BENCHMARKING THE EVOLUTION OF PERFORMANCE AND ENERGY EFFICIENCY ACROSS RECENT GENERATIONS OF INTEL XEON PROCESSORS

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PMBS 24

SC24 Atlanta, GA hpc creates.

INTEL CPU GENERATIONS

- Sapphire Rapids – 2023 Q1
  - Intel 7, first chiplet architecture - 4 compute tiles
  - Up to 56 cores, 350W
  - 8xDDR5-4800 or HBM2E
- Emerald Rapids – 2023 Q4
  - Intel 7, 2 compute tiles
  - Up to 64 cores, 350W
  - 8xDDR5-5600
- Sierra Forest – 2024 Q2
  - Intel 3, 2 compute tiles
  - Up to 192 cores, 350W
  - 8x/12x DDR5-6400
- Granite Rapids – 2024 Q3
  - Intel 3, 3 compute tiles
  - Up to 128 cores, 500W
    - 72 core 6960P tested
  - 12xDDR5-8800 MRDIMM

AMD PROCESSOR GENERATION

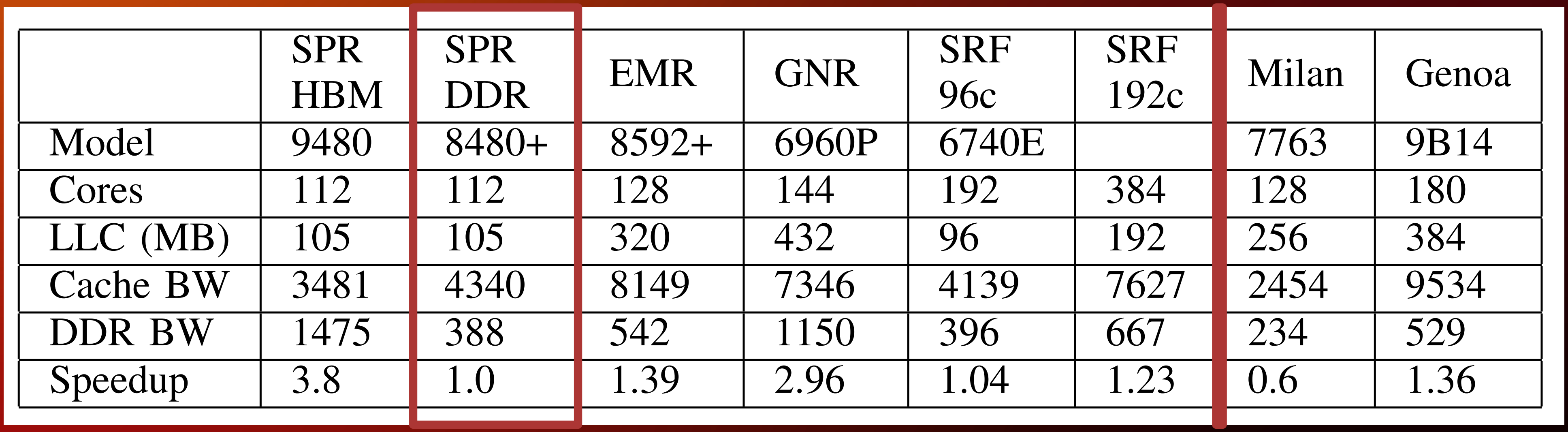
- AMD Milan – 2021 Q1
  - 7 nm, 8 chiplet
  - 64 cores, 280W
  - 8x DDR4-3200
- AMD Genoa – 2022 Q4
  - 5 nm, 12 chiplet
  - 96 cores, 360W
  - 12x DDR5-4800
- AMD Turin – 2024 Q3
  - 3 nm, up to 16 chiplet
  - 128/192 cores, 500W
  - 12x DDR5-6400

PERFORMANCE, EFFICIENCY

- Number of bandwidth-bound codes (mostly explicit PDE solvers)
  - CloverLeaf (low-order), Seismic (high-order), OpenSBLI (large-scale DNS), MG-CFD (FV Euler on unstructured mesh), Volna (FV NLSW on unstructured mesh)
- Compute-intensive: miniBUDE (docking proxy)
- MPI or MPI+OpenMP – many through OPS/OP2 DSLs. icpx/g++ compilers.

