The Chapel Tasking Layer Over Qthreads

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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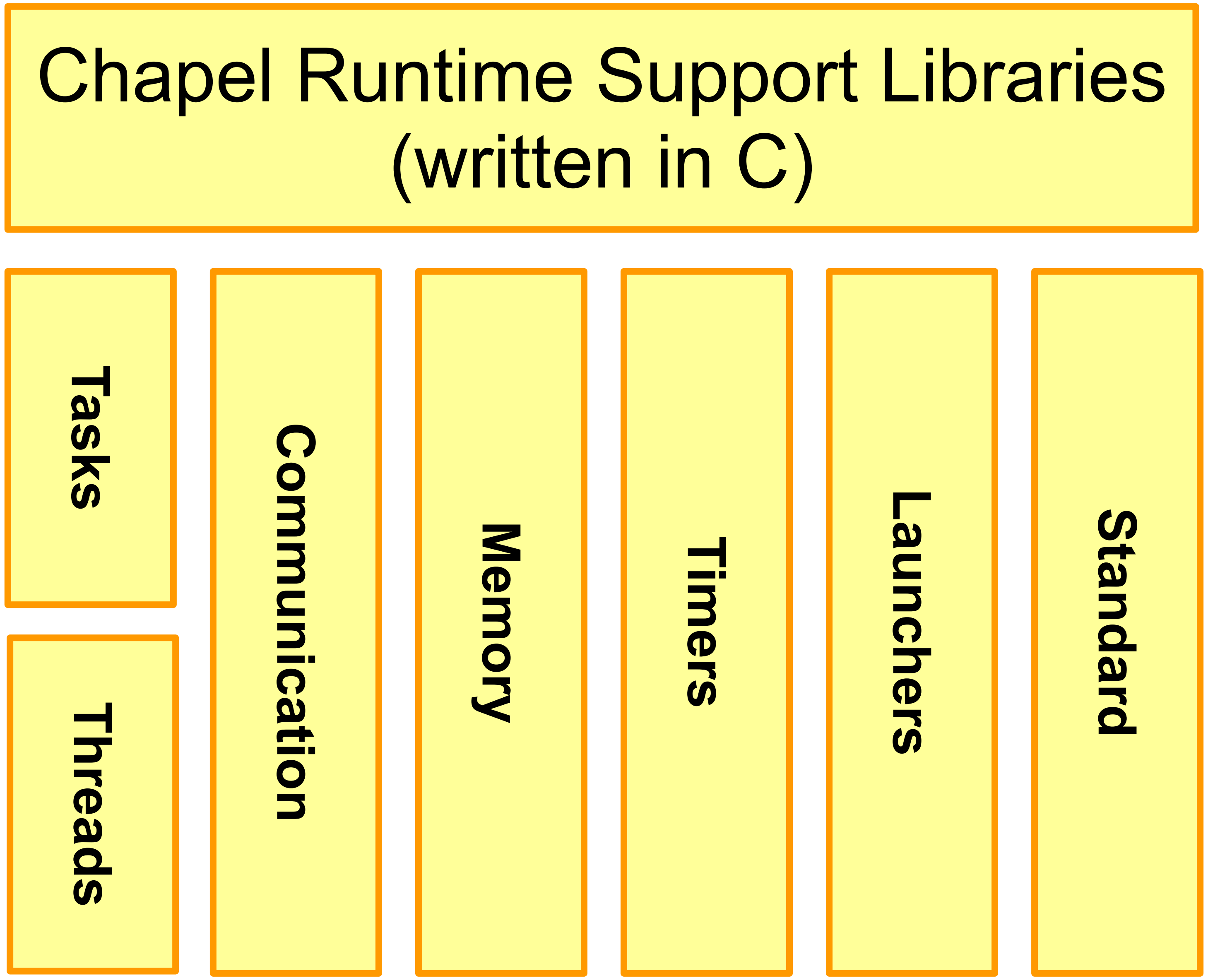
The Structure of Chapel's Runtime



Chapel's Tasking Layer

- **Role:** Responsible for parallelism/synchronization
- **Main Focus:**
  - support begin/cobegin/coforall statements
  - support synchronization variables
- **Main Features:**
  - Startup/Teardown
  - Singleton Tasks
  - Task Lists
  - Synchronization
  - Control
  - Queries
  - ...serialization?

