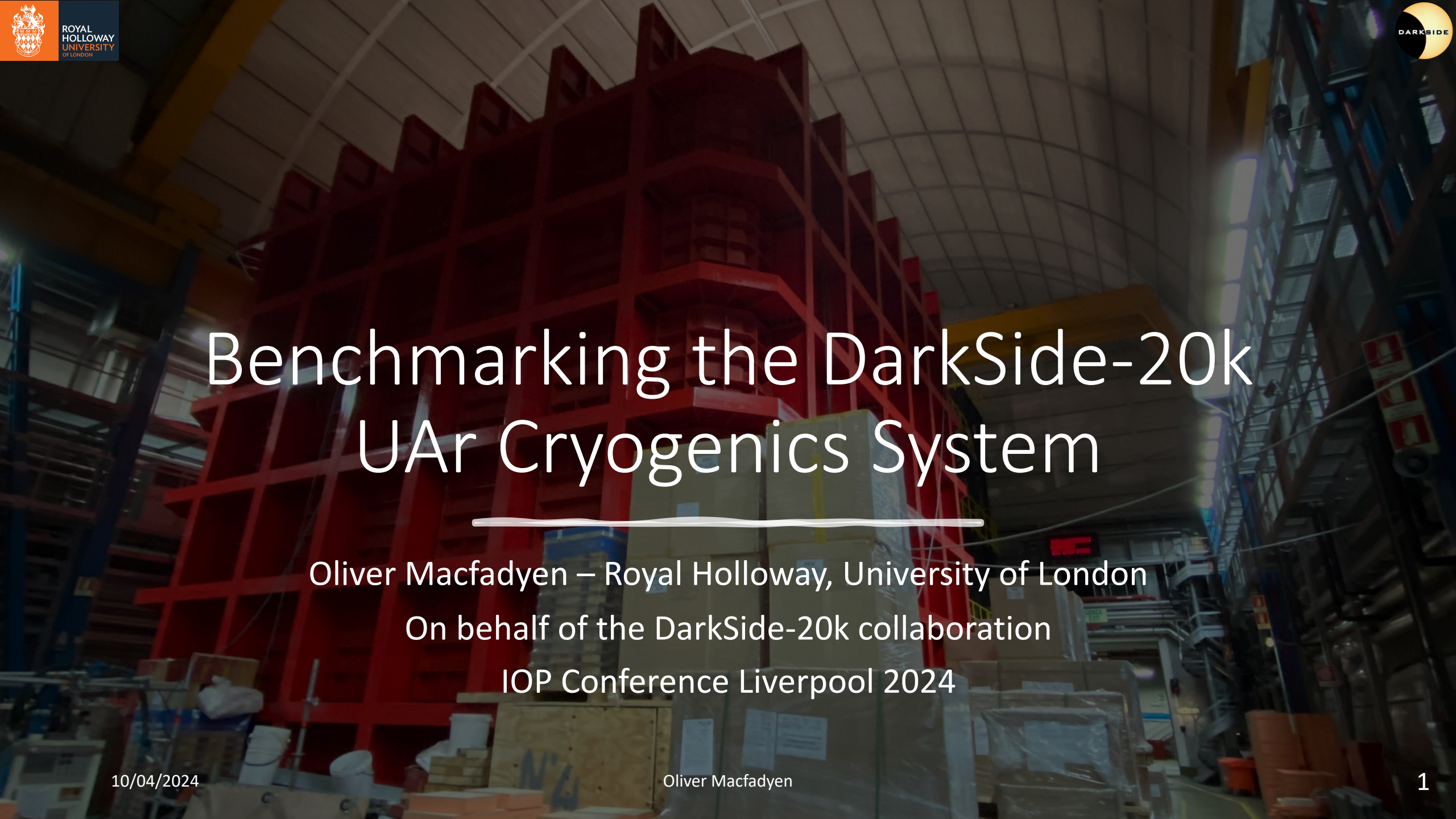


Benchmarking the DarkSide-20k UAr Cryogenics System

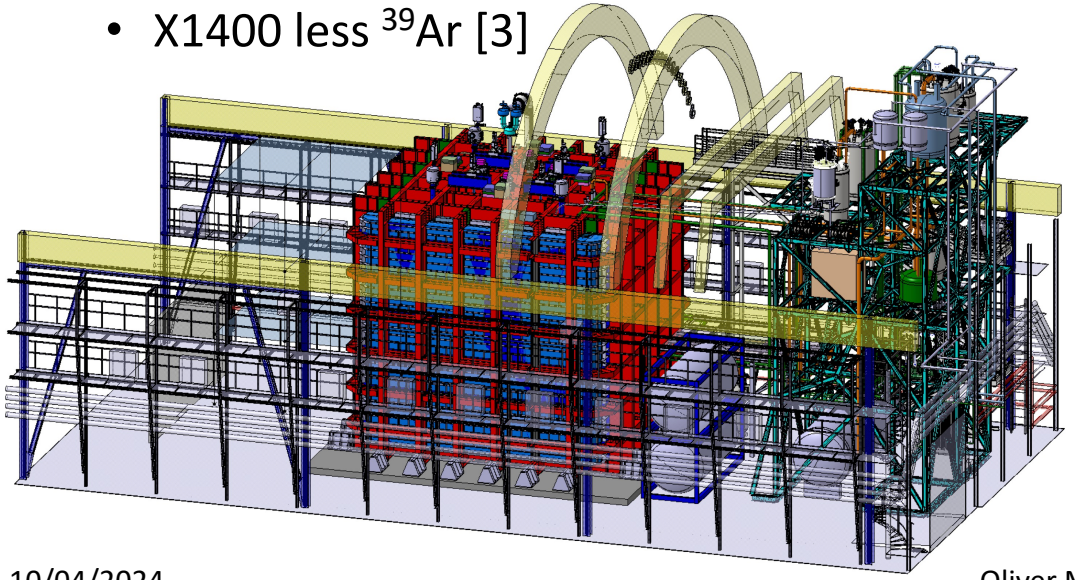
Oliver Macfadyen – Royal Holloway, University of London

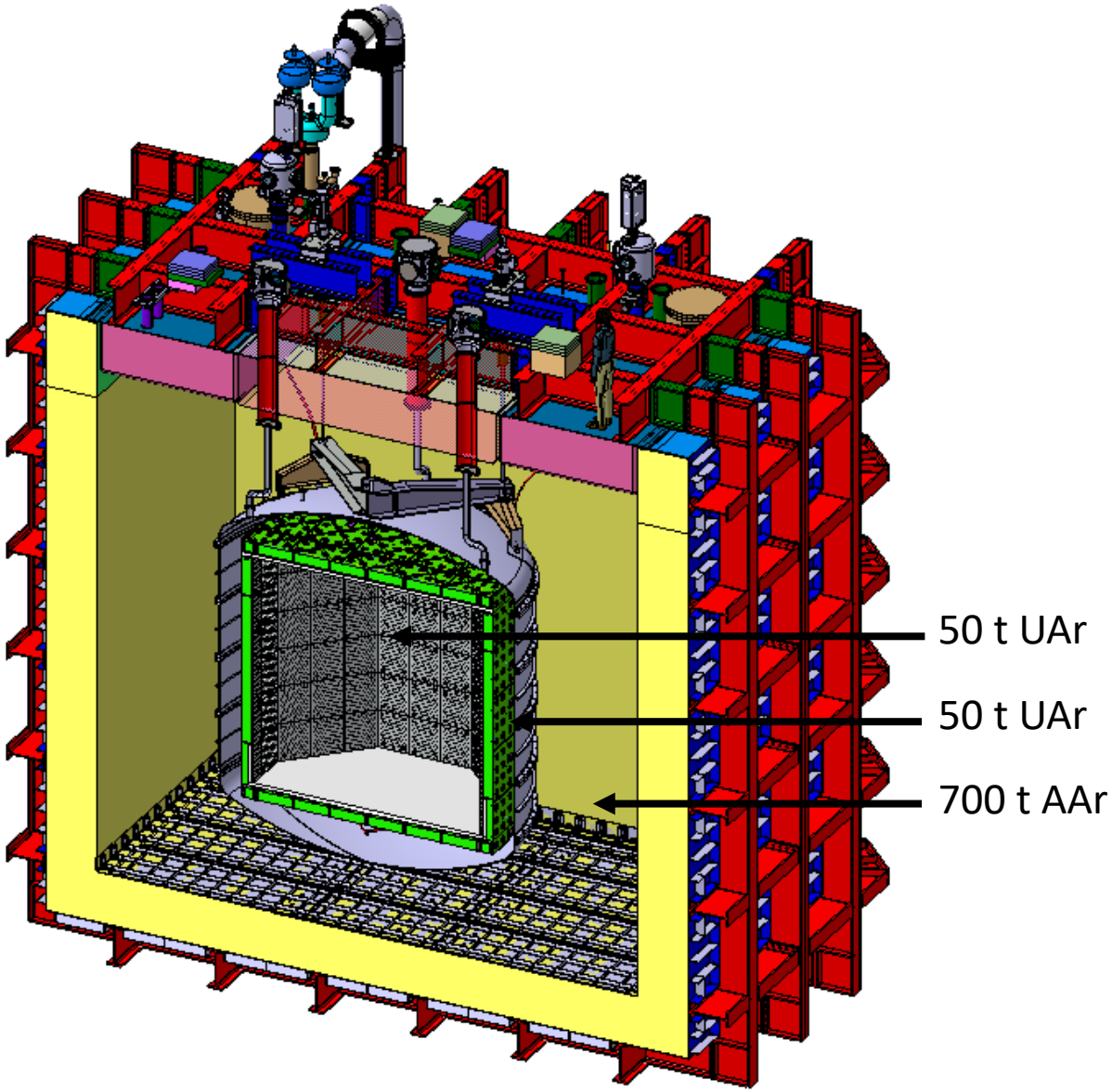
On behalf of the DarkSide-20k collaboration

