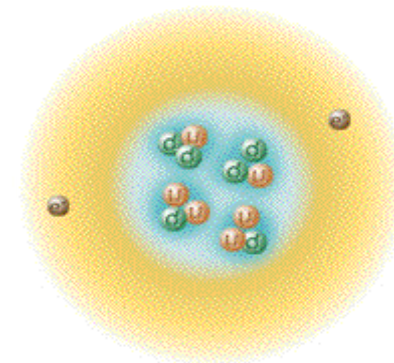


Bei **Licht** betrachtet ein Blick in's Innere des **Nukleons**

Hartmut Schmieden
Physikalisches Institut



dies academicus 4. Juni 2003

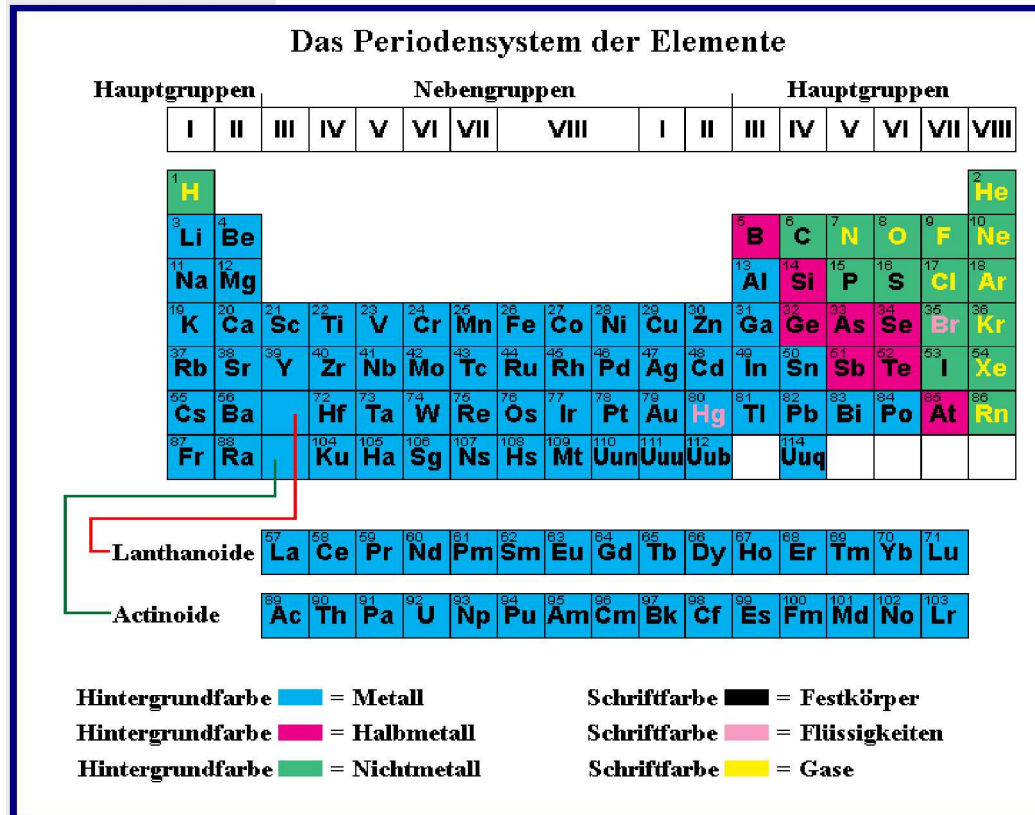
Aufbau der Materie

Die Vorstellungen im Wandel der Zeit

~450 v.Chr.	Empedokles	Feuer, Wasser, Erde, Luft
~450 v.Chr.	Anaxagoras, Demokrit	ατομον (Atomon)
~350 v.Chr.	Aristoteles	Äther
~1800	Dalton	kleinste, unteilbare Bestandteile der Elemente
~1870	Meyer, Mendelejew	Periodensystem
~1920	Planck, Einstein, Bohr	Atomphysik, Quantentheorie

Aufbau der Materie

Die Vorstellungen im Wandel der Zeit



Feuer, Wasser, Erde, Luft

Demokrit

ατομον (Atomon)

Äther

unteilbare Bestandteile der Elemente

W

Periodensystem

~1920

Planck, Einstein, Bohr Atomphysik, Quantentheorie

Standardmodell

Aufbau der Materie

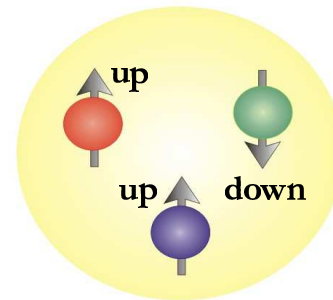
FERMIONS						matter constituents spin = 1/2, 3/2, 5/2, ...	
Leptons spin = 1/2			Quarks spin = 1/2				
Flavor	Mass GeV/c ²	Electric charge	Flavor	Approx. Mass GeV/c ²	Electric charge		
1. ν_e electron neutrino	$<1 \times 10^{-8}$	0	u up	0.003	2/3	Familie	
e electron	0.000511	-1	d down	0.006	-1/3		
2. ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3	Familie	
μ muon	0.106	-1	s strange	0.1	-1/3		
3. ν_τ tau neutrino	<0.02	0	t top	175	2/3	Familie	
τ tau	1.7771	-1	b bottom	4.3	-1/3		

PROPERTIES OF THE INTERACTIONS

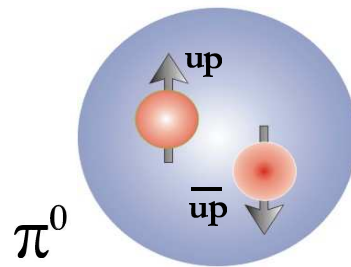
Property \ Interaction	Gravitational	Weak	Electromagnetic	Strong	
		(Electroweak)		Fundamental	Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons

Gebundene Quarks

drei Quarks
(Baryonen)



