Final technical report on the project

**TIME EVOLUTION OF CAPSULE ρR
and
PROTON EMISSION IMAGING OF CORE STRUCTURE**

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A. ρR EVOLUTION AT SHOCK-COALESCENCE TIME AND AT BANG TIME: possible effects of ρR imprinting at shock-coalescence time

i. Measurement with multiple proton spectrometers

Following an earlier prediction [1], absolute measurements of low-mode ρR asymmetry have now been made through spectra of both primary and secondary D^3He protons (their energy losses leaving a capsule are proportional to ρR for each spectrometer line of sight). Definitive observation of asymmetry was first made with secondary protons from D_2 -filled capsules [2]; demonstration of the correlation between drive asymmetry and ρR asymmetry was made with D^3He -filled capsules [3], examined in more detail [4], and culminated [5] in the derivation and experimental verification of a scaling formula $\delta \rho R_{rms} / \langle \rho R \rangle \approx 0.4(C_r - 1) \delta I_{rms} / \langle I \rangle$ relating the rms amplitude of asymmetry in illumination I to the rms amplitude of ρR asymmetry in terms of the radial convergence ratio C_r (showing that the growth in amplitude of these low modes is dominated by Bell-Plesset-like convergence effects). It has also been shown now [6,7] that the same scaling can be applied at individual angles and individual times during implosion, and that separate modes grow at approximately the same rate and maintain their phase at least until compression burn time (see Fig. 1).

FIG. 1. Effects of laser drive asymmetry on ρR asymmetry and ρR asymmetry growth have been inferred from D^3He proton spectra measured at different directions such as those in (a), where each spectrum (3 out of 6 are shown) is decomposed into components from shock bang time (blue) and compression bang time (red). (b) Offsetting capsules from target chamber center resulted in illumination intensity I as a function of angle θ away from the offset direction. $I(\theta)$ resulted in $\rho R(\theta)$ with the same phase, growing in amplitude without phase inversion as shown in (c) and (d). The relationship between the amplitudes of (b), (c) and (d) is consistent with the prediction in ref. [5] that ρR asymmetry growth should proceed primarily through effects of the radial convergence ratio C_r . The data in (b)-(d) are from OMEGA shot 31388 (18 atm D^3He in a 27- μm CH shell; 23 kJ of laser energy). These data are from ref. [7].

ii. Measurement with multiple proton spectrometers plus the proton temporal diagnostic

The symmetry data inherent in multiple proton spectra have now been combined with direct measurements of proton production time evolution to produce more complete information about the time evolution of ρR asymmetries [8]. This has been made possible by the development of the Proton Temporal Diagnostic (PTD), which was developed on OMEGA for studying the D^3He burn history (see Fig. 2) [8,9]. The strength of the D^3He shock burn, and its clear separation from the compression burn (unlike the case for DD or DT), allow

highly accurate timing measurements [8] and makes possible the modeling of capsule structural evolution throughout the time interval from shock coalescence to compression burn.

Because the T_i dependence of the D^3He reaction is much stronger than that of the DD reaction, shock bang time can be measured far more accurately from the proton rate in D^3He implosions than from the neutron rate from either DD or DT implosions. Shock bang is particularly important because it is unaffected by mix [10] and is also one of the best measures of drive efficiency. As an illustration, Fig. 3 shows an example of a proton rate history (measured by the proton temporal diagnostic, or PTD [9]), from a D^3He implosion, and 1-D LILAC simulations of the same implosion. Selection of an appropriate flux limiter (in this case 0.07) results in a simulation that matches the timing of shock bang and compression bang, but the yield does not agree even for the shock bang (at which time the 1-D calculation would be expected to be at its most accurate because of the absence of mix).

By combining the D^3He burn rate with data from multiple proton spectrometers, the time evolution of ρR and pR asymmetries can be inferred as illustrated in Fig. 4 [8]. It was shown that the pRs grew from about 13 mg/cm^2 at shock bang time [8,10] (just before deceleration onset) to between 45 and 80 mg/cm^2 some 350 ps later at compression bang time. In this instance, the pR growth is observed to be asymmetric, an occurrence that apparently depends strongly on illumination conditions [3,7,5]. In addition, it was

shown that ρR asymmetries exist at shock-bang time for nominally symmetric implosions, and that these asymmetries ($l = 1$) are amplified throughout the implosion without any phase changes. It was also shown that ρR asymmetries grow ~ 2 times as fast as the average ρR growth [8].

