Status of R&D on double phase argon detector: the ANKOK project

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Cygnus 2013 , 2013/6/11, Toyama, Japan

"ANKOK" Project

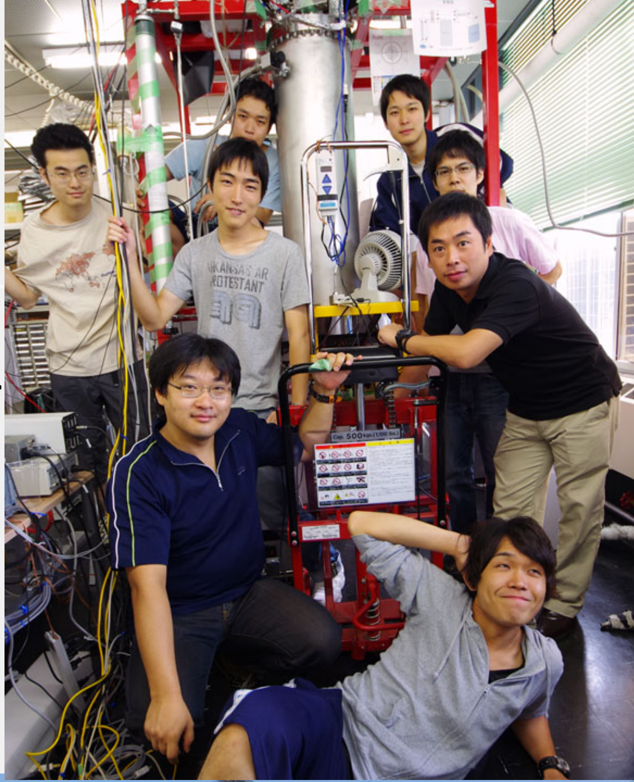
ANKOK = 暗黒 (= Darkness, Blackness)

"Arugon Nisou-gata Kennsyutuki" O K

アルゴン 2相型 検出器

WIMP Dark Matter Search using Double Phase Argon Detector

ANKOK Collaboration

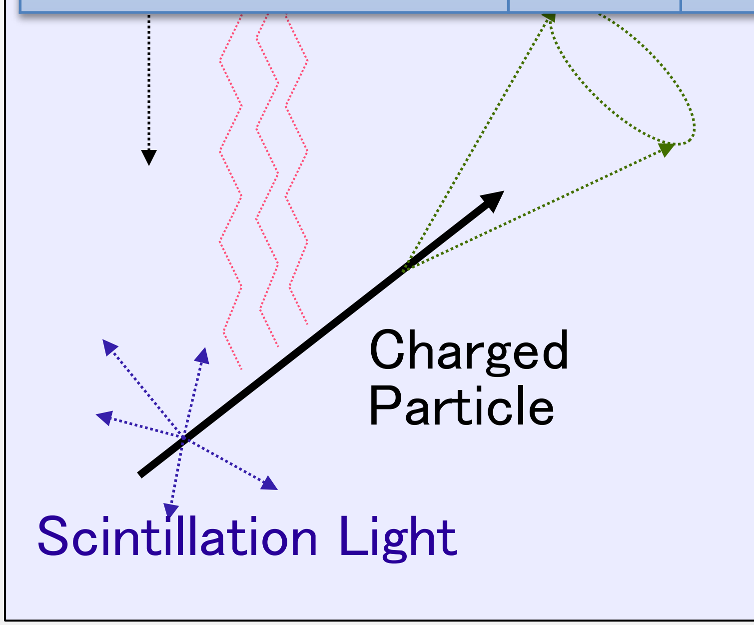


- 2009~2012
  - Establish basic techniques for liquid Argon detector
    - Light, charge readout
    - Liquid argon purity
    - High voltage
- 2012 ~
  - WIMP dark matter search
    - 10 kg prototype detector
- Waseda University
  - 2 staff
    - Kohei Yorita (ATLAS/ANKOK)
    - Masashi Tanaka
  - 6 grad. Students
    - Kaoru Fujisaki
    - Yunosuke Hashiba
    - Asuka Okamoto
    - Masaski Kawamura
    - Toshiaki Kaji
    - Tatsuki Washimi

Outline

- Double Phase Argon Detector
  - Physics Goal
- R&D results
  - 10 kg prototype detector
  - January 2013, Surface Run
    - Basic properties of double phase detector operation
    - Particle Identification performance
- Ongoing effort
- Plan and Summary

	He	Ne	Ar	Kr	Xe	Water
Boiling point (K)	4.2	27	87	120	165	373
Density (g/cm^3)	0.125	1.2	1.4	2.4	3.0	1
Radiation length (cm)	755	24	13	4.9	2.8	36
Scintillation (γ/keV)	20	30	40	25	42	-
Scintillation λ (nm)	80	78	128	150	175	-
Price (yen/L liquid)	2000	50000	1000	100,000	1,000,000	100



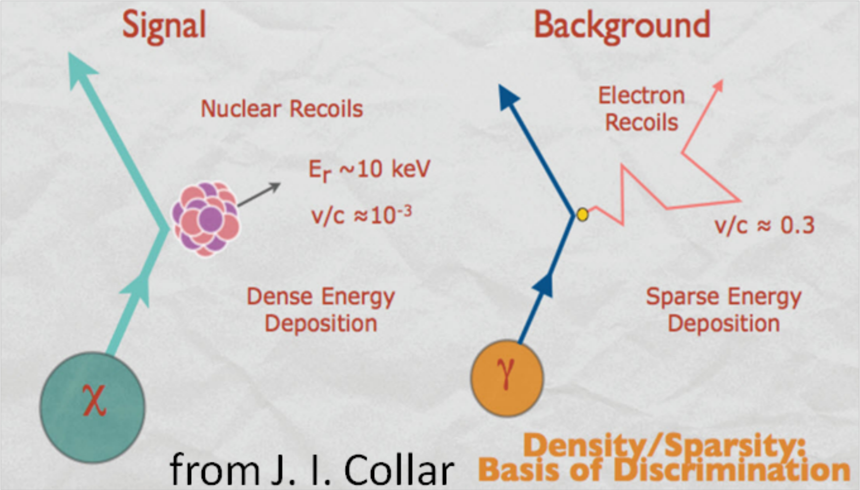
- Density: 1.4 g/cm^3
- Boiling point: -186℃
- Charged particle
  - Ionization electron:
    - ~40/keV
  - Scintillation light:
    - ~40/keV
    - 128 nm (VUV)
  - (Cherenkov light)
- ^{39}Ar background
  - ~ 1 Bq γ/ 1 kg LAr

depends on
particle
electric field
impurity, etc

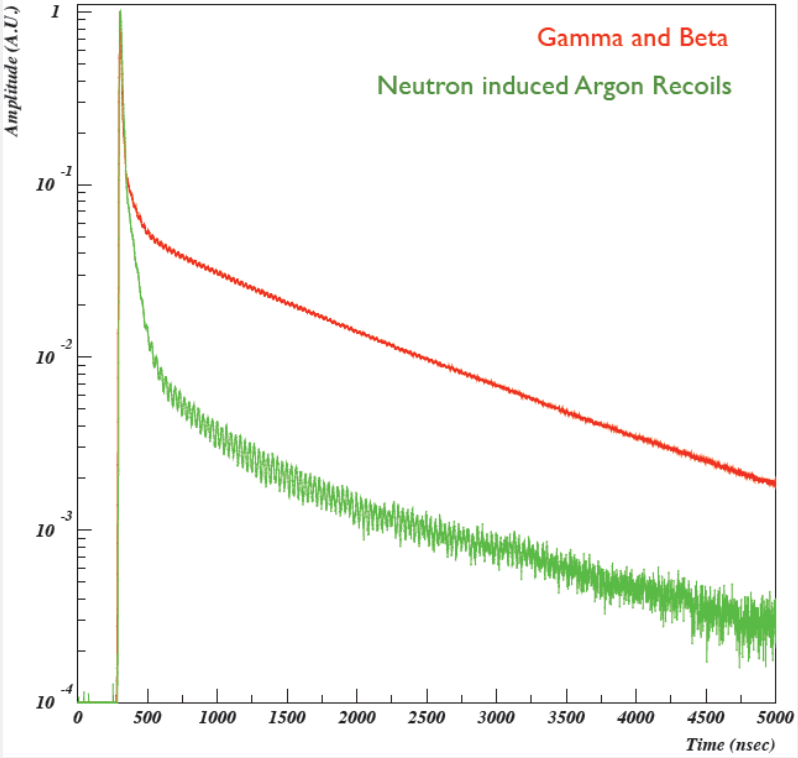
Scintillation Light : Pulse Shape Discriminator

- Scintillation Light
  - Fast and slow component
- Ratio of fast and slow components depends on dE/dx
  - High dE/dx → Slow ↑
  - Low dE/dx → Slow ↓
- Strong γ background reduction
  - > 10^6 reduction available?

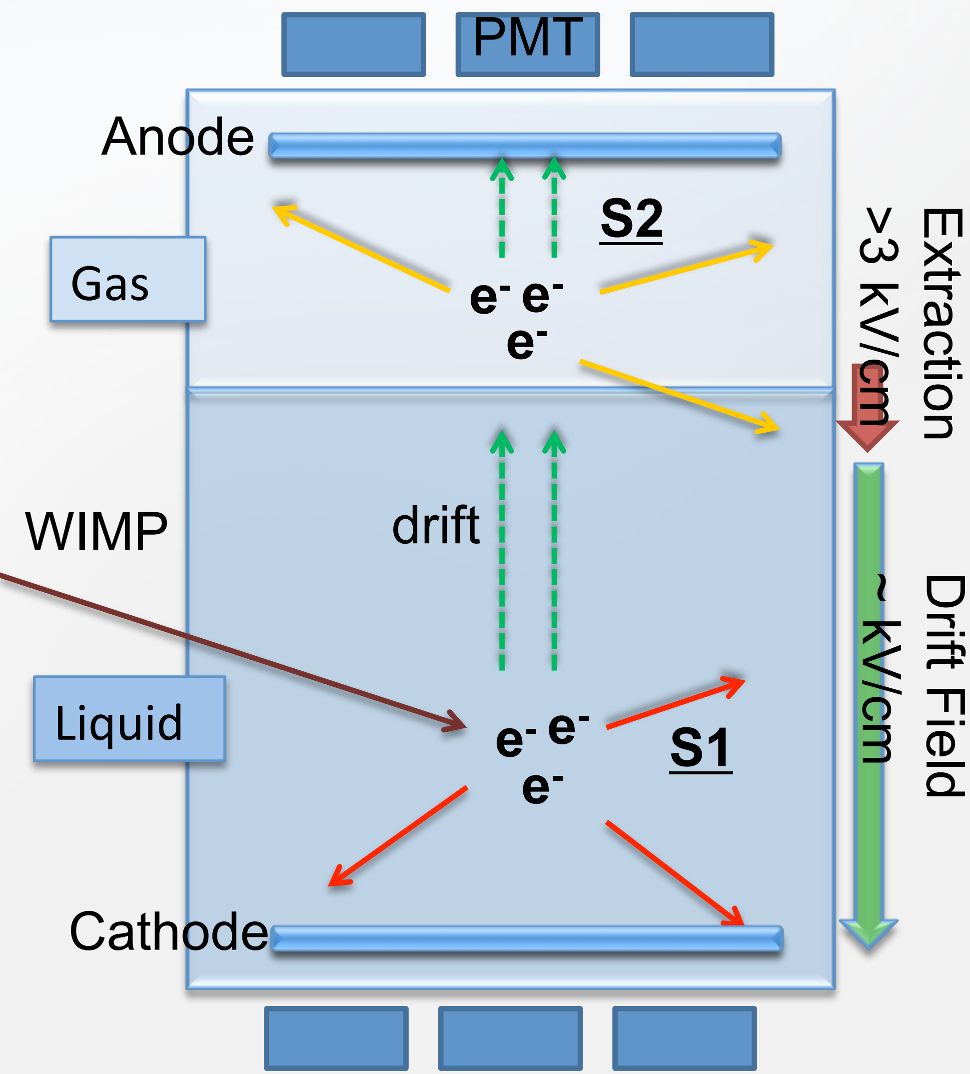
	Fast(ns)	Slow (ns)
Ne	18	15,000
Ar	7	1,600
Xe	4	22

