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Data Analysis of the RASNIK system

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Abstract

The real-time relative alignment monitor (RASNIK) has been taking data continuously since September, 2001. We analyzed a subset of this data on the CDF inner tracking detectors from September 2001 to August 2003. The online graphs of the movement are now color-coded to indicate when there is a physics run with beam. We also applied this color-coding scheme to the data taken over the two year period. It was previously determined that most of the larger movements corresponded to temperature changes and it was hypothesized that a corresponding angular tilt of the sensors was the cause of the disturbance. We investigated using algorithms to cancel out the exaggerated effects of the tilts.

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1 Introduction

The RASNIK system was integrated into the CDF detector for run IIa to check the stability of the detector[[1], [2]]. The system presents a real-time graph of the detector movements updated every 15 minutes [4] with a sensitivity better than 1μm. RASNIK consists of 13 operational motion sensors that we cycle through every 2-3 minutes. The graphs we got from Rasnik did not differentiate between when the detector was taking data, when the detector was running, or when there was an access. During data taking, the detector should not move more than 10μm for B tagging. The detector routinely moves more than this amount when it is not running for many reasons, thermal expansion and accesses being the most common. We were looking up the large movements in the electronic logs (E-logs) but this process is tedious and time consuming. We needed a way to automate the process and quickly tell if a large movement was during a physics taking.

2 Color-Coding the Real-time RASNIK data

We decided to color-code RASNIK graphs to easily distinguish physics runs on the online graphs. First Bill Badgett wrote a small sql-plus script to query the database and return the current run number when physics data is being taken [5]. The script runs for every cycle of the sensors. The RASNIK data files now incorporate this new run information. Second we used Physicist Analysis Workshop (PAW) to recognize the run numbers and color the graph blue whenever physics run data is being taken[6]. The new real-time graphs show in blue when data is being taken and stays black when it is not (Figure 1). These new graphs have so far confirmed that the large movements in the detector are only happening when data is not being taken.

3 Color-coding and Interpreting the old RASNIK data

We started analyzing the RASNIK data by plotting everything we had so far to see all of the movements of the detector [7] This graph showed that the detector tended to stay centered around one position and then jump a large distance (100μm) to another position and then stay centered there. These large jumps only happen a few times and are assumed to have occurred during accesses. Also there is a drift to the

[4] The current graphs are on the web at http://www-cdf.fnal.gov/internal/upgrades/rasnik/main.html

[5] a data run is considered active if crate L1 is active, there is an activation time, the terminate time is NULL, and the integrated luminosity is above 0.1nb^{-1}.

[6] This was accomplished with the help of Charles Plager who showed us how to do a loop in PAW. The graphs are actually made by graphing everything and then superimposing the portions of the graph during a physics run in color on top of the original graph.

