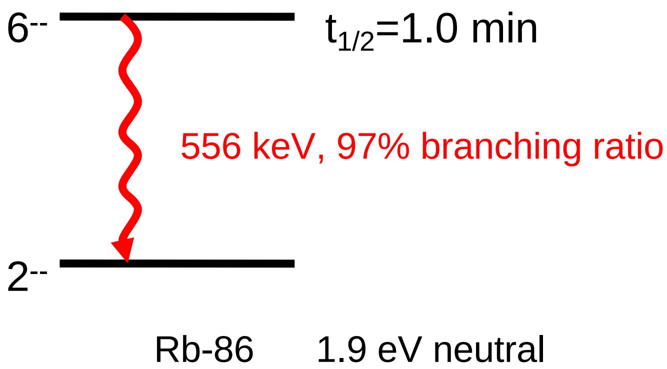
S1127: search for exotic particles in ^{86m}Rb decay

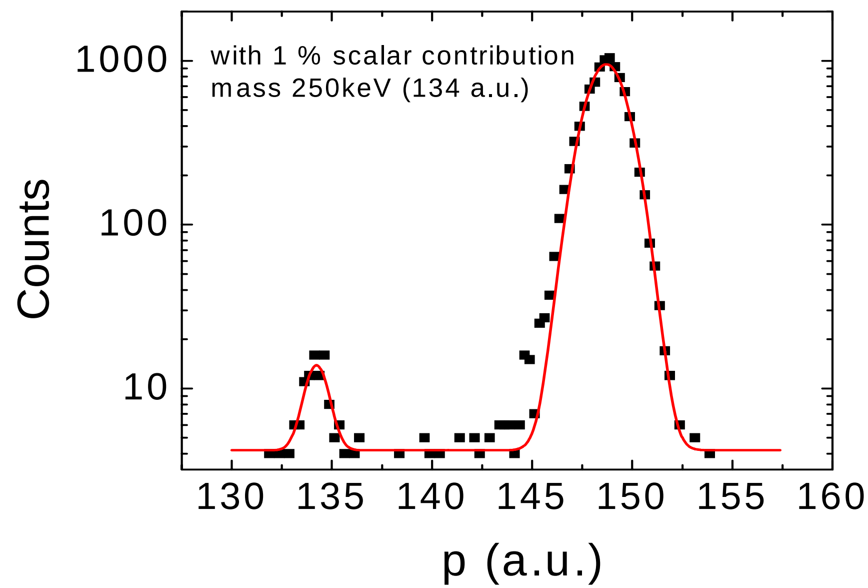
By Tao Kong, Ph.D. student in UBC

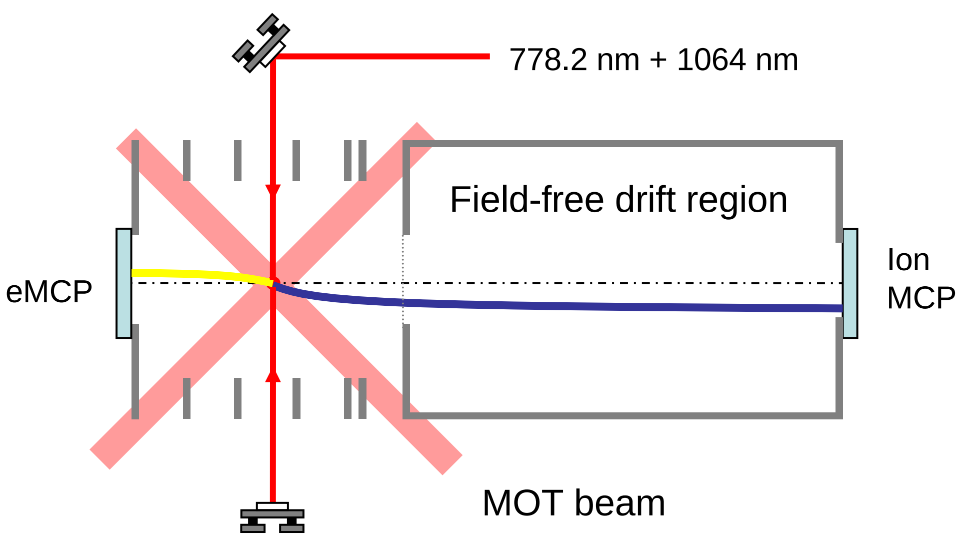
- Scientific justification: overview and update
- Accurate hyperfine splitting of **86g**Rb, **86m**Rb
- Momentum calibrations from internal conversion of **86m**Rb

