2009 Pen Trigger

Pen Collaboration

September 19, 2009

Abstract

For the 2009 run the Pen experiment received a complete trigger overhaul. An overhaul was necessary because beamline elements had changed and the CsI trigger scheme was a relic of the Pibeta days that was not optimal for the Pen experiment.

Contents

1 Introduction

The Pen 2009 trigger involves two stages. The first stage takes the raw input signals from the detector elements (B0,DeG,TgT,CsI, and PH) and produces several raw triggers. Then the raw triggers are fed into the second stage which takes the master trigger (OR of all raw triggers) and produces the gates for the ADCs, digitizer triggers, etc. Section 2 explains the origins of the various detector signals and section 3 explains how the signals are combined to produce the trigger.

1.1 Electronics Rack Layout

There are four racks (1-4,left to right) and each rack has 4 crates (A-D,Top-Bottom). Inside each crate the slots are numbered but the convention for this numbering scheme depends on the type of crate: NIM 1-24,L-R, Camac 1-24,L-R, Fastbus 0-25 R-L, VME none. When referring to a particular module we use the convention RackCrate-Slot (e.g. 4A-15). When a module has multiple channels the channels shall be labeled with lower case letters with the topmost channel begin called a and proceeding through the alphabet as one proceeds down the module (e.g. 4A-15a).

Rack 4 and the bottom section of Rack 3 contain the bulk of the Pen trigger fast electronics. The beamline signals, plastic hodoscope signals, and the CsI signals originate here. Plastic hodoscope summing occurs in 4B. CsI summing occurs in 3D and 4D as well as 4B. The production of the raw triggers also happens in Rack 4. The top half of Rack 3 is dedicated to the production of scalers for various detector elements and triggers. Rack 3 also contains several modules which interface with the DAQ system at trigger time. Racks 1 and 2 are mainly DAQ (ADCs, TDCs, etc.).

1.2 Trigger Modes

It should be noted that some of the trigger modes have a frequency that is too high for the DAQ system to handle. Therefore some of the trigger signals are prescaled.

1.2.1 PHOR

All decay events of interest will leave a signal in the plastic hodoscope and result in the plastic hodoscope trigger (PHOR). The positrons of interest from π_{2e} decays are mono-energetic and as such produce a peak at the decay energy of the positron (above the Michel spectrum) and a tail extending to 0 energy (covered by the Michel spectrum). The count rate from Michel decays is too high to collect every event, therefore the PHOR trigger is prescaled by XXXXXX. The prescaling leads to missing tail events, this is unavoidable. Simulation will be used to extract the tail.

1.2.2 CsI High and Low

The CsI calorimeter, as its name implies, is used for measuring the energy of the decay positrons. The energy of the positrons is useful information to know when an event is worth recording, therefore the energy deposited in the crystal ball is useful in determining the trigger. A sum of energy above a the Michel edge in the crystals in coincidence with a pion stopping in the target is a good indication of a π_{2e} event, this occurrence produces the CsI high trigger (CsIH). The high trigger does not require prescaling because the π_{2e} rate is low enough for the system to handle. The CsI Low trigger threshold (CsIL) is set to XXXXXX and is prescaled by XXXXXX due to the higher count rate. The Low trigger will assist in the extraction of the tail.

1.2.3 Cosmic

No beamline produces beam at all time. To take advantage of this down time many experiments run in cosmic mode and the Pen experiment is no different. Cosmic runs are useful for detector alignment and various diagnostic checks. The scheme for the Cosmic trigger (COS) is a coincidence of large energy in the top and bottom halves of the CsI calorimeter. The threshold for energy in each half is set to a value well above the π_{2e} decay energy.

1.2.4 Random

The random trigger (RND) is a plastic scintillator photo multiplier combo, radiologically shielded from the pen detector.

2 Input Signals

2.1 B0 Counter

The upstream beam counter. This device is a plastic scintillator read out by two PMTs. The signals are summed at the rear of the detector and then sent to the electronics hut by a patch panel that terminates at the top of Rack 4.

