Radiation Measurements in the SPS target area TCC2

- Radiation field
- Radiation quantities
  - Dosimetry = absorbed dose measurement
    - depends on material
    - depends on particle type and energy
  - Particle-flux measurements
    - activation detectors
    - silicon detectors

Radiation fields around HEP conversion targets

- micro-waves (problems of EMC)
- low-energy and high-energy gamma's
- Neutrons (thermal + evap.~ 1 MeV + spal.~ 15 MeV)
- other hadrons (p+, α, π ...), some of high energies (HEP)
- electrons (and positrons)
- other leptons (μ, ν)

Radiation quantities :

- **Fluence** = number of particles / surface area [part / cm^2]
- **Exposition** = created charge / mass unit [C / kg],

  or per volume unit [C / cm^3]
- **Absorbed Dose** = deposited energy per mass unit

  [J / kg = Gy = gray = 100 rad]
- **Linear Energy Transfert** = deposited energy per path length

  (LET or dE/dx)

  [MeV /cm or MeV.cm^2 / g]

Exposition measurement

Exposition = deposited charge per unit mass [C / kg],

or volume [C / cm^3]

1 Röntgen = 1 e.s.u./cm^3 of air = 8.77 mGy (in air)

- Gaseous ionisation chamber (current ~~ dose-rate) **= PMI**
- Solid ionisation chambers :

PIN diode (reverse current ~~ dose-rate)

MOSFET (ΔV_b ~~ absorbed dose)

Measurement of Absorbed Dose

Absorbed Dose = deposited energy per unit mass

[1 J / kg = 1 Gy = one gray

100 erg/gr = 1 rad = 1 cGy]

- Calorimeter = only absolute means

  measure of heat in a given material

  complex and delicate

  [Note: 1 Gy/s = 1 watt/kg]

- many other secondary means...

Dosimeters (in TCC2)

PAD = polymer-alanine dosimeter

RPL = radio-photo-luminescent dosi.

