

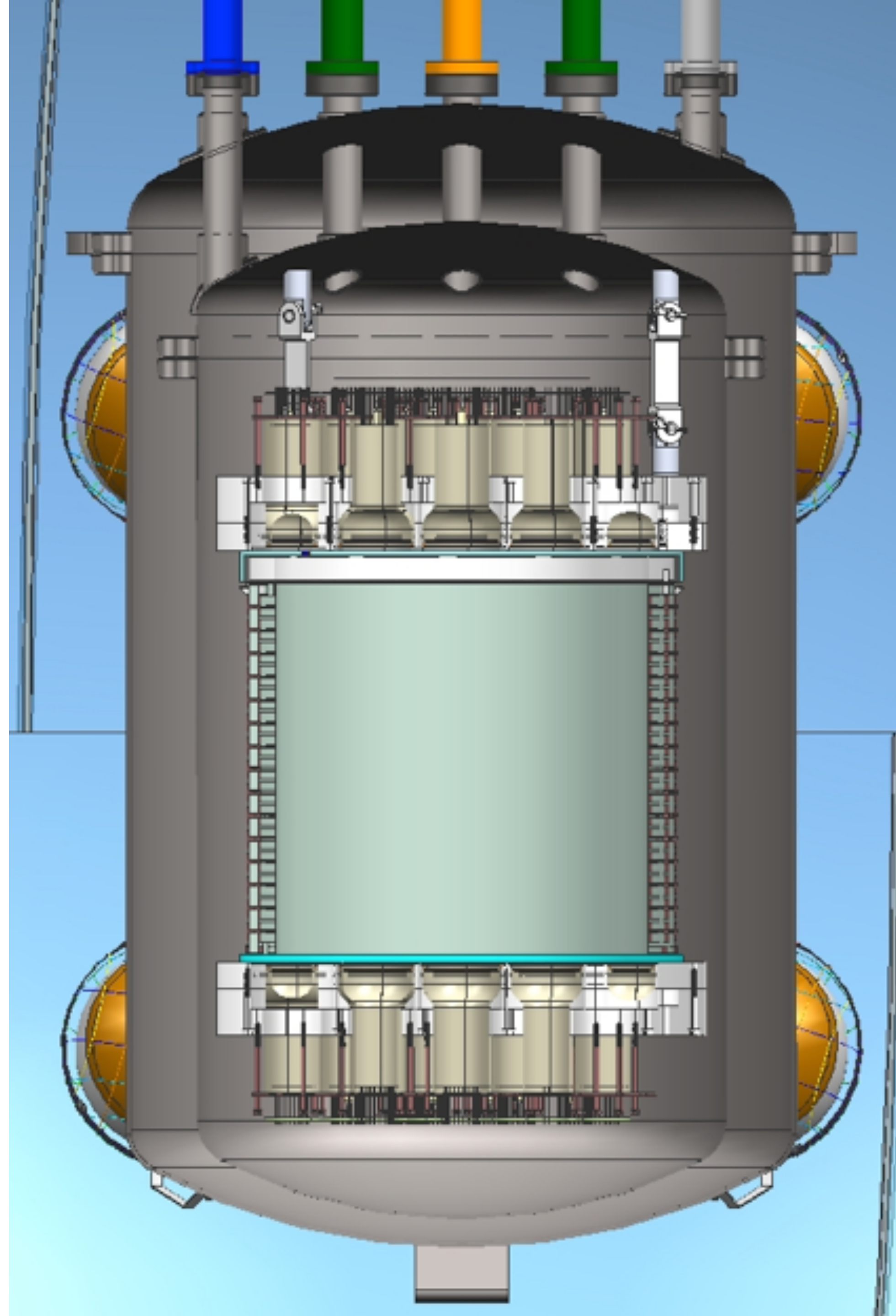
Argon 40: un'impresa complessa

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Catania
3 Dicembre 2015

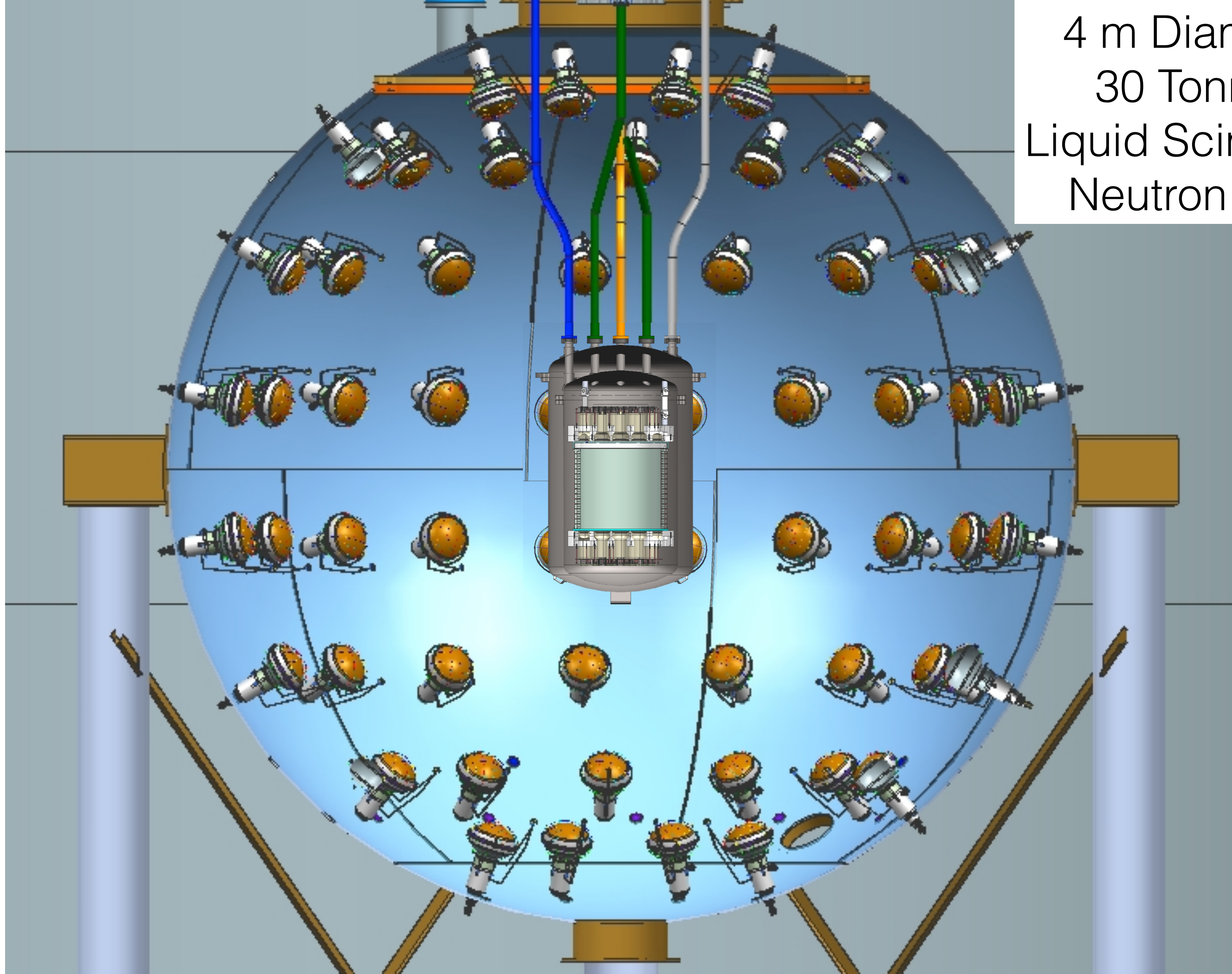
Argon40

- Ambitious program for discovery of heavy dark matter
- Raising the bar: $0.1 \text{ ton}\times\text{yr} \Rightarrow 1000 \text{ ton}\times\text{yr}$
