

# Beamline for Schools

*A physics competition for high-school students*

Welcome to CERN and 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!

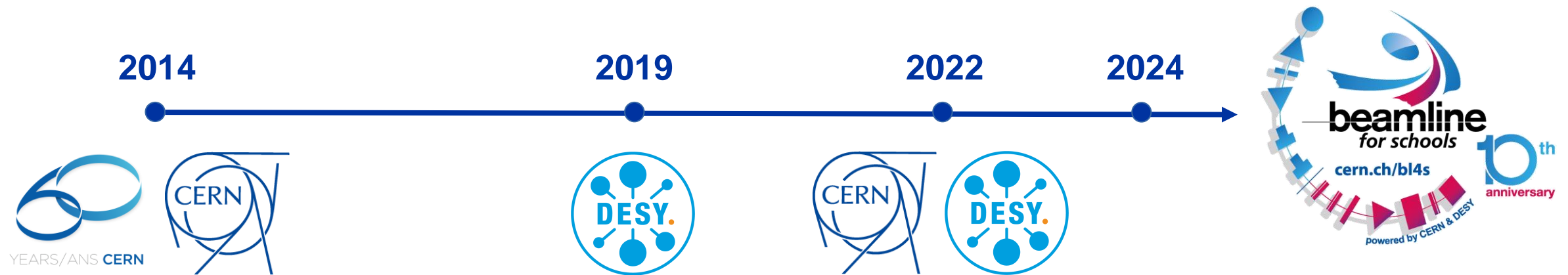
**You can be a scientist**

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 2024 edition is the 10<sup>th</sup> anniversary of the competition!



# Who can participate in BL4S?

- ❖ **Teams:** min. 5, max. 9 people,  $\geq 16$  years old (when submitting your proposal)
- ❖ Enrolled in **high-school** in the school year 2023/2024 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 – **1 team**

**Award for the best outreach proposals:** BL4S t-shirts and telescopes (sponsored by the Belgian project “Stars Shine For Everyone”) – **10 teams**

**Shortlisted teams:** BL4S t-shirts and DIY cloud chamber and pixel detector – **30 teams**



# Winning teams 2024

**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 submission opens in  
January 2024.  
Submission deadline:  
April 10, 2024

Research 2018 Beamline Proposal  
International School Manila

Determining the relationship between the energy of a ... and react with a carbon-based, non-biological ... therapy" — an alternative Me ...  
See Joon Cheon, Yash Kar ...  
Aarushi Tanuja, Ashish Tumb

**Introduction**  
Finding effective safe cancer therapy has ...  
community. Two out of five individuals get diagnosed ...  
The most common treatment options available today ...  
therapy<sup>2</sup>. These methods of treatment come with ...  
extremely painful and known to cause fatigue and ...  
problems, irreversible hair loss, and vomiting<sup>3</sup>. Surgery ...  
that does not necessarily eliminate all cancerous cells ...

Last year, our school ...  
cancer therapy —  $\pi^+$  meso ...  
was scope to develop it ...  
have now come up with ...  
comparisons between pro ...  
skin tissue using graphite ...  
therapy has on human tissue

**Overview and Background**  
Negative pions are ...  
properties similar to heavy ...  
However, pions being high ...

<sup>1</sup>"Cancer Statistics" National ...  
<sup>2</sup>"Types of Cancer Treatment" ...  
<sup>3</sup>"Open D. Medical Chemis ...  
Proc. 2014, p. 764

Liceo Scientifico Statale "T.C.Onesti", Fermo, Italy  
Team TCO-ASA

**Detecting the Elusive  $\Delta^+$  Baryon in an Electron-Proton Inelastic Scattering Through its Decay-Products**  
International School of Geneva, Nations' Flying Foxes  
John Desha, Yousoo Kim, Hiroki Kozuki, Sarah Shafiq, Mihail Slepovskiy, Pen Struelens, Zihong Xu  
Word Count: 2002

**Introduction:**  
Just as scattering visible light off of a cell using a microscope allows us to examine a cell, a collision between resting protons and an electron beam produced by a particle accelerator could allow us to "see" subatomic particles and its miscellaneous interactions otherwise unobservable. Such a collision could result in interesting scattering effects, creation of elusive particles whose decay products can be detected and analyzed to trace back the event, which potentially enables us to further identify properties of the particles.

