Representing Misalignments of the STAR Geometry Model using AgML

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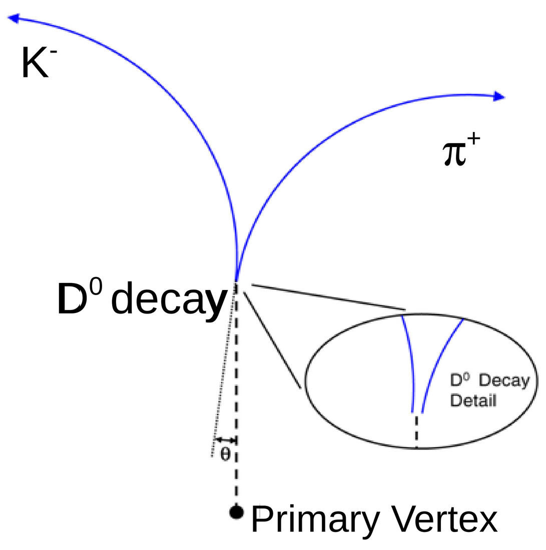
The STAR Heavy Flavor Tracker (HFT) was designed to provide high-precision tracking for the identification of charmed hadron decays in heavy ion collisions at RHIC. It consists of three independently mounted subsystems, providing four precision measurements along the track trajectory, with the goal of pointing decay daughters back to vertices displaced by <100 microns from the primary event vertex. ***The ultimate efficiency and resolution*** of the physics analysis ***will be driven by the quality of the simulation and reconstruction*** of events in heavy ion collisions. In particular, ***the geometry model must properly account for the relative misalignments of the HFT subsystems,*** along with the alignment of the HFT relative to STAR's primary tracking detector, the Time Projection Chamber (TPC).

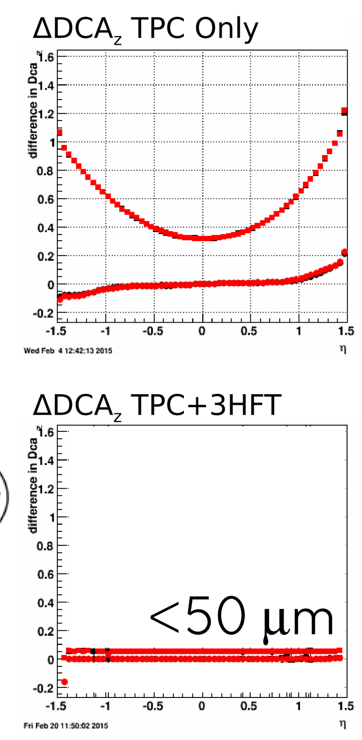
The HFT Physics Program

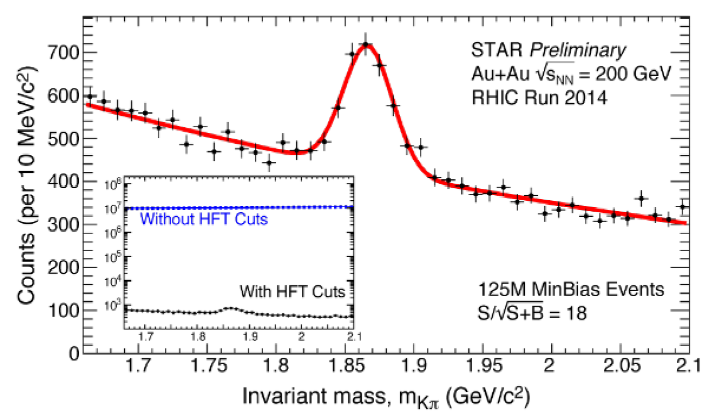
- Charm quarks created early in heavy ion collisions through hard scattering
- Experiences the full evolution of the system
- Probes energy loss mechanisms and extracts medium paramers from QGP

Topological reconstruction necessary to reduce combinatoric backgrounds.

Requires 50 μm pointing resolution, which is achieved by tracking.