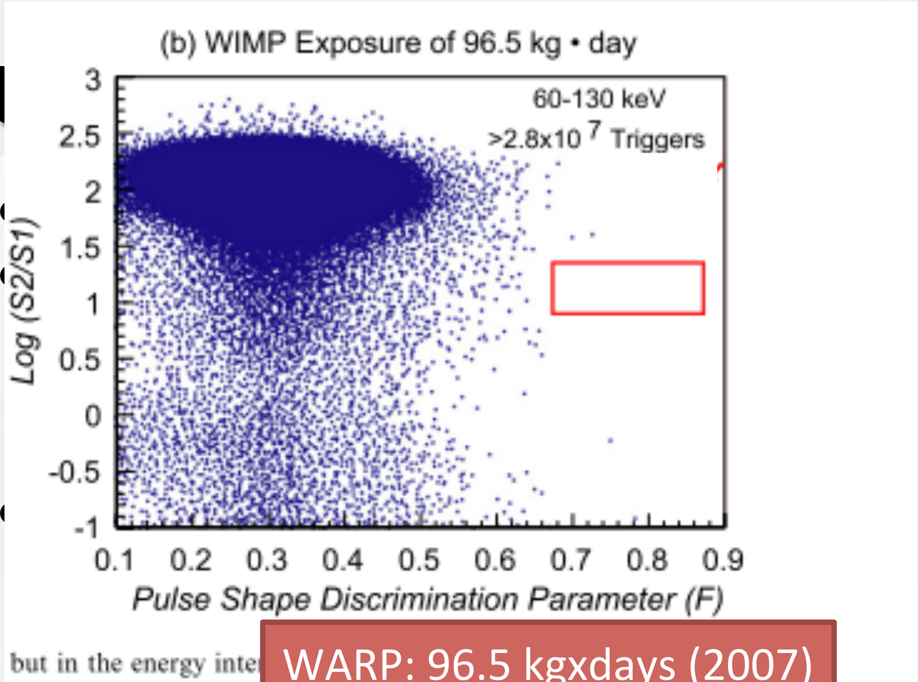


from J. I. Collar

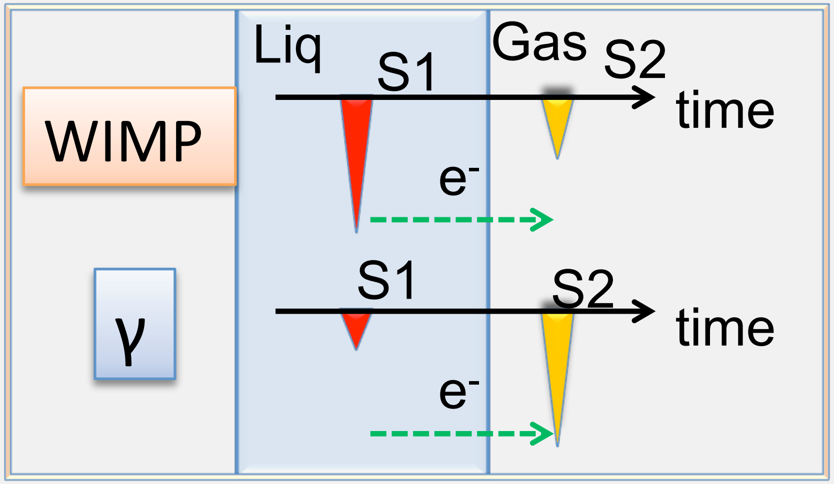


Double Phase Argon Det

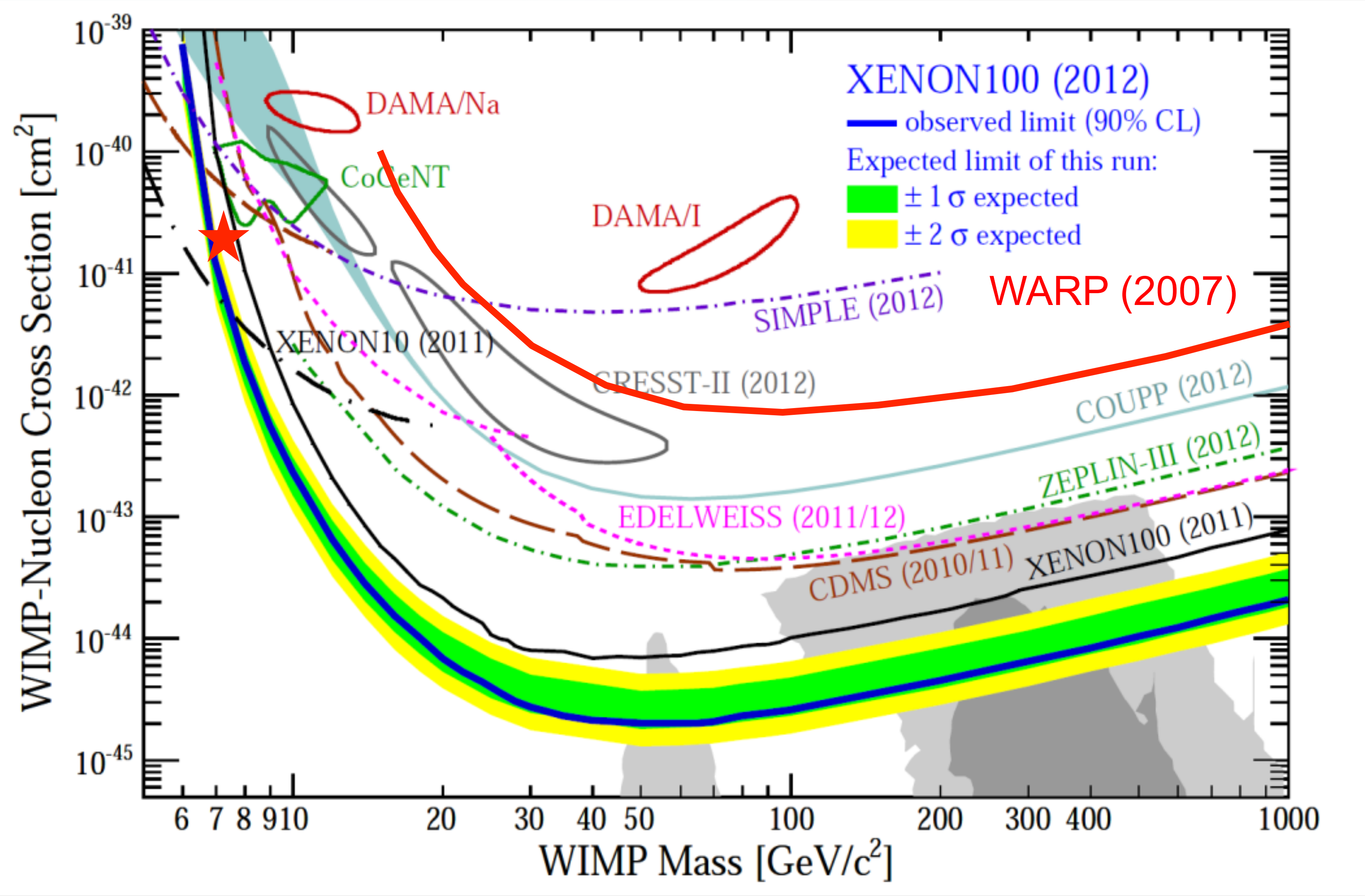




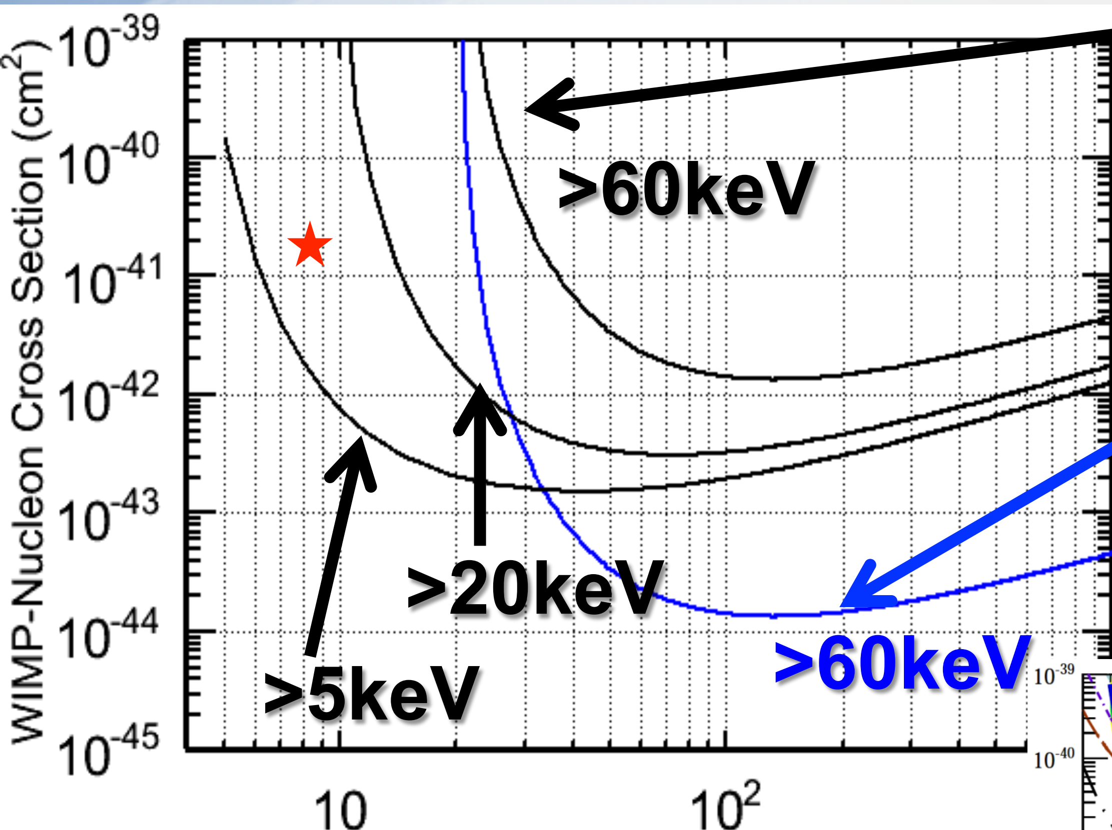
WARP: 96.5 kgxdays (2007)



