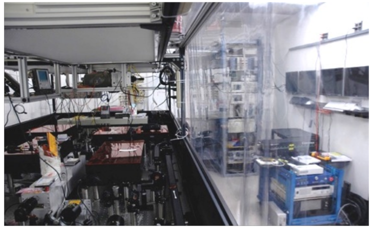
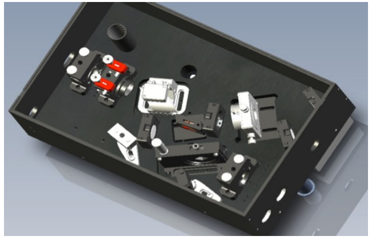
resonance ionization laser ion source
polarized beams
& collinear fast beam laser spectroscopy

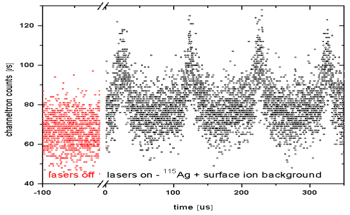
accelerator div facilities & R&D for the ISAC & ARIEL RIB program

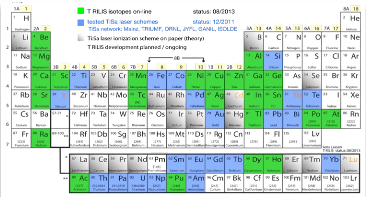
Jens Lassen & Ruohong Li | TRIUMF Accelerator Division

acknowledgements to funding agencies: NSERC, NRC, CFI
Universities: Simon Fraser, Manitoba, Oldenburg, Darmstadt, Heidelberg, Emden-Leer, Mainz
collaborators @ ISOLDE, Leuven, Mainz , GANIL, JYFL, Nagoya, ORNL & TiSa Network



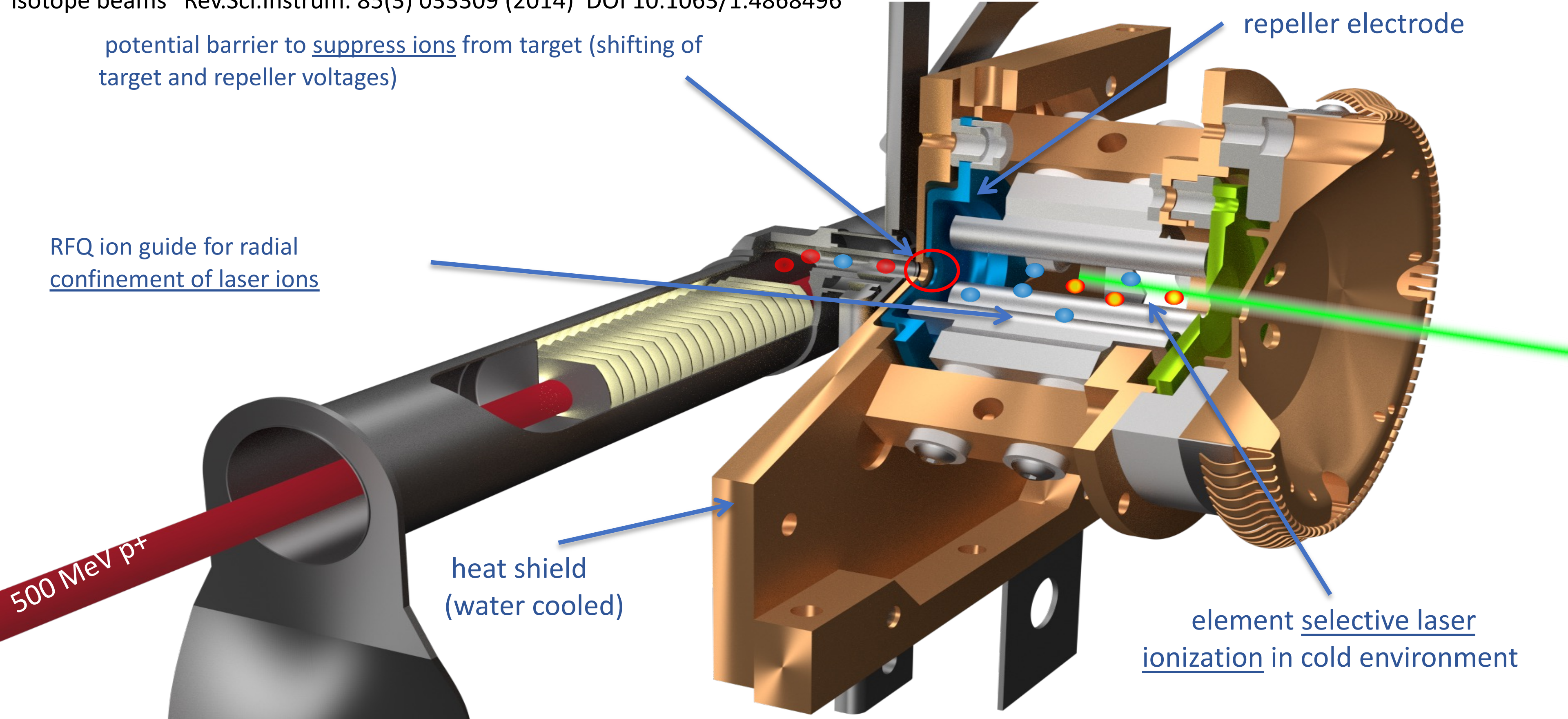






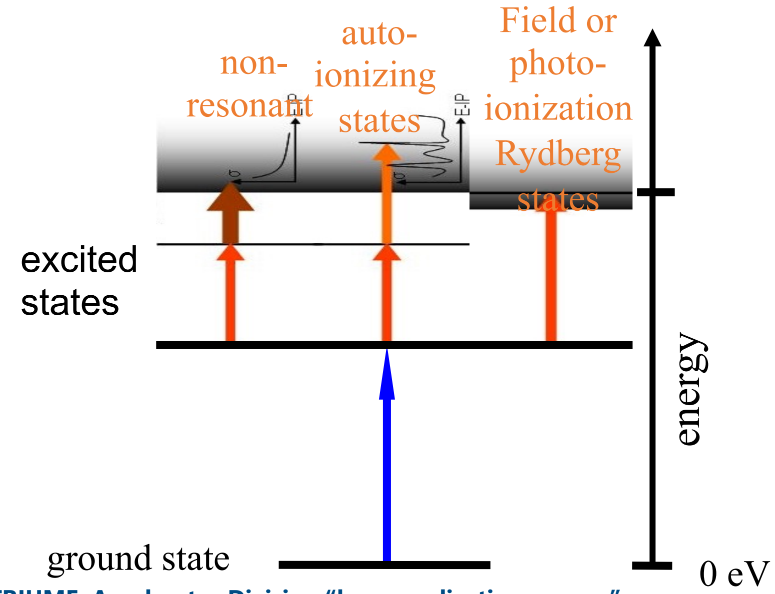
resonant laser ionization & higher selectivity developments

