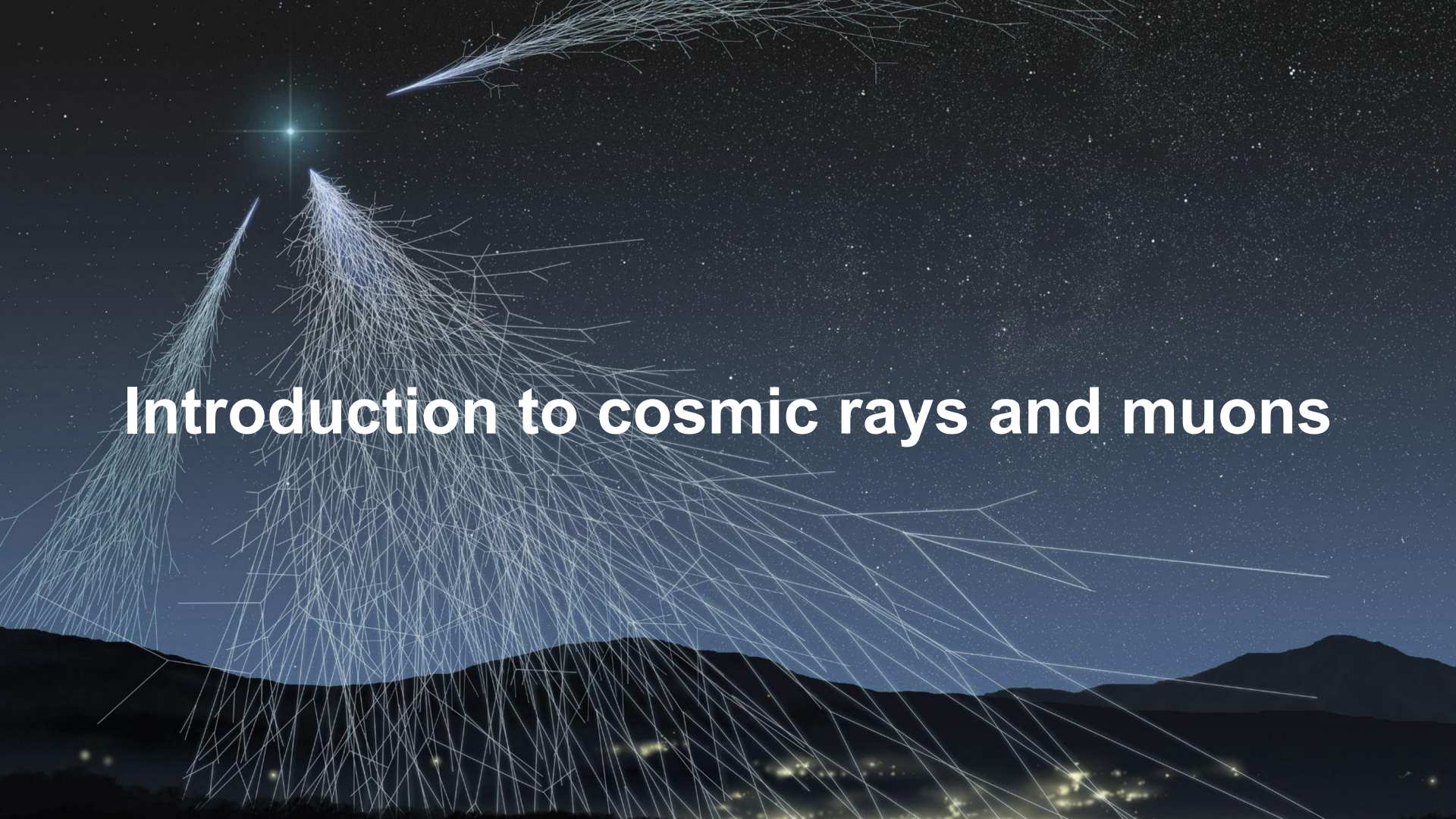
Development and Construction of a Muon Telescope

Ferienakademie 2024
Group 3 - Dark Matter and the Cosmos

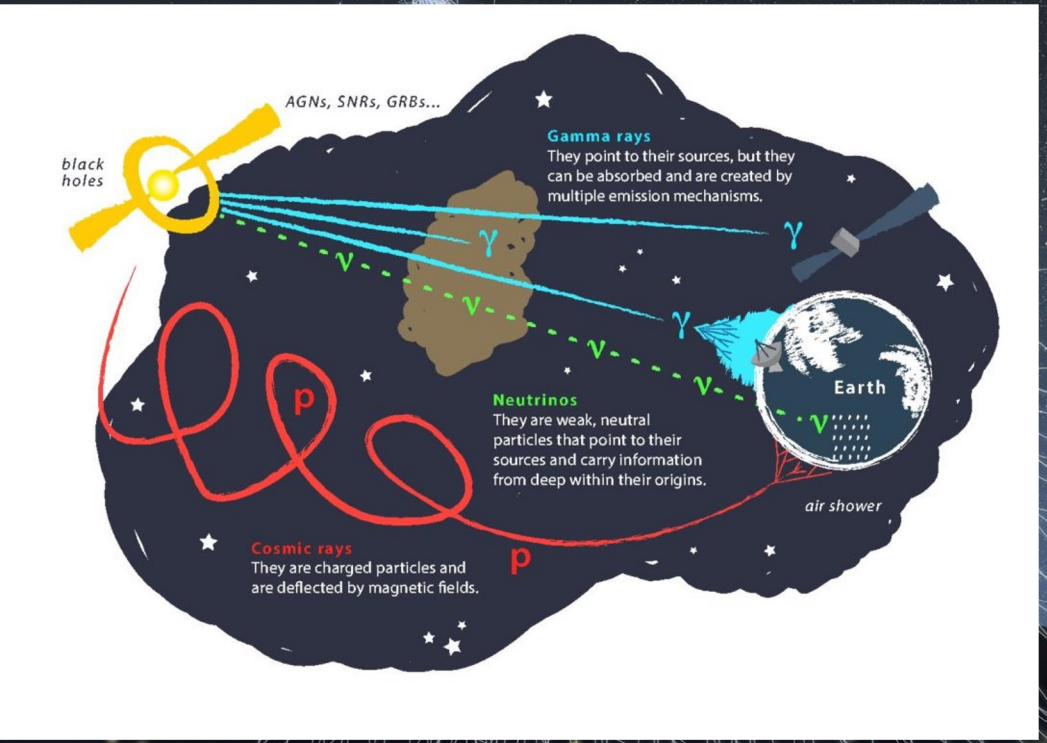
Index

- Introduction to cosmic rays and muons
- Experimental setups and measurements
- Results and discussion
- Uncertainties and efficiency



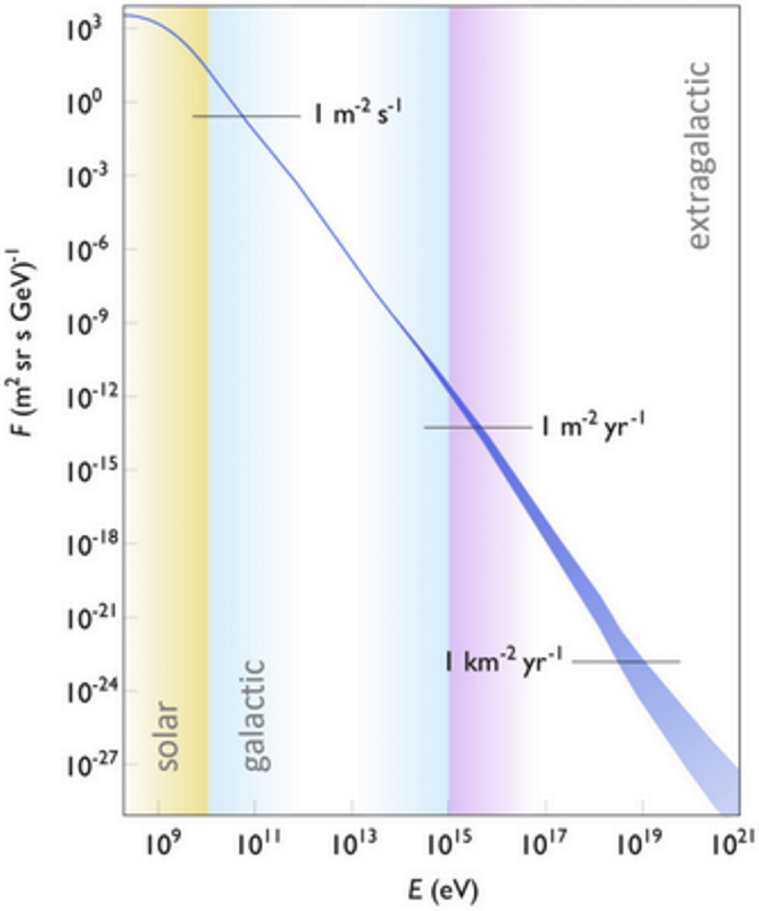
Introduction to cosmic rays and muons

Primary cosmic rays

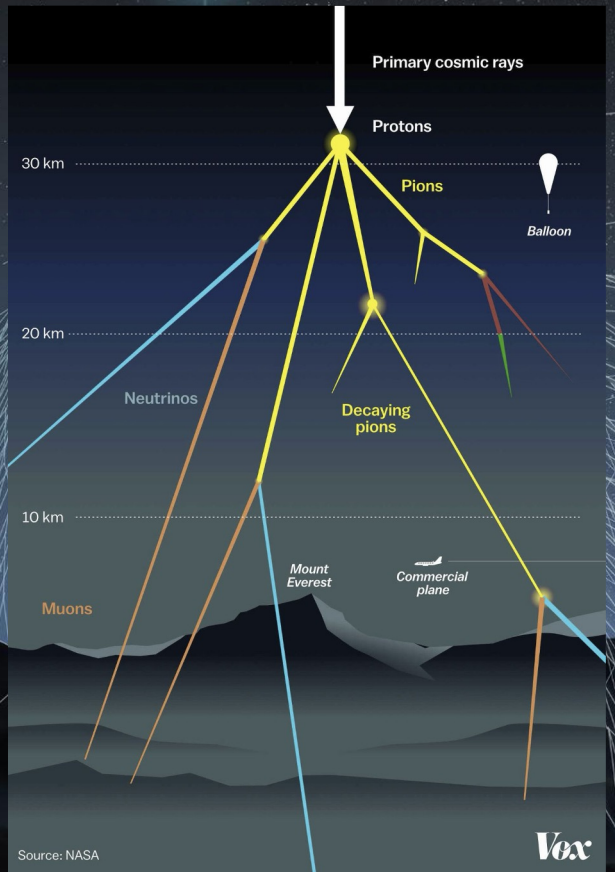


- Particles with (extra)galactic or solar origin e.g.:
  - Fusion processes in sun
  - Supernovas
  - …
- Primarily protons and α-particles

