The Darkside Program

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on behalf of Darkside-50 collaboration

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The Roma International Conference on Astroparticle Physics

Noto, Italy

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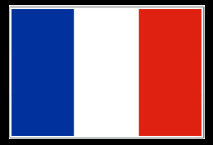
The Darkside Collaboration

IHEP - China
Universite de Strasbourg - France
APC Universite Paris 7 Diderot - France
INFN Laboratori Nazionali del Gran Sasso - Italy
Gran Sasso Science Institute - Italy
INFN and Universita degli Studi Cagliari - Italy
INFN and Universita degli Studi Genova - Italy
INFN and Universita degli Studi Milano - Italy
INFN and Universita degli Studi Napoli - Italy
INFN and Universita degli Studi Perugia - Italy
INFN and Universita degli Studi Roma 3 - Italy
Jagiellonian University – Krakow, Poland
Joint Institute for Nuclear Research - Dubna, Russia
Lomonosov Moscow State University - Moskow, Russia
National Research Center Kurchatov Institute – Moskow, Russia
St. Petersburg Nuclear Physics Institute – Gatchina, Russia
KINR, NAS Ukraine – Keiv, Ukraine
Augustana College - USA
Black Hills State University - USA
University of Chicago - USA
University of Hawaii - US
University of Houston - USA
University of Massachusetts - USA
Princeton University - USA
Temple University - USA
UC Davis - USA
UCL A- USA
Virginia Tech - USA
FNAL, LANL, LLNL , PNNL, SLAC



The Darkside program @ LNGS

- A scalable technology for direct detection search for WIMP dark matter
  - Based on a two-phase argon time projection chamber (TPC)

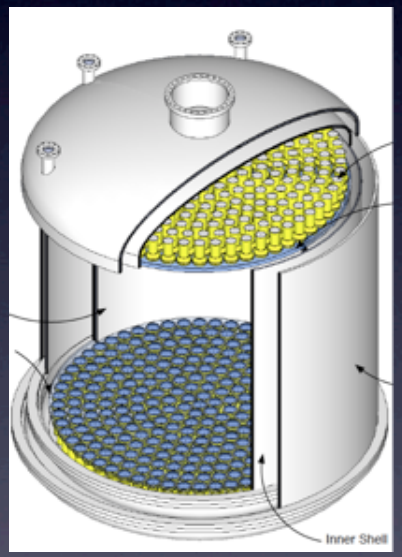
DarkSide-10

technical prototype
no DM goal

DarkSide-50

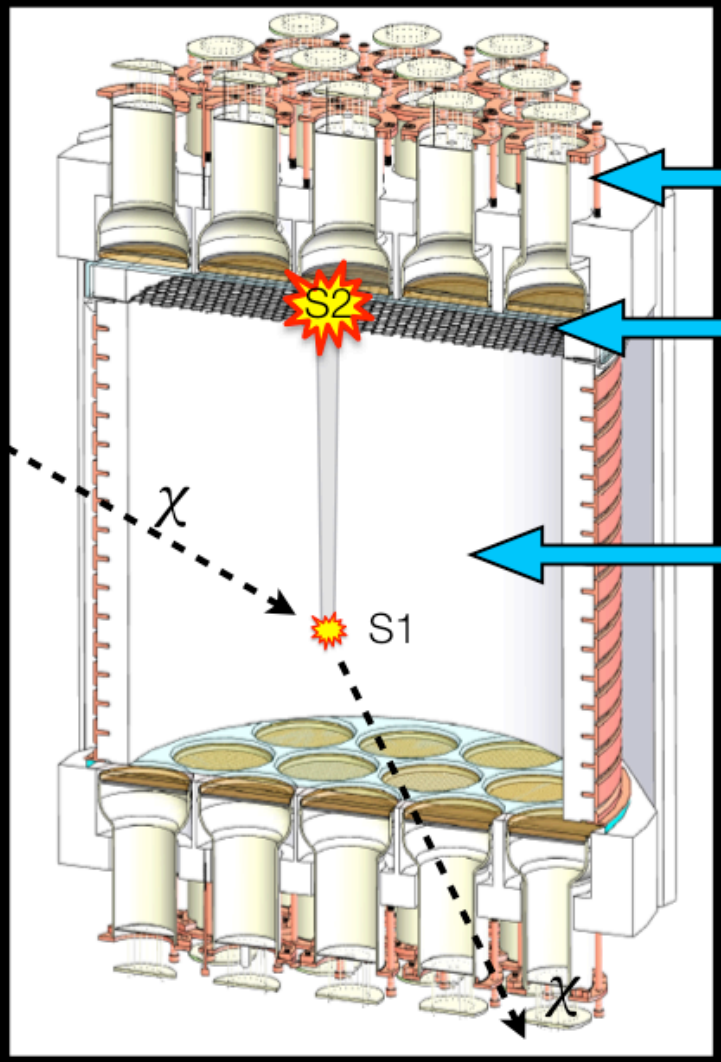
sensitivity
10^{-45} cm^2

DarkSide-G2



sensitivity
10^{-47} cm^2

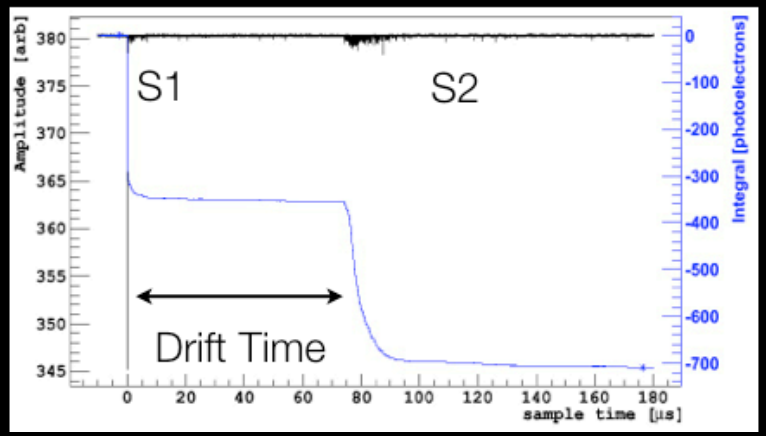
Detecting WIMPs



19 3" Photomultiplier Tubes (Top & Bottom)

Gas Ar (E_{lum} ~ 4200 V/cm)

Liquid Ar (E_{drift} ~ 200 V/cm)



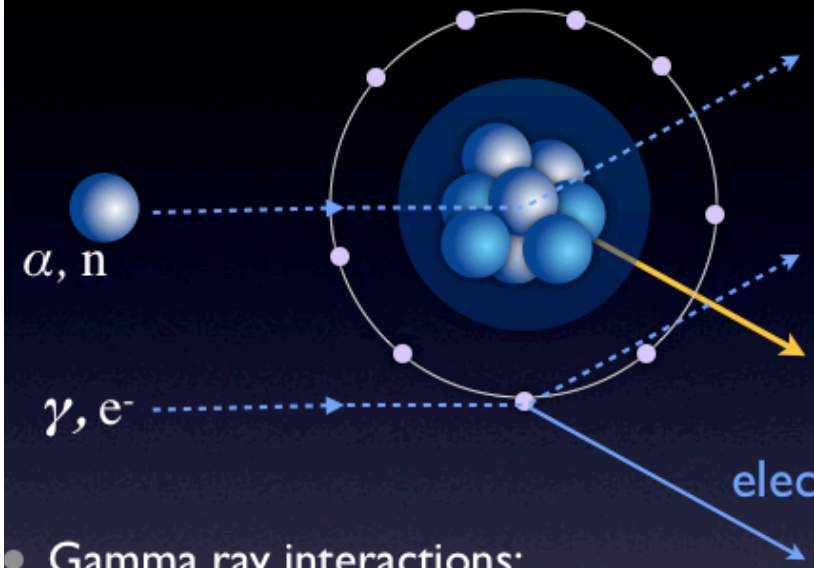
Background

from natural radioactivity:

$\gamma\ e^- \rightarrow \gamma\ e^-$

$nN \rightarrow nN$

$N \rightarrow N' + \alpha, e^-$



- Gamma ray interactions:

  mis-identified electrons mimic nuclear recoil signals

- Neutrons:

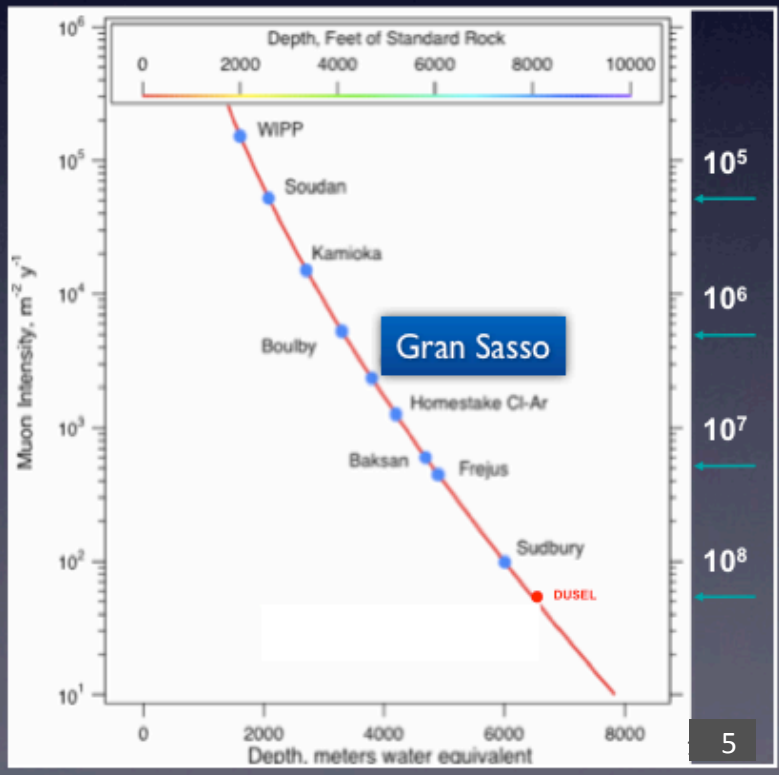
  (α,n), U, Th fission, cosmogenic spallation →

