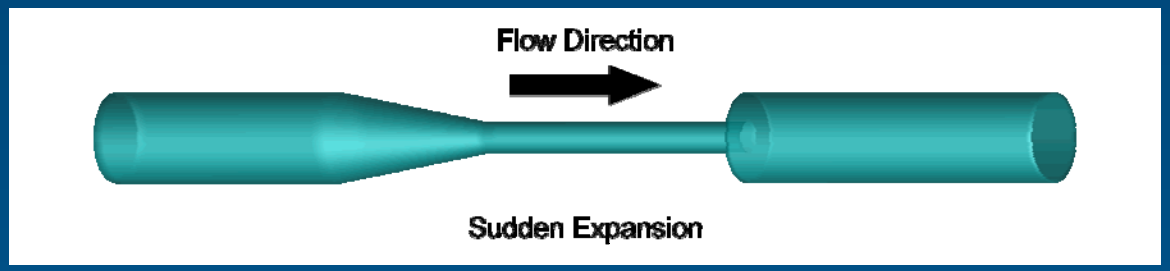
FDA'S Interlaboratory Computational Study Of Flow In A Nozzle Model: Using Experimental Results To Refine Simulations

Sandy F.C. Stewart[1], Prasanna Hariharan[1], Greg W. Burgreen[2], Eric G. Paterson[3], Varun Reddy[3], Steven W. Day[4], Matthew Giarra[4], Keefe B. Manning[3], Steven Deutsch[3], Matthew R. Myers[1], Michael R. Berman[1], Richard A. Malinauskas[1]

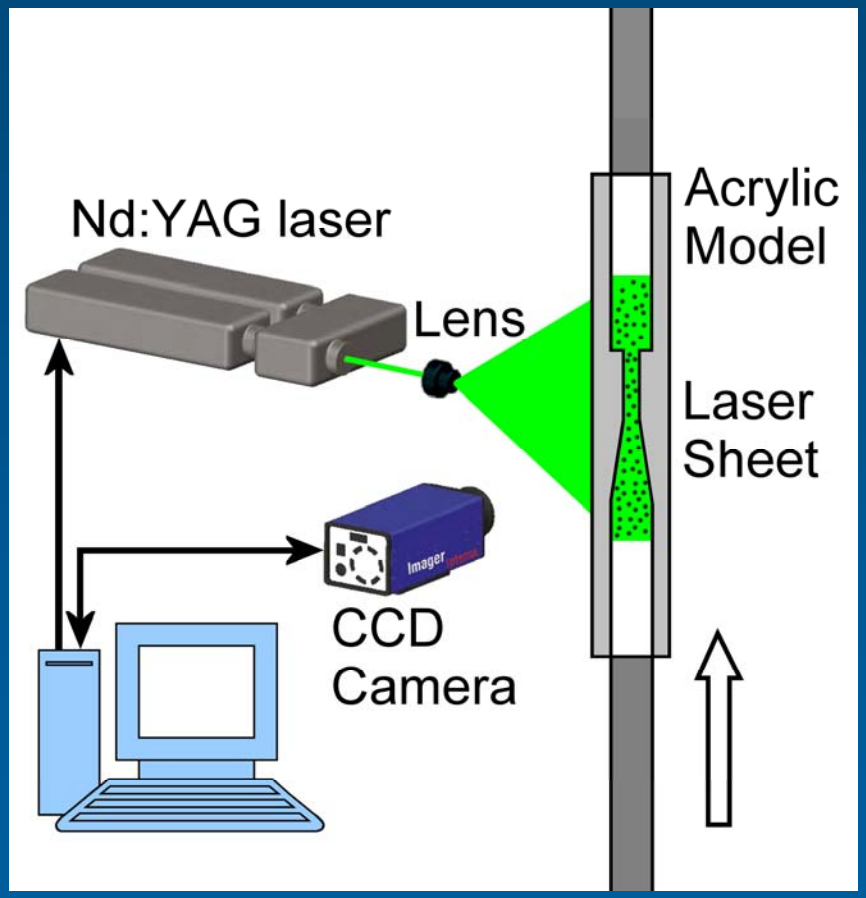
[1]Food & Drug Administration, [2]Mississippi State University, [3]Pennsylvania State University, [4]Rochester Institute of Technology

Computational Round Robin



- 5 flow rates with throat Reynolds number (Re_t) = 500, 2000, 3500, 5000, and 6500
- 28 groups submitted simulation results (including 3 from organizing committee)
- Experimental validation performed via particle image velocimetry (PIV) at 3 labs