Energy distribution



Secondary cosmic rays



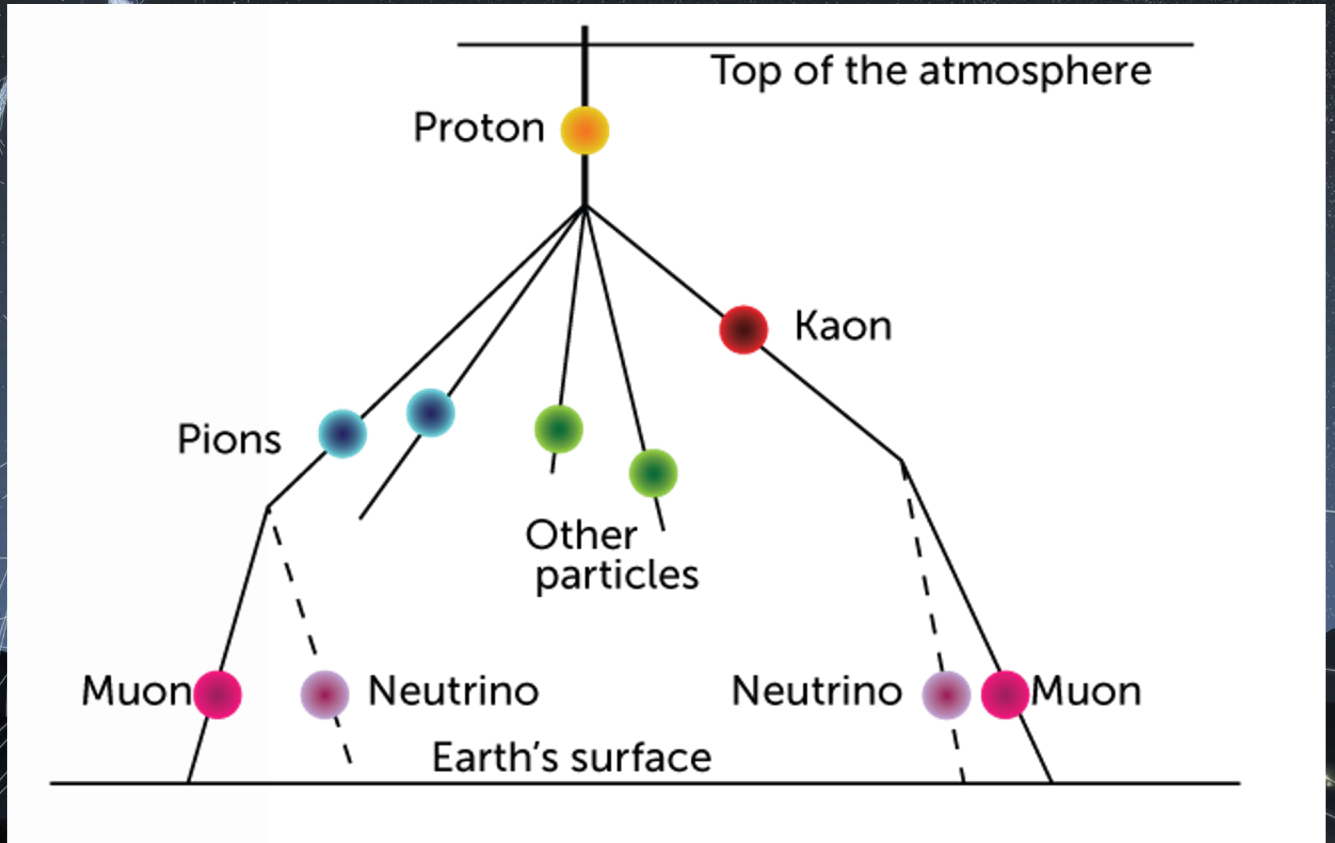
- Reactions of primary cosmic rays in upper atmosphere:
  - Production of baryonic matter:
    - Protons, Neutrons, **Pions, Kaons**

- Decay of Pions and Kaons (very short lived):

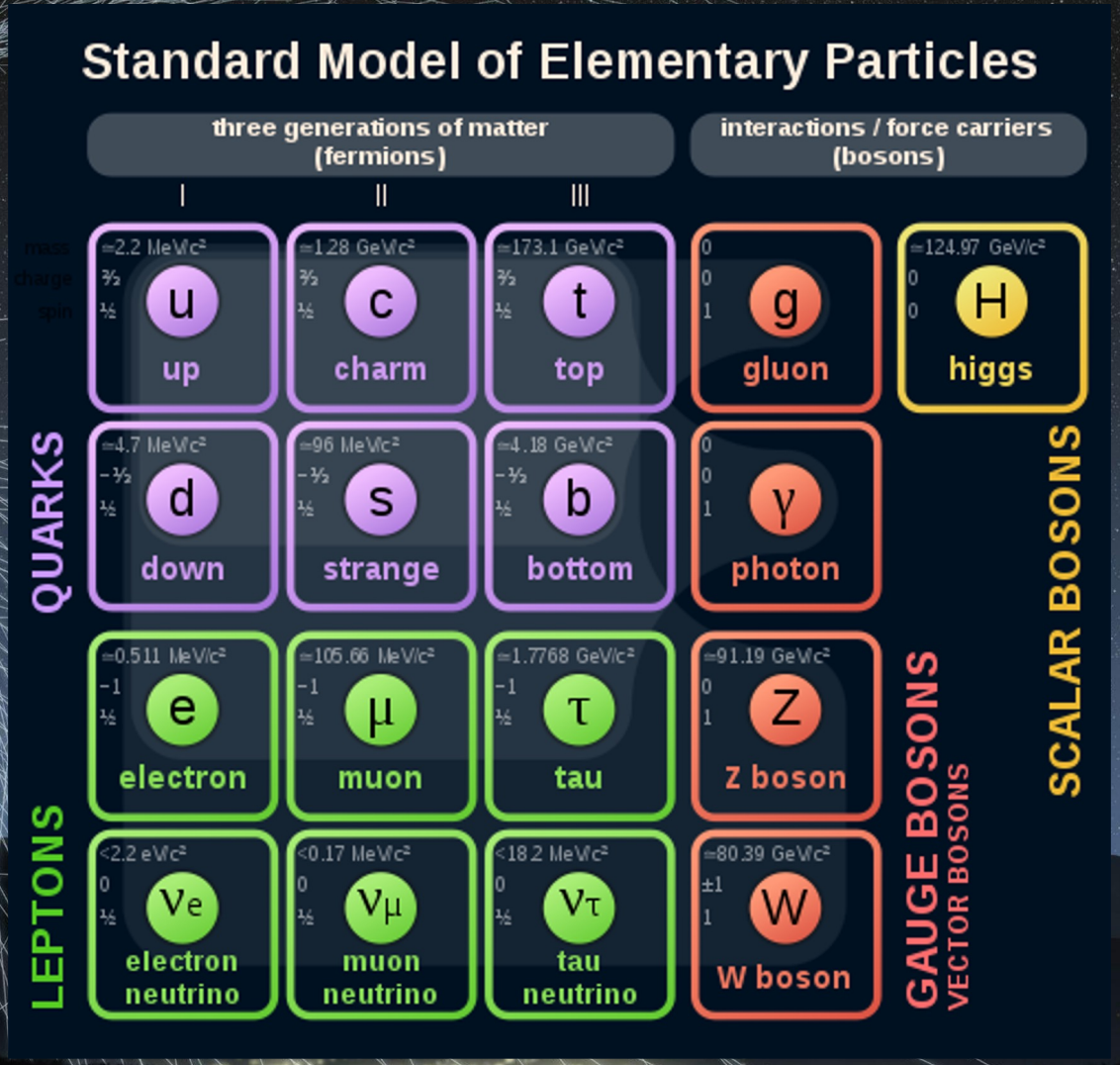
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

