# Gain Variation Study of Central BC-layer Scintillation Counters in D0 Detector

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**Abstract**

BC-layer scintillation counters covers PDT's in B and C layer of central muon system. Scintillation counters in B-layer have been installed in Run-II whereas, counters in C-layer have been in operation since Run-I. C-layer counters were used as cosmic veto counters in Run-I. These counters (with same PMT) in conjunction with A and B layer counters are used in Run-II as part of muon trigger. It is important to monitor time variation in the gain of each tube in order to make sure that muon trigger is efficient. To monitor the gain of each tube, LED calibration data have been taken periodically over the entire period of Run-II operation. In this note we present the collective analysis of this dataset which has been used to identify tubes with significant drop in the gain. Drop in the gain will be compensated by either reducing discriminator threshold or increasing the high voltage so as to keep their efficiency high.

# 1 Introduction

BC-layer scintillation detector is one of the important subsystems of the muon detector. It is used for generating muon trigger (in conjunction with A-$\Phi$ scintillation detector) as well as to get the timing information accurately. B and C-layer counters have been segmented into 8 Octants. Each scintillation counter is readout by two PMTs. Number of counters in each Octant and layer are shown in Table 1. Readout configuration of scintillation detector is well described in [1].

Though B-layer counters have been installed just before start of Run-II, the C-layer counters were in use since Run-I period. The gain of PMT tubes have been degrading monotonically since then due to their exposure to large number of particles produced in collision. During D0 upgrade program for Run-II, a LED calibration system was specially designed to monitor the gain of these tubes. The method used to get the absolute gain of

PMT tube using LED calibration data has been demonstrated and explained in [2]. The LED calibration data has been taken at regular intervals for central scintillation counter system since 2001 during the Run-II period. *Teststand* calibration data collected well before installation of counters and the data recorded just after the installation was used to obtain the operating voltage and discriminator threshold of each of the tube (Early 2002). Data collected after this stage have been used to study the gain of each tube as a function of time. Tubes with significant drop in the gain are identified by comparing the present gain with that at the beginning of Run-II.

Table 1: Distribution of Counters in each Octant

| Octant | Layer | No. of Counters | No. of PMT |
|---|---|---|---|
| 0 | C | 40 | 80 |
| 1 | C | 40 | 80 |
| 2 | C | 40 | 80 |
| 3 | C | 40 | 80 |
| 4 | B | 8 | 16 |
| 4 | C | 40 | 80 |
| 5 | B | 34 | 68 |
| 5 | C | 18 | 36 |
| 6 | B | 34 | 68 |
| 6 | C | 18 | 36 |
| 7 | B | 8 | 16 |
| 7 | C | 40 | 80 |
| | Total | 360 | 720 |

## 2 Data Processing Tools

Readout electronics [1] is spread out in six crates reading different regions of the scintillation detector. LED Calibration runs are taken for each crate separately using DAQ-LOCAL interface to the detector. PMTs are illuminated with LED light pulses with predetermined LED intensity. Intensity has been kept same through out this period of almost 3 to 4 years. The intensity of LED light is monitored using PIN diode. The details of calibration system can be seen in [3]. In each calibration run we first take pedestal run followed by LED run. Pedestal and LED runs are stored in different root files containing ADC and TDC distribution of each PMT as well as PIN channel. Variation in the LED intensity can be studied using corresponding PIN ADC Data. PMT response as a function of time has been studied in two different ways; a) using LED ADC distribution after normalizing with PIN ADC Data and b) by obtaining absolute gain of the tube using LED, PIN ADC data and studying its stability as function of time. (Details of analysis procedure are explained in Section 3). Different tools are developed to accomplish this task and they are described below.

- **Run Database** Often DAQ fails during calibration run and hence all the data collected is not useful for analysis. After taking the run it is certified to be good or bad depending on the quality of the data. All good calibration runs are then tabulated in run-database file containing information about pedestal and LED runs, date of run etc. It is to be noted that root file contains only histograms and date of run information has to be obtained from database file. The database files are named as *rundbXXXX.dat* where *XXXX* indicates year in which data had been taken. For ex. *rundb2003.dat* contains information about all good calibration runs taken during 2003. For illustration, one of the record in *rundb2003.dat* file is shown below.

