# RECENT RESULTS FROM DARKSIDE

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for the DARKSIDE Collaboration

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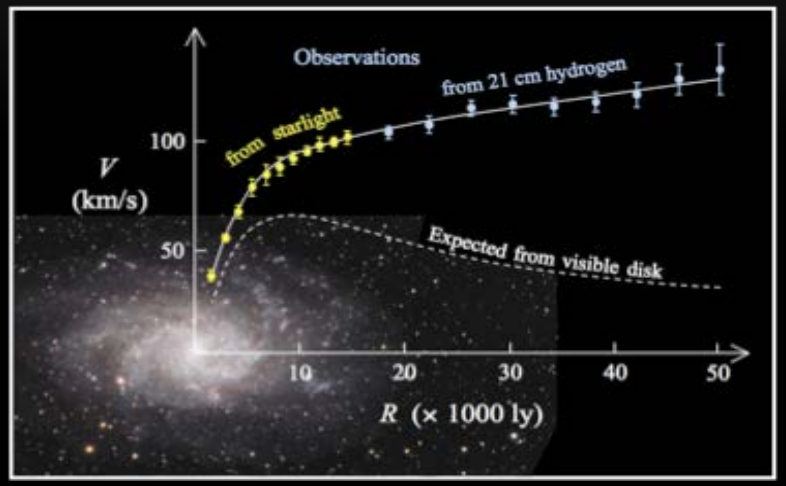
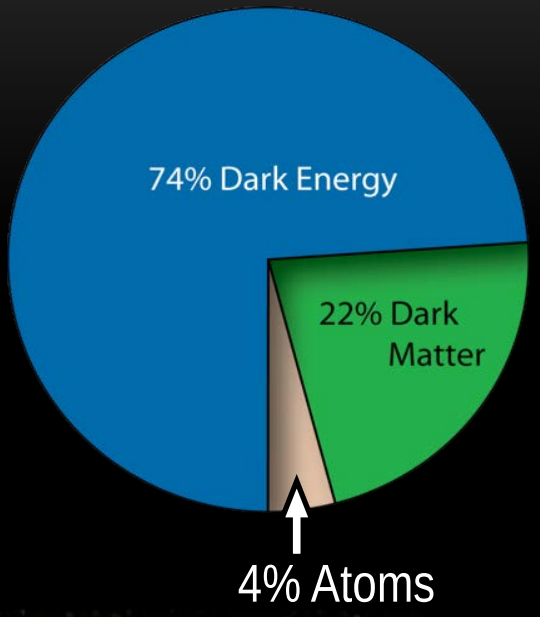
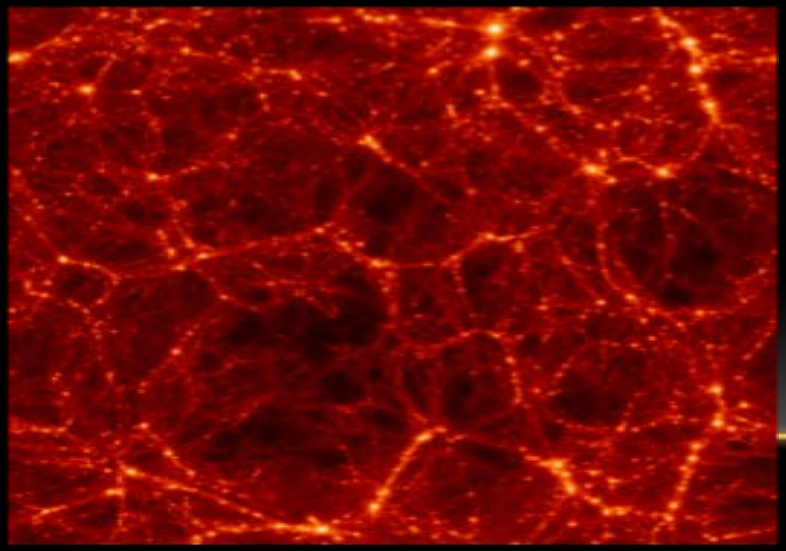
# OUTLINE

- Evidences for dark matter and motivation for direct searches
- The DARKSIDE program
- First physics results from DARKSIDE-50
- Present status of the experiment
- Conclusions

# EVIDENCES FOR DARK MATTER



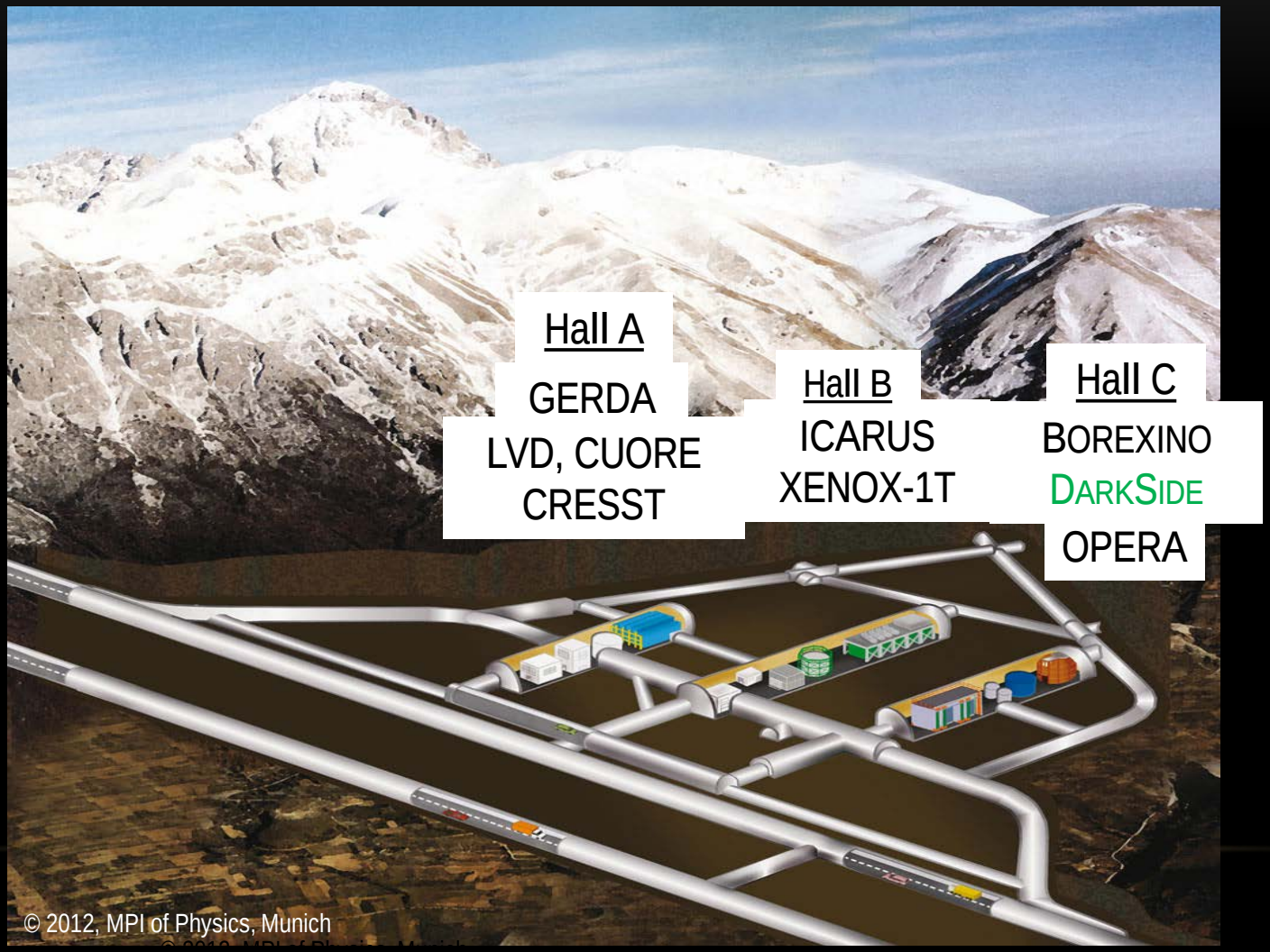



# THE DARKSIDE PROGRAM

- Multi-stage program searching for dark matter direct interactions in low-background detectors deployed at the Gran Sasso underground laboratory.
- Based on a two-phase low-radioactivity argon time projection chamber (TPC)
- Ultra-low background design
- Active suppression of residual backgrounds for true background-free operation

