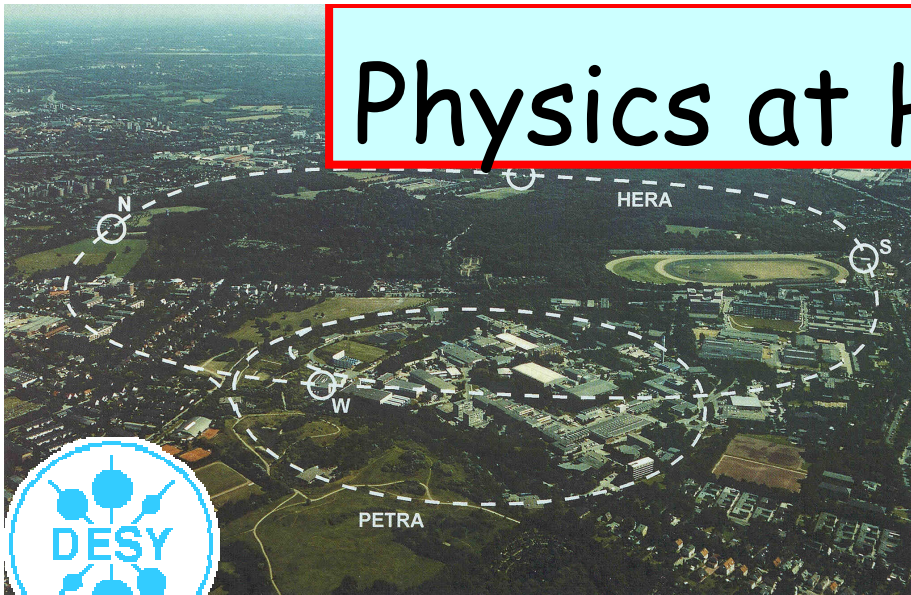


# Physics at HERA (DESY)

Achim Geiser, DESY Hamburg

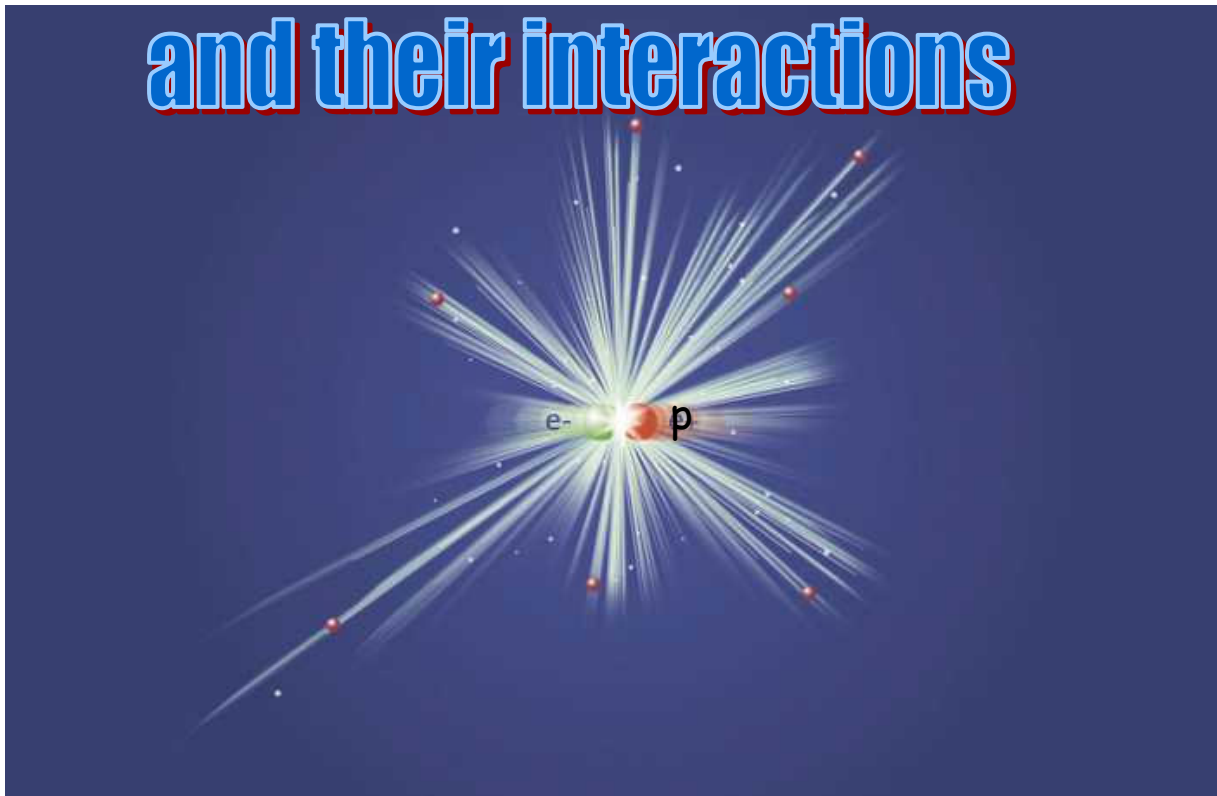
Iasi 4-Seas-Conference  
Iasi, Romania, May 29, 2007



