DS-20k- The Next Step With LAr

Other DarkSide talks at this conference:

A. Fan DS-50 Results (9:40 AM)

P. Agnes g4ds The DarkSide Monte-Carlo (16:30)

B. Rossi SiPM for DS-20k (16:15)

The DarkSide Program Over Time

- 2010-2012; **DS-10** at Princeton-> LNGS
  10 kg normal Ar
  not radiopure, water-block shielding, 8 PMTs

- 2013-present; **DS-50** at LNGS
  153 kg total, 36.9 kg fiducial
  radiopure construction, UAr target (arXiv 1204.6024; see below)
  high efficiency neutron shield/veto
  currently: > 4000 kg-day analyzed, planned exposure 3 years
  8.6×10^{-44} cm^2 @ 1 TeV/c^2, world's 3rd best current limit

- ~2020 **DS-20k** at LNGS (proposed to NSF & INFN 2015)
  30 ton total, 20 ton fiducial
  radiopure construction, DAr target (see below), SiPM sensors
  high efficiency neutron shield/veto
  100 ton-year planned exposure
  $10^{-47}(10^{-46})$ cm^2 at 1(10) Tev/c^2

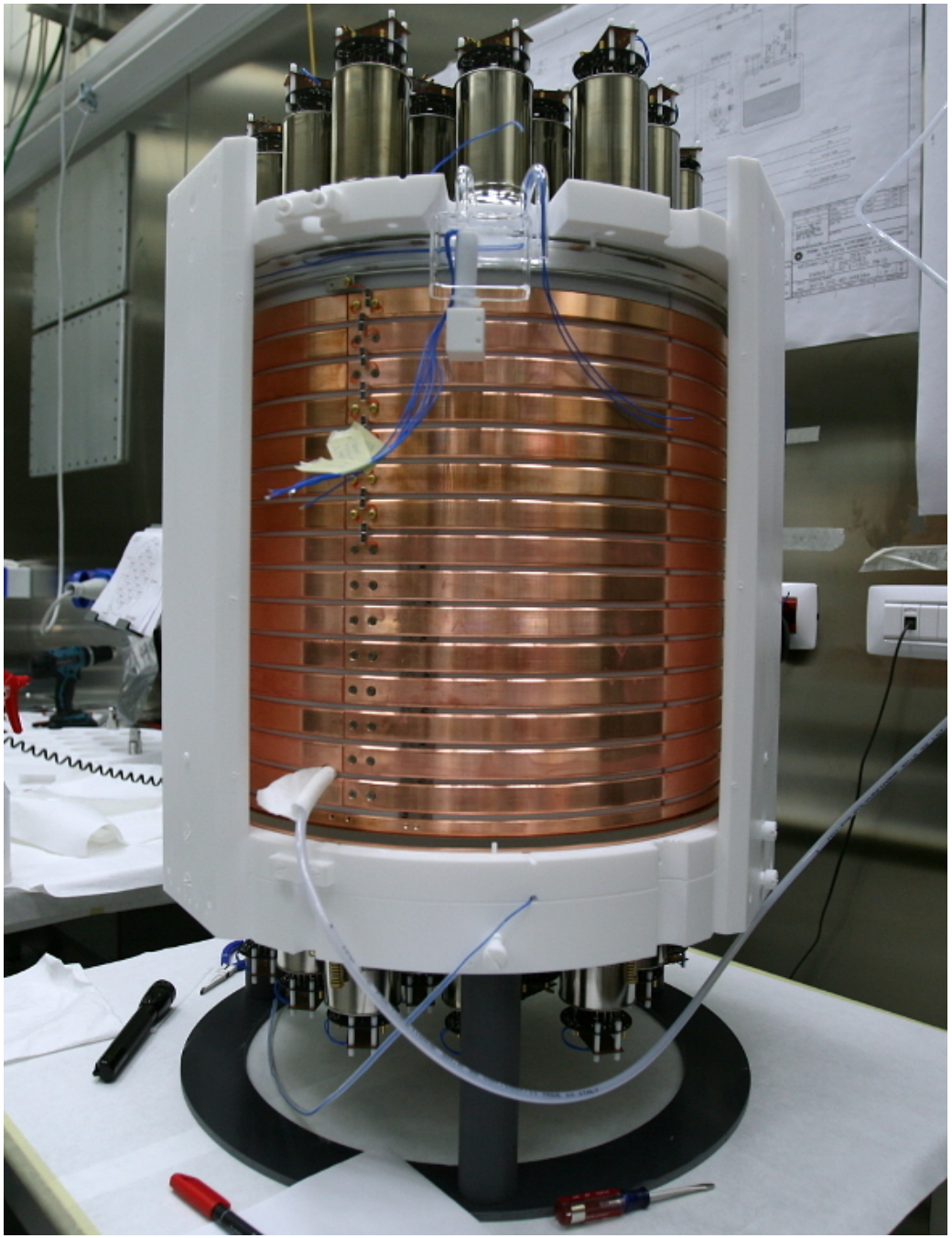
- 202x **ARGO** at LNGS
  1000 ton-year planned exposure
  to reach the solar ν coherent scattering floor
  detailed solar ν studies possible (arXiv 1510.04196)

DS-50 Short Summary

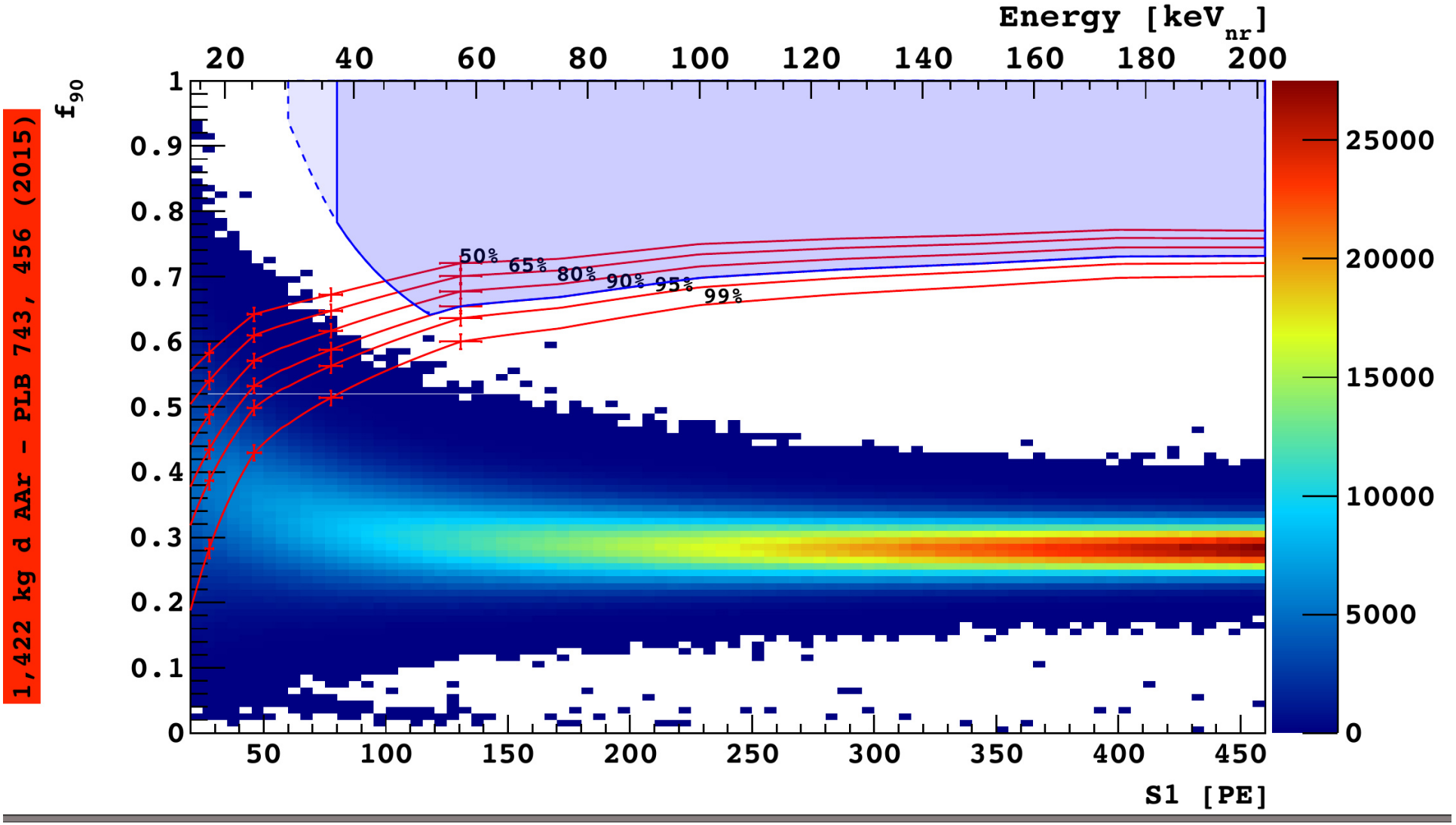
DS-50 is a **background-free** WIMP search as well as a technology demonstrator. Key achievements of DS-50 include (see A. Fan talk this morning for details):

- **PID at 99.999985% level** (1.5e-7 mis-ID) with (mostly) 90+% NR acceptance
- **Radon-suppressed cleanroom** assembly
- Production and use of **153 kg UAr** target, containing ^{39}Ar at 1/1400 of AAr
- Rock-steady, ultra-pure cryo systems with external recirc loop & active cooling
- **Neutron shield/veto system** with 99+% neutron veto efficiency (arXiv 1512.07896)
- 38-channel **cold preamps** with S/N ~25 :1 at 1 PE
- Acquisition & analysis of (currently) **> 650 TB of data (u to 7 TB/day)**

