Grid computation for Lattice QCD

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User Forum

Theoretical problem

- Standard Model: theoretical background of High Energy Physics
- Quantum ChromoDynamics (QCD) is the part of the Standard model describing the strong nuclear interaction
- Part of this theory are quarks and gluons
- Main issue is the quark confinement
- Hard to explore analytically

QCD: The problem

- controls the strong interaction i.e. the fundamental force of Nature related to the binding of the nucleons in the nuclei
- has the structure of a relativistic quantum field theory with non-commutative gauge symmetry of the color group
- does not act directly on the nucleons which are considered composite particles but on quarks and gluon
- they have the unique property of being confined and therefore not directly detectable in the experiments
- quantum effects in the QCD are very relevant because the theory must accomplish the quark confinement effects
- one manifestation of this phenomenon is that the vacuum of the quantum theory, that is the main ingredient of a field theory, has a special topological structure
- our calculation is dedicated to a precise measurements of the topological susceptibility. Due to quantum effects in QCD it can be directly related to experimental results via the Witten Veneziano relation.

Numerical solution

Numerical investigations:

1. Euclidean version of the theory
2. Discretization on an regular hyper cubic lattice
3. Use of the Montecarlo Metropolis algorithm, implementing a importance sampling

Local updating, parallelizable

Long relaxation time

We are interested to investigate equilibrium properties

⇨big number of iterations to accumulate great statistic

⇨long running time

⇨big amount of memory to store data to be analyzed to extract statistically significant data

The problem

- Study topological properties of the SU(3) field to understand confinement
- Configuration: set of values in all the sites of the lattice at a given step of the simulation
- It is necessary to generate lot of configurations for different values of a parameter and for different lattices
- Once the configurations will be accumulated must be analyzed with statistical procedures to extract physical informations

Giusti et al., Physical Review Letters 94:032003,2005

The challenge

Topological susceptibility

$$\chi(p) = \int d^4x\, e^{-ipx} < Q(x) Q(0) >^M$$

is challenging in several ways

- L~1 and a~0.08 fm ⇨dim[D]~2.5 10^5: computing and diagonalizing matrix not feasible
- A standard minimization would require high precision to beat contamination from quasi-zero modes
- At large V the probability distribution has a width which increase linearly with V

Running application

The team:

L. Giusti, L. Del Debbio (CERN)

B. Taglienti (INFN Roma1)

S. Petrarca (Univ. La Sapienza, Roma)

The program:

Based on a idea of Giusti, Hoebling, Lüscher, Wittig (2002)

