Backgrounds: Simulations and Irradiation Test

G. Cibinetto – INFN Ferrara
G. Tellarini – Ferrara University
V. Santoro – INFN Ferrara

Outline

- Background studies (Valentina)
  - update on neutron, photon and charged particle rates
  - new shielding configuration tested
- Neutron irradiation test preliminary results
  - brief introduction and motivation
  - apparatus and data taking
  - first results and conclusions

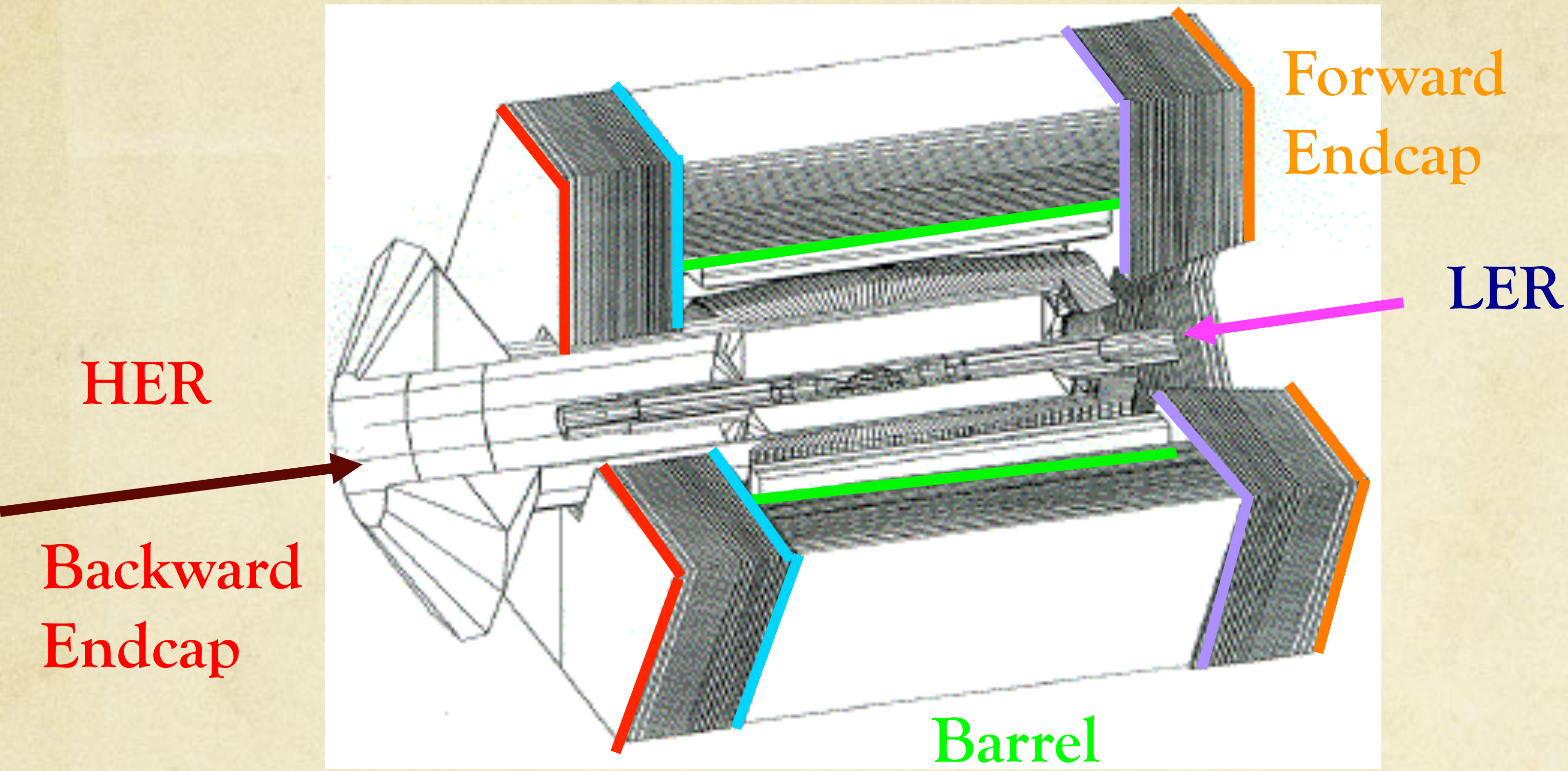
IFR Background

Valentina Santoro
INFN Ferrara

Instrumentation for muon and K_L identification at Super Flavor Factories

09/07/2012

Hot regions



Barrel: innermost layers, mostly neutrons

FWD encaps (hottest region) : inner layers and outer layers (BEAM halo), electron and photons

BWD encaps: inner layers and small radii

Summer 2012 Production

- ✓ New IFR Shielding System
- ✓ Radiative BhaBha events usually the rad-bhabha events are simulated using the cut k= DeltaE/E > 30%, where this parameter is the fraction of of energy in the CM radiated by the photon. This cut ensures that we include 99.999999% of the rad-bhabha losses around ± 10 meters from the IP. Events with low kappa will be simulated separatelly.
- ✓ Radiative BhaBha events: Low kappa 0.5 < kappa < 30% The sample is expected to give a significant contribution to the neutron cloud, mainly from neutrons produced from high energy electrons/positrons hitting on the 1st and 2nd downstream dipoles.

FIRST TIME SIMULATED
Results will be shown @ the CM

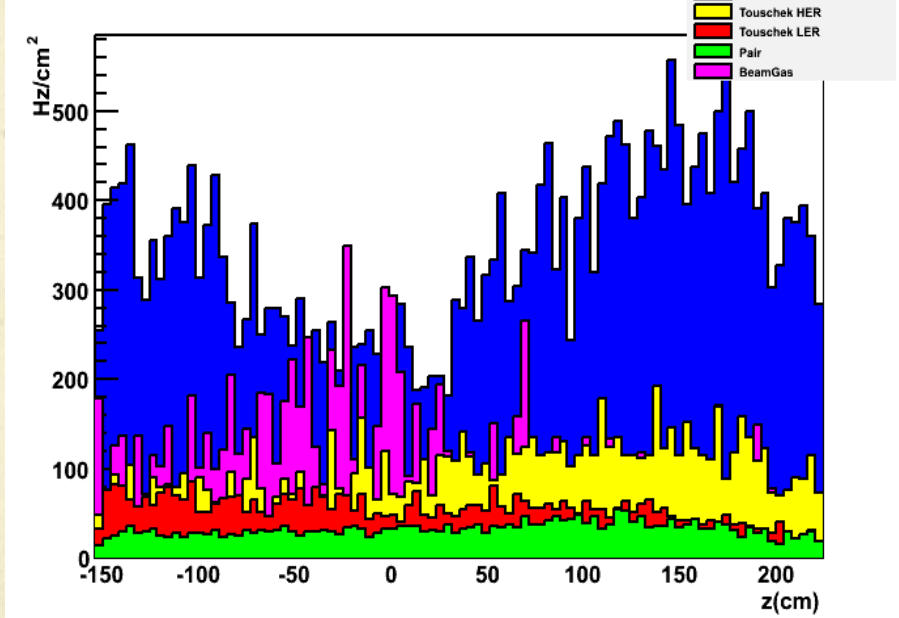
- ✓ Pairs events
- ✓ Touschek events (HER and LER)
- ✓ Beam-gas (HER and LER)
- ✓ Synchrotron radiation from (SR) LER and HER

FIRST TIME SIMULATED
Results will be shown @ the CM

What you will see today

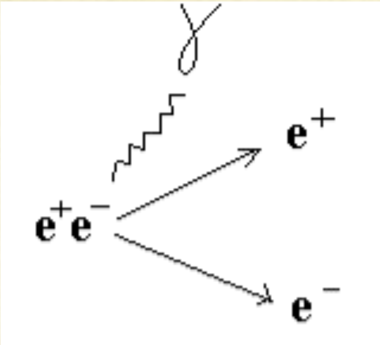
Radiative BhaBha events from the Summer 2012 production compared to the previous production

Rate vs Z-coordinate for Barrel



Reminder: the main contribution to the background are Radiative BhaBha

Effect of the Shielding on Radiative BhaBha Background



Some ``Shielding Physics"

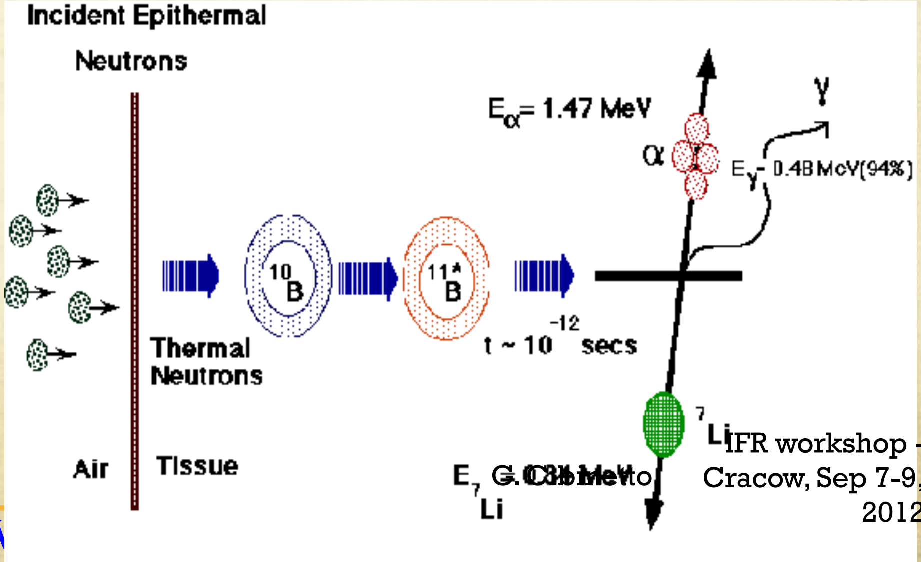
We added a **Polyethylene** $(C_2H_4)_nH_2$.)Boron Loaded (5%) shield for the following reasons

PE has a high hydrogen density which slows neutron particles down so they can be absorbed.

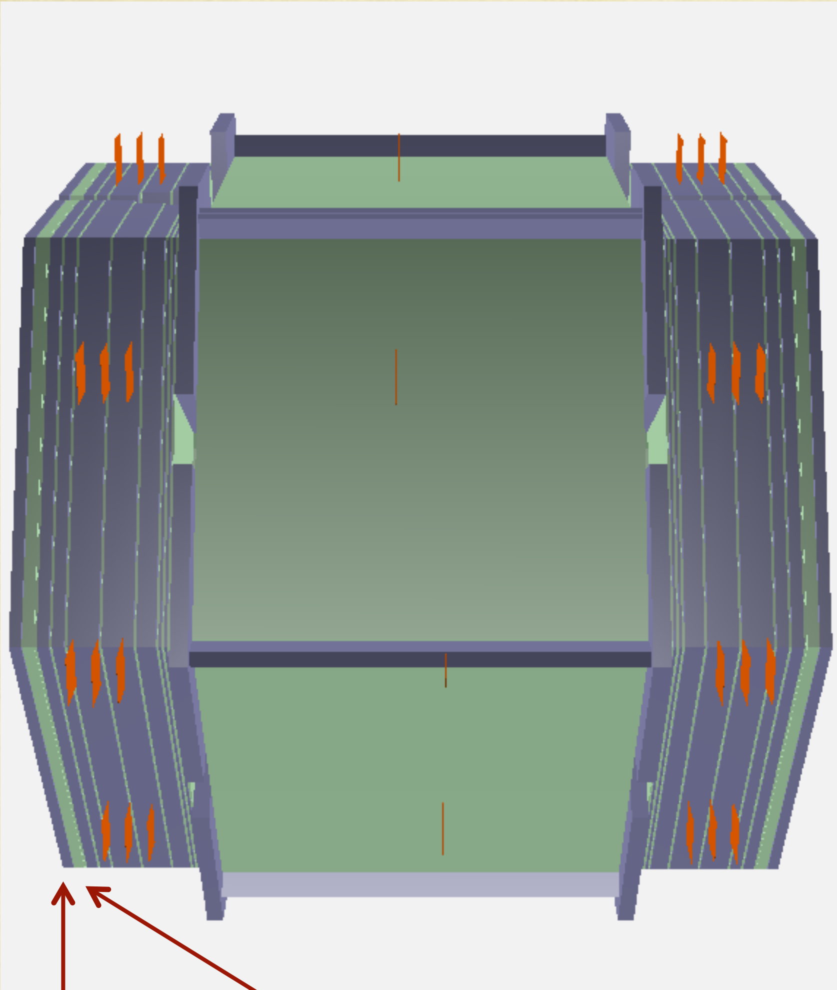
Hydrogen slow down neutron since when a fast neutron collides with a light nucleus, it loses a large fraction of its energy