- Complementary to LHC and raising its energy scale:
 - $500 \text{ GeV} \Rightarrow 1 \text{ TeV} \Rightarrow 10 \text{ TeV} \Rightarrow \dots$
- “Zero Background” absolutely necessary
- Argon 40 investment nets global leading position to INFN

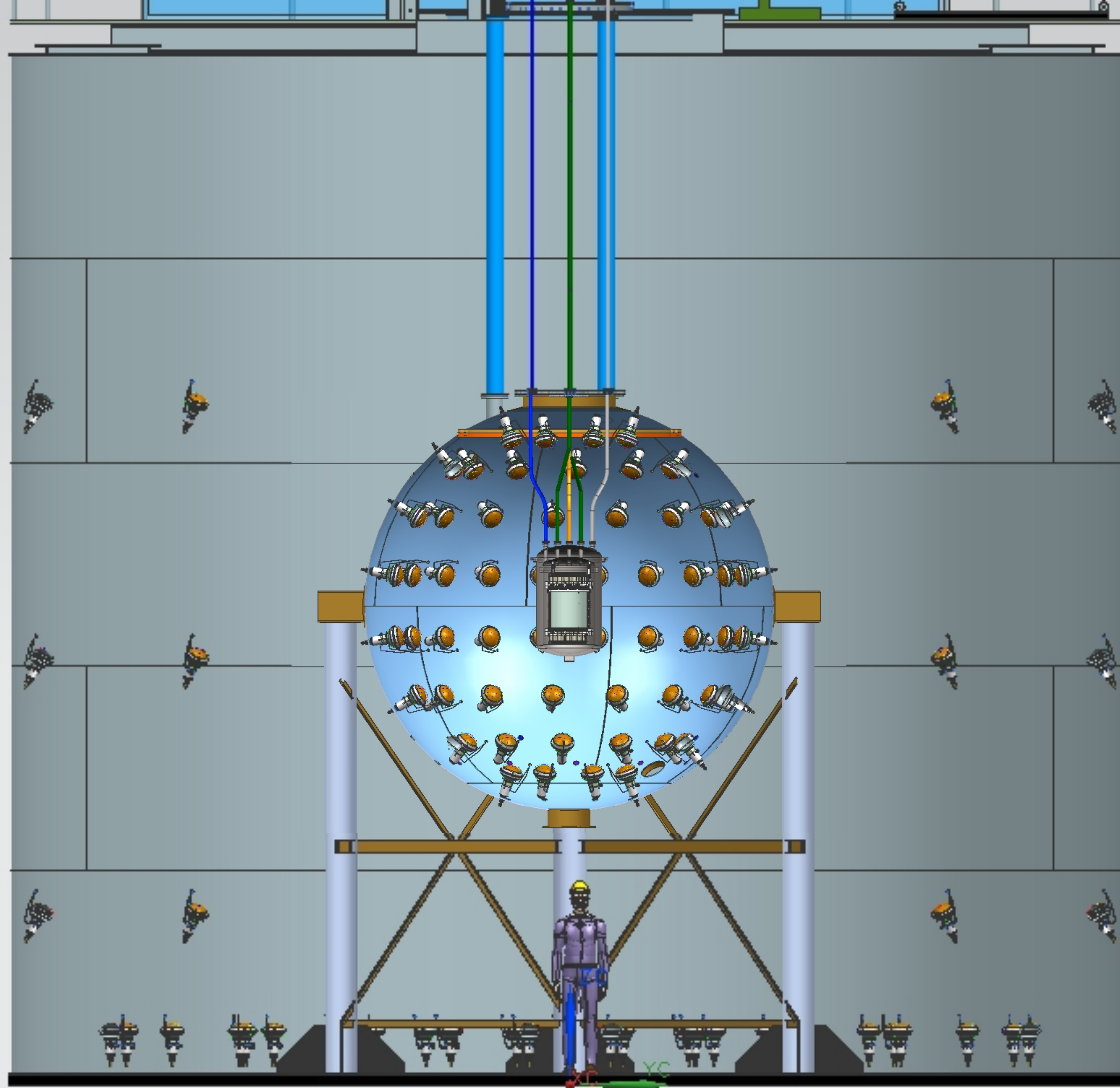
Liquid Argon TPC
153 kg ^{39}Ar -Depleted
Underground Argon
Target



