On line radiation monitoring in the LHC machine with COTS ICs and RADFETs

T. Wijnands TS/LEA, C. Pignard AB/CO

Radiation Monitoring – objective & requirements

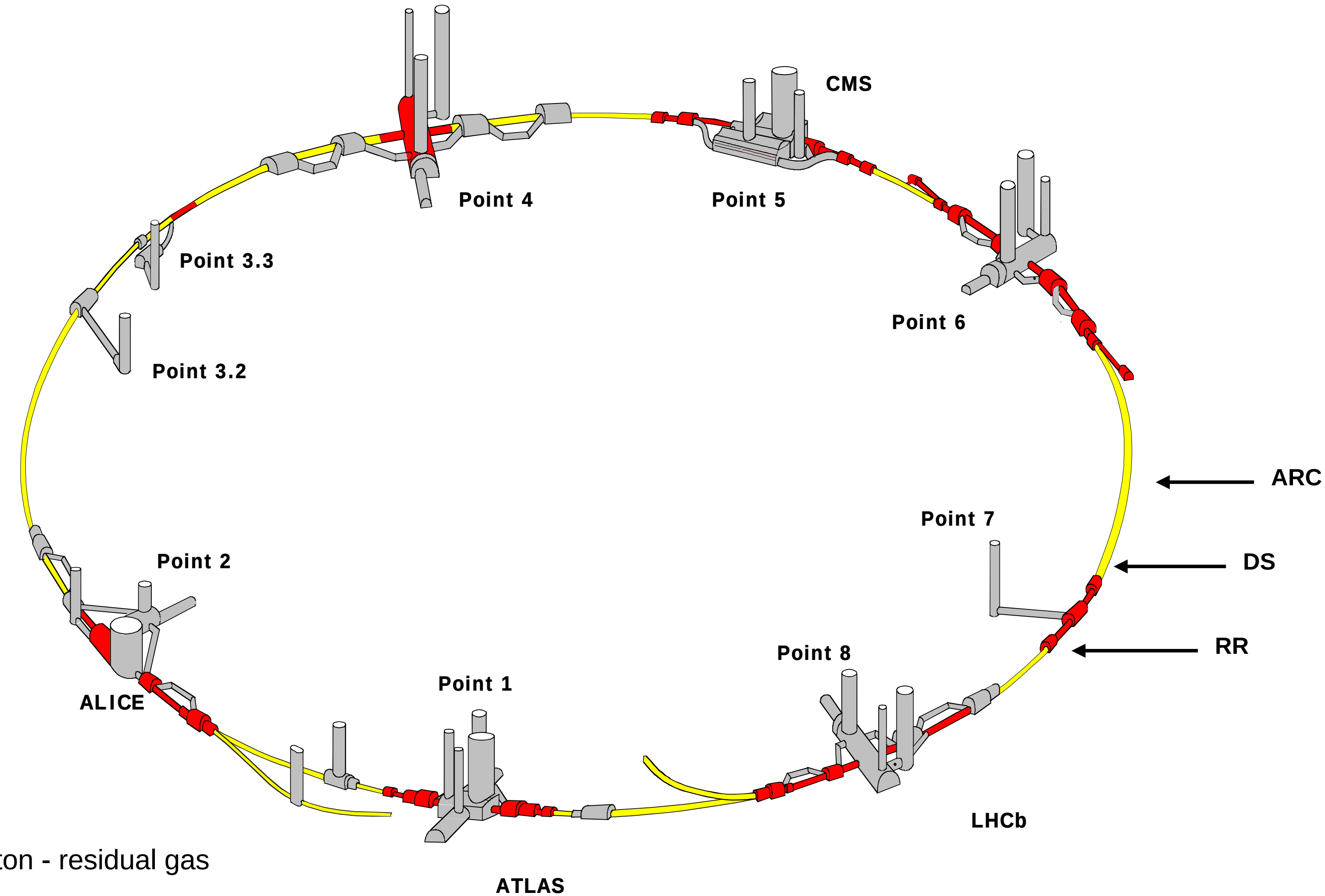
Objective

There is a considerable uncertainty on the radiation environment in the tunnel and on the radiation tolerance of equipment. The radiation monitoring system will help to reduce this uncertainty by providing an early warning as the radiation levels at the location of the equipment increase.

