The OPAL Silicon Microvertex Radiation Monitoring and Beam Dump System

Sylvie Braibant
Indiana University
For the OPAL SI Group

Sixth Topical Seminar on
Experimental Apparatus for
Particle Physics and Astrophysics
23rd May 1996

- The OPAL Microvertex Detector
- Radiation Monitoring
- Beam Dump System
- Conclusions

Acknowledgements: R. Hammerström (CERN) (Electronics)
S. De Jong (Indiana University)
A. Honma (TRIUMF)
O. Biebel (Aachen)
J. Lauber (UCL)
H. Neal (CERN)

The OPAL Microvertex Detector

• 1991-1992 Phase I

- Si Microvertex Detector with r-ϕ readout
- 18 cm long - $|\cos\theta| < 0.83$
- $\sigma(d_0) \approx 18\ \mu m$ and $\sigma(z_0) \approx O_{cz}(1\ mm)$

• 1993-1994 Phase II

- Si Microvertex Detector with r-ϕ and r-z readout
- $\sigma(d_0) \approx 17\ \mu m$ and $\sigma(z_0) \approx 21\ \mu m$

• 1995 Phase II+

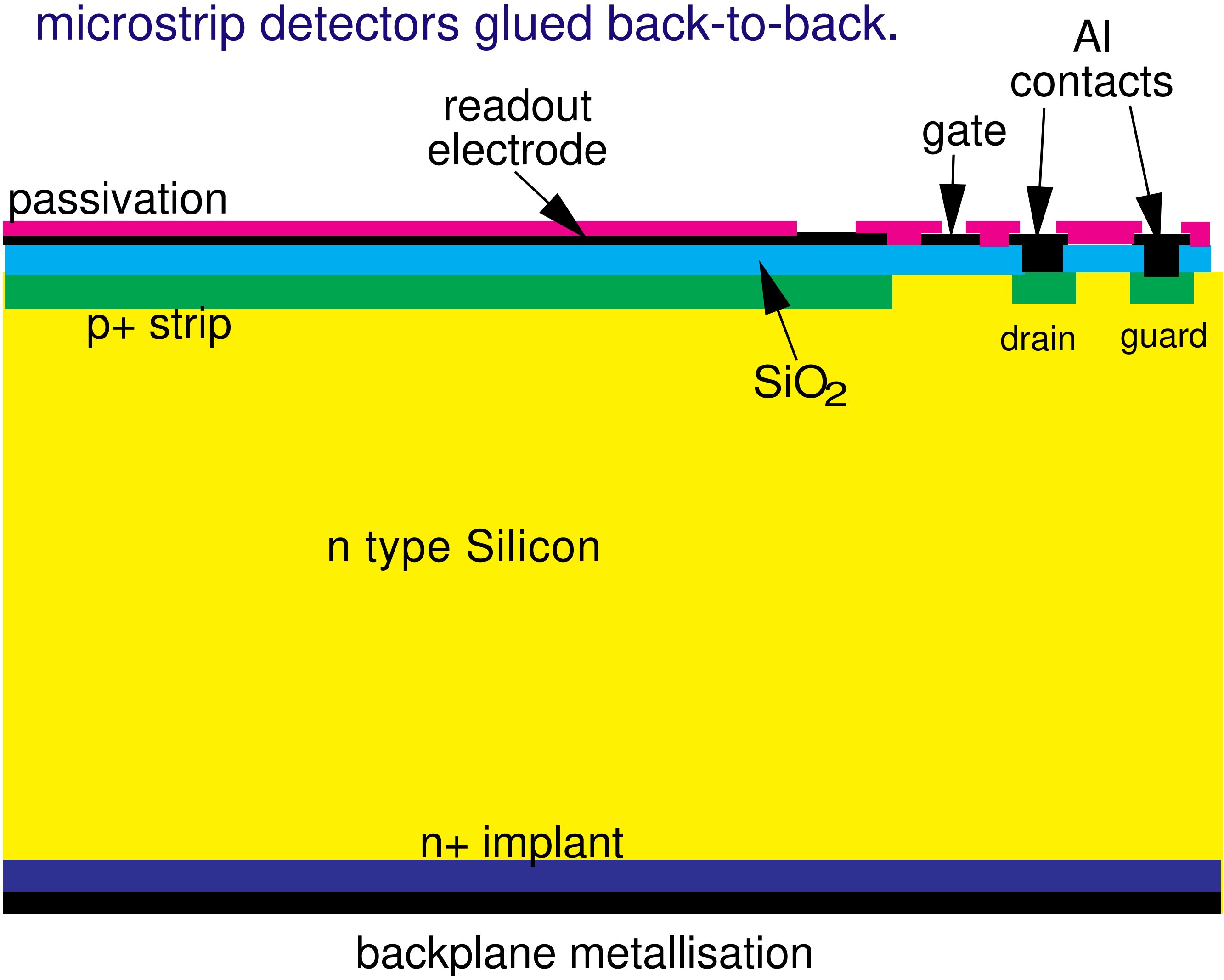
- Partially extended Si Microvertex Detector
- 30 cm long - $|\cos\theta| < 0.93$

• 1996 ... Phase III

- Fully extended Si Microvertex Detector with r-ϕ and r-z readout
- $\sigma(d_0) \approx 17\ \mu m$ and $\sigma(z_0) \approx 21\ \mu m$

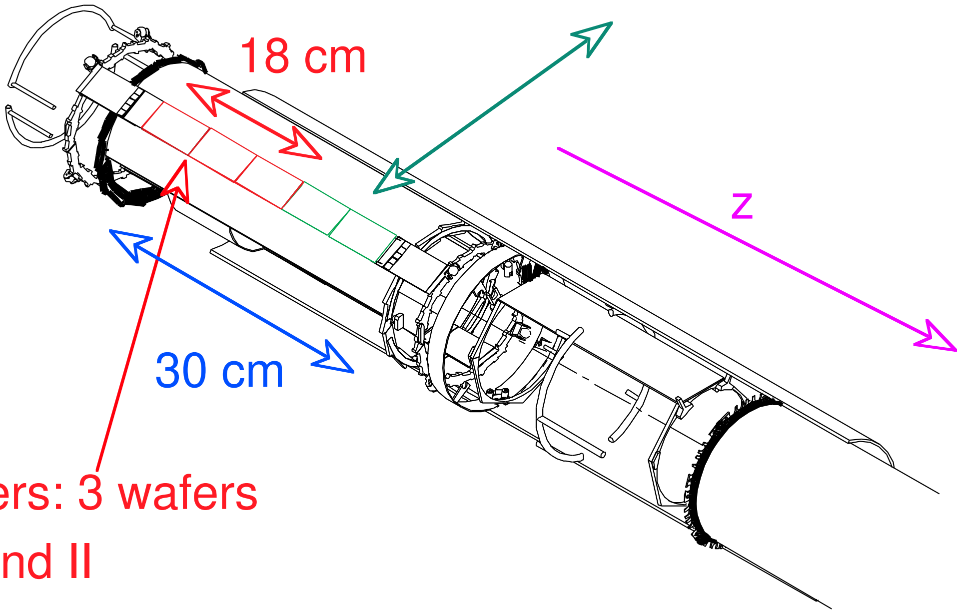
The OPAL Microvertex Detector

- Single-sided FOXFET Wafers (60x33) mm^2 - 250 μm.
- Manufactured by Micron Semiconductor Ltd.
- Two coordinates readout (ϕ-z) using single-sided microstrip detectors glued back-to-back.