B. PROTON EMISSION IMAGING OF NUCLEAR BURN

Measured burn images and burn profiles provide compelling insight into implosion dynamics, including the combined effects of mix, hydro efficiency, and electron and radiation transport. To that end, we developed the multi-camera Proton Core Imaging System (PCIS) [11,12] on OMEGA (Fig. 5) for quantitative, 3-D spatial measurements of the fusion burn region in direct-drive implosions of D^3He -filled capsules. Images from three orthogonal penumbral imaging cameras are processed with special algorithms [11] to find either the surface brightness of the burn region with arbitrary asymmetric structure (Fig. 5) [11,14,15] or the radial profile of D^3He reactions per unit volume when burn is spherically symmetric (Fig. 6) [11,13]. Combined with our other diagnostic measurements of the time evolution of D^3He burn, ρR as a function of angular position, and the time evolution of ρR , PCIS provides a unique tool for studying implosion dynamics and performance.

Figure 5 shows an example of how (intentionally) asymmetric laser drive results in an asymmetric burn region. Similar results for different types and amplitudes of drive asymmetry show clear correlations between drive conditions and burn asymmetry. Figure 6a shows a sample radial profile of burn for a symmetric OMEGA implosion, while Fig. 6b shows examples of how the size of

the burn region varies for different laser energies and shell types. The burn regions of imploded thin-glass-shell capsules get larger with increasing laser energies; the burn regions of thick-plastic-shell capsules are, not surprisingly, significantly smaller than those of glass-shell capsules imploded with the same laser energy. Figure 6c shows that decreasing fill pressure can lead to diminished burn region size, even though shell convergence (as indicated by ρR) does not notably increase. This is supported by our previous finding [14] from studies of similar DT implosions that a reduction of pressure did not lead to much increase in radial convergence, in contrast to predictions of 1D codes, and was probably an indication of increased fuel-shell mix; the reduction in burn region size at lower pressures seen here may be another sign that mix is more extensive, cooling more of the outer fuel region.

C. STUDENT TRAINING AND EDUCATION IN HIGH-ENERGY-DENSITY PHYSICS AND ICF

The MIT group has outstanding graduate and undergraduate students training in ICF and HEDP. They are involved in a wide range of projects from experimental to simulation to theory. The graduate students are deeply engaged in every aspect of our research program, and spend considerable time at LLE working on experiments and working with our collaborators from LLE and from the National Labs. They report their results at the major conferences (DPP, Anomalous, IFSA, HTPD), at National Laboratory workshops and seminars, and at seminars at MIT and LLE, and they write up their work for submission to refereed physics journals. Each graduate student typically has three major first-author publications as well as co-authorship on several (typically 5-7) other major publications by the completion of their thesis. Presently we have five outstanding graduate students: Mr. Ryan Rygg, Mr. Cliff Chen, Mr. Joe DeCiantis, Ms. Sabine Volkmer and Mr. Daniel Casey. We anticipate that at least one more will join us this summer. Graduate students Ryan Rygg and Joe DeCiantis both were awarded 1st Place Excellence Awards for their Graduate Research at the last NNSA symposium.

We have found that the undergraduates are also quite eager to participate and to learn about ICF. The Fusion Product Source gives them hands-on experience with many of the techniques we are using at, or developing for, OMEGA and the NIF. In this past year 11 undergraduates have worked in our group (Ms. Amy Slagle, Mr. Greg Belote, Mr. Gabriel Warshauer-Baker, Mr. Rory Rother, Mr. Andy McLaughlin, Mr. Dylan Consola, Ms. Jessica Lam, Mr. Siddharth Sundar, Mr. Jon Williams, Mr. Dan Dennis, and Ms. Molly Bright). Each had a project for which he or she had primary responsibility.

