Relating Hot Electron Magnetic Confinement to Hard X Ray Spectra in Hohlraums

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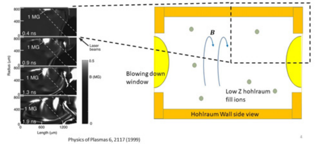
Summary

- Hot electrons are generated from LPI at high laser intensities and can cause deleterious effects
- Recent work in proton radiography and simulations show self generated magnetic fields of ~1MG generated in hohlraums
- Magnetic fields confine hot electrons and cause them to traverse a further path length in low Z hohlraum fill, reducing the hot electron flux hitting the hohlraum wall
- Comparison to hard xray spectra give insight into preheat levels and structure of fields in the hohlraum

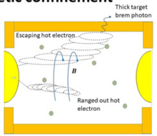
Recent work in proton radiography and simulations show ~1MG self generated magnetic fields in hohlraums



Physics of Plasmas 6, 2117 (1999)

Hot electrons experience additional stopping due to magnetic confinement

- During the picket, hot electrons are generated at the window
- B fields generated by Biermann battery magnetize the electrons and cause them to lose more energy through plasma collisions
- Previous hot electron literature ignores effects of magnetic fields on hot electron trajectories

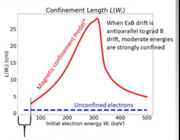


We create a model of confinement due to self-generated electric and magnetic fields using guiding center drifts

1. Assume all guiding centers drift the same distance $d_{gc\ avg}$
2. Using v_{gc} back out unwound distance traveled $L(W_i)$.

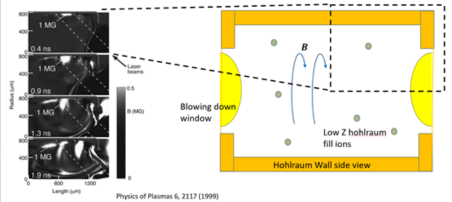
$$v_{gc} = \frac{E \times B}{B^2} + \frac{W_{\perp} B \times \nabla B}{qB^3} + \frac{W_{\parallel} B \times (B \cdot \nabla B)}{qB^4}$$

Greater B fields, larger B field scale length, smaller E fields => fewer electrons at wall



*Using $B = 350kG$, $E = -1.5 \times 10^9 \frac{V}{m}$, $l_B = 150\,\mu m$, $d_{gc\,avg} = 1.0\,cm$

Recent work in proton radiography and simulations show ~1MG self generated magnetic fields in hohlraums.



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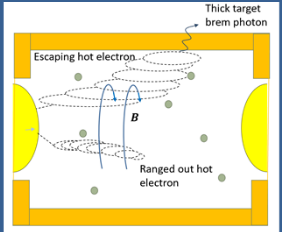
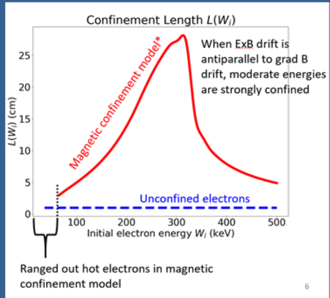
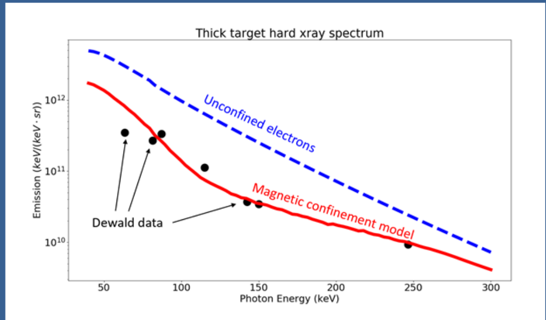
These fields will confine hot electrons and cause increased collisional energy loss and TOF delays that will manifest in the measured hard xray spectra.



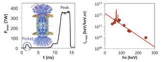
By tracking guiding center drift, we can determine arc length travelled by an electron before it hits the wall.



When comparing to FFLEX data from a NIF experiment studied by Dewald et al, this magnetic confinement can alter the xray spectrum to have a two-temperature profile seen in experiment.



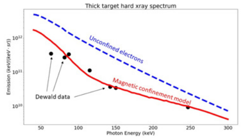
Dewald et al* have explored the relationship between hard xray spectra and hohlraum fill, and we use their data for comparison



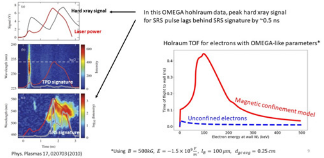
- FFLEX provides time resolved hard x-ray spectra

* Dewald et. al-- PRL 116, 075003 (2016)

The experimental data is well described by magnetic confinement model



This mechanism can also explain delays in hard xray signal via electron TOF

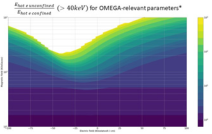


Phys. Plasmas 17, 020703 (2010)

*Using $B = 500kG$, $E = -1.5 \times 10^9 \frac{V}{m}$, $l_B = 100\,\mu m$, $d_{gc\,avg} = 0.25\,cm$

Confinement depends strongly on structure of fields in hohlraum

- Studying hard xray spectra may be used as an additional constraint to break degeneracies in proton radiography of fields in the hohlraum



*Using $l_B = 200\,\mu m$, $d_{gc\,avg} = 3.125\,cm$

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MIT PhD students work on NIF diagnostics (2nd DTn[1], WRF/SRF[2], PRAD[3], MRS-t[4], PTOF[5]) and fundamental physics (hohlraum x-rays and fields[6])

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[4] poster by Justin Kunimune
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