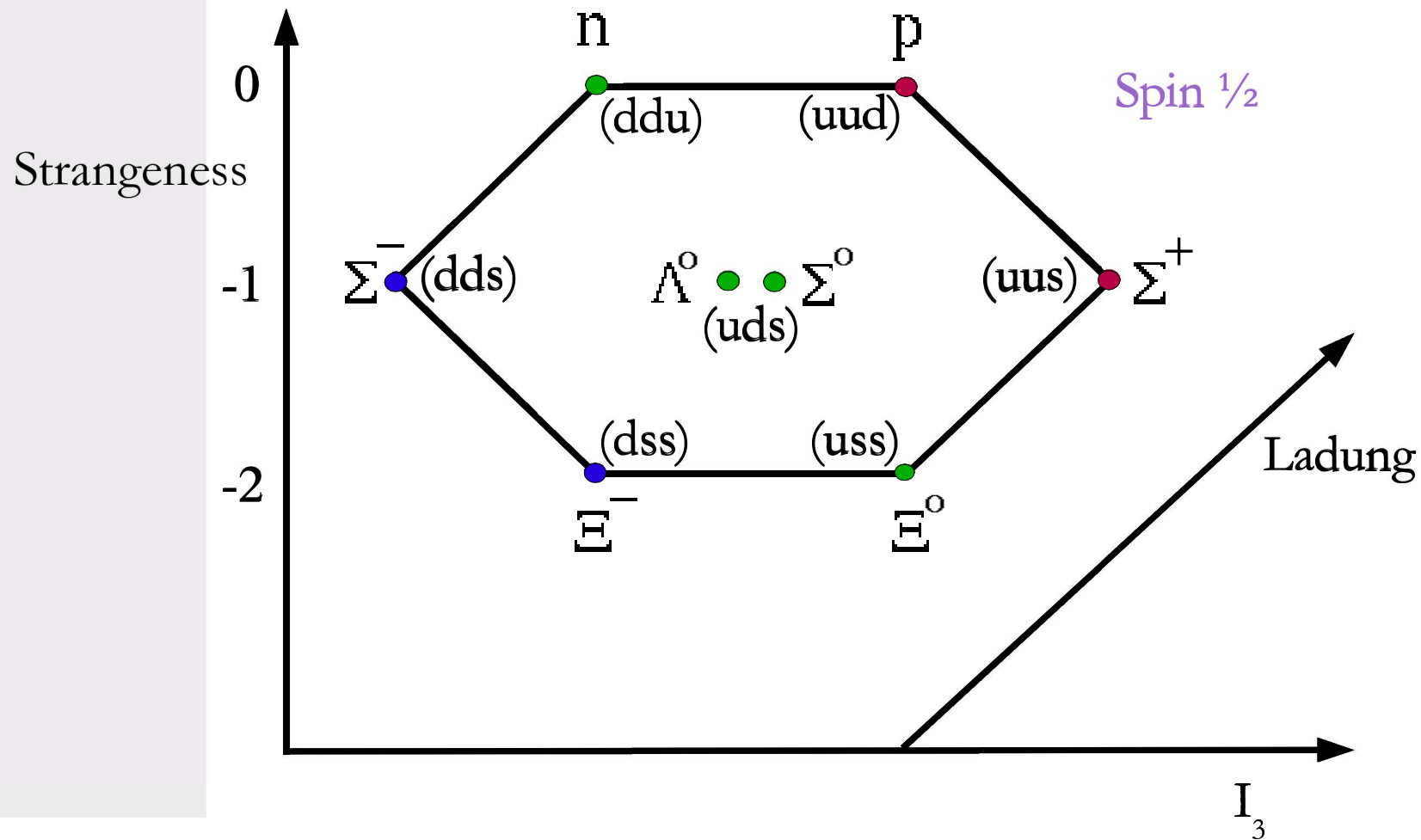
Proton



Quark und Anti-Quark
(Mesonen)

