ToPix2 Single Event Upset data analysis

D. Calvo, Laura Zotti

Thanks to Ralf and Thomas
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A particular thank to F. Faccio

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Julich, 7-11/09/2009

Overview

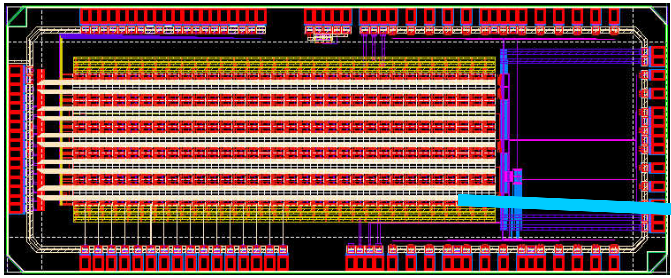
- SEU test for ToPix2
- SEU cross section in a hadrons environment
- hadrons fluence estimation in the pixel detector
- conclusion

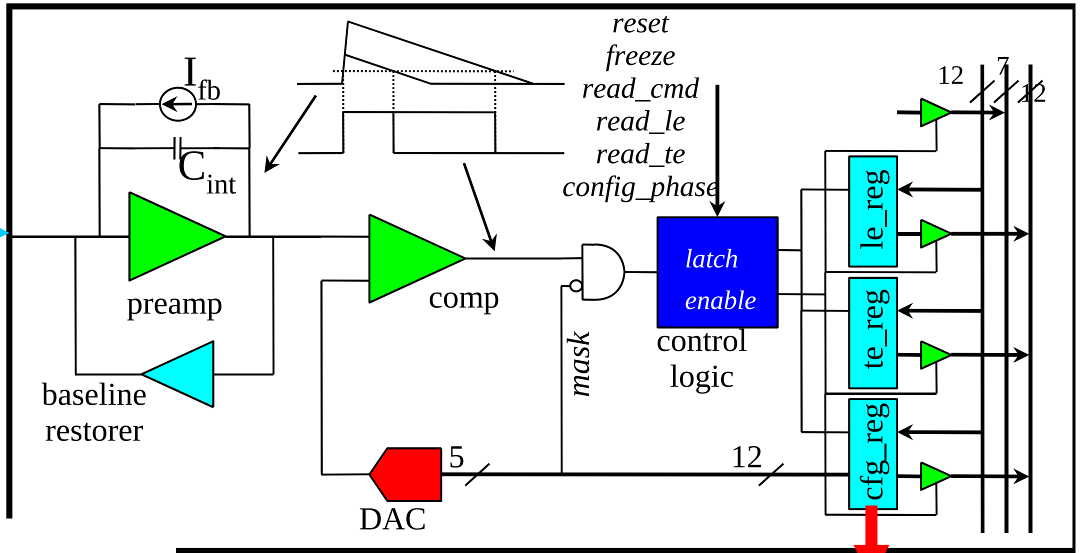
SEU test for ToPix2

D. Calvo

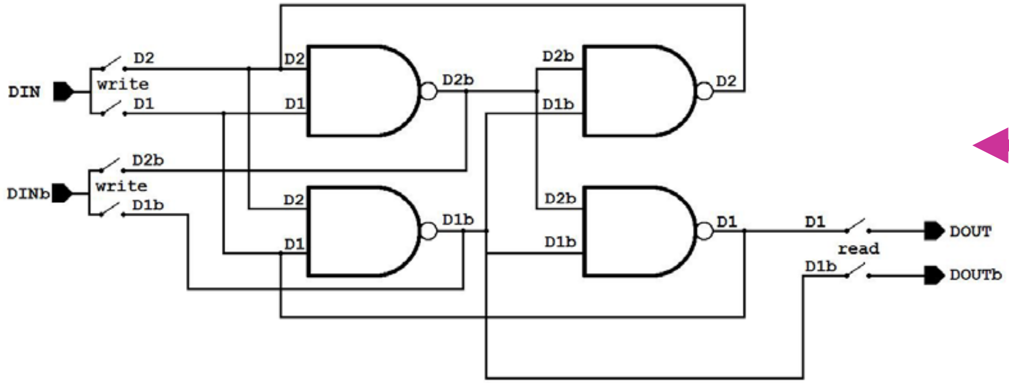
Pixel register in ToPix2

320 instances in the pixel array of ToPix2,
each composed by 12 bit latch made of hardened cell (Dice with baseline design: all pmos devices are located in the same nWell and don't have guard contact separation)

