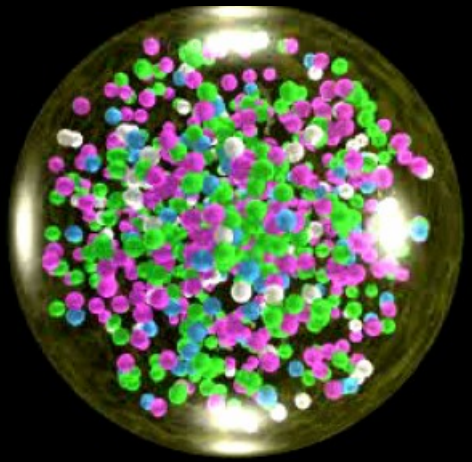
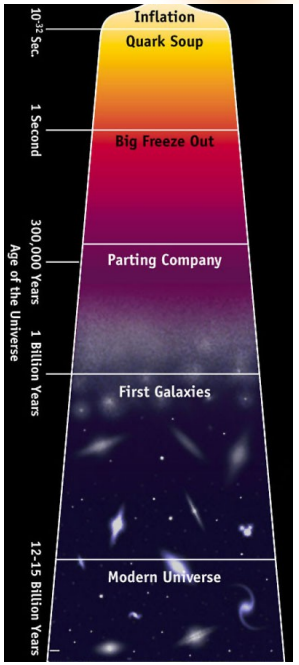
The little bang: understanding the quark gluon plasma

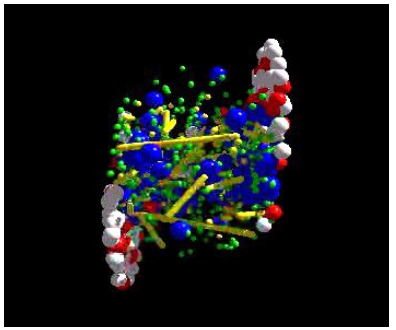


Christine Nattrass
University of Tennessee at Knoxville

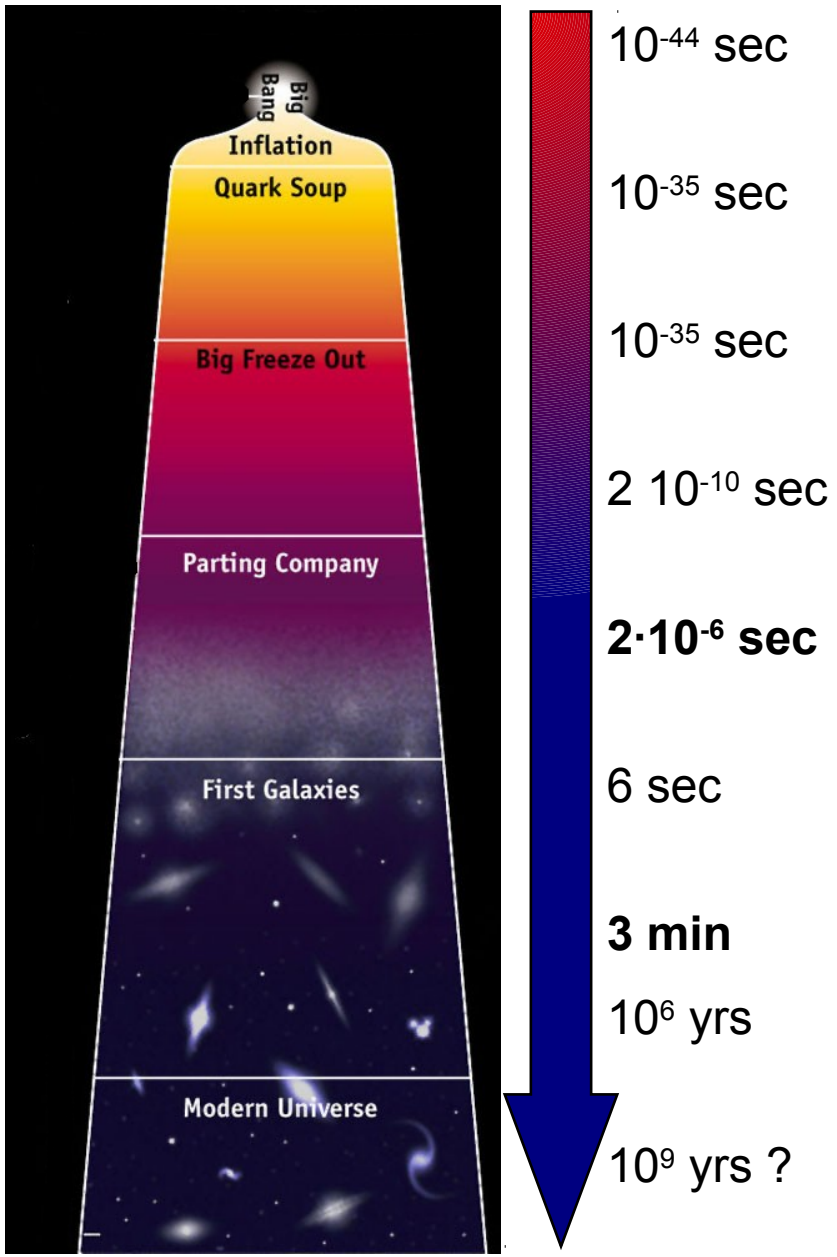
Take home messages

- If we get nuclear matter dense enough, we make a new phase of matter
- This quark gluon plasma is similar to what was present in the early universe
- We can produce a QGP in high energy heavy ion collisions





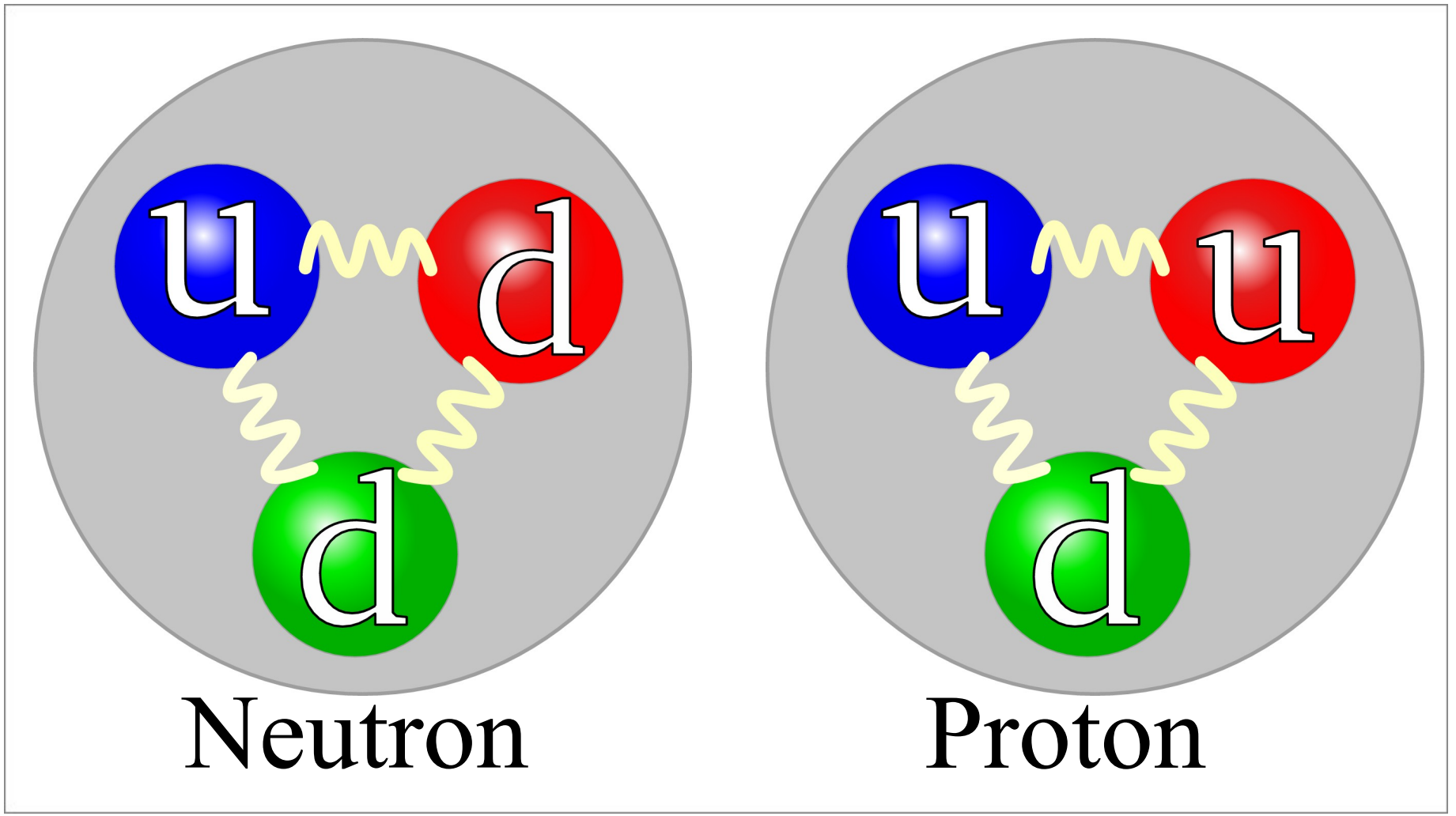
Evolution of the Universe



The universe gets cooler!

