The Cryogenics System for the Underground Argon in DarkSide-20k

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on behalf of the Global Argon Dark Matter Collaboration

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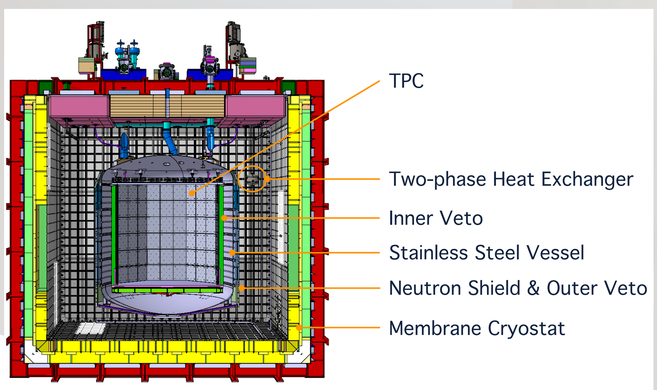
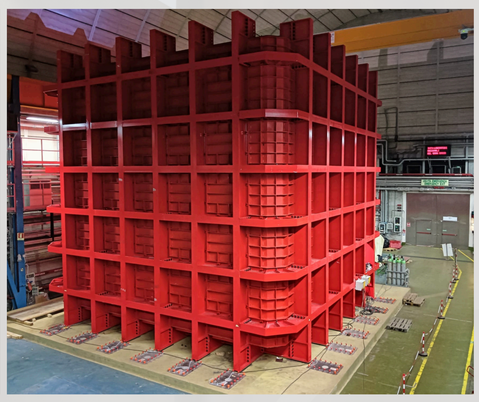
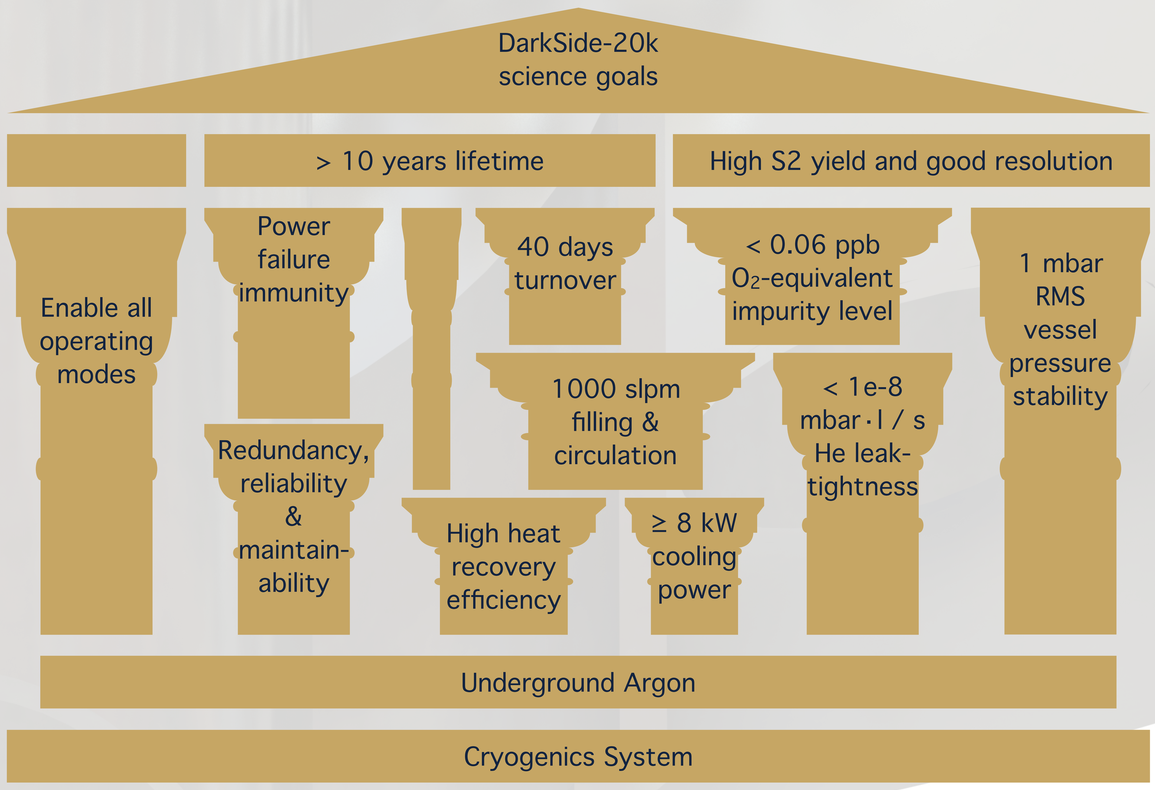
DarkSide-20k