HPD = hydrogen-pressure dosimeter

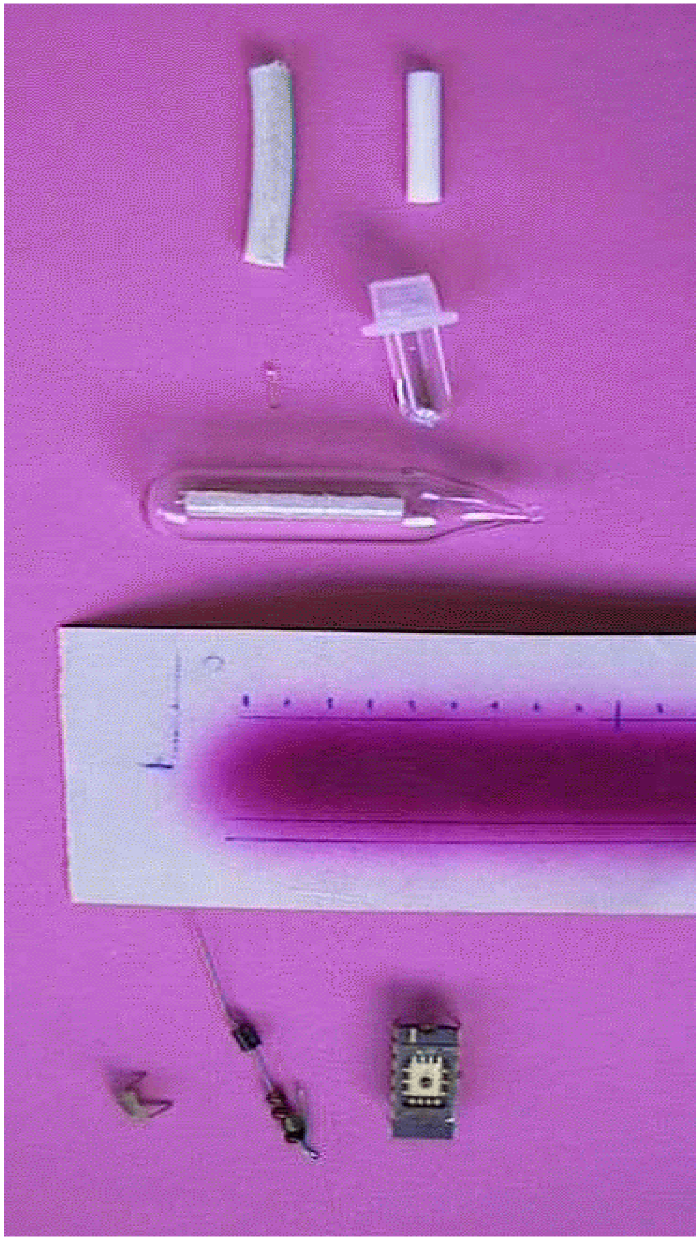
Risø = radio-chromic film

Photo-diodes ; for dose-rate measur.

PIN diodes ; for neutron measur.

Radfet = MOS-FET dosimeter

Activation foils



Absorbed Dose in Various Materials

To be able to calculate the dose in any material, one must know

- the exposure (in R) or the dose in air (in Gy)
- the type(s) of radiation
- the energy-spectrum of the radiation(s)
- the linear energy absorption coefficient(s) [dE/dx in MeV/cm]
- the composition of the material, its density (or elements)

Typical dose measurements around HEP accelerators

γ + neutrons + **HEP**

Usually : 1 Gy (ionisation) + 1~3 x 10^{10} n/cm^2 + 5~10 x 10^8 HEP/cm^2

- dose in H_2O or CH_2 = $f_1 \times d_\gamma + f_2 \times d_n$ (by convention, $f_1 = f_2 = 1$; f_i = dose factors)

  Usually, neutron-dose ~ 5% of gamma-dose

- dose in Si or SiO_2 = $(\sim f_1 \times)\, d_\gamma + f_3 \times d_{nth} + f_4 \times d_{nE} + f_5 \times d_{HEP}$

  In Si, usually, neutron-dose ~ 1% of gamma-dose

- equiv. dose (Sv) = $(\sim Q_1 \times)\, d_\gamma + Q_2 \times d_{nth} + Q_3 \times d_{nE} + Q_4 \times d_{HEP}$

  In many cases, neutron-equiv.dose ~ gamma-equiv.dose

  Q_i = quality factors

Fluence measurement

- If excitations or ionisations (←electromagnetic radiation)

  → photodiodes, Faraday cups...

- If activation (← neutrons, protons…)

  → activation detectors (foils of pure material)

- If induced defects

  → α of silicon (ΔI / fluence.unit volume)

