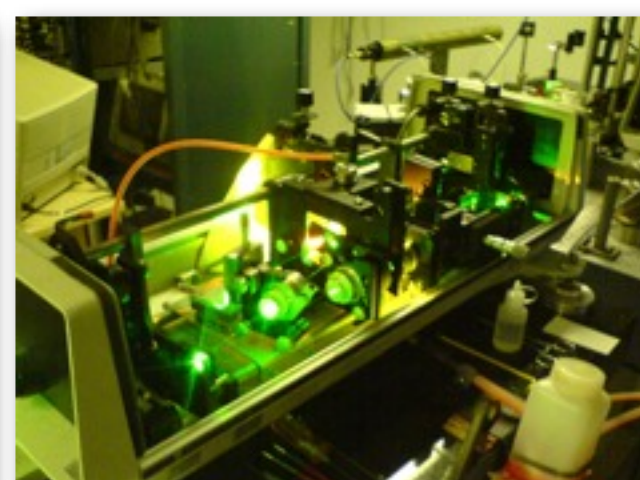
MANCHESTER 1824

The University of Manchester

Searching for new states with collinear laser spectroscopy of pure beams



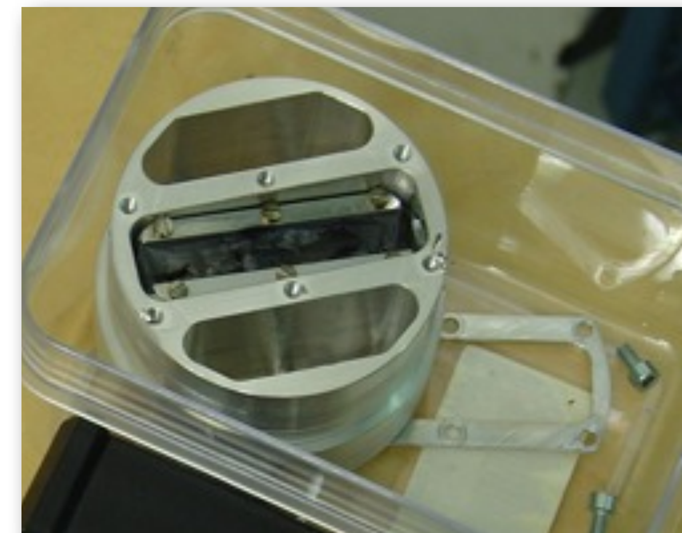
The IGISOL 4 facility, JYFL, Jyväskylä, Finland

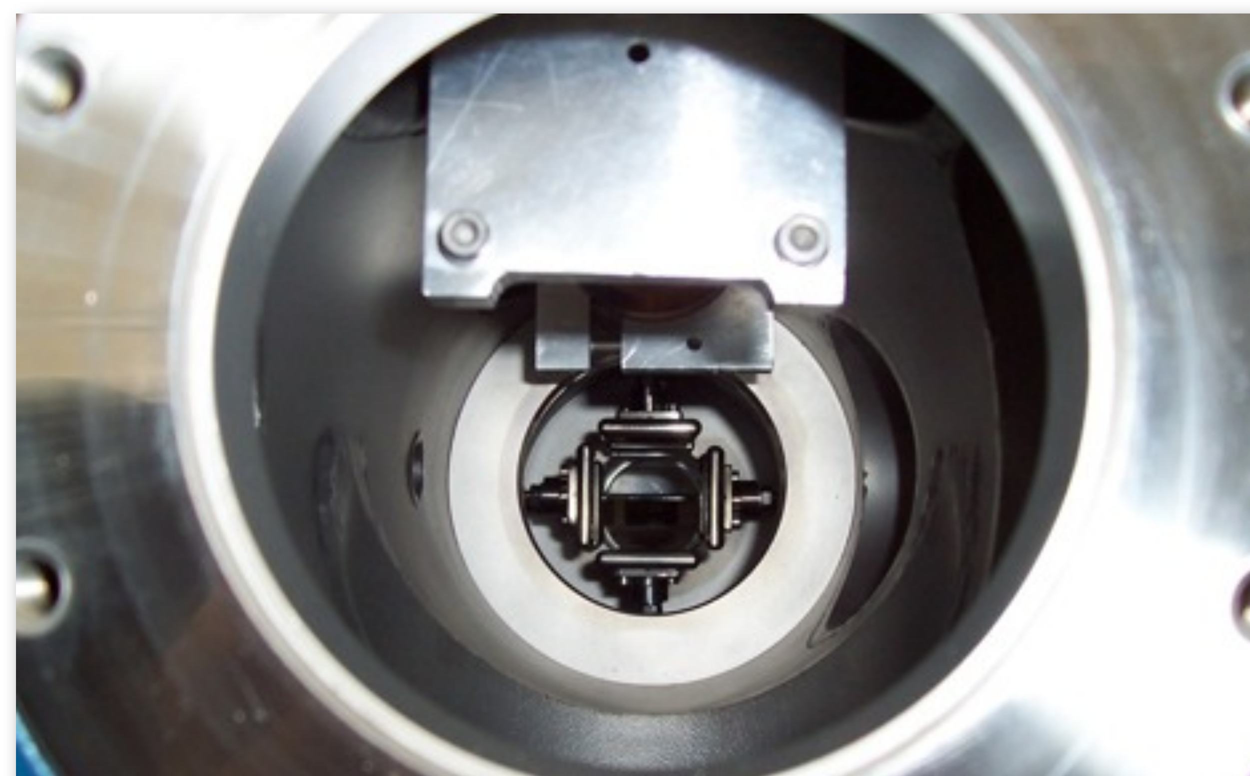
MANCHESTER 1824

The University of Manchester

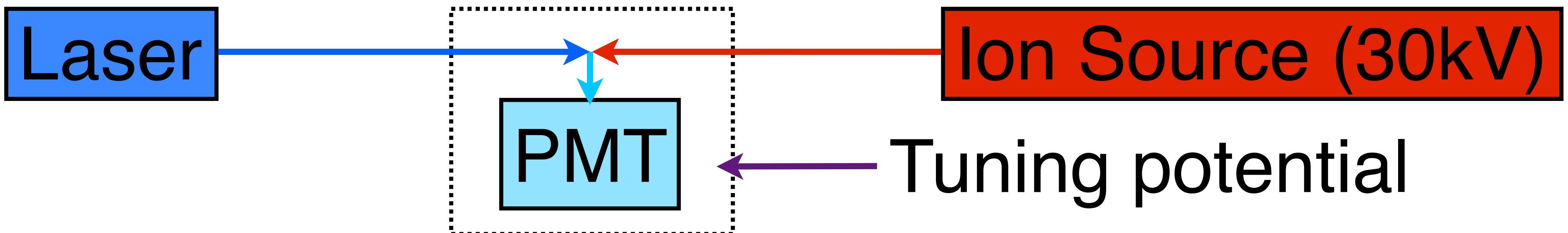
Outline

- Laser spectroscopy of radioactive ion beams
- The new IGISOL facility, JYFL
- Current techniques
- Ion beam purification
- Current status





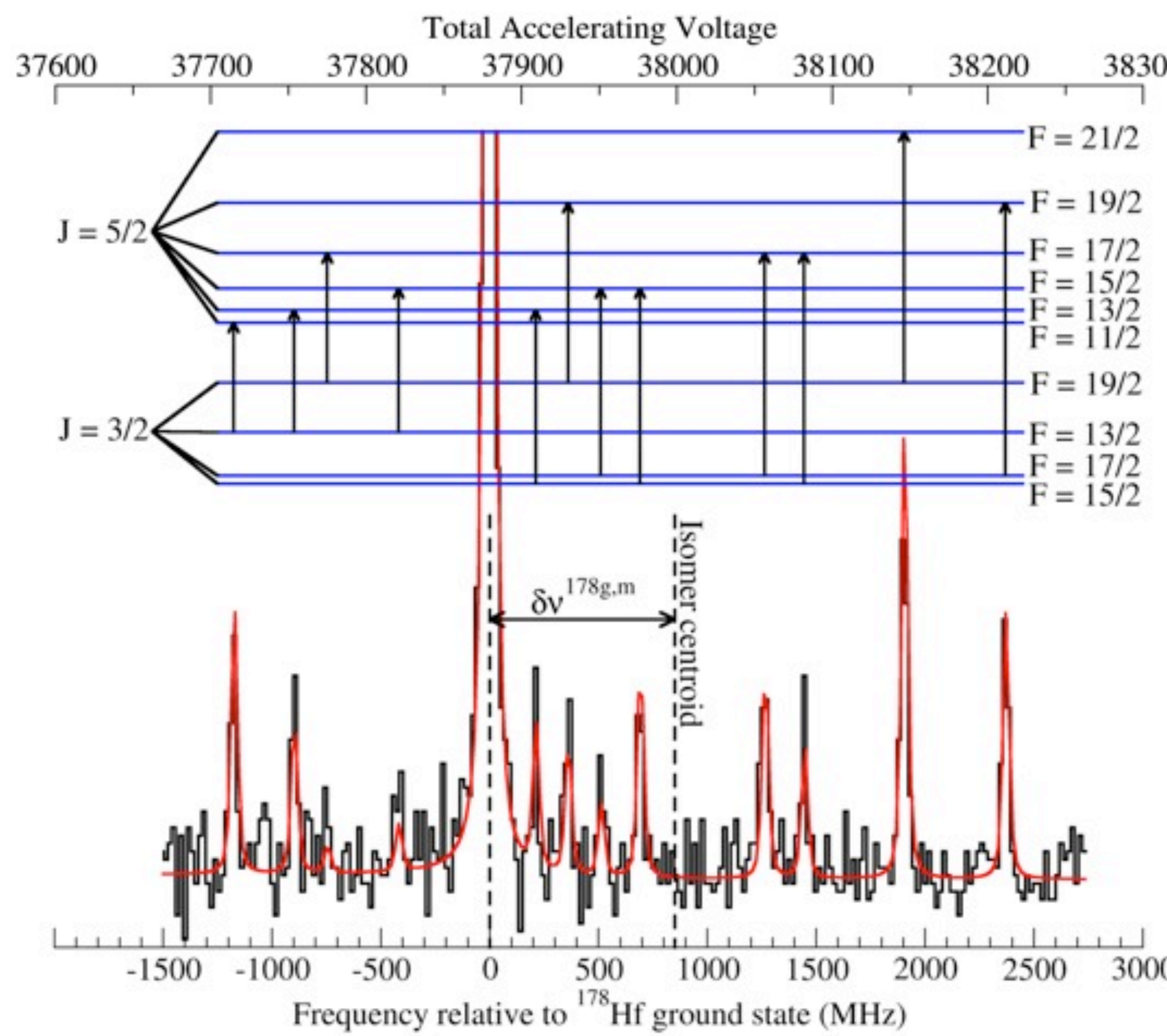
Collinear laser spectroscopy



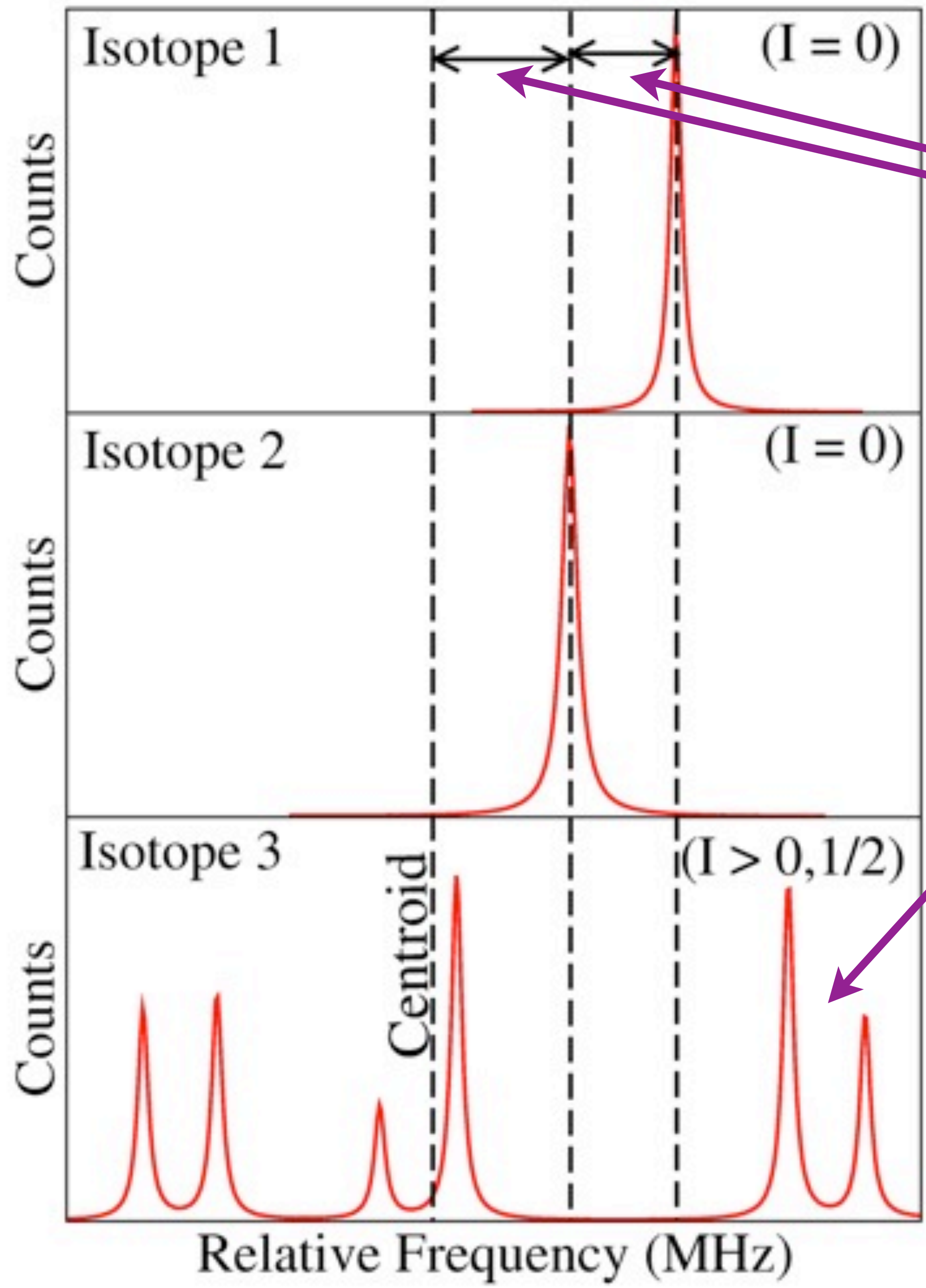
- Used at RIB facilities
- Doppler suppression

