Heater Control and Plasma Optimization

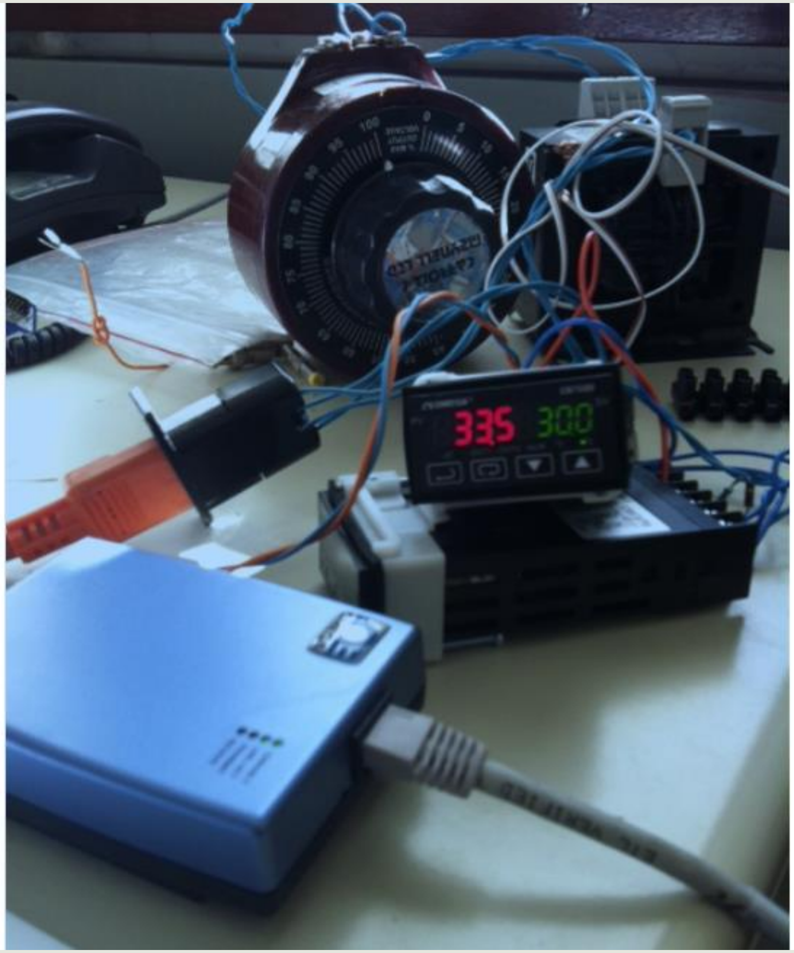
Matthew Bohman

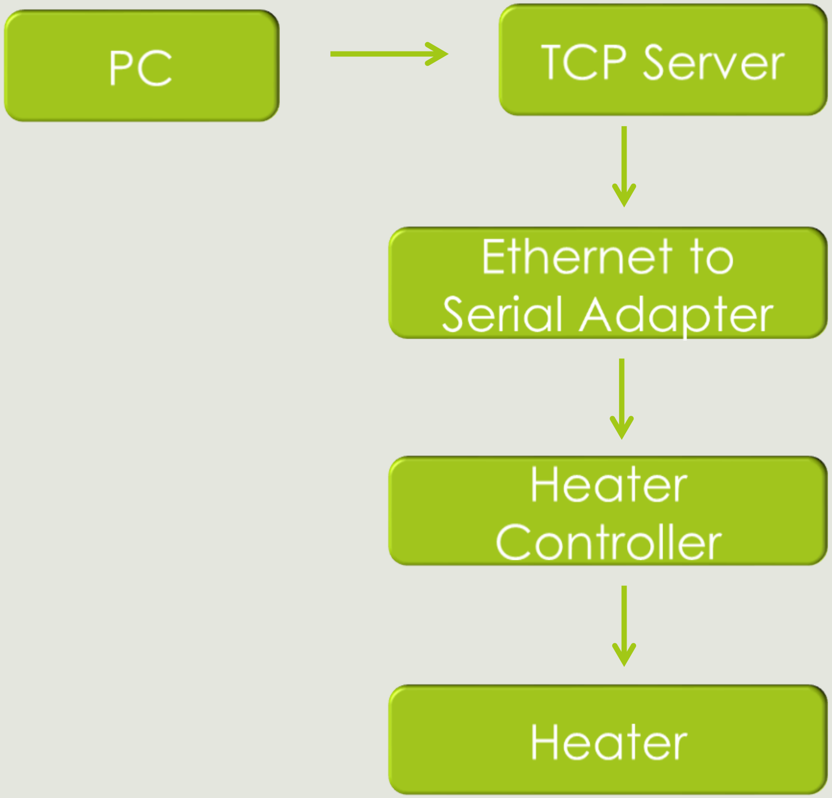
ALPHA Collaboration

University of Michigan
Semester at CERN

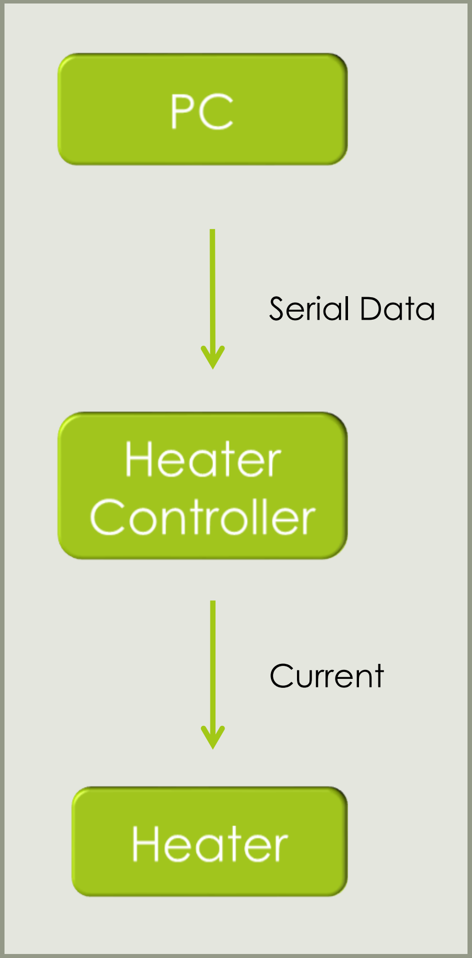
Bakeout and Heater Control

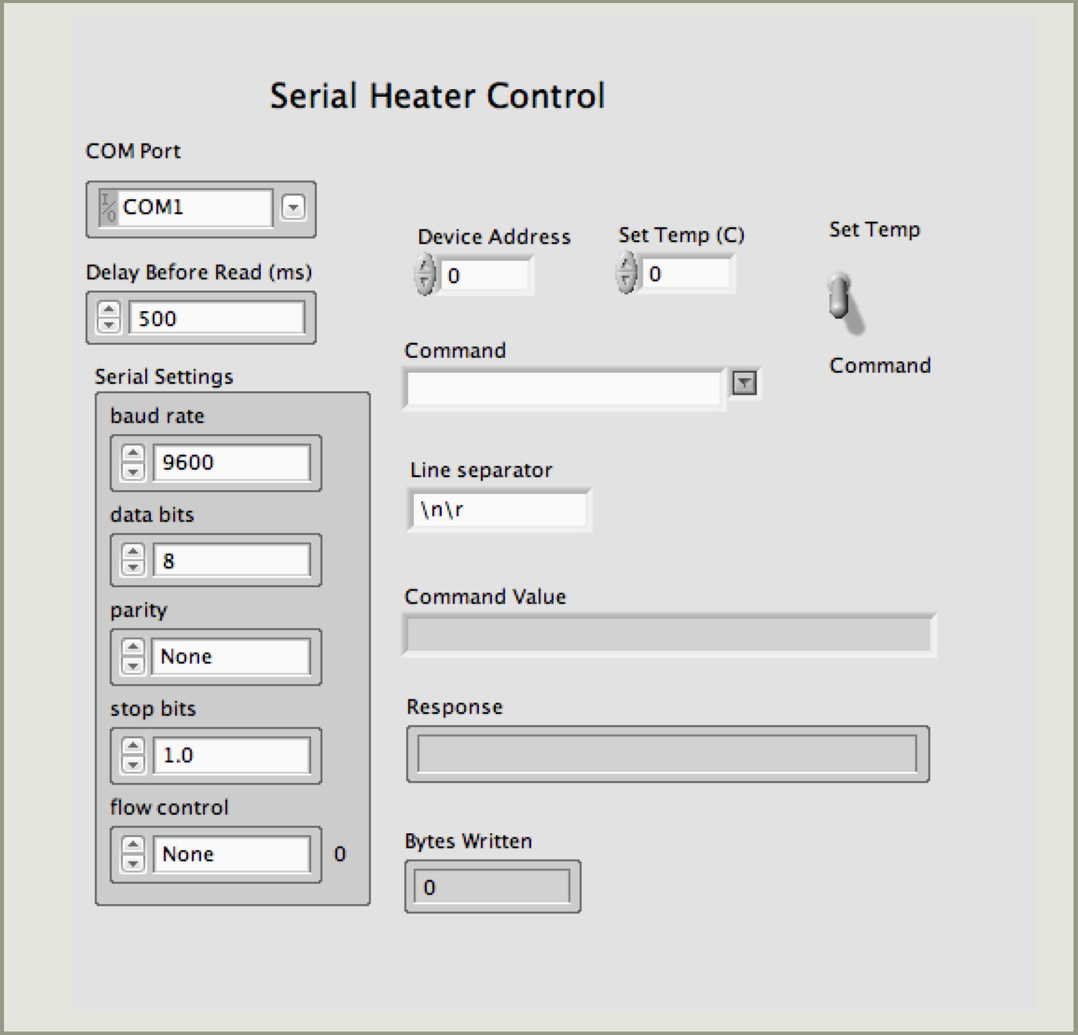
Heater Control Schematic





