Beamline for Schools

A physics competition for high-school students

Welcome to CERN and DESY!

cern.ch/bl4s

powered by CERN & DESY

What will we do in the next hour?

Overview of the competition

- Requirements to take part
- Test-beam facilities
- Particle detectors

Website:
https://cern.ch/bl4s

Q&A session ~35 min

What is BL4S?

Perform your own experiment at a real particle accelerator!

You can be a scientist

Teams of high school students from all around the world can propose an experiment that they want to perform at a particle accelerator.

What is BL4S?

The 2025 edition is the 12th edition of the competition!

Who can participate in BL4S?

- **Teams:** min. 5, max. 9 people, ≥ 16 years old (when submitting your proposal)
- Enrolled in **high-school** in the school year 2024/2026 or gap between school and university
- Each team has to be led by an adult “**team coach**” (max. 2 per team)

Special prizes 2024

Award for the best video proposal: BL4S t-shirts and DIY cloud chamber – **3 teams**

Award for the best outreach proposals: BL4S t-shirts and telescopes (sponsored by the Belgian project "Stars Shine For Everyone") – **15 teams**

Shortlisted teams: BL4S t-shirts and DIY cloud chamber and pixel detector – **50 teams**

Winning teams 2025

Two winning teams will be invited to **CERN** in Geneva, Switzerland, to conduct their proposed experiments (~2 weeks).

One winning team will be invited to **DESY** in Hamburg, Germany.

BL4S will cover the full costs of the winners' stay at CERN or DESY, including travel, accommodation at CERN or DESY, and meals. Before their arrival, the winning teams will have the unique opportunity to work together with scientists to optimise their proposed experiment.

Experiment proposal

Written proposal (~1000 words)

- Motivation (~ 100 words)
- Proposed experiment (~800 words)
- What you hope to take away from this experience (~100 words)

Video proposal

(~1 min, **optional**)

Experiment proposal

The proposals will be evaluated by a committee of scientists.

Evaluation Criteria:

- Feasibility of the experiment
- Motivation of your experiment idea and your participation
- Creativity of the experiment
- Following a scientific method

Experiment proposal

You are not alone!

Get in touch with your national contacts or with us directly (see website)

Outreach proposal

Would you like to win an outreach prize (i.e. a telescope)?

Describe a **science education or outreach activity** that the members of your team have already organised or will organise in their community (up to 200 words; in addition to the 1000 words limit of your written experiment proposal).

Target audience: a part of your community usually less exposed to science

Proposal submission

The submission opens in January 2025.

Submission deadline:

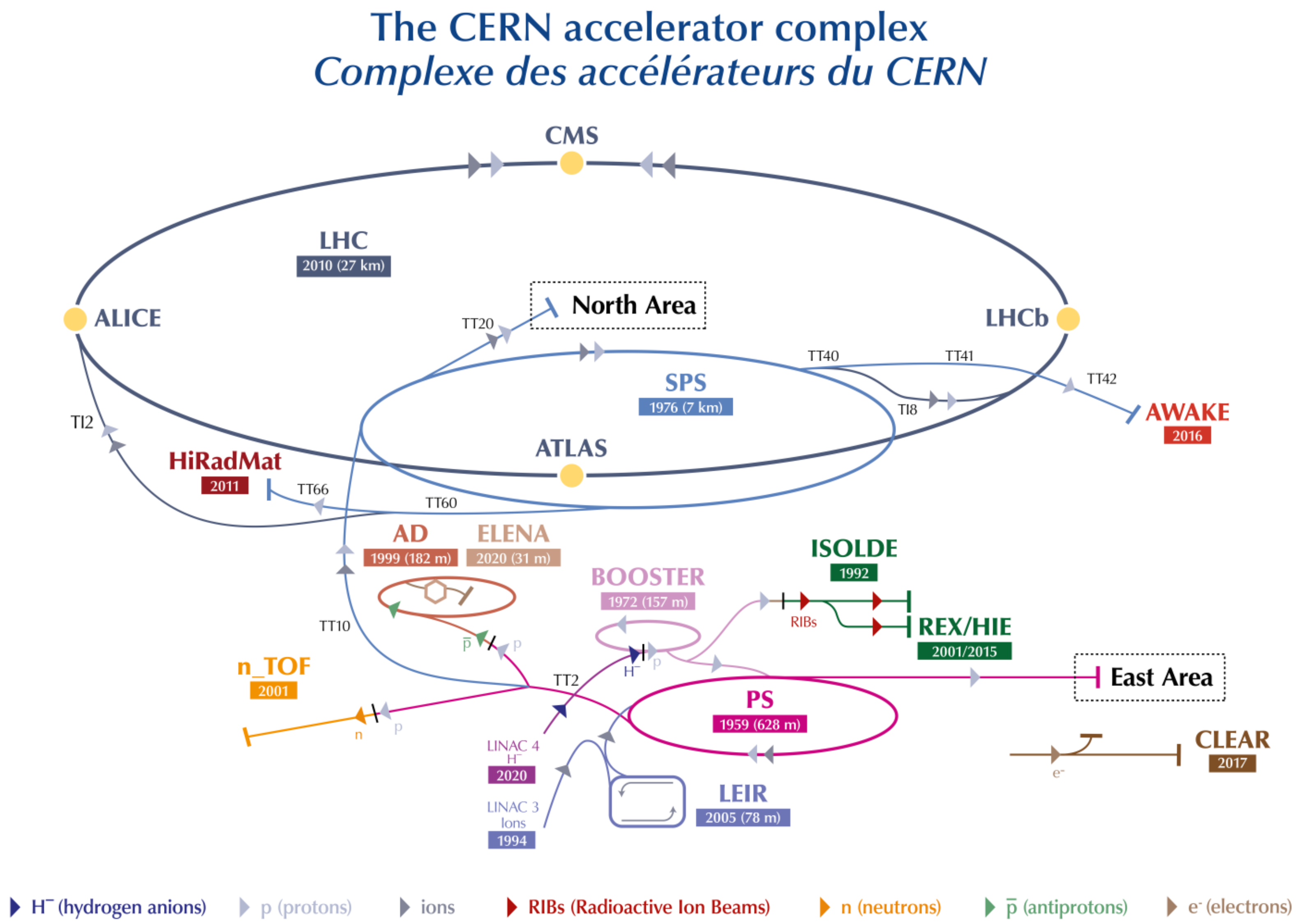
April 10, 2025

Preparing your experiment proposal

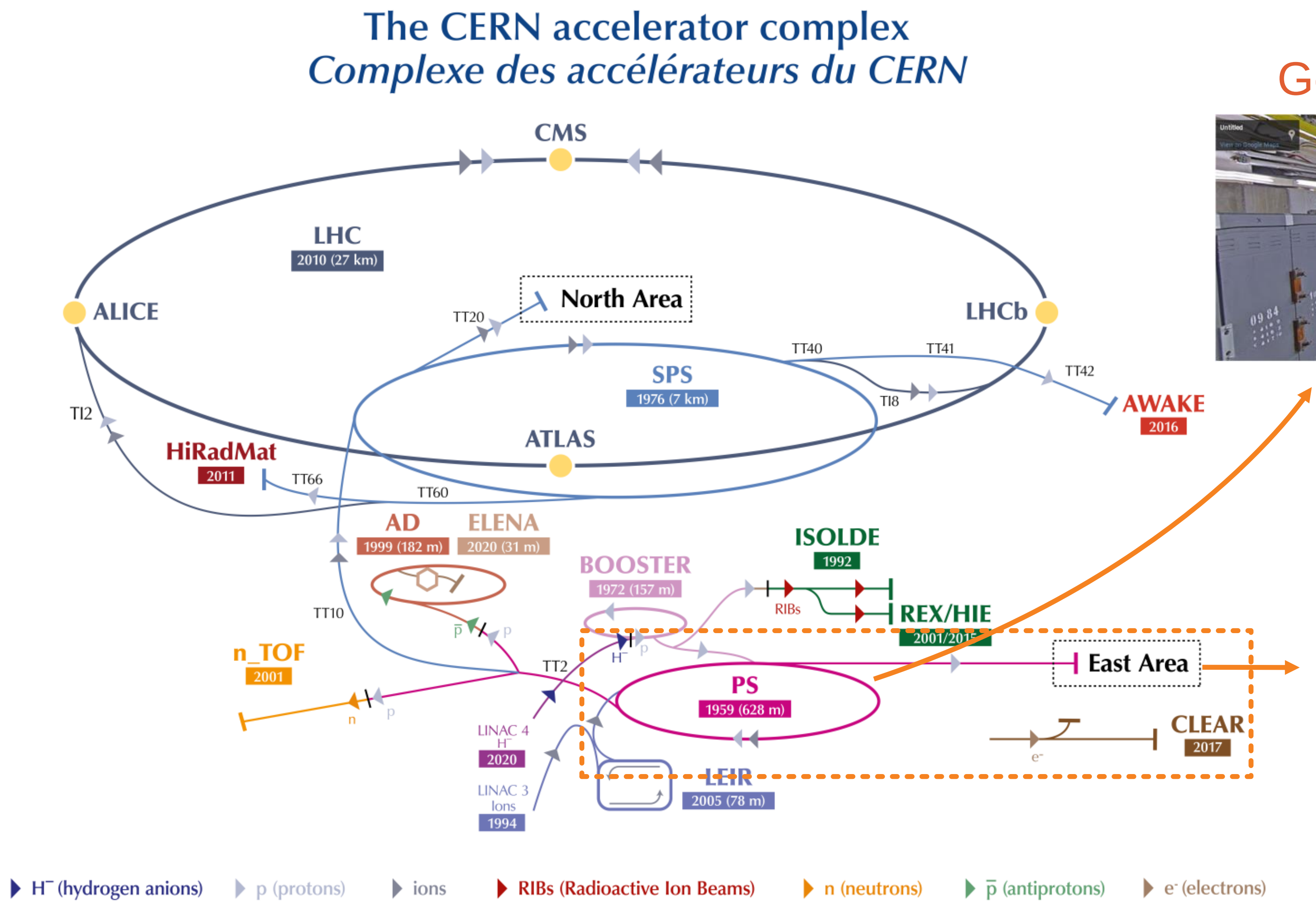
What is a beam and a beamline?

In particle physics, the term **'beam'** refers to a large number of particles moving in the same direction. These particles can be accelerated to high energies.

The term **'beamline'** commonly refers to a straight section of a particle accelerator leading the particles to an experimental area.