The FIFO Tasking Implementation

- **Work-queue model**
  - Function calls for work execution
  - Centralized queue

- **Pros:**
  - Simple, easy to debug
  - Very portable
  - Uses native state management
    - stacks
    - thread/task-specific data

- **Cons:**
  - Task synchronization (`sync`) using thread synchronization (`pthread_mutex_t`)
    - Compute/synch overlap requires oversubscribing (#threads > #cpus)
    - Difficult to provide non-native (non-mutex) synchronization behavior
  - #Task-to-#thread mismatch creates unexpected deadlock potential
  - Does not support work stealing
  - Does not support CPU pinning

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Challenges in Highly-Threaded Runtimes

- **Per-thread state**
  - State vs threads
- **Locality**
  - An afterthought in standard threading models
  - Communication and synchronization are expensive, easy to use accidentally
- **Synchronization**
  - Hard to make portable, maintain guarantees
- **Every Machine is Different**
  - Granularity of sharing (cacheline size)
  - Optimal number of threads (PU count)
  - Communication topology
  - Cache structure
  - Memory model
  - Synchronization Primitives (`CMPXCHG` vs `TNS` vs `CASXA` vs `LDARX/STWCX`)

Qthreads Highlights

- **Lightweight User-level Threading (Tasking)**
- **Platform portability**
  - –IA32/64, AMD64, PPC32/64, SparcV9, SST, Tilera
  - –Linux, BSD, Solaris, MacOSX
- **Locality awareness**
  - –“Shepherd” as thread mobility domain & locality
- **Fine-grained synchronization semantics**
  - –Full/Empty Bits (64-bit & 60-bit)
  - –Mutexes
  - –Atomic operations (Incr & CAS)
- **Locality-aware Workstealing Model**

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Chapel Single Locale Challenges

- **Startup & Teardown**
  - Functions with unspecified scope
  - Synchronization primitives of unspecified scope
- **Unsupported Behavior**
  - Limit on OS Threads
    - Default defined by hardware
  - Forced serialization of tasks
  - Task-local data

Chapel Multi-Locale Challenges

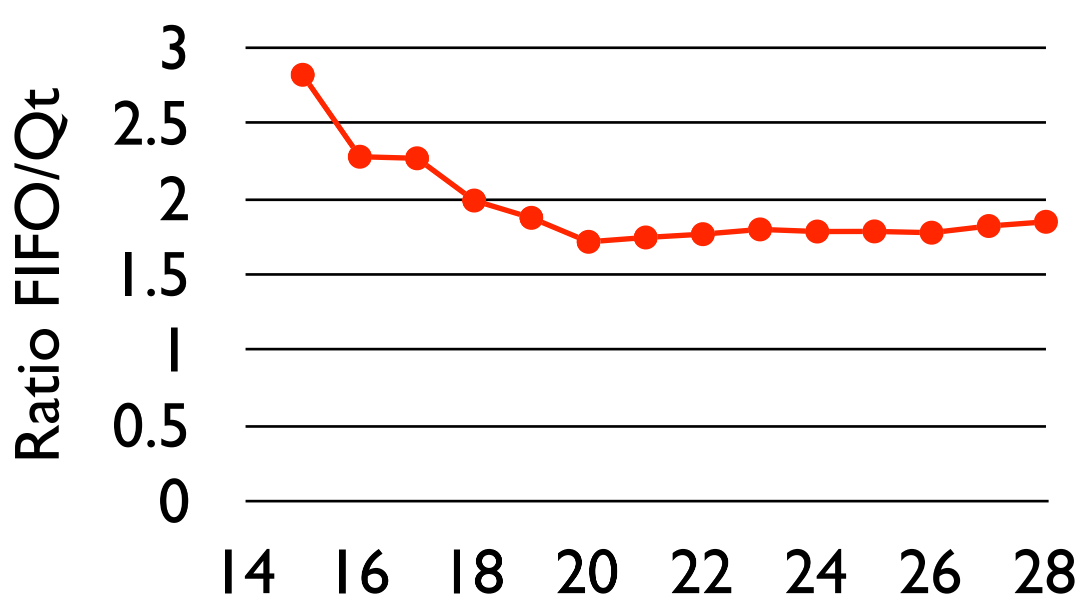
- **Communication (via GASNet)**
  - **Blocking system calls**
    - Dedicated OS thread
    - Possibility for proxying internally
    - Temporary solution: Forked initialization thread
    - Future solution: explicit progress thread creation
  - **External Task Operations**
    - Task creation from outside the task library
      - Memory management issue
      - Also: synchronization issue…
    - Task synchronization outside the task library
      - Proxy-task using thread-level synchronization (pthread_mutex_t)