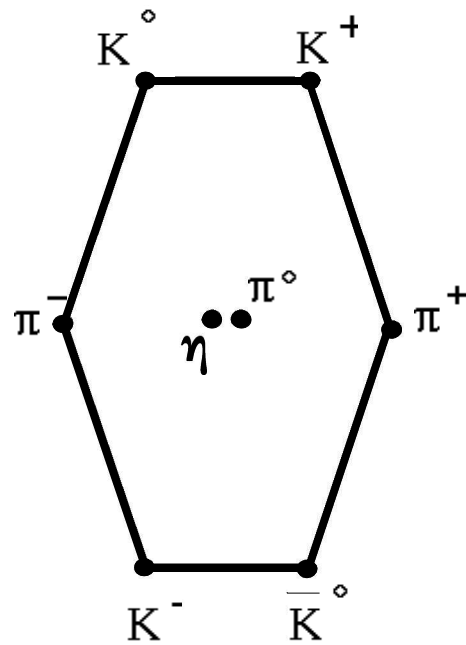
Teilchen – Multipletts

Baryonen

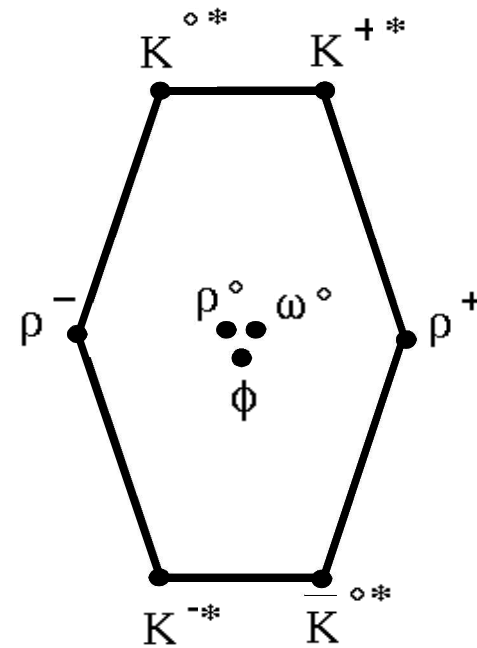


Teilchen – Multipletts

Mesonen

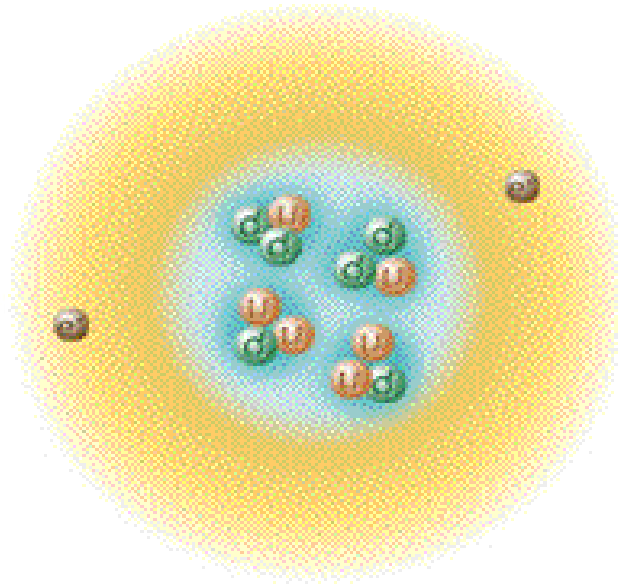


Pseudoskalar
Spin 0



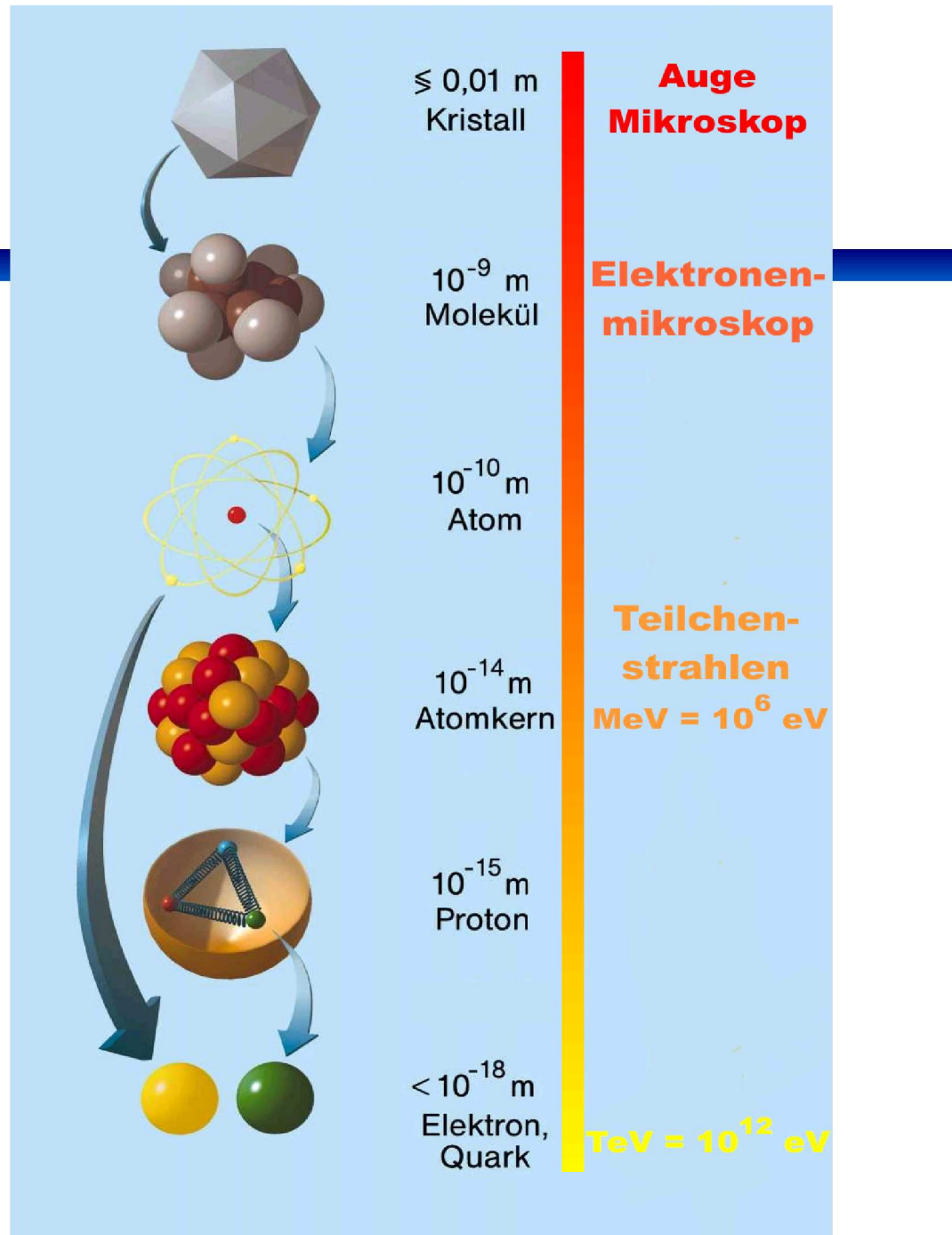
Vektor
Spin 1

Aufbau des Atoms

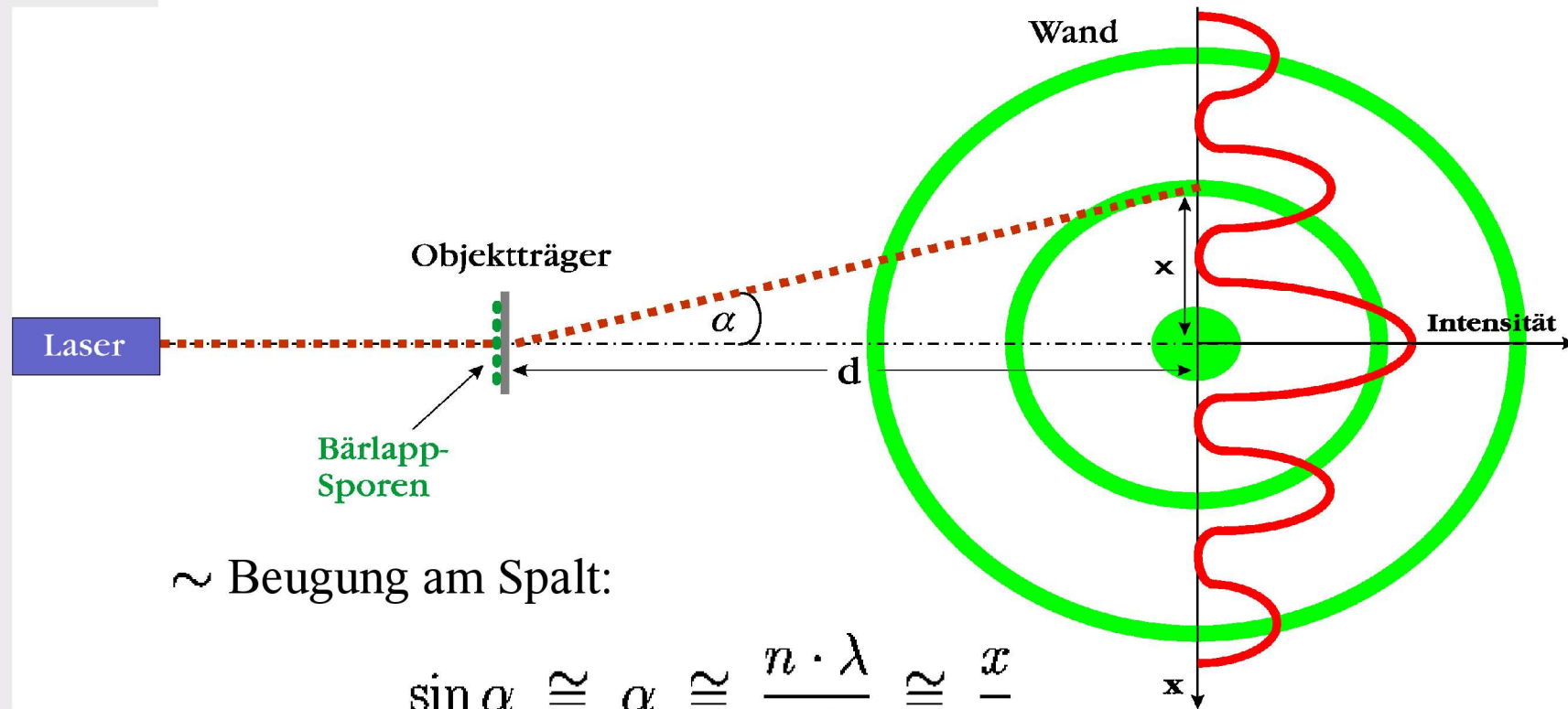


nicht maßstäblich !!

Skalen



Biologische Struktur: Größe von Bärlapp-Sporen



~ Beugung am Spalt:

$$\sin \alpha \cong \alpha \cong \frac{n \cdot \lambda}{R} \cong \frac{x}{d}$$

$$\rightarrow R \cong 10^{-5} \text{ m} = 10 \mu\text{m}$$

Materiewellen

quantenmechanisch:

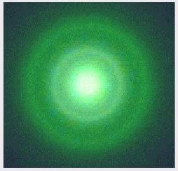
$$\lambda = \frac{h}{p}$$

Louis de Broglie 1924

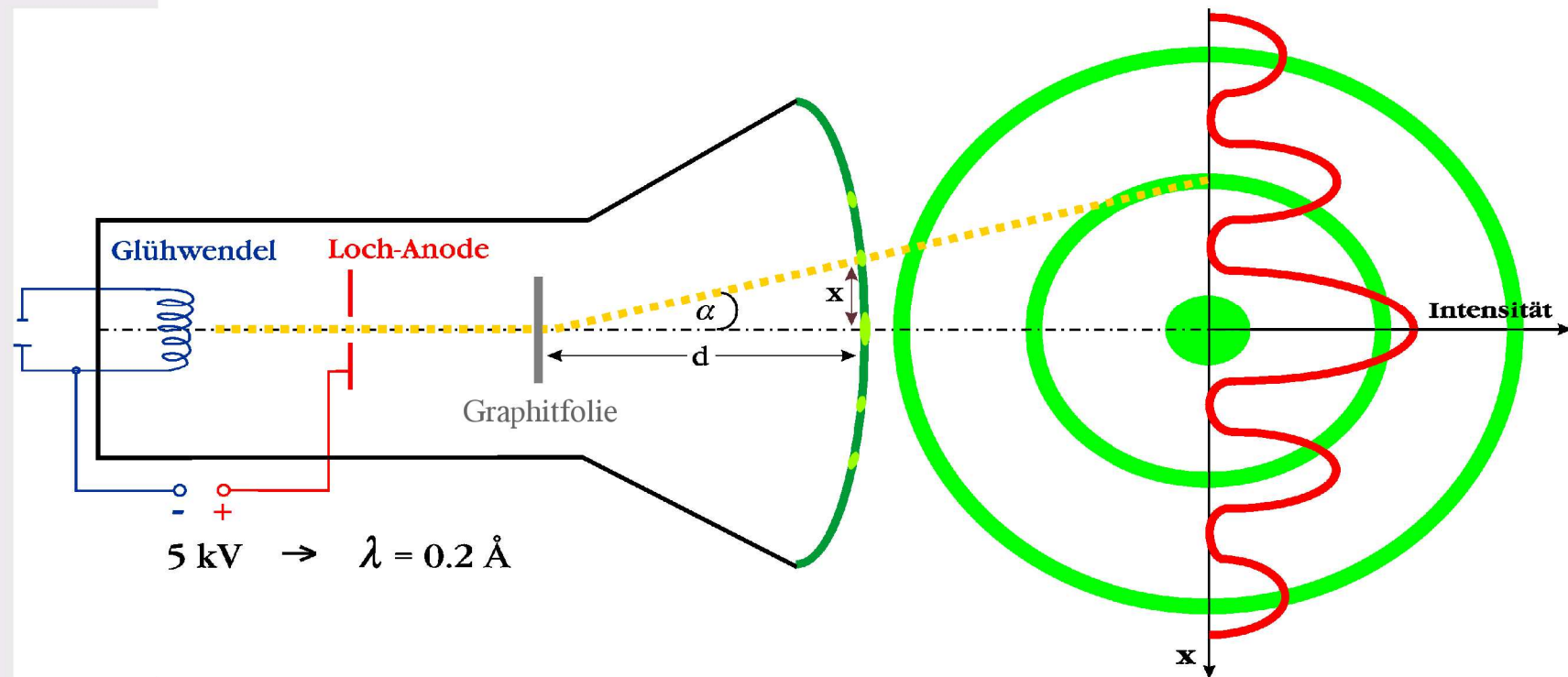
Bsp. Elektron $U = 5 \text{ kV} \longrightarrow E_{\text{kin}} = 5 \text{ keV}$

$$p = \sqrt{2 m E_{\text{Kin}}} \longrightarrow \lambda = 2 \cdot 10^{-11} \text{ m} = 0.02 \text{ nm}$$

z.Vgl. $\lambda_{\text{Licht}} = 500 \text{ nm}$ (grün)



