Measurement of $\rho R$-asymmetry time evolution in implosions at OMEGA

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Outline

- How we measure $\rho R$ asymmetries

- How information about capsule structure at two distinct times is contained in spectra of 14.7-MeV $D^3He$ protons

- Preliminary results indicating that low-mode-number $\rho R$ asymmetries at compression time have observable precursors $\sim 400$ ps earlier, and have been amplified by $\sim x10$
Low-mode $\rho R$ asymmetries are observed by measuring $D^3$He proton energies at different angles.

We measure:
$$\bar{E}(\theta, \phi)$$
$$\Delta E(\theta, \phi) \equiv E_{\text{birth}} - \bar{E}(\theta, \phi)$$

We infer:
$$\rho R(\theta, \phi) [\propto \Delta E(\theta, \phi)]$$
$$<\rho R>$$
$$\delta \rho R(\theta, \phi) \equiv \rho R(\theta, \phi) - <\rho R>$$
$$<\delta \rho R>_{\text{rms}}$$
Low-mode $\rho R$ asymmetries are observed by measuring $D^3He$ proton energies at different angles

“Low-mode” ($\ell \leq 4$), because each $\bar{E} (\theta, \phi)$ averages over a significant part of the shell.

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$$\bar{E} (\theta, \phi)$$
$$\Delta E (\theta, \phi) \equiv E_{\text{birth}} - \bar{E} (\theta, \phi)$$

We infer:

$$\rho R(\theta, \phi) \quad [\propto \Delta E (\theta, \phi)]$$
$$<\rho R>$$
$$\delta \rho R (\theta, \phi) \equiv \rho R(\theta, \phi) - <\rho R>$$
$$<\delta \rho R>_{\text{rms}}$$
We’ll be studying $^{3}$He-filled capsules with thick CH shells

Room temperature capsules:

- 18-24 atm $^{3}$He
- 24-27 $\mu$m CH
- ~500 $\mu$m

60-Beam OMEGA laser:

- Pulse shape: 1-ns square
- Beam smoothing: 2D-SSD + PS
- On-target energy: ~22 kJ
There are two distinct time intervals during implosion when charged particles are generated*

(1) $t \approx 1.7 \text{ ns}$
1st Shock coalescence
$\rho R \sim 13 \text{ mg/cm}^2$

(2) $t \approx 2.1 \text{ ns}$
Compression burn
$\rho R \sim 70 \text{ mg/cm}^2$

Each spectrum can be divided into two components with different information content.
We want to compare structure at the two times

\[ \langle \rho R_S \rangle = a \langle \rho R_C \rangle \] (growth in \( \langle \rho R \rangle \))

\[ \langle \delta \rho R_S \rangle_{\text{rms}} = b \langle \delta \rho R_C \rangle_{\text{rms}} \] (growth in asymmetry amplitude)

\[ \delta \rho R_S (\theta, \phi) = c \delta \rho R_C (\theta, \phi) \] (are angular structures correlated?)
Up to 11 ports on the OMEGA target chamber can be used for charged-particle spectrometers.

- **Yellow** = Wedge-Range-Filter proton spectrometers (WRFs)
- **Light Blue** = Magnet-based charged-particle spectrometers (CPSs)
Multiple spectra can be measured during each shot.
Each spectrum can be divided into two components with different $\overline{E}$.
For each component, there is a $< \rho_R >$ and a distribution of deviations $\delta \rho_R$ from $< \rho_R >$.
We can look for a correlation between asymmetries at the two times by plotting $\delta \rho_{R_s}$ vs. $\delta \rho_{R_c}$.
We need to use data from many implosions

\[\langle \delta \rho R_C \rangle_{\text{rms}} \approx 8 \text{ mg/cm}^2\]

\[\langle \delta \rho R_S \rangle_{\text{rms}} \approx 0.9 \pm 0.5 \text{ mg/cm}^2\]
On average, there is a correlation between $\rho R$ asymmetries at the two times

Compensating for known correlations between uncertainties in $\delta \rho_R$ and $\delta \rho_S$,

$\frac{\delta \rho_S}{\delta \rho_R} \approx 0.04 \pm 0.04$

The part of $<\delta \rho_S>_{\text{rms}}$ correlated with $\delta \rho_R$ is

$(0.04 \pm 0.04) <\delta \rho_R>_{\text{rms}} \approx 0.3 \pm 0.3 \text{ mg/cm}^2$
## Preliminary conclusions

### Shock Time vs. Compression Time

<table>
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<tr>
<th></th>
<th>Shock Time</th>
<th>Compression Time</th>
<th>Interpretation</th>
</tr>
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<tbody>
<tr>
<td>$\langle \rho R \rangle$ (mg/cm$^2$)</td>
<td>13</td>
<td>70</td>
<td>$\langle \rho R \rangle$ grows by $\sim x5$</td>
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<td>$&lt;\delta \rho R&gt;_{\text{rms}}$</td>
<td>0.9 ± 0.5</td>
<td>8</td>
<td>The rms amplitude of low-mode ($\ell \sim 1-4$) structure grows by $\sim x10$</td>
</tr>
<tr>
<td>Part of $&lt;\delta \rho R&gt;_{\text{rms}}$ correlated with compression value</td>
<td>0.3 ± 0.3</td>
<td>8</td>
<td>Some of the structure retains phase coherence, some doesn’t</td>
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- **Future work** has to increase the accuracy of these measurements with:
  - More spectrometers per shot
  - More shots
  - Smaller measurement errors
## Some related talks

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<th>Shock</th>
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<tr>
<td>C. K. Li et al.</td>
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<td>F. J. Marshall et al.</td>
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