



IceCube Masterclass 2024

Astroteilchenphysik

Martin Rongen
Erlangen, 28.03.24



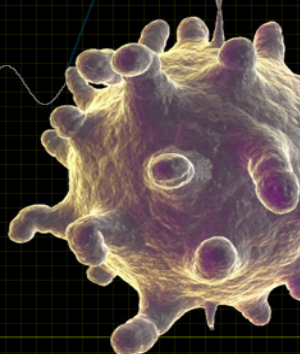
Teilchenphysik




Kodiak Bear
3 m tall
Up to 10 ft = 3 by 10E0 m



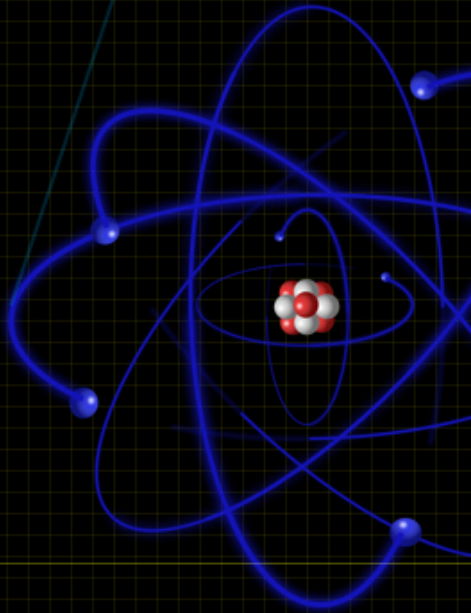
Grain of Salt
.0005 m
.5 mm = 5 by 10E-4 m



Rhinovirus
.00000003 m
30 nm = 3 by 10E-8 m

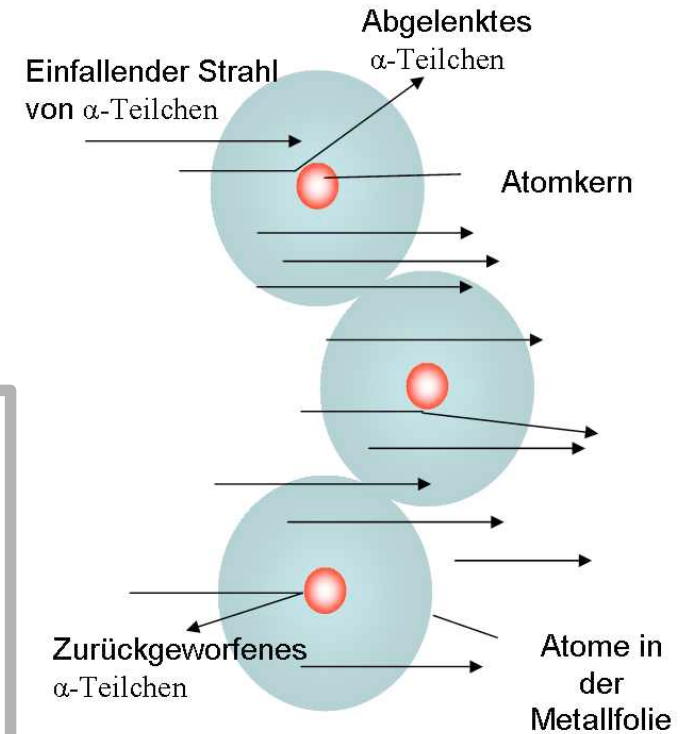
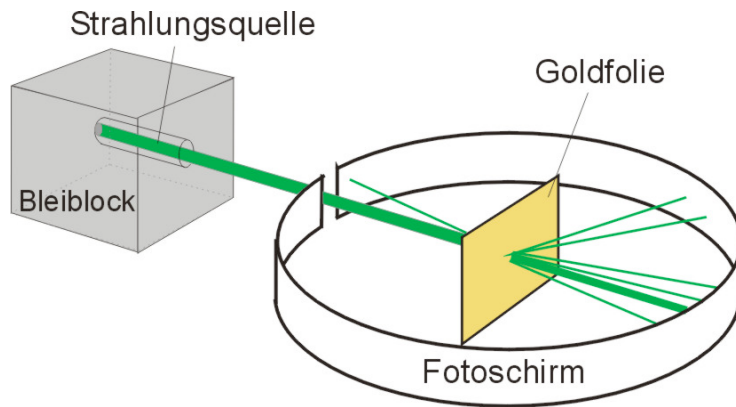


Glucose
.00000000009 m
900 pm = 9 by 10E-10 m

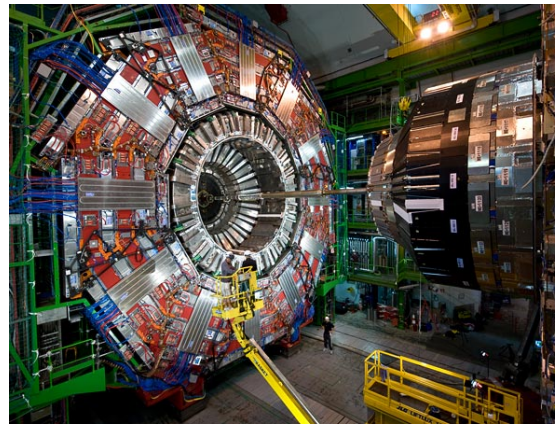


Carbon Atom
.000000000034 m
340 pm = 3.4 by 10E-10 m

Streuexperimente



Ablenkung und Rückstoß von α -Teilchen durch die Atomkerne einer Metallfolie im Rutherford'schen Experiment