IOP Conference Liverpool 2024

DarkSide-20k

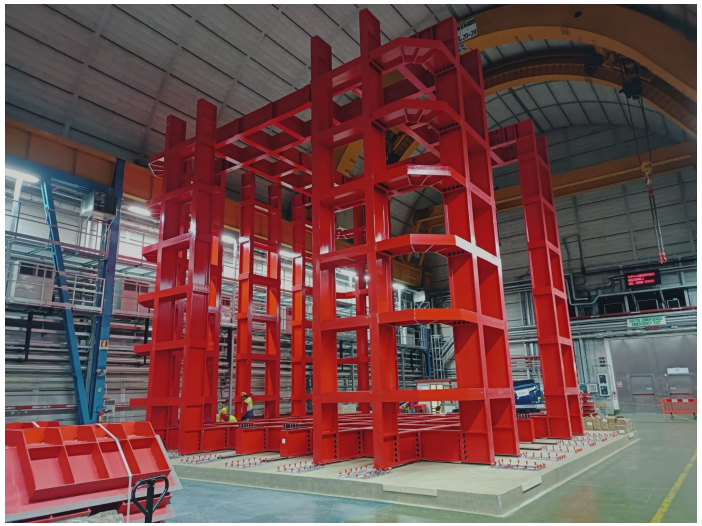
- A direct detection experiment searching for dark matter from keV to >>TeV masses, located at the Laboratori Nazionali del Gran Sasso - INFN
- Unique target of ultra-pure low-radioactivity Argon (UAr) in the inner detector
  - X1400 less ^{39}Ar [3]





DarkSide-20k Construction

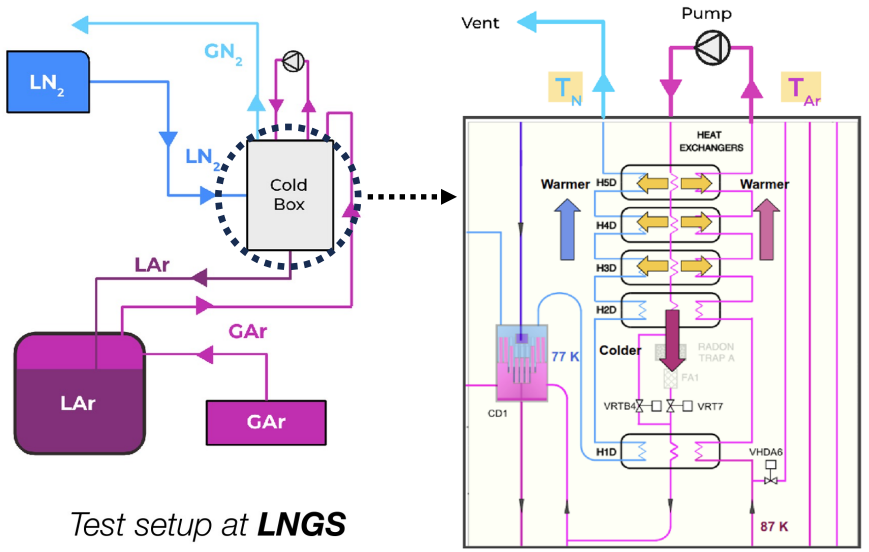
June 2023



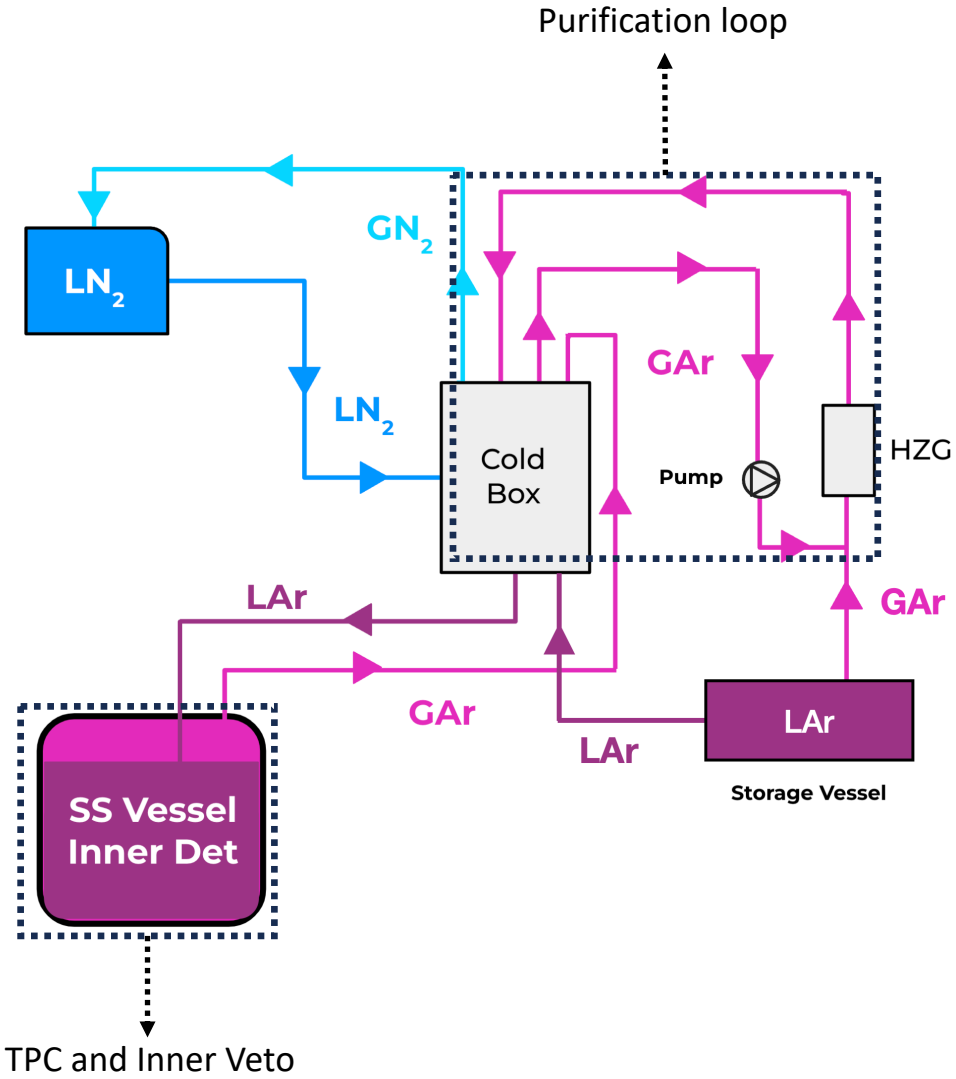
March 2024

DarkSide-20k Cryogenic System

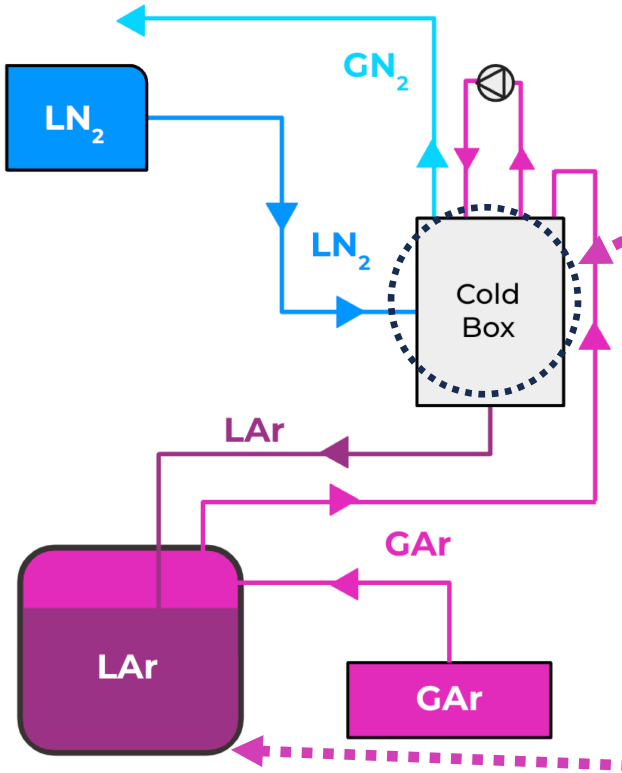
- Goal of 1000 standard liters per minute for recirculation of UAr
  - Improve heat exchange efficiency
- Maintain Argon purity
  - Remove electro negative molecules

