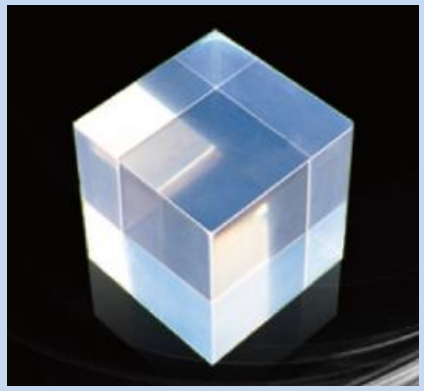
Ultra-high light yield solutions (from IHEP)

- Low temperature CsI+SiPM+TPB solution
- CsI, LY >100000 photons/MeV, 2.5 times better than CsI(Na)
- SiPM, PDE 50%-60%, 2 times better than PMT
- Expected ~50-60 p.e./keVee



CsI

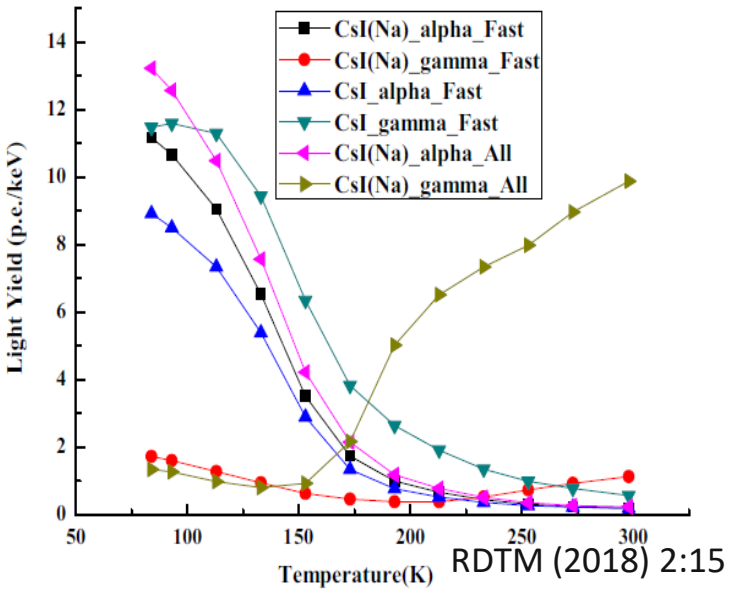
SiPM

TPB (WLS)

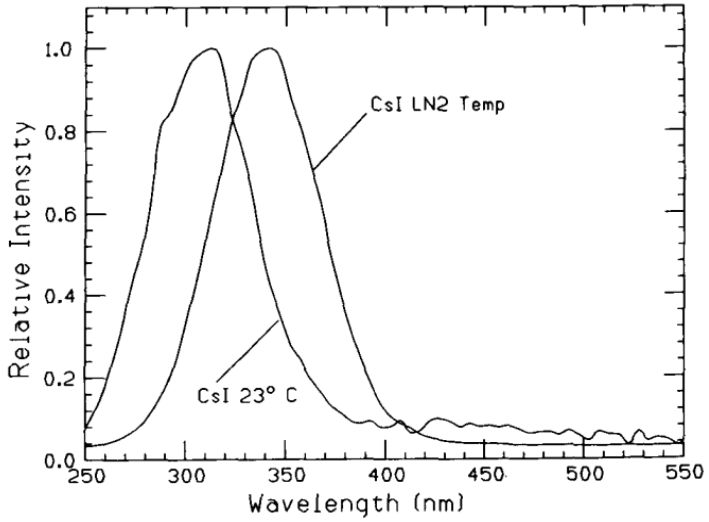
Low temperature

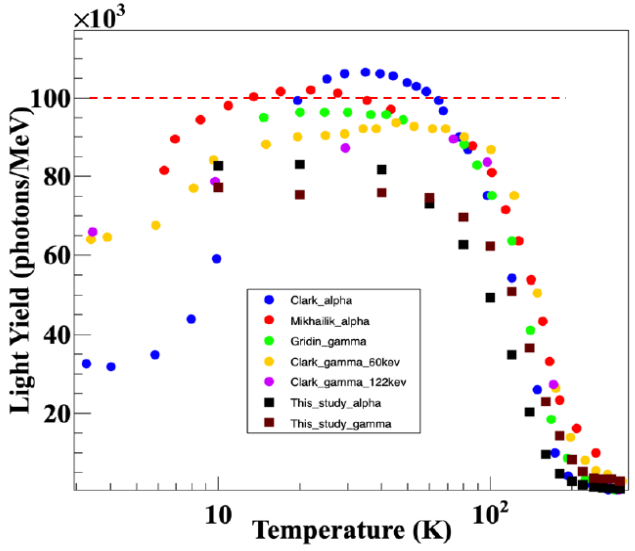
Pure CsI crystals

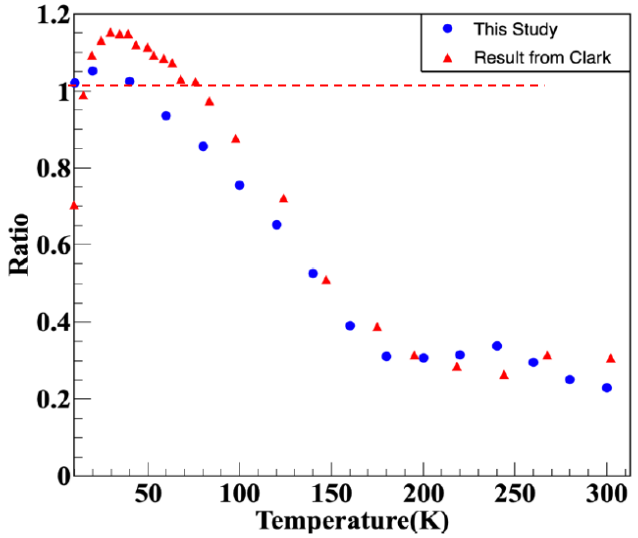
- LY be significantly improved at LT
- The brightest scintillator, 310-340 nm
- QF>100% for alpha/gamma
- QF for nuclear recoil/gamma 10%, 20%???
- LY of CsI(Na), CsI(Tl) is reduced at LT



