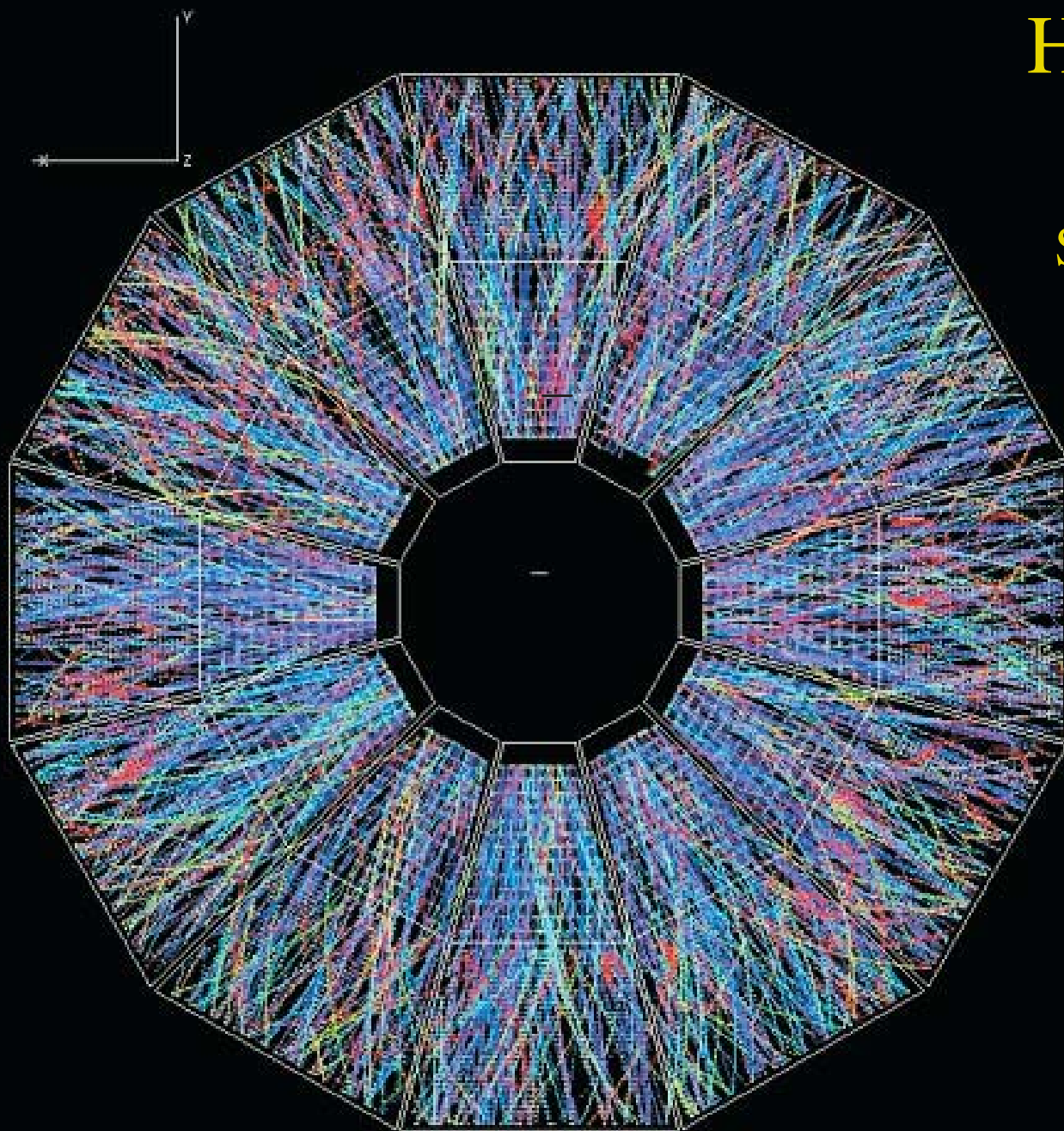# Heavy-Ion e-Lab

W.J. Llope
Summer 2007 Houston
Quarknet Workshop
Rice University
June 13, 2007

Phases of Matter as of ~500 B.C.

Anaxagoras:

All things have existed from the beginning.

But originally they existed in infinitesimally small fragments of themselves, endless in number and inextricably combined.