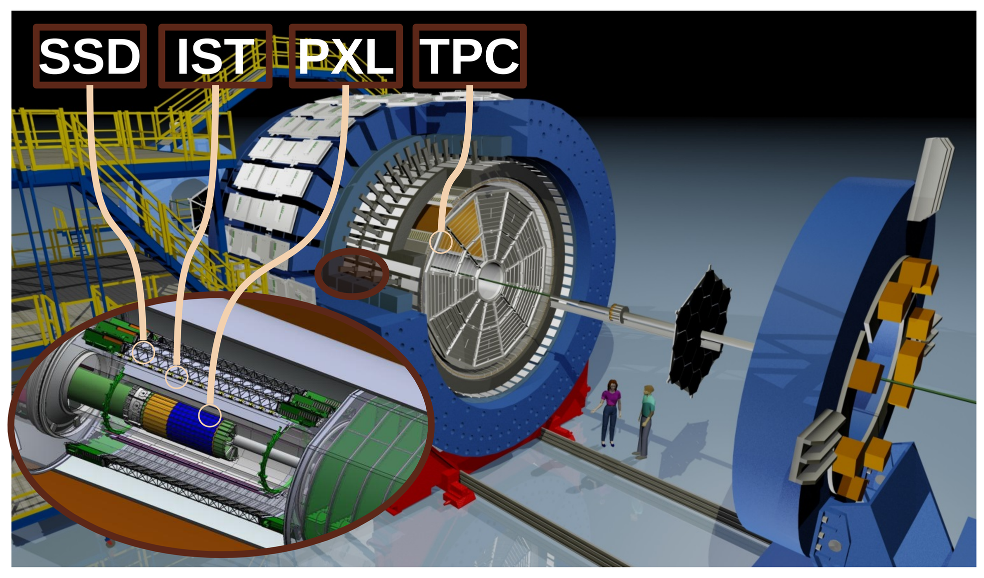






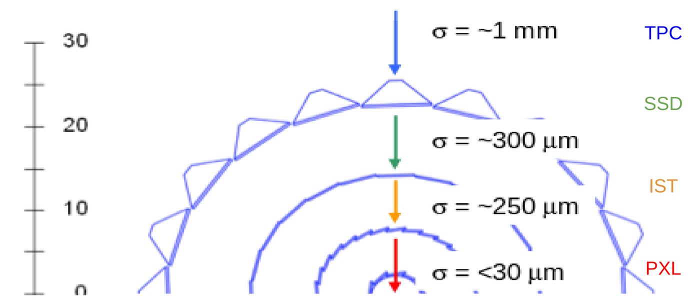
The HFT detector extends STAR's physics reach into the heavy flavor domain, allowing the reconstruction of charmed mesons. Beautiful charm results presented at QM'15, with more on the way for QM'17.

The STAR Detector



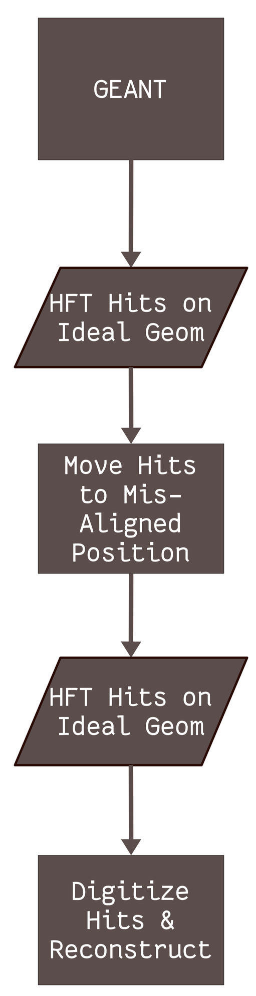
Tracking inwards with gradually improved resolution:

- Time Projection Chamber (TPC)
- Intermediate Silicon Tracker (IST)
- Silicon Strip Detector (SSD)
- Pixel Detector (PXL)



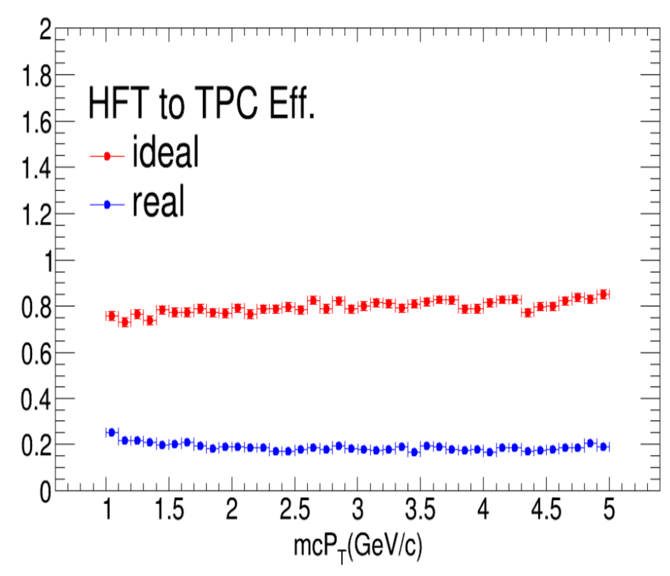
Hit Moving

- TPC era with mm-scale hit resolution – STAR uses hit-moving to account for the misalignments of active detectors
  - Hits simulated using ideal geometry, moved along the track trajectory to the misaligned detector position. The hit is placed at that point



