NIC

LPI experiments with single and multiple NIF beams

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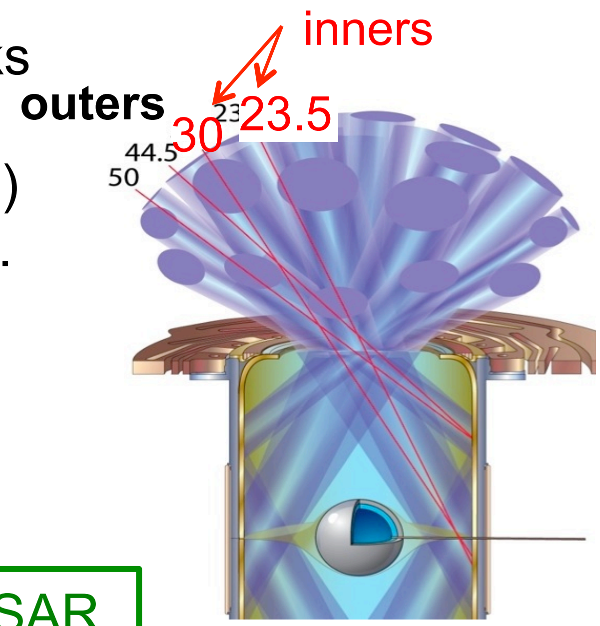
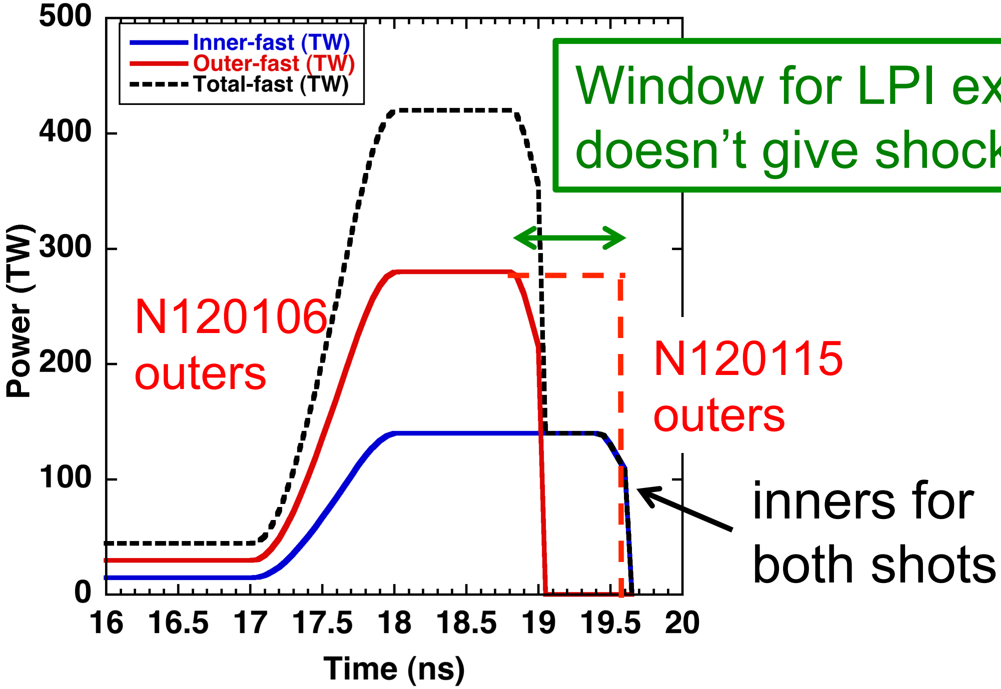
N120106 and N120115: "keyhole" shots isolate effect of outer cones on inners

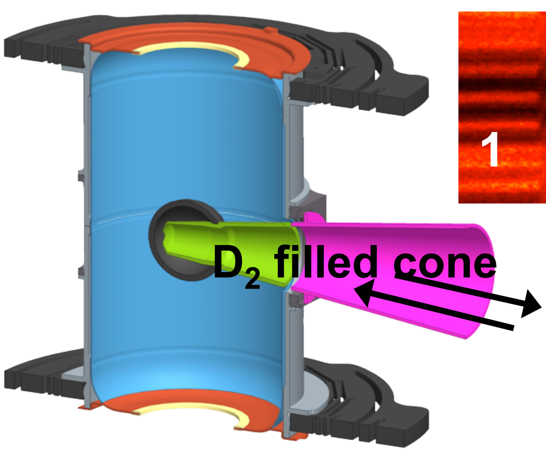
- "Keyhole" targets: VISAR detector: tune first 3 shocks
- "Fast rise" (~1 ns) from third to fourth shocks
- Gold hohlraum with "large" laser entrance hole (LEH)
- 3 laser colors: λ_{30}-λ_{out} = 6.6 Ang., λ_{23}-λ_{30} = 1.5 Ang.
- Same energy, except outers extended in N120115
- Very low inner-cone SBS

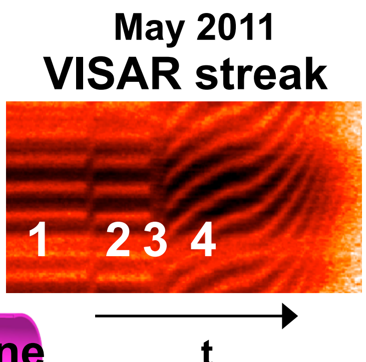


Fourth pulse fast-rise (N120106)

