Calculating the Performance of the HFT & IST System

answers to important questions

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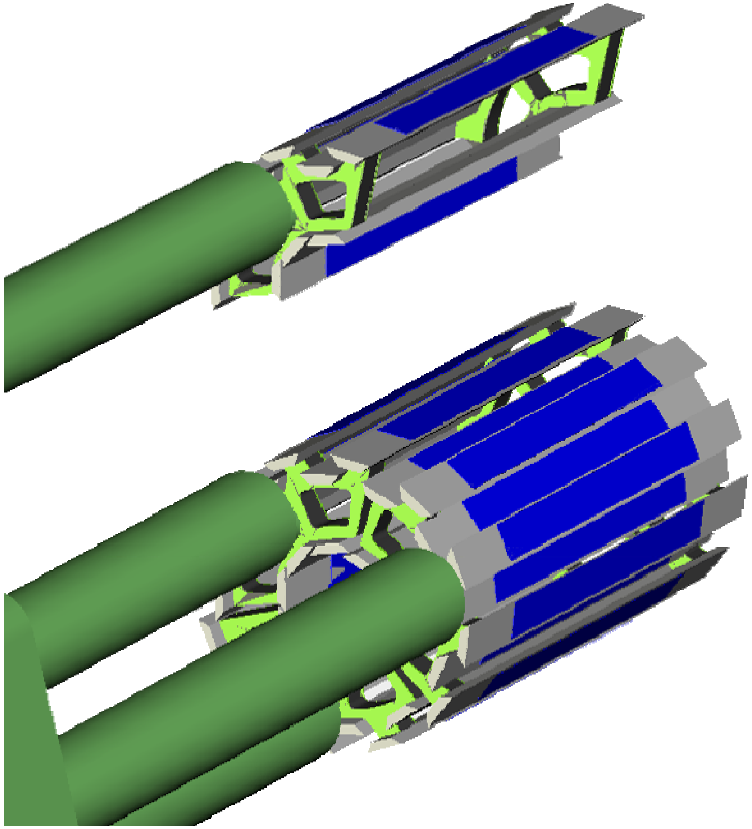
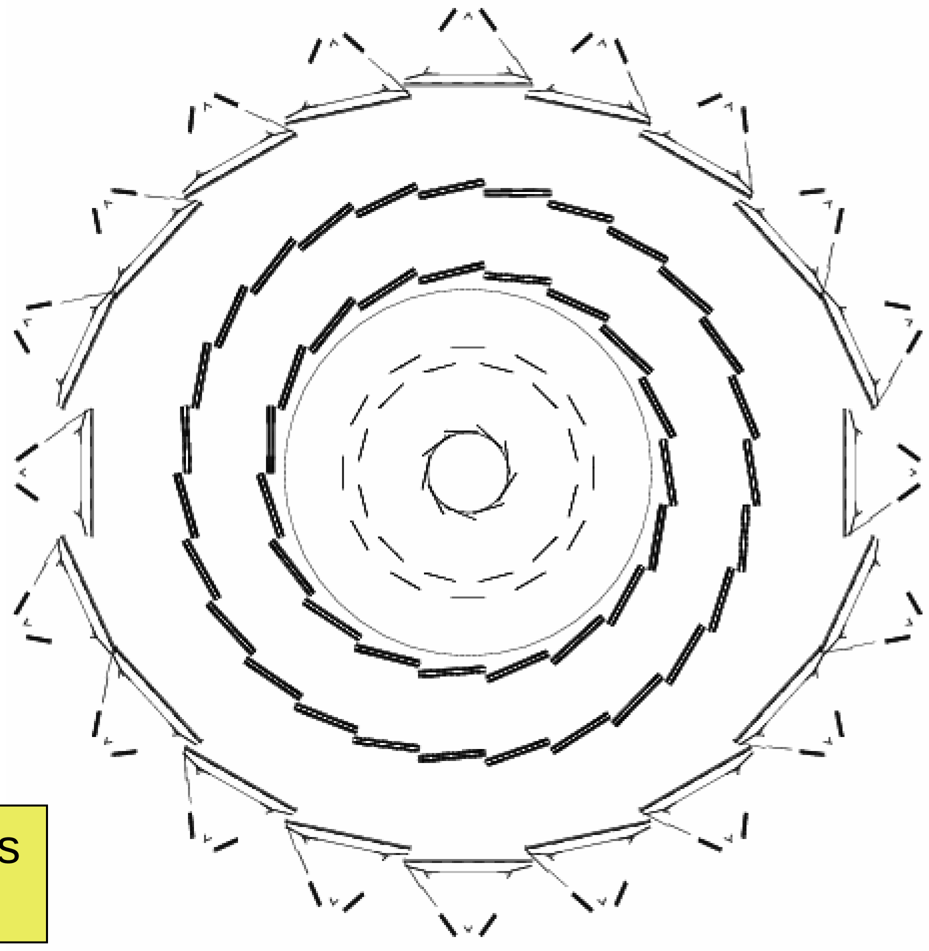
3/3/2007

The HFT+IST Detectors Surround the Vtx with Si

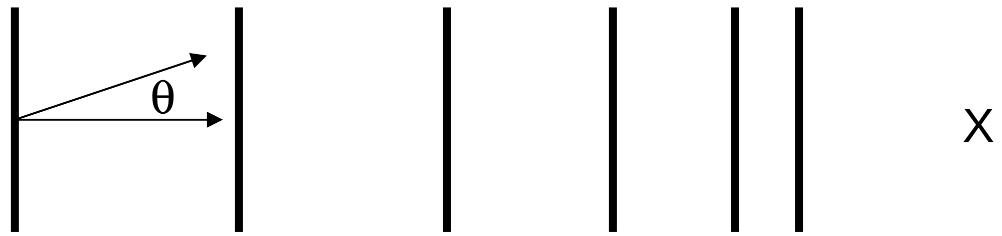


The HFT is a thin detector using 50 µm Si to finesse the limitations imposed by MCS



