
# SynRad Background simulation

*Yuri Soloviev*

*DESY*

# Outlook

- Preamble
- Physics Run
- Phase 2
- Phase 1

# Preamble

Generation of primary charged beam particle and simulation of SynRad photons emission during propagation of initial particles through magnetic field requires very large (unreal) CPU to get full picture of SynRad background (needs to generate a tens of ROF to observe the hits of SynRad photons in PXD).
Two steps of SynRad background simulation:

1. **Primary simulation.** Performs full tracking of beam particle through accelerator magnets with emission of SynRad photons using GEANT4 in basf2 frame. This step has to be performed every time when geometry (beam pipe design,lattice etc.) is varied. Rough estimation of background in PXD can be done already after this step by the hit rate of photons penetrating beam pipe into PXD or by using hit rate in beam pipe and stopping power of it's material. Parameters of SynRad photons (vertex position, momentum components, etc) which hit the target region are stored in the output file. Target region is central beam pipe for Phase2 and Physics run {Z = (-9.25 – 13.75) cm, R ≤ 3} cm and the position of support structure (±2m around IP) for Phase1.
2. **Final simulation.** Output of primary simulation is transformed into HEPEvt file which is used as input for the final step of simulation (occupancy estimation,creation of background files).

# Physics Run

# Physics run

Beam currents : LER - 3.6A, HER – 2.6A, $N_{bunches}$ = 2500.

Lattice files : sler_1689, sher_5767.

Target region : Z = (-9.25 – 13.75)cm, R ≤ 3cm.

Gold plate thickness – 10μm.

Atomic Deexitation processes (FLUO and PIXE) included in Physics list.

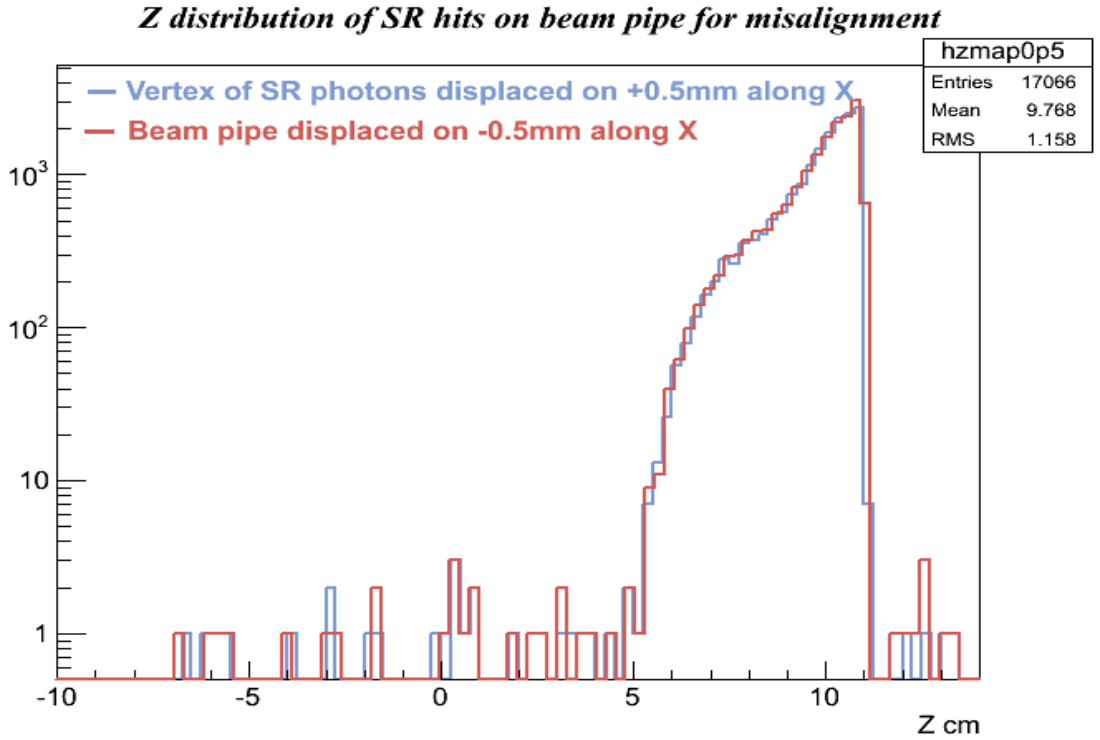
$1.99*10^{10}$ initial beam particles for HER generated ( ~ 30.6% of bunch current) with ideal alignment and gaussian beam shape.
The contribution of LER into SynRad background estimated for sler_1682 and for the Phase2 (sler_1689_dt4-8) as ~3% relative to contribution from HER.

Special case 1 – transverse nongaussian tails of the beam. Simulation is performed with uniformly distributed tails with half width = $20\sigma_{xy}$.

Normalization factor – assuming conservative assumption that fraction of tails beyond $10\sigma_x$ and $30\sigma_y$ ≤ $\boldsymbol{10^{-5}}$ (KEKB TDR). Beam beam simulation gives ≤ $\boldsymbol{5*10^{-7}}$.

# Physics run continued

Special case 2 – misalignment of central beam pipe relative to the beam orbit. Maximal expected misalignment ±0.5mm. Displacement is considered as most “dangerous” misalignment compare to rotation.
SynRad vertex position (X,Y) is shifted in HEPEvt file on 0.5mm with the sign opposite to the displacement of beam pipe.
For the cross-check the simulation was done for misaligned beam pipe. Both methods give statistically compatible results.

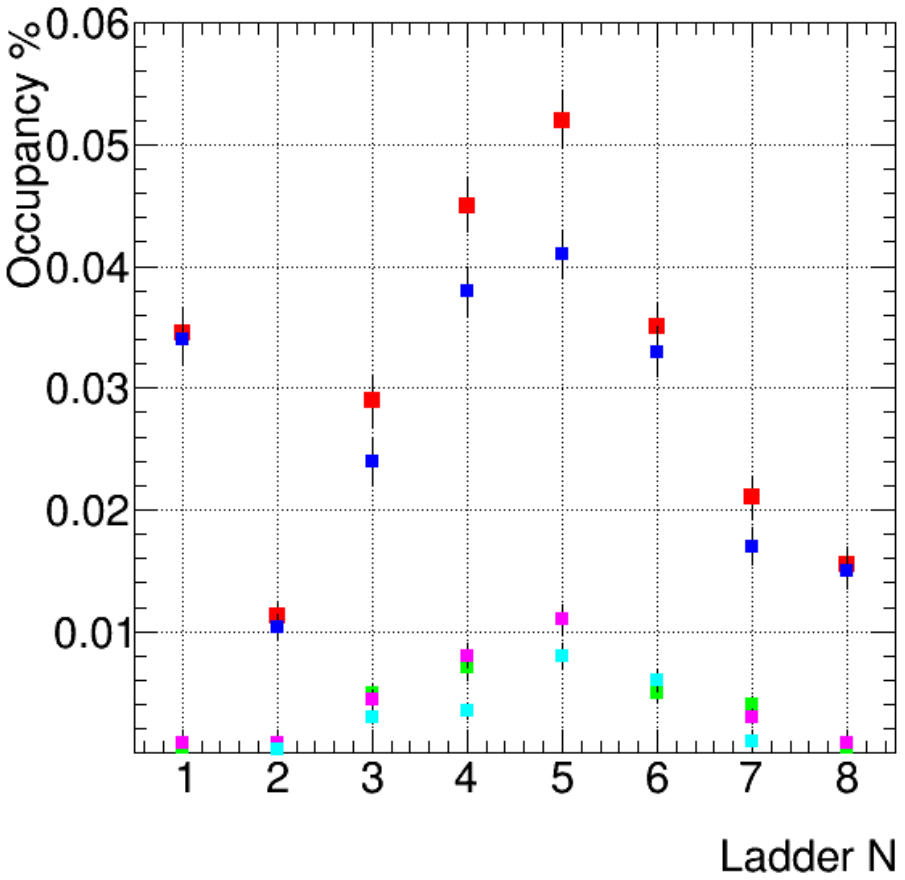



Both misalignment and beam tails cases performed for smaller samples of 4ROF for sher_5753 and compared with the same sample of ideal alignment and gaussian case.

