

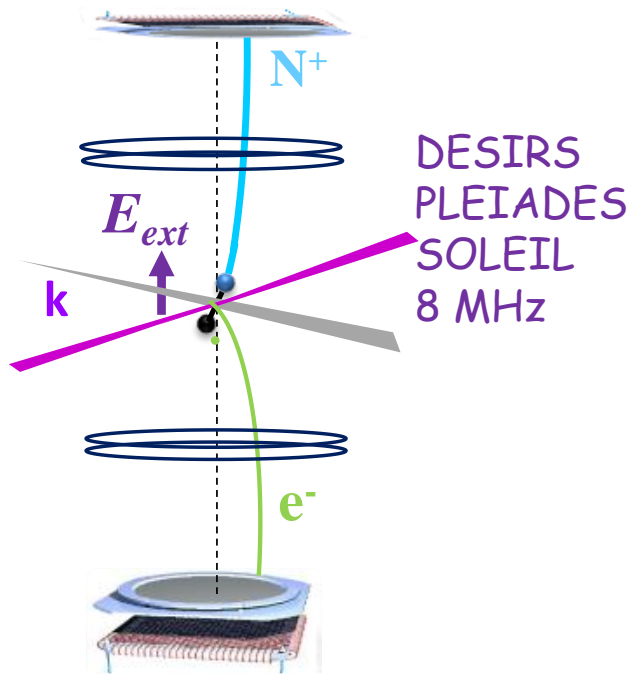
## Plateforme expérimentale ISMO : Electron-ion coincidence 3D momentum spectroscopy

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# Photoionization of atoms & molecules: Electron-ion coincidence 3D momentum Spectroscopy

$$(V_{A^+}, V_e, P)$$



## Coincidence:

Identify the electron(s) and ion(s) from the same PI event ( $e, A^+$ )

Temporal correlation, pulsed light source

$n$  events/pulse  $\ll 1$  (High rep-rate light sources)

3 components of the velocity vectors of each particle

$4\pi$  collection of electrons (and ions)

Energy and angular observables (laboratory frame)

Photoelectron energy spectra: PES

Photoelectron angular distribution: PAD

$n$  events/pulse  $\ll 1$

Lebech et al., RSI 73, 1866 (2002)

$$I_{SB}(\theta) = I_0 \left\{ 1 + \beta P_2(\cos\theta) \right\}$$

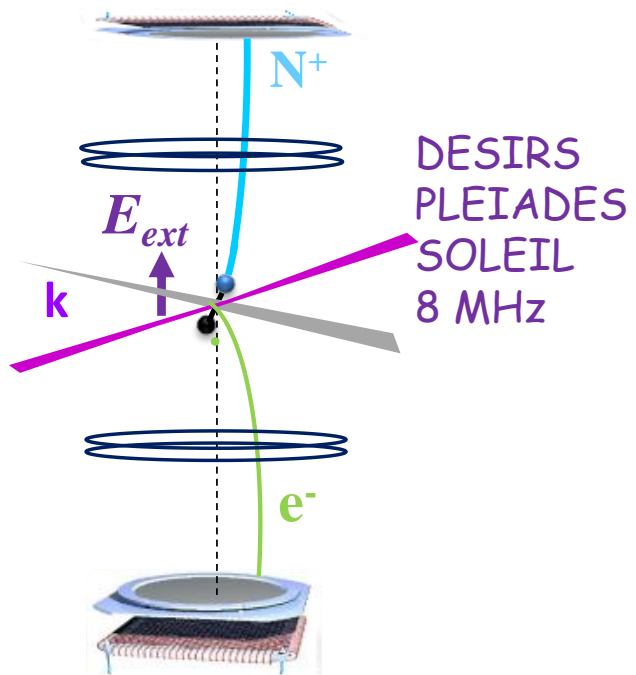
$\beta$  asymmetry parameter

for single photon ionization

Extension multi-photon  $\beta_{2k} P_{2k}(\cos\theta)$ ...