[7] We plotted the data from September, 2001 to August, 2003

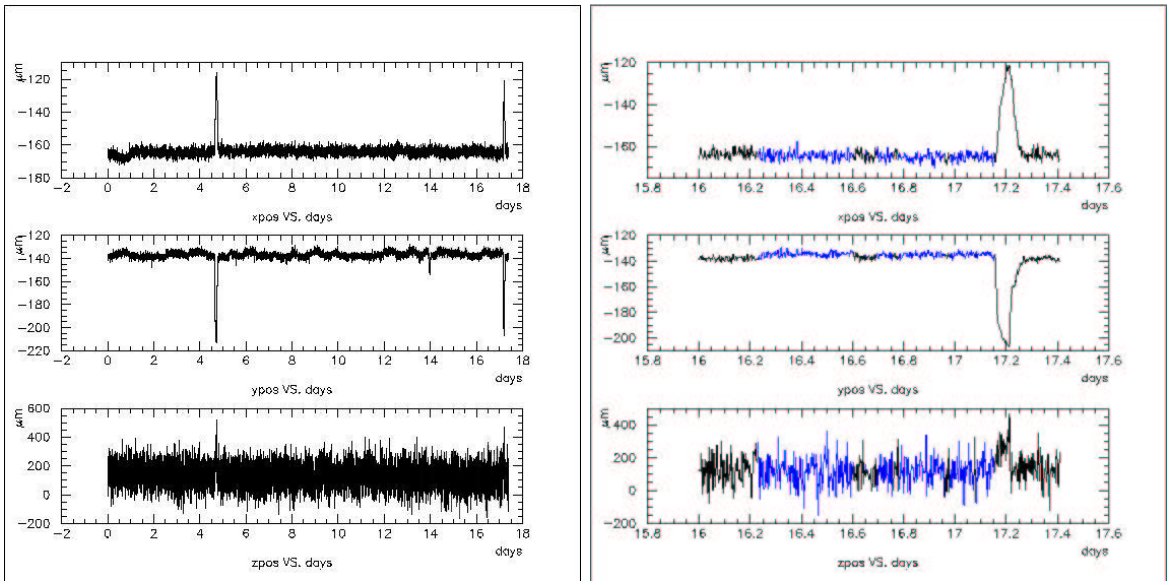

Figure 1: Examples of graphs with and without the coloring. The areas in blue indicate when there was a physics run with beam. The coloring helps to verify that the large movements occur only when no data is being taken.

silicon barrels. It is not apparent on the monthly graphs and is small (a few microns per month at the most). We believe this is probably just the detector "settling" into place.

To better interpret this RASNIK data we decided to color-code the graphs in the same manner as the online ones. We looked up physics runs in the data-base to find when the detector should have been stable[8]. We then cross referenced their start and stop times to the time stamps of the RASNIK data and updated the RASNIK data to include when a physics run was occurring. We confirmed that the largest movements all happened during extended periods of time when no run was occurring. We proceeded to consider the smaller spikes of $< 50\mu$m that seemed to be occurring regularly between runs.

4 Looking at the regular spikes between the runs

We suspected that the large spikes in-between the data runs were a result of exaggerated movements caused by temperature changes. The magnitudes of the movements are suspect because they are large enough that if they were real, the silicon would be banging against the sides of the container and breaking. When the times of the spikes were compared to the temperature records, there was always a correlation

[8]we started at run 1, used only run type 1, required that the silicon be active and the components SVX and SMX where active

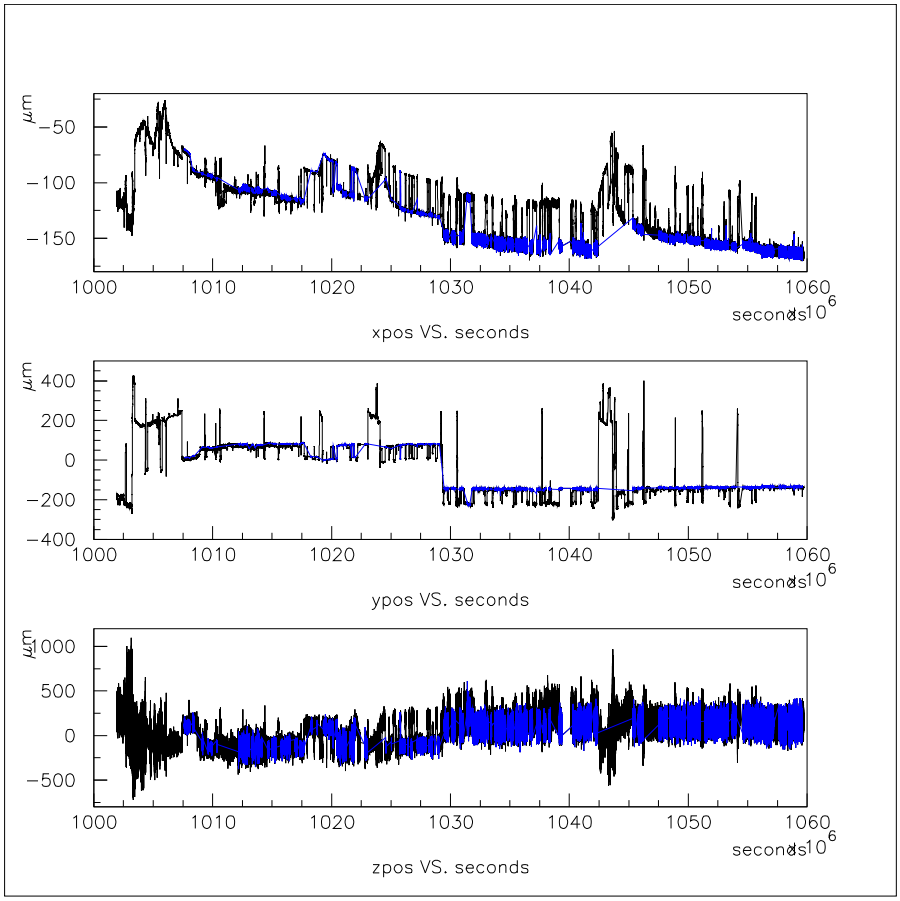

Figure 2: All data taken between September, 2001 and August, 2003 for sensor number 1. The physics runs with SVX and SMX active with a nontrivial amount of luminosity are colored blue. It is during these types of runs that movements over 10μm will interfere with B tagging

