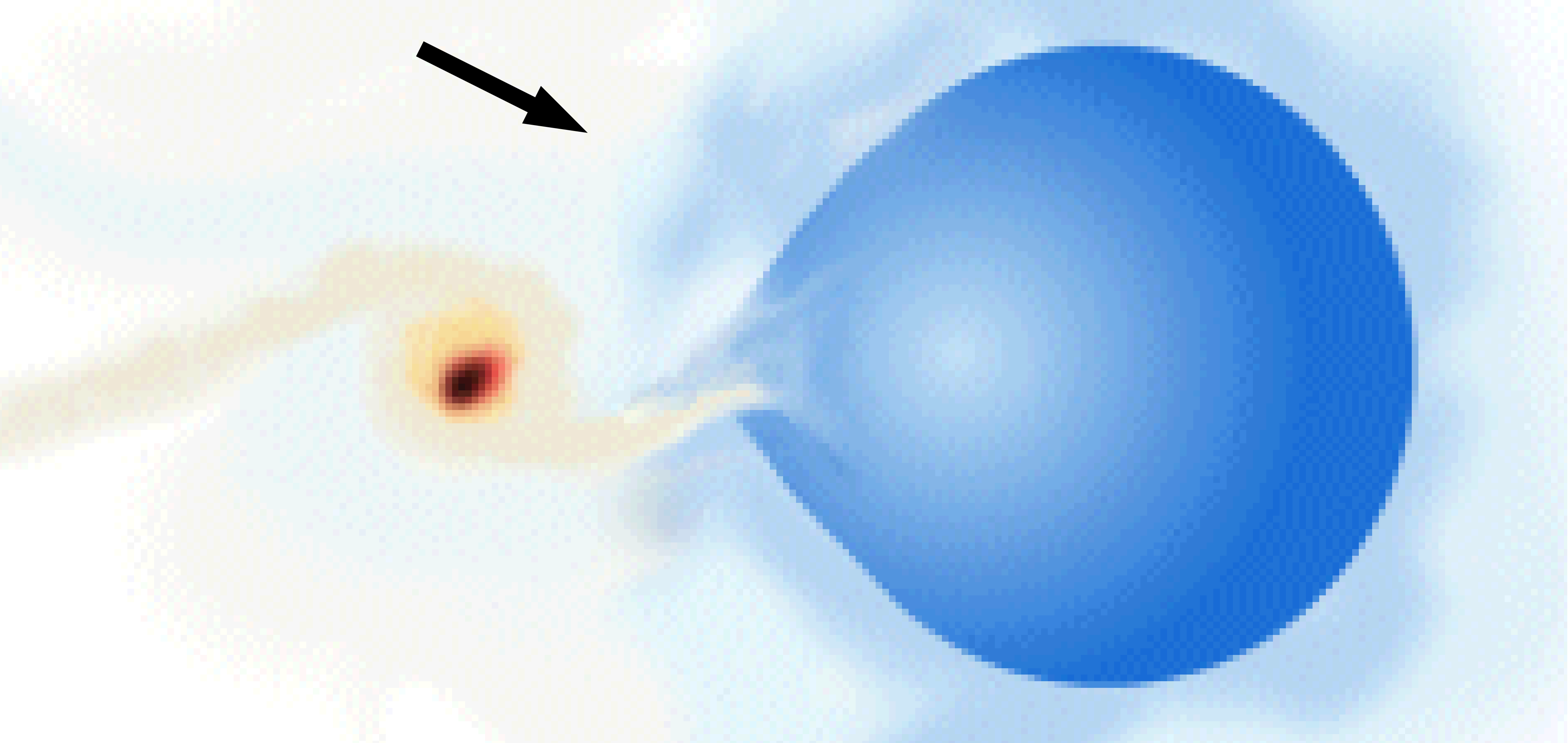
Alternative methods of producing photoionised plasmas in the laboratory



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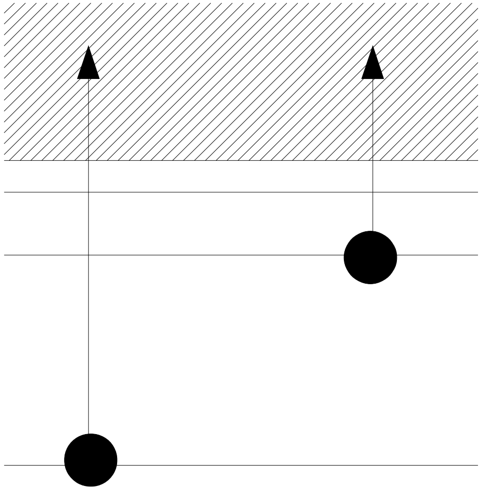
Photoionised astrophysical plasma experiments

