Linearity tests of Hamamatsu high-density SiPMs

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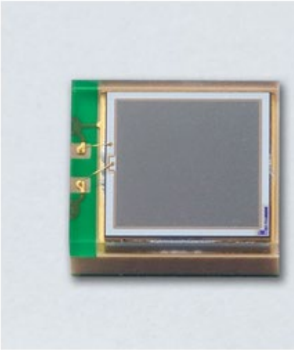
(Ideal) dynamic range for backward ECAL:

- 0.05 – 18 GeV (1:360) - cluster
- 0.005 – 18 GeV (1:3600) – crystal
- Per SiPM (/16): 0.00013 – 1.1 GeV

MPPC

S14160-3010PS



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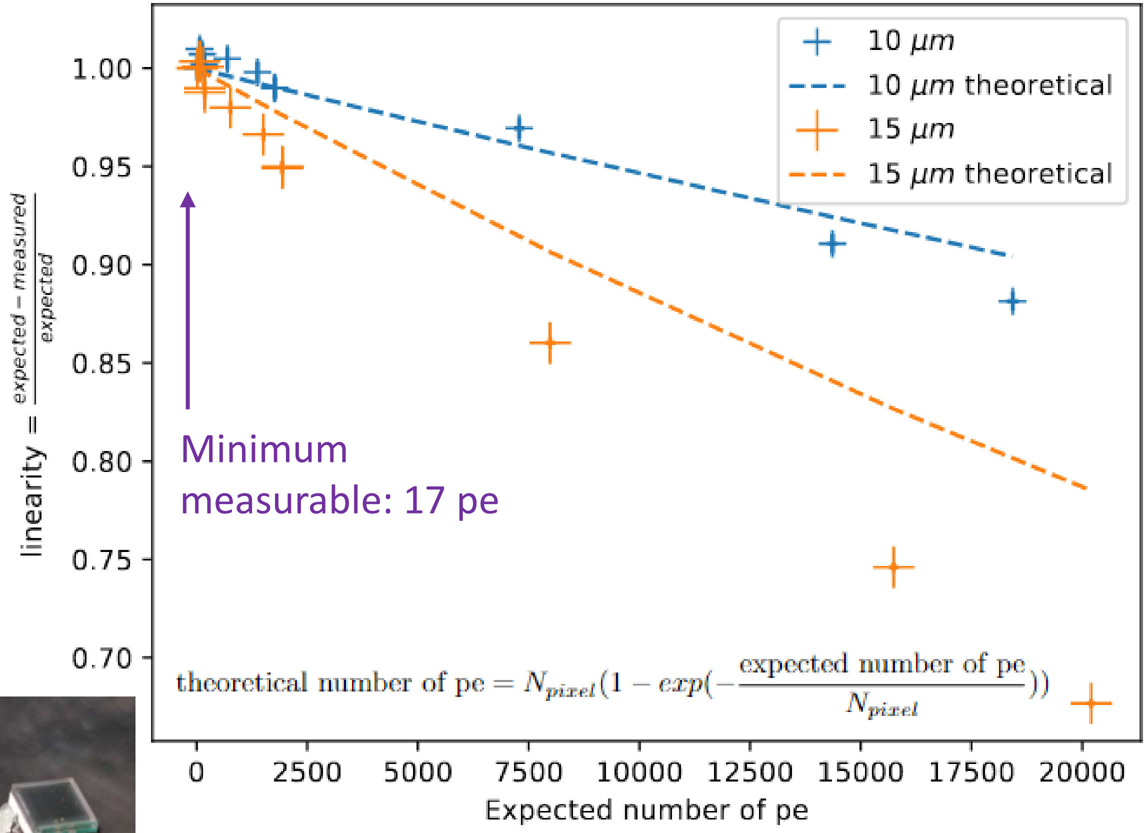
Specifications

Package type	Surface mount type
Number of channels	1 ch
Effective photosensitive area / ch	3 × 3 mm
Number of pixels /ch	89984
Pixel size	10 μm
Spectral response range	290 to 900 nm
Peak sensitivity wavelength (typ.)	460 nm
Dark count/ch (typ.)	700 kcps
Terminal capacitance/ch (typ.)	530 pF
Gain (typ.)	1.8×10^5

Low gain!

