ESRF

Radiation Damage Issues at the ESRF

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Outline

I. Demagnetization of permanent magnets
  - ✓ Example of demagnetization
  - ✓ Steps towards solutions

II. Dosimetry inside of the Storage Ring

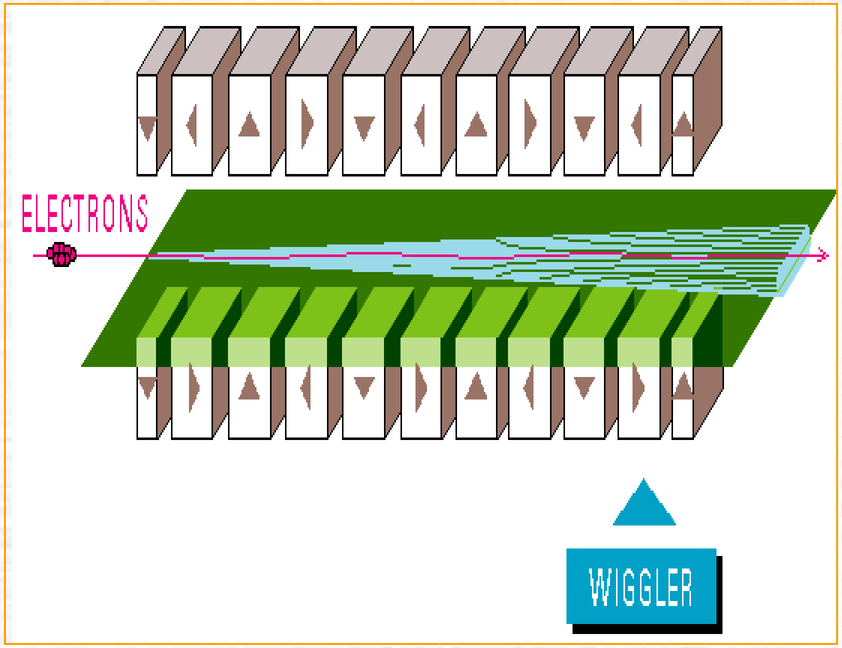
III. Study of the damaged materials and equipment in the Storage Ring

I. Demagnetization of Permanent Magnets

X-ray Production

• 3rd Generation Light Source => optimised for the use of Insertion Devices (Undulator / Wiggler)

• Electron beam passing through permanent magnet assemblies => produces X-rays



Origins of the Demagnetization

The **permanent magnets** are very sensitive to **radiation** and **temperature** increase. Once demagnetized,the spectrum of the ID will be completely spoiled.

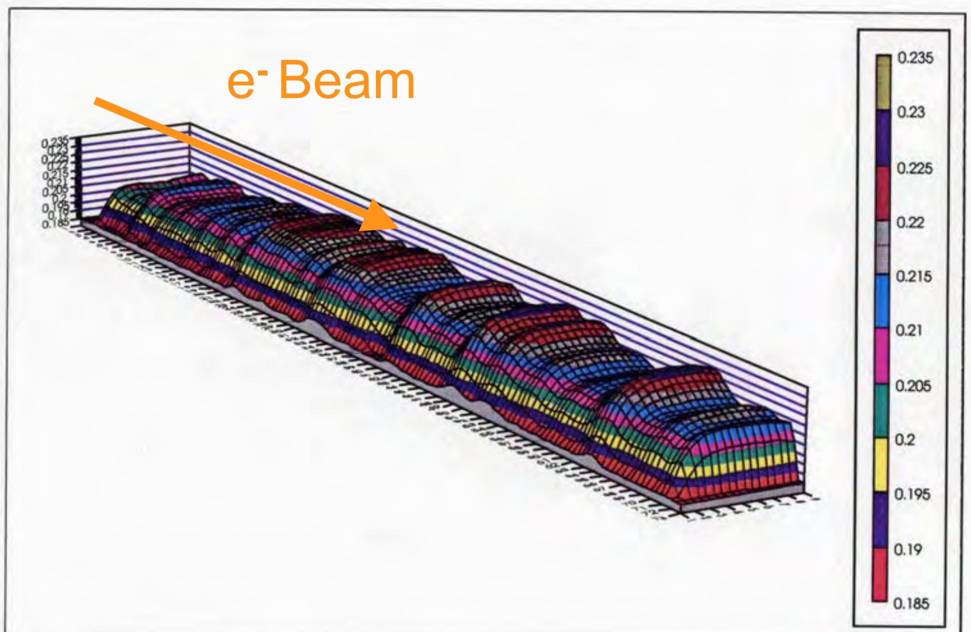
2 Origins:

1. **Electron beam** is hitting the magnet or material in the ID's surroundings
2. The magnets are irradiated, in routine operation, by a cocktail of **X-rays + parasitic radiation** ($\gamma + n$)

Case 1: e^- Beam Hitting the Magnets

During the ESRF commissioning, the **beam** was **mis-steered** and hit the permanent magnet assemblies (on ID6 & ID10).

- Damaged magnets > **50 %**
- **<u>Losses</u>** of more than **<u>10%</u>** (on the peak field) were measured
- Estimated time: a **few minutes** or much less



Presently we are better protected against this kind of accident

Case 2: Demagnetization in Routine Cond.

After **5 years** of having installed an Undulator in the ring, we have magnetically re-measured it and compared it with its initial values.

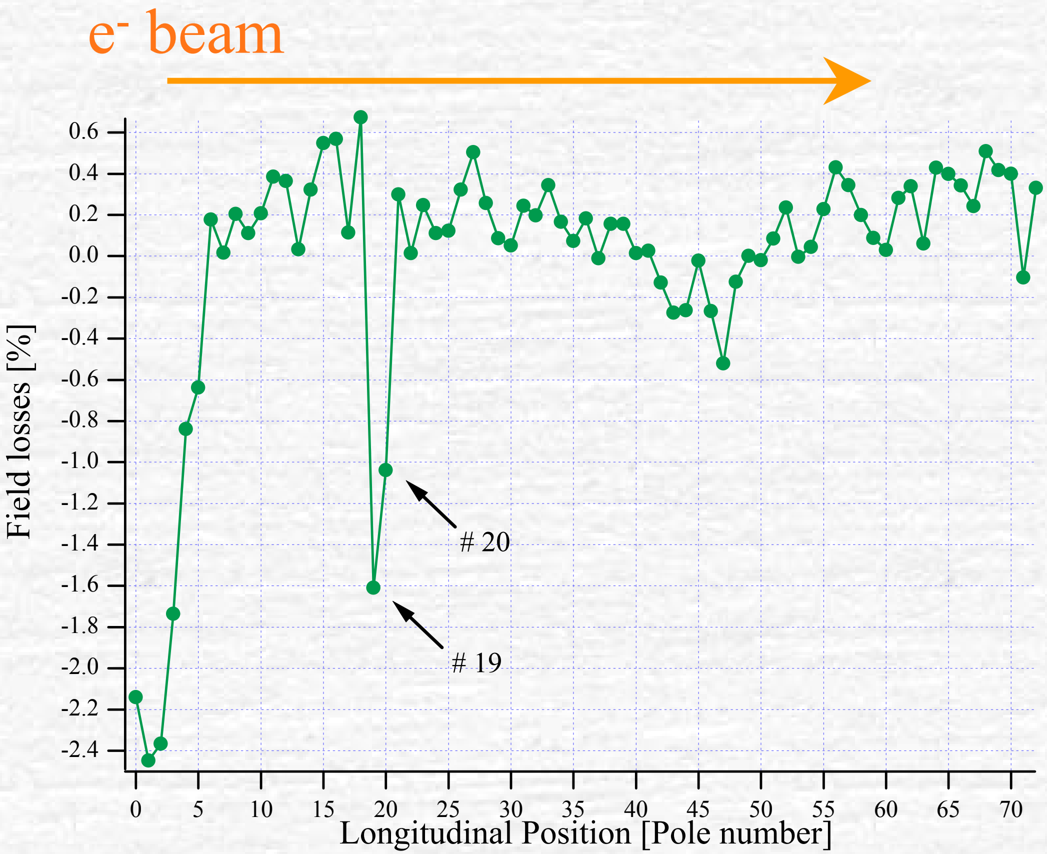
=> Surprisingly the device was **partially demagnetized**!

This long-term demagnetization is easy to understand when one considers that the dosimetry measurements indicate a mean dose rate value of **48 Gy/h**, or 385 Gy/A.h.

This represents a cumulated dose of 1.2 MGy.