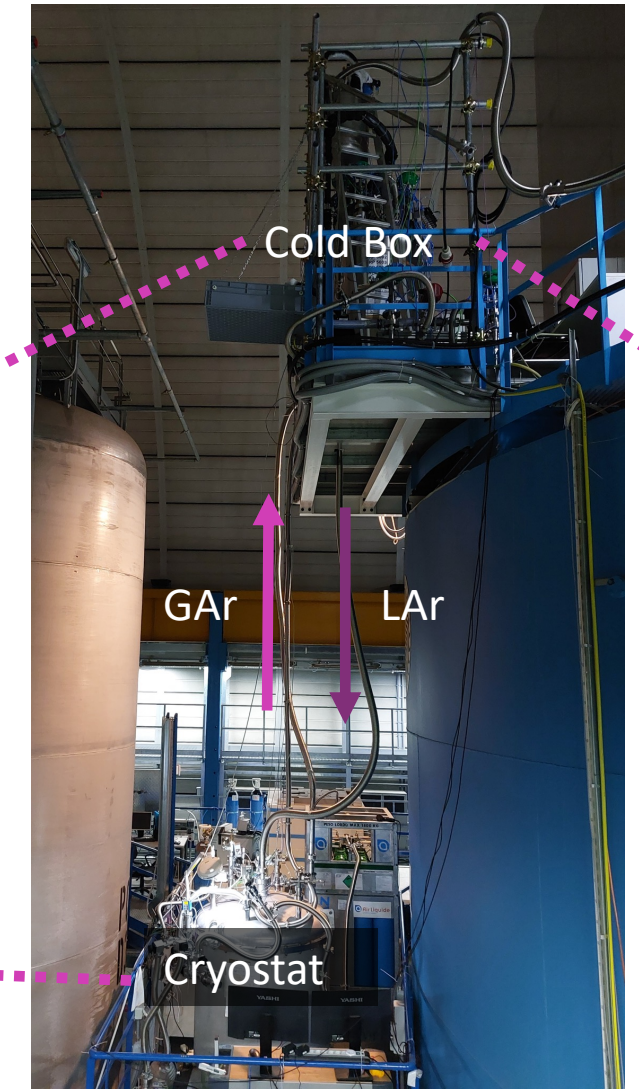


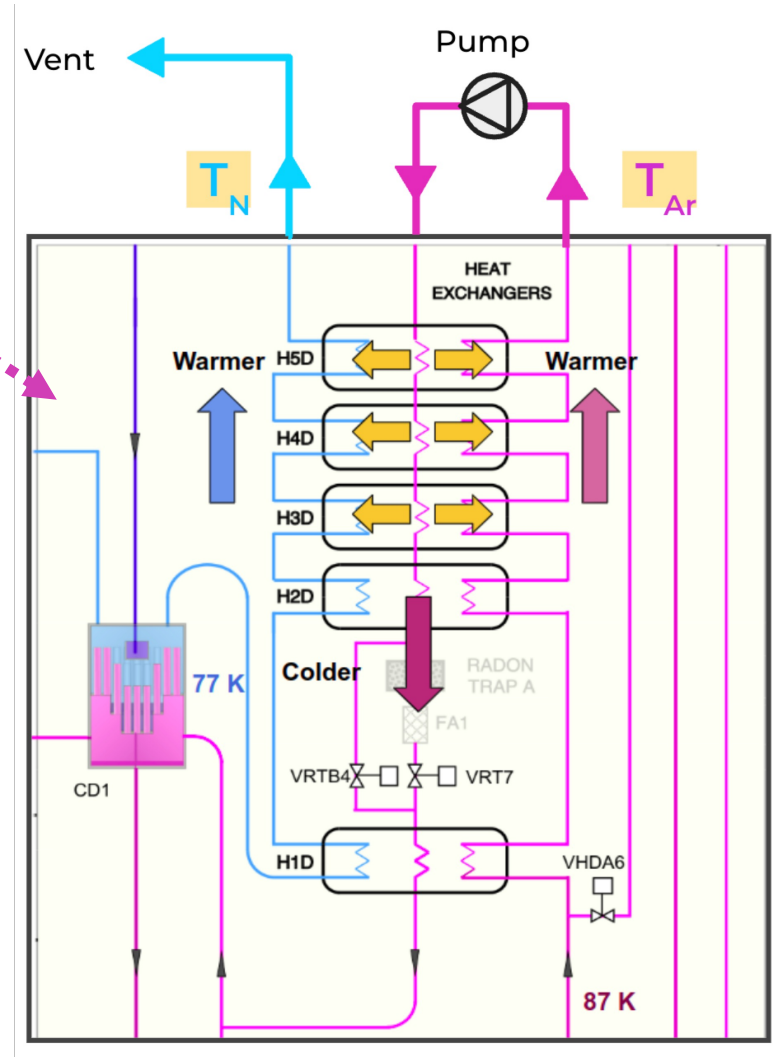
*Test setup at **LNGS***



DS20k Cryogenic Test System

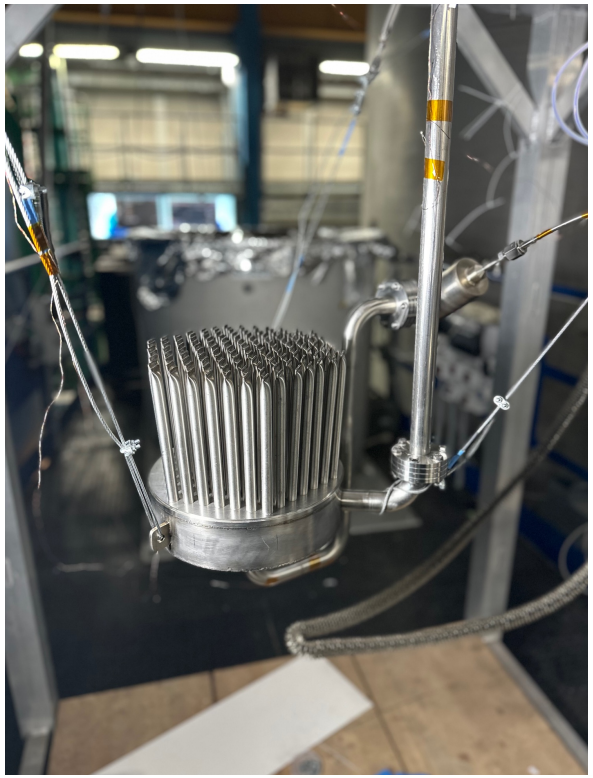






Test of the DarkSide-20k system

- First test at CERN in 2021/22
- Two runs testing the cooling and recirculation at LNGS in 2023/24
  - Test of a mock up of the DarkSide-20k TPC happening this summer
- Change of heat exchanger design between LNGS runs 1 and 2
  - Improve efficiency of heat exchange between the GAr and the LAr
    - Increase maximum flow rate



