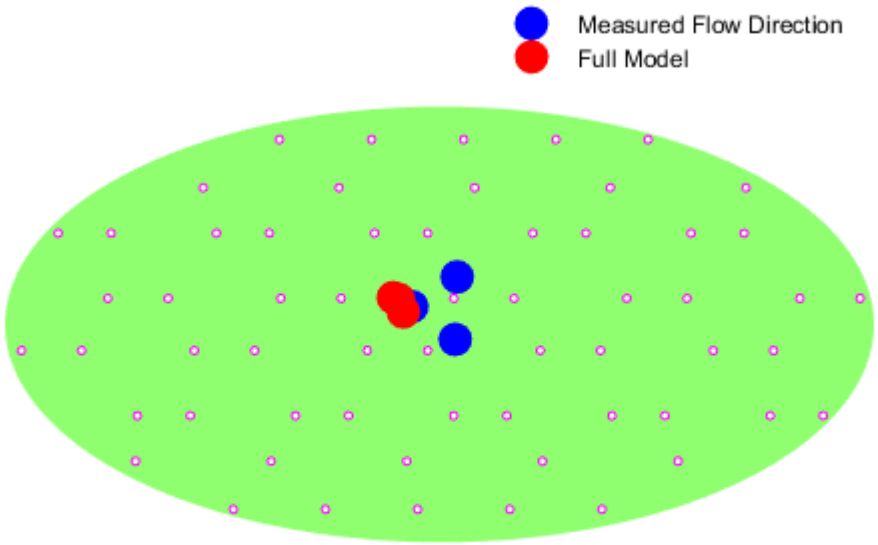
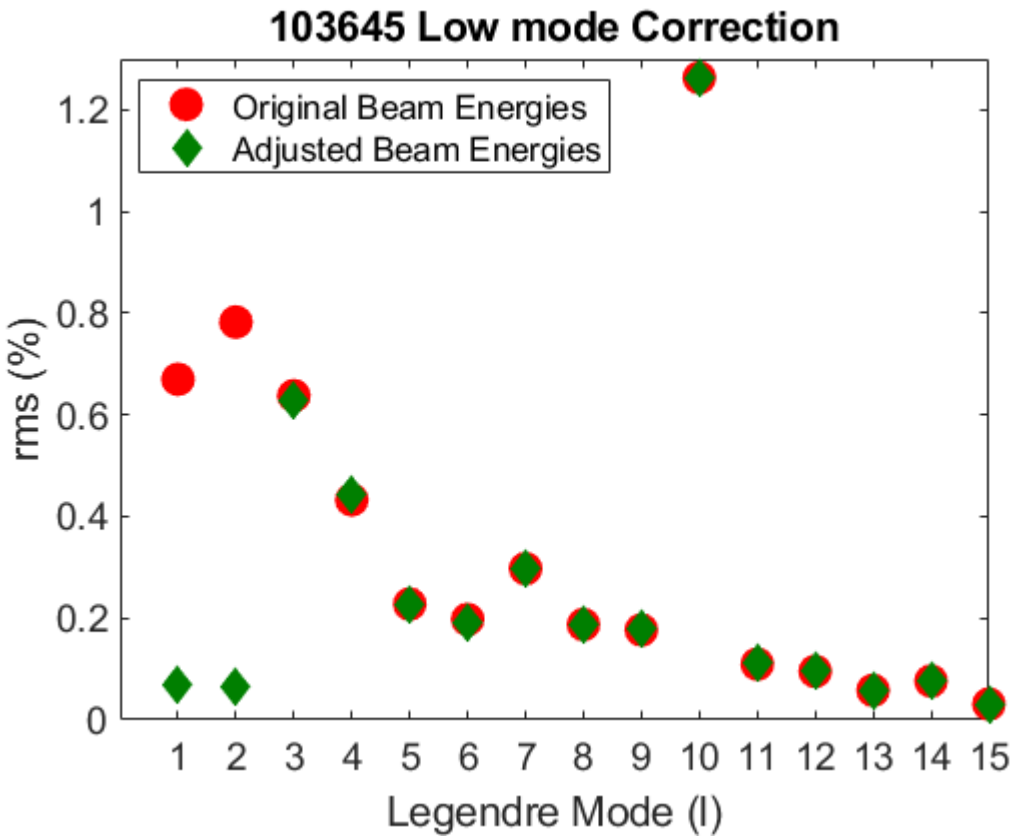
Low-Mode Asymmetries in Direct-Drive Implosion Prediction and Correction Using 3-D Modeling of Beam Balance, Beam Pointing, and Beam-Polarization Cross-Beam Energy Transfer Effects