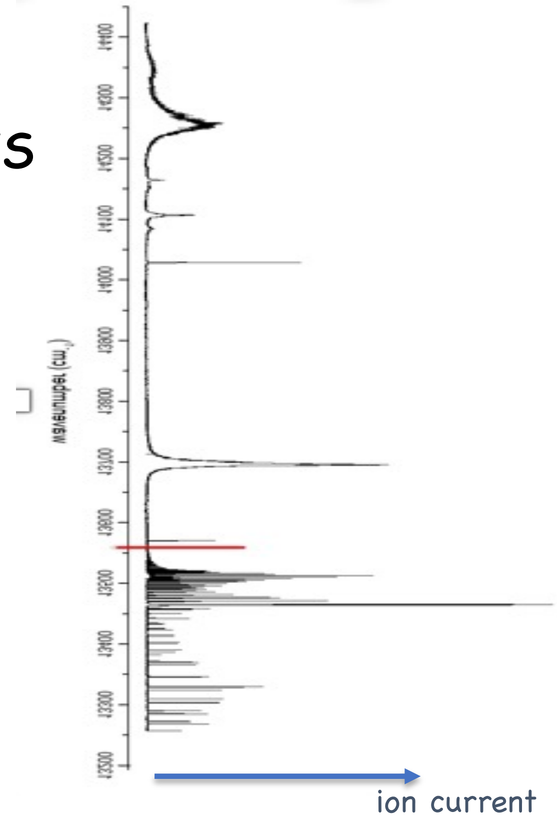
Raeder et al. "An ion guide laser ion source for isobar-suppressed rare isotope beams" Rev.Sci.Instrum. 85(3) 033309 (2014) DOI 10.1063/1.4868496



multi-step resonant excitation to overcome the valence electron binding

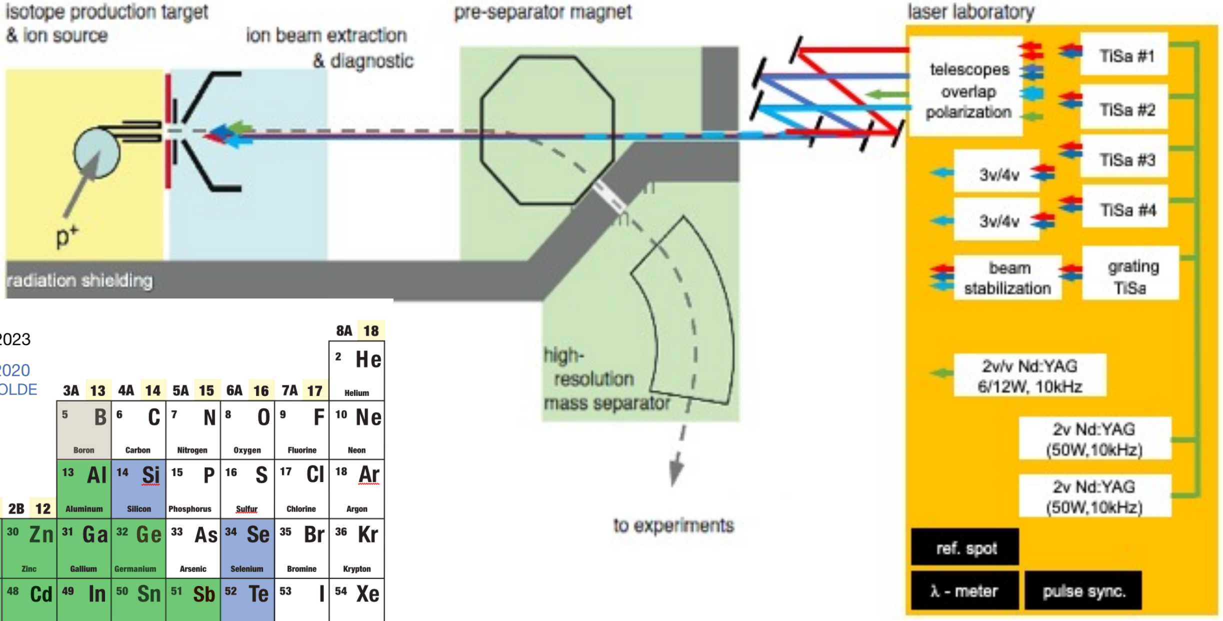
need for atomic spectroscopy
to search for AI
to map IS & HFS

