Room-temperature, ignition-scale hohlraum experiments on NIF

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NIF room-temperature (“warm”) ignition-scale hohlraum experiments with higher-Z gas fill

Does higher Z gas fill improve inner-beam propagation = round implosion with less cross-beam transfer to inners ($\Delta\lambda$)? Jury still out.

Motivation:

- **Hotter hohlraum plasma could reduce inner-beam SRS (more Landau damping)**
- **Higher Z hohlraum gas fill absorbs more laser via inverse bremsstrahlung**
- **Warm shots allow gases that freeze at cryo, e.g. hydrocarbons**
- **Warm shots easier to field, cheaper (no cryo hardware)**

Shape: in-flight shell vs. stagnated hotspot

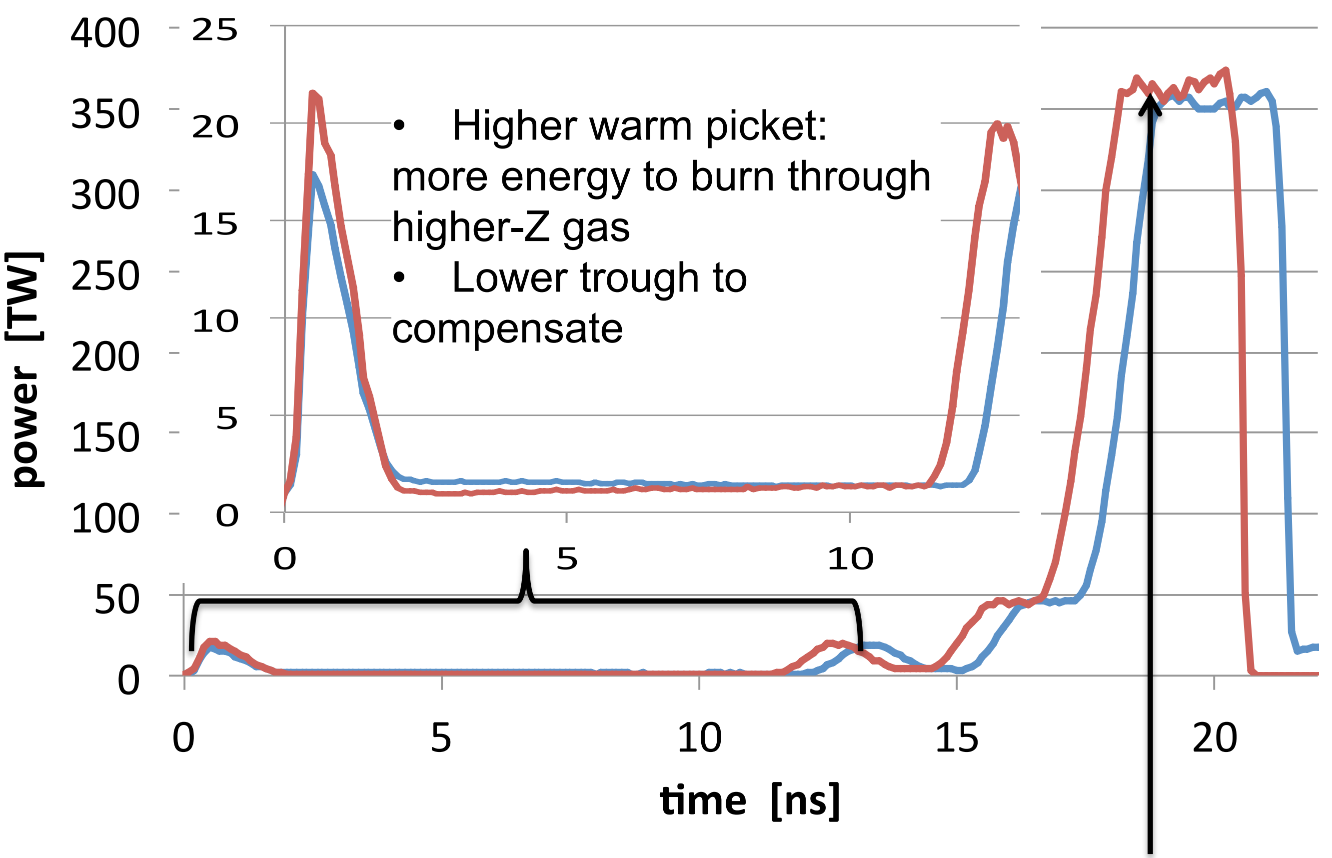
- **Warm hotspots close to round with less $\Delta\lambda$ than cryos**
- **But warm shell pancaked – need more $\Delta\lambda$ to make round**
- **Opposite “swing” of cryos – shell round but hotspot pancaked**

Backscatter: **Warms have less inner-beam SRS, more outer-beam SBS**

- **Pure $\Delta\lambda$ scaling or intrinsic effect of gas fill?**

Warm shots use hydrocarbon gas fills, retuned laser picket and trough

	Cryo	Warm	Comments
Hohlraum fill	0.96 mg/cc He^4	0.82 mg/cc C_5H_{12}	higher Z, same n_e
Capsule fill	D-He^3	propane: $C_3\{H \text{ or } D\}_8$	D, He leak warm



- Main pulses differ: shots have different design histories

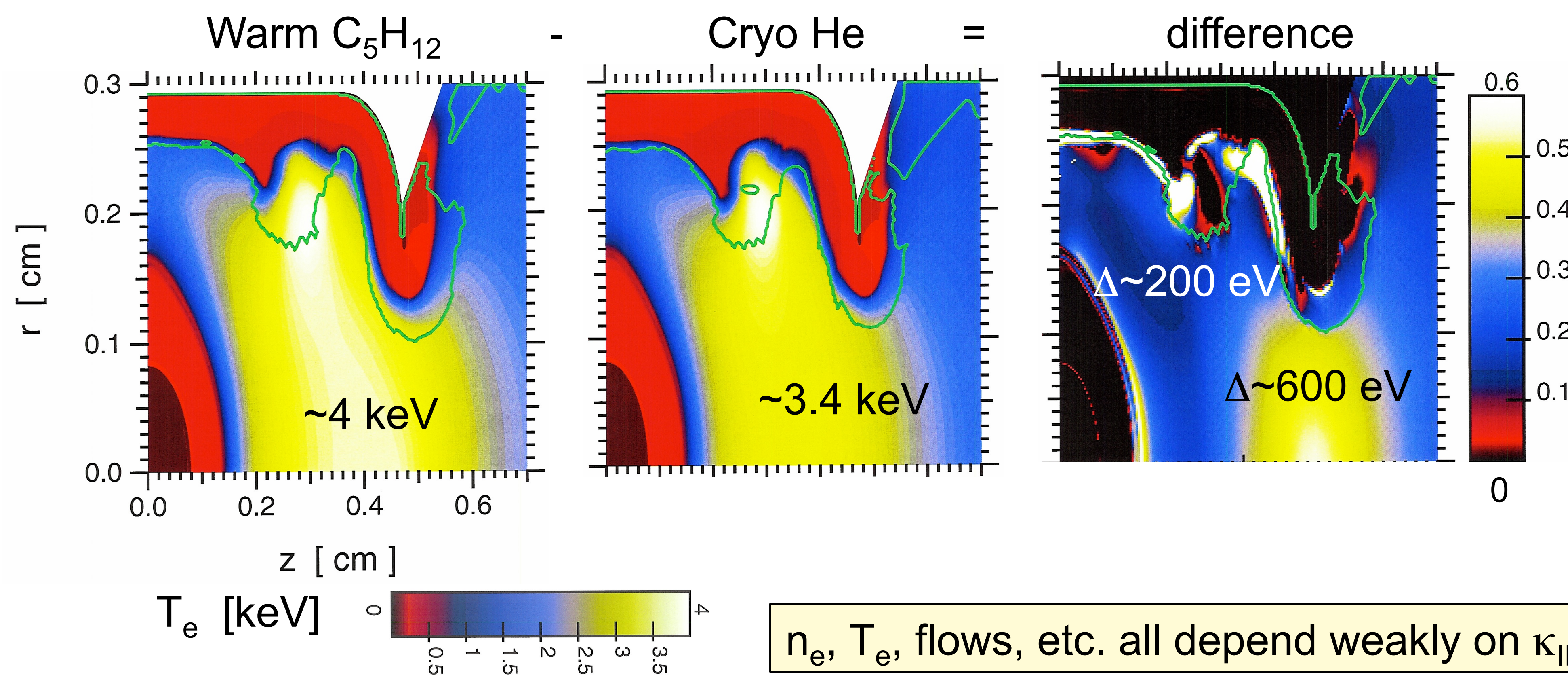
Higher Z hohlraum gas fill increases inverse bremsstrahlung laser absorption, gives hotter plasma