New System


PC
Serial Data
Heater Controller
Current
Heater


Serial Heater Control
COM Port
COM1
Delay Before Read (ms)
500
Serial Settings
baud rate
9600
data bits
8
parity
None
stop bits
1.0
flow control
None
0
Device Address
0
Set Temp (C)
0
Set Temp
Command
Command
Line separator
\n\r
Command Value
Response
Bytes Written
0

Plasma Optimization

Anti-Hydrogen Formation

<u>Radiative Recombination</u>

$$\sigma_{\mathrm{RR}} = 2 \times 10^{-22}\ \mathrm{cm}^2\ \frac{\epsilon_0}{nE_e/\epsilon_0}$$

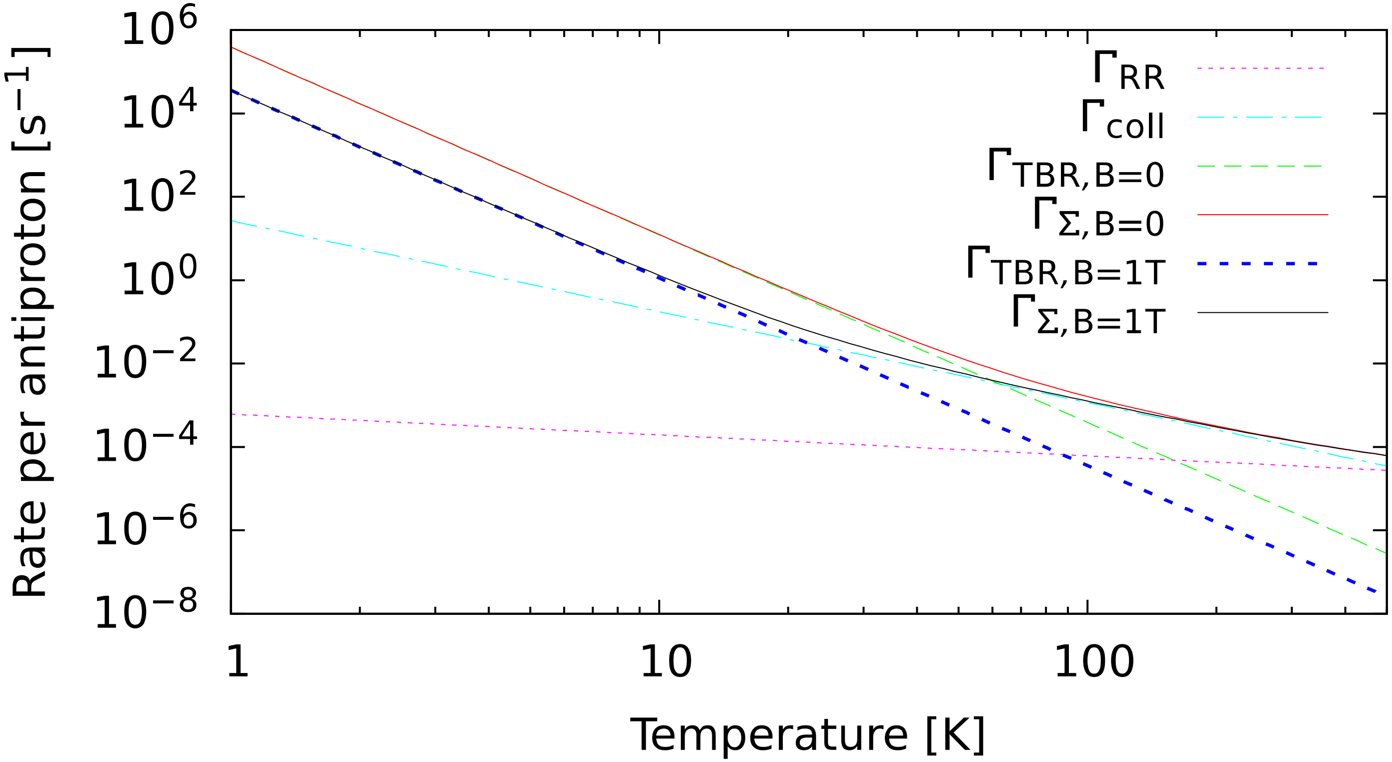
$$\Gamma_{\mathrm{RR}} = 3 \times 10^{-11} \sqrt{\frac{4.2\mathrm{K}}{\mathrm{T}}} \frac{n_e}{\mathrm{cm}^{-3}}\ \mathrm{s}^{-1}$$

