# Internal rolls in Tevatron dipoles?

Tev Magnet Studies Group

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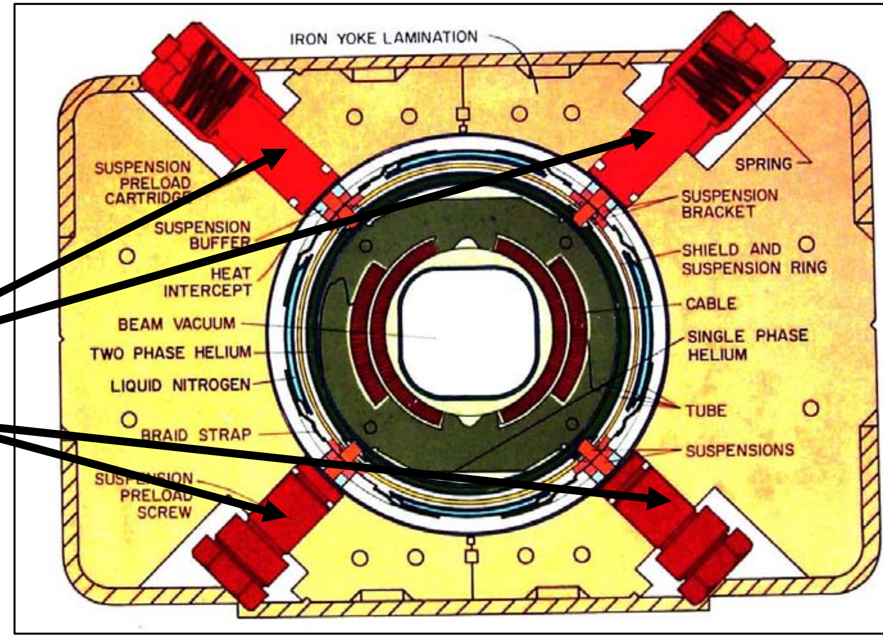
# Internal rolls in Tevatron dipoles?

- Are there internal rotations of the field of Tev dipoles in some fraction of the magnets in the ring?

# suspension scheme of a Tev dipole

- warm iron: cryostat supported in magnet yoke
  - 4 supports, upper are active (“smart bolts”), lower, passive (“dumb”)
  - 9 support stations along the length of the magnets
    - station 5 special
    - anchors the magnet against rotational, longitudinal shifts
    - suspension bolts here mechanically different from the others




- “lift”
  - measure of cryostat position inside the yoke
  - depth of spring-loaded plunger on smart bolts

# the re-shim program

- the “creep” problem
  - G10/G11 suspensions supporting the coils inside the cryostat had shrunk over time
    - coils sank in the yoke
    - up-down asymmetry gave a significant skew quadrupole (1 unit on average)
  - ~1/7 of Tev dipoles corrected by a re-shim program in the fall 2003 shutdown (5/7 done in 2004)
    - lifts of most (almost all) dipoles measured, compared to measurements during manufacturing (“legacy data”)
    - long tail to the distribution of lifts in anchor positions

