CZECH PARTICIPATION AT
FACILITY FOR ANTIPROTON AND ION RESEARCH (FAIR)
AND NUCLOTRON-BASED ION COLLIDER FACILITY (NICA)

Tests of radiation hardness of SiPMs and scintillators

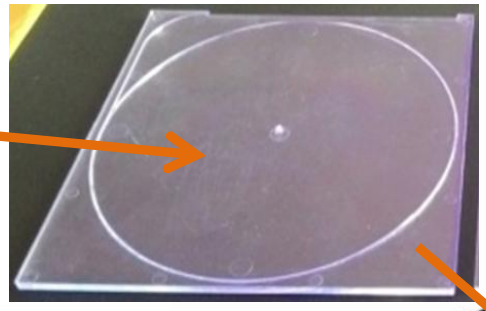
Vasily Mikhaylov on behalf of team of
Nuclear Physics Institute of the Czech Academy of Sciences

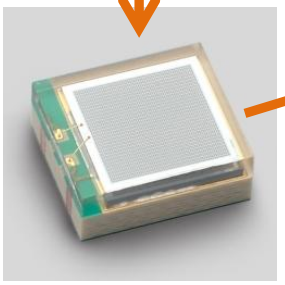
EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
Development and Education

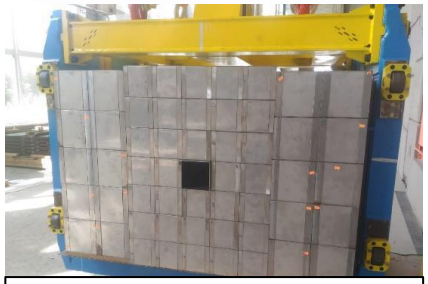
MINISTRY OF EDUCATION,
YOUTH AND SPORTS

Calorimeter radiation hardness

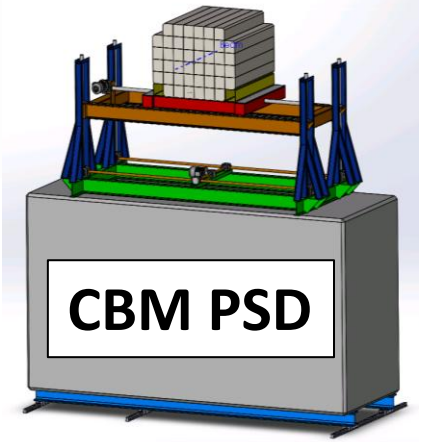
- Proton irradiation study of polystyrene scintillators.
- Simulation of polyethylene neutron shielding.
- Neutron irradiation study of Silicon Photomultipliers.





