中国科学院大学
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中国科学院高能物理研究所
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CryoCsI R&D And Sensitivity to CEvNS

For the 6th Magnificent CEvNS Workshop

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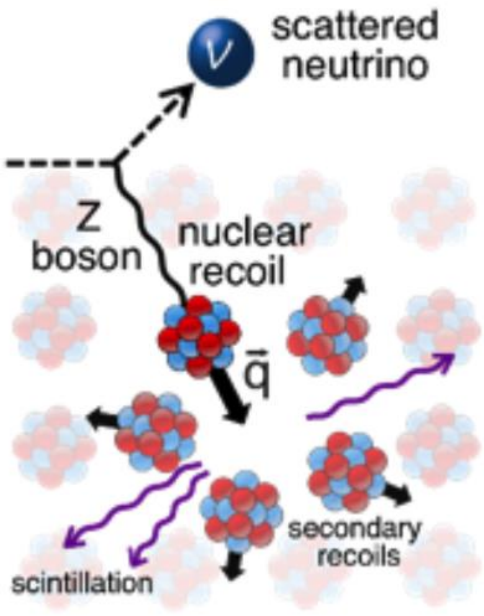
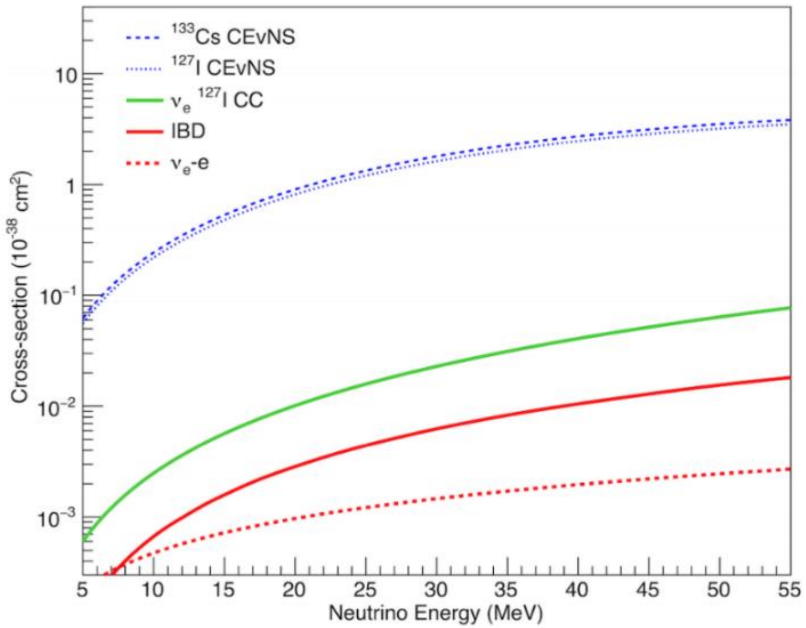
Quick Recap on CEvNS

1.1 CEvNS and Why CryoCsI?

•D. Akimov *et al* DOI:10.1126/science.aao0990





From Daina's report

- Features of CEvNS
  - Big cross section
  - Small signal → Low threshold detector
  - Interesting physics

- Features of CryoCsI
  - Large light yield:
    - 3 times of CsI(Na) @ RT
  - Large QF (Charlie's poster)
    - 8% for CsI(Na) @ RT
    - ~15% for CryoCsI @ 77K

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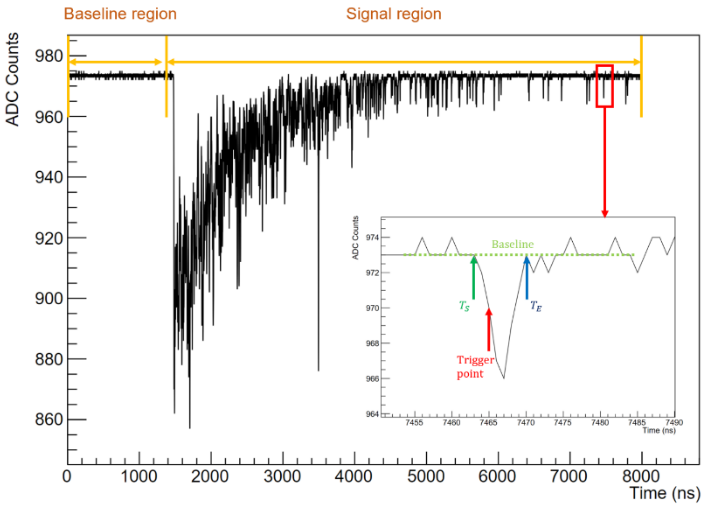
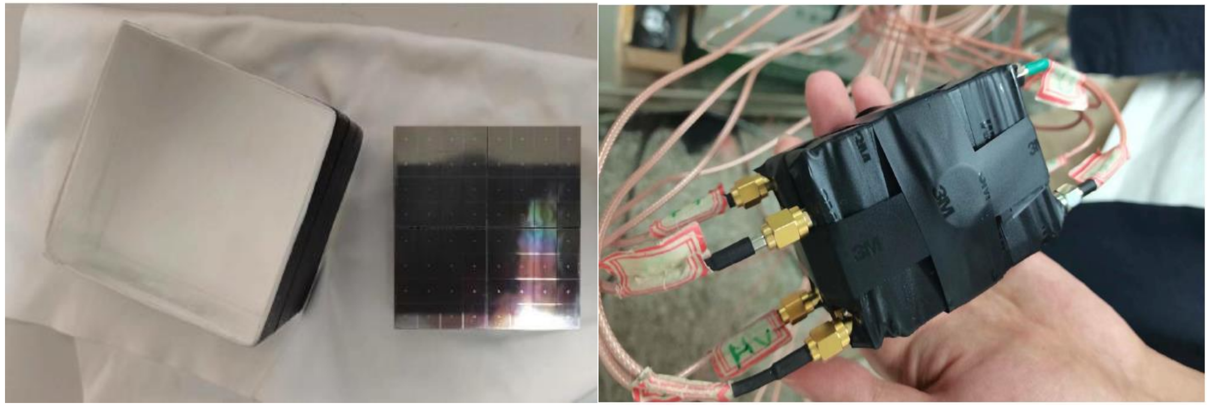
Characterization of CryoCsI

Arxiv: 2402.05026
Arxiv: : 2212.11515

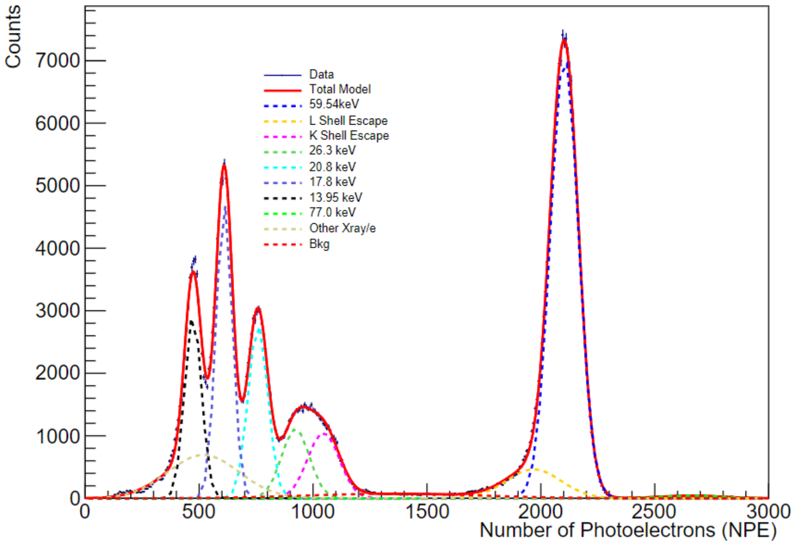
2.1 Experiment setup

- UCAS
  - PMT R11065
  - 2cm^3 cubic CsI crystal from BEIJING HAMAMATSU
  - Cryocooler cooling
  - CsI wrapped by 4 layers of BC-642 PTFE type
  - CsI all surfaces polished
- IHEP
  - SiPM: S14161-6050HS-04 dual readout
  - $5 \times 5 \times 5\ cm^3$: from Beijing Hamamatsu
  - Liquid N_2 cooling
  - TPB coated PTFE
  - CsI all surfaces polished

