Modeling the First Magnetized NIF Hohlraum Implosions

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Modeling Magnetized Warm (MagWarm) platform: approach and goals

Goal is a model that explains MagWarm data well enough to design magnetized, high energy, cryo layered DT targets

Approach: Hohlraum modeling: Lasnex and LHT (Lasnex Hohlraum Template) common model

- "Oggie" multipliers on laser total power, cone fraction (inner beam / total power)
- Common LLNL practice for "tuned" x-ray drive for capsule-only sims

Inputs
Laser power + cone fraction mults.

✓ →

Matched outputs
Shocks
Bantime
Hotspot P2

? →

Free outputs
Yield
Tion
etc.

Questions

- Do multipliers differ for:
  - BigFoot (basis of MagWarm) vs. MagWarm?
  - With vs. without B field?
- Do we match yield and Tion, once we match bangtime and P2?
  - How important is capsule-only physics (mix, fill tube, instabilities)

Summary: Hohlraum modeling of MagWarm platform close on *relative* Tion and yield increase w/ B field, *absolute* yields too high

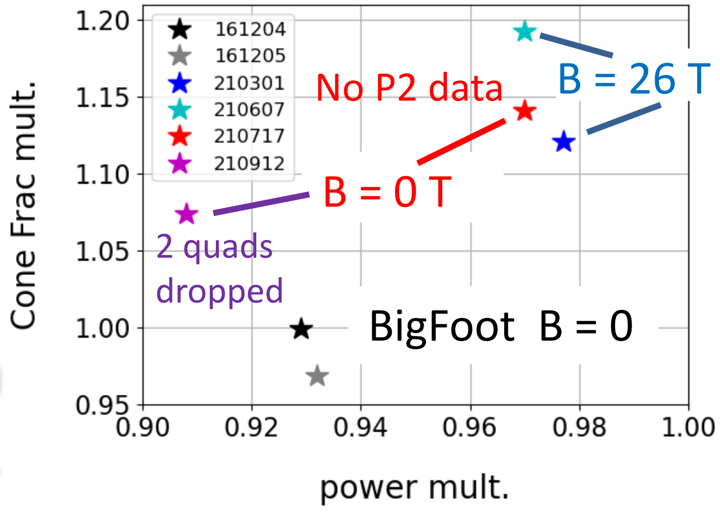
BigFoot 2016 shots: un-magnetized basis for MagWarm platform

- Small laser mults. to match bangtime and hotspot P2
- → Close on yield and Tion!

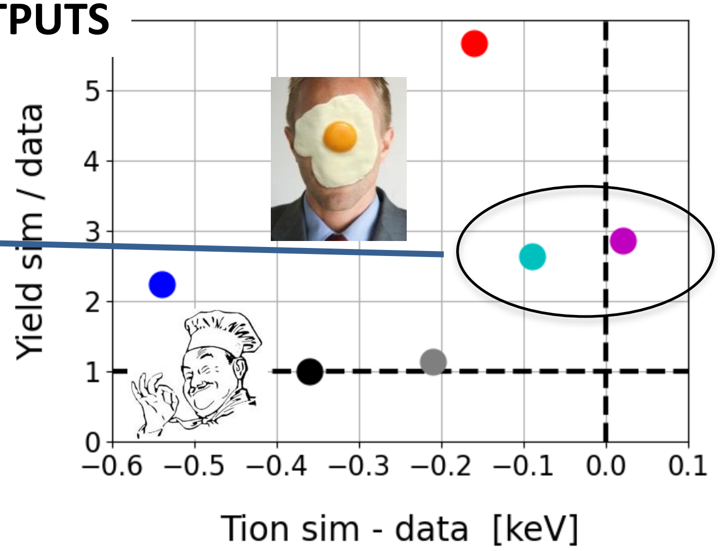
MagWarm (Magnetized Warm) platform: with or without B

- Vs. BigFoot: smaller power mults, larger cone frac mults
- CBET can replace cone fraction mults on one shot studied so far
- B vs. no-B comparison frustrated by shot issues
- Simulations vs. data: Tion close, yield several times higher
- Hohlraum dynamics similar with B or no B, in data and modeling

INPUTS



FREE OUTPUTS

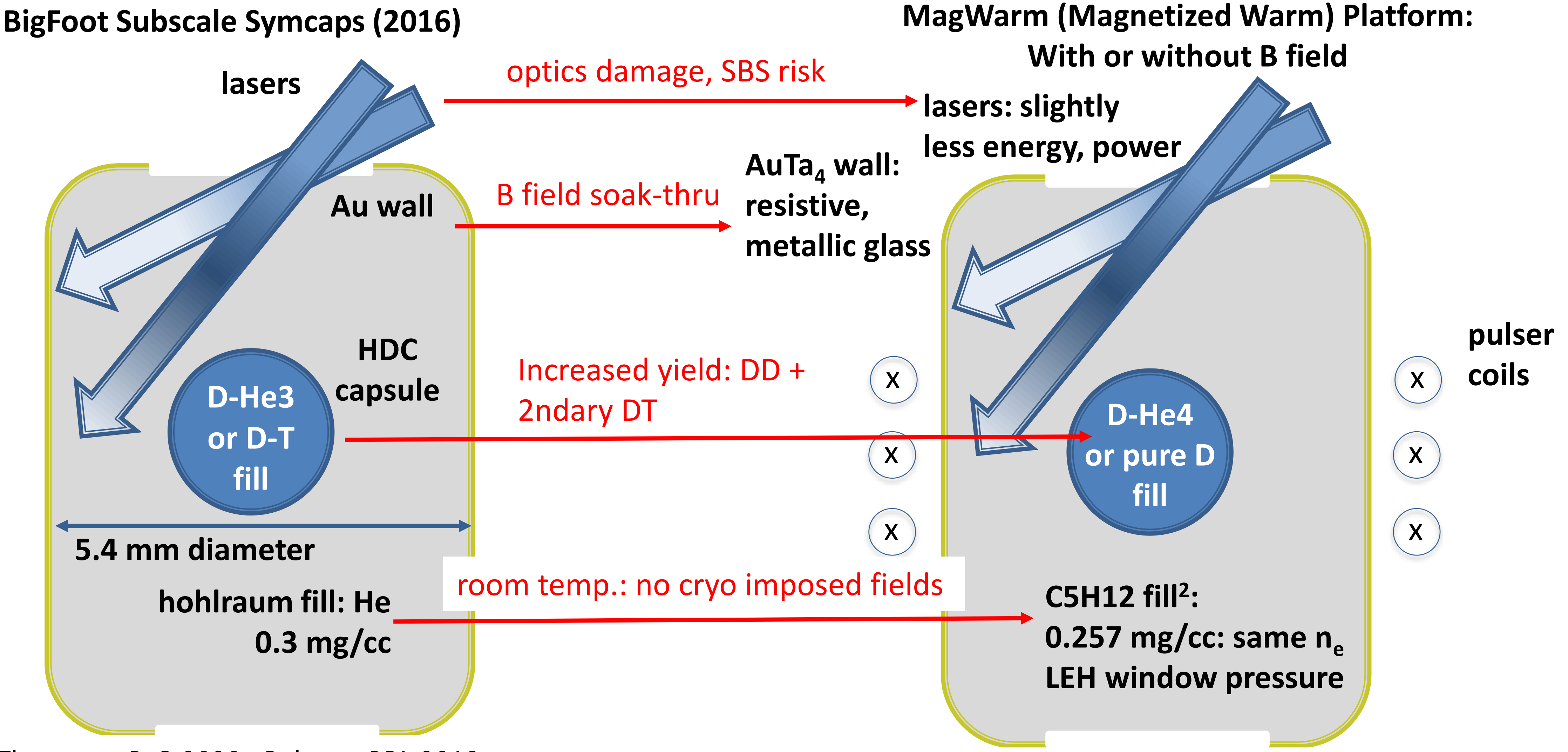


Lasnex captures relative effect of B field pretty well

relative effect of B	Data	Lasnex
DD yield: B / no B	2.90	2.67
T_{ion} [keV]: B – no B	1.08	0.97

N210607: B = 26 T   N210912: B = 0 (less laser energy)

MagWarm (Magnetized Warm) Platform: Subscale BigFoot plus constraints



[1] C. A. Thomas +, PoP 2020; Baker +, PRL 2018

[2] J. E. Ralph, D. J. Strozzi +, PoP 2016

MagWarm platform designed and modeled with Lasnex and LHT (Lasnex Hohlraum Template) Common Model

