# Introducing Qiskit Aer MPI Simulator

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# Overview of MPI Simulator



- Distributed parallel simulation for large number of qubits
  - Parallel simulation on HPC cluster (GPU or CPU)
  - > 30 qubits
  - Supoorts ‘statevector’, ‘unitary’ and ‘density_matrix’ methods
- Multi-shots distribution over processes
  - Shots distribution for small number of qubits (GPU only)

# Running MPI Simulator



- Run Python scripts through mpirun command
  - mpirun -np 4 python circuit.py
- Set ‘blocking_qubits’ parameter to enable distribute large qubits
  - sim = AerSimulator(method='statevector', device='GPU’, blocking_qubits=20)
- Results are returned to each process
  - Read metadata to identify process ID
    - if result.to_dict()['metadata']['mpi_rank'] == 0:

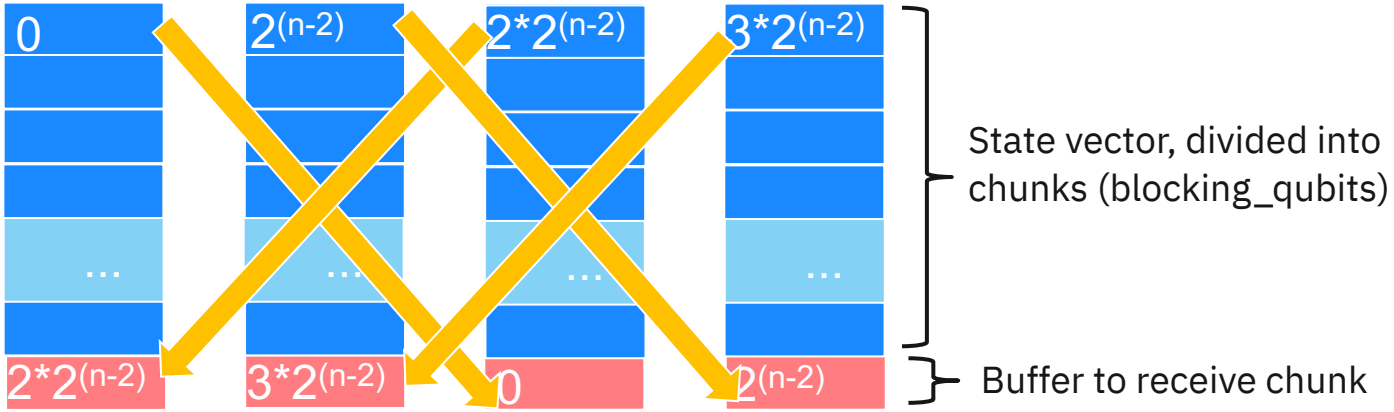
# Script Example for MPI Parallelization



```
from qiskit import *
from qiskit.circuit.library import *
from qiskit.providers.aer import *
sim = AerSimulator(method='statevector', device='GPU', blocking_qubits=20)
shots = 100
depth=10
qubits = 35
circuit = transpile(QuantumVolume(qubits, depth, seed=0),
                    backend=sim,
                    optimization_level=0)
circuit.measure_all()
result = execute(circuit,sim,shots=shots,seed_simulator=12345).result()
if result.to_dict()['metadata']['mpi_rank'] == 0:
   print(sorted(result.to_dict()['results'][0]['data']['counts'].items(),key=lambda x:x[0]))
```