The B0 signal is discriminated to eliminate the positron signal (B0M) and then is sent to the Scaler unit (3A-19), main level 1 logic unit (4A-7), and the agile TDC unit(3B-8).

2.2 Degrader

The degrader is a thin plastic scintillator located just before the mTPC and along with the collimators defines the beam profile. The degrader is read out with a PMT and, like the B0, the signal is sent to the electronics hut via the patch panel.

The degrader signal recieves a low level of discrimination (DGL) and is then sent to the Scaler unit (3A-19), main level 1 logic unit (4A-7), and the agile TDC unit(3B-8).

2.3 Target

The active target is a plastic scintillator read out with a PMT and the signal is sent to the electronics hut via the patch panel.

The target signal recieves a low level of discrimination (TGL) and is then sent to the Scaler unit (3A-19), main level 1 logic unit (4A-7), and the agile TDC unit(3B-8).

2.4 PHOR

Each stave in the plastic hodoscope has a photomultiplier tube at both ends. There are 20 upstream and 20 downstream PMTs. These signals are summed by up and down stream geometry and then the mean time of the two sums is taken to determine the plastic hodoscope trigger. The sum of the hodoscope signals is called PHOR. This summing is done in Rack 4 crate B using several fanin/fanout modules and a mean timer module.

2.5 CsI High/Low Trigger Sum

2.5.1 Constraints

There are 240 crystals in the Pen Calorimeter and of them 220 are to be used in the trigger sum (the remaining 20 are veto crystals along the apertures of the calorimeter). The task is to make a fast sum of the 220 crystals which will be employed in the CsI High/Low trigger. Specialized NIM modules (UVa125 Quad Sum Discriminators) were produced for Pibeta experiment CsI triggers. These units are optimized for the particular signals the calorimeter will produce and therefore are used in the new Pen trigger. The UVa125 modules present a set of constraints on the construction of the CsI component of the trigger. Each module has 4 identical channels and each channel sums and discriminates a maximum of 9 signals.

$$\frac{220\,\text{crystals}}{9\,\text{crystals/channel}} = 24\frac{4}{9}\,\text{channels} \rightarrow \frac{25\,\text{channels}}{4\,\text{channels/module}} \rightarrow 7\,\text{modules} \tag{1}$$

Therefore a minimum of seven modules must be used to accomplish this sum. We currently have 15 working modules so the use of eight or even nine is no problem.

2.5.2 Nomenclature

It would be appropriate at this juncture to discuss the nomenclature used in discussing the new Pen CsI trigger. There are preexisting terms that must not be used. The UVa125 modules are quad sum discriminators. Each one of the four sum discriminators shall be called a *channel.* Referring to the crystal ball there are already units knows as clumps and clusters. Collectively the 9 inputs to a UVa125 channel shall be called a *group.* Conceivably the groups will be made up of different patterns of crystals, a pattern shall be called a *tile.* The groups will then be summed into larger units called *supergroups.* The supergroups are then summed to producing a CsI Top and CsI Bottom signal for the cosmic trigger, these sum of groups are called *übergroups.* The übergroups are also summed to produce the CsI sum (CsISUM).

2.5.3 Tile Assignment

The following criteria were employed to determine the mapping of tiles for the 220 crystals:

1. A tile may have no more than 9 constituent crystals
2. A symmetric tile is preferred (circle>ellipse>line)
3. Fewer tile types is preferred
4. A symmetric tile layout is preferred
5. Showers are contained in as few tiles as possible
6. Use of the preexisting nearest neighbor logic is preferred

The Calorimeter possesses even symmetry about $\theta = 90°$ (see Figure 5). Invoking criteria ?? and 2 we see that a central band must be six crystals across. The calorimeter uses 25 crystals to make a full 360° in ϕ. Since 25 is not evenly divisible by 3 a patching region for the remainder is needed. Taking these ideas into account we produce tiles 1 through 5 (see Figure 1 and Table 2.5.3). It should be noted that tiles 1 through 5 are very similar and the only difference comes from the variance in size of different types of crystals which compose the tiles. After assigning these tiles we are left with the edges, each is two crystal deep. The creation of tiles 7 through 10 was more or less arbitrary and began with selecting a starting point and just counting nine crystals and then beginning the next tile. Tiles 7 and 8 are mirror images.