RDTM (2018) 2:15



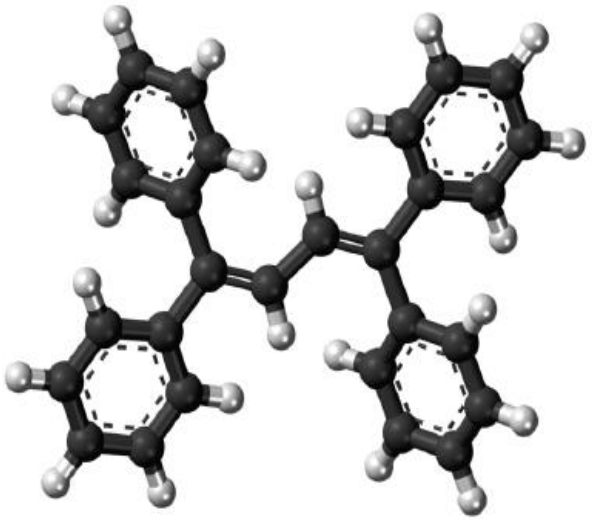




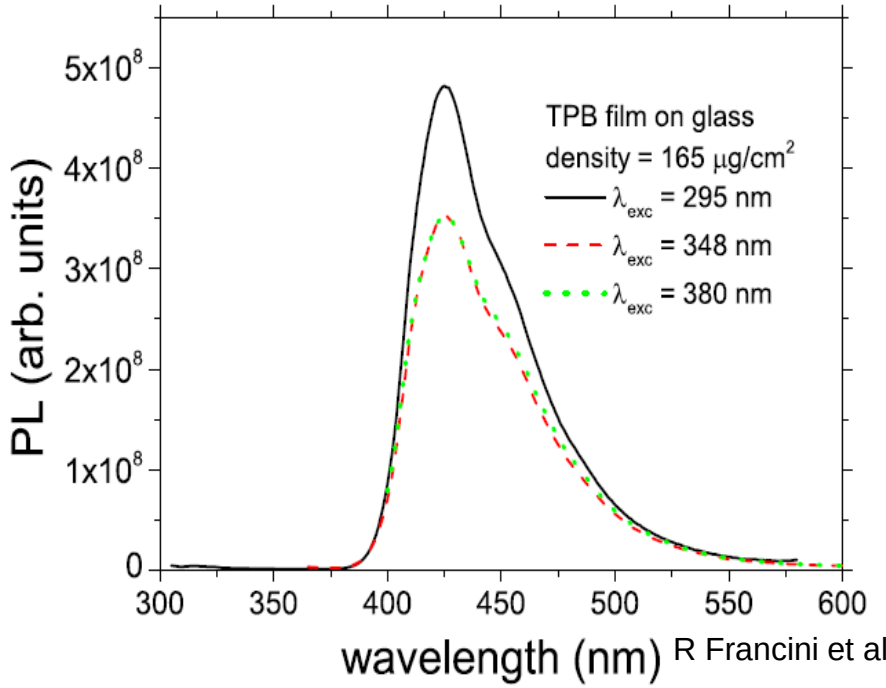
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 37, NO. 2, APRIL 1990 New Physics: Sae Mulli,Vol. 71, No. 5, May 2021, pp. 469475

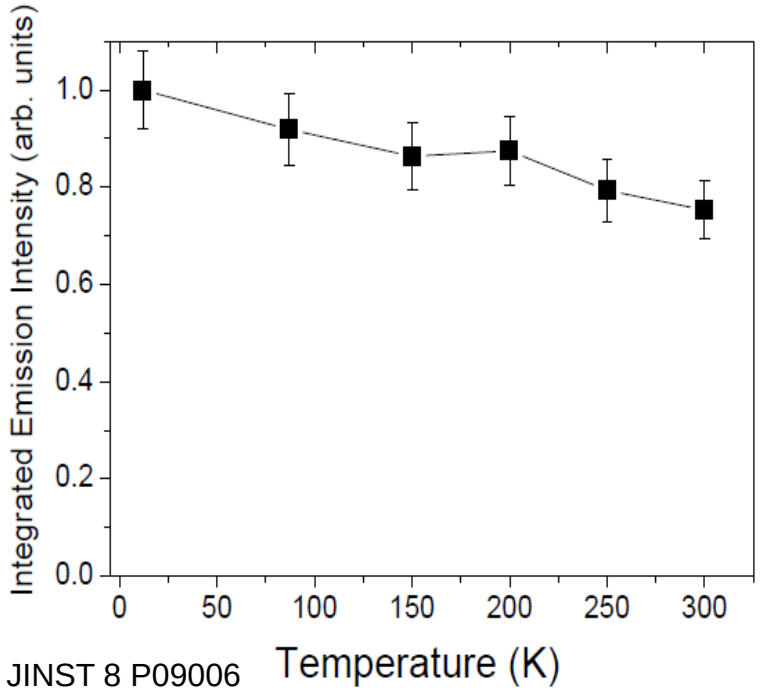
TPB wavelength shifter

- **Shift 340nm to 420 nm, match the SiPMs sensitive spectrum**
- **Performance is enhanced at LT**
- **Widely used in liquid argon detectors**



Tetraphenyl Butadiene (TPB)

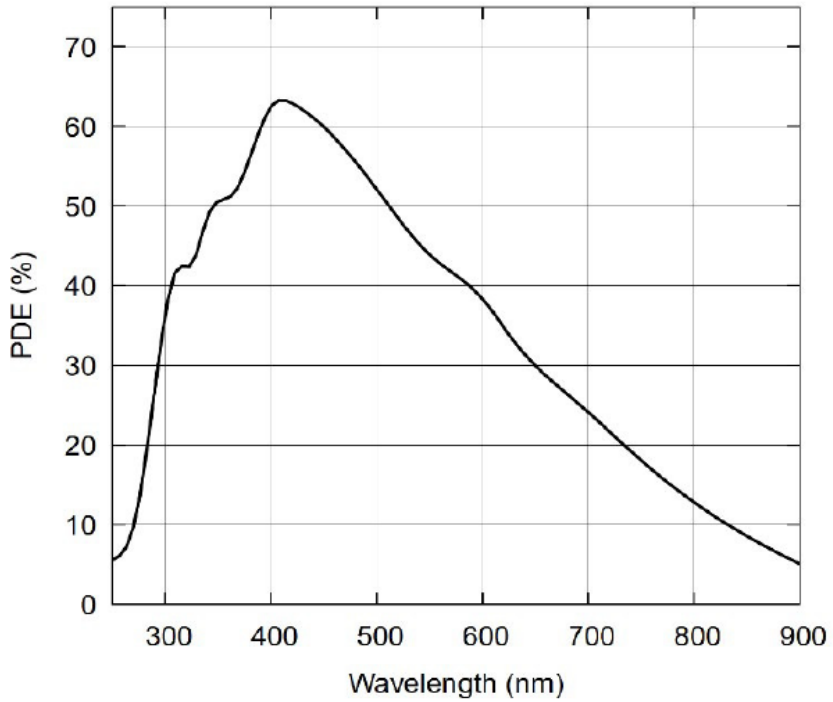




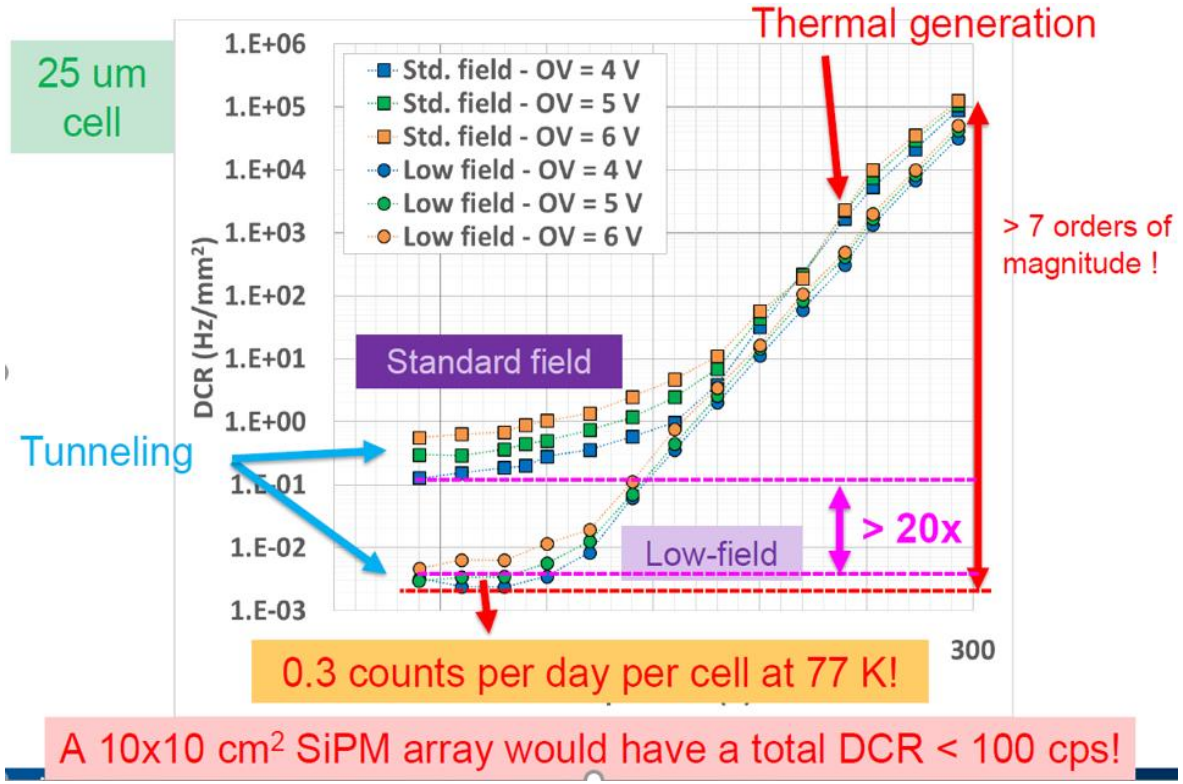
R Francini et al 2013 JINST 8 P09006

SiPMs Performance

- **PDE 50-60% at 420 nm**
- **DCR reduced by 7 orders, < 0.01 CPS/mm² at 77K**
- **Optical cross talk, acts as a photon amplifier**