<u>Three Body Recombination</u>

$$\Gamma_{\mathrm{TBR}} = 8 \times 10^{10} \left(\frac{4.2\mathrm{K}}{T}\right)^{2.18} \frac{n}{\mathrm{cm}^3}^{1.37} \mathrm{s}^{-1}$$

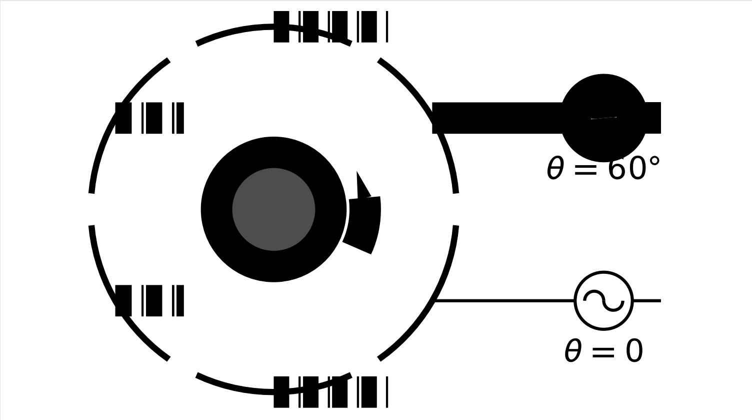
Small, dense, and cold plasmas will maximize anti-hydrogen formation rates