D. GROUP PUBLICATIONS, 2002-2004

- m1. F. H. Séguin, J. L. DeCiantis, J. A. Frenje, S. Kurebayashi, C. K. Li, J. R. Rygg, C. Chen, V. Berube, B. E. Schwartz, R. D. Petrasso, V. A. Smalyuk, F. J. Marshall, J. P. Knauer, J. A. Delettrez, P. W. McKenty, D. D. Meyerhofer, S. Roberts, T. C. Sangster, K. Mikaelian and H. S. Park, “D³He-proton emission imaging for inertial-confinement-fusion experiments (invited)”, *Rev. Sci. Instrum.* **75**, 3520 (2004).
- m2. C. K. Li and R. D. Petrasso, “Stopping of Directed Electrons in High-Temperature Hydrogenic Plasmas”, *Phys. Rev. E* **70**, 067401 (2004).
- m3. C. K. Li, F. H. Séguin, J. A. Frenje, R. D. Petrasso, J. A. Delettrez, P. W. McKenty, T. C. Sangster, R. L. Keck, J. M. Soures, F. J. Marshall, D.D. Meyerhofer, N. Goncharov, J. P. Knauer, P. B. Radha, S. P. Regan, W. Seka, “Effects of Nonuniform Illumination on Implosion Asymmetry in Direct-Drive Inertial Confinement Fusion”, *Phys. Rev. Lett.* **92**, 205001 (2004).
- m4. J. A. Frenje, C. K. Li, F. H. Séguin, J. Deciantis, J. R. Rygg, B.E. Schwartz, S. Kurebayashi, R. D. Petrasso, J. Delettrez, V.Yu. Glebov, F. J. Marshall, D. D. Meyerhofer^{b)}, T. C. Sangster, C. Stoeckl, J. M. Soures, “Measuring shock bang timing and ρR evolution of D³He implosions at OMEGA”, *Phys. Plasmas* **11**, 2798 (2004).
- m5. S. P. Regan, J. A. Delettrez, V. N. Goncharov, F. J. Marshall, J. M. Soures, V. A. Smalyuk, P. B. Radha, B. Yaakobi, R. Epstein, V.Yu. Glebov, P. A. Jaanimagi, D. D. Meyerhofer, T. C. Sangster, W. Seka, S. Skupsky, C. Stoeckl, D. A. Haynes, J. A. Frenje, C. K. Li, R. D. Petrasso, F. H. Séguin, “Dependence of shell Mix on Feedthrough in Direct Drive Inertial Confinement Fusion”, *Phys. Rev. Lett.* **92**, 185002 (2004).

