Parallelization of the Z-Model

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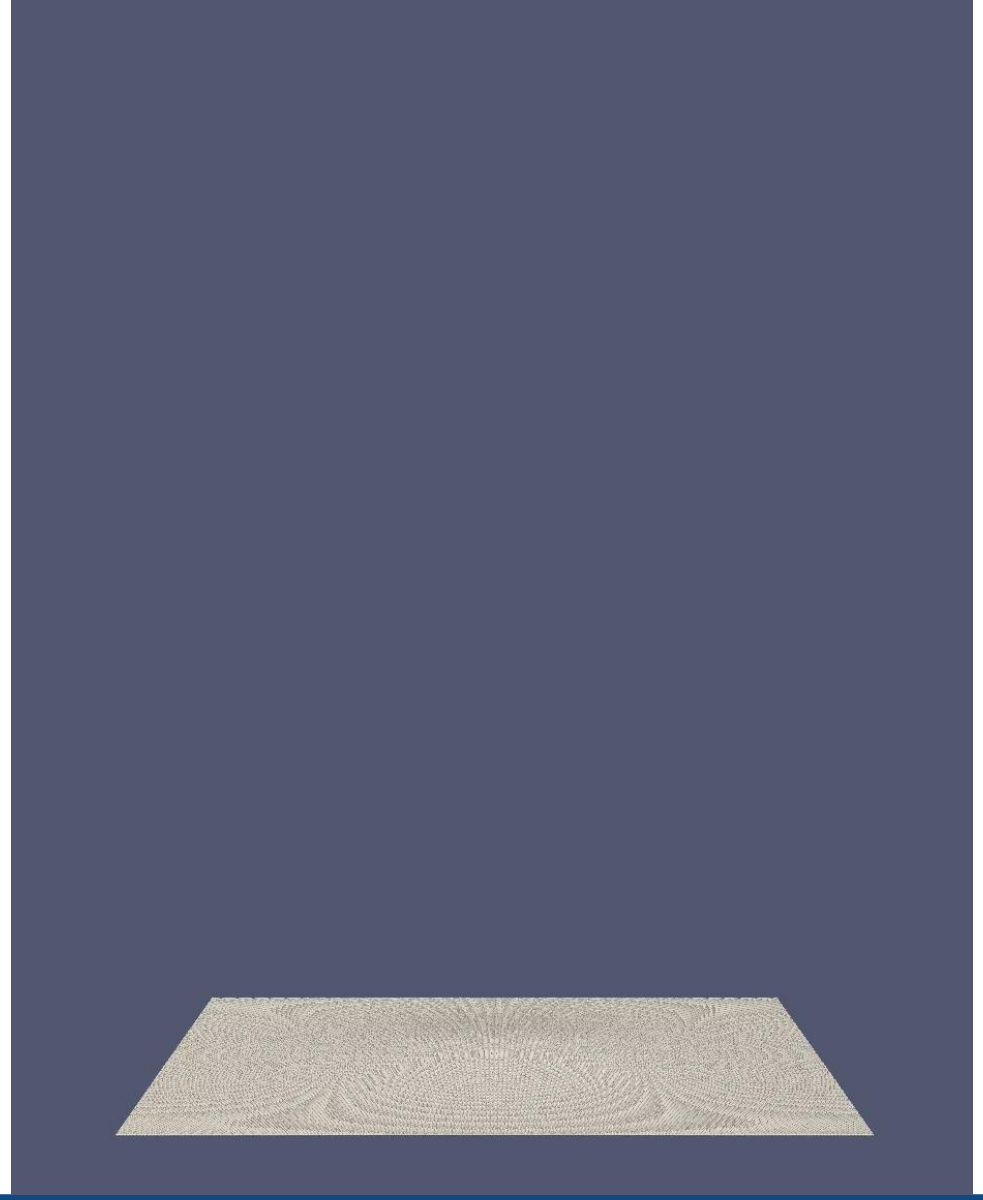
What is Z-Model?

