Laser Ablation Ion Source for Barium Tagging

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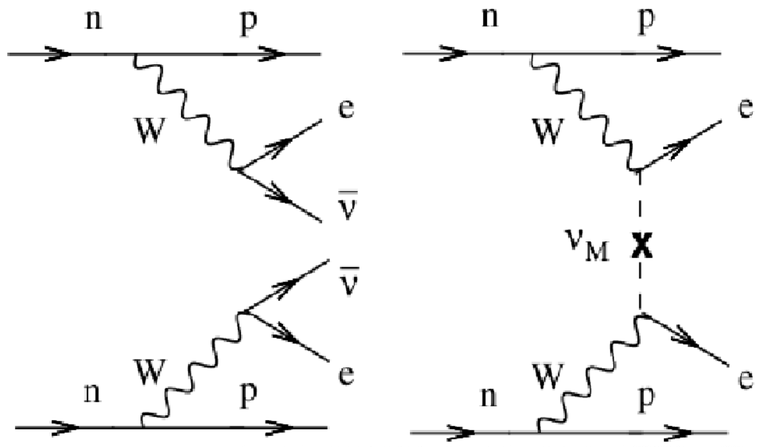
Motivation

nEXO:
- Planned successor to EXO-200
- Future 5-tonne liquid xenon detector
- Potentially for SNOLab in Sudbury, Ontario
- Aims to observe 0νββ decay

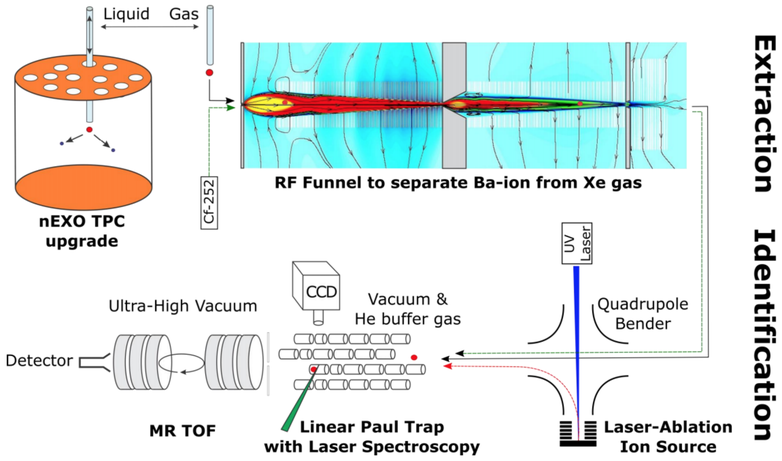
Neutrinoless Double-Beta Decay (0νββ)**:**
- 2νββ**:** two neutrinos, two electrons, observed
- 0νββ**:** no neutrinos, two electrons, theorized
- Ultra-rare decay of Xe^{136} into Ba^{136}
- Estimated half-life of over 10^{26} years
- Observation would indicate that a neutrino is a Majorana particle



Source: F.T. Avignone III et al., Double Beta Decay, Majorana Neutrinos, and Neutrino Mass, arxiv:0708.1033v2 [nucl-ex] (2007)

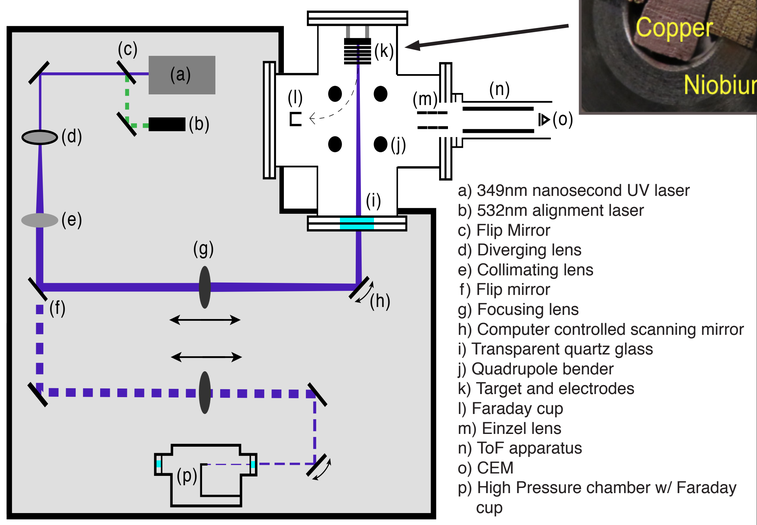
Ba-Tagging:
Innovative low-background ion identification technique that sidesteps most inherent radiation backgrounds of the detector:

1. Using TPC reconstruction, the site of a candidate decay is located,
2. The ion is extracted to gaseous Xe,
3. The ion is guided to spectrometers using RF funnels to reduce Xe pressure (~10^{-9} Torr),
4. Ion identified by laser spectroscopy in a linear Paul trap and by time-of-flight spectrometry in an MR-TOF

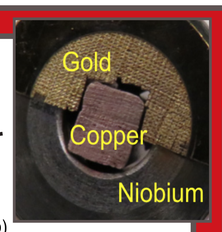


Laser Ablation Source (LAS):
- Acts as a pure source of barium ions for equipment calibration
- Has spin-off applications for mass spectrometery

Apparatus Diagram



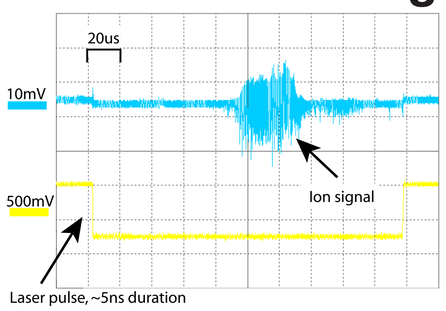
a) 349nm nanosecond UV laser
b) 532nm alignment laser
c) Flip Mirror
d) Diverging lens
e) Collimating lens
f) Flip mirror
g) Focusing lens
h) Computer controlled scanning mirror
i) Transparent quartz glass
j) Quadrupole bender
k) Target and electrodes
l) Faraday cup
m) Einzel lens
n) ToF apparatus
o) CEM
p) High Pressure chamber w/ Faraday cup



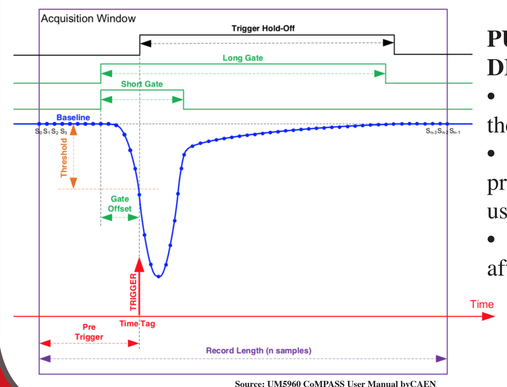
METHOD FOR ION MEASUREMENT

1. Scans are controlled using custom LabVIEW software that packages proprietary drivers with scanning methods
2. Two measurement configurations are available depending on quadrupole settings, each with its own LabVIEW software: time of flight or ion current
3. A raster scan is performed based on initial and final mirror actuator positions and chosen step sizes, scanning along the vertical y-axis
4. At each position, measurements are taken and packaged with the mirror actuator position values (relative to arbitrary zero) and saved for analysis in Python

Time of Flight Data



RAW SIGNAL
- Yellow is a trigger signal from the UV laser controller
- Blue is the amplified ion signal from the ToF channel electron multiplier

