they are shielded or they are not sensitive to low energy photons that could be one of the sources.
- Similar conclusion also from other studies and background tests done in Belle 2 / Beast Detectors (some in next slides)
- More studies & background tests still ongoing to understand the origin of this additional background source … and hopefully reduce it

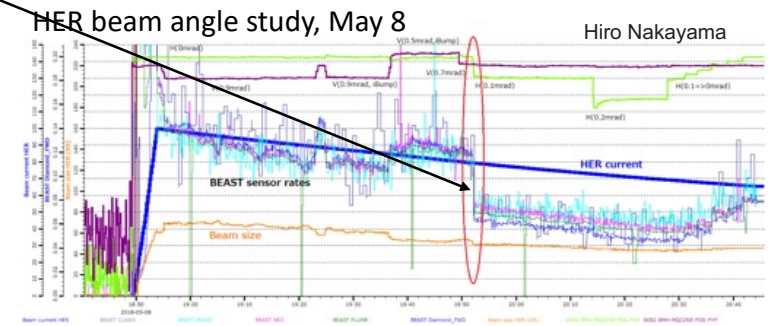
Highlights from Beam Background Group Report to Technical Board

From Sven Vahsen –May 23 2018

Initial beam orbit not optimal and hints of beam "hitting somewhere" → "beam scraping" background

- At last TB meeting, evidence for "beam scraping" backgrounds
  1. Large contribution of non-IP tracks, for "nominal" IP orbit
  2. HER horizontal angle at IP suboptimal, causing large particle backgrounds
- Expected large background reduction achievable by modifying beam orbit
- Plan made (and followed!)
  - adjust IP orbit
  - adjust collimators
  - perform systematic background study





Some improvement seen BUT still some inconsistencies and pattern not clear during recent background studies

An example: Touschek scan with “emittance knob”

- At fixed current changed the vertical beam size , with the emittance knob, and expect Touschek background change accordingly

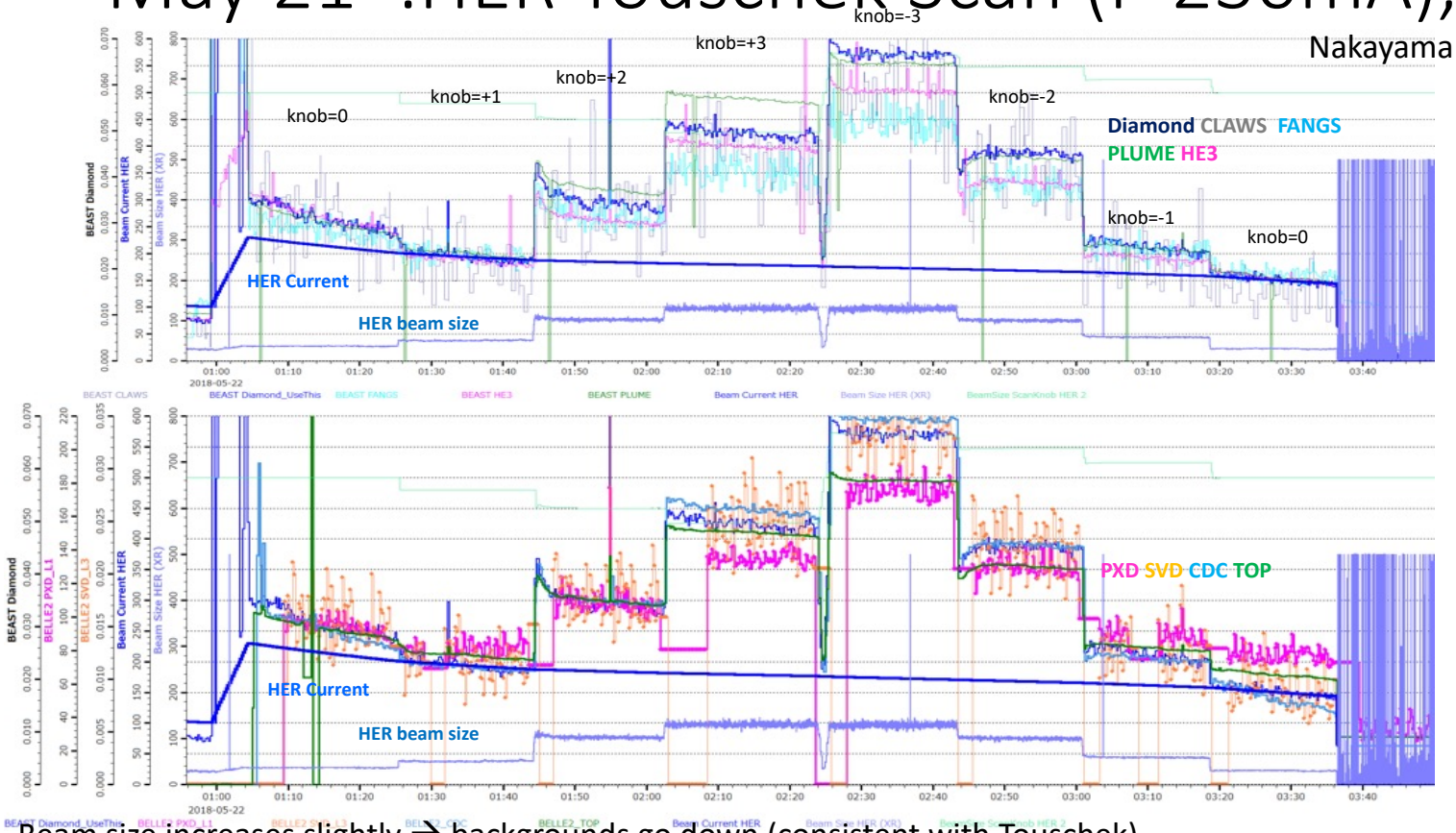
$$\text{Touschek} \propto \frac{I^2}{\sigma \cdot E^3}$$