- Contamination:

  ^{238}U and ^{232}Th decays, recoiling progeny mimic nuclear recoils

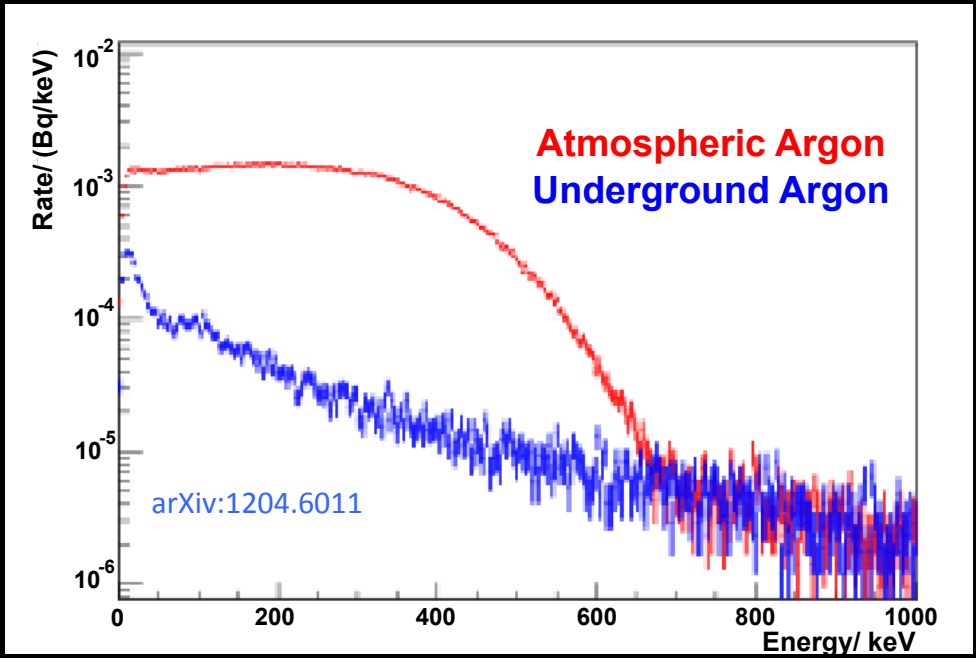
Underground labs

reduction of muon flux by:



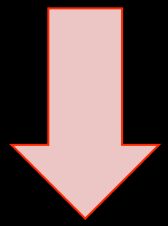
^{39}Ar reduction

- Dominant source of background: ^{39}Ar
- ^{39}Ar radioactivity present in atmospheric argon (1 Bq/kg)
- ^{39}Ar is a cosmogenic isotope, and the activity in argon from underground sources can be significantly reduced compared to atmospheric argon
- Source of underground argon measured to have > 150 times lower rate of ^{39}Ar, compared to atmospheric argon



Darkside-50

Design philosophy based on having very low background levels that can be further reduced through **active** suppression, for background-free operation



Liquid argon TPC,
within a neutron veto,
within a muon veto,
under a mountain

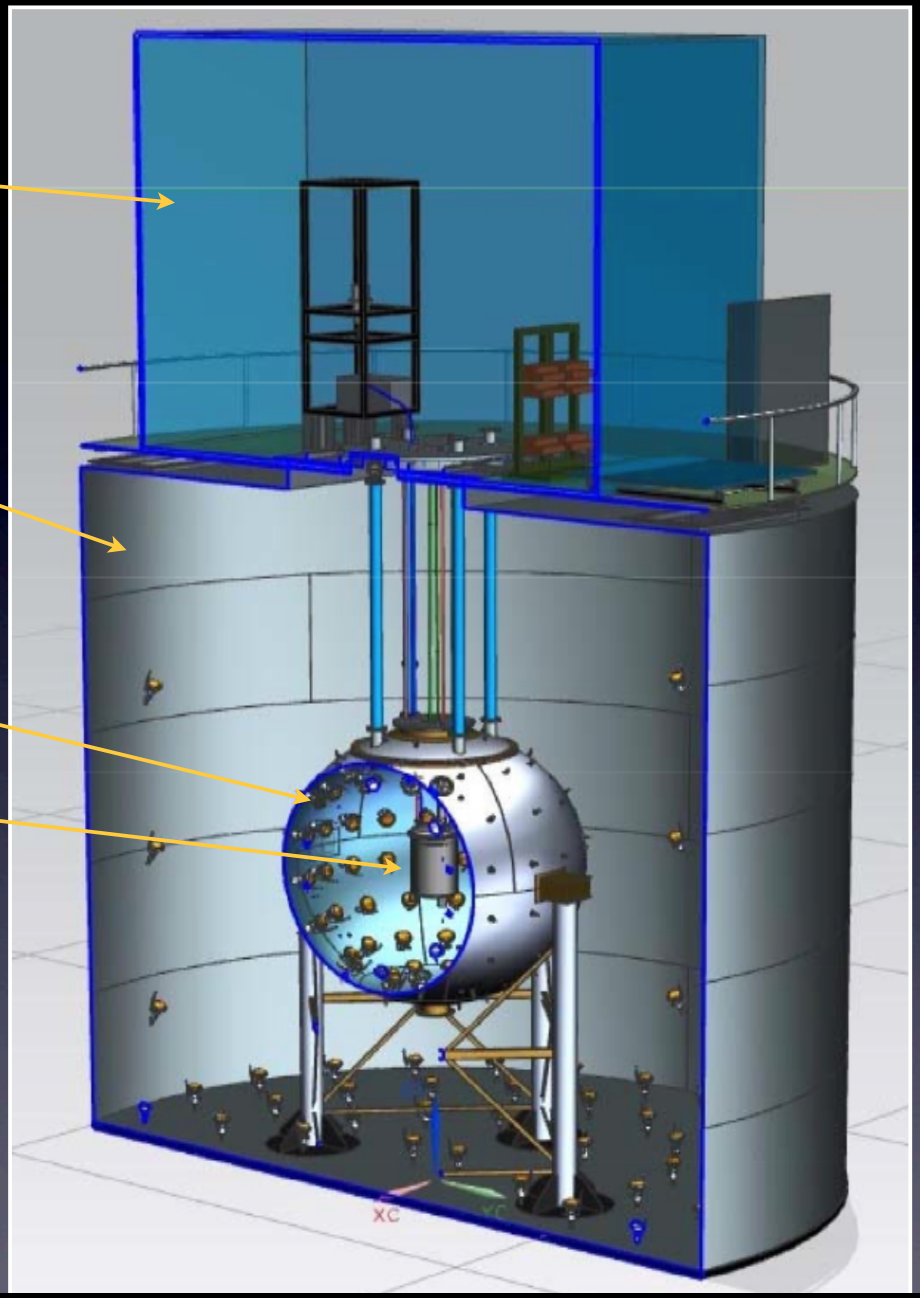
Radon-free clean assembly room
≤ 30 mBq/m^3 in >100 m^3
(CRH)

μ veto and cosmogenic neutron passive shield
1000 ton water Cherenkov
(Borexino CTF)

Radiogenic neutron veto
30 ton borated liquid scintillator
(LSV)

WIMP LAr detector
150 kg of UAr < 6.5mBq/kg
(DS-50 TPC)

DarkSide design



Darkside-50 TPC

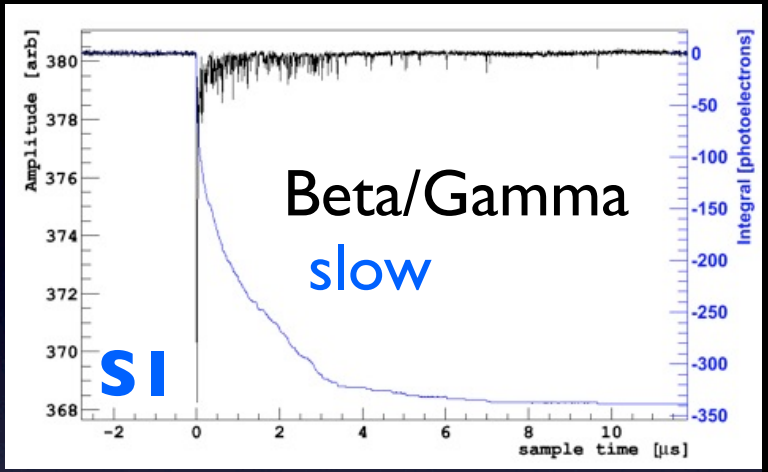
- 50 kg active mass of UAr
- 19 (top) + 19 (bottom) R11065 HQE Hamamatsu 3" PMTs
- ϕ 36 cm × 36 cm drift
- Lateral walls made of high reflectivity polycrystalline PTFE
- All inner surfaces coated with TPB
- Fused silica diving bell (top) and window (bottom) in front of the PMT arrays coated with ITO.

