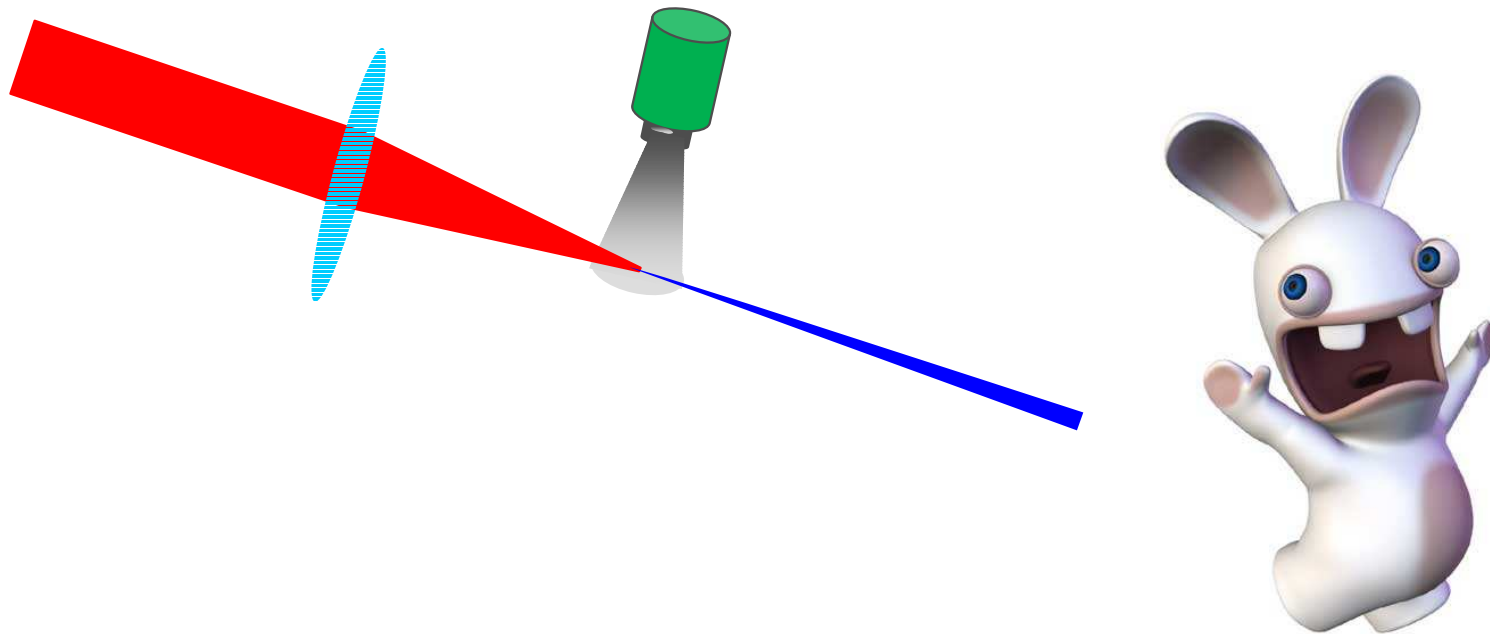


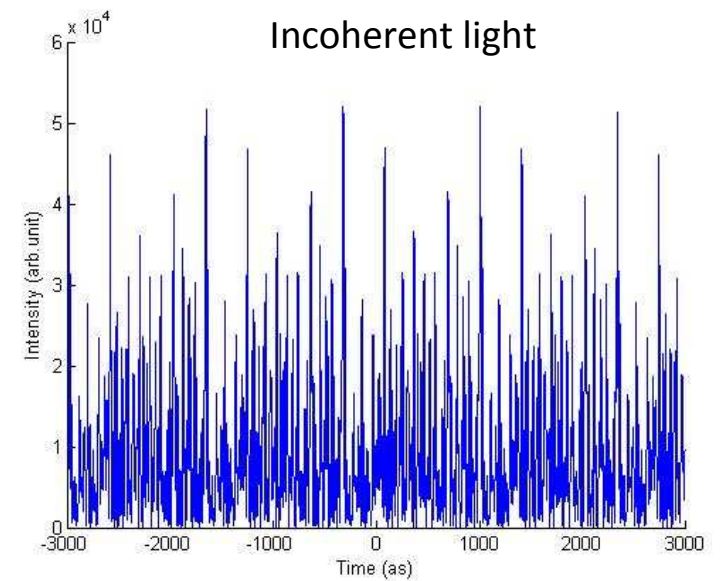
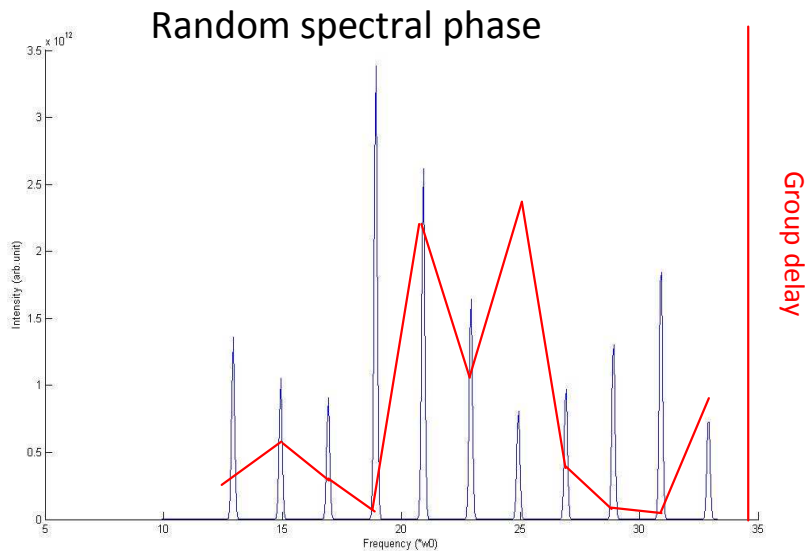
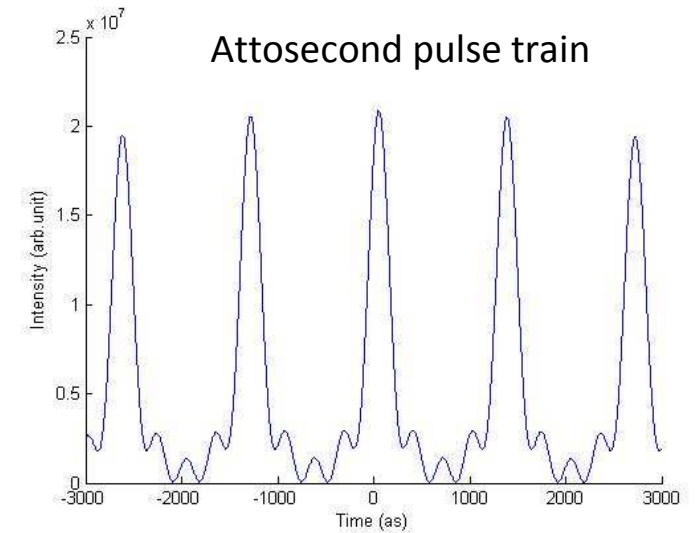
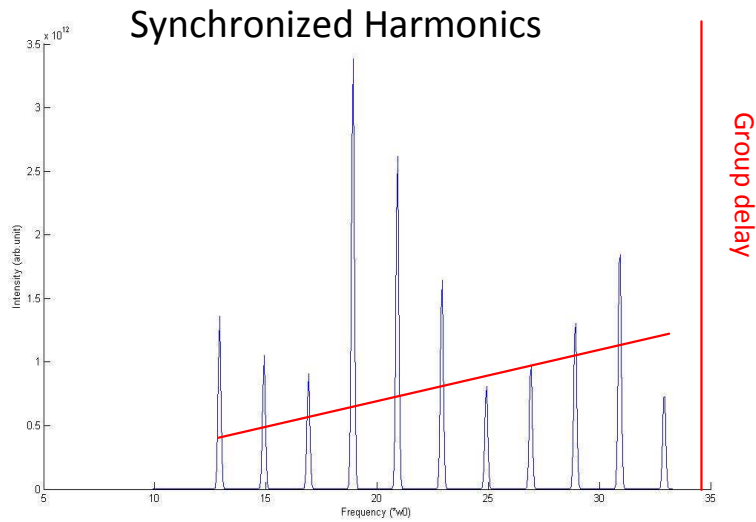
Characterisation and application of XUV pulses : the RABITT method

Reconstruction of Attosecond harmonic Burst By Interference in Two photon Transition