Experimental Validation

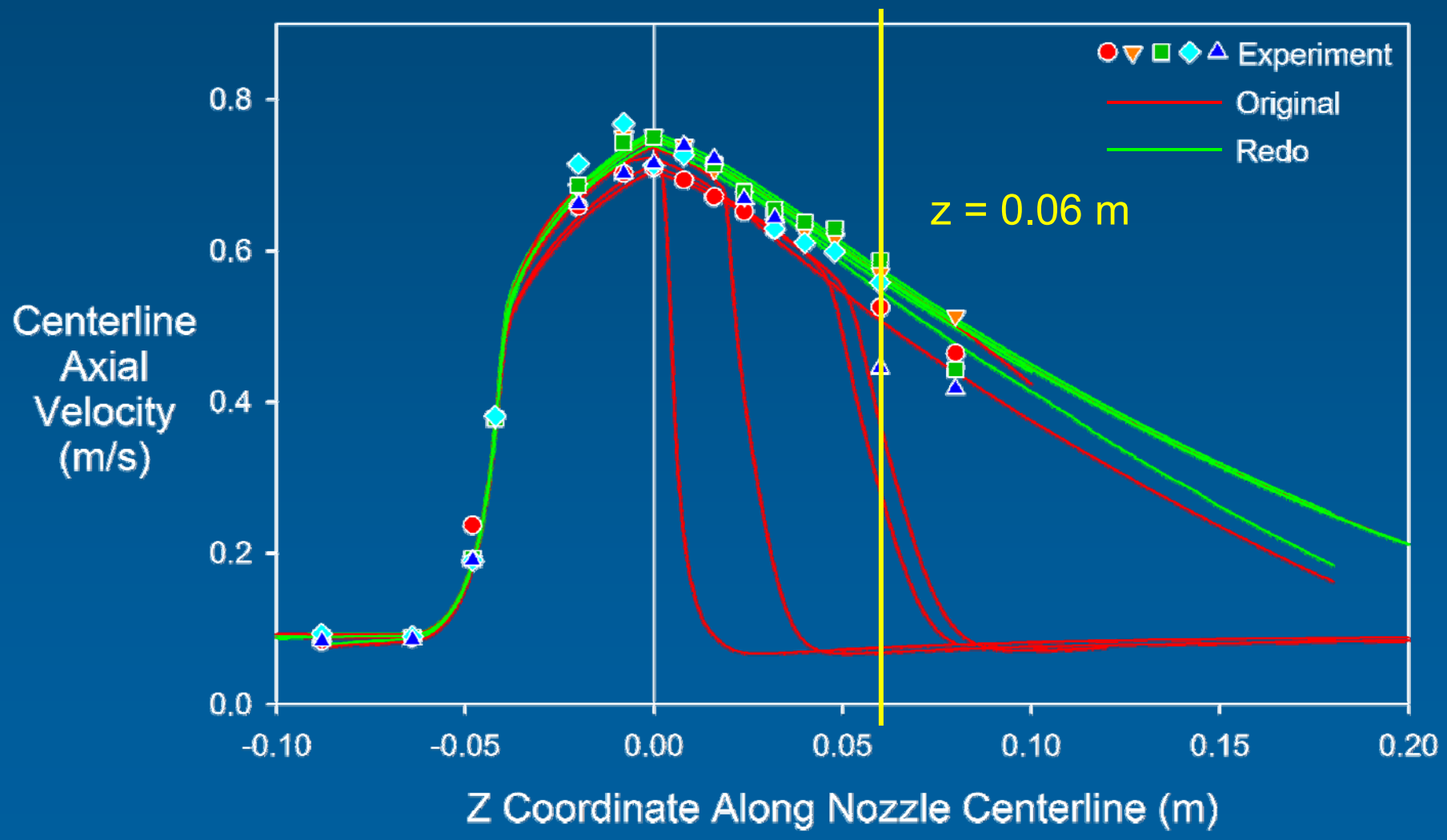


- Blood analog fluid: 50% NaI, 20% Glycerin, 30% water
- Refractive index matches acrylic model
- PIV performed at same Reynolds numbers as CFD
- PIV results scaled to match CFD fluid properties

