Multi-grid experimental apparatus for the study of ultracold Rydberg-Rydberg interaction

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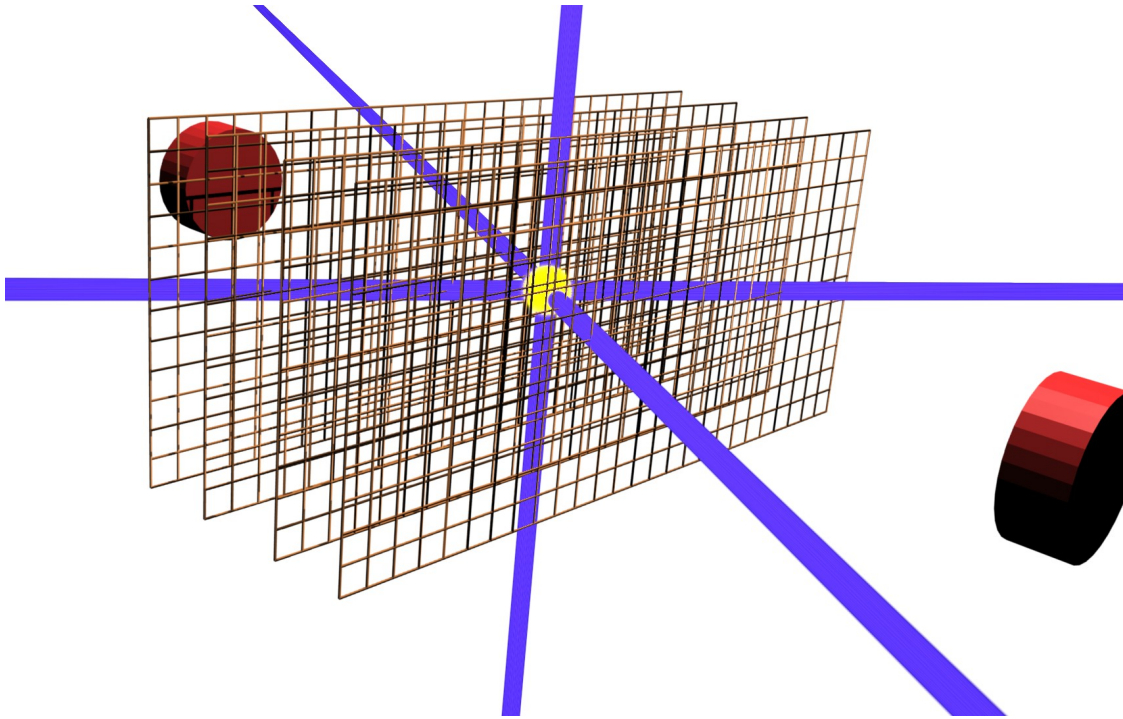
17 June 2011

Apparatus

- Cs MOT
- Four parallel wire grids
- Two MCP detectors for ion and electron detection
- TOF and charged particle imaging
- $6s \rightarrow 6p \rightarrow 7s \rightarrow np$
- $6s \rightarrow 6p \rightarrow ns$



Background

VOLUME 47, NUMBER 6 PHYSICAL REVIEW LETTERS 10 AUGUST 1981

Resonant Rydberg-Atom–Rydberg-Atom Collisions

K. A. Safinya,[a] J. F. Delpech,[b] F. Gounand,[c] W. Sandner,[d] and T. F. Gallagher
Molecular Physics Laboratory, SRI International, Menlo Park, California 94025
(Received 22 June 1981)

VOLUME 80, NUMBER 2 PHYSICAL REVIEW LETTERS 12 JANUARY 1998

Resonant Dipole-Dipole Energy Transfer in a Nearly Frozen Rydberg Gas

W. R. Anderson,* J. R. Veale, and T. F. Gallagher
Department of Physics, University of Virginia, Charlottesville, Virginia 22901
(Received 4 August 1997)