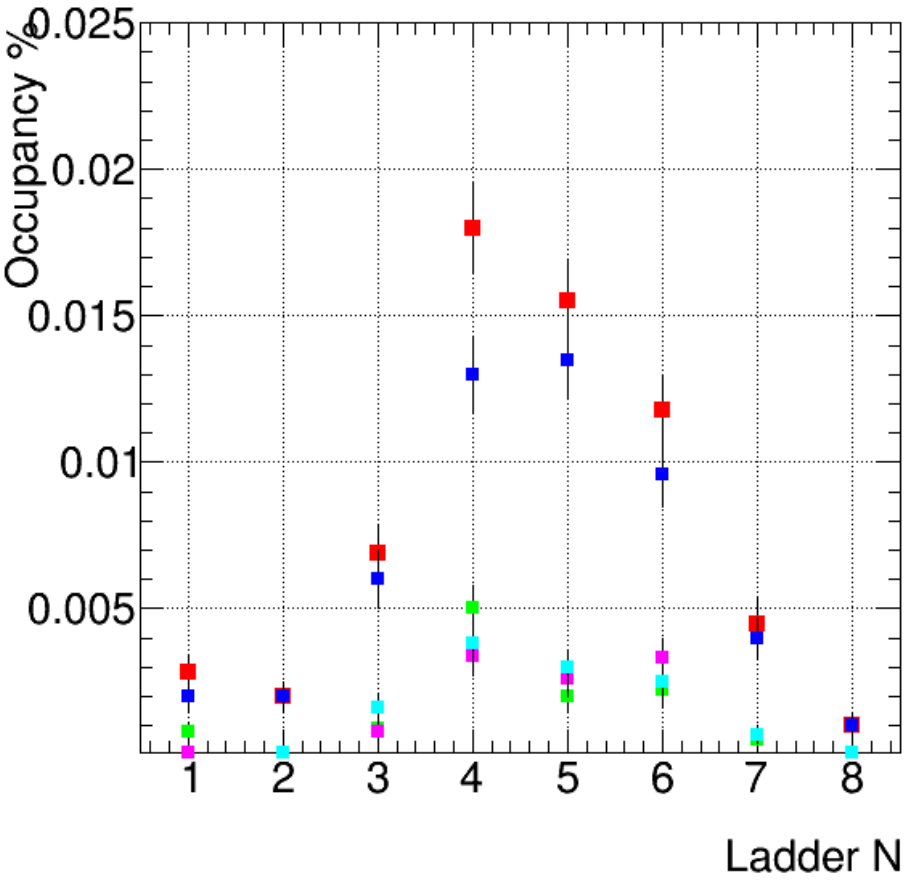
# Physics run continued

## Contribution of beam tails and misalignment to occupancy

Color Code:
Ideal alignment
Misalignment -0.5mm
Misalignment +0.5mm
Uniform Beam Halo ($10^{-5}$)
Total =Ideal + Uniform Halo