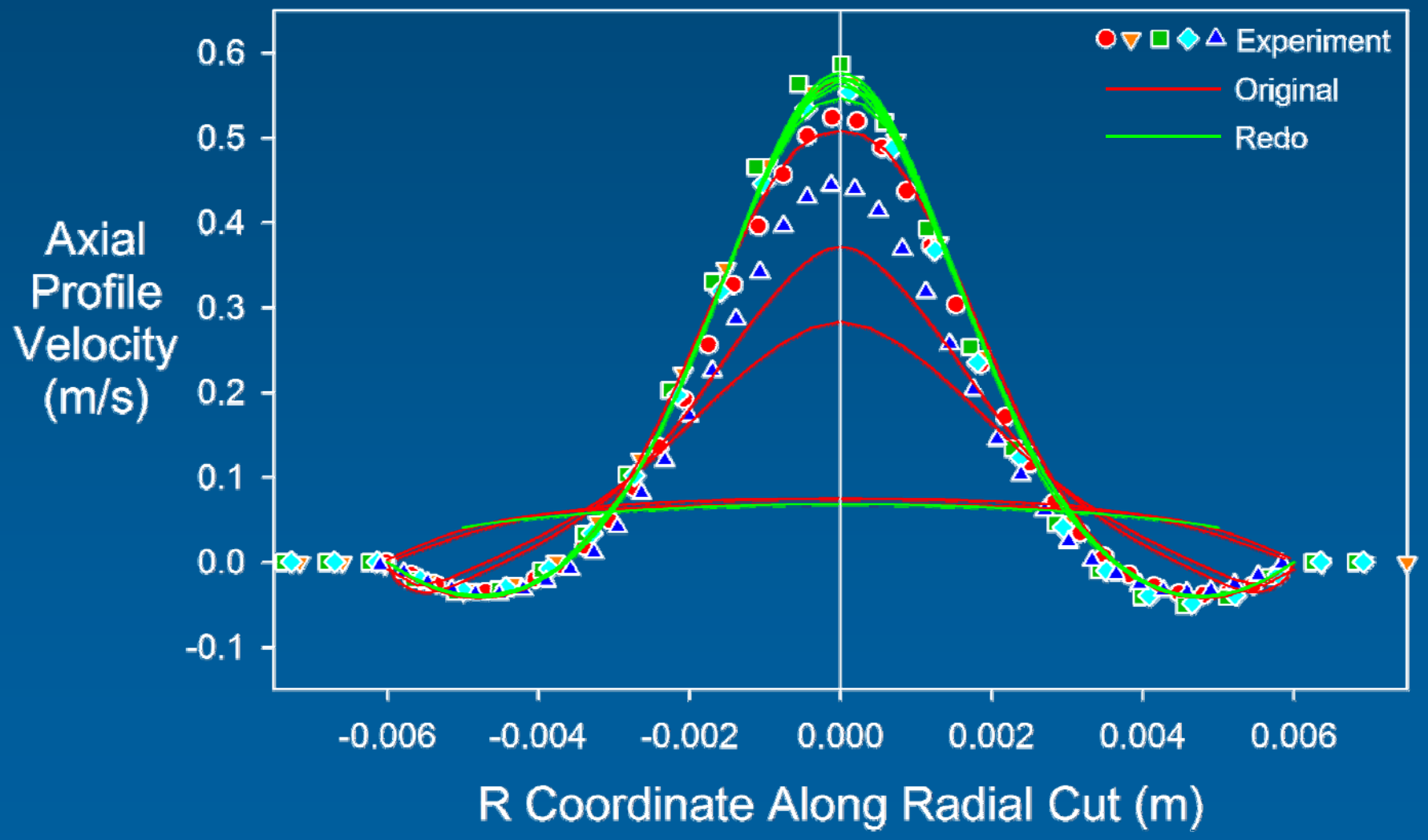
Validating CFD to Experiment

- Asked participants to redo simulations & match results to experimental data
- Sudden Expansion
- Re = 500 and 3500
- 10 outside groups provided redo simulations
- 3 in organizing committee also redid simulations

