Novel neutron detector assembly based on SiPM readout to be coupled with the Active Target for SPES

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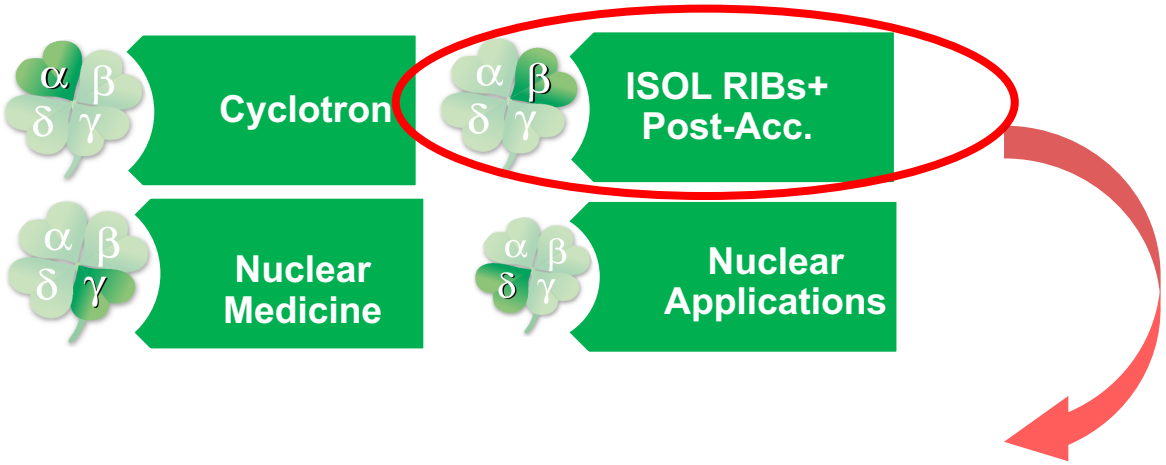
SPES facility at Legnaro (Italy)

➢ **Second generation ISOL facility**

➢ **Production** of **exotic beams** (p-induced fission on **UCx**)

200μA, 40 MeV proton beam

Four phases



Re-acceleration of **exotic beams** with the ALPI linac.
Mainly **Neutron–rich** ions from

Active Target TPC

Active Target + Ancillary detectors

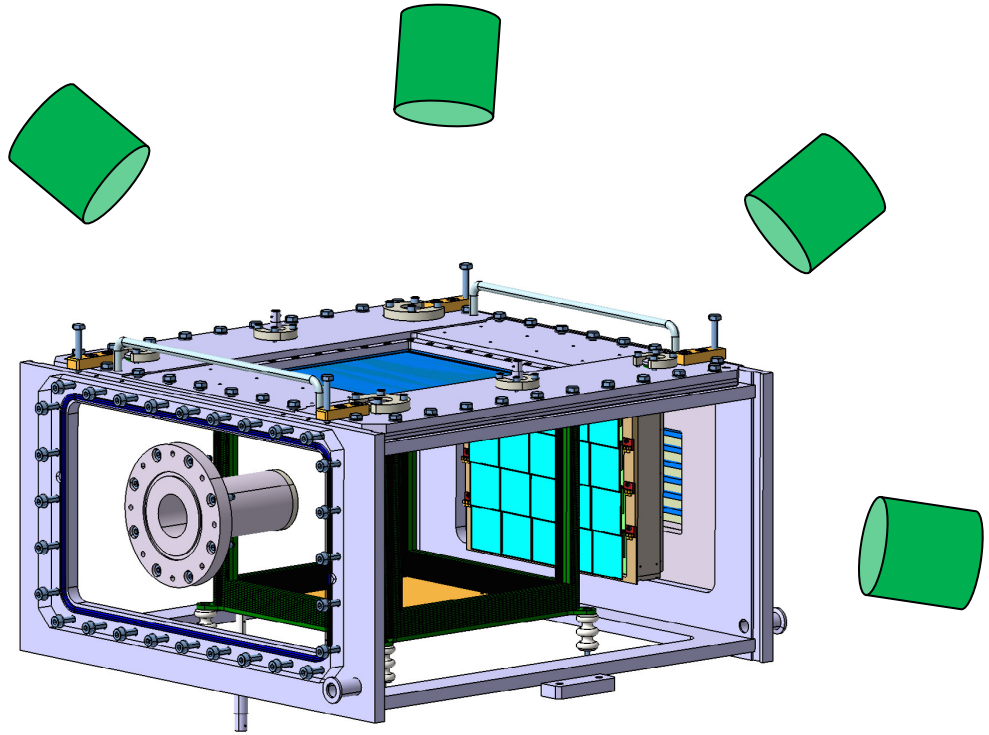
- Develop a compact device capable to discriminate, using pulse shape analysis, between n and γ.

$$^{8}Li + {}^{4}He \longrightarrow {}^{11}B + n$$

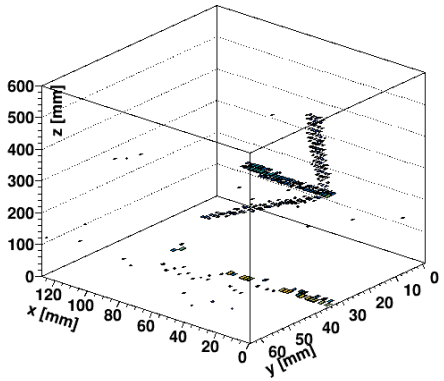
$$^{6}Li + {}^{3}He \longrightarrow {}^{8}B + n$$

$$^{34}Ar + {}^{3}He \longrightarrow {}^{36}Ca + n$$

- Taking advantage of recent improvements in SiPM technology.
  - high gain
  - extremely good timing performance
  - low operative voltage
  - insensitivity to magnetic field