Cf (XUV-IR) RABBITT

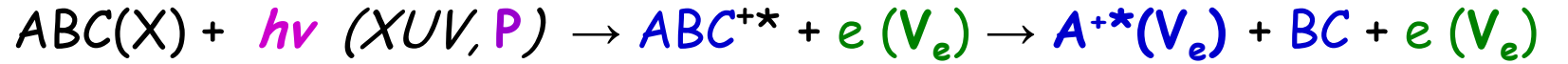
$$(V_{A^+}, V_e, P)$$



$n$  events/pulse  $\ll 1$

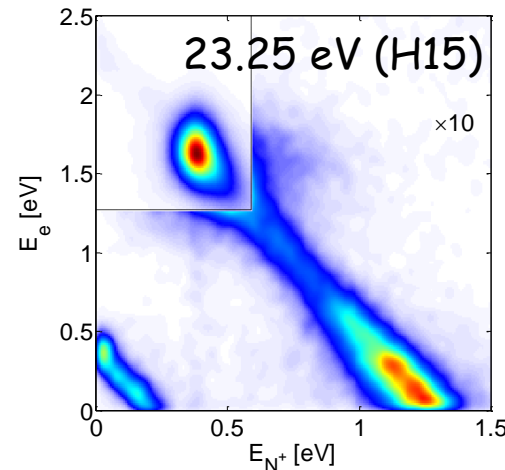
Lebech et al., RSI 73, 1866 (2002)

## Dissociative photoionization of simple molecules

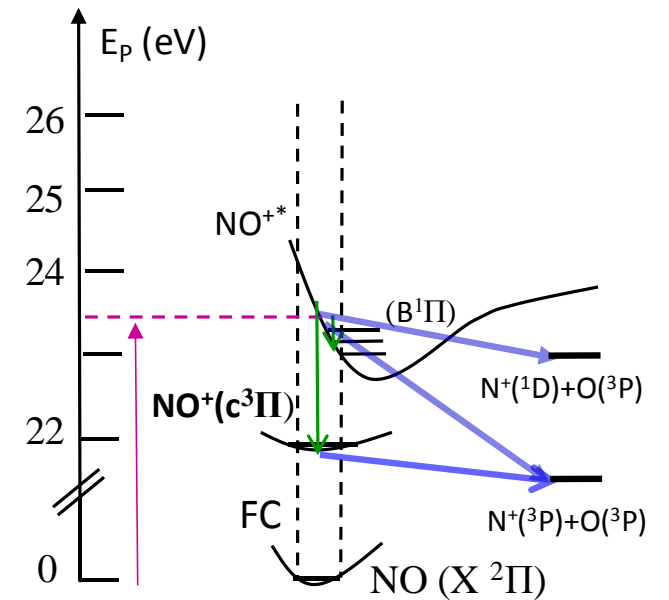


Energy and angular observables (laboratory and **Molecular Frame**)

Kinetic energy correlation diagram  
( $e, N^+$ ) **KECD** resolving power



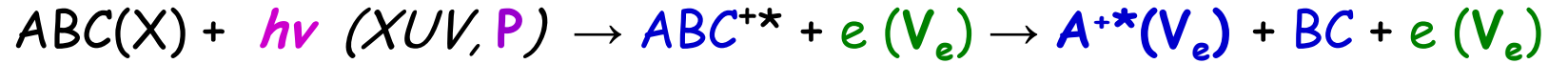
Identify ionic states and dissociation limits  
Branching ratios