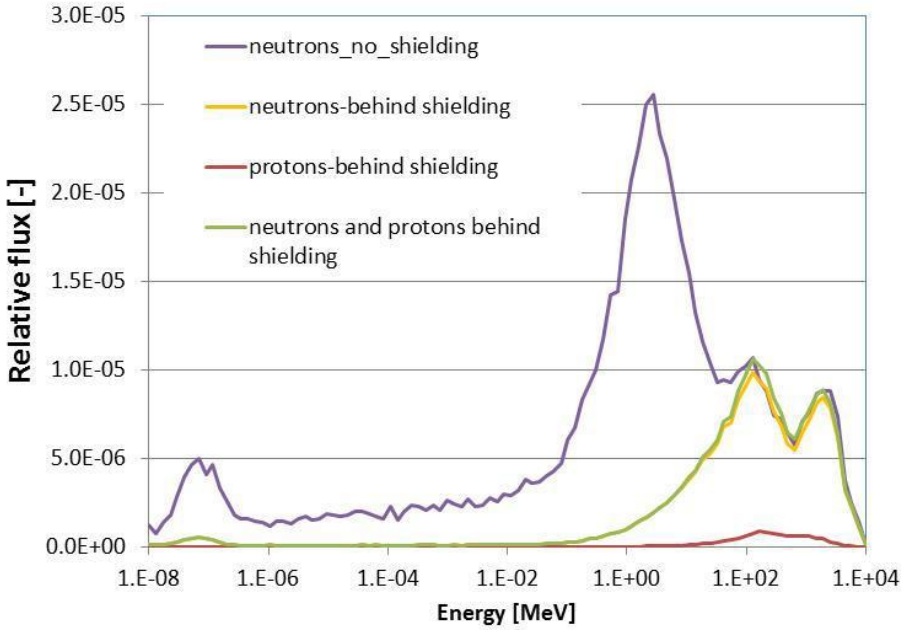


BM@N FHCAL

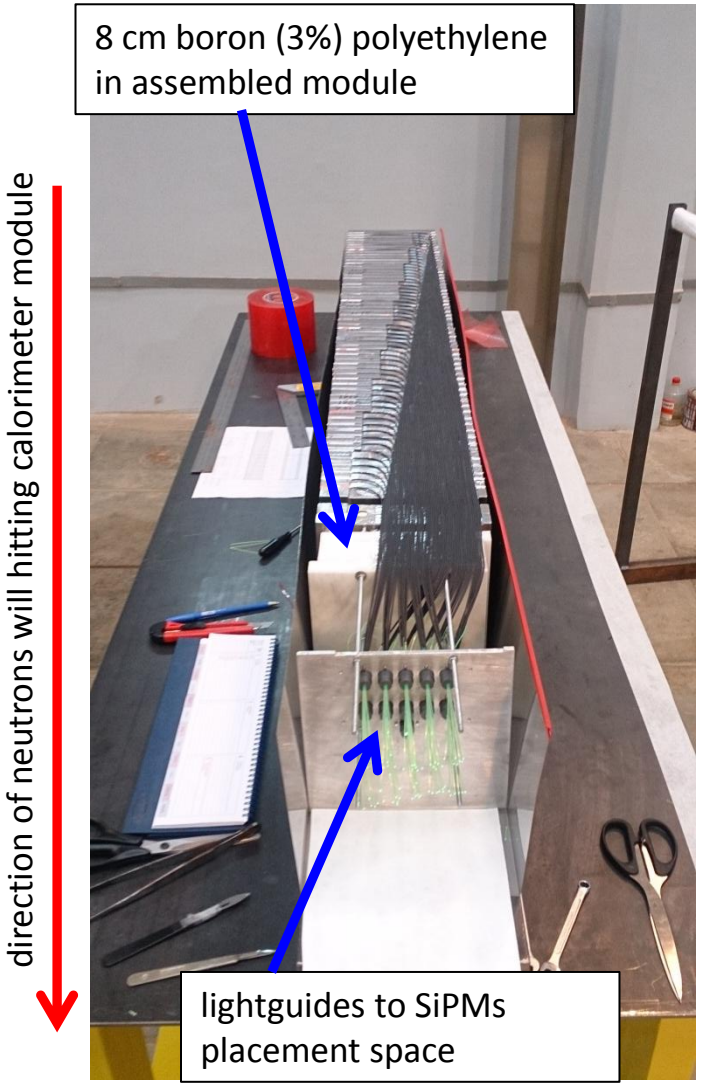


Neutron shielding simulation

- We reduced the neutron flux by 50-70% adding borated polyethylene between the calorimeter module lead/scintillator blocks and SiPMs.
- Low energetic neutrons are shielded the best, so we reduce the neutrons captured in SiPM by silicon and dopants, especially ^{10}B dopant having huge n cross-section.