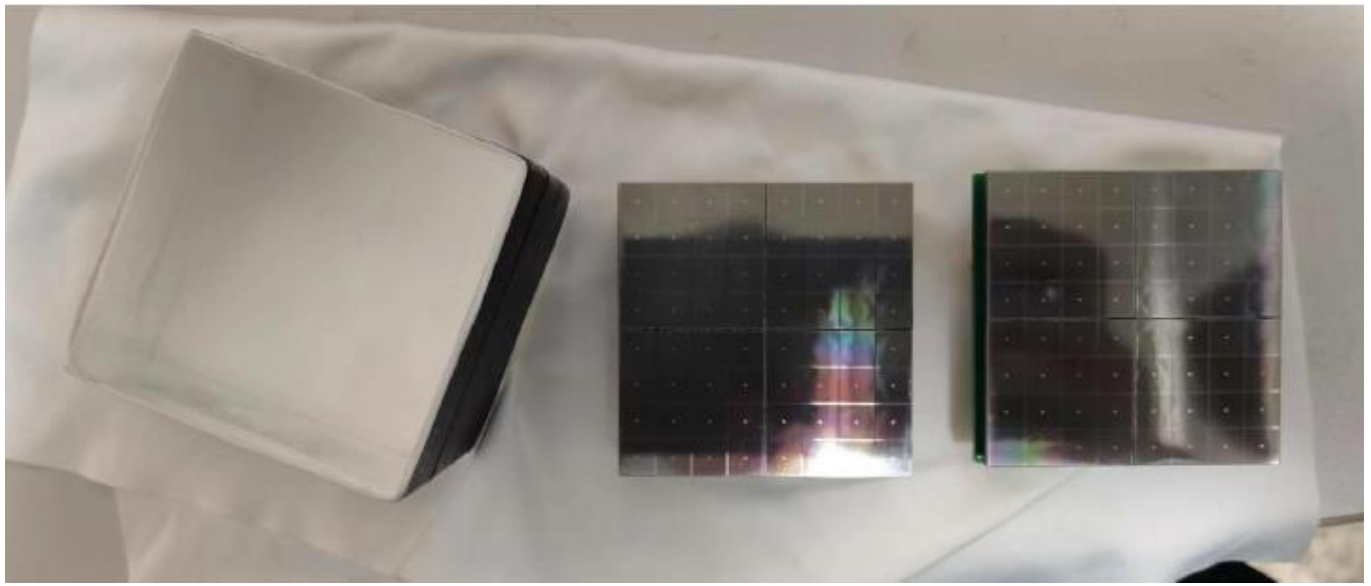
AFBR-S4N66P014M NUV-MT Silicon Photomultiplier

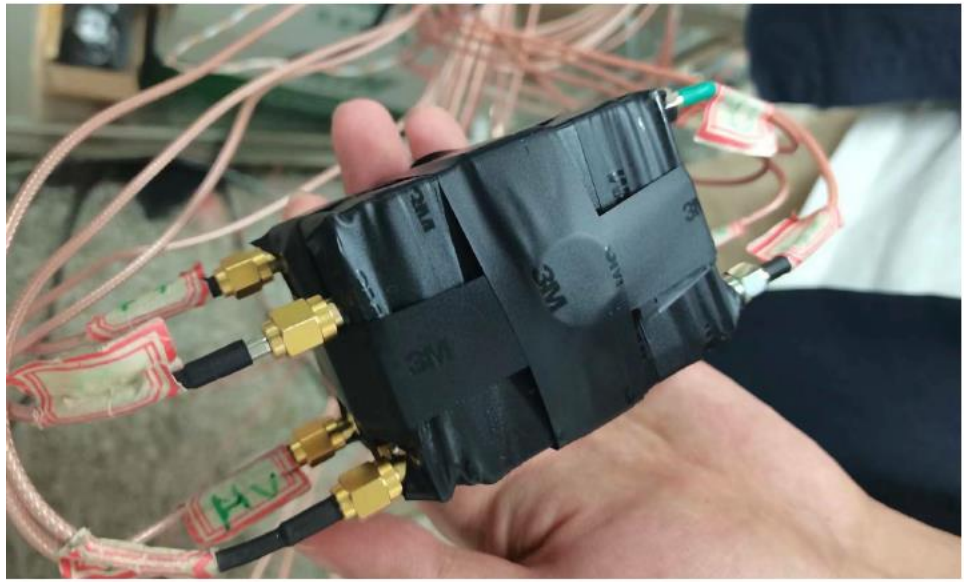


Alberto Gola FBK

Prototype detector

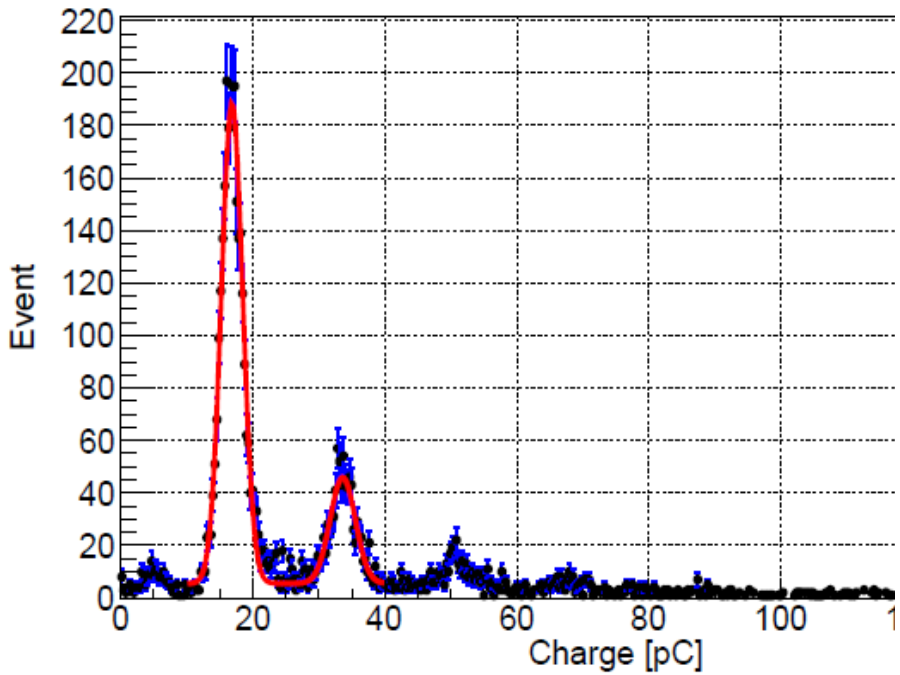
- CsI crystal 5x5x5 cm, 0.56kg, polished
- Packaging with Teflon reflective film without TPB
- SiPMs array, 5x5 cm, two end readout, with TPB
- Cooling to 77 K with liquid nitrogen
- Low temperature front-end amplifier circuit