- Introduction for non-particle physicists
- **HERA as a proton imaging device**
- Electroweak physics at HERA
- HERA as a QCD machine
- (Beyond Standard Model -> talk C. Diaconu)
- Nucleon spin structure
- Conclusions

# What is Particle Physics?

**Particle Physics**  
**= science of elementary particles**  
**and their interactions**





# What is „elementary“?

Greek: atomos = smallest indivisible part

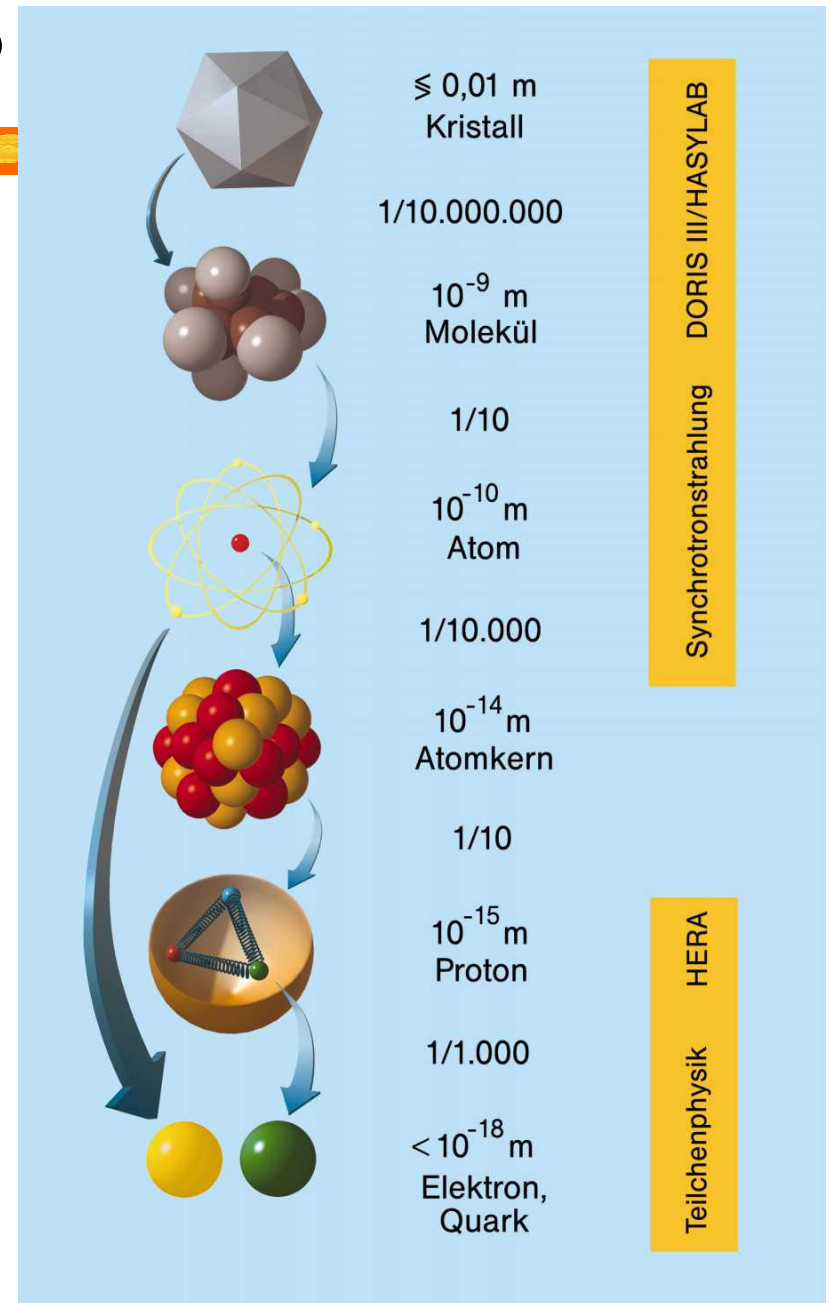
Dmitry  
Ivanowitsch  
Mendeleyev  
1868  
(elements)