Democritus:

everything which is must be eternal

"the void" is not nothing

there are various basic elements, called "atoms" (indivisible) which always existed but can be rearranged into many different forms.

atoms only had several properties

     size, shape, and (perhaps) weight.

all other properties that we attribute to matter,

     e.g. color and taste,

are the result of complex interactions between the atoms in our bodies and the atoms of the matter that we are examining.

EMPEDOCLES
Agrigentinus

Empedocles:

All is made up of four elements (which he called roots):
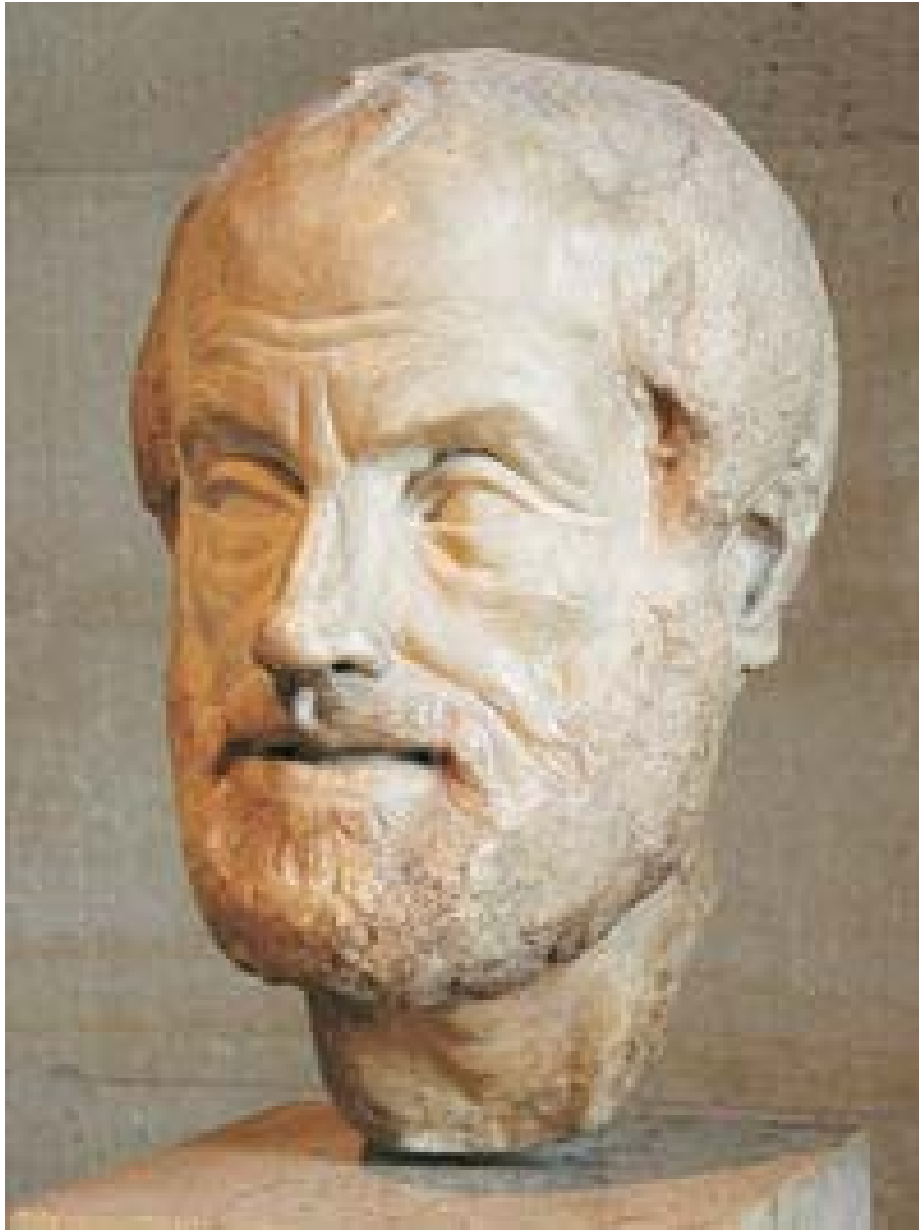   Earth
    Water
    Air
    plus one more.