- m6. P. W. McKenty, T.C. Sangster, M. Alexander, R. S. Craxton, J. A. Delettrez, L. Elasky, R. Epstein, A. Frank, V. Yu. Glebov, D. R. Harding, S. Jin, J. P. Knauer, R. L. Keck, S. Loucks, L. D. Lund, R. L. McCrory, J. Marshall, D. D. Meyerhofer, S. Morse, S. Regan, P. B. Radha, S. Roberts, W. Seka, S. Skupsky, V. A. Smalyuk, J. Soures, M. D. Wittman, J. A. Frenje, C. K. Li, F. H. Seguin, R. D. Petrasso, N. Izumi, J. A. Koch, R. A. Lerche, M. J. Moran, T. W. Phillips, G. J. Schmid "Direct-drive cryogenic target implosion performance on OMEGA", *Phys. Plasmas* **11**, 2790 (2004).
- m7. D. Wilson, C. W. Cranfill, C. Christensen, R. A. Forster, R. R. Peterson, N. M. Hoffman, G. D. Pollak, C. K. Li, F. H. Seguin, J. A. Frenje, R. D. Petrasso, P. W. McKenty, F. J. Marshall, V. Yu. Glebov, C. Stoeckl, "Multi-fluid interpenetration mixing in directly driven ICF capsule implosions", *Phys. Plasmas* **11**, 2723 (2004).
- m8. C. K. Li, F. H. Seguin, J. A. Frenje, R. D. Petrasso, R. Rygg, S. Kurebayashi, B. Schwartz, R. L. Keck, J. A. Delettrez, J. M. Soures, P. W. McKenty, V. N. Goncharov, J. P. Knauer, F. J. Marshall, D. D. Meyerhofer, P. B. Radha, S. P. Regan, T. C. Sangster, W. Seka, C. Stoeckl, "Capsule-areal-density asymmetries inferred from 14.7-MeV deuterium-helium protons in direct-drive OMEGA implosions", *Phys. Plasmas* **10**, 1919 (2003).
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- m10. F. H. Seguin, J. A. Frenje, C. K. Li, D. G. Hicks, S. Kurebayashi, J. R. Rygg, B.-E. Schwartz, R. D. Petrasso, S. Roberts, J. M. Soures, D. D. Meyerhofer, T. C. Sangster, J. P. Knauer, C. Sorce, V. Yu. Glebov, C. Stoeckl, T. W. Phillips, R. J. Leeper, K. Fletcher, S. Padalino, "Spectrometry of charged particles from inertial-confinement-fusion plasmas", *Rev. Sci. Instrum.* **74**, 975 (2003).
- m11. T. C. Sangster, J. A. Delettrez, R. Epstein, V. Yu. Glebov, V. N. Goncharov, D. R. Harding, J. P. Knauer, R. L. Keck, J. D. Kilkenny, S. J. Loucks, L. D. Lund, R. L. McCrory, P. W. McKenty, F. J. Marshall, D. D. Meyerhofer, S. F. B. Morse, S. P. Regan, P. B. Radha, S. Roberts, W. Seka, S. Skupsky, V. A. Smalyuk, C. Sorce, J. M. Soures, C. Stoeckl, K. Thorp, J. A. Frenje, C. K. Li, R. D. Petrasso, F. H. Seguin, K. A. Fletcher, S. Padalino, C. Freeman, N. Izumi, J. A. Koch, R. A. Lerche, M. J. Moran, T. W. Phillips, G. J. Schmid, "Direct-drive cryogenic target implosion performance on OMEGA", *Phys. Plasmas* **10**, 1937 (2003).
- m12. V. A. Smalyuk, J. A. Delettrez, S. B. Dumanis, V. Yu. Glebov, V. N. Goncharov, J. P. Knauer, F. J. Marshall, D. D. Meyerhofer, P. B. Radha, S. P. Regan, S. Roberts, T. C. Sangster, S. Skupsky, J. M. Soures, C. Stoeckl, R. P. J. Town, B. Yaakobi, J. A. Frenje, C. K. Li, R. D. Petrasso, F. H. Seguin, D. L. McCrory, R. C. Mancini, J. A. Koch, "Hydrodynamic growth of shell modulations in the deceleration phase of spherical direct-drive implosions", *Phys. Plasmas* **10**, 1861 (2003).
- m13. V. A. Smalyuk, P. B. Radha, J. A. Delettrez, V. Yu. Glebov, V. N. Goncharov, D. D. Meyerhofer, S. P. Regan, S. Roberts, T. C. Sangster, J.M. Soures, C. Stoeckl, J. A. Frenje, C. K. Li, R. D. Petrasso, F. H. Seguin, "Time-Resolved Areal-Density Measurements with Proton Spectroscopy in Spherical Implosions", *Phys. Rev. Lett.* **90**, 135002 (2003).
- m14. C. K. Li, F. H. Seguin, J. A. Frenje, S. Kurebayashi, R. D. Petrasso, D. D. Meyerhofer, J. A. Soures, J. A. Delettrez, V. Yu. Glebov, F. J. Marshall, P. B. Radha, S. Reagan, S. Roberts, T. C. Sangster, C. Stoeckl, "Effects of fuel-shell mix upon direct-drive, spherical implosions on OMEGA", *Phys. Rev. Lett.* **89**, 165002 (2002).
- m15. J. A. Frenje, C. K. Li, F. H. Seguin, S. Kurebayashi, R. D. Petrasso, J. M. Soures, J. Delettrez, V. Yu. Glebov, D. D. Meyerhofer, P. B. Radha, S. Roberts, T. C. Sangster, S. Skupsky, C. Stoeckl, "Measurements of fuel and shell areal densities of OMEGA capsule implosions using elastically scattered protons", *Phys. Plasmas* **9**, 4719 (2002).
- m16. F. H. Seguin, C. K. Li, J. A. Frenje, S. Kurebayashi, R. D. Petrasso, F. J. Marshall, D. D. Meyerhofer, J. M. Soures, T. C. Sangster, C. Stoeckl, J. A. Delettrez, P. B. Radha, V. A. Smalyuk, S. Roberts, "Measurements of ρR asymmetries at burn time in inertial-confinement-fusion capsules", *Phys. Plasmas* **9**, 3558 (2002).
- m17. J. A. Frenje, C. K. Li, F. H. Seguin, D. G. Hicks, S. Kurebayashi, R. D. Petrasso, S. Roberts, V. Yu. Glebov, D. D. Meyerhofer, T. C. Sangster, J. M. Soures, C. Stoeckl, C. Chiritescu, G. J. Schimid,

