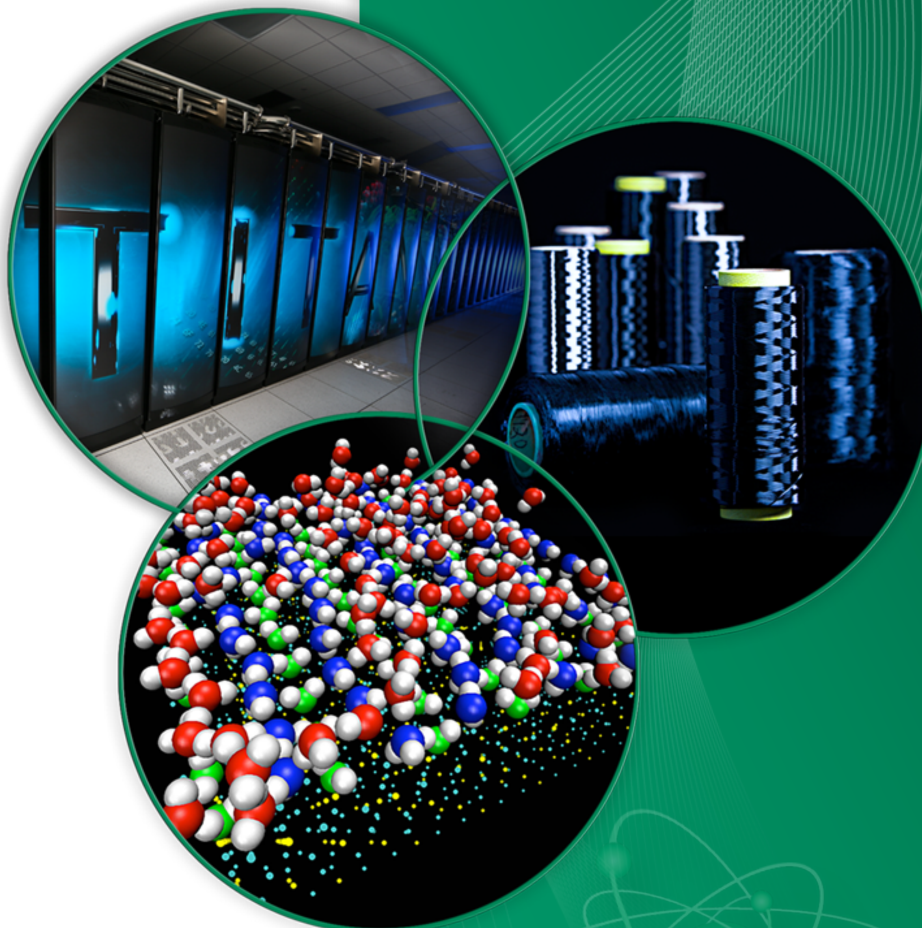
Accelerator Mass Spectrometry and Radioactive Ion Beam Science



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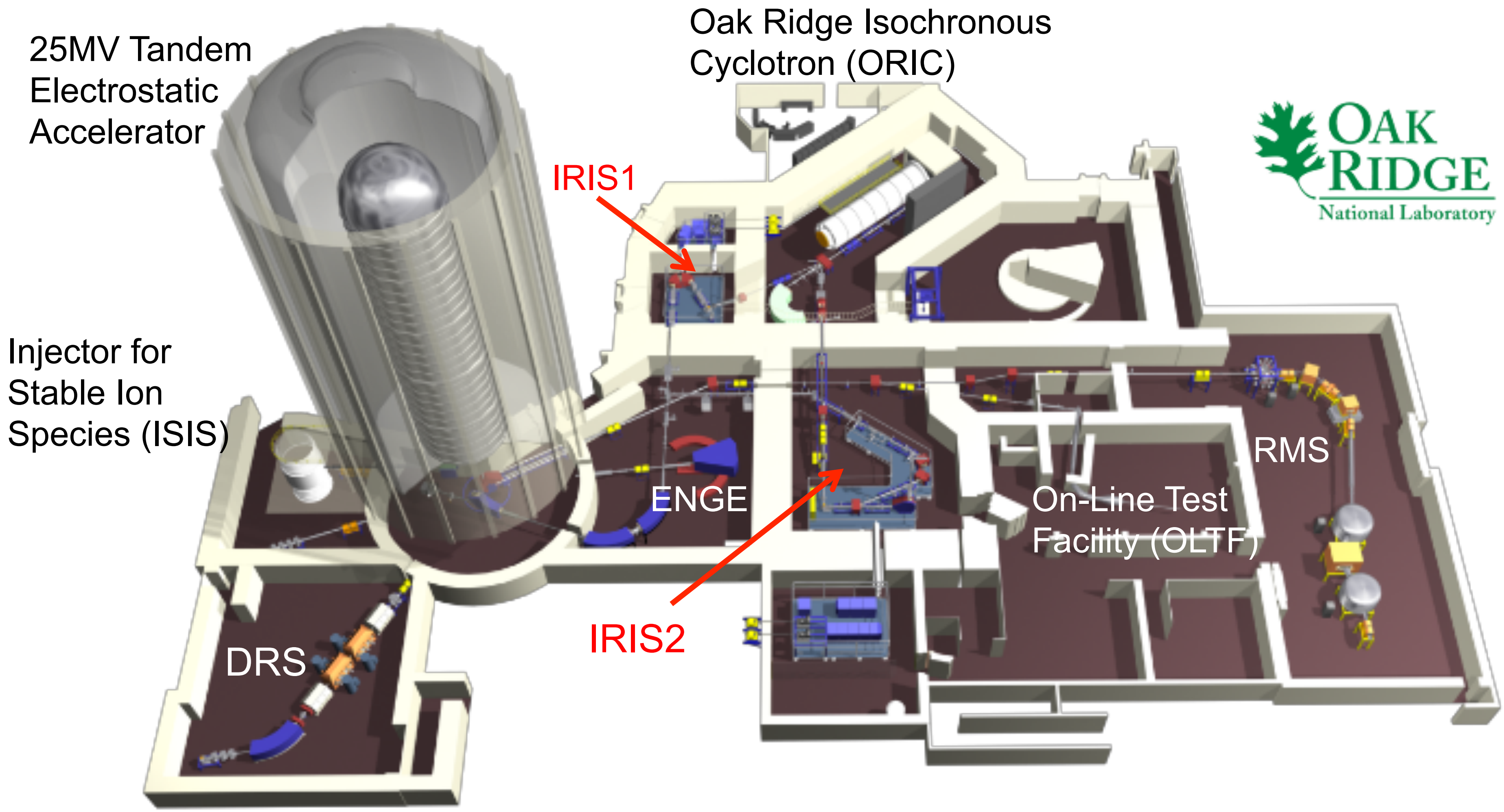
U.S. DEPARTMENT OF ENERGY