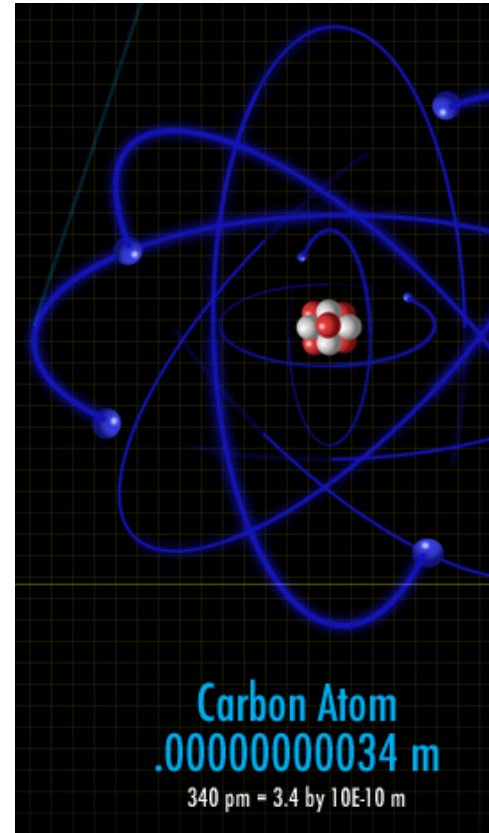


CMS Masterclass

Das Standardmodell

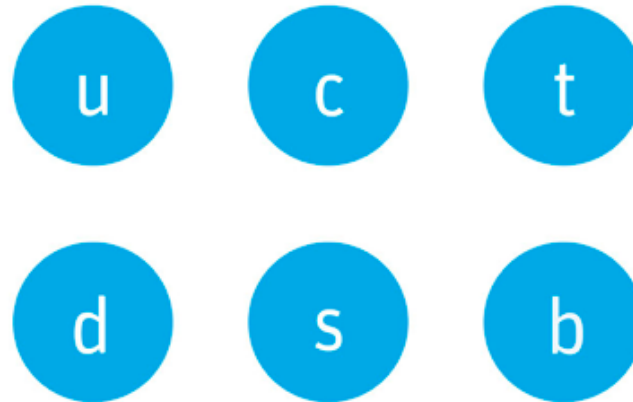
● Quarks

● Leptonen

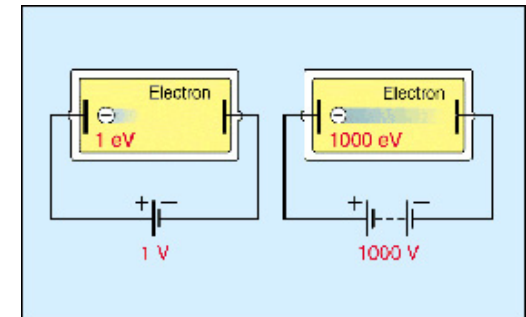


Das Standardmodell

- Quarks
- Leptonen



schwerer 

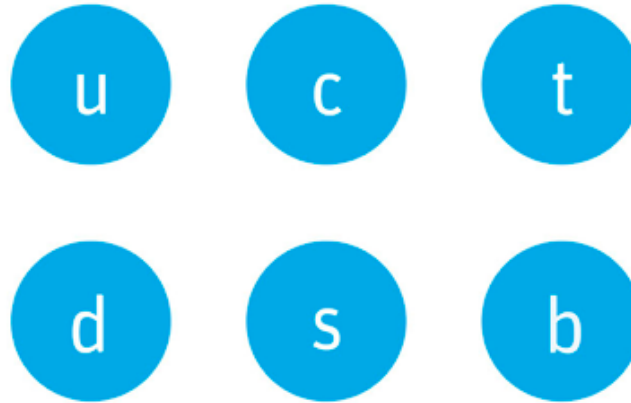


Kilo	10^3
Mega	10^6
Giga	10^9
Tera	10^{12}
Peta	10^{15}

Das Standardmodell

● Quarks

● Leptonen



Periodensystem

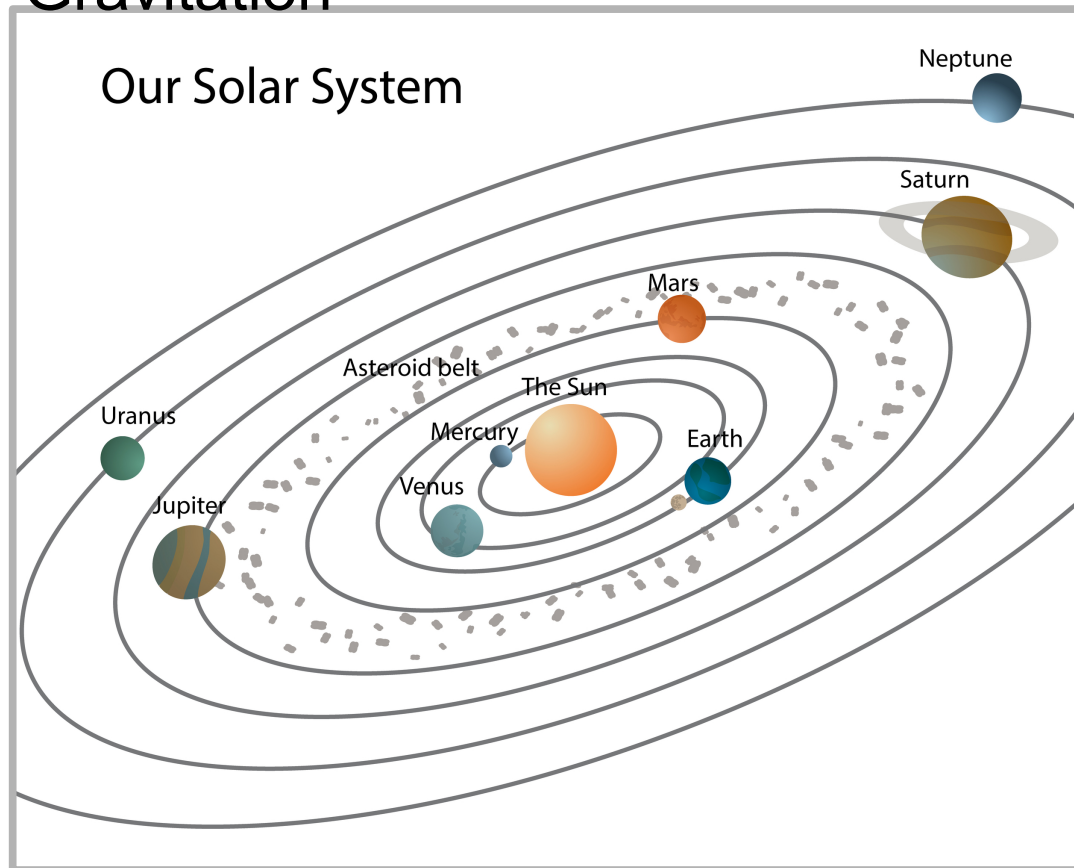
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu				
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr				