$$\kappa_{IB} \propto \left[1 - \frac{n_e}{n_{cr}}\right]^{-1/2} \frac{n_e^{\,2}}{T_e^{\,3/2}} \ln\Lambda \frac{\sum_i f_i Z_i^{\,2}}{\sum_i f_i Z_i}$$

$$\frac{\text{warm } \kappa_{IB}(C_5H_{12})}{\text{cryo } \kappa_{IB}(\text{He})} = \frac{4.57}{2} = 2.29$$

Directly depends on gas fill

Hydra modeling: electron temperature at mid peak power (19 ns):



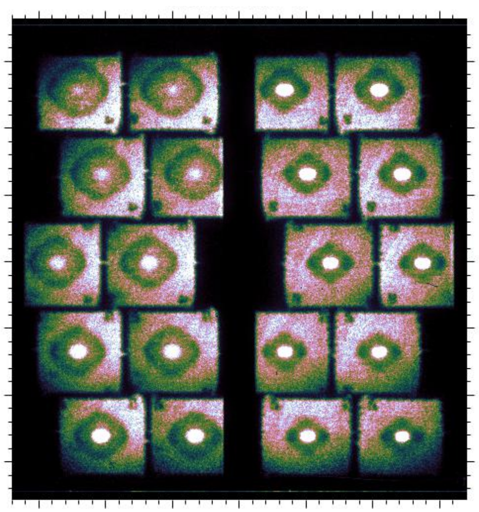
n_e, T_e, flows, etc. all depend weakly on κ_{IB}

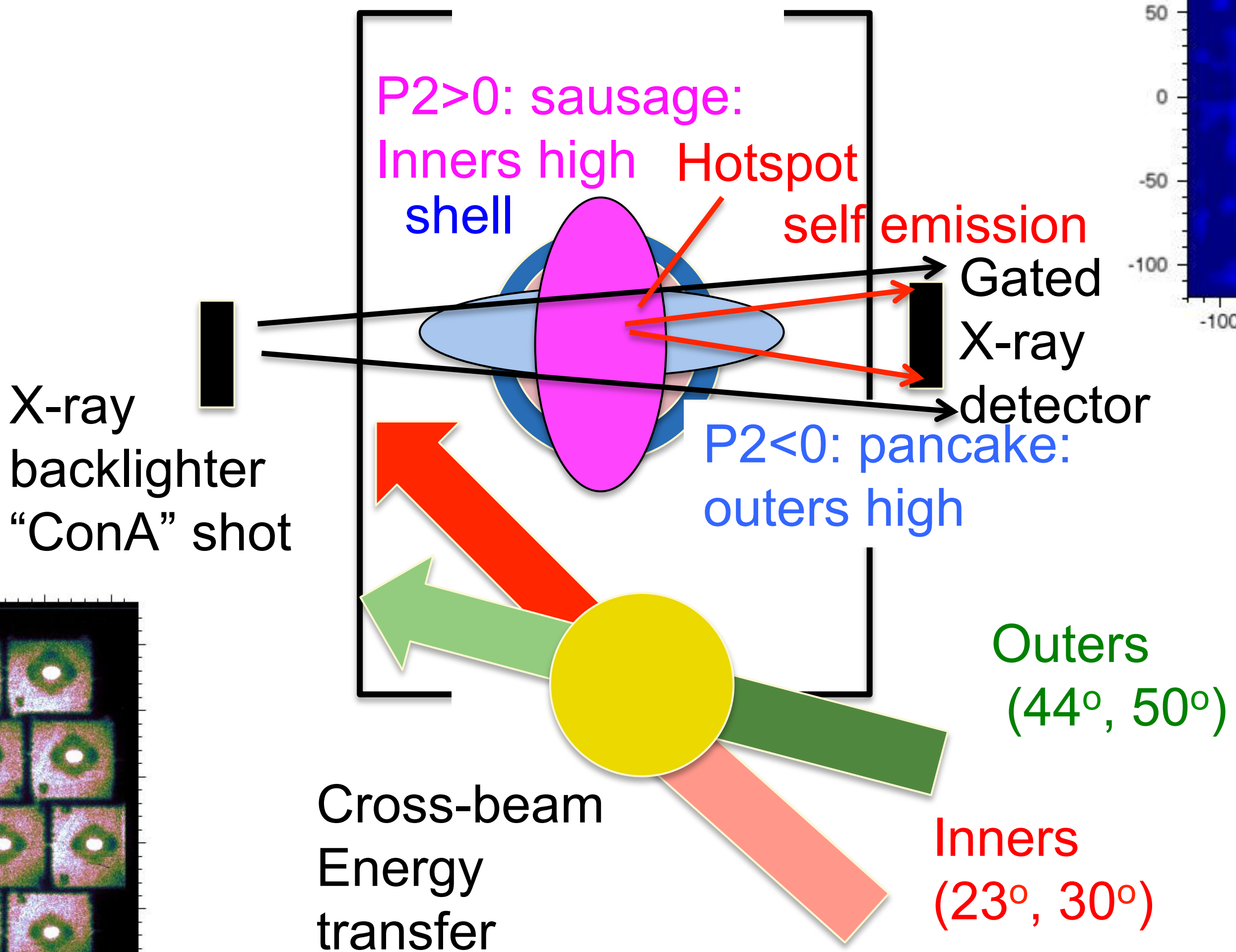
NIF

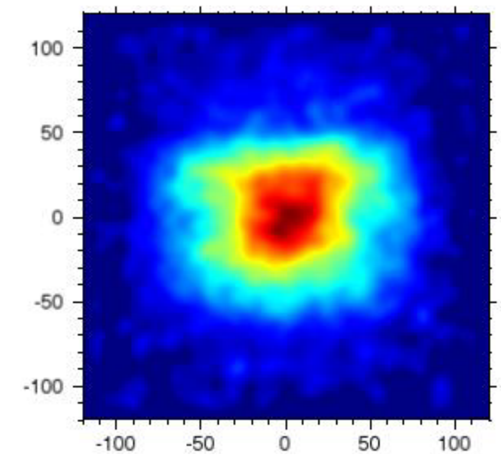
Implosion must be symmetric for ignition