3D modeling of the absorption mode ℓ=1





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Summary

Three dimensional polarization-dependent CBET plus beam balance and pointing are required to model nonuniformity in direct-drive implosions on OMEGA

- Uniform laser energy absorption is essential for successful laser-direct-drive inertial confinement fusion but evidence shows OMEGA implosions are more asymmetric than conventional predictions.
- Laser absorption ℓ=1 mode predictions from a fully three-dimensional model including polarization-dependent CBET, beam energy balance, and beam pointing correlate well with the observed direction of the core flow.
- Low mode absorption non-uniformity might be corrected by adjusting beam balance alone.

Collaborators

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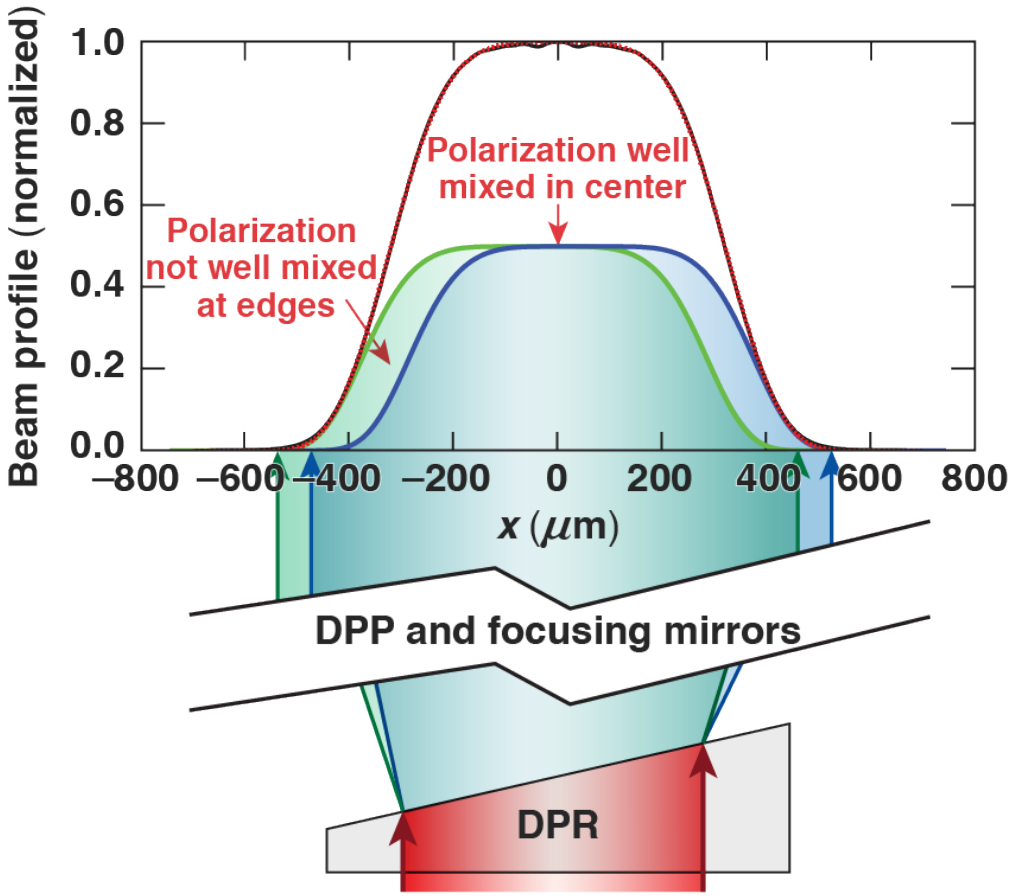
The goal of scaled-ignition on OMEGA requires an on-target, overlapped laser intensity variation of 1% rms[1].

- However, experimental evidence shows OMEGA implosions are more asymmetric than conventional predictions[2,3,4,5].