- use of SSE2
- contains parts in assembler
- no parallelism

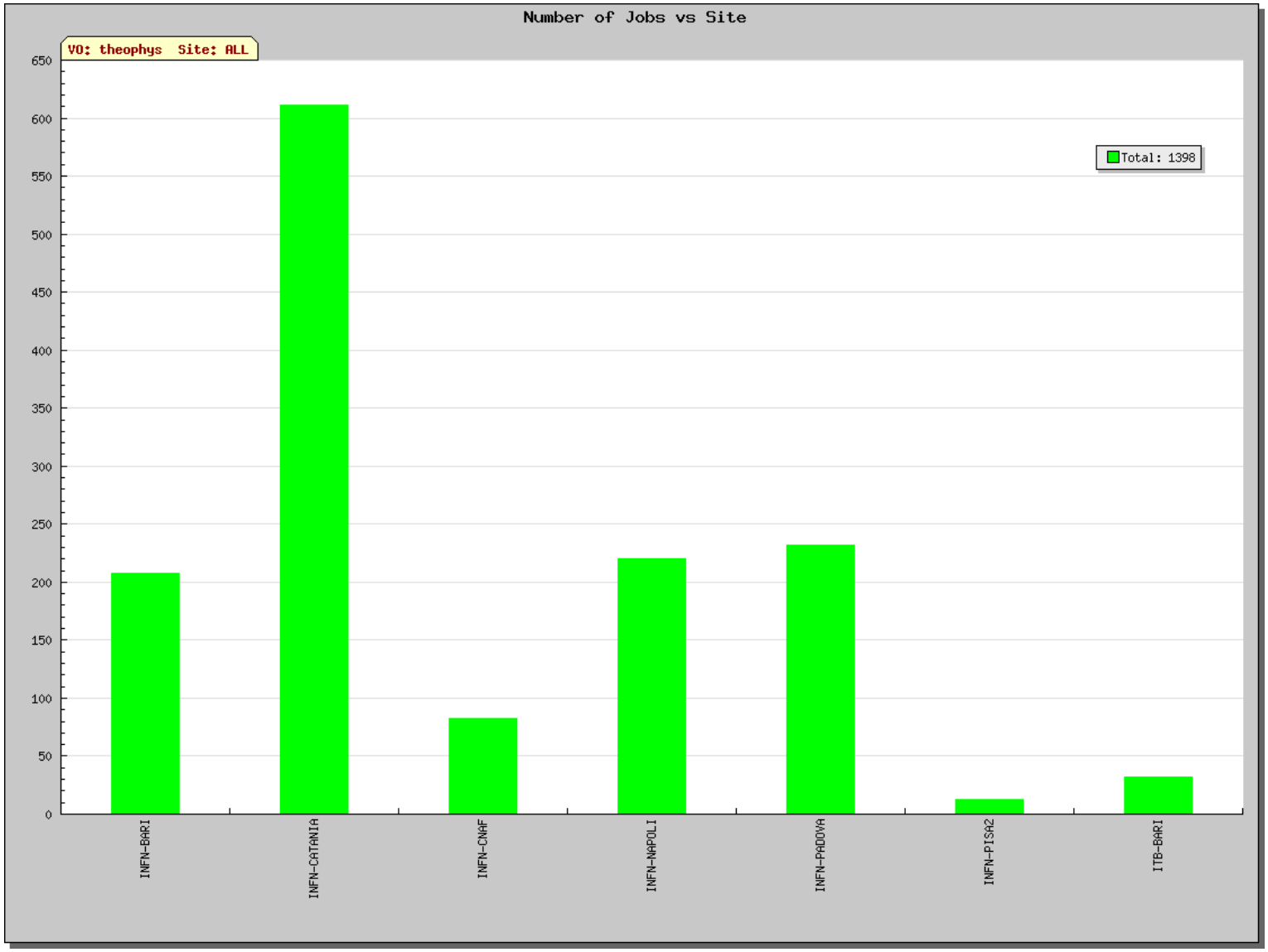
Running environment

The first set of jobs:

- **Lattice 12^4**
- **Each job read 5.7 MB from SE and write the same amount**
- **Extimated cpu time: 10-15 hours**

Infrastructure : INFNGRID

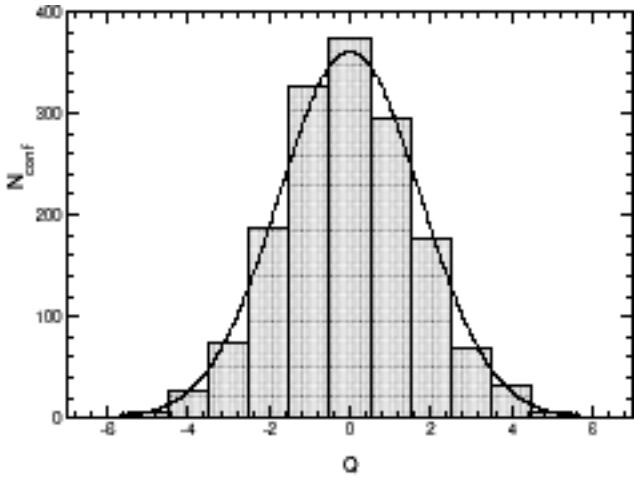
Jobs in the last 28 days



Volume dependence

- Probability distribution at large volume

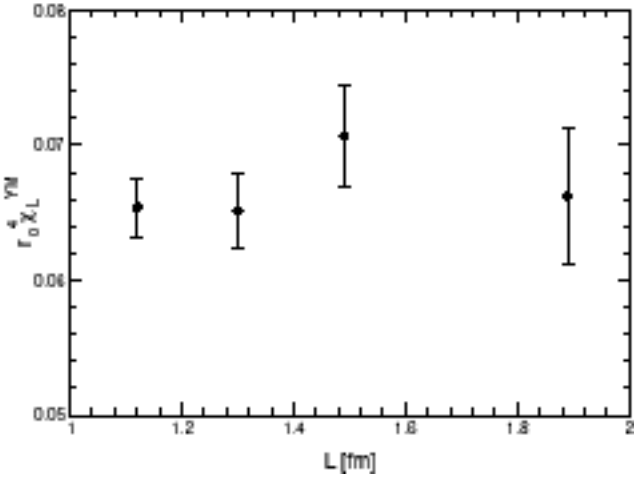
$$P_Q = \frac{1}{\sqrt{2\pi\langle Q^2\rangle}} e^{-\frac{Q^2}{2\langle Q^2\rangle}} \{1 + O(V^{-1})\}$$



- Mass gap in the pure gauge theory $m_g \sim 1.5$ GeV

- $\chi_{\rm L}^{\rm YM}$ goes to the infinite-volume limit as $e^{-m_g L}$

- For $L \gtrsim 1$ fm, $\chi_{\rm L}^{\rm YM}$ is indep. of L within stat. errors



Summary

- From 20/10/2005 more than 20000 CPU hours with 12 hours jobs generating about 36000 configurations
- Good reliability except for short periods with a high failure level
- Planned change in lattice size (14^4) ⇨ jobs about 60 hours long