BEAST Maintenance and Data Analysis

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1 Basic Stuff

Beast is located at the interaction point of KEK-B, in Tsukuba Hall. Electrons come from the Nikko Side and positrons come from the Oho Side. x-axis points out of the ring, y-axis points to heaven, and z-axis runs along the direction of electron. The sign convention is described in Fig. 5.4. A global view of the Beast is given in Fig. 5.4.

2 MOSFET

2.1 Calibration and Making Plots

MOSFETs are little transistors with a well-controlled gate oxide thickness. Drain-to-Source threshold voltage for a certain current and Gate Voltage is the monitored. Radiation damage to the transistor increases the hole concentration just below the oxide (phenomenon called charge-trapping), and thus changes the threshold.

The relationship between the threshold and dose has been calibrated by the company that provides them. There are two kinds of transistors on one module - K-type, and R-type. Very roughly, the calibrations are :

$$\begin{aligned} \text{K-type} &= 13.2 \text{ Rad/mV} \\ \text{R-type} &= 2.4 \text{ Rad/mV} \end{aligned} \tag{1}$$

The K-type has a thinner oxide and therefore is less sensitive to radiation damage.

Fitted functions from the calibration curves are

$$\begin{aligned} \text{K-type} : y &= -4 \times 10^{-6}x^4 + 0.0015x^3 - 0.1991x^2 + 29.464x + 42.377 \\ \text{R-type} : y &= 0.002x^3 - 0.9382x^2 + 288.25x + 641.2 \end{aligned} \tag{2}$$

where y is in mV and x is in kRad. The plots are not shown here. For the sceptic, they are pasted on page 8 of Sahu's Beast Data Analysis log. For more detailed and exact documentation ask Leon Moffitt or his Ausie buddies.

As you will notice, the equation conveniently converts the Rad into mV. We want exactly the opposite. Numerical solution to these equations is done in a program called $\tilde{}sahu/beast/mosfetcal/moscal.f$. It numerically solves the equation - both ways. Please refer to the documentation inside there. You will find the executable *moscal* in that directory. "*source moscal_make*" to make the executable.

Mosfets 1 through 12 are in the inner Beast. 13 and 14 are on the EFC. A mapping of physical position of inner-beast Mosfets is given in Fig.5.4. EFC mosfet positions are trivial - please see the table below. Positions are noted in Fig. 5.4, as well as in file $\sim sahu/beast/mosfetcal/mosfetmap.dat$

Right now we are taking Mosfet data every shift. The data file that contains these readings as a function of time is in $/b01/beast/mosfet/moshistory.dat$. A kumac file that makes a history plot is in the same directory as moshist.kumac.

2.2 Maintenance and Reading Values

As far as the maintenance goes, you are pretty much at Leon's mercy. We are not reading the Mosfets online, because the mysterious reader box generates a 2 MHz noise that creates troubles around. So we normally keep that off, except when we take readings manually.

Once a shift, when there is no beam, or when you deem data taking unimportant, stop taking data, and go to the Beast Cage Floor 2 with a multimeter. There is a black Mosfet reader - set the manual knob to K or R. The power to the box is normally off. It is a grey power supply. Turn it ON, and push the output button so that the red light is ON - now you can read the Mosfets. Power on the black Mosfet reader. A Push-button meters navigate you through different channels. Before you take a reading, press the green manual button a few times. There will be a value on the LCD panel, and it will slowly drift down. Take the value you started with, right after you pressed the green button a few times. Compare the values with previous measurements in the log book. Make sure you are not logging a totally crazy value. MOST IMPORTANT - SWITCH OFF THE MOSFET POWER when you are done.

If possible, log these values in the data file $/b01/beast/mosfet/moshistory.dat$.

3 PIN Diodes

3.1 Concept

Each diode module has two PIN diodes, with a 2 mm Pb layer between them. Essentially it is a rudimentary calorimeter for detecting background at the positions of silicon sensors and hybrid amps of the SVD. The 2mm Pb separation helps separating the spent particle background from synchrotron radiation. A note on its usefulness can be found on the Beast Web page.

