CLAS Note 92-005

Choosing the "Correct" Combination of Sense, Field and Guard Wire Voltages

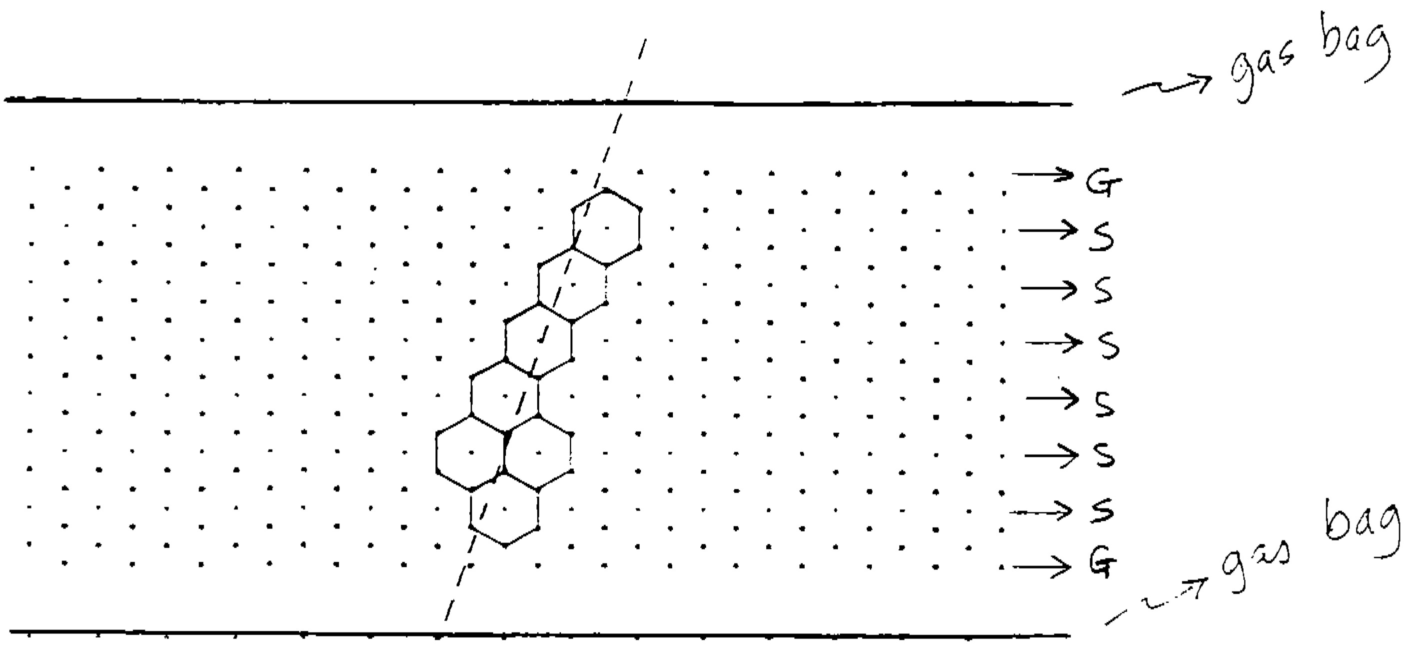
Mac D. Mestayer
March 6, 1992

Abstract:

Using the GARFIELD[1] program, I have studied the problem of how to divide the high voltage among the sense, field, and guard wires in order to achieve equal gain in all layers of the drift chamber superlayer, even in the presence of a grounded gas bag. A definite relation among the three voltages is obtained which achieves equal gain. In addition, a particular solution is discovered which reduces sensitivity to the distance between the gas bag and the first wire plane.

Description of the Problem:

The CLAS drift chambers' wires are arranged in six-layer superlayers with an hexagonal pattern (except for parts of Region 1). At the midplane, the pattern looks like the following:



The structure is seen to consist of equally spaced layers in the following pattern:

(G,F,F,S,F,F,S,F,F,S,F,F,S,F,F,S,F,F,S,F,F,G)

where S, F, and G represent sense, field, and guard wire layers, respectively.

The principles which guide the high voltage division are the following:

1) all sense wires, regardless of layer, should have the same charge density per unit length, and

2) that charge density should be the same as that for an infinite grid of such cells.

