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Refined Calculations of Secondary Nuclear Reactions in Magneto-Inertial Fusion Plasmas

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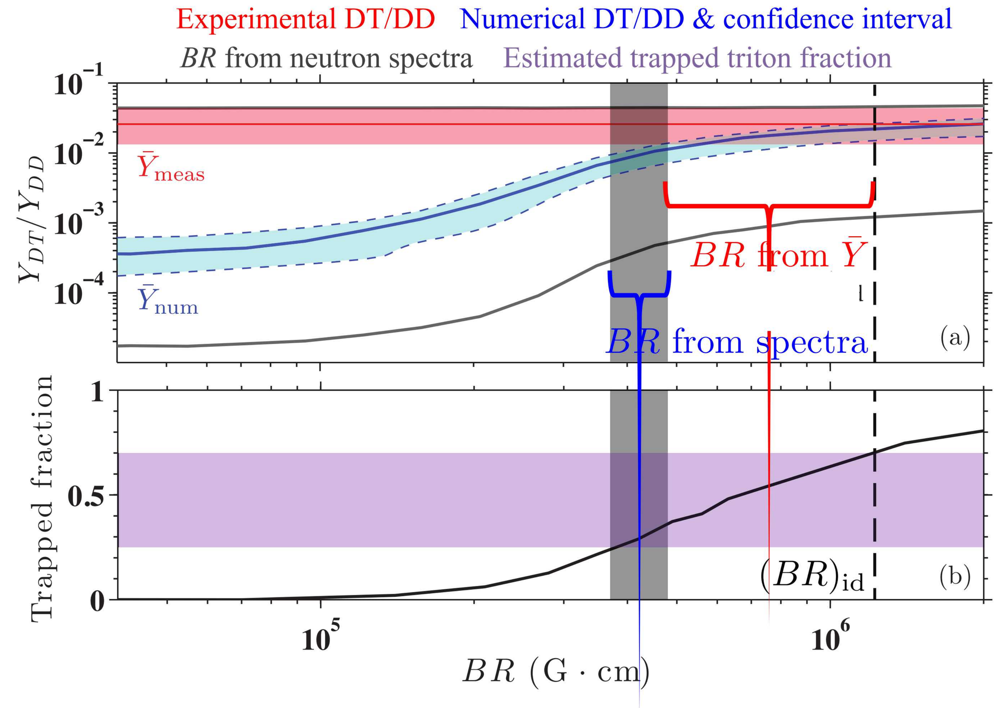
DT/DD neutron yields approximate lower bound for *BR*:

- $Y_{DT}/Y_{DD} \equiv \bar{Y}$ highly sensitive to fuel magnetization
- Triton gyroradius: $R/r_{L,t} \propto BR$
- Reduced model developed to understand physics/scalings of $\bar{Y}$
- Two Sandia-developed codes solve model using *experimental measurements* as inputs
- Consistent with simulations [4]



Uniform plasma model results for z2591

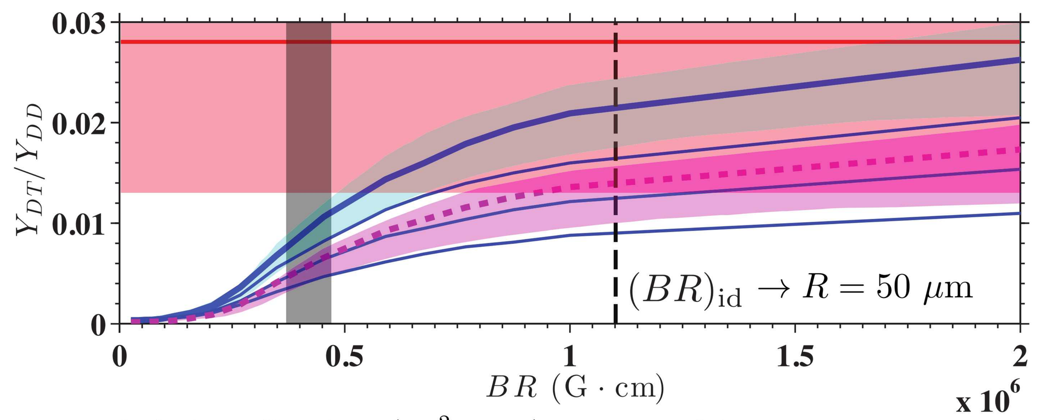
- Indicates $B \gtrsim 80$ MG at $R \sim 50$ um
- Trapped triton fraction: 25 – 70%
- Hot spot magnetic flux lost: 30 – 60%