The IST and SSD form the ingredients of an Inner Tracking Upgrade

Calculating the Performance of the Detector

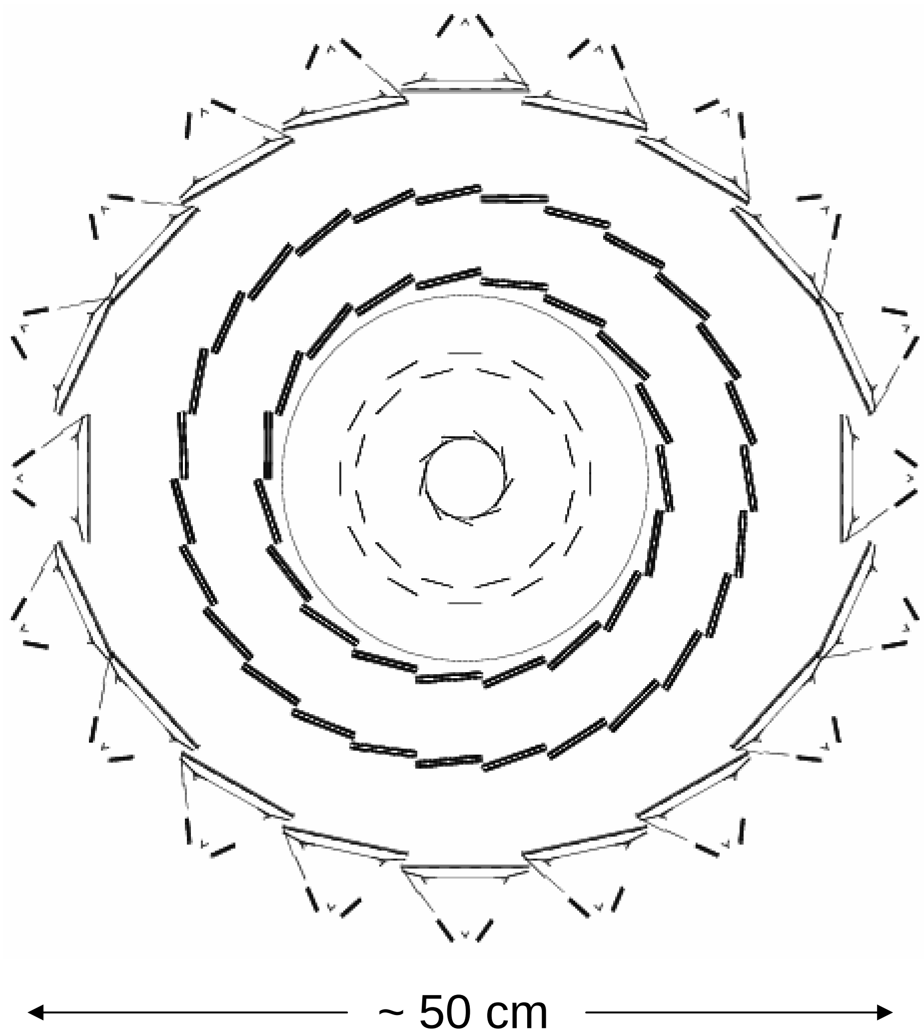


$$[MCS][D][M][MCS][D][M][MCS] \quad \bullet \quad \bullet \quad \bullet$$

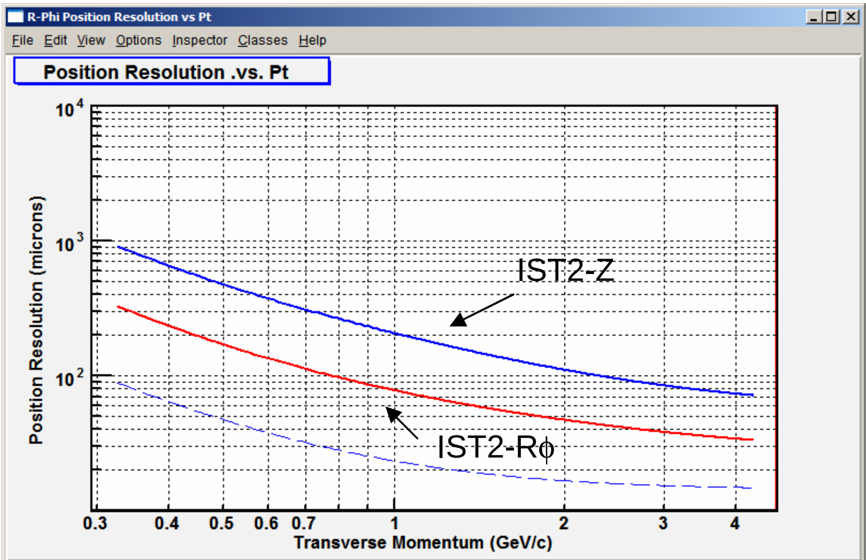
- **Billoir invented a matrix method for evaluating the performance of a detector system including MCS and dE/dx**
  - **NIM 225 (1984) 352.**
- **The 'Information Matrices' used by Billoir are the inverse of the more commonly used covariance matrices**
  - **thus, σ's are propagated through the system**
- **STAR use a very similar method in ITTF**
  - **I go outside-in**
  - **Victor goes outside-in and then inside-out, and averages the results**

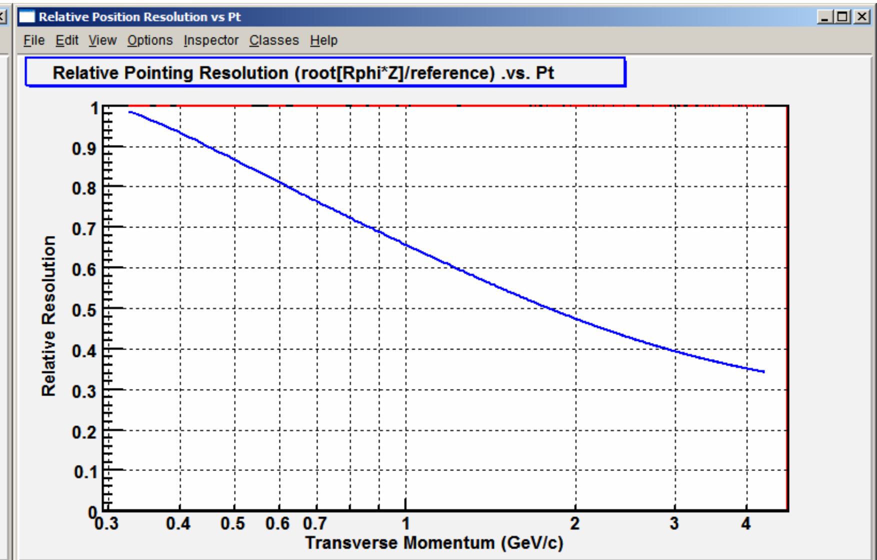
Overview of Si Detectors Inside the TPC

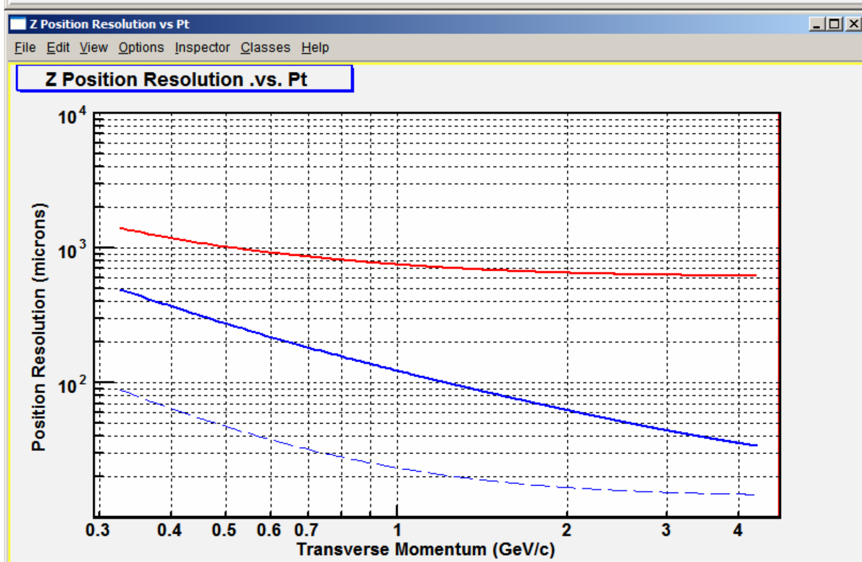
- Goal: graded resolution from the outside → in
- TPC – SSD – IST – HFT
- TPC pointing resolution at the SSD is ~ 1 mm
- SSD pointing at IST2 is ~ 330 μm r-ϕ
- IST2 pointing at IST1 is ~ 250 μm z
- IST1 pointing at HFT2 is ~ 250 μm r-ϕ
- HFT2 pointing at HFT1 is ~ 80 μm symmetric
- HFT pointing at the VTX is ~ 40 μm symmetric



Which way should IST2 strips go? R-ϕ or in Z?







- **Pointing resolution on IST1 is 280 μm by 165 μm with IST2-Z**
- **Pointing resolution on IST1 is 105 μm by 830 μm with IST2-Rϕ**
- **This is very important because it is the product of these terms that is critical in associating hits**

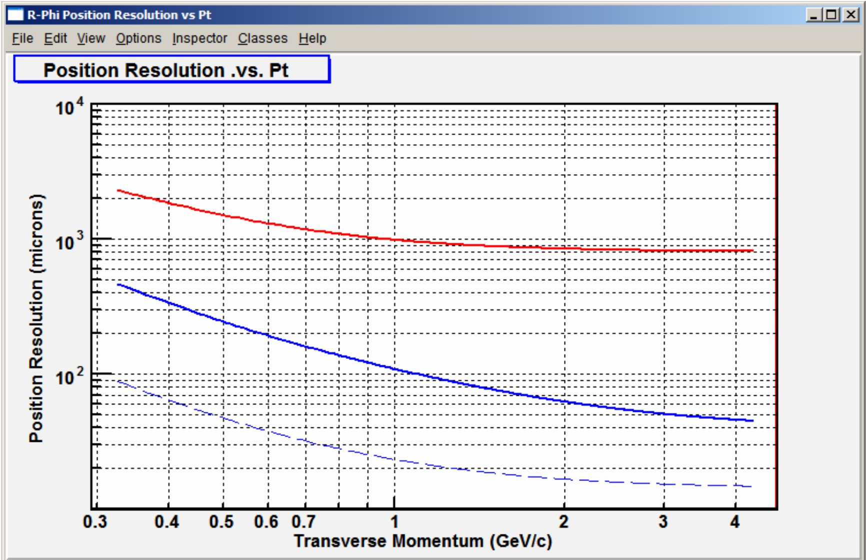
$$Inefficiency \approx 2\pi\sigma_{r\phi}\sigma_z\rho$$