A histogram depicting the collision of a 4.9GeV electron beam with a static source of protons can be seen on Fig 1. The x-axis represents the energy/momentum of the scattered electrons, while the y-axis indicates the number of times an interaction of a specific energy/momentum occurred. The approximate peaks in the band of 3.5–4.2 GeV electrons suggest an inelastic scattering, which we are interested in to investigate.

**ChDR-CHEESE**  
Cherenkov Diffraction Radiation - Characteristic Energy Emissions on Surfaces Experiment  
Silas Rahrberg Estévez, Tobias Baumgartner, Philipp Lowe, Lukas Hildebrandt, Thomas Lebrach, Tobias Thode, Benlhar Nickel, Tristan Matsudovits, Johann Bahl, Werner-von-Siemens-Gymnasium Berlin  
March 31, 2020



# 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

The collage features several documents and diagrams related to particle physics experiments. On the left, a document titled 'Determining the relationship between the energy of a ... and react with a carbon-based, non-biological ... therapy' — an alternative Medicine' is visible, with authors 'See Joon Cheon, Yash Kar, Anushi Tanuja, Ashish Tushik'. Below it is an 'Introduction' section discussing cancer therapy. In the center, a document from 'Liceo Scientifico Statale "T.C.Onesti", Fermo, Italy' is titled 'Team TCO-ASA' and includes a grid diagram. To the right, a document titled 'ChDR-CHEESE' describes a 'Cherenkov Diffraction Radiation - Characteristic Energy Emissions on Surfaces Experiment' by Silas Rahrberg Estévez, Tobias Baumgartner, Philipp Lowe, Lukas Hildebrandt, Thomas Lehrach, Tobias Thode, Benlhar Nickel, Tristan Matskevits, Johann Bahl, Werner-von-Siemens-Gymnasium Berlin, dated March 31, 2020. Below this is a diagram showing two orange triangles labeled 'ChDR' and 'Cheese' with blue wavy lines representing radiation. In the center, a document titled 'Detecting the Elusive  $\Delta^+$  Baryon in an Electron-Proton Inelastic Scattering Through its Decay-Products' from the 'International School of Geneva, Nations' Flying Foxes' is shown. It includes an 'Introduction' and a histogram of  $d^2\sigma/dE'd\Omega'$  vs  $W'$  and  $E'$  showing elastic, inelastic, and deep inelastic scattering regions.

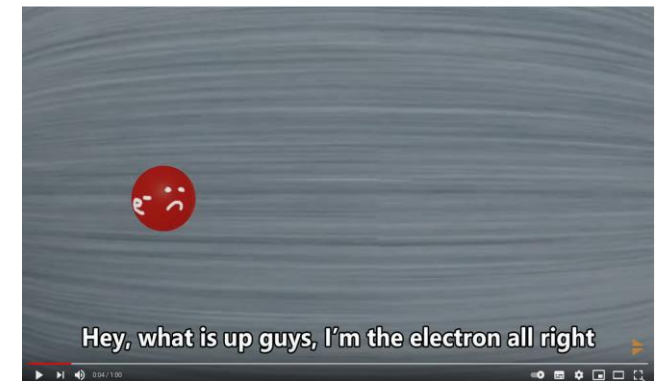


# Experiment proposal

You are not alone!