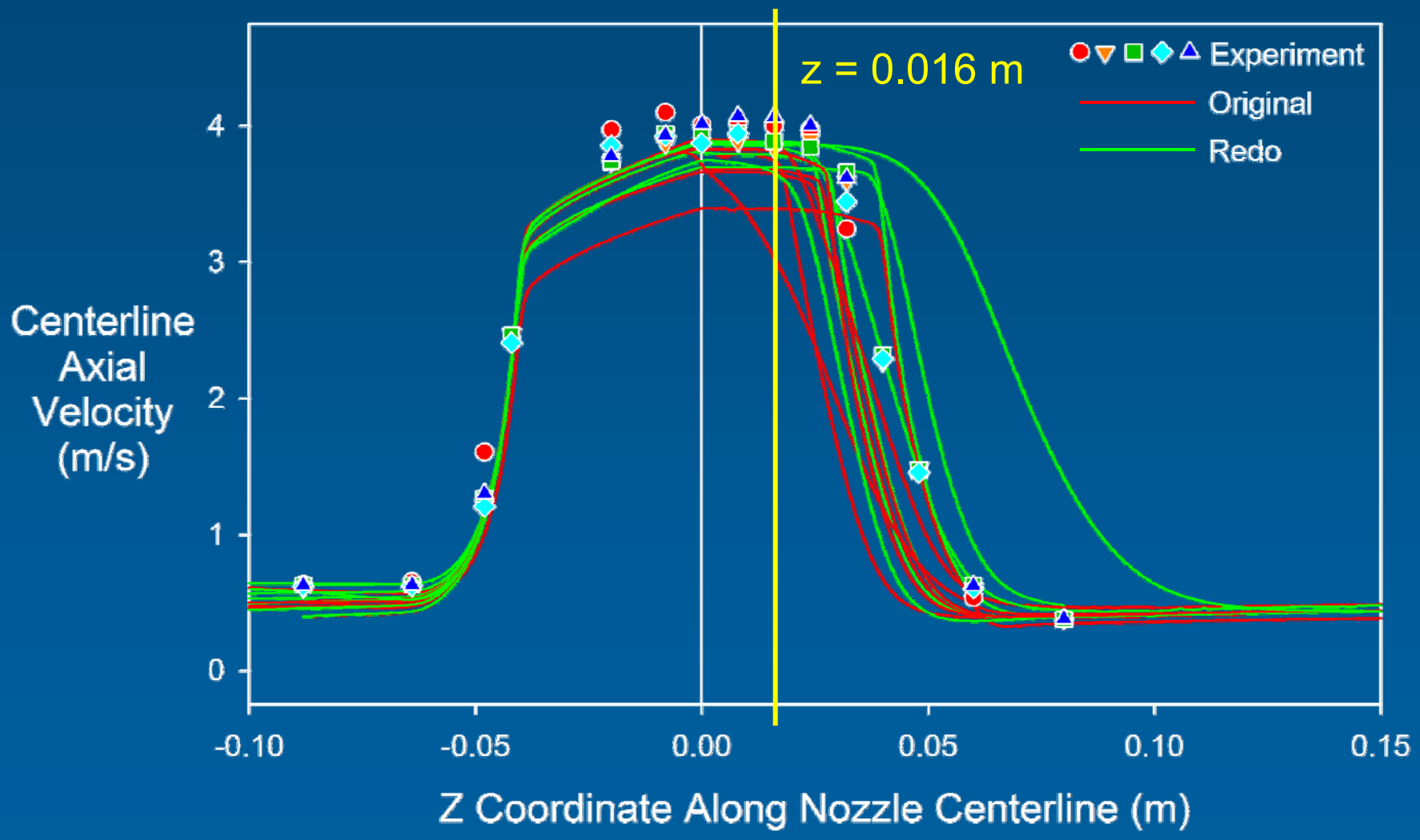
Re_t = 500, Centerline Velocity



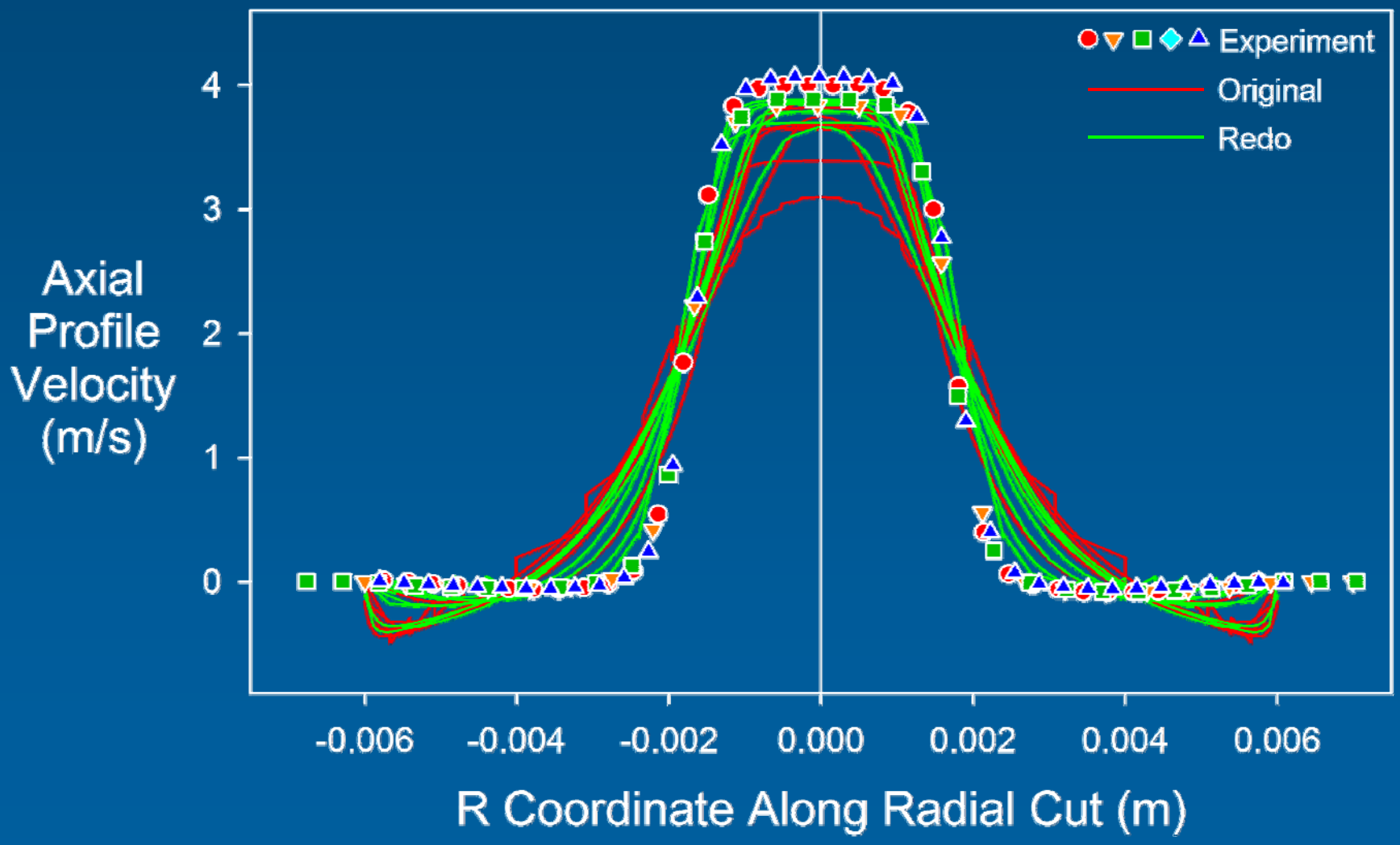
Re_t = 500, Velocity Profile (0.06 m)