'Astrophysical'

- Low density
- Typically complex radiative transport and atomic kinetic problems

Photoionised

- Radiation field dominates the atomic kinetics
- High colour temperature in our case
  - Inner-shell photoionised
- Over-ionised relative to the electron temperature

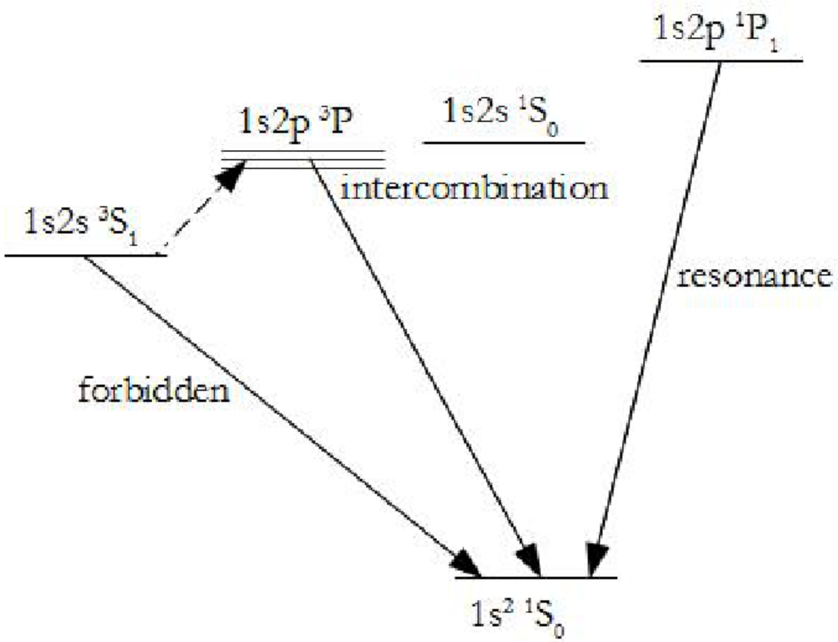


Experiments

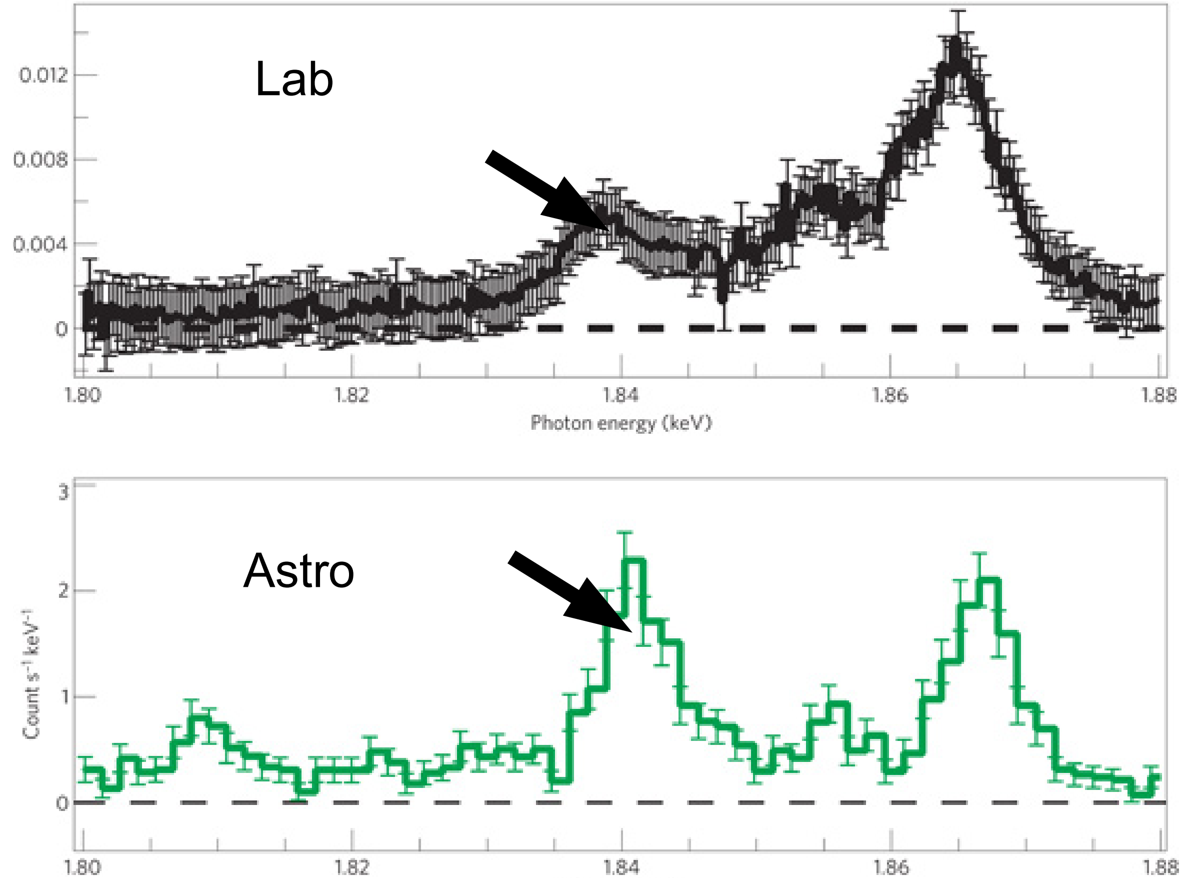
- To calibrate and validate the models
- Allows us to consider simpler cases