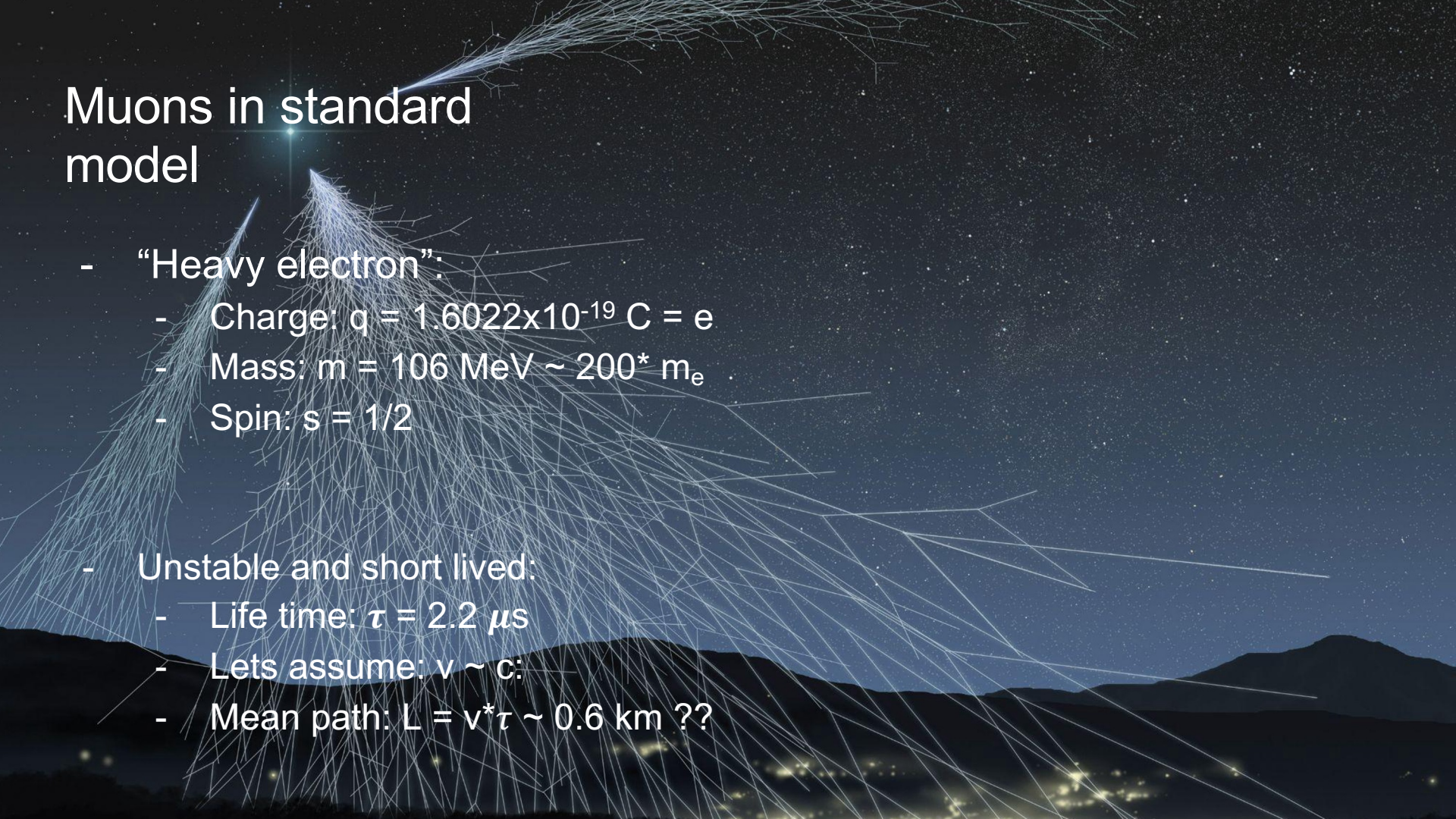
- → Production of muons in upper atmosphere (~10km)

Secondary cosmic rays



Muons in standard model





Muons in standard model

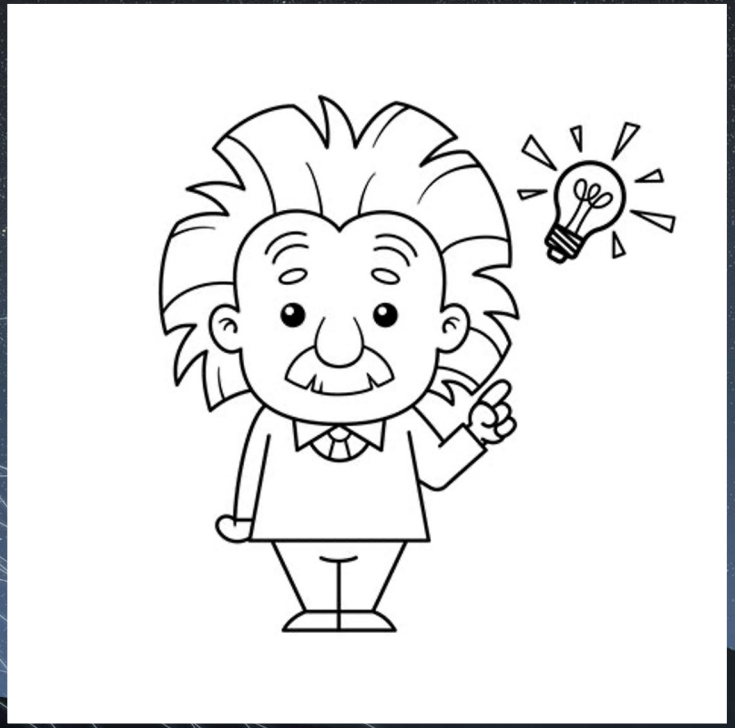
- “Heavy electron”:
  - Charge: q = 1.6022x10^{-19} C = e
  - Mass: m = 106 MeV ~ 200* m_e
  - Spin: s = 1/2

- Unstable and short lived:
  - Life time: τ = 2.2 μs
  - Lets assume: v ~ c:
  - Mean path: L = v*τ ~ 0.6 km ??

Muons in standard model

- “Heavy electron”:
  - Charge: q = 1.6022x10^{-19} C = e
  - Mass: m = 106 MeV ~ 200* m_e
  - Spin: s = 1/2

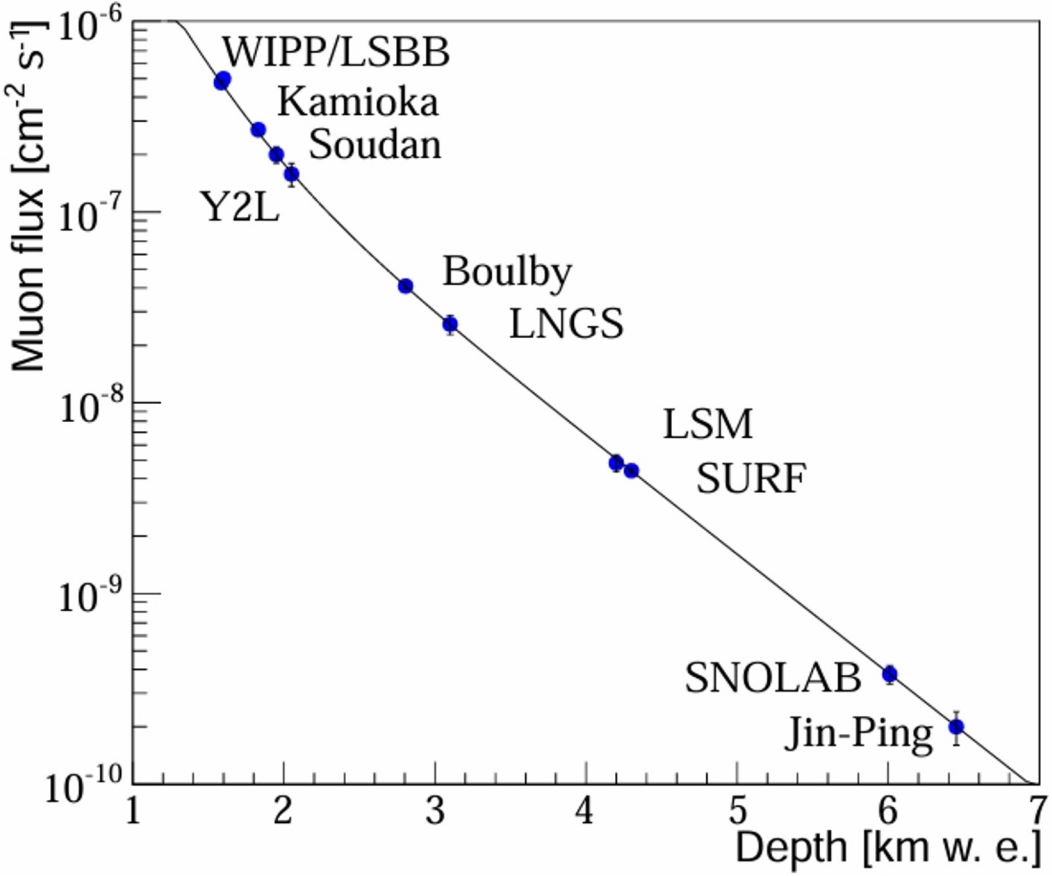
- Unstable and short lived:
  - Life time: τ = 2.2 μs
  - Lets assume v~c:
  - Mean path: L = v*τ ~ 0.6 km



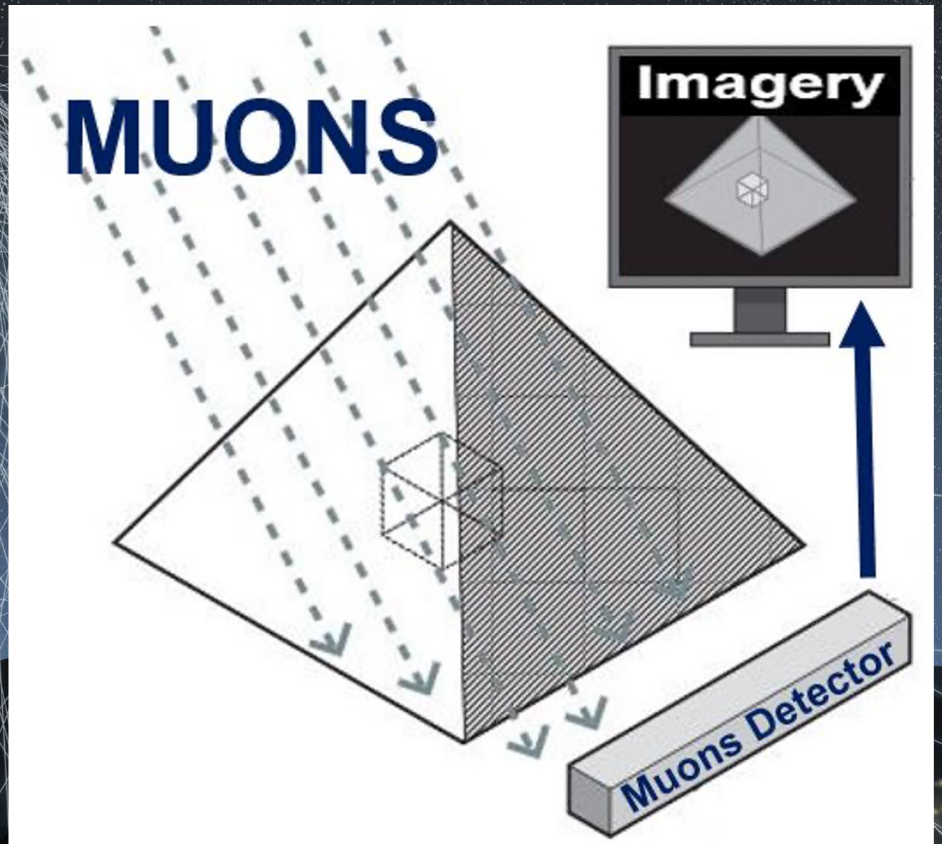
Muon Flux

- Muon Flux at sea level: 1 cm^2/s
- Minimum Ionizing Particle:

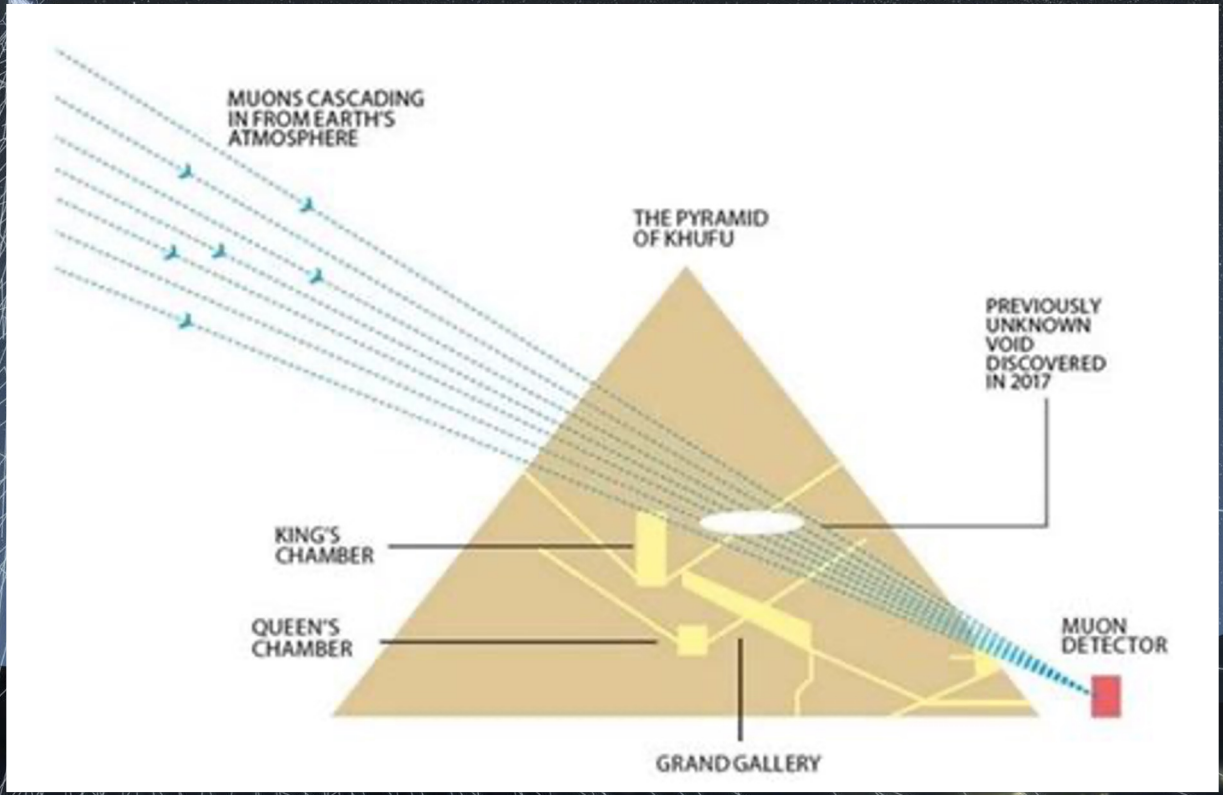
  → Coincidence rate (Later)

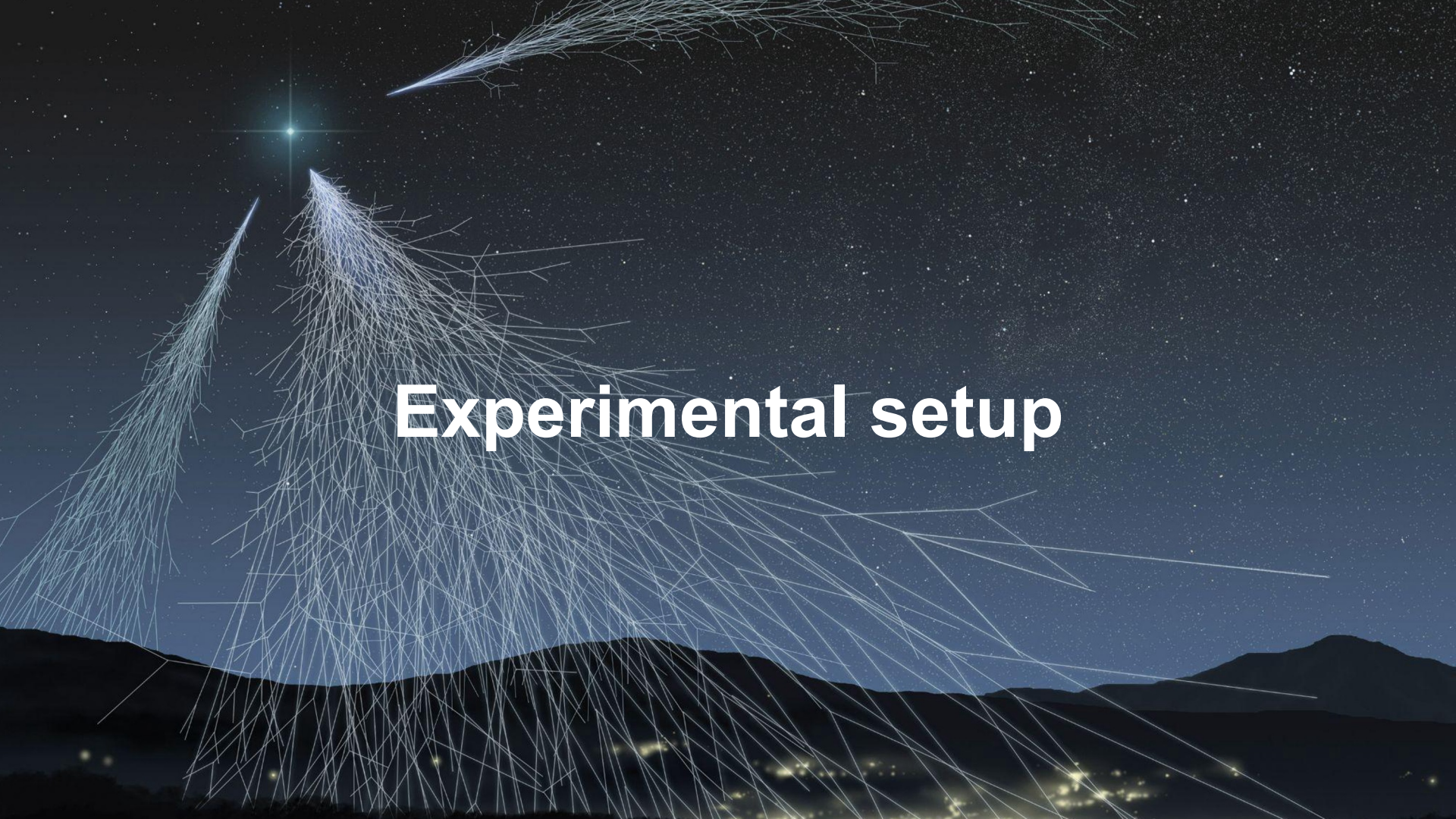


Muongraphy



Muongraphy


MUONS CASCADING IN FROM EARTH'S ATMOSPHERE
THE PYRAMID OF KHUFU
PREVIOUSLY UNKNOWN VOID DISCOVERED IN 2017
KING'S CHAMBER
QUEEN'S CHAMBER
MUON DETECTOR
GRAND GALLERY