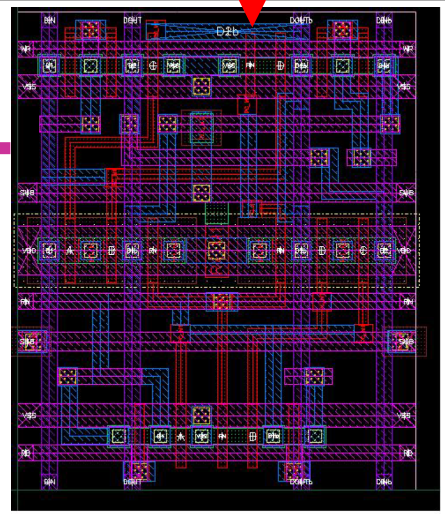




latch2



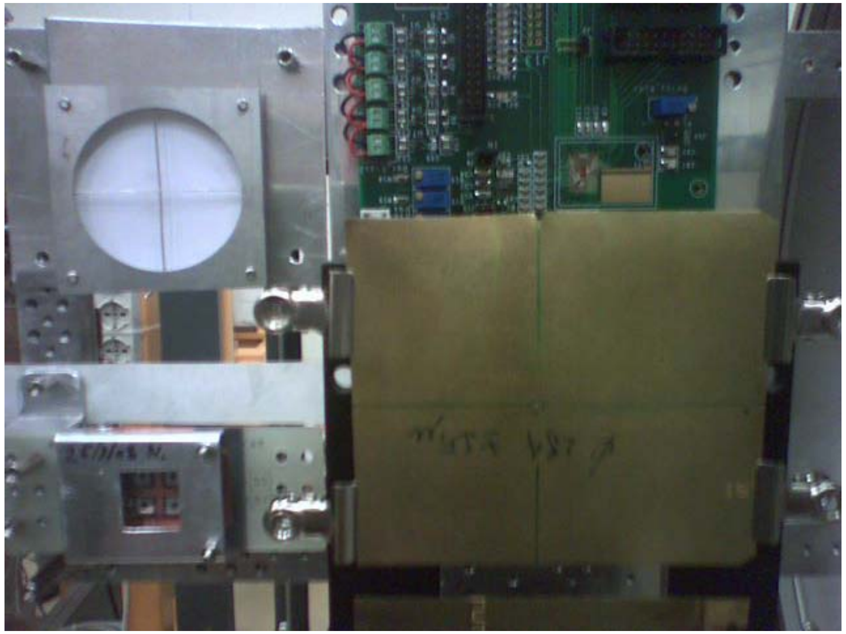
Bit layout

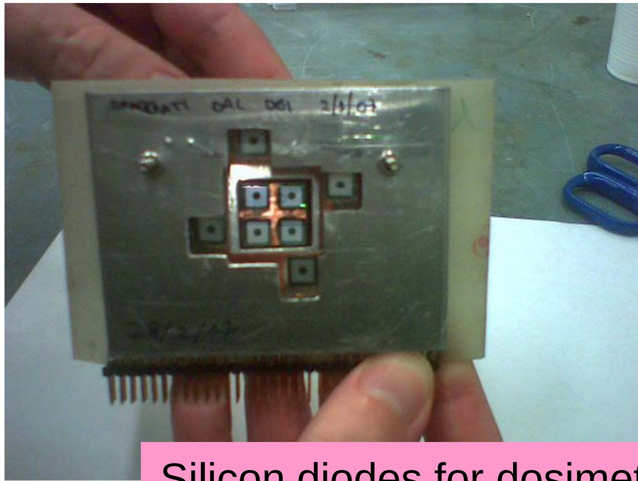


5 x 6 µm

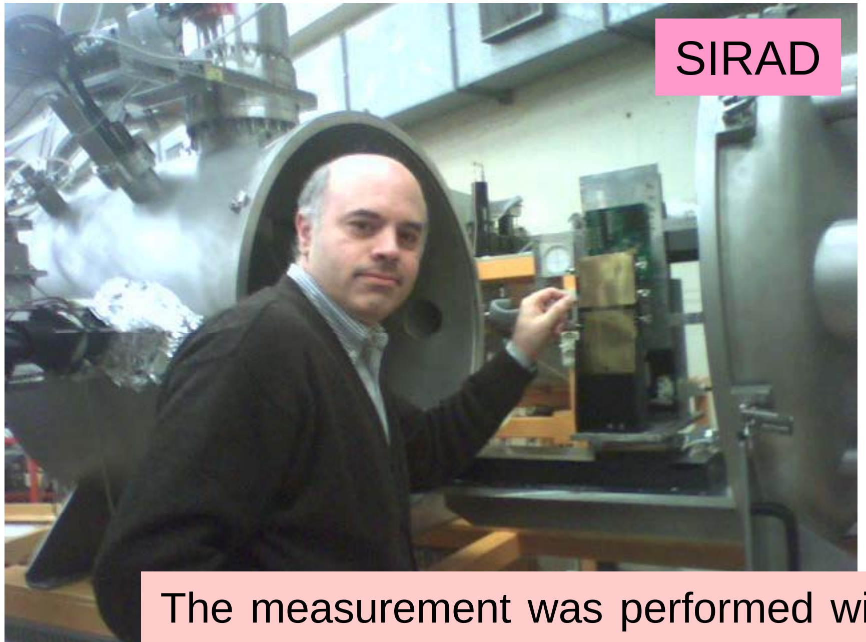
12760 instances /chip (11.6 mm x 11.0 mm) in the final design of ToPix,