# THE DARKSIDE PROGRAM

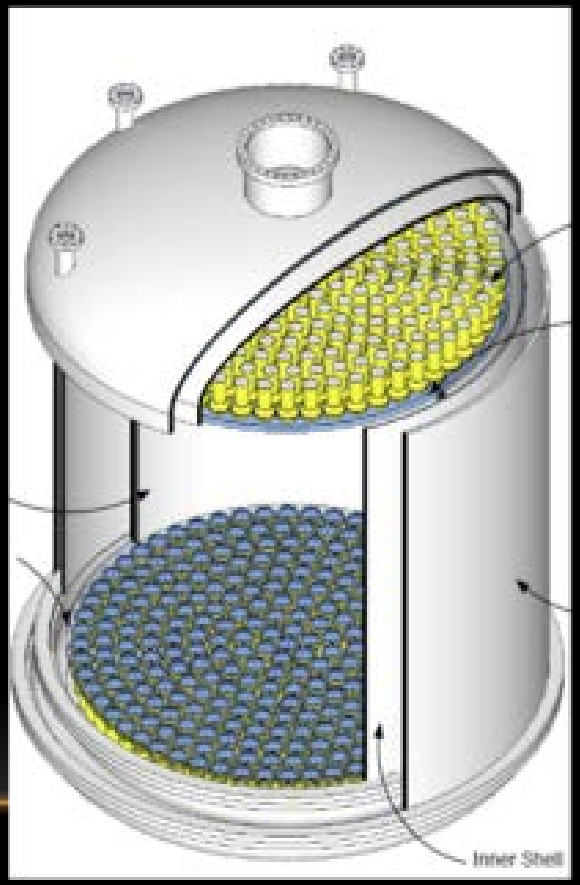


# THE DARKSIDE PROGRAM

DS-10 prototype
(2011)

DS-50 detector
(Since Oct. 2013)

Multi-ton detector
(future)



# DS-50 DETECTOR

Clean room

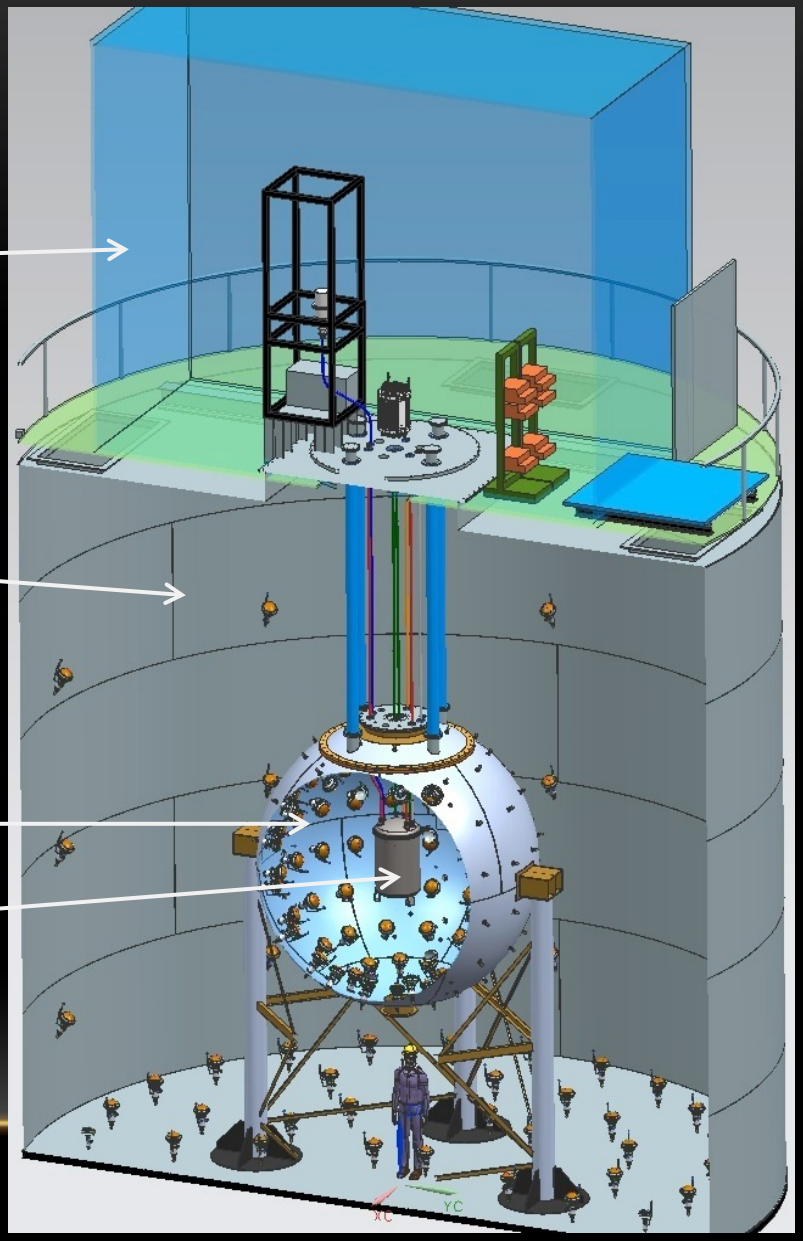
Instrumented water tank (1 kton)

- 80 8” PMTs
- 11 m dia. x 10 m high
- Muon and cosmogenic veto (~ 99.5% efficiency)
- Passive $\gamma$/n shielding