These elements enable a design for DS-20k, to reach 100 ton-year **background-free** exposure and limits of $10^{-47}(10^{-46})$ cm^2 at 1(10) TeV/c^2

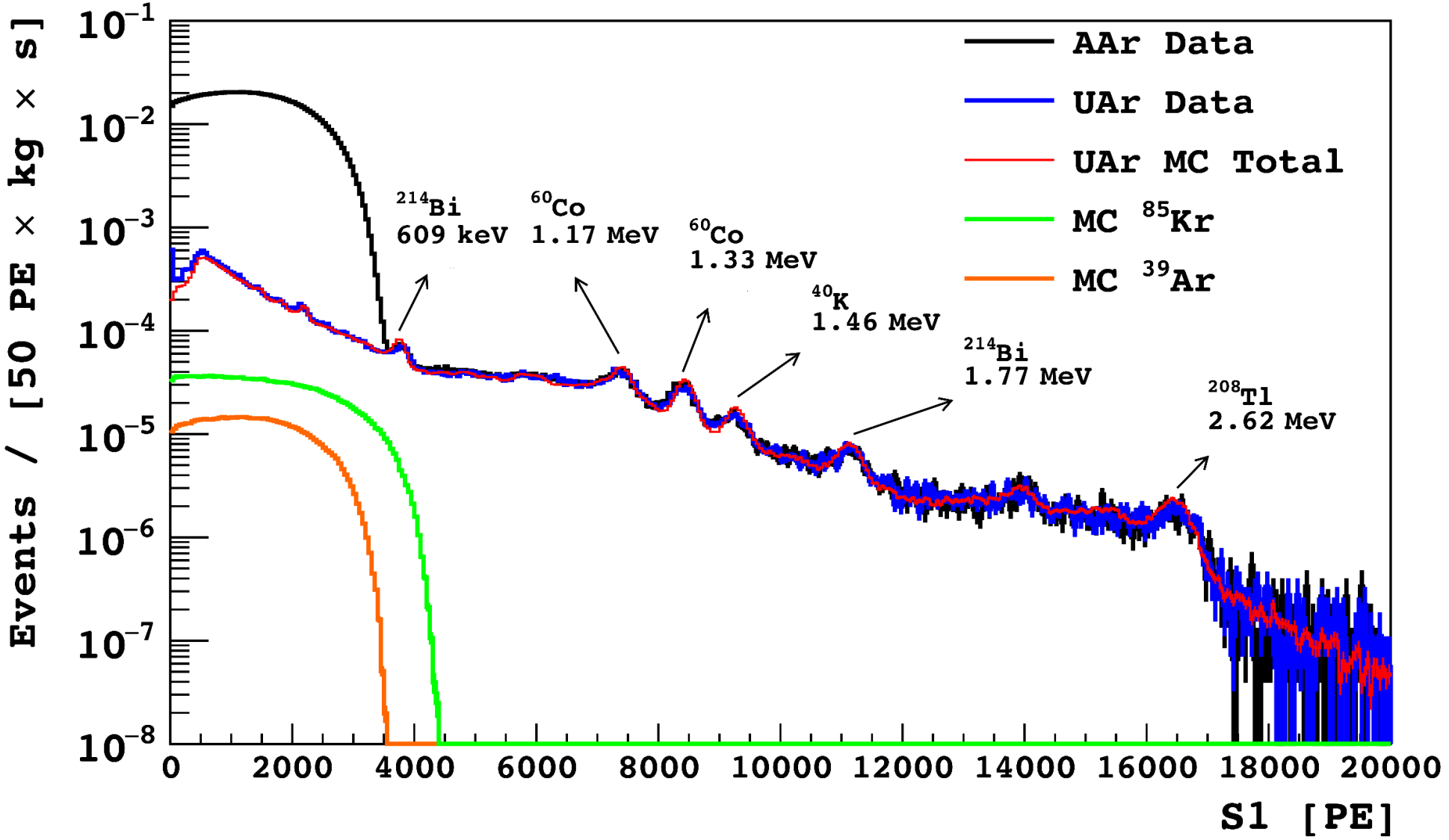


DS-50 PID



1422 kg d **background free** AAr exposure
1.5×10^7 electron recoil events from 1 Bq/kg ^{39}Ar
Zero nuclear recoil candidates in box; expect < 0.1

DS-50 UAr



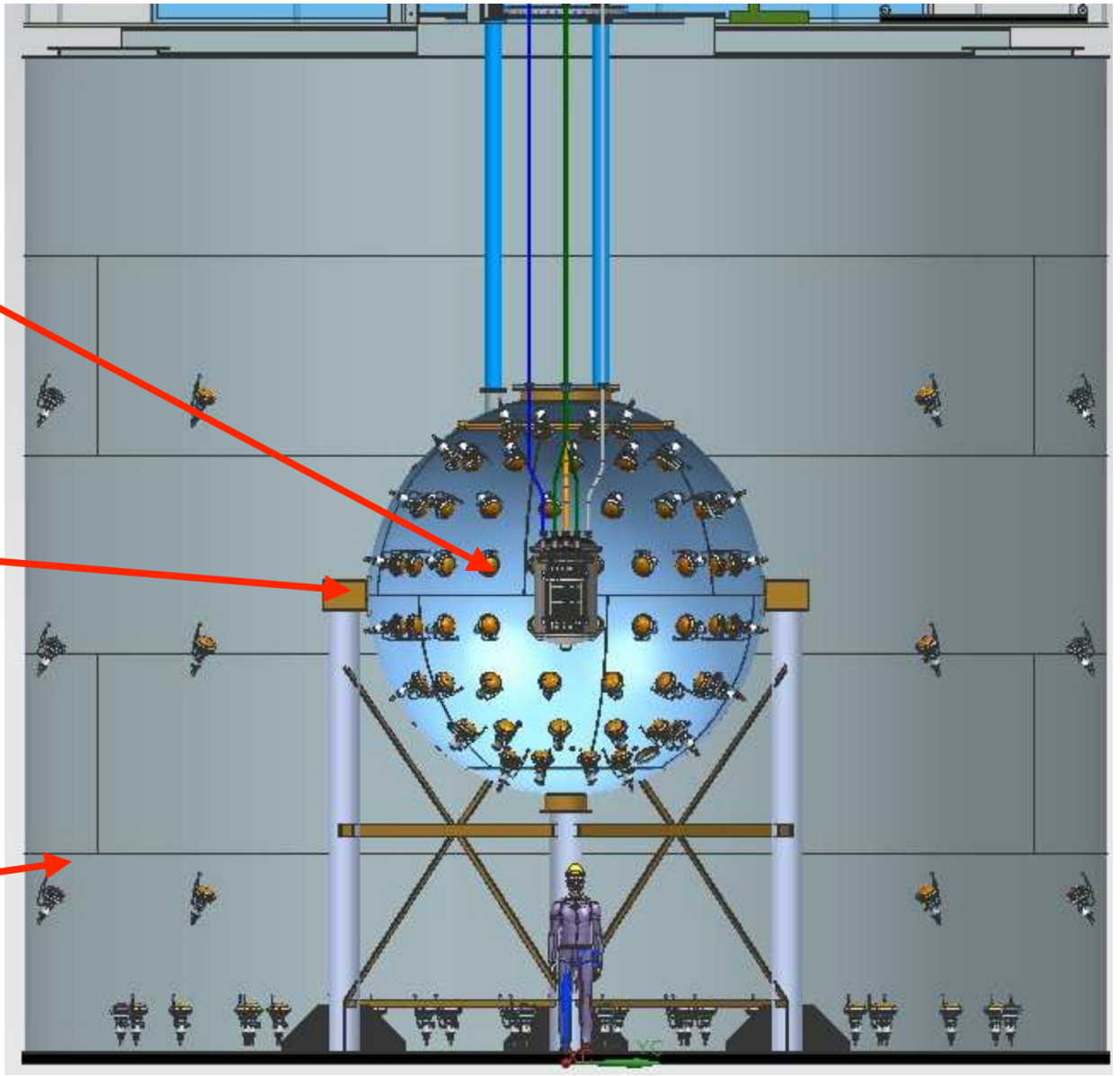
- 153 kg extracted, purified, shipped by sea FNAL-> LNGS
- This spectrum taken with drift field off to improve γ-ray resolution
- Identified γ-ray lines from cryostat & PMT's (identical to AAr case)

DS-50 Neutron Shield/Veto

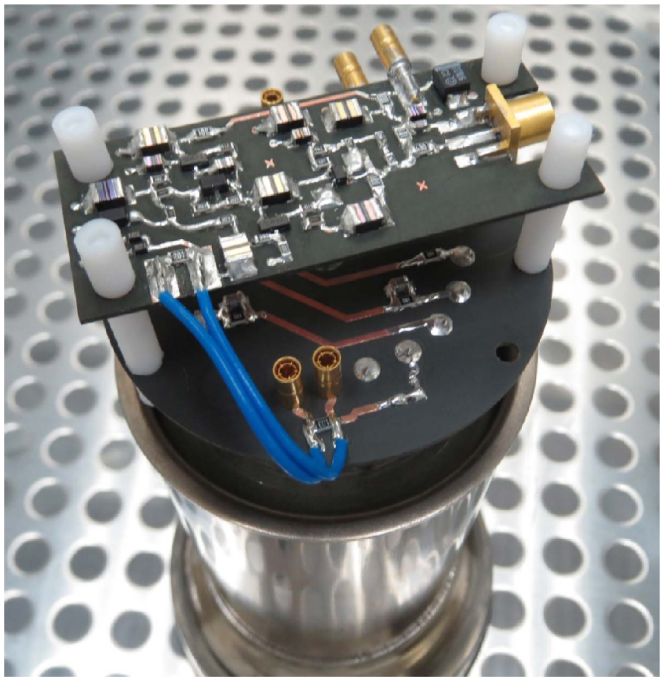
Liquid Argon TPC
153 kg ^{39}Ar-Depleted
Underground Argon
Target

