PICTURES OF THE SUBATOMIC WORLD

Yannick Mathews
Morehouse College
08/22/08

William Detmold

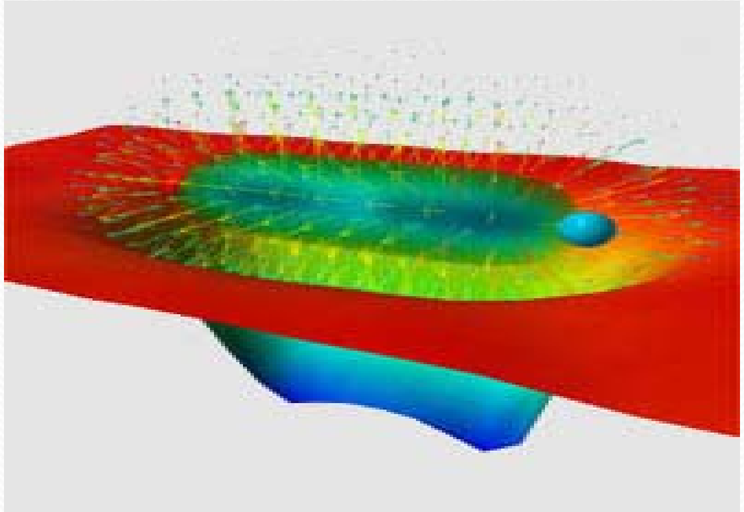
Assistant Research Professor

Utilizing Lattice QCD Will uses complex equations and algorithms to calculate the structure and interactions of various hadrons such as Pions.

OUTLINE

- Quantum Chromodynamics
- The Strong Force
- Lattice QCD
- My Project
- 3-D Plots
- References

Quantum Chromodynamics



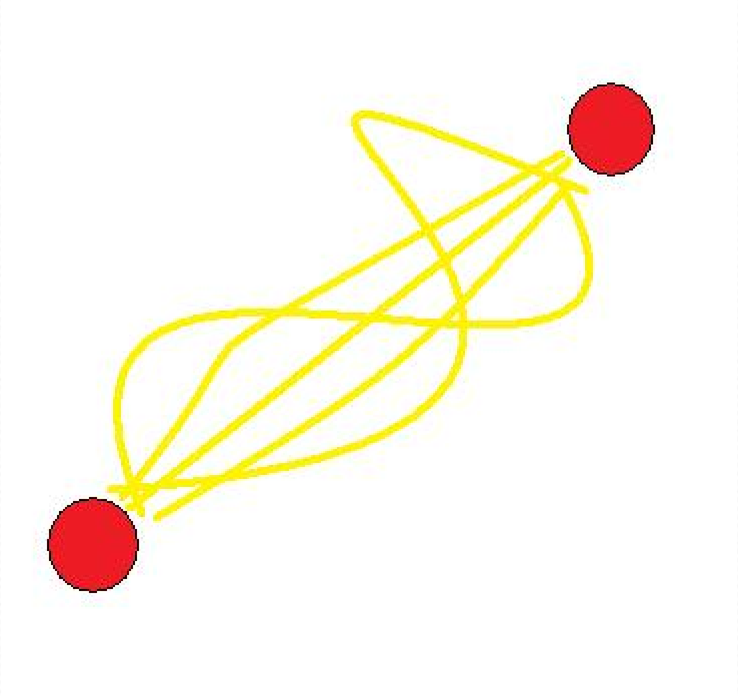
- Modeled after Quantum electrodynamics, QCD is the theory that describes the interaction of quarks and gluons, and the behavior of the strong force.
- The Strong force holds quarks together to form hadrons like protons and Neutrons.
- It also holds protons and neutrons together inside atomic nuclei.
- The source if the strong force is color charge. Whereas in QED particles are either positive or negative in QCD there are three charges: red, blue, and green.
- Quarks exchange gluons which can in turn exchange further gluons due to their inherent color charge.
- This property makes isolating quarks an impossibility. If they are separated then a new quark anti-quark pair is created.

