

Lecture Presentation

Nuclear Magnetic Resonance Logging

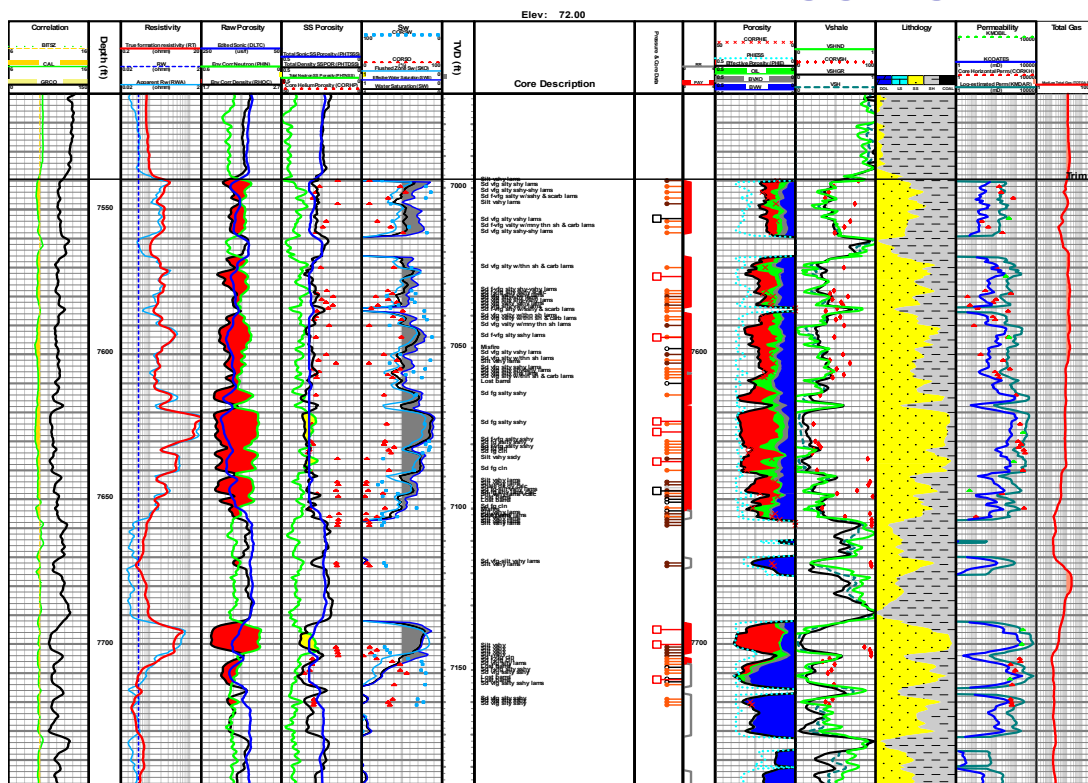
Advanced Multi-Well Formation Evaluation
Lecture Presentation

