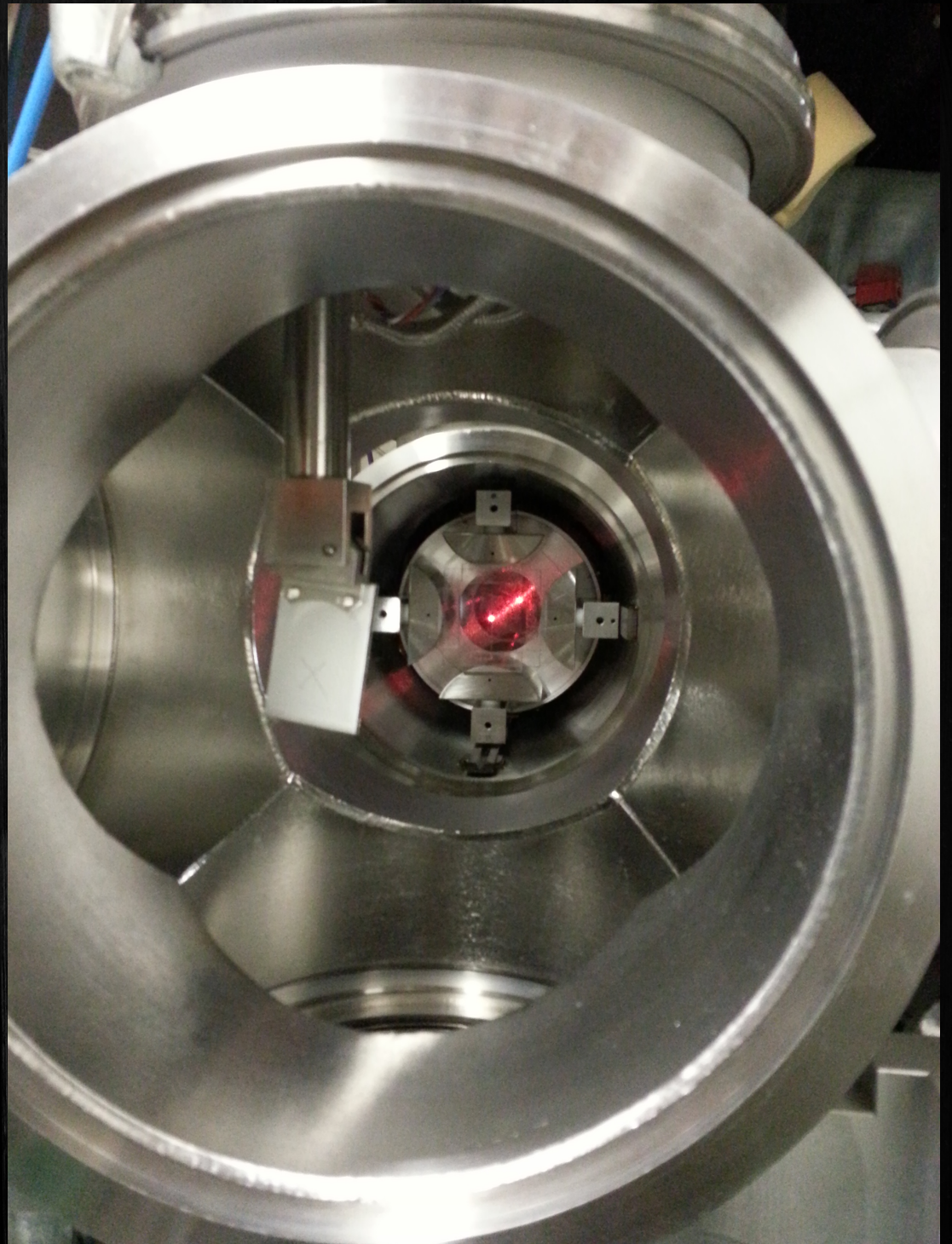
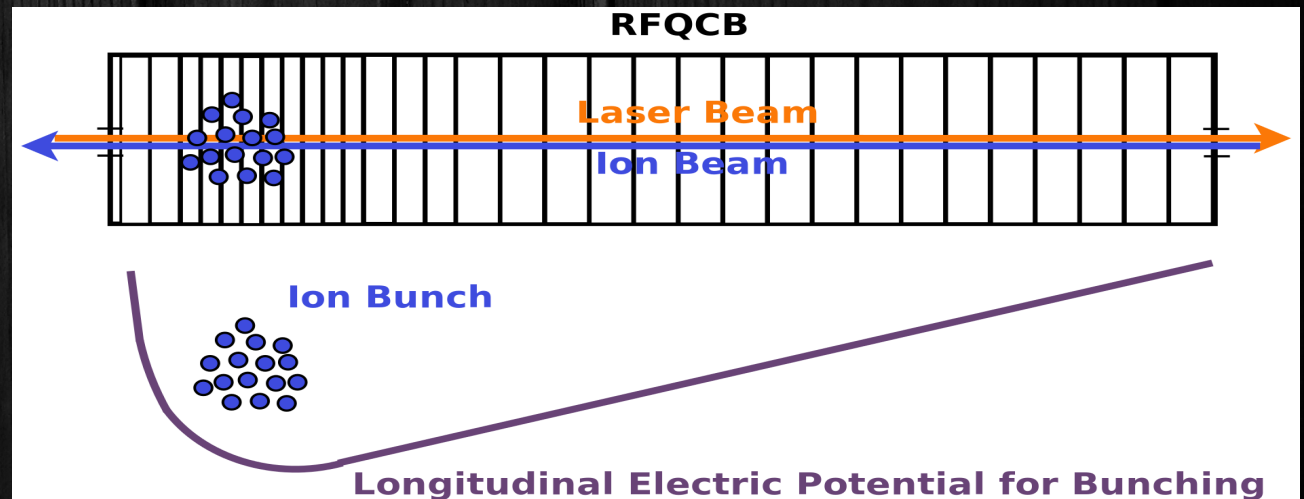