Lattice QCD

- In order to deal with to complexity of the strong interaction theorist use supercomputers and a method known as Lattice QCD to calculate the interactions of quarks and gluons.
- It is a non-perturbative method that treats space-time as a series of discrete points on a grid (lattice).
- In this method quarks exist at these lattice points and gluons exist in the links between them.
- In these calculations quarks are placed on the lattice points and their movements and interactions are then simulated according to the rules of QCD.
- This method is time consuming and computationally expensive but also widely applicable.

Lattice QCD

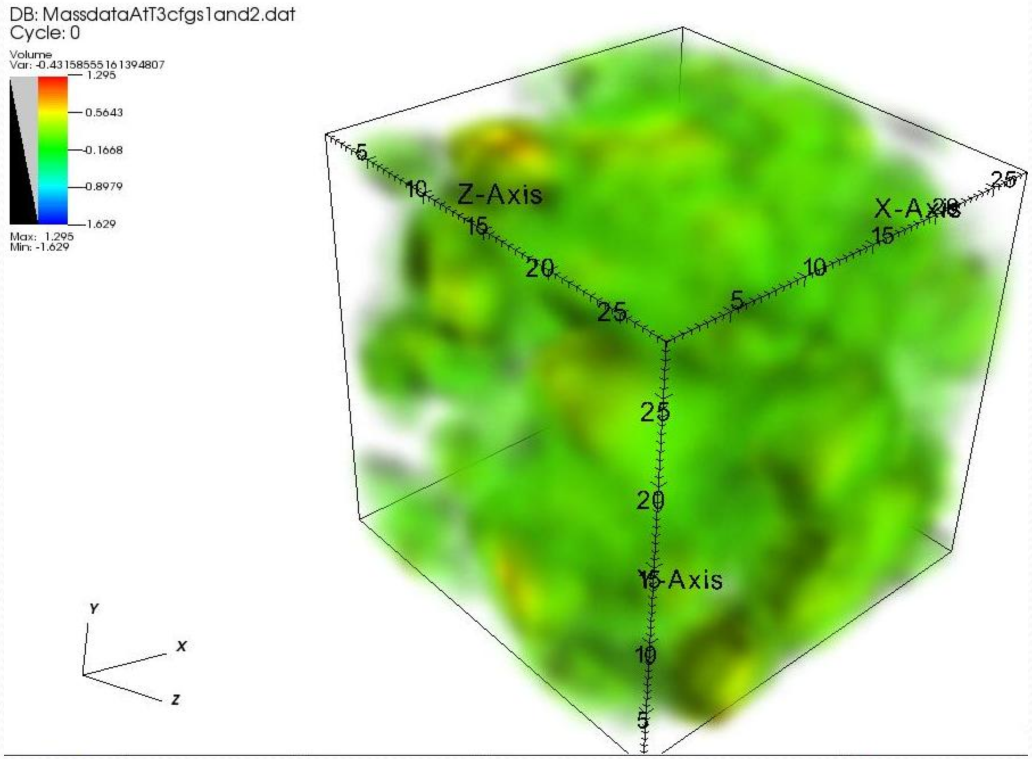
- 28x64
- 20 Source Files of different configurations
- Each file corresponds to a different path
- 6 hrs to generate on 128 cores simultaneously
- Athena Cluster at CENPA

