# Neutron irradiation test at FNG (I)

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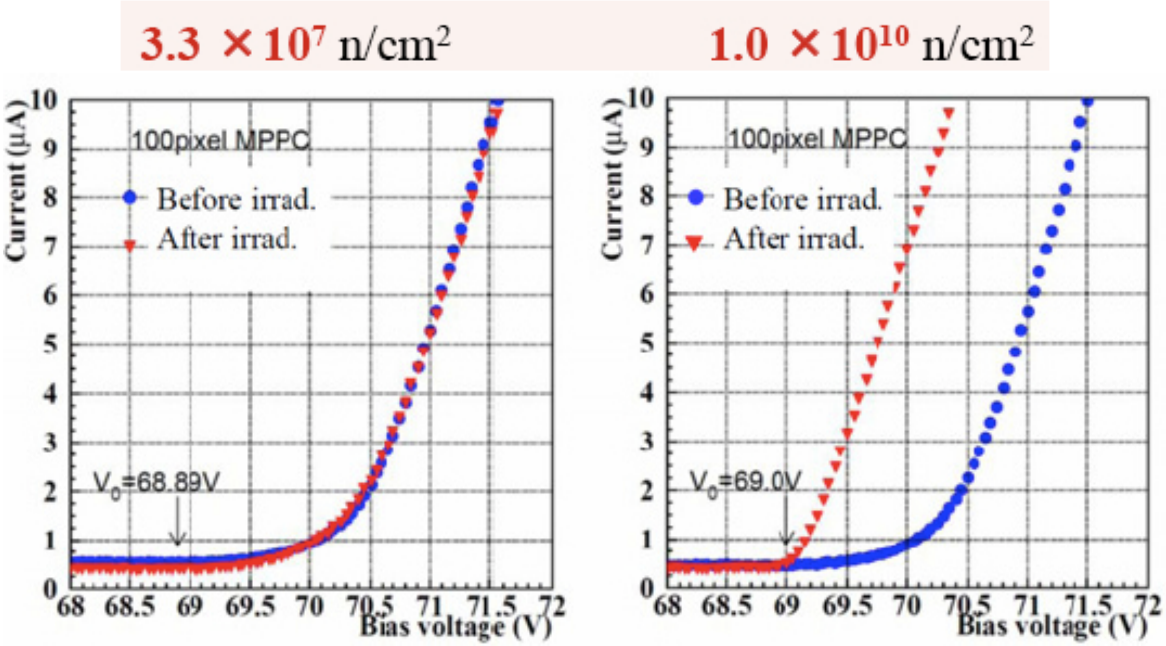
# Outline

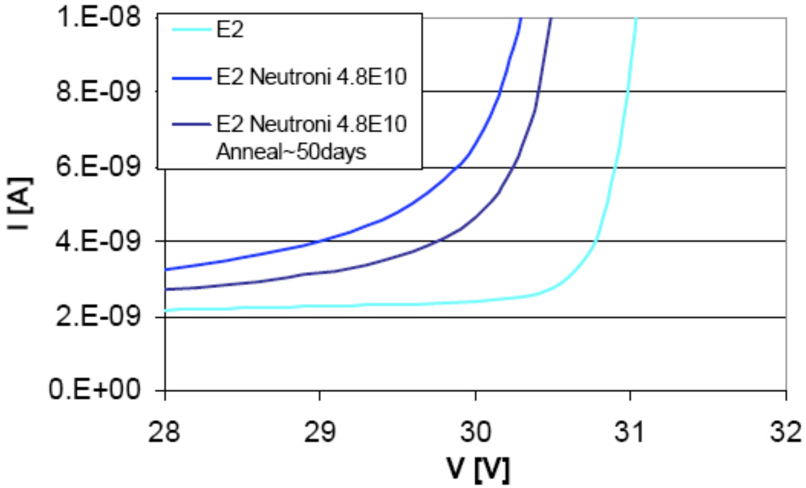
- Introduction to the neutron irradiation test
- Test setup
- Preliminary results
  - Temperature and bias corrections
  - gain measurements
  - light yield
  - I'll focus on the characterization: more results will be presented by Davide

# Motivation

- First studies show that MPPC can be damaged by high neutron rates.
- Test done before and after irradiation show an increase of the dark current and rate.