Window for LPI experiments! VISAR doesn't give shock data this late

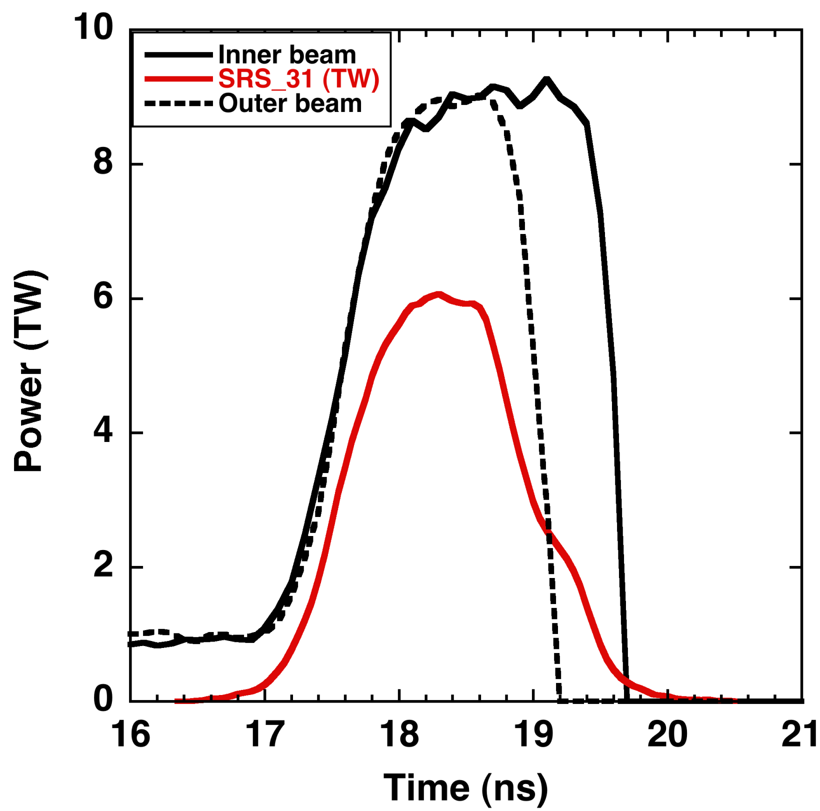




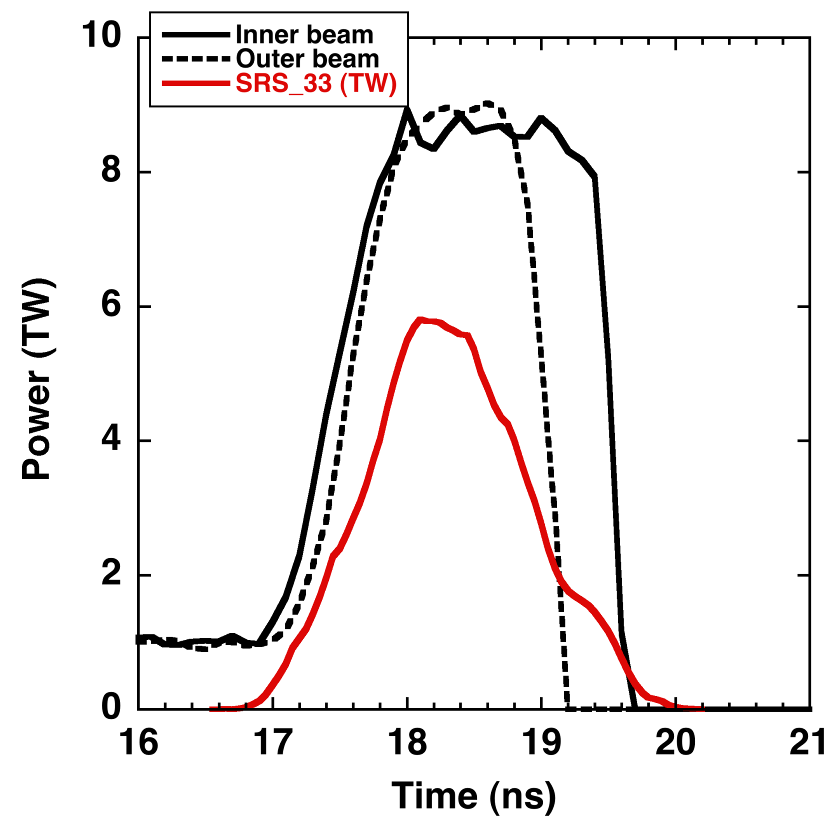


N120106: SRS on both inner cones drops when outers turn off

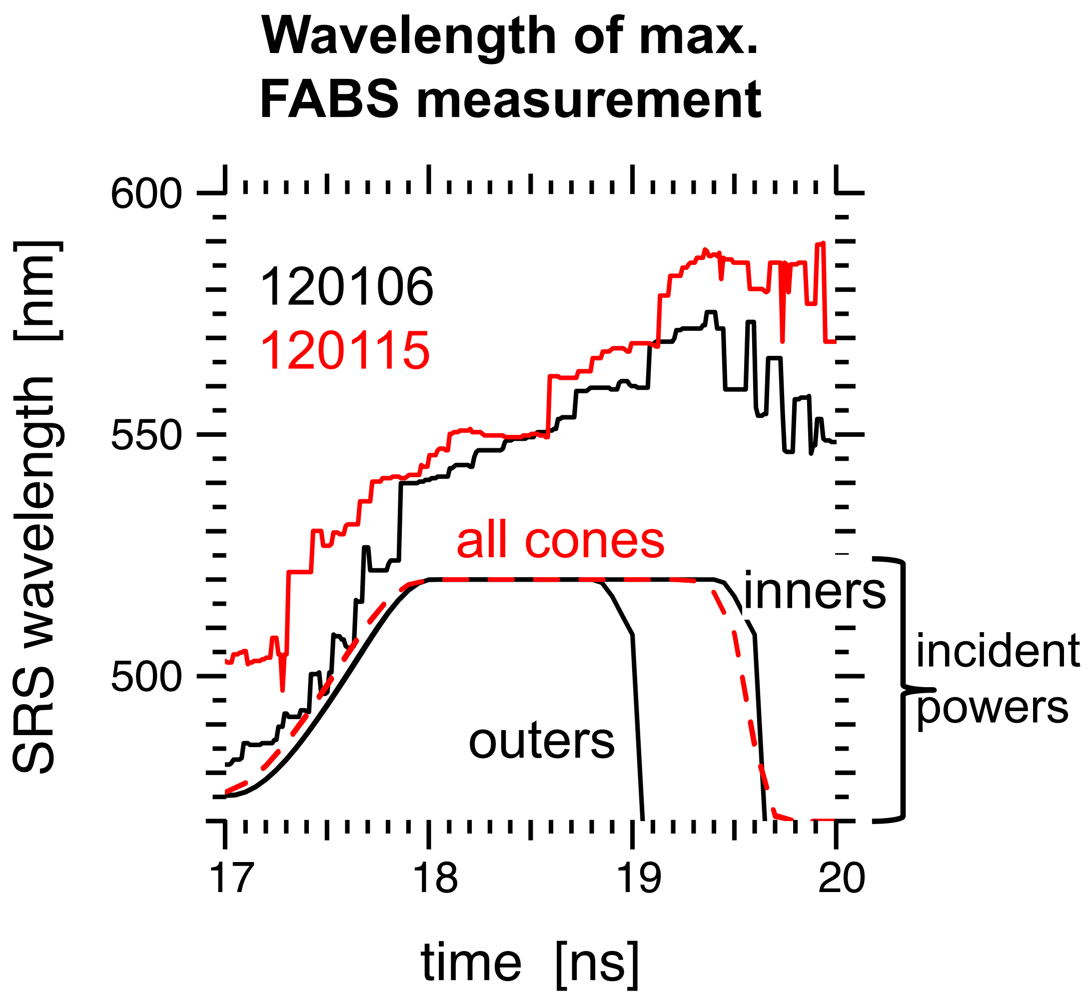
30° quad

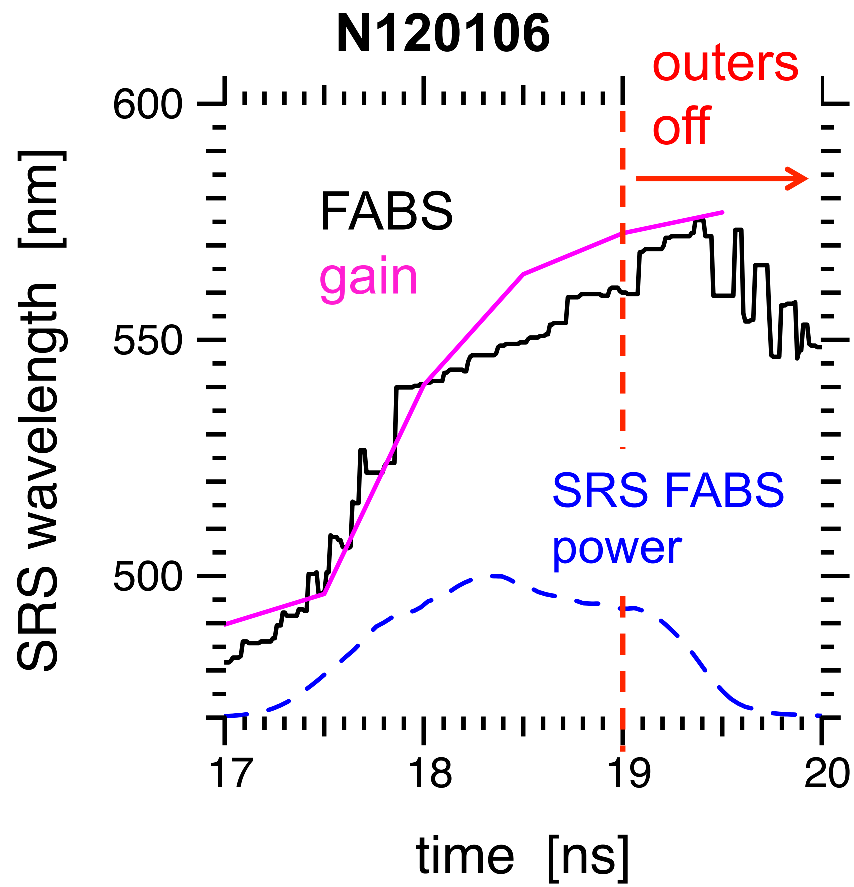


23° quad



SRS spectrum on 30° cone evolves similarly if outers truncated or not; gain spectrum within ~10 nm

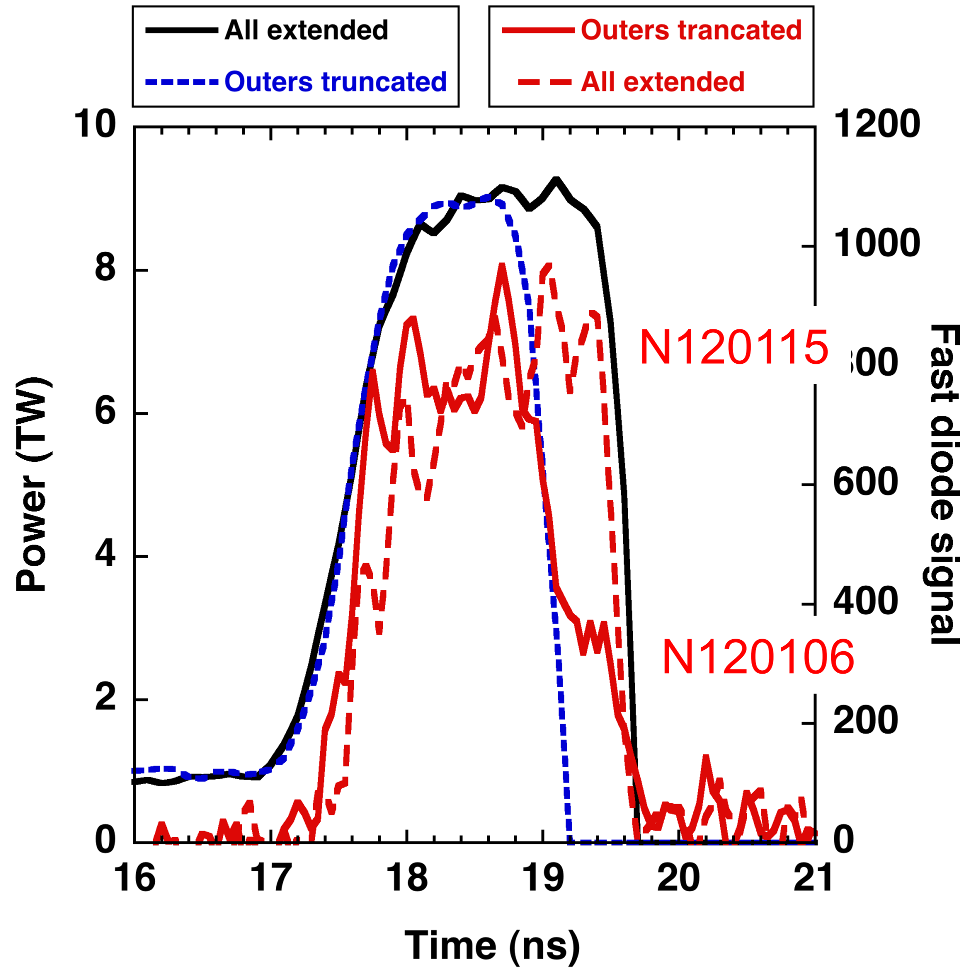




Gain spectrum from Hydra rad-hydro by H. Robey with high-flux model; low-flux model gives 20-30 nm longer wavelength