Maximum Argon Flow Test

Comparison of two heat exchanger designs

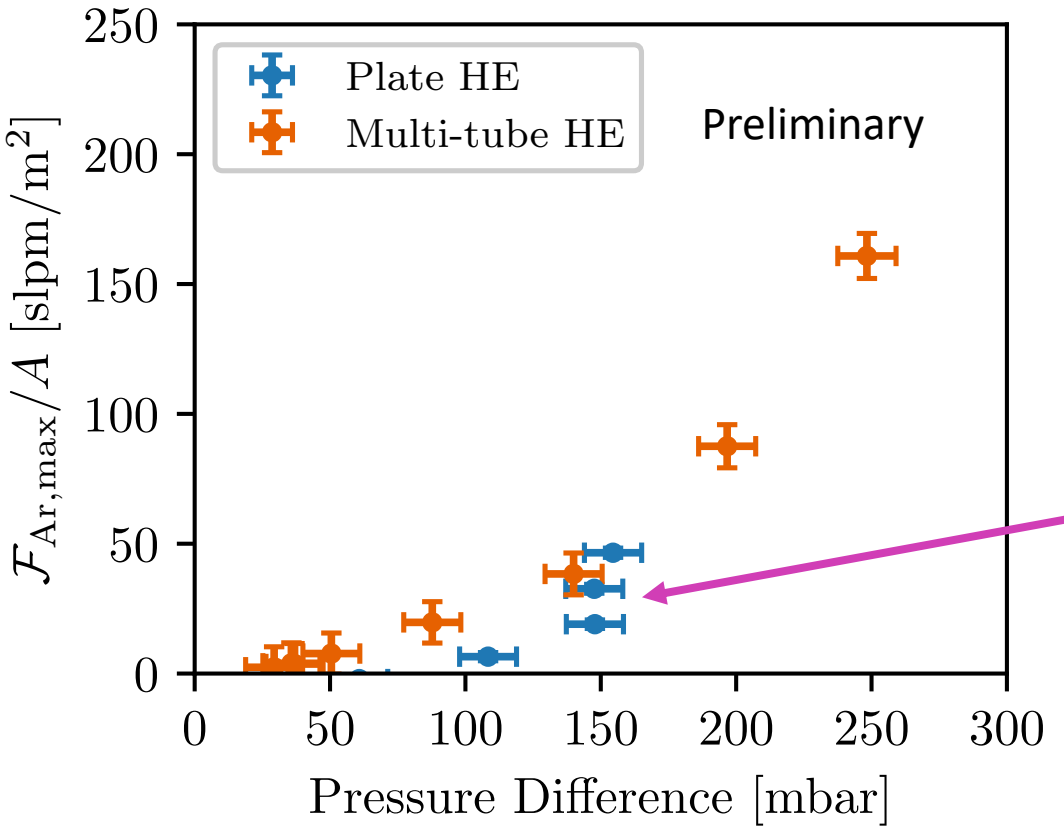
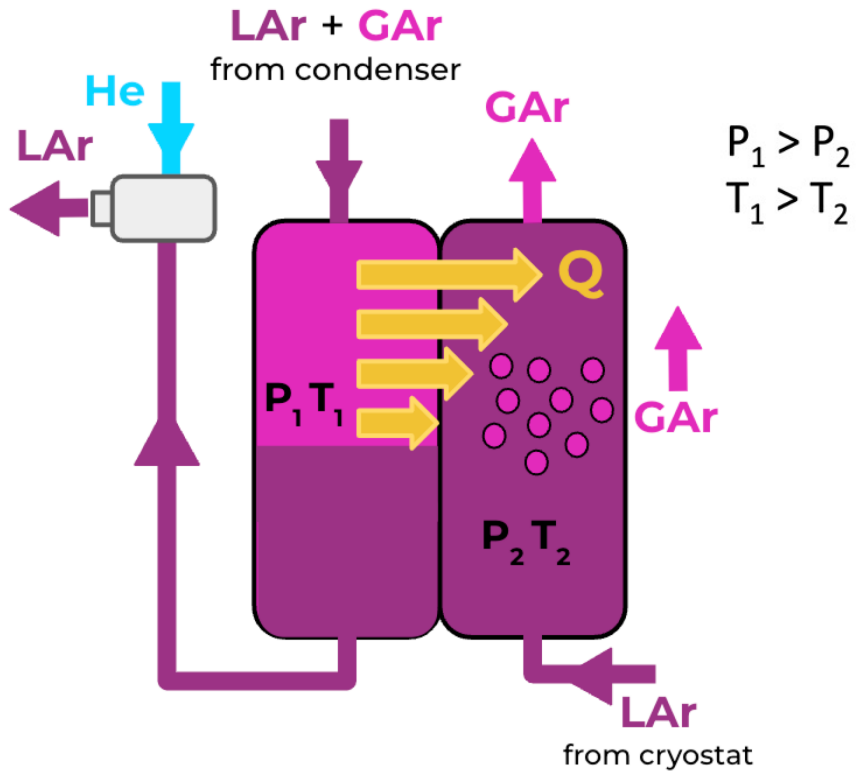
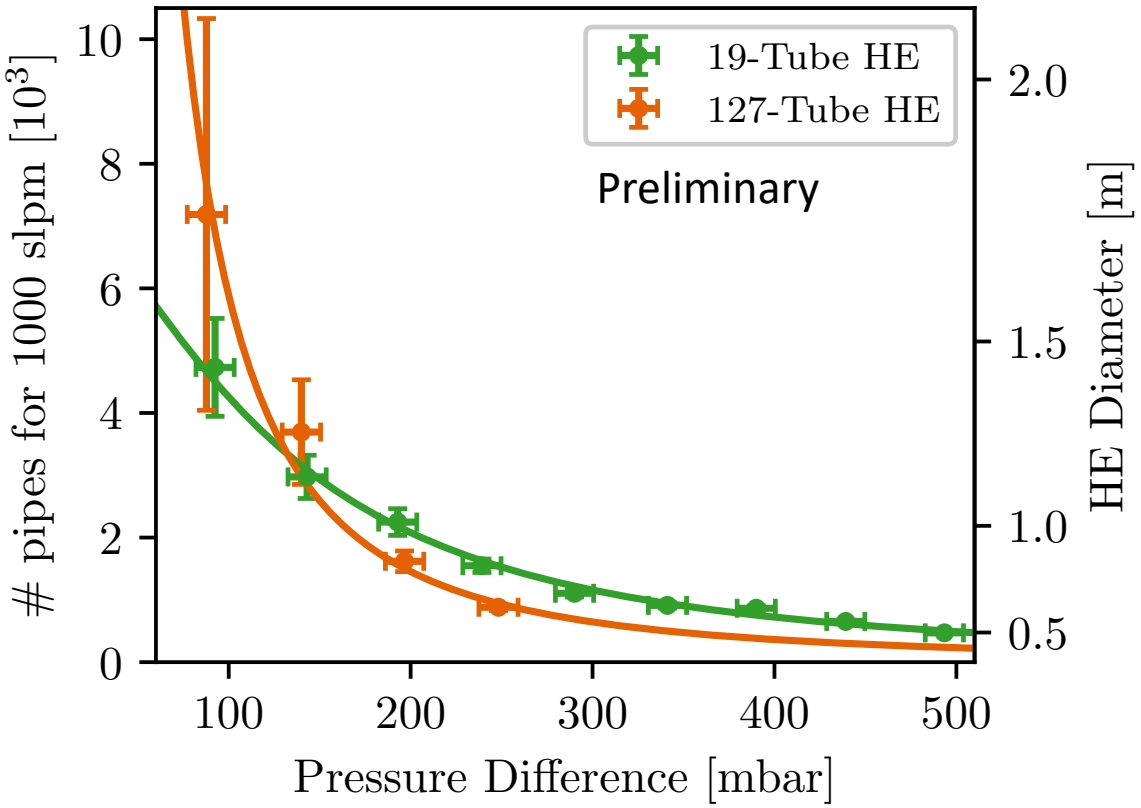


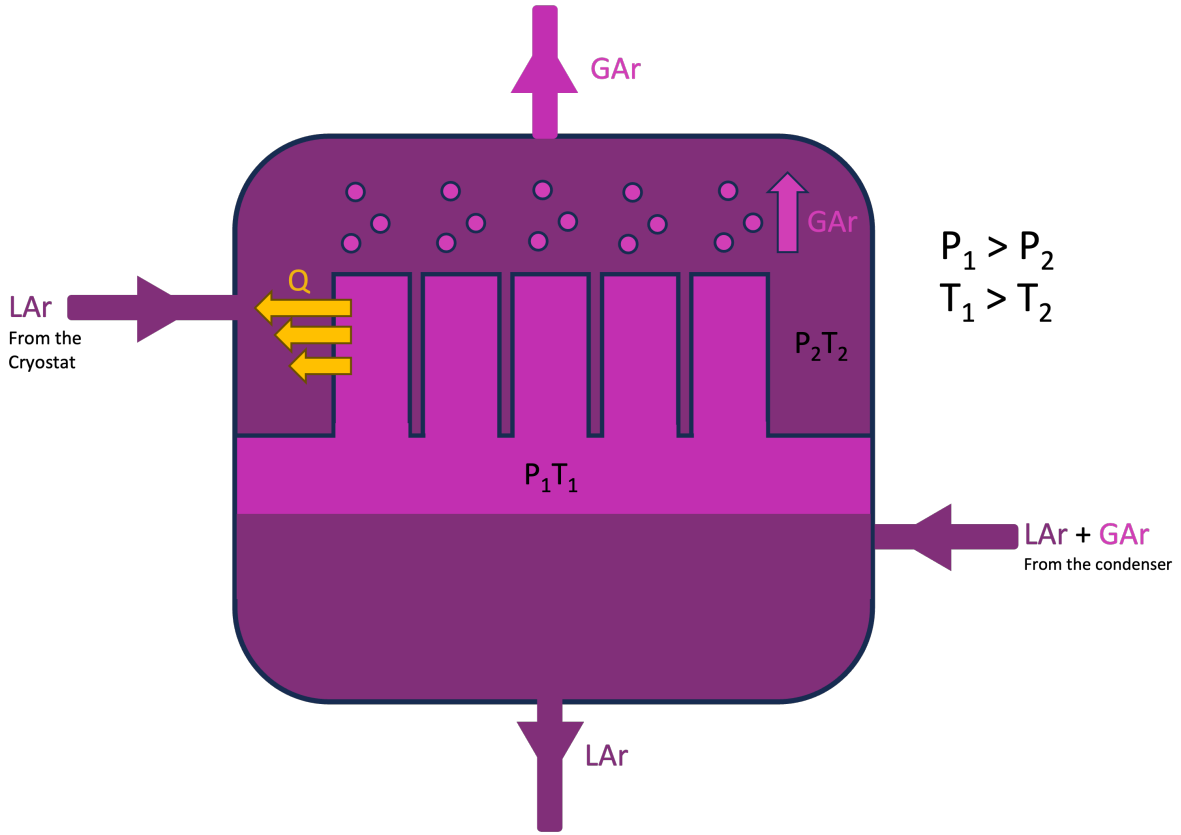
Plate Heat Exchange (LNGS Run 1)