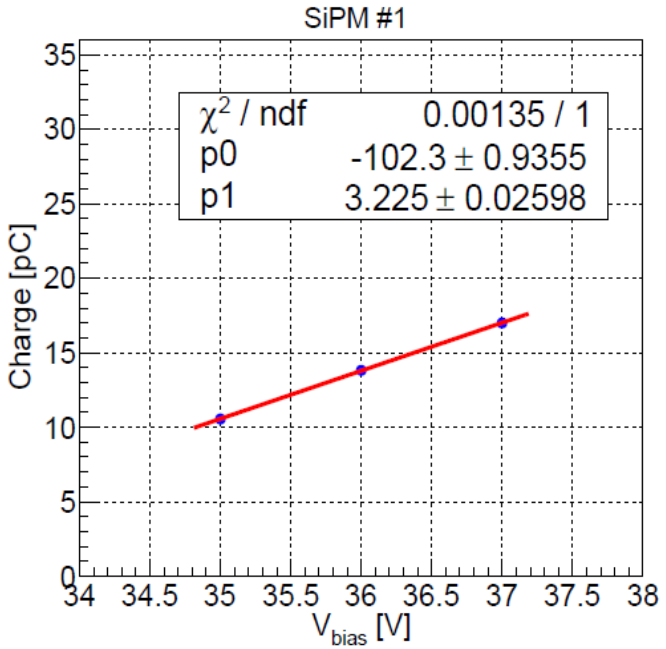


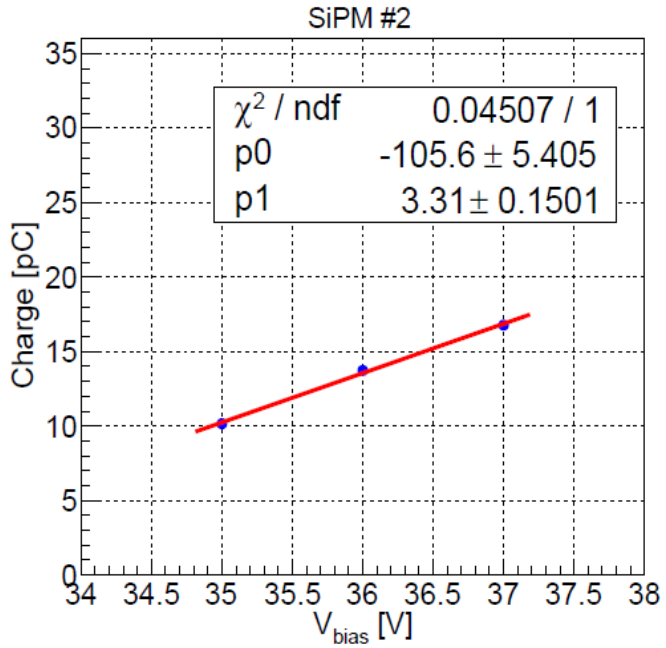


SiPMs array performance

- SiPM and preamplifier run stably at low temperatures
- Single photoelectron resolution is very good
- Consistency of the two arrays is very good
- DCR ~0.1 Hz/mm² @35V bisa