each composed by 12 bit latch (total number of 153120 bit latch /chip)

Experimental setup at SIRAD (INFN-LNL)

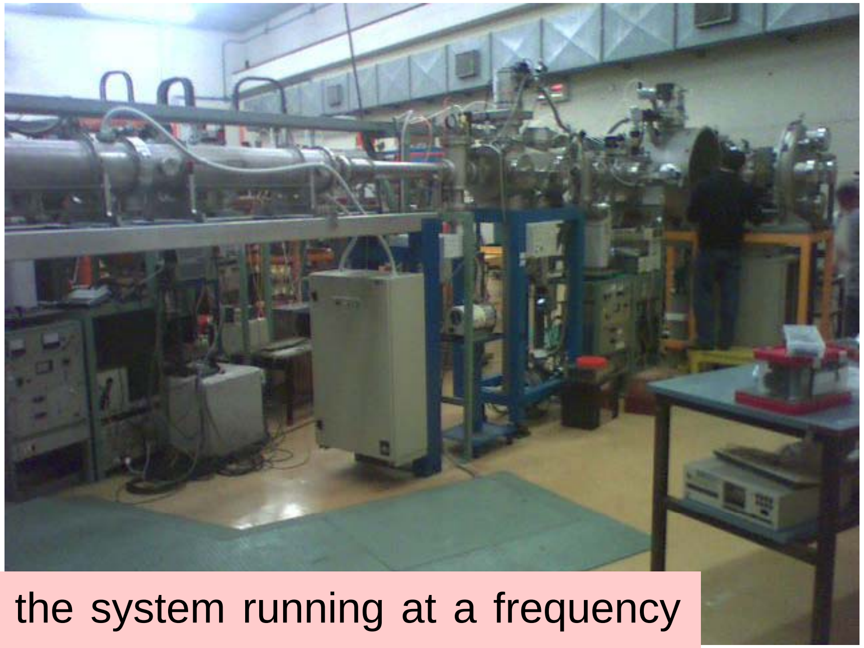




Silicon diodes for dosimetry



SIRAD



The measurement was performed with the system running at a frequency of 10MHz, due to the long cables (2m)