Beam
Developments
using Optical
Pumping in
ISCOOL



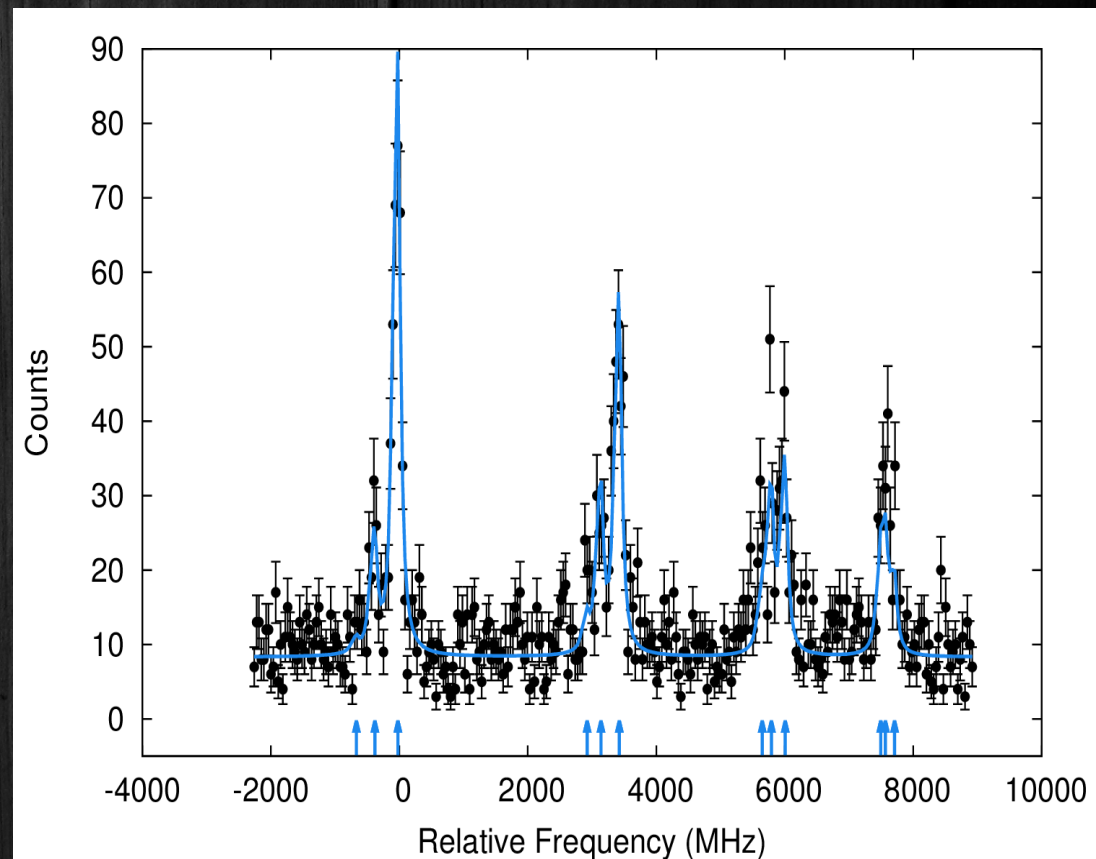
Optical Pumping Theory

- Use laser light to excite ions out of the ground state
- This is most effective if done while the ions are trapped in the cooler → can use pulsed lasers and low power
- Was used successfully at the beginning of June to do spectroscopy on metastable ionic Mn



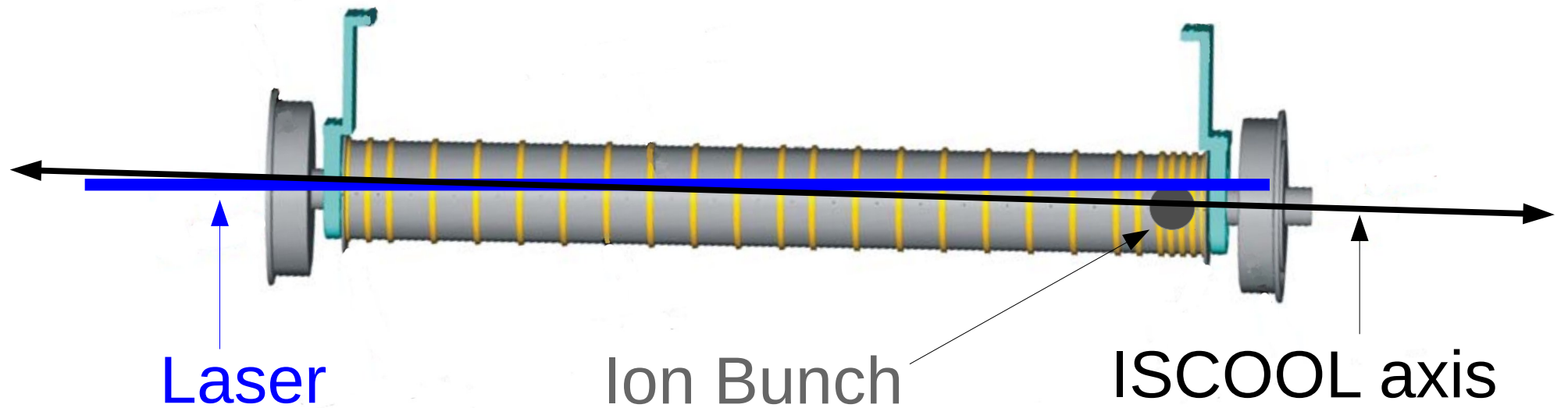
Why Optical Pumping: Atomic Mn

- Atomic Mn experiment carried out at COLLAPS in 2012
- Goal was to determine the spins, magnetic dipole and electric quadrupole moments → another transition needed!