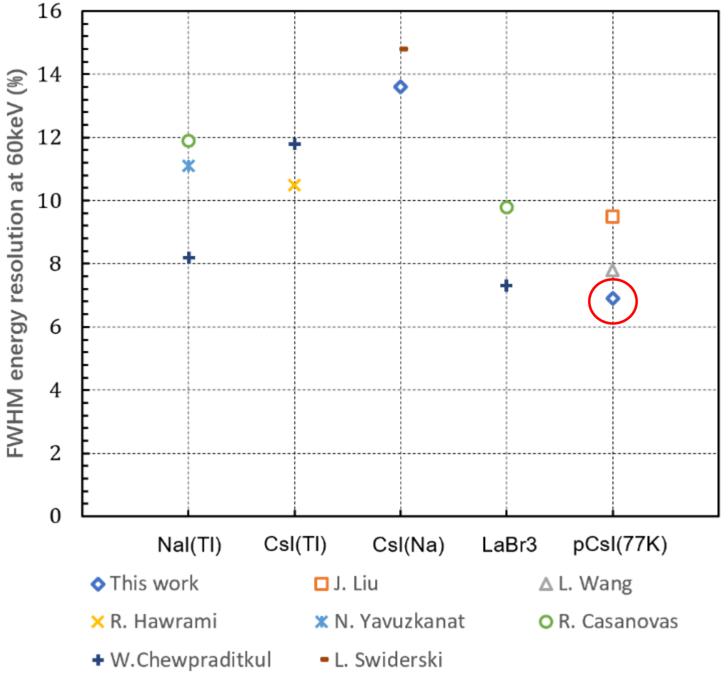


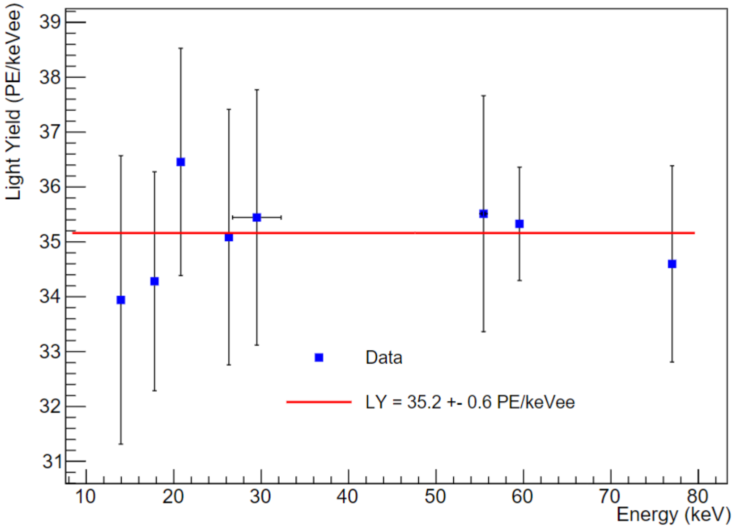


2.1 The light yield and energy resolution @ 77K



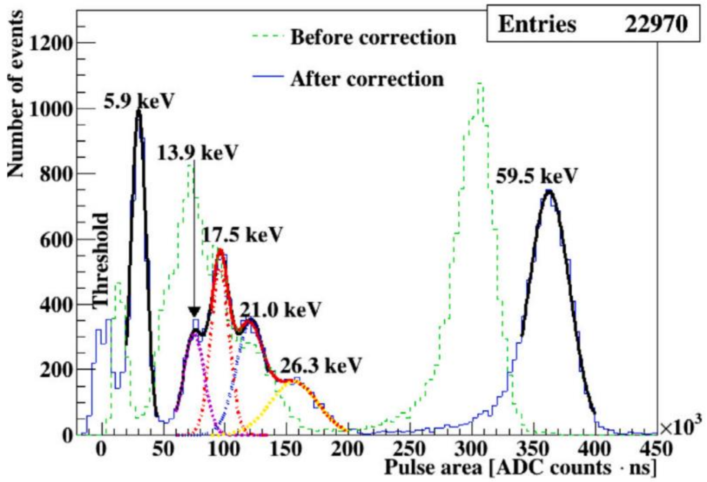
- LY = 35.2PE/keVee
- FWHM Resolution: 6.9% @ 60keV