PXD Occupancy Layer1 Sensor1

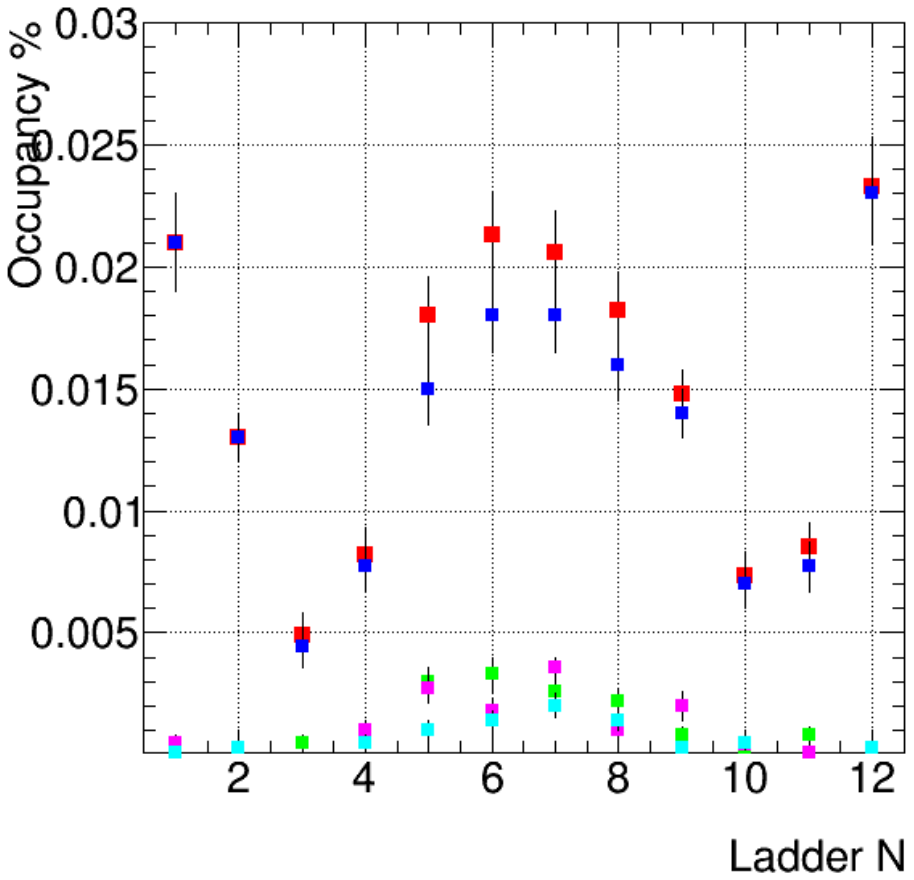



PXD Occupancy Layer1 Sensor2

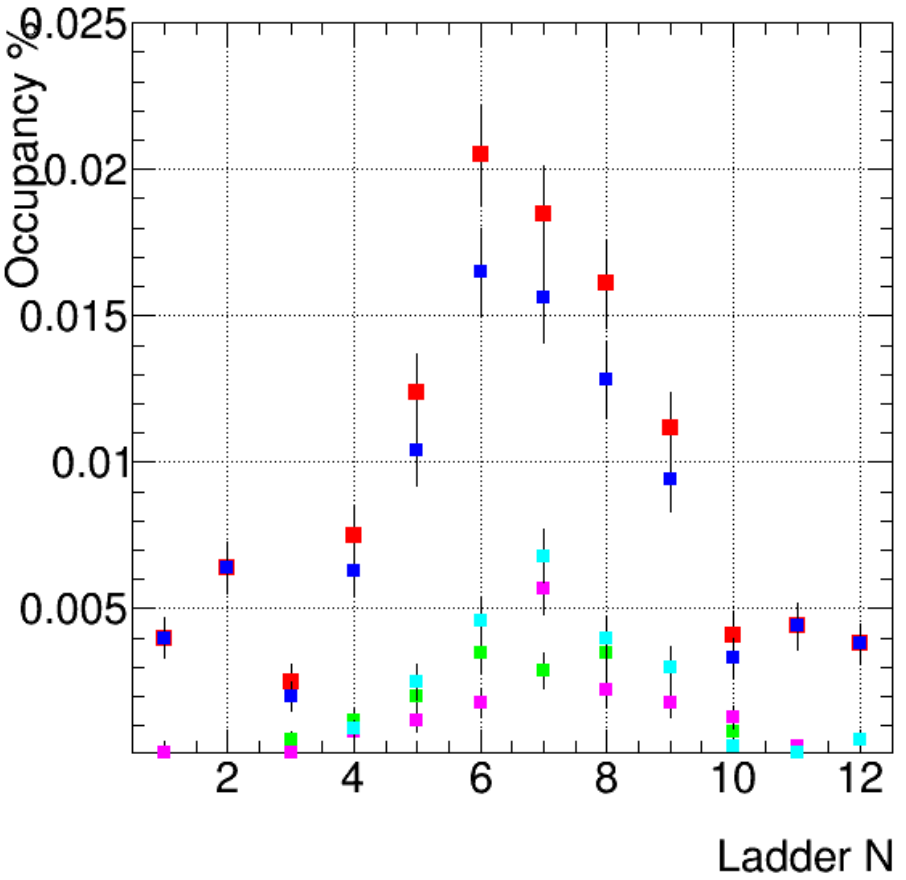
# Physics run continued

## Contribution of beam tails and misalignment to occupancy

Color Code:
Ideal alignment
Misalignment -0.5mm
Misalignment +0.5mm
Uniform Beam Halo ($10^{-5}$)
Total =Ideal + Uniform Halo