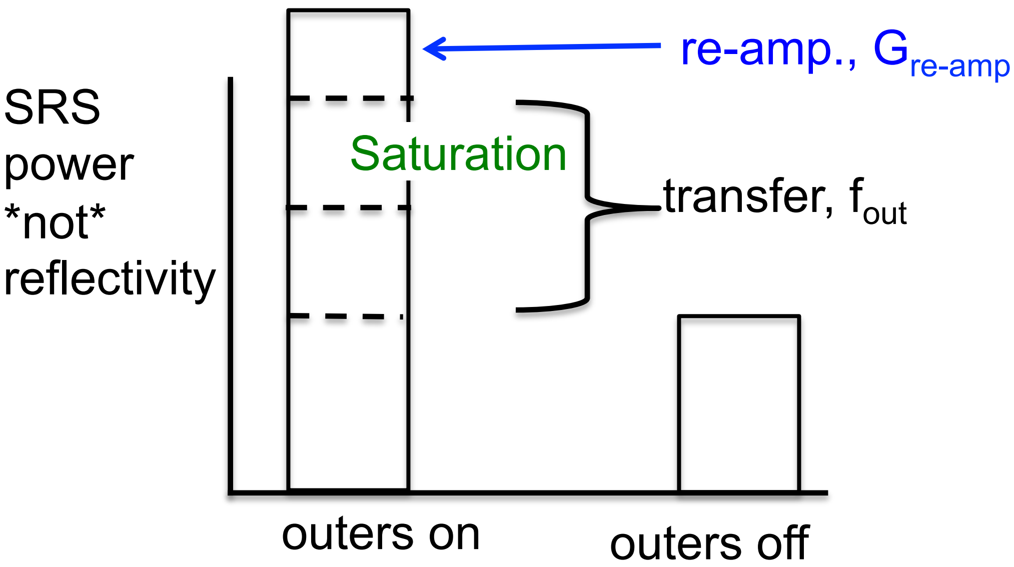
N1201{06, 15}: SRS power when outers are off is 40% of value with outers on

SRS data for 30° cone

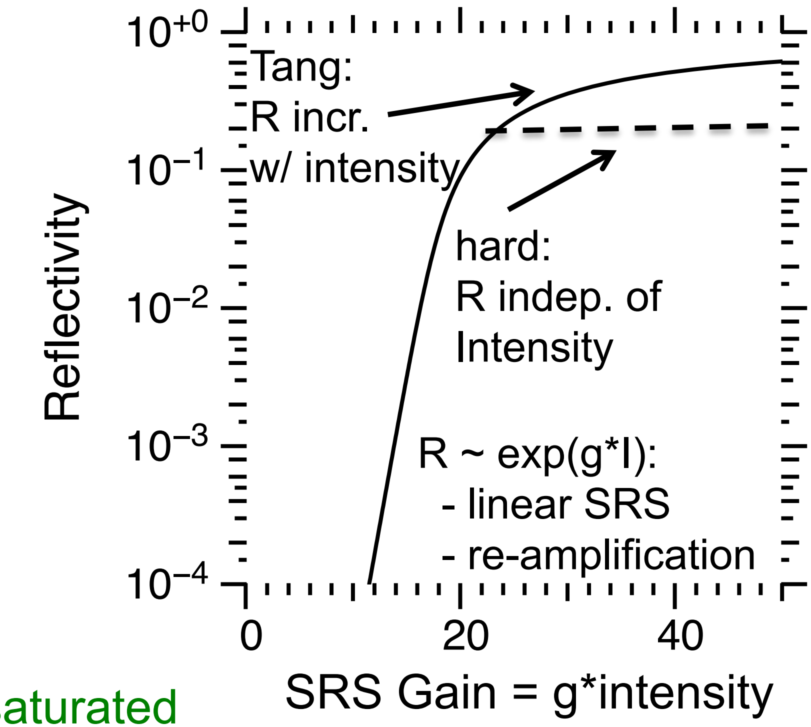


30^{o} cone SRS power: N120106 (outers off) / N120115 (outers on): **0.4**

Inner SRS drops when outers off: no power transfer, no re-amplification, less saturation



Linear gain; Tang vs. hard saturation



When outers off:

Decreases because transfer stops

Decreases if Tang (not hard) saturated

Decreases because re-amplification stops

$$P_{30}^{SRS} = P_{30}^{inc} \cdot R(g * I_{30}) \cdot R_{\text{re-amp}}$$

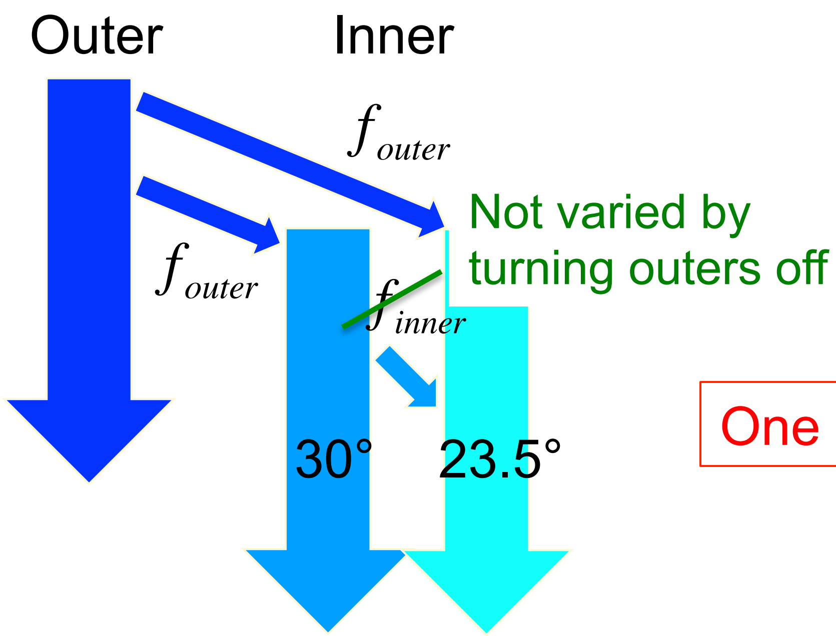
$$P_{30} = P_{30}^{inc} + \frac{1}{2} f_{out} P_{out}^{inc}$$

$$R_{\text{re-amp}} = \exp[G_{\text{re-amp}}]$$

Two unknowns: f_{out}, $G_{re\text{-}amp}$

SRS light from one beam amplified when crossing another beam [P. Michel et al.]

