

Laser Spectroscopy at the Cyclotron Institute

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Cyclotron Institute



Karthein Lab
Texas A&M University

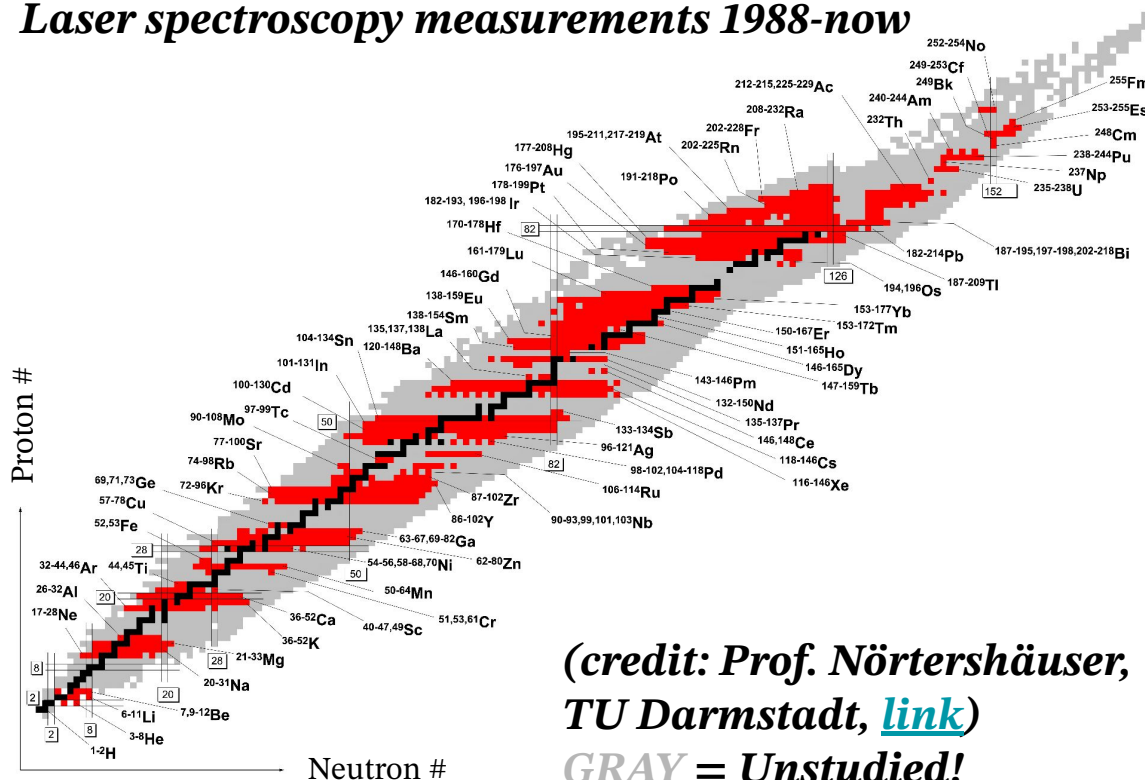
Content:

- Motivation and laser spectroscopy technique
- Current developments at the Cyclotron Institute
- Integrating ML&AI into precision measurement

Motivation

Laser spectroscopy provides precise nuclear measurements that challenge theory and advance security, energy, and environmental research!

