

Development of In Gas Laser Ablation Source

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Neutrinos and Neutrinoless Double Beta Decay ($0\nu\beta\beta$)

Known

- Neutrinos are weakly interacting particles
- Neutrinos have mass

Postulated

- Are neutrinos their own antiparticle?
- Can neutrinos violate lepton number conservation?

Search for $0\nu\beta\beta$ → lepton number violating decays

The nEXO Experiment

- A proposed neutrinoless double beta decay ($0\nu\beta\beta$) detector
 - 5 tonne LXe enriched with 90% ^{136}Xe
 - Time Projection Chamber (TPC) for 3D event reconstruction



Ba-Tagging

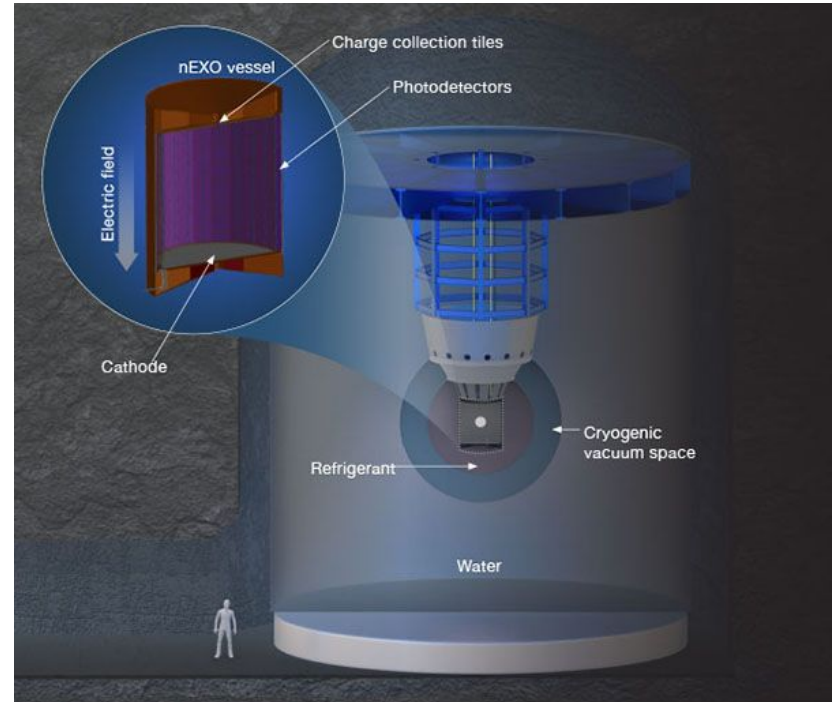


Image taken from <https://nexo.llnl.gov/nexo-overview>

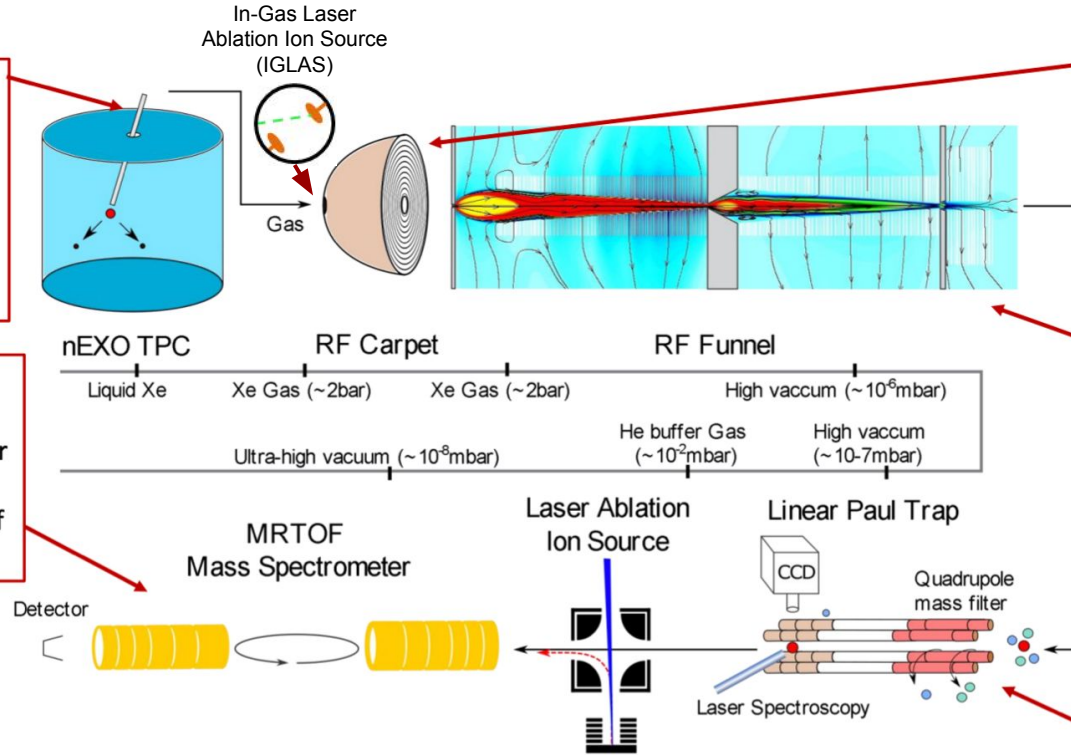
Canadian Ba-Tagging Scheme

Stage1:

Extraction of detector volume around the location of the decay to gas phase using a capillary tube.