No. Tubes needed for 1000 slpm



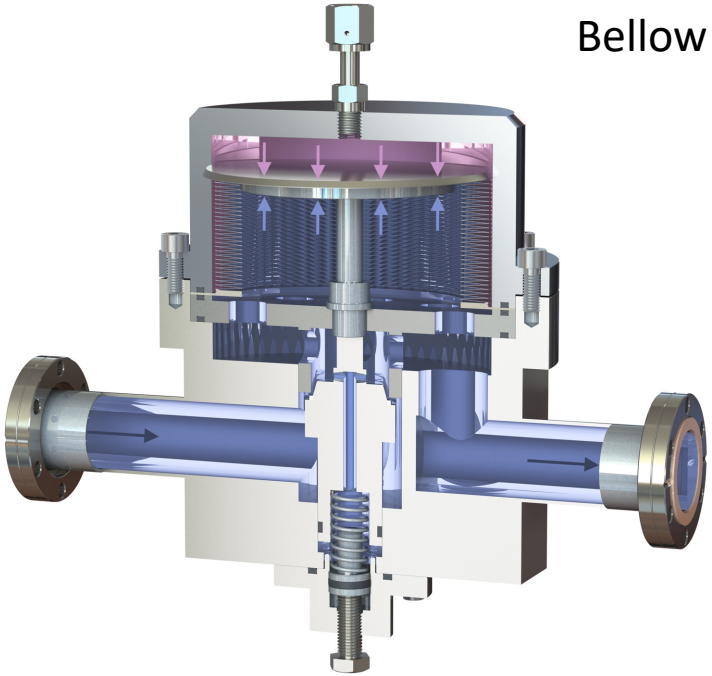
Tube Heat Exchange (LNGS Run 2)



Cooling Control

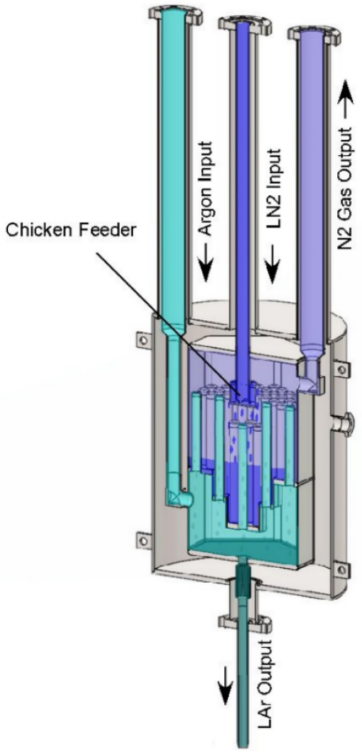
- Cooling power controlled by boil-off nitrogen gas flow
- Nitrogen flow controlled by two different types valves