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- m18. F. H. Seguin, C. K. Li, J. A. Frenje, D. G. Hicks, K. M. Green, S. Kurebayashi, R. D. Petrasso, J. M. Soures, D. D. Meyerhofer, V. Yu. Glebov, P. B. Radha, C. Stoeckl, S. Roberts, C. Sorce, T. C. Sangster, M. D. Cable, K. Fletcher, S. Padalino, “Using secondary-proton spectra to study the compression and symmetry of deuterium-filled capsules at OMEGA”, *Phys. Plasmas* **9**, 2725 (2002).
- m19. S. P. Regan, J. A. Delettrez, F. J. Marshall, J. M. Soures, V. A. Smalyuk, B. Yaakobi, R. Epstein, V. Yu. Glebov, P. A. Jaanimagi, D. D. Meyerhofer, P. B. Radha, T. C. Sangster, W. Seka, S. Skupsky, C. Stoeckl, R. P. J. Town, D. A. Haynes, Jr., I. E. Golovkin, C. F. Hooper, Jr., J. A. Frenje, C. K. Li, R. D. Petrasso, F. H. Seguin, “Shell Mix in the Compressed Core of Spherical Implosions”, *Phys. Rev. Lett.* **89**, 085003 (2002).
- m20. P. B. Radha, J. Delettrez, V. Yu. Glebov, R. Keck, R. L. McCrory, P. McKenty, D. D. Meyerhofer, F. Marshall, S. Regan, S. Roberts, T. C. Sangster, W. Seka, S. Skupsky, V. Smalymuk, C. Sorce, R. P. B. Town, C. Stoeckl, J. A. Soures, B. Yaakobi, J. A. Frenje, C. K. Li, F. H. Seguin, R. D. Petrasso, K. Fletcher, S. Padalino, C. Freeman, N. Izumi, R. Lerche, T. W. Phillips, “Inference of mix in direct-drive implosions on OMEGA”, *Phys. Plasmas* **9**, 2208 (2002).
- m21. C. Stoeckl, P. B. Radha, J. Delettrez, V. Yu. Glebov, R. Keck, R. L. McCrory, P. McKenty, D. D. Meyerhofer, F. Marshall, S. Regan, S. Roberts, T. C. Sangster, W. Seka, S. Skupsky, V. Smalymuk, C. Sorce, R. P. B. Town, J. A. Soures, B. Yaakobi, J. A. Frenje, C. K. Li, F. H. Seguin, R. D. Petrasso, K. Fletcher, S. Padalino, C. Freeman, N. Izumi, R. Lerche, T. W. Phillips, “First results from cryogenic-target implosions on OMEGA”, *Phys. Plasmas* **9**, 2195 (2002).

E. GROUP CONFERENCE PRESENTATIONS, 2002-2004

46th Annual Meeting of the Division of Plasma Physics (2004, Savannah, GA):

- t1. M. Canavan et al., “A modified accelerator for ICF diagnostic development”.
- t2. J. L. DeCiantis et al., “The dependence of measured burn profiles on capsule and laser parameters”.
- t3. J. A. Frenje et al., “Measurements of time evolution of ion temperature in D³He implosions at OMEGA”.
- t4. C. K. Li et al., “Stopping, straggling and blooming of directed energetic electrons in hydrogenic plasmas”.
- t5. J. R. Rygg et al., “Testing hydrodynamic equivalence of D₂ and ³He mixtures”.
- t6. F. H. Séguin et al., “Studying effects of drive asymmetry on burn asymmetry with proton emission imaging”.

