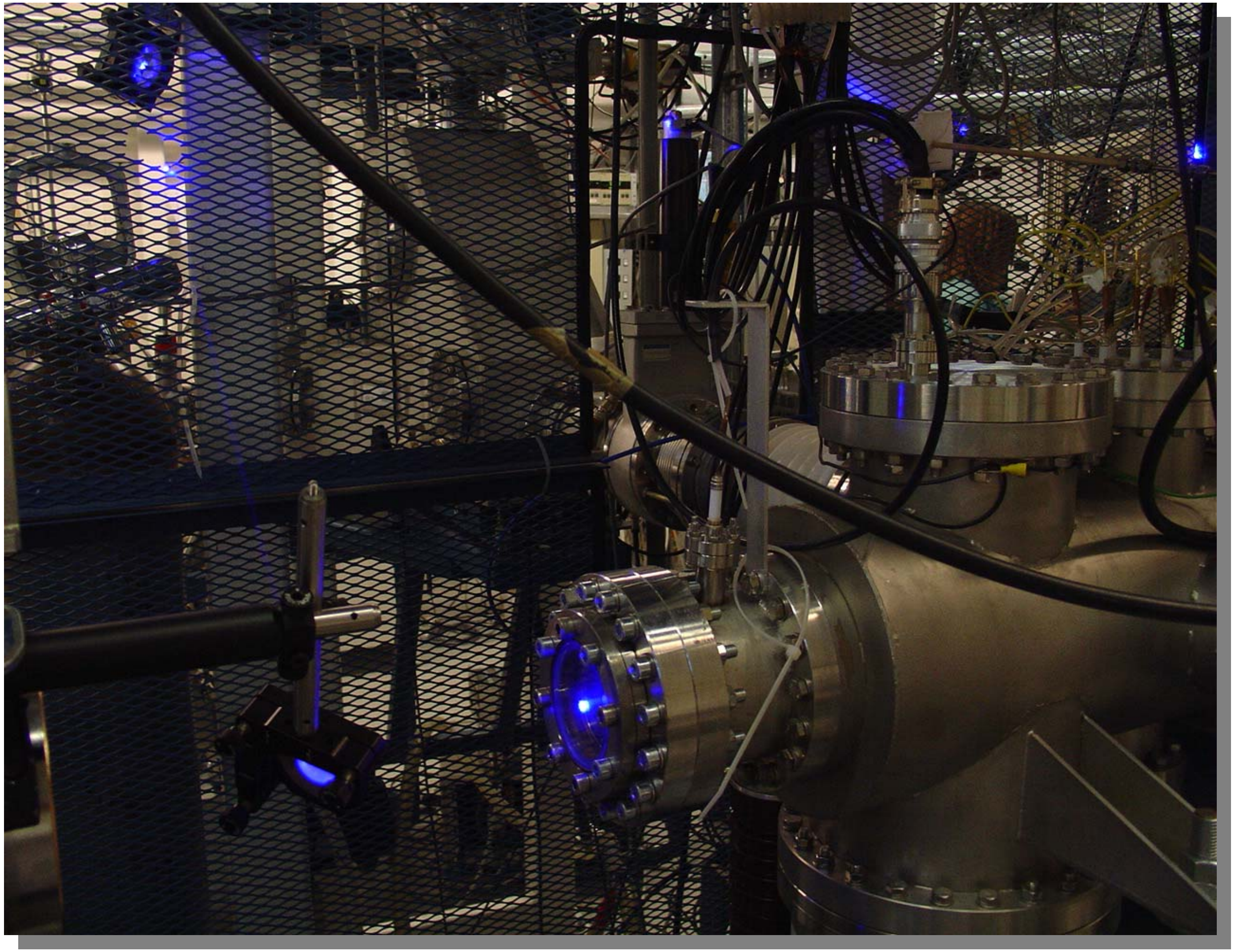
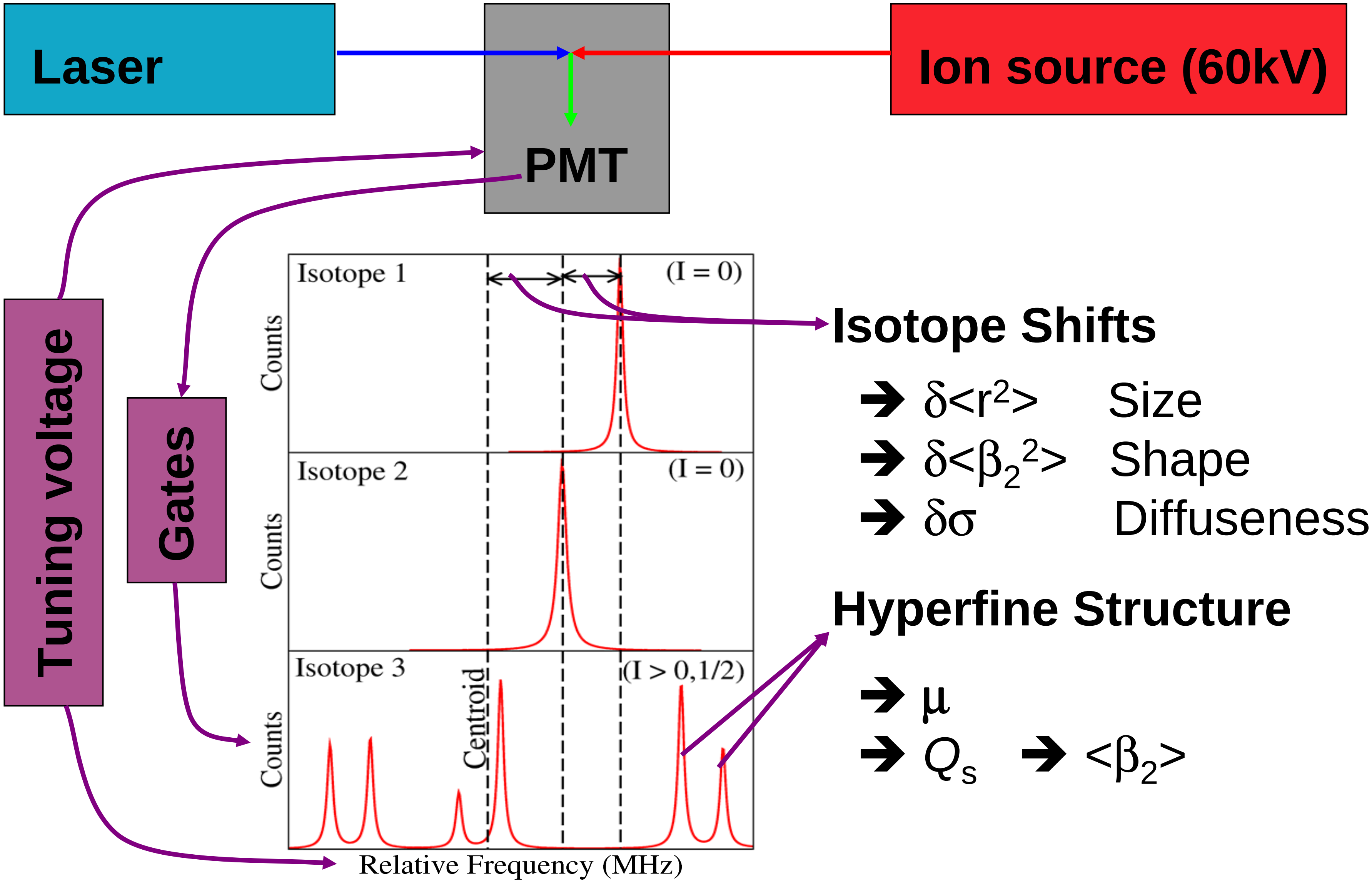
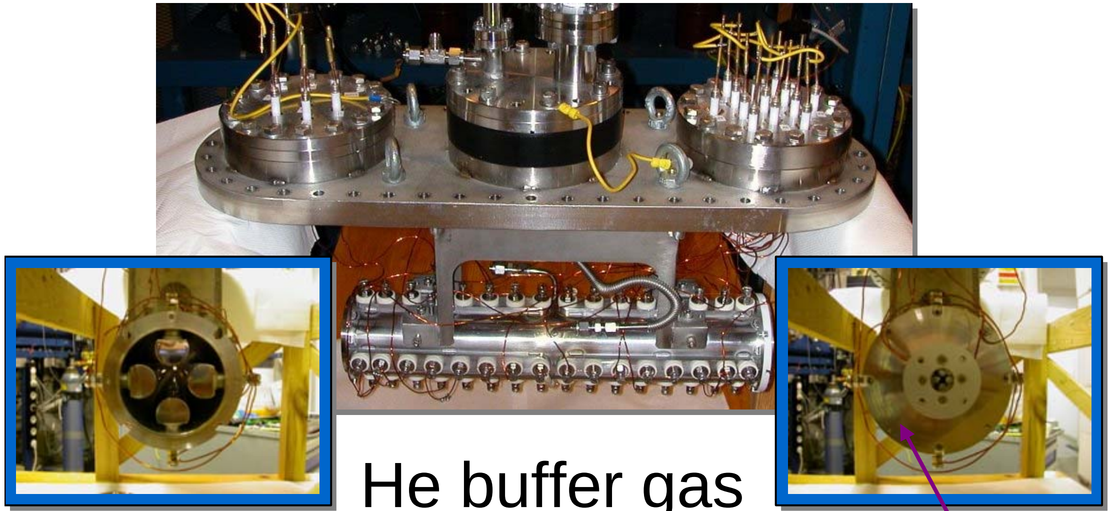
Laser pumping of ions in a cooler-buncher.