Active Target



Ancillary n/γ detectors

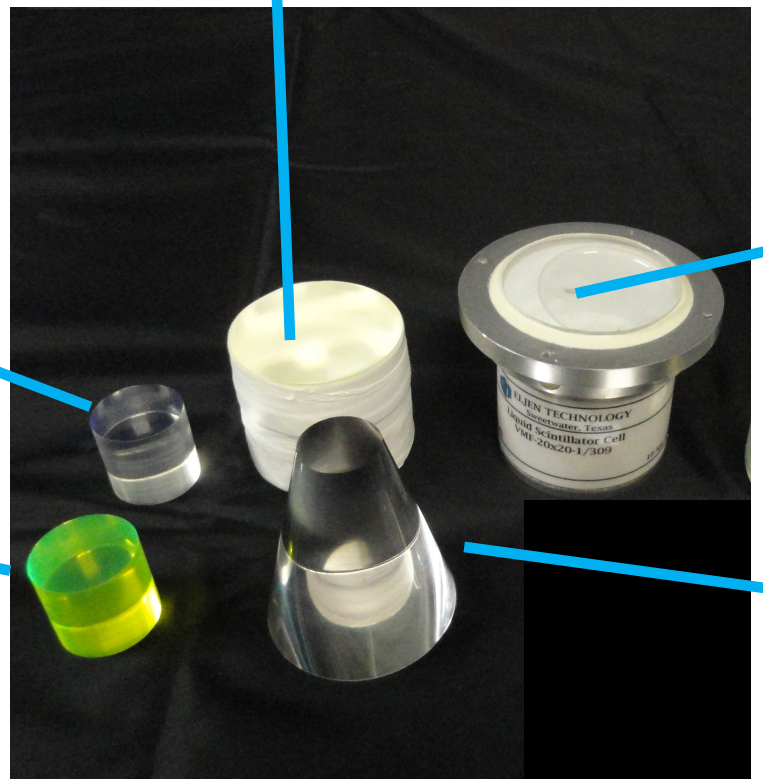
Experimental set-up

Organic scintillator with PSD capabilities

Plastic EJ-299 (2015) (2" x 2")

~ 8000 photons / 1MeV e-

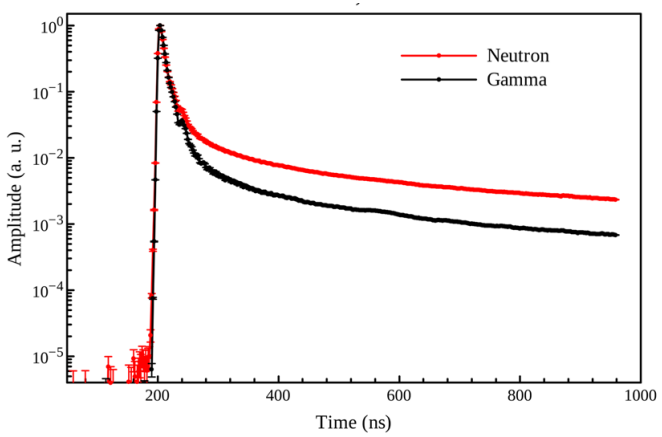
Plastic EJ-276 (1"x 1")



Liquid EJ-309 and EJ-301 (2" x 2")

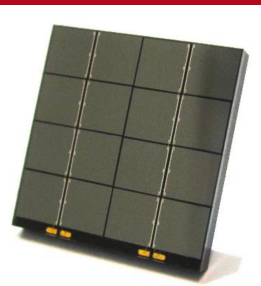
~ 12000 photons / 1MeV e-

Plastic EJ-276G (1"x 1")



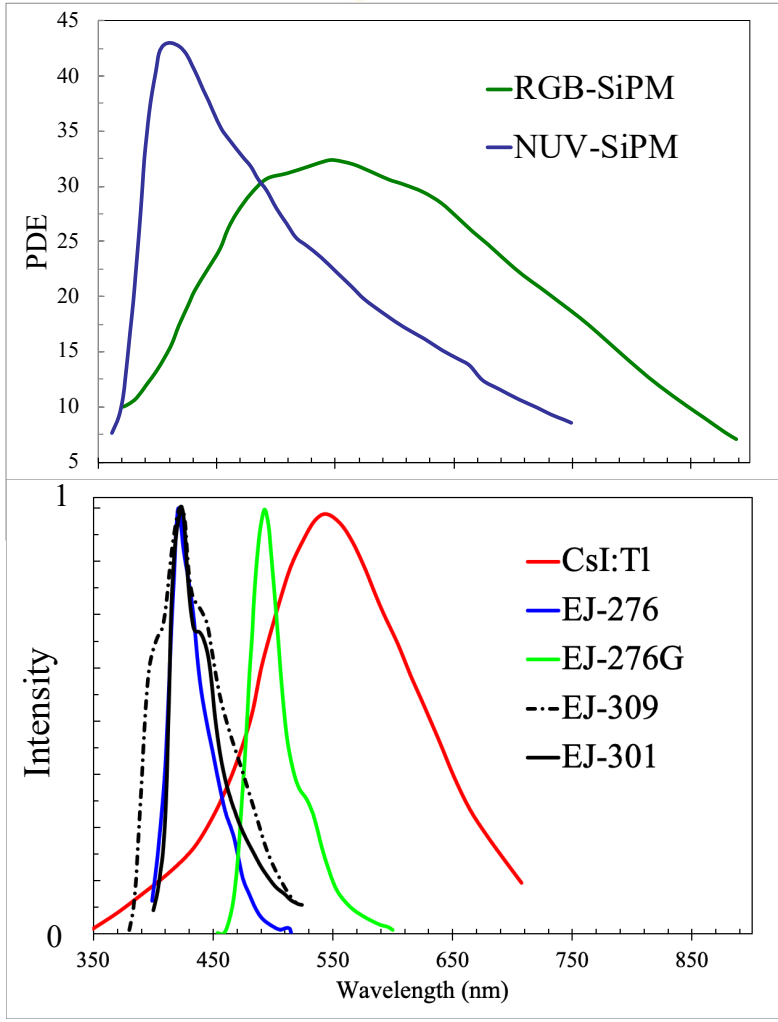
Light guide (75°)

