CPU-Memory Power Shifting on High Performance Computing

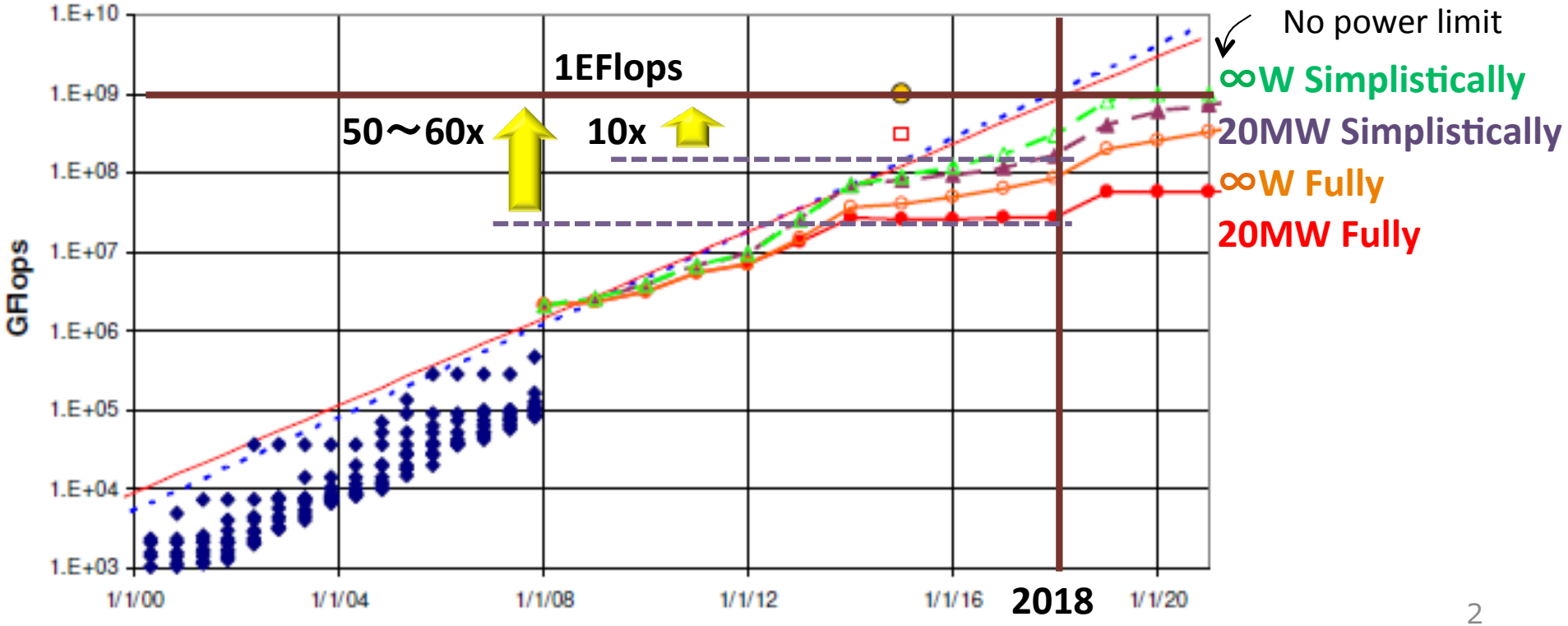
Koji Inoue

Kyushu University

Hitting the Power Wall in HPC!

- DARPA Target: 1Exa-FLOPS@20~30MW
- Need 50x performance/watt improvement
  - E.g., 10PFlops@13MW (e.g. K computer)

Figure 7.14: Light node strawman performance projections



P. Kogge et al., ExaScale Computing Study: Technology Challenges in Achieving Exascale Systems, http://www.cse.nd.edu/Reports/2008/TR-2008-13.pdf