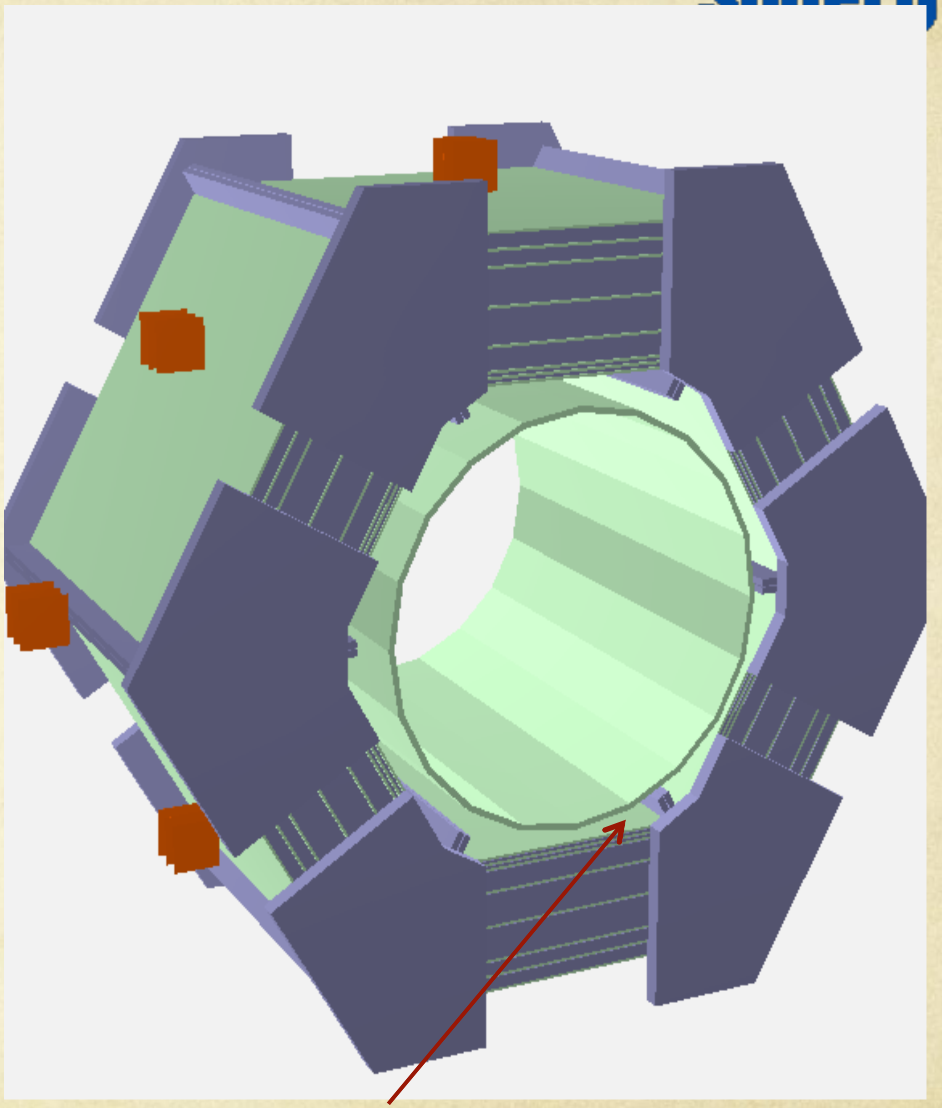
The Boron we used is natural Boron that is composed about 20% ^{10}B and 80% ^{11}B. ^{10}B has a very high cross section for capture of thermal neutron

.



Our Shield Configuration

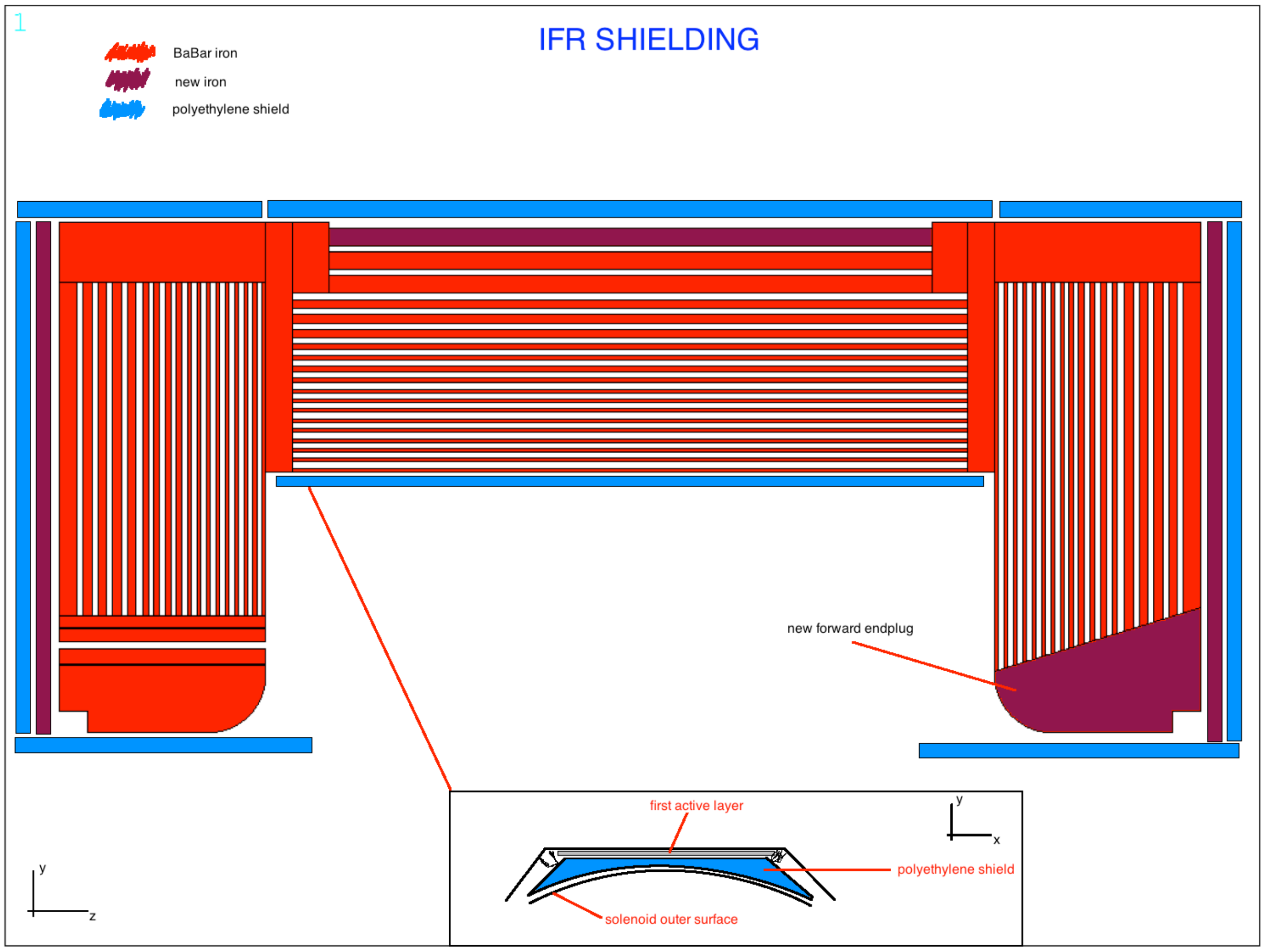




10 cm of PE+10 cm iron

5 cm PE

Shield configuration



This shielding configuration is mechanically rather complicated and probably expensive.

But it's a working prototype we are using to study with the simulation the effect of the shielding materials on the background.

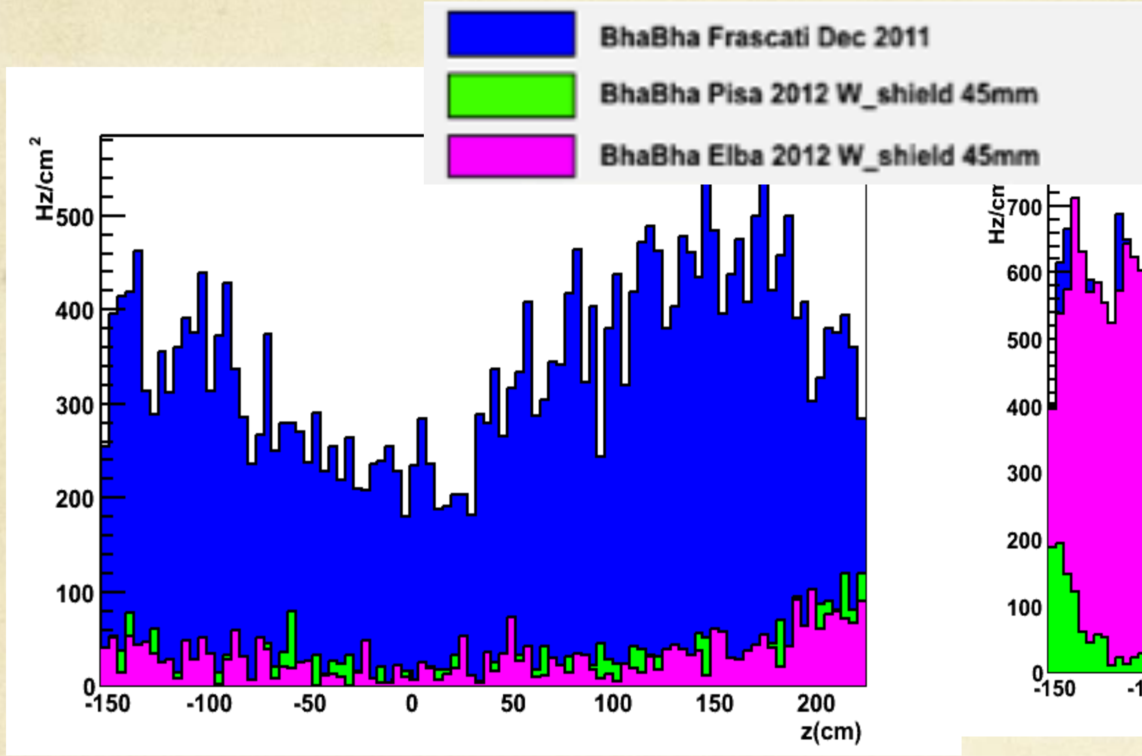
Some beampipe and tunnel shielding will be implemented once the maximum rate allowed will be established.

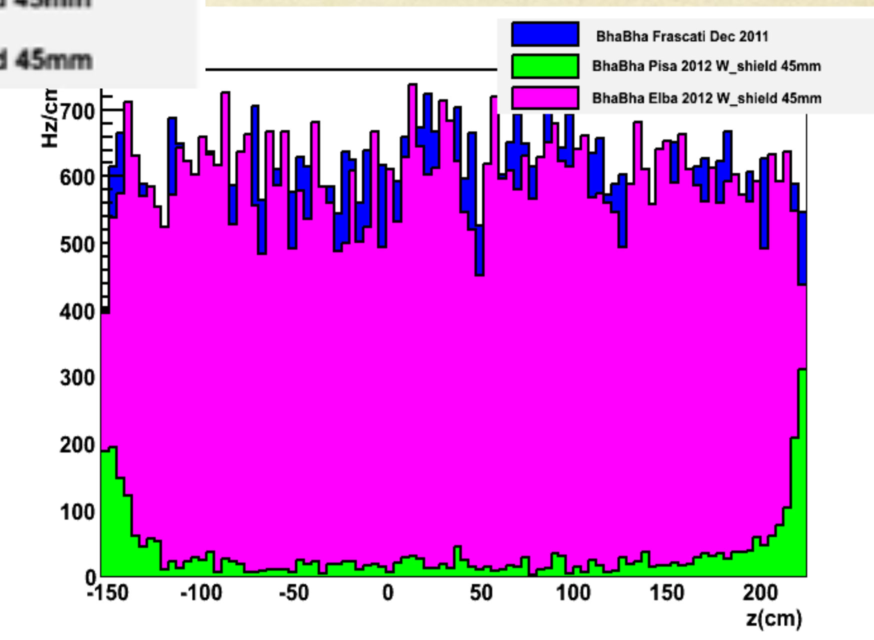
Neutron Distributions for Radiativa BhaBha events