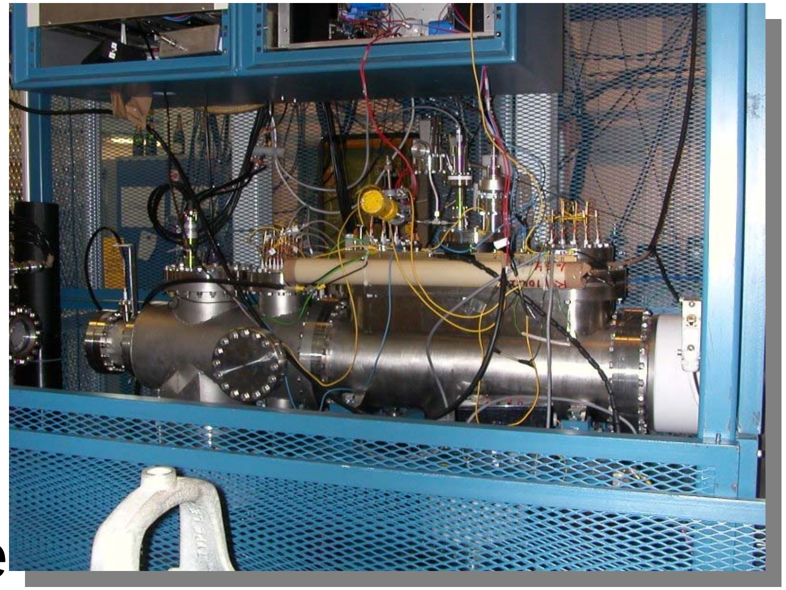


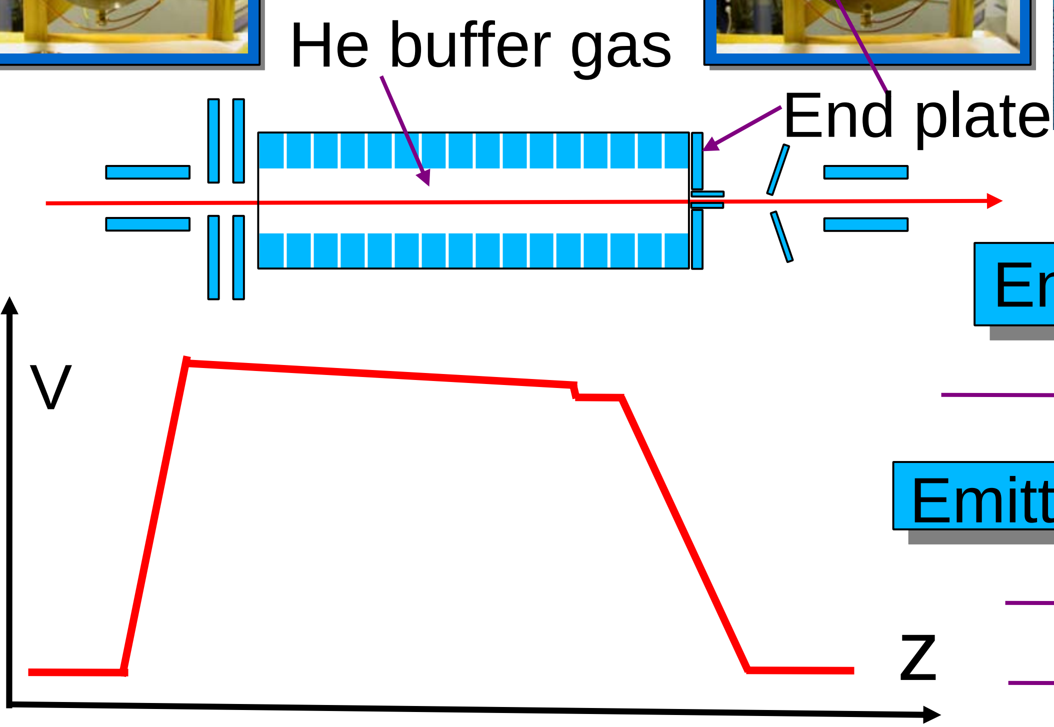
Introduction to laser spectroscopy



Cooling for laser spectroscopy







Energy spread: 5➔1-2 eV

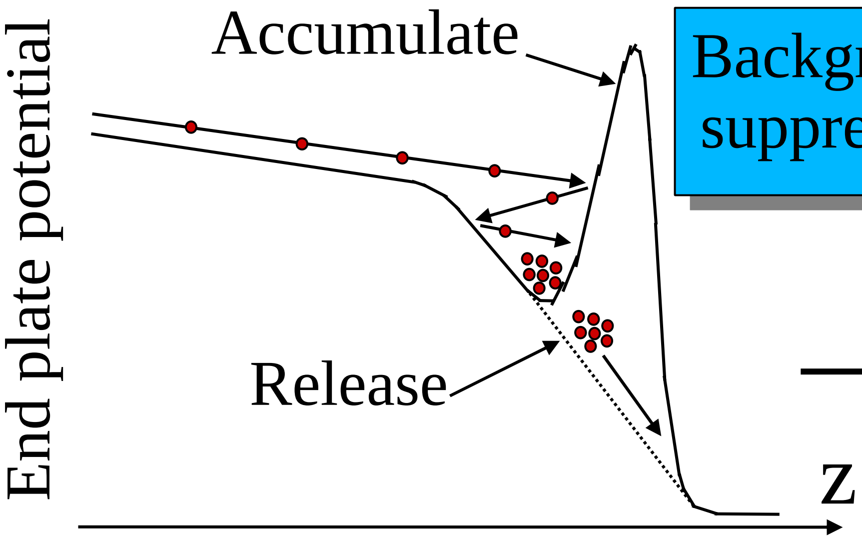
→ Less spectral broadening