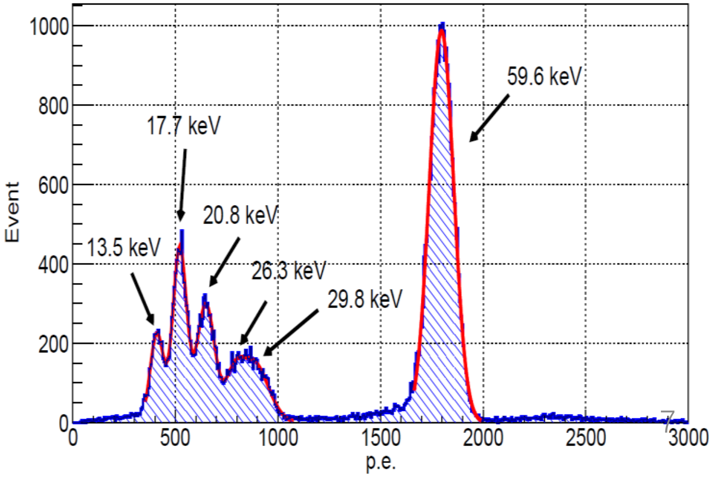
USD: arXiv:2303.05437

$LY = 40.0 \pm 2.4PE/keVee\ FWHM@60keV = 8.8\%$



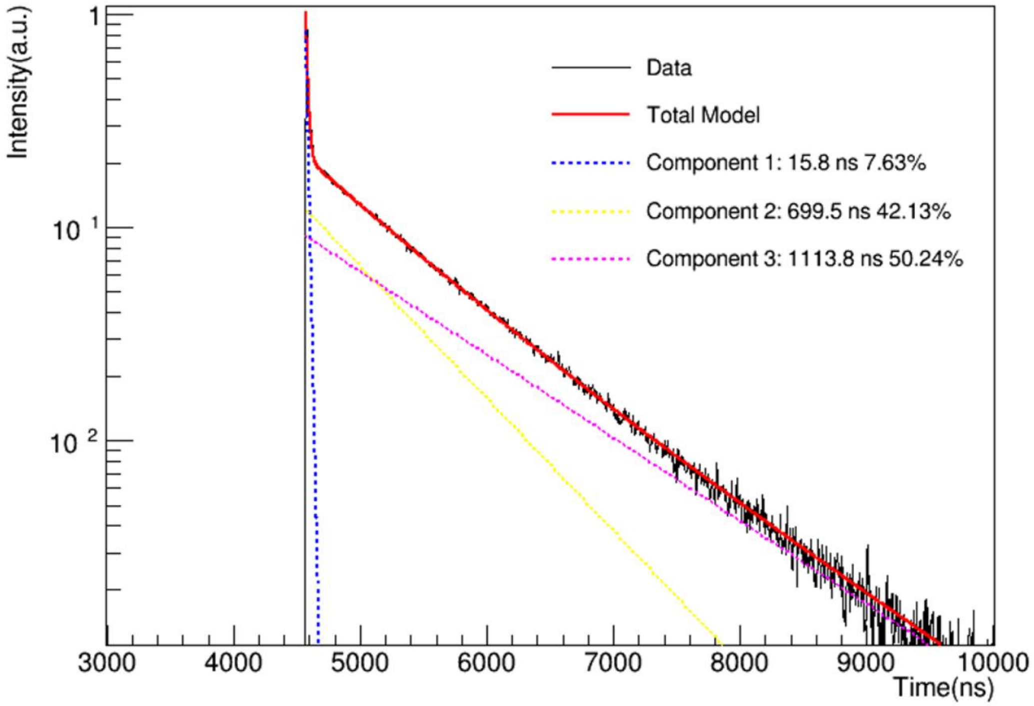
IHEP: arXiv: 2212.11515

$LY = 30.1 \pm 8.1PE/keVee\ FWHM@60keV = 7.8\%$

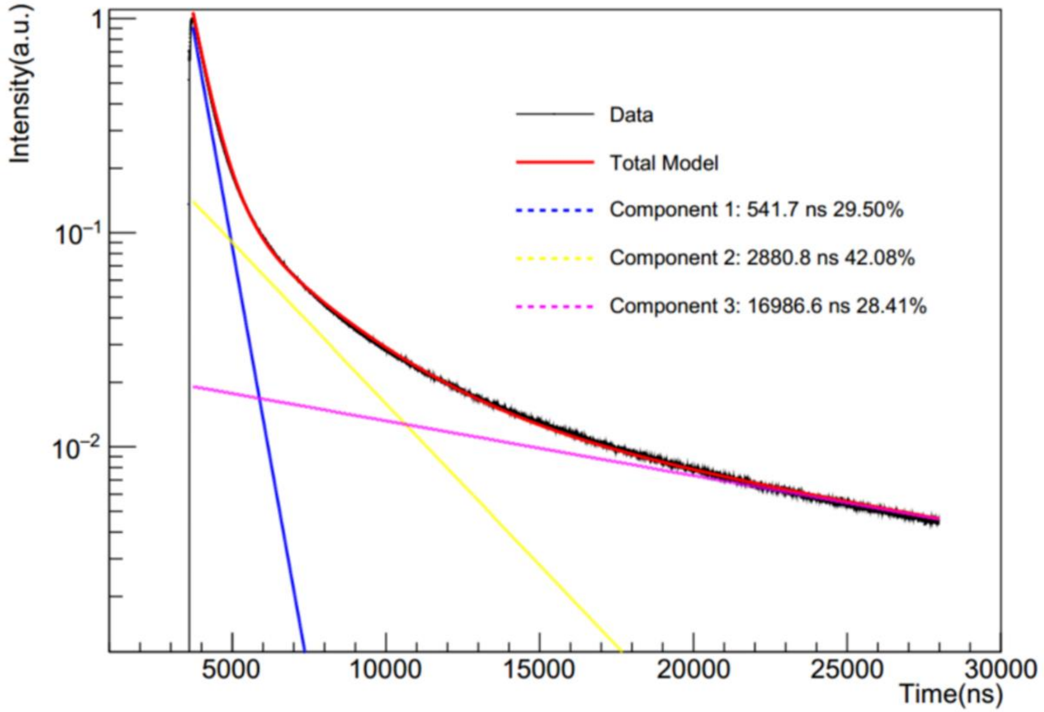


2.2 Decay time of CryoCsI @ 77K

- Pure CsI @ 77K



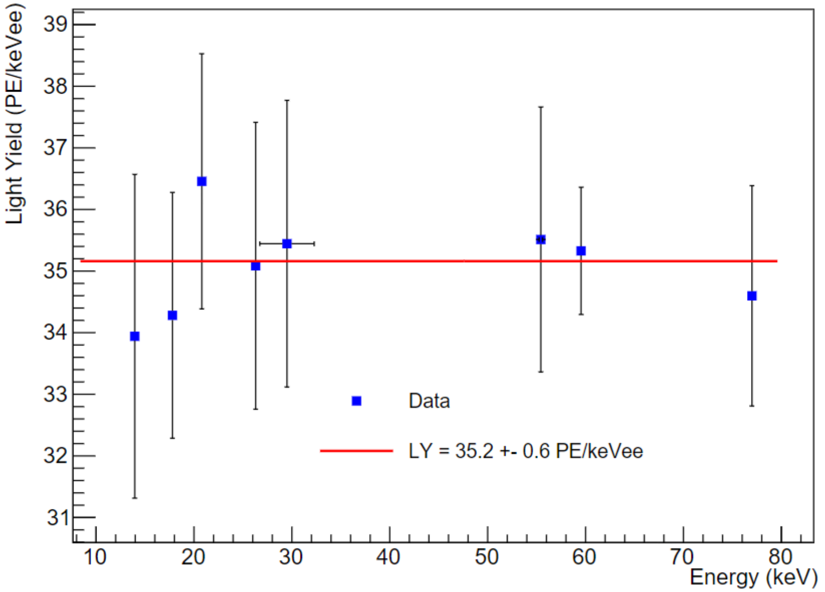
- CsI(Na) @ 293K



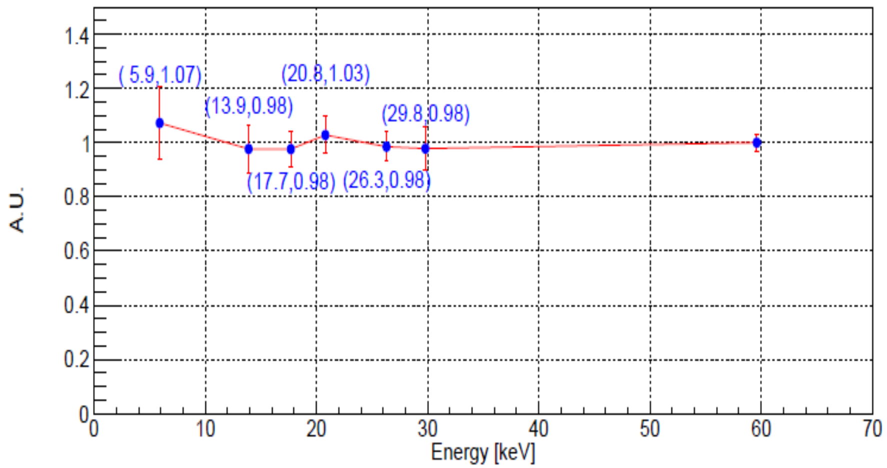
- Much shorter decay time means much weaker afterglow background

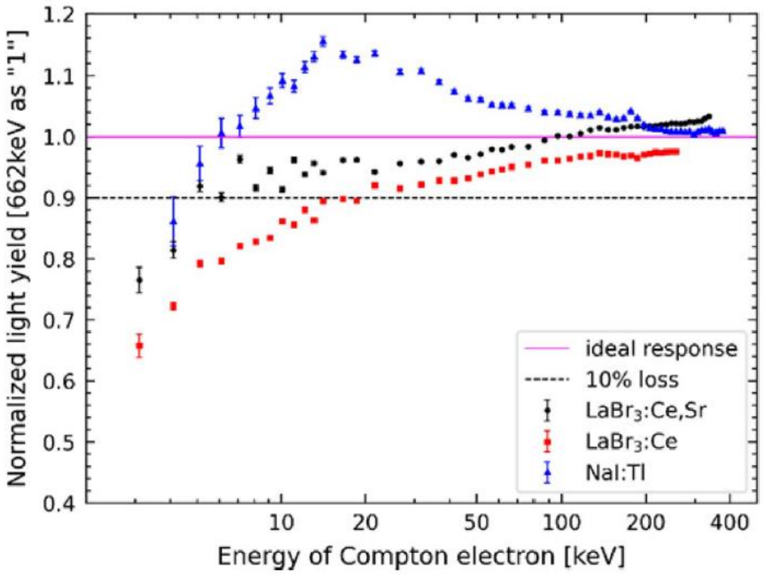
2.3 Linearity of CryoCsI @ 77K

- UCAS



- IHEP





Nuclear Science and Techniques (2024) 35:23

- Excellent linearity, no drop below 10keV
- Significantly better than LaBr3 and NaI:Tl

3

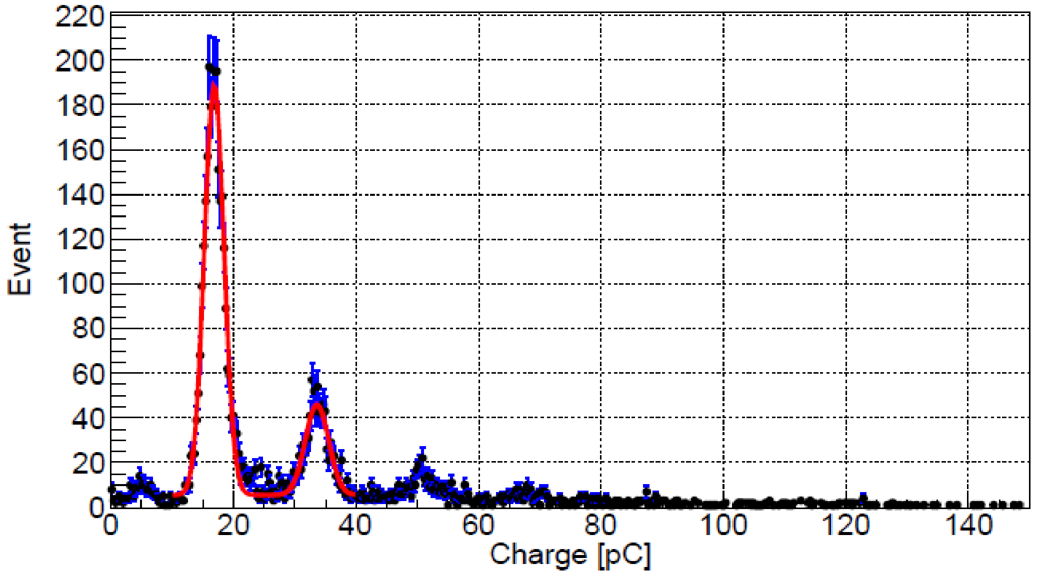
Characterization of SiPMs

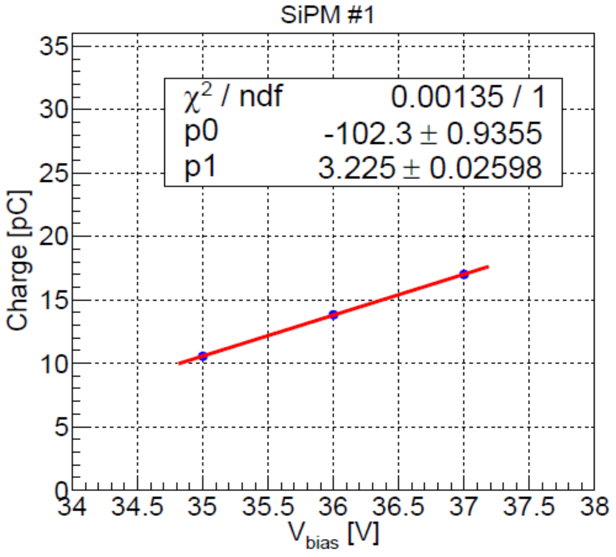
Arxiv: 2212.11515

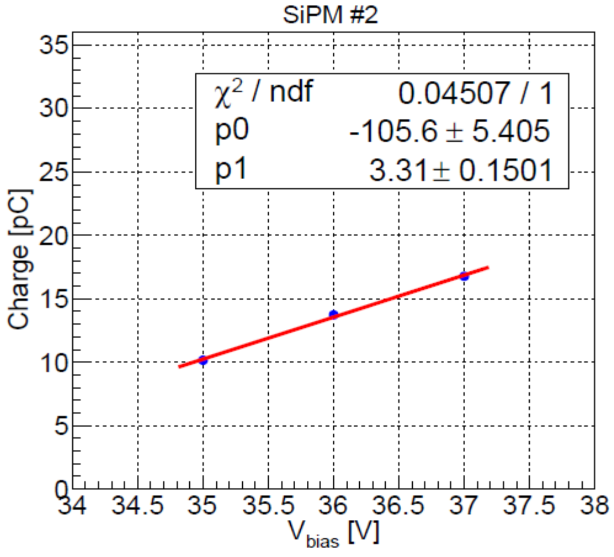
3.1 SPE and Gain

- Lots of efforts dedicated into cryogenic electronics for SiPM (IHEP)
  - https://doi.org/10.3390/s22031099
- 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

