MichiganEngineering

Proton probing of a 1 kJ, 10 ps laser pulse interaction with underdense to near-critical density plasma

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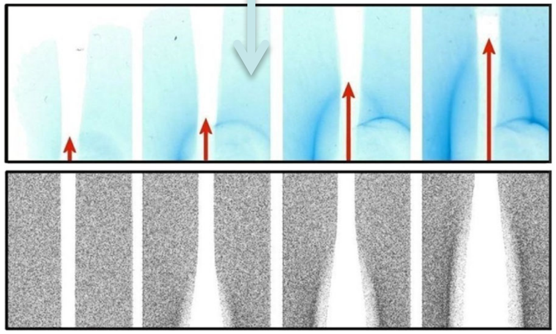
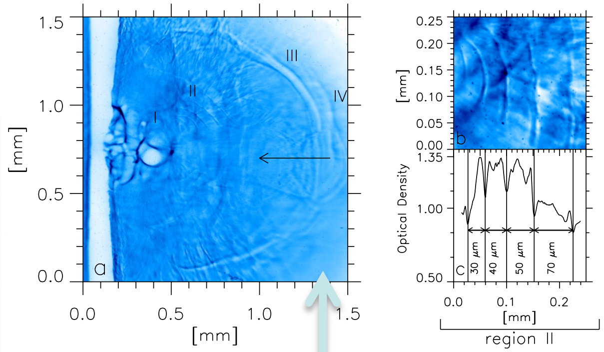
Proton probing

Proton Radiography

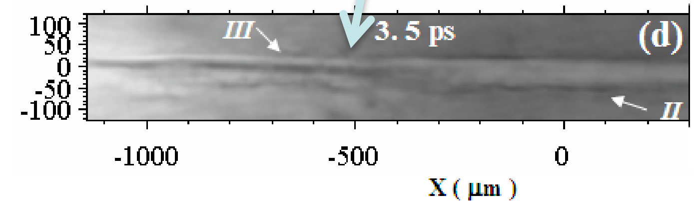
Ultrafast field propagation
K Quinn *et al*, PRL, 102, 194801 (2009)



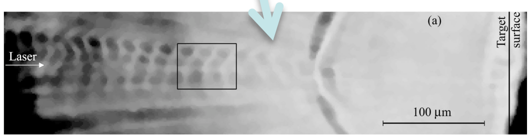


Collisionless shocks
L Romagnani *et al*, PRL, 101, 025004 (2008)

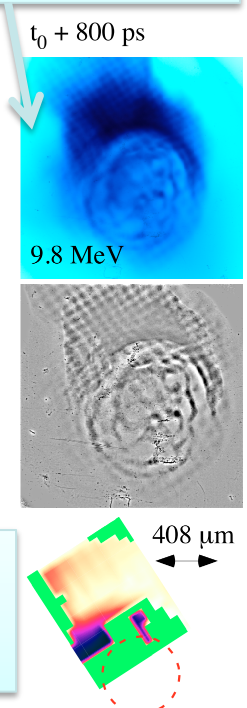
Channel formation imaging in underdense plasma
S Kar *et al*, New Journal of Physics, 9, 402 (2007)



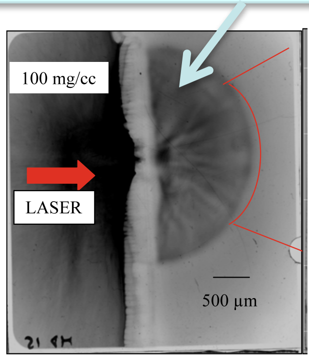
Plasma evolution in laser wake
M Borghesi *et al*, PRL, 94, 195003 (2005)



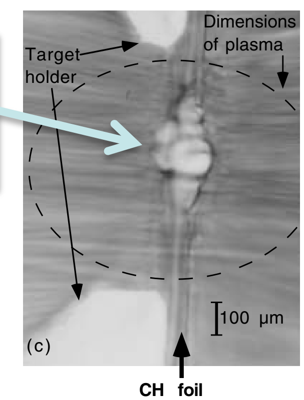
Transport of self-generated magnetic fields
L Willingale *et al*, submitted (2010)

