HELIUM$^3$ GAS SYSTEM FOR CAST

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How to extend \textit{AXION} rest mass search?

- **CAST Phase I with vacuum**
  - $g_{agg} \leq 8.8 \times 10^{-11} \text{GeV}^{-1}$ for $m_a < 0.02 \text{ eV}$

- **To restore lost coherence $\rightarrow$ buffer gas**
  - $P_{a\rightarrow\gamma} = \left( \frac{B g_{a\gamma}}{2} \right)^2 \frac{1}{q^2 + \Gamma^2/4} \left[ 1 + e^{-\Gamma L} - 2e^{-\Gamma L/2} \cos(qL) \right]$

- Which gas, at 1.8 K?
  - $^4\text{He}$, $P_{\text{sat}} = 16.4 \text{ mbar} \rightarrow m_a < 0.43 \text{ eV}$
  - $^3\text{He}$, $P_{\text{sat}} = 135.58 \text{ mbar} \rightarrow m_a < 1.23 \text{ eV}$

- How to scan?
  - Maximize discovery potential within limited time frame
    
    Overlapping the axion mass distribution at FWHM between two consecutive density settings

    Result: increasing step size from 0.08 to 0.12 mbar (at 1.8K)
**Challenge**

**HELUM-3 Gas System**

### Gas Metering
- Stability, Accuracy, Reproducibility
  - \(<0.01\) mbar stability, \(<1\) step reproducibility
- Thermally controlled calibrated volumes
- Metrological Pressure Measurement
- Homogeneous thermalization with superfluid Helium
- Computational Fluid Dynamics modeling
- Amount of gas measured with better than 60 ppm

### Gas Confinement (X-ray Windows)
- High X-ray transmission (Thin)
  - \(15\) μm polypropylene
  - \(~88\%\), PP15 \(>80\%\) (>2keV), \(95\%\) @ 4.2keV
- Robust (Strong-back mesh)
  - \(\varnothing 5.2\)mm, \(0.3\)mm, ↓\(5\)mm
- Hermeticity tested \(<1x10^{-7}\) mbarl\(\cdot\)s\(^{-1}\)
- Pressure Tested
  - All cycled at \(1\) bar (prototype holds 3.5 bar)
- Regularly baked-out to avoid cryopumping
**Challenge**

- **Superconducting magnet resistive transition (Quench)**
  - Rapid temperature rise → Pressure increase (max: 2.9 bar)
  - Goal: Minimize Pressure reach
  - Sub- atmospheric ($P_{\text{max}}/P_0 < 8$)
  - Protection of the cold X-ray windows
- **Requires:**
  - Fast Quench Detection/ Fast Gas Extraction
  - High Flow Conductance
  - Large Expansion Volume (450 litres)

- **Absence of spontaneous thermo-acoustic oscillations**
  - Initial CAST setup: Observed oscillations
  - Oscillations reduce axion-photon conversion probability
  - Investigation of driving parameters
    - Numerical Modeling
  - Installation of diagnosing tools
  - Installation of active and passive measures for elimination

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**Fast Fourier Transform**

![Fast Fourier Transform Graph](image)

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**Miniature Cryogenic Pressure Transducer**

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**Schematic drawing**

- Storage region
- Metering region
- Axion conversion region
- Expansion region (Recovery)

Technical Design Report [CERN-SPSC-2006-029]

**Requirements:**
- Avoid loss of $^3$He
- Absence of TAO’s
- Precision/Reproducibility
- Multiple stepping / Ramping of density

**Constraints:**
- Limited space
- Weight restrictions
- Custom components
- Magnet movement
- Instrumentation
Construction

- MFB, integration model
- MRB, integration model
- Metering region integration model
Construction

- MFB, intervention
- MRB, intervention
- Gas metering panel

SPSC - CAST STATUS REVIEW

HELUM-3 Gas System

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Construction

- Installation of Expansion Volume
- Liquid Nitrogen purification trap
Storage Region

- Cryogenic needle valve
8 Modes of operation
102 Signals with large variety
Flexible operation
Easy user interface/ Remote Operation

PLC for Control & Operation, Supervision + Data Management
Standard control Architecture design
  • UNICOS (UNified Industrial COntrol System) – Reliable + CERN support
  • + Cryogenics dynamics simulation for pre-commissioning
Based on simultaneous generation of:
  • PLC (Programmable Logic Controller) + UPS (uninterruptible power supply)
  • SCADA (Supervisory Control & Data Acquisition)
  • +diagnosing tools, rapid prototyping and regeneration mechanisms
Benefits from *LHC_logging* for long term archiving
  • + TIMBER (Technical Infrastructure Monitoring) interface tools for data analysis

Supplementary DAQ for sensitive instrumentation and analysis software
Final Remarks

..it was an exhausting but rewarding intervention

- Total cost within the budget
  - some unexpected delays occurred

- System was fully commissioned with $^4$He in November 2007 and was used for data taking in December

- Since February 2008 the system is fully operational with $^3$He, and is expected to be essential for the success of the physics runs up to 2010

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Axion 'αξιον εστι’
Axion 'is worth it'

Thank you