Hand Calculations in 3D and a Study of IST Pad Orientation – Long in Z vs Short in Z

I have completed an upgrade of the 2D tools to calculate the pointing resolution of an arbitrary stack of detectors. The new tools are now 3D. This means that the calculations can handle independent detector resolutions in the R-PHI direction and in the Z direction.

The 2D work was covered in my previous report:
http://rnc.lbl.gov/~jhthomas/public/HFT/HFT2Dweb.html
and you can find the appropriate references to the literature in that note. The most important conclusion to be draw from the 2D work is that a refit of the primary vertex after the Si points has been found is extremely useful and enhances the power of the tracking system by a factor of 2 or more.

The code is kept in two files. The 2D code requires 3x3 helix matrices and the 3D code requires 5x5 helix matrices … and thus the codes are named:

/star/u/jhthomas/STAR/hft/Matrix3Resolution.C
and
/star/u/jhthomas/STAR/hft/Matrix5Resolution.C

You *must* compile these macros to run them. They have become too big to run as ordinary macros (ran out of if-else depth, believe it or not). The easiest way to do this is to run 'root4star'. You can also run the macro with ordinary root (not root4star) but you will have to change the iostream library reference from <Stiostream.h> to <riostream.h>. Don't ask me why … it's a root thing. The proper command to execute the macro is this:

```
root> .x Matrix5Resolution.C++
```

The ++ means that you want the macro compiled before it runs. I encourage you to give it a try. You can build a new detector in a matter of minutes and there is a lot to be learned by doing so.

A typical dialogue with the macro looks like this:

```
d-ssd tpc end t-ssd
d-ist2 ssd tpc end t-ist2
d-ist1 ist2 ssd tpc end t-ist1
d-hpd ist1 ist2 ssd tpc end t-hpd
d-hft2 hpd ist1 ist2 ssd tpc end t-hft2
d-hft1 hft2 hpd ist1 ist2 ssd tpc end t-hft1
vtx hft1 hft2 hpd ist1 ist2 ssd tpc end t-vtx
```

"d" designates a dead detector (ie. installed but not active), and "t" designates a targeted detector. An unmarked detector is an active detector (no d, no t).