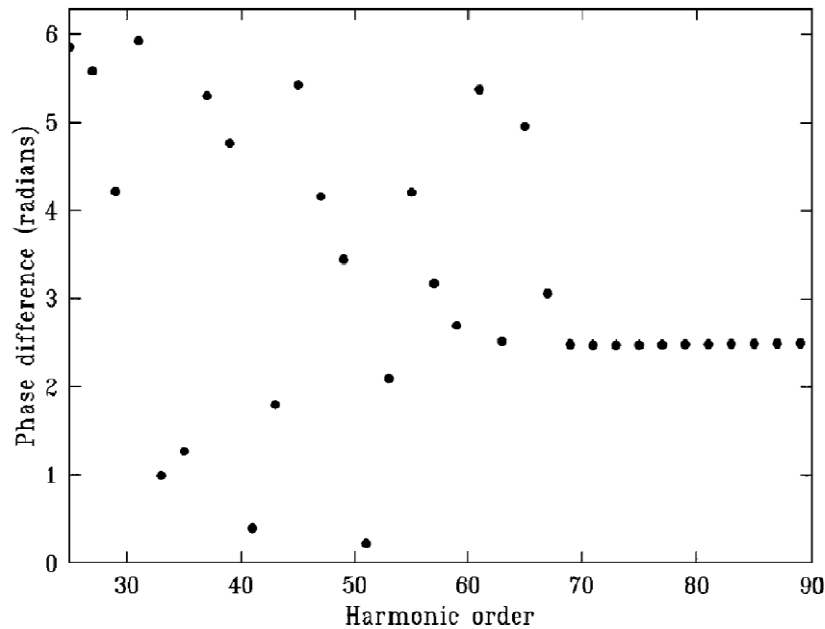
Temporal profile of a group of harmonics

Question: Are the phases of the different harmonics locked?

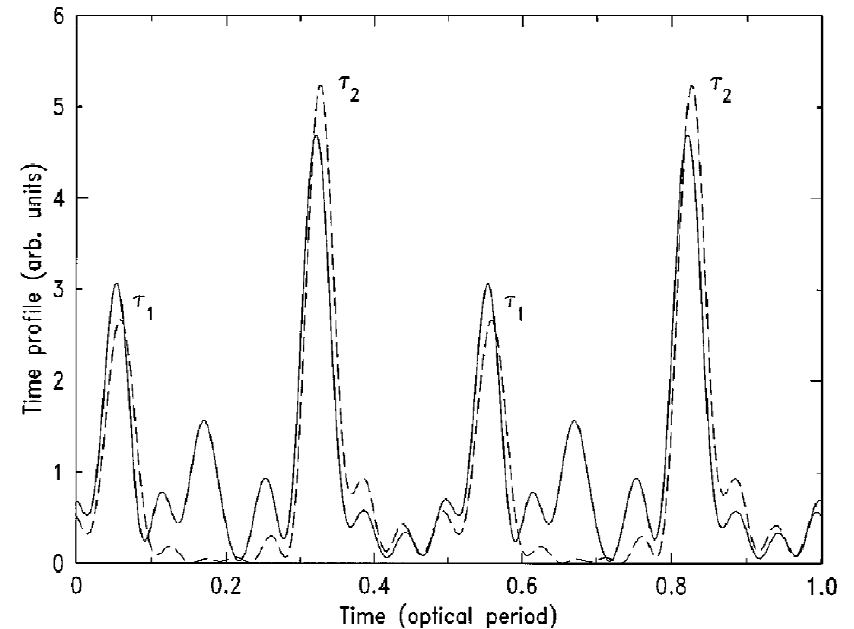


Prediction of the SFA

The spectral phase seems to be random




The temporal profile present 2 attosecond peaks per half period.



Contribution from the short and long trajectory!!

Questions:

_Can we select only one pulse ?  Yes by phase matching

_Can we characterize it ?  Yes using the RABITT technique

Principle of the measurement (RABBIT)

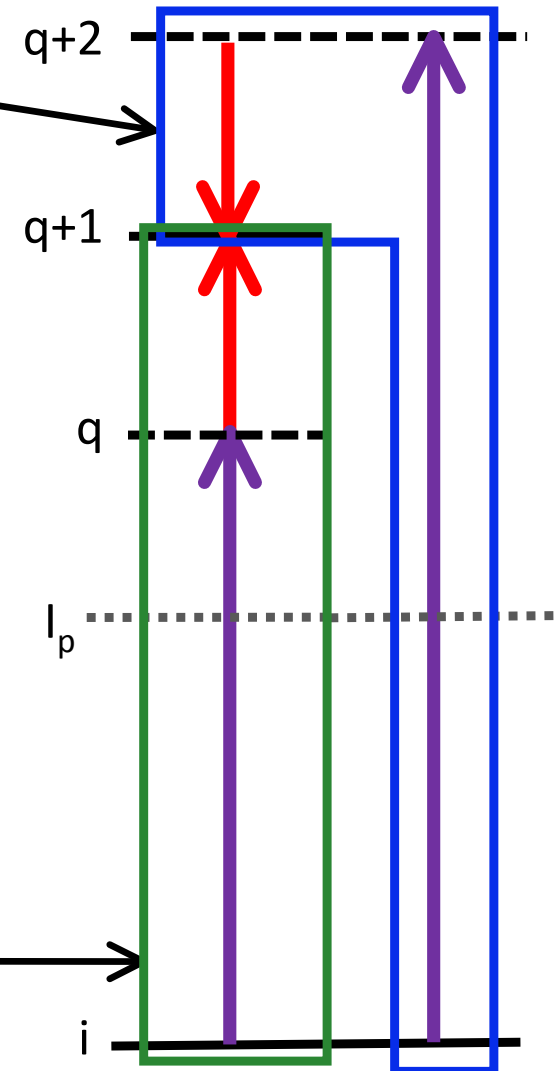
_Ionisation with the XUV field in the presence of a weak infrared field

_Interference between two quantum paths

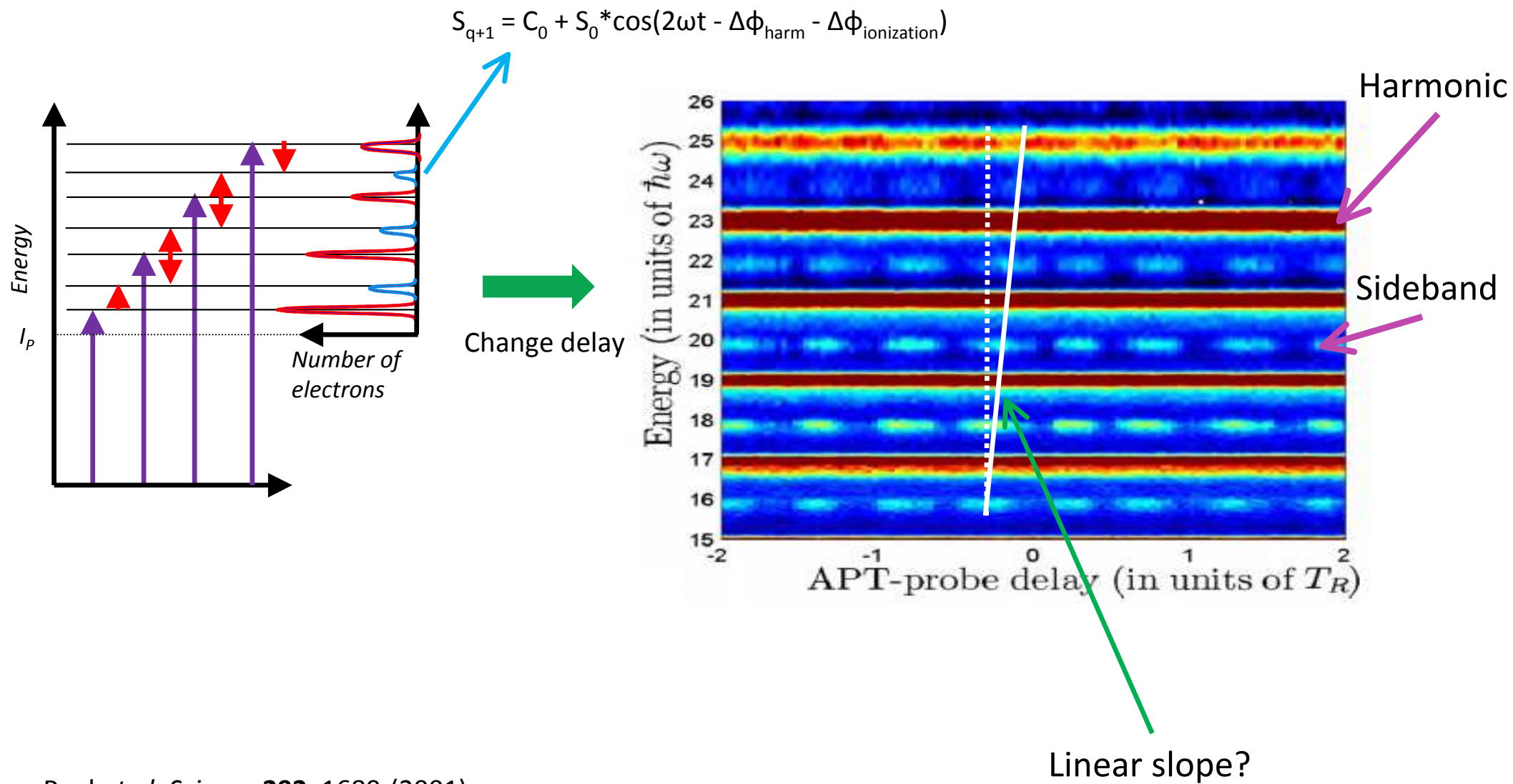
$$S_{q+1} = C_0 + S_0 \cdot \cos(2\omega t - \Delta\phi_{\text{harm}} - \Delta\phi_{\text{ionization}})$$

