

#### What is a particle?

**KSETA** Tutorial

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## **History of the Standard Model**

## Introduction

The Standard Model of particle physics was developed throughout the latter half of the 20<sup>th</sup> century as an result of many discoveries in the same century



## Years of discovery

Discovery of many new particles ...



#### In the early days

- **1897** J. J. Thomson discovers that cathode rays consist of unique particles and measures the charge mass ratio (independent of the cathode material)  $\Rightarrow e^-$  discovered
- 1911 Discovery of the atomic nucleus by E. Rutherford
- 1919 E. Rutherford discovers the proton



#### **The Particle Zoo**

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**1936** C. D. Anderson and S. Neddermeyer discover a new particle in cosmic rays  $\Rightarrow \mu$ 

**1947** Discovery of the Pion  $(\pi)$  and the Kaon (K) in cosmic rays

Meson octet:



q = -1 q = 0

Is there a pattern behind all particles? 1964 Gell-Mann and Zweig postulate the existent of quarks, which the hadrons consist of

## **Discovery of Quarks**



#### Deep inelastic scattering

**1968** At Stanford Linear Accelerator Center (SLAC): Electrons were fired on protons and neutrons in atomic nuclei  $\Rightarrow$ Internal structure of p and ndiscoverd



## Where are the other Leptons ...

#### Tau

**1975** Detection of the  $\tau$  by M. L. Perl and his colleagues at the SLAC-LBL group

- **1930** W. Pauli postulates the neutrino
- **1956** Discovery of  $\nu_e$  using the reaction  $\bar{\nu}_e + p \rightarrow n + e^+$  (C. L. Cowan et al.)
- **1962** Discovery of  $\nu_{\mu}$  by L. Ledermann, M. Schwartz, and Jack Steinberger
- 2000 DONUT collaboration discovers  $\nu_{\tau}$



#### ... and the Bosons?

#### Photon

# **1905** A. Einstein proposes the photon to describe the photoelectric effect (Nobel prize 1921)

W and Z

**1983** Discovery of W and Z at CERN

#### Gluon

**1979** Discovery of g at the DESY in 3-Jet events

## Last but not least, the Higgs

**2012** Discovery of H by CMS and ATLAS collaboration

- H decays into many different particles
- Choose decays with clear signature



## Summary

- Over 100 years of discoveries
- Particle zoo structured with the Standard Model
- A lot of effort was needed to detect all these particles
- Some latest particle discoveries can not be explained by the Standard Model