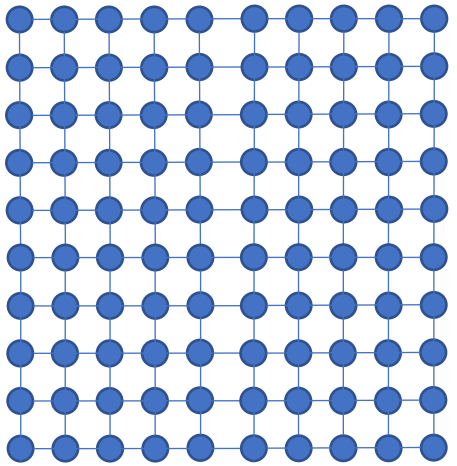
- Simulates the interface between two fluids
- Rayleigh-Taylor Instability or Richtmyer-Meshkov Instability
- By Steve Shkoller at UC Davis

- Raaghav Ramani and Steve Shkoller. “A multiscale model for Rayleigh-Taylor and Richtmyer-Meshkov instabilities”. In: Journal of Computational Physics 405 (2020), p. 109-177.



What is Z-Model?

- 2D mesh of points
- Two types of interactions
  - Neighbor interactions along the mesh
  - Global interactions between all points



What is Z-Model?

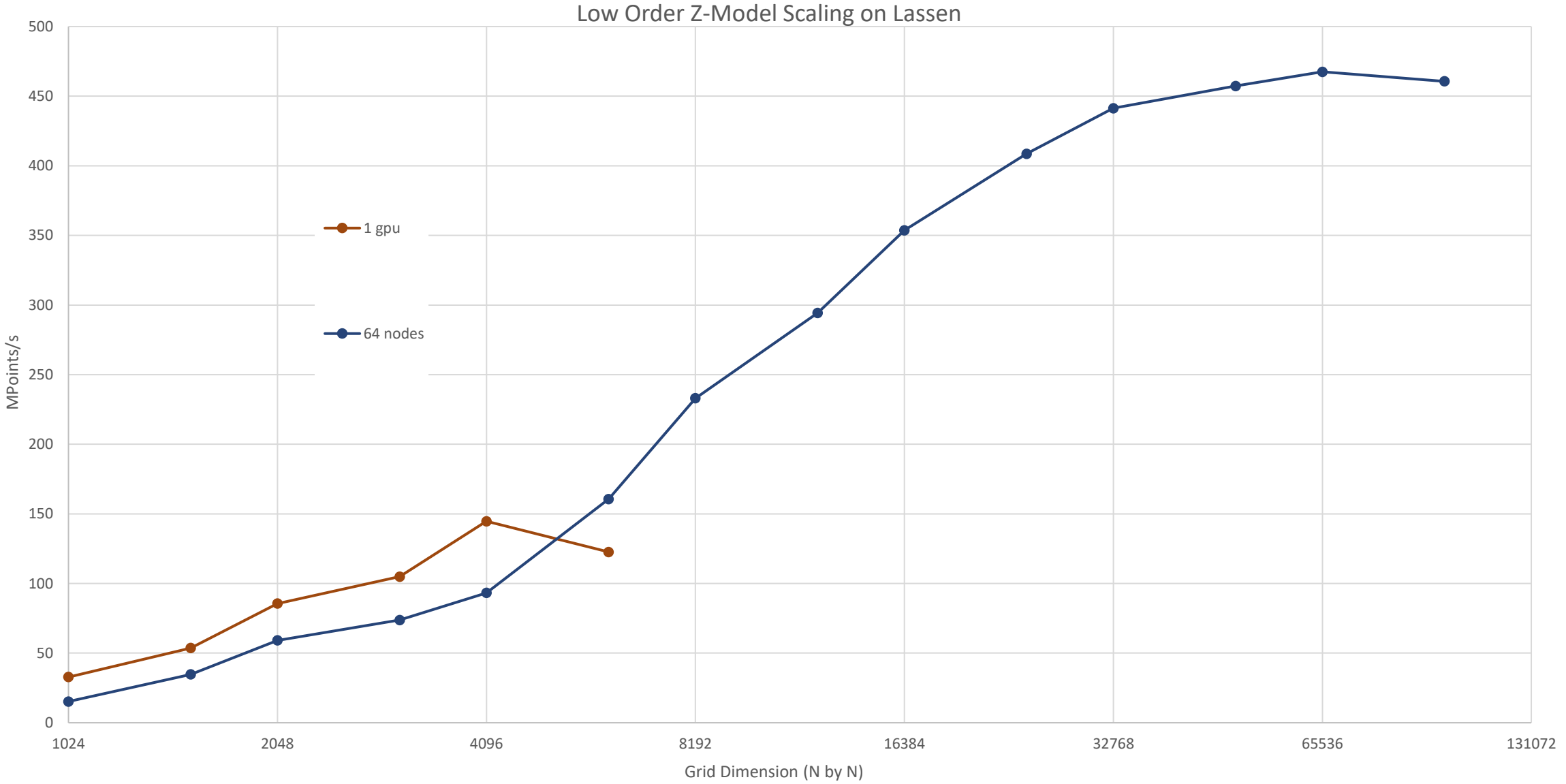
- Two Z-Models
  - Low Order - FFTs to approximate global forces
  - High Order - Direct calculation of global forces