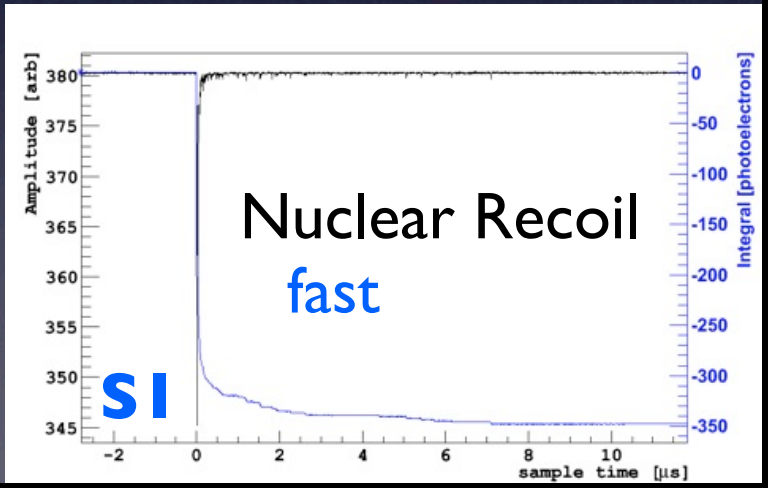
Designed to provide an extremely high light yield
DATA TAKING IS ON GOING