For a six-layer superlayer, the two principles are redundant, but so what, we're not mathematicians here. Before I present the results of specific GARFIELD calculations, let me mention a few things. First, the choice of wire diameters is fixed; being 20, 140 and $140\mu m$ respectively for the sense, field and guard wires. The small sense wire diameter is chosen to keep high voltages as low as possible and to keep wire tensions low, minimizing forces on the endplates. The field wire diameters are chosen to keep the electric field at the field wire surface below $20kV/cm$ in order to minimize the formation of cathode deposits and the generation of dark current. The guard wires' diameters are chosen to be large so that there is no amplification and so that the wires are sufficiently robust as to precisely define the boundaries of the superlayer.

Second, the position of the guard wires is chosen to be precisely at the place where the sense wires in the next layer would be. If the guard wires were at a different location, it is doubtful that any guard wire voltage could achieve the desired condition of equal gain for every plane of sense wires.

GARFIELD Calculations:

The basic cell type studied was a 1 cm hexagonal cell; that is, the distance from sense to neighboring field wire is 1 cm. I studied six kinds of configurations of these cells: (1) an infinite grid of these cells, (2) a one cell configuration; that is, one sense wire surrounded by six field wires, (3) a six-layer superlayer without guard wires, (4) a six-layer superlayer with guard wires, (5) a six-layer superlayer with guard wires and with a ground plane located 2 cm away from the guard wires, and (6) a six-layer superlayer with guard wires and with a ground plane located 1 cm away from the guard wires.

The procedure was the following: I would define the type of superlayer structure and the values of the voltages which I wanted with an input data file. I would then run GARFIELD, go into the FIELD section and use the CHECK WIRE command. The CHECK WIRE command prints out the linear charge density on each of the wires. I would record the charge density for the sense wire in layers 1, 2 and 3. I didn't record the charge densities for layers 4, 5 and 6 because by symmetry (which I verified) they are equal to those for layers 3, 2 and 1. If the charges were equal to a part in 10,000 I considered that I had found the optimum combination; otherwise, I would vary the voltages until I achieved the optimum. My job was made easier by the fact that the optimum charge value was known (it was the value for the infinite grid), and extrapolations to the correct values were very linear. The data are shown on the next page.

Analysis of Data:

Note that in all cases, I have kept V(S)-V(F) = 2400 V. This insures that the interior layers, layer 3 in this case has the correct charge density when the guard wire is adjusted properly. Therefore, V(F) is redundant; it equals V(S) - 2400. So, I have plotted V(S) versus V(G) for those cases marked "OK" in the table; that is, cases numbered 4, 7, 8, 13, 15, 16, 20, and 23 (15 and 16 are almost the same point). See the enclosed figure. Notice that the points lie on three straight lines: for no gas bag, for a gas bag 1 cm away, and for a gas bag 2 cm away. This means that for these conditions, one can choose the sense, field and guard voltages according to the following simple prescription.

all cases: V(S) - V(F) = 2400, and
no bag: V(G) = V(S) - 1060
bag 1cm away: V(G) = 1.95 * V(S) - 2584
bag 2 cm away: V(G) = 1.47 * V(S) -1800.

Note that the curves cross each other at a common point. GRAND UNIFICATION!!! Seriously, this is interesting and important. It means that for this combination of voltages, the charges on the wires do not change if the bag is moved. If the charges don't change, then no work is done. If no work is done, there's NO FORCE ON THE BAG at this point. Another way to think about it is that there is no net electric flux which penetrates a Gaussian surface which is slightly interior to the bag surface. This means that there is NO NET CHARGE on the sense, field and guard wires combined. Physics is fun.

Another point to notice: say that we chose operating point number 8 where the voltages are 2400, 0 and 1725 for sense, field and guard wires respectively. This point is appropriate for a gas bag which is 2 cm from the guard wire plane. Now say that the gas bag is (accidentally) pressed in by 1 cm. We then have the configuration of point number 24. The charge density on the first layer would change from the nominal 281.22 units to 284.54 units. I estimate that this would cause a gain change of about 19%.

Conclusion:

For a superlayer with an hexagonal cell layout including guard wires, I have shown that there is a relationship between guard wire potential and sense wire potential which will mimic an infinite array of hexagonal cells. This is true for any distance between the guard wire plane and a grounded gas bag. If the sense, field and guard wires are set such that their net charge is zero, then there is no force on the gas bag and no dependence of the indivdual layer's charge upon the distance to the gas bag.

References:

[1.] "GARFIELD, A Drift Chamber Simulation Program", R. Veenhof, M. Guckes, K. Peters, HELIOS Note 154.