THE UNIVERSITY of TENNESSEE UT

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

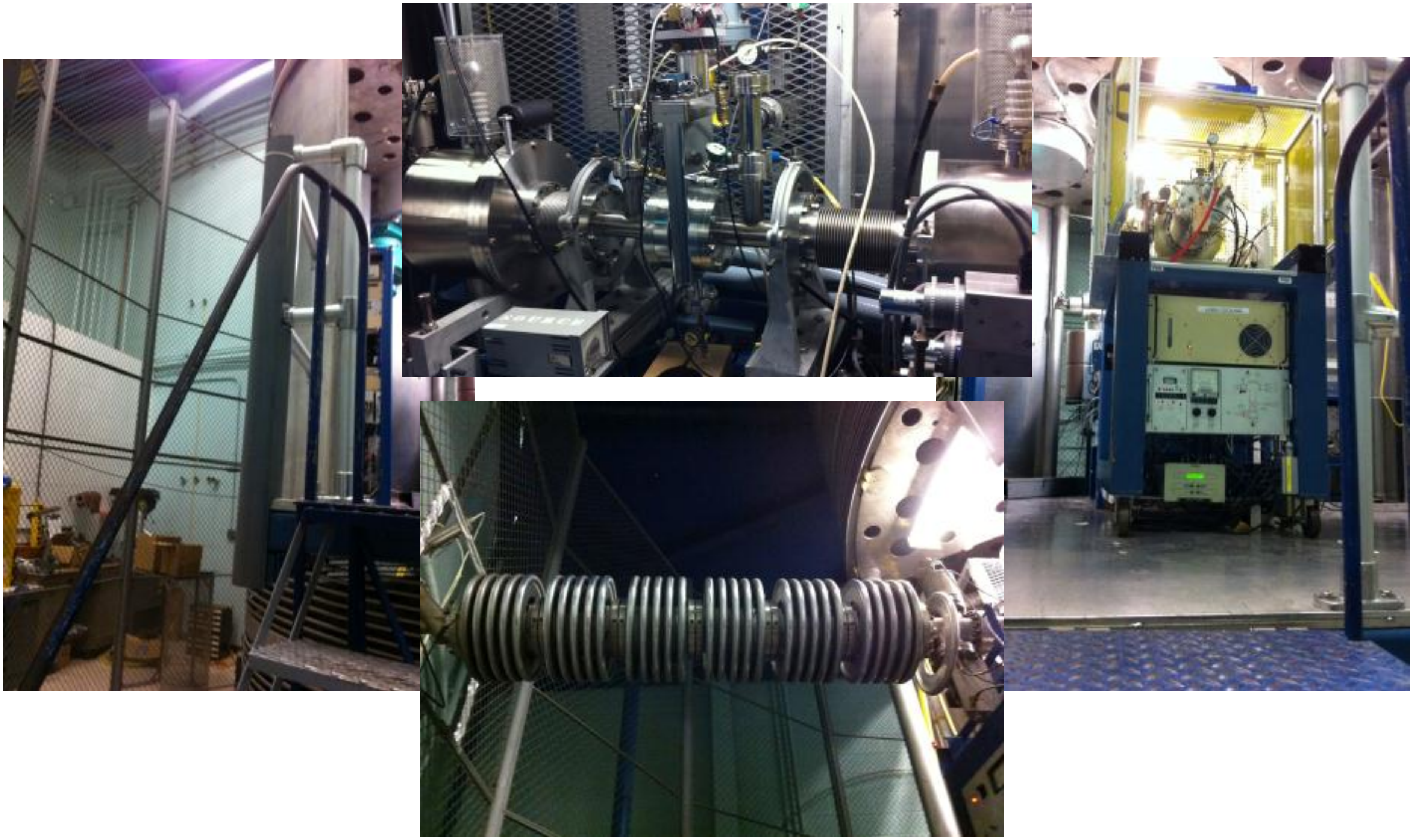
ORNL 25MV Tandem Accelerator



As part of its infrastructure HRIBF has a variety of equipment for beam transport and analysis ideal to do AMS

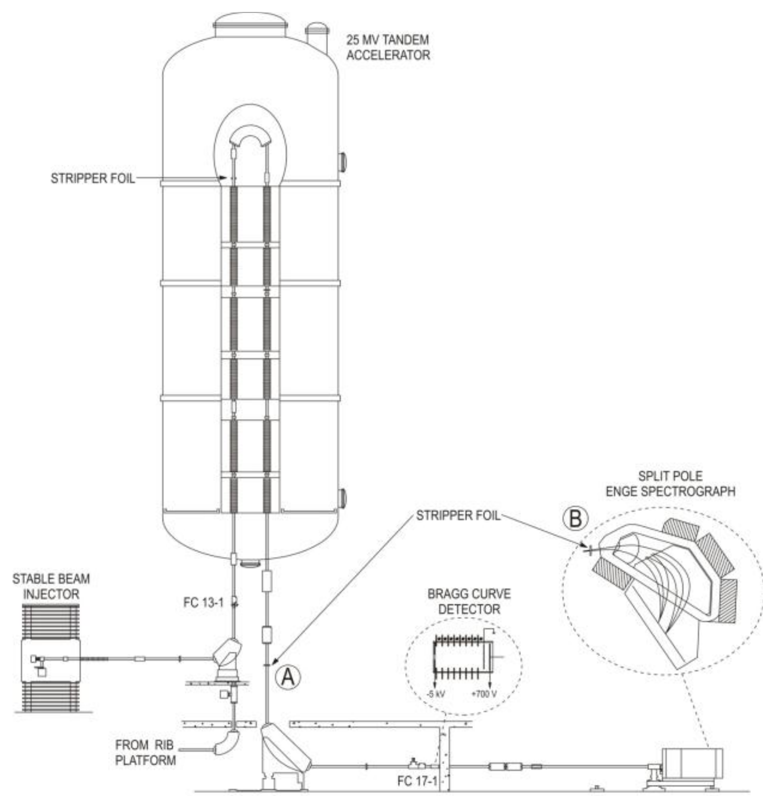
Stable Beam Injector Safety

Specialized equipment used in the accelerator facilities include high voltage platform systems, ion sources, high-current power supplies.

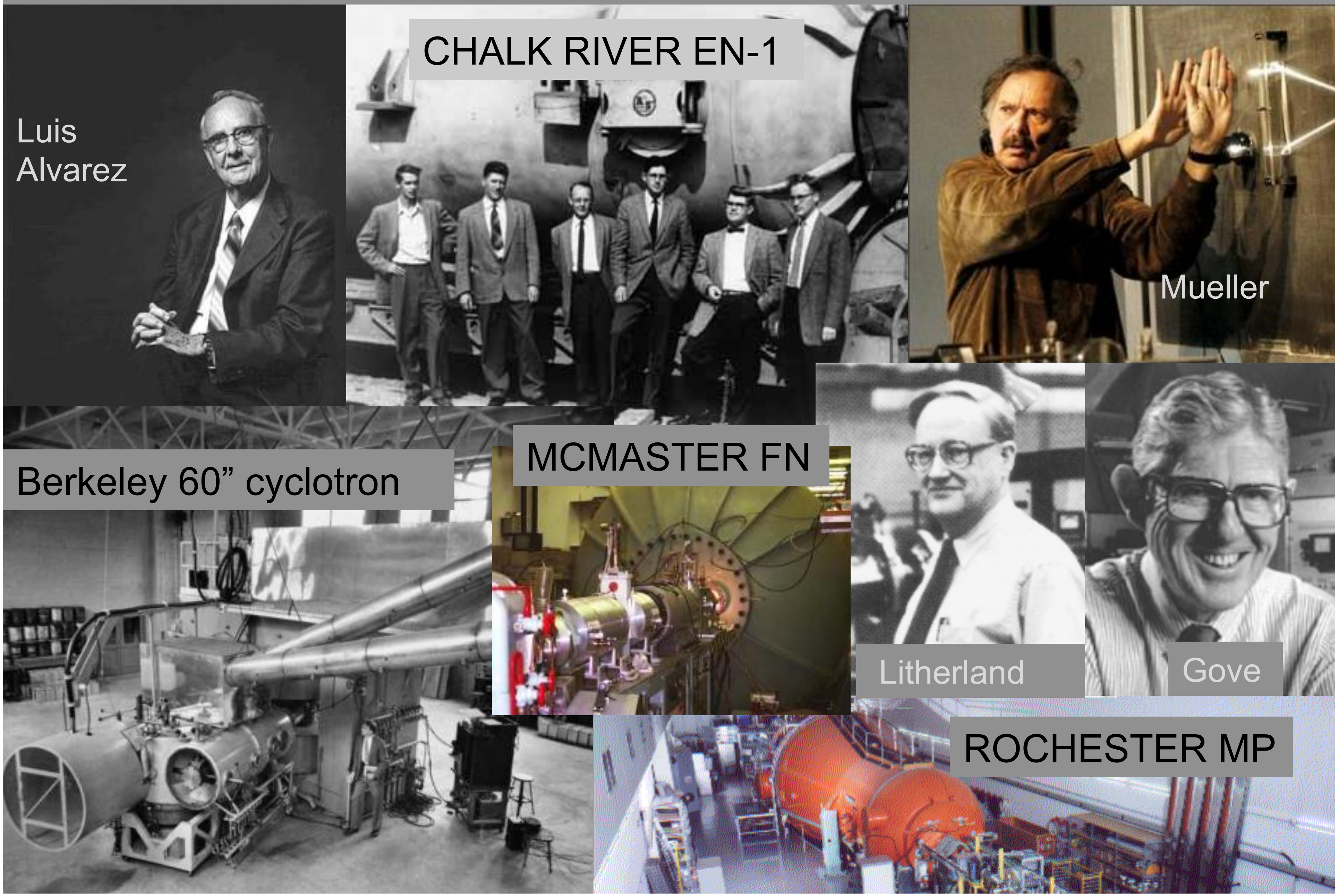


Accelerator Mass Spectrometry (AMS)

AMS is the most sensitive technique for isotopic analysis in which atoms extracted from a sample are ionized; accelerated to high energies; separated according to their momentum, charge and energy; and then individually counted after identification as having correct atomic number and mass.