Nuclear two-body decay:



If a massive particle is emitted, instead of a gamma:

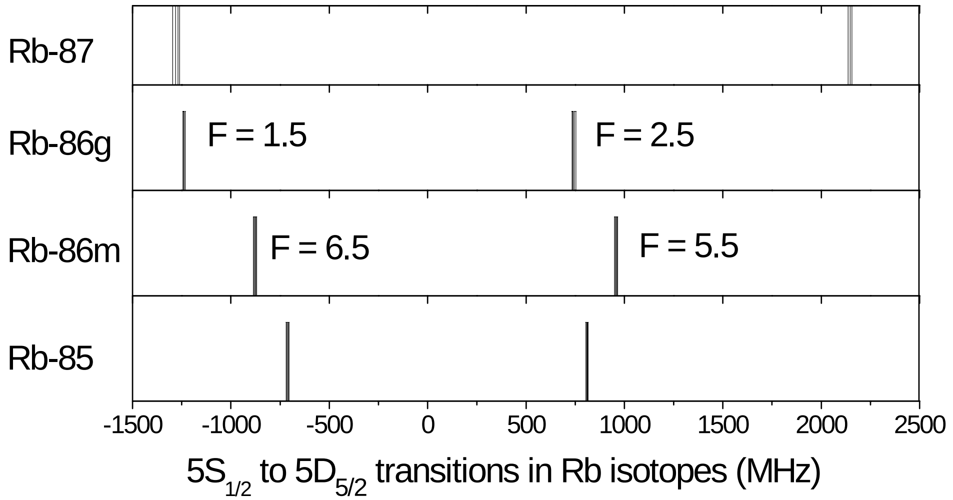


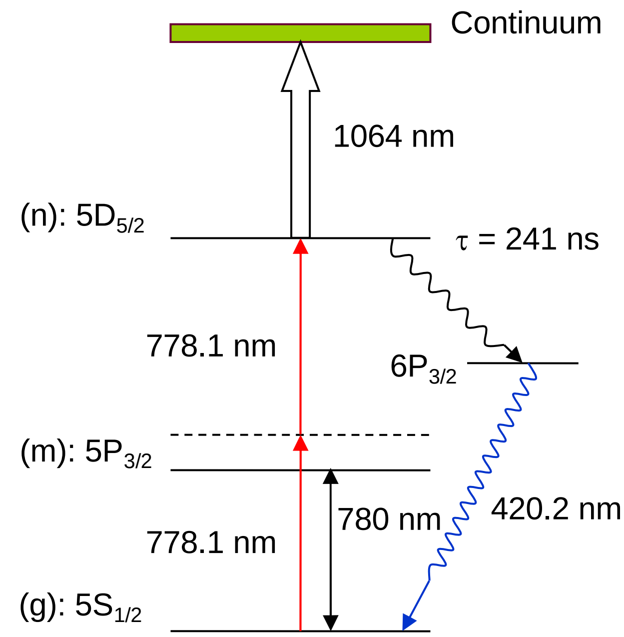


Advantage:
detect anything massive emitted from nuclear transitions, independent of interaction in detector or lifetime.

Challenge:
a) decay daughter Rb-86g is neutral, need to be photo-ionized for detection;
Recoiling speed is ~ 2100 m/s, transit time across the laser beam is ~ 0.5 us.
b) Momentum resolution.