- Several sources of low mode laser absorption nonuniformity have been identified that are persistent shot to shot
  - Beam energy balance
  - Beam pointing
  - Asymmetric CBET due to laser polarization[6]



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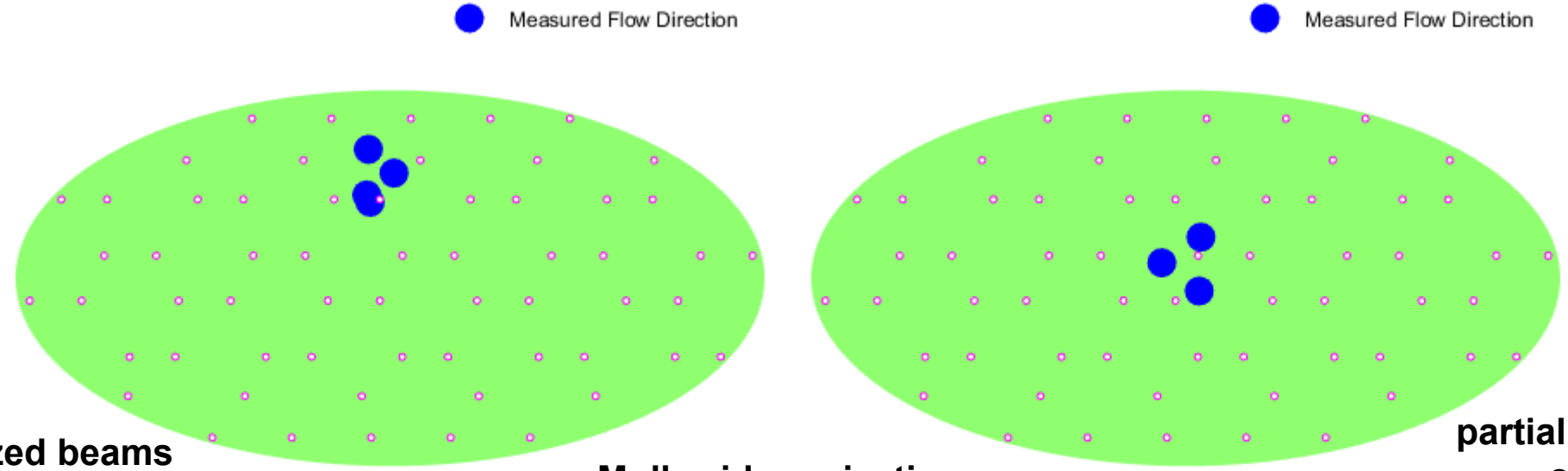
1. R. S. Craxton *et al.*, Phys. Plasmas 22, 110501 (2015).
2. O. M. Mannion *et al.*, Phys. Plasmas 28, 042701 (2021).
3 .A. Lees *et al.*, Phys. Rev. Lett. 127, 105001 (2021).
4 .R. Shah, to be submitted
5. D. H. Edgell, A. M. Hansen, J. Katz, D. Turnbull, and D. H. Froula, Rev. Sci. Instrum. 92, 043525 (2021).
6. D. H. Edgell, P. B. Radha, J. Katz, A. Shvydky, D. Turnbull, and D. H. Froula, Phys. Rev. Lett. 127, 075001 (2021).

A recent multi-day campaign measured the core flow for well characterized implosions to compare with 3D modeling of the absorption ℓ=1 mode



DPRs out
linearly polarized beams
non-circular beam spots
Core Flow: 104-126 km/s