$$E = \frac{1}{2}mv^2$$

$$\Delta v = \frac{\Delta E}{mv}$$



High resolution optical spectra



Isotope Shifts

➔ δ< *r*^{2} >

Hyperfine Structure

➔ μ

➔ Q_s ➔ <β_2>

➔ Nuclear spin

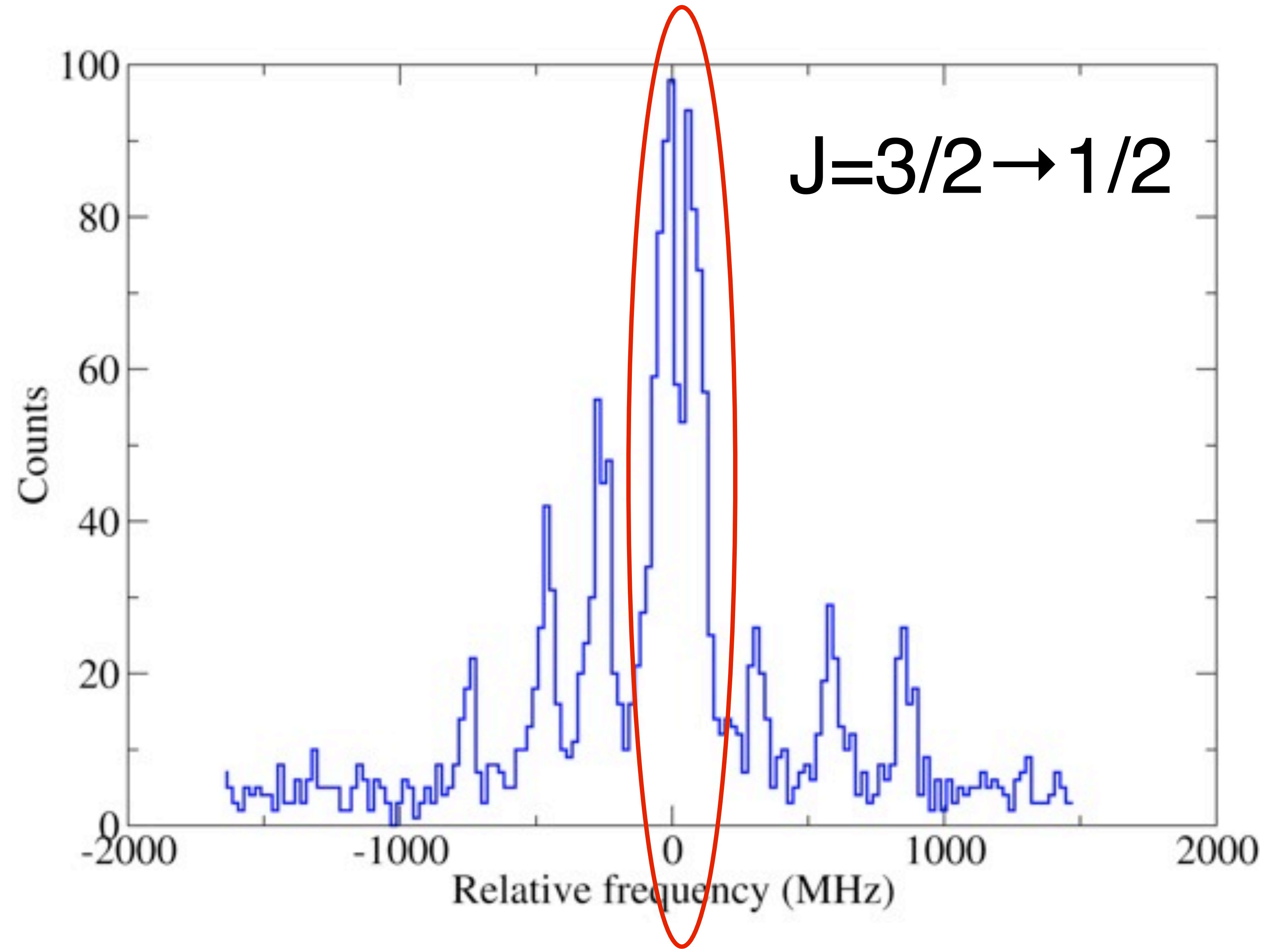
➔ ψ

$$\langle r^2\rangle = \langle r^2\rangle_{\rm sph}\left(1+\frac{5}{4\pi}(\langle\beta_2^2\rangle+...)+3\sigma^2\right)$$

Discovery of new states

A recent example ^{80}Ga:

- Could be too long loved for some decay methods
- Half-life similar to gs
- Too low-lying
  - same mass



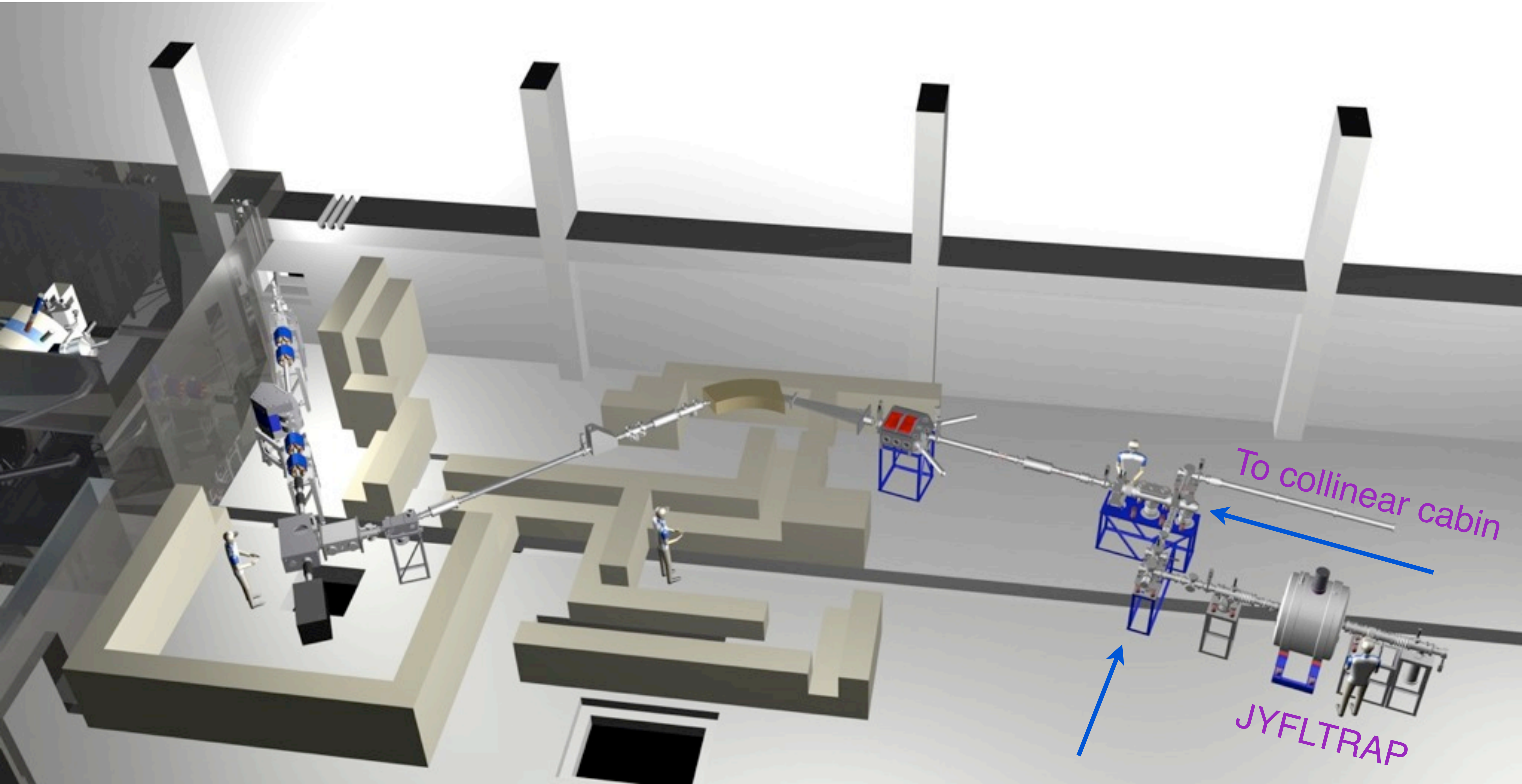
Phys. Rev. C **82**, 051302(R) (2010)

Optical spectroscopy is complements these methods

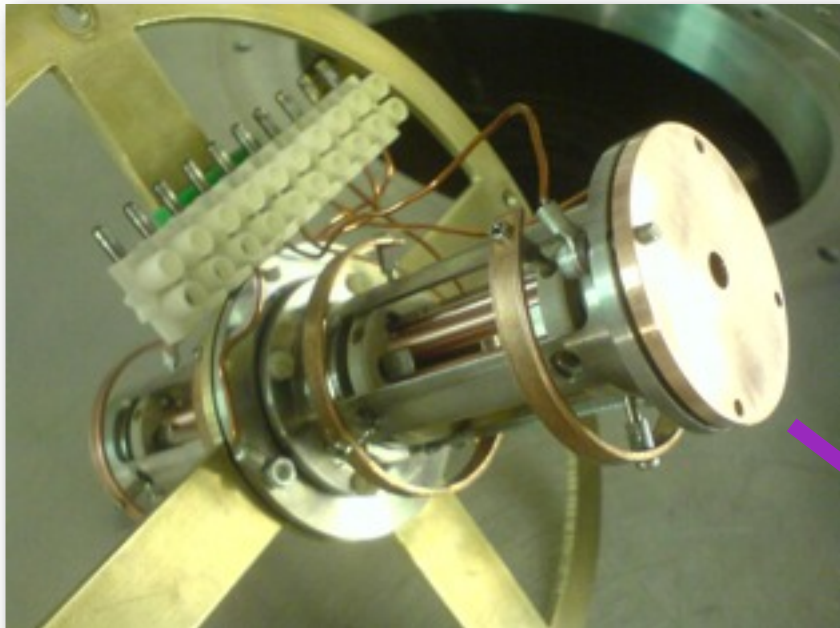
Laser spectroscopy at IGISOL 4

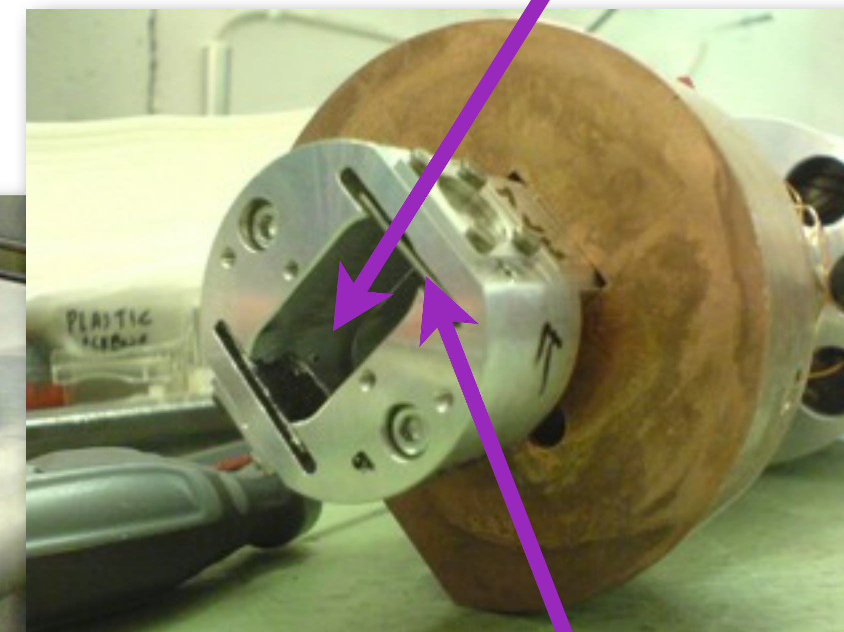
- Dedicated MCC 30/15
- K130 beams (50 MeV)

