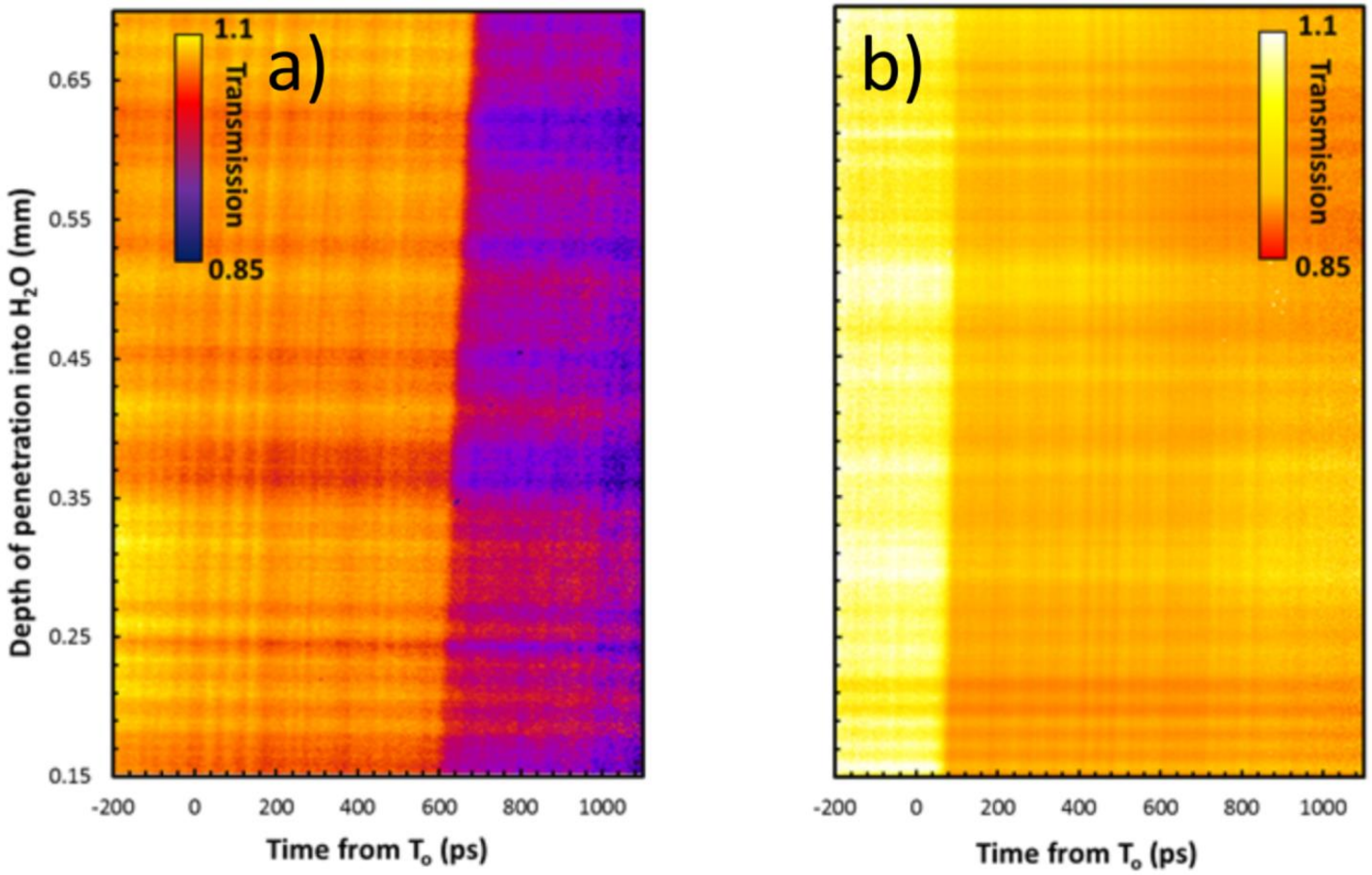
Ultrafast pulsed proton radiolysis in water
Delayed solvation time of electron



b.dromey@qub.ac.uk

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Queen's University Belfast

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- L. Senje
- C-G Wahlström

Lund University

b.dromey@qub.ac.uk

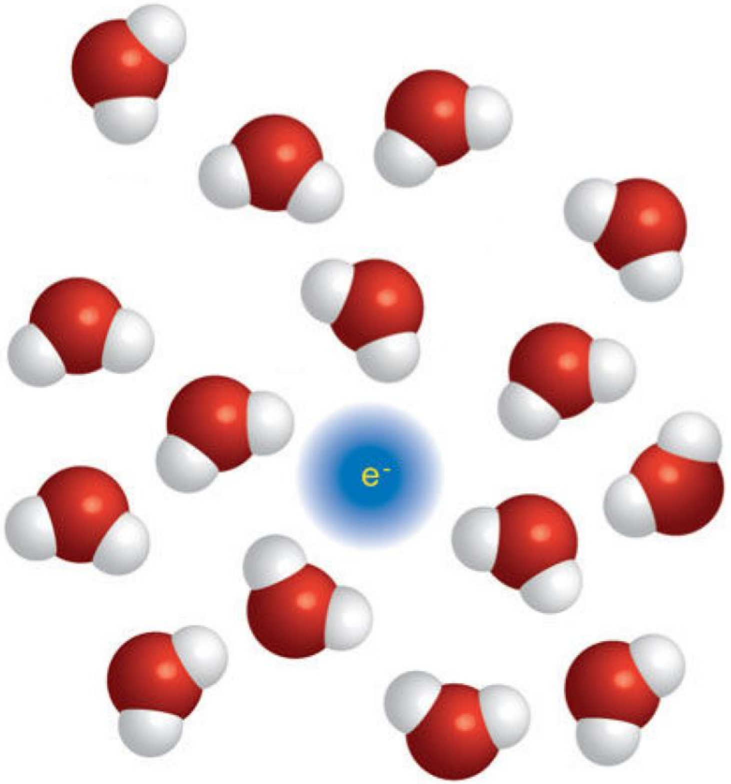
Solvated Electron I

Protons ionise water molecules to produce a radical ion and free electron

$$H_2O \xrightarrow{\text{radiation}} H_2O^+ + e^-$$

Through dipolar interactions the electron is captured by the water, becoming solvated

$$e^- + H_2O \longrightarrow e_{aq}$$



b.dromey@qub.ac.uk

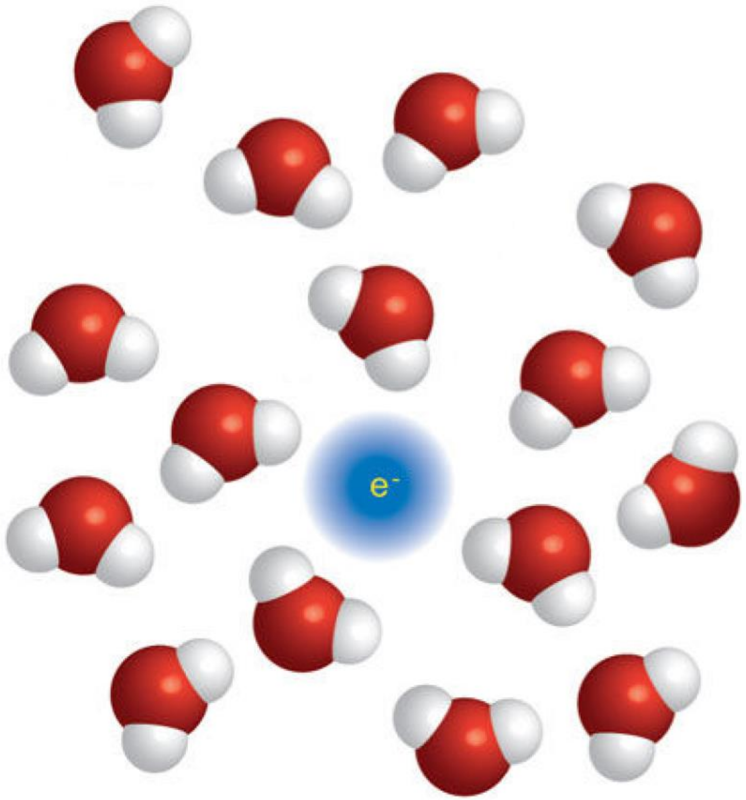
Solvated Electron II

Formation of free and solvated electrons begin radical generation processes which are highly reactive and lead to DNA damage