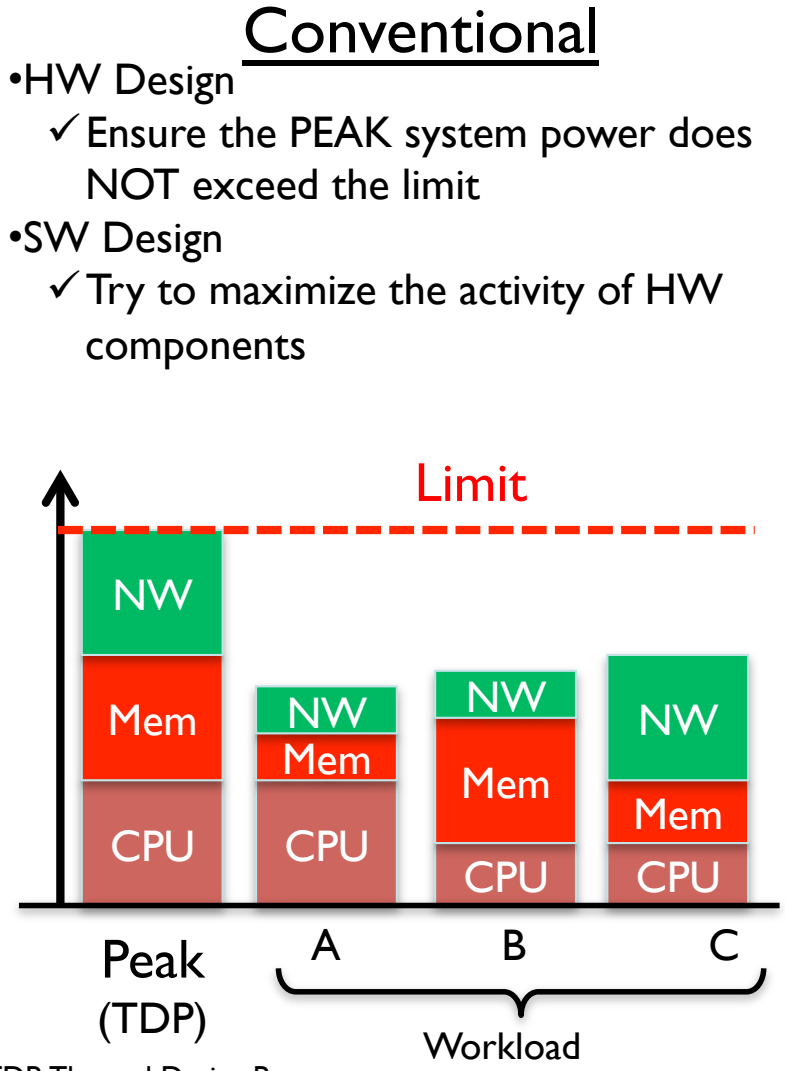
Adaptive Power Management on Overprovisioned Systems