Re_t = 3500, Centerline Velocity

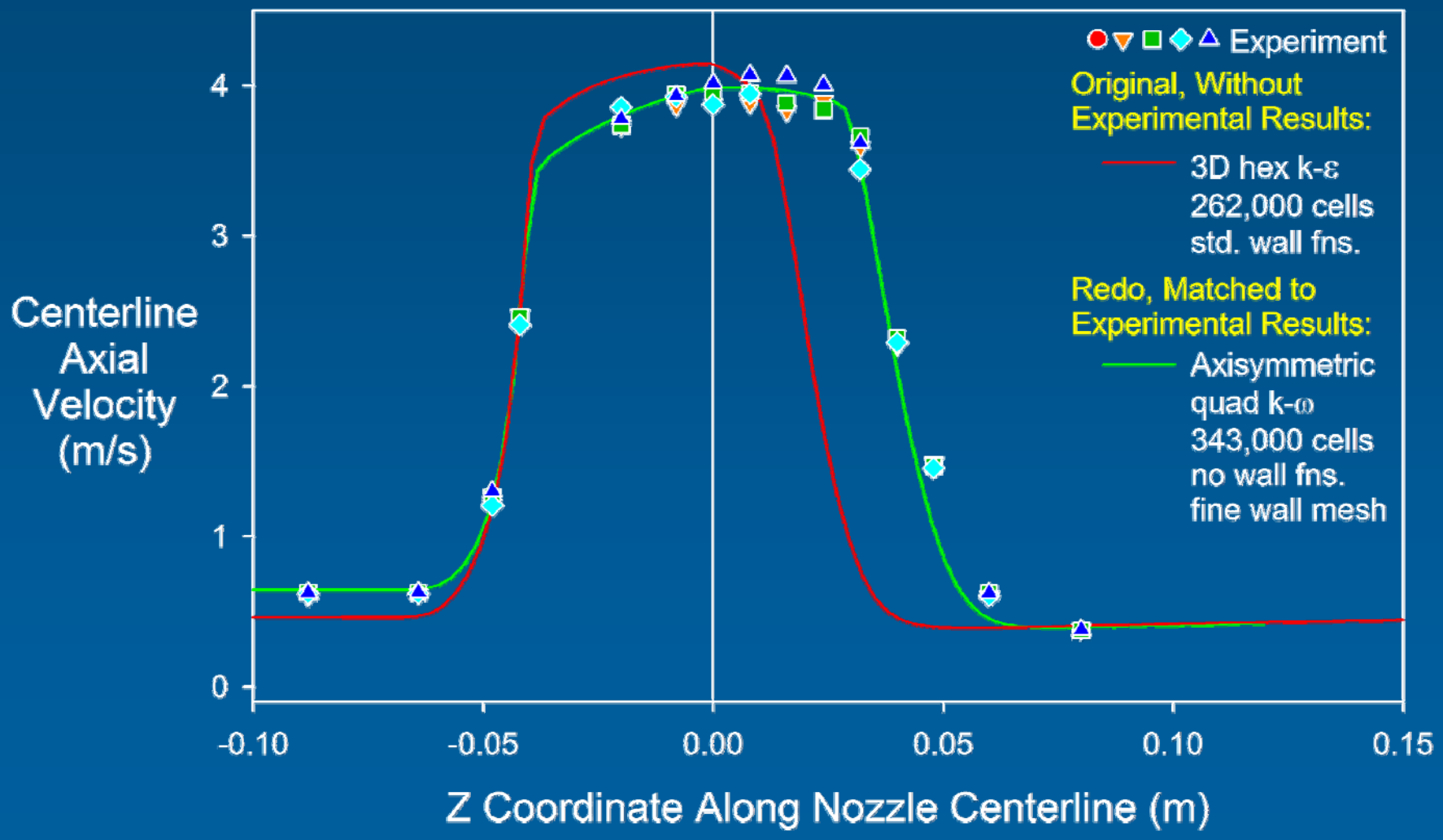


Re_t = 3500, Velocity Profile (0.016 m)



