RADWG-RADMON WORKSHOP SUMMARY TALK

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Introduction

- Seen by LHC Management as extremely important – machine and experiments
- Radiation levels around dipoles expected to be a few Gy integrated dose
  - Practical and economic to put electronics equipment close to machine
- Testing of components has also shown that SEUs very important – due to hadron flux
- Essential to have radiation monitoring system adapted to needs of radiation tolerance understand from the first day

Dosimetry I

- Active Dosimeters – *Online Approach*
  - Various dosimeter types have been studied
    - Total Ionizing Dose (RadFETs, OSL)
    - 1 MeV Equivalent Fluence (p-i-n diodes, PAD)
    - Thermal neutron Detection (OSL doped with ^{10}B, npn bipolar transistors, fission converter on Si)
  - All devices characterised extensively, shown to operate reliably and to meet LHC specification (except the rad-hard properties of OSLs)
  - Customisation and calibration of devices for application to the LHC is needed
  - Can also be used in passive mode

Dosimetry II

- Beam Condition Monitor
  - Discriminate bad beam conditions over normal running conditions
    - Provide fast feedback to machine for optimisation
    - Provide high time-resolution diagnostics
    - Redundant system in experimental areas & supported by machine groups
    - Large dynamic range – 1 to 10^8 MIPS/cm^2/bx
  - Sensor material - CVD Diamond
  - Development & choice of sensor and availability of fast amplifiers has matured to meet the specifications of the BCM system.
  - Don’t forget interface to the machine control system in the to-do list !

Dosimetry III

- Studies have been carried out at CERF on various types of RP survey meters
  - IG5 ionisation chambers, REM counters, HANDI-TEPC
  - Quality assurance and certification
- Measurement of the ambient dose equivalent
- Response of detectors are understood
  - Can choose appropriate detector for various RP tasks

Dosimetry IV

- Beam Loss Monitors
  - Ionisation chambers & SEM detectors
    - Providing time resolution of one LHC turn
  - Design and development of detectors is advancing well
    - Are the associated electronics radiation-tolerant ?
    - Preliminary results from ageing tests of ionisation chambers show small degradation

Dosimetry V

- Passive Dosimetry
  - Hydrogen Pressure Dosimeter, LiF, Dye Film, TLD, RPL and PAD
  - Various measurements in mixed radiation fields
  - Preliminary results show that RPL & Alanine are well-suited for High Level Dosimetry at CERN (including LHC)
  - About 1800 TLDs needed in the LHC experimental areas
    - Further characterisation of devices needed prior to application to the LHC
    - Investment in resources required – reader system & manpower

Dosimetry VI – LHC Machine Radiation Monitoring System

- Large amount of electronic systems in the LHC tunnel (~12.000 crates) and underground areas
- All designs are based on COTS components with variable radiation tolerances
- Prediction of radiation along the ring is based on theoretical models and Monte Carlo codes
- Shielding will be installed in some areas but predicted shielding efficiency may not be achieved
- Damage from Single Events caused by fast neutrons will be first concern
- Monitoring system based on SEU S-RAM counters, RadFETs and pin diodes on a single radiation-tolerant monitoring board
- 125 monitors at start-up; could upgrade up to 4096 monitors
- Conclusions
  - Measure 3 components of the field on-line to determine damage to equipment
  - Recommend to cross-check with passive dosimeters & simulations

Simulations I

- LHC Beam Loss Rates
  - Total pp collision cross-section, beam-gas, Touscheck, IBS
  - Go into arcs, collimation system, dispersion suppressors, IRs, beam dump
  - Loss rates re-evaluated taking into account
    - Updated and more realistic machine parameters
    - In reasonable agreement with earlier 1995 figures

Simulations II

- Radiation levels in IR3
  - DS3 is not the most comfortable location to put electronics
    - Version 6.2+ and Version 6.5
    - Need additional absorbers to protect magnets against quenching
- Radiation levels in IR7
  - Understanding of newly discovered areas of interesting radiation fields – RR73, UJ76, RR77 - has been furthered
    - Studies have found high dose and dose rates in RRs
      - Safety factor of 3 is considered not to be safe.
    - Requires implementation of extra shielding to achieve additional order of magnitude.