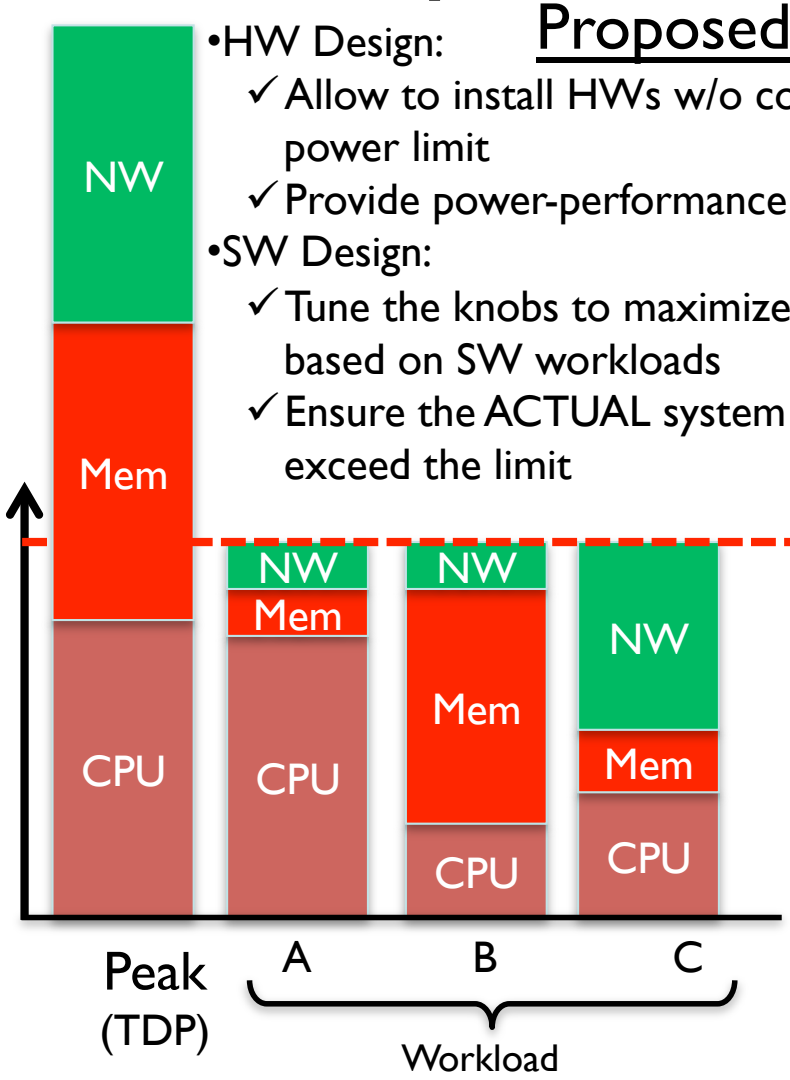
Conventional

- HW Design
  - ✓ Ensure the PEAK system power does NOT exceed the limit
- SW Design
  - ✓ Try to maximize the activity of HW components

Proposed

- HW Design:
  - ✓ Allow to install HWs w/o considering the power limit
  - ✓ Provide power-performance knobs (e.g. DVFS)
- SW Design:
  - ✓ Tune the knobs to maximize the performance based on SW workloads
  - ✓ Ensure the ACTUAL system power does NOT exceed the limit





TDP: Thermal Design Power

Power Budgeting for Green High-Performance Computing

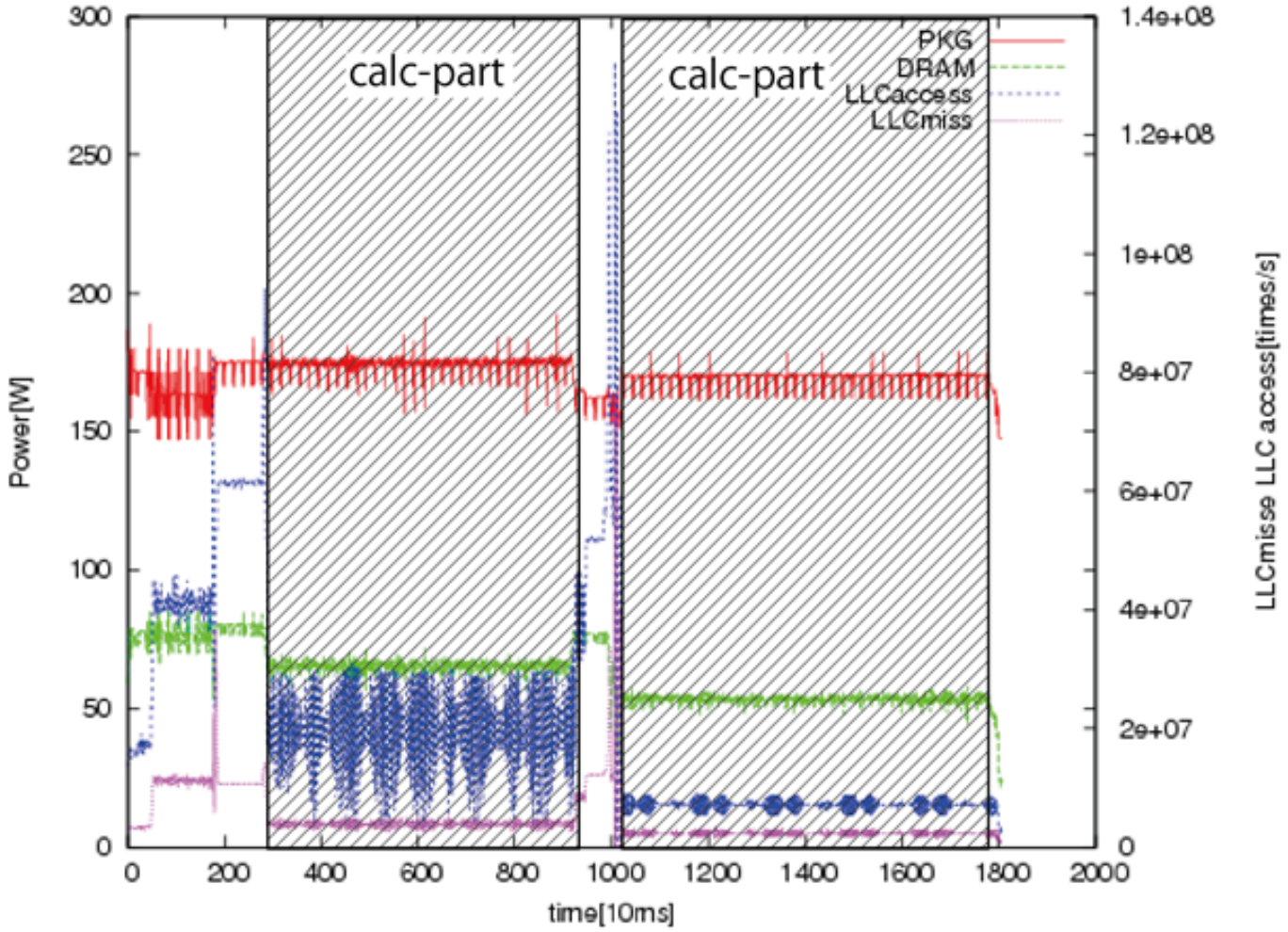
- Power is the 1st order design constraint
- Problem: How can we use the limited power budget effectively?
- Answer: Power Shifting
  - Optimize power budget allocation based on …
    - Characteristics of application programs
    - System Organization
    - Situation of power conditions (energy harvesting, battery, etc.)

