What is the best radial location for IST1?

The STAR tracking upgrade review committee asked us to consider the possibility of moving the first IST layer from 12.0 cm radius to 9.5 cm radius. Their goal was to try to improve the pointing resolution of the tracking system when it is used to point at the HFT.

At first glance, this seems like a good idea. However, a quantitative look at the problem using hand calculations suggests that the improvement is marginal and not needed. An inner IST layer at 12.0 cm is perfectly adequate. Thus, it is desirable to keep IST1 at a radius of 12.0 cm … especially in view of the fact that the number of ambiguous hits on the IST at 9.5 cm is probably not acceptable. (For further details about the ghosting and ambiguous hits see: http://rnc.lbl.gov/~jhthomas/public/HFT/AmbiguousHits.pdf).

In order to do the hand calculations, I have assumed that the HFT will be operating under RHIC II conditions and I have assumed that the detector resolutions are the pixel widths (not pixel width x 1/root(12)). The full parameter set is listed at the bottom of this note.

Figure one shows the calculated Z resolution for the tracking system if IST1 sits at a radius of 12.0 cm (BLUE) or at a radius of 9.5 cm (RED). The pointing resolution is calculated at the outer layer of the HFT (HFT2) and at the inner layer of the HFT (HFT1).

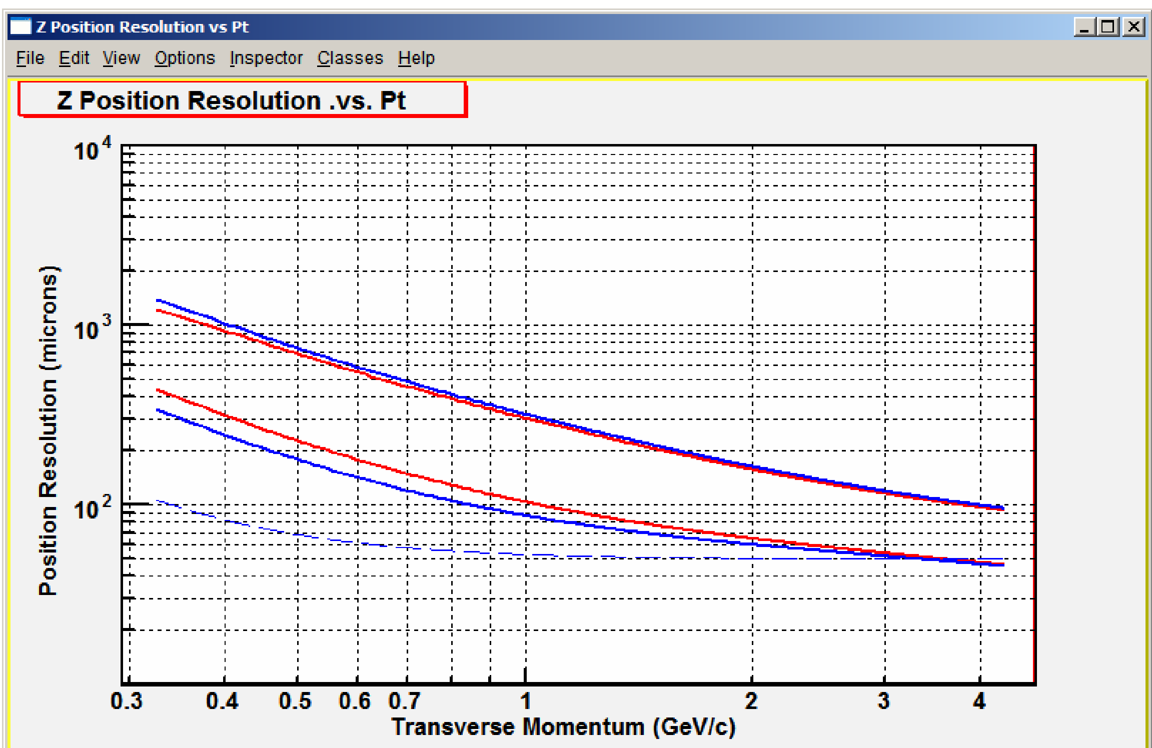

Figure 1: Blue – IST1 at 12.0 cm, Red- IST1 at 9.5 cm. The top set of lines represent the pointing accuracy at HFT2. The middle set of lines represent the pointing accuracy at HFT1, and the dashed line on the bottom is a theoretical estimate of the HFT vertex resolution if the HFT could act alone … no other detectors, and no other sources of MCS.

The figure confirms what we expected. We do not expect the Z resolution onto the face of the HFT to change when IST1 moves from 12 to 9.5 cm radius because IST1 does not have good Z resolution. It is optimized to give good R-Phi resolution (whereas IST2 is assumed to be rotated so that the best resolution is in the Z direction).