Stage5:

Multiple Reflection TOF Spectrometer for systematic studies and determination of ion mass.



Stage2:

RF carpet for efficient transfer of ion from capillary to RF funnel

Stage3:

RF funnel facilitates separation of xenon accompanying the Barium ion.

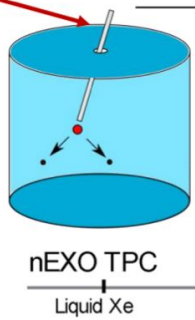
Stage4:

The Linear Paul trap for detection of barium ion via laser fluorescence spectroscopy.

Canadian Ba-Tagging Scheme

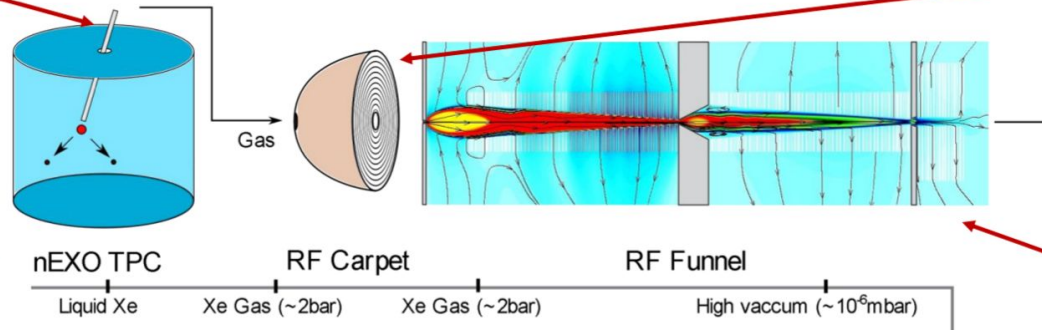
Stage1:

Extraction of detector volume around the location of the decay to gas phase using a capillary tube.



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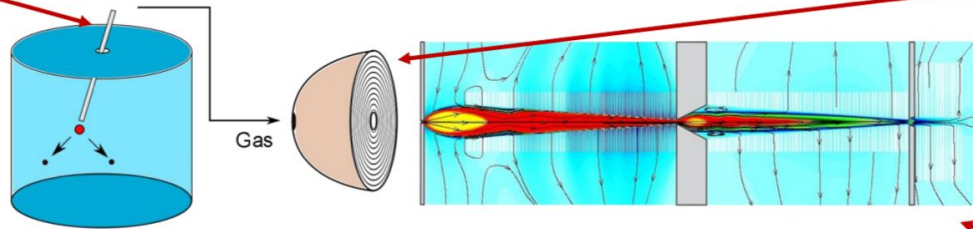


Stage2:
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nEXO TPC
Liquid Xe
Xe Gas (~2bar)
Xe Gas (~2bar)

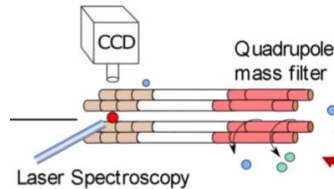
RF Carpet

RF Funnel

High vacuum (~10⁻⁶mbar)