4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto



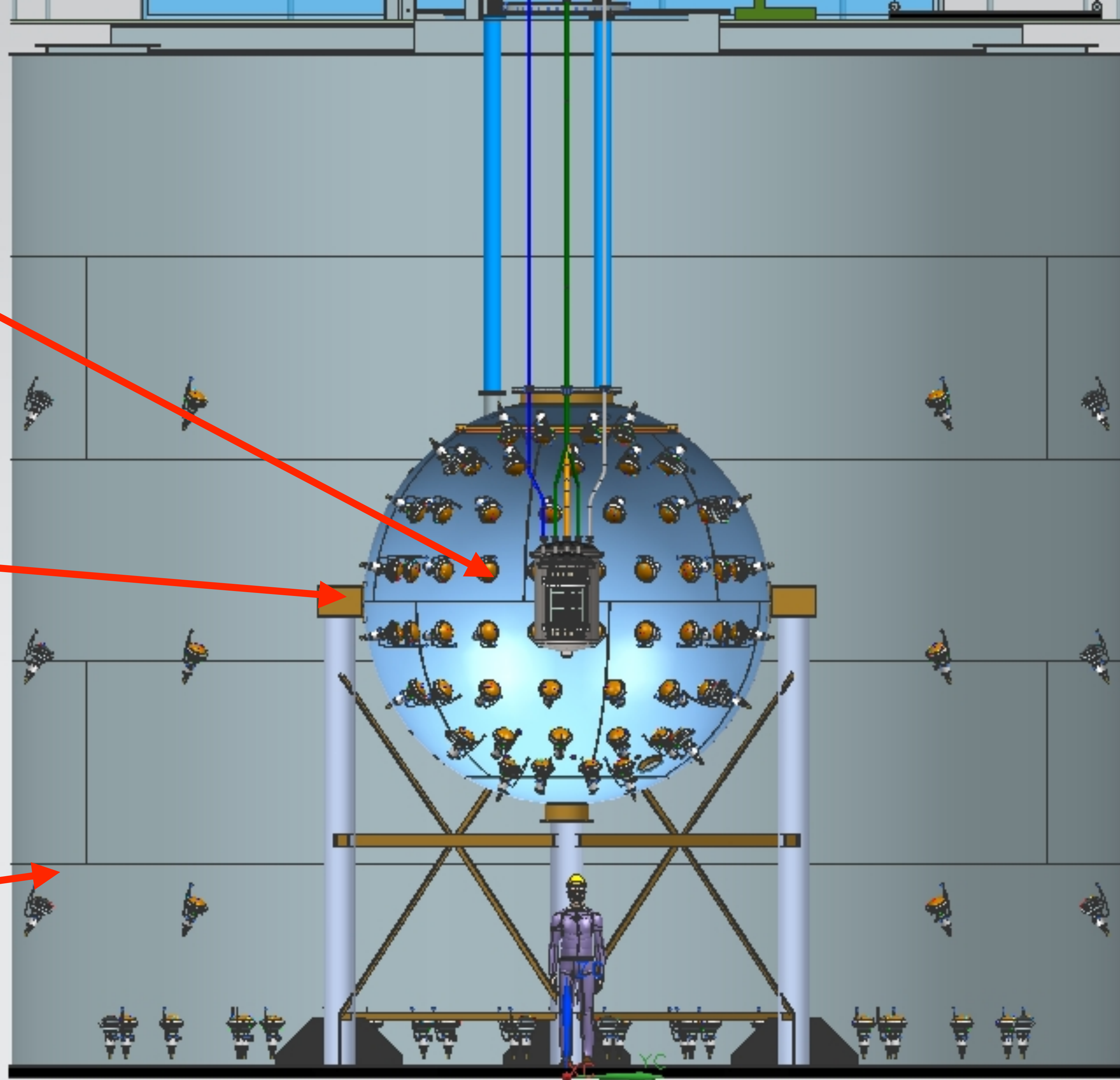
10 m Height
11 m Diameter
1,000 Tonnes
Water Cherenkov
Muon Veto