# “broken anchors”?

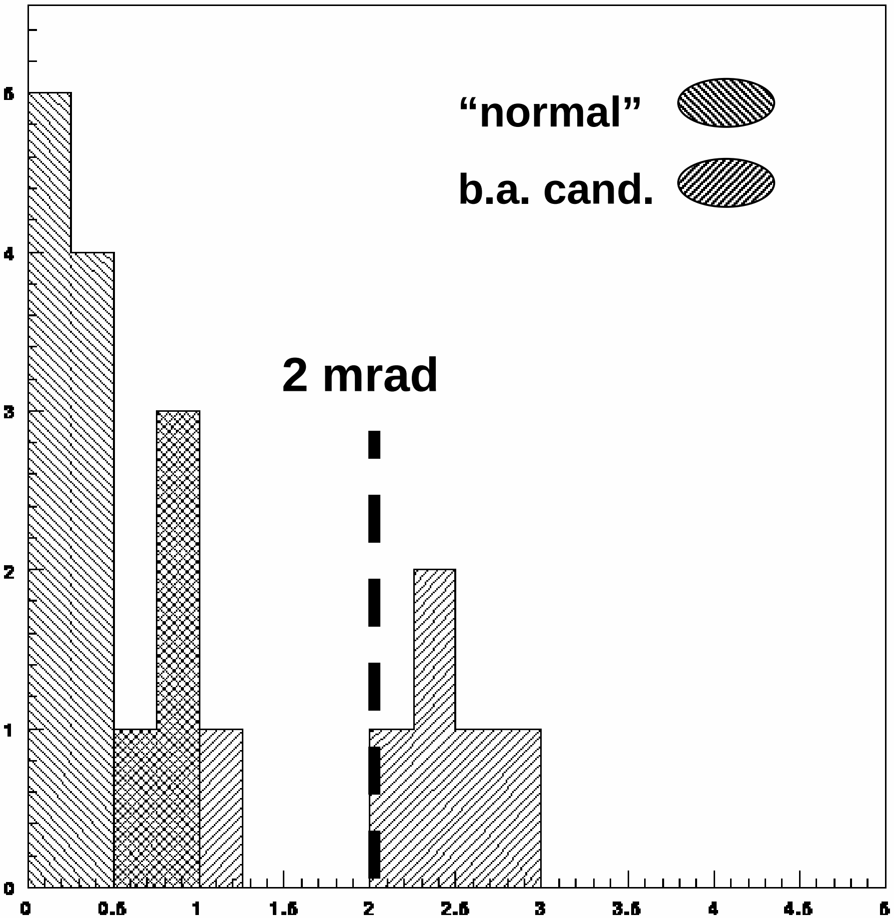
- one explanation:  anchor(s) broken
  - fatigue failure?
  - 10-15% of magnets have anomalous readings
- possible consequences
  - rotation of coils (i.e. field) relative to yoke
    - magnet aligned, dipole field is not
    - longitudinal movement possible, not as important
  - scenarios
    - one time rotation when anchor broke
    - time dependent motion
      - e.g. thermal cycles, magnet excitation, quenches

# studies in MTF

- MTF magnet test program undertaken spring/summer 2004
  - a handful of available magnets had anomalously large lifts relative to legacy data
  - compared to “normal” magnets
    - changes with thermal cycling, powering, quenching
    - figures of merit:  changes in lift, field angle, field harmonics

# changes in field angle

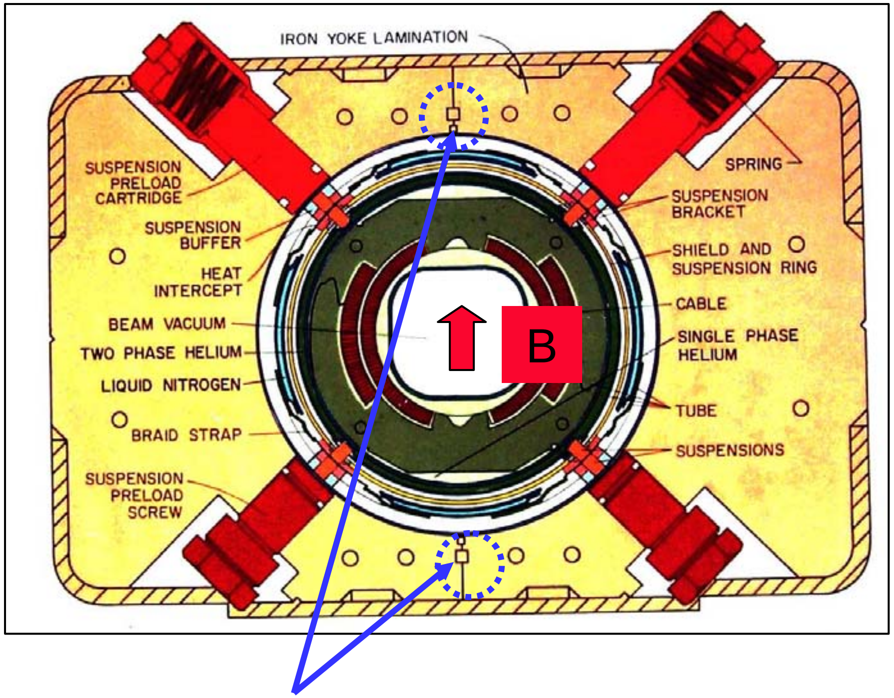
- “broken anchor candidates” show “large” changes in field angle
  - presumably changes since leaving MTF
  - large relative to a sample of non-candidates