The parameters for the macro are shown below. The parameters are slightly different than in my 2D work because we now need to keep track of resolution in the R-PHI direction and in the Z direction. But less obvious is the fact that I am quoting the pad sizes in both dimensions rather than detector resolutions. In principle, the resolution of a pad is 1/root(12) of its width. Thus each dimension, below, could be divided by 3.5 to achieve the sigma for each detector layer. However, past experience has shown that hand calculations do not agree with the Monte Carlo based work describing the same detector and the discrepancy is about a factor of 3 in the quoted resolutions. In other words, the hand calculations are always much better than the Monte Carlo unless you expand the sigmas by a factor of 3; then you get good agreement. Since 1/root(12) is about a factor of 3, I have elected not to apply this factor. Please feel free to do so in your own copy of the code, if you think the Monte Carlo tools have gotten better. However, you should not adjust the resolution for the TPC; only fiddle with the Si resolution in R-PHI and Z. The TPC parameters have been tuned to fit the data and so do not need any further adjustment.

```
#define        Mass                      0.540       // Mass of the test particle
#define        BFIELD                    0.25        // Tesla
#define        AvgRapidity               0.5         // Avg rapidity

#define        VtxResolution             0.3000      // cm
#define        NewVtxResolution          0.0300      // cm
#define        Hft1Resolution            0.0030      // cm  30 x 30    micron pixels
#define        Hft2Resolution            0.0030      // cm  30 x 30    micron pixels
#define        HpdResolution             0.0050      // cm  50 x 425   micron pixels
#define        Ist1Resolution            0.1000      // cm  60 x 1000  micron pixels
#define        Ist2Resolution            0.1000      // cm  60 x 1000  micron pixels
#define        SsdResolution             0.0095      // cm  95 x 4200  crossed strips
#define        TpcResolution             0.0625      // cm  600 x 1500 microns

#define        VtxResolutionZ            0.3000      // cm
#define        NewVtxResolutionZ         0.0300      // cm
#define        Hft1ResolutionZ           0.0030      // cm  30 x 30    micron pixels
#define        Hft2ResolutionZ           0.0030      // cm  30 x 30    micron pixels
#define        HpdResolutionZ            0.0425      // cm  50 x 425   micron pixels
#define        Ist1ResolutionZ           0.0060      // cm  60 x 1000  micron pixels
#define        Ist2ResolutionZ           0.0060      // cm  60 x 1000  micron pixels
#define        SsdResolutionZ            0.2700      // cm  95 x 4200  crossed strips
#define        TpcResolutionZ            0.1500      // cm  600 x 1500 microns

#define        VtxThickness              0.0000      // % Radiation Lengths
#define        BeamPipe1Thickness        0.0015      // % Radiation Lengths
#define        Hft1Thickness             0.0028      // % Radiation Lengths
#define        Hft2Thickness             0.0028      // % Radiation Lengths
#define        BeamPipe2Thickness        0.0015      // % Radiation Lengths
#define        HpdThickness              0.0100      // % Radiation Lengths
#define        Ist1Thickness             0.0150      // % Radiation Lengths
#define        Ist2Thickness             0.0150      // % Radiation Lengths
#define        SsdThickness              0.0100      // % Radiation Lengths
#define        IFCThickness              0.0052      // % Radiation Lengths
#define        TpcAvgThickness           0.00026     // % Radiation Lengths ... Average

#define        VtxRadius                 0.0         // cm
#define        BeamPipe1Radius           2.05        // cm
#define        Hft1Radius                2.5         // cm
#define        Hft2Radius                7.0         // cm
#define        BeamPipe2Radius           8.55        // cm
#define        HpdRadius                 9.2         // cm
#define        Ist1Radius               12.0         // cm
#define        Ist2Radius               17.0         // cm
#define        SsdRadius                23.0         // cm
#define        IFCRadius                47.25        // cm  Middle-Radius of the IFC
```

Results:

I have calculated the pointing resolution at each layer (roughly equivalent to the search radius required at each layer) in the HFT + HPD + IST detector system. The top line in figure one is for the TPC pointing at the SSD. The next line is for the TPC+SSD pointing at IST2. Etcetera. The last line is the sum of all detectors working together.

The dotted line in figure one is the stand alone resolution of the HFT without any other material present. It assumes that the hits can be found (by magic). The dotted line is an exact formula for a two layer detector system; it is not an approximation. Notice that the high pt resolution is better than the two point formula because the TPC is so far away that it yields a tight constraint on the slope of the track even though the pointing resolution is not good.

These results are calculated with the IST strips running along the Z axis so they are short in the R-PHI direction and give the best resolution in the R-PHI direction. Later, I will show you a plot with the IST strips going the other way.