$$H_2O\cdot^{+} \longrightarrow H^{+} + HO\cdot$$

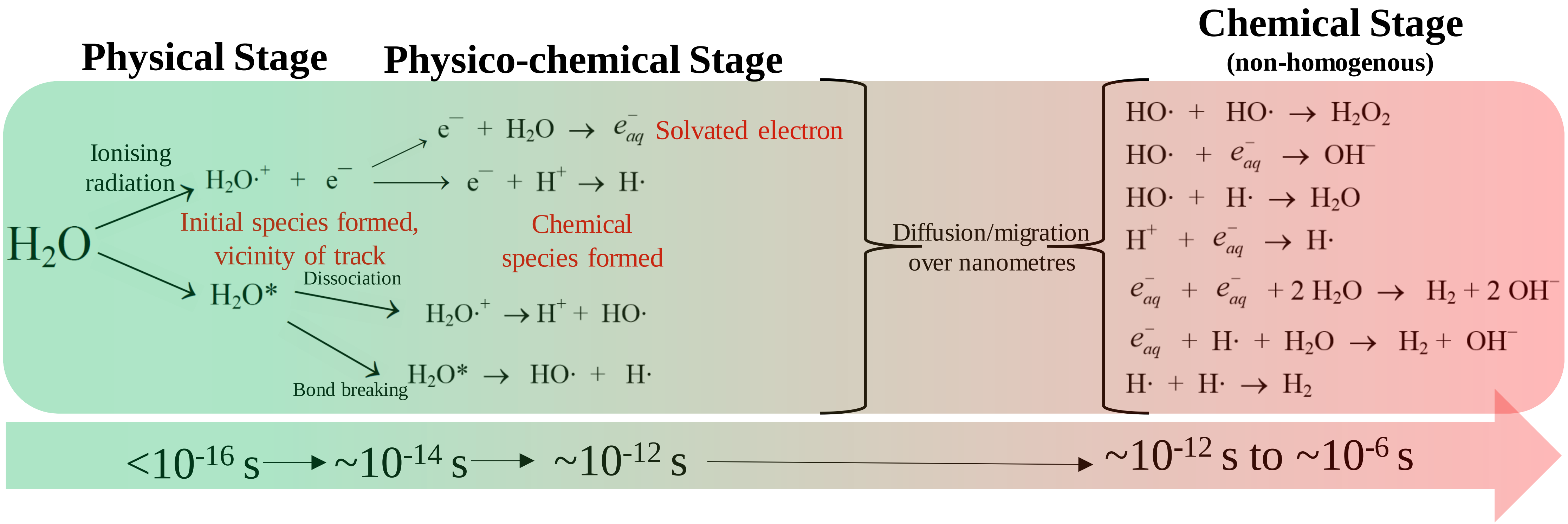
$$e_{aq} + e_{aq} + 2\,H_2O \longrightarrow H_2 + 2\,OH^{-}$$

$$HO\cdot + HO\cdot \longrightarrow H_2O_2$$



b.dromey@qub.ac.uk

Water chemistry (a simple overview, not complete)



e^-_{aq} - broad photoabsorption band centred on 800nm

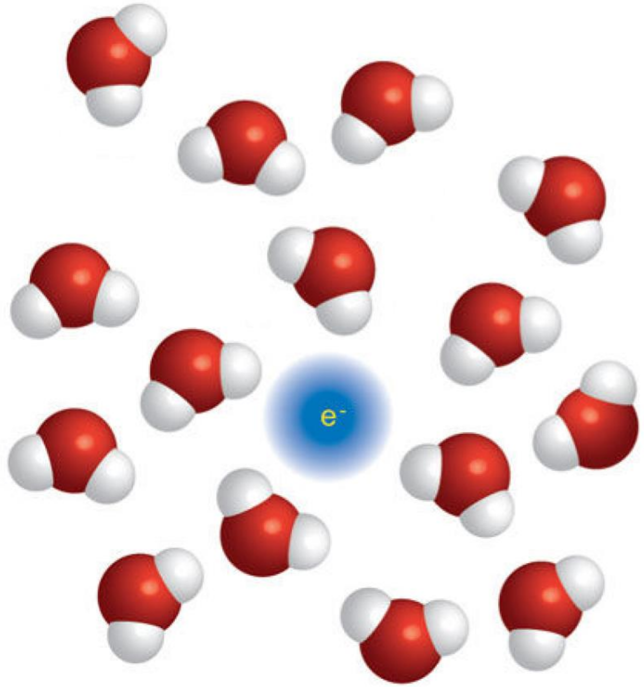
b.dromey@qub.ac.uk

Studying the solvation process using ions

Pulsed ion-radiolysis so far limited by proton pulse duration and probe synchronisation.

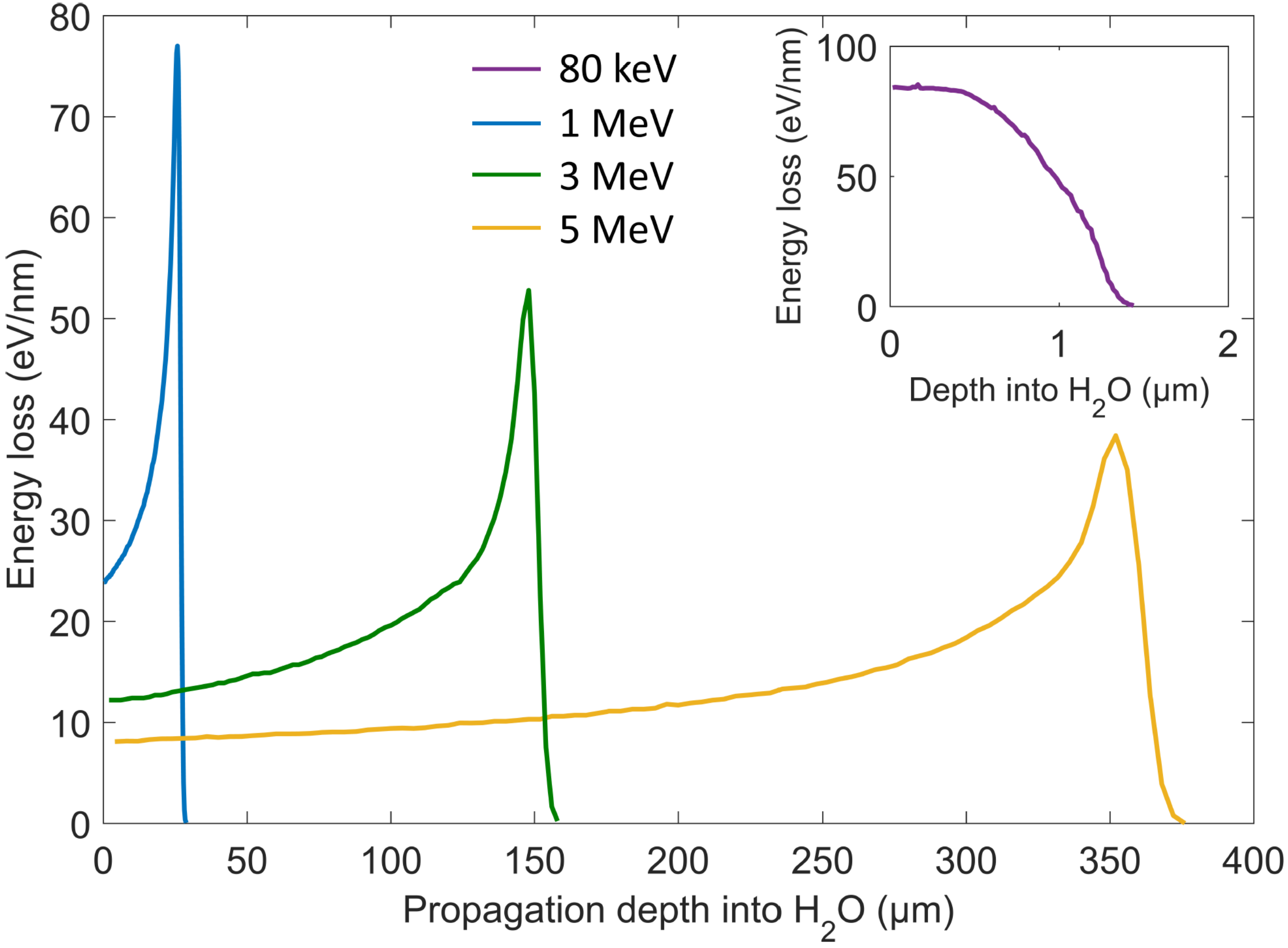
Solvated electron extensively studied due to it's high absorptivity and broad absorption spectrum.