Experimental setup

Setup

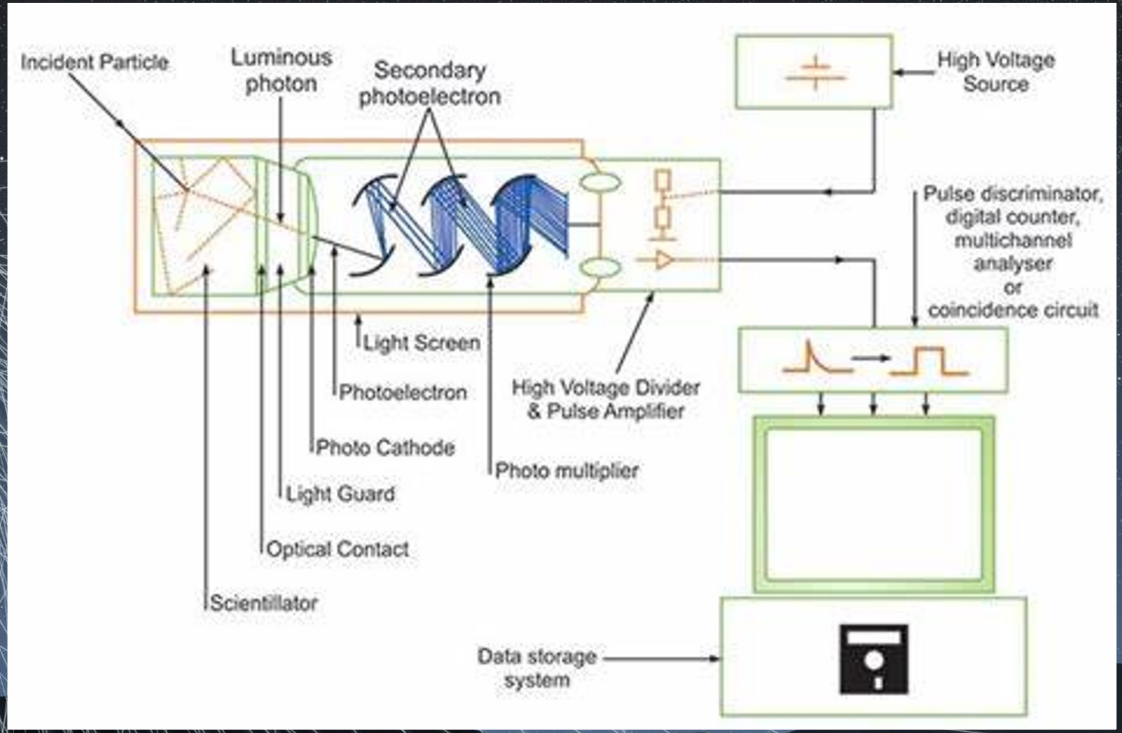
Power supply

Coincidence module

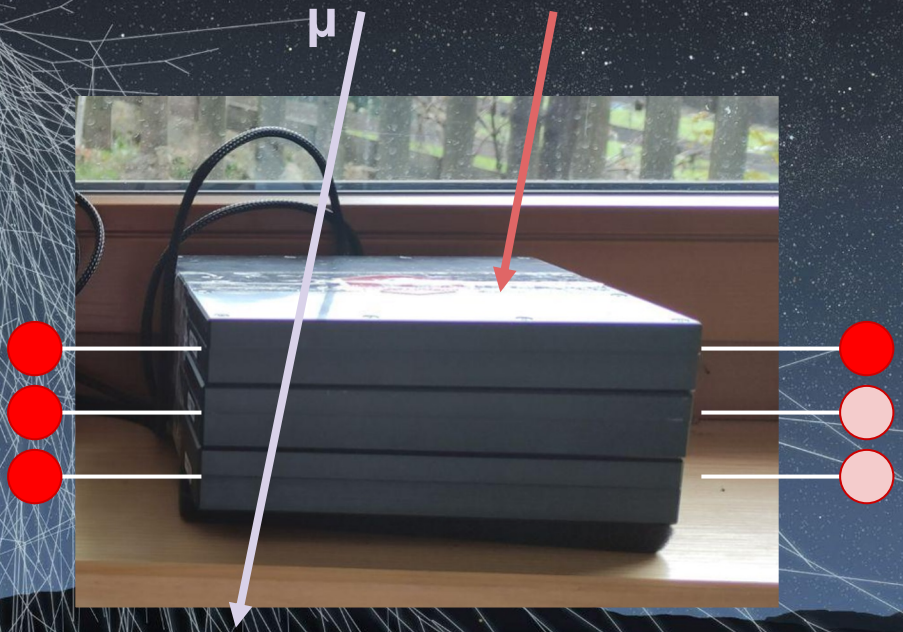
Detection system

Detection system

15×15×1 cm³,
plastic scintillator

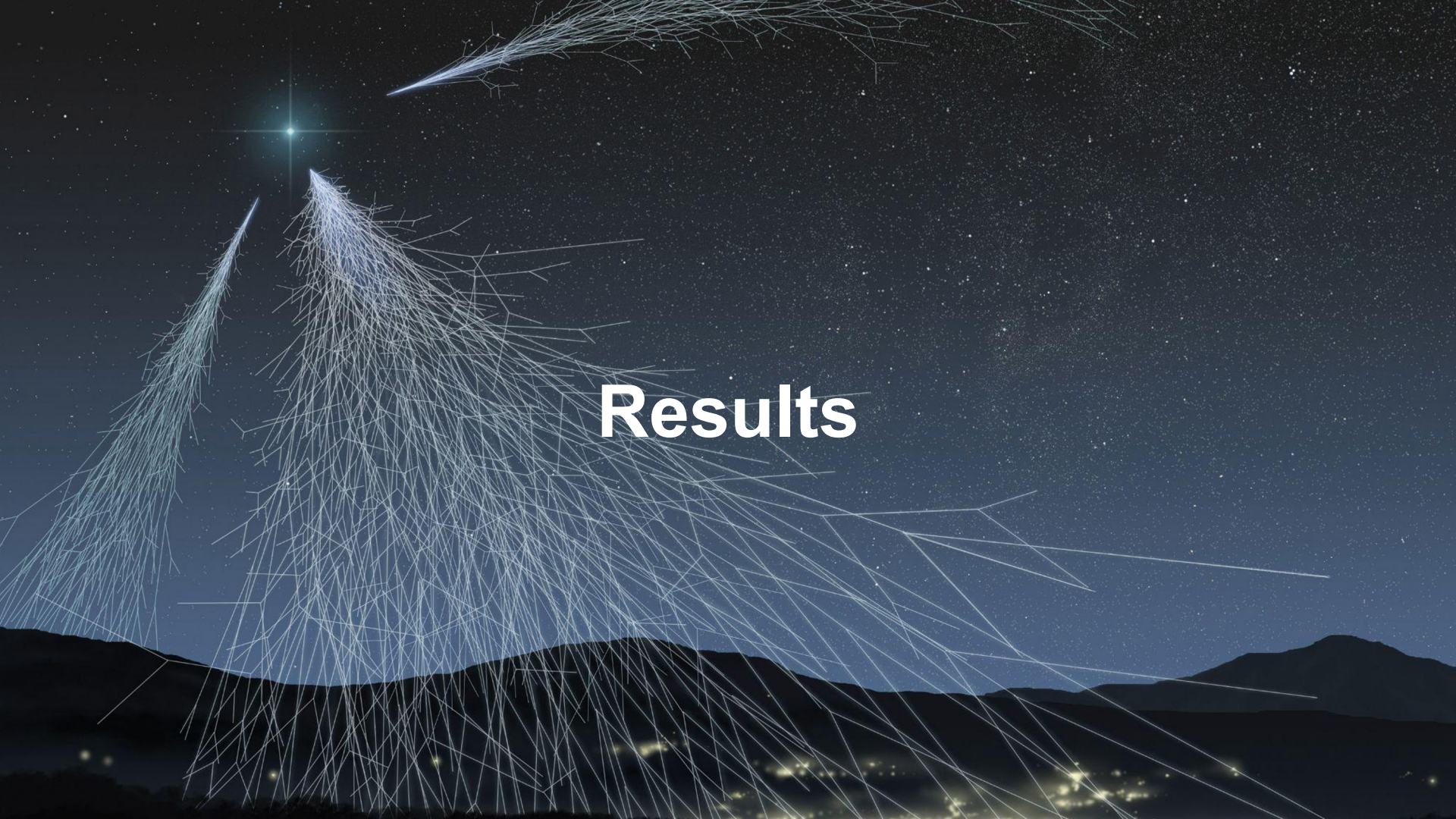


Coincidence module

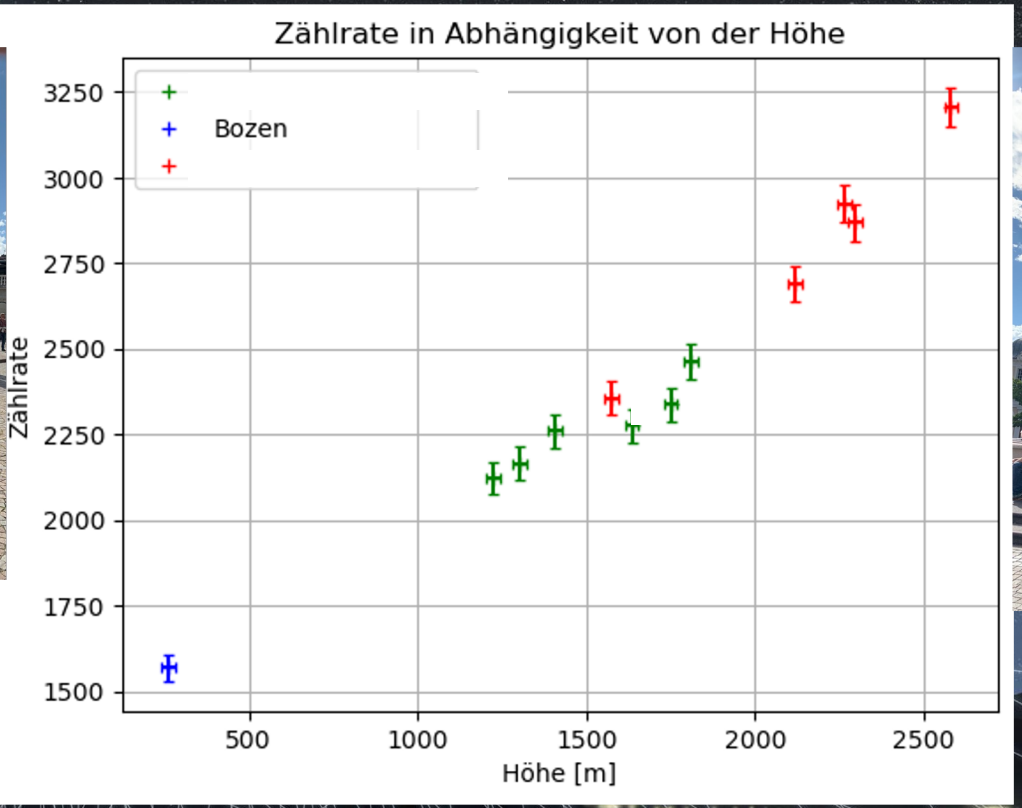


Measurements

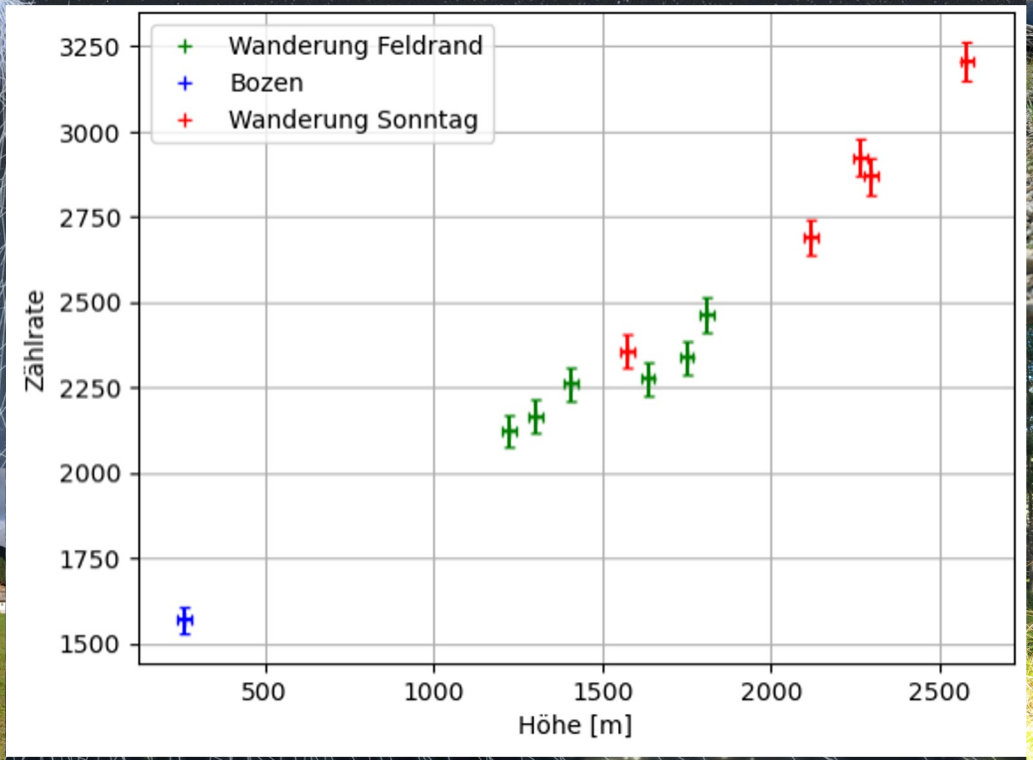
Date	Location	Setup, measurements
25th September	Feldrand	Separated, different angles
26th September	Mine	Stacked, @ different depths
27th September	Bozen, Waltherplatz	Stacked
28th September	Feldrand	Separated, different angles
28th September	Mairwald - Staubecken	Stacked, @ different depths
29th September	Reinswald-Kassianspitze-Latzfonser Kreutz	Stacked, @ different depths
29th-30th Sept.	Feldrand	Stacked, long run
30th-31st Sept.	Feldrand	Efficiency and random coincidence