Attraction: "Philia" (love)

Dissociation: "Neikos" (strife)

Aristotle:

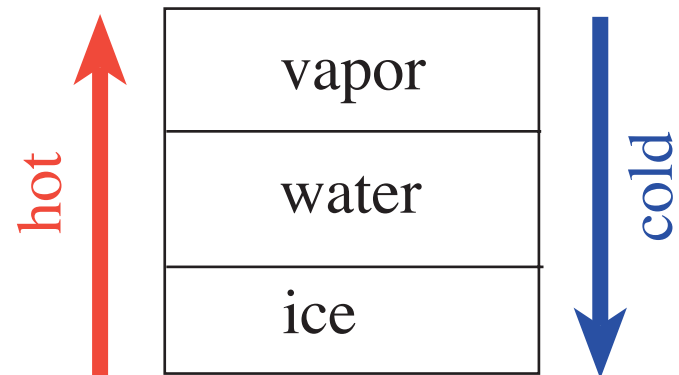There are also qualities such as heat, cold, dryness, and moisture.

When two qualities were combined, they formed the elements.
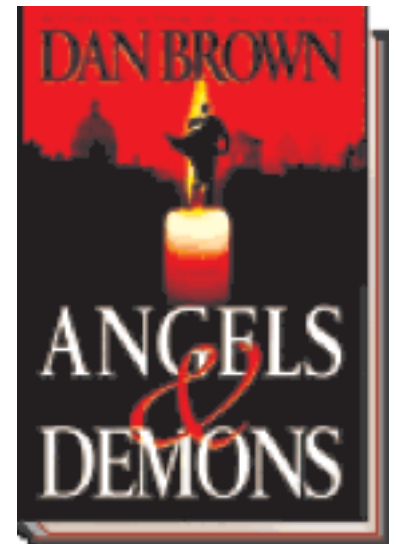
For example,

cold + wet = water
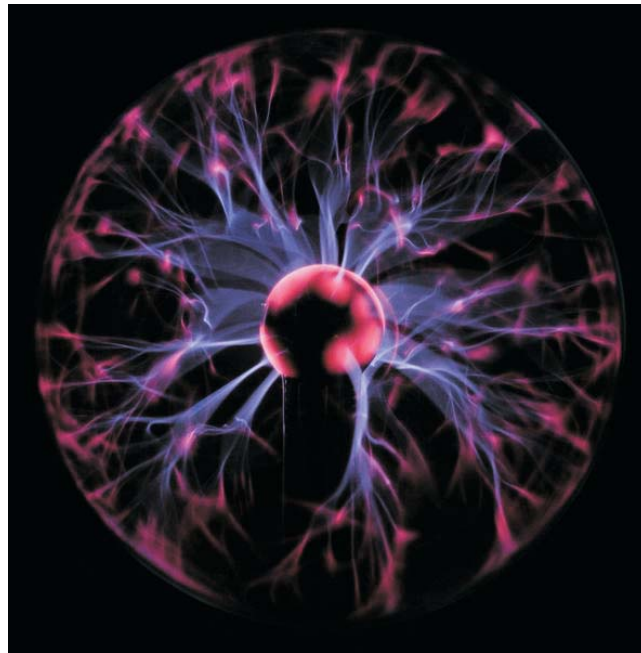
hot + wet = air

Earth's First Phase Diagram!

vapor
water
ice

hot

cold

Then what's Empedocles' Fourth State of Matter?!?!?

"Atomic/Molecular" Plasmas......

Democritus's view holds up for ~2300 years

until an experiment by Rutherford and Geiger published in 1911.

"The Scattering of Alpha and Beta Particles by Matter and the Structure of the Atom," E. Rutherford, Philosophical Magazine, 6th Series, 21:669 (1911).

scattered α-particles off a gold (Au) foil and measured scattering angles

some bounce backwards!
(huh?!?)

⟶ new model of the atom
"Saturnian" or "Rutherford" atom

- atoms are not uniformly dense
- very dense **nucleus** inside every atom

nucleus = protons + neutrons
nucleons are quarks held together by gluons

---

[669]

LXXIX. *The Scattering of α and β Particles by Matter and the Structure of the Atom.* By Professor E. Rutherford, F.R.S., University of Manchester *.