- Chemical scavengers added to determine yields of radiolytic products.
- For high temporal resolution – large uncertainty due to concentration of scavenger required.



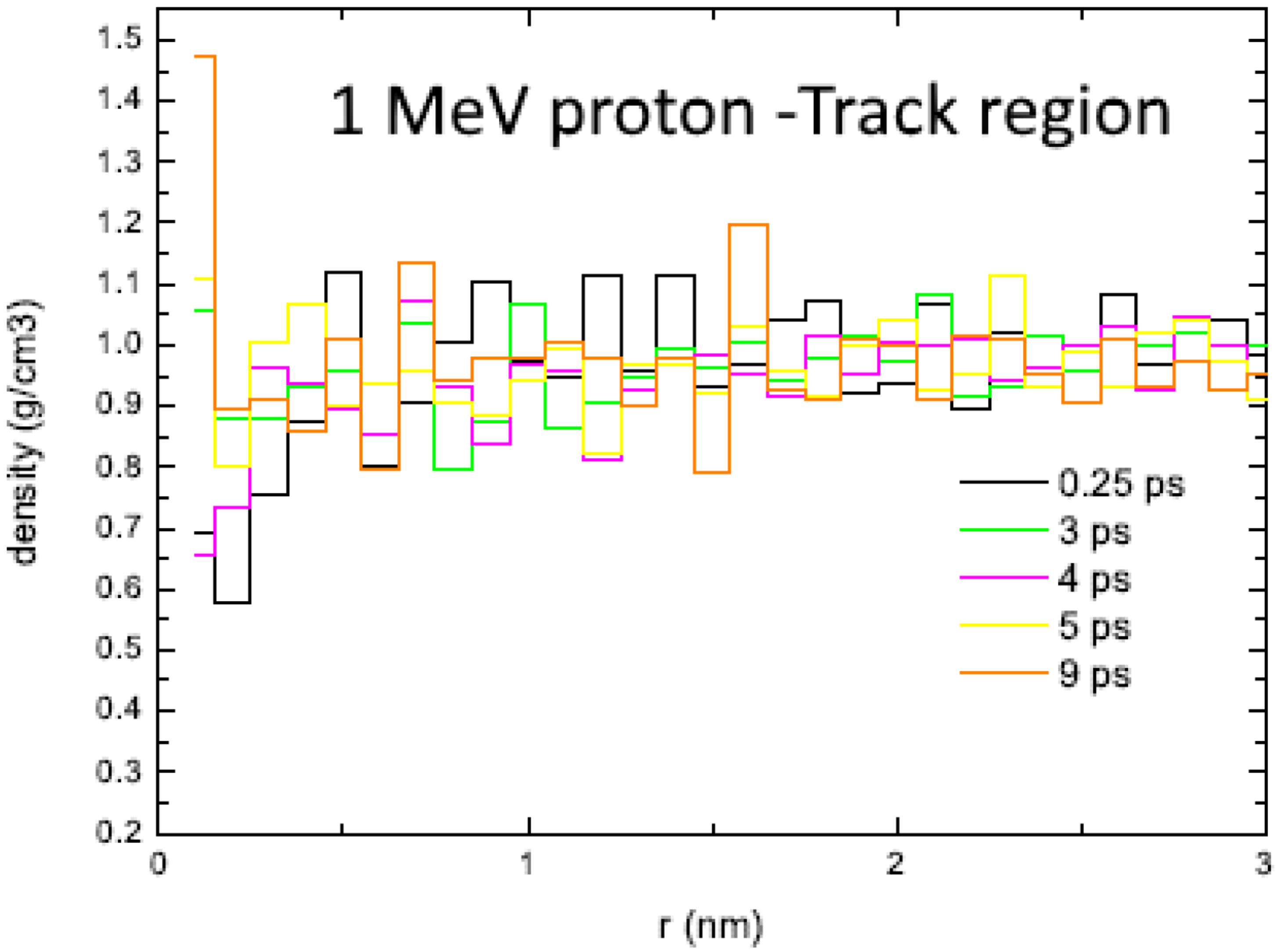
b.dromey@qub.ac.uk

Ion interactions in water – Stopping Power and Bragg region



b.dromey@qub.ac.uk

Ion interactions in water – Water behaviour, non Bragg region



Molecular Dynamics Simulations courtesy of Dr Pablo deVera

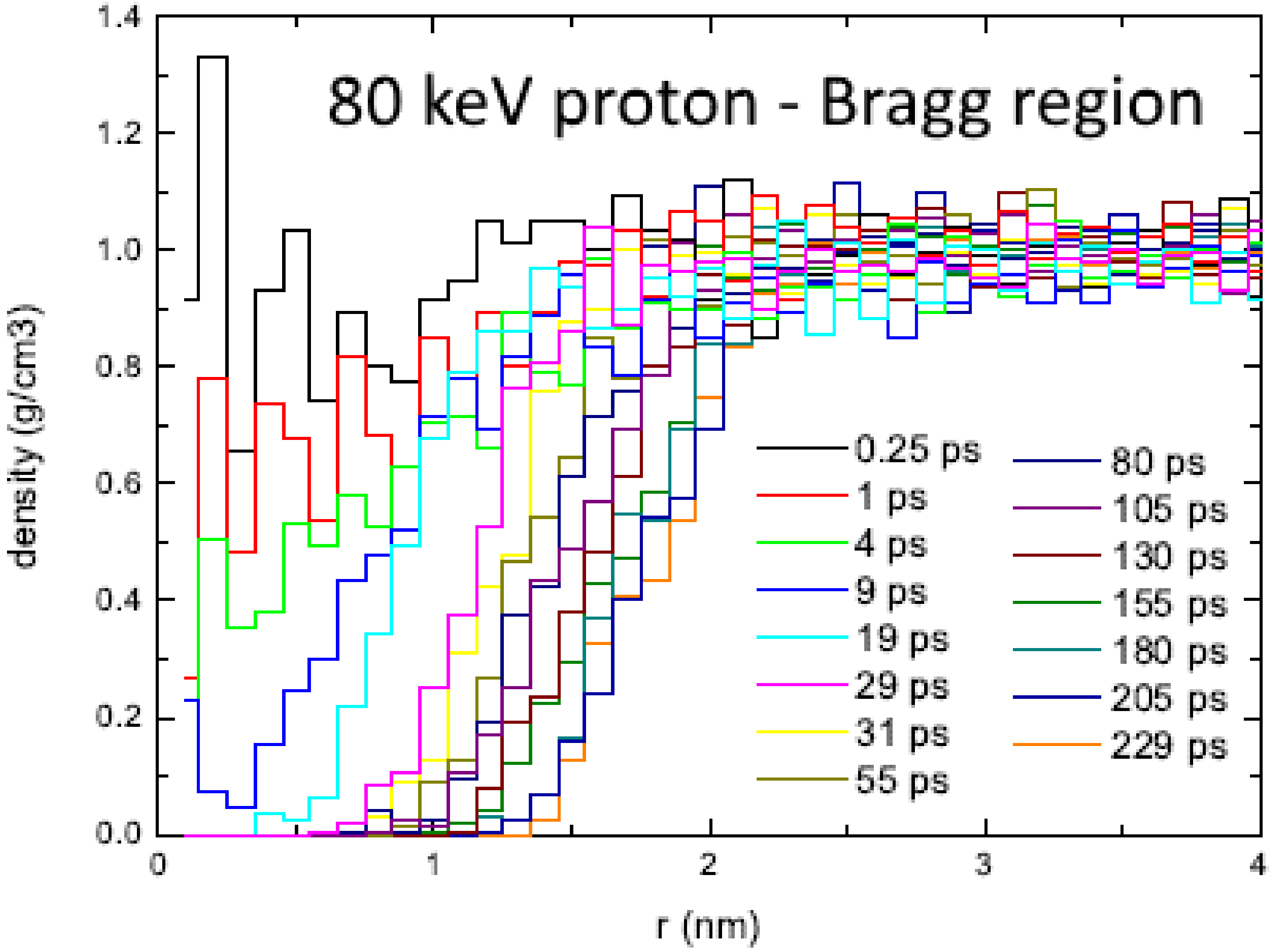
Very little motion of water molecules

Very similar to X-Rays and fast electrons

(Ionisiation, no bulk motion of water)

b.dromey@qub.ac.uk

Ion interactions in water – Water behaviour, Bragg region



Molecular Dynamics Simulations courtesy of Dr Pablo deVera

Very different behaviout

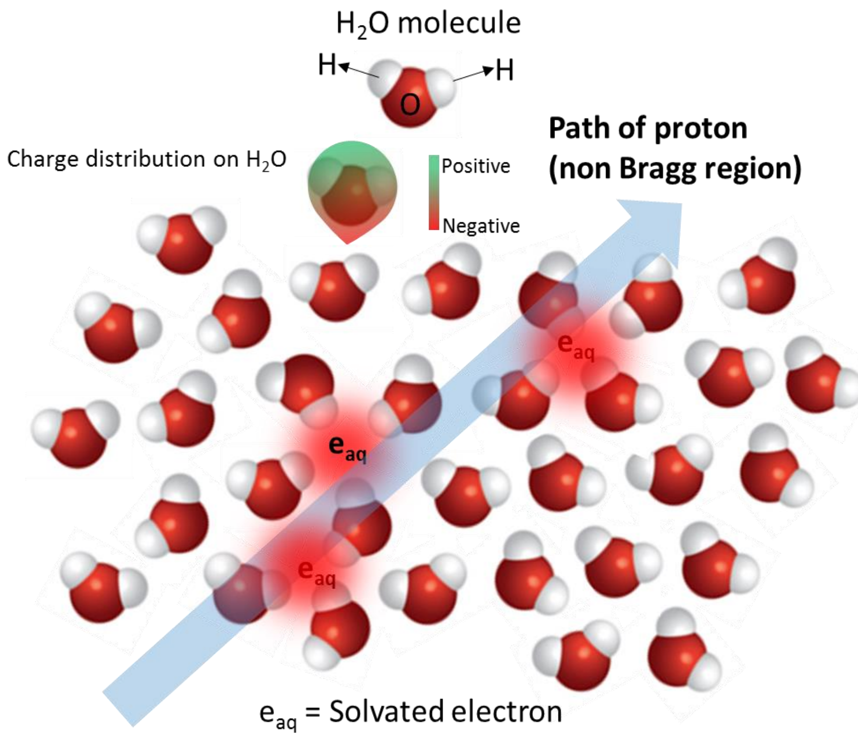
Very similar to X-Rays and fast electrons

(Ionisation, bulk motion of water)