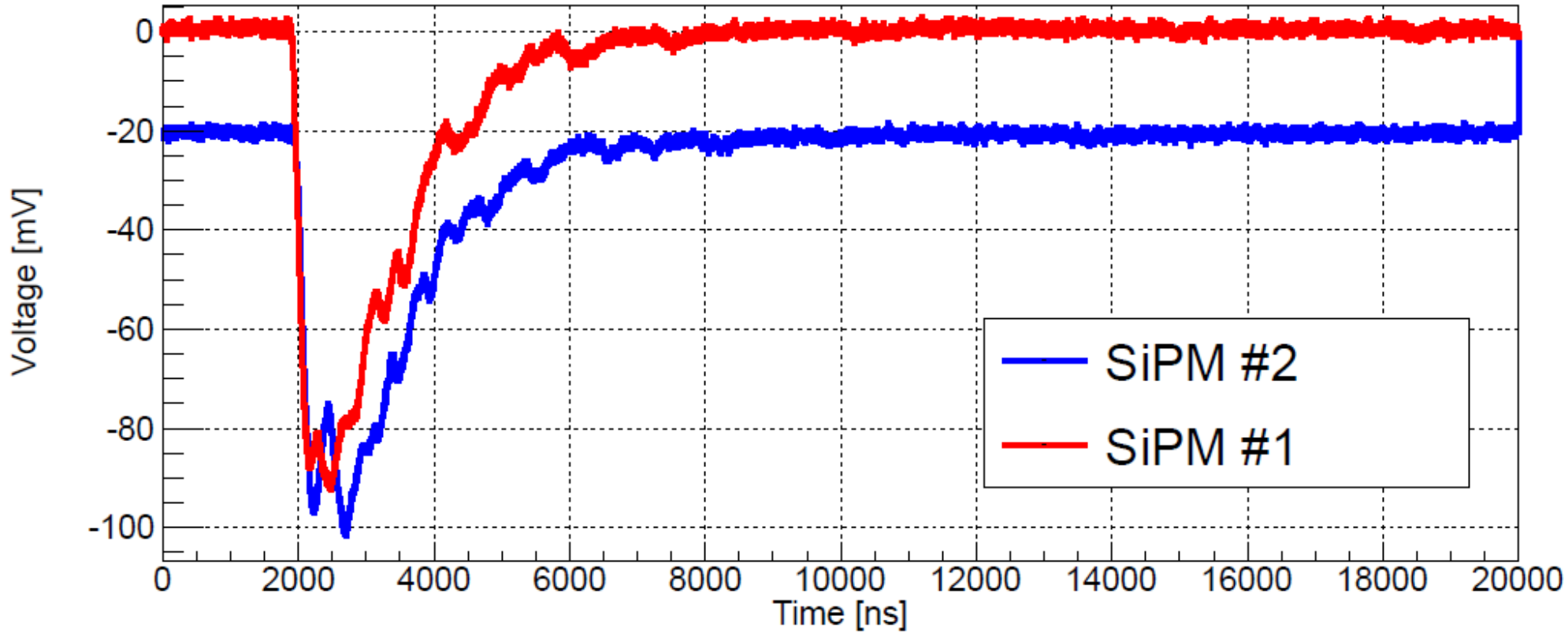




arXiv:2212.11515

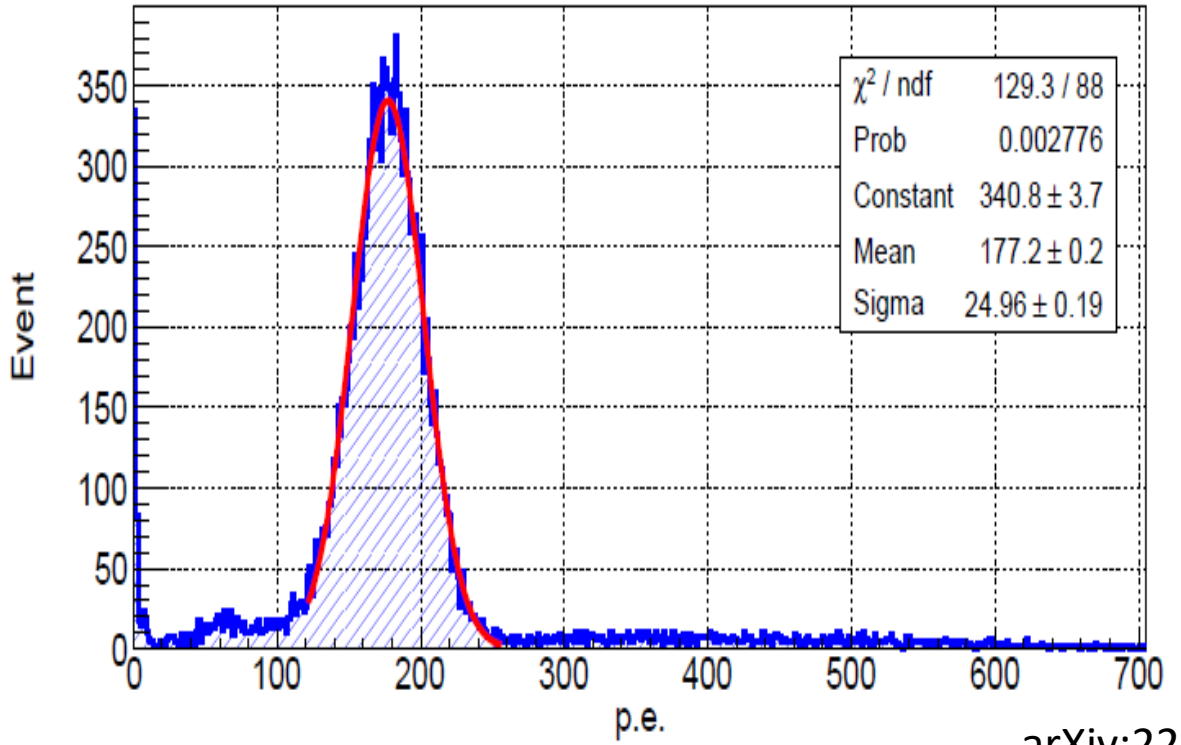
Waveform performance

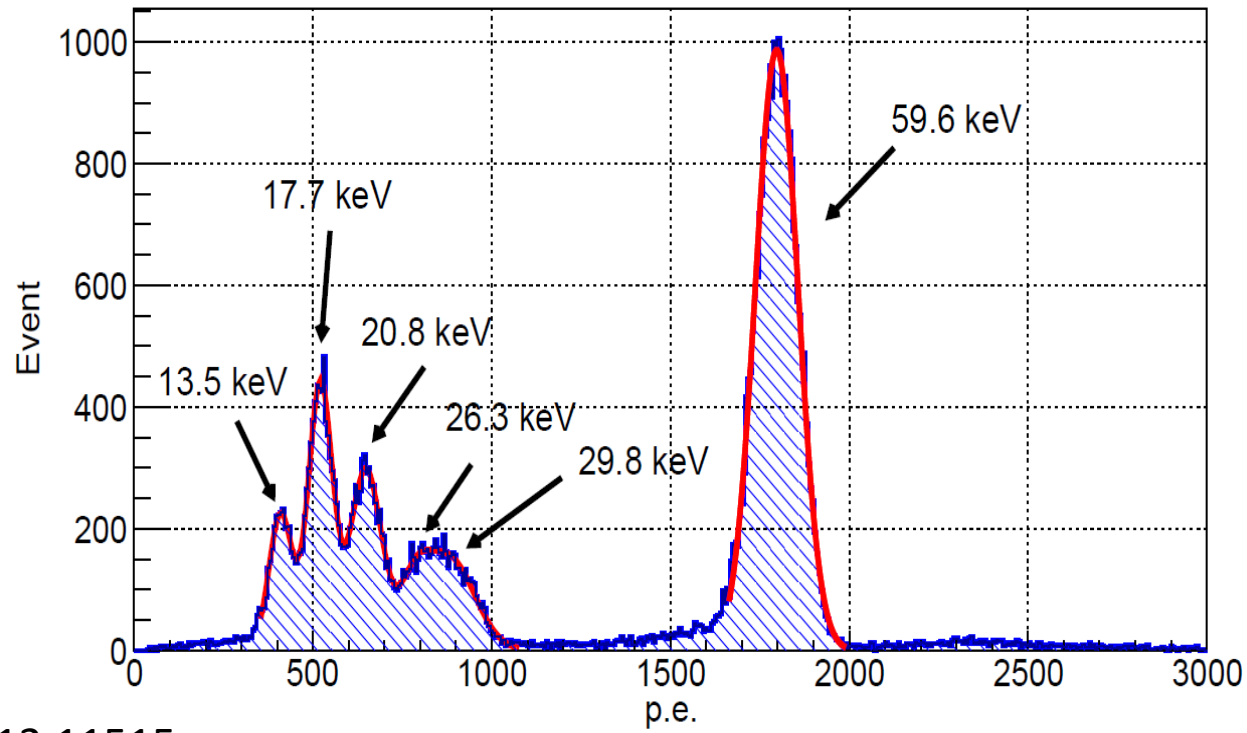
- Decay time ~1 μs, Pulse Width ~3 μs
- Baseline width <5 mV



Energy spectrum

- Test with ^{241}Am and ^{55}Fe
- Excellent energy resolution,fine structures are clearly visible

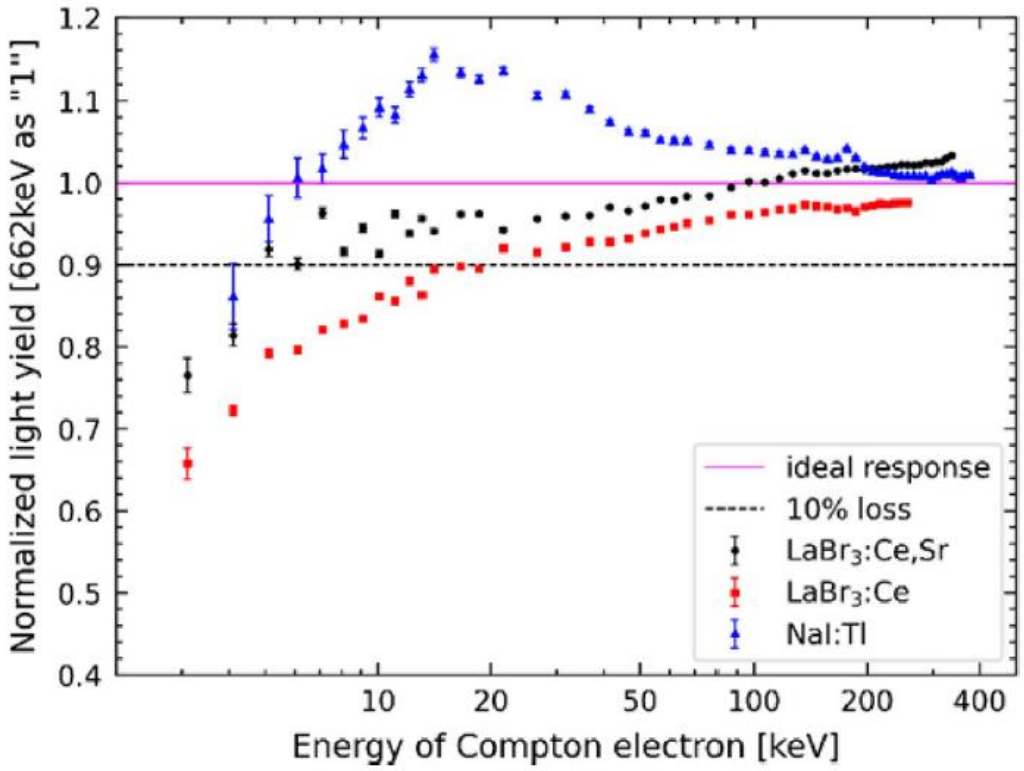




arXiv:2212.11515

Luminescence linearity

- **Excellent luminescence linearity, no drop down below 10keV**
- **Significantly better than $LaBr_3$, NaI:Tl**



