Synchrotron based photoelectron anisotropy determination on laser cooled and trapped atoms

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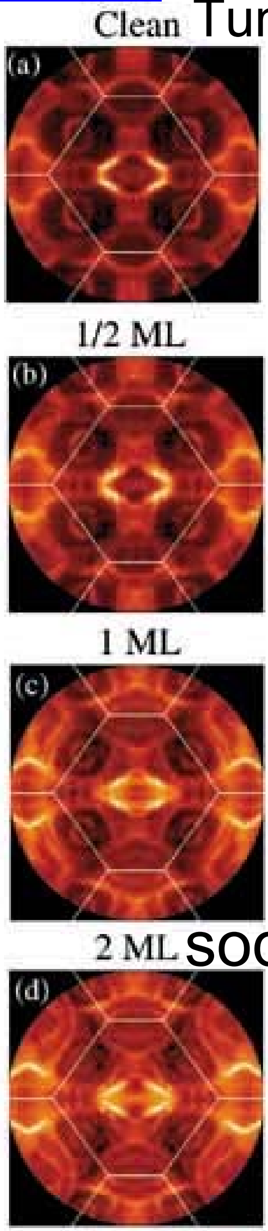
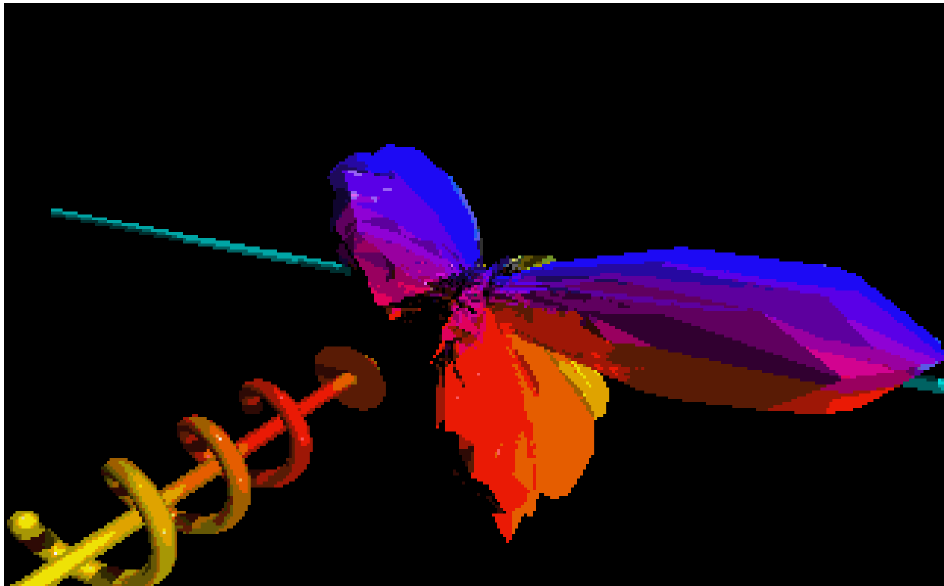
The study of photoelectron-angular distribution can provide significant information about the photo-atom interaction not available from total cross section measurements.

Tungsten



sodium

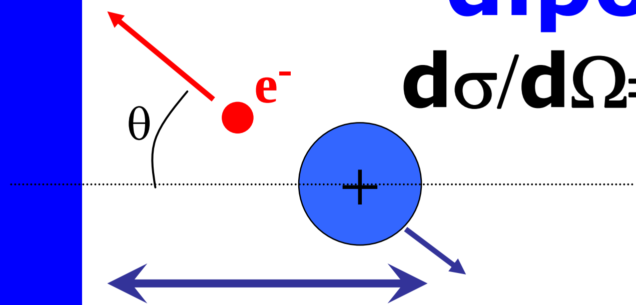
Electron detection suffers from very low efficiency



QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

I. Povis

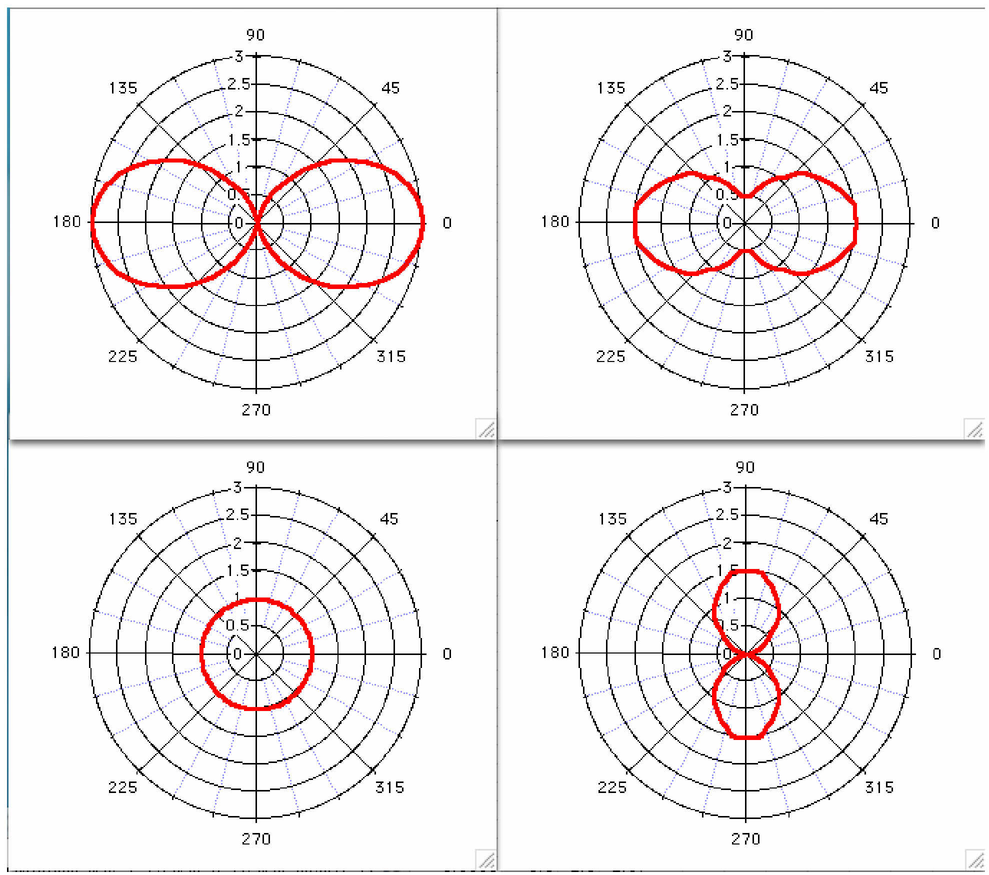
Differential cross section in the dipole approximation



$$d\sigma/d\Omega = \sigma/4\pi[1+\beta(3\cos^2\theta-1)/2]$$

$\beta=2$

$\beta=1$



$\beta=0$

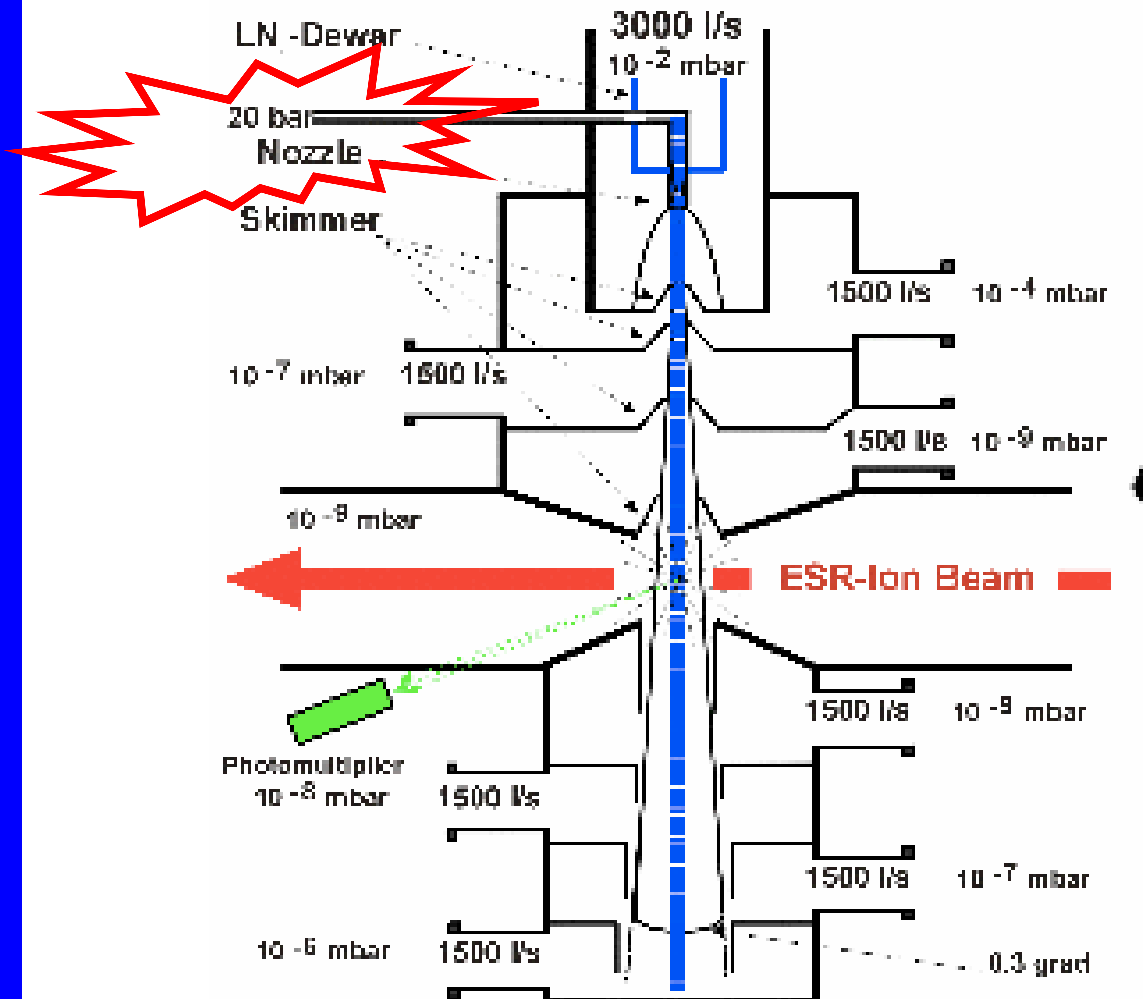
$\beta=-1$

State of the art methods available today

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Rev. Sci. Strum. **69**, 3809 (1998)