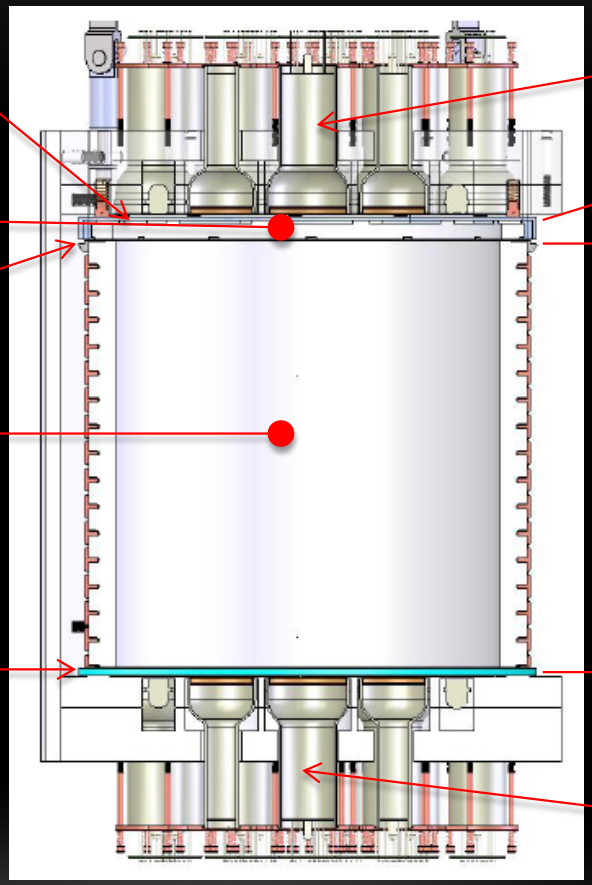
Liquid scintillator detector

Inner detector TPC

All sized for multi-ton TPC

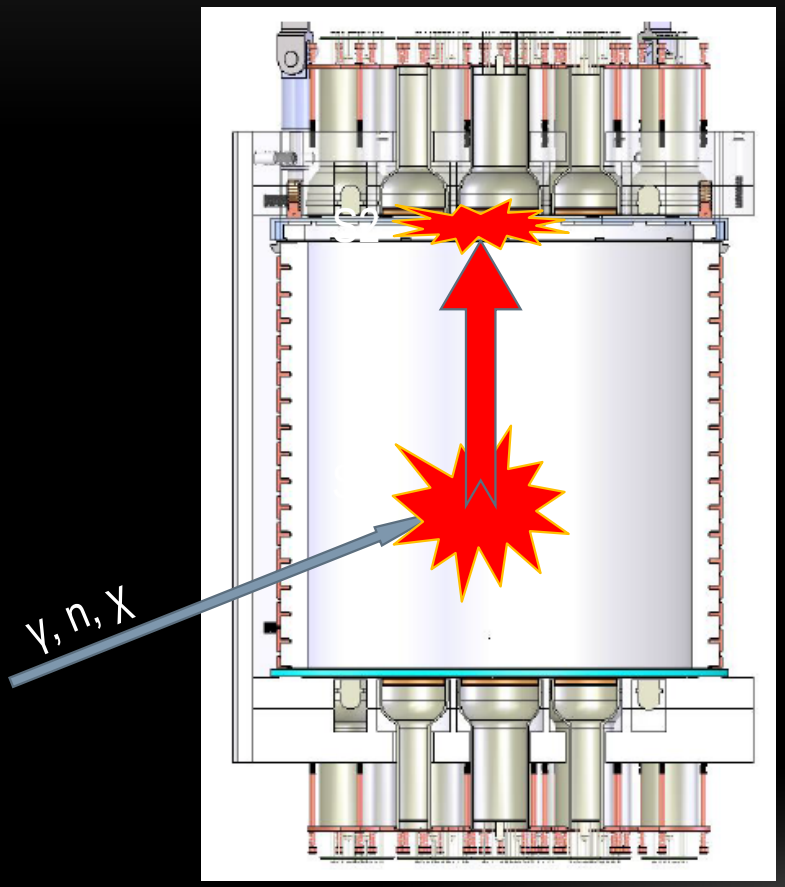


# DS-50 TPC




TPC: 36 cm φ × 36 cm high

# DS-50 TPC

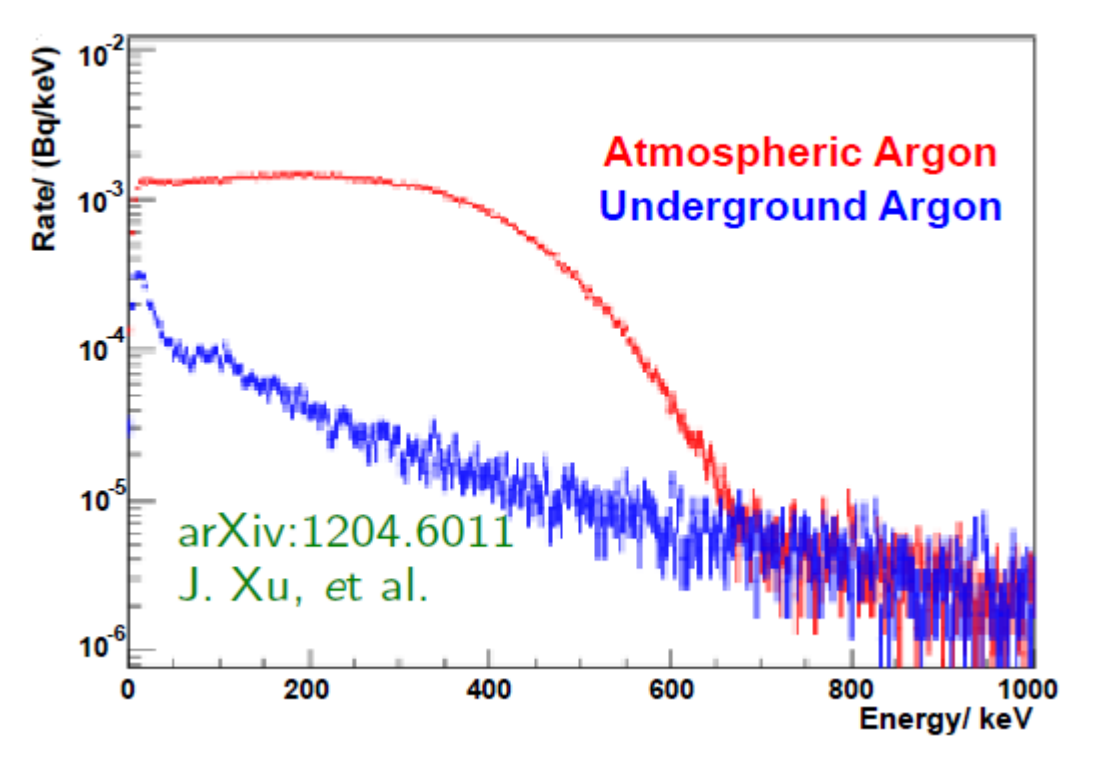



- Nuclear recoil produces primary scintillation light: S1
- Electrons that survive recombination are drifted towards the liquid-gas interface by the electric field
- The electrons are extracted into the gas region, where they induce electroluminescence: S2
- Time difference between S1 and S2 gives Z position, PMT hit pattern gives X-Y position
- Tools for backgrounds rejection:
  - PSD based on S1
  - S2/S1 ratio
  - Position reconstruction