Formation Rates

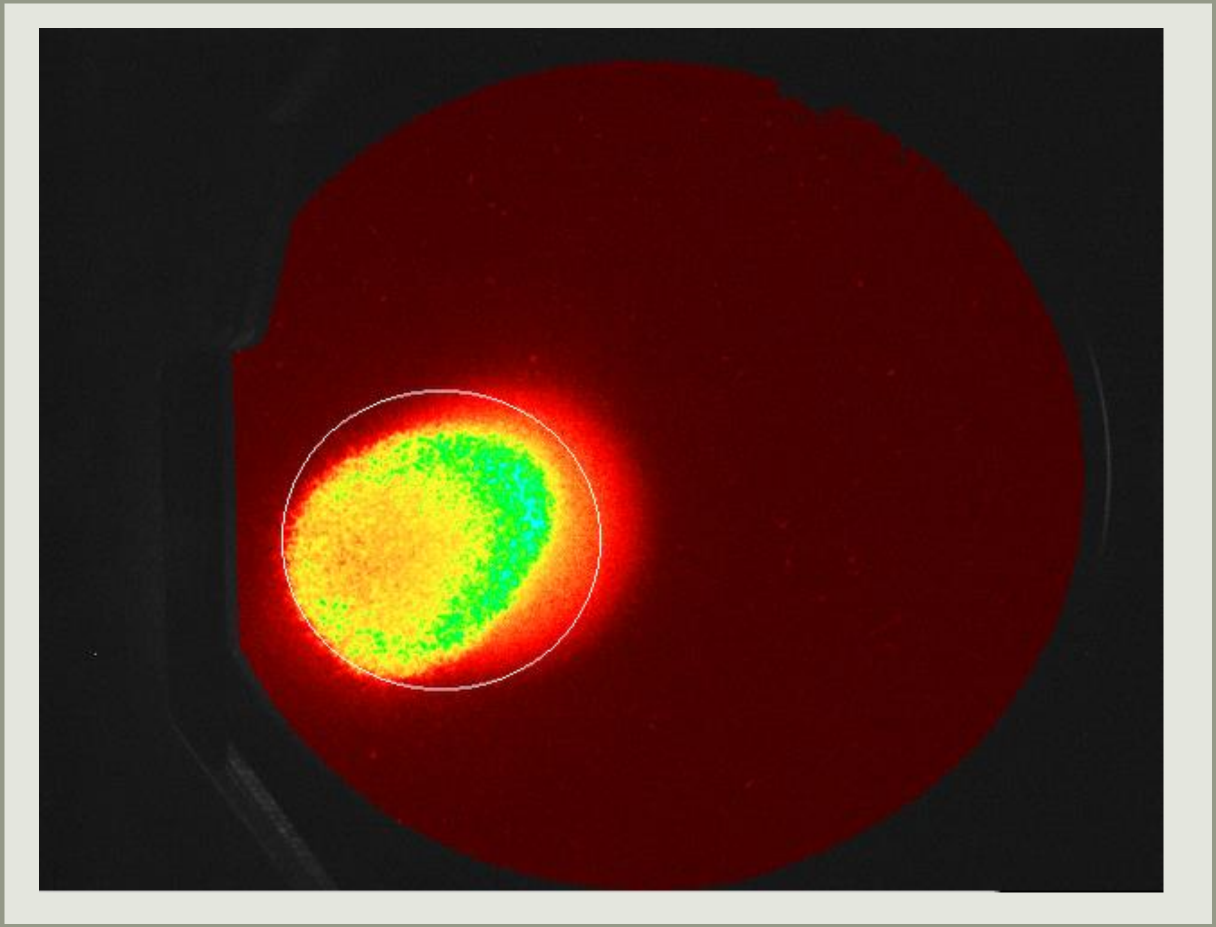


Rotating Wall

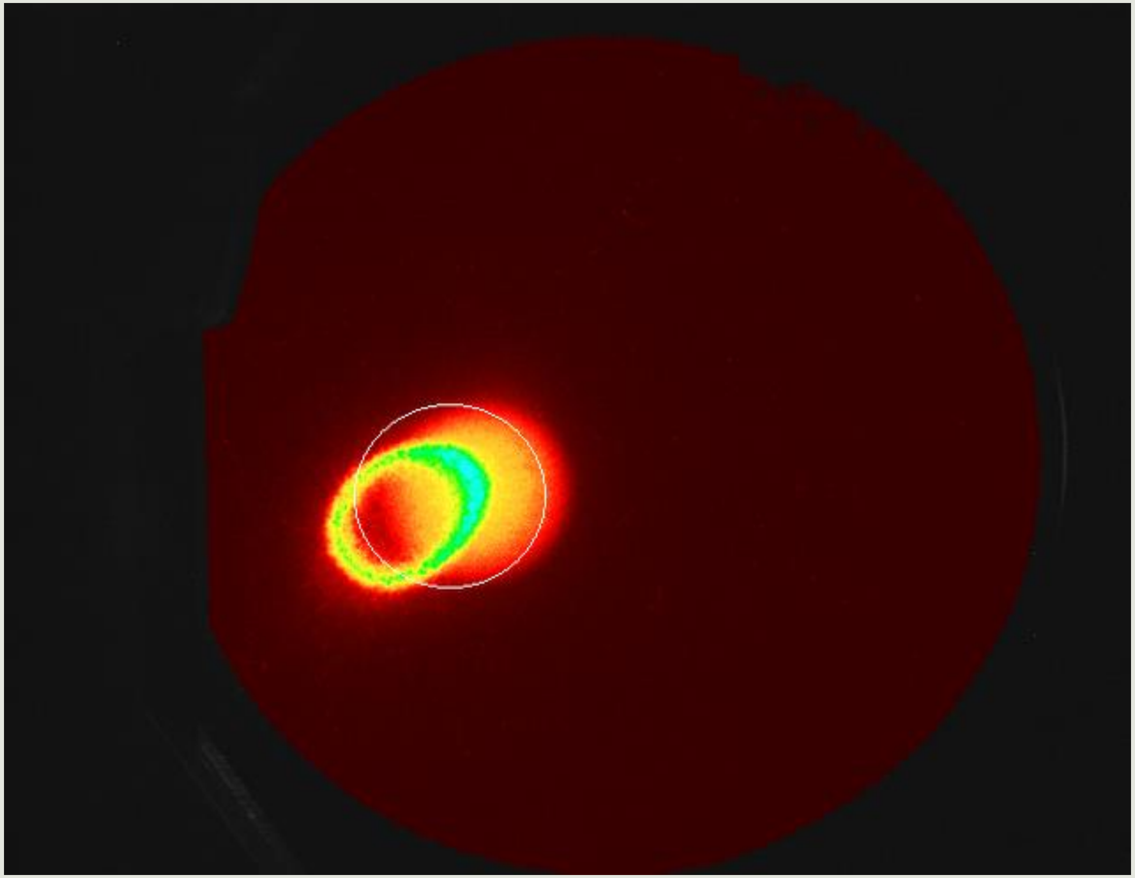
$$\omega_r = \frac{\mathbf{F} \times \mathrm{B}}{B^2} = \frac{en}{2\epsilon_0}\frac{r}{B_z}$$