This division means that we need 26 groups in 4 supergroups.

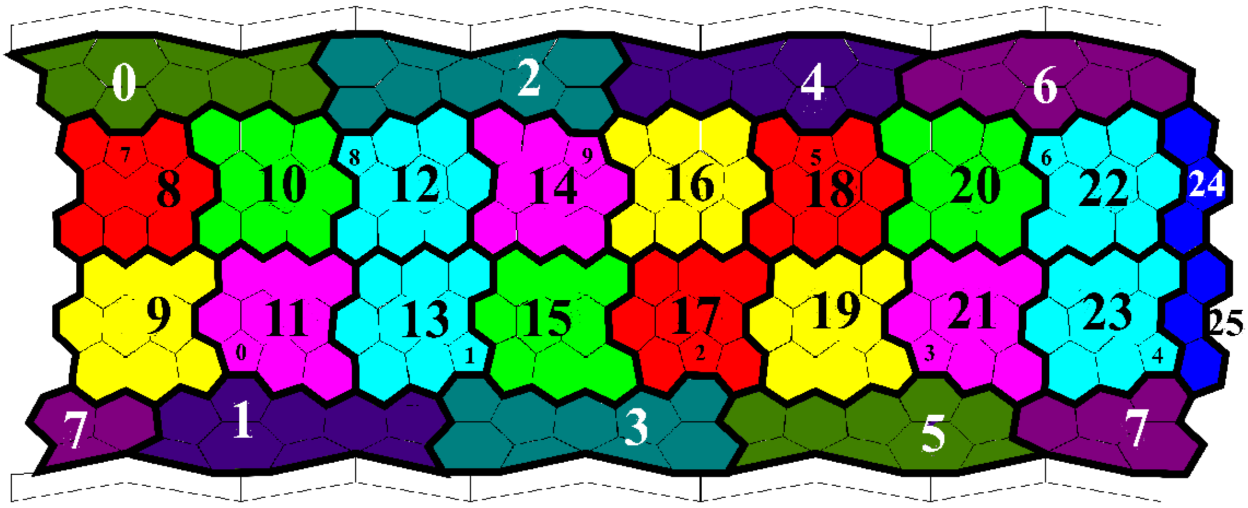


Figure 1: Map of Groups: Large Numbers = Group Numbers ; Small Numbers = Pentagon Numbers

2.5.4 Signal Flow

The crystals are attached to 64 ns BNC cables which run to the electronics hut. There the cables are converted to LEMO and delayed. Then the individual crystal signals are fed into the UVa125 channels (groupers) by group number. These sums are then fed into additional UVa125 channels (supergroupers). Those sums are then summed to produce the CsI Top sum and CsI bottom sum.

Tile #	Color	# of Crystals	# Needed
1	Red	9	3
2	Green	9	3
3	Cyan	9	4
4	Pink	9	3
5	Yellow	9	3
6	Blue	3	2
7	Kelly	9	2
8	Midnight	9	2
9	Marine	9	2
10	Purple	8	2
Totals		220	26