Laser spectroscopy measurements 1988-now

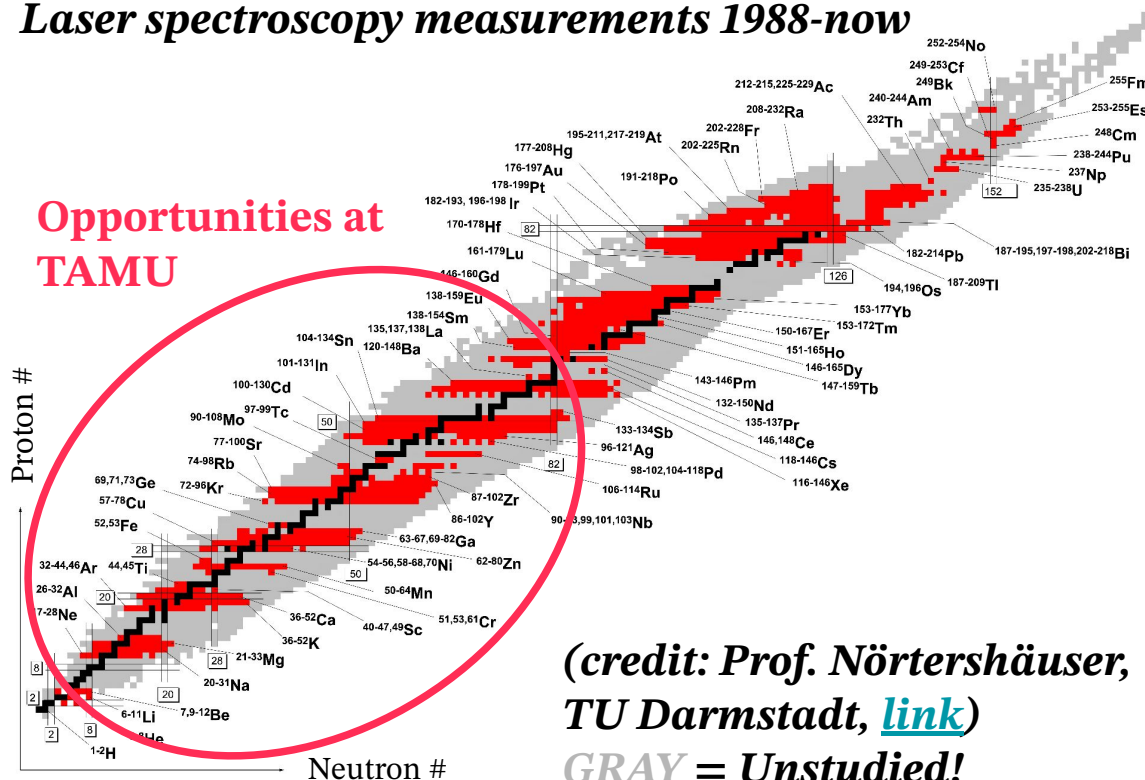


(credit: Prof. Nörtershäuser, TU Darmstadt, [link](#))
GRAY = Unstudied!

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Laser spectroscopy measurements 1988-now

Opportunities at TAMU



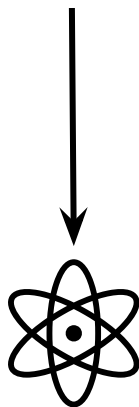
(credit: Prof. Nörtershäuser, TU Darmstadt, [link](#))
 GRAY = Unstudied!

How will we measure?



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- 30 MeV/u ^3He beam on target
 - light-ion fusion-evaporation reactions
 - Stopping, mass separation, bunching

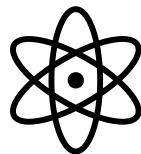
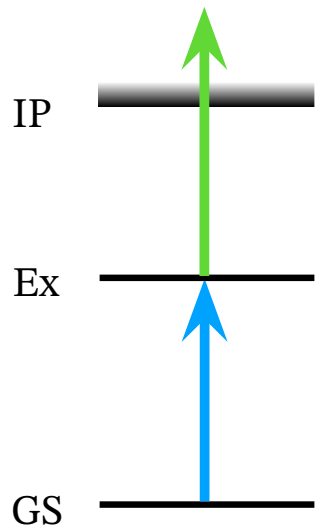
How will we measure?

Resonant Ionization Spectroscopy = detecting ions (instead of photons)



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Cyclotron Institute



→ High background suppression

→ High precision $\lesssim 100$ MHz

How will we measure?

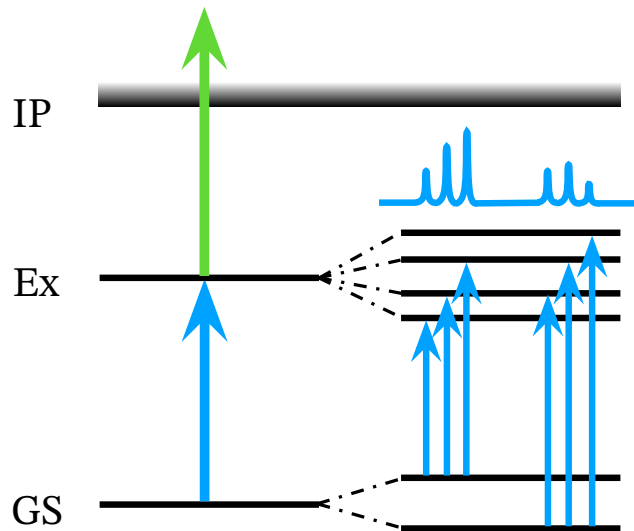
Resonant Ionization Spectroscopy

= detecting ions (instead of photons)