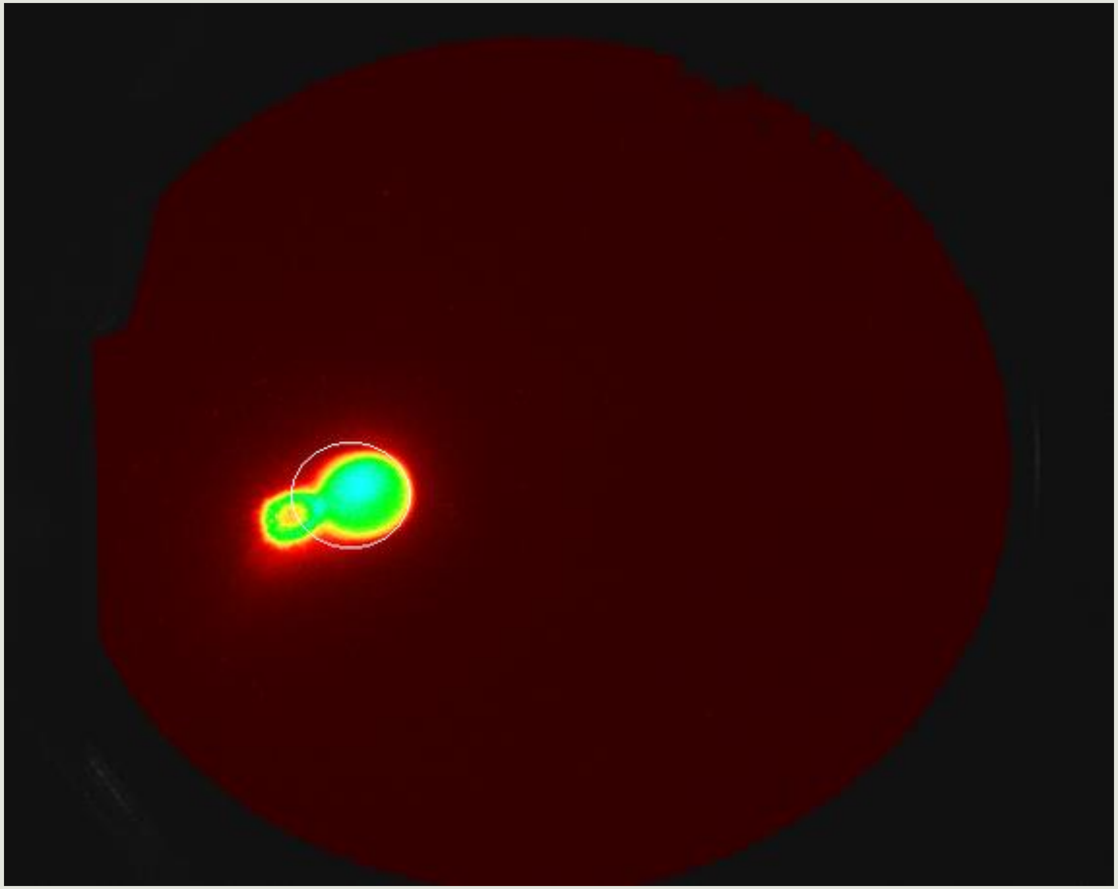
Uncompressed Plasmas



Partially Compressed, Centrifugally Separated



Fully Compressed Plasmas

