# DarkSide @ LNGS: an update

Aldo Ianni for the DarkSide Collaboration

XLI Gran Sasso Scientific Committee
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# DarkSide background rejection strategy

- Screening and selection of detector materials
- Identify and reject cosmogenic muons
  - ✓ **Water Cherenkov Detector**
- Identify and reject radiogenic neutrons from the active mass
  - ✓ **Active veto** based on a boron-loaded liquid scintillator detector
- Two-phase LAr **TPC**
  - ✓ Pulse Shape Discrimination
  - ✓ S2/S1
  - ✓ 3D Fiducial Volume definition to reject surface background
  - ✓ Underground argon with reduced (> 150) cosmogenic $^{39}Ar$

# DarkSide program @ LNGS

- Scalable technology for a two-phase TPC in LAr
  - ✓ **DarkSide-10** (DS-10)
    - 10 kg active mass
    - Operated in 2012 @ LNGS
    - Technical prototype for larger TPC
  - ✓ **DarkSide-50** (DS-50)
    - 50 kg active mass
    - Built inside CTF Water Tank with active neutron veto
    - Launch technology for next generation detectors
    - In operation since Nov 2013
    - Expected WIMP sensitivity $10^{-45}$ $cm^2$ with UAr
  - ✓ **DarkSide-G2**
    - 3600 kg fiducial
    - Can be built inside present DS-50 neutron veto
    - Expected sensitivity $10^{-47}$ $cm^2$