- Compare:
  - Runtime
  - Architectural efficiency (effective BW estimates)
  - Energy efficiency

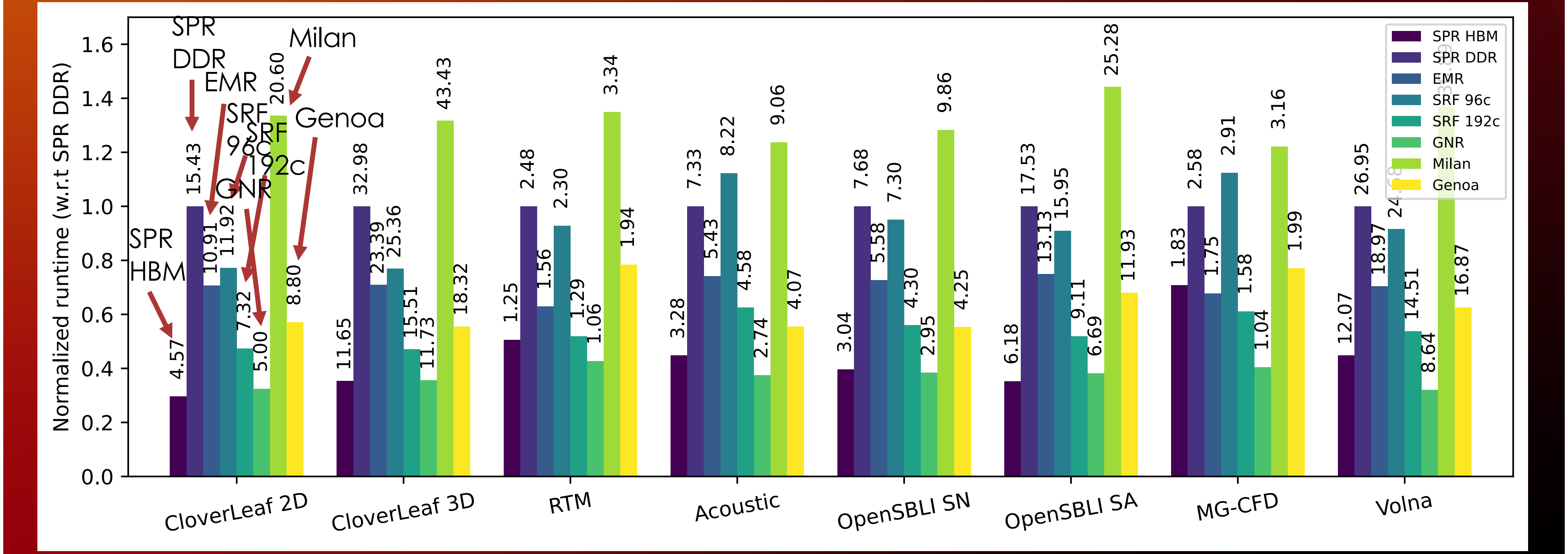
BASELINES



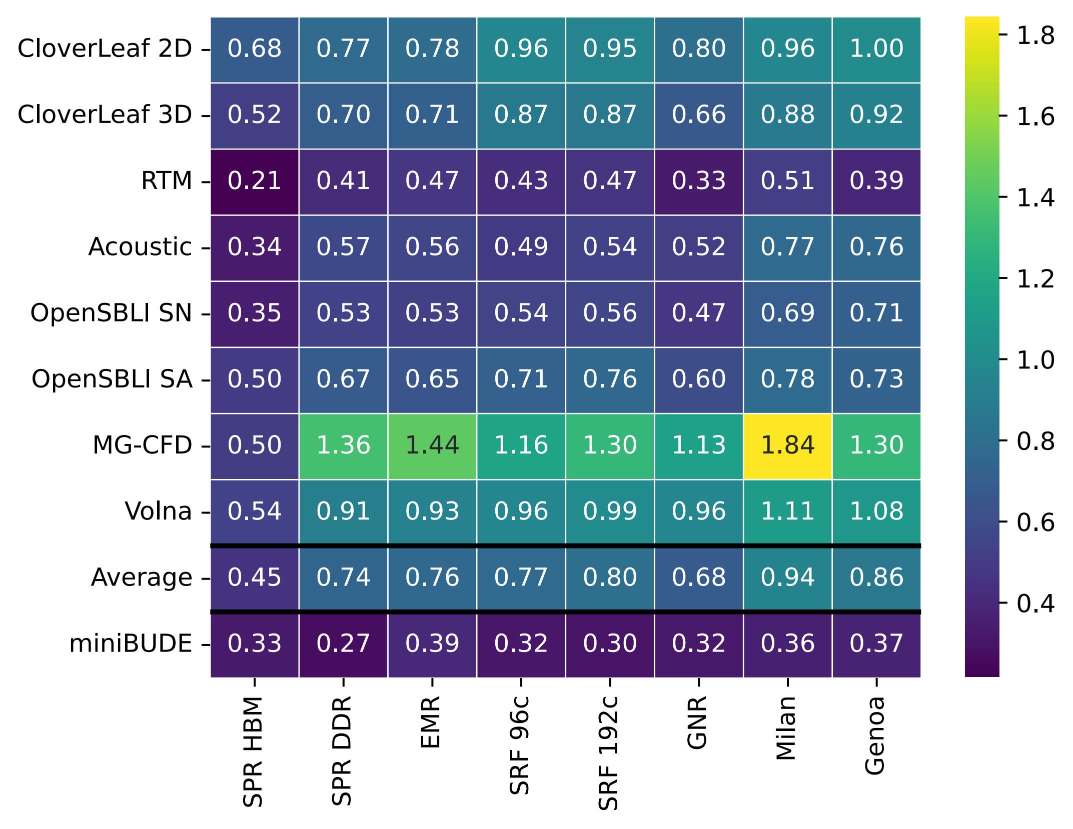
	SPR HBM	SPR DDR	EMR	GNR	SRF 96c	SRF 192c	Milan	Genoa
Model	9480	8480+	8592+	6960P	6740E		7763	9B14
Cores	112	112	128	144	192	384	128	180
LLC (MB)	105	105	320	432	96	192	256	384
Cache BW	3481	4340	8149	7346	4139	7627	2454	9534
DDR BW	1475	388	542	1150	396	667	234	529
Speedup	3.8	1.0	1.39	2.96	1.04	1.23	0.6	1.36

Point of reference

RUNTIME VS SAPPHIRE RAPIDS+DDR5



ARCHITECTURAL EFFICIENCY



	SPR HBM	SPR DDR	EMR	SRF 96c	SRF 192c	GNR	Milan	Genoa
CloverLeaf 2D	0.68	0.77	0.78	0.96	0.95	0.80	0.96	1.00
CloverLeaf 3D	0.52	0.70	0.71	0.87	0.87	0.66	0.88	0.92
RTM	0.21	0.41	0.47	0.43	0.47	0.33	0.51	0.39
Acoustic	0.34	0.57	0.56	0.49	0.54	0.52	0.77	0.76
OpenSBLI SN	0.35	0.53	0.53	0.54	0.56	0.47	0.69	0.71
OpenSBLI SA	0.50	0.67	0.65	0.71	0.76	0.60	0.78	0.73
MG-CFD	0.50	1.36	1.44	1.16	1.30	1.13	1.84	1.30
Volna	0.54	0.91	0.93	0.96	0.99	0.96	1.11	1.08
Average	0.45	0.74	0.76	0.77	0.80	0.68	0.94	0.86
miniBUDE	0.33	0.27	0.39	0.32	0.30	0.32	0.36	0.37