AIM: Low density + Photoionised + Inner shell photoionised

Motivation



(Hill and Rose, PoP 2010
Fujioka, Nat.Phys. 2009)



The forbidden line is a decay from a **metastable state**, so the spectrum shows the population of that state – tests the atomic kinetics

The forbidden line is a characteristically low density phenomenon

New parameter: $$P_Z \approx 0.81 \times \frac{n_e}{\sqrt{T_e} Z^{11}}$$

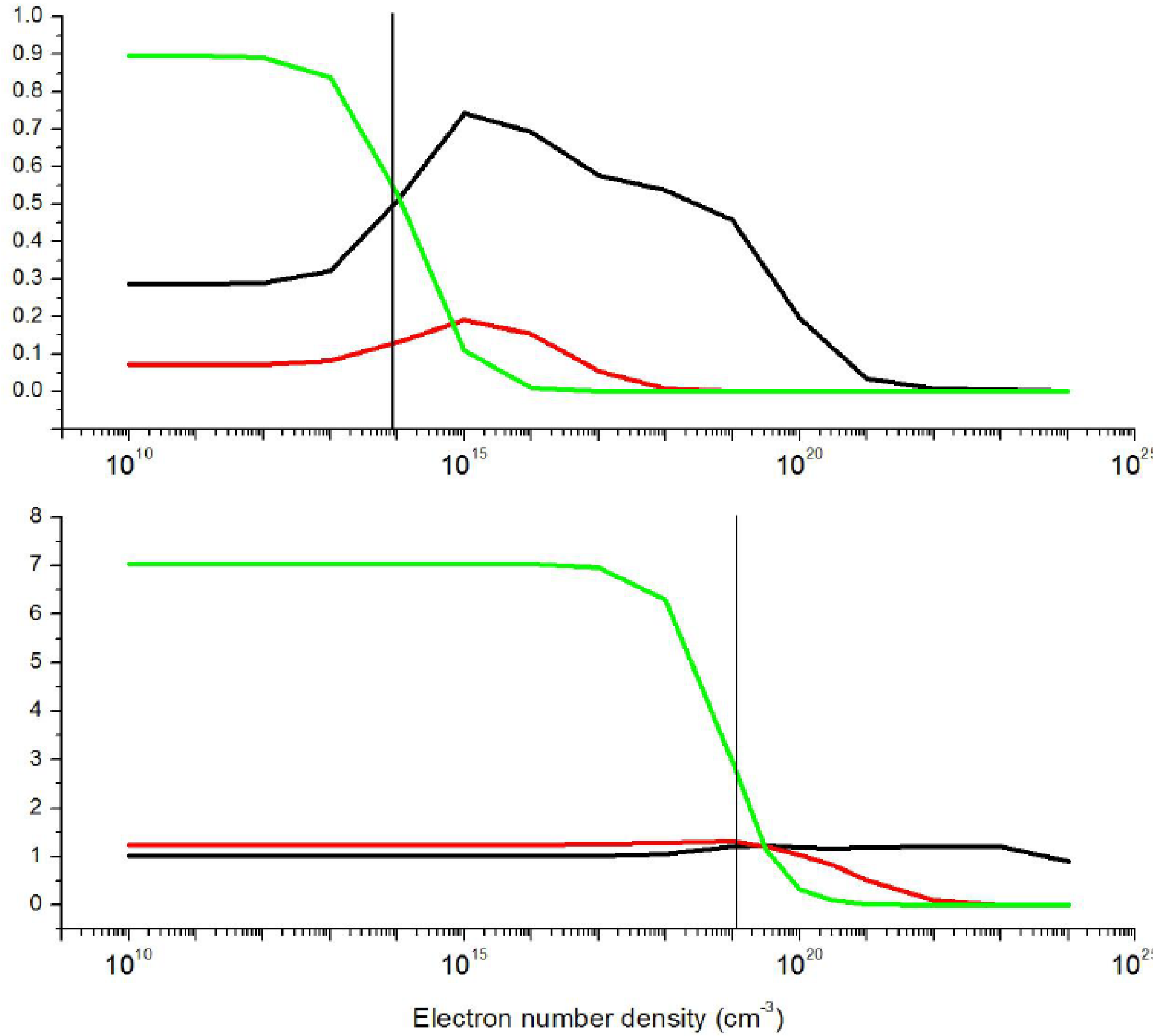
Use of Krypton

Using Krypton exploits the strong Z dependence $P_Z \approx 0.81 \times \frac{n_e}{\sqrt{T_e} Z^{11}}$

Now have low density kinetics i.e. the forbidden line is visible

Silicon

Krypton



(Hill and Rose HEDP 2011)

Parametrisation of recent experiments

Characterised by a large **photoionisation parameter**