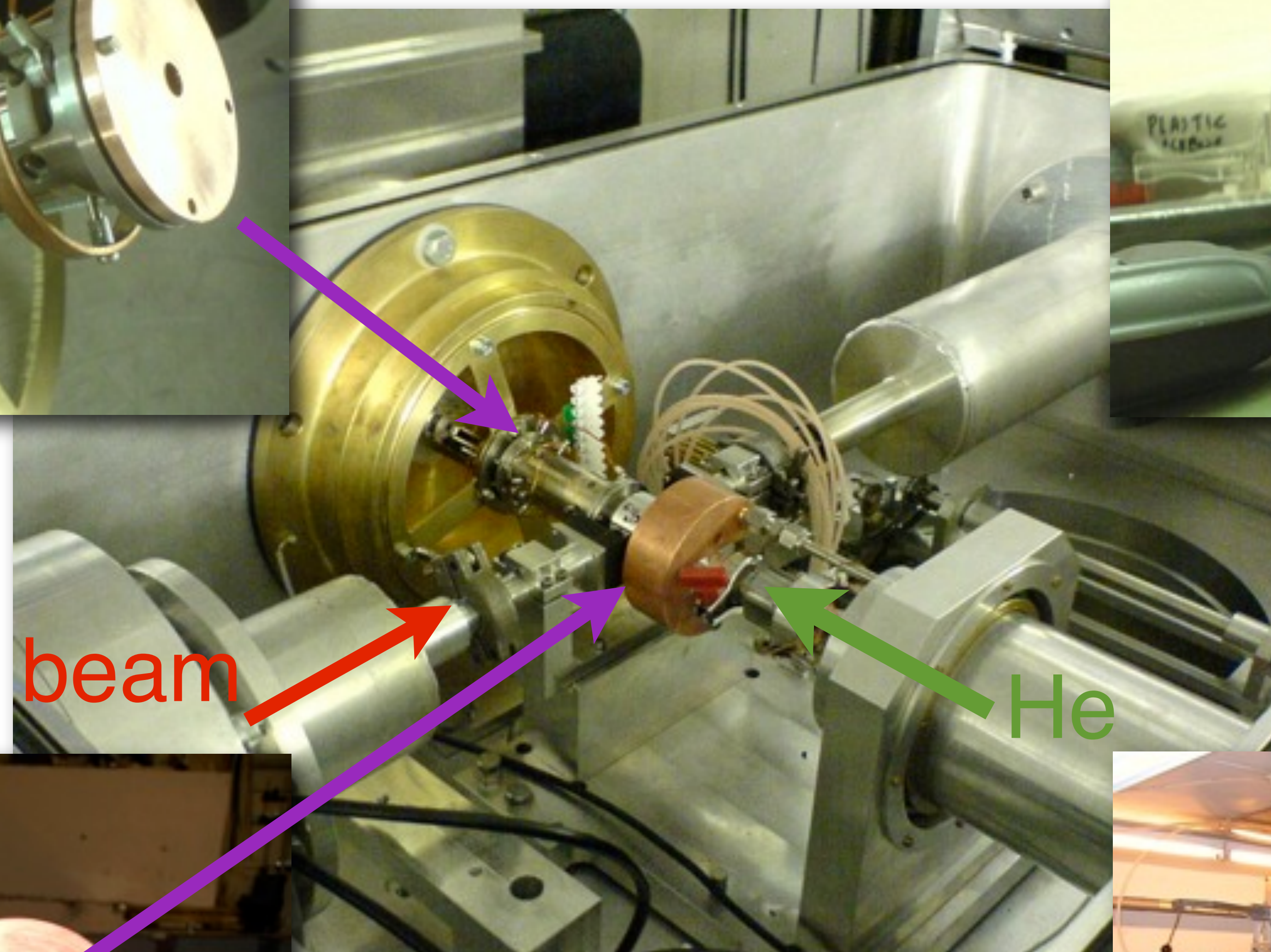
- ^{233}U alpha decay source? (2%)
- ^{nat}Th(p,p3n)^{229}Th @ 50 MeV? (?%) ?
- Shadow gas cell?

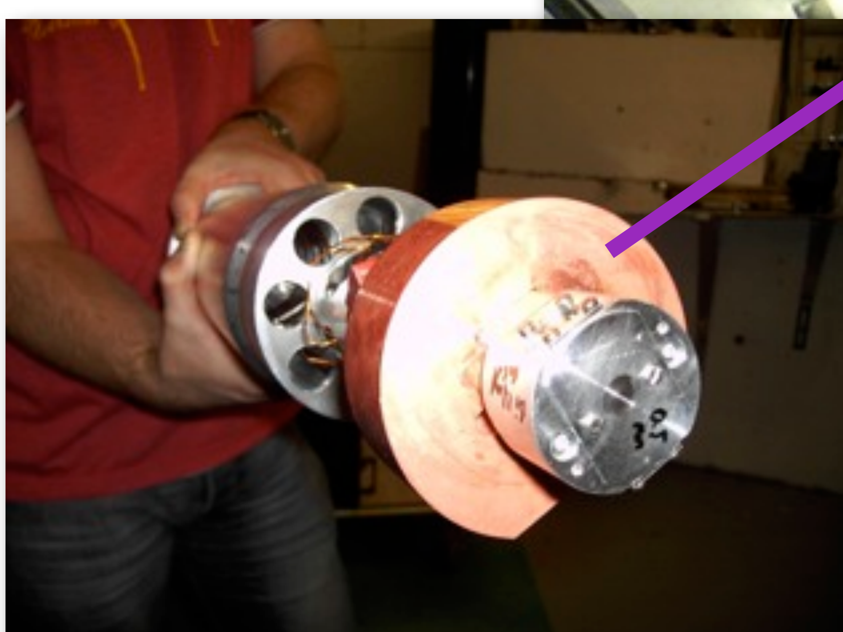


Production at IGISOL



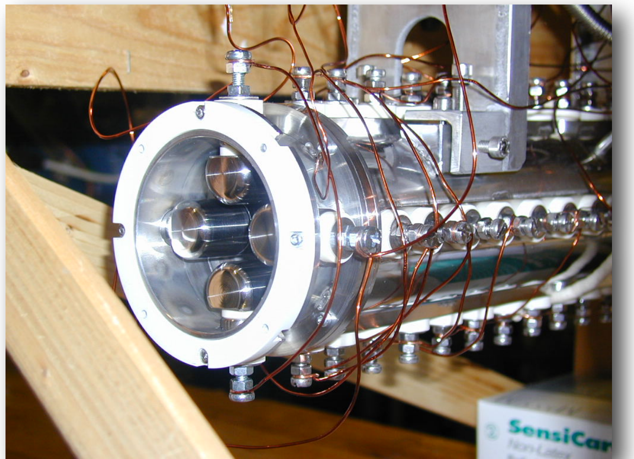


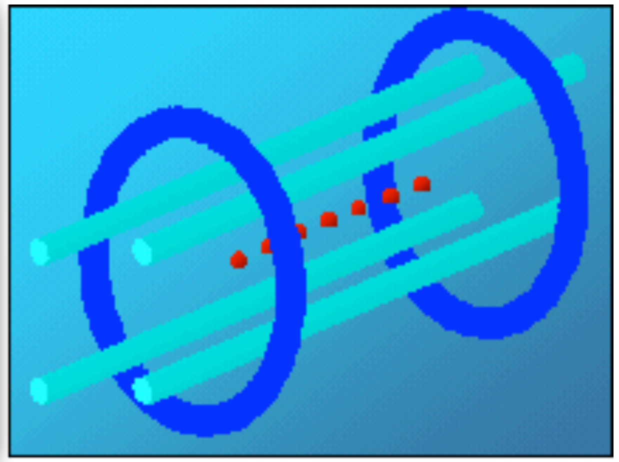


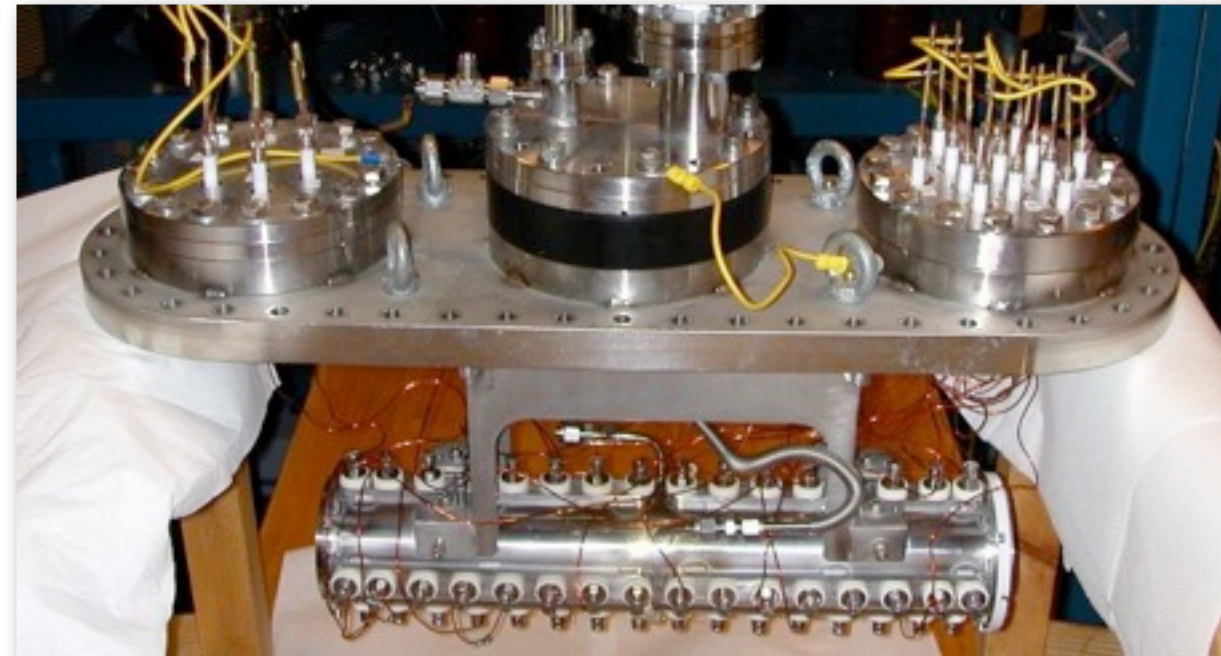


- Fast (sub-ms)
- Universal

Using ion cooler-bunchers

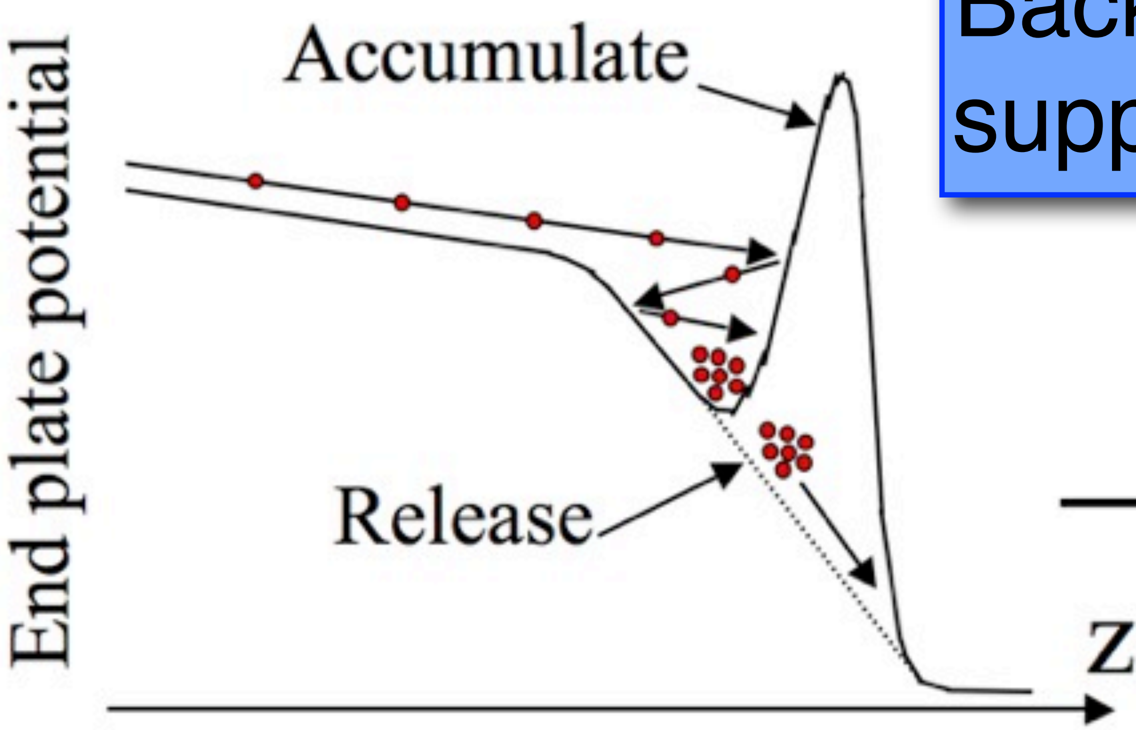




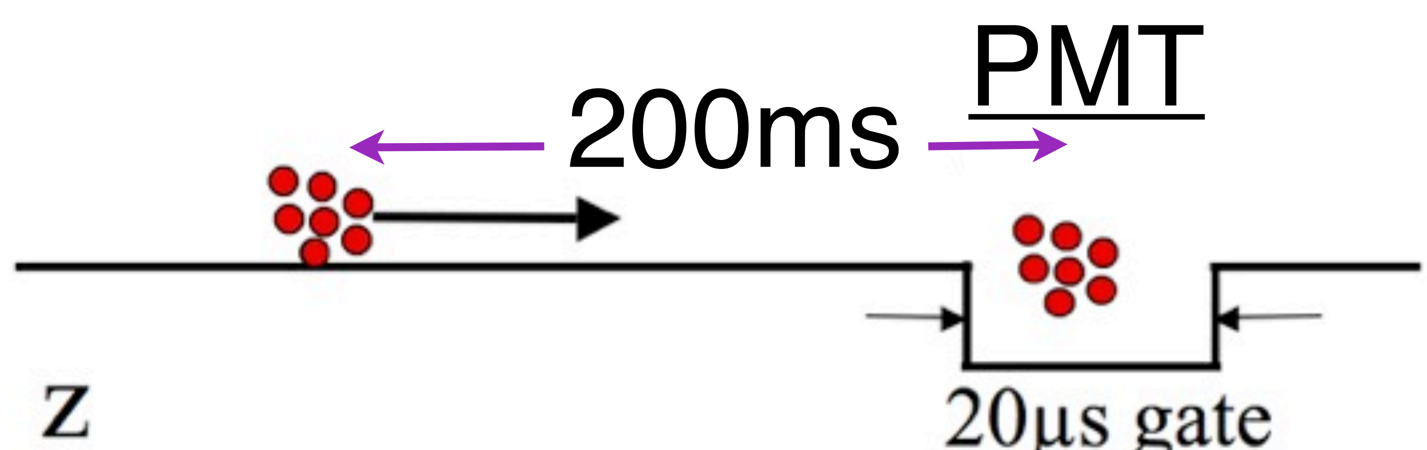


Gas filled RFQ
(→ low emittance)