→ **Molecular Frame Photoelectron Angular Distribution**

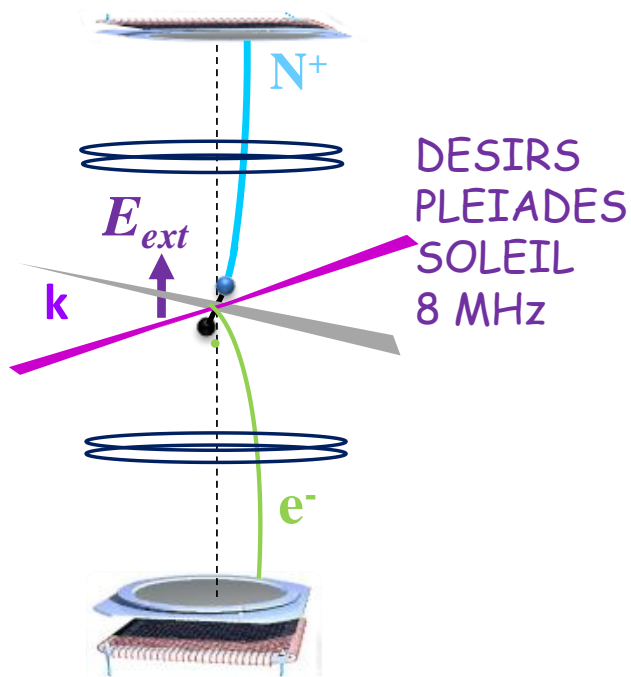
$$(V_{A^+}, V_e, P)$$

Dissociative photoionization of simple molecules

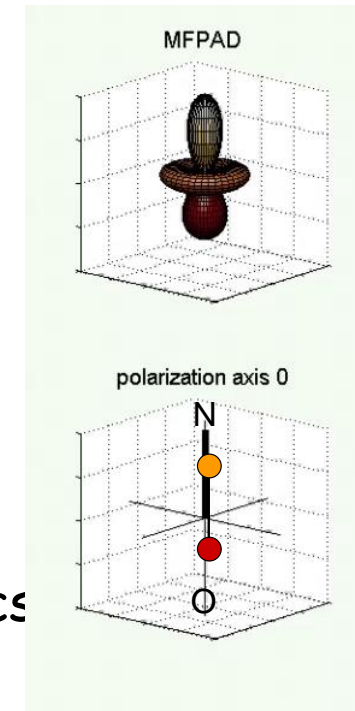
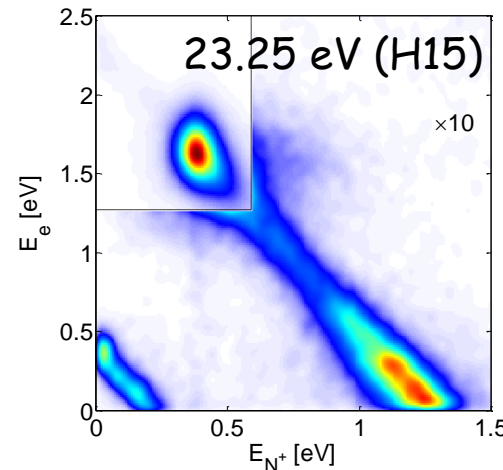
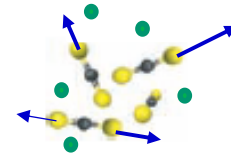


Energy and angular observables (laboratory and Molecular Frame)

Kinetic energy correlation diagram  
( $e, A^+$ ) KECD resolving power



MFPAD



$$T_{fi}(\theta_e, \phi_e, \chi)$$

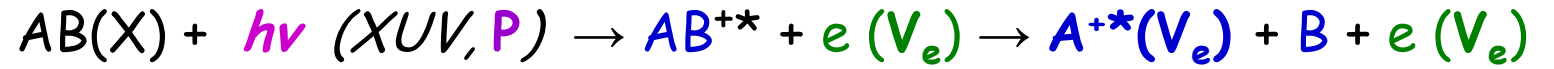
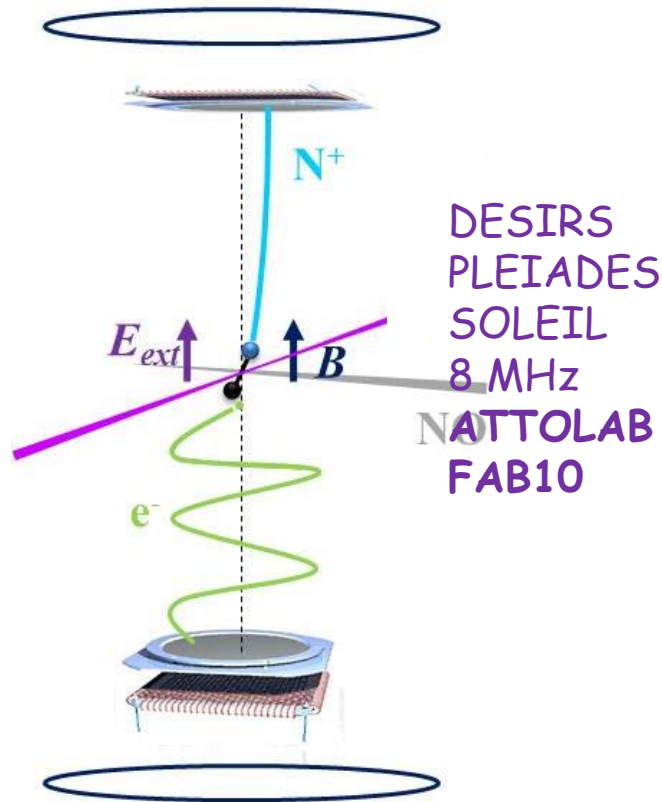
$n$  events/pulse  $\ll 1$