However, changing the location of IST1 improves the R-Phi resolution because the detector is now closer to the HFT. This is shown in figure two: the pointing resolution at the surface of HFT2 improves and is now about the same as the pointing resolution at the surface of HFT1 (RED lines). The change from 200 microns pointing resolution at 750 MeV to 120 microns is only modest, however. This is because the TPC provides a very tight angular constraint on an incoming track and thus every track acts as if it were a 'stiff' track. This decreases the sensitivity of the tracking resolution to the radial position of the detectors. The system would be much more sensitive to the radial location of the IST layers if the TPC were not active.

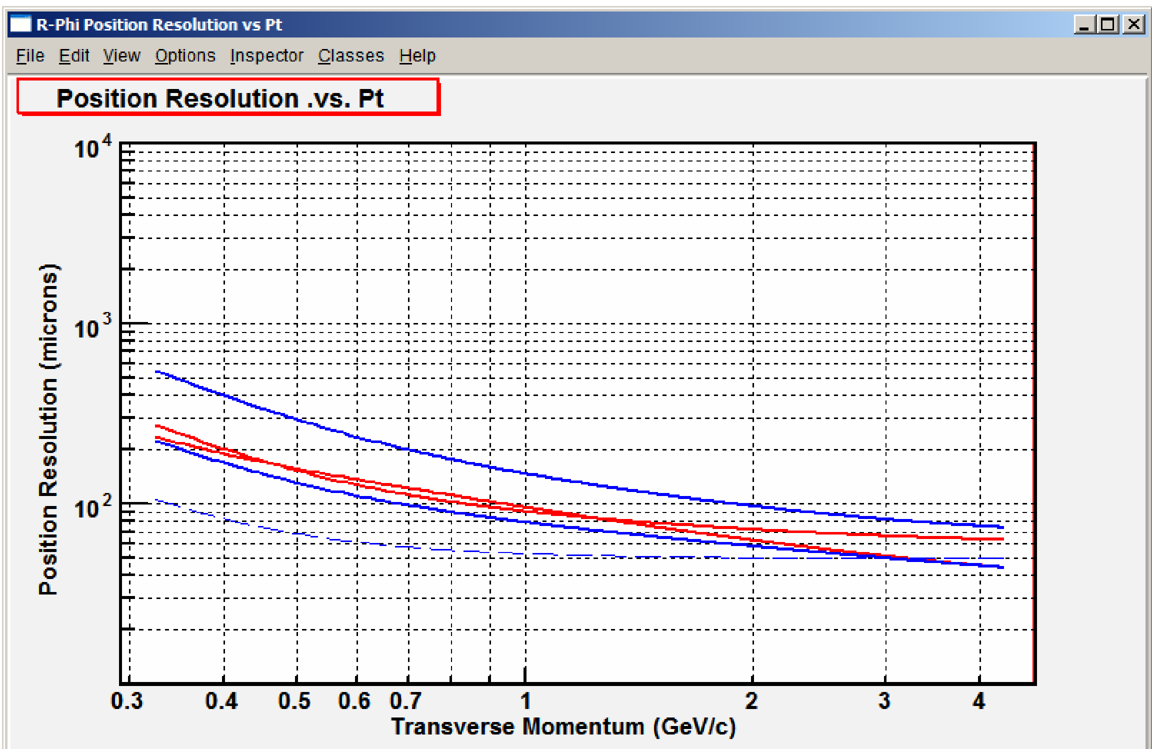

Figure 2: Blue – IST1 at 12.0 cm, Red- IST1 at 9.5 cm. Note that moving IST1 from 12 cm to 9.5 cm improves the R-Phi resolution onto the face of the HFT by a modest amount.

How important is this change in resolution? This is a quantitative question and it depends on the multiplicity of tracks into the HFT, the assumed luminosity, the search radius on the surfaces of HFT2 and HFT1, and even the assumed kinematic cuts in forming a kaon and pion into a D0 candidate.

I have estimate the D0 reconstruction efficiency by calculating the pointing resolution of the system on the two surfaces of the HFT. This allows me to estimate the track density (under RHIC II conditions) that falls within the search radius for a single track. Finally, I square the single track efficiency (1 kaon, 1 pion) and multiply by 0.8 to represent the acceptance and efficiency of the TPC and SSD. I do not try to estimate the effect of the kinematic cuts on the tracks. That is too hard … but we should be able to make relative comparisons, anyway.

Figure three shows the estimated D0 reconstruction efficiency for the two cases. The blue lines shows the efficiency calculated when IST1 lies at 12 cm radius and the red line shows the efficiency calculated when IST1 lies at 9.5 cm radius. The results are nearly identical under fairly conservative conditions. If I had assumed that the tracking system performed better than my assumptions, then the two lines would be even more identical.