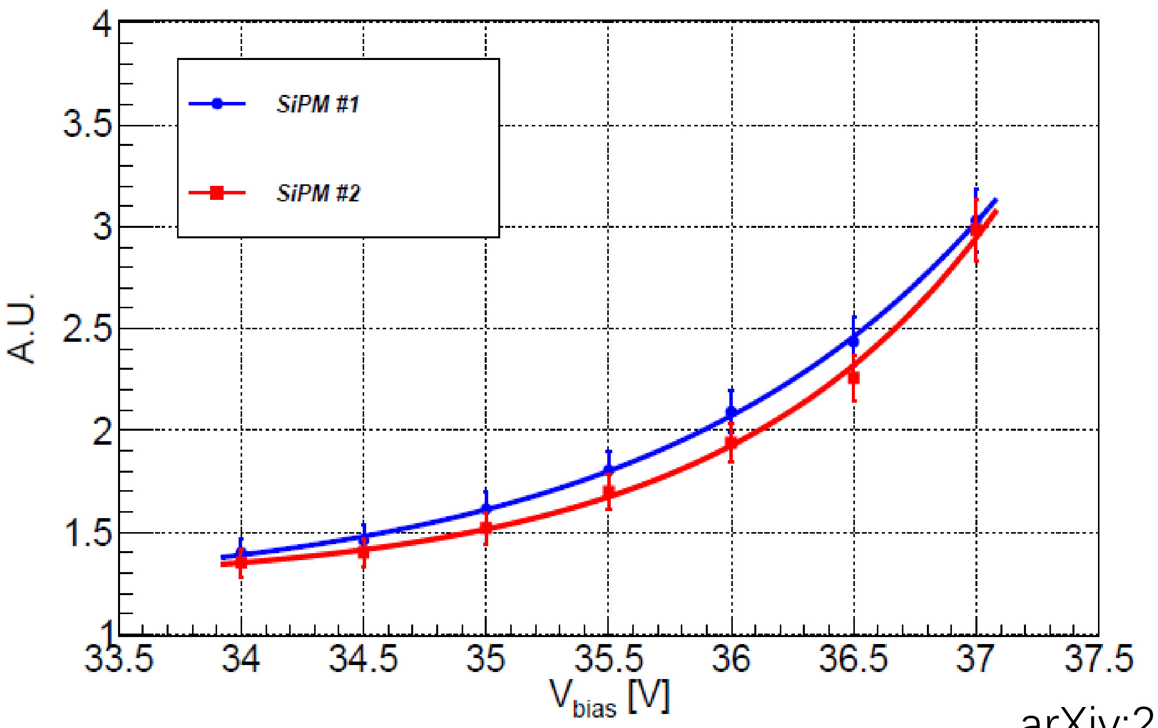


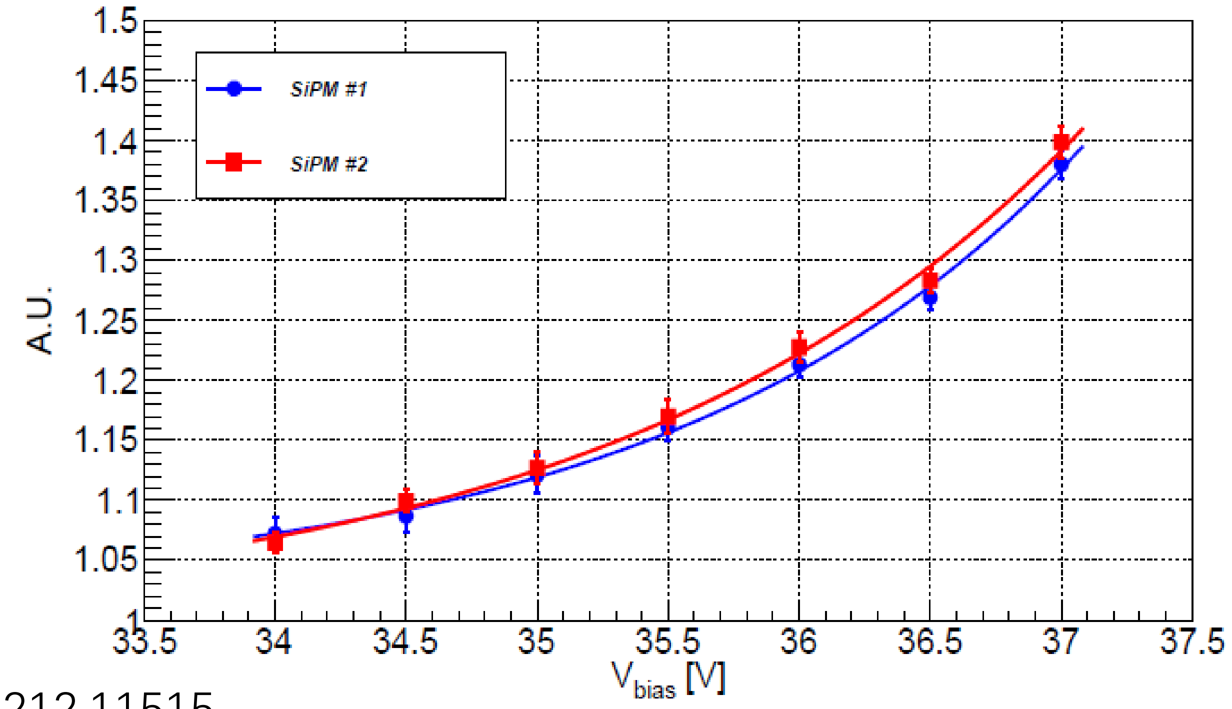




3.2 Influence of SiPMs Cross Talk and After Pulse

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



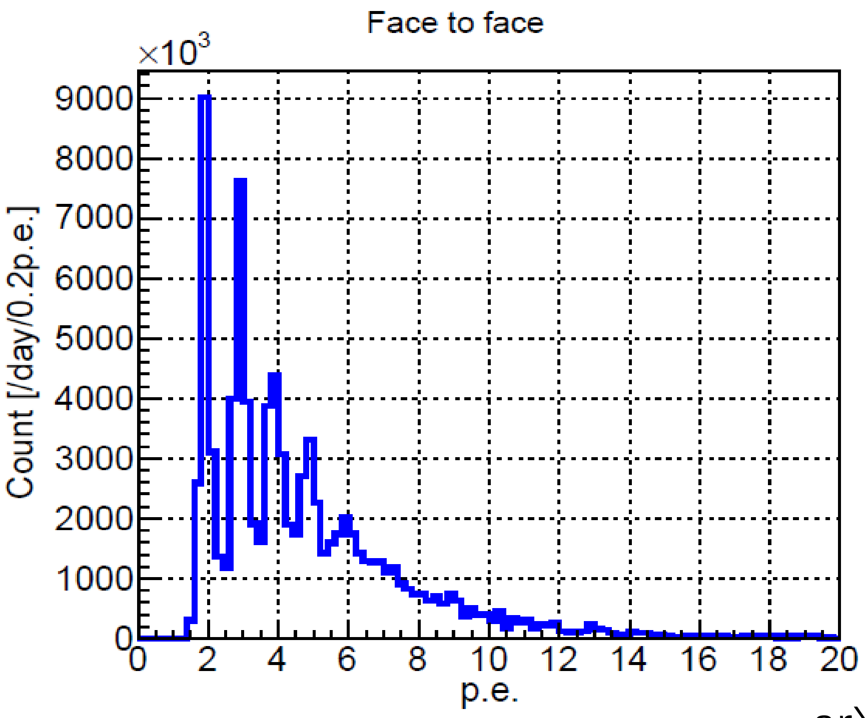


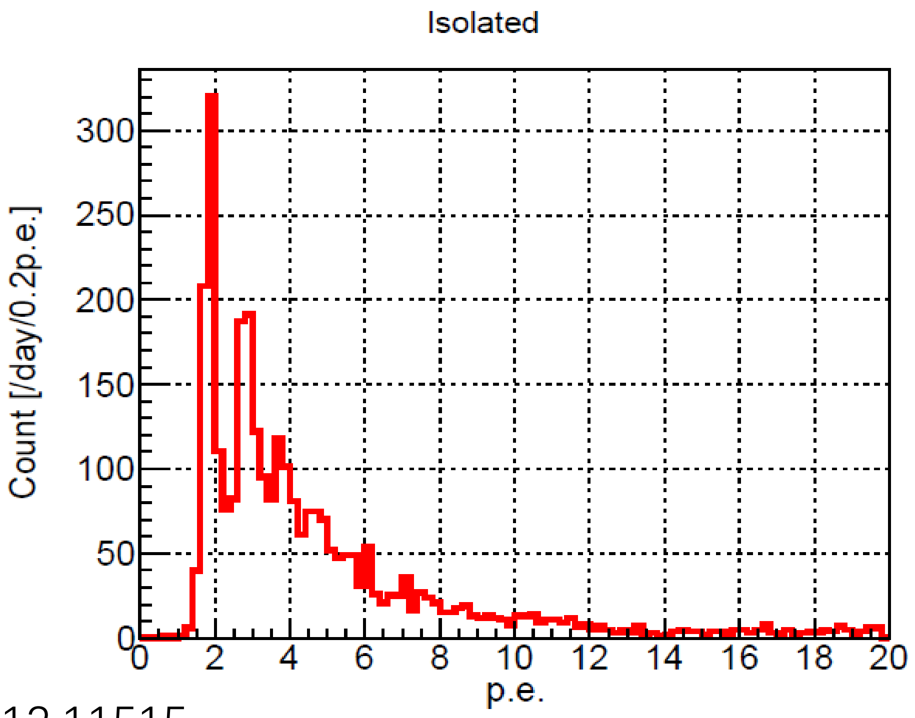
arXiv:2212.11515

3.3 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: 2406.02249





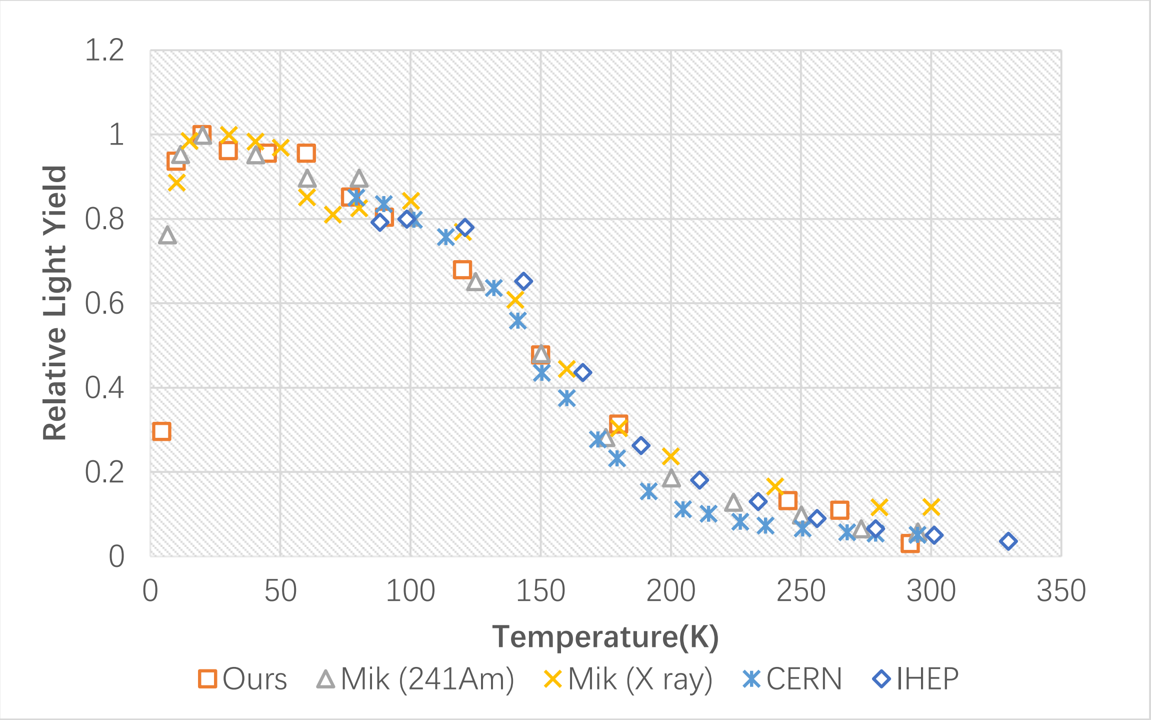
arXiv:2212.11515

Optimization of the light yield

Arxiv: 2402.05026
Arxiv: 2212.11515

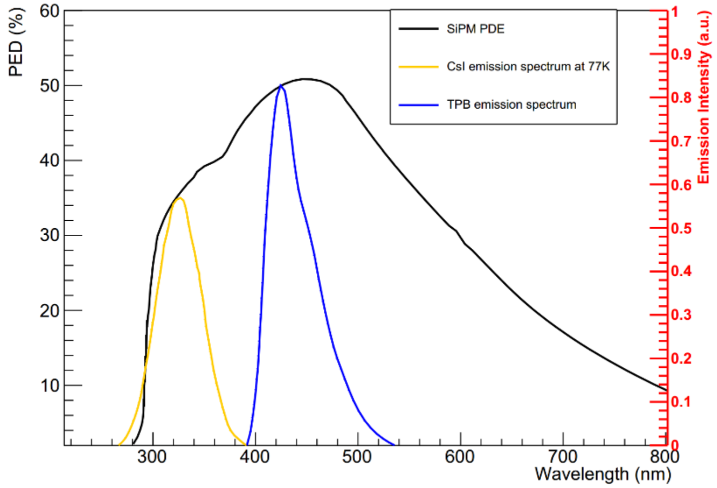
4.1 Influence of temperature and TPB to light yield

- Influence of temperature on light yield

