JOHANNES GUTENBERG UNIVERSITÄT MAINZ

GSI HELMHOLTZ GEMEINSCHAFT

Institut für Kernchemie an der Universität Mainz

Proposal for:

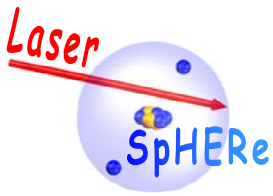
Nuclear Charge Radius Measurement of the Halo Isotope ^{11}Be

with

BeTINa

Wilfried Nörtershäuser

powered by:



Laser Spectroscopy of **H**ighly Charged Ions and **E**xotic **R**adioactive Nucl**e**i
(Helmholtz Young Investigators Research Group)
http://www.kernchemie.uni-mainz.de/laser/

The BeTiNa Collaboration

(Beryllium Trap for Investigating Nuclear Charge Radii)

University of Mainz / GSI Darmstadt
Christopher Geppert, Jürgen Kluge, Natalya Miski-Oglu, Wilfried Nörtershäuser, Rodolfo Sanchez, Monika Zakova

University of Tübingen, Germany
Claus Zimmermann, Guido Ewald

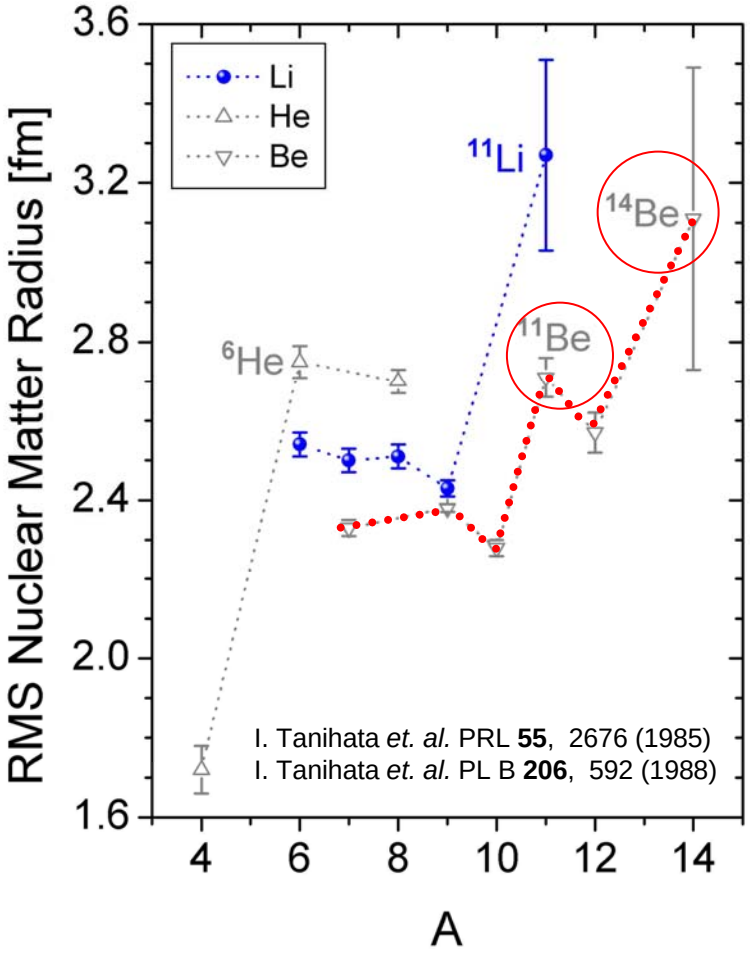
University of Ulm, Germany
Ferdinand Schmidt-Kaler

University of Windsor, Canada
Gordon Drake

University of New Brunswick, Canada
Zong-Chao Yan

Support at ISOLDE from
the ISOLTRAP and the COLLAPS Collaboration
(Klaus Blaum, Alexander Herlert, Magda Kowalska, Rainer Neugart, etc.)

Nuclear Matter Radii



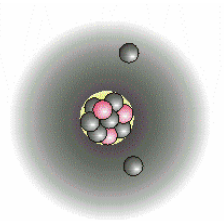
^{6}Li	^{7}Li	^{8}Li	^{9}Li	^{11}Li
∞	∞	838 ms	178 ms	8.6 ms
1^{+}	$3/2^{-}$	2^{+}	$3/2^{-}$	$3/2^{-}$

