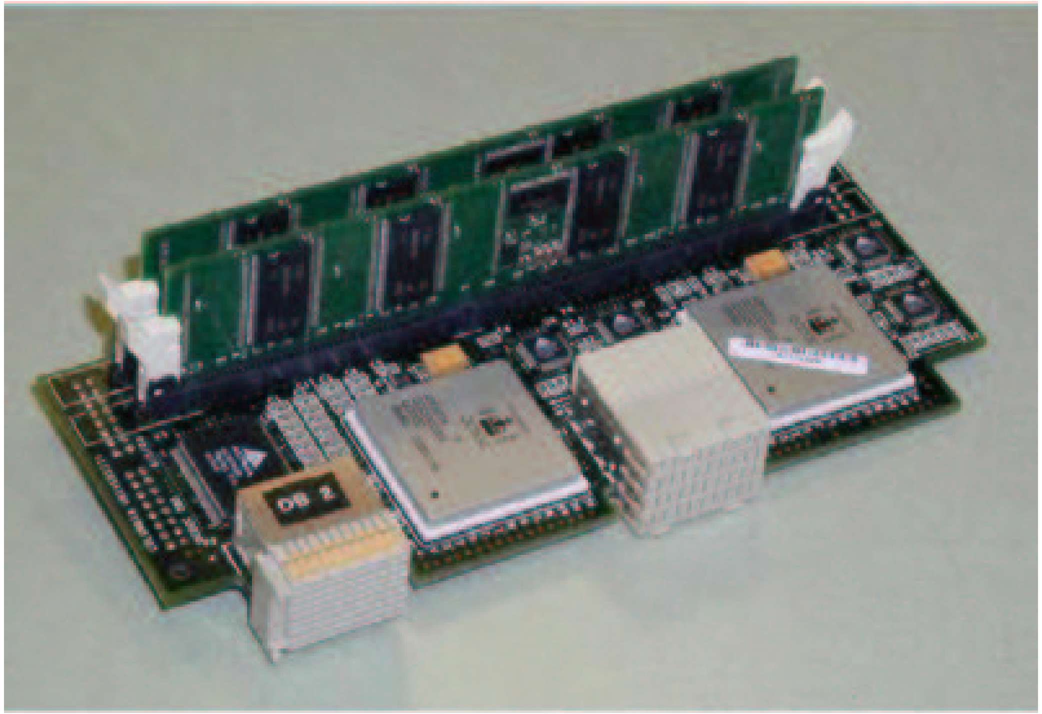
LATTICE GAUGE PLANS

Michael Creutz



Lattice gauge theory is a powerful tool

Successes

- Confinement Quark Confining Dynamics
- Hadronic spectrum
- Verification of chiral symmetry breaking $m_\pi^2 << m_\rho^2$
- Deconfinement at high temperature $T_c \sim 150$ Mev
- Matrix elements to test standard model (K decays, etc.)

Future Potential

Experiments need lattice results for interpretation

- plasma at BNL; $g-2$
- structure functions at JLAB
- weak decays at FNAL, SLAC, BNL, CLEO

