# Bridge++ 2.0: Benchmark Result on Supercomputer Fugaku

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Lattice QCD code Bridge++
http://bridge.kek.jp/Lattice-code/

## Bridge++ code set

C++ object oriented framework
Portable, easy to read, and extendable keeping reasonable performance
Standard fermions, HMC, some measurements with test suite
Version 1.0 release: 2009 new architectures have appeared since then

Extended to flexible data layout : **version 2.0** (“alternative”)
Y.Akahoshi et al. J.Phys.Conf.Ser. 2207 (2022) 1, 012053

-SIMD version for AVX-512
I.K and H.Matsufuru, EPJ Web Conf 175 (2018) 09002; Lecture Notes in Computer Science, vol 10962 (2018) 456.

-GPU version with OpenACC
-yet another SIMD version for A64FX (Fugaku, etc.)

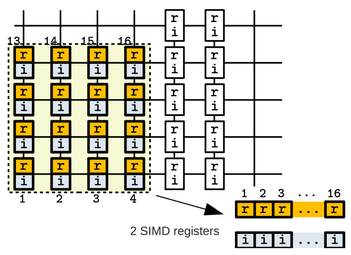
## Fugaku

https://www.r-ccs.riken.jp/en/fugaku/

RIKEN Center for Computational Science (R-CCS), Kobe, Japan
the same place as K-computer
No. 2 of the Top 500
(No.1 in Jun.2020-Nov.2021)
Peak: 488 PFlops (2.0 GHz)
with 158,976 nodes
CPU: A64FX, 3,072 GFlops,
32GB HBM on chip
48+2(or 4) cores
Interconnect: TofuD

## Code tuning for Fugaku

Re/Im parts are treated separately
2-dim site packing: 1x16, 2x8, 4x4, 8x2 [single prec.]
Use of Arm C-Language Extension (ACLE) [=intrincis]
Scalable Vector Extension (SVE): 512 bits




T. Aoyama, I.K., K. Kanaya, H. Matsufuru and Y. Namekawa, PoS LATTICE2022 (2023) 284.
I.K., K. Nitadori and H. Matsufuru, HPCASIA-Workshop 2023 [doi:10.1145/3581576.3581610], to appear.

Manual prefetch (partially)
MPI persistent communication + Fujitsu extension
(acceleration by the assistant cores)
Use of the special solver for Fugaku (QWS) as a part of MG solver

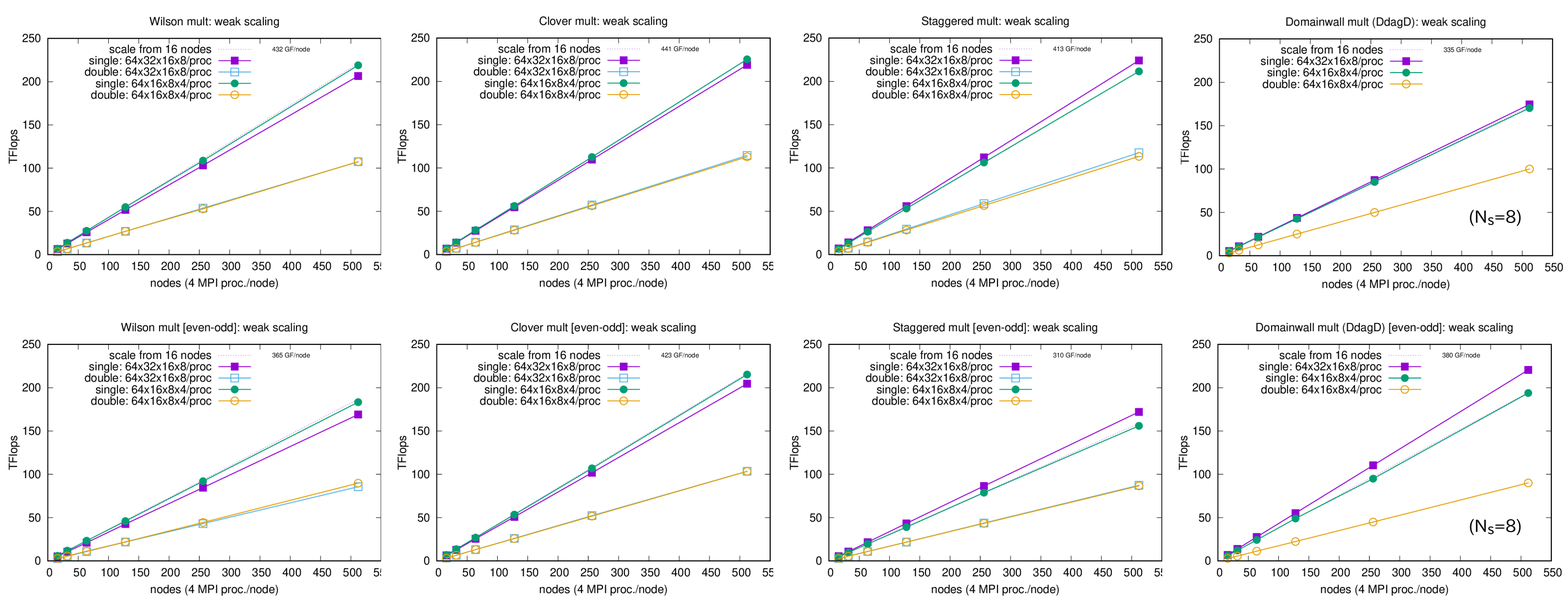
QCD Wide SIMD library (QWS) https://github.com/RIKEN-LQCD/qws

