The Development of Low Threshold Dual Phase Argon Detector for CEνNS

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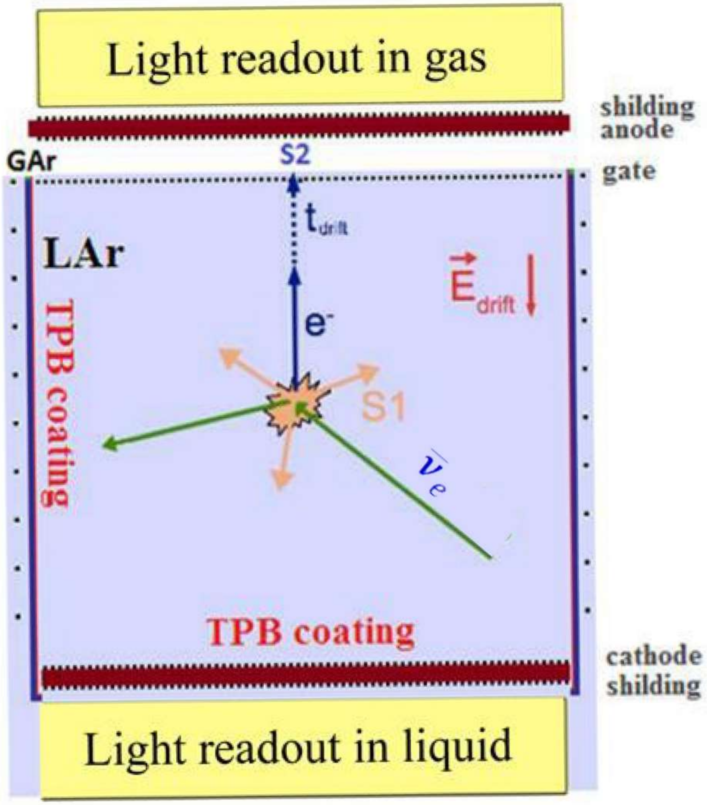
On Behalf of Dual Phase Argon Working Group (IHEP BISEE etc....)

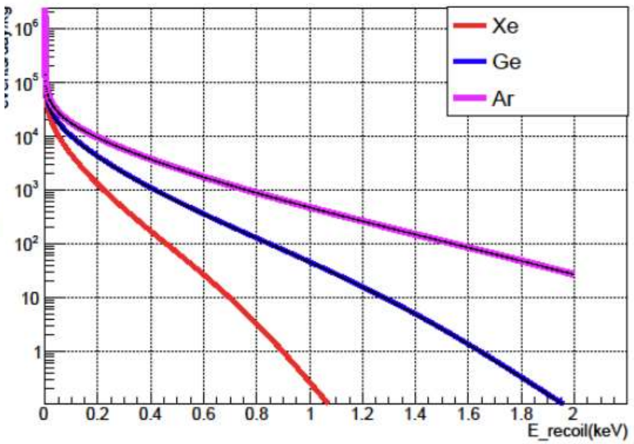
- **The Status of Dual Phase Argon Detector**
- **The Future Plan for Tai Shan Power Plant Measurement**

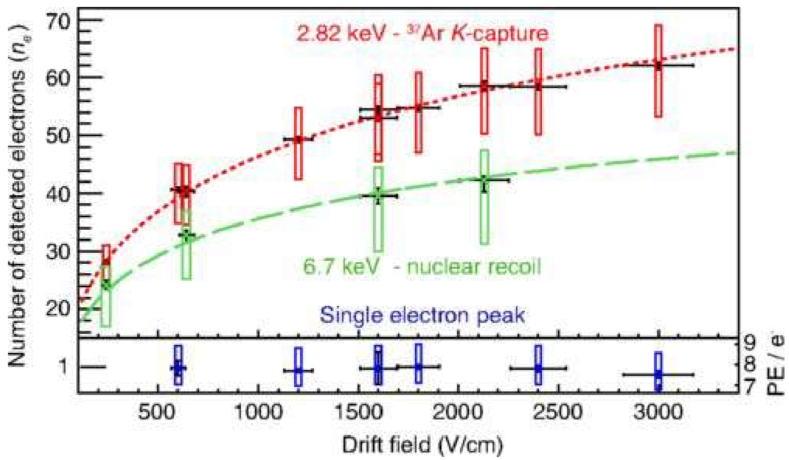
2nd -3rd Nov 2018, Chicago, IL USA

The Dual Phase Argon Detector for Reactor CEνNS Measurement



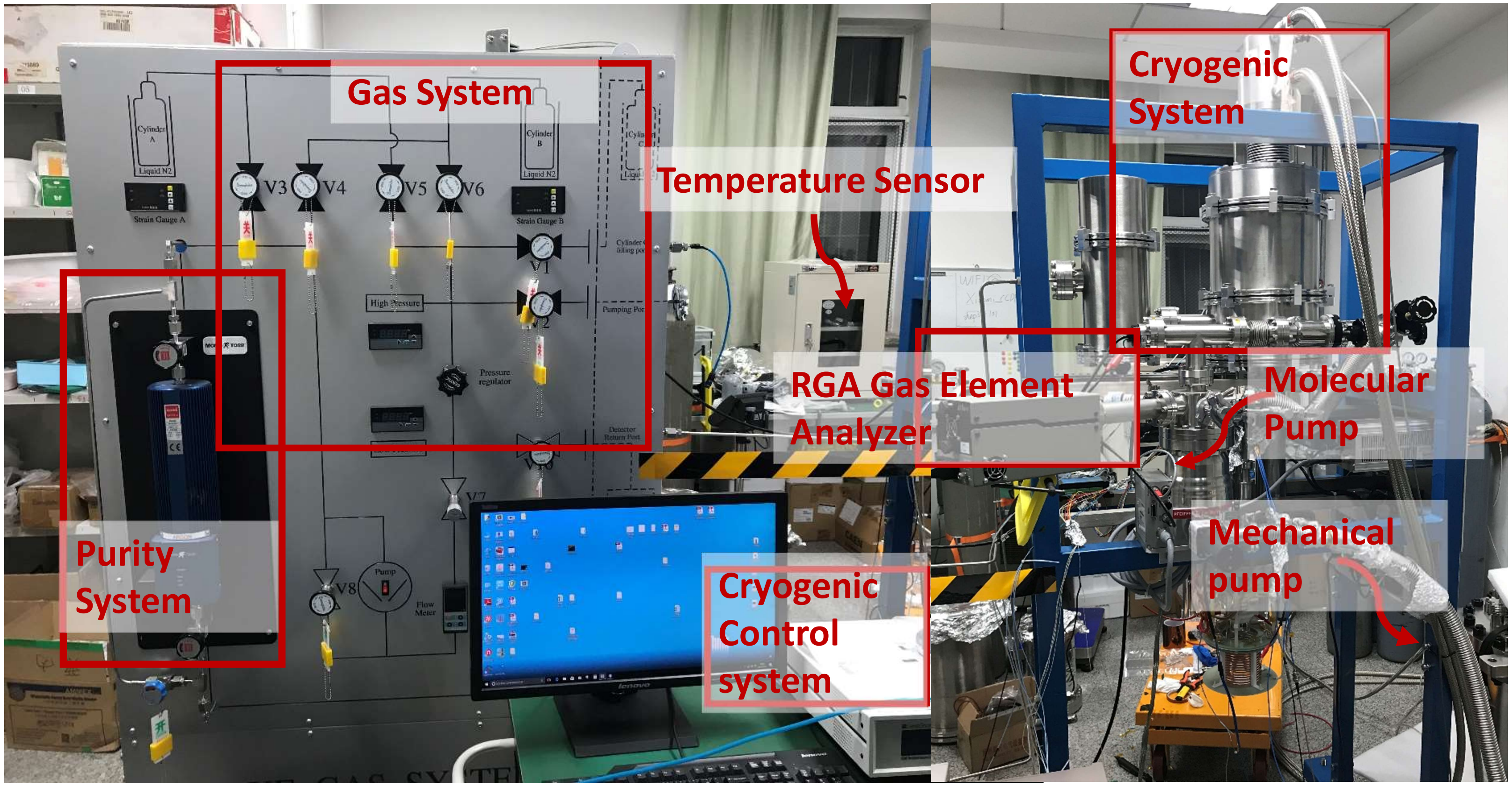
- **Easy and Cheap for Larger Volume**
- **Low threshold ~0.1keVee can be reached**
- **The lowest energy reported up to data is(6.7 keVr) for Ar recoil calibration**
- **Atmospheric argon will be overwhelmed by 39Ar decay**
- Only read S2 to reach low threshold
- SiPM readout with low radio purity and high QE
- The Inner Stainless Steel Container will be replaced by PTFE to reduce background