Current Experiments

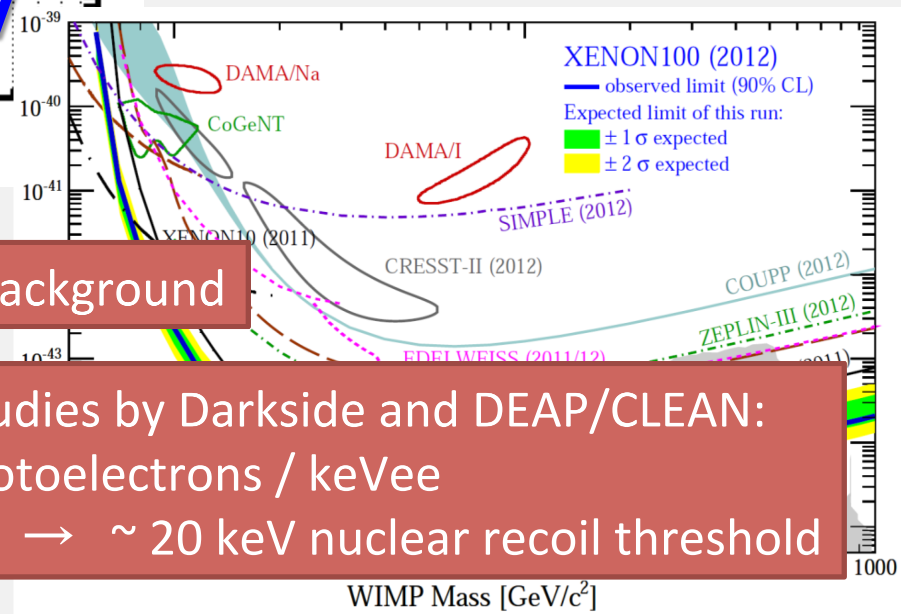


Physics Goal



WARP(2007)
Er>60keV、100kg・day

WARPx100
→ Er>60keV、10^4kg.day



High WIMP mass
→ Larger detector volume

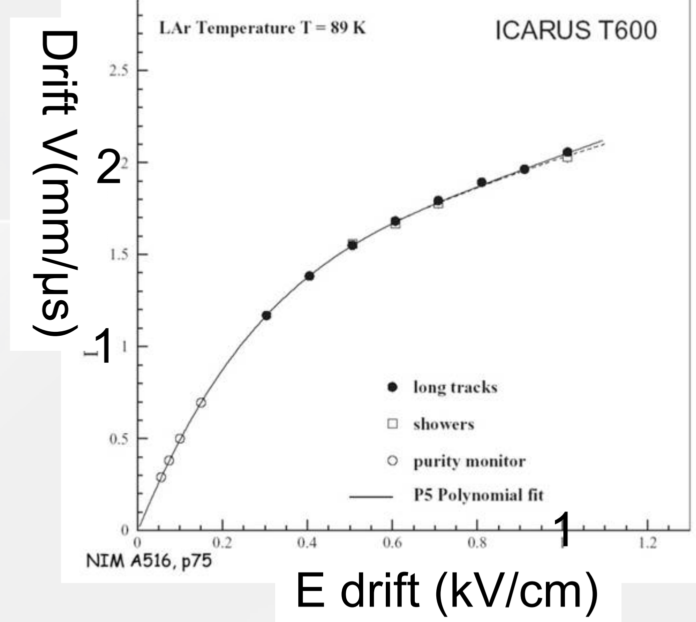
+ Low Background

Low WIMP mass:
→Lower energy threshold
→Light collection efficiently

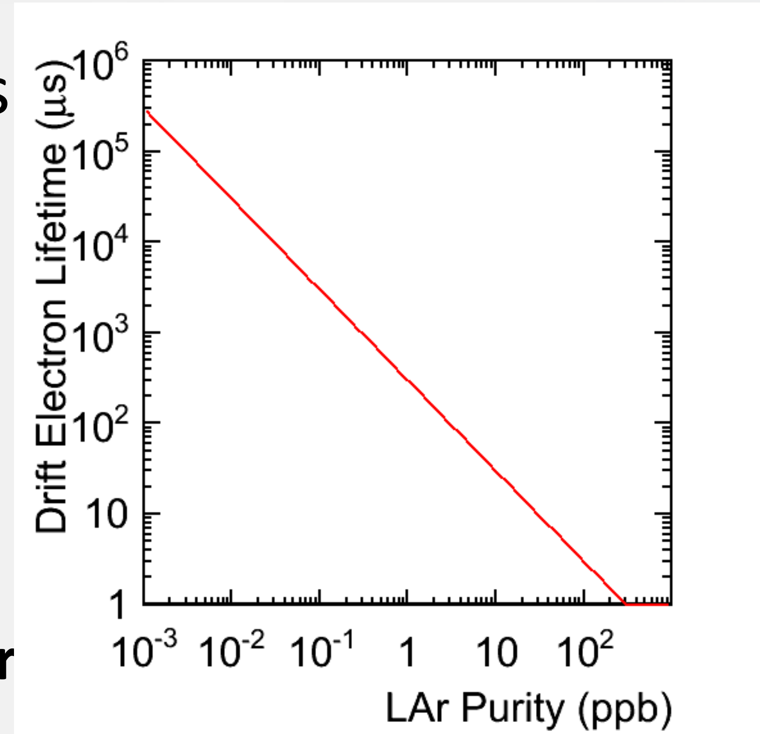
Prior studies by Darkside and DEAP/CLEAN:
~ 5 photoelectrons / keVee
→ ~ 20 keV nuclear recoil threshold

Electron Drift and Liquid Argon Purity

- Drift Velocity
  - ~ 2mm/µs @ E = 1 kV/cm
  - 500 µs for 1m drift, V = 100 kV

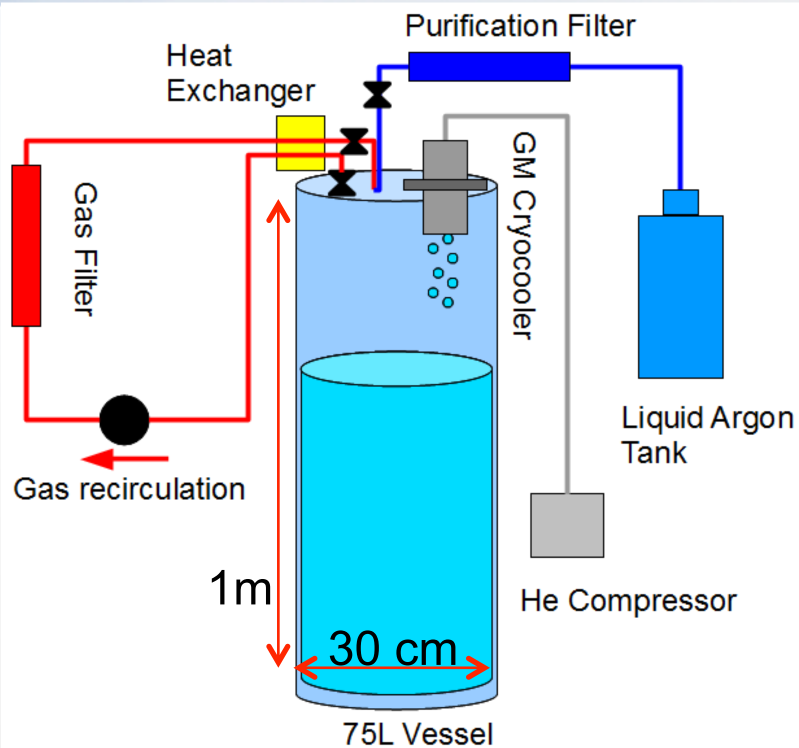


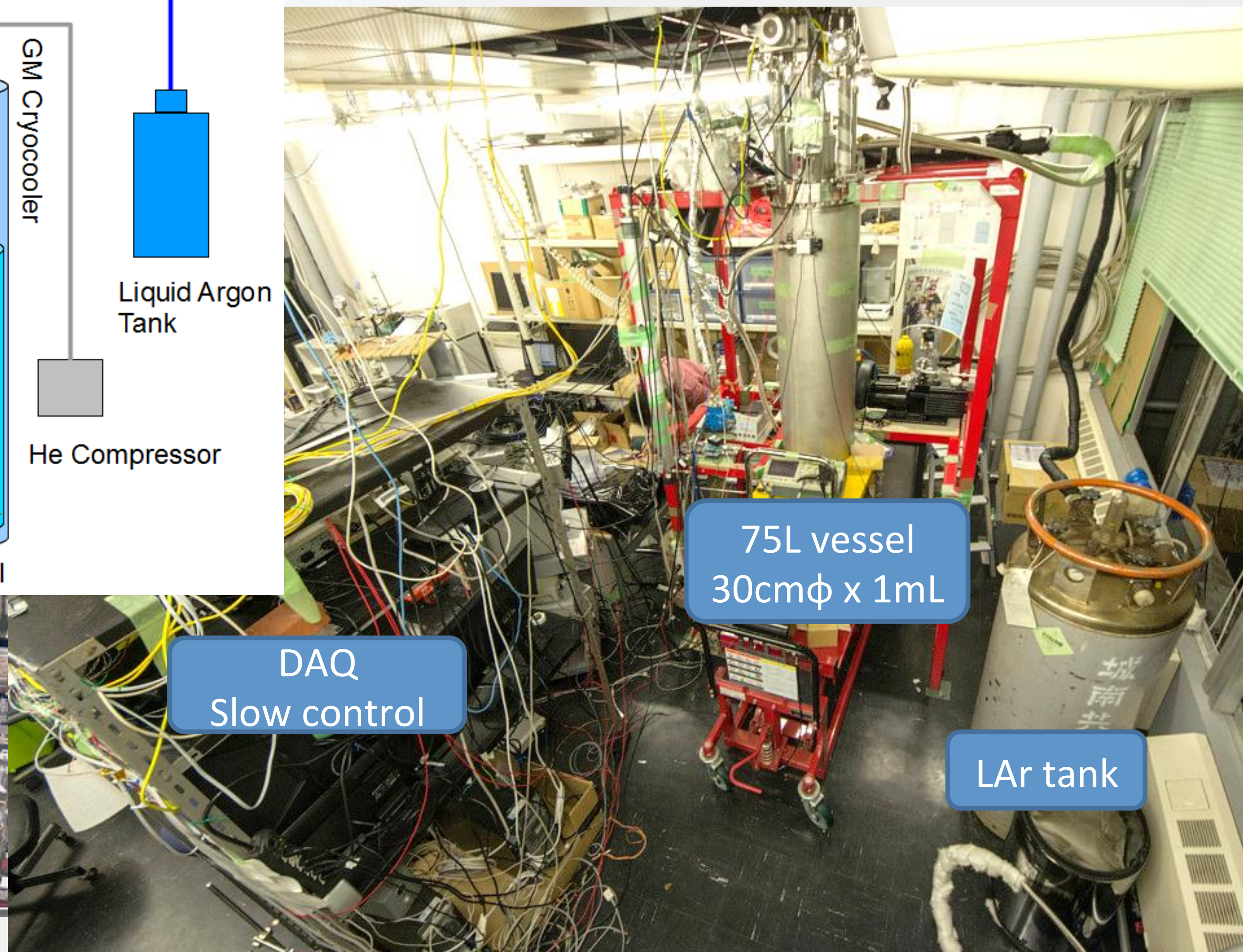
- Electronegative impurities in liquid argon absorb drift electrons
  - Oxygen, water, organic
  - Commercial LAr: ~1 ppm O_2 equiv.
  - 1 ppb: τ = 300 µs
  - 1m (500 µs) drift: < 1 ppb



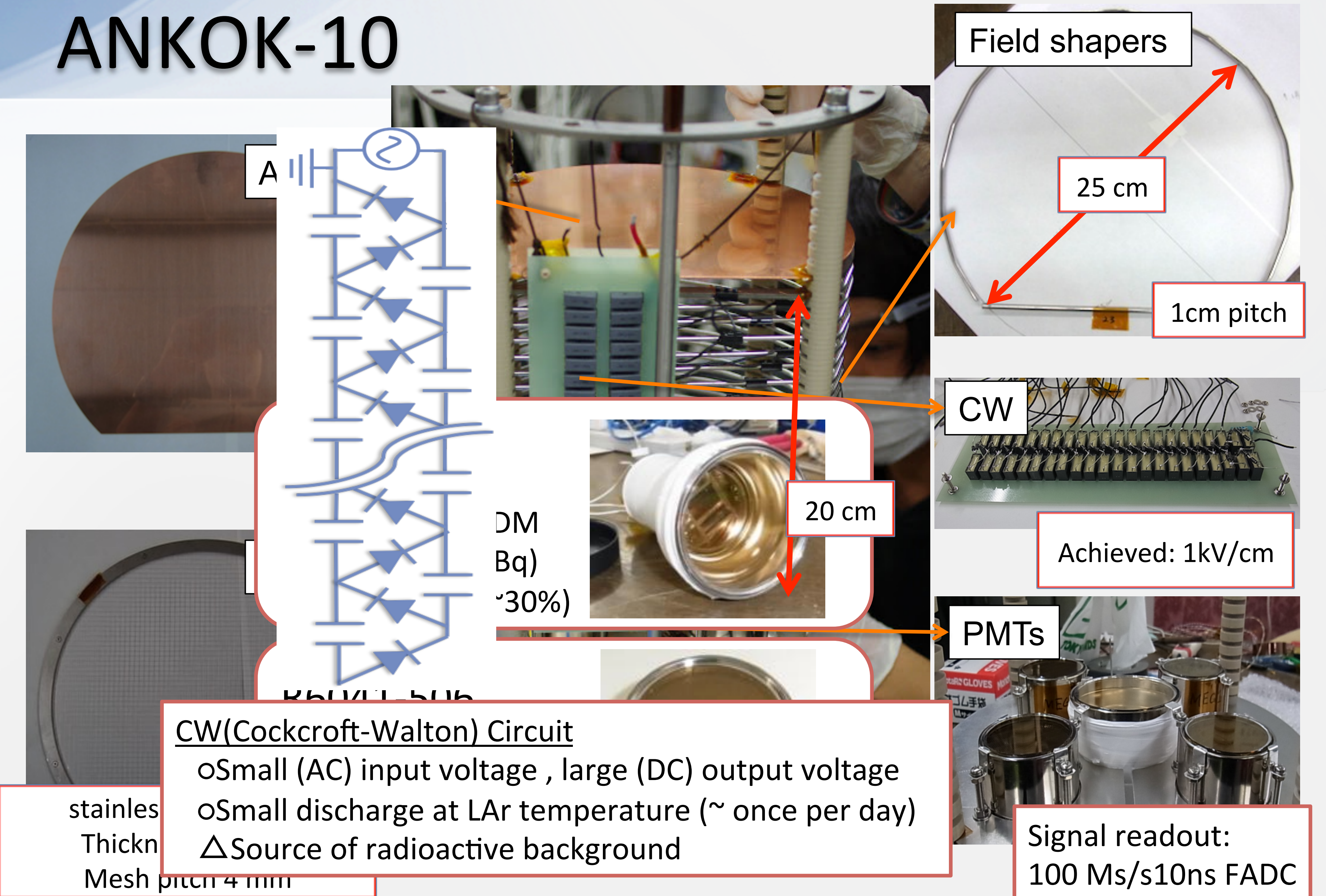
- **High voltage and high purity**
  - **Essential R&D issue for LAr detector**