$$\Phi_{\text{harm}}(q+2) - \omega t + \phi_{\text{ionization}}(q+2)$$

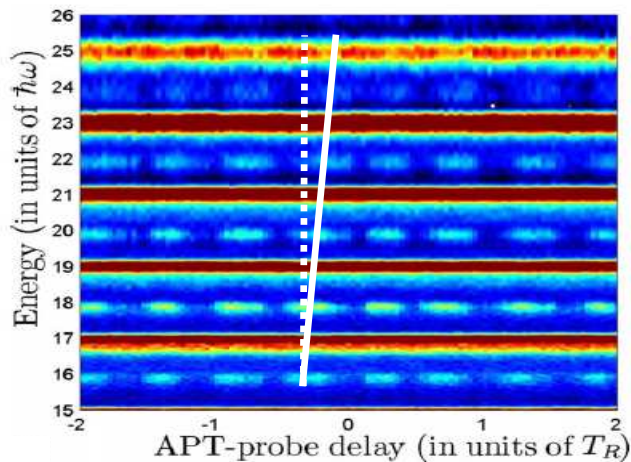
$$\Phi_{\text{harm}}(q) + \omega t + \phi_{\text{ionization}}(q)$$



Photoelectron spectrum



How to analyse the photoelectron spectrum



Sideband intensity:

$$S_{q+1} \sim \cos(2\omega t - \Delta\phi_{\text{harm}} - \cancel{\Delta\phi_{\text{ionization}}})$$

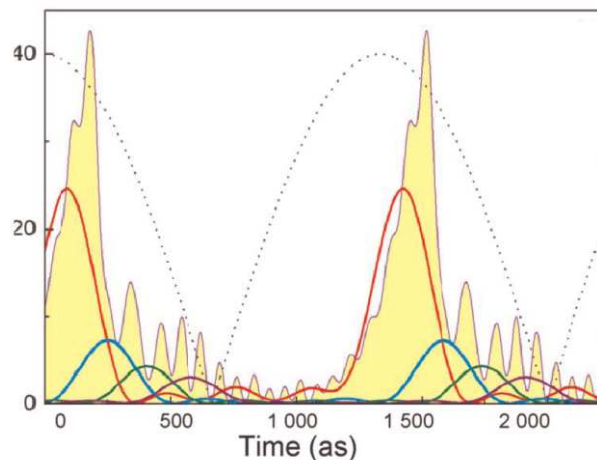
$$\begin{aligned} \Delta\phi_{\text{harm}} &= \phi_{\text{harm}}(q+2) - \phi_{\text{harm}}(q) \\ &\sim 2\omega_0 * d\phi_{\text{harm}}(q+1)/d\omega \\ &\sim 2\omega_0 * \mathbf{t_e(q+1)} \end{aligned}$$

Emission time

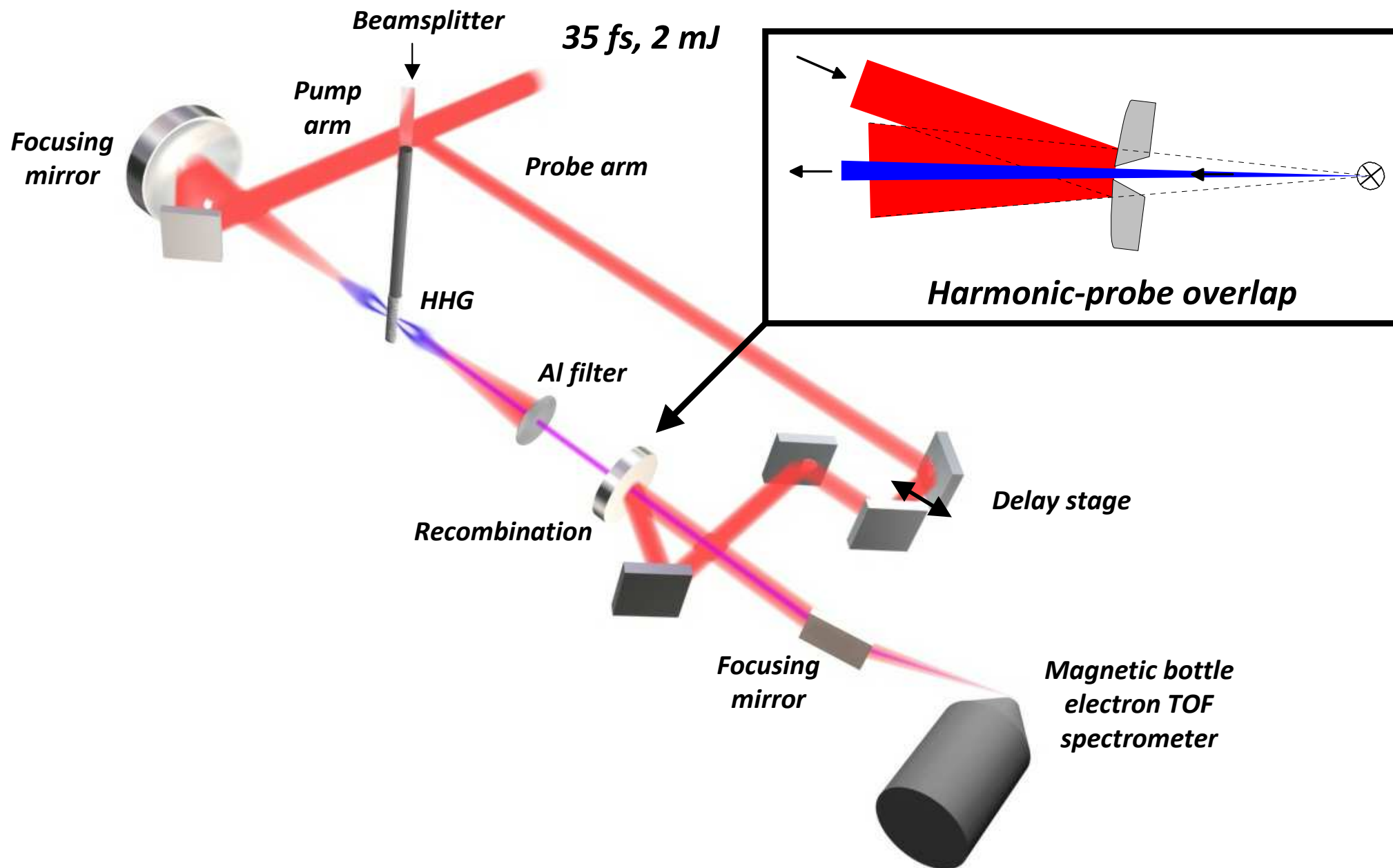
The linear slope means that the emission time varies linearly between the harmonics ➔ Constant chirp (Group delay dispersion)!!!