Photon background dominated by continuous laser scatter



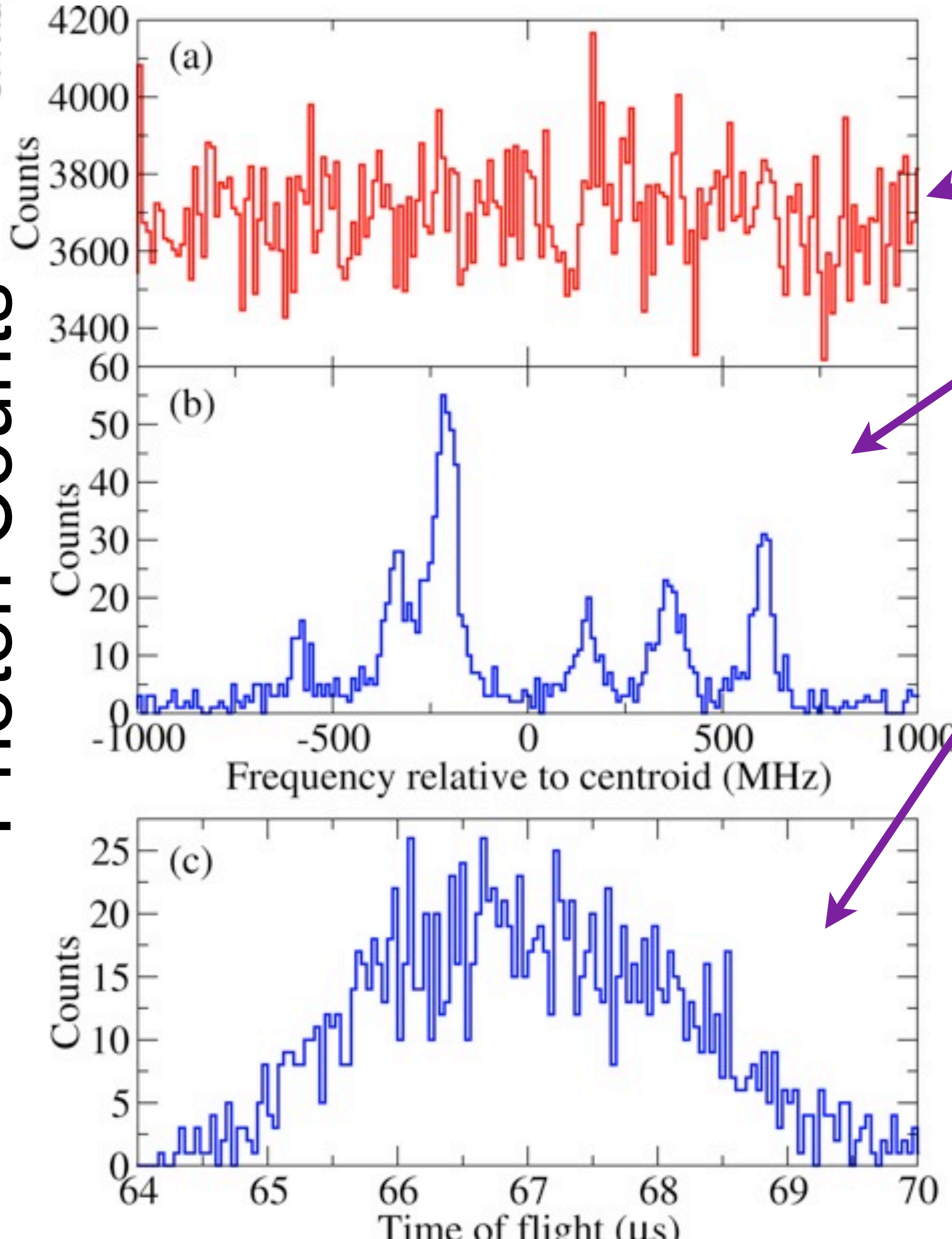
$$\frac{\text{Background}}{\text{suppression}} = \frac{\text{200ms accumulation}}{\text{20µs gate width}} \sim 10^4$$



MANCHESTER 1824
The University of Manchester

Gating on an ion bunch

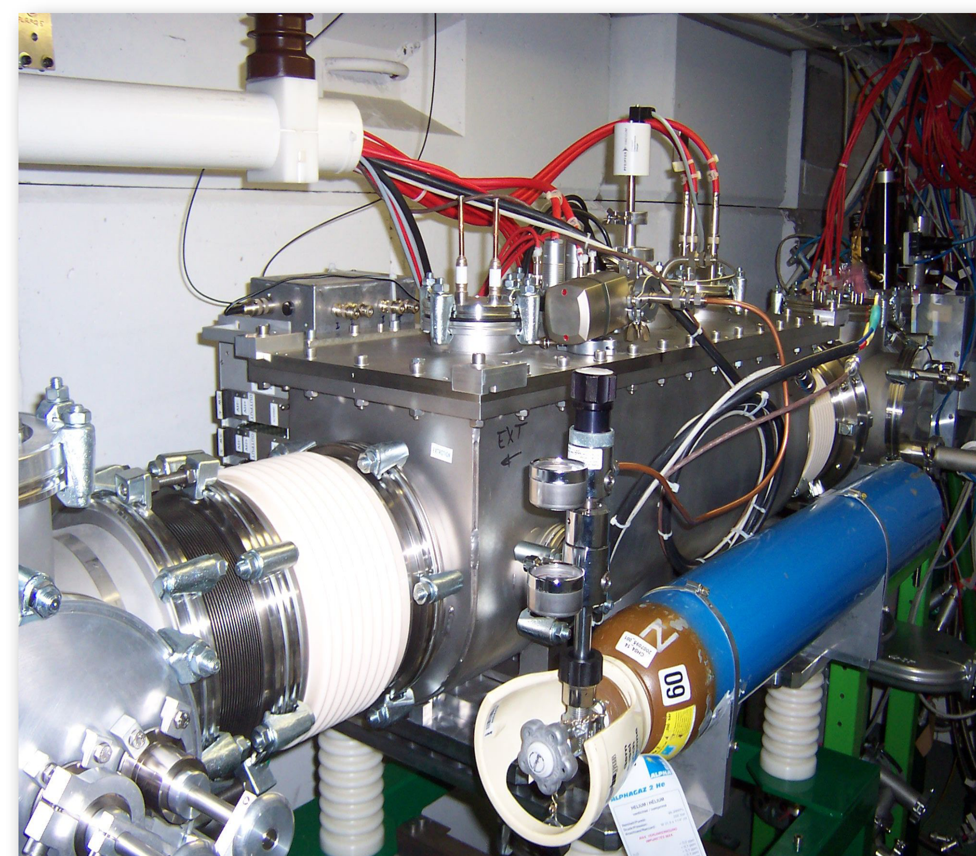
Photon Counts



Ungated

Gated (64μs - 70μs)

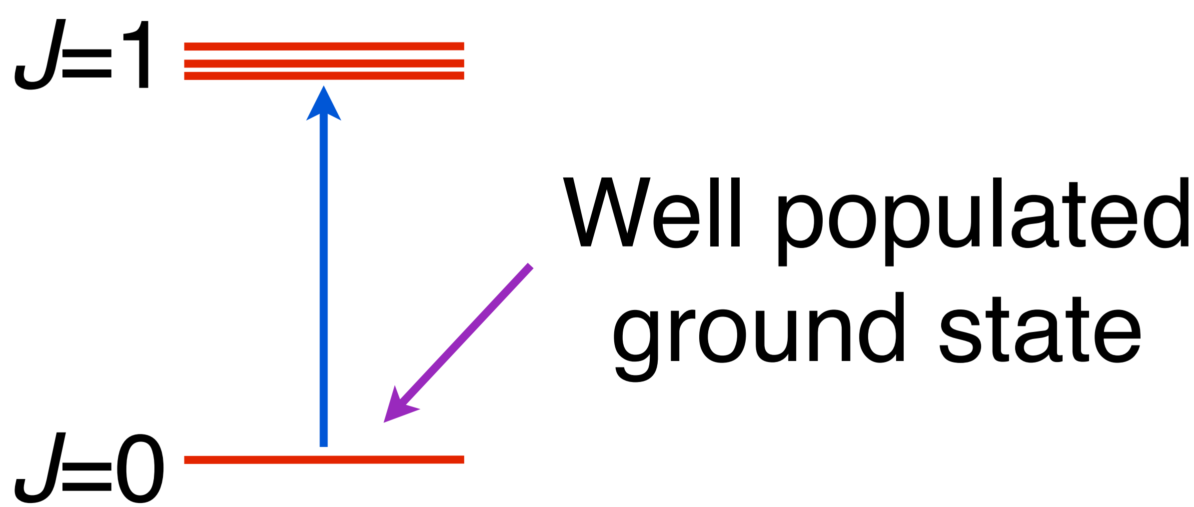
Time of flight (50ms accumulation)