Ernest  
Rutherford  
1911  
(nucleus)  
(Nobel 1908)

**elementary**  
= **no detectable**  
**substructure**

Murray  
Gell-Mann  
1962  
(quarks)  
(Nobel 1969)

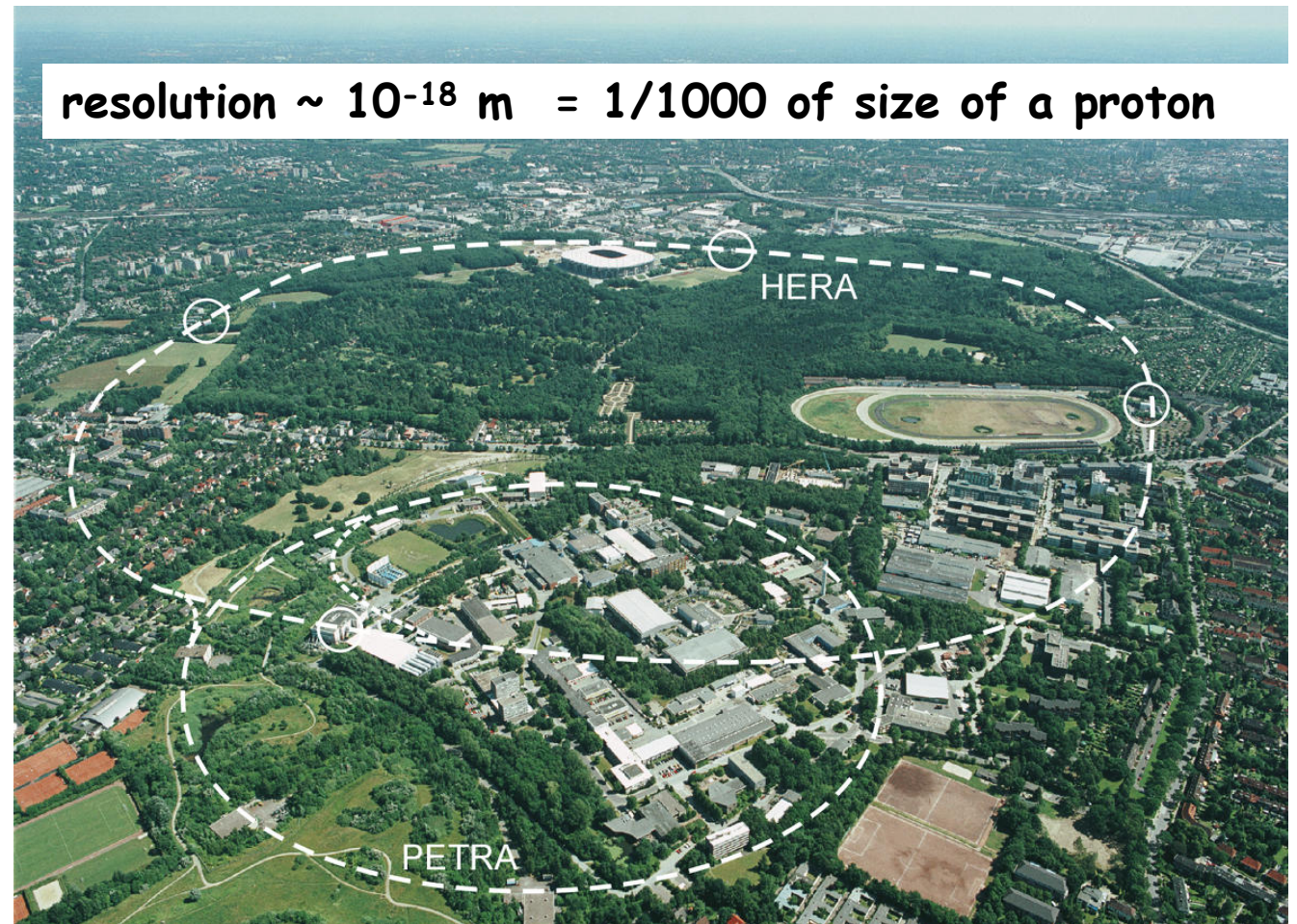


# How to determine the „structure“ of a particle?

- microscope:
- low resolution
  - > small instrument
- high resolution
  - > large instrument