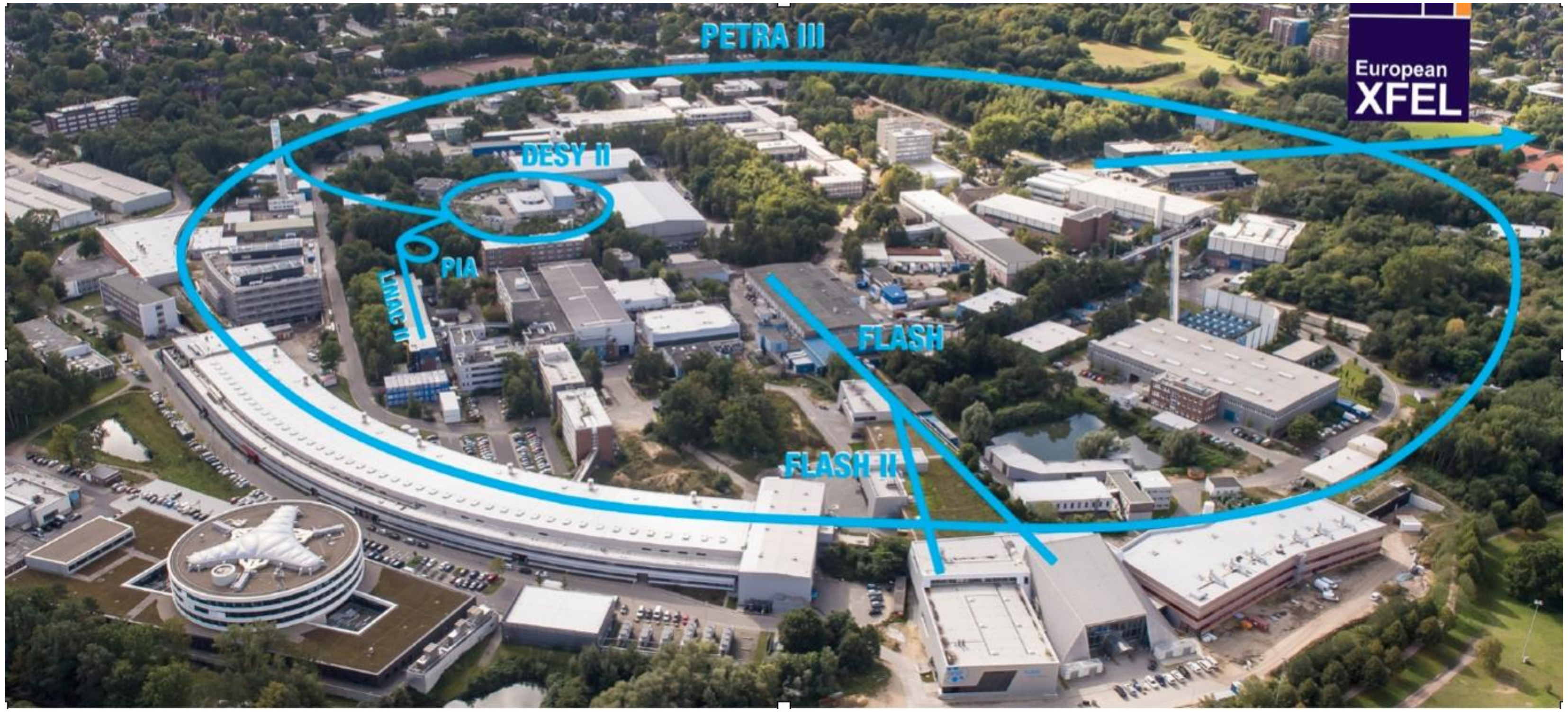


- Particles are accelerated for many **different experiments**
- **Different types of particles** are available for permanent experiments (ATLAS, CMS, ALICE, LHCb, etc..) and for temporary users
- BL4S winners are **temporary users of CERN's beams**



Google Streetview in PS

East area



- **Electron accelerator complex**
- PETRA III is the larger accelerator, a synchrotron providing photons for experiments in material science, chemistry, geology, etc.
- BL4S winners are temporary users of the **DESY II beamlines**

- Experimental areas ‘T’
- Control rooms ‘Hut’

A beamline

… is a straight section of a particle accelerator leading the particles to an experimental area.

This experimental area might look empty ⇨ You can fill it with your experiments! :)

Experiment requirements

The proposed experiment must be designed in a fixed target configuration.

- **Fixed target configuration:** beam crossing or passing close to a target (solid, liquid, gas)
- **Experiment design:** beam, target, detectors, and trigger/readout

$e^- e^- e^- e^- e^- e^-$ beam

? target

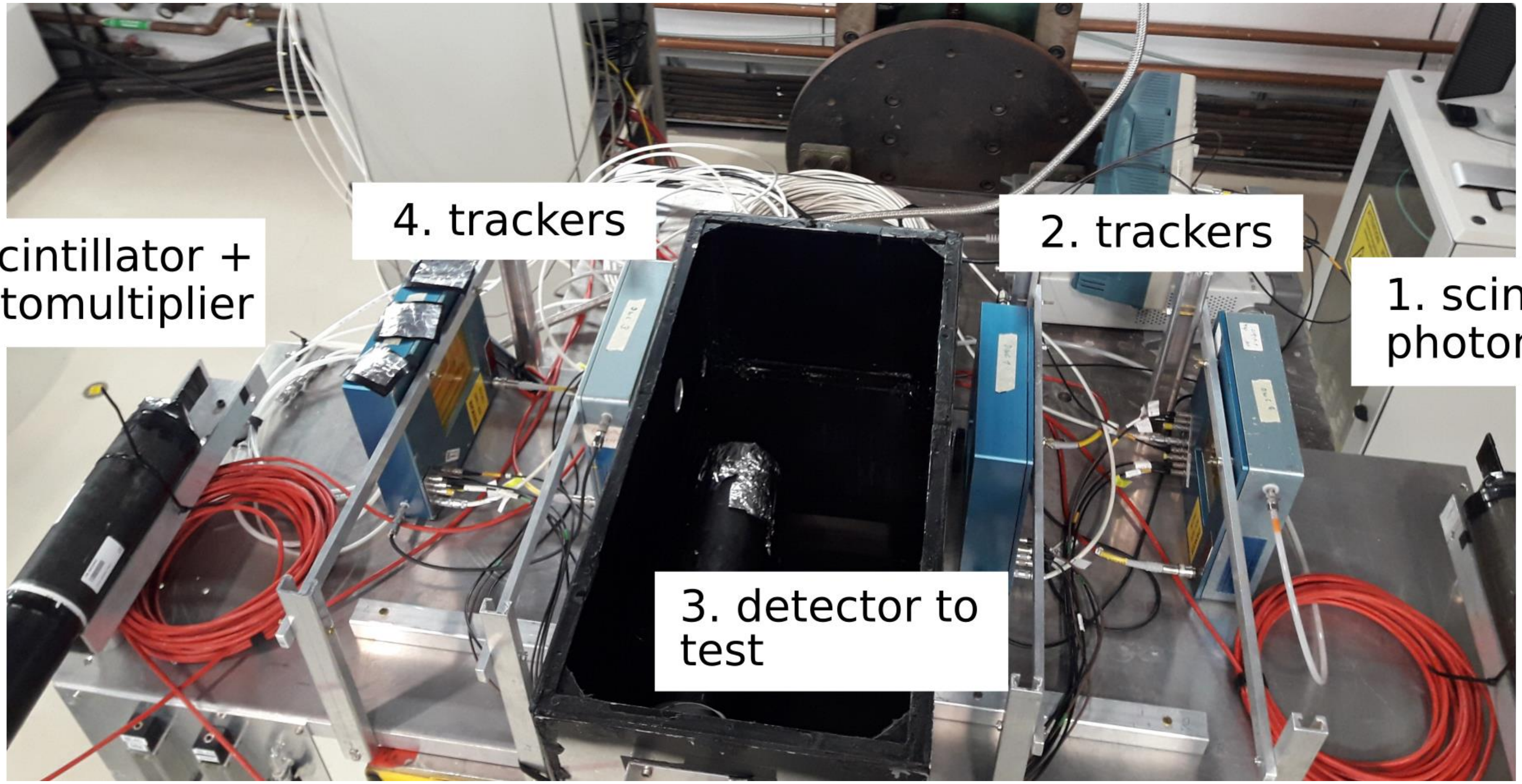
(new) particles moving in many different directions