§ 1. IT is well known that the α and β particles suffer deflexions from their rectilinear paths by encounters with atoms of matter. This scattering is far more marked for the β than for the α particle on account of the much smaller momentum and energy of the former particle. There seems to be no doubt that such swiftly moving particles pass through the atoms in their path, and that the deflexions observed are due to the strong electric field traversed within the atomic system. It has generally been supposed that the scattering of a pencil of α or β rays in passing through a thin plate of matter is the result of a multitude of small scatterings by the atoms of matter traversed. The observations, however, of Geiger and Marsden † on the scattering of α rays indicate that some of the α particles must suffer a deflexion of more than a right angle at a single encounter. They found, for example, that a small fraction of the incident α particles, about 1 in 20,000, were turned through an average angle of 90° in passing through a layer of gold-foil about ·00004 cm. thick, which was equivalent in stopping-power of the α particle to 1·6 millimetres of air. Geiger ‡ showed later that the most probable angle of deflexion for a pencil of α particles traversing a gold-foil of this thickness was about 0°·87. A simple calculation based on the theory of probability shows that the chance of an α particle being deflected through 90° is vanishingly small. In addition, it will be seen later that the distribution of the α particles for various angles of large deflexion does not follow the probability law to be expected if such large deflexions are made up of a large number of small deviations. It seems reasonable to suppose that the deflexion through a large angle is due to a single atomic encounter, for the chance of a second encounter of a kind to produce a large deflexion must in most cases be exceedingly small. A simple calculation shows that the atom must be a seat of an intense electric field in order to produce such a large deflexion at a single encounter. Recently Sir J. J. Thomson § has put forward a theory to

* Communicated by the Author. A brief account of this paper was communicated to the Manchester Literary and Philosophical Society in February, 1911.
† Proc. Roy. Soc. lxxxii. p. 495 (1909).
‡ Proc. Roy. Soc. lxxxiii. p. 492 (1910).
§ Camb. Lit. & Phil. Soc. xv. pt. 5 (1910).

Fire as we know it:

Uses: grilling burgers
       heating homes
       birthday parties
       clearing rainforests
            → fantastically useful stuff!

but what is it?

a hot soup (a "plasma") consisting of the components of molecules+atoms:
    electrons and photons (light & heat) and ions