Results

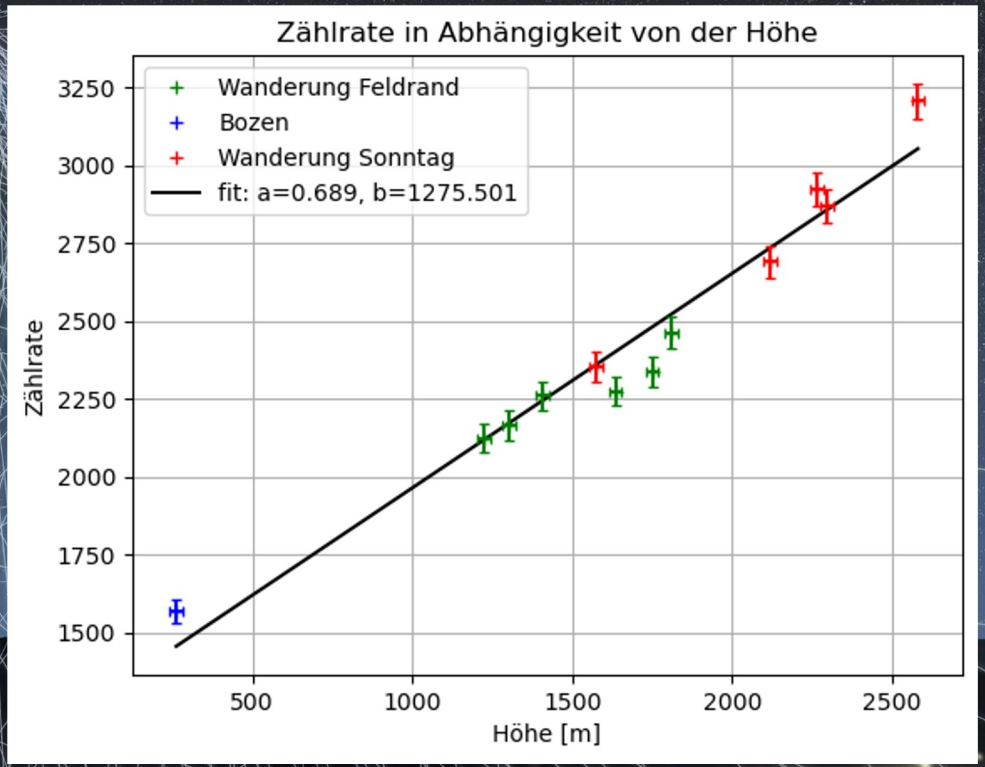
Count rate VS altitude



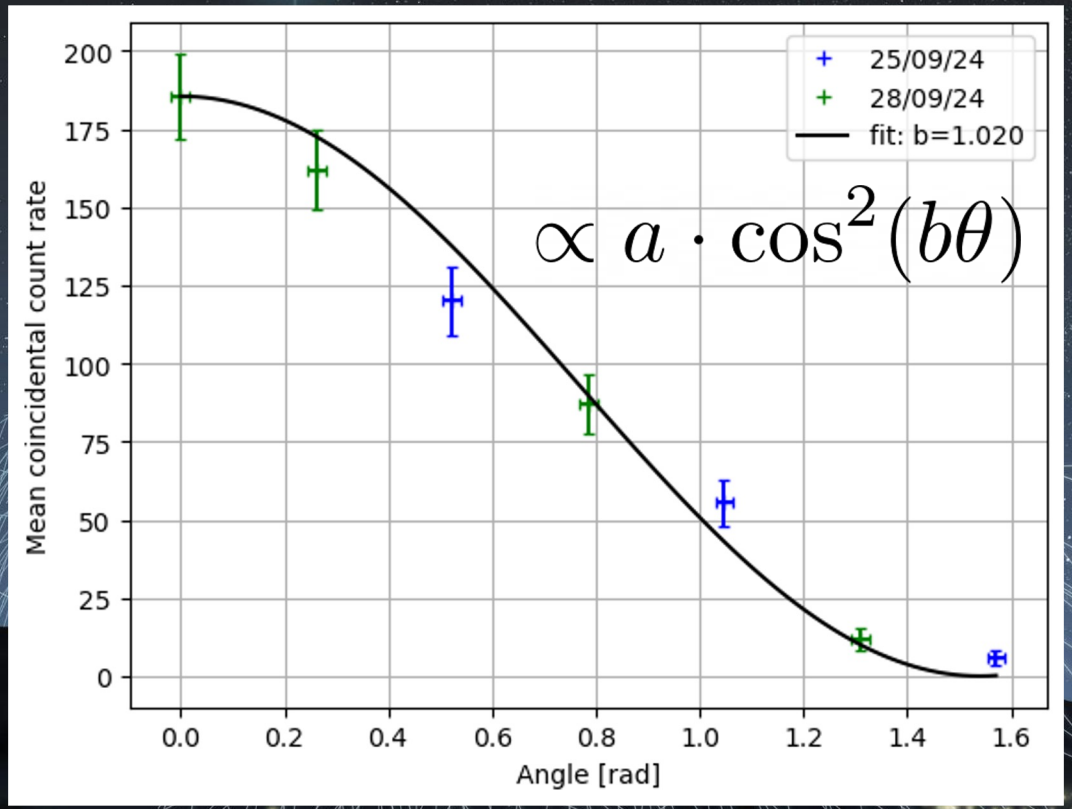
Count rate VS altitude

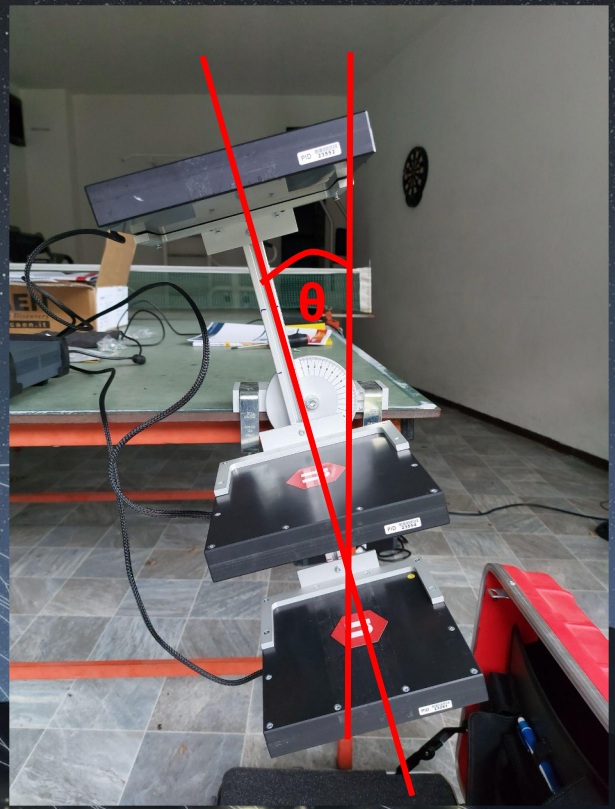


Count rate VS altitude

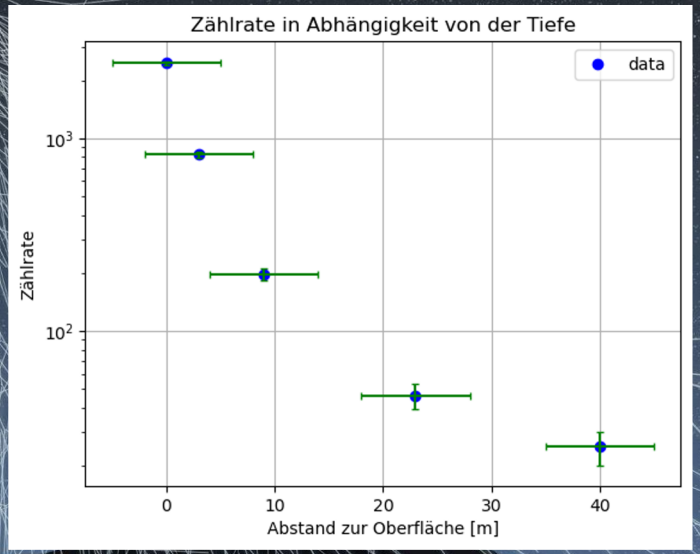


Winkelabhängigkeit

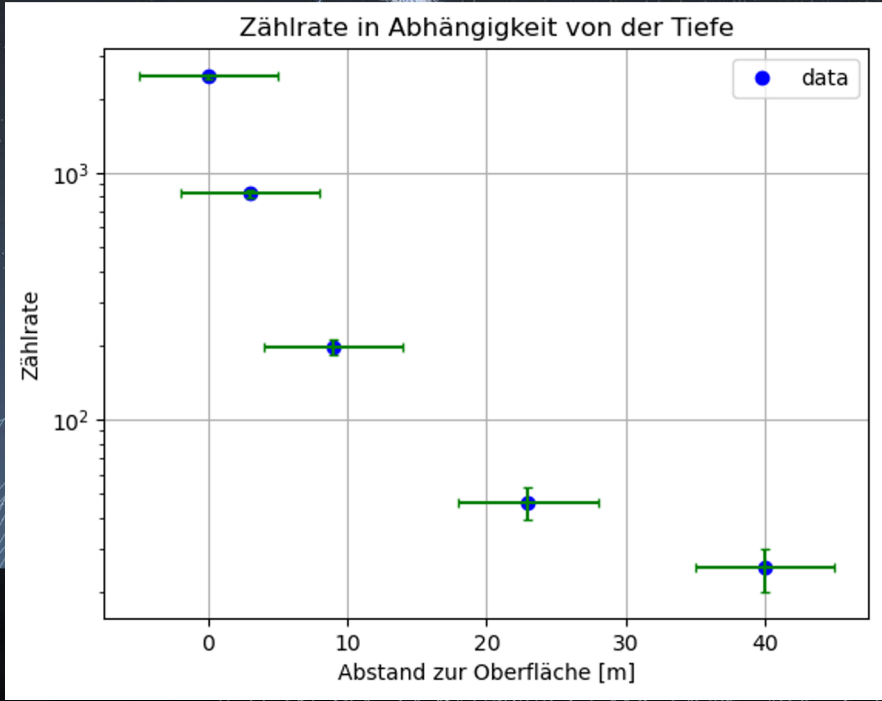


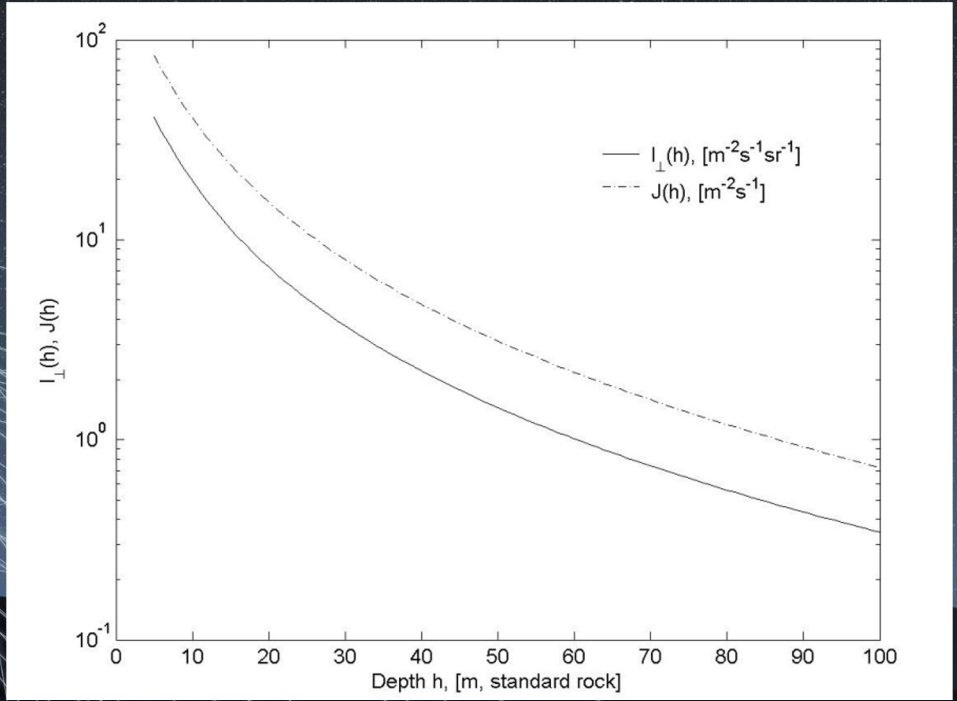