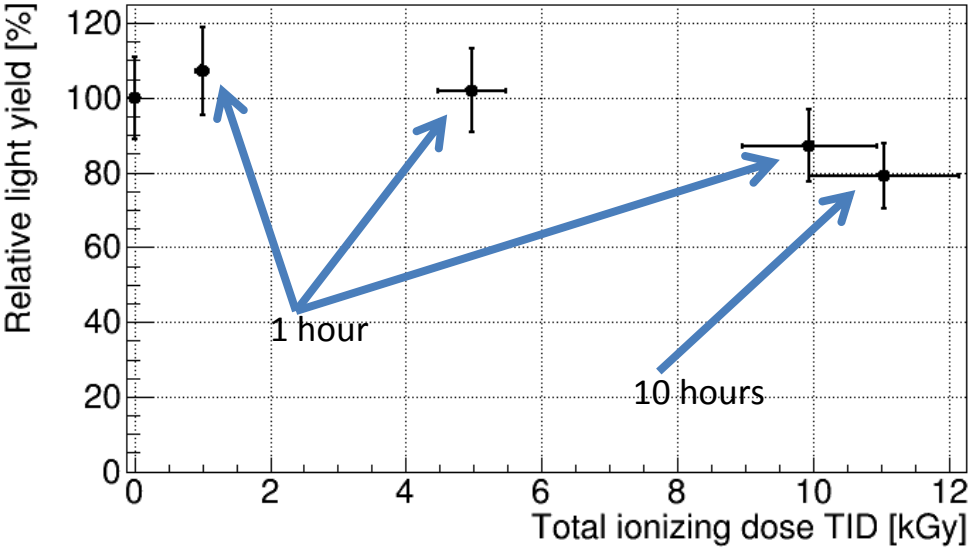
Contribution of O. Svoboda



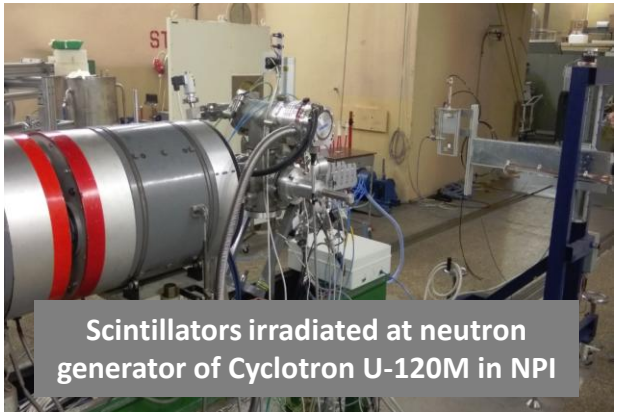
V. Mikhaylov, Tests of radiation hardness of SiPMs and scintillators, CREMLINplus WP2 kick-off meeting, 01.07.2020

Irradiation tests of scintillators

SiPM + Scintillator measurement setup in NPI

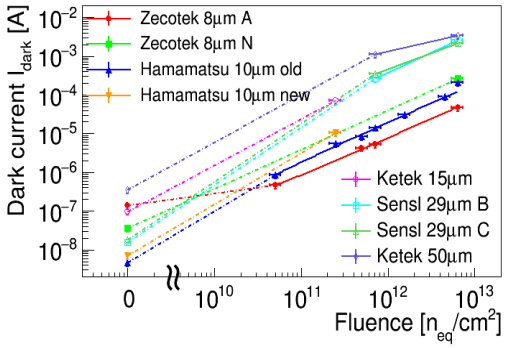


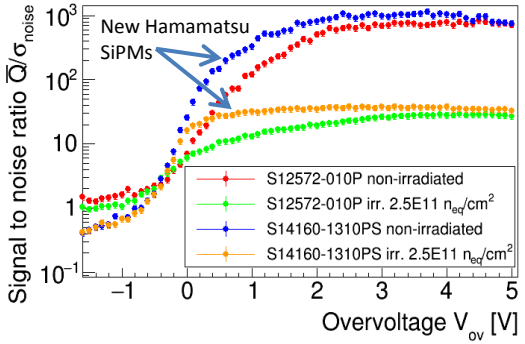
2 tests conducted in 2019 by V. Kushpil, N. Karpushkin, V .Mikhaylov, A. Ivashkin (takes this photo)