Many thanks to George Zimmerman for help esp. with MHD

MHD model: full Braginskii single-fluid

- All terms included: Biermann, Nernst, Righi-Leduc, Hall, Seebeck, …
  - Revised coefficients vs. $\omega_{ce}\tau_{ei}$ and Z [J. Saddler, C. Walsh, H. Li, PRL 2021]
- **Nernst term multiplied by 0.1, based on Tod Woods' modeling of NIF Au bubble experiments**
- Self-generated azimuthal B always included: "Biermann battery" effect
- **Imposed B:** initial B_r and B_z from analytic solution for thin, finite-length solenoid
  - Agrees well with full COMSOL modeling of coils from B. Kozioziemski
  - B field we quote is B_z at capsule center

Lasnex + LHT model: other details

- High electron heat flux limit f = 0.15
- HDC EOS 9061 – best physics at LLNL
- Non-LTE physics: 2020 DCA models, all materials inline, except Au and Ta tables [Howard Scott, Judy Harte]
  - Big runtime savings vs. inline, esp. with two hi-Z species
- Laser Entrance Hole (LEH) hardware included
- Inline CBET not included by default, we are exploring
- Multi-species hydro not included: small effect in Bigfoot symcaps

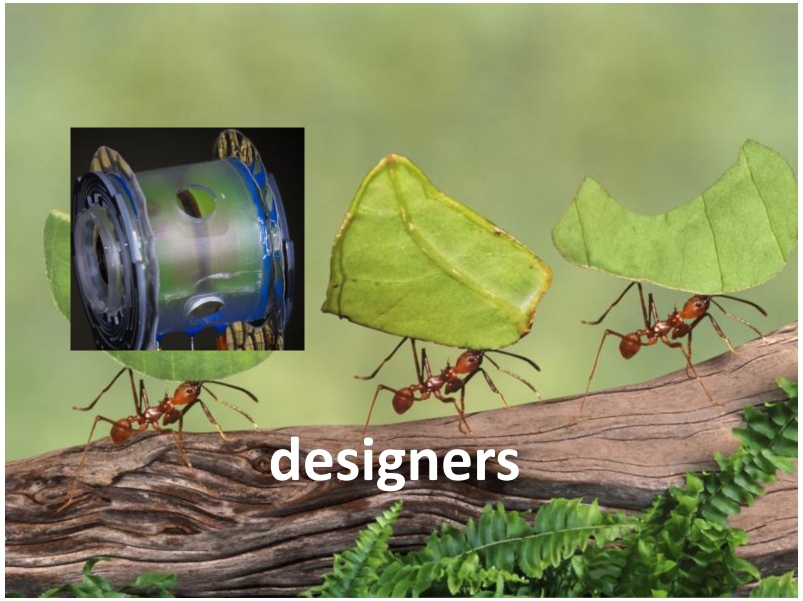
Modeling strategy: use 2016 BigFoot[1] shots for power multipliers for shock timing, and to validate approach

	N161115-2	N161204-3	N161205-3
Shot type	Keyhole: shock timing	Symcap	Symcap
Capsule fill	liquid D2	D-He3	D-T
Capsule dopant	0.23% W	0.24% W	undoped

1 C. A. Thomas +, PoP 2020; K. L. Baker +, PRL 2018

ANTS (Automated NIF Tuning Suite) tool

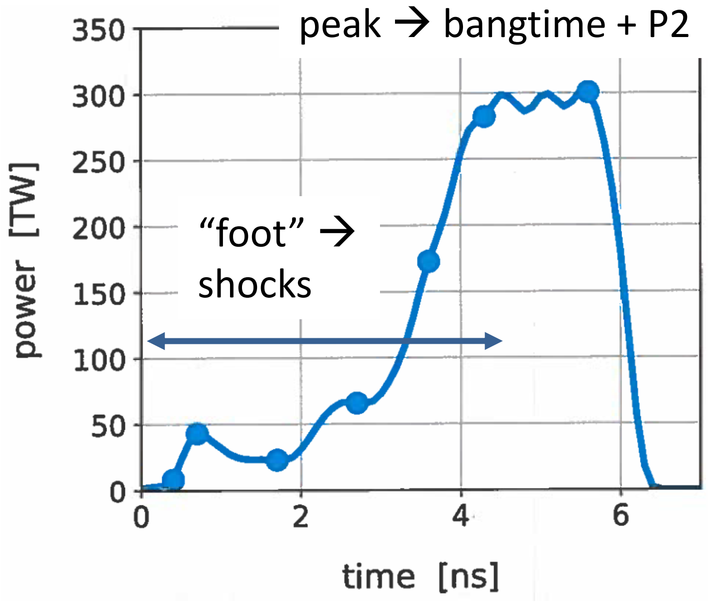
- Developed by Chris Weber
- Find laser power and cone fraction multipliers
- **Power multipliers:**
    - Foot: match shock timing data: keyhole shots
    - Peak: Capsule bangtime: symcap shots
- **Cone fraction (inner cone / total power) multipliers:**
    - Foot: none
    - Peak: Hotspot x-ray self-emission P2 moment: symcap shots

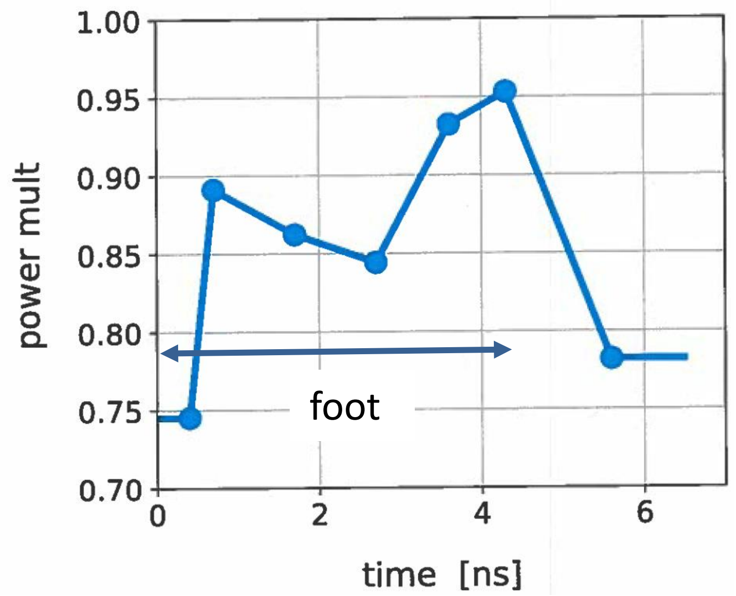


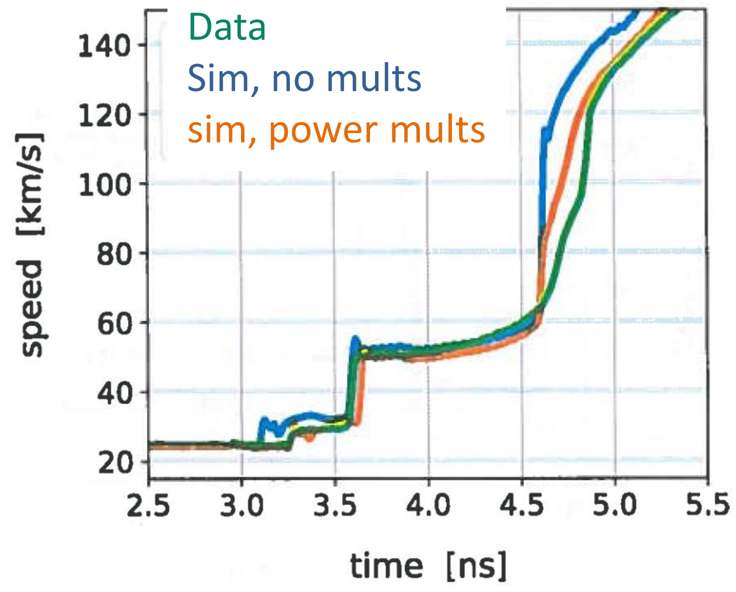
BigFoot 2016 keyhole: ANTS (Automated NIF Tuning Suite): time-dependent laser power multipliers to match shock timing data

Keyhole shot: tune shock timing
N161115-2

Incident laser power **x** **Laser power multipliers: Typical for NIF hohlraums** **=** **Shock speed on waist**