e^- p $\bar{p}$ e^+ K

detector

Note that we cannot perform collider-type experiments in BL4S

An experimental setup



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Some useful questions

- How do high-energy particles interact with matter?
- How can we detect high-energy particles?
- What can we learn from interactions of particles with matter?
- How can we use these phenomena (e.g. applications in medicine or industry)?

Find a phenomenon that triggers your curiosity and start to draft your experiment!

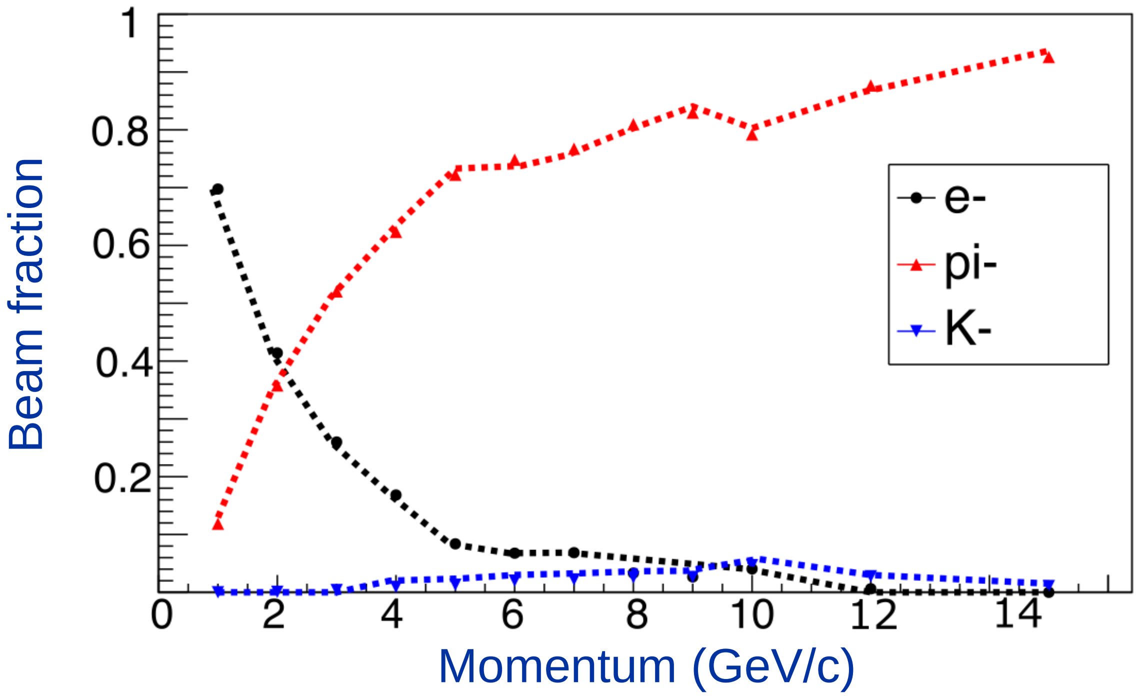
Example experiments: https://beamline-for-schools.web.cern.ch/sites/default/files/BL4S_Example_Experiments2025.pdf

Beam properties at CERN

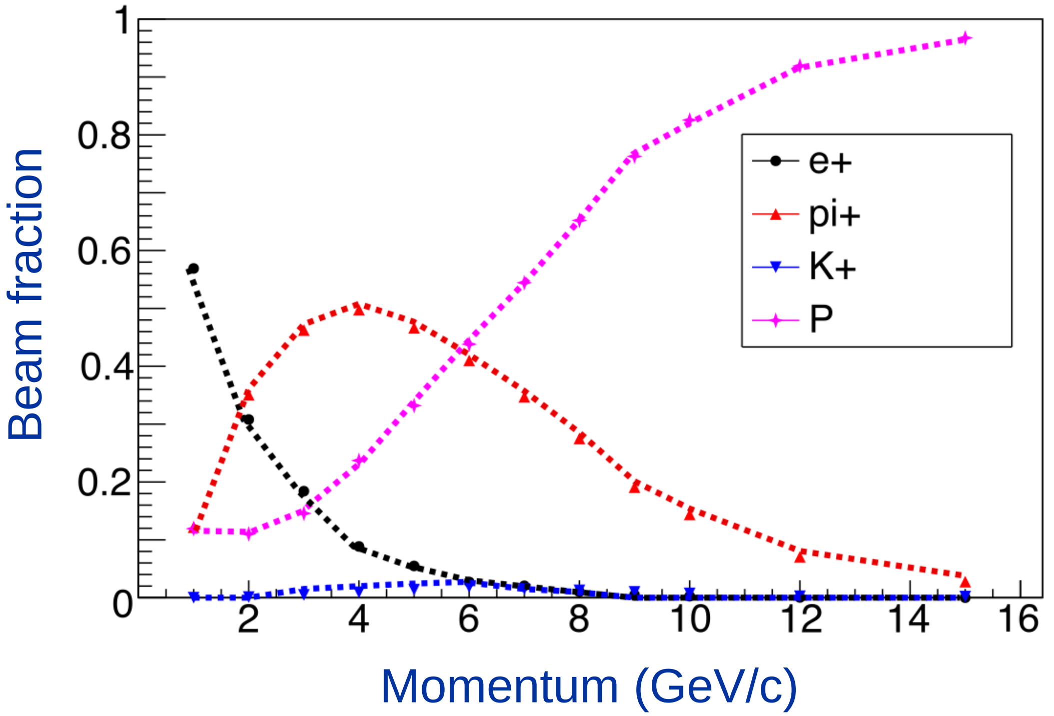
- Protons accelerated by the Proton Synchrotron (up to 26 GeV; ‘primary beam’) are smashed into a target.
- The energy of the protons transforms into the energy of new particles. These new particles ('secondary beam’) are available for the users.
- Users can select the particles’ electric charge (positive or negative) and their energies.
- **Beam diameter:** ~ 2 cm

