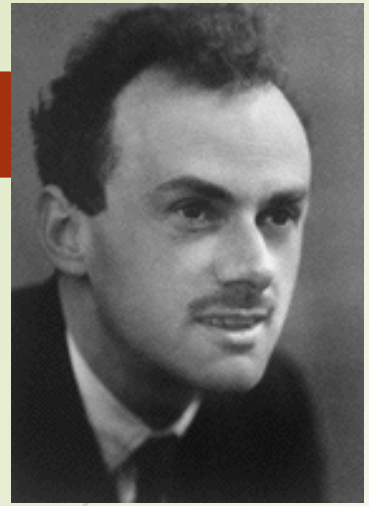
Hadron Physics

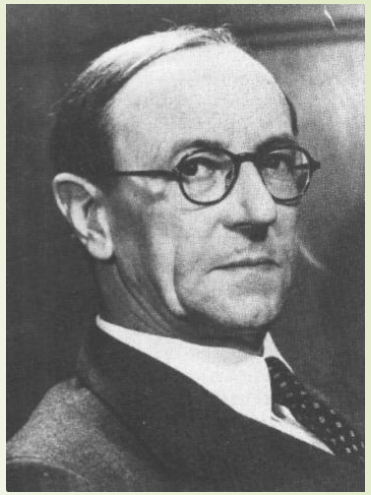
Past and Future



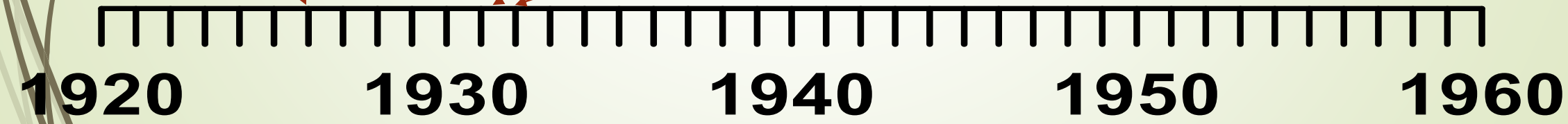
Paul A, M, Dirac
Relativistic Electron Theory

S. Chandrasekhar
Chandraselhar limit

Wolfgang Pauli
Neutrino



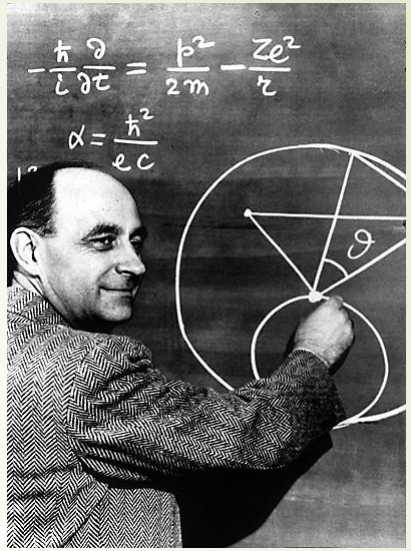
James Chadwick
Discovery of neutron



W. Heisenberg
Nuclear Structure

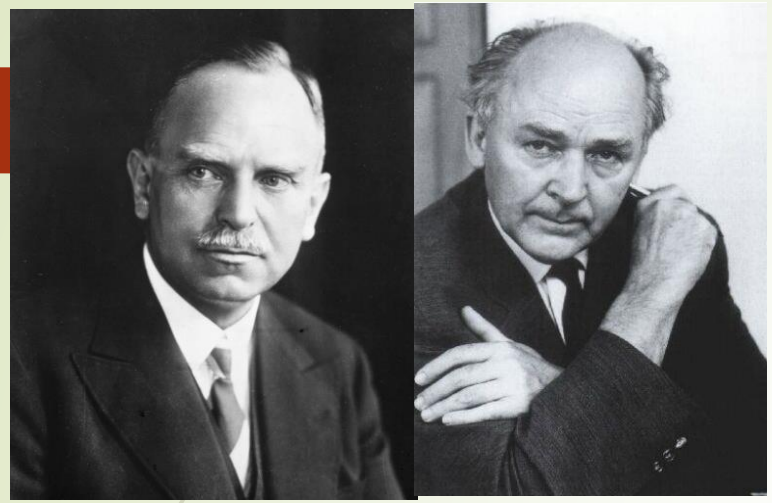
Carl D. Anderson
Discovery of Positron

Hideki Yukawa
pi-meson



E. Fermi
Theory of beta Decay
(currentxcurrent)

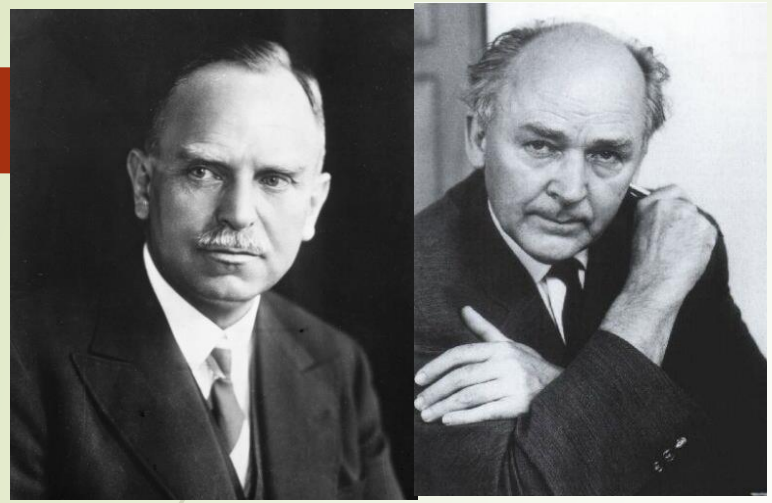
Ettore Majorana
Real solution for fermions