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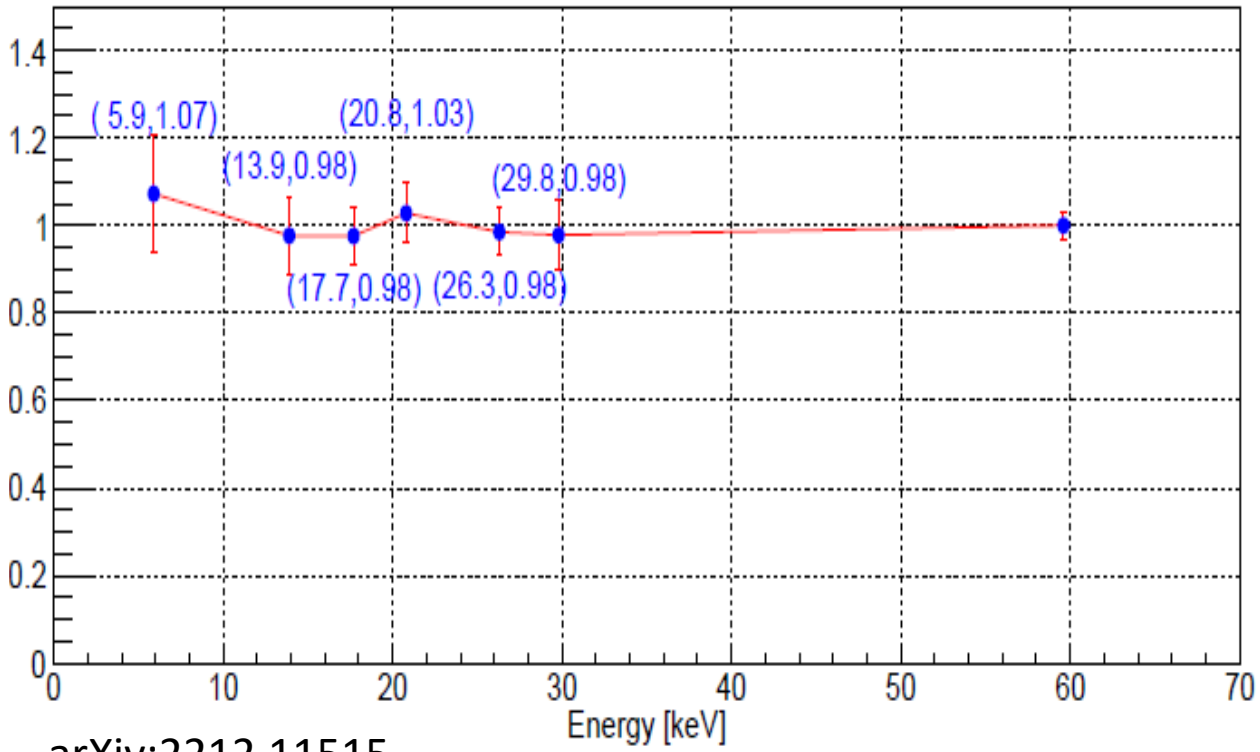
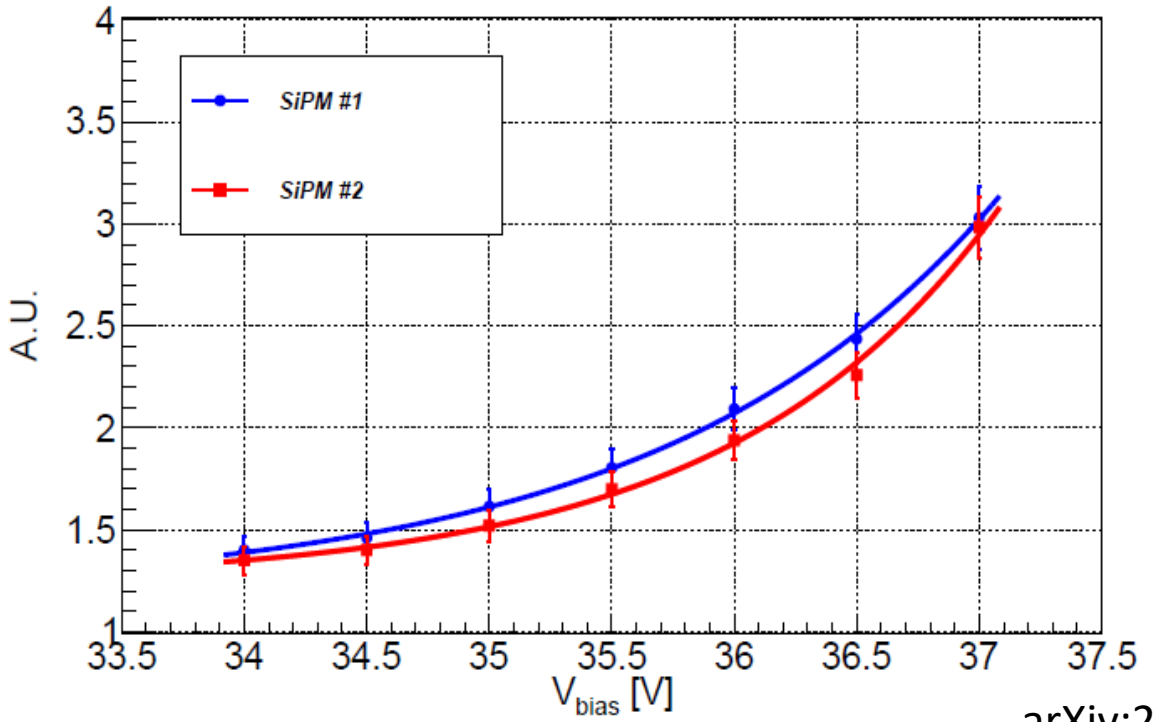
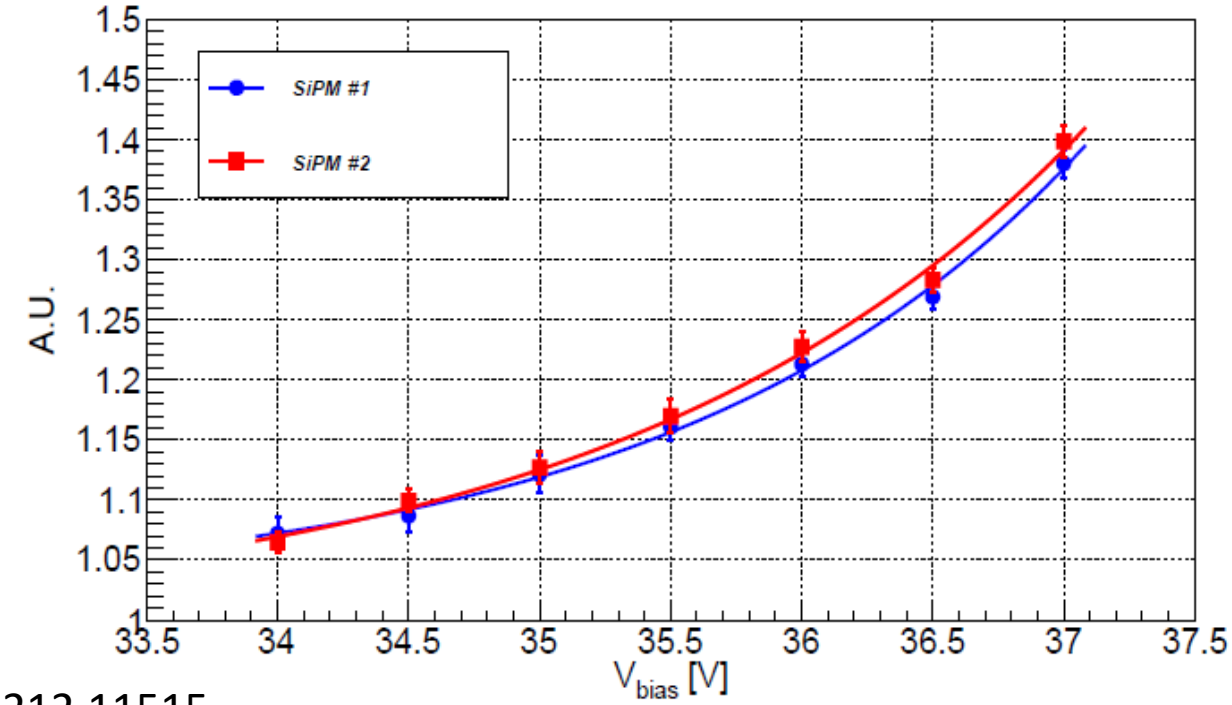


arXiv:2212.11515

Influence of SiPMs Cross Talk and After Pulse

- CT, AP significantly increasing the measured p.e. number
- Internal CT, AP triples the number of p.e. at 37 V_{bias}
- External CT 1.4 times the number of p.e. at 37 V_{bias}