3.2 Diode as a Detector

Each diode is a Hamamatsu S2744-08 with silicon volume of 20 mm $\times$ 10 mm $\times$ 300 μm. Full depletion occurs at about 35 volts. To take into account charge accumulation by any radiation damage, we operate at a reverse bias of 60 Volts. Leakage current of each diode is amplified and converted to a voltage with an amplification factor of 100 mV/nA. The voltages are read by the IOTech modules to a precision better than 1 mV.

Assuming it takes 3.6 eV to produce an eh pair, for the given silicon volume and amp gain, we get

$$1\text{Volt} = 25\text{mRad/sec} \tag{3}$$

It may be noted that for 1 nTorr vacuum and beam currents of 2.6 A for positron and 1.1 A for electron, the nominal background dose is 25 kRad/yr from spent electrons. (1 yr = 10^7 sec). So the best case equation is

$$25\text{kRad/yr} \equiv 2.5\text{mRad/sec} \equiv 1\text{nA} \equiv 100\text{mV} \tag{4}$$

3.3 Diode Mapping

Physical positions of the diodes are given in Fig 5.4.

The diodes numbers don't map sequentially to the IOTech read-out channels. The patch is given in Fig 5.4. It is incorporated in the analysis program with the routine

This patch is already installed in the software (*analyzer* of Unidaq as

```
void diode_patch(long patch[])
```

in

```
beast-include.c
```

3.4 RTDs inside Diode Module

Each diode module has an platinum resistance thermometer, called RTD. They are read out by the RTD. The mapping is sequential, for example, RTD-1 is in Diode-module-1 and so on...

It is known that the leakage current of PIN diodes changes drastically with temperature. To calculate out this effect from real radiation effect, we need to know the diode temperature, and hence we use RTDs in diode modules.

The temperature has been very stable in the cave, to better than a degree centigrade. So we haven't had the need to calibrate the diode leakage current with RTD measurements.

I will write a code to make this correction soon.

3.5 Diode Bias Voltage

The diodes get completely depleted at about 35 volts. We decided to run them at 60 V to deplete any additional region damaged by radiation. At this high voltage, however, a large amount of instantaneous dose causes a *funnel* through the diode, and causes a short between the n and p sides. So that diode can't be used anymore. Of course, the symptom is a large leakage current with very little bias.

In order to avoid this we operate diodes at a very low bias - such as 3 V. The evergy deposit needs to be rescaled accordingly. We use the formula -

$$\text{depletion depth} \propto (V_{bias} - V_{junc}) \tag{5}$$

where $Vjunc$ is 0.7 volts.

Since, the dose is proportional to the depletion depth, and full depletion occurs at 35 V, the calibration needs to be changed as

$$1\text{Volt} = 25\text{mRad/sec} \times \frac{V_{bias} - 0.7}{35 - 0.7} \tag{6}$$

V_{bias} needs to be clamped at 0.7 V and 35 V for this equation.

4 Drift Chambers

4.1 Concept

There are 21 inner tubes and 32 outer proportional tubes in Beast. The tubes are all 54.61 cm long, inner diameter of 1.219 cm, wall thickness of 0.0508 cm, and are of aluminum. The anode wire is gold plated tungsten of 50 μm dia. We flow HRS gas (Ar 89%, CO_2 10%, CH_4 1%) in them. The inner tubes are packed in three quadrants I2, I3 and I4, seven in each. The outer tubes come in eight octants, O1 through O8, four in each.

The general mapping is given in Fig 5.4.

Of course, there is a need for mapping, since we screwed up the cabling. The tube scaler and DVM mapping scheme is given in Figs 5.4 and 5.4. This patch is already installed in the software (*analyzer* of Unidaq as

```
void tube_patch(long patch[])
void tube_patch_dvm(long patch[])
in

beast-include.c
```

For pulse debugging it may be necessary to look at the pulses at the patch panel. The mapping for scalers on the aluminum patch panel in the beast cage is given in Fig 5.4.