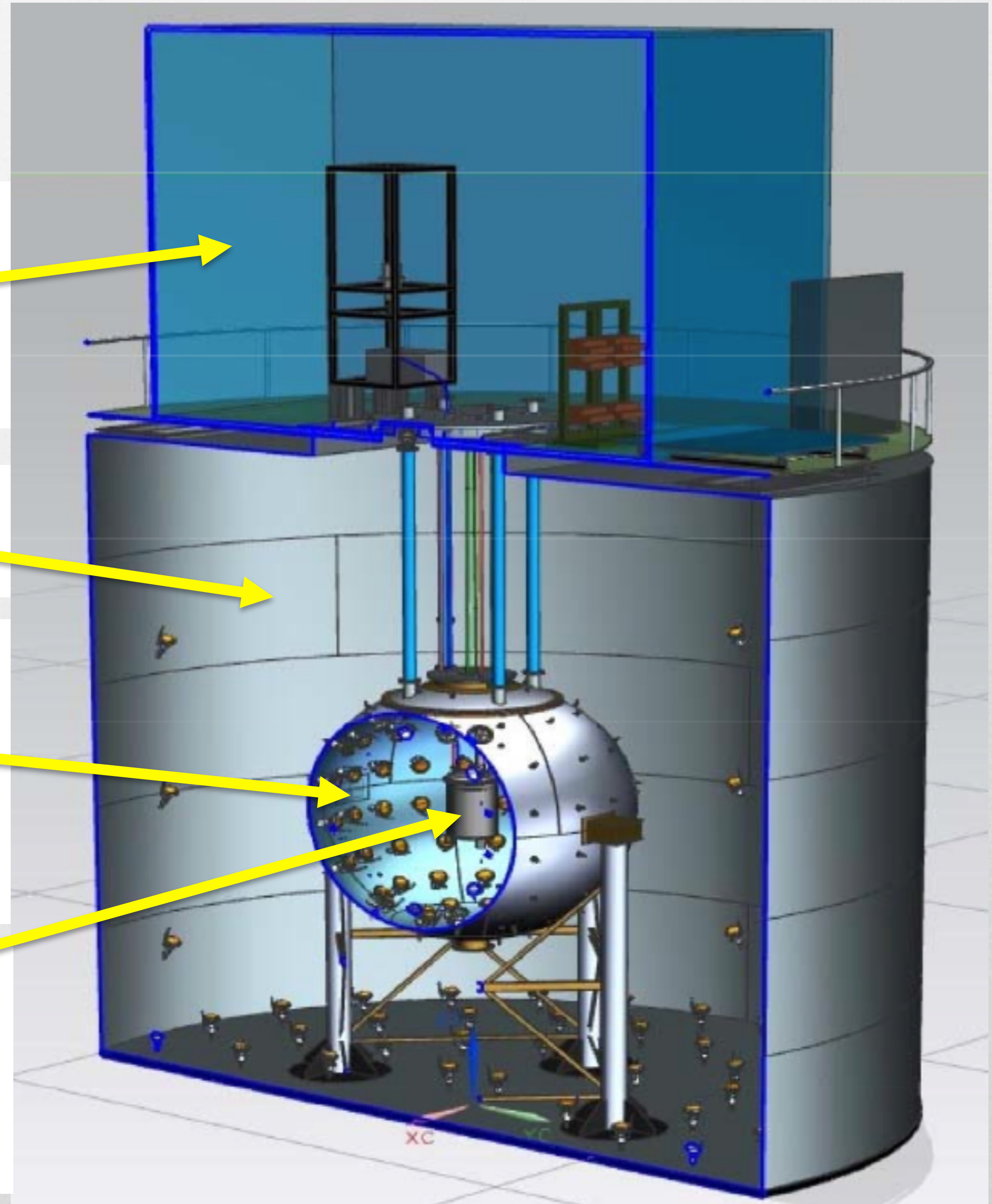
# DS-50 @ LNGS

**Rn-free clean room**
($10\text{-}15\ mBq/m^3$ in $110\ m^3$)
Used for assembling TPC
and deployment

**Water Cherenkov** muon veto:
$10^3\ m^3\ H_2O$ with 76/80 8” PMTs

**Boron-loaded liquid scintillator**
(50% TMB + 50% PC) as
neutron veto with 108/110 8”
PMTs

**150kg LAr TPC** with 2 x 19
3” PMTs
AAr at present with 1Bq/kg $^{39}Ar$
UAr with < 6.5 mBq/kg $^{39}Ar$




Water Cherenkov

# TPC hanging in LSV

# PMTs + Cold-Amps in LAr

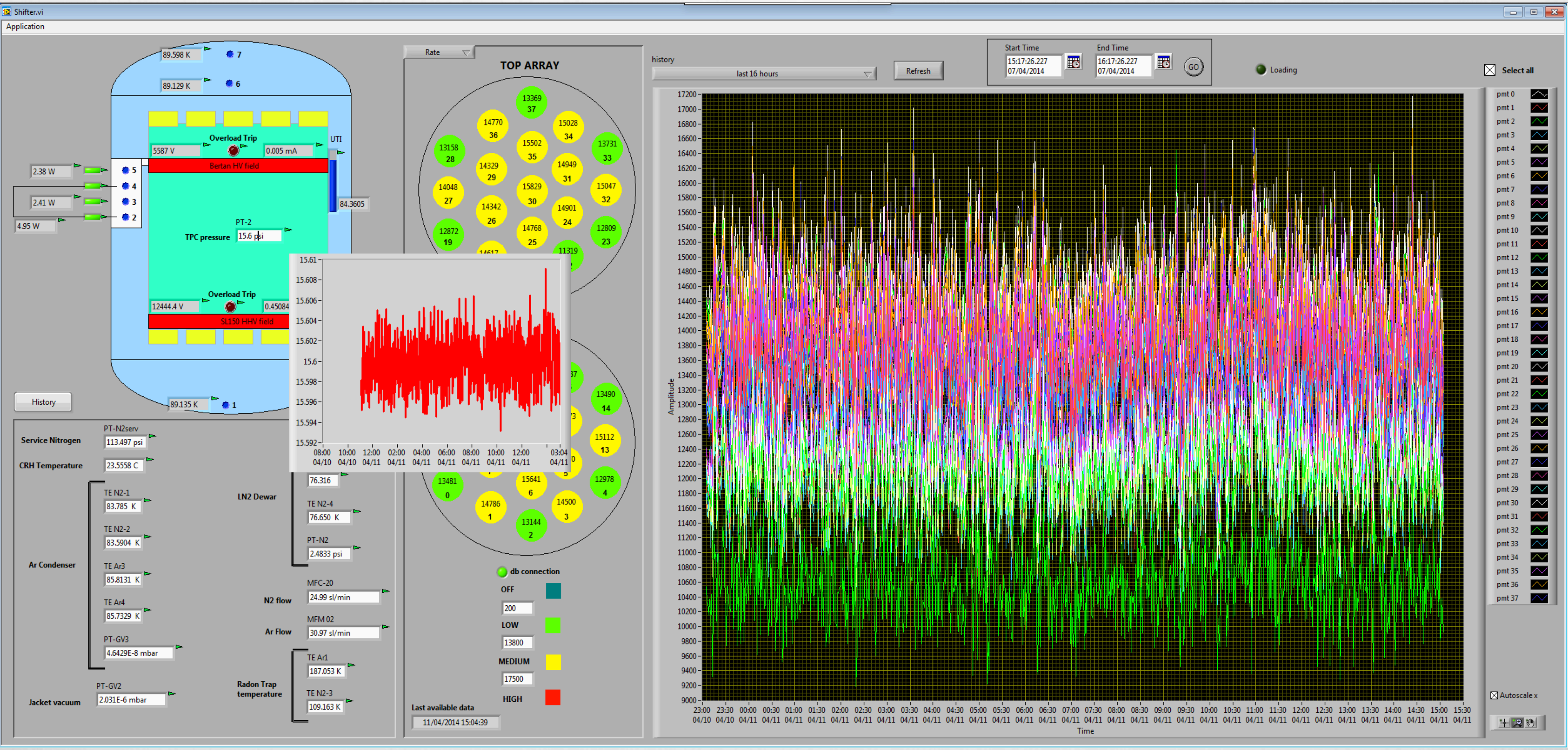
R11065 PMTs

PMT Gain = $3 \times 10^5$

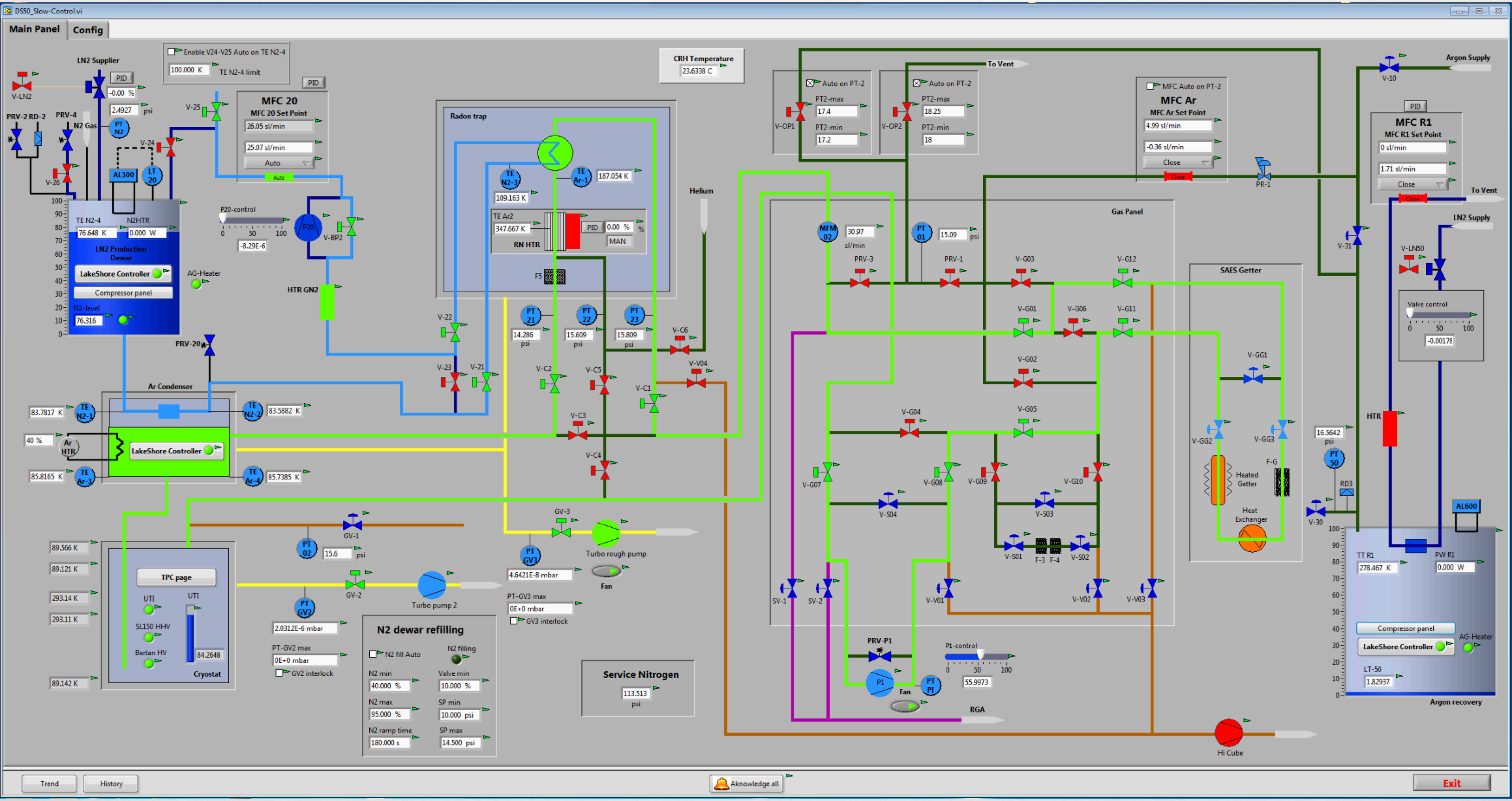
PMT HV ~ 1200 V

Noise 3 mV on 200 MHz

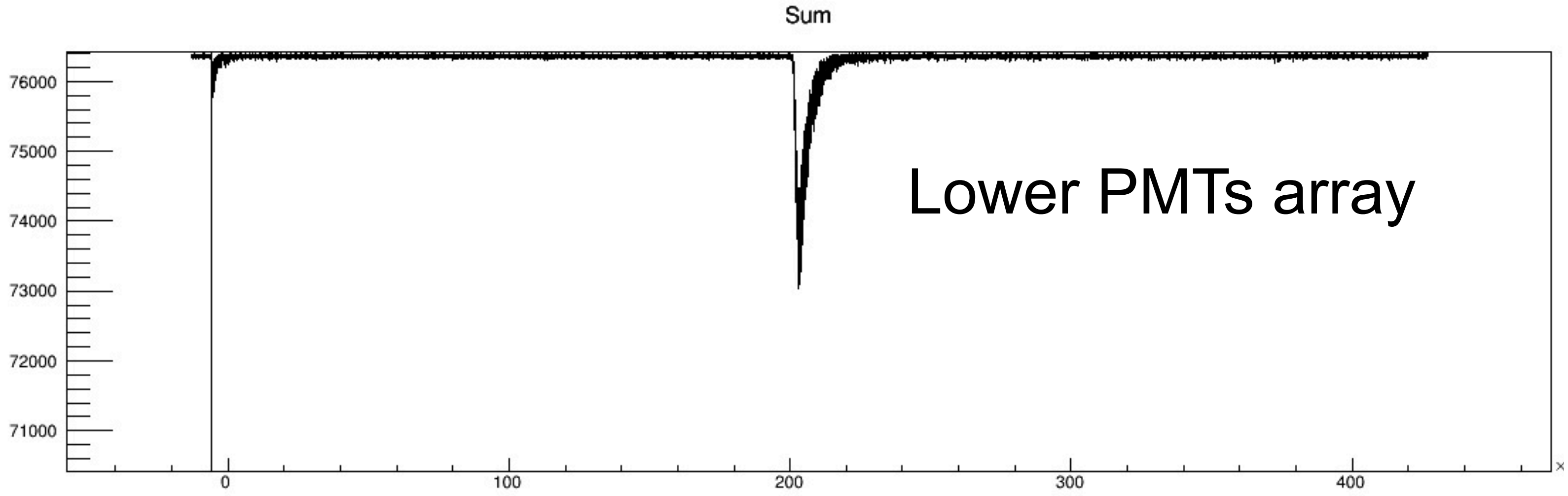