**HERA = giant  
electron  
microscope**

29. 5. 07

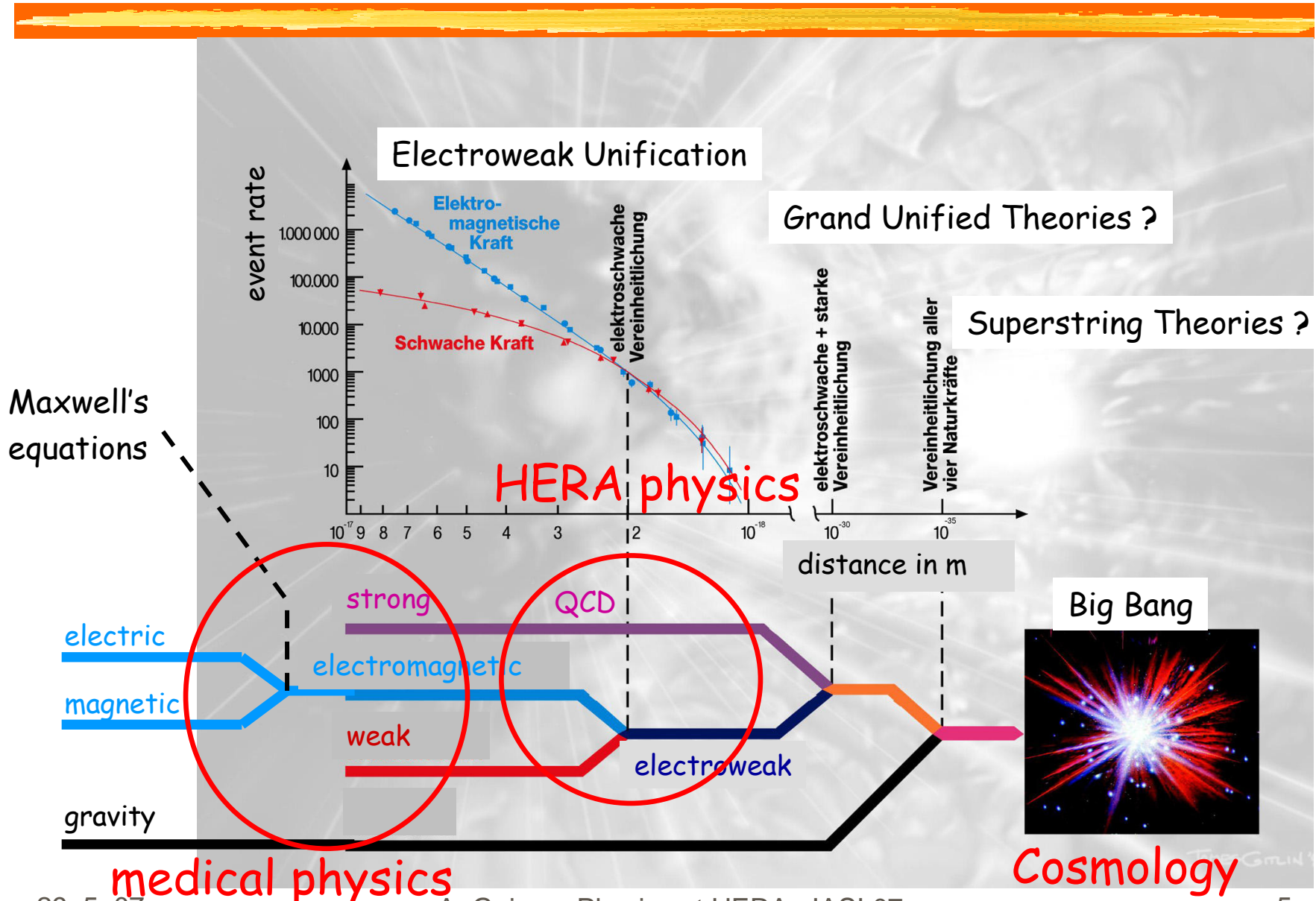


First and only large e-p collider

A. Geiser, Physics at HERA, IASI 07



# Which interactions?



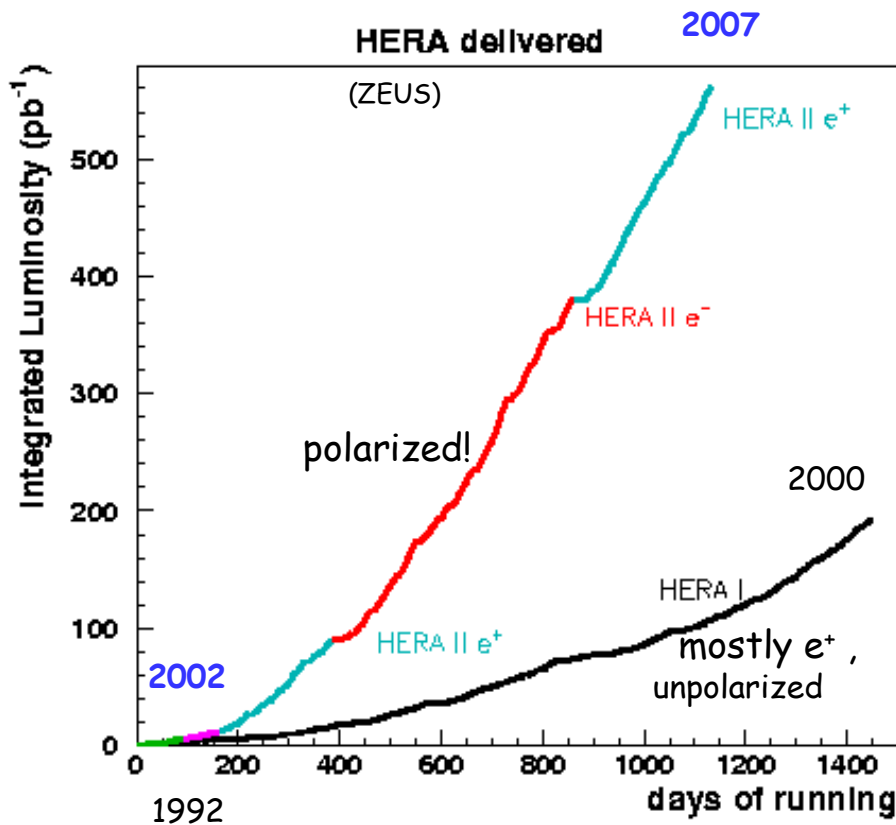
# The HERA ep collider and experiments

The image shows an aerial view of the HERA collider facility. Three inset photographs provide details of the experiments: H1 (left), HERMES (top center), and ZEUS (right). The HERMES experiment is labeled with an