Reheating matter?
Need temperatures around $1.5 \cdot 10^{12}$ K
~10^6 times hotter than the core of the sun

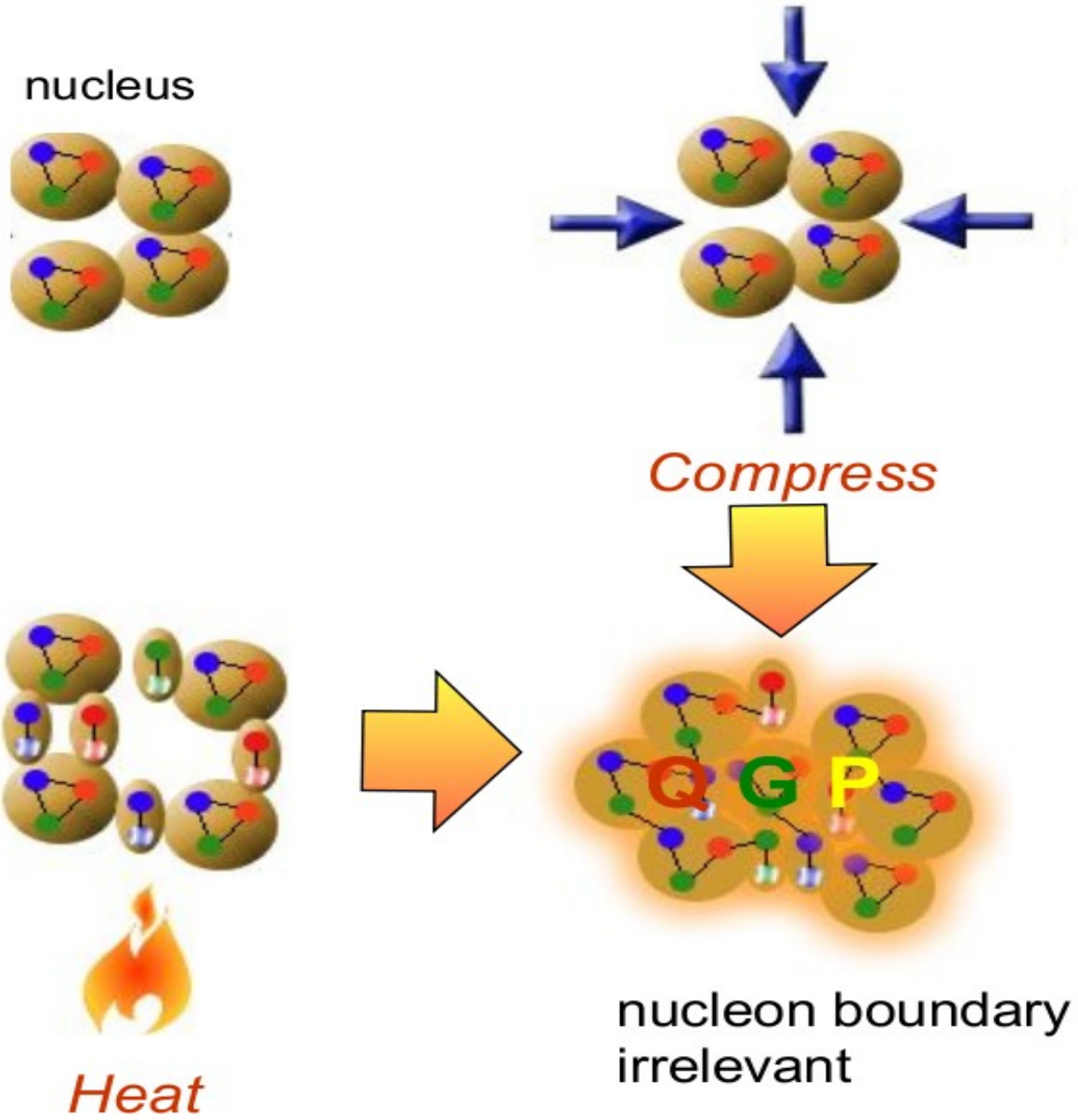
Nucleons – the proton and neutron



http://en.wikipedia.org/wiki/Image:Quark_structure_neutron.svg

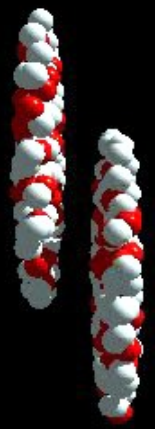
http://en.wikipedia.org/wiki/Image:Quark_structure_proton.svg

How can we see “free” quarks?

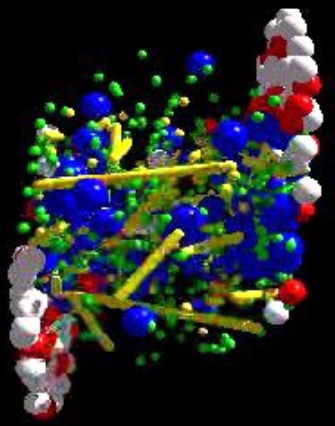


Making a QGP in the laboratory

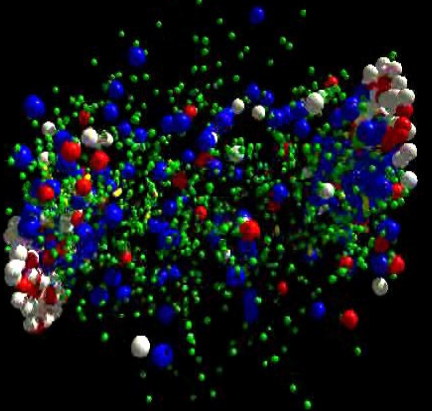
Relativistic pancakes



Quark soup

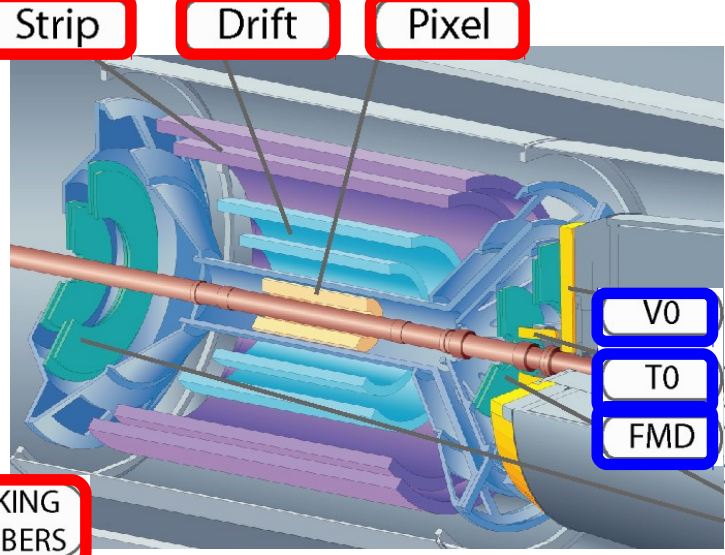


Explosive hadron soda




CMS
5.3 miles
LHCb
1.4 miles
ALICE
ATLAS
LHCf

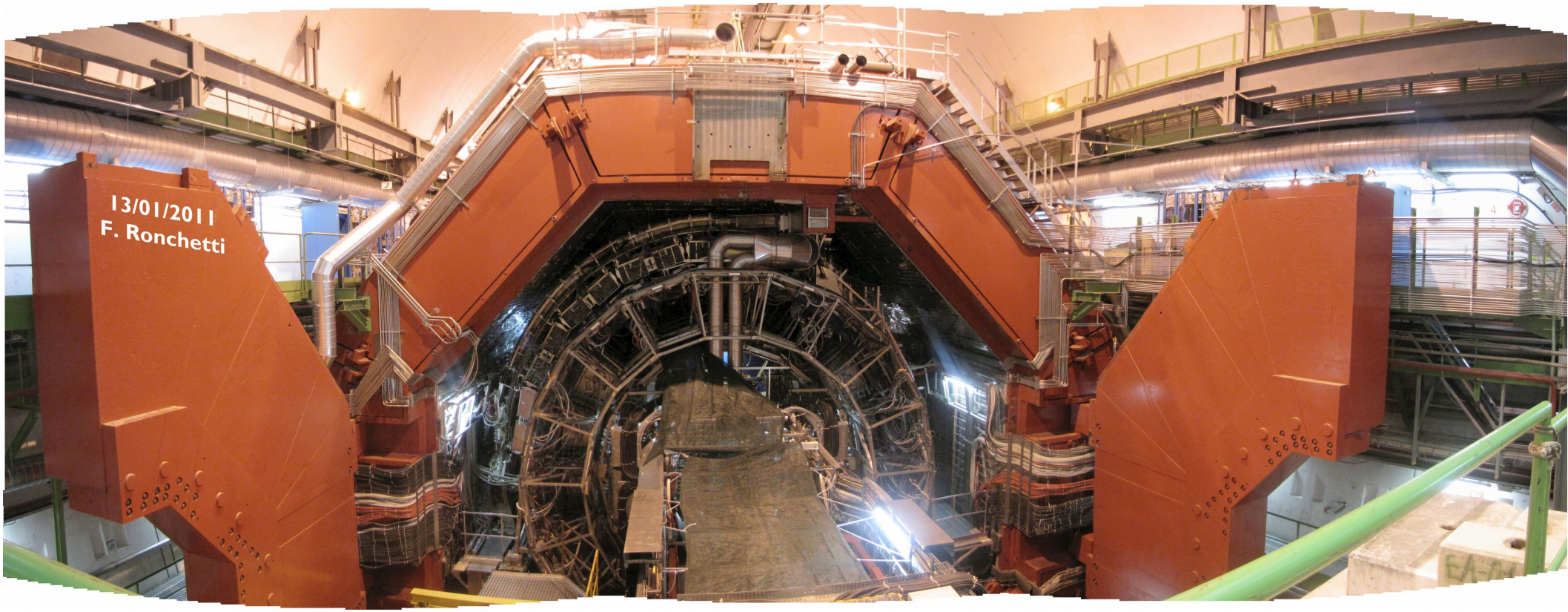
Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18