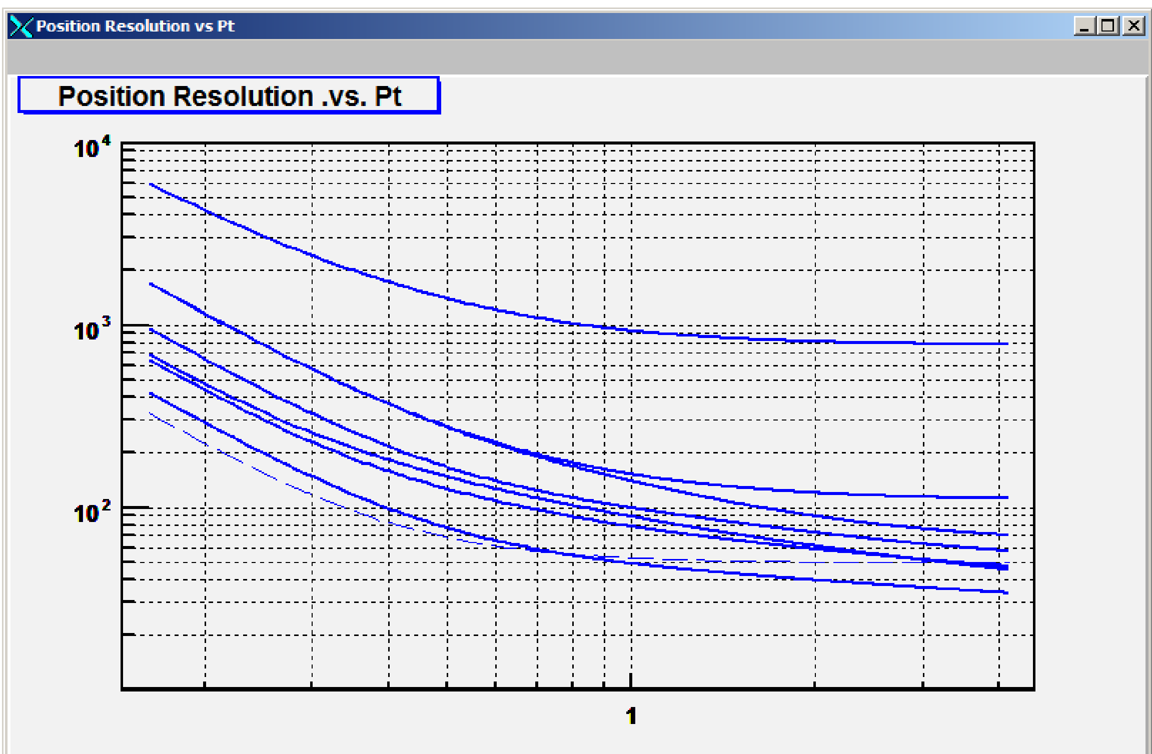

Figure One: R-PHI resolution from our 3D calculation – The IST strips are oriented to give the best resolution in the R-PHI direction. Microns on the Y axis, GeV on the X.