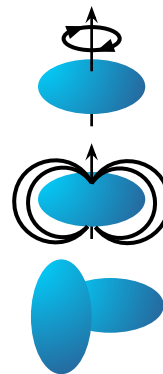
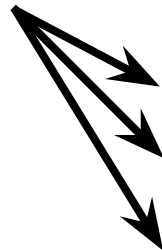
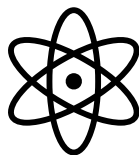
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→ High background suppression

→ High precision $\lesssim 100$ MHz



Nuclear spin

Magnetic moment

→ Nuclear magnetic field

Quadrupole moment

→ Nuclear deformation

How will we measure?

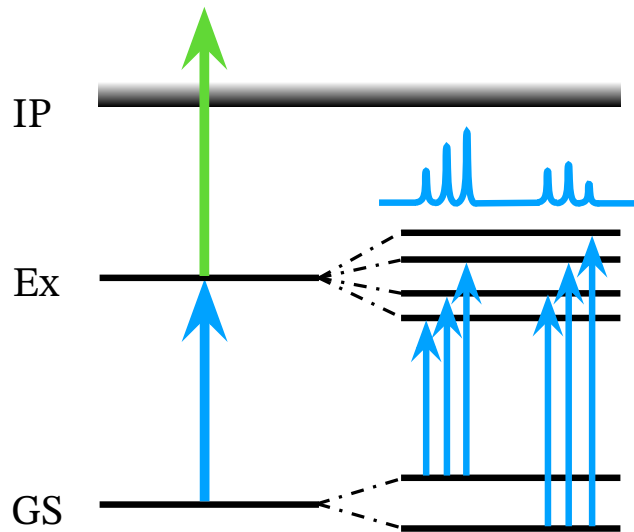
Resonant Ionization Spectroscopy

= detecting ions (instead of photons)



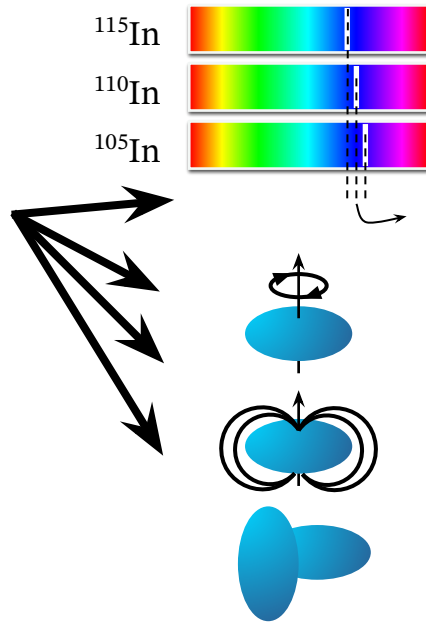
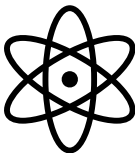
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→ High background suppression