b.dromey@qub.ac.uk

Ion interactions in Water – a schematic of nanocavitation

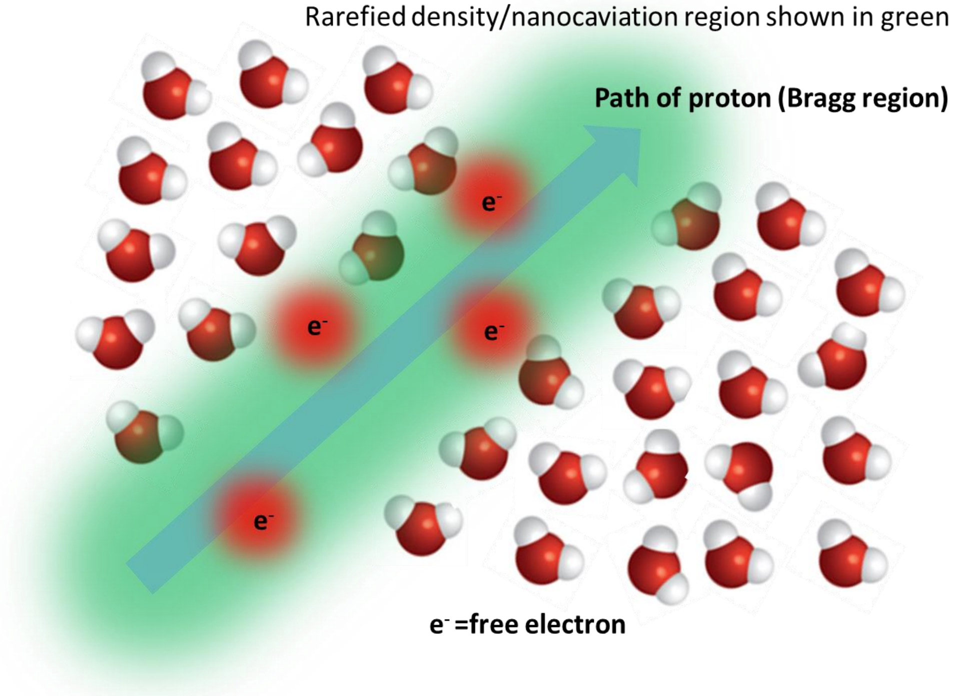
Outside Bragg peak region



Bragg peak region

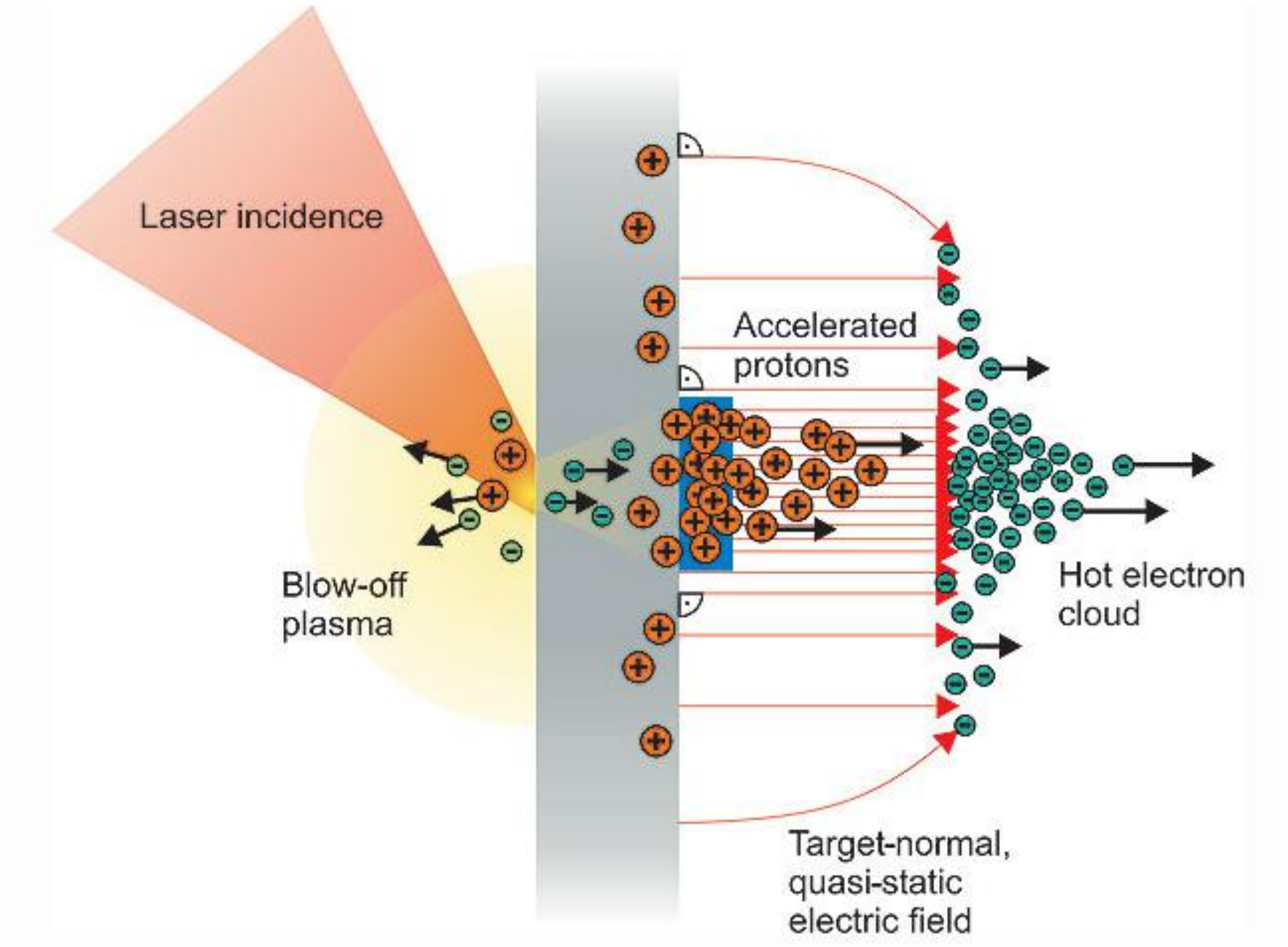
From Figure 3 the fast nano cavitation front has moved > 1.5 nm in < 0.25 ps $\Rightarrow$ >3.3 eV

The vertical binding energy of $e^{-}_{aq} \approx 3.7$ eV. For comparison thermal energy is ≈ 0.025eV



b.dromey@qub.ac.uk

Target Normal Sheath Acceleration – an ultrafast source



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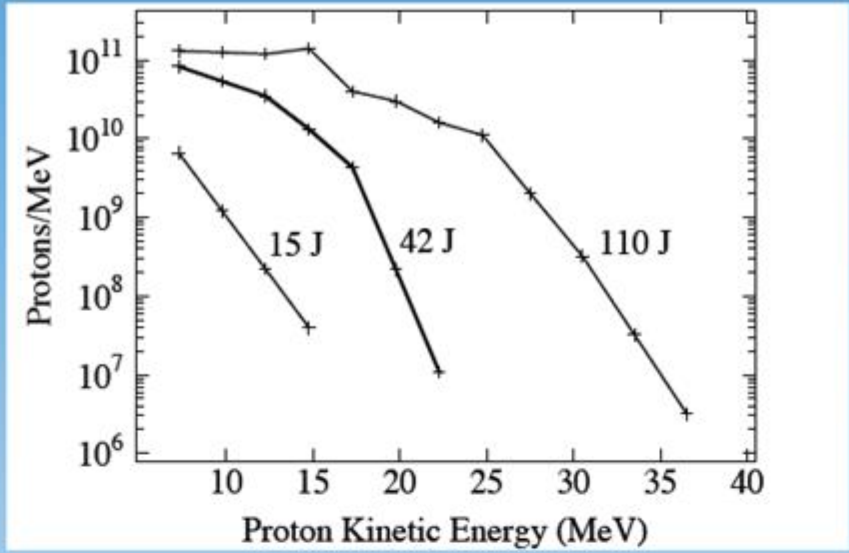
b.dromey@qub.ac.uk

Target Normal Sheath Acceleration – an ultrafast source

Typical results



- Target: 10µm Al
- Temperature
  ~ 1.8 MeV for 12 J
  ~ 5 MeV for 85J
- Energy conversion
  $\eta \sim 2\ 10^{-3}$ for 12 J
  $\eta \sim 5\ 10^{-2}$ for 85 J
  $\eta \sim 1\ 10^{-1}$ for 400 J