between the two. It seems that when the silicon is turned off, the temperature controls in the detector overcompensates and the temperature drops a few degrees Celsius. This causes the beam pipe to contract and create an angular movement in the projector part of the RASNIK system. The larger the temperature change the larger the movement seen, but the readings returned to the same place when the temperature returned to its stable, running value. It was estimated by David Goldstein that this exaggeration is on the order of ten times the actual movement [1].

The first thing we did was try to confirm that the spikes were being caused by angular movements from temperature changes. Due to the construction of the cross-bracing to which the RASNIKs are glued, a contraction in the beampipe should show a movement on all of the inner silicon sensors in the radial direction from the beam pipe. Consulted the hand-drawn placement of the projectors, we estimated the angles the projectors were set at to within 10 degrees, the reading could now be rotated to

Figure 3: When the angle that the projector is mounted changes, an exaggerated movement of the mask is detected. This causes a normal sensor reading like the image on the left to be replaced by the one on the right that indicates a large movement.

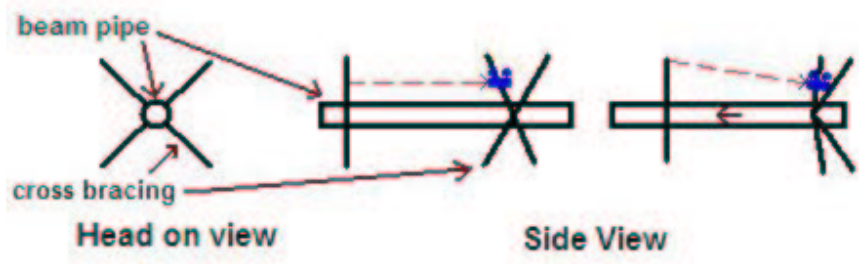

Figure 4: The change is angle is most likely caused by movements of the cross bracing that the projector is mounted on. When the beam pipe moves, usually from thermal expansion and contraction, the RASNIK system registers a much larger movement.

CDF coordinates, so the sensors' x, y, and z axises lined up with CDF's and each other. The direction of the movements could now be compared to their location in CDF coordinates. Analysis of the new graphs showed that the large movements from each sensor were always in a specific direction and that that direction was radial. All of this evidence supports the theory of an exaggerated angular movement as opposed to a real one. The smaller movements ($< 5\mu > m$) were found to be in all directions as would be expected from such small movements of the detector.

5 Technique for correcting the spikes

When looking at the East Barrel RASNIK sensors, we noticed that the two sensors that are directly across from each other over the beam pipe might be able to cancel out the error. After rotating the values to CDF coordinates, the magnitude of the spikes from the two sensors were approximately the same and in opposite directions. We hypothesized that arithmetically averaging the two outputs of the sensors would cancel the "false" movements and still keep real translational movements because those are in the same direction for both sensors. This arrangement assumes that the barrel is moving as a unit and is not expanding or contracting much. The results show an approximately ten-fold decrease in the spikes while keeping the small movements