Rb-86g photo-ionization scheme:





Advantage of the Doppler-free two-photon transitions:

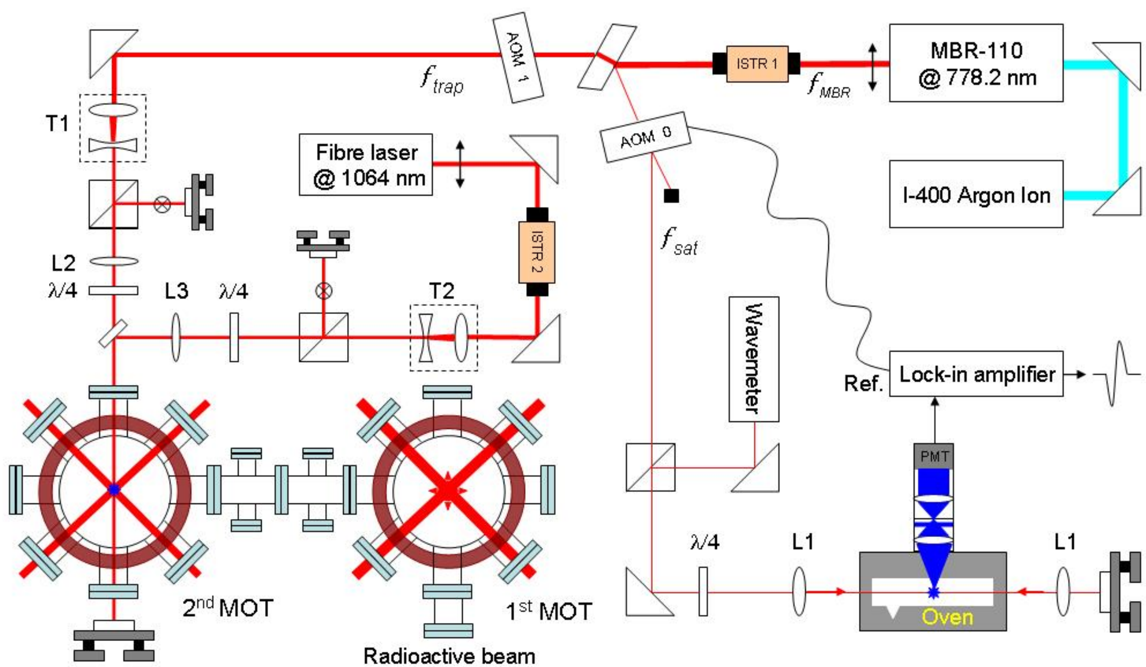
a) transition rate is velocity-independent, Doppler freq. shifts are canceled, no need to scan the laser.

b) no change to the recoil momentum.

Requirements:

a) high laser intensity: four passes cage system for both MBR and Fiber laser.

b) Narrow linewidth of $5D_{5/2}$: accuracy of the two-photon transition frequency to be < 0.1MHz. Scan AOM 0.