Emittance: 25➔2-4 π mm.mrad

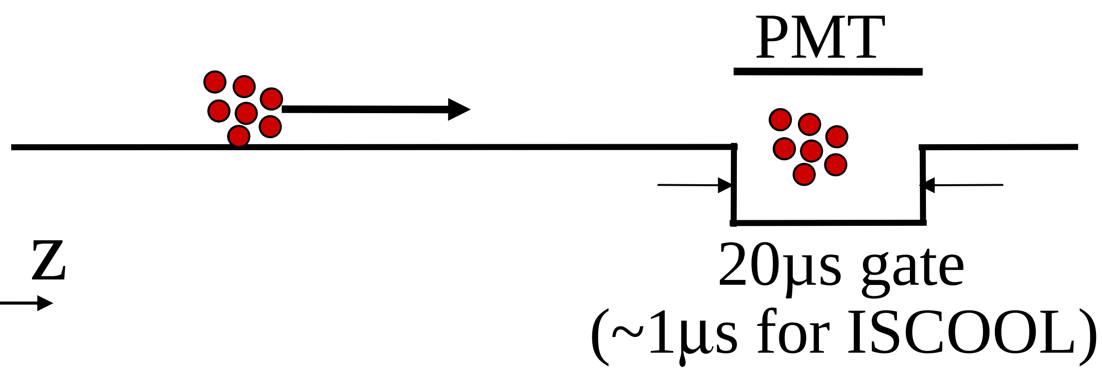
→ Better laser-ion overlap

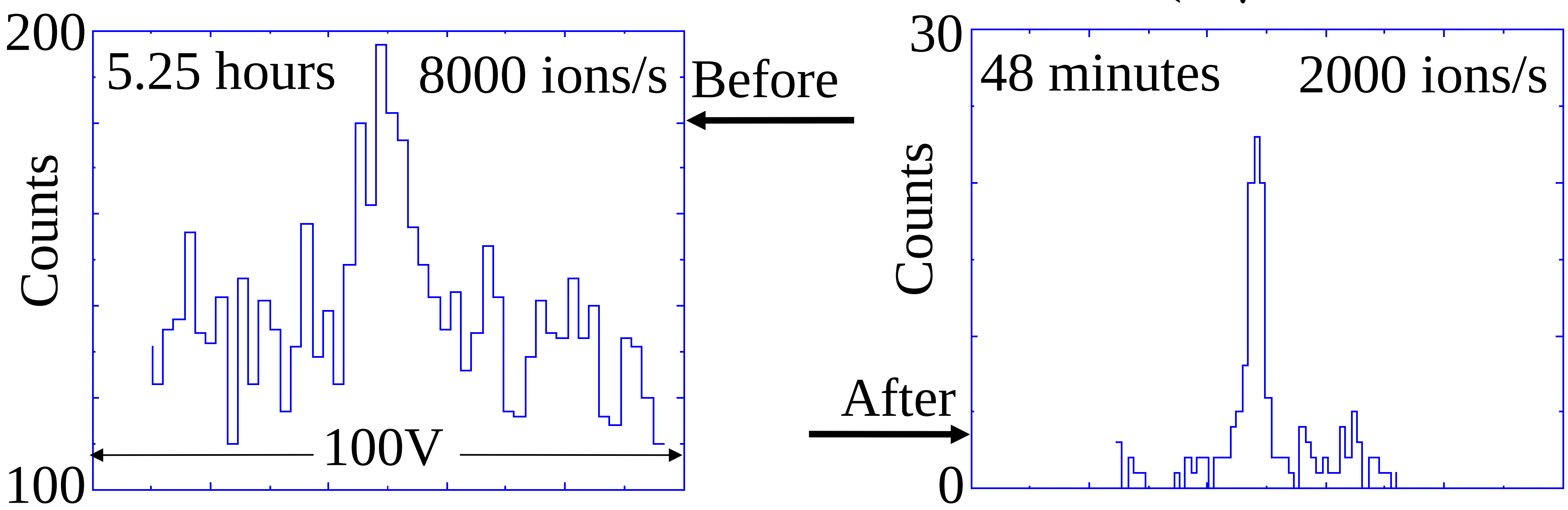
→ Reduced peak skewing

Bunching for laser spectroscopy

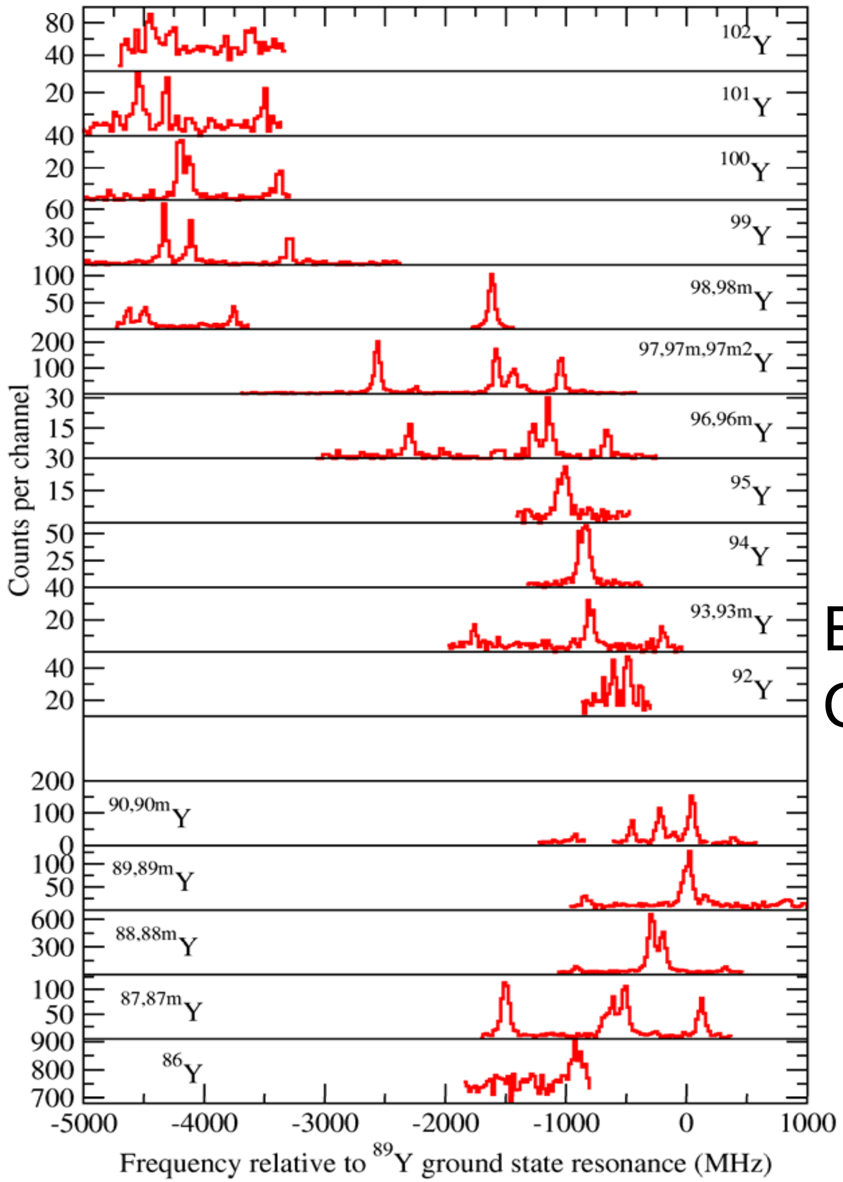