$$\xi = \frac{l}{n_e}$$

The importance of the radiation field rates relative to the plasma rates

Experiment	Year	Materials	Density cm^{-3}	T_e (eV)	T_r (eV)	ξ (prefactor)
Bailey [6]	2001	Ne	$10^{18}(n_i)$	10-100	50	7 (4π)
Morita [50]	2001	C	$2 \times 10^{19}(n_i)$	8	80	–
Foord [21]	2004	F, Na, Fe	$2 \times 10^{19}(n_e)$	150	165	20-25 ($16\pi^2$)
Wang [75]	2008	N	$1.4 \times 10^{19}(n_e)$	20	80	20-25 (4π?)
Fujioka [25]	2009	Si	$10^{19}(n_i)$	30	480	5.9 ($16\pi^2$)
Hall [34]	2010	Ne	$2 - 8 \times 10^{18}(n_i)$	30	300	2.5-3 (4π)
Astrophysical case		H-Fe	$10^9 - 10^{13}(n_e)$	10	1000	$\sim$ 1000 (1)

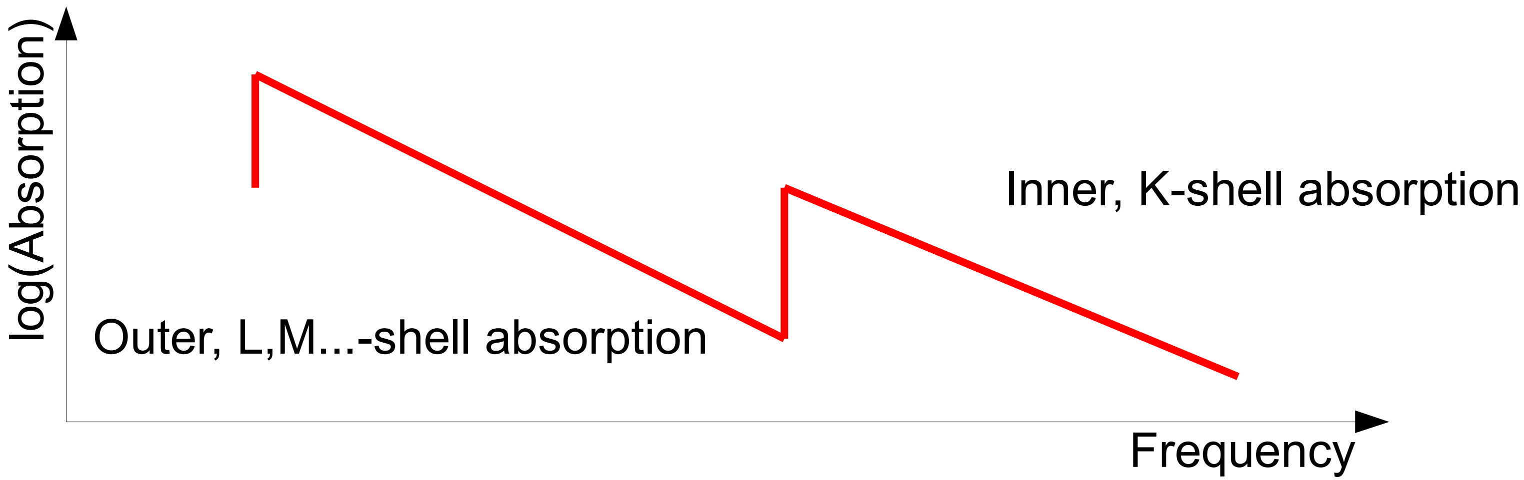
However, limited, since takes no account of the frequency distribution of the incident radiation field or the absorption cross-section