4.2 Calculating Gas Gain

Gas gain was calculated by combining a theoretical formula and curve-fitting. Following Sauli's Yellow Report, gas gain

$$M = e^{2\sqrt{\frac{kNCV_0 a}{2\pi\epsilon_0}}\left(\sqrt{\frac{V_0}{V_T}}-1\right)} \tag{7}$$

where V_0 = applied voltage, V_T = Threshold voltage, C= chamber capacitance $= \frac{2\pi\epsilon_0}{\ln(b/a)}$, a = radius of anode wire, b = inner radius of tube, ϵ_0 = dielectric constant for gas = 8.85 pF/m, N = Number of gas molecules per unit volume, $k = 1.81 \times 10^{-17}\ cm^2/V$.

We take the data of scaler counts rate as a function of HV. The counts rate should follow the expression -

$$C = P_3 e^{P_1 \sqrt{V_0} \sqrt{V_0/P_2}} \tag{8}$$

By fitting the data to this expression, the $V_T = P_2$ can be obtained. This is done with the program *~sahu/beast/dccal/dcfit.kumac* . Using this fit, we know that the $V_T = P_2 = 1.25$ kV. Using this value in the gain equation above, we can determine the gas gain at any given voltage. This is done in the program *~sahu/beast/dccal/sauli.f* .

4.3 Calculating Dose Rate

DC gain of the chamber amplifier is 22 mV/μA. Using density of Argon 0.0018 gm/cc, and assuming it takes 25 eV to create an ion pair, it can be calculated that (page 139 of Sahu's logbook)

$$1 \text{ mR/sec} = 1.05 \times 10^{-3} \times G \text{ mV} \tag{9}$$

where G is the gas gain.

After calculating G from the program cited in the previous subsection, the dose rate can be calculated with this equation by observing the amp output.

5 Data Analysis

5.1 Where are the Data Files ?

The DAQ program based on Unidaq writes events into two kinds of files - binary file and ntuple file. Binary files are in */b01/beast/dat/r*******.dat* and ntuple files are in */b01/beast/hb/r*******.hb* . Description of the ntuple is given on the page
http://www.phys.hawaii.edu/~ beast/operation/ntuple_beast_v3.html

These files have been copied from the beast1beast computer : *.dat* files from *~beast/rundata/* area and *.hb* files from *~beast/analyzer/* area.

Sometimes you may have to regenerate the *.hb* file from the corresponding *.dat* file. Follow this procedure -

1. go to ∼*beast/analyser* on beast1.
2. edit *offline.kumac* (change r0000495.dat → r*******.dat)
3. type *ana_d_off*
4. type *exec offline*

That should be it. Now you can copy the ntuple file to an appropriate area on bwg and open with PAW.

5.2 Getting the Accelerator Info

The latest informations on Accelerator parameters are available only from the KEK-B computer *abco1* all the time. The relevant parameters such as current, pressure, start and stop time, date etc. are normally registered in data files in text format. This file can directly be used for analysis. We plan to copy and update this file once everyday in the official BEAST area in the B-computer so that people can do their analysis without caring for this. The essential informations regarding the location of the data files for the users are as follows.

1. The official beast area in bwg machine is */b01/beast/vacuum_current* where the Data files are kept and will be updated.

2. Data file format is *yymmdd_yymmdd i.e.* to indicate the history of Accelerator parameter between the yymmdd(begin)_yymmdd(end) period.

How to read the data files and analyze them ??

To answer this question we have made some example files which the users can take a look at and do accordingly. The example analysis file is kept in the directory */b01/beast/vacana* in bwgxxx machines. A Fortran program *vacana.f* file is supplied which reads the Data files and make the hbook file.

At present the Data files to be analyzed are listed in another file *filelist.dat*. The Fortran program *vacana.f* opens the *filelist.dat* file and loops over all the listed data files to read them. In order to know which accelerator parameters are read by the program please take a look at the Fortran program *vacana.f* and one of the Data files. Several parameters are calculated inside the *vacana.f* file which are written into n-tuple and finally saved in an hbook file upon program completion. Once this hbook file is produced, it can be read with PAW to extract parameters from the n-tuple.

What the users should do ???

