Study of the electromagnetic background rates in CLAS12

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Abstract

Simulations of beam-related background were performed for two CLAS12 configurations: FT operational and FT present but not operational. The rates in various detectors were calculated: Drift Chambers (DC), High Threshold Cerenkov Counter (HTCC), Forward Time-Of-Flight (FTOF), Forward Tagger (FT) and the electromagnetic calorimeter (ECAL). The geometry includes the latest engineering models of the target, beamline, vacuum line, torus and shielding.

Simulated Detector, Beam and Target Configuration

This simulation study is based on the two CLAS12 standard configurations. The Moller cone geometry corresponds to the final engineering design [1], [2], [3]. The beamline, target, shielding, torus components and vacuum beamline geometry were incorporated in geant4 directly from the engineering CAD models.
For each event, 124,000 electrons going through the target within a 250 ns time window were simulated. This corresponds to the full CLAS12 10^{35} $cm^{-2}s^{-1}$ luminosity on a 5cm LH2 target. Simulations were performed for both 10.6 GeV and 6.4 GeV beam energy. Here results for the highest energy are reported: rates and occupancies for the lower energy were anyway found to be similar with differences of the order of 10%.
The geometries of the two configurations are described below:

- FTOn: FT is operational. The Moller shield starts at z=877 mm from the target center.

- FTOff: FT is present but not operational. The FT tracker is replaced by shielding. The Moller shield starts at z=430 mm from the target center, and additional shielding is present to connect it to the FT.

The two configurations are shown in Figure 1. For the FTOn configuration both polarities of the torus field were simulated.