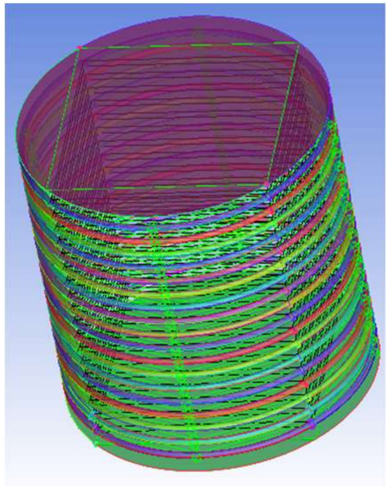
The Prototype of Dual Phase Detector

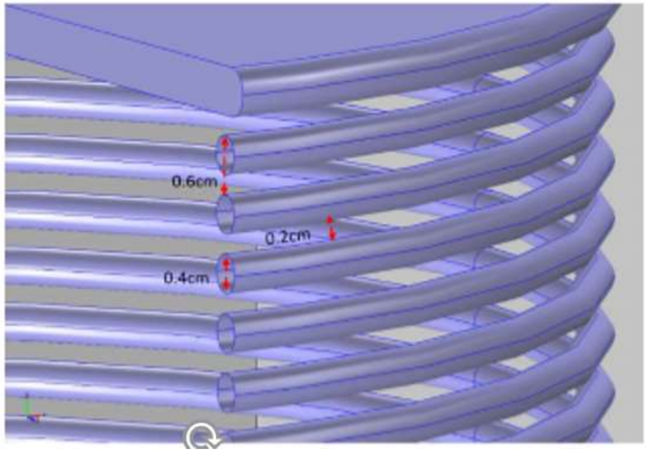
- Based on the Dual Phase Detector at IHEP,
- Original design for Xeon,
- But we used for Argon test to study some key technology.

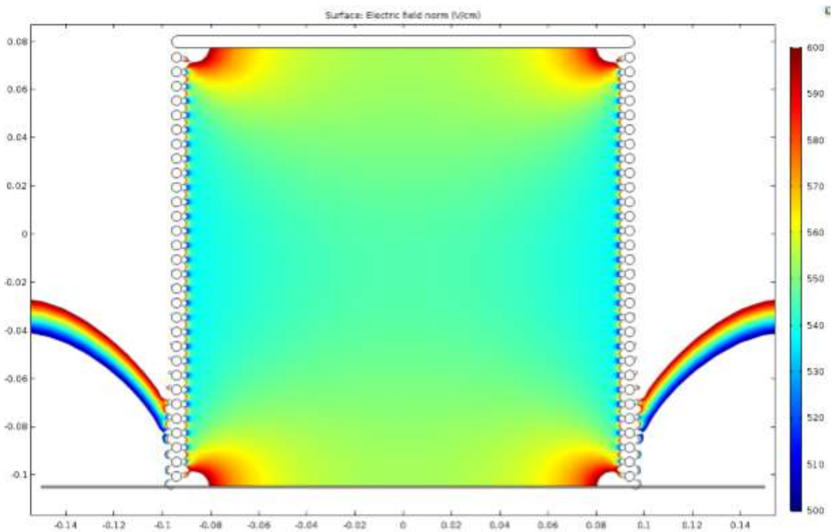


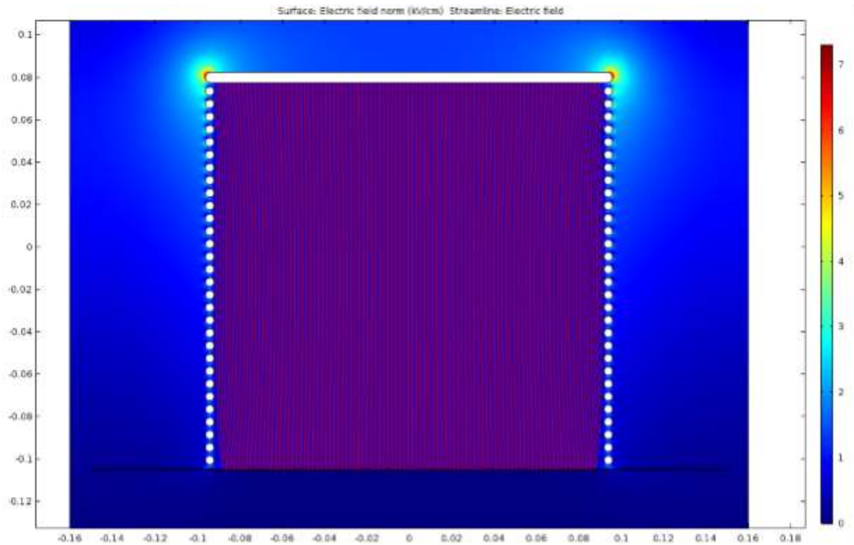
The Electric Field Simulation

Shaping Ring Numbers： 16
Gas Gap： 8mm
Liquid Gap： 106mm
Outer Diameter： 180mm
Inside Diameter： 90mm