→ High precision $\lesssim 100$ MHz



Isotope shift

→ Nuclear size, deformation

Nuclear spin

Magnetic moment

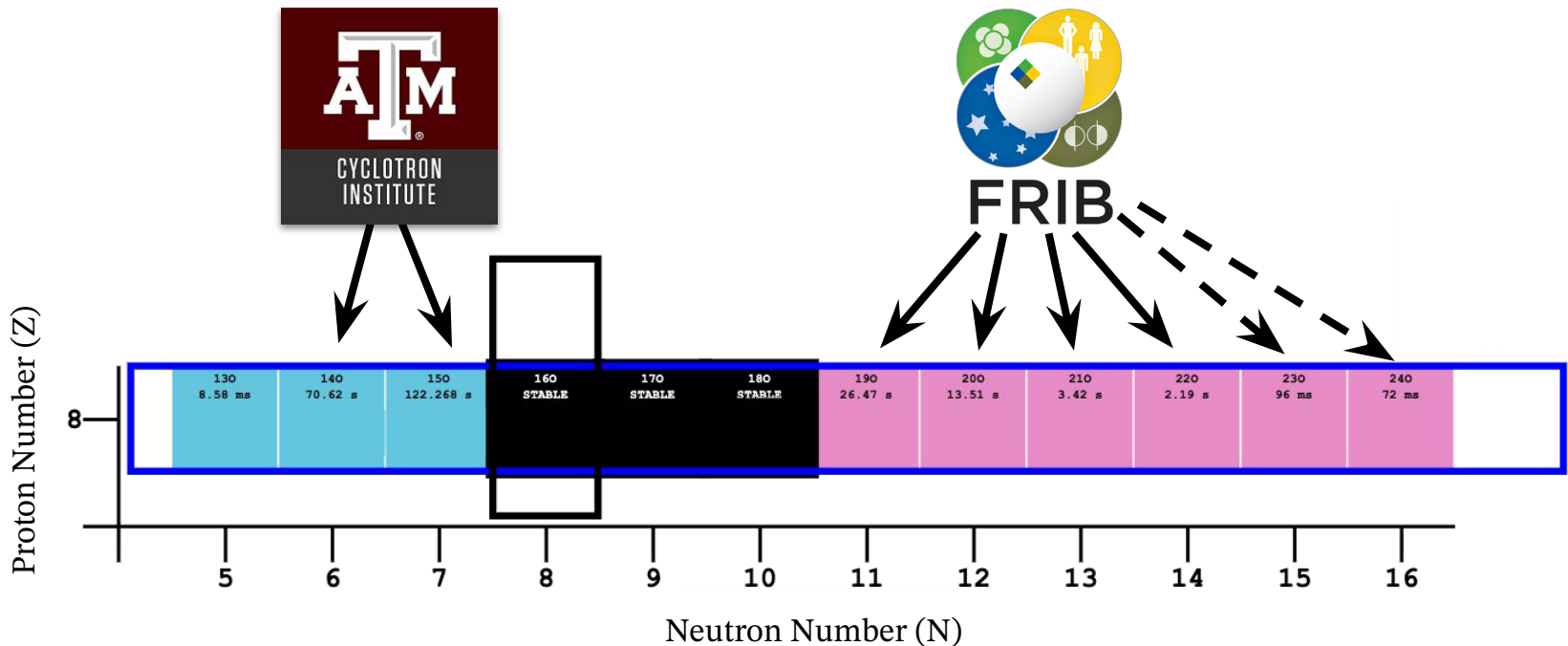
→ Nuclear magnetic field

Quadrupole moment

→ Nuclear deformation

First Case: Oxygen

- Oxygen is the only proton-magic element that has yet to be precisely measured with laser spectroscopy!
- BECOLA/RISE @ FRIB approved experiment for neutron-rich Oxygen isotopes.
- Opportunity at the Cyclotron Institute to probe neutron-deficient Oxygen isotopes near the proton dripline.