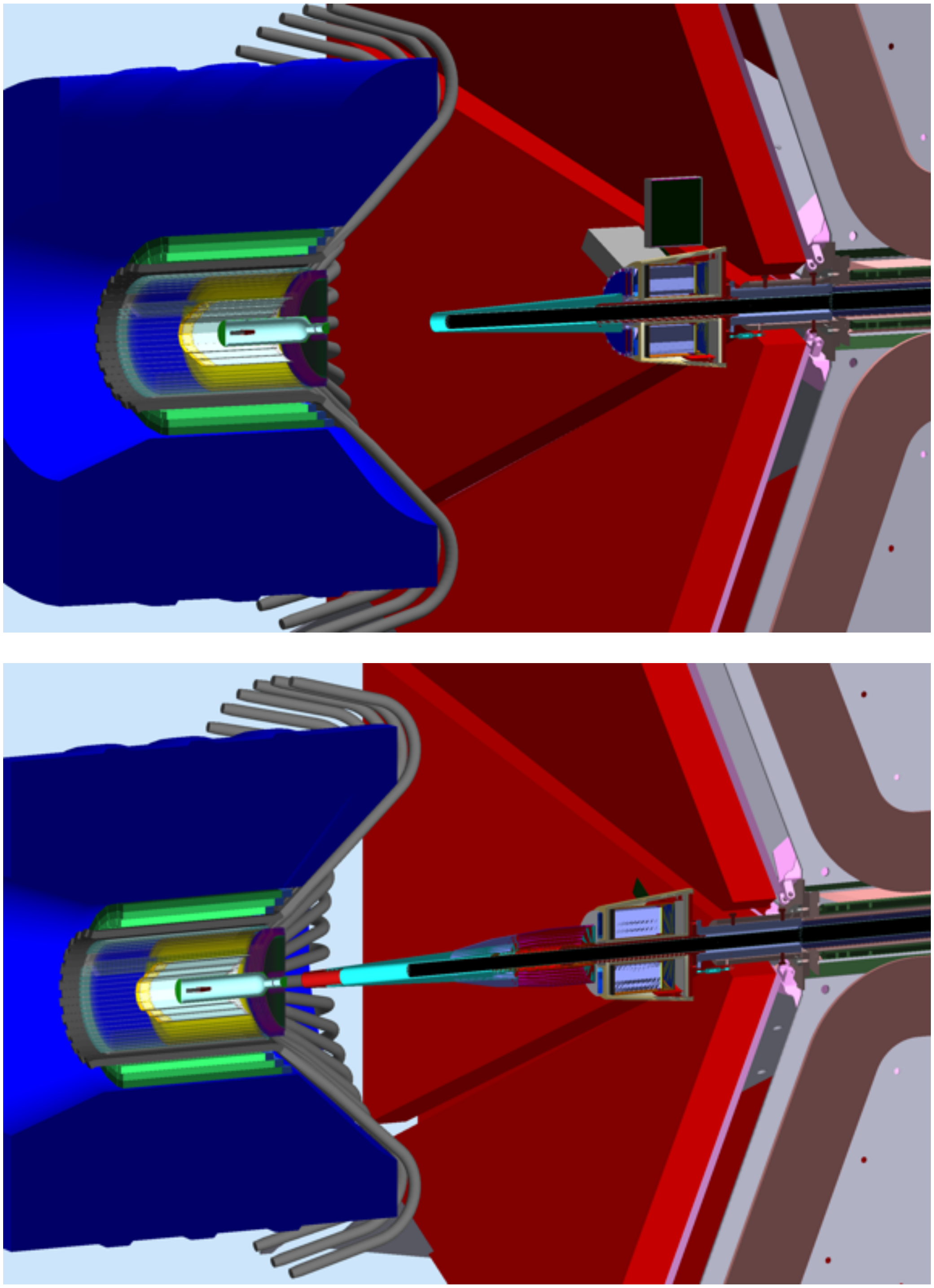

Figure 1: The two possible CLAS12 configurations. Top: FTOn; the FT is operational. To clear its acceptance at forward angles (2.5^0-4.5^0 degrees) the Moller shield (cyan color) is attached to the FT tracker, starting at z=877 mm from the target. Bottom: FToff; the FT is present but not operational. The FT tracker is replaced with a shield. The Moller cone is placed at z=430 mm from the target and additional shielding minimize background in Region 1 Drift Chambers.

Rates in the DCs

a. **FTOn Configuration, in-bending and out-bending electrons:**
The larger occupancy is in Region 1. There is no difference in the occupancy or the hit distribution for the two torus polarities, see Figure 2. Historically the desired DC occupancy limit is 3%.

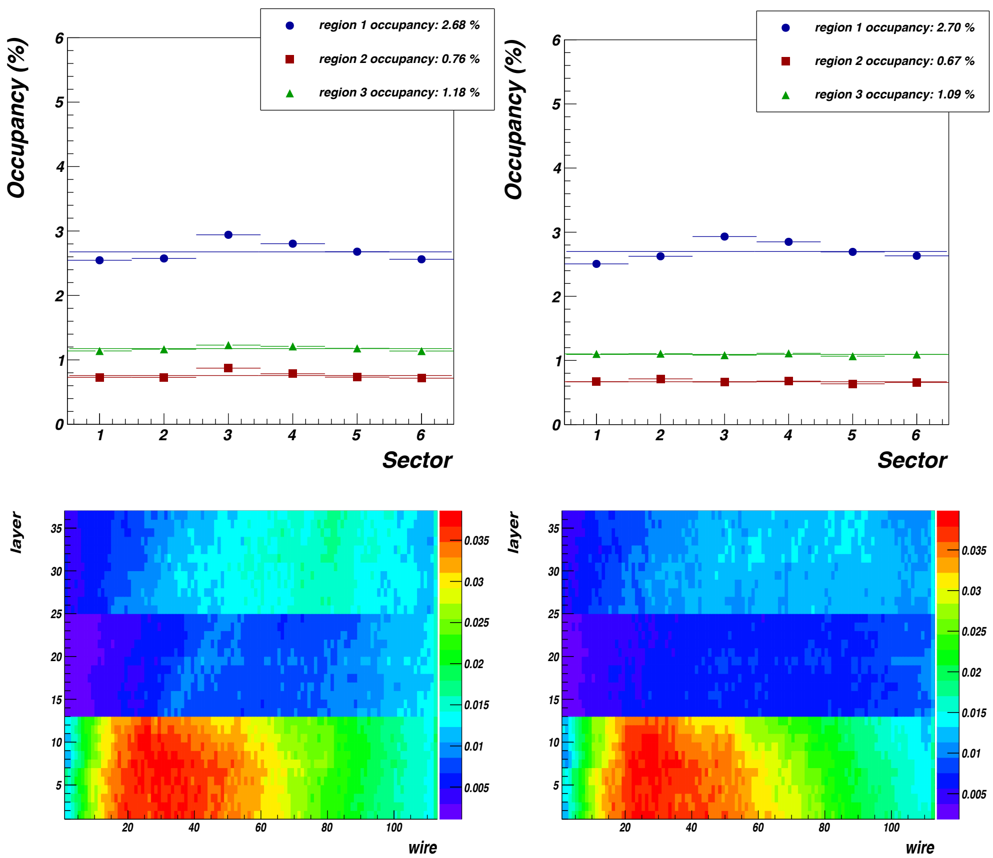

Figure 2: Results for DC rates for electron in-bending (left column) and out-bending (right column). Top: the occupancies are below 3% for region 1 and below 1.2% for region 3. Bottom: layer versus wire hit distribution: the two torus polarities show very similar distributions.

b. FTOff Configuration, in-bending:

The occupancy is much lower in all regions, see Figure 3.
The hit distribution is qualitatively similar to the FTOn configuration.