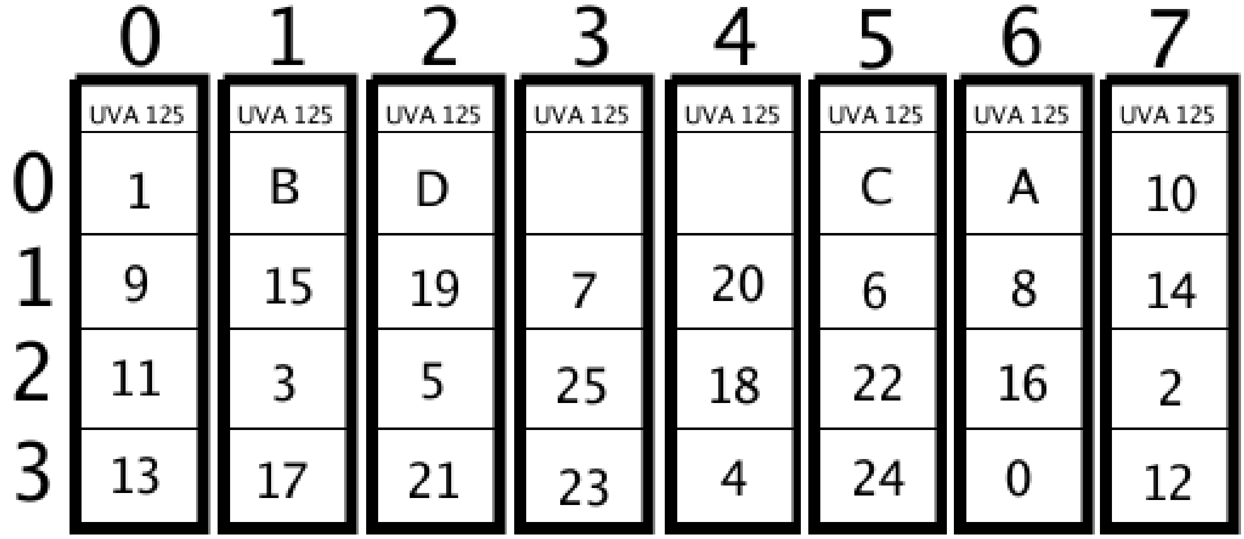
Table 1: Tile Details

Group #	Tile #	UVa125	SuperGroup	Constituent Crystal #s								
0	7	6,3	C	217	117	207	67	17	107	168	68	218
1	7	0,0	D	60	200	110	10	100	210	161	61	201
2	9	7,2	C	118	208	18	108	219	169	69	19	119
3	9	1,2	D	11	111	101	211	162	62	202	112	12
4	8	4,3	A	209	109	165	215	65	115	15	105	205
5	8	2,2	B	102	212	163	63	203	113	213	13	103
6	10	5,2	A	166	216	66	116	16	106	206	167	
7	10	3,1	B	164	64	14	204	114	104	214	160	
8	1	6,1	C	27	7	57	97	47	37	137	87	147
9	5	0,1	D	194	94	154	170	180	120	130	70	20
10	2	7,0	C	157	128	28	178	78	38	197	188	138
11	4	0,2	D	80	30	0	140	40	50	90	190	150
12	3	7,3	C	8	58	158	48	98	179	88	148	198
13	3	0,3	D	181	131	81	171	71	31	121	21	1
14	4	7,1	C	129	29	9	79	39	49	189	139	89
15	2	1,1	D	141	41	51	191	91	151	172	122	182
16	5	6,2	A	59	159	125	99	175	75	149	199	185
17	1	1,3	B	132	72	82	142	32	42	22	2	52
18	1	4,2	A	25	5	55	35	45	95	135	85	145
19	5	2,1	B	192	92	152	183	173	123	23	73	133
20	2	4,1	A	155	126	26	176	76	36	195	186	136
21	4	2,3	B	83	33	3	143	43	53	193	93	153
22	3	5,2	A	6	56	156	46	96	177	86	146	196
23	3	3,3	B	184	134	84	174	74	34	124	24	4
24	6	5,3	A	127	77	187						
25	6	3,2	D	144	44	54						

Table 2: Group Details

SuperGroup #	UVa125 Location	Constituent Groups #s						
A	6,0	4	6	16	18	20	22	24
B	1,0	5	7	17	19	21	23	
C	5,0	0	2	8	10	12	14	
D	2,0	1	3	9	11	13	15	25

Table 3: SuperGroup Details



	0	1	2	3	4	5	6	7
	UVA 125	UVA 125	UVA 125	UVA 125	UVA 125	UVA 125	UVA 125	UVA 125
0	1	B	D			C	A	10
1	9	15	19	7	20	6	8	14
2	11	3	5	25	18	22	16	2
3	13	17	21	23	4	24	0	12

Figure 2: NIM module layout: Interior numbers = group numbers

The signal is baseline stabilized (aka high-pass filtered). One pair of Top/Bottom signals goes to discriminators for the cosmic trigger. The other pair is summed to produce the CsI sum which is then discriminated (via computer control) before being ANDed with the PiGate to produce the CsI raw trigger signals (CsIH and CsIL).