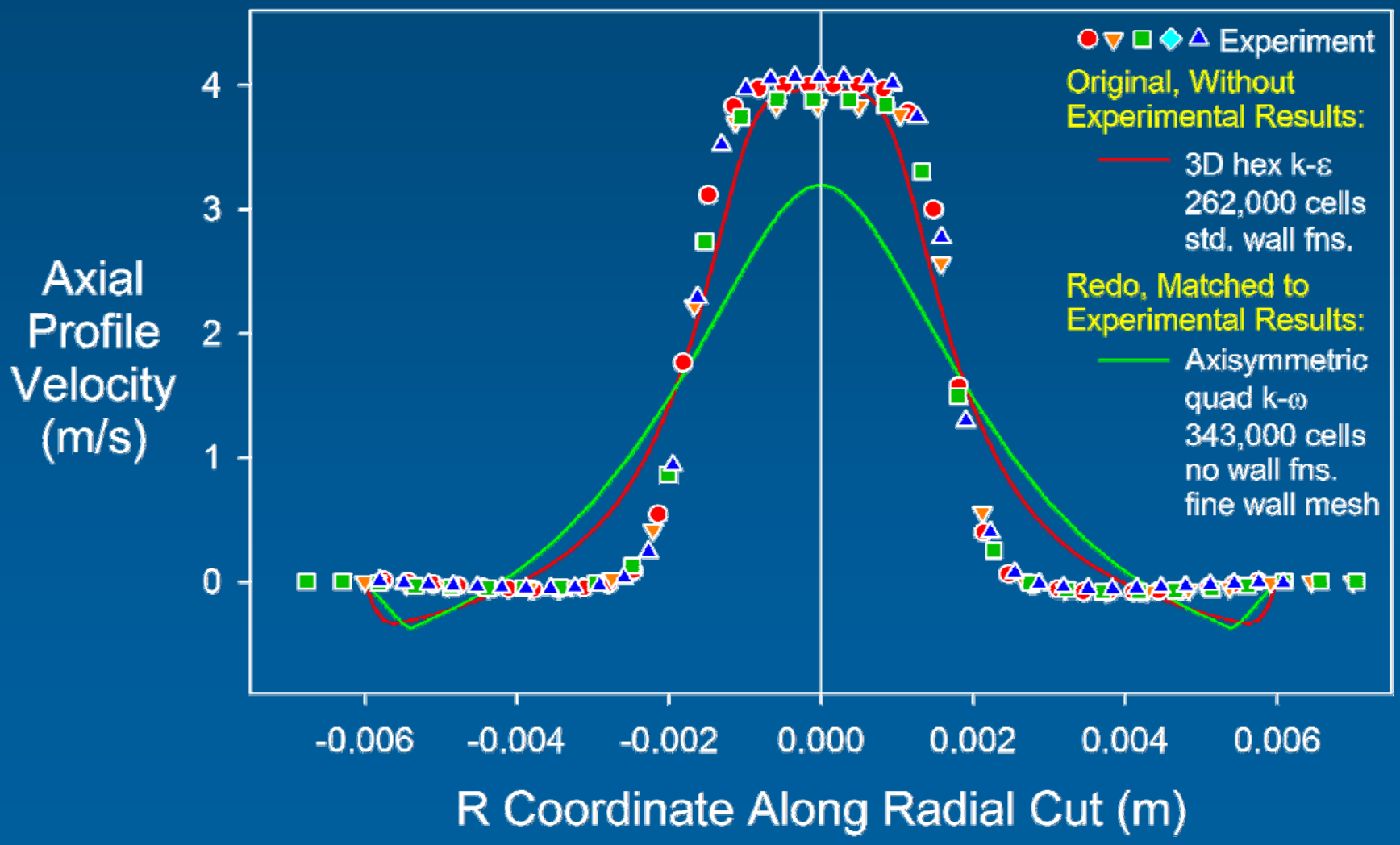
Simulation Redo – Internal Study

Re_t = 3500, Centerline Velocity