Theory errors often dominate

Remove quenched approximation

TERASCALE COMPUTING ESSENTIAL TO PROGRESS

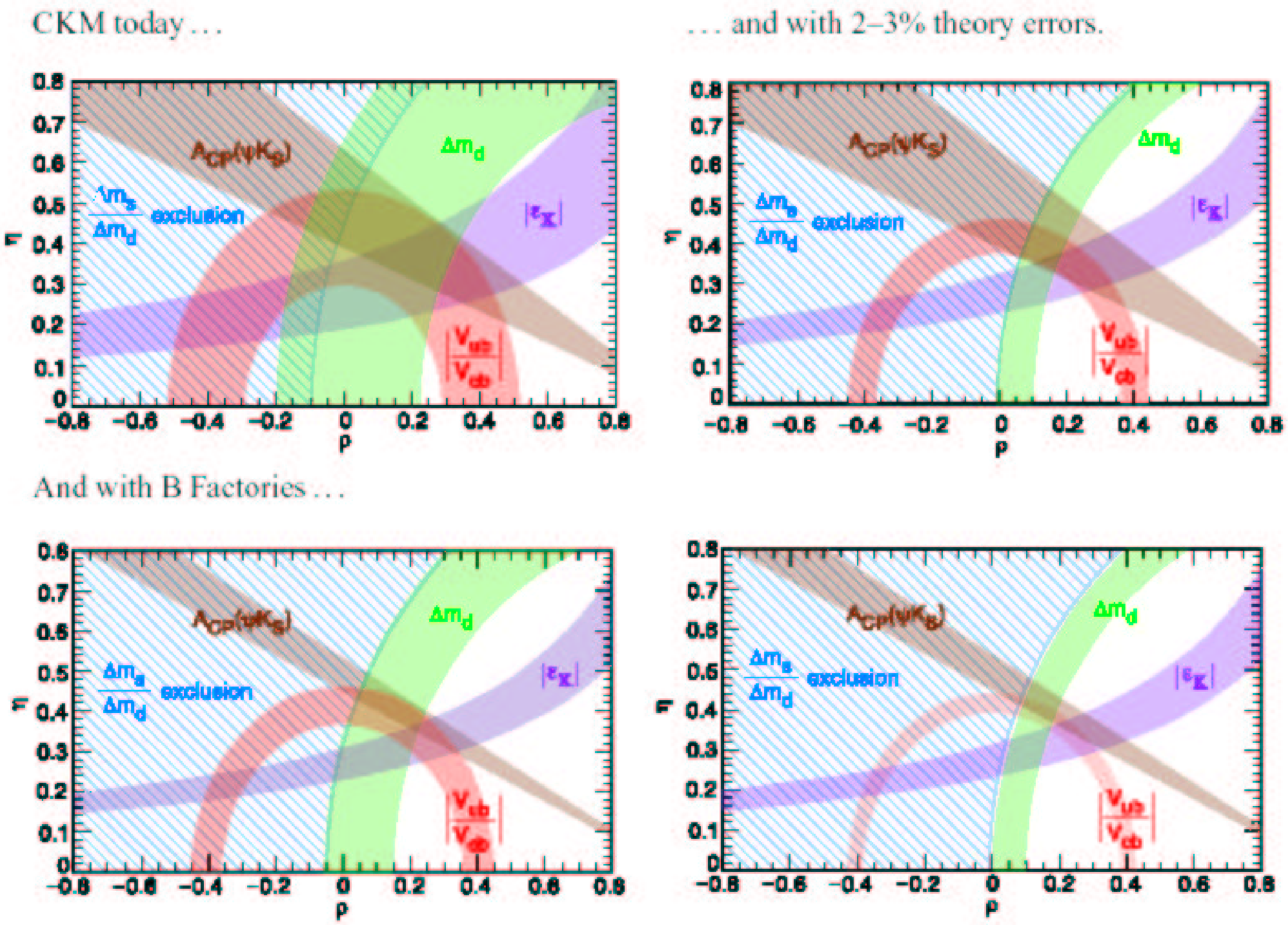
Impact of Increased Computing Resources

Measurement	CKM Matrix Element	Hadronic Matrix Element	Non-Lattice Errors	Current Lattice Errors	Lattice Errors 0.6 TF-Yr	Lattice Errors 6.0 TF-Yr	Lattice Errors 60. TF-Yr
ε_K ($\bar{K}K$ mixing)	$\mathrm{Im}\, V_{td}^2$	$\hat{B}_K$	10%	20%	12%	5%	3%
ΔM_d ($\bar{B}B$ mixing)	$\lvert V_{td}\rvert^2$	$f_{B_d}^2 B_{B_d}$	6%	30%	16%–26%	8%–10%	6%–8%
$\Delta M_d / \Delta M_s$	$\lvert V_{td}/V_{ts}\rvert^2$	ξ^2	—	12%	8%	6%	3%–4%
$B \to \binom{\rho}{\pi} l\nu$	$\lvert V_{ub}\rvert^2$	$\langle \binom{\rho}{\pi} \rvert (V-A)_\mu \lvert B\rangle$	7%	15%	10%–13%	5.5%–6.5%	4%–5%
$B \to \binom{D^*}{D} l\nu$	$\lvert V_{cb}\rvert^2$	$\lvert \mathcal{F}_{B\to\binom{D^*}{D} l\nu}\rvert^2$	2%	4.4%	3%–4%	1.8%–2%	1%–1.4%

Impact of lattice QCD on the determination of CKM matrix elements. The non–lattice errors in the fourth column are primarily experimental. The last three columns show the improvements in lattice errors that we estimate would be obtained with computers sustaining 0.6 and 6.0 and 60. Tflops for one year.