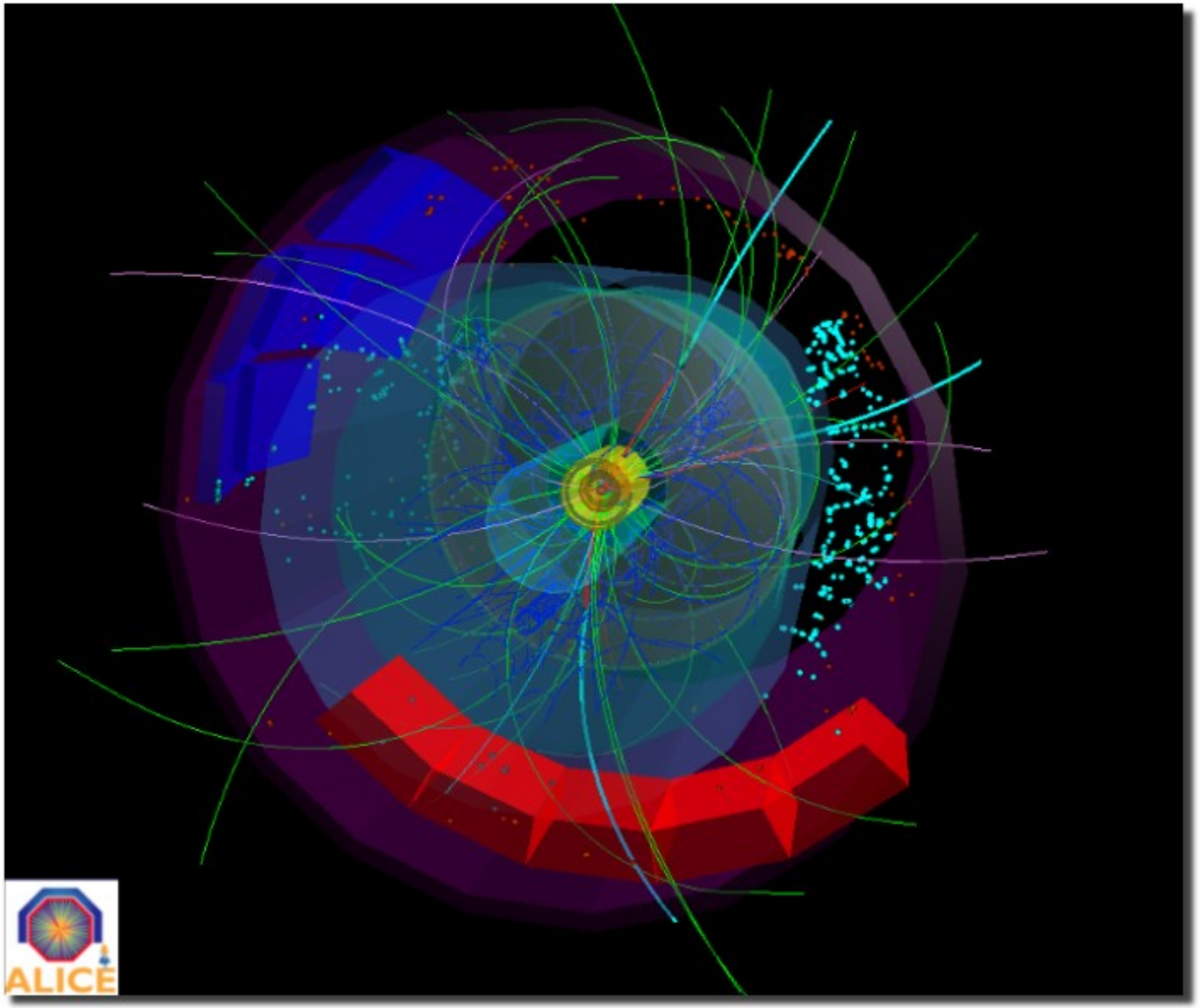
ACORDE
ITS
FMD
T0 & V0
EMCAL
TRD
HMPID
TRACKING
CHAMBERS
PMD
ZDC
~116m from I.P.
MUON
FILTER
V0
T0
TPC
TRIGGER
CHAMBERS
ZDC
~116m from I.P.

Trigger detectors: When do we have a collision?
Tracking detectors: Where did the particle go?
Identification detectors: What kind of particle is it?
Calorimeters: How much energy does the particle have?