NIF chamber

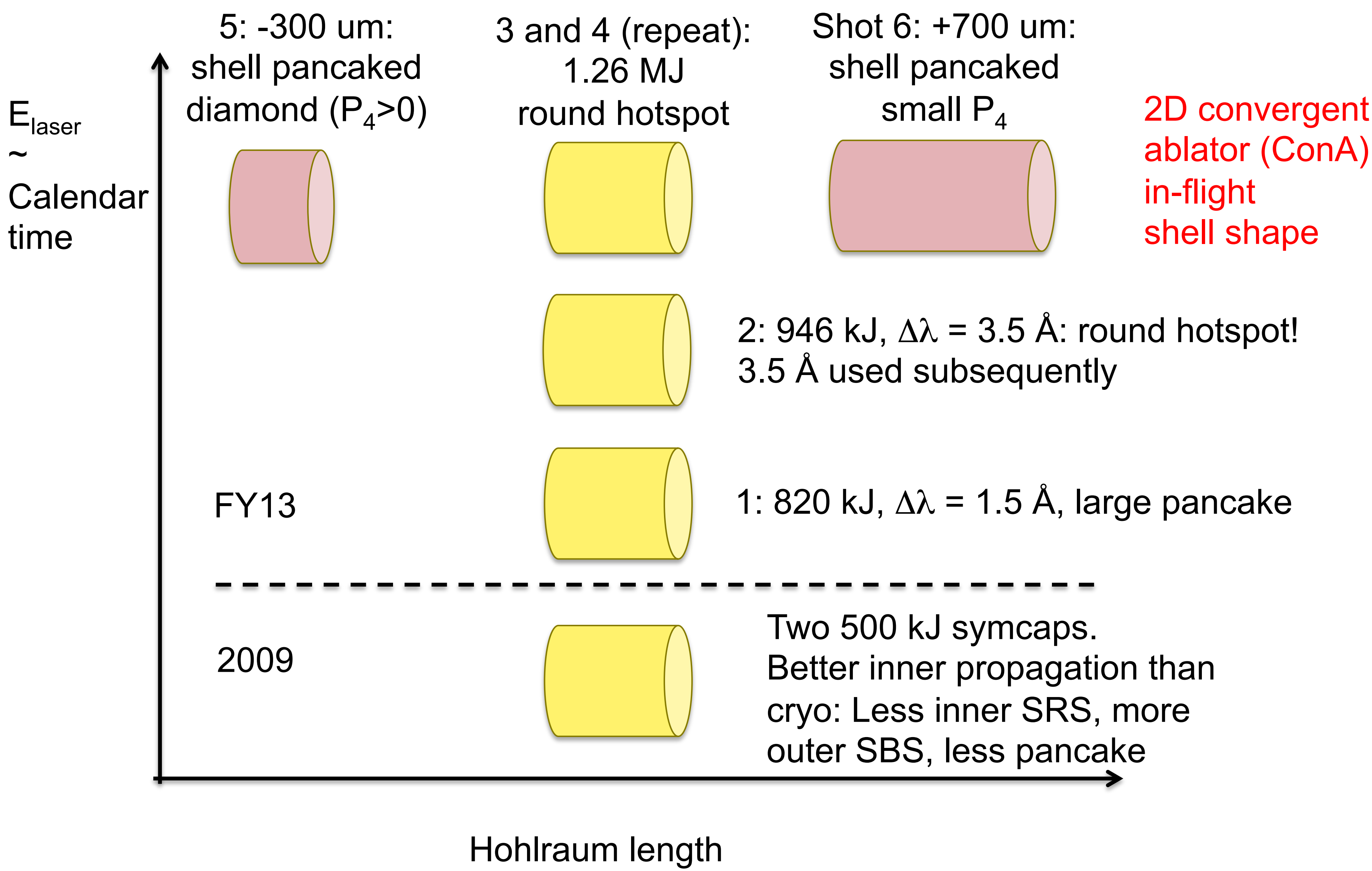
gravity



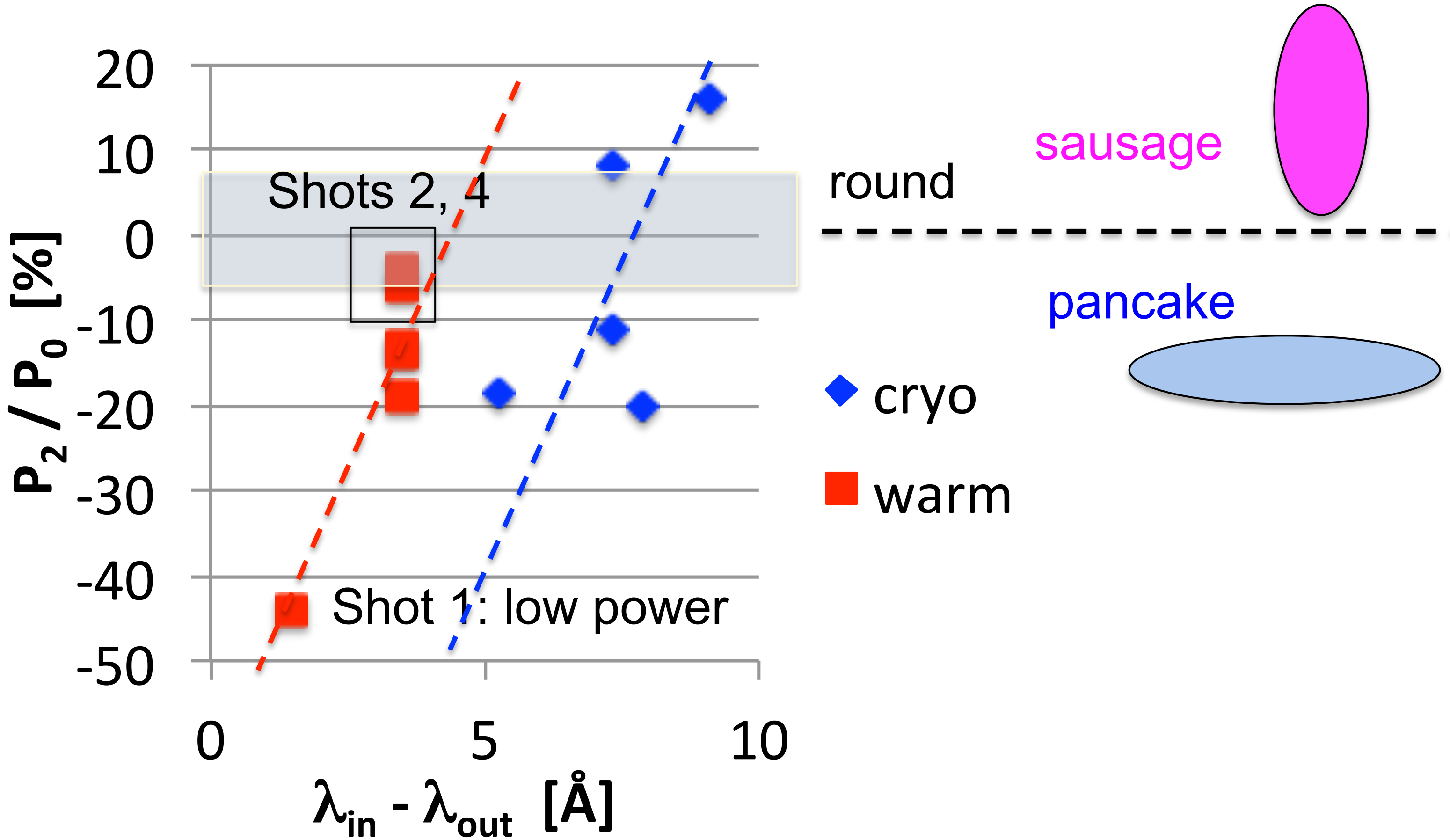




Warm shot history



Hotspot shape: less transfer to be round warm vs. cryo

