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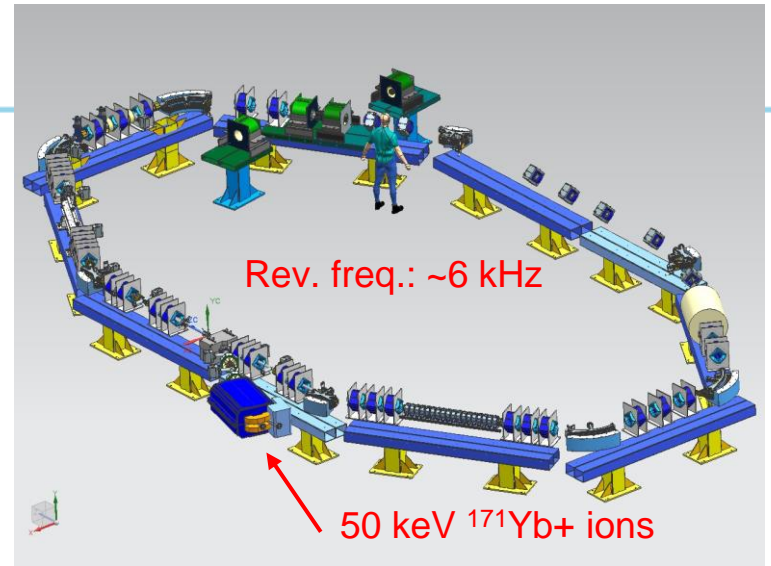
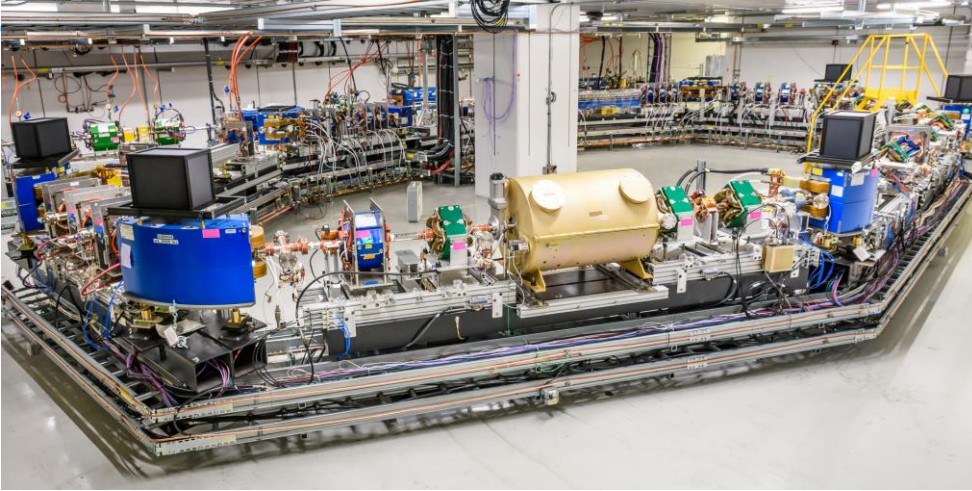
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# **Ion coulomb crystals in the Fermilab IOTA ring: lifetime estimates**

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# Fermilab IOTA ring (40-m circumference, 50 – 150 MeV/c momentum range)



- Present status: operating with relativistic electrons ( $\sim 100\text{-}150$  MeV)
- **This proposal:** add a 50-keV (120-MeV/c momentum)  $^{171}\text{Yb}^+$  ion source, install counter-propagating lasers for Doppler laser cooling and extra ion diagnostics.