Toru Matsumura for the KEK Detector Technology Project




- Similar results confirmed by FACTOR collaboration also on SiPM
- Still poor documentation in literature

# The BaBar neutron rates

Quoting J. Va'vra

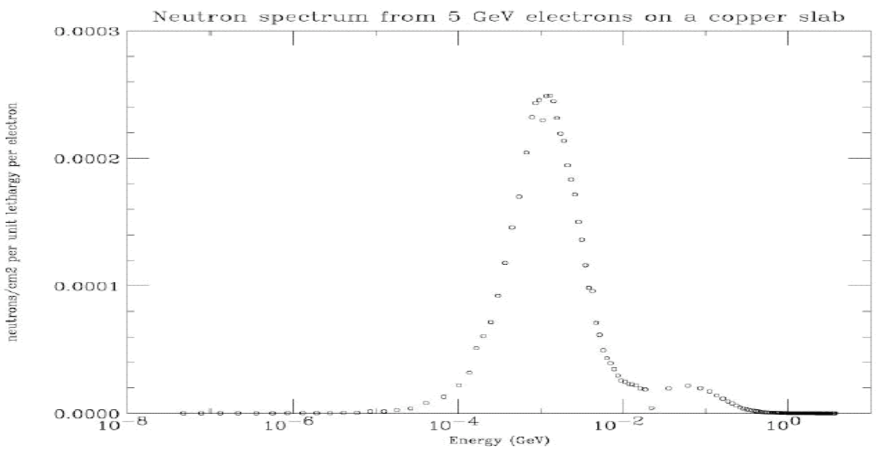
Assume, naively I should say, that the there is a single source coming from radiative Bhabhas striking some region between Q3&Q4. Its position was worked out from the two counter rates assuming assuming the spherical propagation.

Using this spherical model, I estimate a rate of ~$1.6x10^9$ Hz going into 4pi for a BaBar luminosity of $7x10^{33}$.

From there I can estimate rates at various detector faces in BaBar and compare them to the CMS rates. I have no way to verify that these rates are correct. However, Chris O'Grady told me that a rate of DCH FPGA resets was consistent with my flux estimate on the DCH face, if he uses some LHC R&D data.

**3) Incident neutron flux into various detectors at ~$7x10^{33}cm^{-2}sec^{-1}$:**

| **BaBar Detector** | Dist. to the source [cm] | **Inc. rate** [Hz/cm$^2$] |
|---|---|---|
| **RPC** - forward small radius | ~140 | ~$6.5x10^3$ |
| **EMC** - forward small radius | ~90 | ~$1.6x10^4$ |
| **DCH** - electronics backward end | ~250 | ~$2.0x10^3$ |
| **DIRC** - front end entry into SOB | ~450 | ~$6.2x10^2$ |
| **VTX** – middle section | ~130 | ~$7.5x10^3$ |




Roberto Fasso from SLAC radiation group calculated energy spectra of these neutrons at BaBar using Fluke program. Assuming 4-9 electrons striking Cu or Fe flange, they are typically 1-2 MeV neutrons. I include his simulated spectrum.

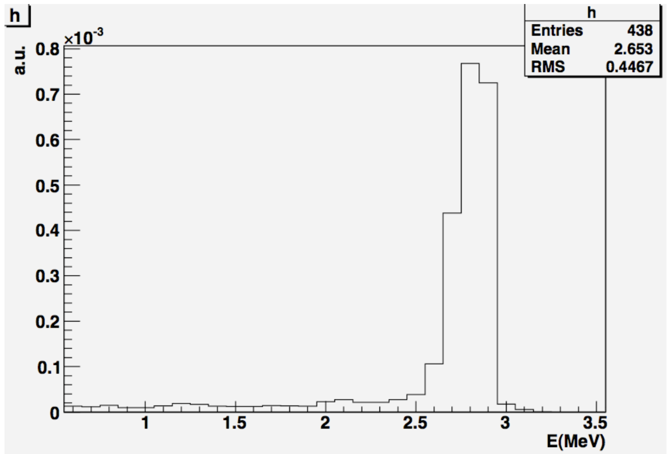
Last but not necessarily the least. Every neutron ends its life with a few Gammas of a few MeV. That is a final additional background.