Power Measurement/Control Platform

- Intel RAPL (Running Average Power Limit)
  - Measurement
    - CPU package
    - DRAM
  - Control (Capping)
    - CPU package
    - DRAM (no support in CX400)
- Power management APIs
  - Insert APIs into application source codes
  - Fine-grain measurement and control

PRIMERGY CX400		
CPU	Architecture	8 cores Xeon E5 2680
	Frequency	2.7GHz (172.8GF)
	Cache	L2: 256KB/core L3: 20MB/CPU
DRAM	DDR3-800	8GB x 8 /CPU
B/F	51.2/172.8	0.30
Node	Number of CPUs	2
	Memory size	128GB
System	Number of nodes	1476 (23616 cores)
	Rmax	510.1 TFlops
	Node comm.	InfiniBand FDR

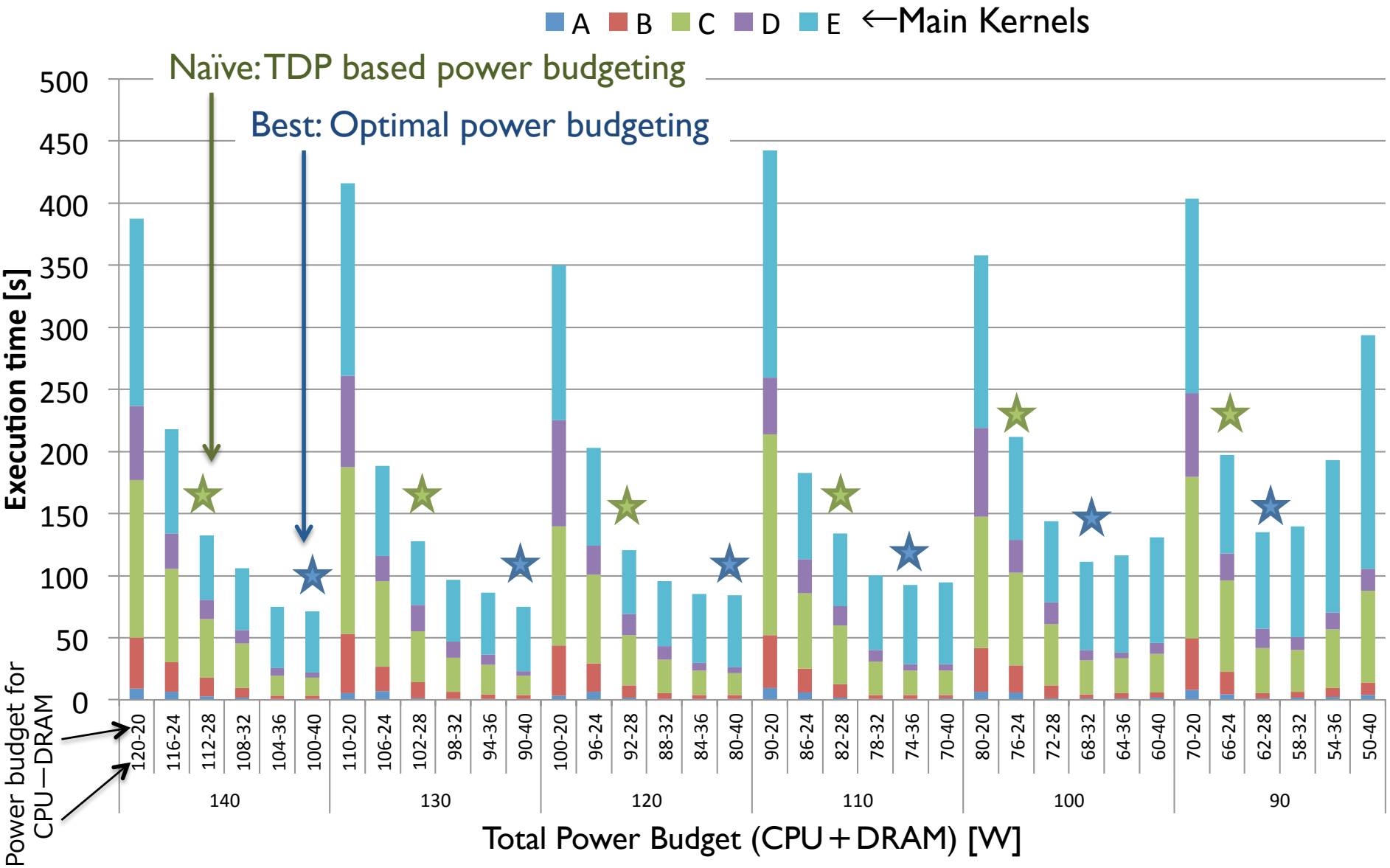
Power Characteristics
~ A Case for MHD Simulation ~