schwerer



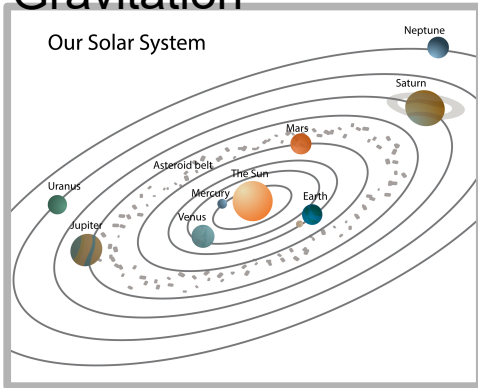
Die Kräfte

Gravitation

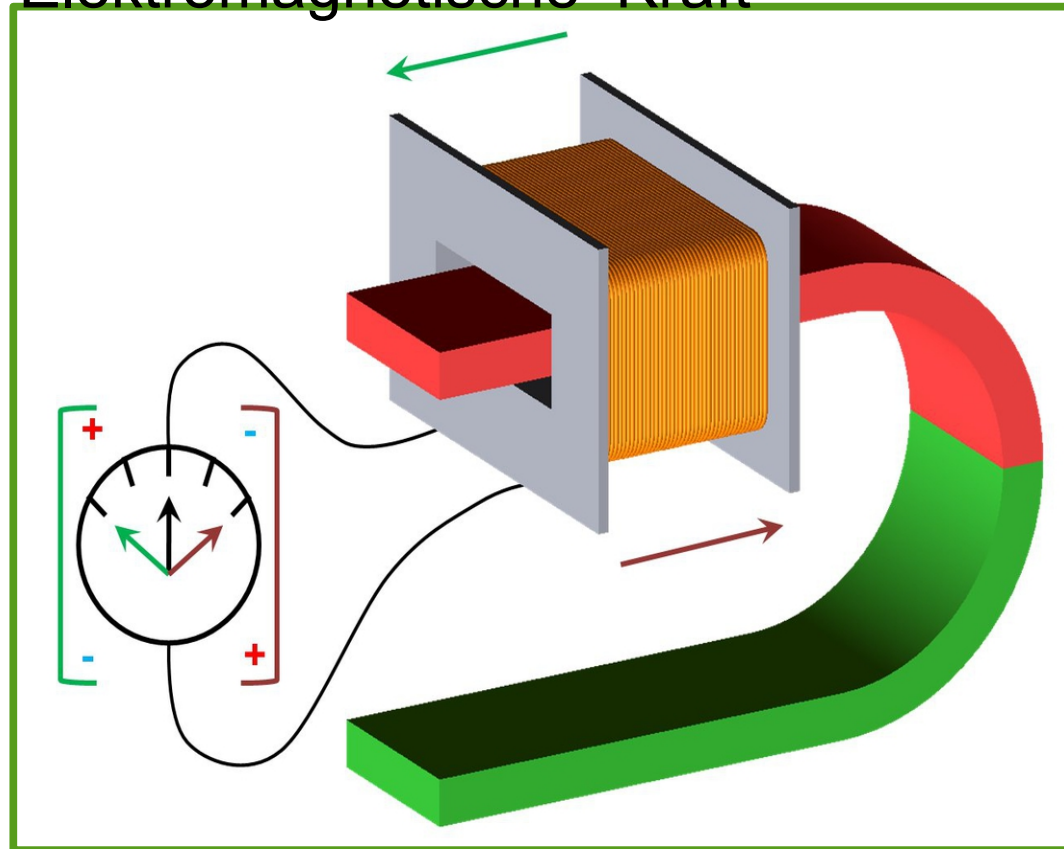


Die Kräfte

Gravitation

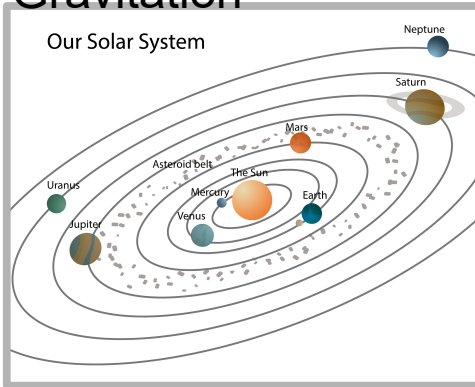


Elektromagnetische Kraft

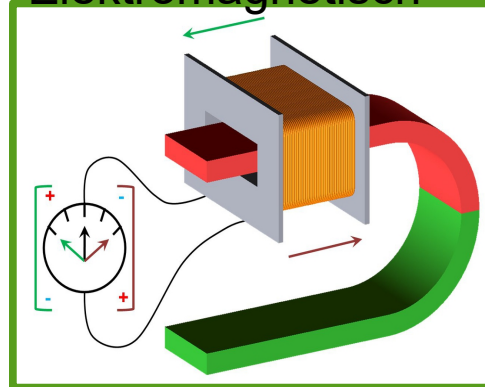


Die Kräfte

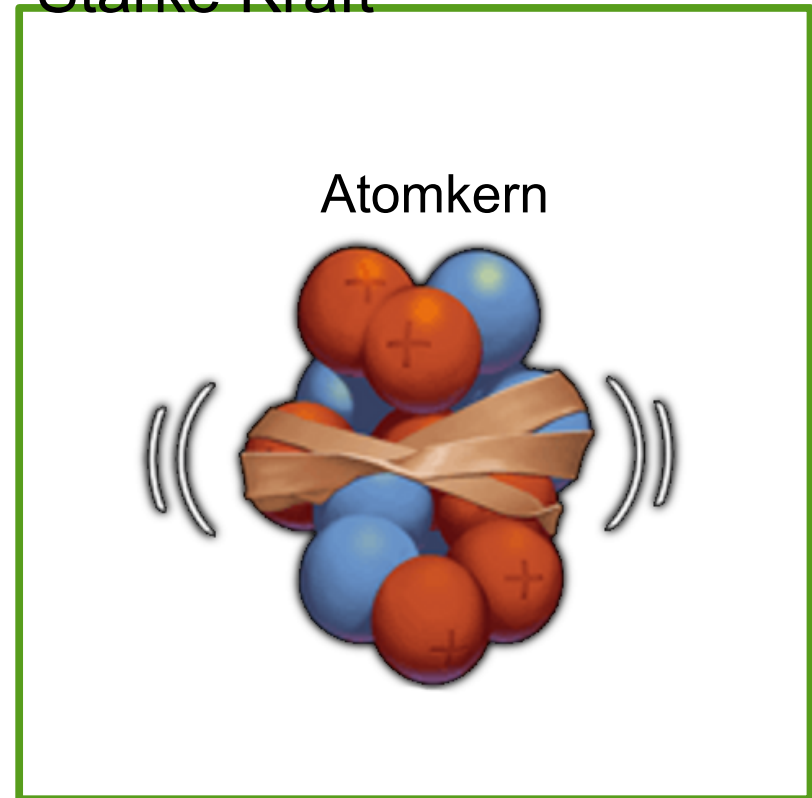
Gravitation



Elektromagnetisch

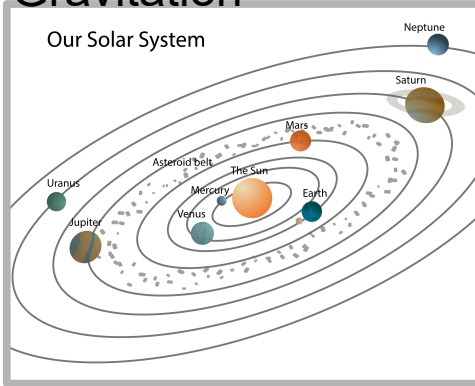


Starke Kraft

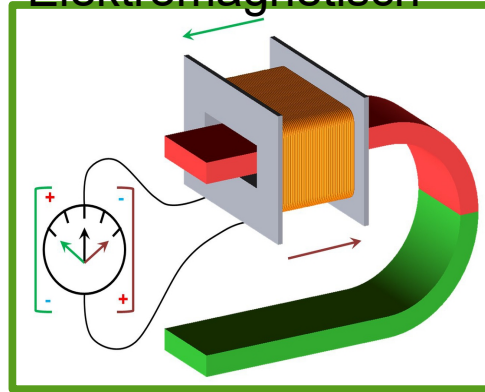


Die Kräfte

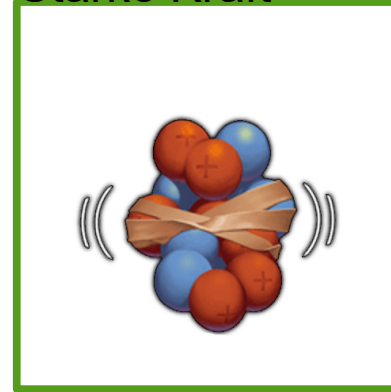
Gravitation



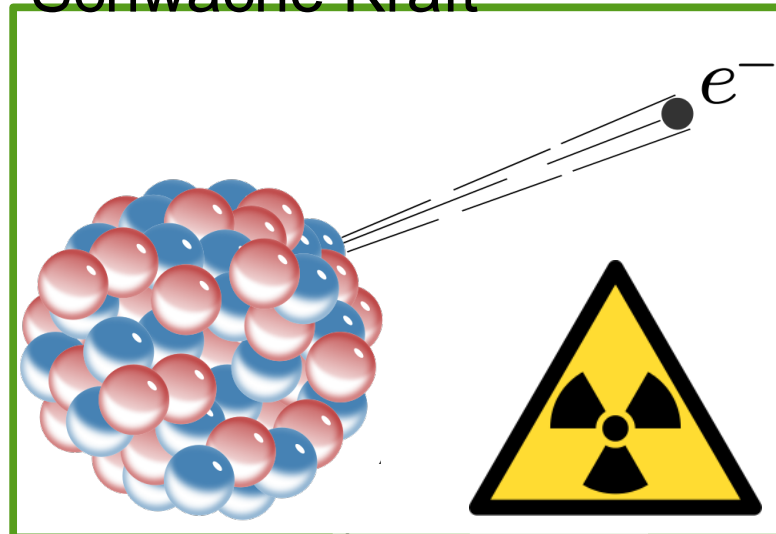
Elektromagnetisch



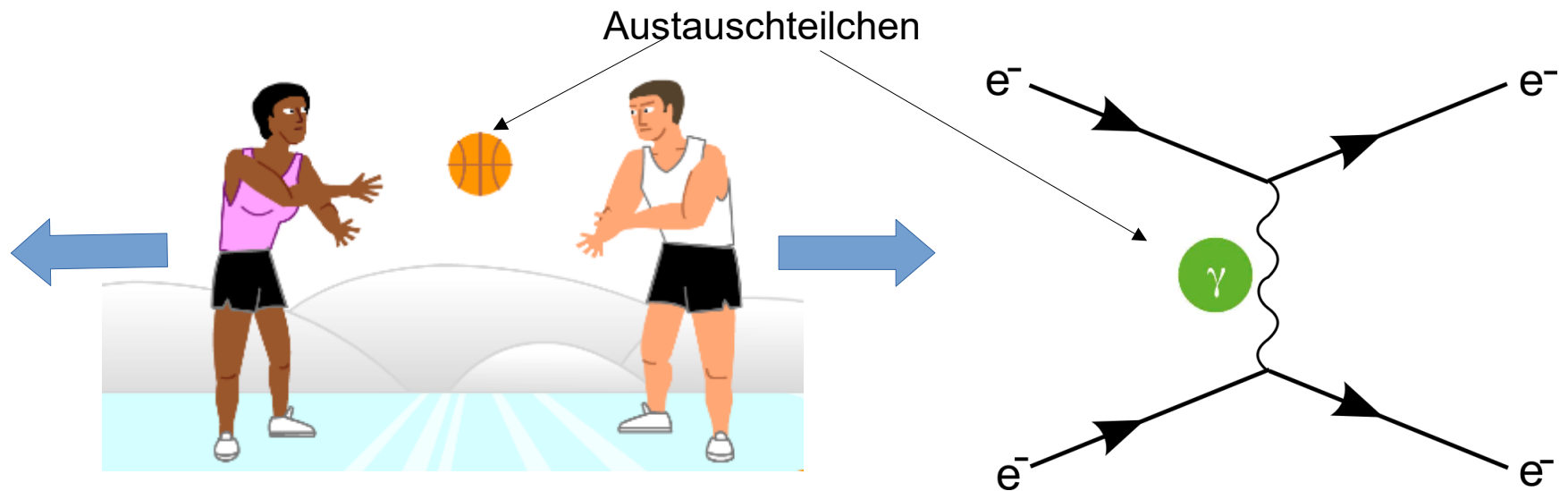
Starke Kraft



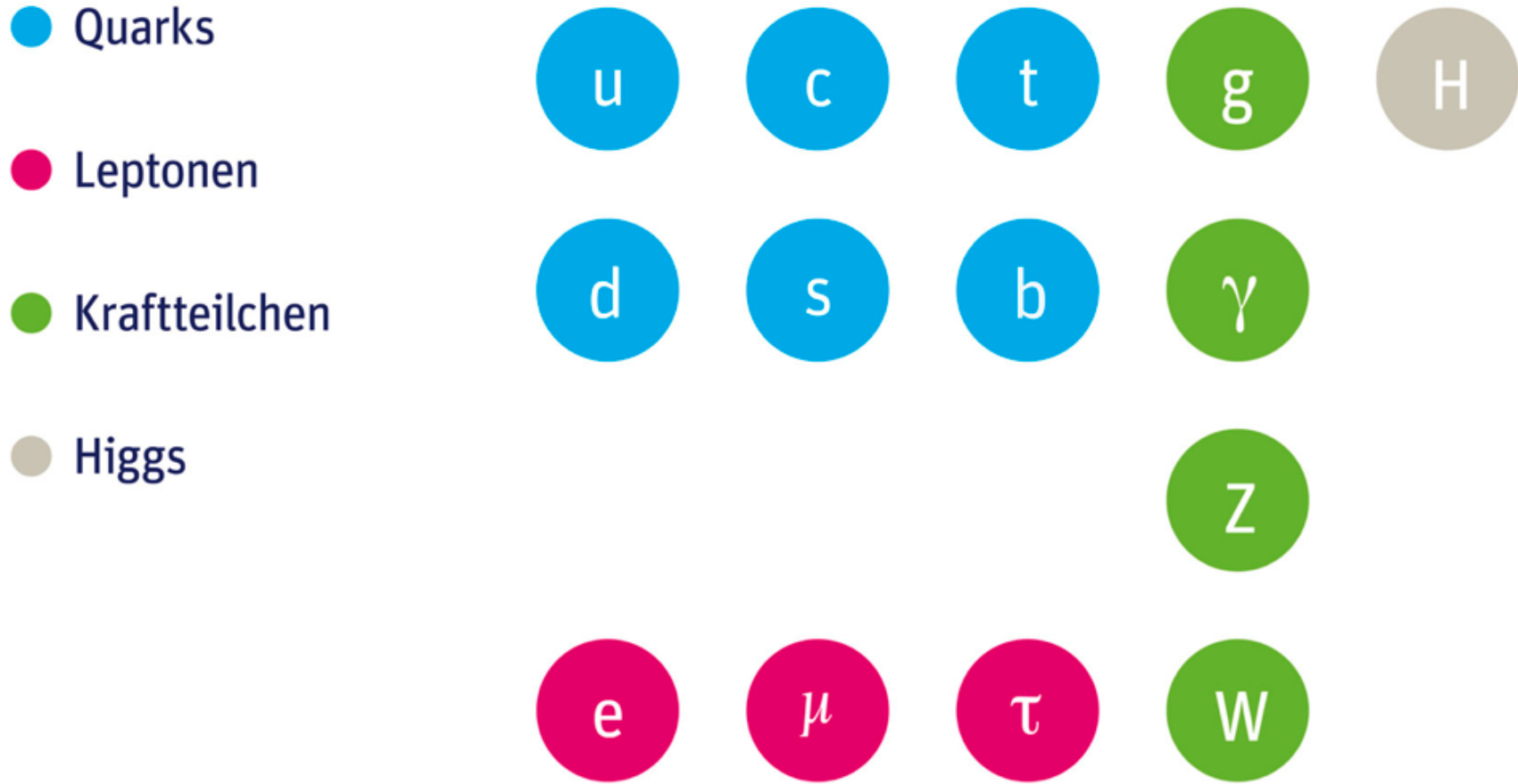
Schwache Kraft



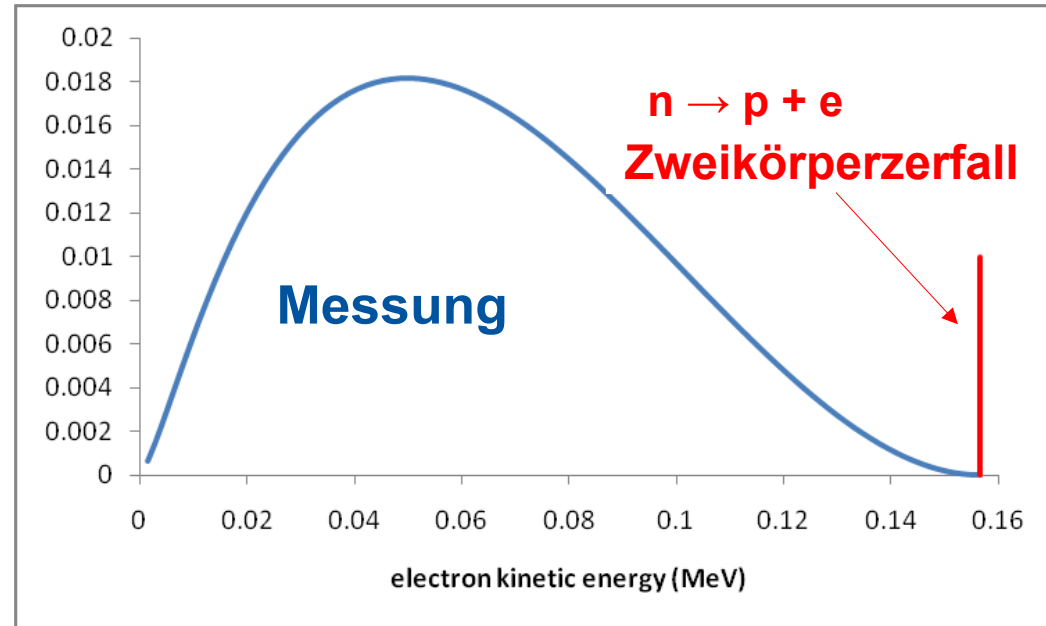
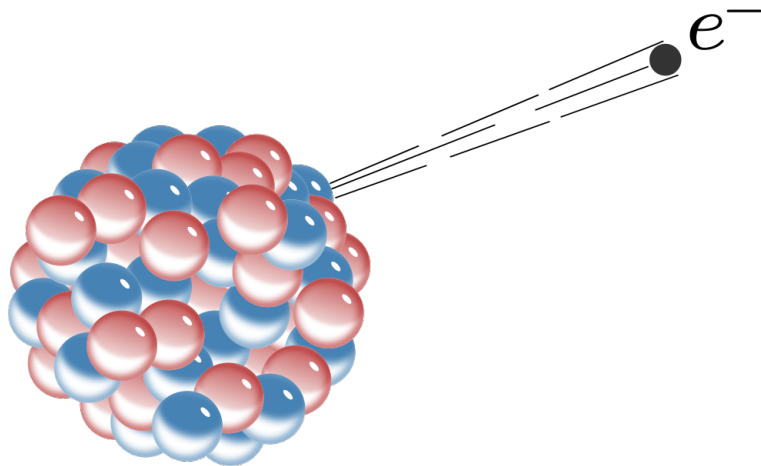
Die Kräfte im Teilchenbild



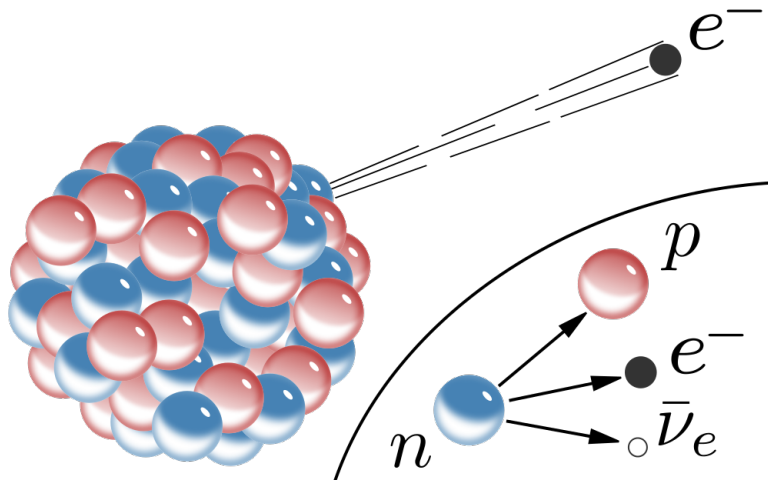
Die vollständige(?) Standardmodell



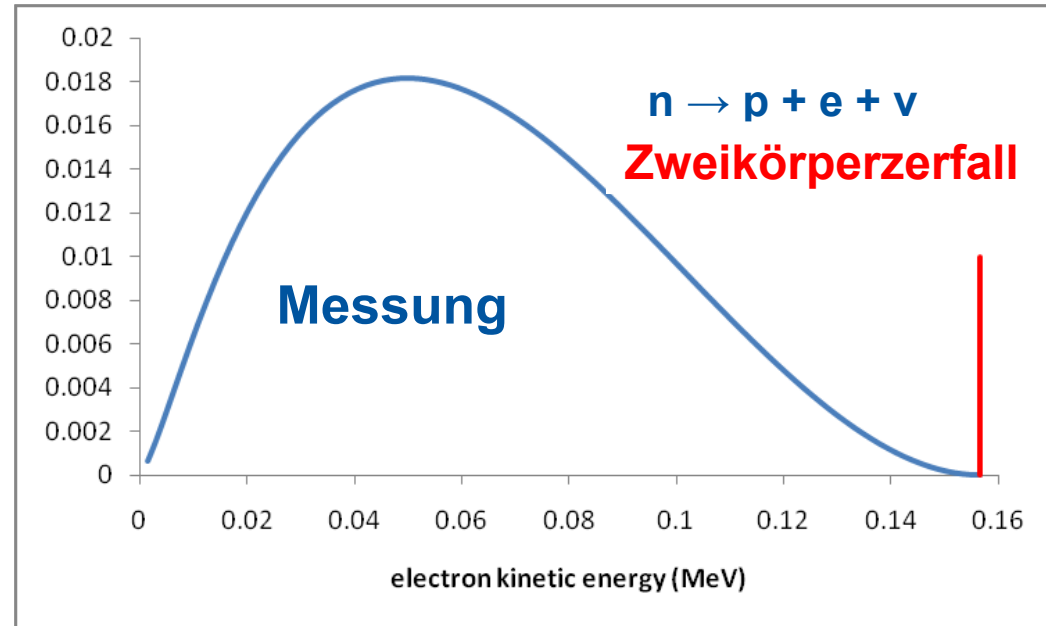
Der β -Zerfall



Der β -Zerfall



I have done a terrible thing, I have postulated a particle that cannot be detected.



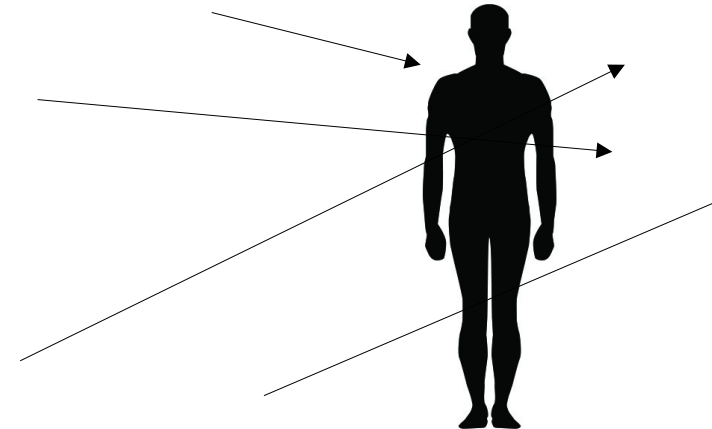
Das Neutrino

- Elektrisch ungeladen und fast masselos