Significantly underestimates tracking efficiency with μm- scale hit resolution

- No chance to recover hits initially out of acceptance
- Tracks undergo energy loss and multiple scattering at the *ideal* position, introducing aditional resolution effects
- Moved hits may appear in different sensor than simulated, may encounter different material effects and thus may not follow ideal trajectory



Misalignment Use Cases & Requirements

- The HFT physics program requires simulations which account for the many small misalignments of the active layers
- Requires a framework connecting the geometry model to the alignment tables stored in the database.
- Needs to support current simulation framework -- partial misalignment of G3 geometry package
- Needs to support path to full misalignment -- using the ROOT geometry package

Acknowledgements: I would like to thank my co-authors for their assistance in this project, as well as Mustafa Mustafa from LBNL and Zach Miller from UIC for testing our current hit-mover scheme and performing tests on the new misalignment scheme.

[1] The abstract geometry modeling language (AgML): experience and road map toward eRHIC Jason Webb et al 2014 Journal of Physics: Conference Series 513 022036

The STAR AgML Geometry Model

Simulations of the STAR detector rely on a geometry model implemented using AgML, an XML-based language for declaring the properties, content and placement of volumes within the geometry tree.

- AgML placement syntax and libraries extended to support misalignments
- Current implementation permits misalignment of IST and SST ladder assemblies, PXL sectors
- Support for misaligning individual sensors will be available when we begin using the ROOT geometry in simulation

```
<Placement block="PXLA" in="PXMO"  konly="MANY"
           x="xpos" y="ypos" z="zpos"
           ncopy="sector">

   <Rotation alphaz="alphaz"/>
   <Rotation alphax="alphax"/>
   <Rotation alphay="alphay"/>

   <Misalign table="Geometry/pxl/pxlHalfOnPxl"
             row="(sector-1)/5" opts="group" />
   <Misalign table="Geometry/pxl/pxlSectorOnHalf"
             row="sector-1" />

</Placement>
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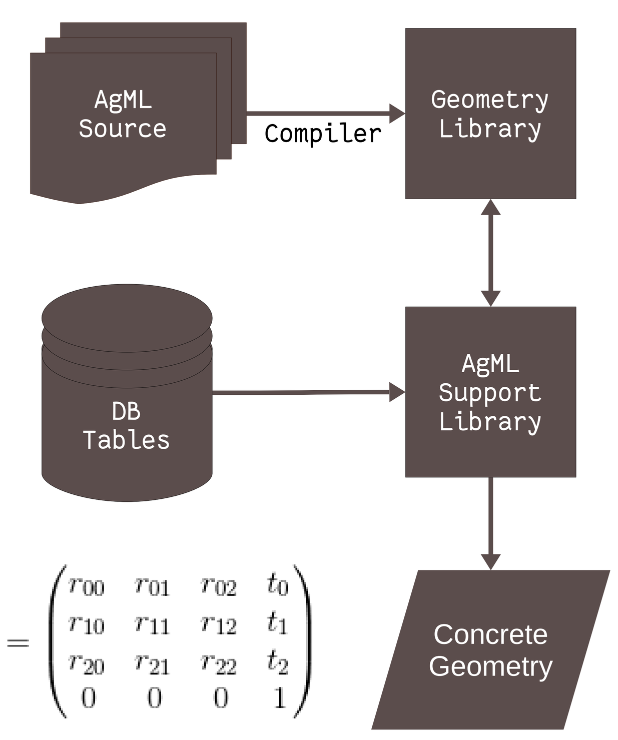