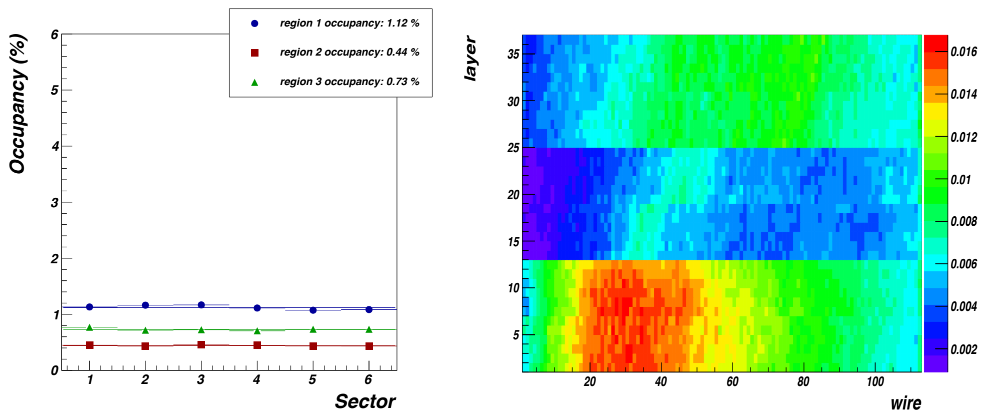

Figure 3: Results for DC rates for the FTOff configurations. Left: the occupancies are significantly lower than for the FTon geometry. Right: layer versus wire hit distribution.

Rates in the HTCC

a. **FTOn Configuration, in-bending and out-bending electrons:**
The largest rate is in the inner HTCC ring. There is no significant difference in the hit rates or distribution for the two torus polarities, see Figure 4. The first ring sees a 100 kHz rate w/o threshold, reduced to about 25 kHz with a 3 npe threshold and 12 kHz with a 10 npe threshold. See Figure 6 for a reference picture of the four HTCC rings.