- Masse:



- “Geisterhaft”, nimmt nur an schwacher WW teil
(10-11 Wahrscheinlichkeit beim Flug durch die Erde @ 1 MeV)
- Durch euch fliegen etwa $5 \cdot 10^{14}$ Sonnenneutrinos pro Sekunde



Die vollständige(?) Standardmodell

● Quarks

● Leptonen

● Kraftteilchen


● Higgs



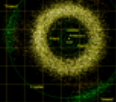
Astrophysik



Kodiak Bear
3 m tall
Up to 10 ft = 3 by 10E0 m

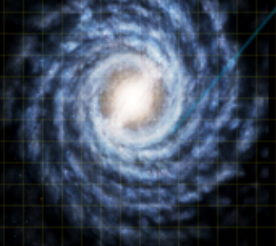


Earth
12,756,000 m in diameter
You live here. 1.28 by 10E7 m



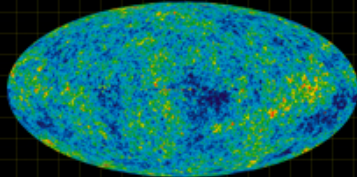
Solar System
30,000,000,000,000 m in diameter
(.003 light years across / 200 au)

The main planetary and subplanetary objects within the radius of the known dwarf planets (the farthest being Eris, which strays no more than 100 au from the sun - an au being the distance from Sun to Earth). We'll therefore treat the radius of the solar system as 100 au and its diameter as 200 au. There's a bit of arbitrariness here since the Sun's gravitational field extends indefinitely and there are other objects much further away within its pull, such as the Oort Cloud (estimated at 50,000 au).



