Module Performance of the Silicon Vertex Tracker

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This note presents the findings on the performance of the 66 modules, 132 module sides, of the Silicon Vertex Tracker (SVT).

Each of the 66 modules of the SVT has two sides—top and bottom. Each side has three types of senors: Hybrid, Intermediate, and Far.

Figure 1 shows, for the top and bottom sides of the modules, the distribution of the *burn-in currents* measured at Fermilab and the distribution of the *calculated currents*. The *calculated current* of a side comes from the measured currents of the pristine sensors used on that side; these currents were measured by Hammamatsu.

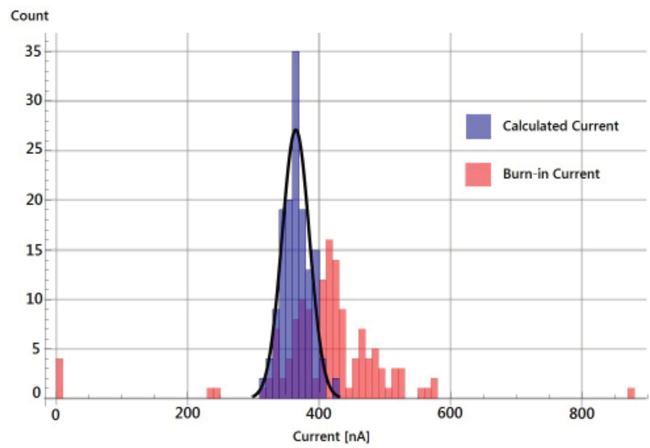

FIG. 1. Distribution of calculated currents and burn-in currents for the module sides. The calculated current data fit a Gaussian distribution; burn-in current data do not have a Gaussian distribution.

The *calculated current* data are fitted with a Gaussian, which has a mean value of 375 nA and a σ of ~30 nA. The *burn-in current* data do not follow a Gaussian distribution, perhaps due to the lack of stringent quality control at the time of module fabrication at Fermilab.

Figure 2 shows, for the assembled SVT modules, the distribution of currents of the module sides measured in December 2015 at JLab and the *calculated current*.

December data and its associated Gaussian are shifted by 110 nA to align the mean value, 265 nA, with the mean value of the *calculated current* data. December currents have a mean value lower than the *calculated current* because the electronics of the modules were cooled (to 10°C). For both distributions, the Gaussian fits are nearly identical with a σ of ~30 nA.

Figure 3 shows that the January 2016 data have a mean value of 240 nA and a σ of ~30 nA. The mean value of the January data is lower than the mean value of the December data by 25 nA because the electronics were cooled (to 7°C).

A module side is considered to perform poorly if either of the following conditions is satisfied:

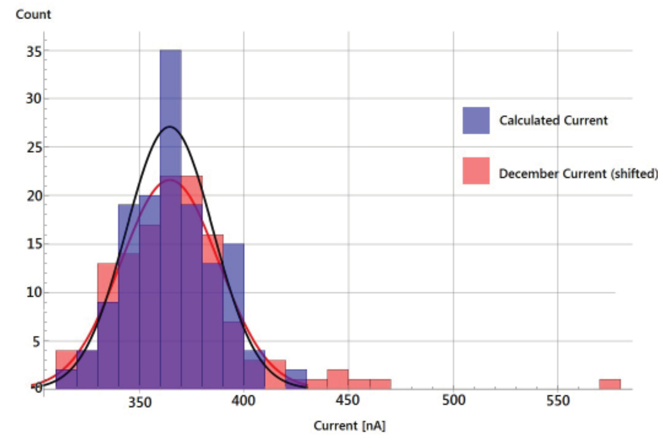

FIG. 2. Original currents and December currents. The December currents are shifted up by ~110 nA to display the nearly identical standard deviation for both distributions. Gaussian curves have been fitted on the original and December currents.