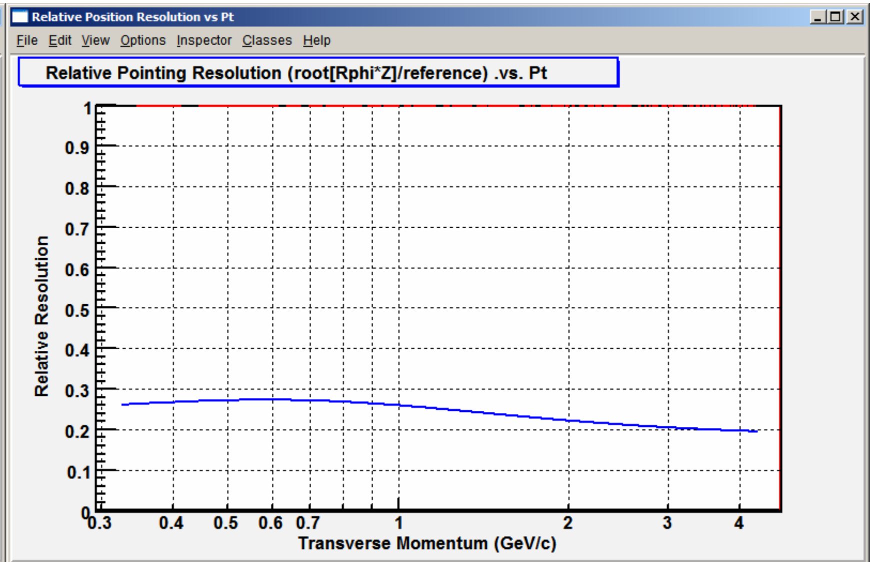
The IST2 strips deliver the best performance when they increase the Z resolution of the system

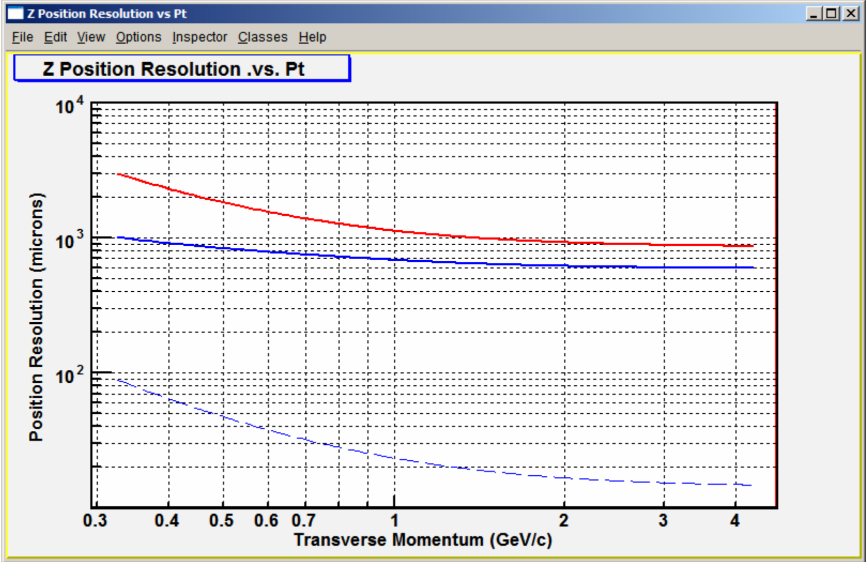
What if?

- **What if we only get 2 hits out of three?**
  - **what if one detector is inefficient?**
  - **what if one detector is dead?**

TPC pointing at IST2 – what happens if the SSD dies?







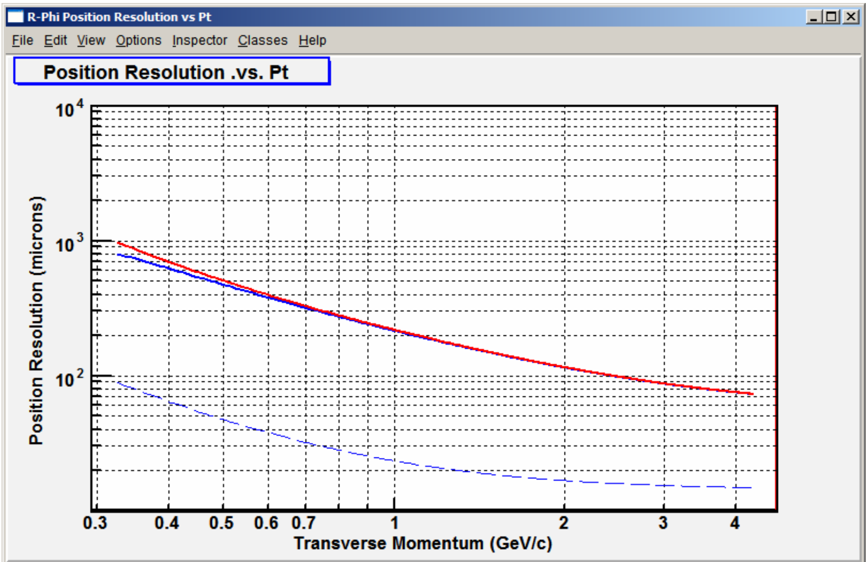
- **Pointing resolution on IST2 is 150 µm by 735 µm with the SSD**
- **If the SSD dies, this jumps up to 1125 µm by 1325 µm**
- **This is very important because**

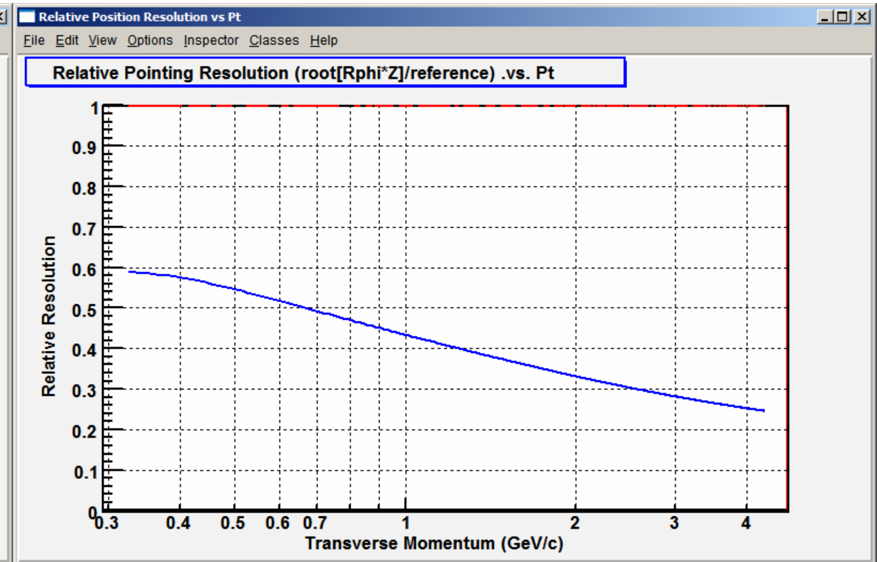
$$Inefficiency \approx 2\pi \sigma_{r\phi} \sigma_z \rho$$

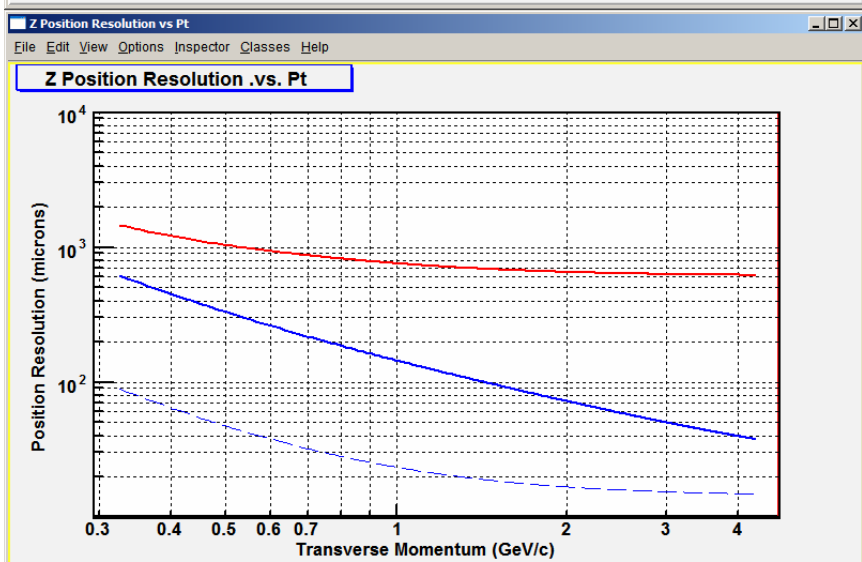
and the hit density we can tolerate is 0.25*0.25 => 1/16

The SSD is a critcal part of the HFT+IST pointing system

IST2 pointing at IST1 – what happens if IST2 dies?