High vacuum (~10⁻⁷mbar)

Linear Paul Trap



Stage2:
RF carpet for efficient transfer of ion from capillary to RF funnel

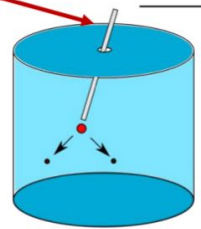
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Detector

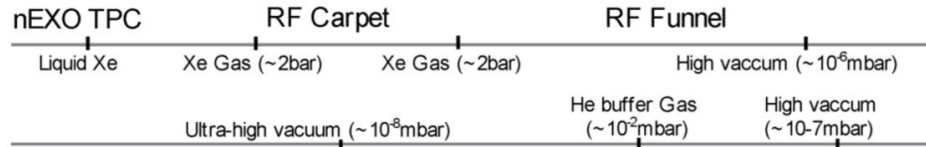
MRTOF
Mass Spectrometer

Laser Ablation
Ion Source

Linear Paul Trap

Laser Spectroscopy

Quadrupole
mass filter



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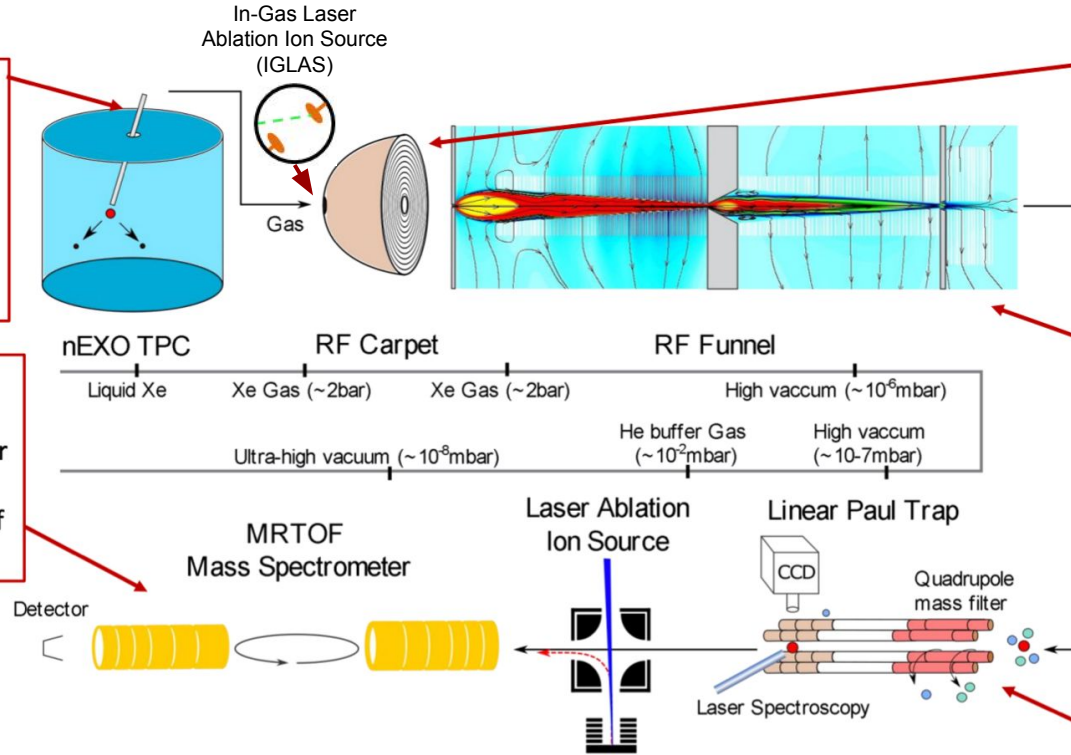
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What is Laser Ablation?

- Focused laser to release ions from surface of target

Advantages?