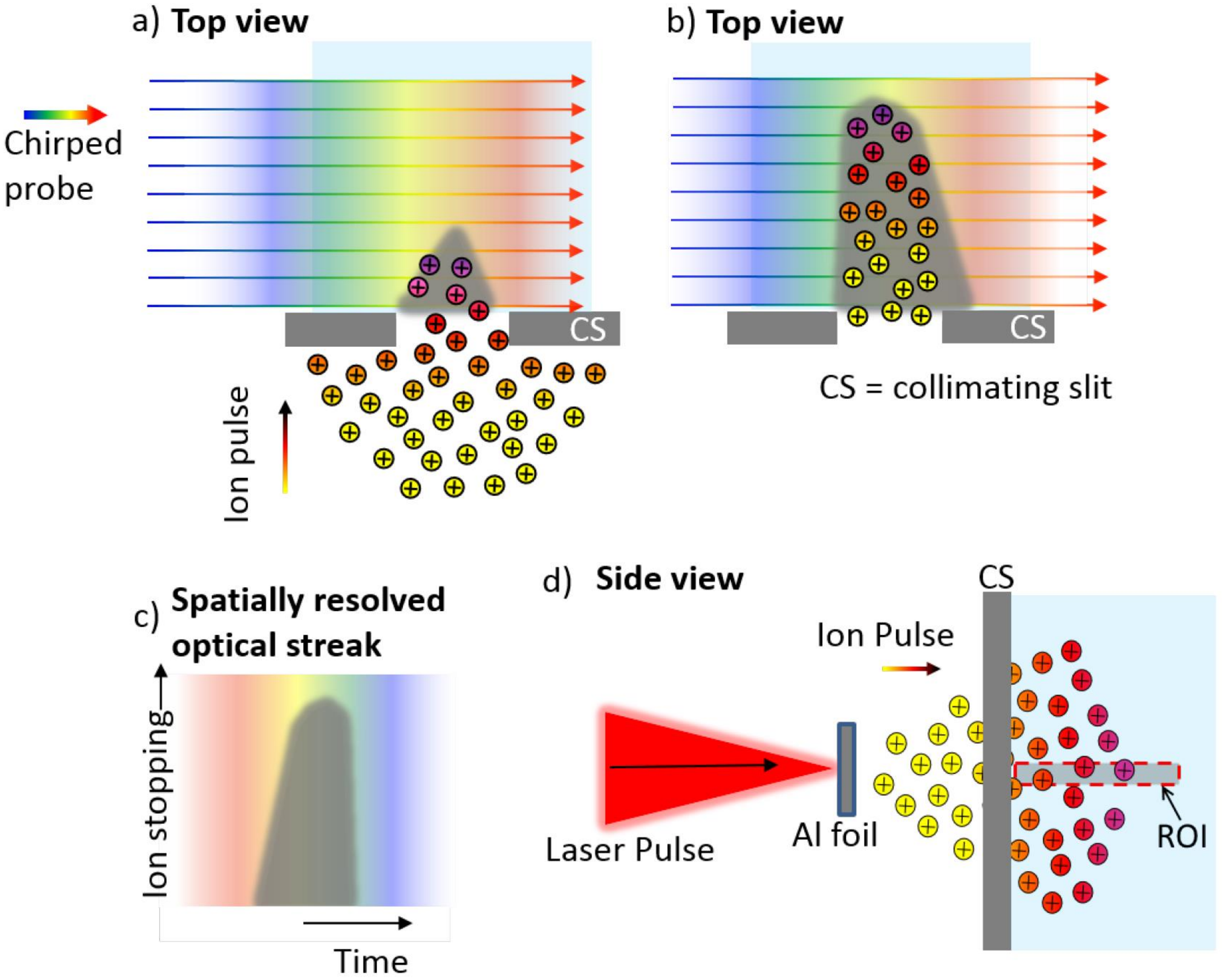
Broadband spectrum

Cone Narrowing with increasing E

Typical divergence:
30-60°

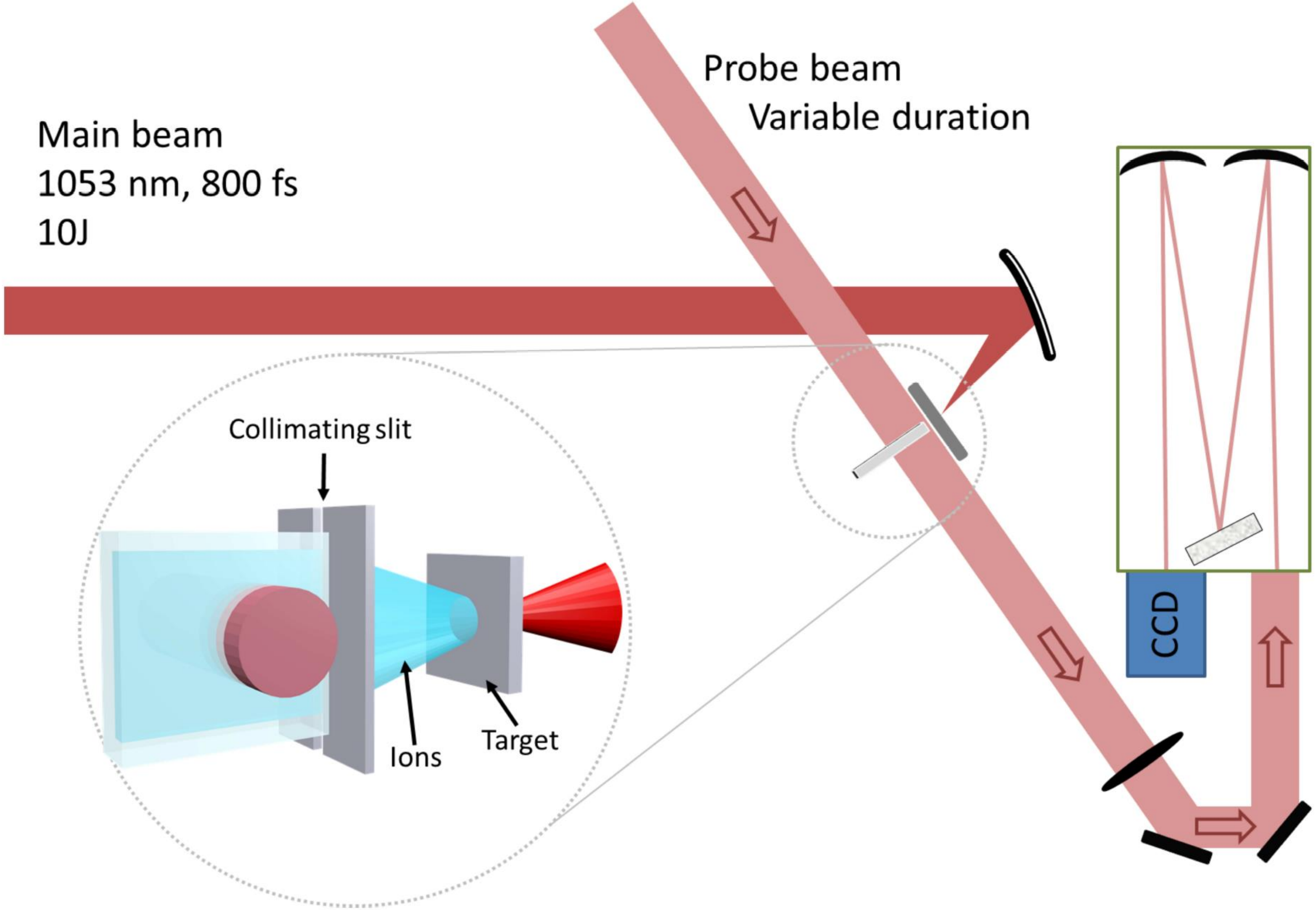
b.dromey@qub.ac.uk