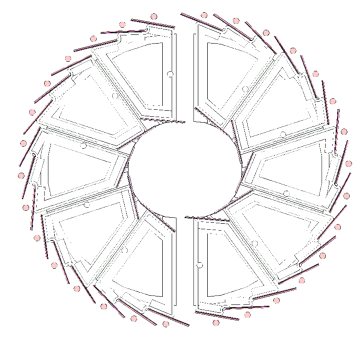
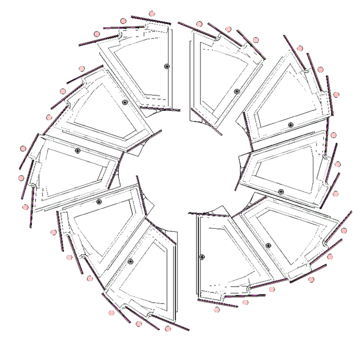


$$T = \begin{pmatrix} r_{00} & r_{01} & r_{02} & t_0 \\ r_{10} & r_{11} & r_{12} & t_1 \\ r_{20} & r_{21} & r_{22} & t_2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$



1 cm translation along X applied to sectors 6-10 *before* placement of the sectors.



1 cm translation along Y and -0.5 cm translation along X applied to odd sectors *after* placement.

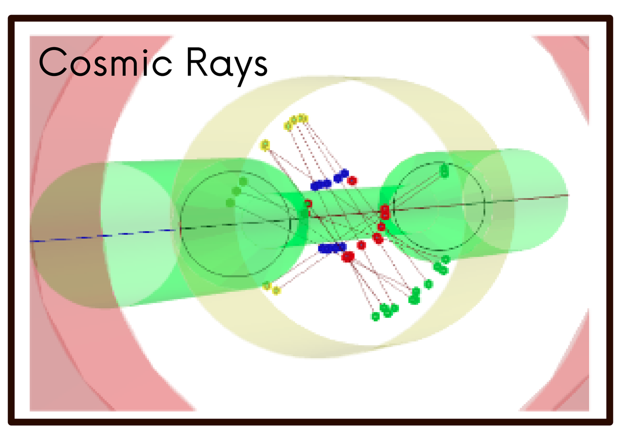
AgML source describes the ideal alignment. Misalignement matrices stored in the database. The AgML support library is responsible for computing the transformation matrix of each physical volume.

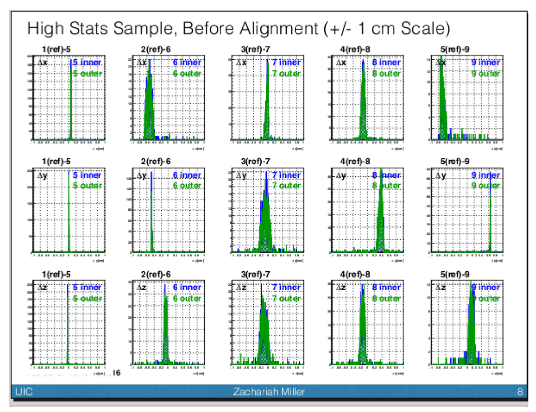
Testing with the HFT Alignment Software

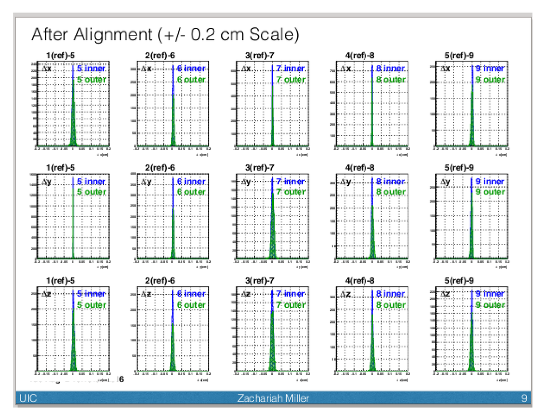
Test the misalignment framework using simulated cosmic ray events and the HFT detector alignment procedure

- Straight line extrapolation of hit pairs to opposite sectors
- Minimize residuals
- Measure alignment relative to pixel sector 1

Alignment procedure converges to the misalignment parameters applied to the pixel detector after a few iterations. Validation of the procedure with the IST and SSD is a work in progress.







Summary and Status

- AgML has been extended to provide support for the misalignment of detector volumes in simulations
- The framework connects the ideal geometry mode, defined in the AgML source code, to the misalignment tables extracted from data analysis and stored in the database
- The code supports our existing GEANT3 based simulations, allowing for the misalignment of detector volumes. Pixel sectors, and IST/SST ladder assemblies as test case
- The functionality to misalign physical volumes in the ROOT geometry can be enabled, once we have migrated our simulations to use the ROOT geometry (concurrent project)
- Experimental alignment procedure was able to extract the parameters used for a misaligned simulation of the pixel detector, promising a path forward for misaligned simulations with the full HFT and other precision detectors.

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