Milky Way Galaxy
1,140,000,000,000,000,000,000 m in diameter
(120,000 light years across)

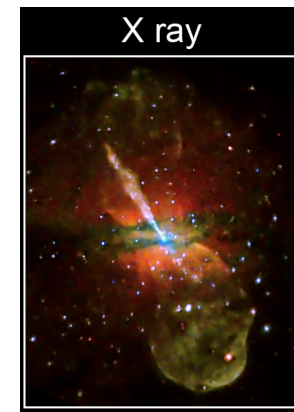
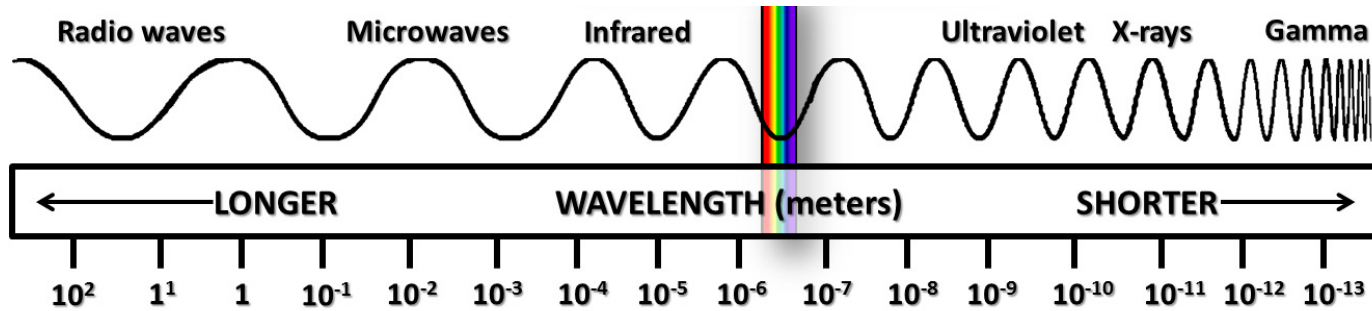
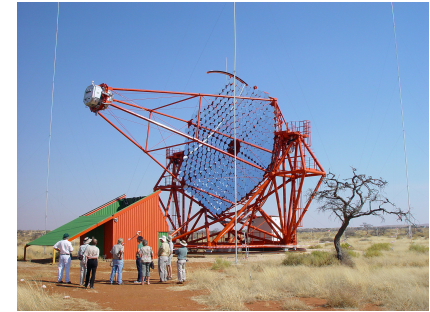
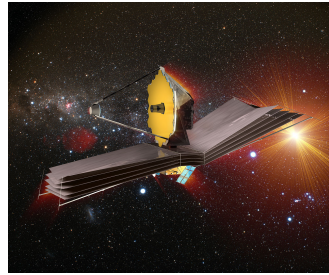
Spiral galaxy in which we find ourselves
1.14 by 10E21 m in diameter



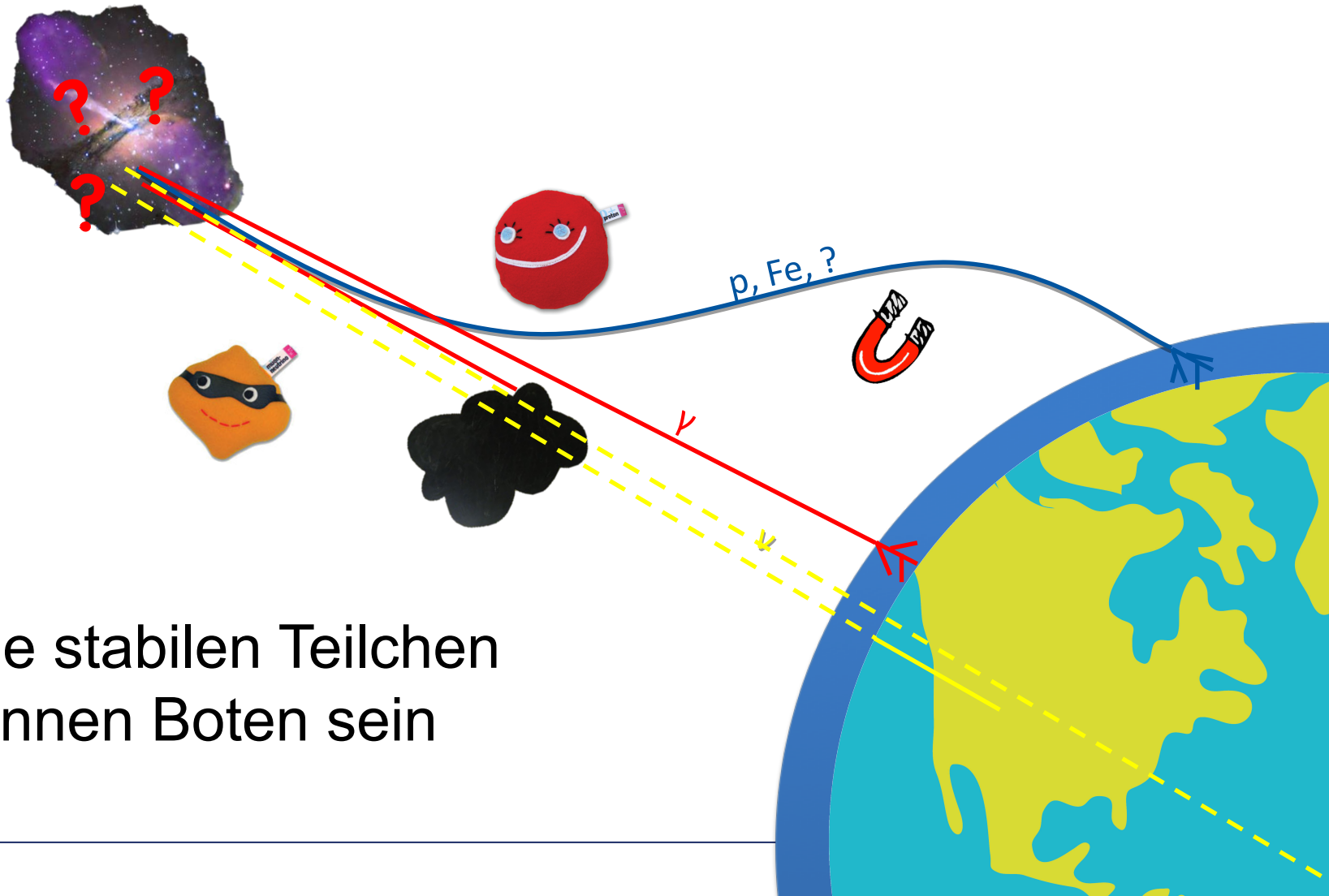
The Observed Universe
248,000,000,000,000,000,000,000 m in diameter

Gamma Ray Burst 090429B is 13.1 billion ly from Earth suggesting a radius for the observed universe of that distance and thus a diameter twice that distance; note that the universe is 13.7 billion years old, indicating that this gamma ray burst happened 600 million years after the Big Bang
2.48 by 10E26 m across

Photon-Astronomie



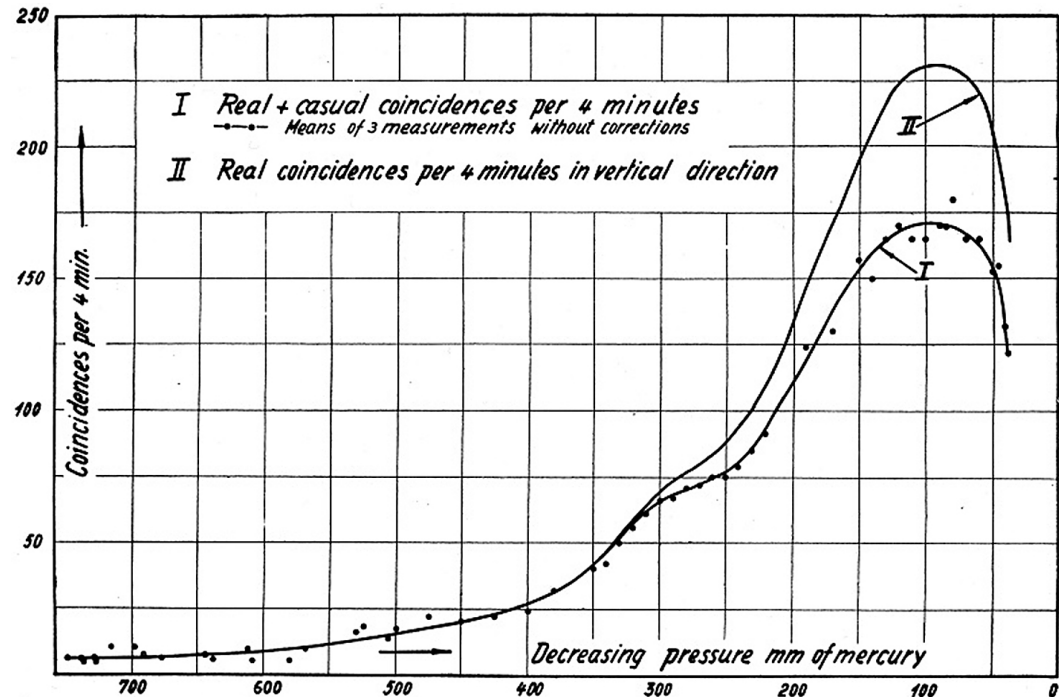
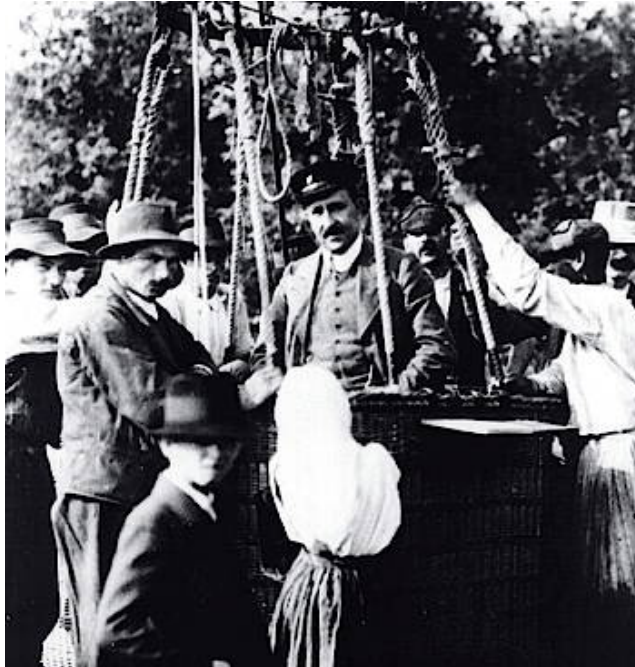
Was hat das mit Teilchenphysik zu tun?