HEPAP, February 9, 2004 – p.5/24

Impact of Reduced Lattice Errors



The impact of the B factories and improvements in lattice calculations on parameters of the CKM matrix. CLEO-c Collaboration (2001).

HEPAP, February 9, 2004 – p.7/24

The Lattice SciDAC Project

66 US lattice theorists; 9 member executive committee:

R. Brower, (Boston U.) N. Christ (Columbia U.), M. Creutz (BNL), P. Mackenzie (Fermilab), J. Negele (MIT), C. Rebbi (Boston U.), S. Sharpe (U. Washington), R. Sugar (UCSB) and W. Watson, III (JLab)

Two prong approach

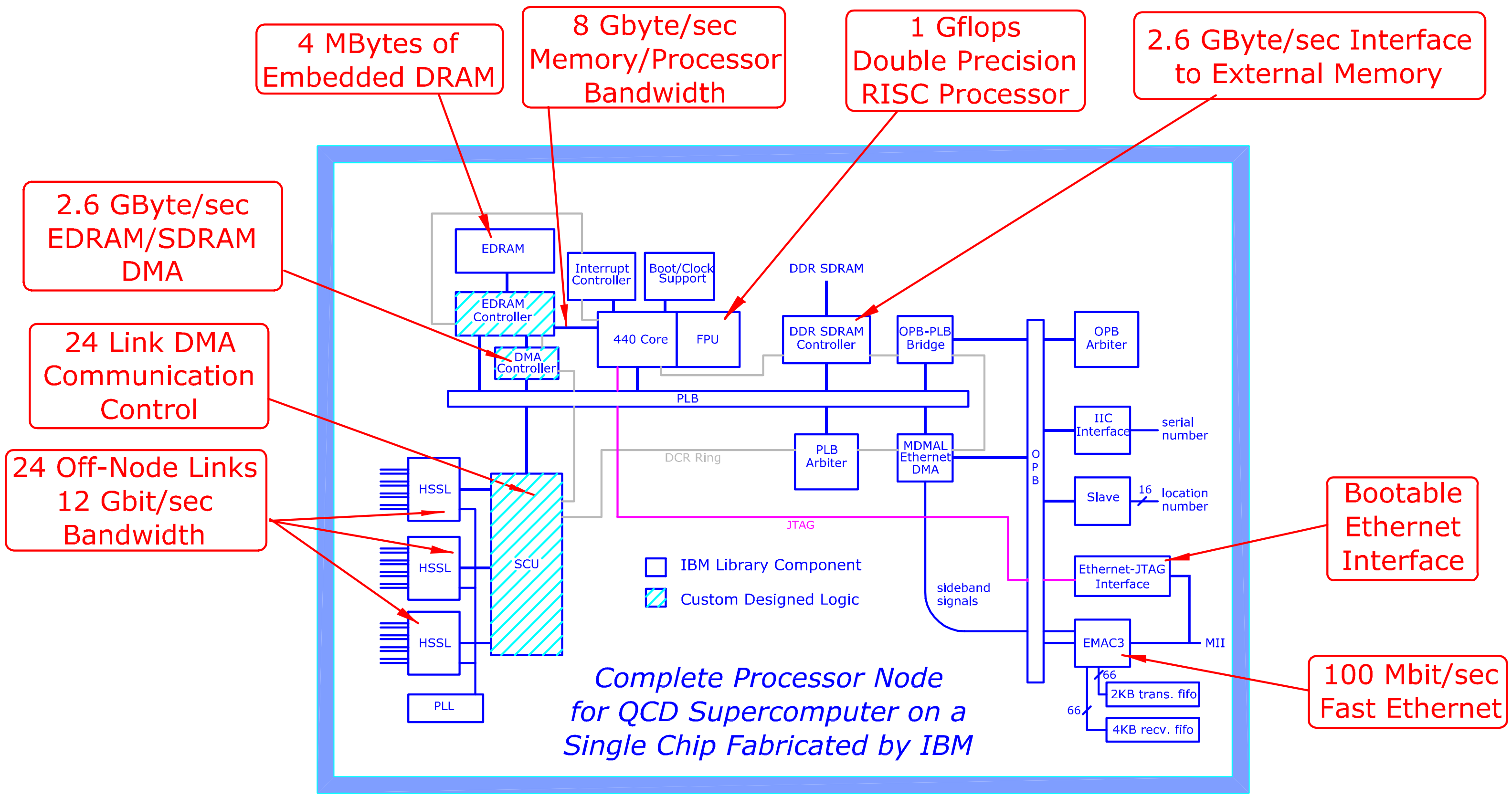
- QCDOC at BNL
- commodity clusters at Fermi Lab and Jefferson Lab
- $\sim 3 \times 10$ Teraflops distributed computing facility

