Instrumentation, Controls, and Alignment

Introductory comments

- This is a very broad set of topics
- Instrumentation (including equipment protection) and Controls: about 10% of total collider cost
- Reliability and Radiation Hardness
  - Integrate strategies into design process
- Two subgroups
  - Alignment and correction
  - Coffin designers

Alignment & Correction

Alignment Decay

- **Order of Magnitude: (Shiltsev)**
  - **uncorrected orbit develops ~1mm distortion in ~1 day**
  - **quad-to-quad misalignments of ~0.25mm develop in ~1 year**
  - **“perfect” orbit correction requires ~0.5 T-m correctors at each quad**

Conventional Orbit Correction Methods

- One H/V corrector at each F/D quad for each bore
- Low Field: 0.5 T-m conventional correctors dissipate ~1kW at each halfcell (1MW/tunnel)
- High Field: (Tev~LHC) 50 Amp SC corrector supply (~150Watts)
- Probably OK for air cooling

Strategies to Reduce Corrector System Costs

- **Reduce corrector strength**
  - don’t require 100% orbit correction at each quad (factor 5-10?)
- **Clump Correctors near access shafts**
  - allow orbit oscillation to develop in arcs between service buildings
- **Frequent Re-alignment of Quads**
  - automation? Beam on alignment?

Mechanical Realignment

- **Conventional Survey/Alignment**
- **Automatic Alignment Machine**
  - **“remote-controlled wrench”**
  - **moving on track or built into magnet moving vehicle**
- **“Stepping Motors” on each adjuster**
  - **NLC approach**

Stepping Motor Alignment

- “few watts” vs. few x 100 Watts for powered correctors
- alternative motors:
  - geared-down steppers
  - thermoelastic motors
  - thermoelastic pistons
- Move Quads (hi field), entire magnet(low field) or pole tips

Survey

- **Pre-first-orbit alignment ~250u**
  - **laser tracker**
  - **built into magnet-mover vehicle**
- **Beam-based alignment**
  - **quad shunts measure quads-BPMs**
  - **components between quads interpolated optically or with stretched-wire system**

Concrete Example and Issues Raised in Its Examination: Instrumentation for a standard arc section of the VLHC

- Examination of a system package expected to be common in VLHC
- Goals for overall systems issues:
    - redundancy requirements
    - fault tolerance (related to redundancy)
    - time required to diagnose/repair
    - new technology opportunities
- Instrumentation is used in the broad sense
    - beam instrumentation
    - equipment configuration
    - equipment monitoring
    - environmental monitoring
- Particular attention should be paid to system interdependencies
    - Some systems should be similar or use similar hardware
    - Some systems should be difficult to interconnect
    - Commonality of basic components is beneficial
- Major Conclusions:
    - We can identify no especially challenging devices or needs
    - Careful attention should be paid to lifetime issues
    - Some systems should be carefully segregated from others
- This is neither an exhaustive list nor an exhaustive analysis of any system.
- Practical guidelines should be established, but not blindly applied.

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Instrumentation for a standard arc section of the VLHC

- All subsystems should be readily diagnosable remotely
  - to reduce in-tunnel repair time
  - to aid scheduling of repair/replacement at down times
- Subsystems for instrumentation include
  - Remote power-down, hard reset mechanisms
  - Beam-related instrumentation
    - BPM's
    - Magnets (locally powered or local monitoring)
      - Main Dipoles (e.g., quench protection)
      - Dipole Correctors
      - Quadrupoles
      - Sextupoles
    - Quench monitors
    - Cryogenics (unspecified; system may be independent)
    - Magnet positioning devices
    - Various unspecified interlocks
    - Beam Loss monitoring (slow and fast)
    - Vacuum status, valve status
    - Environmental measures
      - Temperature
      - Humidity
      - Radiation levels and integrated dose

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Instrumentation for a standard arc section of the VLHC

- Radiation environment in the tunnel pushes some systems into a shielded environment
  - Placement of these devices requires generation of realistic radiation maps
  - Some guideline must be established to trigger shielding of devices
- Provision of common shielded housing is a good option
  - Multiple "safe" locations might be available
  - Different systems might live in one "coffin"
  - Each such system should be independently connectorized (don't disconnect BPM's to do something else).
  - Radiation monitoring inside each "coffin"
    - remotely readable for the location
    - passive device (e.g., TLD) for each modular piece may be useful

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Instrumentation for a standard arc section of the VLHC

Overall Conclusions and Recommendations:

- Minimize single-point failure modes
  - system level MTBF through, e.g., redundancy
  - not targeting component MTBF
- Reduce time to diagnose and repair
  - Provide remote access to necessary information
  - allow efficient scheduling of routine repairs
- Control and instrumentation systems such as those for VLHC must be integrated across the various subsystems from a very early stage of design.
- Systematic development and implementation of integration criteria
  - Identify strongly coupled systems (e.g., magnets/cryogenics)
- Similar systems should be exploited through use of common components
- Critical system separation must be enforced, through incompatible design if necessary
- Certain critical systems (e.g., cryogenics) should have negligible control overlap with often-modified ones (e.g., BPM's)

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Future R & D

- **Radiation map of VLHC tunnel**
  - **will affect: equipment coffin location, special needs for shielded areas in tunnel, loss monitor selection and layout, fiber layout**
- **Measurement of ground motion at proposed site**
  - **water leveling system measurements**
- **Detailed study of orbit correction requirements and algorithms**
  - **reduce corrector strength**

Future R & D

- Tunnel Robot
- Study electronics in radiation environments
  - Tests at SPS in collaboration with the LHC project.
  - Recovery from single event upsets - reset system
- Special systems for the insertions
  - Profile measurements - Required accuracy, synchrotron light monitor, effect of synchrotron light on ionization monitor
  - Collimators
  - Others devices can probably be implemented with current state of the art technology

Future R & D

- Mechanical position sensor development
  - Commercial LVDTs are sensitive to magnetic fields. In collaboration with industry, an alternative device should be identified or developed. This is particularly important for the current low field proposal with its expected stray fields.
- Accelerator specific links
  - Apply commodity technology to data networks
  - Need other links that have deterministic latency and/or exceptional reliability
  - Timing, Beam Permit, Reset,...

Conclusions

- So far…
  - No deal stoppers