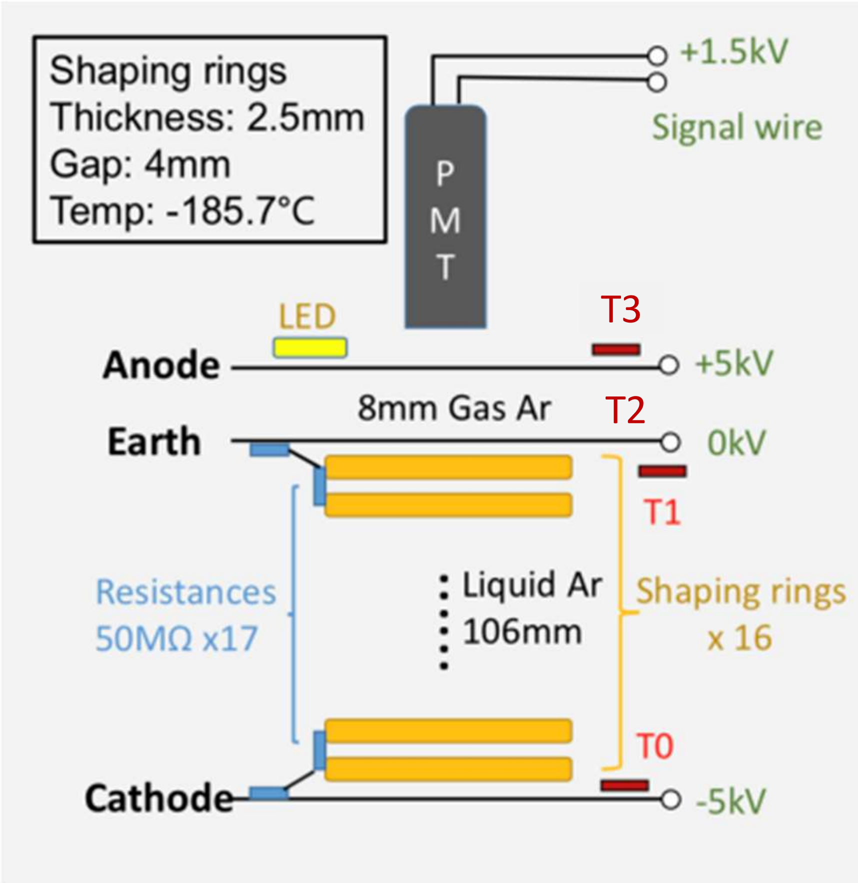


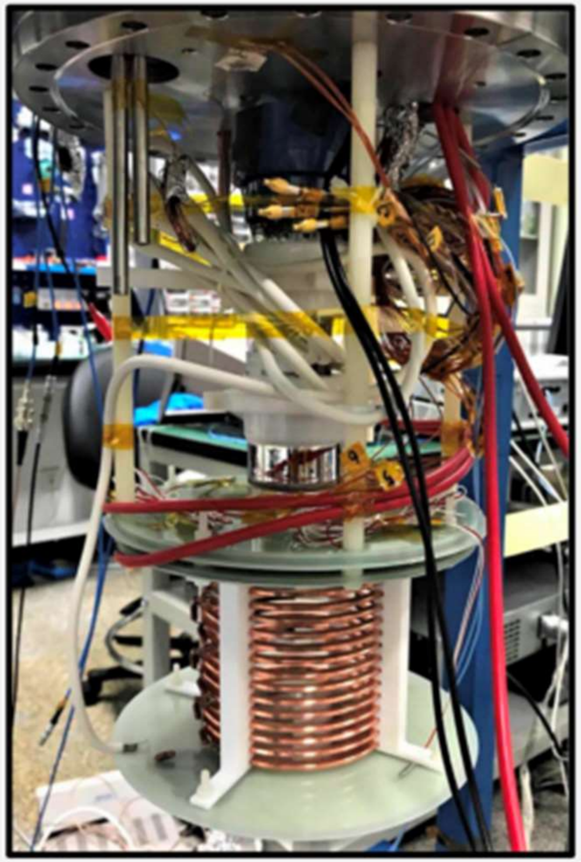


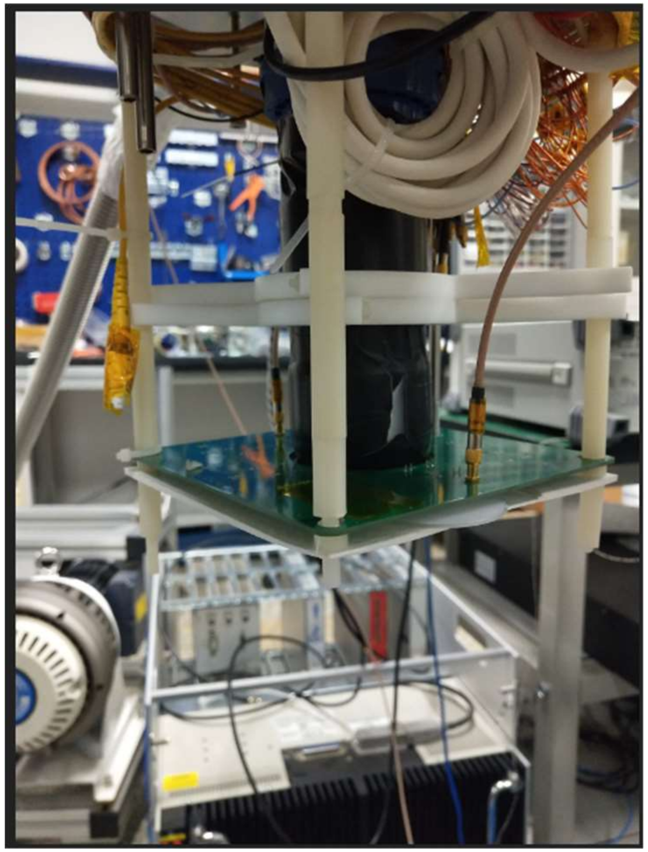




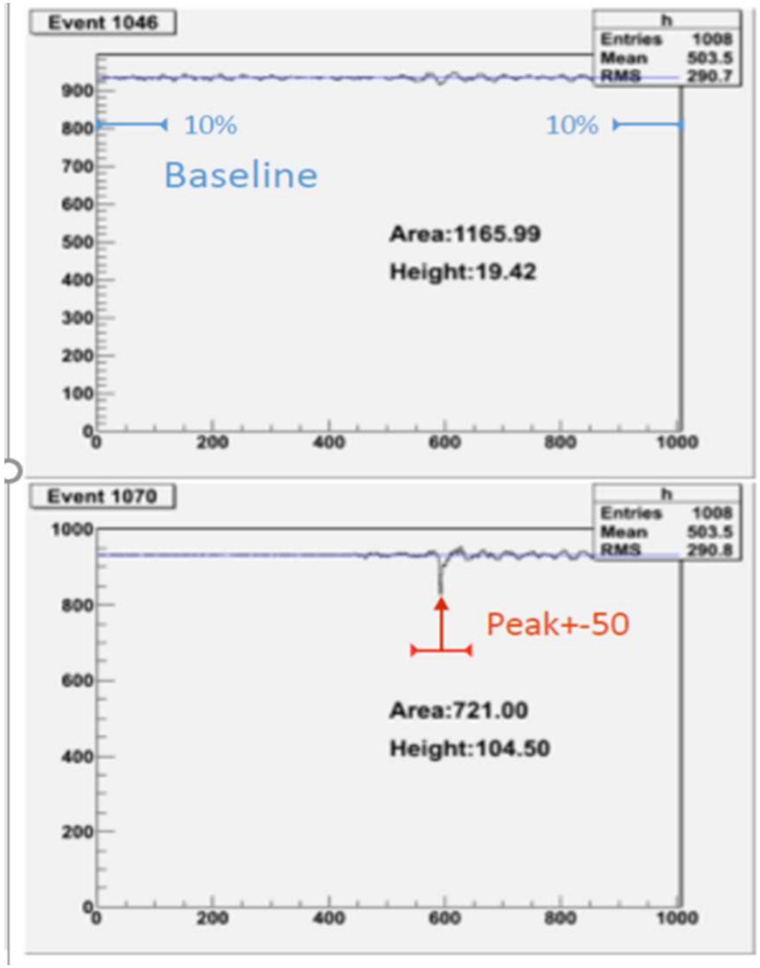
The Structure of TPC

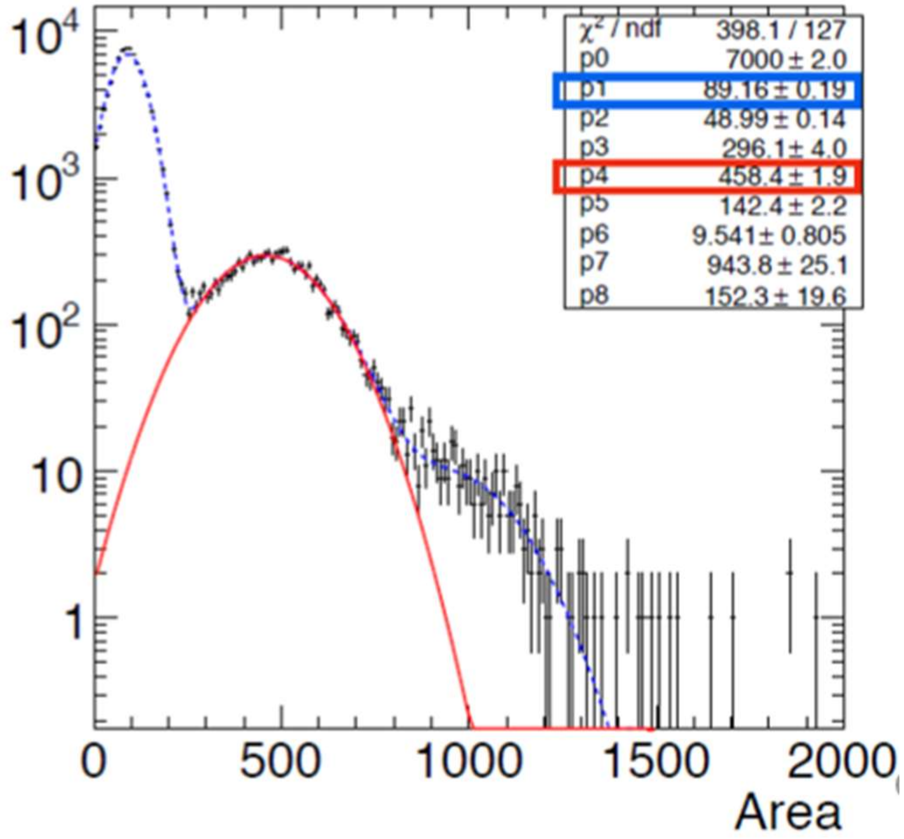




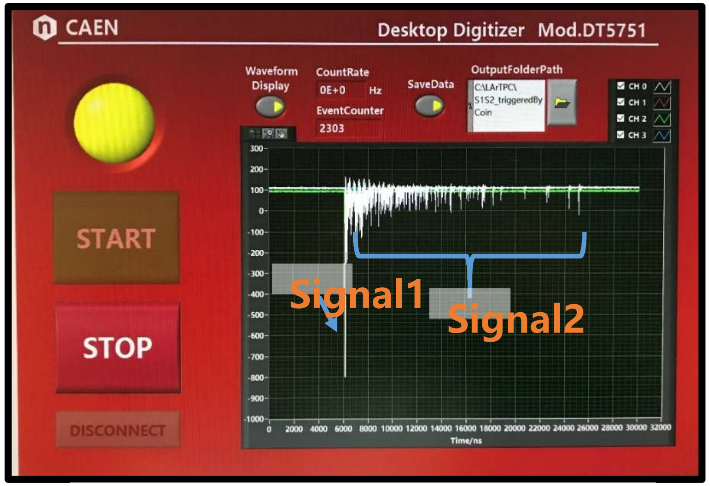


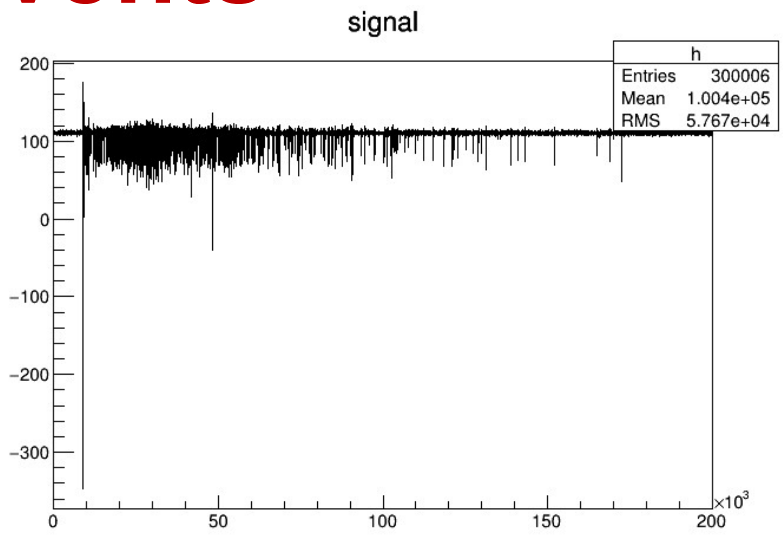
The LED Calibration

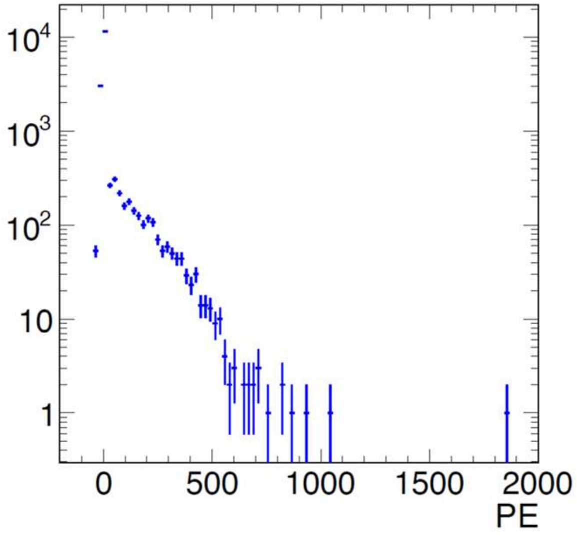


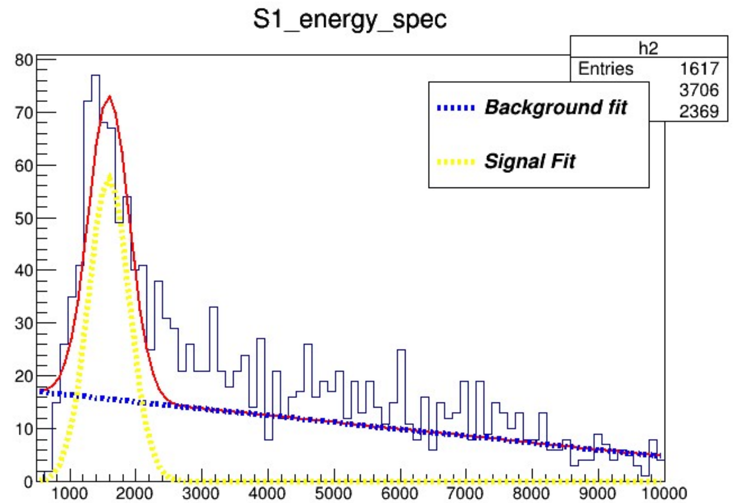


The Muon Events

