Argonne NATIONAL LABORATORY

^{39}Ar Detection at the 10^{-16} Isotopic Abundance Level with Atom Trap Trace Analysis

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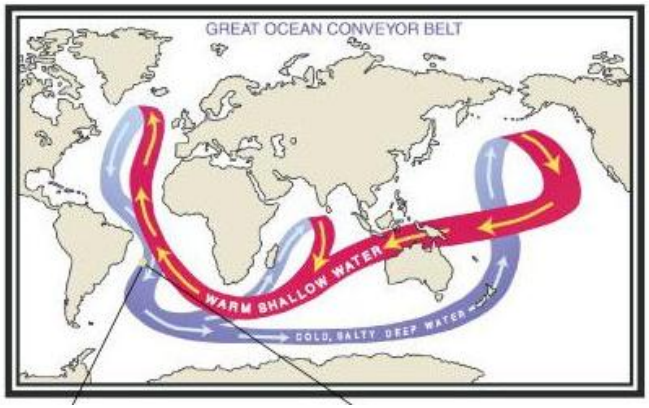
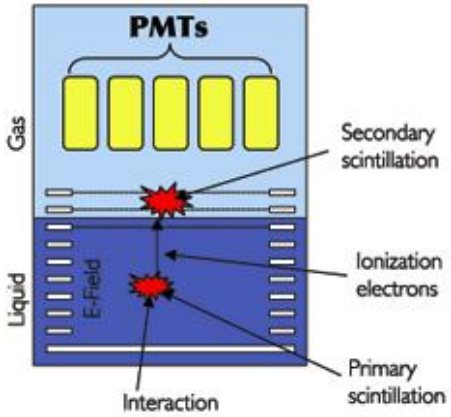
Radioargon Dating - ^{39}Ar

cosmogenic isotope; half-life = 270 years; ^{39}Ar/Ar = 8 x 10^{-16}





WIMP Argon Programme

Radio-Argon Dating :

- 50 – 1000 year range
- study ocean and groundwater
- previously with LLC and AMS

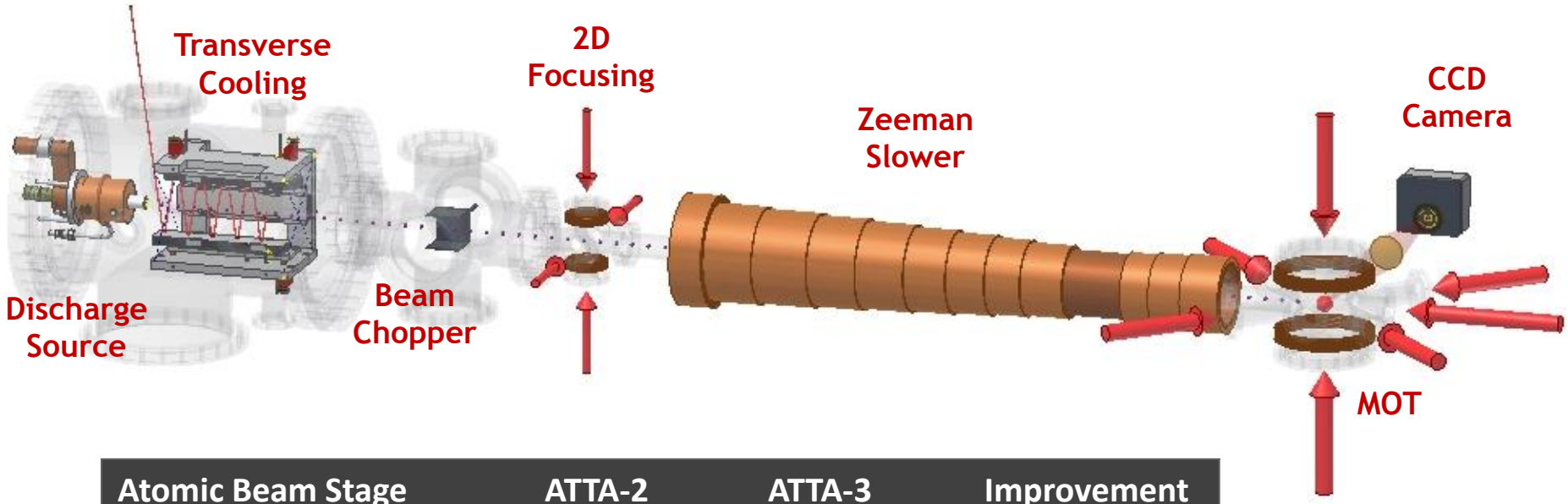
Dark Matter Searches :