Waseda LAr Teststand





10kg Prototype Detector ANKOK-10



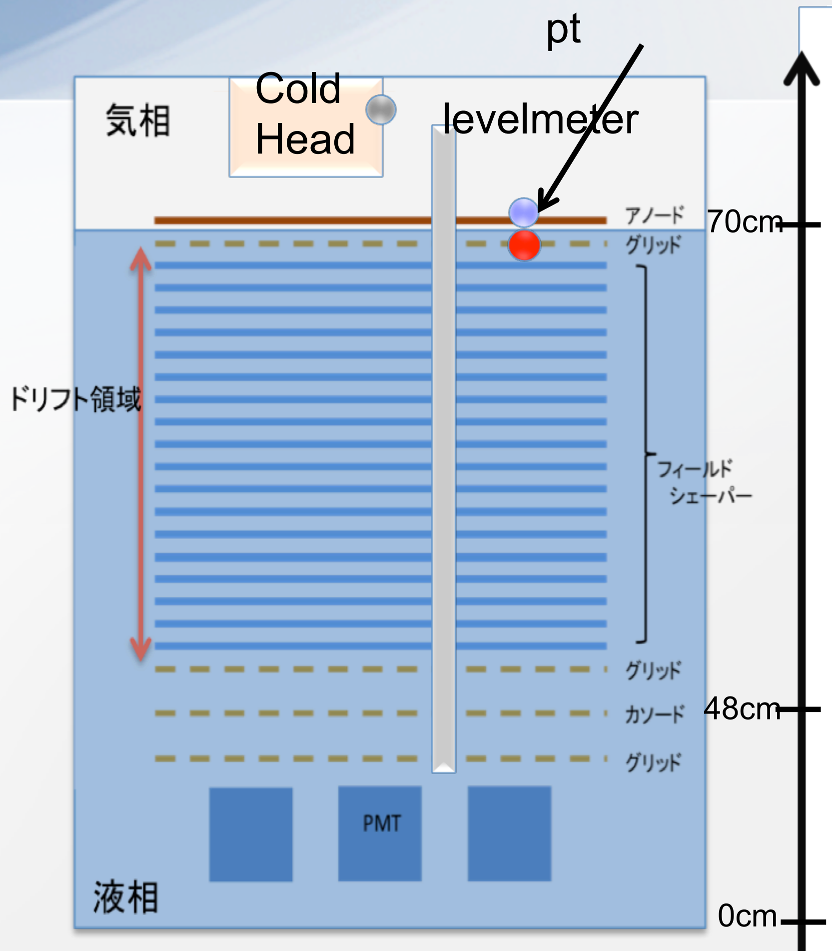
CW(Cockcroft-Walton) Circuit

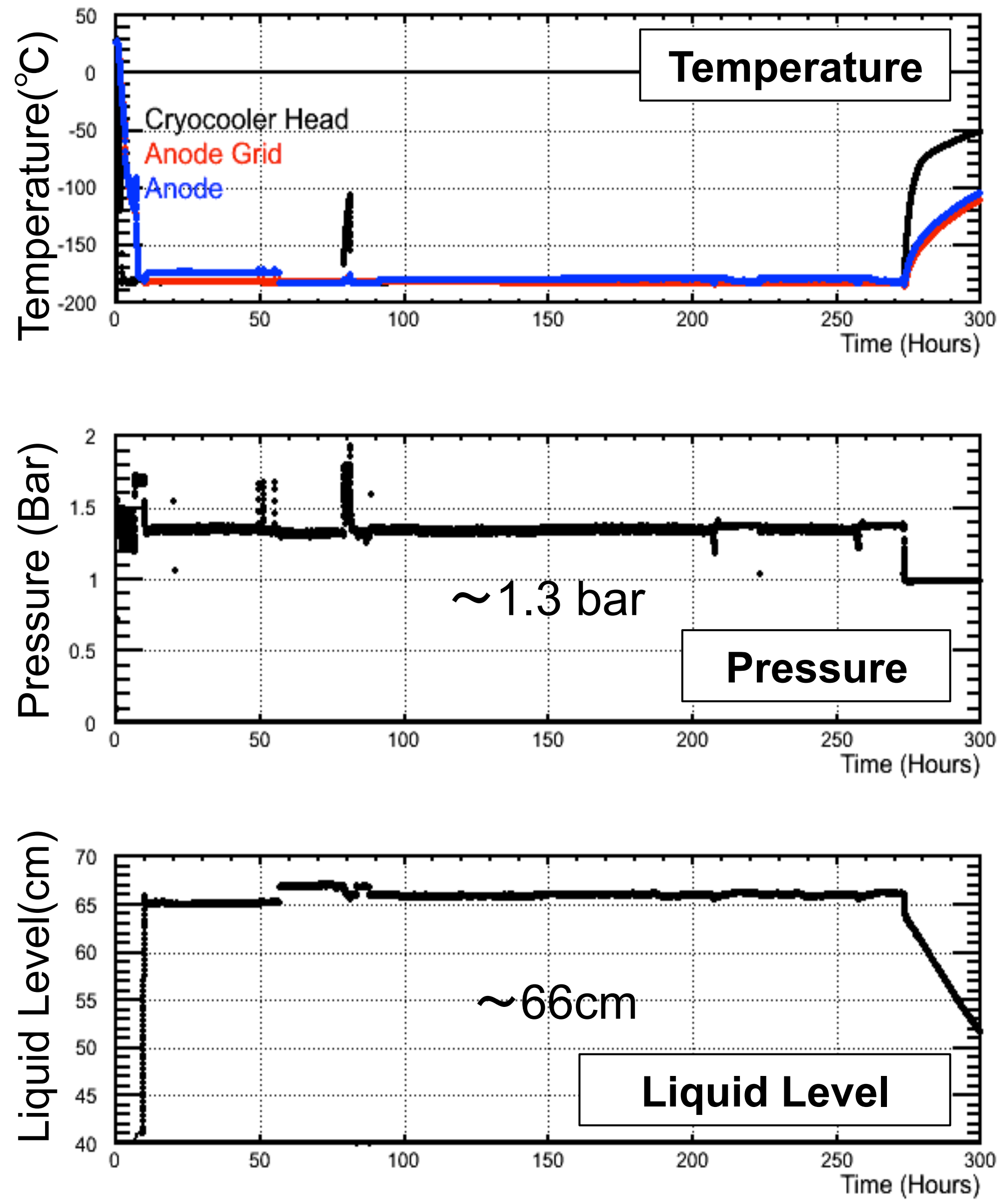
○Small (AC) input voltage , large (DC) output voltage

○Small discharge at LAr temperature (~ once per day)