Beam properties at CERN

Negative beam



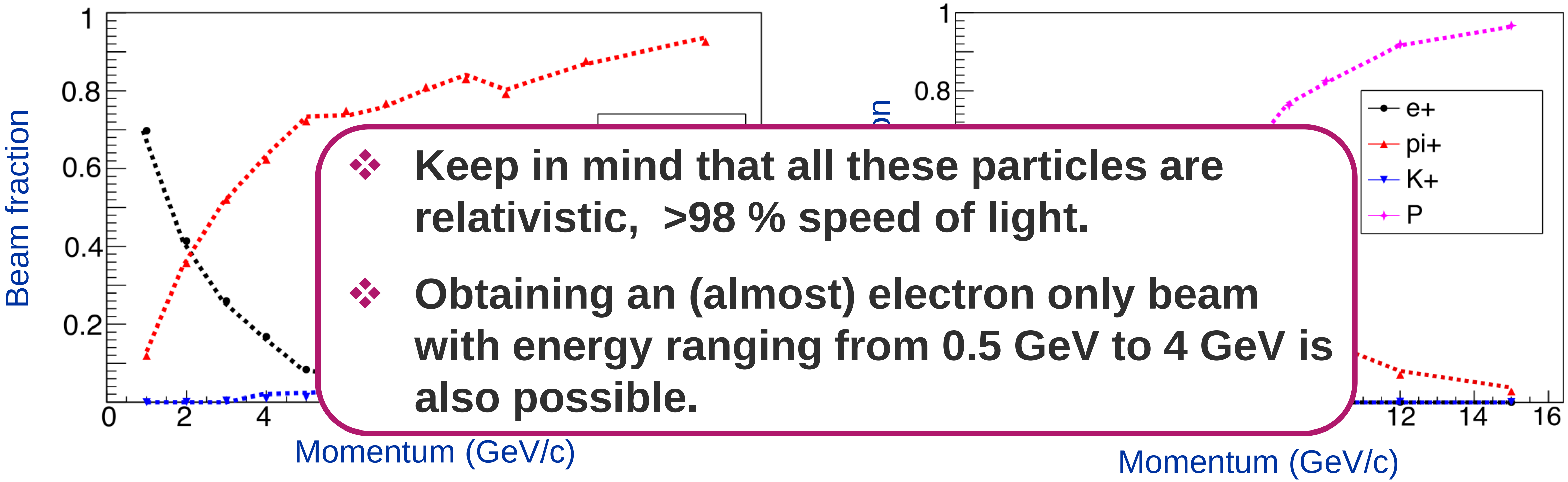
Positive beam



Protons or pions, respectively, make up the highest fraction of particles.

Energy range: 0.5-15 GeV

Beam properties at CERN



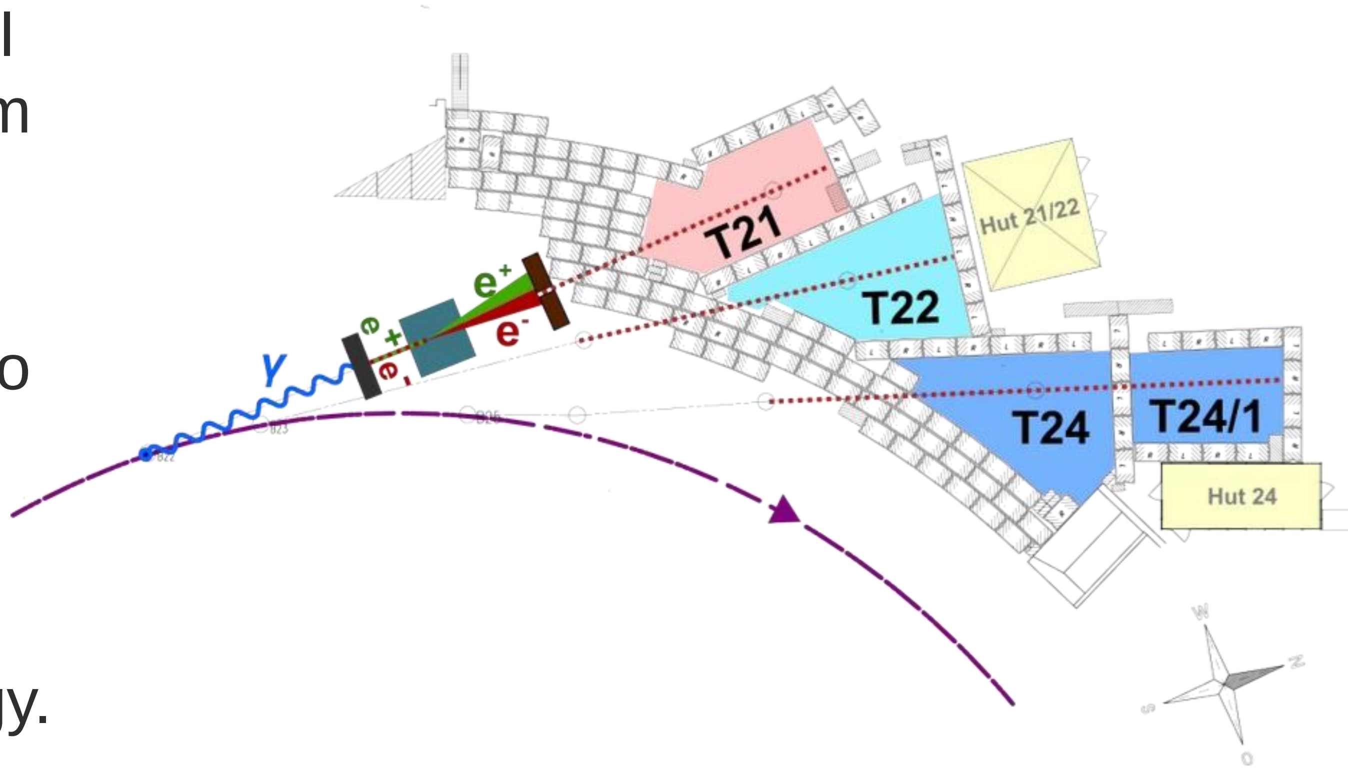
- **Keep in mind that all these particles are relativistic, >98 % speed of light.**
- **Obtaining an (almost) electron only beam with energy ranging from 0.5 GeV to 4 GeV is also possible.**