Cold target recoil ion momentum spectroscopy



QuickTime™ and a
GIF decompressor
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However, there has been considerable experimental effort over the years to reduce the velocity distribution of the ions. The use of supersonic beams in ionization experiments is one method that results in a much smaller transverse velocity spread. Another example is the use of laser cooling techniques leading to very ‘‘cold’’ trapped atoms with temperatures down to;1 μK—or colder in the case of Bose–Einstein condensation.

T. Reddish Rev. Sci. Instr. **72**,p1330 2001

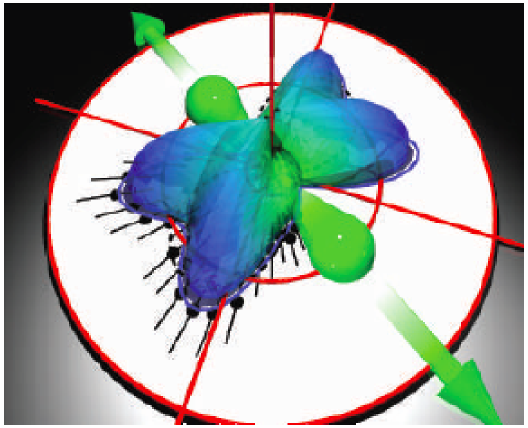
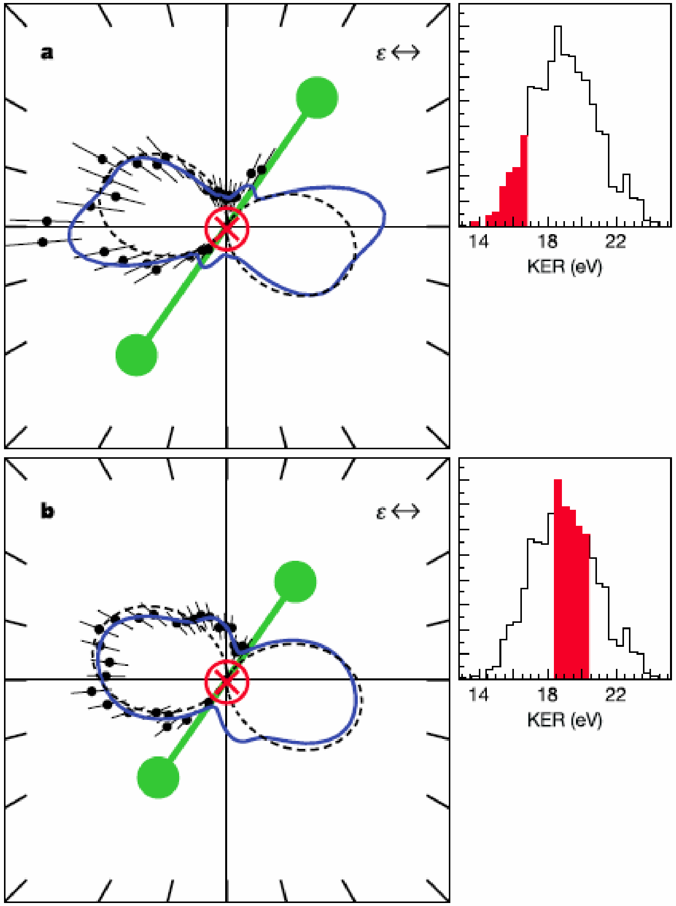


Figure 1 A three-dimensional 'photograph'[1] of the double ionization of deuterium molecules,

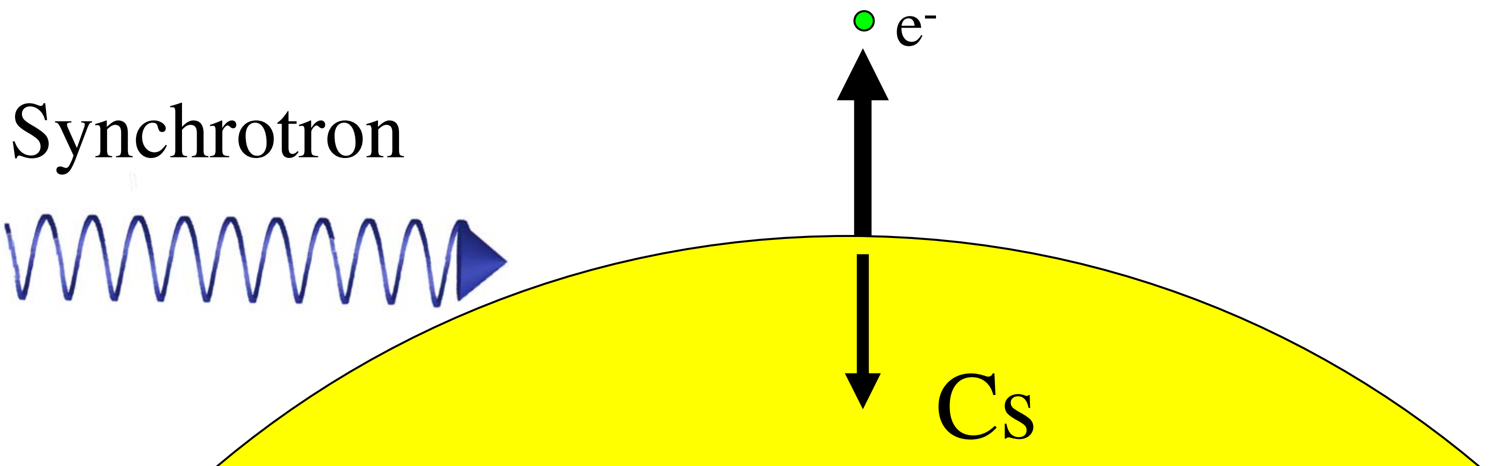
T. Reddish Nature **431**, p404 2004



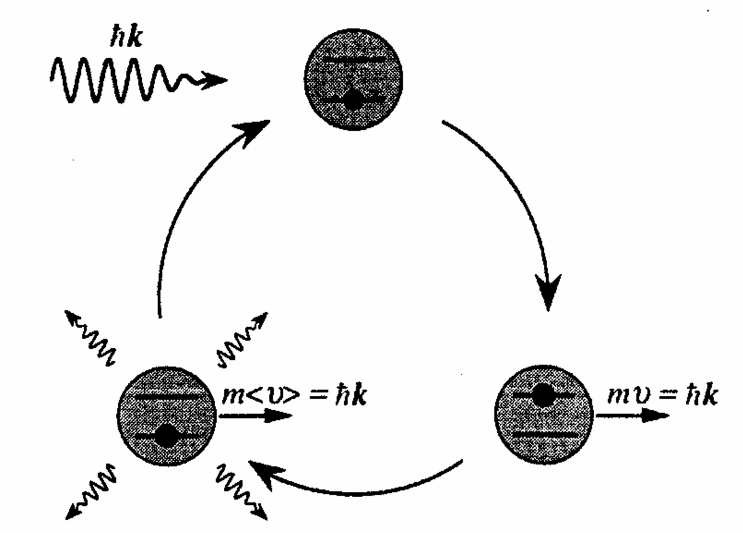
Nature **431**, p437 2004

Using ions we get 4π angular detection efficiency
The problem is:

- The thermal energy prior to ionization is in the meV range.
- The recoil energy is about μeV !
- **solution**: use very cold samples.
- With supersonic jets it is possible to achieve thermal energy of 10 μeV in 1D.