34th Annual Anomalous Absorption Conference (2 - 7 May 2004, Gleneden Beach, OR):

- t7. C. K. Li et al., “Effects of Nonuniform Illumination on Implosion Asymmetry in Direct-Drive Inertial Confinement Fusion”.
- t8. C. K. Li and R. D. Petrasso, “Stopping and Scattering of Directed Energetic Electrons in High-Temperature Hydrogenic Plasmas”.
- t9. J. A. Frenje, et al., “A High-Resolution Neutron Spectrometer for ρR_{fuel} and T_i Measurements at OMEGA and the NIF”.
- t10. J. R. Rygg et al., “An Empirical, Dynamic Mix Model for ICF Implosions”.
- t11. J. DeCiantis et al., “Studying the Burn Region in ICF Implosions with Proton Emission Imaging”.

15th Topical Conference on High Temperature Plasma Diagnostics (19 – 22 Apr. 2004, San Diego, CA):

- t12. F. H. Séguin, “Proton Spectrometry and Imaging for Studying Performance and Dynamics of Inertial-Confinement-Fusion Experiments”. (Invited talk)
- t13. M. J. Canavan et al., “Diagnosing DT Cryogenic Fizzles at the NIF”.
- t14. J. DeCiantis et al., “Studying the Burn Region in ICF Implosions with Proton Emission Imaging”.

- t15. J. Frenje et al., “A Magnetic Recoil Spectrometer (MRS) for ρR_{fuel} and T_i Measurements of Warm, Fizzle and Ignited Implosions at the NIF”.
- t16. C. K. Li et al., “First Spectrometry of Charged Particles from Indirect-Drive Capsule Implosions”.

DOE SSAA Symposium (29 – 31 March 2004, Albuquerque, NM):

- t17. C. K. Li et al., “Effects of Nonuniform Illumination on Implosion Asymmetry in Direct-Drive Inertial Confinement Fusion”.
- t18. C. K. Li and R. D. Petrasso, “Stopping of Directed Energetic Electrons in High-Temperature Hydrogenic Plasmas”.
- t19. J. A. Frenje et al., “A high-resolution neutron spectrometer for ρR_{fuel} and T_i measurements at OMEGA and the NIF”.
- t20. J. DeCiantis et al., “Studying the Burn Region in ICF Implosions with Proton Emission Imaging”.
- t21. J. R. Rygg et al., “An Empirical, Dynamic Mix Model for ICF Implosions”.

45th Annual Meeting of the Division of Plasma Physics (27 - 31 Oct. 2003, Albuquerque, NM):

- t22. J. A. Frenje et al., “Measurements of Shock-Timing of $D^3\text{He}$ Implosions at OMEGA”. (Invited talk)
- t23. M. J. Canavan et al., “Diagnosing DT Cryogenic Fizzles at the NIF: Using Charged-Particle Spectrometer (CPS) Measurements of Knock-on D, T, & p and Magnetic Recoil Spectrometer (MRS) Measurements of Down-Scattered Neutrons”.
- t24. J. DeCiantis et al., “Imaging $D^3\text{He}$ Burn Profiles of OMEGA Implosions”.
- t25. J. A. Frenje et al., “A Magnetic Recoil Spectrometer (MRS) for Precise ρR_{fuel} and T_i Measurements of Warm and Cryo Targets at OMEGA and the NIF”.
- t26. S. Kurebayashi et al., “Use of Secondary Nuclear Particles for Studying Areal Density in D_2 -Filled Inertial Confinement Implosions”.
- t27. C. K. Li et al., “Using Charged Particles to Measure ρR and ρR Asymmetries for Indirect-Drive Implosions”.
- t28. R. D. Petrasso et al., “Utilizing Shock Burn to Study Omega Capsule Dynamics When Mix is Insignificant”.
- t29. J. R. Rygg et al., “Experimental Studies of Time-Dependent Mix in OMEGA Direct-Drive Implosions”.
- t30. F. H. Seguin et al., “ ρR -Asymmetry Time Evolution Following Low-Mode Drive Asymmetry at OMEGA”.
- t31. V. Yu. Glebov et al., “Proton Temporal Diagnostic for ICF Experiments on OMEGA”.
- t32. J. P. Knauer et al., “Direct-Drive ICF Implosions with Picket-Fence Pulse Shapes”.
- t33. P. W. McKenty et al., “Direct-Drive Cryogenic Target Implosion Performance on OMEGA”.
- t34. T. C. Sangster et al., “Experimental Results from Cryogenic D_2 Implosions on the OMEGA Laser”.
- t35. C. Stoeckl et al., “Direct-Drive Fuel Assembly Experiments with Fast-Ignitor Cone Targets on OMEGA”.