- Larger beam size should give lower background BUT it was not the case after first step!
- Further increase of the beam size caused instead an additional increase of the background → probably beam tails hitting somewhere and the effect increases for larger beam size

May 21st:HER Touschek Scan (I=230mA),

$$\text{Touschek} \propto \frac{I^2}{\sigma \cdot E^3}$$

Nakayama



FANGS, HE3
less sensitive to knob

PLUME
more sensitive to knob

PXD,TOP
less sensitive to knob

Beam size increases slightly → backgrounds go down (consistent with Touschek)

Beam size increases more → backgrounds *increase*. Unexpected and inconsistent with Touschek → scraping beams? SR?
faster-than-linear increase with beam current, and seen in TOP. More scraping than SR?

Knob = +3 vs -3 give same beam size, but quite different background levels. A strong hint that should be followed up!

Background Situation Now

Tech Board Meeting May 23
Sven Vahsen

1. Beam gas (Coulomb scattering + bremsstrahlung): larger than simulation, due to high dynamic pressure, but continuously decreasing with vacuum scrubbing
2. Touschek: Now (with 601 bunch collision fill pattern) seems to be visible at IP for both LER and HER. Not a large fraction of total BG at IP, but currently limiting both LER and HER lifetime.
3. Luminosity backgrounds (e.g. Bhabbha): still need to be studied.
4. Injection backgrounds: Were intolerably large until recently, but substantially reduced May 19th. Working group formed to improve. Tanaka San is Belle II representative.
5. ~ 10 keV x-rays seen in FANGS and PXD: Source not yet fully understood. Are these SR and/or secondary artifacts from scraping beams?
6. Scraping beams: Major, unexpected background component. Not understood. Could change significantly as optics improve and beta* change.
7. Beam/beam backgrounds (colliding beams disturbing each other) : small, masked by background reduction due to beam blow up right now.

Ideas for Next Steps

- More dedicated background studies planned to understand the origin of the 2 unexpected additional sources: “scraping” background / Synchrotron Radiation
- Both can change as optics improves and beta* change!
- Stay tuned…

- Beam studies
  - HER + LER Beam size studies at smaller beta* (tonight! see backup slide for plan)
  - Luminosity background study
- Analysis 1: Systematic study of backgrounds composition in beam size scans
  - Beam-gas ~ I*P
  - Touschek ~ I^2/σ
  - Scraping ~ σI ?