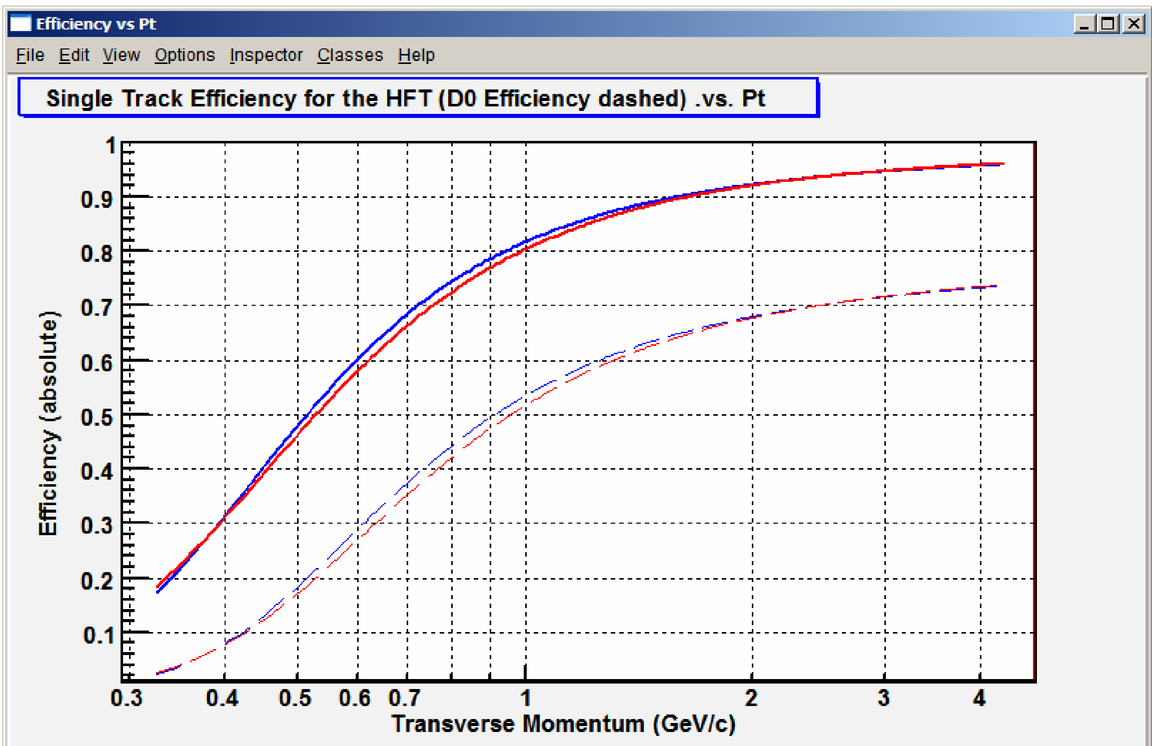

Figure 3: The single track efficiencies for tracks 'found' in the HFT are shown by the solid lines. Blue – IST1 at 12.0 cm, and Red- IST1 at 9.5 cm The estimated D0 reconstruction efficiency is represented by the dashed lines.

Why?

The reason the radial location of IST1 is not so important is because the R-Phi resolution at 12 cm is already good enough to find tracks on the surface of the HFT (HFT2).

The highest density of tracks occurs at HFT1 (not on HFT2) and moving IST1 inwards does not improve the pointing resolution on HFT1. The pointing resolution on HFT1 is dominated by the resolution of HFT2 and the long track pointing back to the TPC which gives a tight angular constraint on the direction of the track. As a result, the IST helps us associate hits on HFT2 with the fit-tracks but it does not play a very important role in associating hits on HFT1 with those tracks. This gives us some latitude in choosing the radial location of the IST layers … and once the IST system is good enough to find hits on HFT2 … that is good enough and we should not move the IST1 in closer due to the ghosting and ambiguous hits problem.