Electron recoil discrimination

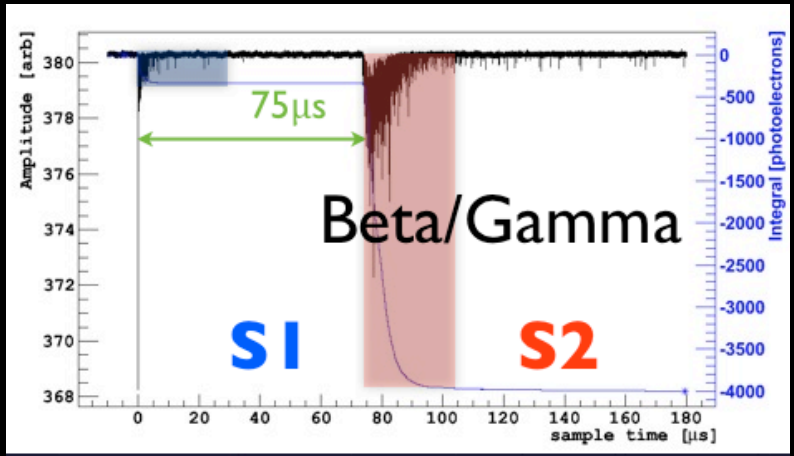
Background discrimination

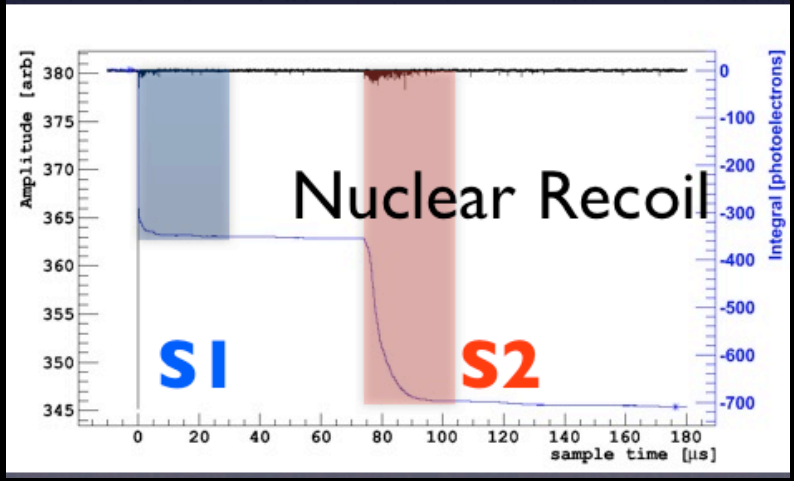
Pulse shape discrimination





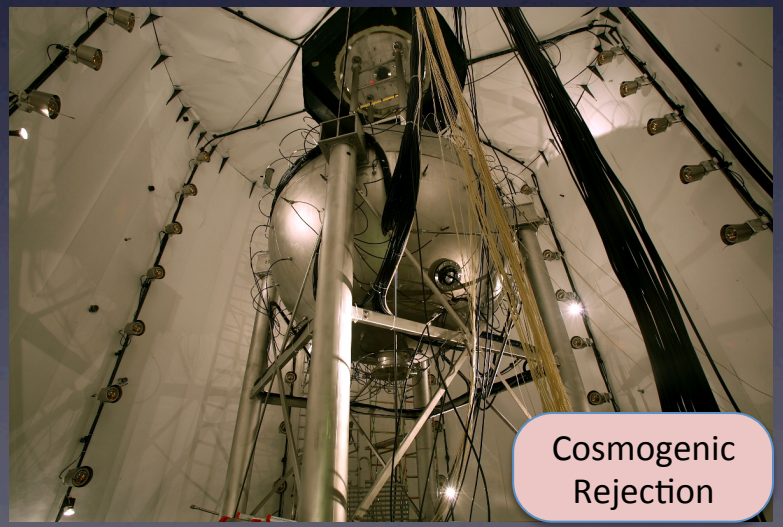
Charge-to-light ratio

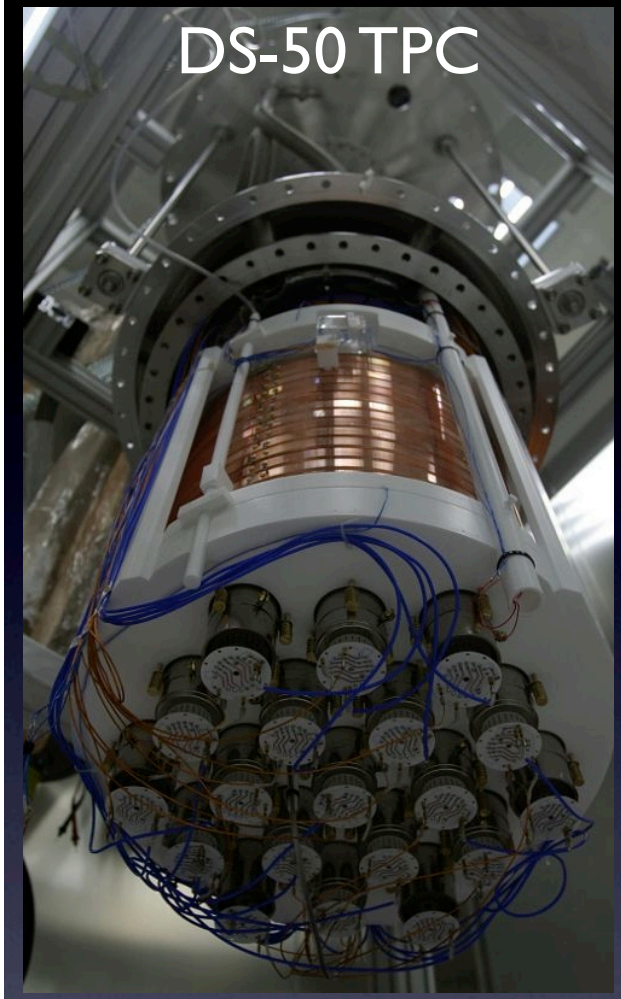


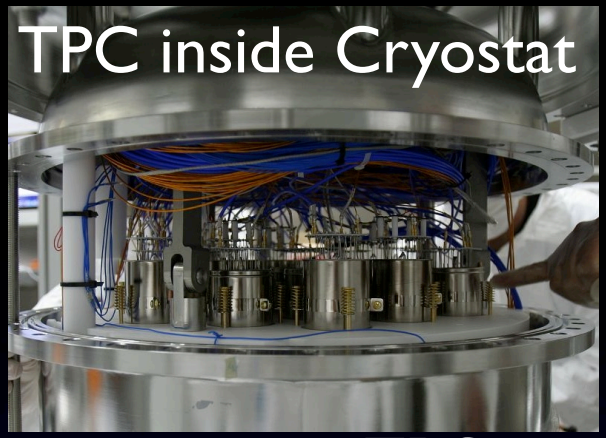


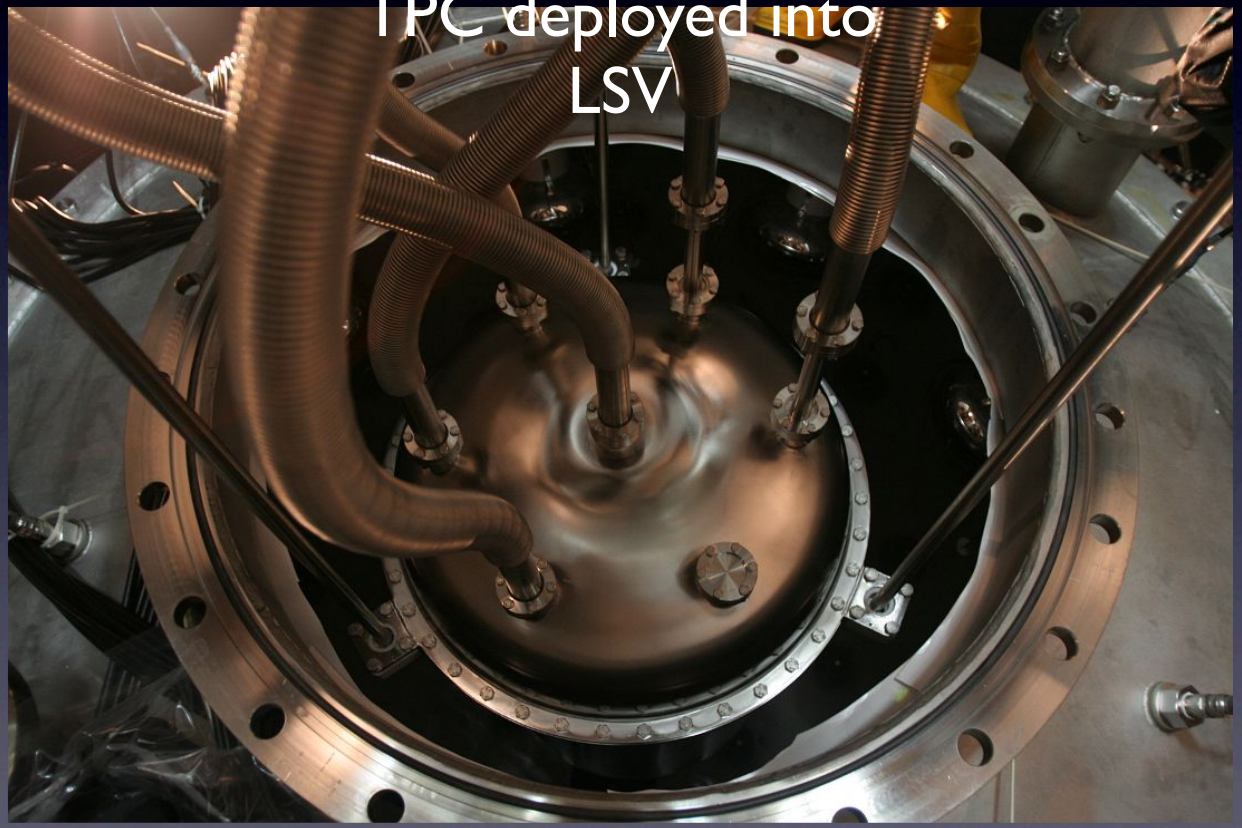
Neutron veto and muon veto

- The TPC is surrounded by a 30 ton boron-loaded liquid scintillator spherical veto, 4m diameter, instrumented with 110 low background 8" PMTs
- neutrons which escape the inner detector are detected via (n,α) reaction on ^{10}B
- >99.5% efficiency for radiogenic neutron detection, >95% for cosmogenic neutron detection A.Wright et. al, NIM A 644, 18 (2011)
- The LSV is installed inside a Water Cherenkov detector (Borexino CTF), 10 m height, 11 m diameter, filled with 1000 ton ultra-pure water, observed by 80 upward facing PMTs
- muon veto and passive shielding against external neutrons and gammas