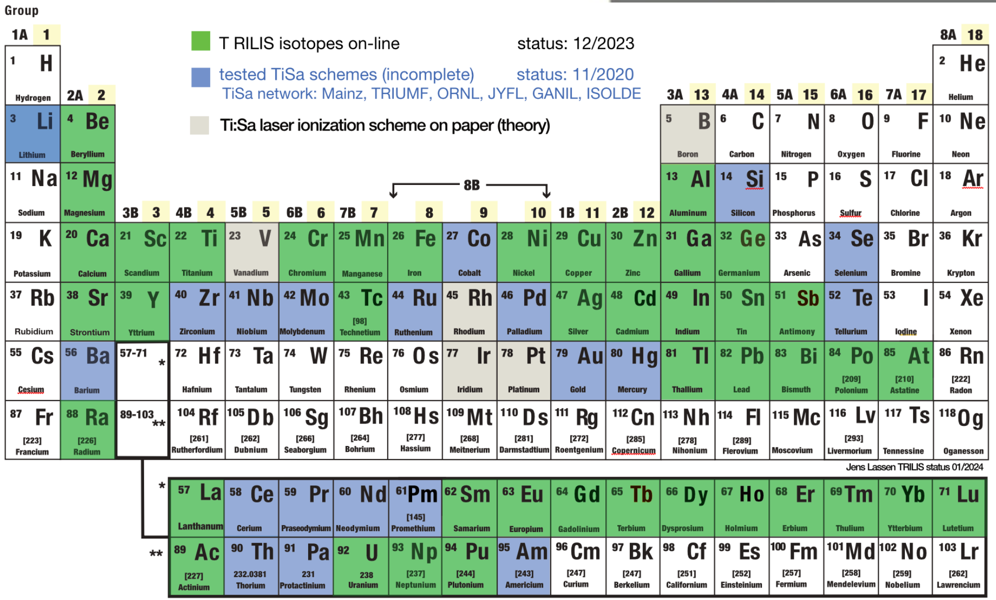




sample spectrum Sb with Rydberg series and autoionizing states

all solid state –TRI LIS laser resonance ionization laser ion source

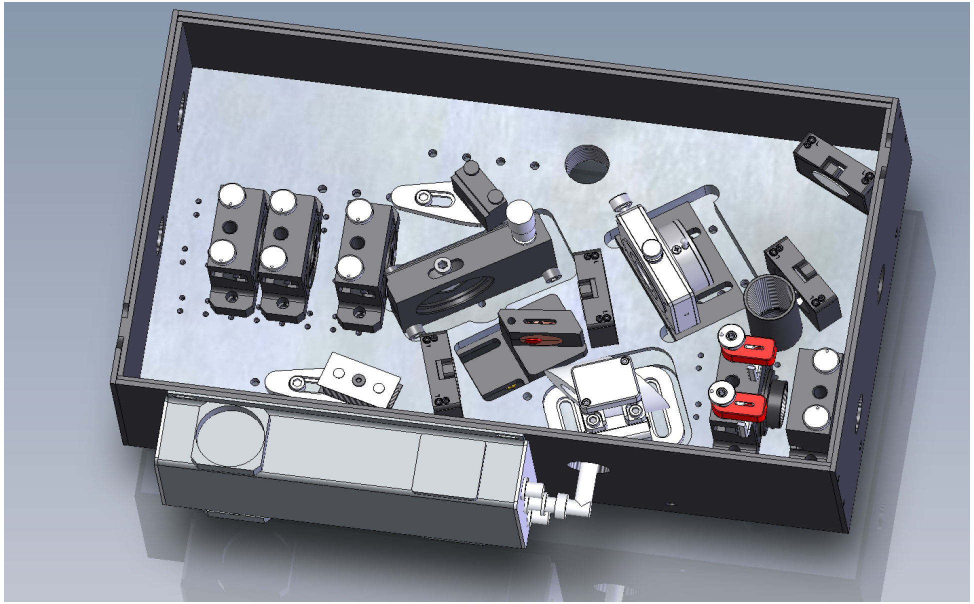


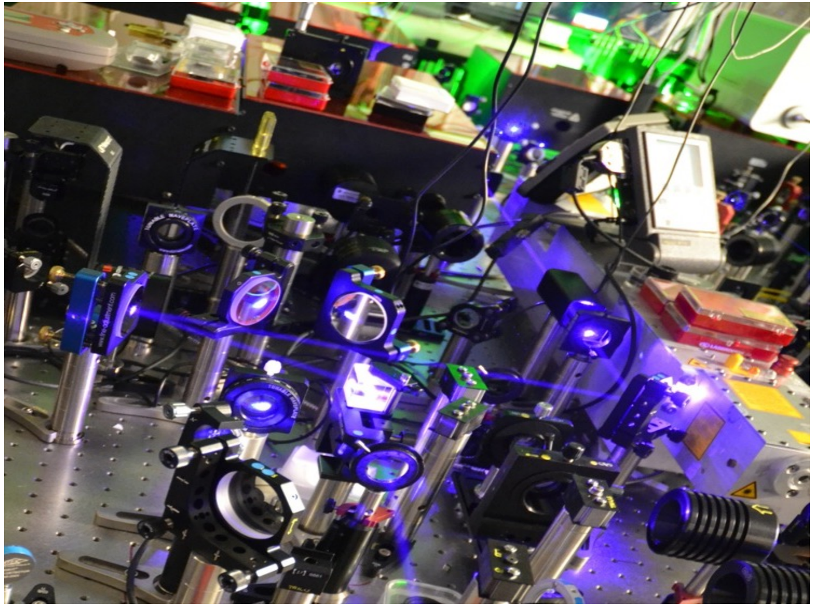


TRILIS provides 75% of ISAC RIB's
about 20 beam periods of 14 different elements /y
>2000 h of operation
increasing complexity to achieve
higher, purity, intensity, & versatility

future ARIEL LISe and LISp laser ion sources to be run in parallel

TRIUMF TiSa RILIS (T RILIS) laser system MK5 (2017)





laser system specifications:

10kHz rep. rate, Q-switched
linewidth: < 5GHz (as low as 600 MHz)
wavelength: 690-990 nm
power: 2/5W IR @ 10/20W, 10kHz pump

laser developments:
TiSa lasers MK7 (ALIS)
pump lasers (soon) as commercial ns systems disappear

laser excitation schemes
laser spectroscopy of AI states
HFS & IS of heavy isotopes

nuclear spin polarized beams & collinear laser spectroscopy

collinear spectroscopy -> highest selectivity (Doppler-free)
-> highest sensitivity (velocity bunching)