Case 2: Demagnetization in Routine Cond.

Longitudinal Measurement of the Peak Field (after 5 years)

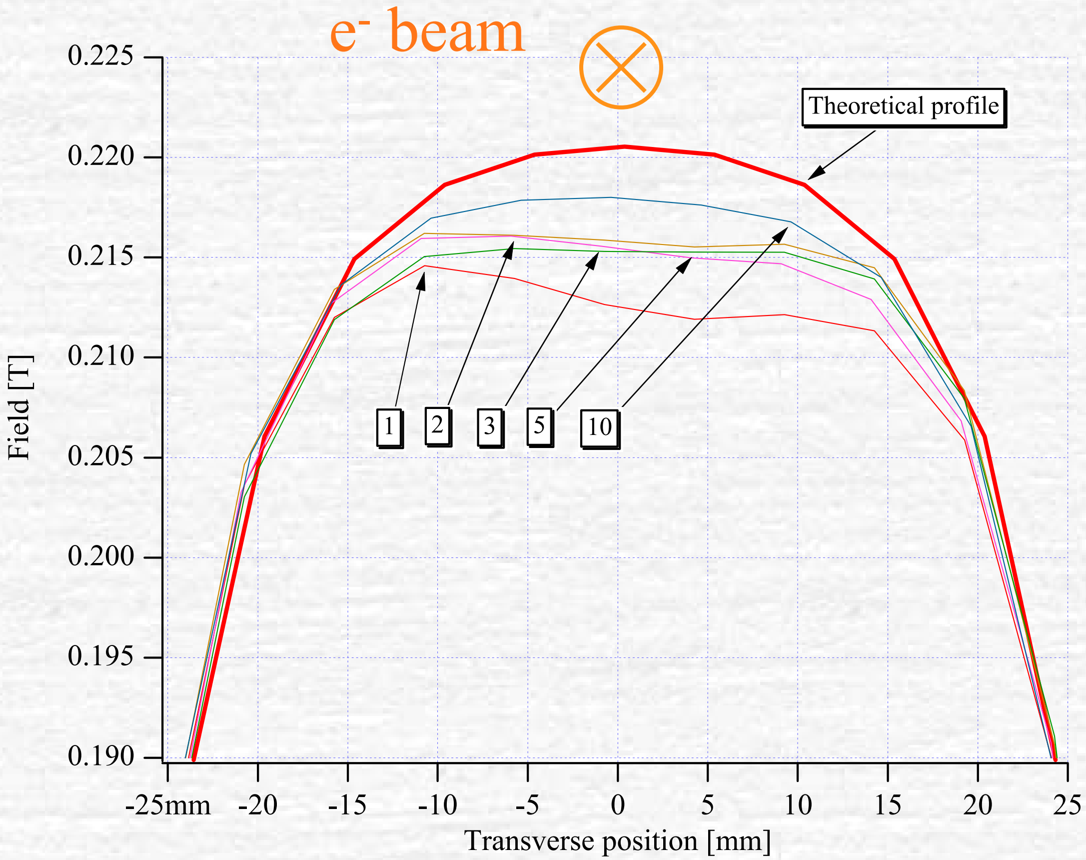


=> 6 entry poles are affected + 2 others (#19 & 20)

Normalized Field Losses of the Peak Field

Case 2: Demagnetization in Routine Cond.

Transversal Measurement of the Peak Field (after 5 years)



Transverse field homogeneity over the poles 1,2,3,5 and 10 of the upper jaw assembly

Steps Towards Solutions?

1. Test many types of magnetic materials in various conditions and geometries
2. Cost/benefit analysis for each material
3. Reduce the losses in the Storage Ring
4. Follow up the harmonics degradation on the corresponding Beamlines