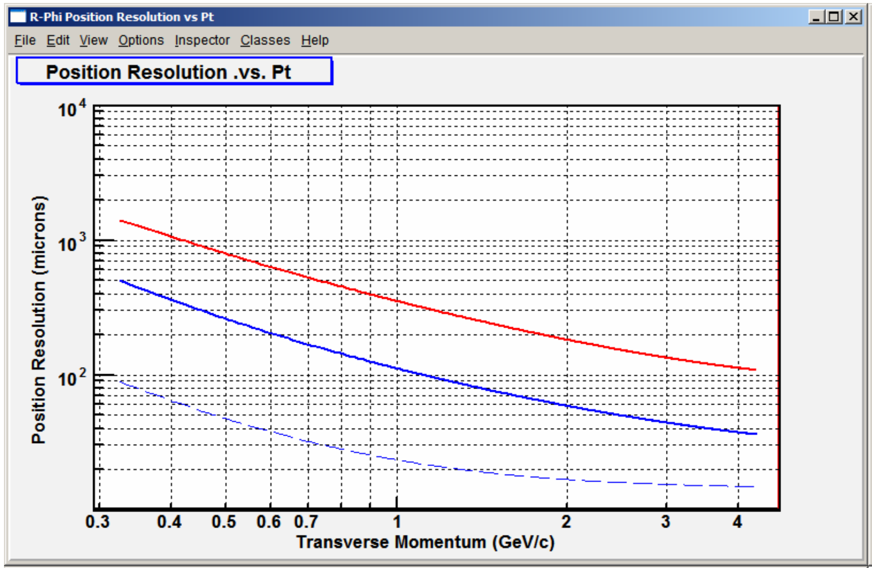


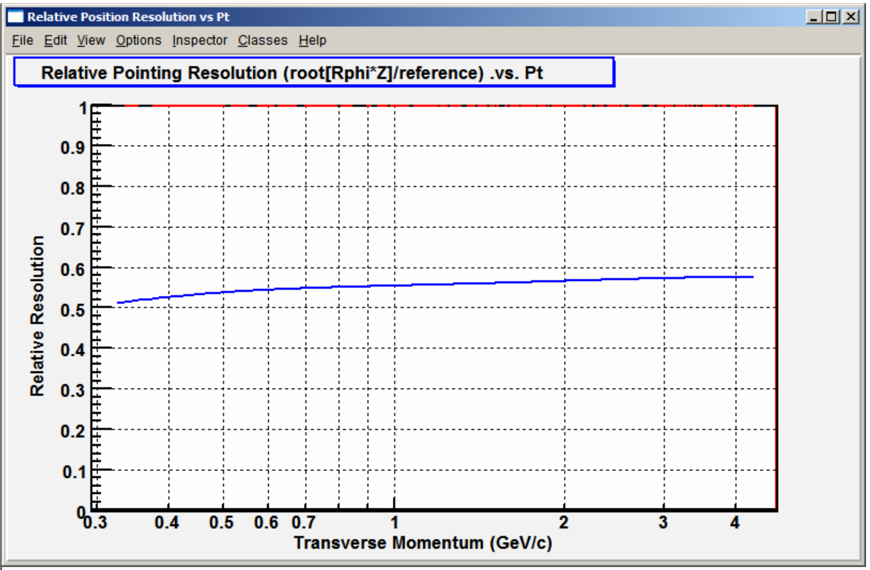


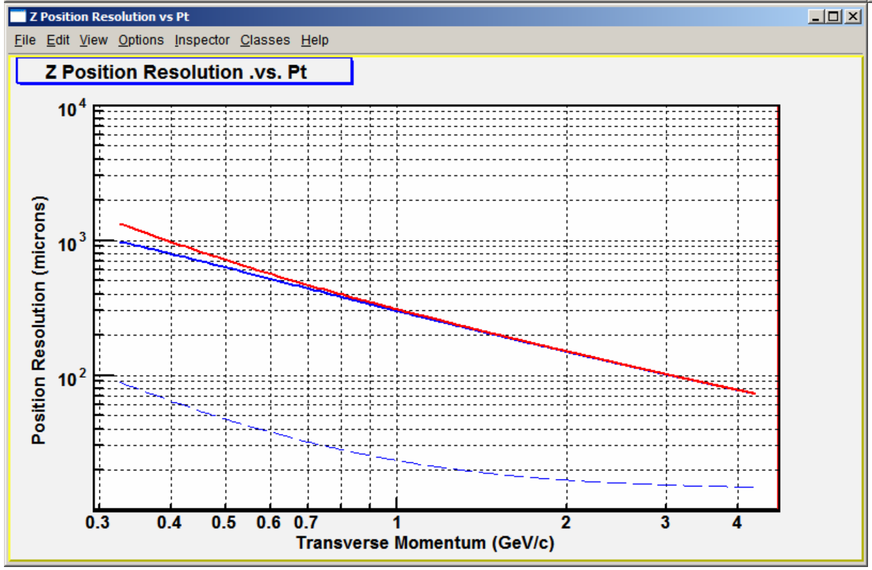


- Pointing resolution on IST1 is 290 μm by 200 μm with IST2++
- If IST2 dies, this jumps up to 300 μm by 840 μm
- The hit density we can tolerate for the same inefficiency is 0.48*0.48 => 1/4

IST1 pointing at HFT2 – what happens if IST1 dies?