One-parameter model for cross-beam energy transfer from outer to inner cones



$$P_{23,30} = P_{23,30}^{inc} + \frac{1}{2}\Delta P_{out}$$

$$\Delta P_{out} = \text{total power xfer from outer to inner cones}$$

One unknown

$$= f_{out} P_{out}^{inc}$$

$$P_{out}^{inc} = P_{44}^{inc} + P_{50}^{inc} \approx 4 P_{30}^{inc}$$

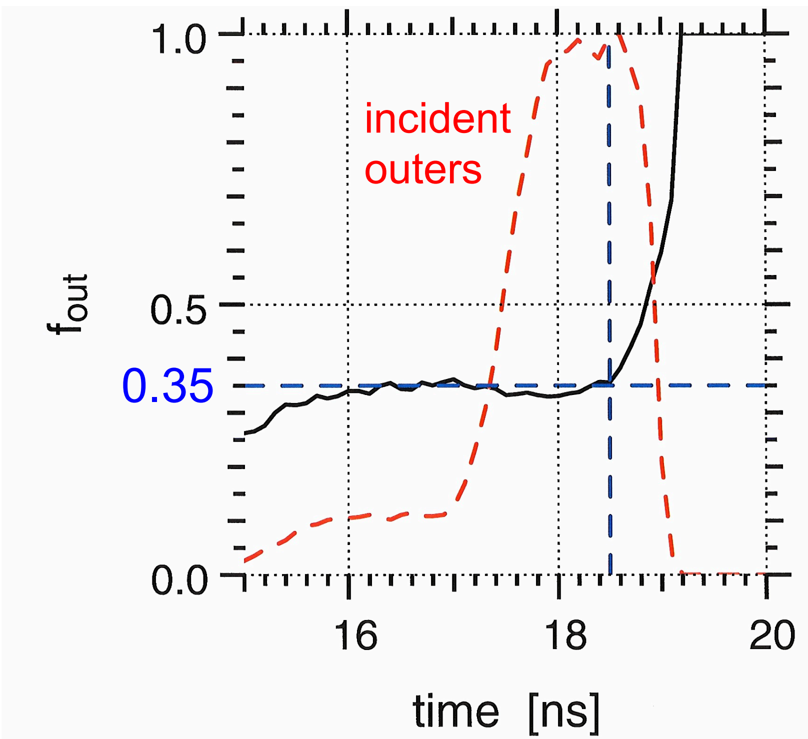
$$P_{23,30} = P_{23,30}^{inc}(1 + 2 f_{out})$$

f_{out} = fraction of outer-cone power transferred to inner cones

We neglect spatial non-uniformity in transfer, which should be looked at (R. L. Berger)

Measured ratio of SRS powers relates transfer and re-amplification

Power transfer from H. Robey's post-shot Hydra of N120106

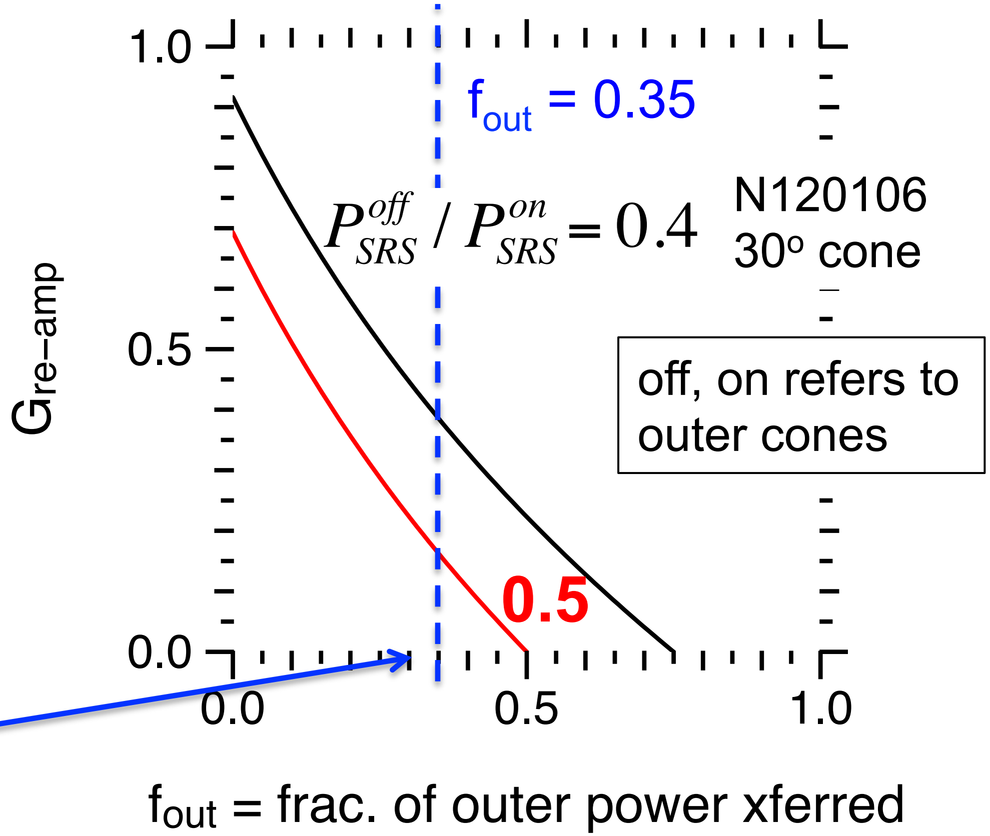


- f_{out} ~ 0.35 agrees w/ capsule symmetry data (R. Town)
- Hydra's f_{out} passes basic check: inconsistent w/ SRS drop if f_{out} > $G_{re\text{-}amp}$ = 0 values

$$\frac{P_{SRS}^{on}}{P_{SRS}^{off}} = \rho \cdot (1 + 2 f_{out}) \exp G_{\text{re-amp}}$$

$$\rho = \frac{R(g * I_{30}^{on})}{R(g * I_{30}^{off})} \rightarrow 1$$

hard saturation: maximizes $G_{\text{re-amp}}$



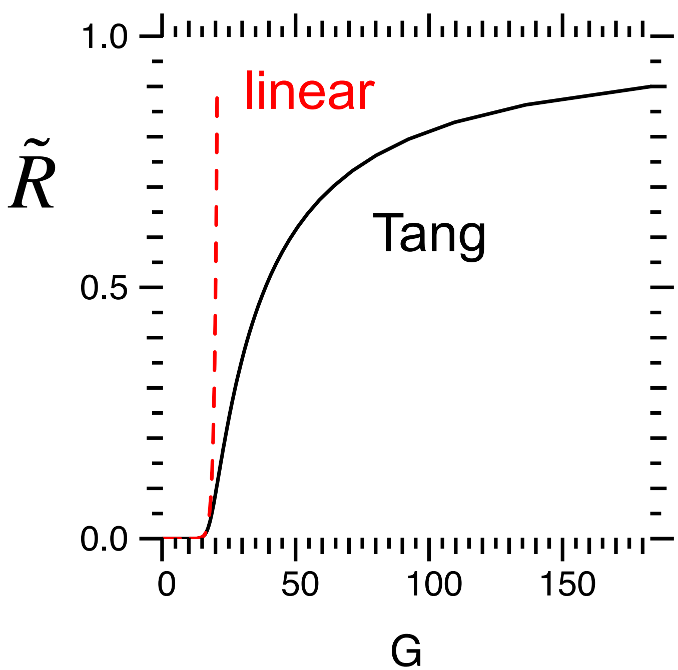
Allow for saturation to vary with intensity

- $G_{\text{re-amp}}$=0: SRS changes only due to power transfer; $G_{\text{re-amp}}$>0 lowers A, raises G
- Neglect change in g = role of plasma conditions in gain
    - — measured spectra similar for N120106 and N120115

$$A \equiv e^{-G_{\text{re-amp}}} \frac{P_{SRS}^{on}}{P_{SRS}^{off}} = \rho\left(1+2f_{out}\right) = \alpha(f_{out}, G)$$

$$\rho = \frac{R(P_{30}^{on})}{R(P_{30}^{off})} = \frac{R(G\cdot(1+2f_{out}))}{R(G)}$$

$$G \equiv g I_{30}^{inc}$$



Tang formula: coupled-mode eqs. w/ pump depletion

$$\tilde{R}\left(1-\tilde{R}+\tilde{s}\right) = \tilde{s}\exp\left[G\left(1-\tilde{R}\right)\right]$$