Barrel

Rate L0 vs Z-coordinate for Barrel

Rate L7 vs Z-coordinate for Barrel



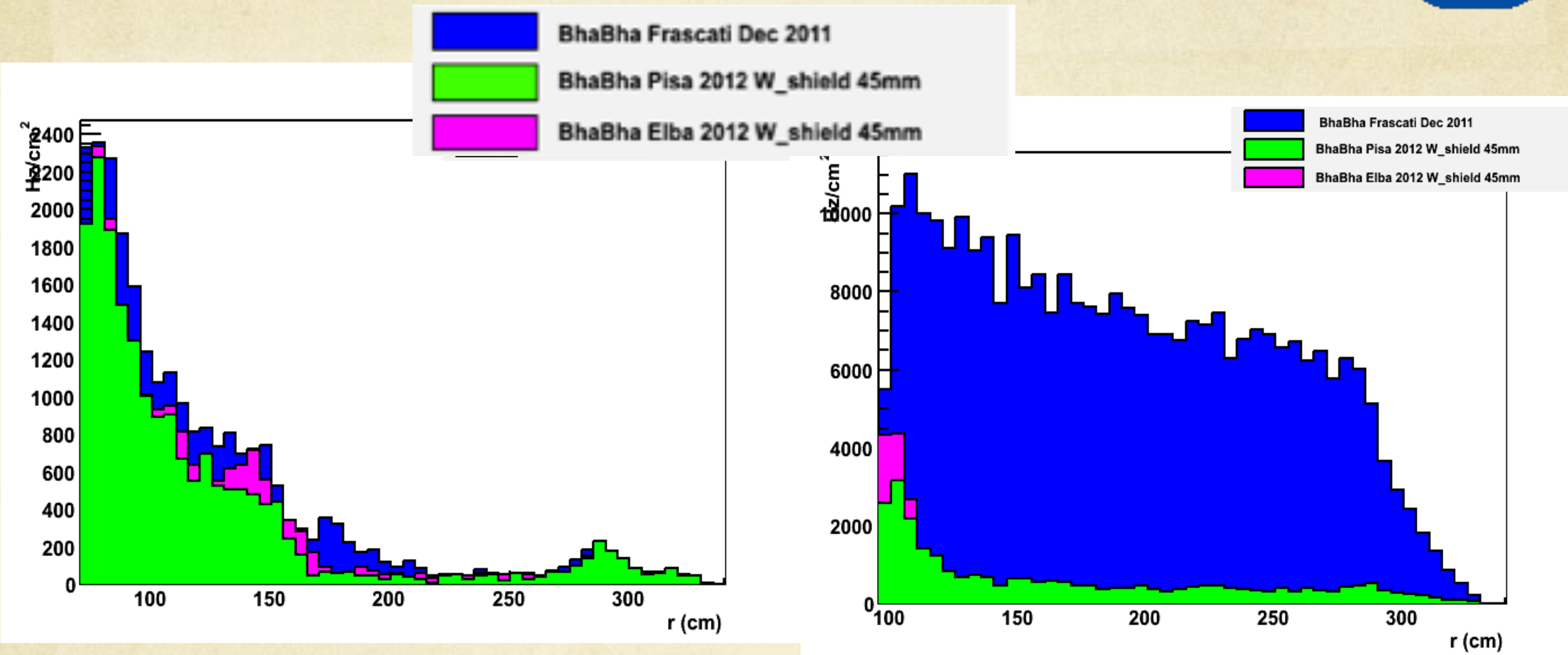


Significant reduction of the neutron rate on Barrel L0 and Barrel Layer 7 ~1 order of magnitude

Neutron Distributions for Radiativa BhaBha events

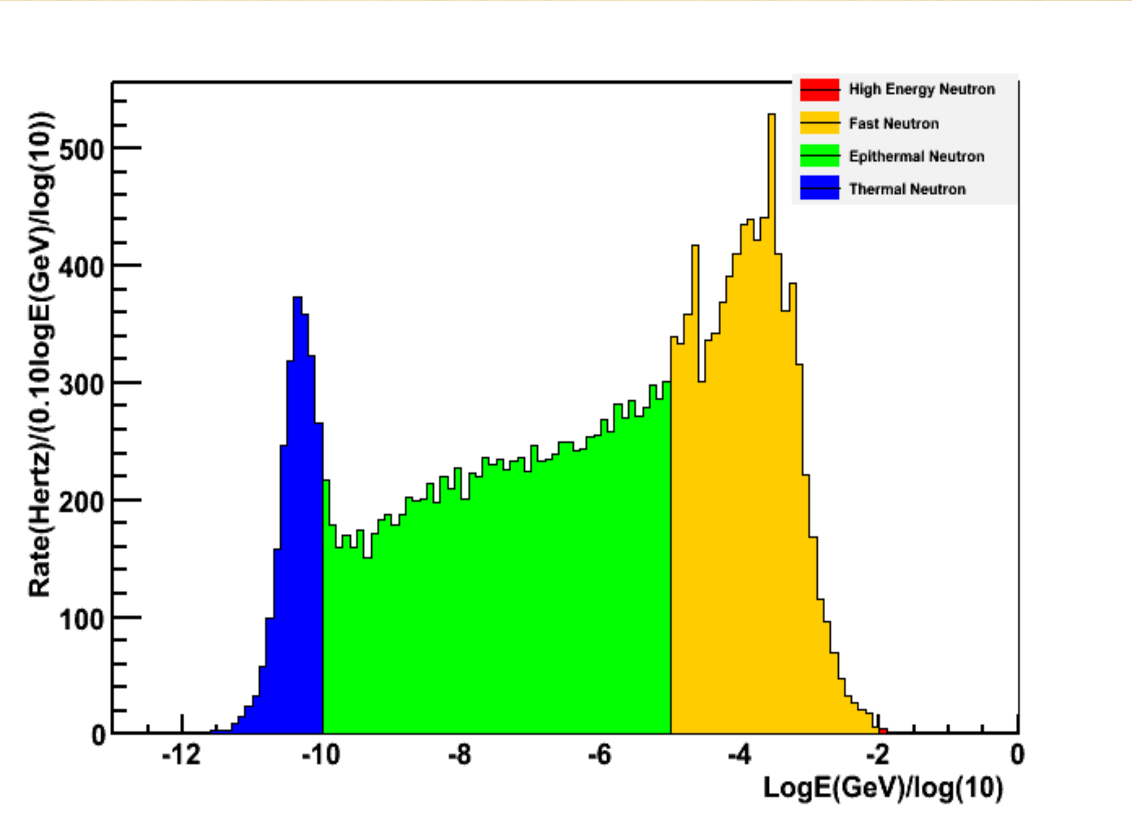
ENDCAP

Rate L0 vs Z-coordinate for FWD | **Rate L7 vs Z-coordinate for FWD**



Significant reduction of the neutron rate on FWD L7 but this does not happen on L0 since the L0 is not shielded

Reminder: Who are our neutrons ?



High Energy Neutrons have energy >100 MeV

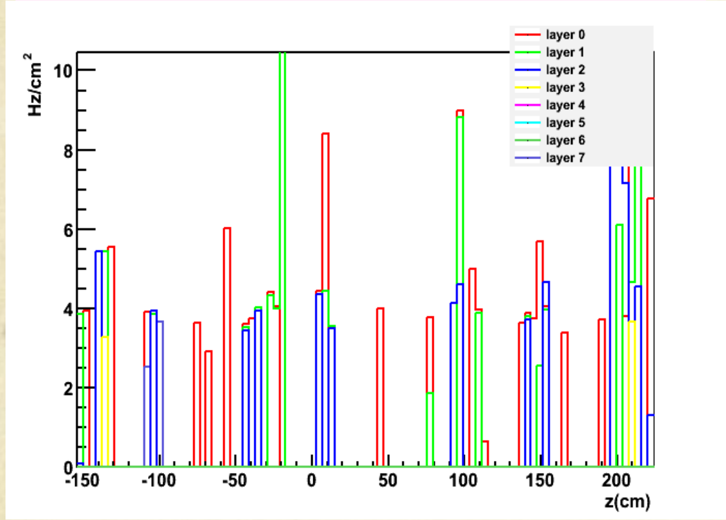
Fast Neutron have energy 10 KeV -100 MeV