Physics implications for MagLIF

- Electron magnetization also achieved
- Triton trapping → α-trapping in DT fuel
- ***Ignition-relevant*** regime [5,6]

DT/DD neutron yield also constrains fuel-pusher mix:

- Mix possible from beryllium liner
- Mix lowers $\bar{Y}$ curves at high *BR*
- Max possible *BR*, $(BR)_{id}$, assumes perfect flux compression
- Data suggests Be atom fraction <10%, upper bound: ~20%

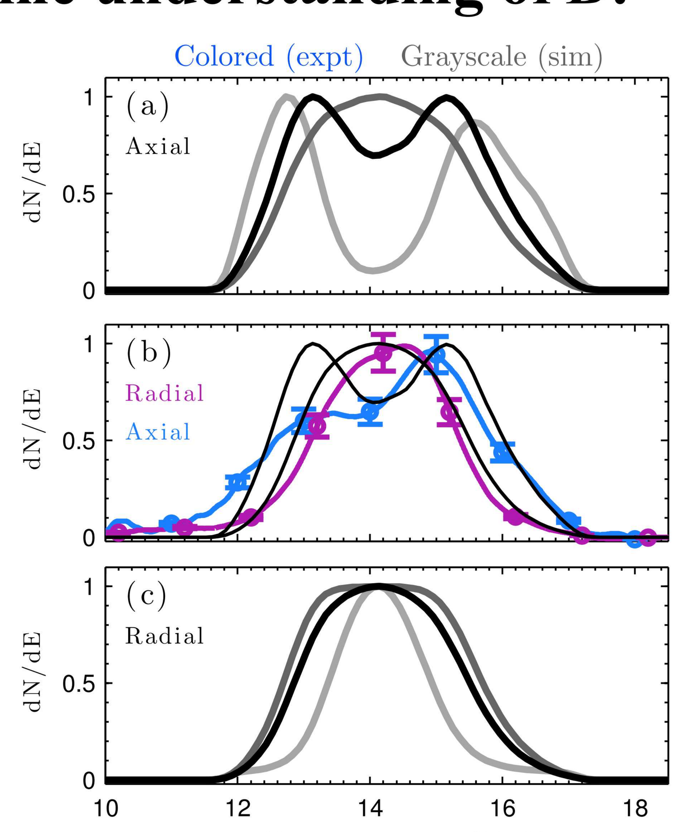


dashed : $\rho_d R = 1$ mg/cm², $n_{Be}/n_{tot} \equiv c_{Be}$: 0.1

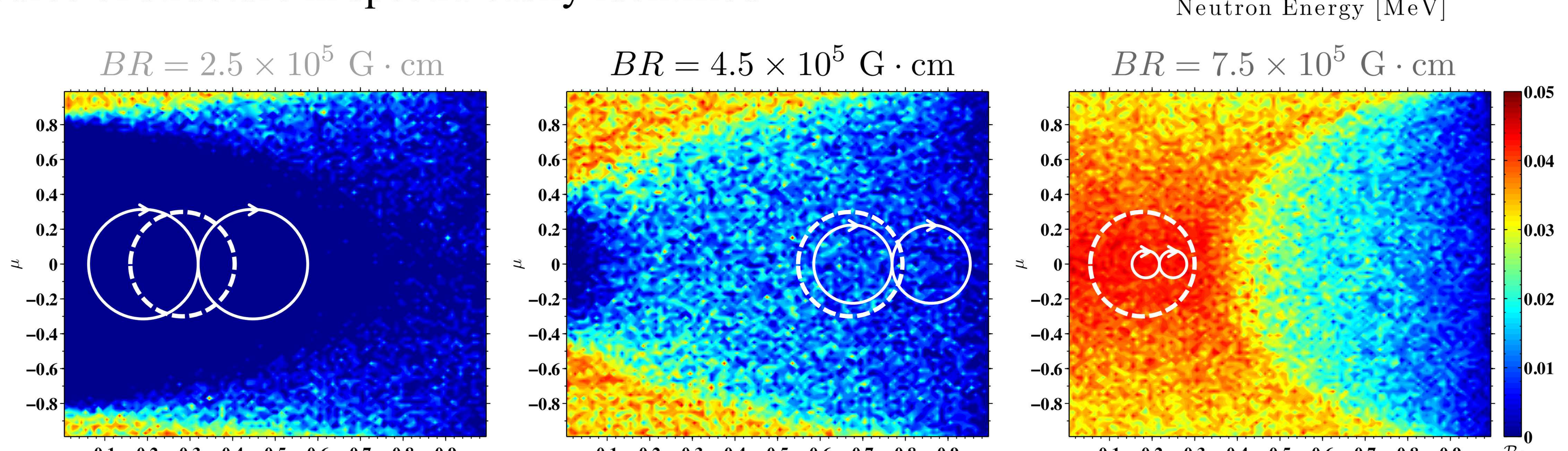
solid : $\rho_d R = 2$ mg/cm², c_{Be} (ascending order) : 0.3, 0.2, 0.1, 0

