2008 International ANSYS Conference

Mesh and Numerics Issues In a Turbomachinery CFD Analysis

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Scope of Presentation

- Mesh and Numerics Issues In a Turbomachinery CFD Analysis

or

- How to Get Into (and Out of) Bad Trouble Even with Good Code

or

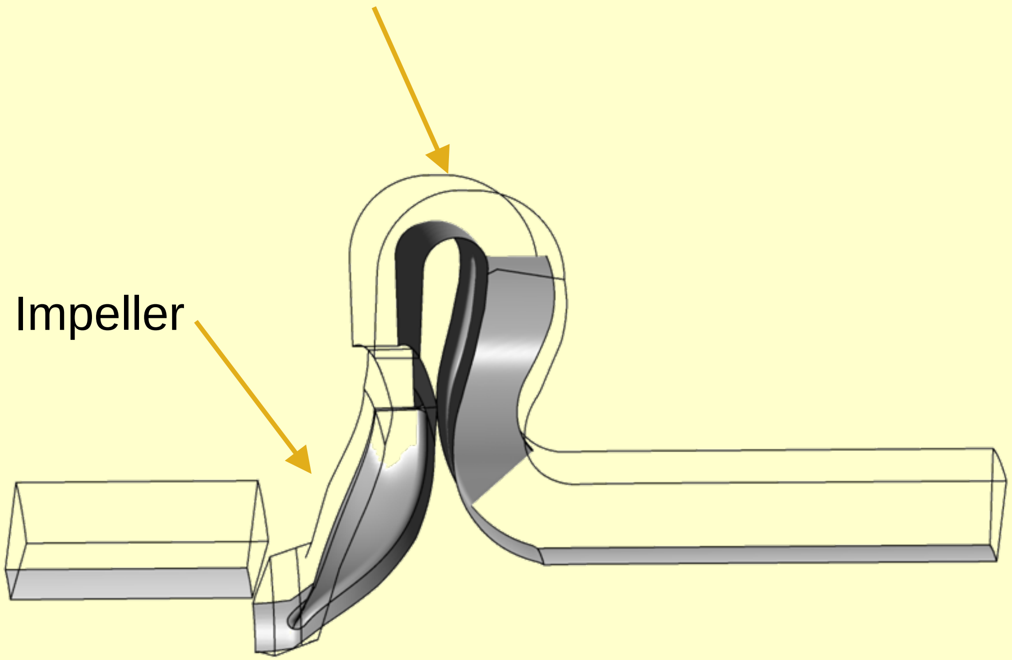
- How to Explain to Your Boss Why These Things Take So Long

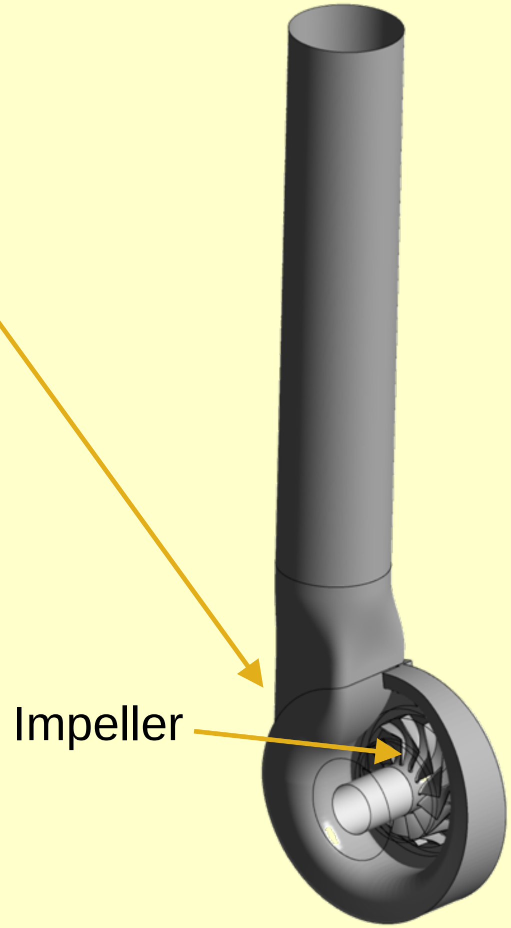
Scope of Presentation

- Excerpts from a larger task
- Not presented in chronological order
- Two CFD-specific issues:
  - Effect of mesh type and numerics on results
  - Selection of MFR interfaces

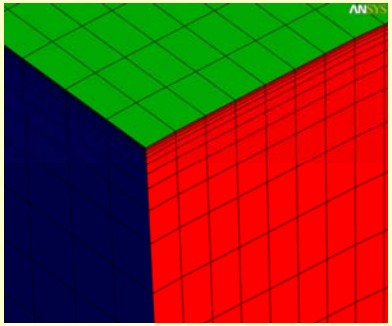
Scope of Presentation

- ANSYS CFX, ANSYS ICEMCFD
- Comparison of a compressor volute with a return channel

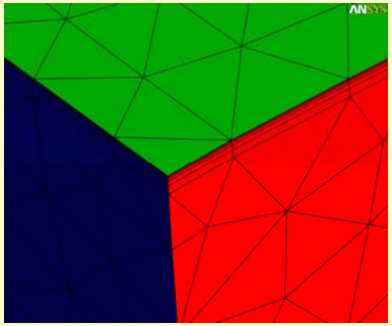




Hex Versus Tet/Prism Mesh



- Hex advantages
  - Runs faster (roughly 3 times)
  - Uses less memory (about half)
  - Often fewer nodes for similar resolution across passages (anisotropic density)
  - Maybe more accurate
- Tet advantage
  - Easier to build for complex geometry



The Mesh Question

- All models used hex mesh, until volute
- Volute used tet/prism, and somewhat lower density because of size
- Volute loss coefficient was unexpectedly low
- Was this result real? Or caused by mesh type, or mesh density, or some other difference?
- Launched a mesh study...