$$\text{Background suppression} = \frac{\text{eg. 200ms accumulation}}{\text{20}\mu\text{s gate width}} \sim 10^4$$





Yttrium results



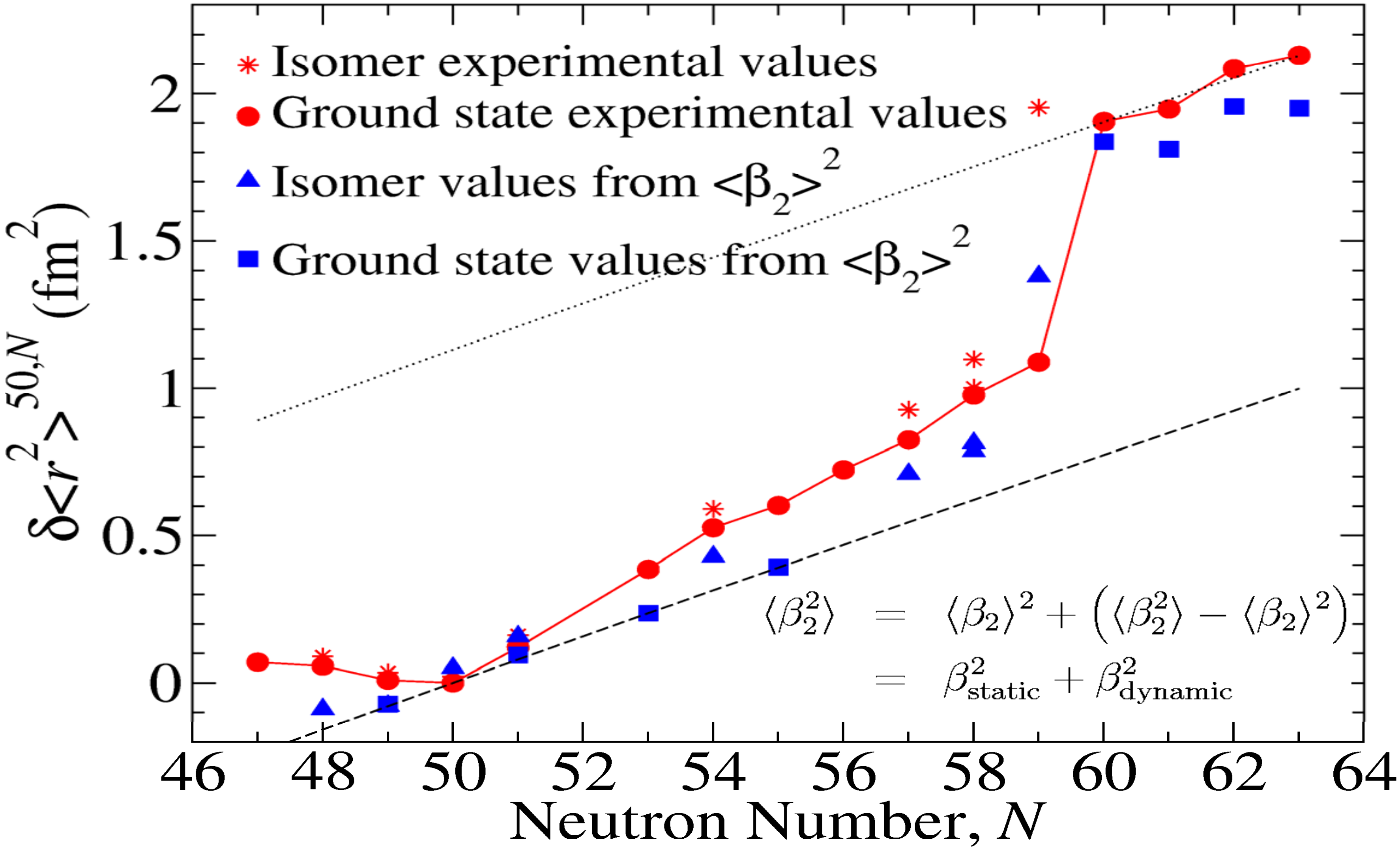
J=0 ➔ J=1 electronic transition

➔ 3 peaks (maximum) for each nuclear state gives $\delta\langle r^2\rangle$, μ and Q_s