Optical streaking technique



b.dromey@qub.ac.uk

Observing ultrafast proton interactions in a single shot



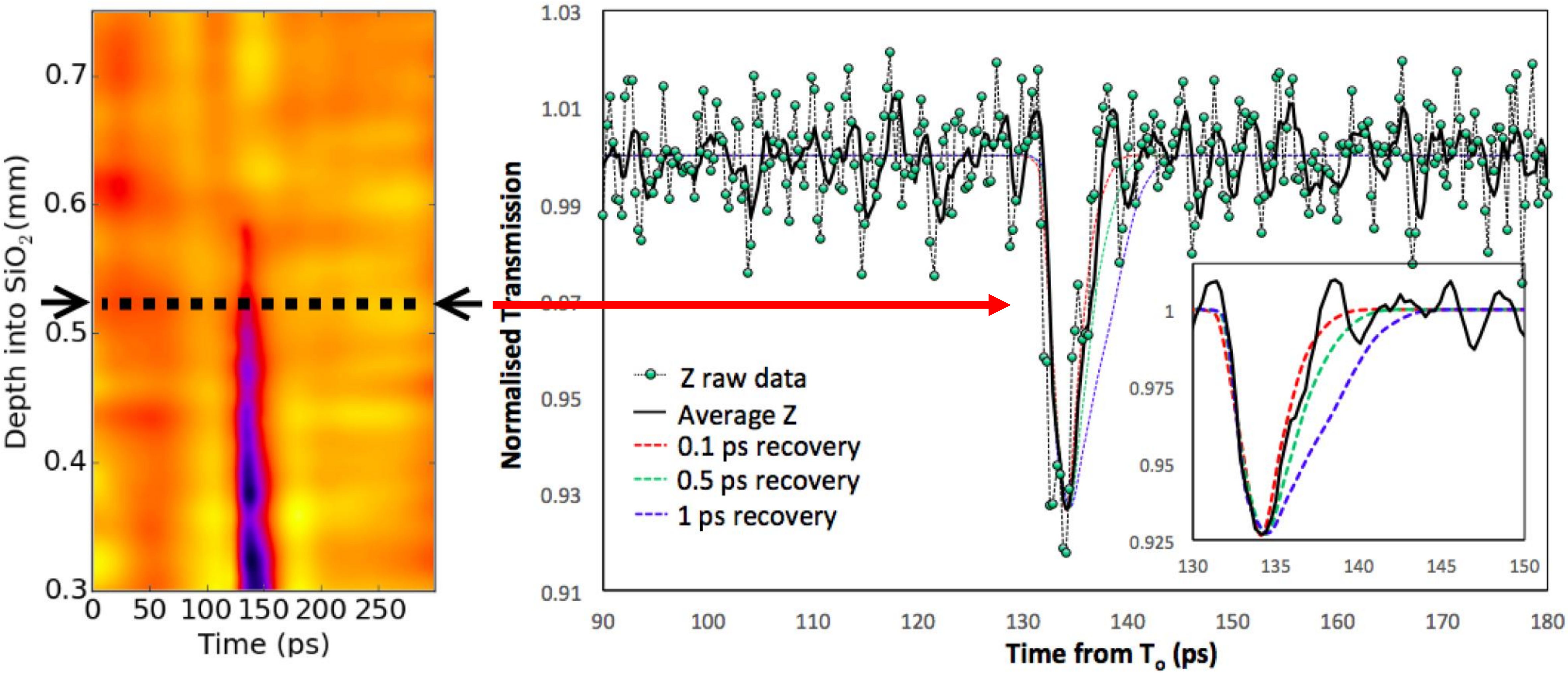
Schematic
(not to scale)