Secondary DT neutron spectra refine understanding of *B*:

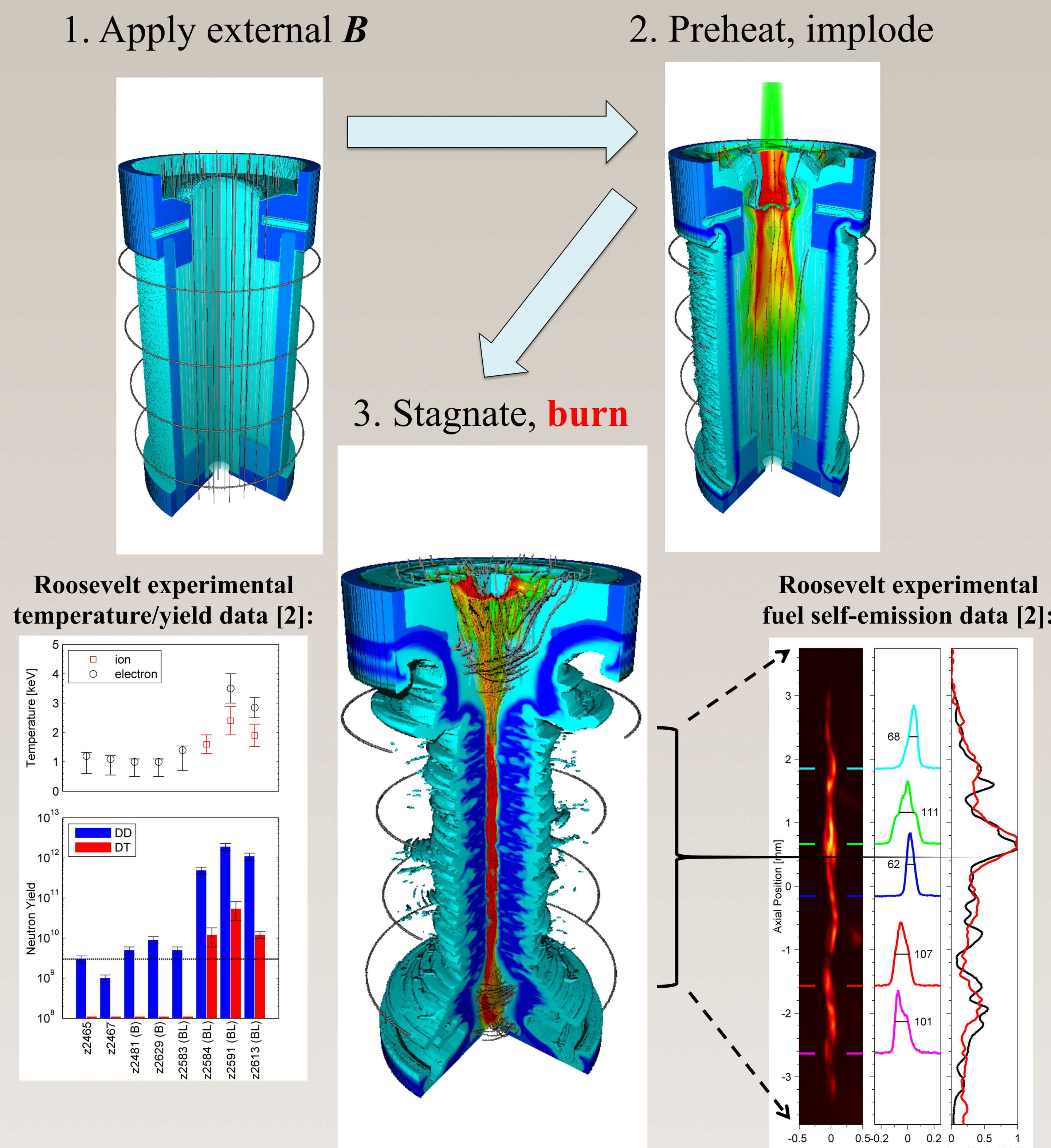
- Measured DT neutron energy spectra anisotropic
- Calculated spectra match data well, suggesting narrower range: $BR \approx 4(\pm 0.7) \times 10^5\mathrm{G \cdot cm}$
- Axial view shows double-peak, due to Doppler shift from most reactive tritons
- Radial view shows single peak
- *Spectra features highly sensitive to BR!*