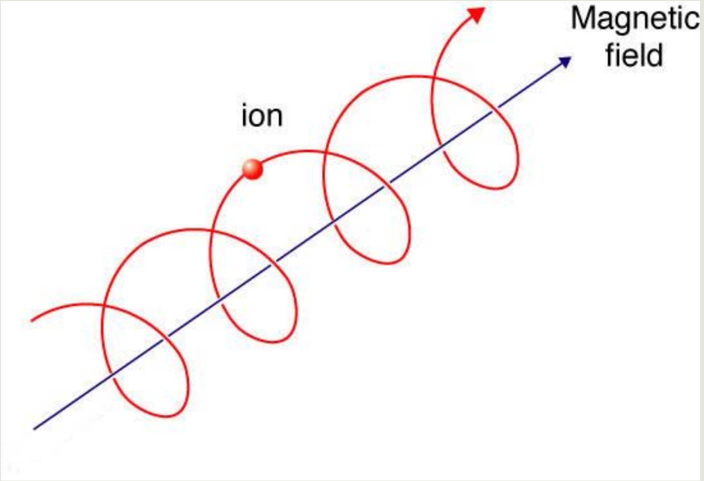


Cooling

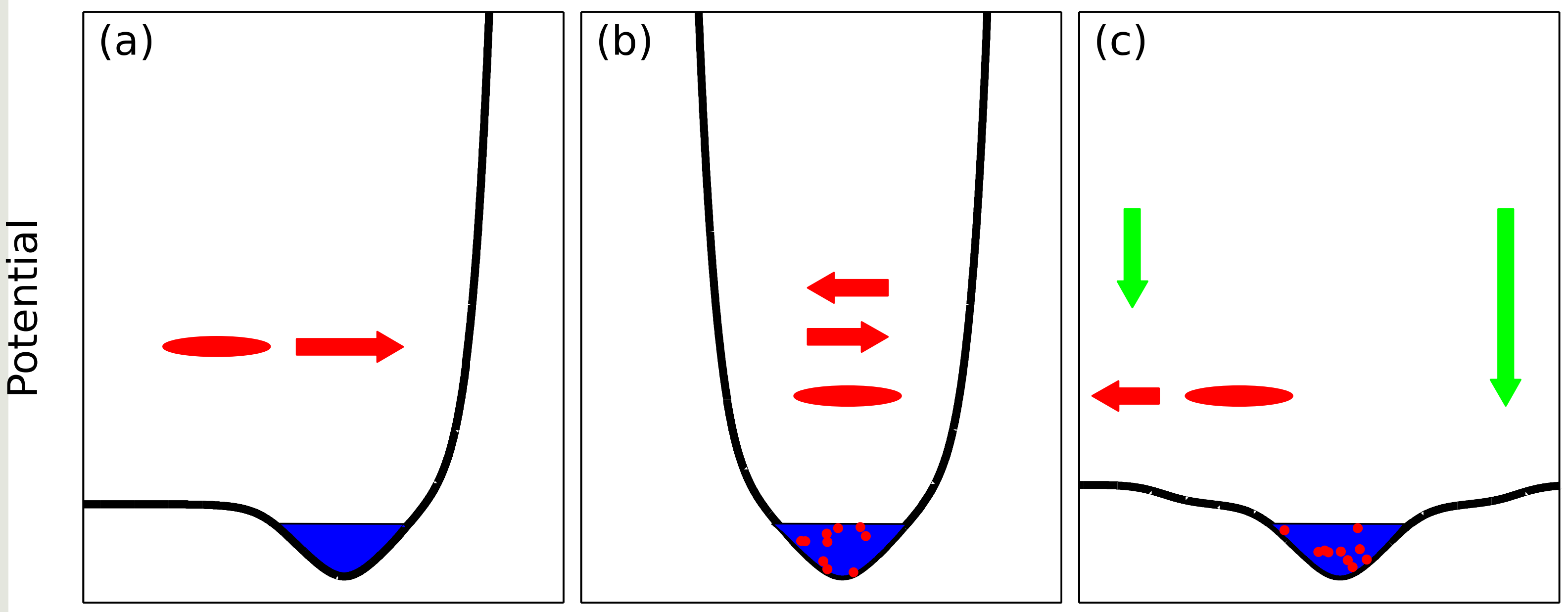
$$\mathbf{F} = q\left(\mathbf{E} + \mathbf{v} \times \mathbf{b}\right)$$