# The idea

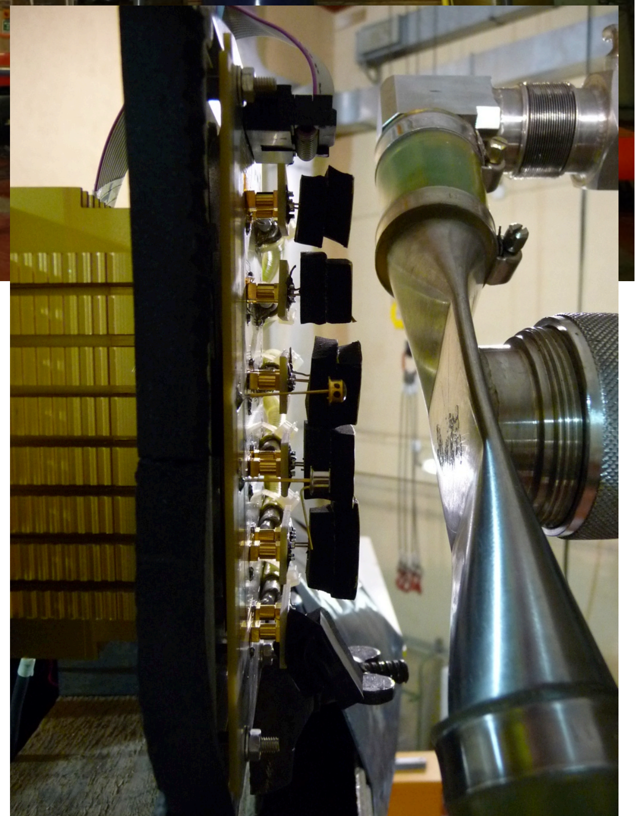
- Perform online measurements of currents and rates, during the irradiation, to see where the SiPM starts degrading.
- Trying to understand when the SiPM/MPPC became unusable
- Identify any possible shield or remediation