# Slow Control System



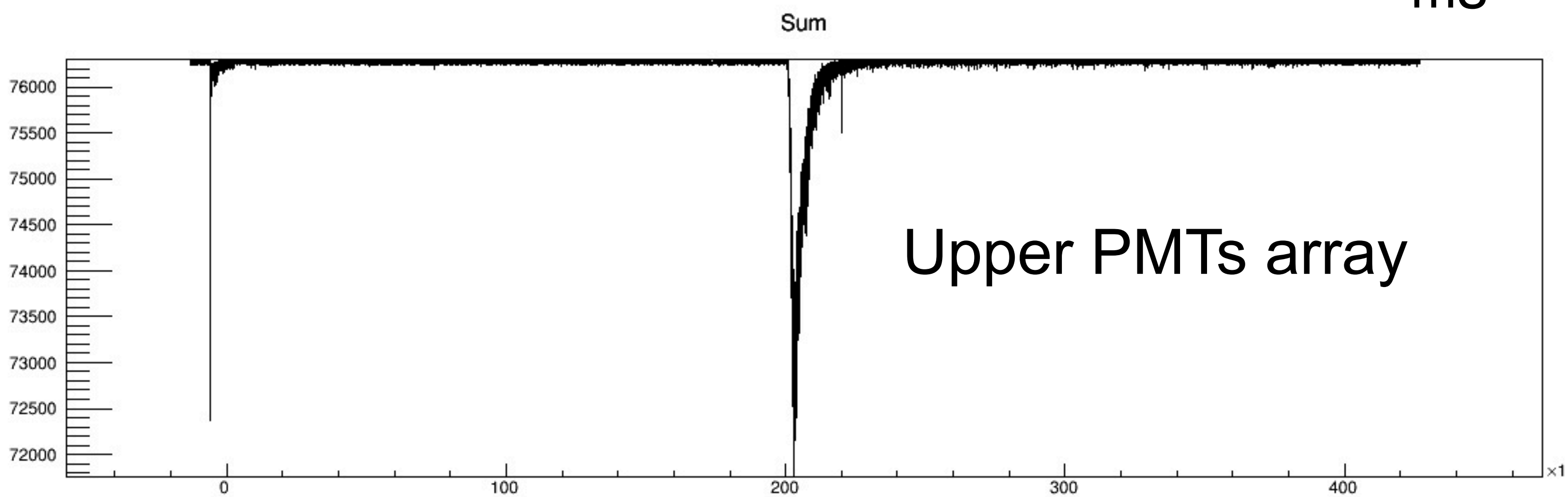
# Slow Control System



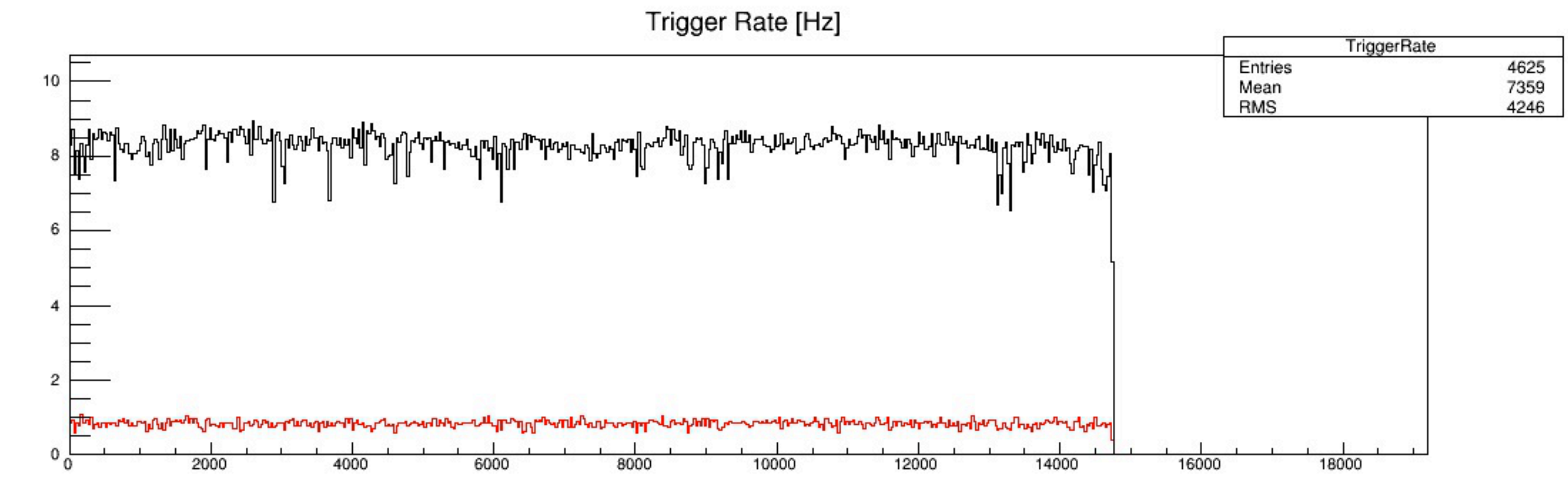
# S1 and S2 signals

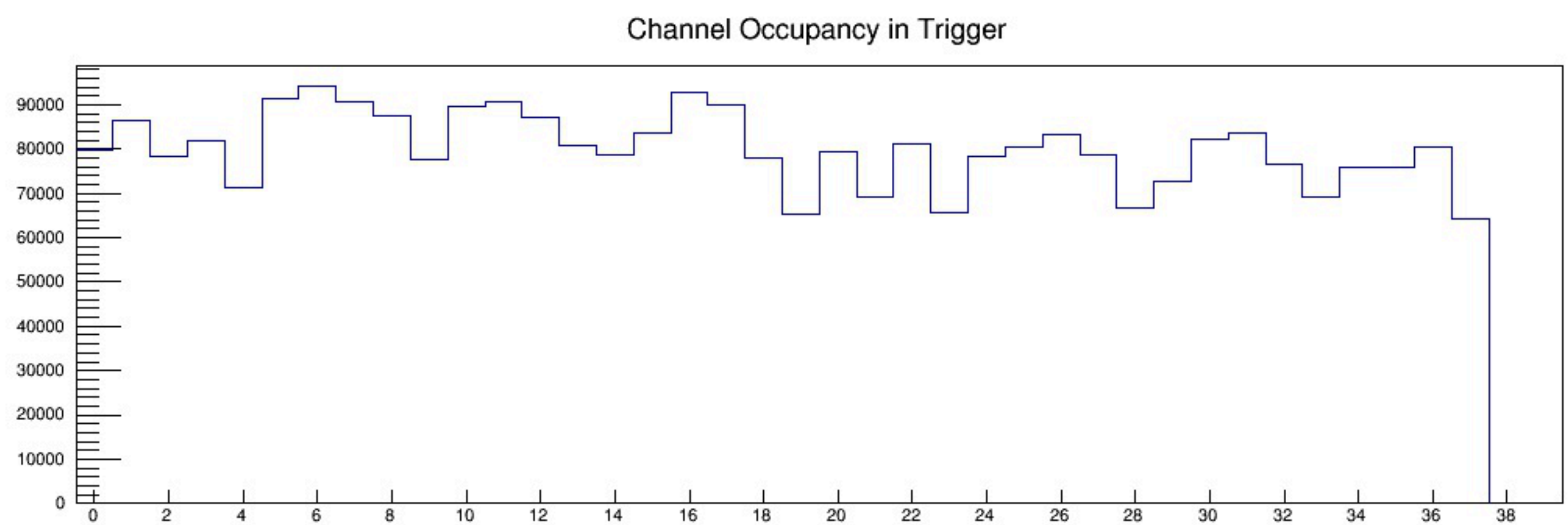



ms

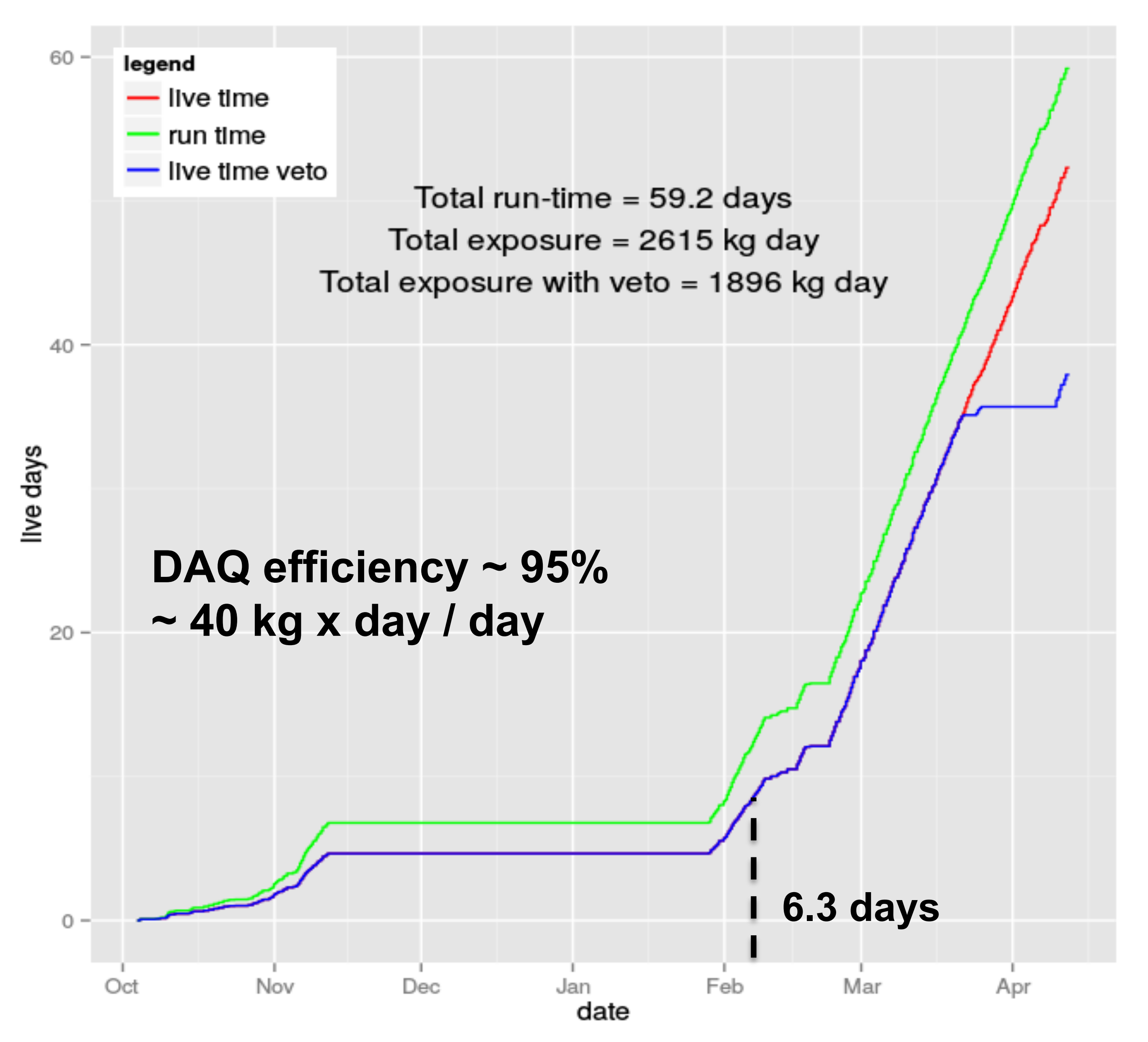


# Trigger: 3PMTs && < 380p.e.



# Livetime



legend
live time
run time
live time veto
Total run-time = 59.2 days
Total exposure = 2615 kg day
Total exposure with veto = 1896 kg day
DAQ efficiency ~ 95%
~ 40 kg x day / day
6.3 days
live days
60
40
20
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
date

# Pulse Shape Discrimination in LAr

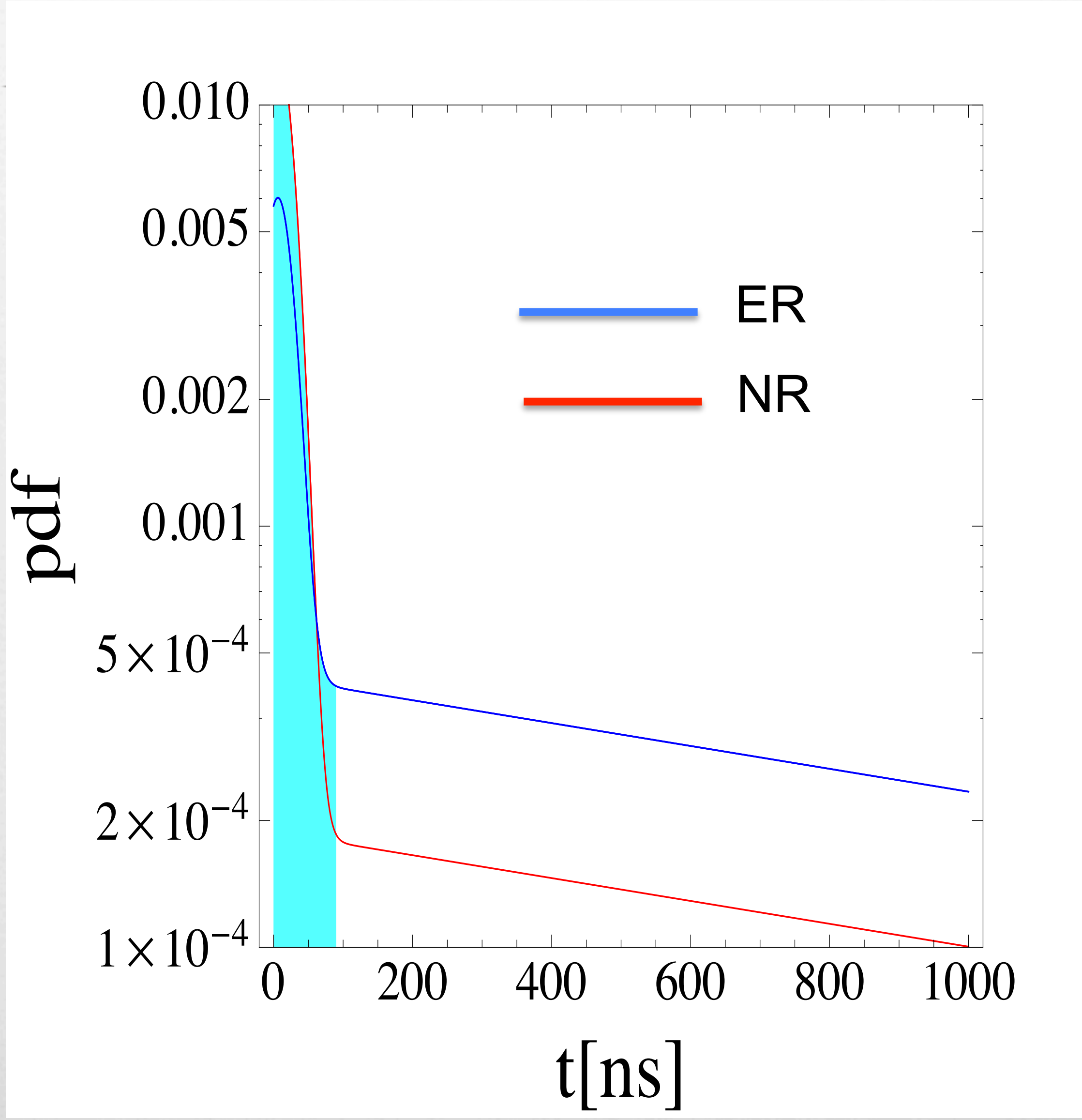
$$f(t)=\left(\frac{q}{\tau_F}e^{-t/\tau_F}+\frac{1-q}{\tau_S}e^{-t/\tau_S}\right)$$