Accelerators and AMS pioneers



AMS and Radioactive Ion Beams (RIB)

Most interesting RIBs are short-lived
^{17}F ($t_{1/2}$ = 65 s)

- Common problems/ needs:
  - Production
  - Isobar removal
  - Stable machine operation
  - Low intensity beam diagnostics

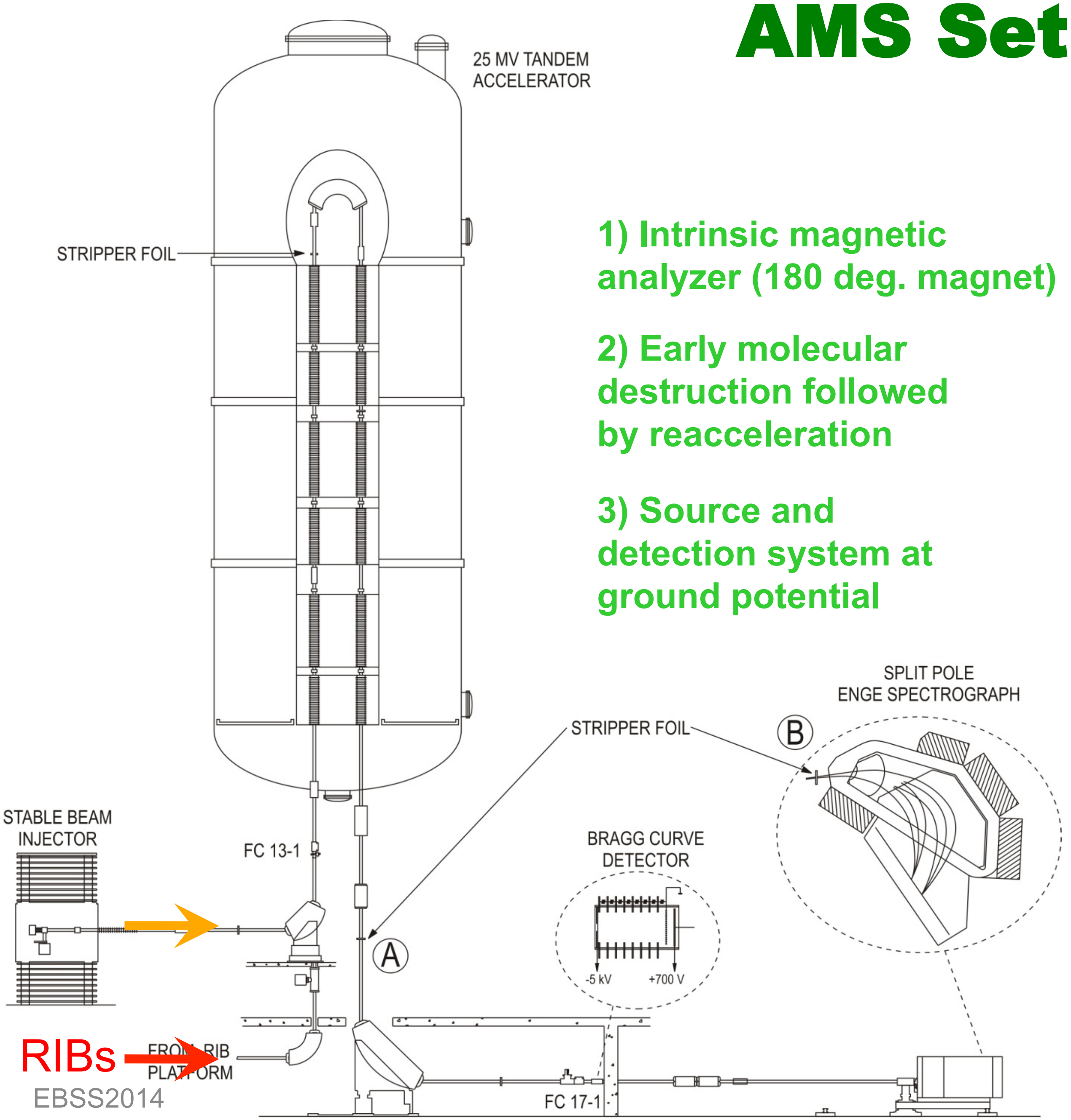
In AMS: long-lived species
^{36}Cl ($t_{1/2}$ = 3.01 x 10^6 a)

- Good detection tools
  - Bragg Detector
  - Projectile X-ray
  - TOF
  - Gas filled magnet
  - Beam monitors

We have concentrated in:

Development of AMS methods; methodology; pilot experiments; proof-of-principle tests; detection systems for heavier species; ion optics; transmission

AMS Setup at HRIBF



1) Intrinsic magnetic analyzer (180 deg. magnet)

2) Early molecular destruction followed by reacceleration

3) Source and detection system at ground potential

AMS 9

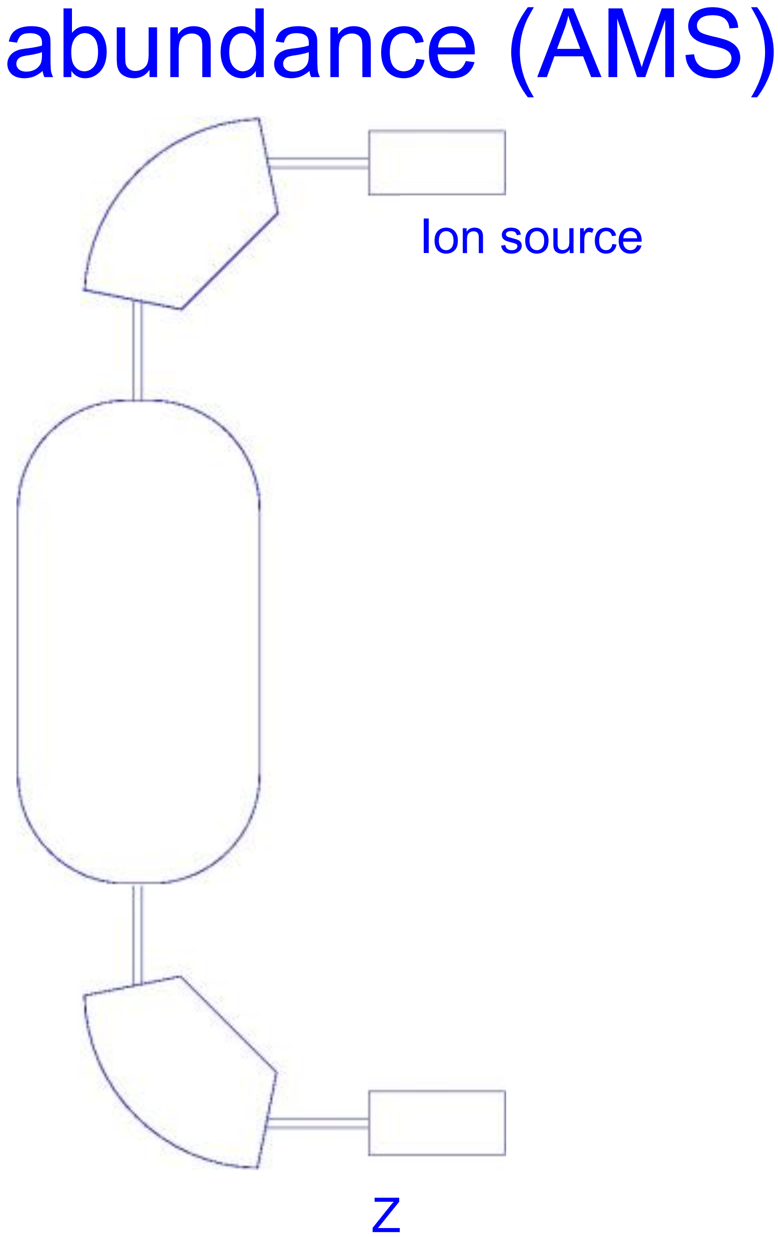
Opportunistic mass measurements at the HRIBF