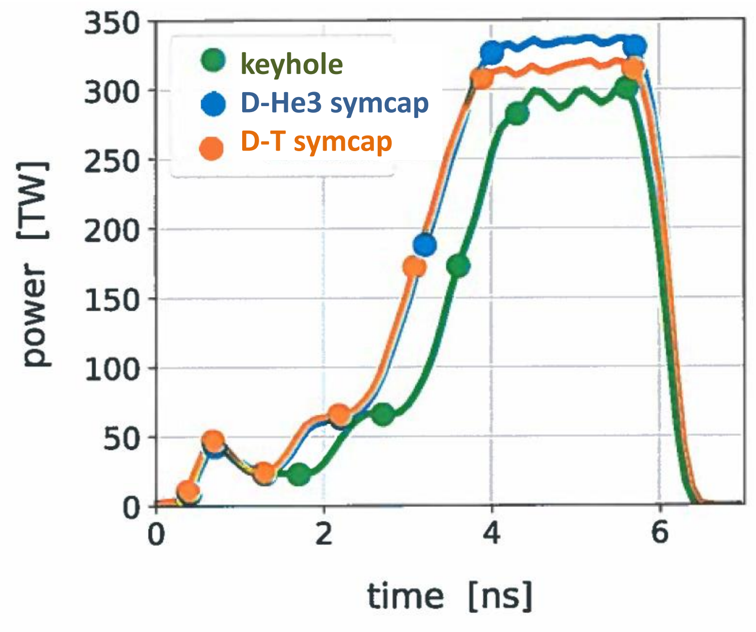






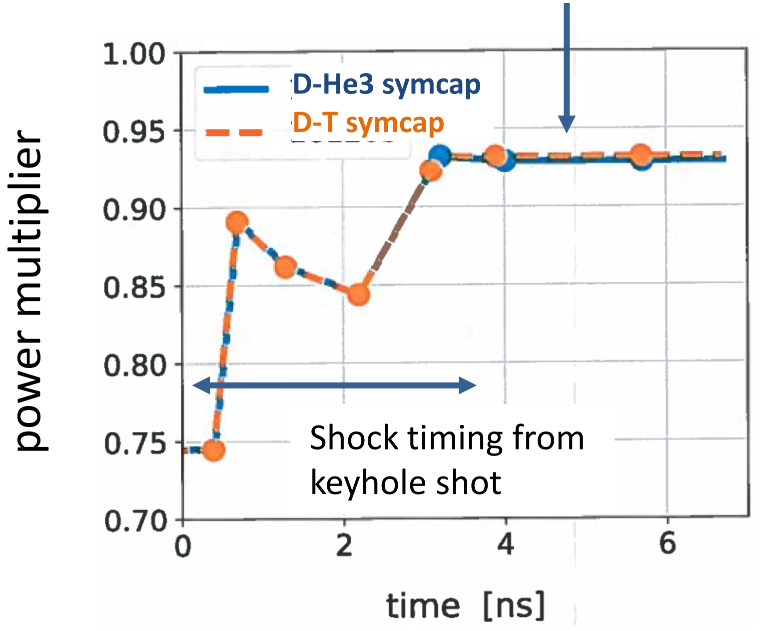
BigFoot 2016 symcaps: ANTS: small laser power and cone fraction multipliers to match bangtime and P2

Incident laser:
points = ANTS control times



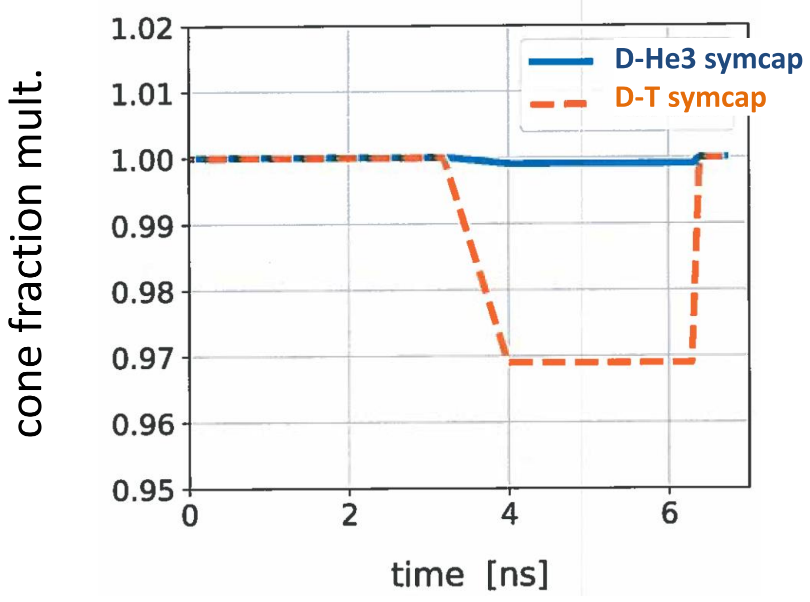
N161204-3: D-He3 W-doped symcap
N161205-3: D-T undoped symcap

Symcap bangtimes → peak power mult. = 0.93



Power mults "smaller" (closer to unity) than typical current full-energy NIF shot: 0.85 – 0.9

Symcap hotspot P2 → Cone fraction mult. = 0.97 – 1.0



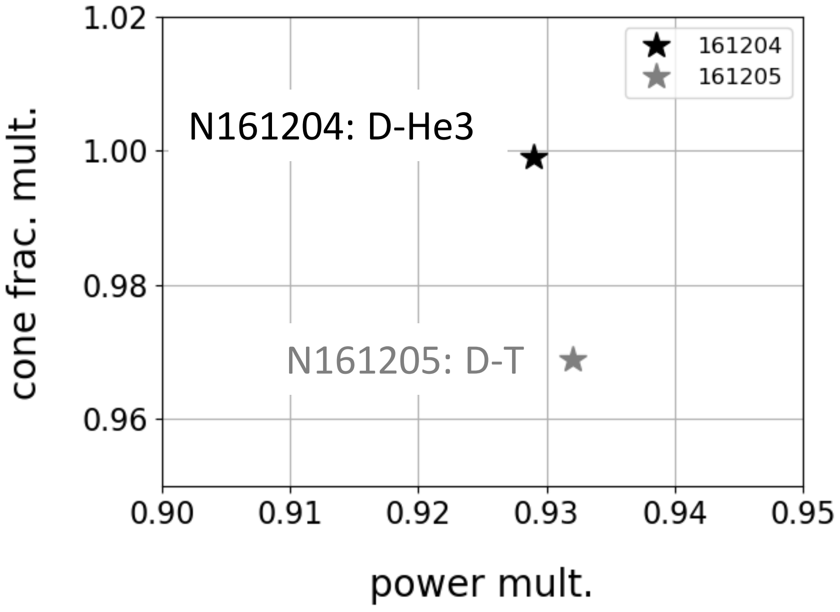
Cone fraction = inner / total power
0.97 multiplier small: CF decreased from 0.28 to 0.97*0.28 = 0.272

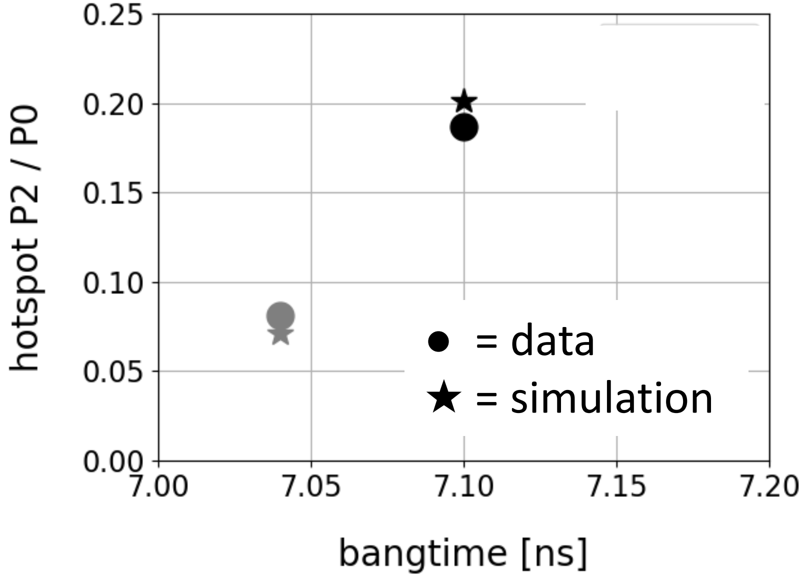
Bigfoot 2016 symcaps: laser multipliers to match bangtime and P2 → good agreement on yield and Tion