(Measurements compatible with Hamamatsu's number)

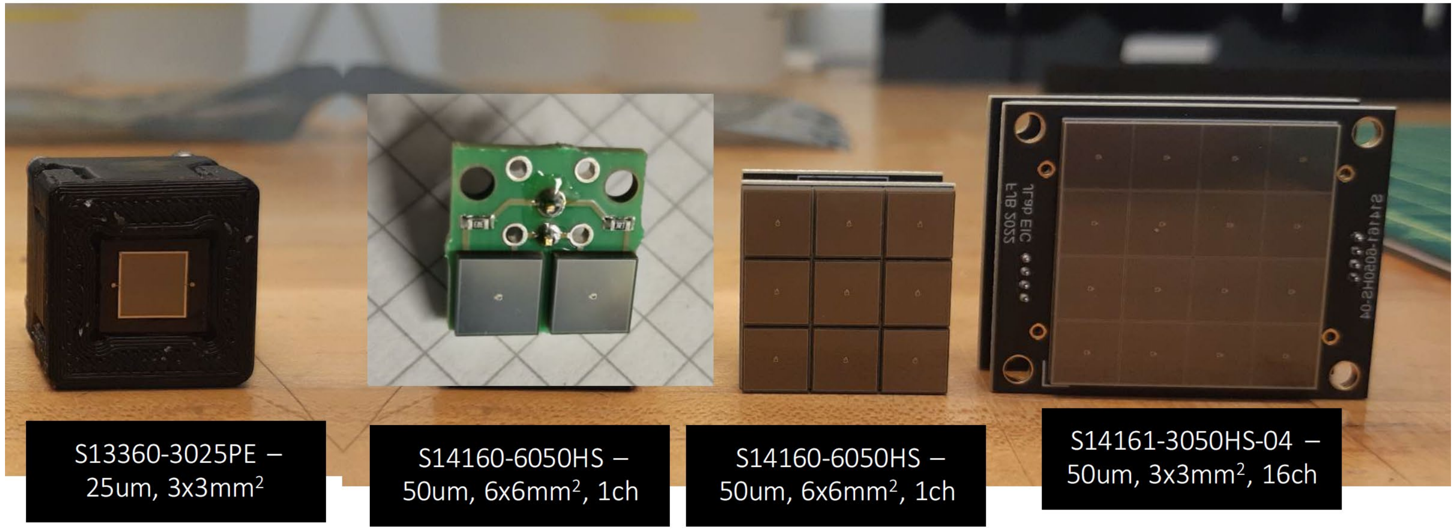
Measured with calibrated LED and filters (20 ns squared pulse)



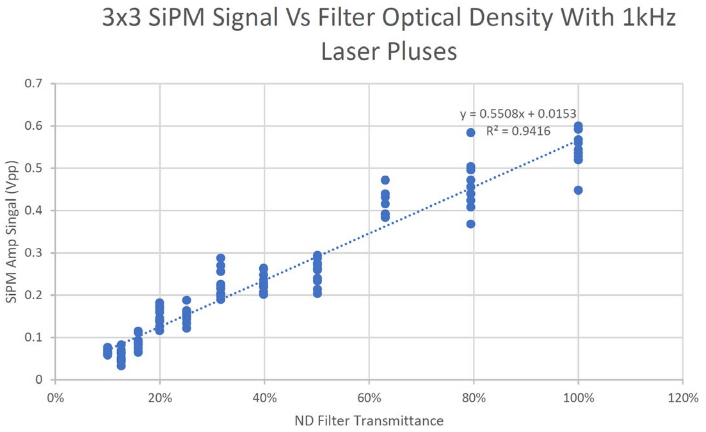
Setup: 1-cm coax
+ low pass filter
+ × 227 preamp

Tests of Matrix Configurations

CUA, AANL, JLab, Crytur, and EEEMCAL Consortium + eRDXXX

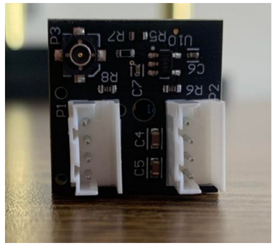


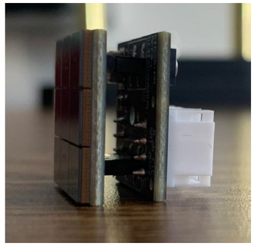
Testbench tests of JLab arrays laser pulse response, signal linarity, dynamic range, single cell tests [Link to full report]