Step 1: Test of Magnetic Materials

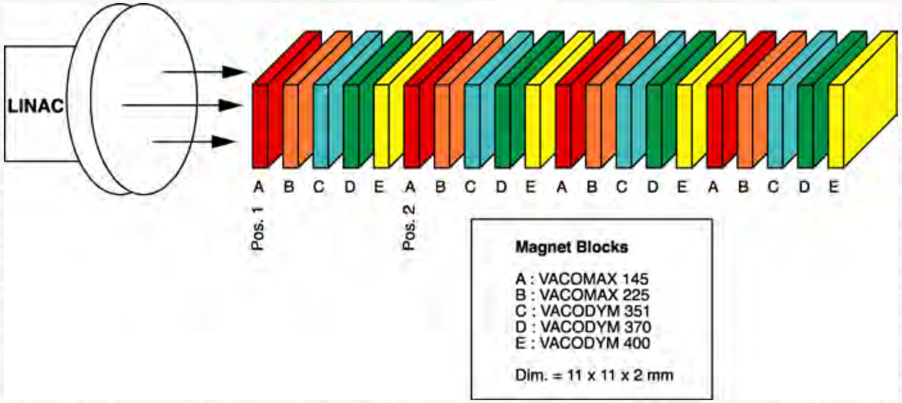
The experiments undertaken by Bizen et al.(SPring-8) are of great interest for the ID community and should be part of a joint program in order to test more suppliers and grades at different energies.

!! The **nature of the radiation** (*) has a particular effect on this process. The radiation type used for testing the magnets should be identical to the one that the future magnet assemblies will have to sustain!!

(*) ^{60}Co irradiations are not sufficient …

Step 2: Cost/benefit analysis for each material

Initial irradiation experiments of permanent magnets were carried out at ESRF in 1993 by using the LINAC



E_{LINAC}	180 MeV
I_{Beam}	50 mA
Pulse Length	2 μs
Repetition Rate	1 Hz
Beam Cross Section	1 mm^2
Power	18 W

=> estimated dose received by the first magnet of the stack is around <u>0.7 MGy</u>

Step 2: Cost/benefit analysis for each material

1st conclusion of this experiment:

- Within the same material family, the **lower the coercivity**, the more the magnet is **subject to losing its magnetization**,

BUT within this family, **a higher coercivity induces a poor Remanence**, which will induce a weaker peak field !

Step 2: Cost/benefit analysis for each material

<u>2nd conclusion of this experiment:</u>

• The **SmCo magnets are much more resistant to demagnetization** than the NdFeB ones.

BUT their **Remanence is weaker!**

=> The selection of the right material is not trivial

Step 3: Reduce the losses in the SR

GOALS = reduce the losses

- at **injection**
- during stable **stored beam**
- **limit** the total beam losses following **equipment failures**.

SOLUTIONS (used at ESRF):

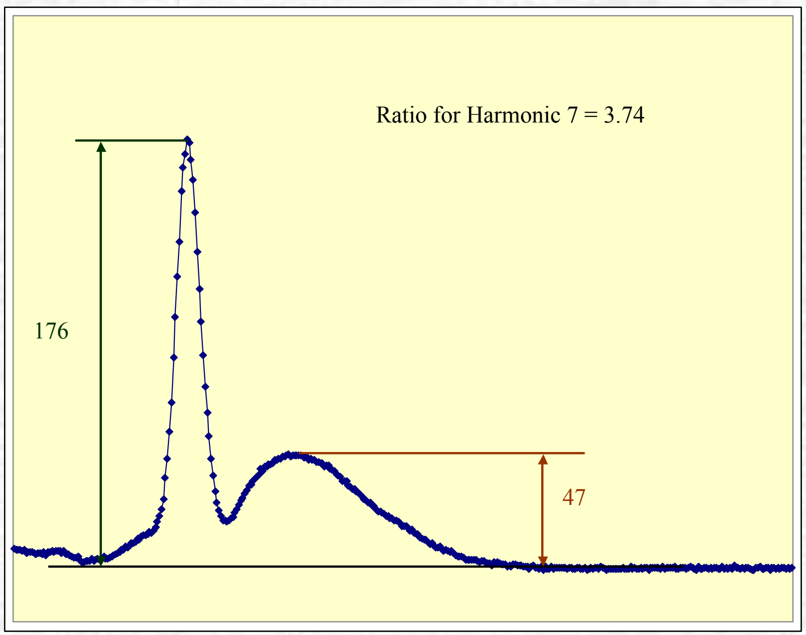
- Scraper protection: **concentrate the losses** in a known area & reduce the losses at the entrance of each small aperture
- Machine optics: **reduction of the vertical ß fct** in the middle of the straight section (=> increase the vertical acceptance)
- Injection: **increase the injection efficiency** (80 <η<100 %)
- Topping up : the **refill** does **not require** the stored beam to be **killed**