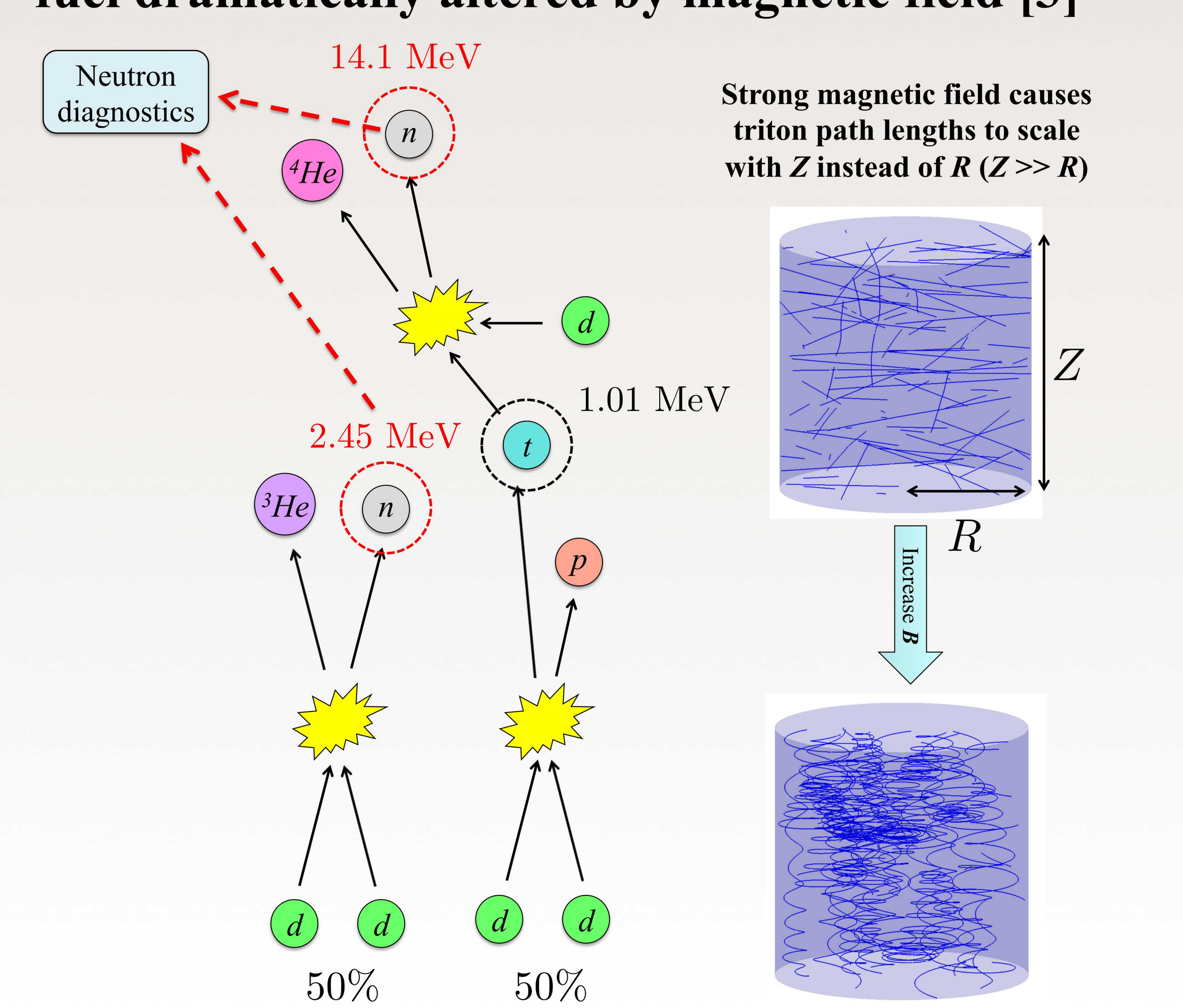
- Figures below show triton reaction probability ($\mathcal{R}_i$) based on initial radial position and pitch-angle relative to magnetic field ($\mu = \cos\theta$), source of structure in spectra easily identified