PXD Occupancy Layer2 Sensor1

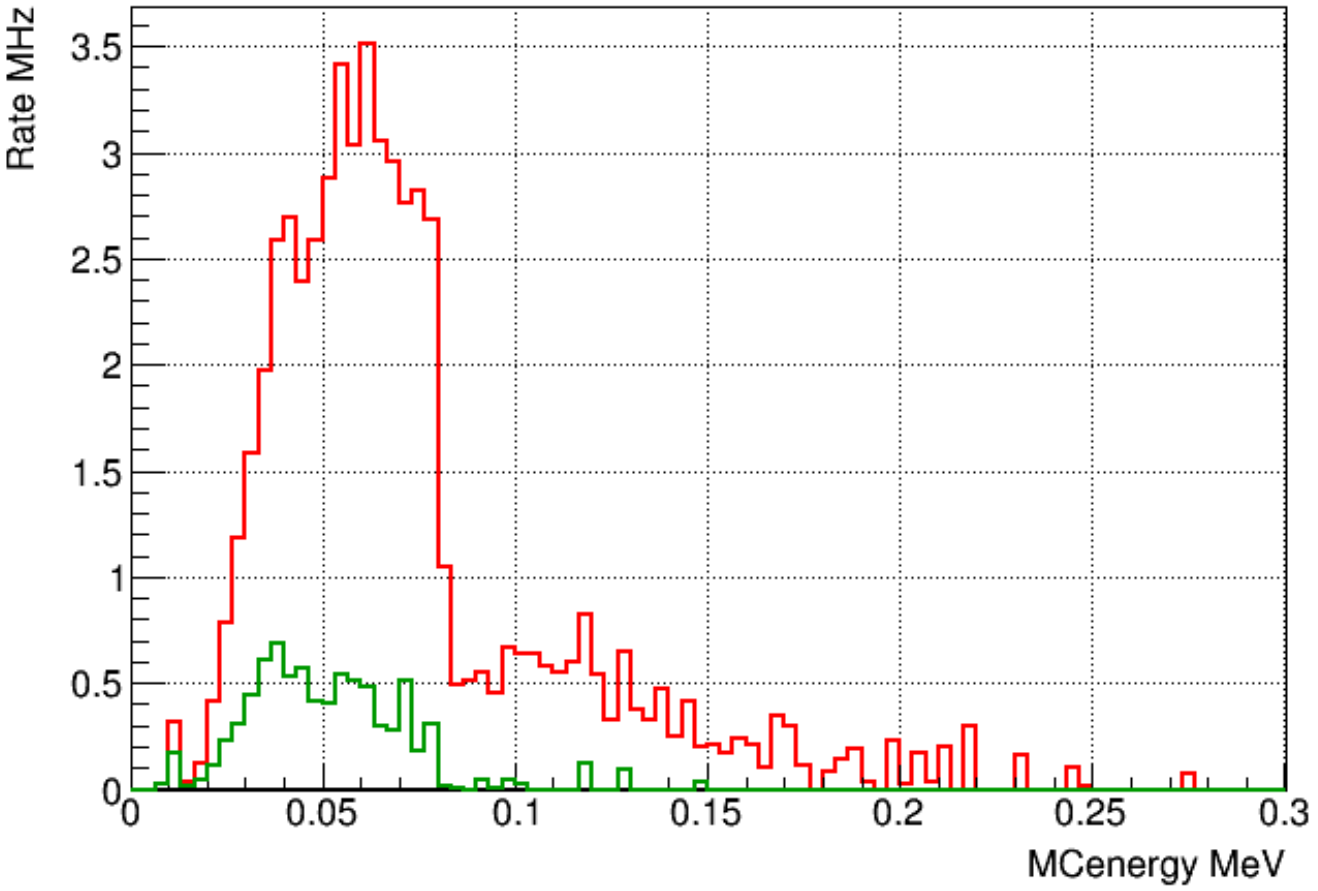



PXD Occupancy Layer2 Sensor2

# Physics run continued

## Energy spectrum

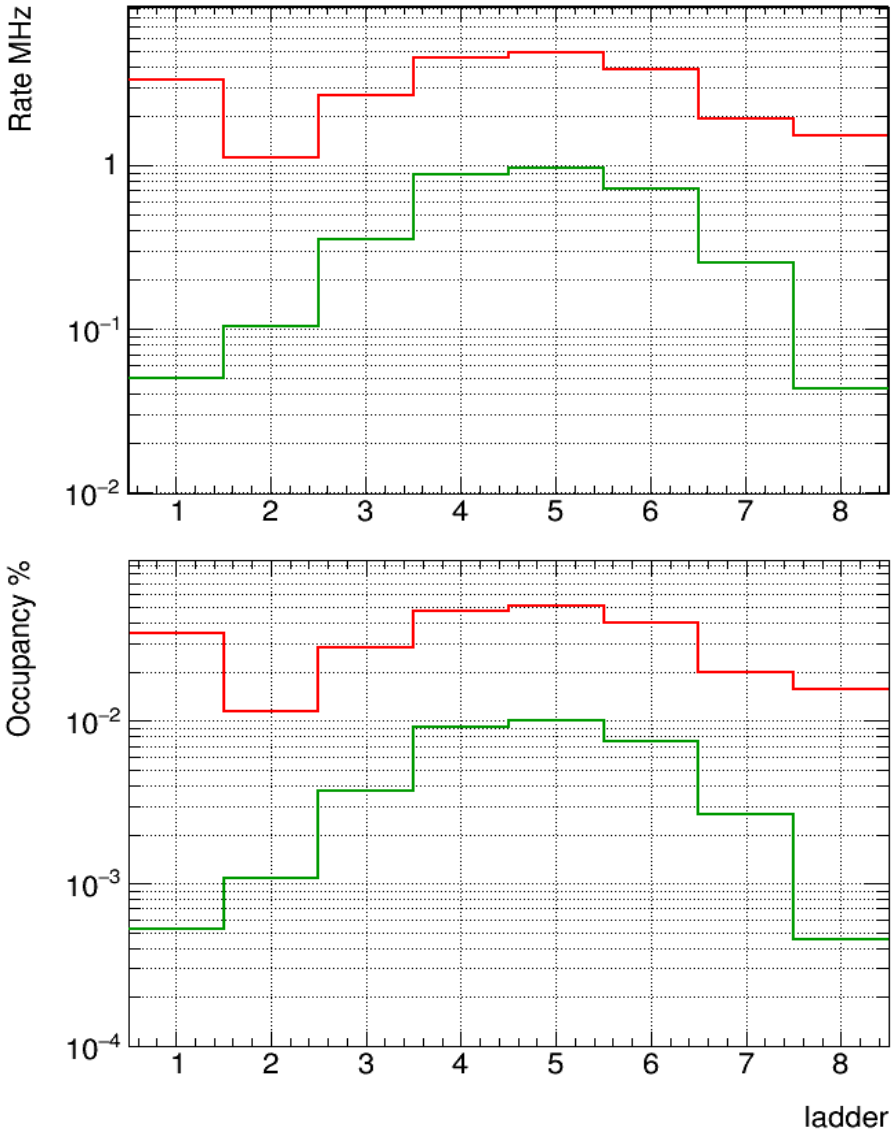
Color Code: Tail's fraction $10^{-5}$, Gaussian shape of the bunch