△Source of radioactive background

January, 2013 Surface Run

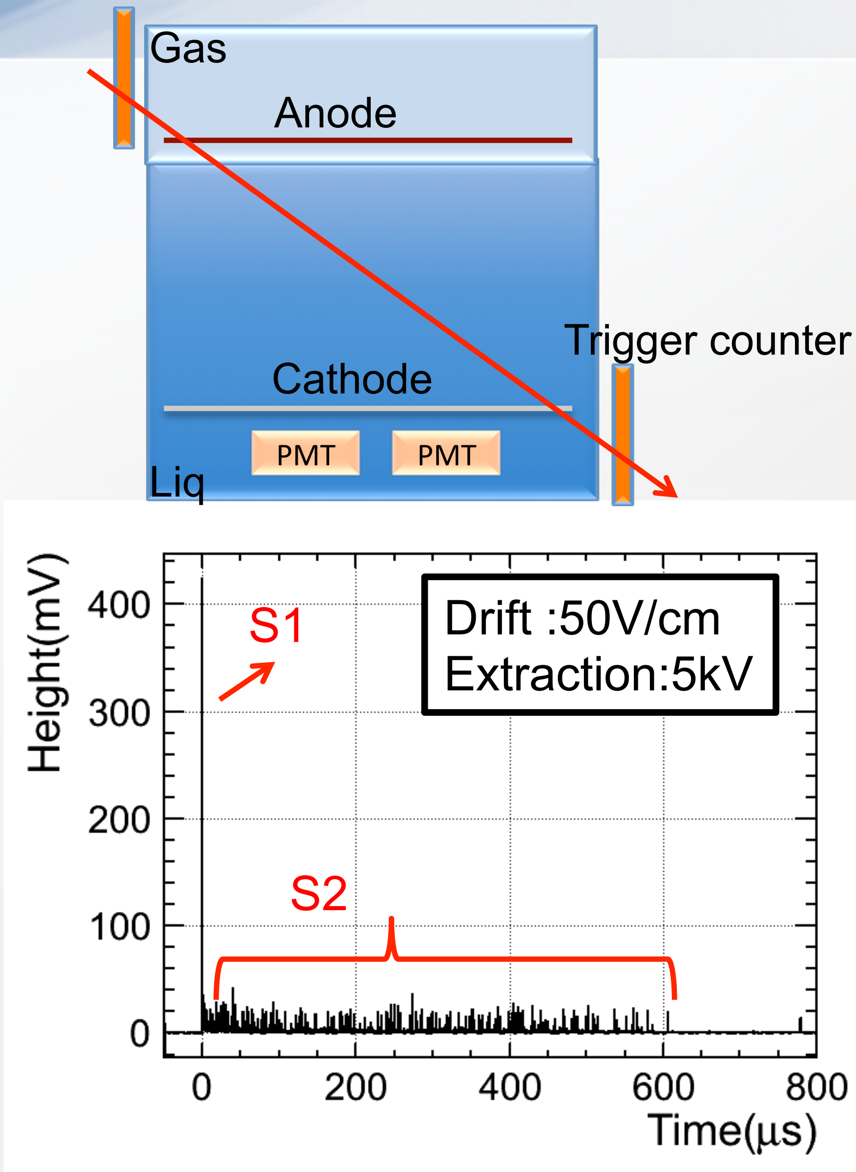




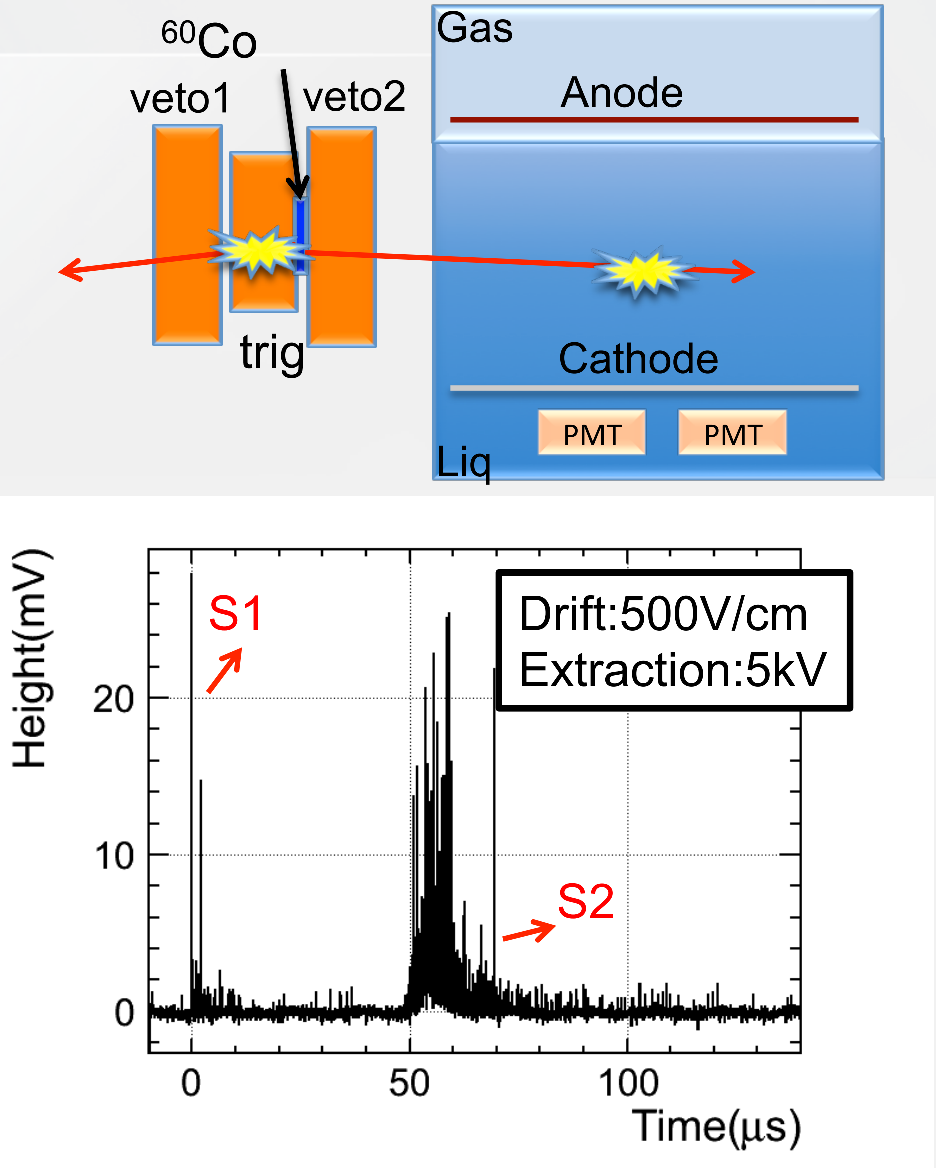
- ✓ ~50L LAr Filling in few hours
- ✓ Liquid level kept within ~ 1mm
- ✓ 10 days stable operation
  - ✓ pressure, temperature

Typical Event(mu,gamma)