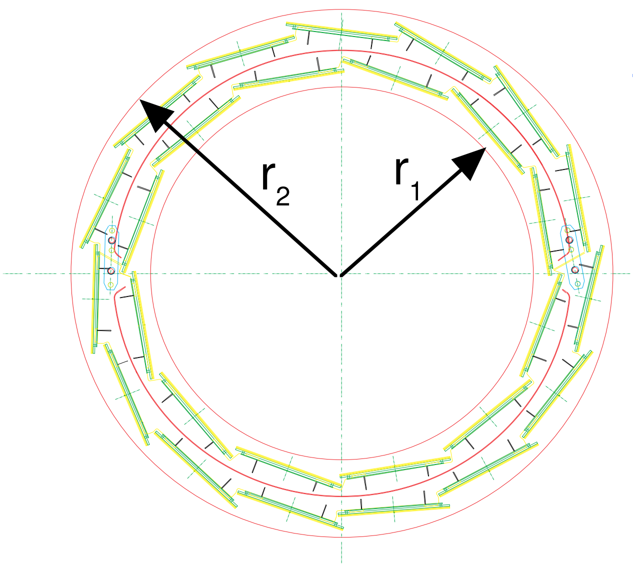


- p-n junction are reversed biased to provide a wide region depleted of charged carriers.
- Incoming particles will create electron-hole pairs.

The OPAL Microvertex Detector



• Two concentric layers: Inner barrel with 12 ladders
Outer barrel with 15 ladders



1 detector ladder =
1 long + 1 short ladder

Min. radius r_1: 54 mm

Max. radius r_2: 80 mm

• Phase II+: only 20 short ladders were available and therefore only the outer barrel was installed.

Radiation Monitoring

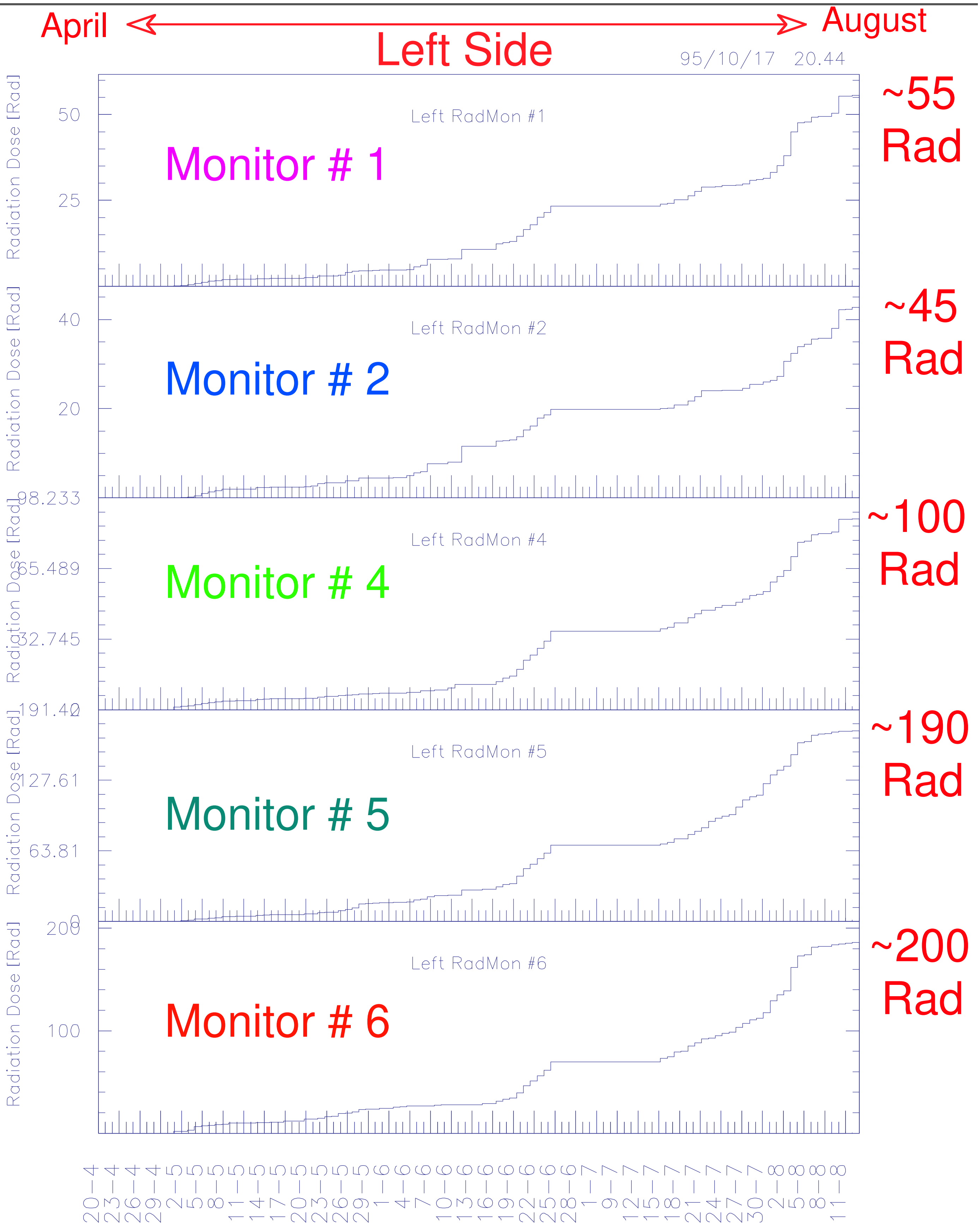
- **Aim:**
  - Measure radiation dose close to the beam pipe from the LEP machine (monitoring of integrated dose per day).
  - Protect the Si detector against high radiation by provoking a "clean" beam dump in case of high radiation.

- **Radiation Damages:**
  - Bulk damage due to displacement of atoms from their lattice sites causing increasing leakage current, changes in doping concentration ...
  - Surface damage due to charge build-up causing increasing surface leakage current, affecting inter-strip isolation ...
  - Electronics damage is the weakest point in our case .... i.e. the MX7 microplex chip used on the long ladders.