energy is released from the breaking of (molecular) bonds in the
    wood, propane, gasoline, or whatever is burning...
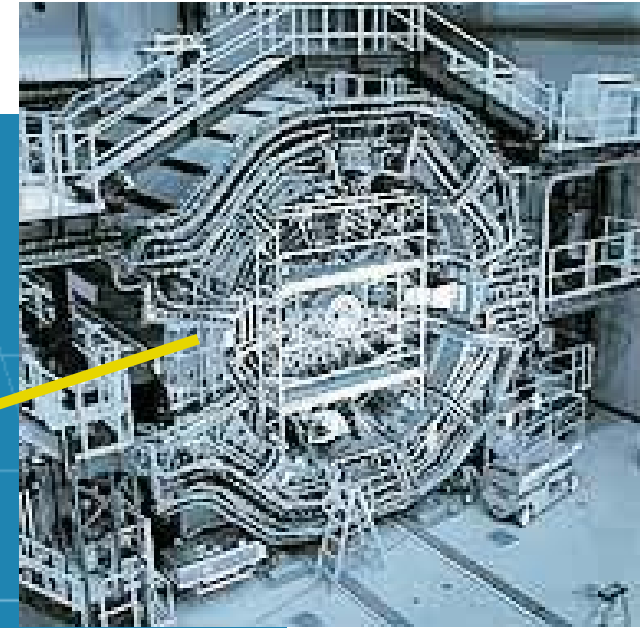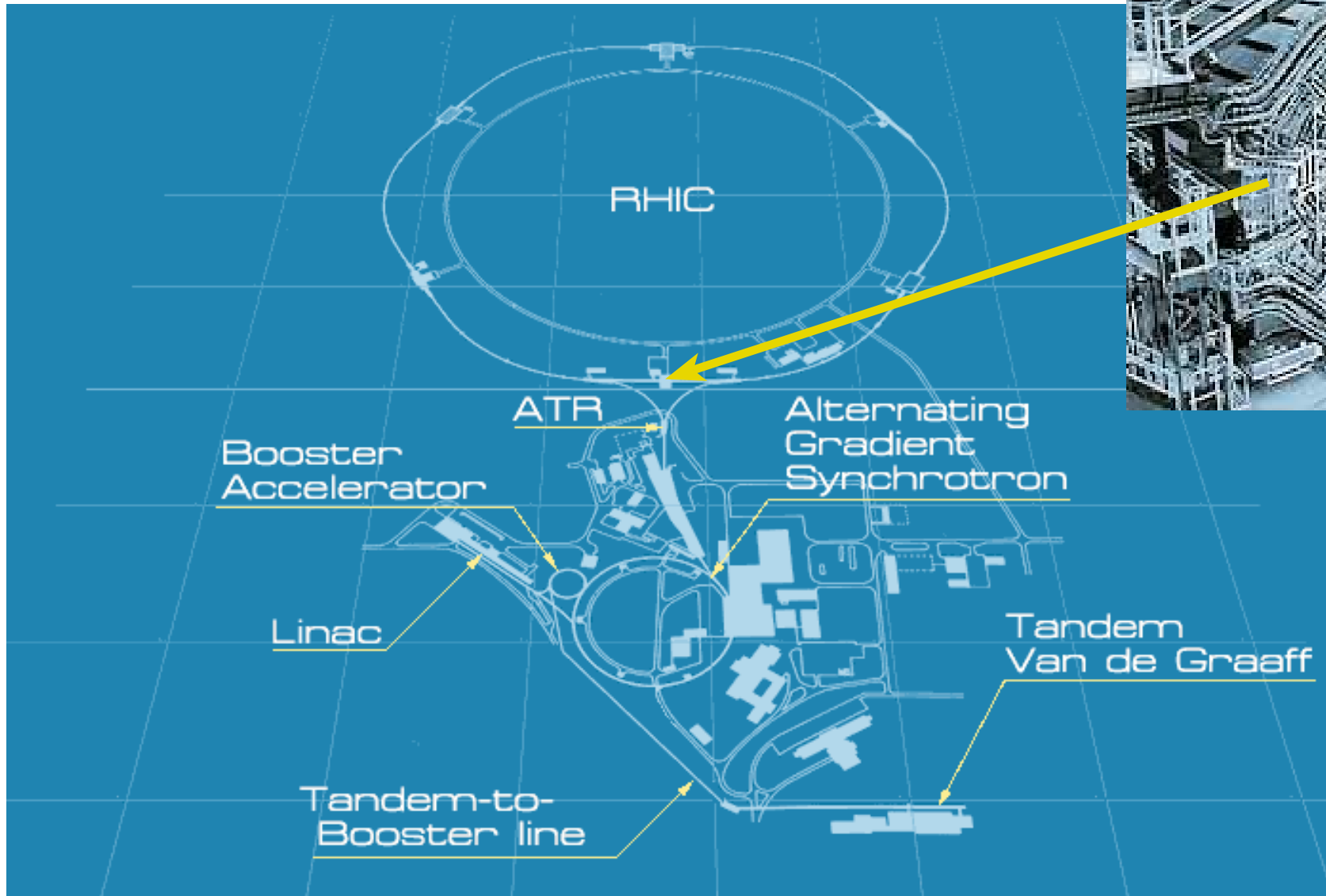

so how about a *"nuclear" plasma*?

i.e. a hot soup consisting of the components of *nuclei*....
    protons and neutrons (really "quarks" and "gluons")

bonds here are ~10,000 times stronger than atomic/molecular bonds...