$$\text{GDD} = d^2\phi_{\text{harm}}/d\omega^2$$

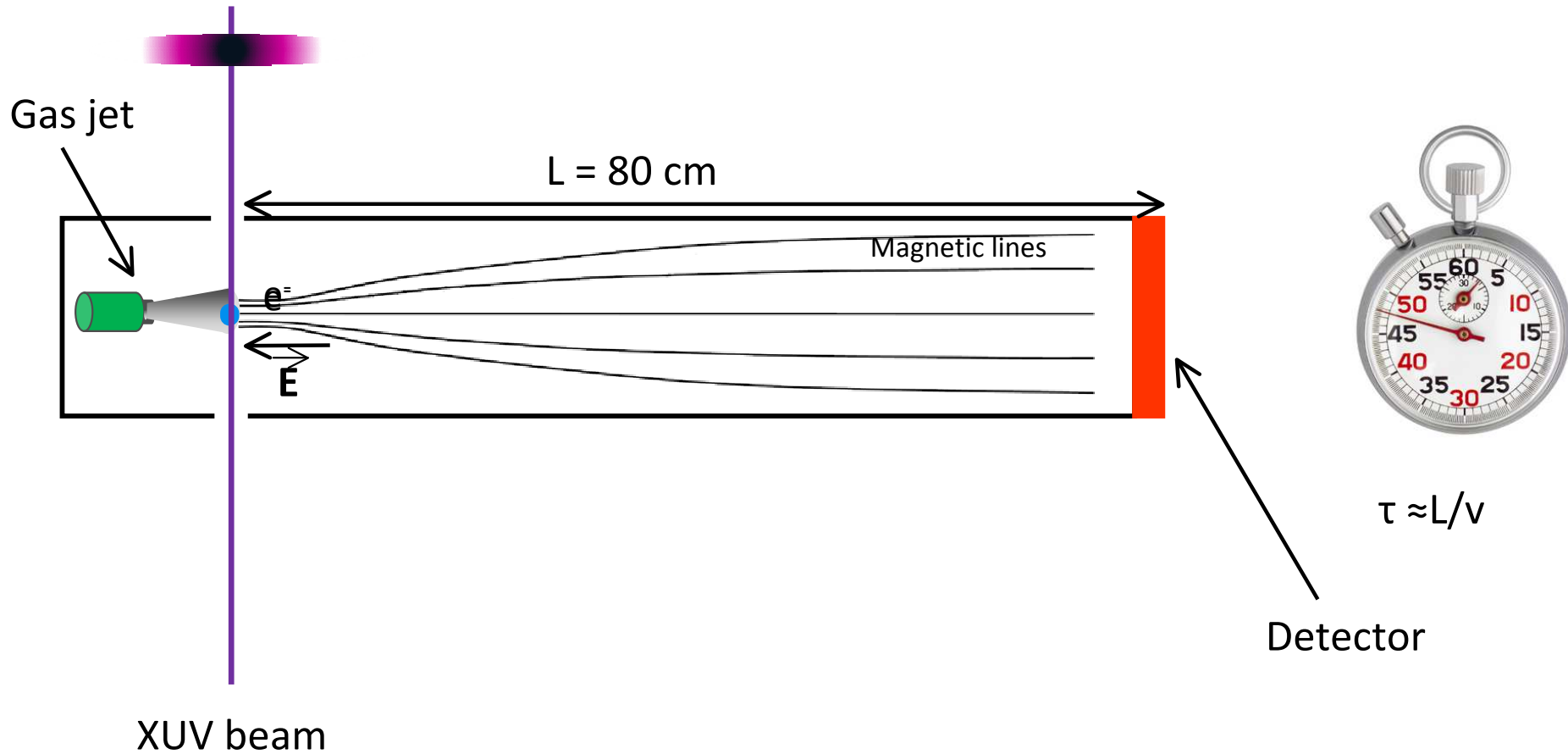
Reconstruction of the pulse (130 as):