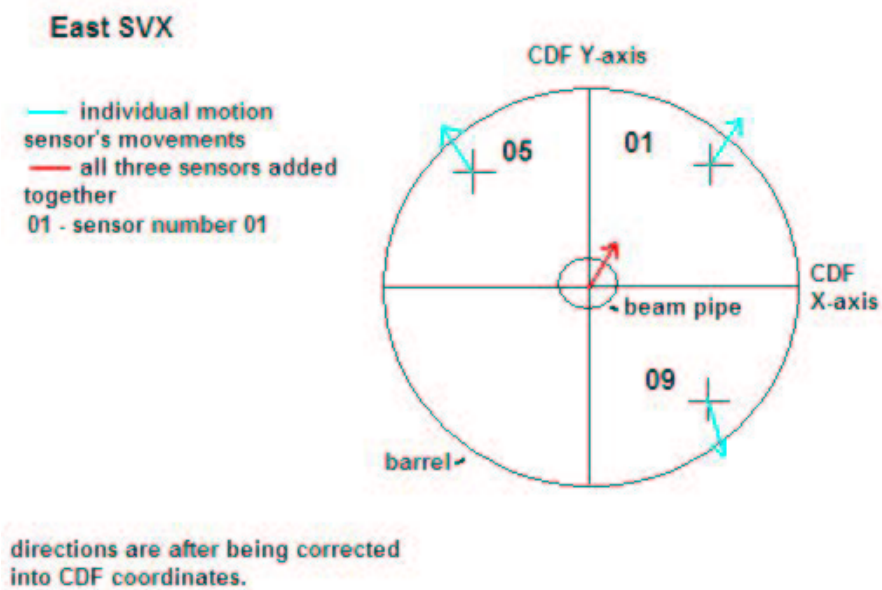

Figure 5: The alignment of the three RASNIK sensors on the East SVX barrel and the movement they show during a large movement that was observed during a temperature change. The movement was radial for all three sensors, suggesting that either the barrel was expanding (unlikely) or that the movement was somehow being magnified.

(Figure 6). The spikes would ideally be completely canceled out, but the angles of the sensors relative to cdf coordinates is not exact and the supports do not seem to move the projector in a perfectly straight line. Also there is no guarantee that the two opposite sides will move exactly the same. Furthermore any movements in opposite directions from the two sensors would tend to cancel each other out. To fix this problem, the third sensor on the east barrel could be used to check and see if a spike is being generating on all three sensors in the radial direction. When this happens the graphs could be colored a different color to show that the movement is being exaggerated here, or the magnitude of the graph could be reduced by some factor. The problem with this system is that there is no other system in the detector designed to detect movements with a precision like RASNIK and so there is no way to confirm that the correction is really translating what is going on in the detector. The West Barrel only has two working sensors that are at a 90 degree angle with respect to the beam pipe and so the cancellation technique could not work quite the same there. For these reasons and the inherent inability to verify the results after canceling the exaggerated movements, the technique of averaging the two sensors and then canceling out the extra movements is not used on the new graphs.

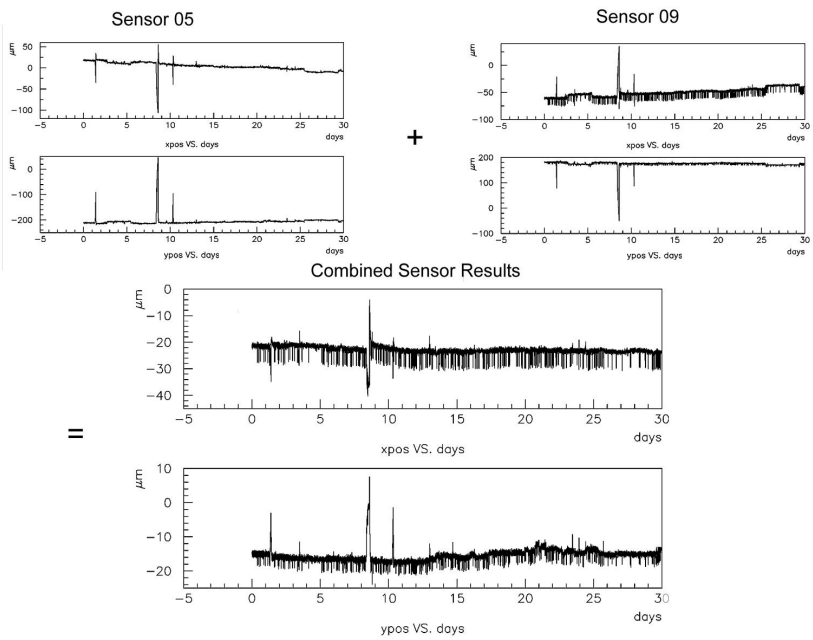

Figure 6: A RASNIK graph with and without the canceling technique

6 Shape of Large Movements

The larger movements (in the $50\mu - 300\mu$ range) have a particular shape to go with their specific angle. When graphed two dimensionally, one observes that the sensor shows a reading that moves off in a mostly straight line until it peaks and then quickly "sweeps" back to a normal reading again as shown in Figure 7 and 8. We do not understand the shape of this movement yet.