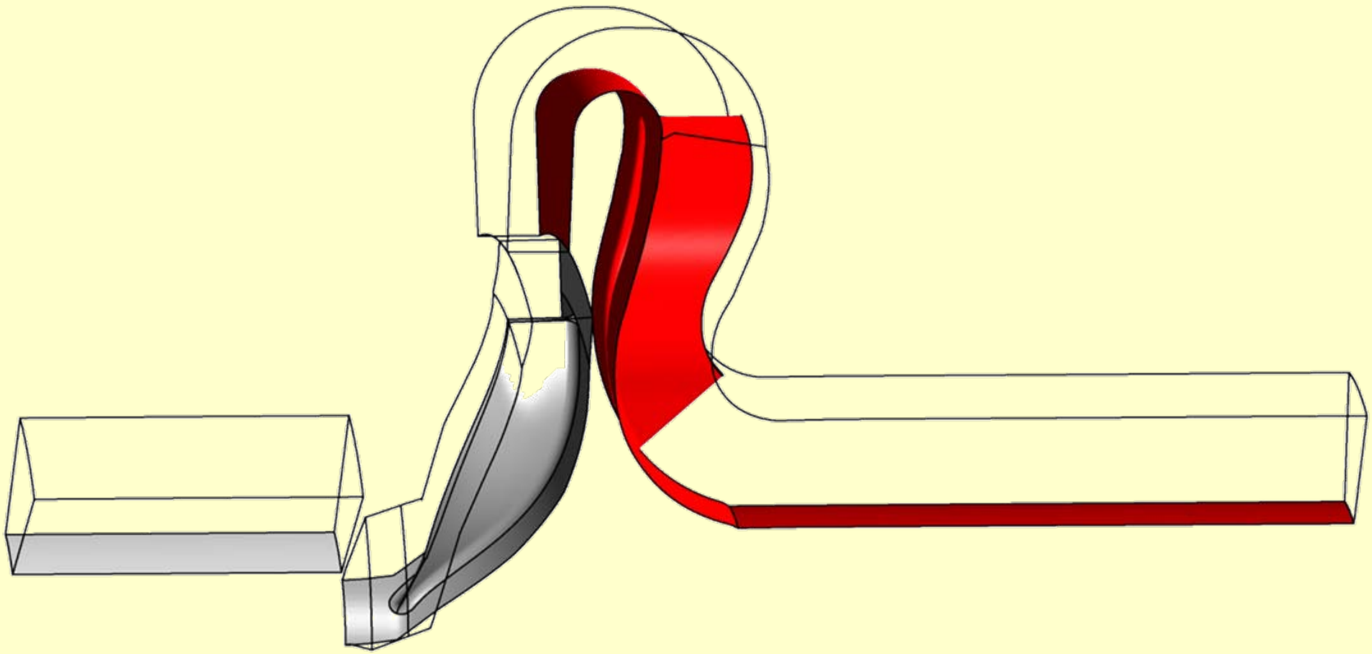
The Mesh Study — Grids

- Four versions of the single-passage return channel model, same geometry and conditions

Model	Mesh Type	Nodes	Description
Coarse hex	Hex	305,680	Global coarsening to be similar to fine tet
Fine hex	Hex	650,644	Original model
Coarse tet	Tet / Prism	179,590	Similar to volute
Fine tet	Tet / Prism	582,617	Global refinement of tets (not prism layers)

The Mesh Study — Models

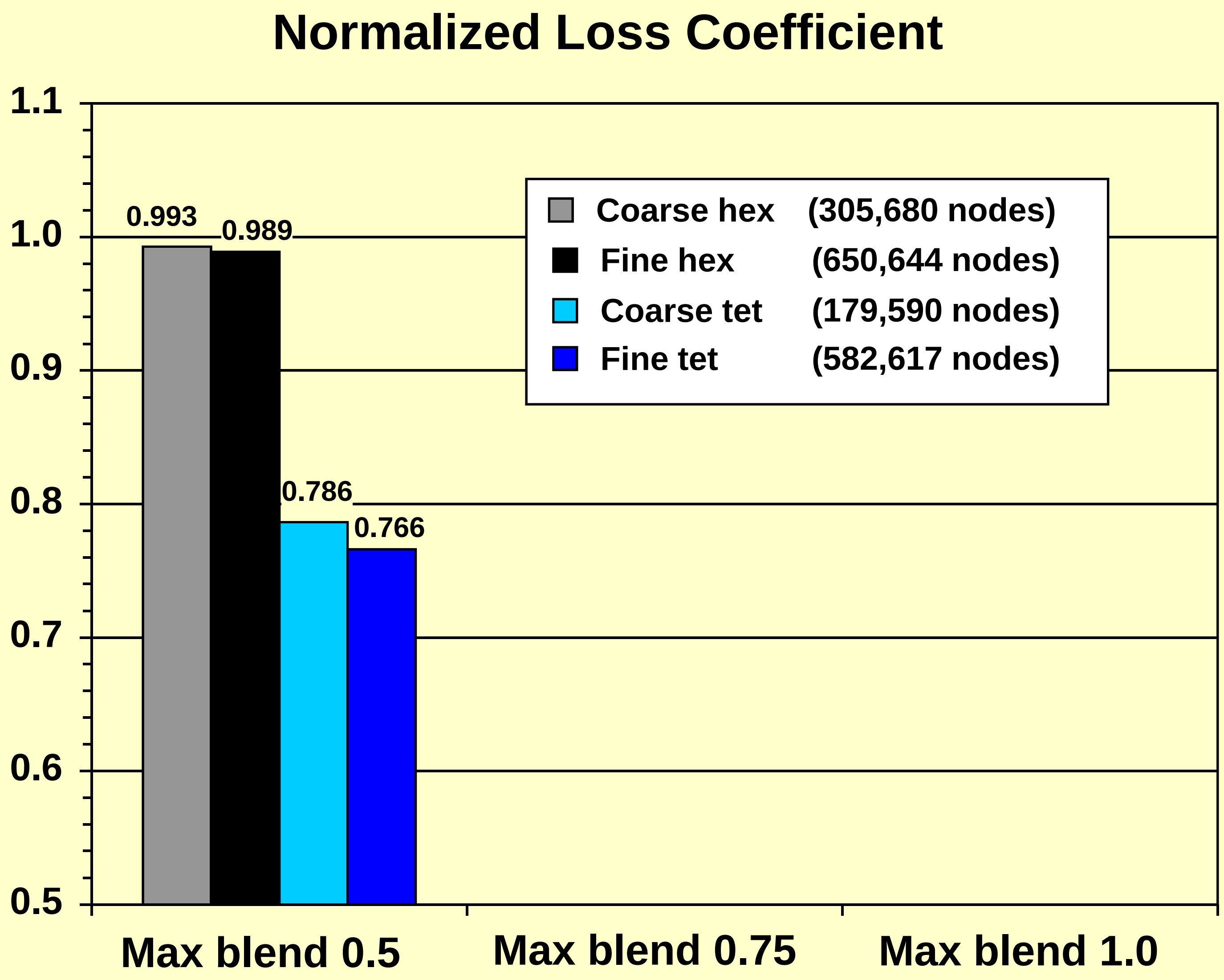
- Inserted each return channel model into the compressor stage model; same inlet and impeller