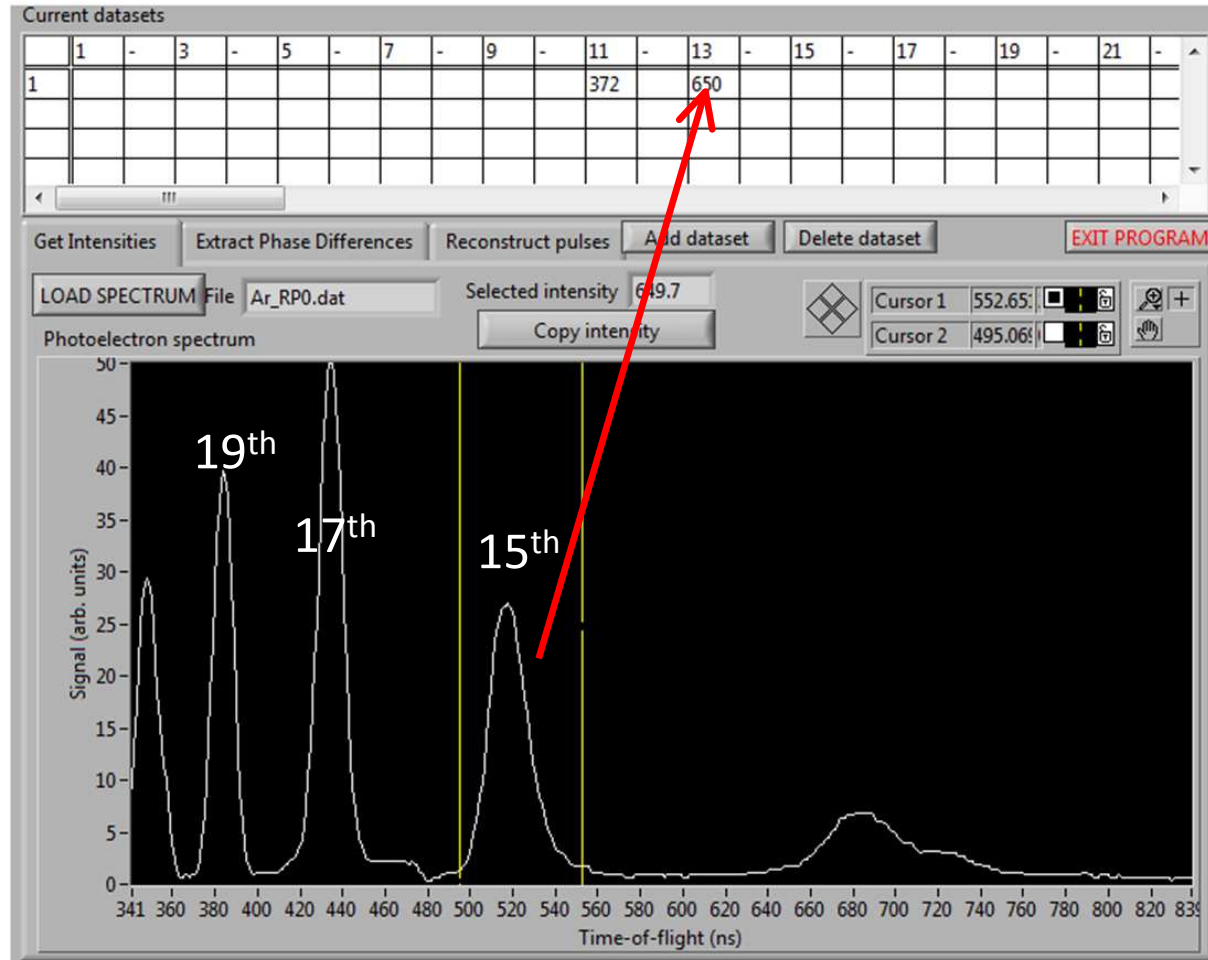
Cross-correlation setup



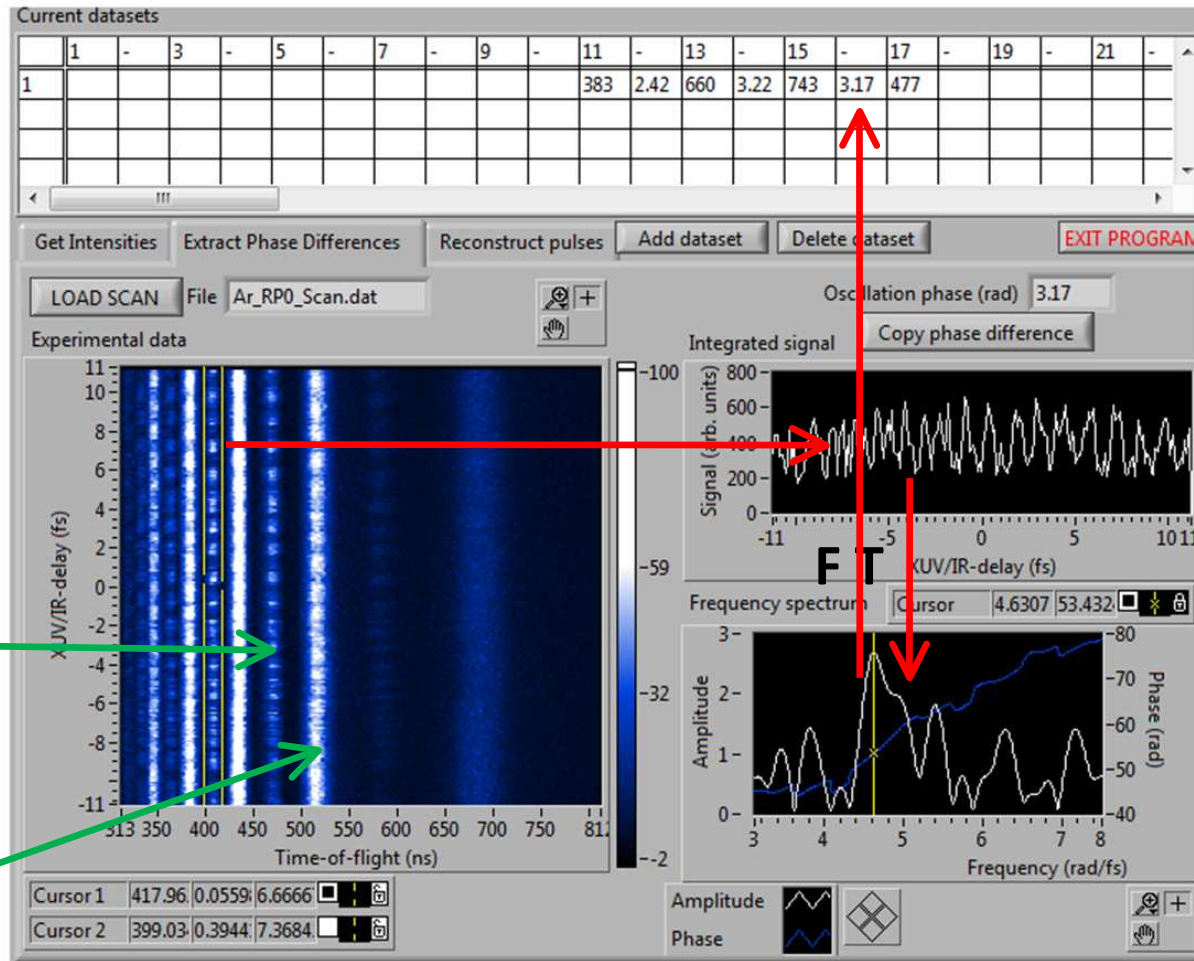
Magnetic Bottle Electron Spectrometer (MBES)



Labview program



Labview program



Sideband

Harmonic

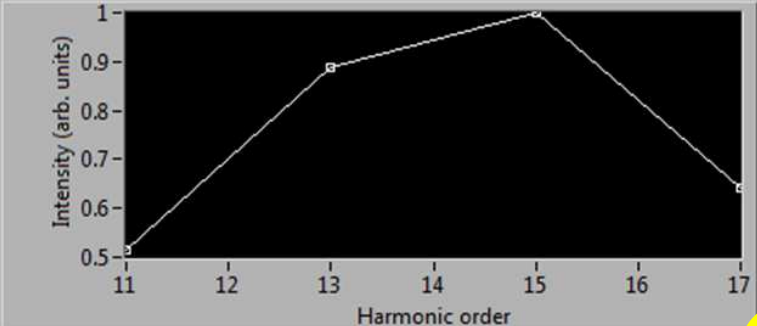
Labview program

Current datasets

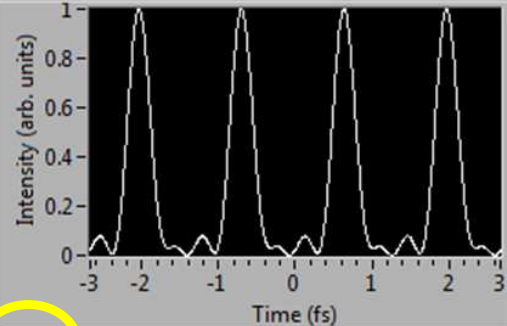
	1	-	3	-	5	-	7	-	9	-	11	-	13	-	15	-	17	-	19	-	21	-
1											383	2.42	660	3.22	743	3.17	477					

Get Intensities Extract Phase Differences Reconstruct pulses Add dataset Delete dataset EXIT PROGRAM

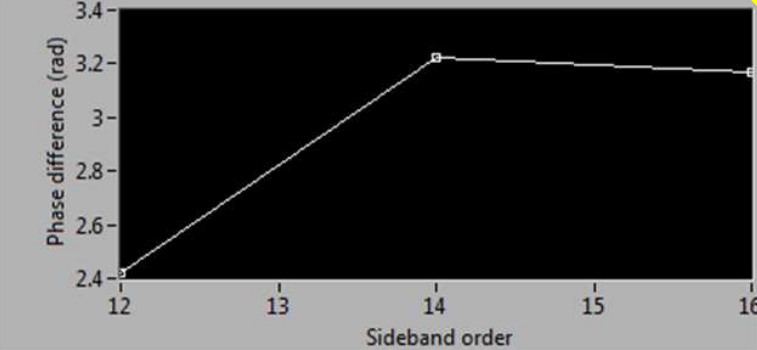
Intensities




Temporal Profile



Phase differences



324 as



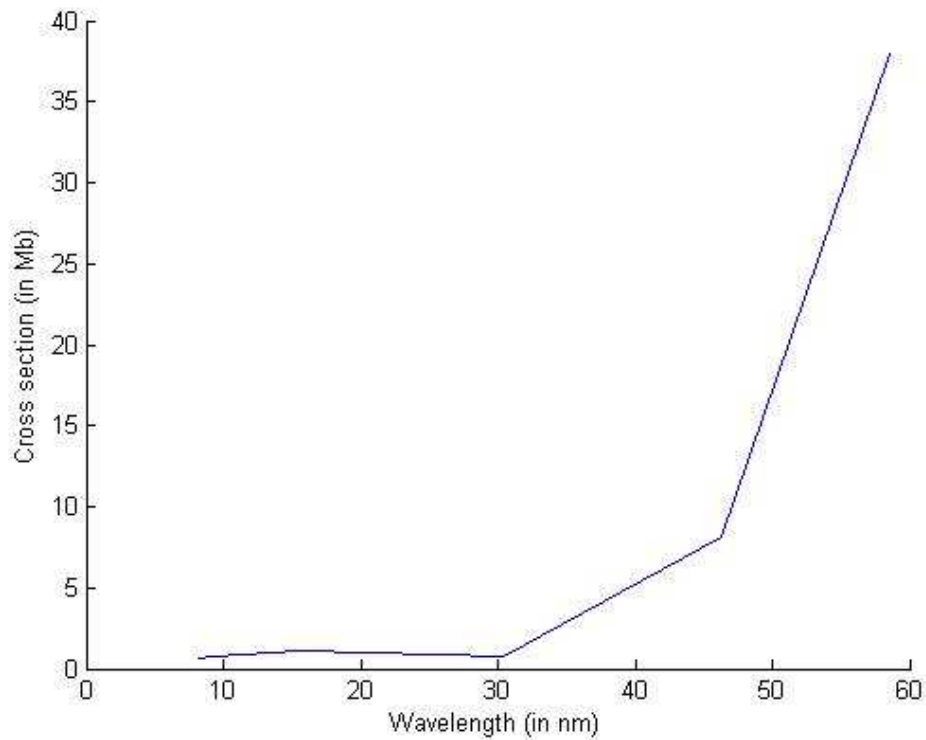
Ignore absolute delay
IR freq. (rad/fs)
2.35