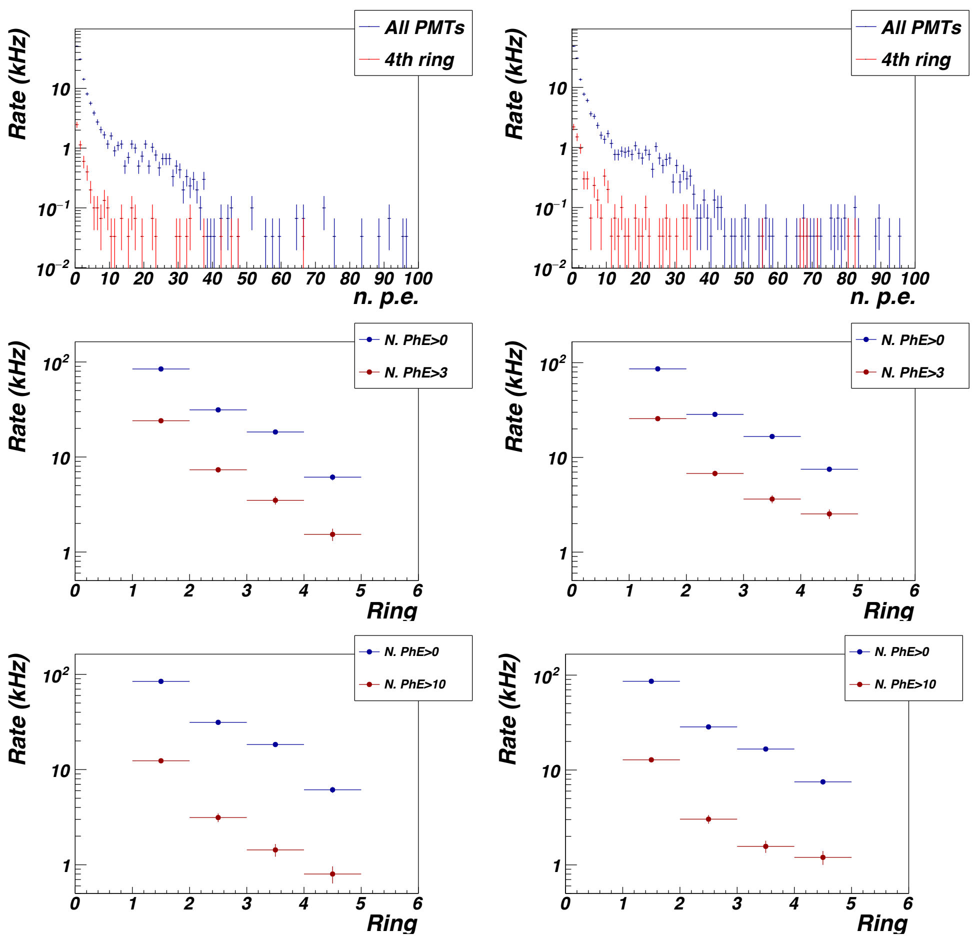

Figure 4: Results for HTCC rates for electrons in-bending (left column) and out-bending (right column). Top row: number of photoelectrons. Middle and bottom row: rates in the four HTCC rings, number 1 being the closest to the beam.

b. FTOff Configuration

There is no significant difference in the hit distribution compared to FTOn, see Figure 5. The rates are reduced. The first ring sees a 60 kHz rate w/o threshold, reduced to about 20 kHz with a 3 npe threshold and 10 kHz with a 10 npe threshold. See Figure 6 for a reference picture of the four HTCC rings.

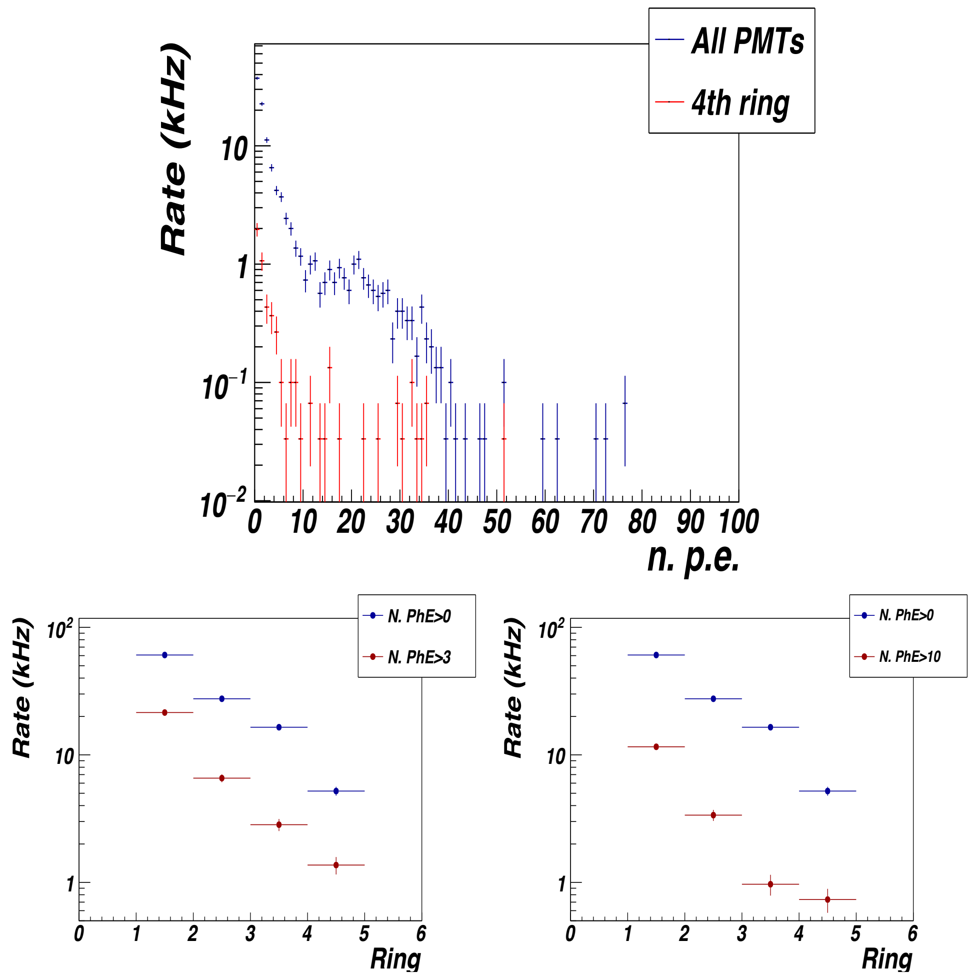

Figure 5: Results for HTCC rates for electron in-bending and FTOff configuration. Top row: number of photoelectrons. Bottom row: rates in the four HTCC rings, number 1 being the closest to the beam.