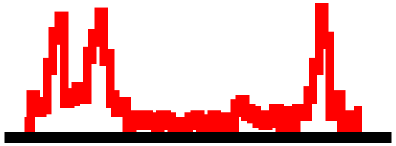
Efficiency:-
One resonant photon per 2000 ions

- Shape change at N=59
- 98m is well deformed

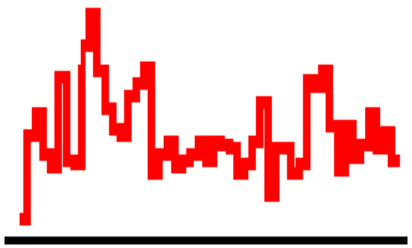
Yttrium charge radii



Problem 1: Spin determination

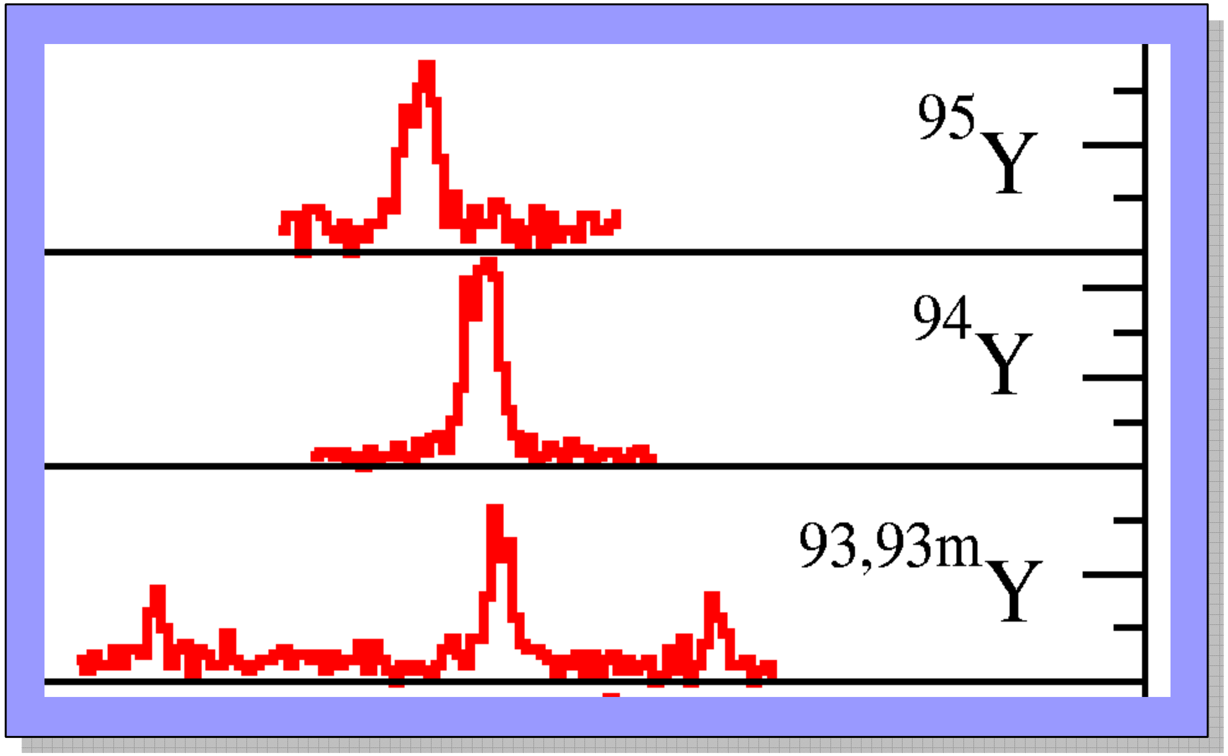


A	I^π	A_{hf} (MHz)	B_{hf} (MHz)	μ (μ_{N})	Q_{s} (b)	$\delta\nu^{98,98\mathrm{m}}$ (MHz)
98m	(4)	−88.3(0.6)	+324.7(4.2)	+2.98(2)	+1.73(19)	−2746(3)
98m	(5)	−73.7(0.4)	+339.1(4.2)	+3.11(2)	+1.80(20)	−2735(3)