Mollweide projections

DPRs in
partially polarized beams
circular beam spots
Core Flow: 84-97 km/s

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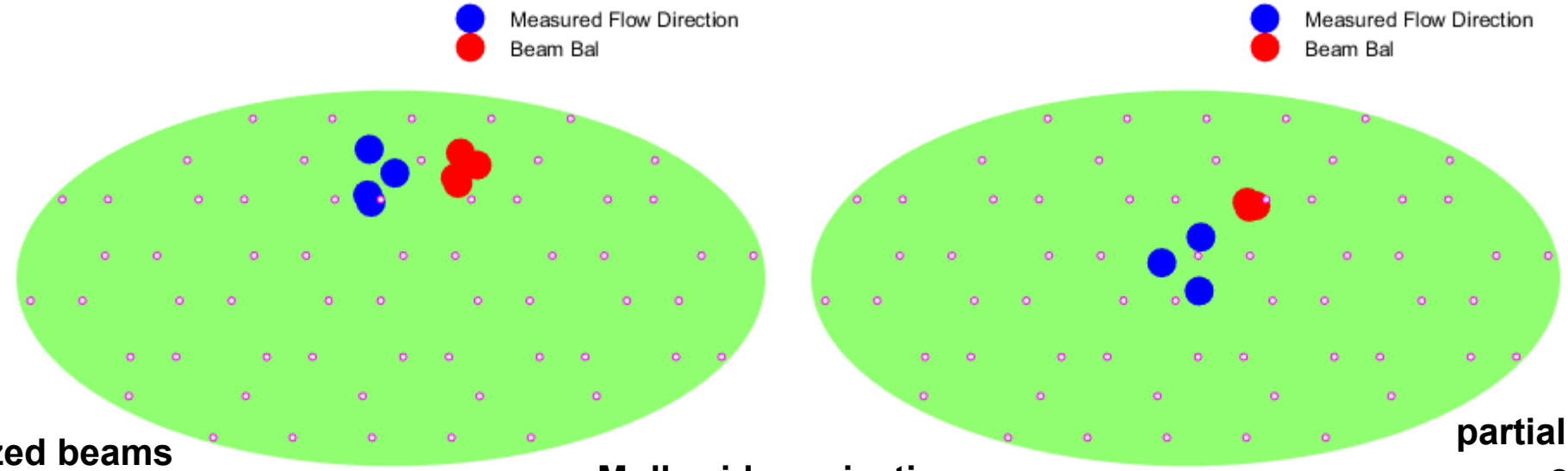

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DPRs in
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Core Flow: 84-97 km/s

Mode 1 rms (%)
Beam Power Balance 0.61

Mode 1 rms (%)
Beam Power Balance 0.65

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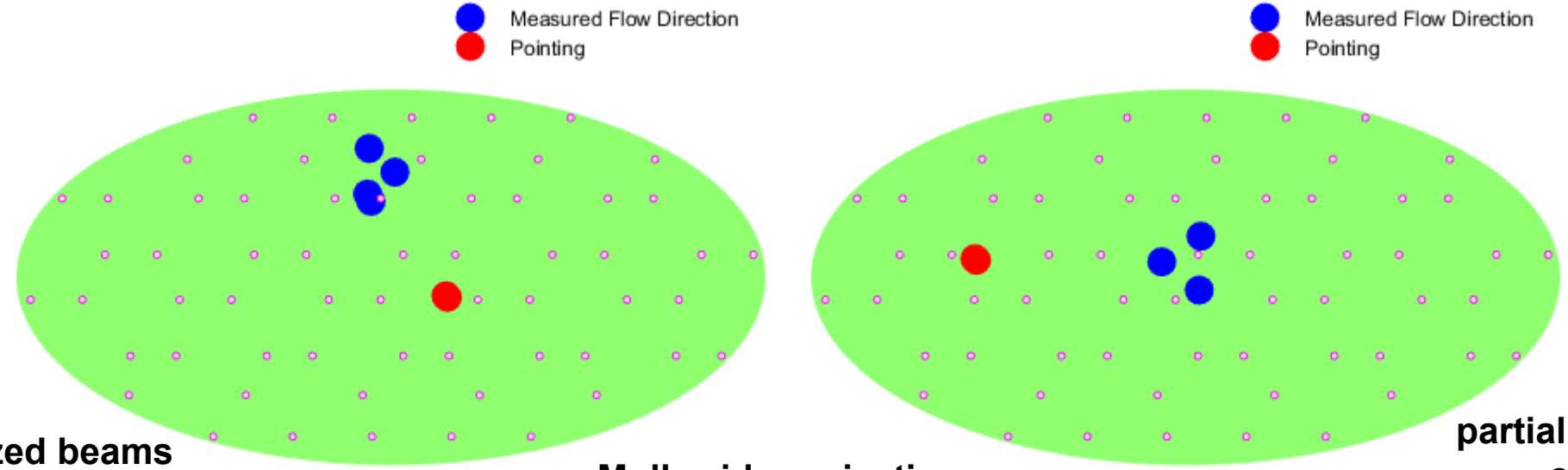

