TRAPPING RADIOACTIVE IONS WITH ISOLTRAP

Mariya Trichkova
Content (what are you going to see?)

- Where is the ISOLTRAP setup
- The principle of mass measurement with 2 of the ISOLTRAP devices – Penning trap and MR-TOF
- Recent results from MR-TOF
- My task – justification and overview
- My task – progress
Where is the ISOLTRAP experiment?

- **ISOLDE**: Nuclear physics studies
- $E(p)$ @ PS Booster: 1.4 GeV
- $E(p)$ @ LHC: 7 TeV
What do we measure and how?

\[ E = mc^2 = (N \cdot m_e + Z \cdot m_n + Z \cdot m_p) c^2 - \text{Binding energy} \]

- Flexible setup of 4 mass spectrometers
- They can be used independently or
- 3 of them for preparation and 1 for precise measurement
The Penning trap

\[ E = m \cdot c^2 \]

\[ \omega_c = \frac{eB}{m} \]

**ISOLDE beam:**
- quasi-continuous
- 60 keV kinetic energy
- isobaric contamination

**Precision Penning trap:**
- cooled bunches of few ions
- low kinetic energy
- only the ion of interest

Reference ion source

ISOLDE
- 60 keV ion beam

RFQ cooler and buncher

HV platform

MR-TOF mass separator

BN beam gate

ND:YAG 532nm

ToF detector
MCP 3 / channeltron

MCP 2

MCP 1

Precision Penning trap
B = 5.9T

Preparation Penning trap
B = 4.7T

Multi-reflection time-of-flight (MR-TOF) separator

\[ E_{\text{kin}} = qU = \frac{mv^2}{2}, \quad U, q = \text{const} \]

\[ t \propto \frac{1}{v} \propto \sqrt{m} \]
Multi-reflection time-of-flight (MR-TOF) separator

\[ t \propto \frac{1}{\nu} \propto \sqrt{m} \]

\[ A = 149 \]

\[ Z = 65 \]

\[ N = 84 \]

A detailed view: the vacuum system

**ELEMENTS:**
- PreVacuum Pump
- High Vacuum Pump
- PreVacuum Valves
- High Vacuum Valves

**CREATED CONDITIONS:**
- Pressure: 1E-3 mbar
- Pressure: 1E-8 mbar

**Valves controls**
- Opened/Closed

**Pressure controls**

![Diagram of the vacuum system](image)
The task

ELEMENTS:
- PreVacuum Pump
- High Vacuum Pump
- Valves

CREATED CONDITIONS:
- Pressure: $1 \times 10^{-3}$ mbar
- Pressure: $1 \times 10^{-8}$ mbar

DEVICES FOR CONTROL AND MEASUREMENT OF THE CONDITIONS
- Pressure sensor
- Valves Controller
- Digital read-out NI USB 6501

LabVIEW

Connection to a computer or laptop.
Current stage (1)

Front panel

Block diagram
Current stage (1)

Front panel

Block diagram

4 channels
Current stage (1)
Current stage (2)

Assembled in compact and stable form:
THANK YOU
Acknowledgements

D. Atanasov  
D. Kiessler  
S. Kreim  
V. Manea  
I. Murray  
A. Welker  
F. Wienholtz
The hyperbolic Penning trap

- **Dipole excitation**
- **Segmented ring top view**
- **Quadrupole excitation**

Increase $\rho_-$

Convert $\rho_-$ to $\rho_+$

Excitation at $\omega_c = eB/m$:
maximum radial-energy gain, minimum TOF

$$F = -\mu(\nabla \cdot B) = -\frac{E_r \partial B}{B} \frac{\partial z}{\partial z}$$

Time of flight

$^{160}$Yb$^+$

mean time of flight (μs)

excitation frequency - 569411.51 (Hz)
4. Precision ~ trapping time
1-10 keV precision for 2000 events: 1 s
($\sigma_m/m = 10^{-6}-10^{-8}$)

3. Final cooling step: 100 ms
Final purification step: 200 ms
$m/\Delta m = 10^4-10^5$

1. Cooling and bunching: 20 ms

2. Purification: 50 ms
$m/\Delta m = 10^5$
What do we measure and how?

Penning trap

\[ \omega_c = \frac{eB}{m} \]

\[ E = m \cdot c^2 = (N \cdot m + Z \cdot m + Z \cdot m) \cdot c^2 - \text{Binding energy} \]
Here is how it looks like…