Functional requirements :

- ➔ Measure radiation damage in Silicon
- ➔ Monitor damage caused by : Single Events, Dose and MeV neutrons
  - ⇒ measure the 3 components of the field simultaneously and independently
    - Direct ionisation
    - Cumulative ionisation
    - Cumulative neutron damage
- ➔ ~1 Hz time resolution on the measurements
- ➔ Remote-online measurements (to keep maintenance to a minimum)
- ➔ Make data available to all equipment groups & operators via standard operational software

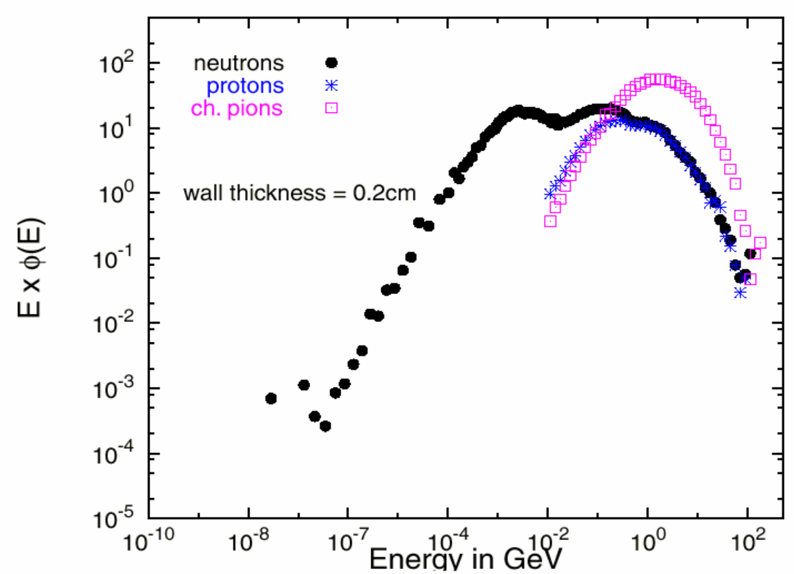
Radiation levels - global distribution