QCDOC

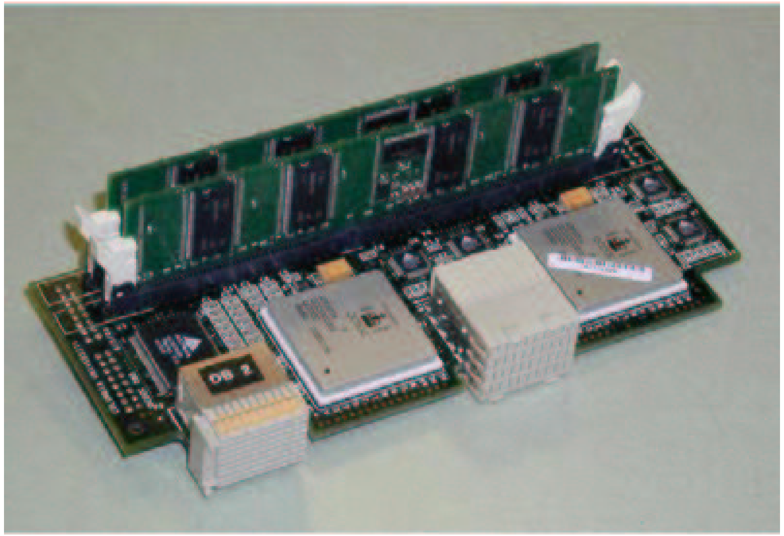
- next generation after QCDSP
- designed by Columbia University with IBM
- on design path to IBM Blue Gene
- Power PC nodes connected in a 6 dimensional torus
- processor/memory/communication on a single chip

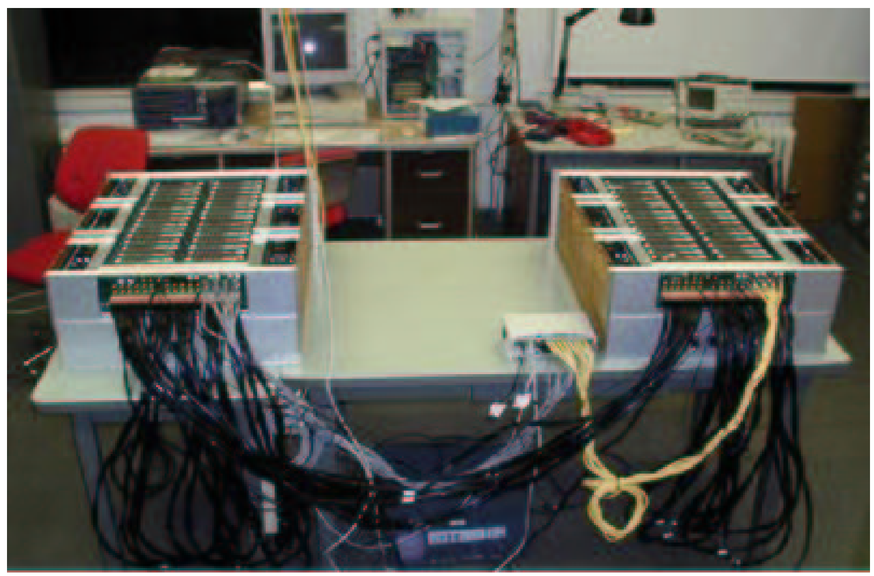
QCDOC places entire node on a single custom chip