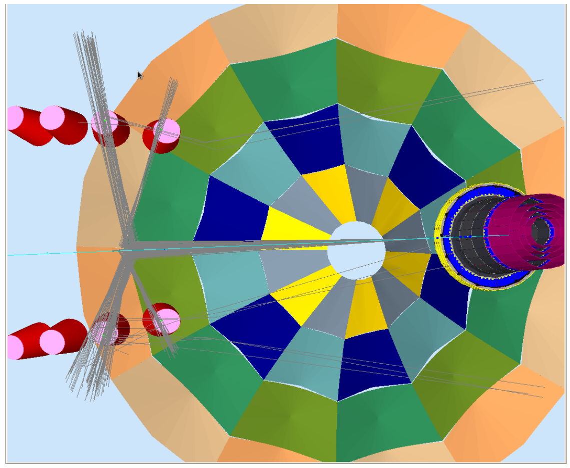

Figure 6: The four HTCC mirror rings in the simulation.

Rates and PMT currents in the FTOF

a. FTOn Configuration, in-bending and out-bending electrons

Rates for 1 MeV threshold on the energy deposition and PMT currents [4] for FTOF counters are shown in Figure 7. Rates increase with the counter length and with the increase of solid angle, reaching a maximum of 700 kHz for the Panel-2 counters. Similarly, the maximum PMT currents are seen in the same detector elements and are of the order of 15 μA. The dependence on the field polarity is negligible for rates while it is of the order of 10% for the currents. The rates strongly depend on the threshold, going from a maximum of about 6 MHz for 0 threshold, to the 700 kHz for 1 MeV(as shown in Fig. 7), to 70 kHz for 5 MeV.

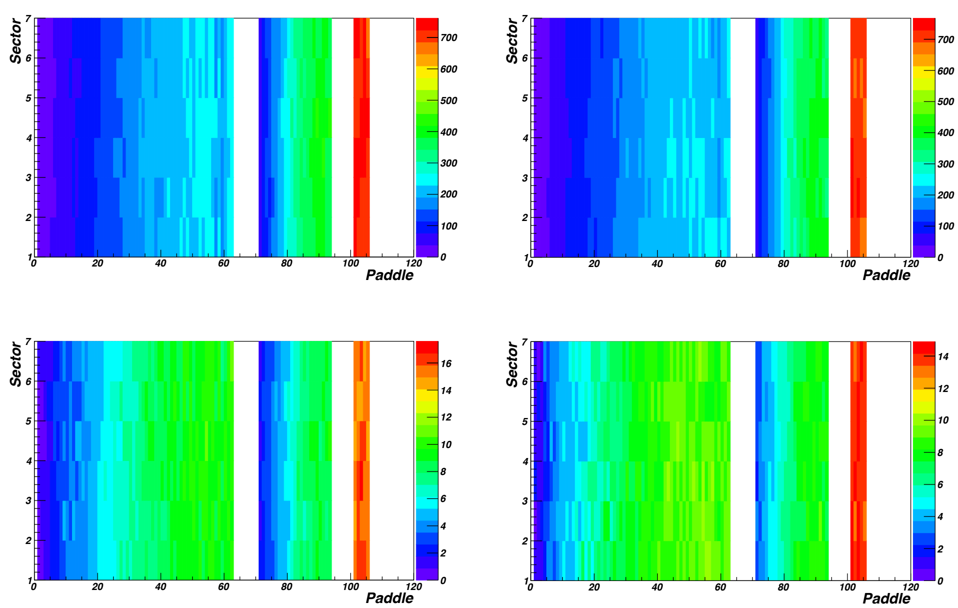

Figure 7: Results for FTOF rates (top) and PMT currents (bottom) for electrons in-bending (left column) and out-bending (right column). Rates are calculated for a 1 MeV threshold on the energy deposited and are expressed in kHz while currents are in μA. The different sets of x bins from left to right correspond to Panel-1B, Panel-1A and Panel 2 counters.

b. FTOff Configuration

Rates and currents for the FTOff configuration are significantly reduced compared to FTOn. As shown in Fig. 8, rates for 1 MeV threshold are reduced by about a factor 2, while currents drop by about 30%. This is consistent with the currents being dominated by low energy hits due to particles coming from the target. The rate dependence on the energy thresholds is similar to the FTOn configuration, going from a maximum of about 3.5 MHz for 0 threshold, to the 400 kHz for 1 MeV (as shown in Fig. 8), to 50 kHz for 5 MeV.