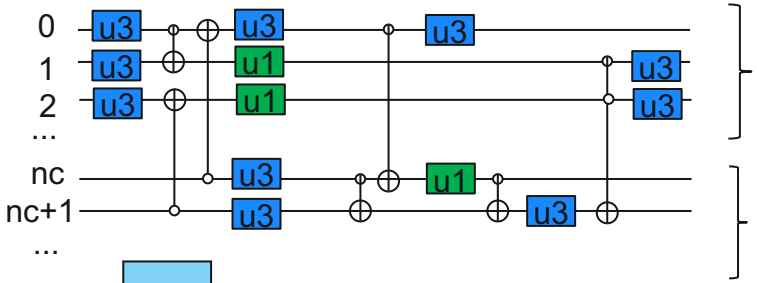
# Chunk Based Parallelization





# Cache Blocking Technique

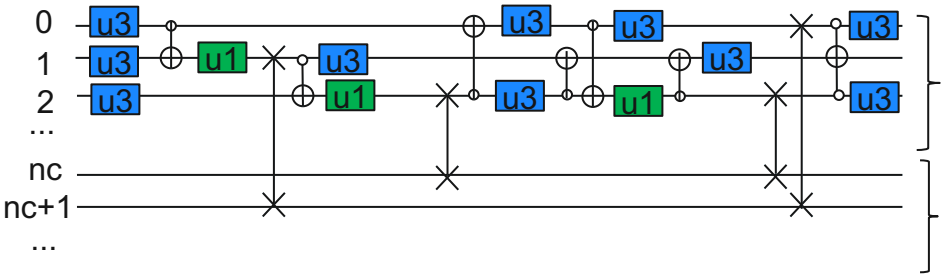





In chunk

Out of chunk : **data exchange required**

Inserting swap gates to move all gates into chunk




In chunk : gates can be simulated without data exchange

Out of chunk : no gate operations only swap gates need data exchange between chunks

# Chunk Swap Optimization

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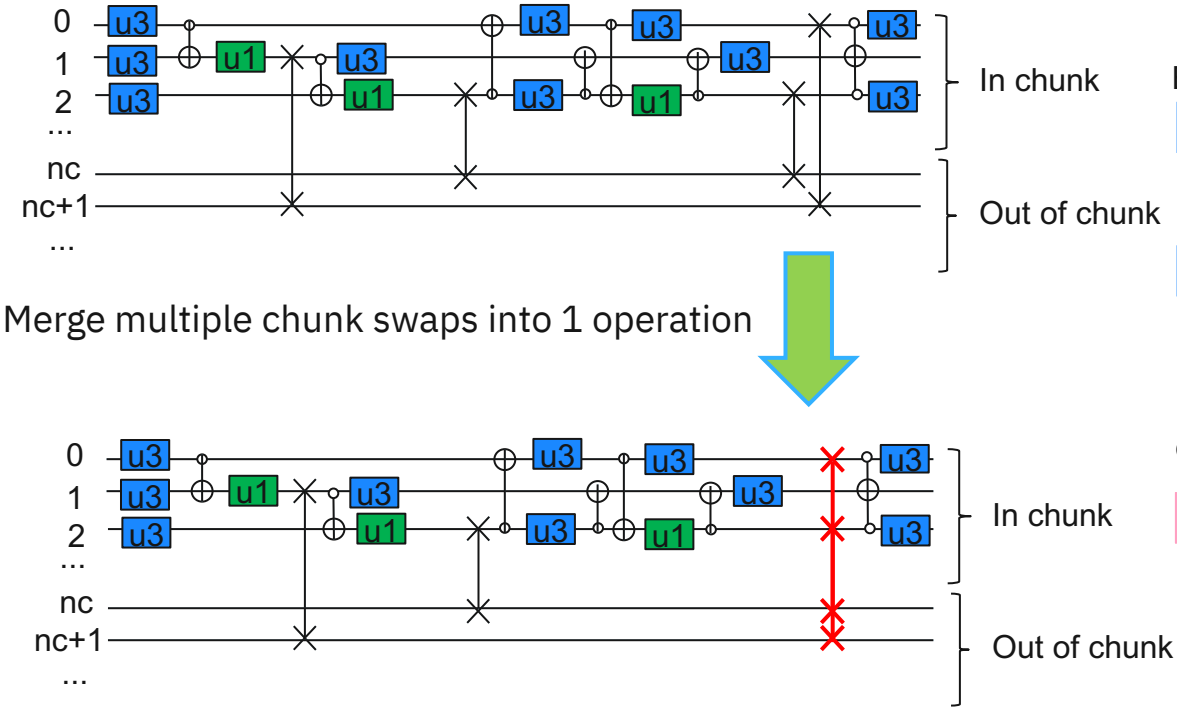
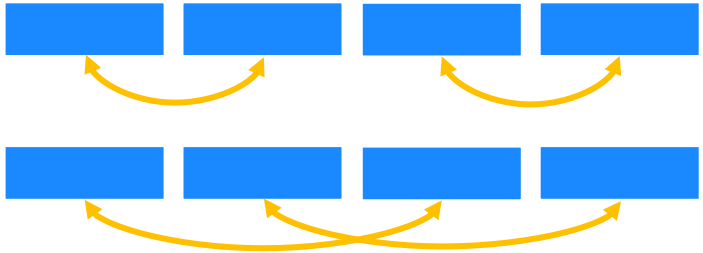