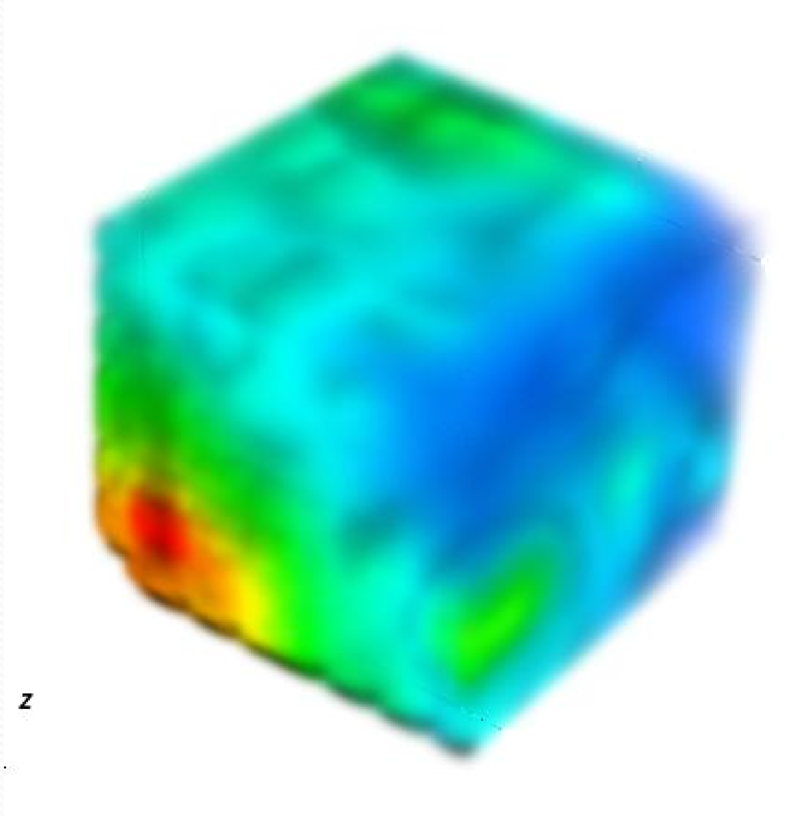


Lattice QCD

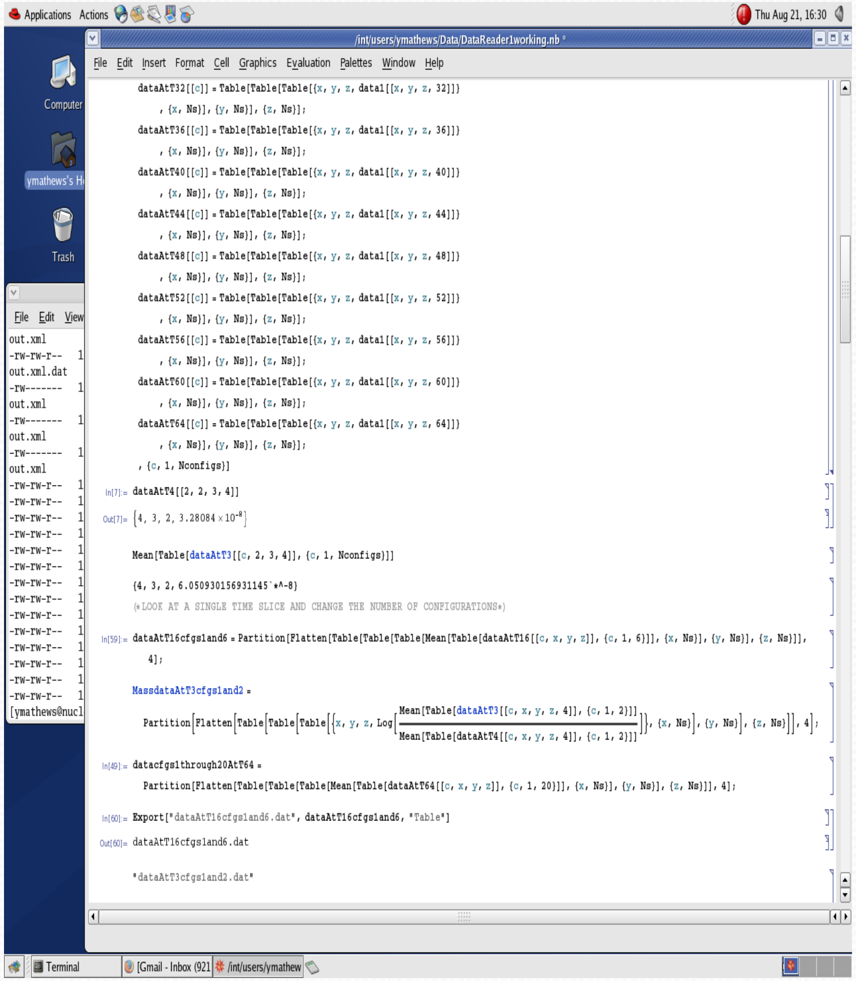
- Can be used to calculate the mass of various hadrons.
- There exist various methods with varying degrees of accuracy
- Can also be used to predict the existence of other unknown particles such as hybrids and glueballs .
- Used to calculate the mass of the Pions as well as the probability of their locations over time.