⇒ A useful monitoring tool is the Beam Loss Detector

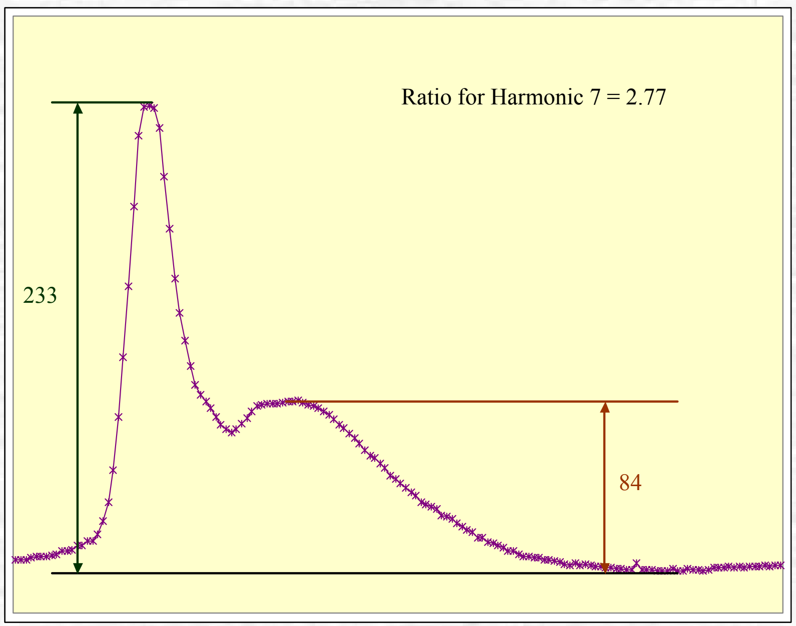
Step 4: Follow-up of the harmonics

For all the sensitive ID segments (magnets close to the beam) the users are requested to monitor the spectrum of the ID 3x per year.

Spectrum measurement after installation



Spectrum measurement **after 3 years**



II. Dosimetry Inside of the Storage Ring

Dosimeters

To follow the degradation of ESRF equipment, 2 kinds of Dosimeters were provided by the CERN's TIS-TE group:

- Polymer-Alanine Dosimeter (PAD)
- Radio Photo Luminescent dosimeter (RPL)

Following the 24 dose measurements, we have concluded that the **PAD** tends to **underestimate the dose** by a few tens of percent (due to low energy X-rays) whereas the **RPL overestimates it** by a factor of two to five.