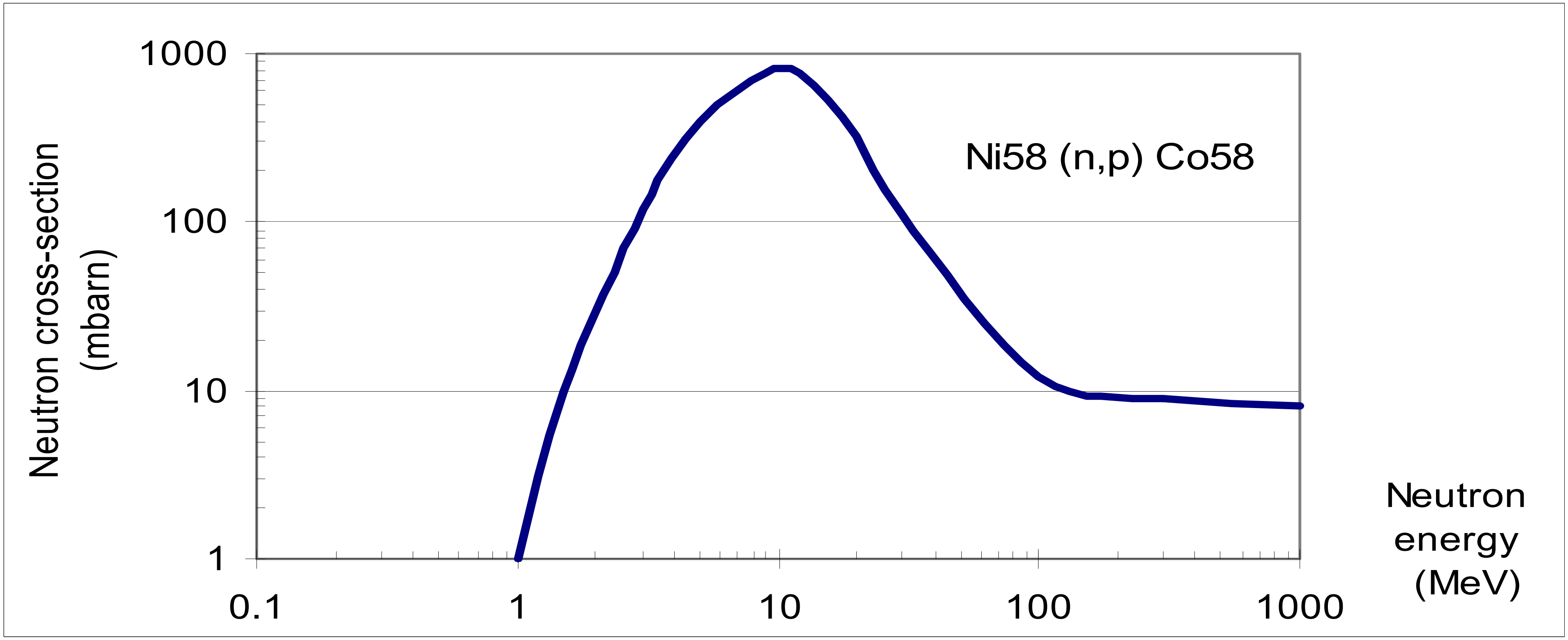
  → change of resistivity → PIN diodes

Note : flux unit = part / cm^2 . s

Fluence measurement by activation foils

Activity = $A = \phi \, . \, \sigma \, . \, N_o \, . \, [\, 1 - \exp(-\lambda . t_i)] \, . \, \exp(-\lambda . t_e)$

Ex : $_{28}Ni^{58} + {_0}n^1 \text{ ---> } {_1}p^1 + {_{27}}Co^{58} + \gamma$ (n,p reaction)



Silicon diodes for Neutron measurement

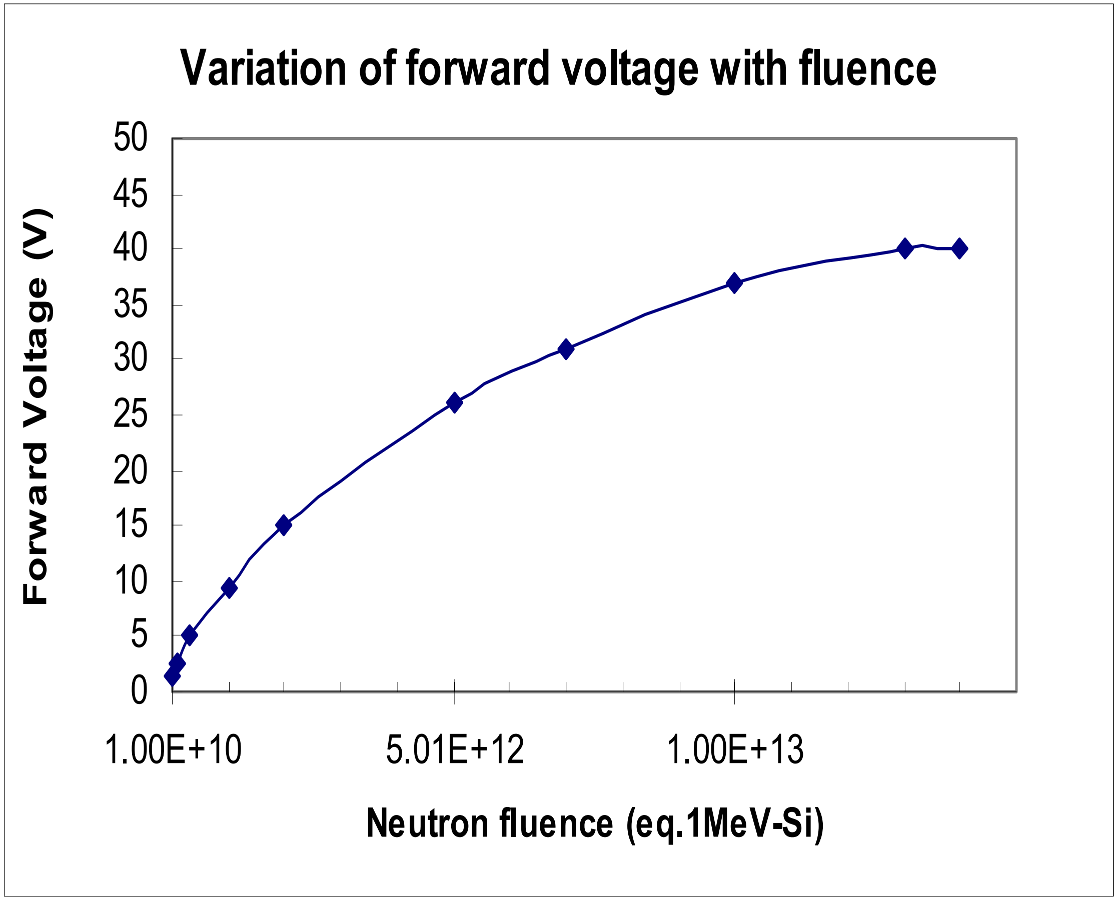
Diode type = DN 156 by Harshaw (USA)