- LAr detectors (WARP, DEAP/CLEAN)
- ^{39}Ar major background
- search for old / depleted Argon

ATTA-2: ^{81}Kr loading rate ~10 atoms/h (^{81}Kr/Kr ~5×10^{-13})

-> one ^{39}Ar atom every 3 days

ATTA-3 Loading Rate Improvements

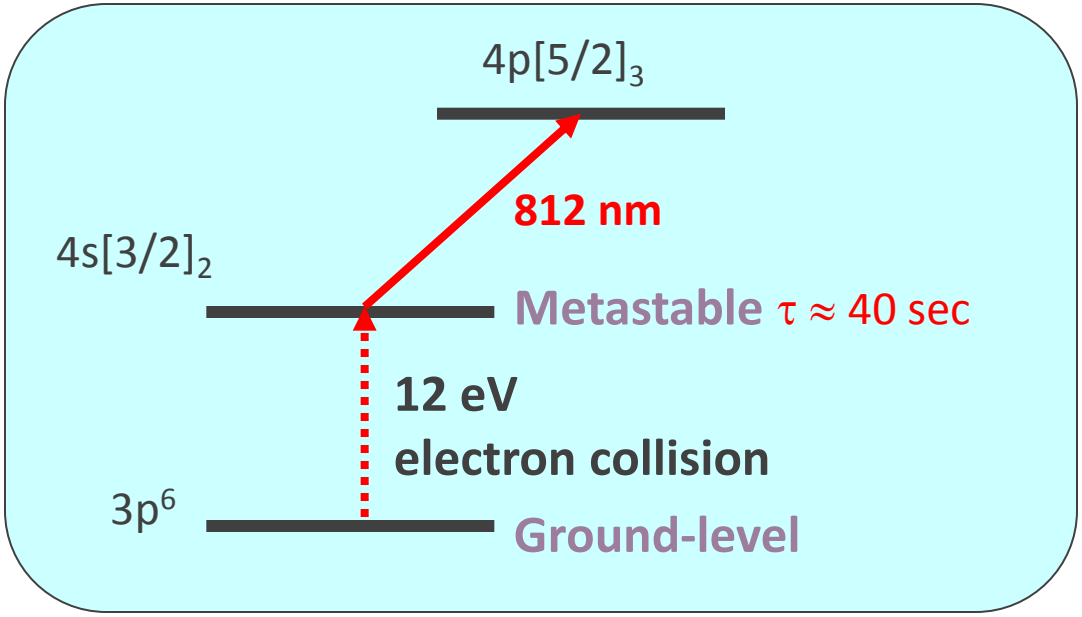


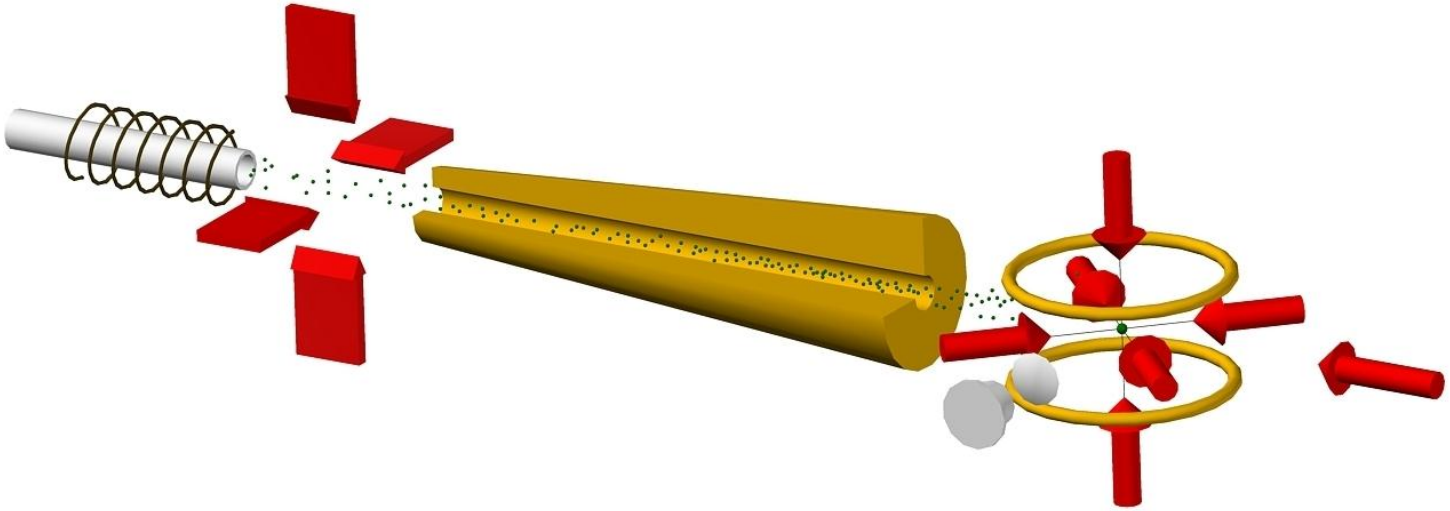
Atomic Beam Stage	ATTA-2	ATTA-3	Improvement
LN_2 pre-cooling	N.A.	2	x2
Transverse Cooling	70	140	x2
Sidebands in T.C.	N.A.	3	x3
2D-MOT	N.A.	3	x3
New Zeeman Slower	1000	3000	x3
More Trapping Power	N.A.	1.5	x1.5