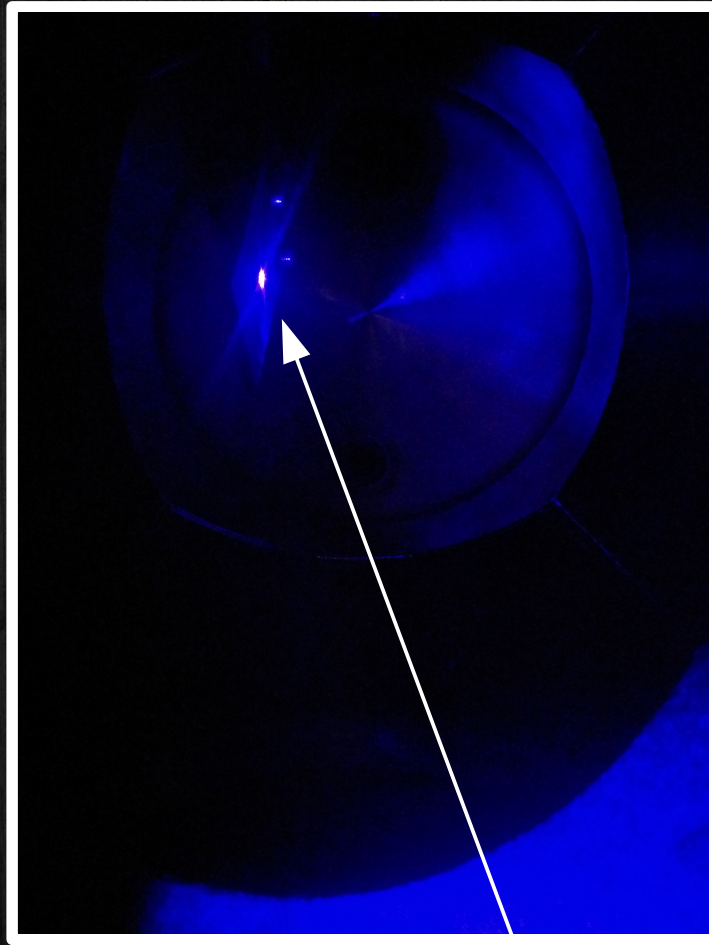


Challenges for Optical Pumping

The laser and the ion bunch were not overlapping due to the misalignment of ISCOOL



Re-aligned ISCOOL



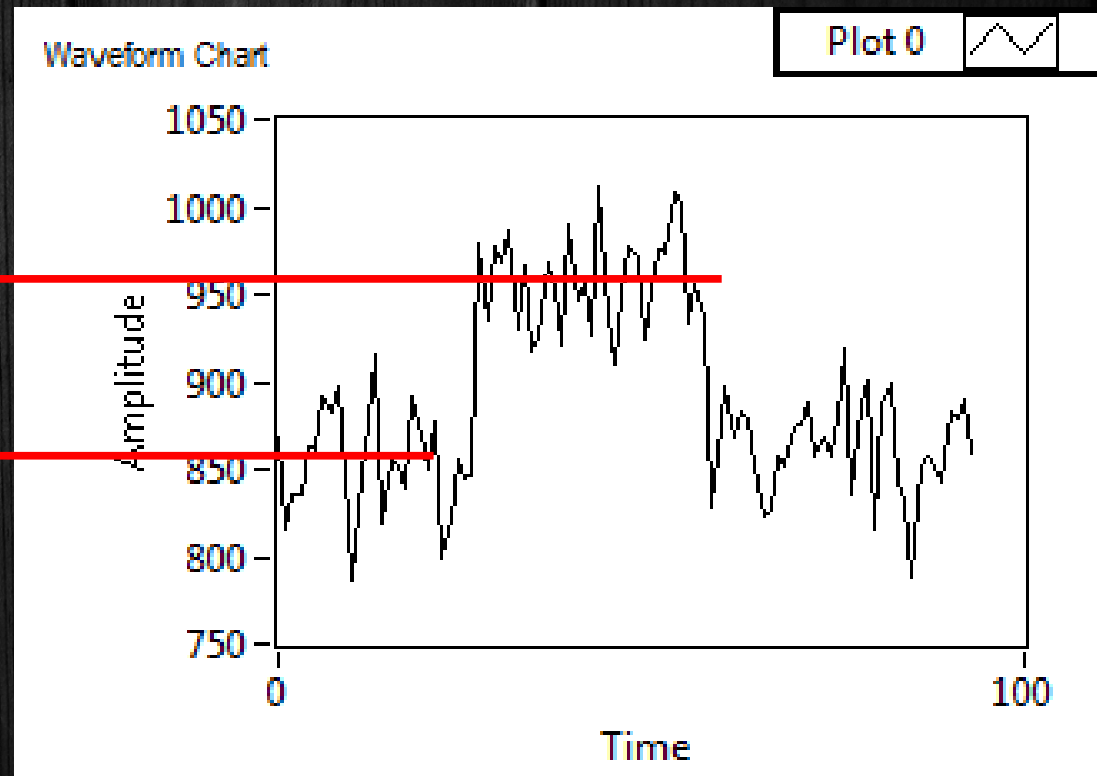
Laser spot after passing through the cooler

The Test Case: ^{88}Sr

- First tried optical pumping using a special property of ^{88}Sr – the excited state charge exchanges resonantly with the gas in the charge-exchange cell while the ground state does not