G.O.Hahn & F. Strassmann
Discovery of Nuclear Fission

H. A. Bethe
CNO Cycle

L. Meitner & O.R. Frisch
Theory of Nuclear Fission



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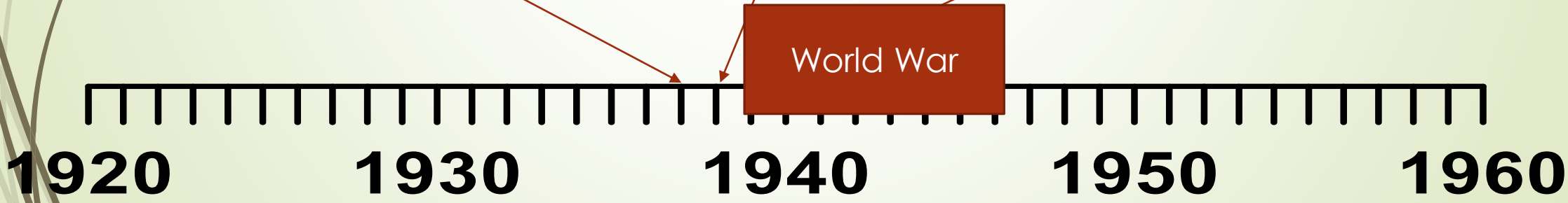
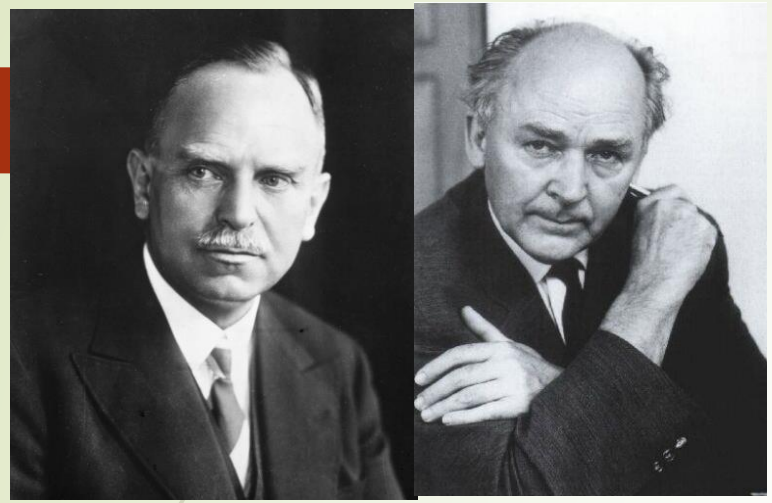




G.O.Hahn & F. Strassmann
Discovery of Nuclear Fission

H. A. Bethe
CNO Cycle

L. Meitner & O.R. Frisch
Theory of Nuclear Fission

World War

Nuclear Era

1920 1930 1940 1950 1960


MONSTER DEATH TOLL MOUNTS!
180 Known Dead;
1500 Injured
DAMAGE ESTIMATED AT


DAMAGE ESTIMATED AT
$300,000,000

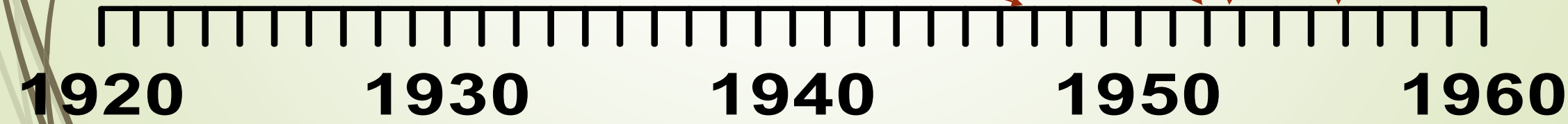
Era of Accelerators

C. Lattes, G.Ochialini, C. Powell
Discovery of pion

Discovery of
K, Λ, Σ, Ξ

Strangeness
(Nakano-Nishijima)

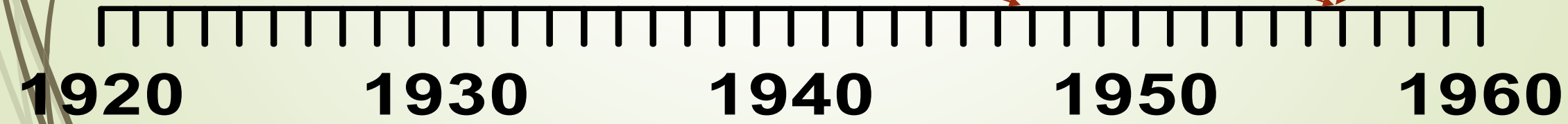
$Q=I_3+(B+S)/2$
NNG



C. Lattes, G.Ochialini, C
Discovery of pion

T.D. Lee & C.N. Yang
Parity Violation

C.S. Wu
^{60}Co experiment



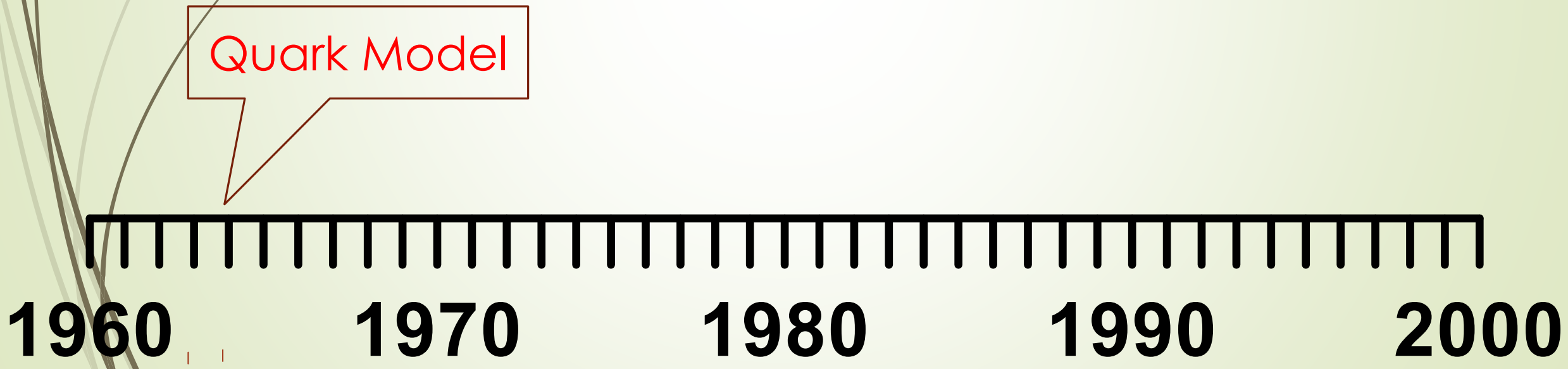
Uncertainties in '60

- Too many elementar particles.
- Increase of σ_{pp}
- Elementary particles are indestructible, but have internal structures...
- strong interactions considered as a hopeless case for quantum eld theory