$$\tau_F = 7ns$$

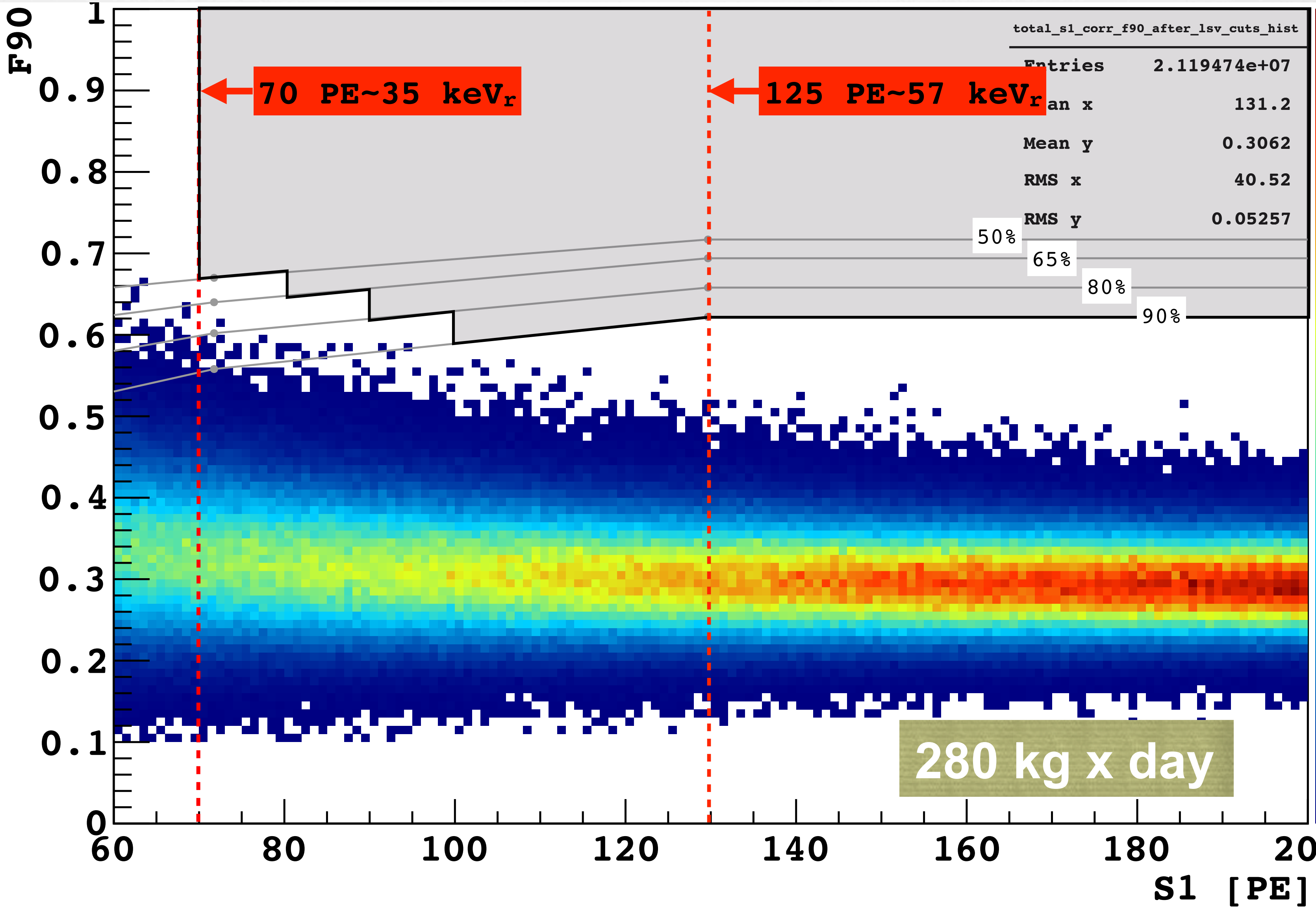
$$\tau_S = 1600ns$$

$$q=\begin{cases} 0.3 \text{ ER} \\ 0.7 \text{ NR} \end{cases}$$

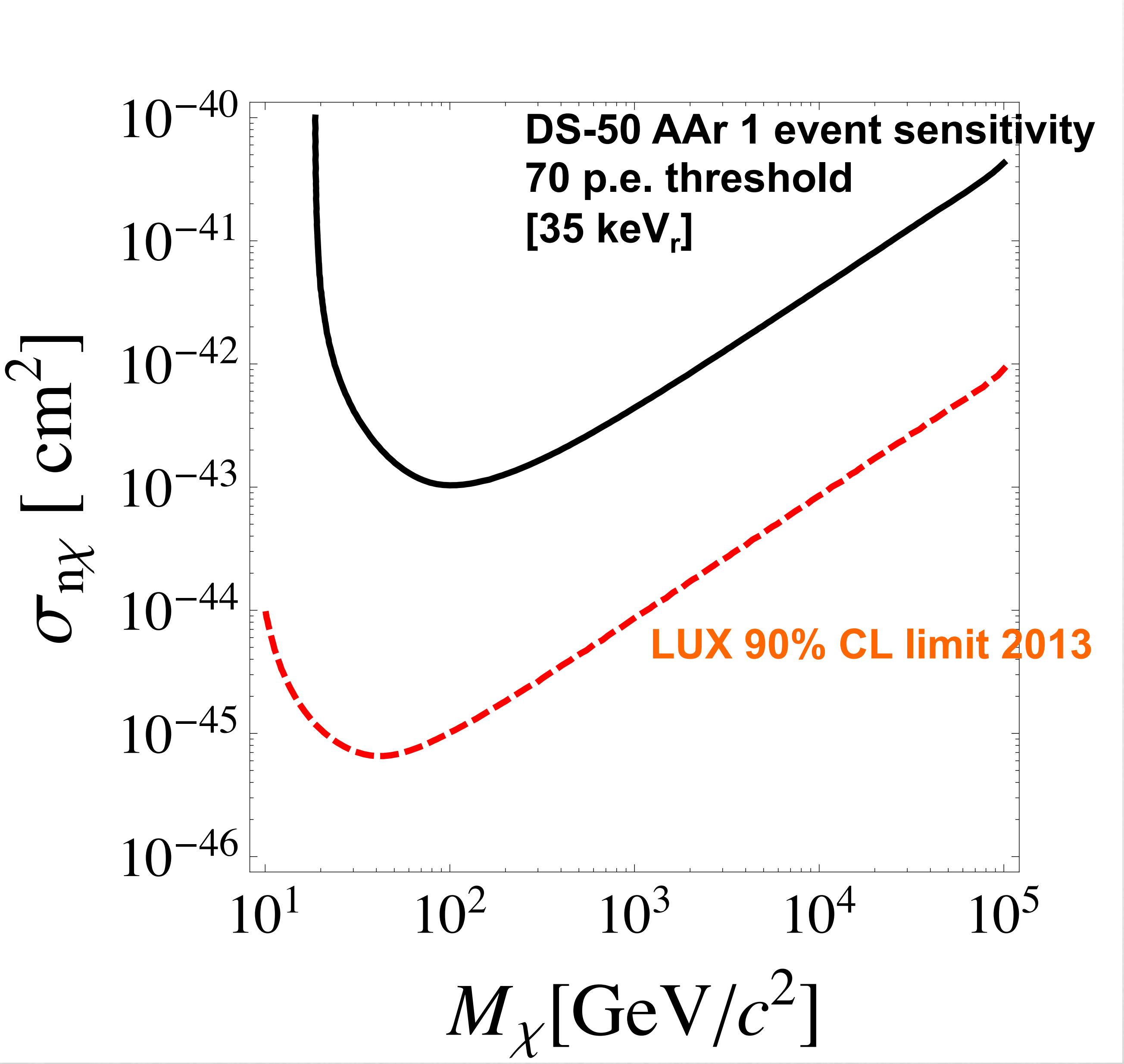
$$F_{90}=\frac{\int_0^{90ns} dt\, f(t)}{\int_0^{\infty} dt\, f(t)}=\begin{cases} 0.3 \text{ ER} \\ 0.7 \text{ NR} \end{cases}$$