# The FNG

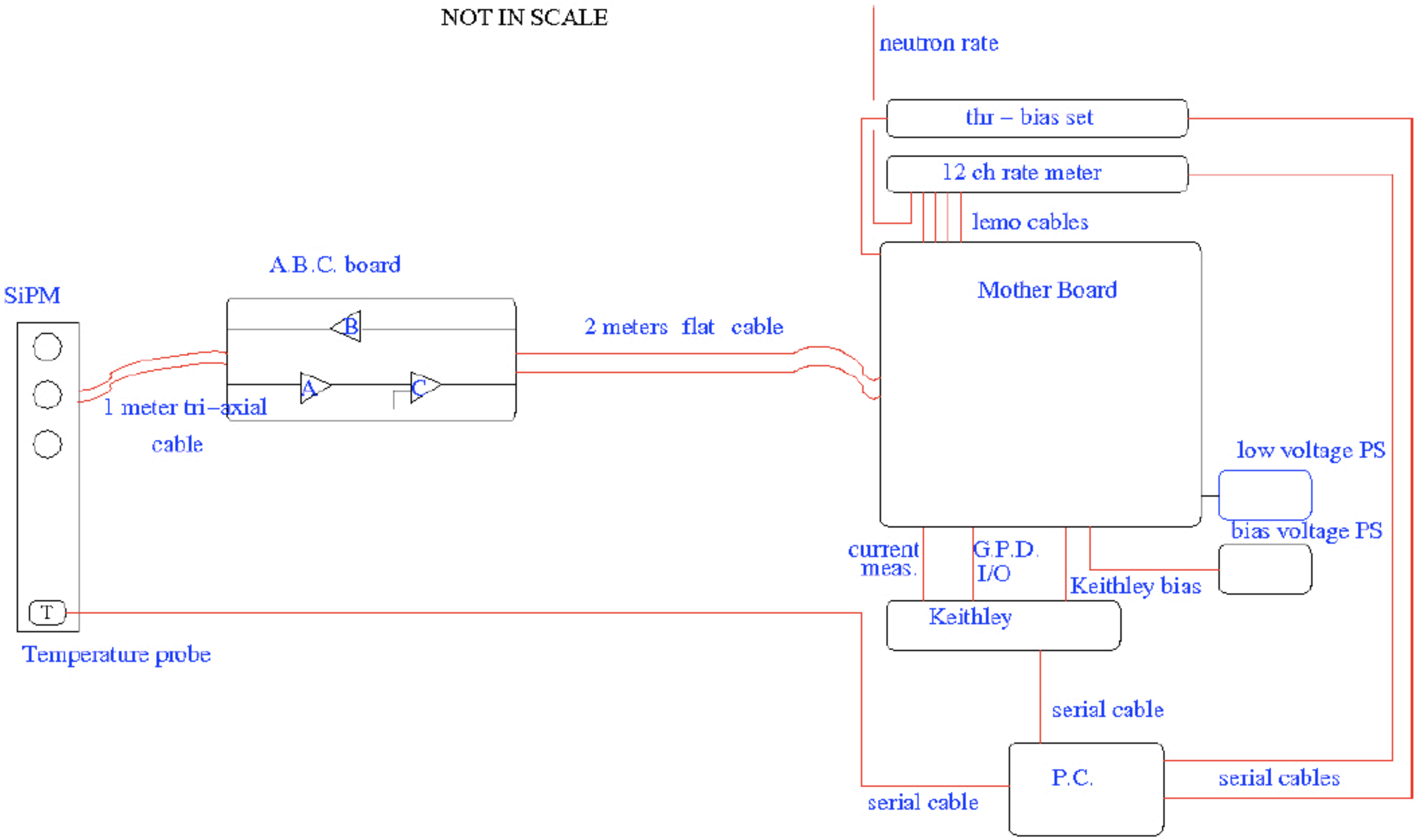
HAEFELY

h
h
Entries 438
Mean 2.653
RMS 0.4467
×10^-3
a.u.
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
1.5
2
2.5
3
3.5
E(MeV)

# Test setup



NOT IN SCALE
neutron rate
thr – bias set
12 ch rate meter
lemo cables
A.B.C. board
SiPM
B
A
C
2 meters flat cable
1 meter tri–axial
cable
Mother Board
low voltage PS
bias voltage PS
current
meas.
G.P.D.
I/O
Keithley bias
Keithley
T
Temperature probe
serial cable
P.C.
serial cables
serial cable

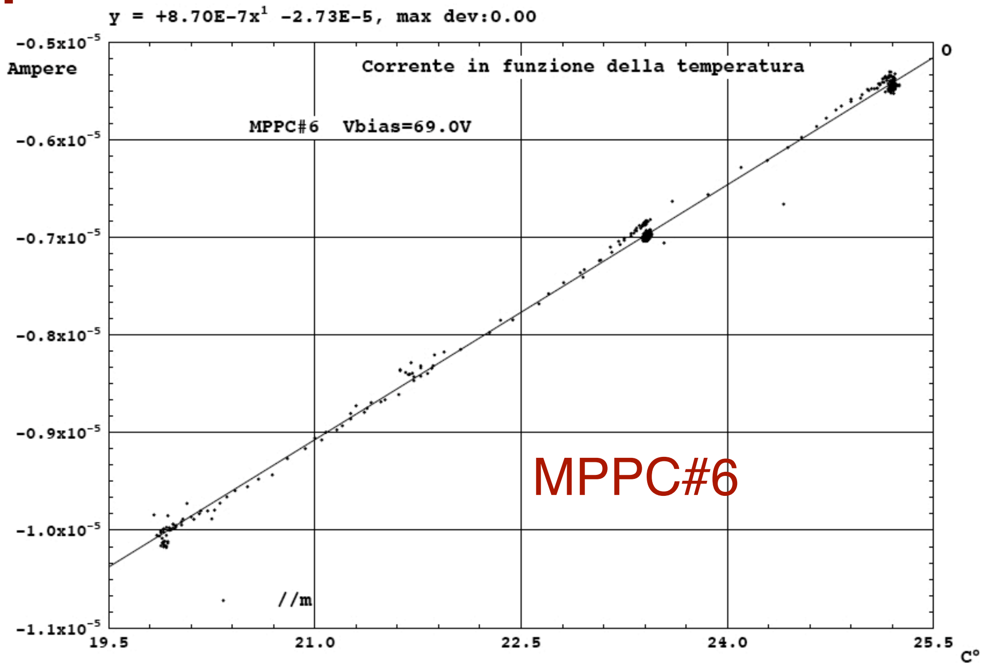
# Data taking

- The week of May 18-22 we went to the ENEA in Frascati and tested
  - Some SiPM 1x1mm$^2$
  - Few MPPC 1x1mm$^2$
  - One SiPM 2x2mm$^2$
  - Also performed irradiation test of the readout electronics
- Integrated equivalent dose up to ~7.3 $10^{10}$ n(1MeV)/cm$^2$