*02012003 52 cr52_5099.root cr52_5100.root cr52_5100.root BC run OK*

- **Data Processing** As mentioned before calibration root file contains only ADC and TDC histograms of each PMT or PIN. They have to be processed to extract parameters that are useful for this study. Software have been developed to process ADC histograms of PMT and PIN to obtain parameters like pedestal mean and RMS of PMT and PIN channel using *pedestal run*. Gaussian peak, gaussian sigma for each PMT channel and corresponding PIN channel which is shining that PMT are obtained using *LED signal runs*. Using pedestal subtracted peak and sigma for PMT and PIN, we obtain an absolute gain of that tube as described in [2]. All this information along with PMT address available in various formats is stored in the output file in the ASCII format. The output file also contains a flag indicating the quality of histogram fit for each channel. There is one output file for each calibration run with a naming convention of *InputFile.out_v09* where v09 is the version of the software (*pmtcalib_v09.C*) used to process these root files. All the parameters that are needed for gain studies can be accessed through these *.out_v09 files. However, it is not convenient to access them through large number of .out files particularly when one to wants analyze data based on different selection criteria. Utility by name *Fill_tuple.C* is developed which reads each record from all output files and populates them in a single tree *scint.root*. Next level program *pmtcalib_analyse.C* loops through all the records and does time dependent analysis of certain parameters (for ex. gain) stored in the root-tuple to identify PMTs with reduced gain. Details of analysis procedure is described in next section. Flow chart of data processing is shown in Fig. 1

# 3 Data Analysis

The root-tuple (*scint.root*) contains several parameters (such as fitted ADC peak, gain etc) for each PMT and PIN channel which are used for PMT gain studies. The gain of the tube as a function of time is obtained by two different methods described below.

## 3.1 Method-1

Since intensity of LED has been kept same all through the Run-II period, we expect ADC peak to be same at all times for a given PMT if its gain has not dropped. Any PMT showing significant reduction in this peak at present time w.r.t. that at the beginning of Run-II will be the candidate for gain correction. However, LED intensity can change slightly for various reasons which can be compensated by normalizing PMT ADC peak with fitted PIN ADC peak. Stability of LED intensity can be seen in Fig. 2 which shows PIN ADC