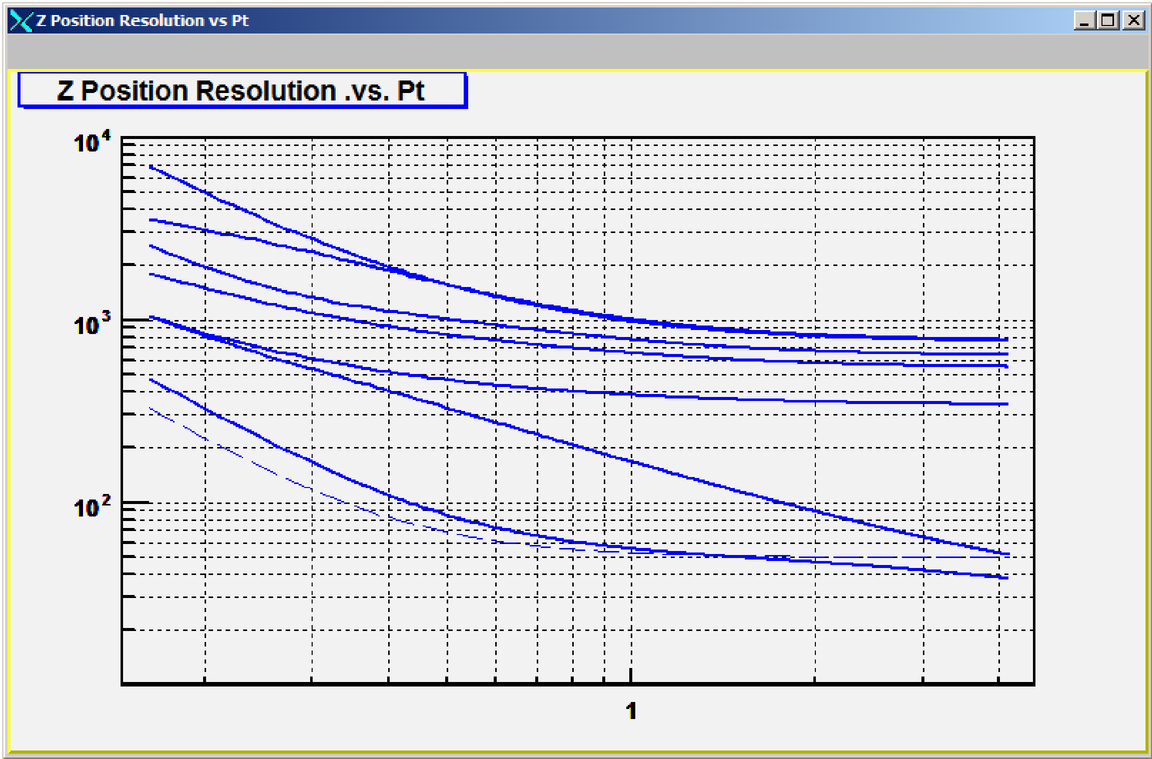

Figure Two: Z resolution from our 3D calculation – The IST strips are oriented to give the best resolution in the R-PHI direction. Microns on the Y axis, GeV on the X axis.

From figures one and two, it is easy to tell that the IST strips are oriented to give the best resolution in the R-PHI direction. All you have to do is to look for the gaps in the data.

Before we turn our attention to the case where the IST strips are rotated, let's look again at the 2D calculation. Figure three shows the 2D calculations. The parameters are exactly the same as in figures one and two, however, the area of the pads are now represented by a one dimensional pad parameter that repesents same square area as the original rectangle. Thus, a 60 x 1000 micron pad is represented in the 2D code by a pad dimension of sqrt(60*1000) = 250.

Figure three shows results that are approximately the mean of the results calculated in the R-PHI and Z directions, separately. This is just what you would expect for the equivalent area method employed in the 2D calculation.