electron energy of  $e (27.6 \text{ GeV})$ . The ZEUS experiment is labeled with a total energy of  $318 \text{ GeV}$ . A diagram at the bottom right shows the collision point where a proton beam ( $p (920 \text{ GeV})$ ) and an electron beam ( $e (27.6 \text{ GeV})$ ) meet, resulting in a total energy of  $318 \text{ GeV}$ .

**HERA I:  $\sim 130 \text{ pb}^{-1}$  (physics)**  
**HERA II so far:  $\sim 400 \text{ pb}^{-1}$  (physics)**  
**data taking till mid-2007**

# HERA I and HERA II

HERA I + II luminosity:



HERA I:

- $E_e = 27.5 \text{ GeV}$ , electron or positron
- $E_p = 820 \text{ GeV}$  1992-97  
920 GeV since 1998

HERA II:

- detector and luminosity upgrade, polarized beams, both e<sup>+</sup> and e<sup>-</sup>
- efficient data taking since fall 2003
- running till end of June 2007, **data analysis at least till 2010**



# Particle Physics = People



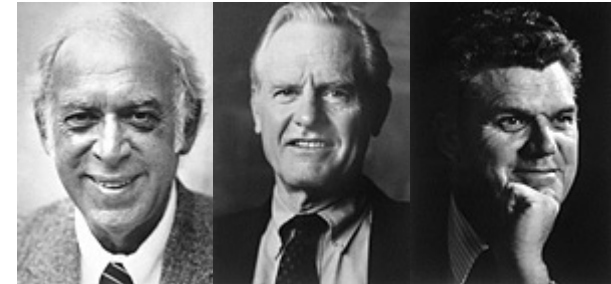
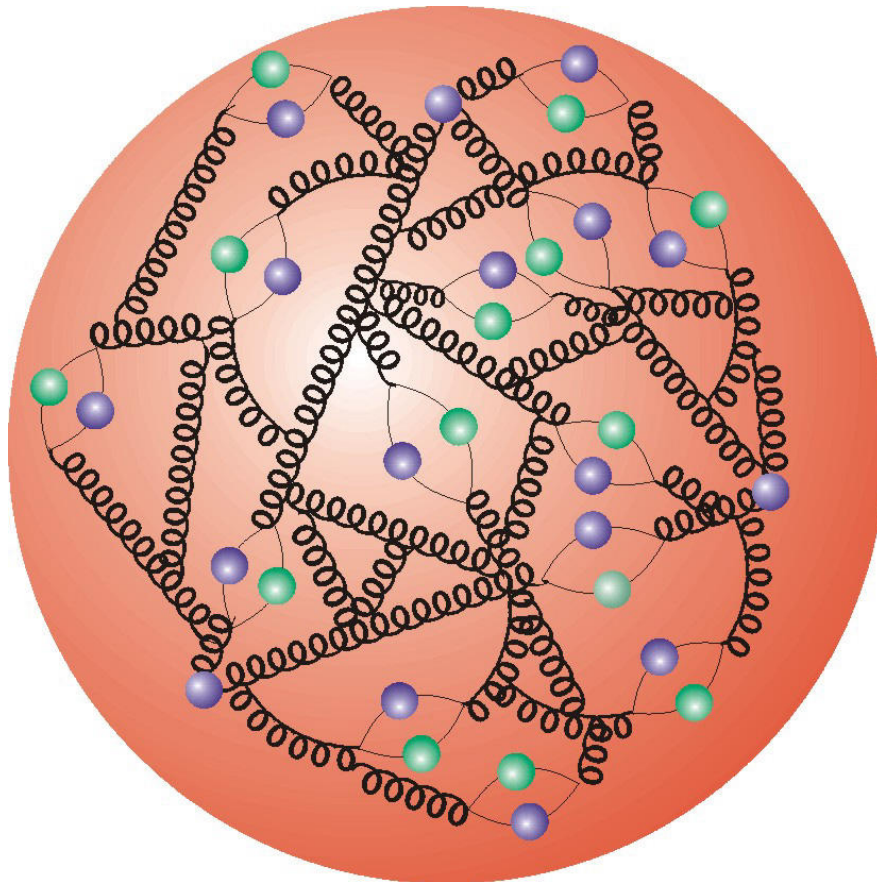
29. 5. 07