1. Copy the files, *vacana.f, makefile, filelist.dat* from */b01/beast/vacana* to their own directory and edit whatever you want.

2. The path for the Data files are explicitely provided in the Fortran program *vacana.f* so that it will automatically read those data files which are listed in the *filelist.dat*.

3. Once all the above files are copied into a directory, run *make* to produce an executable file for *vacana.f*.

4. Run the executable file to read the Data files and generate the hbook file (currently the example hbook file is *pvsi.hbk*). You can choose your own and edit the Fortran program file.

What parameters are filled in the n-tuple ???

A total of 11 parameters are filled in one n-tuple which are listed below. It's pretty much on the interest of the concerned users..

1. par(1) : Date (yymmdd) <— (year-month-date)
2. par(2) : Time (hhnnss) <— (hour-minute-second)
3. par(3) : Time_hr (hour)
4. par(4) : lcur (LER Current) (mA)
5. par(5) : hcur (HER Current) (mA)
6. par(6) : lervacd02 (LER Vacuum Pressure) (nT)
7. par(7) : hervacd01 (HER Vacuum Pressure) (nT)
8. par(8) : lerdpdi (LER Dynamic Pressure, dP/dI) (nT/mA)
9. par(9) : leramphour (LER Amp-hour, $\int I dt$) (Amp-hour)
10. par(10) : herdpdi (HER Dynamic Pressure, dP/dI) (nT/mA)
11. par(11) : heramphour (HER Amp-hour, $\int I dt$) (Amp-hour)

You can add anything you want ...

5.3 Diode Analysis

To be written later.... You can do it by extracting the relevant parameters from the n-tuples.

5.4 Chamber Analysis

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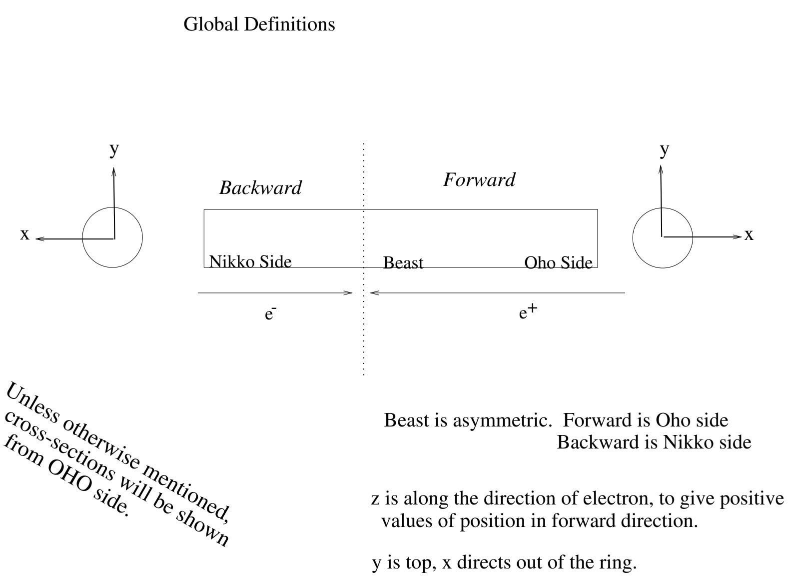


Figure 1: Sign Convention in Beast

Figure 2: Beast Snapshot

Mosfet No.	Type	R	Phi	Z
----------	----	-	---	-
1	I1	3.3	-25	12.0
2	I1	3.3	-25	0.0
3	I1	3.3	-25	-6.0
4	I2	3.3	65	12.0
5	I2	3.3	65	0.0
6	I2	3.3	65	-6.0
7	I3	3.3	155	12.0
8	I3	3.3	155	0.0
9	I3	3.3	155	-6.0
10	I4	3.3	245	12.0
11	I4	3.3	245	0.0
12	I4	3.3	245	-6.0
13	EFC Oho	11.5	90	60.0
14	EFC Nikko	12.0	90	-43.0

