GEM DIGITIZATION WITH DEAD REGIONS AND DIVIDED STRIPS

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1. Introduction

PVDIS GEM strip occupancy has been shown to be as high as 80% in GEM 1 due to photon backgrounds.[1] In the downstream GEMs the photon hot spot is well separated from the high x_{bj} DIS electrons[2] and rates can be reduced by turning off high voltage in the areas of the GEMs outside the signal stripe. Upstream, the photon hot spot is not separated from the DIS stripe, and dead HV regions can do little to reduce the maximum occupancy. It has instead been suggested to divide some of the GEM strips into two substrips, one at low radius and one at high radius, to be read out separately, with about half the background rate in each compared to an undivided strip.

The digitization code has been modified to improve simulation of dead HV regions and provide for divided strips, and occupancies have been estimated using these enhancements.

2. Arbitrary polygonal dead HV regions

Provisions for dead HV regions had previously been added to the digitization code and were used in the previously cited study of occupancies. To simplify the task, the dead regions were required to be rectangular and aligned parallel to the symmetry axis of each GEM sector. In addition the left and right edges of each sector were made dead to account for the chamber frame.

This feature has now been upgraded to allow dead HV regions to be arbitrary polygons. (An algorithm for efficiently checking whether a hit falls inside a polygon is not obvious; the approach used was based on that in Ref. [3].) Polygons are specified in the digitization database file `db_gemc.dat` as follows:

```
gemc.gem1.n_HV_sector_off = 2
gemc.gem1.HV1.bound = -0.3800 -0.0200 0.3800 0.0700 0.3800 0.1400 0.0000 0.0900 -0.3800 0.0300
gemc.gem1.HV2.bound = 0.0000 -0.0900 0.3800 -0.0800 0.3800 -0.1400 0.0000 -0.1000
```

Here the first line indicates there are two dead regions in this sector. In the next two lines the vertices of the polygons are specified as x and y coordinate pairs in the plane coordinate system. This system is one in which the origin is the center of the bounding box of the GEM sector and the x axis is on the sector's symmetry axis.

3. Divided strips

The digitization code now handles divided strips. Strips may be divided into a maximum of two substrips, labeled 0 for the section at smaller radius and 1 for the section at larger radius. The avalanche charge is divided between the two substrips by integrating it over the lengths and widths of the substrips.

The output of the code is modified to contain substrip information. For each substrip, there are specified a channel number unique to the substrip, a strip number (running from 0 to $n_s - 1$, where n_s is the number of strips) and a substrip number (0 for undivided strips, 0 or 1 for divided strips).

The mapping between strip/substrip number and channel number is provided by a function in the `TSolGEMPlane` class. The current mapping has the first n_s channels as strip n, substrip 0, followed by n_d channels for substrip 1 of the n_d divided strips.

Divided strips are specified in `db_gemc.dat` as follows:

```
gemc.gem32.gem32x.divsegment = -0.25 -0.15 -0.25 0.15
gemc.gem32.gem32y.divsegment = -0.25 -0.15 -0.25 0.15
```

This specifies two divisions, one for the u plane (for historical reasons denoted "gem32x") and one for the v ("gem32y"). The x and y coordinates for the two endpoints of a line segment, called the "division segment", are given in the plane coordinate system. Any strip intersecting this division segment is divided at the point of intersection. (Note that for simplicity, we do not check whether that intersection occurs within the physical bounds of the sector: If the division segment extends past the sector edge, short strips intersecting the sector edge before the point where they would intersect the division segment are still regarded as divided, with all their charge being assigned to substrip 1.)

The clustering code has been minimally modified to accept the new output format. The clustering algorithm is unchanged: it looks for adjacent channels above threshold, splitting such groups into two or more clusters when it finds sufficiently deep local minima in the charge deposition. Where adjacent channels correspond to different geometries, *e.g.* at a boundary between undivided and divided strips, or between the last substrip 0 and the first substrip 1, such clustering may be nonsensical. A more sophisticated approach to clustering in the presence of such boundaries needs to be developed. For now, we work around this by dividing *all* strips in a sector, and deadening the edges.

