Toy MC model of supersector geometry

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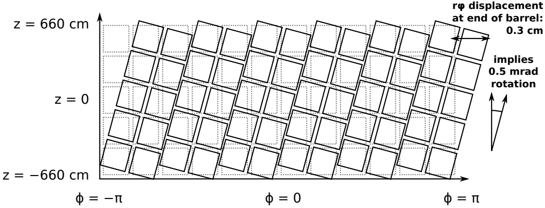
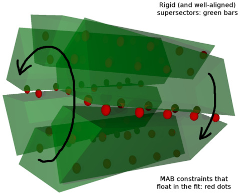
Motivation

- This "supersector rotation" model that we've been talking about is hard to visualize
- I wanted to make sure that I was thinking correctly about it, e.g. deriving the right conclusions about local x and y residuals



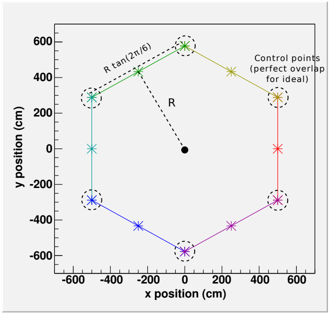


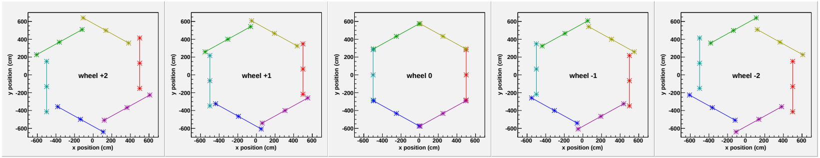
Toy MC

- Built a simple model of rigid-body supersectors in Python/ROOT
- Applied a supersector rotation (confirmed quantitative predictions)
- Searched for weak modes
  - it turns out that this is a fairly simple system; easy to diagnose

Toy MC

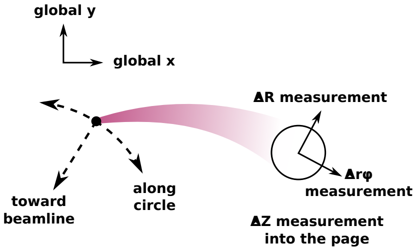
- Consists of six planes
  - perpendicular to rays from the beamline ($x = 0$, $y = 0$)
  - distance R from beamline
  - widths $= R \tan\left(\frac{2\pi}{6}\right)$, so that they just touch
- Apply rotations, translations to test deformations
- Monitor distance between control points along edges (without any deformation, this distance is exactly zero)
  - example with an exaggerated supersector rotation applied:





Imagine we have a device at each control point which can measure

- ΔR: displacement toward or away from beamline
- $\Delta r\phi$: displacement perpendicular to beamline
- ΔZ: displacement parallel to beamline



located at R_{pos}, ϕ_{pos}, Z_{pos}.

If we had a supersector rotation of $\phi_z = 0.5$ mrad, the device would see:

- $\Delta R = \phi_z \left(Z_{\text{pos}} \right) = 0.3$ cm at end of barrel
- $\Delta r\phi = 0$ (for all R_{pos}, ϕ_{pos}, $Z_{\text{pos}}\ldots$ completely insensitive)
- $\Delta Z = \phi_z \left(\dfrac{2\pi R_{\text{pos}}}{6} \right) = 0.2$ cm at station 1

in agreement with intuition. Is that consistent with current measurements? What are the current measurements?

- Another question: even if the measurements are sensitive to a simple supersector rotation, could it be masked by other degrees of freedom?
- Answer: no, not for any ϕ-symmetric deformations, at least...

Method

- In addition to the twist angle, allow three more degrees of freedom:
  - the other two rotation angles ϕ_x, ϕ_y and a radial displacement r of each supersector
  - all supersectors get the same angle/displacement (that's why we're limited to ϕ-symmetric cases)
- Fix supersector rotation $\phi_z = 0$ or 0.5 mrad, allow other degrees of freedom to float in Minuit
- Minimize $(\Delta R)^2 + (\Delta r\phi)^2 + (\Delta Z)^2$

Results

- With or without ϕ_z fixed at 0.5 mrad, (ϕ_x, ϕ_y, r) minimize to $(0, 0, 0)$
- Correlation ($\mathrm{Corr}_{ij} = \mathrm{Cov}_{ij}/\sqrt{\mathrm{Cov}_{ii}\mathrm{Cov}_{jj}}$) of $(r, \phi_z, \phi_y, \phi_x)$ has negligible off-diagonal terms:

$$\begin{pmatrix} 1 & -2\times10^{-5} & -5\times10^{-5} & 0.0002 \\ -2\times10^{-5} & 1 & -3\times10^{-10} & 2\times10^{-8} \\ -5\times10^{-5} & -3\times10^{-10} & 1 & -4\times10^{-9} \\ 0.0002 & 2\times10^{-8} & -4\times10^{-9} & 1 \end{pmatrix}$$

  so these degrees of freedom are nearly independent of one another

  (ϕ_z is the supersector twist angle)
- Dropping terms in the χ^2 (that is, assuming that the devices only measure one or two coordinates, not all three) leads to insensitivity for some parameters, but not hiding of the supersector rotation
  - that is, we don't get a bad χ^2 with ϕ_x, ϕ_y, or r fixed to zero that is recovered when they're allowed to float
  - again, they seem to be highly independent of one another in this model

Conclusions

- Toy MC of rigid supersectors
  - quantitatively confirmed intuition about expected residuals trends
  - allowed for a semi-systematic search for weak modes (only considered ϕ-symmetric modes)
- The system is fairly simple, characterized by measurement resolution in ΔR, $\Delta r\phi$, ΔZ
  - supersector rotation model is constrained only by ΔR, ΔZ
  - if either is measured with better than 2–3 mm, then the model is well-constrained
  - it can't hide in any ϕ-symmetric weak modes: the ΔR, ΔZ resolutions directly determine the constraint
- If there are significant misalignments inside the supersectors (as track-based residuals seem to indicate), then this model doesn't apply