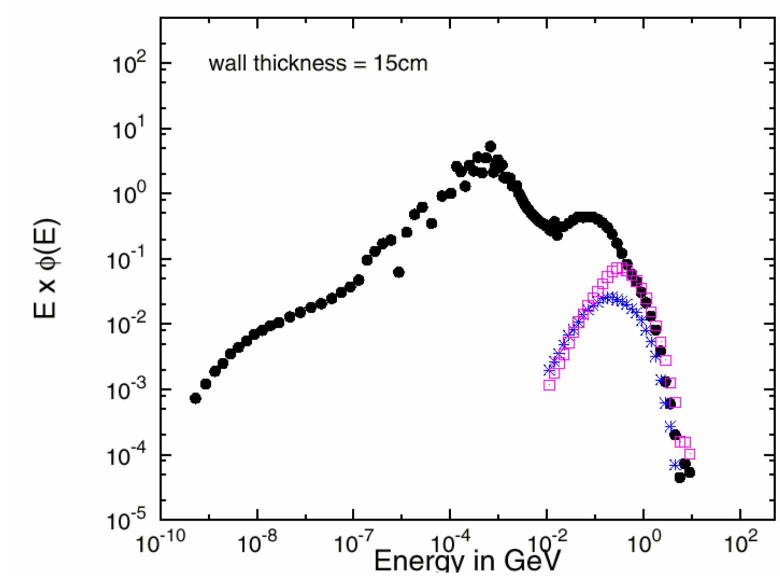


Proton - residual gas

Proton - point losses

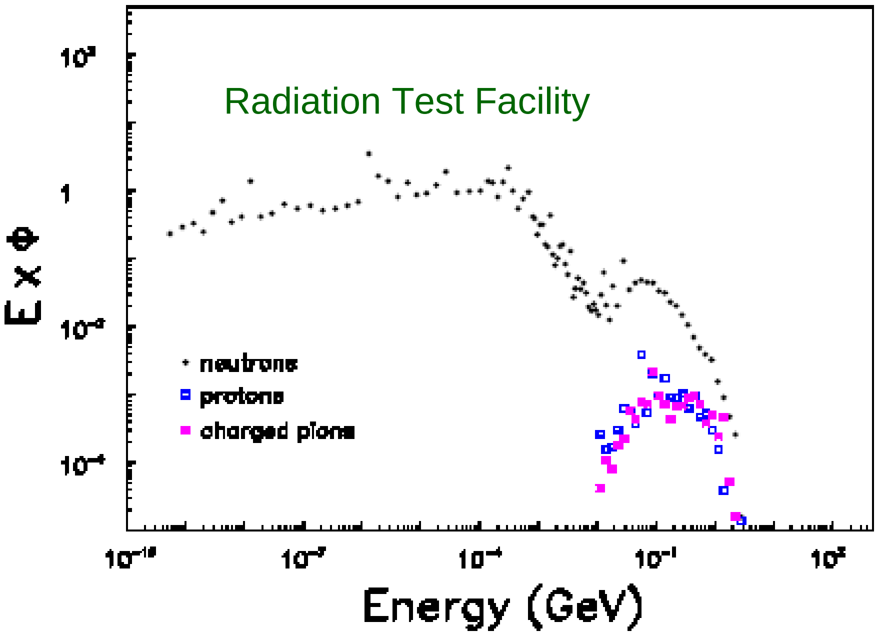
Particle Spectra in LHC tunnel

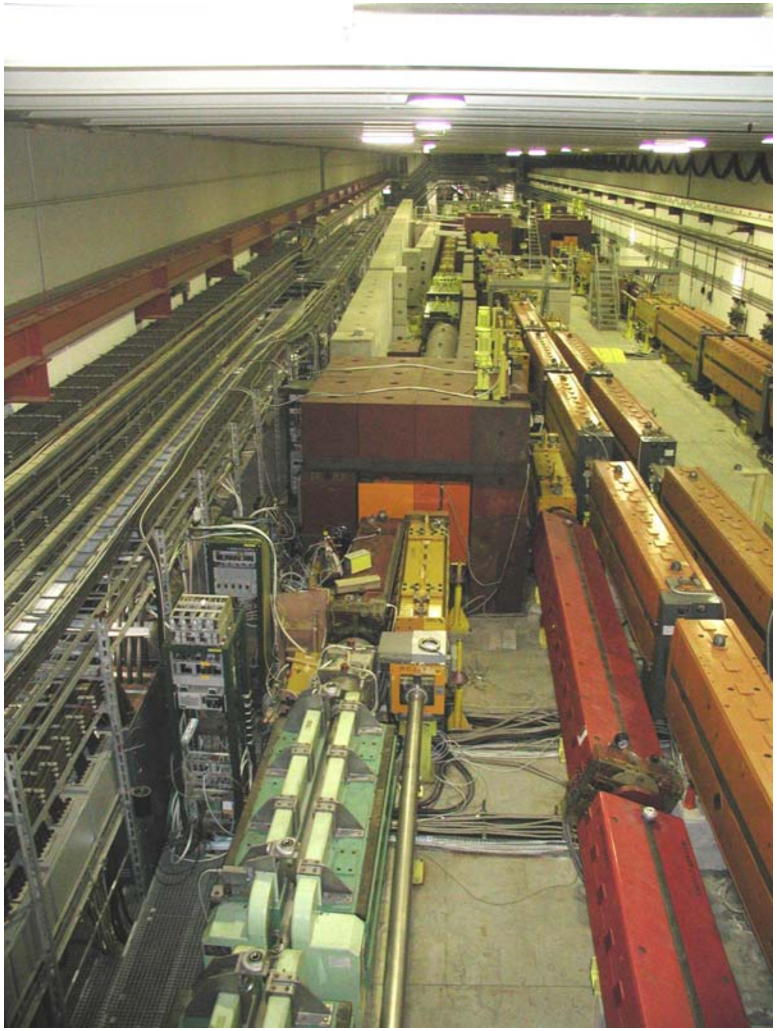




Shielding LHC tunnel (ARC) depends on

- ➔ **Thickness and type of material surrounding the beam pipe**
- ➔ **Increase in thermal neutrons with increasing shielding**
- ➔ **Increase in thermal neutron tail of spectra in presence of concrete walls/floor due to reflections**
- ➔ **Particle spectra are independent on Incident particle (proton) energy if E_p > few GeV**