Depth Measurements

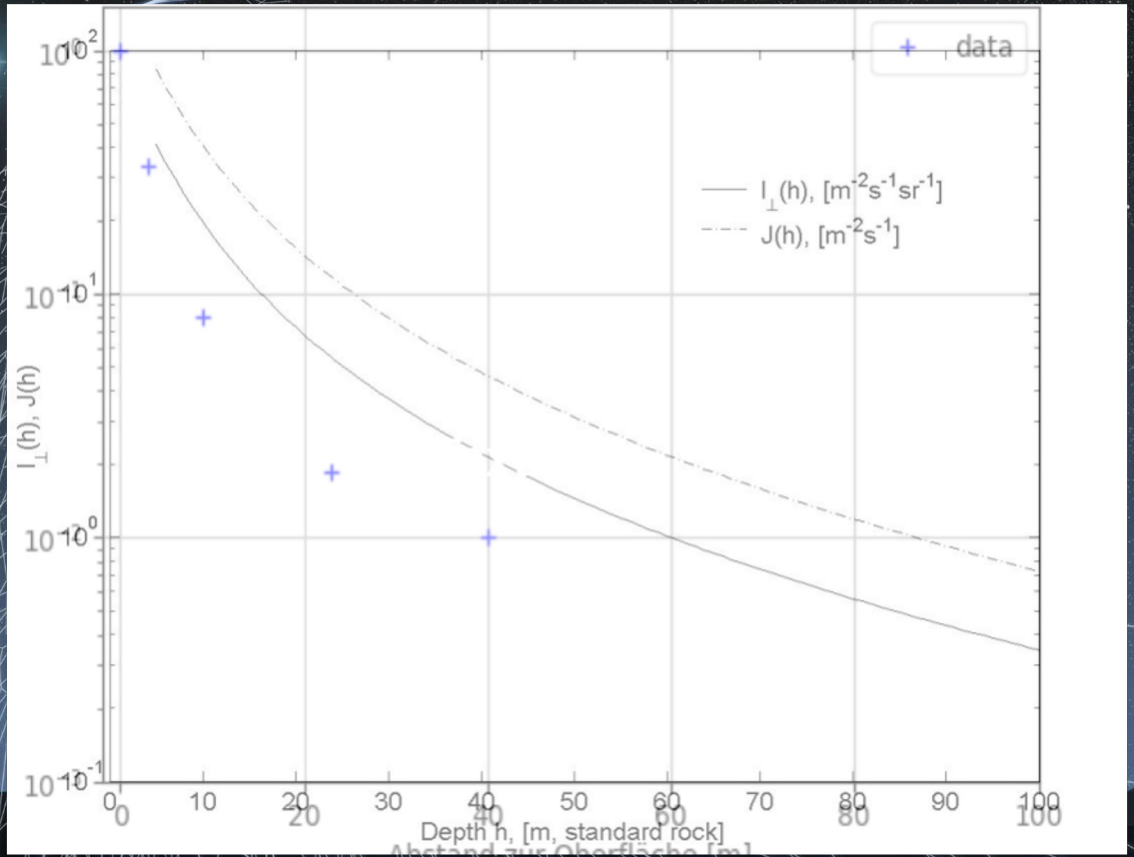


Depth Measurements

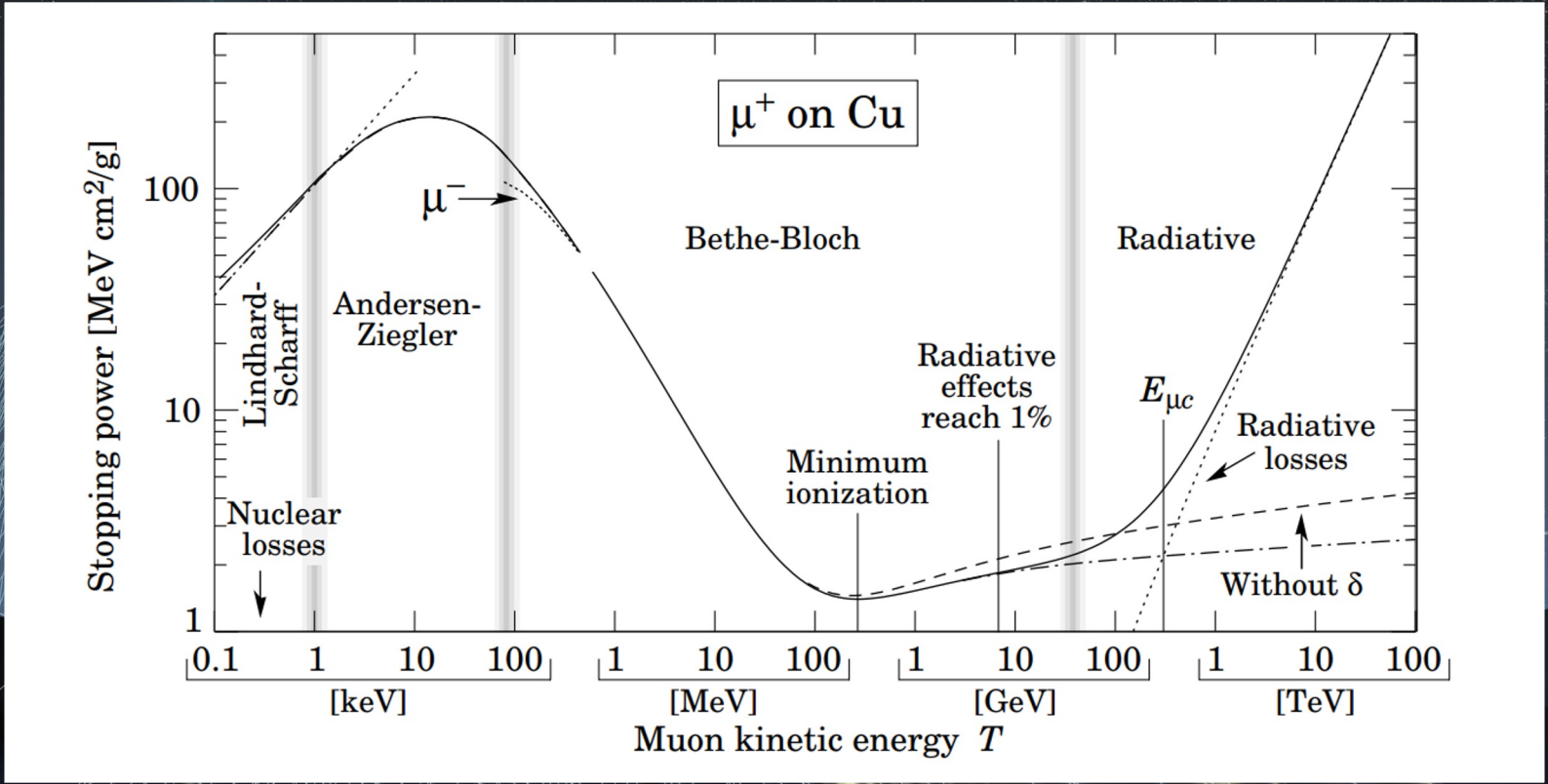




[1] Cosmic muon flux at shallow depths underground., Bogdanova, Gavrilov, Kornoukhov, Starostin


data
$I_\perp(h)$, [$m^{-2}s^{-1}sr^{-1}$]
J(h), [$m^{-2}s^{-1}$]
$I_\perp$(h), J(h)
Depth h, [m, standard rock]
Abstand zur Oberfläche [m]