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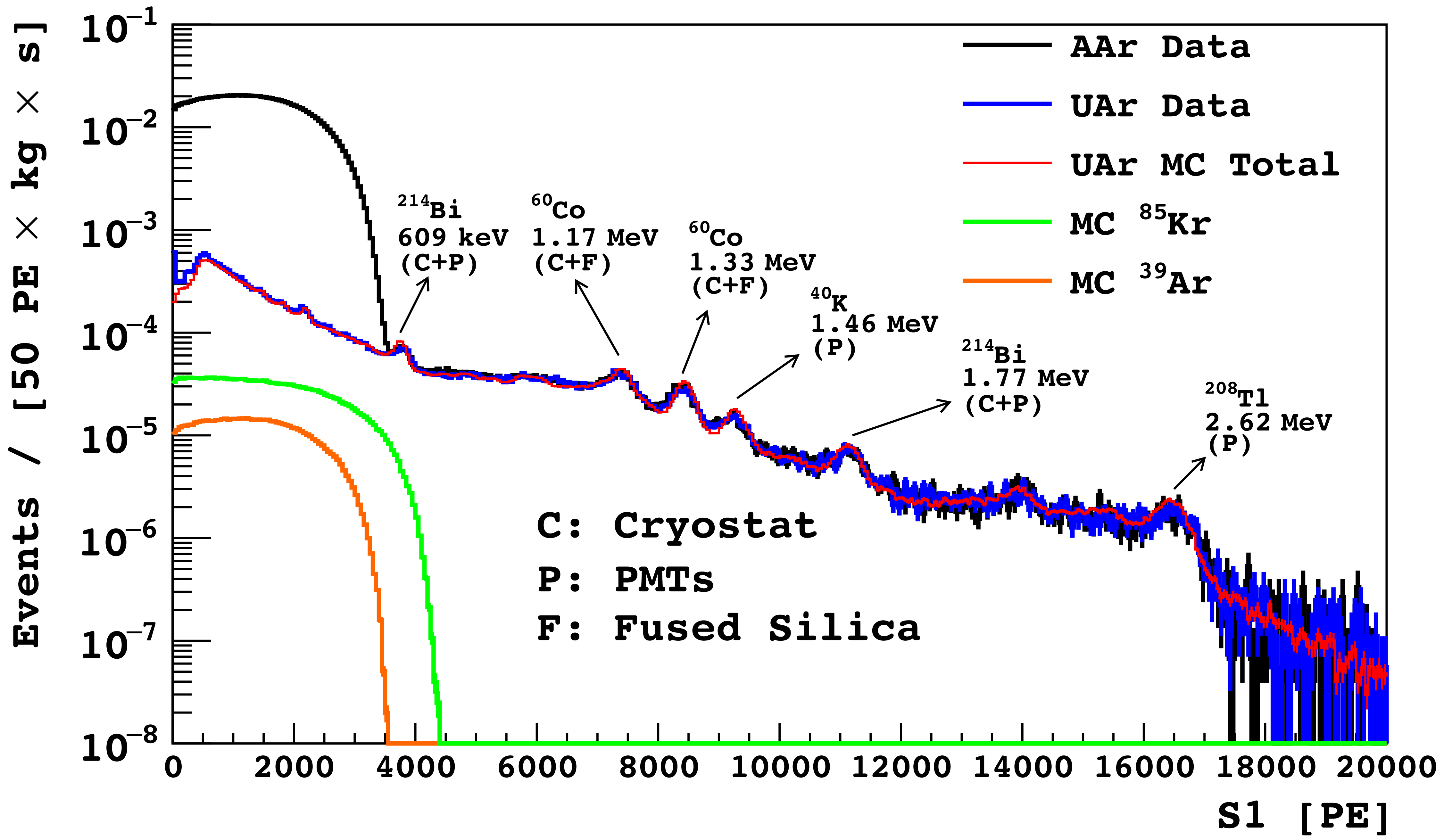
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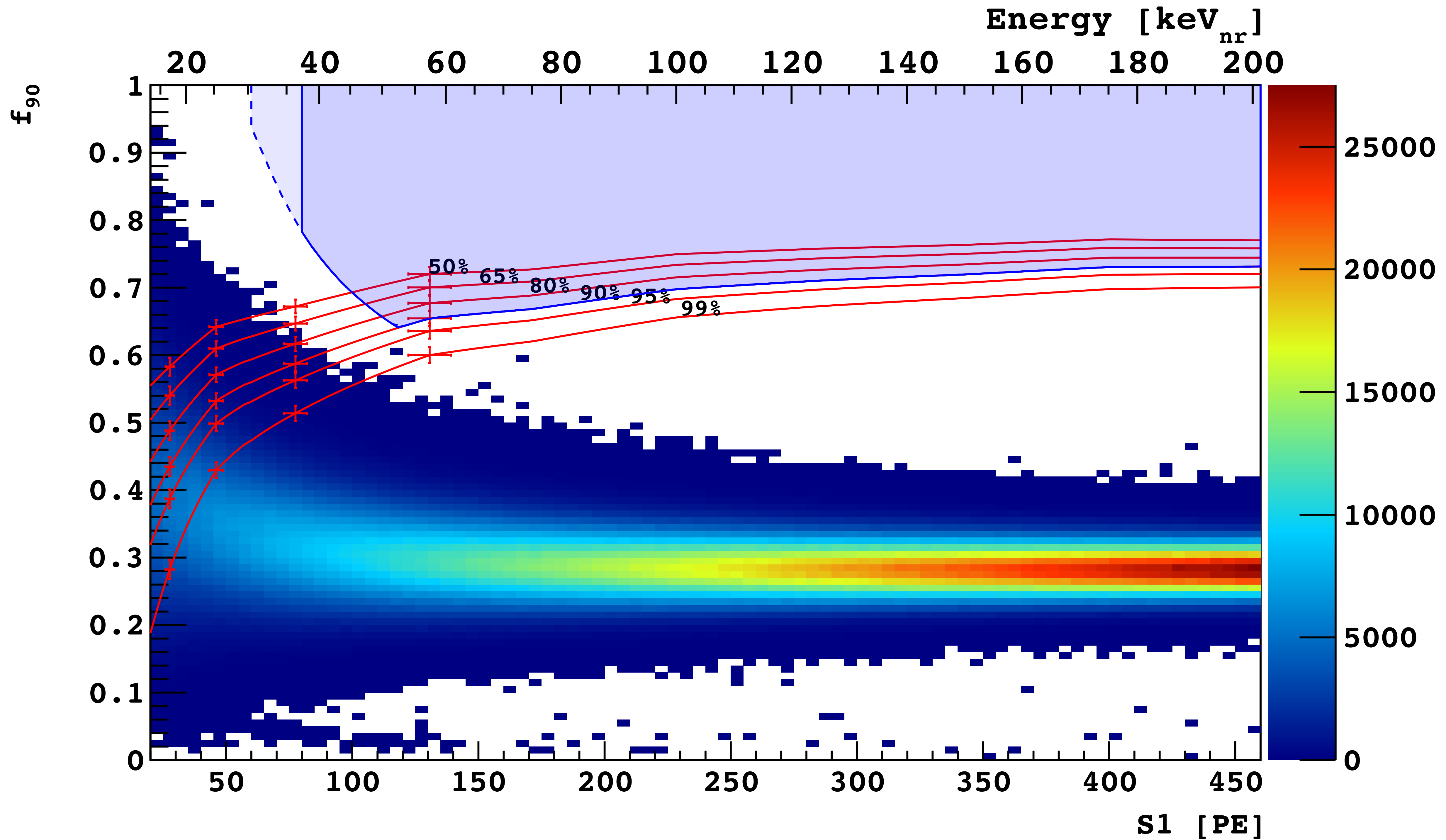