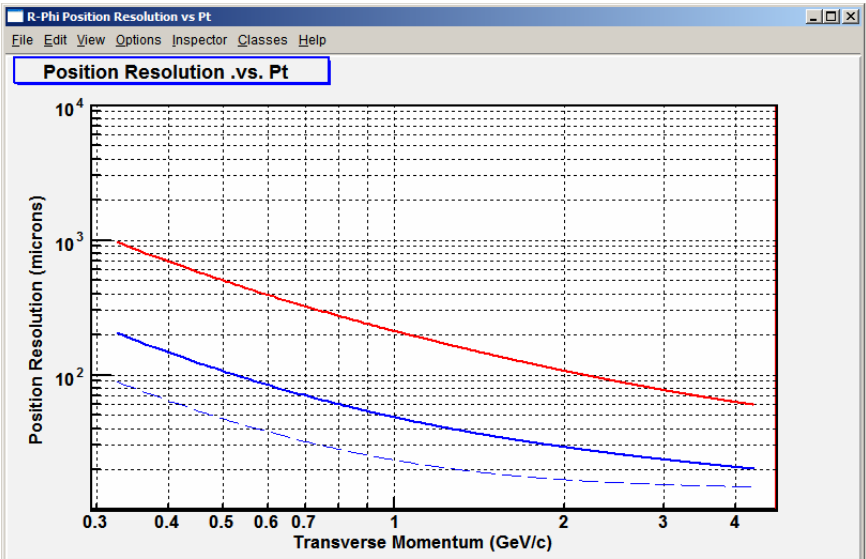


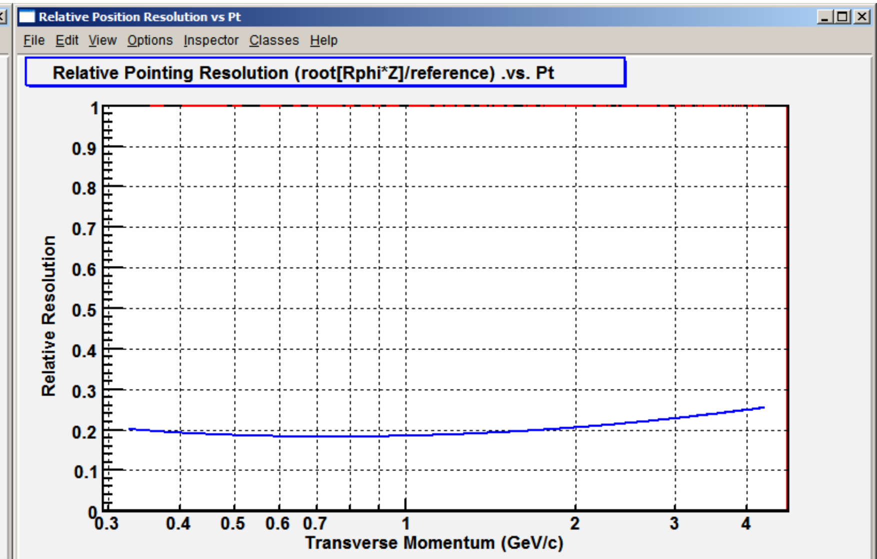


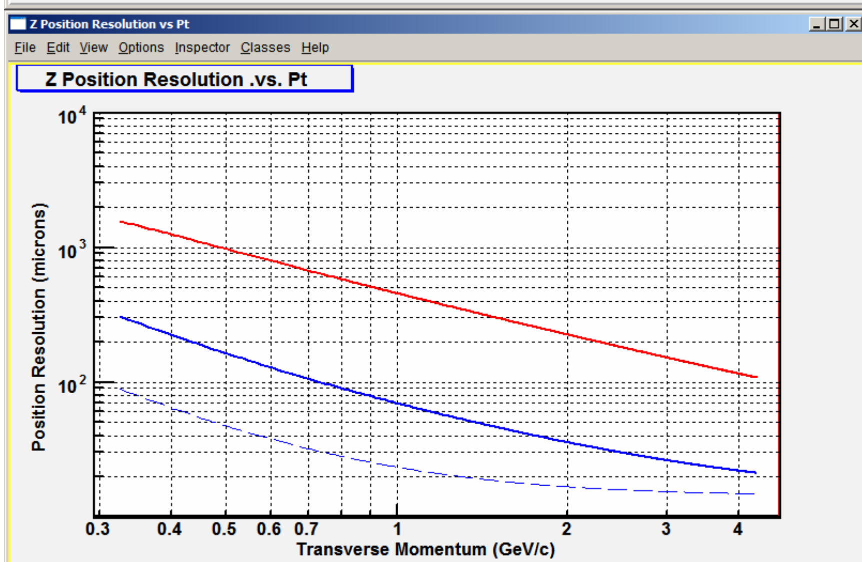


- **Pointing resolution on HFT2 is 150 μm by 400 μm with IST1++**
- **If IST1 dies, this jumps up to 480 μm by 425 μm**
- **The hit density we can tolerate for the same inefficiency is 0.55*0.55 => 1/3**

HFT2 pointing at HFT1 – what happens if HFT2 dies?



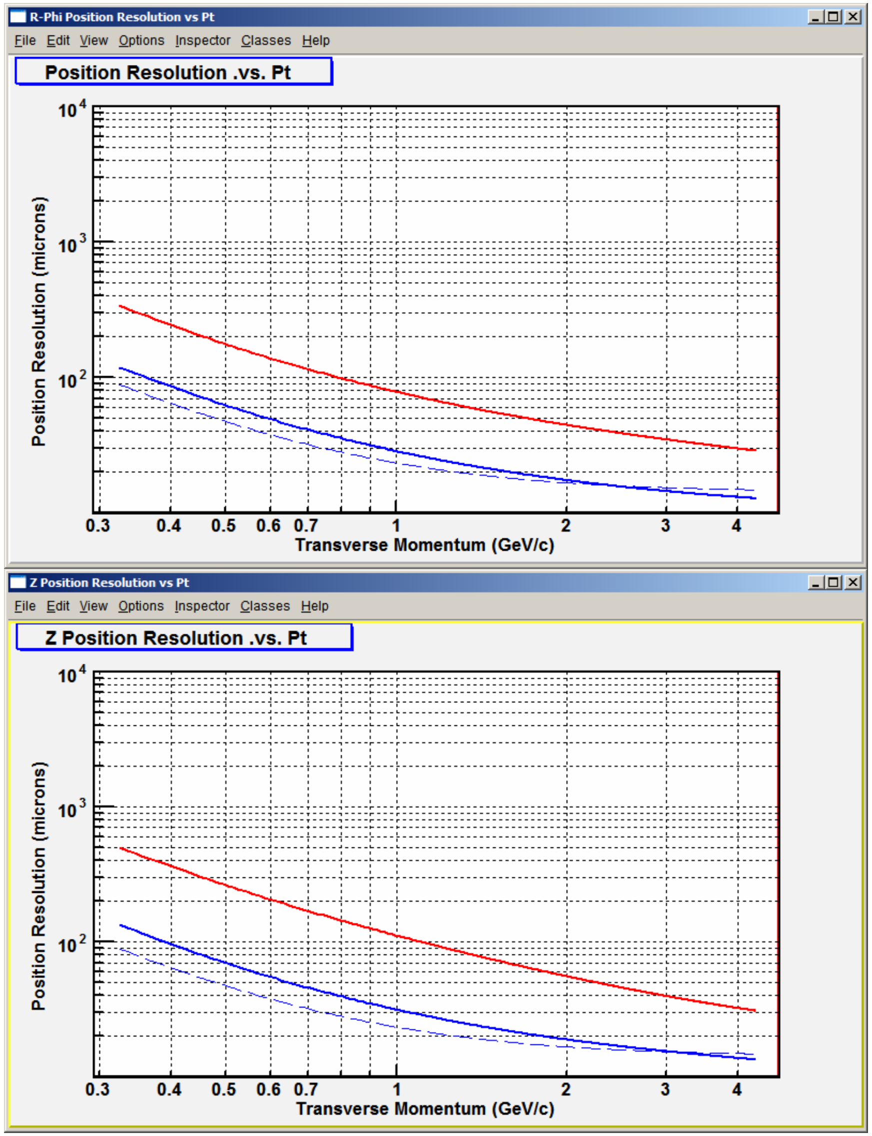




- **Pointing resolution on HFT1 is 65 μm by 95 μm with HFT2++**
- **If HFT2 dies, this jumps up to 295 μm by 615 μm**
- **The hit density we can tolerate for the same inefficiency is 0.18*0.18 => 1/30**

But ….

If HFT1 dies, well … we can't do much without it



- **Pointing resolution at the vertex (without a vertex constraint) is 38 μm by 42 μm with HFT1++**
- **We can't do (much) physics if HFT1 dies because the pointing resolution at the vertex becomes 105 μm by 150 μm**

Lessons learned from this exercise

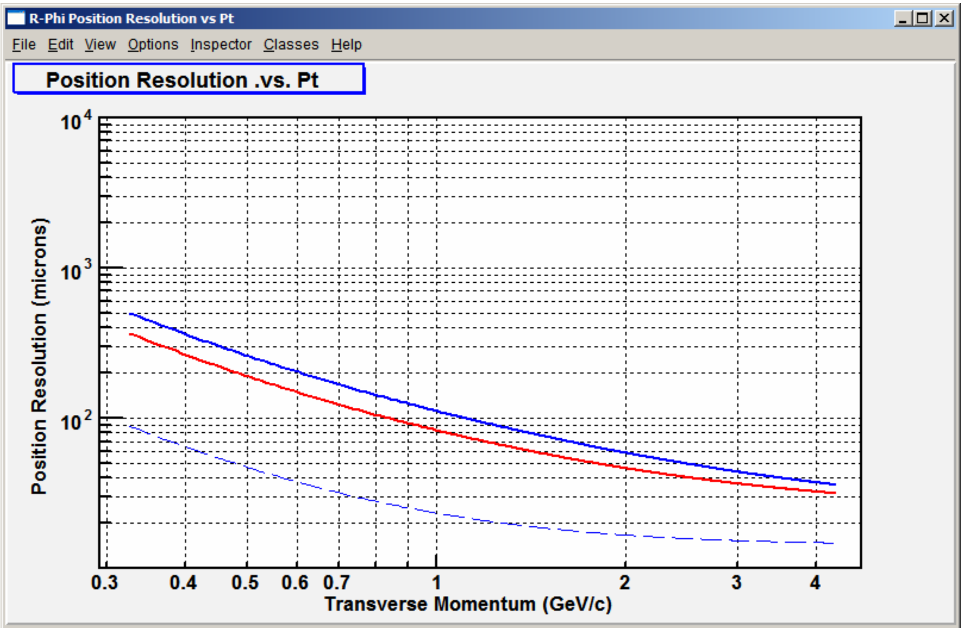
- **All of the detectors are important**