7 Future Ideas

The current RASNIK system could be improved by integrating the temperature readings with the movement data to help guarantee that the large movements are all caused by temperature changes. The few other movements could probably be explained by accesses but if others were found it would be interesting to see what was causing them. This could also help to confirm or deny the validity of the current cancellation technique, or reveal a better way to compensate for temperature changes. Looking at known solenoid movements in the beam pipe [9] and then seeing if the RASNIK data supported the hypothesis about beam pipe movement would also be useful. A further analysis of the West side barrel and its correlation with the East barrel might

[9] When the beam pipe moves as a whole in one direction instead of moving in both directions when it expands or contracts

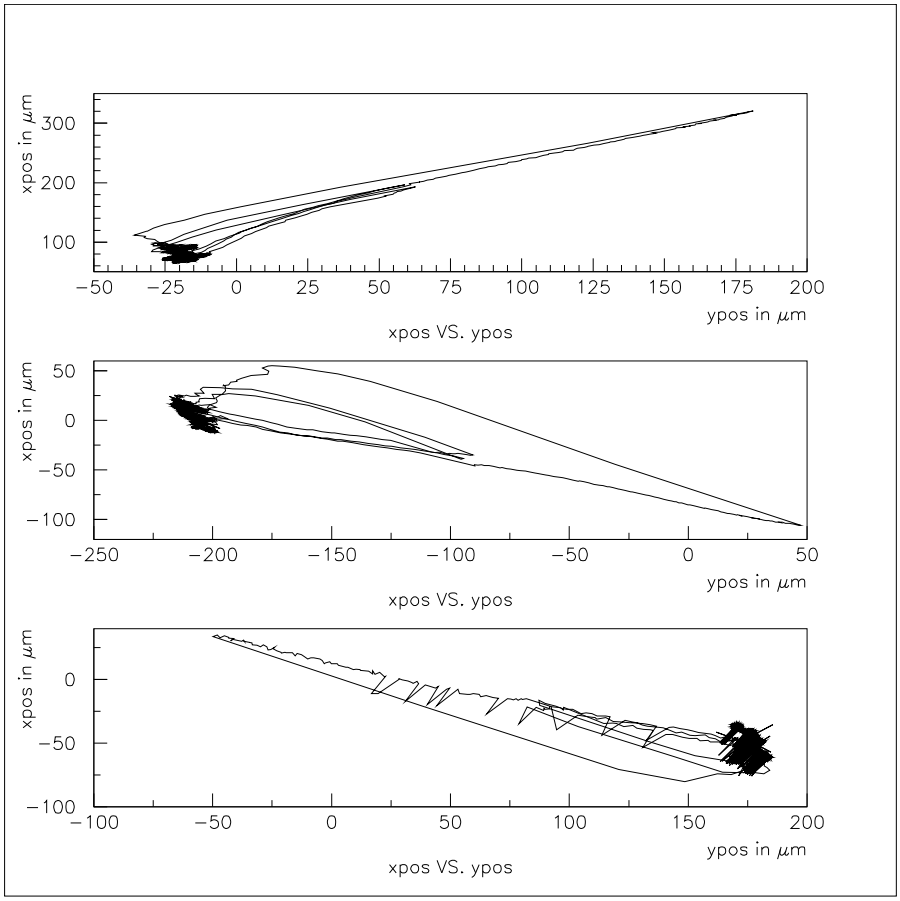

Figure 7: These graphs plot all of the data points seen in the three RASNIK sensors in the month of April, 2001. The top graph is sensor 01, the middle sensor 05, and the bottom sensor 09. Notice how the large spikes all go in a specific direction for each sensor, yet the small movements (the black blob in each) are evenly distributed in all directions. Also, the large spikes go out at one angle and come back in at another. The straighter line connecting the farthest point to the "blob" is the path the sensors trace on the way out to the spike.

also bright some light to what is happening or at the very least add a certain reliability to finding when a movement is caused by a temperature change. The data from the last two years could also be checked to make sure that the large, permanent movements also had corresponding global realignment periods. The slight drift the sensors detected might also have some importance to understanding what changes the detector has undergone since it was installed 3 years ago.