MANCHESTER 1824

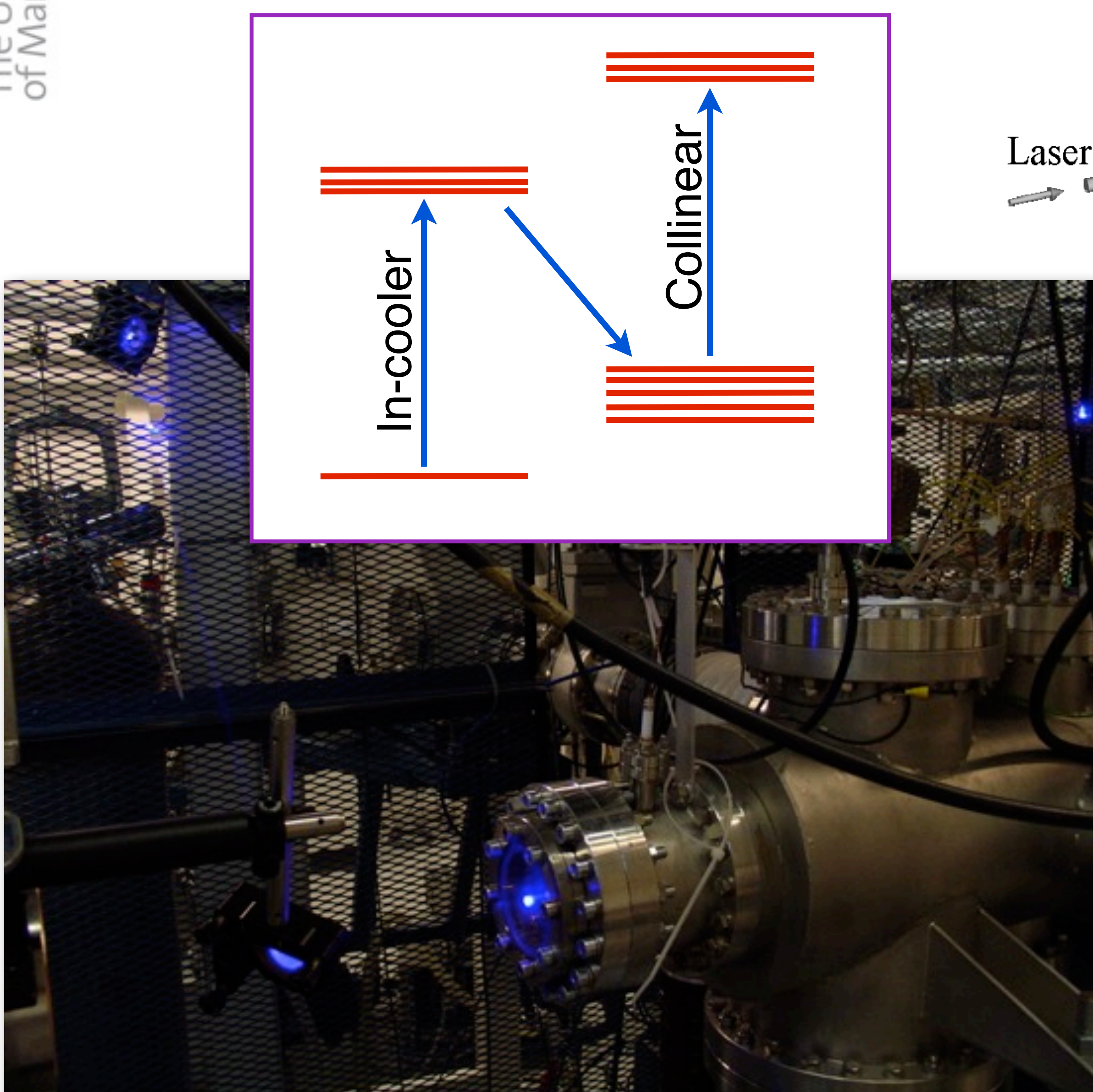
The University of Manchester

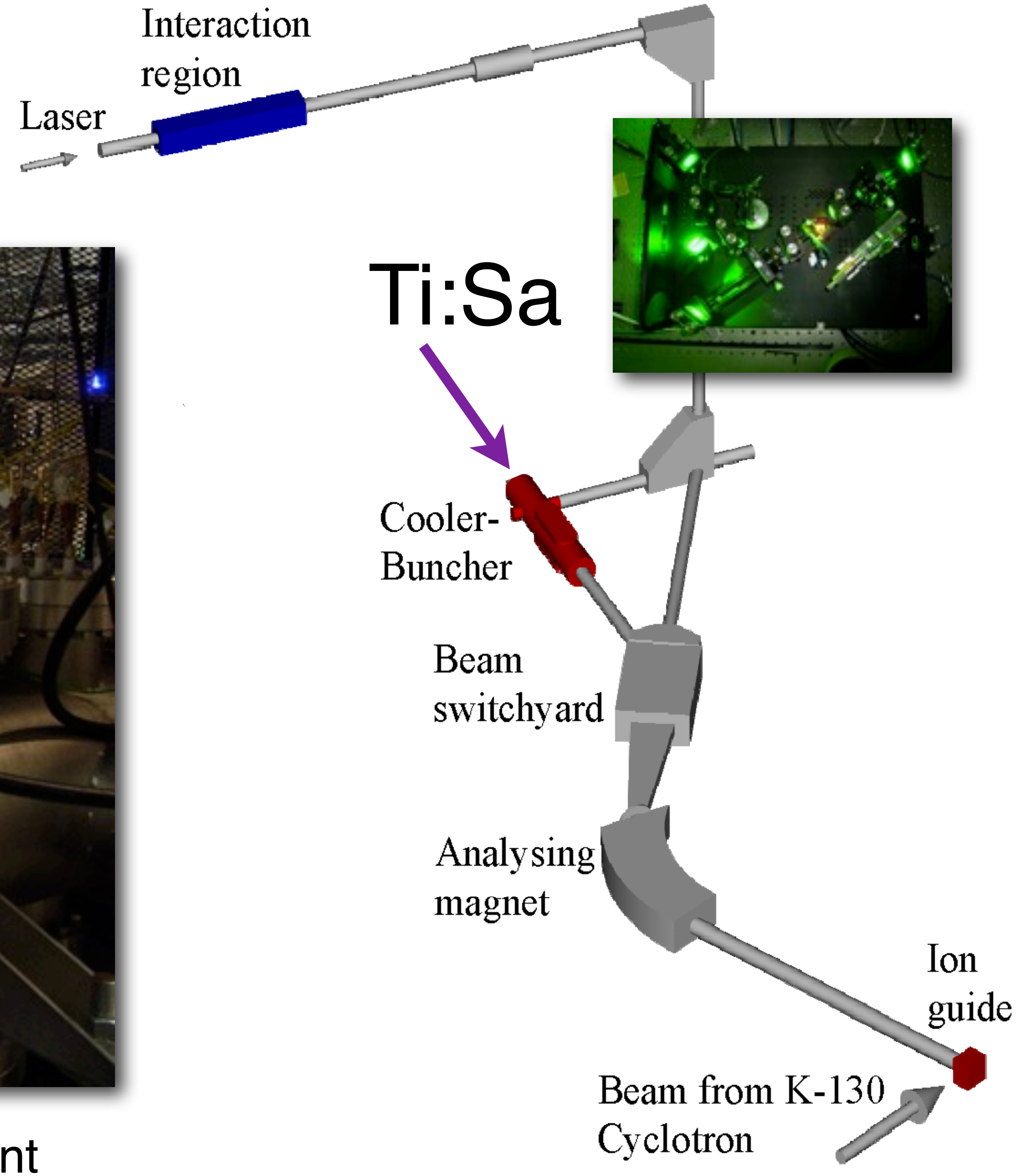
Spectroscopy from ground states



But....	eg.
• 0→1 gives μ, Q_s, $\delta\langle r^2\rangle$, ~~*I*~~	Y,Nb
• No accessible transitions (HR, cts)	Mo,Mn
• Not necessarily the most efficient	Nb,Mn
• Like to separate laser and detection λ	Ca
• Difficult to calibrate atomic factors	Y
• Hyperfine anomaly?	Ta
• Second order perturbed?	Ta

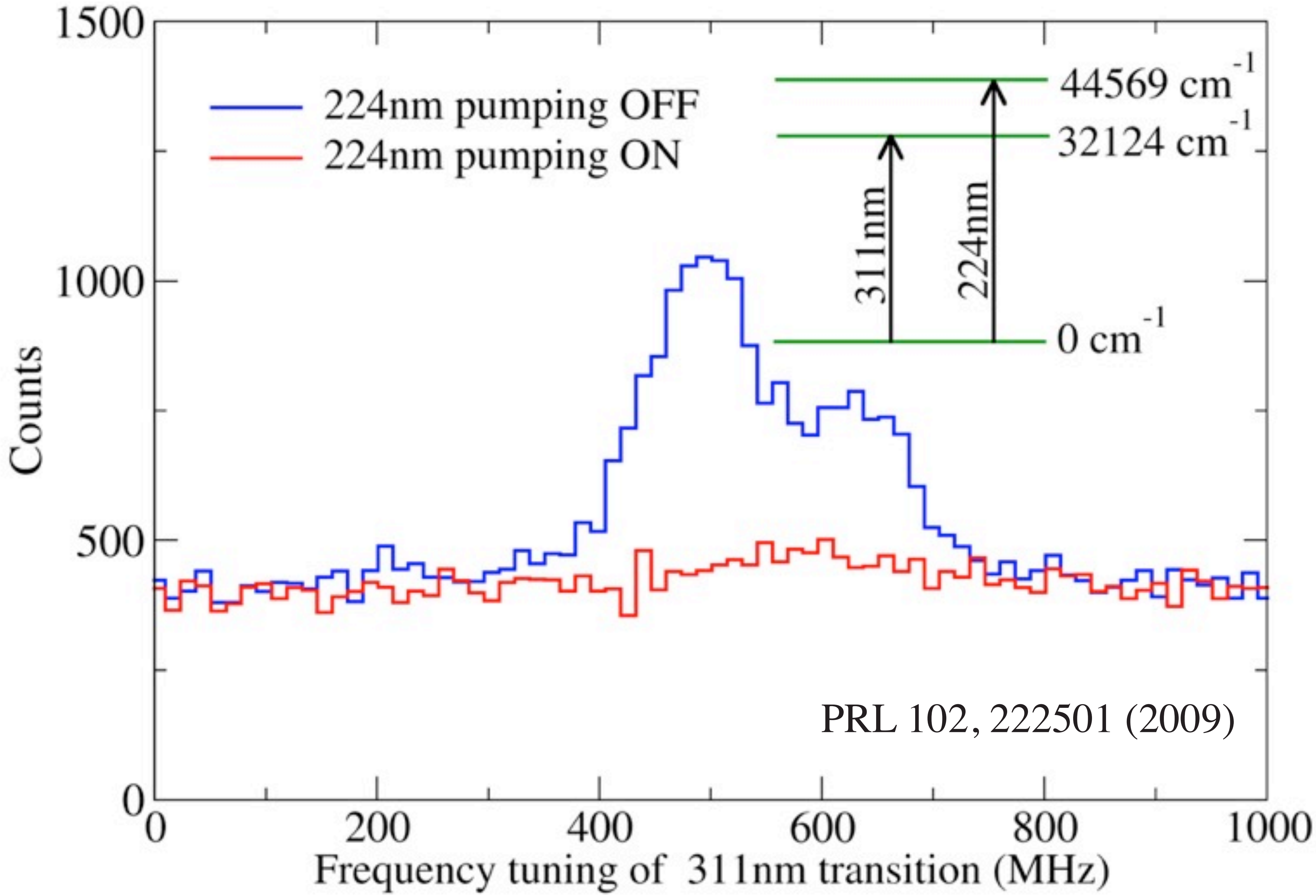
Pumping in the cooler





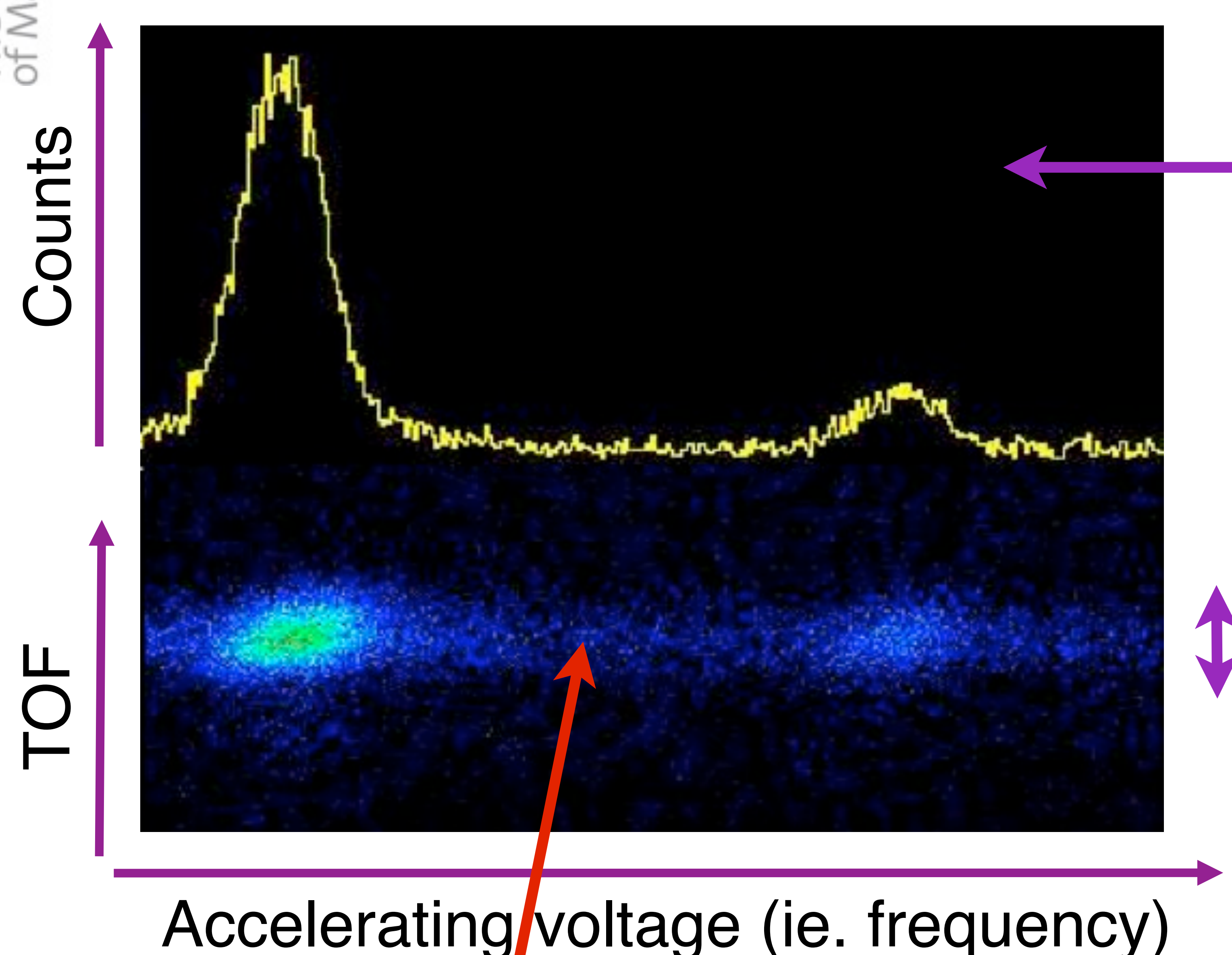
- Focus of slow / trapped ions ➜ always efficient
- Can use broadband/pulsed lasers ➜ large λ range

Optical pumping efficiency



Complete depopulation of the (yttrium) ground state

Ions also cause background



Optical spectrum projected

Gate applied

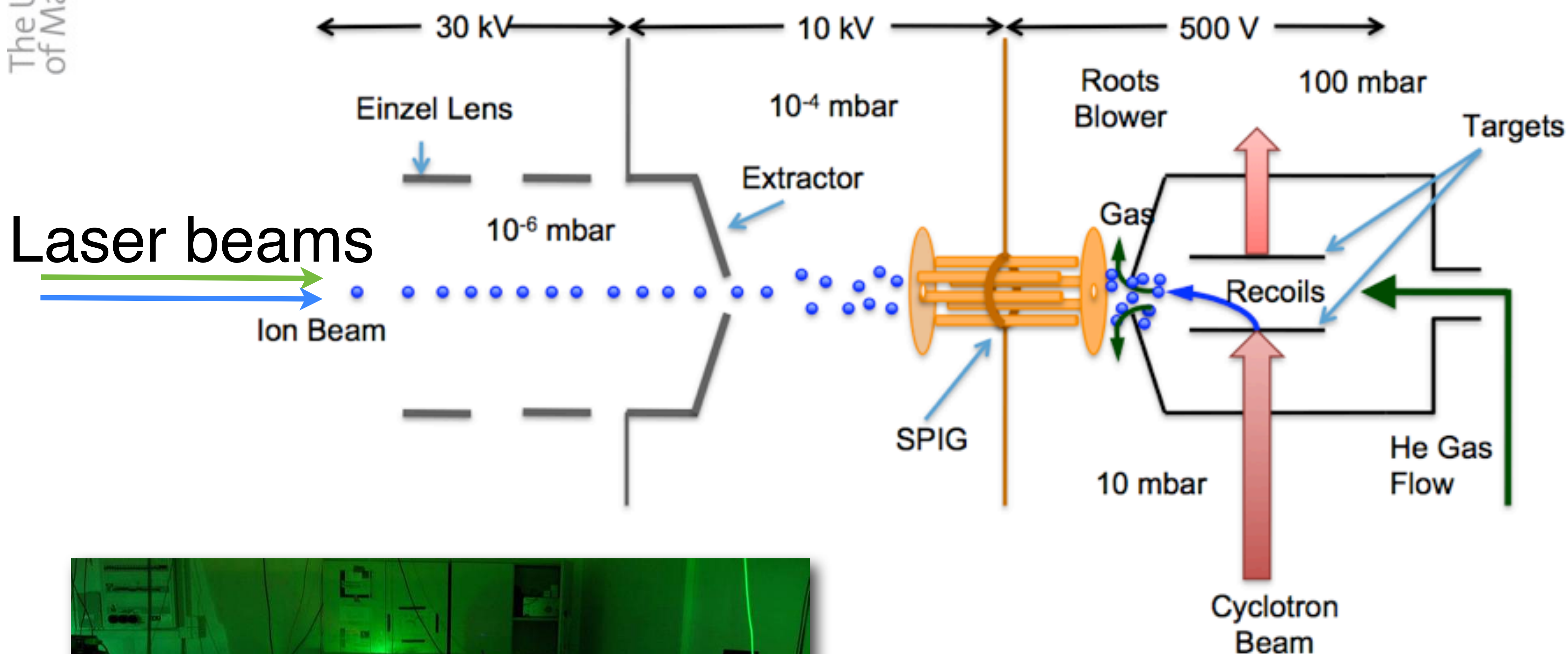
(eg. 10µs of 100ms cycle)

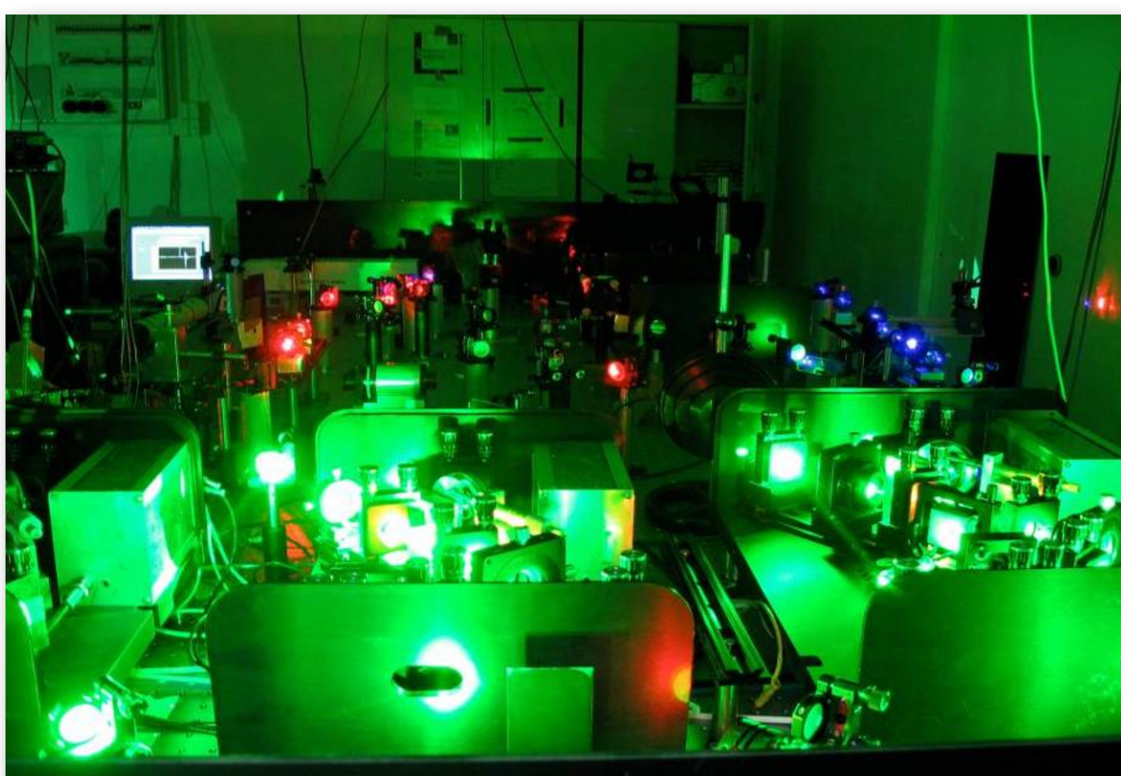
Isobaric contaminants have same TOF (m/q dep.)