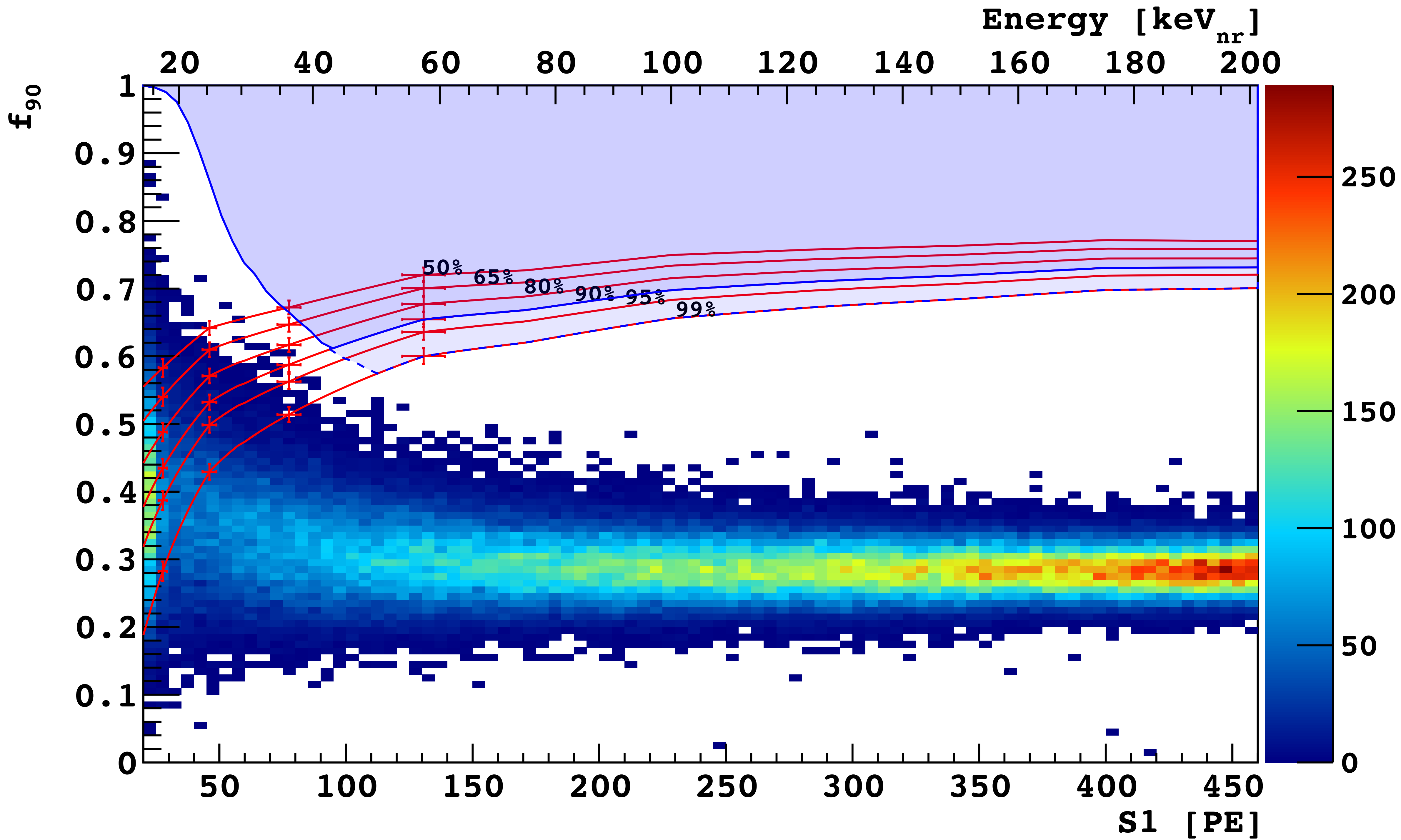
DarkSide-50 Milestones

- Oct 2013: three detectors commissioned, cryostat filled with AAr
- Oct 2014: WIMP search results with 1422 kg d AAr exposure
- Fall 2014: Calibration campaign
- Winter 2014: Refurbishment of LSV, ^{14}C rate from 150 kHz to 0.3 kHz
- Apr 2015: cryostat drained and filled with 153 kg of UAr
- Oct 2015: WIMP search results with 2616 kg d UAr exposure