- WIMP detector currently under construction in Hall C at LNGS
- Dual-phase TPC with 50 t underground argon (UAr) target and 50 t UAr inner veto volume in a stainless steel vessel
- 650 t atmospheric argon (AAr) shield and outer veto
- UAr from a CO_2 well in Colorado has ~1400 times lower ^{39}Ar content
- See talks on DarkSide-20k and UAr at this conference!

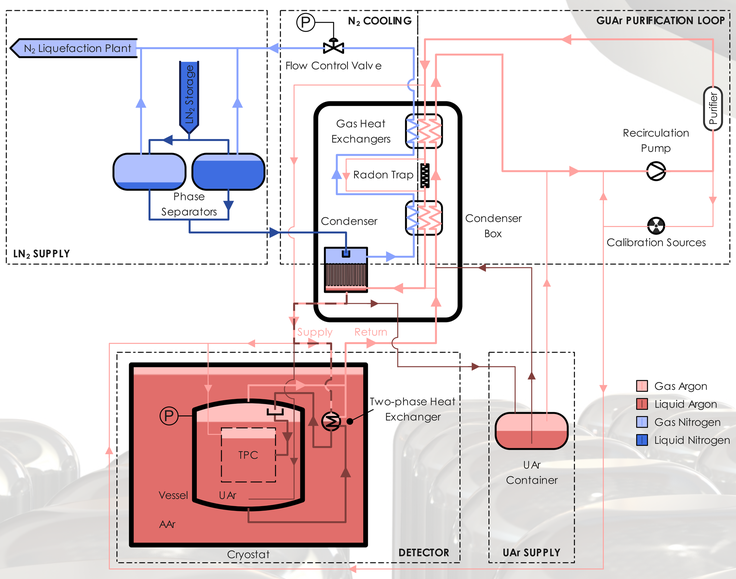




Cryogenics System Requirements



Conceptual Design



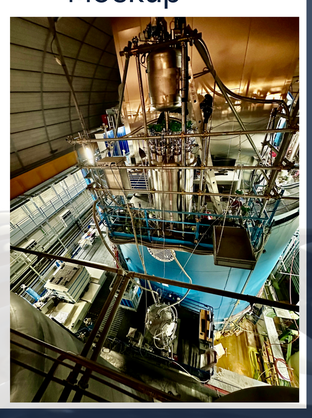
Testing Facilities

CERN Cryolab

- Fabrication, construction, commissioning
- First efficiency & recirculation tests

LNGS Hall-C

- Thorough benchmarking
- Detector Mockup

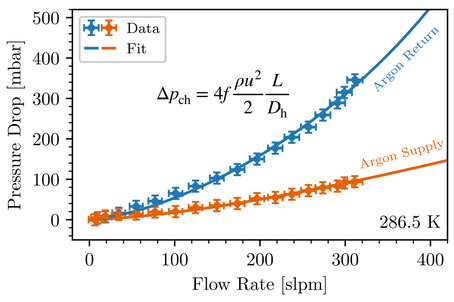


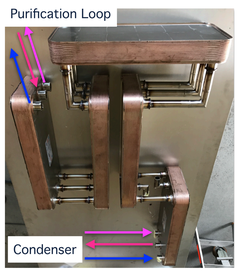
Preliminary Commissioning & Benchmarking Results

Circuit Resistance

- Dominated by dual-circuit heat exchanger cascade
- Modelled with Darcy-Weisbach equation and Muley friction factor

$$f = \left(\frac{\alpha}{30}\right)^{0.83}\left[\left(\frac{30.2}{\mathrm{Re}}\right)^{5} + \left(\frac{6.28}{\mathrm{Re}^{0.5}}\right)^{5}\right]^{0.2}$$