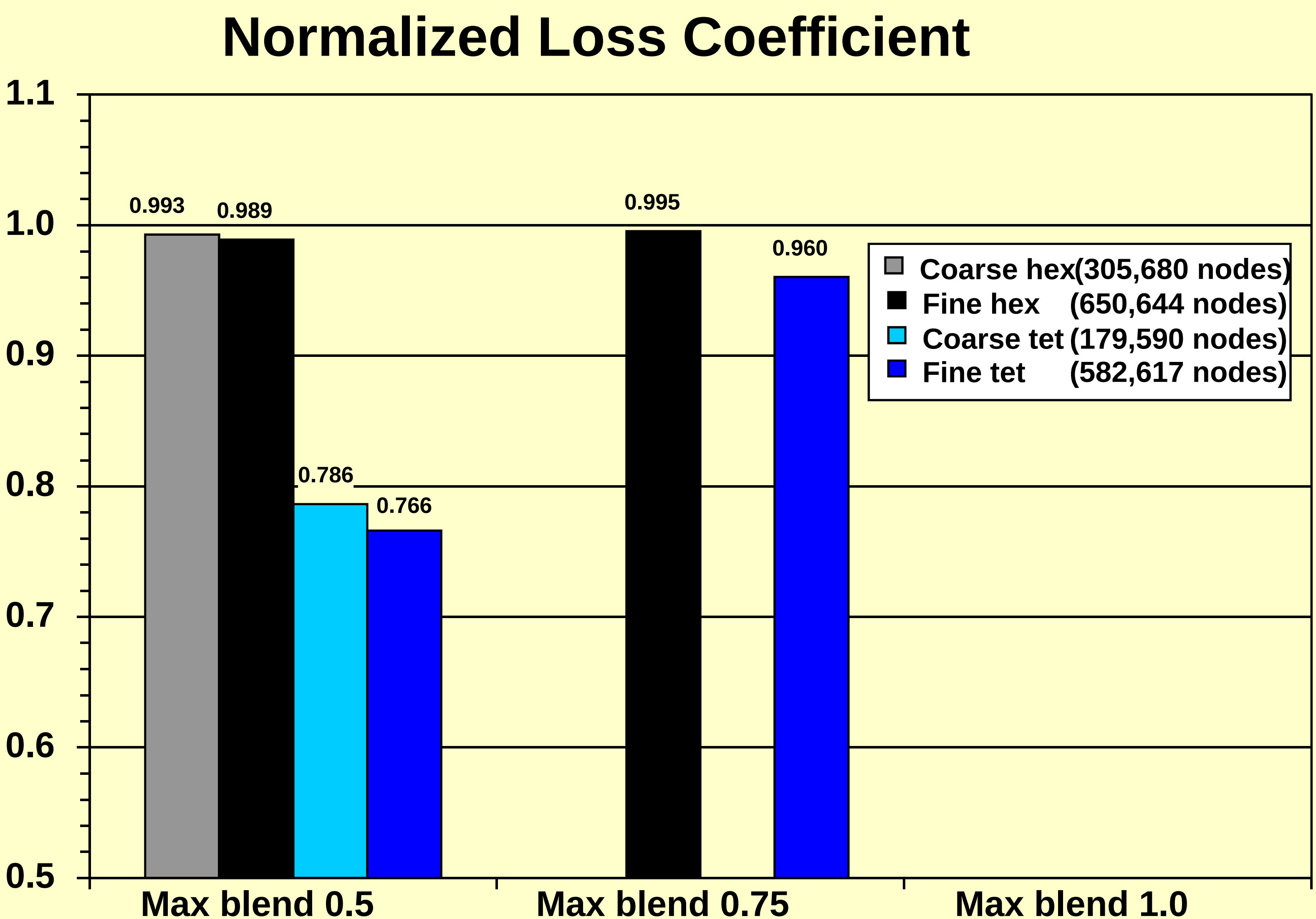
The Mesh Study — Other Parameters

- A long exploration of possible influences besides mesh
- Finally focused on Maximum Blend Factor used with high-resolution scheme
- Maximum Blend Factor had been set to 0.50, lower than recommended, because of convergence problems
- It was hoped that the runs, while less accurate in the absolute sense, would provide good comparisons