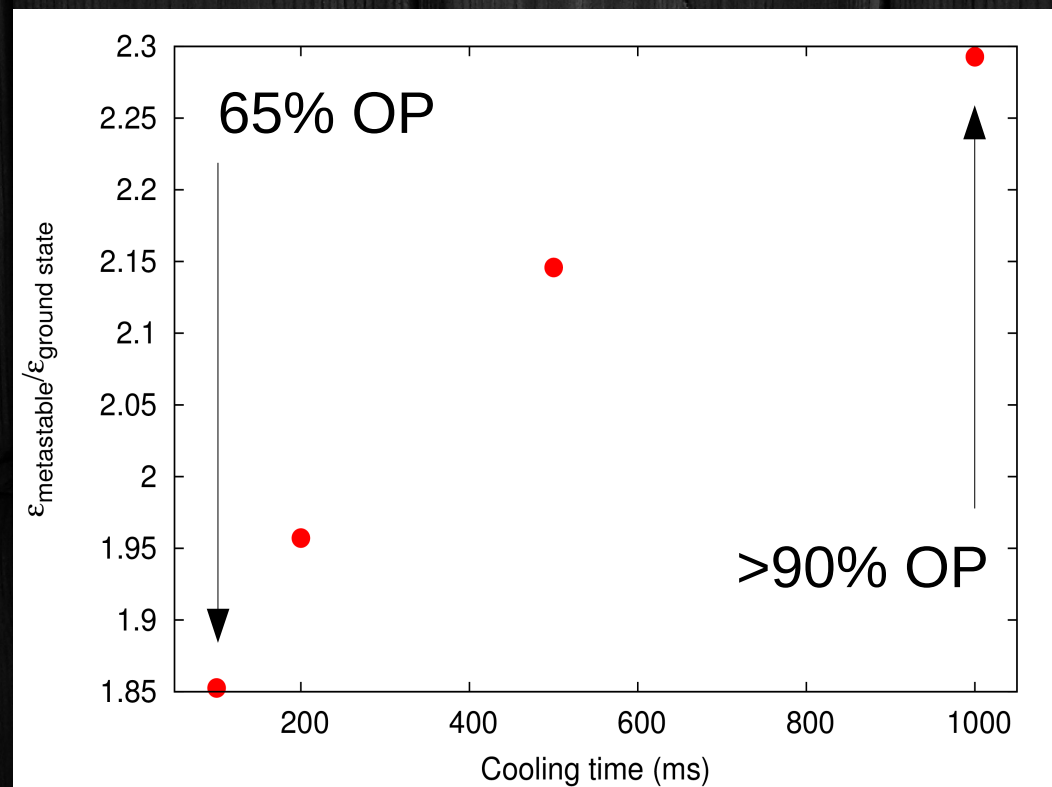
Neutral particles seen with optical pumping

Neutral particles seen without optical pumping



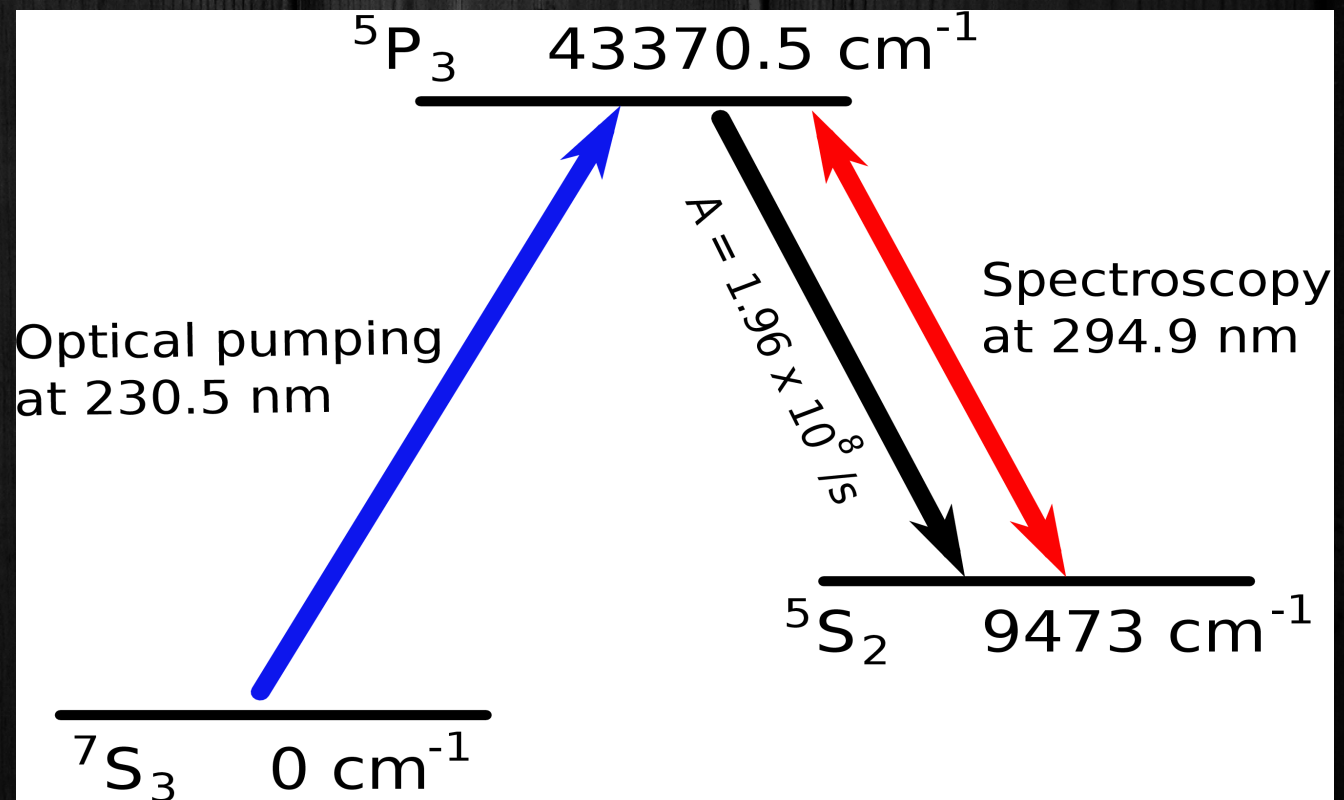
^{88}Sr Results

- Estimates of efficiency depend on three unknowns – the contaminants in the beam, the percentage of the beam optically pumped and the efficiency of the charge-exchange cell