Description and Motivation

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Conventional Well Logging

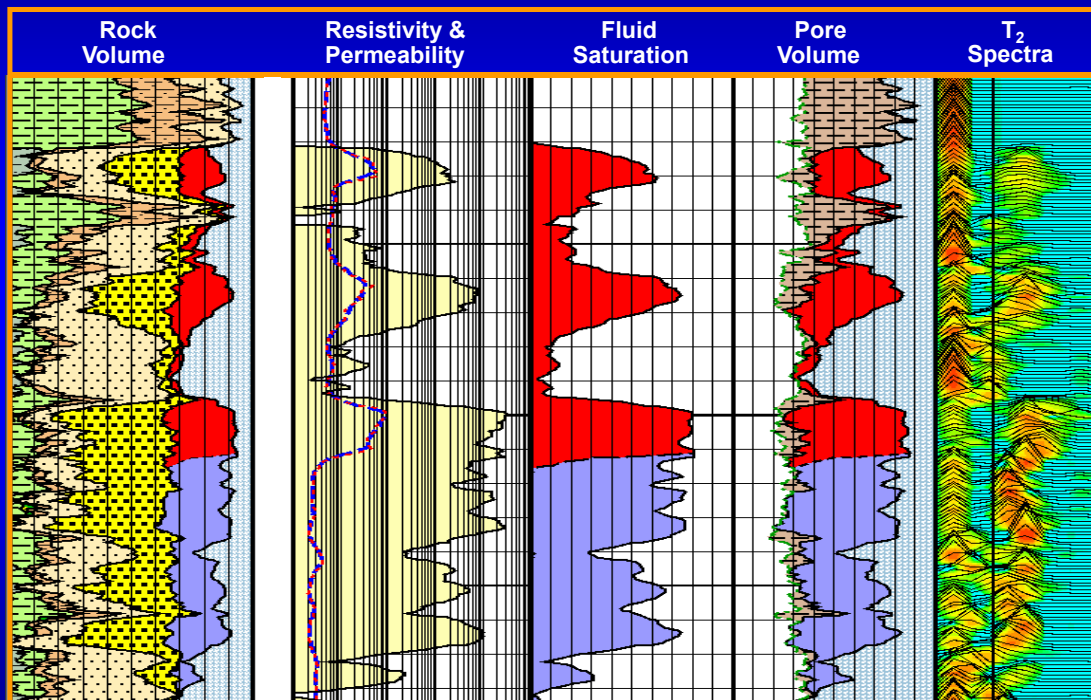


Show me the money!!