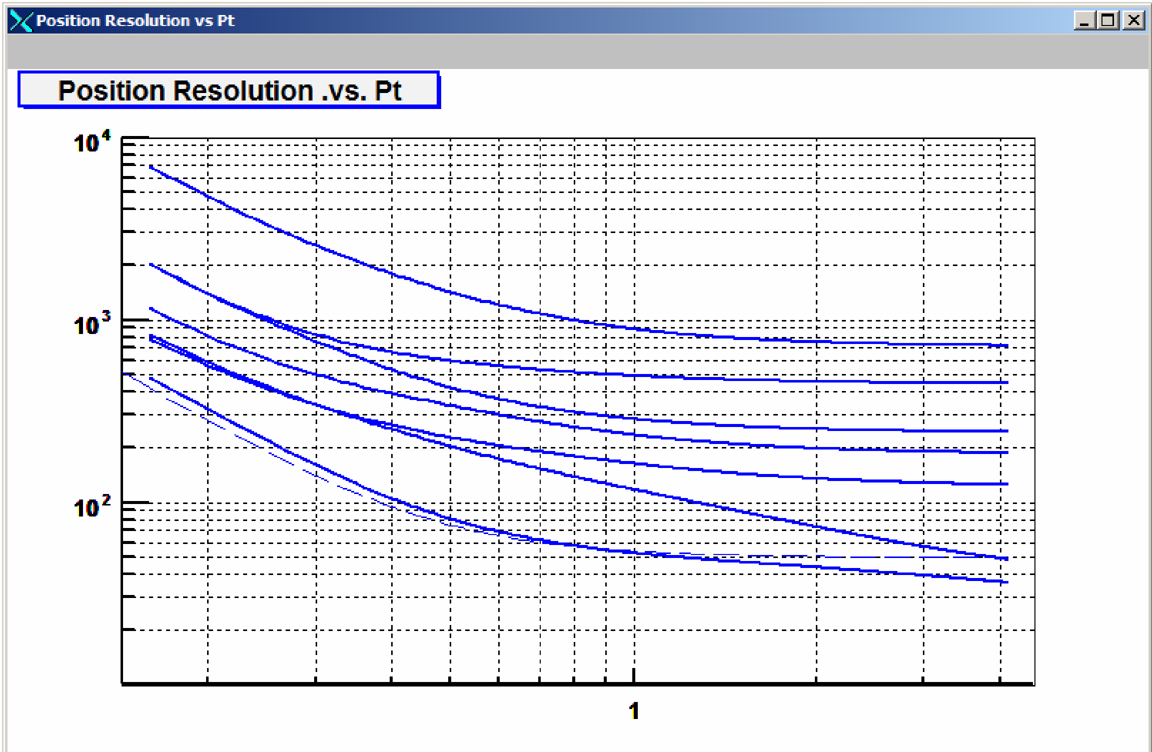

Figure Three: 2D calculation – Using the equivalent area of pads, we see the average of the r-phi and z resolution seen in figures one and two. The top line represents the resolution of the TPC pointing at the SSD, etc.

Now lets turn our attention to the case where the IST strips are rotated in order to achieve the best resolution in the Z direction. This is interesting, and my be useful, because the SSD has its worst resolution in the Z direction. Figures four and five show the pointing resolution in the R-PHI direction and in the Z direction for the rotated IST layers.

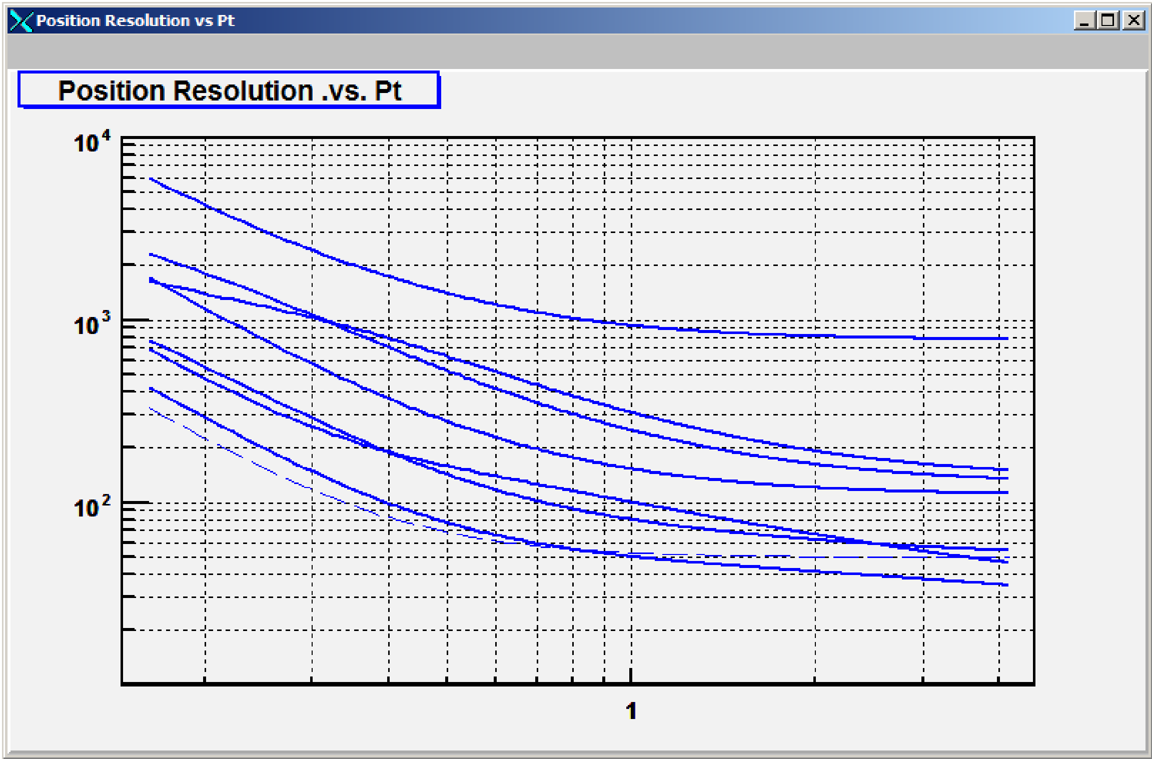

Figure Four: R-PHI Resolution from our 3D calculation – The IST strips are rotated to give the best resolution in the Z direction. Note that the pointing resolution at the layers before the HFT is not as good as in figure one.