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DPRs in
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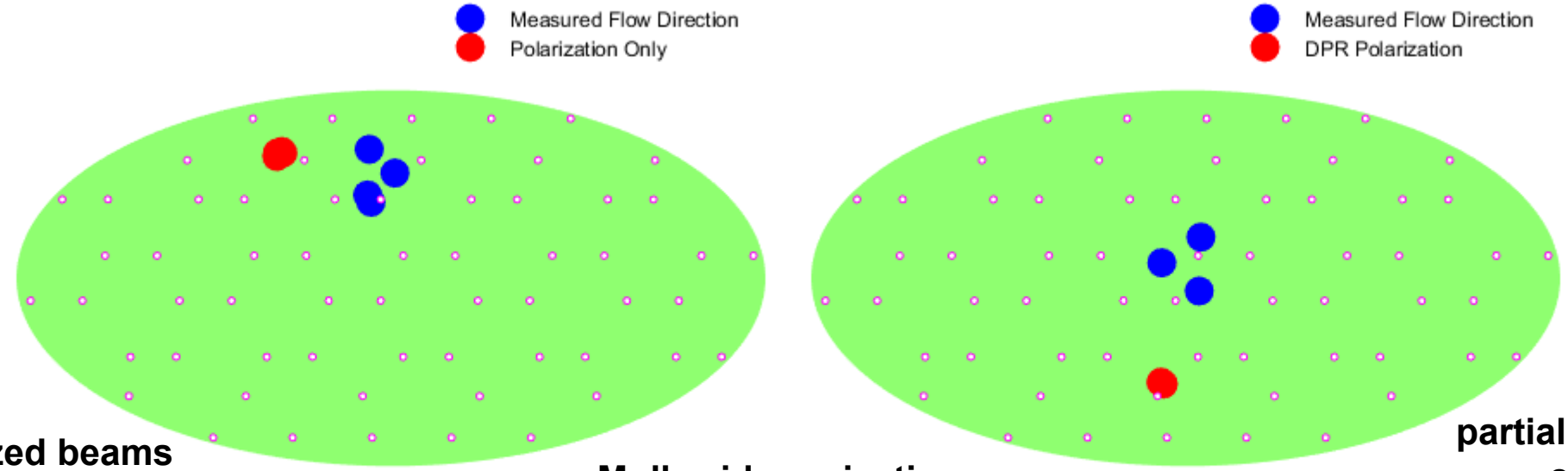
Mode 1 rms (%)

Beam Power Balance 0.61
Beam Pointing 0.76

Mode 1 rms (%)

Beam Power Balance 0.65
Beam Pointing 0.56

A recent multi-day campaign measured the core flow for well characterized implosions to compare with 3D modeling of the absorption ℓ=1 mode



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DPRs in
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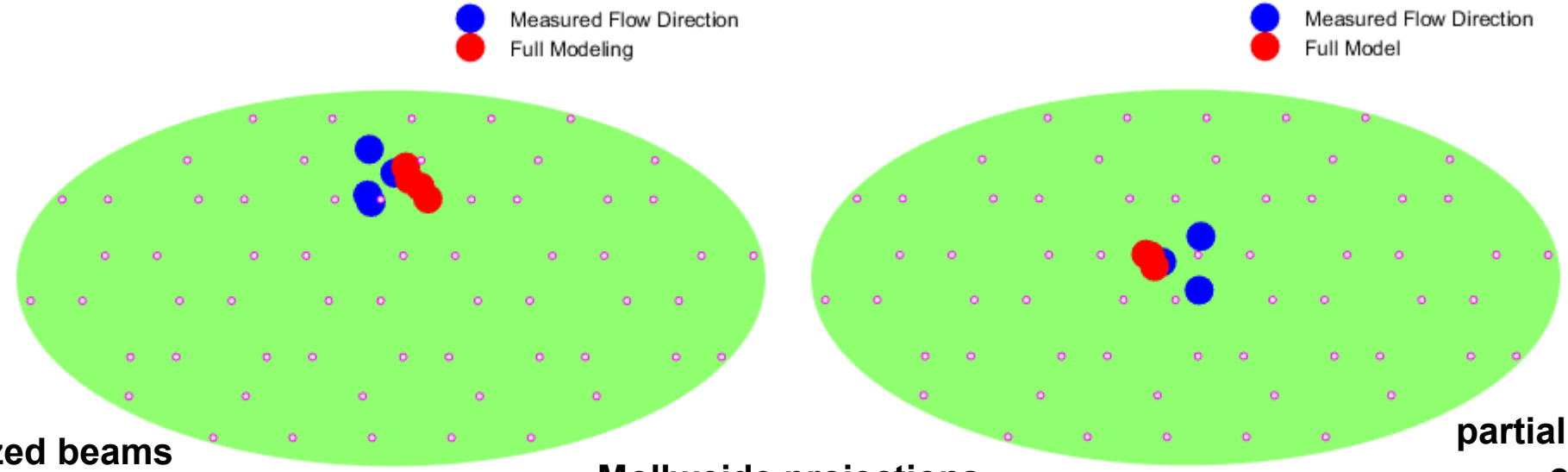
Mode 1 rms (%)