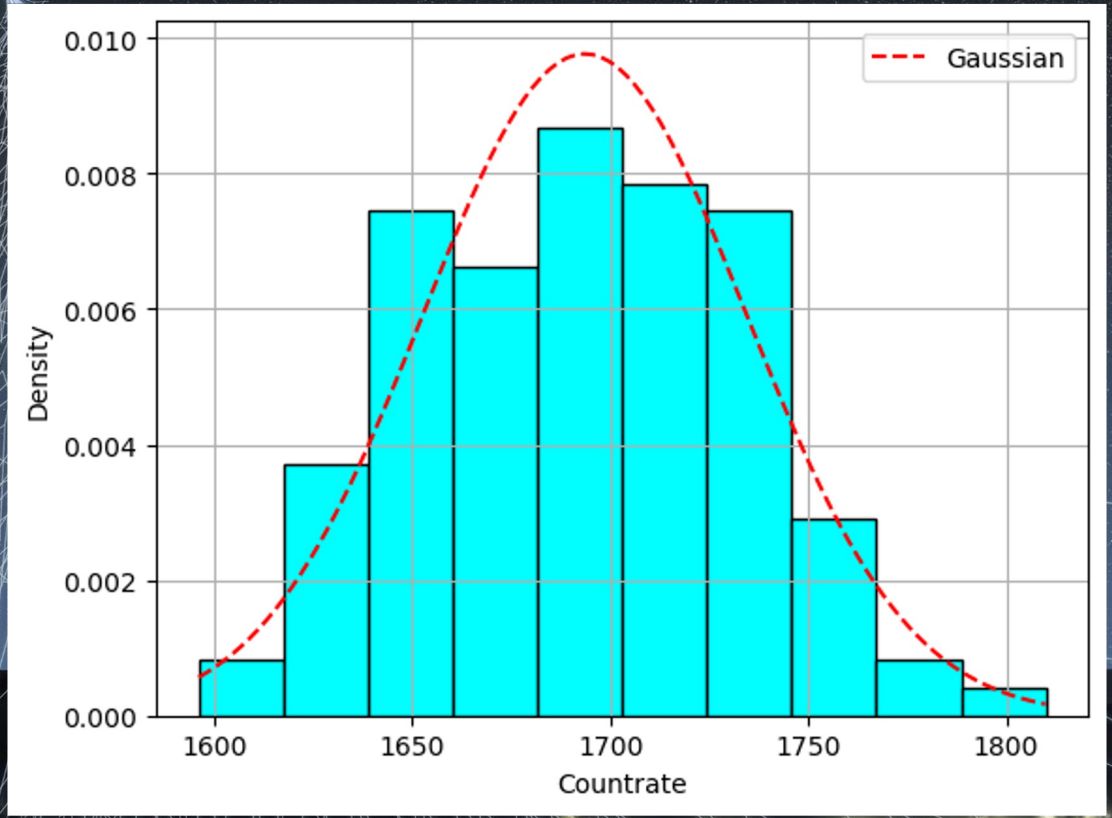
Bethe-Bloch Curve



[2] MUON STOPPING POWER AND RANGE TABLES 10 MeV–100 TeV, Groom, Mokhof, Striganov

Long run measurement

Avg = 1693.5
Var = 1668.3

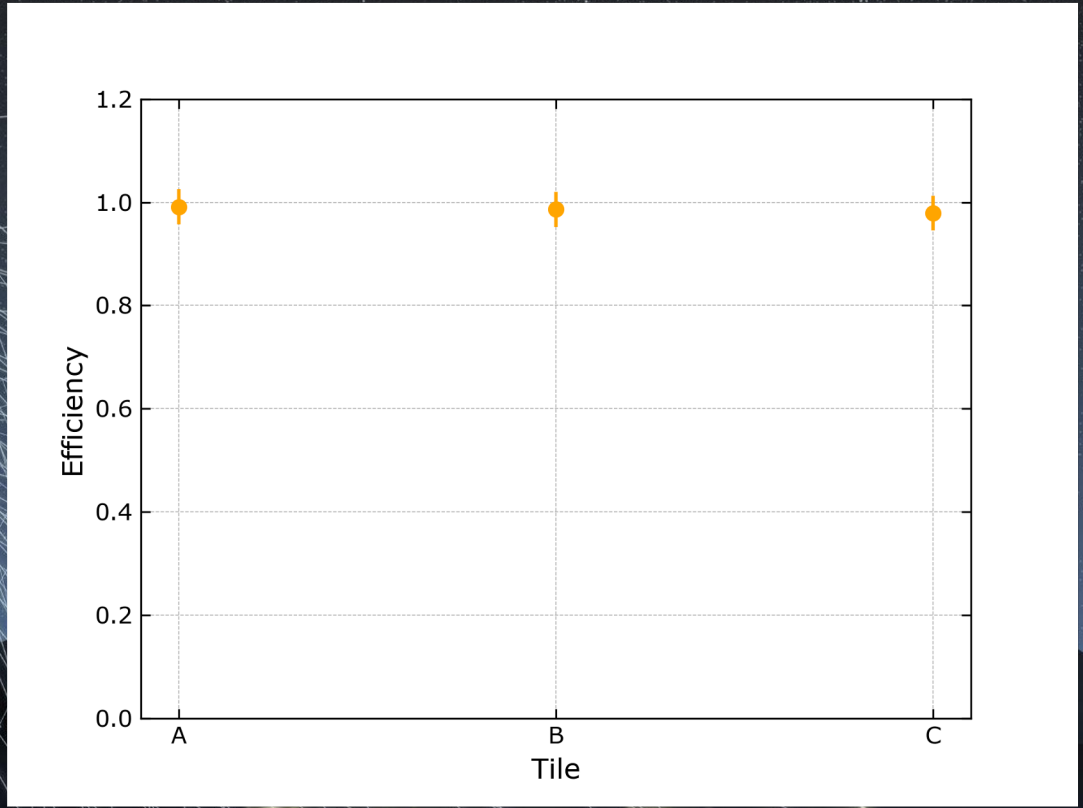



Uncertainties and efficiency

Efficiency

$$\epsilon_A = \frac{N_{ABC}}{N_{BC}}$$

A	99,1%
B	98,6%
C	97,9%



Random coincidences