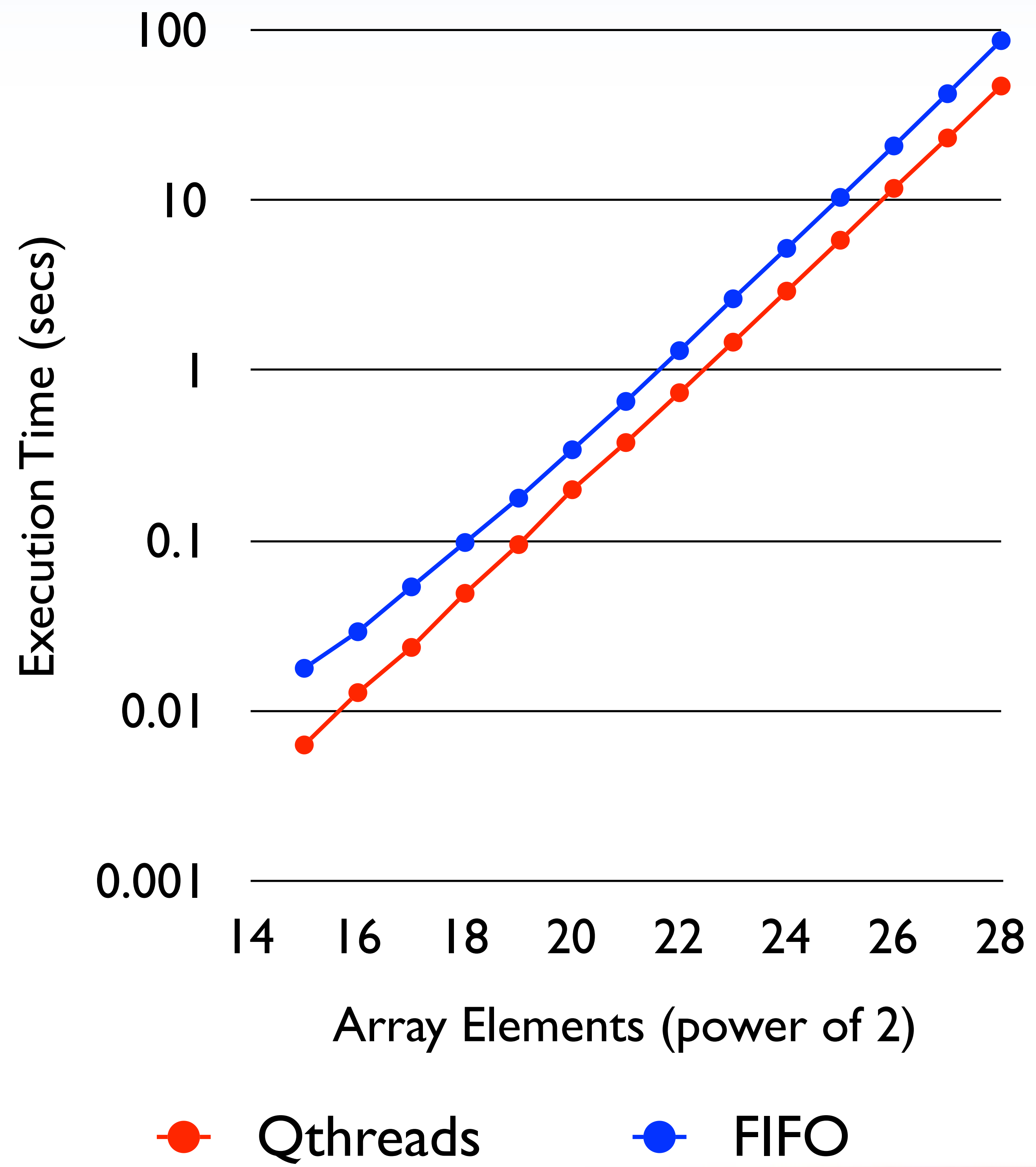
Future Work

- **Synchronization**
  - Tasking interface assumes only mutex semantics
  - MTA/Qthreads interface provide fast FEB semantics
  - Implementing FEB semantics with a mutex implemented with FEB operations is silly and slow
- **Stack Space**
  - Problem common to all tasking interfaces
  - Currently requires guess-and-check
  - Potential directions:
    - Technically possible to calculate stack requirements (e.g. gcc 4.6)
    - Technically possible to move stack variables to heap
      - Moves the memory management problem

Performance: Raw Tasking

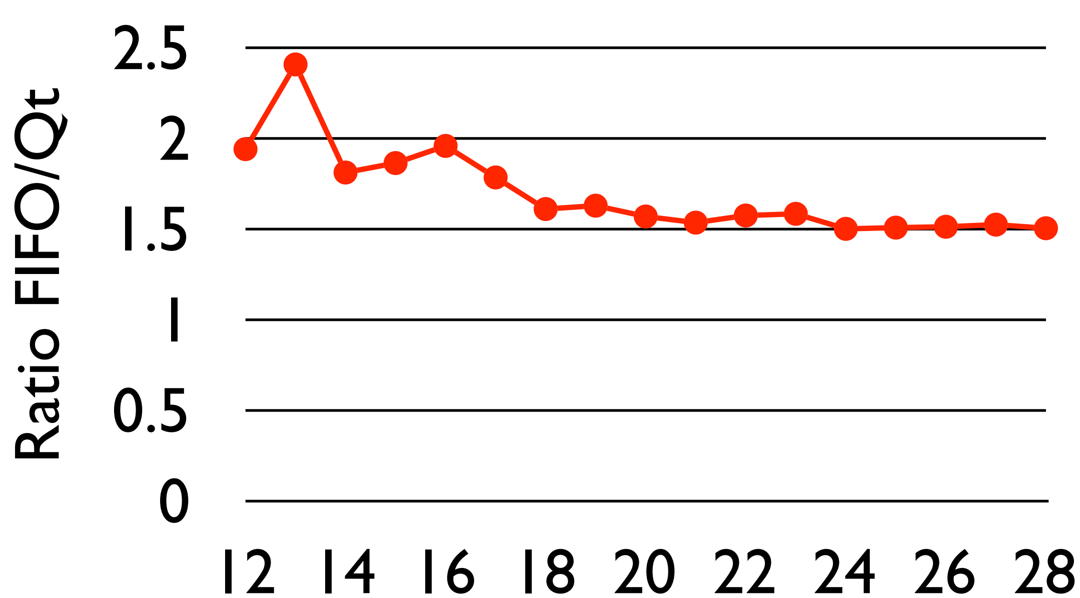
- **QuickSort**
  - –Naïve implementation (serial partitioning)
  - –Uses recursive `cobegin`
  - –Serialization threshold
    - For best comparison, set high to avoid serialization

