ATLAS Inner Detector alignment studies with B Physics channel, $B_d^0 \rightarrow J/\psi K^{0*}$

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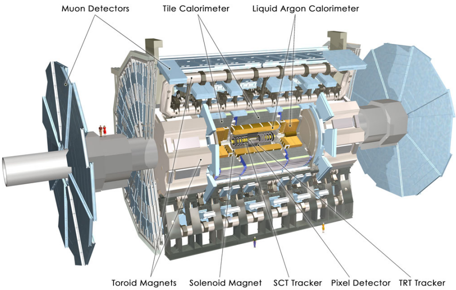
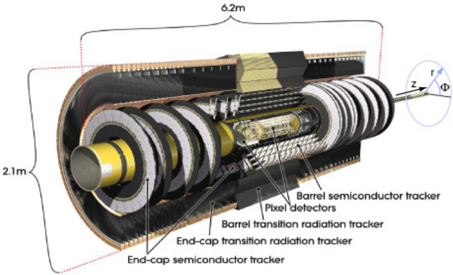
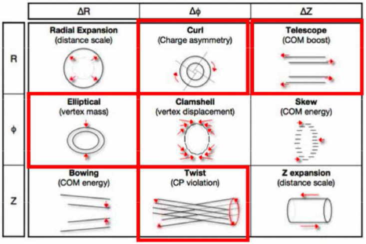


- The ATLAS detector is a multi purpose detector built to study high energy proton-proton collisions at the LHC at CERN, in Geneva, switzerland.
- In modern particle physics experiments, a good understanding of the detector is essential for any measurement.

- The ATLAS B physics program offers many interesting opportunities for troubleshooting Inner Detector (ID) alignment:
  - Well known observables such as J/ψ mass, B_d^0 mass and B_d^0 lifetime, to test the understanding of detector performances, for instance ID misalignment, magnetic field and material.
  - High cross section and trigger rates to record many of these events in the early data taking period.
  - B physics also requires that detector is well understood because B measurement at LHC are projected to acheive higher sensitivity to prove new physics in the heavy flavour sector.
- This presentation concentrates on the first steps of the B Physics program for Inner Detector alignment tests.



The ATLAS inner detector

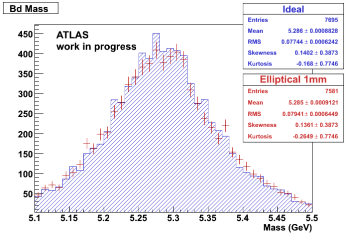


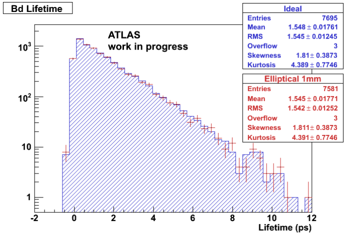
The "Weak modes"

- The ATLAS inner detector may have different positioning or geometry deformations relative to the design, this is known as "misalignment".
- The new positions need to be precisely determined using real data.
- The alignment procedure is a complex mathematical procedure that works with high p_T (very straight) tracks.
- It is the responsibility of physics groups to ensure that this procedure is validated and monitored with known physics objects, such as masses and lifetimes of B_d^0, J/ψ and Z.
- This presentation focuses on the role of B physics to monitor alignments.

Determination of B_d^0 mass and lifetime with both material and misalignment effects

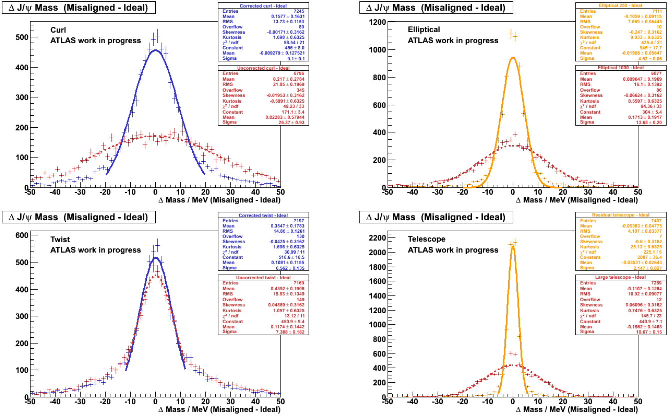
- Detector performance for physics observables (masses and their detected resolutions, σ) is affected not only by misalignment, but also by imprecise knowledge of material in detector.
- Current ATLAS simulation indicates that in B physics (low p_T sector) material effects contribute typically 90% to imperfections. The remaining 10% is dominated by misalignment while magnetic field uncertainties are considered negligeable.
- In this study, we propose a method allowing to disentangle misalignment effects from material effects in order to monitor the misaligment and its subsequent corrections.