My Project


DB: MassdataAtT3cfgs1and2.dat
Cycle: 0
Volume
Var: -0.43158555161394807
1.295
0.5643
-0.1668
-0.8979
-1.629
Max: 1.295
Min: -1.629
Z-Axis
X-Axis
Y-Axis
5
10
15
20
25
Y
X
Z


Z

Manipulating the Data

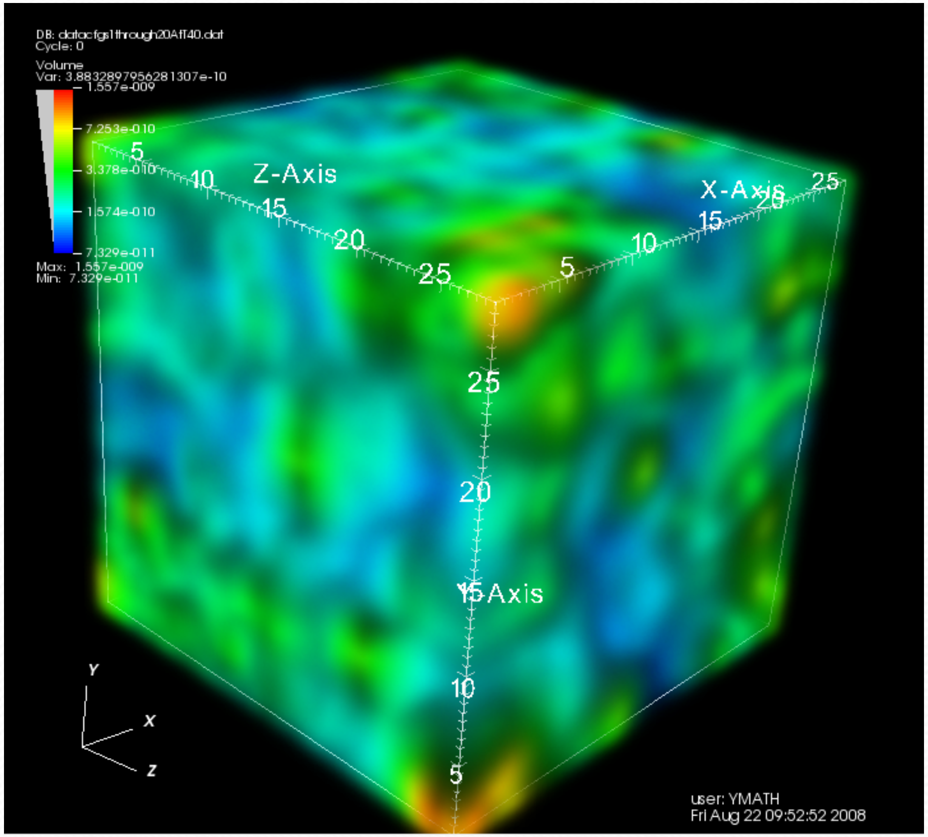


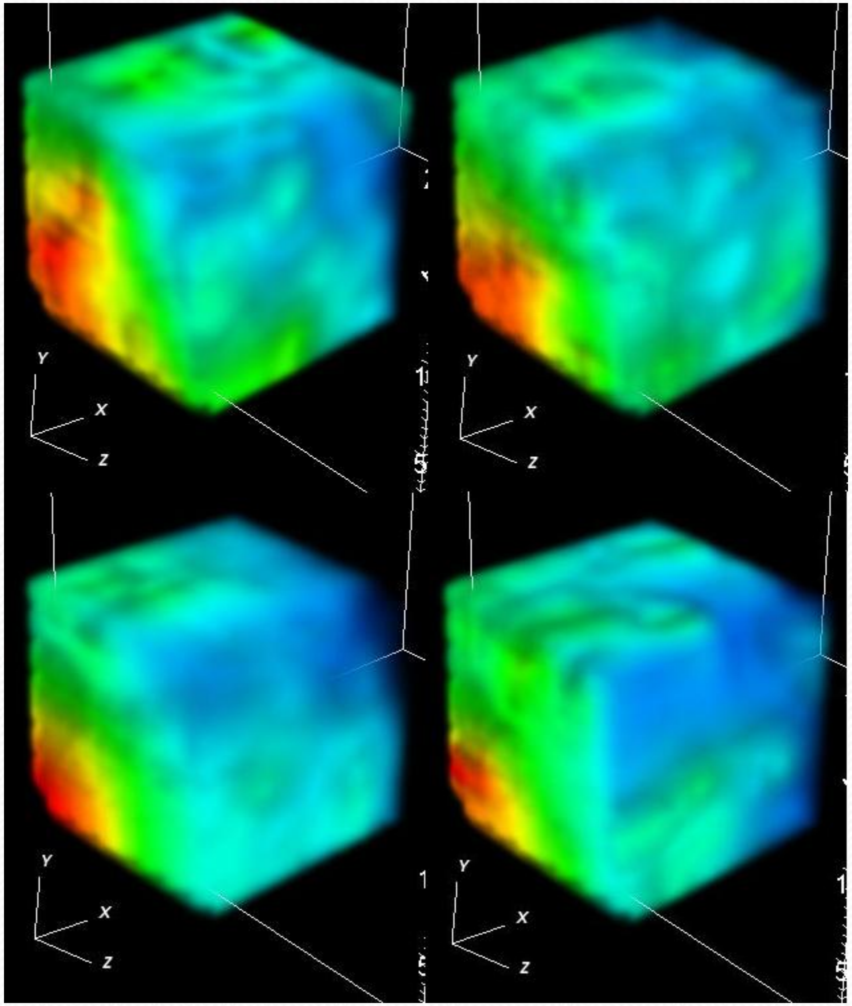
```
out.xml
-rw-rw-r--  1
out.xml.dat
-rw-------  1
out.xml
-rw-------  1
out.xml
-rw-------  1
out.xml
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
-rw-rw-r--  1
[ymathews@nucl
```

```
    dataAtT32[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 32]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT36[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 36]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT40[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 40]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT44[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 44]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT48[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 48]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT52[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 52]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT56[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 56]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT60[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 60]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    dataAtT64[[c]] = Table[Table[Table[{x, y, z, data1[[x, y, z, 64]]}