Note also that the digitization code simplifies simulation of crosstalk by allowing any channel to crosstalk with a channel 32 channels away from it in either direction. This means, for example, a substrip 0 near one edge of a sector can crosstalk with a substrip 1 near the opposite edge. A more realistic simulation would confine crosstalk to channels sharing the same APV chip.

4. GEM ANGULAR OFFSETS

In 2016 we agreed to change the GEM and baffle offsets, for compatibility with a Cerenkov design in which the first sector is bounded by the vertical (y) axis. To match this, GEMs 2 and 3 also have vertical sector boundaries. GEMs 1, 4, and 5 are offset to account for electrons' bending in the magnetic field. The baffle offset was then set to send the photon hot spot toward the chamber frame in each sector.

Since the hot spots and high x_{bj} DIS stripes overlap in the upstream GEMs, a consequence of this design choice is that a fraction of the DIS signal is lost in the GEM frame.

This was regarded as an acceptable sacrifice to reduce background rates. However, with divided strips, it may now make more sense to re-orient the baffles to keep the full DIS stripes within the live areas of the upstream GEMs.

It should be noted that the earlier occupancy work was done with an older convention of azimuthal angular offsets between the GEMs and the baffles, in which the hot spots were away from the sector edges. This complicates comparisons of the occupancies.

5. Geometry

Figure 1 shows hit positions in GEMs 1, 2, and 4. In the top of each plot are shown data from the DIS generator, with primary electrons having $Q^2 > 6$ (GeV/c)^2, $W > 2$ GeV, and $x_{bj} > 0.55$ shown in red and other hits in black. In the bottom are shown hits (primarily photons) from the GEANT generator. The green line segments in the GEM 1 and 2 plots are the division segments used in the occupancy study, and the polygons shown in blue are the dead HV regions. GEMs 3 and 5 are similar to GEMs 2 and 4. No strips in GEMs 4 or 5 were divided. x and y coordinates are in the plane coordinate system.

The choice of division segments was based on simply trying a few possibilities and choosing the best ones. Small improvements might be possible with fine tuning. The dead HV regions were drawn to enclose most of the detector areas outside the DIS stripes.

6. Occupancy

Figure 2 shows occupancies as a function of strip number for the two strip directions (u and v) in the five GEMs in four analyses, with dead HV regions on or off and strip division on or off. Sector edges are always taken as dead. The input data set is DIS electrons plus 100% background. Occupancy here is defined as the fraction of events in which the (sub)strip's maximum charge sample is above a threshold of 4 times the pedestal width of 20.7 ADC channels. Note, then, that the summed occupancies for two substrips can be greater than the occupancy for the undivided strip. In GEM1, u direction, the maximum occupancies with no dead HV regions and no strip division are about 40%, versus about 80% in [1]. This difference is due to the difference in the angular offset between the baffles and the GEM. However in the v direction the maximum occupancy still is similar to the previous value, close to 80%.

In general, the chosen dead HV regions do reduce occupancies, but since in the upstream GEMs the dead areas are far from the photon hot spots and the occupancies already were low there, we see little or no reduction in the maximum occupancies. Dead areas do reduce maximum occupancies in the downstream GEMs, though in these GEMs even the maximum occupancies without dead regions are less than 15%. With dead regions most downstream occupancies are well under 10%.

Divided strips in the upstream GEMs reduce maximum occupancies. In GEM 1, v direction, the maximum of about 80% with undivided strips becomes about 50% with divided strips. In the u direction and in GEMs 2 and 3, maximum occupancies are around 20% or less.