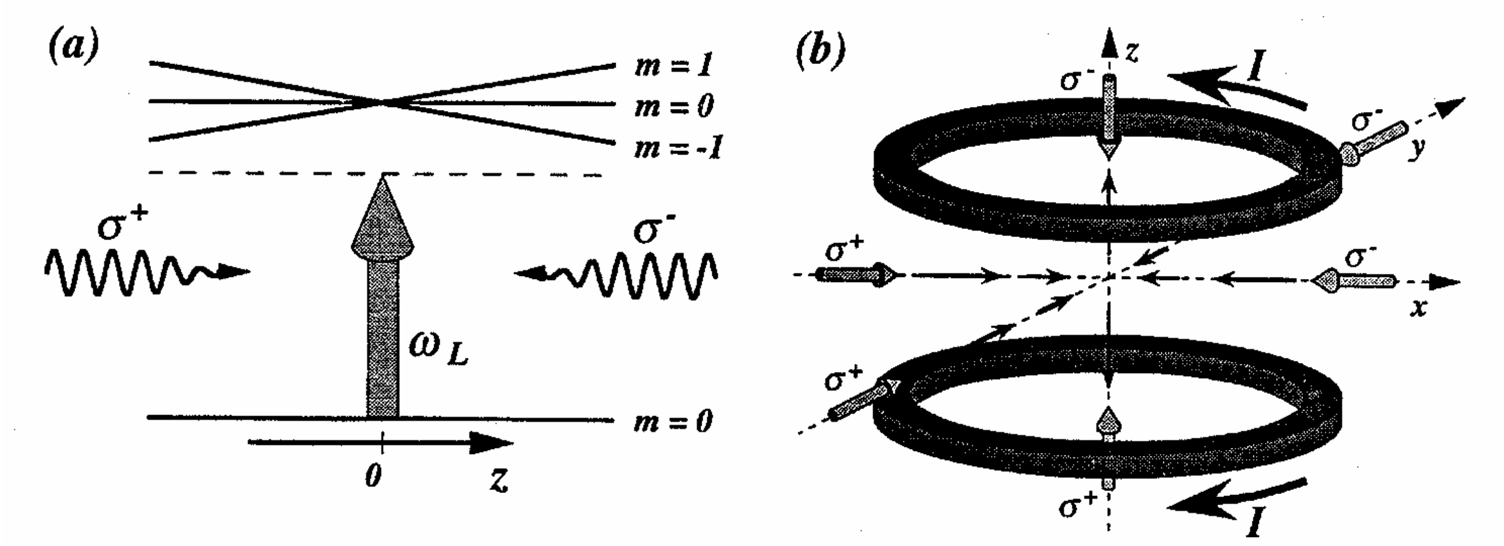
Laser cooling and trapping



MOT- Magneto-optical trap

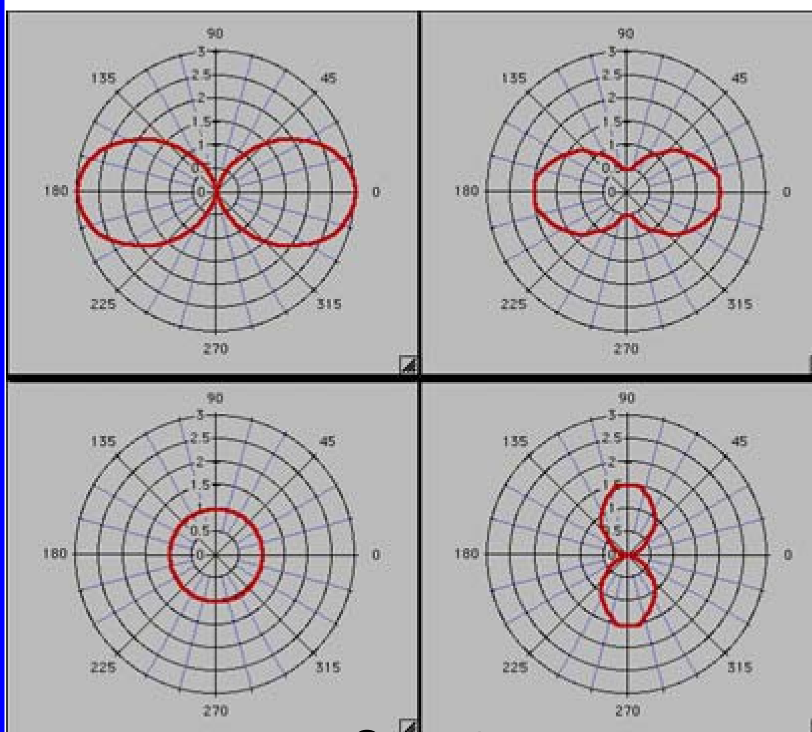
- Contain up to 10^9 atoms
- Temperature 10-100 μK
- Density up to 10^{12}atoms/cm^3

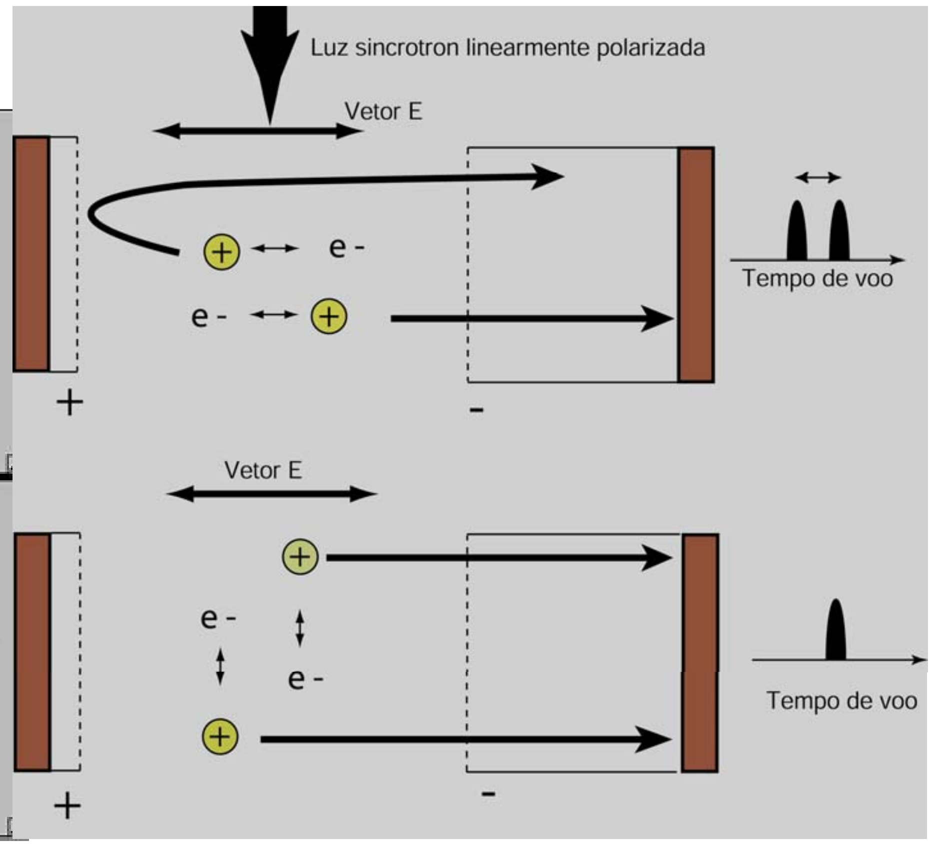
- Spontaneous emission- symmetrical distribution



Time of flight line shape as a function of β

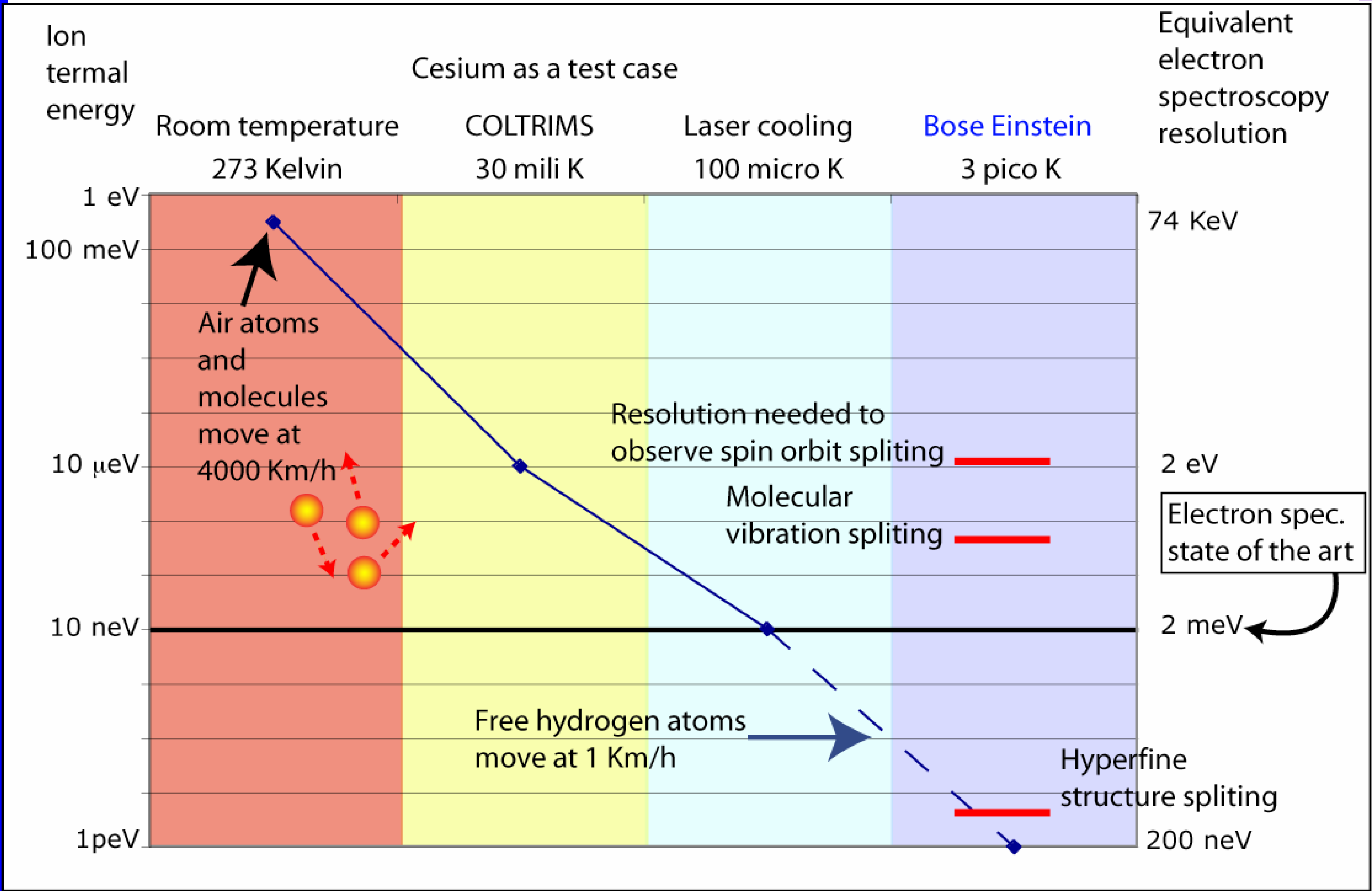
$\beta > 0$





$\beta \leq 0$

Where we are compared to other methods.