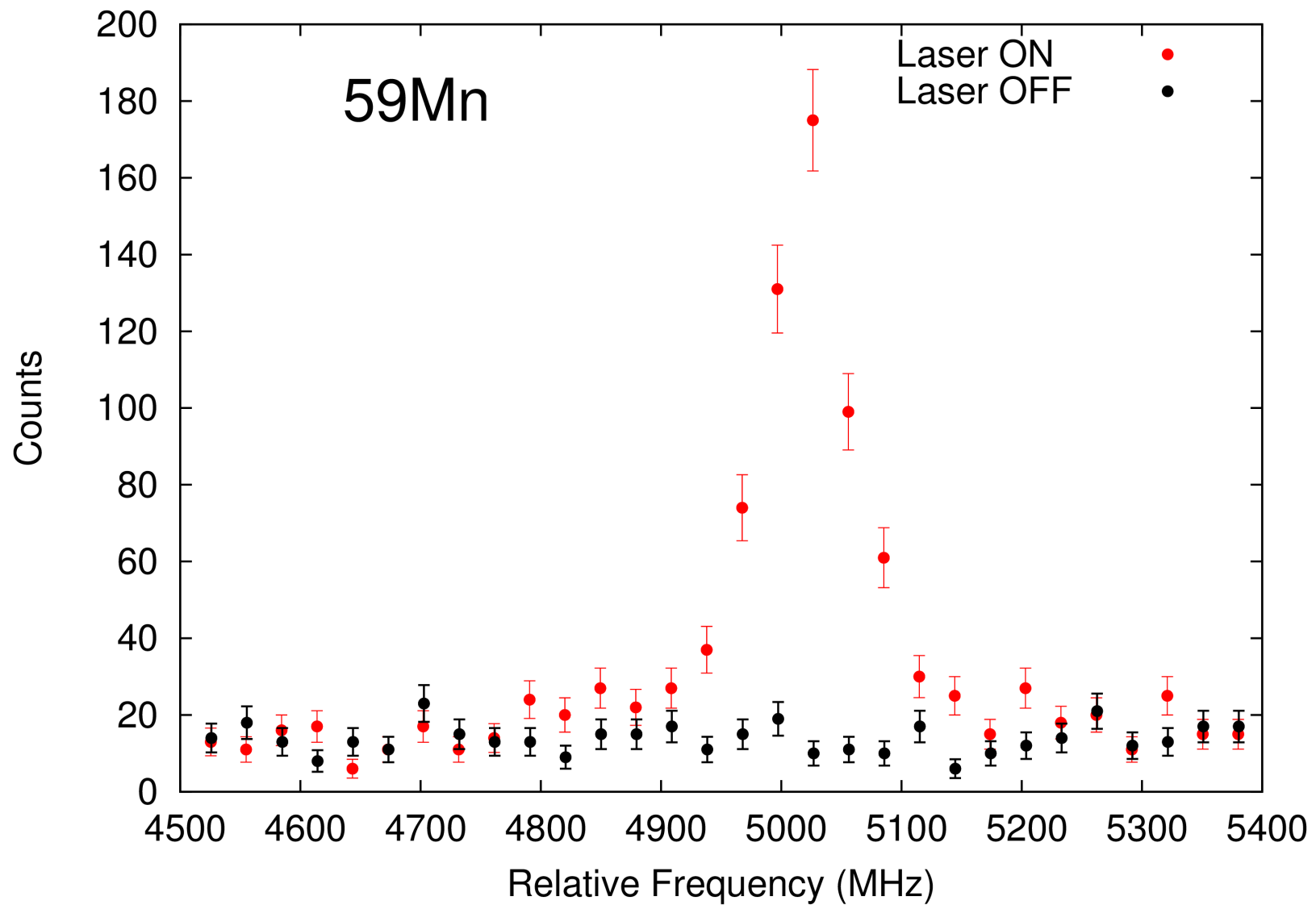


First OP Physics case: Ionic Mn

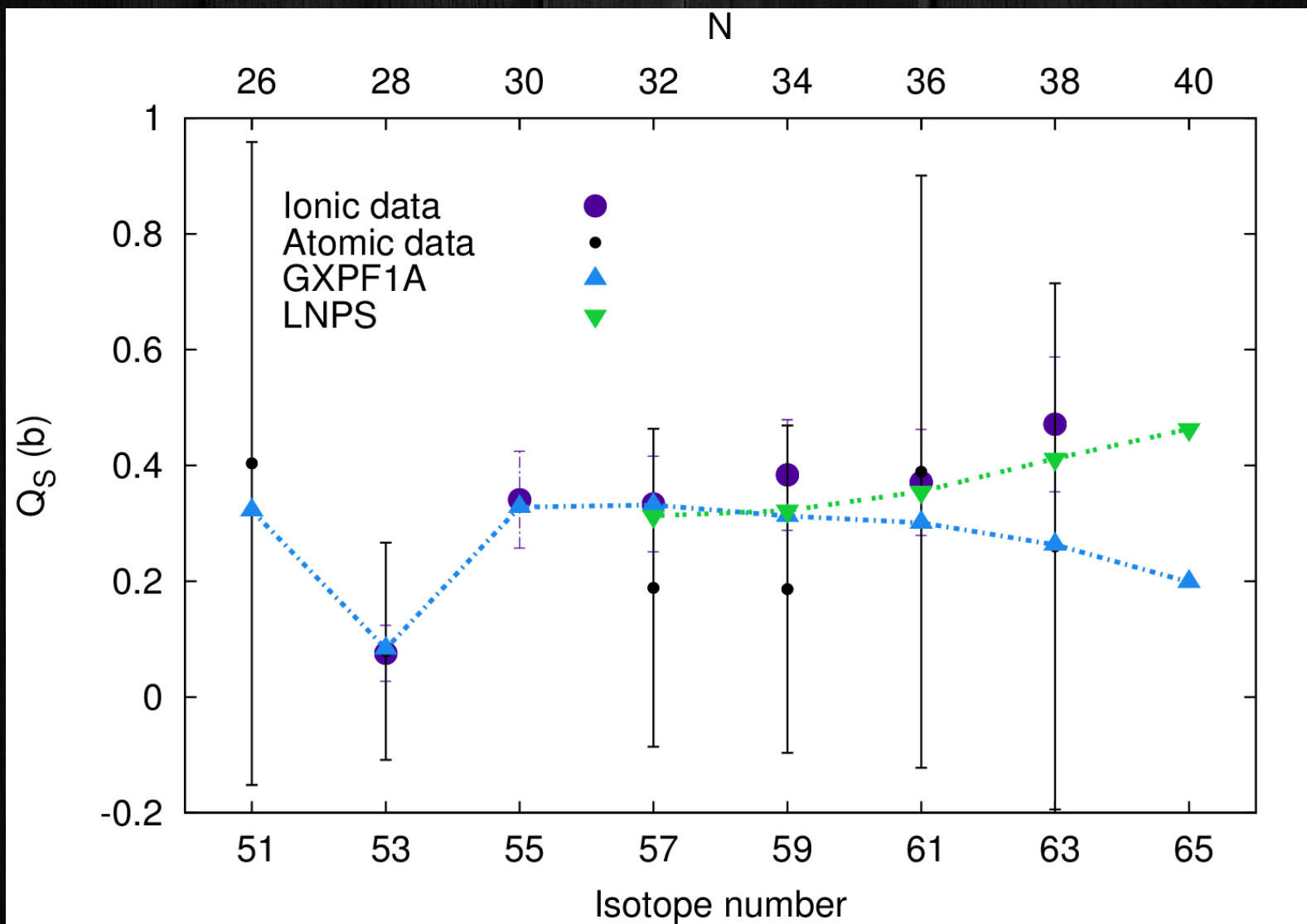
- With the ISCOOL re-aligned, spectroscopy was attempted on Mn ions using an optically pumped transition



Ionic Mn Results



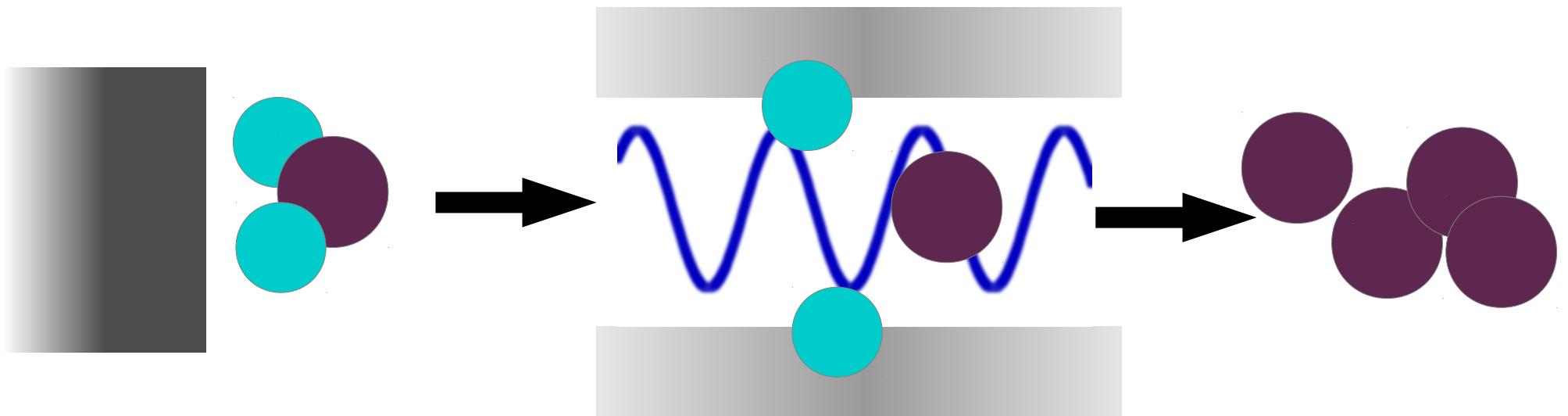
Quadrupole Moments



Very preliminary!

Future Physics Cases

- Refractory beams
 - Technique could be used to produce beams such as Hf or Ta



Element of interest
extracted as a
molecule

Laser induced
disassociation
in the cooler

Beam of the
required element
exits cooler

Future Physics Cases

- 2+ ionization
 - Extra ionization step taken in the cooler
 - Could be used for beam purification among other things
- Other optical pumping physics cases