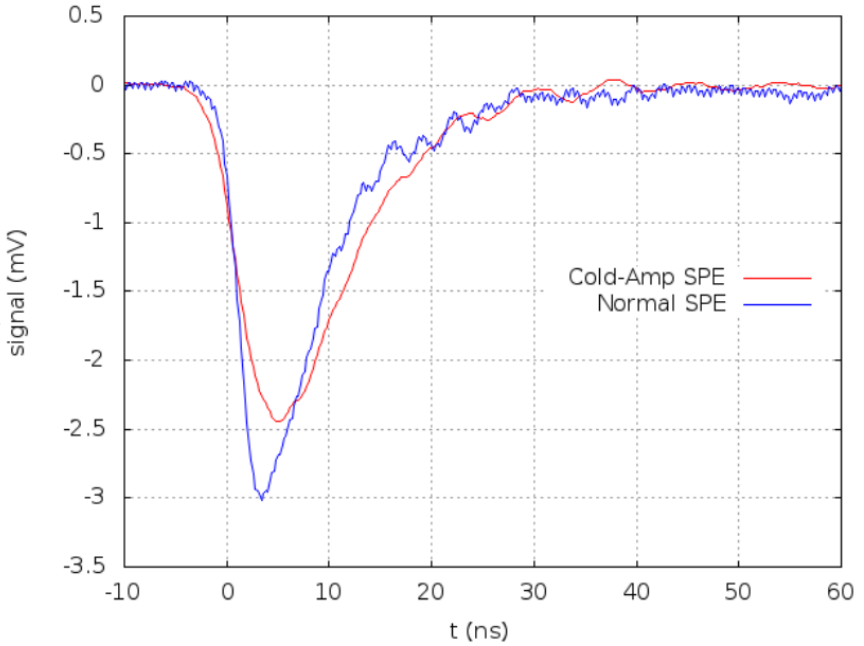
4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto

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



DS-50 Cold Electronics

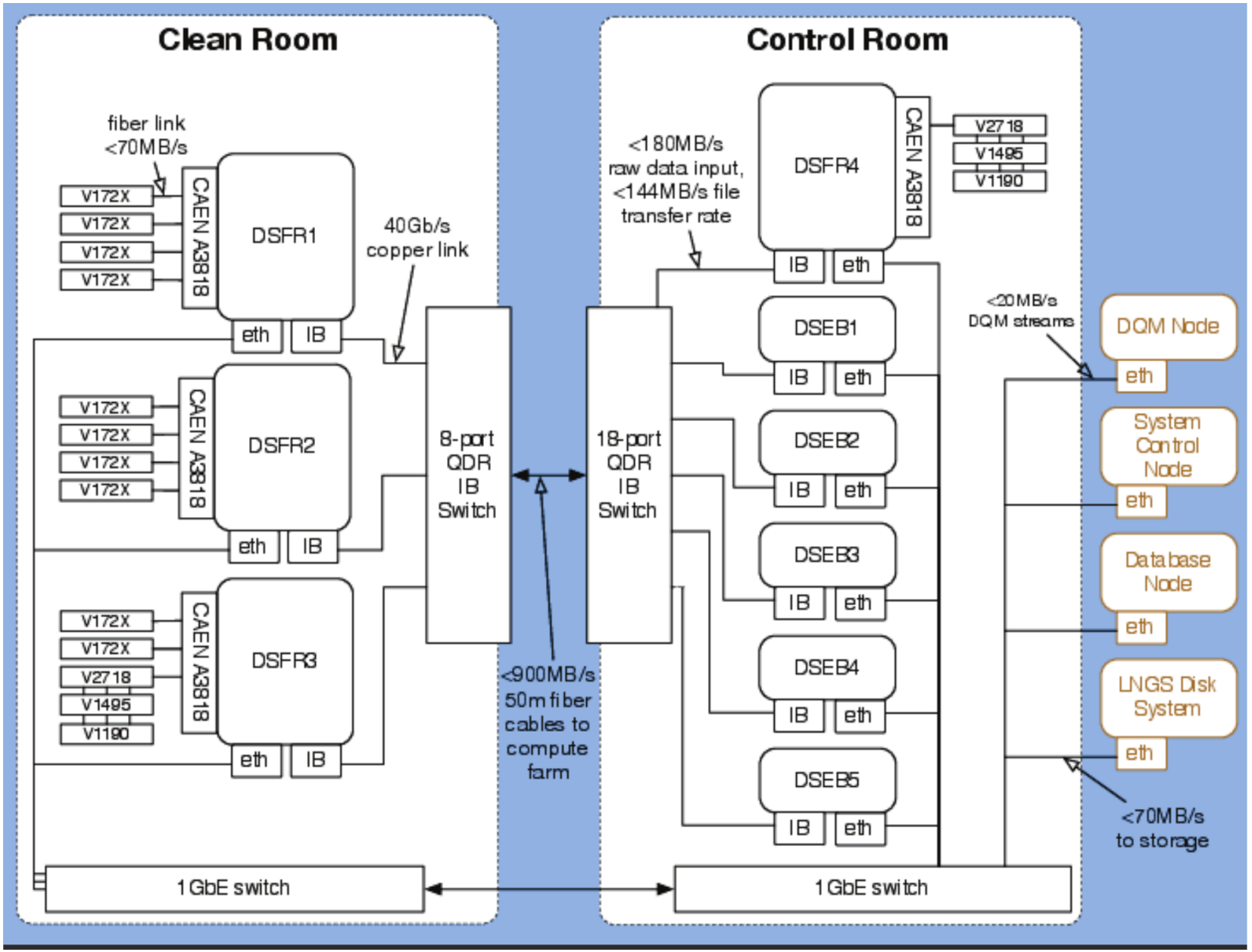




SPE pulse w/ & w/o amp

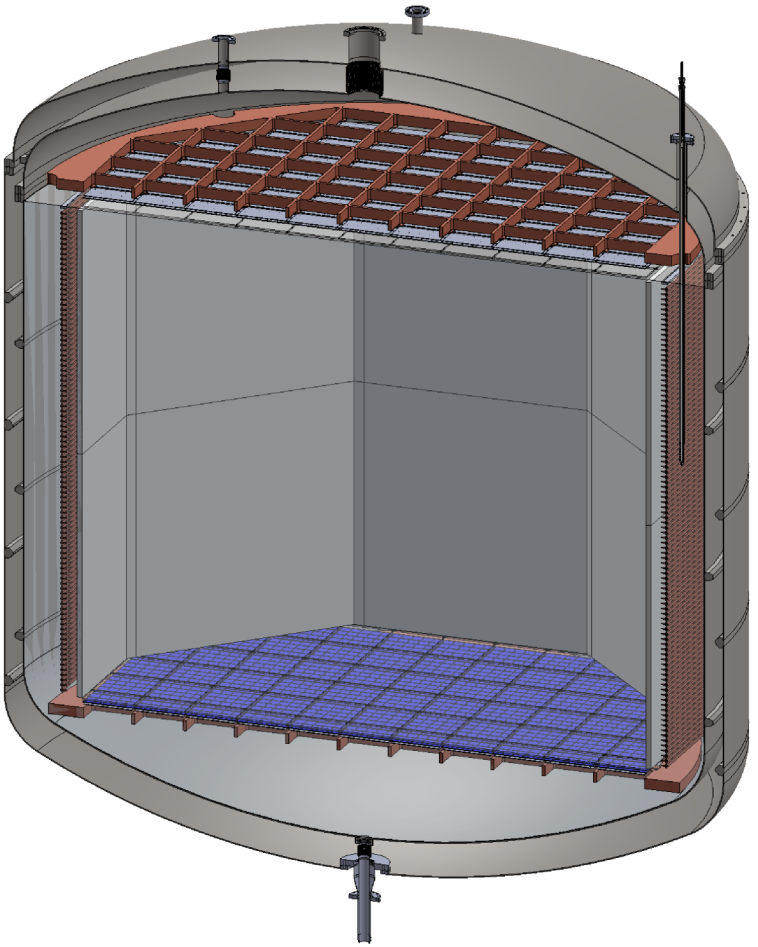
- Transimpedance amplifier & cable driver for Hamamatsu R11065 PMT's
- Effective gain 7 V/V compared to PMT alone
- Runs immersed in LAr
- Designed & fabricated by LNGS-UH