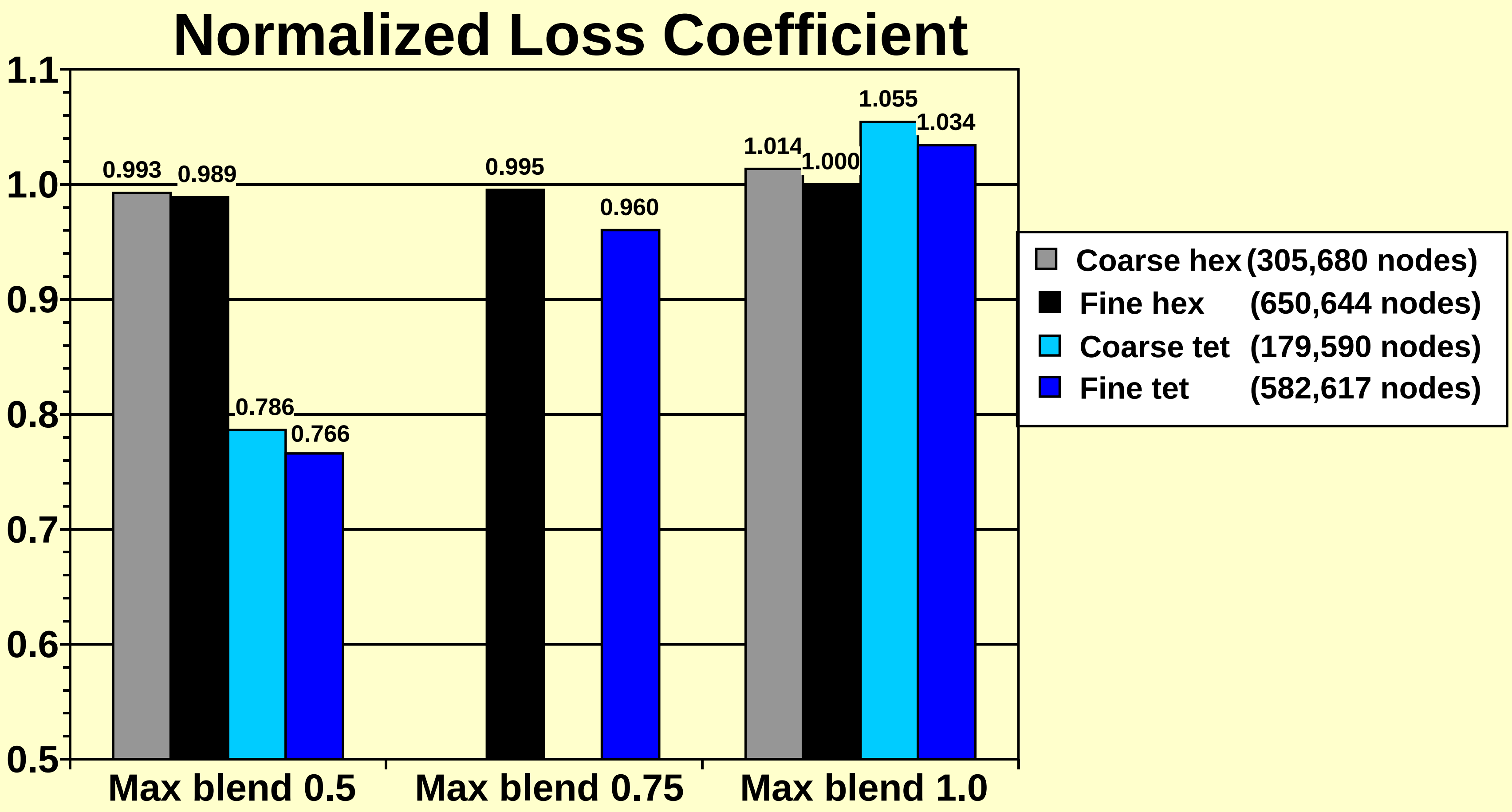
The Mesh Study — 0.5 Max Blend



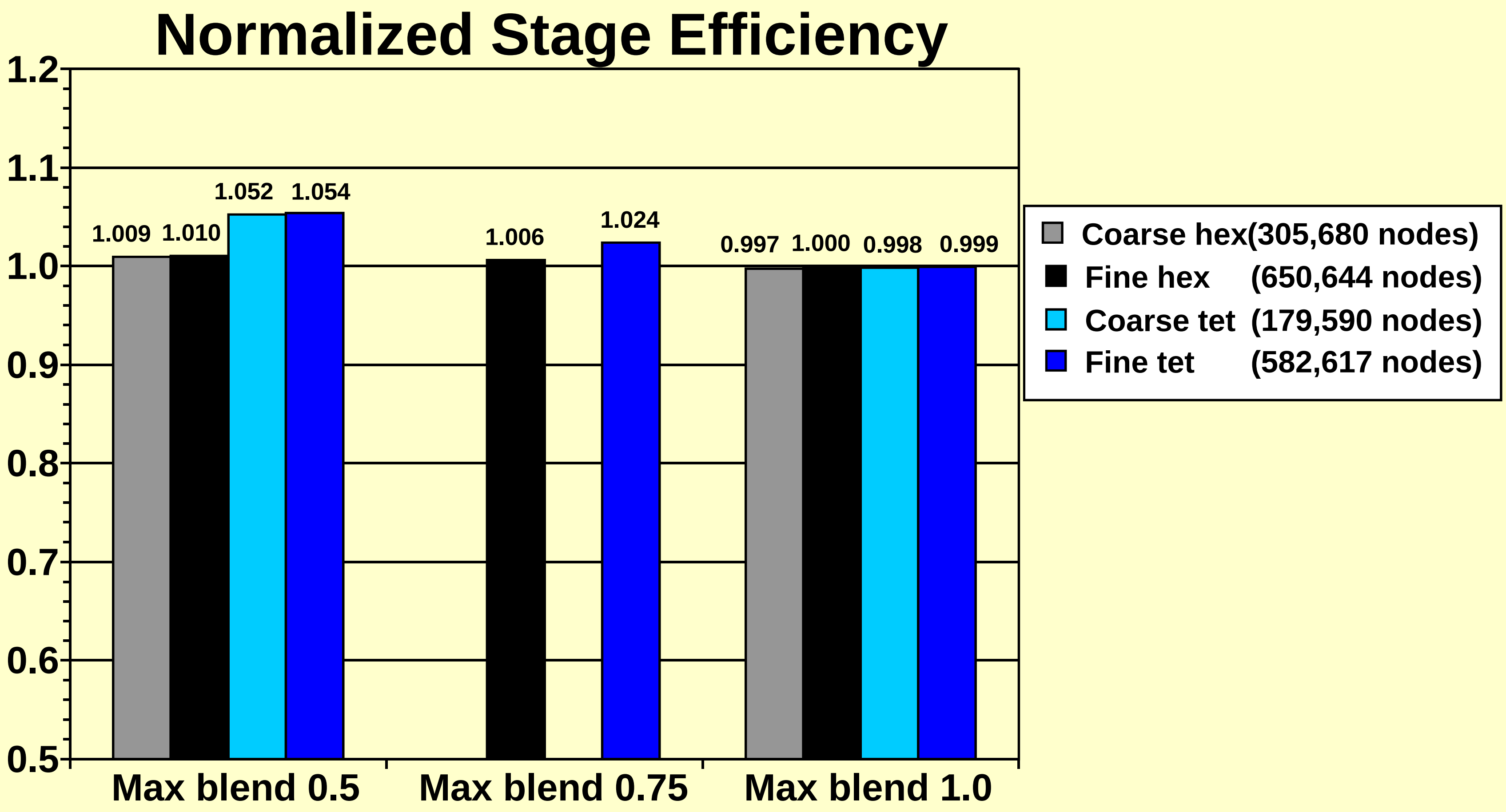
The Mesh Study — 0.75 Max Blend



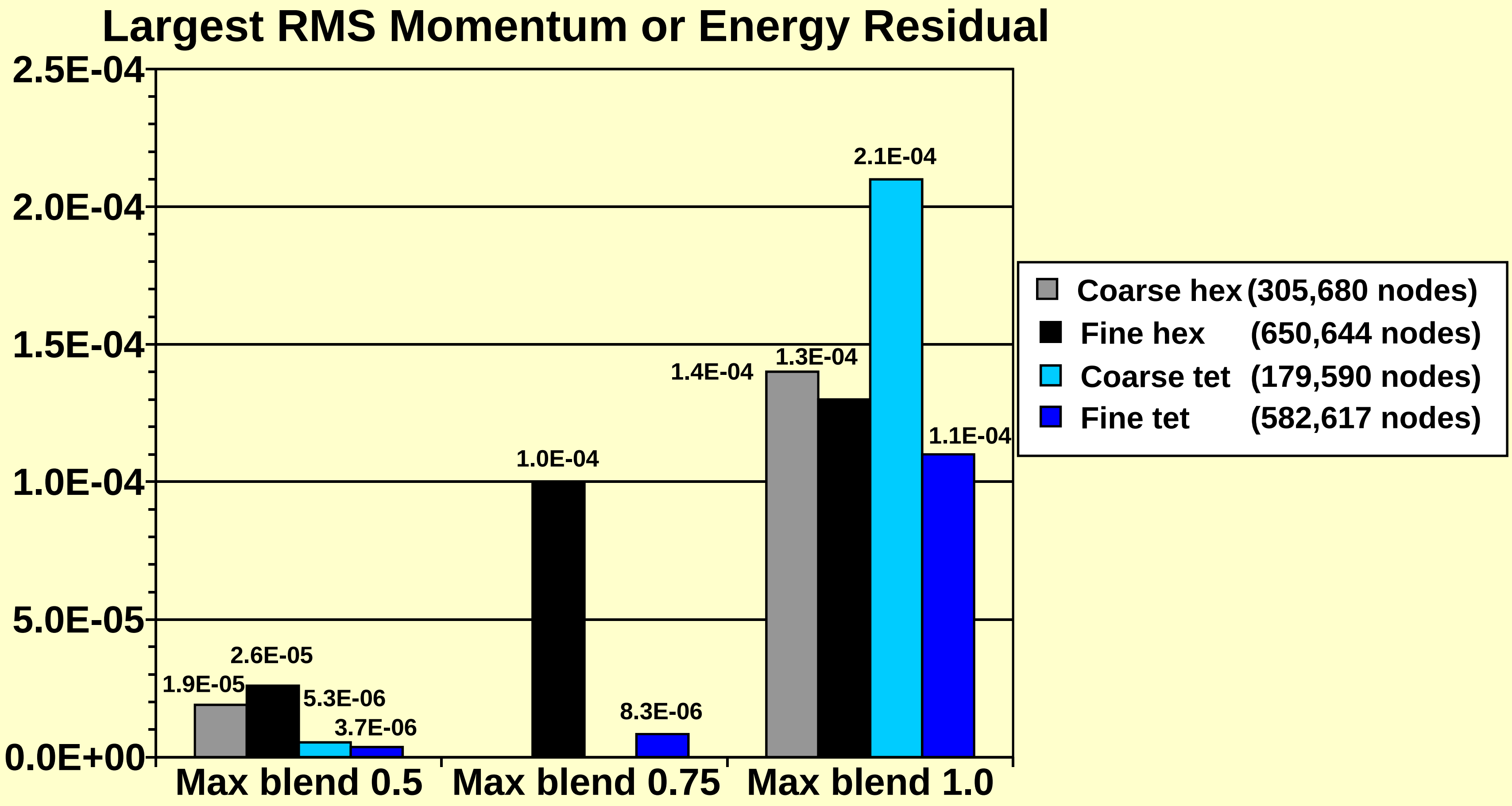
The Mesh Study — 1.0 Max Blend



The Mesh Study — Efficiency



The Mesh Study — Convergence

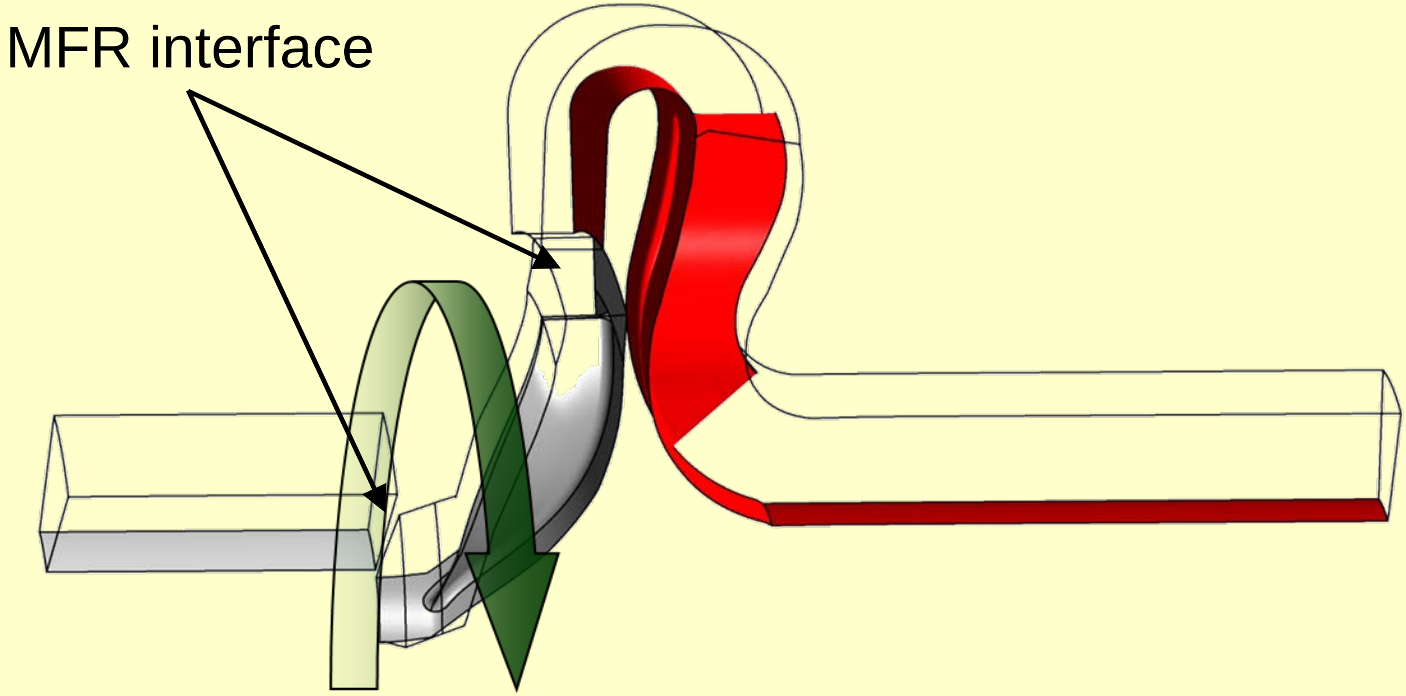


The Mesh Study — Convergence

- “Grid convergence” by node count alone is not enough
- Re-think definition of convergence
- Run residuals down as much as possible
- Use monitor expressions (like pressure ratio) and run until they’re stable
- Output a couple of sets of results, calculate performance on each, and compare them
- **Higher-order solution gives accuracy and consistency, more important than low residuals**

MFR Interfaces

- Three ways in ANSYS CFX to change between stationary and rotating frames of reference



MFR Interfaces — Stage

- Steady-state approximation to transient
- Circumferential averaging
- Loses wakes and other circumferential variations
- Theta extents needn't match (single passage)
- For high rotation speed

MFR Interfaces — Frozen Rotor

- Steady-state approximation to transient
- No averaging
- Can capture circumferential nonuniformity
- Can over-emphasize circumferential effects by not allowing rotor to move
- Results can depend on rotor position
- For low rotation speed