Similarly with A=102 and A=100

Problem 2: Collapsed ground states



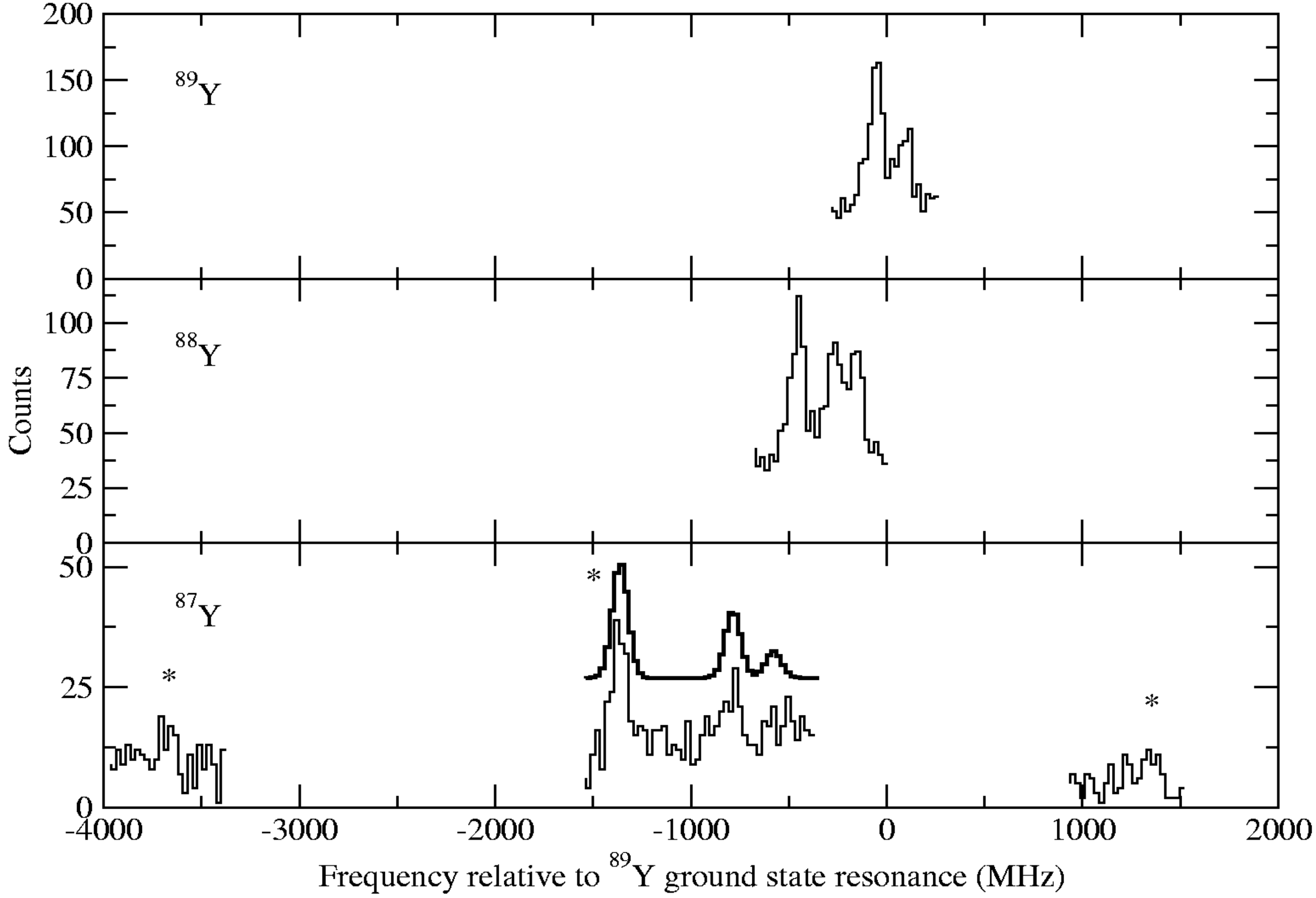
Spin ½

Spin 2

Spin ½ + isomer peak

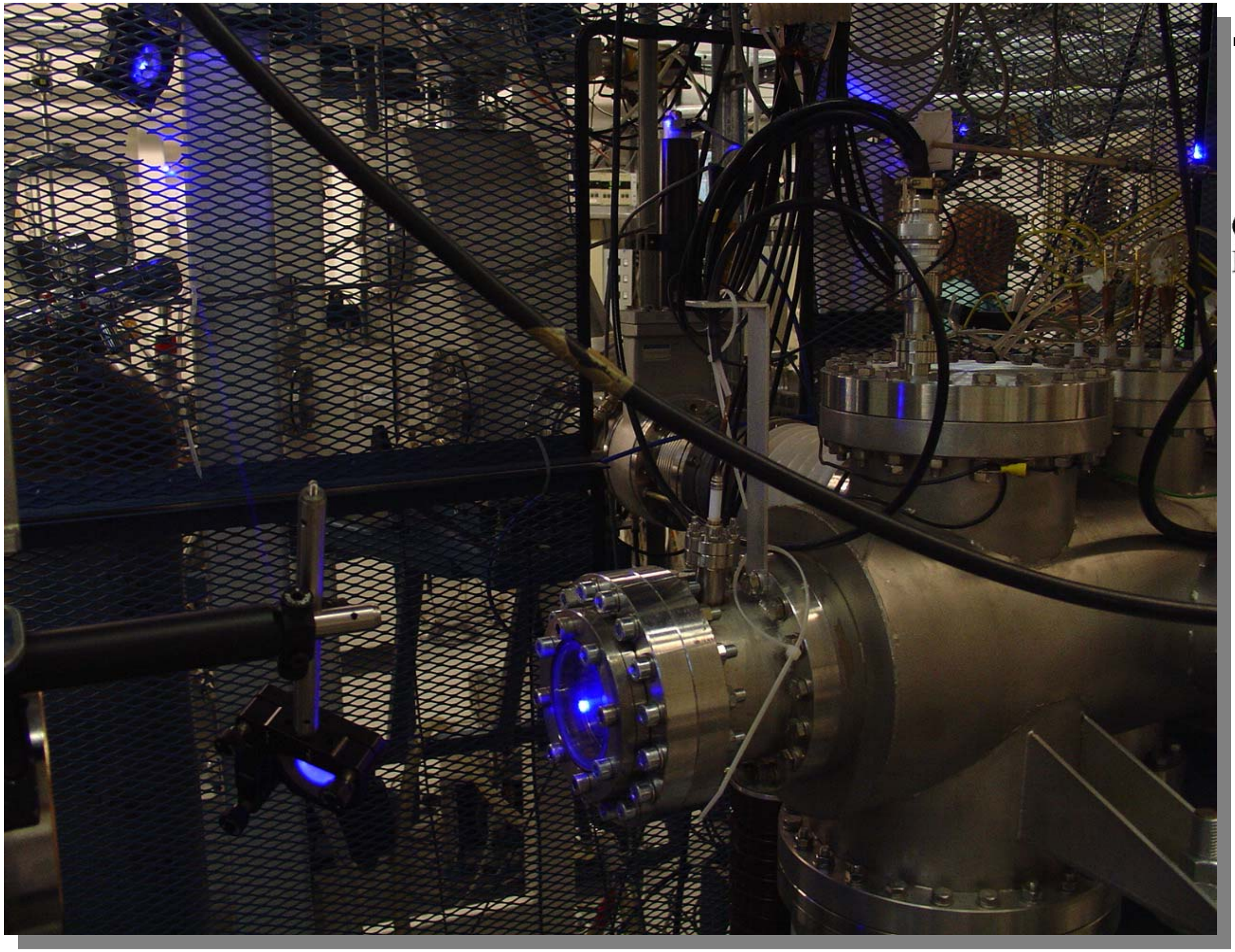
Difficult to resolve underlying peaks and ordering