DS-50 7 TB/day DAQ

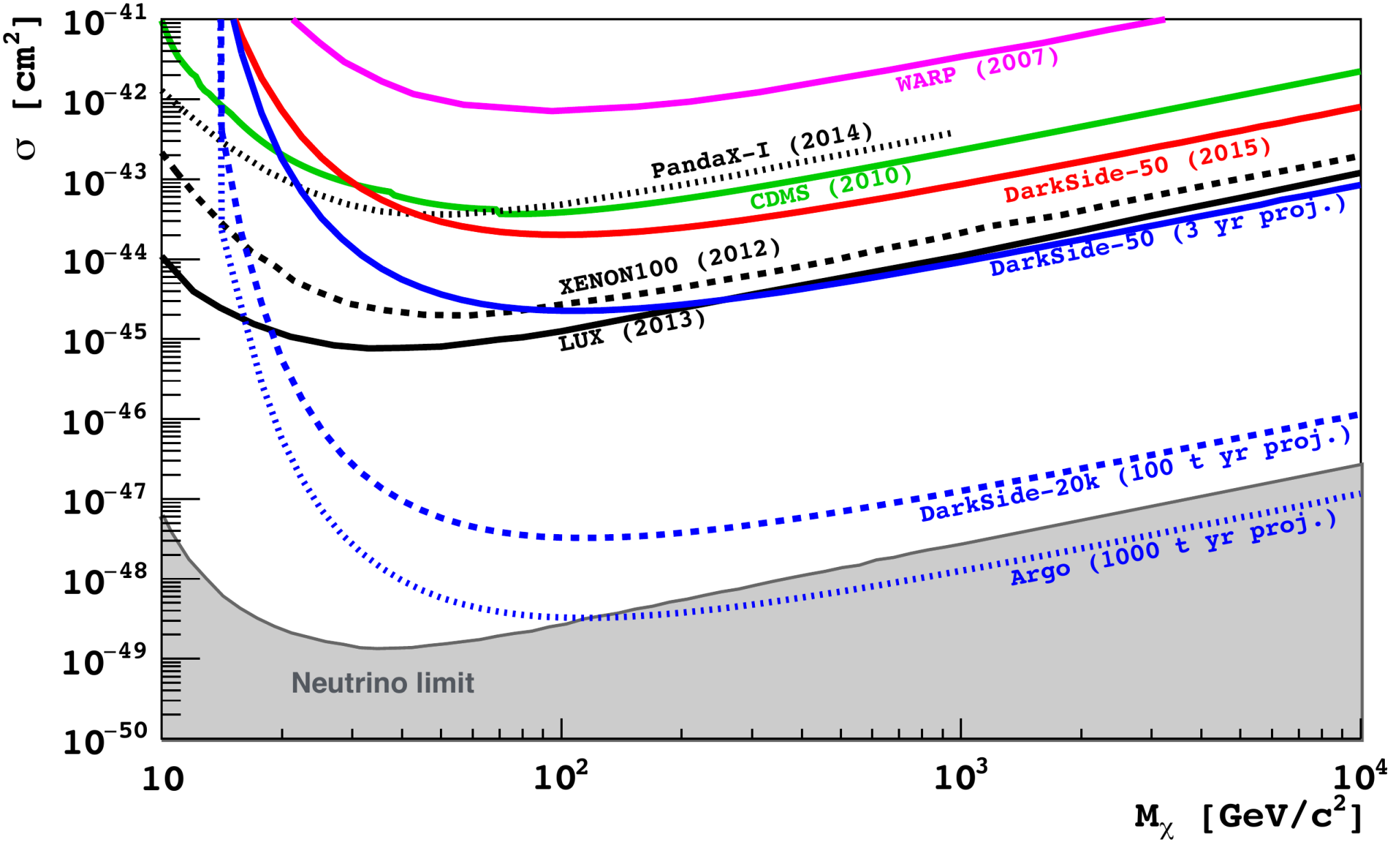


DS-20k Basic Parameters

- Proposals to NSF, INFN Dec. 2015
- Active volume 356 cm diameter, 241 cm tall
- DAr fill (see below) 23(20) Tonne active(fiducial)
- 50 KV total HHV
- SiPM light detectors top & bottom, immersed in LAr
- New LSV + WCD veto system (LSV essential for radiogenic neutrons)
- New INFN-funded UAr & DAr plants
- Aiming for:
  100 ton-yr **background free** exposure
  $\sigma(WN) < 10^{-47}$ (10^{-46}) cm^2 at 1(10) TeV/c^2



DS-20k Projected Limits



DS-20k **Background (-free)** Budget

- Based on **detailed Geant4/FLUKA MC**
  - Radionuclide contents from DS-50 materials assays
  - Cosmic ray muons from accurate LNGS simulation (arXiv 1406.6081)
  - >>100 ton yr exposure simulated

- **ER**:
  - dominated by **^{39}Ar**
    - with DS-50 PSD, require rate reduction x.01 from UAr
      Aria project "DAr" to provide this, see below
  - **^{85}Kr:**
    - with DS-50 PSD, neglibible after one extra distillation of UAr
  - **Cryostat, etc. gamma rays** negligible with DS-50 PSD
  - **Radon daughters** in LAr:
    - **~μBq/kg** measured in DS-50; negligible with DS-50 PSD
  - **ν_{solar}-e scattering:**
    - ~2x10^4 ER in exposure(!); negligible after DS-50 PSD

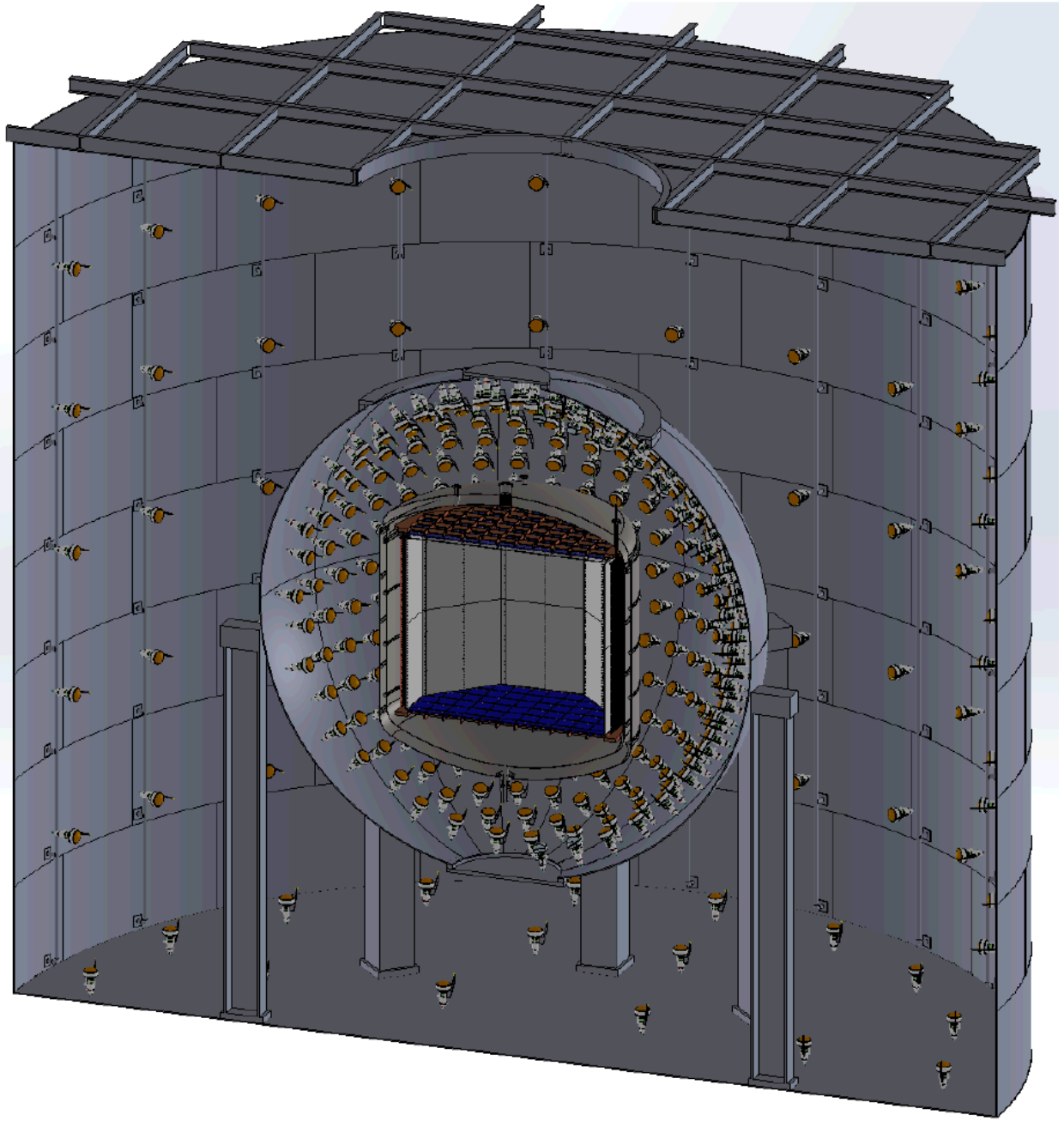
- **NR**:
  - **(n,α)** and fission decays in SS(Cu) cryostat and PTFE liner:
    - a few tens(a few) interactions in exposure, fully cut/vetoed
  - CR **muon-induced neutrons** (incl. β-delayed) also fully cut/vetoed
  - **surface α's**- negligible after fiducial and other cuts, based on DS-50 experience

DS-20k and Vetoes

- New 14x14 m WCD
(3.5 m active shielding on all sides)