Experimental set-up
Advansid Large Area SiPMs



- Arrays (16 ch) SiPM AdvanSiD

	RGB-SiPM	NUV-SiPM
SiPM size	4x4 mm^2	
Cell number	9340/ch	
Cell size (pitch)	40μm× 40μm	
Recharge time constant	50 ns	70 ns
Peak sensitivity wavelength	550 nm (32.5 %)	420 nm (43 %)
Breakdown voltage, typ	27 V	26 V
Dark Count Rate	< 200kHz/mm^2@ 4V OV	< 100kHz/mm^2@ 4V OV

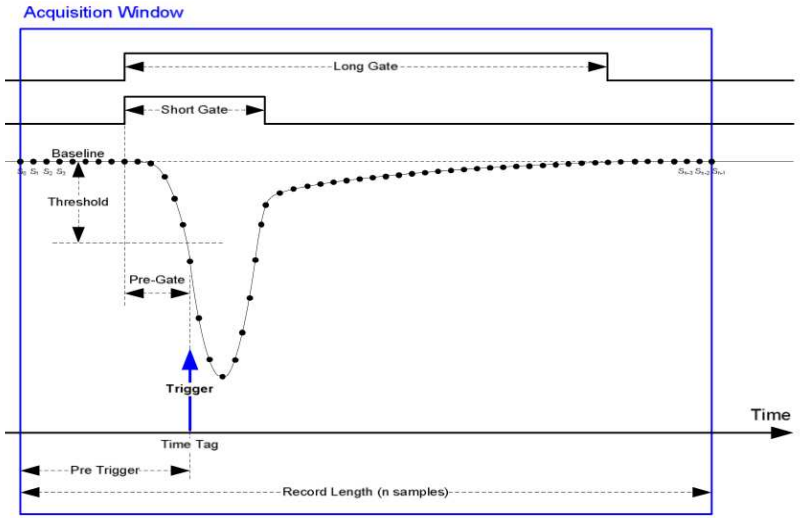


For comparison:

PMT Hamamatsu 2", H1949-51 (rise time = 1.3 ns)

Experimental set-up
DAQ

- Pulse recording and run online advanced algorithms (FPGA) for digital pulse processing (PSD, etc.)



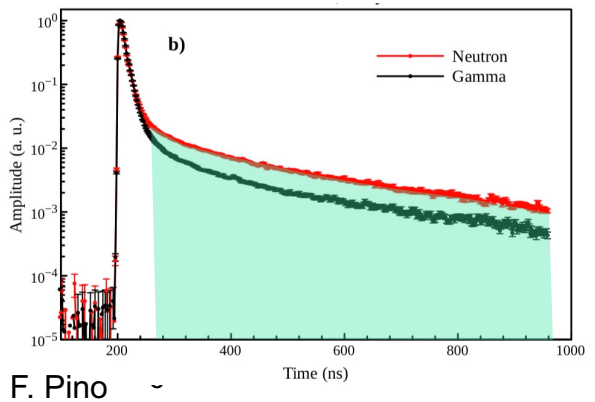
- Sampling rate: 250 MHz (725)
- ADC resolution: 14 bit
- Possibility to get for each event (pulse):
  - Partial integral, Q_{fast}
  - Total integral, Q_{total}