  → S-matrix theory, Dispersion relaations, Regge

Landau : " It is well known that theoretical physics is at present almost helpless in dealing with the problem of strong interactions. We are driven to the conclusion that the Hamiltonian method for strong interactions is dead and must be buried, although of course with deserved honour."

Establishment of QCD



Establishment of QCD

Salam-Weingerg

Han-Nambu

Parton Model

Quark Model

1960 1970 1980 1990 2000

Establishment of QCD

Color Singlet
Fritzch &Gell-Mann

Han-Nambu

Parton Model

Quark Model

1960 1970 1980 1990 2000

Establishment of QCD

Color Singlet
Fritzch &Gell-Mann

QCD Lagrangian
Fritzch, Leutwyler, Gell-Mann

Quark M

Han-

1960 1970 1980 1990 2000

Establishment of QCD

Color Singlet
Fritzch &Gell-Mann

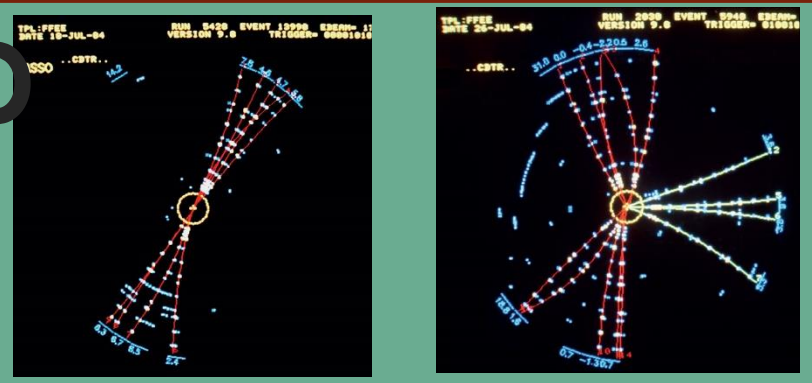
QCD Lagrangian
Fritzch, Leutwyler,
Gell-Ma

Asymptotic Freedom
Gross, Politzer,Wilzcek

1960 1970 1980 1990 2000

Establishment of QCD

Color Singlet
Fritzch &Gell-Mann



Discovery of quark and gluon jets
(Feynman 1975)

QCD Lag
Fritzch, Leut
Gell-M

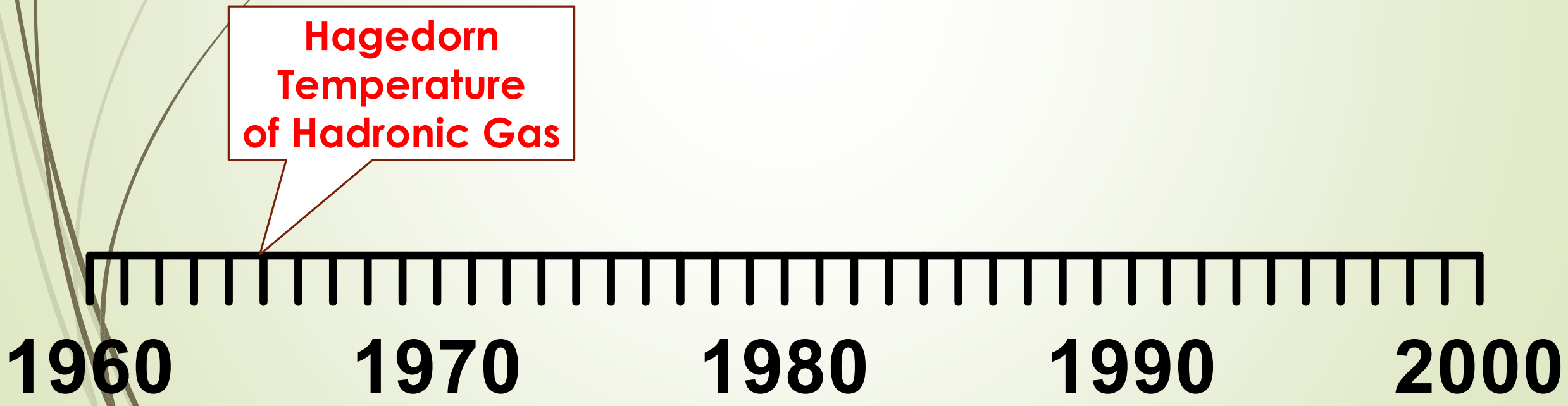
Han-N nbu

Quark M de

Asymptotic Freedom
Gross, Politzer,Wilzcek

1960 1970 1980 1990 2000

Bulk Properties – Relativistic Nuclear Physics



Bulk Properties – Relativistic Nuclear Physics

Discovery of Pulsar
(neutron star)

Hagedorn
Temperature
of Hadronic Gas

1960 1970 1980 1990 2000

Bulk Properties – Relativistic Nuclear Physics

Nuclear Matter
EoS-Neutron Star

Discov of Pulsar
(ne on star)

Hag n
Temp ture
of Had ic Gas

1960 1970 1980 1990 2000

Bulk Properties – Relativistic Nuclear Physics

Nuclear Matter
EoS-Neutron Star

Discov of Pulsar
(ne on star)