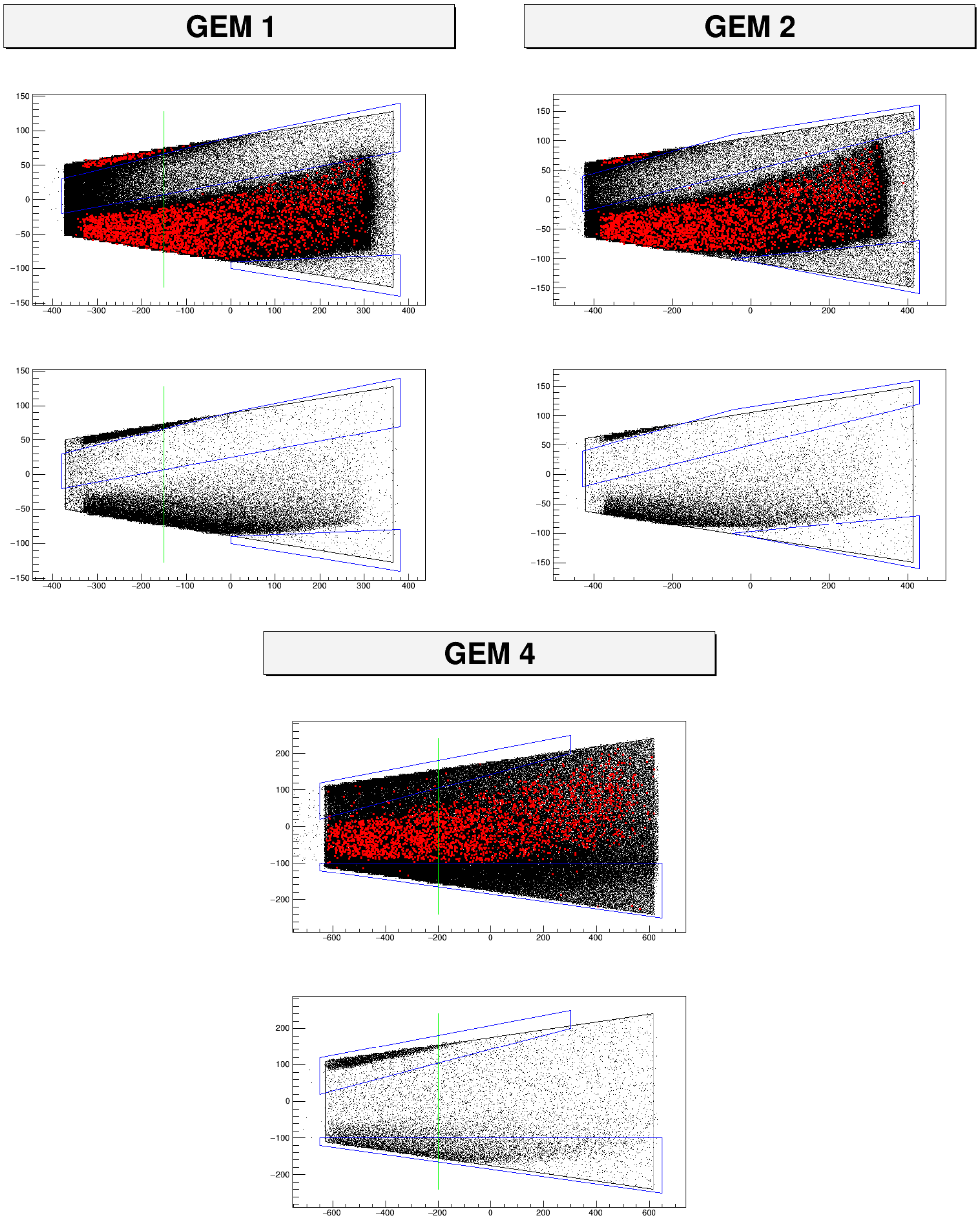

FIGURE 1. (Top plots) Hit positions of high x_{bj} DIS electrons (red) and other hits from DIS generator data (black) in GEMs 1, 2 and 4. (Bottom plots) Hit positions from GEANT generator data. Green line segments are division segments; blue polygons are HV dead regions. See text for details.