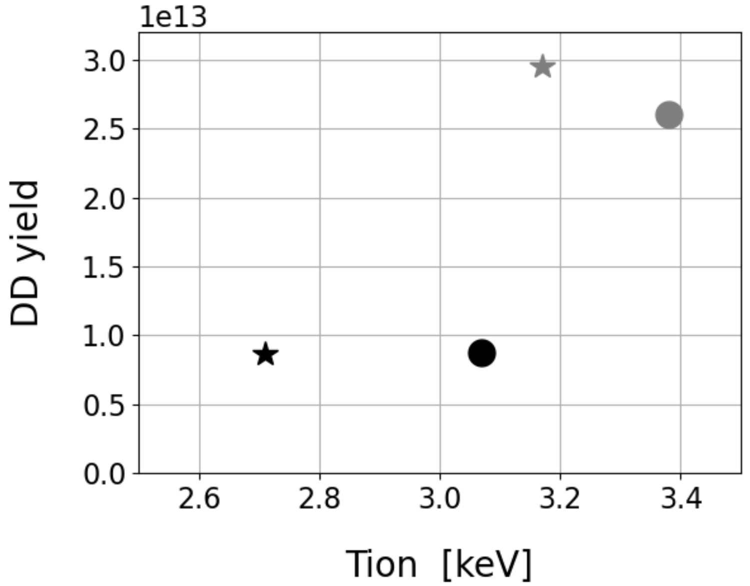
INPUTS:
laser power and cone frac mults.