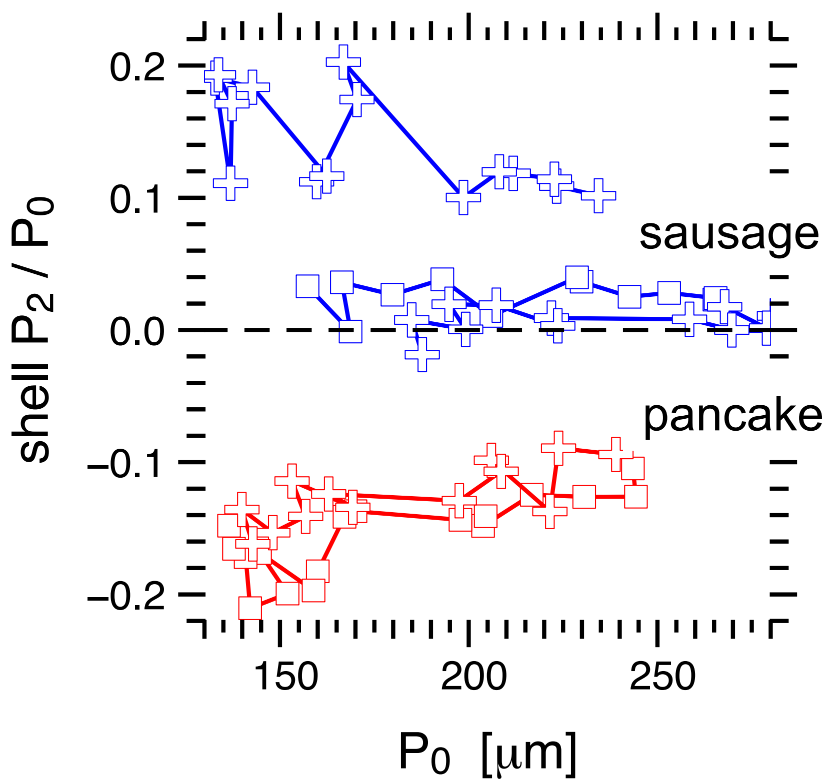


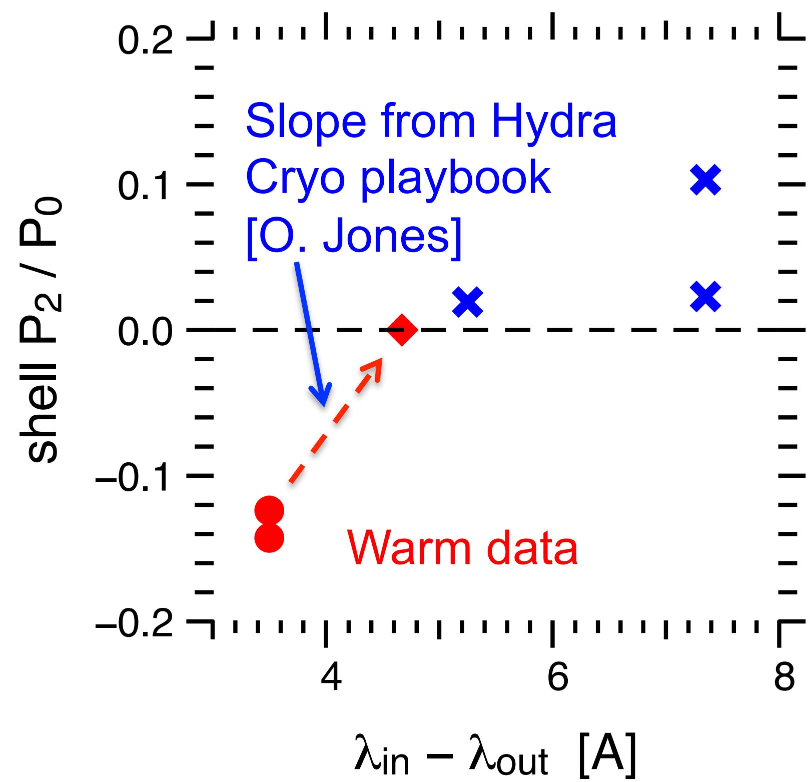
- After shots 2 and 4 we chose $\Delta\lambda$ = 3.5 Ang. as giving round hotspot