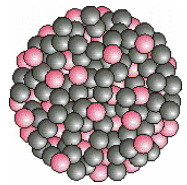
Neutron Halo Nucleus

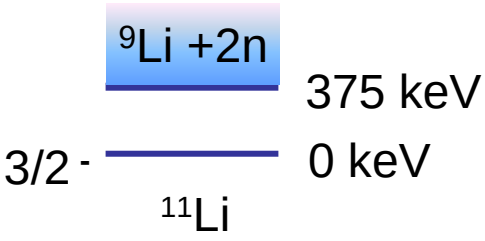
Stable Nucleus

^{11}Li = ^{9}Li + n + n

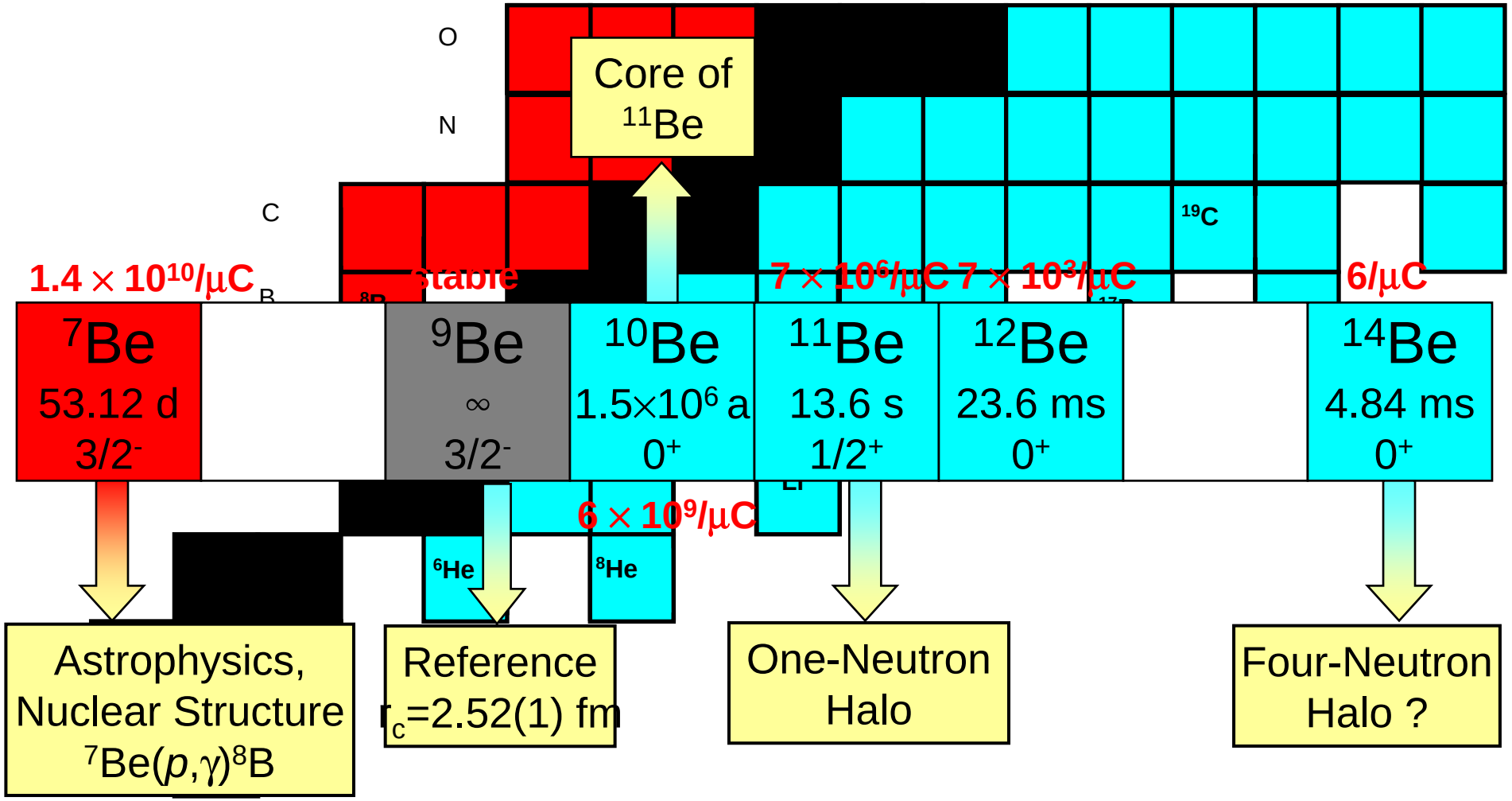
^{208}Pb





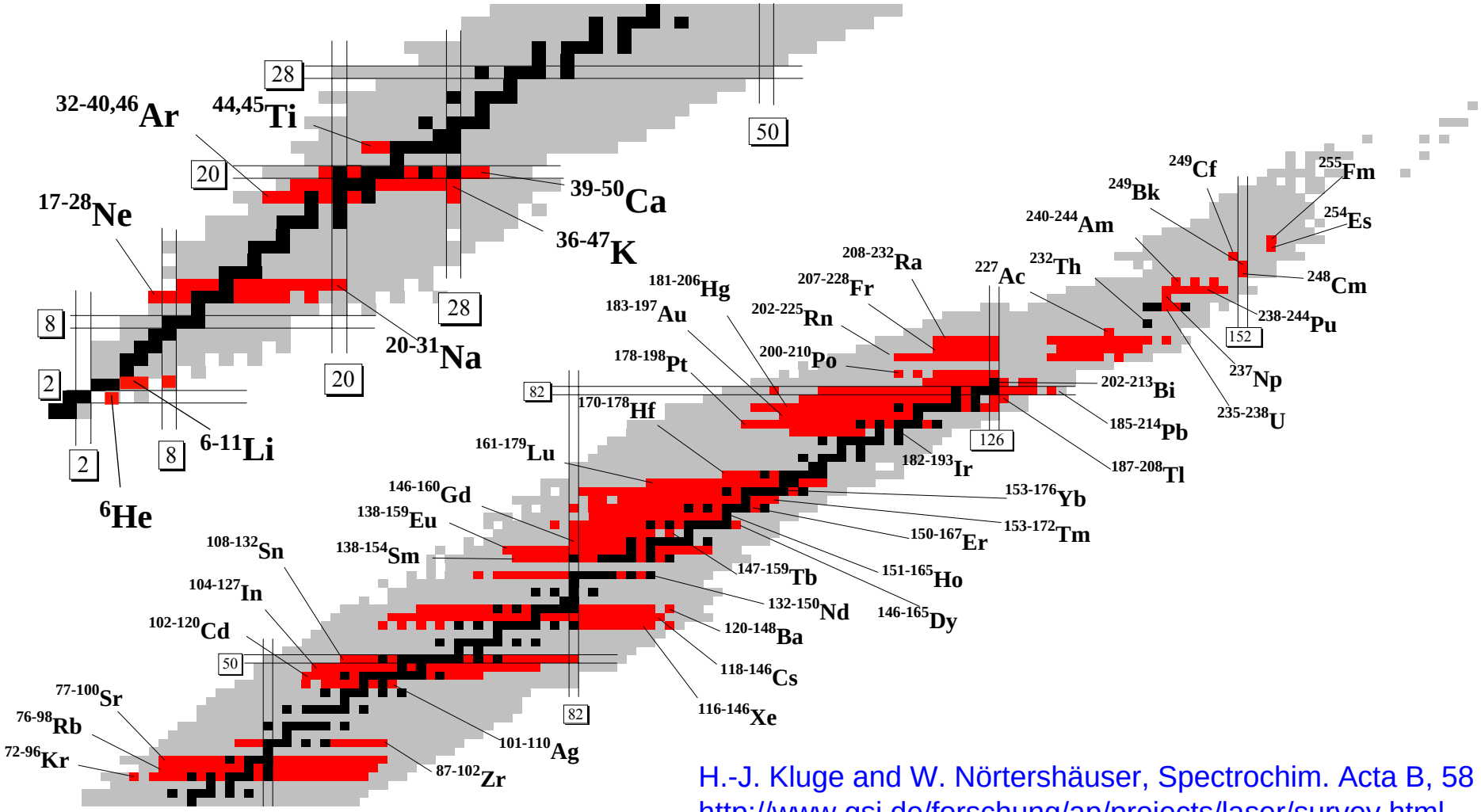


Beryllium Isotopes of Interest



Summary of Charge Radii Measurements on Radioactive Nuclei

Exclusive approach for a model-independent $<r_c^2>$ determination of short-lived



H.-J. Kluge and W. Nörtershäuser, Spectrochim. Acta B, 58 (20

http://www.gsi.de/forschung/ap/projects/laser/survey.html

Isotope Shift

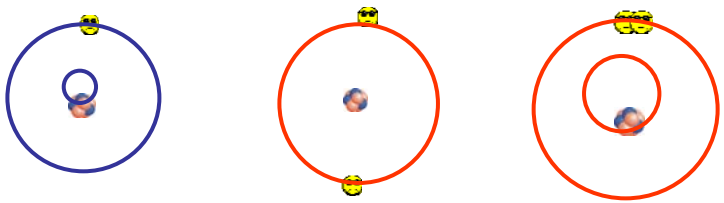
= Frequency difference in an electronic transition between two

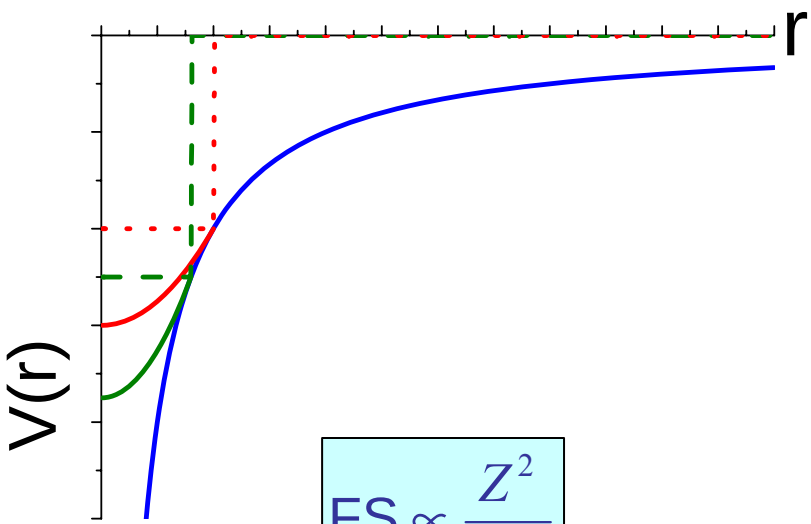
$$\Delta\nu_{IS} = \Delta\nu_{MS} + \Delta\nu_{FS}$$

$$\frac{2\pi Z}{3} |\psi(0)|^2 \delta\langle r^2\rangle$$ **Field Shift**

Mass Effect

$\Delta\nu_{MS} \sim (A-A')/AA'$





$$MS \propto \frac{A - A'}{AA'} \xrightarrow{A \gg 1} \frac{1}{A^2}$$

$$FS \propto \frac{Z^2}{\sqrt[3]{A}}$$

Charge Radius Determination of Light Elements

$$\Delta\nu_{IS} = \Delta\nu_{MS} + \Delta\nu_{FS}$$

$$\Delta\nu_{FS} = \frac{2\pi Z}{3}\,\Delta|\psi(0)|^2\,\delta\langle r^2\rangle$$

EXPERIMENT

THEORY

$$\textbf{Charge Radius } \delta\langle r^2\rangle^{A,A'} = \frac{\Delta\nu^{A,A'}_{\text{measured}} - \Delta\nu^{A,A'}_{\text{MS, Theory}}}{C}$$

Field effect for light atoms on the order of 1 MHz, mass effect some 10 GHz

→ High Accuracy in Experiment **and** Theory required!