Beam Power Balance 0.61
Beam Pointing 0.76
Linear Polarization 0.67

Mode 1 rms (%)

Beam Power Balance 0.65
Beam Pointing 0.56
DPR Polarization 0.39

A recent multi-day campaign measured the core flow for well characterized implosions to compare with 3D modeling of the absorption ℓ=1 mode



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partially polarized beams
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Core Flow: 84-97 km/s

Mode 1 rms (%)

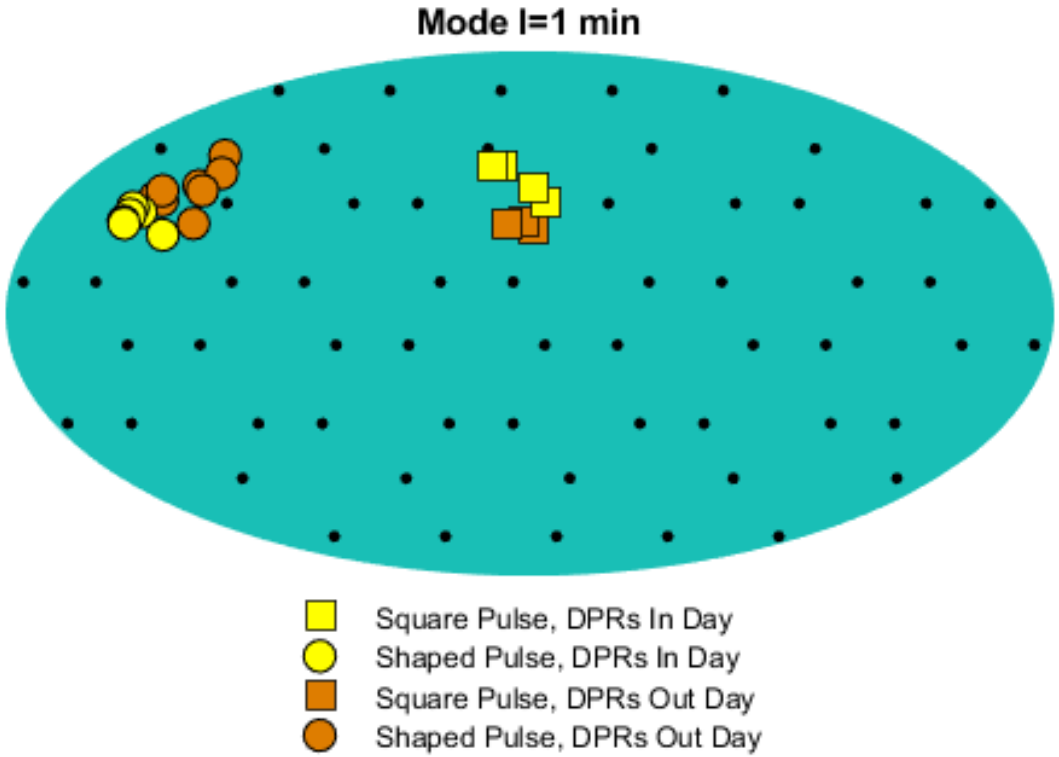
Beam Power Balance 0.61
Beam Pointing 0.76
Linear Polarization 0.67
All of the Above 1.21

Mode 1 rms (%)