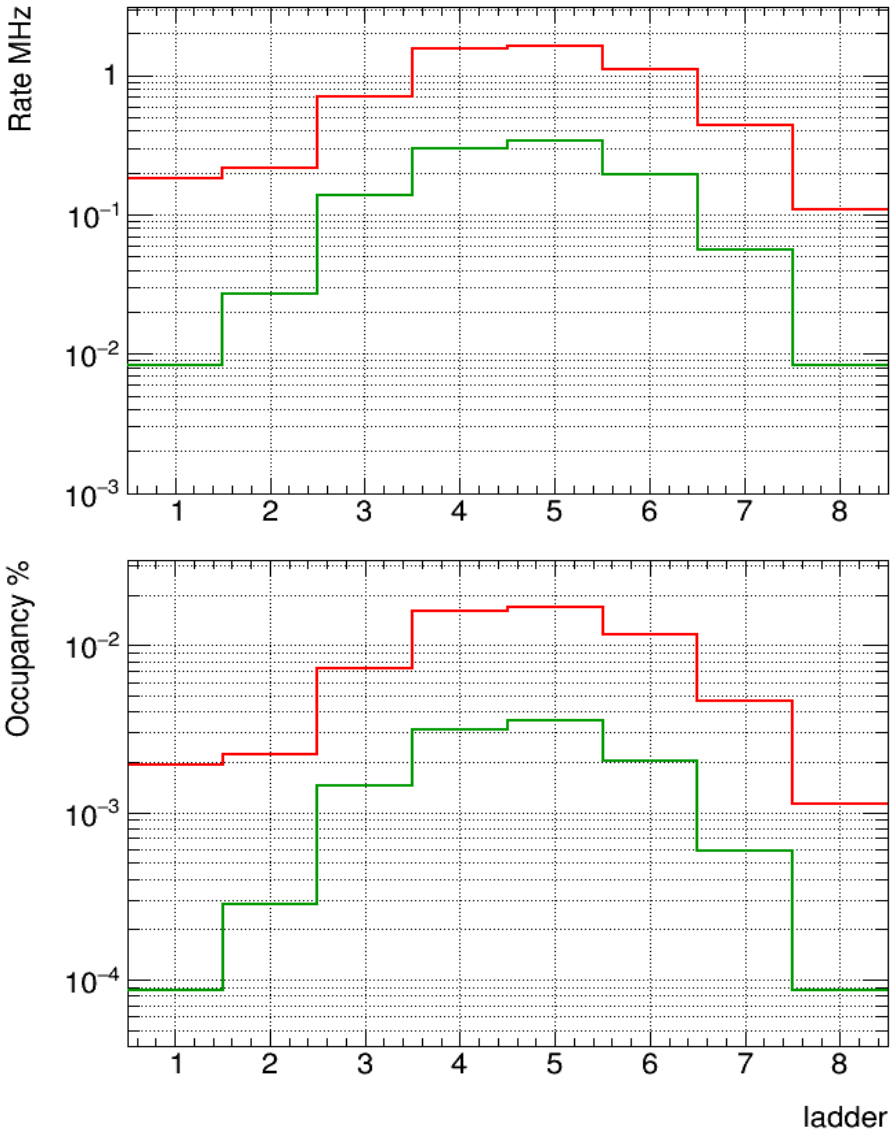
# Physics run continued

## Hit Rates & Occupancy

Color Code: Tail's fraction $10^{-5}$, Gaussian shape of the bunch




Layer1 Sensor1

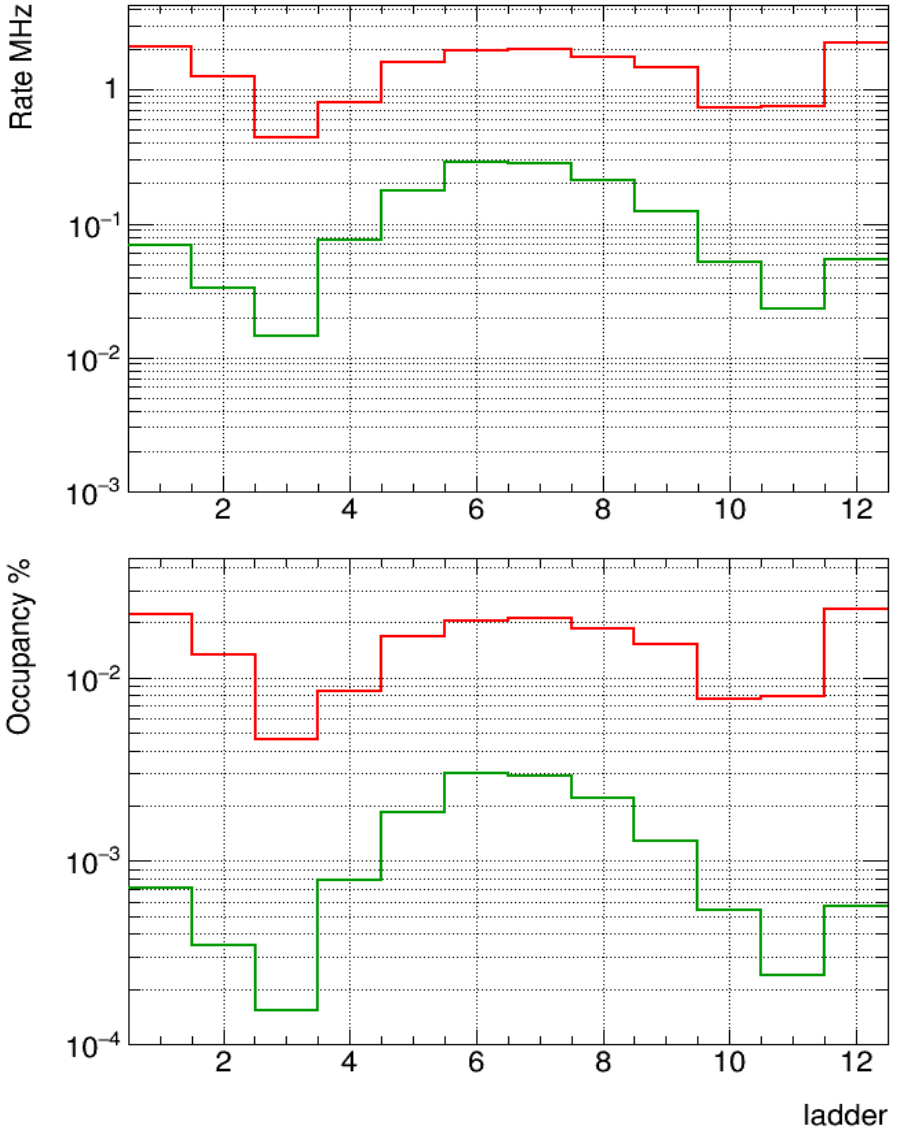



Layer1 Sensor2

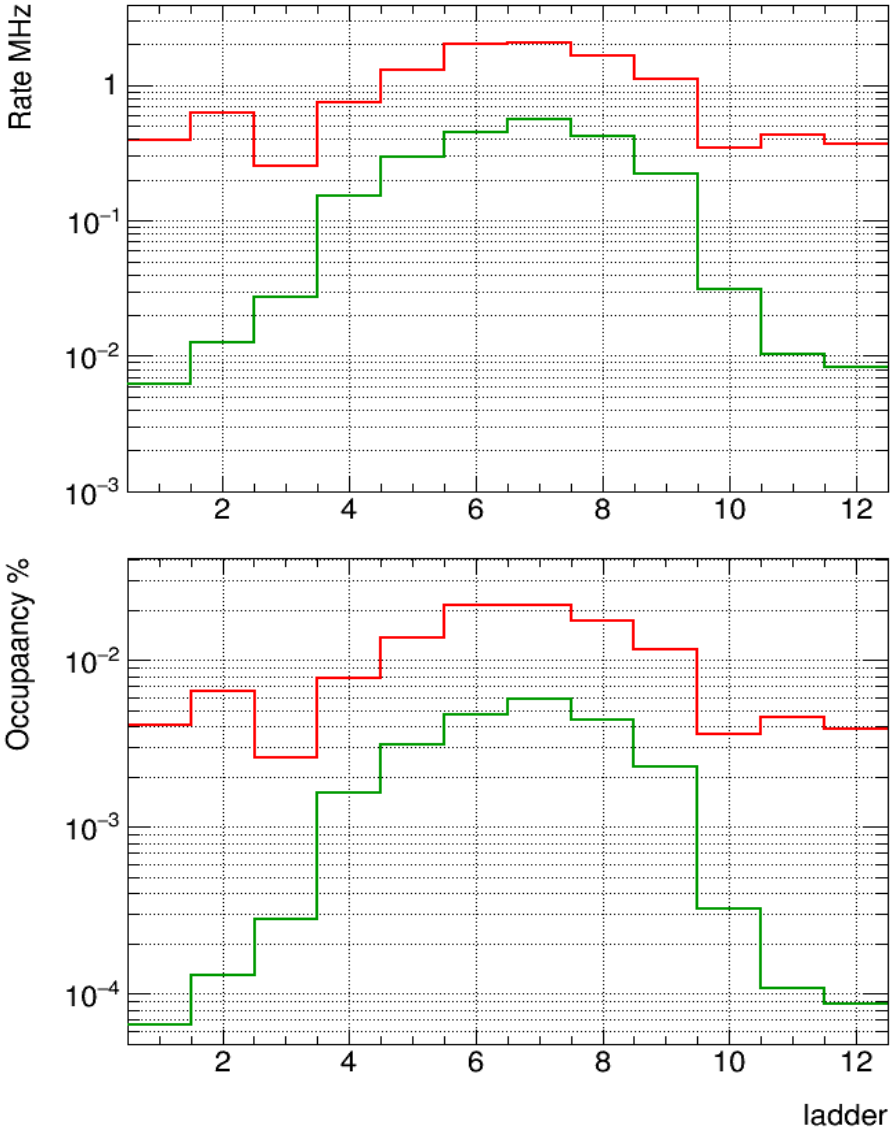
# Physics run continued

## Hit Rates & Occupancy

Color Code: Tail's fraction $10^{-5}$, Gaussian shape of the bunch




Layer2 Sensor1




Layer2 Sensor2

# Phase 2

# Phase 2

Beam currents : LER - 1A, HER – 0.8A , $N_{bunches}$ = 2500 (last stage of Phase 2 and first stage of Phase 3).

Lattice files : sler_1689_dt4-8, sher_5767_dt4-8 ($\beta_x$ : *4, $\beta_y$ : *8) (last stage of Phase 2 and first stage of Phase 3)

Target region : Z = (-9.25 – 13.75)cm, R ≤ 3cm.

Gold plate thickness – 6.6μm.

Atomic Deexitation processes (FLUO and PIXE) included in Physics list.

$2.14*10^{10}$ initial beam particles for HER generated ( ~ 107% of bunch current).
$3.51*10^{10}$ initial beam particles for HER generated ( ~ 140% of bunch current).

Simulation is performed both for HER and LER and the contribution of SynRad background from LER estimated to ~3% related to HER.

# Phase 2

## Hit Rate and Occupancy

Estimated rates and occupancy from SynRad photons for ladder 1, which will be installed. Lower (first) value related to gaussian shape of the bunch, high (second) value related to the tail's fraction $10^{-5}$.

| | | Sensor 1 | Sensor 2 |
|---|---|---|---|
| Layer 1 | Rate KHz | (20 — $10^{3}$) | (10 — 65) |
| | Occup % | ($2*10^{-4}$ – $10^{-2}$) | ($10^{-4}$ – $7*10^{-4}$) |
| Layer 2 | Rate KHz | (10 — 650) | (5 — 130) |
| | Occup % | ($10^{-4}$ – $7*10^{-3}$) | ($5*10^{-5}$ – $1.4*10^{-3}$) |

( High values reported in Trieste was calculated using wrong scaling factor :-( )

# Phase 1

# Phase1 - Primary simulation

- Magnets around IP in Phase1:
  HER:
  ZHQLC2LE(BEND) dS = (5.24827 – 5.59267)m
  QLC2LE(QUAD) dS = ( 5.839 – 6.398)m
  BLC1LE(BEND) dS = (7.50549 – 11.105490)m
  LER:
  BLCWRP(BEND) dS = (5.538129 – 7.768419)m
  BLC1RP(BEND) dS = (8.268419 – 10.498709)m

  Correction magnets are not taken into account.

- Effective length of the magnet = magnet length +1/2 length of the slope of the field at each edge.
  Value of magnetic field:
  For the bending magnets - constant field inside effective length, for the quad magnet field = field gradient * deviation from the central orbit inside effective length.