Cs Cooper Minimum

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

S. Manson and A. F. Starace Rev. Mod. Phys. **54**,389 (1982)

Sc open shell atom

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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TIFF (LZW) decompressor
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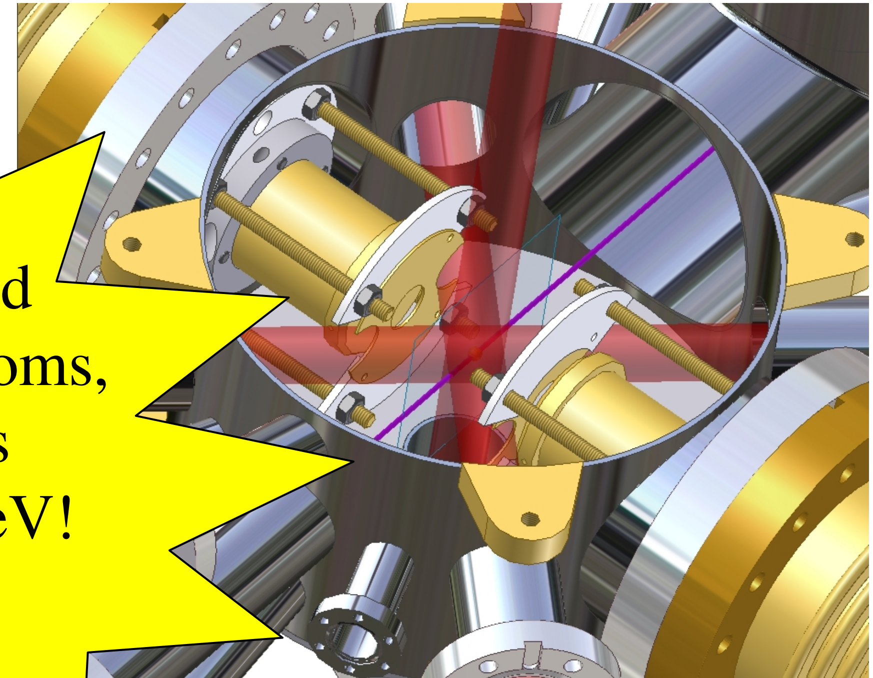
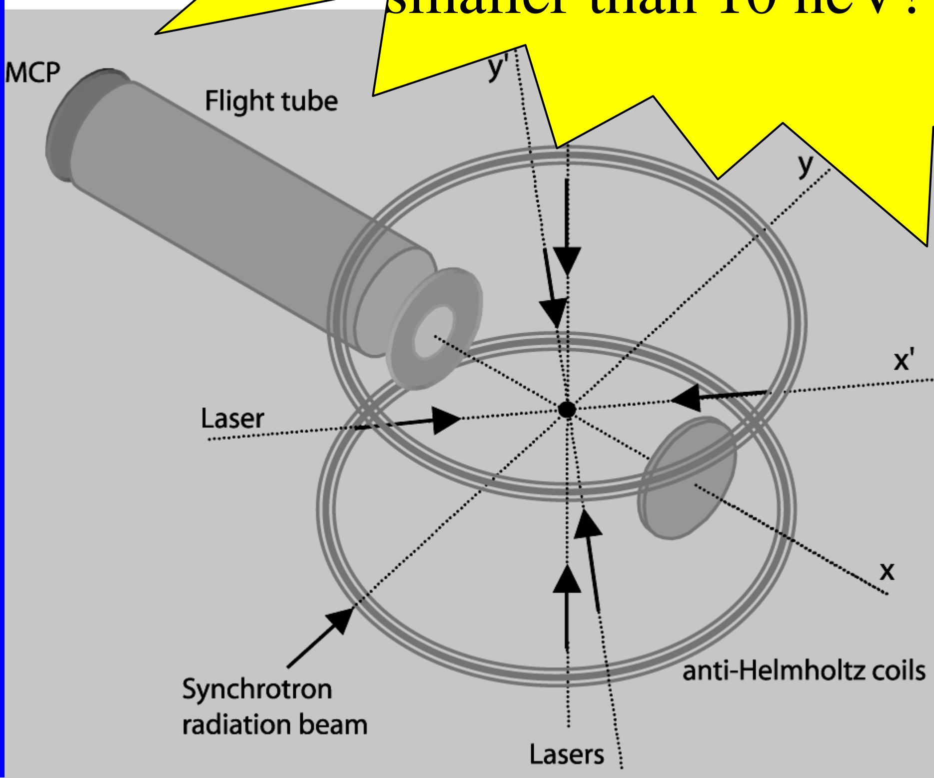
Z. Altum S. Manson, Phys. Rev. A **R 61**, 030702-1 (2000)

Experimental set-up

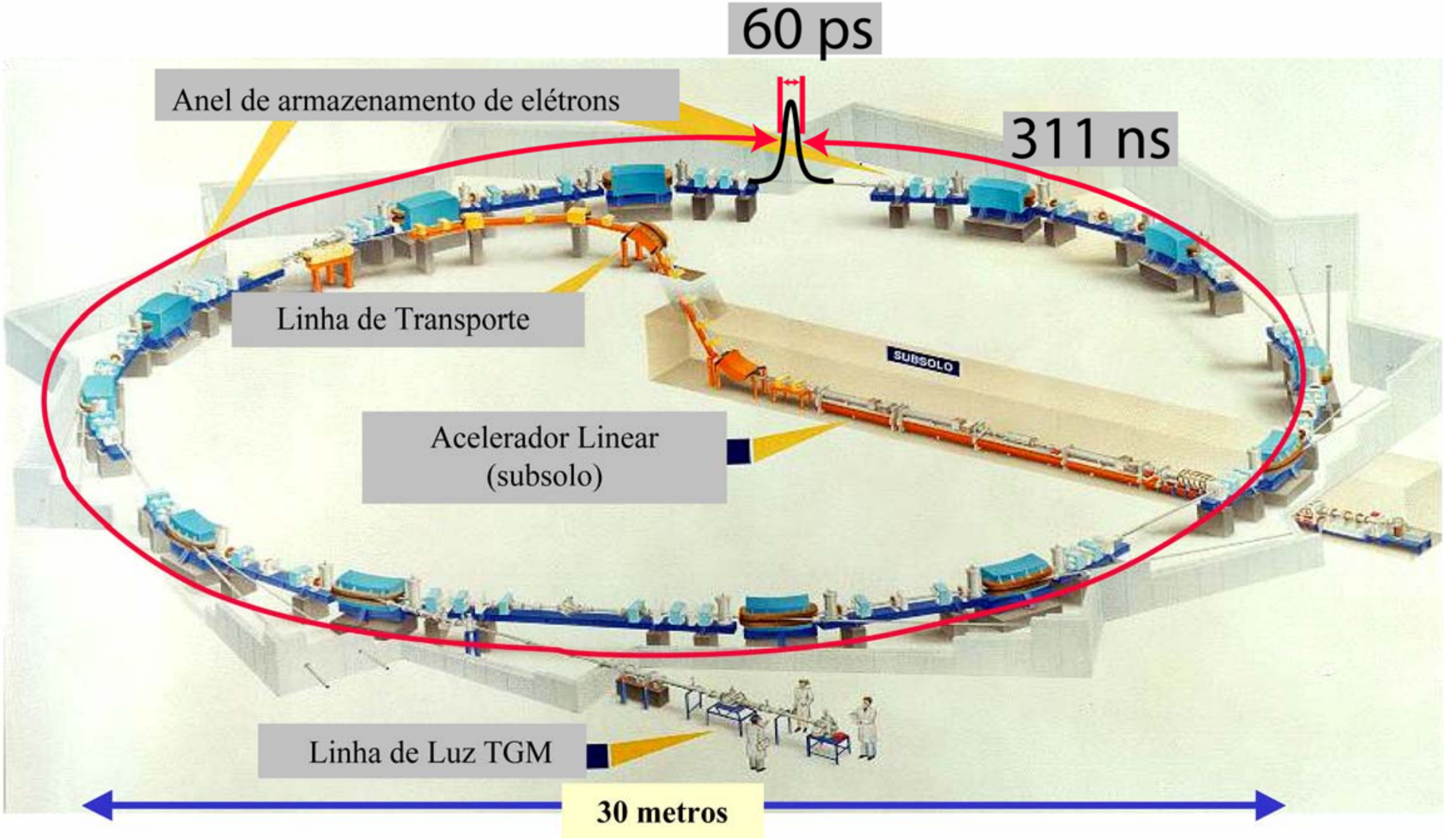


We have achieved
with laser cooled atoms,
thermal energies
smaller than 10 neV!