**|difference| field angle w.r.t. lugs (mrad)**

# the "Kaiser coil"

- is it possible to check for field rotation in situ?
- yes, via the Kaiser coil
- flux loop embedded in the yoke of a Tevatron dipole
  - loop parallel to the main field
  - sensitive to the *__relative__* orientation of field (i.e. cryostated coil assembly) and yoke
  - voltage proportional to d$\phi$/dt, $\phi$ is the flux linking the loop
  - note: a perfectly aligned magnet produces *__no__* signal

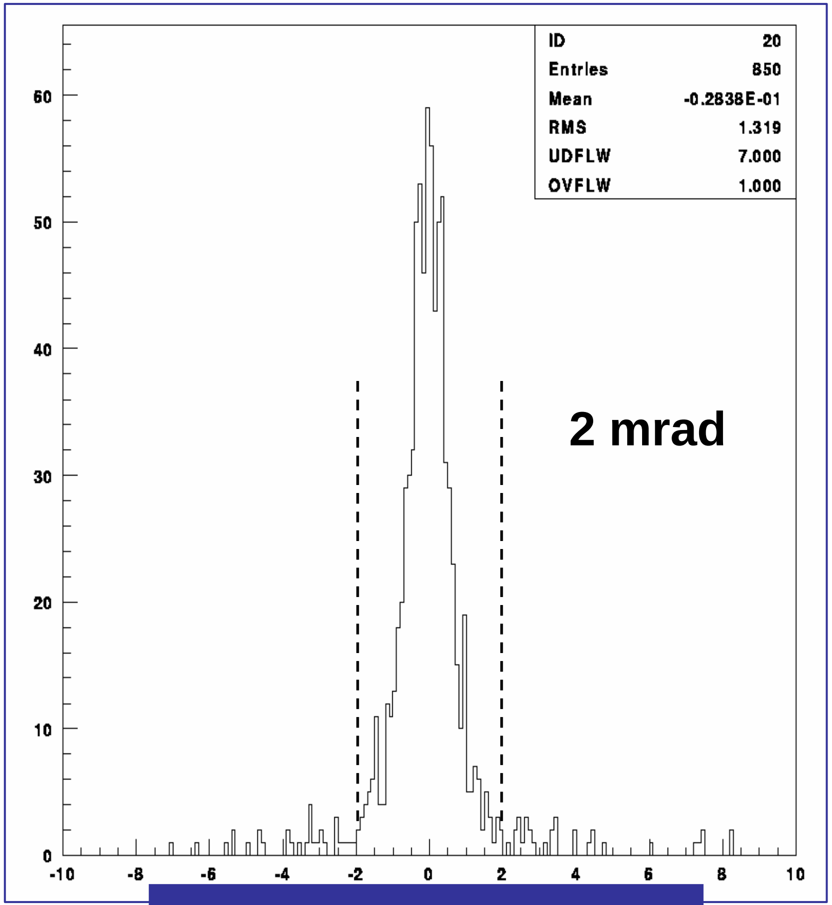



coil windings

# in situ field angle measurements

- kaiser coil signal sensitive to the *relative* orientation of field and yoke
  - exactly what changes if broken anchors have allowed the cryostat to rotate in the yoke
  - in principle remedial action could be taken
- system developed to excite magnets and measure flux
  - all dipoles measured cold during the 2005 shutdown
    - a special thanks to the AD operators/TD techs who took this data
  - looked for changes relative to legacy data