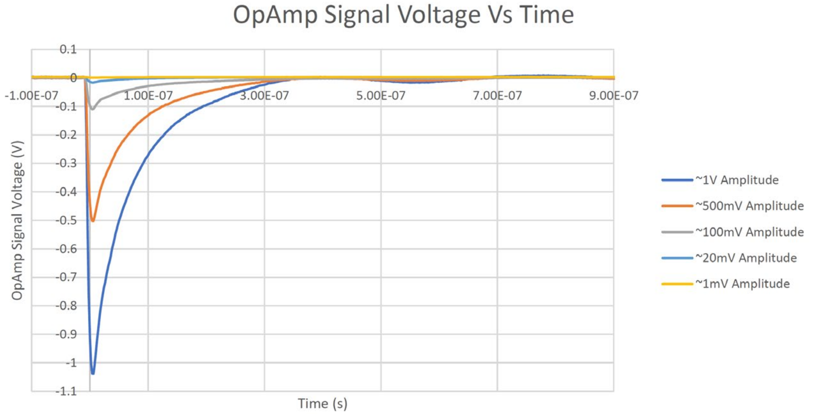
Configurations

- Single SiPM (JLab FEG)
- Two SiPMs (INFN-GE)
- 3x3 Array (JLab FEG)
- 4x4 Array (JLab FEG and Crytur)



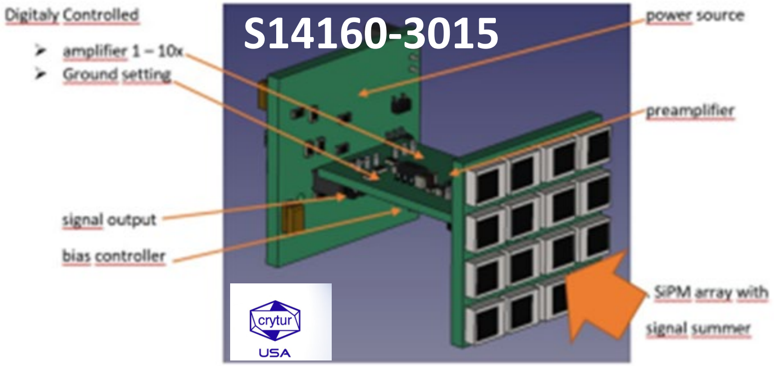


For the JLab FEG designs the PCB consists of a stack of two PCBs. The bottom board contains the SiPM and a thermal correction circuit for the SiPM bias voltage. The top board contains a pre-amp circuit, coaxial connector and 4-pin ribbon connector for low voltage power and SiPM bias.



Testing for prototype beam tests

- Single PE Test: 5-7 mV amplitude for PE and 600pW of area
- Cosmic Test to set the amplitude to cover the dynamic range and to tune the amplification (avoid saturation)



The scaling of the SiPM response amplitude from 1 to 9 SiPMs is a factor of 8

Compare Hamamatsu S14160-3015 and S14161-6015

S14160-3015 characteristics

- 3 mm x 3 mm
- PDE 32% (420 nm)
- 15 µm microcells
- Anode capacitance 530 pF
- Dark count rate 700 kcps (typ.)
- VOP variation within reel ±0.1V (± 8% gain)

➢ 16 pcs to fill 20 mm x 20 mm

➢ Active fill: 36% of area

➢ Rough computation for # activated cells for 15GeV deposited in crystal: 1588/SiPM

➢ Expected Integral Non-linearity at 15GeV: 1.26%

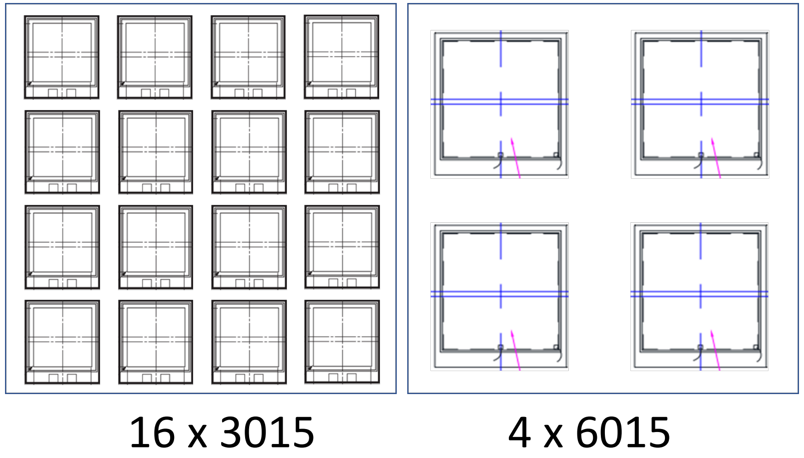
- Only fit 4 14160-6015 units on 20 mm x 20 mm
- Comparison with 16 14160-3015 (3 mm x 3 mm)