Epithermal Neutron are Neutrons with energy 10 KeV and 0.1 ev

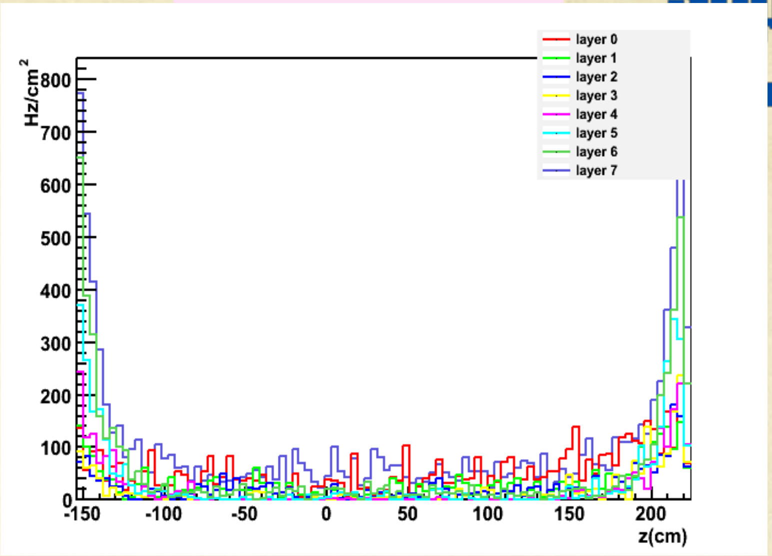
Thermal Neutron have energy <0.1 eV

Barrel Neutron Rate divided by Neutron Categories

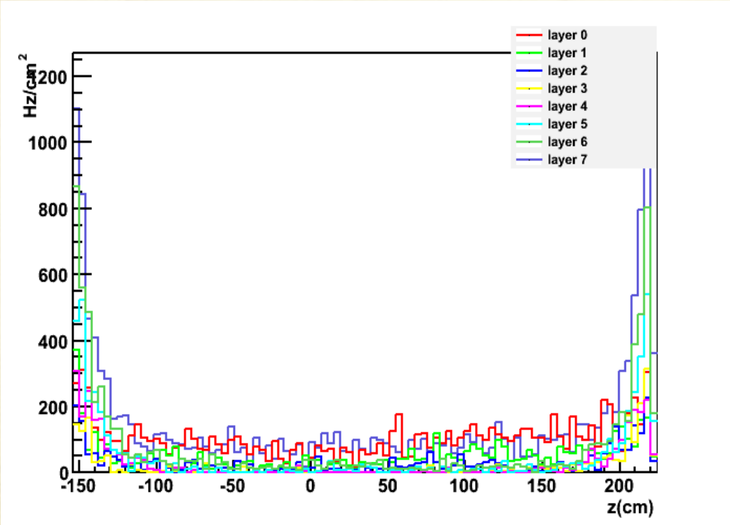
High Energy Neutrons



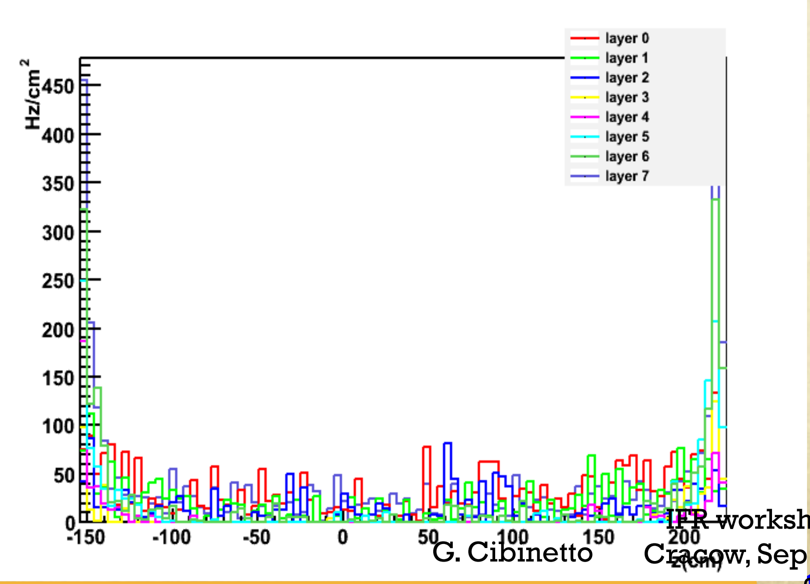
Fast Neutrons



Epithermal Neutrons

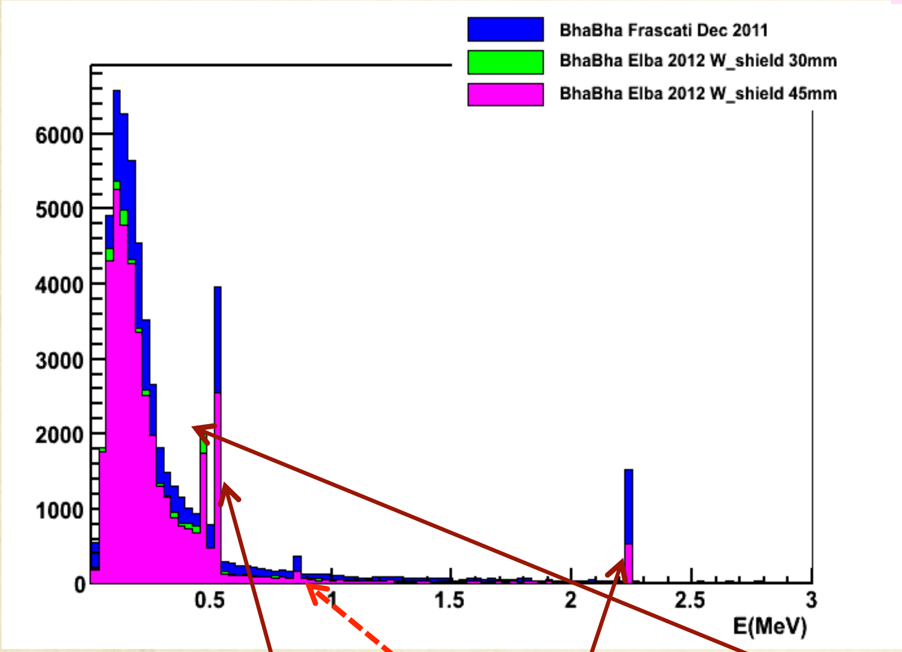


Thermal Neutrons

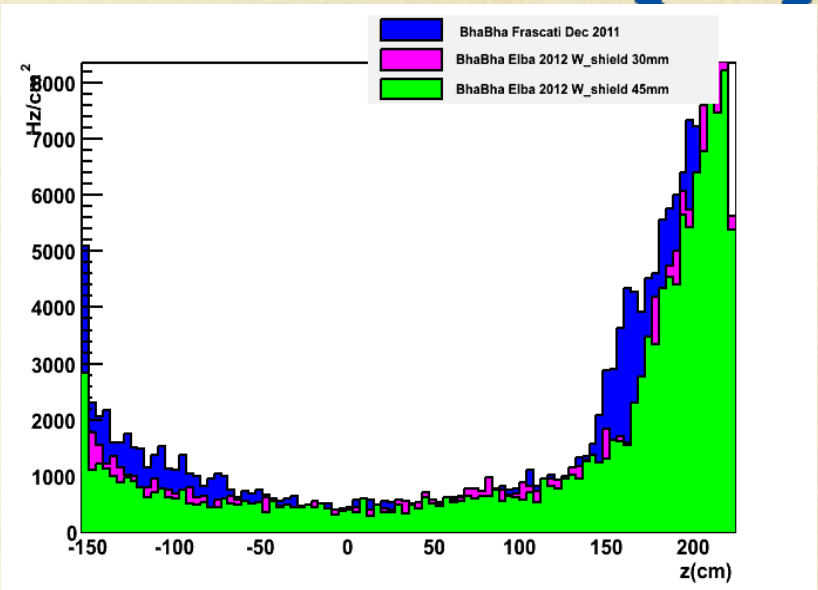


Photons Distributions

Barrel: Photon Energy Distribution



Rate vs Z-coordinate for Barrel



The Energy distribution for FWD and BWD Endcap are similar

Photons of energy ~0.512 MeV are from annihilation radiation

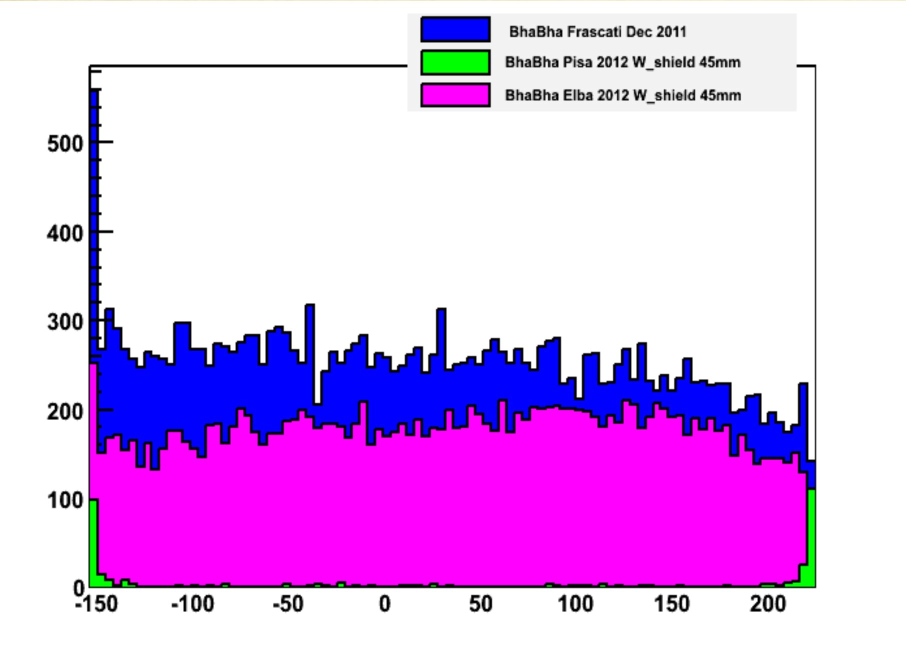
Photons of energy ~0.847 MeV are due from neutron inelastic scattering on Fe^{56}

NEW: Photons of energy ~0.48 MeV are from neutron capture on B^{10}

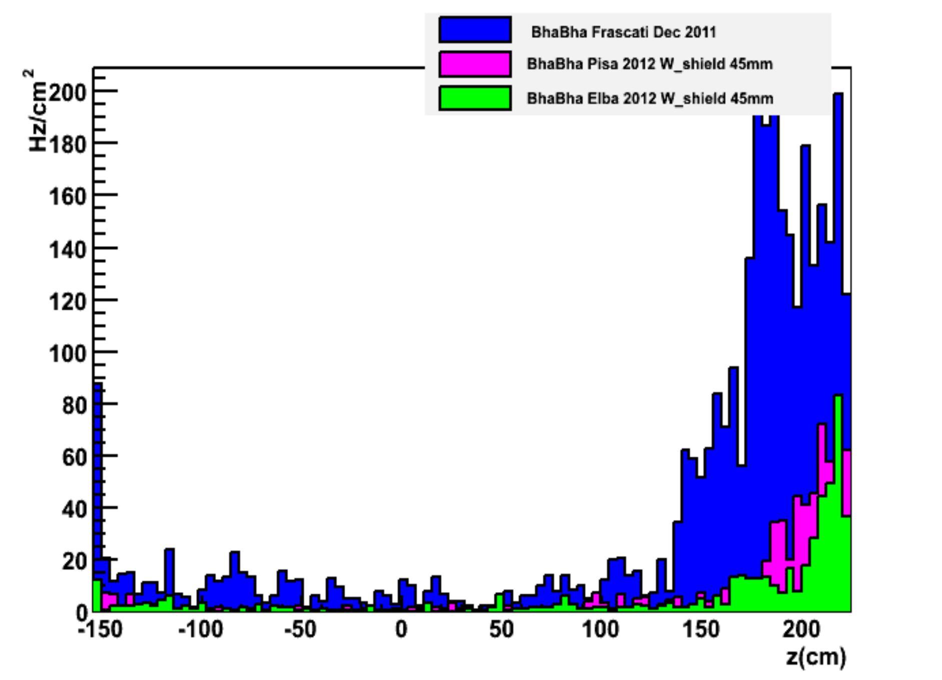
Photons of energy ~2.223 MeV are from neutron capture on Hydrogen

Electrons Distributions

Rate L7vs Z-coordinate for Barrel



Rate L0vs Z-coordinate for Barrel



The Energy distribution for FWD and BWD Endcap are similar

Significant reduction of the electron rate on Barrel L0 and L7

Our Shielding Strategy has worked extremely well

On the other hand ....

Shielding the Background from 753 B.C.

Summary and Future Plans

- ✓ Radiative BhaBha background, have been studied after the addition of the shielding. The results seem bery promising
- ✓ Other background sources after the shielding effects will be studied in the next days hope ready for the CM
- ✓ IFR TDR background uploaded 2 days ago

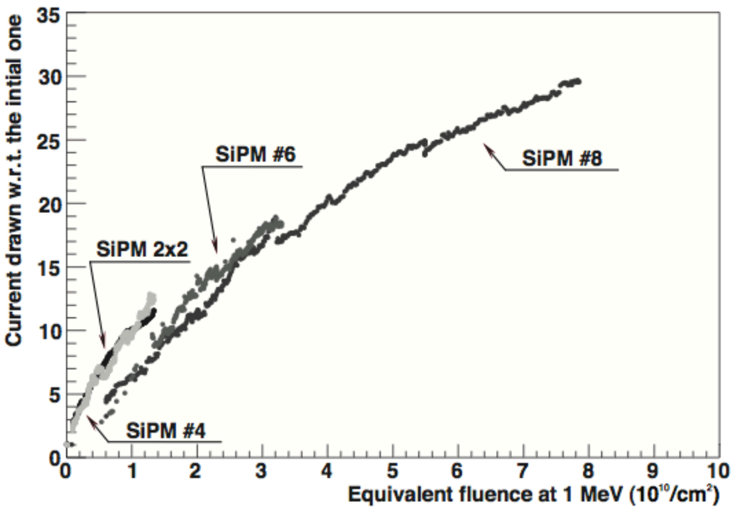
Preliminary results from the neutron irradiation test at Gelina

G. Tellarini
and
G. Cibinetto
on behalf of the IFR group

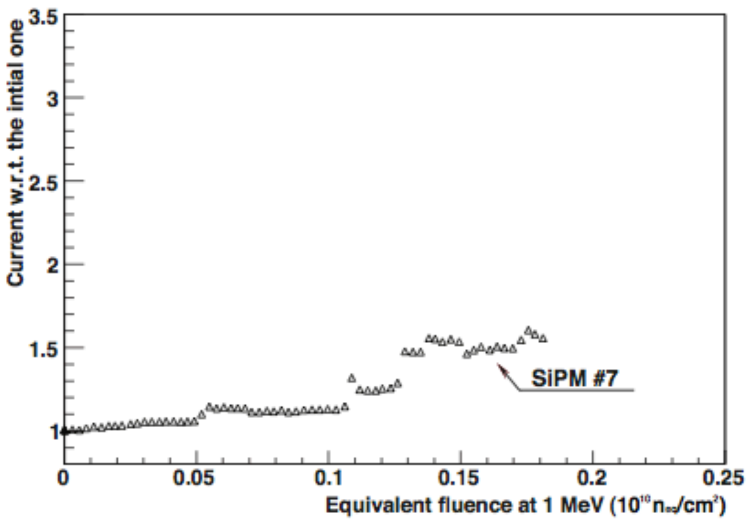
thanks to A. Montanari, V. Santoro, N. Tosi for providing useful plots and data

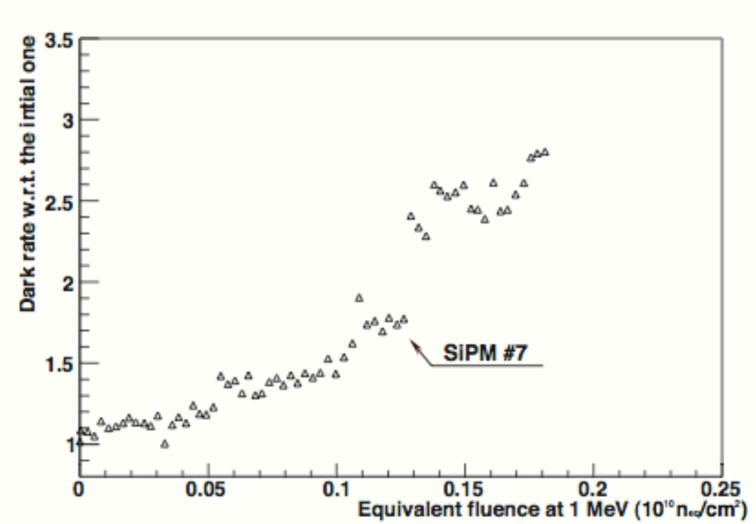
NIM A - Volume 623, Issue 3, 21 November 2010

Previous studies



- From our previous study at the ENEA FNG with 2.5MeV neutrons.
- SiPM start deteriorating after 109 neq/ cm2.
- SiPMs continue working but with worst performances (increasing of current, rate, and decreasing of the capability of detecting signals)





What else do we know

- Silicon damage doesn't largely depend on the temperature (but dark current does);
- Silicon damage doesn't largely depend on the Vbias (but dark current does);
- Damage depends on
  - Integrated dose
  - Neutron energy
  - Neutron flux (?)
- SiPM damage also depends on SiPM technology.