MHD: Magneto Hydro Dynamics

CPU: Intel Xeon E5-2620 x 2 sockets
Memory: 16GB x 8 (128GB)

Potential of Static Power Budgeting



CPU: Intel Xeon E5-2620 x 2 sockets
Memory: 16GB x 8 (128GB)

Analysis

Highest performance

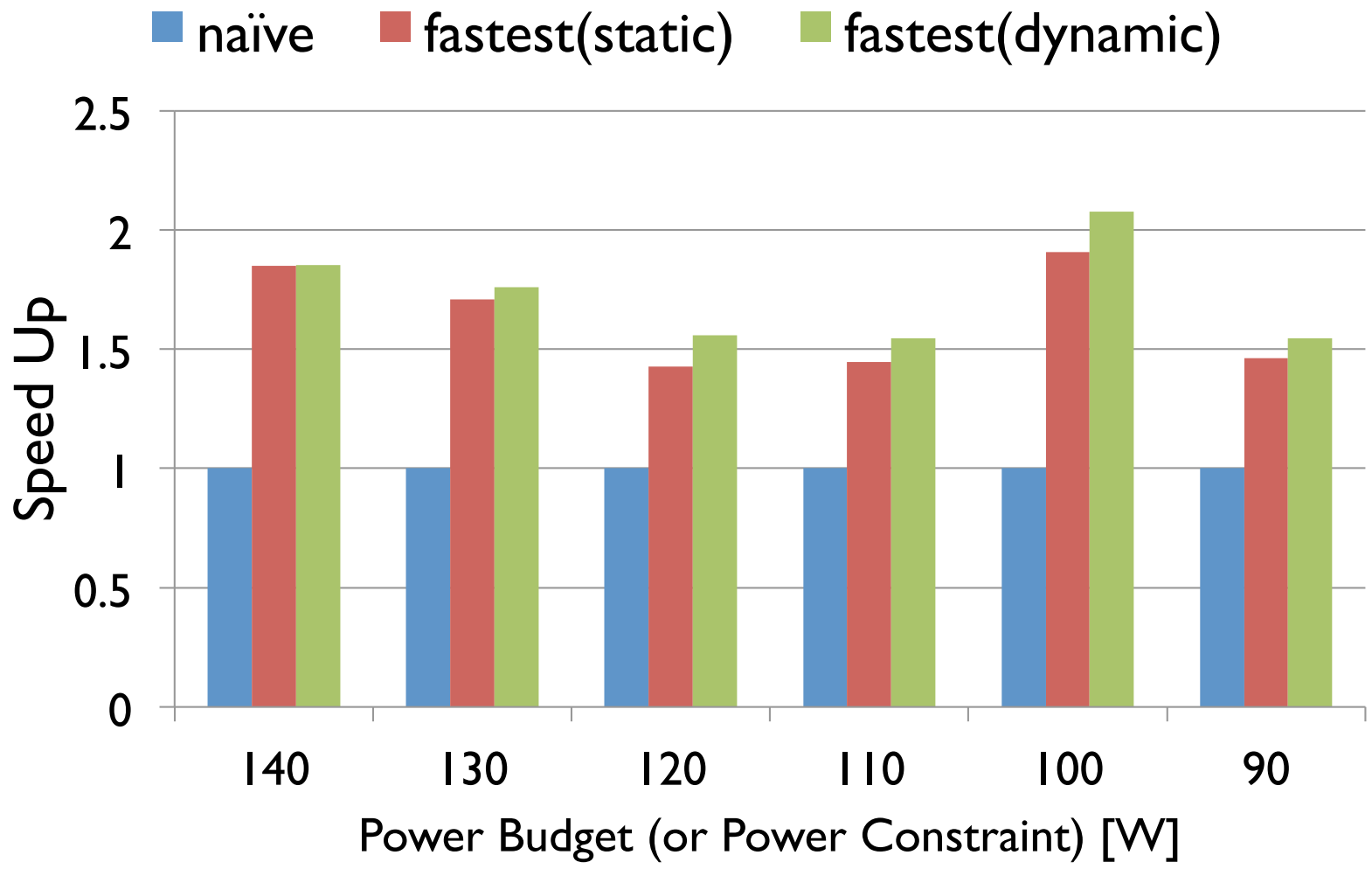
		A	B	C	D	E
140	120–20	9.04436	40.78316	127.411	59.36324	151.098
	116–24	6.37768	23.91736	75.42682	28.38964	83.65048
	112–28	2.86352	14.76684	47.2427	15.87258	51.5267
	108–32	1.53968	8.1761	35.55314	10.96	49.97478
	104–36	0.82382	2.66794	15.68744	6.34678	49.24056
	100–40	0.83454	2.7584	14.0136	4.62882	49.22654
130	110–20	5.62726	47.62156	134.2444	73.36722	155.1247
	106–24	6.92304	19.572	68.97942	20.4666	72.72526
	102–28	1.4581	12.82234	40.79068	21.28478	51.45904
	98–32	1.0092	5.53238	27.5923	12.7634	49.50754
	94–36	0.85158	3.46384	23.91928	8.51032	49.55542
	90–40	0.86138	2.78592	15.77782	3.70614	51.70394
120	100–20	3.3495	40.38996	96.09186	85.20938	124.9532
	96–24	6.46996	22.5775	71.62598	23.6602	78.54256
	92–28	1.53528	10.01838	40.30686	17.10306	51.372
	88–32	0.85936	4.34696	26.94304	11.1015	52.6243
	84–36	0.94046	2.9368	19.52648	6.35926	55.61054
	80–40	0.8968	3.0781	17.52374	4.53542	58.24958