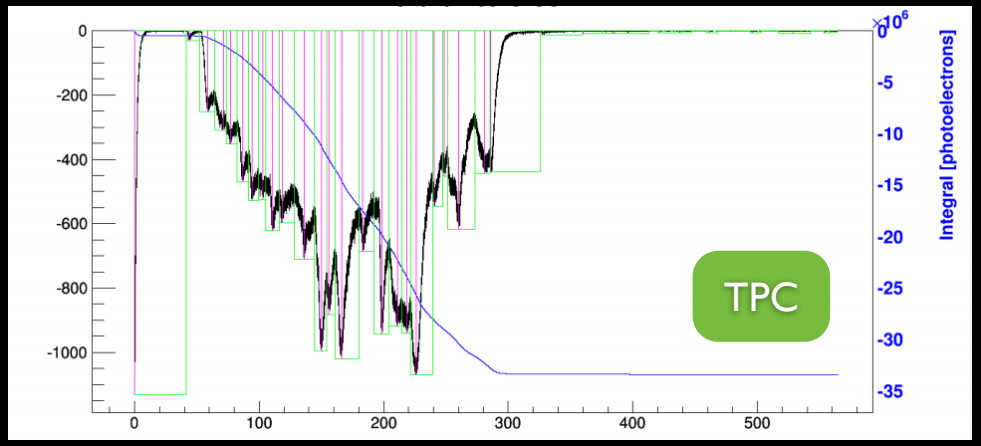
DS50-TPC Assembled, Deployed

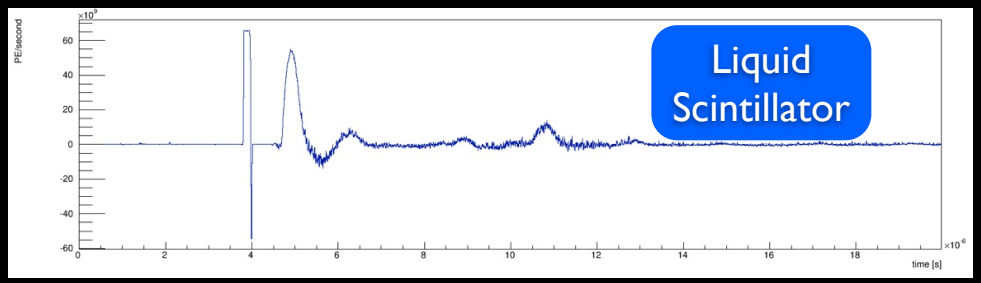
TPC hanging in LSV

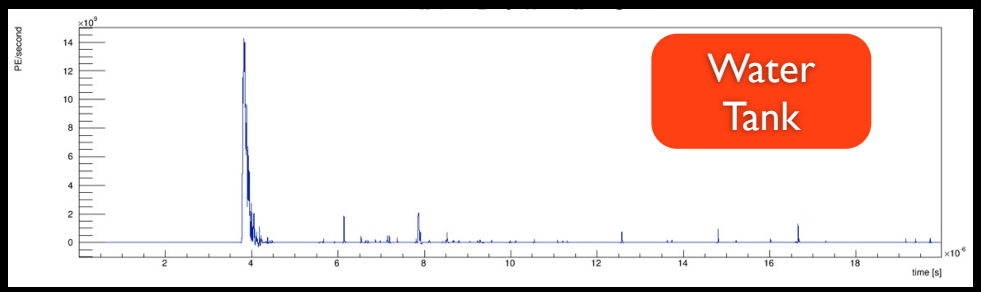
View inside the Water Cherenkov

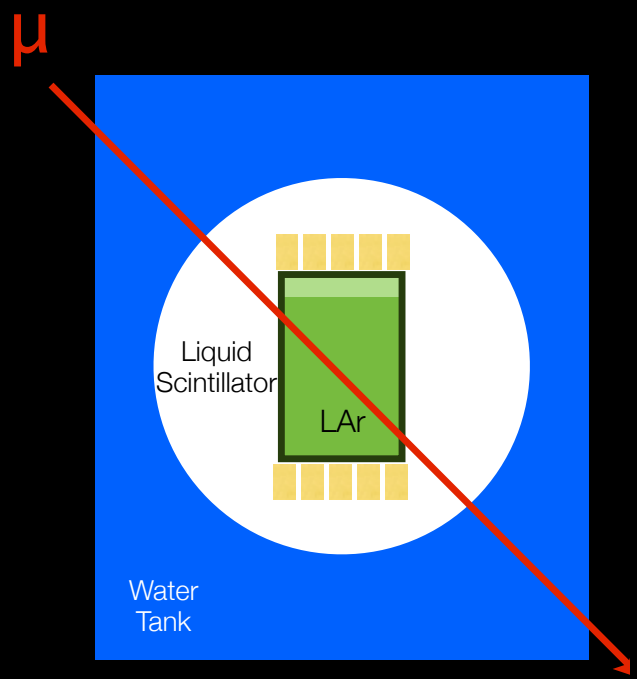
DS-50

All three detectors are currently operating





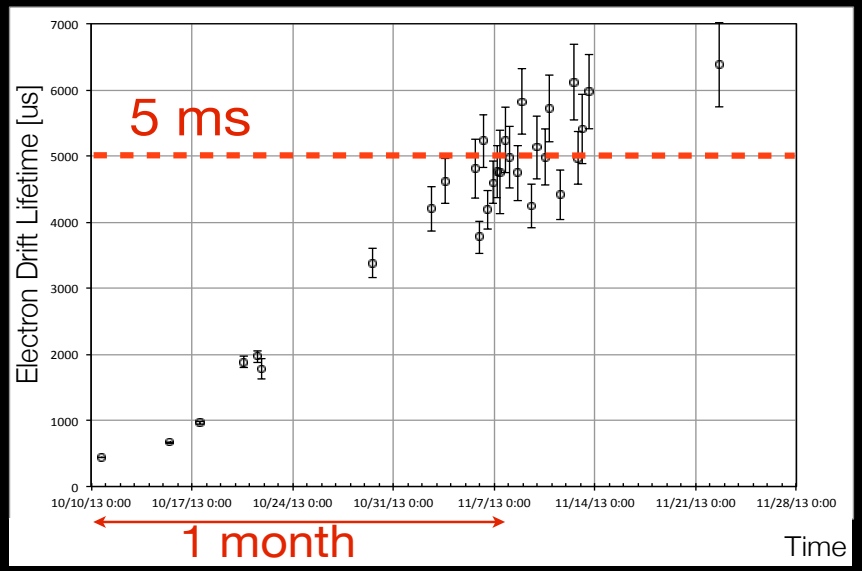




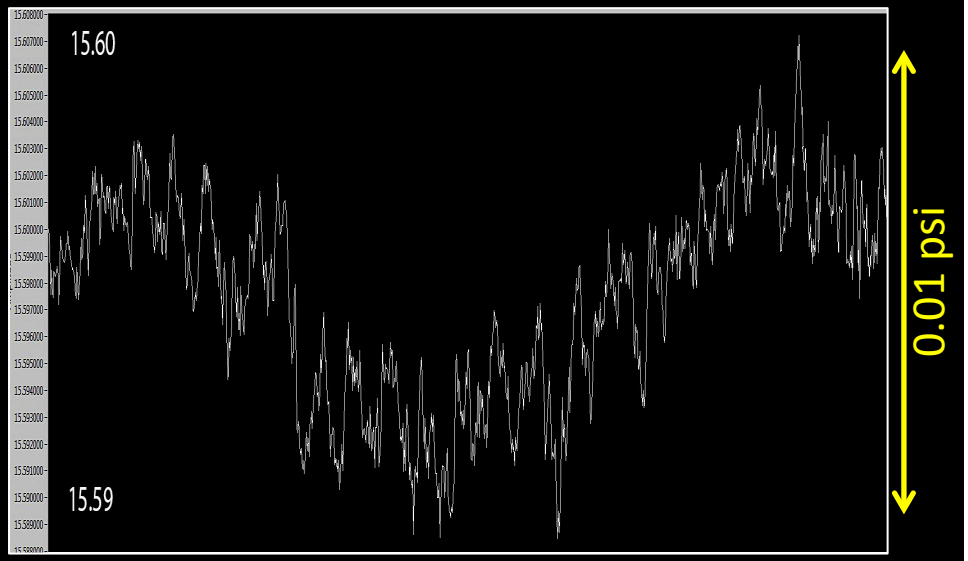
TPC commissioning

- Closed loop Ar recirculation (~30 slpm)
- Gaseous phase purification using commercial getter
- Cryogenic charcoal trap to remove Rn contamination

- Cryogenic system working in an extremely stable condition
- Max cooling power 300 W
- Max recirculation speed 75 kg/day



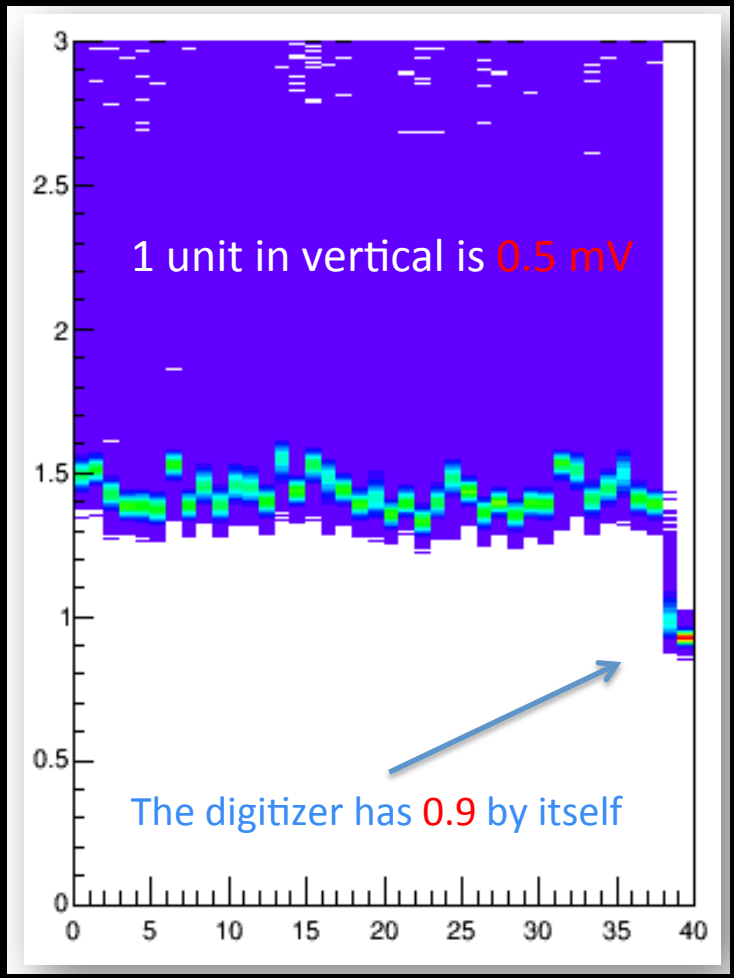
Electron drift lifetime **> 5 ms**, compared to max. drift time of **~ 375 µs**



LAr cryostat pressure showed very high stability

TPC commissioning: residual noise

19 R11065 PMTs working at a gain of 3×10^5 equipped with very low noise cold Amplifiers

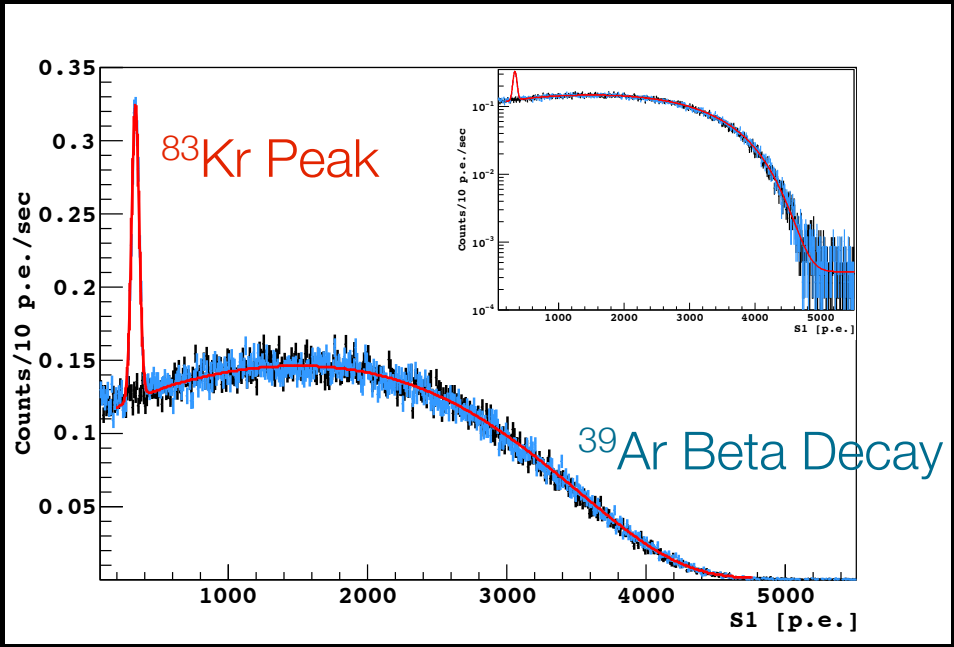


- Electronic noise about 700 μV
- Contribution of the digitizers 450 μV

The amplification of 240 V/V provides the same order of noise of the digitizer

TPC commissioning: calibration

- TPC currently filled with atmospheric argon (1 Bq/kg)
  → ^{39}Ar β decay spectrum
- ^{83m}Kr gas deployed into detector
  41.5 keVee and half-time=1.83 hr



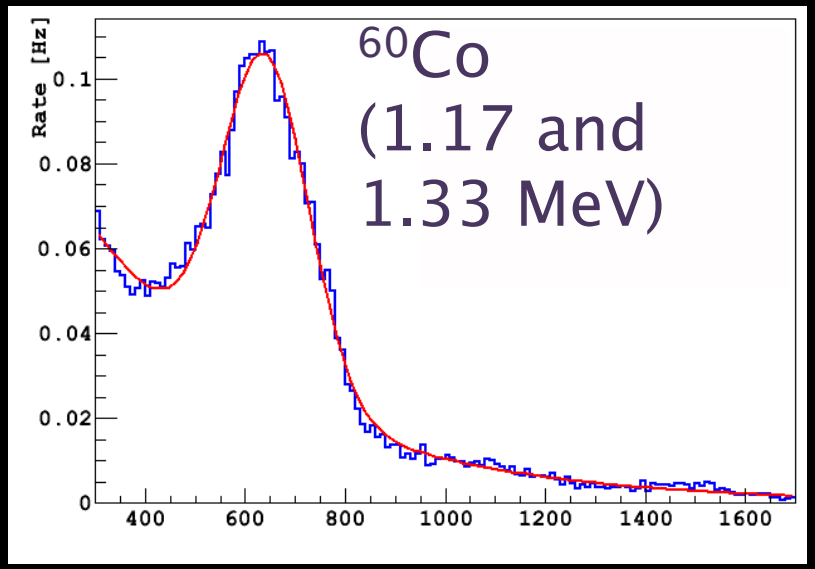
ER callibration at null field
- dominated by ^{39}Ar
- 83mKr decays
- Fit to the ^{39}Ar and ^{83m}Kr

Light Yield
8 PE/keV$_{ee}$

Measured light yield exceeds previous projections of 6 PE/keVee

Neutron Veto commissioning

- Neutron veto setup to trigger on events in the liquid Ar TPC
- Use high energy coincident ^{60}Co events from cryostat stainless steel to evaluate light yield in scintillator