Figure 3: Mosfet location

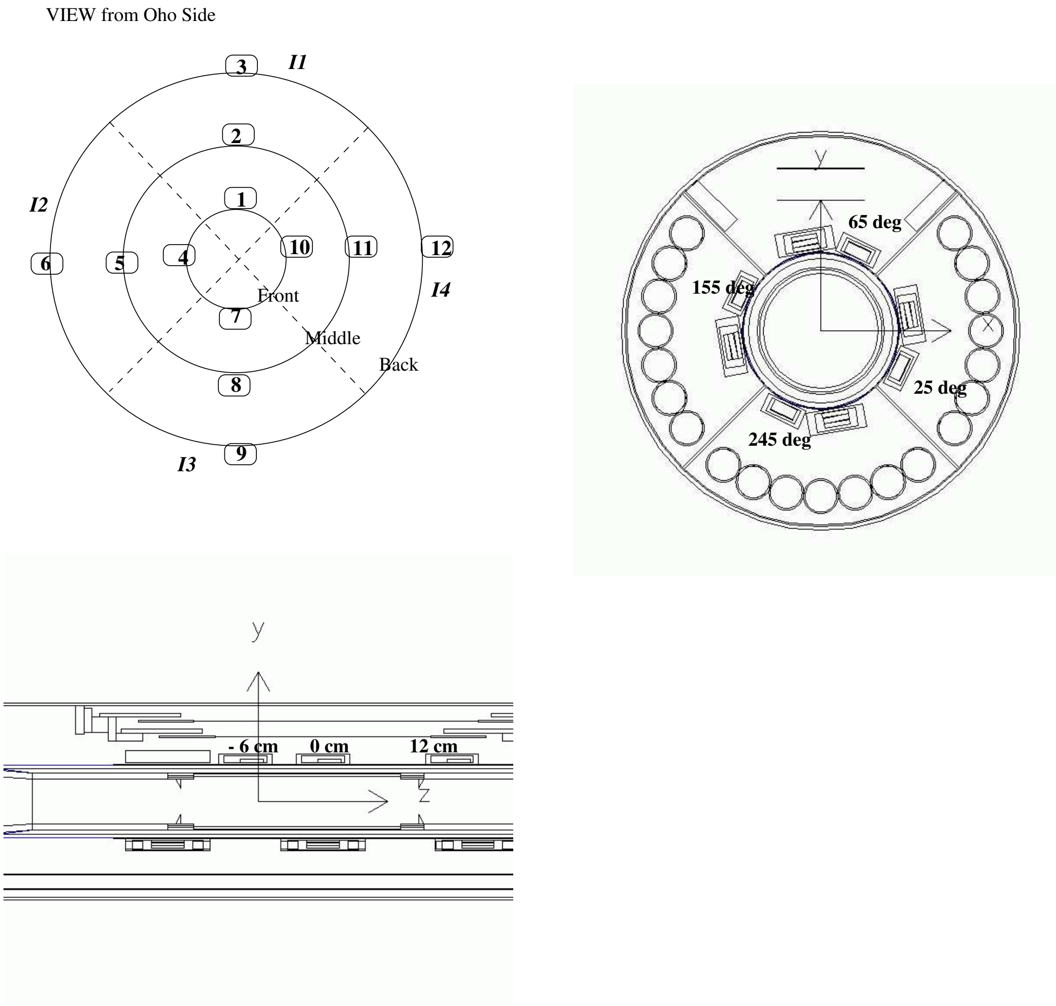
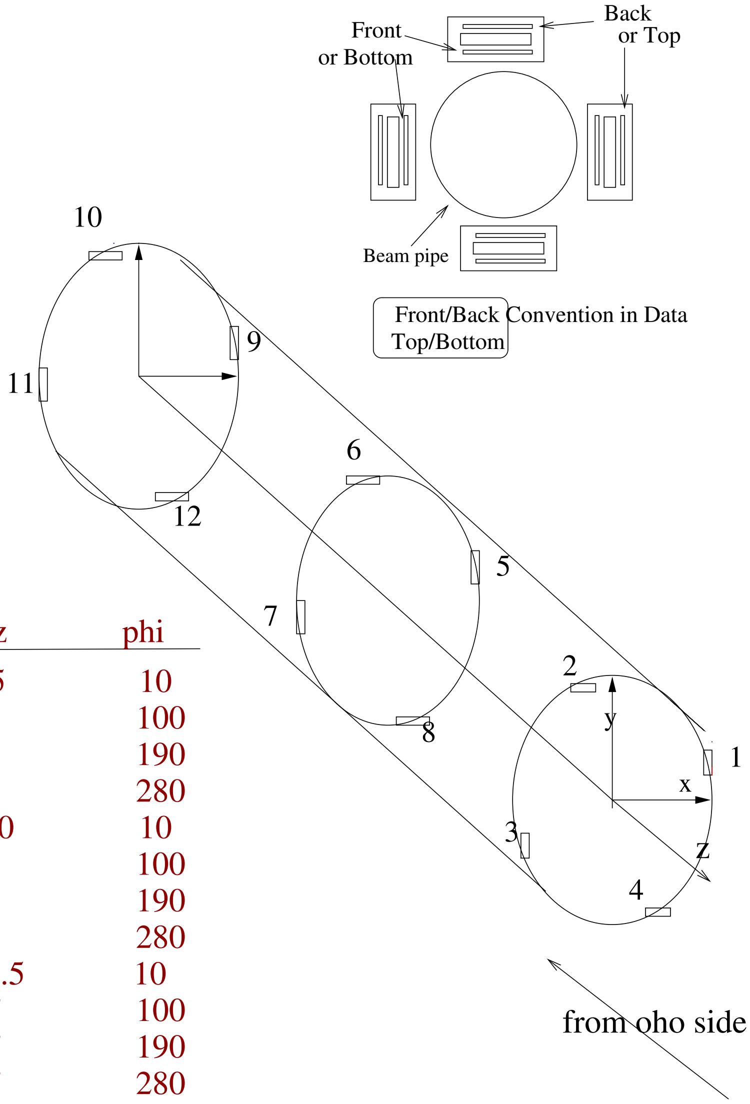