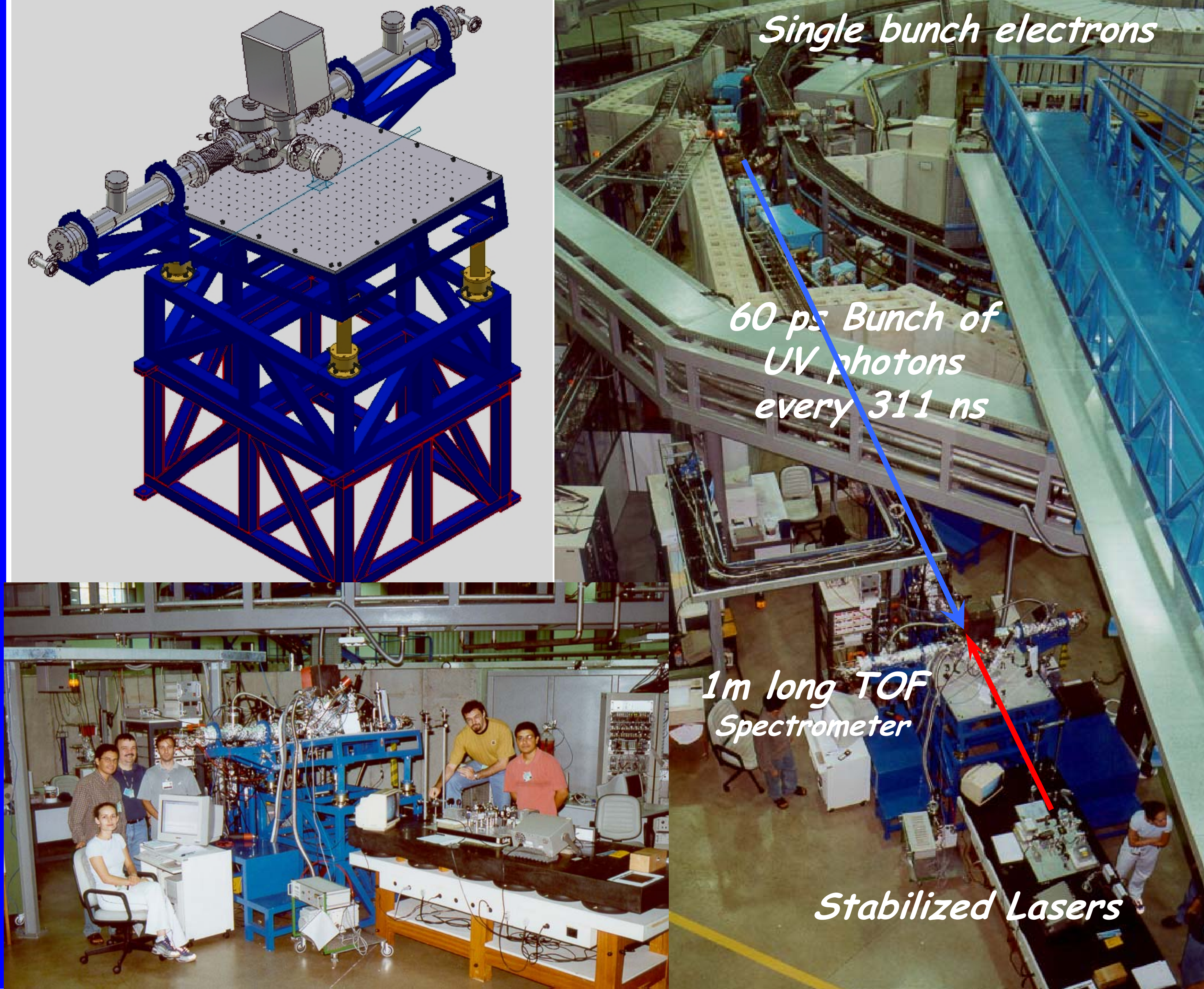


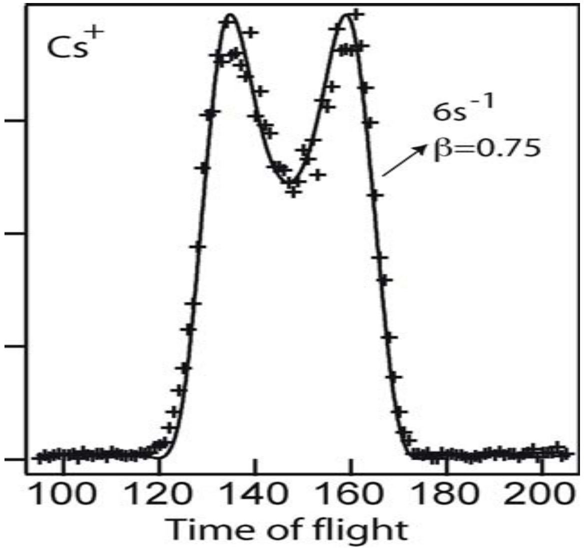
L. Coutinho et at.
Phys. Rev Lett.
93,183001(2004)

Single Bunch: exploring the time dimension



Usually there are 147 bunches separated by 2ns


Single bunch electrons
60 ps Bunch of
UV photons
every 311 ns
1m long TOF
Spectrometer
Stabilized Lasers