Suggests higher Z improves inner beam propagation

But warm 2D ConA's (last two shots) revealed pancaked in-flight shell

Cryo
warm

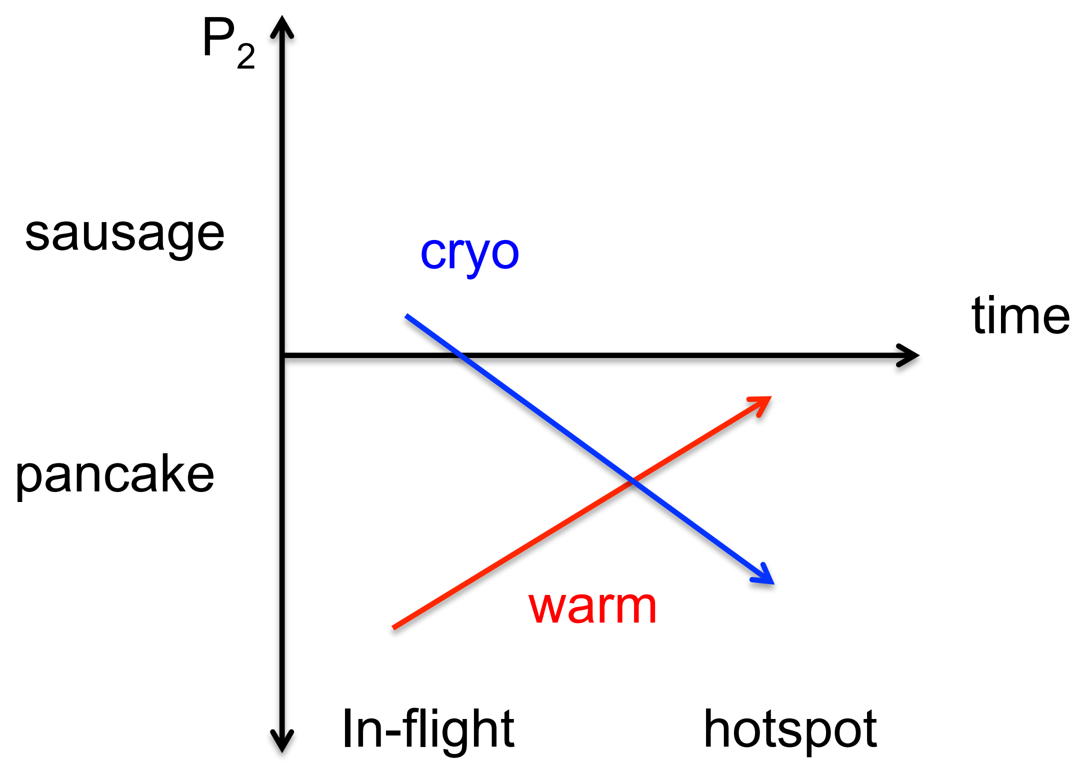




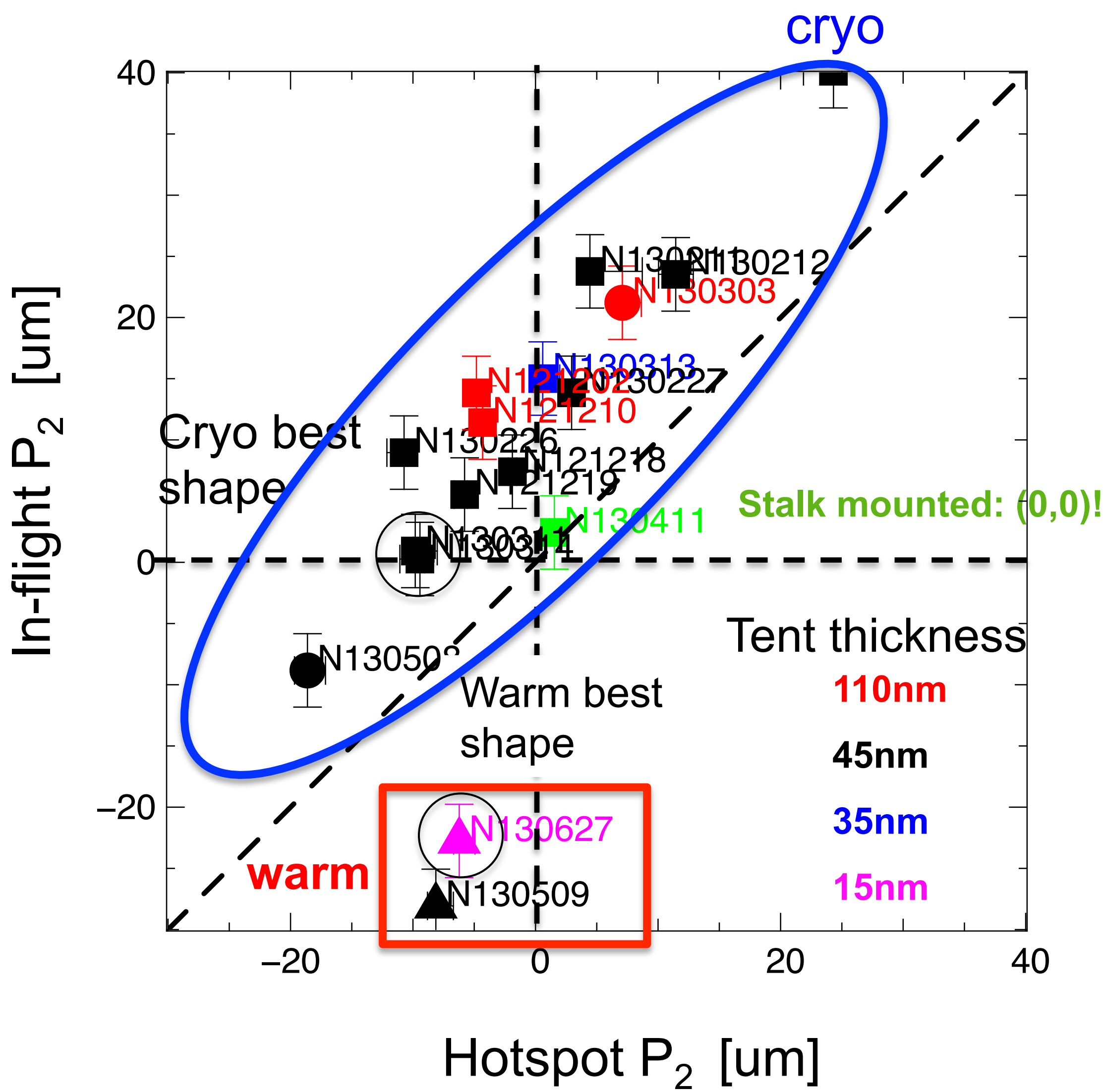
Hydra playbook [O. Jones]: $\Delta\lambda$ = 4.7 Å to make warm shell round

Best shape shots

	E_{laser} [kJ]	P_{peak} [TW]	Hohlraum length	$\Delta\lambda$23,30 [Å]
Cryo N130314	1340	360	+700 um: low shell P_4	6.0, 4.5
Warm N130627	same	1.06x	same	3.5, 3.5



In-flight shell and hotspot shapes "swing" oppositely for warm vs. cryo: pure Δλ scaling or gas Z effect?



P_4[1] and tent distorting hotspot shape

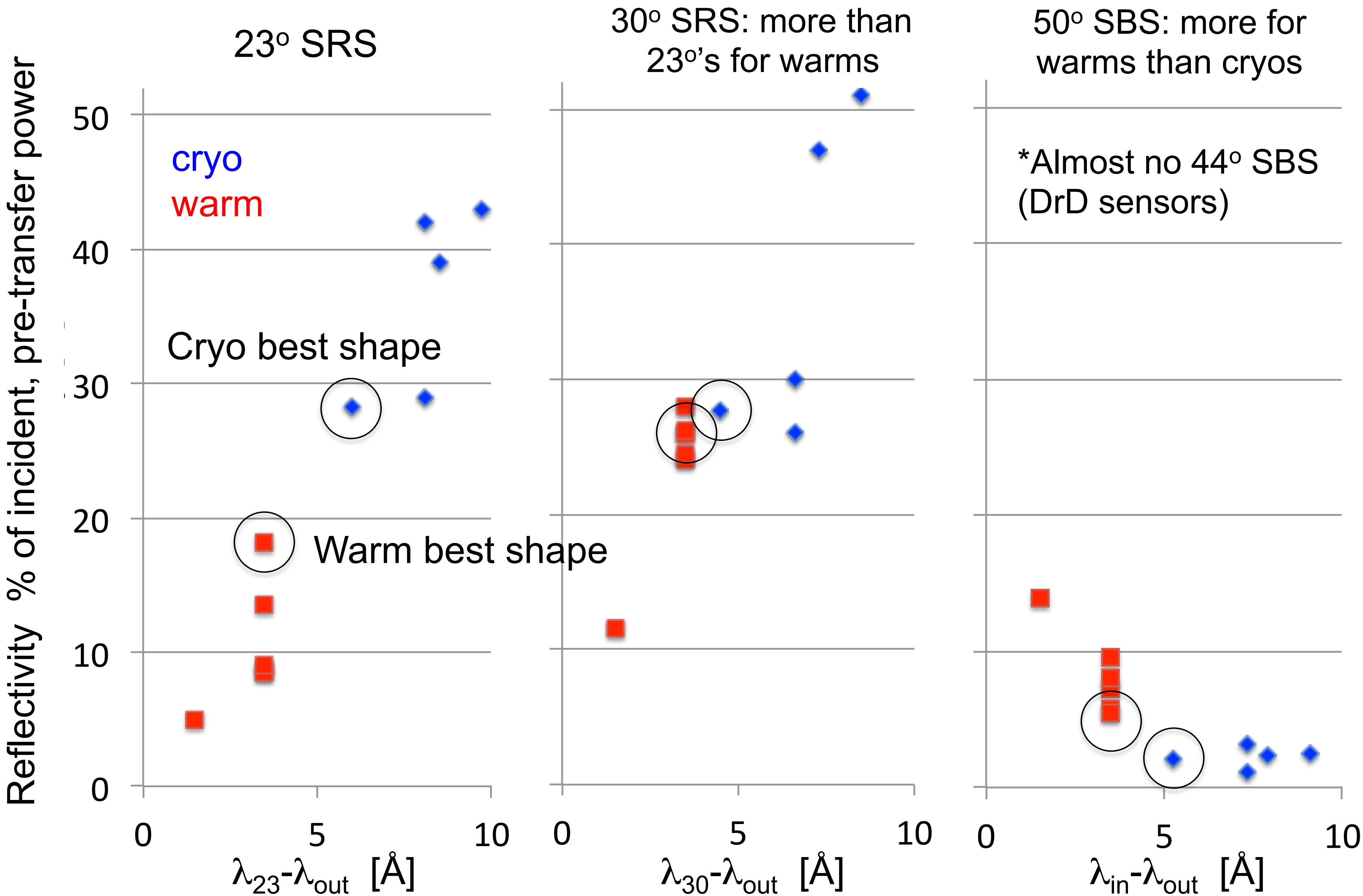
Tent talks (already happened): Nagel, Haan, Town

Warm hotspot also complicated by propane capsule fill: cooler hotspot, signficiant shell emission

Plot courtesy R. Town

[1]R. H. H. Scott et al., PRL 2013

Warms have less inner SRS, more outer SBS than cryos. Pure Δλ scaling, or gas fill effect?