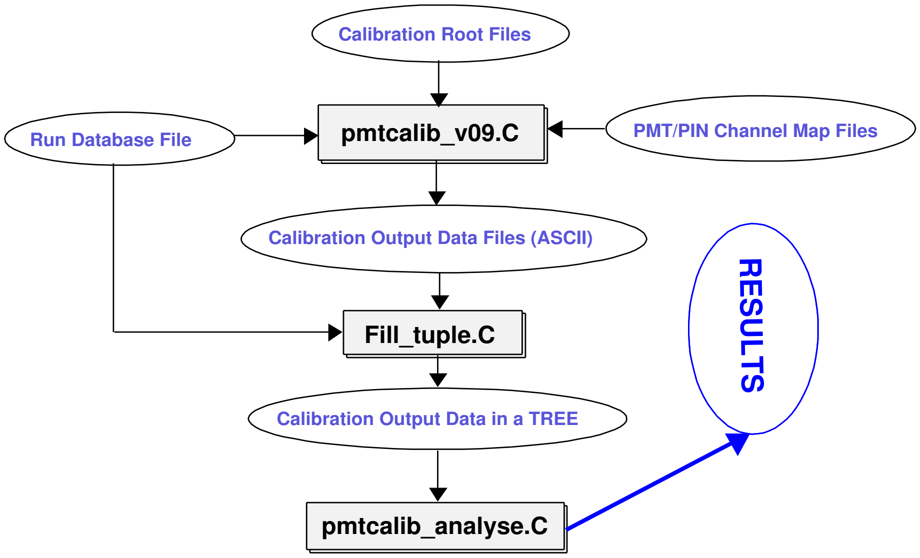


Figure 1: Flow chart of data processing scheme

peak as a function of day number (Day count starts from 01/01/2001). In Fig. 3 we show the distribution of ratio of PMT to PIN peak as a function of day number for two tubes. Ratio is quite steady for a stable tube (PDT-220 PMT-4) indicating that gain has not changed whereas a tube with significant gain loss (PDT-220 PMT-13), the ratio is seen to be steadily decreasing with time. Present gain for this tube has gone down by about 20%. It is to be noted that PMT ADC peak represents the relative gain of the tube. Though PMT/PIN ratio is a robust parameter to monitor for gain stability, any loss in the PIN gain over last 3-4 years can affect the accuracy of this method. In order to find the fractional reduction in PMT gain, we take average of first two value of the ratio and divide the ratio at every point by this average. This essentially normalizes first point to the unity gain and hence normalized gain at subsequent point represents fractional loss in the gain at that time. Time variation of normalized gain obtained using PMT/PIN ratio method is shown in Fig. 3. Relative PMT gain at present is obtained by taking average of last two normalised gain measurements. Distribution of present gain of tubes in B and C layers for various Octants is shown in Fig. 5, 6. It can be seen that the gain of tubes in C-layer of Octant 0 have deteriorated more than those in any other Octants. Tubes in C-layer of Octant-6 showed wide fluctuations in the ratio and hence we could not monitor the gain of these tubes. Data for tubes in this Octant shows that LED intensity has been increasing rapidly with time. Tubes other than Octant-6 with present gain less than 0.95 were shortlisted and after manually going through various PMT response related plots they were identified to be candidates for gain correction.

### 3.2 Method-2

The absolute gain of the tube is estimated using fitted peak and sigma of PMT ADC distribution with the correction factor of PIN distribution. Estimation of the gain does not require operation of LED system at the same intensity as in case of Method-1. Due to uncertainty