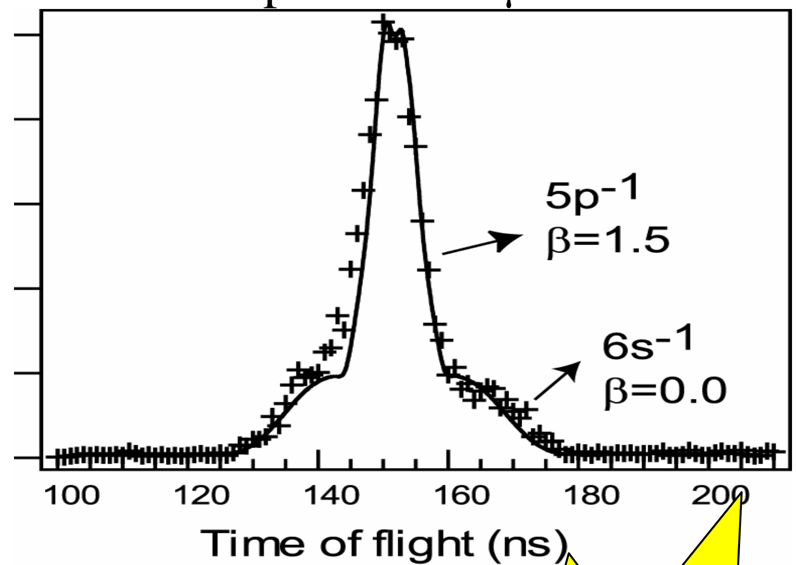
Photons: **16.0** eV

Ions: 51.3 μeV

Photons: **17.0±0.3** eV

6s Ions: 55.3 μeV

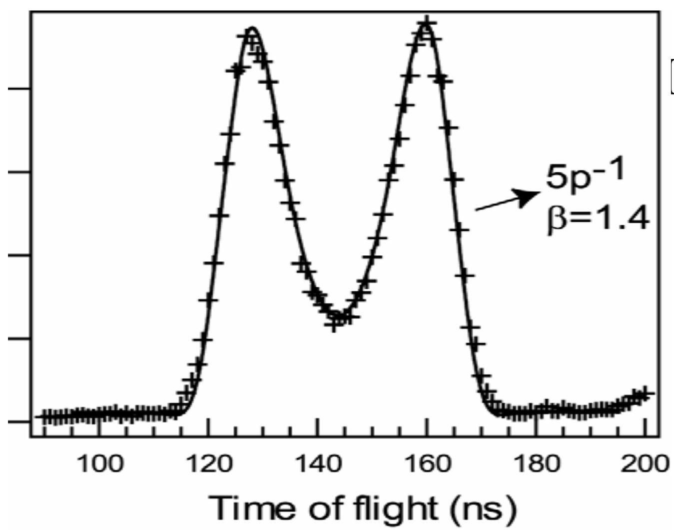
5p Ions: 0.9 μeV



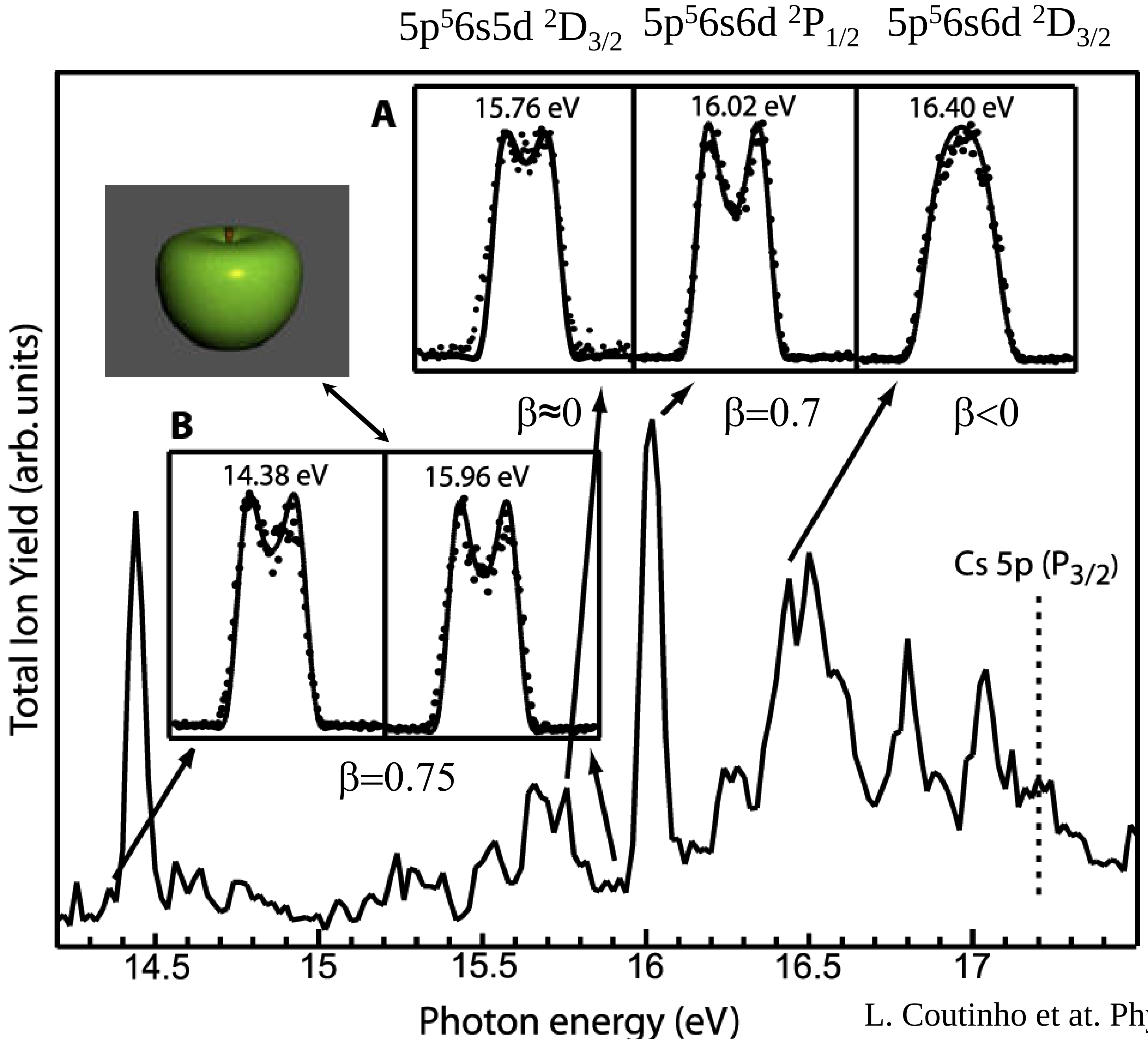
L. Coutinho et at. Phys. Rev Lett. **93**,183001(2004)

Photons: **35.0 eV**

Ions: 74.3 μeV

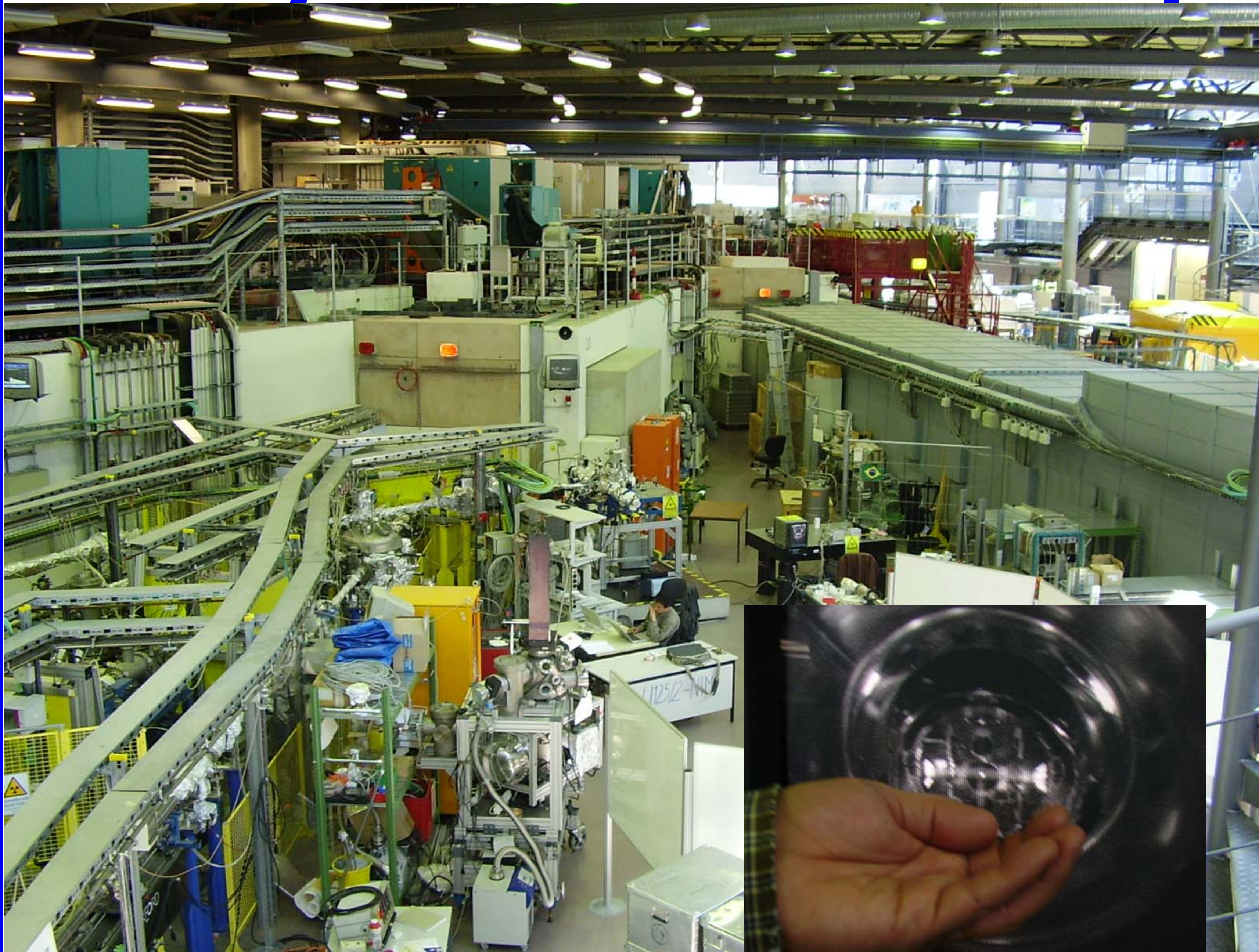


Recoil from ejected electron from 6s and 5p

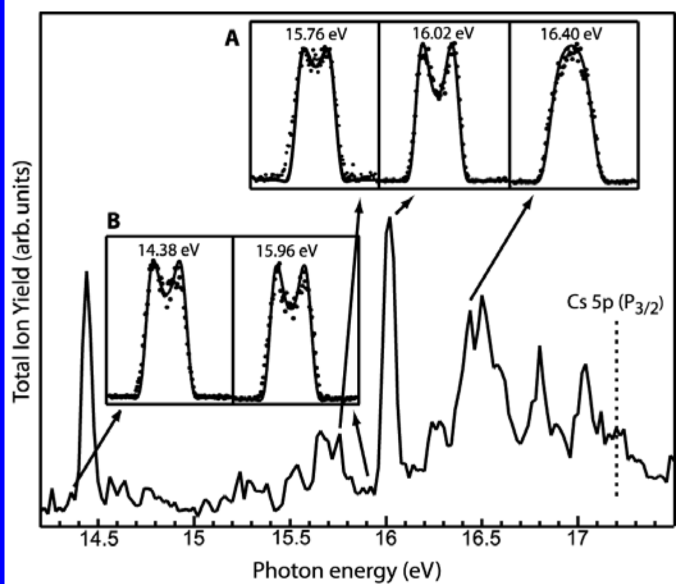


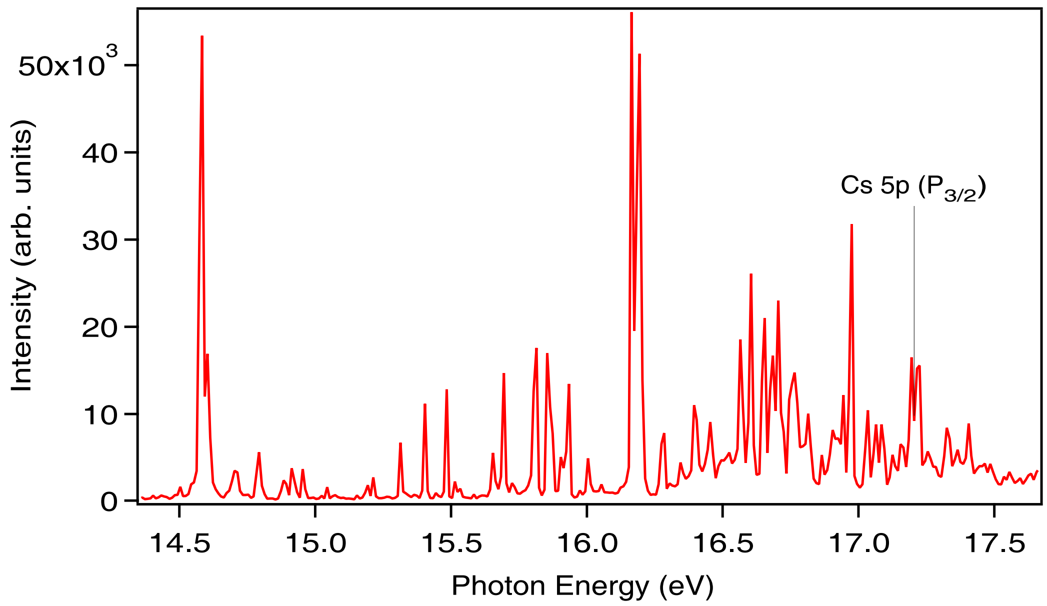
L. Coutinho et at. Phys. Rev Lett. **93**,183001(2004)