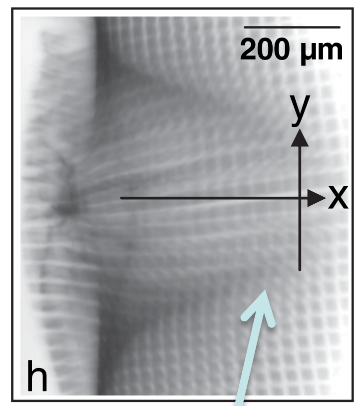


Relativistic electron propagation
B Ramakrishna *et al*, Astrophys Space Sci, 322, 161 (2008)

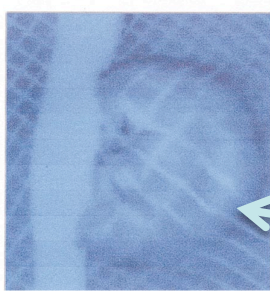


Soliton formation
M Borghesi *et al*, PRL, 88, 135002 (2002)





Proton acceleration fronts
L Romagnani *et al*, PRL, 95, 195001 (2008)



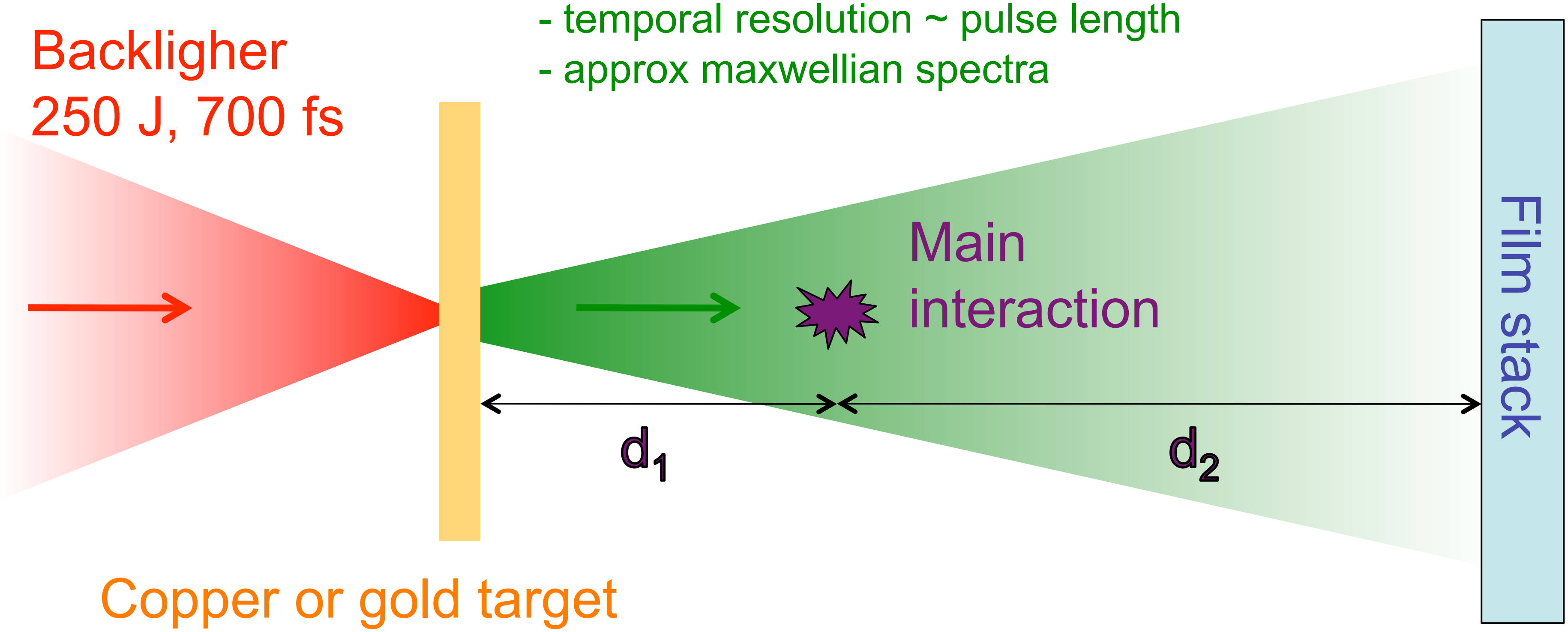
Plasma and field evolution
AJ MacKinnon *et al*, Rev Sci Inst, 75, 3531 (2005)