Lebech et al., RSI 73, 1866 (2002)

Valence and inner shell photoionization  
Photoionization and photo dissociation dynamics  
**Time-resolved at the atto & femtosecond scale: ATTOLAB**

# E-A+ coincidence 3D momentum Spectroscopy: Instrumentation from SOLEIL to ATTOLAB FAB-10

$$(V_{A^+}, V_e, P)$$



Localized interaction region (mm), supersonic molecular jet

Controlled trajectories of  $e$  and  $A^+$  in electrostatic fields (extraction and focusing lenses) or electrostatic + magnetic fields

Use of **position and time-sensitive detectors** (impact of each particle)

**Multi-channel plates (MCPs) and delay line anodes**

Temporal metrology : Multichannel Time to Digital Converters (DTPI platform)

Data acquisition and analysis of multidimensional observables

ATTOLAB support: Advanced CIEL set-up and new spectrometer well adapted for measurements with an attosecond pulse (APT)

Gisselbrecht et al., RSI 76, 013105 (2005)

Lebech et al., RSI 73, 1866 (2002)

S.J. Weber et al RSI 86, 033108 (2015)

# CIEL @ ATTOLAB -SE10 : high rep-rate IR/XUV beamline

IR laser : 23 fs, 2 mJ, 10 kHz, CEP

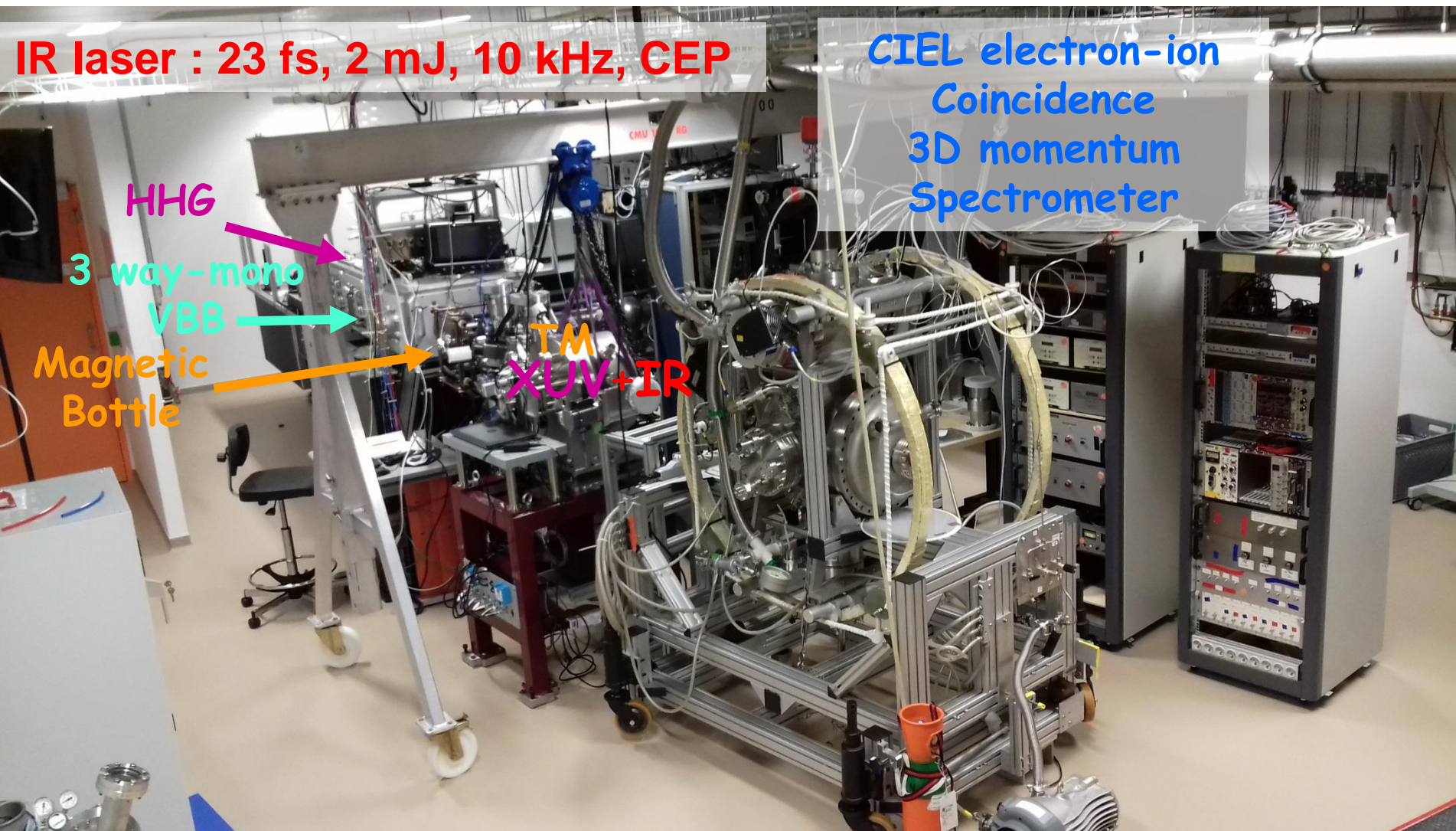
CIEL electron-ion  
Coincidence  
3D momentum  
Spectrometer