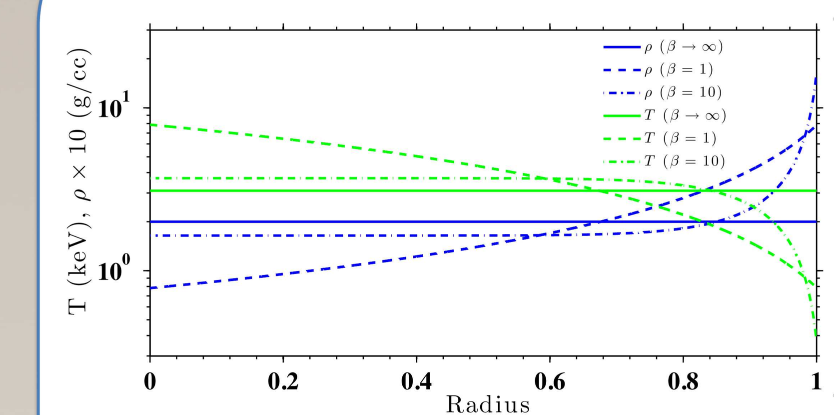
Magnetized Liner Inertial Fusion (MagLIF): Magnetic field essential for performance



Secondary fusion reactions in pure deuterium fuel dramatically altered by magnetic field [3]



New analysis examines isobaric 1D fuel profiles:



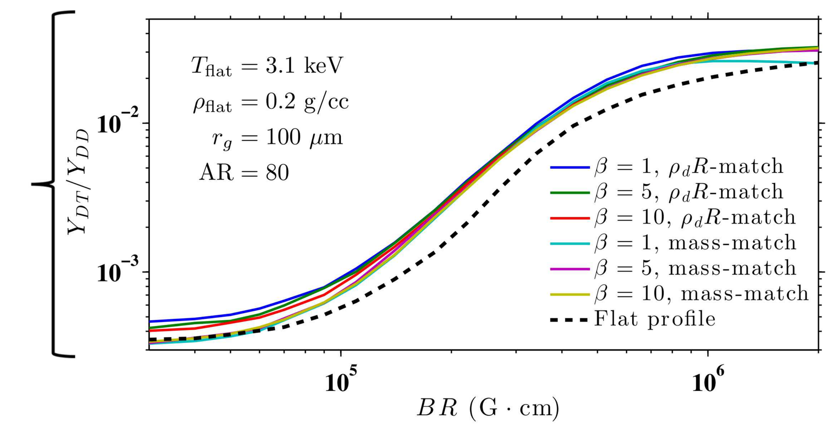
- Power law density, temperature, B_z:

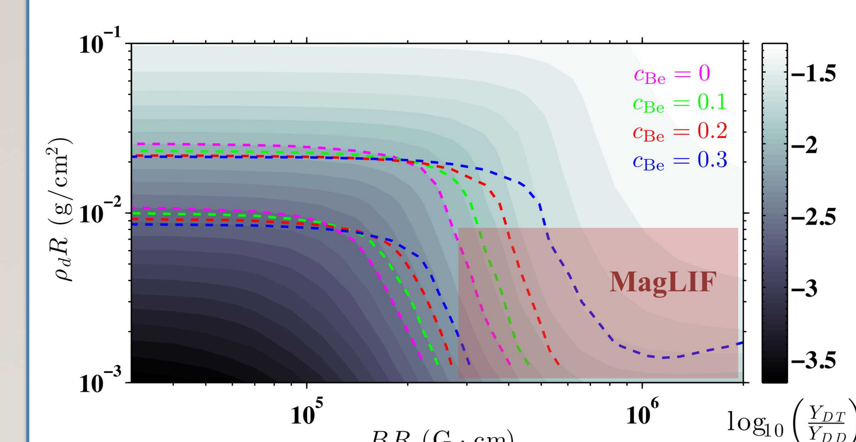
$$T = T_c\left[1 - \left(\frac{r}{r_g}\right)^\beta \left(\frac{T_c - T_b}{T_c}\right)\right] \qquad {}^*\chi(r) \equiv \frac{\langle Z\rangle + 1}{m_p\langle A\rangle}$$

$$\rho = \rho_c \frac{\chi(0)}{\chi(r)}\left[1 - \left(\frac{r}{r_g}\right)^\beta \left(\frac{T_c - T_b}{T_c}\right)\right]^{-1} \qquad {}^*B_z \propto \rho$$

- Normalizations tuned to flat profiles, using DD primary yields or 12 keV photon yields + either fuel areal density or total mass

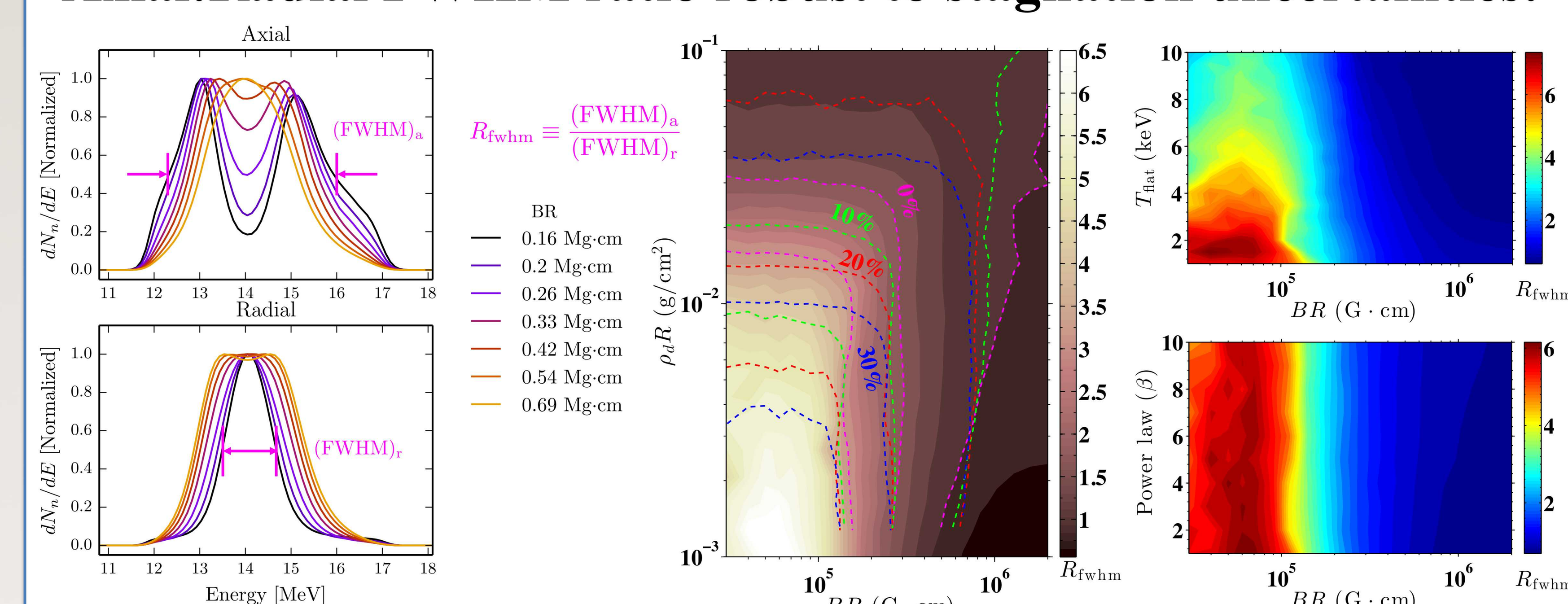
- 1D profiles exhibit almost universally higher DT/DD ratios than "equivalent" flat profiles
- Due primarily to redistribution of flux to fuel periphery, better fast ion trapping
- Reduces inferred lower bound for *BR*