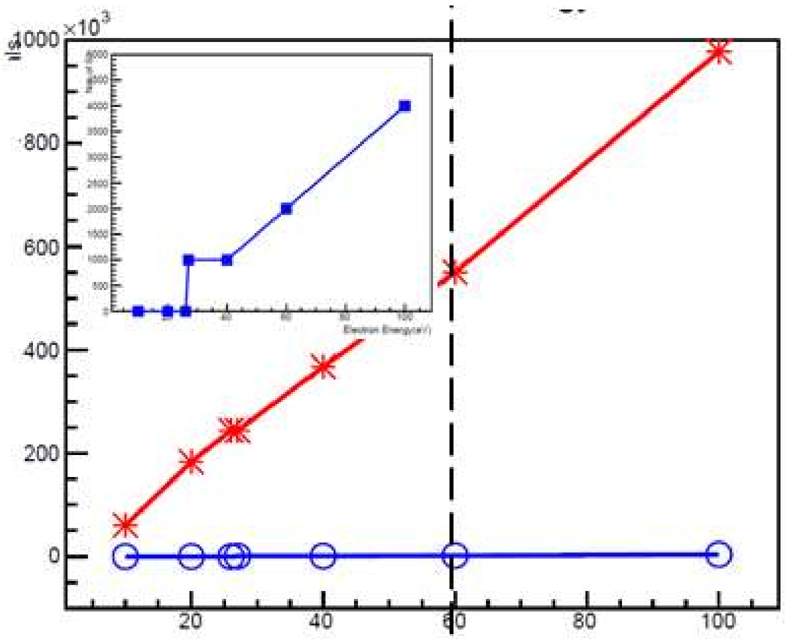


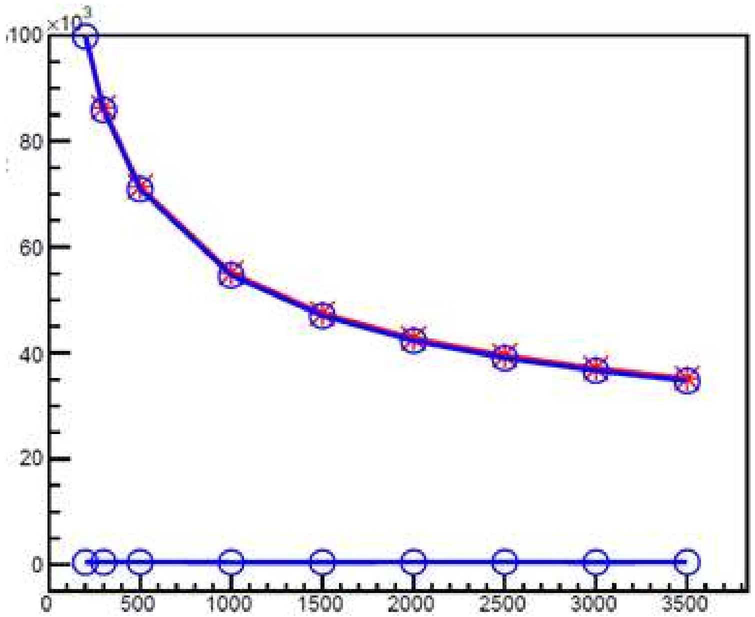


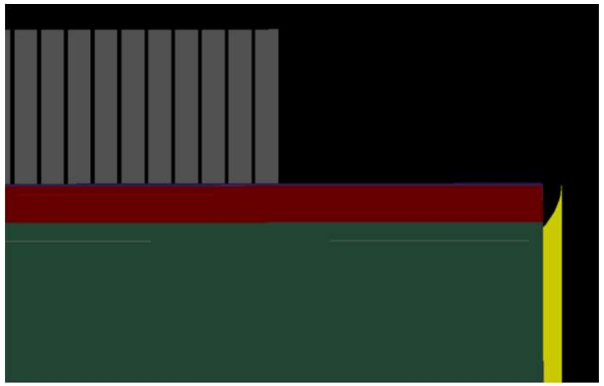




Simple Geant4+NEST Simulation







- The length of gas gap and liquid gap
- Simulation the Electric Field
- Electron recombination probability and electron drift time
- Photoelectric efficiency of SiPM
- The detectable S1 light and S2 light.

The Development of Cold Readout for SiPM

	PMT	SiPM
Maximum PDE	10~40%	30~60%
Gain	10^5~10^7	10^5~10^7