HHG

3 way-mono  
VBB

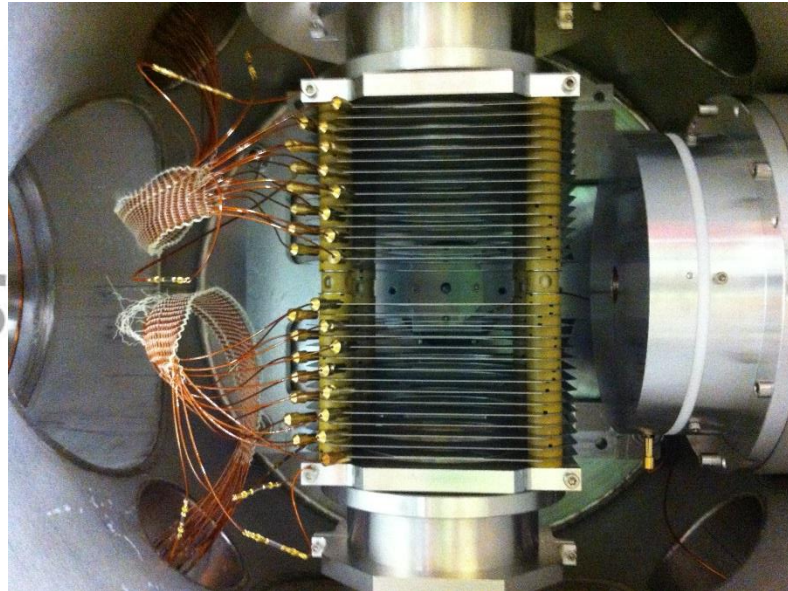
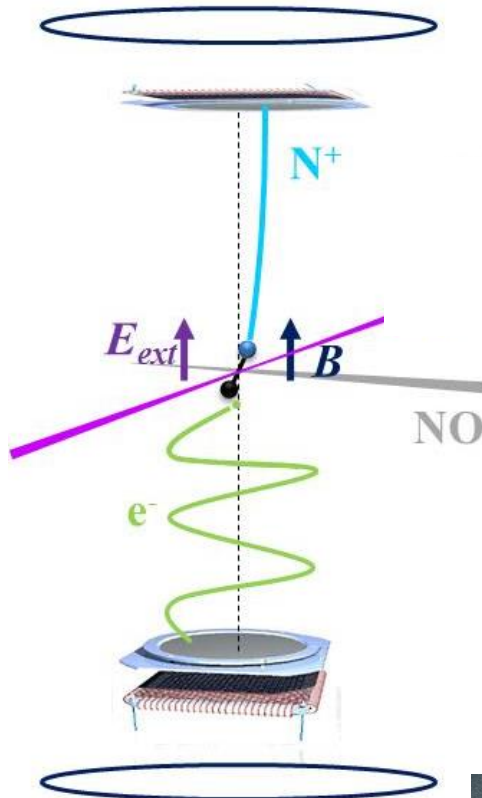
Magnetic  
Bottle