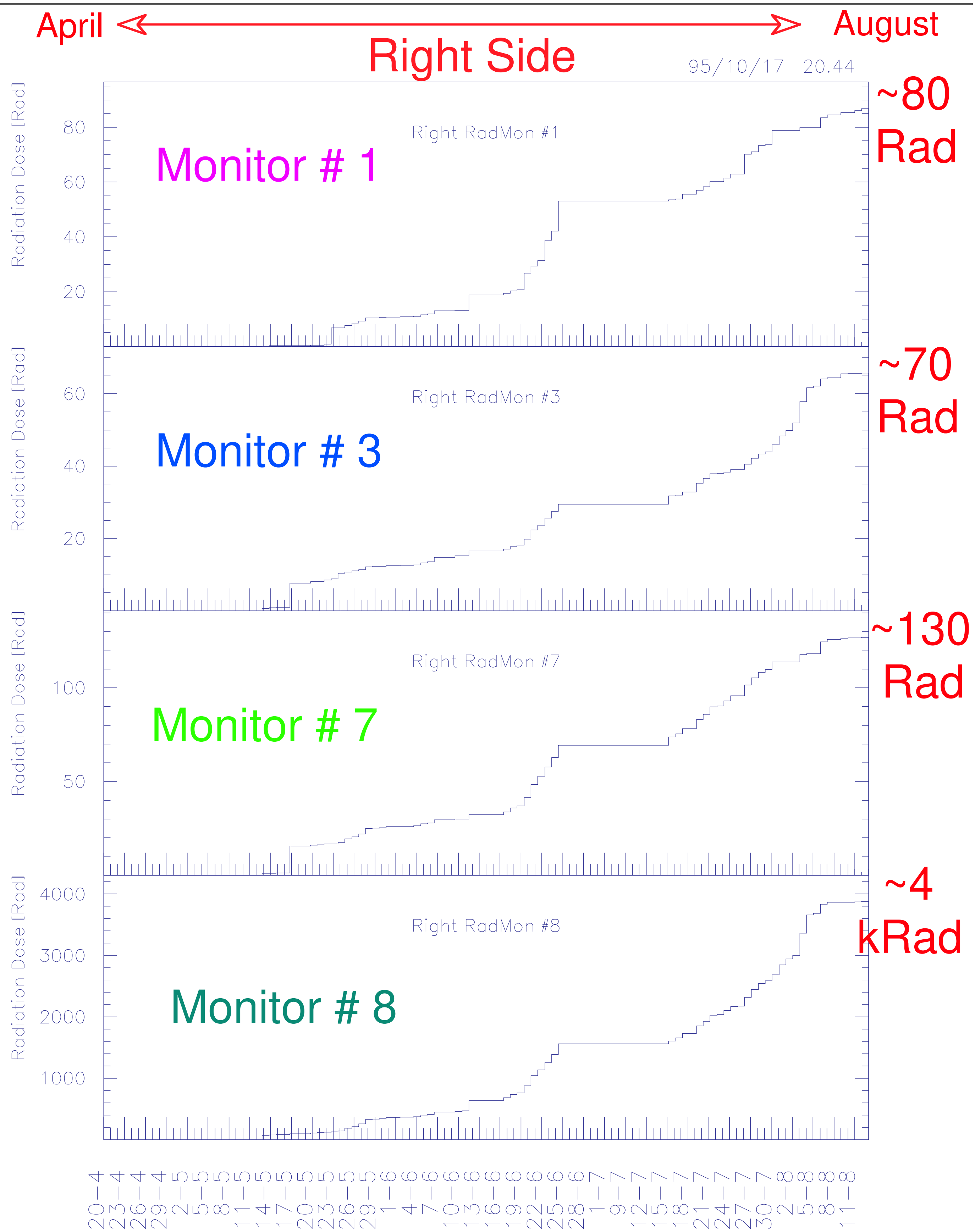
Radiation Monitoring

- **"Acceptable" doses:**
  - FOXFET detectors are ok up to more than 500 kRad.
  - Radiation-soft version of the MX7 microplex chip : loss of S/N at 3 kRad and major deterioration at 6kRad.
  - $\rightarrow$ 3 kRad = total acceptable dose in its lifetime in OPAL.
  - In use since 1993 until the year 2000 $\rightarrow$ desired lifetime of 8 years.
  - If radiation dose equally distributed over the years $\rightarrow$ ~300 Rad per year integrated dose.
  - Experience over the last 3 years: we get about 100 to 200 Rads per year.
  - BUT radiation levels for LEPII operation will be higher than current (LEP I) doses. Reasonable estimate for LEPII : two to three times more radiation.

SI Radiation Dose (Rad) in 1995



SI Radiation Dose (Rad) in 1995



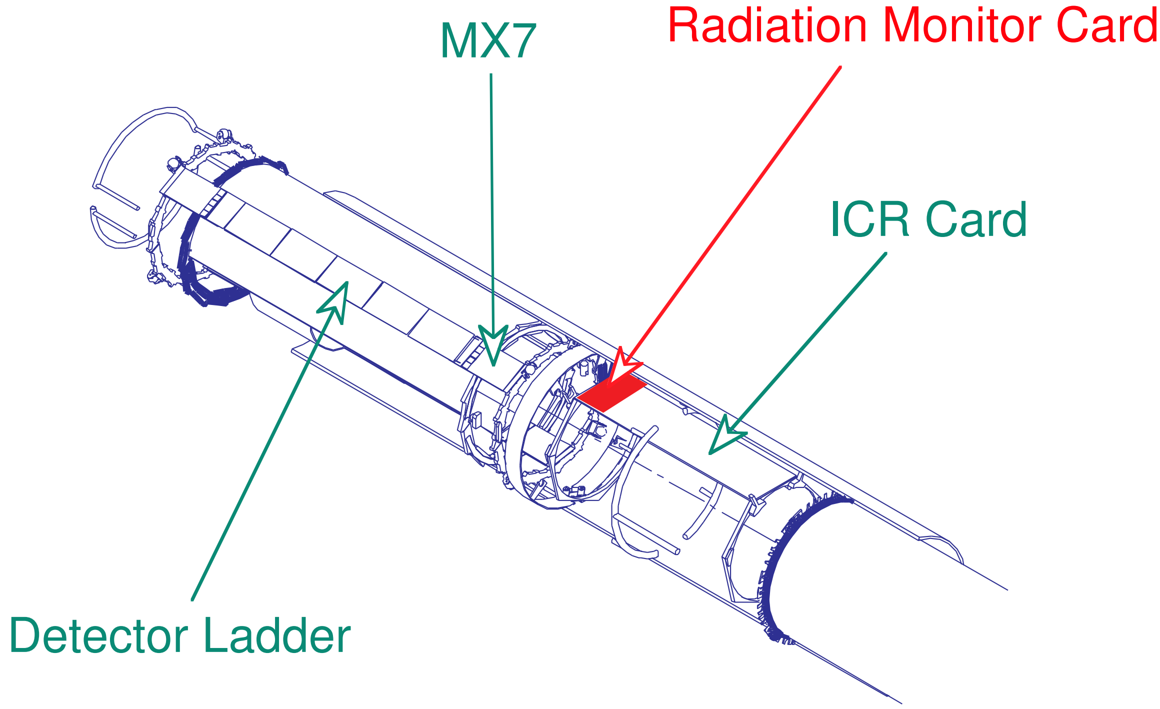
Radiation Monitoring

- **"Pencil" beam incidents:**
  - In June 1992, a high intensity beam broke ~200 channels (1 cm^2) . Estimated dose required to cause this damage corresponds to more than 5 kRad / 1 cm^2 (whole LEP beam).

- **Continuously high dose:**
  - During injection.
  - Unstable beams.