VOLUME 80, NUMBER 2 PHYSICAL REVIEW LETTERS 12 JANUARY 1998

Many-Body Effects in a Frozen Rydberg Gas

I. Mourachko, D. Comparat, F. de Tomasi, A. Fioretti, P. Nosbaum,* V. M. Akulin,† and P. Pillet
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(Received 4 August 1997)

PHYSICAL REVIEW A **82**, 052501 (2010)

Direct evidence of three-body interactions in a cold ^{85}Rb Rydberg gas

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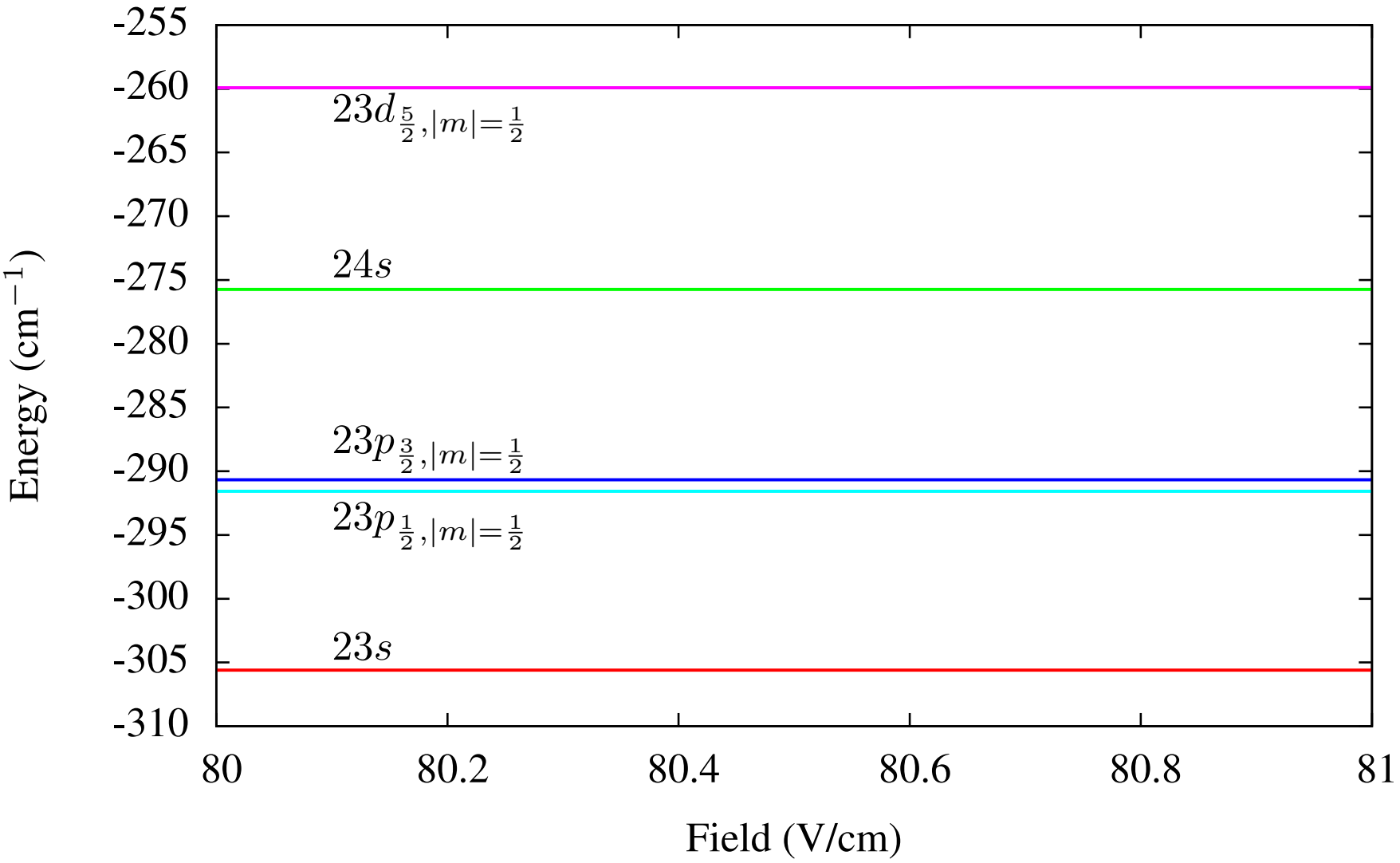
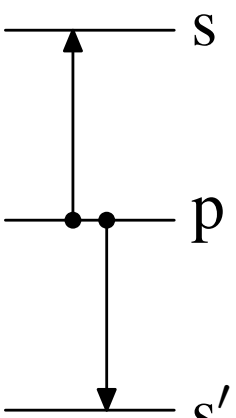
(Received 6 June 2010; published 1 November 2010)