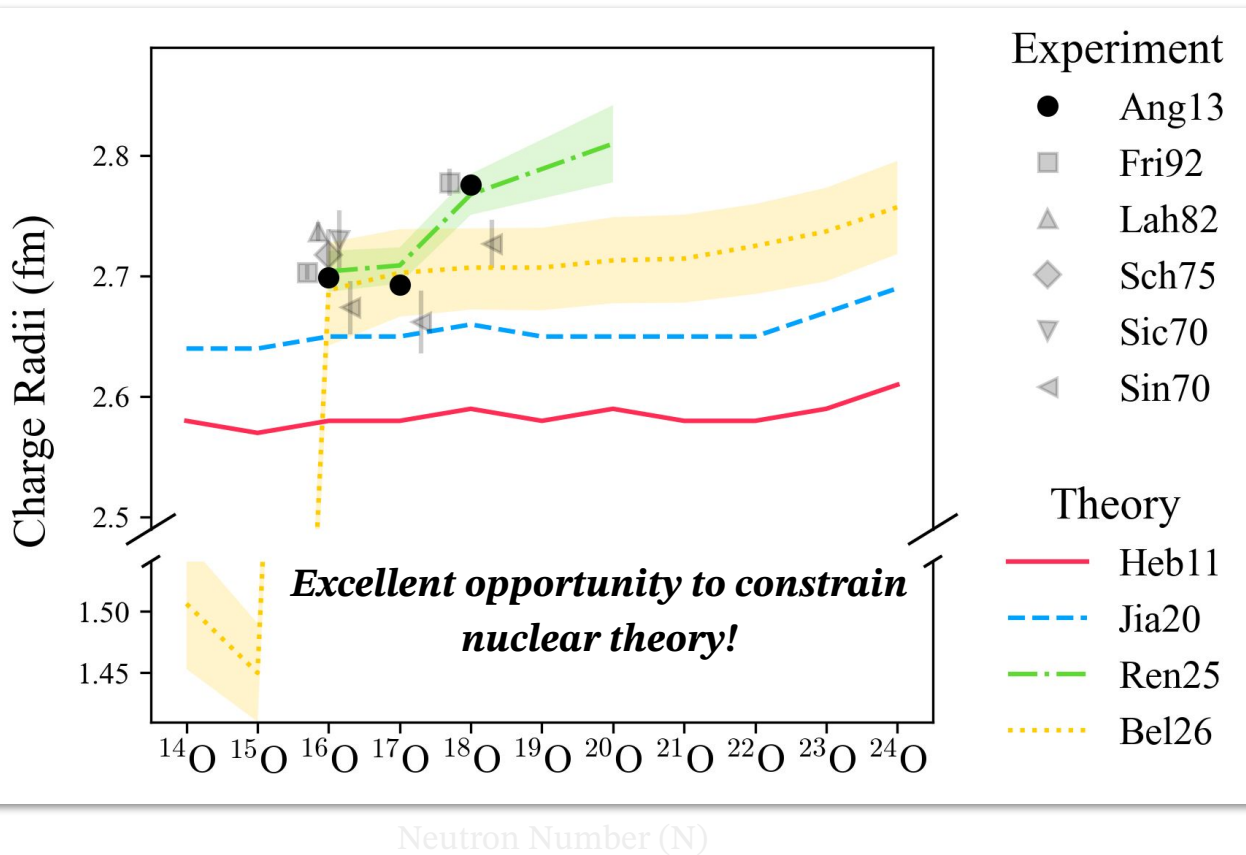
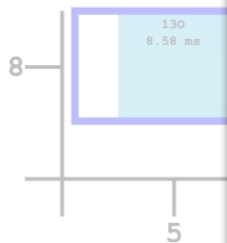


First Case: Oxygen

- Oxygen is t
- BECOLA/E
- Opportuni

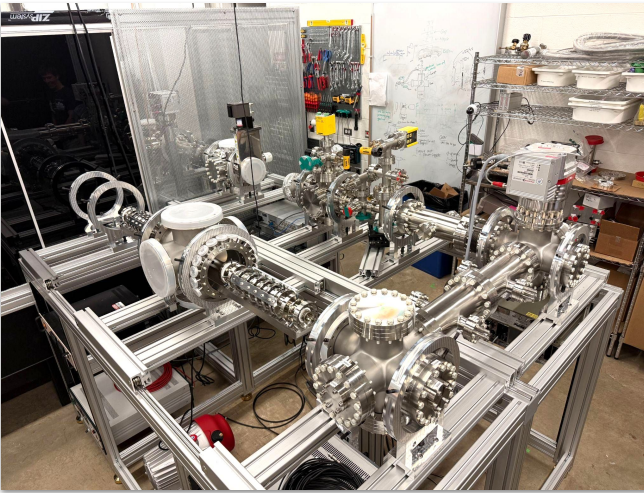
Electroscopy!
proton dripline.

Proton Number (Z)