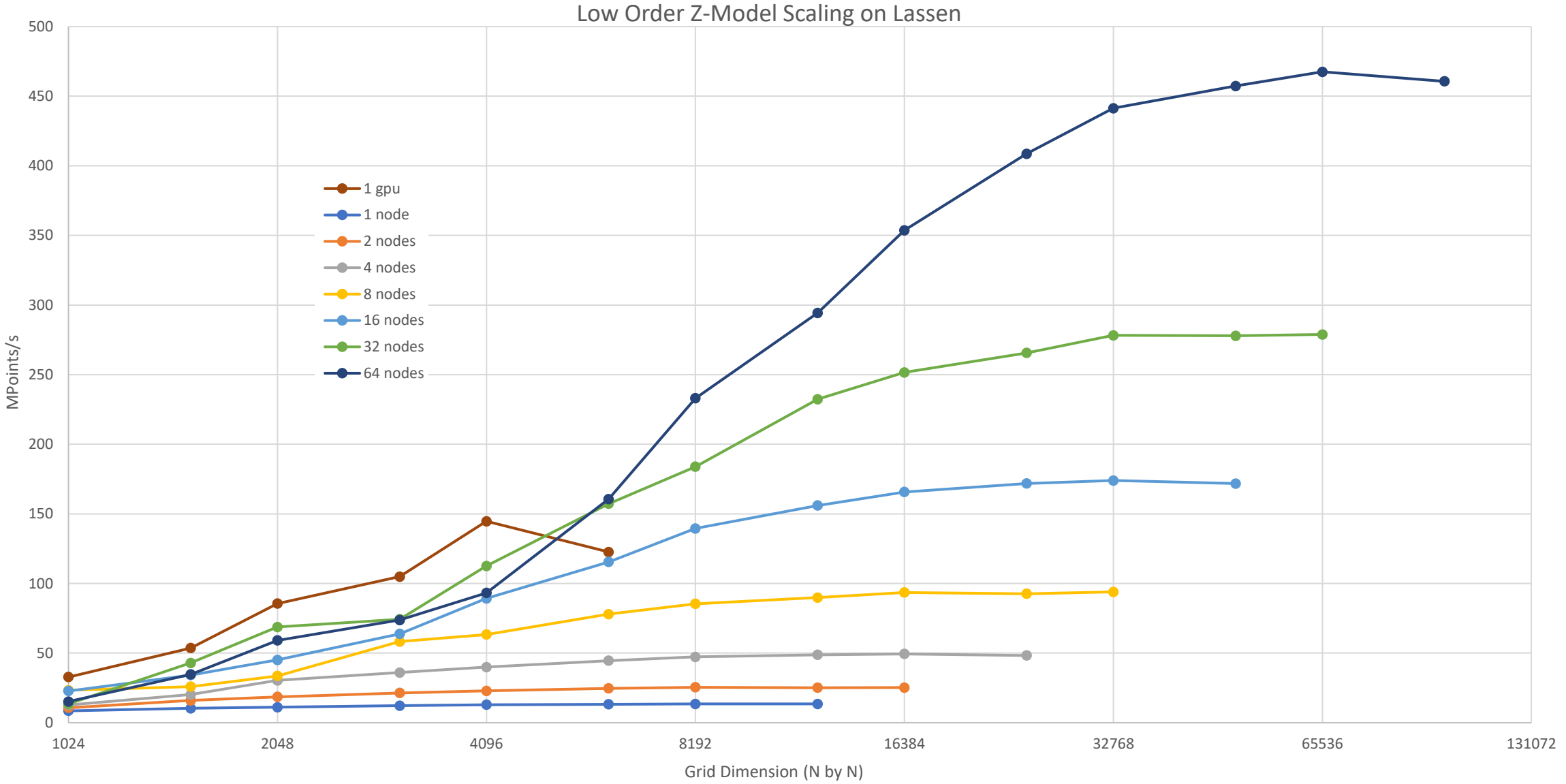
Why Z-Model?