Required: Accurate Theory

non-relativistic ground state energy of atomic ground states

Helium : 2.903 724 377 034 119 598 311 (1) **Rel. Accuracy:** 5×10^{-22}

Lithium: 7.478 060 323 650 3 (71) **Rel. Accuracy:** 1×10^{-12}

G.W.F. Drake *et al.*, PRA **65**, 054501 (2002)
Z.-C. Yan and G.W.F. Drake, PRA **66,** 042504 (2003)

Example of an Isotope Shift Calculation:

μ/m	11454.668 801	± 0.000 029
$(\mu/m)^2$	-1.793 864	± 0.000 004
$\alpha^2\,\mu/m$	0.190	± 0.055
$\alpha^3\,\mu/m$, 1 e^-	-0.078	± 0.005
$\alpha^3\,\mu/m$, 2 e^-	0.011 2	± 0.000 2
Total MS	**11453.00**	**± 0.06 MHz**

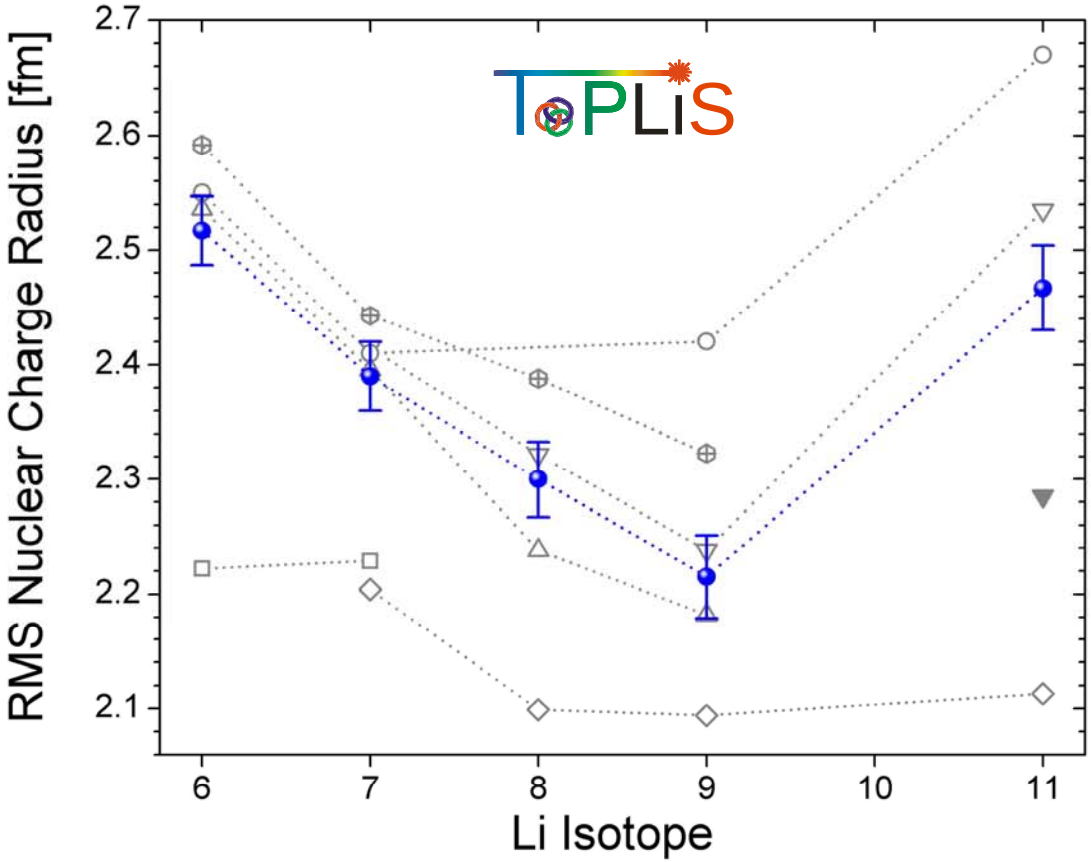
$2s\ ^2S_{1/2} - 3s\ ^2S_{1/2}$ transition mass shift calculation for $^7Li - ^6Li$

Z.-C. Yan and G.W.F. Drake,
PRA **66,** 042504 (2002)

Recent Measurements

December 2003:
^{6,7,8,9}Li at GSI Darmstadt, High-Resolution RIMS
G.Ewald et al., PRL 93, 113002 (2004)

March 2004:
^{6}He in a MOT at Argonne
L.-B. Wang et al. PRL 93, 142501 (2004)



Experiment
- Isotope Shift (this experiment, 2004)

Theory
- *ab initio* No-Core Shell Model
- Large-Basis Shell Model (P. Navrátil 2003, 1998)
- Greens-Function Monte Carlo (S. C. Pieper 2001/2002)
- Stochastic Variational Multi Cluster (Y. Suzuki, 2002)
- Fermionic Molecular Dynamics (T. Neff, 2005)
- Dynamic Correlation Model (M. Tomaselli, 2002)

September / October 2004
^{11}Li at TRIUMF
R. Sanchez et al., PRL 96, 033002 (2006)

Required: Accurate Theory

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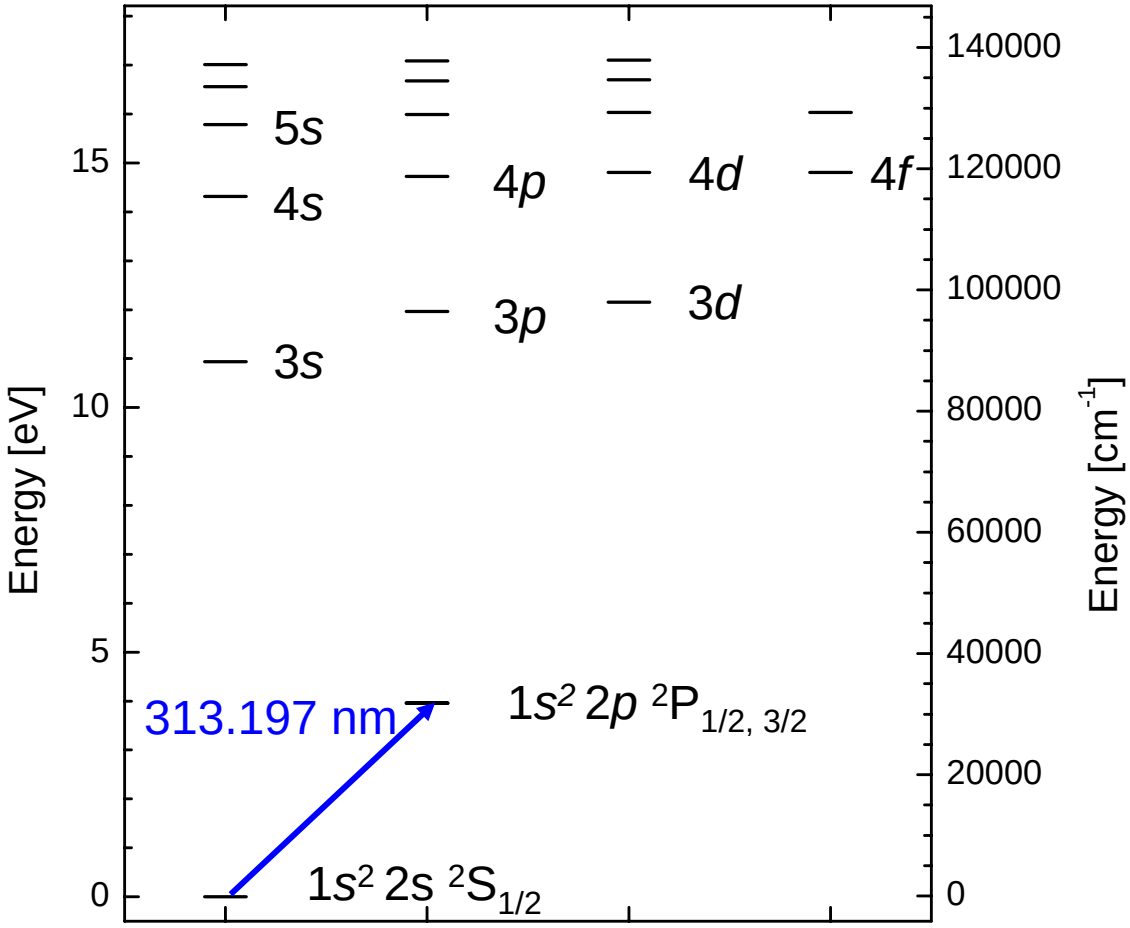
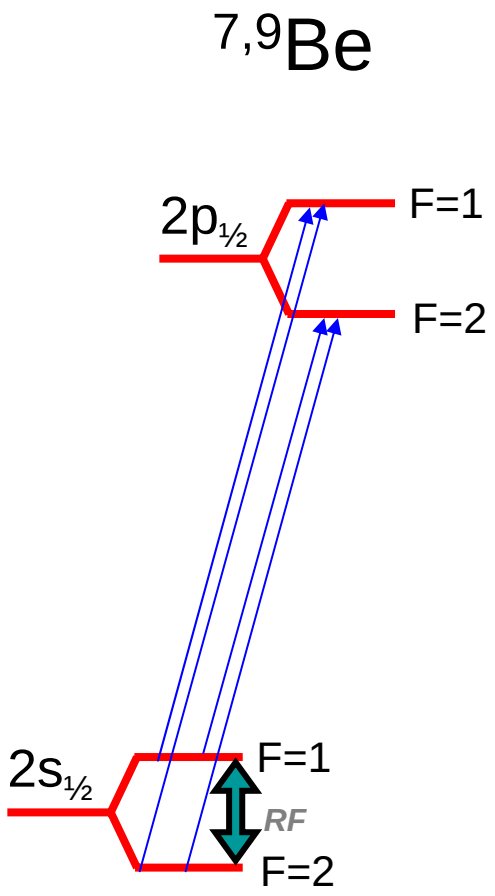
Z.-C. Yan and G.W.F. Drake,
PRA **66,** 042504 (2002)