Jury out on whether higher Z gas fill improves inner beam propagation

- Warm and cryo shots have different symmetry and backscatter
- Purely due to $\Delta\lambda$ or gas Z effect?
- Need to compare implosions with good symmetry throughout time
- Not achieved yet warm, maybe cryo (stalk vs. tent mount)
- Time-varying $\Delta\lambda$ or cone fraction may be needed
- Should check early time symmetry of warm shots – keyhole, re-emit

- BACKUP SLIDES

Jury out on whether higher Z gas fill improves inner beam propagation

Cryo shape:

- 2D ConA's: in-flight P_2 sausage and P_4
- Reduce $\Delta\lambda$ to remove P_2, +700 um hohlraum to remove P_4
- Round shell swings to pancaked hotspot – tent?

Warm shape:

- Opposite P_2 swing from cryo: shell pancake but hotspot round!
- More $\Delta\lambda$ needed to remove shell P_2
- Warm hotspot complicated by cool hotspot (propane), shell emission

To settle if high-Z gas improves inner beam propagation, need to compare implosions with good symmetry throughout time

Time-varying $\Delta\lambda$ or cone fraction may be needed - warm and cryo

Should check symmetry and strength of warm first 3 shocks - keyhole or re-emit shot

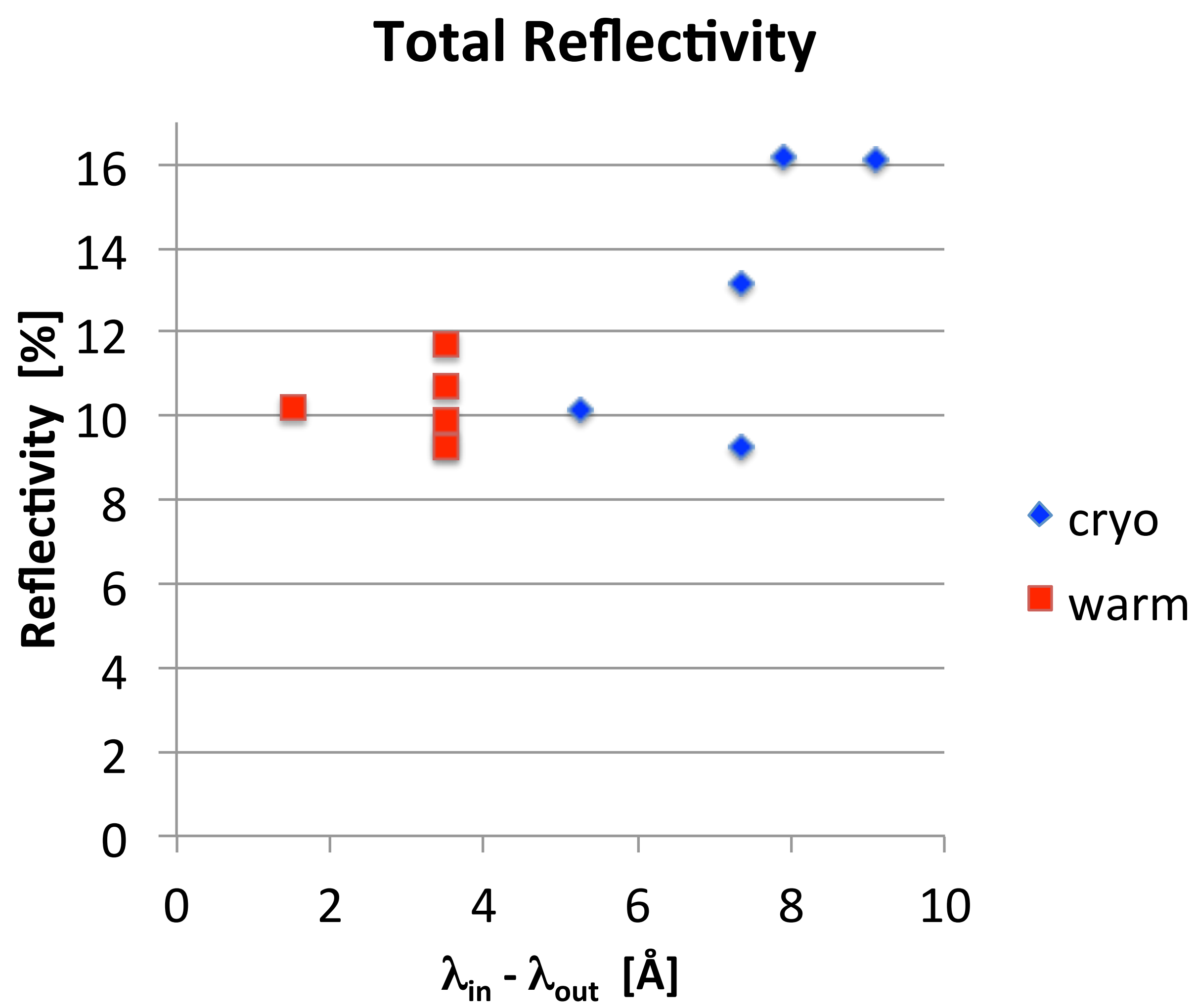
Other relevant presentations – all before this one!

Tent and shape:
O. Jones, IFSA 2013
S. Nagel, Wed. AM, NO4.00014
S. Haan Tues. PM, JO7.00001

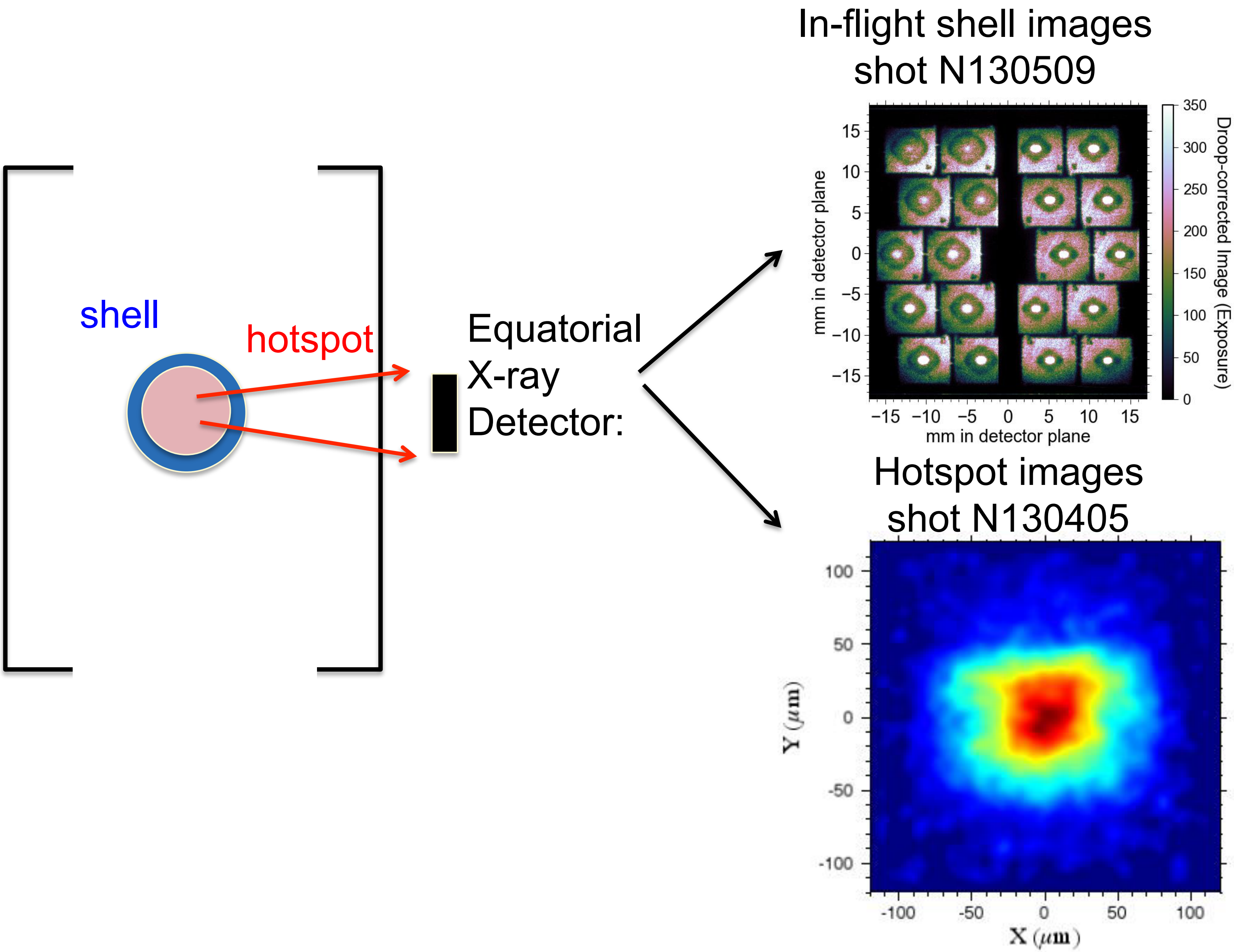
Low-mode asymmetries:
A. Kritcher Wed AM NO4.00004
R. Town Wed PM QI3.00002