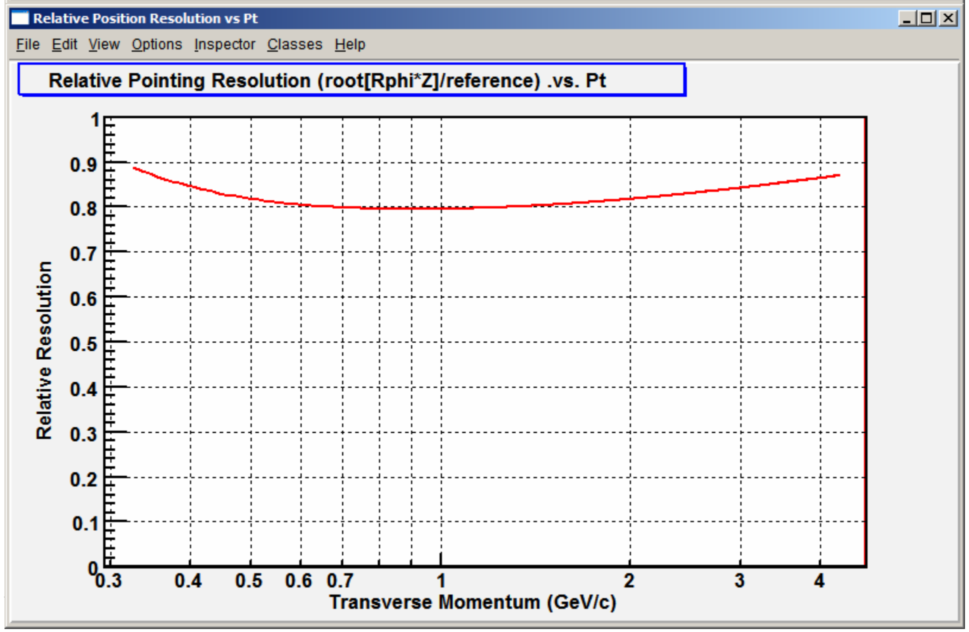
- **The SSD and the HFT are especially critical elements in the system**

- **We can do limited physics if one of the IST layers dies (or is missed due to inefficiencies) but without the SSD or HFT on the track, the value of the track for physics is quite restricted.**

Other Topics

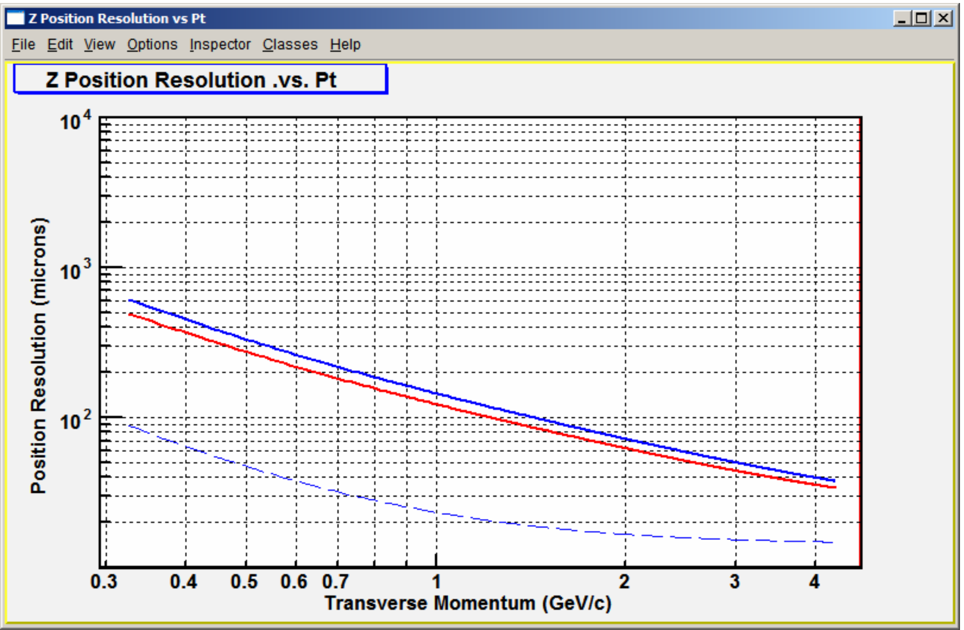
MCS from the Pad Layers

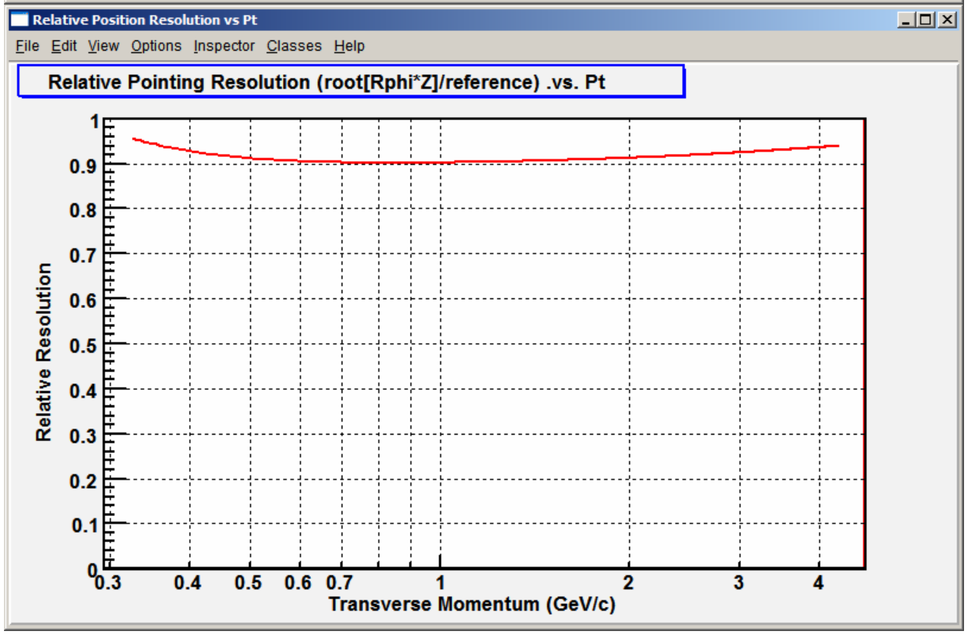




- **The pointing resolution of the system looking at HFT2 improves if we remove the pad layers**
  - **MCS limited**
  - **most of the gain is from the pad layer at IST1 because it is nearest HFT2**
- **The pointing resolution decreases from 150 μm x 400 μm to 110 μm x 350 μm**
- **The effective gain is 20% for the average pointing resolution and this will yield higher efficiency for D^0s**

Focus on the Pads at IST2





- The pointing resolution onto IST1 improves if we remove the pad layer at IST2 … again due to MCS
- The pointing resolution decreases from 290 µm x 200 µm to 280 µm x 165 µm
- The effective gain is 10% for the average pointing resolution applied to hits on IST1

Lessons learned so far …

- ✓ **We have designed an excellent pointing device for the HFT**
  - **It has graded resolution as a track is traced from the outside $\rightarrow$ in**
  - **It is minimalist in design (this is good). It just achieves our pointing resolution specification and doesn't go beyond it**
  - **It is MCS limited**
  - **Further improvements are possible**

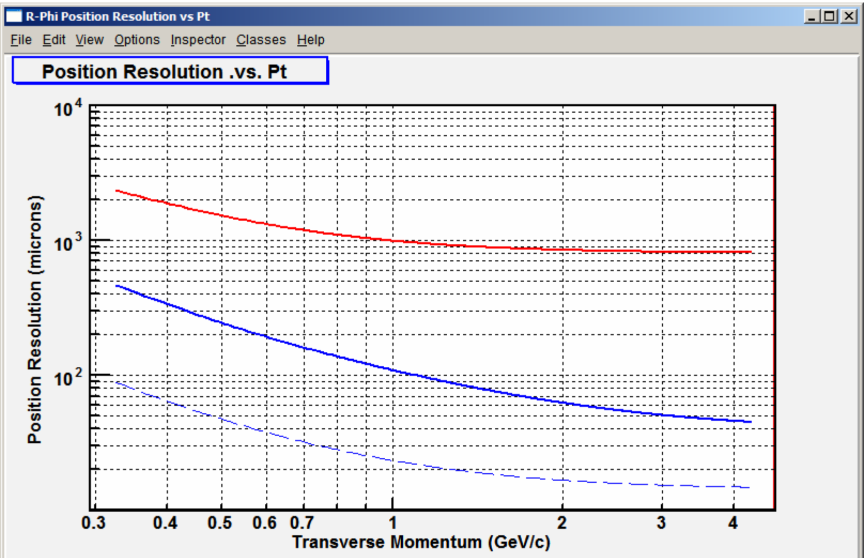
- ✓ **The pointing resolution can be improved by removing the pad layers from the canonical design of the IST**