GARFIELD Results on High Voltage Division								
No.	Cell Type	V(S)	V(F)	V(G)	Q(LYR 1)	Q(LYR 2)	Q(LYR 3)	OK?
1	infinite grid	2400	0	-	281.19	-	-	yes
2	one cell	2400	0	-	322.75	-	-	
3	6-lyr, no guard	2400	0	-	295.10	283.08	281.48	
4	6-lyr, guard	2400	0	1340	281.24	281.21	281.20	yes
5	"	2400	0	2400	267.56	279.36	280.92	
6	"	2400	0	0	298.52	283.54	281.55	
7	"	1060	-1340	0	281.24	281.21	281.20	yes
8	6-lyr, grd, 2cm to bag	2400	0	1725	281.22	281.20	281.19	yes
9	"	675	-1725	0	272.53	280.04	281.02	
10	"	1000	-1400	325	274.17	280.26	281.05	
11	"	1000	-1400	700	270.27	279.73	280.97	
12	"	1000	-1400	-300	280.67	281.14	281.19	
13	"	1000	-1400	-350	281.19	281.21	281.20	yes
14	"	1200	-1200	0	280.63	281.13	281.18	
15	"	1250	-1150	0	281.41	281.23	281.20	yes
16	"	1230	-1170	0	281.10	281.19	281.19	yes
17	"	0	-2400	-1800	280.83	281.17	281.19	
18	6-lyr, grd, 1cm to bag	1500	-900	0	284.16	281.61	281.26	
19	"	1400	-1000	0	282.45	281.38	281.22	
20	"	1325	-1075	0	281.16	281.20	281.20	yes
21	"	2400	0	-1950	316.6	285.98	281.92	
22	"	2400	0	1950	282.57	281.38	281.22	
23	"	2400	0	2100	281.26	281.20	281.19	yes
24	"	2400	0	1725	284.54	281.64	281.26	

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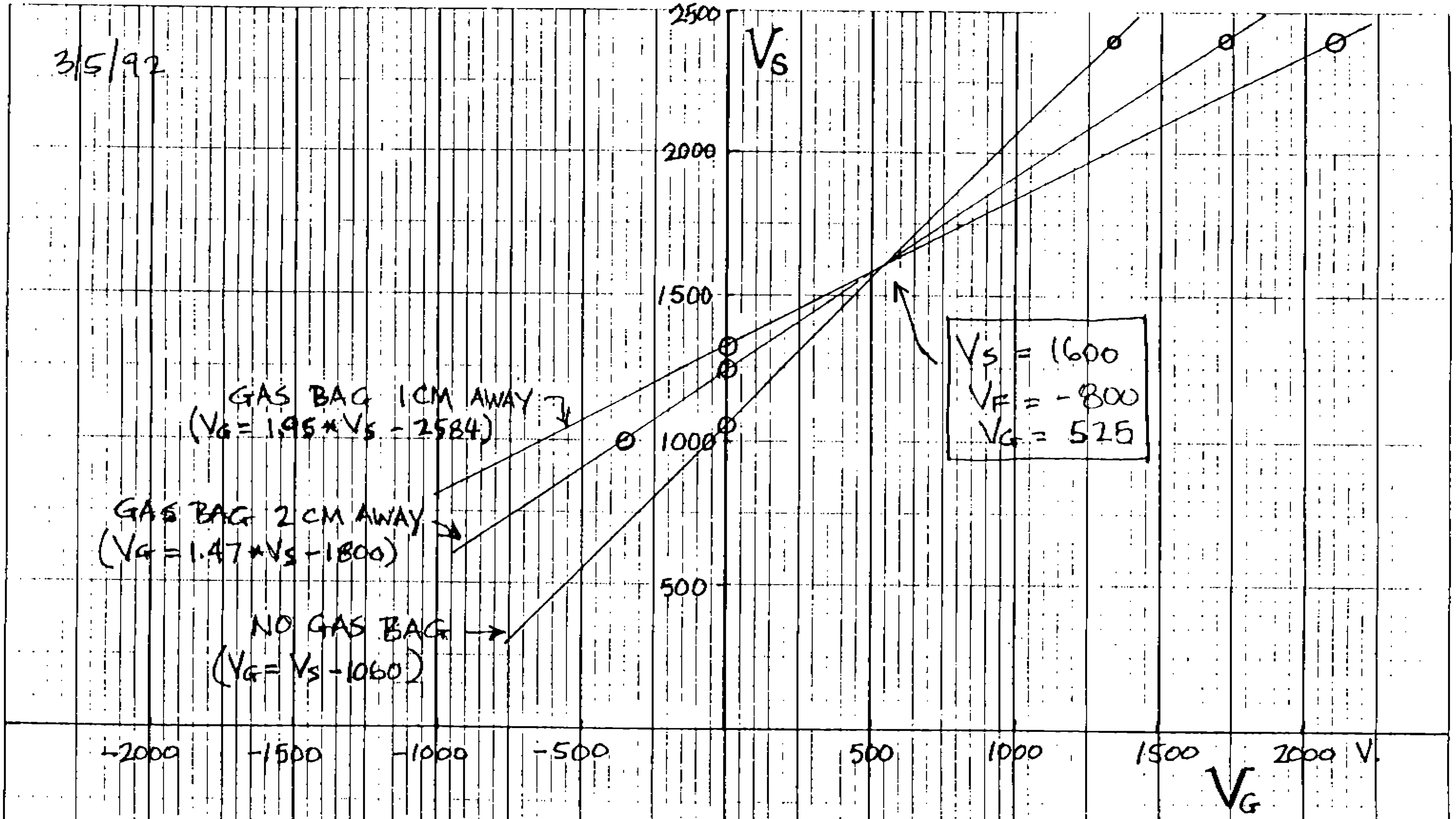