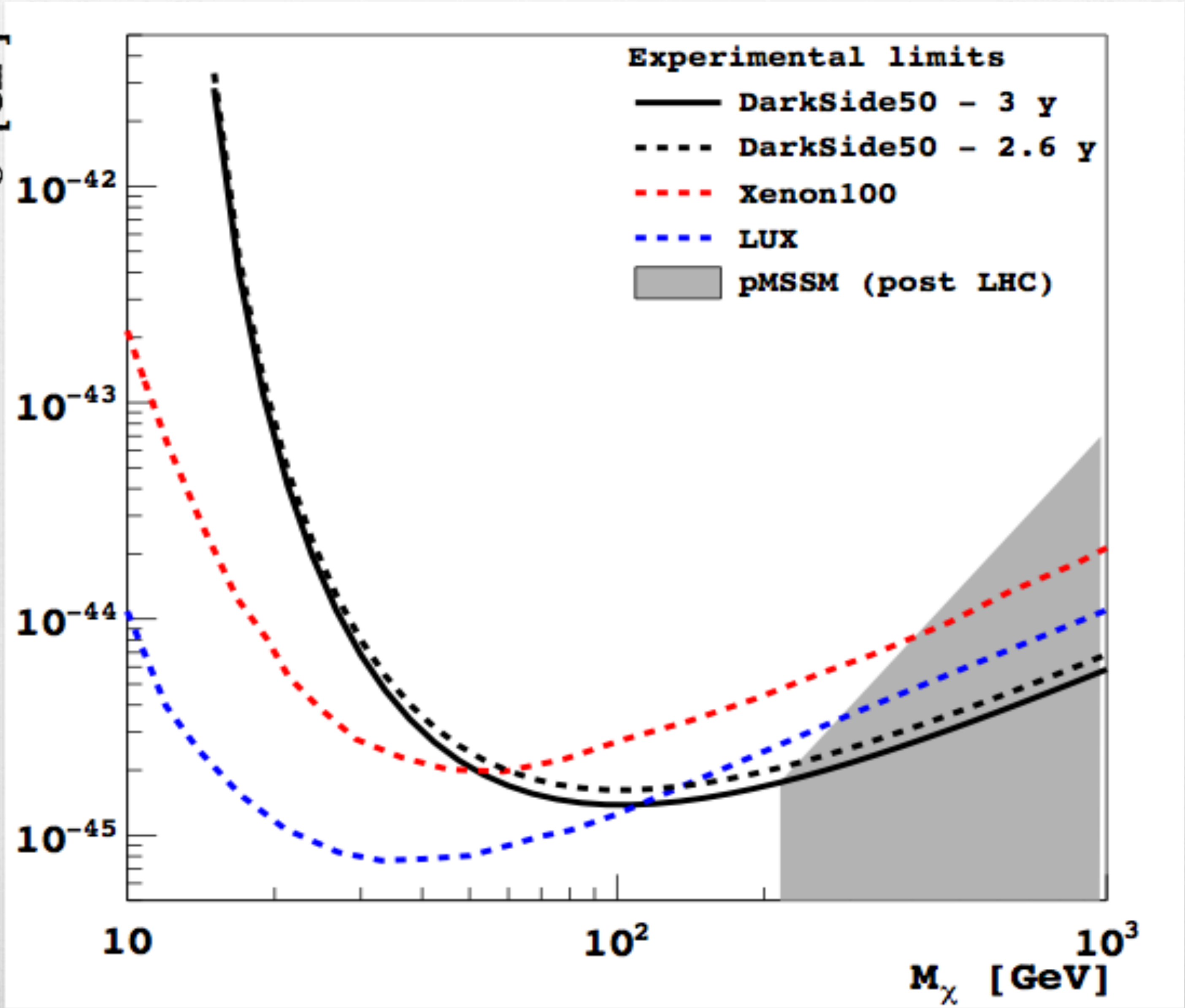
# Pulse Shape $F_{90}$



# DS-50 sensitivity with 280 kg x day



# DS-50 expected sensitivity with UAr



# Neutron veto

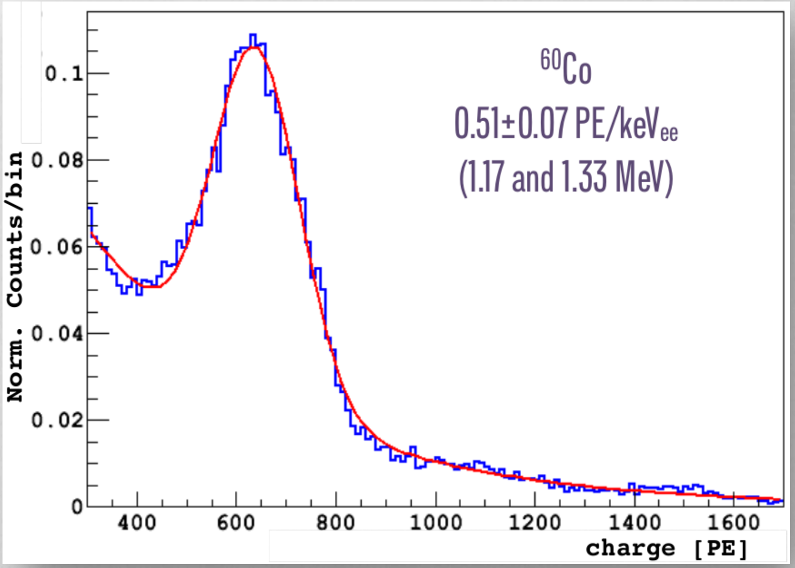
- 30 tons of boron-loaded liquid scintillator
  - 50% TMB [ $B(OCH_3)_3$] + 50% PC + 3 g/l PPO

$$^{10}B(19.9\%) + n \begin{cases} \rightarrow & ^{7}Li(\mathrm{g.s.}) + \alpha,\ 6.4\% \\ \rightarrow & ^{7}Li^{*} + \alpha,\ ^{7}Li^{*} \rightarrow {}^{7}Li + \gamma(478\mathrm{keV}),\ 93.7\% \end{cases}$$

- 108 8” PMTs
- High reflectivity of inner surface of containment vessel
- n-veto expected performance: < 1 event in 3 years after n-veto rejection and TPC cuts

# Neutron veto at present

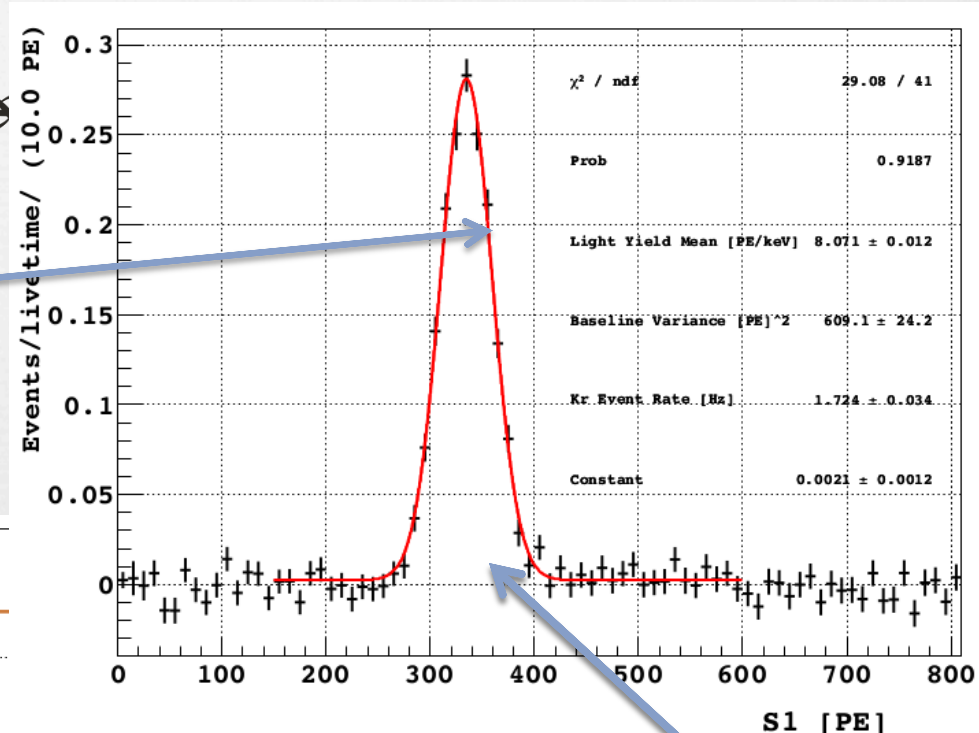
- Determined a high $^{14}C$ contamination from TMB
  - ~$10^{-13}$ $^{14}C/^{12}C$
  - understood origin of contamination
  - clear roadmap to fix the issue
- High Light Yield measured from $^{14}C$ spectrum, $^{60}Co$ contamination in steel of cryostat (~ 13 mBq/kg) and from $^{208}Tl$



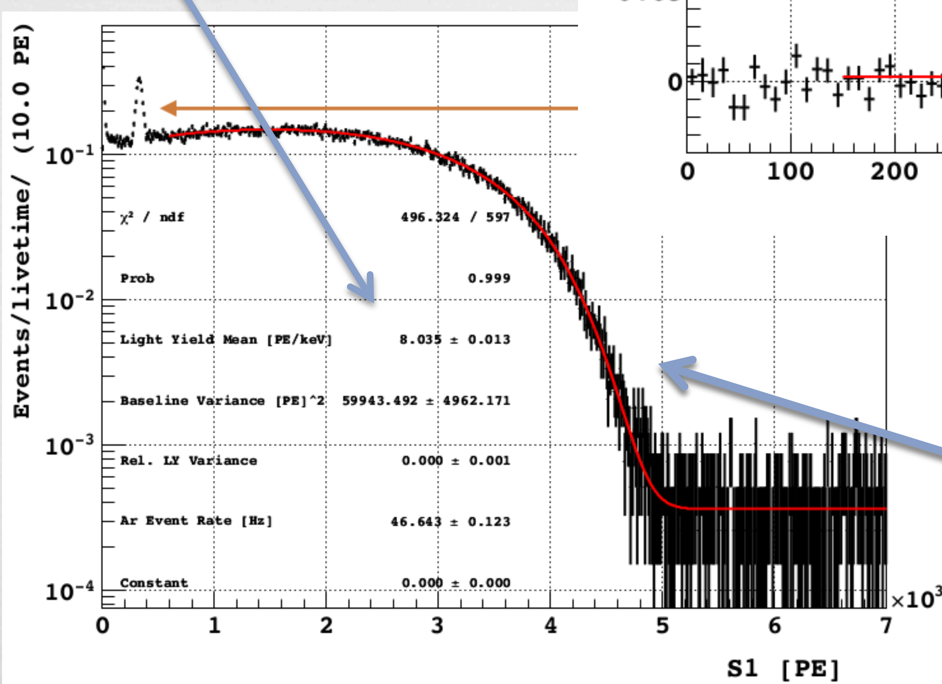
# TPC

- In operation S1/S2 mode with 50 kg AAr
- Expected 1-2 neutron/month (mainly from measured activity of PMTs) w/o veto cut with R11065 PMTs. Veto rejection factor = 100: need a n-veto
- In operation with 38 3” R11065 PMTs
  - Gain stability 1-2%
  - HV: $E_{drift}$ = 200 V/cm, $E_{extraction}$ = 2.8 kV/cm
  - Light yield ~ 8 p.e./keVee
  - Electron lifetime ~5ms
    - To compare with max drift time of ~ 400 ms
  - $^{83m}$Kr internal calibration (two times) 41.5 keVee sum line