Bellow Valve

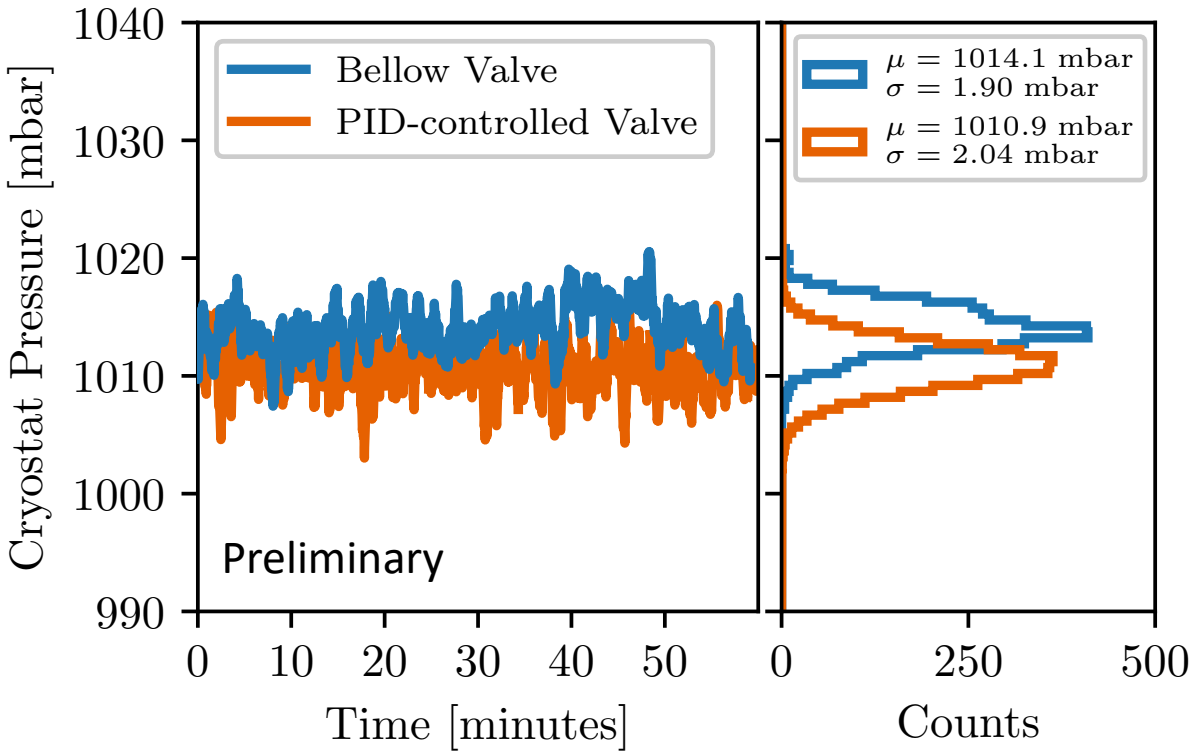


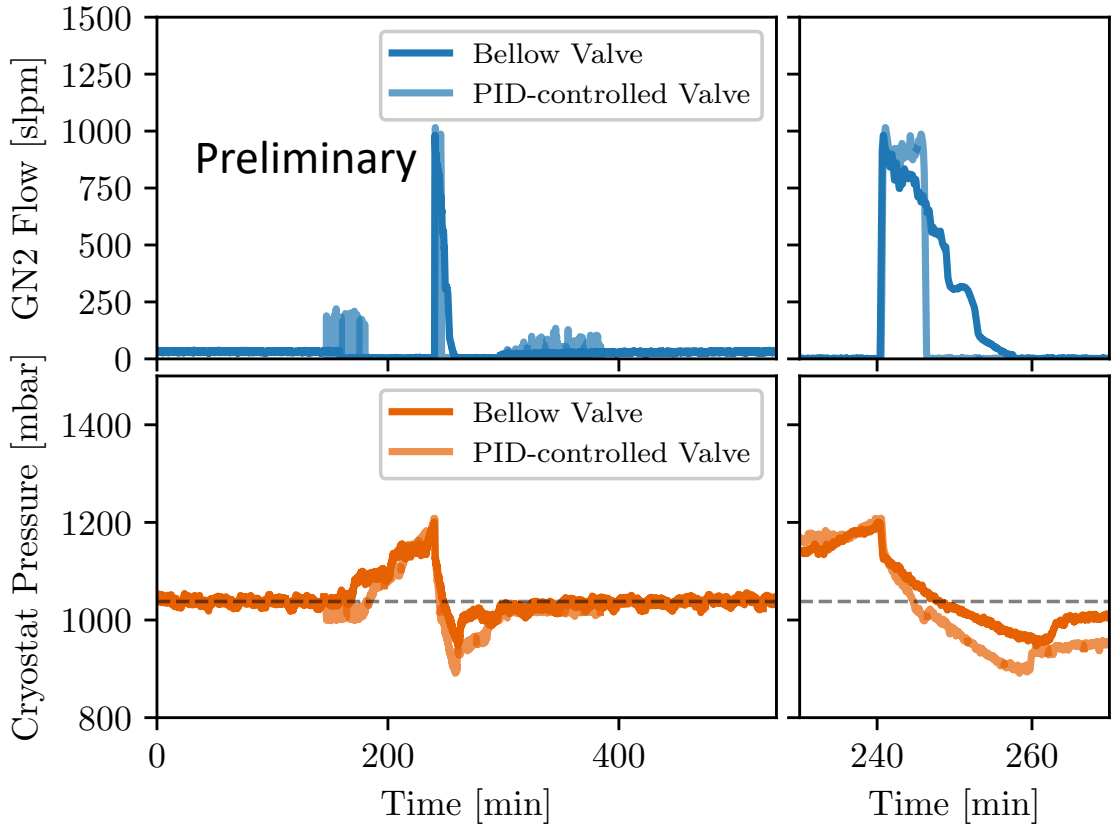
PID Valve

Condenser



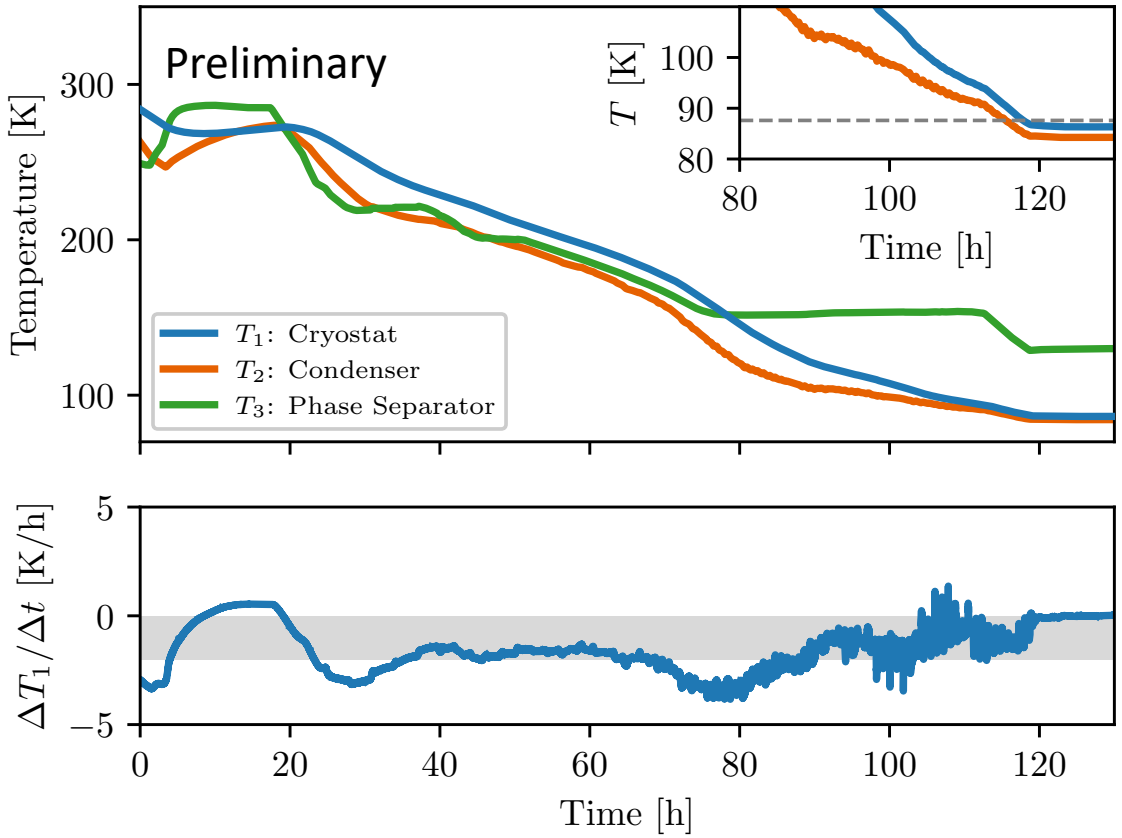
Pressure Stability and Valve Response

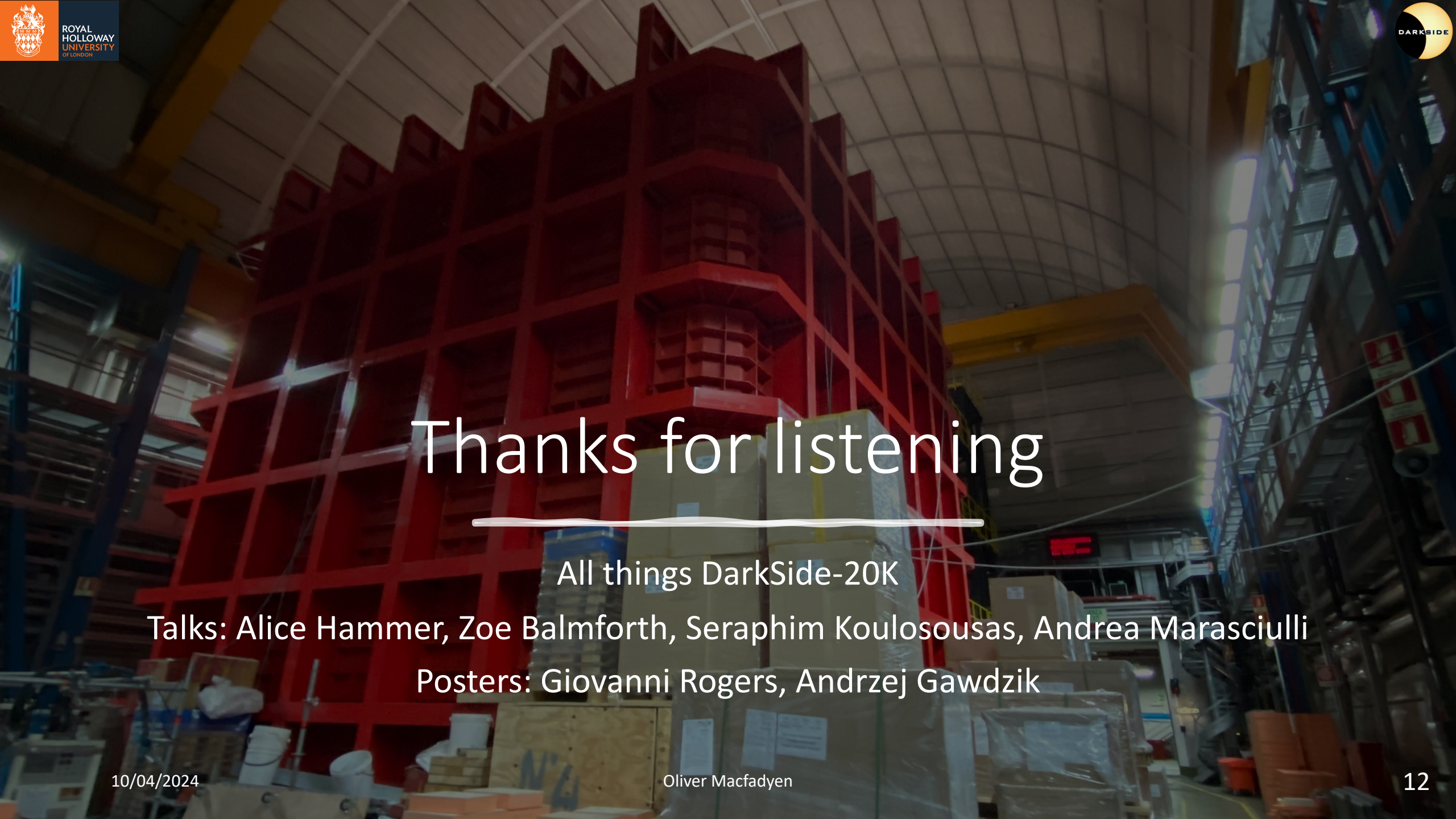




Outlook

- Cryogenic benchmarking complete
- System performance confirms modeling
  - Cooling at a rate compatible with the mockup specification
- Integration of a DarkSide-20k mockup TPC





Thanks for listening

All things DarkSide-20K

Talks: Alice Hammer, Zoe Balmforth, Seraphim Koulosousas, Andrea Marasciulli

Posters: Giovanni Rogers, Andrzej Gawdzik

References

[1] TheDarkSide-20k TPC and underground argon cryogenic system. https://scipost.org/SciPostPhysProc.12.069

[2] Results from the first use of low radioactivity argon in a dark matter search. https://journals.aps.org/prd/abstract/10.1103/PhysRevD.93.081101

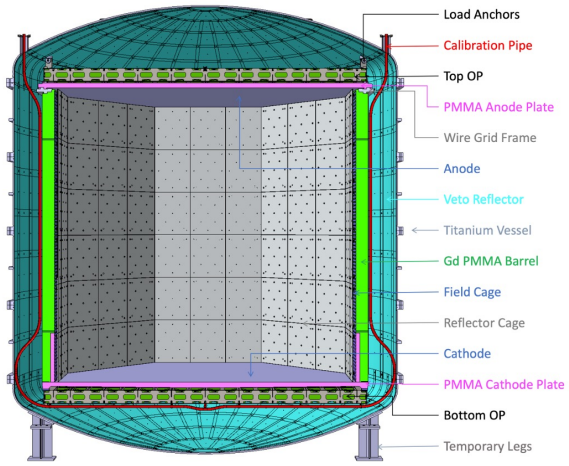
[3] DarkSide 50 results

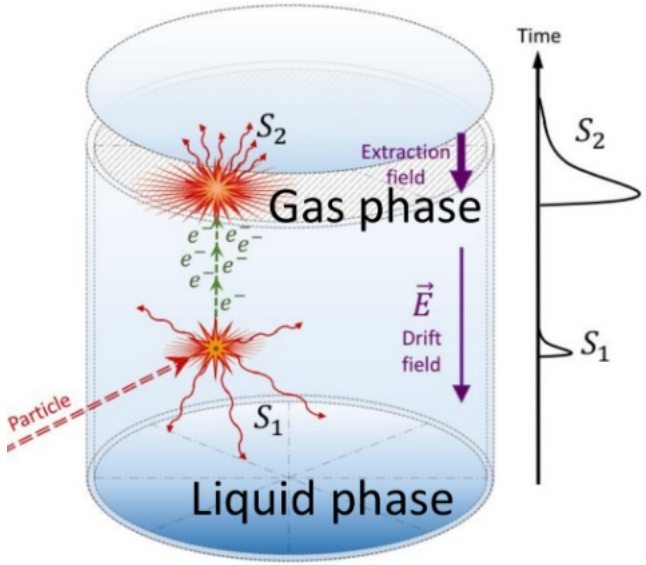
https://journals.aps.org/prd/abstract/10.1103/PhysRevD.93.081101

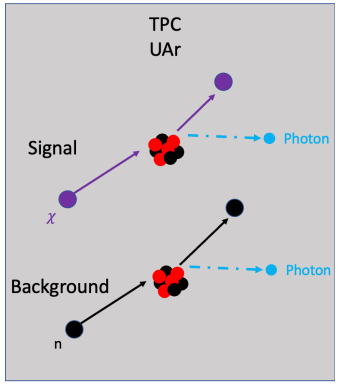
Extra Material

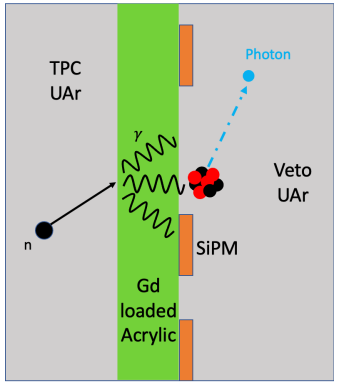
Time Projection Chamber (TPC)