- Alle stabilen Teilchen können Boten sein



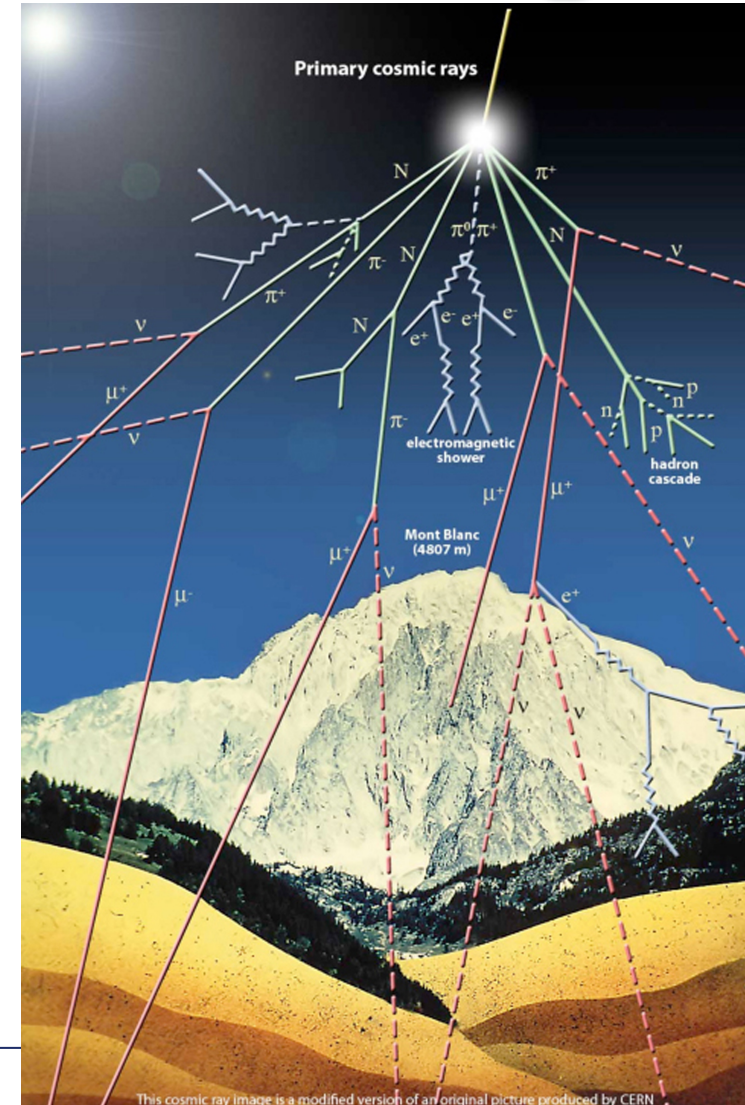
Höhenstrahlung



- Radioaktivität nimmt (entgegen der Erwartung) mit der Höhe zu
→ die Erde muss von geladenen Teilchen getroffen werden

Luftschauer

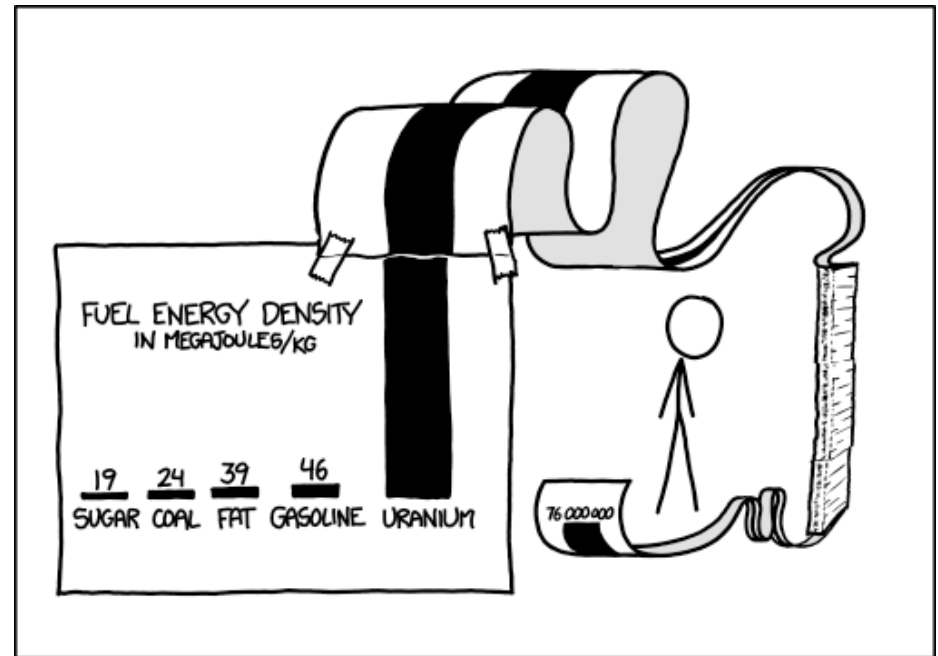
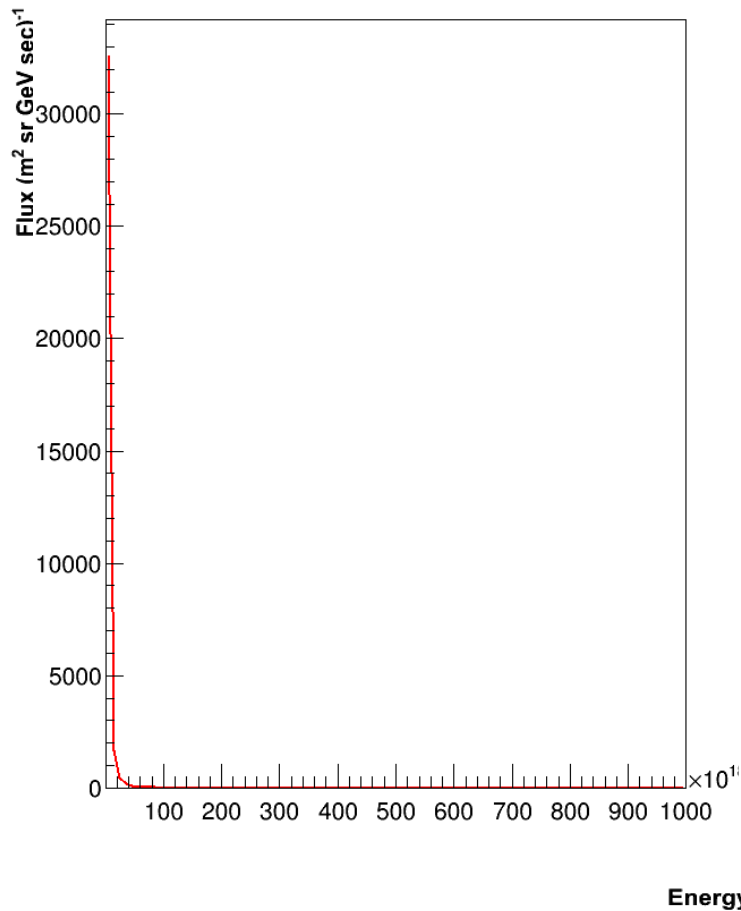
- Primärteilchen interagiert hoch in der Atmosphäre und bildet Schauerfront
- Sekundärteilchen zerfallen (teilweise) auf dem Weg zum Boden
- Am Boden kann der “Fußabdruck” der Schauerfront gemessen werden





Energiespektrum

Cosmic Ray Spectra of Various Experiments

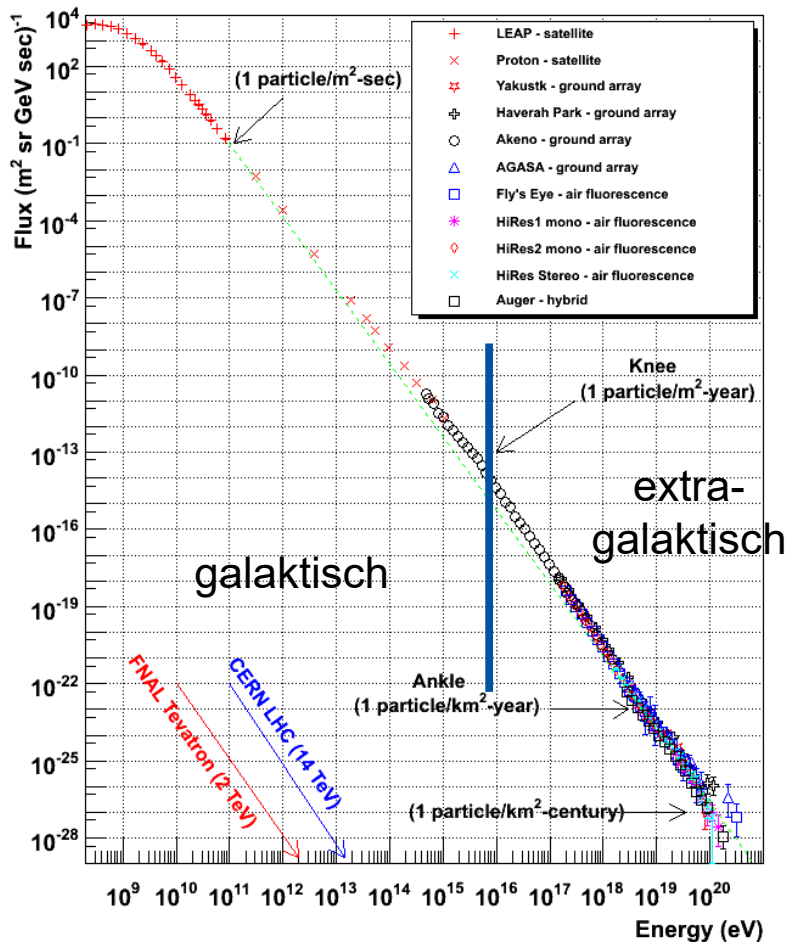


SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT PROPERLY.