- Provides a low-rate source of a specific ion
- Allows for synchronization with rest of ion optics
- We have experience with laser ablation in vacuum

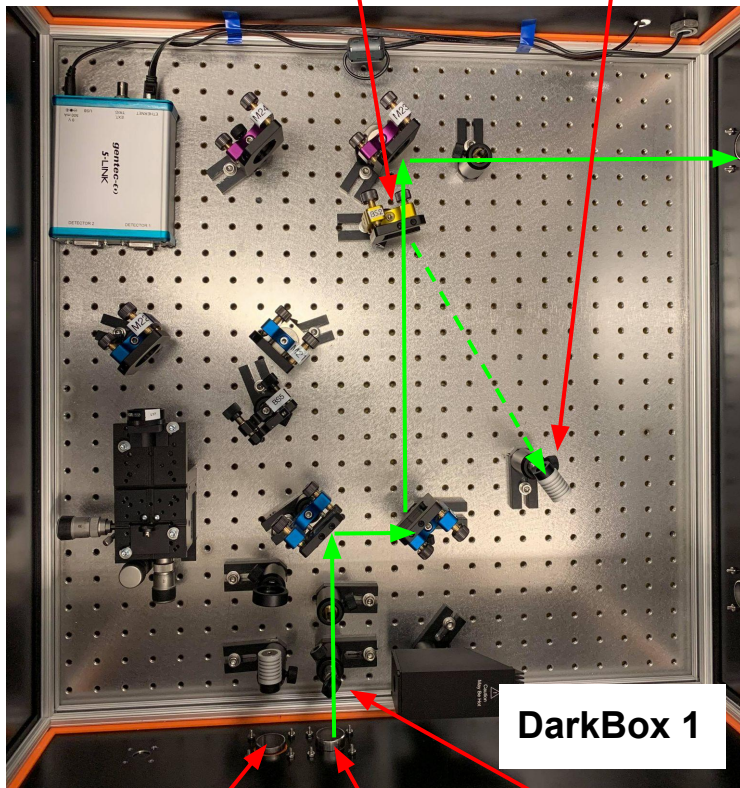


Thesis, M.M.Peregrina

Set Up

Beam Splitter

Beam Dump/
Energy Meter



DarkBox 1

355 nm

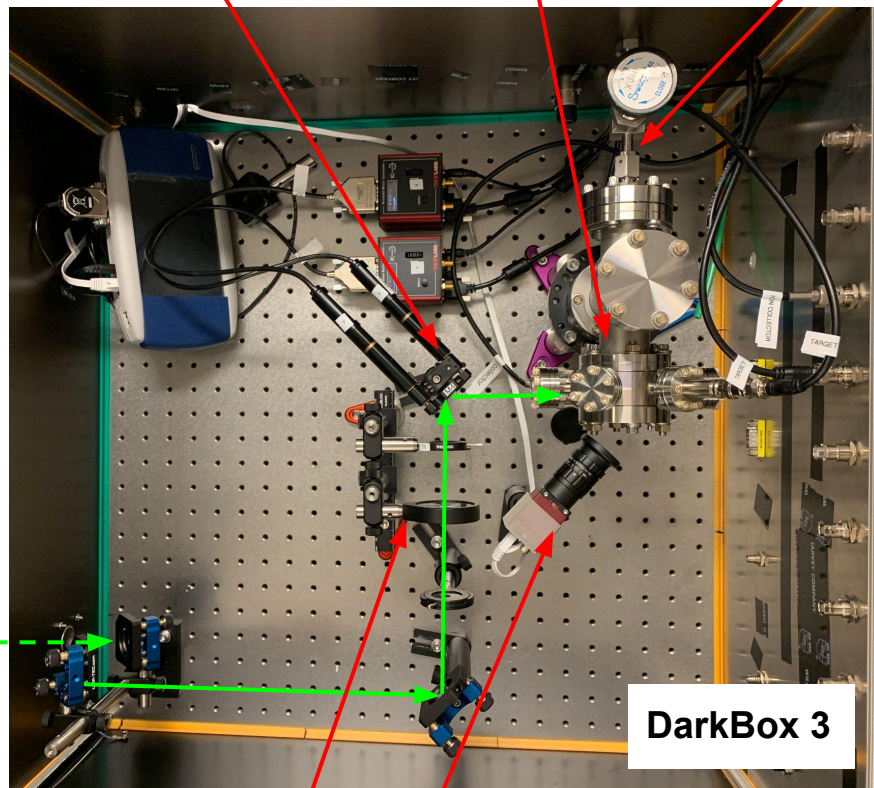
532/1064 nm

Dichroic Mirror

Motorized Mirror

In-Gas LAS