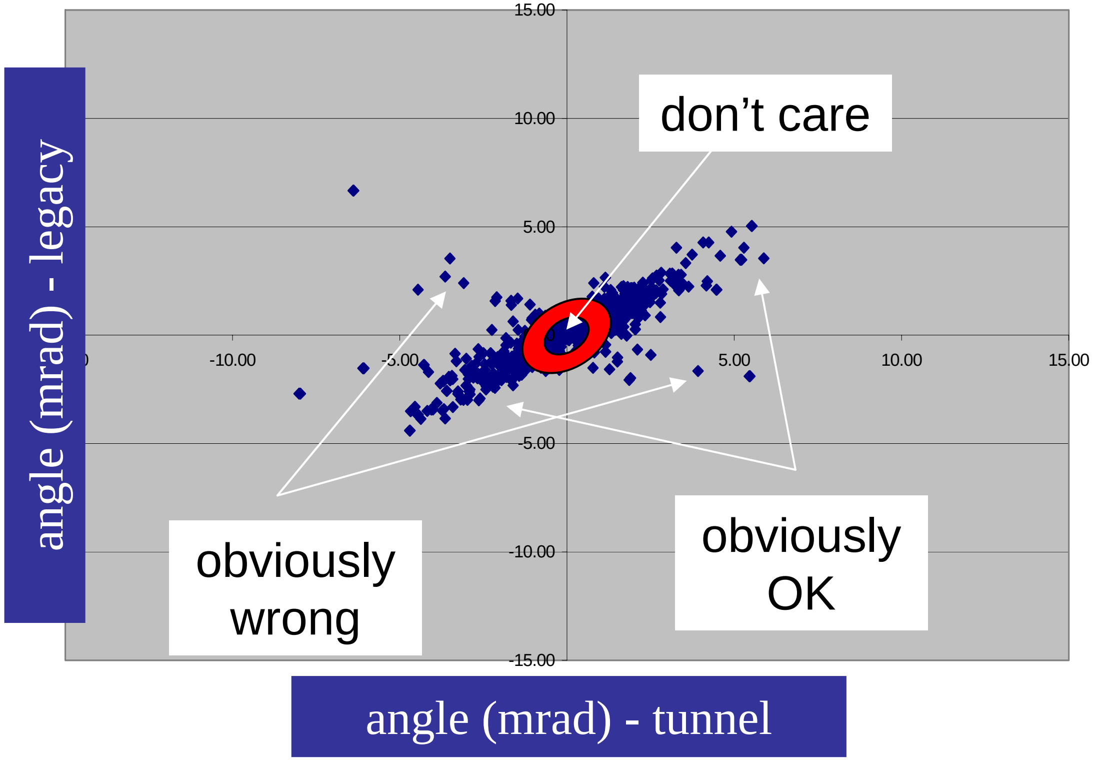
# comparison to legacy data (1)




ΔAngle (mrad) → tunnel-legacy

- 1st pass
  - no obvious "2nd population"
  - tail beyond 2 mrad
  - dominated by polarity issues
    - measured angles have the same magnitude, different sign

# comparison to legacy data (2)




- after fixing all "known" polarity problems
  - 33 magnets fail 2 mrad cut
  - 11 remain after further review
    - 5 mrad largest difference

- |$\Delta$angle| > 15 mrad $\rightarrow$ broken windings/connectors

# summary/status

- not much evidence for large field misalignments based on Kaiser coil measurements
  - no 2nd population, only a tail
  - ~1% of magnets |$\Delta$angle| 2-5 mrad
  - magnets identified as suspicious from lift data show only slightly larger |$\Delta$angle| than others
    - the mining of ancient data to refine the “suspicious” list goes on
- a fraction of magnets were measured warm and again when they were cold
  - may help resolve polarity issues
  - cold-cold comparisons without reference to legacy data