- ABCD software

https://github.com/ec-jrc/abcd/

- **AmBe ($2x10^5$ n/s)**
- **^{22}Na γ source**

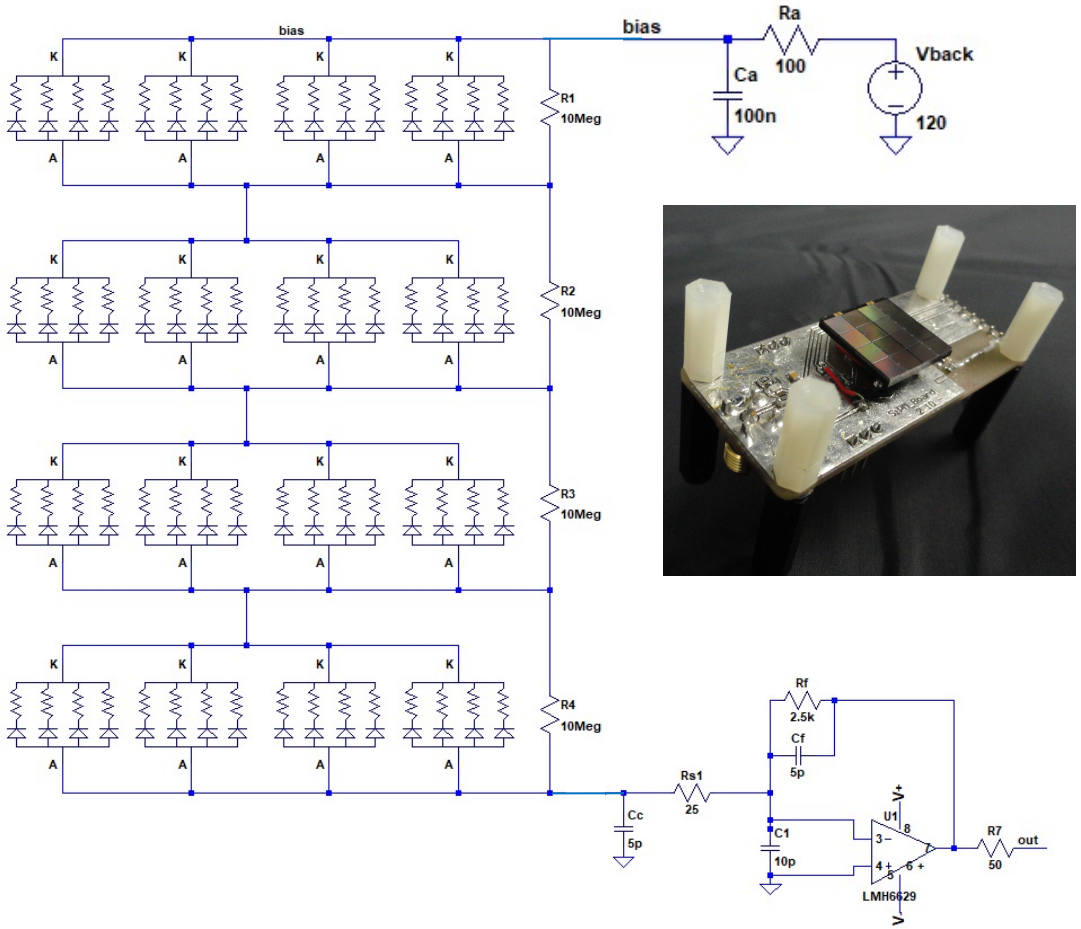
Double gate integration method for PSD

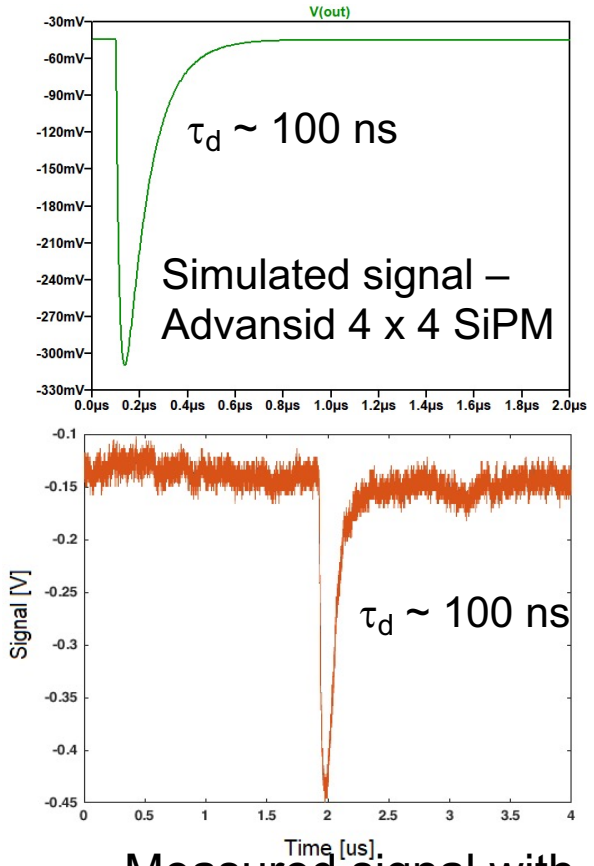


$$\frac{Q_{total} - Q_{fast}}{Q_{total}} = \frac{Q_{tail}}{Q_{total}}$$

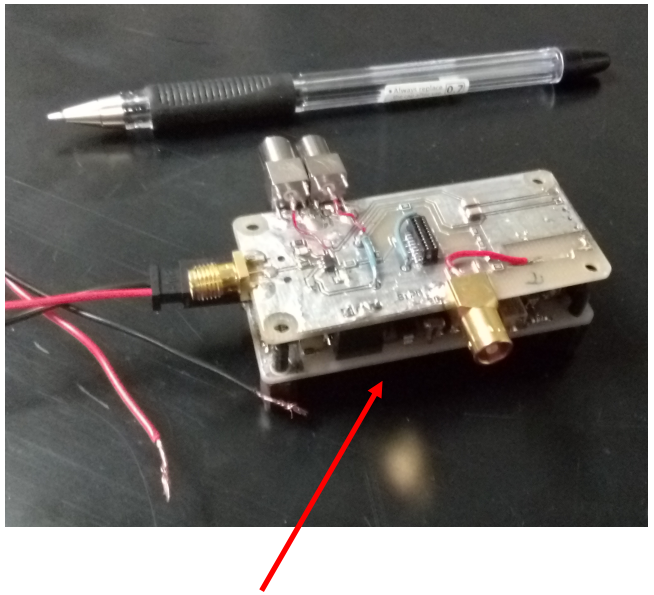