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

The collage features several documents and diagrams related to particle physics experiments. At the top left, a document titled "Research 2018 Beamline Proposal International School Manila" discusses cancer therapy. To its right is a document from "Liceo Scientifico Statale 'T.C. Onesti', Fermo, Italy" for "Team TCO-ASA" with a grid diagram. Below these are two more documents: "Detecting the Elusive  $\Delta^+$  Baryon in an Electron-Proton Inelastic Scattering Through its Decay-Products" from the International School of Geneva, Nations' Flying Foxes, which includes a graph of  $d^2\sigma/d\Omega dE'$  vs  $W$  and  $E'$  showing elastic, inelastic, and deep inelastic scattering regions; and "ChDR-CHEESE Cherenkov Diffraction Radiation - Characteristic Energy Emissions on Surfaces Experiment" from the University of Hamburg, featuring a diagram of a ChDR and Cheese detector setup.



# Proposal extension

## 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 BL4S experiment proposal).

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



# Preparing your experiment proposal

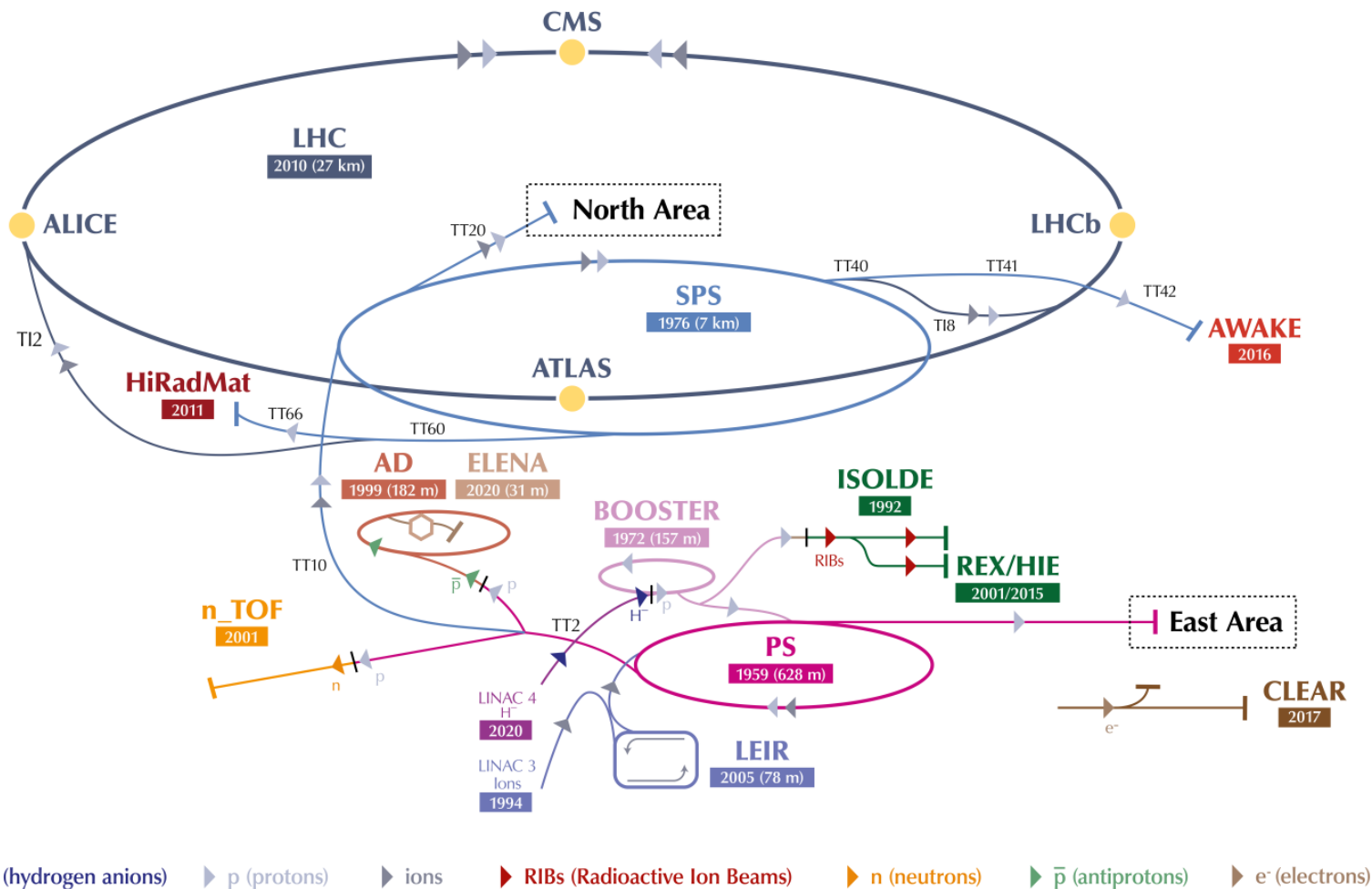
## What is a beam and a beamline?