Usage of Kerma factors according to ASTM E-722:

$$\Phi eq.1MeV(Si) = \frac{\int \Phi(E).K(E).dE}{K(1MeV)}$$

Calibration curve of the type:

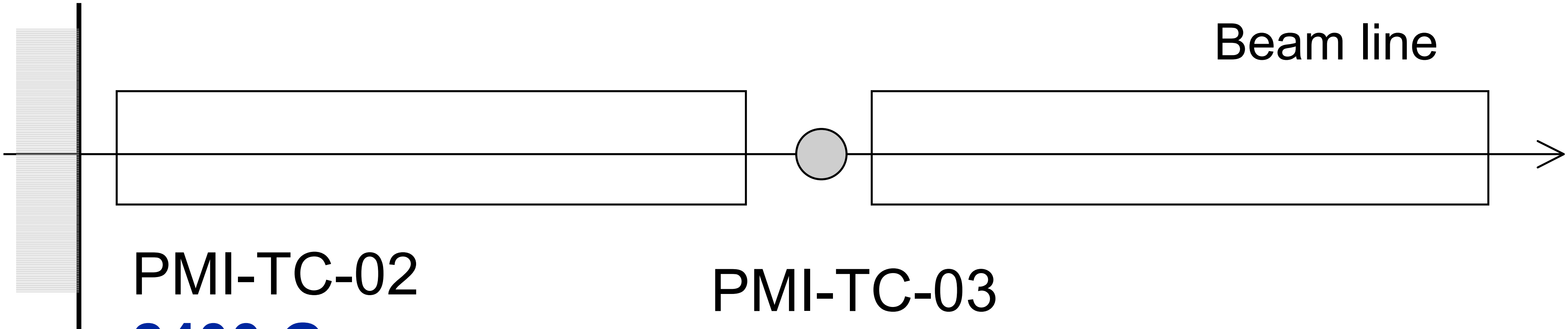
$$U_f = U_{fo} + U_{sat} [\,1 - \exp(\xi\Phi)]$$



Conclusions / radiation measurement

- Measurement of absorbed dose
  - depends on the radiation types and energy spectra,
  - depend on the considered material !
- Measurement of particle fluences
  - must be adapted to particle type(s) and energies
  - must be adapted to the intensity and duration of irradiation

Results in TCC2 for 2001 ± 30%



PMI-TC-02
2400 Gy
2e13 n.cm-2

PMI-TC-03
2650 Gy
3.5e13 n.cm-2

PMI-TC-01
950 Gy
5e12 n.cm-2

PMI-TC-04
780 Gy
3e12 n.cm-2

PMI-N4
500 Gy
3e12 n.cm-2