➔ Bunching doesn’t help here

➔ Purity will reduce this background

FURIOS laser ion source



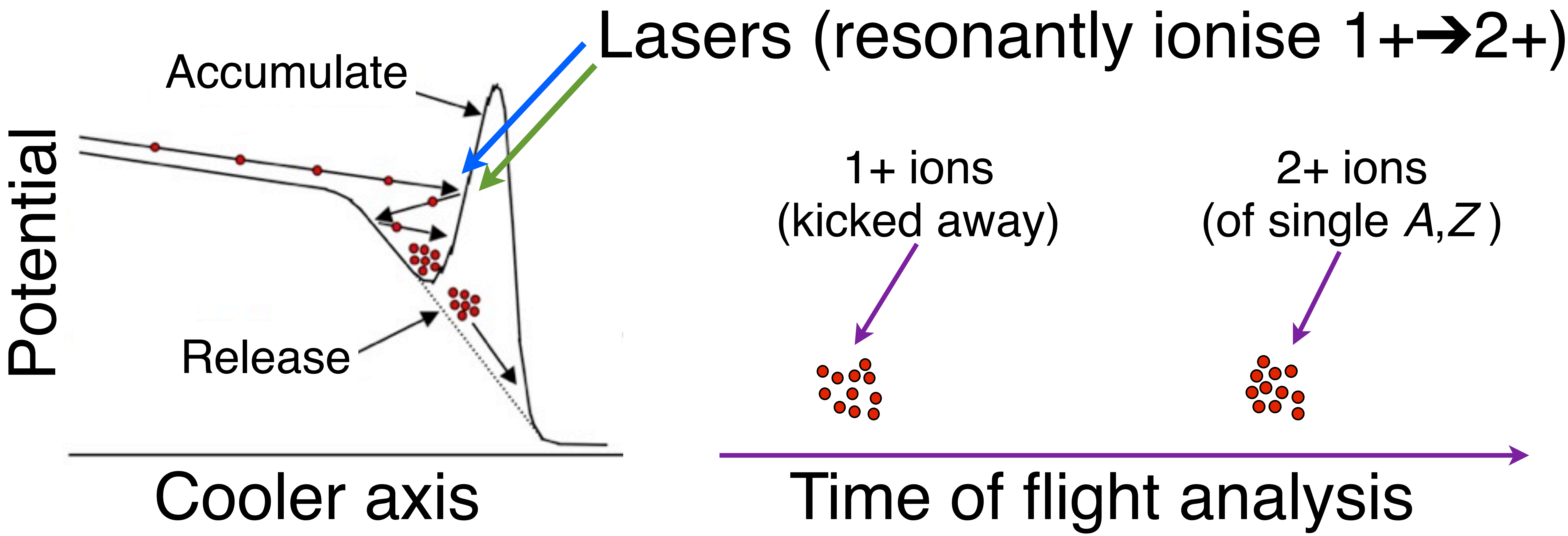


For HR collinear work:-

- Increased yield
- Increased purity

→ increase still further?

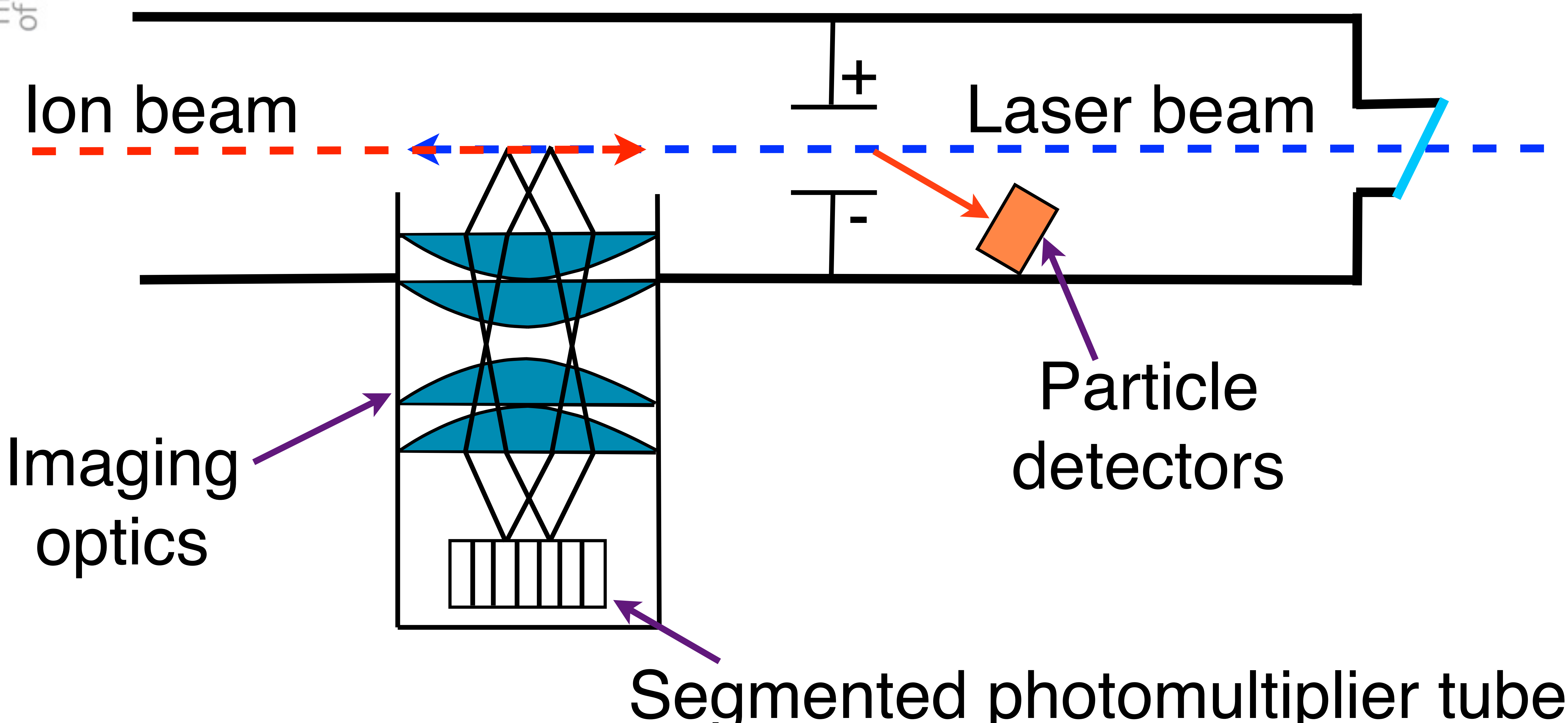
Providing ultra-pure beams



→ Pure beam of single *A* **and *Z***

→ No contaminant will have m/q selected by magnet **and** $m/(2q)$ selected by TOF (or other device)