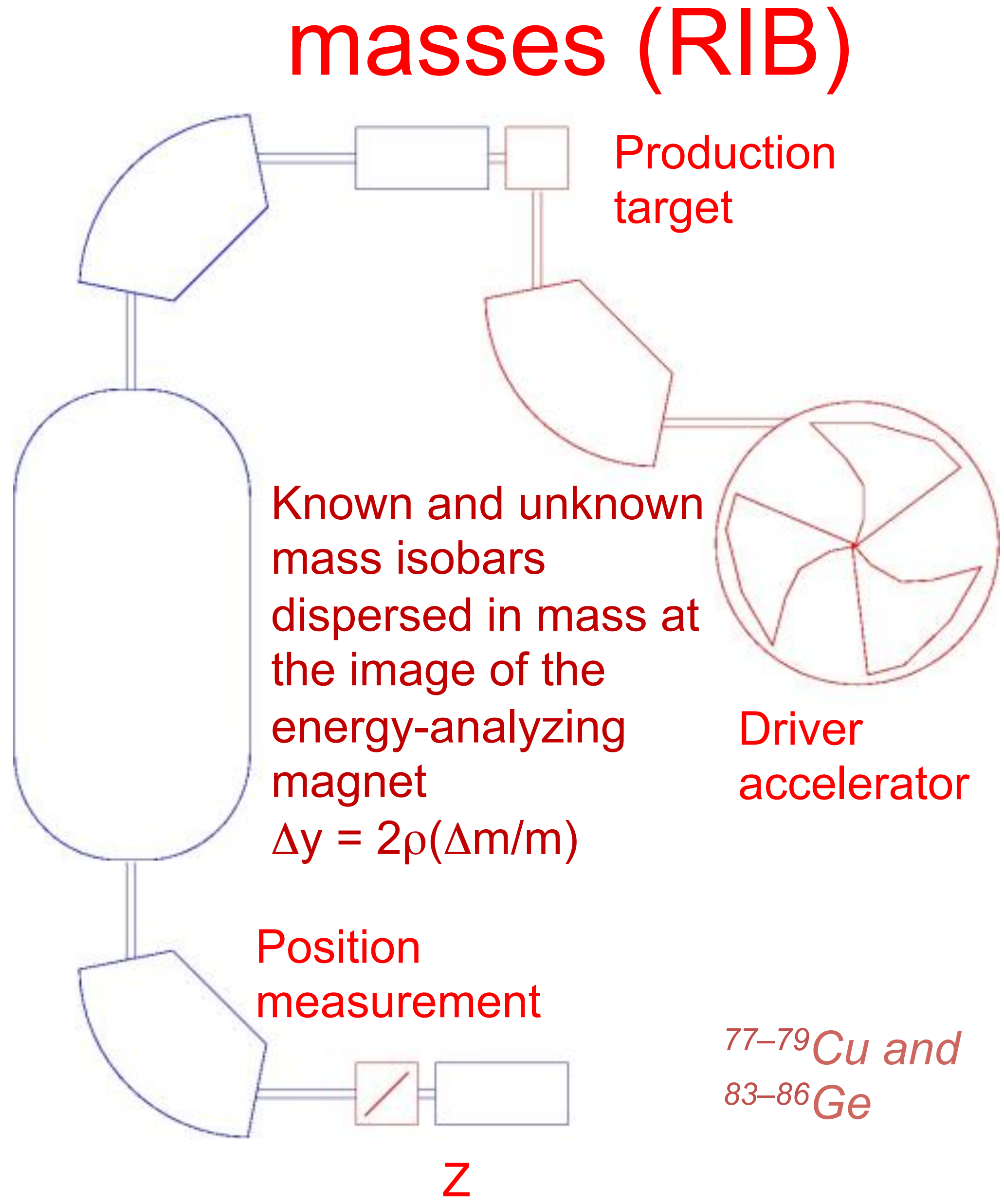
$^{77–79}$Cu and $^{83–86}$Ge

AMS10

Pushing the Limits of AMS - Measurement of ^{36}Cl in seawater samples

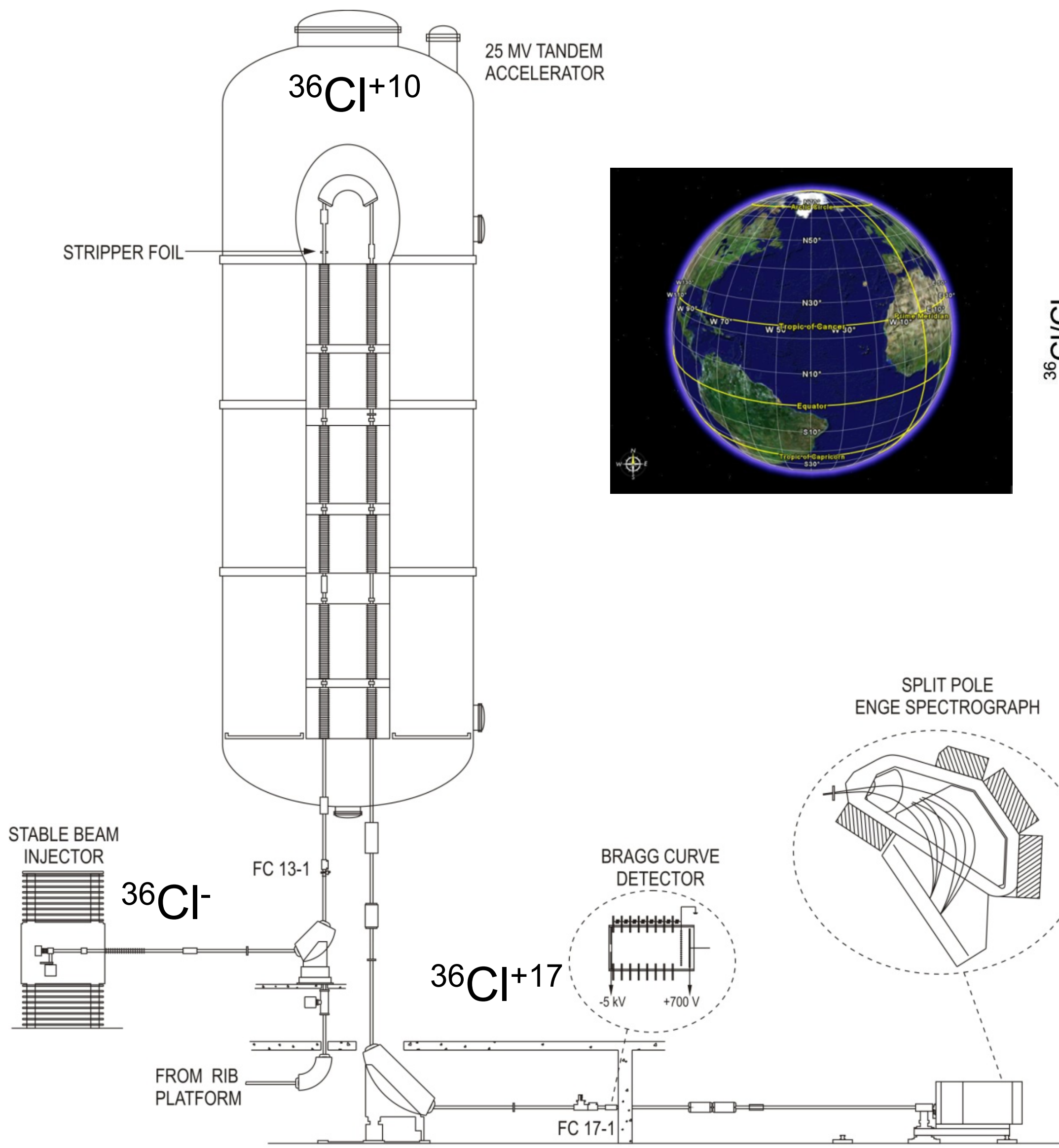
AMS and RIBs



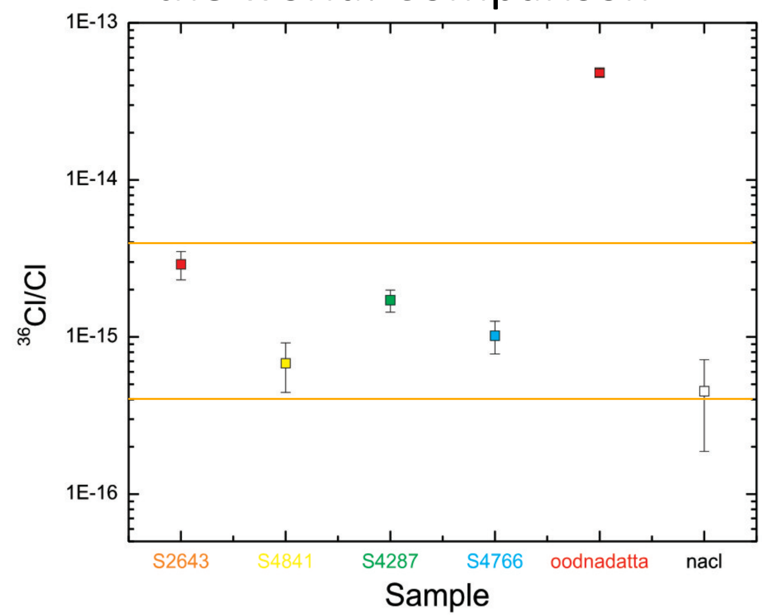


P. A. Hausladen et al., NIM B 223 (2004) 176 and IJMS 251, 2-3 (2006)119

AMS setup at ORNL



^{36}Cl in seawater samples from around the world: Comparison



Pushing the limits of accelerator mass spectrometry by an order of magnitude

Measurement of ^{36}Cl in seawater samples

A. G-U, et al. NIM B 259 (2007)123

International Interest in ORNL results

	Prof. Carlo Rubbia *CERN and National Institute of Nuclear Physics, Italy*	The future of fission breeding reactors
10:30am-11:15am	**Prof. Werner Burkart** *International Atomic Energy Agency, Vienna, Austria*	Nuclear Sciences: sustainable contribution to the United Nations millennium development goals
11:15am-11:45am	*Coffe Break*	
Session I	**Underground Physics**	
11:45am-12:15pm	**Prof. Gianpaolo Bellini** *(Invited)* *University of Milano and INFN Milano, Italy*	Geoneutrinos
12:15pm-12:30pm	**Prof. Wolfango Plastino** *University of Roma Tre and INFN Roma Tre, Italy*	Uranium groundwater anomalies at LNGS: from the neutron flux background to the geodynamic processes
12:30pm-2:00pm	*Lunch*	
2:00pm-2:30pm	**Prof. William E. Kieser** *(Invited)* *University of Ottawa, Canada*	Fluoride sample matrices and reaction cells – new capabilities for isotope measurements in Accelerator Mass Spectrometry
2:30pm-2:45pm	**Dr Alfredo Galindo-Uribarri** *Oak Ridge National Laboratory, USA*	Pushing the detection limits of rare isotopes using Accelerator Mass Spectrometry