✓ → **MATCHED OUTPUTS:**
Bangtime, x-ray P2

? → **FREE OUTPUTS:**
DD Yield*, T_{ion}



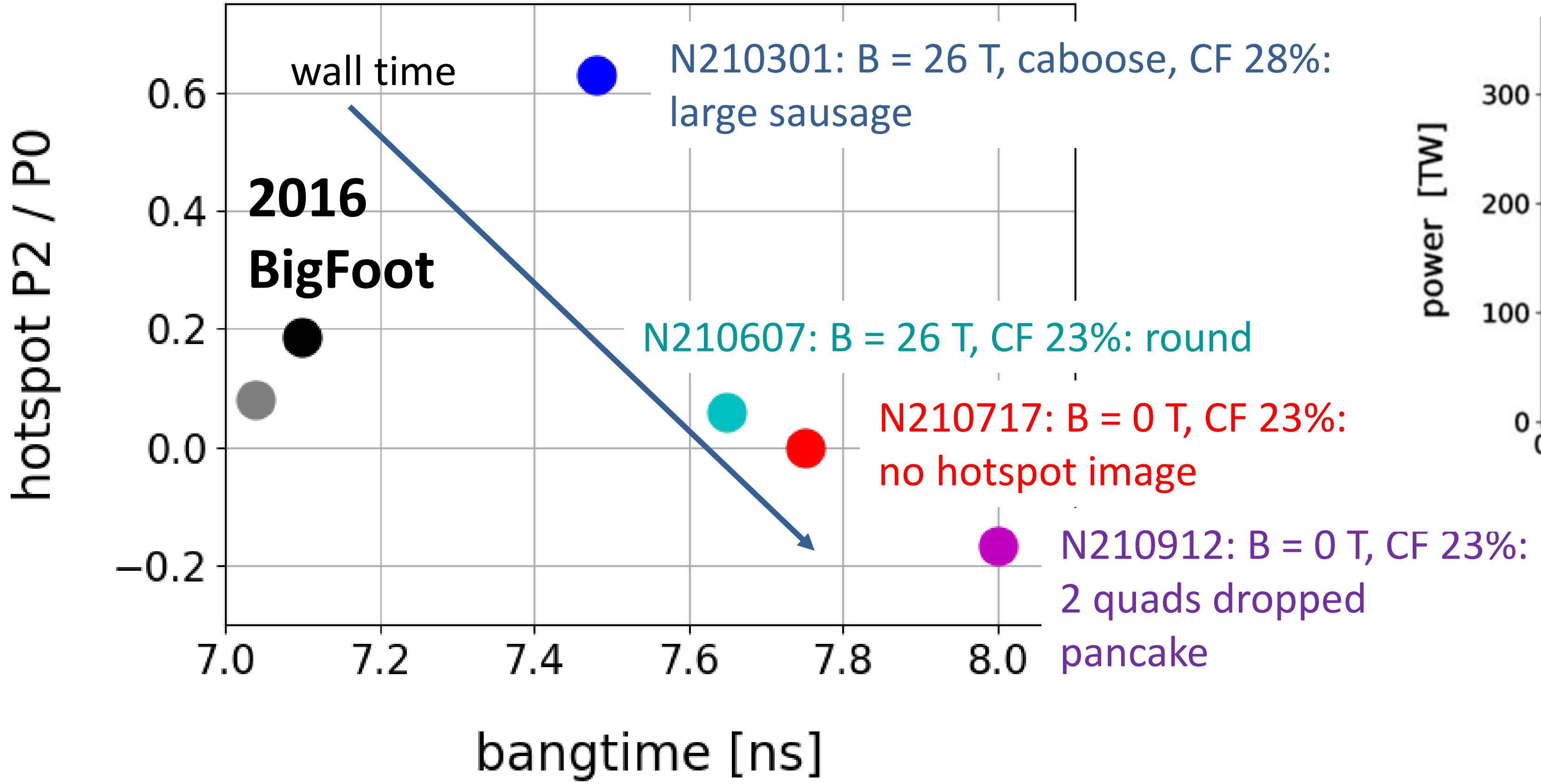


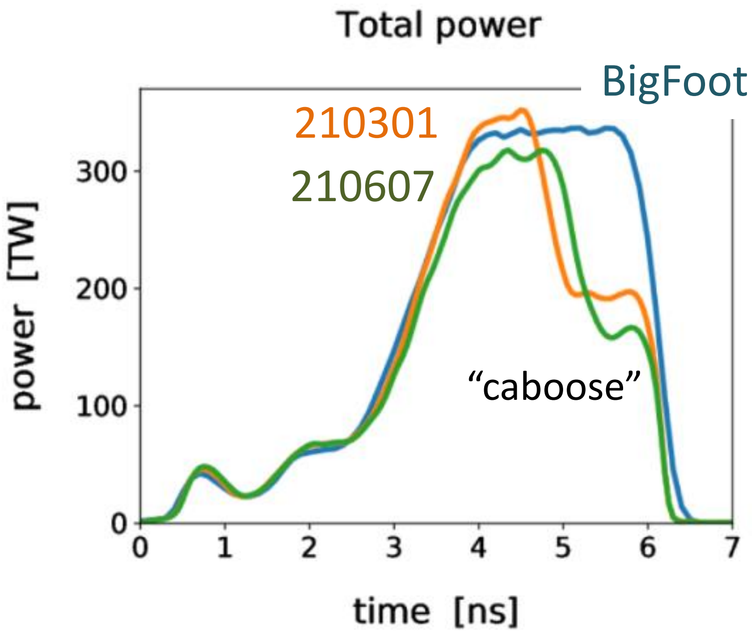


* shots with not pure D capsule fill yields *10

MagWarm symcaps: We model 4 shots with progressively less laser energy

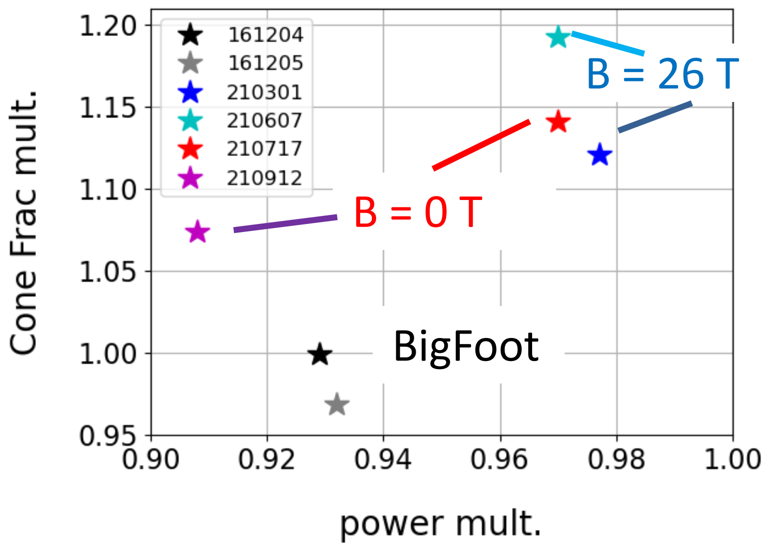
Measured data





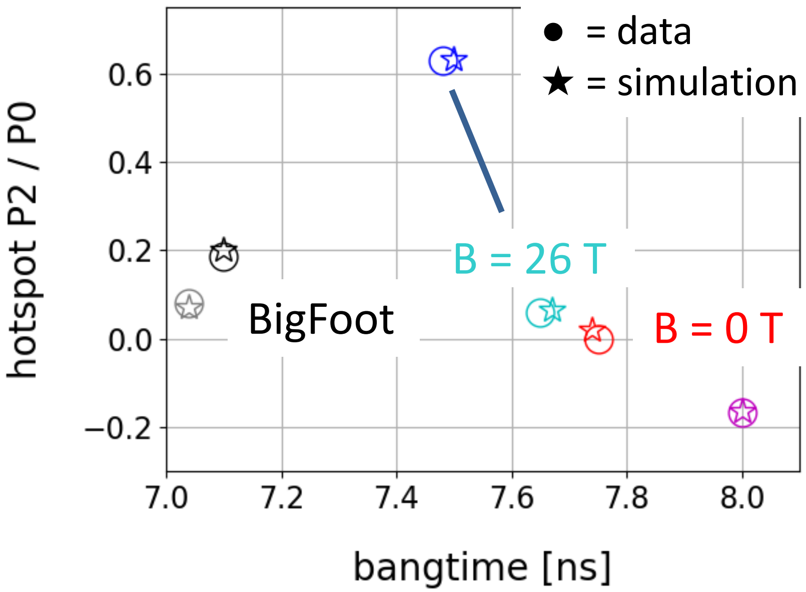
MagWarm symcaps: laser multipliers: 3 similar shots and one oddball, no clear difference for B vs. no B

INPUTS:
laser power and cone frac mults.



BigFoot D-3He
BigFoot D-T
MagWarm B = 26 T, sausage
MagWarm B = 26 T, round
MagWarm B = 0 T, no shape data, sim. tuned round
MagWarm B = 0 T, 2 quads dropped, pancake

MATCHED OUTPUTS:
Bangtime, x-ray P2

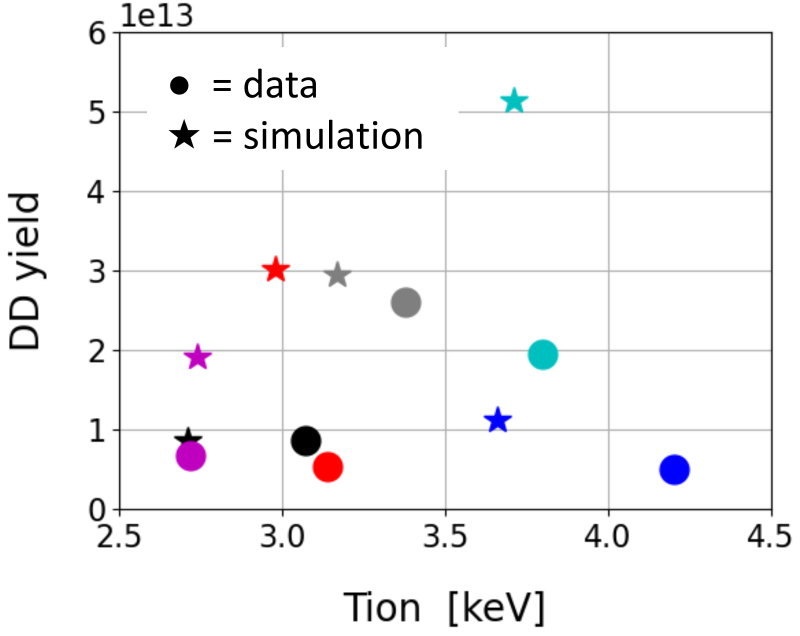


3 similar shots: 2 with B, 1 no B
- Small power mults! Less than BF
- Cone fraction mults. more than BF: CBET could be at play and different from BF

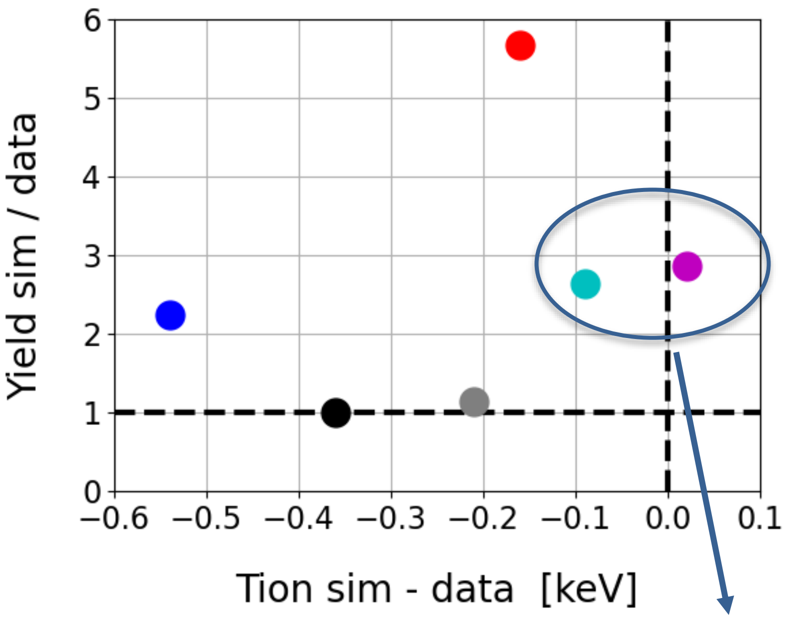
1 oddball shot (no B): 2 laser quads dropped, different cones:
- Up-down asymmetry, long "coast time"
- Power mult. more than other 3 shots
- Cone fraction mult. b/t BF and other 3

MagWarm symcaps: Simulated yield > 2x data – unlike BigFoot

FREE OUTPUTS:
DD Yield, T_{ion}



Sim vs. data:
Yield ratio and Tion difference



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* shots with not pure D capsule fill yields *10

Lasnex captures relative effect of B field pretty well

relative effect of B	Data	Lasnex
DD yield: B / no B	2.90	2.67
T_{ion} [keV]: B – no B	1.08	0.97

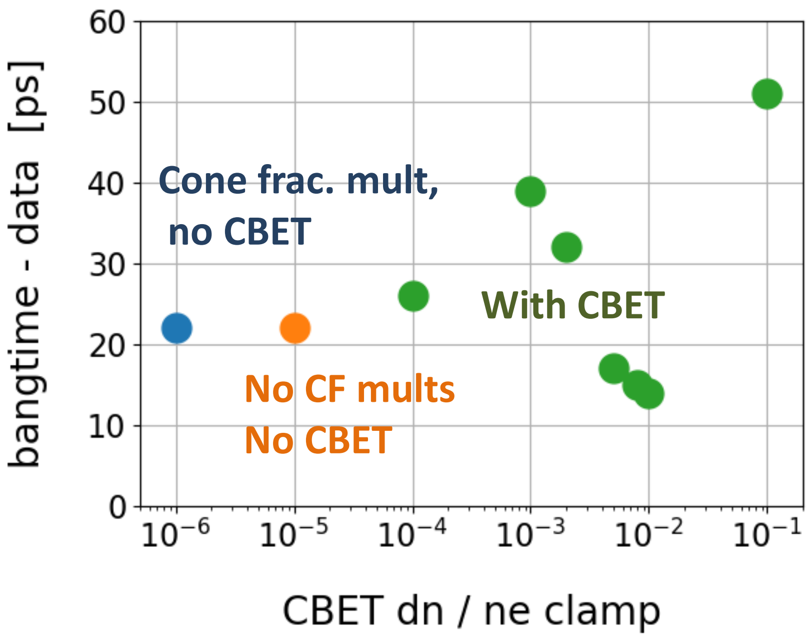
N210607: B = 26 T   N210912: B = 0 (less laser energy)