Same

- Cell size
- PDE
- Gain
- Sensitive area
- Operating voltage

Different

- Anode capacitance
  - 530 pF (3015) vs. 2500 pF (6015)
- Dark count rate (typ.)
  - 700kcps (3015) (x16 = 11.2 Mcps)
  - 3 Mcps (6015) (x4 = 12.0 Mcps)

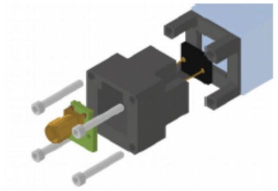


CUA ordered S14161-6010 (50) and S14160-6015 (50) for testing – first items expected in late spring, the next batch in early fall

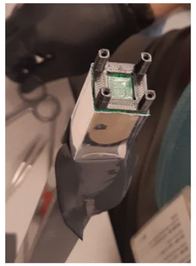
Tests of Matrix Configurations with beam at JLab

CUA, AANL, JLab, Crytur, and EEEMCAL Consortium + eRDXXX

Assembly of SiPM and crystal/glass blocks



(b)



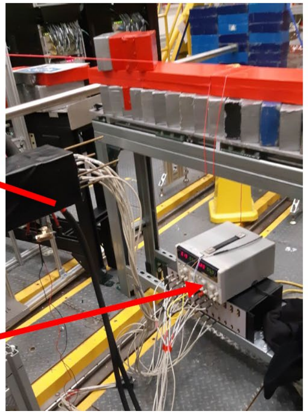
(c)

(d)

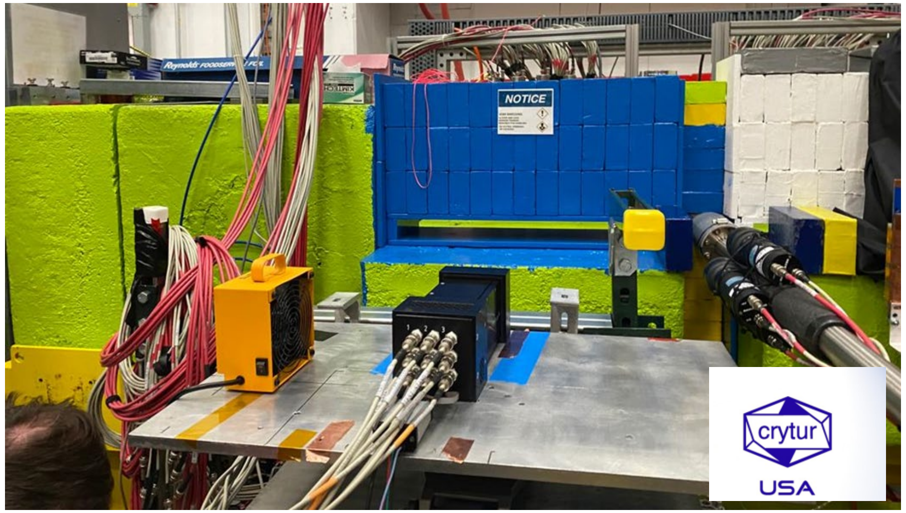
(e)

Fig.13: 3x3 Prototype with SiPM readout system in Hall-D. The prototype aligned the way that beam is heating in the center

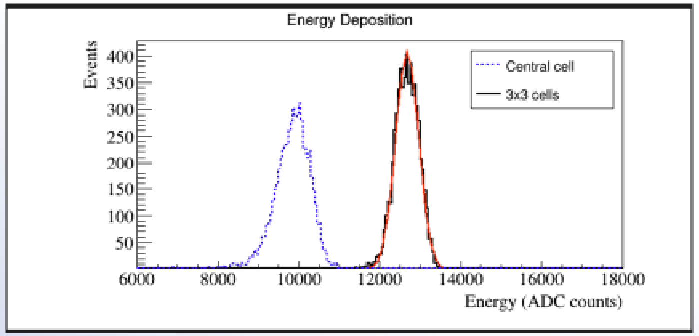
Preamplifier and power supply.