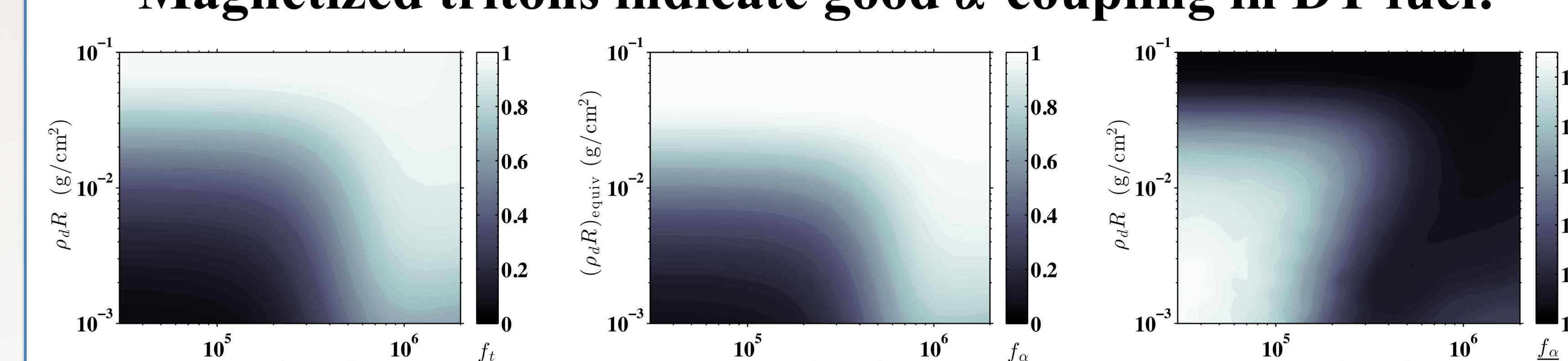
- DT/DD sensitive to ρR and mix—2 challenging quantities to measure/infer. Is there more robust method to infer *BR*?
- If *BR* can be determined independently, better chance of constraining mix with DT/DD ratio

Axial:Radial FWHM ratio robust to stagnation uncertainties:



R_{fwhm} demonstrates robustness to uncertainties in mix, ρR, temperature, and profile shape

Magnetized tritons indicate good *α*-coupling in DT fuel:



α energy deposition *always* better than triton deposition: $1 \le \frac{f_\alpha}{f_t} \lesssim Z_\alpha^2 \left(\frac{A_t}{A_\alpha}\right)^{1/2} \left(\frac{E_t}{E_\alpha}\right)^{1/2} \approx 1.9$

References:

[1] T. J. Awe *et al.*, Phys. Rev. Lett. 111, 235005 (2013).
[2] M. R. Gomez *et al.*, Phys. Rev. Lett. 113, 155003 (2014).
[3] P. F. Schmit, P. F. Knapp *et al.*, Phys. Rev. Lett. 113, 155004 (2014).
[4] A. B. Sefkow *et al.*, Phys. Plasmas. 21, 072711 (2014).
[5] S. A. Slutz *et al.*, Phys. Plasmas 17, 056303 (2010).
[6] M. M. Basko, A. J. Kemp, and J. Meyer-ter-Vehn, Nucl. Fusion 40, 59 (2000).

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