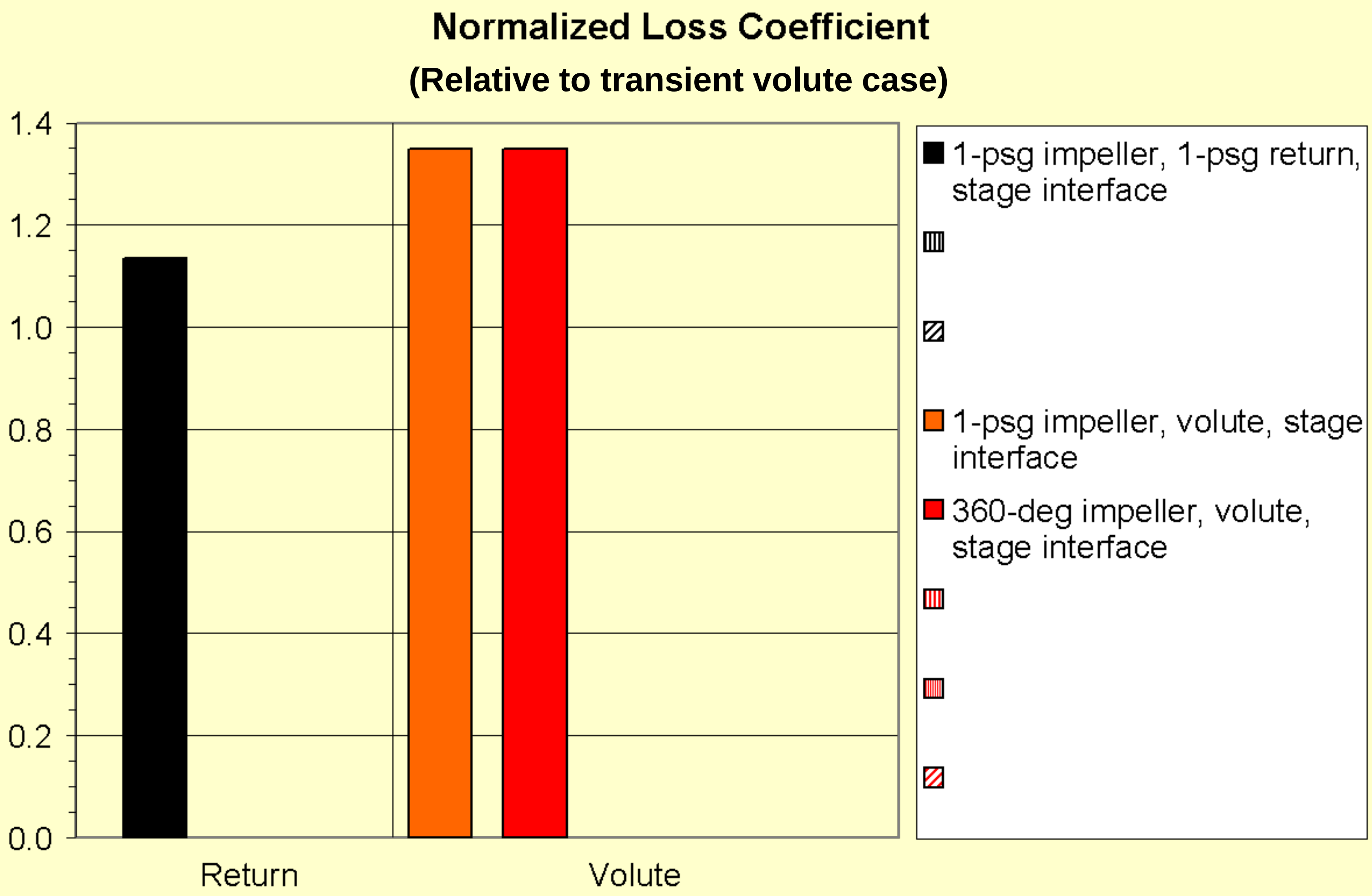
MFR Interfaces — Transient

- Most accurate
- Slow to run
- Hard to postprocess

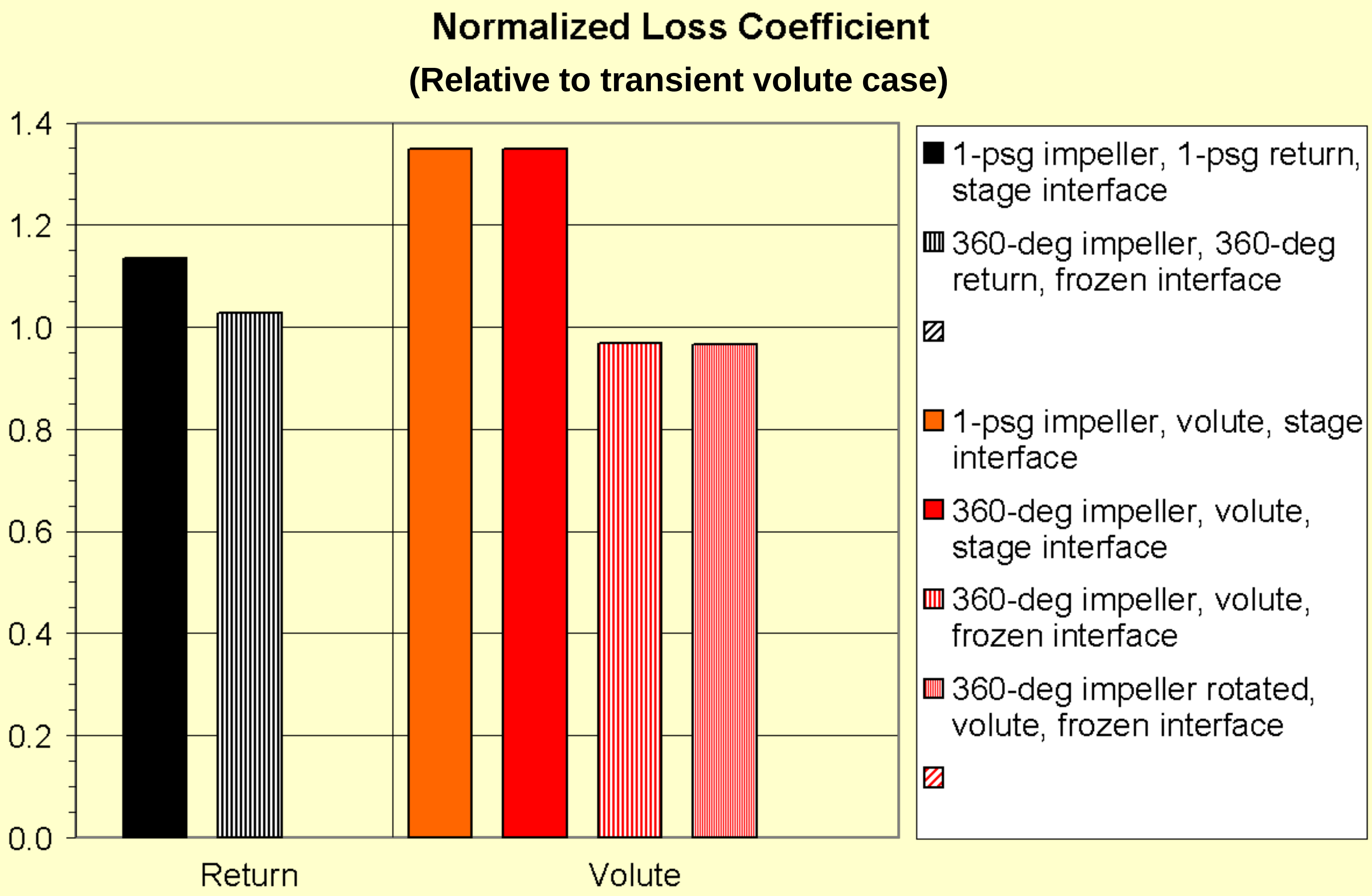
The Interface Question

- Usually avoid transient for high-level look at performance
- Stage often used for high-speed bladed components, like impellers with return channels
- Frozen rotor usually used for radially asymmetrical components, like volutes
- Rotation speed: impeller rotates through 4 vane pitches as a particle passes through it, and about 3.5 more as particle passes through diffuser
- *Which interface to use?*