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.

# The CERN accelerator complex

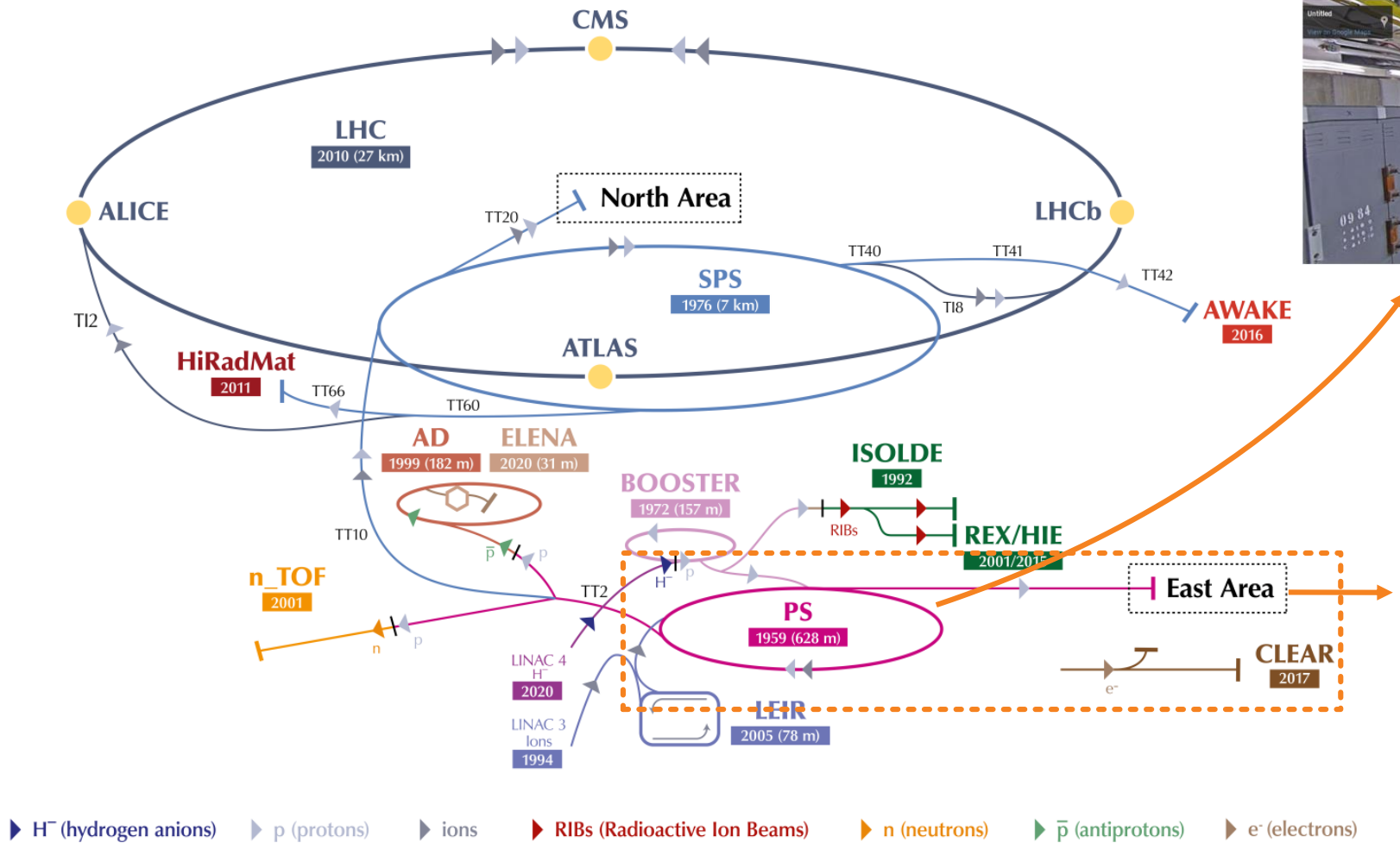
## Complexe des accélérateurs du CERN



- ❖ 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**