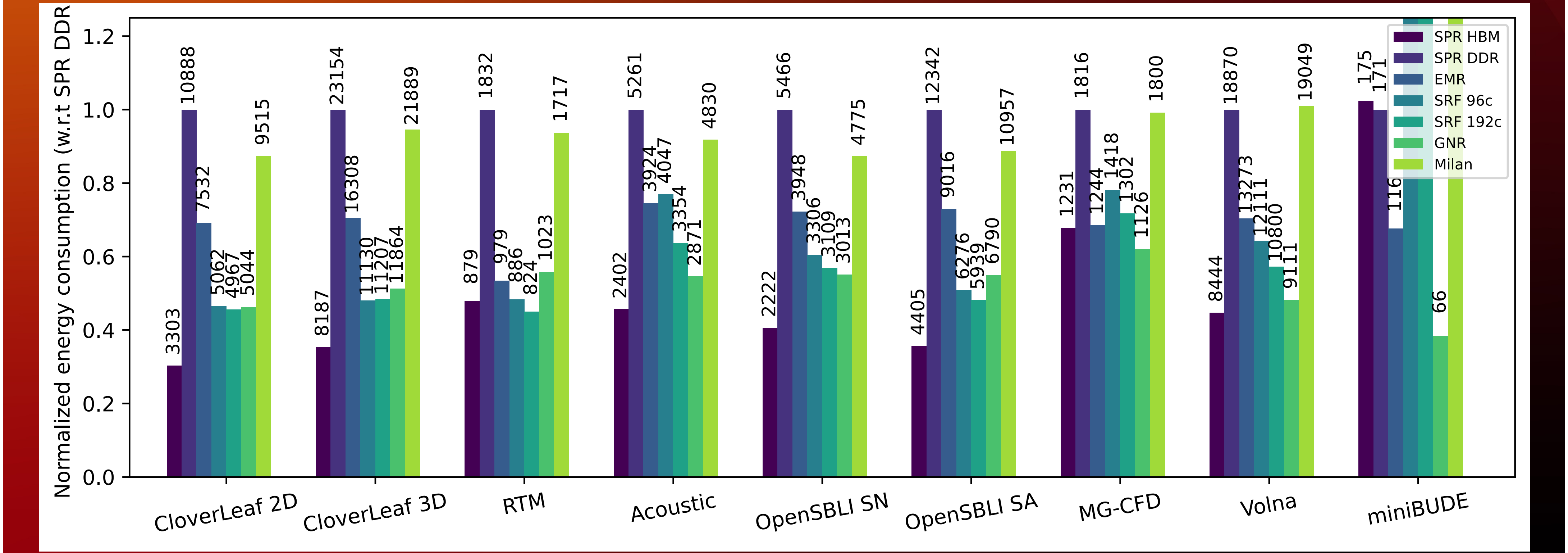
- Effective BW: array size in each loop
  - Above 1.0 if cache re-use across loops
- Significant MPI overheads on Seismic apps (30-50%)
  - Especially SPR+HBM and Genoa
- miniBUDE: fraction of peak GFLOPS/s at all-core turbo
  - Not always documented

BALANCED IMPROVEMENT VS SPR+DDR?

- How much did overall performance improve vs. the improvement in bandwidth?
  - $(\text{runtime}/\text{runtime}_{\text{SPR}})/(\text{Peak BW}/\text{Peak BW}_{\text{SPR}})*100$
- SPR+HBM: same compute - only 64%
- EMR: +8 cores, 3x cache size, 1.4x BW – 98%
- GNR: +16 cores, 4.1x cache size, 3x BW – 91%