Energiespektrum

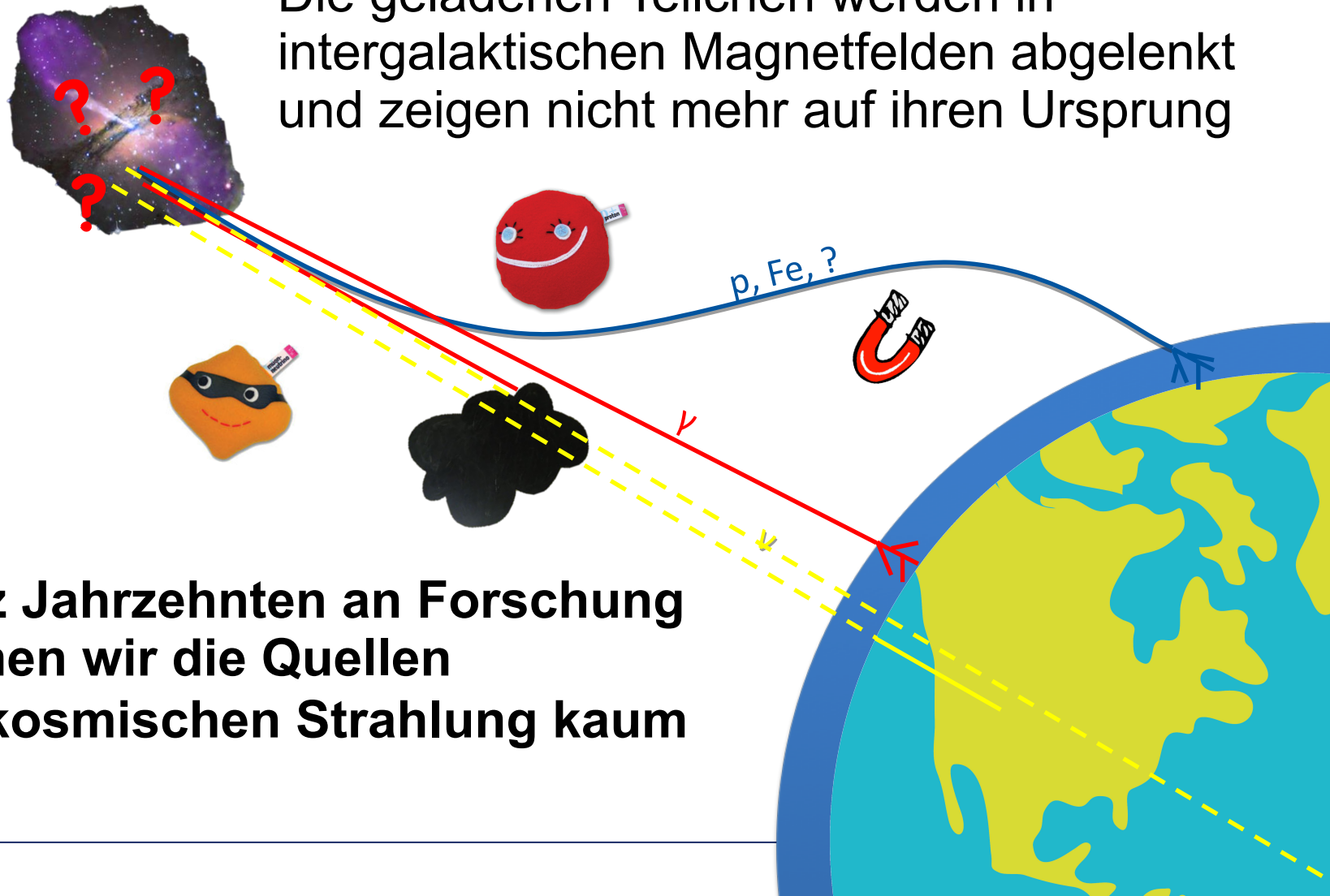
Cosmic Ray Spectra of Various Experiments



- Doppellogarithmisch Achsen
(Eine Größenordnung pro Strich)
- Anzahl $\sim E^{-2,x}$
- Substrukturen geben
Aufschluss über
veränderte Herkunft

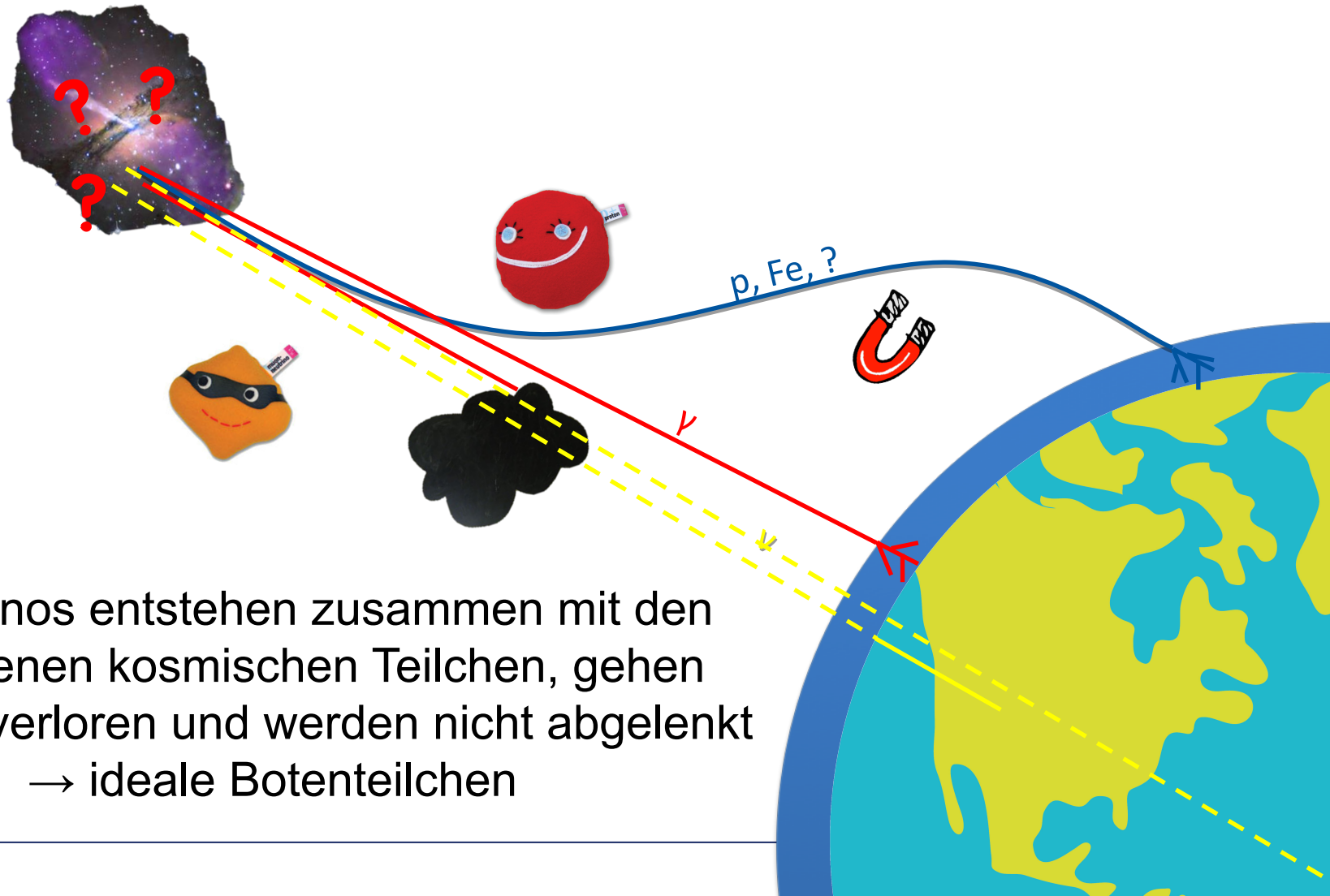
Richtung

Die geladenen Teilchen werden in intergalaktischen Magnetfeldern abgelenkt und zeigen nicht mehr auf ihren Ursprung



→ trotz Jahrzehnten an Forschung kennen wir die Quellen der kosmischen Strahlung kaum

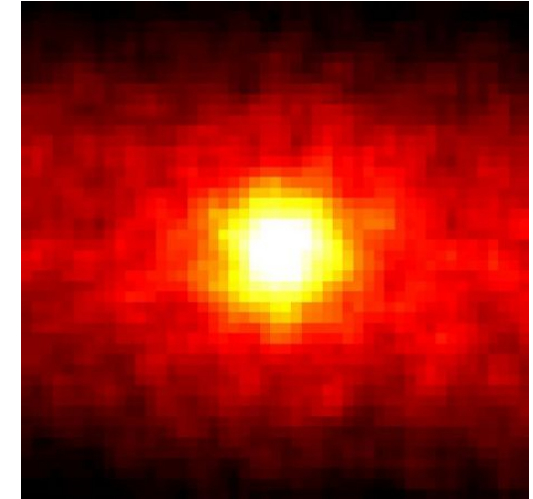
Neutrino-Astronomie



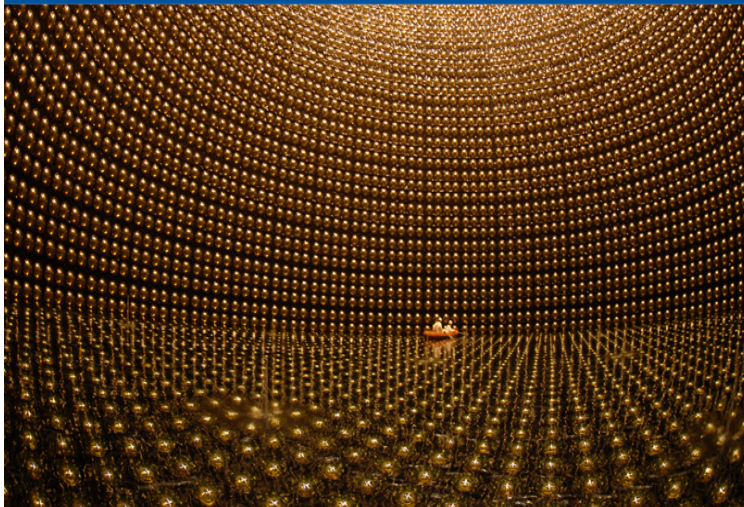
- Neutrinos entstehen zusammen mit den geladenen kosmischen Teilchen, gehen nicht verloren und werden nicht abgelenkt
→ ideale Botenteilchen

Neutrino - Quellen

- Sonne ($7 \cdot 10^{10}$ pro cm^2 und Sekunde)
~5000 pro Jahr gemessen
- SN1987a (Sternexplosion)
24 Neutrinos gemessen