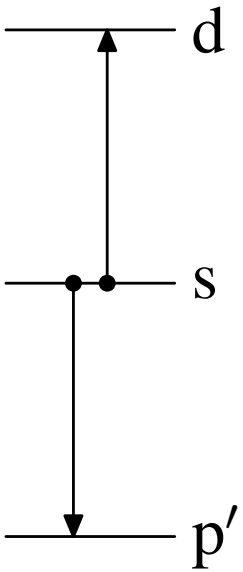
Cs Stark Map


-255
-260
-265
-270
-275
-280
-285
-290
-295
-300
-305
-310
Energy (cm^{-1})
$23d_{\frac{5}{2},|m|=\frac{1}{2}}$
$24s$
$23p_{\frac{3}{2},|m|=\frac{1}{2}}$
$23p_{\frac{1}{2},|m|=\frac{1}{2}}$
$23s$
80
80.2
80.4
80.6
80.8
81
Field (V/cm)

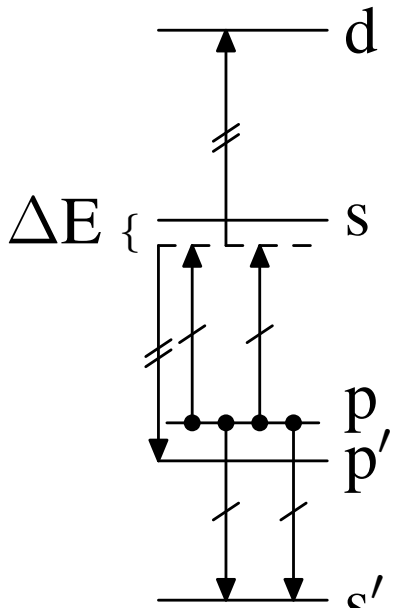
Energy Difference



80.2 V/cm



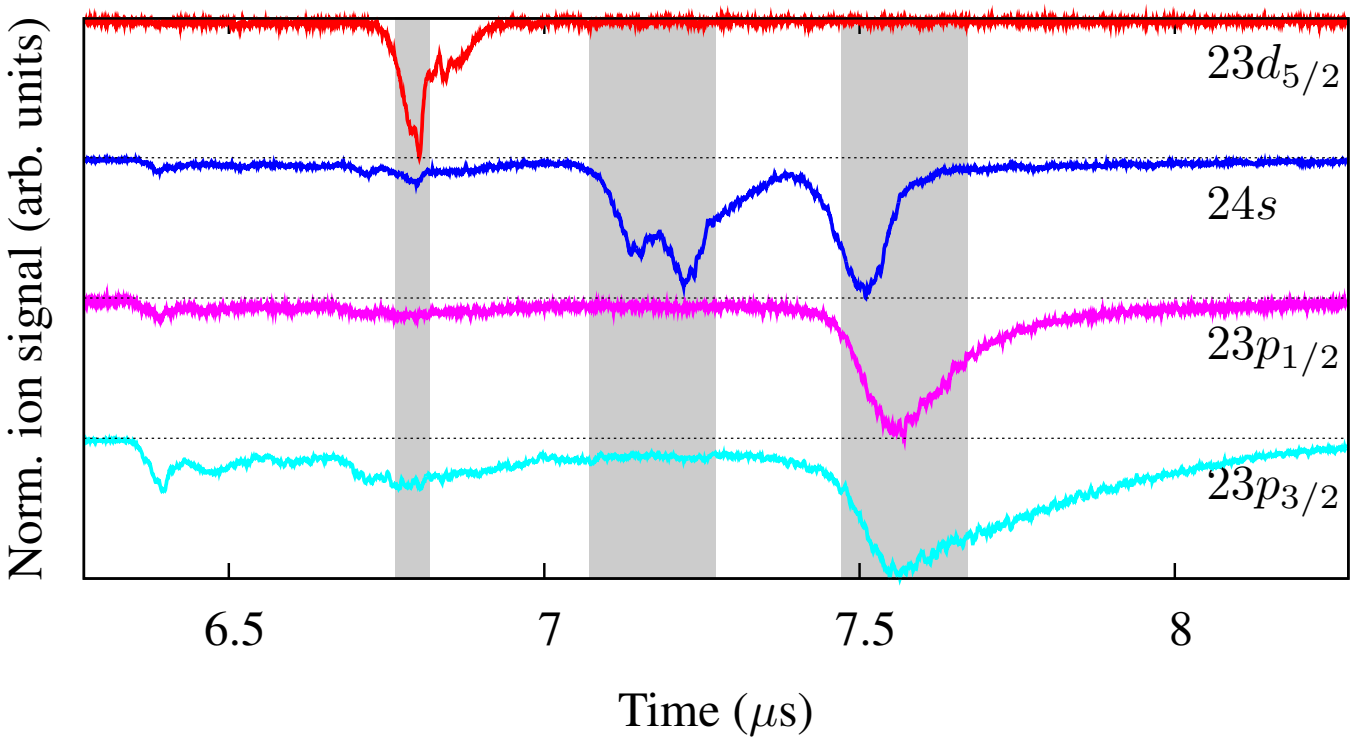
80.7 V/cm



80.25 V/cm

Oscilloscope Traces

500 ns excitation in 79 V/cm, 2 μs delay, SFI