SiPM (array 4x4) preamplifier design and characterization

- 4 series x 4 parallel SiPM
- Transimpedance amplifier based on Ultra-Low Noise, High-Speed OpAmp (LMH6629)



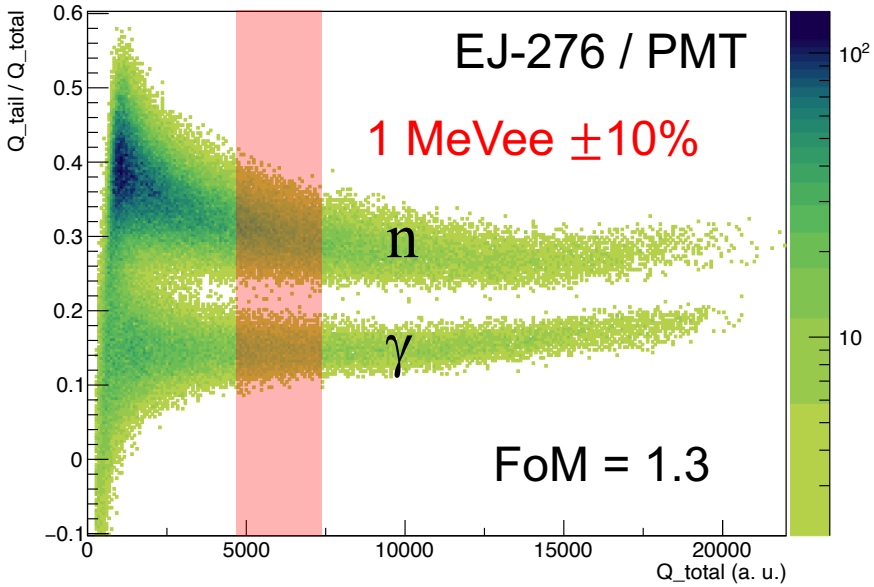


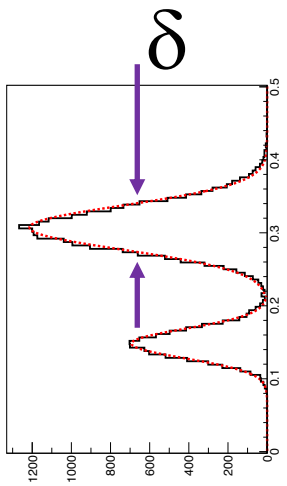
Measured signal with 4ns laser pulse



Supply/bias board:
- Input 9V-14V
- Output +2.5V -2.5V / 120V

Plastic EJ-276 1"x 1"