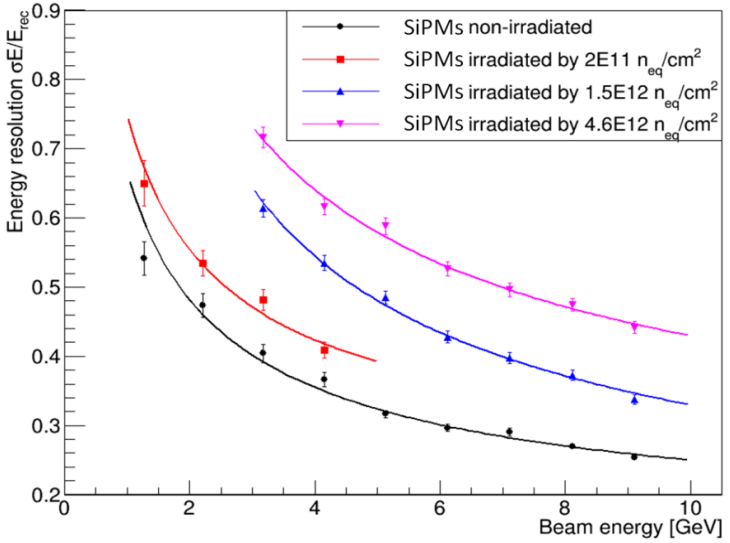


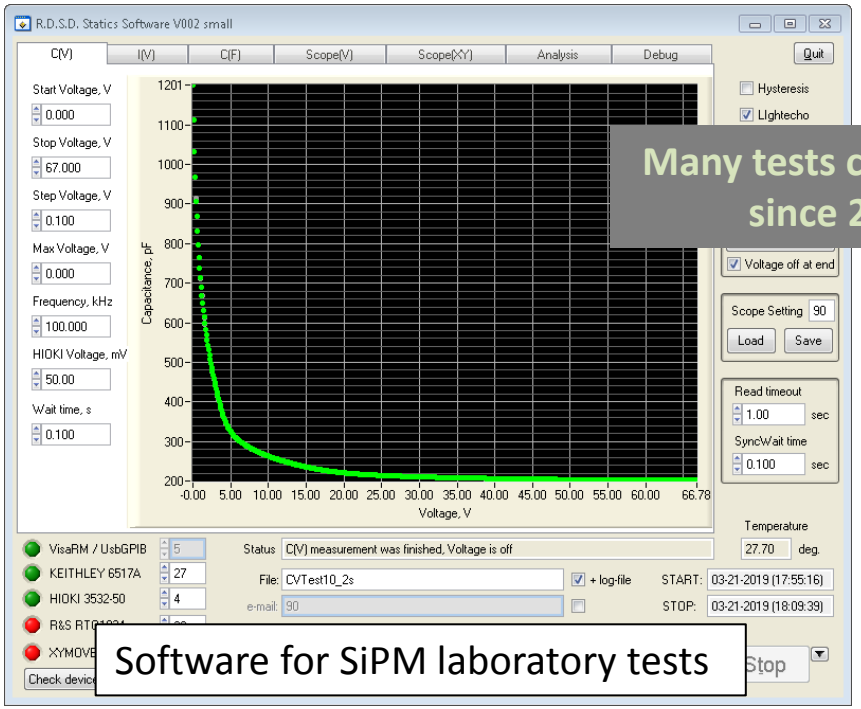
Scintillators irradiated at neutron generator of Cyclotron U-120M in NPI