2.5.5 Modifications

The majority of the wiring for the 2009 Pen Trigger was taken from the initial Pibeta cluster trigger scheme. Now the LEMO delay cables for each crystal are connected directly to the UVa125 modules (groupers). Large bundles of 5 ns cables, which previously connected the splitters to the UVa125 modules, were removed.

2.5.6 Trigger timing

It is critical for the CsI signals to register at the same time. A spread in CsI signal time leads to a poorly defined start for the timing of the entire trigger. Therefore we must measure the report time of every crystal and line them up. Then the whole CsI sum can be delayed to the appropriate position. The method we employ to do this is to exploit the fixed timing difference between the CsI signal and the PHOR signal (the time of flight for positrons from one to the other is below the precision of this measurement). We can suppresses accidentals by only accepting events where the struck crystal contains a large fraction of the total energy (upon further examination struck fractions of greater then 0.5 are acceptable for this analysis). Figure **??** shows the spectrum for the

ÜberGroup	Consitutent Group #s
α	4,5,6,7,16,17,18,19,20,21,22,23,24
β	0,1,2,3,8,9,10,11,12,13,14,15,25

Table 4: Group Crystal Constituents

average of all crystals along with the spectra for a few crystals. We measured the peak deviation from the mean and then inserted or removed cables to align all the CsI signals. Figures **??** and **??** show the results of the timing calibration. We aligned all of the crystals so that their timing relative to PHOR is the same. Then we delayed the CsI sum as necessary. [some of the figures have not been included yet, once they are produced they will be added]

2.6 CsI Cosmic Trigger Sum

2.6.1 Signal Flow

The CsI top sum and CsI bottom sum are discriminated to a level above typical π_{2e} energies. These discriminated signals are then ANDed and the output is the cosmic trigger.