- ✓ **The radiation length budget can be decreased by removing the pad layers**

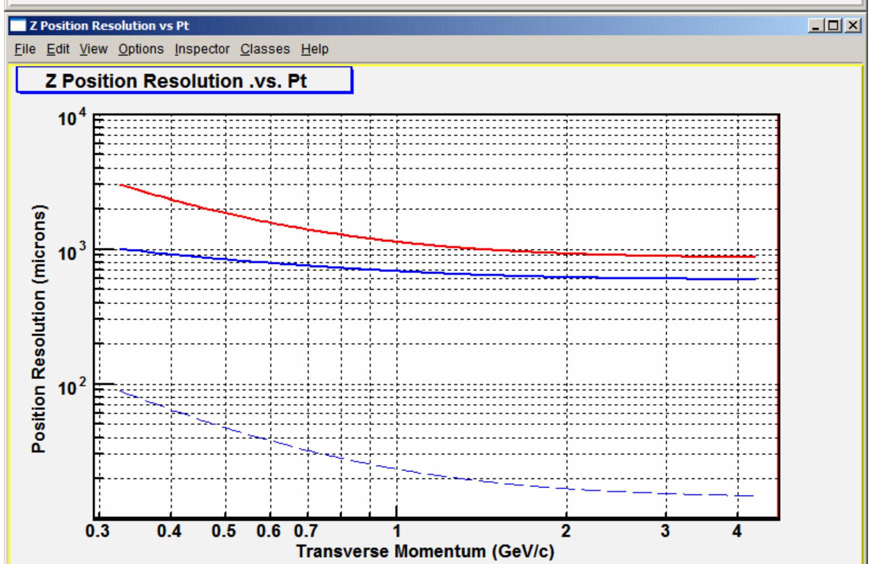
- ✓ **Costs may be reduced by removing the pad layers**

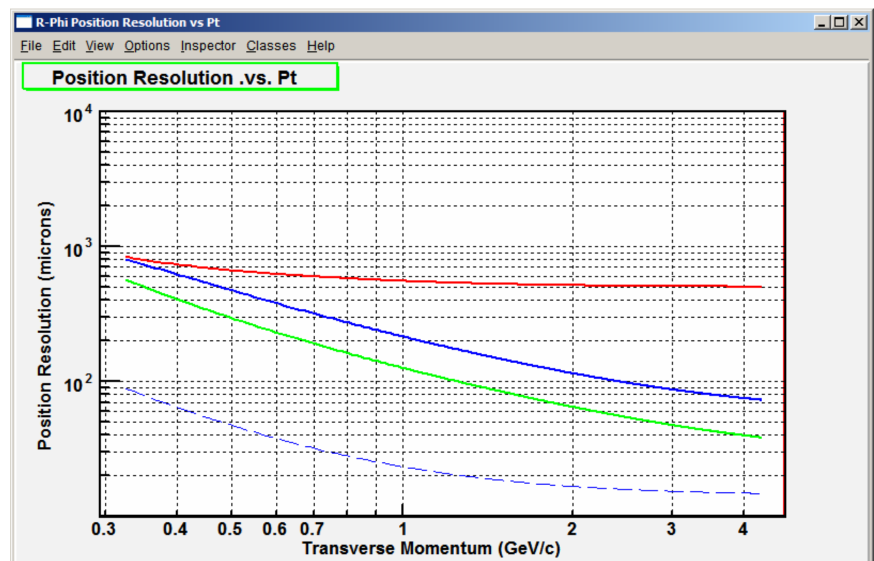
- ☒ **Does the pointing system have enough redundancy?**

The SSD is Critical to Success … what if we lose it?

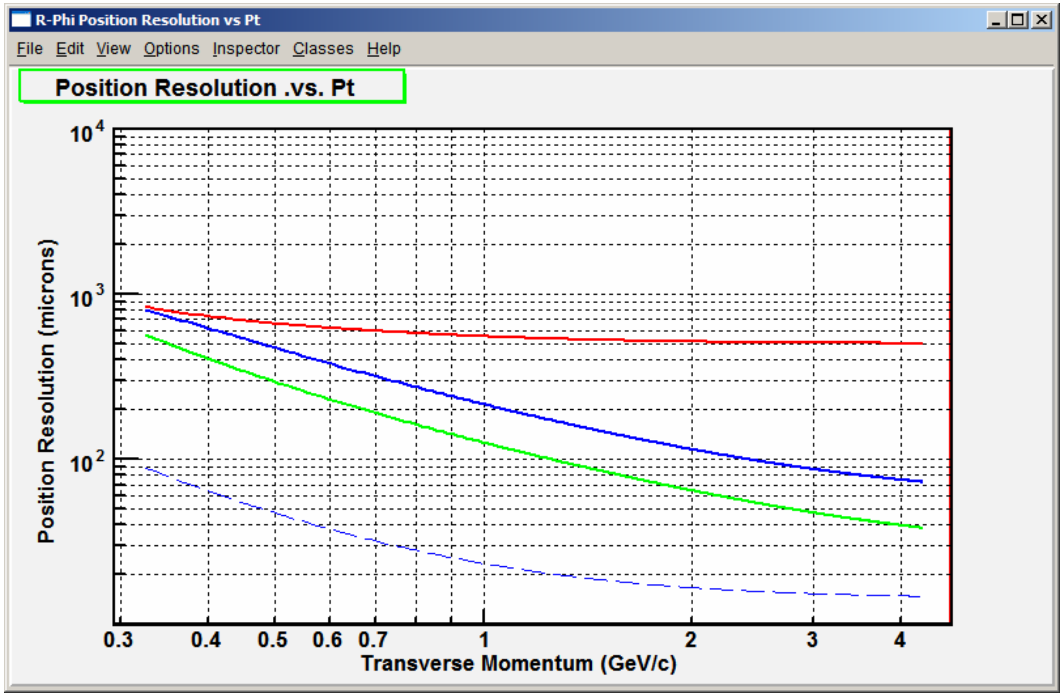


- **Two things happen … one of which we didn't cover earlier**
  - **The TPC pointing onto IST2 is worse than before because we lost the SSD**
    - **4x worse resolution (up to 16x more inefficient)**
  - **IST2 pointing onto IST1 is worse than before because the TPC is so far away**





Replacing the Pads at IST2 with Strips in Rϕ



- Replacing the <u>pads</u> on IST2 with <u>strips</u> going the other way can help regain the information lost if the SSD hit is lost
  - Blue – canonical configuration with SSD
  - Red – canonical configuration with a dead SSD
  - Green – extra strips with a dead SSD
- In fact, the extra strips improve the pointing at IST1 by 25%
  - but they cannot help regain the efficiency lost between the TPC and IST2