  Assume SR=0 and use the beam size study data to fit for these three components?
- Analysis 2: Determine if low-energy x-ray BGs due to SR or scraping
  - X-ray BG in FANGS/PXD vs beam size
  - High-Z0 BG in CDC vs beam size

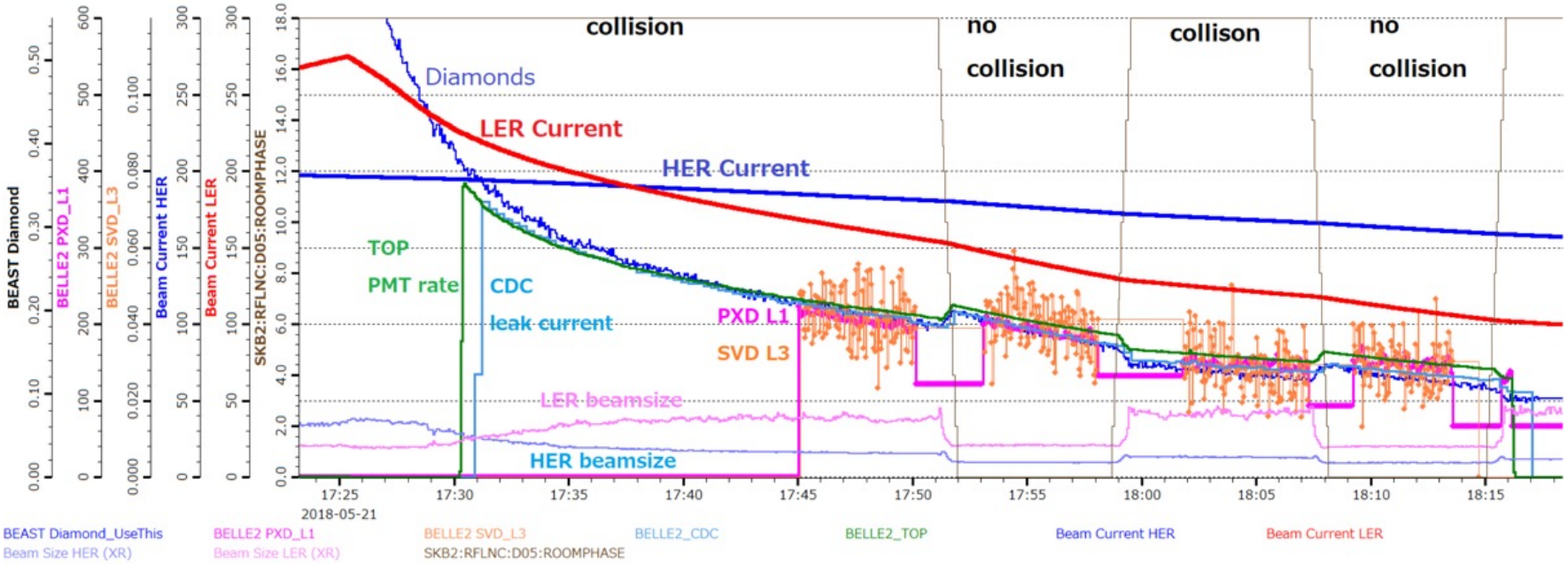
  If these vary together, it would suggest photons are due to scraping

→Need help and analysis by Belle II detector people!

- Belle II occupancies versus beam currents, and more sophisticated studies are very important. Please ask your detector experts to produce these and share with the beam background group.