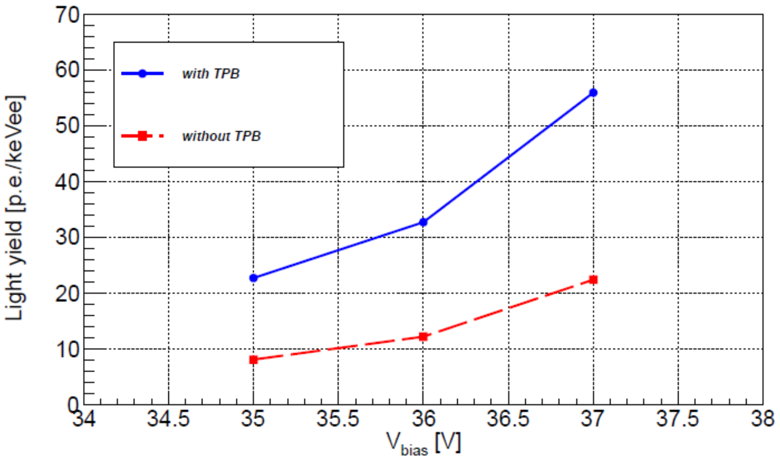


  - Normalized to their maximum value
  - Agrees well with other literatures
  - LY drops < 20K, consistent with Mik's result
  - Influence of temperature on PMT QE included

- Influence of TPB coating on light yield



IHEP

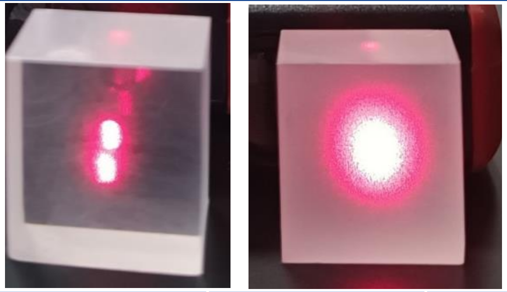


https://doi.org/10.1007/s41605-018-0039-1
https://doi.org/10.1016/S0168-9002(01)01239
https://doi.org/10.1002/pssb.201451464

4.2 Influence of surface treatment and crystal shape

- Influence of the surface treatment of CsI to LY
  - Light ouput surface is always polished
  - Change the status of other five surfaces.