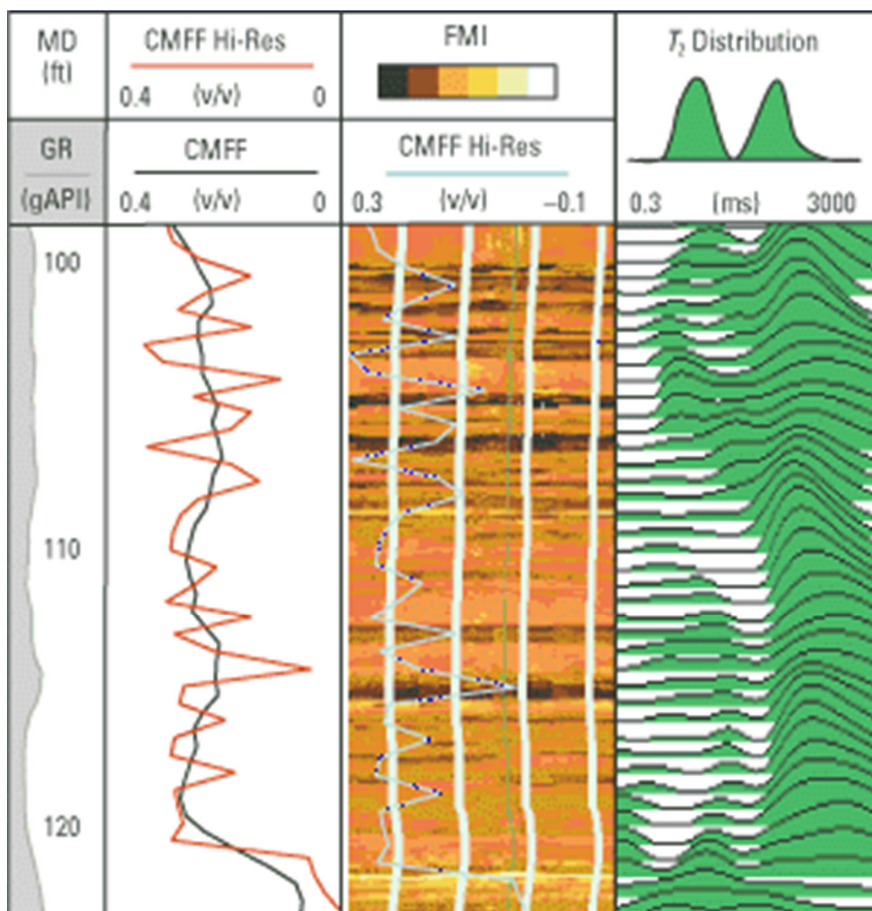
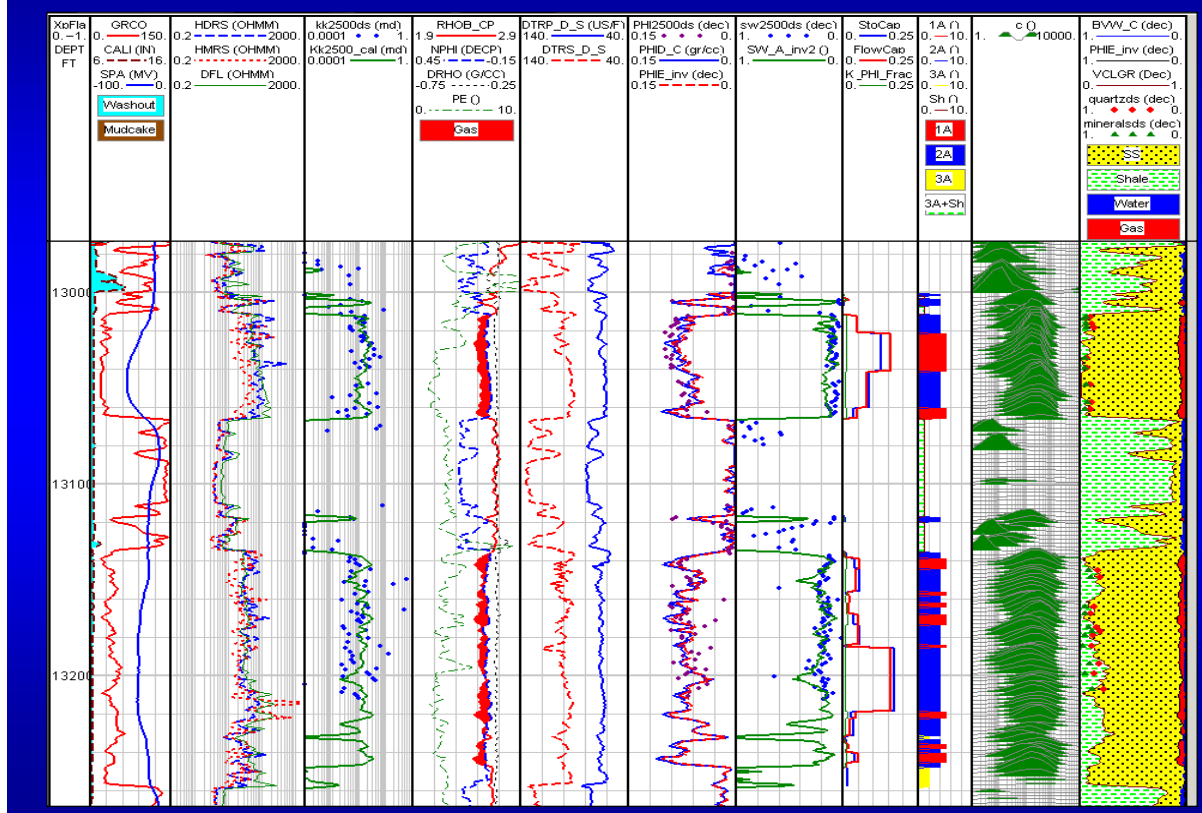
- What are the porous and permeable rocks?
- What are the in-place hydrocarbon reserves?
- What are the petrophysical properties of the hydrocarbon-bearing formations ?
- Is the hydrocarbon-in-place producible?
- What are the best completion and production strategies?

permeability ($\equiv k$),
porosity ($\equiv \phi$), &
saturation ($\equiv S$)