Practical session
XTRA summer school
Porquerolles, May 2005
Per Johansson, Lund

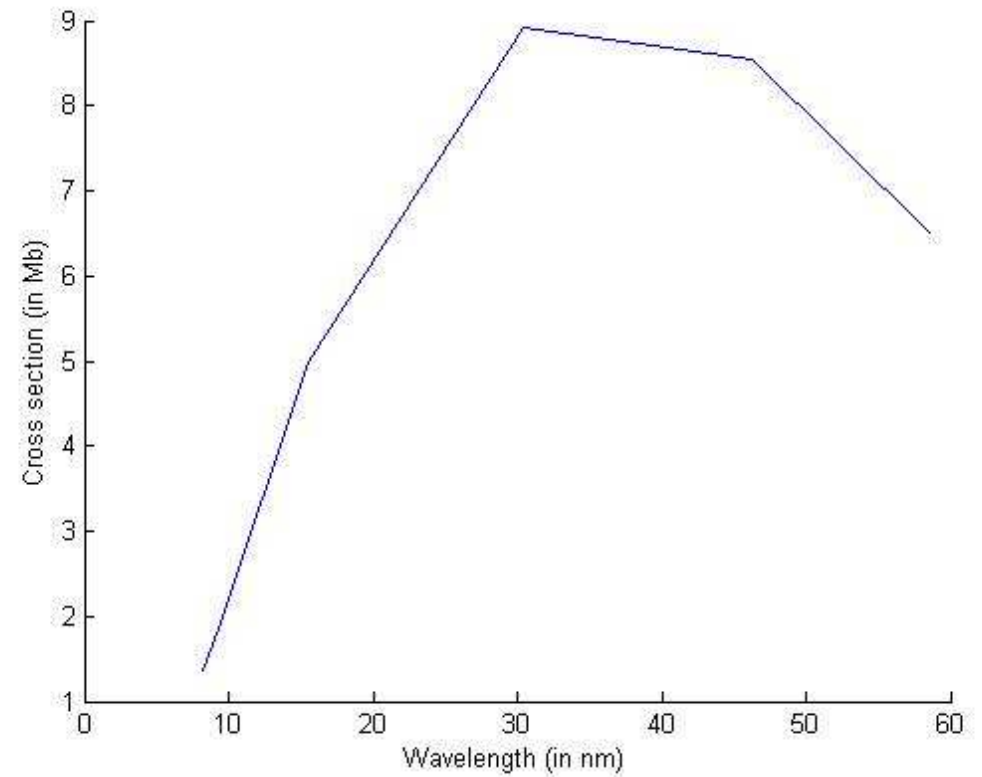
Useful data

Cross section

Argon ($I_p=15.76$ eV)



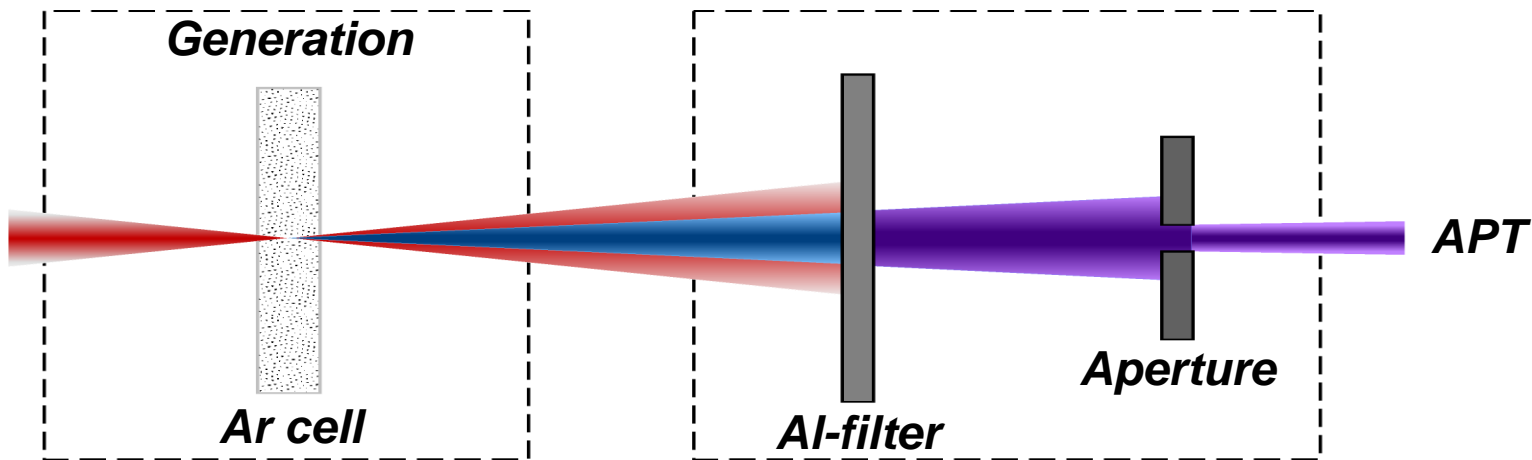
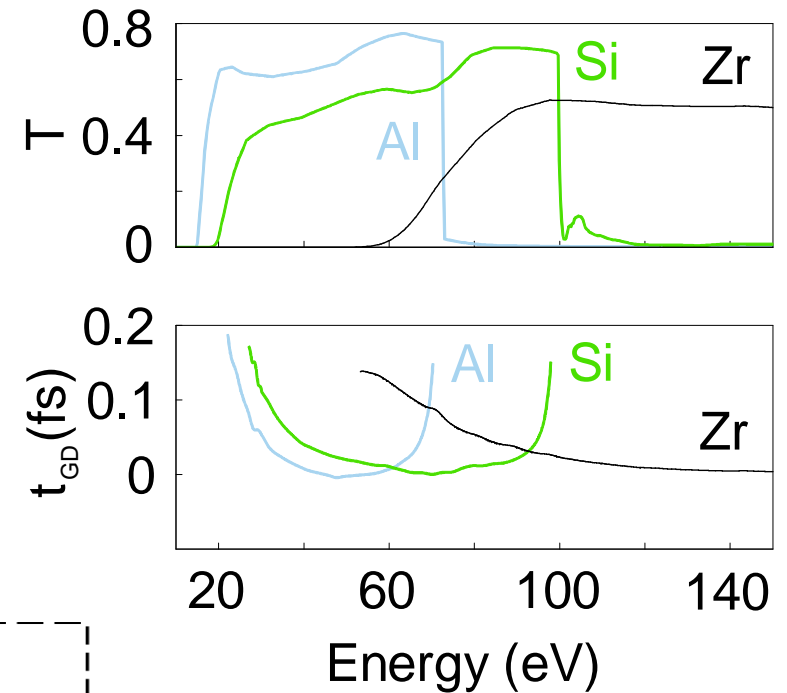
Neon ($I_p=21.56$ eV)



Application 1: Pulse compression using filters

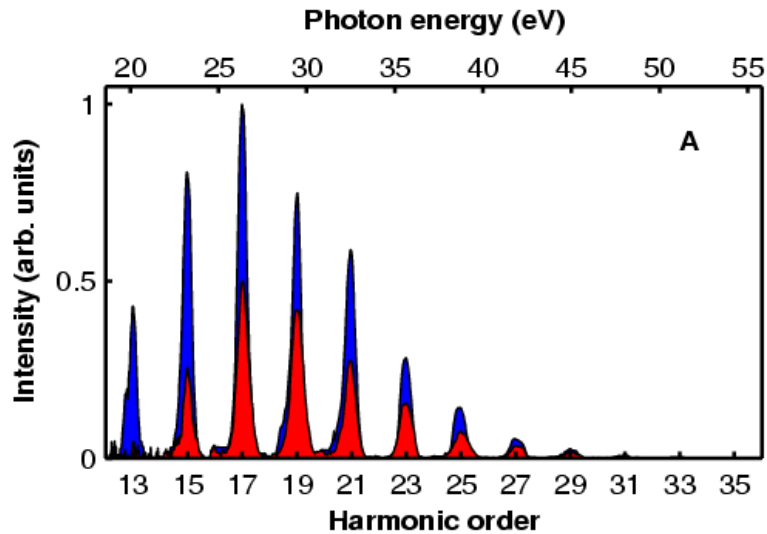
Can we compensate the attosecond chirp?

Yes, using metallic filters ($GDD < 0$)

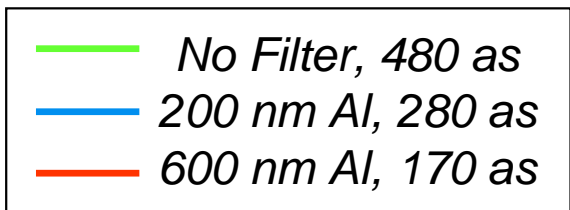
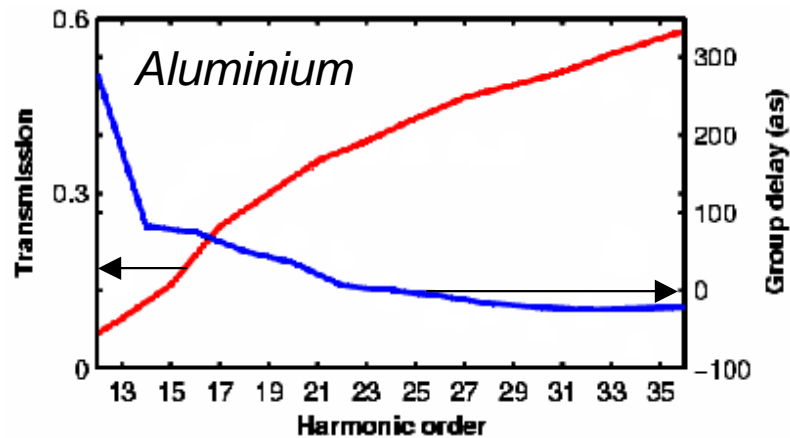
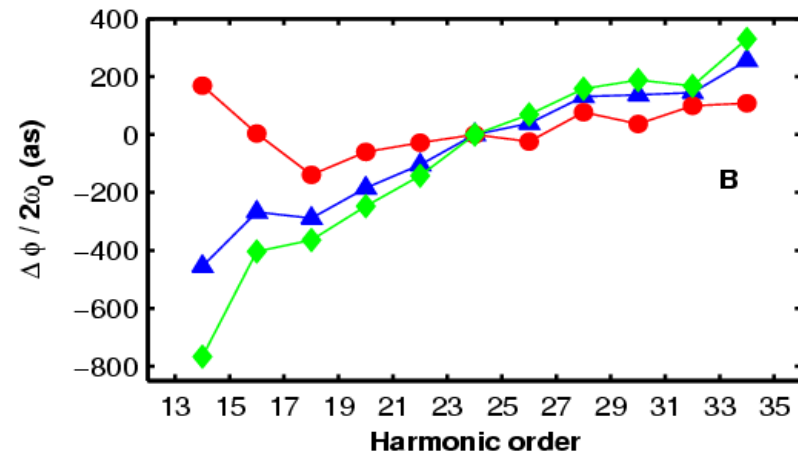