Probe ion induced
a) opacity (free electrons in conduction)
b) Photabsoption bands
c) Polaristation effects

b.dromey@qub.ac.uk

Proton pulse duration measurements using SiO_2

3.5 ± 0.7 ps proton pulse duration

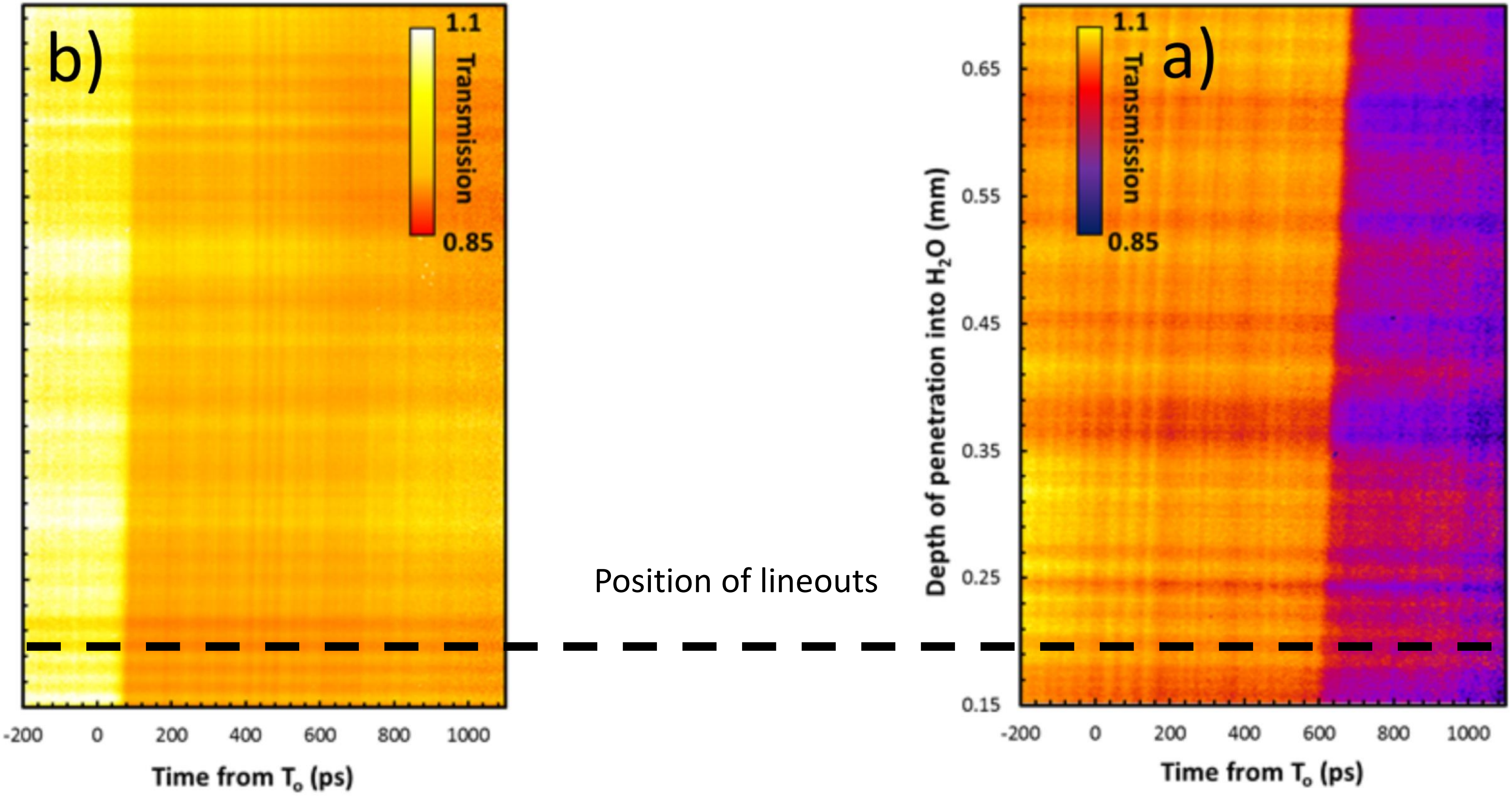


b.dromey@qub.ac.uk

Experimental results optical streak of solvated electron dynamics

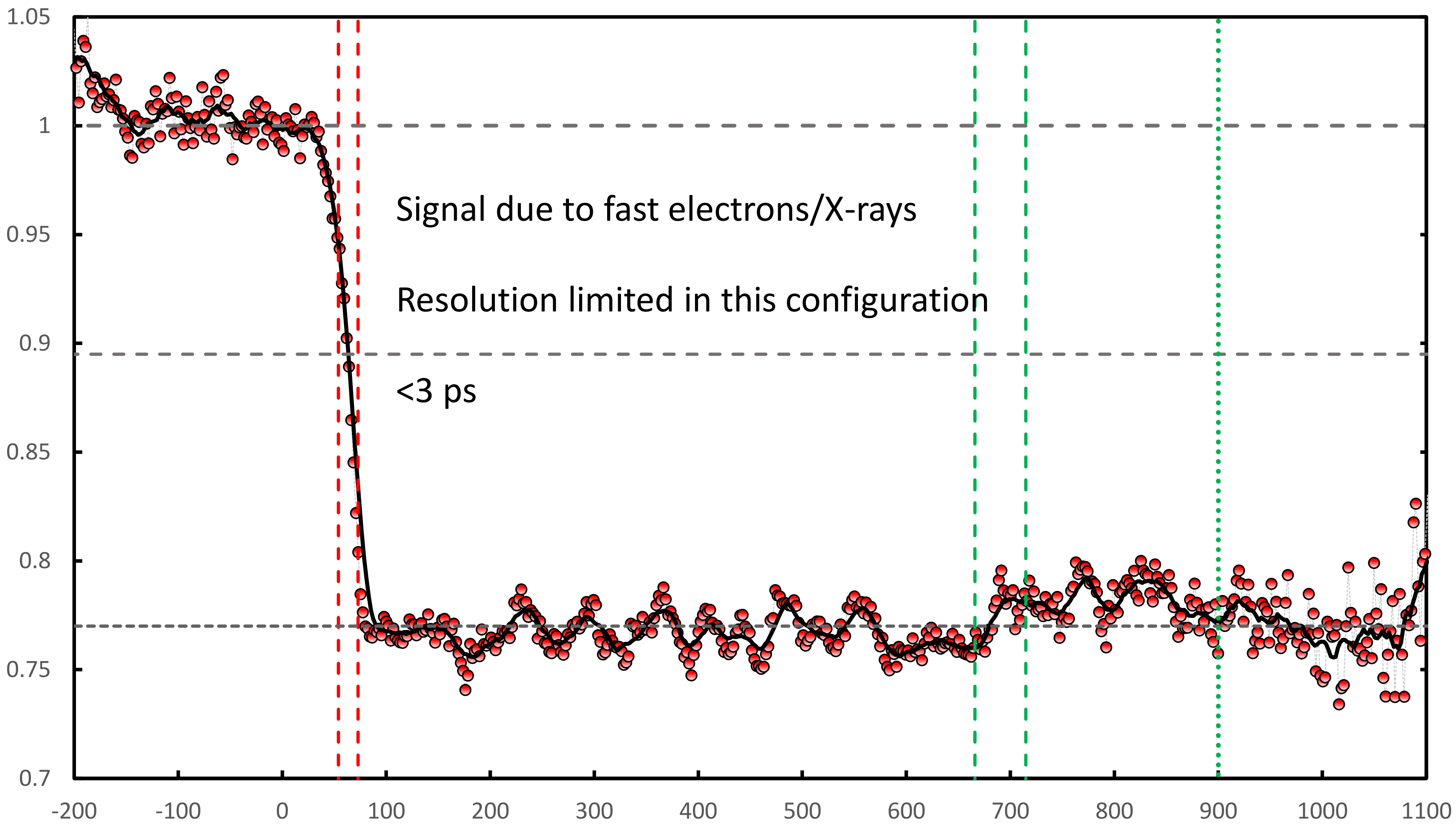
Fast electrons and prompt X-rays long scalelength conditions **interacting in water**