Operating Voltage	~kV	<100V
Dark noise(room T)	1~50kHz	~50kHz/mm^2
Correlated noise rate	Low(<~10%)	High(10~60%)
Capacitance	~10pF	~20pF/mm^2
Radio purity	Bad	Good

Many readout options, many ASICs
Trying to chose 2~3 of them to develop

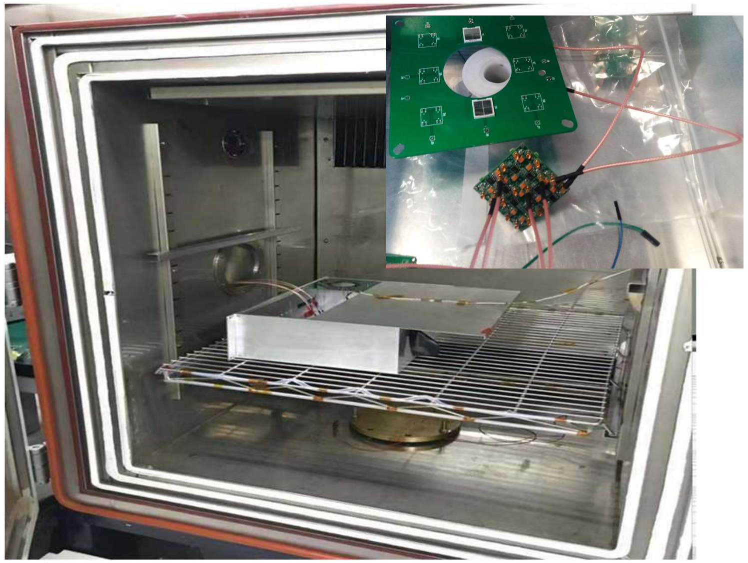
➢ **From the nEXO pre-amplifier**

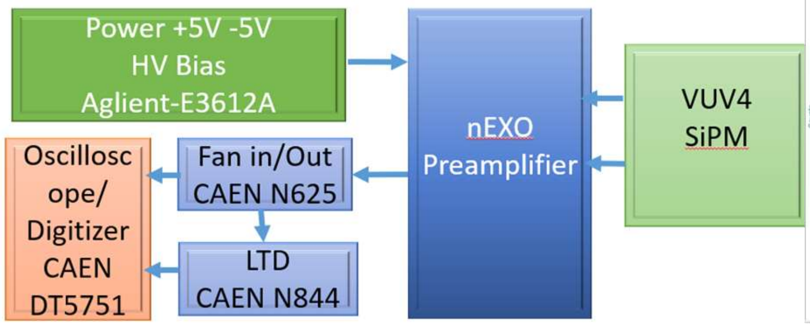
- Concrete components, the ASIC is under design.
- Developed for cold electronics (-104 degree)
- Has been tested by nEXO