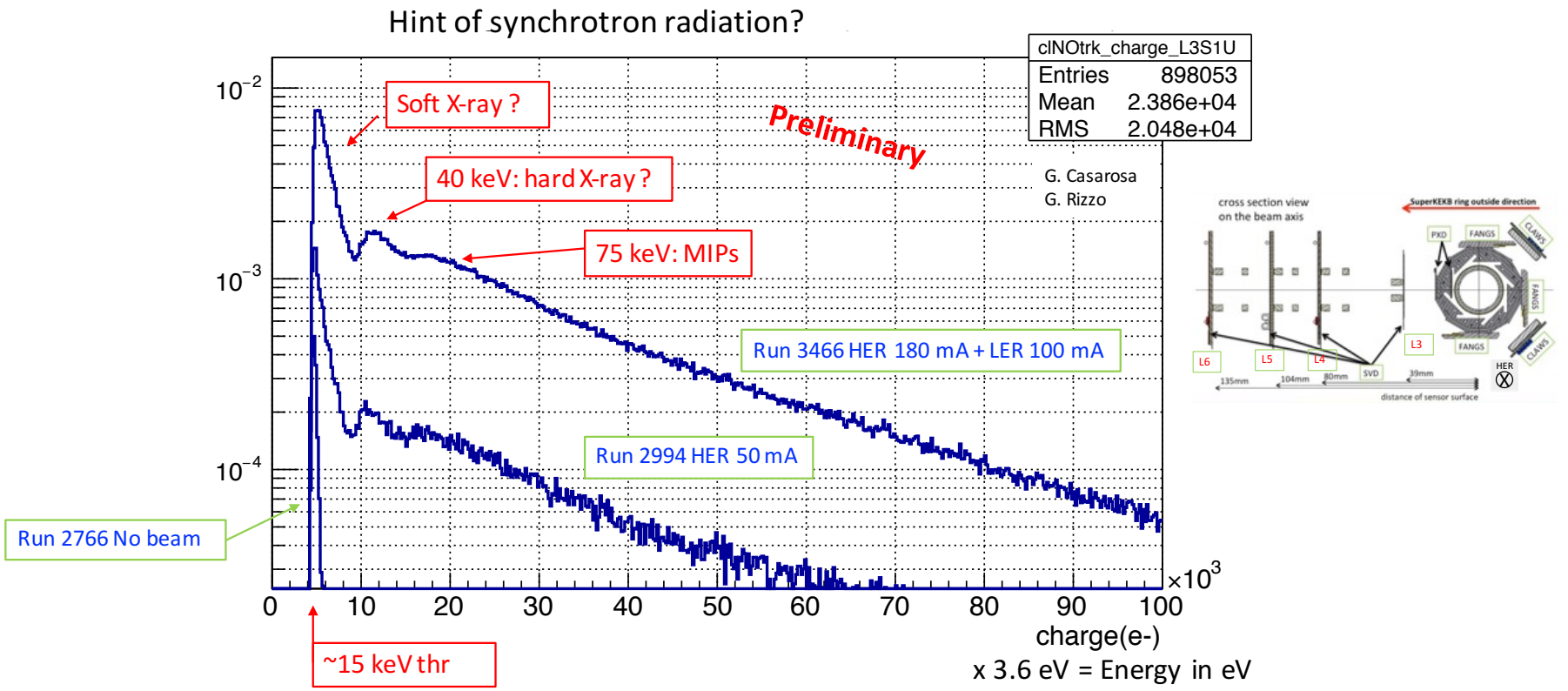
backup

Beam/Beam background test, May 21



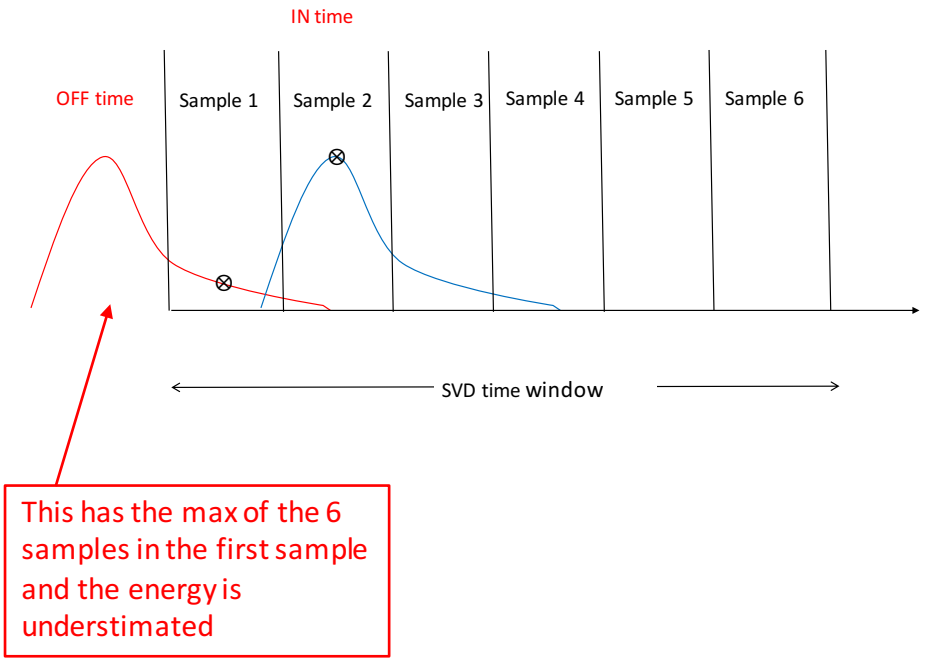
- When beams are brought into collision
  - beam size blows up (especially LER)
  - backgrounds in all detectors go *down*.
- Presumably due to Touschek background decreasing as the beams blow up. No large extra BG component during collisions at the moment.