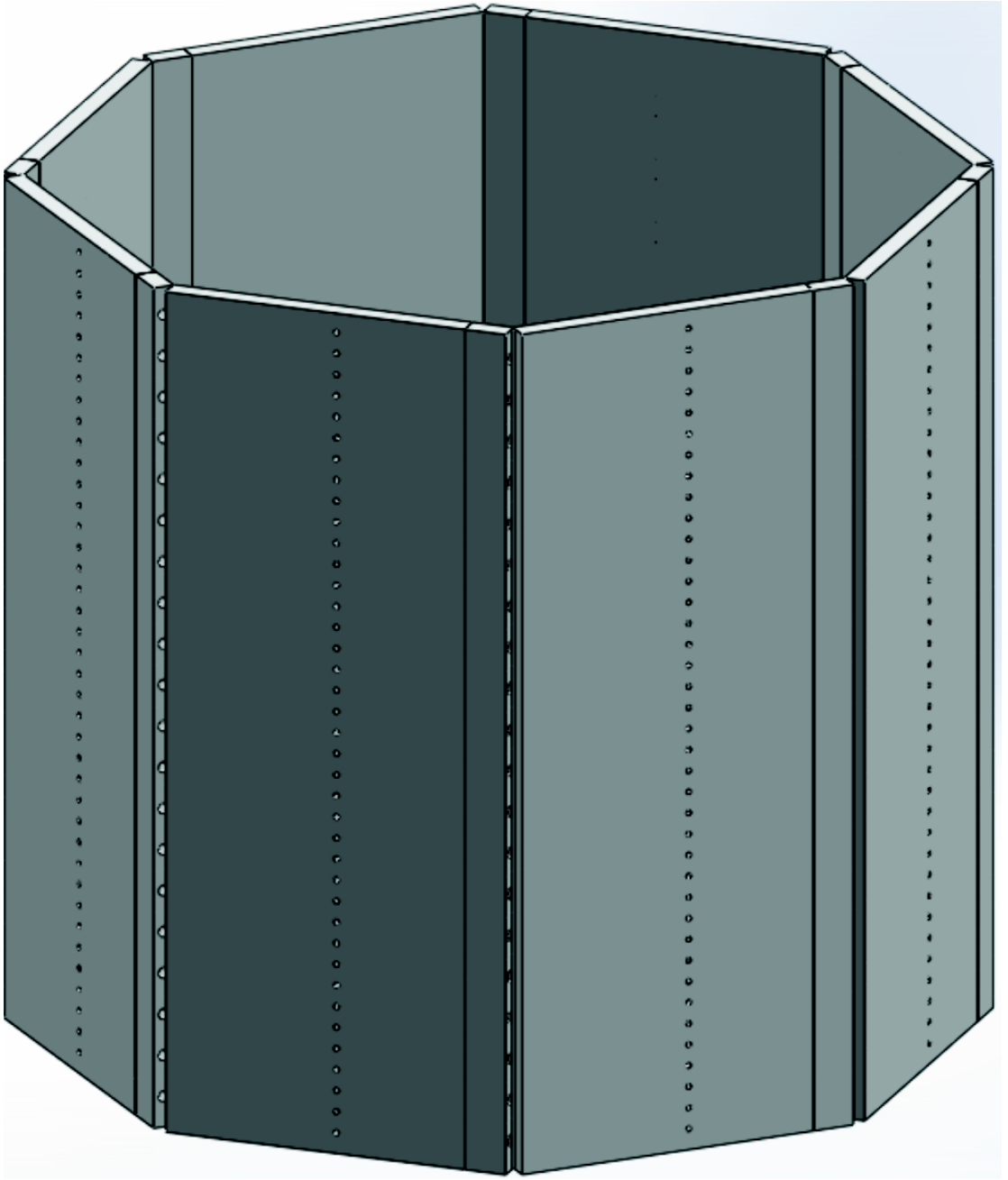
- New 7 m Φ LSV (essential for radiogenic neutrons)

- Not shown:
DAr emergengy recovery port
(bottom)
Cabling & recirculation (top)



DS-20k TPC Reflector

Octagonal PTFE reflector
Slit-panels joined together
No gaps when cooled
Fully scalable in Φ and L
Split-ring field cage outside reflector as in DS-50



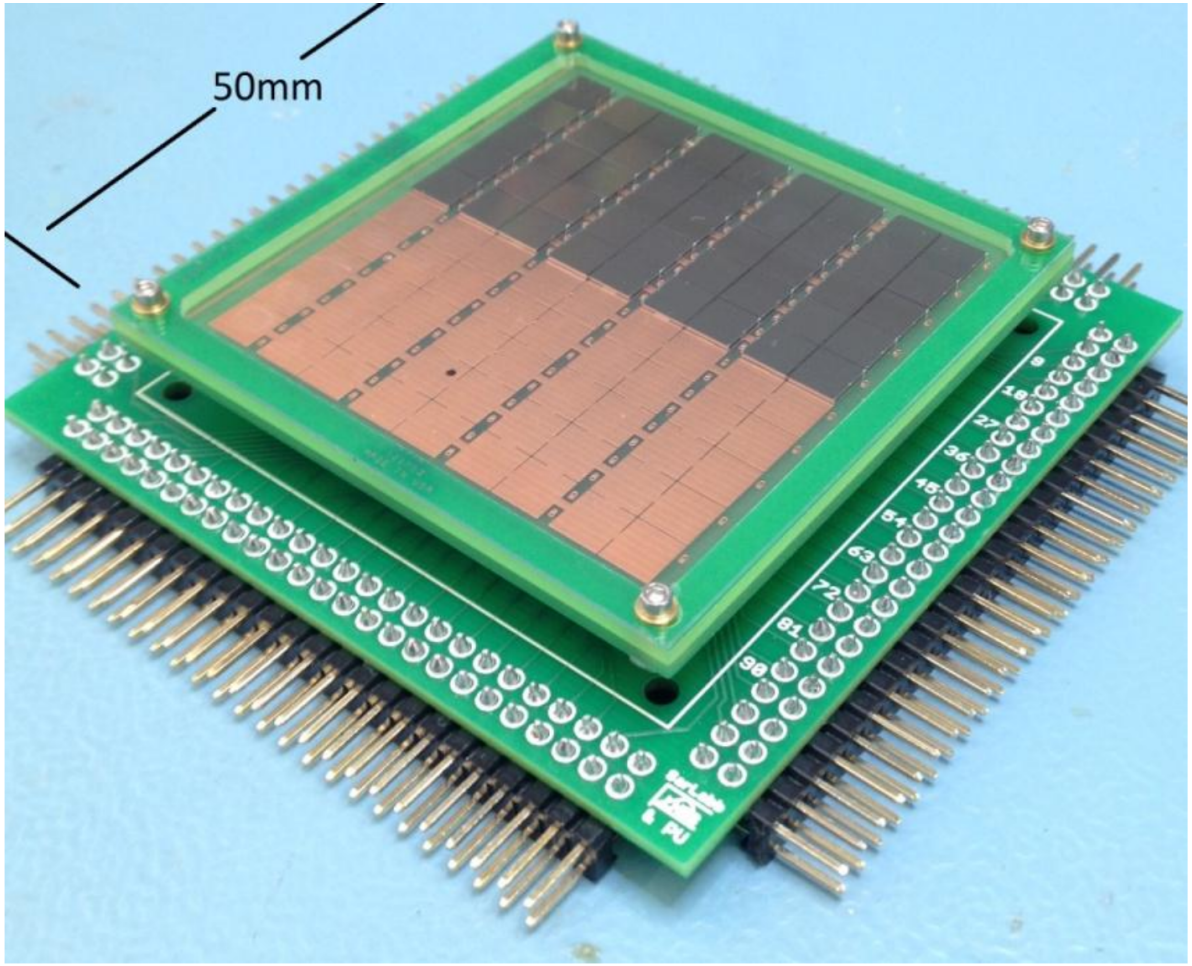
DS-20k TPC Light Sensors - SiPMs

see e.g. Catalanotti et al, doi:10.1088/1748-0221/10/08/P08013
(B. Rossi talk here)

Commercially available silicon single-photon counting devices

- Effective QE ~ 40%
- Geiger-mode gain >10^6
- Fast, subnanosecond timing
- No HV
- Large area arrays > 90% coverage commercially available
- Very compact, very low radioactivity
- Mfr's: FBK to perform/support R&D and LFoundry in charge of large-scale production and assembly
- SiPMs love to run at LAr temperature!

13-institute DS-20k R&D effort underway - collaborators welcome!