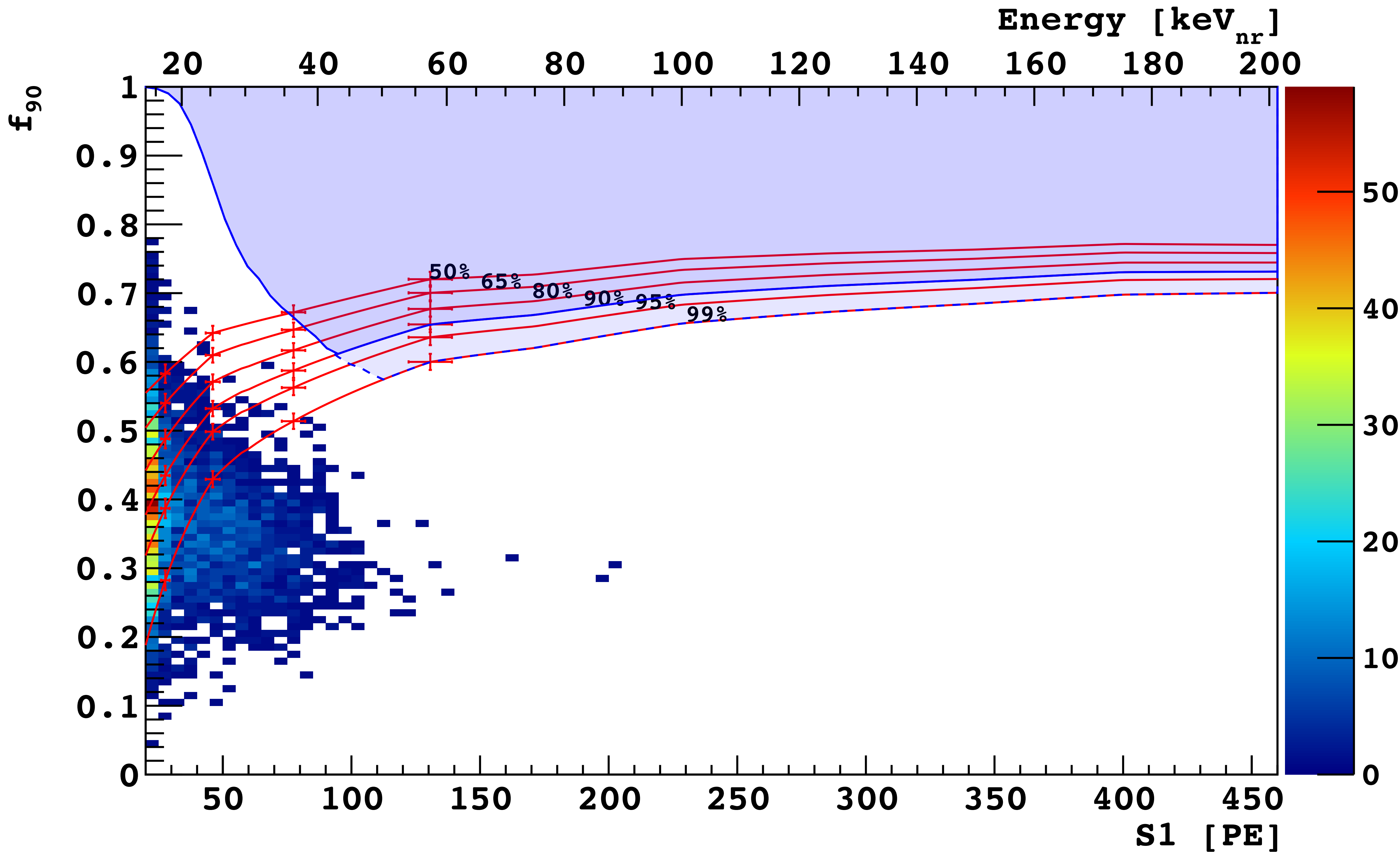


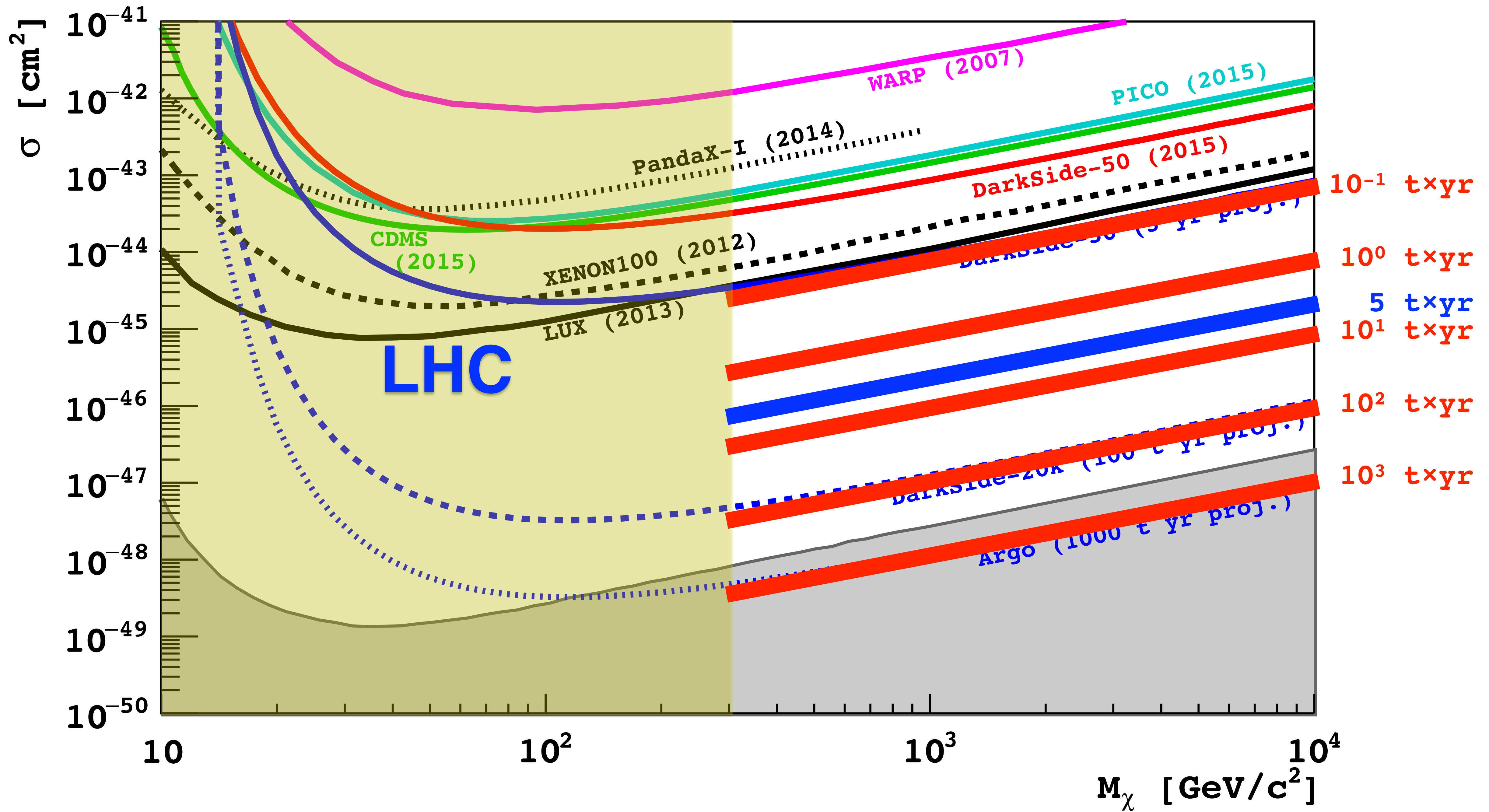
1,422 kg d AAr - PLB 743, 456 (2015)