# Disclaimer

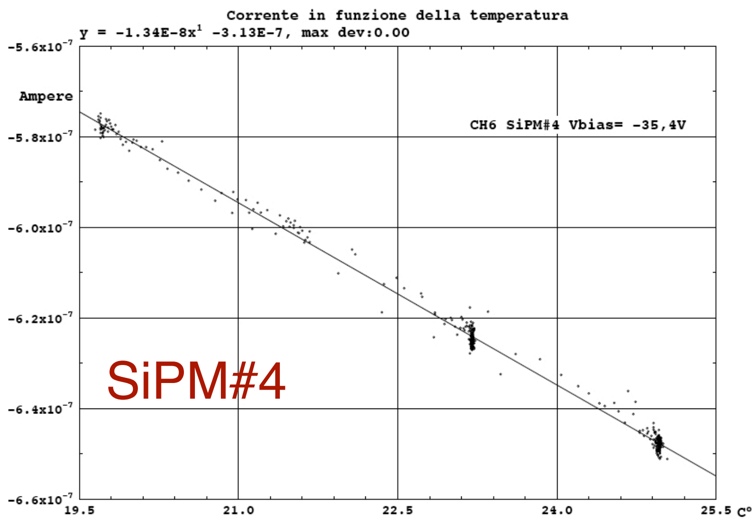
All the results shown in the following are more qualitative than quantitative and must be considered preliminary

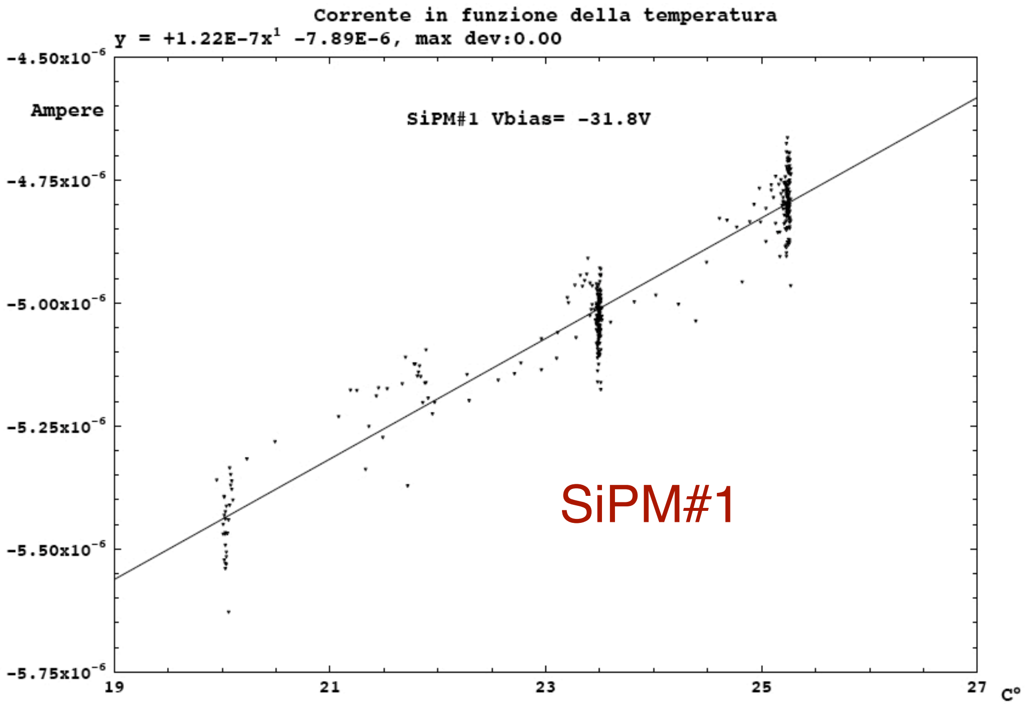
# Temperature corrections




The temperature dependence of the current has been measured carefully and will be taken into account when needed.

Current variations with the temperature for the SiPM are lower than for the MPPC but not fully understood