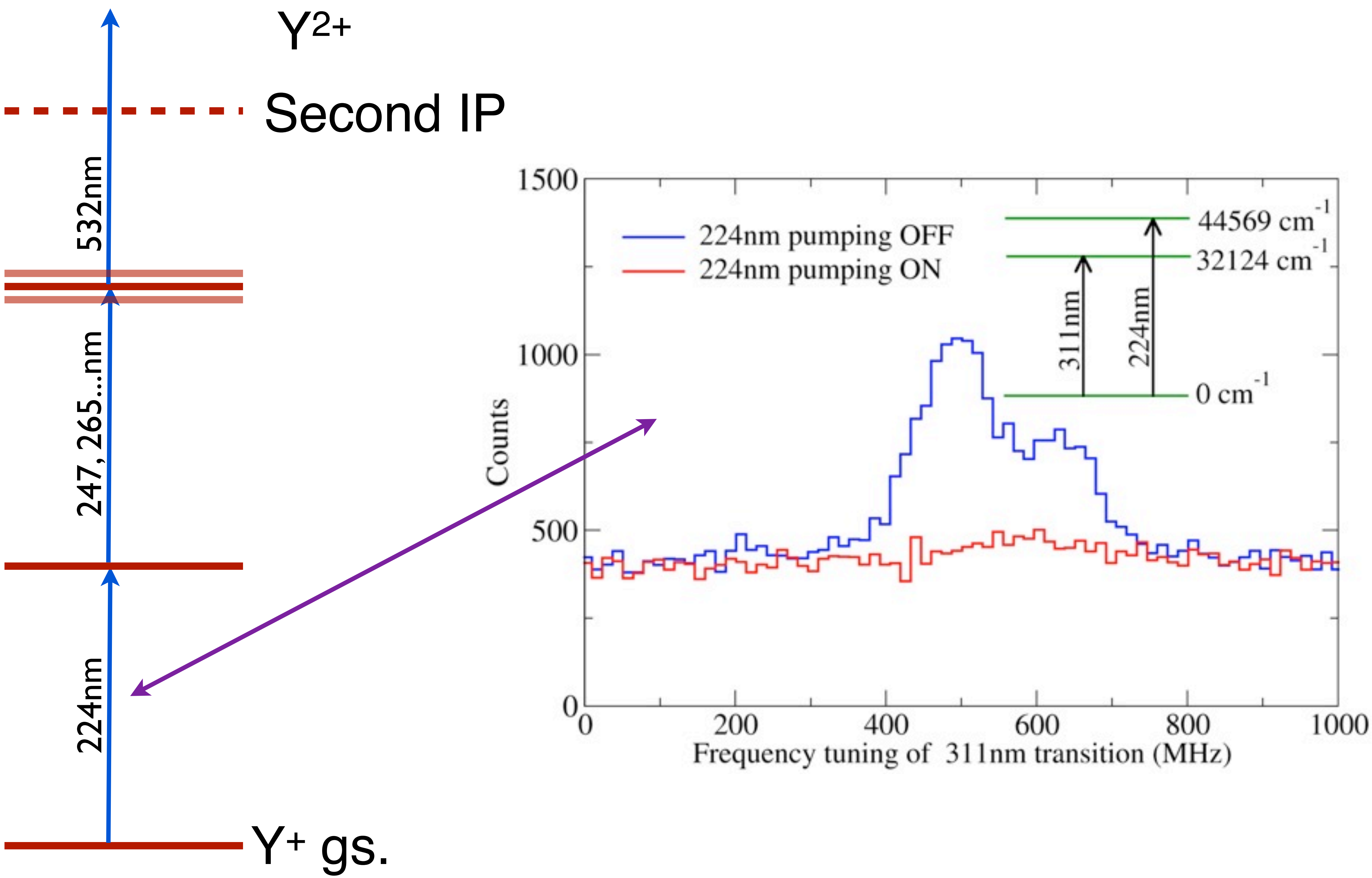
Photon-Ion coincidence



Isobaric contamination caused “false” coincidences

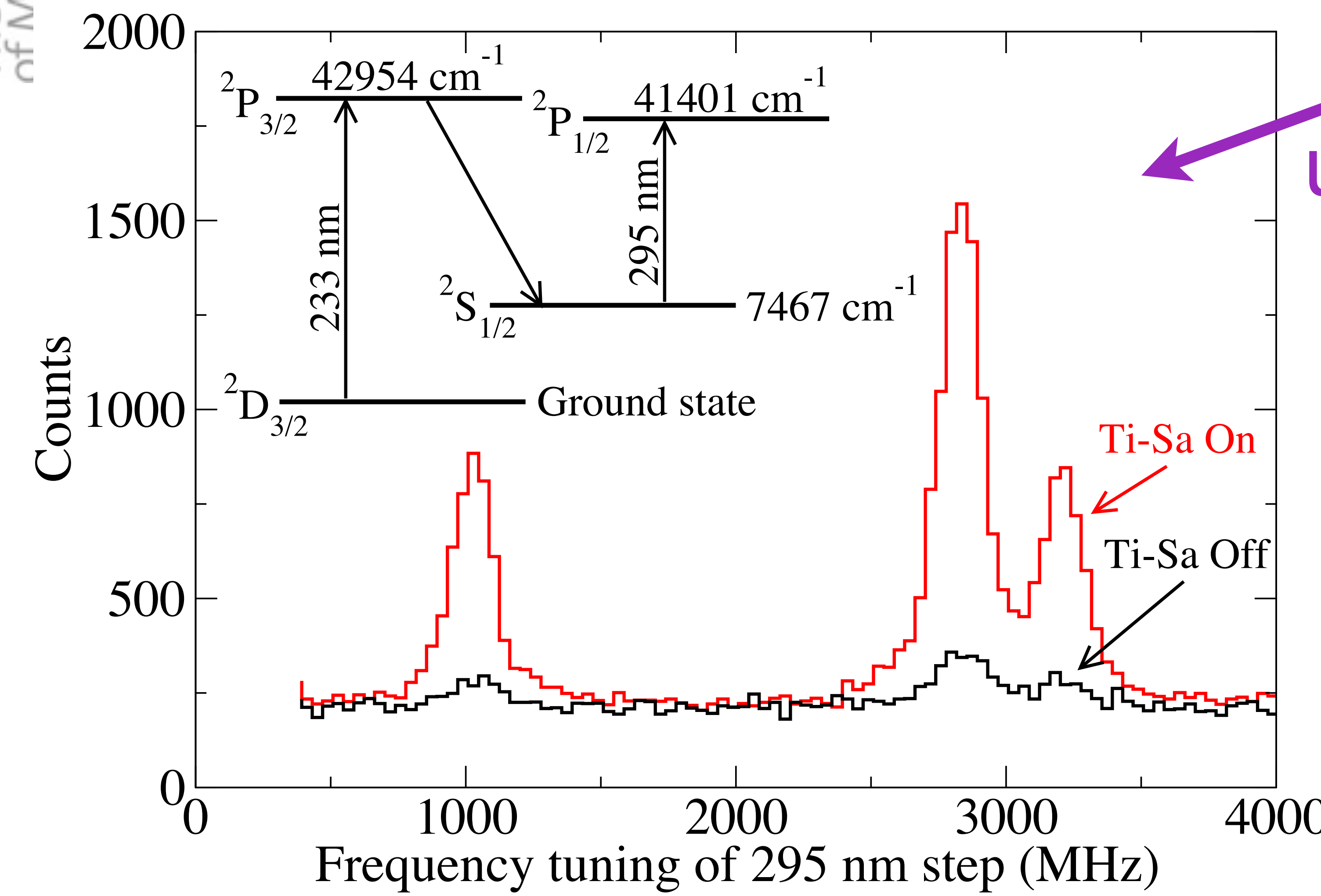
Better timing resolution (few ns), few atom/s sensitivity

Producing pure yttrium beams



MANCHESTER 1824
The University of Manchester

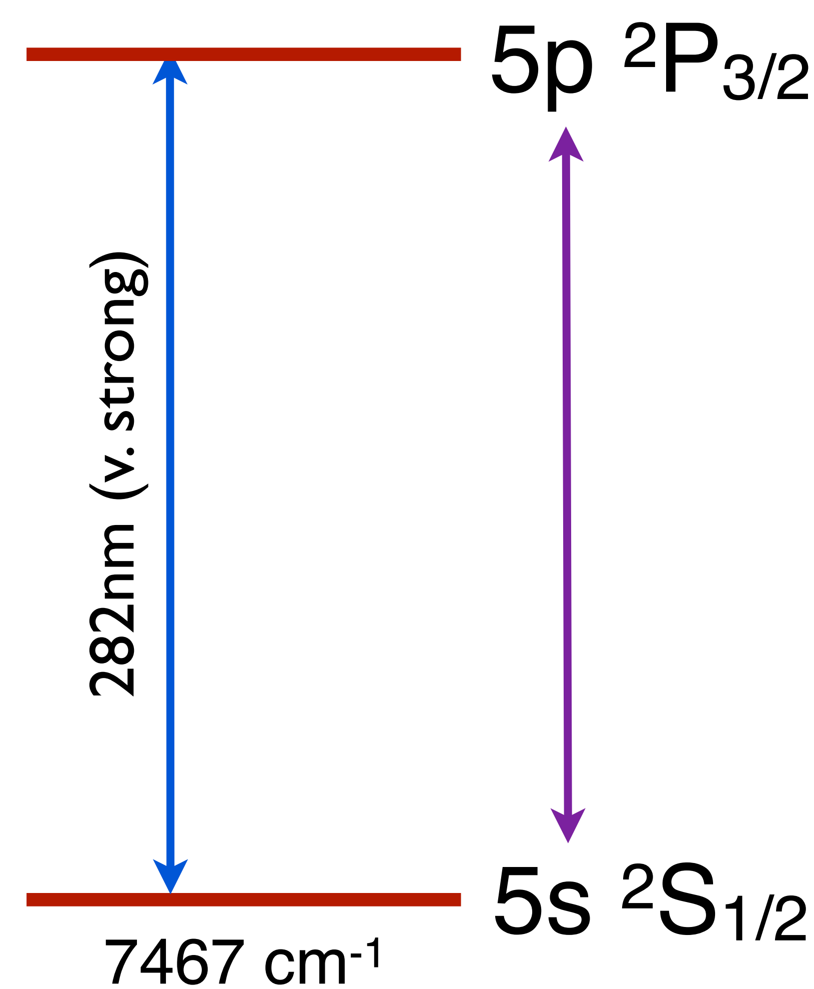
Spectroscopy scheme Y^{2+}



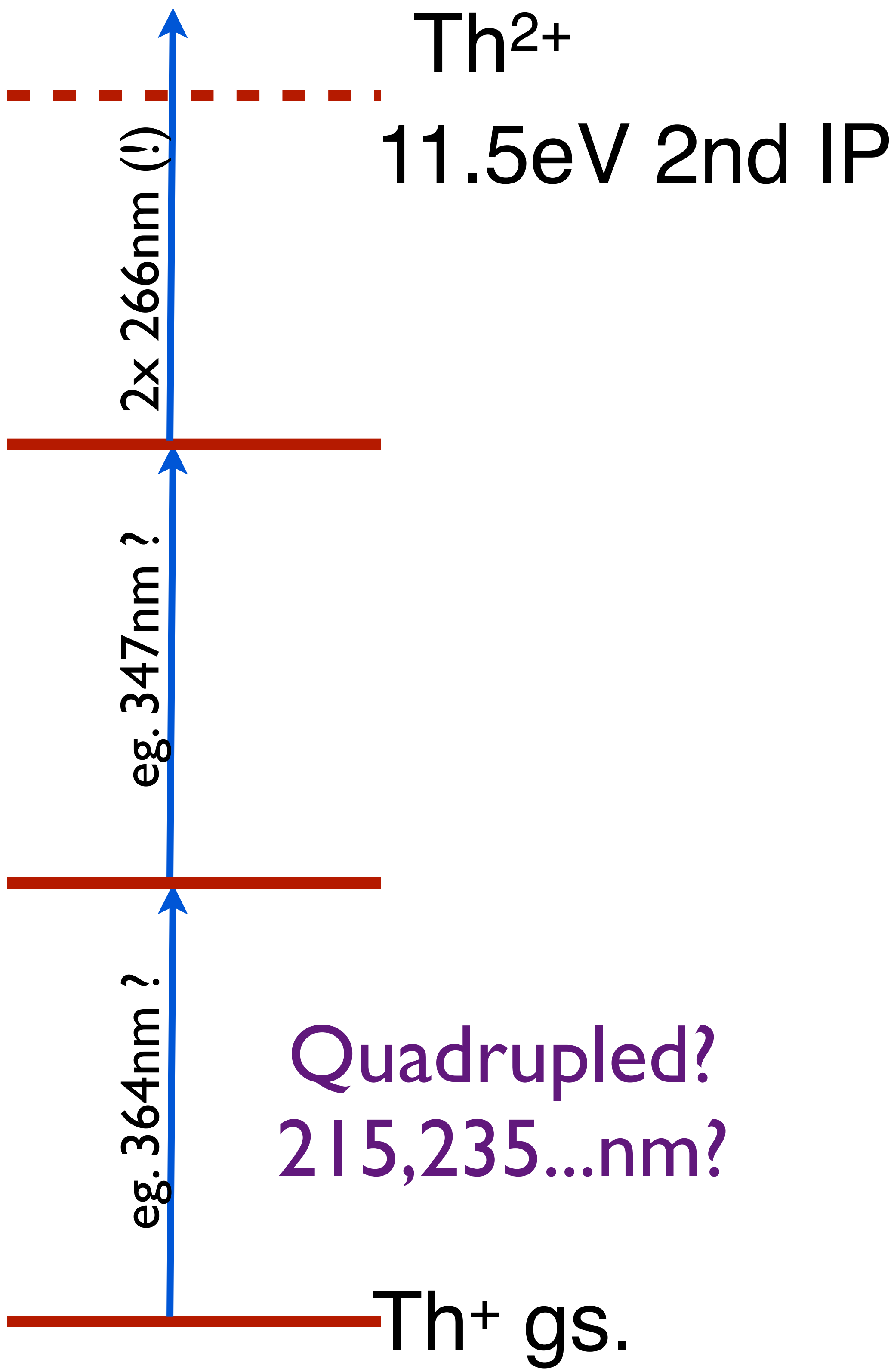
Test at JYFL IGISOL using natural 2+ production

Metastable state enhanced with in-cooler pumping but can tune second step to populate 5s6d prior to ionisation ➜ 5s

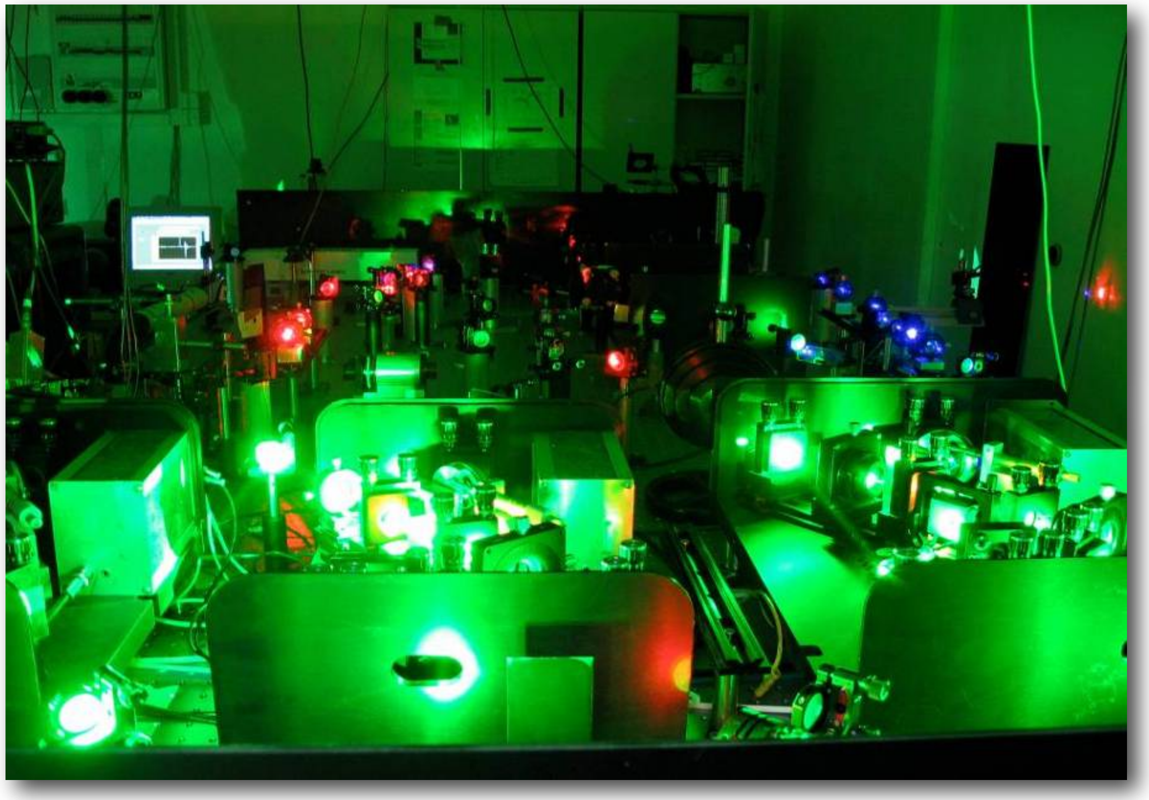
Use:



Producing pure ^{229}Th beams



Quadrupled?
215,235...nm?