QCDOC ASIC DESIGN



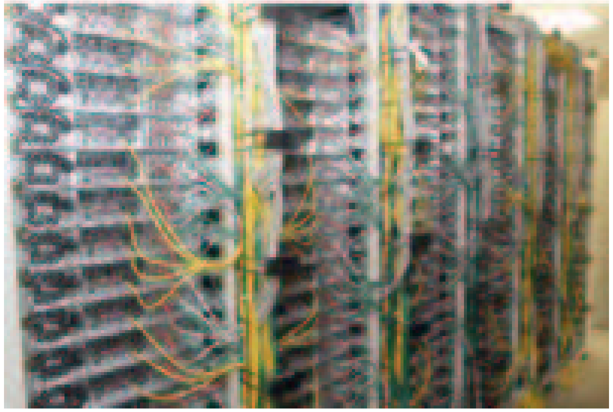
Misson-critical, custom logic (hatched) for high-performance memory access and fast, low-latency off-node communications is combined with standards-based, highly integrated commercial library components.





128 node prototype

128 node dual 2.4GHz P4 Myrinet cluster, commissioned at FNAL in January 2003



256 node single 2.66 GHz P4 Gigabit Ethernet cluster, commissioned at JLab in September 2003

DOE panel review, Feb. 2003

Frank Wilczek (MIT) - chair

Roy Briere (CMU)

David Ceperley (NCSA-UIUC)

Candy Culhane (NSA)

Lynn Kissel (LLNL)

Michael Ogilvie (Washington Univ)

Robert Swendsen (CMU)

Peter Varman (NSF)

‘‘In short, we feel the scientific merit of [the] suggested program is very clearly outstanding.’’

HEPAP, February 2004:

- strong endorsement of overall plan

Schedule

- chip design: done --- first chips delivered beginning of June
- 384 node prototype at Columbia now running
- 5 teraflop sustained RIKEN and UKQCD machines, 2004
- ? teraflop US community QCDOC 2004 ?
- 5-8 teraflop clusters at JLAB and FNAL: end of 2005
- QCDOC-II? in early planning stages

Proposed 10 teraflop-sustained community machine -- funding?

- $2M 2004, $2M 2005 from DOE HEP
- DOE Nuclear contribution not known
- DOE Advanced Scientific Computing contribution not known
- Columbia will bridge 2005 committments to 2004

Hardware plans elsewhere

Germany: 12 teraflop/s sustained apeNEXT in 2004

Italy: several teraflop/s sustained apeNEXT in 2004

UK: 5 teraflop/s sustained QCDOC in 2004

RBRC: 5 teraflop/s sustained QCDOC in 2004

Japan:

- currently sustain approximately 1 teraflop/s
- beginning to use the Earth Simulator
- 10-20 teraflop/s (KEK) 2006
- 10-20 teraflop/s (CCP) 2007

Resources at National supercomputing centers

Many US lattice gauge theorists get cycles at

- NERSC, ORNL, NSF PACI supercomputing centers

Inadequate for needs

- largest grant to SciDAC project: sustain 0.2 teraflop/s

Not suitable to generate gauge configurations at

- small lattice spacings
- physical quark masses

BNL: a renowned Center for Lattice Gauge Theory

Outstanding existing lattice strength

- BNL High Energy Theory MC, Soni, Berruto
- BNL Nuclear Theory Petreczky
- SciDAC Jung, Petrov
- ITD Stampf, Bennet (QCDOC software)
- RBRC S. Aoki, Dawson, Hatta, Izubuchi, Nemoto, Noaki, Ohta, Sugihara, Wettig, Yamada
- UConn/BNL Blum
- Princeton/BNL Laiho
- Columbia Christ, Mawhinney, postdocs, many students
- APS Heller

RBRC

- 600 GFlops peak QCDSP, dominates current US resources
- 5 TFlops sustained QCDOC, 10,240 nodes, this summer

New BNL lattice group under Nuclear Theory under consideration

Potential strong interactions with

- RHIC and Atlas Computing
- DOE Grid Computing (PPDG)
- BNL Center for Data Intensive Computing
- Biology (see http://www.bnl.gov/CompBio/)

Strong existing scientific base for a BNL Topical Computing Facility