Figure 4: Mosfet Location



Diode #	Module	z	phi
1 & 2	1	17.5	10
3 & 4	2	"	100
5 & 6	3	"	190
7 & 8	4	"	280
9 & 10	5	5.0	10
11 & 12	6	"	100
13 & 14	7	"	190
15 & 16	8	"	280
17 & 18	9	-7.5	10
19 & 20	10	"	100
21 & 22	11	"	190
23 & 24	12	"	280

ODD = TOP/BACK ; EVEN = BOTTOM/FRONT diode

Figure 5: Diode Location

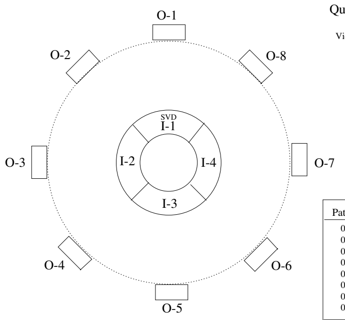
Patch Panel for Diodes

What goes in at Beast		What appears at IOTech	What goes in at Beast		What appears at IOTech
I-1	1	17	I-2	7	23
	2	18		8	24
	3	19		9	1
	4	20		10	2
	5	21		11	3
	6	22		12	4
What goes in at Beast		**What appears at IOTech**	**What goes in at Beast**		**What appears at IOTech**
I-3	13	5	I-4	19	11
	14	6		20	12
	15	7		21	13
	16	8		22	14
	17	9		23	15
	18	10		24	16

Figure 6: Diode Patch

Quadrant Nomenclature

Viewed from OHO side



Signal Cabling

Patch No.	Cable	AmpBox
01	5	4 top
02	2	4 bottom
03	14	6 top
04	12	6 bottom
05	6	7 top
06	8	7 bottom
07	11	8 top
08	1	8 bottom
I2-A	7	1 top
I2-B	4	1 bottom
I3-A	3	2 top
I3-B	9	2 bottom
I4-A	13	3 top
I4-B	10	3 bottom