insensitive to isobaric contamination
independent of $t_{1/2}$

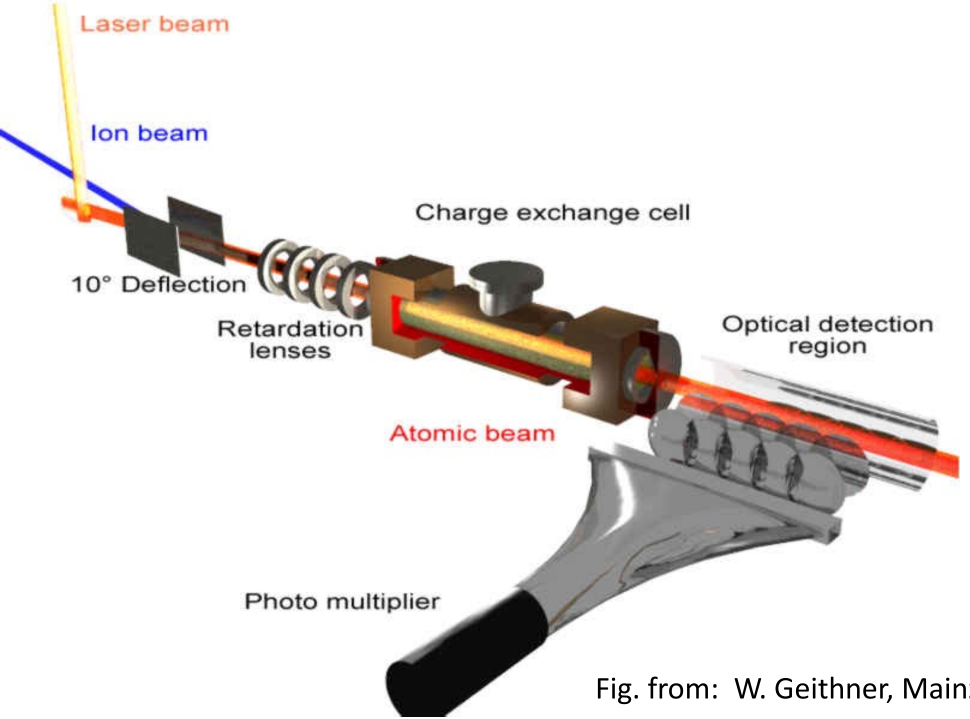
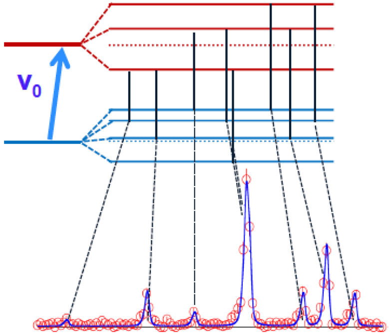
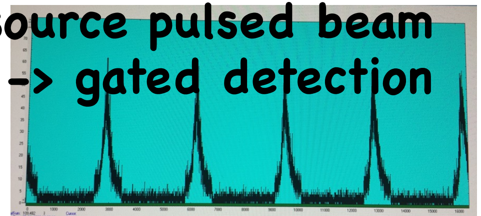


Fig. from: W. Geithner, Mainz U.

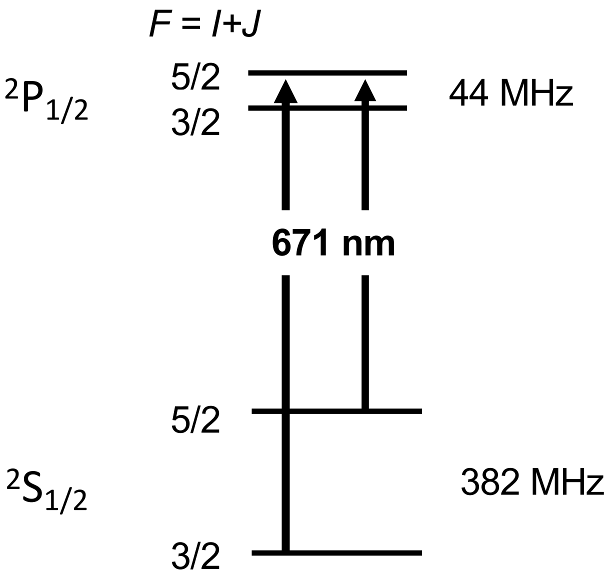


sensitive detection
upgrades i.p.

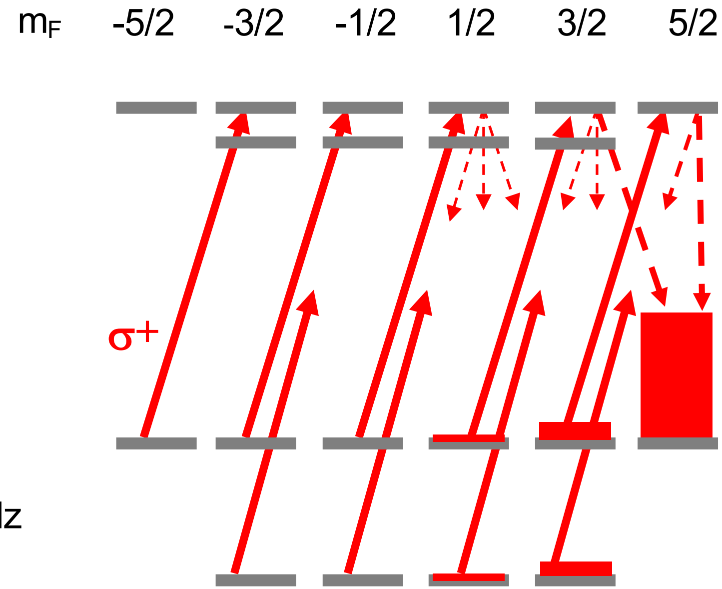
RILIS laser ion source pulsed beam
-> gated detection



optical pumping: example ^8Li -> orients nuclear spins



hyperfine structure…



…with magnetic sub-states

- electro-optic modulator (EOM) puts 381 MHz sidebands on laser frequency, -> both ground state hyperfine levels are pumped from dissertation Kraemer (U Mainz 2010)