        , {x, Ns}], {y, Ns}], {z, Ns}];
    , {c, 1, Nconfigs}]

In[7]:= dataAtT4[[2, 2, 3, 4]]

Out[7]= {4, 3, 2, 3.28084 × 10^-8}

  Mean[Table[dataAtT3[[c, 2, 3, 4]], {c, 1, Nconfigs}]]

  {4, 3, 2, 6.050930156931145`*^-8}
  (*LOOK AT A SINGLE TIME SLICE AND CHANGE THE NUMBER OF CONFIGURATIONS*)

In[59]:= dataAtT16cfgs1and6 = Partition[Flatten[Table[Table[Table[Mean[Table[dataAtT16[[c, x, y, z]], {c, 1, 6}]], {x, Ns}], {y, Ns}], {z, Ns}]],
           4];

  MassdataAtT3cfgs1and2 =
                                                        Mean[Table[dataAtT3[[c, x, y, z, 4]], {c, 1, 2}]]
    Partition[Flatten[Table[Table[Table[{x, y, z, Log[-------------------------------------------------]}, {x, Ns}], {y, Ns}], {z, Ns}]], 4];
                                                        Mean[Table[dataAtT4[[c, x, y, z, 4]], {c, 1, 2}]]

In[49]:= datacfgs1through20AtT64 =
           Partition[Flatten[Table[Table[Table[Mean[Table[dataAtT64[[c, x, y, z]], {c, 1, 20}]], {x, Ns}], {y, Ns}], {z, Ns}]], 4];

In[60]:= Export["dataAtT16cfgs1and6.dat", dataAtT16cfgs1and6, "Table"]

Out[60]= dataAtT16cfgs1and6.dat

  "dataAtT3cfgs1and2.dat"
```

- The Data consisted of 20 large files that needed to be read in and averaged
- Once the files were received the data would need to be manipulated again to be read by the graphing software
- Using Mathematica we were able to get rid of excess variables and average the configurations in order to get the desired data set in a usable format.