Chamber

to Xe Gas
Cart



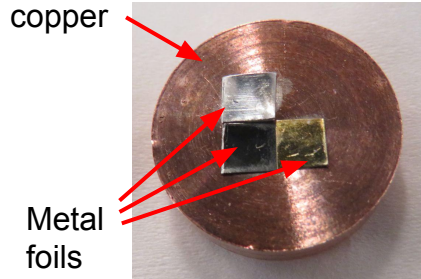
DarkBox 3

Focusing Lens

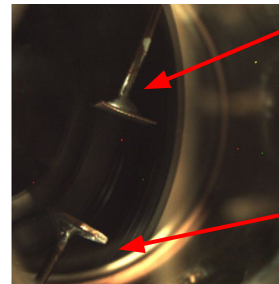
Camera (Joseph Torsiello - Aug 23, 18:00 EST)

IGLAS Chamber

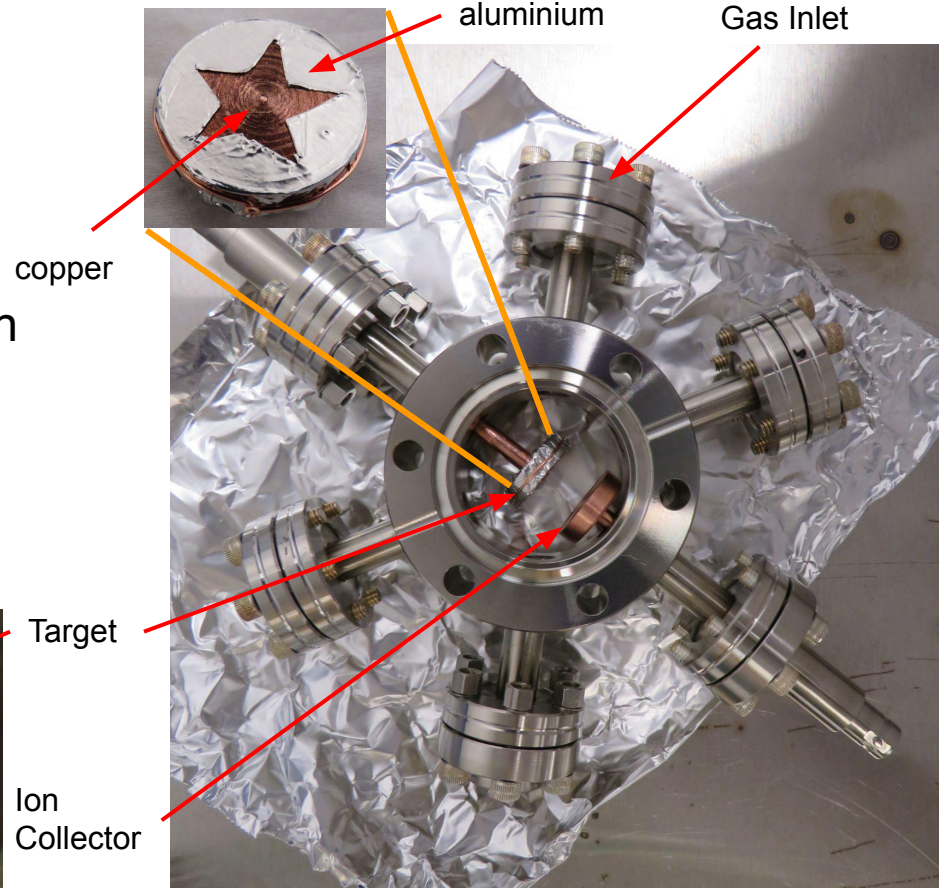
- Two parallel copper plates separated by $\sim 0.8\text{mm}$
- Chamber at vacuum or filled with gas
- Different metals for calibration