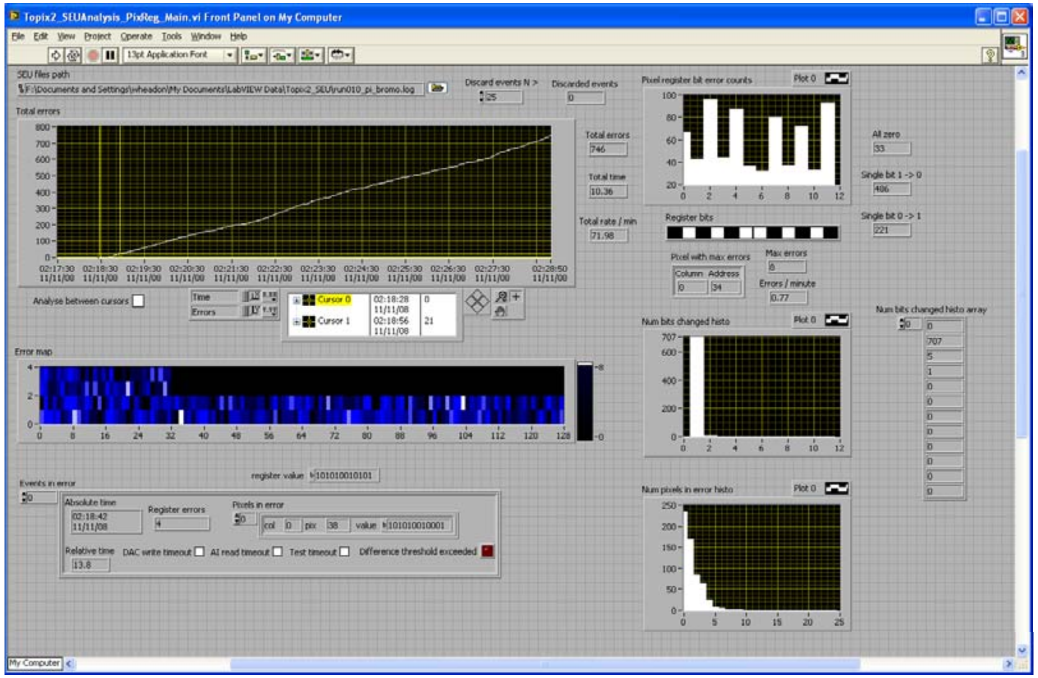
Ion beam test

2 beam tests were performed at SIRAD with the following ions

Ion	Beam angle[°]	LET[MeV cm2/mg]
O	0	3.0
	30	3.5
F	0	3.9
	30	4.5
Si	30	10.3
Cl	0	12.9
	30	14.9
Ni	0	27.8
Br	0	38.5
	30	44.4