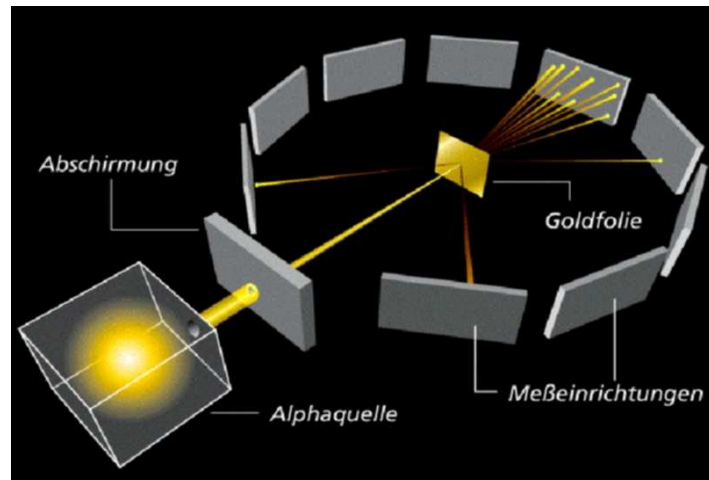
Elektronenbeugung



$$R \cong \frac{d}{x} \cdot \lambda \cong 2,5 \cdot 10^{-10} \text{ m} = 2,5 \text{ \AA}$$

Rutherford Experiment

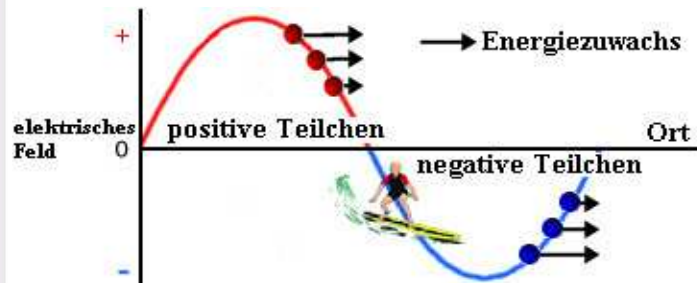
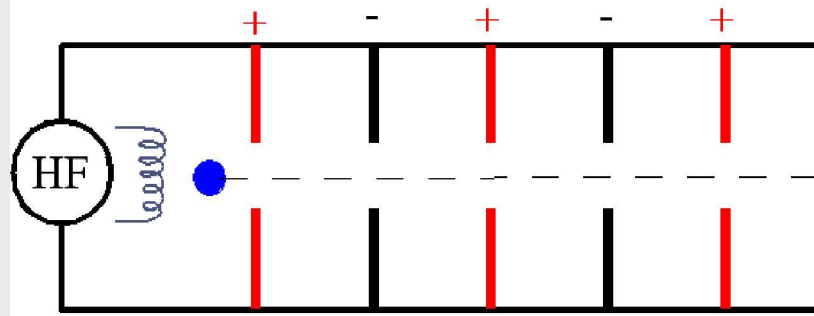
Geiger & Marsden 1909



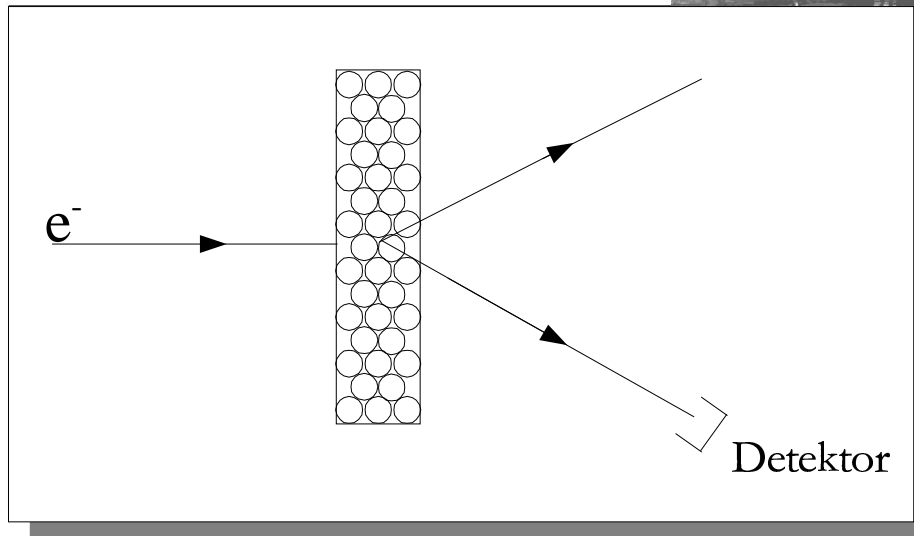
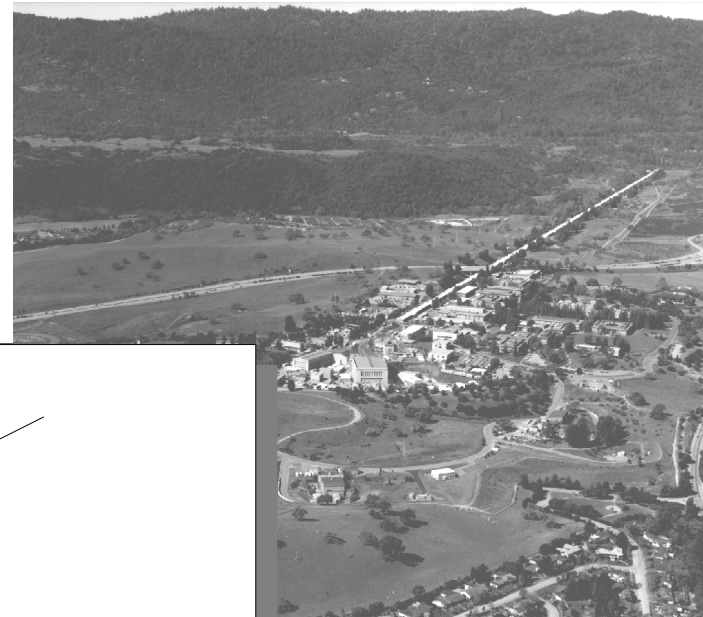
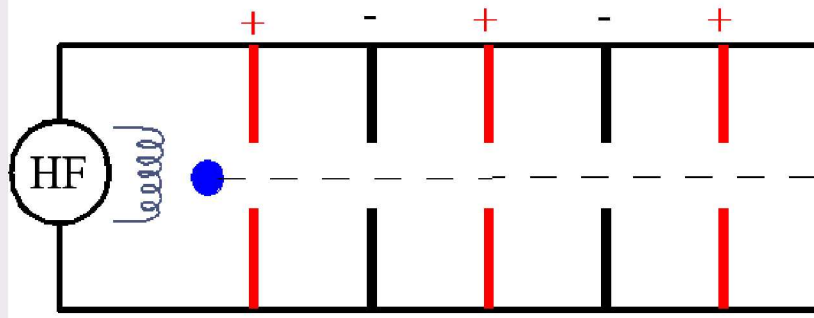
- die meisten α -Teilchen ungestreut
↳ Raum im Atom fast „leer“
- einige α -Teilchen werden rückwärtsgestreut

$$\frac{d\sigma}{d\Omega} \sim \frac{1}{\sin^4 \frac{\Theta}{2}} \quad \hookrightarrow \text{„punktförmiger“ Kern}$$

Linearbeschleuniger



Linearbeschleuniger



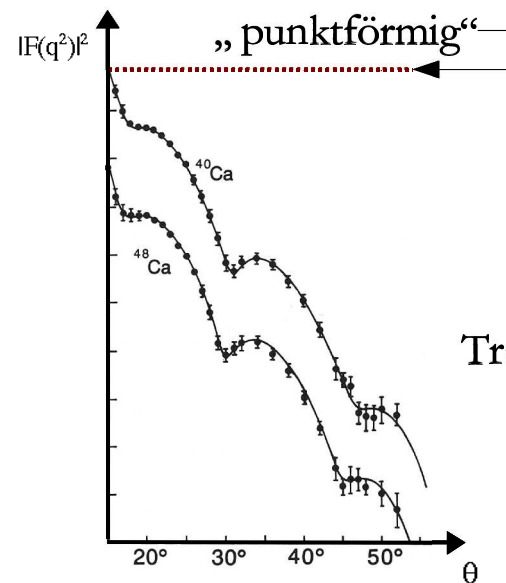
Ausgedehnter Atomkern - Ladungsverteilung