Hag n
Temp ture
of Had ic Ga

Quark Star
N. Itoh

1960 1970 1980 1990 2000

Bulk Properties – Relativistic Nucle

Nuclear Matter
EoS-Neutron Star

Discov of Pulsar
(ne on star)

Hag n
Temp ture
of Had ic Ga

Quark Star
N. Itoh

- Lee-Wick Nuclear Isomer
- Use of High Energy Nuclear Collision – Greiner, et al
- Walecka Model
- Bear Mountain Summer School
- Hadronic Resonance Gas...
- Cooper-Frye

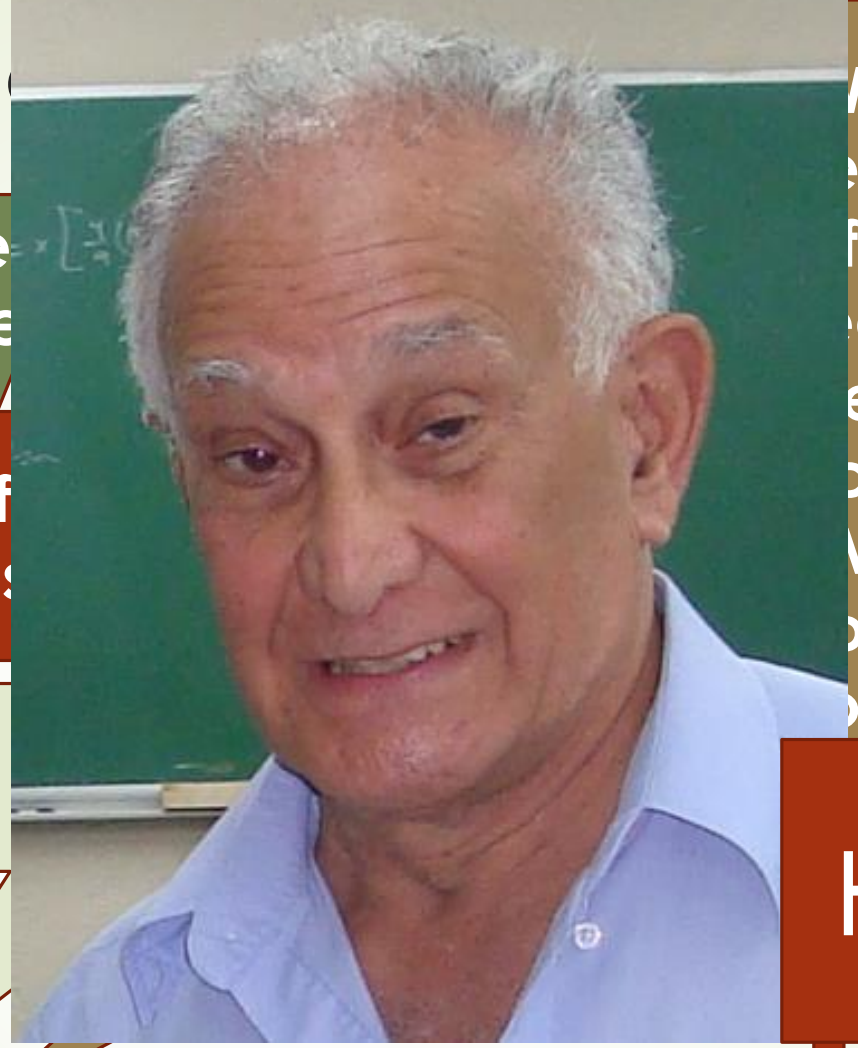
1960 1970 1980 1990 2000

Bulk Properties – Rel

Nucle
EoS-Ne

Discov of
(ne on s

Hag n
Temp ture
of Had ic Ga



ick Nuclear
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f High Energy
ar Collision –
er, et al
cka Model
Mountain Summer
ol
nic Resonance

Hadron Physics !

1960 1970 1980 1990 2000

And many colleagues as (sorry for not complete…)

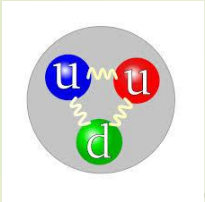
- Victoria E. Herscovitz
- Sá Borges
- Fernando Navarra
- Marina Nielsen
- M. Beatriz Gay
- Sergio Duarte
- Debora Menezes
- Gastão Krein
- Miriam Bracco
- Cesar Vasconcellos
- Marcelo Chiapparini
- Tobias Federico
- Manuel Malheiro
- Marcio Menon
- Lauro Tomio
- Manuel Robillota
- F. Steffens
- :
- :

Roles of Hadron Physics in Brazil

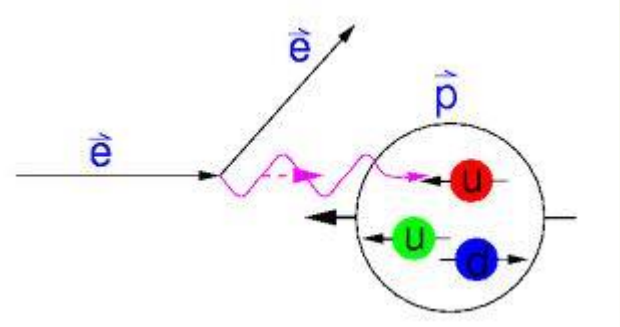
- Aggregation of research groups in the national scale.
- Stimulation for the students and young generations to the state-of arts researches.
- Educative and training aspects of graduaate students.
- Offers the chances of visibility for young people.