Aluminium filters

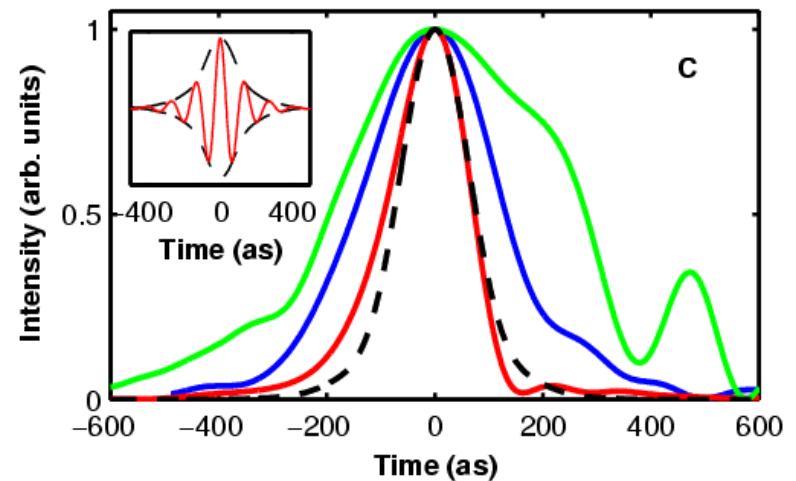
Harmonic Spectrum



Harmonic phase difference (delay)

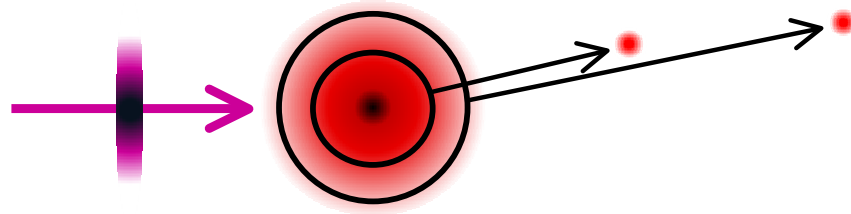


Reconstructed pulse



Application 2: Photoemission measurement delay

How long does it take for an electron to be photoionized?



- Group delay of an electron wave packet during photoemission

electron propagation:

$$\hbar \frac{d\eta}{d\epsilon} = \tau_W$$

← Scattering phase

optics: pulse propagation

$$\phi(\omega) \Rightarrow GD(\omega) = \frac{d\phi}{d\omega}$$

Wigner time delay

Scattering phase: phase of the one photon matrix element.

$$M_a^{(1)}(k_a) \propto e^{i\eta_1(k_a)}$$

How do we measure τ_w ?

Principle of the measurement (2)

(RABBIT)

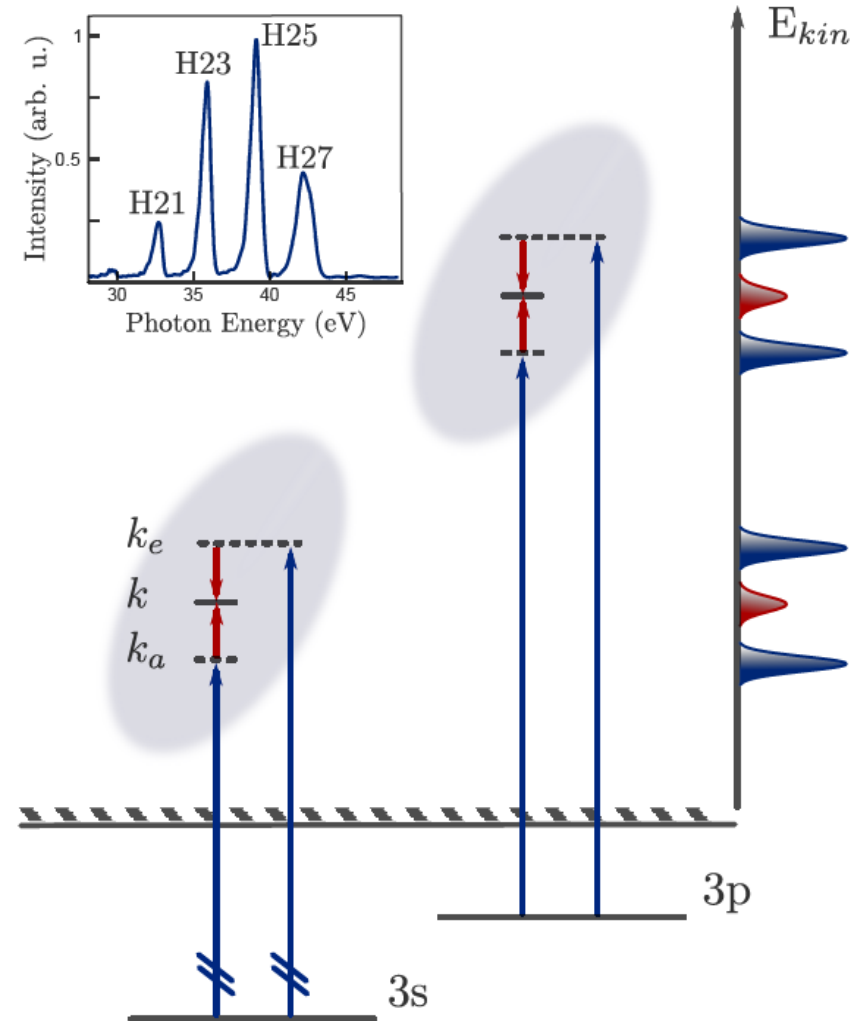
Ionisation from two different states (3s-3p)

Oscillations of the sidebands:

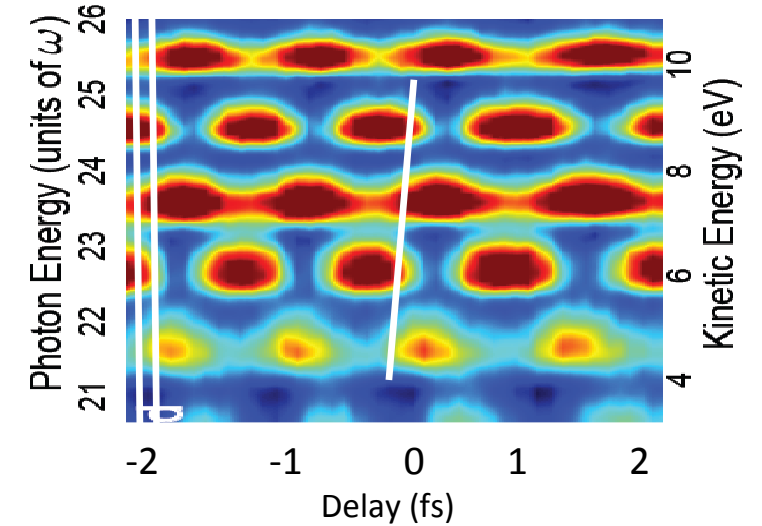
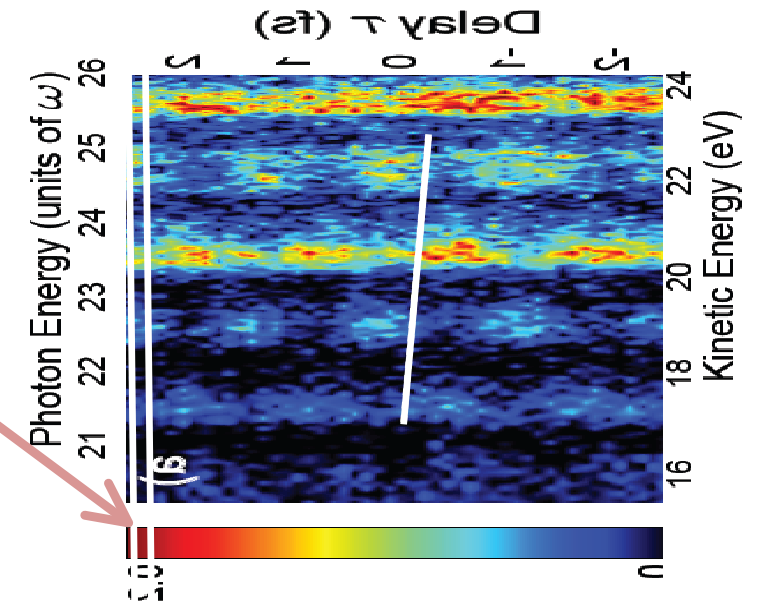
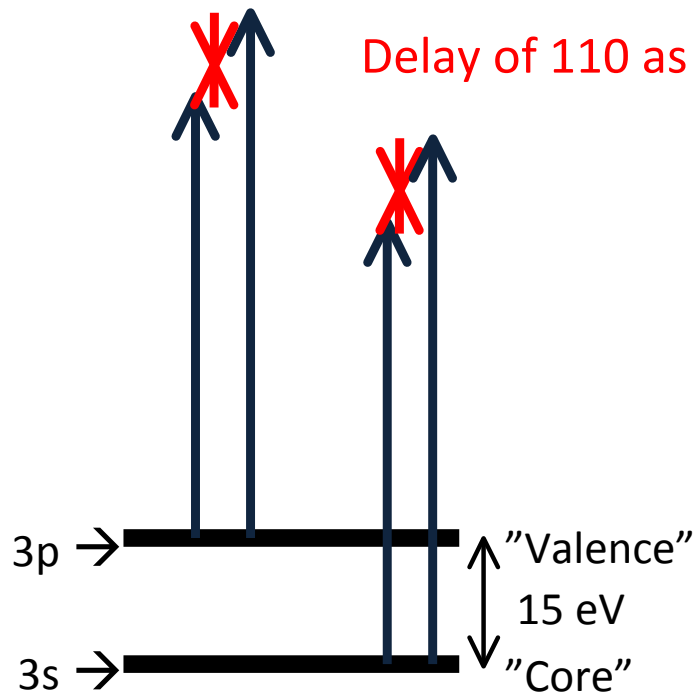
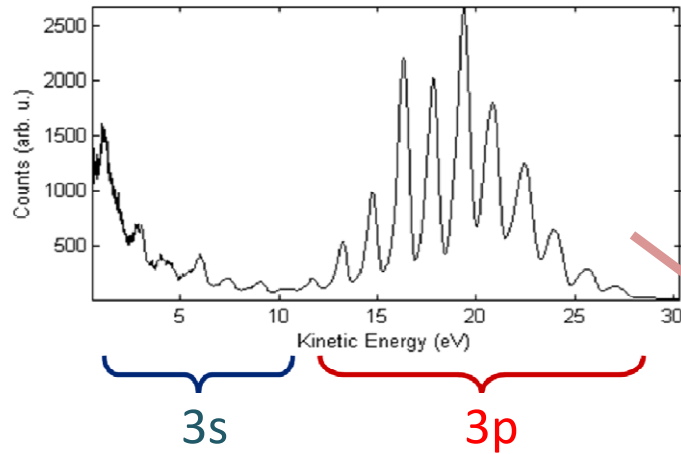
$$\cos(2\omega t + \Delta\phi_{\text{harm}} + \Delta\eta(3p) + \Delta\phi_{\text{cc}}(3p))$$

$$\cos(2\omega t + \Delta\phi_{\text{harm}} + \Delta\eta(3s) + \Delta\phi_{\text{cc}}(3s))$$

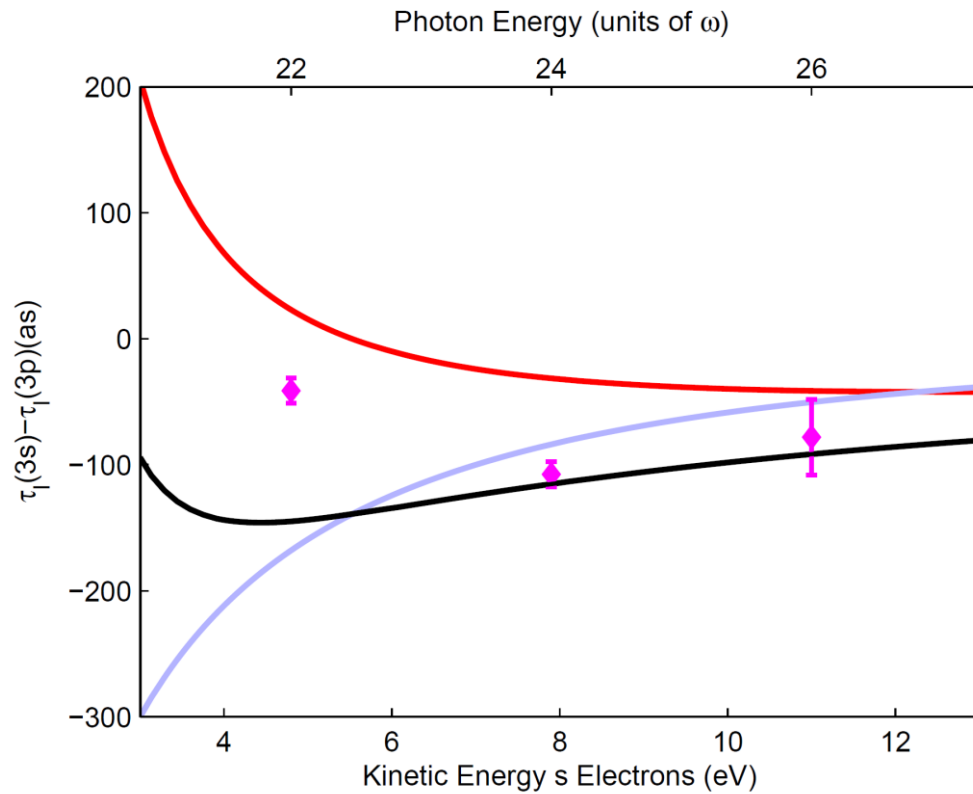
Shift!



Experimental results



Experimental results



Wigner time delay:

$$\hbar \frac{d\eta}{d\epsilon} = \tau_W$$

Continuum-continuum contribution

Total

Experiment

Good agreement at high energy

Low energy: contribution from the core and resonance

Labview program: change settings

The screenshot displays a Windows 7 desktop environment. In the background, a Microsoft PowerPoint window titled 'RABBITT.pptx' is open, showing a slide with the text 'Labview program'. In the foreground, two Windows Control Panel windows are open:

- Region and Language:** This window is set to 'Swedish (Sweden)'. It shows date and time format options: Short date (yyyy-MM-dd), Long date ('den 'd MMMM yyyy'), Short time (HH:mm), Long time (HH:mm:ss), and First day of week (måndag). Examples provided are: Short date: 2011-04-08, Long date: den 8 april 2011, Short time: 10:33, and Long time: 10:33:39.
- Customize Format:** This window is set to the 'Numbers' tab. It shows the 'Example' section with 'Positive: 123 456 789.00' and 'Negative: -123 456 789.00'. Other settings include: Decimal symbol (.), No. of digits after decimal (2), Digit grouping symbol (), Digit grouping (123 456 789), Negative sign symbol (-), Negative number format (-1.1), Display leading zeros (0.7), List separator (;), Measurement system (Metric), Standard digits (0123456789), and Use native digits (Never).

The Windows Start menu is open, showing various system settings such as Device Manager, Folder Options, Indexing Options, Location and Other Sensors, Notification Area Icons, Personalization, QuickTime (32-bit), RemoteApp and Desktop Connections, System, Windows CardSpace, Windows Defender, Devices and Printers, Fonts, Internet Options, Mail (32-bit), NVIDIA Control Panel, Phone and Modem, Realtek HD Audio Manager, Sound, Taskbar and Start Menu, Backup and Restore, Default Programs, Display, Getting Started, Java, Mouse, Parental Controls, Power Options, Recovery, Speech Recognition, Troubleshooting, and Windows Firewall.

The taskbar at the bottom shows the current slide is 'Slide 11 of 11', the theme is 'Office Theme', and the system language is 'Swedish (Sweden)'. The system tray on the right shows the date and time as '11/8'.