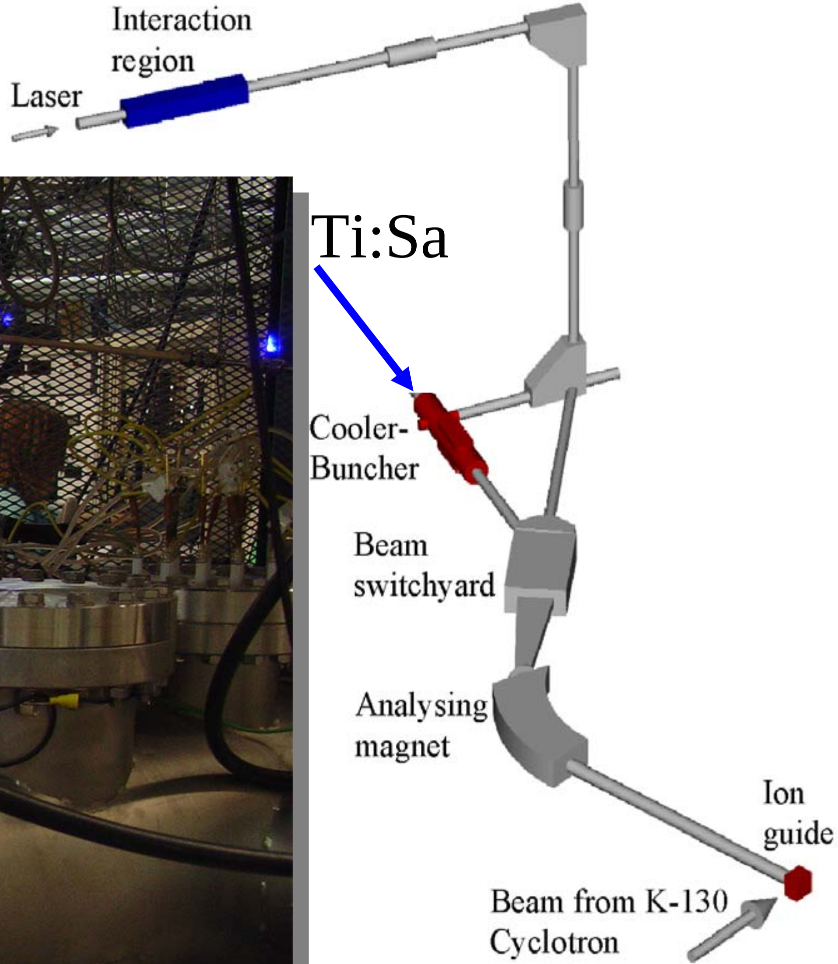
Other (gs) yttrium transitions?



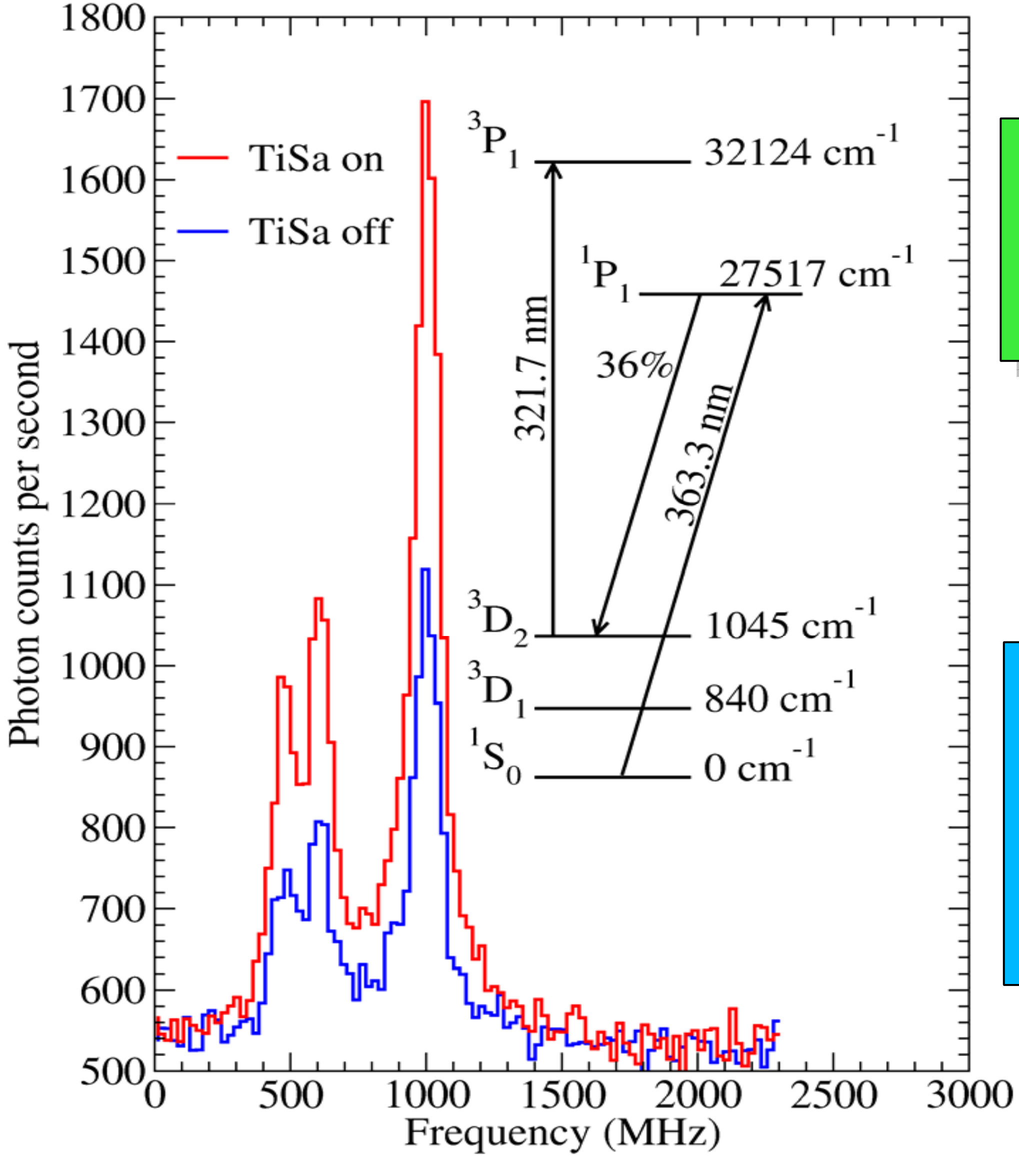
311nm J=0 → J=1 transition (2002) – 1 in 17000 efficiency