- To keep update the continuos and quick developments of the research field.
- Offers wider vision of physics ...
- :
- :

Pin-point Study

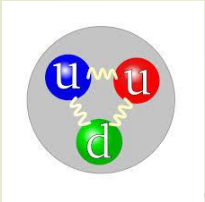


Proton

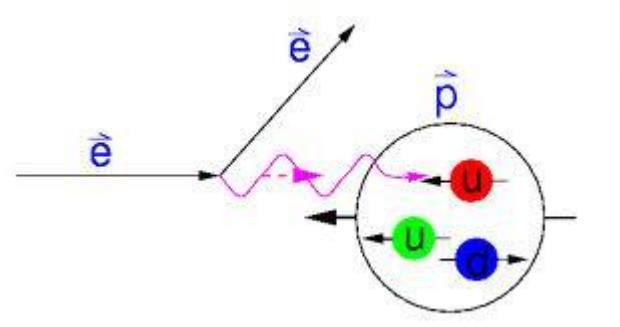


Deep inelastic Collisions

Pin-point Study

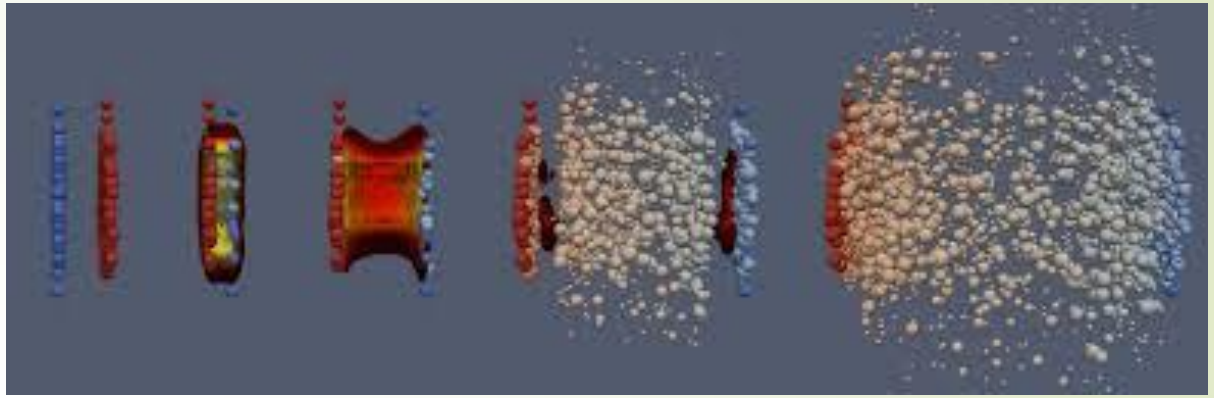


Proton



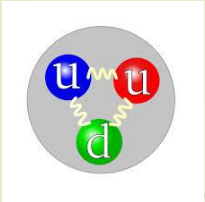
Deep inelastic Collisions

Bulk Property Study



Relativistic Heavy Ion Collisions

Pin-point Study



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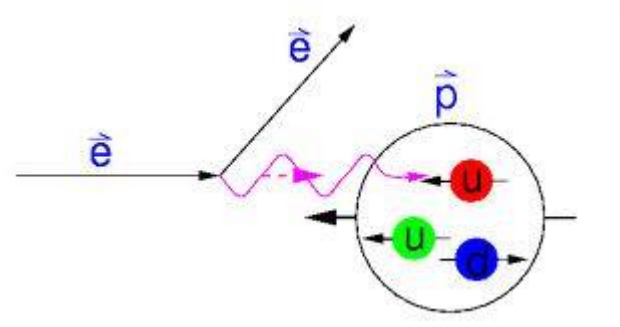
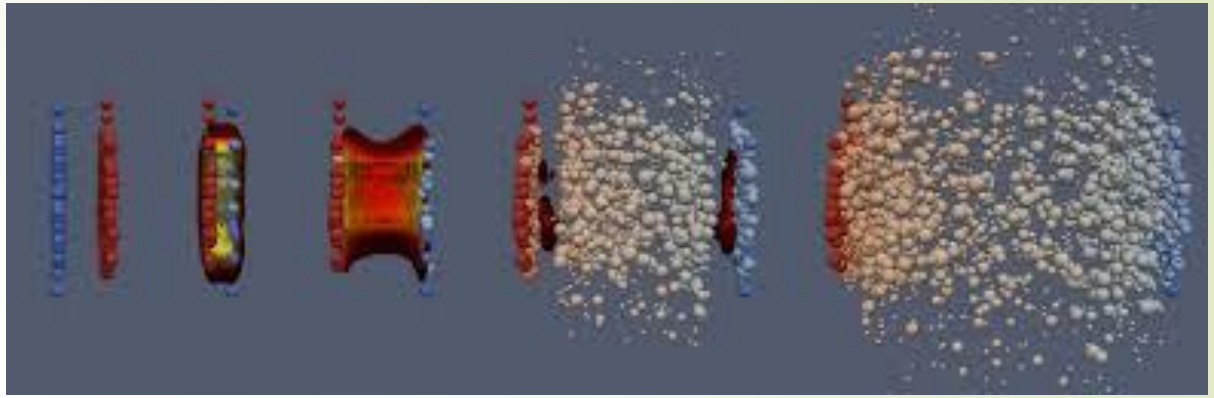