$$r_L = \frac{mv_\perp}{|q|B}$$

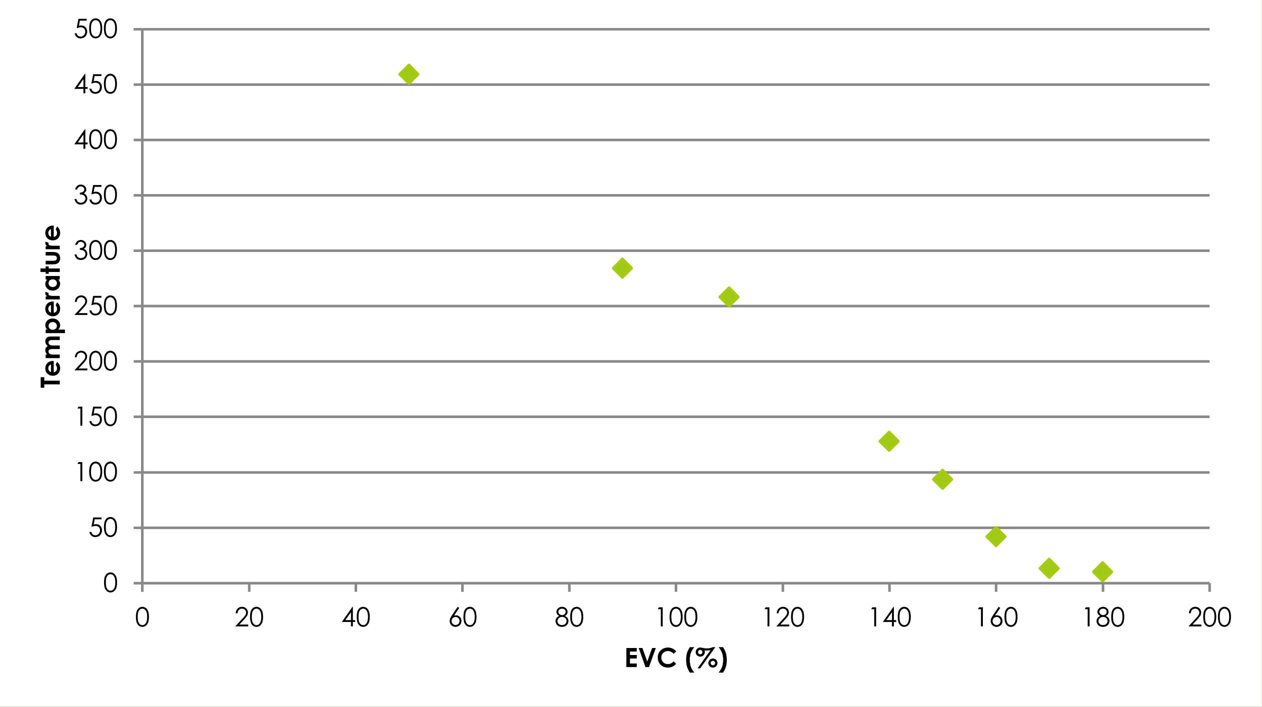
$$\frac{-dE}{dt} = \frac{\sigma_t B^2 v^2}{c\mu_0}$$



Evaporative and Sympathetic Cooling



Evaporative Cooling



Sources:

Slide 6, 7, 8, 13: images and equations from

E. Butler, Antihydrogen formation, dynamics and trapping, Ph. D. thesis, Swansea University (2011).

Slide 12: image from EUROfusion