Irradiation tests of Silicon Photomultipliers



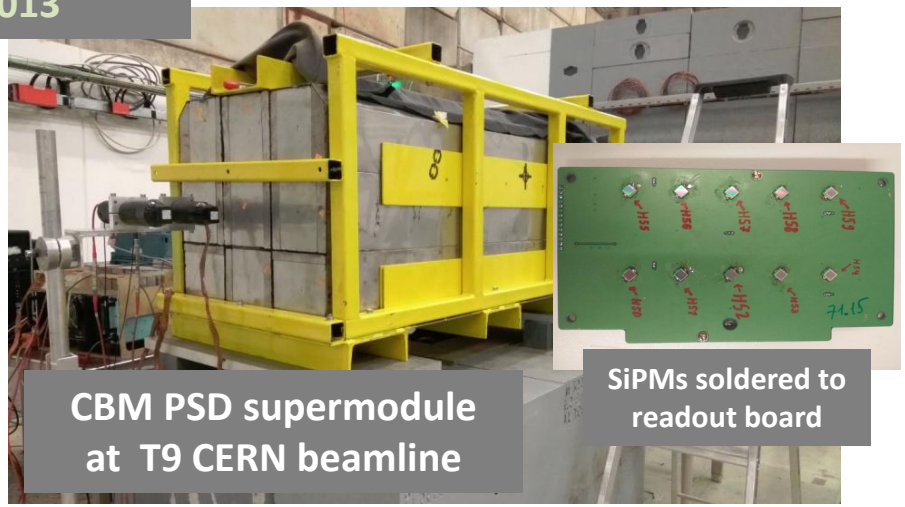






Software for SiPM laboratory tests

Many tests conducted since 2013



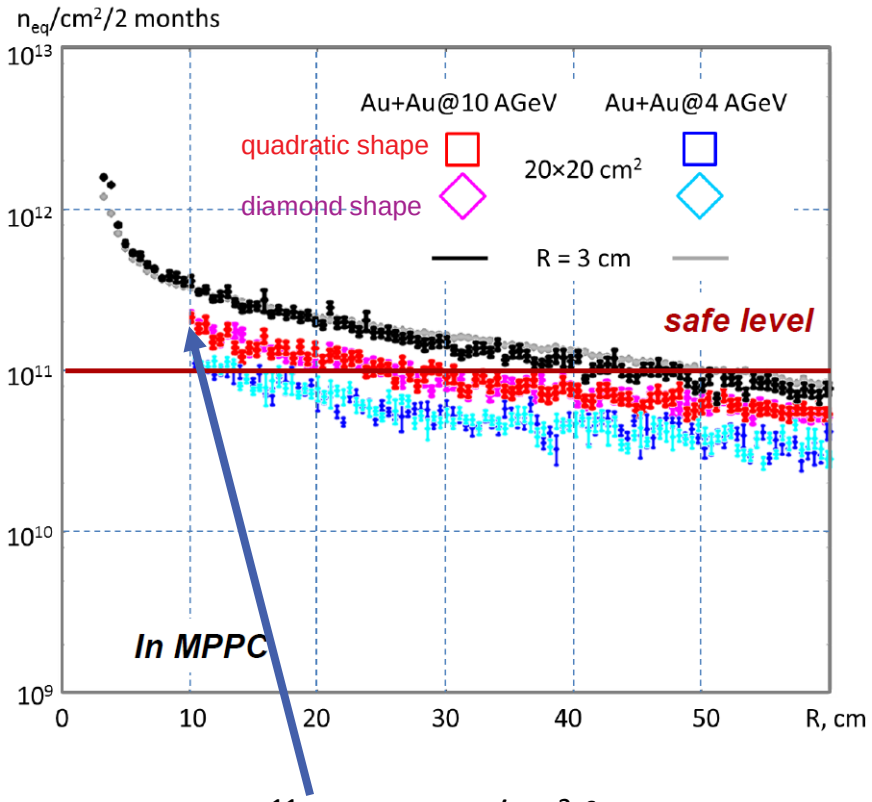
CBM PSD supermodule at T9 CERN beamline

SiPMs soldered to readout board

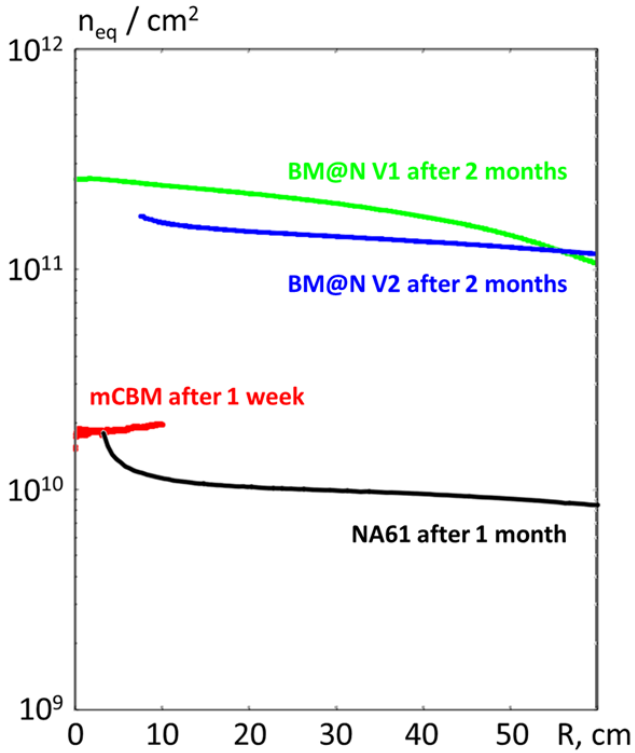
backup

Calorimeter radiation conditions

Enlarged beam hole 6x6 cm^2 -> 20x20 cm^2 significantly reduces the radiation damage