- Using this method, material and misalignment effects are intertwined, and cannot be disentangled.

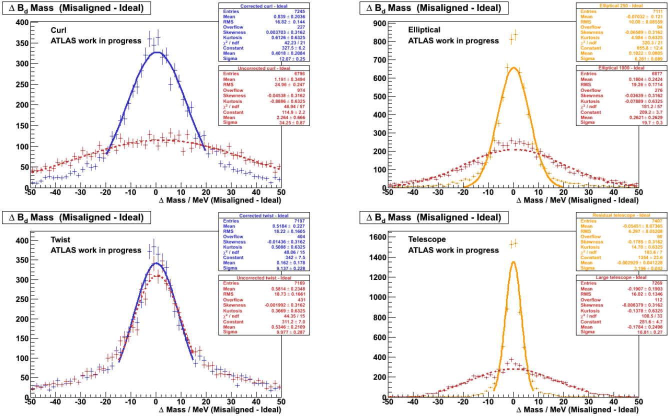
- Multiple scattering effects can be removed by comparing the same event before and after alignment.
- The ID group will deliver alignment corrections to re-reconstruct the events.
- The B physics group will plot difference before and after re-reconstruction: i.e. ($\Delta M = Mass(J/\psi)_{After} - Mass(J/\psi)_{Before}$ for event i)
- Here, we illustrate the procedure by comparing corrected, large misalignments and small misalignments to the ideal alignment.



Legend

Corrected - ideal
Uncorrected (large) - ideal
Residual uncorrected - ideal

B_d^0 Mass(misaligned - ideal)



Legend

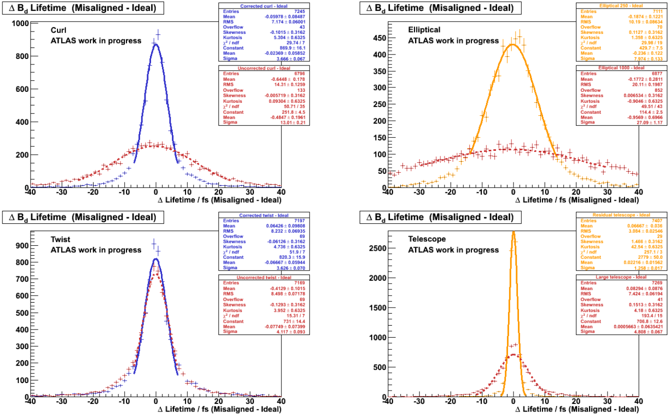
Corrected - ideal

Uncorrected (large) - ideal

Residual uncorrected - ideal

- These plots demonstrate that B_d^0 mass is sensitive to some misalignments, while not sensitive to others (Twist).
- Those that are sensitive can be used as a demonstation that the correction improve measurement (Curl).

B_d^0 Lifetime (misaligned - ideal)



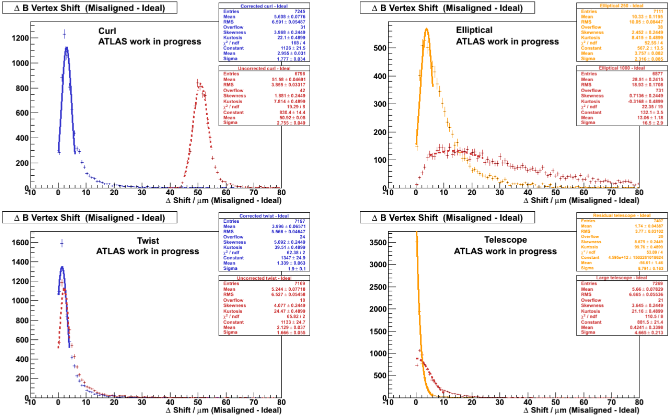
Legend

Corrected - ideal
Uncorrected (large) - ideal
Residual uncorrected - ideal

- The B_d^0 lifetime has similar dependencies on reconstruction as its mass.