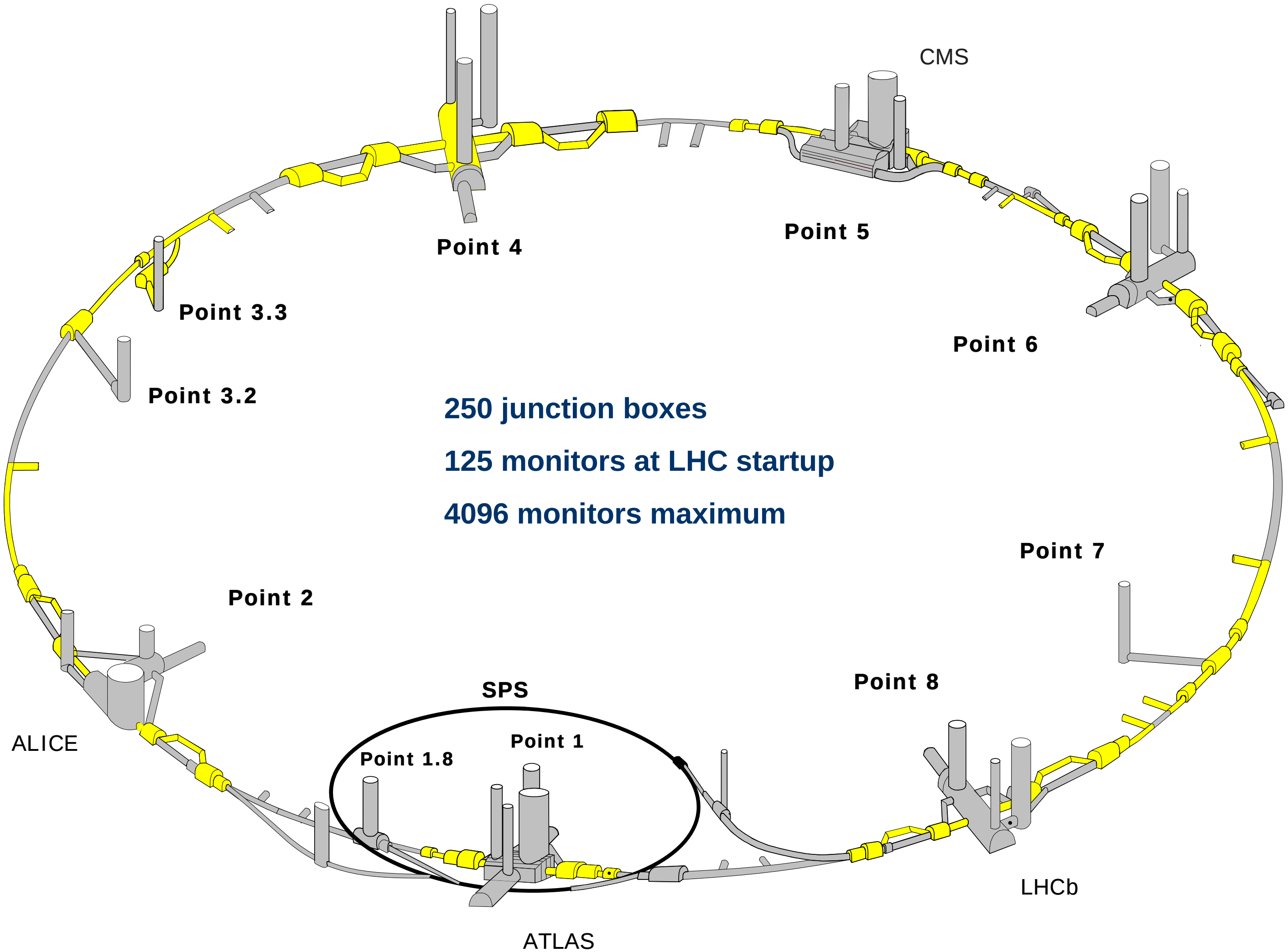


Radiation Test Facility

- ➔ Dose rate 1 to 20 Gy [Si] per day
- ➔ 1 MeV neutrons 8 x 10^{10} per Gy
- ➔ 20 MeV hadrons 4 x 10^{9} per Gy