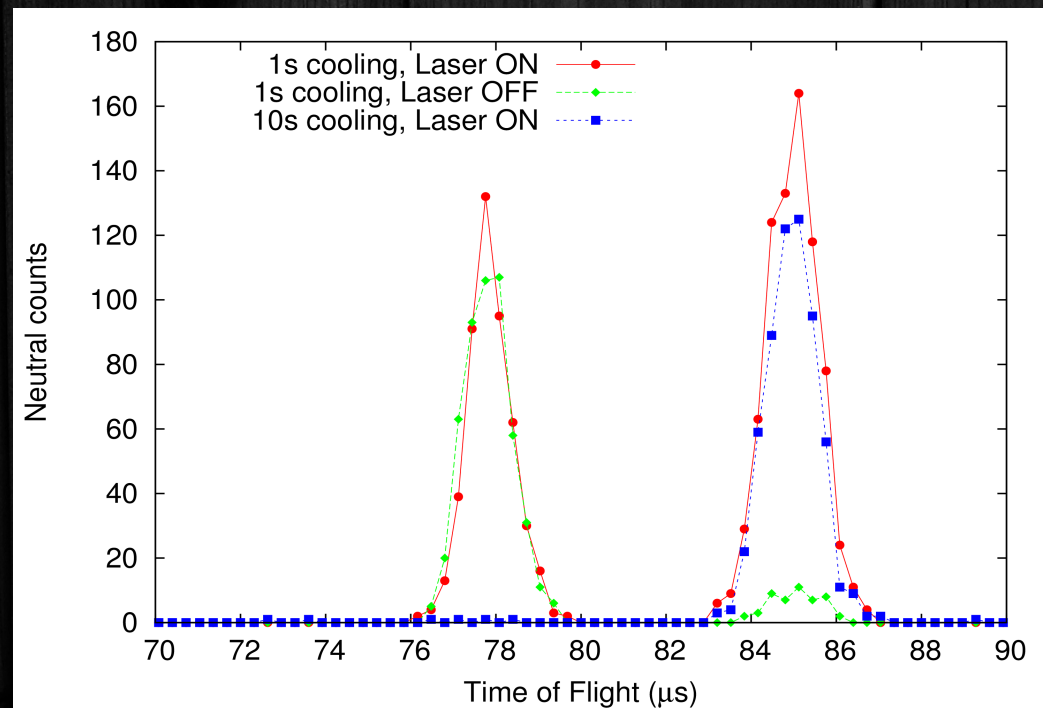
	IIA 2A												IIIA 3A	IVA 4A	VA 5A	VIA 6A	VIIA 7A	Helium 4.003
3	4												5	6	7	8	9	10
Li 6.941	Be 9.012												B 10.811	C 12.011	N 14.007	O 15.999	F 18.998	Ne 20.180
11	12		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Na 22.990	Mg 24.305		IIIB 3B	IVB 4B	VB 5B	VIB 6B	VII B 7B	VIII 8	VIII 8	VIII 8	IB 1B	IIB 2B	Al 26.982	Si 28.086	P 30.974	S 32.066	Cl 35.453	Ar 39.948
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
K 39.098	Ca 40.078	Sc 44.956	Ti 47.88	V 50.942	Cr 51.996	Mn 54.938	Fe 55.933	Co 58.933	Ni 58.693	Cu 63.546	Zn 65.39	Ga 69.732	Ge 72.61	As 74.922	Se 78.09	Br 79.904	Kr 84.80	
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
Rb 84.468	Sr 87.62	Y 88.906	Zr 91.224	Nb 92.906	Mo 95.94	Tc 98.907	Ru 101.07	Rh 102.906	Pd 106.42	Ag 107.868	Cd 112.411	In 114.818	Sn 118.71	Sb 121.760	Te 127.6	I 126.904	Xe 131.29	
55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Cs 132.905	Ba 137.327		Hf 178.49	Ta 180.948	W 183.85	Re 186.207	Os 190.23	Ir 192.22	Pt 195.08	Au 196.967	Hg 200.59	Tl 204.383	Pb 207.2	Bi 208.980	Po [208.982]	At 209.987	Rn 222.018	
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	
Fr 223.020	Ra 226.025		Rf [261]	Db [262]	Sg [266]	Bh [264]	Hs [269]	Mt [268]	Ds [269]	Rg [272]	Cn [277]	Uut unknown	Fl [289]	Uup unknown	Lv [298]	Uus unknown	Uuo unknown	

Future Developments

- In order to implement these physics cases, we need an estimate of the optical pumping efficiency in the cooler → dedicated beam time
- This depends on:
 - Laser/ion overlap
 - Trapping time
 - Saturation per laser pulse
 - Experimental setup factors (charge exchange efficiency, transition used, etc.)

Future Developments

- Molecular formation inside the cooler was observed during the 88Sr tests



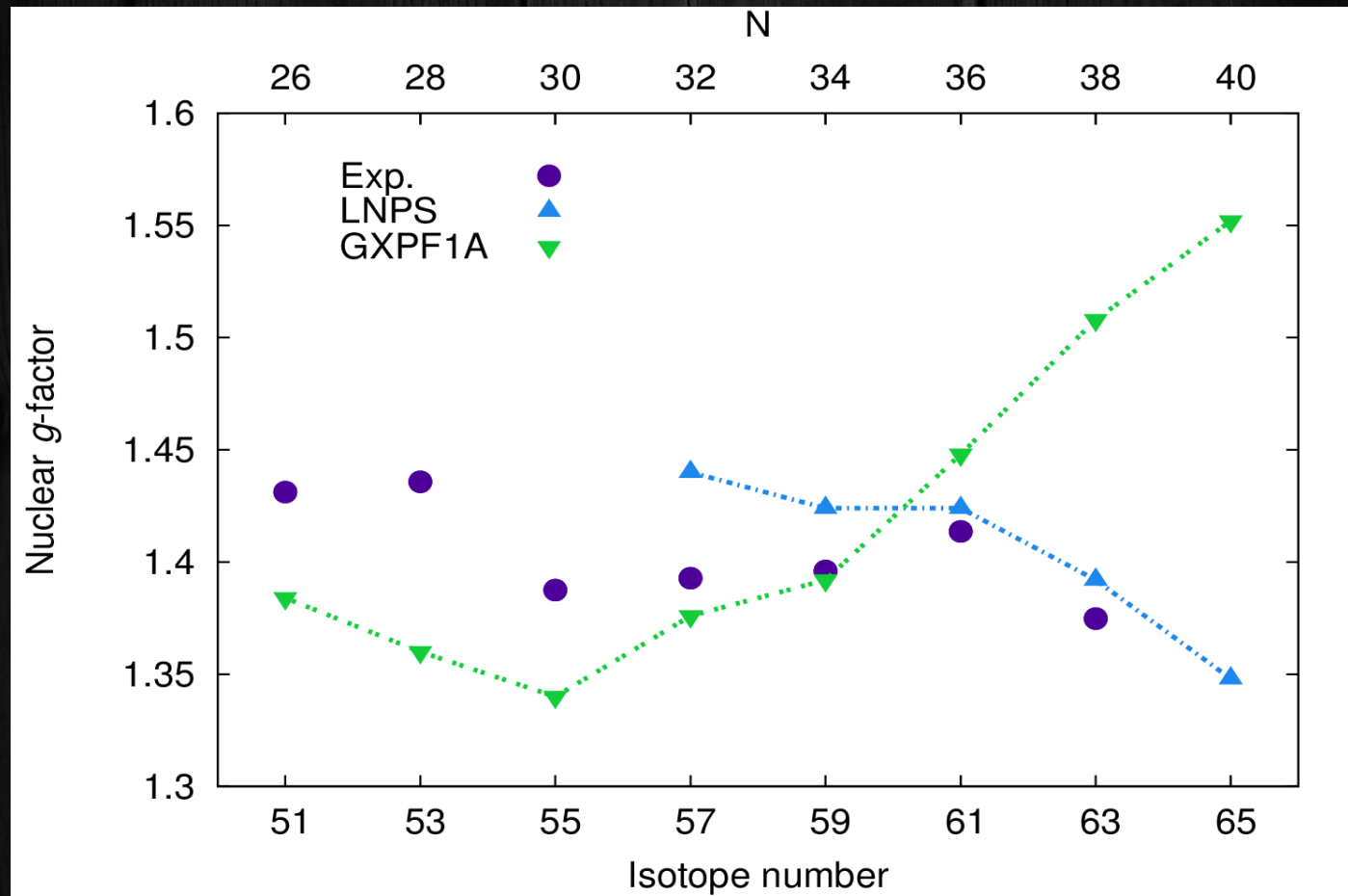
- Investigation of dynamics inside the cooler will shed light on the overall efficiency of the process under different circumstances