FIG. 1 : For a 6-layer superlayer WITH guard wires
1 CM CELL ; 20, 140 & 140 μm dia. for S, F, G
$V_S - V_F = 2400$ V. ; V_S vs. V_G for equal gains on all layers.

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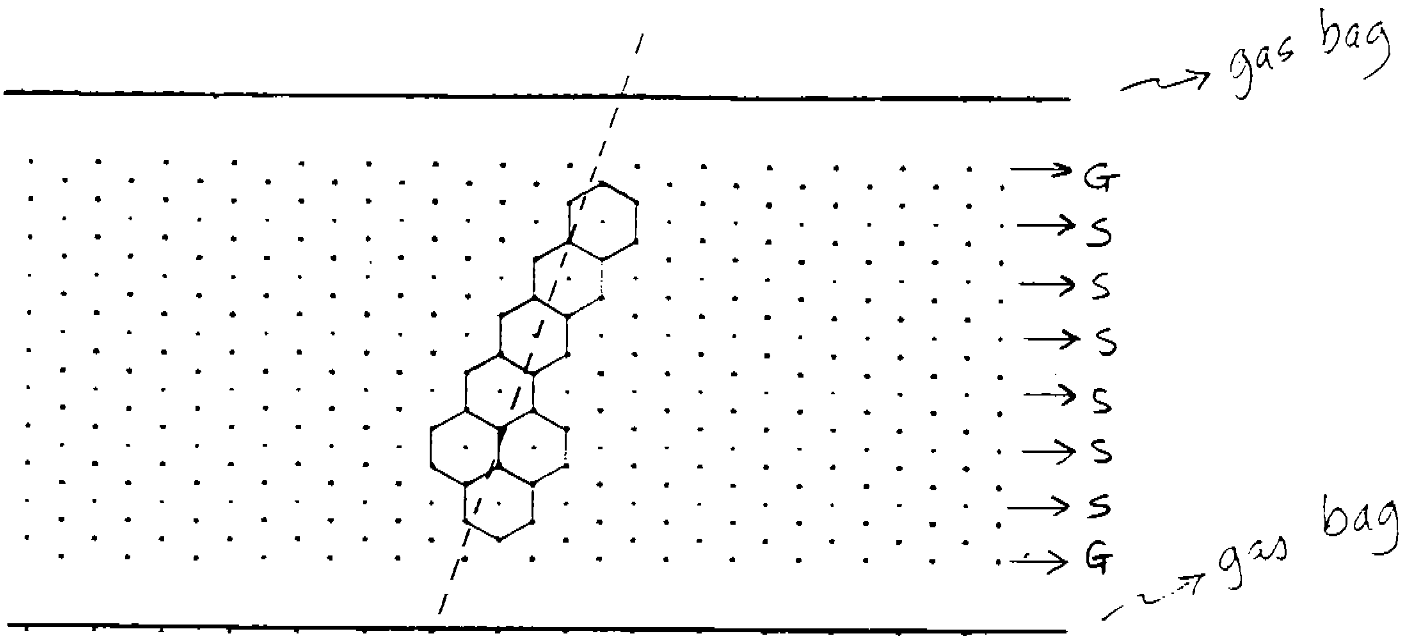

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