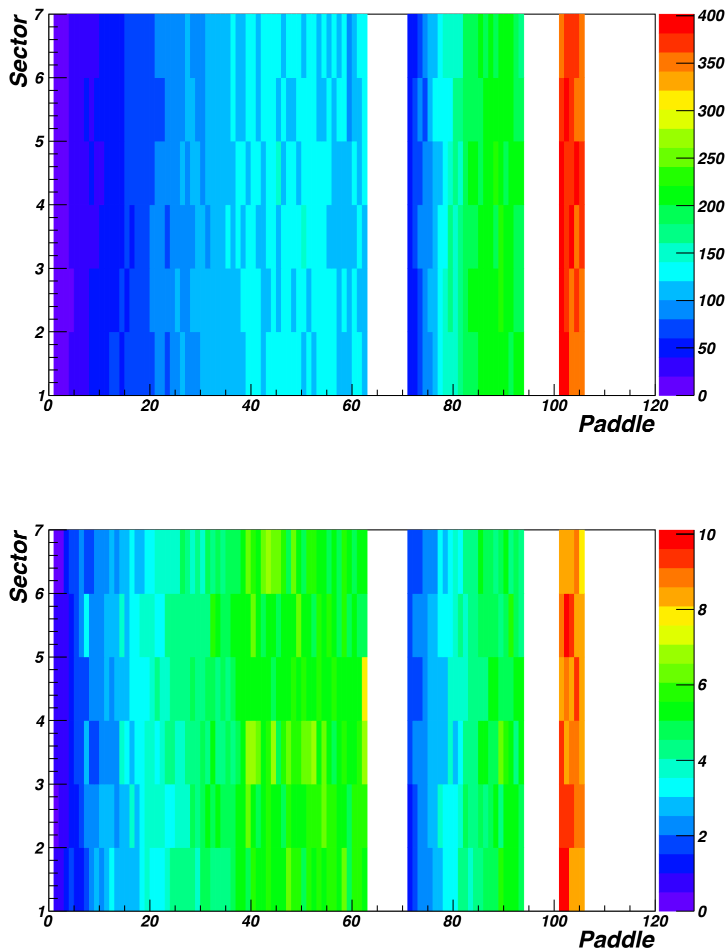

Figure 8: Results for FTOF rates (top) and PMT currents (bottom) for electrons in-bending and FTOff configuration. Rates are calculated for a 1 MeV threshold on the energy deposited and are expressed in kHz while currents are in µA. The different sets of x bins from left to right correspond to Panel-1B, Panel-1A and Panel 2 counters.

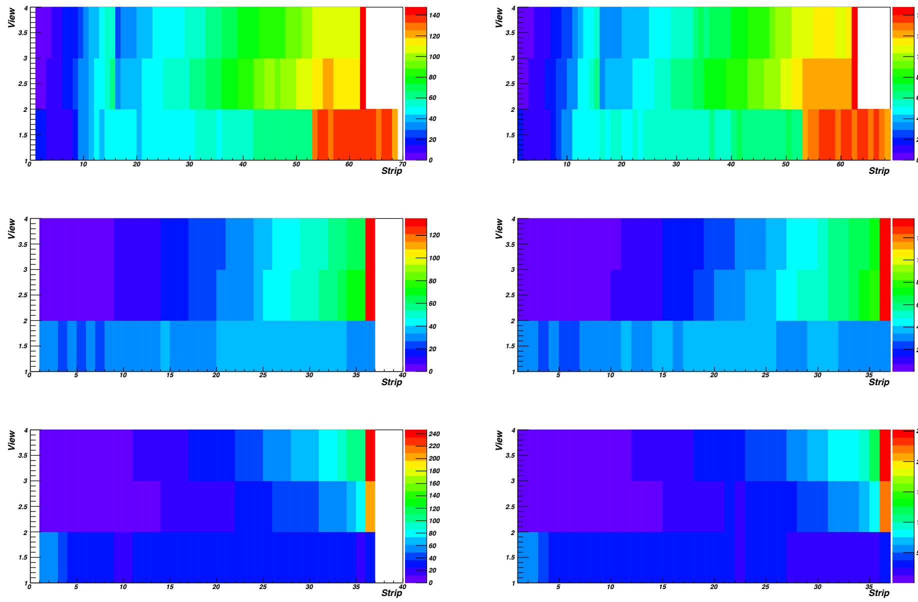

Figure 9: Results for ECAL sector rates for PCAL (top), ECin (middle) and ECout (bottom) for electrons in-bending (left column) and out-bending (right column). Rates are calculated for a 1 MeV threshold on the energy deposited and are expressed in kHz.