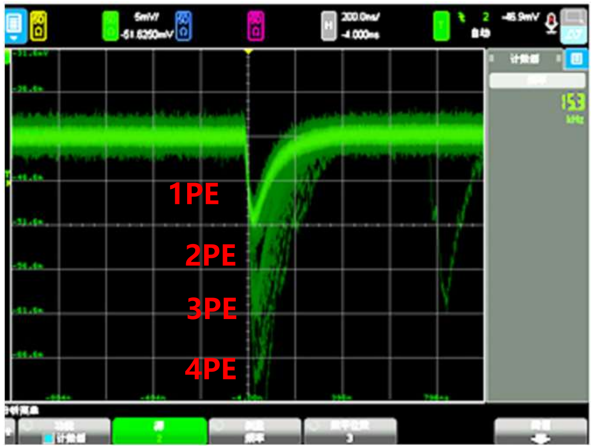
➢ **Another 2 cold pre-amplifier**

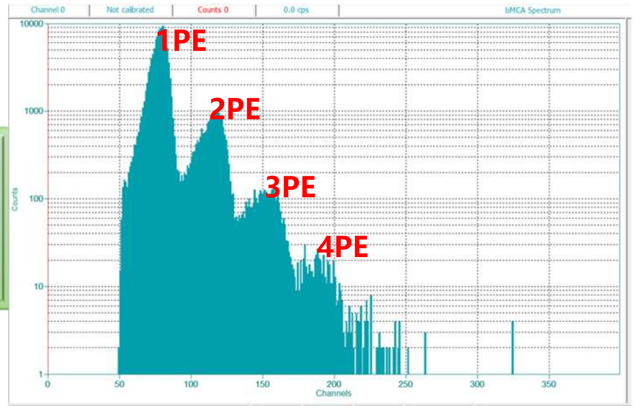
One suggestions from Darkside
Another one from INFN