# Light yield @ null field



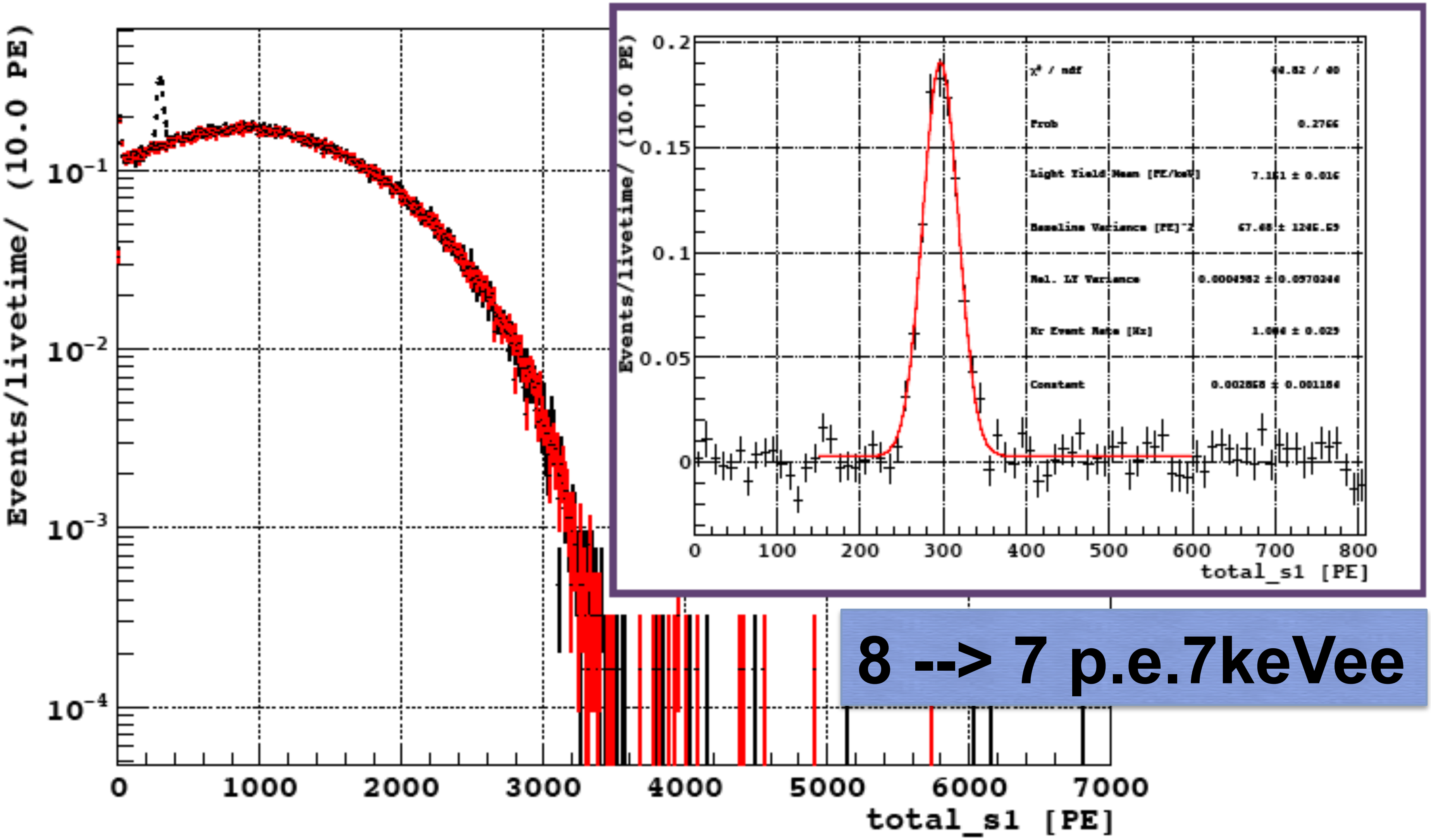

Light Yield ~ 8 pe/keV$_{ee}$
at **null field**




$^{83m}$Kr peak
41.5 keV, $T_{1/2}$=1.83h

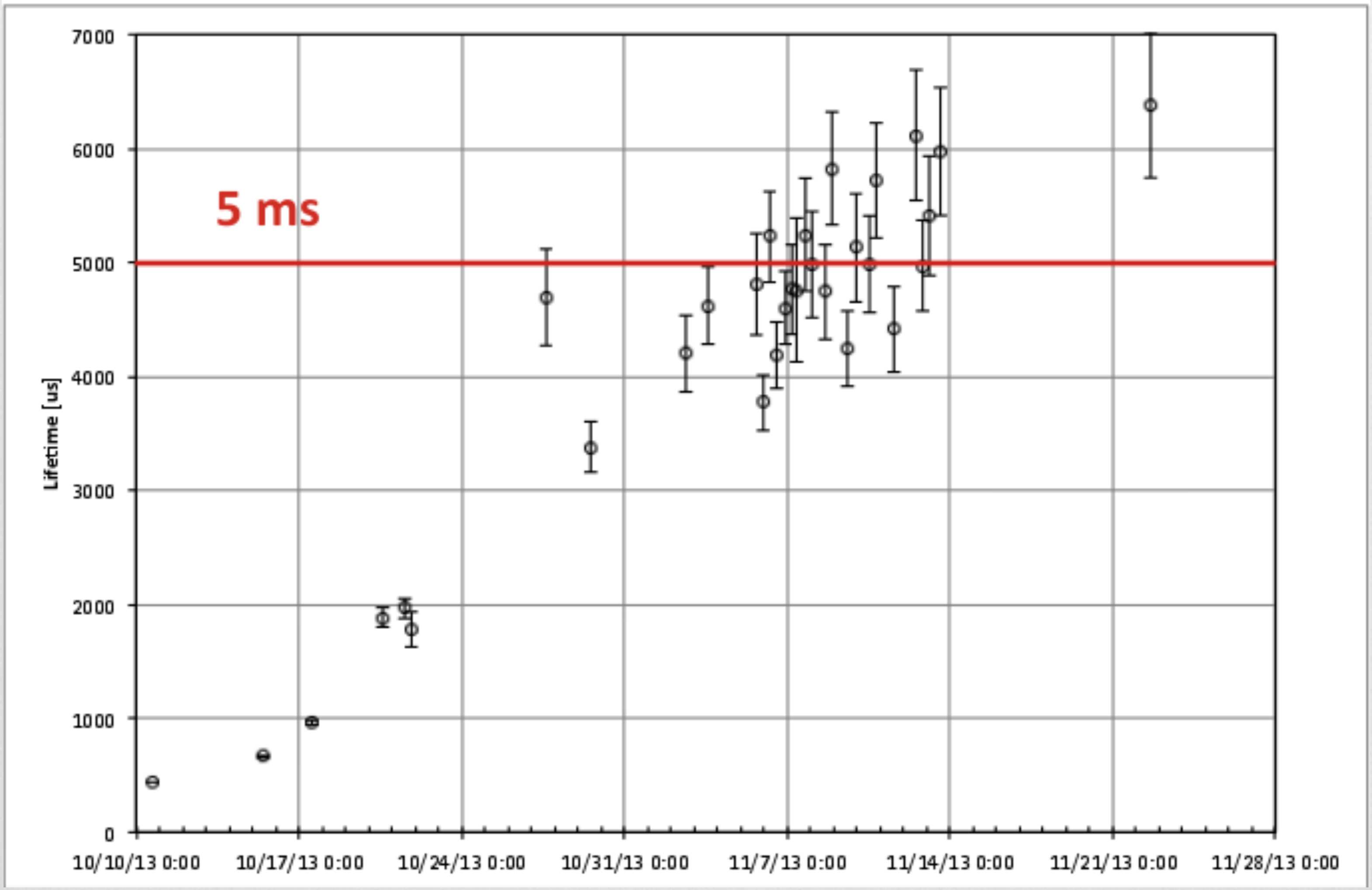
$^{39}$Ar spectrum
565 keV

# Light Yield @ 200V/cm




8 --> 7 p.e.7keVee

# e$^-$ life time



7000
6000
5000
4000
3000
2000
1000
0
Lifetime [us]
5 ms
10/10/13 0:00
10/17/13 0:00
10/24/13 0:00
10/31/13 0:00
11/7/13 0:00
11/14/13 0:00
11/21/13 0:00
11/28/13 0:00

# Summary of 1st DS-50 data

- In operation with AAr since Oct 2013
- TPC (AAr), neutron veto and muon veto commissioned
  - Analyzed 280 kg x day
  - S2/S1 and x-y cut still under development
  - neutron veto light yield ~ 0.5 p.e./keVee
  - neutron veto scintillator acquired with TPC trigger
  - neutron veto scintillator with high $^{14}C$ contamination
- No background in PSD in upper 50% NR acceptance region in $3x10^7$ events
- LY @ null field ~ 8 p.e./$keV_{ee}$
- Rn contamination from Bi-Po < 0.85 mBq/kg_Ar
- Already collected data for 2615 kg x day (50kg LAr) as of April 12th

