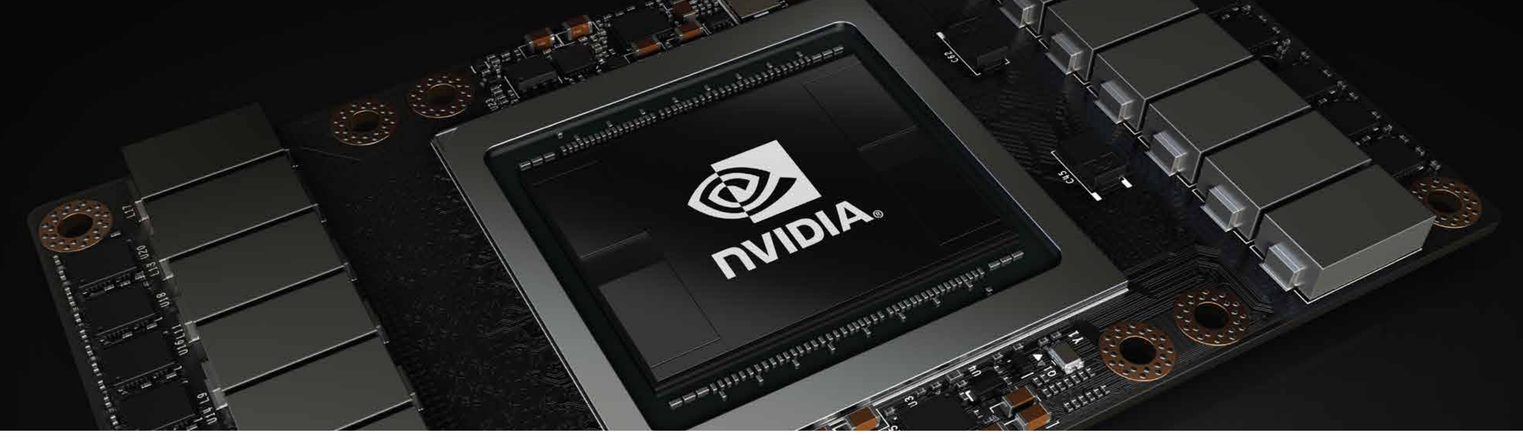
# LATTICE QCD ON NVIDIA® TESLA® V100



# APPROACHING QUDA 1.0

## QUDA: A LIBRARY FOR QCD ON GPUs

QUDA is an open source community-developed and NVIDIA-supported library for performing LQCD calculations on GPUs, leveraging NVIDIA's CUDA platform. QUDA provides highly optimized mixed-precision linear solvers, eigen-vector solvers, gauge-link fattening and fermion force algorithms.

**Supported fermion types are: Wilson, Wilson-clover, twisted mass, twisted mass clover, naïve staggered, improved staggered (ASQTAD or HISQ), domain-wall (4-d or 5-d) and möbius.**

Use of multiple GPUs in parallel is supported throughout the library, with inter-GPU communication achieved using MPI or QMP. Several commonly-used LQCD applications integrate support for QUDA as a compile-time option, including Chroma, MILC, CPS, BQCD, TIFR and tmLQCD.

## WHY GPUs?

- LQCD simulations are typically memory-bandwidth bound, and so run very efficiently on GPUs.
- LQCD simulations have high degrees of data parallelism that can be expressed effectively using the single instruction multiple data (SIMD) paradigm. This makes LQCD ideal for GPU deployment.
- Most LQCD calculations require only local communication on the 4-d lattice. This makes them suitable for deployment on multiple GPUs through partitioning the lattice into disjoint equal sub-lattices and distributing these between GPUs.

## Approaching QUDA 1.0

QUDA is under active development as well as being a production-ready library. As it approaches version 1.0 the development focus concentrates on

- Ease of Development an Stability
- Improved Multi-GPU Scaling
- Readiness for Exascale

## EASE OF DEVELOPMENT AND STABILITY

QUDA leverages modern C++11 to simplify code development and achieve high performance.
A flexible git workflow, relying on GitHub pull requests and build testing via Jenkins CI is employed for rapid and flexible development. Cmake is used for build configuration, allowing for running unit based on googletest through ctest.