Inline SRS Hydra modeling:
M. Marinak, Wed. AM, NP8.00090

Overall reflectivity slightly lower on warms. Pure $\Delta\lambda$ scaling, or gas fill effect?



P2 shape: positive for sausage (prolate), negative for pancake (oblate)



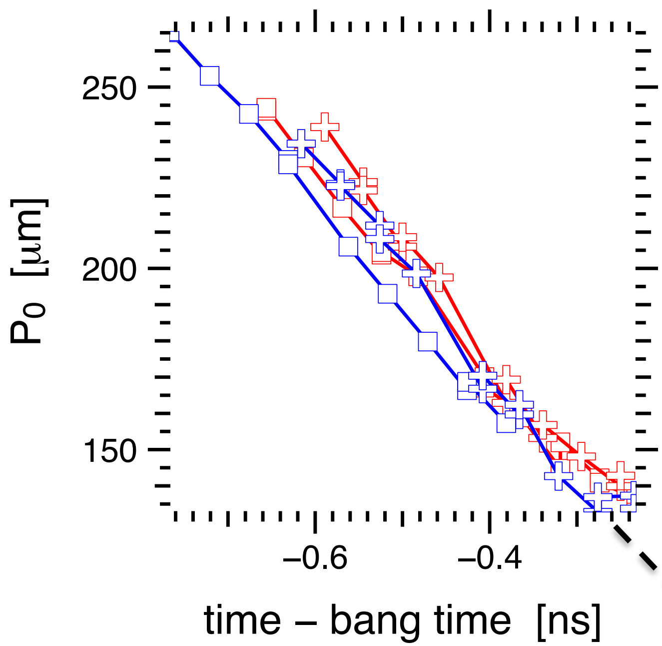
- **Nuclear:** Deuterated propane C_3D_8 -> up to 2.6E11 neutrons, T_{ion} up to 1.7 keV

But: 2D ConA shots show warms have large in-flight pancake, cryos had in-flight sausage

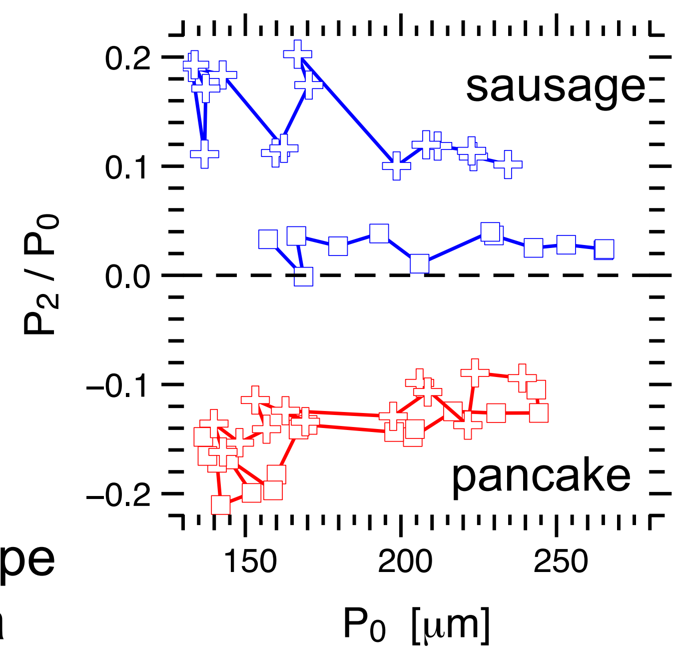
Red: warm
Blue: cryo
□: L_{hohl} -300 μm
✚: L_{hohl} +700 μm

□: N121219: cryo -300 μm
✚: N130211: cryo +700 μm
□: N130509: warm -300 μm
✚: N130627: warm +700 μm