Deep inelastic Collisions

Rice

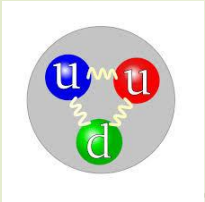
Examine carefully…

Bulk Property Study



Relativistic Heavy Ion Collisions

Pin-point Study



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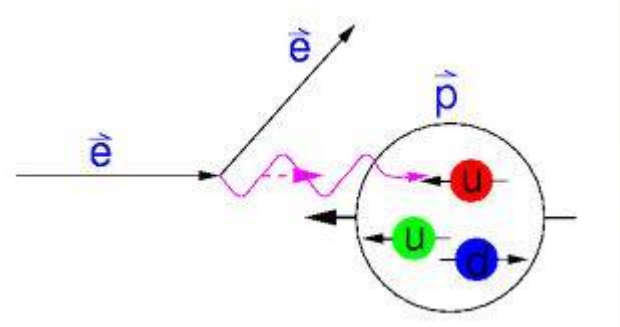
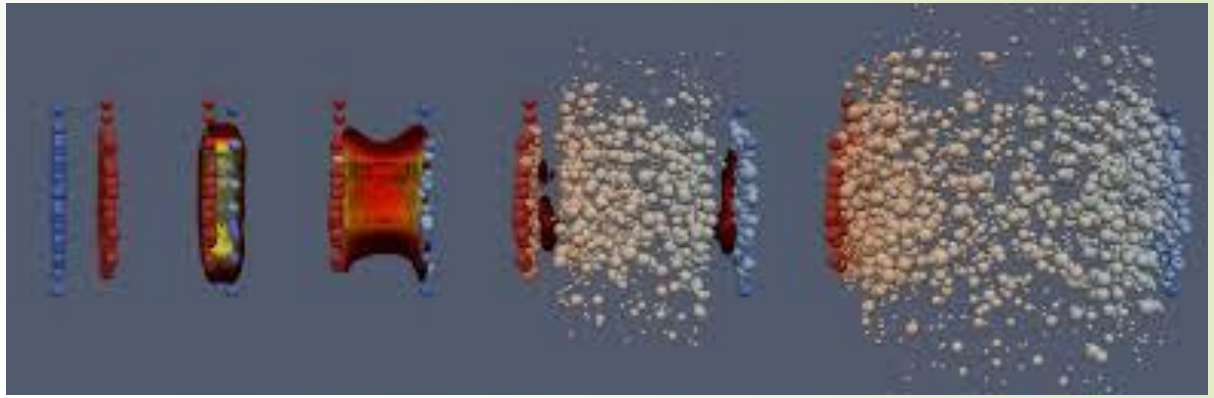


Deep inelastic Collisions

Rice

Examine carefully…

Bulk Property Study



Relativistic Heavy Ion Collisions

Cooking the rice….