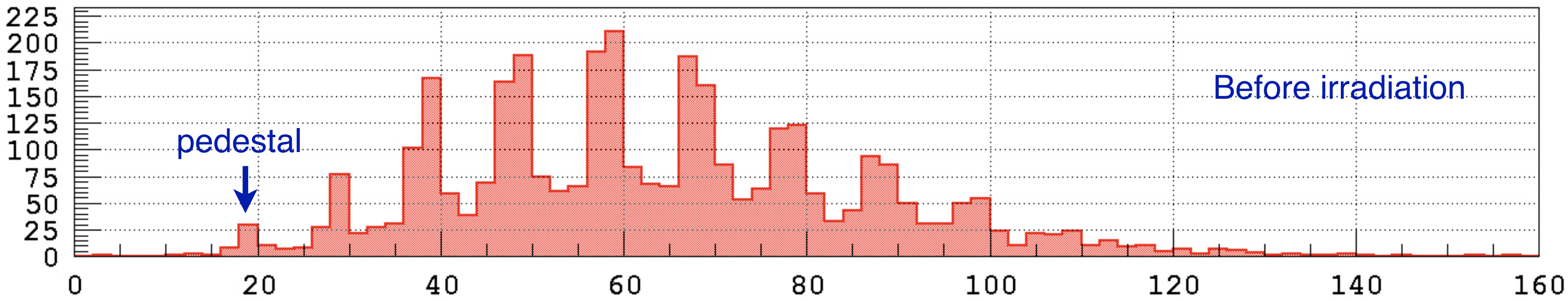
# Bias corrections

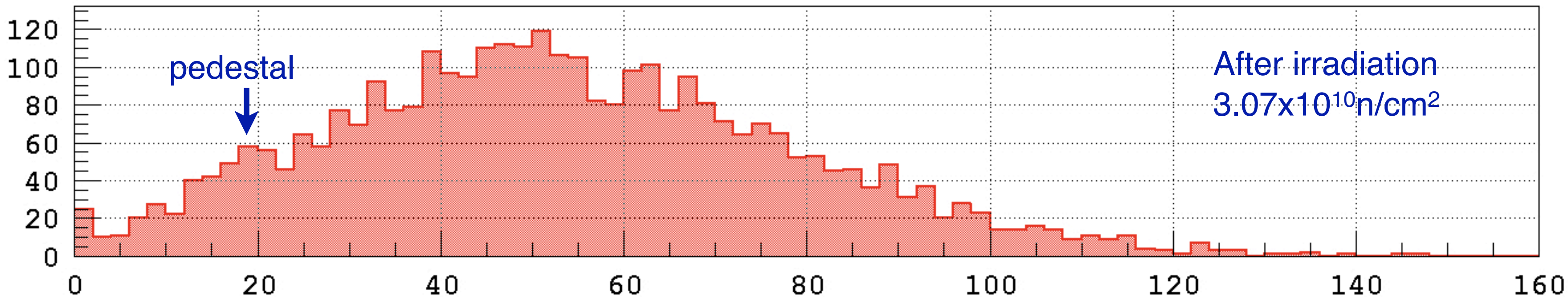
Difference between the Vbias set and applied need to be taken into account

Channel by channel calibration done.