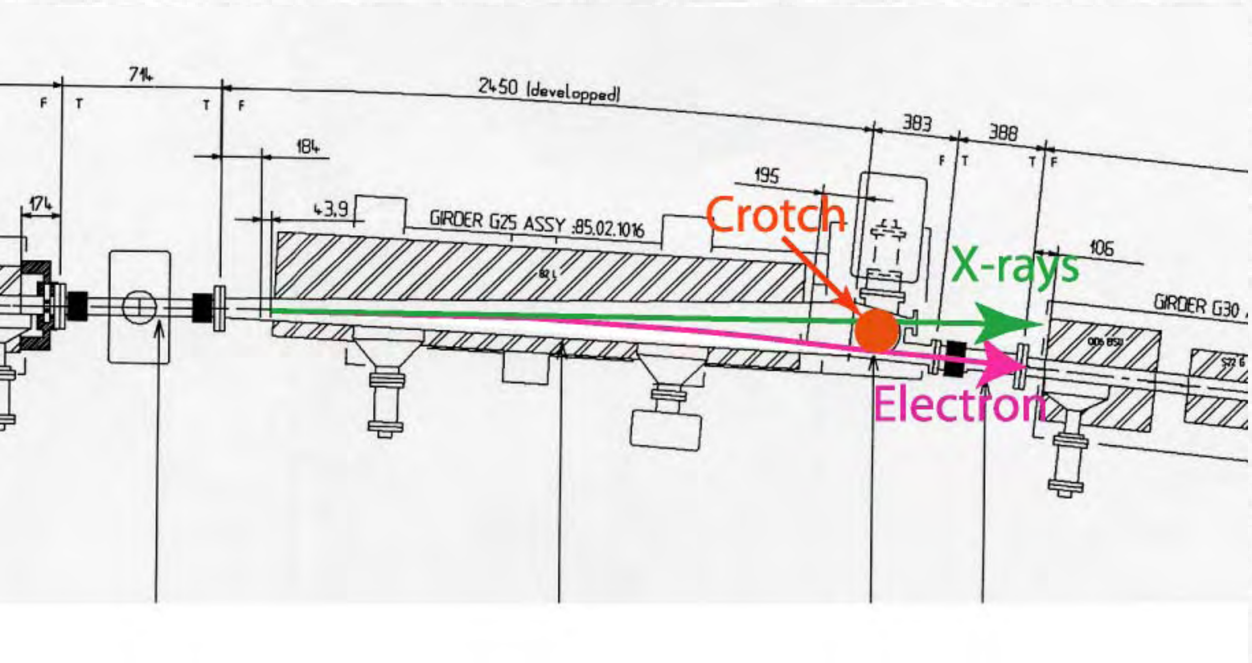
Parasitic Radiation Generation

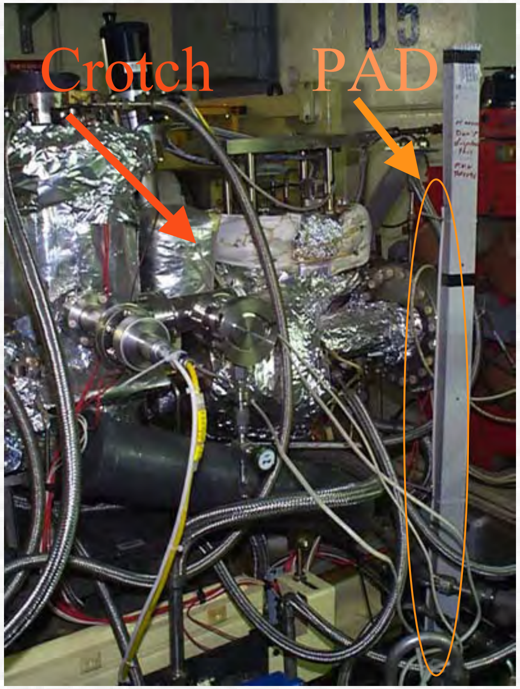
In addition to the **intense X-rays** produced, a **parasitic radiation** is created **(n+ γ)** which is **generated by :**

- the **interactions** between the e^- beam and the **residual gases**
- the **scraping effects** induced by the vacuum vessels' inner aperture
- the **e^- beam losses**.

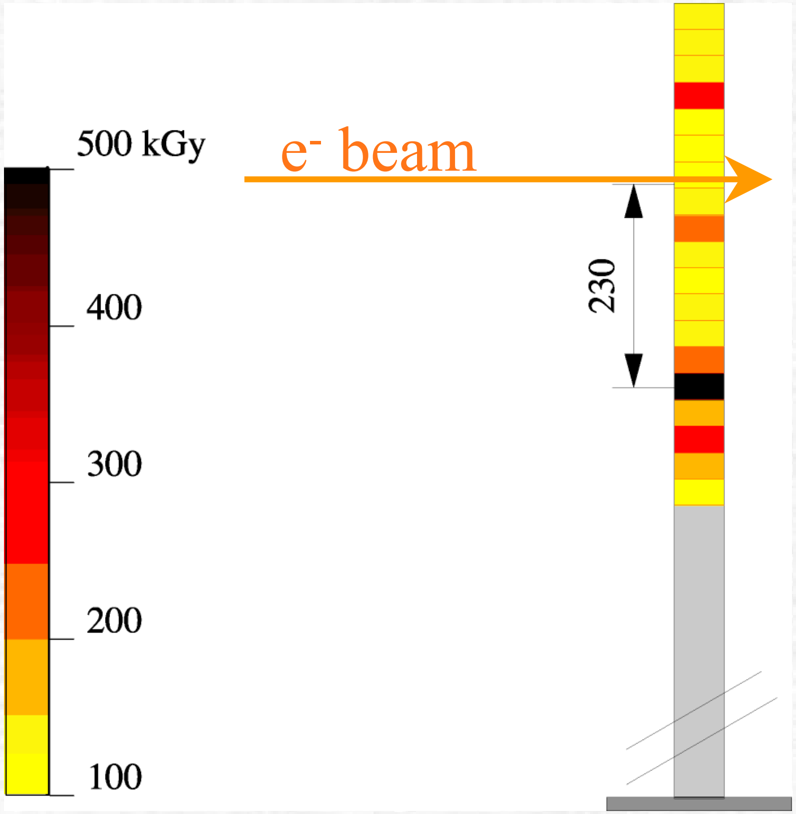
The hottest areas in the SR

- **Injection** zone
- Close to the **Scrapers**
- Around the 64 **Crotch Absorbers** (stop the X-rays not emitted in the users' direction)