Polish



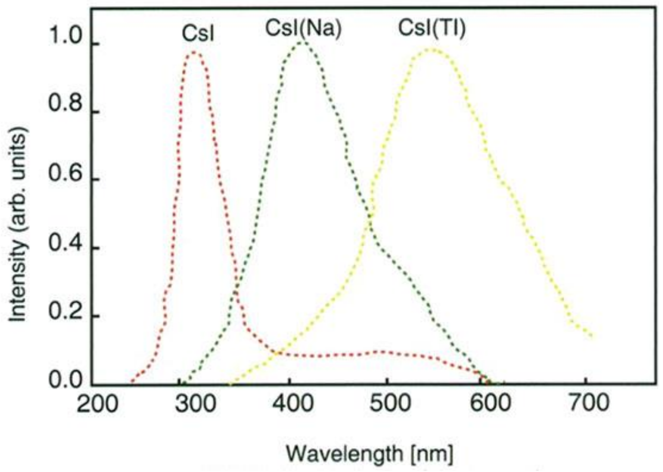
Ground

Sample Number	1	2	3	4
Ground/Polished(293K)	0.62	0.68	0.63	0.68
Ground/Polished(77K)	0.68	0.70	-	-

Crystal	CsI(Na)	CsI(Tl)
Ground/Polish	0.95	1.0

Guess: Microstructures of surfaces absorb UV light

  - Conclusion: Polished surfaces increase the LY
  - This conclusion stands for both 77K and 293K



- Influence of the shape of CsI to LY

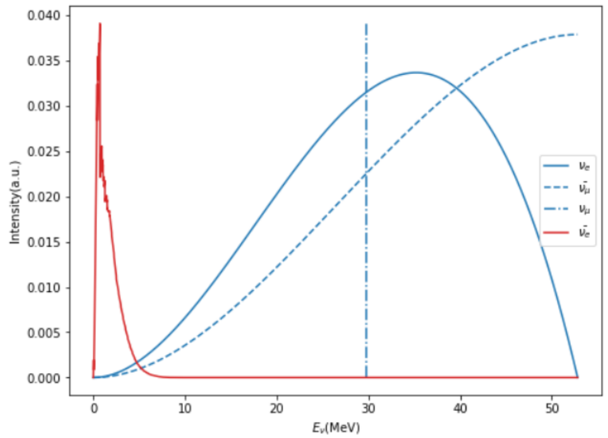
Sample Shape	Cylindrical ($\Phi 2.5\times 2 cm^3$)	Cubic ($2 \times 2 \times 2\ cm^3$)
LY @ 77K	33.9 PE/keVee	35.2 PE/keVee

4

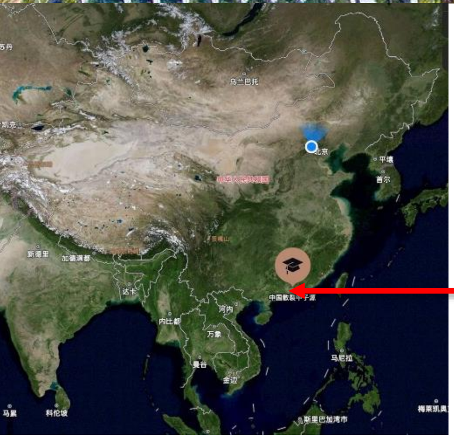
Expected Sensitivities

Arxiv 2303.13423
Arxiv 2212.11515

4.1 The China Spallation Neutron Source (CSNS)



Huang, Ming-Yang *Chinese Physics C* 40.6 (2016): 063002.

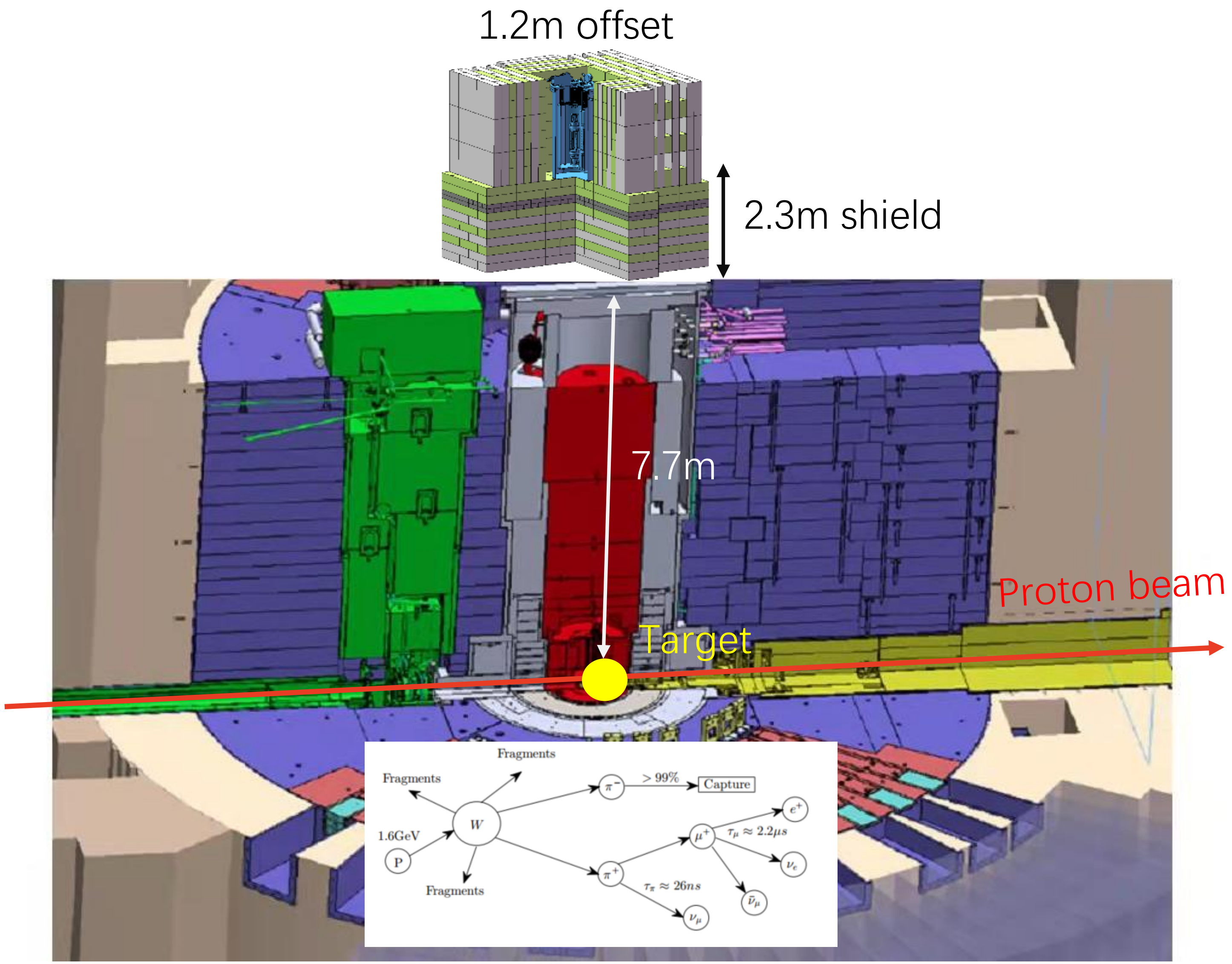


Guangdong Province

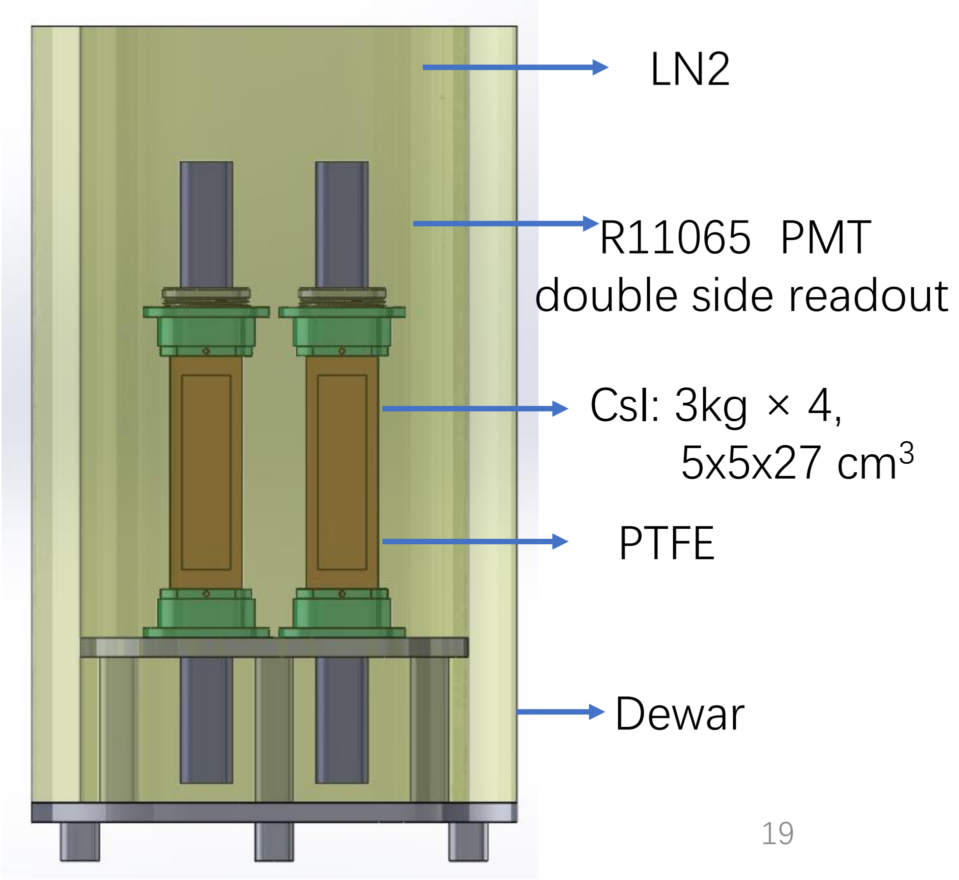
- Neutrino production
  - Neutrinos via Pion (DAR)
  - 0.17/proton/flavor
  - 25Hz