Measured energy resolution is consistent with that of the same 3x3 array with PMT readout



Preliminary results



Energy deposition in the central module 5 and in the full prototype (3x3). The energy is given in units of flash ADC counts.
ADC amplitudes, sampled with a rate of 250 MHz, are summed up in the 64 ns wide window (16 samples x 4 ns = 64 ns)

Preliminary energy resolution for the 3x3 matrix ~2%

Hall-D tests Spring 2023: RO performance

✳ Scintilex glas blocks

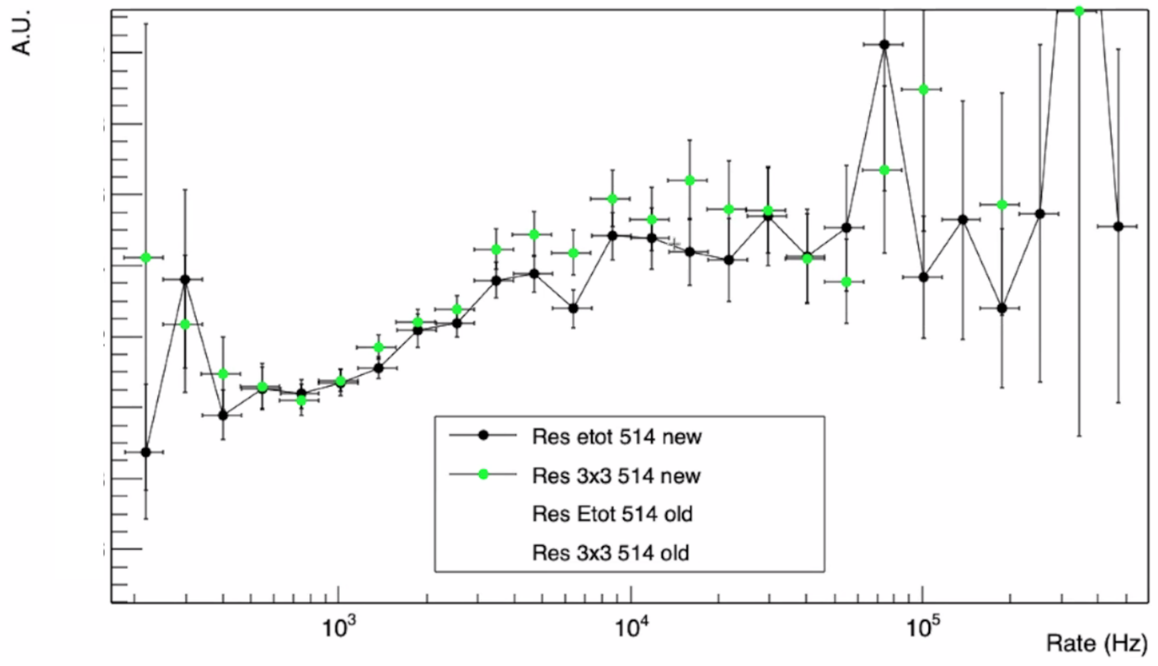
- 5x5 2x2x40 cm3 blocks
- SiPM: 2x 6x6 mm2, 50um, Hamamatsu, mounted on a PCB
- Installed in Hall-B CR and on Hall-D PS e+/e- beam

- Custom preamp board + custom bias board (transimpedence preamp developed for HI and CLAS12 FT APD readout with reduced gain)
- During tests, we noticed some instabilities studied in details after-while



V_{bias} (-> sipm gain) dependence on drained current (severe issue for CAL resolution)

- **The Proto-Cal energy resolution depends on data rate (?!)**
- **This issue is traced back to the sipm biasing circuit**