MagWarm symcaps: Inline CBET: model moves power to inner beams, can explain shape data with clamp

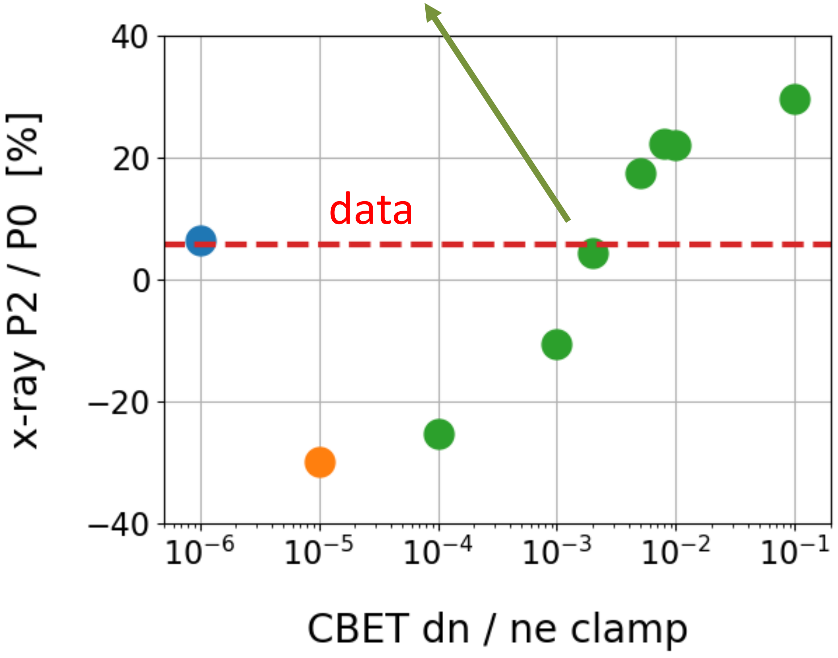
Runs of N210607: B = 26 T, round hotspot

- All use power mults. from run with cone fraction mult. tuned to match data
- No cone fraction mult.

CBET and cone fraction mult. have little effect on bangtime



Inline CBET with clamp $\delta n/n_e$ $2*10^{-3}$ matches data



Other shots being studied: Bigfoot, MagWarm B = 0

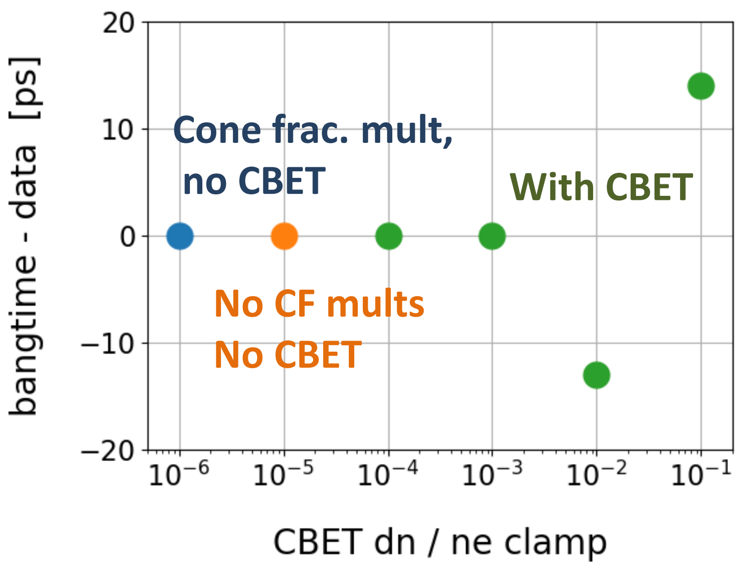
CBET modeling of several current NIF campaigns agrees with data for smaller clamps $\delta n/n_e \sim 10^{-2}$

MagWarm symcaps: Inline CBET: Un-magnetized shot: Inline CBET model explains shape data with lower clamp

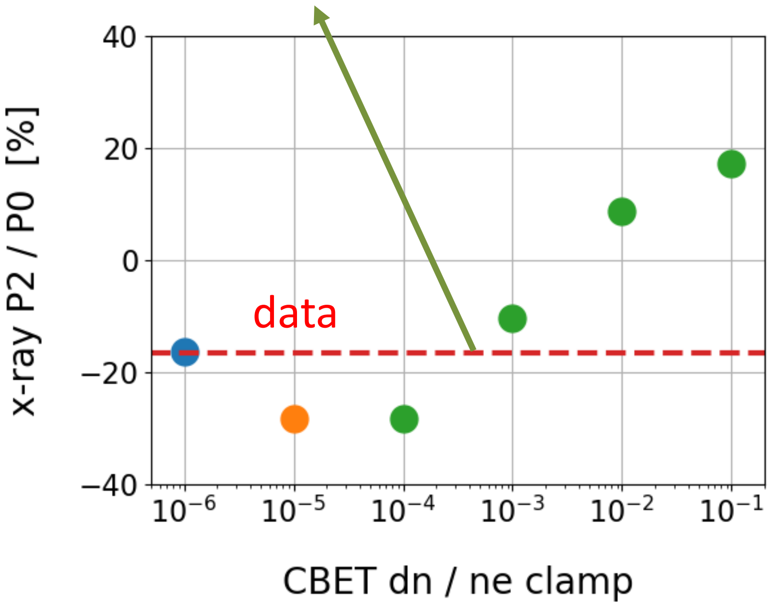
Runs of N210912: B = 0 T, 2 dropped quads, pancaked hotspot

- All use power mults. from run with cone fraction mult. tuned to match data
- No cone fraction mult.

CBET and cone fraction mult. have little effect on bangtime



Inline CBET with clamp $\delta n/n_e$ ~ $5*10^{-4}$ matches data

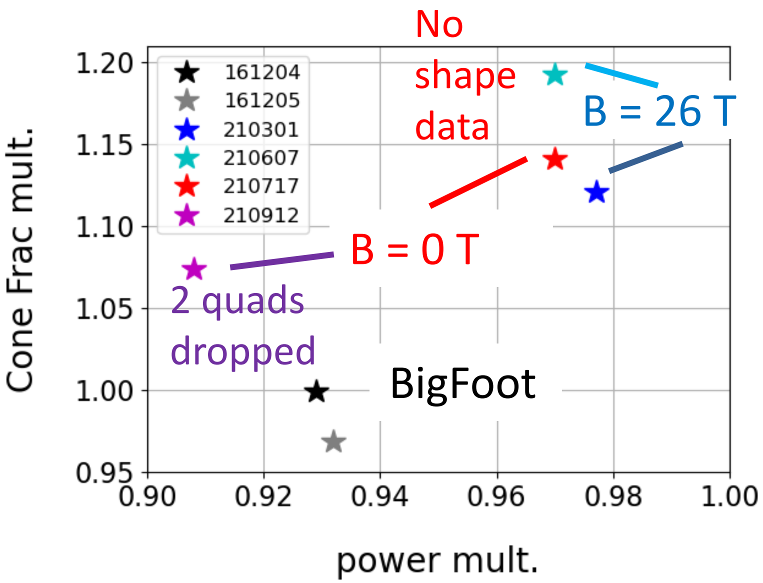


Why lower clamp to match data with no B than with?