Loading Rate

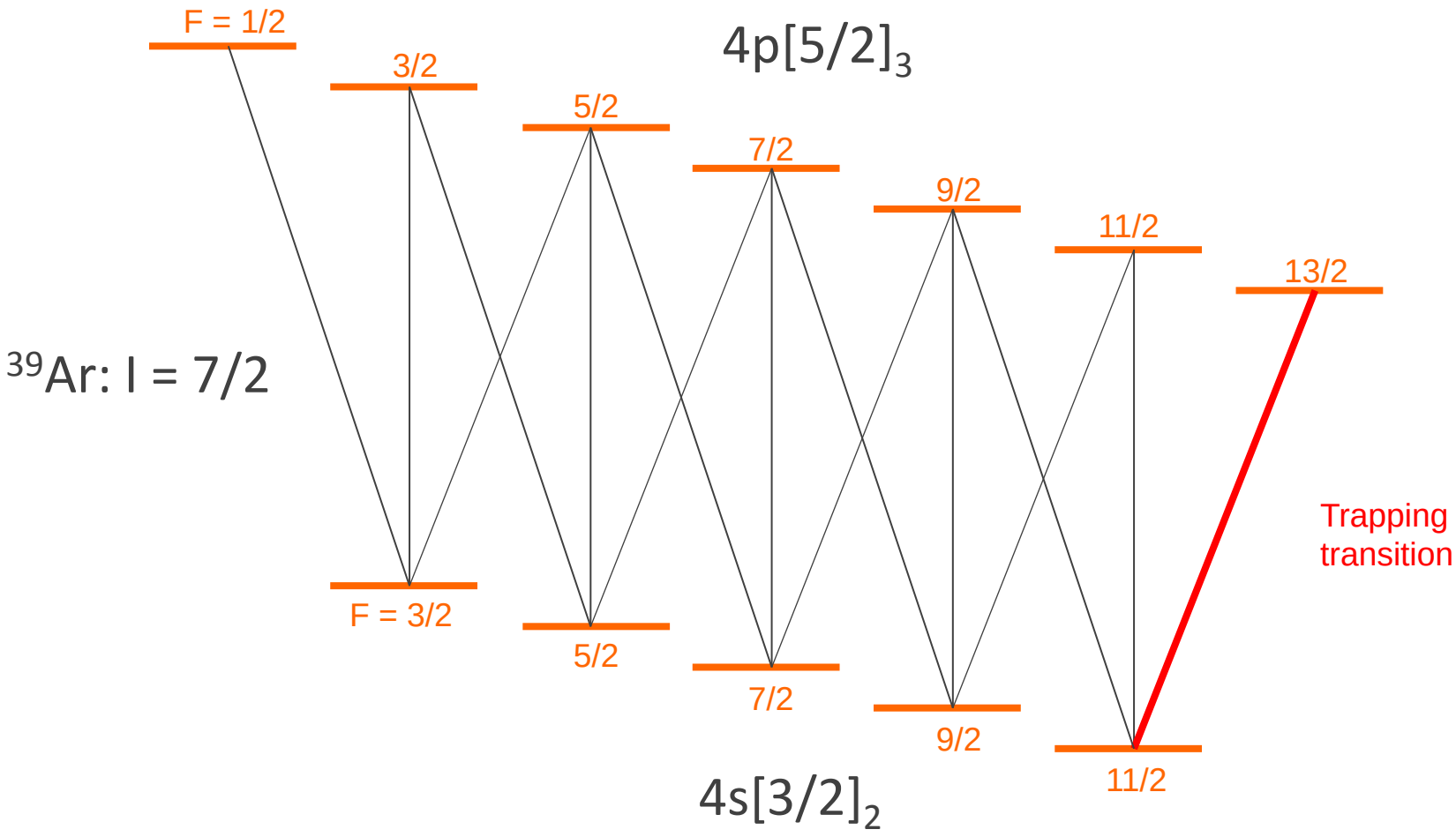
x 160

Argon Atom Level Diagram

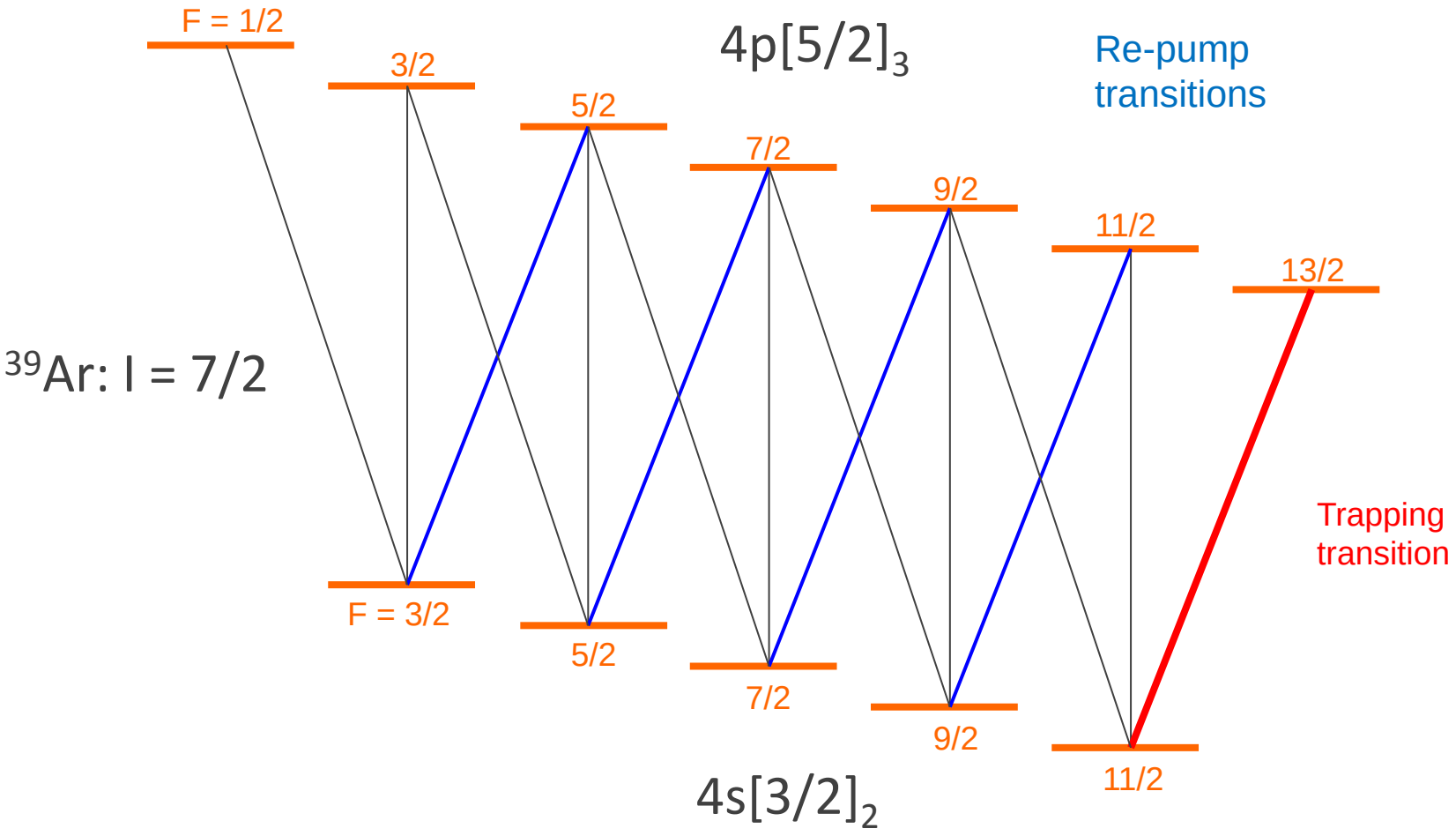




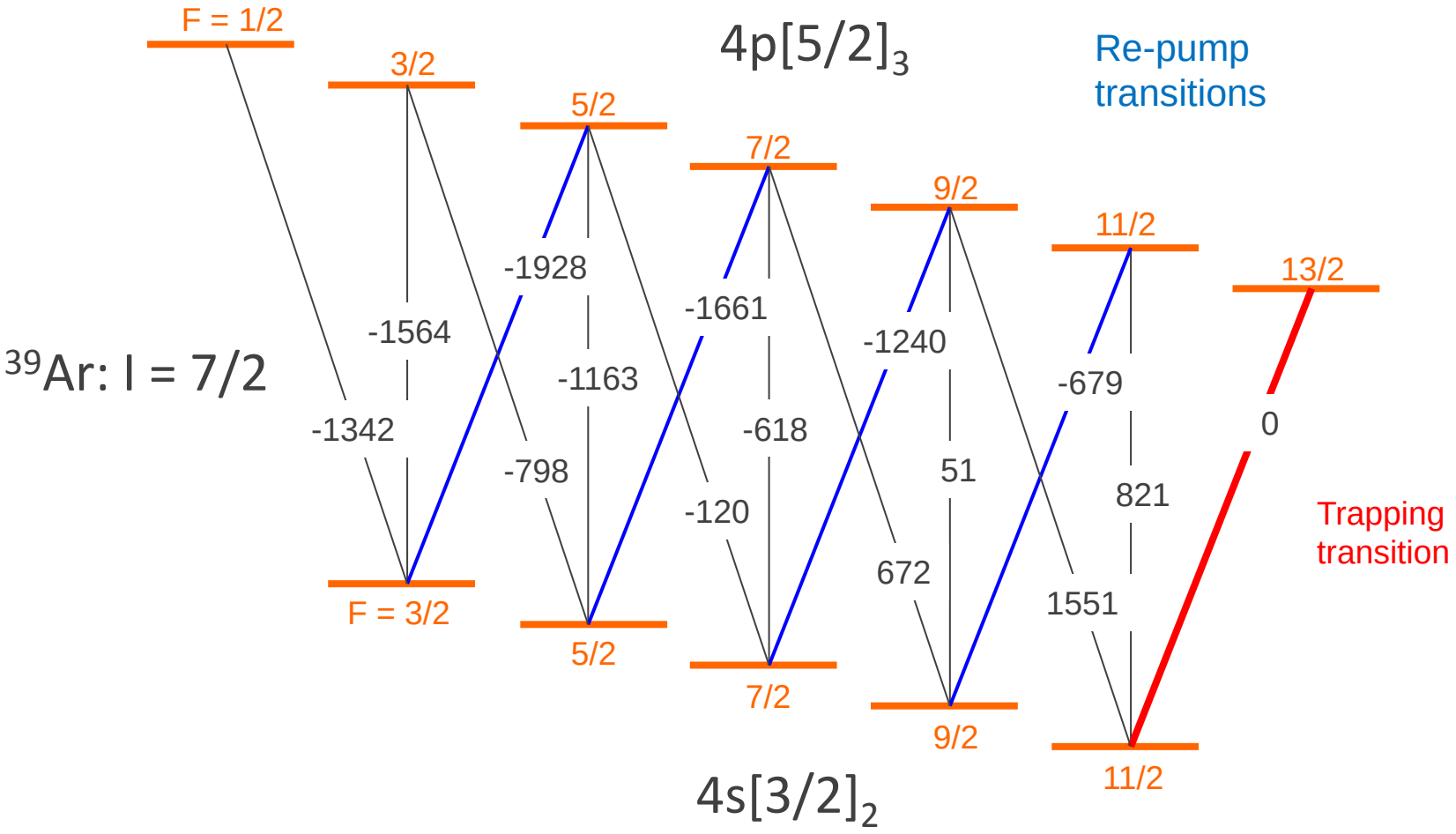
^{39}Ar Hyperfine Structure



^{39}Ar Hyperfine Structure