# UNIQUE FEATURES OF DARKSIDE

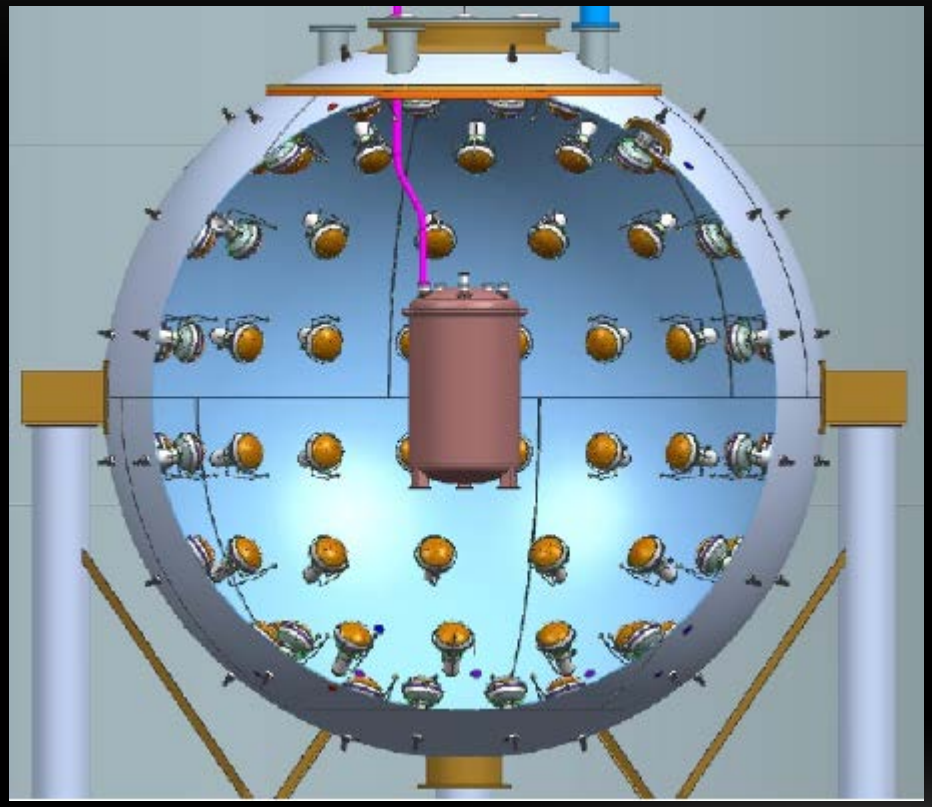
- Argon depleted with $^{39}Ar$: underground argon (UAr)
- Liquid scintillator veto for neutrons
- $^{222}Rn$-free clean rooms

# UNDERGROUND ARGON (UAr)




- $^{39}$Ar radioactivity in atmospheric Ar (~1 Bq/kg) limits its usability as a WIMP target
- $^{39}$Ar is of cosmogenic origin
- Source of underground argon ($CO_2$ well near Cortez, Colorado) measured to have > 150 times lower rate of $^{39}$Ar (< 7 mBq/kg), compared to atmospheric argon
- Large-scale production possible (multi-ton Ar detectors)

# LIQUID SCINTILLATOR VETO



- 4 m diameter sphere containing 50% PC + 50% trimethyl borate (TMB) scintillator (30 ton)
- Instrumented with 110 8” PMTs
- Veto of neutrons coincident in the TPC and provides in situ measurement of the neutron background rate
- Neutron capture results in 1.47 MeV $\alpha$, capture time 2.3 $\mu$s
- Veto efficiency: >95% for cosmogenic neutrons and >99.5% for radiogenic neutrons (MC)

# $^{222}$Rn-FREE CLEAN ROOMS

- Class 10 - 100
- Radon daughters plating out on surfaces of the detector may cause dangerous alpha-induced nuclear recoils
- Dedicated scrubbing system reducing $^{222}$Rn concentration in the air down to ~1 mBq/m$^3$ has been implemented
- DARKSIDE clean rooms are supplied with the $^{222}$Rn-free air
- $^{222}$Rn content in the clean rooms is monitored online by a dedicated detector

Typical radon in hall C air ~ 30 Bq/m$^3$

Cleanroom radon levels 5 – 50 mBq/m$^3$

# SHORT DS-50 TIME LINE

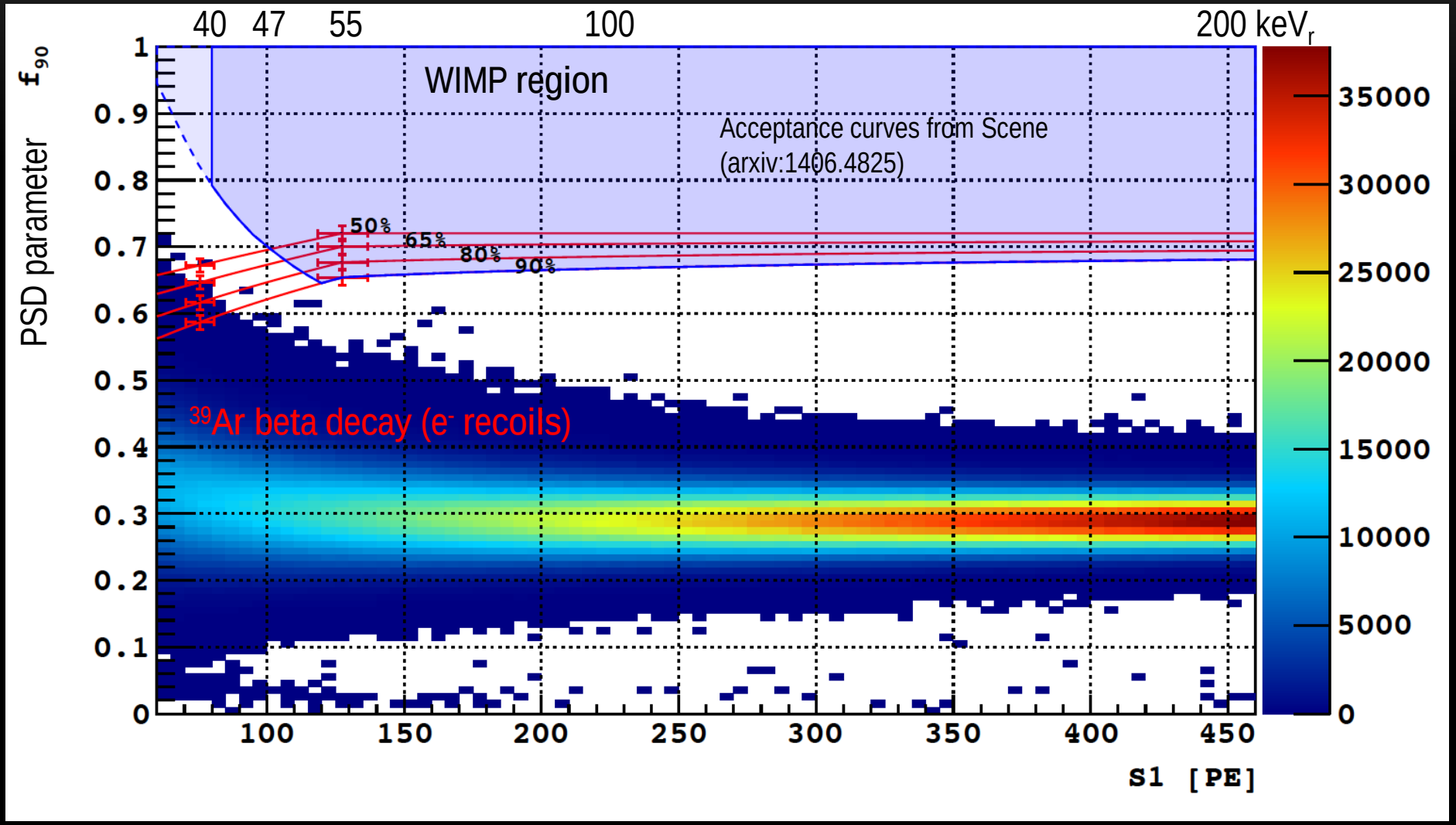
- Oct. 2013: TPC, Neutron Veto and Muon Veto commissioned. TPC filled with atmospheric argon (AAr)
- Nov. 2013 - Jan. 2014: improvements of DAQ, data handling and processing
- Jan. - June 2014: physics data taken with high $^{14}C$ content in LSV
- June 2014 – now: removal of high $^{14}C$ rate TMP, recovery of PPO, calibration campaigns with $^{60}Co$, $^{133}Ba$, AmBe (high and low rate) $^{137}Cs$ and $^{83m}Kr$.