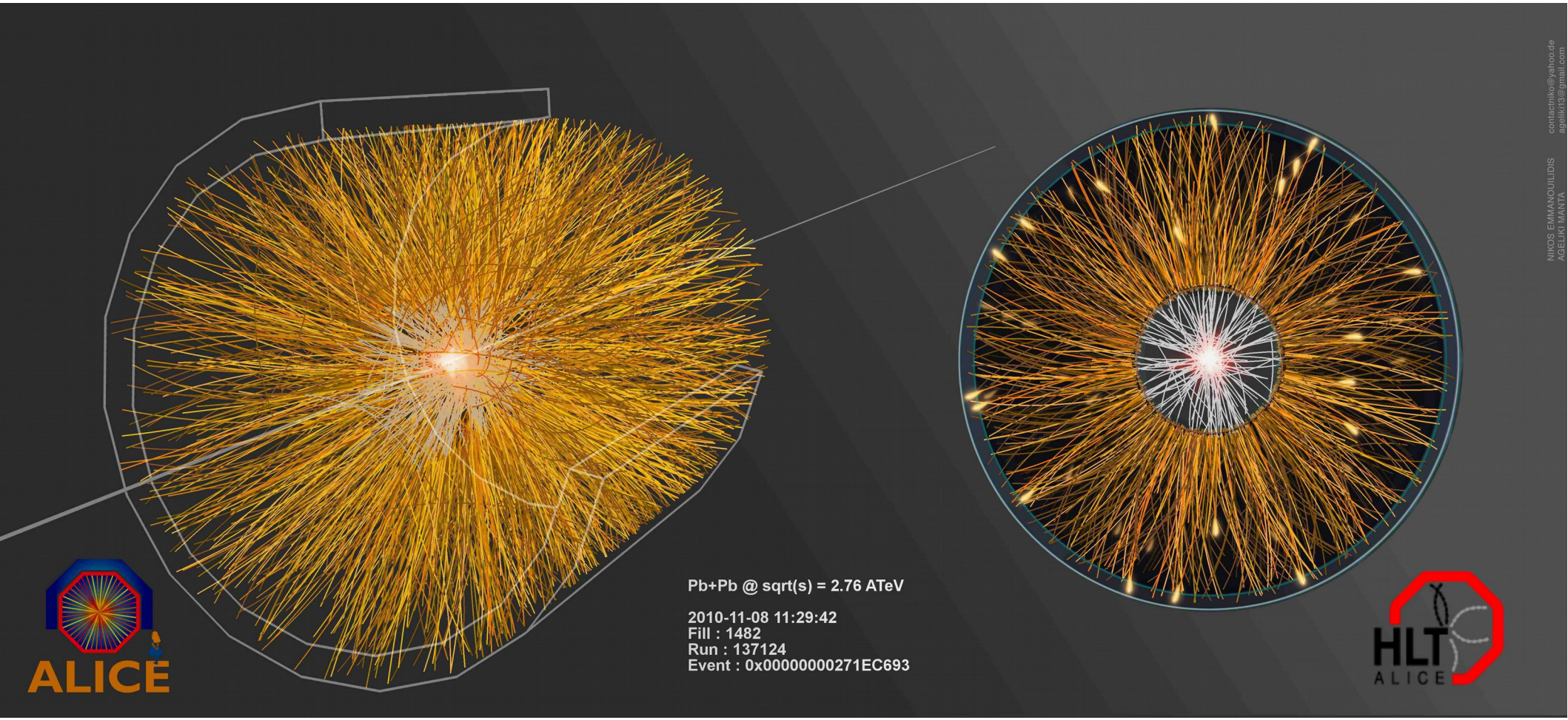
TOF
PHOS
DIPOLE
MAGNET
ABSORBER


13/01/2011
F. Ronchetti

p+p collisions



Pb+Pb collisions



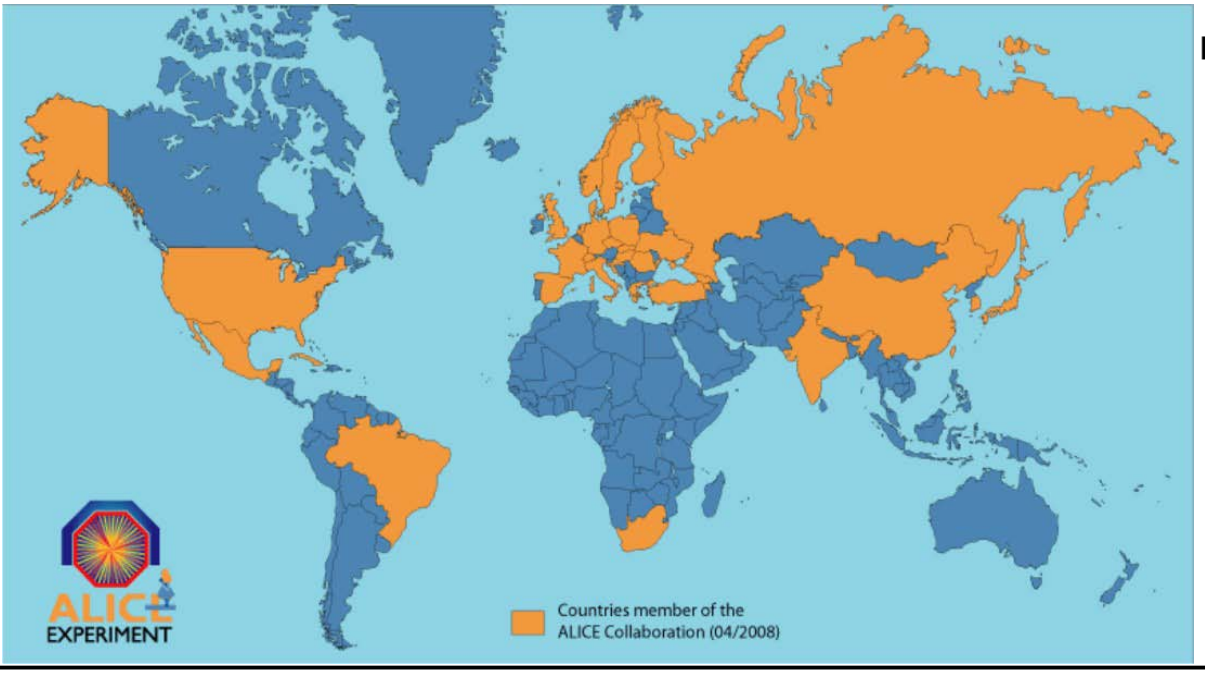
The ALICE Collaboration

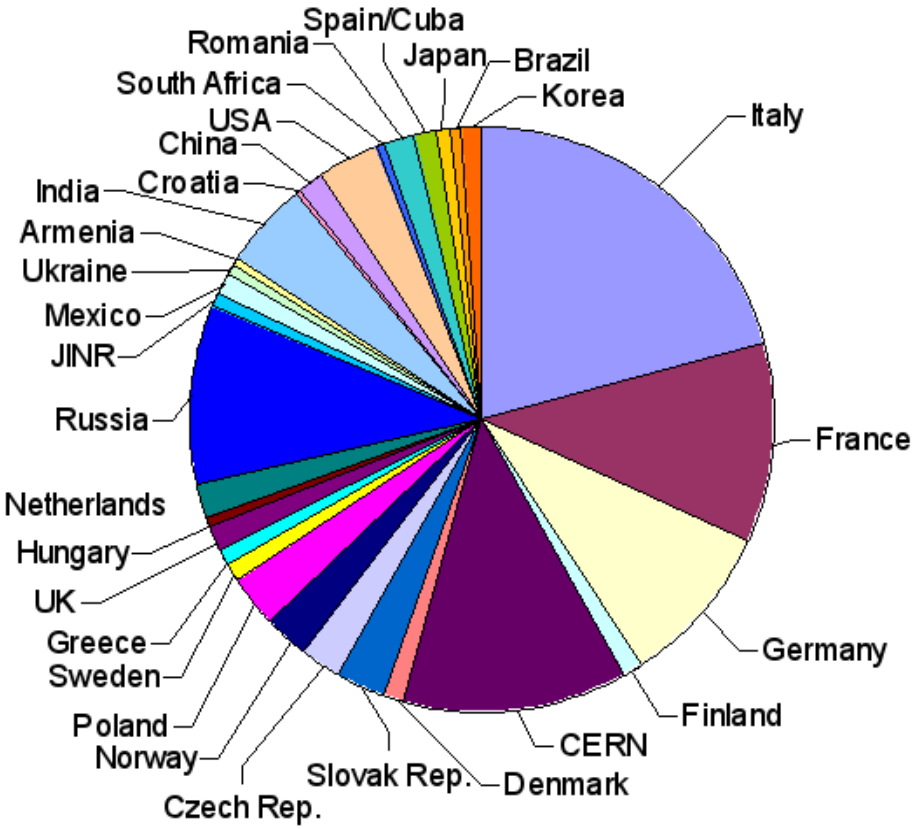
~1000 Members
63% from CERN
member states

~30 Countries

~100 Institutes

~$150 million Capital cost
(+magnet)





Scales

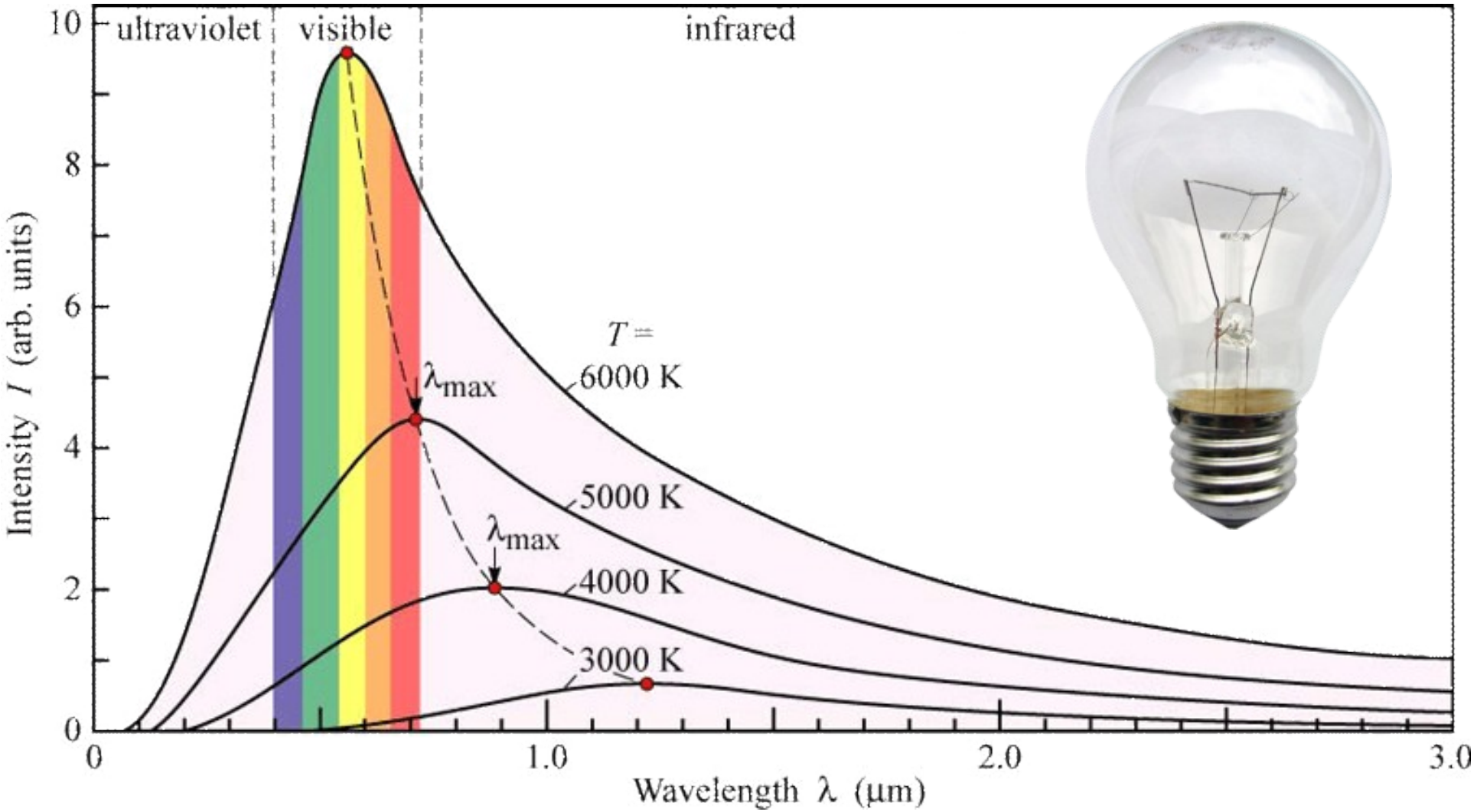
- Time: ~10^{-23} seconds
  - 1 minute for us ~ 1,000,000 lifetimes of the universe for QGP
- Energy: 1 TeV ~ 10 trillionths (10^{-11}) of a Calorie
  - About the amount of energy if two mosquitoes collide
  - About 1 trillionth of a candy bar
- Energy density: ~6-8 GeV/fm^3
  - 10^{35} times that of a candy bar (~trillion trillion trillion candy bars)
  - About the energy density if you packed the energy that could be released from a million kg of fuel for a nuclear power plant into a cube with each side the width of a hair
- Temperature: ~1.5 billion Kelvin
  - A million times hotter than the core of the sun