- We can look at global communication
- We can look at coupled codes
  - Combine Z-Model with a CFD solver

Low Order Z-Model Implementation

- Written in Kokkos/Cabana/Cajita
- Scales up to 98k x 98k mesh on 64 Lassen nodes (256 v100s)
- Runs at 450 Mpoints/s
- 170 iterations per hour with a 98k x 98k mesh


Low Order Z-Model Scaling on Lassen
MPoints/s
500
450
400
350
300
250
200
150
100
50
0
1 gpu
64 nodes
1024
2048
4096
8192
16384
32768
65536
131072
Grid Dimension (N by N)


Low Order Z-Model Scaling on Lassen
MPoints/s
Grid Dimension (N by N)
1 gpu
1 node
2 nodes
4 nodes
8 nodes
16 nodes
32 nodes
64 nodes
0
50
100
150
200
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300
350
400
450
500
1024
2048
4096
8192
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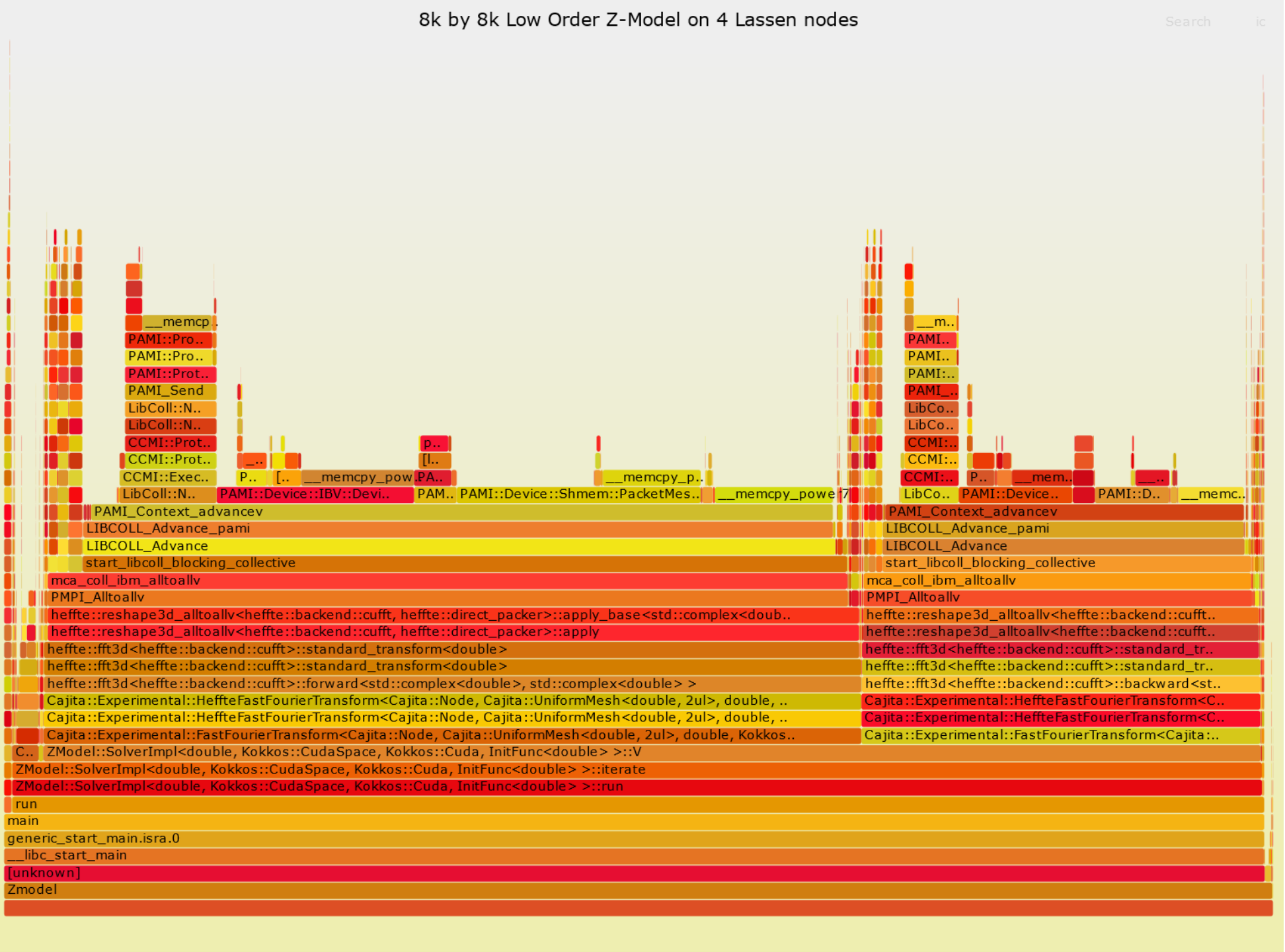
65536
131072