A. Geiser, Physics at HERA, IASI 07



# HERA as a proton imaging device

first at SLAC ~1970

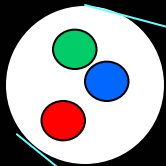


Jerome I. Friedman   Henry W. Kendall   Richard E. Taylor  
(Nobel 1990)

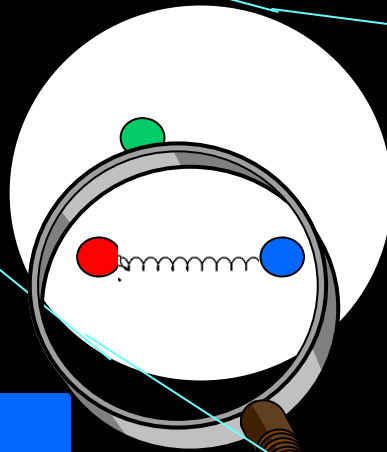
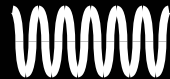
**structure  
of the  
proton**

# Inside the proton

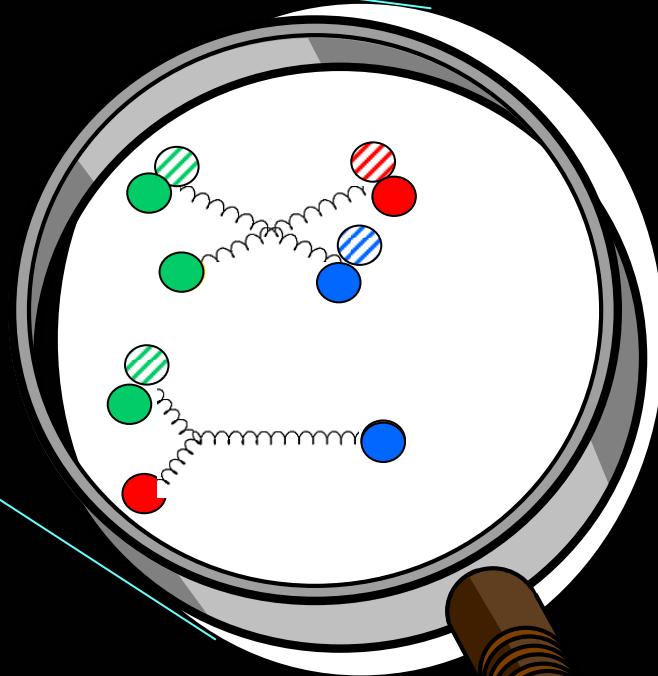
Low  $Q^2$  (large  $\lambda$ )



Medium  $Q^2$  (medium  $\lambda$ )



Large  $Q^2$  (short  $\lambda$ )