GOALS AND EXPECTATIONS



NMR Combined with Conventional Logs

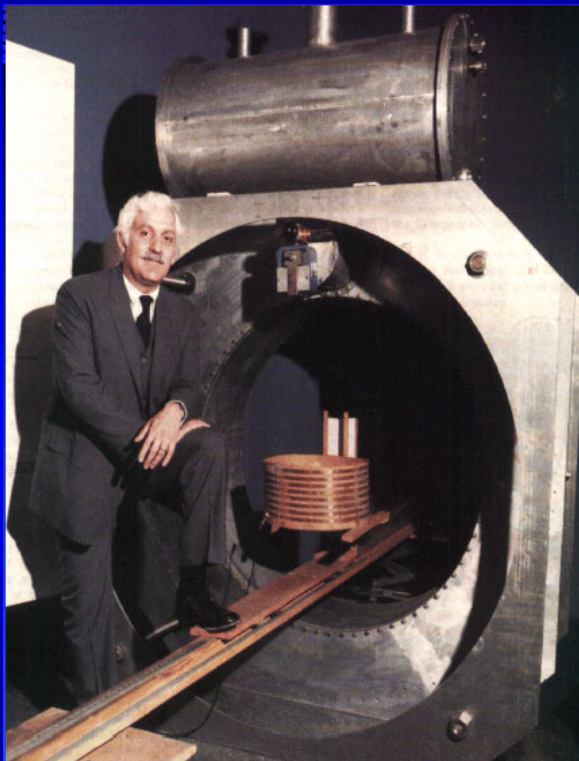


**NMR + LOG
COMBINATIONS**

NMR APPLICATIONS

- Low resistivity pay (high S_{wir})
- Shaly sands (effective ϕ)
- Improved reserves estimation (Net Pay and S_o)
- Reservoir Quality (ϕ_e , k , V_{sh} , Q_v , Grain Size, ...)
- Producibility (Pore Size, k , $S_{Moveable}$ Fluid, ...)
- Porosity (complex mineralogy, dolomitization, ...)
- Hydrocarbon Typing (DTW, DTE)
- Viscosity Estimation (Diffusion measurements)

THE BEGINNING ...