Rates in the ECAL

a. FTOn Configuration, in-bending and out-bending electrons

Rates for 1 MeV threshold on the energy deposition for ECAL strips are shown in Figure 9. The highest rates are in general found at the largest angles. No significant dependence on the field polarity is observed. As for the FTOF, the ECAL rates strongly depend on the threshold, going from a maximum of about 2.5 MHz for 0 threshold, to the 400 kHz for 0.1 MeV, to 140 kHz for 1 MeV (as shown in Fig. 9).

b. FTOff Configuration

Rates for the FTOff configuration are reduced compared to FTOn on by about 10% as shown in Fig. 10. The rate dependence on the energy thresholds is similar to the FTon configuration and reported in the previous paragraph.

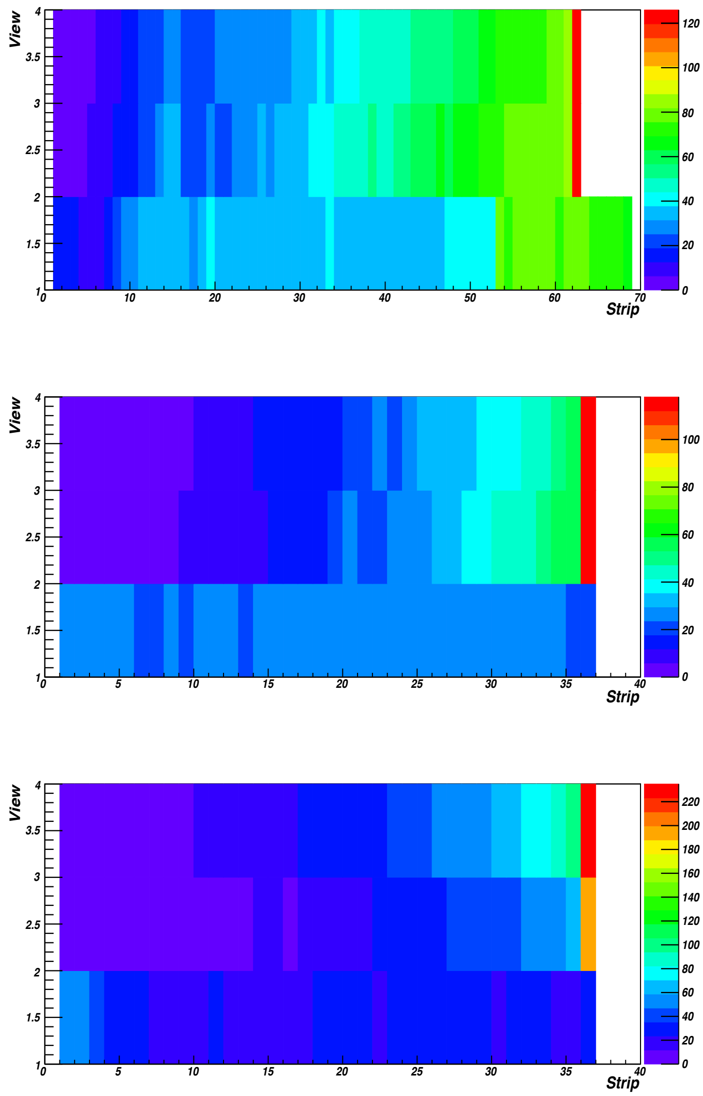

Figure 10: Results for ECAL sector rates for PCAL (top), ECin (middle) and ECout (bottom) for electrons in-bending and FTOff configuration. Rates are calculated for a 1 MeV threshold on the energy deposited and are expressed in kHz.

Rates and PMT currents in the CTOF

Rates for CTOF counters do not depend on the beamline configuration or the field polarity but only on the threshold, varying from about 5 MHz for 0 threshold to about 150 kHz for 1 MeV threshold on the energy deposition. PMT currents are estimated to be in the range of 50 μA.