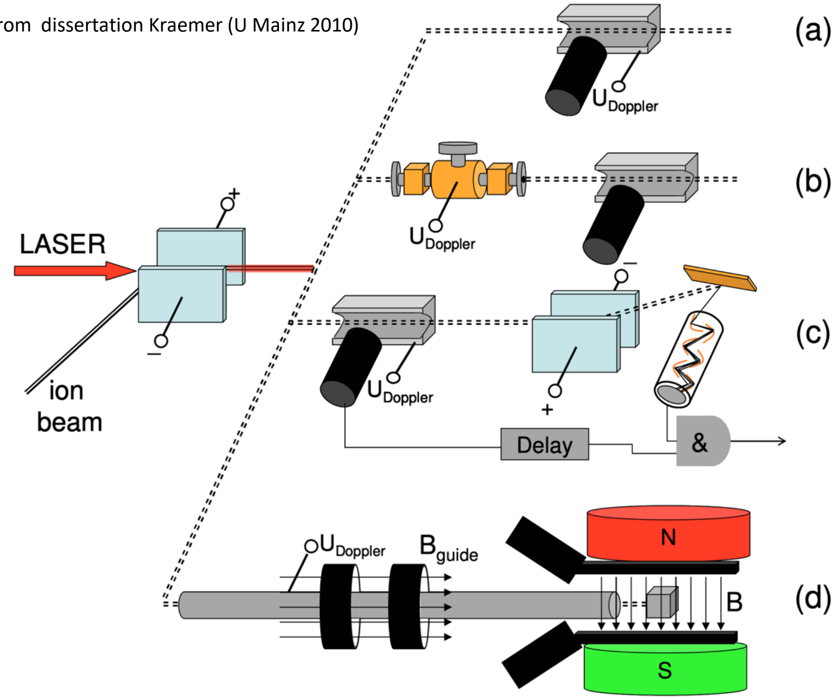


Figure 3.5.: Principle of collinear laser spectroscopy and the different possible extensions. (a) shows the classical optical detection with ions. The tuning voltage is applied to the mirror in the optical detector. (b) combines the optical detection with a charge exchange to perform spectroscopy with atoms. To increase the signal to noise ratio the optical detection can be combined with a subsequent particle counting, shown in (c). In the case of short-lived radioactive nuclei the β-asymmetry detection can be applied after optical pumping with σ polarized light in a guiding field as it is shown schematically in (d).

(not shown: collinear RIS)

polarizer operation:
3 different elements with about 1200h /y

development goals: new spin polarized species
requires collinear laser spectroscopy

nuclear moments & shapes from atomic hyperfine-structure
i.e. laser spectroscopy

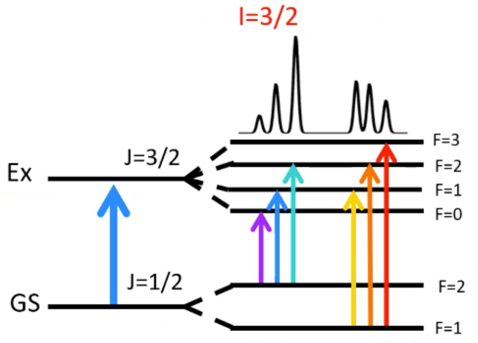
- Nuclear spin *I*
- Magnetic dipole moment *μ*
- Electric quadrupole moment *Q*
- Changes in the mean square charge radii $\delta\langle r^2\rangle$

ΔE= A·K/2 + B·{3K(K+1)/4 -I(I+1)J(J+1)}/{2(2I-1)(2J-1)IJ}
K = F(F+1)-I(I+1)-J(J+1)

$$A = \frac{\mu_I B_J}{IJ}$$

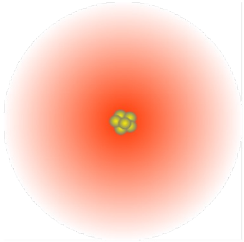
$$B = eQV_{zz}$$

$$\delta\nu^{AA'} = M\frac{m_{A'} - m_A}{m_A m_{A'}} + F\,\delta\langle r^2\rangle^{AA'}$$