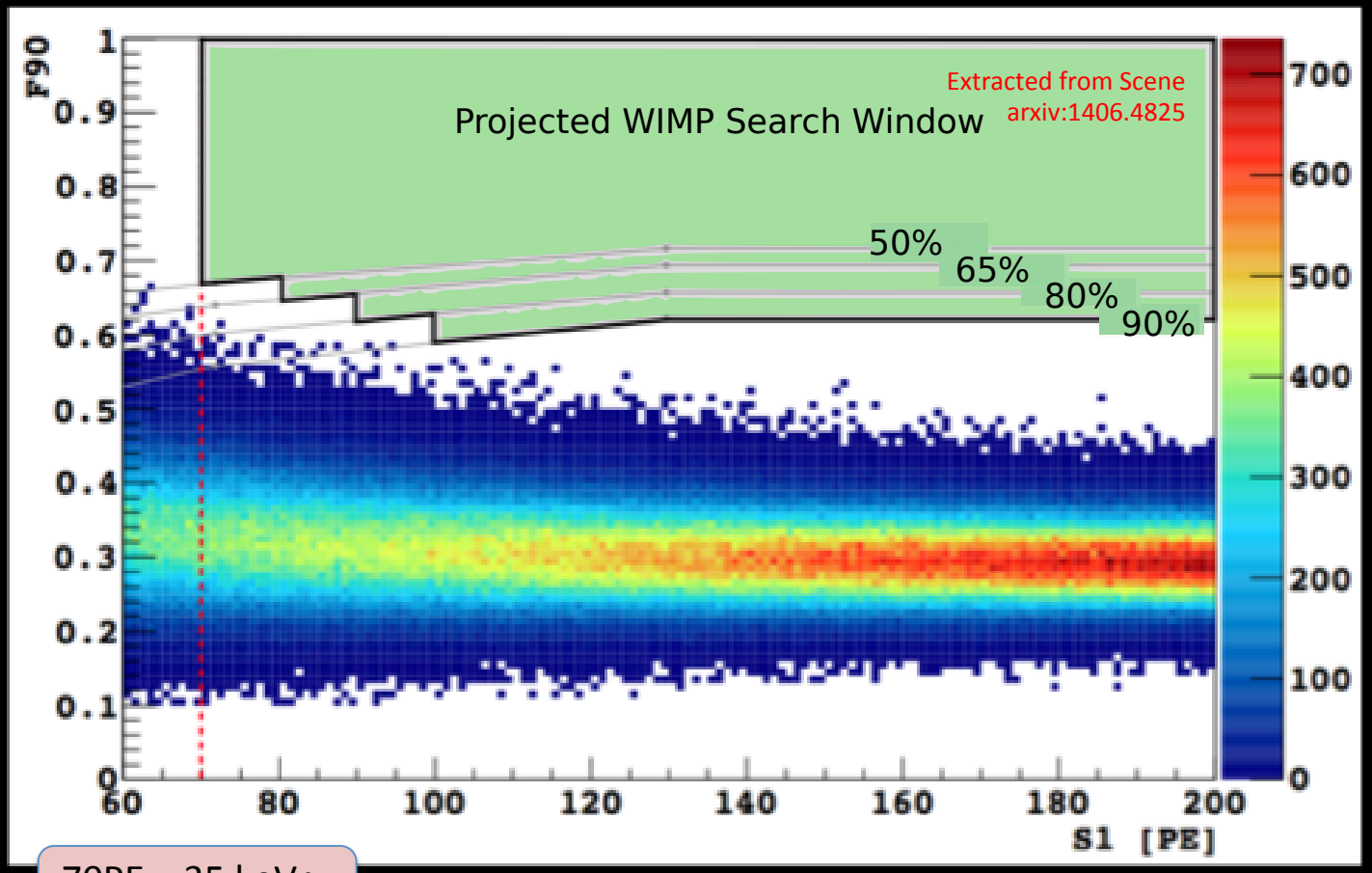


Light yield ~ 0.5 PE/keVee
sufficient to detect ~ 50 keVee α from neutron capture

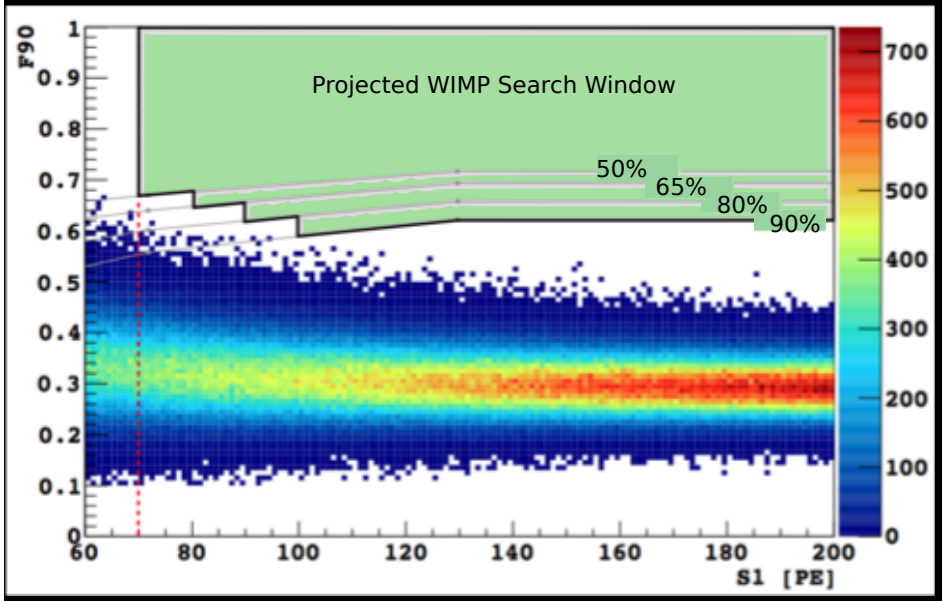
- Found high rate at low energies due to intrinsic ^{14}C in (biogenic) TMB
- Removed TMB from Scintillator (achieved a reduction: 50% →0.16%)
- Identified new batch of low-14C (underground) TMB

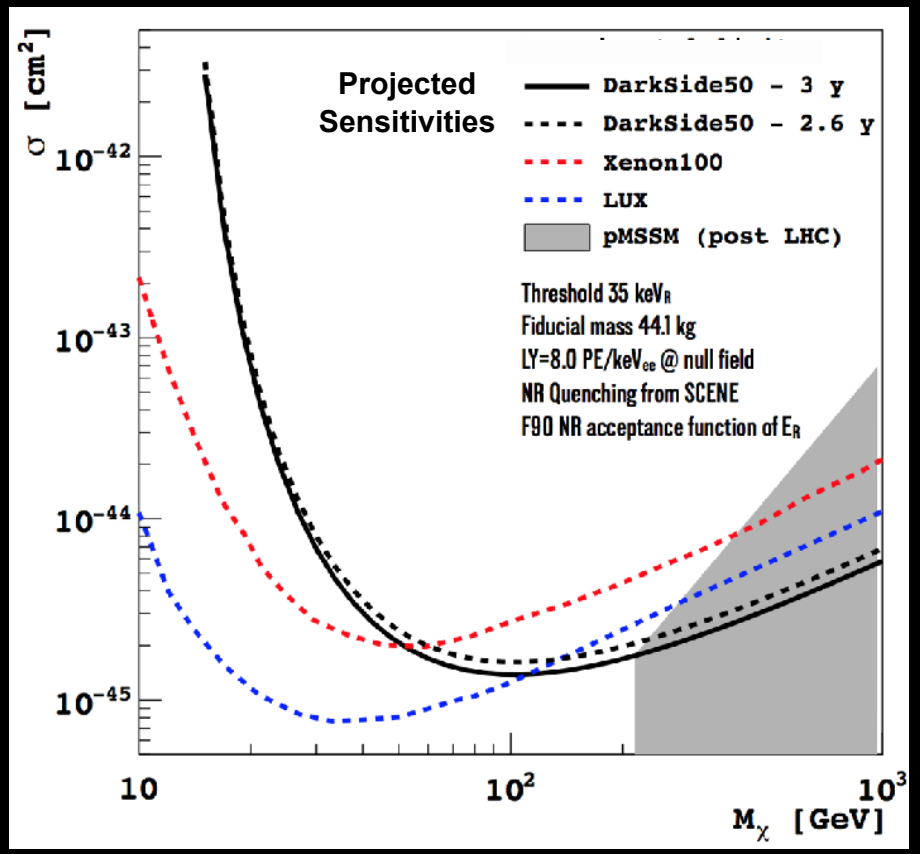
Initial exposure (280 kg-days)

We have **PROVEN** that S1 PSD at 200 V/cm (+ z fiducialization from S2) can efficiently suppress the dominant ER background that we expect in **2.6 years** of DS-50 UAr run, while maintaining high acceptance for WIMPs.