2,616 kg d UAr - arXiv:1510.12345 (2015)





“Zero Background” condition
(<0.1 background events)
necessary to conduct
discovery program

What are the backgrounds for
large scale, high mass dark
matter searches?

Scatters of pp solar neutrinos
on electrons

Radioactive noble gases (^{39}Ar)

Elastic Scatters of pp Solar Neutrinos on Electrons

- 200 events/tonne \times yr in ROI
- 200,000 background events @neutrino floor
- Defeated in argon thanks to β/γ rejection better than $1 \div 1.6 \times 10^7$

^{39}Ar Rejection

1,422 kg×day (@AAr)

x1400
(^{39}Ar AAr/ ^{39}Ar UAr)

5.5 ton×yr (UAr)

additional active
isotopic depletion
and higher light yield

1,000 ton×yr (UAr/DAr)

Based on what we know today,
can a depleted argon
experiment be background free
at the scale of 1000 tonnes \times yr?

Yes

“Whoever controls depleted argon, controls the future of dark matter searches”

(L.P.)

Who is in control?

INFN

NSF

Impact of Basic Research on Industry



Air Products and Helium: A Success Story

- Based on research for underground argon funded by US NSF, the discovery of a sustained fraction of helium in the Kinder Morgan CO₂ stream
- A \$200 million investment by Air Products resulted in the most modern helium extraction plant
- Production started in June 2015 accounts for 15% of the total production by the US govt at the National Helium Reservoir

Cryogenic Distillation Column at Fermilab



Goals of Future Program

- Procurement of 30 tonnes by 2020 in support of DarkSide-20k
 - 100 tonne \times yr background free exposure for dark matter
- Procurement of 300 tonnes by 2030 in support of Argo
 - 1000 tonne \times yr background free exposure for dark matter
 - Precision solar neutrino measurements
- Possible procurement of larger quantities to enable solar and supernova relic neutrino physics in DUNE

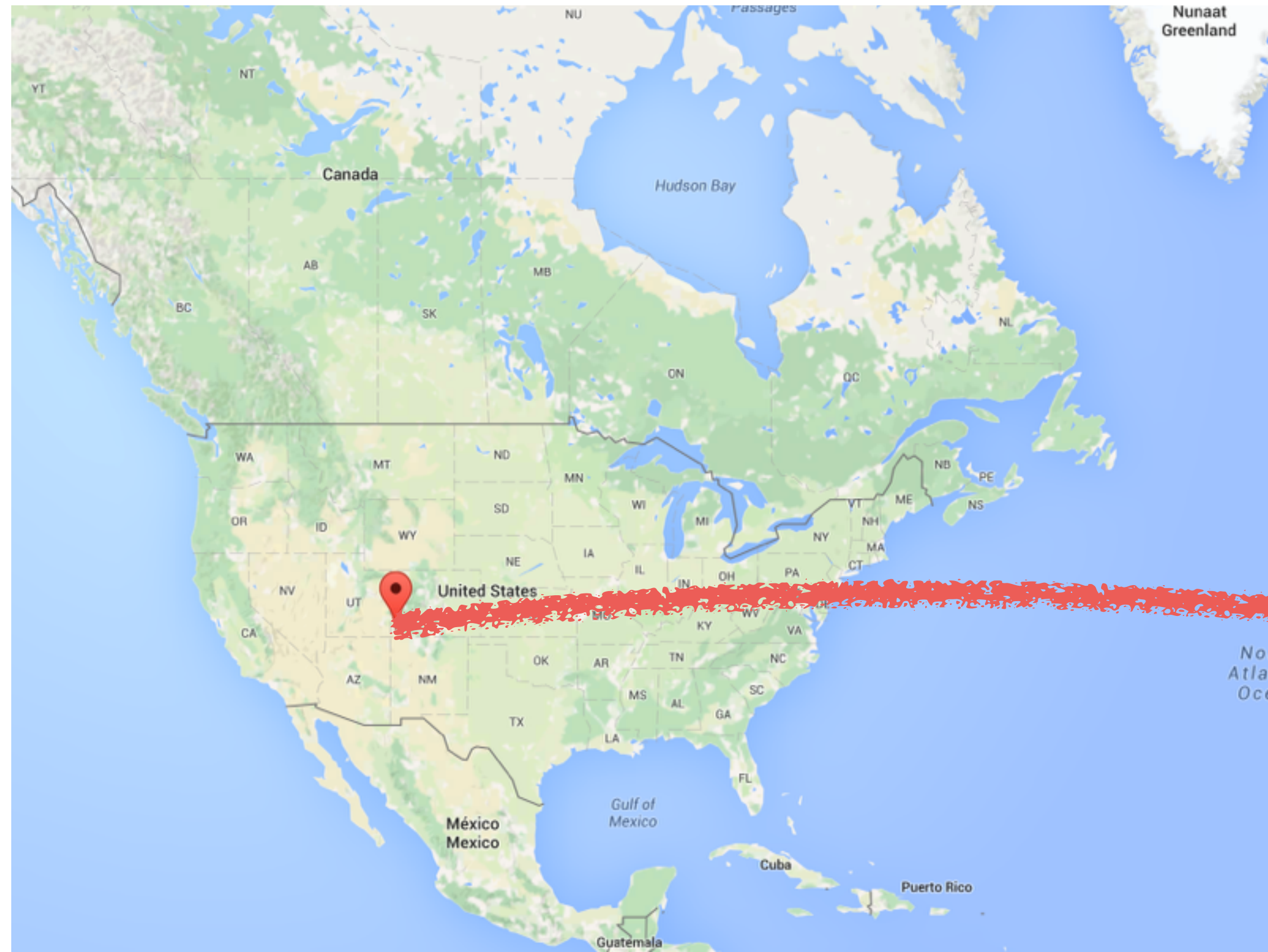
Urania

- The goal is to build a plant capable of extracting UAr at a rate of about 100 kg/d from the Cortez, CO source
- Cooperation with Air Products and utilization of a premium stream from their He extraction plant may result in a significant boost of production with the same plant