3rd International Conference on Inertial Fusion Sciences and Applications (7 - 12 Sept. 2003, Monterey, CA):

- t36. C. K. Li et al., “ ρR Asymmetry in Spherical Implosions of Inertial Confinement Fusion”.
- t37. J. A. Frenje et al., “Measurements of Shock-Coalescence Timing of $D^3\text{He}$ Implosions at OMEGA”.

- t38. J. A. Frenje et al., "A Novel Magnetic Recoil Spectrometer (MRS) for Precise ρR_{fuel} and T_i Measurements of Warm and Cryo OMEGA Implosions, and Warm, Fizzle and Ignited NIF Implosions".
- t39. P. W. McKenty et al., "Direct-Drive Cryogenic Target Implosion Performance on OMEGA".

33rd Annual Anomalous Absorption Conference (22 - 27 June 2003, Lake Placid, NY):

- t40. C. K. Li et al., "Using Charged Particles to Measure ρR and ρR Asymmetries for Indirect-Drive Implosions".
- t41. J. A. Frenje et al., "Measurement of Shock-Coalescence Timing and ρR Evolution of $D^3\text{He}$ Implosions at OMEGA".
- t42. J. A. Frenje et al., "A Magnetic Recoil Spectrometer (MRS) for Precise ρR_{fuel} and T_i Measurements of Warm and Cryo Targets at OMEGA and the NIF".
- t43. F. H. Seguin et al., "Time Evolution of ρR Asymmetries in OMEGA Direct-Drive Implosions".
- t44. R. Rygg et al., "The Effects of Implosion Asymmetry on Shock Coalescence in OMEGA Experiments".
- t45. S. Kurebayashi et al., "Using Secondary Protons and Neutrons to Study ρR_{fuel} ".
- t46. J. DeCiantis et al., "Imaging DD and $D^3\text{He}$ Burn Profiles on OMEGA Implosions".

44th Annual Meeting of the Division of Plasma Physics (11 - 15 Nov. 2002, Orlando, FL):

- t47. C. K. Li et al., "Capsule Areal Density Asymmetries and Time Evolution Inferred from 14.7-MeV Protons in OMEGA Implosions". (Invited talk)
- t48. R. D. Petrasso et al., "Proton Core Imaging Spectroscopy (PCIS) of OMEGA Implosions".
- t49. F. H. Seguin et al., "Measurement ρR -Asymmetry Time Evolution in Implosions at OMEGA".
- t50. J. A. Frenje et al., "Effects of Fuel-Shell Mix in Implosions of Plastic Capsules on OMEGA".
- t51. R. Rygg et al., "Investigation of OMEGA Capsule Dynamics Using Shock Flash Measurements".
- t52. S. Kurebayashi et al., "Relationship of Secondary Nuclear Production to Implosion Characteristics at OMEGA".
- t53. B. Schwartz et al., "Investigation of OMEGA Capsule Dynamics Using Shock Flash Measurements".

32nd Anomalous Absorption Conference (21 - 26 July 2002, Oahu, Hawaii):

- t54. R. D. Petrasso et al., "Capsule Areal Density Non-Uniformities and Evolution Inferred from 14.7-MeV Proton Line Structure in Omega $D^3\text{He}$ "mplosions".
- t55. C. K. Li et al., "Effects of Fuel-Shell Mix upon Direct-Drive, Spherical Implosions on OMEGA".
- t56. V. A. Smalyuk et al., "Areal-Density-Growth Measurements with Proton Spectroscopy on OMEGA".

14th Topical Conference on High Temperature Plasma Diagnostics (8 - 12 July 2002, Madison, Wisconsin):

- t57. C. K. Li et al., "Charged-particle Spectroscopy on OMEGA Laser Facility". (Invited talk)
- t58. J. A. Frenje et al., "A Magnetic Deuteron Recoil (MDR) Neutron Spectrometer for ρR_{fuel} Measurements of Cryogenic DT Targets on OMEGA and NIF".

CEA-DOE workshop (Feb 2002, LLNL):

- t59. C. K. Li et al., "Recent Results of Implosion Physics Studies for Direct-Drive ICF experiments".
- t60. T. C. Sangster et al., "OMEGA Direct-Drive ICF experiments".

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