Protons or pions, respectively, make up the highest fraction of particles.

Energy range: 0.5-15 GeV

Beam properties at DESY

- Electrons accelerated by the DESY II (synchrotron) send out energy in form of photons with up to 10 GeV. These photons are smashed into a target.
- Energy of the photons transforms into the energy of electron-positron-pairs at different energies.
- The user can select the particle type (positive or negative) and their energy.
- **Beam diameter:** ~ 2 cm



Beams and detectors: https://beamline-for-schools.web.cern.ch/sites/default/files/Beams_Detectors__BL4S2025.pdf

?

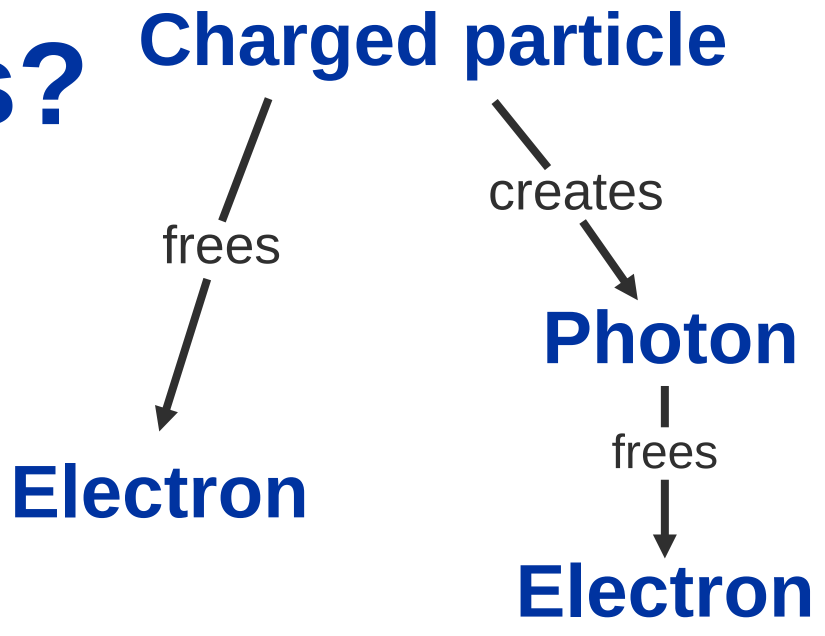
You don’t need to express a preference.
Build your experiment according to your scientific needs.
The evaluation committee will assign you to the laboratory that fits your experiment’s requirements best.

Detectors

- Different detectors are available for BL4S
- The choice depends on the purpose of your experiment
- Each detector has its own readout system (you don't need to worry about that)
- The data-acquisition system controls all the detectors and the experiment (you don't need to worry about that)

Beams and detectors: https://beamline-for-schools.web.cern.ch/sites/default/files/Beams_Detectors__BL4S2025.pdf

How can we detect particles?