Argon Purification Unit

- A set of elemental process units:
 - The first cryogenic column removes the bulk of CO₂ and CH₄
 - The Pressure Swing Adsorption columns removes the traces of CO₂ and CH₄
 - The second cryogenic column removes N₂ and He
 - The third cryogenic column refines the argon-rich stream detector-grade argon

Urania to Aria to LNGS



Aria

- The purpose of Aria is the reduction of ^{39}Ar in the target of the DarkSide detectors
- The method of isotopic separation is cryogenic distillation
- The project is supported by INFN, US NSF, and Regione Autonoma della Sardegna

Isotope Vapor Pressure

- First measurements of relative volatility of argon isotopes by Boato and Scoles in the 1960's
- Detailed measurements of the $p(^{36}\text{Ar})/p(^{40}\text{Ar})$ relative volatility
- General model to calculate the vapor pressure ratio of argon isotope developed by Fieschi and Terzi
- Small difference in ratio of volatilities $O(10^{-3})$ requires thousands of equilibrium stages

Seruci Wells



Seruci in Sardinia an excellent location





5

1

4

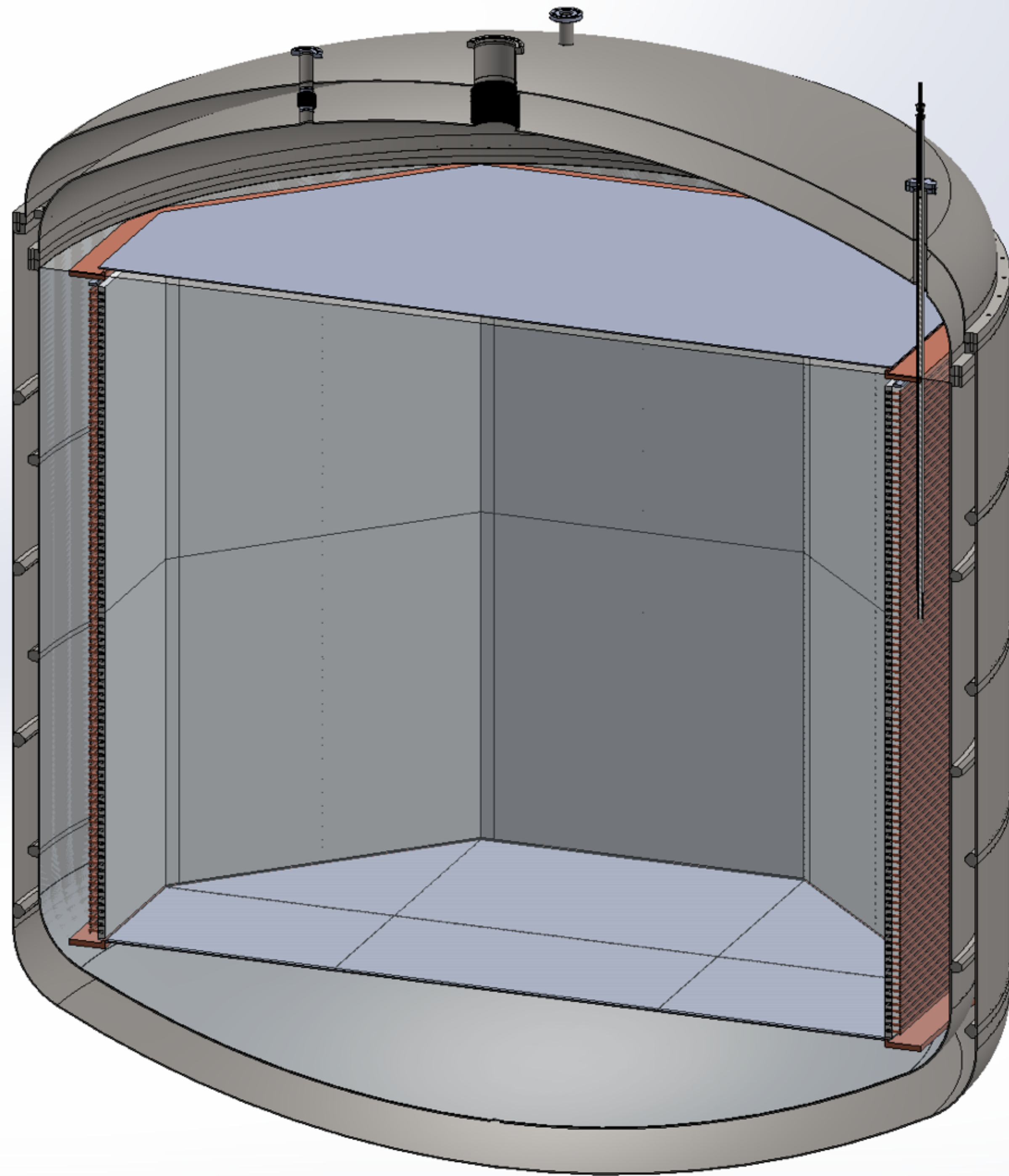
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DarkSide-20k: Proposal to INFN and NSF December 4, 2015





The End