Implication for SuperB

- Due to the high neutron rate in SuperB we shall:

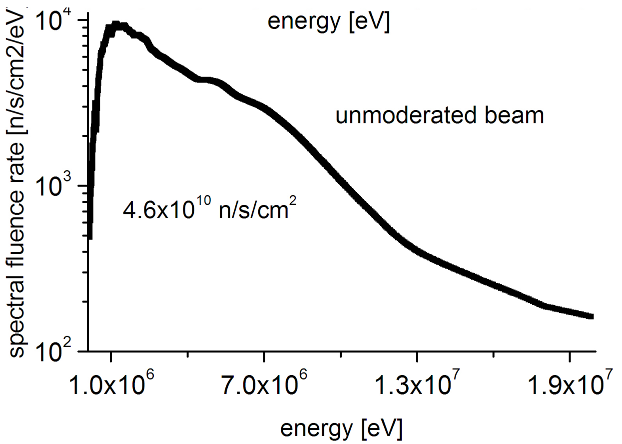
  1. Carefully study the neutron rate with simulations

  2. Study the SiPM damage with irradiation tests and establish the performances of such devices after irradiation.

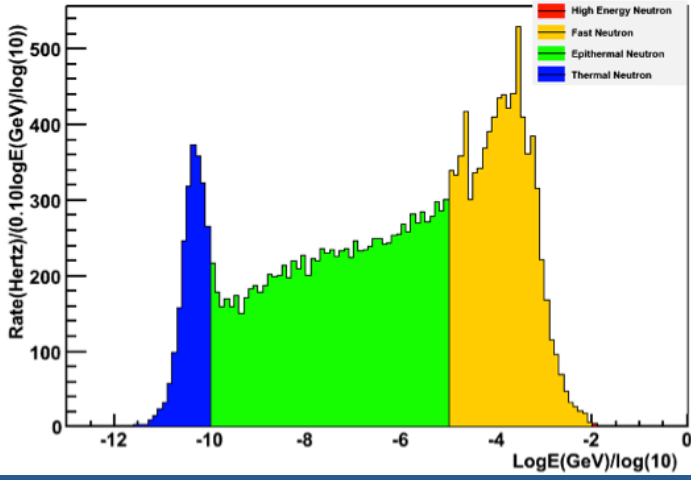
  3. Design the IFR detector in order to take into account both point 1 and 2.

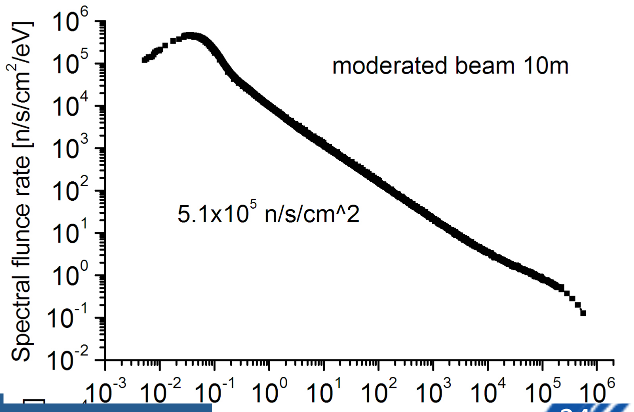
GELINA at IRMM

- This facility has a moderated neutron which has a spectrum that reproduces quite well part of the SuperB neutron spectrum; the low energy part.



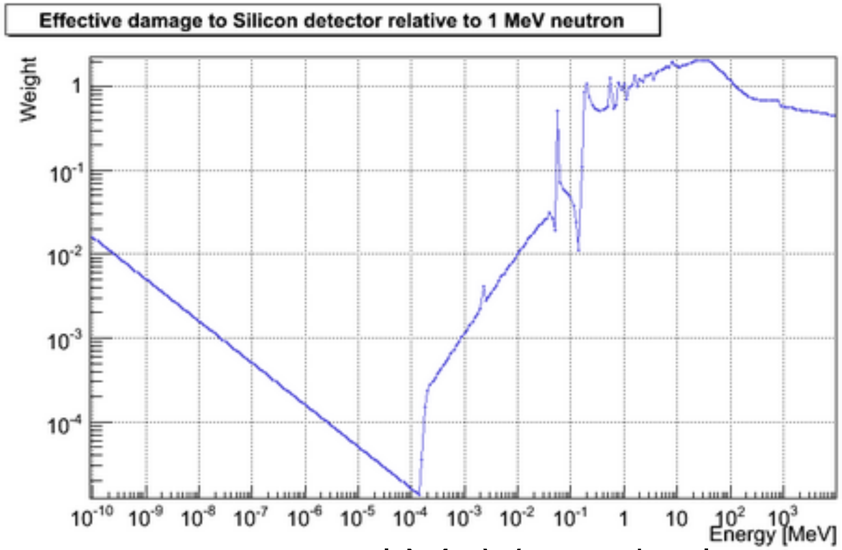
- Neutrons are produced by an electron beam on an uranium target via the same mechanism that occurs in SuperB





Purpose of the test

- Most of SiPM irradiation tests have been done with energetic neutrons; low energy neutrons are supposed to have less impact on silicon damage.

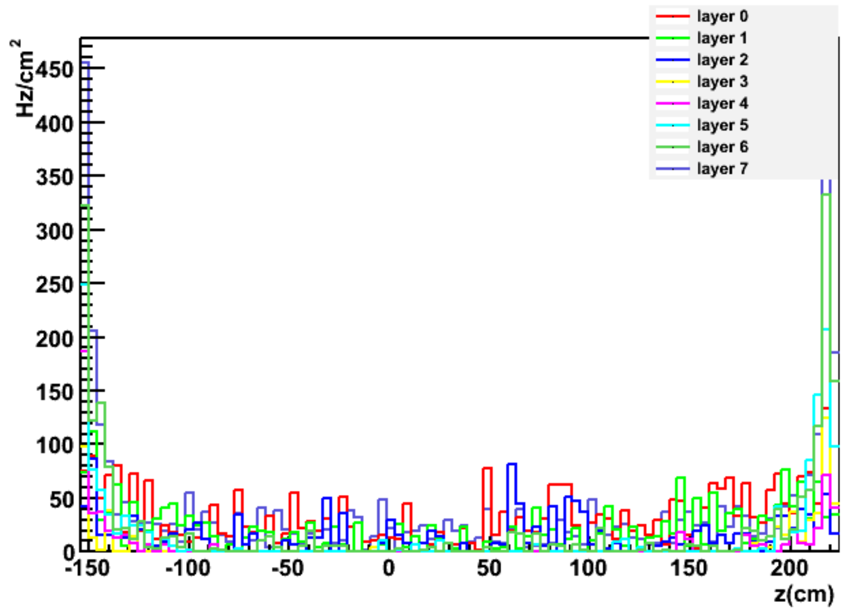


- We use to normalize all the neutron rates to 1MeV equivalent dose. Is that completely valid for SiPM technology? Is the effect of nuclear reactions happening with low energetic neutron correctly taken into account in the weight?

- The purpose of this test is to check that with an very performing apparatus.

Required rates

- From Valentina's talk we expect an average rate of 50Hz/cm^2 of thermal neutrons in the innermost layers of the barrel, and a bit more epithermal neutrons (<10keV)



- That makes about 10^{10} low energy neutrons per cm^2 per running year (including x5 safety factor)

- We planed to integrate the equivalent of about 5 years of running (5×10^{10}n/cm^2) in two weeks of data taking.

- Unfortunately we there was and issue with the machine that lowered the intensity to less than ½ of the nominal value and we took a couple of extra days to setup our apparatus so we got up to ~1.86 n/cm^2 (and is not so bad).