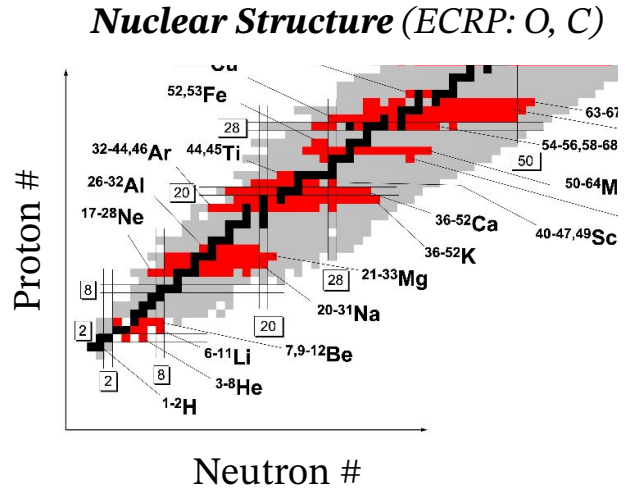


Off-line Development

 *Off-line laser lab (startup)*



Develop similar setup @ Cyclotron →

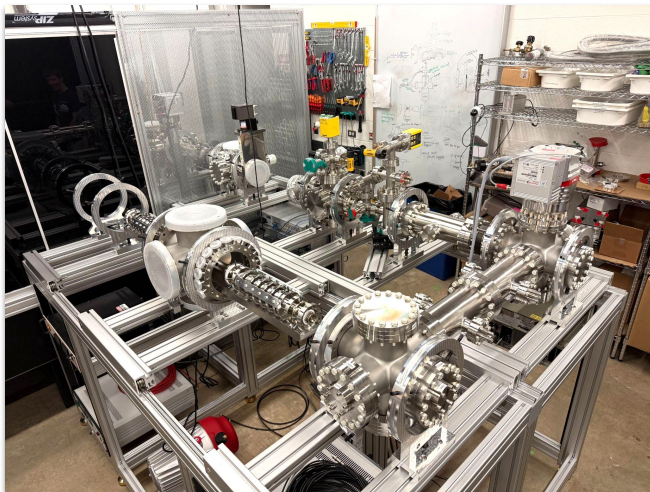


+ *radioactive molecules*
(*fundamental symmetries,*
nuclear astrophysics)*

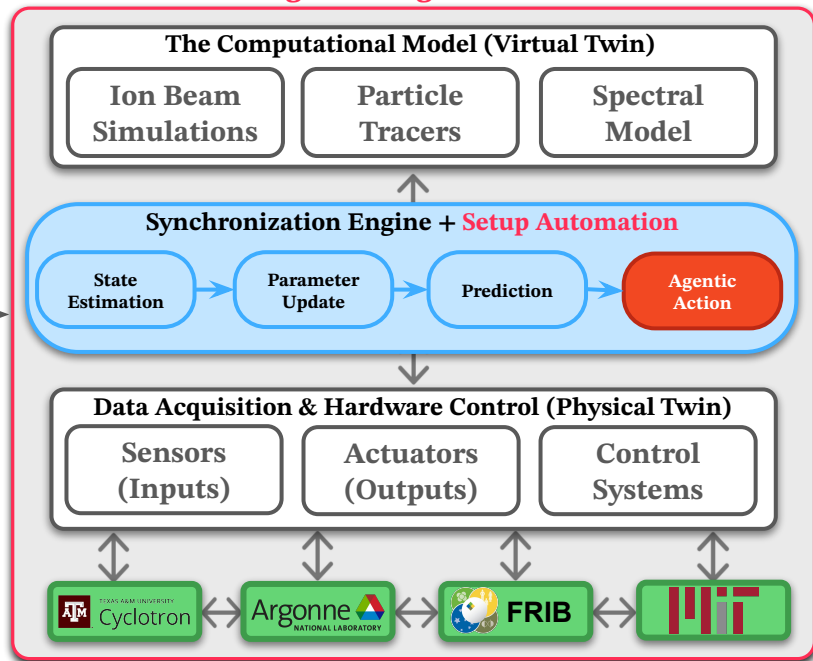
Agentic Digital Twins



Our Lab = Test bed for RIB Facilities



Agentic Digital Twin



Agentic Digital Twins for Precision Setups (traps, lasers, ...)

- automate + accelerate tuning & measurements
- Scale from university labs (A&M, MIT) to accelerator facilities (A&M-Cyclotron, ANL, FRIB)

