AP alignment issues: summary report

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Summaries of Talks

There were four talks at the workshop focused on AP issues related to the alignment of IR magnets. J.P. Koutchouk discussed the criteria necessary to determine the alignment tolerances of the quadrupoles. Misalignments can cause the beams to be less than perfectly centered at the IPs. This lack of complete overlap leads to a loss of luminosity and an increase in the background in the detectors. The allowed loss of luminosity from misalignments is limited to 2% from a single magnet and 5% from all the magnets. This criterion alone requires that the IR quadrupoles to be aligned to within a few microns, a tolerance which is physically not achievable. Hence orbit corrections to compensate for misalignments will be essential. Other optics parameters which need to be controlled include: β beating at the IPs, dispersion at the IPs, absolute and relative positions of the IPs - both transverse and longitudinal, the crossing angle, separation between the beams, betatron coupling, variation of the tunes, leakage of the closed orbit and the dynamic aperture. The available geometric aperture is 1.6mm including both transverse misalignments of the beam pipe and motion of the fiducials over time. Experience with LEP showed that the fiducials move by as much as 1mm over the course of a year. For the LHC however, wires stretched across the experimental halls will be used to continuosly monitor the radial positions of the triplets. Assuming that this will allow the drift of the fiducials to be contained within 0.3mm, a total of 1.3mm will be available for the transverse motion of the beam pipe.

The alignment of the IR quadrupoles will be known only after installation in the tunnel - except for the relative alignment between Q2a and Q2b which will be determined at FNAL. The longitudinal space between Q2a and Q2b is mostly occupied by a corrector magnet and there is no room for an inter-connect. Consequently these quadrupoles will be welded together and placed in a common cryostat at FNAL before shipping to CERN. T. Sen addressed the question of how good the relative alignments of Q2a and Q2b need to be in order to satisfy all the AP alignment criteria. It was shown that an efficient way to correct for their relative misalignments is to align the common cryostat in the ring to provide self-compensating orbit and coupling corrections. If the cryostat can be placed as desired, the relative alignment tolerances are:

Relative Alignment Tolerances for Q2a/Q2b

Transverse displacements	Pitch and yaw	Roll
0.5mm	0.1mrad	1mrad

These misalignments when self-compensated have no significant effect on the luminosity, physical and dynamic aperture and coupling. With self-compensation, the correctors in MCBX and MCQS need be used only to correct the misalignments of the other two quadrupoles Q1 and Q3 in the triplet. The relative transverse alignment tolerance between Q2a and Q2b is well within the total tolerance placed on the alignment of the beam pipe. A full report of this work was published as FNAL report Conf-99-304 and is available on the workshop website in the references section or visit http://fnalpubs.fnal.gov/archive/1999/conf/Conf-99-304.pdf

F. Pilat reported on the transverse offsets and roll tolerances of the corrector packages MCBX and MCQS which house nonlinear corrector coils. The method used was similar to that used for estimating the tolerances of corrector packages in RHIC. Calculations of the dynamic aperture with corrector misalignments suggest the following tolerances:

Alignment Tolerances for MCBX/MCQS

Transverse displacements	Roll
0.5mm	5mrad

The experience gained during the process of aligning magnets in RHIC was reported by D. Trbojevic. Different techniques were used to measure the magnetic center of the quadrupoles - magnetic measurements with a colloidal cell and also a harmonic antenna as well as mechanical measurements. These were well correlated and were used for cross calibration. Small twists in quadrupoles were corrected by rolling them around the magnetic center to eliminate the roll while larger twists required weld stripes on the cold mass. During cooldown, there was significant shrinkage in both transverse and longitudinal directions. In some cases the ends moved by nearly 4cm. Considerable software and database development was required in order to efficiently flag differences between designed and measured magnet parameters during the production run of magnets. Some of this software package (TRIPSTAT) may be profitably used during the production of the LHC IR magnets.

Further Questions

Following the discussions, the following AP issues were recognized as requiring further study:

- Importance of local variations in straightness and twist.

  Measurements of the model magnets show that variations in straightness are less than 25μm over 2m. The expected twist is of the order of 0.2mrad/m. These are small variations and are not expected to have a significant impact. Nevertheless analysis is needed to confirm that variations of these magnitudes do not impact the beam quality.

- Robustness of the self compensation of Q2a and Q2b.

  The individual offsets required for Q2a and Q2b demand knowledge of the ratios of beta functions at their locations. With exact self-compensation of Q2a and Q2b, the correctors MCBX and MCQS are not required to correct their relative misalignment. Since the optics functions are usually known to an accuracy of 10% at best, the robustness of the compensation scheme to optics errors and the required corrector strengths need to be examined. It is expected that the compensation will be robust against optics errors in the arcs but it may be slightly sensitive to local errors in the IRs.

- Data transfer between BNL, FNAL, KEK and CERN.

  Data transfer protocols for the exchange of production magnet data between BNL, FNAL, KEK, and CERN need to be finalized. Preliminary agreement on a common database structure was achieved at the ”Workshop on the US-LHC Magnet Database”, held in 1998 (see the workshop summary at http://www.rhichome.bnl.gov/LHC/org/workshop.html). A final agreement on the database structure, and the initial implementation of data transfer protocols, requires active participation by appropriate members of the four laboratories.

- Alignment of triplet quads in the tunnel.

  J.P. Koutchouk suggested that CERN might explore the possibility of aligning the triplet quadrupoles not in a straight line but offset in order to maximize the physical aperture given the fact that the crossing angle will cause an orbit offset in these magnets.