Typical particle spectra of high energy proton beam hitting a target

Layout & number of radiation monitors

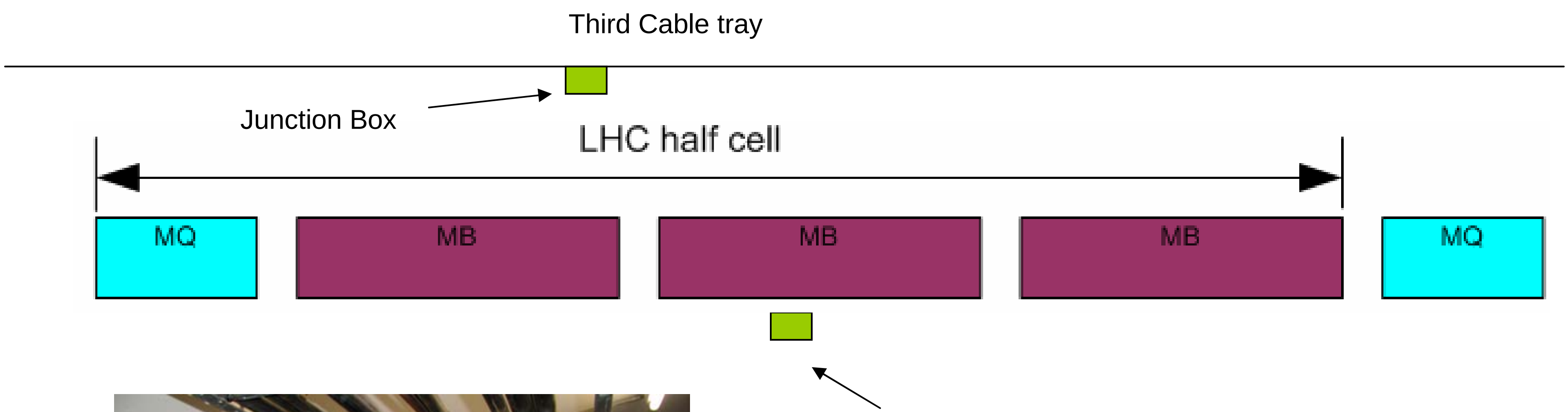


250 junction boxes

125 monitors at LHC startup

4096 monitors maximum

Location of Junction box and monitors - ARC



Radiation Monitor

Can be placed at max 25 meters from junction box

Any location within half cell (max 32 per half cell)

Junction box with signal cabling in ARC

CBWS Version 3.0

Aluminum casing with cover and sides partially removed

Size : 11 x 9 x 5 cm

(i.e medium sized cigar box)

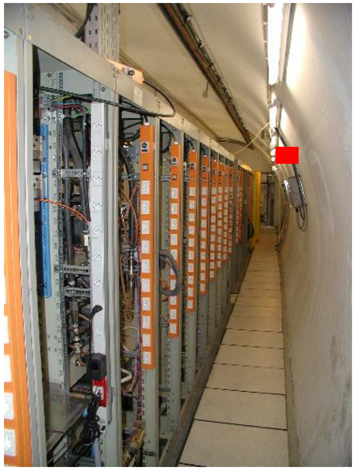
Location of Junction box and monitors – RR,RE

Large RR (RR13,17,53,57)

Small RR (RR73,77)

Alcoves (RE 38,22)