Vertical Distribution of the Dose in a Crotch Vicinity



A **60 cm long PAD** was installed vertically at a distance of 30 cm from a crotch (ID6-1) for 7 months (= 500 Ah)

Surprisingly the **Max. Dose (500 kGy) was not measured on the Beam plane but much more below it.**

The cascading mechanism is complex.

III. Damaged Materials and Equipment in the Storage Ring

List of Damaged Materials

- Hollow copper wire electrical insulator materials

  ⇒The polyolefin thermoshrinking sheaths (Integrated Dose = 2 MGy) were replaced by EPDM

- Cooling hoses

  ⇒The thermoplastic materials became brittle and were replaced by an EPDM

- Opto-electronic absolute encoders

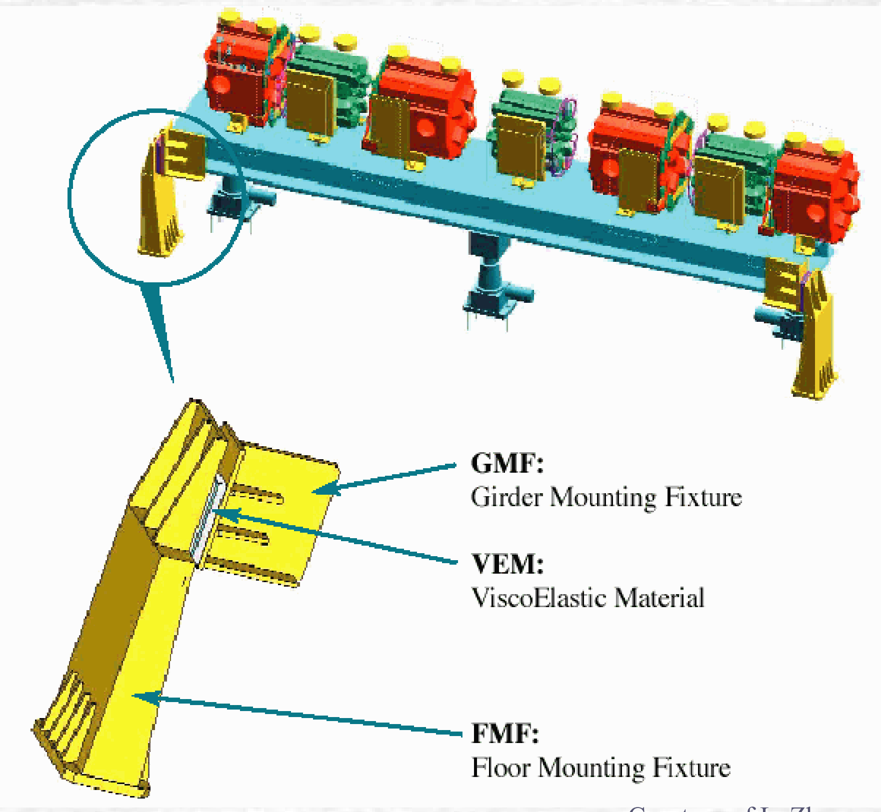
  ⇒A lead shielding of 25 mm thick has reduced the failure rate by 90 %

List of Damaged Materials

- 224 multiplexers are distributed around the Storage Ring (to pick-up the signals from the BPMs)
  - ⇒A 2 mm lead box has reduced the failure by a factor of 5
- Electrical cables (triaxial cable powering the vacuum gauges)
  - ⇒The polyethylene insulator & its **PVC** jacket are very vulnerable to the radiation. A cable (with the same elec. charact.) with an **EVA jacket** has been successfully tested. A full cell will be equipped with this new cable.

List of Damaged Materials

- ViscoElastic Materials (for Damping Links)
  - ⇒A 2 mm lead protection is reducing the dose by a factor of 100.



Courtesy of L. Zhang

VEM are very sensitive to radiation aging