State selection in an ion cooler





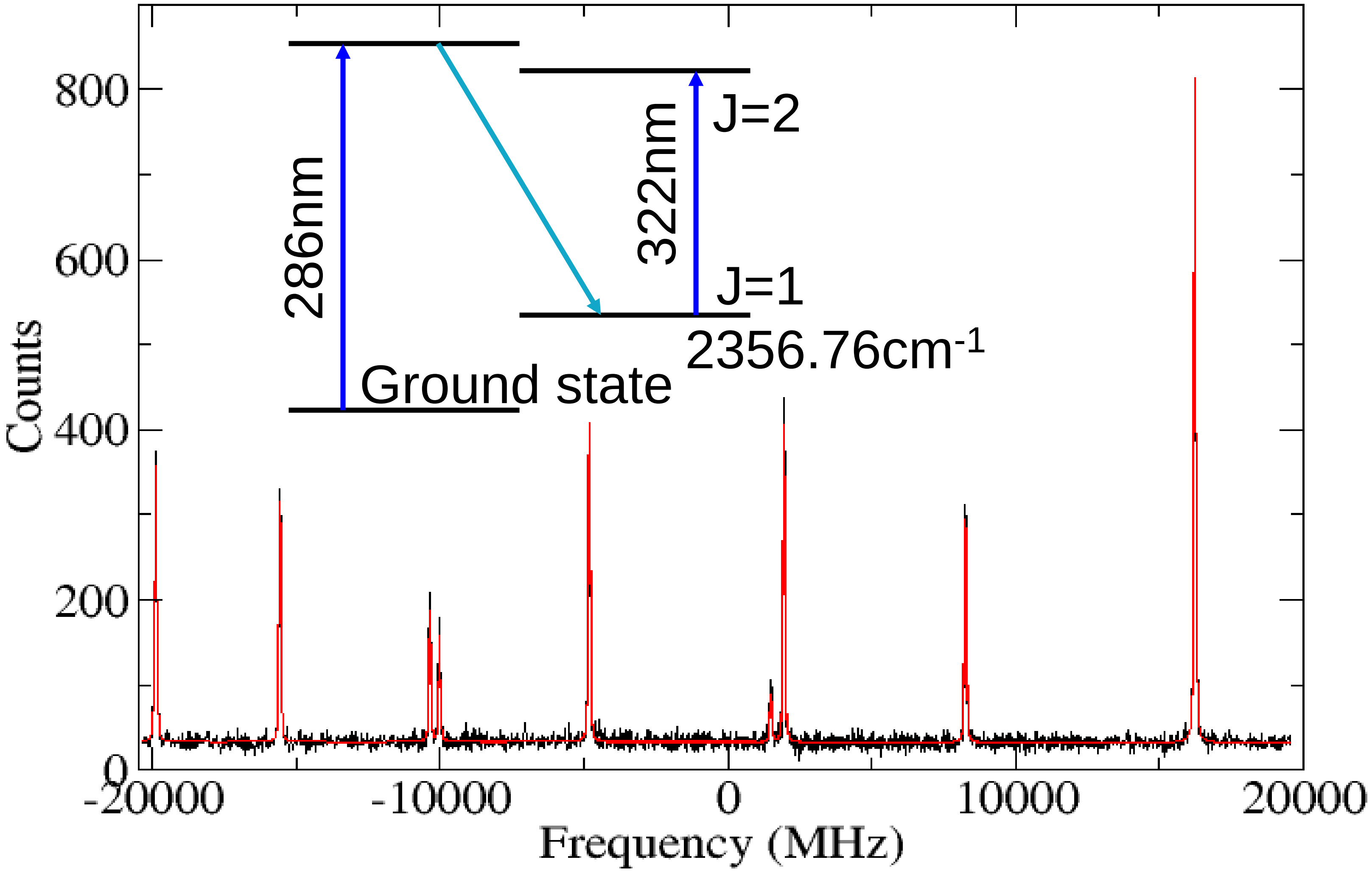
363 nm pumping of yttrium



1 photon for every 6000 ions
becomes 1 for every 3000 ions
(End of the beam line)

- Indifference to bunching
- Pumping saturates < 30mW
- Can use broadband lasers

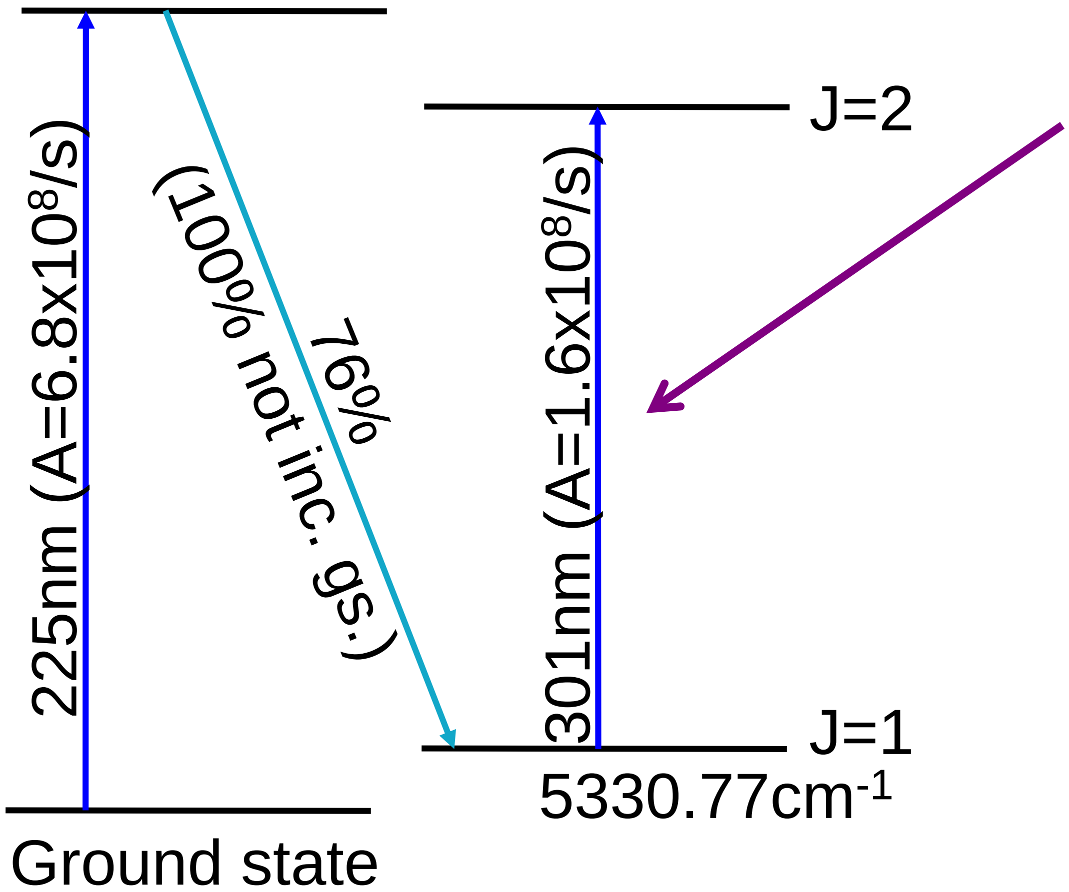
Laser spectroscopy of niobium



50% increase due to pumping ➔ 1 photon per 2700 ions

Other cases

Tantalum



Most efficient (ionic or atomic) transition

Others may have:-

- Poorer strength
- Lower metastable populations (without pumping)
- Higher spins
- Hyperfine mixing

Also schemes identified for Os, Re and others

Summary

- Method of controlling state population
- Choose transitions on basis of strengths, spins, splitting and charge state
- Cooler provides a focal point of slowly travelling ions
- Ti:Sa lasers provides wider range of wavelengths
  and bandwidth or pulsing does not matter
- Tested for yttrium, niobium; other cases being considered.

The collaboration

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