- Dual phase signifies that there is a liquid and a gas phase
- Particle interacts with the Liquid UAr (LUAr) generating the first prompt light S1 and ionisation electrons
- Electrons drift upwards in the 200 V/cm electric field towards the gas phase where they produce a second prompt light identified as S2
- S1 and S2 both detected using arrays of Silicon Photo Multipliers (SiPMs) where the xy position can be calculated using the number of the channel that was triggered and the z depth by the time difference between the S1 and S2 prompts

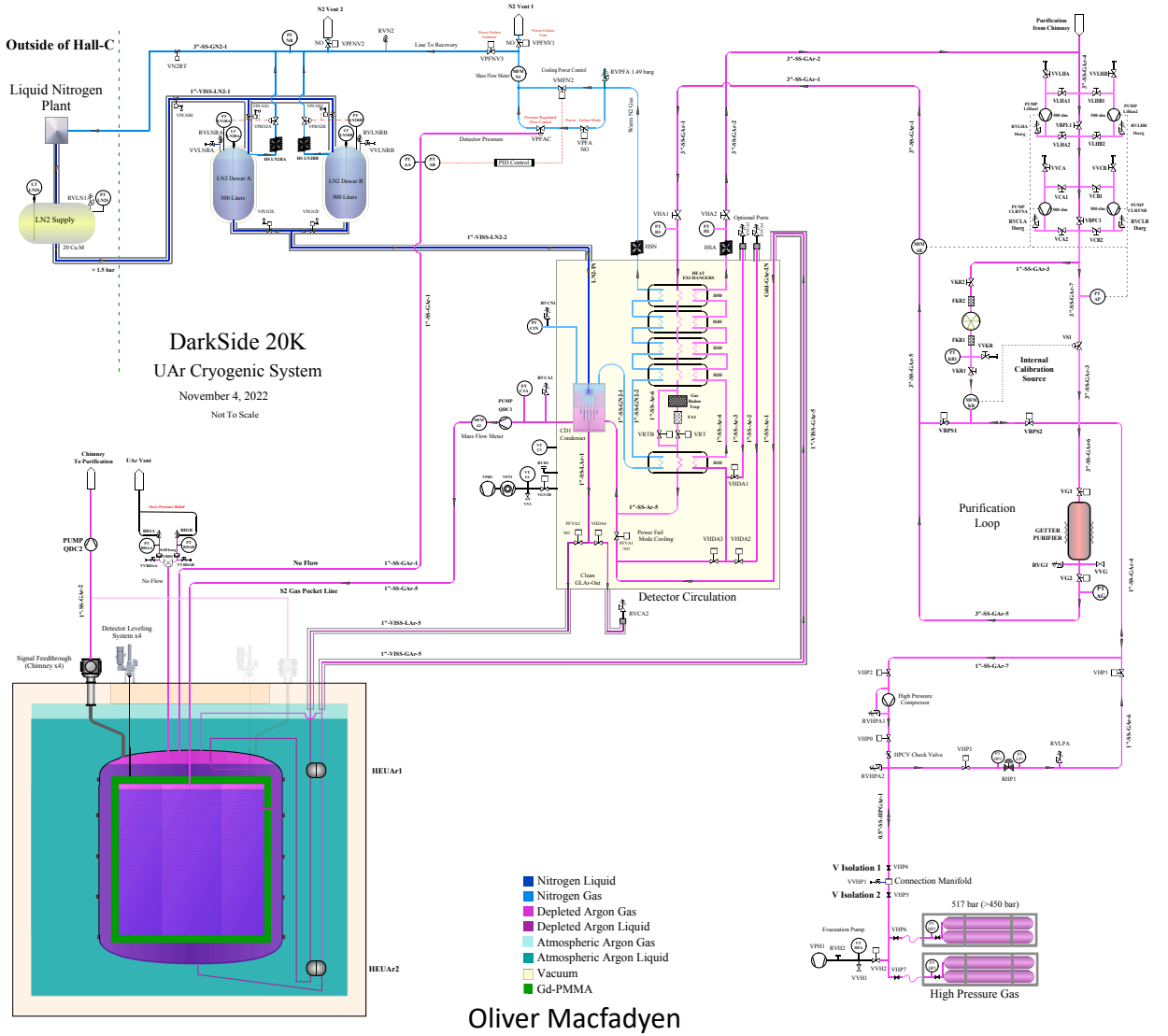




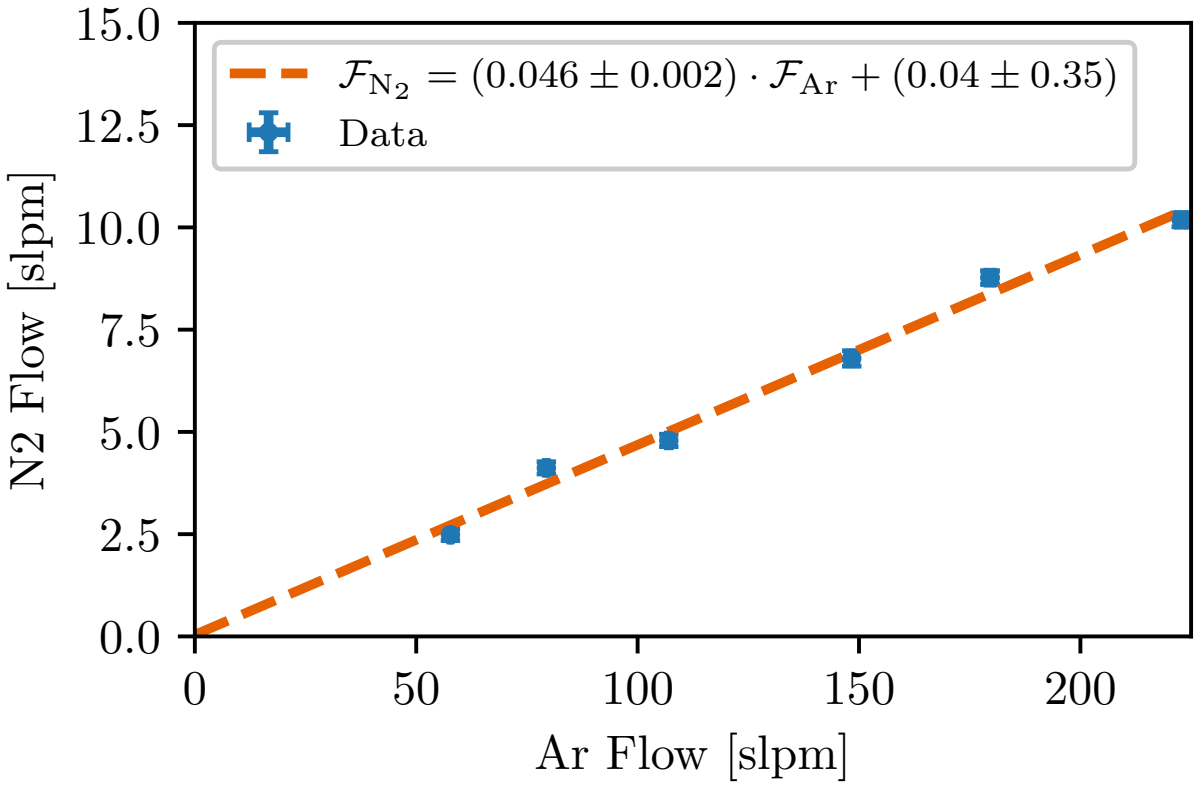


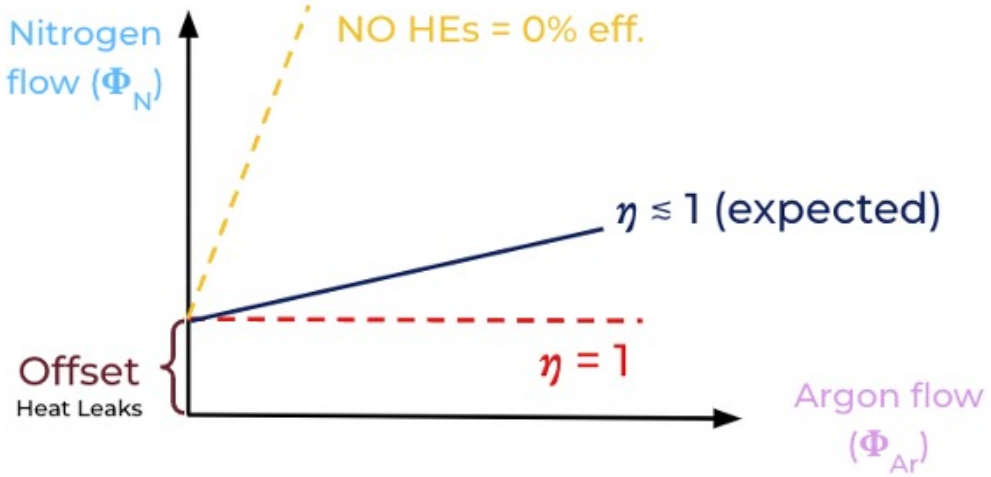


DarkSide 20k UAr Cryogenic System



System Efficiency

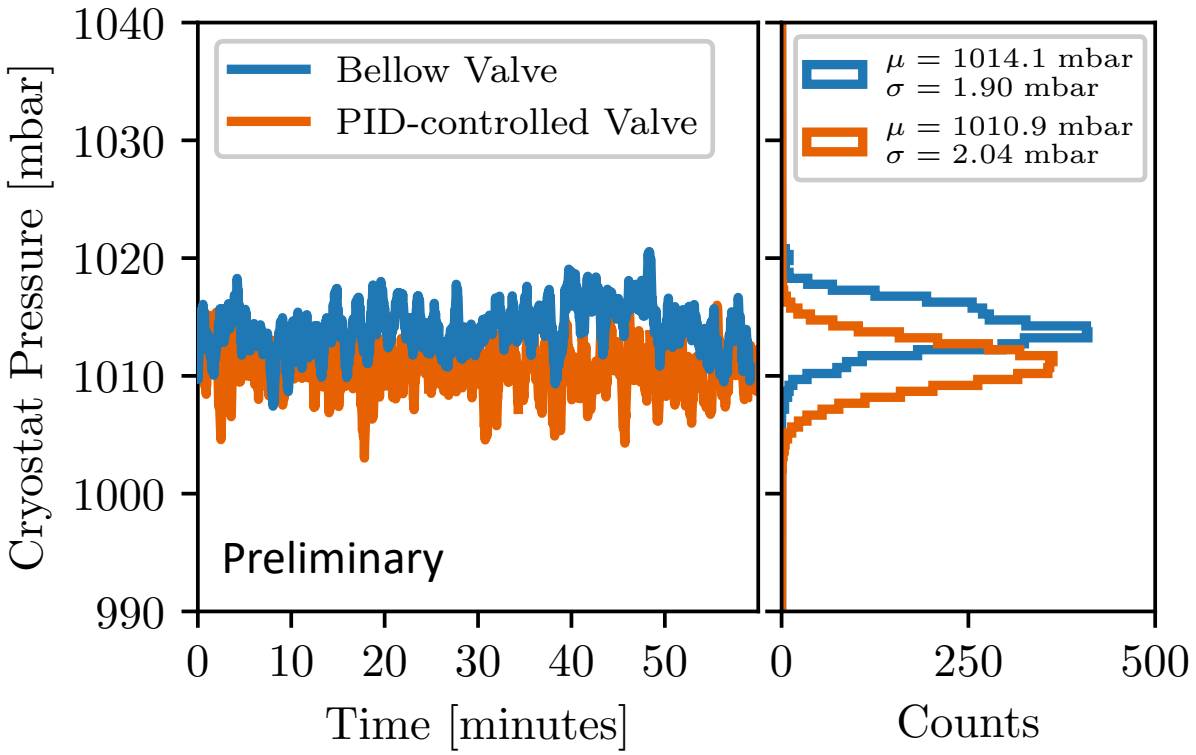


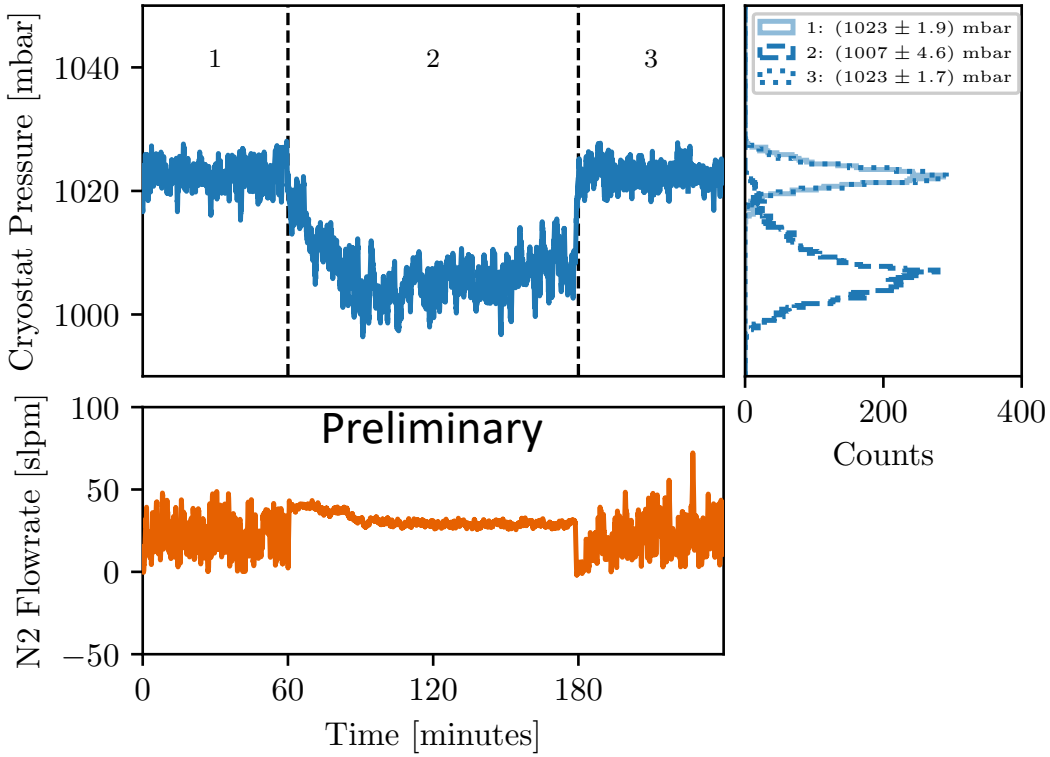


$$\eta = 1 - \frac{\dot{m}_N \Delta h_N}{\dot{m}_{Ar} \Delta h_{Ar}} = 1 - C_1 \frac{\Phi_N}{\Phi_{Ar}}$$