Scales

- Number of particles: ~2000-3000
  - Same number as in 1 μm^3 = 1/16 in^3 of air
- Size of QGP: 1 $fm^3 = 10^{-45}$ m^3
  - If this room were the size of the solar system, the QGP could fit in 1 cm^3
- Data volume: PB ~ 1,000,000 GB
- Data rates: ~1 PB/month written to disk, a few GB/second

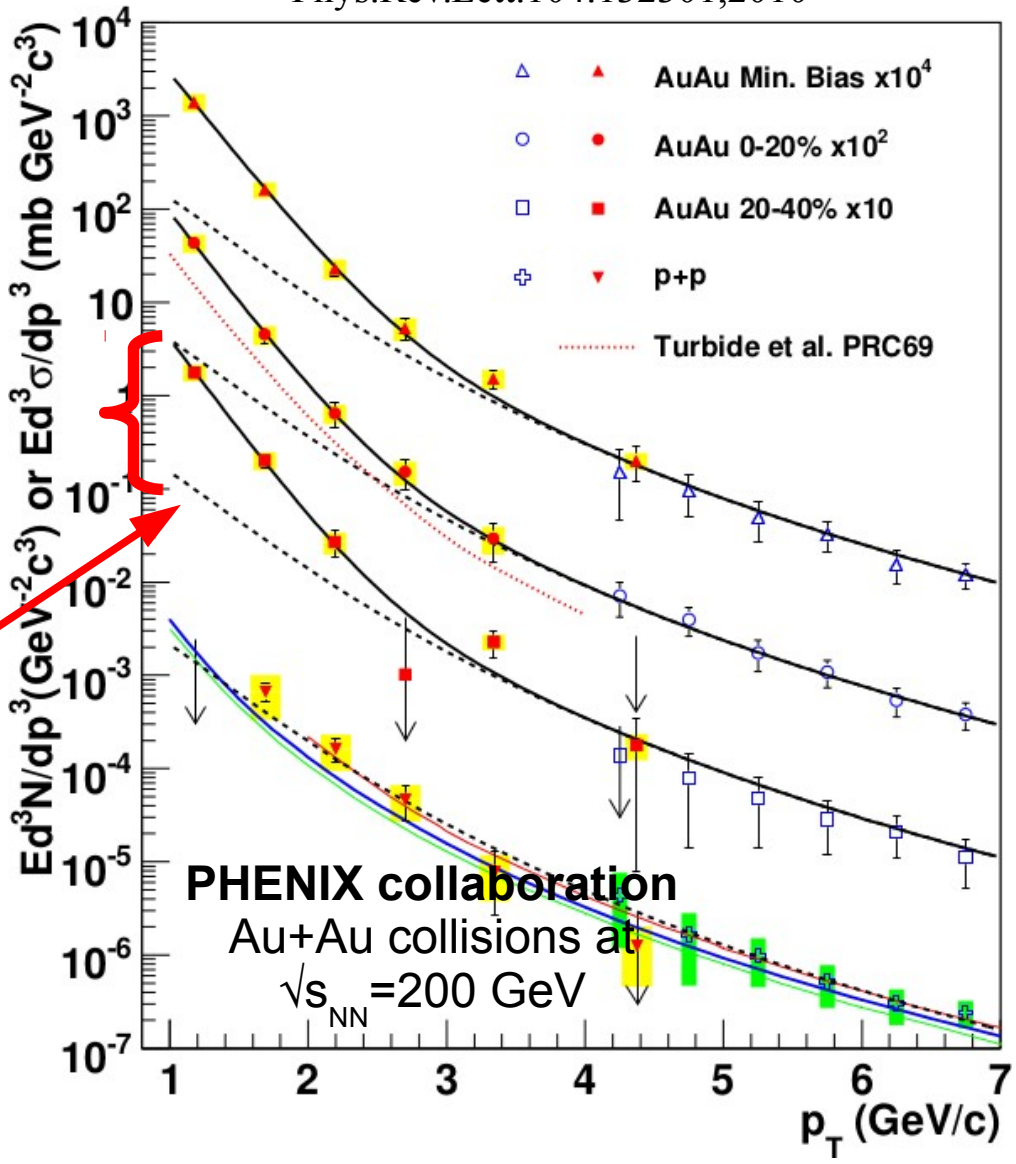
Measuring temperature

Thermal photons



Thermal photons

Phys.Rev.Lett.104:132301,2010



Thermal photons

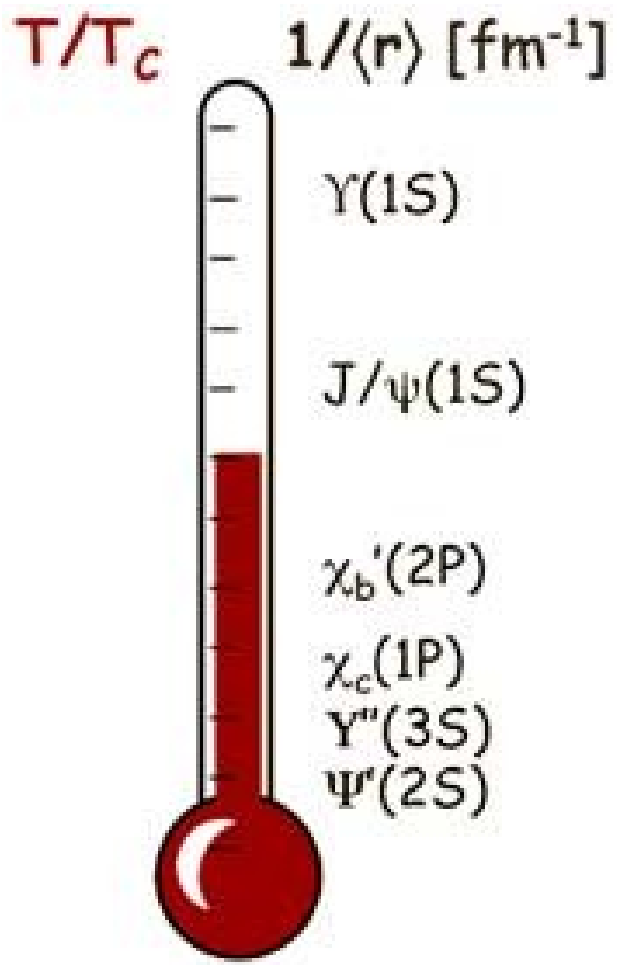
Other processes

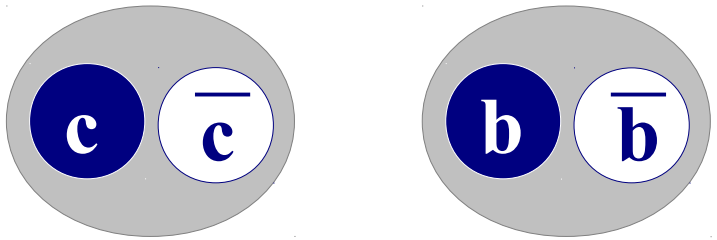
Inverse slope:
T = 221 +/- 19 (stat) +/- 19 (syst) MeV

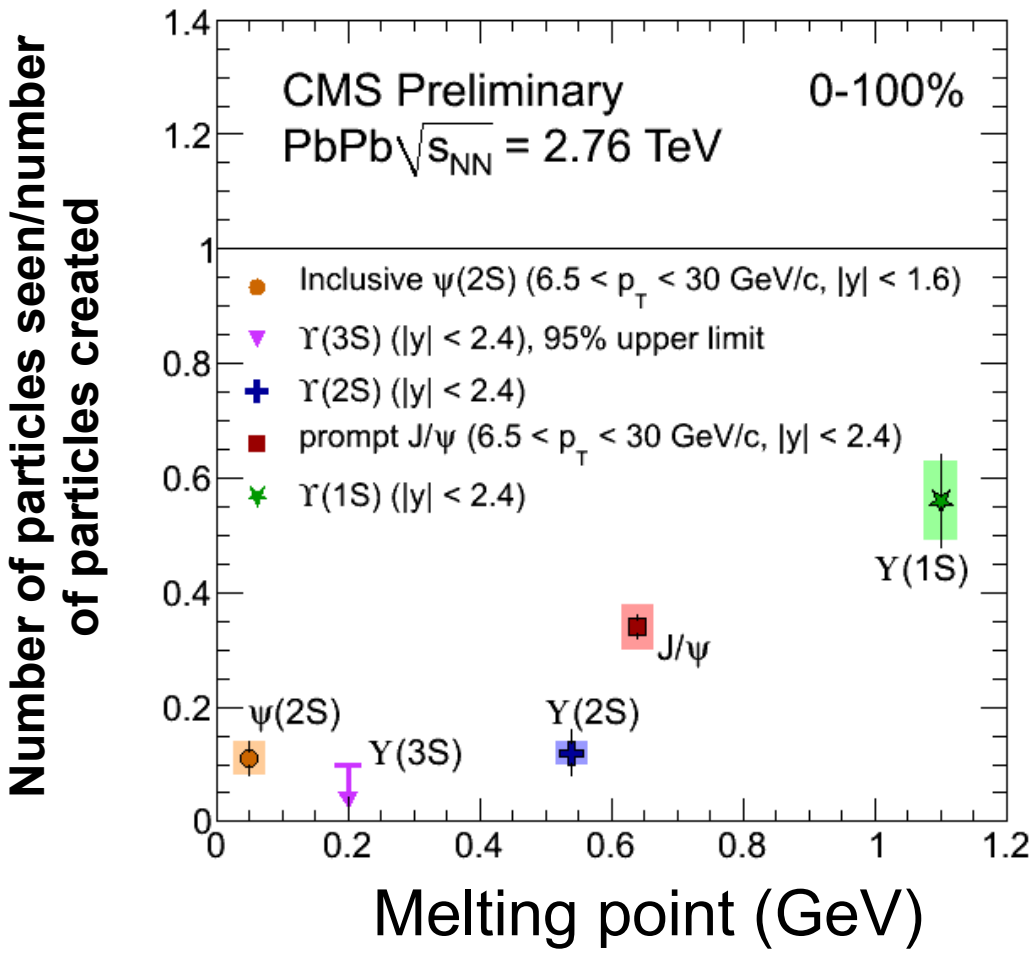
Consistent with models with T=300-600 MeV