Our setup @ GELINA

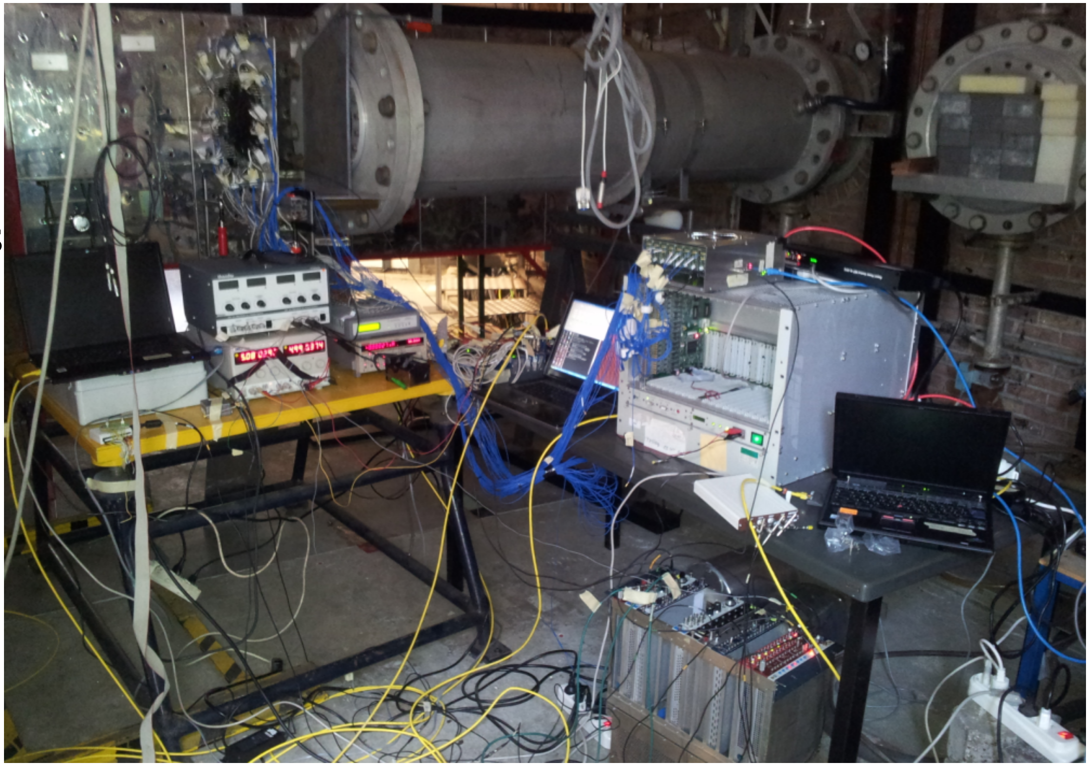
The Bologna-Ferrara multi-purpose setup

Dark current online monitoring

Dark count online monitoring

I-V characteristics of the devices

Threshold scan

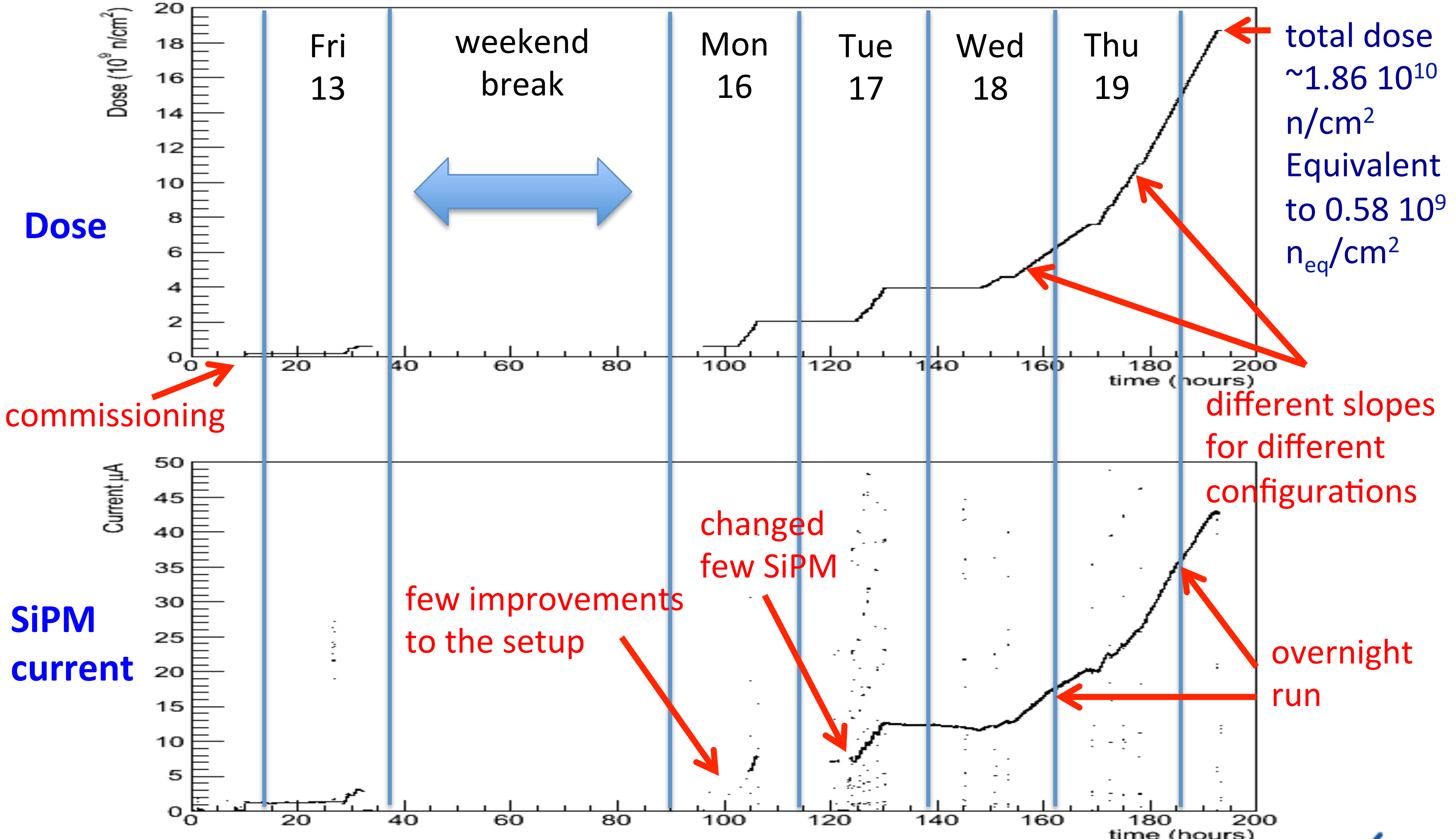


Noise charge spectra

Cosmic ray detection

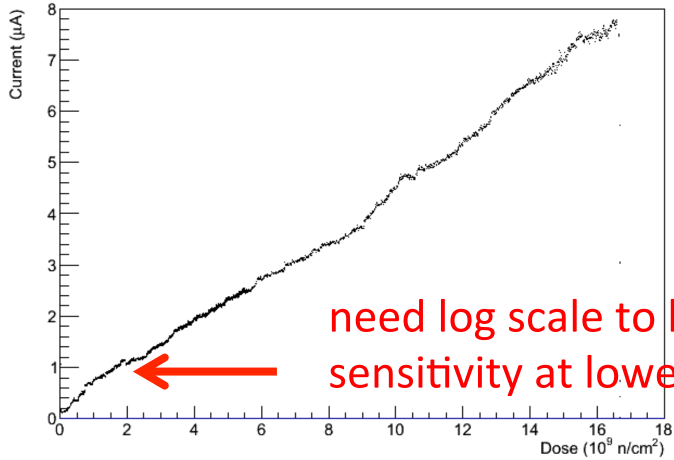
Cosmic ray device characterization

Data taking time-lapse

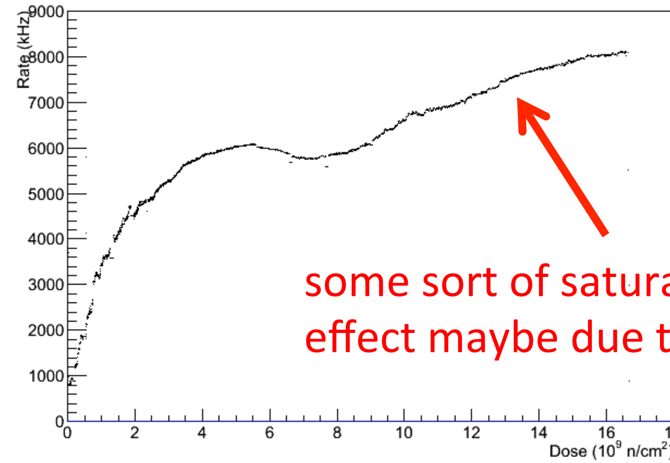


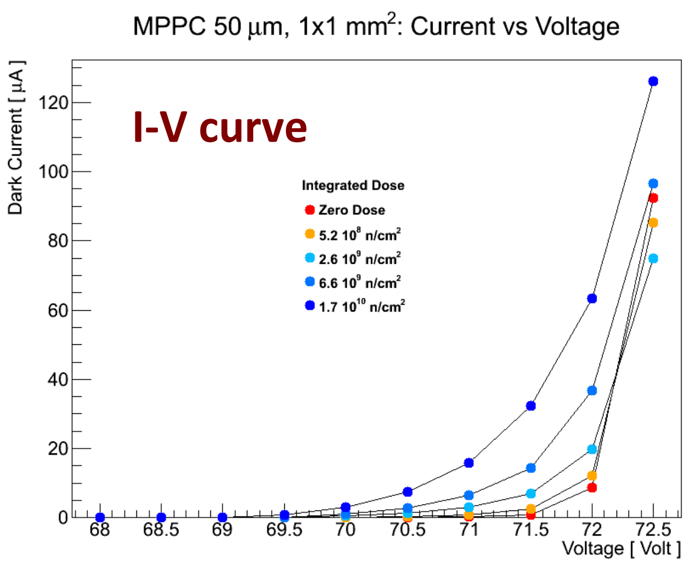
Few examples of our potential – MPPC 1x1mm^2 50um cell

Current vs dose

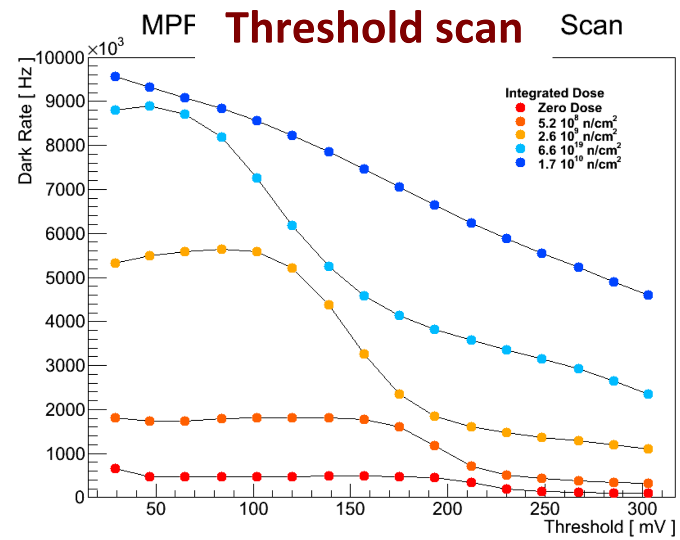


Dark rate vs dose

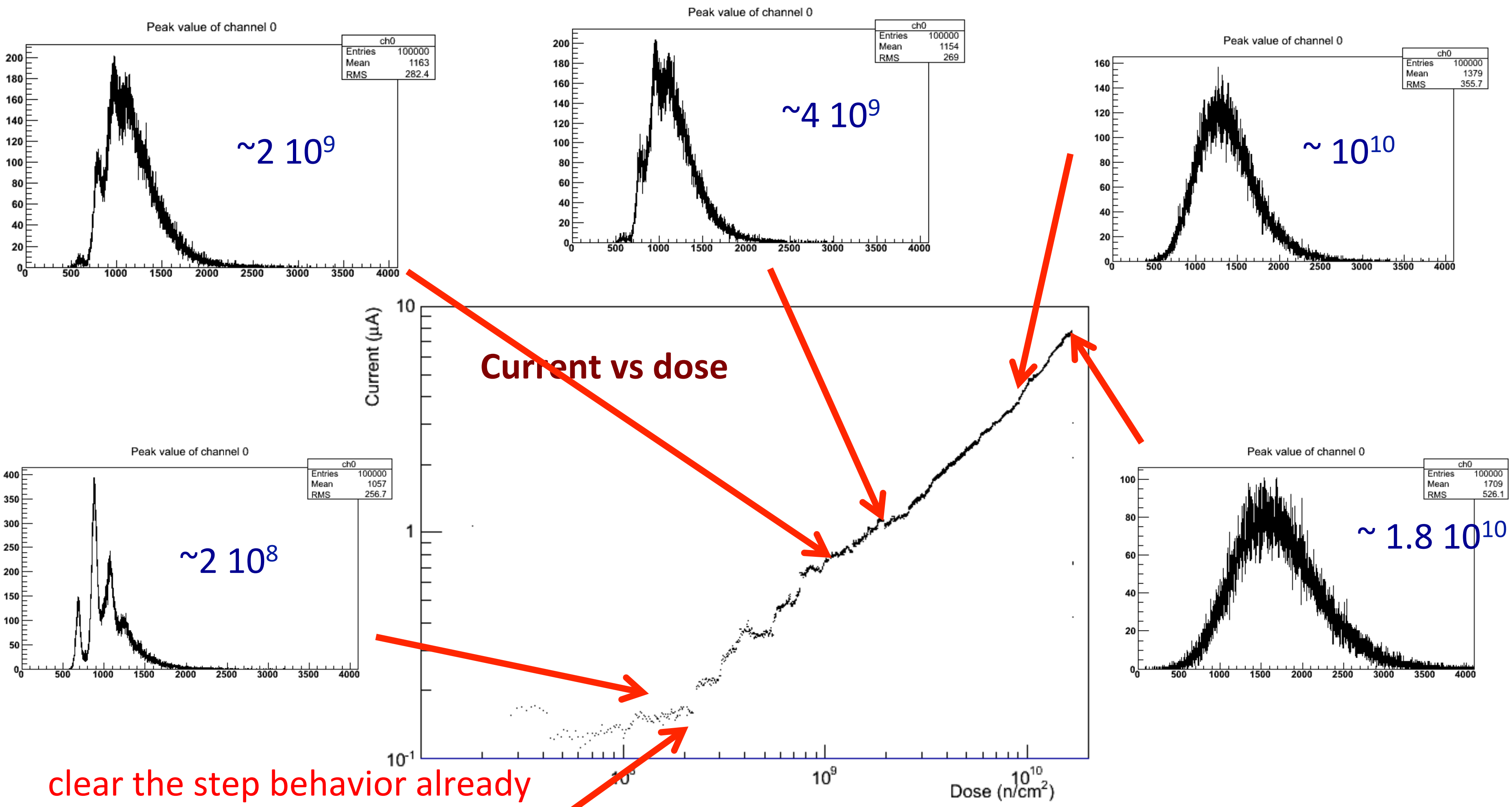




Threshold scan



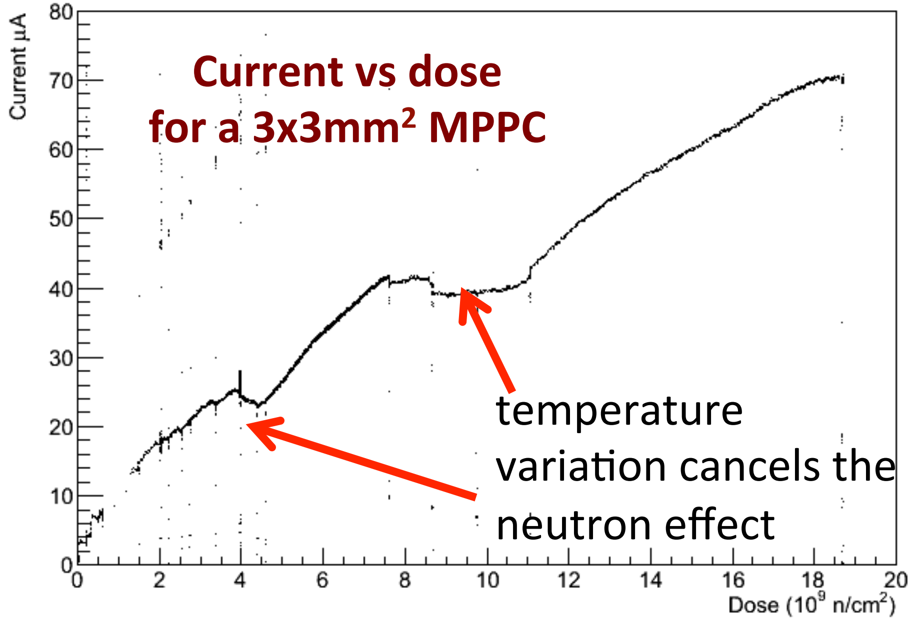
MPPC 1x1mm^2 50um cell – Charge spectra



clear the step behavior already observed in our previous test

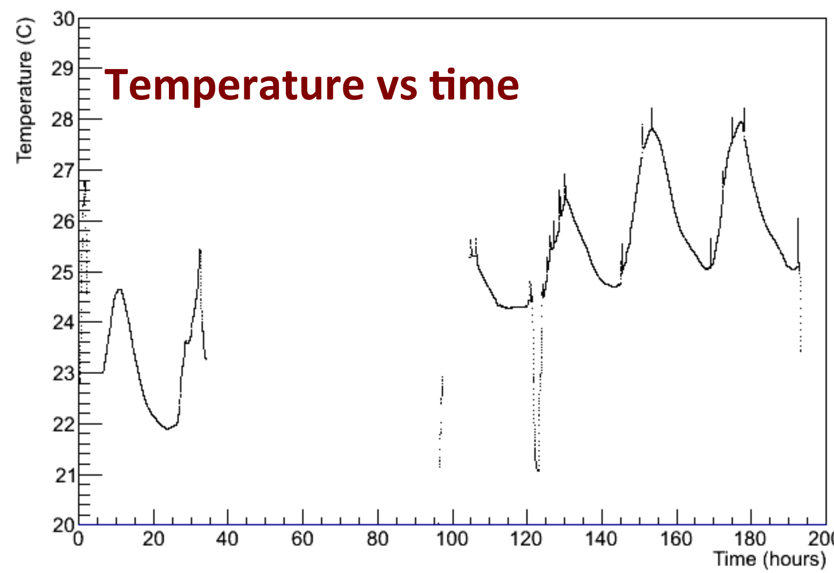
Dark count spectra are a courtesy of Alessandro Montanari and Nicolo' Tosi (Bologna)