SEU measurement

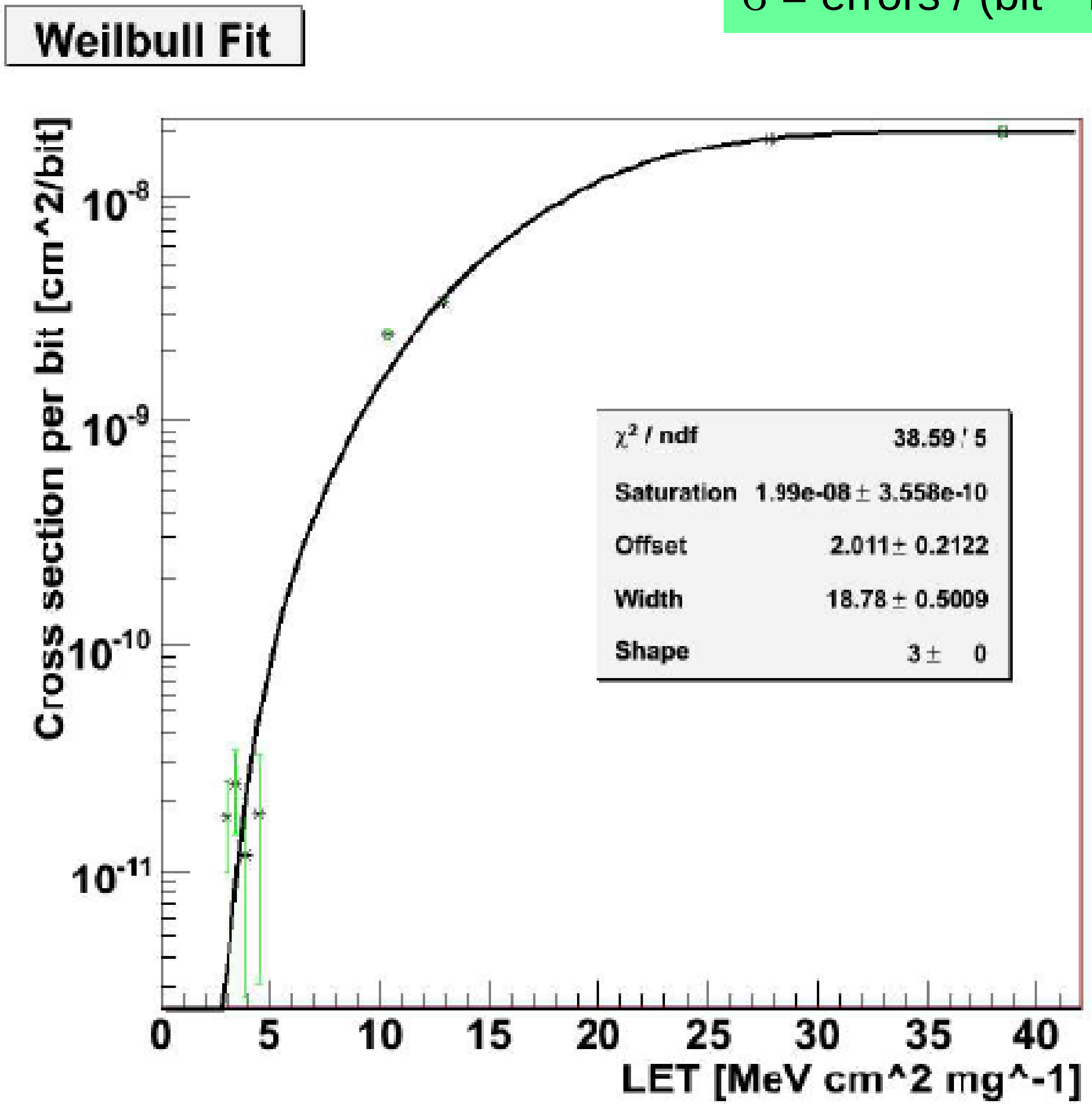
• every register is written and compared after 2 s
• if a bit in the register is changed, the control program increases the error counter
• the register is written again
• the register is written by a 12 bit sequence made of alternatively 0 and 1 values



Screen shot of the analysis program to check the data

Heavy ion SEU cross section

σ = errors / (bit・ion fluence)



SEU cross section in hadrons environment

SEU cross section in hadron environment

Method to estimate SEU in an hadron environment:
M. Huhtinen, F. Faccio - CERN
Computational method to estimate SEU rates in an accelerator environment
NIM A 450 (2000) 155-172

Main parts of this method (from the reference article):