Energy Released in SVD L3 from beam background



Check effect of OFF time particle on Energy spectrum

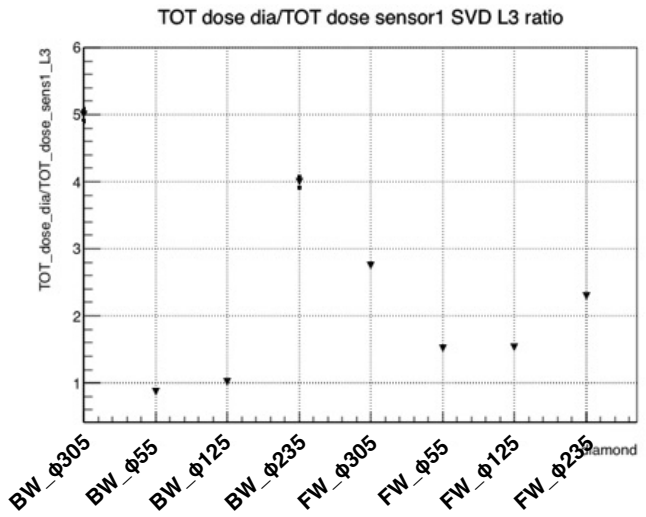
- With random trigger particle from beam background (continuous) that arrive before the SVD time window is opened, "OFF time" , can have the energy underestimated
- True for all particle MIPs or eventual X rays
- To check this effect can look at the energy spectrum for clusters that have the seed with the max of the six APV samples in the different time slots