# Phase1 - Primary simulation

- ParticleGun parameters:

  $\varepsilon_{HERx}$ = 4.45nm  $\varepsilon_{LERx}$ = 1.95nm  $\varepsilon_y/\varepsilon_x$ = 10%

  (Y.Ohnishi “Commissioning tools and optics”, March 13, 2015, Super KEKB.)

  α and β  from sher_5767_phase1.disp file for S = 11.61m
  (generation point for HER),
  from sler_1689_phase1.disp file for  S = 3005.25m
  (generation point for LER).

- Target region for SynRad  ± 2m around IP (~dimensions of support structure).

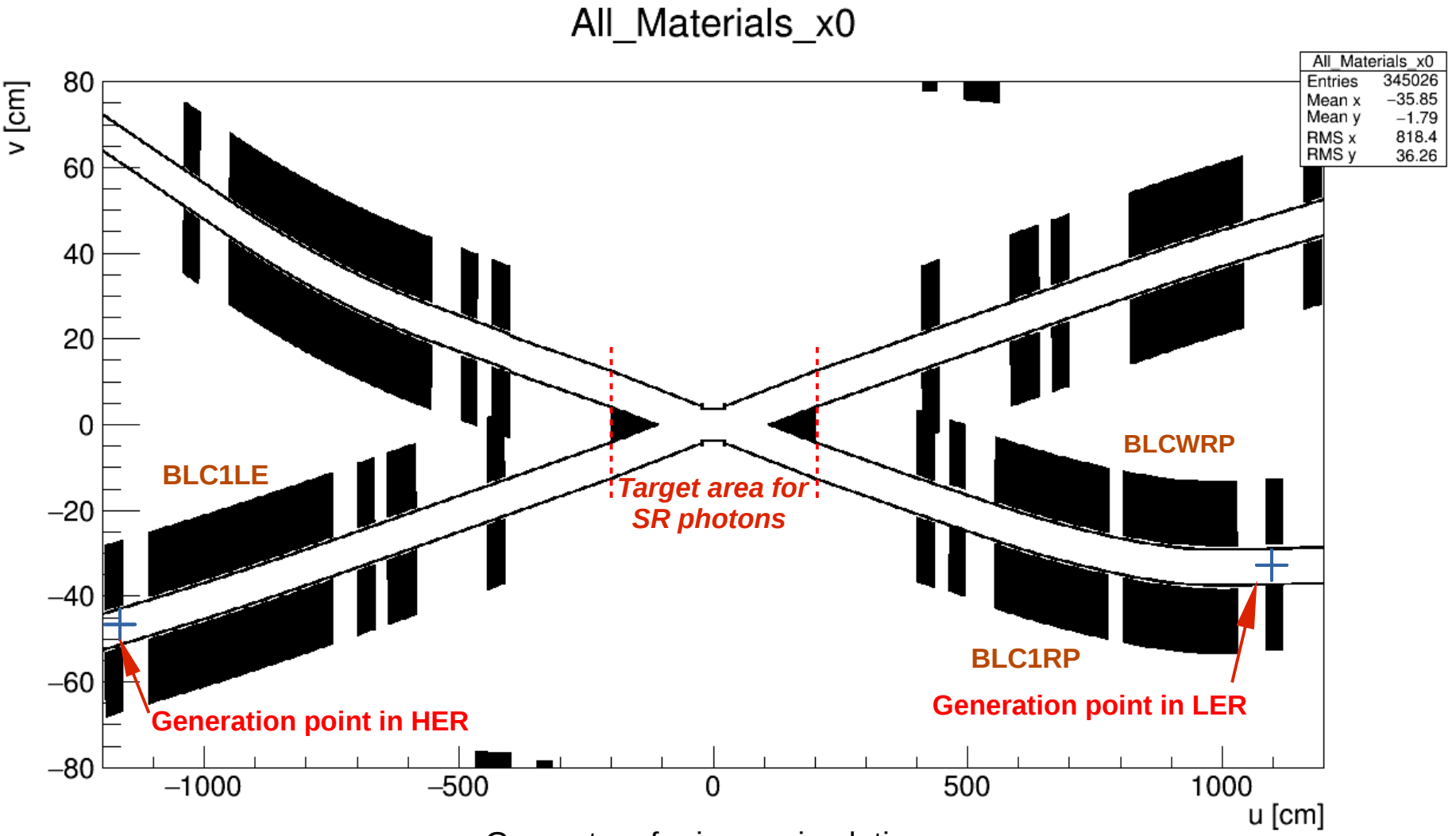
- The thickness of the Al beam pipe wall – 4mm → Ethr = 14KeV.
  (Fraction of transmitted intensity ~ $10^{-6}$).
  The value of 10KeV  kept in simulation.

- Different beam pipe design → new beam pipe geometry code for Phase1.

- Ideal alignment and gaussian shape of the bunch.

- 2.5*$10^{10}$ initial particles $(e^+/e^-)$ → 1 bunch of 1a current for HER and LER.
  1a current will be used only for vacuum scrubbing in Phase1,otherwise much lower currents.

# Phase1 - Primary simulation




Geometry of primary simulation

Most of the SynRad photons in the target area are from BLC1LE and BLC1RP magnets.