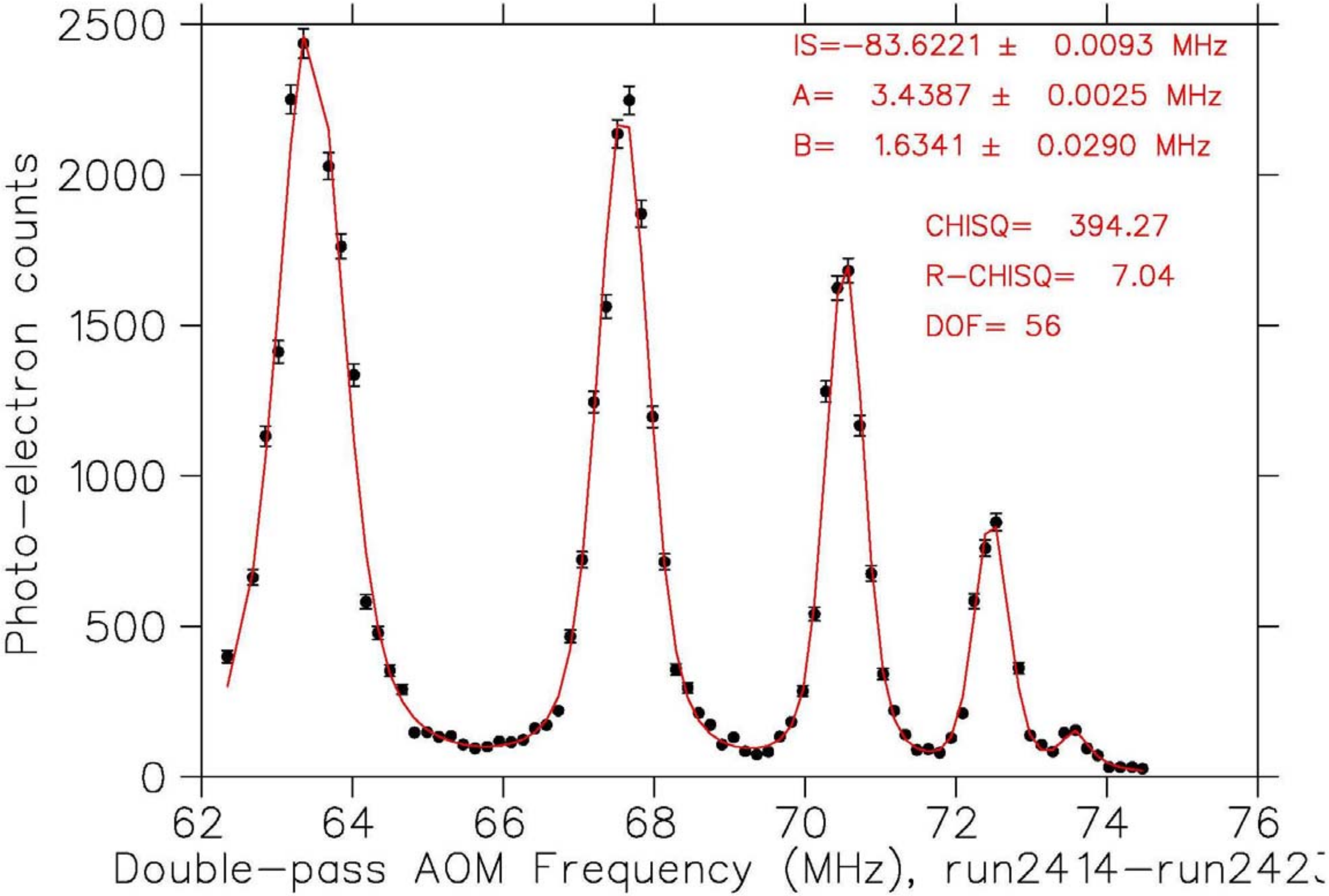


High-resolution two-photon spectroscopy in ^{86m}Rb, ^{86g}Rb

- Maximize the photo-ionization efficiency.
- Direct measurement of $5D_{5/2}$ state hyperfine constants, A and B.
- Higher accuracy of $5S_{1/2}$ magnetic dipole constant, $As_{1/2}$ for ^{86m}Rb.
- high-accuracy measurement of Isotope shifts for ^{86m}Rb and ^{86g}Rb.
- Deduce specific mass shifts of $5D_{5/2}$ states for ^{86m}Rb and ^{86g}Rb, better understanding of nuclear charge radius in those isotopes.