P_0 = radius



P_2

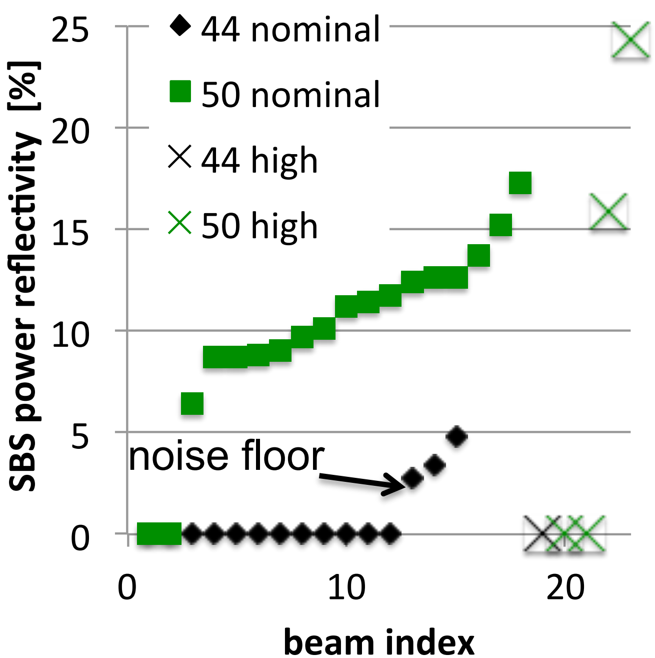


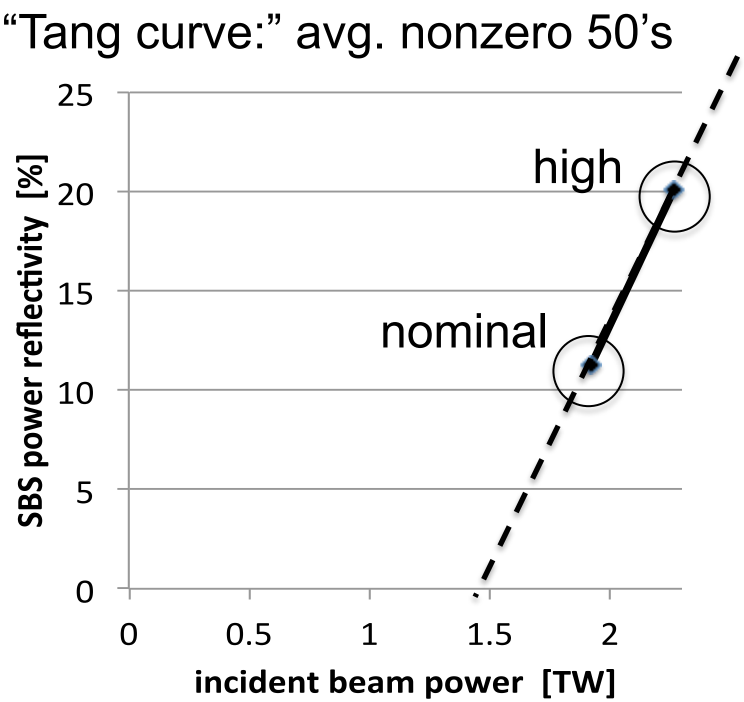
No shape data

Hotspot ~ 50 μm

Outer beam SBS: DrD sensors show more on cone 50 than 44, and give power scaling

N130125:
970 kJ shot





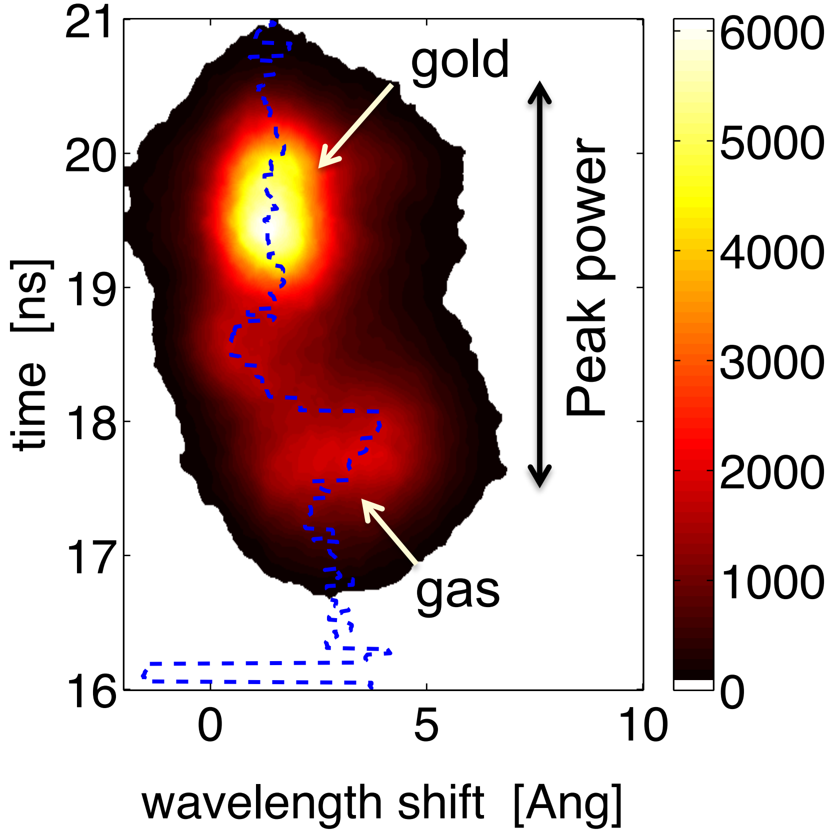
- DrD = drive diagnostic sensor - at least one beam in each quad
  - 3ω power history - forward and backward (separated in time)
- N130125: one quad on each cone had 18% higher power: power scaling on one shot!

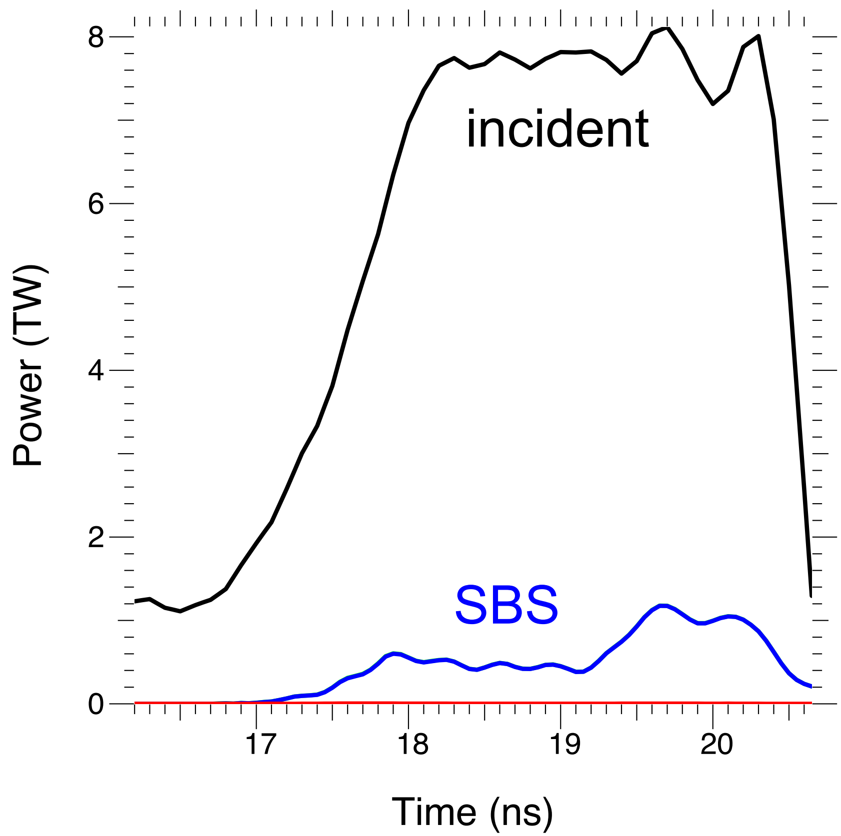
- Why more SBS on 50's than 44's?
  - 50 focal spot smaller -> higher intensity
  - Cross-beam energy transfer calculations: post-transfer power on 50's > 44's
  - Could be pure intensity scaling; plasma conditions may also play role

SBS on 50° outer cone

N130405:
1.3 MJ shot

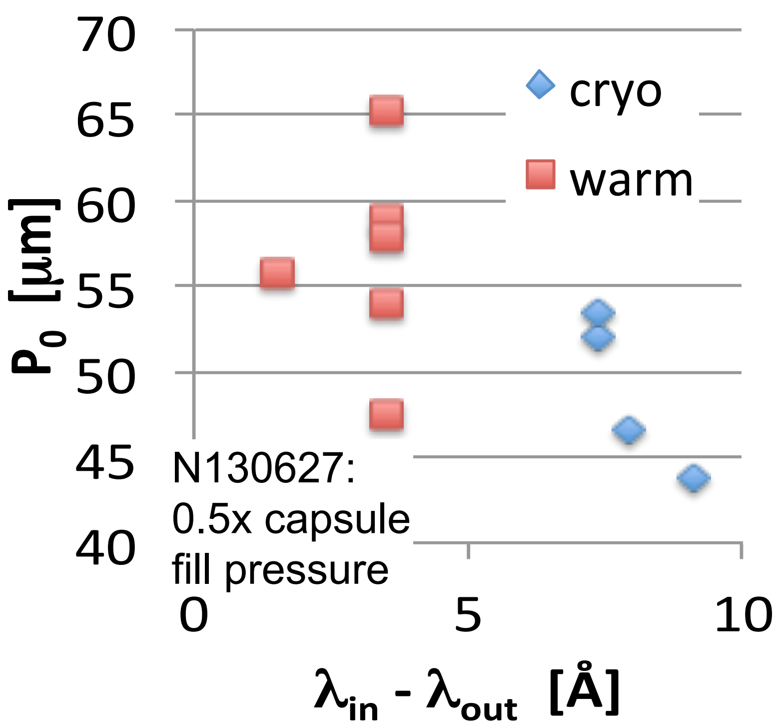
SBS FABS spectrum





- Cryo shots show some outer SBS late in time, esp. for longer pulses or high power
- Warm platform good for studying outer SBS and mitigation – cheaper, reproducible

Warm radius slightly larger: cooler hotspot, shell emission?




NIF