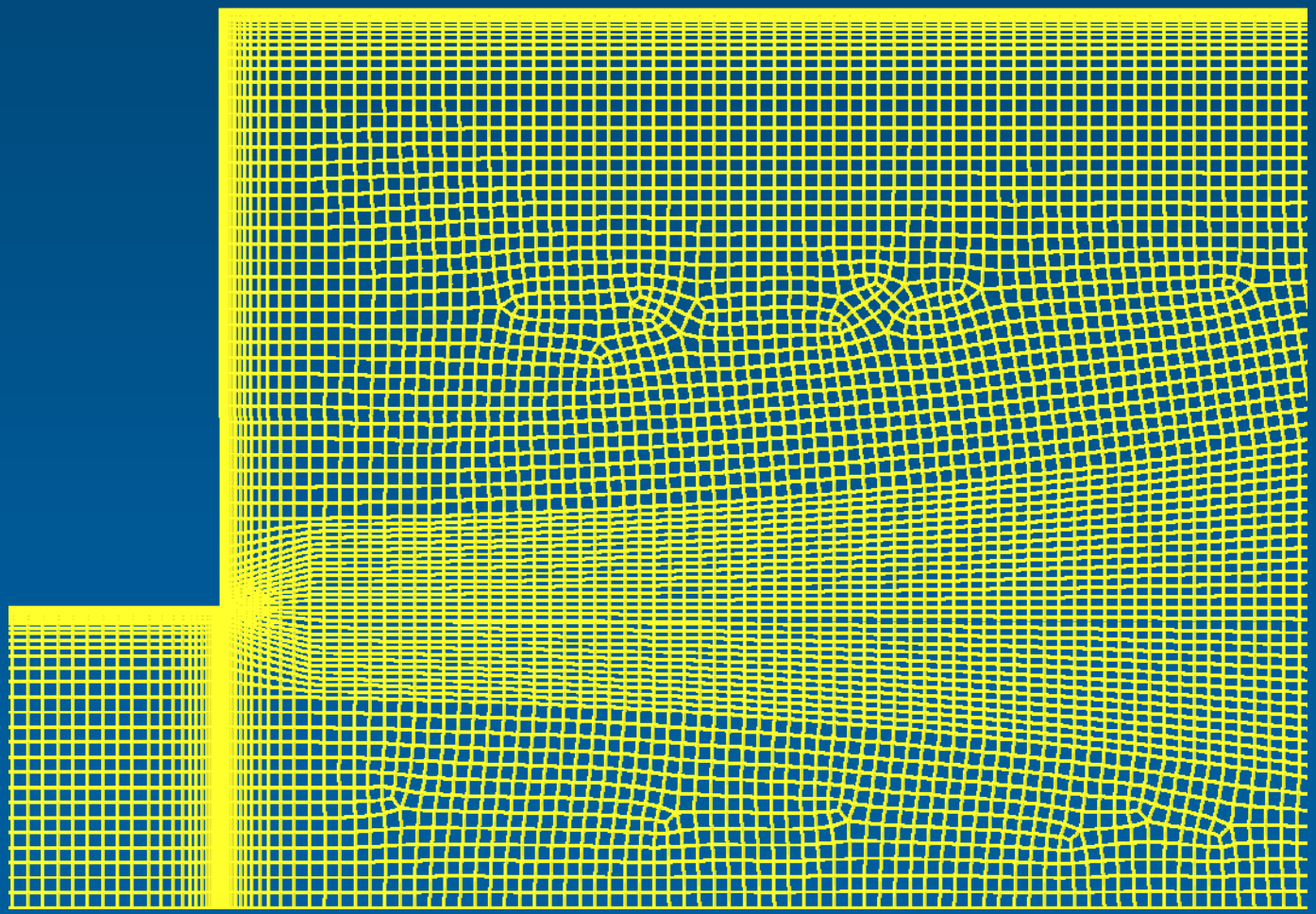
Simulation Redo – Internal Study

Re_t = 3500, Velocity Profile (0.016 m)