**> Friday 15:00 (Software Development Session):**
'Developing QCD Algorithms For NVIDIA GPUs Using the QUDA Framework'

## IMPROVED SCALING

QUDA exploits various techniques to improve communication between GPUs on multiple levels:

- CUDA IPC for direct P2P transfers within fat nodes over NVLink and PCIe
- GPU Direct RDMA for internode communication
- Topology aware scheduling of communication

## US TO BUILD TWO FLAGSHIP SUPERCOMPUTERS

OAK RIDGE National Laboratory — Lawrence Livermore National Laboratory

| SUMMIT | SIERRA |
|---|---|
| 150-300 PFLOPS Peak Performance | > 100 PFLOPS Peak Performance |

- IBM POWER9 + NVIDIA Volta V100
- NVLink high-speed interconnect
- > 40 TFLOPS (DP) per node
- > 4600 nodes (Summit)
- Initial deployment in 2017

## TESLA VOLTA V100

21B transistors
815 mm²

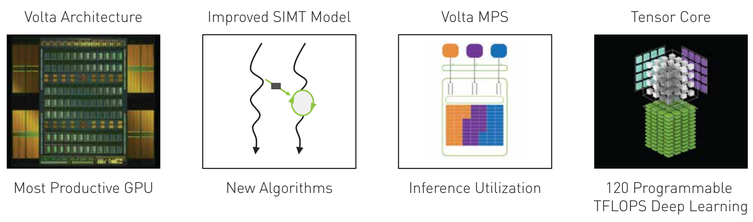
80 sm
5120 CUDA Cores
640 Tensor Cores

16 GB HBM2
900 GB/s HBM2
300 GB/s NVLink

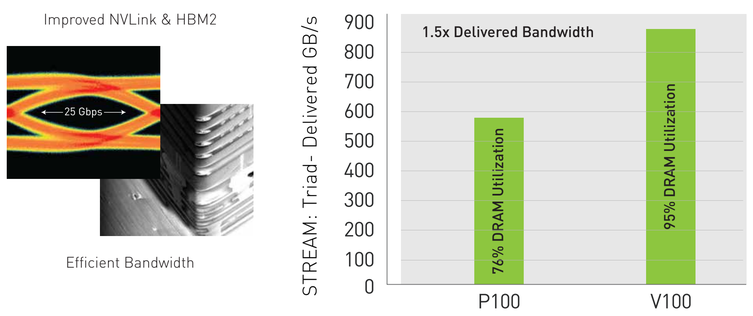
## GENERATIONAL IMPROVEMENTS

| | P100 | V100 | RATIO |
|---|---|---|---|
| FP64/FP32 | 5/10 TFLOPS | 7.5/15 TFLOPS | 1.5X |
| HBM2 Bandwidth | 720 GB/s | 900 GB/s | 1.2X |
| NVLink Bandwidth | 160 GB/s | 300 GB/s | 1.9X |
| L2 Cache | 4 MB | 6 MB | 1.5X |
| NVLink Bandwidth | 1.3 MB | 10 MB | 7.7X |