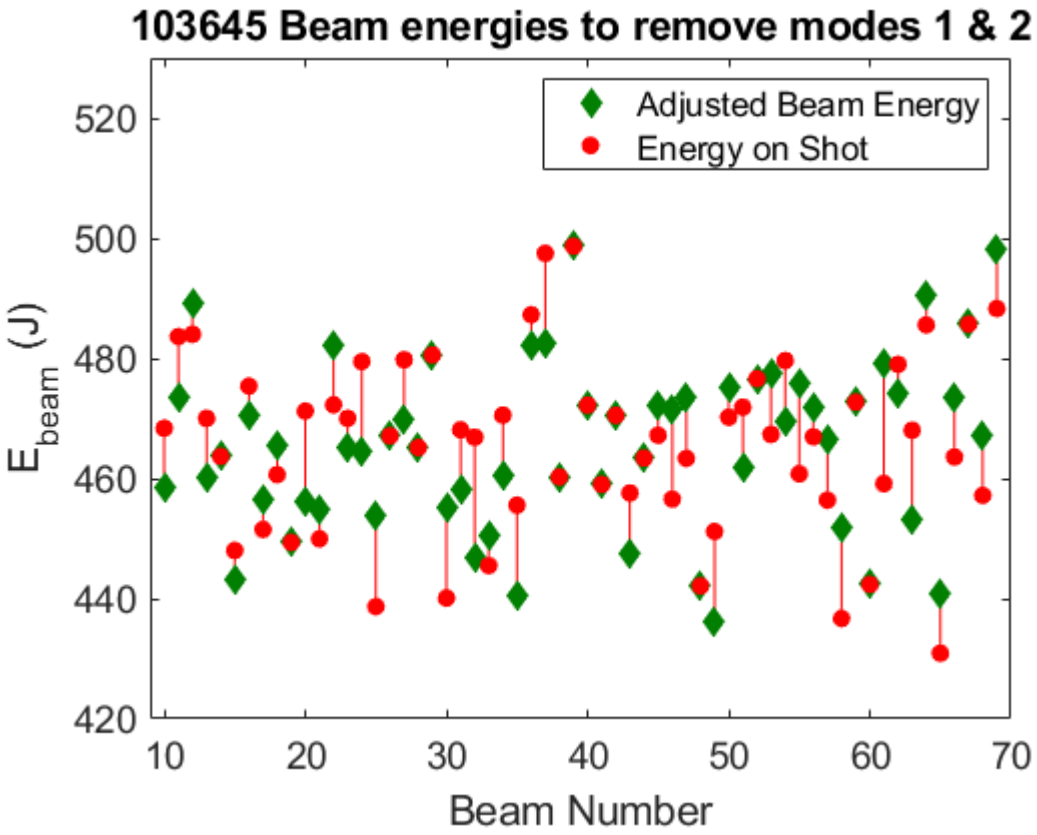
Beam Power Balance 0.65
Beam Pointing 0.56
DPR Polarization 0.39
All of the Above 0.69

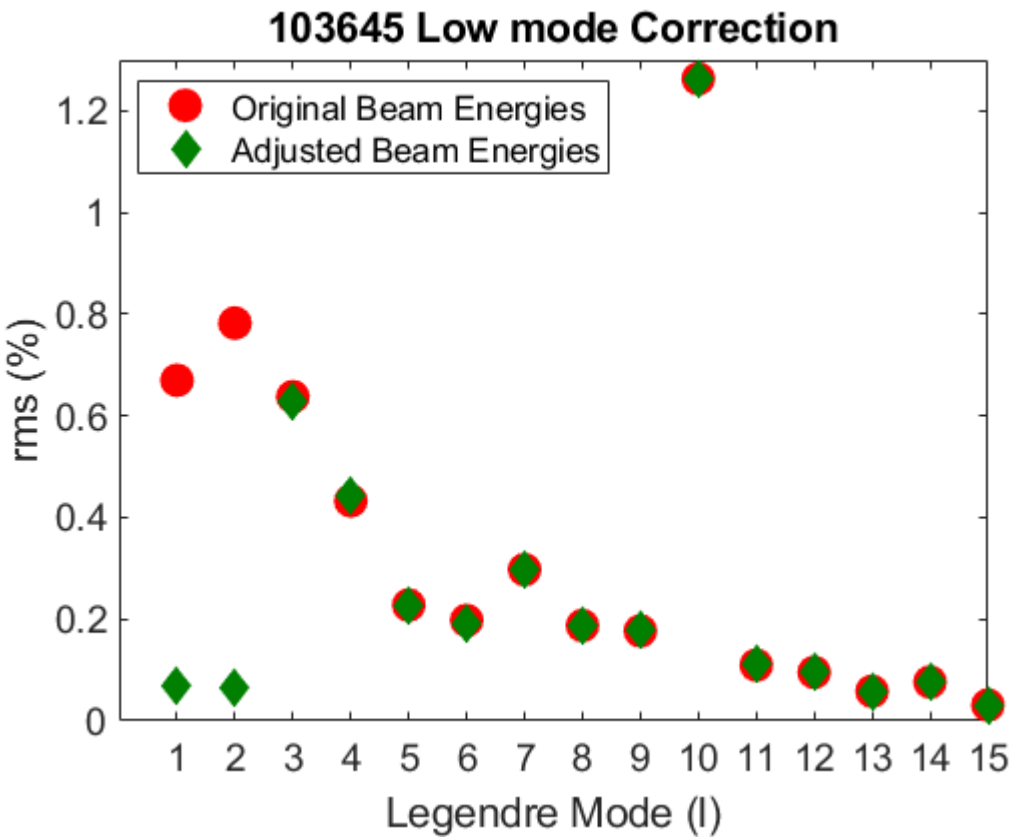
It should be possible to correct low modes using the beam energy balance