# The CERN accelerator complex

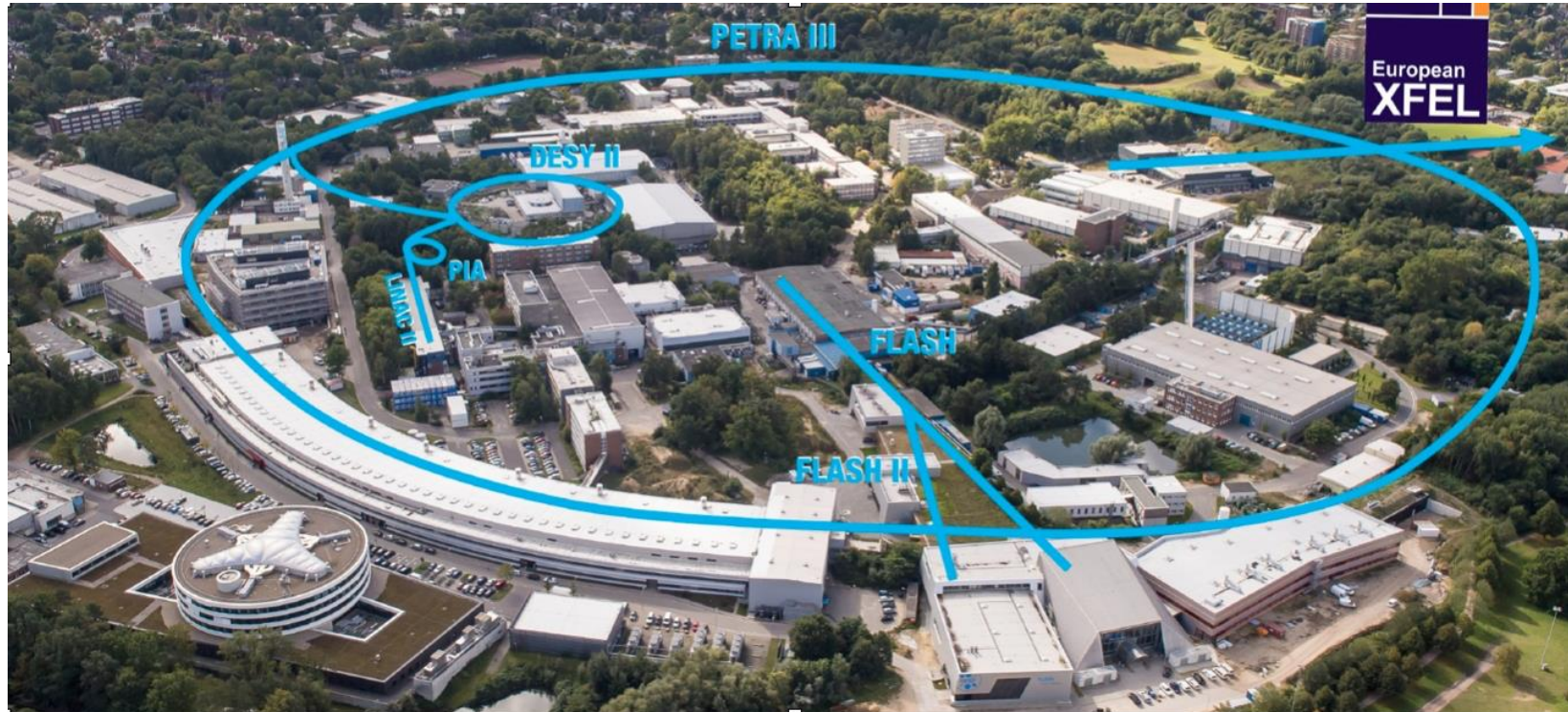
## Complexe des accélérateurs du CERN



## 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! :)**



**'T09' at CERN:**  
**~ 5 m x 10 m**

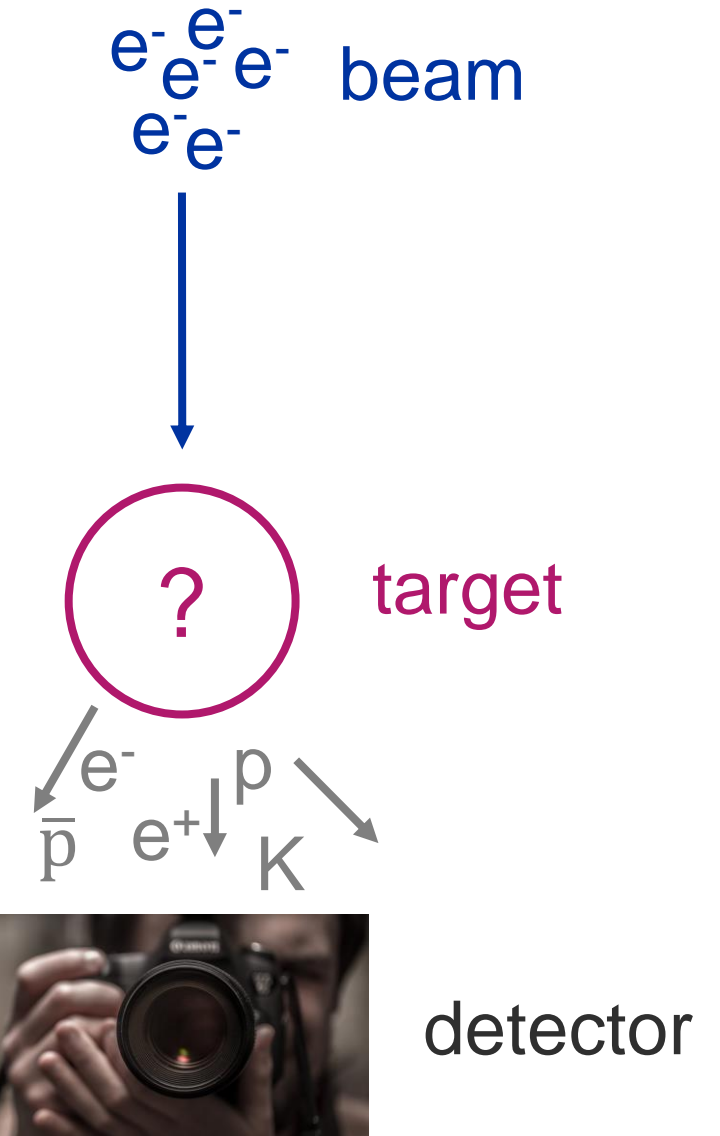