# DS-50 PHYSICS RUN

- DS-50 detector:
  - All 38 TPC channels working
  - Purification (~3 kg/h) provides electron drift lifetime >5 ms ($t_{drift}$ < 400 μs)
  - (46.4 ± 0.7) kg active mass AAr (151 kg total mass)
  - Light yield of 8 p.e./$keV_{ee}$ (zero field) achieved
  - Trigger rate of ~16 Hz
  - ~78% duty cycle
- 47.1 live days (1422 kg×day exposure) of background-free AAr data accumulated
- Acuired 1422 kg×day of AAr data corresponds to 0.6 t×yr with UAr (~2 decades of $^{39}$Ar-free DS-50 operation)

# DS-50 RESULTS

ArXiv:1410.0653



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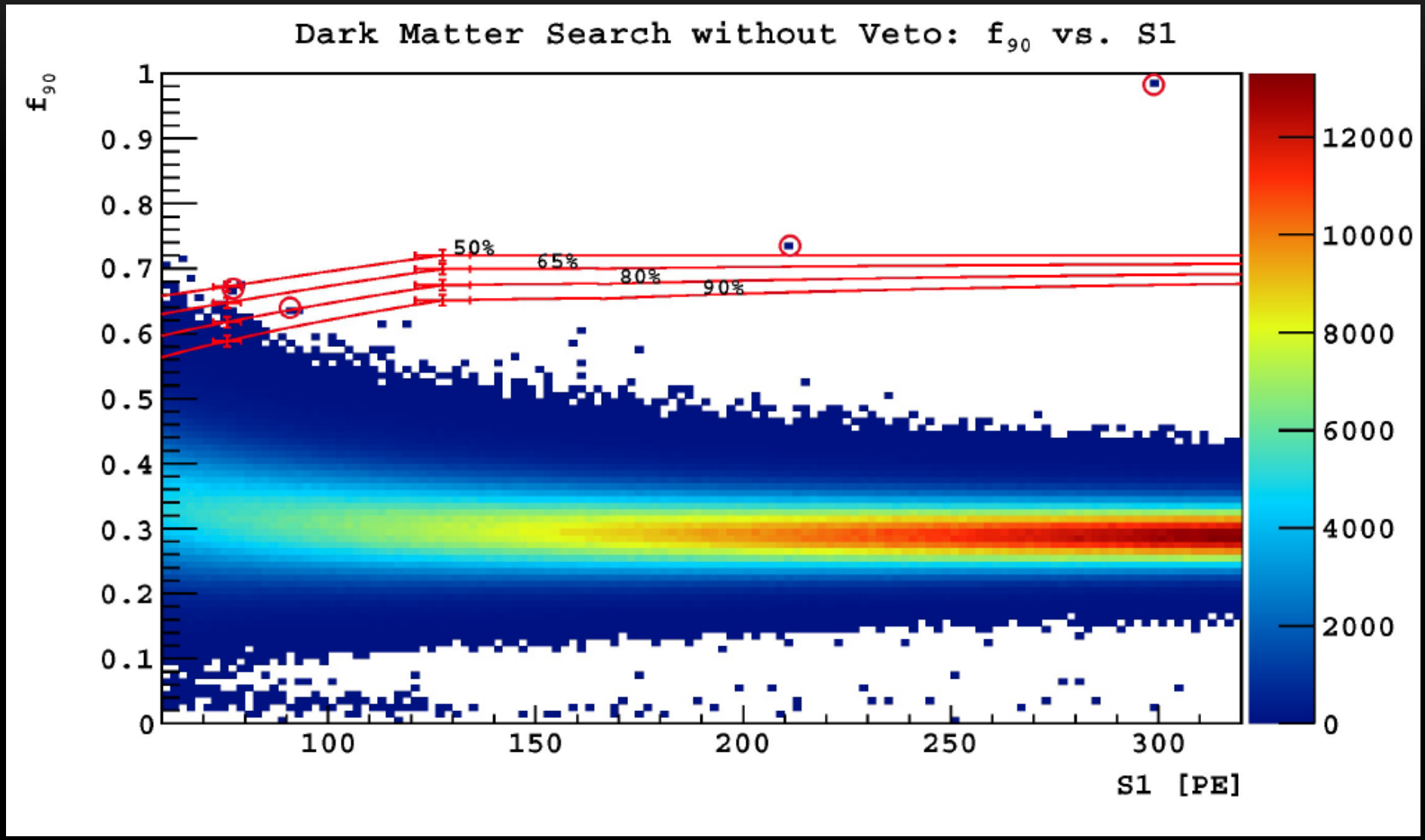

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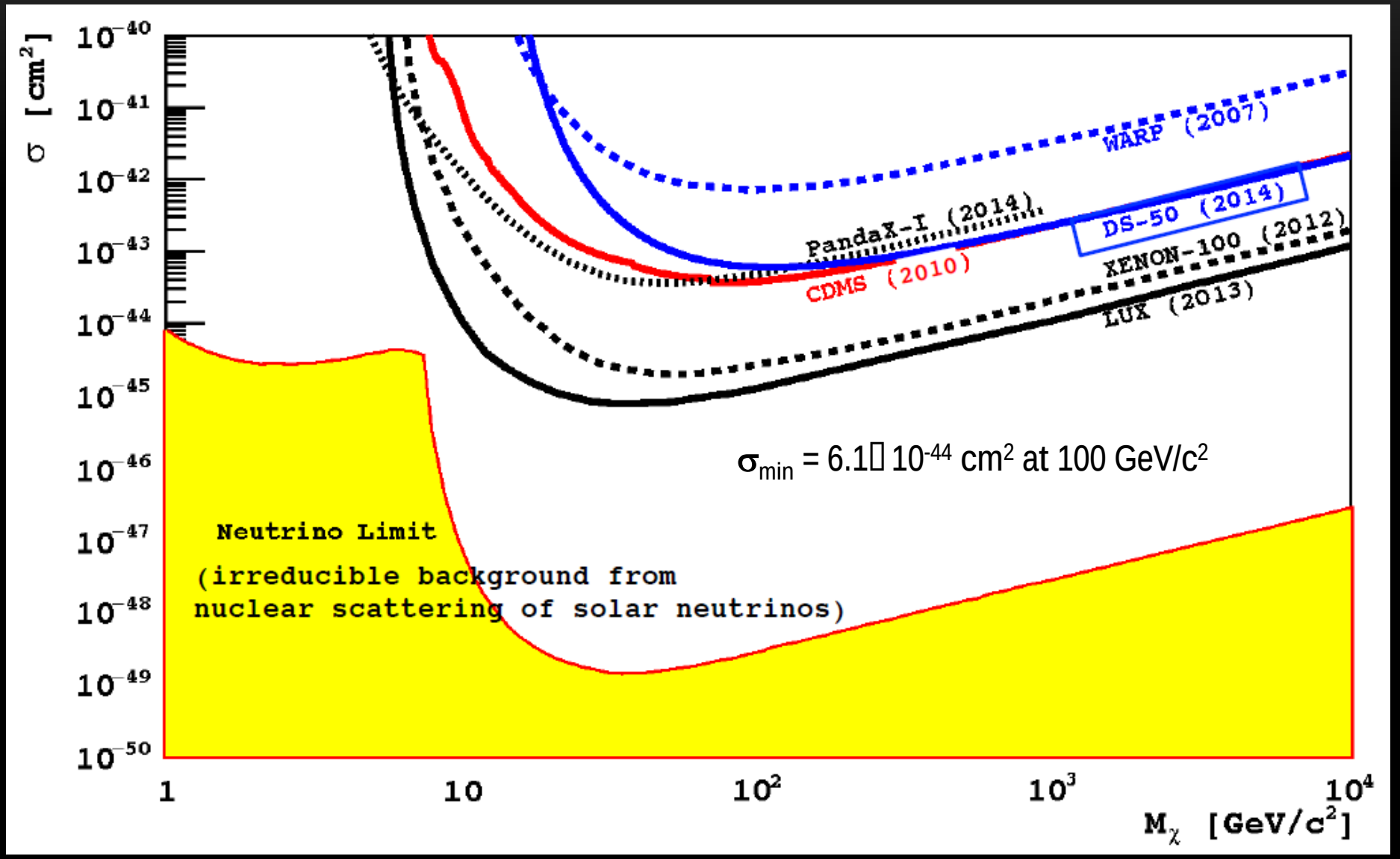