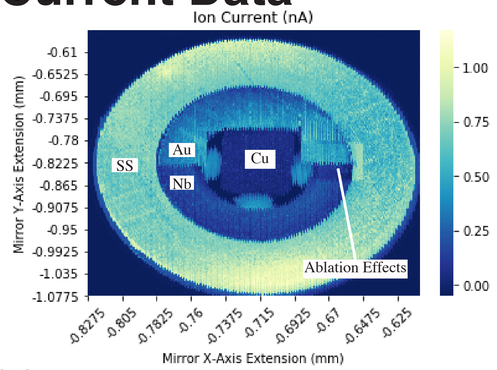


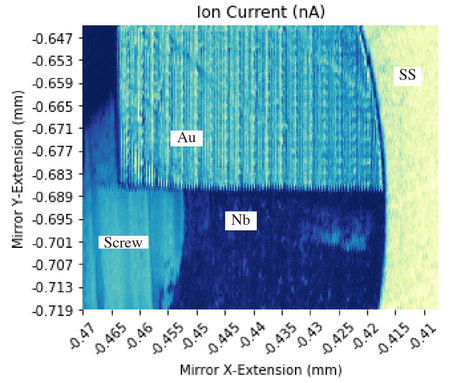
Source: UM5960 CoMPASS User Manual byCAEN

PULSE SHAPE DISCRIMINATION
- Raw data rate is too large for the computer ot record
- Pulse shape discrimination prevents the recording of useless noise in between events.
- Takes snapshot before and after a trigger

Ion Current Data

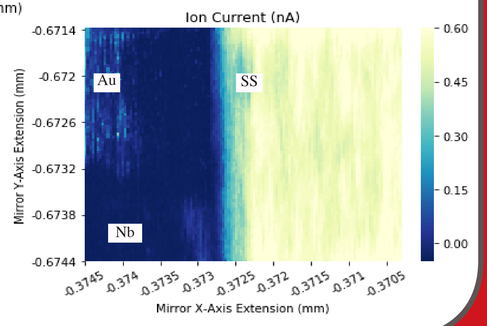
FULL SCAN
Mirror increments: 2.5μm
Step size on target: TBD
Total Steps: 241x359





10X ZOOM
Mirror increments: 0.5μm
Step size on target: TBD
Total steps: 251x251

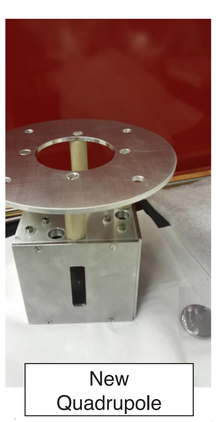
The linear stripes are either due to scanning mirror instability or previous ablation.



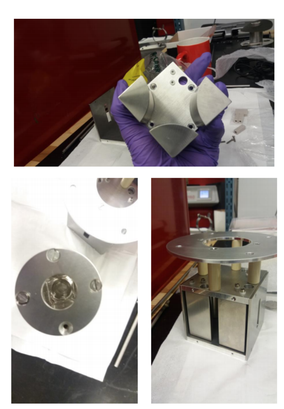
50X ZOOM
Mirror increments: 0.1μm
Step size on target: TBD
Total steps: 126x126

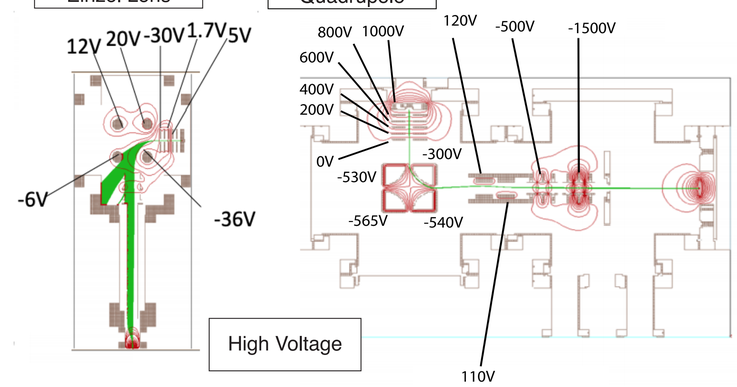
Continuing Improvements

New Einzel Lens



New Quadrupole





- Femtosecond laser for tighter ion energy distribution and reduced ablation damage
- Measurement hardware for high pressure chamber
- LabVIEW interface improvements and ToF data acquisition integration

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