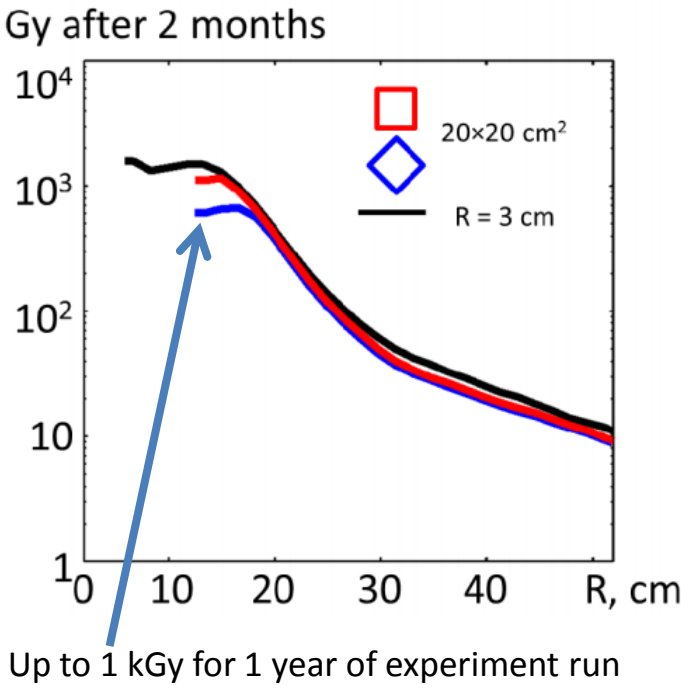


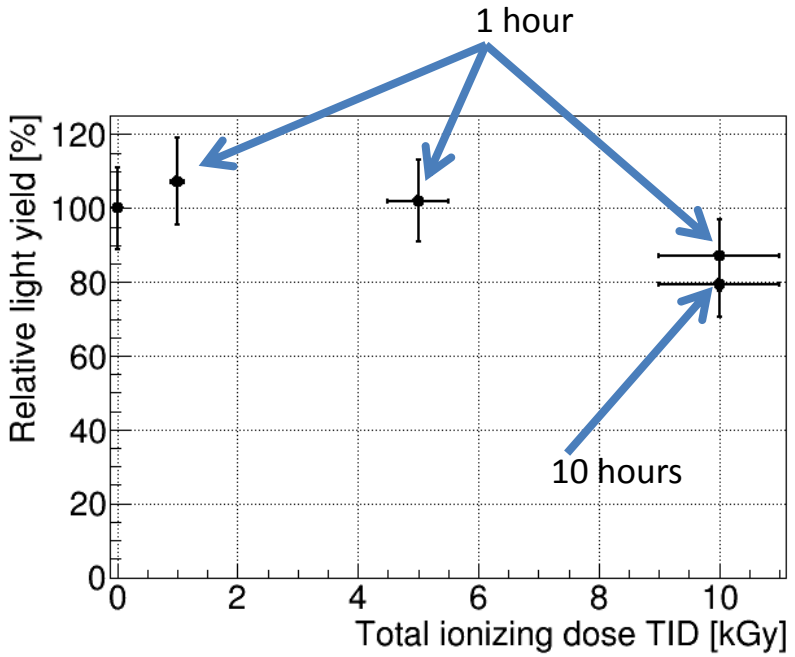
up to 2x10^{11} neutrons$_{eq}$/cm^2 for SiPMs located 10 cm close to the beam center



Simulation by A. Senger

Scintillator irradiation test

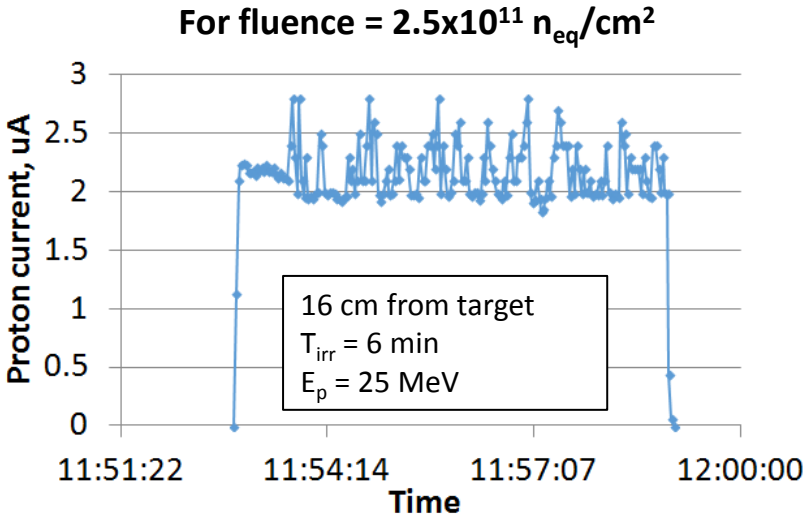


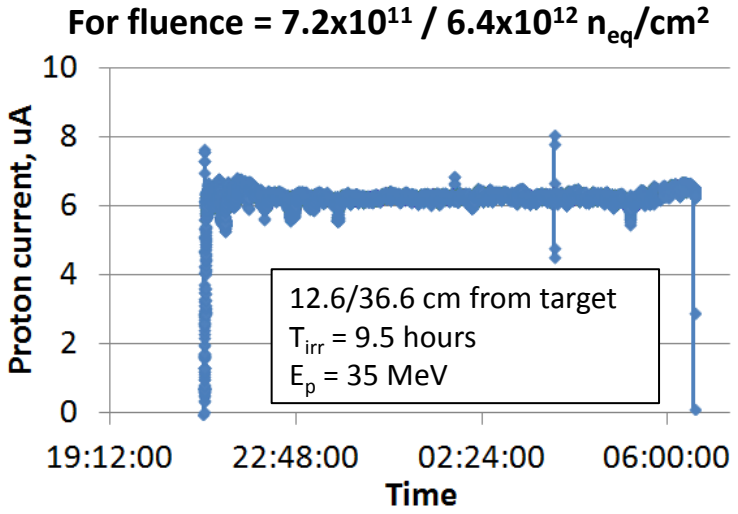


- Scintillators were irradiated at NPI cyclotron by 1, 5, 10 kGy during 1 – 10 hours
- Light yield did not decrease up to 5 kGy. After 10 kGy it decreased by up to 20 %

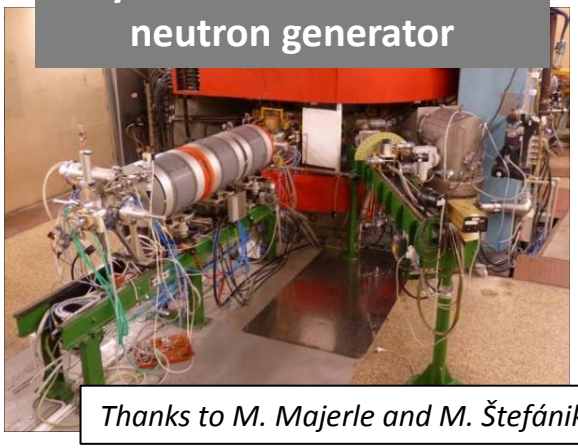
Work was done by V. Kushpil, V. Mikhaylov, A. Ivashkin and N. Karpushkin