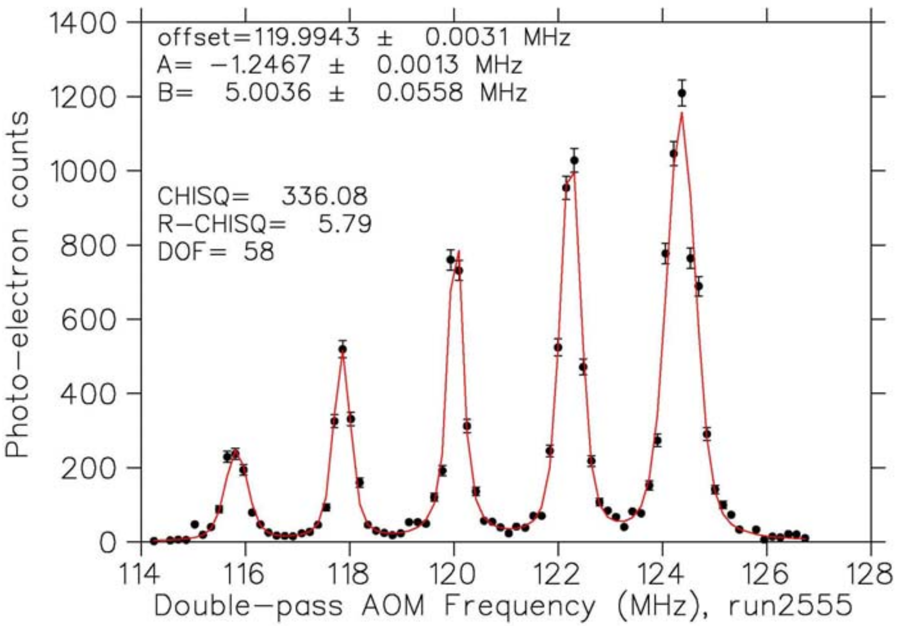
Preliminary result 1: Rb-86g, $5S_{1/2}$ F=2.5 → $5D_{5/2}$ F=4.5 ….. 0.5

$As_{1/2}$ has been determined by beta-NMR method: -1578.753 +/- 0.001 MHz

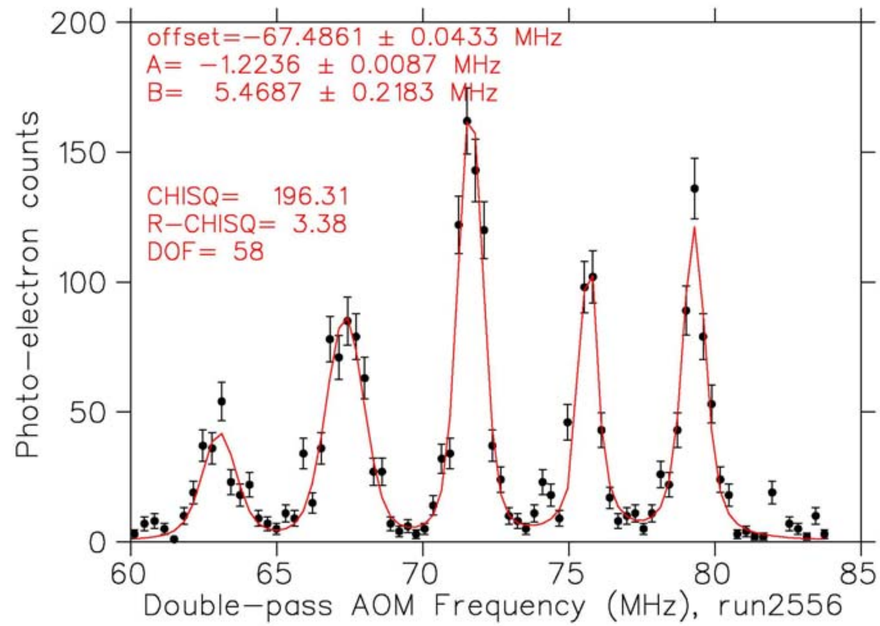


Preliminary result 2: Rb-86m

Rb-86m, $5S_{1/2}$ F=6.5 → $5D_{5/2}$ F=8.5 ….. 4.5



Rb-86m, $5S_{1/2}$ F=5.5 → $5D_{5/2}$ F=7.5 ….. 3.5



Offset = f($As_{1/2}$, IS) ⟶ $As_{1/2}$ and isotope shift for Rb-86m

Error analysis in progress…

- Enough statistics, statistic error ~ 10 kHz.
- Systematic errors:
  - Zeeman shifts due to the trapping B field.
  - Trap cloud position w.r.t. MBR beam.
  - Locking of MBR.
  - Power broadening.
  - No big effects from A.C. Stark shifts.

  - Mostly determined when working on Rb85/87.