# Gain measurement

LED on SiPM

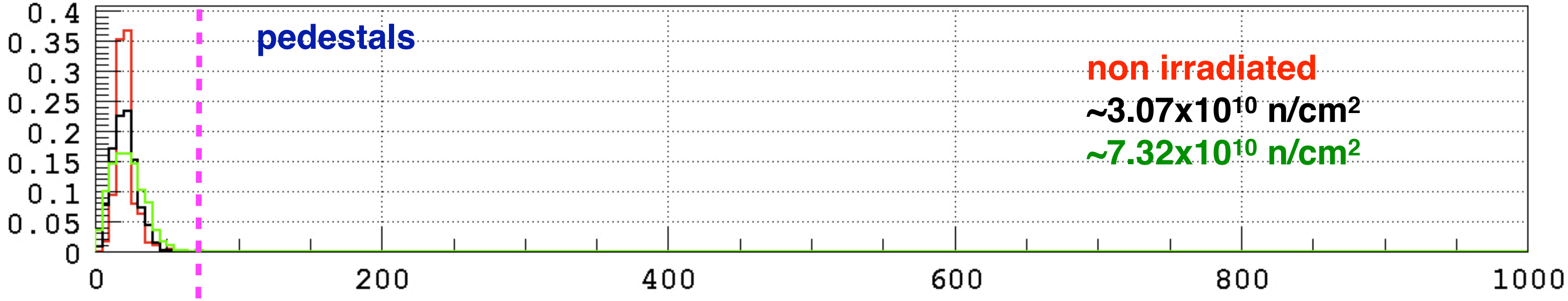


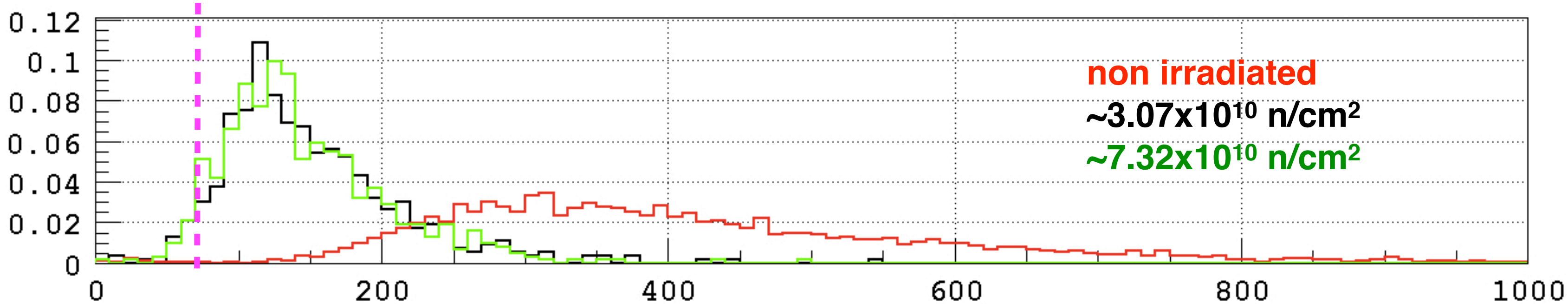




After irradiation it's impossible to distinguish the peak in the charge distribution.
The distribution also peaks at lower values.

# Light yield: SiPM

Scintillators + 1 Kuraray + SiPM @ 10 cm



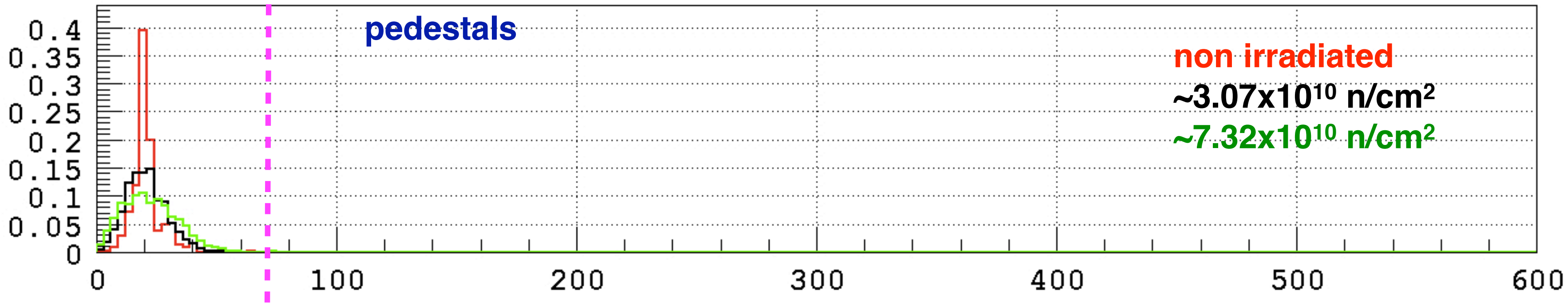



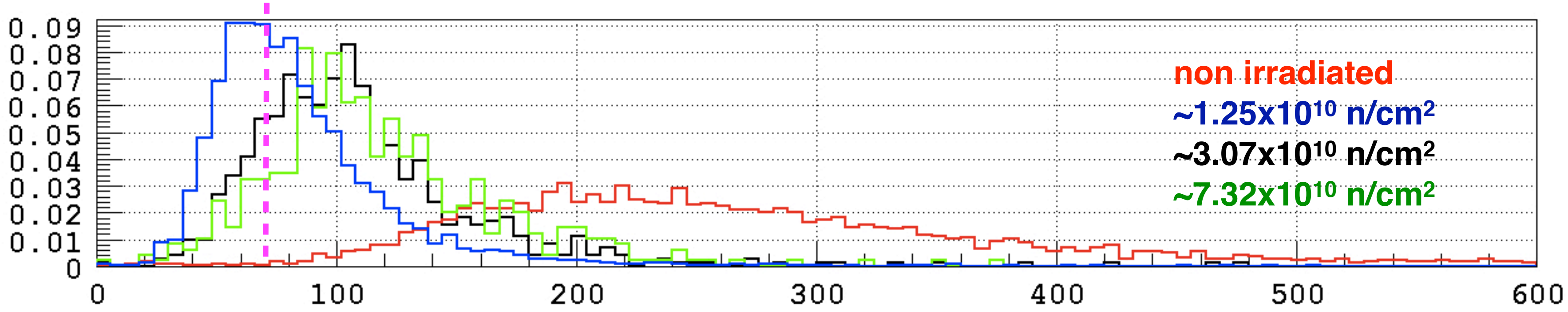

After irradiation

The light yield is about one half.
Efficiency still >95%
Pedestal broader
No trivial dependance on the dose