Proton source and propagation

M Borghesi *et al*, Rev Sci Inst, 74, 1688 (2003)
M Borghesi *et al*, Laser and Part Beams, 20, 269 (2002)

Proton beam accelerated via TNSA
- laminar acceleration ➔ good spatial resolution
- temporal resolution ~ pulse length
- approx maxwellian spectra

Backligher
250 J, 700 fs



Copper or gold target
50 µm x 2 mm x 2 mm

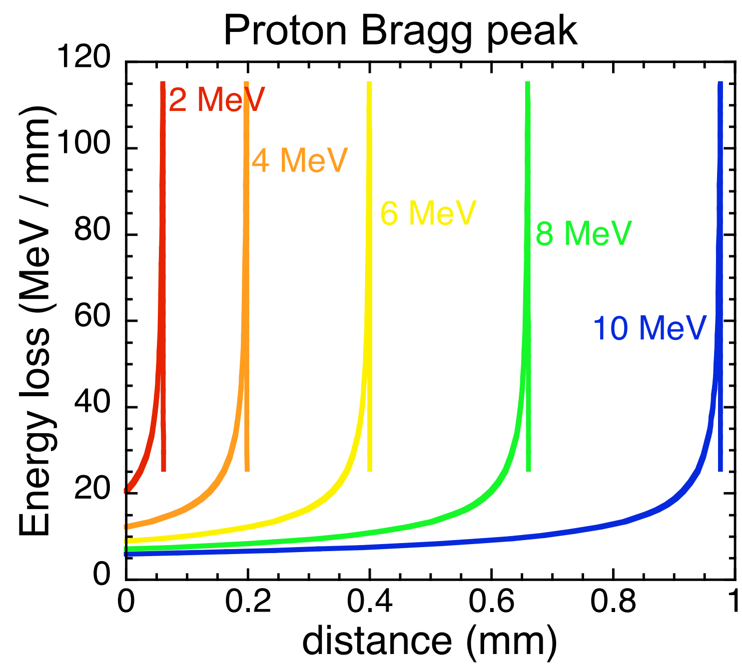
Magnification $\approx (d_1 + d_2) / d_1$

Proton probing with Omega EP

Proton beam detection

- Each film in the stack corresponds to a well defined proton energy
- High energy protons are traveling fast ➔ arrive earlier
- Low energy protons are traveling slower ➔ arrive later
- Proton images for a 'movie' of the interaction