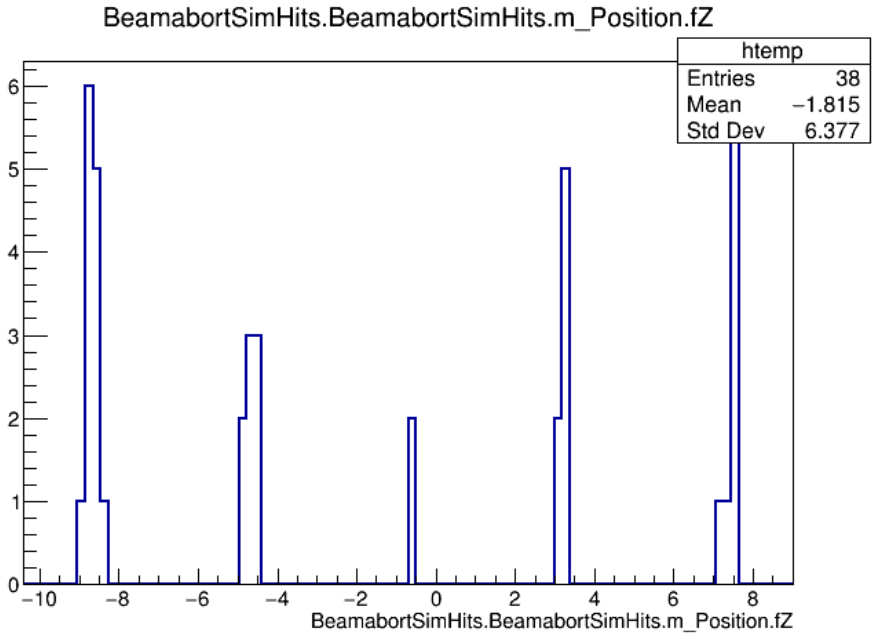
# Phase1 - Final simulation

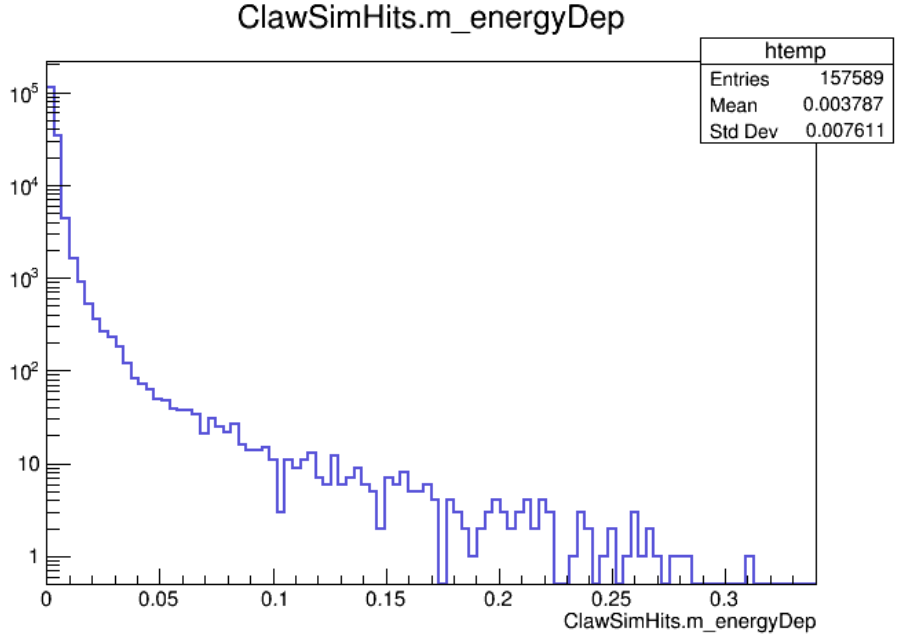
- 100 ROF (2msec real time) are generated both for HER and LER.
  Assuming beam current of **1a** for both HER and LER in Phase1.

- Phase1 detectors included : BGO, Pindiode, Csi, Claw, Beamabort, He3tube,Microtpc.

  **<u>No SimHits observed in all detectors</u>** both for HER and LER.

- Crosscheck:
  Momentum and energy in HEPEvt file converted from KeV to MeV.
  Simulation for 20nsec real time produces SimHits in all detectors.

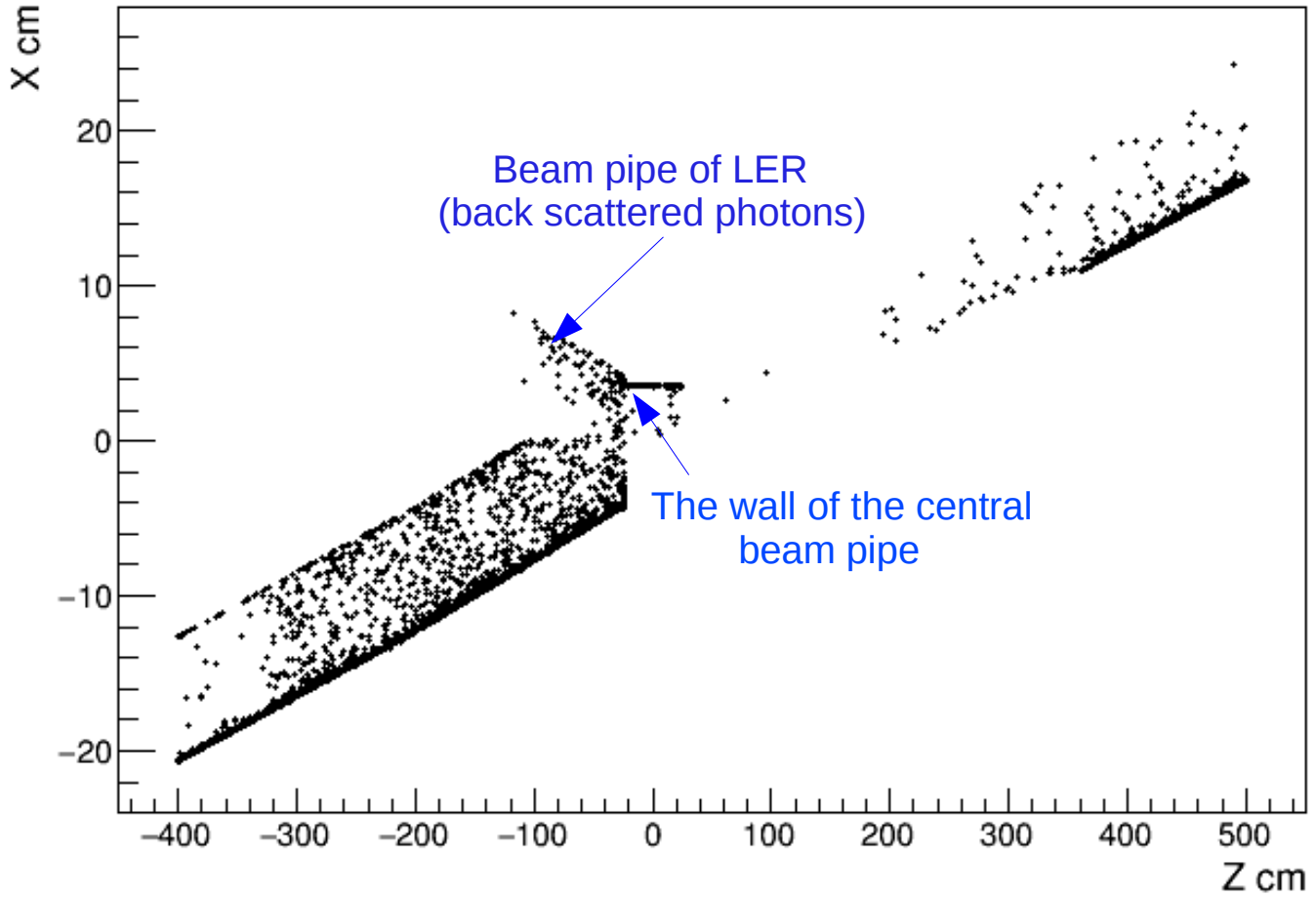


# Phase1 - Final simulation

Where are the hits ?

20ns file generated keeping all hits ~ 3.3*$10^6$ photons
4.5% - left detector at the end of the world volume
95.5% - stopped in the detector (beam pipe)



# Conclusions and plans

- Physics run - large spread of predictions for hit rate and occupancy due to unknown fraction and shape of transverse beam tails. Even with conservative assumption of flat tails distribution the occupancy in PXD is tolerable.