Acknowledgements

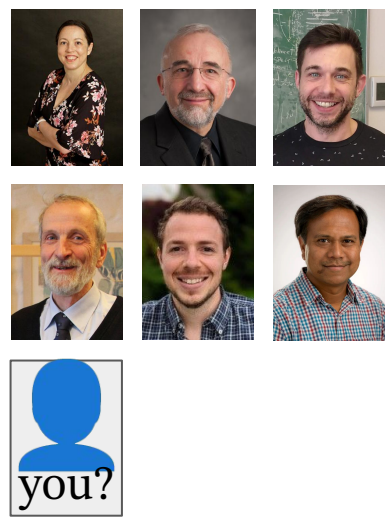
Group @A&M



Experimental Collaborators



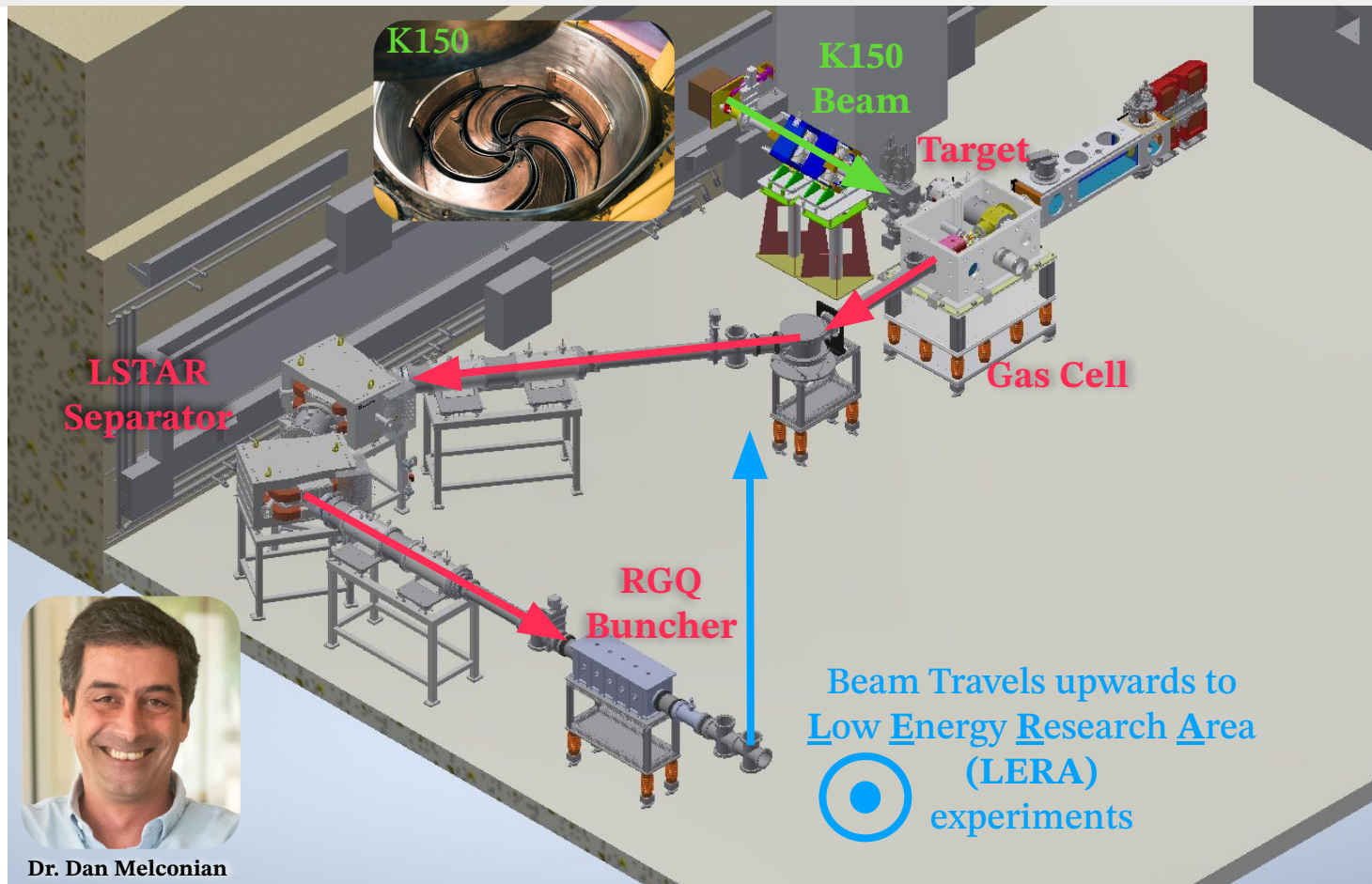
Theory Collaborators



Funding



Light ion-guide Separator for Texas A&M's Rare isotope beams (LSTAR)



Dr. Dan Melconian

Preliminary Laser Spectroscopy Layout

- Insulated, temperature / humidity controlled space.
- RIS and Molecular Spectroscopy