Conclusions

- Optical pumping has now been proven to work for physics cases at ISOLDE
- The quadrupole moments of neutron-rich Mn have been measured for the first time and results will soon be published
- More tests are needed to benchmark this technique for refractory beams and 2+ ionization
- The efficiency of the optical pumping process in the cooler should be investigated

Thank You

Atomic Mn Results

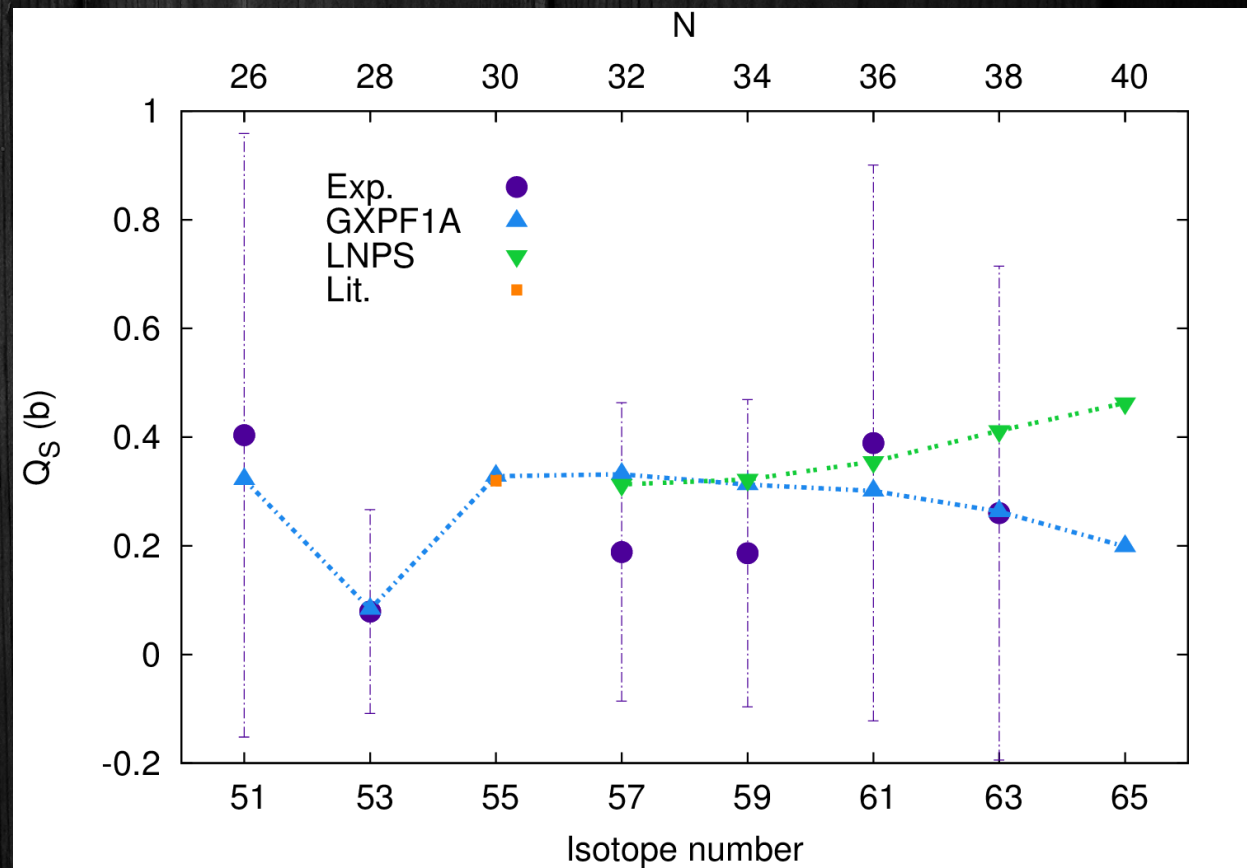


- Comparison of extracted g-factors ($g = \mu / I$) to theory gives us insight into nuclear structure in this region

Atomic Mn Results

- No quadrupole moments extracted due to the transition used → we need a different transition

Ionic transition from an optically pumped state will provide measurable quadrupole moments



88Sr Results

- Measured the effect of OP vs various parameters, like cooling time, laser power and wavelength