so-far only possible for three-electron systems → go for Be^+

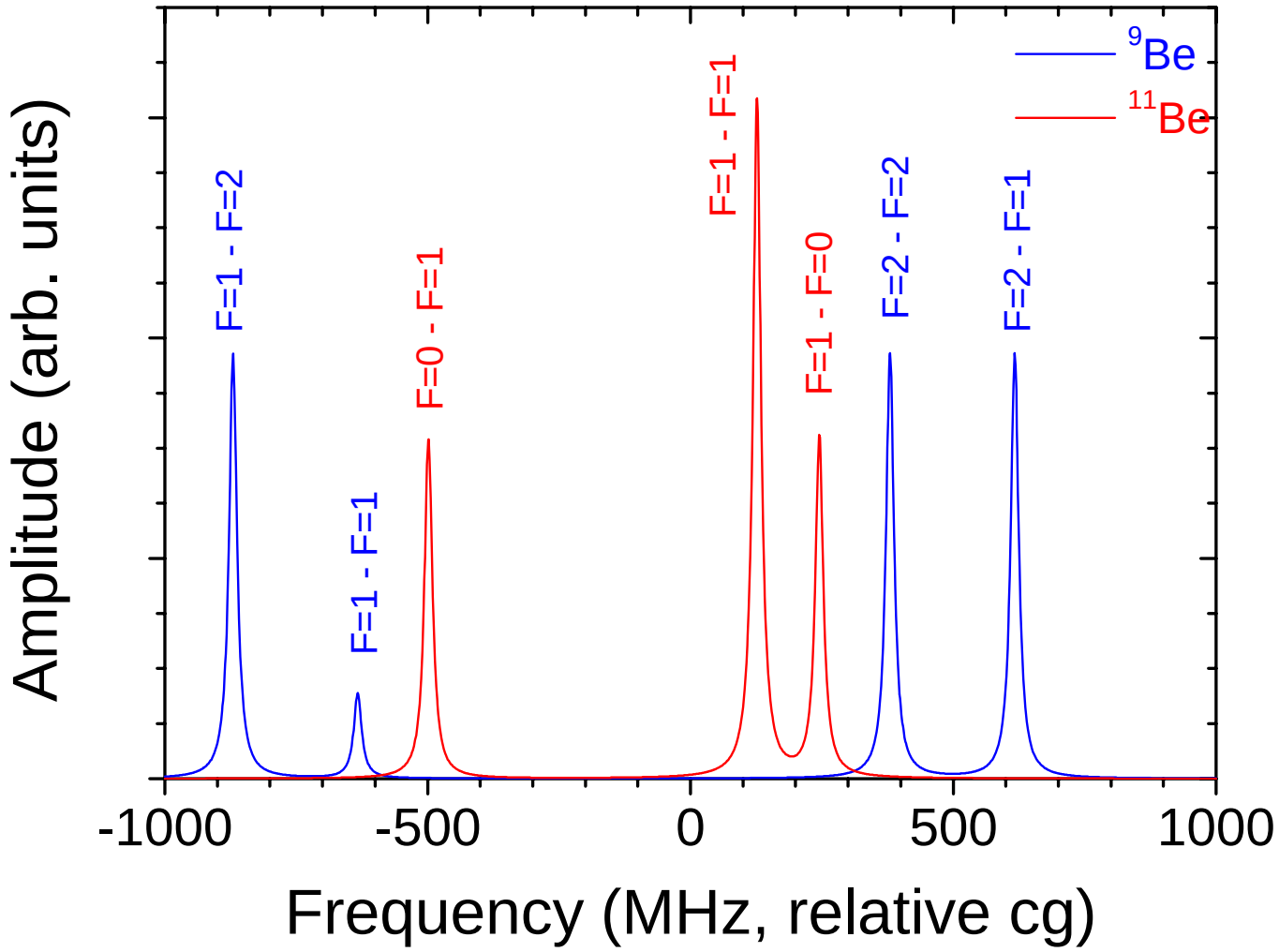
Be^+ Level Scheme

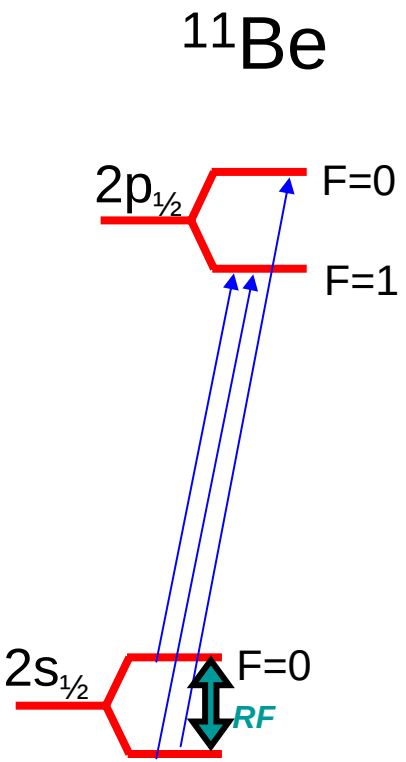




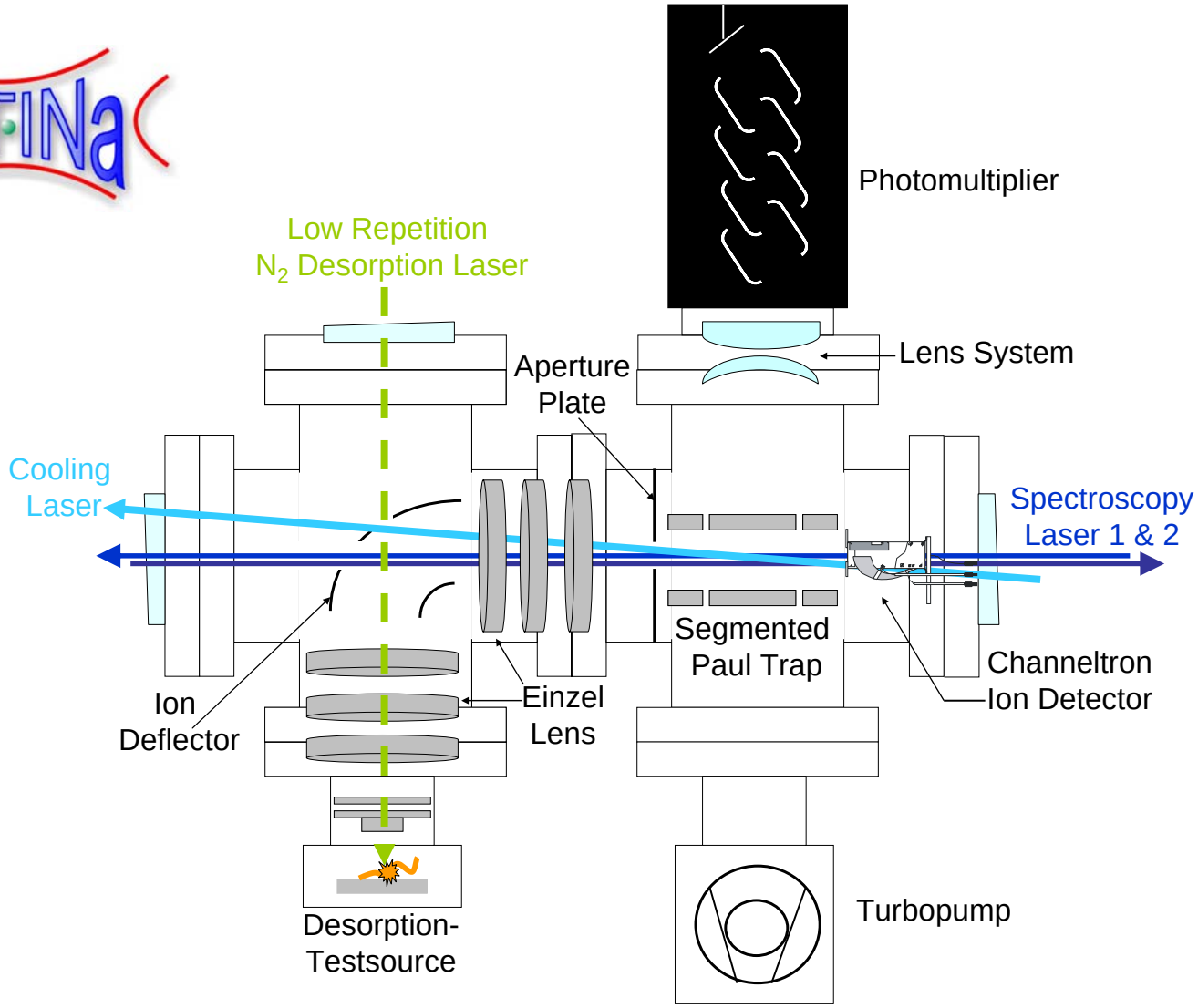
Simulated Spectra

$\Gamma_{nat} \approx 20$ MHz

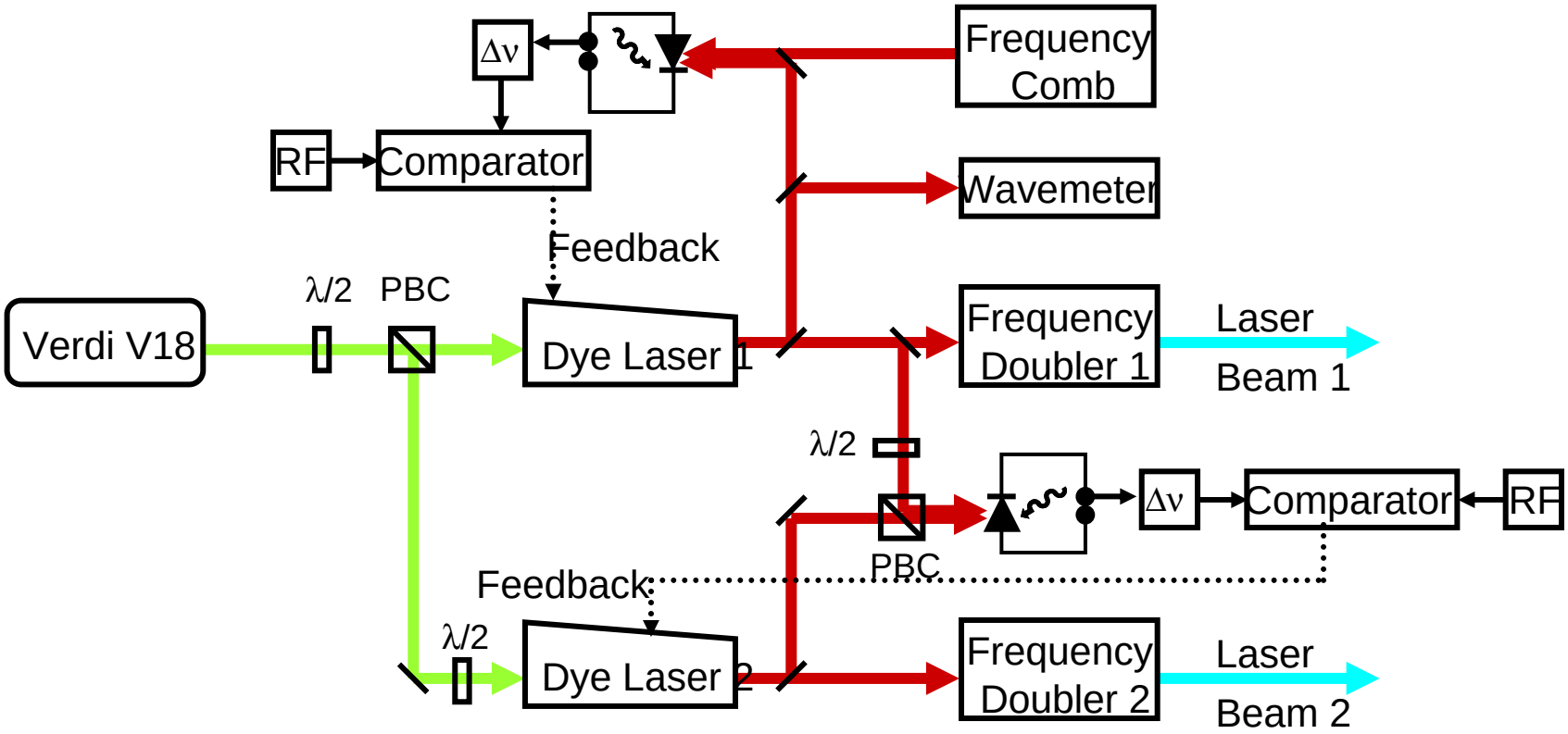




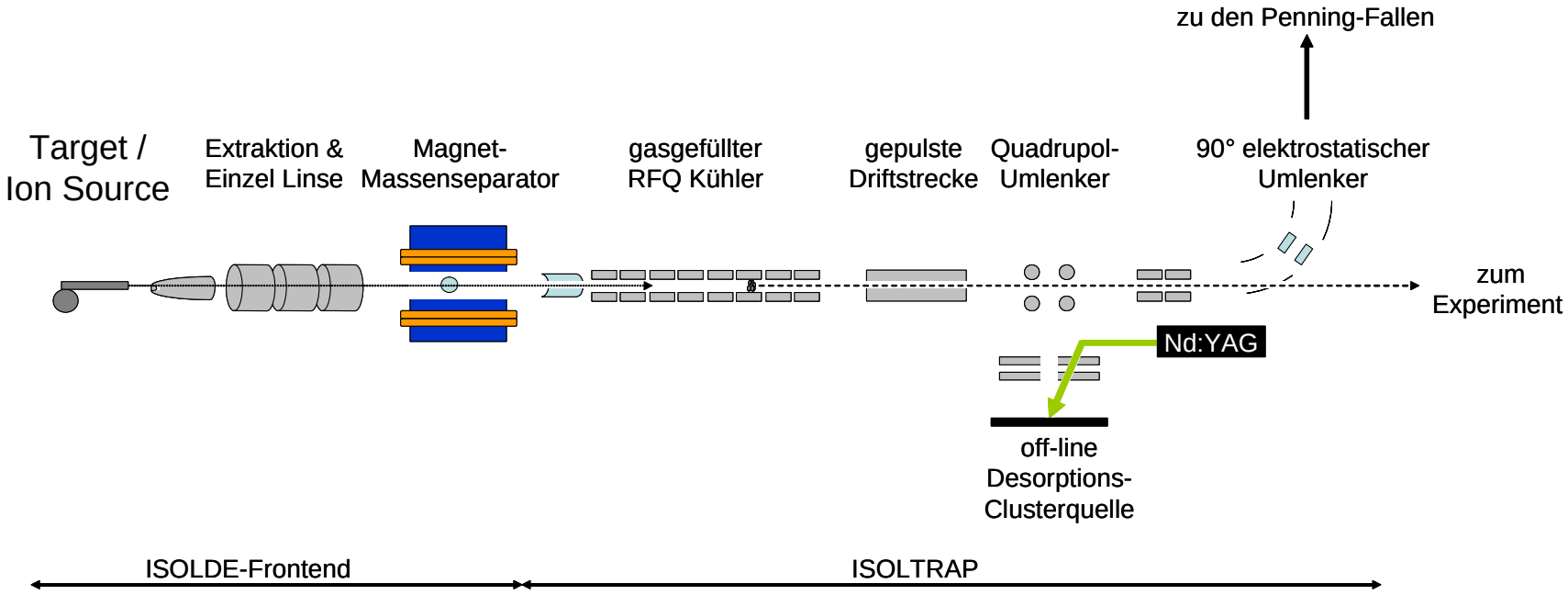
Experimental Setup



Laser System



BeTINa @ ISOLDE



Timetable

Quarter of year 2006-2008	1	2	3	4	5	6	7	8	9	10	11	12
Development												
Lasersystem and Stabilization	■	■	■	■	■	■	■					
Design and Manufacturing of the Paul Trap	■	■	■	■	■	■	■					
Design and Test of the Detection System		■	■	■	■	■						
Data Acquisition System	■	■	■	■	■	■	■	■	■	■	■	■
Off-line Ion Source + Ion Optics	■	■	■	■	■	■	■					
Preparing Work at ISOLTRAP		■			■							
Tests with ^{9}Be at Mainz												
Complete Assembly					■	■	■					
Test Measurements						■	■	■				
^{11}Be at ISOLDE												
Setup and Tests								■	■	■		
Measurements										■	■	
Publishing Results											■	■