- use of a Weibull fit to experimental heavy-ion SEU data in order to quantify the SEU sensitivity of the circuit
- explicit generation and transport of nuclear fragments and detailed accounting for energy loss by ionization
- reasonable Sensitive Volume (1x1x1 μm^3)

the method predicts the SEU cross sections for protons rather accurately

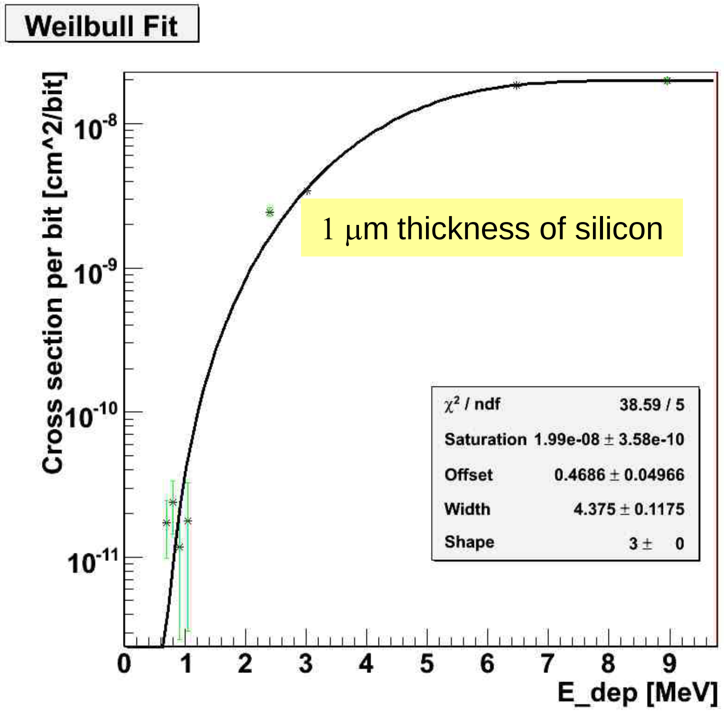
Information about different radiation types (from the cited article):

- “..*neutrons and protons of the same energy produce almost identical upset rates if the incident energy exceeds 20 MeV*
- *all particles and energies elastic scattering gives a negligible contribution to the SEU rate*
- *the upset rate for 10 GeV protons is only slightly than for 200 MeV protons ..”*

-> All hadrons (energy > ~20 MeV) can be assimilated to protons for SEU effects

SEU cross section in hadron environment

From:
Test with heavy ions of ToPix2 at SIRAD (INFN-LNL)



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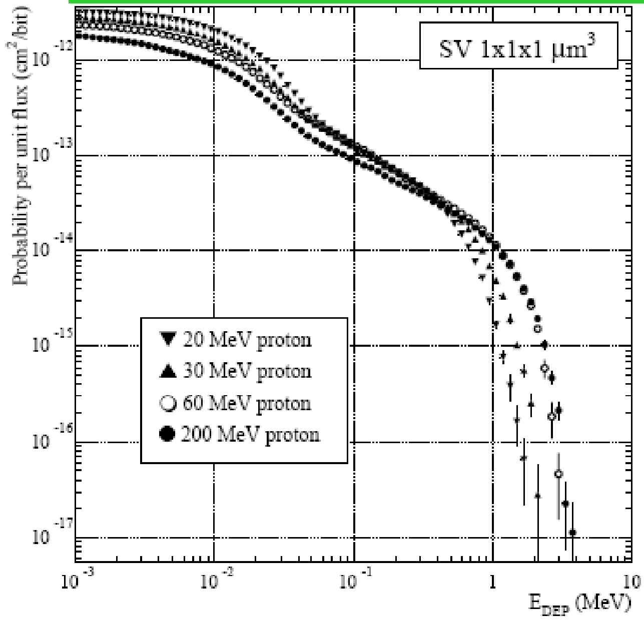


Fig. 6. Energy deposition probabilities for protons of different energies. The curve shows the probability to have within the SV an ionizing deposition greater or equal to the indicated E_{dep} value.