2:45pm-3:00pm	**Prof. Manuel Garcia-Leon** *University of Sevilla, Spain*	Environmental radioactivity measurements with accelerators: AMS at CNA
3:00pm-3:15pm	**Dr Mariaelena Fedi** *University of Florence and INFN Florence, Italy*	Applications of radiocarbon measurements in environmental studies at LABEC, Florence
3:15pm-4:30pm	**Poster Session I** *(Coffee and Tea)*	

Study of $^{12}CH_2^{2+}$ and other doubly charged molecules

NIM B5 (1984) 208

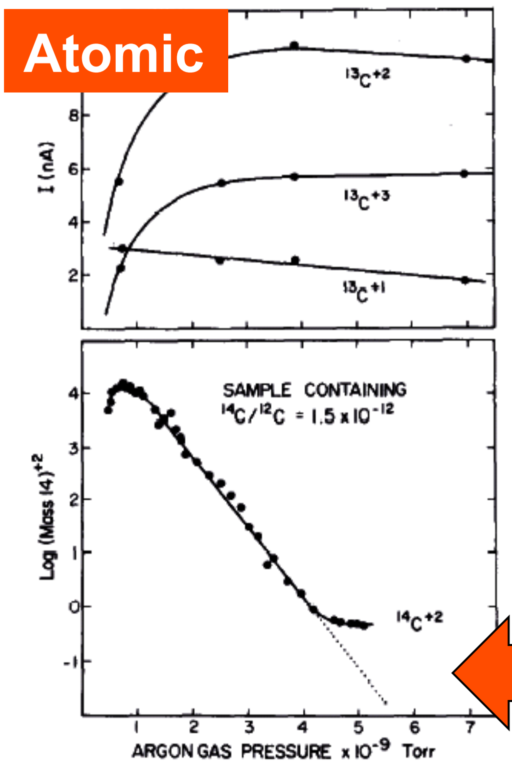
THE $^{12}CH_2^{2+}$ MOLECULE AND RADIOCARBON DATING BY ACCELERATOR MASS SPECTROMETRY

H.W. LEE, A. GALINDO-URIBARRI *, K.H. CHANG, L.R. KILIUS and A.E. LITHERLAND

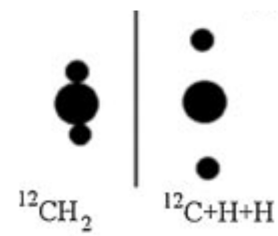
ISOTRACE Laboratory, University of Toronto, Toronto, Ontario M5S 1A7, Canada

The $^{12}CH_2^{2+}$ molecule has been studied and it was found that the molecule can be effectively eliminated thus allowing detection of $^{14}C^{2+}$ at low terminal voltages of a tandem accelerator. Some implications of this discovery for radiocarbon dating are discussed.

Atomic



$^{14}C^{+2}$



Beams of doubly ionized molecules from a tandem accelerator, **A. G-U et al. J. Chem. Phys. 83(1985)1**

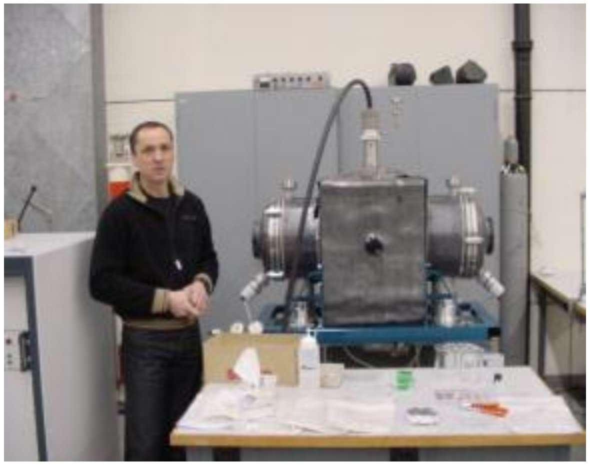
Small doubly charged molecules: $^{10}B^{11}B$, $^{10}B_2$, $^{11}B^{12}C$, $^{9}Be^{14}N$, $^{12}C^{13}C$, $^{12}C^{13}CH$, ^{12}CN, $^{12}C_2H$, $^{12}CH_2$, $^{9}Be^{16}O$, $^{10}B^{16}O$

About 3 cases reported Molecular Spectra …G. Herzberg

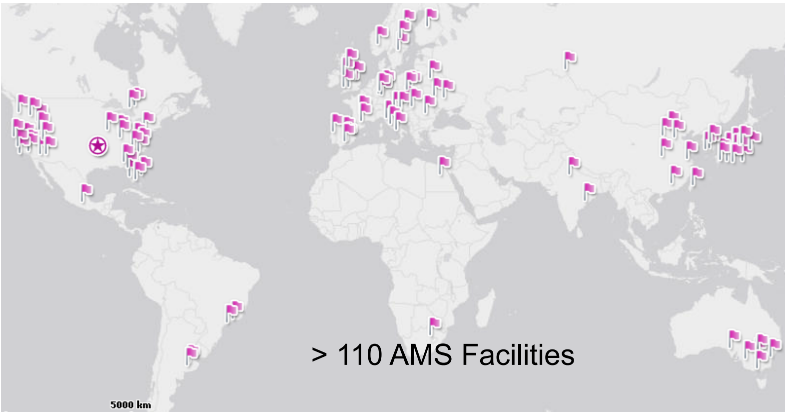
Exponential destruction of molecules in the gas stripper at the HV terminal

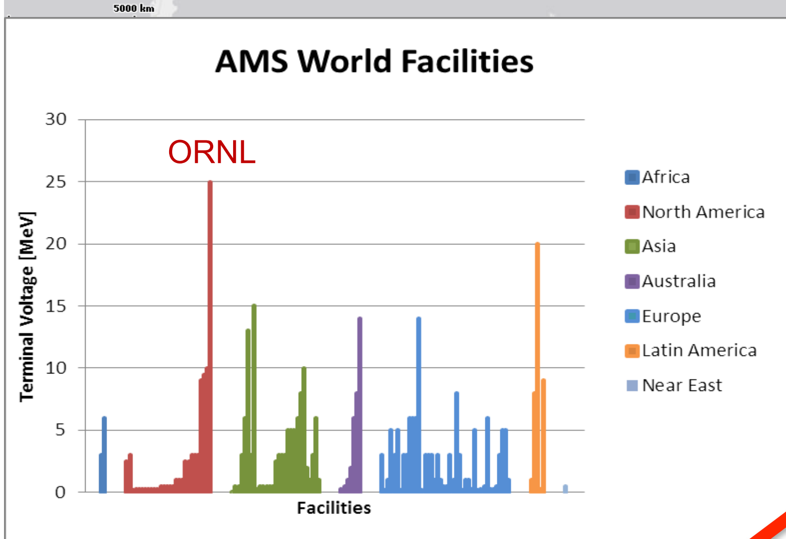
→ Development Small AMS Machines

(e.g. Zurich: 0.5 MV and 0.25MV)