  ~ 2000 kg x day usable for further background studies

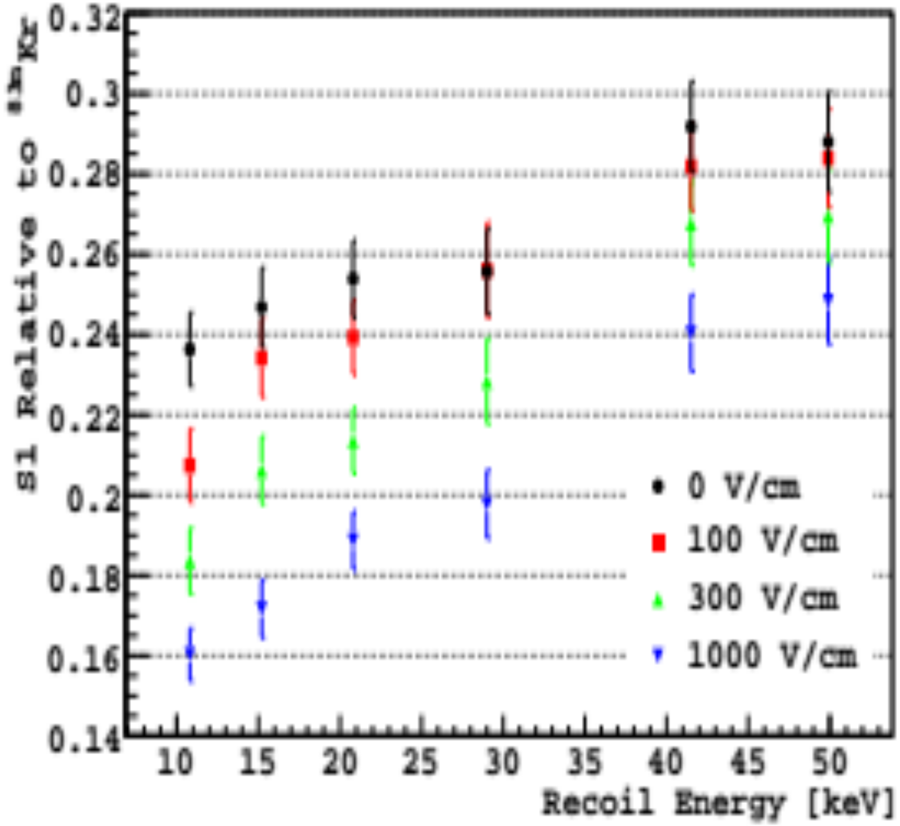
# Future Goals

- More data with AAr
  - $^{39}$Ar spike test
  - neutron calibration: deployment system in preparation
  - improve fiducialization
- Replace PC+TMB with PC: soon
  - ✓ 600l of PC+TMB distilled to separate components
  - ✓ plan: dispose TMB and re-use PC
- Using new TMB (samples from two companies measured)
- Replace AAr with UAr: Aug-Sep
  - reduce $^{39}$Ar background by a factor > 150

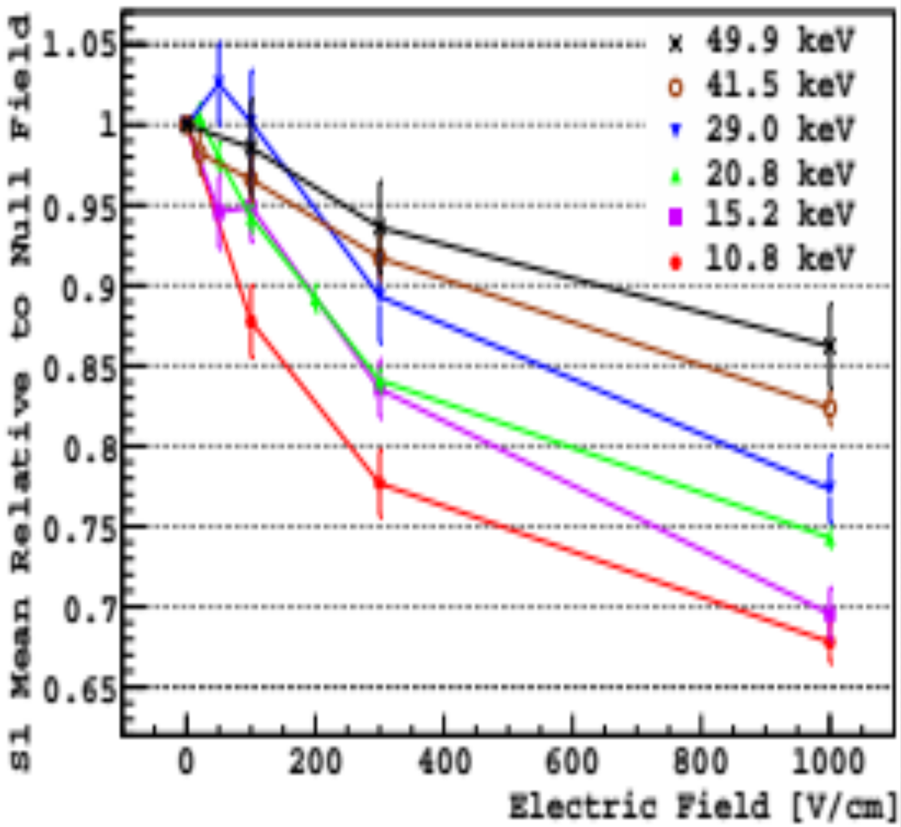
# Thank you

# Spare

# Scene

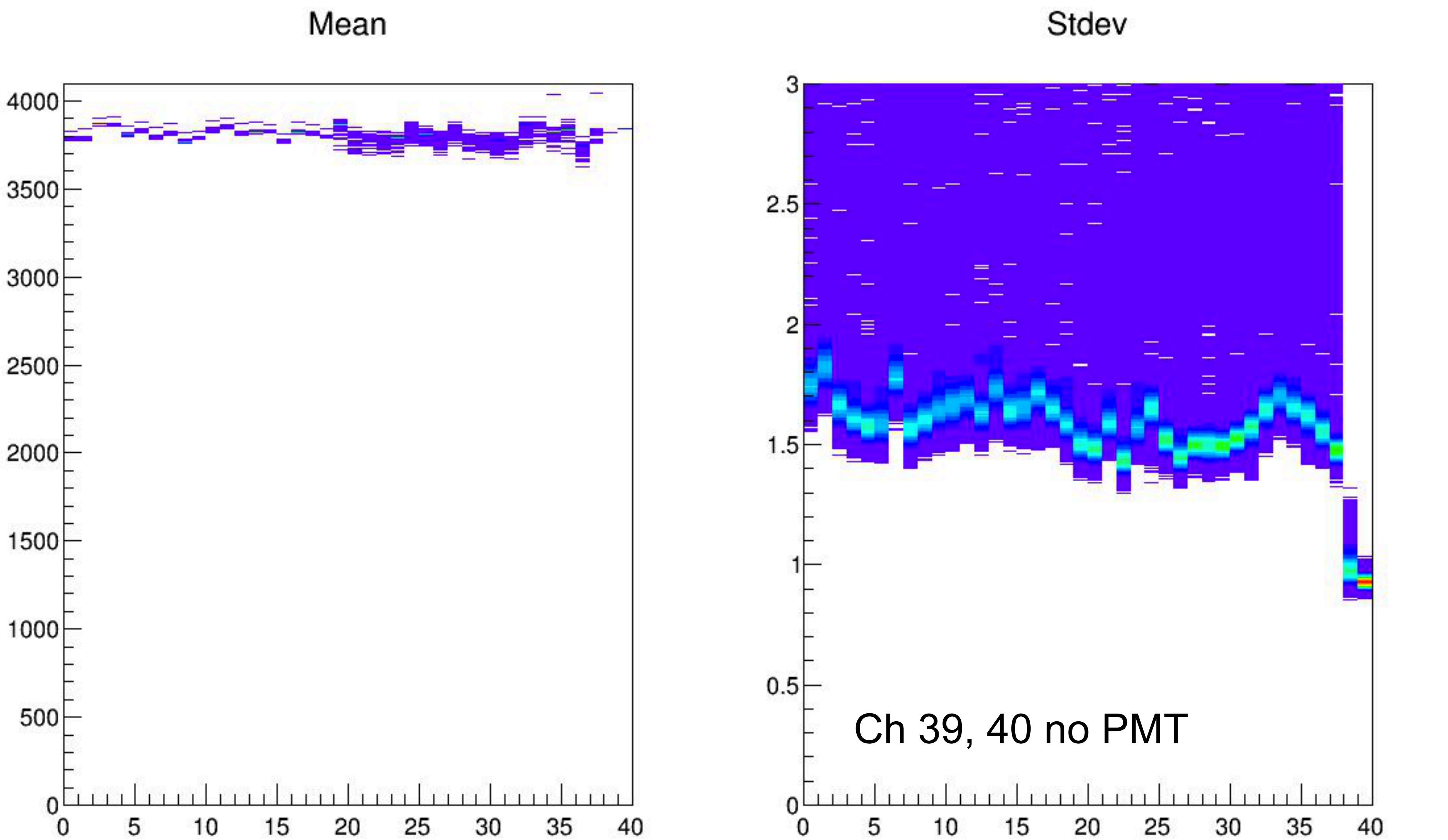


S1 Relative to $^{83m}$Kr
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
10 15 20 25 30 35 40 45 50
Recoil Energy [keV]
0 V/cm
100 V/cm
300 V/cm
1000 V/cm