Multi-metal targets with new target design



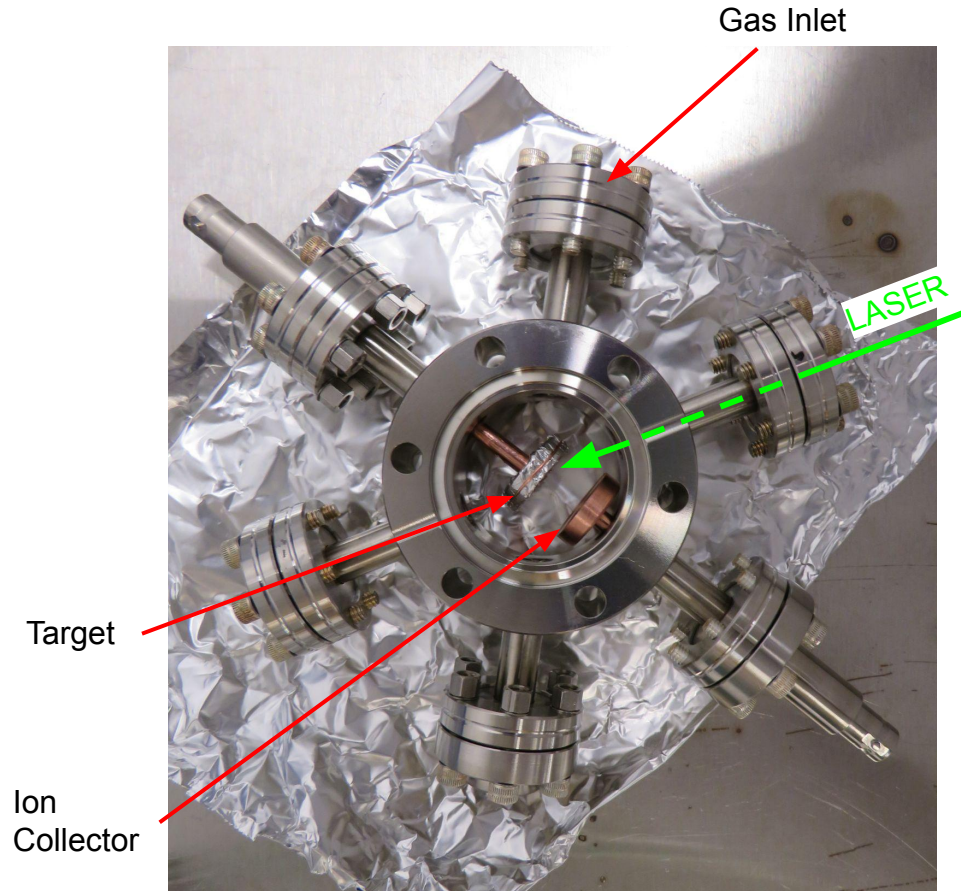
Old Targets Design



New Targets Design for In-Gas Laser Ablation Source (IGLAS)