$$\Sigma = \sum_i P_i \left(\sigma_{i+1} - \sigma_i\right) \cdot A^{-1}$$

A: cross sectional area of the sensitive volume

SEU cross section in hadron environment

Total cross section for proton irradiation [cm^2/bit]
SV: 1x1x1 μm^3

20MeV	30MeV	60MeV	200MeV
$3.63 \cdot 10^{-17}$	$1.24 \cdot 10^{-16}$	$5.81 \cdot 10^{-16}$	$7.01 \cdot 10^{-16}$

As reference (private communication of F. Faccio):
normal cell -> ~ 10^{-14} cm^2/ bit
hardened cell -> ~ $10^{-15} \div 10^{-17}$ cm^2/bit (obtained with protons measurements)

SV:1x1x0.5μm^3
@ 200MeV protons
Total cross section: 1.84E-15

Hadrons fluence in the pixel detector

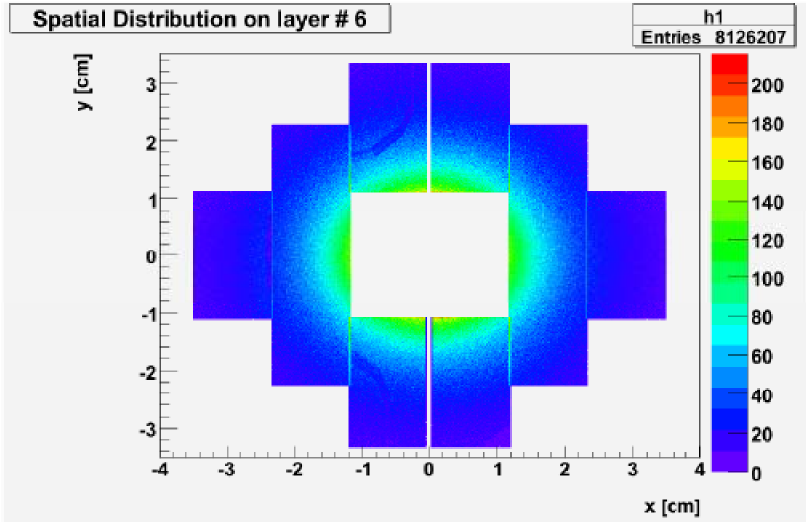
Hadrons fluence in the pixel detector

❖ 8.5 million of antipp events

❖ disks with sensors, readout chip, carbon foam and cooling pipes with water

❖ observed the spatial distribution of particles on the disks

❖ fluence of hadrons on small disks obtained evaluating the total particle number divided by the sensor surface, and then corrected (over estimation) by the ratio between the hot and cold spatial distribution region (~ 6).



	Barion fluence [Mhit/(s cm^2)]	Meson fluence [Mhit/(s cm^2)]	Hadron fluence [Mhit/(s cm^2)]
Disk 1	0.9	3.2	4.1
Disk 2	0.8	4.92	5.8

SEU in PANDA using DICE architecture

SEU/ (bit · s · cm^2): $7.01 \cdot 10^{-16} \cdot 5.8 \cdot 10^6 = 4.0658 \cdot 10^{-9}$

SEU/ cm^2 in PANDA

SEU/ (s · cm^2): $4.0658 \cdot 10^{-9} \cdot 12$ [bit] 10^4 [pixel readout/cm^2] = $4.88 \cdot 10^{-4}$

SEU/ (h · cm^2): $4.88 \cdot 10^{-4} \cdot 3.6\ 10^3 = 1.8$

SEU /ToPix in PANDA

SEU/ (s · chip): $4.0658 \cdot 10^{-9} \cdot 12$ [bit] 12760 [pixel readout/chip] = $6.23 \cdot 10^{-4}$

SEU/ (h · chip): $6.23 \cdot 10^{-4} \cdot 3.6 \cdot 10^3 =$ **2.3**

Conclusions

- ❖ estimated upper limit of 2.3 SEU/(h·chip) for PANDA antipp environment
- ❖ the value for antipN: to be done. More generated events!
- ❖ the implemented DICE architecture (first level of radiation hardness) isn't sufficient for the PANDA environment