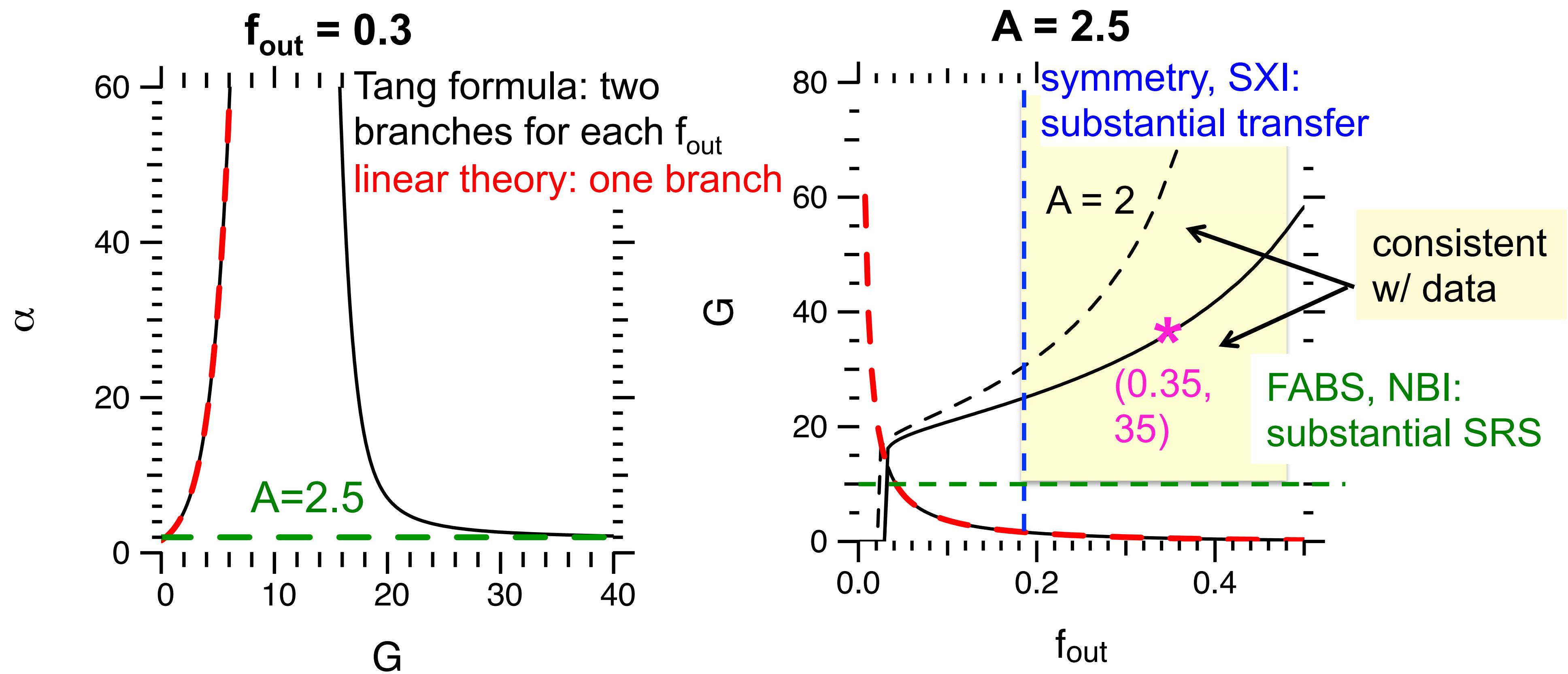
$$\tilde{R} = \frac{\omega_0}{\omega_1} R \qquad \tilde{s} = \frac{\omega_0}{\omega_1}\frac{I_{1\text{seed}}}{I_0} \to 10^{-9}$$

Manley-Rowe

linear theory

$$R = s\exp G; \qquad G = \frac{1}{2f}\ln\left[\frac{A}{1+2f}\right]$$

Inner-cone SRS is strongly saturated



- Small drop in SRS for large transfer:
  - Linear branch requires small gain, not consistent w/ large SRS
  - Consistent w/ large gain on strongly-saturated, pump-depleted Tang branch
- Estimating G and f_{out}:
  - N120106: SRS power ~ 28% incident when outers off; wavelength = 570 nm
  - No re-absorption of scattered light: R_{tilde} = 0.45, G = 35 -> f_{out} = 0.33 – near sims!
  - R_{off} / R_{on} = 0.45 / 0.67 = 0.67;   I*dR/dI = 0.2

Conclusions for N120106 and N120115: effect of outer cones on inners

- Inner cone SRS power approximately **doubled** by presence of outer cones
- Hydra modeling, and symmetry scaling with $\Delta\lambda$, suggest 35% of outer beam power transferred at time outers shut off
- Measured SRS decrease consistent with this 35% transfer, and with modest outer-inner re-amplification gain exponent of at most 0.15 - 0.4
- Saturation: neglecting re-amp. (which *minimizes* saturated gain): {large SRS, large transfer, and small SRS drop when outers} imply SRS is strongly saturated, not in linear regime

March keyholes: one inner cone extended – "single-quad" LPI experiments!

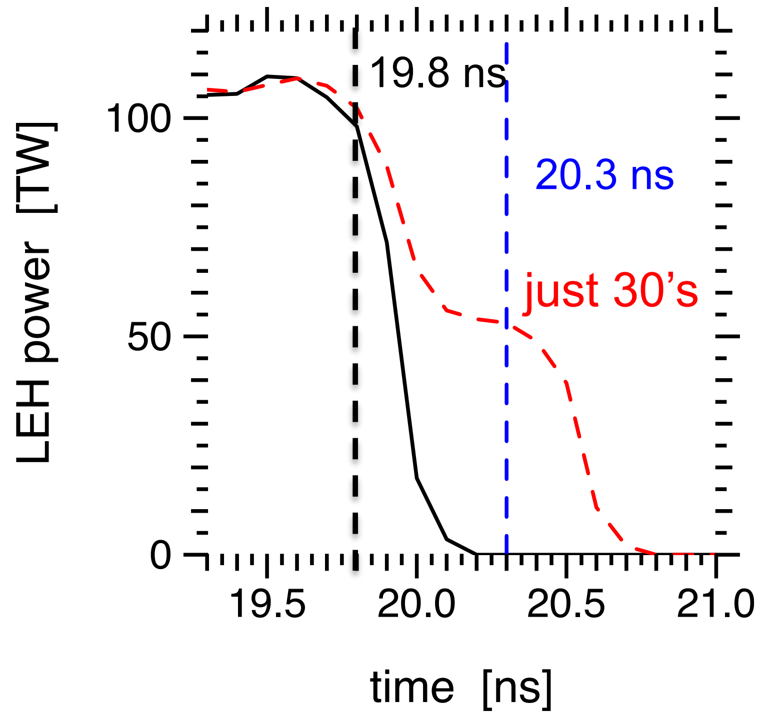
- But in a rapidly evolving, maybe azimuthally-asymmetric, hohlraum…
- Slow (3 ns) rise of fourth pulse
- "small" LEH
- 3-color scheme: $\lambda_{30} - \lambda_{out}$ = 7.3 Ang.; $\lambda_{23} - \lambda_{30}$ = 1.2 Ang.
- Single-quad expt. if no re-amplification of one inner quad by others on same cone
  - — Power transfer excluded by azimuthal symmetry

shot	hohlraum	peak power [TW]	extended cone
N120229	DU	420	30
N120303	DU	420	23
N120304	Au	420	30
N120305	DU	320	30

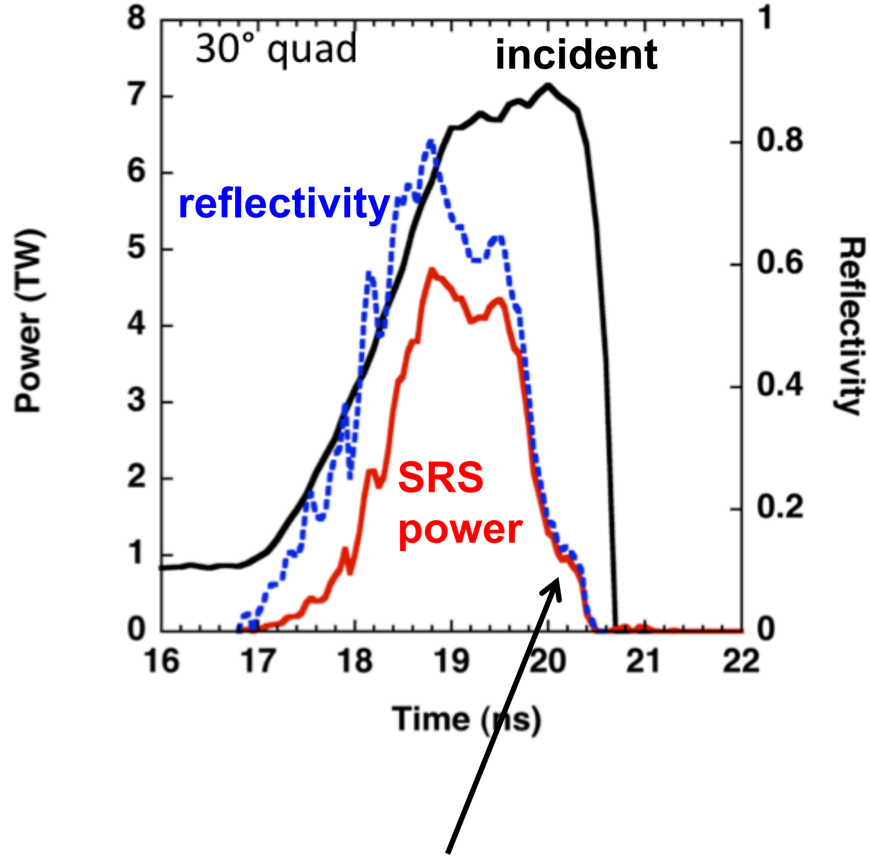
← shot we study (N120305)

