**Multi-scale Lattice Field Theory Algorithms—Preparing for Exascale**

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**S2-S2I: Scalable Hierarchical Algorithms for Extreme Computing (SHARE) goal is to developing and implementing fast “adaptive multi-level solvers targeting multiple GPUs.”**

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**Problem: LHC: p + p -> “Higgs” + QCD stuff [1]**

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**Multi-scale Physics \(\rightarrow\) Multilevel Solvers**

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**QFE: Quantum Finite Element Methods [6-7]**

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**Target Heterogeneous: IMB/NVIDIA (GPU) or Cray/Intel(Phi)**

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**Accelerated Computing**

**5x Higher Energy Efficiency**

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**“QCD on CUDA” – http://lattice.github.com/quda**

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**Adaptive Smooth Aggregation Multigrid**

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**Multi-scale Physics \(\rightarrow\) Multilevel Solvers**

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**References**

1. SciDAC-3 HEP: Searching for Physics Beyond the Standard Model: Strongly-Coupled Field Theories at the Intensity and Energy Frontiers
4. R. Babich, M. Clark, M. Cheng, Adaptive Multigrid Solvers for LGCD on GPUs, Lattice 20
6. R. Brower , G. T. Fleming, A. Gasbarro, T. Raben, C-I Tan and E. Weinberge, Quantum Finite Elements for Lattice Field Theory, Lattice 2015

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**GPU technology + MG \(\rightarrow\) Reduces $ cost by over a factor of 1/100.**


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**Mixed precision with reliable updates**

Using a mixed-precision solver incorporating “reliable updates” (Clark et al., arXiv:0911.3191) with half precision greatly reduces time-to-solution while maintaining double precision accuracy.

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**Hierarchical algorithms on heterogeneous architectures**

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**MG on Accelerators**

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**Coarse Grid Operator Performance**

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**QFEM: Barrows ideas from FEM for PDEs and Regge Calculus [7] for Quantum Gravity to renormalize and simulate Quantum Fields on Curved Manifolds**

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**Industry Collaboration: NVIDIA**

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NVIDIA has hired two former BU Doctoral Fellows:
Mike Clark leading the QUDA project (code design and new algorithms)
Ron Babich evaluates future architectures for QCD kernels (cache size, memory latency, bandwidth etc.) Rich Brower is a NVIDIA CUDA Fellow