○Cosmic Muon

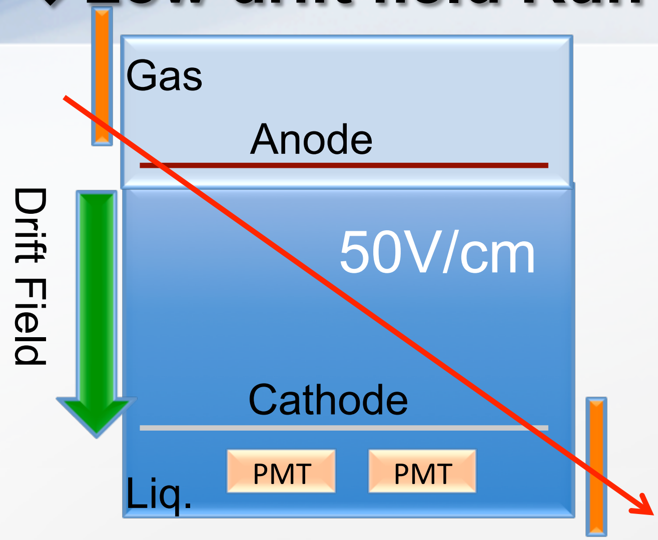


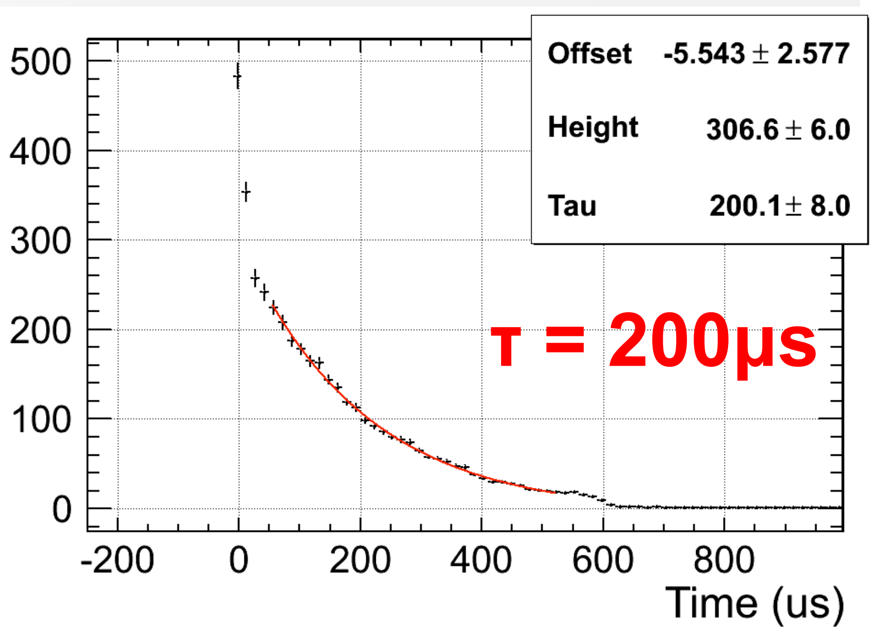
○ Gamma



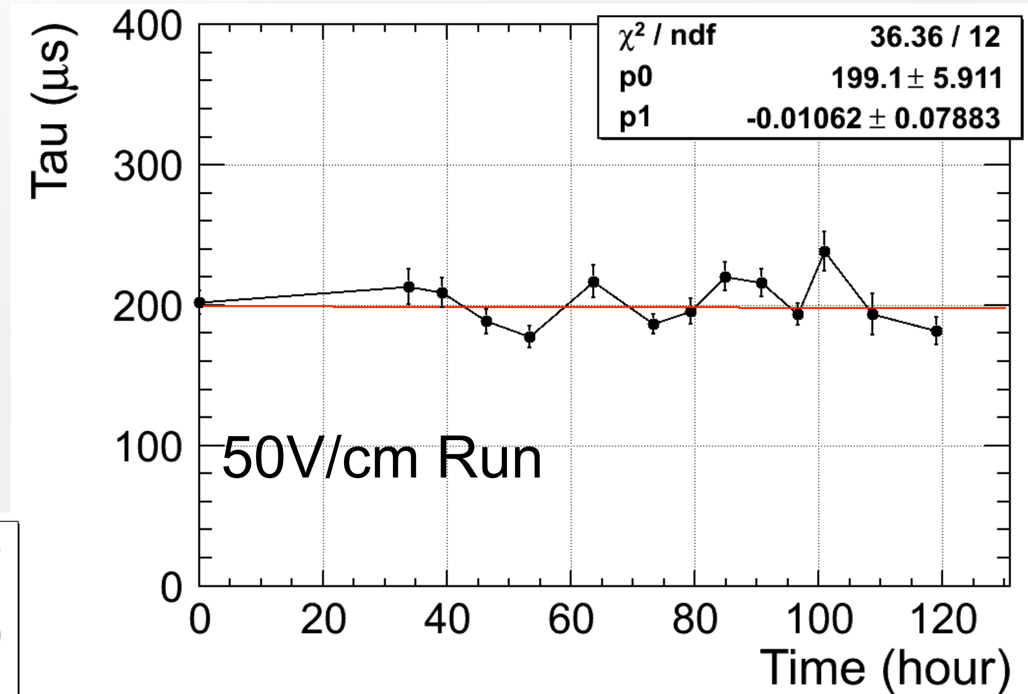
Liquid Argon Purity

◆Low drift field Run





◆ Purity stability（5 days）



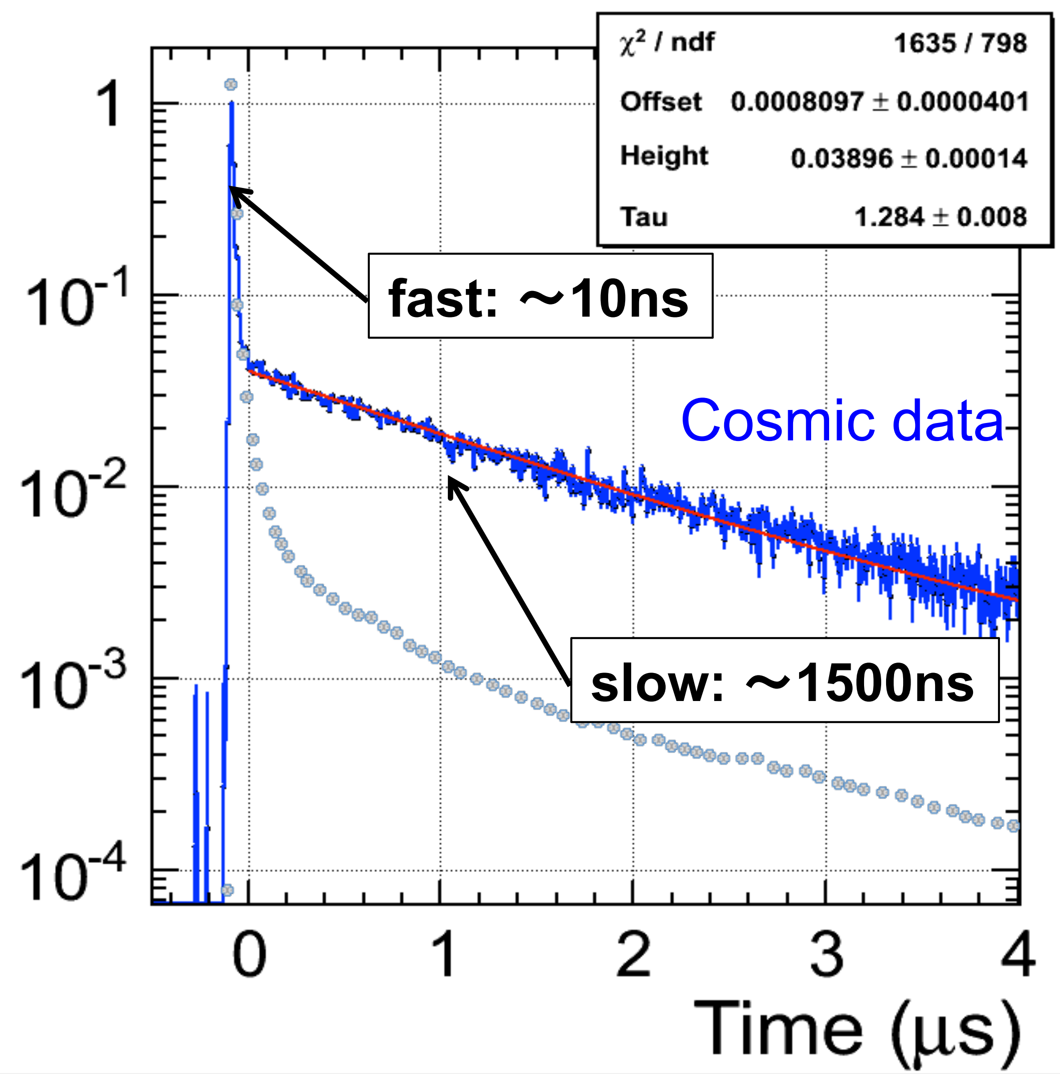
✓ **τ = 200μs → 1.5ppb O_2 equiv.**

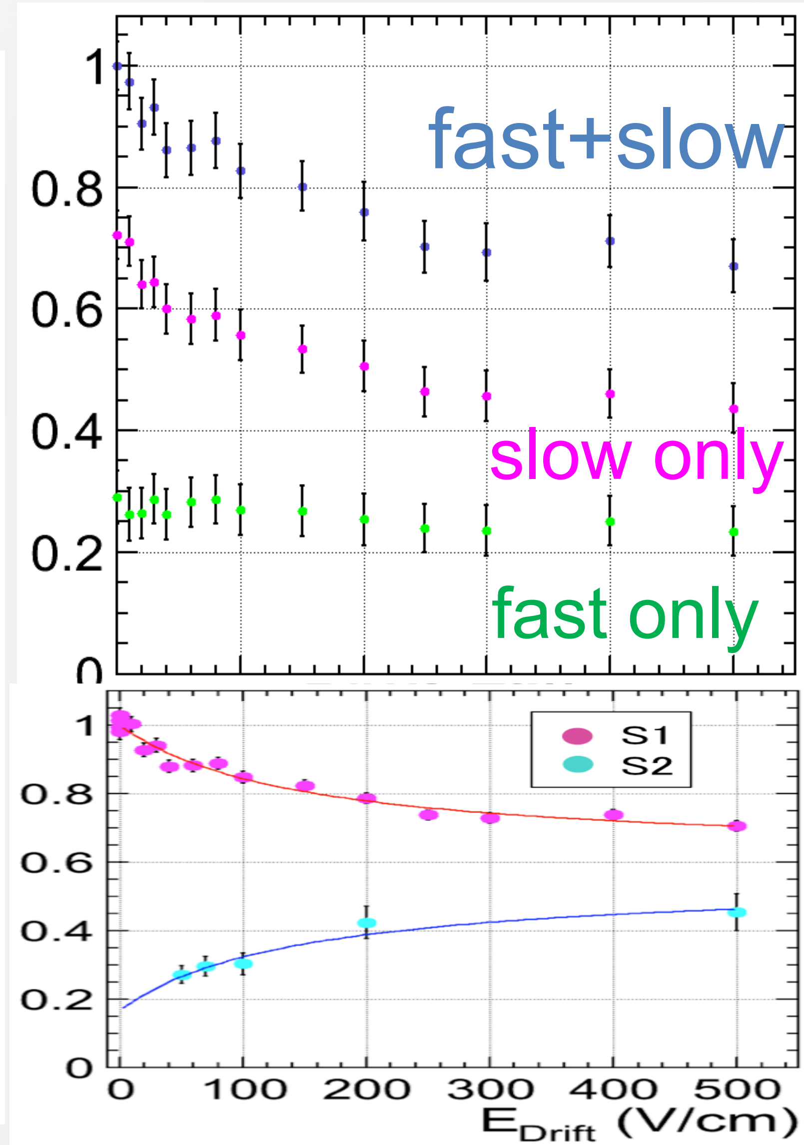
1kV/cm drift field（2mm/μs）

~ 40 cm drift can be achieved

S1 Pulse Shape, E Dependence

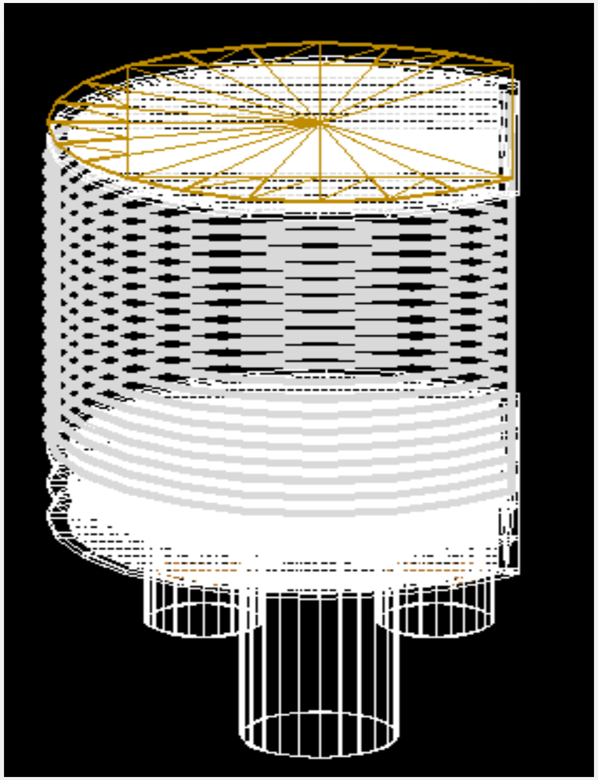
◆ Drift Field Dependence



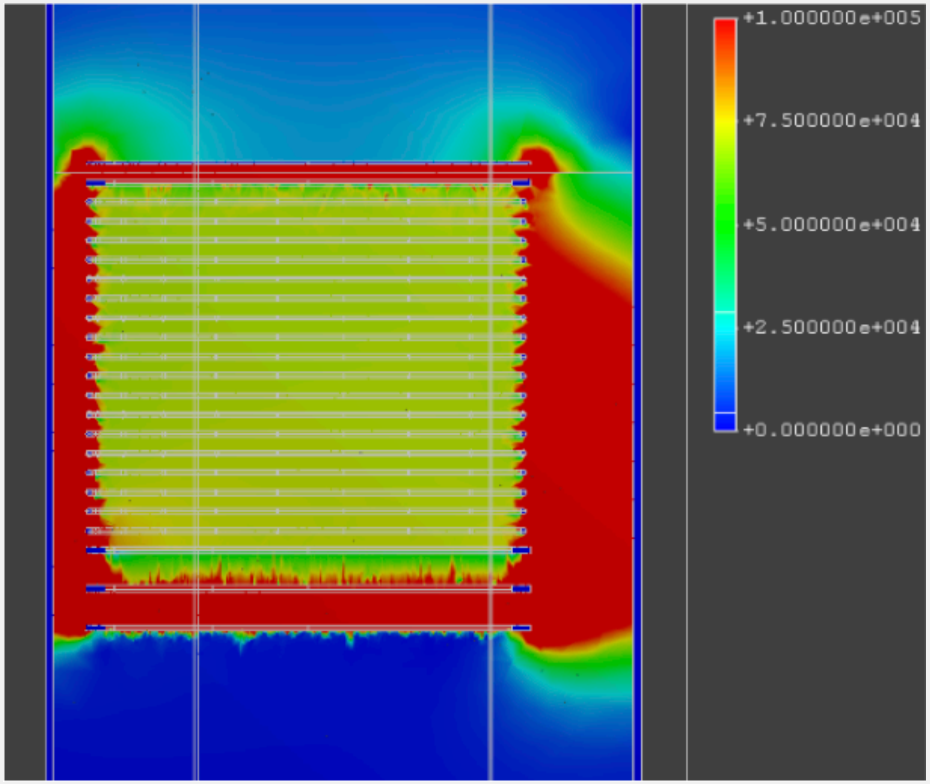


Detector Simulation

- Optical Photon simulation
  - Geant 4
  - S1, S2 detection efficiency for each PMTs



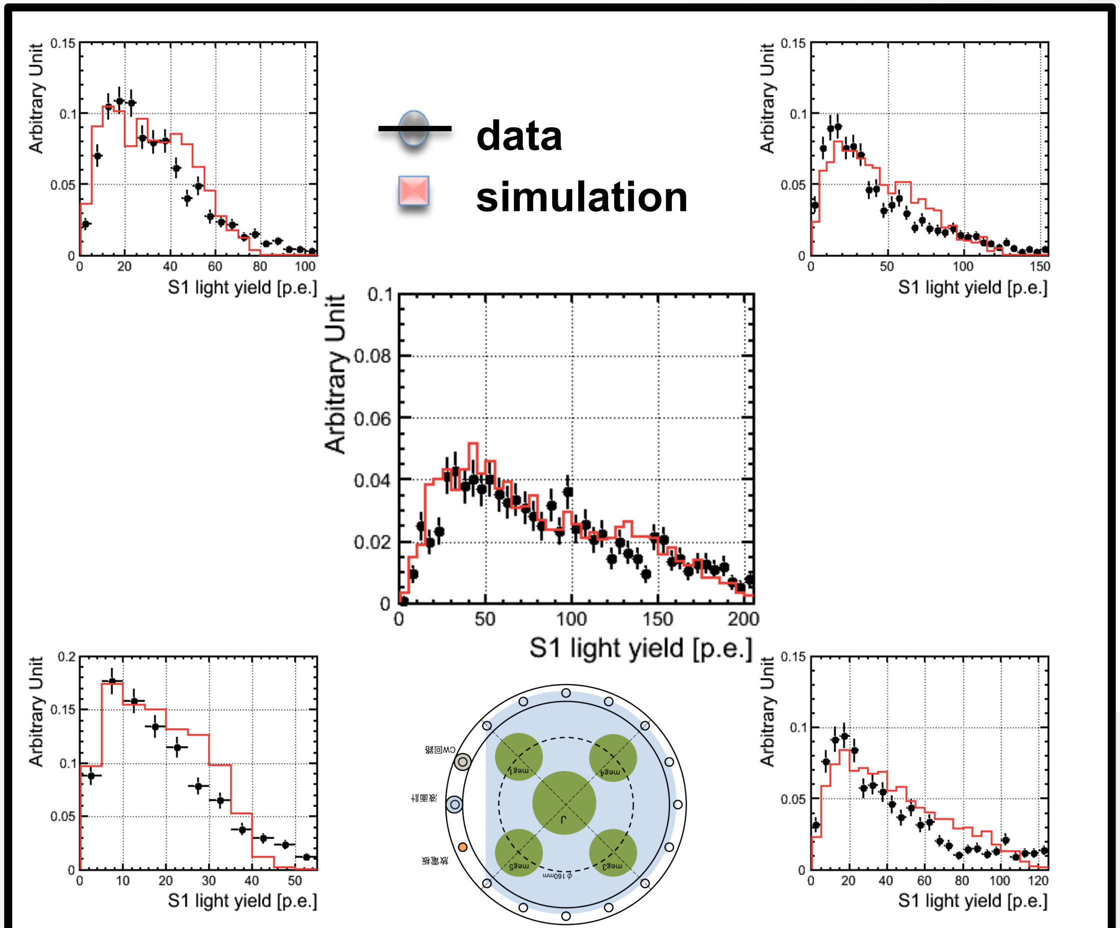
- Electric Field Simulation
  - FEMTET (Murata software)
  - Electron drift and S2 emission



