Hadron Physics
Past and Future
W. Heisenberg
Nuclear Structure

Carl D. Anderson
Discovery of Positron

Hideki Yukawa
pi-meson

E. Fermi
Theory of beta Decay
( current \times current)

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
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

1920  1930  1940  1950  1960
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
Era of Accelerators

Q = I_3 + (B + S)/2

Strangeness
(Nakano-Nishijima)

Discovery of pion

C. Lattes, G. Ochialini, C. Powell

Discovery of \( K, \Lambda, \Sigma, \Xi \)
C. Lattes, G. Ochialini, C. Powell
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 $\sigma_{pp}$
- Elementary particles are indestructible, but have internal structures...
- strong interactions considered as a hopeless case for quantum field theory

- S-matrix theory, Dispersion relations, 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

Quark Model
Establishment of QCD

- Salam-Weinberg
- Han-Nambu
- Quark Model
- Parton Model
Establishment of QCD

- Parton Model
- Quark Model
- Han-Nambu
- Color Singlet
  Fritzch & Gell-Mann
- Weingerg
- Establishment of QCD
Establishment of QCD

- 1960: Development of Parton Model
- 1970: Proposal of Quark Model
  - Fritzch & Gell-Mann: Color Singlet
  - Han-Nambu: Parton Model
- 1980: Development of QCD Lagrangian
  - Fritzch, Leutwyler, Gell-Mann
- 1990: Further developments and applications
Establishment of QCD

1960
1970
1980
1990
2000

- Quark Model
- Han-Nambu
- Color Singlet Fritzch & Gell-Mann
- QCD Lagrangian Fritzch, Leutwyler, Gell-Mann
- Asymptotic Freedom Gross, Politzer, Wilzcek
Establishment of QCD

- **1960**: Han-Nambu & Gell-Mann
- **1970**: Fritzch, Leutwyler
- **1980**: QCD Lagrangian
- **1990**: Asymptotic Freedom
- **2000**: Fritzch & Gell-Mann

Key Events:
- **Discovery of quark and gluon jets (Feynman 1975)**
- **Color Singlet**
- **Parton Model**

Quark Models: Parton Model

- **1960**: Han-Nambu & Gell-Mann
- **1970**: Fritzch, Leutwyler
- **1980**: QCD Lagrangian
- **1990**: Asymptotic Freedom
- **2000**: Fritzch & Gell-Mann

Key Discoveries:
- **1960**: Nambu, Gell-Mann
- **1970**: Fritzch, Leutwyler
- **1975**: Asymptotic Freedom
- **1990**: Fritzch & Gell-Mann
Bulk Properties – Relativistic Nuclear Physics

Hagedorn Temperature of Hadronic Gas
Bulk Properties – Relativistic Nuclear Physics

Discovery of Pulsar (neutron star)

Hagedorn Temperature of Hadronic Gas
Bulk Properties – Relativistic Nuclear Physics

- Hagedorn Temperature of Hadronic Gas
- Discovery of Pulsar (neutron star)
- Nuclear Matter EoS-Neutron Star

Bulk Properties – Relativistic Nuclear Physics

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- Quark Star N. Itoh

Bulk Properties – Relativistic Nuclear Physics

- Hagedorn Temperature of Hadronic Gas
- Discovery of Pulsar (neutron star)
- Nuclear Matter EoS – Neutron Star
- 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

Bulk Properties – Relativistic Nuclear Physics

Hagedorn Temperature of Hadronic Gas

Discovery of Pulsar (neutron star)

Nuclear Matter EoS – Neutron Star

Quark Star

N. Itoh • Lee - Wick Nuclear Matter

High Energy Nuclear Collision – Greiner, et al

Walecka Model

Bear Mountain Summer School

Hadronic Resonance Gas...

Cooper - Frye Hadron Physics


Hadron Physics!
And many colleagues as (sorry for not complete...)

- Victoria E. Herscovitz
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- Marina Nielsen
- M. Beatriz Gay
- Sergio Duarte
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- 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.
- Educatve and training aspects of graduate students.
- Offers the chances of visibility for young people.
To keep update the continuous and quick developments of the research field.
Offers wider vision of physics ...
Pin-point Study

Proton

Deep inelastic Collisions
Pin-point Study

Deep inelastic Collisions

Proton

Bulk Property Study

Relativistic Heavy Ion Collisions
Pin-point Study

Deep inelastic Collisions

Bulk Property Study

Relativistic Heavy Ion Collisions

Rice

Proton

Examine carefully...
Pin-point Study

Proton

Deep inelastic Collisions

Examine carefully...

Rice

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 Fukushima & Htsuda 2010
Some Challenging Questions

- Neutrinos: Origin of the mass, Majorana?
- Dark Matter?
- How far can ab-initio QCD approaches go?
- Matter dominance in the Universe?
- 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)?
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