# PARTICLE PHYSICS

**HST2026 Study Group 7**

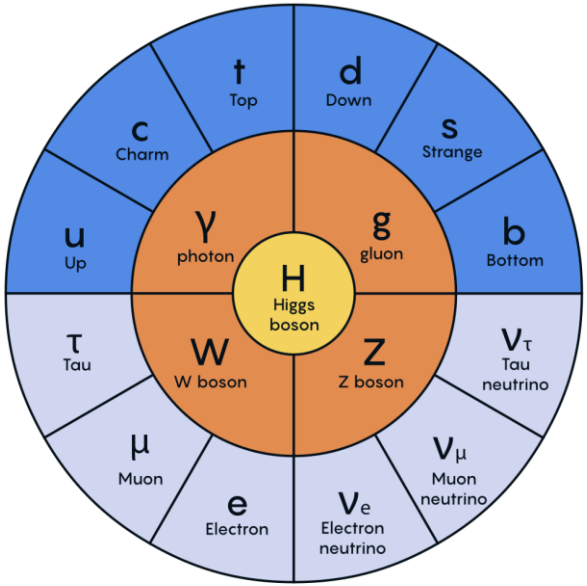
# Key Ideas in Particle Physics

**What?**

**Why?**

**How?**

*The catalog of known particles & forces is the Standard Model (SM)*



# Curriculum & Classroom Connections

## Radioactivity

Alpha, Beta and Gamma decays is an opportunity to connect with particle physics:

- Conservation of Energy momentum and charge
- The difference between subatomic and elementary particles

## The properties of matter

The definition of Matter as anything that has a mass and a volume.

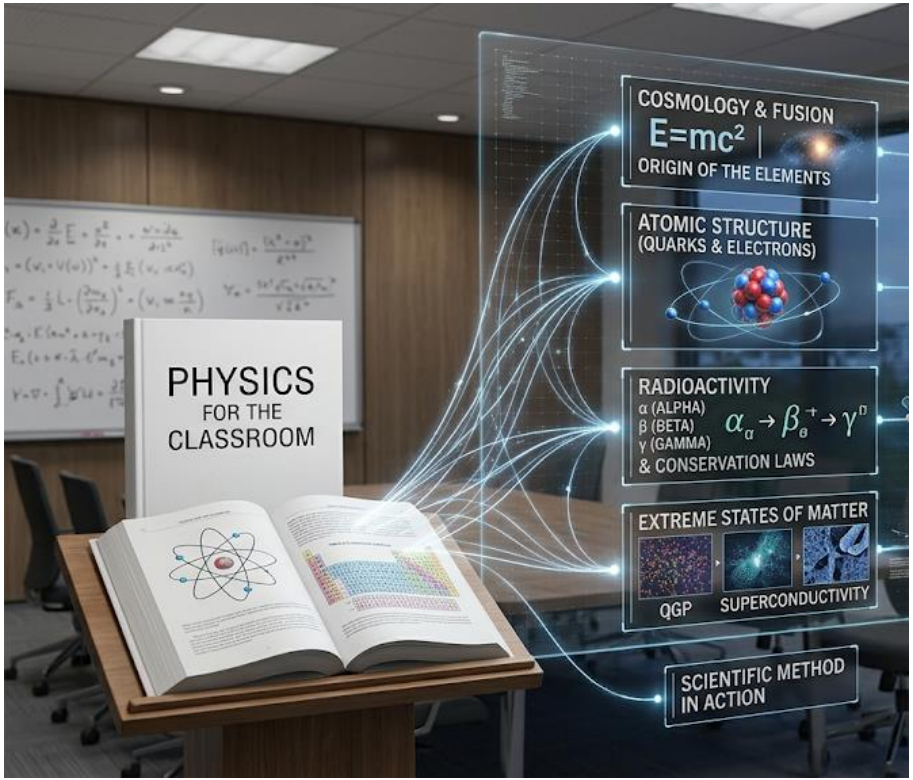
The quantum properties of some materials in extreme temperature conditions (superconductivity, QGP)

## The atomic structure

The difference between subatomic particles and elementary particles, the origin of the elements through the Big Bang ($E=mc^2$) and fusion in the stars.