3 Trigger

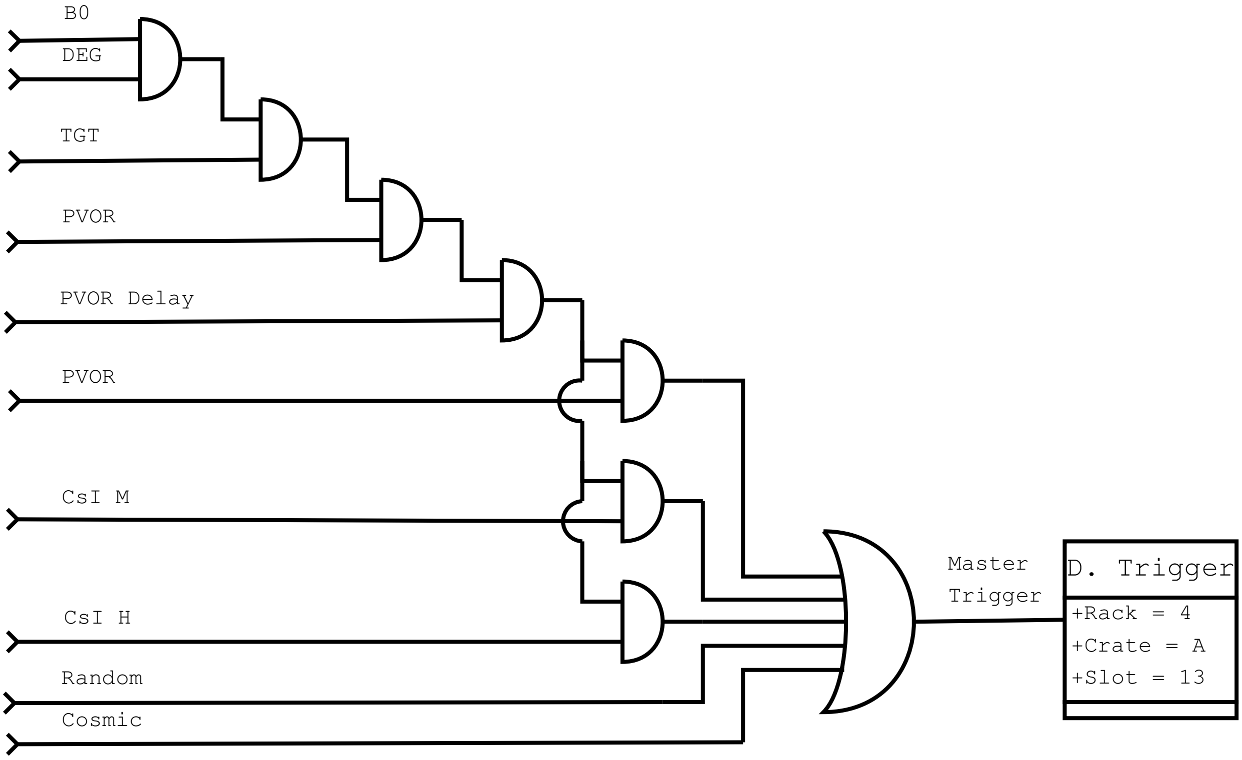


Figure 3: Stage 1 Trigger Logic w/o Details

3.1 Stage 1: Signals to Raw Trigger

All of the raw signals receive discrimination and shaping along the way, as well as various delays (only major delays are indicated in this document). This section explains the production of the following triggers CsI High, CsI Medium, PHOR and Cosmic starting from B0, DG, TG, PHOR, CsIH/L, COS. Figure 3 is a schematic of the stage 1 trigger logic.

3.1.1 Logic Unit 4A-7

This module is a quad four-fold logic unit. Currently only three channels (a,b,c) are used and all are operated in the AND gate configuration. All three of the channels send their output to scalers and logic further down the stream. This unit is represented by the first 3 and gates in figure 3.

- Channel a: B0 AND DEG
- Channel b: a AND TGT
- Channel c: b AND PHOR

The output of channel c goes to 4B-21a (another AND gate) along with PHOR. A careful observer will notice that channel c is the the AND of b and PHOR, and then inquire why this signal would be ANDed with PHOR again. This point is subtle. The timing of an AND gate is giving by the second signal to arrive. The anding of c and PHOR is actually using a delayed PHOR. We ensure that the PHOR is the second signal to arrive and therefore the timing is determined by the PHOR. We want the PHOR to determine the timing because it is a few ns wide as opposed to the 280 ns width of the pigate.

3.1.2 4B-23 Strobed Coincidence Module

The strobe for this unit is the AND of 4A-7c and PHOR. The three decay parts of the trigger (PHOR,CsIM,CsIH) are each fed into a channel and then the outputs are sent to scalers and 4A-11, the master trigger unit. The master trigger unit takes the OR of all the different triggers (PH,CsIM,CsIH,RNDM,Cosmic,Clock) and sends it to 4A-13b Discriminating Trigger. The D.Trigger module is the starting point of the second level of the trigger system. Module 4B-23 is represented by the three AND gates that are lined up vertically.

3.2 Stage 2: Raw Trigger to Gate

The output of the 4A-13b D. Trig is sent to a whopping seven places. The reset logic for the unit is shown schematically in Figure 4.

- Fastbus ADC gate
- AND with $\overline{Pigate}$ → Prompt ADC gate
- Aquris Trigger
- Anode Trigger
- Trigger Register Gate 3B-13
- Master trigger reset (in OR with DAQ)