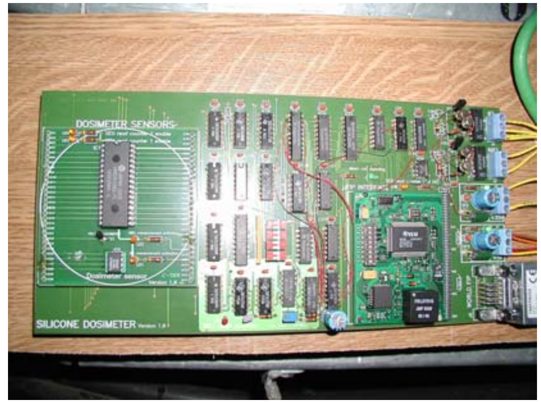
↔



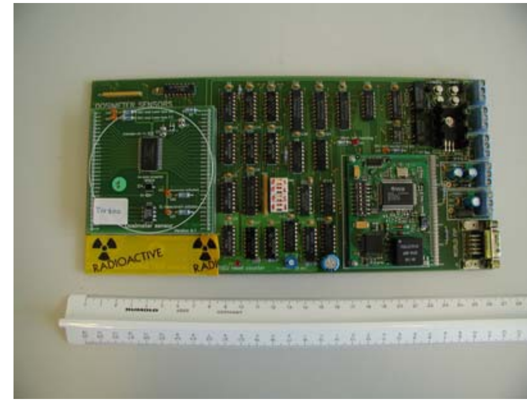
■ Junction box

Radiation Monitoring – readout boards

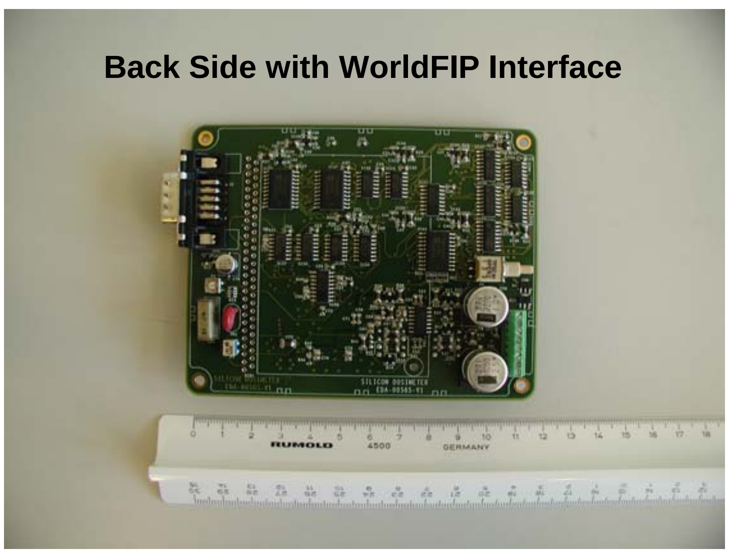
Si Dosimeter V1 – July 2002



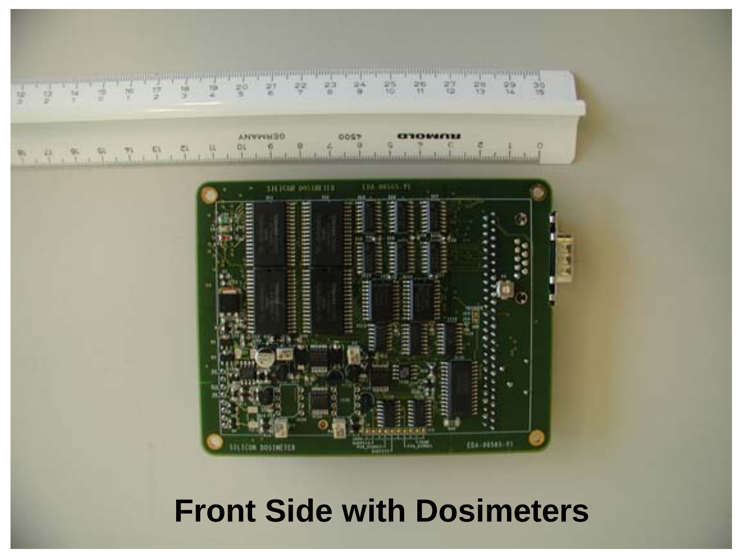
Si Dosimeter V2.1 – August 2003



Si Dosimeter V2.2 – September 2003



Si Dosimeter V3.0 – April 2004

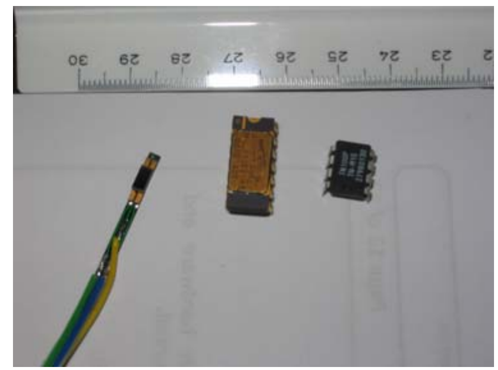


Si Dosimeter V3.0 – April 2004

Radiation Sensors

- ➔ **SEU counter : Toshiba TC554001AF**
  - **Measure radiation induced voltage spikes over a reversed biased p-n junction**
  - **Number of “0-1 or 1-0” in SRAM direct proportional to the hadron fluence (E> 20 MeV)**

TOSHIBA TC554001AF-70L



- ➔ **Dose sensor : RADFET**
  - **Measure trapped charge in gate oxide**
  - **I-V change proportional to TID**

- ➔ **Neutron sensor : SIEMENS BPW34**
  - **Measure conductivity variation at high forward injection**
  - **I-V change proportional to 1 MeV eq. neutrons**

SIEMENS BPW34

- ➔ **Beam off** – remnant dose rates 1-2 mSv/hr
- ➔ Measure with 4 different dosimeters (acknowledgement : SC/RP)

Eberline FHT191 N Ionisation chamber

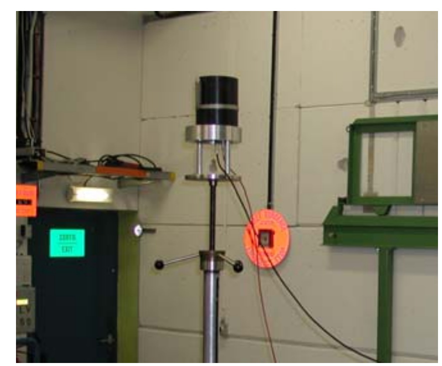
- **Energy range 35 keV ... 7 MeV**
- **Dose rate measurement from 10 nSv/h up to 10 Sv/h**
- **Suited for pulsed radiation fields**

T&N Radfet 502

- **Energy range ?**