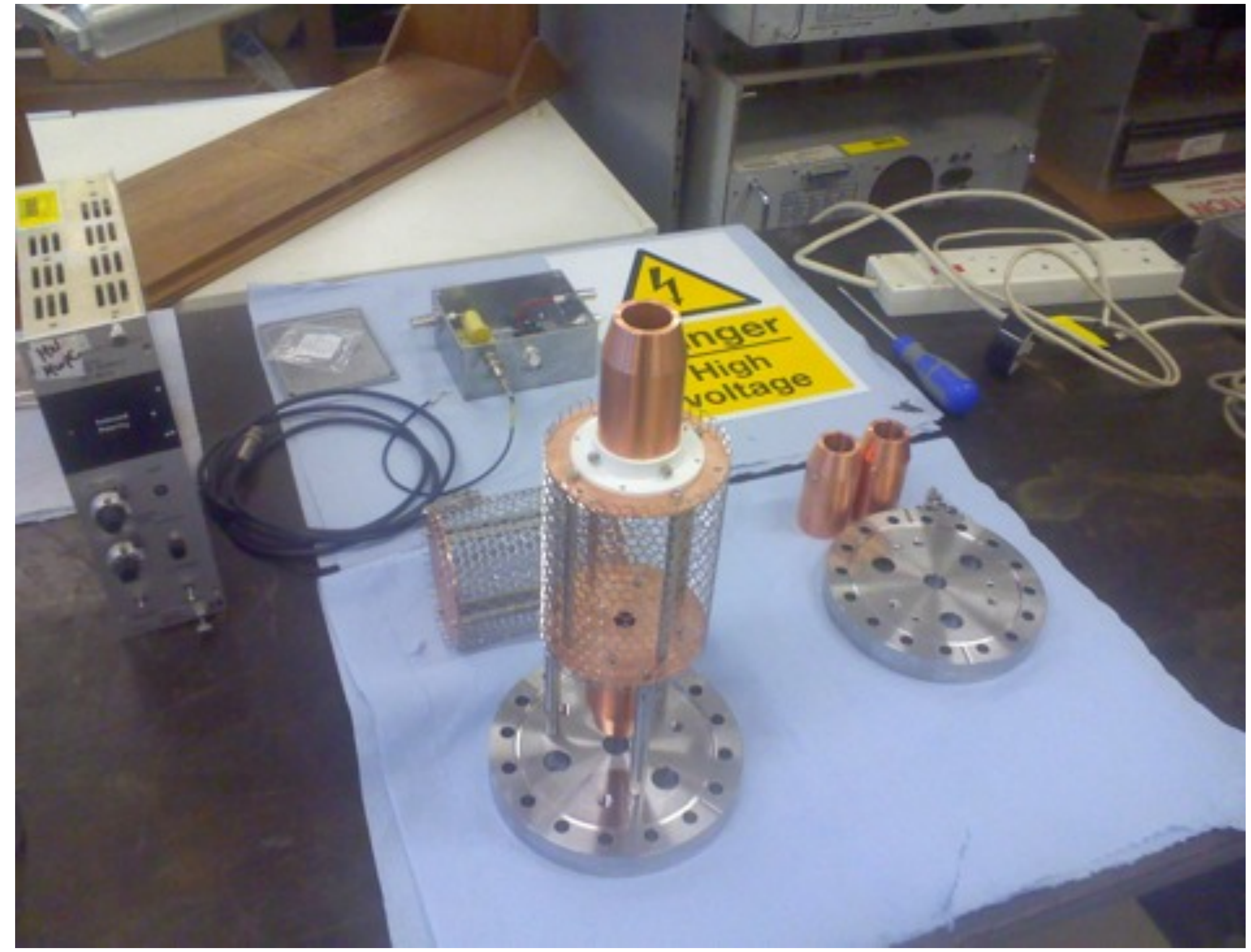


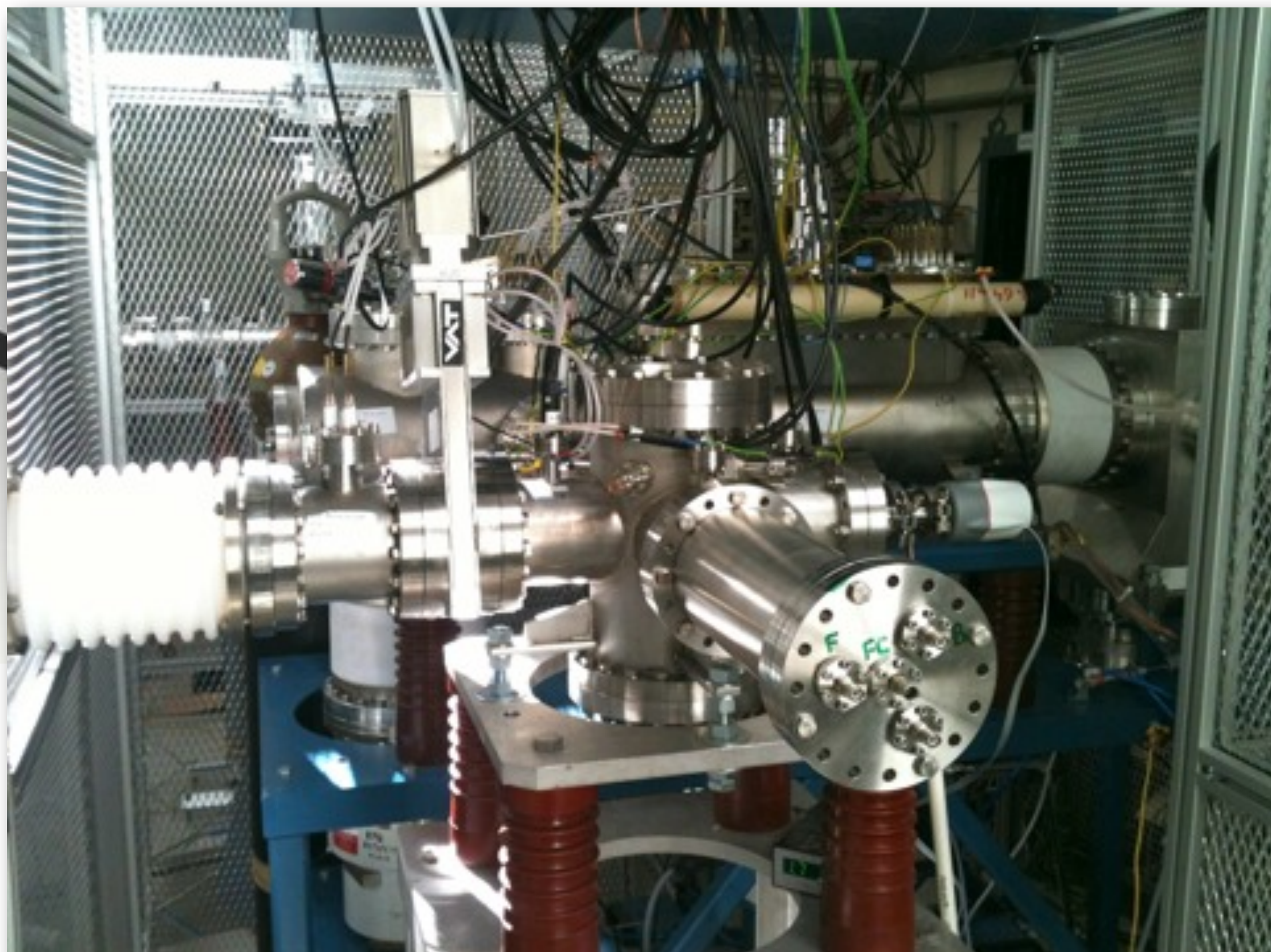
Intra-cavity doubling now available

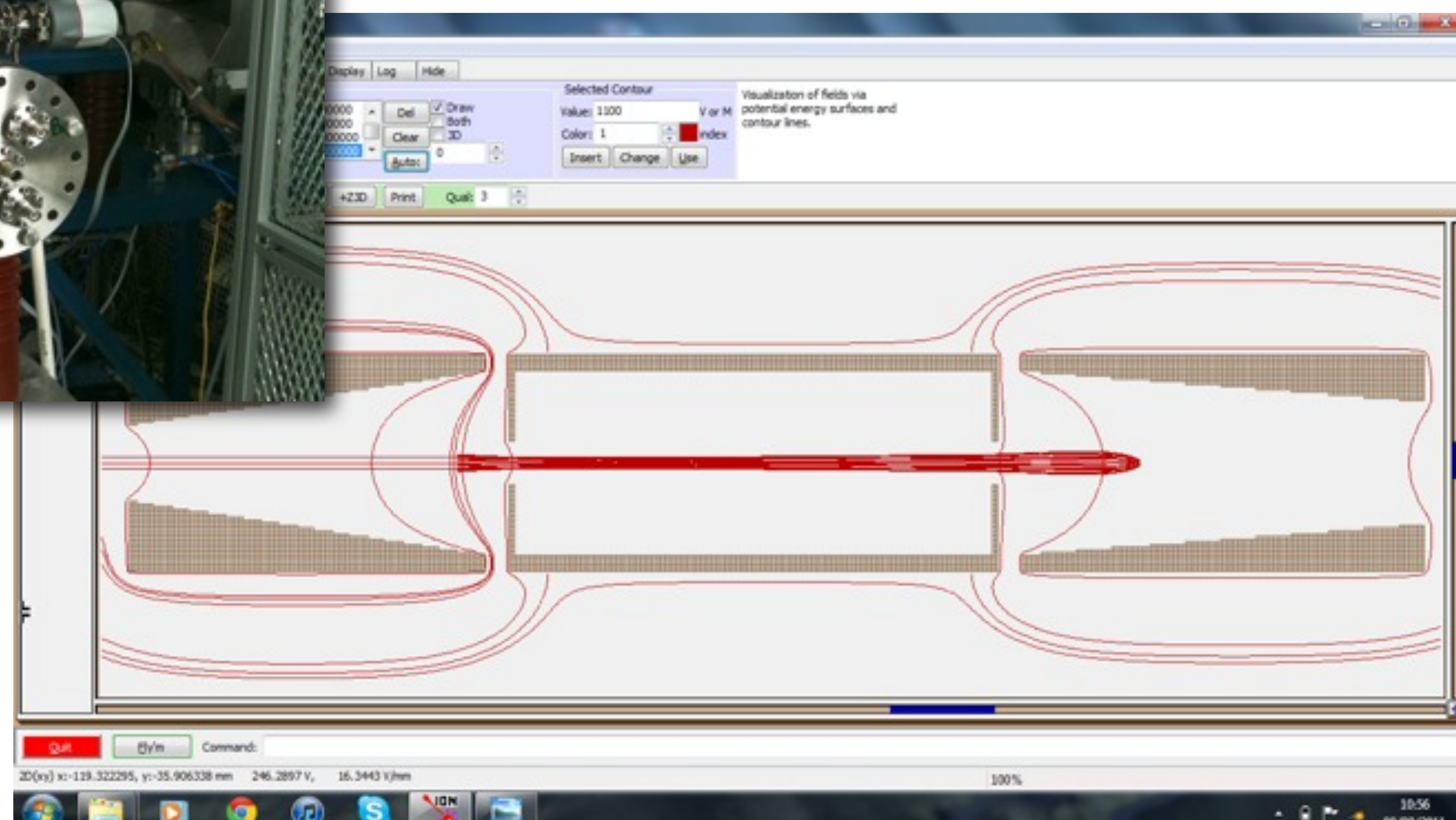
Open questions

- Other Th^{+} levels/transitions?
- Resonant final step?

Gas or UHV?







→ UHV pumping
(>1eV)

MANCHESTER 1824

The University of Manchester

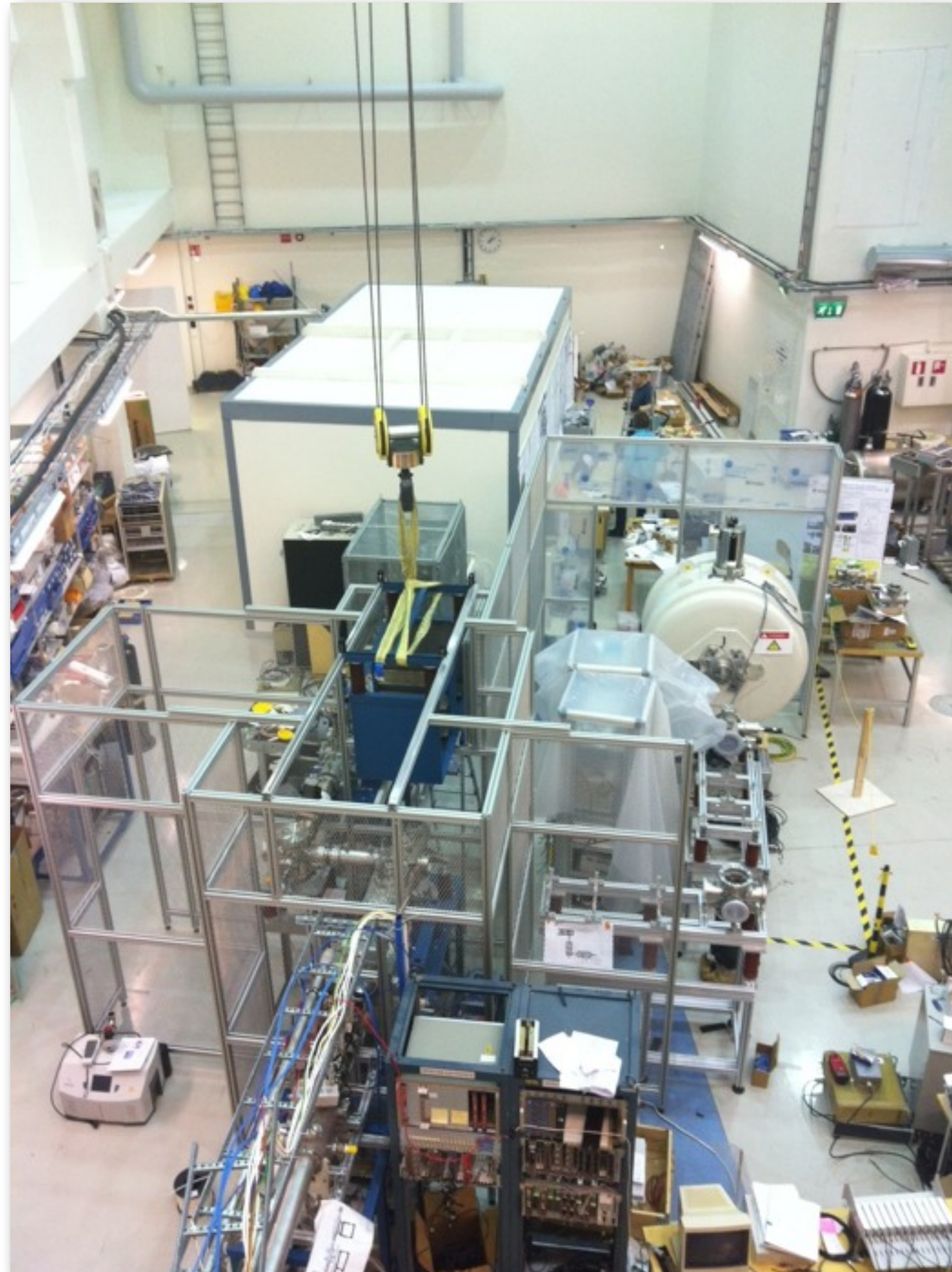
January 2012

(from switchyard)

Present status

- Laser line in place
- Under vacuum
- Ions from IGISOL

- Need to cable up ion optics
- Optimise cooler transmission
- Scheme development
- ^{229g}Th measurement



MANCHESTER
1824
The University
of Manchester

Summary

- Aim to use laser spectroscopy
  to directly measure the isomeric state (and properties)
- The IGISOL has been recently upgraded
  and offers a variety of production mechanisms

- Need to enhance the sensitivity of the technique
- Develop ion-resonance-ionisation schemes
- Measure gs first (spectroscopy transition fully resolved?)
- Decide on the most promising reaction for population