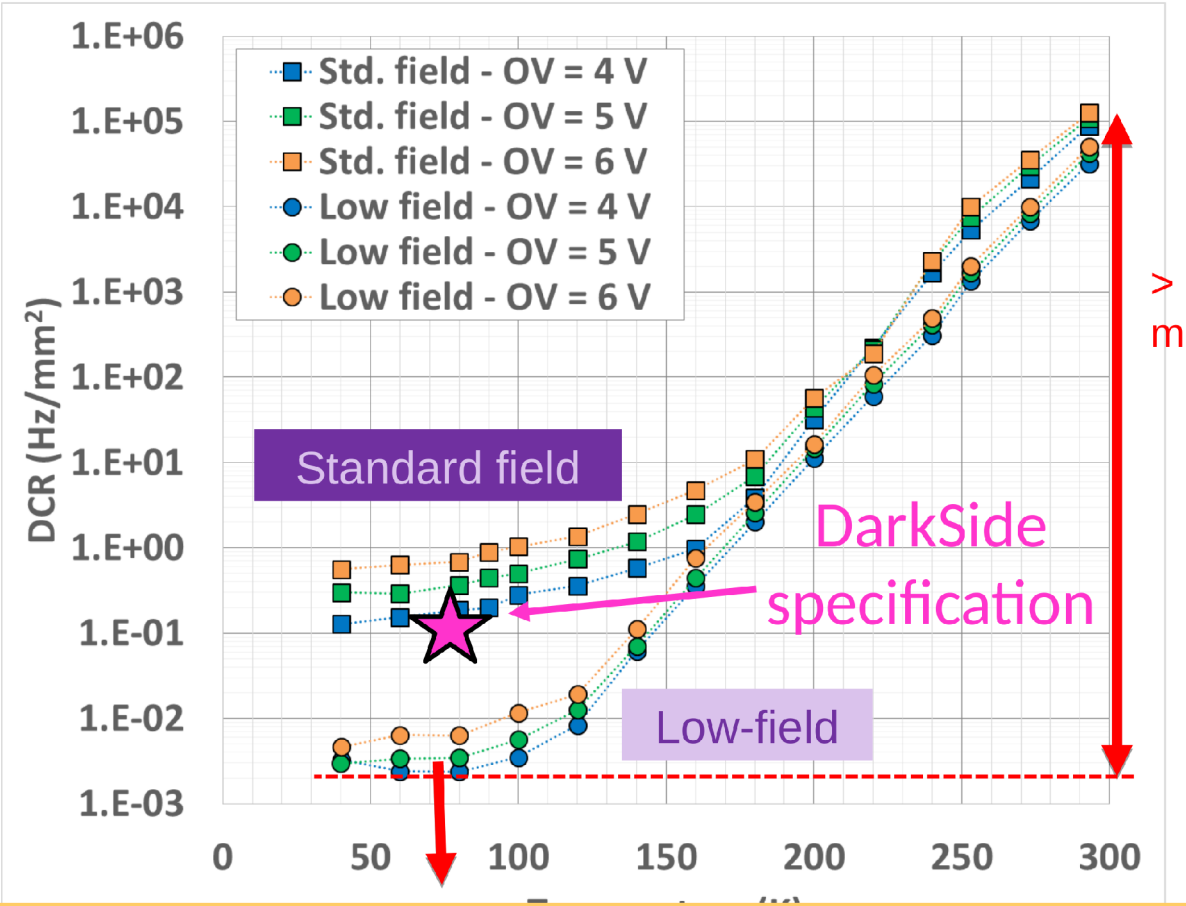
Prototype array assembled at Princeton

Big R&D News- Dark Rate at 87 K

FONDAZIONE BRUNO KESSLER

NUV-HD: DCR @ LN

INFN Istituto Nazionale di Fisica Nucleare



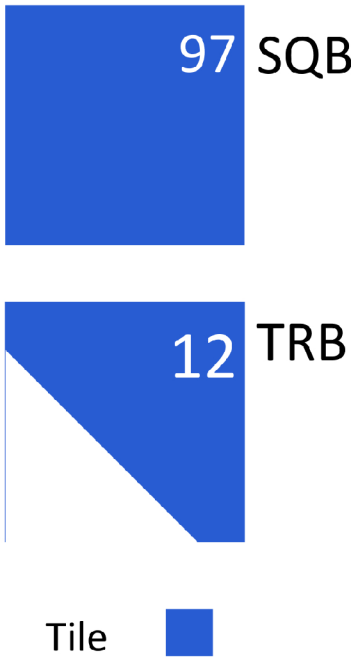
A 10x10 cm² SiPM array would have a total DCR < 100 Hz!

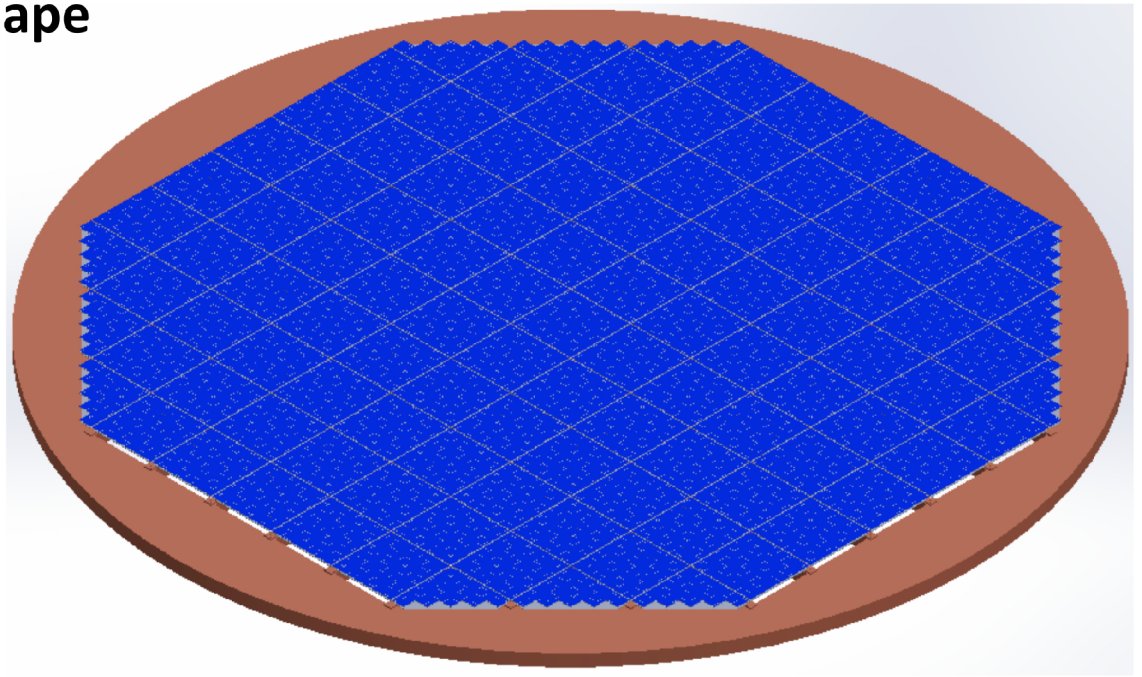
R&D toward: 50x50 mm radiopure tiles in 25x25 cm motherboard arrays....

Top / Bottom SiPM Assembly:

To form octagon shape

Two types of mother boards: 25 cm x 25 cm

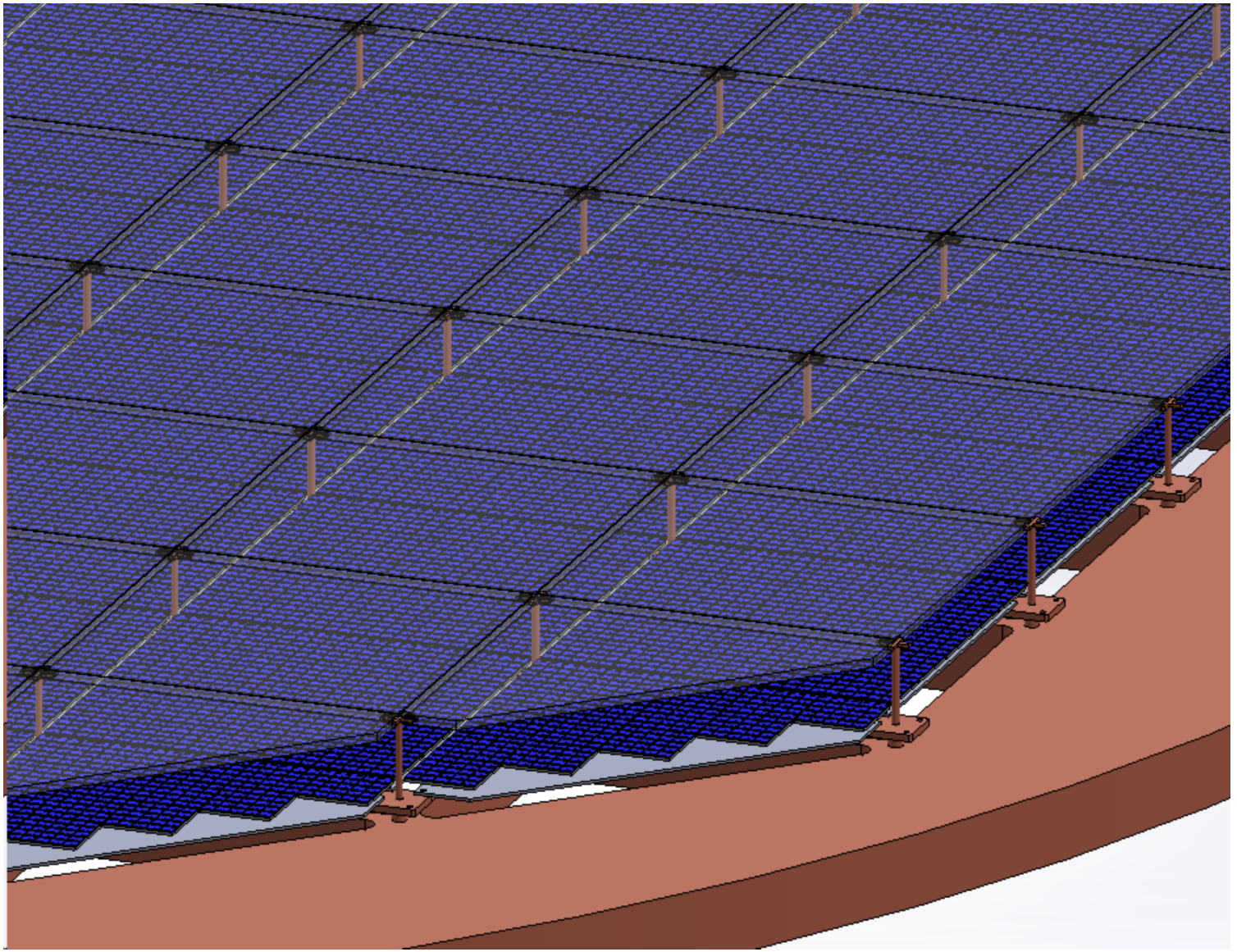




Top + bottom: 5210 channels

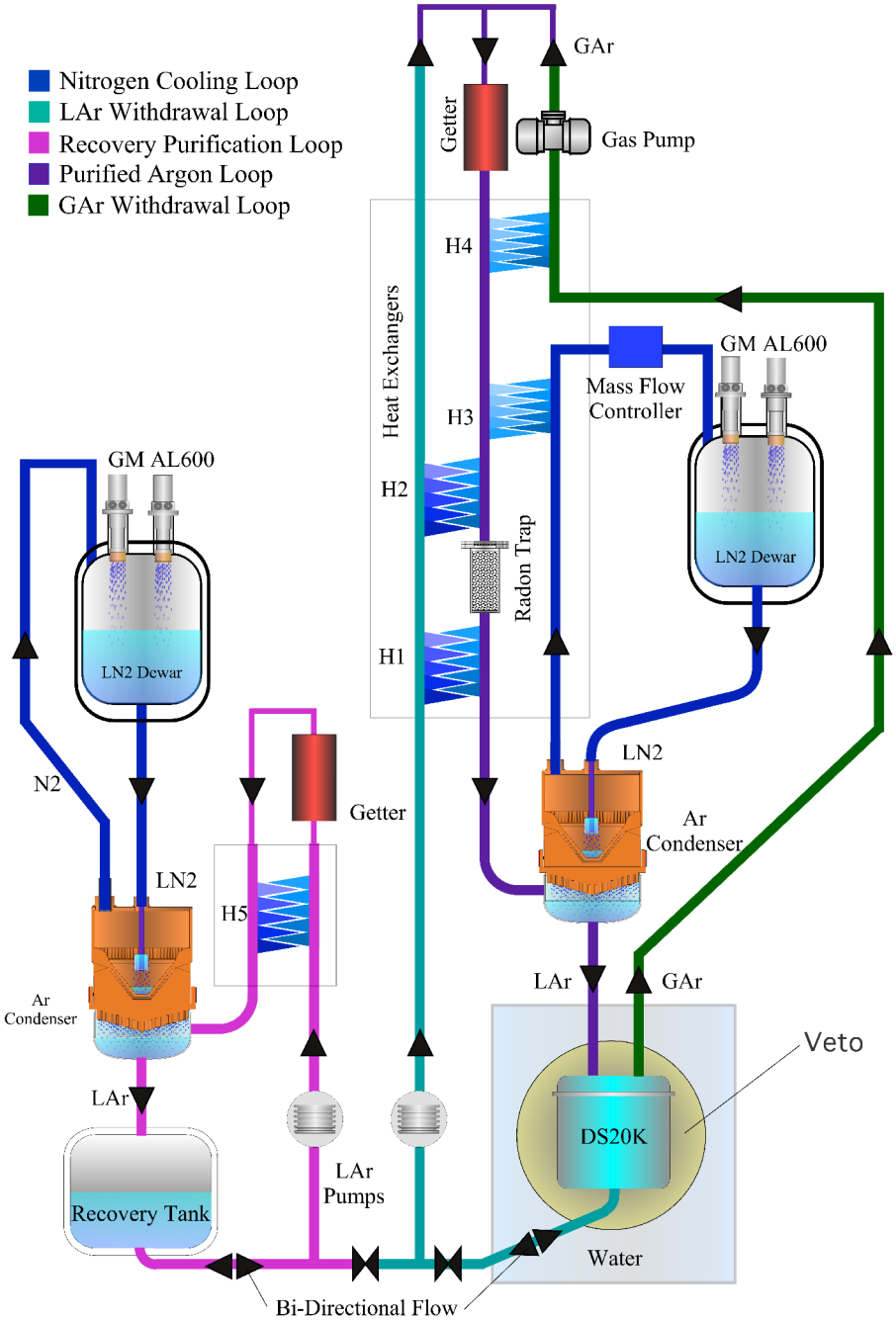
97 SQB mother boards with total of 2425 tiles
12 TRB mother boards with total of 180 tiles
Total tiles (channels) on anode or cathode: 2605

SiPM Tiles and Windows in DS-20k



1000 slpm Recirculating Cryosystem

- Two loops- gas (GWL) and liquid (LWL)
- Both pass through heated getter
- Re-liquefied using LN heat exchange
- Entire inventory pass-through in ~14 da
- GWL fed by cold electronics + heat leak
- LWL uses heat exchangers to recover enthalpy
- LWL probably turned off once initial purity achieved



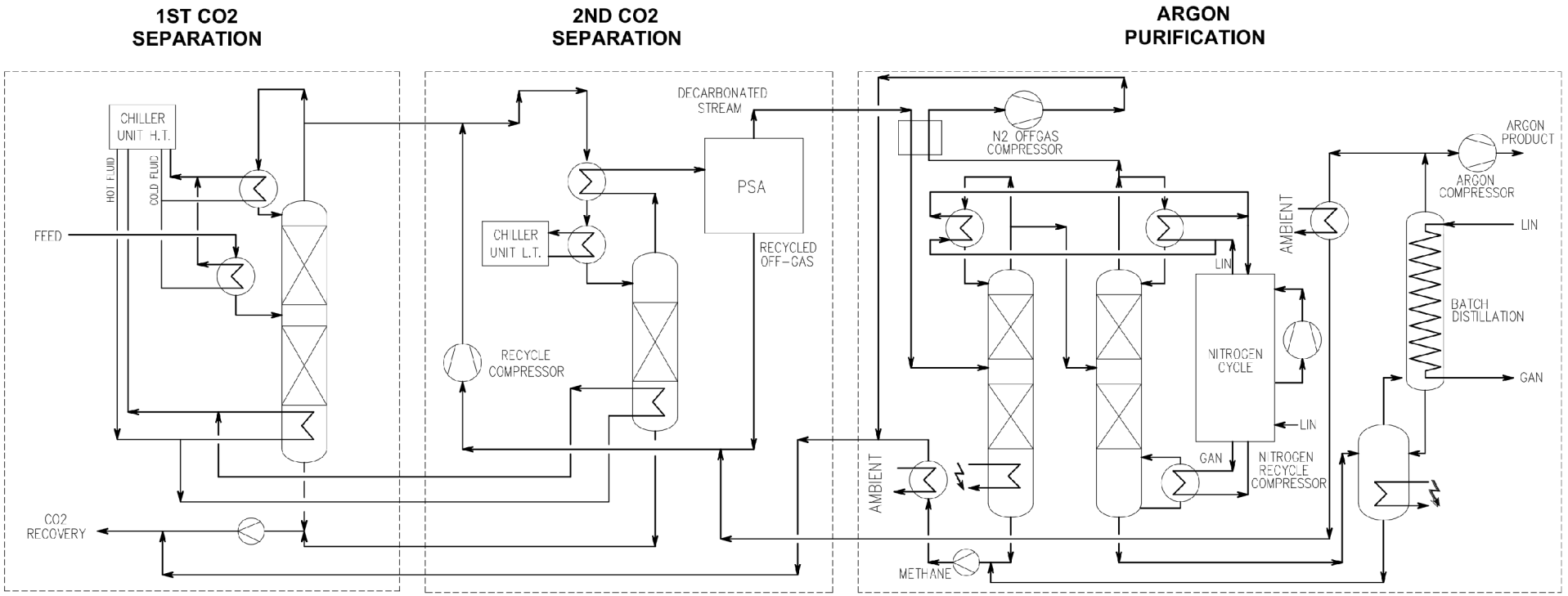
UAr and DAr Sources

Two products, two projects:

- "Urania" - extraction of UAr from Doe Canyon CO_2 well, source of DS-50 target.
  - 2x liquifier/stripper removing CO_2
  - then PSA and cryodistillation to isolate UAr
  - Projected rate ~100 kg purified UAr/day

- "Aria" - 350 m tall cryogenic distillation columns in Carbosulcis Seruci mine (Sardinia).
  - Projected ^{39}Ar reduction factor 10 per pass
  - Seruci I(II) throughput 10(150) kg Ar/day
  - DAr of interest for dating and other sensitive proportional counter assays

Urania



Design feasibility study, siting and gas source agreements complete
Funding in process

Aria- Mine Refurbishment Construction Started

SARDINIA post
le notizie di oggi per la Sardegna di domani

HOME PRONTO INTERVENTO CRONACA POLITICA ECONOMIA AMBIENTE CULTURE PHOTOGALLERY VIDEO INCHIESTE BLOG SPORT NOVAS INNOVAZIONE

Il presidente Pigliaru: “Crediamo nel progetto Aria”. E cita Microsoft e Google

25 luglio 2015 Economia

La sala convegni della Grande miniera di Serbariu non era gremita, alla presentazione del progetto Aria. Eppure erano presenti ospiti illustri come il presidente della Regione sarda Francesco Pigliaru, i deputati Francesco Sanna e Emanuele Cani, l’amministratore unico della Carbosulcis, fresco di nomina, Antonio Martini, il sindaco di Gonnesa nonché capogruppo PD in consiglio regionale Pietro Cocco. E poi c’erano gli scienziati, Cristian Galbiati, coordinatore del progetto, e il presidente dell’Istituto Nazionale di Fisica Nucleare Fernando Ferroni, i veri protagonisti della serata per un argomento di grande importanza scientifica ed economica. Francesco Pigliaru, nel suo intervento conclusivo, dopo quasi due ore di interventi e spiegazioni scientifiche, spiega perché la Regione sarda crede in questo progetto: “L’intervento di denari pubblici da parte della Regione è limitato a poco più di 2 milioni di euro in circa tre anni. Ben poca cosa, comunque, in confronto ai tanti denari pubblici sprecati in mega progetti che non hanno prodotto nulla in questi anni. Ma qui siamo di fronte a un piccolo progetto che potrebbe rivelarsi una cosa enormemente importante, per il territorio e per la Sardegna tutta. Un polo tecnologico di livello internazionale”.