In 1985

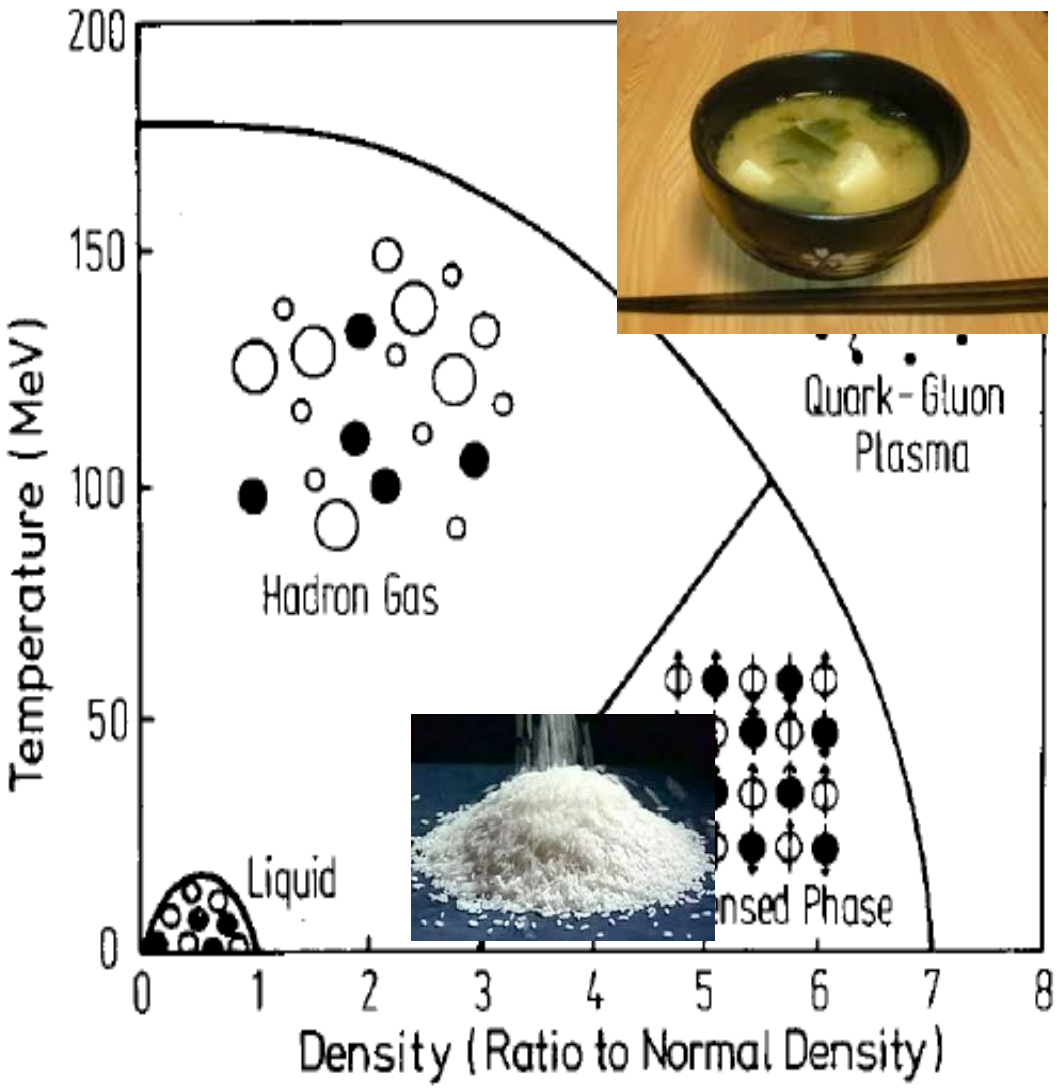
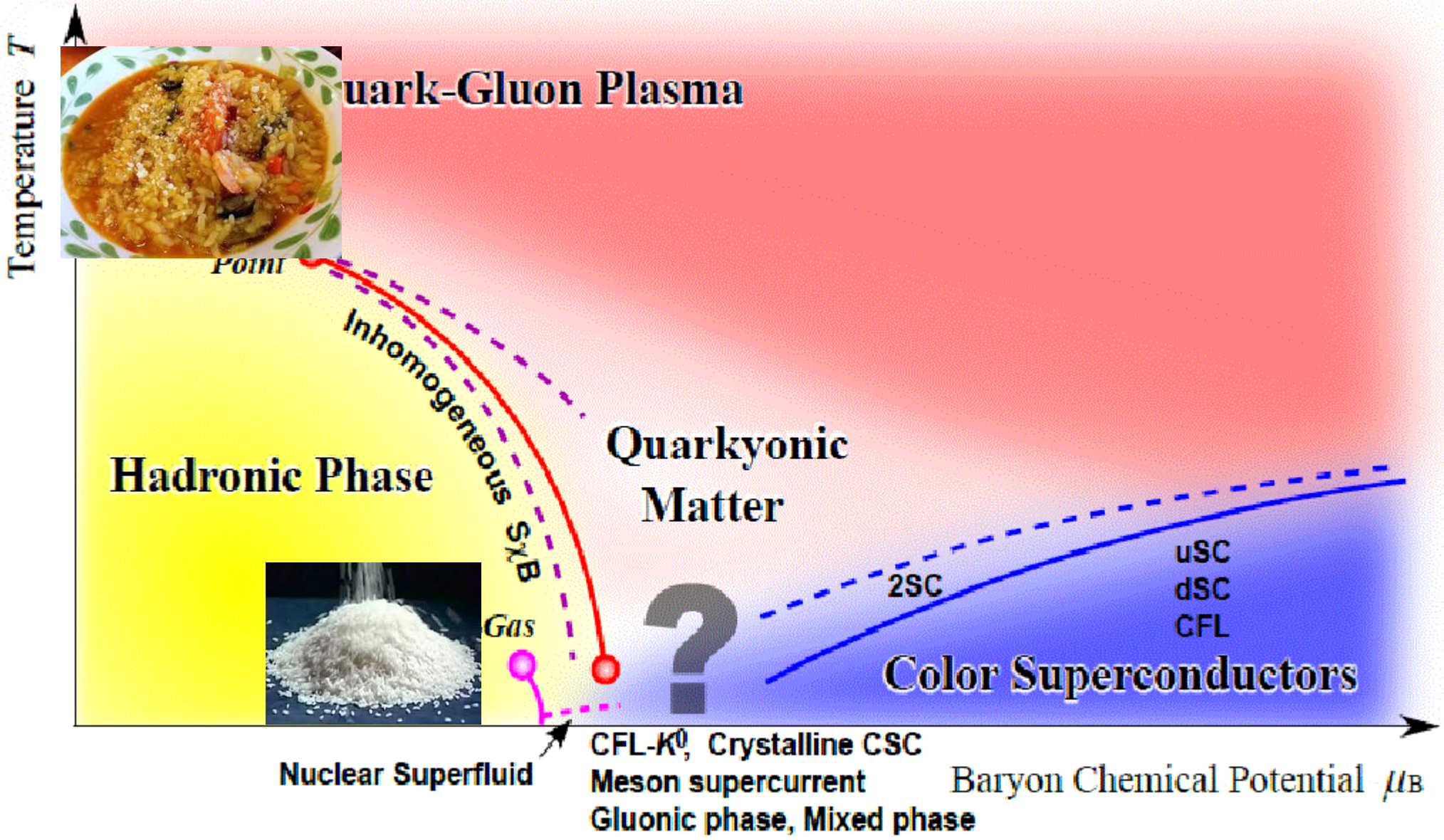
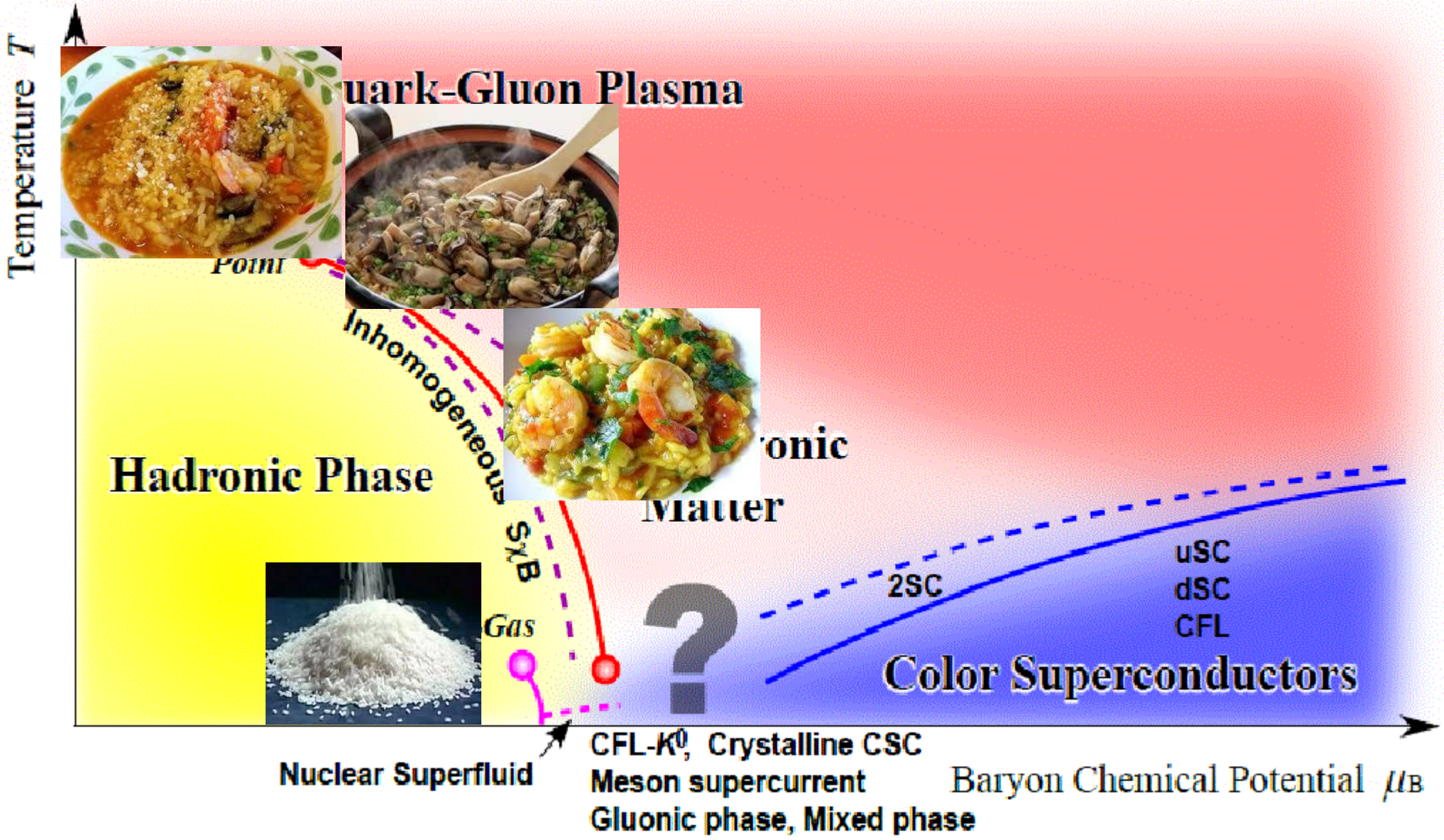