R Hofstadter (Stanford):
Nobelpreis 1961

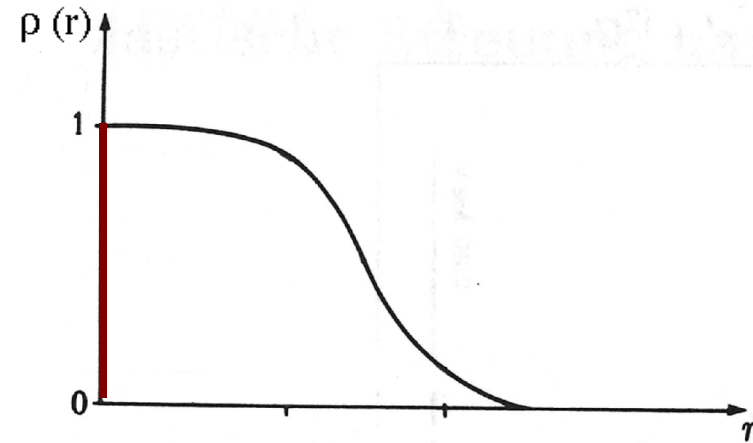
elastische e^- -Streuung

$E \approx 100 \text{ MeV}$

$\lambda \approx 10 \text{ fm}$



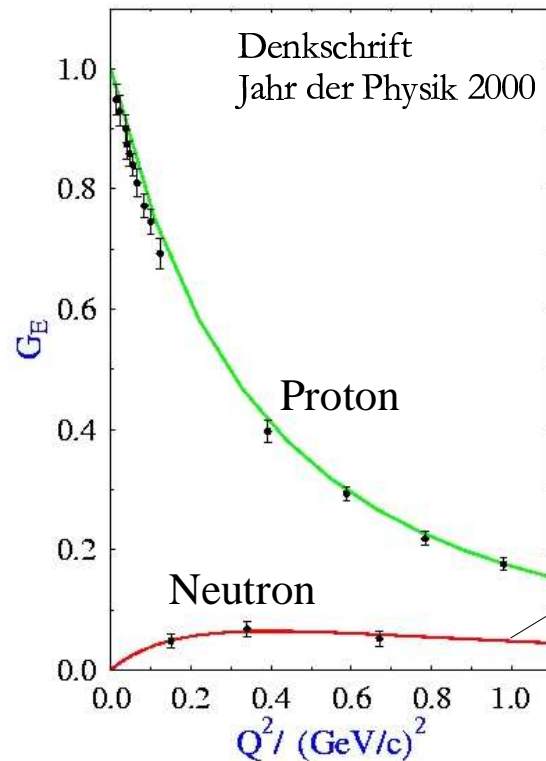
Fourier-
Transformation



Ausgedehntes Nukleon

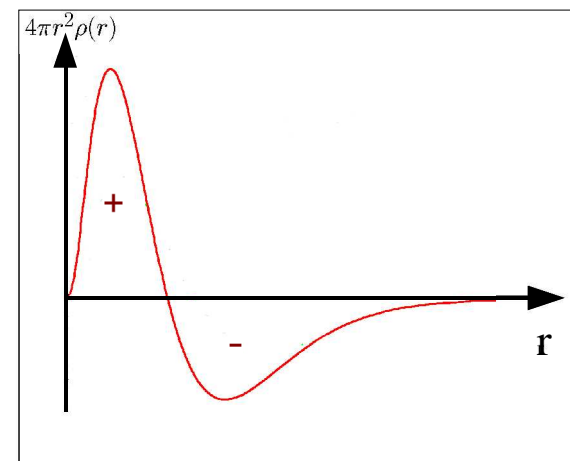
Ladungsverteilung Proton & Neutron

elastische e^- -Streuung: $E \approx 1 \text{ GeV} \rightsquigarrow \lambda \approx 1 \text{ fm}$



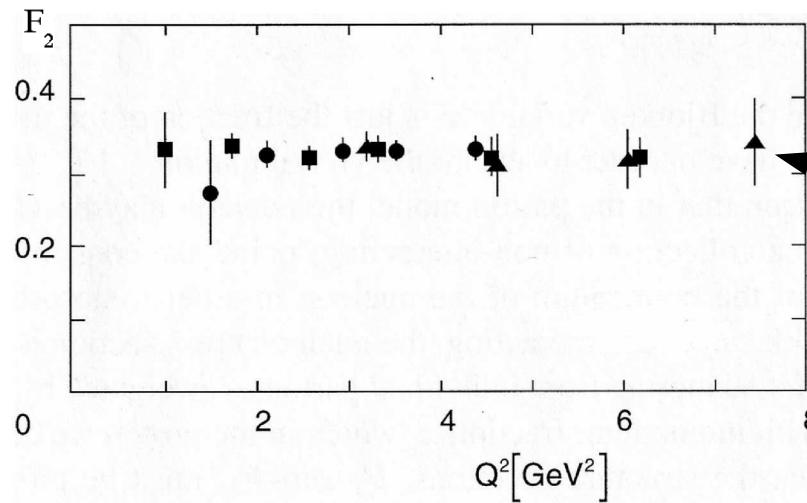
$$p : \sqrt{\langle r_E^2 \rangle} \sim 0.8 \text{ fm}$$

$$n : \langle r_E^2 \rangle \sim -0.1 \text{ fm}^2$$



Tiefinelastische Streuung

scaling



H. W. Kendall, Nobel Lecture
Rev. Mod. Phys. 63 (1991) 597

konstant

↳ punktförmige Konstituenten

→ Quarks

- punktförmige Partonen

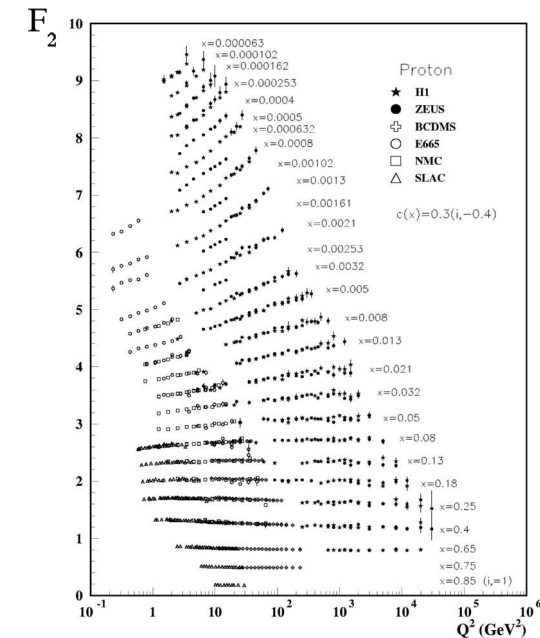


- masselose Quarks

$$m_u \approx 4\text{MeV}$$

$$m_d \approx 8\text{MeV}$$

$$m_s \approx 160\text{MeV}$$



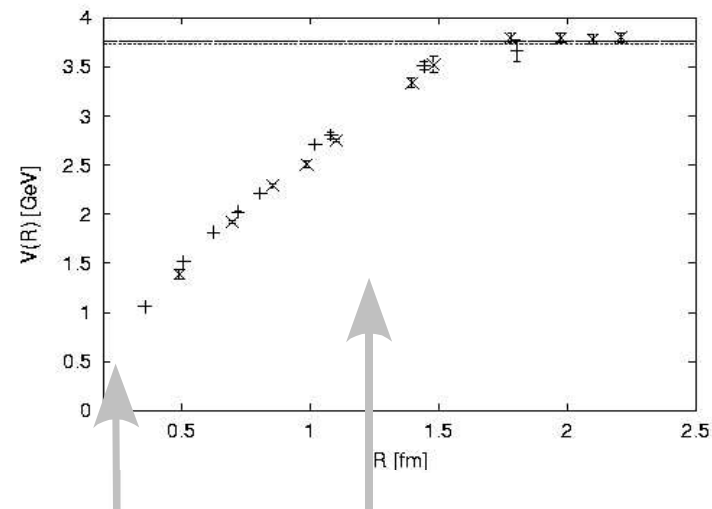
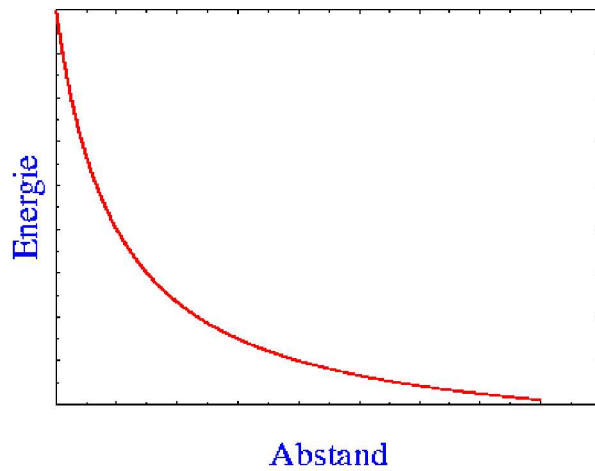
Freiheit im Gefängnis