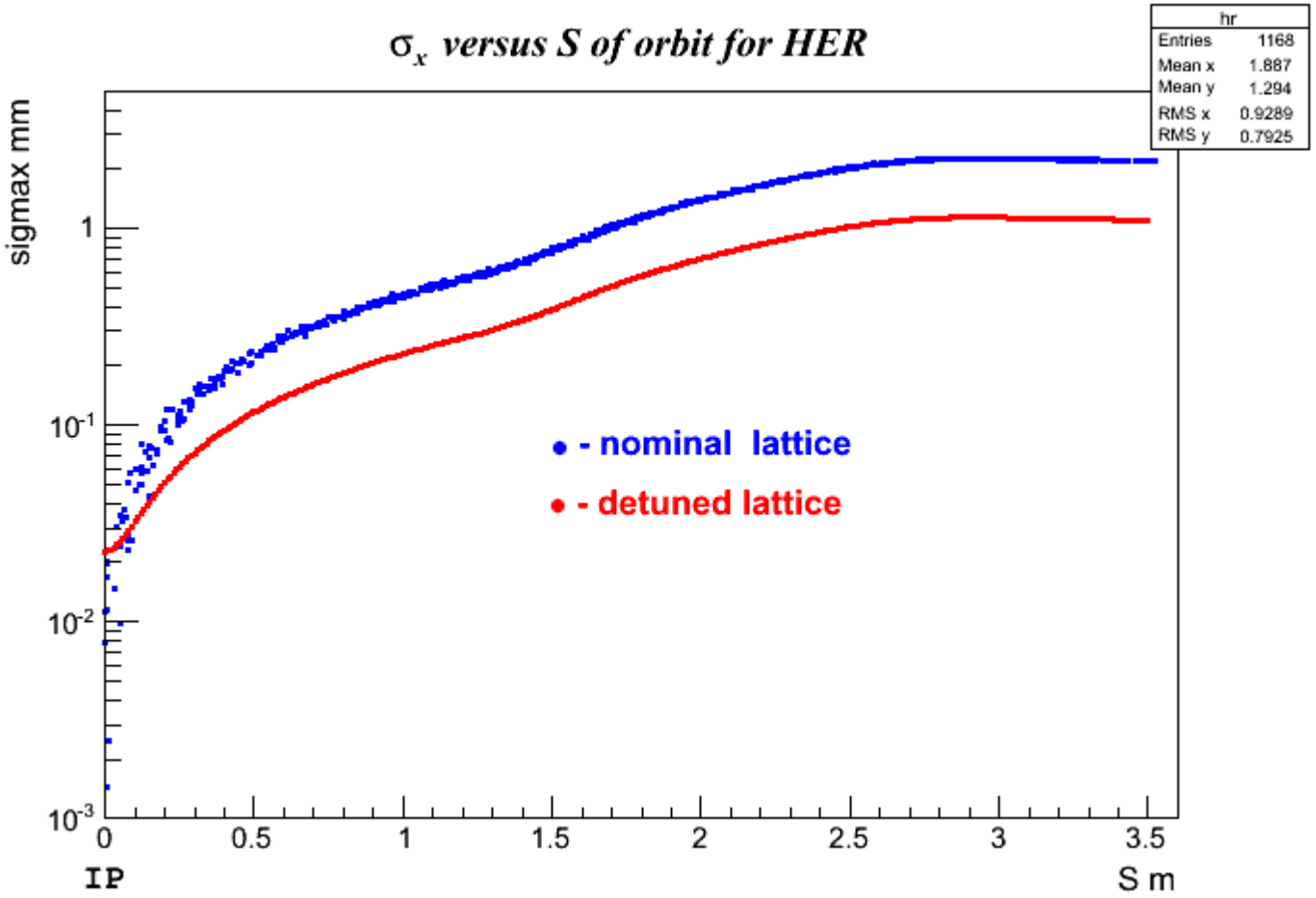
- Phase 2 - similar large spread due to unknown fraction of tails. The rates and occupancy for installed ladder 1 of PXD are predicted.
  Next step to simulate SynRad for Phase 2 in MC campaign for BEAST II.

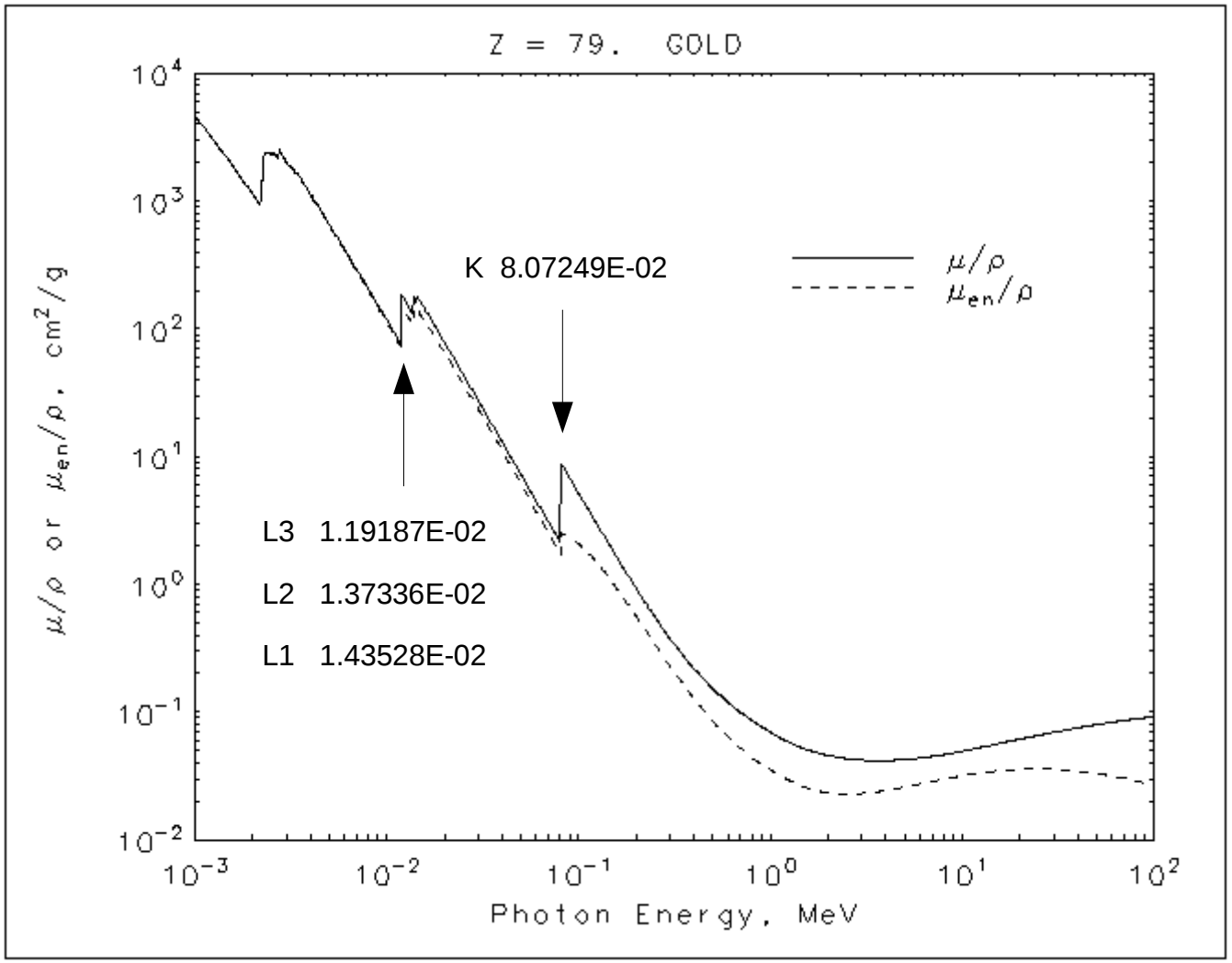
- Phase 1 - simulation of 100ROF (2msec) gives no hits in all detectors. Apparently most of SynRad photons are absorbed in beam pipe walls.

Thank you for your attention

# Additional material

# Beam size in X plane versus S orbit




Z = 79. GOLD
K 8.07249E-02
L3 1.19187E-02
L2 1.37336E-02
L1 1.43528E-02
μ/ρ
μen/ρ
μ/ρ or μen/ρ, cm²/g
Photon Energy, MeV

# Phase2/3 Summary

## Energy Spectrum