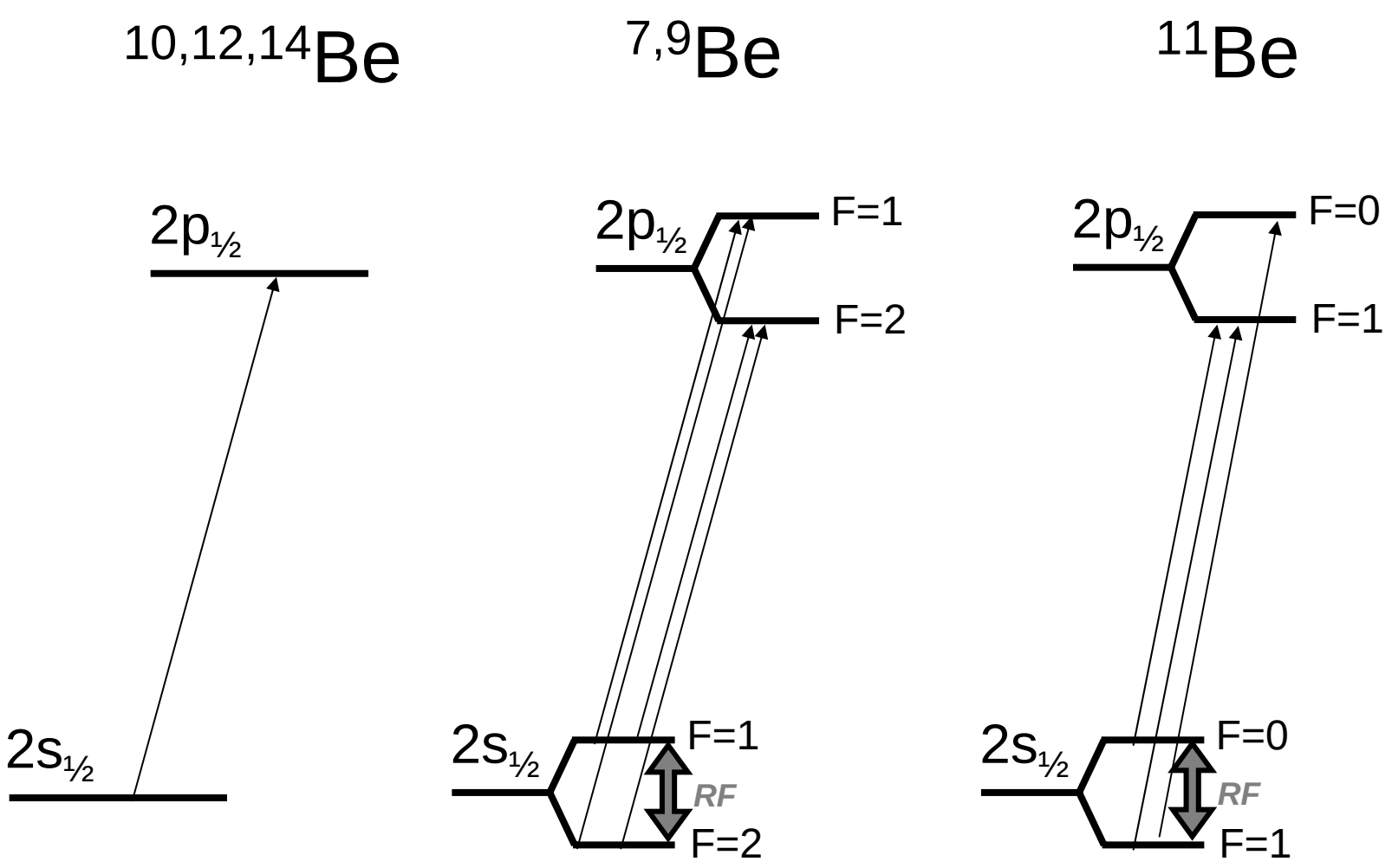
Goal: Measurements at ISOLDE in 2008

Thank you

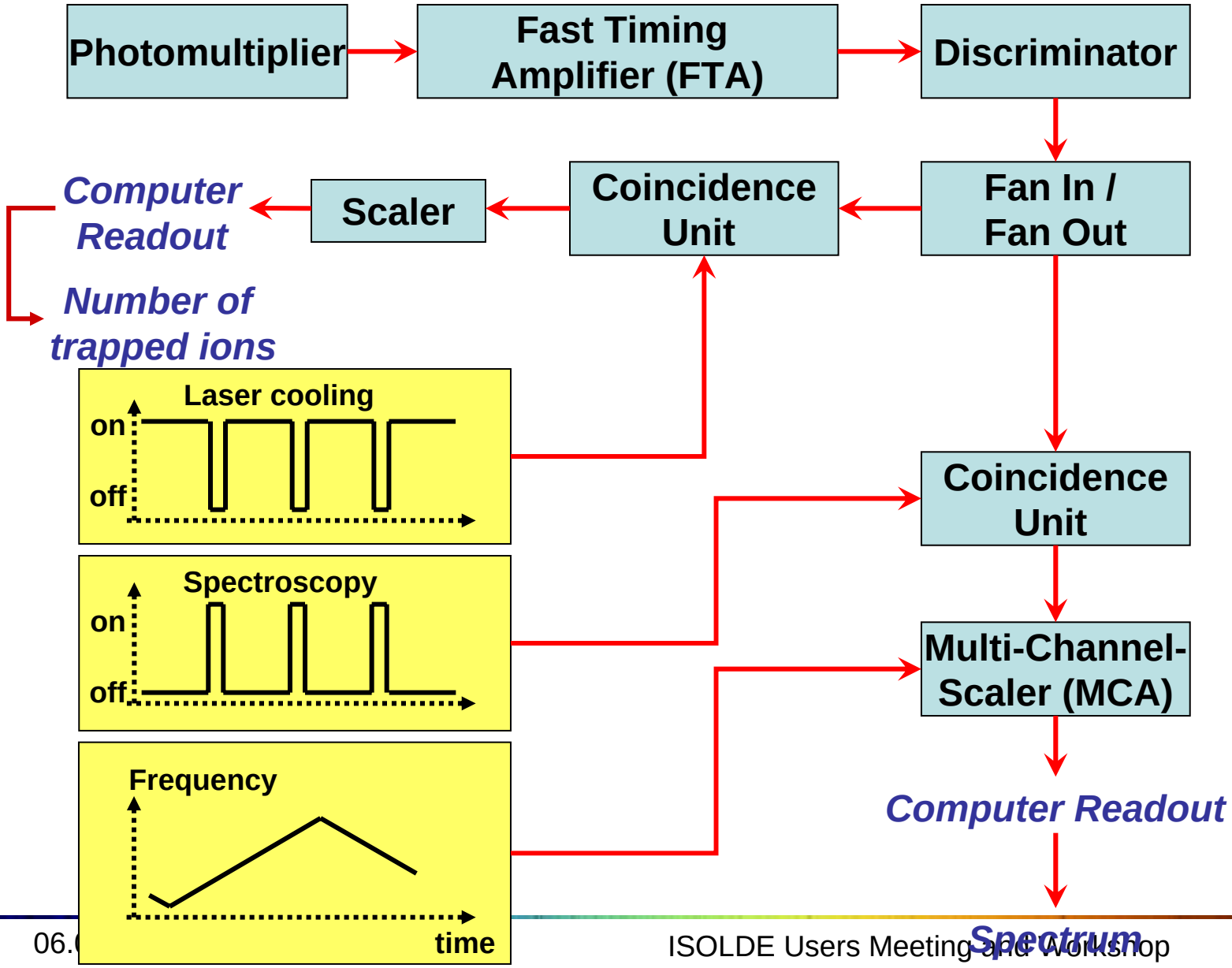
for

your attention

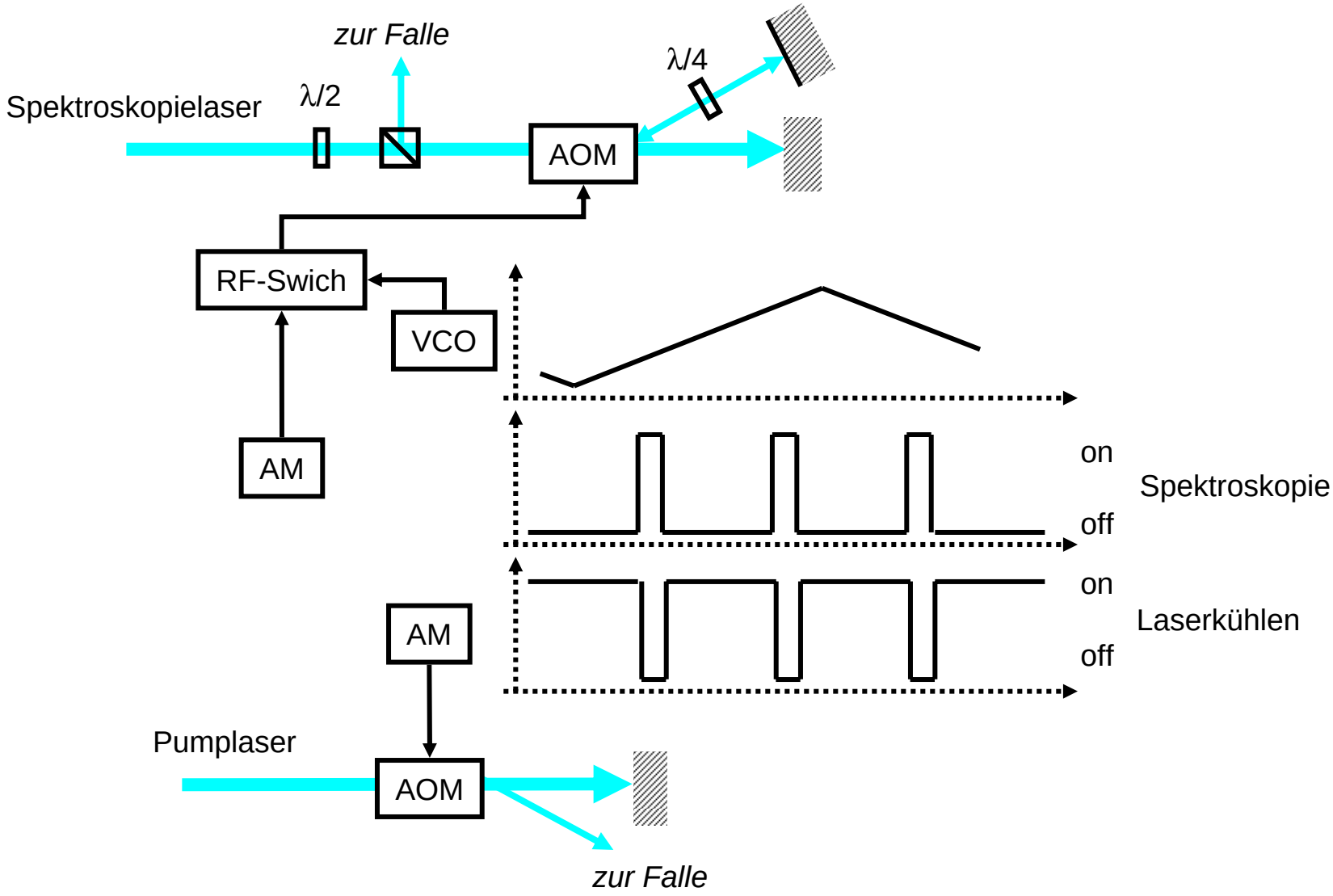
Level Schemes for Cooling and Detection



Scanning and Cooling – Sorting Photons

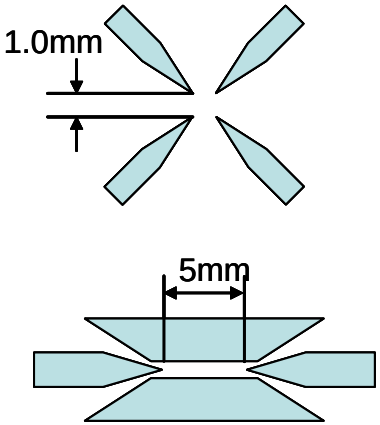


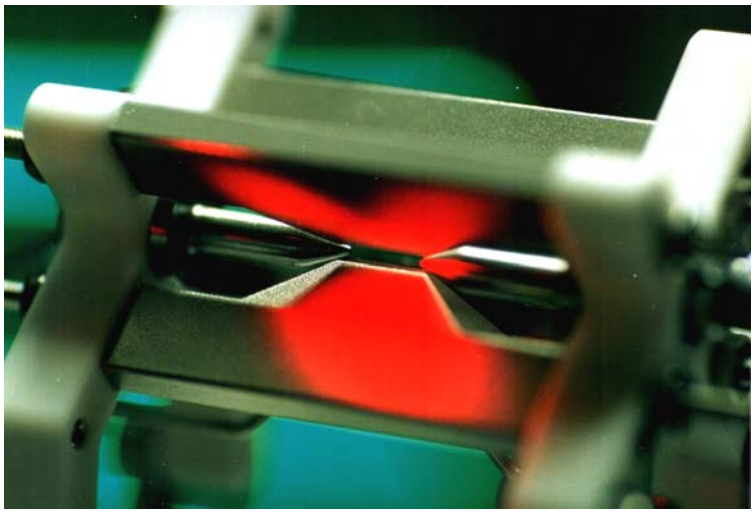
Scanning and Cooling - Realization

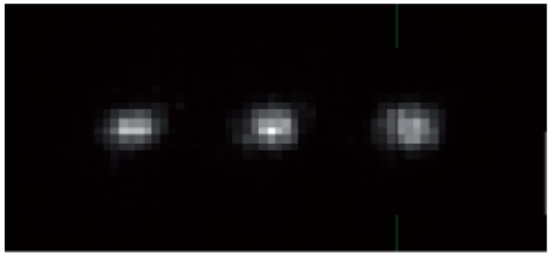


Paul Trap Designs

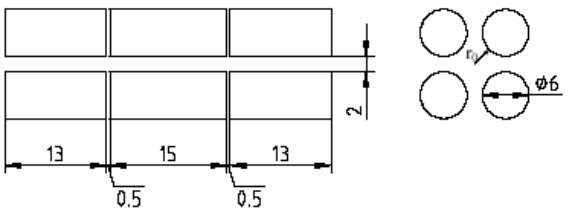
(a)

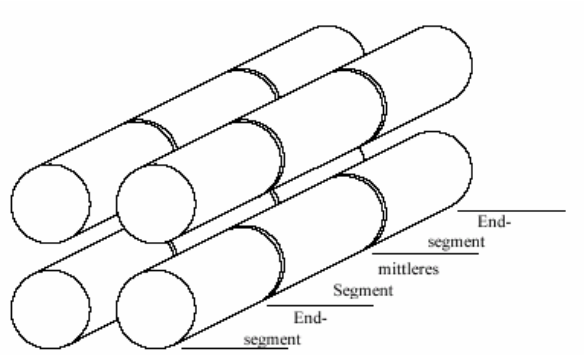