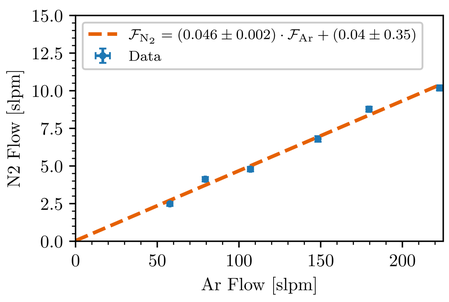


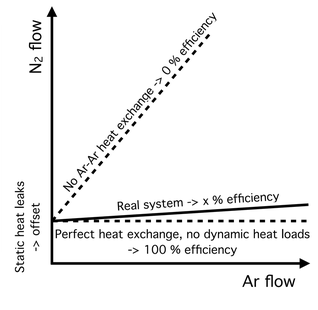


Heat Recovery Efficiency

- Define efficiency measure by nitrogen consumption per argon flow:

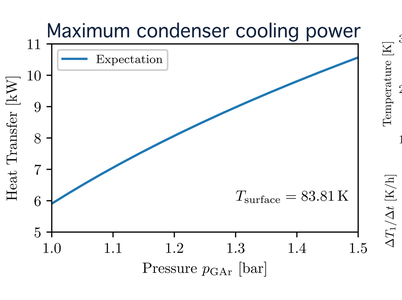
$$\eta := 1 - \frac{\rho_{N_2}}{\rho_{Ar}}\left|\frac{\Delta h_{N_2}}{\Delta h_{Ar}}\right|\frac{\mathrm{d}\mathcal{F}_{N_2}}{\mathrm{d}\mathcal{F}_{Ar}} = 95\,\%$$

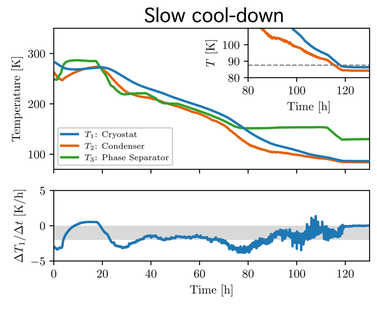




Cooling Performance

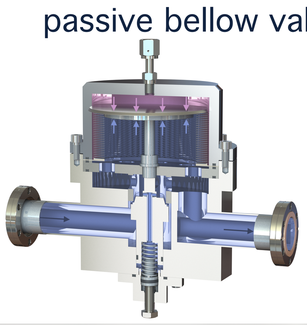
- 8 kW total cooling power (latent heat in condenser + gas enthalpy in gas-gas heat exchangers) at 1000 slpm
- Detector cool-down with cold gas only

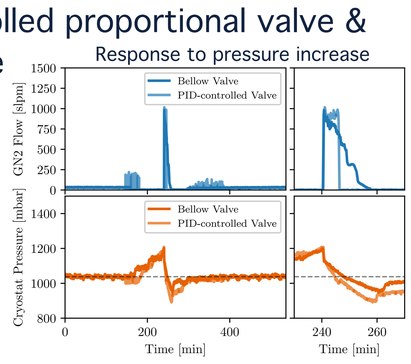




Cooling Control

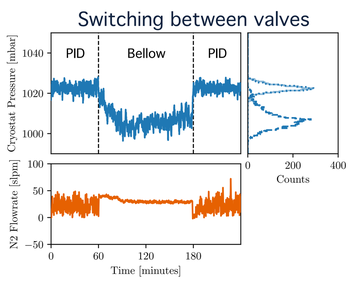
- Cooling power (= GN_2 nitrogen flow) based on cryostat pressure
- Independent flow-control valves: pneumatically actuated PID-controlled proportional valve & passive bellow valve

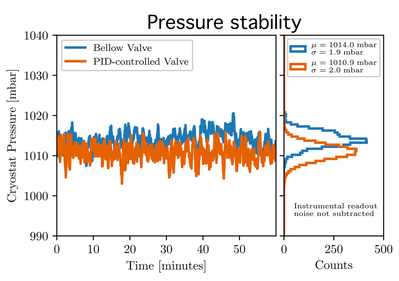




Pressure Stability

- Pressure stability within 0.1 mbar (bellow valve) and 0.2 mbar (PID valve) RMS after subtraction of electronic noise with principal component analysis





Maximum Argon Flow Rate

- Boil-off gas for recirculation efficiently produced in two-phase heat exchanger
- Heat transfer capability of different geometries assessed