$$F_{Lad.} \sim \frac{e^2}{r^2} \sim \frac{\alpha}{r^2}$$

$$F_{Farb.} \sim \frac{q_{Farb}^2}{r^2} \sim \frac{\alpha_{eff}}{r^2}$$

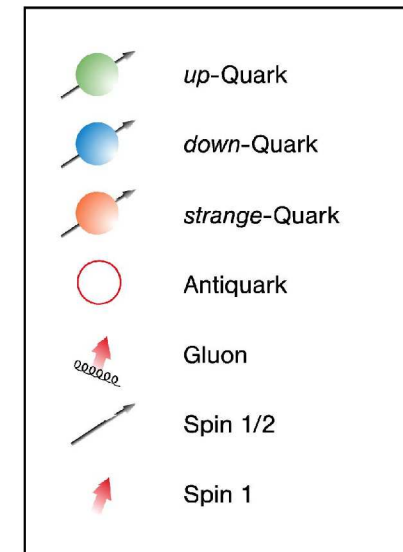
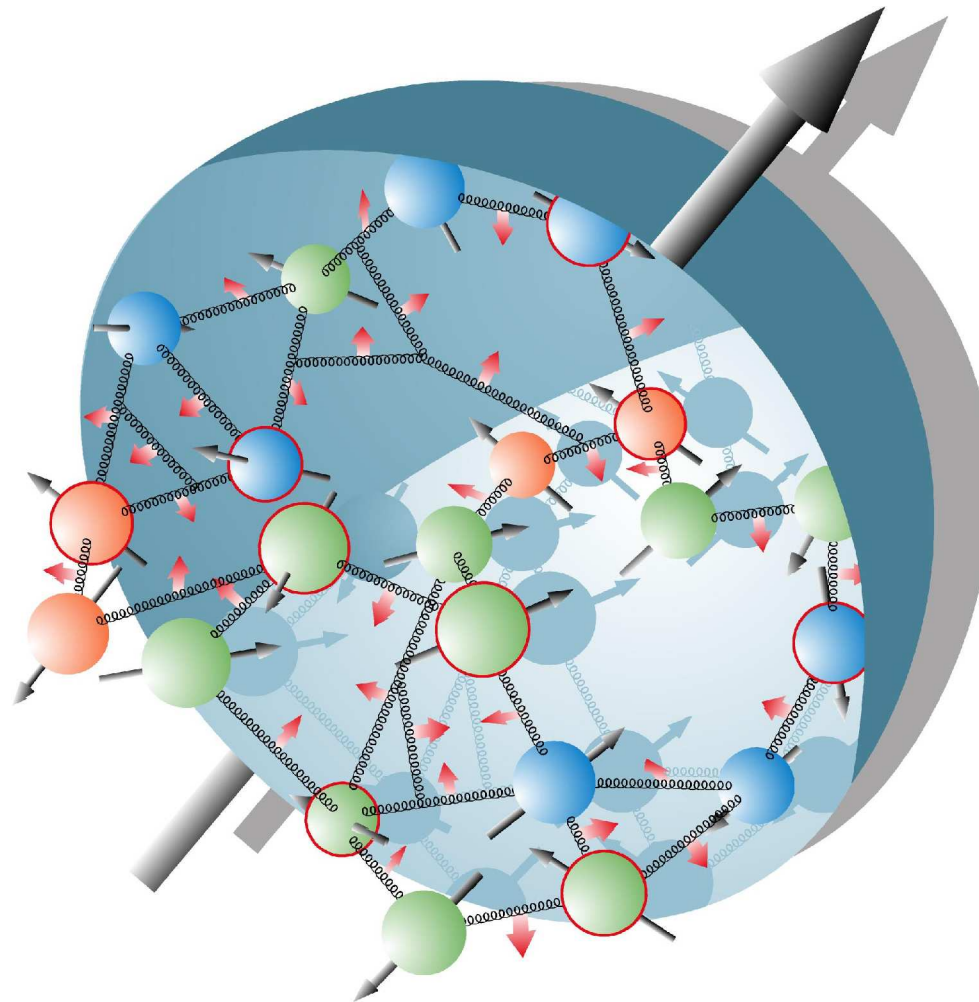
$$E_{Lad.} \sim \frac{1}{r}$$

$$E_{Farb.} \sim r \quad !$$

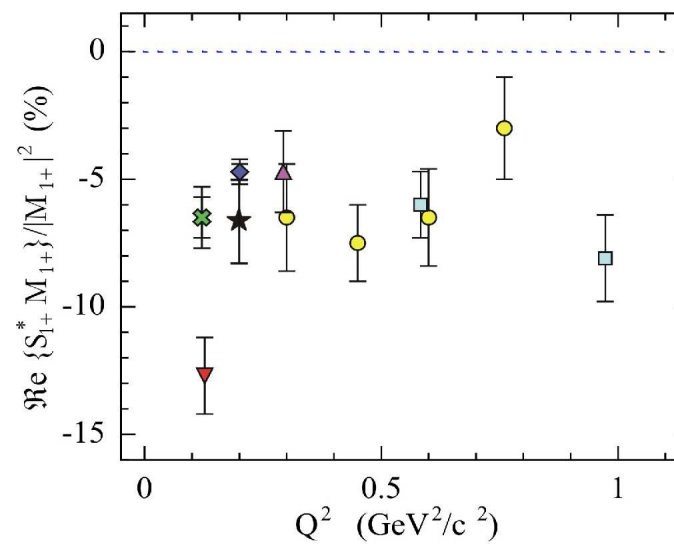
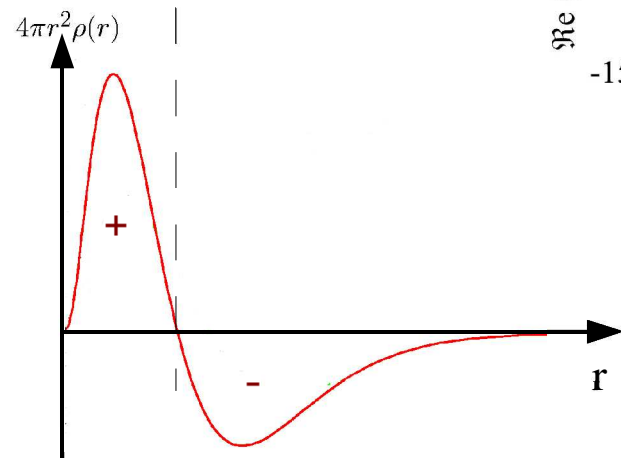
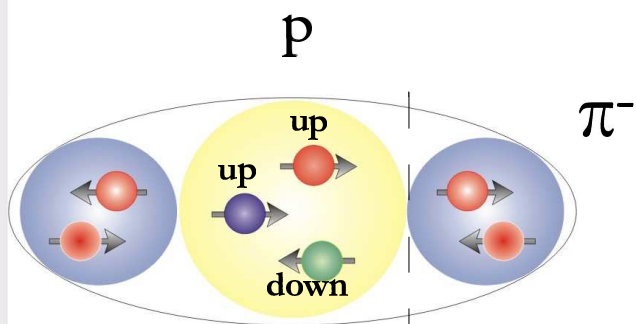