N120305: “single-quad” 30° cone SRS ~ 15-20%

Incident powers



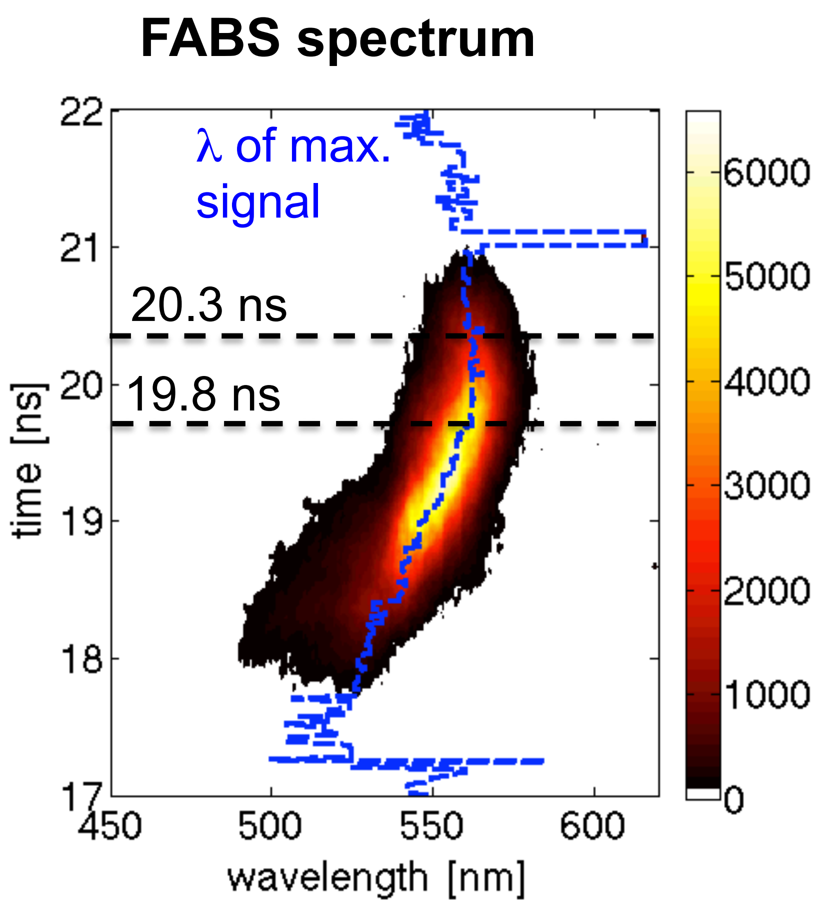
SRS from deconvolved NBI movie

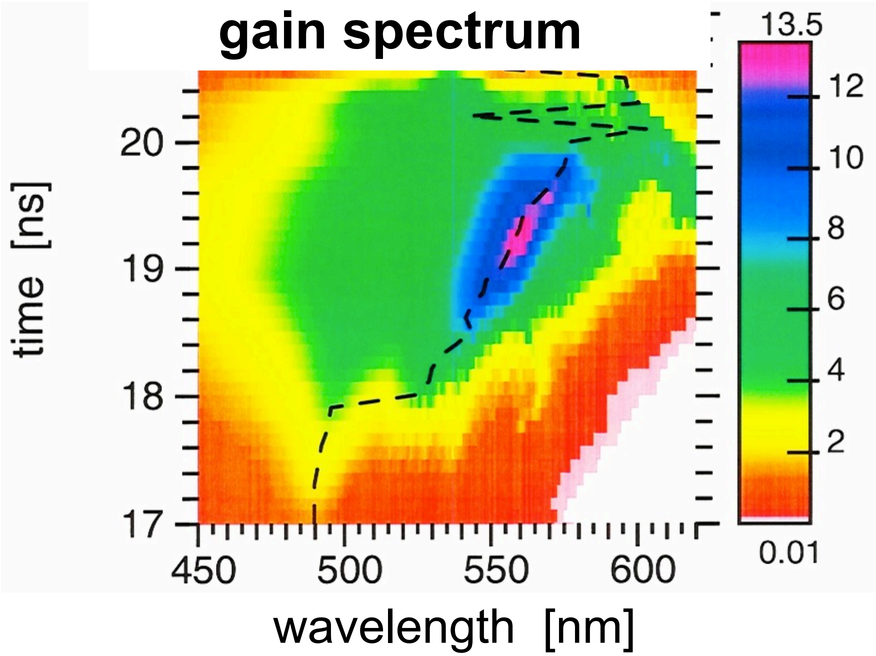


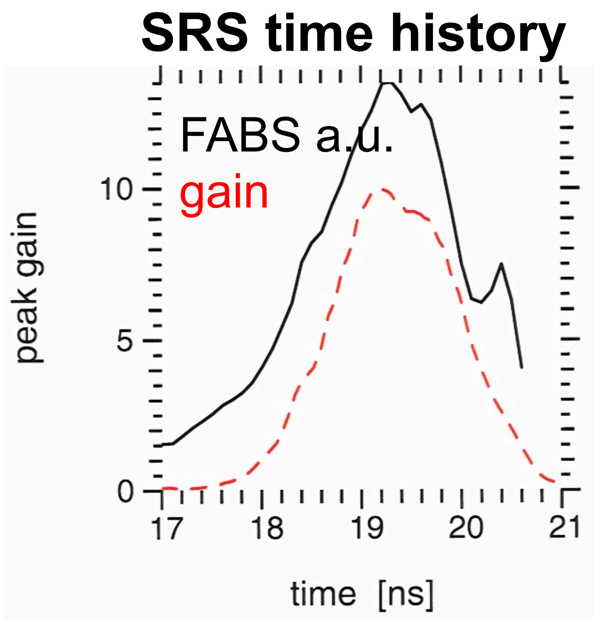
plateau when just 30’s on; ~15-20% SRS reflectivity depending on shot

SRS power starts dropping <u>before</u> other cones turned off – complicates analysis