Temperature effect

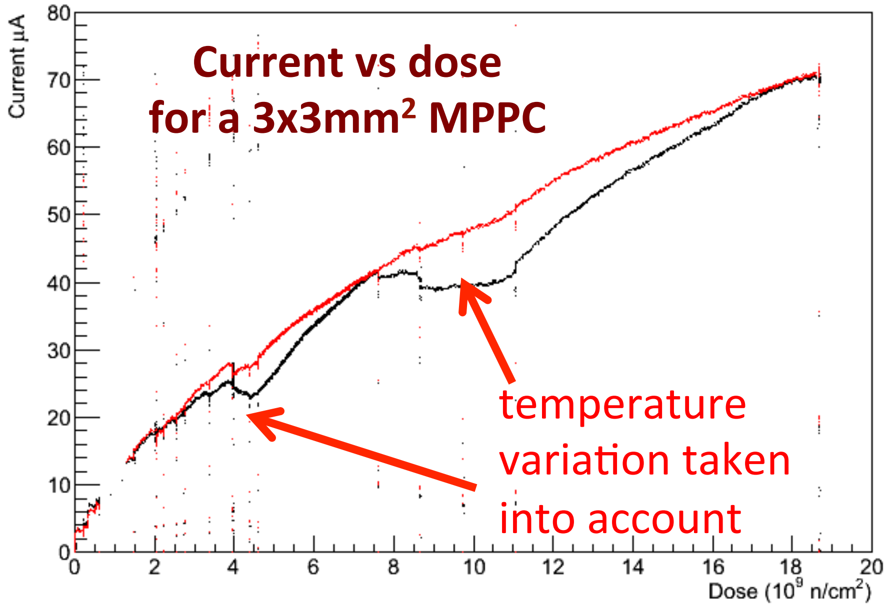


- It's well known how well the SiPM gain, current and rates depend on the temperature.
- Especially the MPPC can be largely affected by temperature variation.

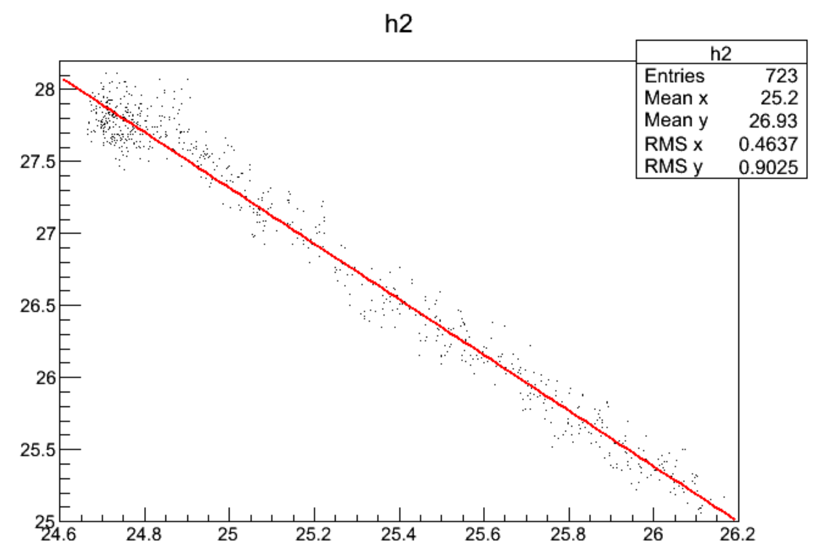
Temperature was monitored but no bias correction has been applied during the test.



Temperature calibration

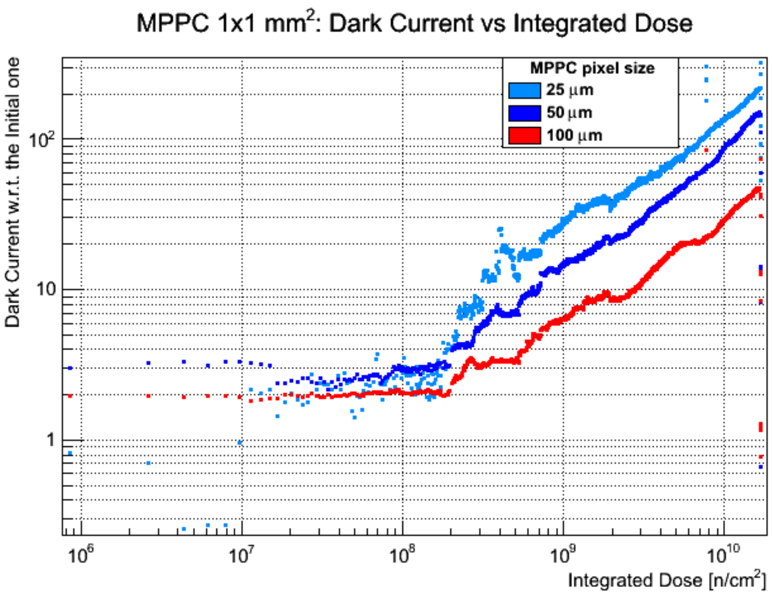


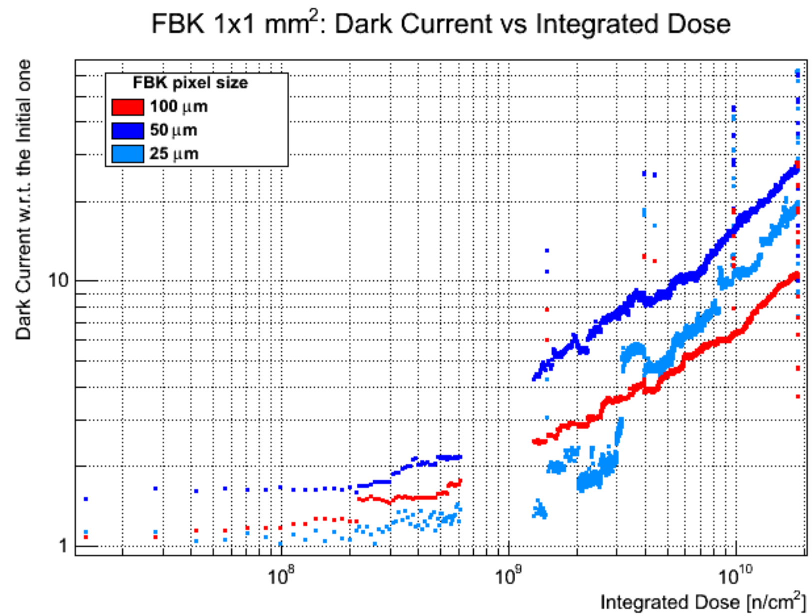
- We used overnight runs with no beam to calibrate the current vs temperature behavior and we use the results of the fit to correct the data..

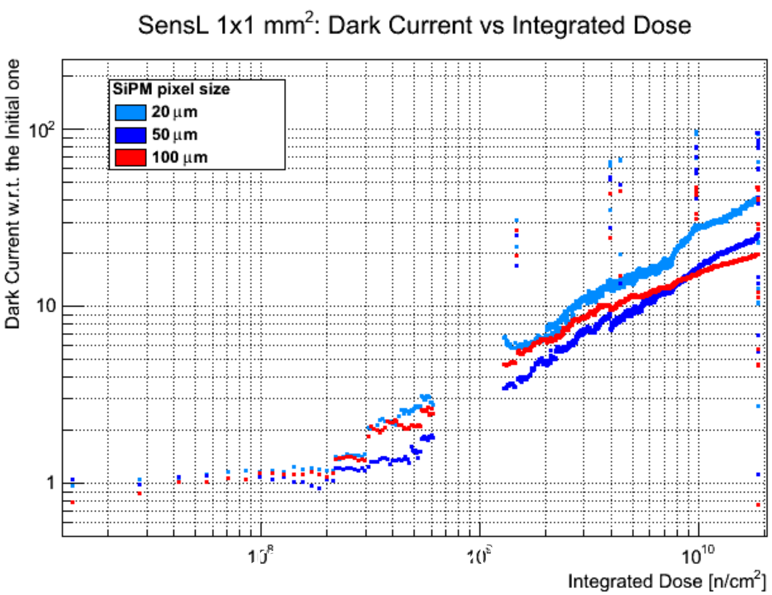


- Including the temperature effect is certainly better but it doesn't change a lot the conclusions of this test;
- Therefore, since it's also painful make such a calibration (and correction) channel by channel, we decided to drop it.

Different cell size

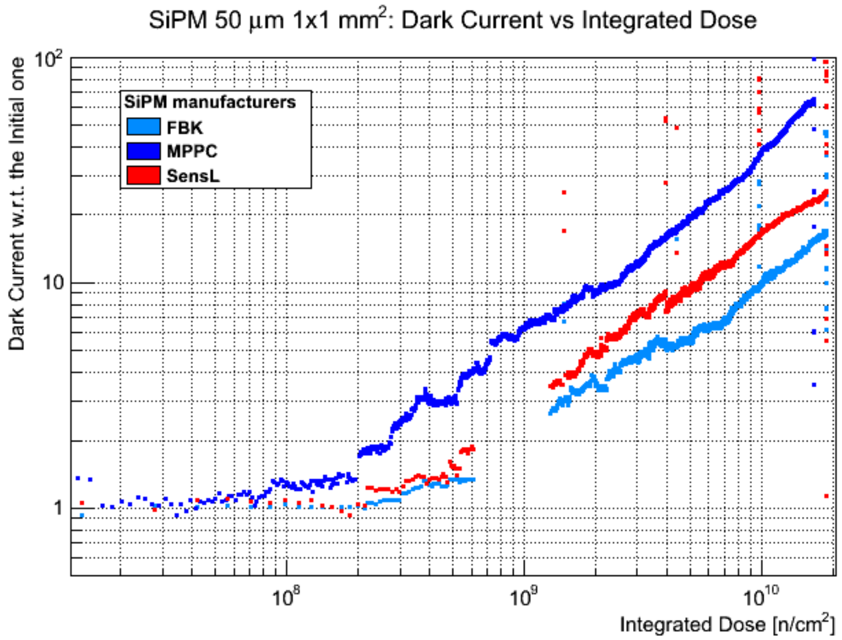




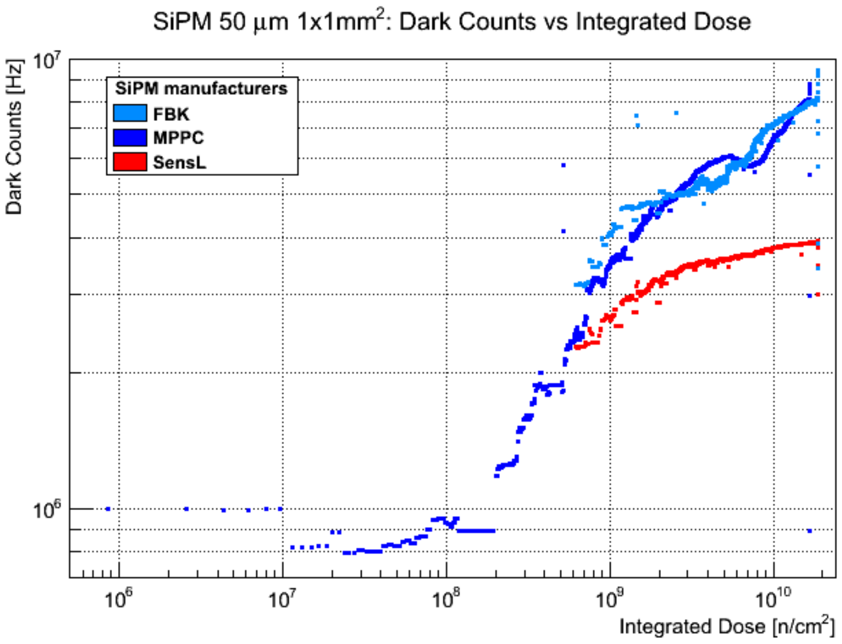


- Current vs integrated dose for MPPC, SensL and FBK devices.
- In the sample plots are reported the currents normalized to the initial ones for different cell size.