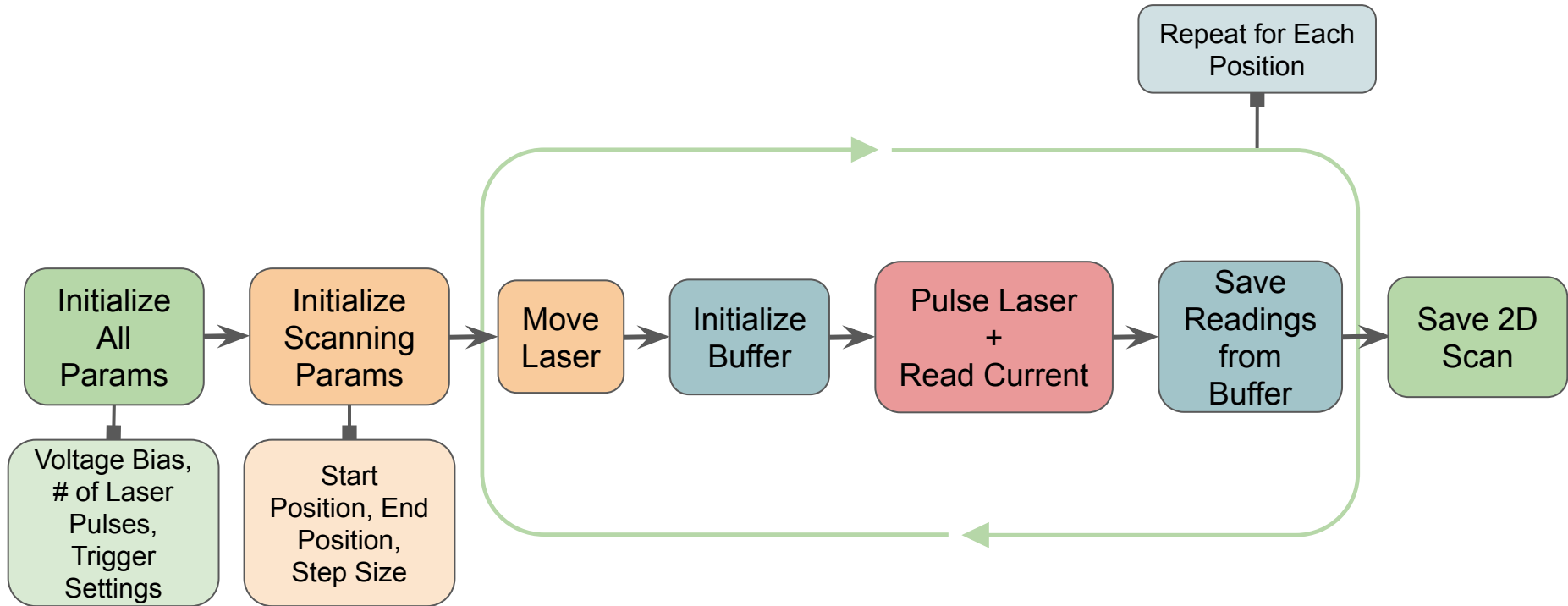
IGLAS - Measurement

1. Ions are ablated off the surface of the target
2. Apply voltage bias to drift ions from target to ion collector
3. Signal read as ion current on collector and target



IGLAS Chamber

Measurement Cycle



Data Acquisition - LabView Control Panel

Intensity Plot of Current

Voltage Bias Settings

PS error out

status	code	status	code
✓	0	✓	0

Picoammeter Error Out

status	code	status	code
✓	0	✓	0

Save Data!

File Path: D:\IGLAS\Scan data

File Name: Your_Filename_Here

Save Data

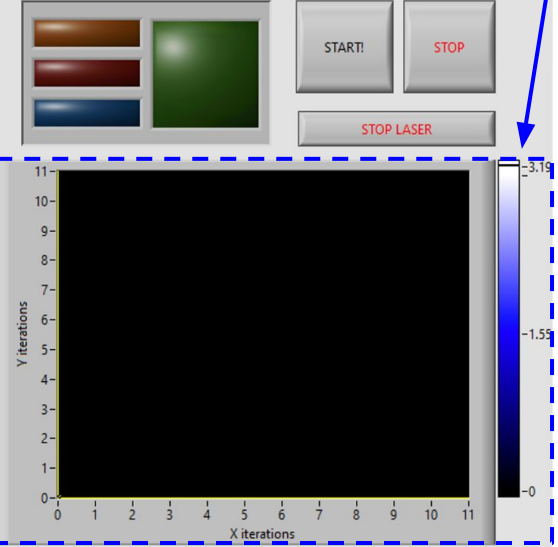
Target Holder and Ion Collector

CH1 Output state CH2 Output state CH3 Output state

CH1 Set Voltage [V]	CH1 Measured Voltage [V]	CH2 Set Voltage [V]	CH2 Measured Voltage [V]	CH3 Set Voltage [V]	CH3 Measured Voltage [V]
5.000	0.000	3.000	0.000	3.000	0.000

CH1 Set Max Current [A]	CH2 Set Max Current [A]	CH3 Set Max Current [A]
0.100	0.100	0.100