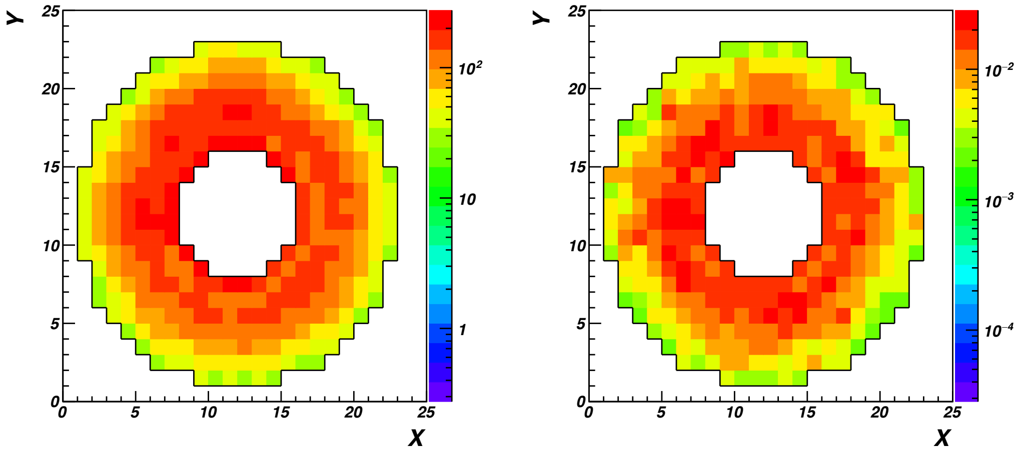

Figure 11: Rates (left) in kHz and energy deposition per unit of time (right) in MeV/ns for the FTCAL crystals in the FTOn configuration.

Rates and radiation doses on the FT detectors

The estimated rates in kHz and energy deposition per unit of time in MeV/ns for the FTCAL in the FTOn configuration are shown in Fig. 11. The maximum rates reaching about 100 kHz are observed for the innermost crystals that are closer to the beamline.

Fig. 12 shows the radiation dose in rad/h on the FTCAL for the FTOn and FTOff configurations, respectively. The maximum dose of about 3-4 rad/h is well within acceptable limits for both configurations. These differs, however, for the distribution within the calorimeter volume because of the additional shielding used in the FTOff case.

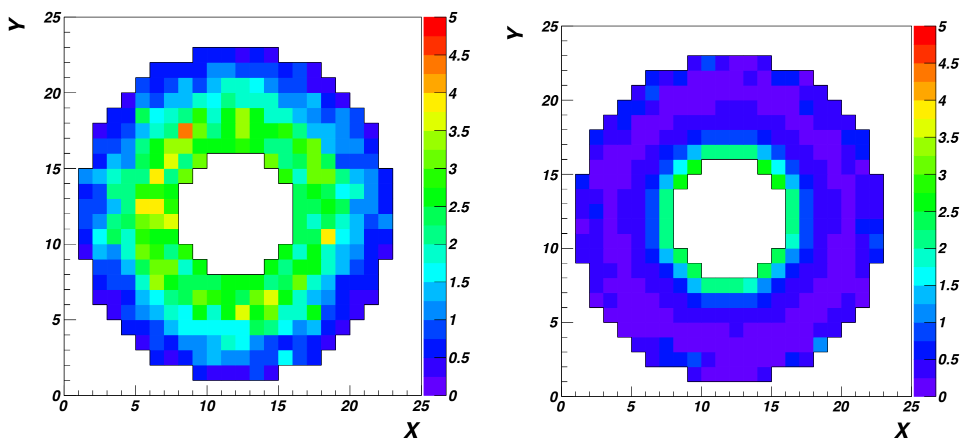

Figure 12: Radiation dose in rad/h on the FTCAL for the FTOn (left) and FTOff (right) configurations.

References

[1] R. De Vita and M. Ungaro, ***CLAS12-note 2016-006****:* Moller shield simulations: comparison of the GEMC-optimized layout and the engineering design.

[2] R. De Vita, L. Elouadrhiri, R. Miller, S. Stepanyan, M. Ungaro, C. Wiggins, M. Zarecky, A. Kim and J. A. Tan, ***CLAS12-note 2017-012****:* Corrections to CLAS12 vacuum beamline

[3] M. Ungaro, ***CLAS12-note 2017-013****:* Corrections to CLAS12 target design.

[4] D.S. Carman, ***FTOF-note 2014-06****:* Forward Time-of-Flight PMT Currents.