Fig. I.1. Phase diagram of nuclear matter shows the fundamentally different states that have been conjectured. Experimentally, only the point (1, 0) is known [Stö85].

Taken from Stöcker&Greiner **1985**



Taken from Fukushima&Htsuda **2010**



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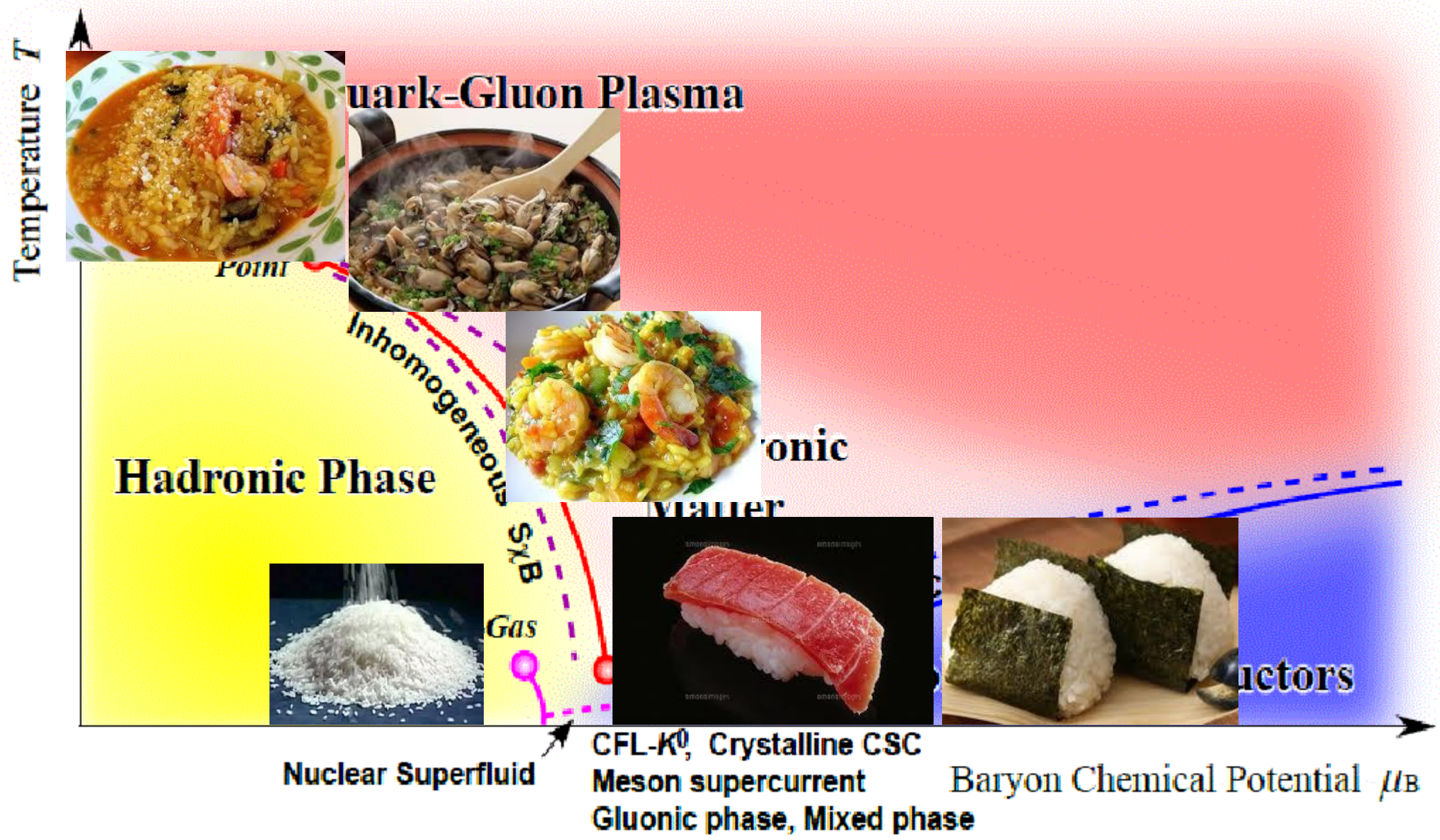

Taken from Fukushima&Htsuda **2010**

Future - Some Challenging Questions

- The Standard Model, OK ? Why? Why Generations ? Is Higgs elementary?
- Neutrinos : Origin of the mass, Majorana ?
- Dark Matter ?
- How far can ab-initio QCD approaches go ?
- Matter dominance in the Unverse?
- Quark Confinement ?
- Why perturbative QCD valid (asymptotic state) ?
- Equation of State of QGP-Hadronic Matter
- Supernova Explosion (should be robust)
- Structure of Superdense stars, Magneters, Observables..
- Neutron-Star mergers
- Lack of zero metal stars
- Supersymmetry ?
- Strings, extradimensions are real (observables)?
- :
- :

Thanks to

and

Débora
Marcus
Dimiter
Emmanuel
Fabio Braghin
Luciano
Murilo
Varese