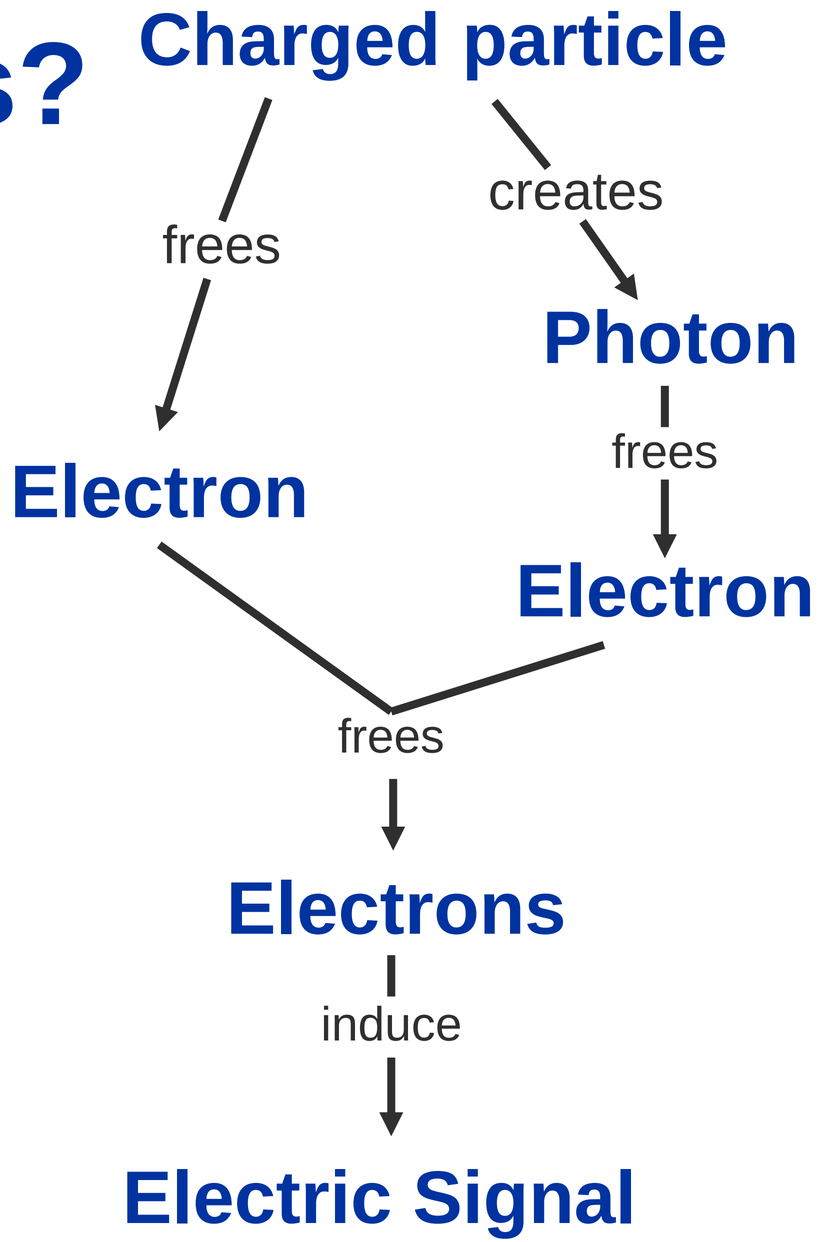


Electrically charged particle transfers some of its kinetic energy to the detector material

(1) Electrons are freed (e.g. ionisation)

(2) Photons are created (e.g. scintillation or Cherenkov) **that subsequently free electrons** (e.g. photoelectric effect)

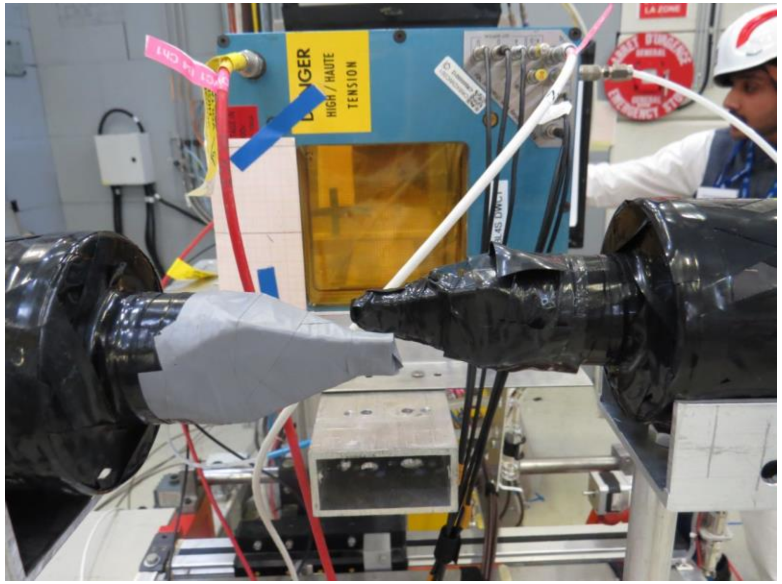
How can we detect particles?



- **Avalanche effect:** the electron gains kinetic energy in an electric field and transfers kinetic energy to another electron, which is freed and so on …
- **Electrostatic induction:** when the electrons approach the read-out electrode, they induce an electric signal

Detectors of type (1)

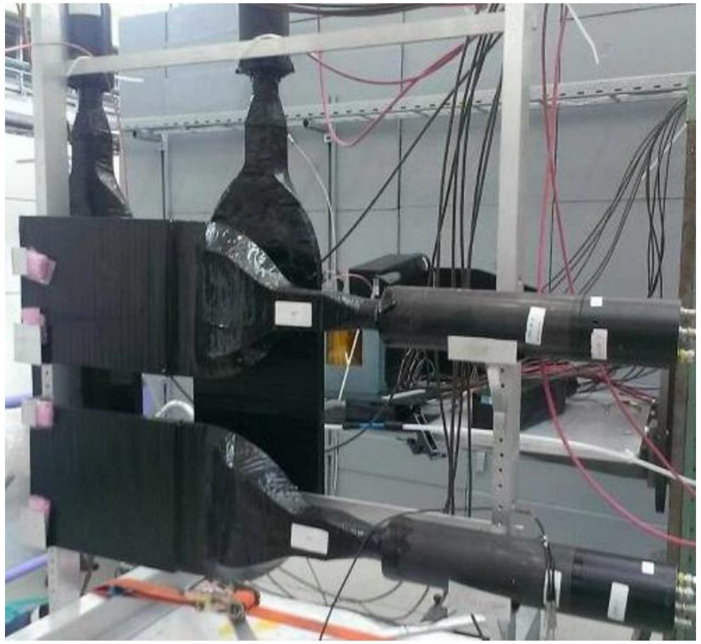
- Delay Wire Chamber – 2D tracker with an area of 10x10cm and a resolution of 200−300μm ⇨ Where?
- Beam telescope from silicon pixel detectors – 3D tracker with an area of 2x2 cm ⇨ Where?
- WENDI detector for neutrons



Detectors of type (2)