Temporal imaging window = 73 ps

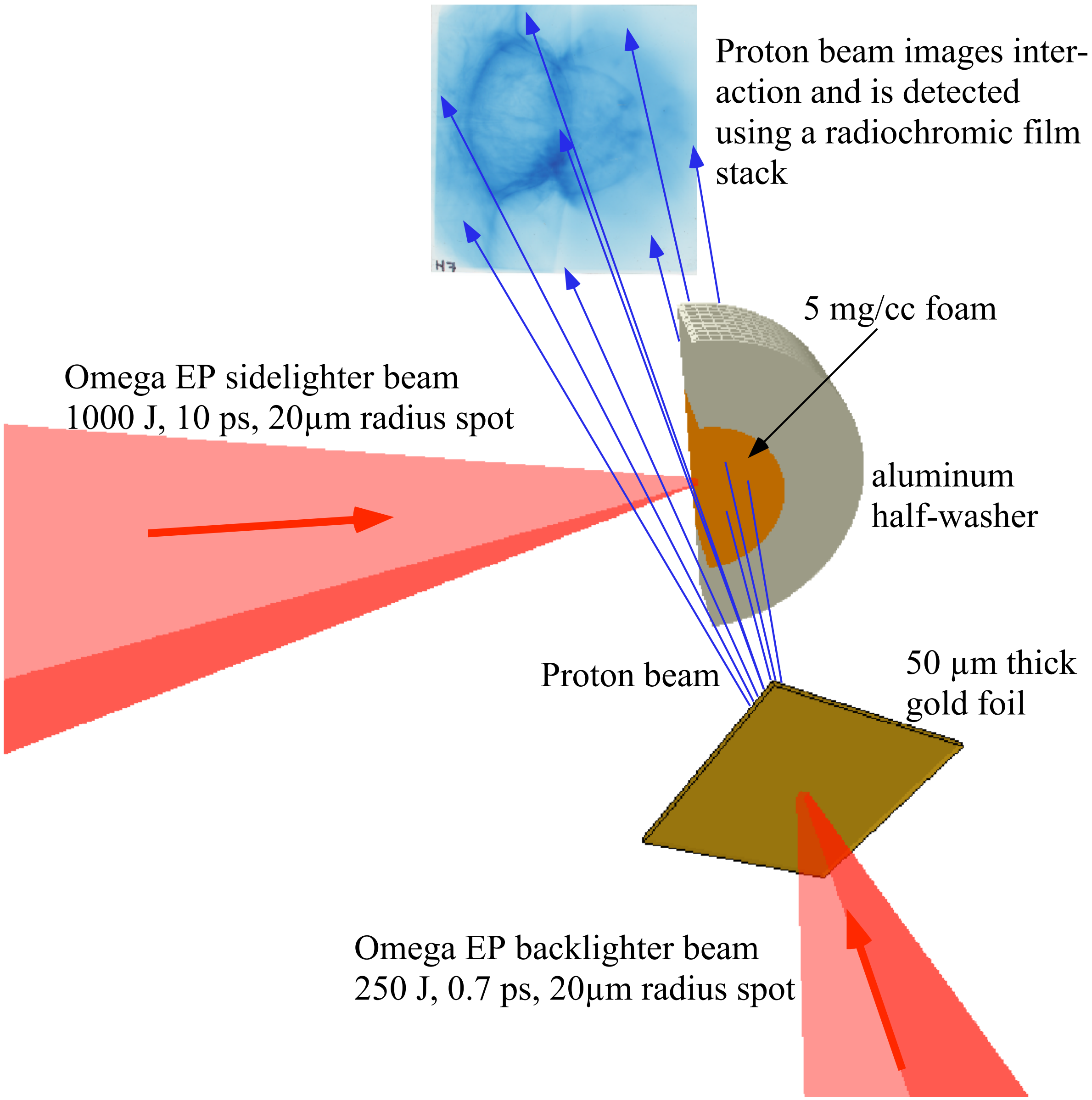


Film layer	Proton energy (MeV)	time to reach interaction (ps)	temporal spacing (ps)
1	9	121.19	
2	10.6	111.82	9.4
3	12	105.21	6.6
4	13.4	99.67	5.5
5	15.2	93.71	6.0
6	17	88.74	5.0
7	18.6	84.94	3.8
8	20.6	80.84	4.1
9	22.4	77.63	3.2
10	25.1	73.49	4.1
11	29.5	68.02	5.5
12	33.5	64.03	4.0
13	40.3	58.68	5.3
14	46.3	55.00	3.7
15	54.6	50.96	4.0
16	61.9	48.12	2.8

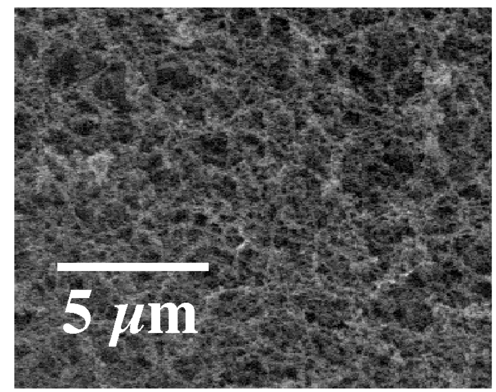
Temporal considerations

- Relative short-pulse beam timings in Omega EP are assessed using UFXRSC (Ultra-Fast X-Ray Streak Camera)
- Relative long to short pulse timings can be assessed using PJX and XMON
- Protons take some time to travel from the source foil to the interaction (i.e. proton generation laser pulse needs to arrive before the main interaction)
- Jitter between backlighter and sidelighter pulses (due to different seed pulses) appears to be ≈ ± 20 ps
  - Can be largely absorbed by the large temporal window of the film pack (73 ps)

Near-critical density plasma



Foam structure



Near-critical density plasma