T_c ~ 170 MeV

Quarkonium-thermometer



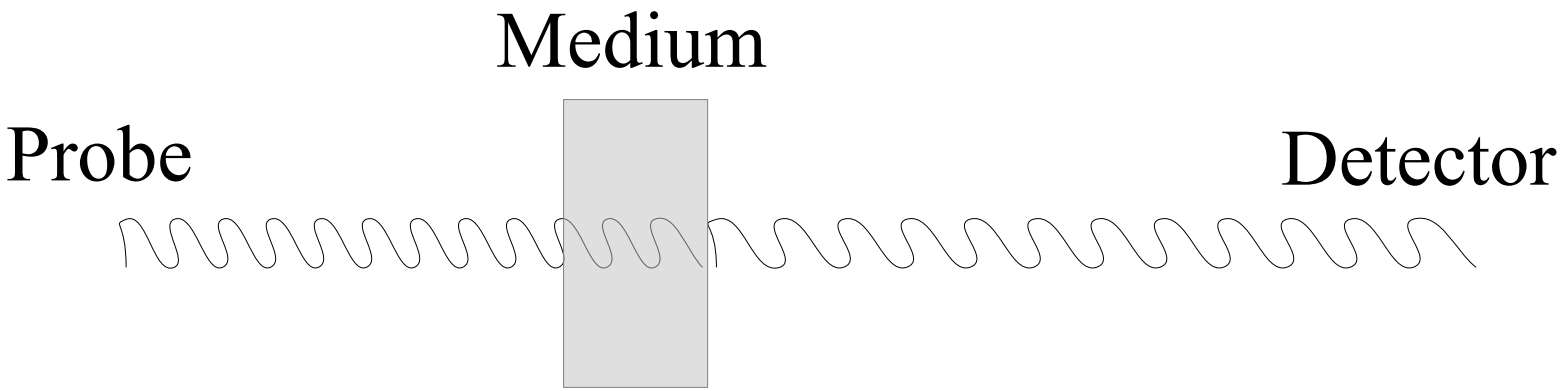




CMS-PAS HIN-12-014, HIN-12-007

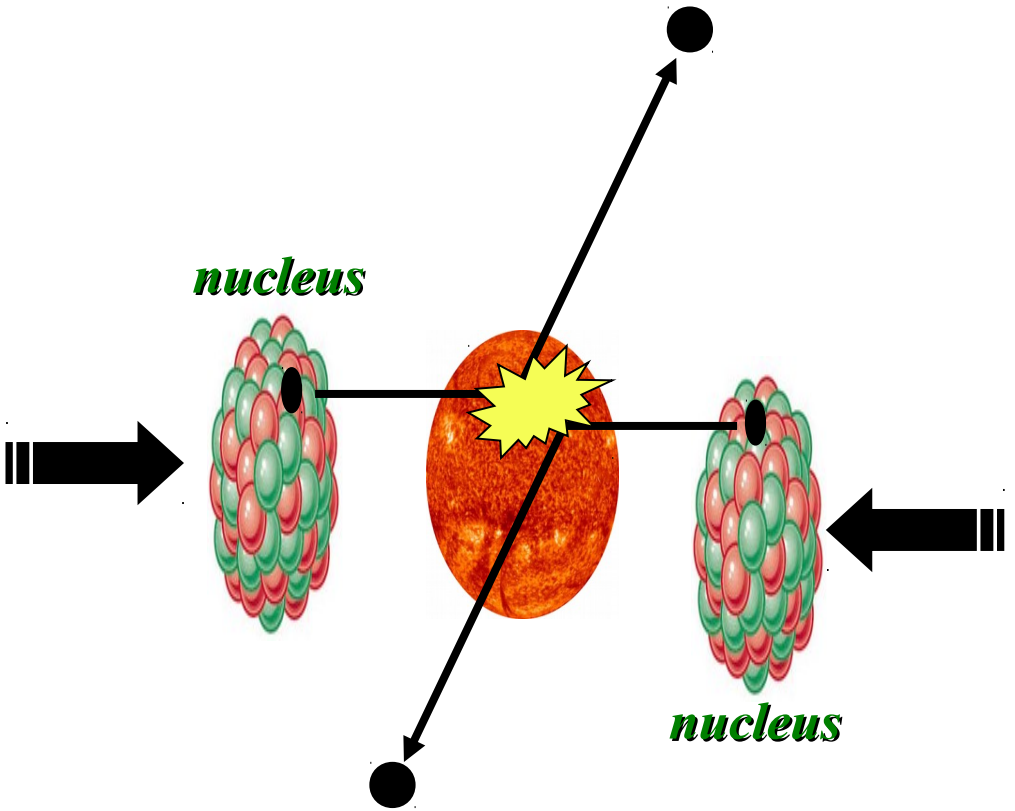
Imaging the Quark Gluon Plasma

Probing the Quark Gluon Plasma



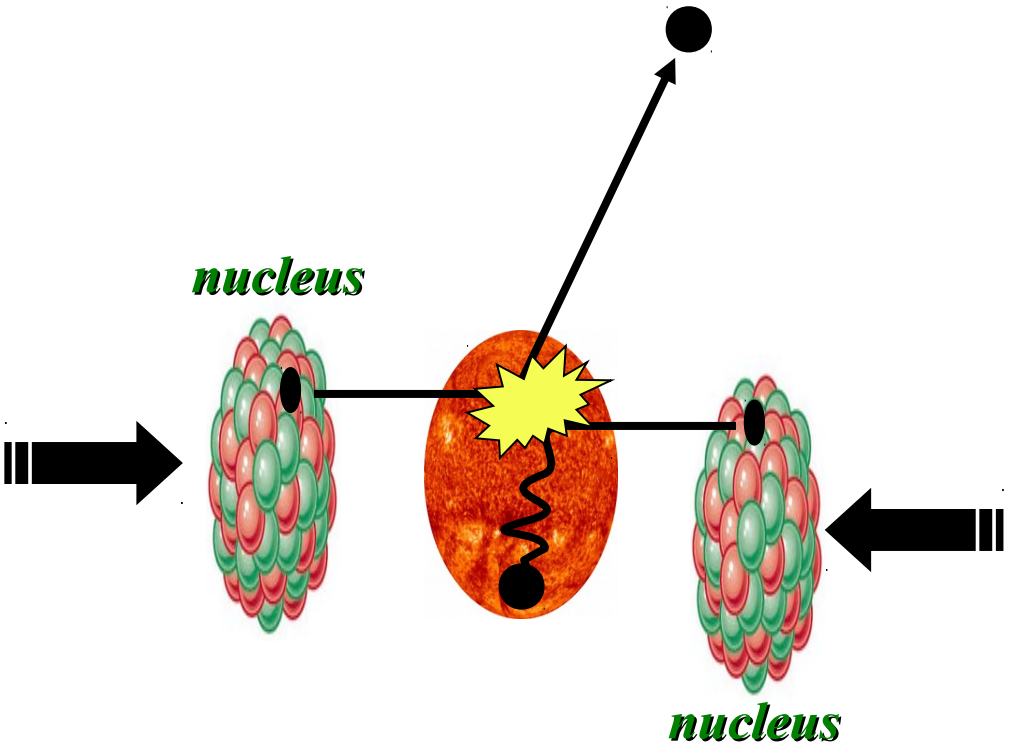
Want a probe which traveled through the collision
QGP is very short-lived (~1-10 fm/c) →
cannot use an external probe