AMS Today



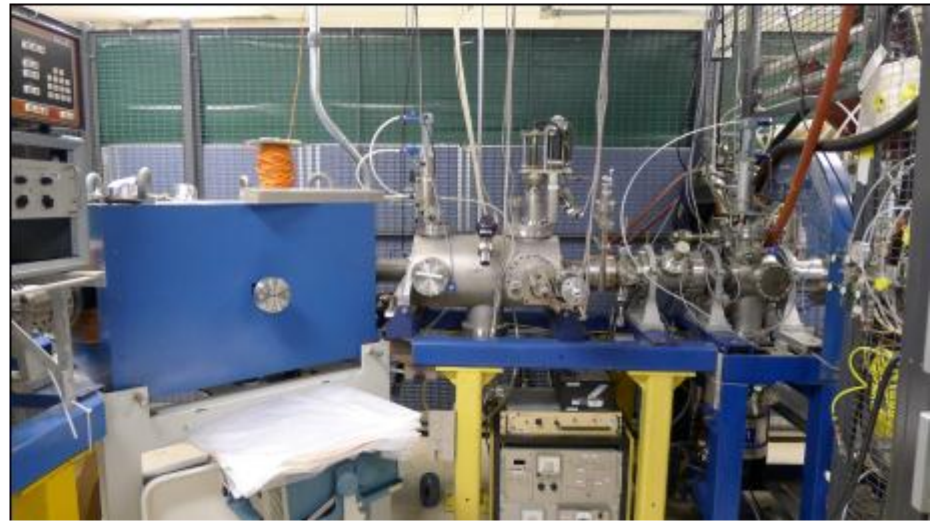


$^{14}C^{+1}$

$^{14}C^{-1}$

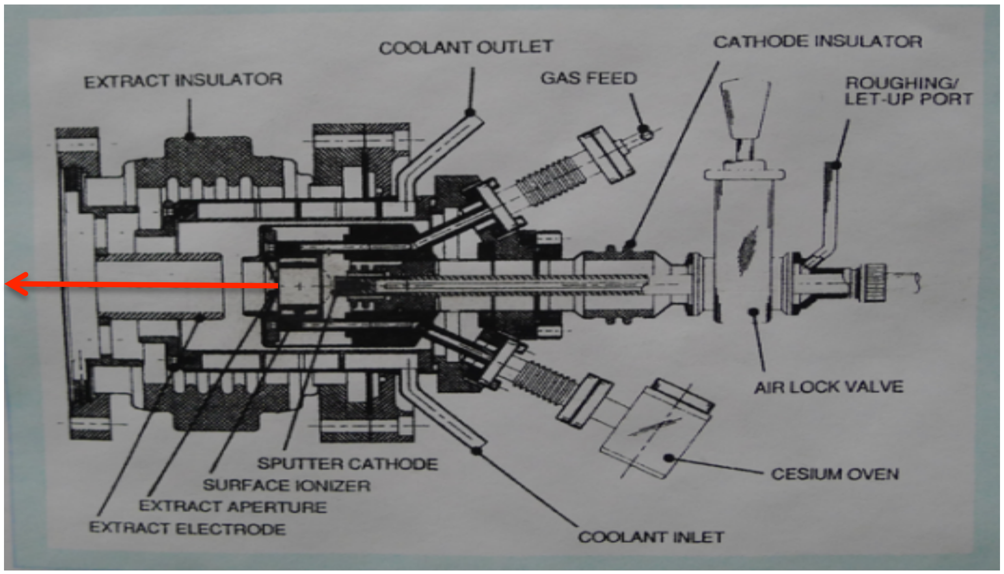
$^{14}N^{-1}$

Tests of ^{26}Al with Low-Energy Test Stand
Use of AlN^{-}

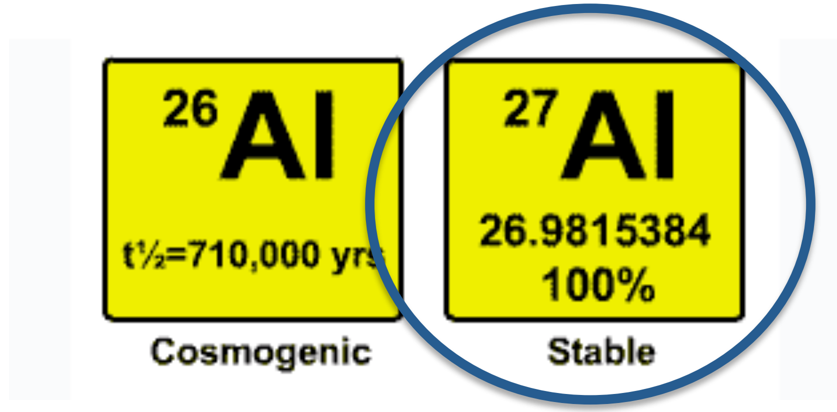


Low-Energy Experiments

Cs Sputter Negative Ion Source



- Cathode= 3 kV
- Ionizer= 27 Amps
- Cesium oven= 200°C
- Source voltage= 20 kV
- Acceleration voltage= 200 kV