N120305: SRS spectrum on 30° cone

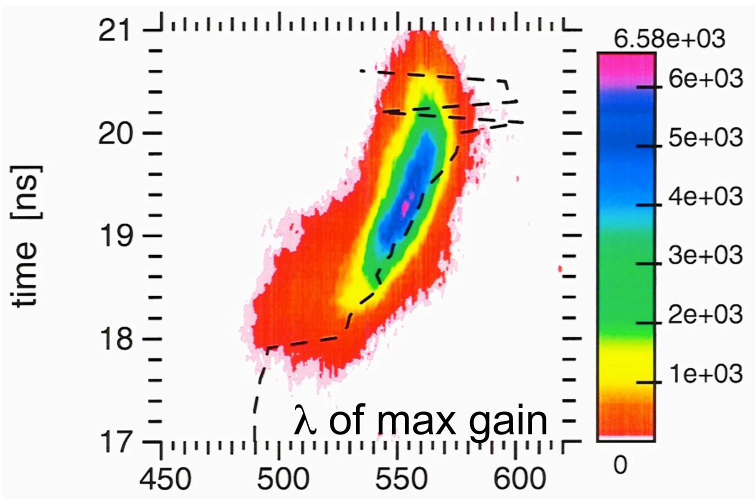




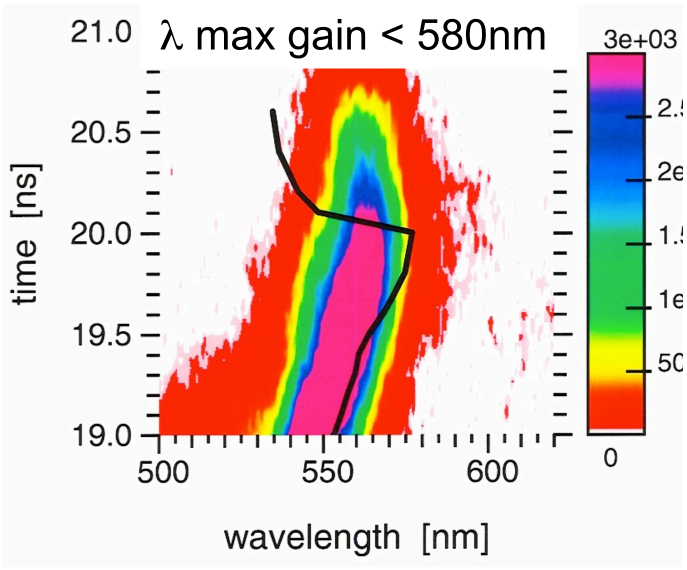


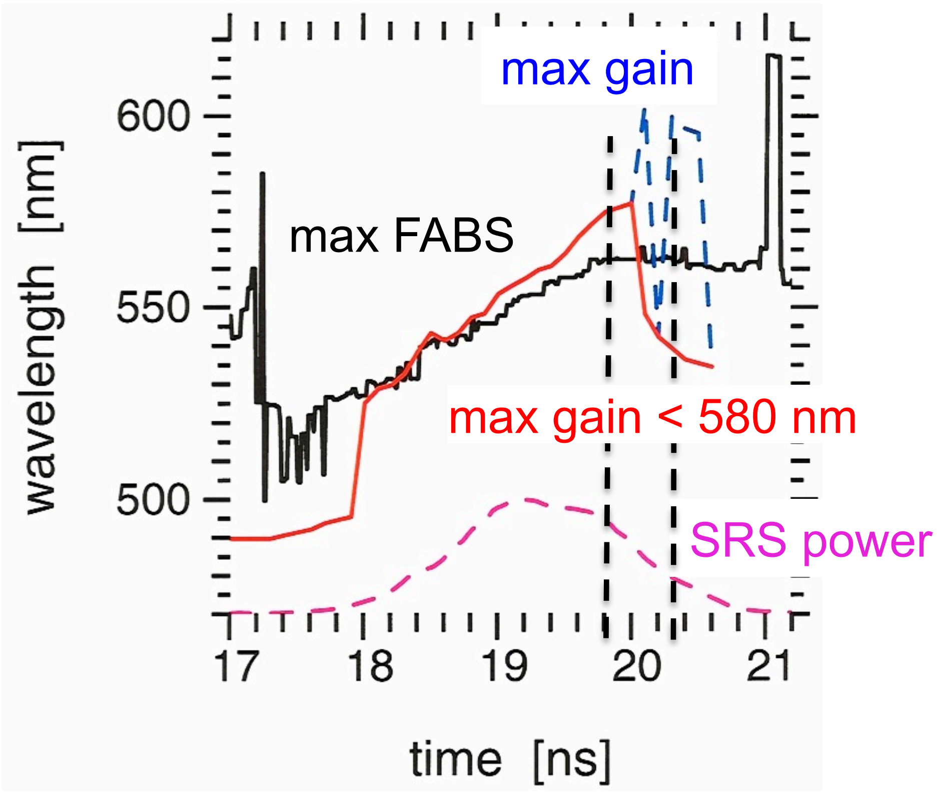
N120305: 30° cone SRS: FABS and linear gain agree when all cones on, differ when just cone 30 on

FABS spectrum



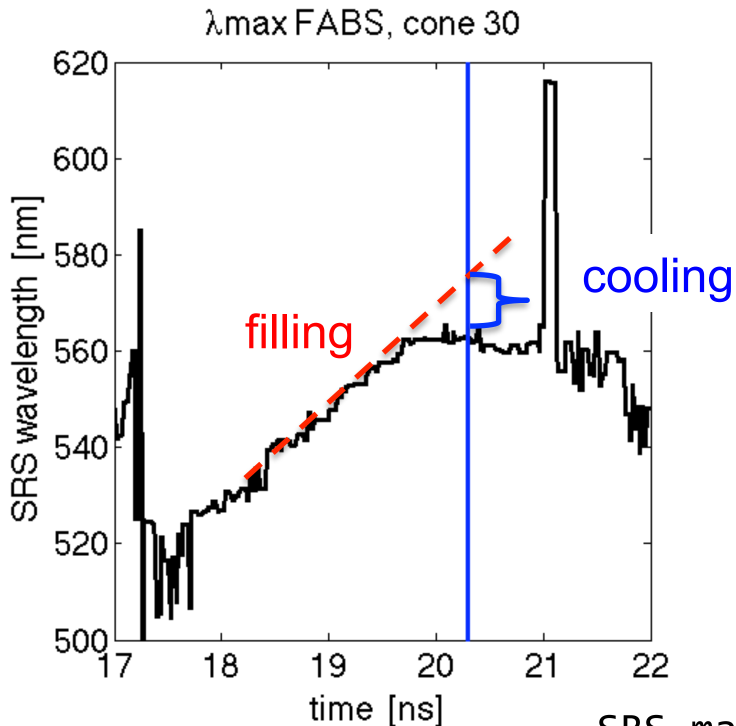
zoomed late, and capped





Multi-quad effects not essential to match spectrum

N120305: 30º cone SRS FABS spectrum: filling and cooling rates



SRS matching conditions: λ, T_e -> n_e

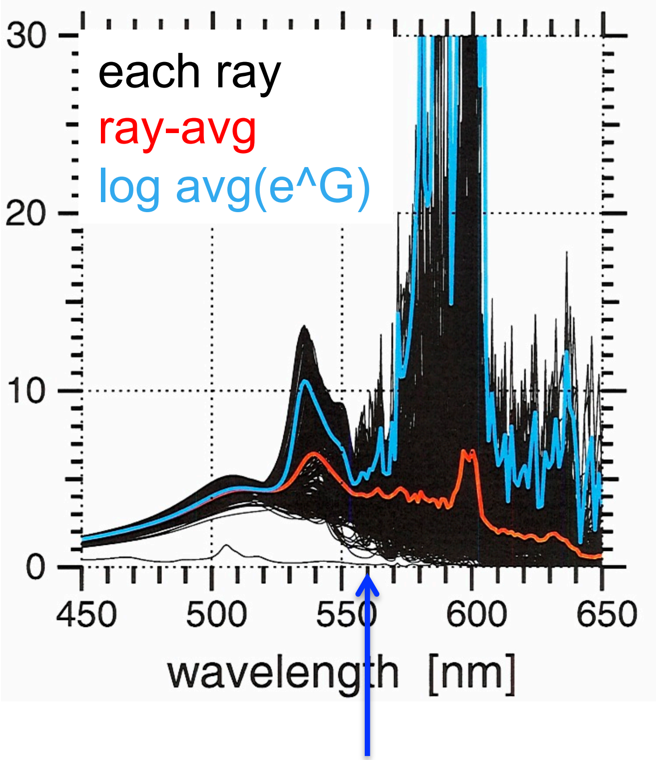
t [ns]	λ [nm]	n_e/n_{cr} [1.5 keV]	n_e/n_{cr} [3 keV]
19	545	0.102	0.069
19.5	558	0.115	0.082

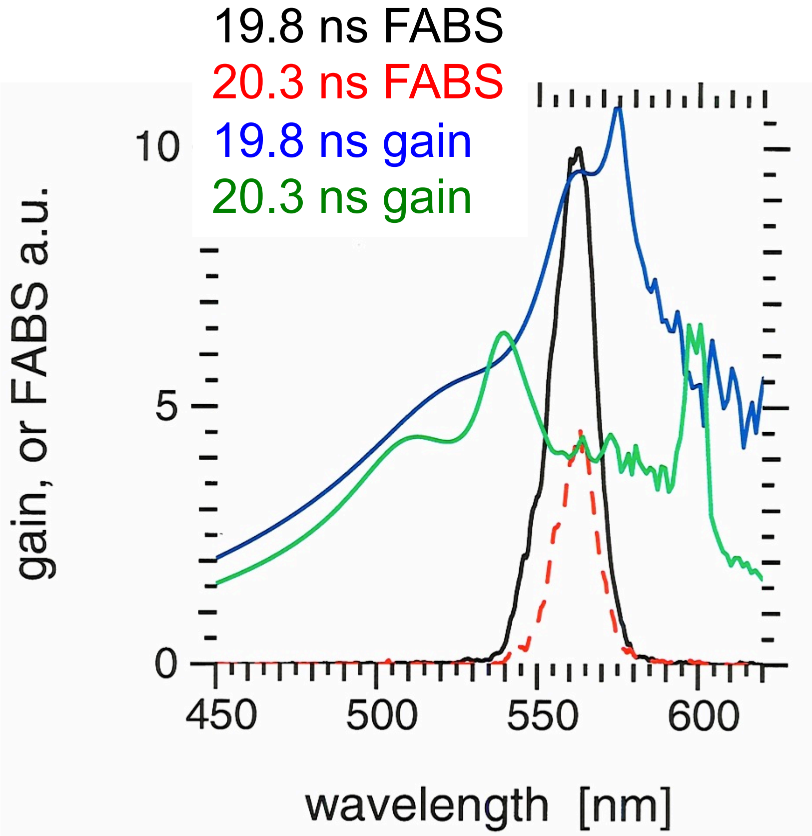
fill rate: dn_e/dt = 0.026 n_{cr}/ns for 1.5 or 3 keV!

cooling rate: 0.1n_{cr} and 2.3 keV match with 560 nm.
To keep wavelength constant, dn_e/dt = 0.026 is balanced by dT_e/dt = -1.1 keV/ns

N120305: 30º cone SRS: what happens when other cones turn off

SRS gain, t = 20.3 ns





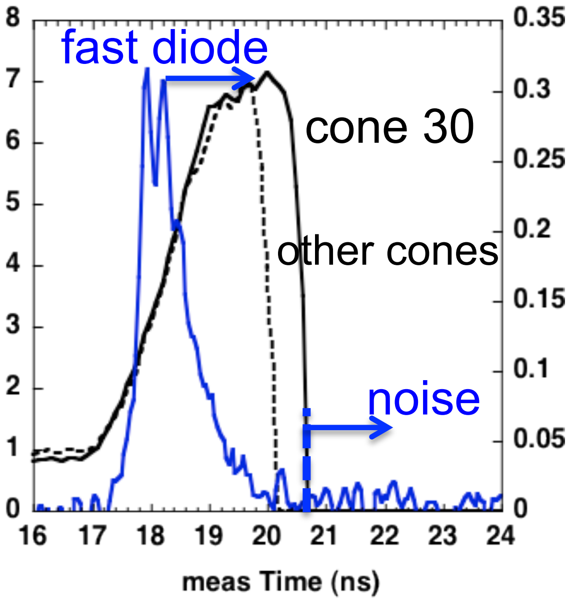
- FABS wavelength of 560 nm in "dead zone" of gain spectrum:
  - LPI physics (speckles, inflation) not likely to fix that
  - Plasma conditions likely wrong

Why gains blueshifted at late time?