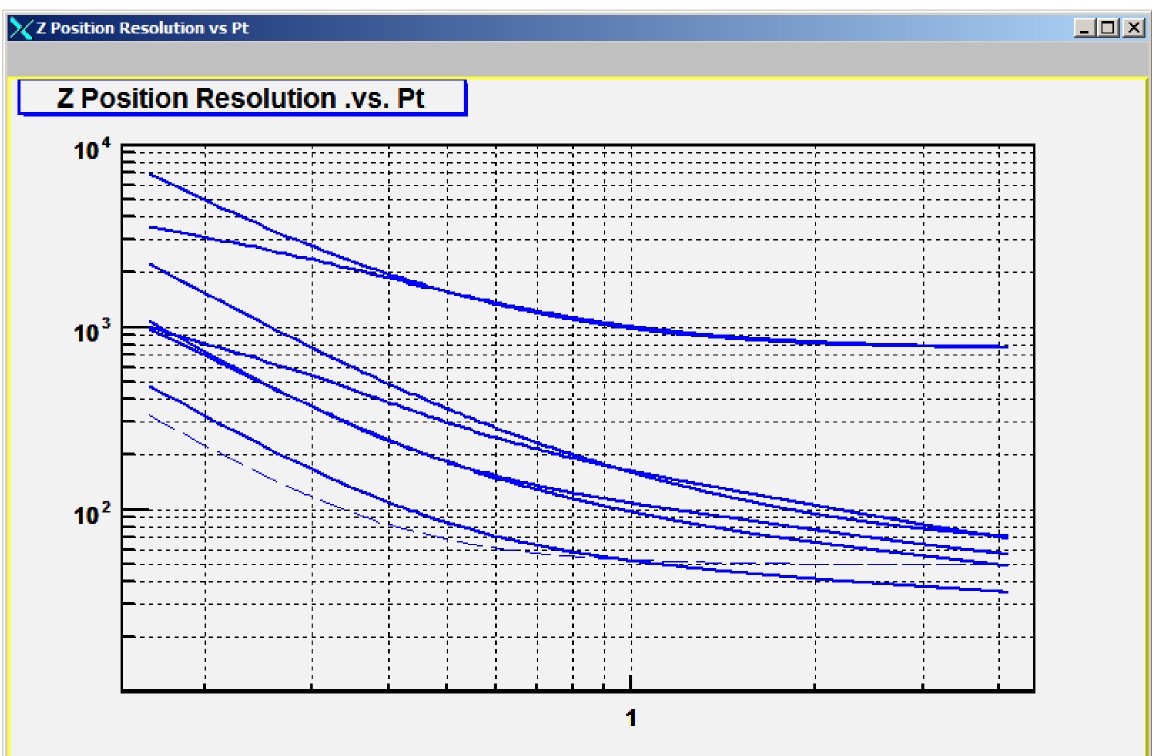

Figure Five: Z resolution from our 3D calculation – the IST strips are rotated to give the best resolution in the Z direction.   Note that the pointing resolution at the layers before the HFT is better than in figure two.

Conclusion:

Rotating the IST layers so that they have the best resolution in the Z direction is probably a good idea. If we build all of the layers envisioned on 10/10/2006 (ie. HFT1 HFT2 HPD IST1 IST2 SSD) then the excellent resolution in the Z direction fills in the gaps caused by the asymmetric resolution of the SSD. As a result, the pointing resolution of the detector system is more symmetric (R-PHI resolution ~ Z resolution) at each radius and I can only imagine that this helps the tracking algorithms in ITTF.

We should re-address this conclusion if we choose to build fewer layers.