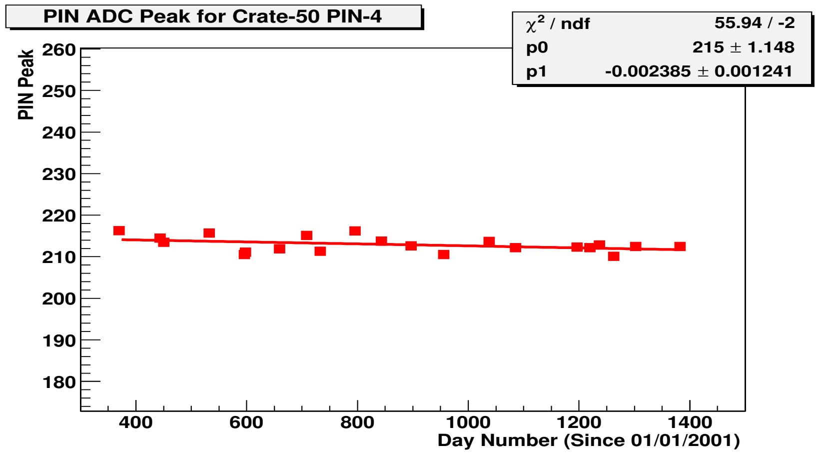


Figure 2: PIN response during RunII period

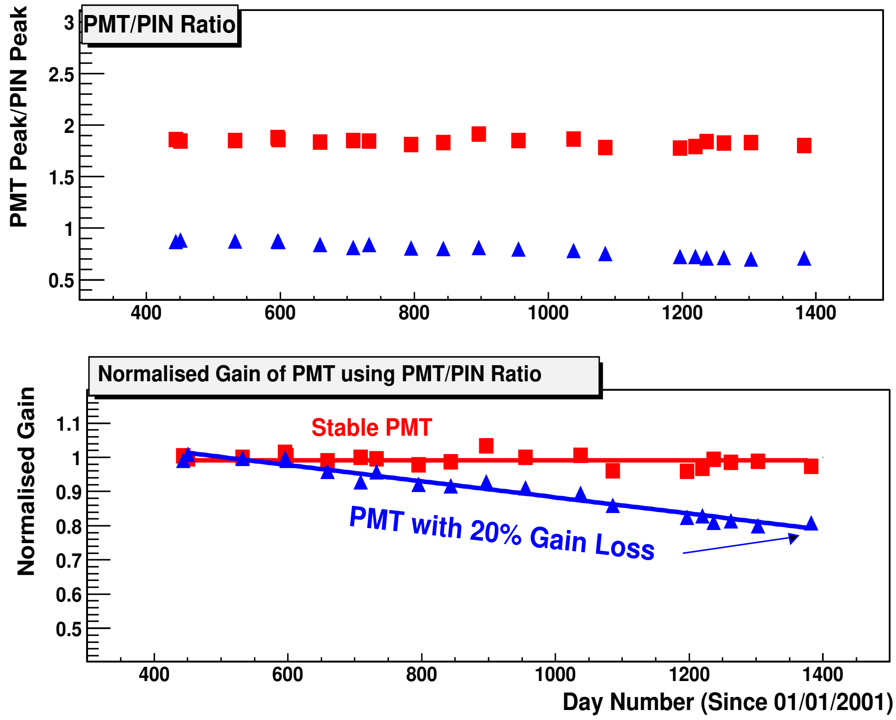


Figure 3: a) Time variation of PMT/PIN ratio for stable and unstable tubes. b) Time variation of normalised gain for the same tubes during RunII period

in various fitted parameters used for estimation of gain, the accuracy of the gain is coarser than the PMT/PIN ratio used in the earlier method. However absolute gain can be used as complimentary method for monitoring change in gain with time. Fig. 4 shows variation of absolute gain with time for two tubes. The upper panel is for a tube with steady gain and lower panel is for a tube with a substantial loss in the gain with time. We normalise the gain to unity at the beginning of the Run-II. Subsequent data are normalised with the same scale factor. With this, the gain of a tube significantly less than unity would indicate a loss in the gain. Normalisation scheme is same as that followed in Method-1. Shortlisted candidate PMT's from both the methods are compared with each other to get the average fall in the gain.

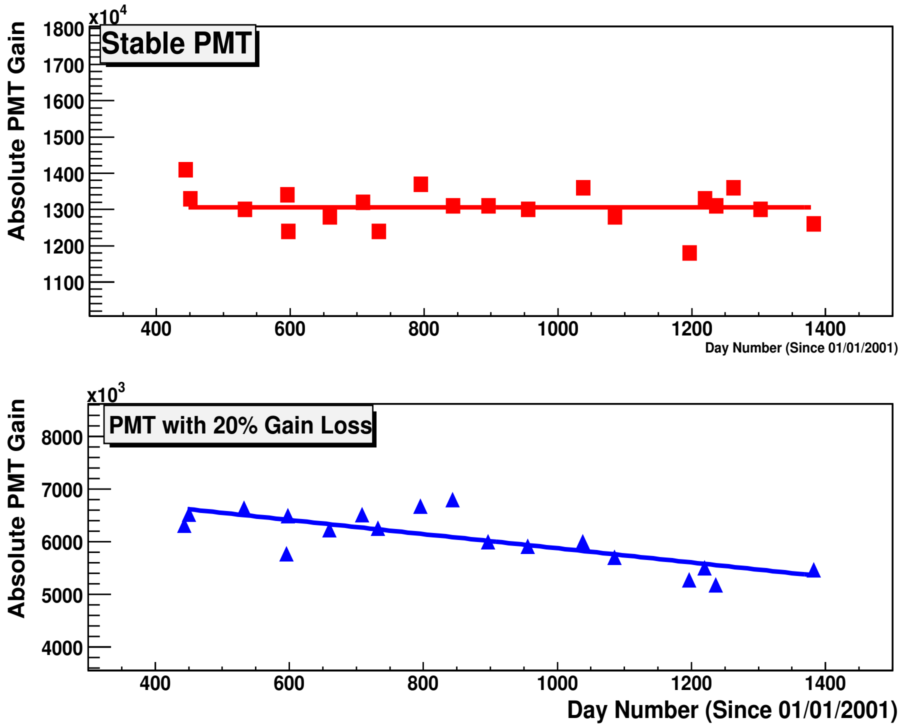


Figure 4: Time variation of absolute PMT gain for stable and unstable tubes during RunII period