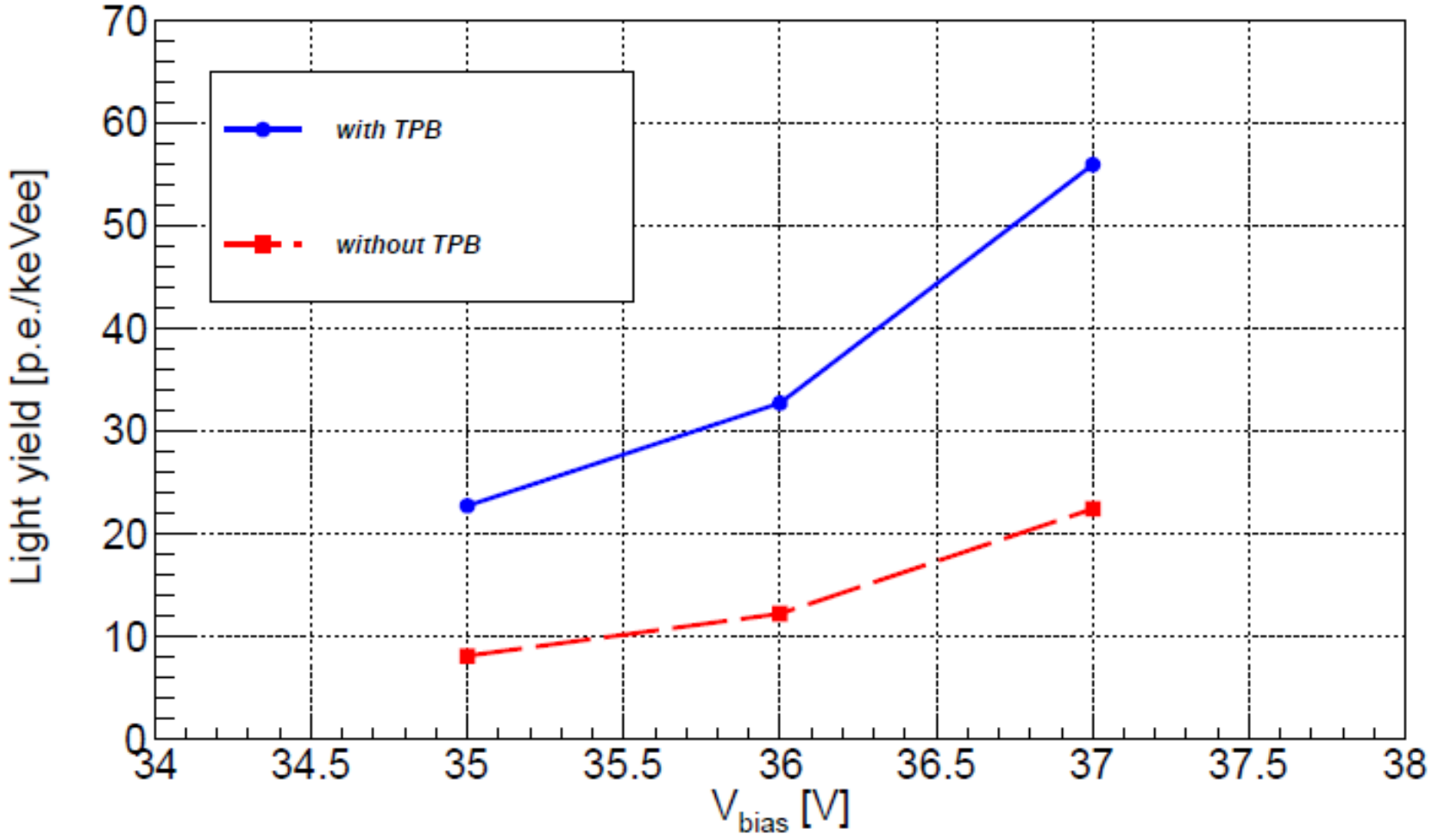




arXiv:2212.11515

Influence of TPB

- **Photoelectrons number is doubled with TPB**

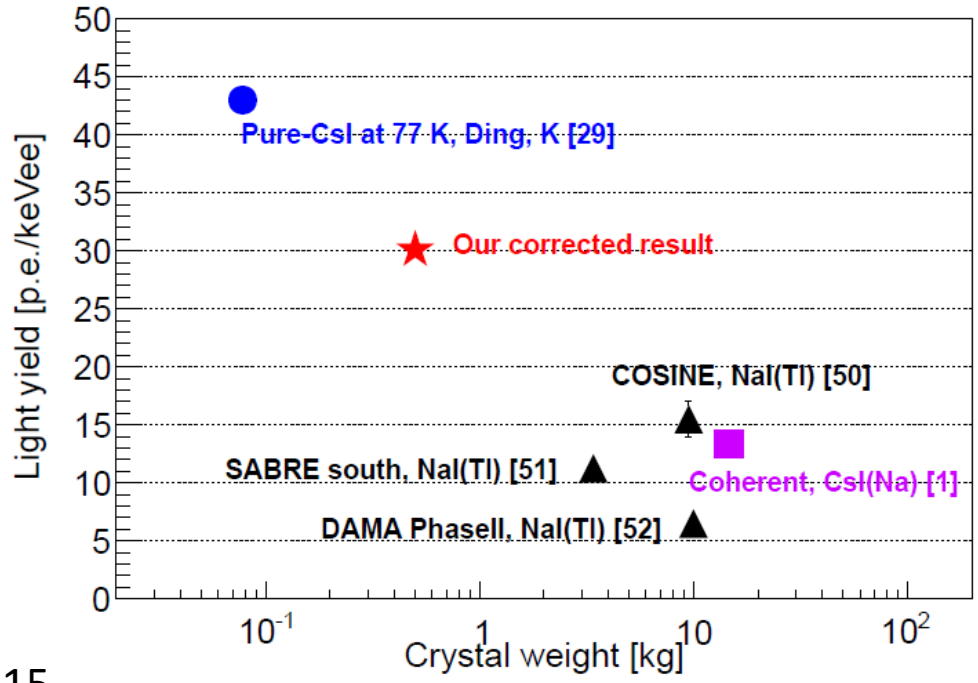


arXiv:2212.11515

Light yield

- The measured p.e. number increases significantly with increasing bias voltage, 30 to 122 p.e. /keVee
- 122.7 p.e./keVee, a world record
- 30.1 p.e./keVee, after CT subtract (50% PDE at LT?)

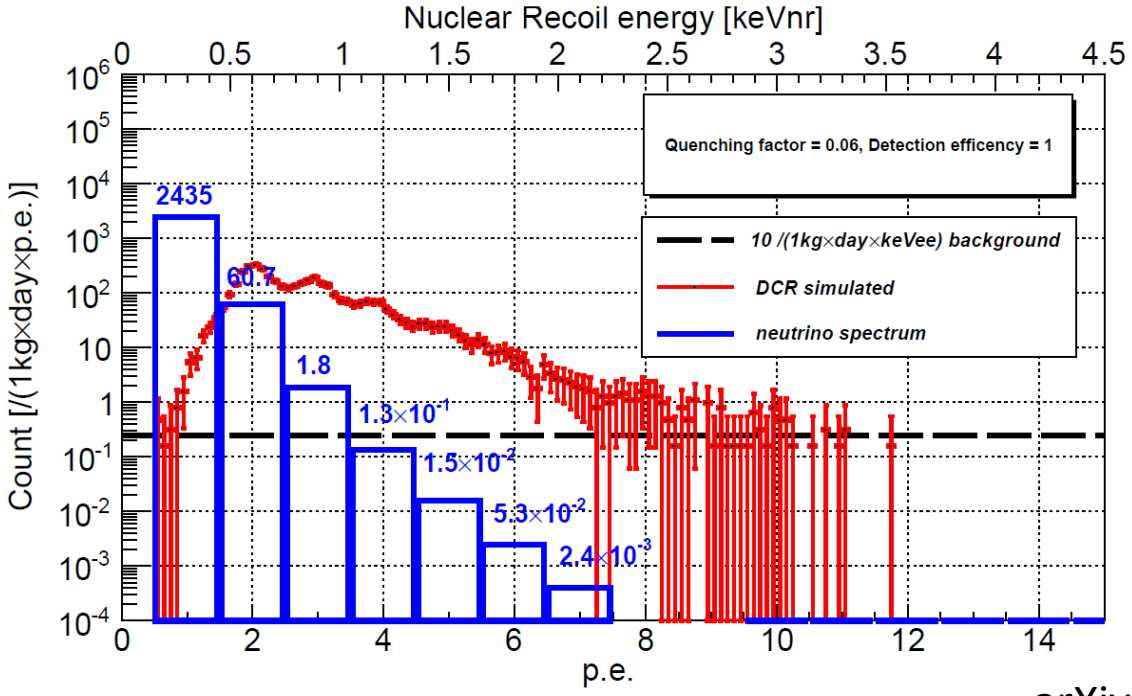
V_{bias} (V)	p.e.	resolution	measured LY	corrected LY
34.0	176.8	14.3%	30.0±4.3	20.9±3.1
34.5	206.4	14.4%	35.0±5.0	23.4±3.6
35.0	241.4	14.4%	40.9±5.9	25.8±4.0
35.5	286.7	15.4%	48.6±7.5	26.7±4.3
36.0	359.4	16.2%	60.9±9.9	28.2±4.8
36.5	473.5	19.7%	80.2±15.8	29.0±5.9
37.0	723.8	26.0%	122.7±32.2	30.1±8.1