Extrapolated efficiency of 94.8%

Pressure Stability and Switching Response

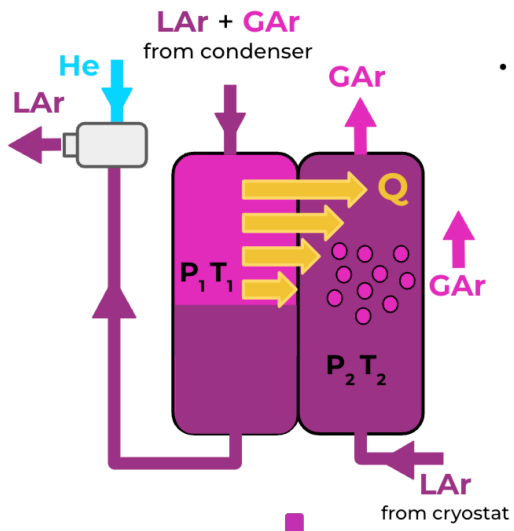




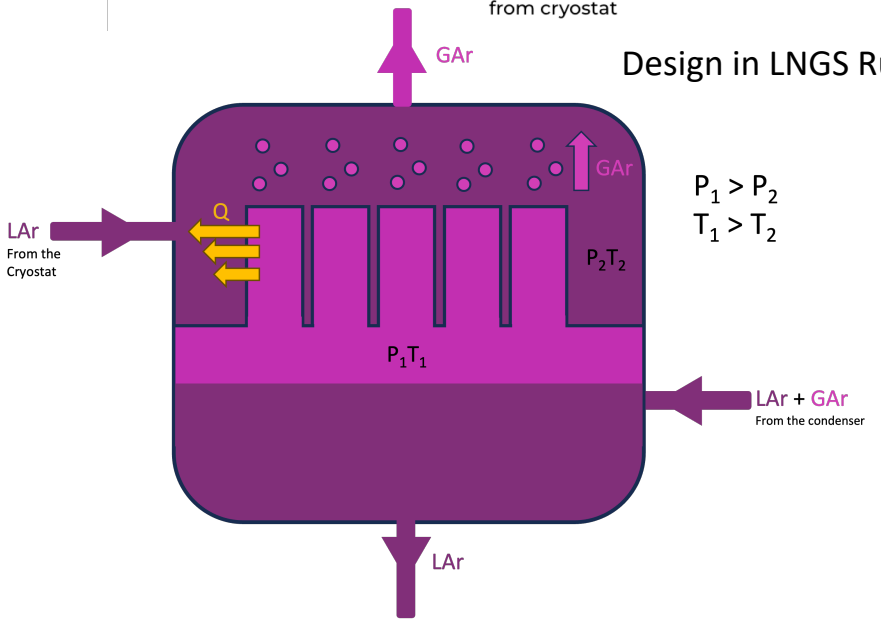
UAr Heat Exchanger Diagram

- Both designs:
  - LAr + Gar mix arriving from the condenser
  - LAr arriving from the cryostat
  - Heat exchange occurs between the two
  - LAr + GAr mix condenses and goes into the cryostat
  - GAr (produced from LAr from the cryostat) circulates through the purification loop
- Design 1:
  - Heat exchange between the gas inside the left section and the liquid in the right section
  - GAr causes reduction in surface area available for heat exchange and so causes a loss in efficiency
- Design 2:
  - The Gar from the condenser rises to inside the tubes
  - Increased surface area for heat exchange greatly improves potential flow rate

• Design in LNGS Run 1



Design in LNGS Run 2



$P_1 > P_2$
$T_1 > T_2$