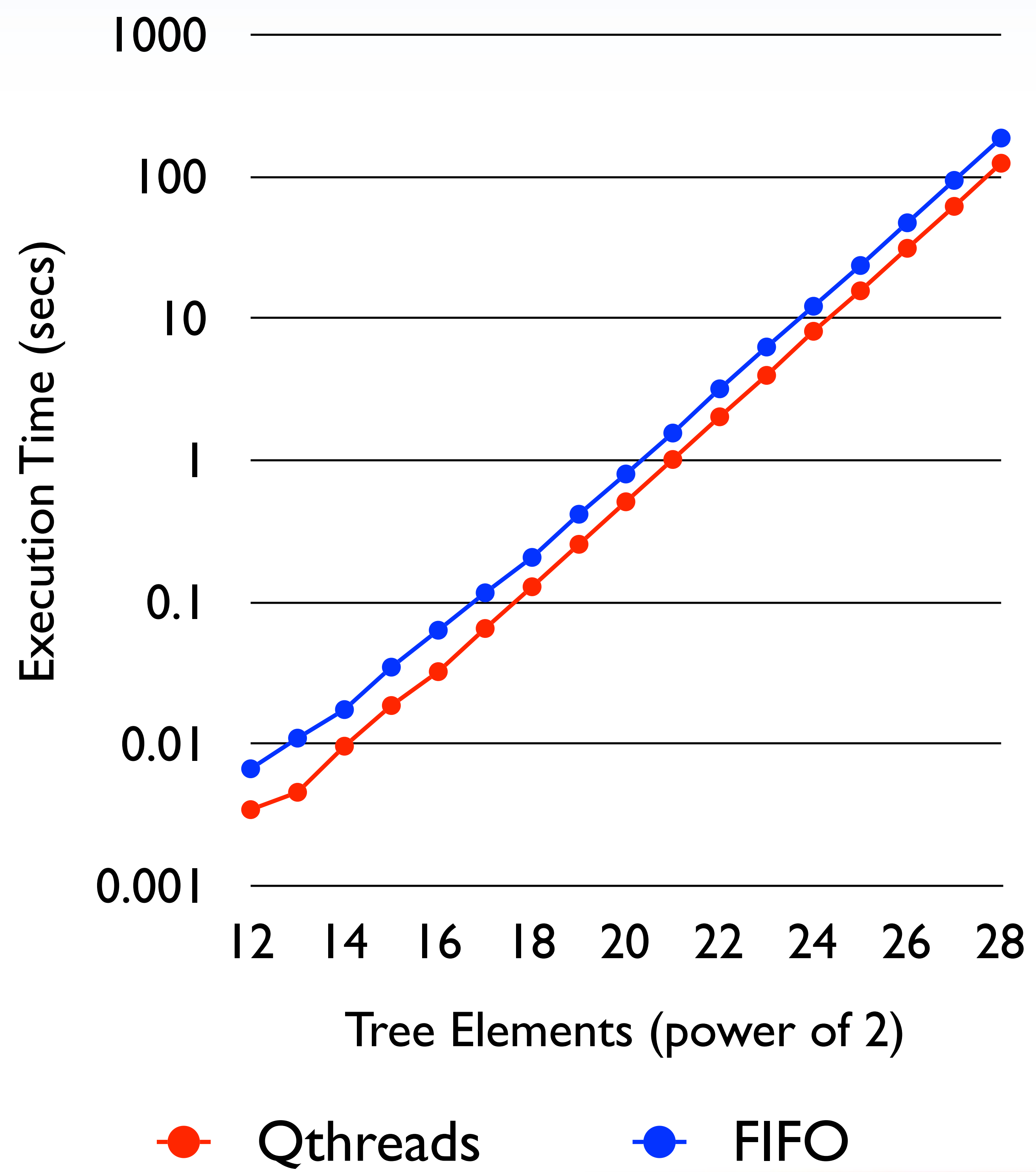




Performance: Raw Tasking

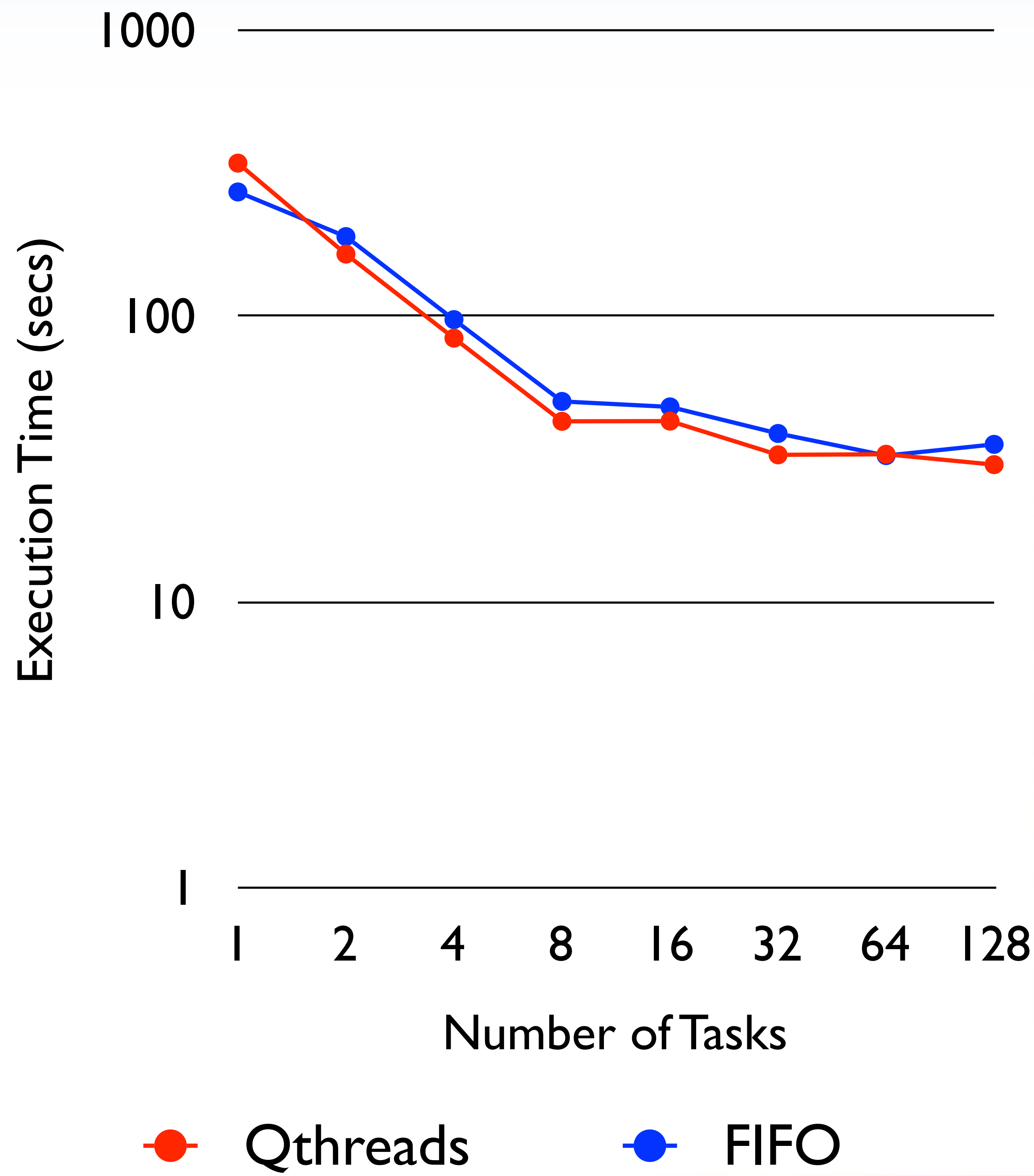
- **Tree Exploration**
  - –Constructs binary tree
  - –Assigns Unique ID
  - –Computes sum of IDs
  - –Uses recursive `cobegin`