DS-50 projected sensitivity





Assumptions

- PSD as demonstrated
- No S2/S1 rejection
- Fiducial mass 44kg (z-cut only)
- NR energy & pulse shape taken from SCENE

DS-50 summary and plan

- **Detector running since Oct. 2013 with atmospheric Ar**
- **LAr TPC exceeded desired light yield**
- **Demonstrated excellent PSD performance background from ^{39}Ar: 2.6 years of DS-50**
- **Currently acquired and analyzed 2500 kg-days (55 days)**
  - Data being used to improve understanding of S2 signal, x-y position reconstruction, S1-S2 correlations
- **Neutron veto: High rate of ^{14}C found in TMB**
  - During last 2.5 months performed operations to remove TMB
  - **TMB removed** – achieved 600x reduction - Will replace with low-14C TMB
- **Source calibration**
  - Plan to acquire gamma and neutron data very soon
  - Source insertion system installation on going
- **Underground argon**
  - Switch to using underground argon foreseen at the beginning of 2015

First physics results to be published soon

Darkside future prospects

G2 ($s \approx 10^{-45} cm^2$) **US NSF-DOE:**

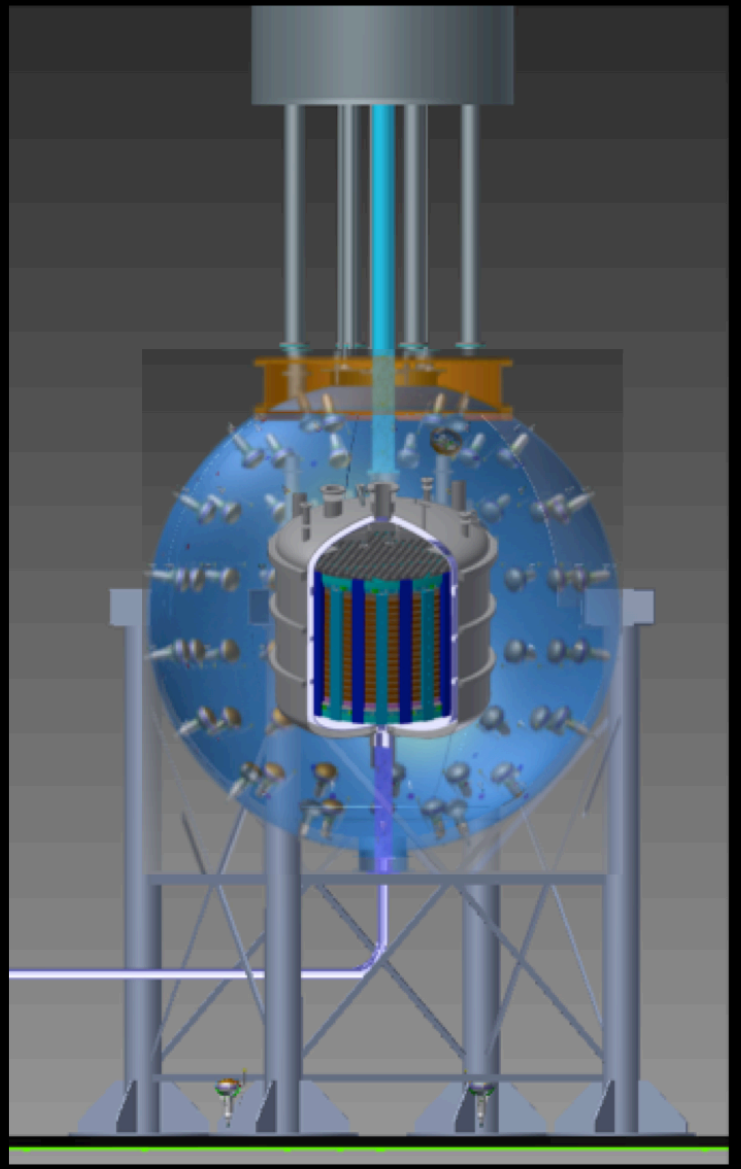
- DarkSide-G2 proposal declined (LZ, SuperCDMS, ADMX funded)
- The program will include R&D to test and develop technologies for future experiments, consistent with the recent P5 recommendations.

G3 ($s \approx 10^{-47} cm^2$) **EU H2020 INFRADEV-1-2014** (Research Infrastructures)

- DARWIN proposal (Xenon, DarkSide, ArDM groups) for multi-ton noble liquid detector submitted on Sep. 2

R&D activities:

- **Underground Argon provision and purification**
- Cryostat design materials for low radioactivity (Stability of pressure in gas region, Thermodynamics for smooth liquid-gas interface)
- **Photosensors**
- **Front-End & Digitizer (cables, noise, radioactivity)**

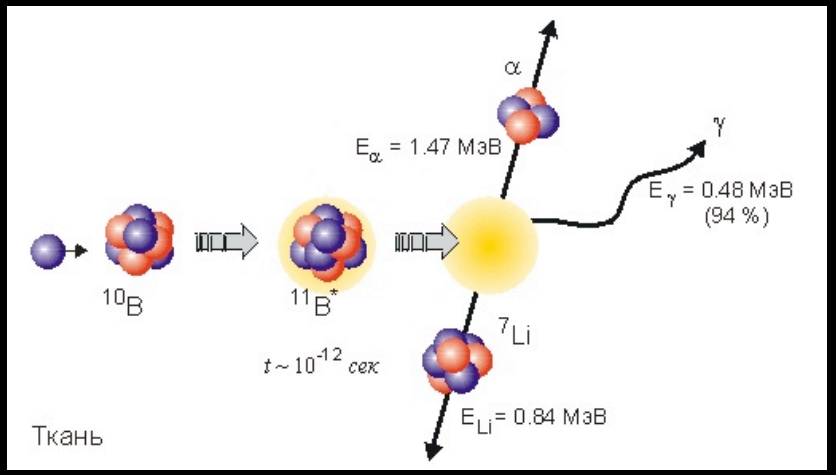


Thank you

Neutron Rejection

Borated Liquid Scintillator

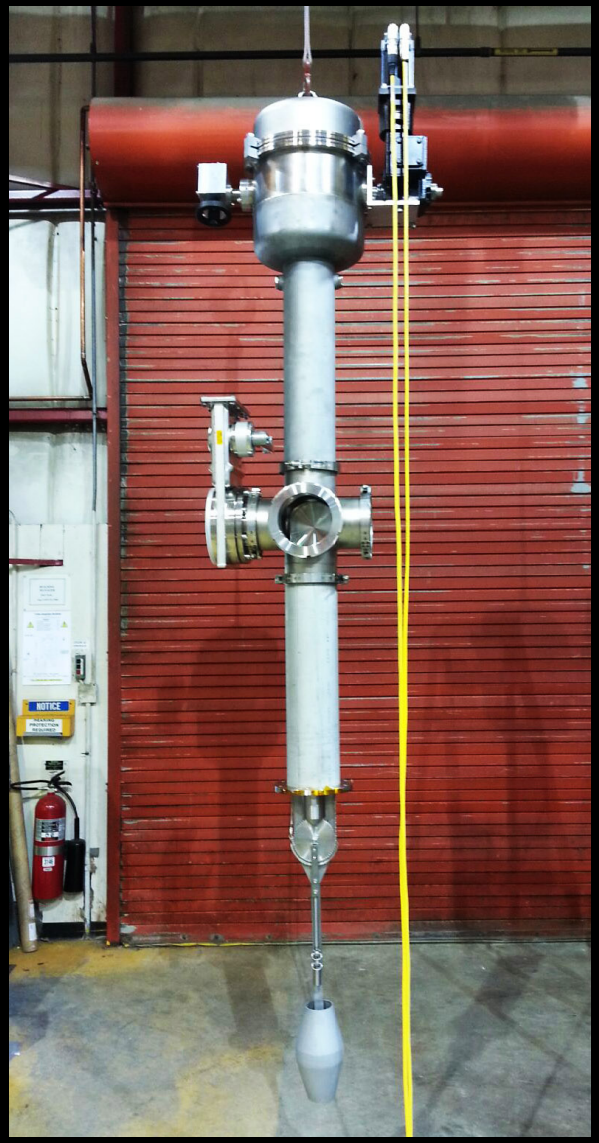
- High neutron capture cross section on boron allows for compact veto size
- Capture results in 1.47 MeV α particle - detected with high efficiency
- Short capture time (2.3 μs) reduces dead time loss