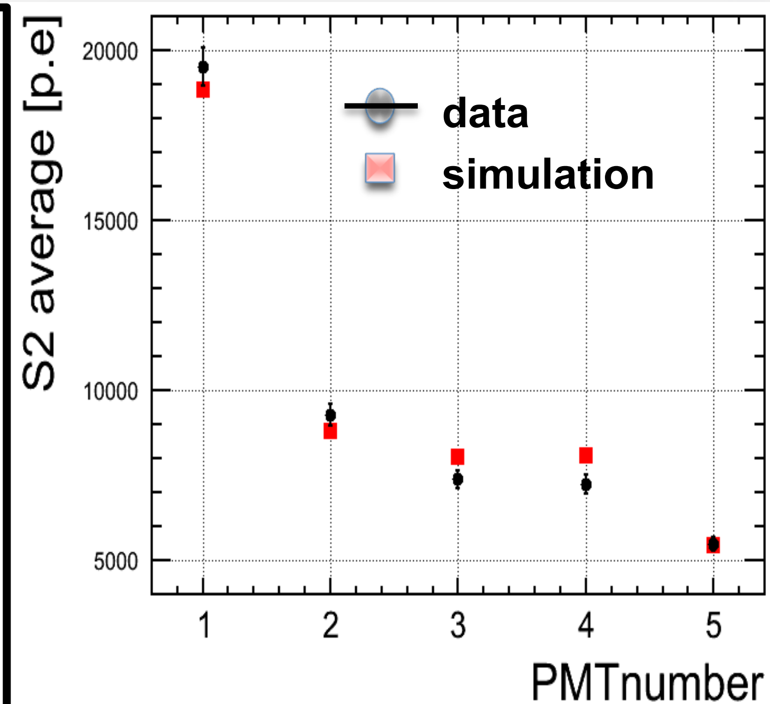
Simulation

◆ **Cosmic events**

✓ **S1 Light yield**

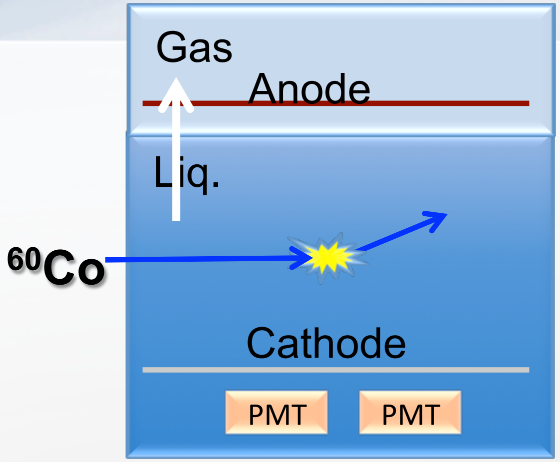


✓ **S2 Light yield**

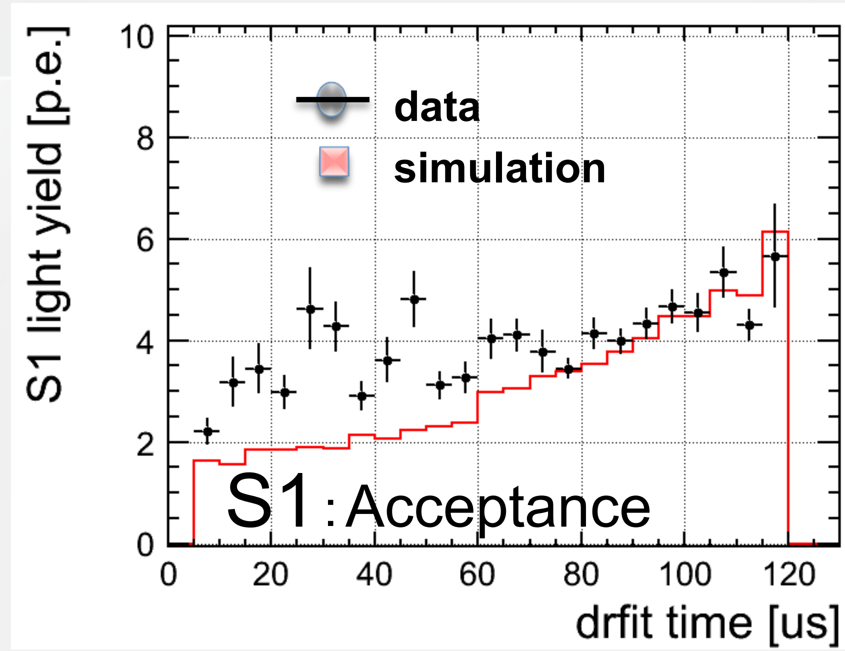


Cosmic data and simulation is in reasonable agreement

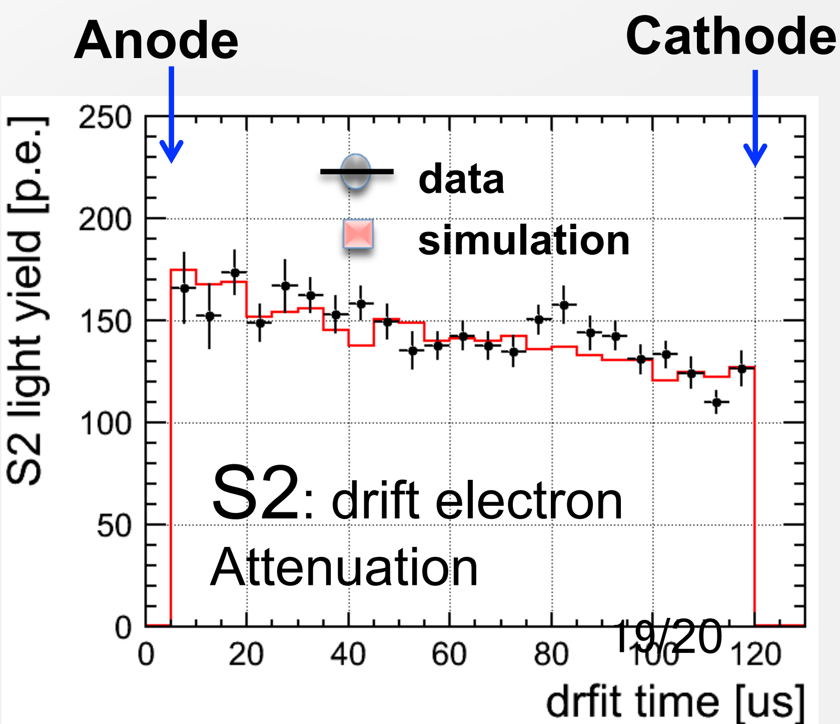
^{60}Co γ Data



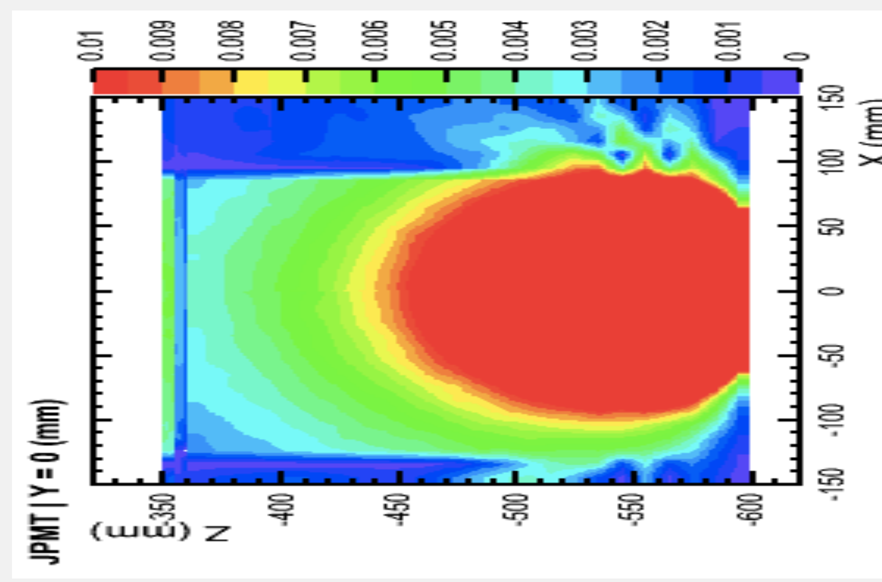
Gas
Anode
Liq.
60Co
Cathode
PMT
PMT



S1 light yield [p.e.]
data
simulation
S1 : Acceptance
drfit time [us]

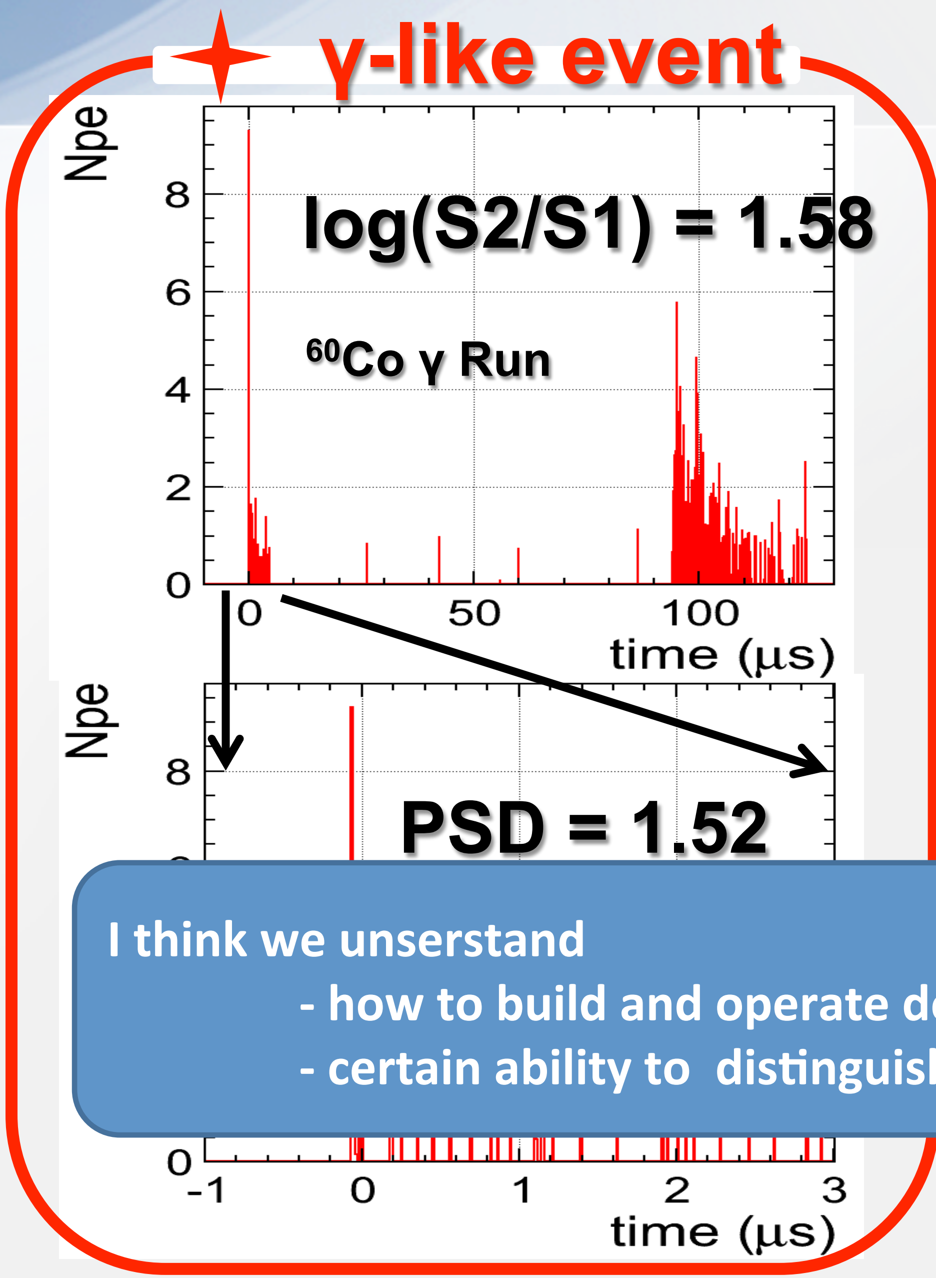


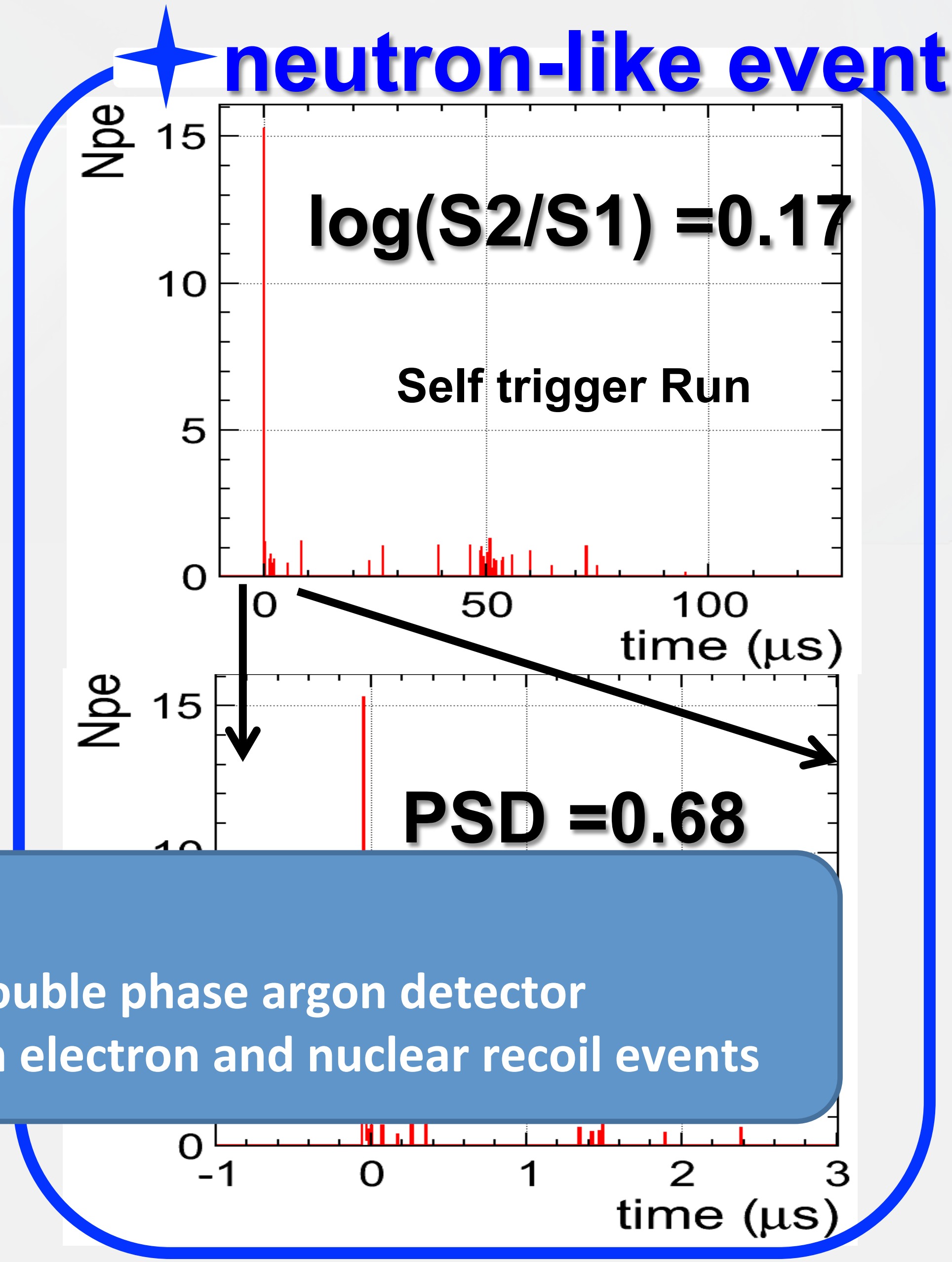
Anode
Cathode
S2 light yield [p.e.]
data
simulation
S2: drift electron
Attenuation
drfit time [us]