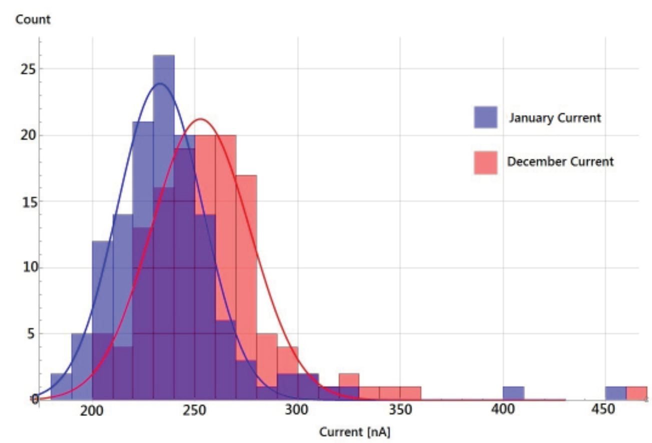

FIG. 3. December and January currents. Gaussian curves are fitted on both December and January distributions. It is shown that the January values fall behind the December values by ~25 nA. The values above 400 nA are being investigated.

1) $V_D - V_O > 10$ V, where V_D is the highest depletion voltage of the three sensor types that are used on a module side and V_O is the operational voltage.

2) $I_{V_O} - \langle I \rangle > \sigma_{\langle I \rangle}$, where I_{V_O} is the current draw of the module side at V_O, $\langle I \rangle$ is the average current draw of the module sides, and $\sigma_{\langle I \rangle}$ is the standard deviation.

Poorly performing modules were identified using the above conditions in SQLite query.

SQLite query results on the December data showed that 13 module sides were performing subpar, while January data indicated that there were 14 module sides. There were 12 module sides common to both months, Table I.

Sensors for the SVT came from 12 batches; 10 of the 12 batches had been used on poorly-performing modules, Fig. 4.

Sensor batch VAF77889 has a significantly higher failure rate compared to the other batches, a consequence of low statistics because this batch was used on a poorly-performing module side only once (out of a total of two uses).

Upon analysis of the failure rate of a batch based on the total usage, no correlation between batch numbers and poorly-performing module sides was determined.

The analysis assumes that all sensors on a poorly-performing module side are not working properly, which is not a correct assumption, but one which has to be made because there is no way of isolating the three sensors on a module side while the module is in the assembly.

To conclude, of the 132 module sides, 12 sides perform poorly. Since most of the poorly-performing sides are the bottom side, it is believed the poor performance is a consequence of fabrication issues.

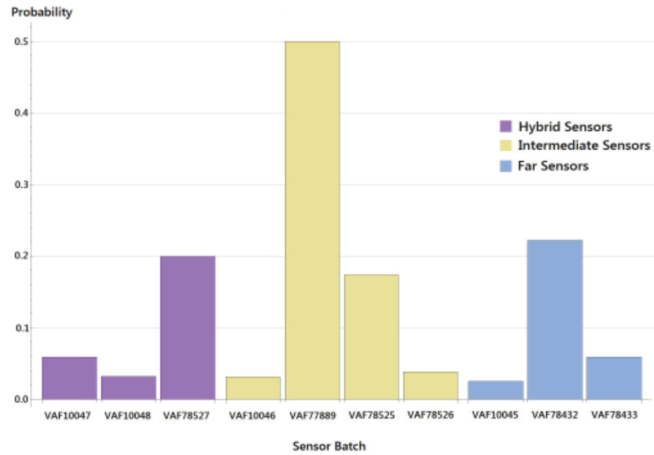

FIG. 4. Bar chart showing sensors found on poorly-performing module sides and the probability of finding each sensor batch type on these modules per overall usage of each batch. No correlation was found between the poorly-perfoming modules and sensor batches.

Poorly-Performing Modules							
				December		January	
Region	Sector	Module ID	Side	V_O [V]	I_{V_O} [nA]	V_O [V]	I_{V_O} [nA]
3	9	P11	T	85	328	85	293
3	9	P11	B	85	300	85	273
3	10	P87	B	85	348	85	317
3	11	P16	T	85	328	85	298
3	11	P16	B	85	314	85	287
3	17	P13	B	85	352	85	301
4	1	P10	B	21	279	25	325
4	5	P15	B	85	305	85	279
4	9	P54	B	10	208	65	237
4	11	P69	B	85	468	85	405
4	15	P47	B	85	331	85	304
4	18	P9	B	85	298	85	273

TABLE I. Modules found to be poorly-performing in December and January, identified by a SQLite query. Targeted modules were those with $V_O < 70$ V or those with $I_{V_O} > 295$ nA for December 2015; for January 2016 $I_{V_O} > 270$ nA. These cut-off values were determined by adding the standard deviation (for both months $\sigma \sim 30$ nA) to the mean value of the currents of that month.