Parameters in these calculations:

```
#define        Mass                     0.540       // Mass of the test particle in
#define        BFIELD                   0.5         // Tesla  (test data taken at 0.25
#define        AvgRapidity              0.5         // Avg rapidity, MCS calc is a
#define        Luminosity               1.e28       // Luminosity of the beam (RHIC I ==
#define        Sigma                    15.0        // Size of the interaction diamond
#define        dNdEta                   170         // Multiplicity per unit Eta  (AuAu
#define        CrossSection             10          // Cross section for event under
#define        IntegrationTime          0.2         // Integration time for HFT chips (
#define        BackgroundMultiplier     4.0         // Increase multiplicity in detector
#define        SiScaleFactor            1.0         // For scaling Si pad sizes.  (eg
#define        EfficiencySearchFlag     0           // Define search method. ChiSquare =

// Most likely Detector parameters you may want to tune are in the block starting here:

#define        VtxResolution            0.3000      // cm  Test data wants 3 mm vertex
#define        VtxResolutionZ           0.3000      // cm  Test data wants 3 mm vertex

#define        NewVtxResolution         0.0300      // cm  NewVertex to study effect of a
#define        NewVtxResolutionZ        0.0300      // cm  NewVertex to study effect of a

#define        RefitVtxResolution       0.0030      // cm  Refit Vertex to study effect
#define        RefitVtxResolutionZ      0.0030      // cm  Refit Vertex to study effect

#define        BeamPipe1Resolution      RIDICULOUS  // Beampipe is not active as a

#define        Hft1Resolution           0.0030      // cm  30 x 30   micron pixels
#define        Hft1ResolutionZ          0.0030      // cm  30 x 30   micron pixels

#define        Hft2Resolution           0.0030      // cm  30 x 30   micron pixels
#define        Hft2ResolutionZ          0.0030      // cm  30 x 30   micron pixels

#define        BeamPipe2Resolution      RIDICULOUS  // Beampipe is not active as a

#define        HpdResolution            0.0050      // cm  50 x 425  micron pixels ...
#define        HpdResolutionZ           0.0425      // cm  50 x 425  micron pixels ...

#define        Ist1Resolution           0.0060      // cm  60 x 1920 micron pixels ... Z
#define        Ist1ResolutionZ          0.1920      // cm  60 x 1920 micron pixels ...
//#define        Ist1Resolution           0.1920      // cm  60 x 1920 micron pixels ...
//#define        Ist1ResolutionZ          0.0060      // cm  60 x 1920 micron pixels ...

//#define        Ist2Resolution           0.0060      // cm  60 x 1920 micron pixels ...
//#define        Ist2ResolutionZ          0.1920      // cm  60 x 1920 micron pixels ...
#define        Ist2Resolution           0.1920      // cm  60 x 1920 micron pixels ...
#define        Ist2ResolutionZ          0.0060      // cm  60 x 1920 micron pixels ...

#define        SsdResolution            0.0095      // cm  95 x 4200  microns double
#define        SsdResolutionZ           0.2700      // cm  95 x 4200  microns double

#define        IFCResolution            RIDICULOUS  // IFC is not active as a detector

#define        TpcResolution            0.0575      // cm  600 x 1500 microns ...Test
#define        TpcResolutionZ           0.1500      // cm  600 x 1500 microns ...Test

// End of 'most likely' block, but there are more parameters, below.
```

```
#define        VtxIndex                 0
#define        BeamPipe1Index           1
#define        Hft1Index                2
#define        Hft2Index                3
#define        BeamPipe2Index           4
#define        HpdIndex                 5
#define        Ist1Index                6
#define        Ist2Index                7
#define        SsdIndex                 8
#define        IFCIndex                 9
#define        TpcIndex                 10
#define        VtxThickness             0.0000  // % Radiation Lengths
#define        BeamPipe1Thickness       0.0015  // % Radiation Lengths (as in 0.01 == 1%)
#define        Hft1Thickness            0.0028  // % Radiation Lengths (0.0028 new 0.0036
#define        Hft2Thickness            0.0028  // % Radiation Lengths (0.0028 new 0.0036
#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 per
#define        VtxRadius                0.0     // cm
#define        BeamPipe1Radius          2.05    // cm (2.05 new 1.50 old)
#define        Hft1Radius               2.50    // cm (2.5  new 1.55 old)
#define        Hft2Radius               7.00    // cm (7.0  new 5.00 old)
#define        BeamPipe2Radius          8.55    // cm (8.55 new 6.05 old)
#define        HpdRadius                9.2     // cm (9.2  HPD,6.0  SVT)
#define        Ist1Radius              12.0     // cm (12.0 IST,10.0 SVT, option 9.5 IST)
#define        Ist2Radius              17.0     // cm (17.0 IST,14.0 SVT)
#define        SsdRadius               23.0     // cm
#define        IFCRadius               47.25    // cm  Middle-Radius of the IFC ... its
#define        TpcInnerRadialPitch1     4.8     // cm
#define        TpcInnerRadialPitch8     5.2     // cm
#define        TpcOuterRadialPitch      2.0     // cm
#define        TpcInnerPadWidth         0.285   // cm
#define        TpcOuterPadWidth         0.620   // cm
#define        InnerRows1               8
#define        InnerRows8               5
#define        InnerRows               (InnerRows1+InnerRows8)
#define        OuterRows               32
#define        TpcRows                 (InnerRows1 + InnerRows8 + OuterRows)
#define        RowOneRadius            60.0     // cm
#define        RowEightRadius          93.6     // cm
#define        RowFourteenRadius      127.195   // cm
```