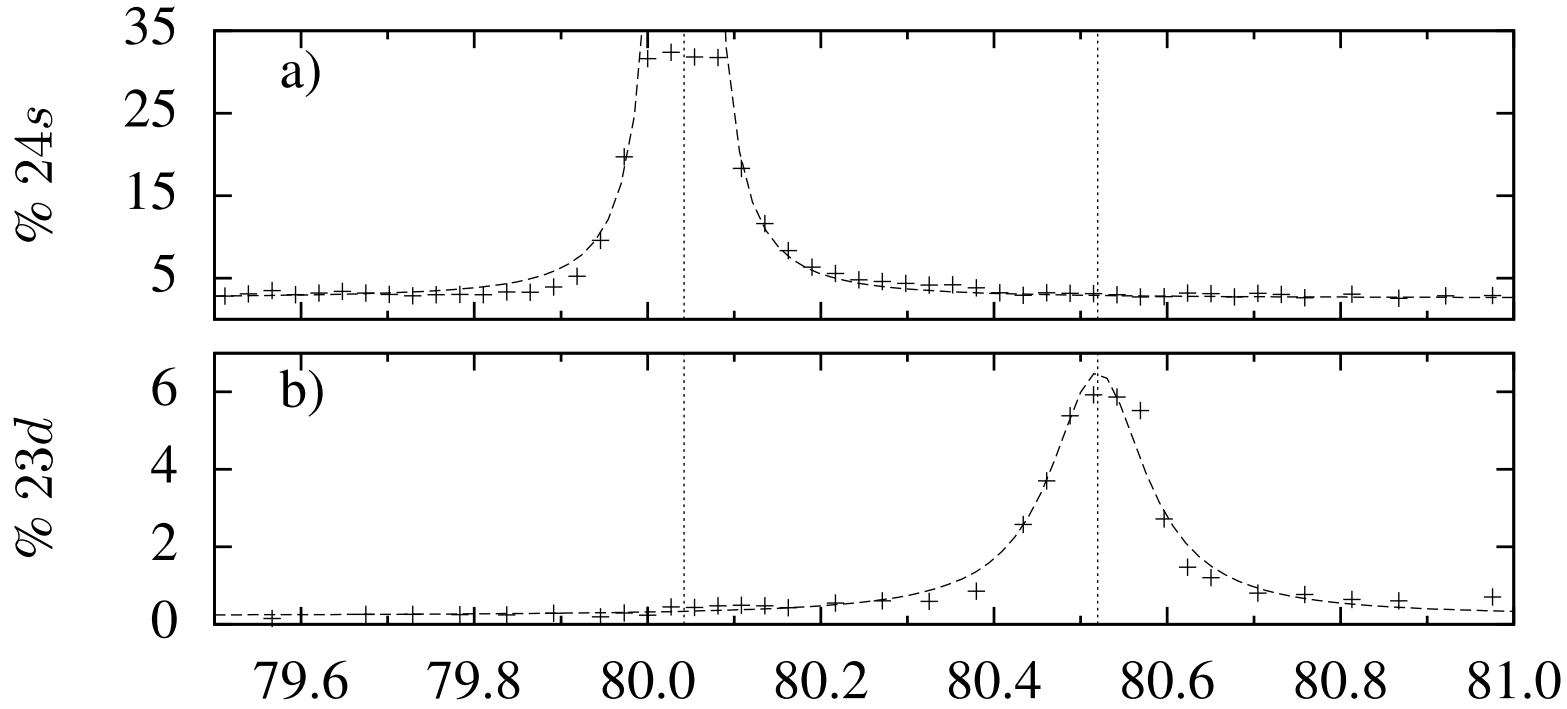


$$\begin{pmatrix} d_{out} \\ s_{out} \\ p_{out} \end{pmatrix} = \begin{pmatrix} 1.0494 & -0.1911 & -0.1223 \\ -0.039 & 2.559 & -0.3257 \\ -0.0104 & -1.3685 & 1.448 \end{pmatrix} \begin{pmatrix} d_{in} \\ s_{in} \\ p_{in} \end{pmatrix}$$