		A	B	C	D	E
110	90–20	9.55334	42.42236	161.6456	45.89492	182.9402
	86–24	6.1914	18.98878	60.79354	27.37266	69.43712
	82–28	1.74454	10.76196	47.38888	15.74866	58.19622
	78–32	0.97586	2.98458	26.81844	9.20046	60.2556
	74–36	0.98752	2.83744	19.68414	5.0287	64.08158
	70–40	1.02242	2.75304	19.81506	5.04108	66.17626
100	80–20	6.20774	35.24548	106.0428	71.4866	138.7436
	76–24	5.99138	21.68094	74.81612	26.12136	83.27296
	72–28	1.25226	10.13248	49.56568	17.4538	65.46454
	68–32	1.15174	3.3722	27.47576	8.14828	71.01516
	64–36	1.4323	3.81416	28.06454	4.52192	78.44644
	60–40	1.63522	4.39828	31.2576	8.44862	85.29442
90	70–20	8.25766	41.06074	130.4021	67.02224	156.8064
	66–24	4.15348	18.50054	73.70576	21.39618	79.58886
	62–28	1.37868	4.27844	36.21752	15.17108	78.01822
	58–32	1.75086	4.76856	33.86146	10.23006	89.12674
	54–36	2.5374	6.83384	47.383	13.47268	122.7257
	50–40	3.96664	10.0048	73.85626	17.86022	188.0572

Execution time of each kernels [sec]

CPU: Intel Xeon E5-2620 x 2 sockets
Memory: 16GB x 8 (128GB)

Potential of Dynamic Power Budgeting



Conclusions

- Summary
  - Power is the most serious issue for post-petascale computing
  - The Keys: "Overprovision" and "Power budgeting (capping)"

- Ongoing Work
  - Find the best power budgeting (semi-)automatically
  - Maximize effective performance under power constraints