8k by 8k Low Order Z-Model on 4 Lassen nodes
Search
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PAMI::Prot..
PAMI_Send
LibColl::N..
LibColl::N..
CCMI::Prot..
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Zmodel
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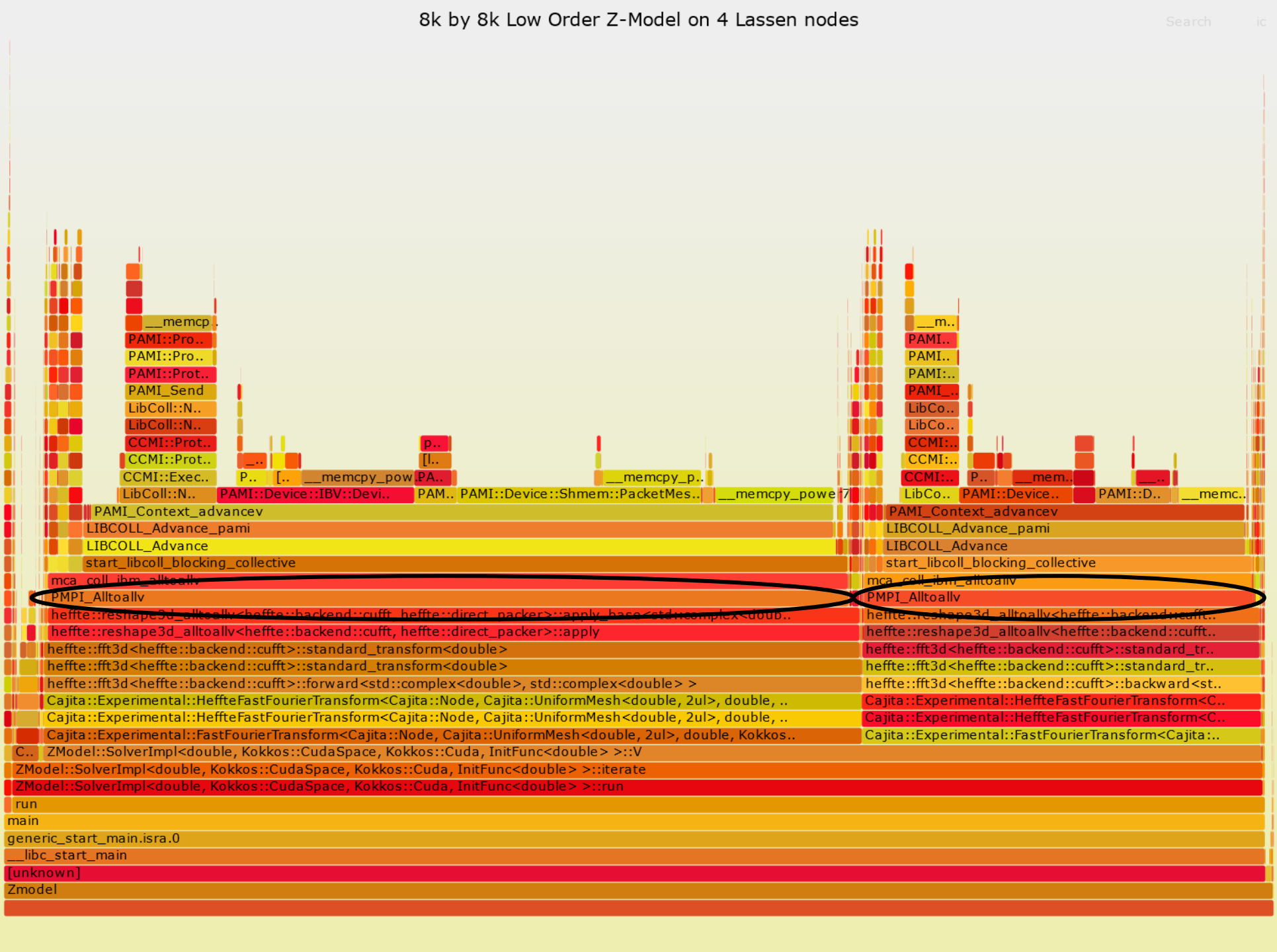
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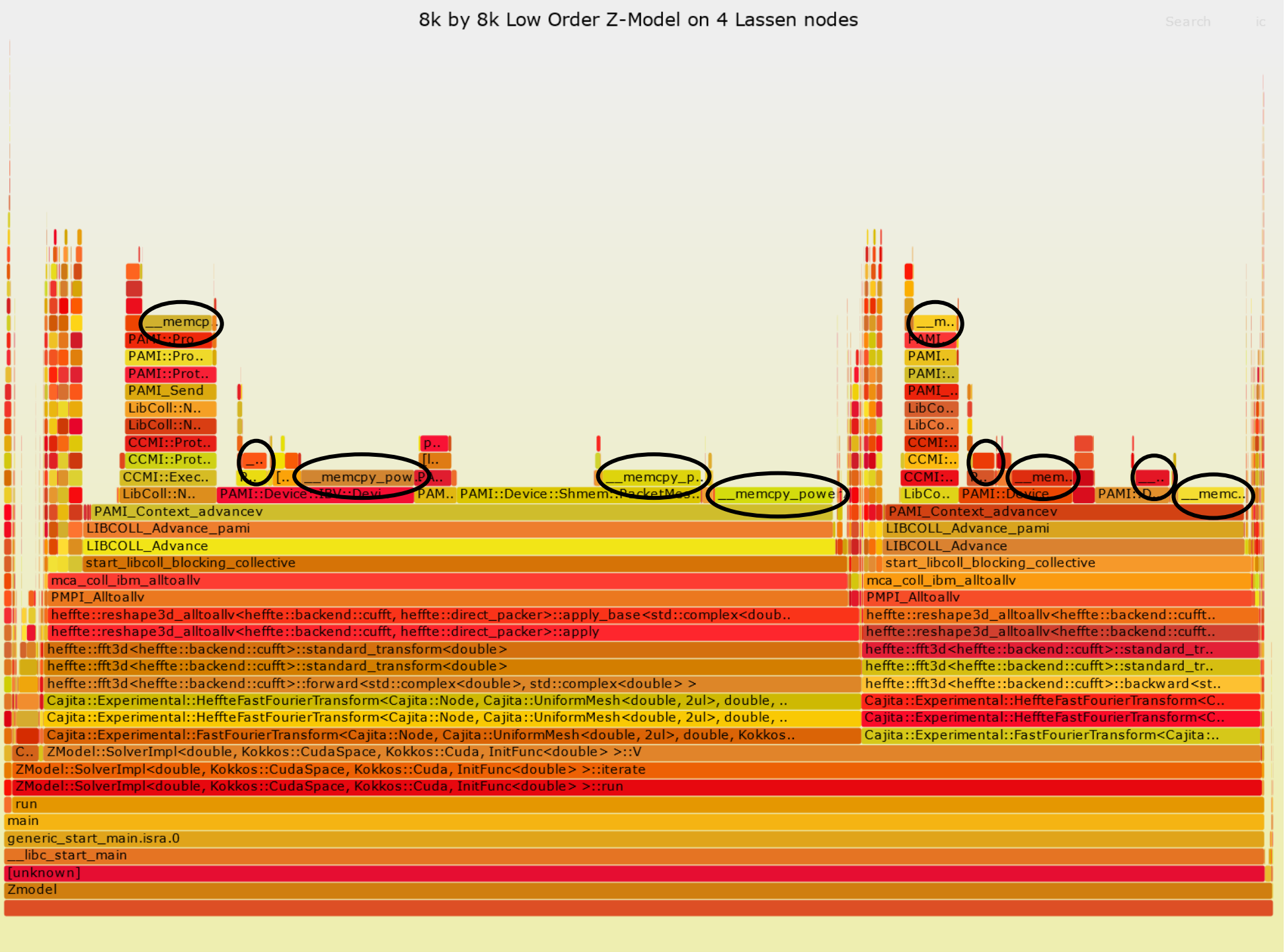
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Zmodel