asymptotische Freiheit confinement

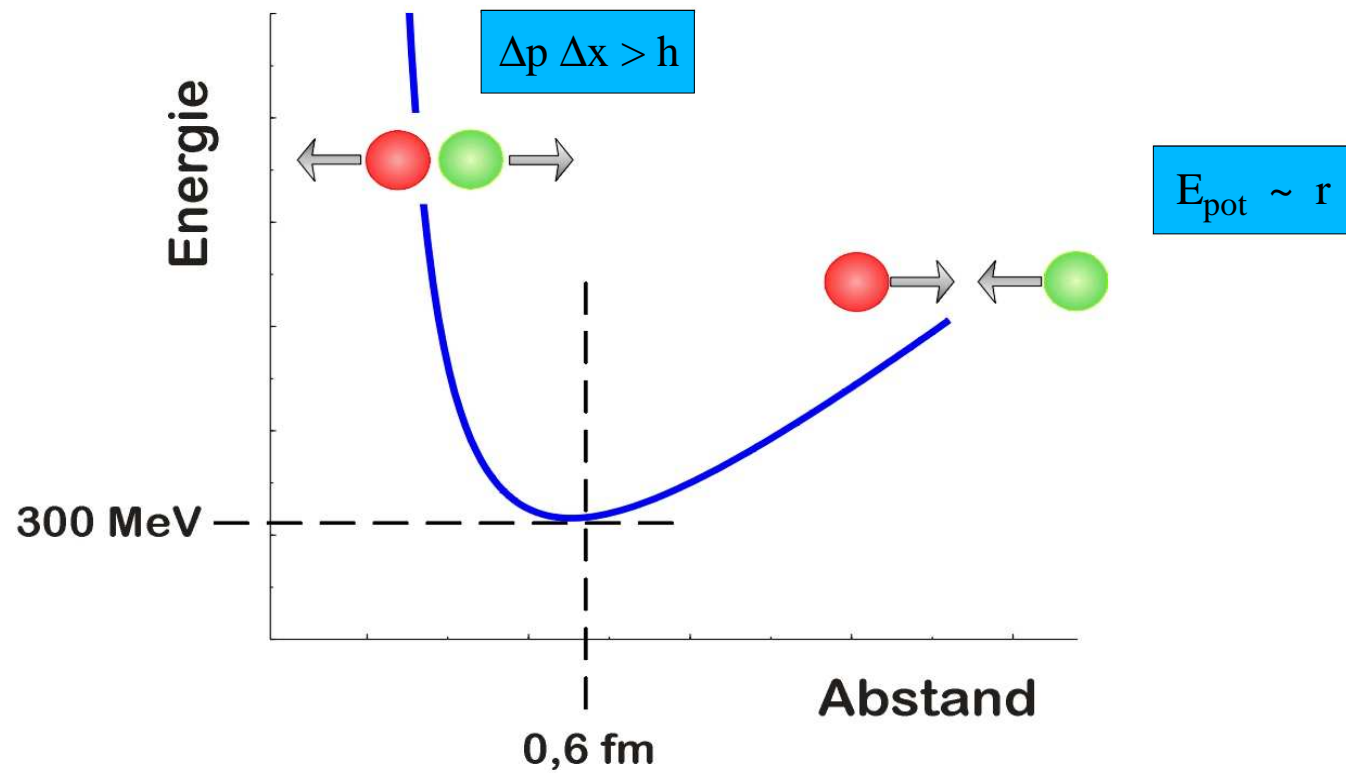
Das **Vielteilchen** – Nukleon



Mesonische Struktur



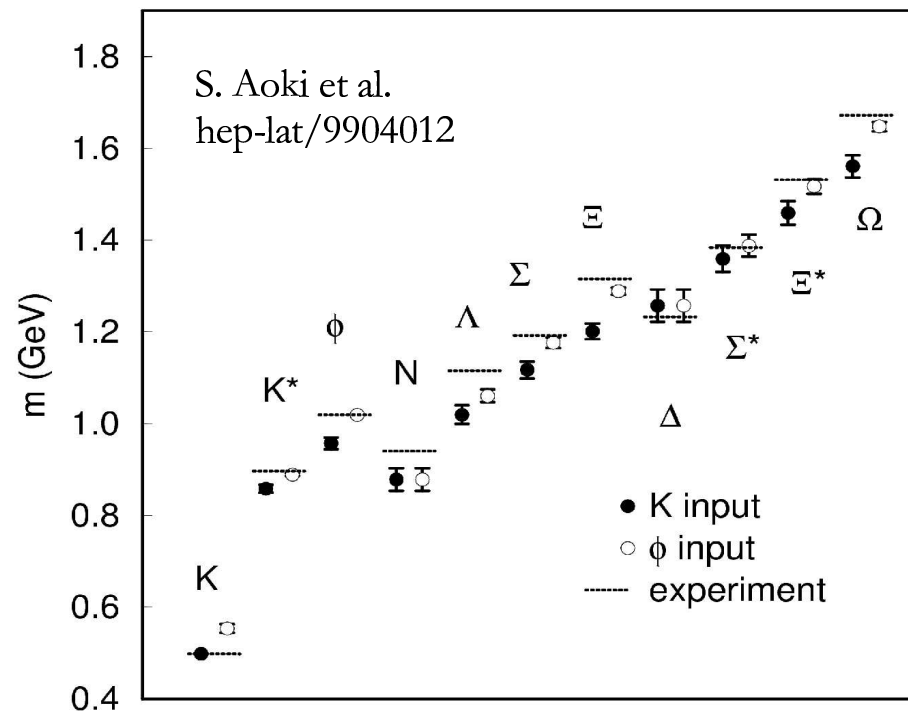
Masse & Ausdehnung



Anregung des Nukleons

Atombau \longleftrightarrow Elektrodynamik \longleftrightarrow Spektrallinien

Nukleonbau \longleftrightarrow Quark- Gluondynamik \longleftrightarrow Anregungsspektrum



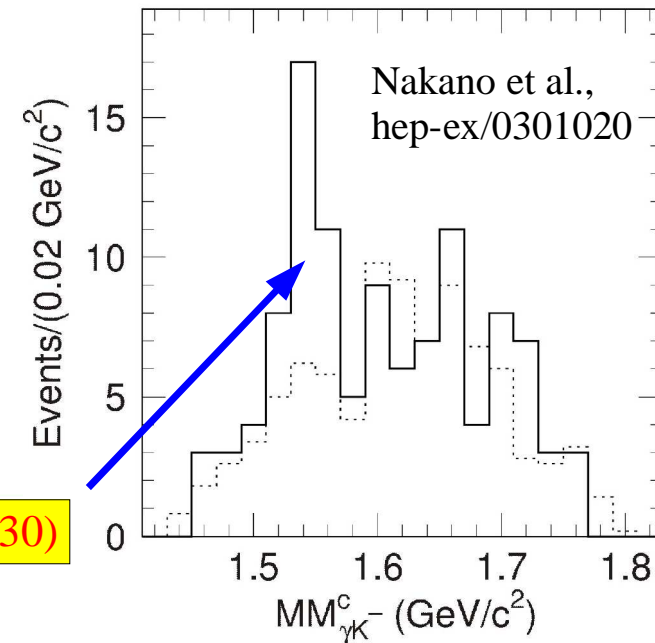
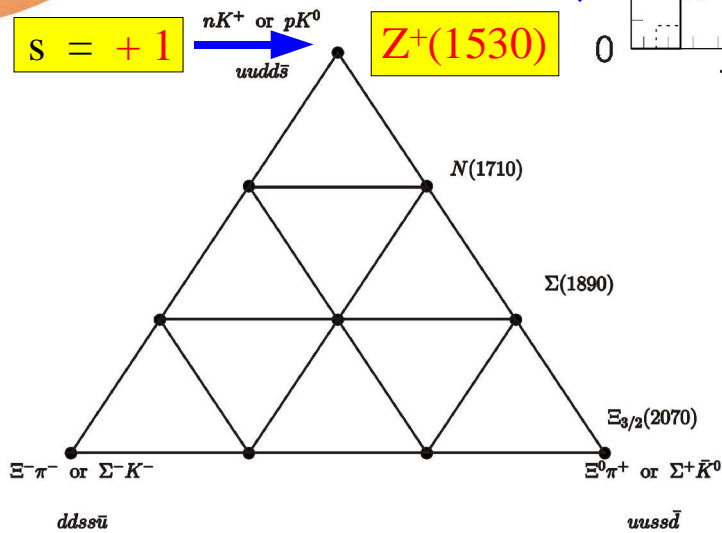
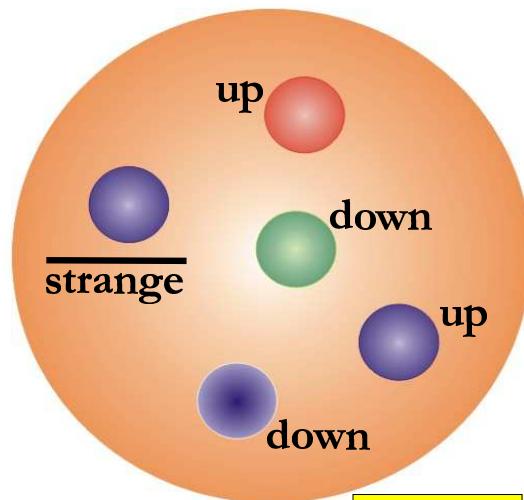
qualitativ ok