# Light yield: SiPM

Scintillators + 1 Kuraray + SiPM @ 150 cm



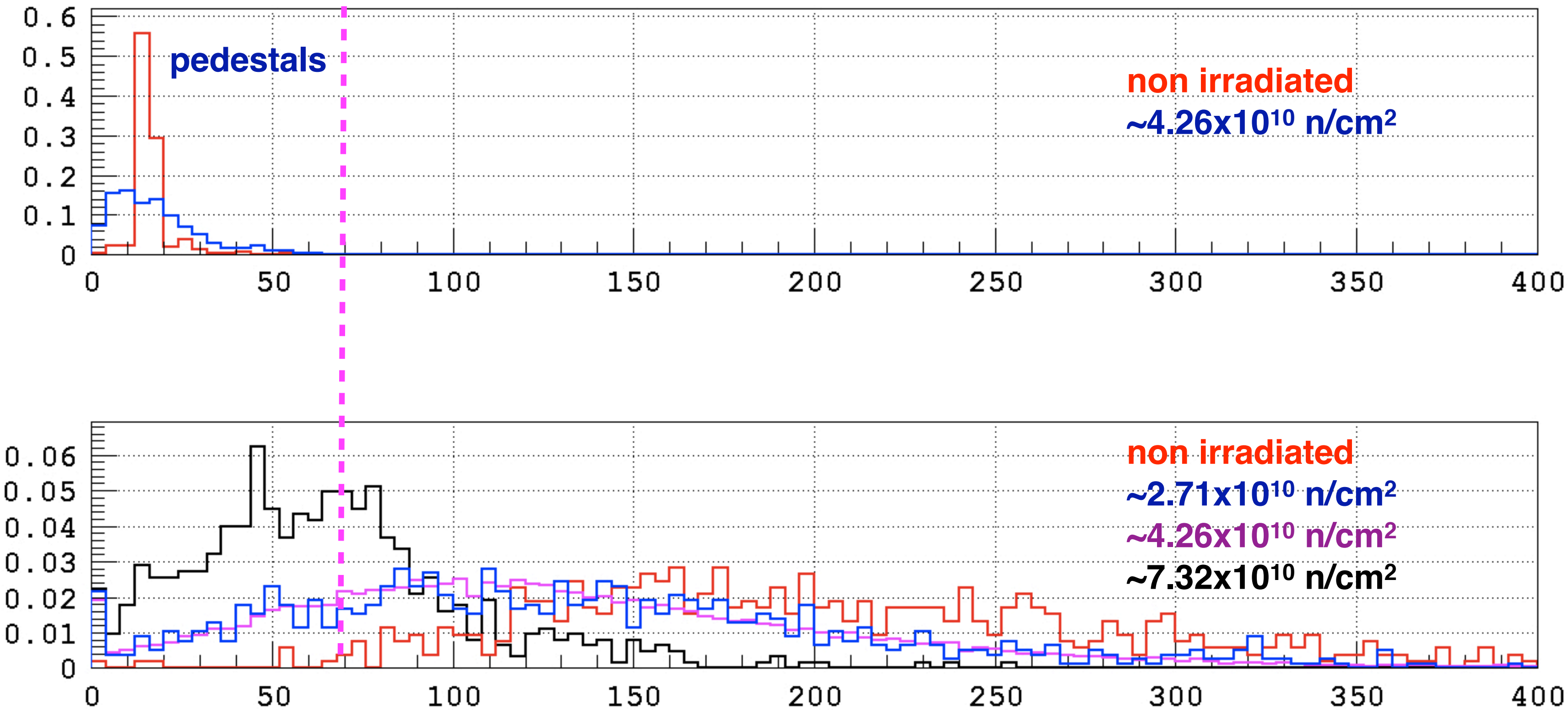




After irradiation

The light yield about one half.
Efficiency much lower
Pedestal broader
No trivial dependance on the dose

# Light yield: SiPM

Scintillators + 1 Kuraray + MPPC @ 150 cm




After irradiation

The light yield lower.
Efficiency much lower
Pedestal broader
Dose dependance?

# Impact on the IFR

- IF preliminary results are confirmed SiPM can be damaged with a dose of $10^9$ n/cm$^2$
- With a rate of $10^3$ Hz/cm$^2$. With $31 \times 10^6$ sec/y x 5 years ~ $15 \times 10^{10}$ n/cm$^2$. Super B may count another factor 100!
- We must work on a shielding that reduces at least of a factor $10^4$ the neutron rate on the IFR.
- Is that feasible? Better to shield the neutron source? Interaction with the MDI needed.

# Next steps

- Improvements to the setup:
  - Use the Keithley to feed the SiPM gives more precise current measurements
  - Add the possibility to measure the ADC spectra online
- More tests:
  - Test possible shielding
  - Test damage from thermal neutrons
- More statistics