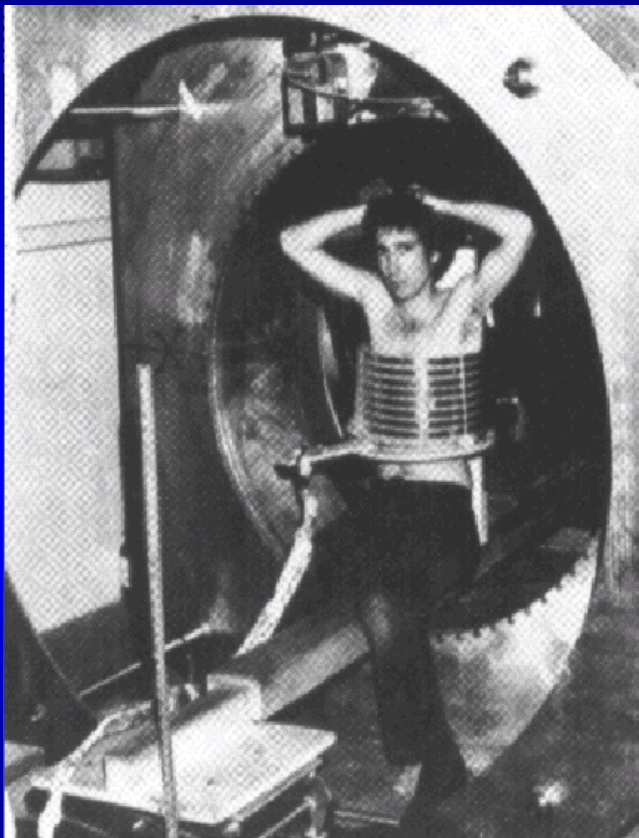
Dr. Raymond Damadian
July 3, 1977

with “Indomitable” now
at the Smithsonian
Institute



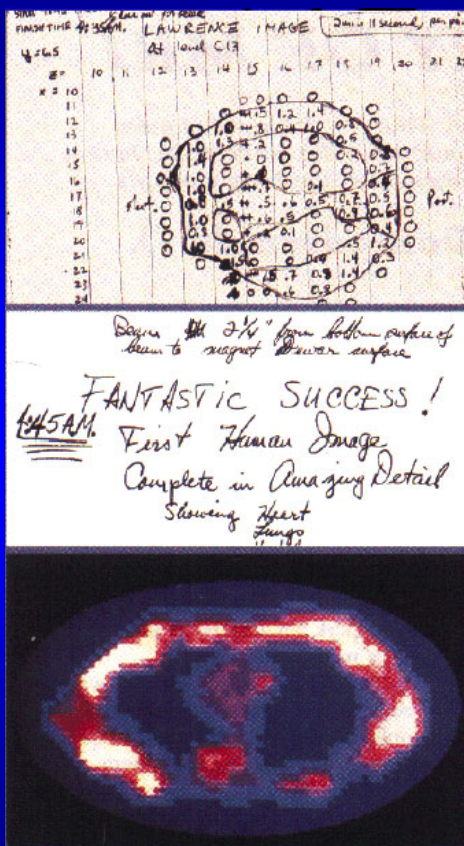
Dr. Damadian

**First test failed
because body mass
was too large**



Assistant Larry Minkoff

**Test was successful
because of smaller
body mass**



FIRST HUMAN IMAGE

“Fantastic success!”
“Complete in amazing
detail
showing heart and
lungs”
of Larry Minkoff