C. LaLicata

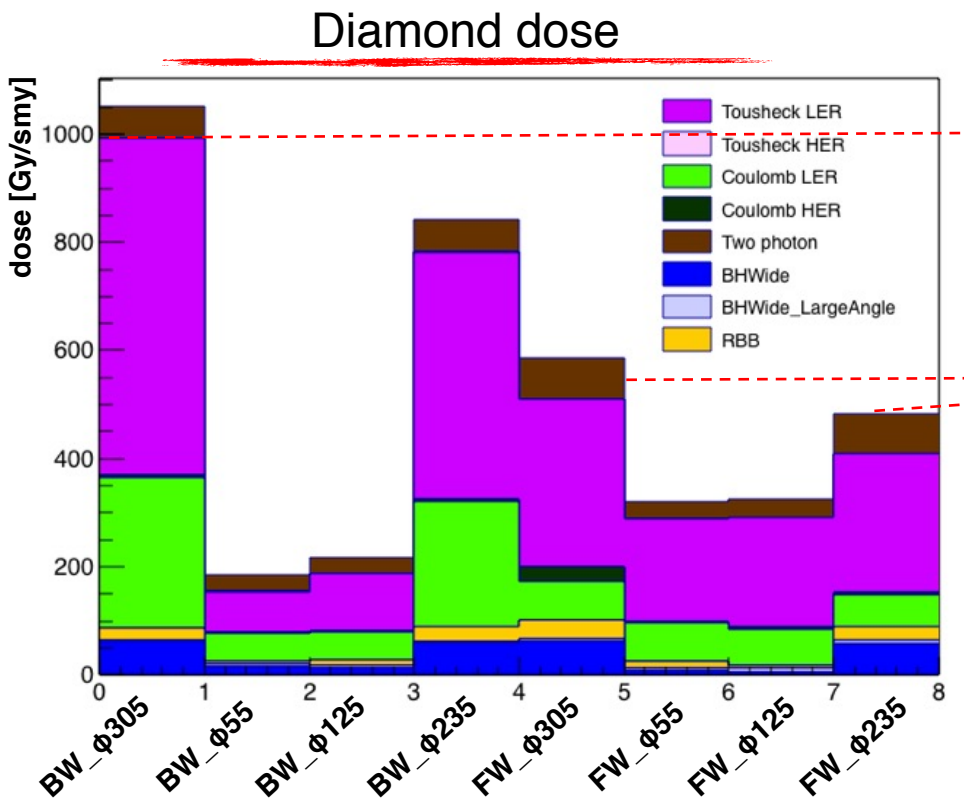
Diamond dose

Ratio total dose in diamond and L3 sensor1



	Touschek LER (Gy/smy)	Touschek HER (Gy/smy)	Coulomb LER (Gy/smy)	Coulomb HER (Gy/smy)	two photon (Gy/smy)	BHWide (Gy/smy)	BHWideLargeAngle (Gy/smy)	RBB (Gy/smy)	TOT (Gy/smy)
BW_φ305	623 ± 16	0	278 ± 10	2.8 ± 0.7	60 ± 1	63 ± 1	6.0 ± 0.4	22 ± 4	1054 ± 19
BW_φ55	75 ± 5	0.2 ± 0.1	52 ± 4	1.3 ± 0.6	30 ± 1	15 ± 1	4.4 ± 0.4	6 ± 1	184 ± 7
BW_φ125	107 ± 6	0	51 ± 4	2.1 ± 0.8	29 ± 1	14 ± 1	3.4 ± 0.3	9 ± 2	216 ± 8
BW_φ235	456 ± 13	0.6 ± 0.5	232 ± 9	5 ± 1	59 ± 1	60 ± 1	3.4 ± 0.3	27 ± 3	843 ± 16
FW_φ305	311 ± 10	0	71 ± 4	16 ± 3	76 ± 2	62 ± 1	11 ± 0.6	34 ± 5	581 ± 12
FW_φ55	188 ± 7	0	71 ± 5	3.5 ± 1.3	34 ± 1	8.2 ± 0.5	6.1 ± 0.5	11 ± 3	321 ± 9
FW_φ125	203 ± 8	0	66 ± 4	4 ± 1	34 ± 1	6.8 ± 0.4	3.4 ± 0.3	6 ± 2	323 ± 9
FW_φ235	255 ± 9	1.3 ± 0.9	58 ± 4	6 ± 1	74 ± 2	58 ± 1	6.5 ± 0.5	24 ± 4	483 ± 11

Phase 2 diamonds simulation



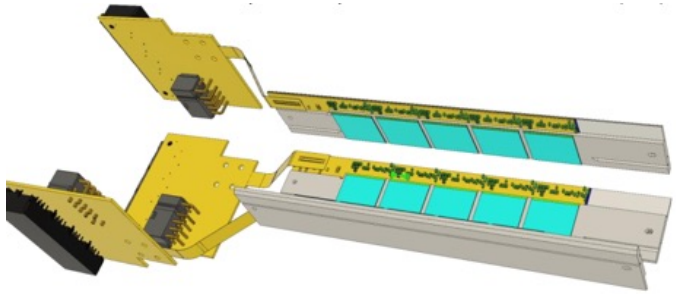
1000 Gy/yr → 10 mrad/s → 1 nA

FW diamonds ch 2-3 ~500 Gy/yr → 5 mrad/s → 0.5 nA

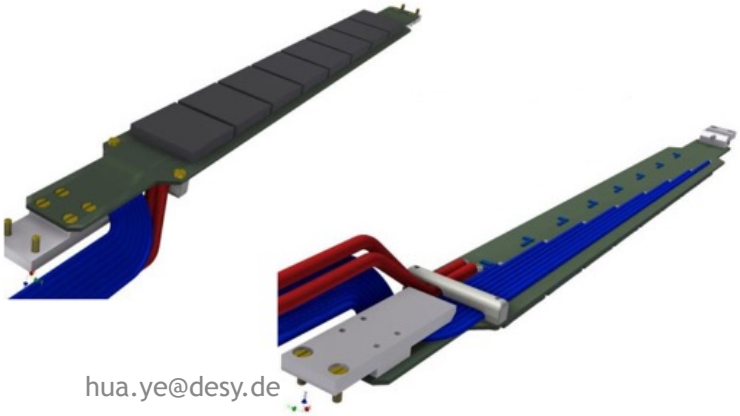
RBB: too low statistics. Problem with file production

FANGS, CLAWS and PLUME

FANGS: planar pixel with ATLAS IBL readout (FE-I4)
To investigate the Synchrotron Radiation (SR) and deposited energy spectrum of background.



CLAWS: Plastic scintillators with SiPM readout
To study the time evolution of beam injected background and its decay constant



PLUME: double-layer MIMOSA pixels
To study the spatial distribution and direction information of the beam injected background.