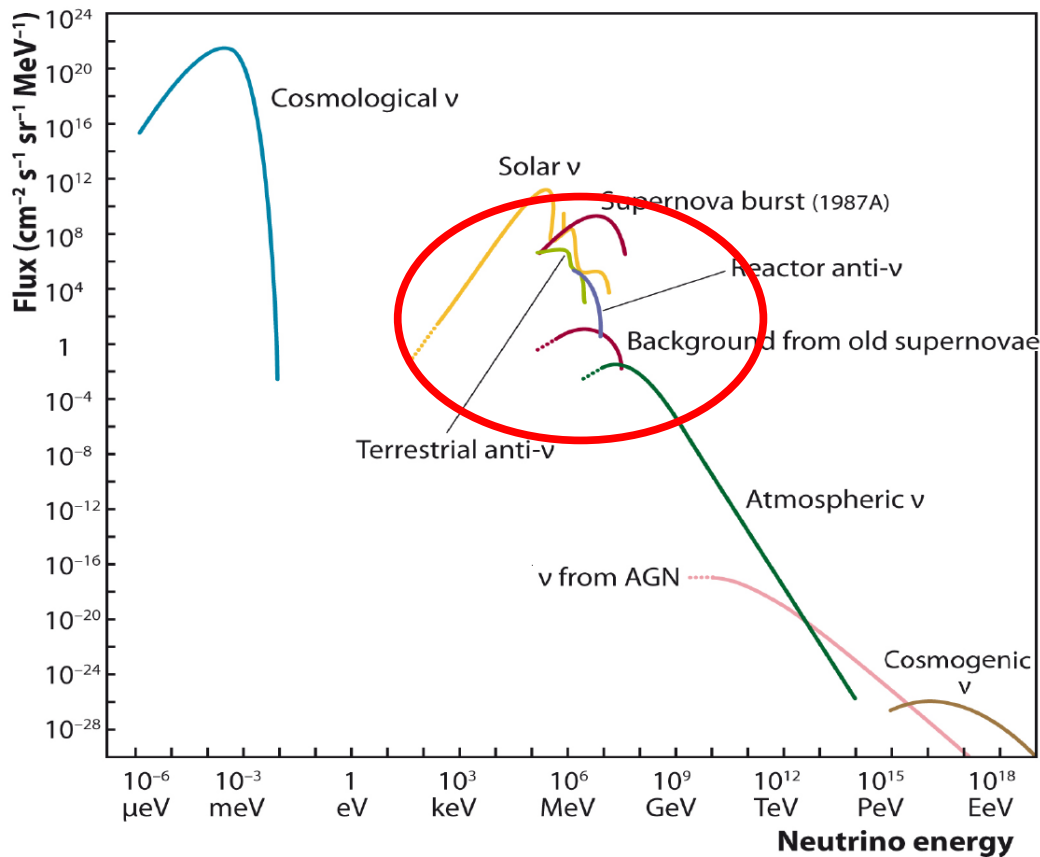


Detektor ~ 0,00003 km³



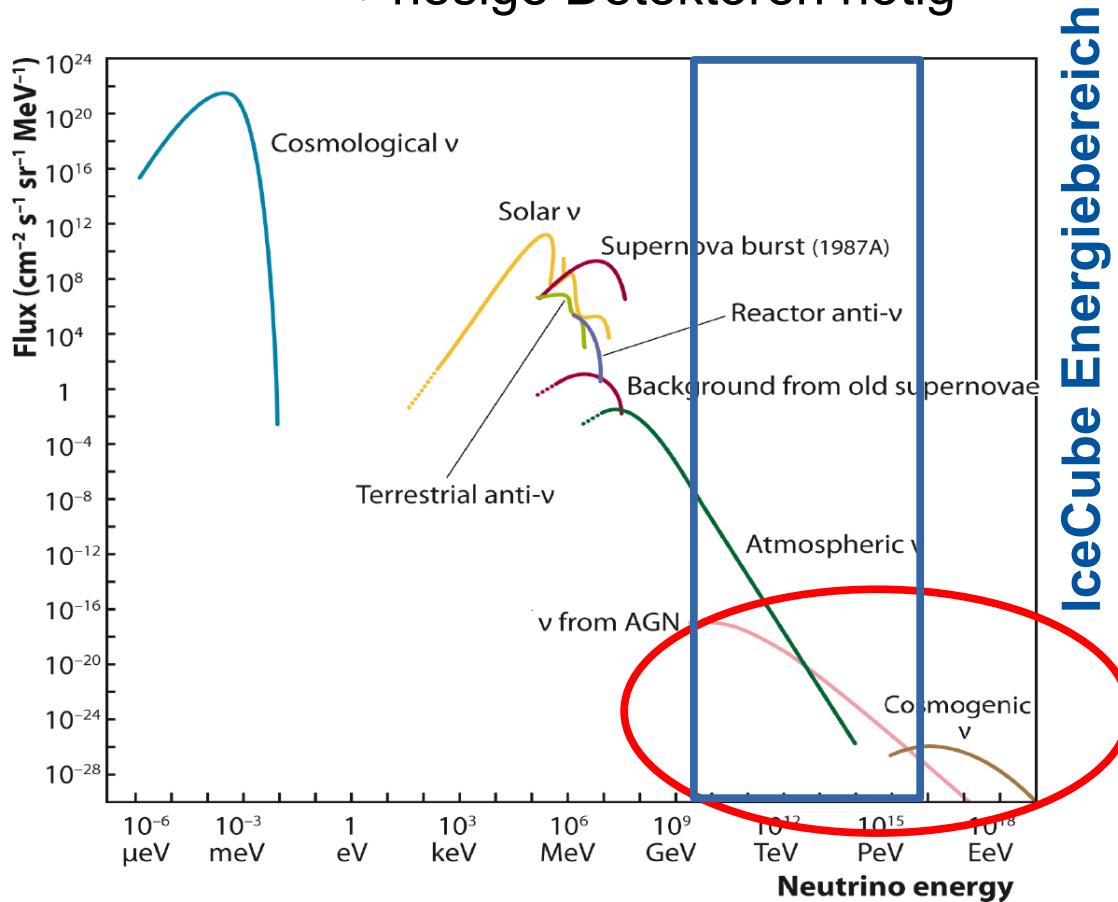
Herausforderung 1

- Nur wenige Ereignisse pro km² und Jahr erwartet
→ riesige Detektoren nötig



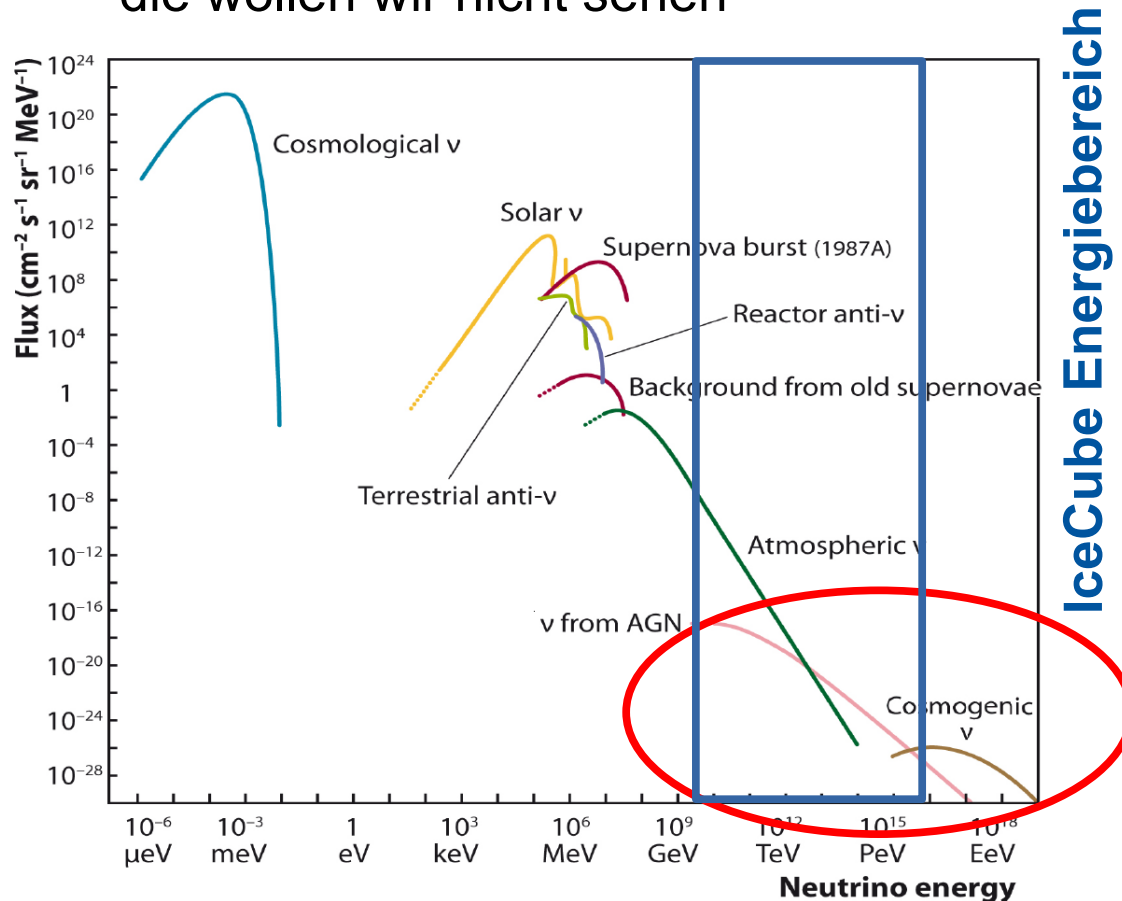
Herausforderung 1

- Nur wenige Ereignisse pro km² und Jahr erwartet
→ riesige Detektoren nötig



Herausforderung 2

- Neutrinos entstehen auch in den Luftschauern geladener Teilchen, die wollen wir nicht sehen



Wir haben 2013 die ersten extrasolaren Neutrinos gefunden (wie siehe nächsten Vortrag), aber die füllt sich nur langsam.