Kurt Wüthrich,
1938.
Nobel Prize in
Chemistry 2002



Sir Peter
Mansfield, 1933.
Nobel Prize in
Medicine 2003

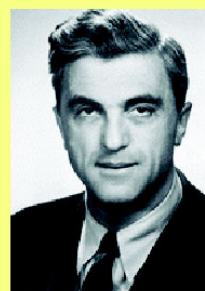
Some Nobel Prizes in NMR



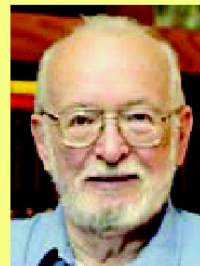
ENC Boston 1995

Richard R. Ernst,
1933.
Nobel Prize in
Chemistry 1991

Edward Mills
Purcell,
1912 - 1997.
Nobel Prize in
Physics 1952

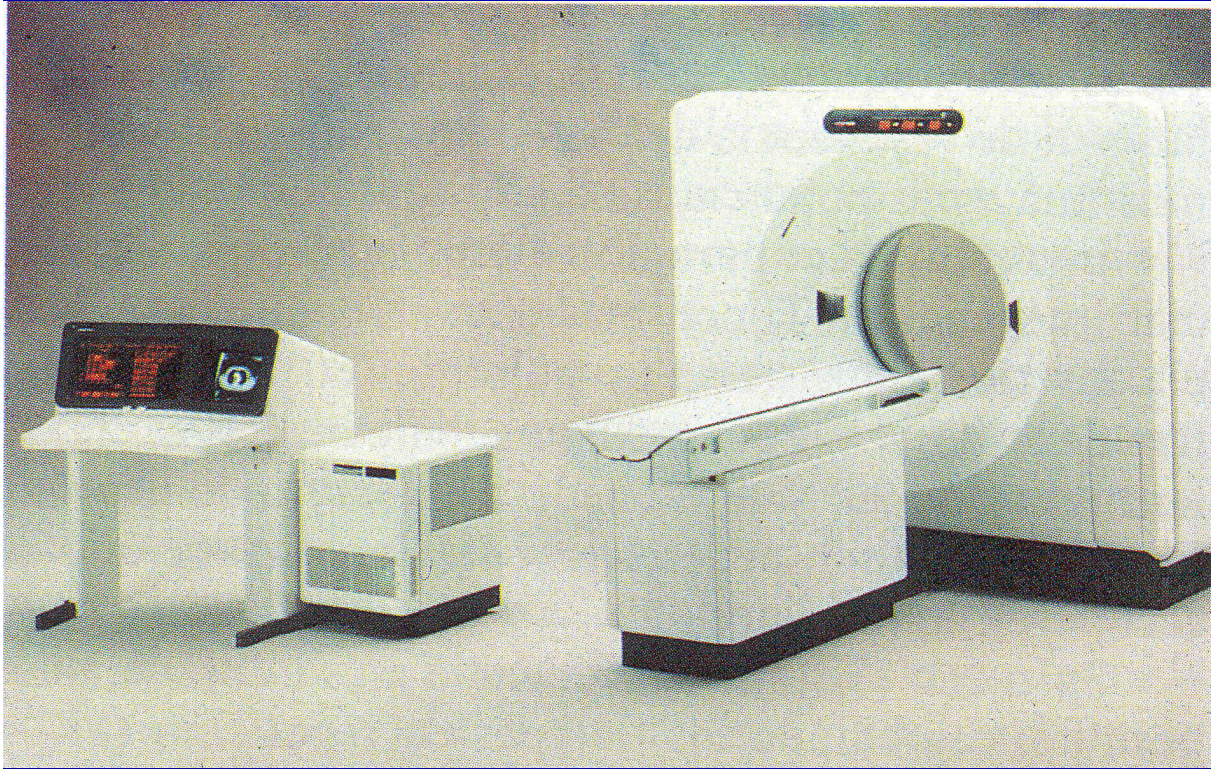


Felix Bloch,
1905 - 1983.
Nobel Prize in
Physics 1952

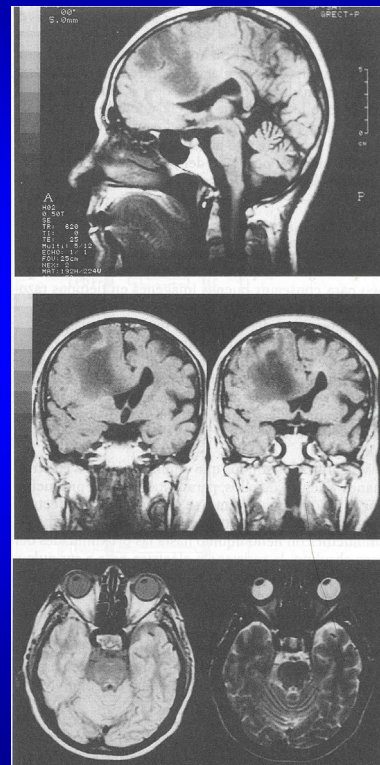


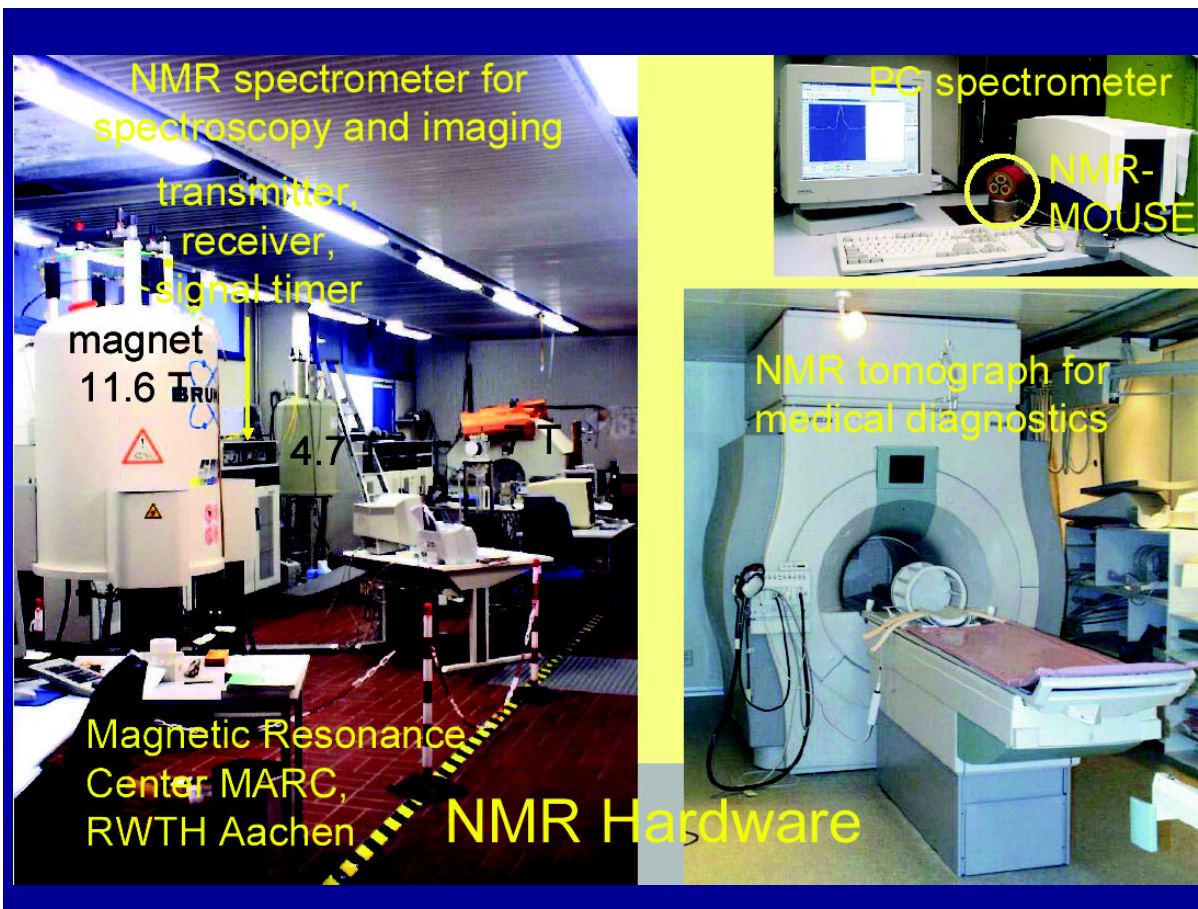
Paul Lauterbur,
1929.
Nobel Prize in
Medicine 2003

MODERN MEDICAL MRI SYSTEMS



MODERN MRI





History of NMR

- 1945: First successful detection of a NMR signal by **Felix Bloch** (Stanford) and **Edward Purcell** (Harvard): Nobel prize in Physics **1952**
- 1949: Discovery of the NMR echo by Erwin Hahn
- 1951: Discovery of the chemical shift by J. T. Arnold and F. C. Yu
- 1951: Discovery of the indirect spin-spin coupling by W. G. Proctor
- 1953: Earth field NMR for well logging by Schlumberger-Doll
- 1966: Introduction of Fourier NMR by **Richard Ernst**, Nobel Prize in Chemistry **1991**
- 1971: NMR imaging by **Paul Lauterbur** and **Peter Mansfield**, Nobel prize in Medicine **2003**
- 1971: Two-dimensional NMR by Jean Jeener, later multi-dimensional NMR by Richard Ernst
- 1975: Multi-quantum NMR and spectroscopy by T. Hashi, later by Alex Pines and Richard Ernst
- 1977: High-resolution solid-state NMR spectroscopy by John Waugh, Ed Stejskal, and Jack Schaefer
- 1979: 2D Exchange NMR by Jean Jeener. Application to protein analysis in molecular Biology by **Kurt Wüthrich**, Nobel prize in Chemistry **2002**
- 1980: Unilateral NMR in process control and medicine by Jasper Jackson
- 1984: Hyper polarization of xenon by William Happer
- 1995: Commercialization of well logging NMR by NUMAR