- Scaler

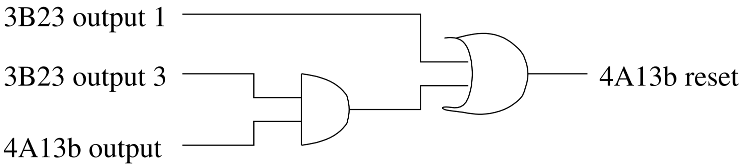


Figure 4: Reset Logic for 4A-13b unit: Believed to be incorrect

3.2.1 Fastbut ADC Gate

3.2.2 Prompt ADC Gate

4 Resources

Pen Crystal Identification Scheme Web-page

Technical Specs for UVa125 Quad Sum Discriminators

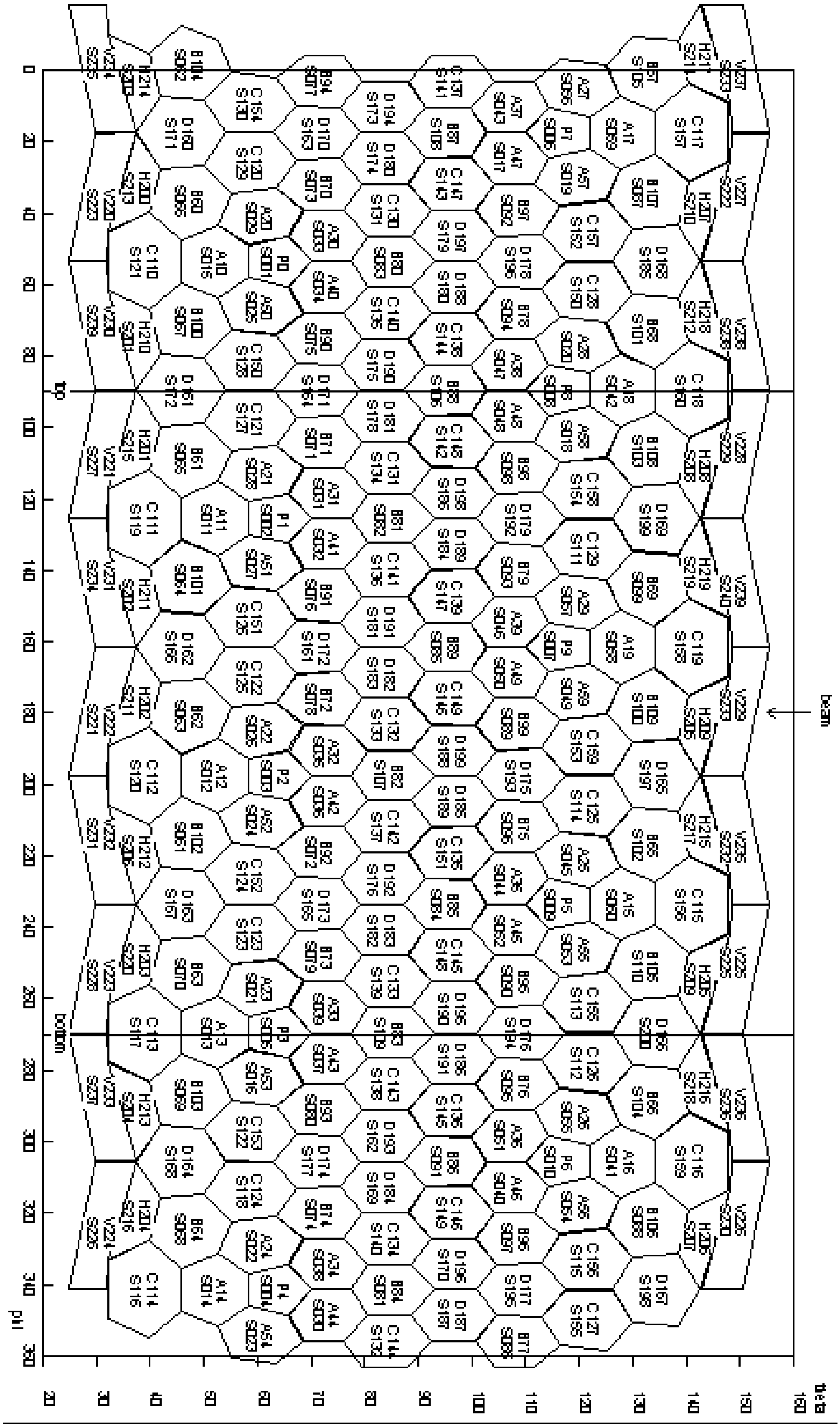


Figure 5: The top number in each crystal is its number.