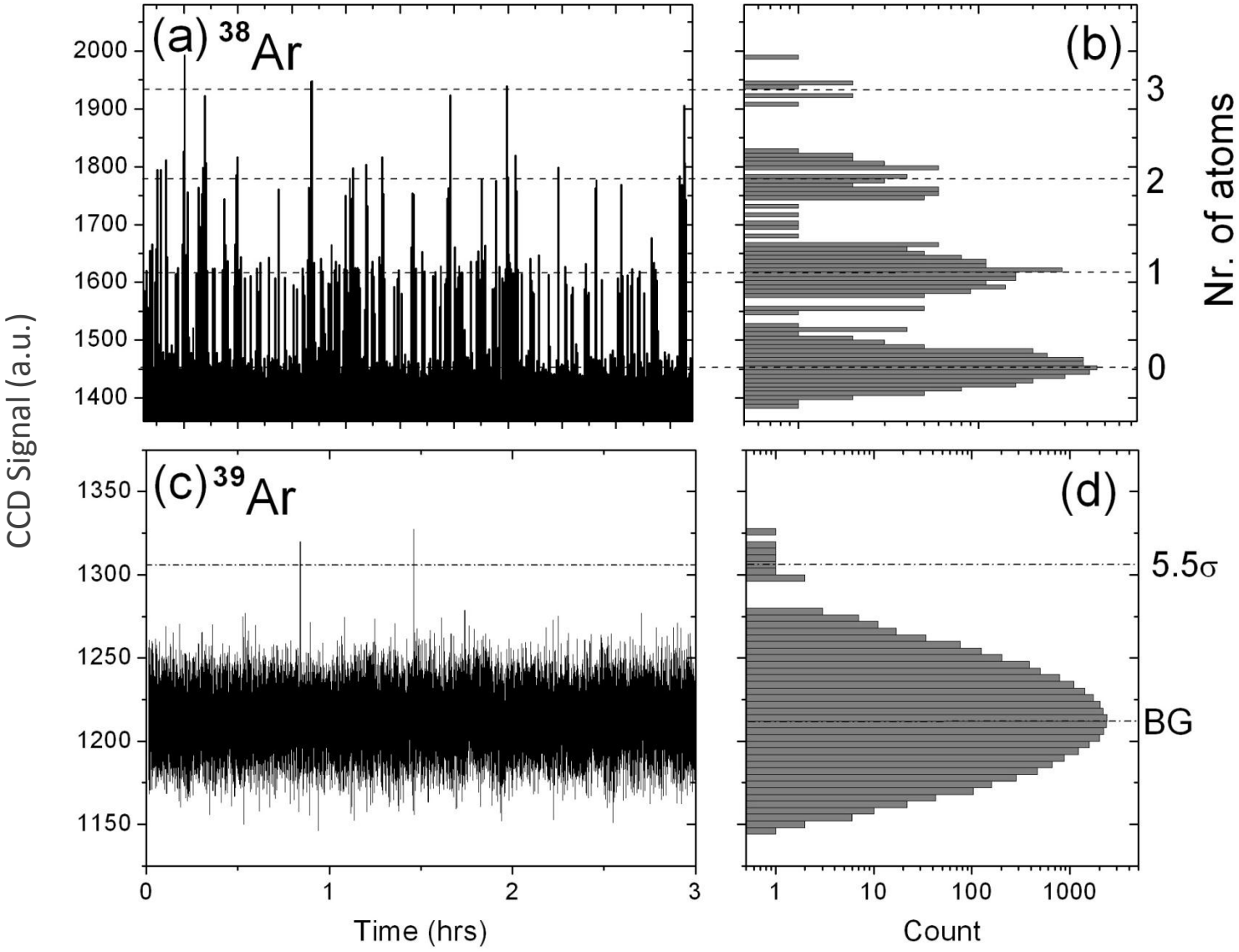
^{39}Ar Hyperfine Structure



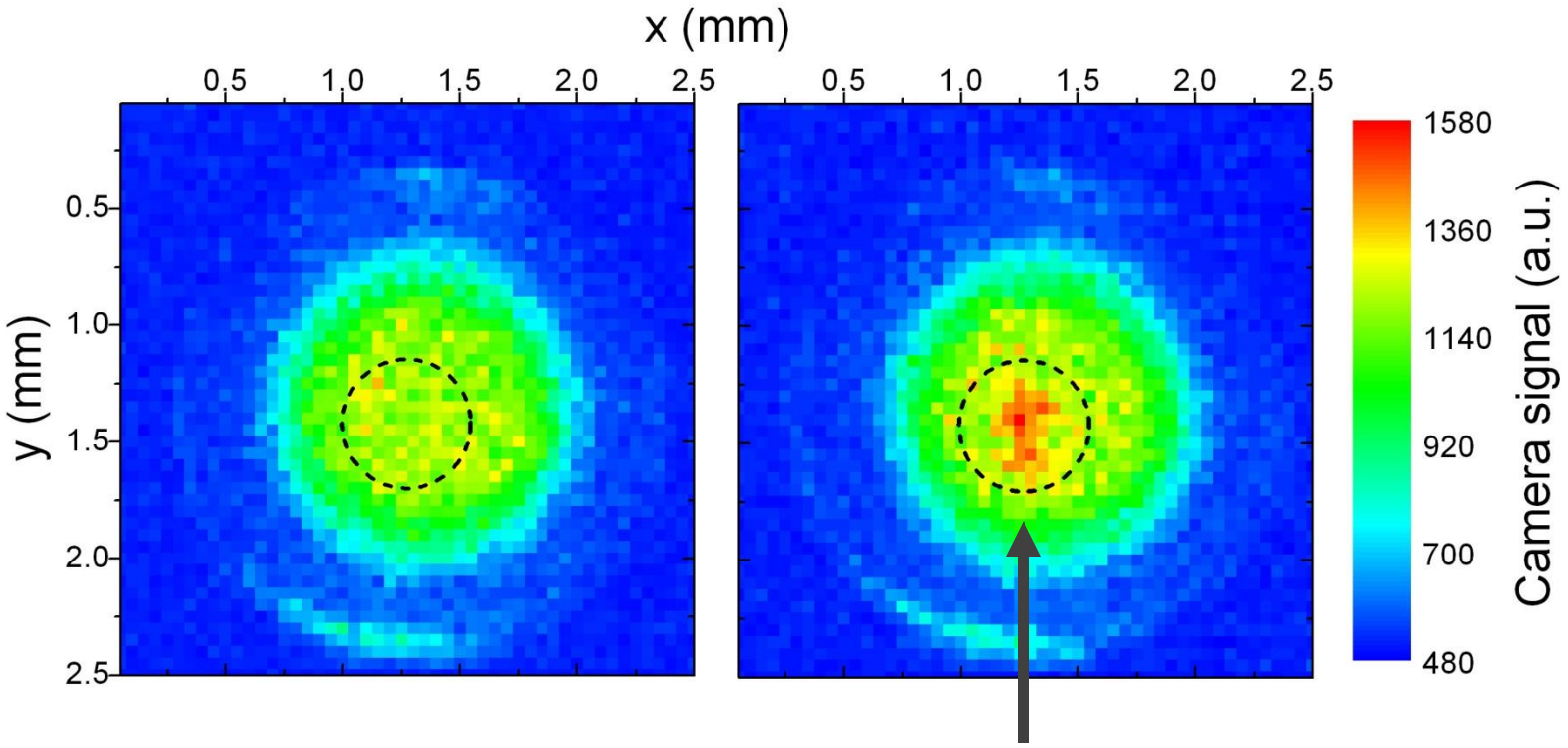
Frequencies in MHz

J. Welte *et al.*, Rev. Sci. Instr. **80**, 113109 (2009)
W. Williams *et al.*, Physical Review A **83**, 012512 (2011)