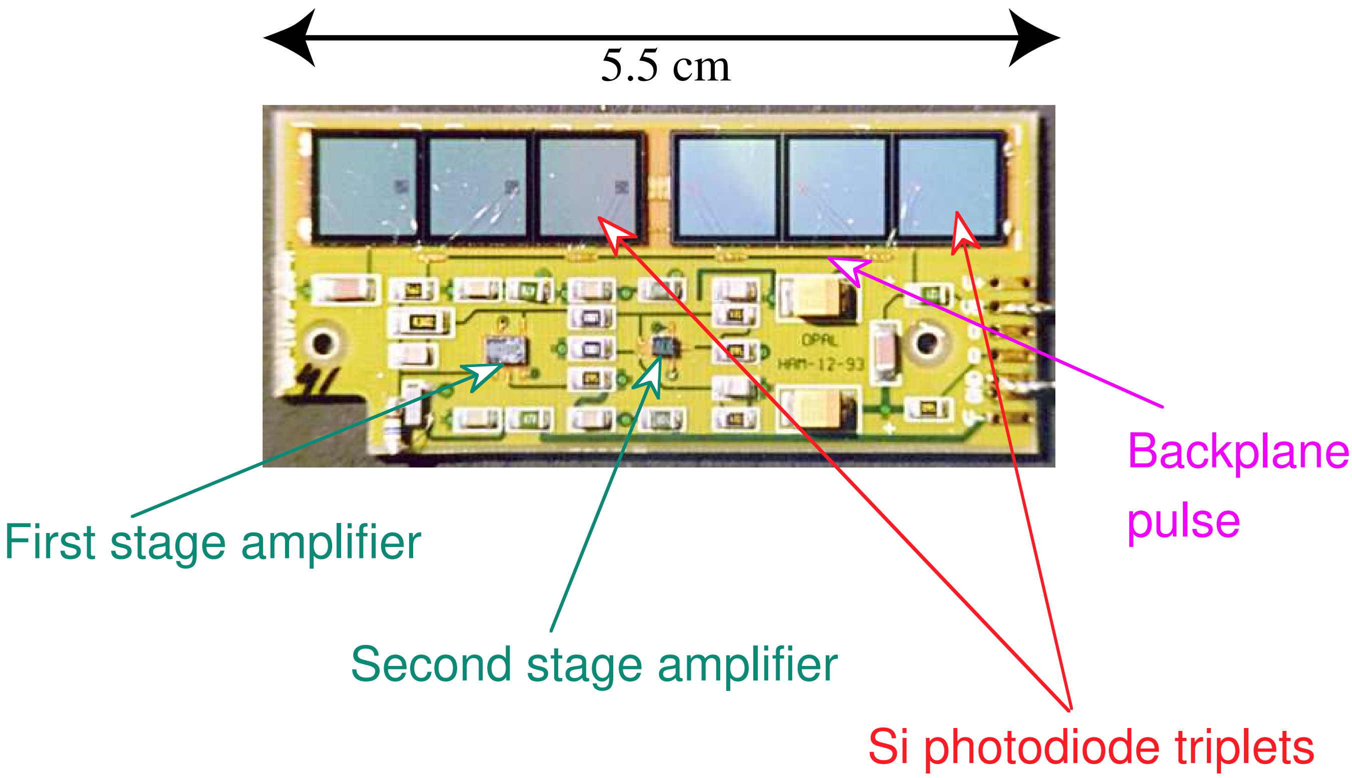
- **Actions:**
  - Display radiation level in OPAL control room.
  - Monitoring of integrated dose per day.
  - Injection Inhibit.
  - Alert LEP operation / EIC (Engineer in charge).
  - Beam dump system.

SI Radiation Monitors



- System consists of 7 detector modules mounted on either side of the Si microvertex detector.
- Each module is equipped with 6 silicon photodiodes of 8x8 mm^2 size and 250 μm thickness made of the same material as the microvertex detector (in total 42 photodiodes on each side).
- Modules are mounted below the interconnect ICR cards facing the beam pipe , i.e. a mere 2 mm from the beam pipe.
- Two extra modules have been glued to the front faces of the OPAL SiW luminometer ~ about 2.5 m from the interaction point.

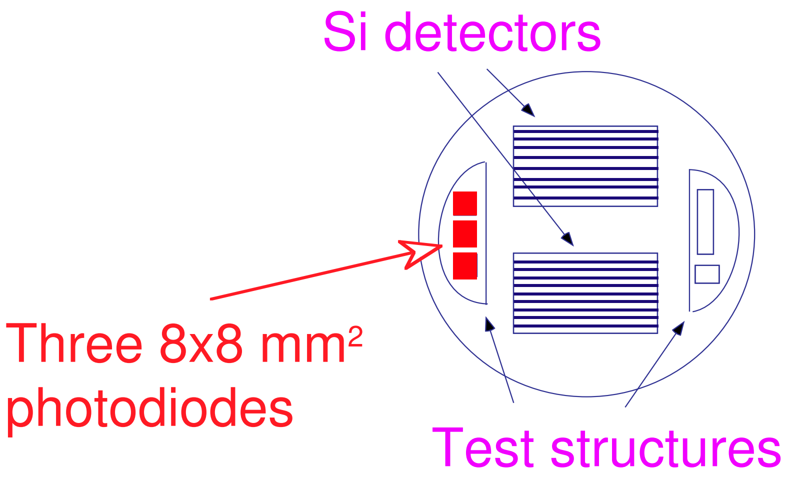
SI Radiation Monitors



- Each diode is a p-n junction operated at a given reverse bias voltage. This forms a sensistive region depleted of mobile carriers and sets up an electric field that sweeps charge produced by radiation to the electrodes.
- Consequences of radiation result in a current in the diodes. This current is converted to a voltage and amplified.
- The diodes are readout in parallel.

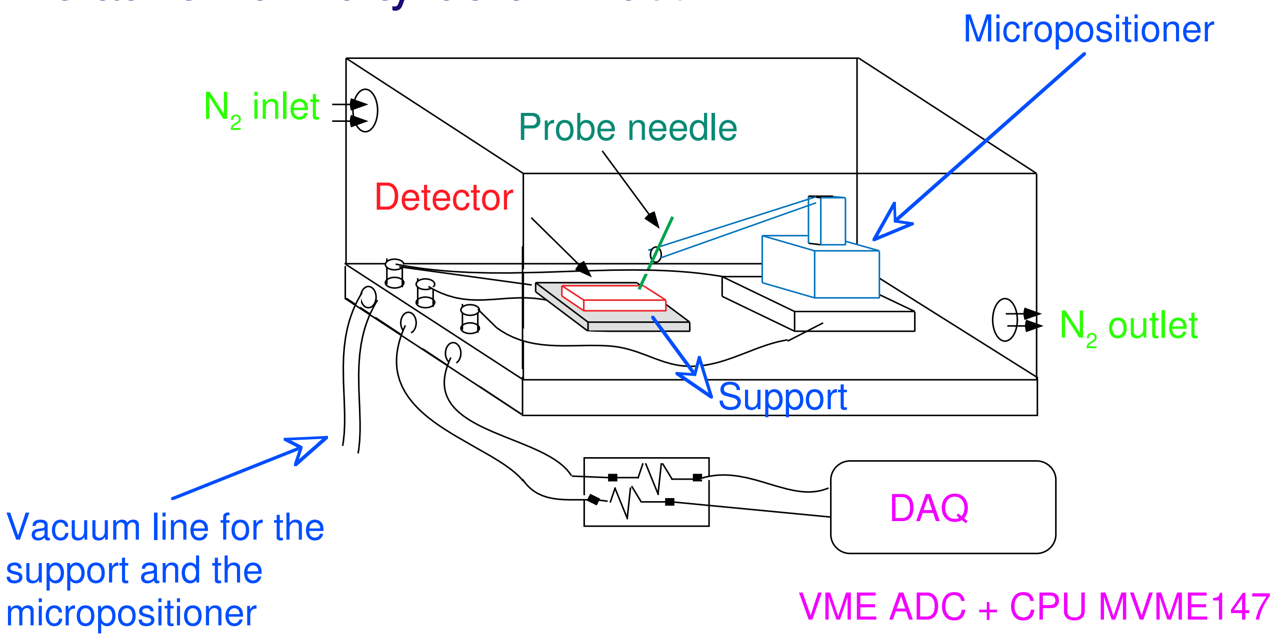
Photodiode Triplets Selection

- Typical wafer with SI detectors and test structures



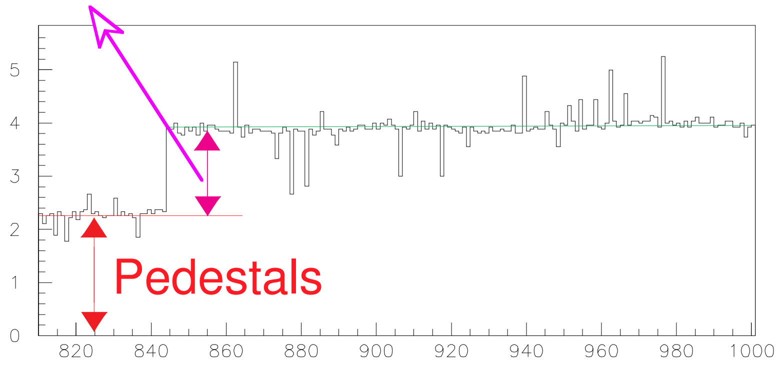
- Selection of diode triplets based on:
  - Visual inspection using a microscope
  - The three diodes must have similar depletion voltage
  - Low and stable leakage current

- Diodes leakage current measured in a shielded custom made probe station. Nitrogen was used to keep the relative humidity below 20%.