Probes of the Quark Gluon Plasma



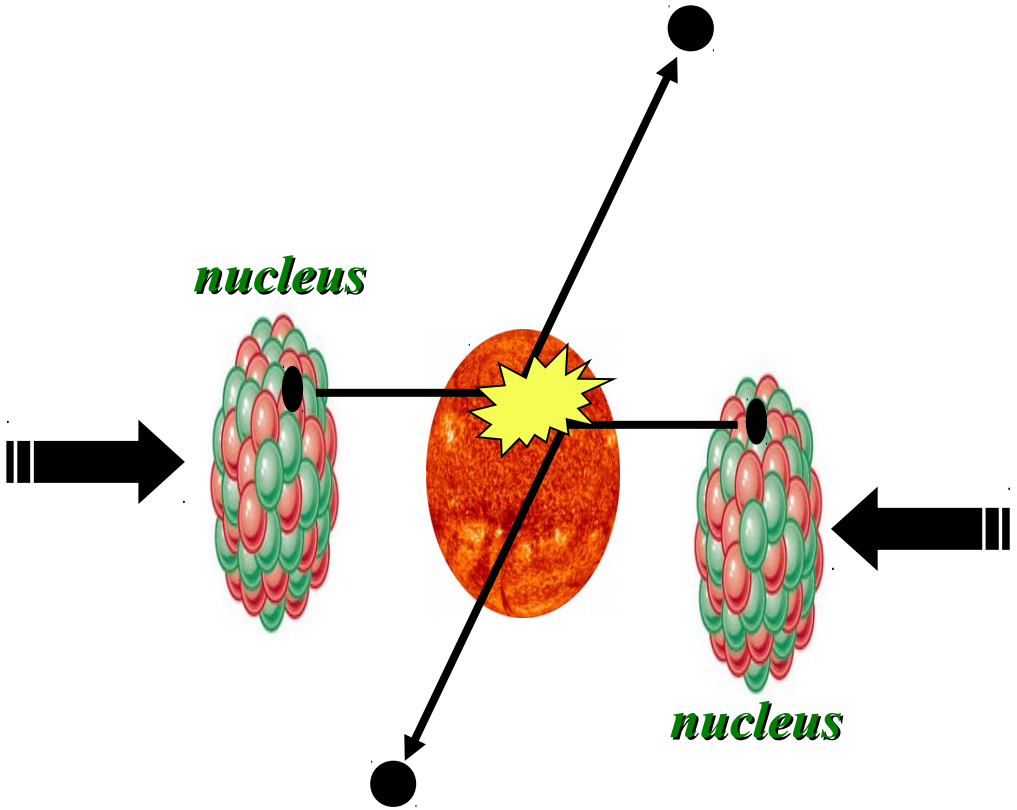
Want a probe which traveled through the medium
QGP is short lived → need a probe created in the collision

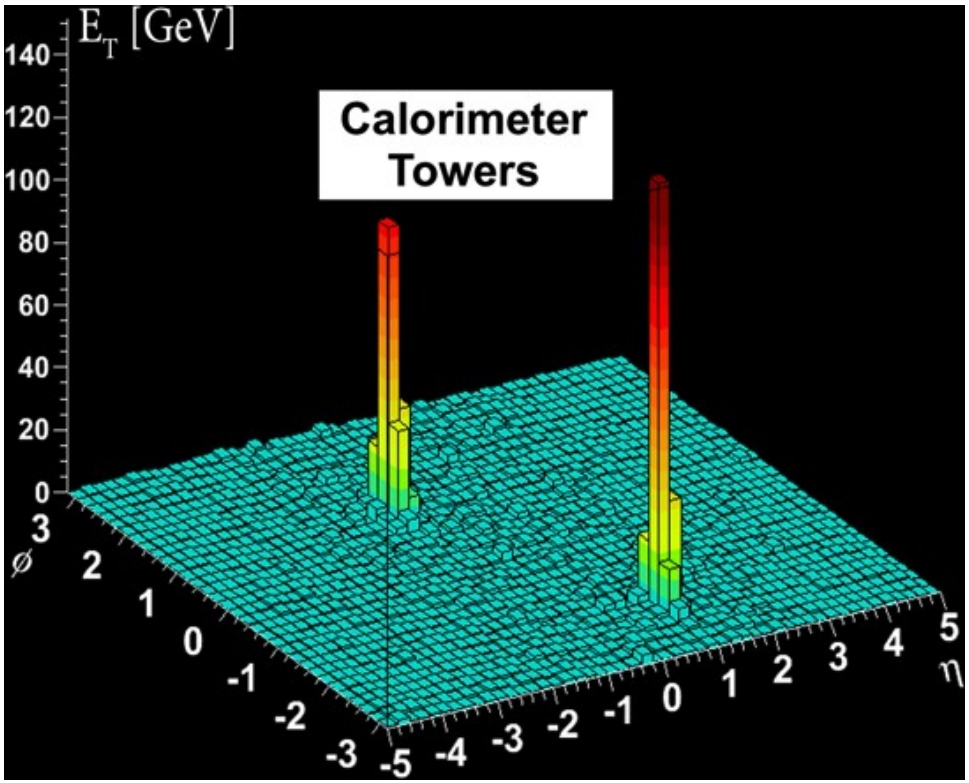
Probes of the Quark Gluon Plasma



Want a probe which traveled through the medium
QGP is short lived → need a probe created in the collision
We expect the medium to be dense → absorb/modify probe

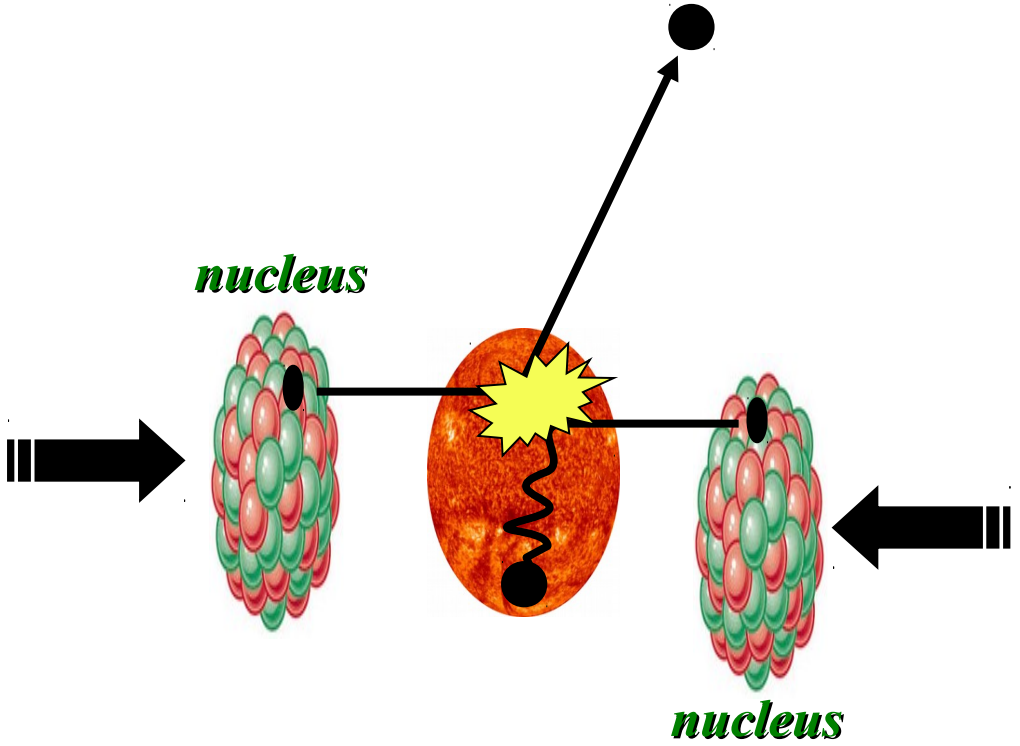
Jets

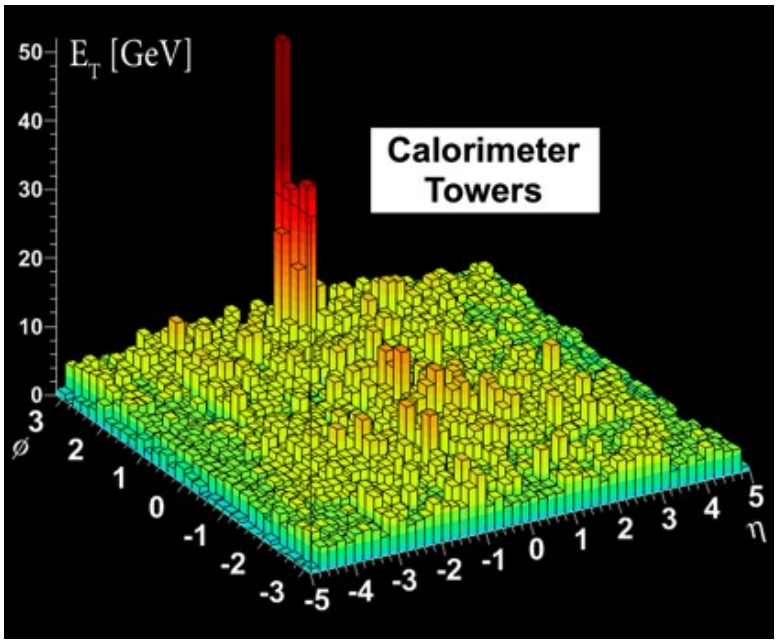




- Quarks and gluons are confined – we don't see them outside of mesons and baryons
- Instead we see a cone of particles around the outgoing quark or gluon
- Looking at jets analogous to spectroscopy

Quenched jets

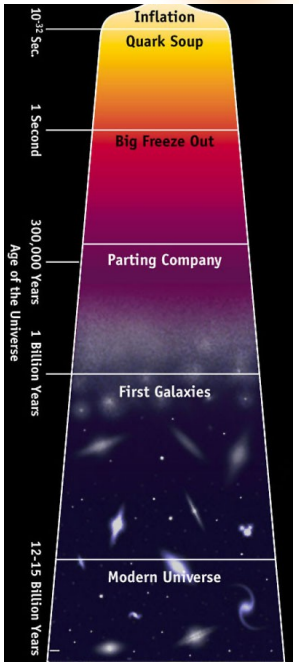


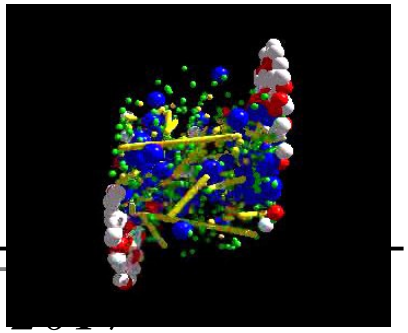


- One of the jets is absorbed by the medium
- The quark or gluon has equilibrated with the medium
- Phys. Rev. Lett. 105, 252303 (2010)