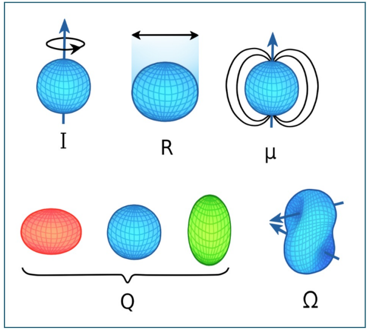


Atomic parameters either form calculations or

$$\mu = \frac{AI}{A_{ref} I_{ref}} \mu_{ref}$$

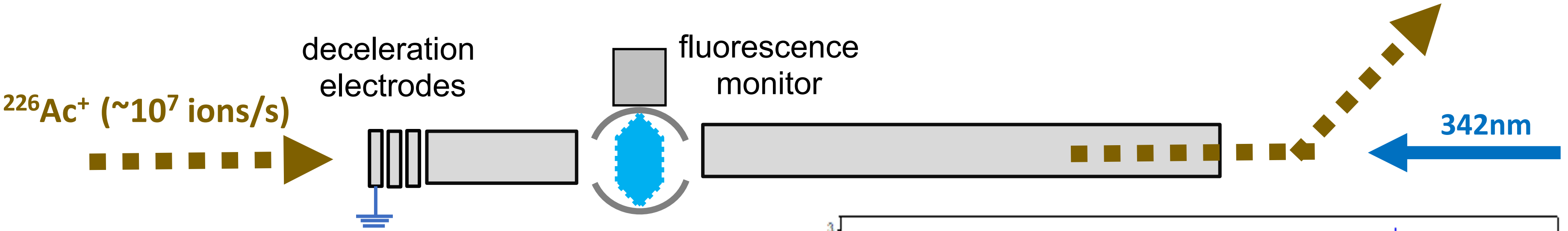


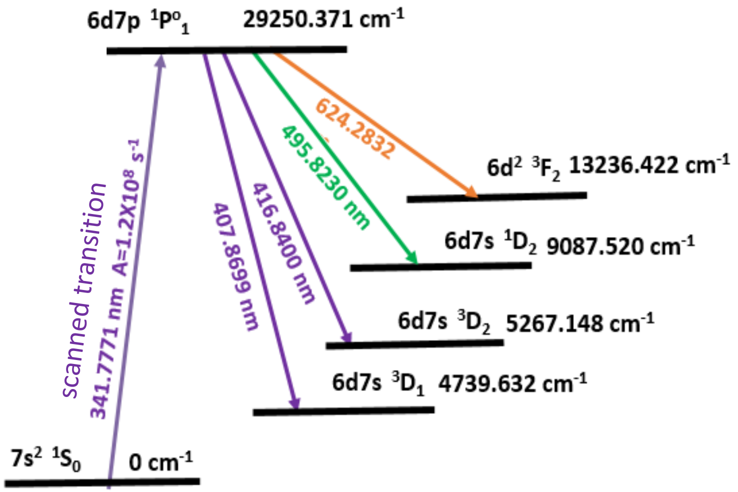
x 10^5

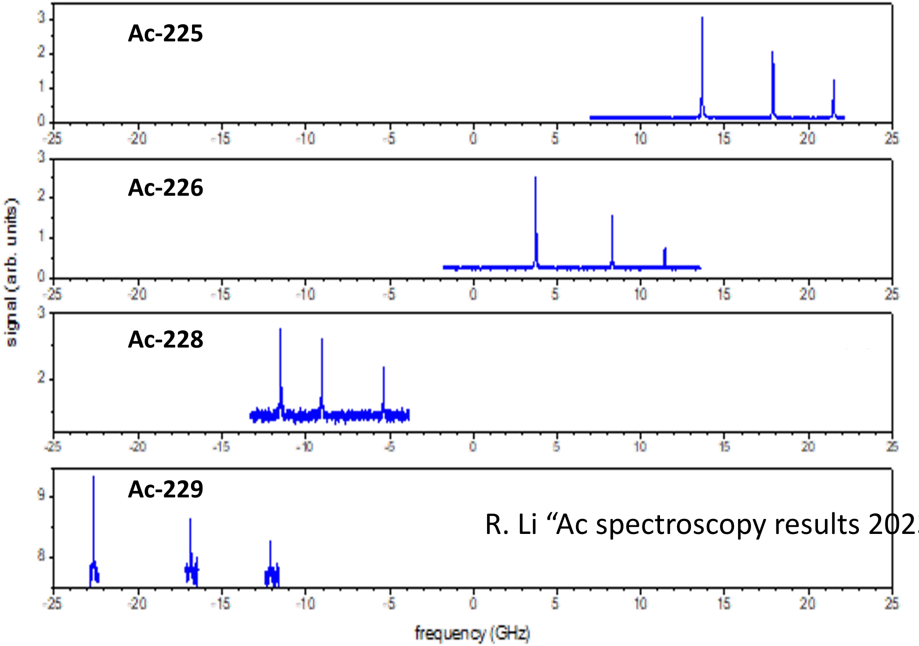


International conference on HYPERFINE interactions and their applications

collinear fast beam laser spectroscopy @ TRIUMF



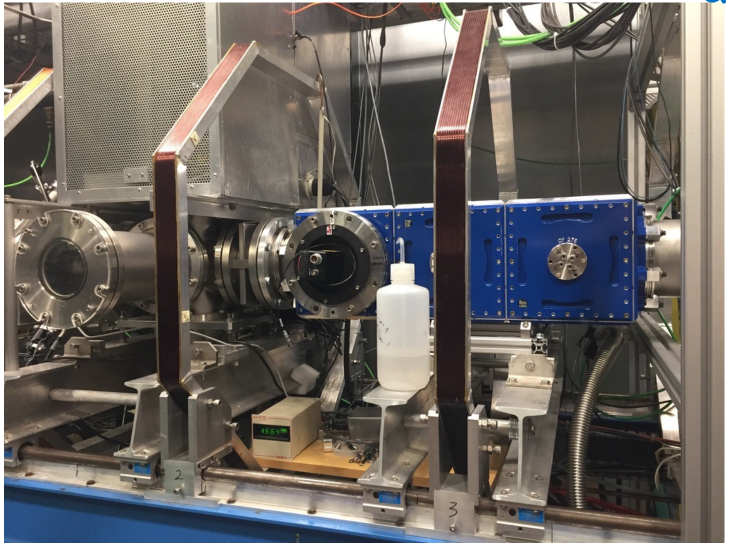




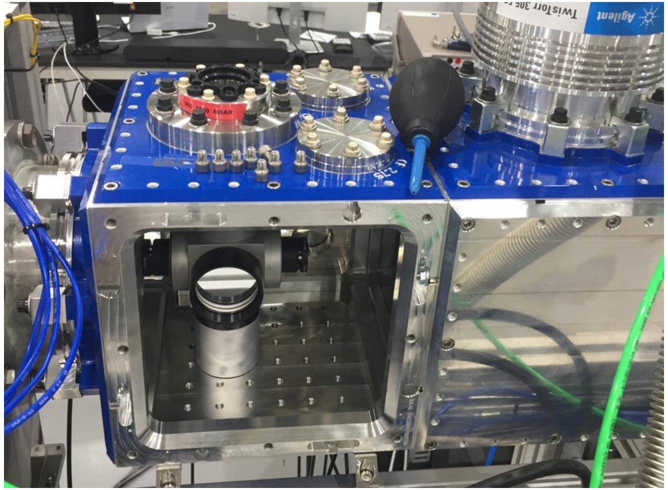
R. Li “Ac spectroscopy results 2023”

polarizer / collinear fast beam laser spectroscopy beamline

for custom detection setups
& quick re-configuration to polarized beams operation



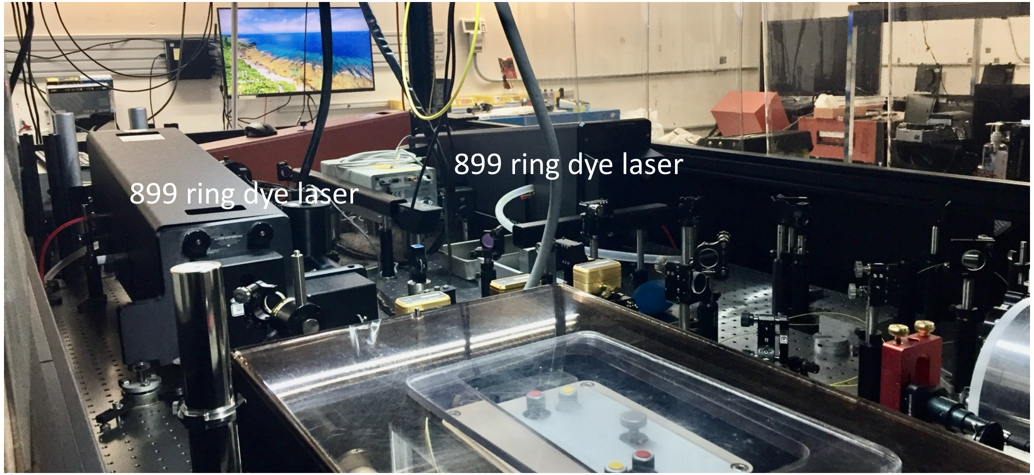
vacuum separated charge exchange cell
& versatile user-section for detection setups



uv – optical detection region for At
(MSc. Katarina Preocanin)