Set Voltage



Picoammeter Settings

Picoammeter and Batch Mode Settings

Trigger Delay: 0

NPLC: 0.01

Rep Rate Divide By (1-10): 1

Batch Size: 10

Remaining Pulses: 0

Set Rep Rate

Set Start

HOME MOTORS

Surface Scan Settings

Kinesis X Control: 27002137

Kinesis Y Control: 27002008

Starting X Position: 8.859

End X Position (mm): 9.475

Starting Y Position: 6.005

End Y Position (mm): 6.283

of Steps X: 2

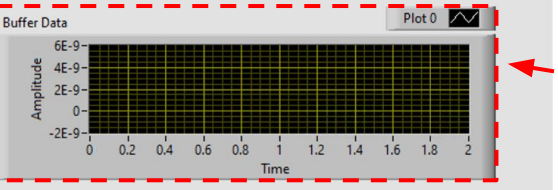
Current X Position: 9.38000

of Steps Y: 2

Current Y Position: 6.00000

Set Start

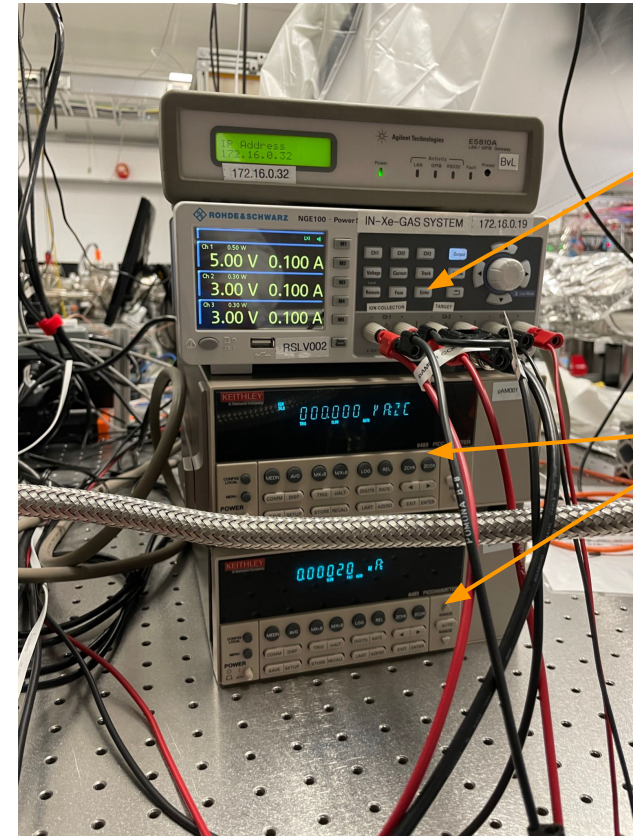
HOME MOTORS



Buffer Readings

Triggering Measurements

- Readings from Keithley Picoammeter are triggered by TTL signal from Q1 laser
- At each position, laser is fired a set number of times and the readings are loaded into a buffer
- All readings in buffer are returned and buffer is cleared before moving to next position



Power Supply

Picoammeter

Moving Forwards

Demonstrate in-vacuum operation works in new setup
(Scan multi-element targets for calibration)



Increase pressure inside IGLAS chamber



Test different gases (helium, argon, xenon)



Barium ablation in xenon gas at 10bar pressure

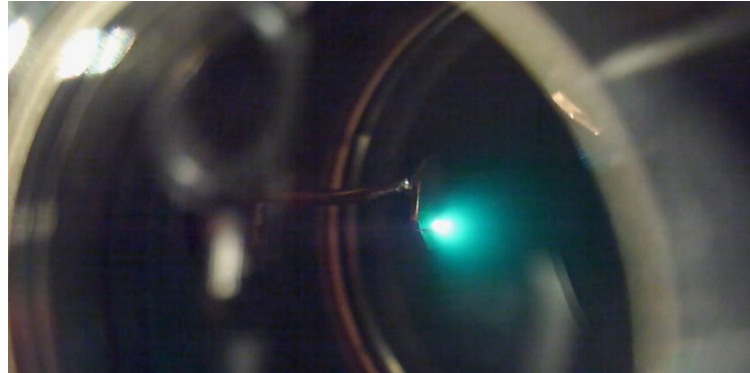
Experimental Controls

Measure ion current signals as a function of different parameters:

- 1) Pressure up to 10 bar
 - 2) Different gas environments
 - 3) Electric field dependence
 - 4) Multi-material targets
 - 5) Different laser wavelengths (266 nm, 355 nm, 532 nm, 1064 nm)
 - 6) Laser energy and repetition rate up to 10 Hz
 - 7) Laser spot size on target
- } Laser Fluence

Conclusion

- Laser ablation has been tested in vacuum in IGLAS and measured ion currents up to 80 nA
- Making progress towards scanning in an in-gas laser ablation source for the Ba-tagging setup



349nm laser on copper target in vacuum taken by Melissa Medina Peregrina.

Acknowledgements



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Canadian Astroparticle Physics Research Institute



NSERC
CRSNG

INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION



McGill
UNIVERSITY

*Fonds de recherche
sur la nature
et les technologies*

Québec 



Thank You for Listening!