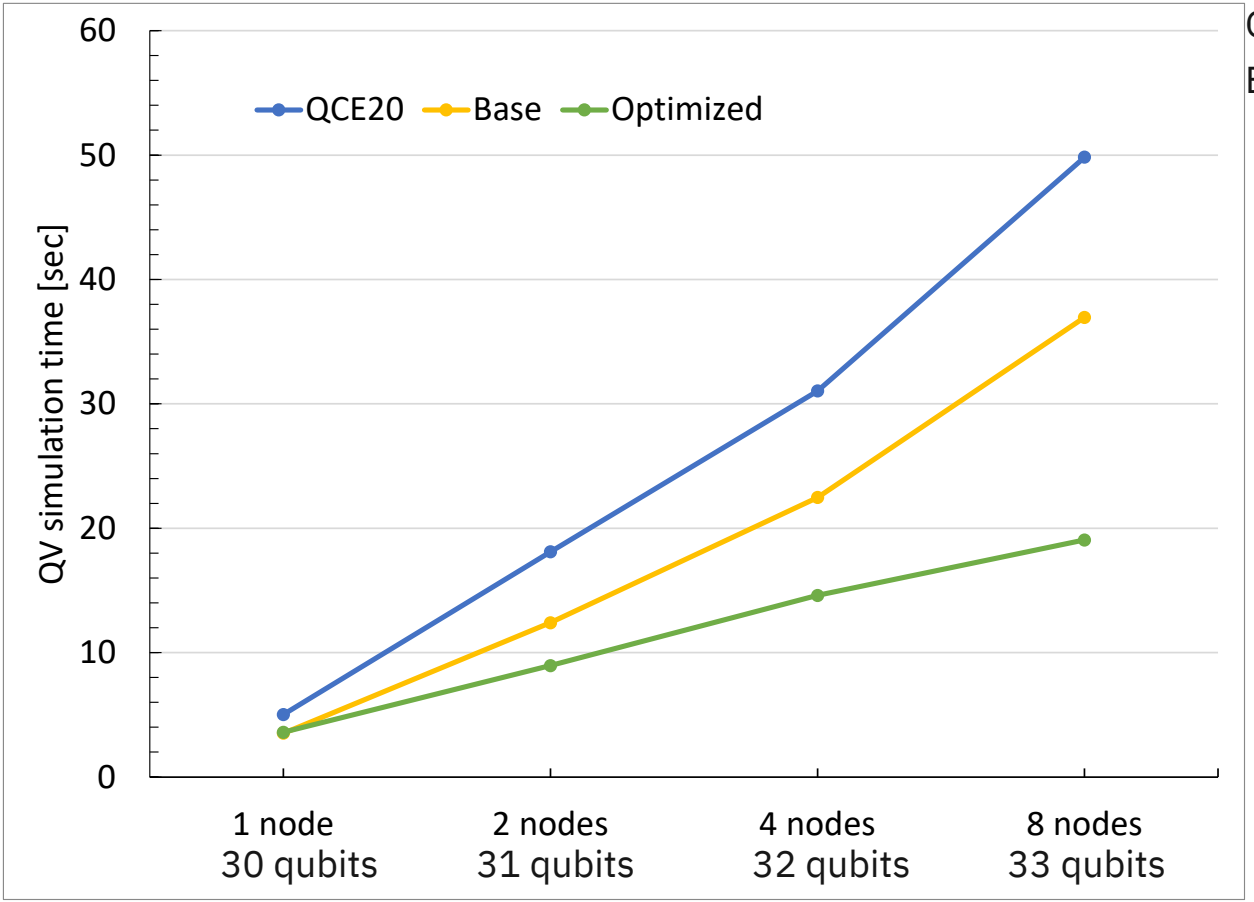

Each chunk swap exchanges whole chunks



Multiple chunk swaps can be done by one all-to-all communication

# Performance Improvement






Weak scaling, 30 qubits / node

QCE20: Performance reported at QCE20

Base:w/o multi-chunk swaps

IBM Power System AC922

6x NVIDIA Tesla V100