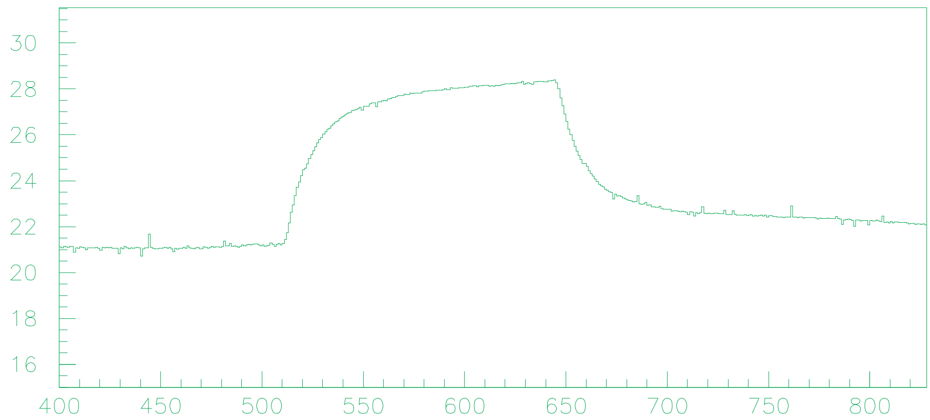
Photodiode Triplets Selection

Leakage Current (nA) Typically: 1-2 nA



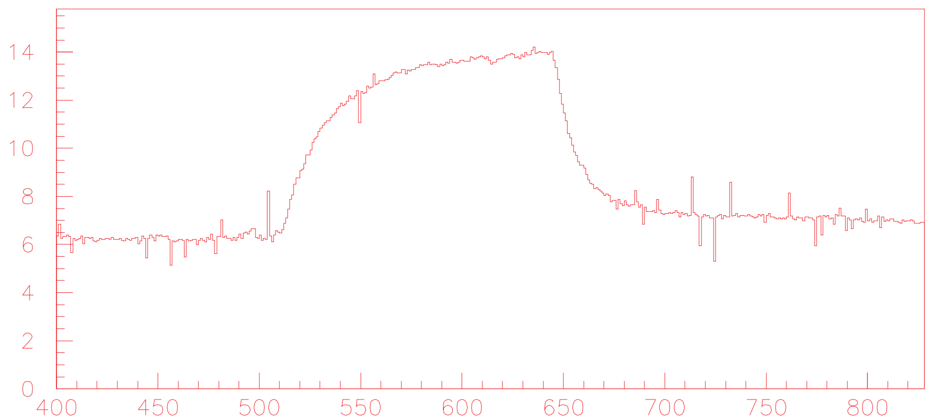
Time (min)

Temperature (Degrees C)



Time (min)

Leakage Current (nA)



Time (min)

Radiation Monitors Front-end cards

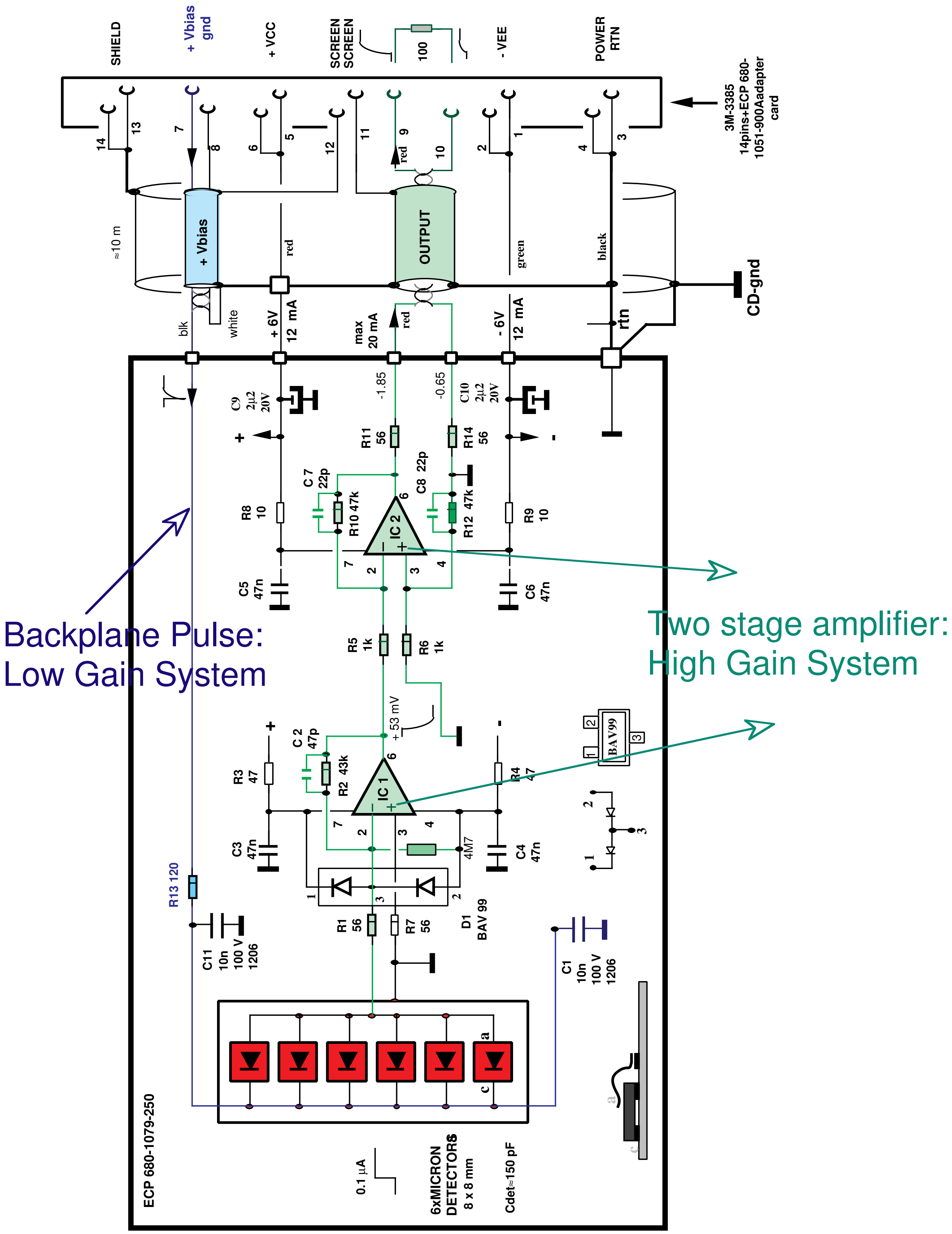
- System must:
  - Be FAST (can distinguish EVERY beam crossing) and produce a beam dump in less than 1 msec.