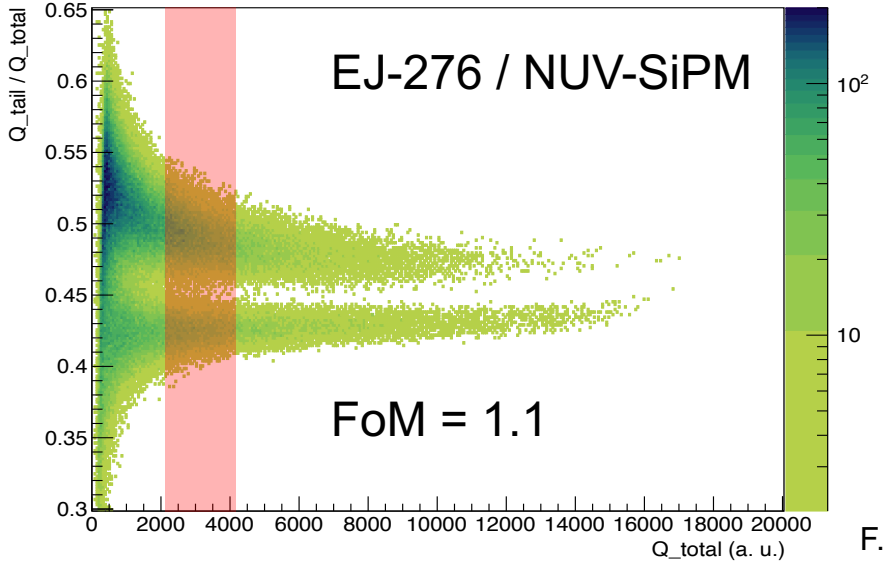


Δ

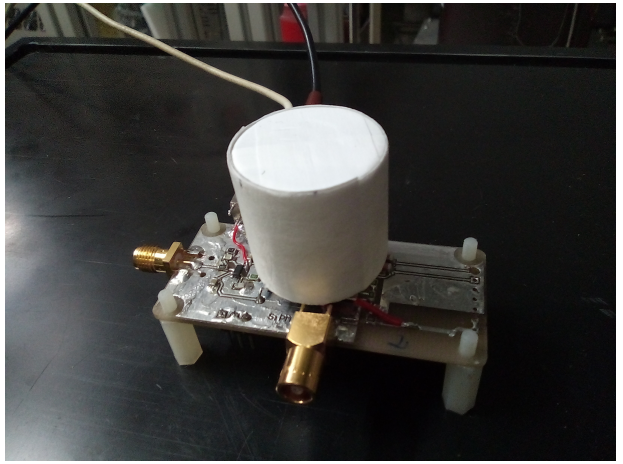
Difference between centroids

$$FoM = \frac{\Delta}{\delta_n + \delta_\gamma}$$

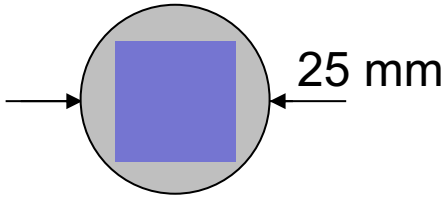
FWHM



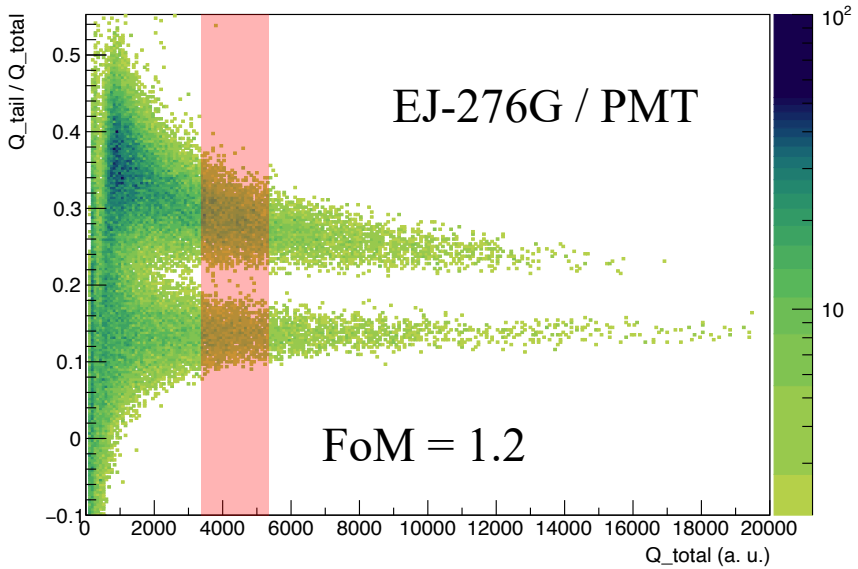
Overvoltage (Vov) = 4 V

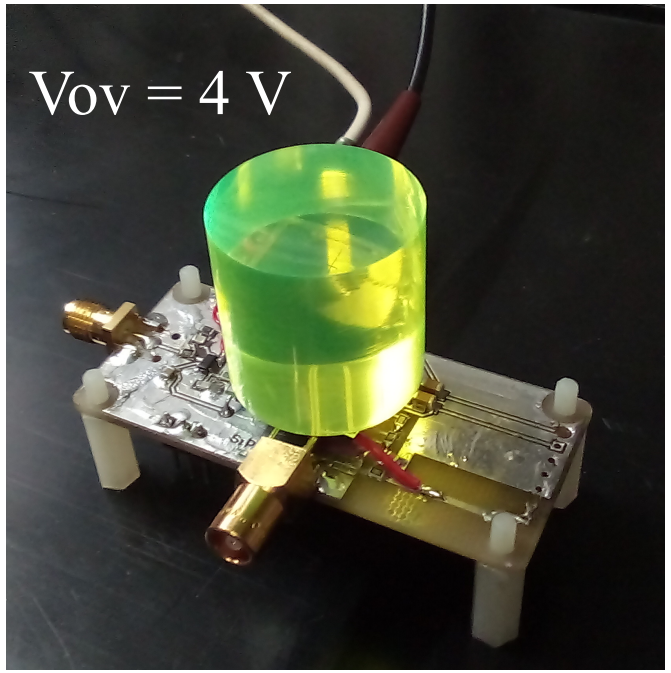


Covered surface ~ 60%

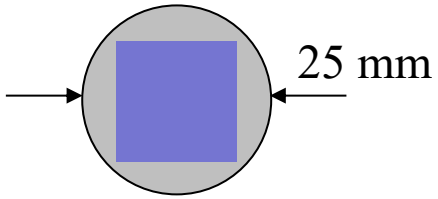


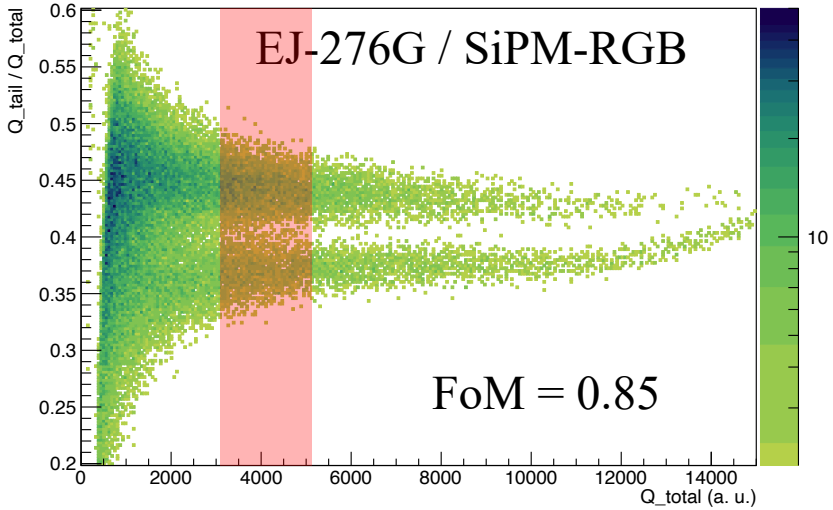
Plastic EJ-276G 1"x 1"