# Basic parameters

## Ions: 171 Yb +

$$\underline{A} := 171 \quad \underline{M} := 931.5 \quad \underline{T} := 300 \quad \underline{k} := 1.38 \cdot 10^{-23}$$

$$\underline{c} := 3 \cdot 10^{10} \quad \underline{L} := 4000 \text{ m -- IOTA circumference}$$

$$\underline{K} := 50 \cdot 10^{-3} \quad \text{MeV -- kinetic energy}$$

$$\gamma := \frac{K + A \cdot M}{A \cdot M} \quad \beta := \sqrt{1 - \frac{1}{\gamma^2}}$$

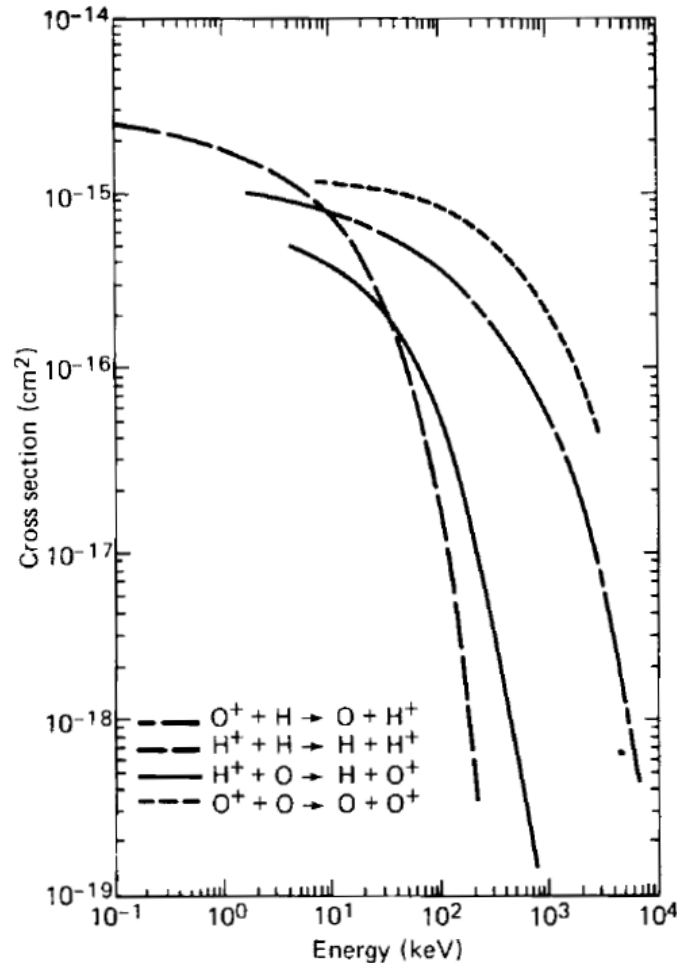
$$\beta \cdot c = 2.377 \times 10^7 \text{ cm/s -- ion velocity}$$

$$\frac{\beta \cdot c}{L} = 5.943 \times 10^3 \text{ Hz}$$

$$\beta \cdot A \cdot M = 126.209 \text{ MeV/c}$$

$$\frac{K \cdot 10^6}{A} = 292.398 \text{ eV/amu -- kinetic energy per nucleon}$$

# Charge-exchange cross section (example)



**Fig. 1:** Charge-exchange cross sections of energetic  $H^+$  and  $O^+$  ions as a function of total ion energy for electron pickup from cold neutral hydrogen and oxygen (figure is taken from a compilation by McEntire and Mitchell, 1989).

- From: Detection of Energetic Neutral Atoms, Peter Wurz

[http://wurz.space.unibe.ch/paper\\_bad\\_honnef.pdf](http://wurz.space.unibe.ch/paper_bad_honnef.pdf)

## Lifetime estimates

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- Assume that the main loss mechanism is the charge exchange with residual (neutral) atoms/molecules:
  - $A^+ + B \rightarrow A + B^+$
  - In our case the kinetic energy is about 300 eV/nucleon
  - Cross-section is estimated at  $1e-16 \text{ cm}^2$

$$\text{Pressure: } p := 1 \cdot 10^{-10} \text{ torr}$$

$$n := \frac{p \cdot 133.3}{k \cdot T \cdot 10^6} \quad n = 3.22 \times 10^6 \text{ 1/cm}^3$$

$$\sigma := 1 \cdot 10^{-16} \text{ cross-section, cm}^2$$

$$\tau := (n \cdot \sigma \cdot \beta \cdot c)^{-1} \quad \tau = 130.659 \text{ seconds}$$