- Neutrino Flux: $2.42 \times 10^{10}\ /cm^2h$ per flavor @ 10.5 m (7.7m + 2.3m shield + offset)
- 40% of COHERENT @ SNS 19.5m

4.2 Experiment design



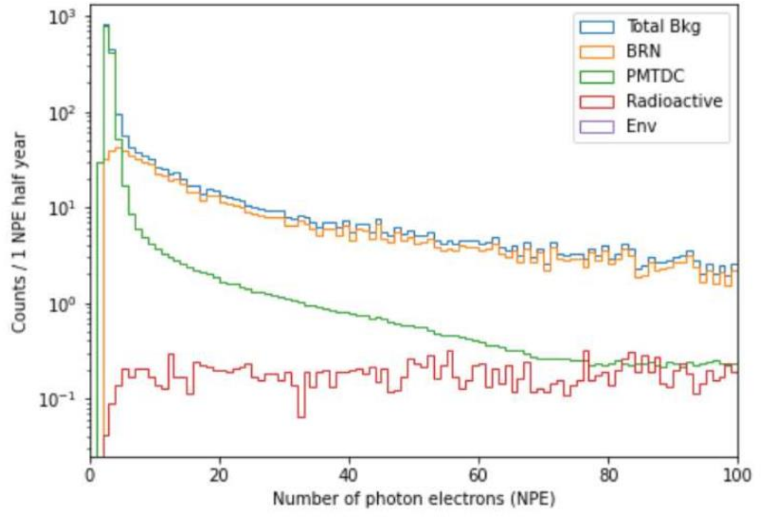
- Design Summary
  - 10.5m from target
  - 12kg CryoCsI with multiple modules
    - Neutron background suppression
  - Dual PMT read out
    - Dark counts suppression

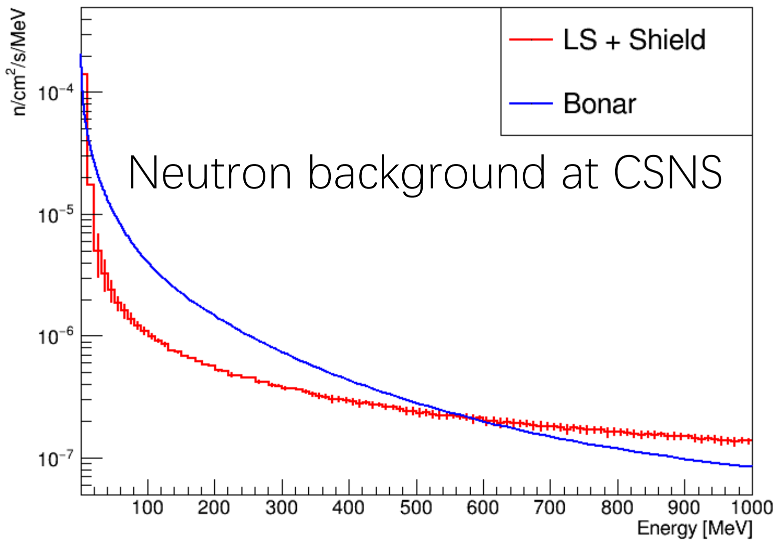


4.3 The Backgrounds

- Beam related neutron dominate
- Dark counts is important

Background type	Number of events in 0.5 year	MC simulated	Event rate after cut (per 0.5 year)
Radioactive background	1.66×10^6	1.87×10^7	7
Environmental gamma	4.72×10^8	10^{10}	0.1
PMT dark count	1.87×10^6		~ 160
Beam related neutrons	2.69×10^5	10^7	~ 666
Neutrino induced neutrons	-	-	negligible
Comic ray induced radioactive isotopes	-	-	negligible