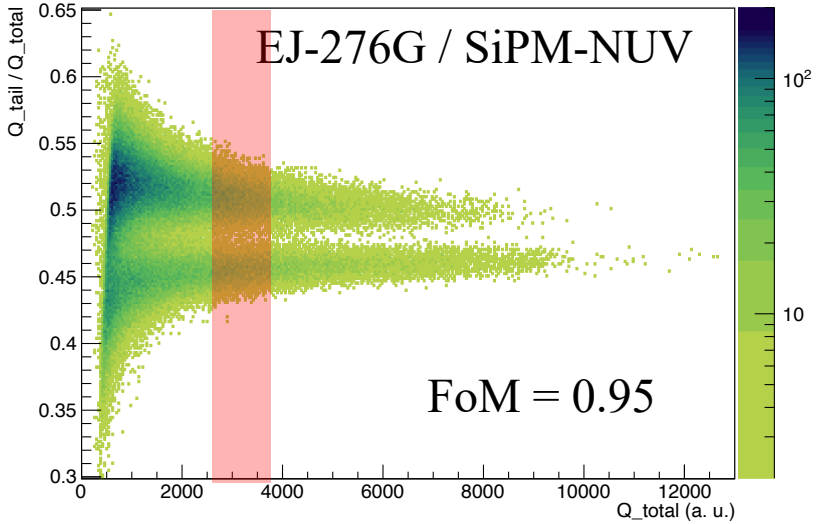




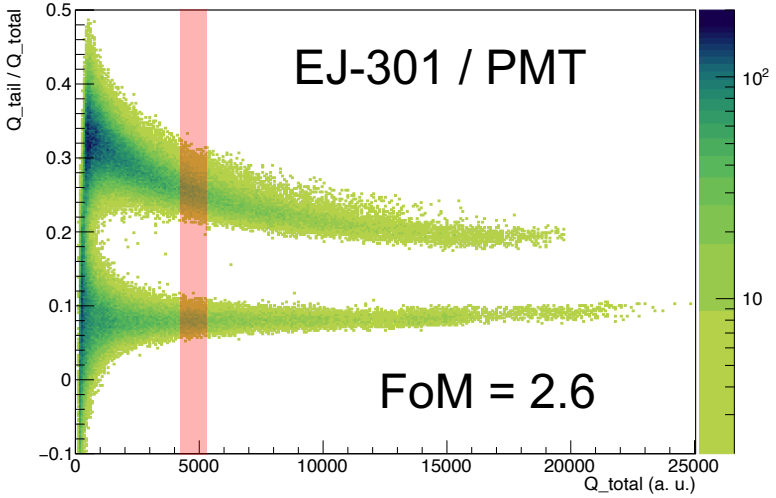
Covered surface ~ 60%

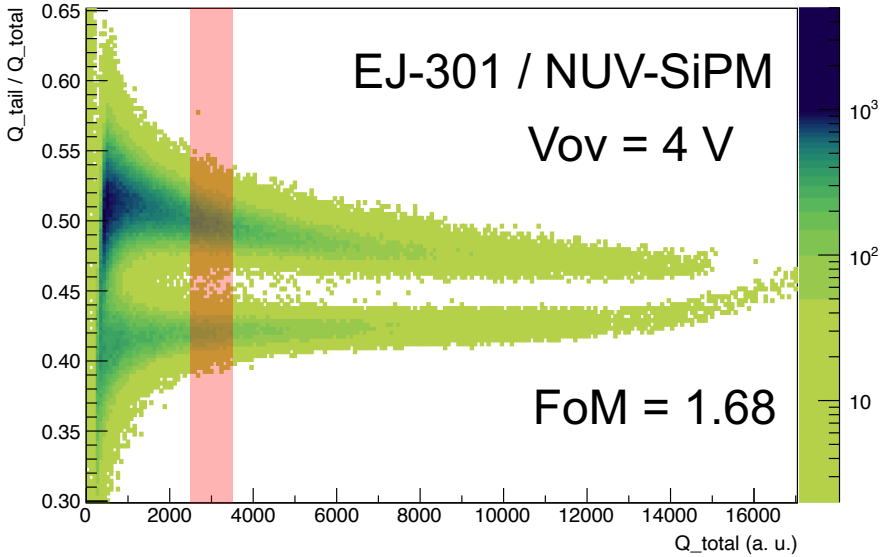


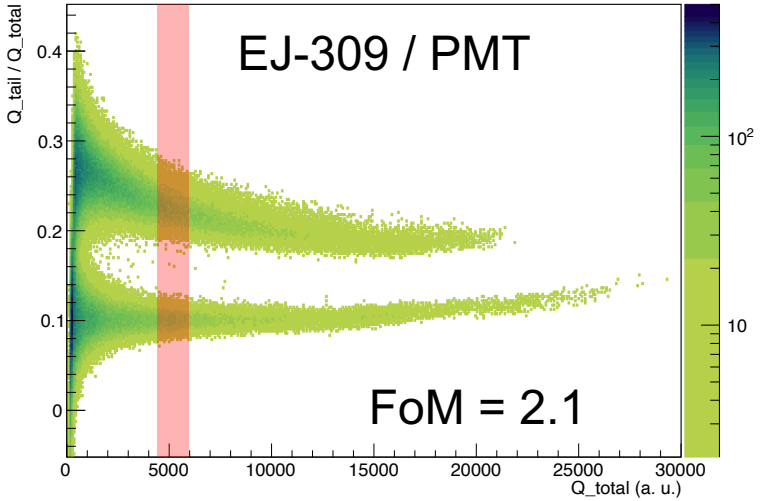


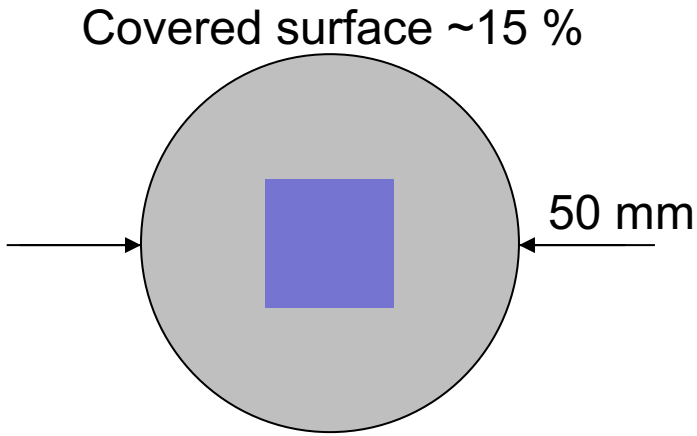


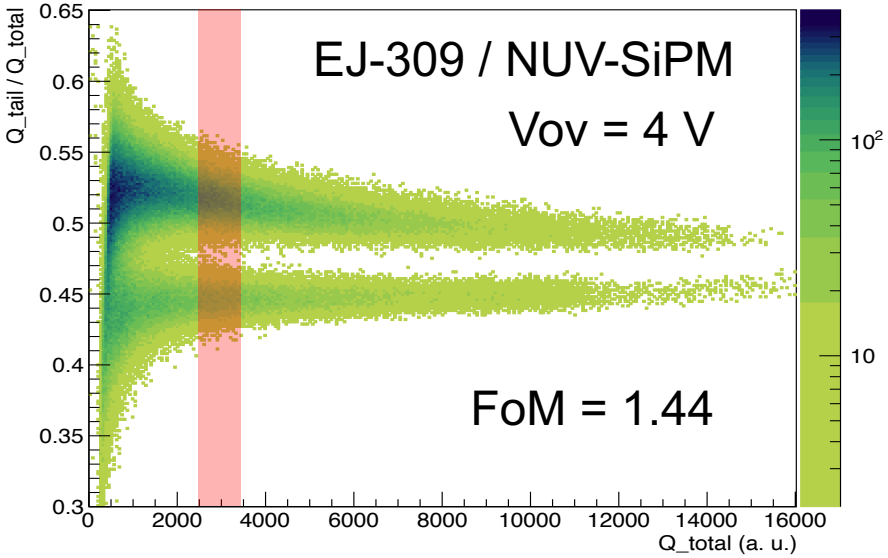
2"x 2" Liquid Scintillators, EJ-301 and EJ-309