Plans for Innovative DAQ

Based on experience gained with DS-50, which sustained **7 TB/day** peak data storage rate with AAr:

- TPC data stream 38 PMT digitizers at 250 MSPS +38 at 100 MSPS
- Veto data 190 PMT digitizers at 1.25 GSPS
- Event builders performed **lossless compression on the fly**
- To cut ^{39}Ar data rate, a sophisticated **Level-Two type trigger** was implemented in the EvB computers- “the G2 Trigger”

- DS-50 almost entirely **COTS electronics and commodity CPU's**

For DS-20k:

- **>5000 tile channels** rather than 38 + 190 PMT's
- **Aggressive zero suppression** at digitizer level + TDC's for energy reconstruction and triggering
- Reduce data rate to below **1 TB/day**
- **Considering** possible full-software (“HLST”) **triggerless DAQ** with full analysis stream running on the fly

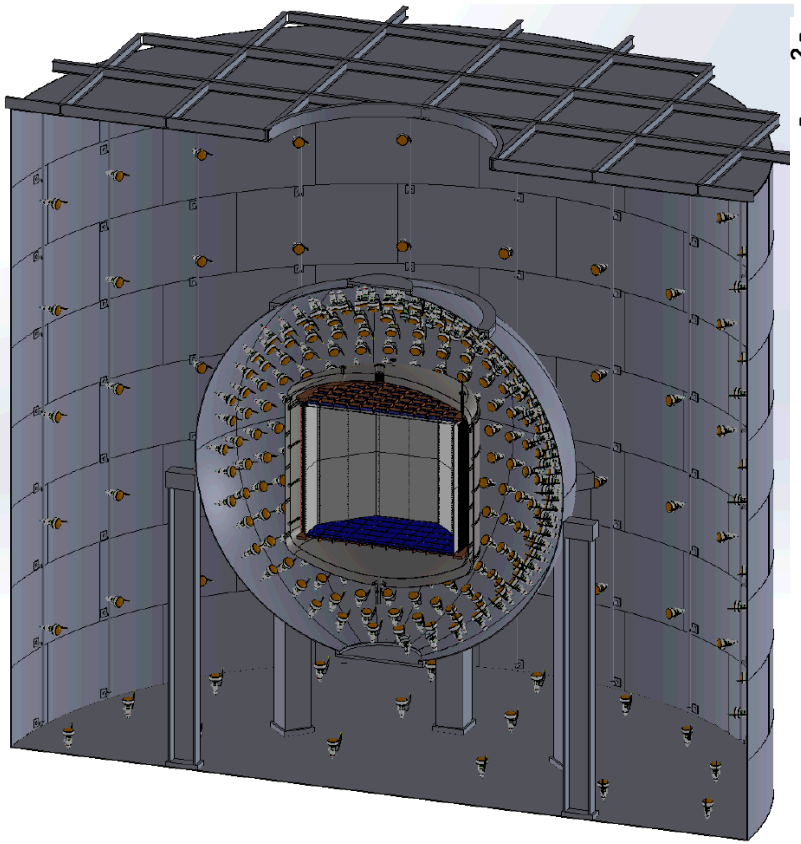
- Detailed estimates => handled by **100 cores** for conversion, logging, event building + **100 cores** for reconstruction in real time

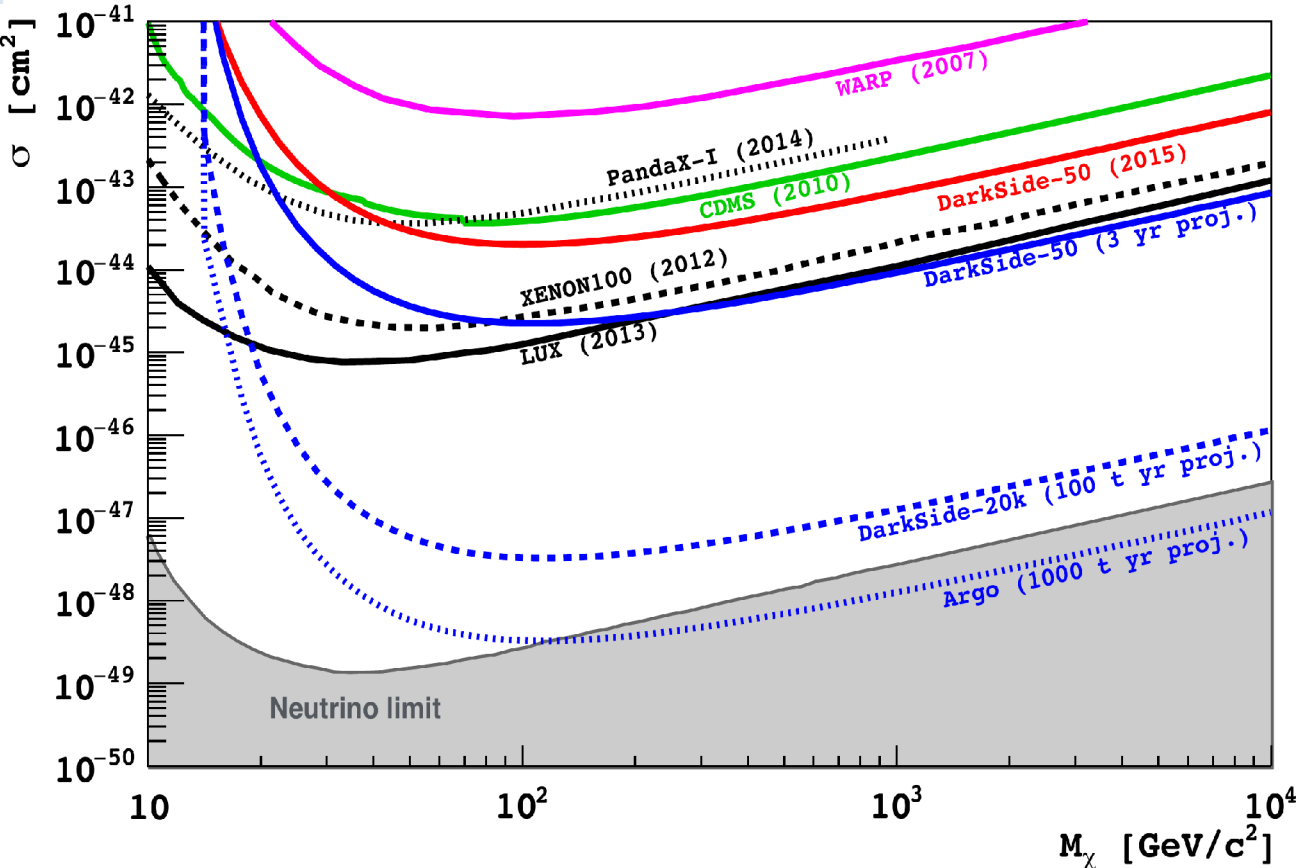
Summary

DS-20k is designed for 100 ton-year **background-free** exposure with LAr, using new technology to seek high-mass WIMPs down to 10^{-47} cm^2.

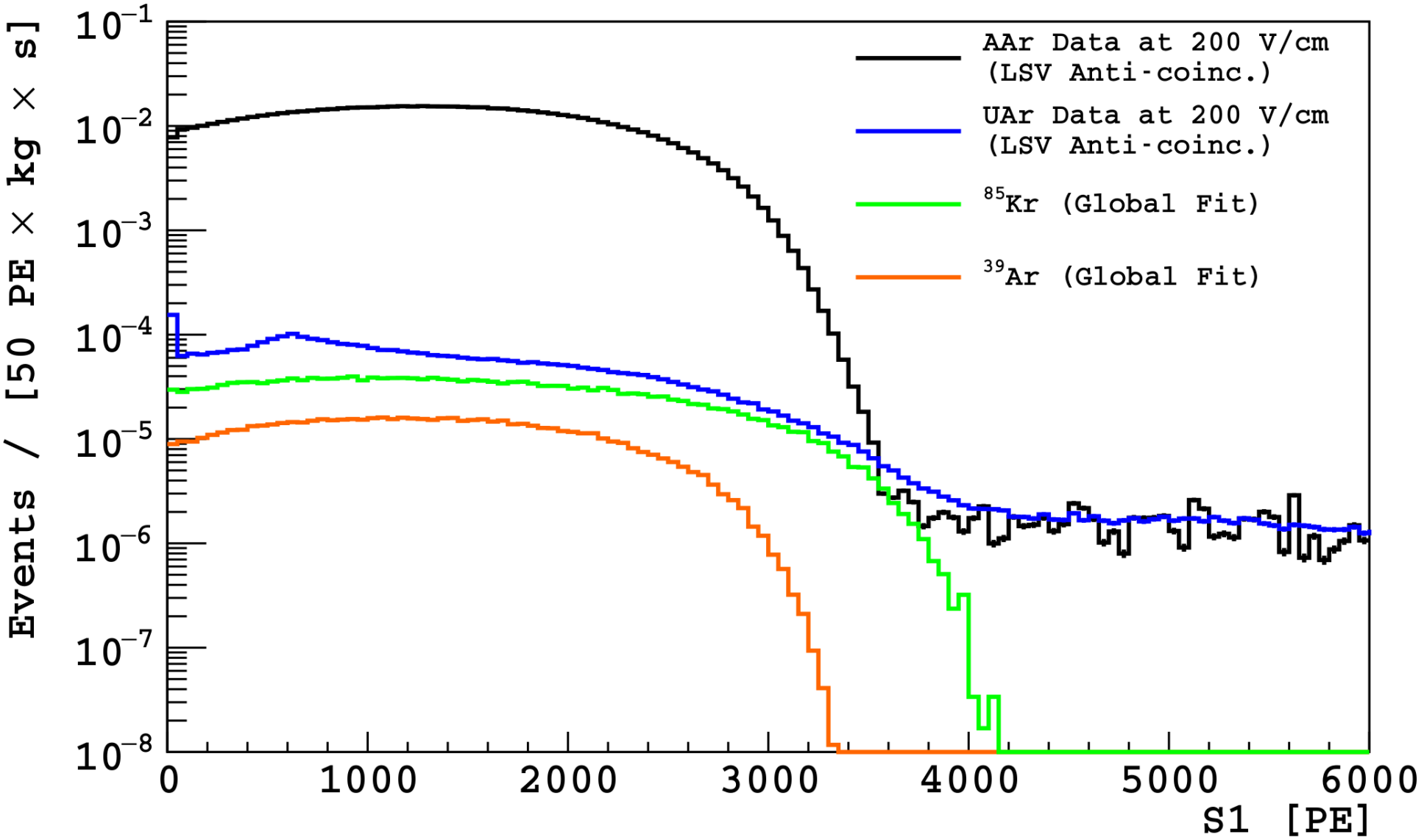
Operating on aggressive schedule for end-2020 start

New U.S. and international collaborators sought!





(EXTRA) DS-50 UAr



- This spectrum with standard 200 V/cm drift field => allows γ-ray suppressing cuts
- ^{39}Ar barely visible; ^{85}Kr a surprise (confirmed by βγ decay)
- Kr efficiently removable by distillation if we had thought to do it