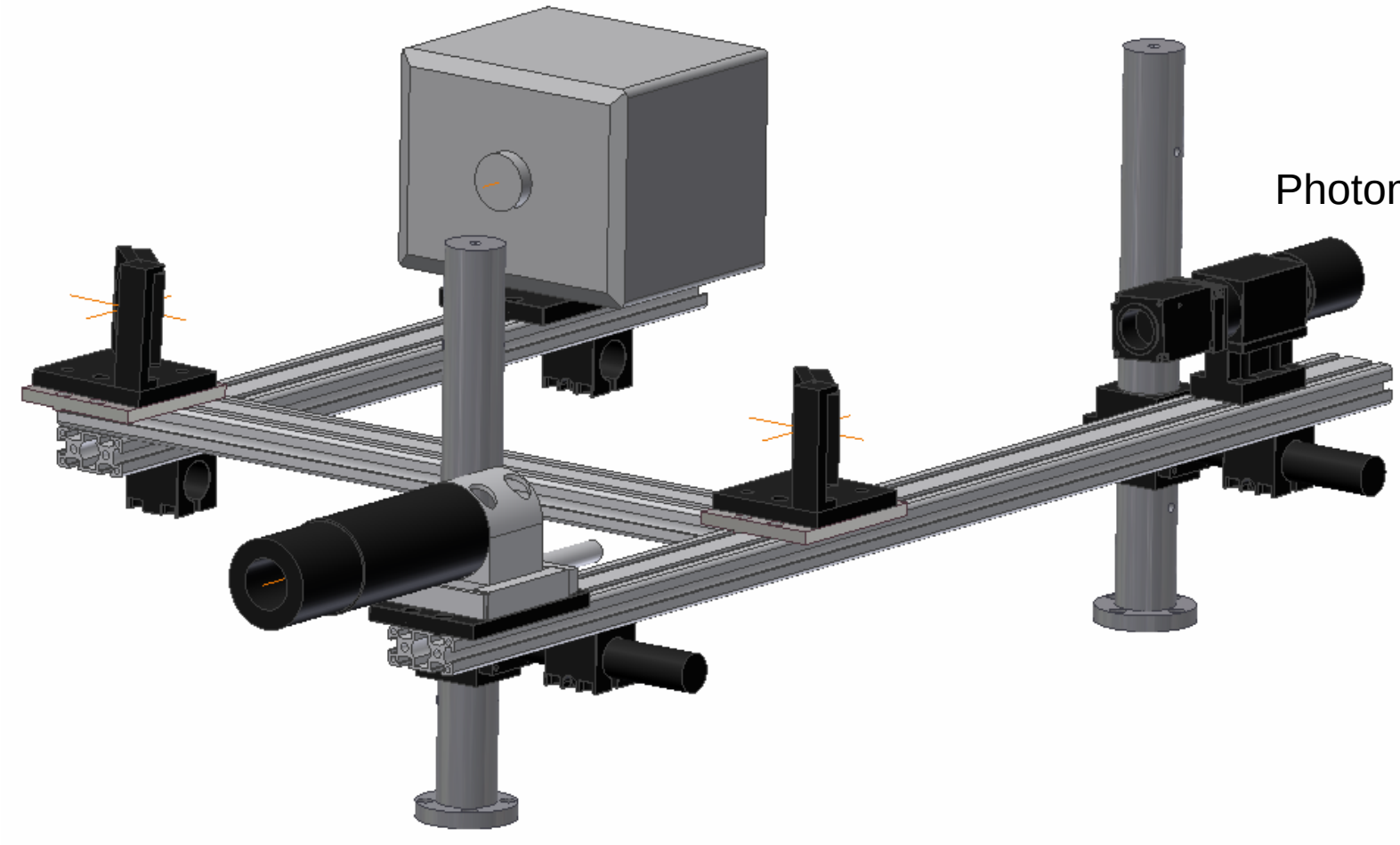
(b)





Optical Detection System

CCD Camera iXon UV up to 500 frame/s



Photomultiplier

Production Rates

Tab. 1: Spins, Massen [1], Produktionsraten, Halbwertszeiten, Massen- [2] und Ladungsradien [5] der verschiedenen Berylliumisotope. Die effektiven Masseradien in [2] wurden unter Annahme einer gaussförmigen Verteilung gewonnen, der Ladungsradius von ^{9}Be stammt aus der elastischen Elektronenstreuung. [10].

Isotop	I^{π}	Masse [amu]	Produktionsrate @ ISOLDE	$T_{1/2}$	R_{rms}^{matter} [fm]	R_{rms}^{charge} [fm]
^{7}Be	$3/2^{-}$	7.0169298 (7)	$1{,}4\times10^{10}/\mu A$	53d	$2.33 \pm 0{,}02$	?
^{9}Be	$3/2^{-}$	9.0121822 (10)	-	∞	$2{,}38 \pm 0{,}01$	$2{,}519 \pm 0{,}012$
^{10}Be	0^{+}	10.0135338 (10)	$6\times10^{9}/\mu A$	1.6 My	$2.28 \pm 0{,}02$	?
^{11}Be	$1/2^{+}$	11.0216577 (69)	$7\times10^{6}/\mu A$	13,8 s	$2{,}71 \pm 0{,}05$	?
^{12}Be	0^{+}	12.026921 (16)	$7\times10^{3}/\mu A$	21,3 ms	$2{,}57 \pm 0{,}05$	?
^{14}Be	0^{+}	14.04289 (14)	6 /μA	4,4 ms	$3{,}11 \pm 0{,}38$	?

Outline

- Motivation
- Charge Radii of Light Nuclei at the Dripline
- Theory
- Experimental Approach
- Outlook - Timetable