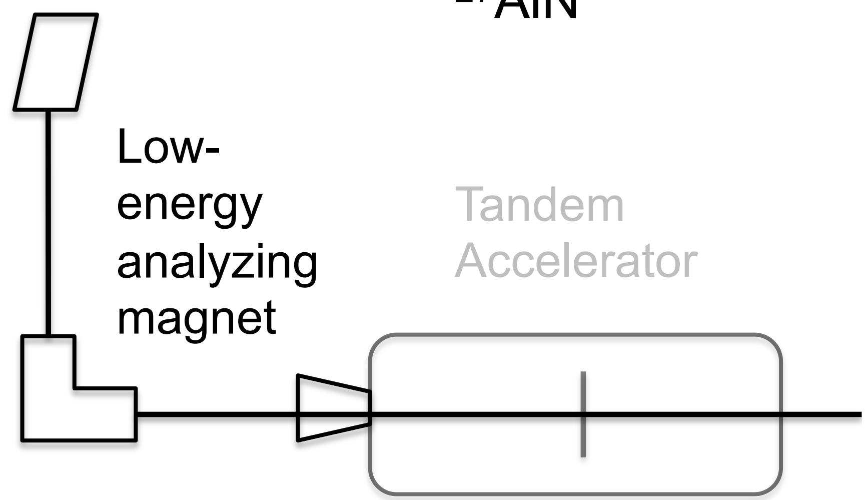


$^{27}Al^-$
$^{27}AlO^-$
$^{27}AlN^-$

Negative ion source

Low-energy analyzing magnet

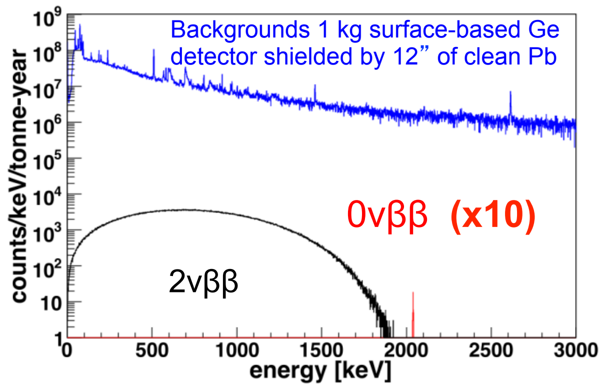
Tandem Accelerator

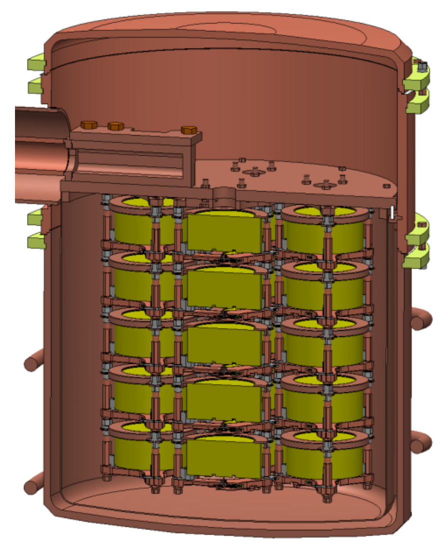


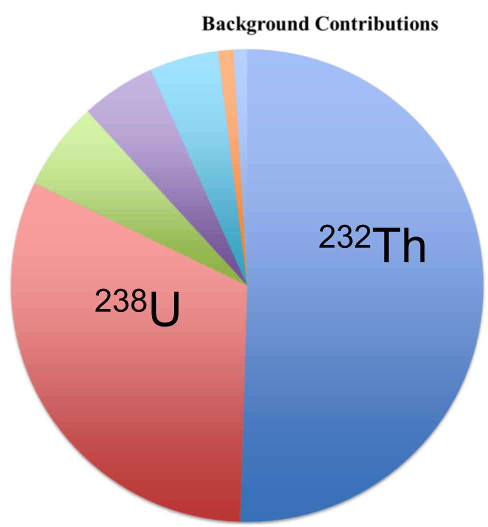
FC-I13

Search for neutrinoless double beta decay: ultra low background requirement

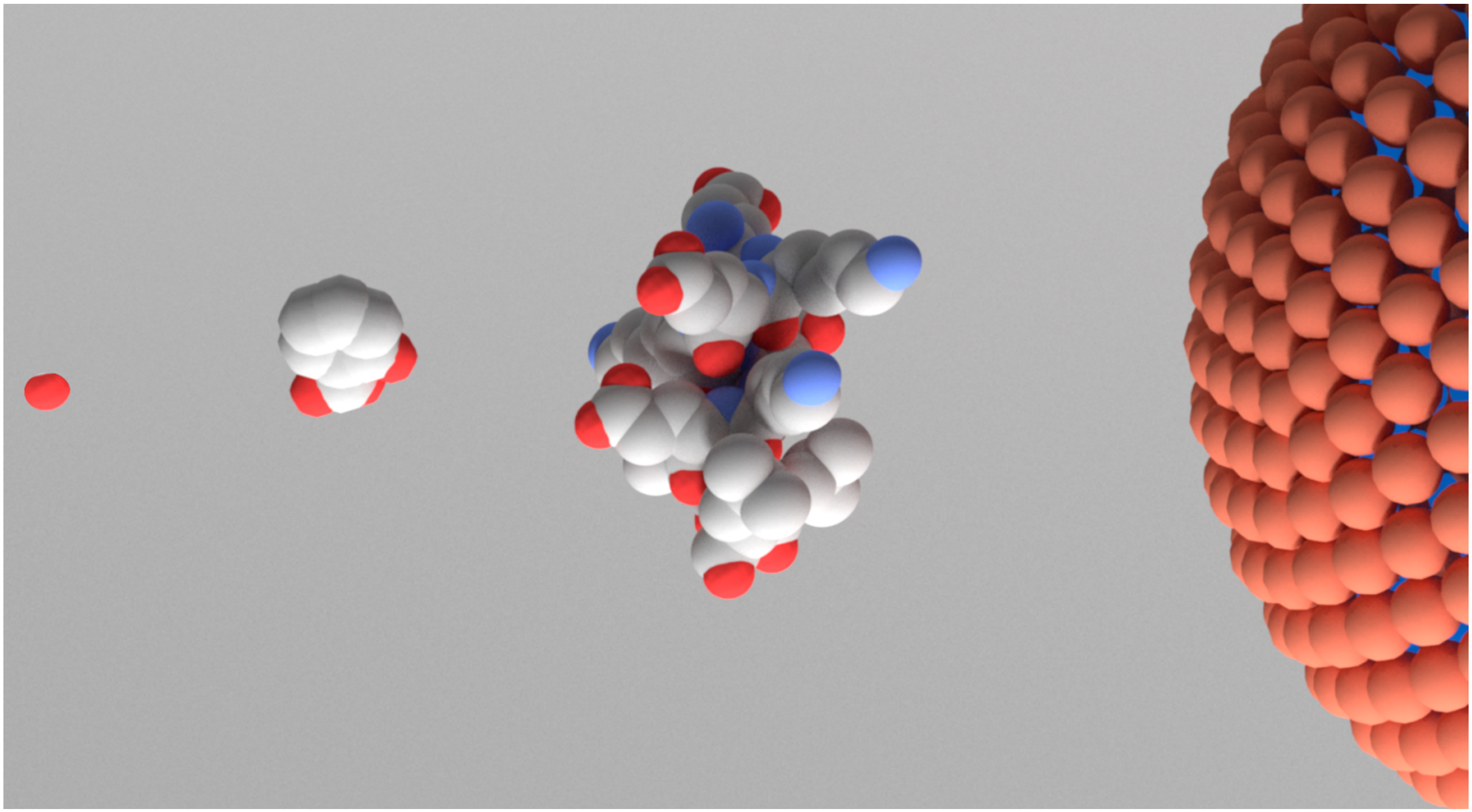
A ^{76}Ge 0νββ experiment funded by DOE-NP and NSF,