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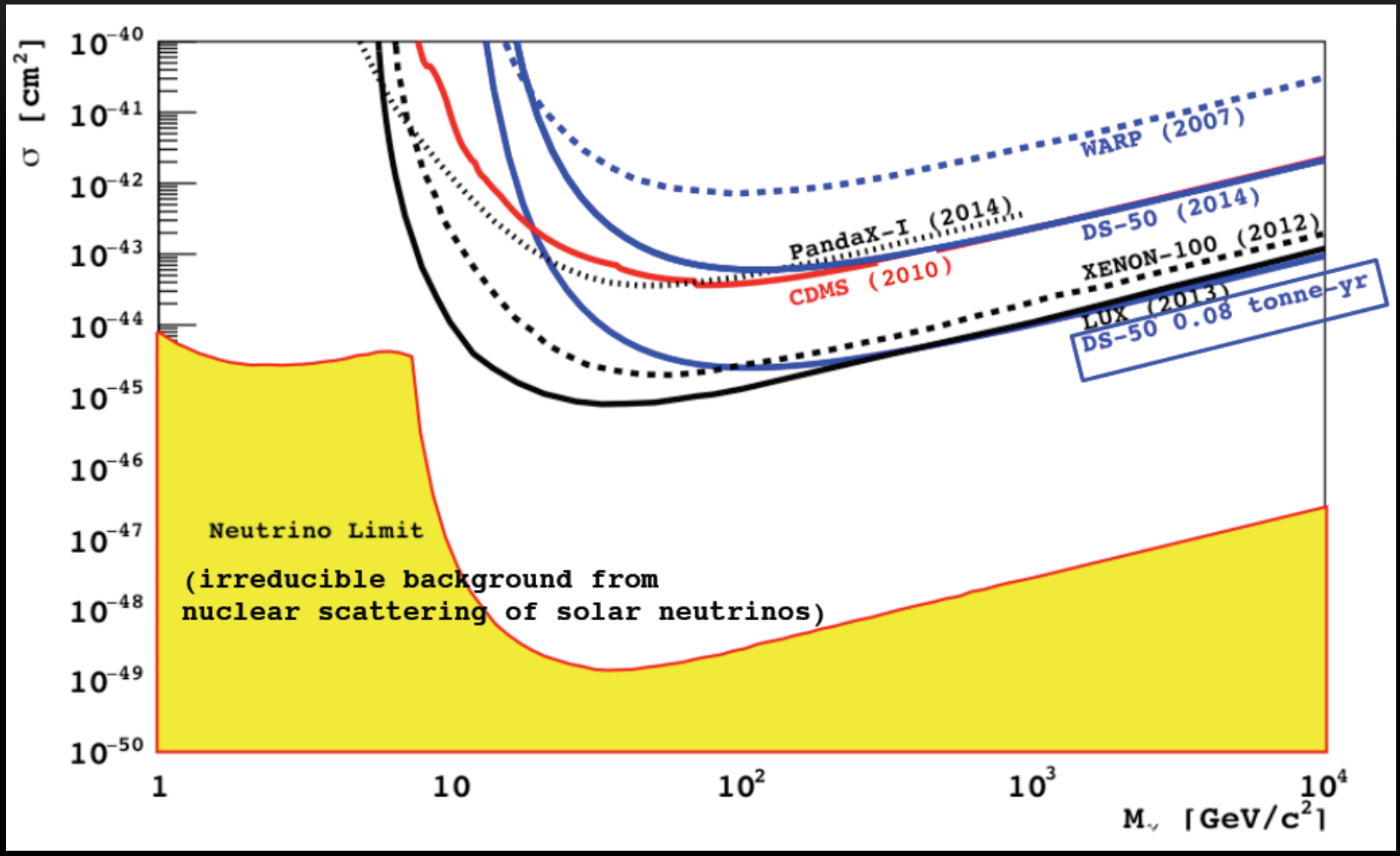


# PRESENT STATUS OF THE EXPERIMENT

- High $^{14}C$ rate TMB has been removed from the LS
- Calibration of TPC/LSV with low-rate AmBe source recently completed, calibration with $^{83m}Kr$ ongoing
- 141.7 kg of UAr delivered to LNGS two weeks ago, additional 14.6 kg of UAr will be shipped from Fermilab next week. In total 156.4 kg of UAr available (153 kg needed for the DS-50 detector)
- Getter purification system to reach the detector grade purity of UAr under preparation at LNGS
- UAr filling in the next weeks
- Goal: acquire 0.08 t×yr exposure (~3 yr) to demonstrate background control

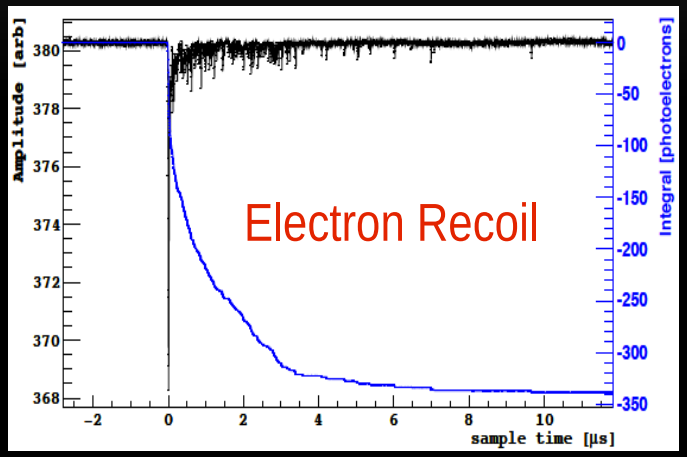
# CONCLUSIONS

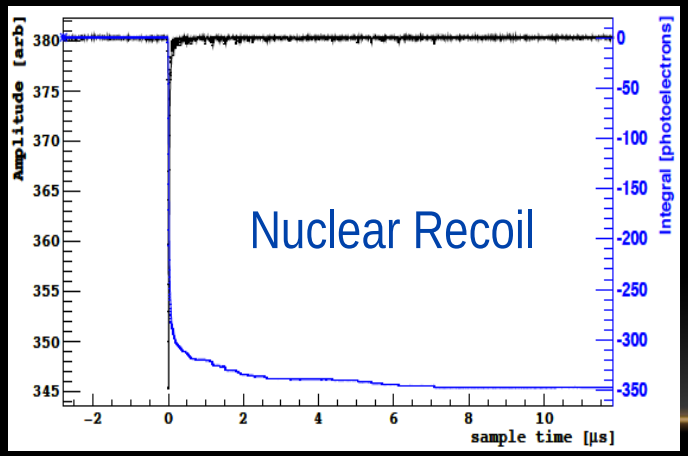
- 1422 kg×day of truly background-free exposure has been demonstrated with AAr (> 20 yr of $^{39}$Ar-free operation of DS-50 with UAr)
- Filling of UAr into the DS-50 detector scheduled for the next weeks (almost all needed UAr already at LNGS)
- Production and purification of UAr at large scales feasible, at a multi-ton scale UAr cheaper than Xe
- Technology based on UAr-TPCs can provide truly background-free operation (PSD, easiness in purification from $^{222}$Rn)
- DS-like multi-ton UAr-based experiment very competitive in comparison to Xe-based experiments
- DARKSIDE is exploring possibilities to push for a O(5 t) experiment with new technological breakthroughs (low-temperature SiPMs)