Neutron irradiation experiments





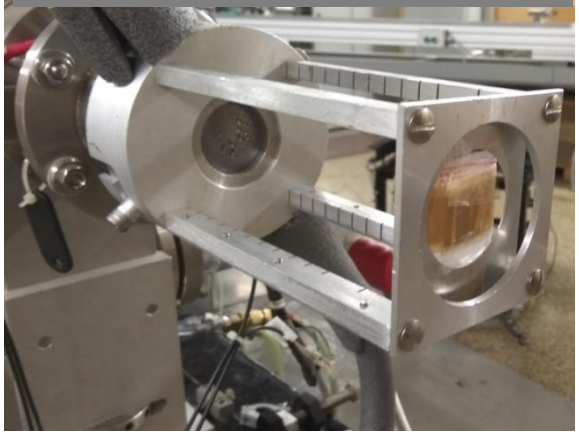
Cyclotron U-120M with neutron generator



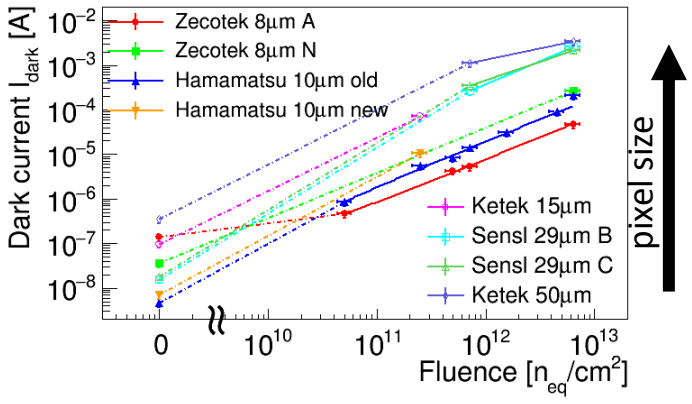
Thanks to M. Majerle and M. Štefánik

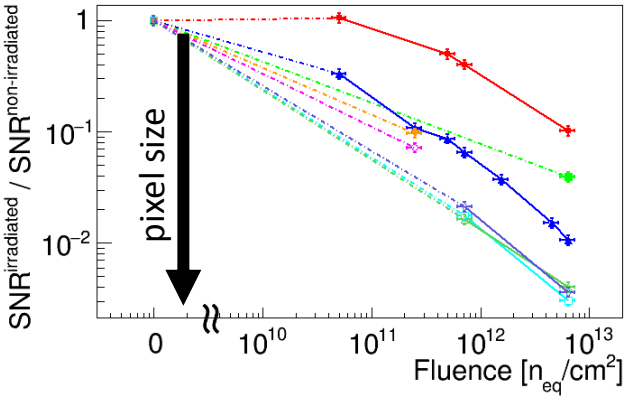
SiPMs and Au foil prepared for irradiation

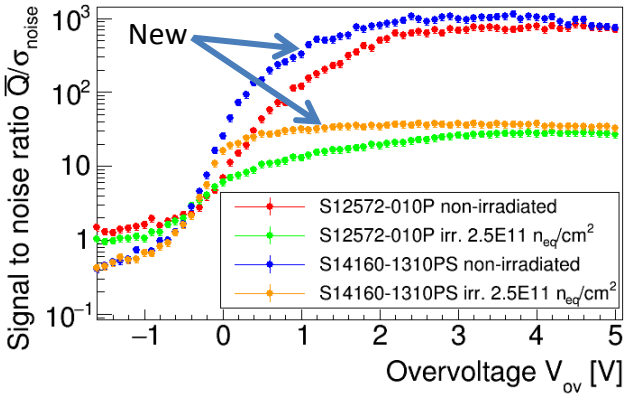
SiPMs located at the holder

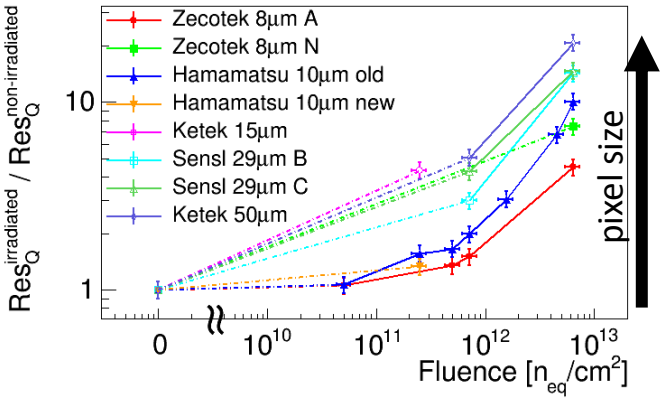


SiPM performance: dark current and response to LED









Linear dependence of dark current on fluence was observed.