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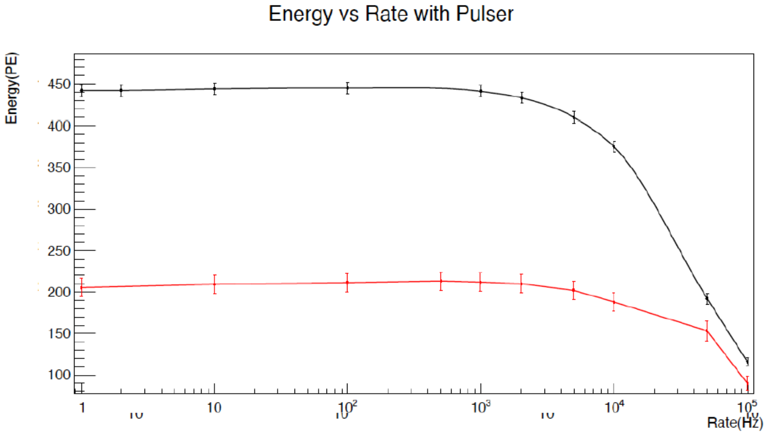
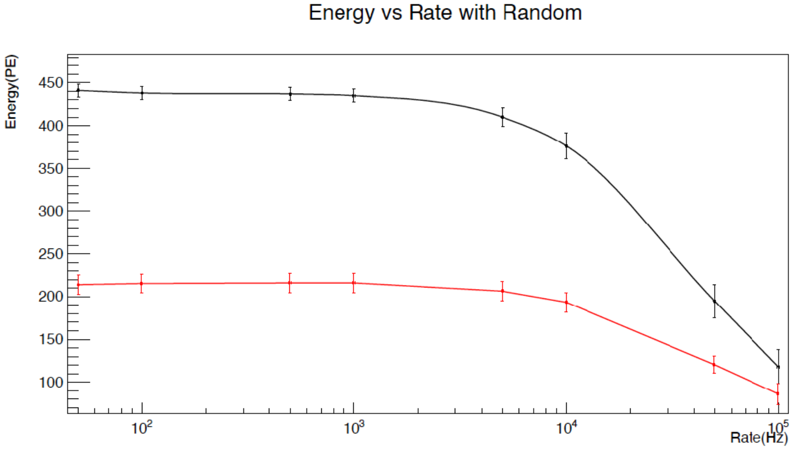
V_{bias} (-> sipm gain) dependence on drained current (severe

- A combination of large number of firing cells with a high rate causes a large current request that (may) affects the Vbias changing the sipm working point (gain)
- In case of not periodic input (e.g. Poissonian) this degrades the resolution





Black: 450pe signal
Red: 200 pe signal

- Pulser: periodic signal (generator at fixed rate)
- Random: using a sipm noise to mimic a Poissonian distribution with same rate

Conclusions

- **The drop in sipm gain is visible at a different rate, depending on the number of firing cells (Npe)**

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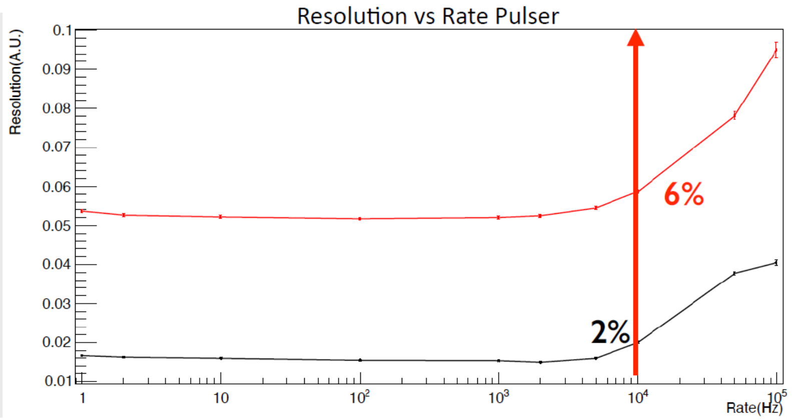

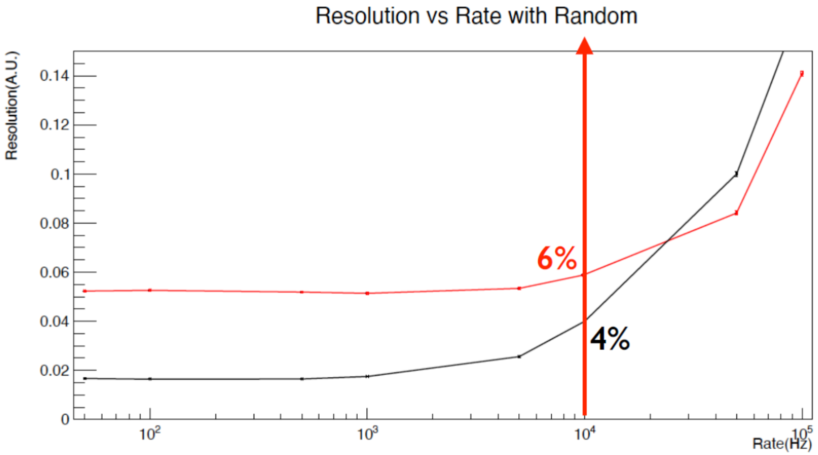

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Conclusions

- **The drop in sipm gain is visible at a different rate, depending on the number of firing cells (Npe)**
- **The resolution gets worse when larger Npe is involved. The effect is anticipated in case of Poissonian rate**