# BACKUP SLIDES

# PSD: F90

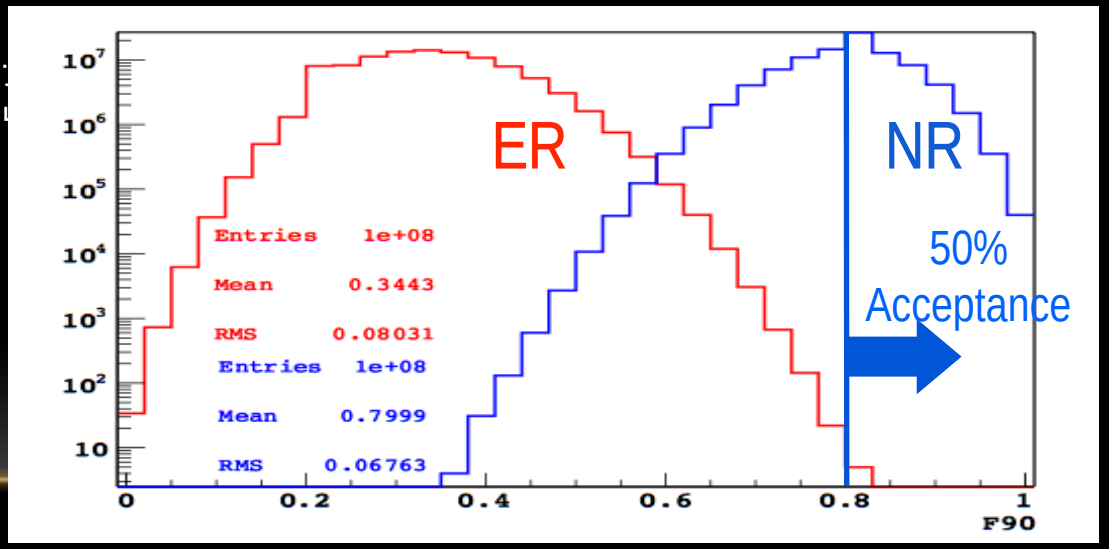
Electron and nuclear recoils produce different excitation densities in the argon, leading to different ratios of singlet and triplet excitation states