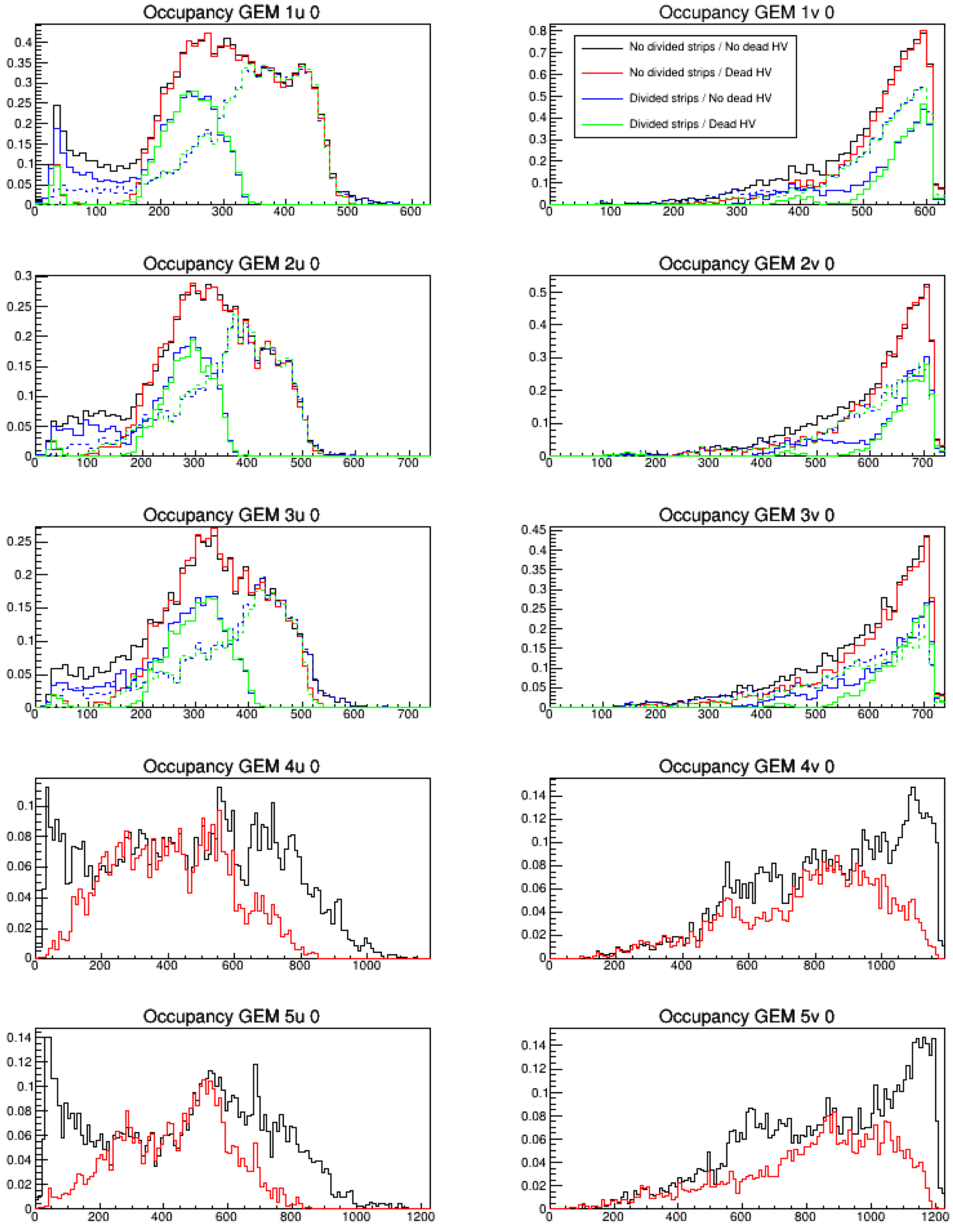

Figure 2. Occupancies versus strip number, for each of five GEMs (rows) and two strip orientations (columns). Red and green lines are with dead HV regions; blue and green lines are with divided strips. Solid (dashed) lines are for substrip 0 (1).

References

[1] Weizhi Xiong, “SoLID Tracking for the PVDIS configuration”, March 2017 SoLID collaboration meeting (https://solid.jlab.org/cgi-bin/public/ShowDocument?docid=23)

[2] R. Holmes, “Electron-photon separation in the CLEO2 baffles”, 3 March 2017 (https://solid.jlab.org/cgi-bin/private/ShowDocument?docid=8)

[3] Darel Rex Finley, “Point-In-Polygon Algorithm — Determining Whether A Point Is Inside A Complex Polygon”, 2007 (http://alienryderflex.com/polygon/)