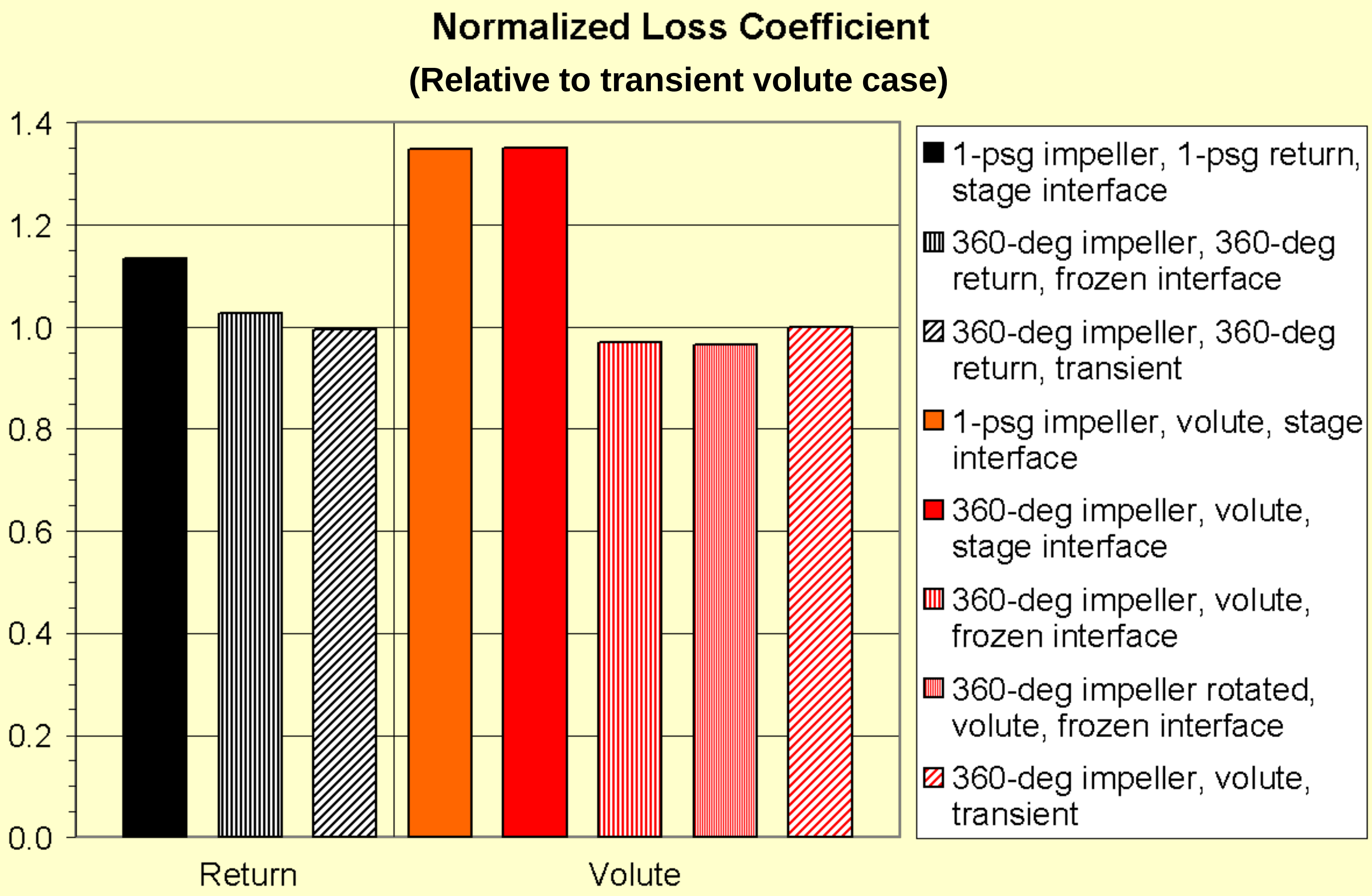
The Interface Study — Stage



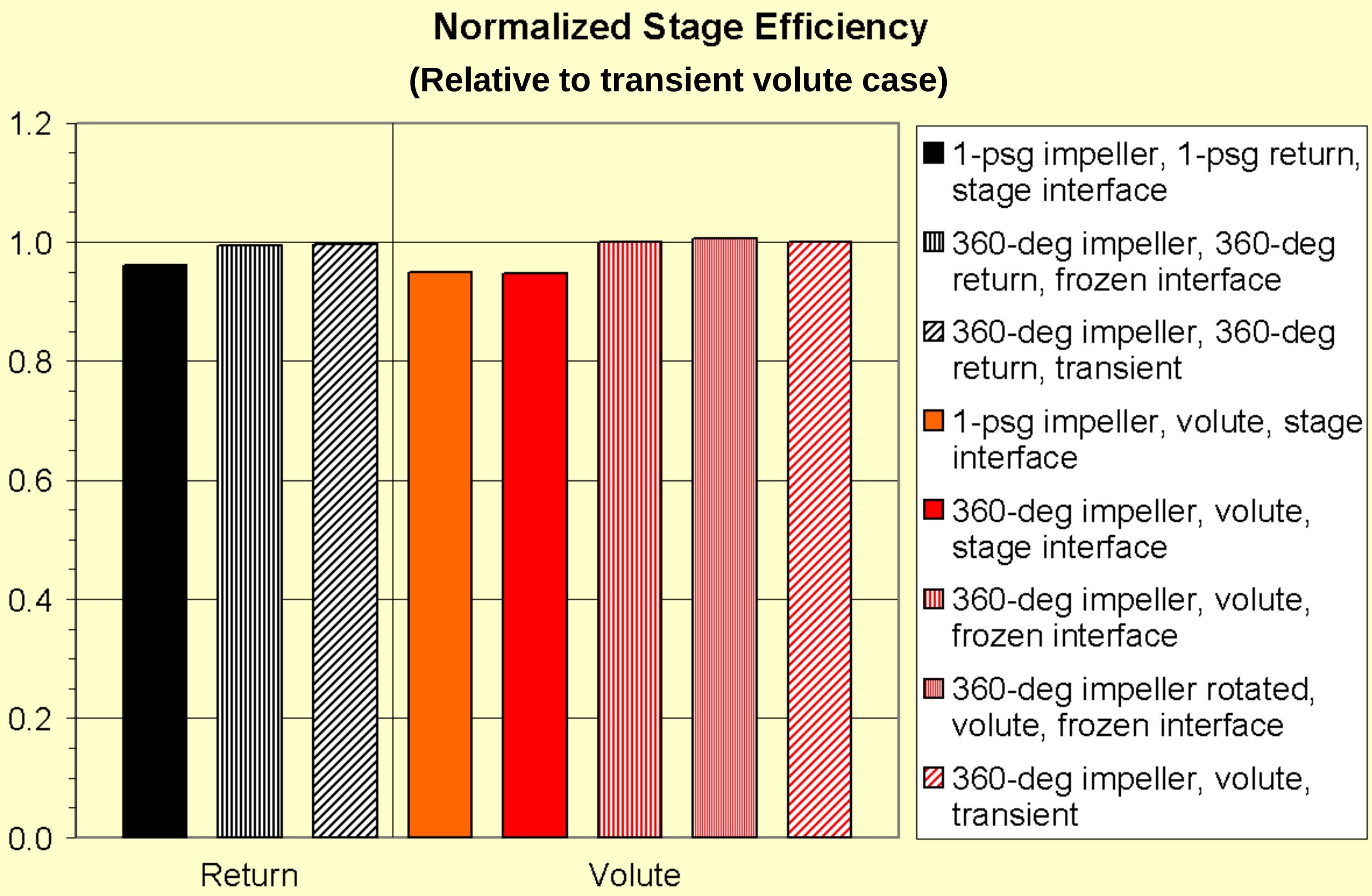
The Interface Study — Frozen Rotor



The Interface Study — Transient



The Interface Study — Transient



The Interface Study — Conclusions

- In this case, frozen rotor gave results much closer to transient, even for return channel
- Can use frozen rotor with confidence for other operating points and similar geometries
- Don’t know how general this result is
- **This sort of comparison should be made for every new class of problem**

Overall Recommendations

- Always try to run high-resolution with no maximum blend factor
  - Convergence might be poor
  - Check convergence by monitoring expressions and comparing overall performance at different iterations
- Try to compare stage, frozen rotor, and transient interfaces for a new class of problem
  - Frozen rotor might be better even for bladed passages

Overall Recommendations

- Pay attention to CFD-specific mesh and numerical issues, and budget some time for them
  - *CFD has become much easier to use over the years, but still requires more than “pressing the button” or “turning the crank” (so far)*