  - Cover range from 1 single MIP to 10^8 particles/beam crossing
- Two systems:

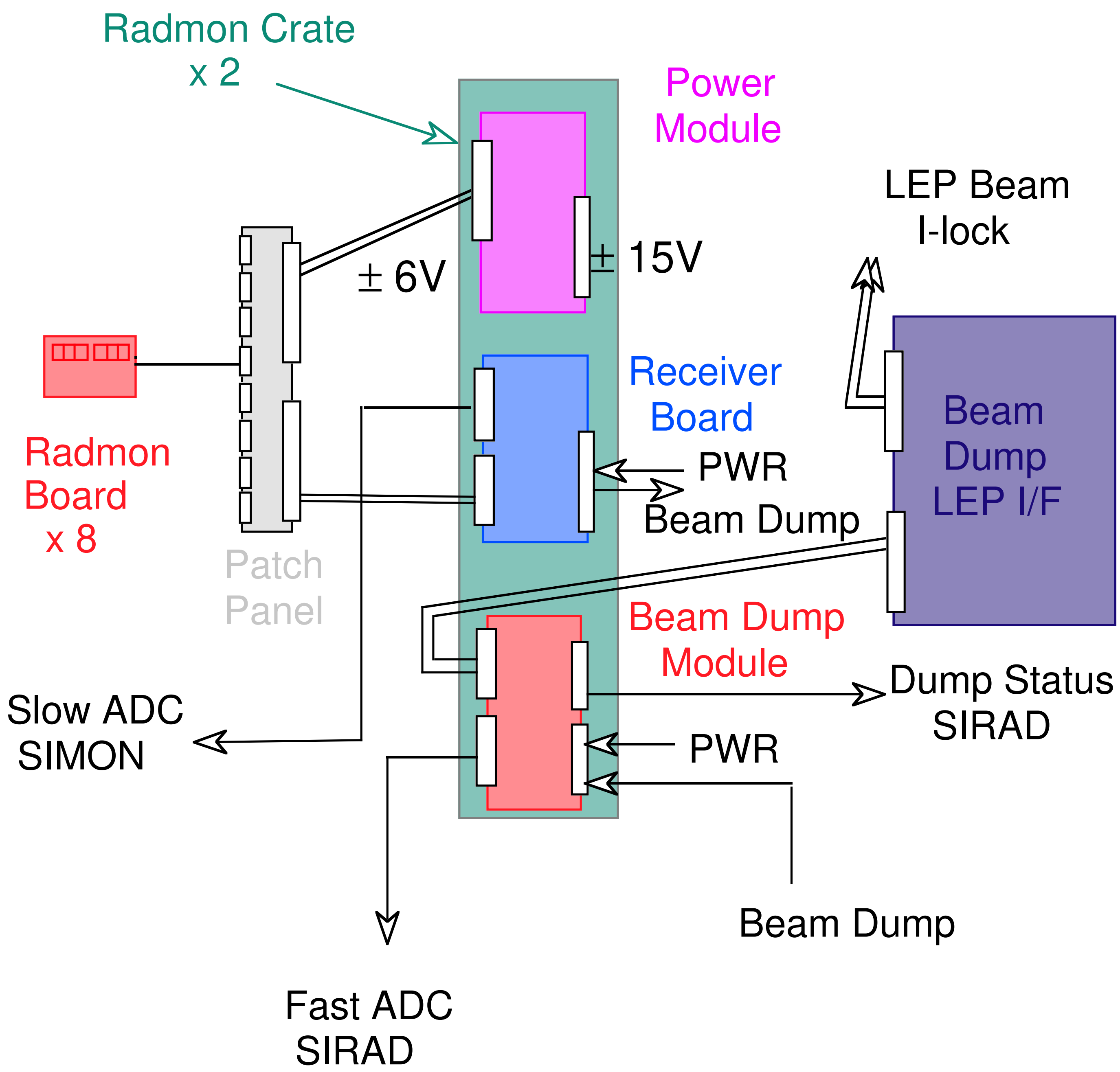
High Gain system	Low Gain system
Dose measurement: Front-end amplified signals	Beam Dump signal: Unamplified backplane pulses
25 mRad/h - 250 Rad/h	50 Rad/h - 250 kRad/h

- AC coupled signals to avoid baseline shifts due to leakage current variation.

Radiation Monitor Amplifier Card



Radmons and Beam Dump System



Beam Dump System

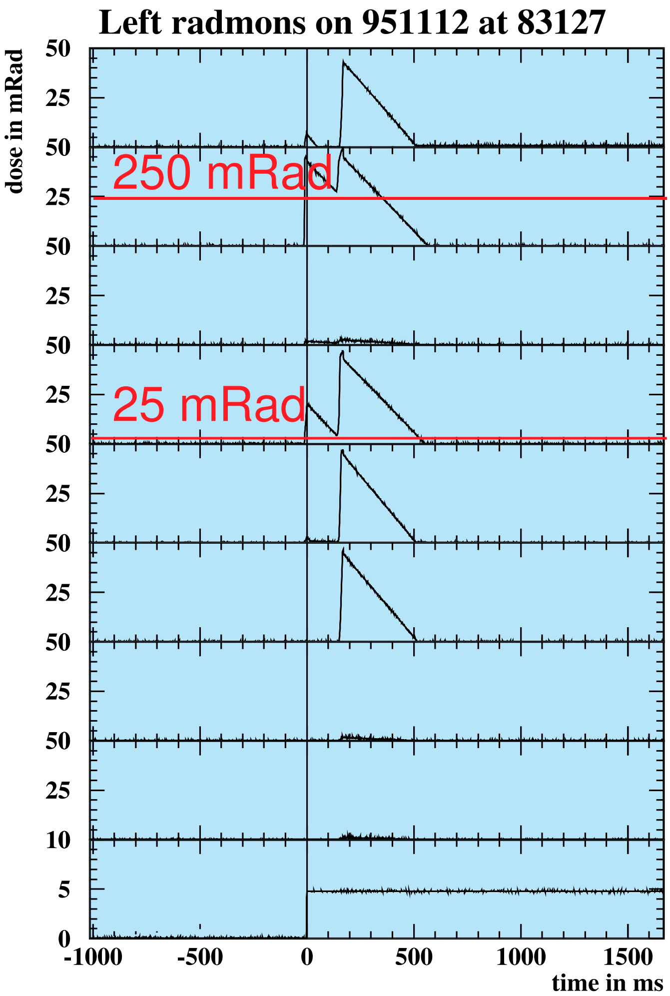
- Principle:
  Each of the 4 LEP experiments can trigger a beam dump by breaking a LEP current loop. A "beam kicker", that steers the beams out of the machine in a "clean way", is activated.