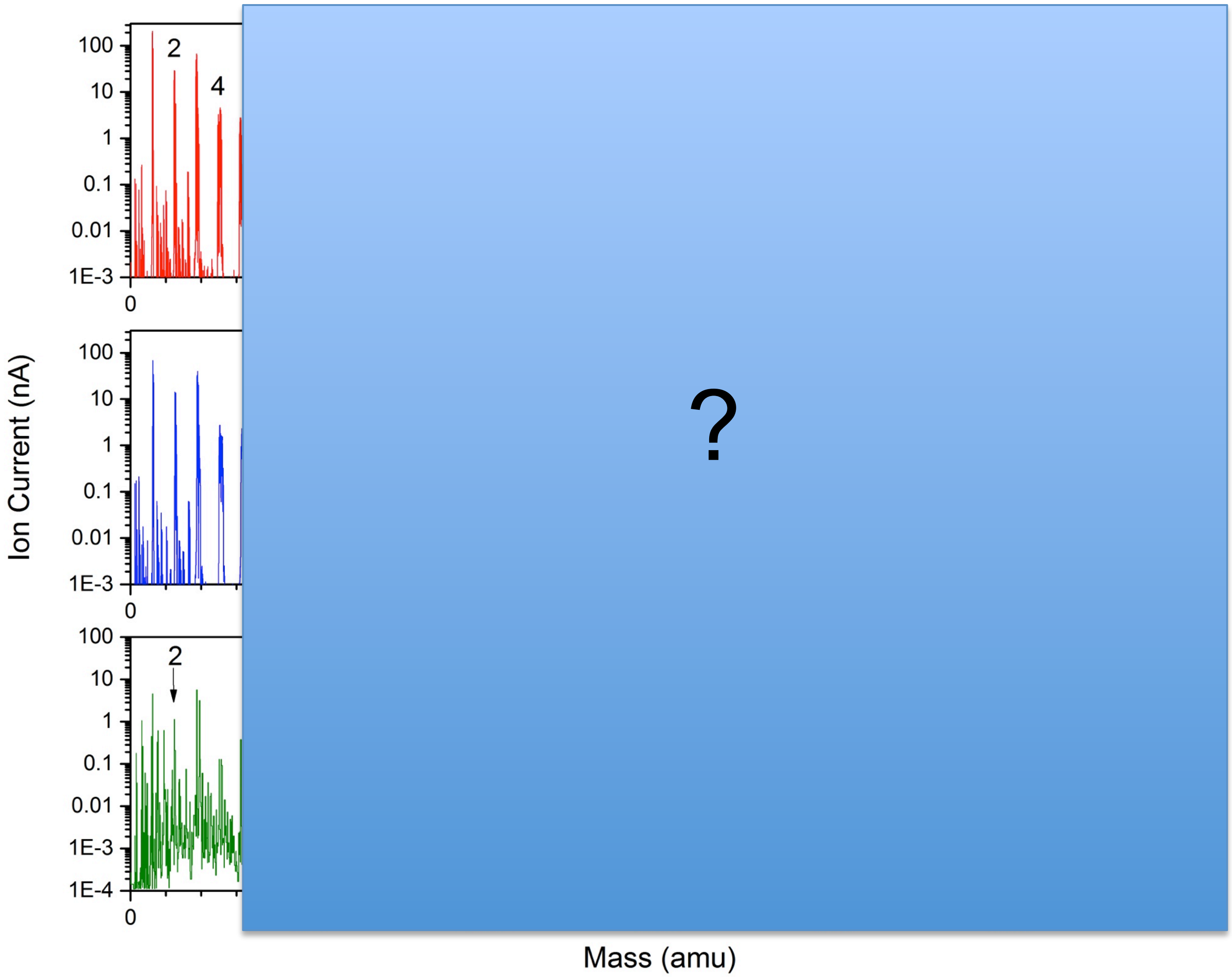




Atoms, Molecules and Clusters



Mass spectra of negative clusters

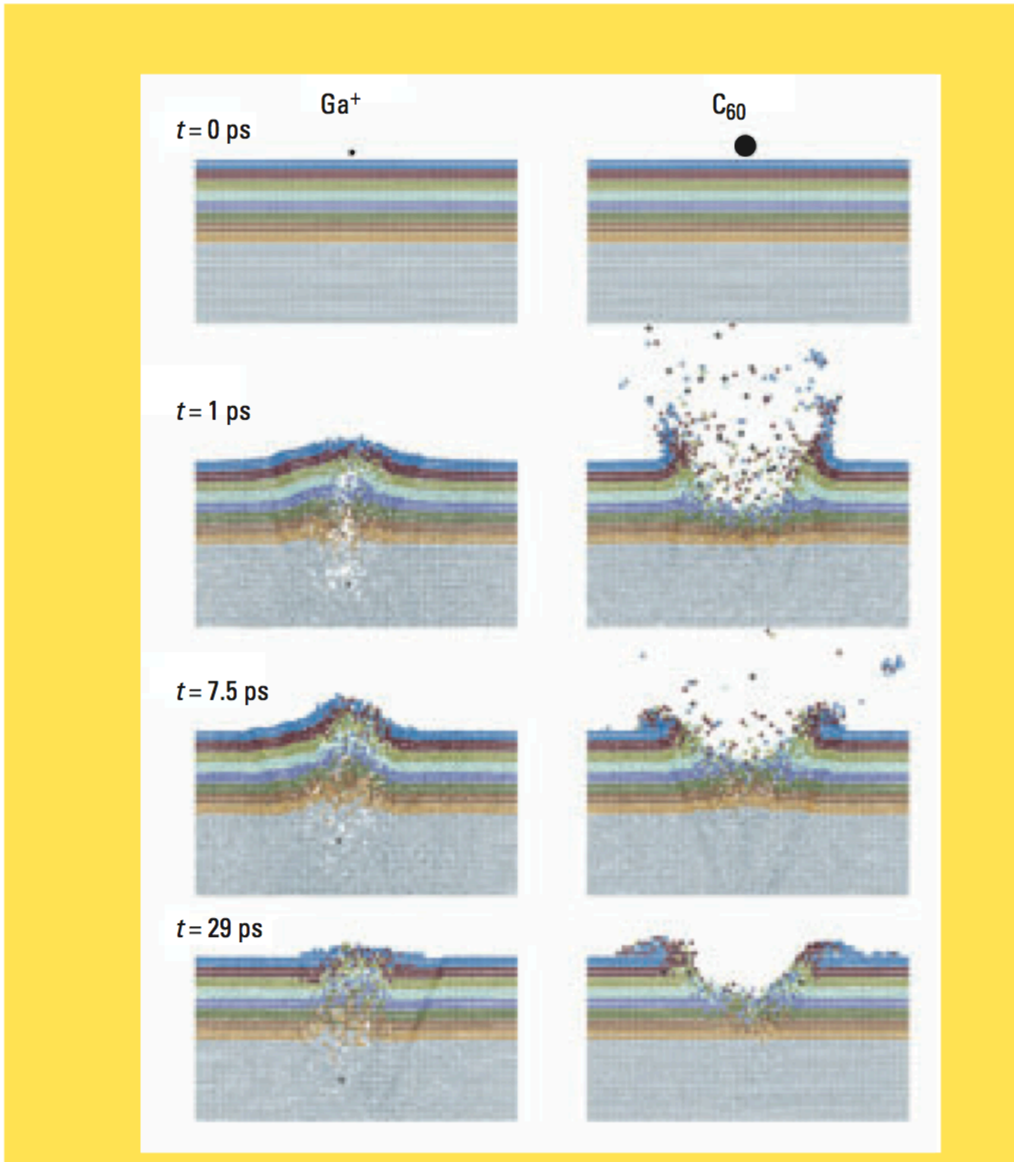


Cluster beams

How big?
Can we form cluster beams of negative ions?
How intense?
At what energy?
How fragile?
Can we form clusters of same isotope?
Do the intensities reflect some structure?
How fast the current drops as a function of n?
How do the atoms organize?
Samples of Cu, ultra-pure Cu, ^{63}Cu, ^{65}Cu, Au, C

$$F(n,x) = p^{x}(1-p)^{n-x}\frac{n!}{x!(n-x)!}$$

Cluster vs Atom sputtering



Extra Material

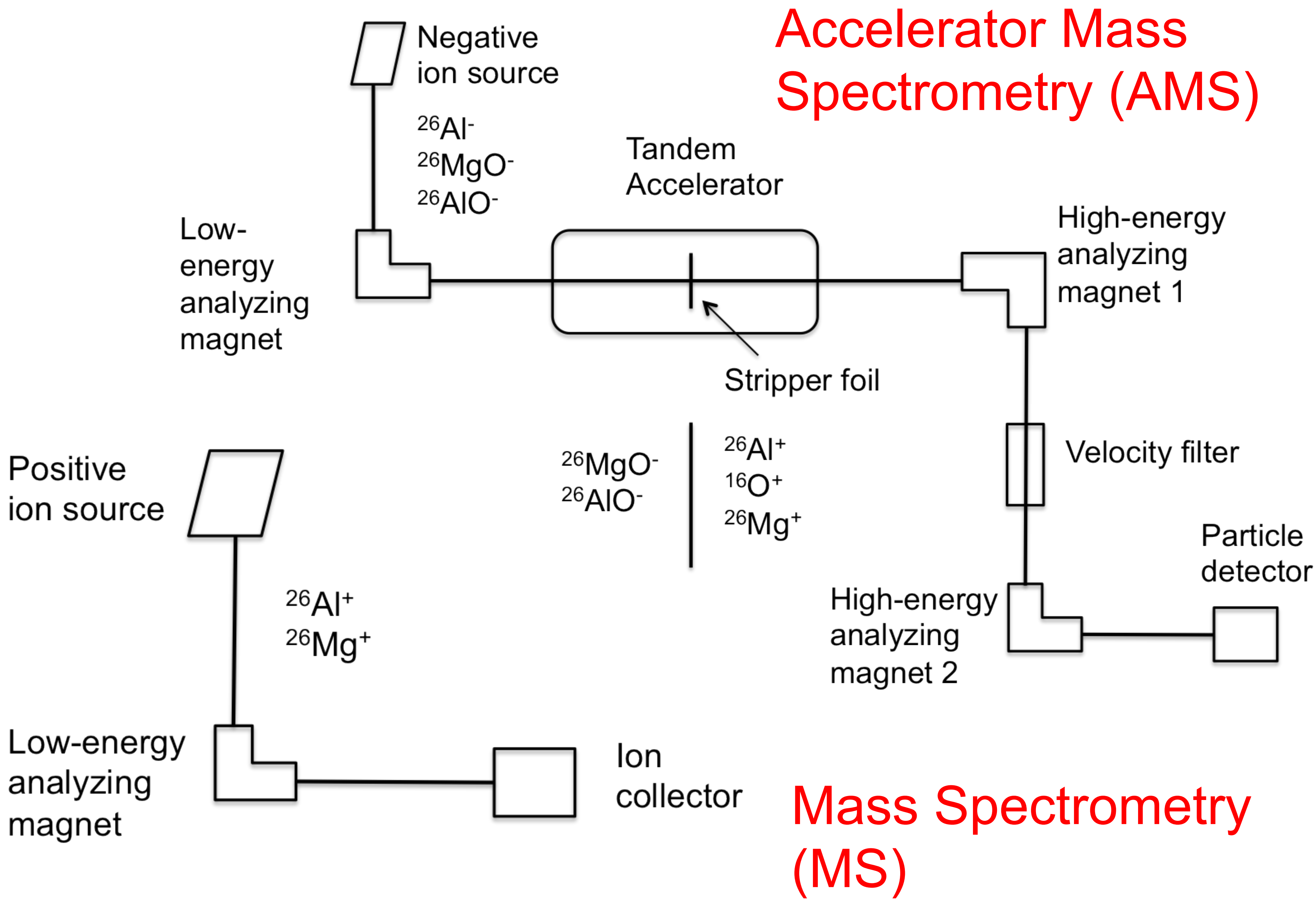
A sample material such as AlN or AlF_3 is expected to perform better

AlN

- Nitrogen has a low electronegativity
- *R. Flarend et al. (2004)*Preliminary study of AlN as a novel source material
- *G. Selvaduray and L. Sheet (1993)* Synthesis methods for AlN from Al_2O_3

AlF_3

- *W. E. Kieser et al. (2012)* Fluoride matrices for enhanced anion production
- *L. Wacker et al. (unpublished)* The potential of Be fluoride compounds
- *X.L Zhao et al. (2012)* Studies of Pu AMS measurements using PuF_4
- Useful carrier for other elements such as Be, Ca, Pb, Sm, Nd and Pu


Accelerator Mass Spectrometry (AMS)
Negative ion source
$^{26}Al^-$
$^{26}MgO^-$
$^{26}AlO^-$
Tandem Accelerator
Low-energy analyzing magnet
High-energy analyzing magnet 1
Stripper foil
$^{26}MgO^-$
$^{26}AlO^-$
$^{26}Al^+$
$^{16}O^+$
$^{26}Mg^+$
Velocity filter
Particle detector
High-energy analyzing magnet 2
Positive ion source
$^{26}Al^+$
$^{26}Mg^+$
Low-energy analyzing magnet
Ion collector
Mass Spectrometry (MS)