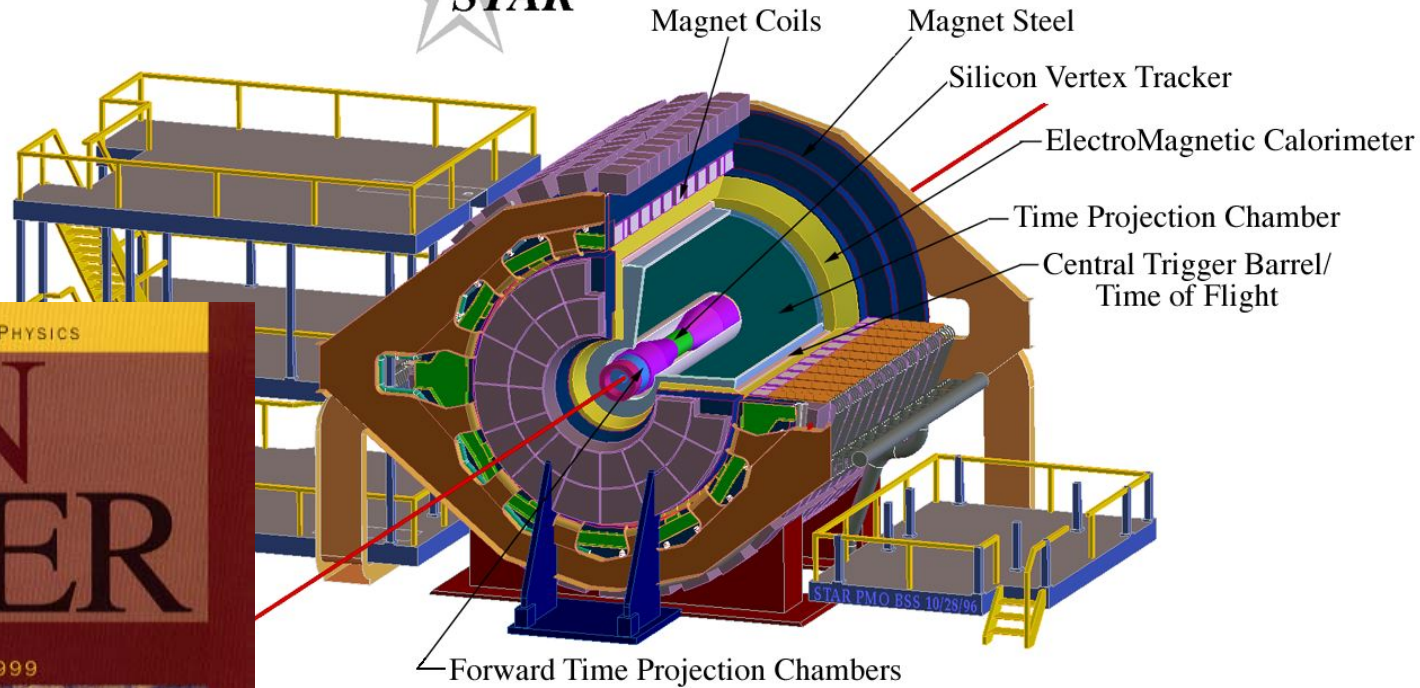   Quark-Gluon Plasma == the whole universe at an age of a few μsec?

Now less than 100 years later, we can accelerate Au nuclei to the speed of light and collide them with other Au nuclei!!!

RHIC

ATR

Booster Accelerator
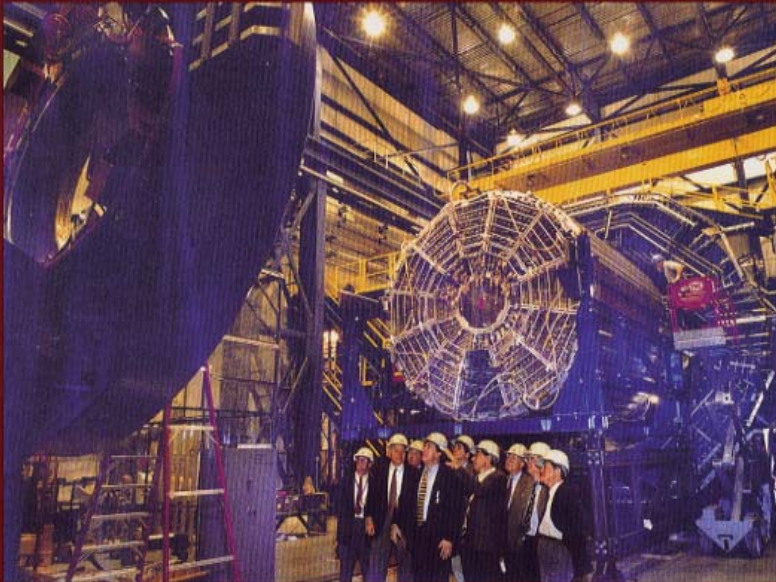
Alternating Gradient Synchrotron

Linac

Tandem Van de Graaff

Tandem-to-Booster line

Solenoidal Tracker at RHIC

STAR

Magnet Coils

Magnet Steel

Silicon Vertex Tracker

ElectroMagnetic Calorimeter

Time Projection Chamber

Central Trigger Barrel/
Time of Flight

Forward Time Projection Chambers

"tracking"
measure paths of charged particles
infer momenta and trajectories

"calorimetry"
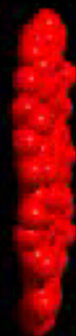dense detector to stop particles
measure energy

"time of flight"
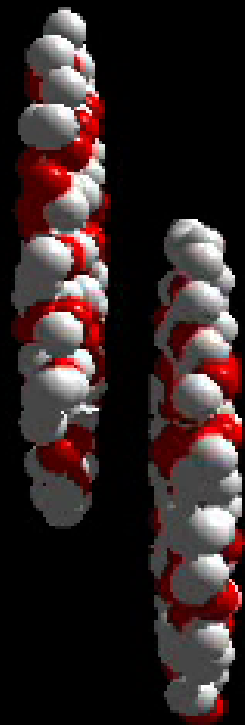measure flight times for known
momenta and path lengths

QuarkNet - Associate Teacher Institute at Rutgers University -
Summer 2002

Au+Au E_{cm}=200 AGeV

t=-19.89 fm/c

H. Weber / UrQMD Frankfurt/M

STAR and its Time Of Flight (TOF) system....