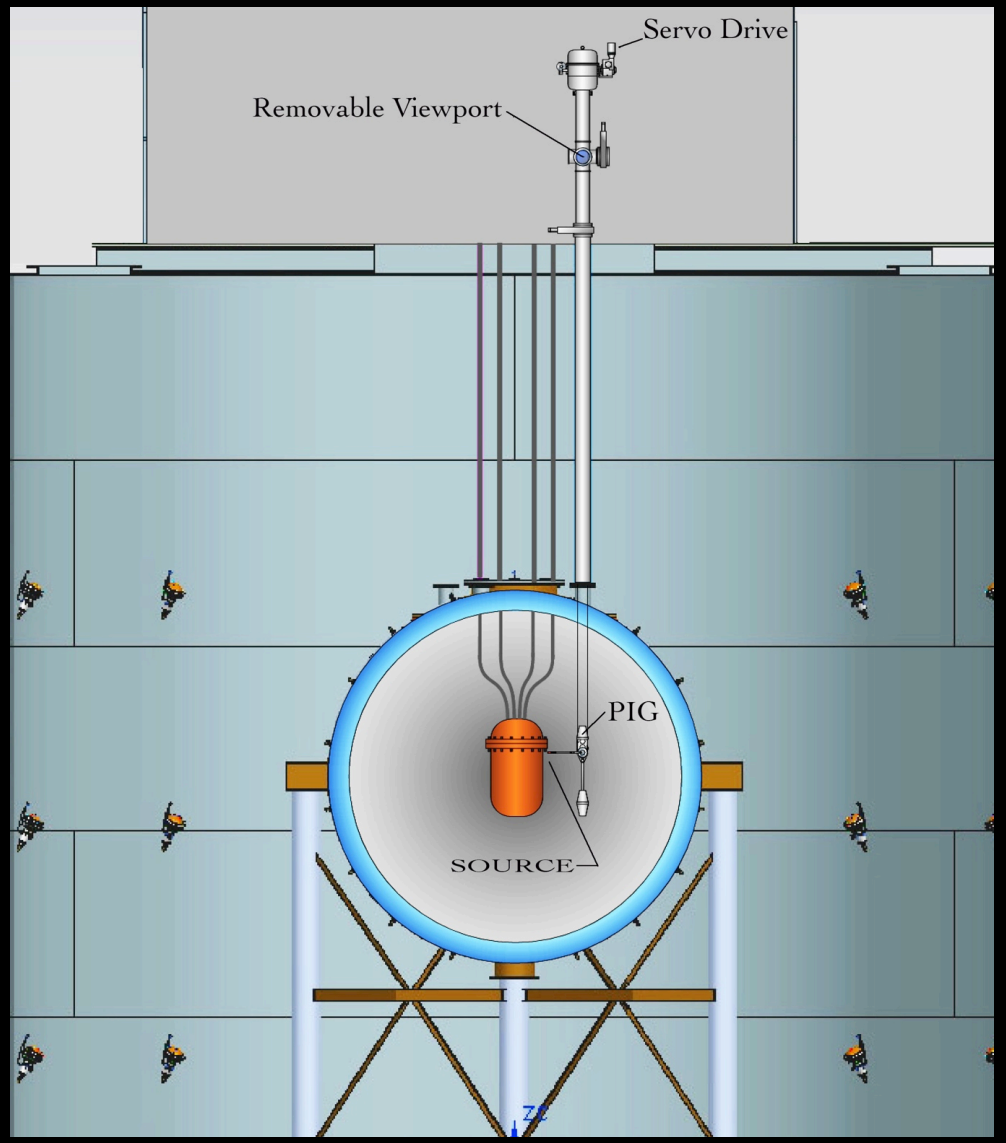


	Veto Efficiency (MC)
Radiogenic Neutrons	> 99%*
Cosmogenic Neutrons	> 95%

Nuclear Instruments and Methods A 644, 18 (2011)

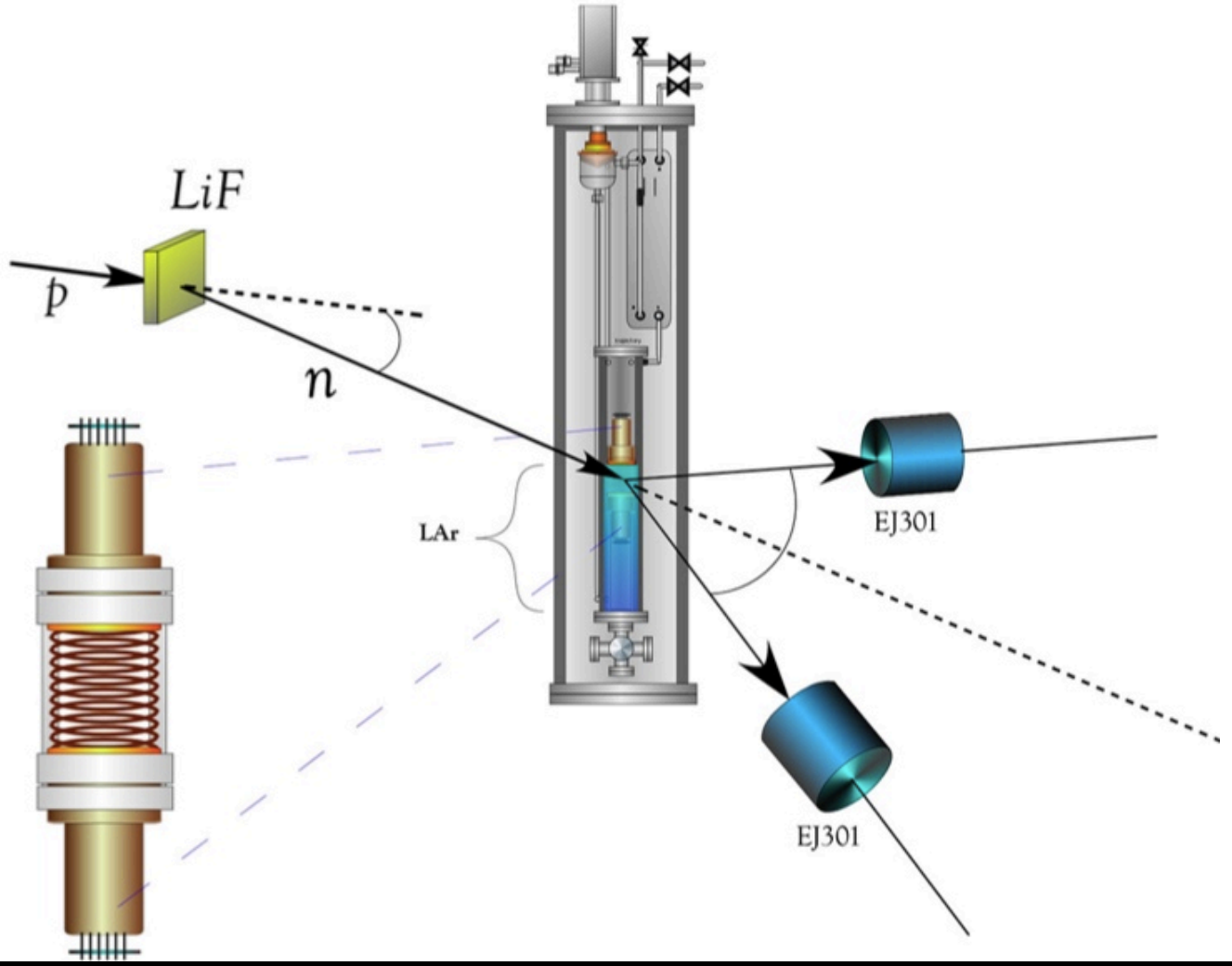
Calibration source system



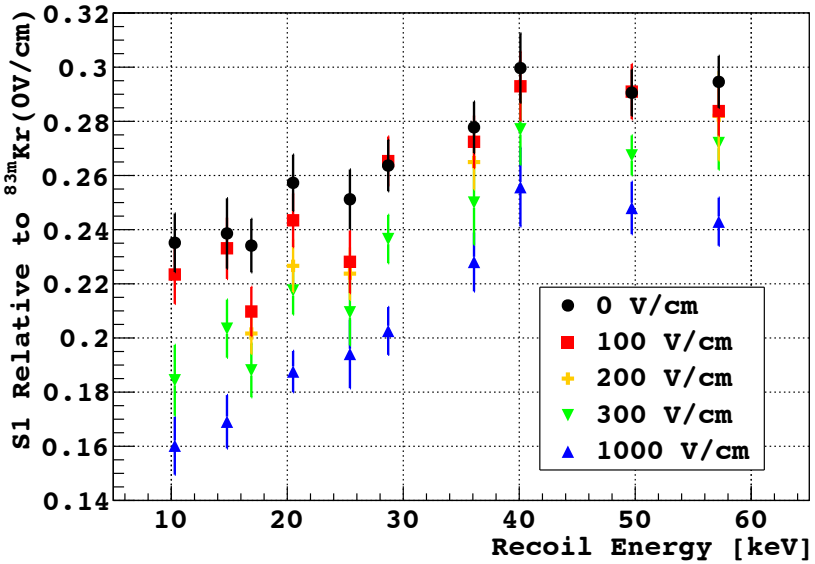


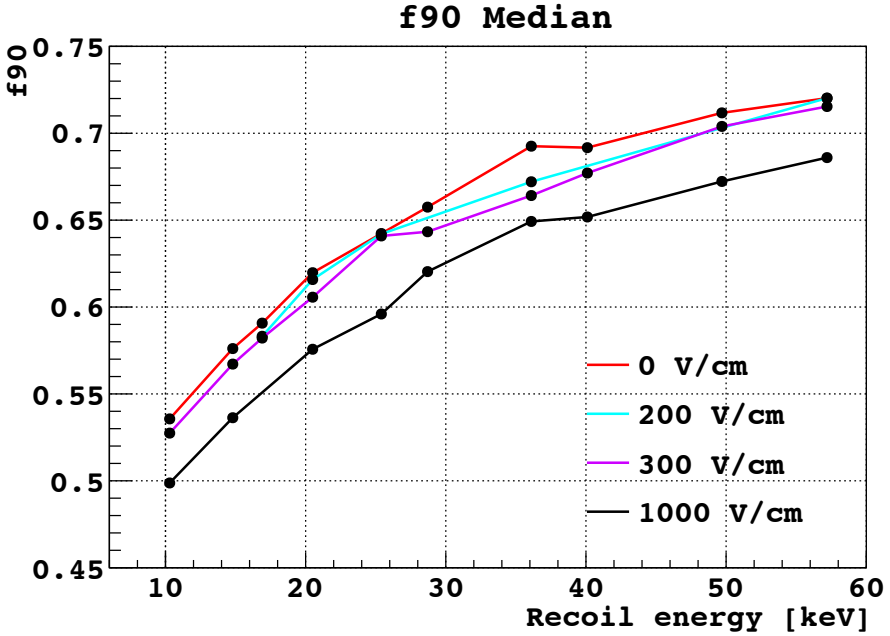
SCENE Experimental Scheme

(Scintillation and Ionization Efficiency of Noble Elements)



Nuclear Recoil Scintillation Yield and Pulse Shape vs Drift Field





Paper on most recent results:
H. Cao et. al.
arXiv:1406.4825