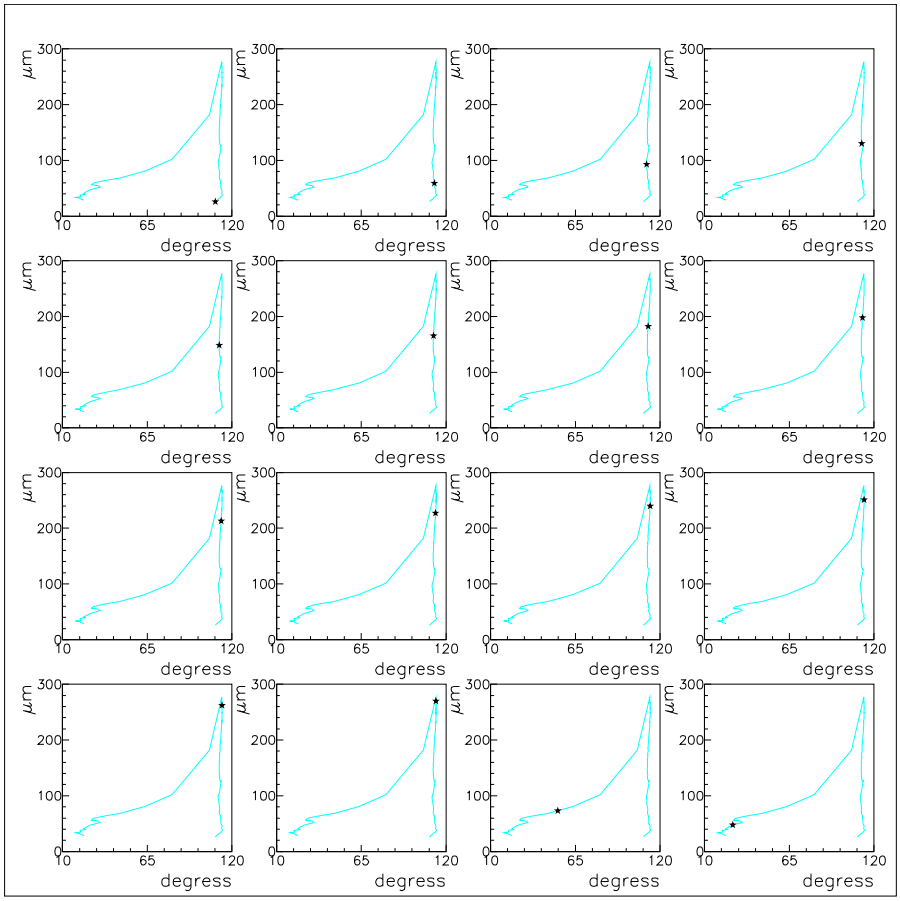

Figure 8: The graphs in the figure are "snap-shots" of the sensor readings during a large movement. The graphs are in polar coordinates with the angle on the x-axis and the radius on the y-axis. Time progresses as the dot traces the sensor from the right side of the peak to left. Notice how the dot slowly climbs to the peak and then once at the top, quickly sweeps to the side.

8 Conclusion

We update the real-time graphs of the detector's movements to be color-coded so that they are blue when data is being taken. This has made it easy to determine whether any movements seen will affect any data or not. The data from the last two years has been combined into graphs that show a few large, permanent movements that are being attributed to accesses. These graphs have also shown a slight drift to the location of the barrels even when they are stable and taking data. After cross-referencing the two years of sensor movements to data taking runs, it was shown that the large movements were during long periods of inactivity for the detector. It was hypothesized that most of the temporary sensor movements were really just an exaggerated movement caused by temperature changes in the detector. These findings

were supported by rotating the axis of the sensors to CDF coordinates and comparing the results to what was suspected. A technique was proposed that canceled the exaggerated movements, but was unverified and so is not applied on the current system. A future version of RASNIK with a few updates could solve all of the current problems and be integrate into the Ace's warning panel to tell when something in the detector is moving when it should not be.

References

[1] D. Saltzberg and D. Goldstein, CDF internal note #6182 (2002).

[2] D. Goldstein and D. Saltzberg, Nucl. Instr. and Meth. A 506, 92 (2003). 2, 4 2