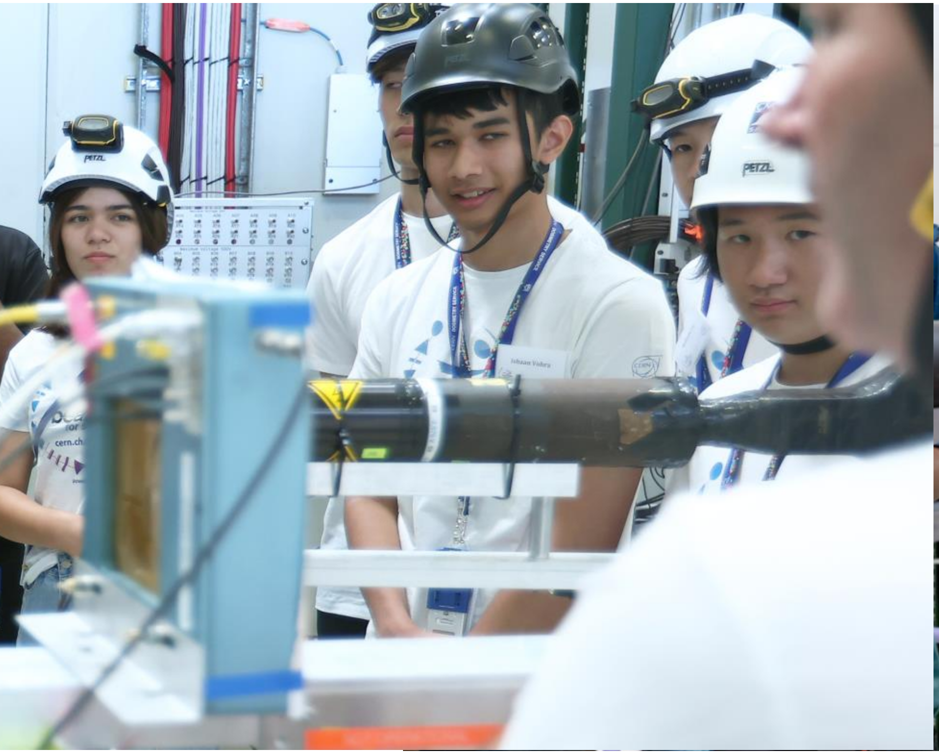
- Scintillators + photomultipliers – particle counting, trigger, time-of-flight measurements
  ⇨ How many? When?
- Threshold Cherenkov detectors ⇨ What type of particle?
- Lead crystal calorimeter (Cherenkov) + photomultipliers – energy of particles, with a volume of 10x10x37 cm

You are free to design and test your own detector!



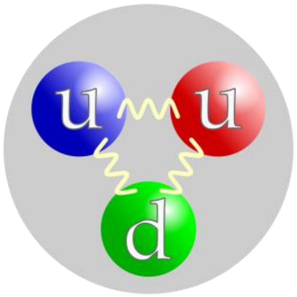
It’s time to design your experiments!

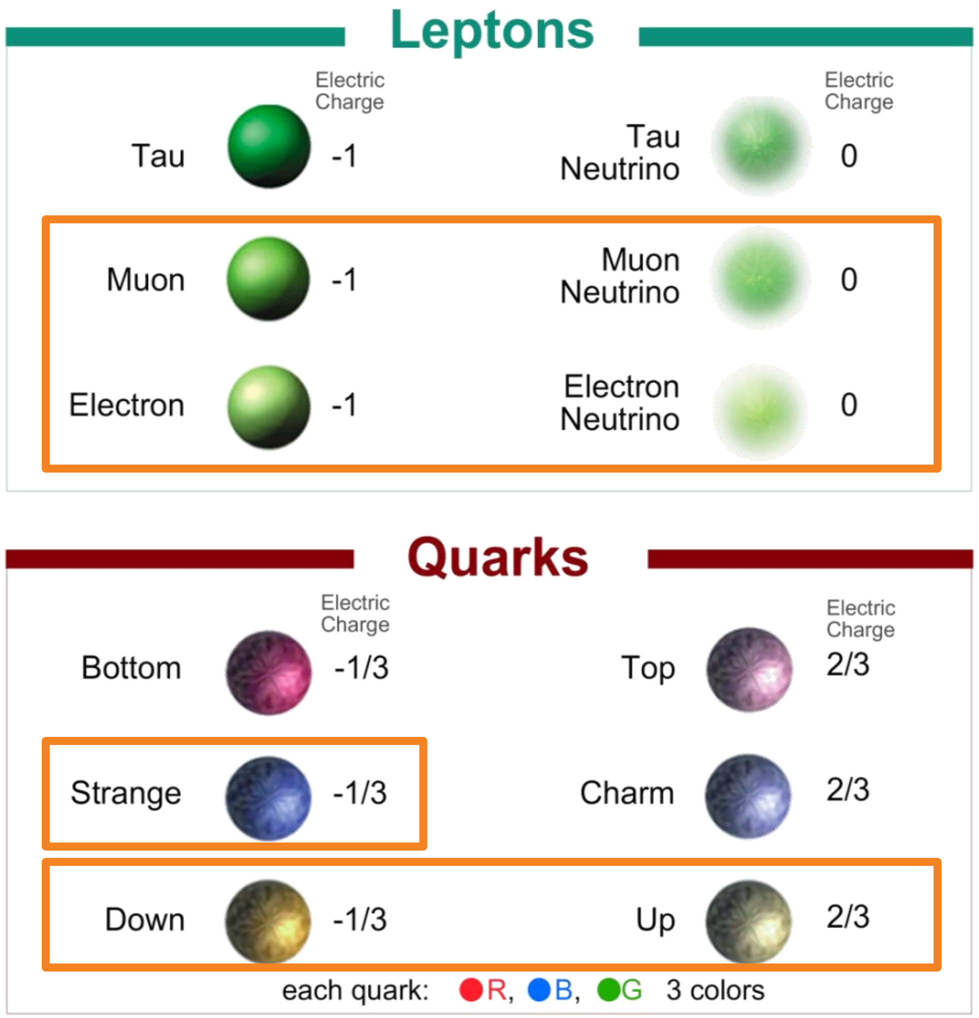
Questions?




Beam properties

- Protons: uud
- When they interact with a target they can produce different particles, both elementary and not.
- Given the energy provided by the PS, one can have **electrons, muons and particles composed of u,d, and s quarks (pions and kaons)**.





The particle drawings are simple artistic representations