# 4 Results

LED calibration data have been used to monitor the gain of PMT using methods described in Section 3.1 and Section 3.2. Both the methods have worked quite satisfactorily for most of the tubes except for tubes in C-layer of Octant-6. Tubes with present gain drop of more than 5% w.r.t. starting gain are listed the Table 2. Distribution of gains of tubes as of end of 2004 is shown for C-layer in each Octant separately in Fig. 6. We observe that most of the tubes in Octant-0 shows significant loss in the gain. Inclusive distribution of present gain of tubes from Octant-1,2,3,4,5 and 7 is also shown in the same Figure. Whereas, distribution of present gain for all tubes in B-layer is shown in Fig. 5. As expected, in this layer, most of the tubes are quite in healthy state as of end of 2004. Only two tubes have been identified with loss of about 10% gain in B-layer. All tubes having more than 5% loss are listed in Table 1.

Using these values new discrimination threshold or new operating HV will be estimated so as to make sure that these tubes continue to trigger efficiently on MIPs. We need to study the channels where calibration system has failed to give good quality data.

# References


[1] Central Muon Upgrade Scintillator Front-End Crate Addresses
T. Diehl, A.Ito, Mao, E. Podschweit, D. Hedin, D0 Note 003642

[2] D0 Muon Scintillator Gain Determination
S. Doulas, S.R. Dugad, A.S. Ito, D0 Note 003861

[3] LED pulser system for D0 Muon Scintillation counters
P. Hanlet *etal*, Nuclear Instruments and Methods in Physics Research, **A521**, 343, (2004)


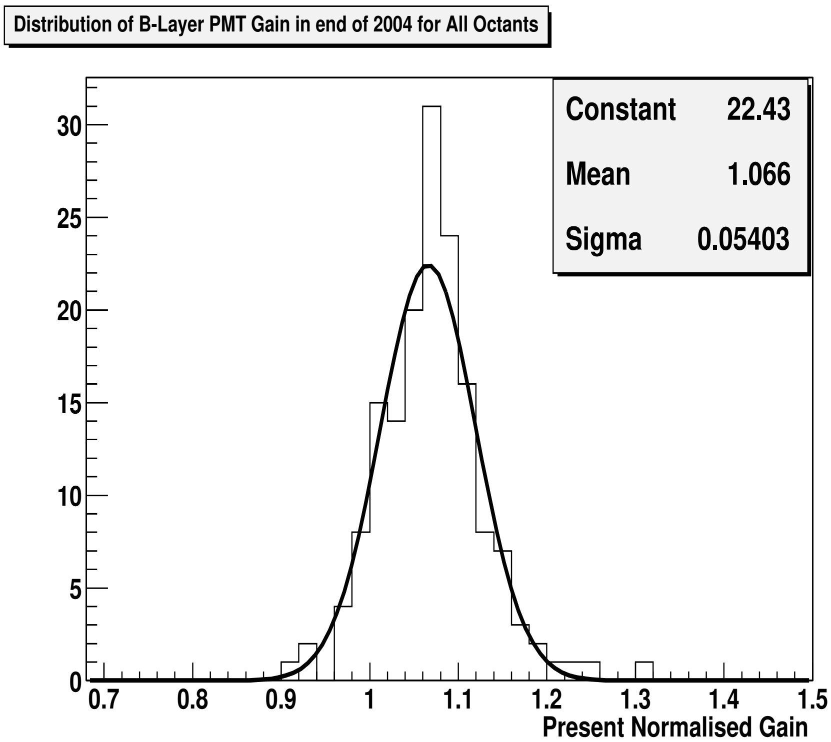


Figure 5: Distribution of present normalised gain for PMT tubes in B-layer of all Octants.