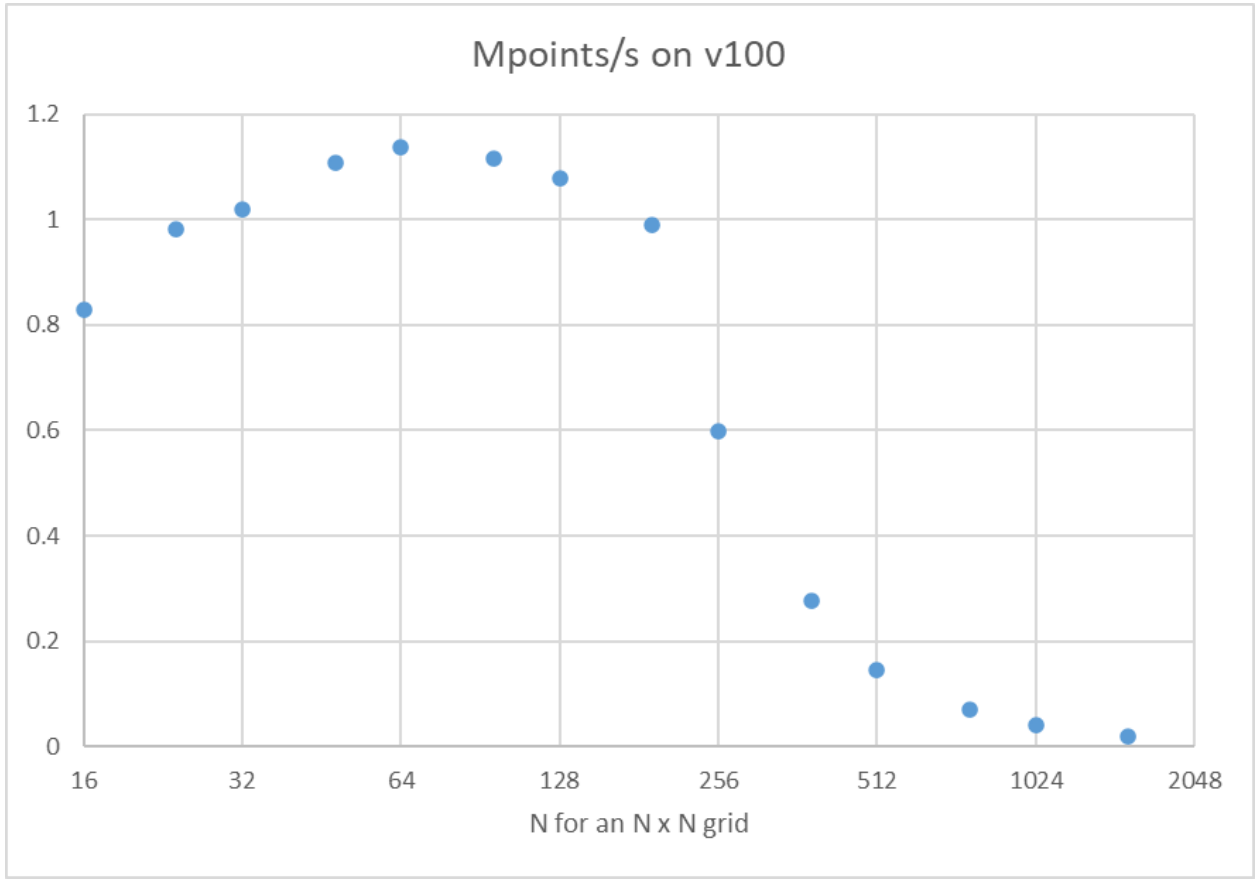
Low Order Z-Model Implementation

- Next Steps
  - Find source of mid-scale inefficiency
  - Working UTK and CMU about FFTs
  - Working with ECP-COPA (Stuart Slattery at ORNL) on FFTs in Cajita

High Order Z-Model Implementation

- Shared memory application written in Cuda
- Test program to figure out how to implement in distributed memory

High Order Z-Model Implementation



High Order Z-Model Implementation

- Bound by direct global forces calculation (O(n^4))
- At n=1024, 99.99% of the time is spent in global forces calculation
- Direct calculation does not scale
- Need approximate algorithms
  - Barnes-Hut
  - Fast Multipole Method (FMM)

High Order Z-Model Implementation

- Barnes-Hut or FMM lets us look at:
  - Hierarchical communication
  - Data migration
  - Global redistribution

Conclusion

- Parallelized the low order Z-Model
  - Looking into FFTs and global communication
- Parallelizing the high order Z-Model
  - Looking into Barnes-Hut/FMM and hierarchical communication