Argon Single Atom Signals



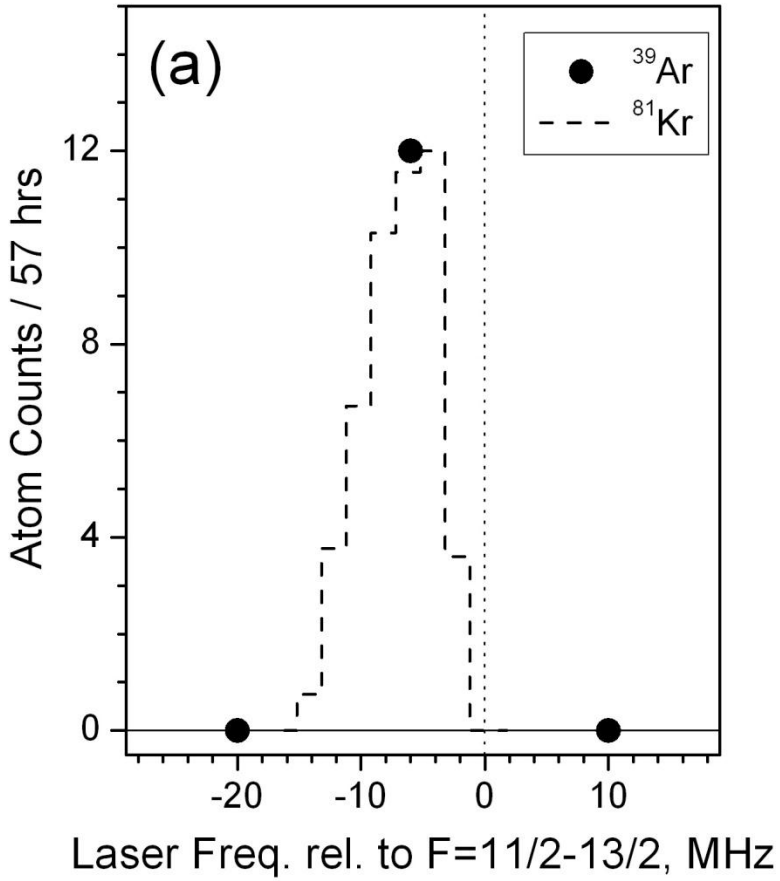
Ar-39 Single Atom Picture

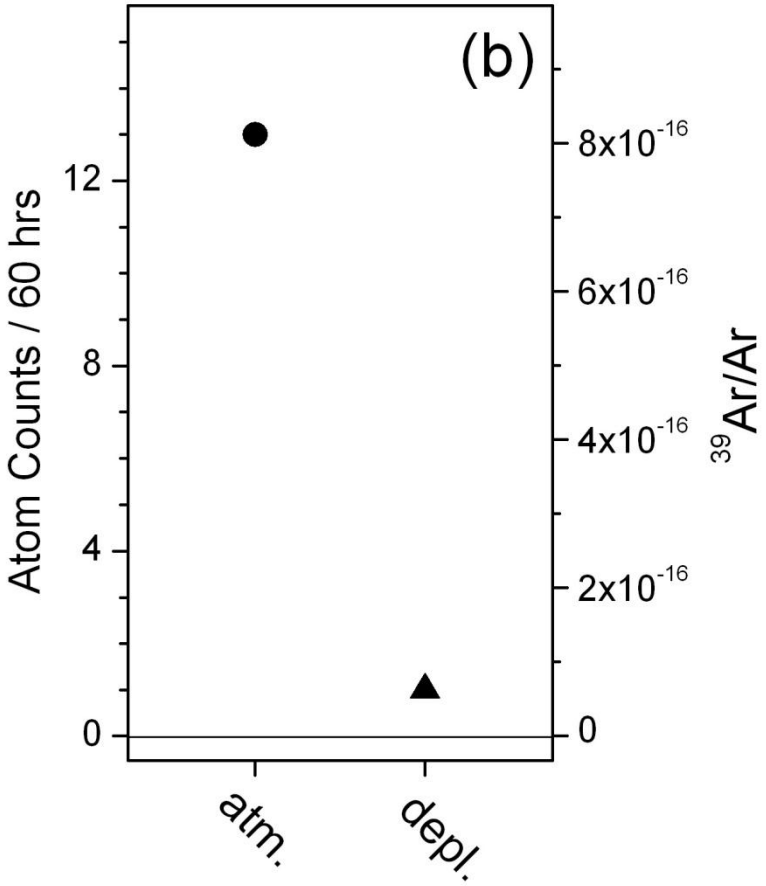


CCD camera picture

One ^{39}Ar Atom

^{39}Ar at Parts-per-quadrillion





Atmospheric ^{39}Ar/Ar = 8x10^{-16}

Depleted ^{39}Ar/Ar < 1x10^{-16}

Radioargon Dating Outlook

Current status of ^{39}Ar ATTA @ Argonne

- ^{39}Ar detected in atmospheric and old water sample
- No isotopic/isobaric interference (< 1×10^{-16})
- Loading rates

  ^{38}Ar: **1.3×10^{9} atoms/s** (I.A. 0.063 %)

  ^{39}Ar: **5 atoms/day** for atmospheric sample
- Sample consumption rate

  10 mL (STP) /day with *partial* recirculation

Next Steps

- Improve HFS re-pumping, continuous counting

  -> ^{39}Ar loading rate **100 atoms/day**
- Implement *full* recirculation

  -> **0.5 mL (STP) / day**
- Build dedicated argon trap and laser system

Thank You!

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http://www.phy.anl.gov/mep/atta/