Summary

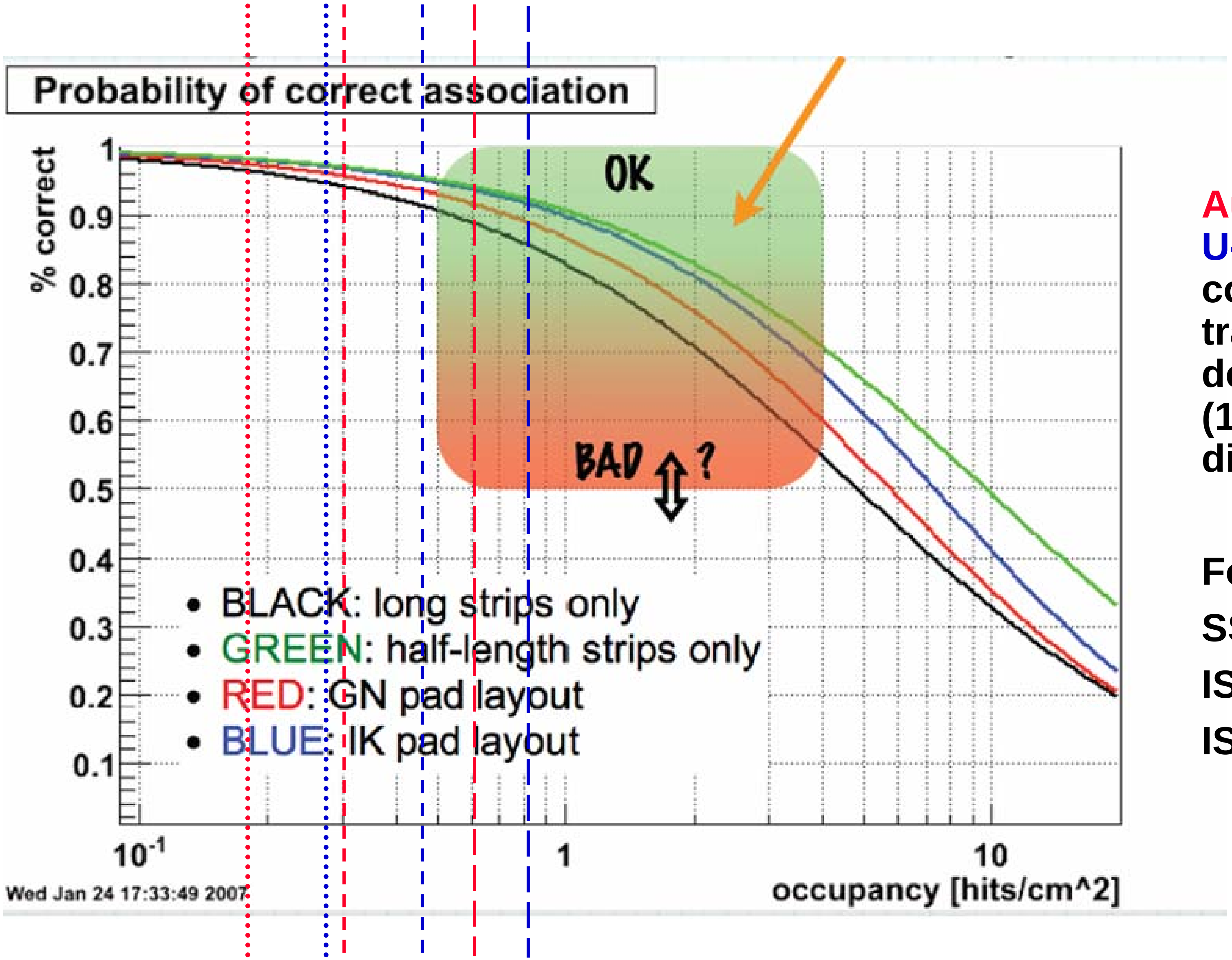
- **We have designed an excellent pointing device for the HFT**
  - **The pointing resolution can be improved by removing the pads from the canonical design of the IST**
  - **The radiation length budget can be decreased by removing the pads**

- **Ghosts and ambiguities can be dealt with in a different way without affecting these conclusions**
  - **For example, half length strips on IST1**
  - **See talks by Gene VB and Howard W**

- **The SSD is critical to the success of the HFT+IST system**

- **We can build some valuable redundancy into the pointing system by replacing the <u>pads</u> at IST2 with <u>strips</u> going the other way**

Gene's Plot Annotated



Au-Au and U-U central collision track densities (15 cm σ diamond)

For the

SSD ⋯⋯

IST2 – – –

IST1 — —

Parameters used in this study

```
#define     Mass                    0.494     // Mass of the test particle in GeV/c**2
#define     BFIELD                  0.5       // Tesla  (test data taken at 0.25 Tesla)
#define     AvgRapidity             0.5       // Avg rapidity, MCS calc is a function of crossing angle
#define     Luminosity              1.e28     // Luminosity of the beam (RHIC I == 3.e27, RHIC II == 1.e28)
#define     Sigma                   15.0      // Size of the interaction diamond (cm)  (assume 30/15 cm RHIC I/II)
#define     dNdEta                  170       // Multiplicity per unit Eta  (AuAu MinBias = 170, Central = 700)
#define     CrossSection            10        // Cross section for event under study (AuAu MinBias = 10 Barns)
#define     IntegrationTime         0.2       // Integration time for HFT chips (milliseconds) (eg 4.0 or 0.2)
#define     BackgroundMultiplier    4.0       // Increase multiplicity in detector (e.g. 2x Globals, 2x BackGround)
#define     SiScaleFactor           0.288     // For scaling Si pad sizes.  (eg 1/root(12) = 0.288 )
#define     EfficiencySearchFlag    1         // Define search method. ChiSquare = 1, Simple = 0.  ChiSq is better.

// 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 constraint
#define     VtxResolutionZ          0.3000    // cm  Test data wants 3 mm vertex constraint
#define     NewVtxResolution        0.0300    // cm  NewVertex to study effect of a refit vertex
#define     NewVtxResolutionZ       0.0300    // cm  NewVertex to study effect of a refit vertex
#define     RefitVtxResolution      0.0030    // cm  Refit Vertex to study effect of HiRes refit
#define     RefitVtxResolutionZ     0.0030    // cm  Refit Vertex to study effect of HiRes refit
#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     Ist1Resolution          0.0060    // cm  60 x 4.0  micron  and cm (Half length 60x2.0)
#define     Ist1ResolutionZ         4.0000    // cm  60 x 4.0  microns and cm (Half length 60x2.0)
#define     Ist1PrimeResolution     0.1200    // cm  1.92 mm x 1.20 mm pads (60x4 strips)
#define     Ist1PrimeResolutionZ    0.1920    // cm  1.92 mm x 1.20 mm pads (60x4 strips)
#define     Ist2Resolution          4.0000    // cm  60 x 4.0
#define     Ist2ResolutionZ         0.0060    // cm  60 x 4.0
#define     Ist2PrimeResolution     0.1920    // cm  1.92 mm x 1.20 mm pads (60x4 strips)
#define     Ist2PrimeResolutionZ    0.1200    // cm  1.92 mm x 1.20 mm pads (60x4 strips)
#define     SsdResolution           0.0095    // cm  95 x 4200  microns double sided crossed strips @ 35 mRad
#define     SsdResolutionZ          0.2700    // cm  95 x 4200  microns double sided crossed strips @ 35 mRad

// End of 'most likely' block, but there are more parameters on the next page.
```

Add’l Parameters used in this study

```
#define      VtxThickness           0.0000  // % Radiation Lengths
#define      BeamPipe1Thickness     0.0018  // % Radiation Lengths (as in 0.01 == 1%)
#define      Hft1Thickness          0.0028  // % Radiation Lengths (0.0028 new 0.0036 old)
#define      Hft2Thickness          0.0028  // % Radiation Lengths (0.0028 new 0.0036 old)
#define      BeamPipe2Thickness     0.0018  // % Radiation Lengths
#define      Ist1Thickness          0.0075  // % Radiation Lengths
#define      Ist1PrimeThickness     0.0075  // % Radiation Lengths
#define      Ist2Thickness          0.0075  // % Radiation Lengths
#define      Ist2PrimeThickness     0.0075  // % Radiation Lengths
#define      SsdThickness           0.0100  // % Radiation Lengths
#define      IFCThickness           0.0052  // % Radiation Lengths
#define      TpcAvgThickness        0.00026 // % Radiation Lengths ... Average per TPC row  (i.e. total/45 )
#define      VtxRadius              0.0     // cm
#define      BeamPipe1Radius        2.05    // cm (2.05 new 1.50 old)
#define      Hft1Radius             2.5     // cm (2.5  new 1.55 old)
#define      Hft2Radius             7.0     // cm (7.0  new 5.00 old)
#define      BeamPipe2Radius       8.55     // cm (8.55 new 6.05 old 11.5 proposed) JT test
#define      Ist1Radius            12.0     // cm (12.0 IST,10.0 SVT, option 9.5 IST)
#define      Ist1PrimeRadius       12.1     // cm (12.1 IST1Prime)
#define      Ist2Radius            17.0     // cm (17.0 IST,14.0 SVT)
#define      Ist2PrimeRadius       17.1     // cm (17.1 IST2Prime,14.0 SVT)
#define      SsdRadius             23.0     // cm
#define      IFCRadius             47.25    // cm  Middle-Radius of the IFC ... its about 1.29 cm thick
```