HV Assignment

Quadrant	Cable
I-1	--
I-2	20
I-3	19
I-4	18
All Outer	21

Figure 7: Proportional tube quadrants and octants

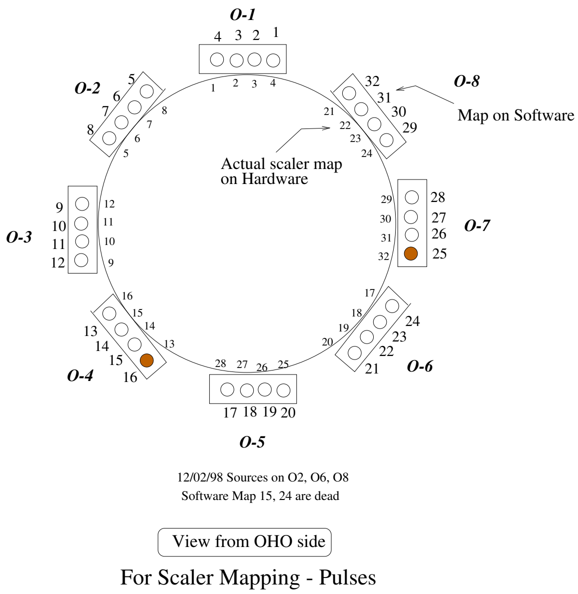


Figure 8: Outer Chamber map

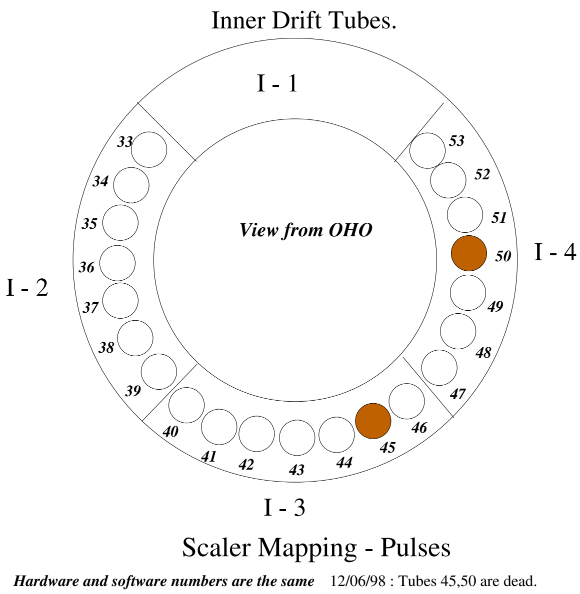


Figure 9: Inner Chamber map

Chan #	on Patch		Unidaq scaler	IOTech DVM	Chan #	on Patch		Unidaq scaler	IOTech DVM
----	--------		------	------	----	--------		------	------
1	O-1	1	4	28	33	I-2 A	4	33	1
2		2	3	27	34		3	34	2
3		3	2	26	35		2	35	3
4		4	1	25	36		1	36	4
5	O-2	1	8	32	37	I-2 B	4	37	5
6		2	7	31	38		3	38	6
7		3	6	30	39		2	39	7
8		4	5	29	XX		1	XX	8
9	O-3	1	12	36	40	I-3 A	4	40	9
10		2	11	35	41		3	41	10
11		3	10	34	42		2	42	11
12		4	9	33	43		1	43	12
13	O-4	1	16	40	44	I-3 B	4	44	13
14		2	15	39	45		3	45	14
15		3	14	38	46		2	46	15
16		4	13	37	XX		1	XX	16
17	O-7	1	28	52	47	I-4 A	4	47	17
18		2	27	51	48		3	48	18
19		3	26	50	49		2	49	19
20		4	25	49	50		1	50	20
21	O-5	1	20	44	51	I-4 B	4	51	21
22		2	19	43	52		3	52	22
23		3	18	42	53		2	53	23
24		4	17	41	XX		1	XX	24
25	O-8	1	32	xx					
26		2	31	xx					
27		3	30	xx					
28		4	29	xx					
29	O-6	1	24	48					
30		2	23	47					
31		3	22	46					
32		4	21	45					

Figure 10: Chamber hook-up at patch panel