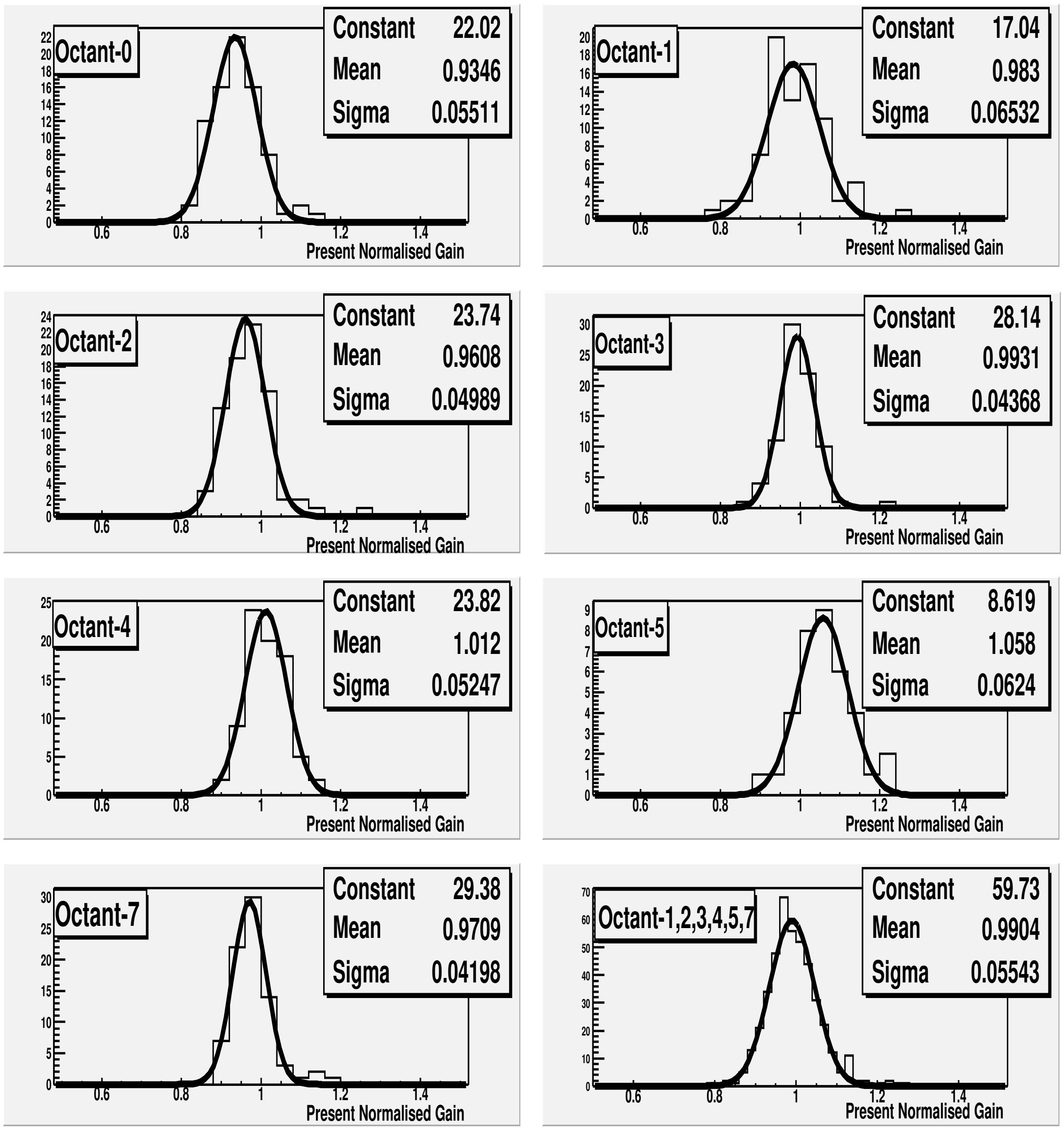


Figure 6: Distribution of present normalised gain for PMT tubes in C-layer of each Octant. Last figure shows inclusive distribution (except Octant 0 and 6).