TPC provides
 momenta of tracks to $\Delta p/p \sim 1\text{-}2\%$
 track total **path length**s to a few millimeters
   over 2.1-2.9m flight path...

surrounding the TPC with a detector that can measure the tracks'
time of flight (TOF) allows the following calculation, track by track:

 p from TPC tracking
 s from TPC tracking, & STAR geometry

$$\Delta t = t_{stop} - t_{start} \text{ from TOF}$$

$$s = \beta c \Delta t \quad \rightarrow \text{TOF gives } 1/\beta....$$

$$\rightarrow m = p/\gamma\beta c \quad \rightarrow \text{Particle Identification!}$$
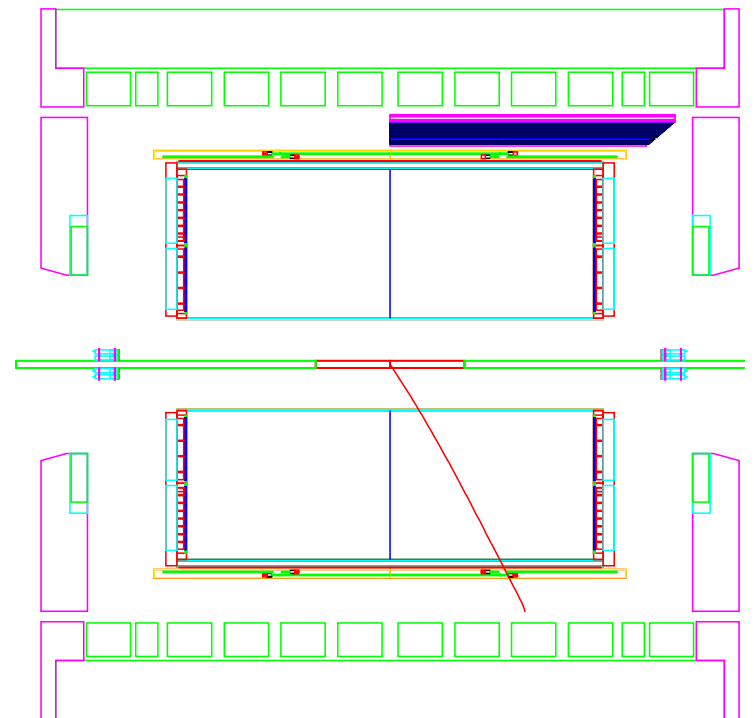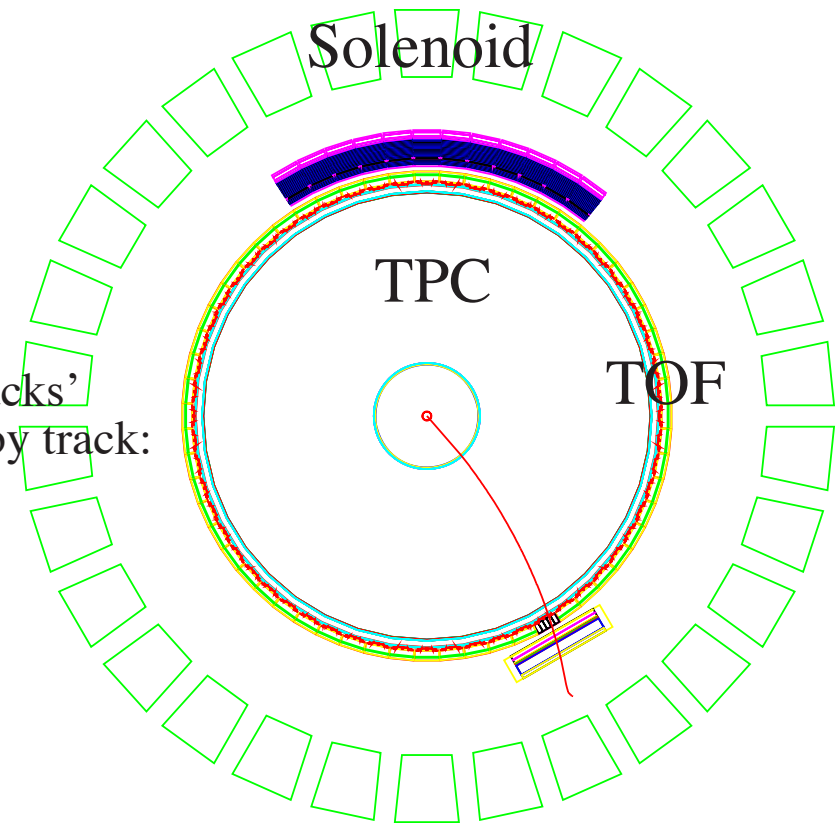
Mass resolution of a TOF system is:
 $\Delta M/M = \Delta p/p \oplus \gamma^2 [\Delta s/s \oplus \Delta t/t]$