Bessy and laser ball cup

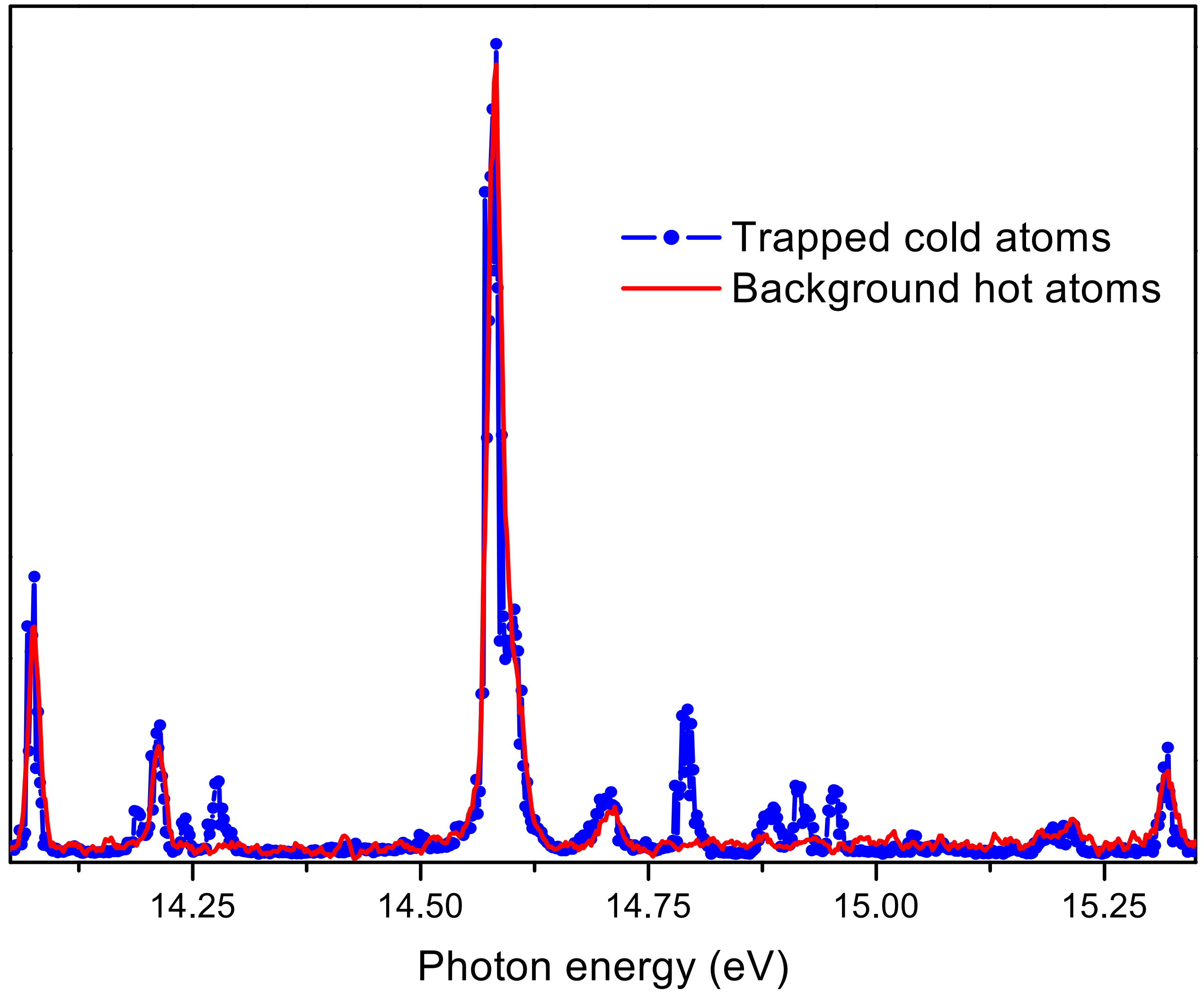


New measurements at Bessy

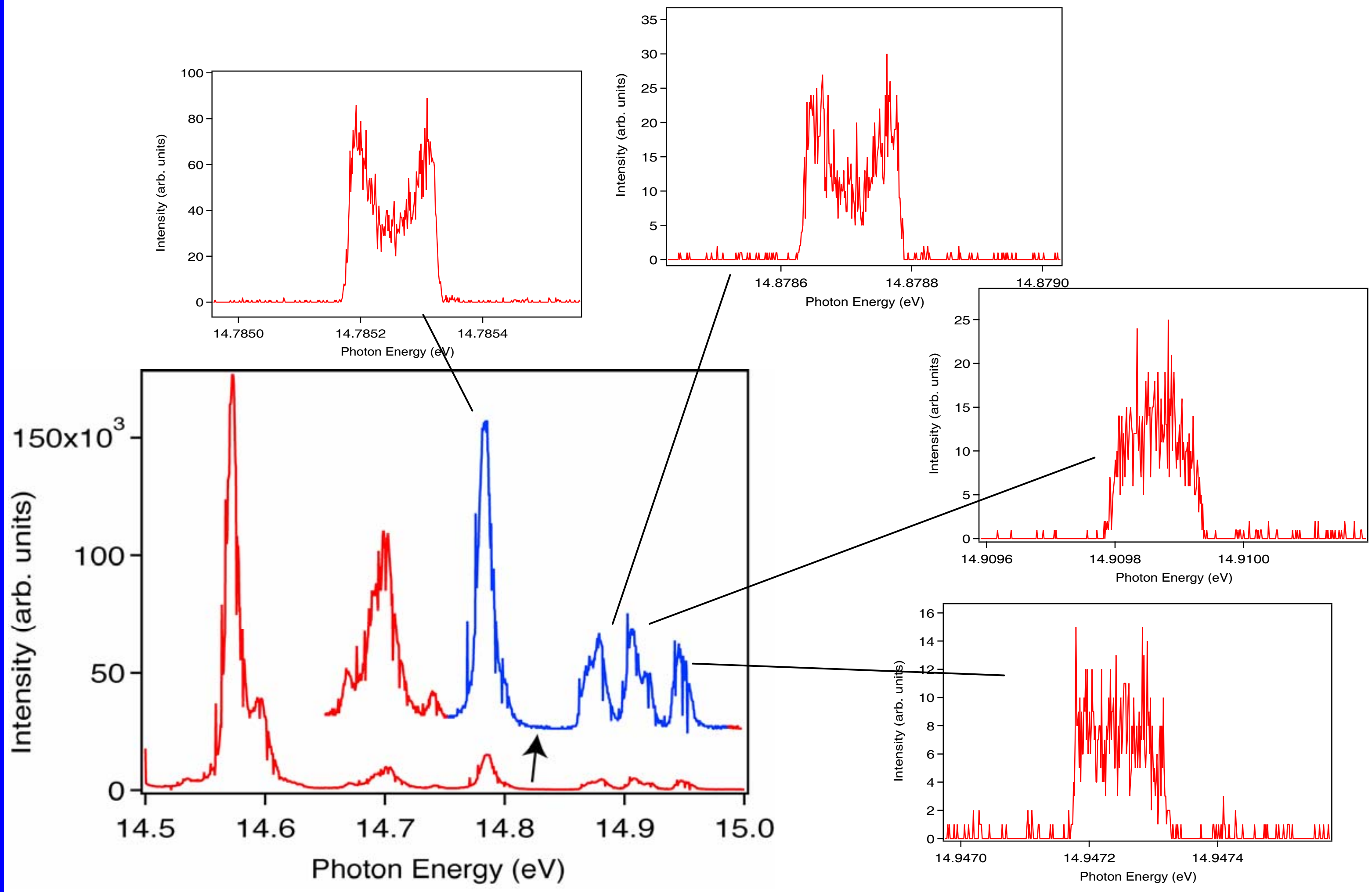




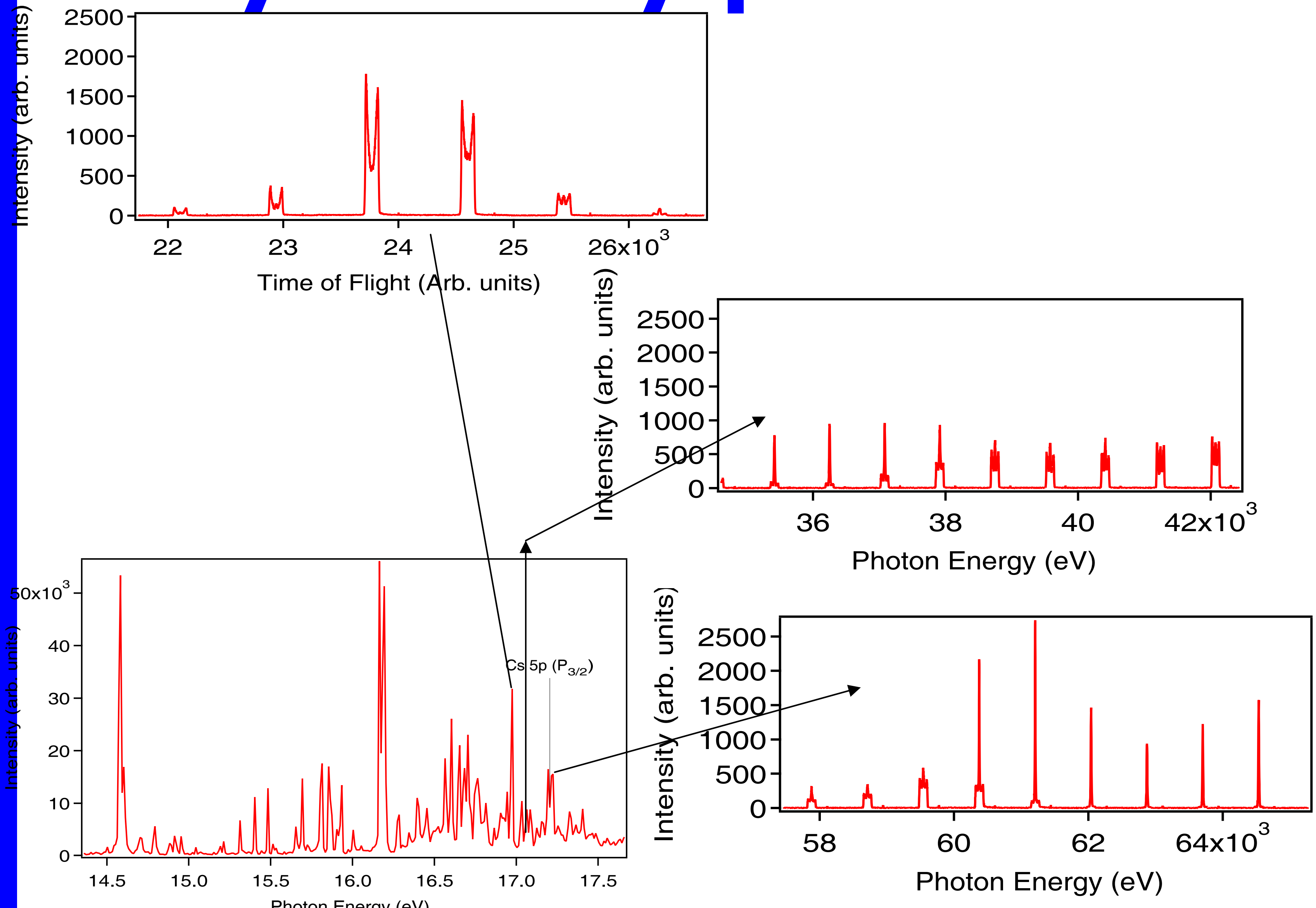
Probing laser excited atoms



Beta parameter Initially excited atoms



5p threshold and asymmetry parameter



Conclusions

- We have demonstrated a novel technique capable to measure with high precision photoionization angular distribution of laser excited atoms
- Angular distribution can not be obtained almost as fast as TIY spectra.
- We have observed a new class of Copper minima due to interchannel coupling

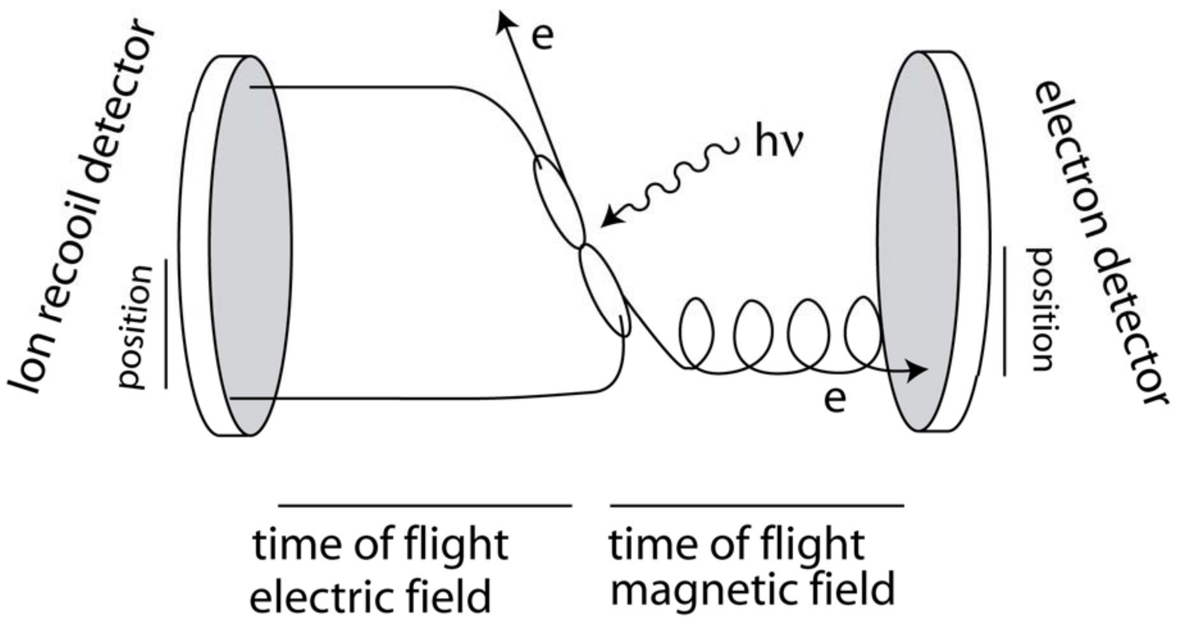
Ultra-cold polar and none polar molecules

- Cold means 1-1000mK, ultra cold <1mK
- Last nine years started from 0 to 9 techniques
- They are easy to be manipulated with electromagnetic fields and be traped.
- Chemical reactions have been shown to occur rapidly at temperatures near zero Kelvin.
- Once the amount of molecules produce a large can we find a new state of matter? Ultra cold chemistry can be developed? Quantum computers from polar ultra cold molecules since the large electric dipole moments of polar molecules produce a strong inter-particle interaction.