- For last year test: Beam dump signal sent out if coincidence of two channels above the following thresholds:

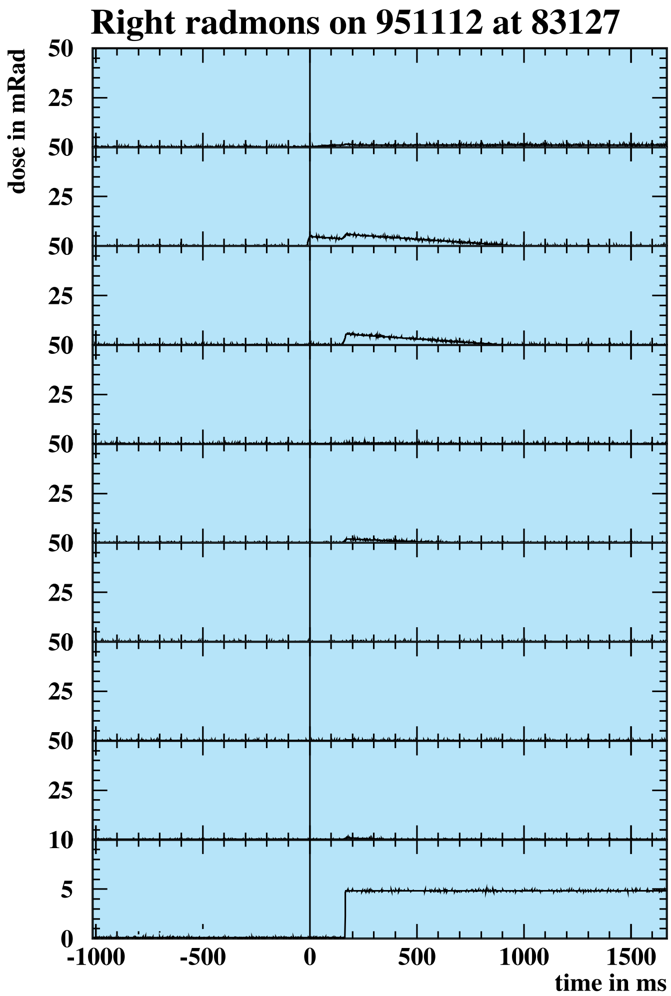
  DUMP: > ~250 mRad (5 V)
  ALARM: > ~25 mRad (0.5 V)
  (last year test thresholds)

Beam Dump System

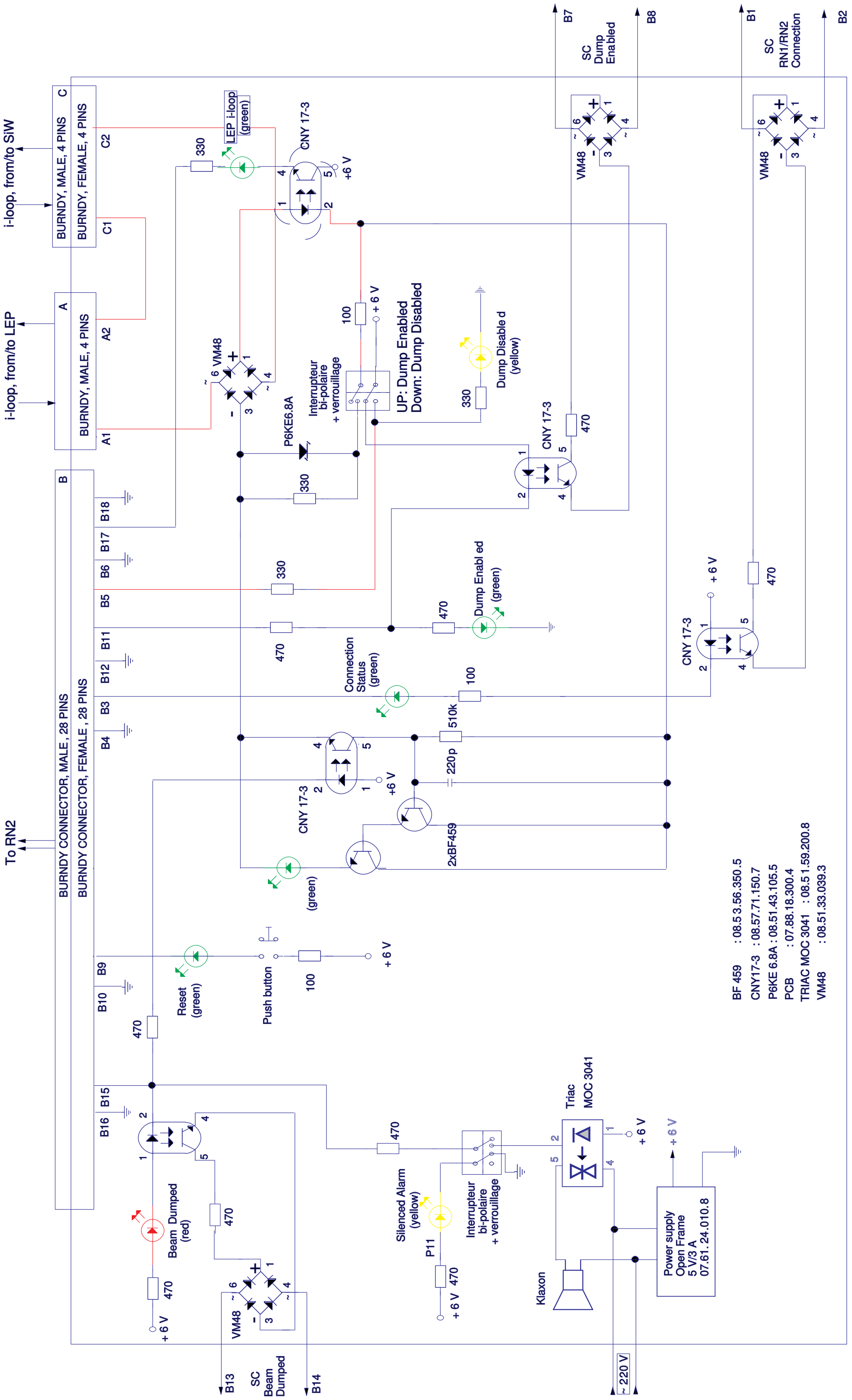
x 10



x 10



Beam Dump LEP Interface



Beam Dump System Test

- Test of a full prototype at the end of last year was successful.

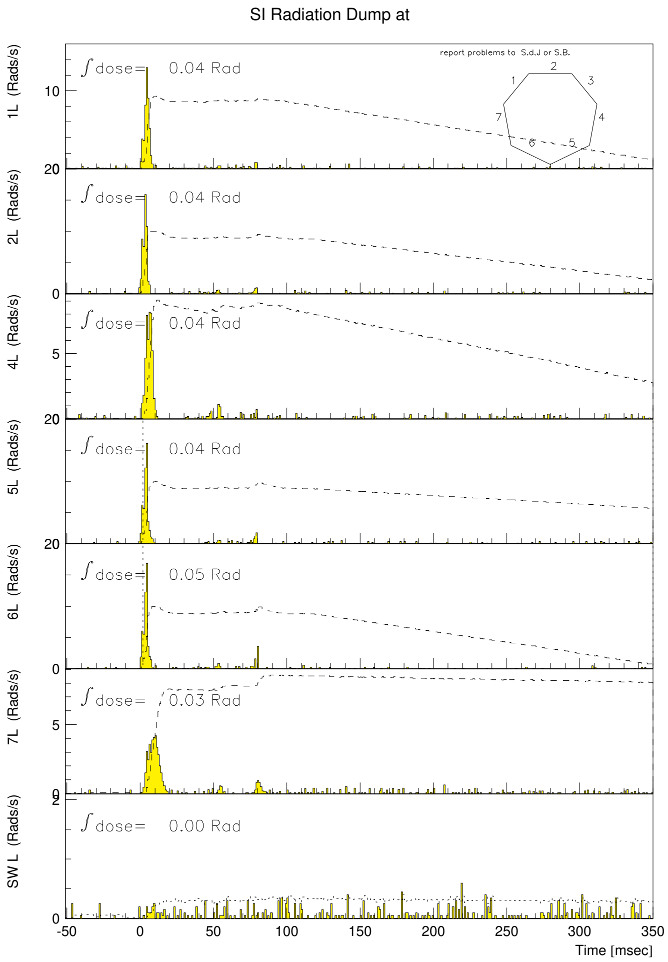
- No spurious Beam Dumps.