Then, with the TPC tracking & a $\Delta t = 100$ps TOF system:

- $\pi/K/p$ direct PID: ~0.3 GeV/c $< p <$ 1.7-1.9 GeV/c
- $(\pi+K)/p$ direct PID: ~0.3 GeV/c $< p <$ 2.8-3.0 GeV/c

     i.e. just what STAR needs....

Solenoid

TPC

TOF

http://wjllope.rice.edu/HIeLab/

The Heavy-Ion e-Lab
Welcome!

Application Download

Installation Instructions

[Windows XP installer](#) (zip)

Mac OS X installer (tgz)

Linux installer (tgz)

Documentation

Workbook (online)

Workbook (PDF)

[Application Help](#)

[Movie for v.1](#) (Quicktime)

Forums

[Support](#)

[Discussions](#)

Related Sites

[RHIC Home Page](#)

[RHIC Broadcast](#)

[STAR Home Page](#)

[i2u2](#)

[e-Labs](#)

Contact

W.J. Llope, *Rice University*

heavyionelab@gmail.com

The Heavy-Ion e-Lab is an outreach project intending to allow young science students to visualize and analyze actual data collected by the "STAR" experiment at "RHIC" - the highest total-energy collider now operating on the east end of Long Island, New York.

The primary goal of this project is to let these students work with the data using a tool that is highly intuitive and fairly self-explanatory. The students are thus not required to learn an complicated or arcane programming language to begin making their way through this project. This tool is a Graphical User Interface (GUI) that was developed expressly for this project and which runs under Windows XP, Mac OS X, and Linux.

Throughout the project, the students will learn the basic concepts involved in making "histograms." These are a simple graphical method of viewing the landscape of the data. The data made available is that from a "Time of Flight" (TOF) system called "TOFp/pVPD". This system's function in STAR is to provide information that allows "Particle Identification" - that is, to identify whether a given "track" in the STAR experiment is a pion, a Kaon, or a proton.

After becoming comfortable with forming and reading histograms, the students will attack two technical sources of smearing in this TOF information - the so-called "slewing" effect and the "light propagation time" effect. The GUI provides the tools that the student will need to remove these effects from the data, thus exposing the full power of TOF for particle identification in STAR.

The GUI is arranged as a series of tabs, and each tab concentrates on a specific topic to be learned during the course. A workbook provides many additional details that the student will need, while an online documentation system provides on-the-spot help for each tab in the GUI separately. The workbook includes questions that the student will need to answer - only the GUI itself is needed.

If you are a student, a science teacher, or an experienced programmer, **you can help improve this project!!** please contact me via e-mail, and/or join the community via the online forums.

http://wjllope.rice.edu/forums/
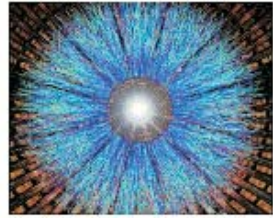
wjllope.rice.edu
forums for collaboration

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🖻 Profile   📭 Log in to check your private messages   ⊙ Log in

The time now is Tue Jun 12, 2007 1:26 pm

wjllope.rice.edu Forum Index   View unanswered posts

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Heavy-Ion e-Lab Support to report program crashes or bugs....	1	1	Mon Apr 02, 2007 11:53 am wjllope ➔▯

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