Take home messages

- If we get nuclear matter dense enough, we make a new phase of matter
- This quark gluon plasma is similar to what was present in the early universe
- We can produce a QGP in high energy heavy ion collisions

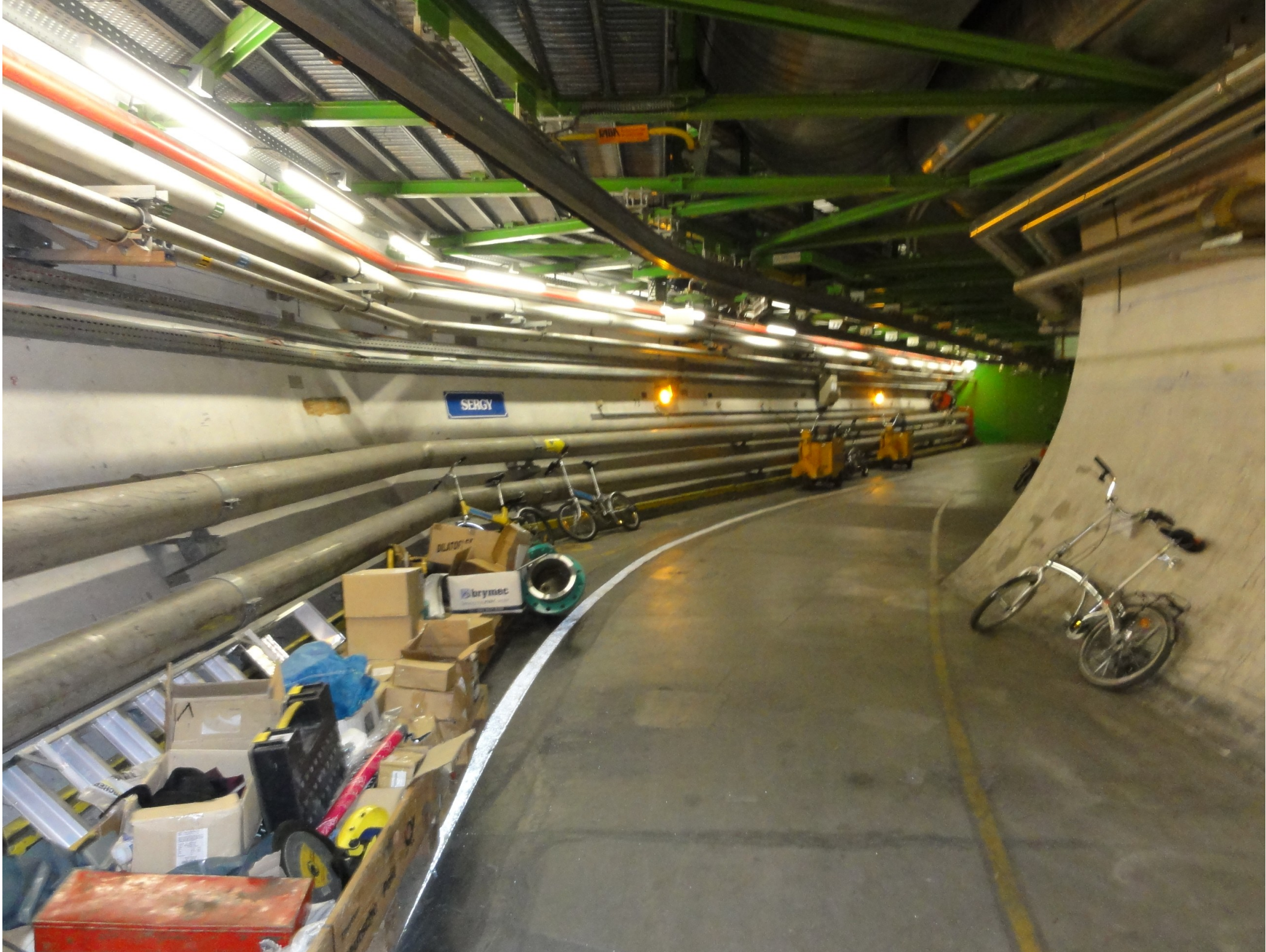


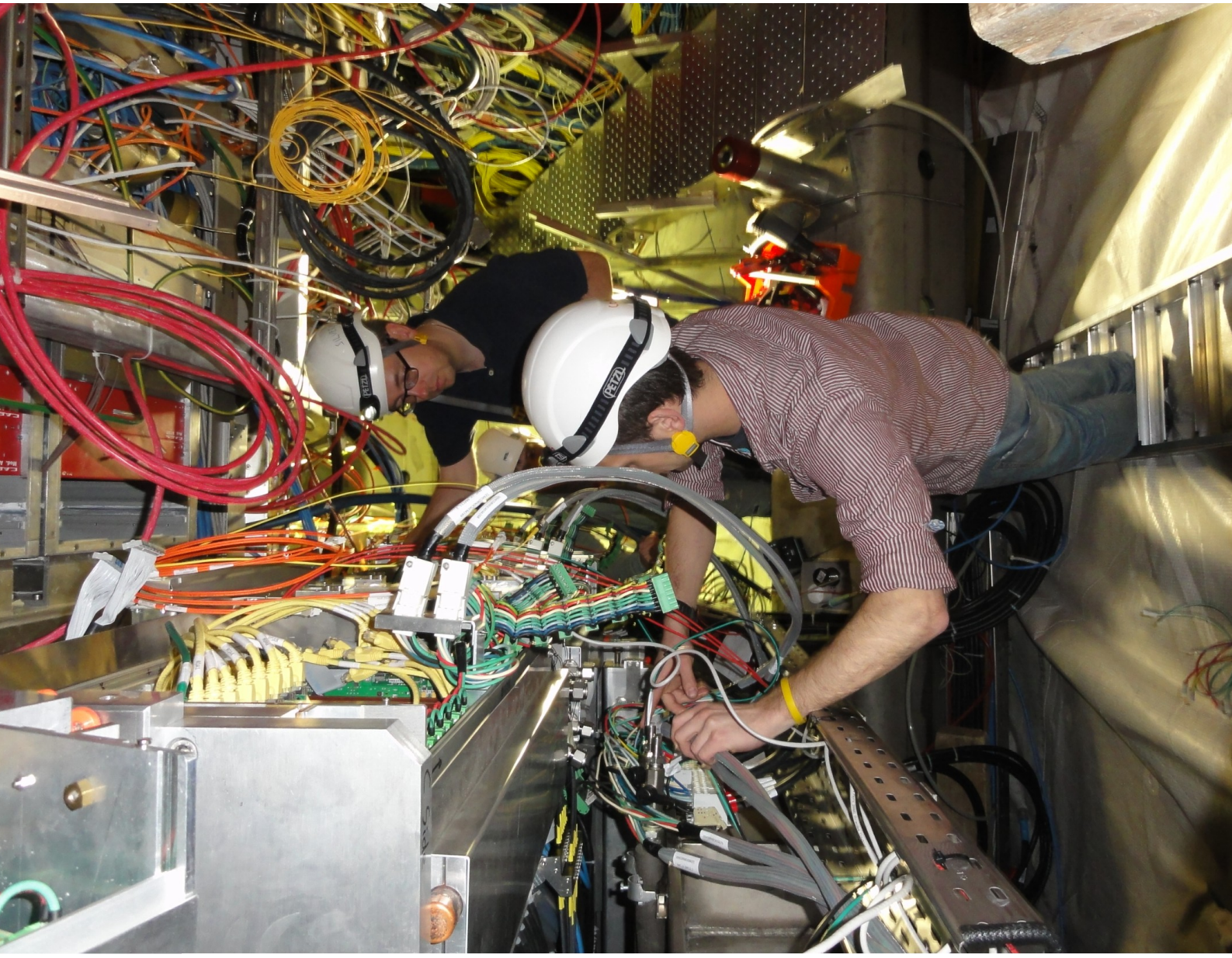


What I spend my time doing

- Programming (c++) - analyzing data
- Writing and giving talks – 3 research talks, 1 seminar, 2 posters, 1 software tutorial, and lots of talks (>30) at internal meetings in 2010
- Hardware work: assembling & testing the detector
- Working with graduate students
- Outreach: blogging for ALICE, giving tours of PHENIX to the public...
- Writing papers and conference proceedings
- Reviewing the work of my collaborators
- Running our journal club
- Reading papers
- Taking shifts – including being on call 24/7
- Teaching
- Advising undergraduate students
- Supervising/mentoring students & post docs on research
- Reviewing papers, proposals


TREE FRIENDS


SERGY
brymec


PETZL
PETZL


Entrance Forbidden

Resources

- US LHC blog and Facebook page
- Experiments
  - Relativistic Heavy Ion Collider: STARPHENIX
  - Large Hadron Collider: ALICE ATLAS CMS LHCb TOTEM
- Event displays and pretty pictures from ALICE
- Really cool ATLAS event animation
- Links to articles in the press on PHENIX
- Scientific American article