Protons from short scalelength conditions **interacting in water**



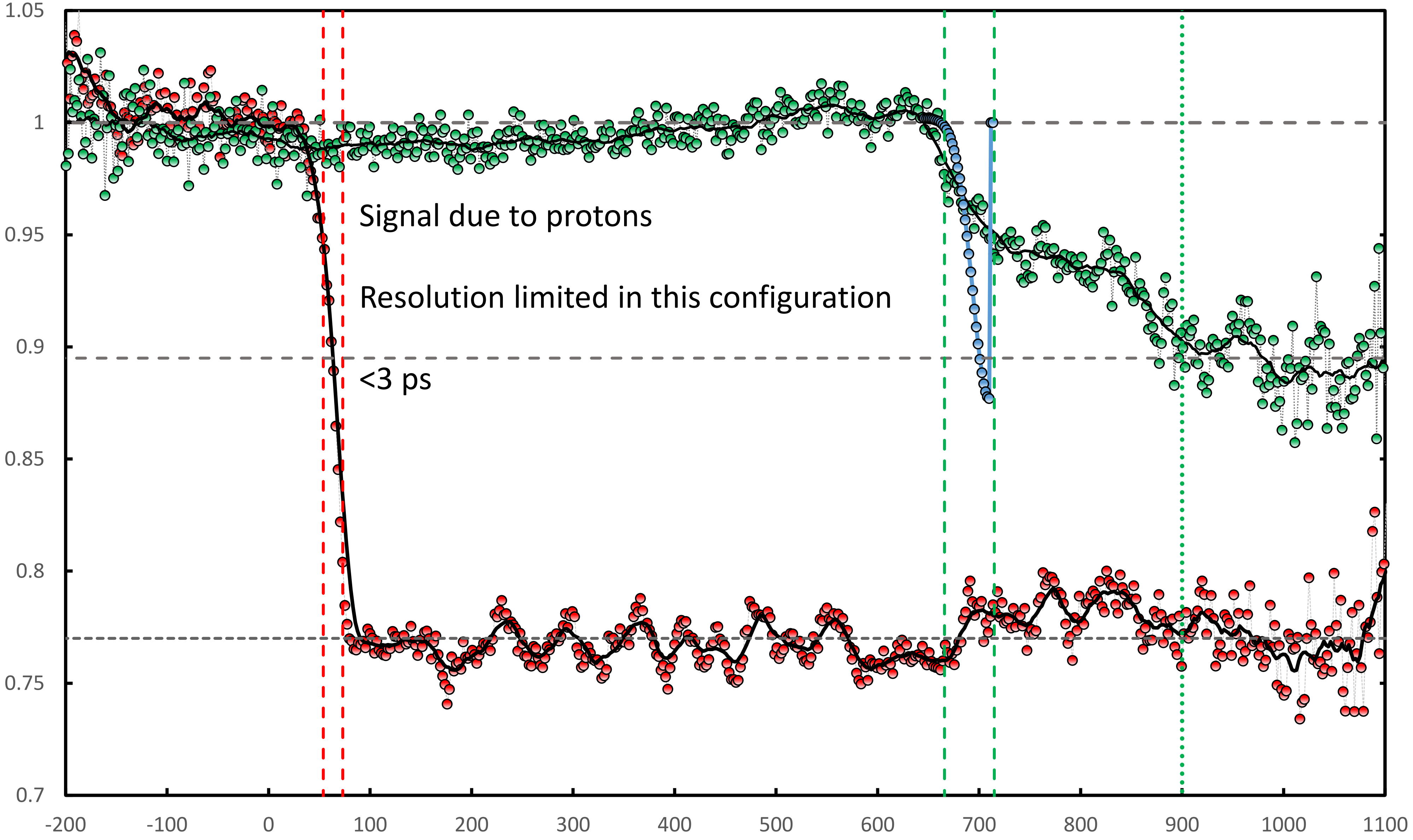
b.dromey@qub.ac.uk

Experimental results



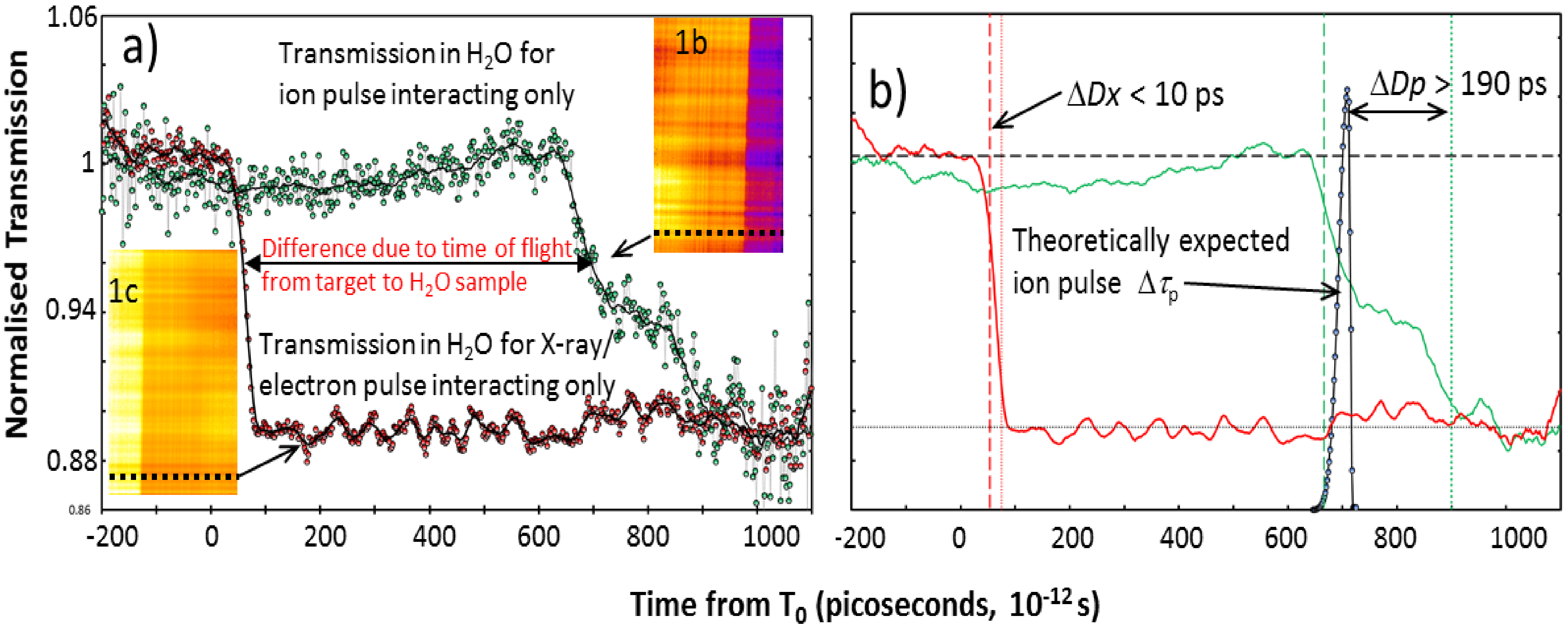
b.dromey@qub.ac.uk

Experimental results



b.dromey@qub.ac.uk

Experimental results



Clear evidence of delayed solvation due to nanocavitation

b.dromey@qub.ac.uk

Queen's University Belfast

- **Demonstrated that TNSA provides a suitable source for studying nascent radiation chemistry in water**

- **Clear evidence that behaviour is different for electrons/X-rays and protons**

- **Next step will be to study cytotoxic species simulateously**

Thank you for listening

b.dromey@qub.ac.uk