B_d^0 transverse Vertex Shift (misaligned - ideal)

- The "Shift" is the absolute value of the difference in the transverse plane between the position of the misaligned vertex and the ideal vertex.



Legend

Corrected - ideal
Uncorrected (large) - ideal
Residual uncorrected - ideal

- The difference in behaviour between curl, twist and elliptical modes is particularly striking for this variable.
- This picture demonstrates that B_d^0 vertex shift is a sensitive indicator of curl misalignment.

Conclusions

- This study developed a method to monitor effects of alignment on physics varaibles.
- Different types of misalignments produce different effects and thus the plots can serve as indicator of certain types of misalignment.
- The study will continue to include backgrounds.
- The plots can be used for real data monitoring.

Questions, comments, please contact ldemora@cern.ch

The alignment procedure by the ID alignment group

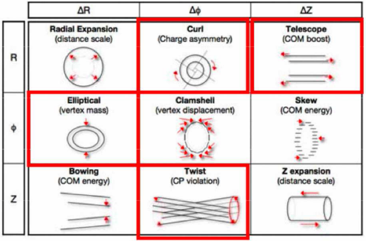
- Alignment process (at the simplest level, experts might disagree):
  1. ATLAS produces a set of data with some alignment.
  2. Perform offline Global χ^2/DOF minimization, a complex mathematical procedure, to produce a new set of alignment constants. [see indet-pub-2005-002 for mathematical formalism]
  3. Detector is then considered "re-aligned", and data can be prepared again with new constants.
  4. Repeat χ^2/DOF minimization when more data is available to produce an improved set of alignment constants.

- **Weak modes are global deformations to a perfectly aligned detector that leave the fitted tracks χ^2/DOF unchanged.**
- Even with larged numbers of ID tracks, weak modes can be difficult to dectect.
- The ID alignment group have created some samples to demonstrate these weak modes, both before and after alignment.
  - The "uncorrected" ("unaligned" or "large") samples were expected to:
    - not be realistic
    - provide an obvious effect on physics.
  - The corrected ("aligned" or "residual") samples were expected to be an estimate of remaining weak modes after alignment.
- The strength of the weak mode deformation is arbitrary in these datasets but approximates to what the ID alignment experts would expect to observe.

MOVE SLIDE 3 AND 4 IN BACK UP SLIDES.

A sample of exclusive 20K $B_d^0 \to J/\psi K^{0*}$ was repeatedly reconstructed with each of the following alignments.

- Ideal alignment
- Uncorrected and corrected Curl misalignment $\Delta\Phi = c_{curl_1} \cdot R + \frac{R}{c_{curl_2}}$
- Uncorrected and corrected Twist misalignment $\Delta\Phi = c_{twist} Z$
- 2 samples of uncorrected Elliptical misalignment (large and residual). $\Delta R = \frac{1}{2} c_{elliptical} \cdot cos\,(2\Phi)\, R$
- 2 samples of uncorrected Telescope misalignment (large and residual). $\Delta Z = c_{telescope} R$



The "Weak modes"

These 4 deformations are considered to be the most dangerous to alignment: [see ATL-COM-INDET-2009-03]

- They retain helical trajectories for particles coming from the interaction point, such that the interaction point is a fixed point under any of those transformations.
- Not all modes are allowed by the physical/geometrical construction of the ID:
  - Certain deformations are unlikely to occur. (i.e. mechanical supports don't allow certain groups of modules to move with respect to each other.)
  - Some modes cannot be represented in the Athena geometry model. (i.e. modules cannot be bent internally.)