Removes signal overlap and BB transfer

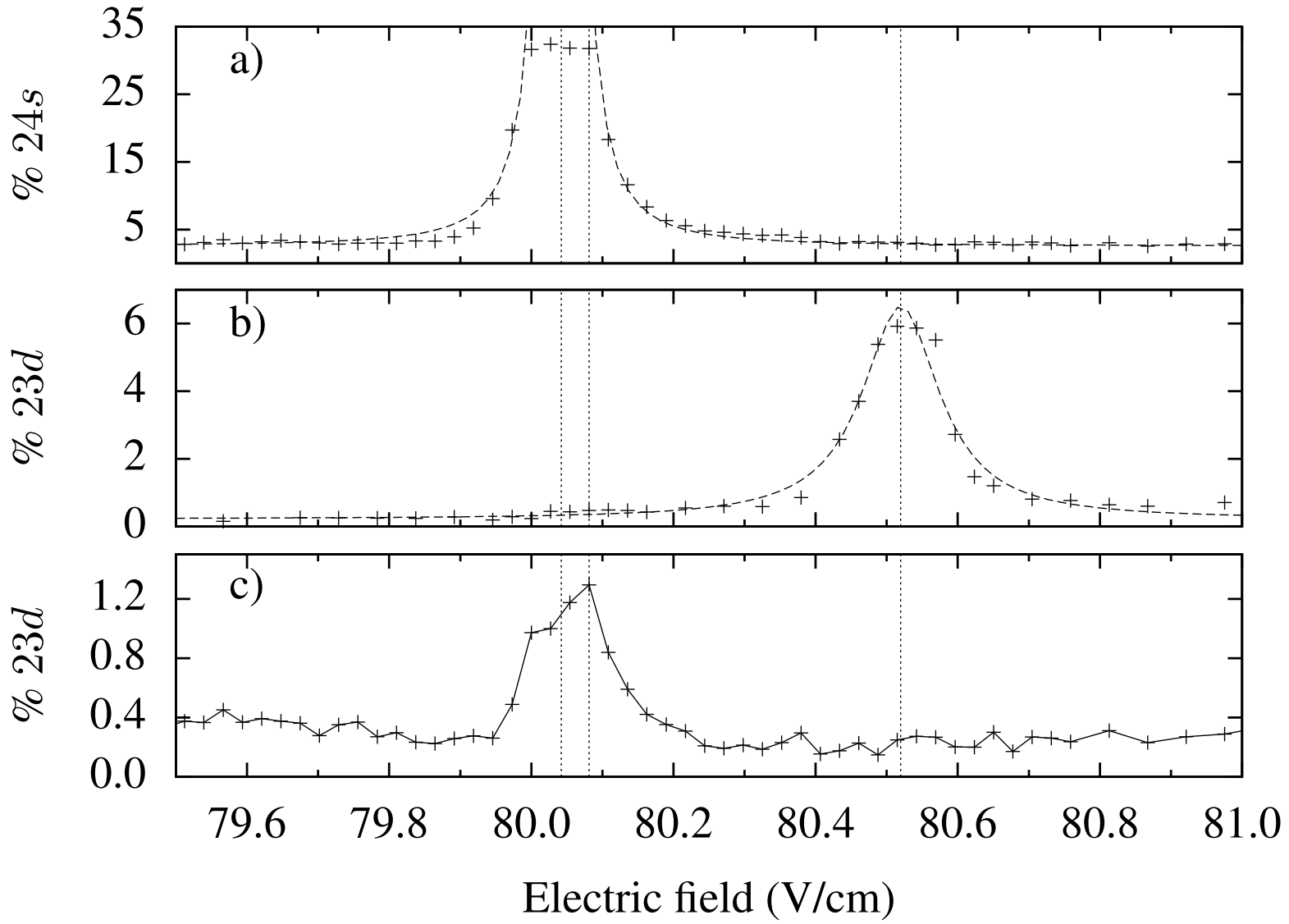
Two Body Resonances

$$23p_{3/2} + 23p_{3/2} \rightarrow 23s + 24s$$

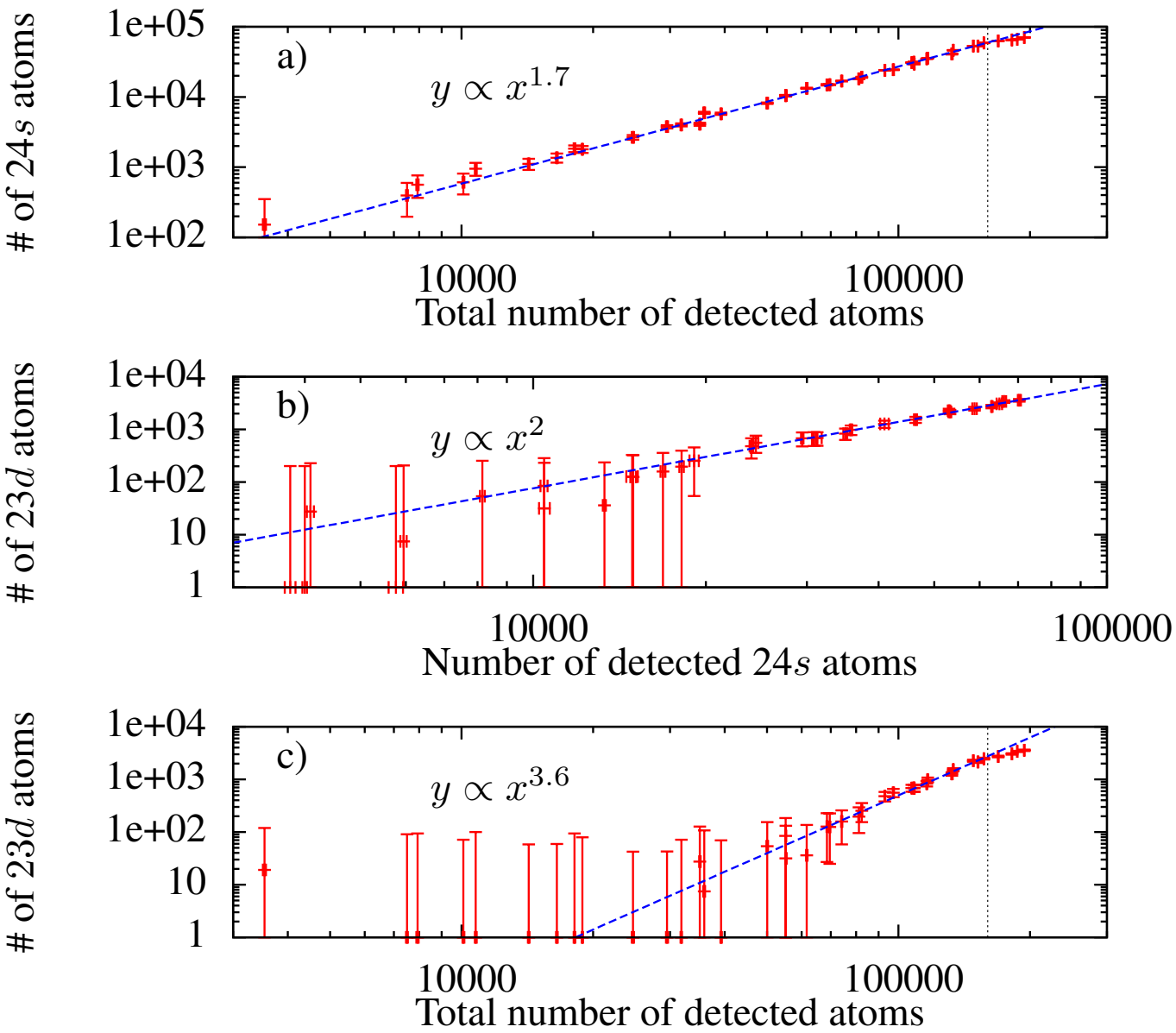


$$24s + 24s \rightarrow 23p_{1/2} + 23d_{5/2}$$

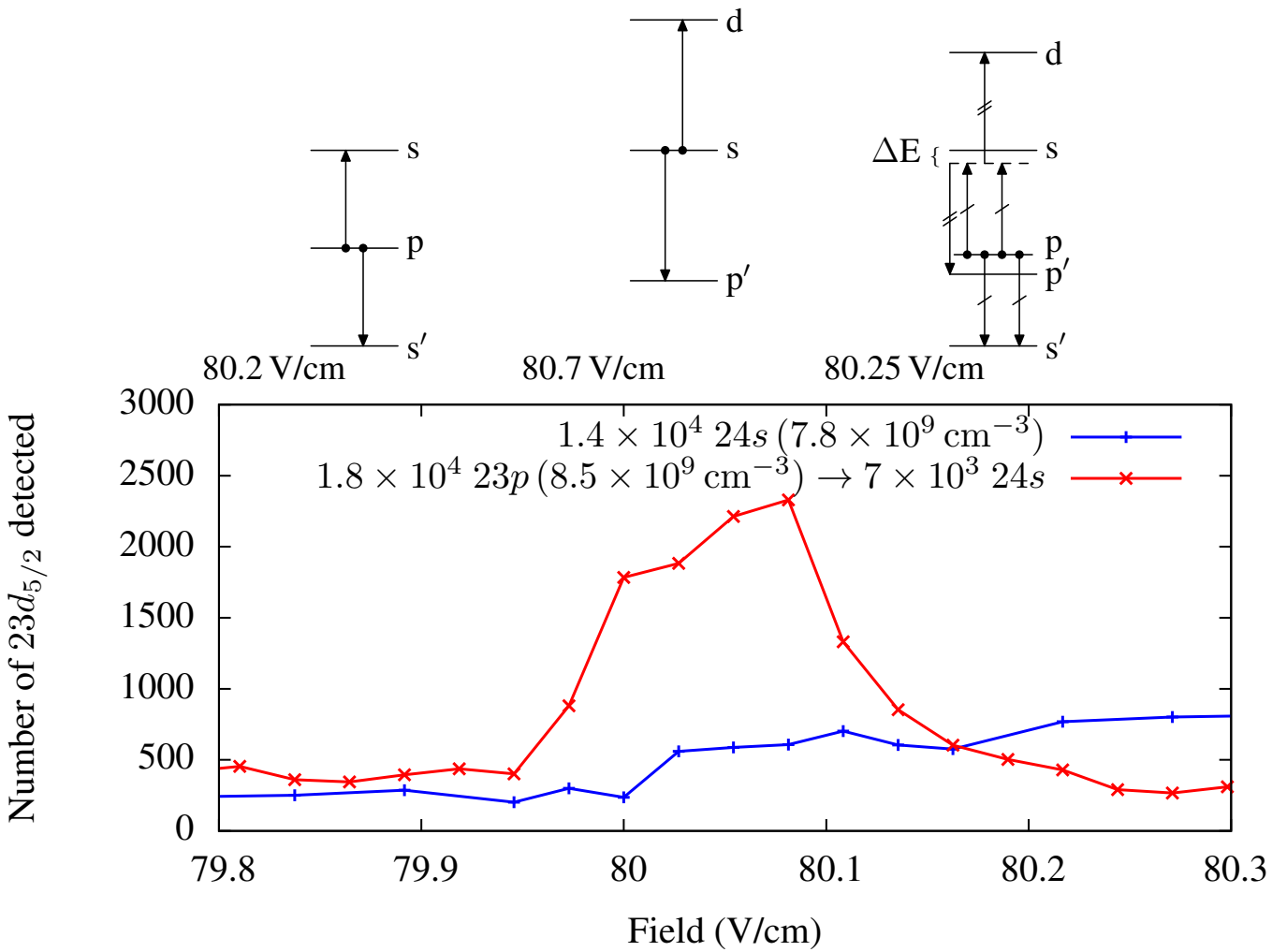
$4 \times 23p_{3/2} \rightarrow 2 \times 23s + 23p_{1/2} + 23d_{5/2}$



Intensity


a)
$y \propto x^{1.7}$
# of 24s atoms
1e+05
1e+04
1e+03
1e+02
10000
100000
Total number of detected atoms
b)
$y \propto x^{2}$
# of 23d atoms
1e+04
1e+03
1e+02
10
1
10000
100000
Number of detected 24s atoms
c)
$y \propto x^{3.6}$
# of 23d atoms
1e+04
1e+03
1e+02
10
1
10000
100000
Total number of detected atoms

True 4-body process?



On-resonant 4-body process creates more $23d$ atoms than off-resonant two-body $s \rightarrow d$ process!

Conclusions

- New apparatus for Rydberg and ion/electron imaging experiments
- Observation of direct product of Stark-tuned 4-body Rydberg interaction
  - Density scaling approaching n^4
  - On-res. 4-body process $>$ Off-res. 2-body process
- Next: Further control multibody Rydberg interaction via RF or B-field.