Same cell size (50um) different brand



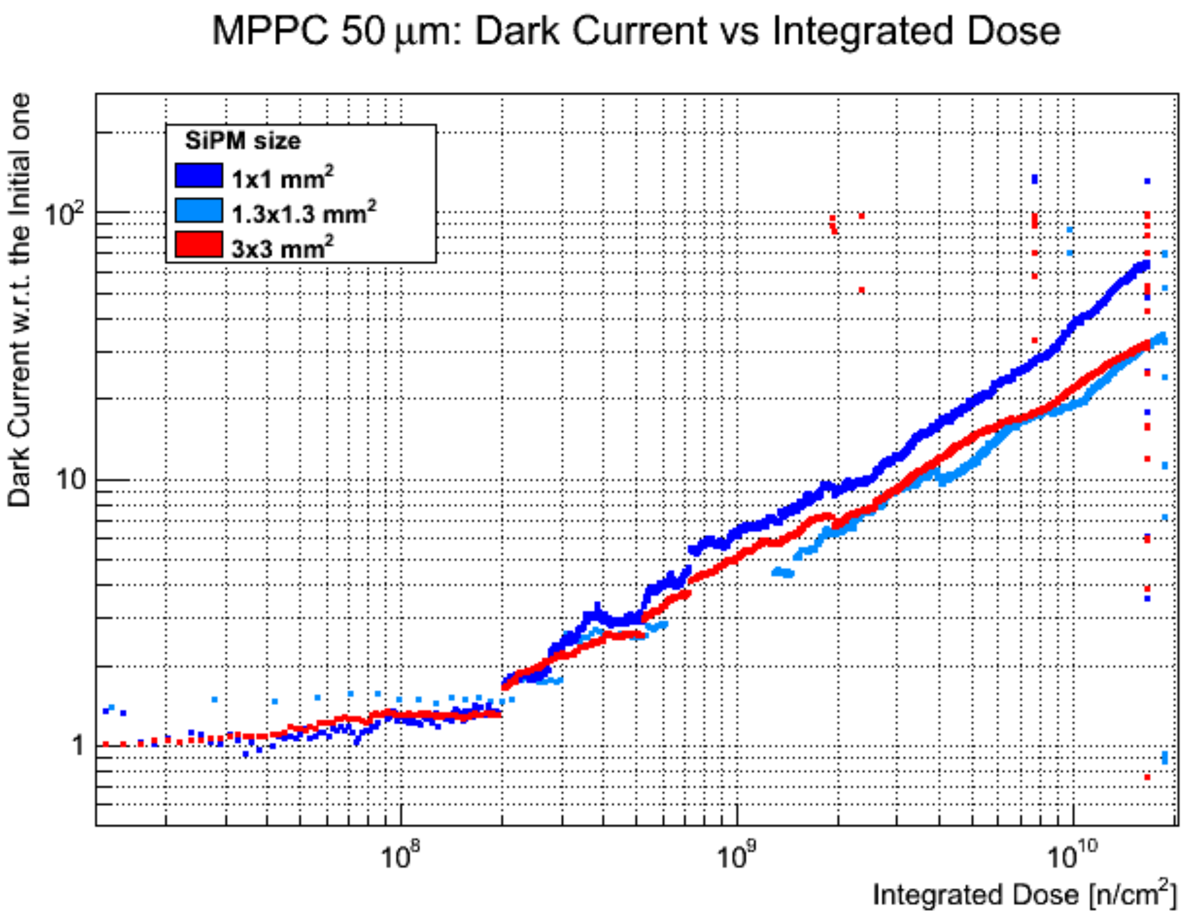
Currents vs dose



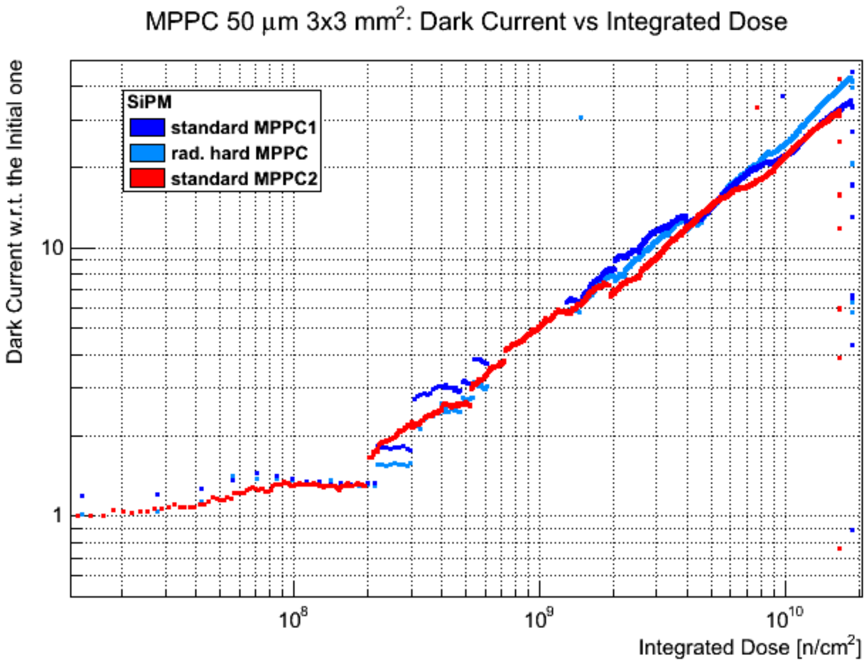
Dark counts vs dose

Same brand, same cell, different size…

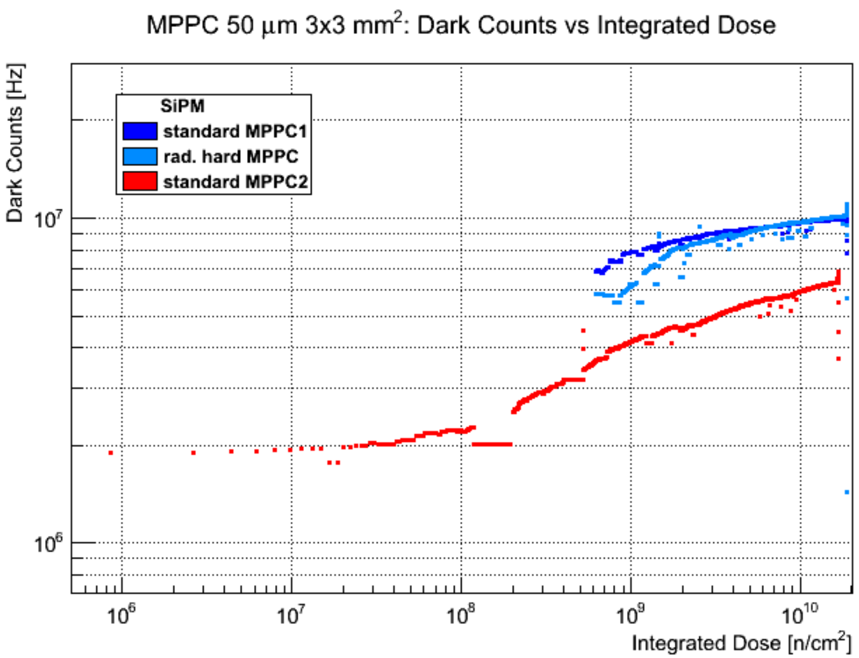
… and different packaging



MPPC radiation hard

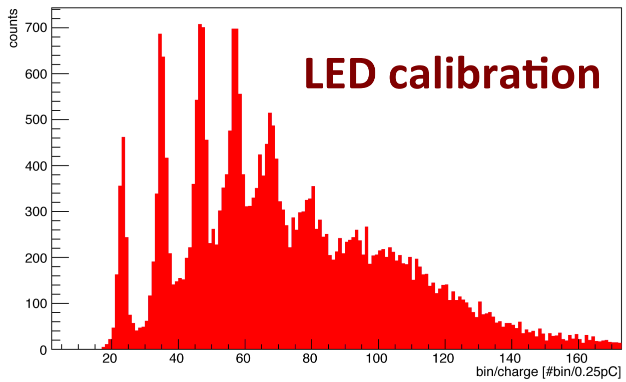


Special MPPC radiation hard have also been tested.



No particular difference with the other ones can be observed from currents and rates analysis.

MPPC rad hard with cosmic test

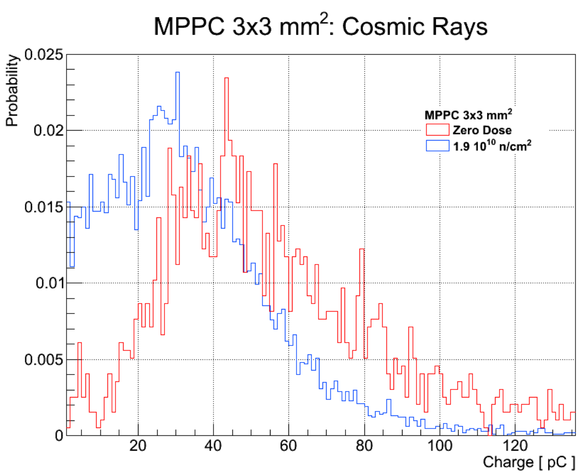


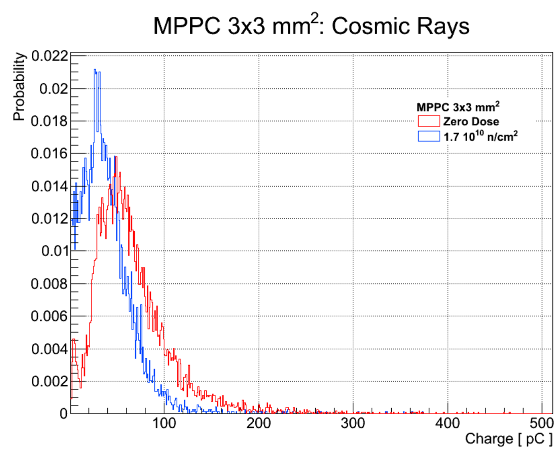
The light yield has been also measured before and after the irradiation with using a scintillator bar.

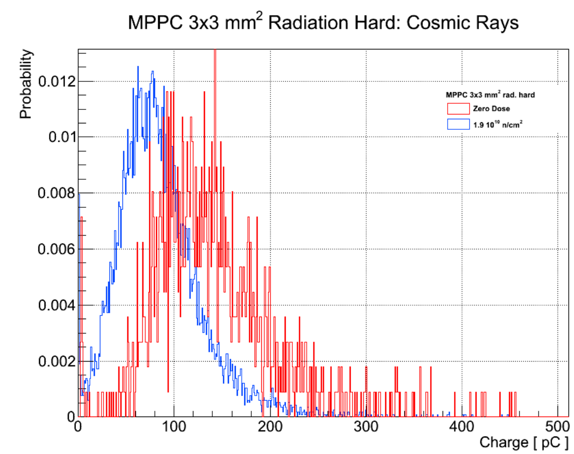
No final results yet, need more careful studies; but at a first sight

- the efficiency loss is not negligible
- the rad hard devices performs like the others

Cosmic ray spectra







What is left

- We need to finalize some analysis:
  - I showed only few plots, we need to do a careful characterization of all the devices
  - Understand some issues and strange behavior (e.g. single rate saturation)

- Do more tests to study possible annealing effects
  - with cosmic ray (light yield)
  - with the GELINA setup (currents and rates)

- Refine doses calculation (we are waiting for some calibration constants from the facility experts)

What has been learned so far

- MPPCs current seems to rise faster than the SensL and FBK SiPM.
- MPPC radiation hard devices look like the non rad hard.
- Low energy neutrons are probably more dangerous than we expected.

  - "Are we dead now?"
  - "No!"
  - "So we are safe!"
  - "mmm… fifty-fifty"

Homework

- Next steps need to be planned and prepared in details.
- We have a powerful apparatus for radiation damage measurements, so let's use it!
- What we missed here was a careful characterization of all the devices before the irradiation: currents, rates, i-v and light yield with cosmics.
- We can also add more feature to our setup but more important is to set the boundary conditions; we need to have a detection module layout, establish the minimal light we wand to detect with it and the maximum dark rate allowed.
- And then see up to what dose the SiPM can make it.
- And then again go back to the simulation and work on shielding to be sure we can make it.