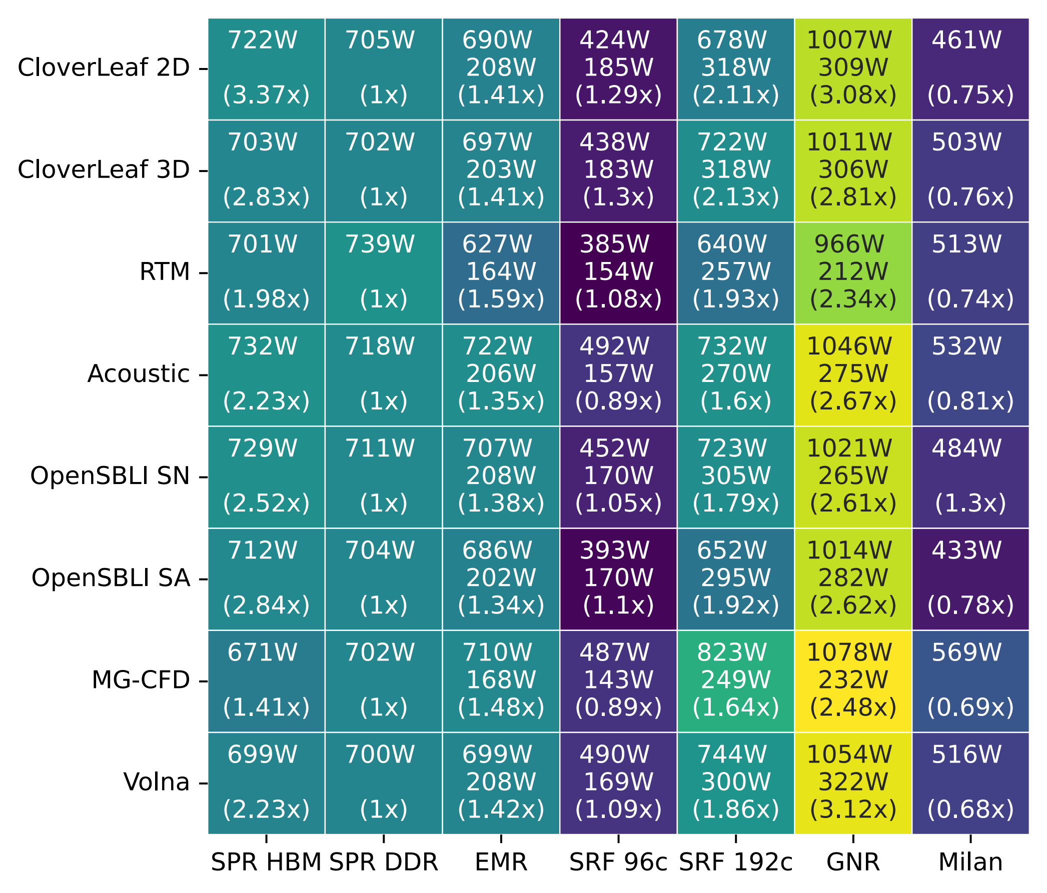
- SRF 96 core: +40 cores, 0.85x cache size, 1.04x BW – 105%
- SRF 192 core: +136 cores, 1.71x cache size, 1.7x BW – 110%

ENERGY EFFICIENCY VS SAPPHIRE RAPIDS



POWER

- 250W TDP for SRF 96c
- 280W TDP for Milan
- 350W TDP for SPR, EMR, SRF 192c
- 360W TDP for Genoa (no RAPL)
- 500W TDP for GNR
- Plus RAM



	SPR HBM	SPR DDR	EMR	SRF 96c	SRF 192c	GNR	Milan
CloverLeaf 2D	722W (3.37x)	705W (1x)	690W 208W (1.41x)	424W 185W (1.29x)	678W 318W (2.11x)	1007W 309W (3.08x)	461W (0.75x)
CloverLeaf 3D	703W (2.83x)	702W (1x)	697W 203W (1.41x)	438W 183W (1.3x)	722W 318W (2.13x)	1011W 306W (2.81x)	503W (0.76x)
RTM	701W (1.98x)	739W (1x)	627W 164W (1.59x)	385W 154W (1.08x)	640W 257W (1.93x)	966W 212W (2.34x)	513W (0.74x)
Acoustic	732W (2.23x)	718W (1x)	722W 206W (1.35x)	492W 157W (0.89x)	732W 270W (1.6x)	1046W 275W (2.67x)	532W (0.81x)
OpenSBLI SN	729W (2.52x)	711W (1x)	707W 208W (1.38x)	452W 170W (1.05x)	723W 305W (1.79x)	1021W 265W (2.61x)	484W (1.3x)
OpenSBLI SA	712W (2.84x)	704W (1x)	686W 202W (1.34x)	393W 170W (1.1x)	652W 295W (1.92x)	1014W 282W (2.62x)	433W (0.78x)
MG-CFD	671W (1.41x)	702W (1x)	710W 168W (1.48x)	487W 143W (0.89x)	823W 249W (1.64x)	1078W 232W (2.48x)	569W (0.69x)
Volna	699W (2.23x)	700W (1x)	699W 208W (1.42x)	490W 169W (1.09x)	744W 300W (1.86x)	1054W 322W (3.12x)	516W (0.68x)

CONCLUSIONS

- Rapid evolution with interesting trade-offs
- Intel's differentiated product lines – evolution vs. SPR
  - SRF 96 core: Slightly higher performance (1.09×) but at a 1.4× lower power
  - SRF 192 core: Significantly higher performance(1.87×), at the same power
  - GNR: Even higher performance (2.72×), but at 1.44× more power
- MRDIMM may be a critical differentiating factor vs. AMD
  - Big advantage for memory-bound codes
- Still behind with energy efficiency – process issues