JPMT | Y = 0 (mm)
Z (mm)
X (mm)

Particle Identification





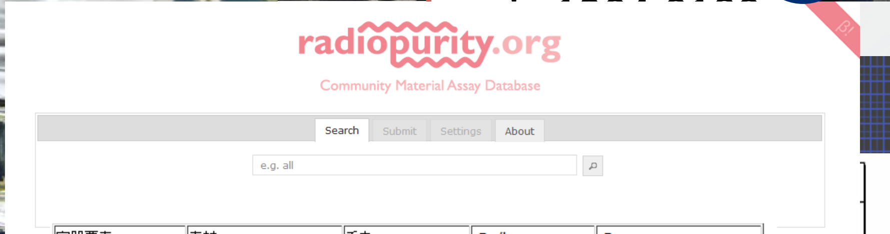
I think we unserstand

- how to build and operate double phase argon detector
- certain ability to distinguish electron and nuclear recoil events

Ongoing Effort

- ①Increase light collection efficiency
  - Achieve the level of prior studies (~ 5 pes/keVee = 20 keV Er threshold)
    - < 1 pes/keVee for the 10 kg prototype detector
  - Further incensement using new technique
    - use VUV MPPC, infrared Ar scintillation
- ②Understand background
  - radioactive and environmental
  - gamma and neutron

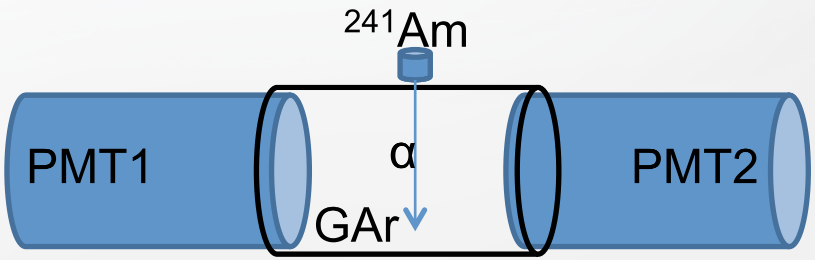
Liquid scintillator
Toluene + PPO + PC

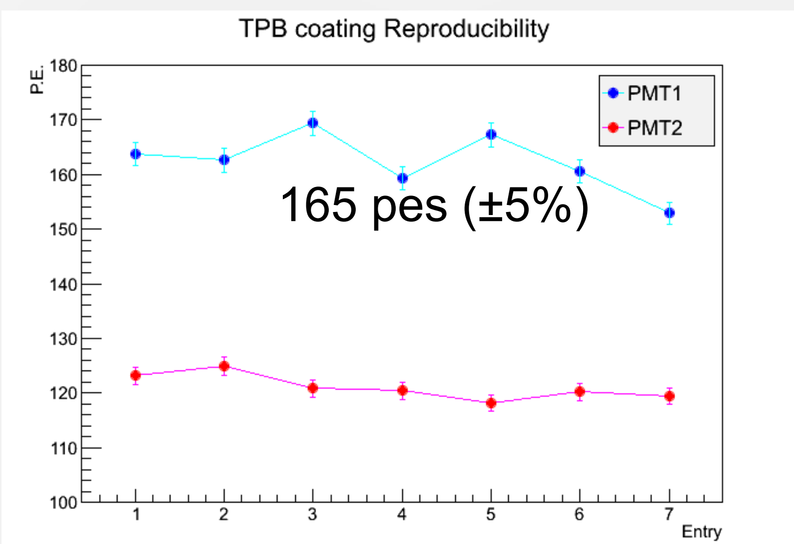


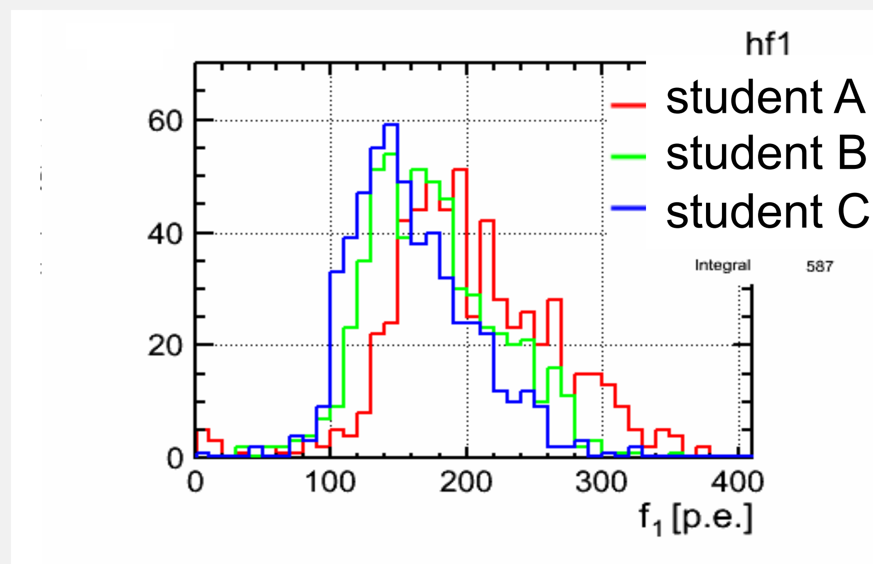
容器要素	素材	重さ	Bq/kg	Bq
容器	ステンレス	100kg	156.7m	15.67Bq
冷凍機ヘッド	銅	10kg	14.22m	0.1422Bq
フランジ	ステンレス	40kg	35.74m	1.43Bq
支柱	PEEK		-	-
アノード	銅	30g	14.22m	0.42mBq
CW固定	FRP	10g	647	6.47Bq
CW素子	抵抗、コンデンサ		-	-
シェーバー	ステンレス	200g	156.7m	31.3mBq
グリッド	ステンレス	30g	156.7m	4.7mBq
PMT固定部品	アルミ	20g	14.55	291mBq
ケーブル	-	100g	457.8μ	45.78μBq
カプトンテープ	ポリイミド			
放電棒本体	FR4	5g	647	3.24Bq
放電棒素子	抵抗、コンデンサ		-	-
放電棒おもり	鉛	25g	298.54m	7.4mBq
テフロンひも	PTFE		16.3m	
はんだ	鉛		298.54m	
ねじ	ステンレス		156.7m	
PMT	-	5	7.45m/個	37.25mBq
PMTグリッド	アルミ	20g	14.55	291mBq
光ファイバー	石英ガラス		-	-

TPB coating optimization

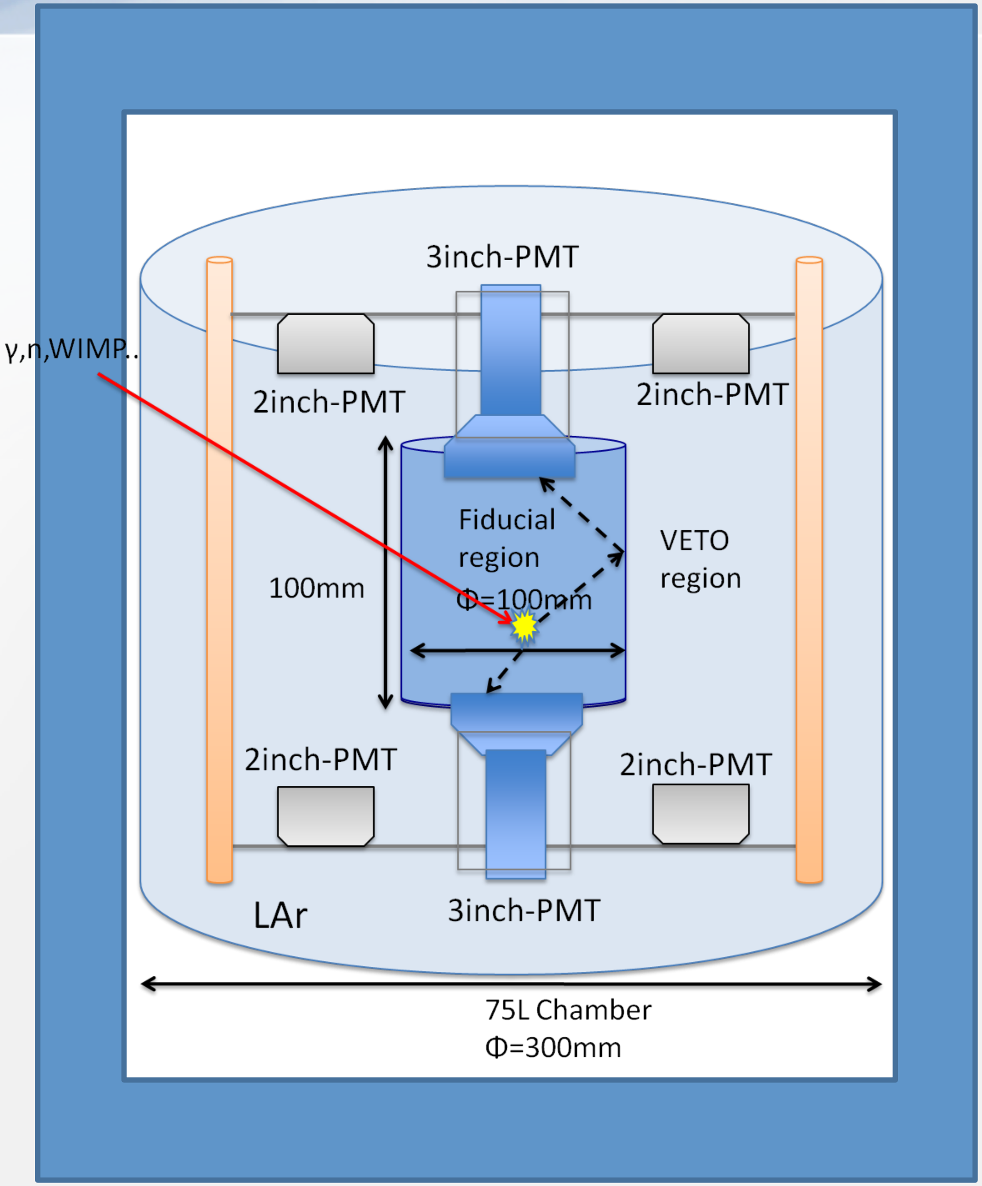
- TPB: Wavelength shifter
  - 128 nm Ar scintillation light → 430
  - 1 toluene + 5% pararoid + 0.5% TPB







Plan for Next Step (summer 2013 surface Run)



- Single phase detector
  - 10cm ϕ x 10 cm L (1 kg)
  - 2 x 3" PMTs (high Q.E.)
  - Maximum LCE
    - TPB coating, reflector, etc
  - PSD should provide ~10^6 γ reduction
- Active VETO by surrounding LAr
  - 4 x 2" PMTs
- Water shield to reduce neutron background

- Based on the result of this run, we will design the detector for physics Run

Summary and Plan

- WIMP dark matter search using double phase argon detector : ANKOK project

- We have build 10 kg prototype detector
  - demonstration of double phase argon detector
  - measure basic properties of the double phase detectors
  - evidence for electron/nuclear recoil separation

- Ongoing effort
  - Increase light collection efficiency
    - = lower Er threshold, = better electron/nuclear separation
  - Understand radioactive and environmental background
- Plan
  - Optimize the detector in terms of physics sensitivity
  - take surface physics Run
  - Go underground!