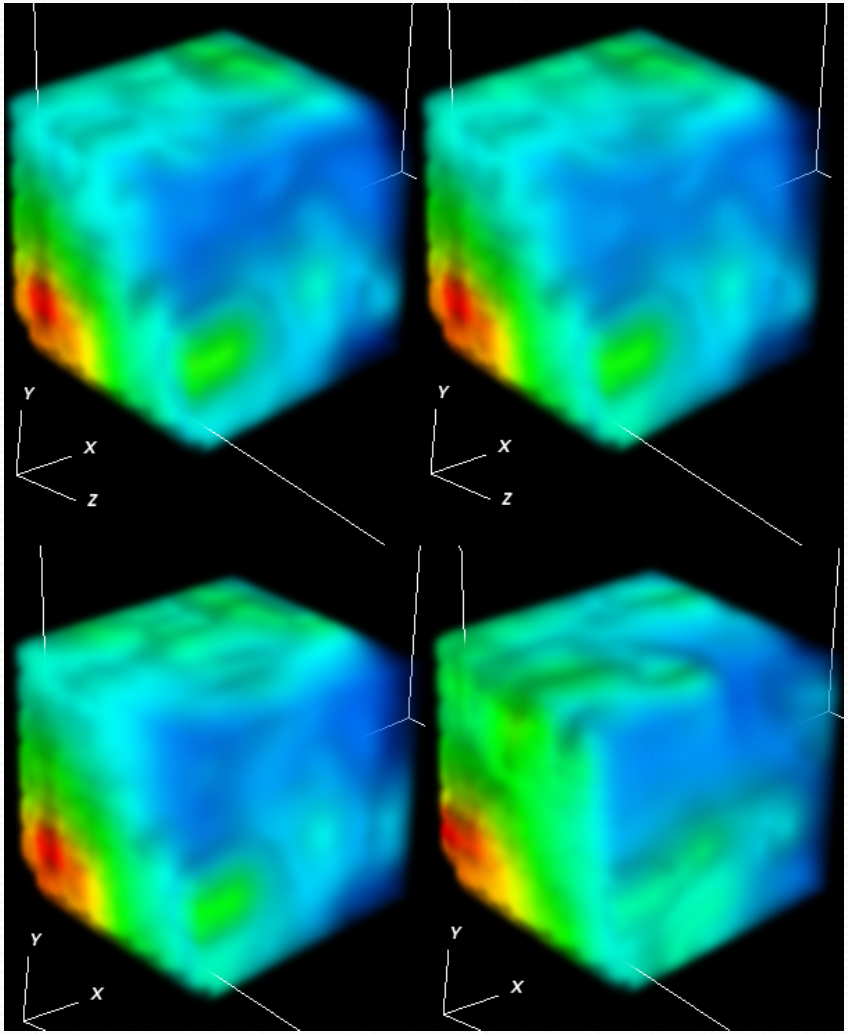
Graphs and Plots



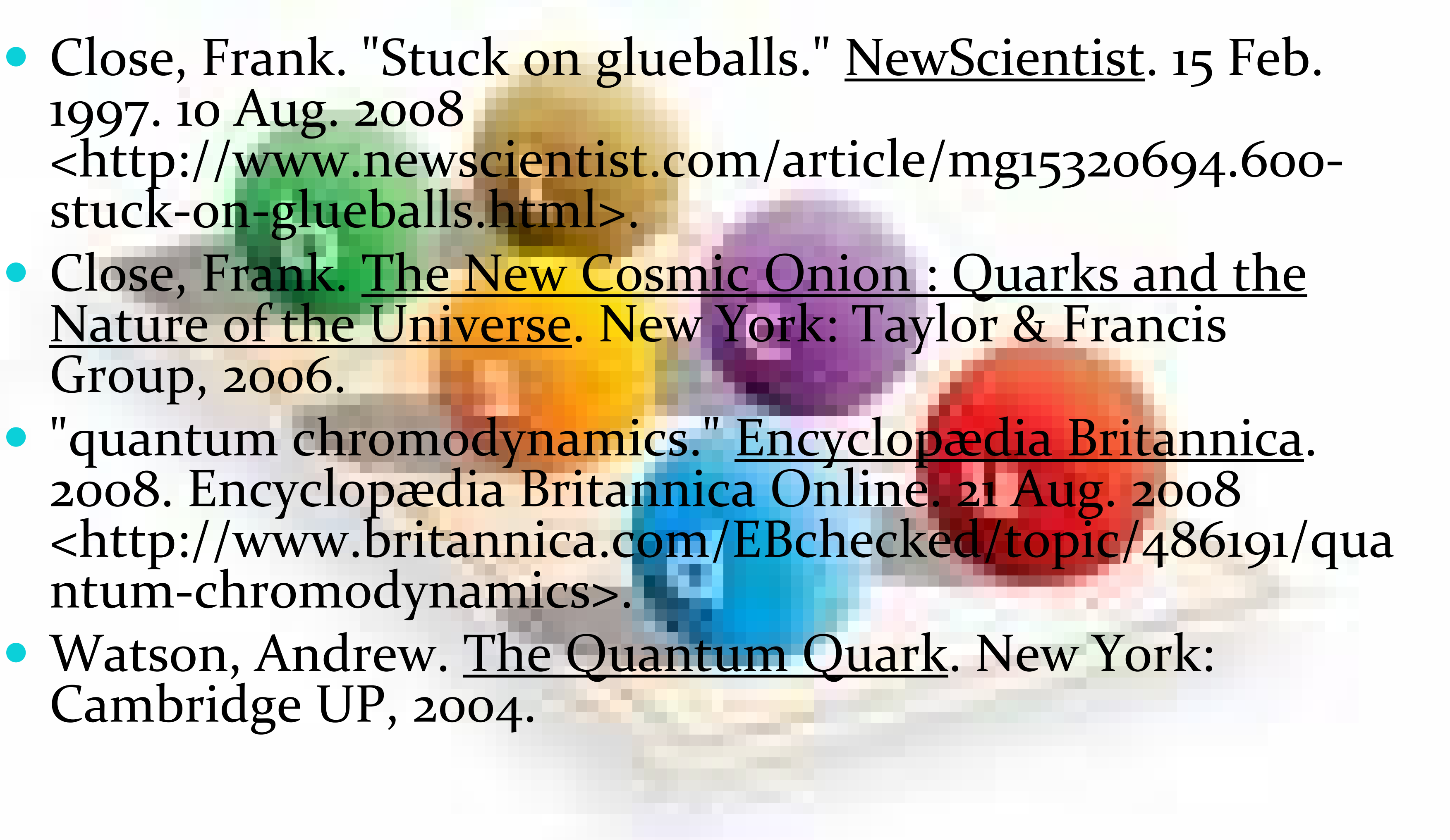


Graphs and Plots

- The colors indicate the probability of a Pion existing at the given points for a specific time.
- Red is the highest probability
- Blue is the lowest probability
- As the number of configurations increase, the more accurate the data.
- This results in smoother plots



References



- Close, Frank. "Stuck on glueballs." NewScientist. 15 Feb. 1997. 10 Aug. 2008 <http://www.newscientist.com/article/mg15320694.600-stuck-on-glueballs.html>.
- Close, Frank. The New Cosmic Onion : Quarks and the Nature of the Universe. New York: Taylor & Francis Group, 2006.
- "quantum chromodynamics." Encyclopædia Britannica. 2008. Encyclopædia Britannica Online. 21 Aug. 2008 <http://www.britannica.com/EBchecked/topic/486191/quantum-chromodynamics>.
- Watson, Andrew. The Quantum Quark. New York: Cambridge UP, 2004.