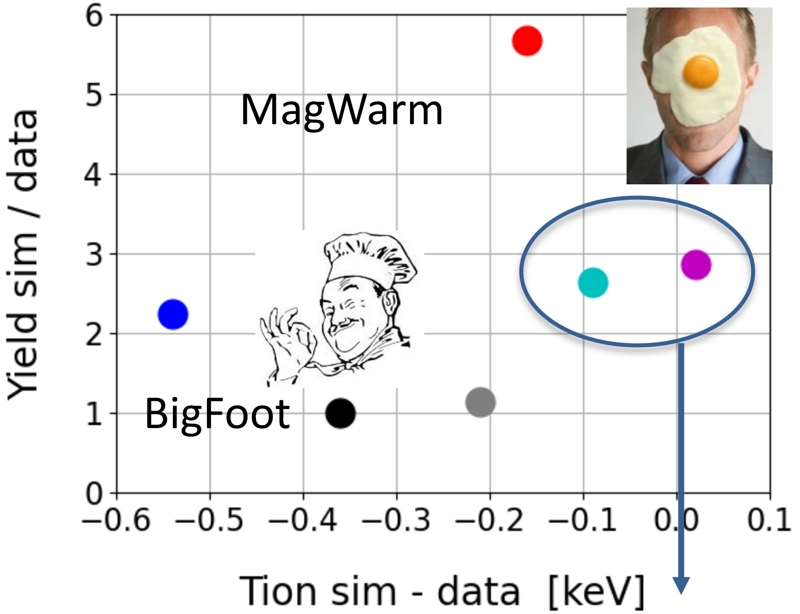
- Less laser energy →Longer coast time?
- Direct effect: B field alters magnetized CBET coupling?
- Indirect effect: plasma conditions B vs. no B

Conclusions: Lasnex hohlraum modeling of BigFoot and MagWarm platforms

Laser multipliers aren't clearly different with B vs. no B



Lasnex modeling captures relative effect of B field pretty well, absolute yields > 2x data



relative effect of B	Data	Lasnex
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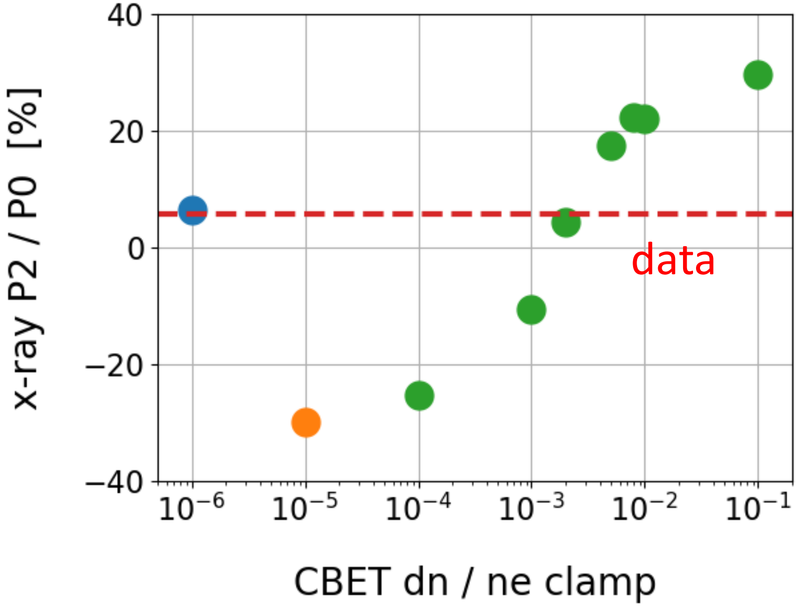
T_{ion} [keV]: B – no B	1.08	0.97

Inline CBET with clamp $\delta n/n_e$ $2*10^{-3}$ matches data: B = 26 T, round hotspot shot



Future work on modeling MagWarm: open questions

Why is modeled yield near data for BigFoot but high for MagWarm?

- ***Not*** due to B field: larger difference for B = 0 MagWarm shots
- Need high-resolution capsule-only modeling for hydro instabilities, fill tube, mix, etc.
  - Maybe that explains it
- “Caboose” / longer coast time
- Lower capsule fill density
- Shock timing: tuned for BigFoot not MagWarm
- AuTa4 hohlraum spectrum

Magnetized LPI

- CBET
  - Indirect effect: B field changes plasma conditions
  - Direct effect: magnetized CBET coupling: Yuan Shi, John Palastro; potential Omega expt’s
- Backscatter very low on all MagWarm shots: any B field effect small

Good collaboration opportunities

Goal is model that explains MagWarm data well enough to design magnetized, high energy, cryo layered DT targets

BACKUP BELOW

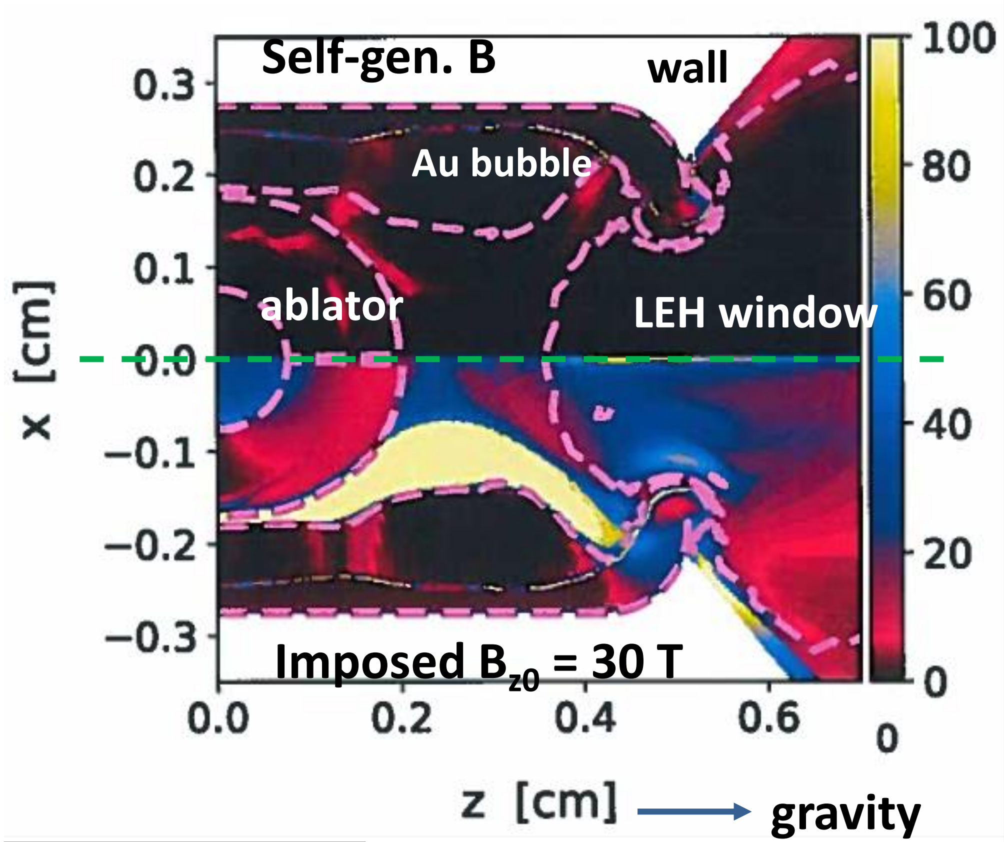
MagWarm platform: 4 symcaps modeled

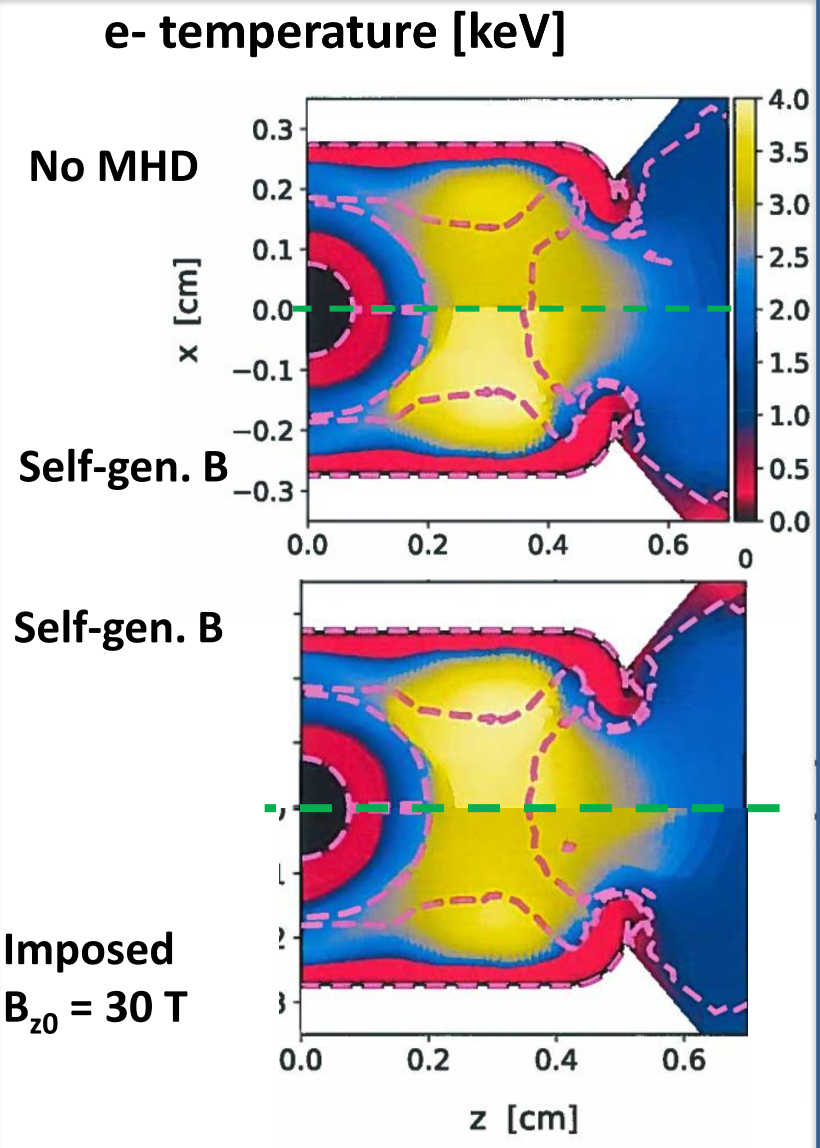
Shot	Platform	B field [T]	capsule fill [mg/cc]	peak cone frac	Laser energy [kJ]	Comment
N161204-3	BigFoot	0	D3 ^{3}He7	28	1091	
N161205-3	BigFoot	0	D T	28	1064	
N210301-1	MagWarm	26	D3 ^{4}He7	28	926	Hotspot very sausaged
N210607-2	MagWarm	26	D	23	883	Lower CF + energy, hotspot round
N210717-1	MagWarm	0	D	23	875	No shape data, sim. tuned round
N210912-1	MagWarm	0	D	23	840	2 quads dropped, pancaked