SiPM signal response was measured during illumination with 10 ns short pulses from 400 nm LED.

Pulse height was chosen such that signal was detectable by all the SiPMs (very high).

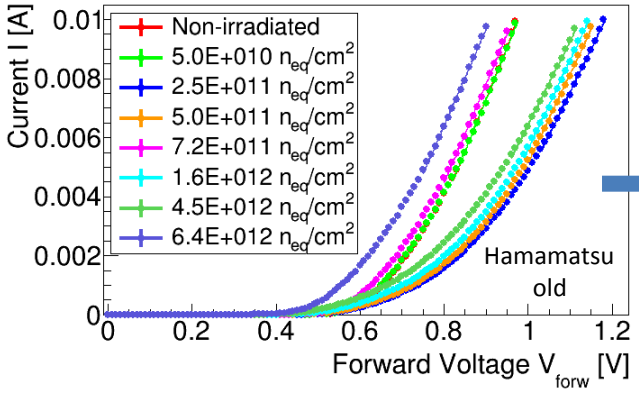
Signal to noise ratio = $\int_{signal} / \sigma_{signal}$
Resolution = $\sigma_{signal} / \int_{signal}$

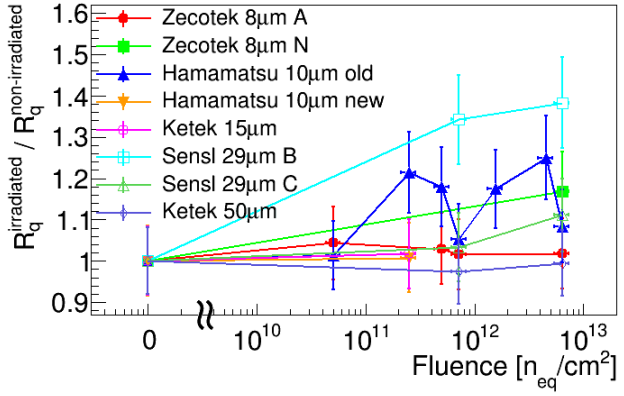
Overvoltage is 1 V for graphs with fluence dependence.

Zecotek SiPMs cannot withstand rates > 10 kHz – not suitable for CBM.

- Hamamatsu SiPMs are the best, probably due to very small pixels
- New version performs slightly better

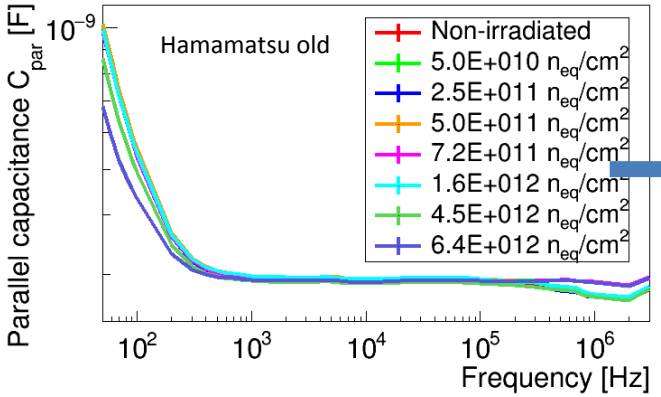
SiPM performance: quenching resistance and pixel capacitance

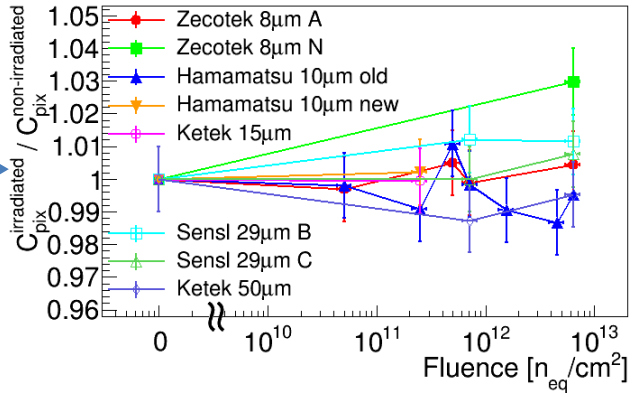




At higher range of forward voltage
$R_q \approx N_{pix} / (dI_{dark}/dV_{forw})$

At intermediate frequency ~ 10 kHz and around bias voltage
$C_{pix} \approx C_{par} / N_{pix}$





➢ Quenching resistance and pixel capacitance did not change significantly