Online Tests of the Advanced Cryogenic Gas Stopper at NSCL

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Motivation for an Advanced Cryogenic Gas Stopper (ACGS)

Room Temperature Linear Gas Cell Limitations:
- Molecular Recombination
- Extraction time ≈ 60 – 200 ms
- Saturation above $10^6 – 10^7$ cps

Solutions:
- Cryogenic Temperatures
- Push Plates & Wire-Carpet in Mid Plane
- Rectangular Geometry for rapid charge removal
Rapid Removal of e-He⁺ Pairs
- Novel geometry reduces space charge effect from incoming beam

Reduce Molecular Ion Formation
- Cryogenic temperatures of 50 K Freeze contaminants to surface

Faster Transport Speeds and Simplified Maintenance
- 9 Bare wire-carpet modules with single-frequency 4-Phase RF surfing

Simple and Efficient Ion Extraction
- DC funnel and circular mini-carpet with nozzle
Design of the ACGS
Unique and Novel Features Support Maintainability and High Performance

- **Segmented Push Plates**
  - For variable push fields
  - Able to measure Bragg Peak

- **PT Coolers**
  - Reduces gas contaminants

- **Funnel and Mini-Carpets**
  - Simplifies Geometry

- **9 Bare Metal Wire-Carpet Modules**
  - For faster transport
  - Ease of maintenance
The ACGS Installed in Beam-Line

Funnel and Mini-Carpets
Simplifies Geometry

PT Coolers
Reduces gas contaminants

Segmented Push Plates
For variable push fields
Able to measure Bragg Peak

9 Bare Metal Wire-Carpet Modules
For faster transport
Ease of maintenance
Transport in the ACGS uses Single-Frequency 4-Phase Ion Surfing

\[ E_p \]

\[ v_w \]

\[ v_{ion} \]

\[ e^- \]

\[ He^+ \]

AFG

AFG

Channel 1

Channel 2

Wire-Carpet

Signal Generator

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K R. Lund, September 2018, Slide 6
The ACGS Wire-Carpet
Bare Metal Wires to Avoid Charge Up and Minimize Radiation Damage

Wire-Carpet specs: 250 × 150 mm; 376 CuBe wires 50 µm OD; 400µm pitch
Fabrication: Made by hand; pre-tensioned to accommodate thermal contraction
Operation: 30 Torr @ 50 K; $E_p$ up to 100 V/cm; 3-10 MHz Frequency
Offline Tests Confirm Wire-Carpet Concept
Transport Efficiency of 100% with Speeds up to 70 m/s

- $^{39}$K$^+$ ion source:
  - $E_p = 15$ V/cm, $P = 60$Torr, $T = 300$K
- Fast transport at operating condition
- High Efficiencies above 3 MHz RF Wave
First Online Tests with $^{47}$K Successful

- Beam rate from A1900 $2.5 \times 10^7$ pps with 94% purity
- $\text{H}_2\text{O}$ reduced when cryogenic
- All internal components work as designed

$\text{T} = 100 \text{ K}$

$P = 56 \text{ Torr}; f = 4.5 \text{ MHz}$
$V_{\text{RF}} = 70-120 \text{ V}_{\text{pp}}$ $E_p = 5-30 \text{ V/cm}$
Modules Turned on in Pairs
Summary

- ACGS has been constructed and commissioning is underway
- All metal wire-carpet and single-frequency, 4-phase ion surfing has been demonstrated
- First online test at cryogenic temperature successful
- Transition to operations soon
Thank you

- Wide transport frequency for 40AMU and greater
- Faster transport speeds
- No losses between carpet transitions (RT and 50K)
- Investigate 8-Phase RF wave
  - Increase RF Amplitude Voltage to improve Efficiency
- Further study nozzle geometry
**47K Initial Tests**

![Graph showing D1000 Rate (kcps) across different settings: All Off, Mini-Only, Mini-Funnel, Mini-7, Mini-5, Mini-3, All On.]

- **Rate 300K**
- **Rate 100K**

**47K after ACGS (cps)**

- **47K**
- **47K(H2O)**

![Mass (AMU) plot with peaks for 47K and 47K(H2O) with rates 300K and 100K.]

- **Rate 300K**
- **Rate 100K**
ACGS Carpet Distance at 100Torr

\[ \nu_d \text{ (Volt)} \]

\[ pd \text{ [Torr cm]} \]

- **He**
- **Ne**
- **Ar**
- **H\(_2\)**
- **N\(_2\)**
Gas Cells are “bottle neck” for all Low-Energy experiments and to ReA
Transport Efficiency (%)

Ep (V/cm)

Pang 2011 3.5MHz 170Vpp 60Torr
ACGS Prototype 2016 3.5MHz 100Vpp 60Torr

Pang 2011 30Torr 2MHz
ACGS Prototype 2016 3.5MHz 30Torr 100Vpp
3.5MHz, 100Vpp
20161118

Push Field (V/cm)

Transport Efficiency (%)

RF Amp (Vpp)

$E_p = 5\text{V/cm}$
$E_p = 40$ V/cm

1 Stopped ion = $10^6$ He$^+$

10$^7$ pps

10$^8$ pps
Distance (mm) vs. Push Field (V/cm) for 90% Helium Transported.
\[
\begin{align*}
\text{[H}_3\text{O(H}_2\text{O)}] &+ \\
\text{[H}_3\text{O(H}_2\text{O)}_2] &+ \\
\text{[CH}_3\text{H}_2\text{O)} &+ \\
\text{[CH}_3\text{H}_2\text{O)}_2 &+
\end{align*}
\]
- Max gap 400µm
- Max offset of ~1mm
- Able to overcome misalignment losses