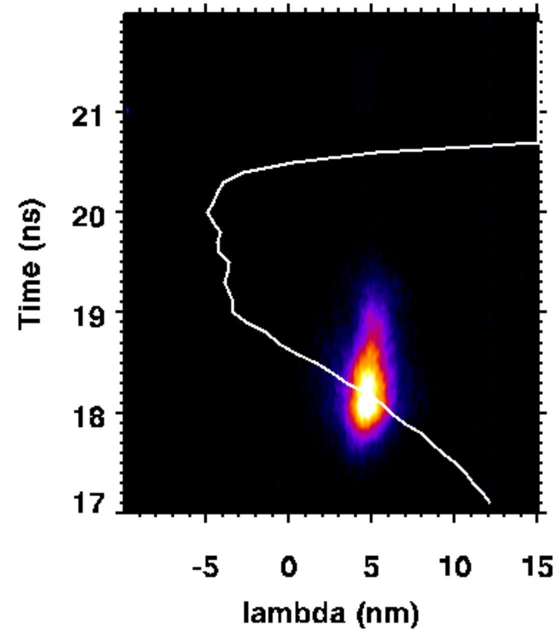
- Azimuthal non-uniformity:
  - Plasma really hotter in beams?
- Rad-hydro codes have trouble when laser turned off?

N120305: SBS on 30° cone: gains ~ 1.5 Ang. redshifted vs. measurement

SBS power [TW]



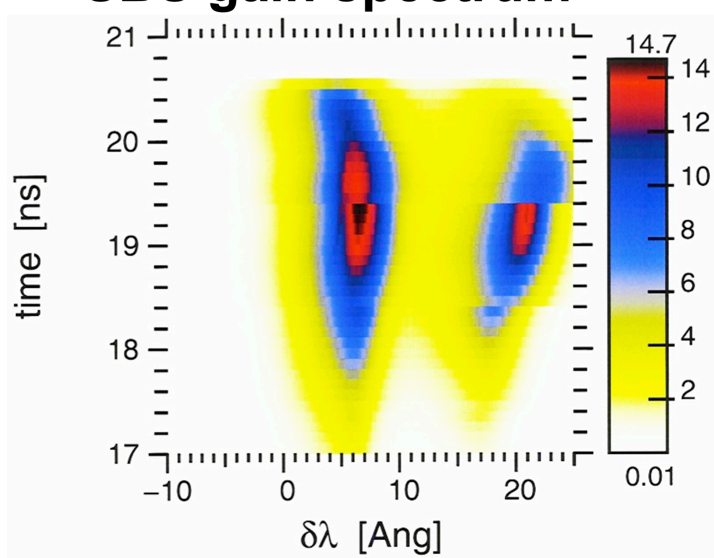
FABS SBS spectrum

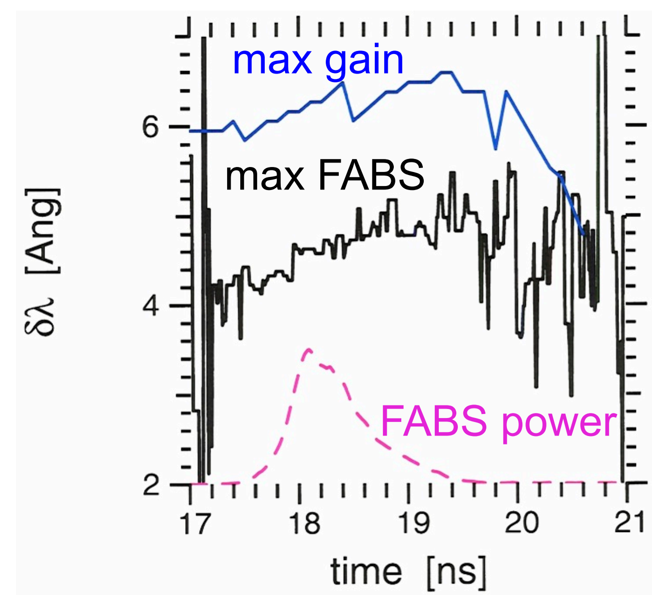


Time-dependent n_e[1] may explain redshift [R. L. Berger]

[1]T. Dewandre, J. R. Albritton, E. A. Williams, Phys. Fluids 1981

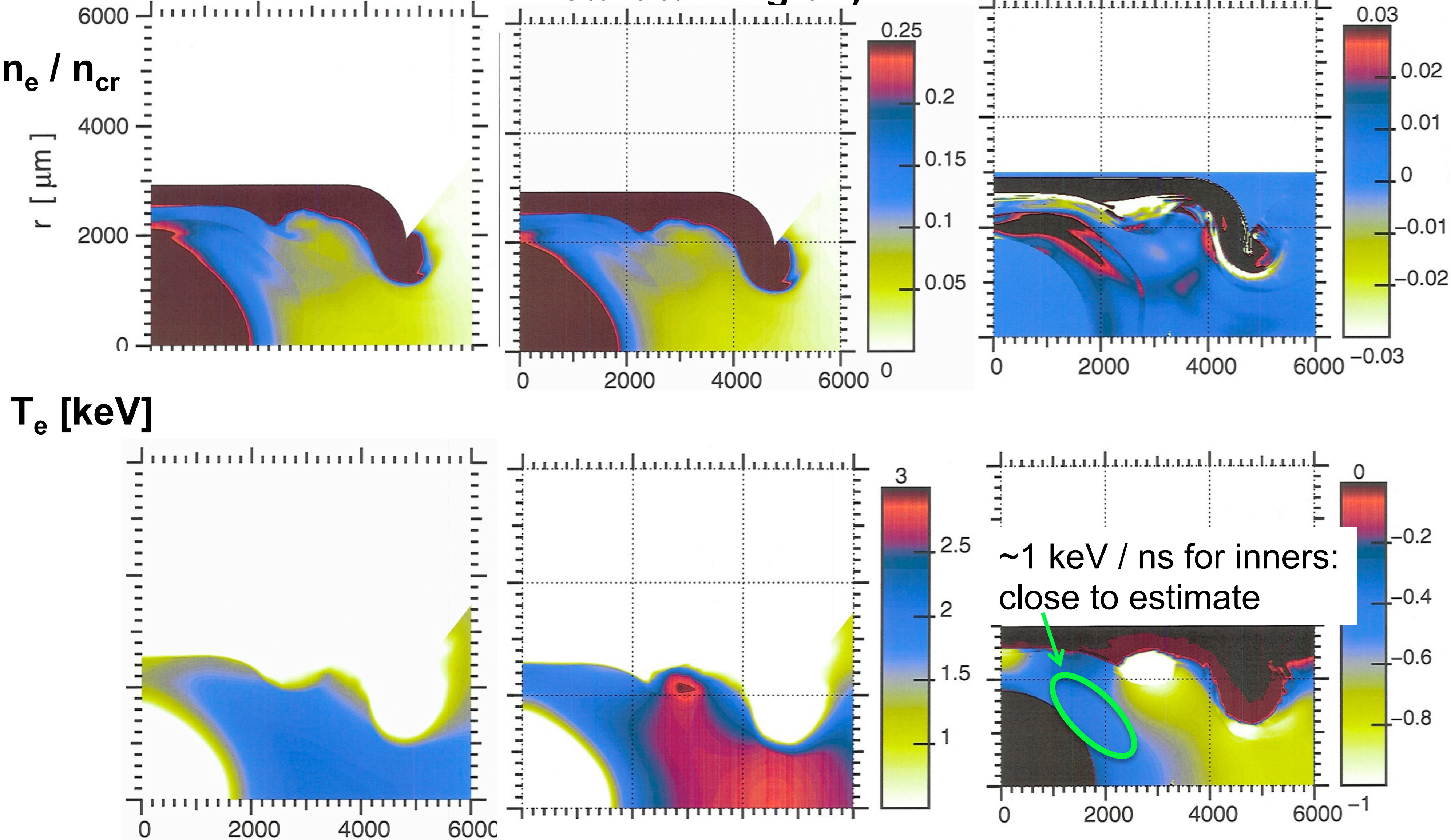
SBS gain spectrum





N120305: plasma maps from H. Robey's R-Z post-shot Hydra runs

20.3 ns (just 30's on) - 19.8 ns (other cones start turning off) = difference



Conclusions on March 2012 keyholes

- Measured single-quad inner-cone SRS ~ 15-20%
- When all cones on, single-quad gain spectrum close to data
  — multi-quad effects not essential
- Gain spectrum changes more when just 30's are on than data –
  — rad-hydro plasma conditions likely wrong, perhaps due to degraded drive
- SBS gain spectrum ~ 1.5 Ang. redshifted vs. data
  — time-dependent density may explain