Redefining the radiation field

Still need to **Inner shell photoionise** the plasma...

Temperature of Planckian needed Z^2 – impracticable

However, the Krypton only 'sees' the radiation at frequencies where it absorbs



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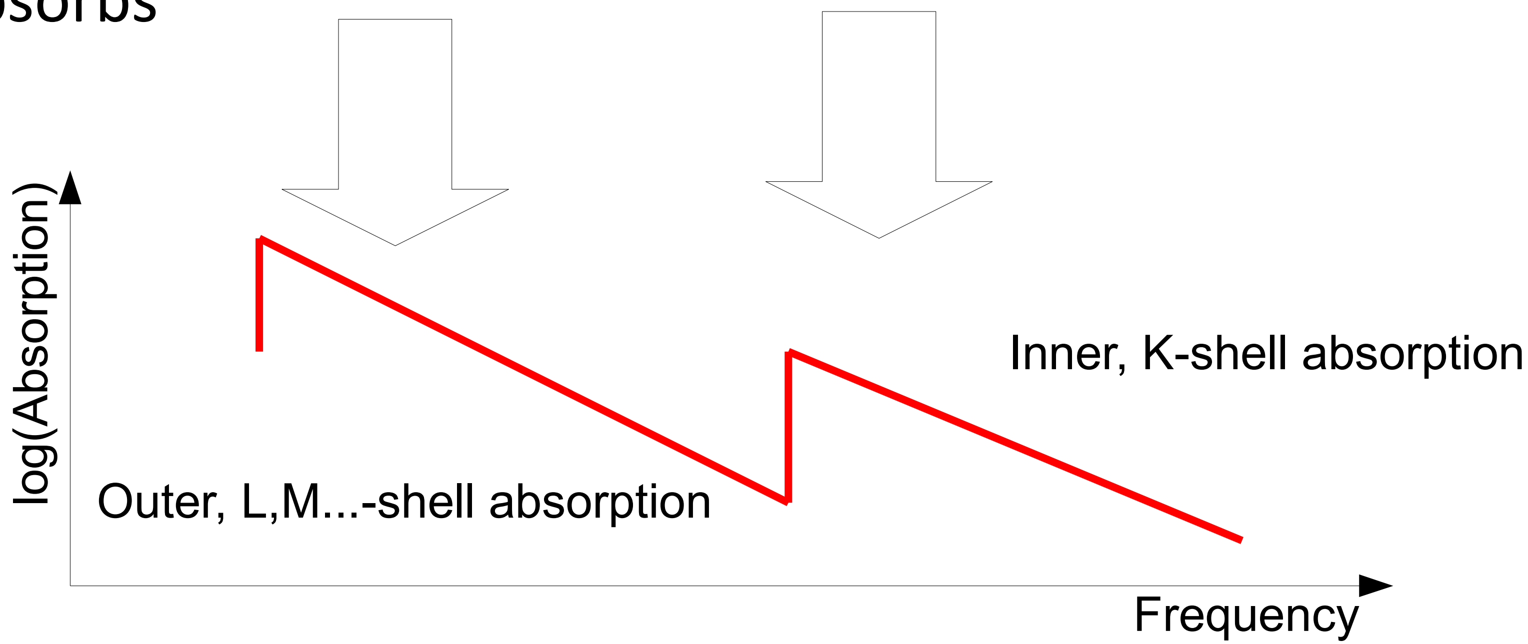
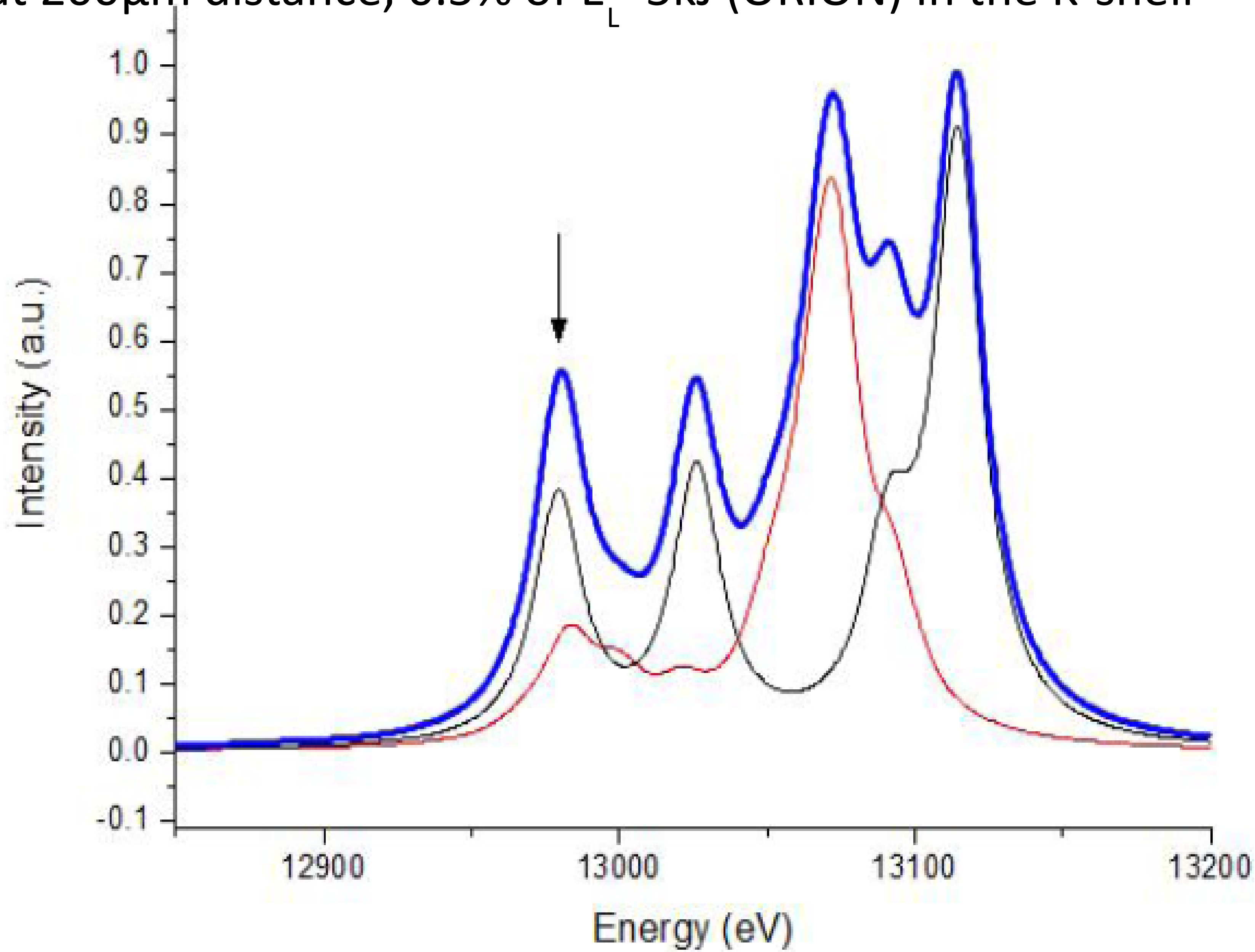


Such radiation fields exist: Underdense targets (Babonneau, PoP 2008)