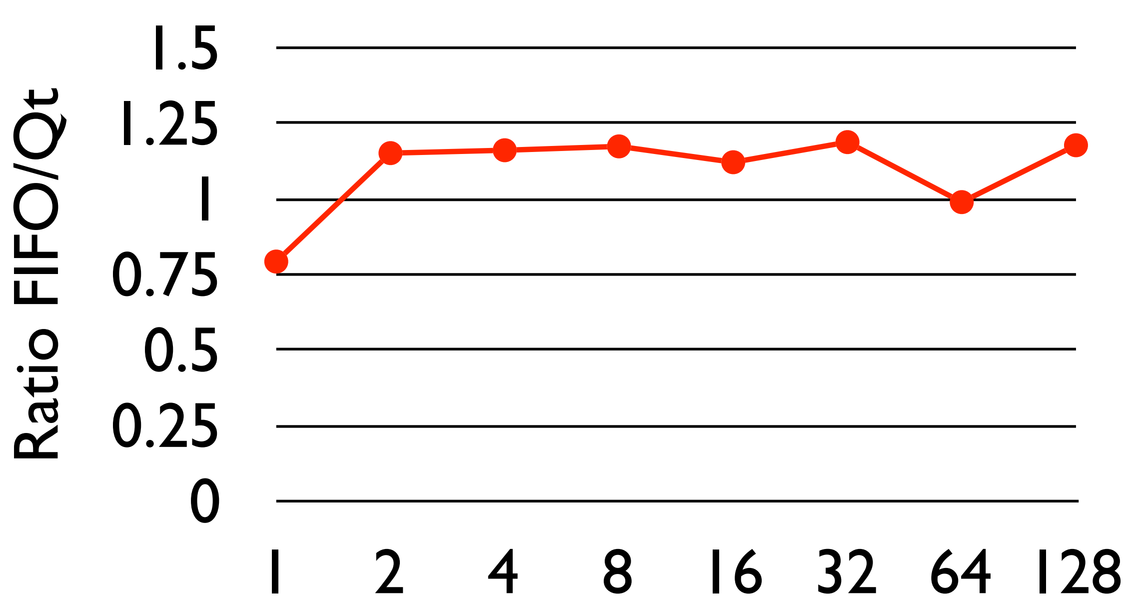




Performance: Data Parallel

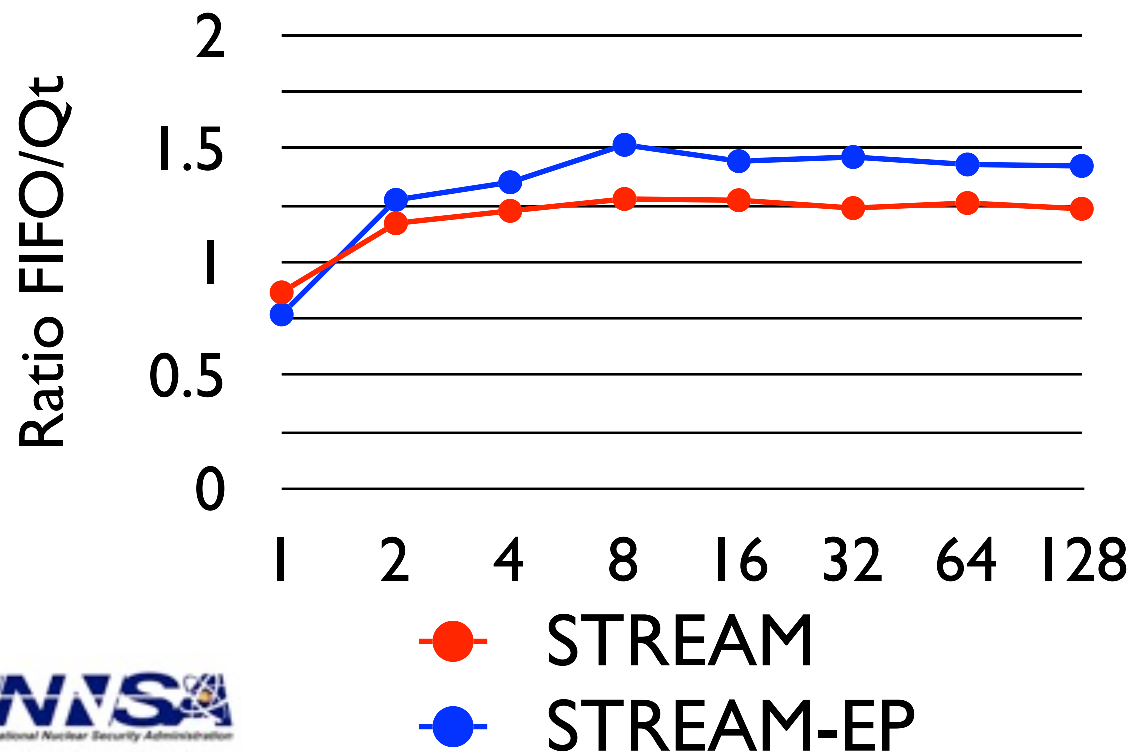
- **HPCC RandomAccess**
  - GUPS (random integer updates)
  - Stresses Memory System
  - Uses `forall`