Anzahl
&
Struktur



„**fehlende**“ **Resonanzen**
exotische Zustände

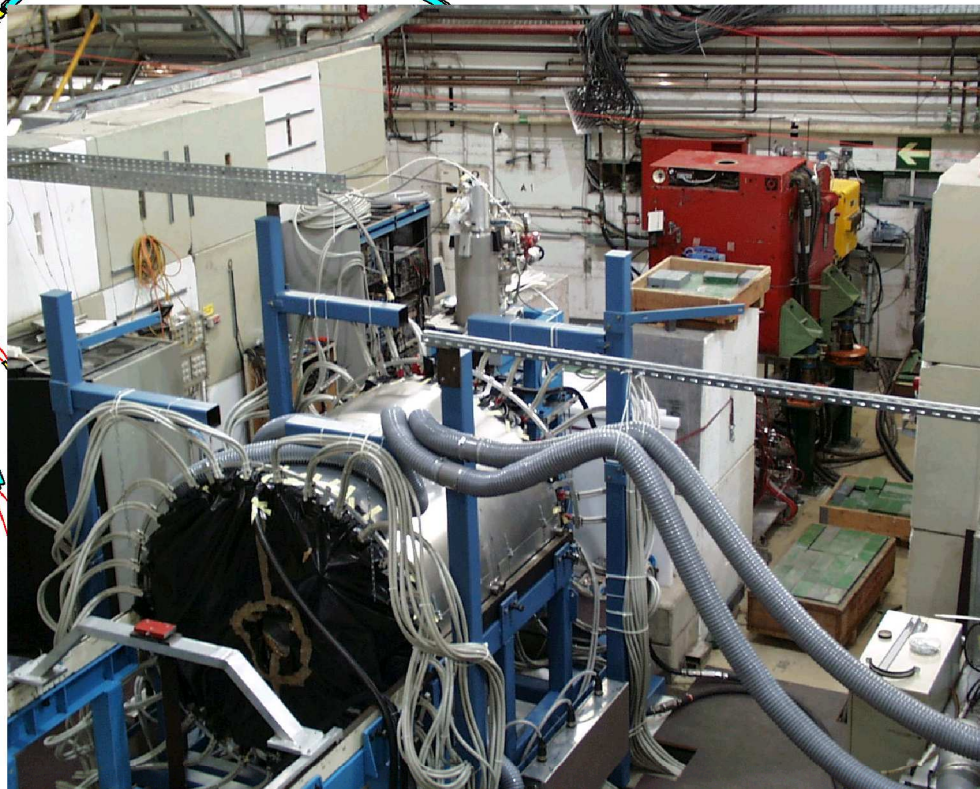
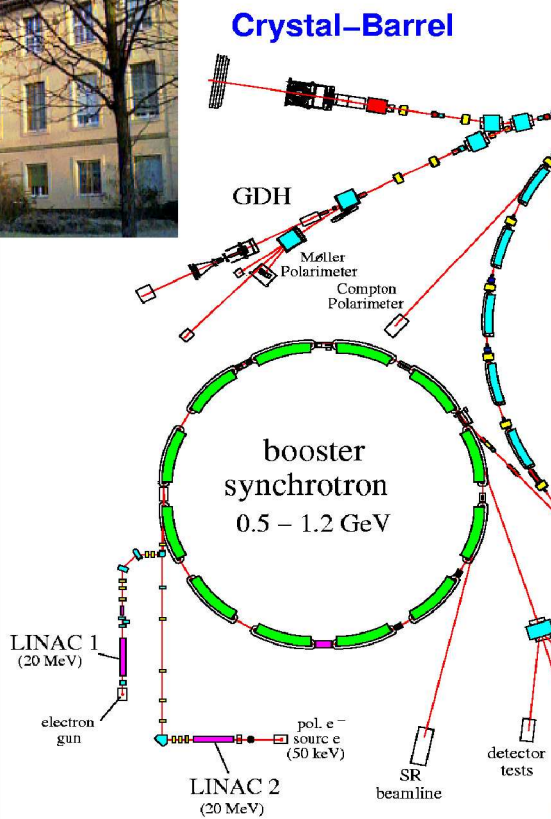
Exotika : *pentaquarks?*



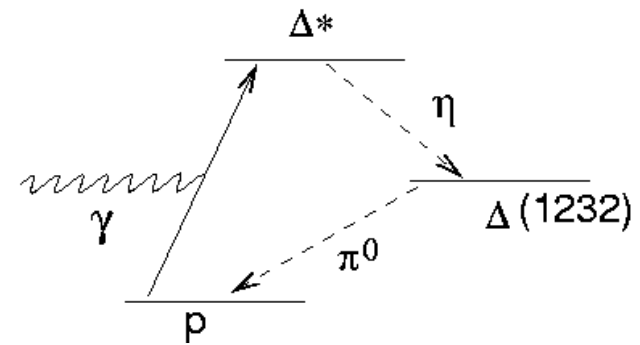
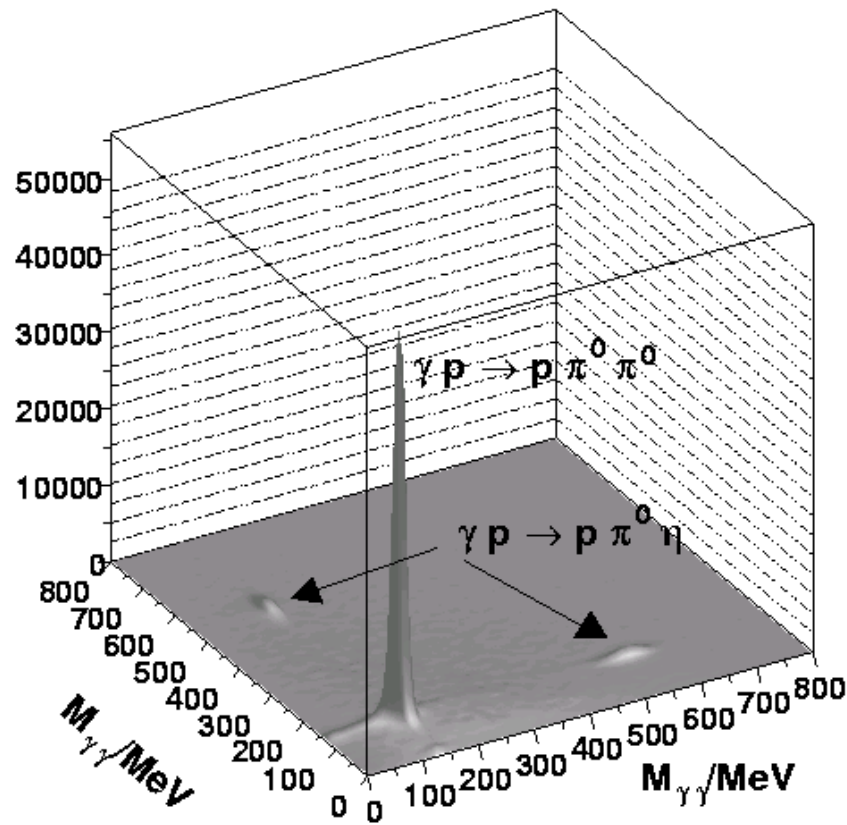


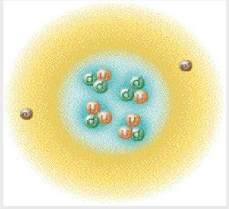
ELekttronen Stretcher Anlage

Physikalisches Institut Universität Bonn



Zerfalls-Kaskaden CB@ELSA



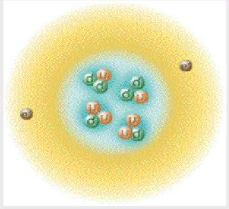


Bei **Licht** betrachtet

ein Blick in's Innere des **Nukleons**

- Standardmodell
- Mikroskop & Teilchenbeschleuniger
- scaling & Partonen
- Asymptotische Freiheit & Confinement
- Masse & Ausdehnung
- Anregung

<http://hsag.physik.uni-bonn.de>



Bei **Licht** betrachtet ein Blick in's Innere des **Nukleons**

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DANK AN

D. Elsner

F. Klein

A. Süle

M. Kortmann

<http://hsag.physik.uni-bonn.de>