## The scientific research in general

Particle physics is a great example of application of the scientific method



# Potential Students' Conceptions & Challenges

## Lots of new terms

Students can be discouraged by the amount of new vocabulary

## Scale visualization

Students might be confused by what is smaller than what.
Cells - Molecules - Atoms - Subatomic particles - Elementary particles

## In conflict with their prior knowledge

It is very different from classical physics. Some definitions have to change. The wave-particle duality can be counter intuitive

## Extreme abstraction

- There is almost no direct hands-on experiment to do in class.
- Analogies can be useful but sometimes misleading.
- The ball misconception of the particle and the outdated planetary models of the atom

# Best Practice Example

**The atomic structure** **Students play a game that connect particle physics with the structure of a subatomic particle**

They have to build a particle with quarks depending on a certain budget of charge and properties they receive. These could be represented with 6 flavors of chocolates that have different properties (Baryon number and Charge) on their nutrition facts. Their mission would be to create a specific Baryon. Our mystery particle has a total charge of +1, baryon number of 1 and strangeness of -1.

| Quark | Symbol | Charge | Baryon Number | Strangeness |
|---|---|---|---|---|
| up | u | $+\frac{2}{3}$ | $\frac{1}{3}$ | 0 |
| down | d | $-\frac{1}{3}$ | $\frac{1}{3}$ | 0 |
| charm | c | $+\frac{2}{3}$ | $\frac{1}{3}$ | 0 |
| strange | s | $-\frac{1}{3}$ | $\frac{1}{3}$ | -1 |
| top | t | $+\frac{2}{3}$ | $\frac{1}{3}$ | 0 |
| bottom | b | $-\frac{1}{3}$ | $\frac{1}{3}$ | 0 |

# Useful Material & Resources

## CERN

- CERN Educational resources
- The mystery box experiment Lego OR 3D print Link
- The personality quiz
- DIY cloud chamber + video
- DIY Particle Detector (advanced material required)
- Particle Builder board game
- Particle Twister
- Quark Puzzle 3D print
- cernland.net

### Other resources

- PhET simulations
- Einstein-First
- Quantum Girls
- QuarkNet
- ParticleAdventure
- Glow in the dark
- Flame colors
- Photoelectric effect
- Plasma ball

## PERIMETER INSTITUTE

- The wooden block
  to introduce the concept of scientific modelling
- The two slits experiment & Sand in a cup
  to investigate the nature of the electron and the particle-wave duality
- Beyond the atom
  - Taming the particle zoo to sort cards to find patterns
  - Bubble chamber detective to use their knowledge of magnetic fields and forces, conservation of momentum, and conservation of charge to infer.
  - Feynman diagram cards to study and manipulate

## YouTube CH

- CERN for an immersion to the greatest experiments
- ScienceClic for great overviews, all levels
- Kurzgesagt to spark curiosity and wonder
- Veritasium for clear demonstrations
- ATLAS Experiment & CMS Experiment
  For short interviews with familiar faces

# HST2026 Study Group 7

Marianne (Norway), Maria (Greece), Abdulrahman (Lebanon), Gloria (Italy), Saf (Belgium)

## One way in which our thinking has changed…

*We never imagined before* ***how research at CERN pushes the boundaries of technology****. The innovations developed for particle physics have found applications far beyond CERN, from medical imaging and cancer treatment to computing and space research.*

*This experience has shown us that* ***publicly funded projects can achieve extraordinary results*** *when they are supported by strong governance, a clear vision, and a culture of excellence.*

## Highlights, snapshots, farewell messages…

We feel extremely lucky to have participated in this program and look forward to bringing CERN's messages into our classroom and inspire the next generation of researchers

**Thank you** Anja, Milena and all the lecturers for making this HST 2026 experience so enriching !!