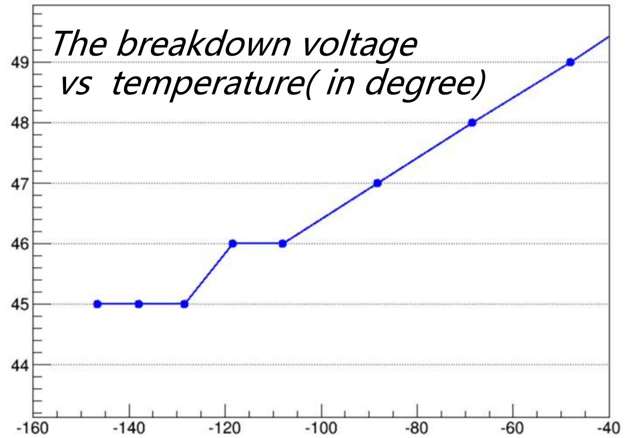
LAB test of nEXO Cold Readout

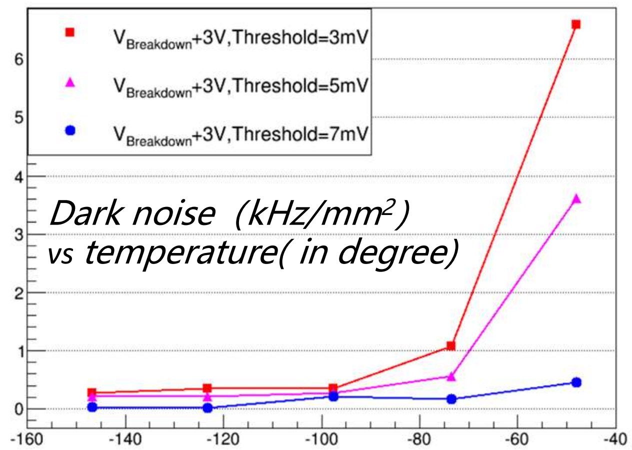






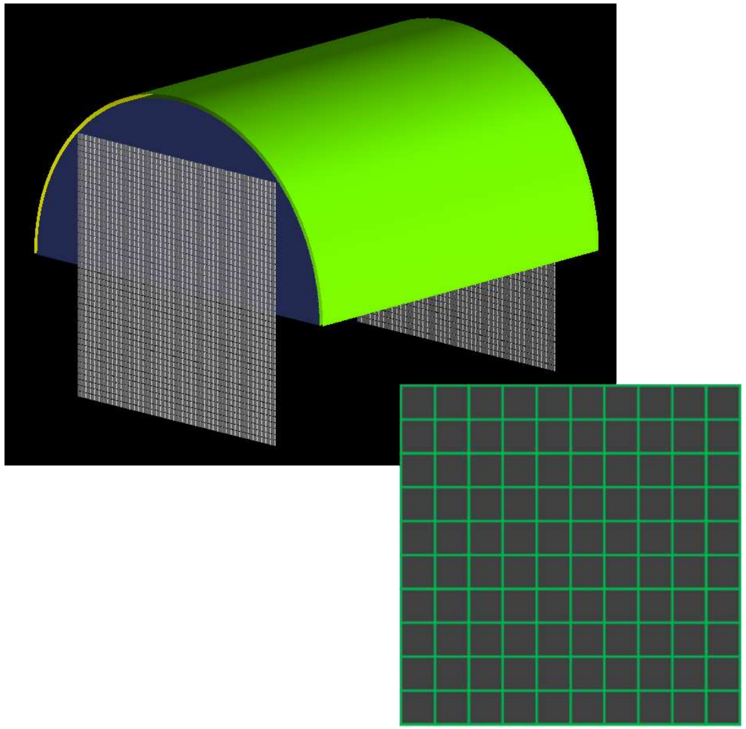


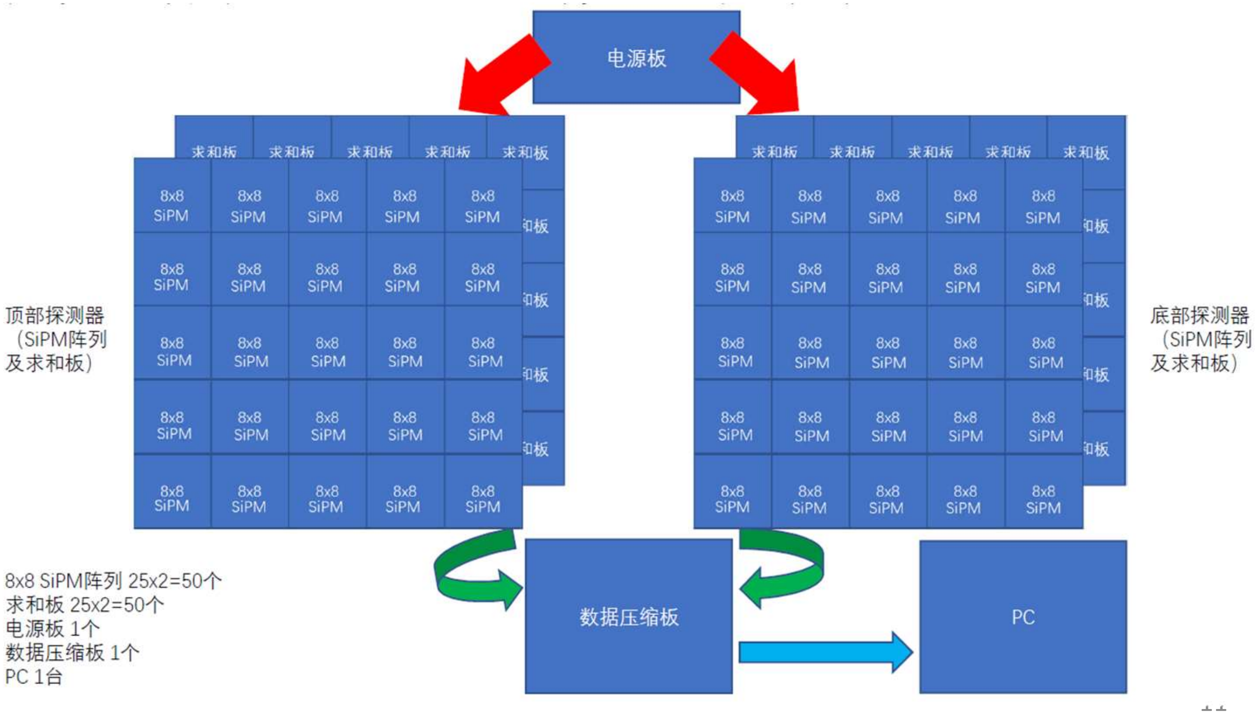




The Next Step for Large Area SiPM Readout

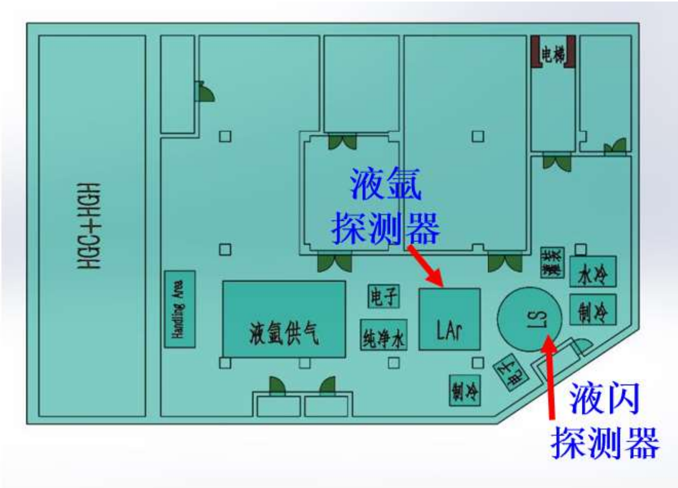
- Digitizer can be done SiPM by SiPM, have good signal noise ratio, but the thermal power will be high and also the cost
- Sum all the SiPM together，lower thermal power and cost, but bad noise ratio

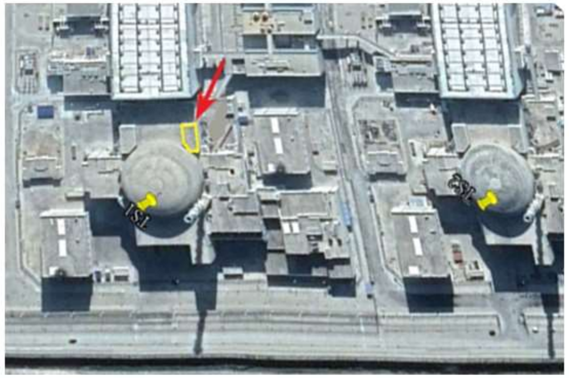




The TaiShan Nuclear Power Plant

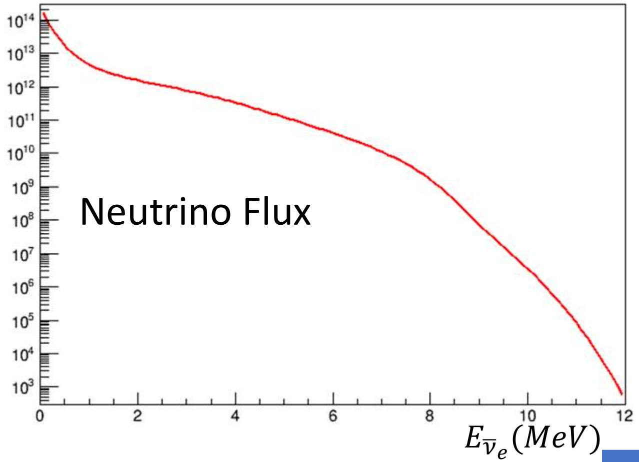
- **4.6 GW,** started operation 4months ago
- Spacious room at 10 m underground, **~31m horizontally from core**
- Access by elevator 1.4x1.8 m



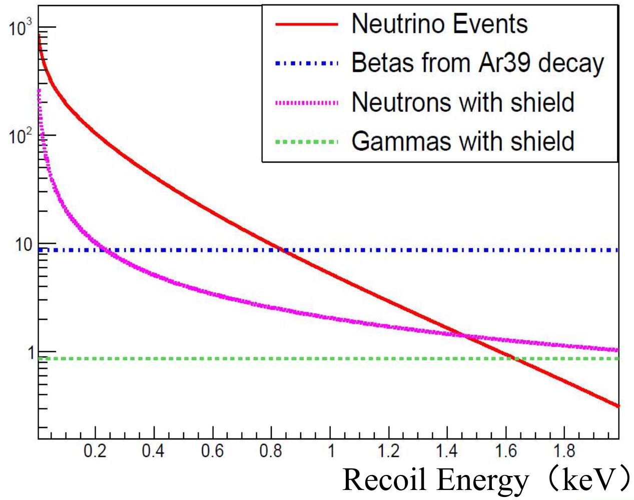


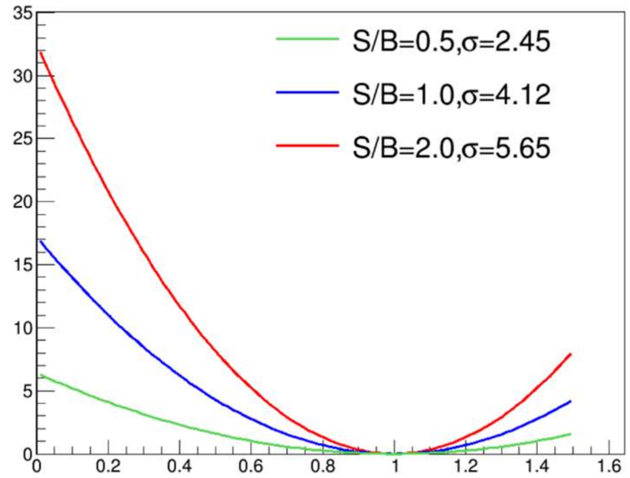
The Expected Events

- ✓ **Thermal Power is 4.6 GW**
- ✓ **Distance to the core 31m**
- ✓ **Average flux ~$4.66 \times 10^{13} cm^{-2} s^{-1}$**
- ✓ The expected events per day:



For half a year, with S:B=1:1, the expected standard deviation 4.12





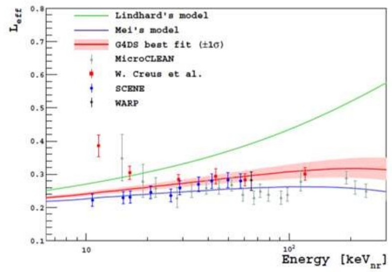


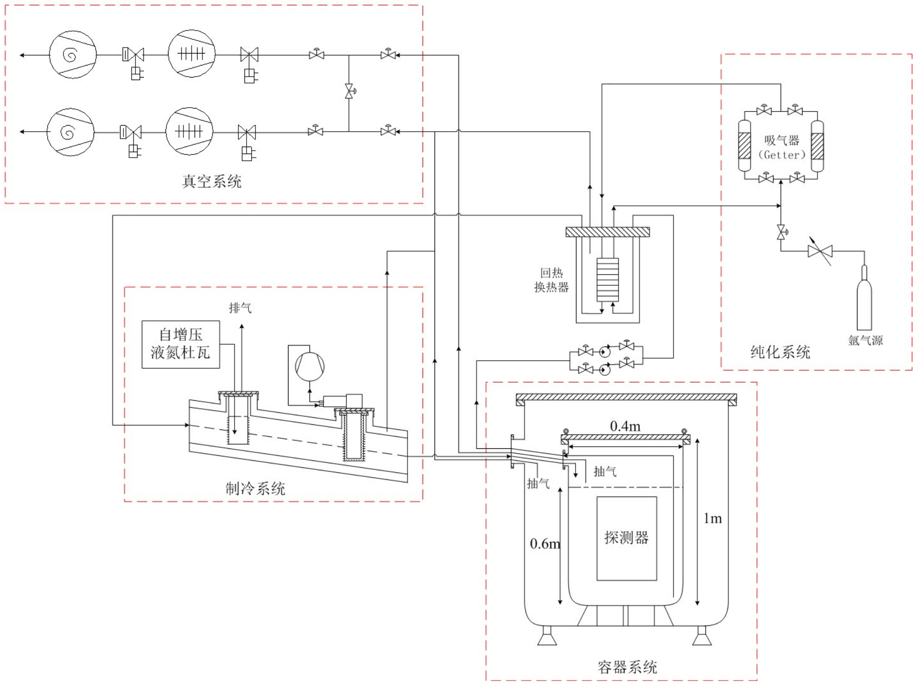
Figure 21. Comparison of the Lindhard and Mei models with the G4DS best fit of the DarkSide-50 data. SCENE [47], MicroCLEAN [48], WARP [49], and W. Creus *et al.* [50] data sets are also shown.

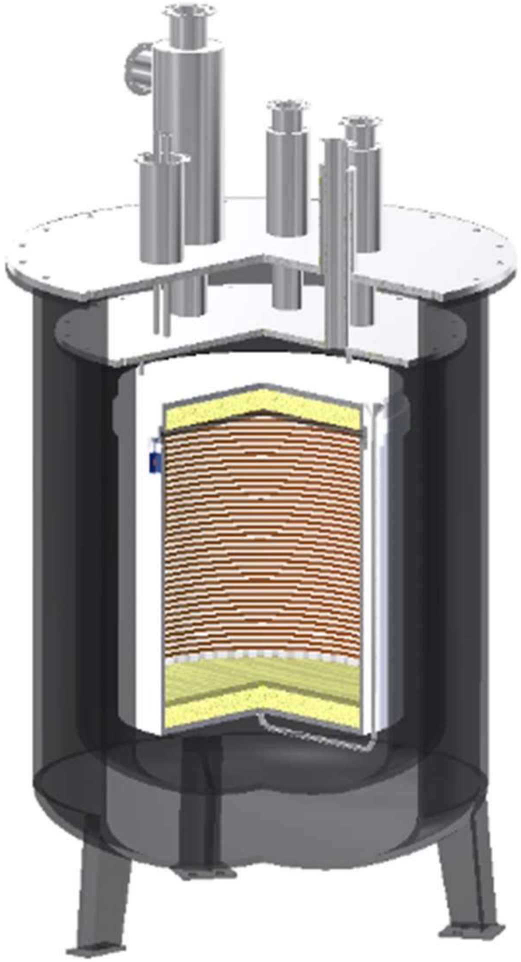
Threshold	Events/day (Nr)	Events/day (ee)
0keV	14549	3323
0.1keV	4146	947
0.2keV	2638	602
0.3keV	1776	406
0.4keV	1232	282

	本底来源	电子散射本底	放射性中子散射本底/宇宙线中子本底
Signal	中微子>0.1keV	5.68×10^4 （等效电子散射）	
TPC Background	^{39}Ar	$<1.2\times10^7$ / <0.008	-
	熔融石英	$1.65\times10^4/2.0\times10^{-5}$	$0.17/4.3\times10^{-4}$ $0.21/1.3\times10^{-5}$
	聚四氟乙烯	$2400/3.0\times10^{-6}$	$0.39/9.8\times10^{-4}$ $2.7/1.6\times10^{-4}$
	无氧铜	$2250/2.8\times10^{-6}$	$5.0\times10^{-3}/1.3\times10^{-5}$ $1.5/9.0\times10^{-5}$
	不锈钢	$5.5\times10^4/3.4\times10^{-5}$	$2.5/6.3\times10^{-3}$ $30/0.018$
	PMTs	$1.3\times10^6/1.6\times10^{-3}$	$19.4/4.8\times10^{-2}$ $0.34/2.0\times10^{-5}$
Environment Background	水/水箱/岩石/反应堆中子/gamma	$15000/9.0\times10^{-6}$	$4\times10^{-3}/9\times10^{-6}$ $20/0.013$
Cosmic Background	宇宙线muon	1800/100kg	
	快中子		180/100kg
	总的本底	1.3×10^7/~200	→2.25×10^4~5.68×10^4~1.13×10^5

The Planned Dual-phase Argon Detector Design

- ✓ FV: 100kg~300kg (not final decided)
- ✓ Low threshold: 0.1keV
- ✓ S2 light readout to reach low threshold
- ✓ SiPM instead PMT for low radiative
- ✓ Low radiative material: Acrylic instead stainless like DEAP-3600





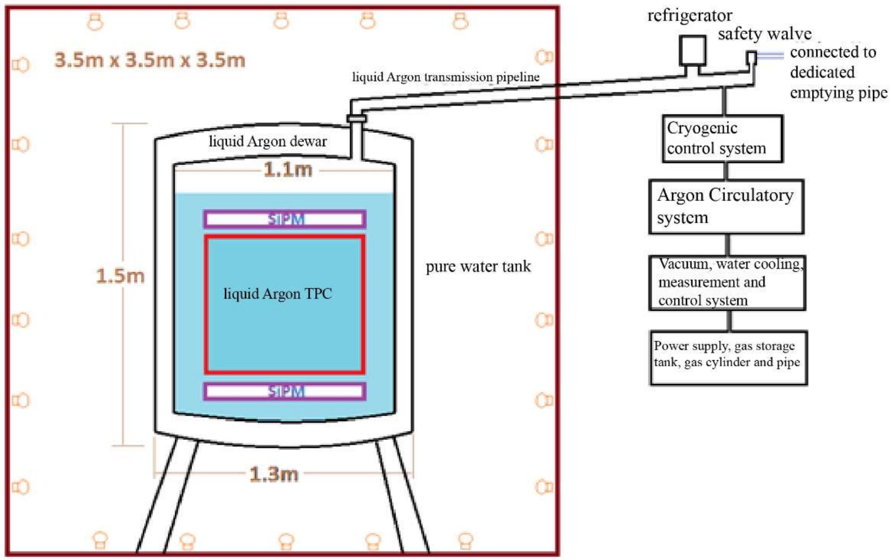
Summary and Next Steps

Summary:

- Dual-Phase Argon Detector for reactor CEνNS process in TaiShan Power Plant
- Some primary study did based on Dual-Phase Detector system
- The cold pre-amplifier for SiPM
- Only S2 signal will be read to reach 0.1keV threshold
- Acrylic instead stainless

Next Steps:

- The background analysis and Shielding System design
- The detailed technique design for TPC
- The Development for Cold readout system for SiPM
- .....



The R&D just start, The Science is ongoing …