- **Beam energy balance is very persistent over a shot day**
  - **for the same pulse shape**
- **Small adjustments to beam energies could compensate for persistent low modes due to not only the beam balance but also CBET polarization and beam pointing**



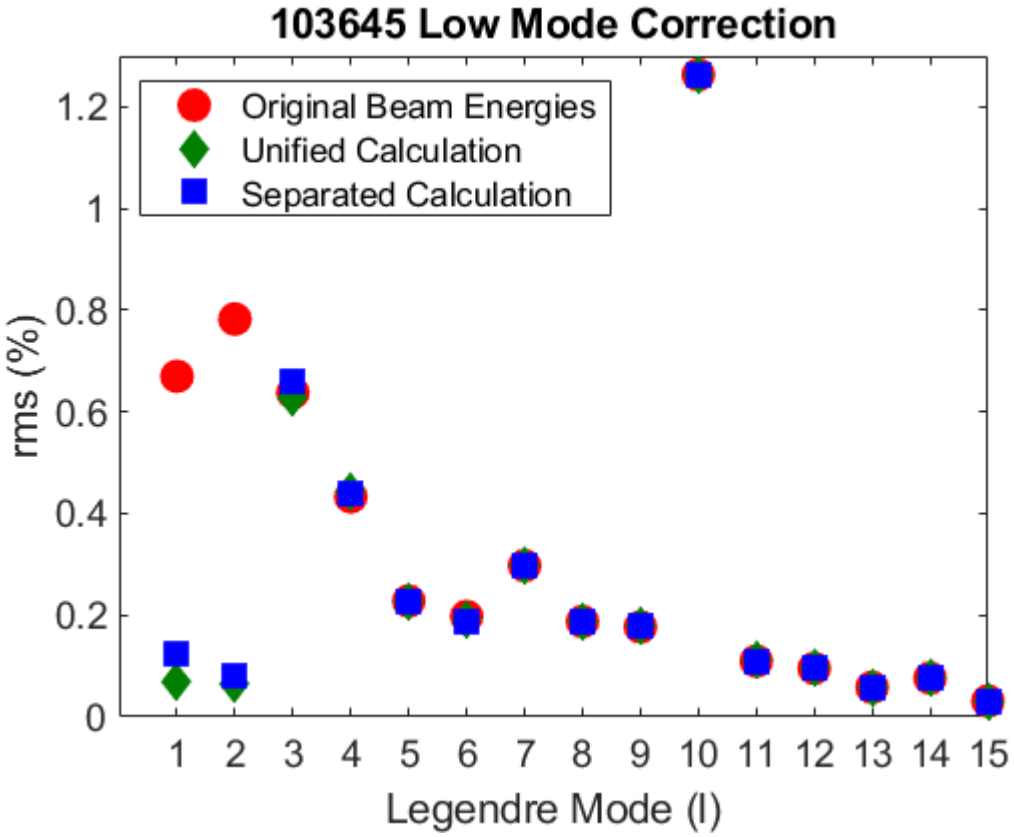
Predictions indicate that the ℓ = 1 & 2 modes could be greatly reduced by modest adjustments in beam energies





- **Beam energy changes limited to adjustments of ±5J, ± 10J, ± 15J, etc. (based on laser operation limits)**

On a shot day, CBET polarization effects must be pre-calculated then combined with non-polarized calculations of the beam balance & pointing effects



The absorption low modes may soon be significantly reduced by upgrades to OMEGA

- **Physical changes to OMEGA over the next couple of years should significantly reduce the absorption nonuniformity**
  - **A Target Alignment Monitoring System (TAMS) will allow frequent targeting checks and beam pointing correction throughout the course of a shot day (~ 1 year)**
  - **Random Continuous Polarization (RCP) plates are being implemented to remove the non-uniformity due to the DPRs and polarization CBET (~ 2 years)**

- **Beam energies could still be adjusted to minimize residual low modes**

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