Choose a slightly higher Z than Krypton e.g. **Molybdenum**

Simulation

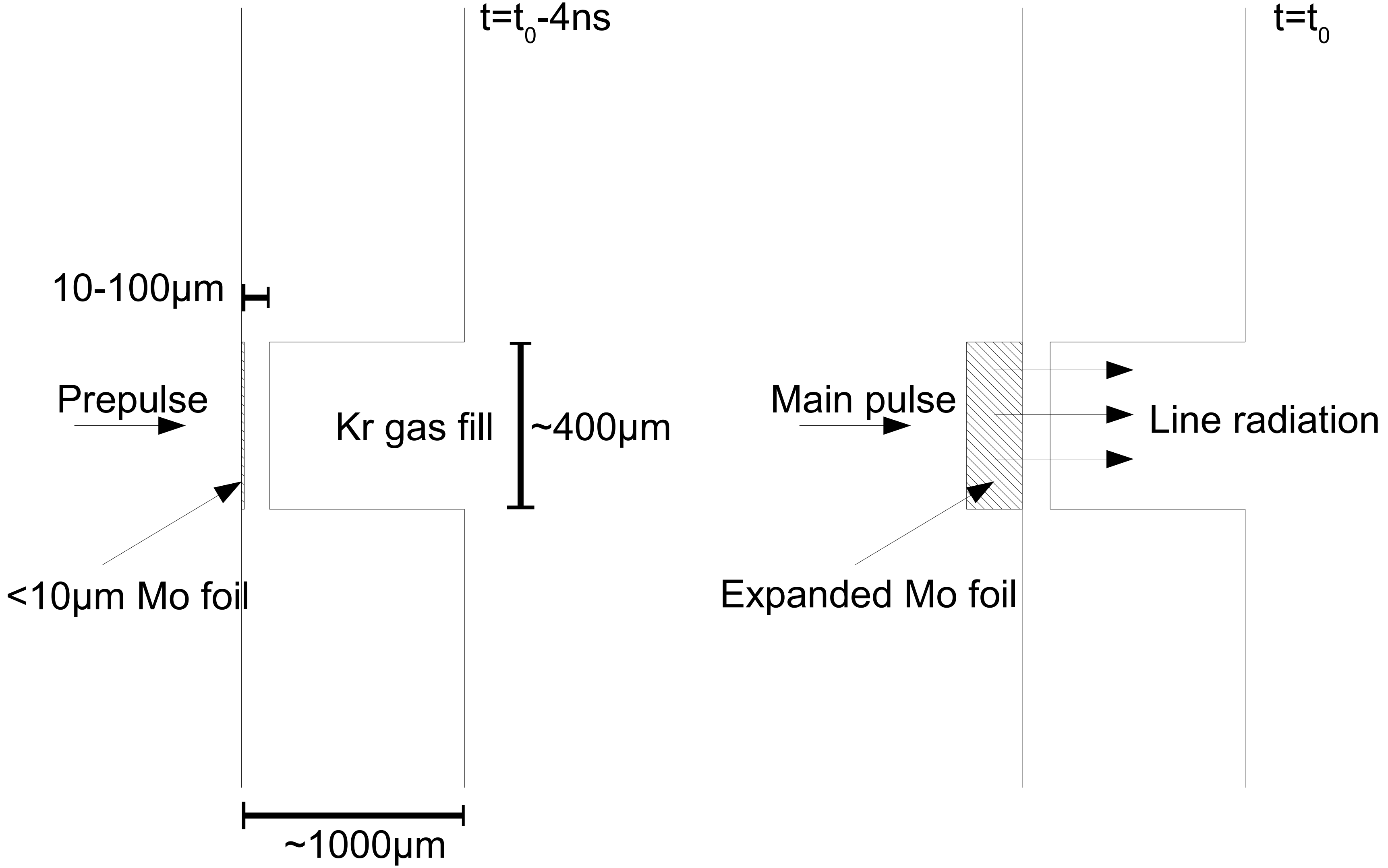
Krypton, T_e=200eV, n_e=10^{18}cm^{-3}, ionised by a Molybdenum underdense target at 200μm distance, 0.5% of E_L=5kJ (ORION) in the K-shell



Experimental design I

Krypton confined in a gas cell, Molybdenum patch on wall

thick walls possible – effect on solid C is minimal – allows a wide range of densities