- Possible molecules to be formed RbCs,KRb,KCs.
- Reported 10^{12}molecules/cm^{-3}.

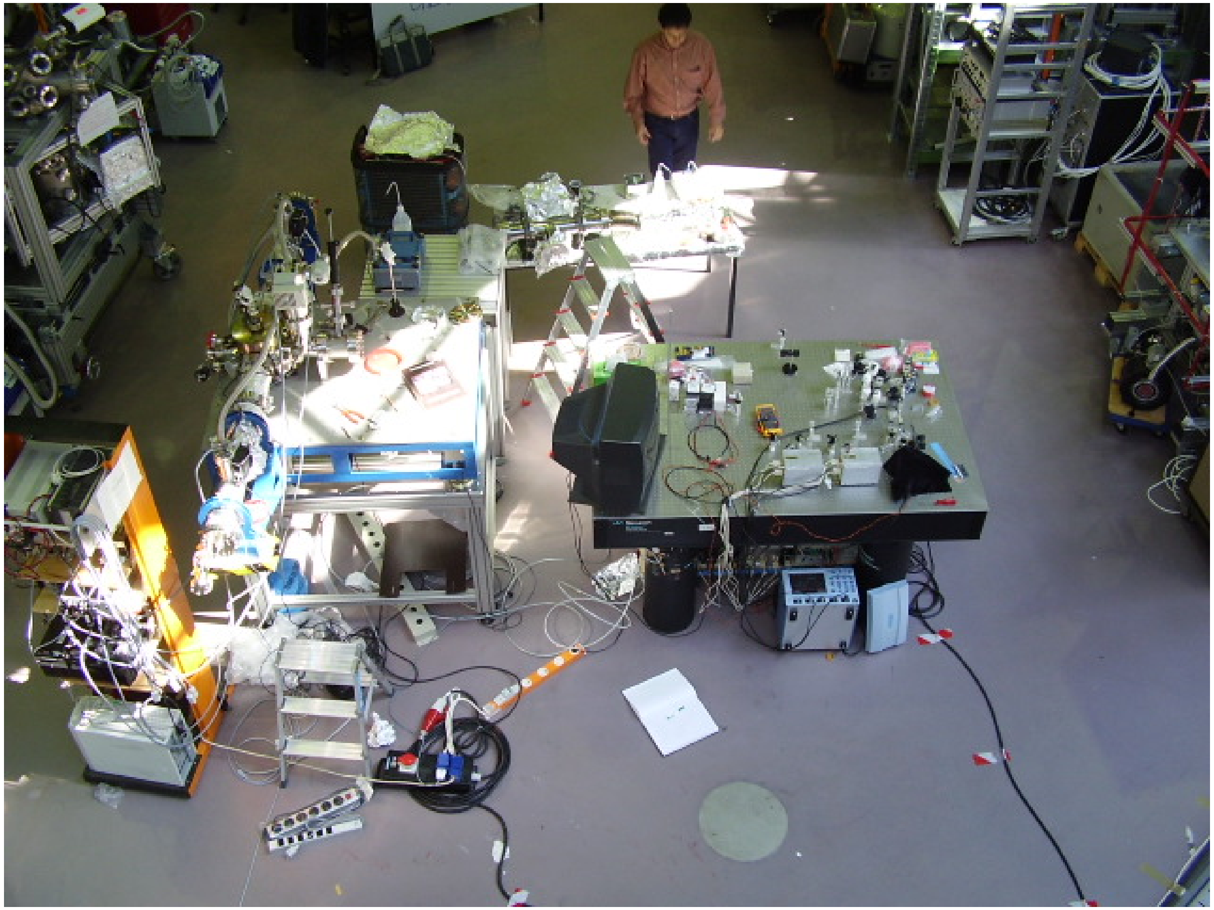
Interesting questions we would like to address

- How can we control better chemical reactions and collisions in general?
- How far can we improve our understanding of many body physics using ultra-cold polar and none polar molecules?
- What dynamical effects will we find when we ionize from excited electronic and vibrational states of cold molecules?
- What is the double ionization limit of Rb_2 and Cs_2 molecules?
- Does the angular distribution of photoelectrons follow the current theory close to the double ionization threshold ?
- Do we see also interesting changes in the angular distributions of photoelectrons outside the resonances? For this studies we will need pre-aligned molecules.

Experimental details connected IRMS on Ultra-cold Molecules



Shining in Bessy



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- Vacuum group: Tatiane, Thiago, Hélio, Reginaldo and Marcelo Juni;