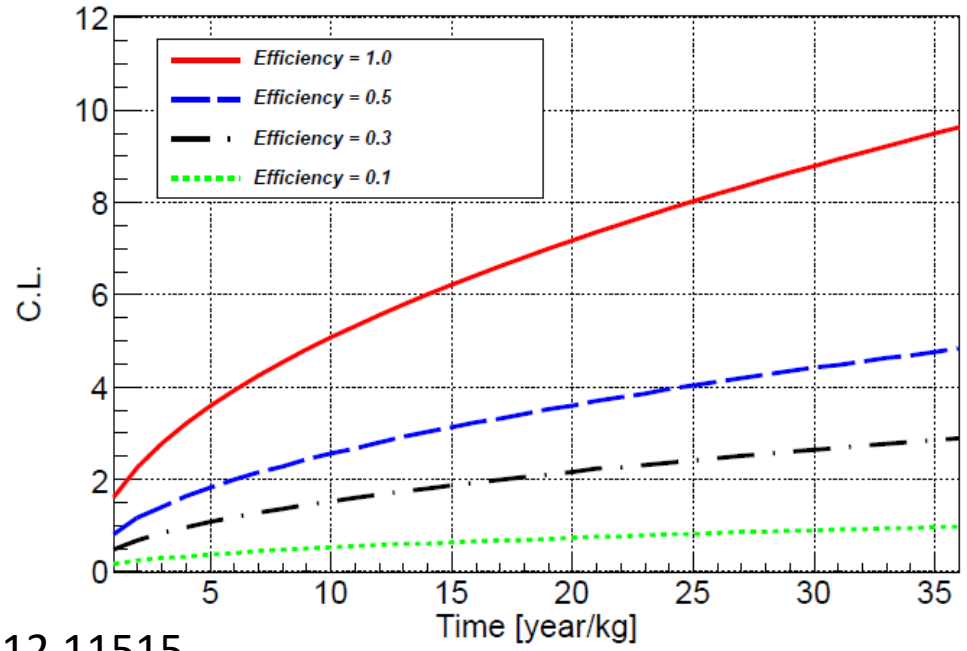


arXiv:2212.11515

Potentials in the CEvNS detection

- 35 m distance to a 4.6 GWth reactor
- QF=0.06, DCR= 0.1 CPS/mm^2, DCR dominant background,
- Threshold 2 p.e., good chance for reactor CEvNS observation
- If QF ~15%?, DCR~0.01?, better sensitivity

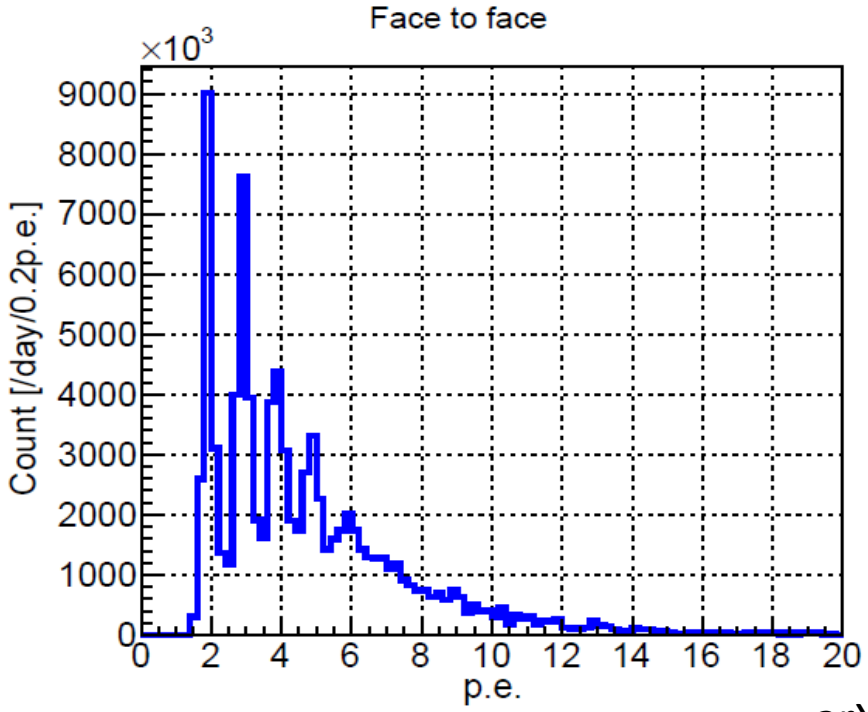


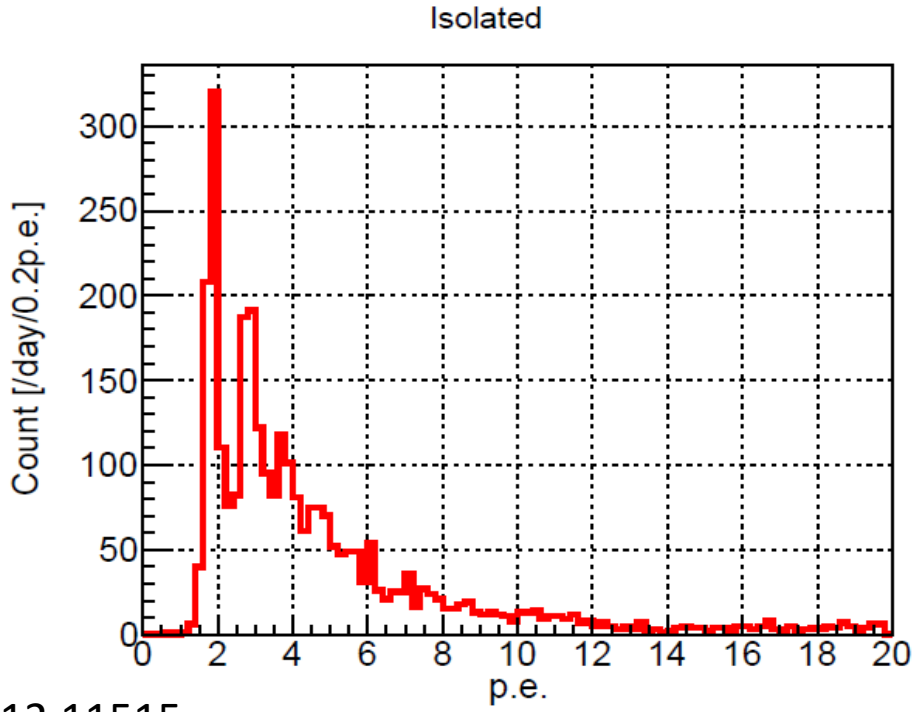


arXiv:2212.11515

Issue of SiPMs eCT coincidence events

- Events rate of eCT coincidence is very high
- 5 orders larger than accidental coincidence of DCR
- Big issue for low threshold detectors
- Need do further study, single-ended readout, correlation with iCT





arXiv:2212.11515

Summary

- Ultra-high light yield solution is proposed by IHEP
- The prototype detector works well
- Good chance for reactor CEvNS detection
- eCT issue need further study