- **Dose rate measurement from 100 nSv/h**
- **Suited for pulsed radiation fields**

Automess Dose Rate Meter 6150AD6

- **Energy range: 60 keV - 1.3 MeV**
- **Dose rate measurement from 0.01 μSv/h - 9.99 mSv/h**
- **Only for RP purposes**



PMI – Ionisation chamber

- **Energy range ?**
- **Dose rate measurement from 1 μSv/h**
- **Not designed for pulsed radiation fields**

LHC radiation test facility – remnant dose rate TCC2

➔ PMITC010	0.46 mSv/hr
➔ Eberline FHT191N	0.59 mSv/hr
➔ Automess 6150AD6	0.56 mSv/hr
➔ Radfet	0.53 mSv/hr

Radiation board

- Mandatory when you use the RADFET and PIN diodes in the LHC machine
- Design heavily based on experience/advice from RADWG members and RADECS community (Precision Voltmeter QPS - R. Denz, ELMB – B. Hallgren, RADFIP – M. A. Rodriguez, Low Beta Jacks – A. Marin, Radiation Effects Unit ESTEC - ESA)
- Key design issues: radiation tolerance, current source, temperature compensation
- Prototype readout board V2 was meant as a "proof of principle"
  - Readout design validated during 2003 SPS proton run
  - Used for calibration test dosimeter I.e.

    60 MeV protons, 60 Cobalt, 0.8 MeV neutrons for resp. SEE, TID and NIEL
- Readout board V3 is meant for final test and pre-series production
  - Readout design validated again during 2004 SPS proton run
  - Will be used for final calibration test of dosimeters