Table 2: List of Counters with Reduced Gain

| PDT | Tube No. | Present Gain | PDT | Tube No. | Present Gain | PDT | Tube No. | Present Gain |
|---|---|---|---|---|---|---|---|---|
| 200 | 1 | 0.88 | 200 | 2 | 0.83 | 200 | 3 | 0.83 |
| 200 | 5 | 0.88 | 200 | 8 | 0.89 | 200 | 9 | 0.80 |
| 200 | 10 | 0.88 | 200 | 11 | 0.92 | 200 | 13 | 0.81 |
| 200 | 14 | 0.82 | 200 | 15 | 0.87 | 200 | 16 | 0.91 |
| 210 | 1 | 0.81 | 210 | 2 | 0.91 | 210 | 3 | 0.87 |
| 210 | 4 | 0.87 | 210 | 5 | 0.93 | 210 | 6 | 0.85 |
| 210 | 7 | 0.84 | 210 | 8 | 0.85 | 210 | 9 | 0.85 |
| 210 | 10 | 0.88 | 210 | 11 | 0.92 | 210 | 12 | 0.85 |
| 210 | 13 | 0.91 | 210 | 14 | 0.87 | 210 | 15 | 0.90 |
| 220 | 1 | 0.91 | 220 | 2 | 0.89 | 220 | 5 | 0.87 |
| 220 | 7 | 0.90 | 230 | 1 | 0.90 | 230 | 2 | 0.91 |
| 230 | 3 | 0.92 | 230 | 5 | 0.91 | 230 | 6 | 0.89 |
| 230 | 10 | 0.92 | 230 | 11 | 0.91 | 230 | 12 | 0.89 |
| 240 | 2 | 0.93 | 240 | 13 | 0.93 | | | |
| 201 | 3 | 0.88 | 201 | 6 | 0.82 | 201 | 1 | 0.90 |
| 201 | 7 | 0.78 | 201 | 8 | 0.91 | 201 | 12 | 0.92 |
| 201 | 15 | 0.90 | 211 | 8 | 0.92 | 211 | 11 | 0.94 |
| 221 | 9 | 0.90 | 221 | 10 | 0.87 | 221 | 11 | 0.92 |
| 221 | 12 | 0.85 | 221 | 13 | 0.85 | 221 | 15 | 0.92 |
| 221 | 16 | 0.92 | 231 | 4 | 0.90 | 231 | 6 | 0.90 |
| 231 | 14 | 0.91 | | | | | | |
| 202 | 1 | 0.91 | 202 | 4 | 0.90 | 202 | 5 | 0.91 |
| 202 | 6 | 0.89 | 202 | 7 | 0.93 | 202 | 8 | 0.91 |
| 202 | 13 | 0.87 | 202 | 15 | 0.86 | 202 | 16 | 0.89 |
| 212 | 11 | 0.90 | 232 | 1 | 0.93 | 232 | 4 | 0.91 |
| 232 | 7 | 0.90 | 242 | 2 | 0.90 | 242 | 3 | 0.92 |
| 242 | 6 | 0.87 | 242 | 9 | 0.93 | 242 | 11 | 0.86 |
| 242 | 12 | 0.92 | 242 | 13 | 0.88 | | | |
| 203 | 7 | 0.92 | 203 | 12 | 0.92 | 203 | 15 | 0.87 |
| 243 | 1 | 0.89 | 243 | 2 | 0.92 | 243 | 6 | 0.90 |
| 243 | 12 | 0.93 | 243 | 13 | 0.88 | | | |
| 204 | 3 | 0.89 | 204 | 4 | 0.93 | 234 | 10 | 0.92 |
| 234 | 13 | 0.88 | 244 | 2 | 0.88 | 244 | 4 | 0.90 |
| 244 | 5 | 0.90 | | | | | | |
| 245 | 9 | 0.92 | | | | | | |
| 207 | 2 | 0.95 | 207 | 3 | 0.95 | 207 | 4 | 0.92 |
| 207 | 5 | 0.89 | 207 | 7 | 0.88 | 207 | 8 | 0.88 |
| 207 | 10 | 0.90 | 207 | 11 | 0.93 | 207 | 13 | 0.95 |
| 207 | 14 | 0.93 | 207 | 16 | 0.92 | 217 | 10 | 0.89 |
| 227 | 2 | 0.90 | 227 | 4 | 0.92 | 227 | 7 | 0.92 |
| 227 | 8 | 0.92 | 227 | 9 | 0.93 | 227 | 10 | 0.92 |
| 227 | 13 | 0.89 | 227 | 14 | 0.91 | 237 | 4 | 0.91 |
| 237 | 7 | 0.91 | 237 | 14 | 0.92 | 247 | 9 | 0.89 |
| 116 | 15 | 0.90 | 107 | 1 | 0.92 | | | |