Simulations III

- Radiation levels in UJ32 & RE38
  - Beam-gas interactions dominate
  - RE38 – shielding will reduce radiation by order of magnitude
    - Electronic equipment not radiation hard by design
      - Recommend shielding
  - UJ32
    - Existing wall is adequate shielding
      - Dose is not an issue and electronics expected to operate within specification
      - Energetic neutrons may be a problem for power distribution racks close to the beam -> monitor neutron flux

Rad-hard Electronics & Photonics I

- LHC Experiments
  - COTS vs. custom-made depends on number of chips and complexity
  - High radiation environment & practical implementation requires custom-designed electronics
    - COTS vs custom-made depends
    - Significant advancement in ASICS
      - DMILL 0.8 μm -> CMOS 0.25 μm -> DSM 0.13 μm & beyond
  - Can we follow speed of development in industry, i.e. MediaMarkt™?
    - TID – YES!!!
    - SEU – NO!!!

Rad-hard Electronics & Photonics II

- Solid-state Cameras for LHC Instrumentation
  - Synchrotron light telescope @ IR4 to measure transverse beam profiles
  - Want to use commercially available equipment – low unit volume
    - in 380 Gy/yr environment
  - After 10 Gy, level of damaged pixels is too high, making the E2V CCD camera unusable at LHC
  - Solutions
    - Shielded areas
    - New radiation-tolerant cameras now available
      - Choice of cameras for different radiation areas
      - CID & APD technology

Rad-hard Electronics & Photonics III

- LHC Machine Optical Fibres
  - Quench Protection System, Power Converters, Cryogenics System, BLM/BPM
  - Fibres in tunnel will suffer radiation-induced attenuation
    - Depending on total accumulated dose & dose rate
    - a-SiO_2 doped with impurities (Ge, P, F)
    - Preference to use Ge-doped rather than Ge-P doped fibres
    - Following tests, fibres at IR7 needed to be removed

Experience from other Labs

- Tevatron (CDF & D0)
  - Multiple techniques to monitor radiation
    - TLDs – good for accurate low-to-medium dose evaluation
    - PIN diodes – extend to higher dose values
    - Beam loss/halo measurements – halo counters & beam shower counters
    - Diamond detector
    - Bonner spheres
    - Complementary and redundant system !
- VME power supply failures

Experience from other Laboratories

- RHIC
  - Equipment failures
    - VME chassis power supplies
    - Beam Position Monitors
  - Radiation monitoring with TLDs
  - Solutions
    - Move equipment out of alcoves – expensive
    - Switch to rad-tolerant power supplies for VME chassis

Conclusions & Outlook

- Require understanding of the sensitivity of technical equipment to local radiation (in machine & areas)
  - e.g. through Monte Carlo simulations
- Necessary to monitor radiation fields during early commissioning of the LHC in order to prepare for high intensity running and prepare appropriate shielding or other measures.
  - Develop appropriate radiation dosimeters applicable to machine, areas and experiments
- Need to consider the spurious & special machine operating conditions
  - e.g. scrubbing runs, accidental beam losses
- Collaboration & synergy between LHC machine, experiments, other labs and space agencies is encouraged.

Good (converging) progress has been shown but a great deal of interesting works remains to be done to realise the above goals

Acknowledgements

- Many thanks to speakers, chairpersons and organising committee for a successful & fruitful workshop
- The large turn-out and lively question/discussion sessions confirm strong interest in the field
- Hope to see you all again one year from now at the 5th RADWG-RADMON Workshop
  - In the meantime, let's press ahead and complete the studies and systems in time for LHC operation in 2007
- (All presentations available on workshop site http://agenda.cern.ch/fullAgenda.php?ida=a044378)