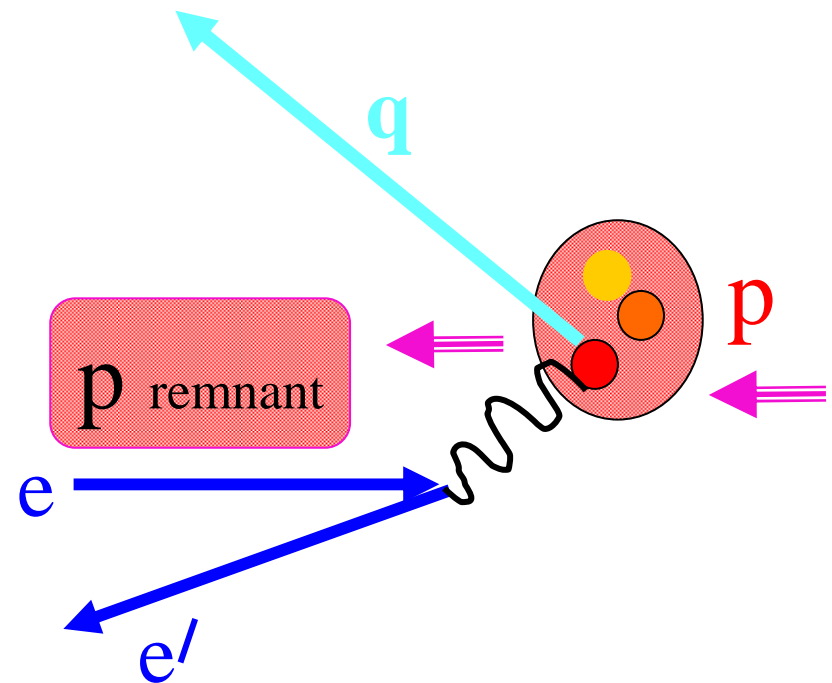
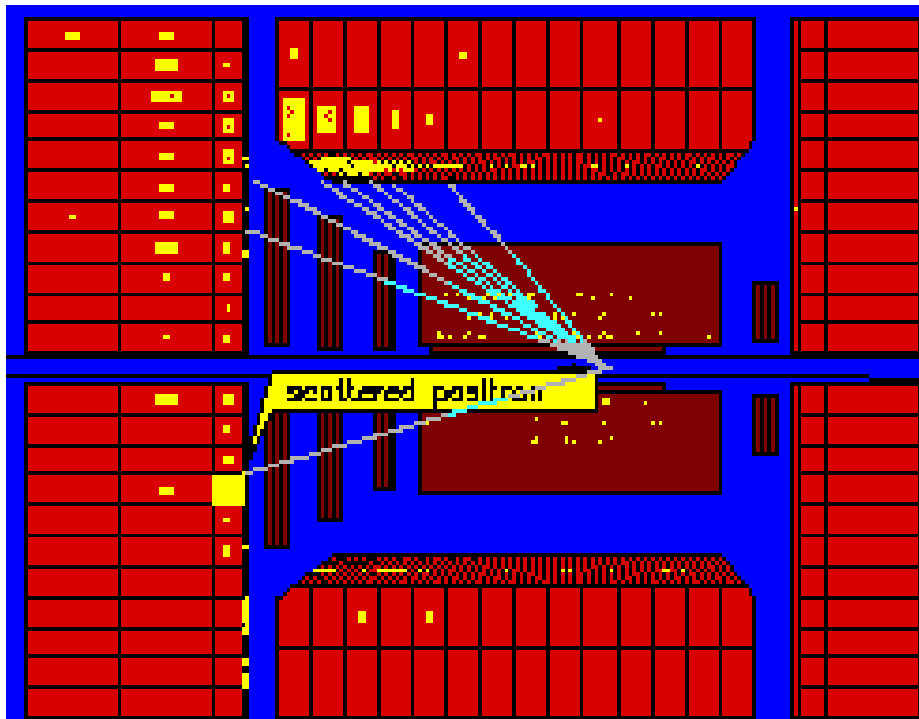
Heisenberg's UP allows gluons, and  $q\bar{q}$  pairs to be produced for a very short time.

At higher and higher resolutions, the quarks emit gluons, which also emit gluons, which emit quarks, which.....

At highest  $Q^2$ ,  $\lambda \sim 1/Q \sim 10^{-18}$  m



# Deep Inelastic ep Scattering at HERA



Measure parton density functions (PDF)  
= density of quarks and gluons in proton

# Kinematics of Deep Inelastic Scattering (DIS)

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