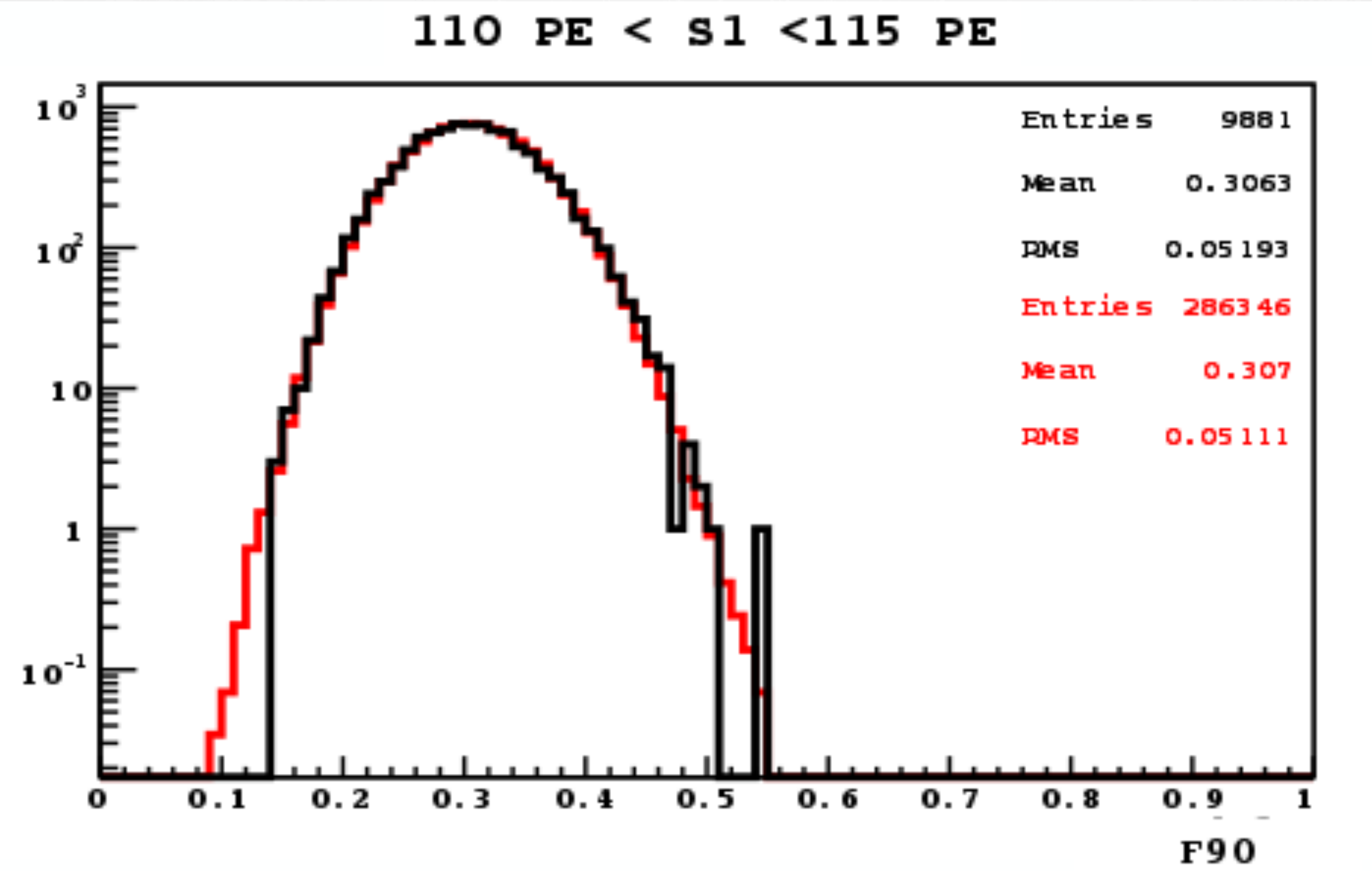



S1 Mean Relative to Null Field
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0 200 400 600 800 1000
Electric Field [V/cm]
49.9 keV
41.5 keV
29.0 keV
20.8 keV
15.2 keV
10.8 keV

# Baseline


Mean
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
Stdev
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
Ch 39, 40 no PMT

# PSD simulation

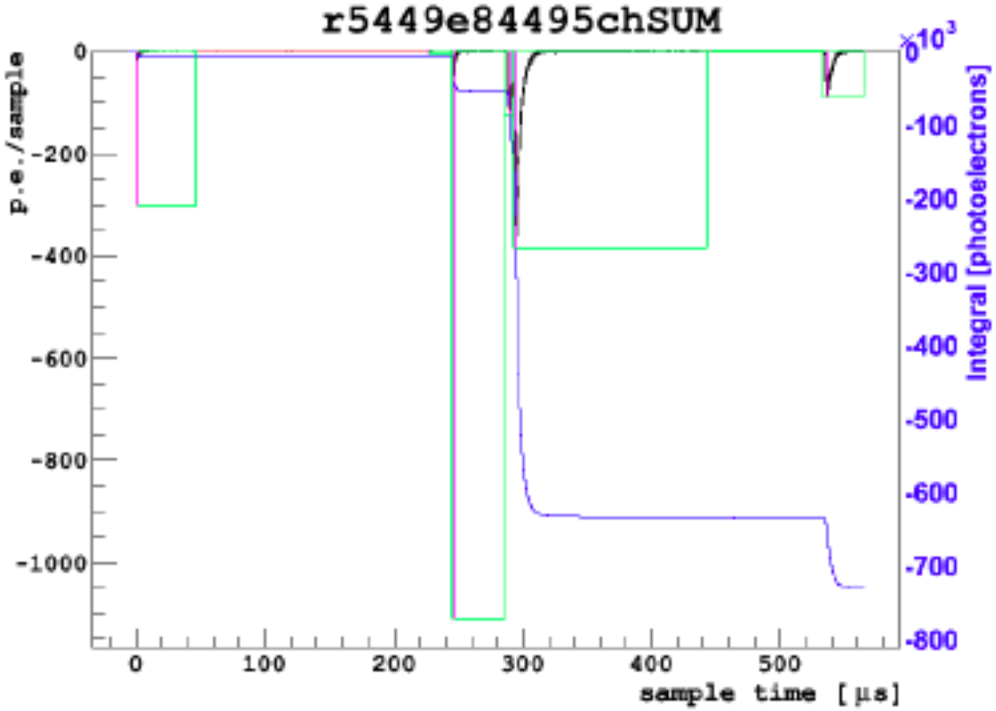



data

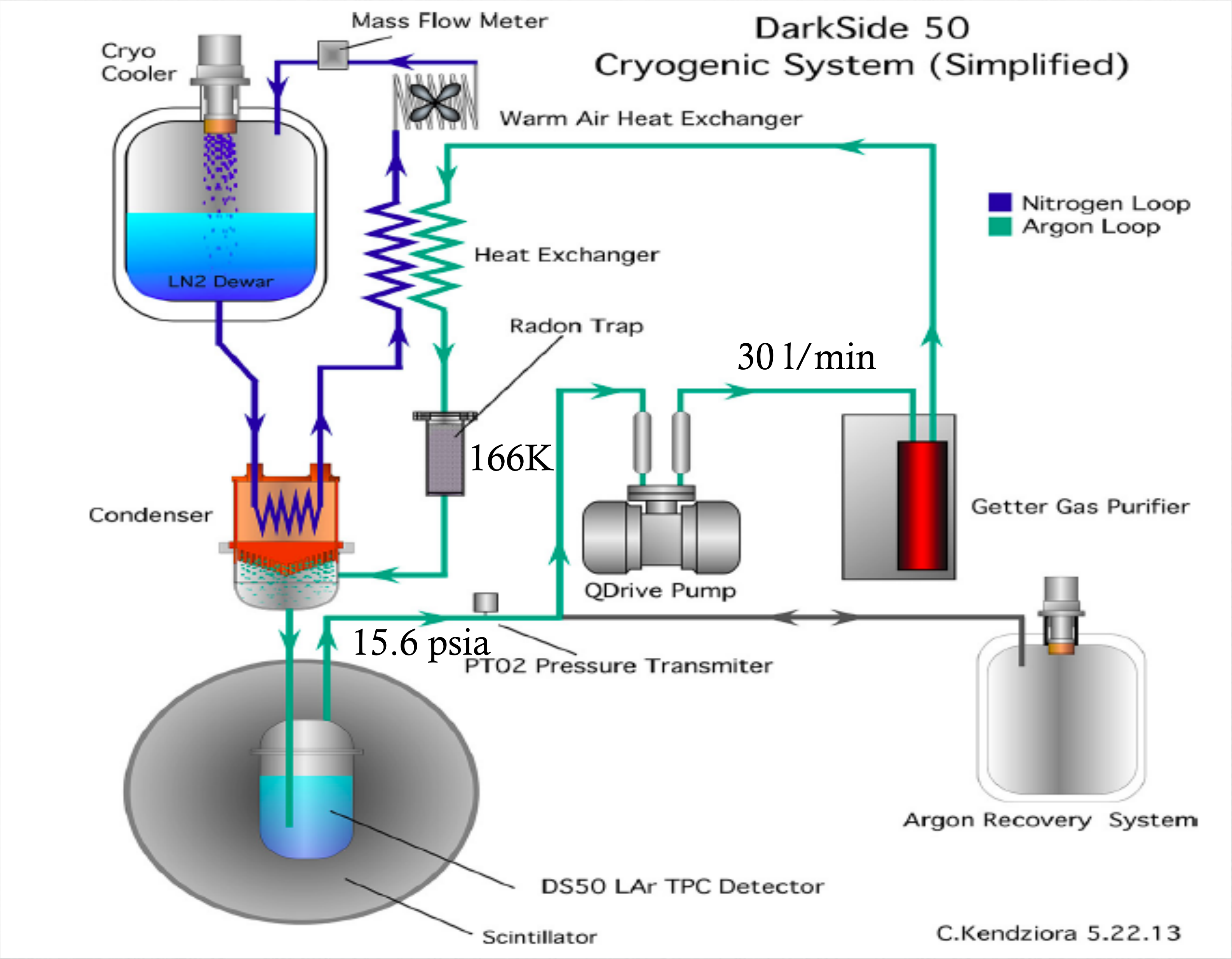
simulation

# $^{214}$Bi-$^{214}$Po

- $^{214}\mathrm{Bi} \underbrace{\rightarrow}_{\tau=29\,\mathrm{min}} \beta^- + ^{214}\mathrm{Po} \underbrace{\rightarrow}_{\tau=236\,\mu\mathrm{s}} \alpha + ^{210}\mathrm{Pb}$
- Clear alpha signal made clearer by coincidence at same-z.



# Cryogenic for DS-50 TPC



# DETECTING TPC-VETO COINCIDENCES