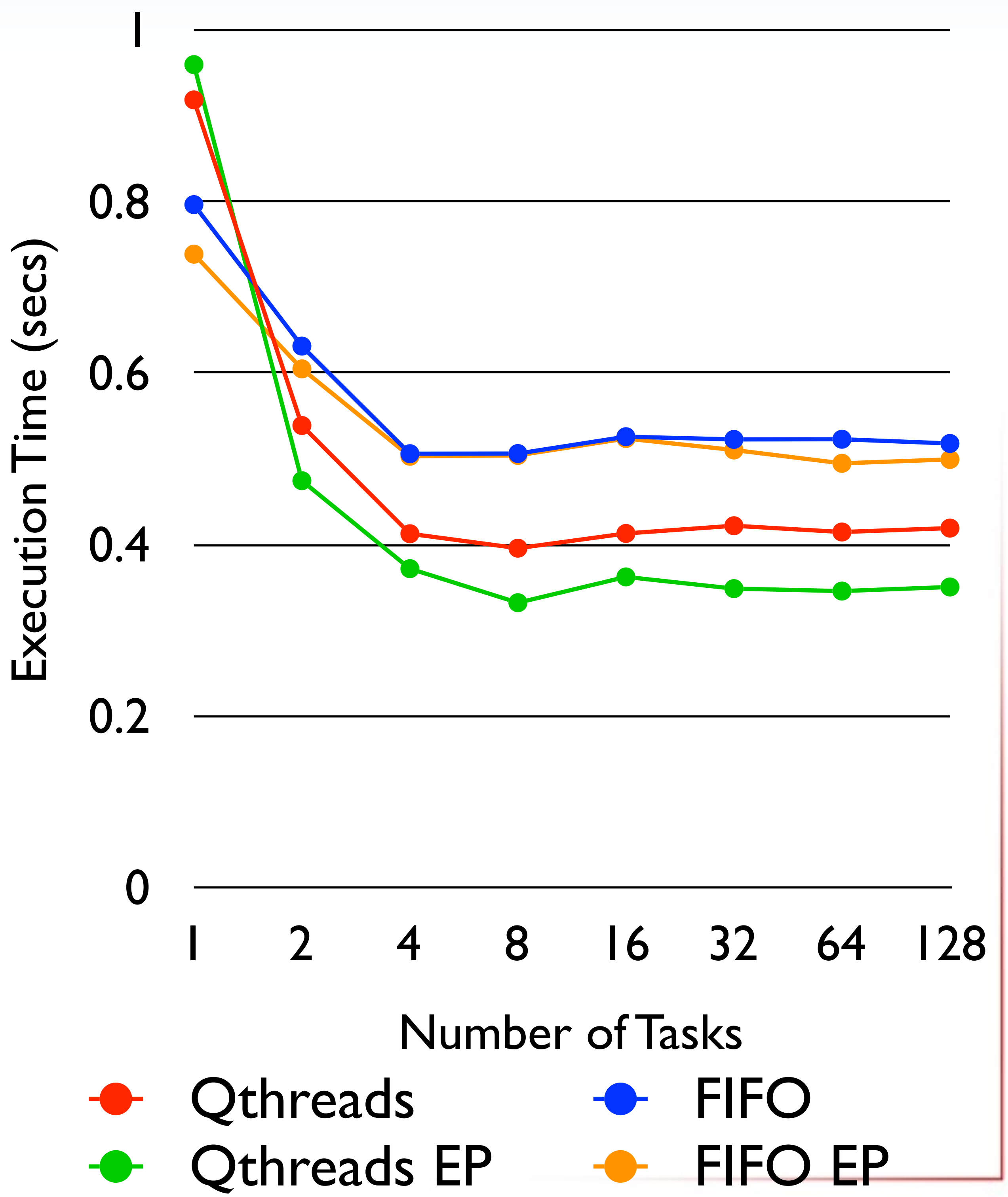




Performance: Data Parallel

- **HPCC STREAM (-EP)**
  - Memory Bandwidth & Vector Kernels
  - EP version avoids communication
  - Uses `forall`
  - Synchronization surprisingly important





Thank You!

Questions?

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