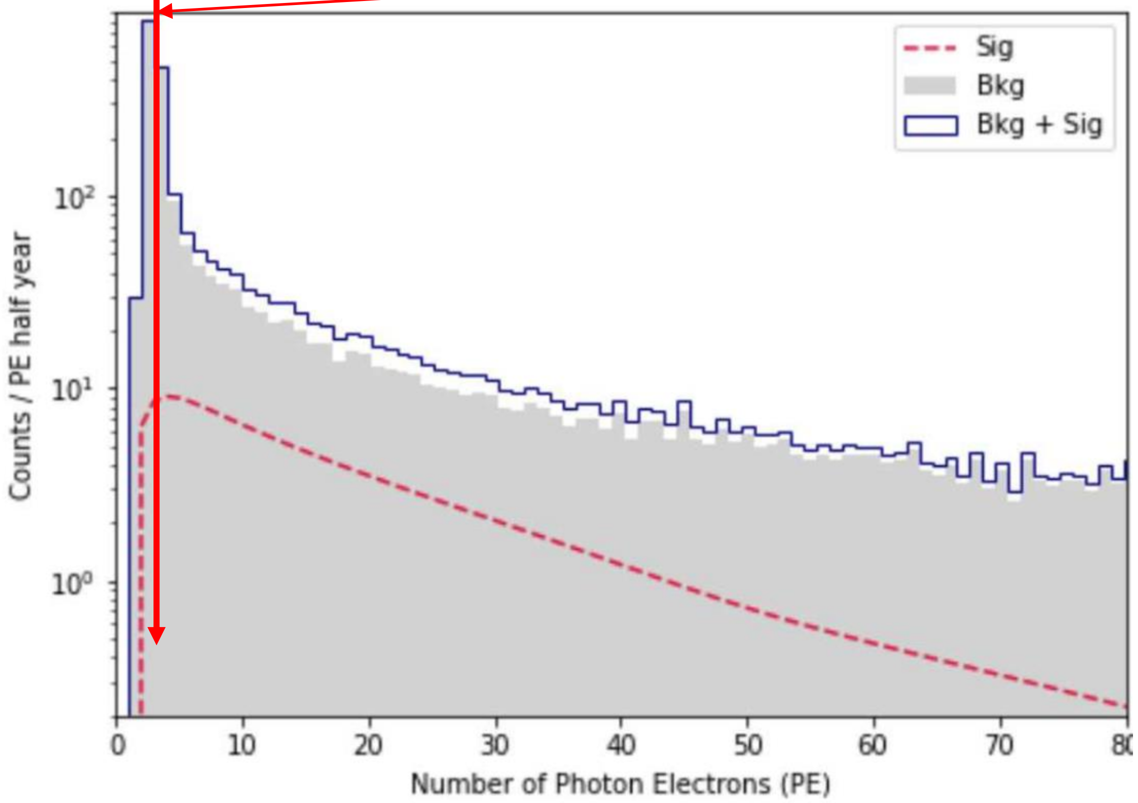
4.4 Expected Sensitivities

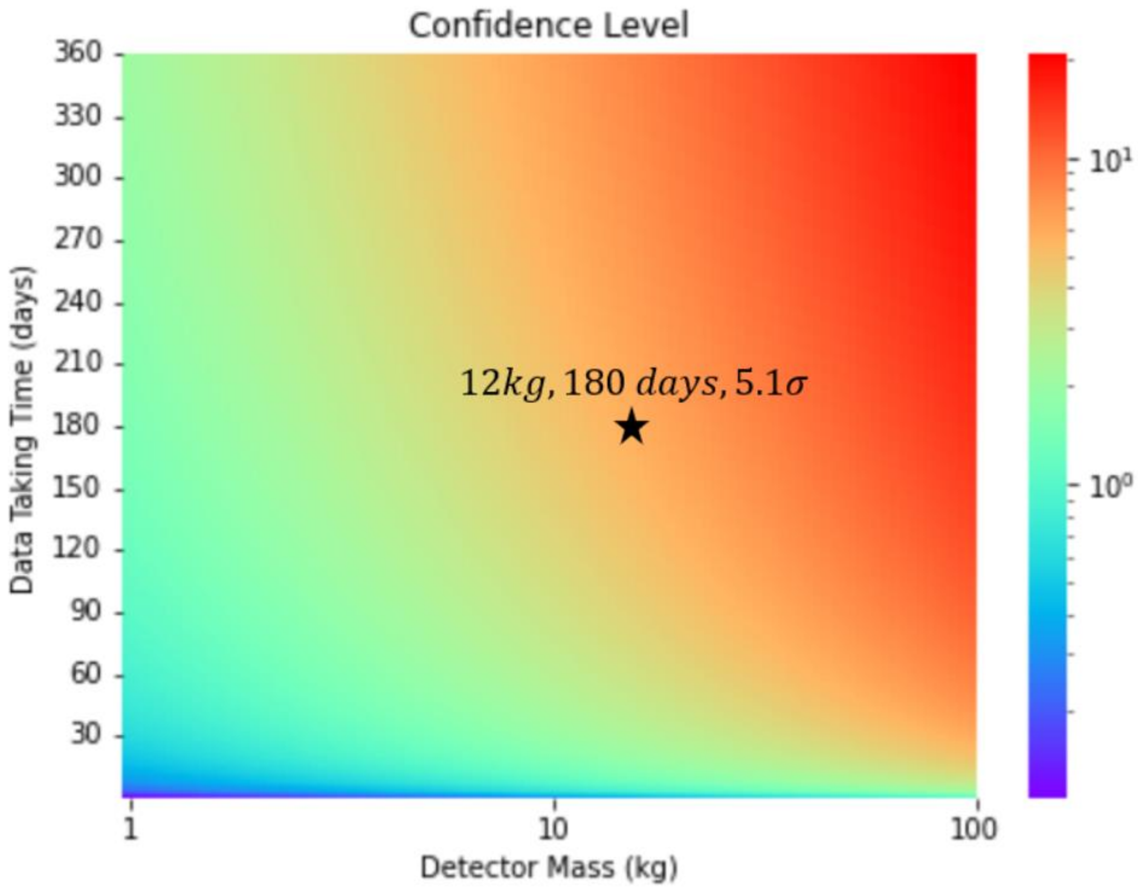
Collar QF Applied(108K)

https://arxiv.org/pdf/2101.03264

New QF will enhance this sensitivity (Charlie's poster)

cut   Contribution from PMT dark count

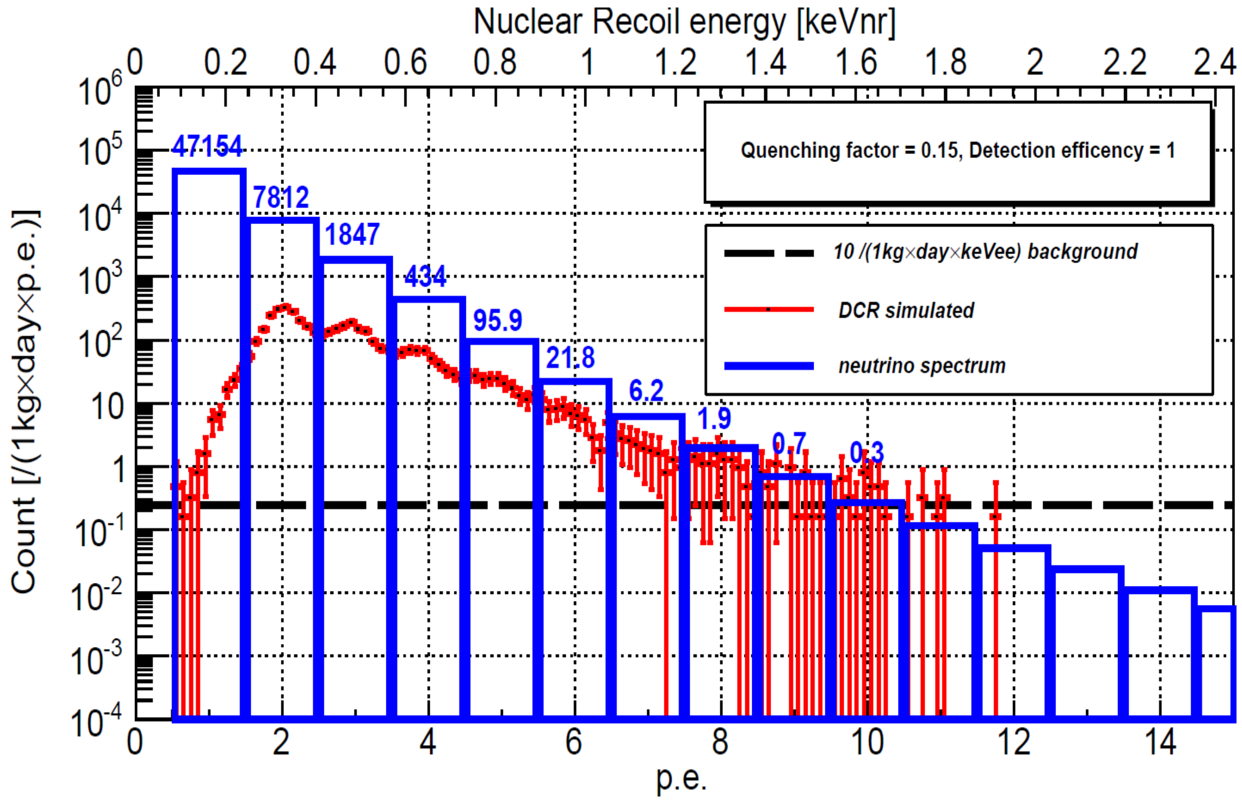


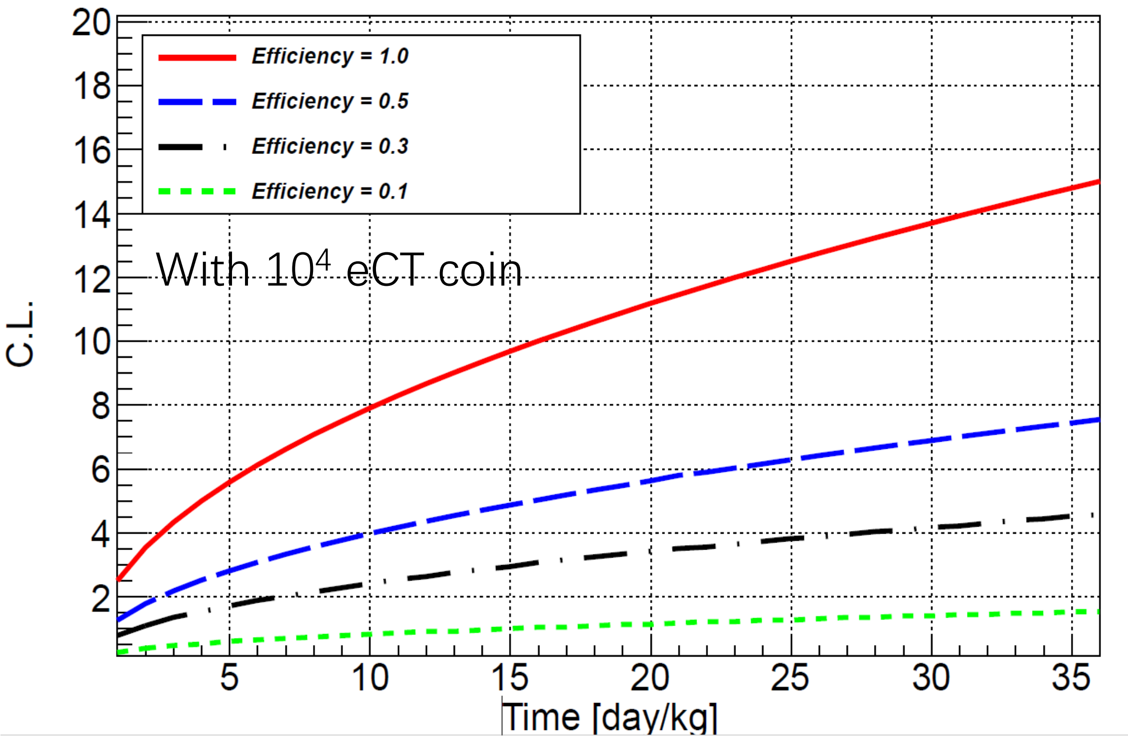


- NPE threshold taken as 4 in the following background estimation， Equivalently ~ 2.6keVnr threshold
- Potential to further down to 3。Background dominated by PMT dark count coincidence.
- Expected C.L. in 180 days: 5.1σ

4.5 Expected Sensitivities for Reactor CEvNS

- 35 m distance to a 4.6 GWth reactor
- Threshold 2 p.e
- If QF ~15%?, DCR~0.01?, better sensitivity
- Good chance for reactor CEvNS observation





5

Summary

Summary and Prospect

5.1 Summary

- CryoCsI has remarkable light yield, unprecedented energy resolution and good linearity as well as larger QF
  - A good low threshold detector
- CryoCsI has shorter decay time compared to CsI(Na)
  - Reduce the afterglow background
- Internal and external crosstalk are notable features of SiPM which leads to overestimated LY without correction.
- Polished surfaces and TPB coating increases the light yield of CryoCsI
- Good chance both in CSNS and rector CEvNS