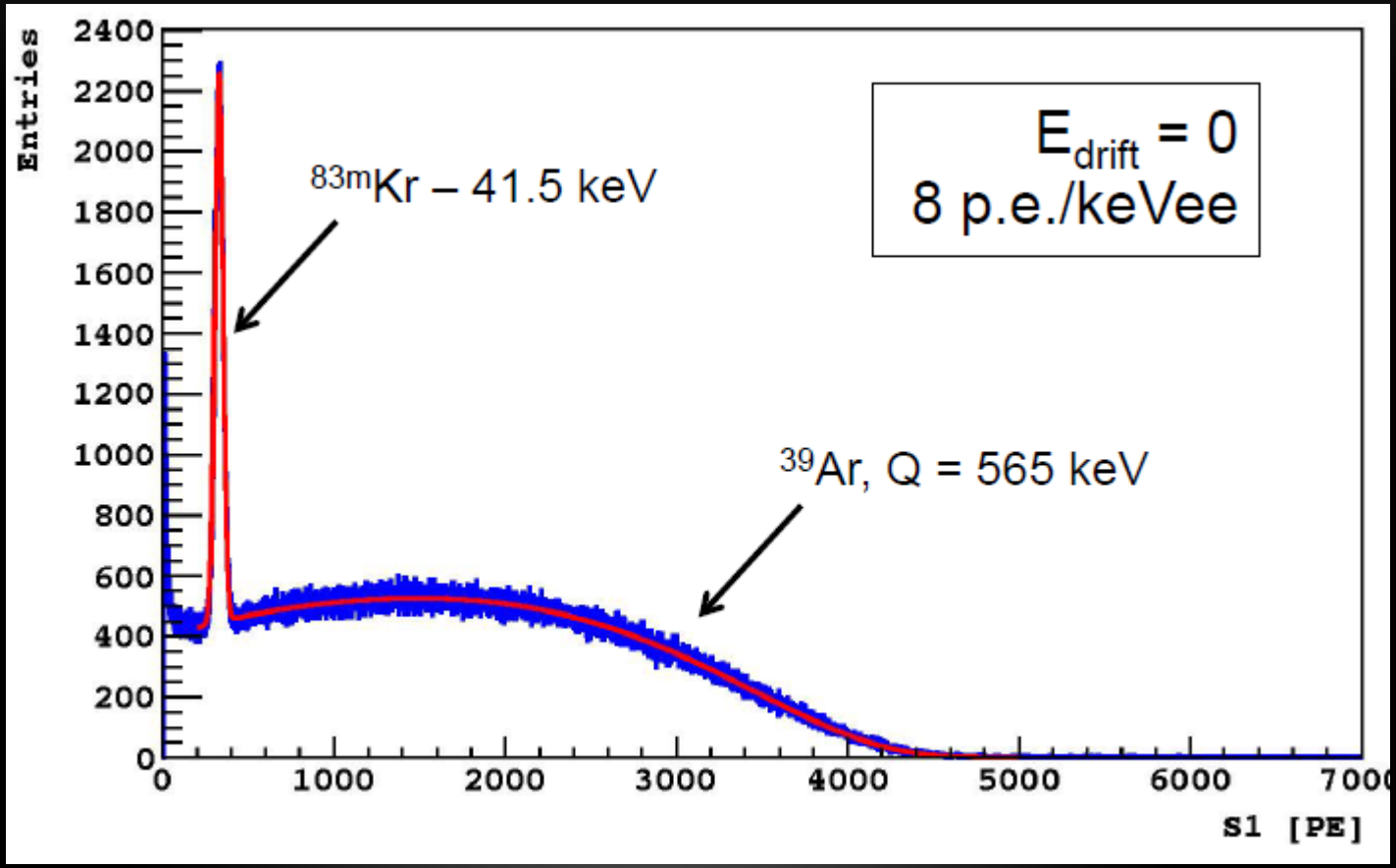




Simple discriminant: F90 = fraction of scintillation light in first 90 ns

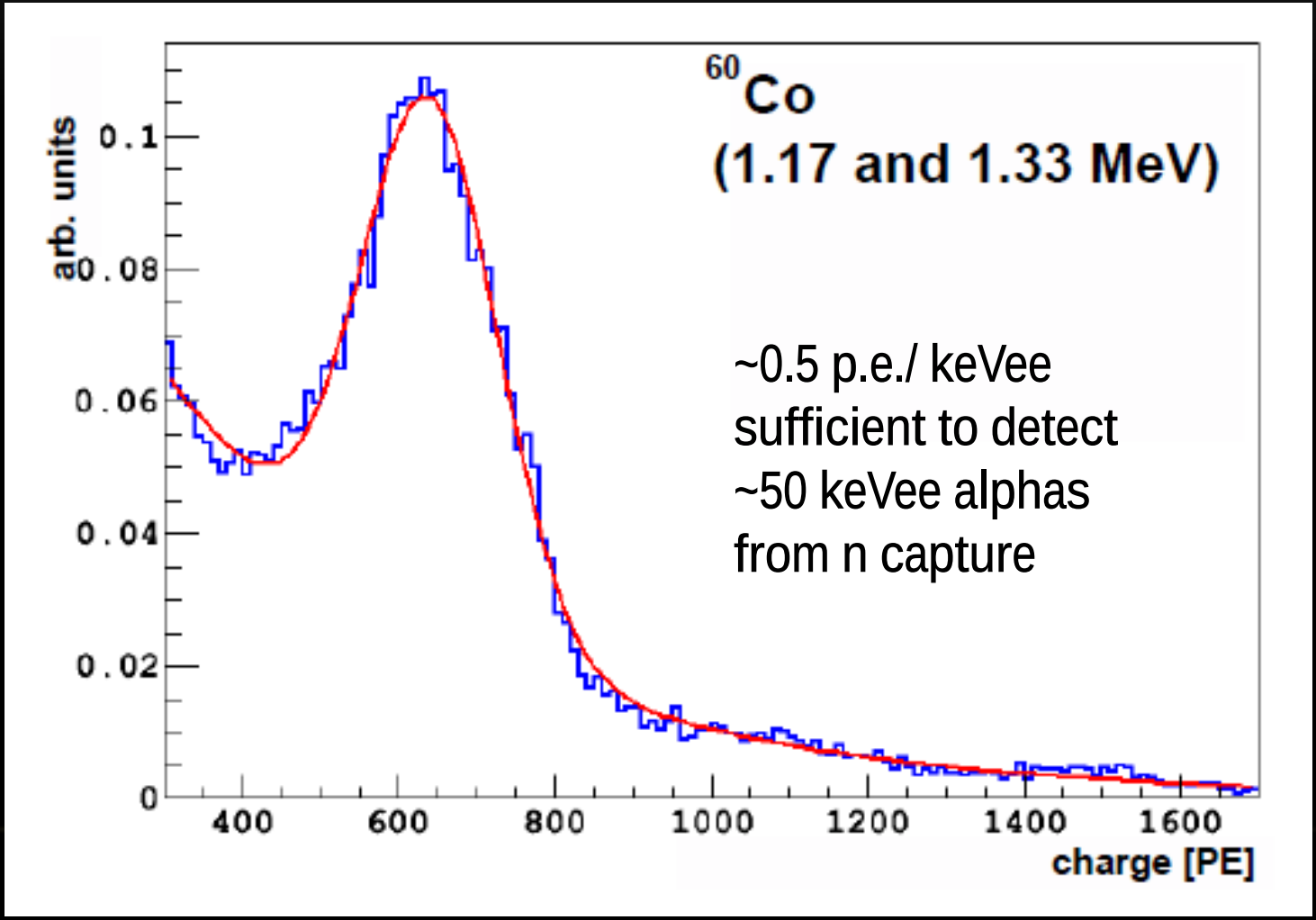
- f90 ≈ 0.7 for nuclear recoils
- f90 ≈ 0.3 for electron recoils
- Electron rejection as high as $10^8$ with sufficient p.e. statistics



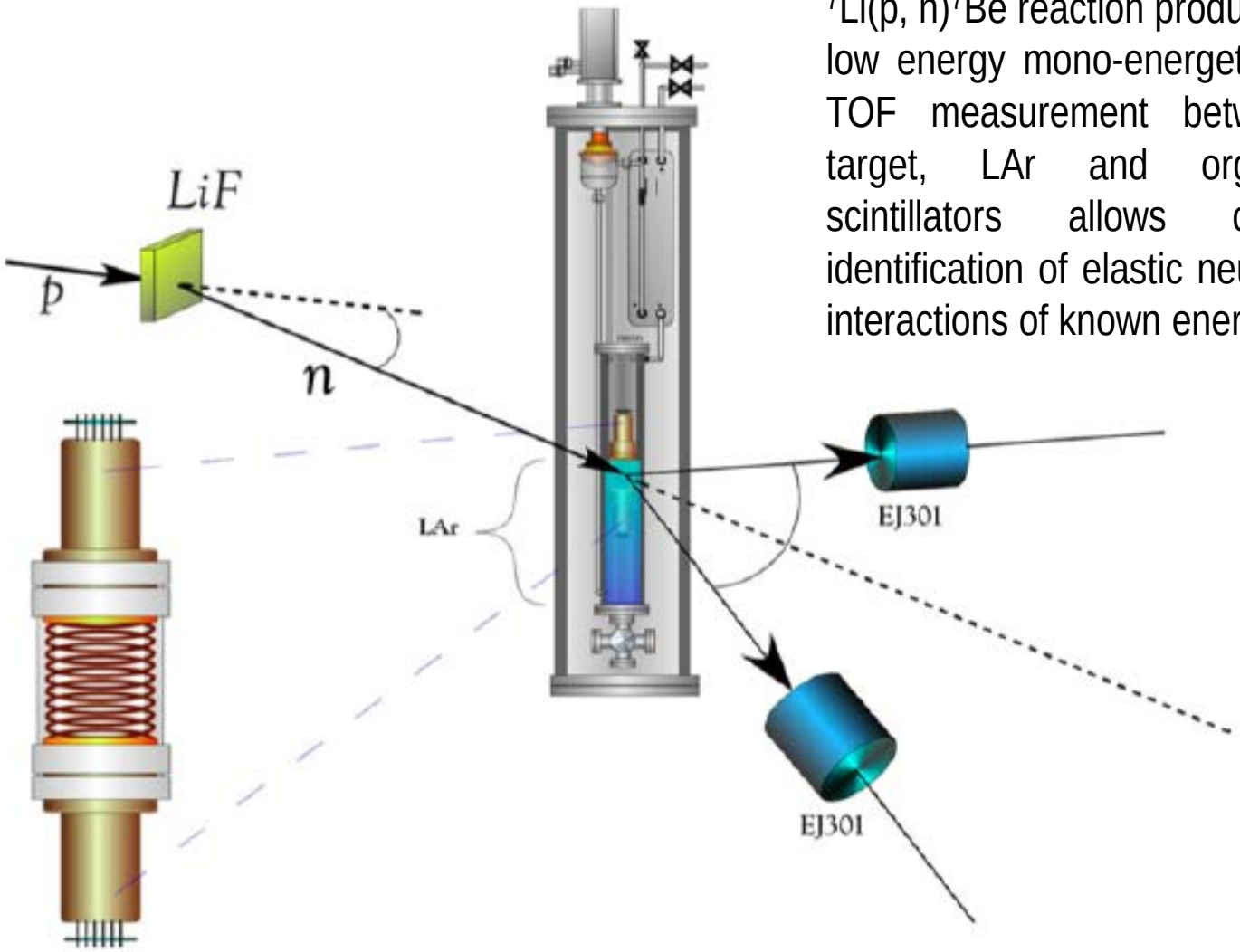
# TPC CALIBRATION



# LSV CALIBRATION



# SCENE




$^{7}Li(p, n)^{7}Be$ reaction produces low energy mono-energetic *n*. TOF measurement between target, LAr and organic scintillators allows clean identification of elastic neutron interactions of known energy