## ARCHITECTURAL IMPROVEMENTS

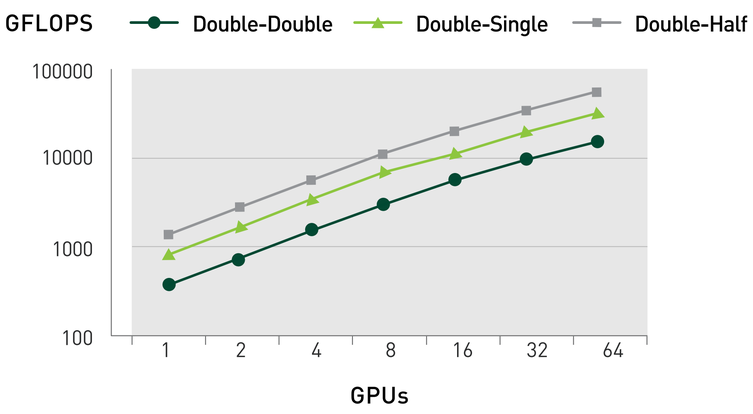



## IMPROVED MEMORY SUBSYSTEM

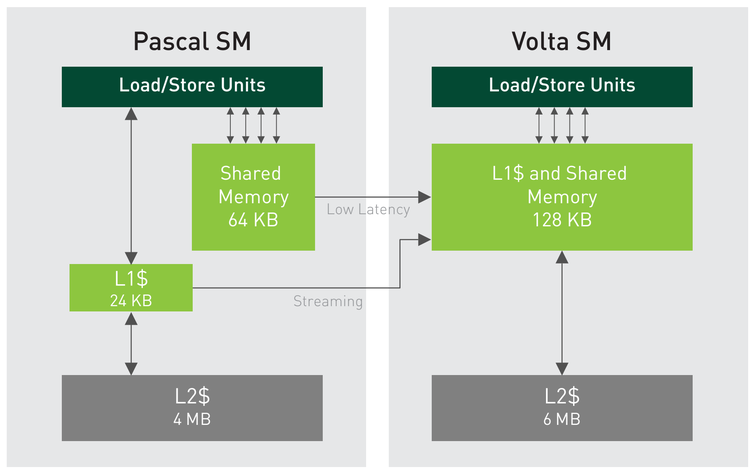



## SOLVER SCALING ON SATURN V (DGX-1NODES)

Volume per GPU = $24^4$x16, Mixed precision Shamir CG, 8 P100 GPUs per node

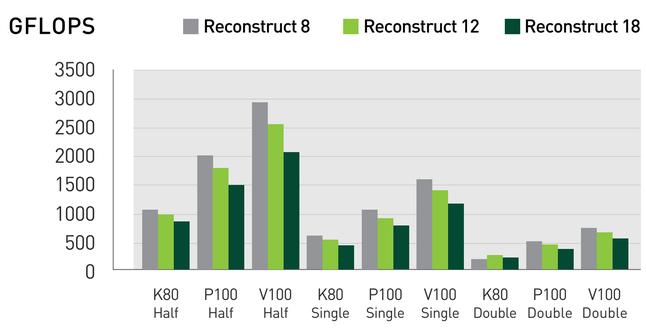



## ENHANCED L1 CACHE



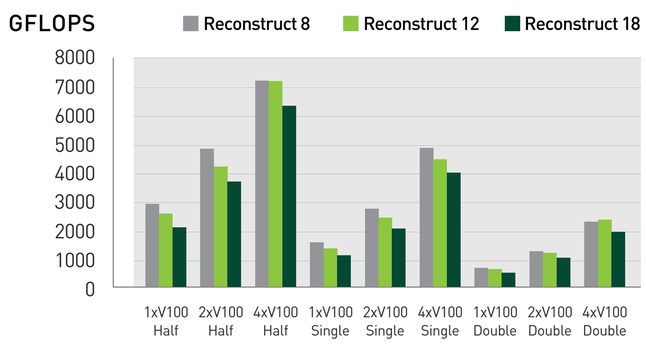

## WILSON CLOVER DSLASH

Volume = $32^4$



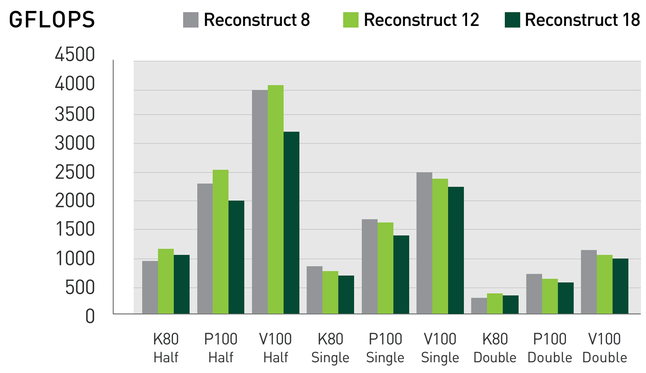

## MULTI-GPU WILSON CLOVER DSLASH

Global Volume = $32^4$, NVLink



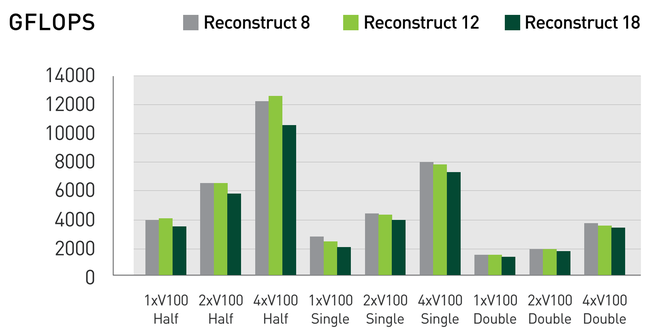

## MÖBIUS DSLASH

Volume = $32^4$x16



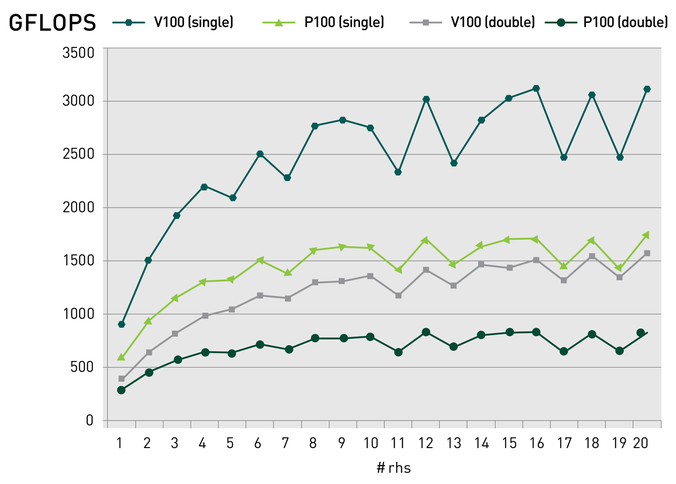

## MULTI-GPU MÖBIUS DSLASH

Global Volume = $32^4$x16, NVLink




## HISQ Dslash for multiple rhs

Volume = $24^4$, Gauge reconstruct




## REFERENCES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