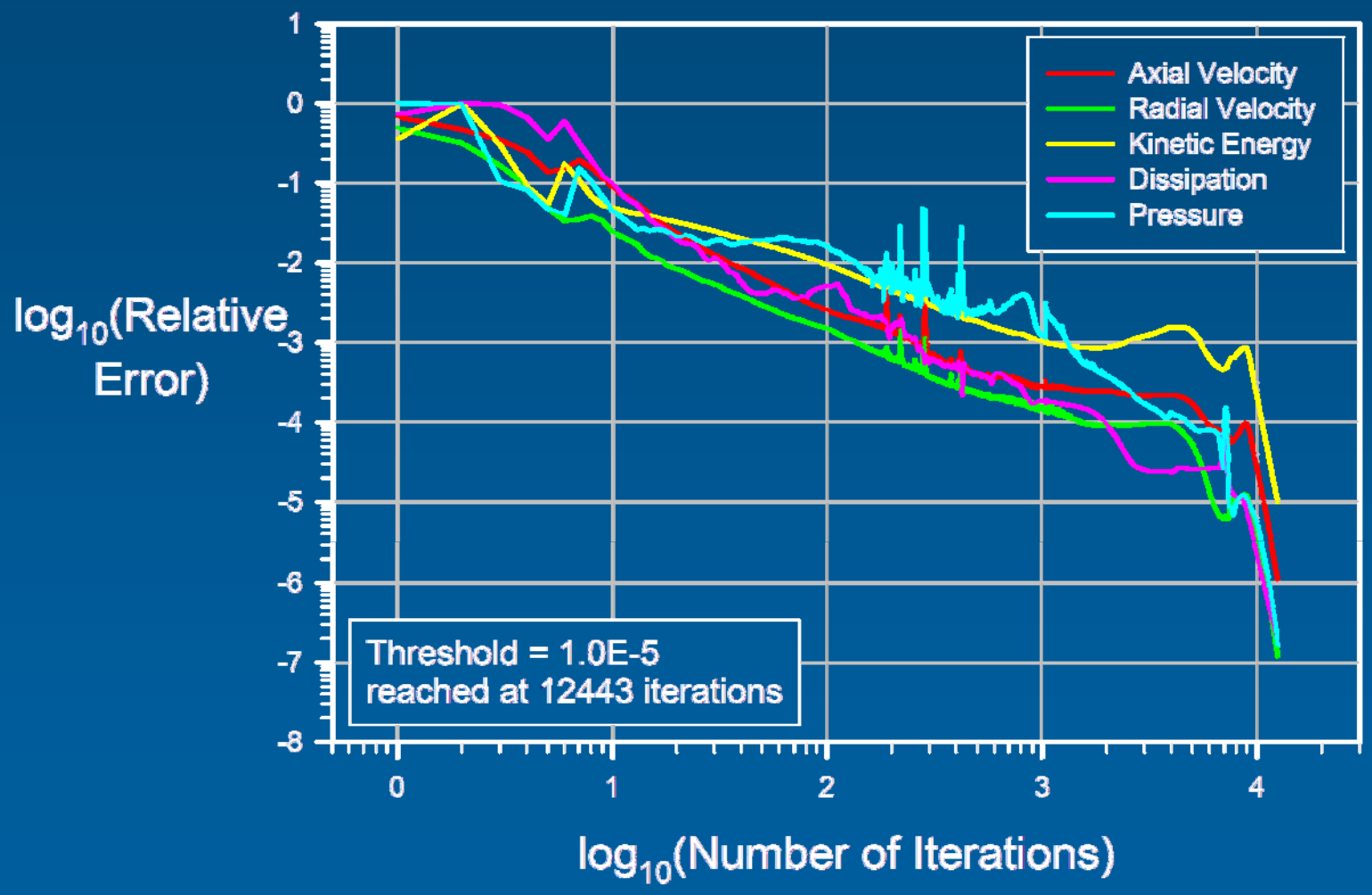
Mesh Used in Internal Study Redo

Re_t = 3500 (k-ω, fine mesh, no wall functions)



Convergence in Internal Study Redo

Re_t = 3500 (k-ω, fine mesh no wall functions)



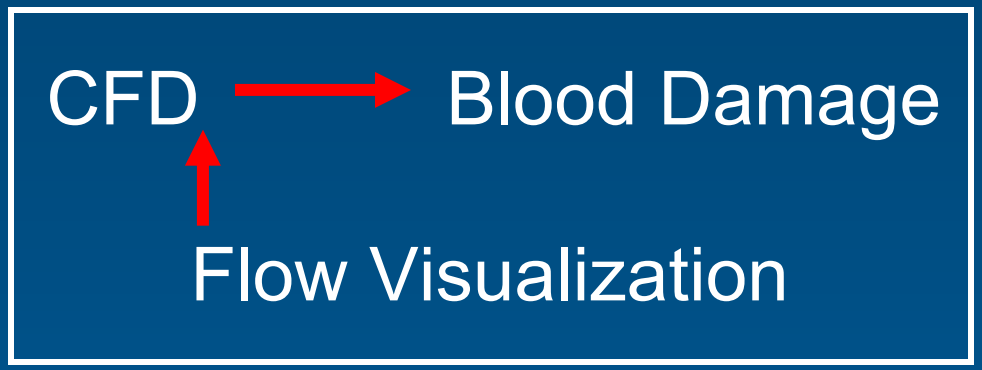
A Few Best Practices

- Choose appropriate physics
  - Choose the right turbulence model if needed
- Choose appropriate boundary conditions and inlet/outlet lengths
- Ensure conservation of mass
- Grid refinement studies are necessary but must be combined with other good practices
- In the transitional regime, experimental results may not be unique

A Few Best Practices

- Transitional cases may require time-dependent or LES model to fully capture details
- Good methods from ***this*** study may not be transferable to ***other*** devices/flow regimes
- Good convergence criteria is essential
- VALIDATION
- VALIDATION
- VALIDATION

Future of FDA Project



- Blood damage testing under way at 3 labs for comparison
- VAD prototype is being tested for future interlaboratory CFD/PIV study
- FDA to work with standards group (AAMI, ASME)

Acknowledgments

We sincerely thank our 49 study participants, from 6 countries

Yared Alemu
K. Amano
J. Ashton
Mehdi Behbahani
Catrin. Bludszuweit-Philipp
Danny Bluestein
Parnian Boloori-Zadeh
Alistair Brown
Scott Corbett
Julien de Charentenay
D. de Zelicourt
Wade Dummer
K. Fraser
Leonid Goubergrits
Kurt Graichen
Linden Heflin
Darren Hitt
Marcus Hormes
Marc Horner
Xueying Huang
S. Krishnan
S. Kühne
Patricia Lawford
Ming Li
Z. Li
William Louisos
Takehisa Mori
Alex Medvedev
Joerg Mueller
Sei Murakami
Mariagrazia Pilotelli
M. Polster
N. Reuel
T. Schauer
E. Sirois
Ken Solen
Ulrich Steinseifer
Wei Sun
S. Takahashi
Masaaki Tamagawa
K. Tan
Dalin Tang
Ertan Taskin
Z. Teng
R. Toyao
Dan White
Z. Jon Wu
M. Xenos
Ajit Yoganathan