TM  
XUV+IR



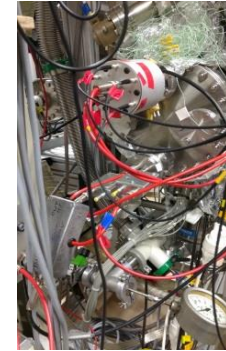
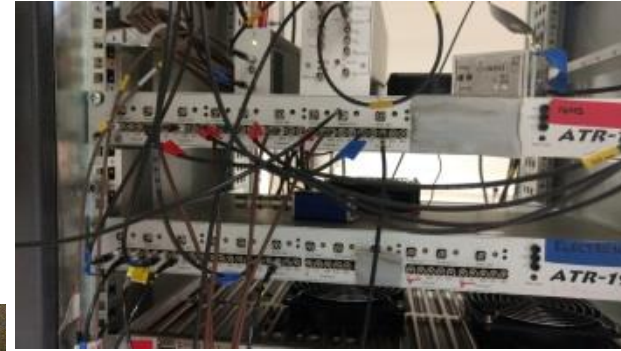
# E-A+ coincidence 3D momentum Spectroscopy: Instrumentation from SOLEIL to ATTOLAB FAB-10

Control of ultra-high vacuum: primary pumps, turbopumps  
Residual Gas Analyzer, gauges, baking control



Gas targets

Molecular jet

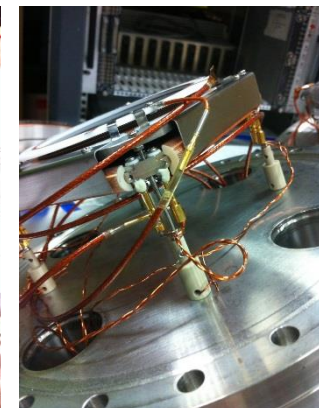
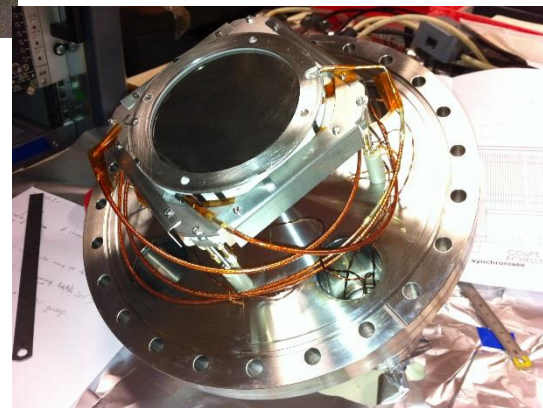


Delay-line detectors and MCP signal amplifiers  
High-voltage power supplies

Acquisition electronics, CFDs, oscilloscopes

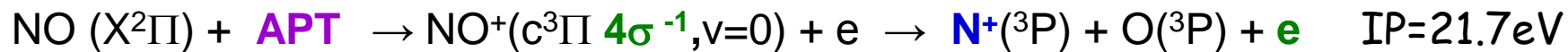
Time sensors: x channels Time-to-Digital Converters