## Benchmark Result

updated from T. Aoyama et al., PoS LATTICE2022 (2023) 284.

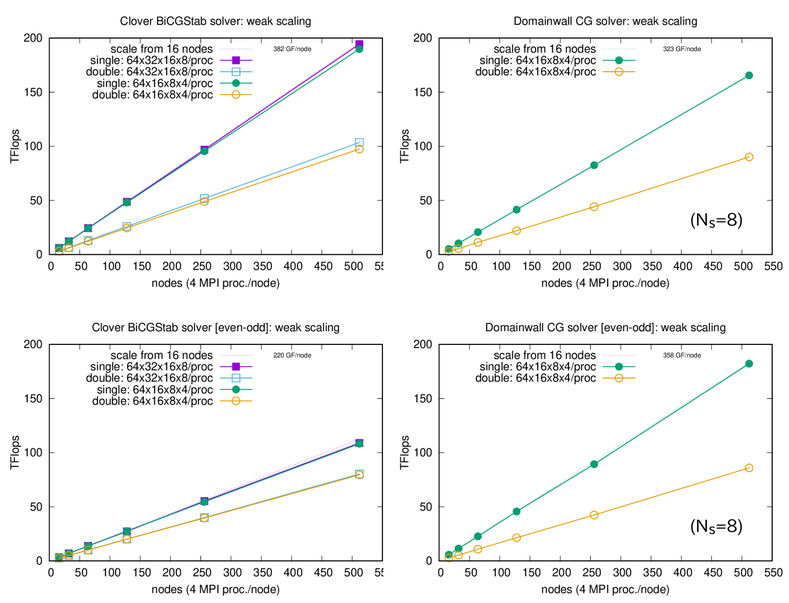
### Weak scaling of Dirac Operator Multiplications