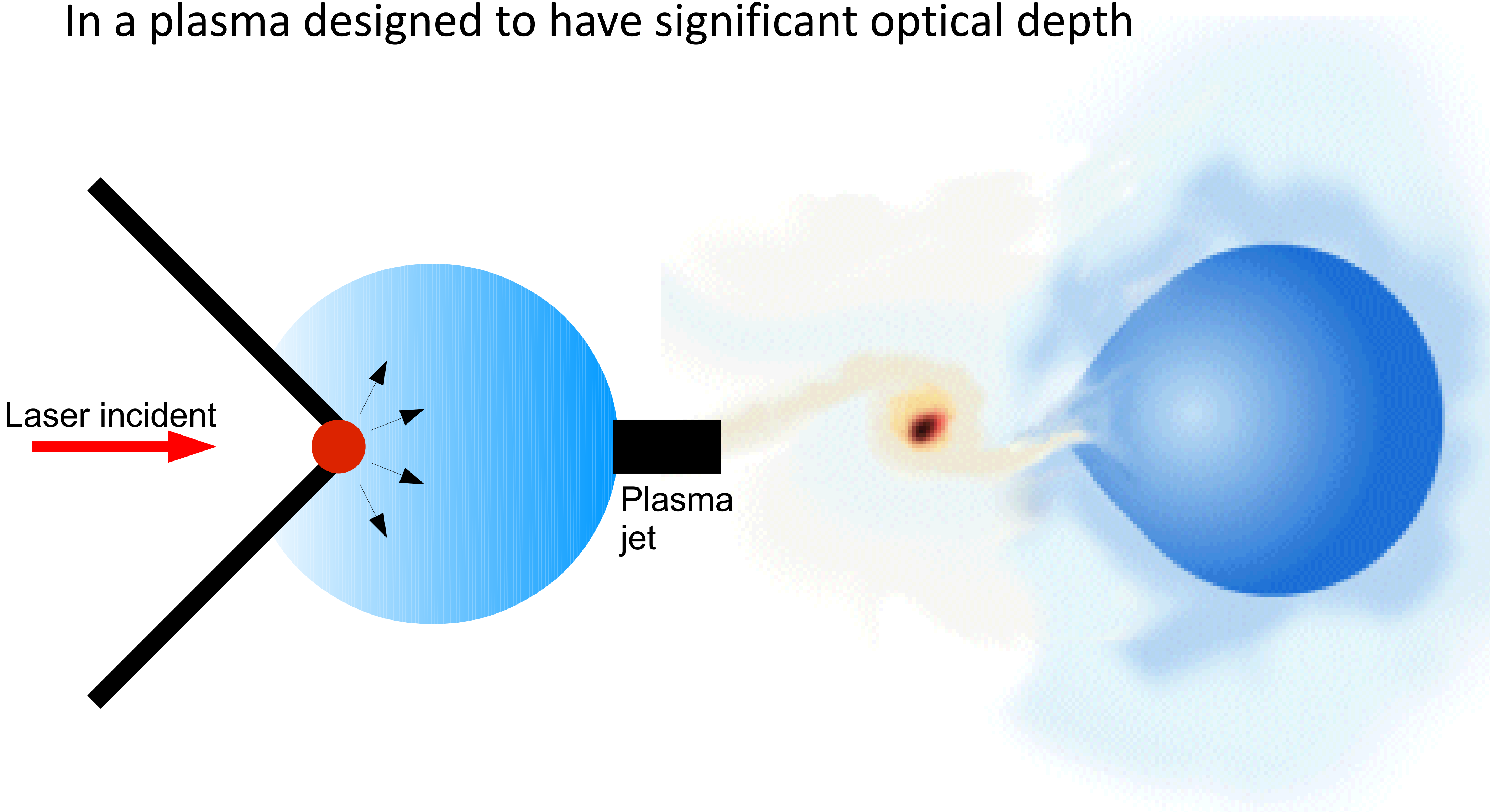
Shocks, heating through wall etc. not important (Renaudin, PRE 1994)

Experimental design II

The incident laser is unidirectional, will allow embedding of the source within a plasma, for example:

In the vicinity of colliding expanding gas puffs

In a plasma designed to have significant optical depth



Conclusions

Have discussed a new method of producing photoionised plasmas with:

- Low density kinetics at lab densities
- Inner shell photoionisation

The experiment is practicable – involves a fusion of available experimental techniques

Has unique capabilities e.g. embedding of sources and non-destructive to adjacent solids

Provide new test for atomic physics, atomic kinetics and radiative transport models