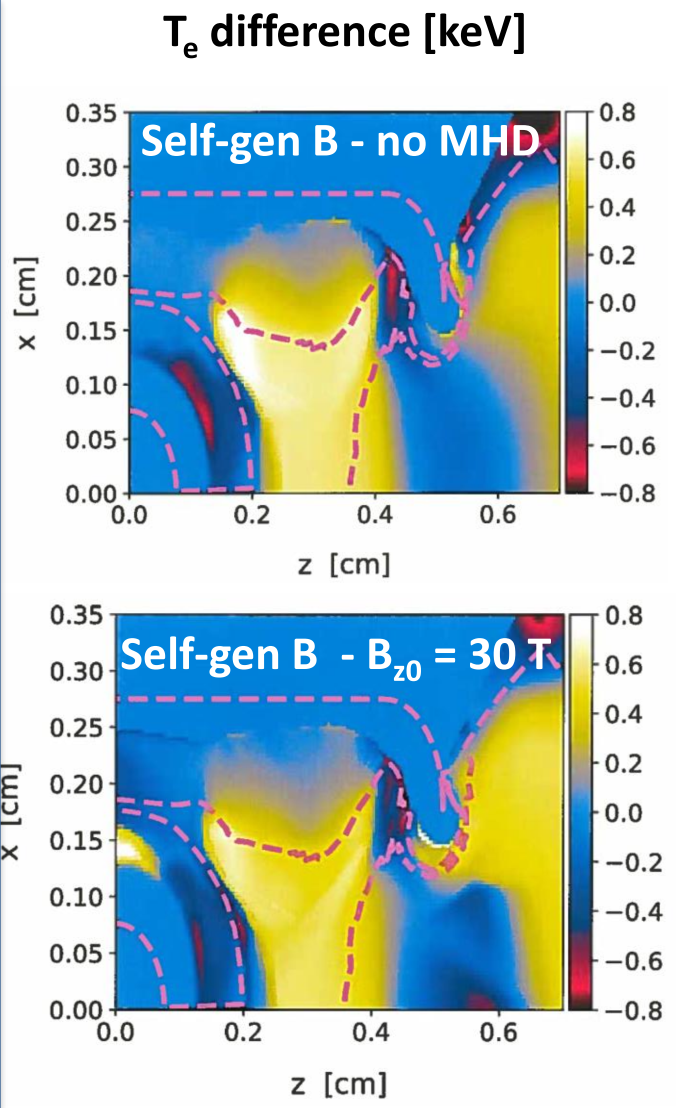
- N201228-1 and N210620-1 did not return useful capsule data
- N220110-1 had capsule leak: very low hohlraum fill 0.01 mg/cc of D2, hard to model

Hohlraum dynamics: frozen-in B field, small temperature change

4.5 ns: early peak power

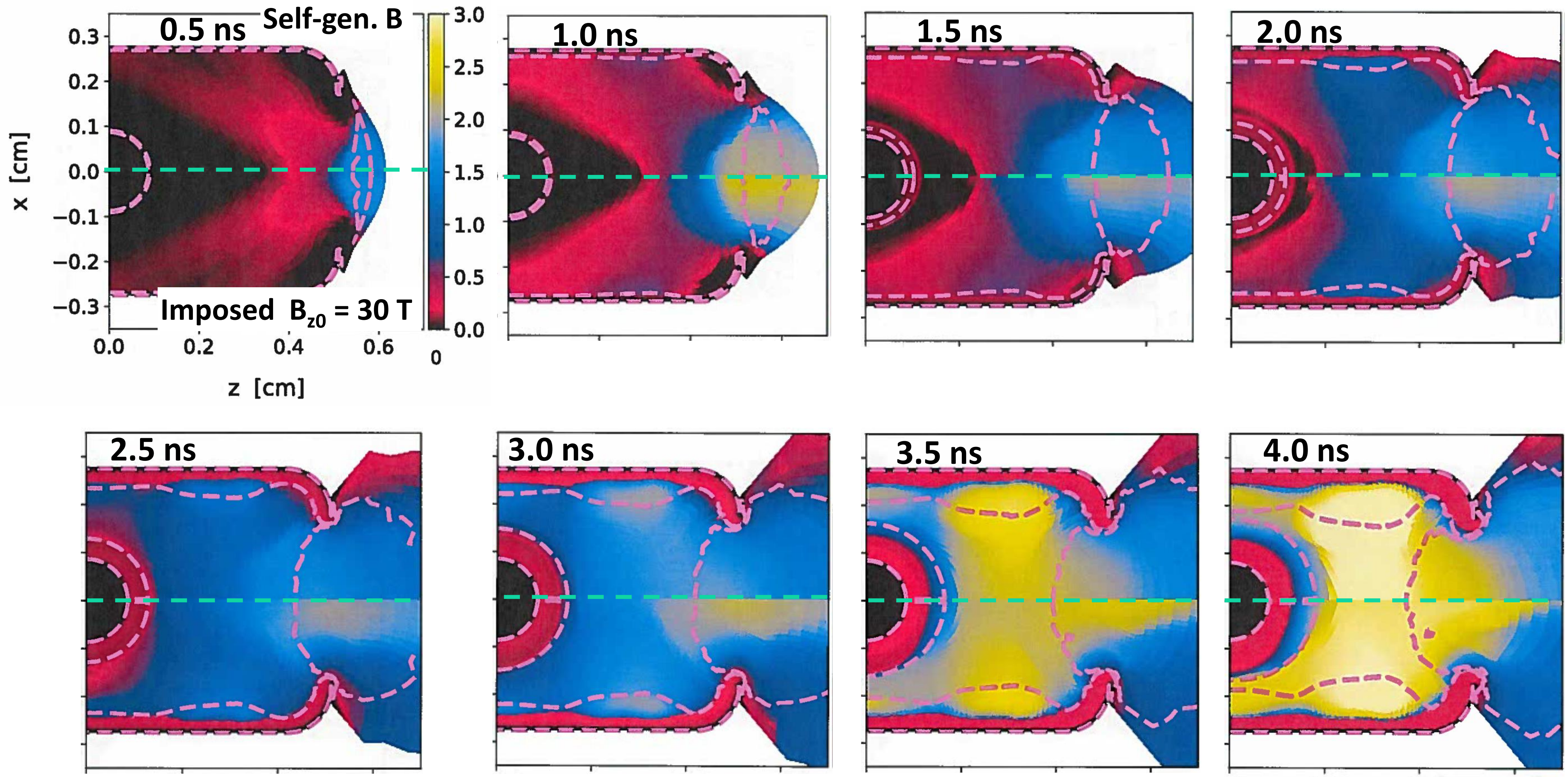






BigFoot Symcap

T_e [keV] Movie: hotter in LEH w/ imposed B, not in rest of fill



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