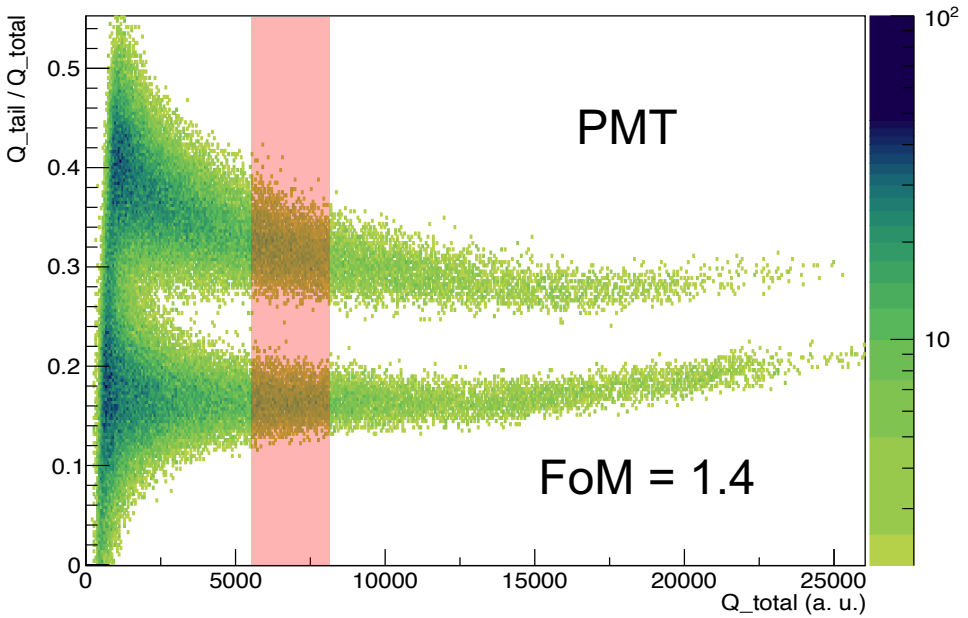


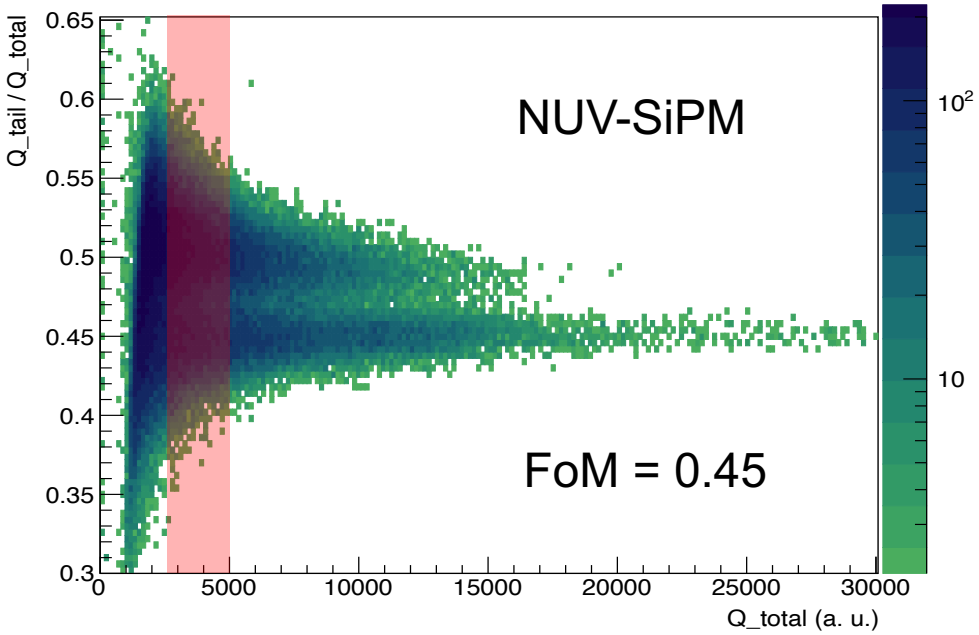




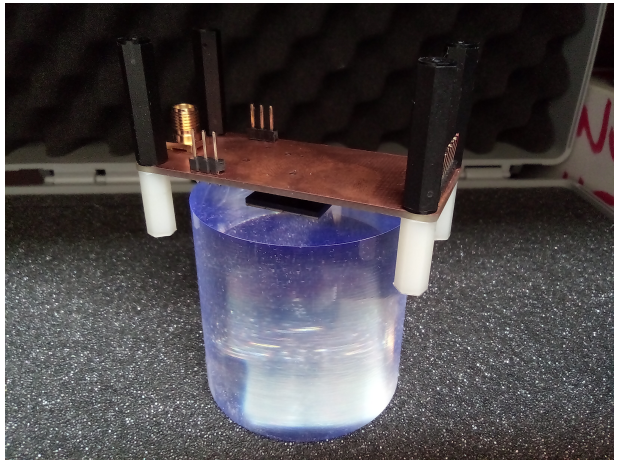


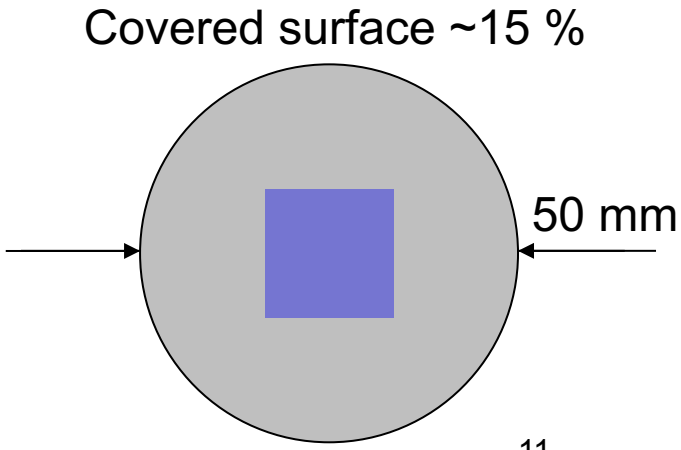
Plastic Scintillator EJ-299 (2015) 2"x 2"





- Plastic EJ-299 light yield is 65% respect to liquids
- Light guide -> doesn't help!
- Cover more area?





Conclusions and next steps

- Main achievement:
  - Good n/γ discrimination using large area SiPM read-out / large-sized scintillators
    - Till now reported only using small SiPMs and plastic scintillators (~ units of cm^3)

Next steps

- New read-out configurations (covered area and light yield)
- Faster digitizer
- Alternative data analysis, FFT

Active Target

Depending on the case of study (reaction):

- Coverage of large solid angle -> Liquids
- Small solid angle-> Plastics
- $SrI_2(Eu)$, CsI(Tl) / SiPM; for gamma and charge particles

Thank you!!!