Wilson | Clover | Staggered | Domainwall



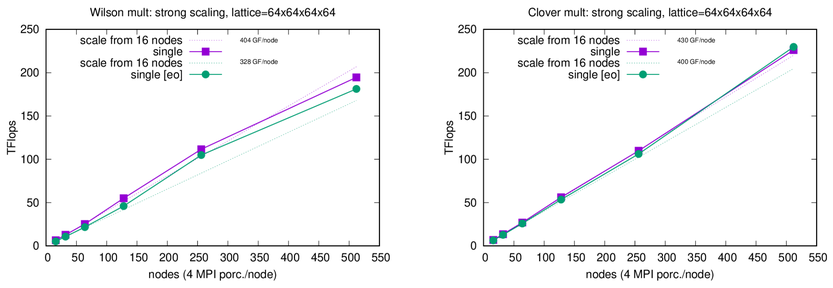

### Weak scaling of solvers

Clover | Domainwall

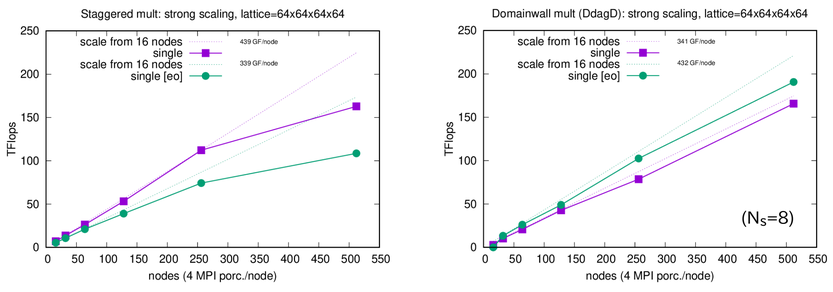



### Strong scaling of Dirac Operator Multiplications

Wilson | Clover



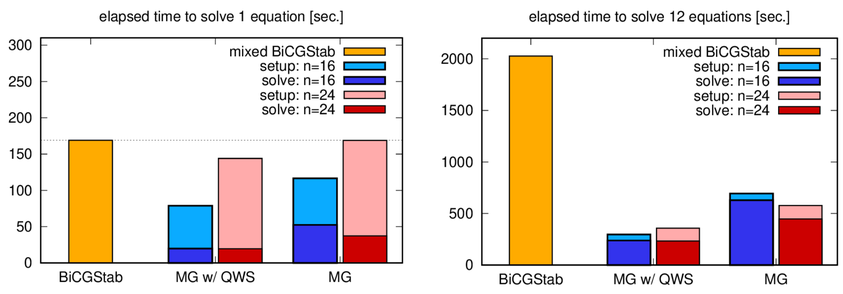

Staggered | Domainwall




### Multigrid Solver

2-level multigrid solver for Clover fermion
K-I. Ishikawa et al. PoS LATTICE2021(2022) 278

a variant of DDαAMG A. Frommer et al. , SIAM J. Sci. Comput. 36 (2014) A1581
smoother: multiplicative SAP, single prec. :from QWS
coarse solver: BiCGStab, single prec.
outer: FBiCGStab

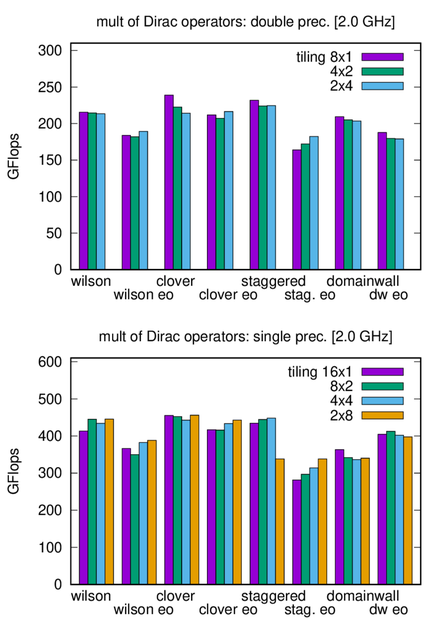



$96^4$ lattice, $M_\pi$=145 MeV configuration [PACS] on 216 nodes

cf. LDDHMC (reimplementation of QWS for HMC) : 52 sec/solve

### SIMD tiling

1 node @2.0 GHz




64x16x16x8 lattice on 1x1x2x2 MPI porc.
MPI boundary comm. is forced to every directions

Fujitsu C/C++ compiler version 4.8.1 tcsds-1.2.36, clang mode
option: `-Kfast -Rpass-missed=inline -mllvm -inline-threshold=1000`

env. variables: `FLIB_BARRIER=HARD`
`XOS_MMM_L_PAGING_POLICY=demand:demand:demand` (default on Fugaku, though)

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