Precise centering devices: different beamlines



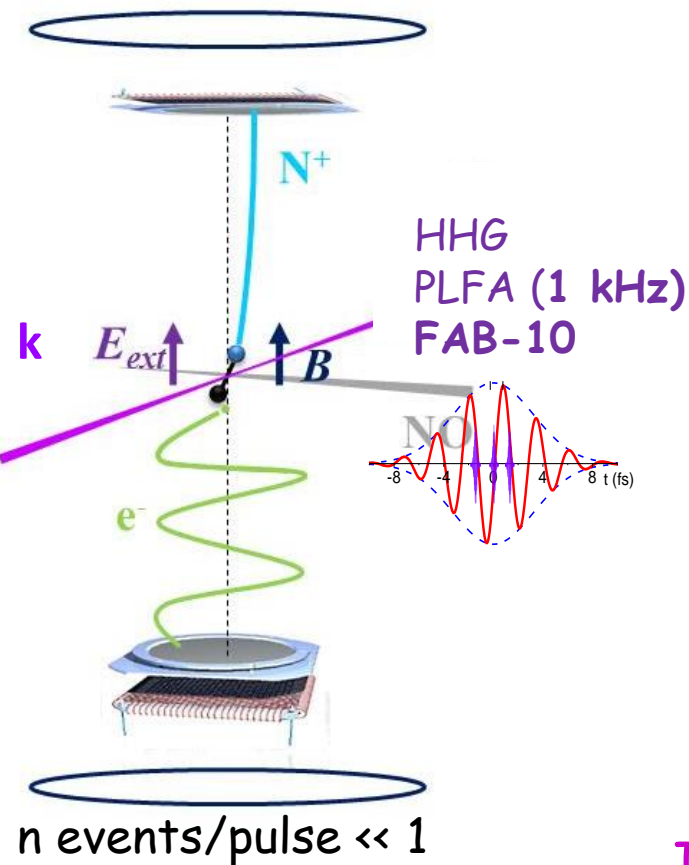
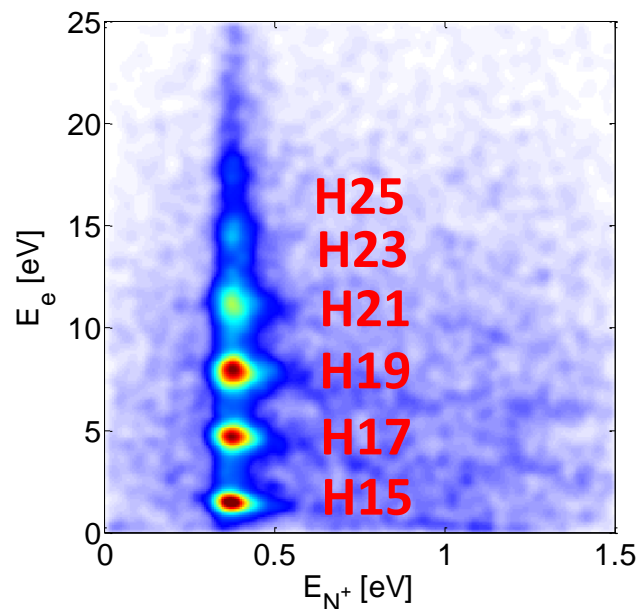
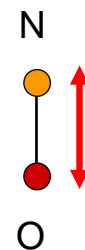
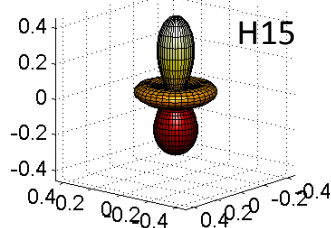
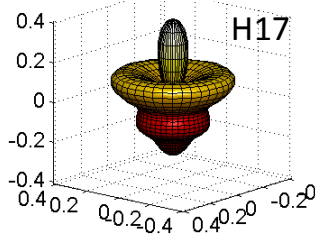
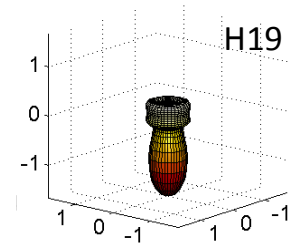
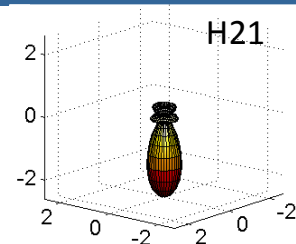
Optical  
Devices

# MFPADs by a comb of high-order harmonics (Attosecond Pulse Train)



$(V_{N^+}, V_e, k)$

$4\sigma \rightarrow \sigma^*$   
shape resonance



**RABBITT experiments**  
Rare gases: Ar, Ne  
Ionization delays in MFPADs  
in progress

$T_{fi}(\chi, \theta_e, \phi_e)$  for each HH H15-H23 range  
Veyrinas et al., *Faraday Discussions*, 2016, **194**, 161 - 183

J. Joseph, F. Holzmeier et al in preparation  
F. Holzmeier, J. Joseph et al in preparation



# Acknowledgements

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Merci à tous