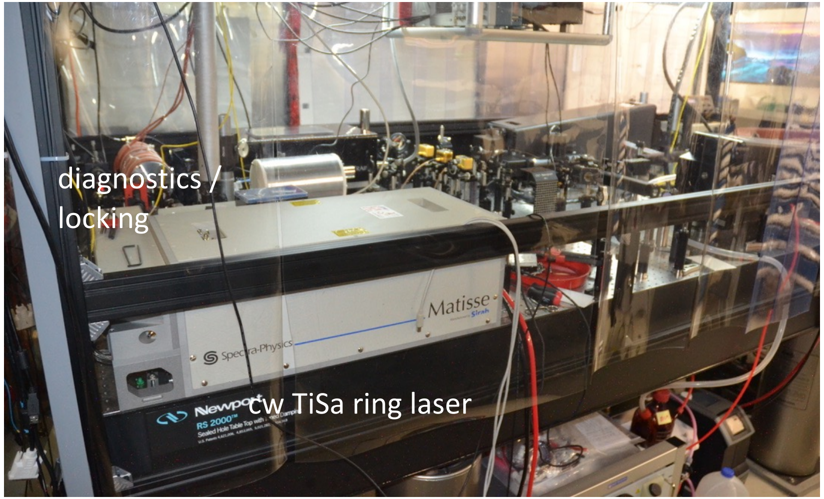
new CFBS beamline section & laser upgrades financed through
NSERC experiment grants (R. Li, J. Lassen)

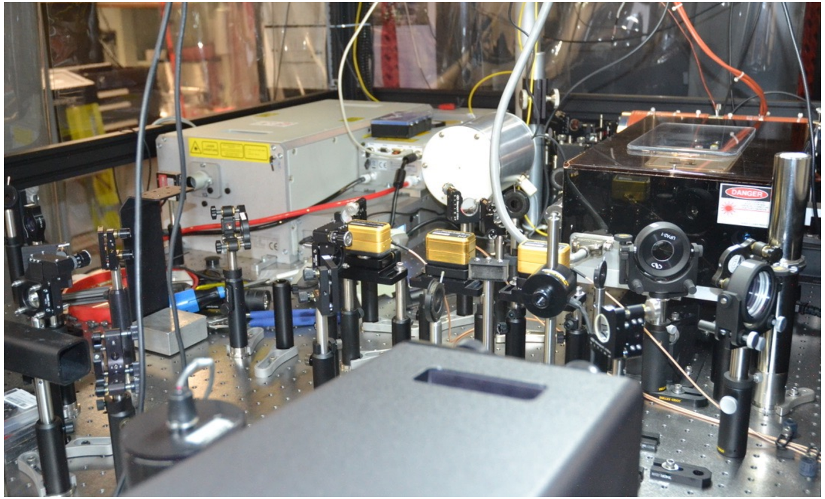
old collinear laser spectroscopy equipment & lab now RadMol (S. Ettenauer)



solid state laser (MatisseCS)
and 2nd ring dye laser
for polarizer
& CFBS

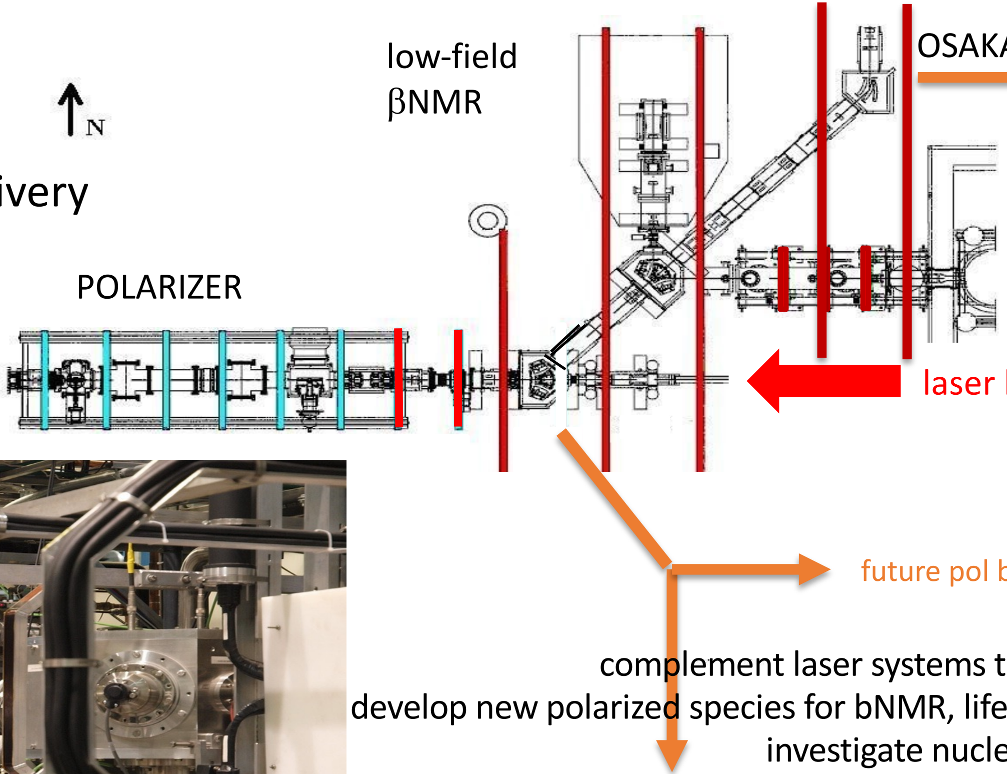
2nd frequency doubler (wavetrain)

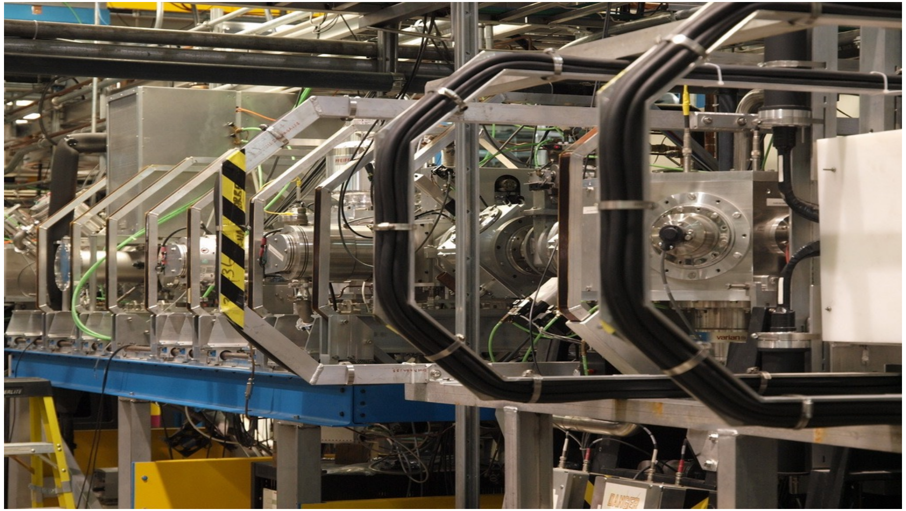




multi-element polarized beams & future end stations

about 1000 h/a beam delivery





development axes:

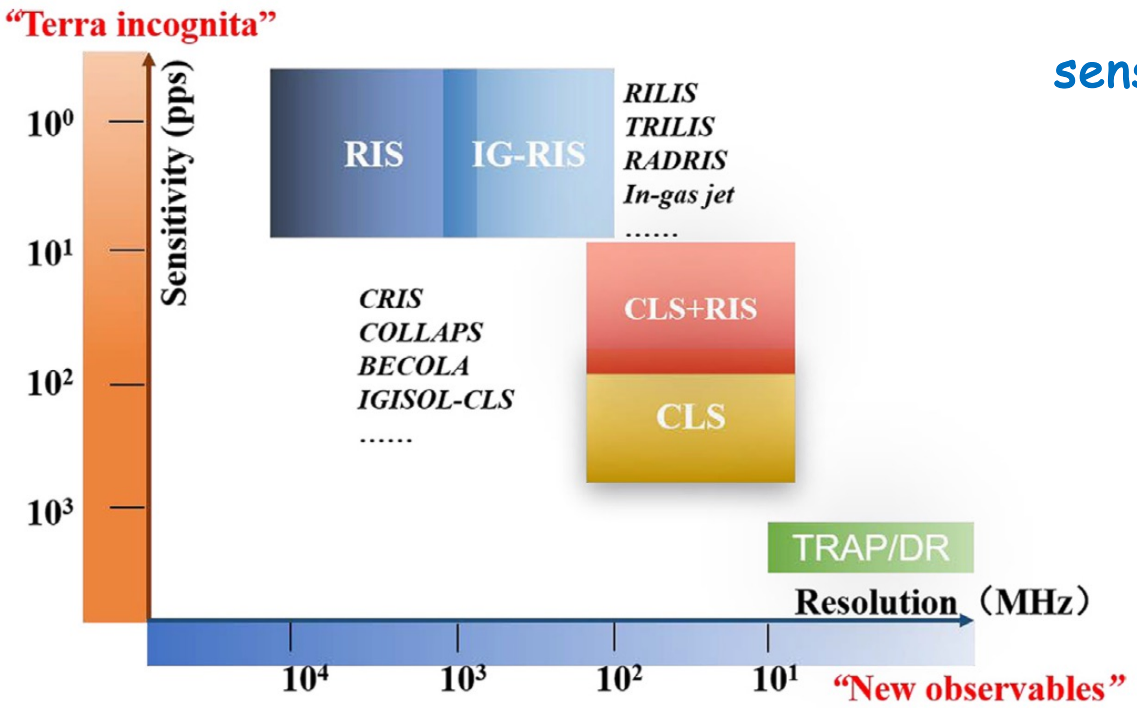
complement laser systems to allow for “user cfbs”

develop new polarized species for bNMR, life- and nuclear sciences

investigate nuclear moments & shapes

develop a universal polarizer

deliver polarized beams of highest quality & availability from ISAC & ARIEL



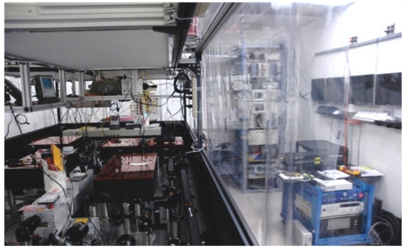
sensitivity vs resolution frontier
with current techniques

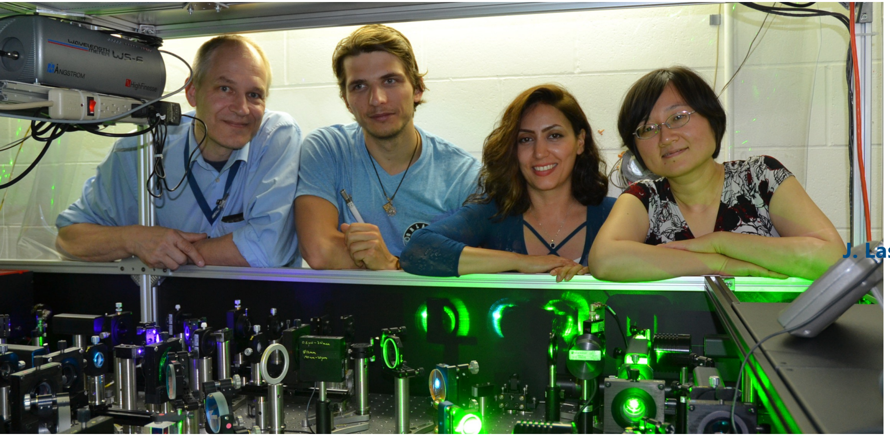
TRIUMF RILIS, polarizer & colliner fast beam laser spectroscopy

part of accelerator division RIB delivery infrastructure
primary mission beam delivery & related R&D

more elements ✓
increased intensity & beam purity ✓
higher uptime (laser & techniques R&D) ✓
scientific interest in
laser spectroscopy (atomic data) ✓
laser development ✓

questions ?
comments ?





TRIUMF: Alberta | British Columbia | Calgary Carleton | Guelph | Manitoba | McMaster Montréal | Northern British Columbia | Queen's Regina | Saint Mary's | Simon Fraser | Toronto Victoria | Winnipeg | York

resource requirements:
machine shop access
design office support
controls

J. Lassen| Accelerator Division - RIB dev. – laser applications

funding agencies: NSERC, NRC, CFI

collaborators:
Simon Fraser U, U Manitoba, U Windsor, SMU
U Oldenburg, TU Darmstadt, Hochschule Emden Leer,
U Mainz, ISOLDE , Leuven, GANIL, JYFL, ORNL, Nagoya U , & TiSa Network