- Still, lots of improvements have been performed during the winter shutdown, i.e., new radmon cards (new diodes, new components to adjust gains, etc) , improved electronics ...

Beam Dump System Test

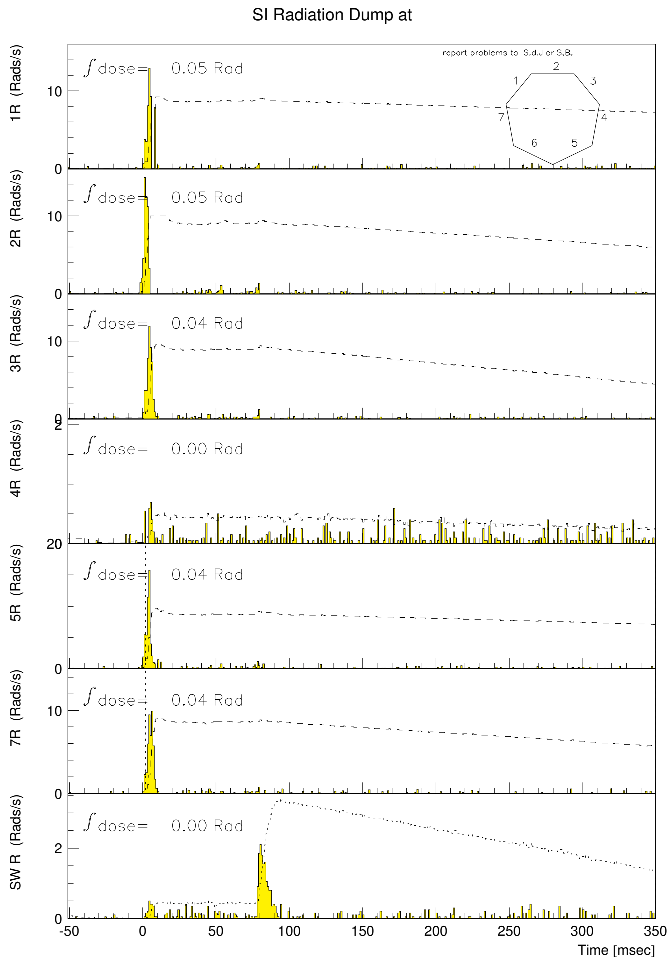
Beam lost due to RF trip. We could have dumped the beams 7 msec before it was over and limit the radiation by 2 orders of magnitude.

Rads/s



Time(msec)

Rads/s



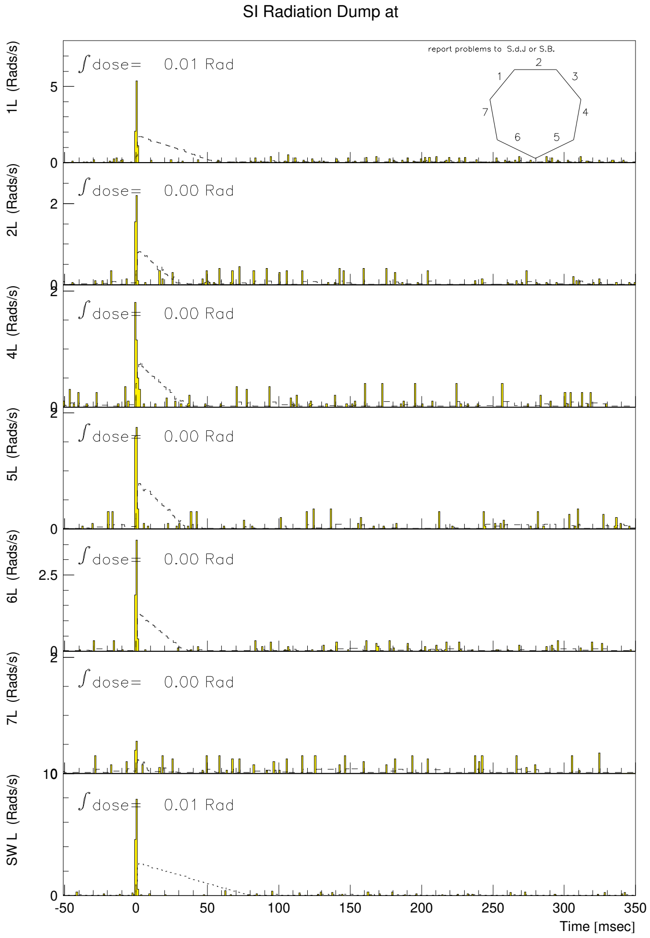
SiW did not dump

Time(msec)

Beam Dump System Test

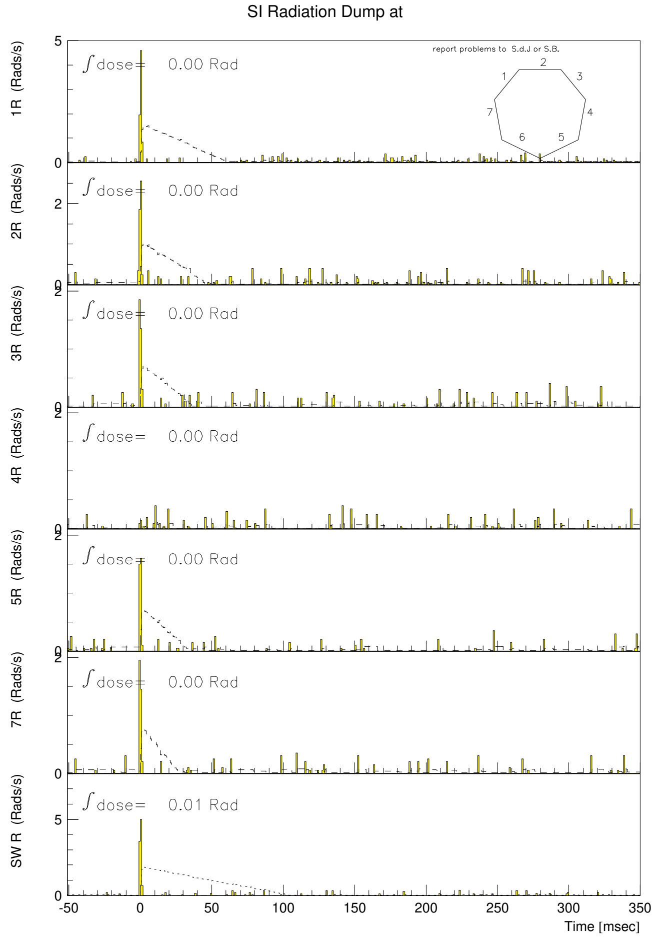
Beam lost due to LEP magnet trip. OPAL SiW luminometer dumped the beams.

Rad/s



Time (msec)

Rad/s



Time (msec)

Conclusions

- During the past years, uncontrolled beam losses resulted in some problems to the OPAL Si microvertex detector.

- We have developed a very effective system which controls rapid beam losses at an early stage of their development, eventually by provoking a beam dump. It provides therefore a very good protection for the Si detector against radiation dose that would take it to the lethal limit. This system consists as well of a good dose integrator providing a very effective monitoring of the integrated dose per day.

- The system relies on a system of Si photodiodes made of the same material as the detector.

- This sytem will be of great use for running at LEPII energies.