# Experiment requirements

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

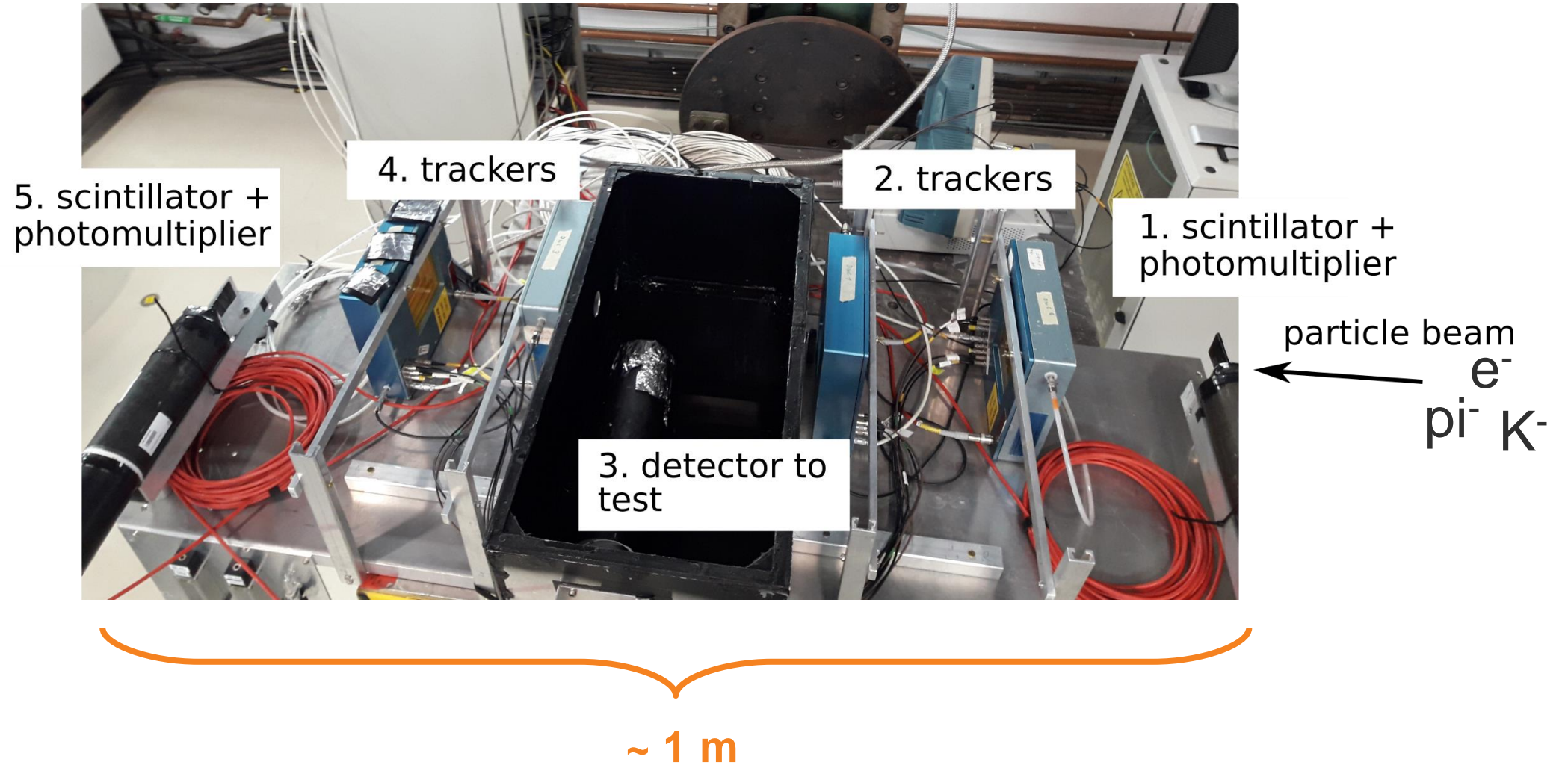
- ❖ **Fixed target configuration:** beam crossing or passing close to a target (solid, liquid, gas)
- ❖ **Experiment design:** beam, target, detectors, and trigger/readout

Note that we cannot perform collider-type experiments in BL4S

(new) particles moving in many different directions



# An experimental setup



# 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)?

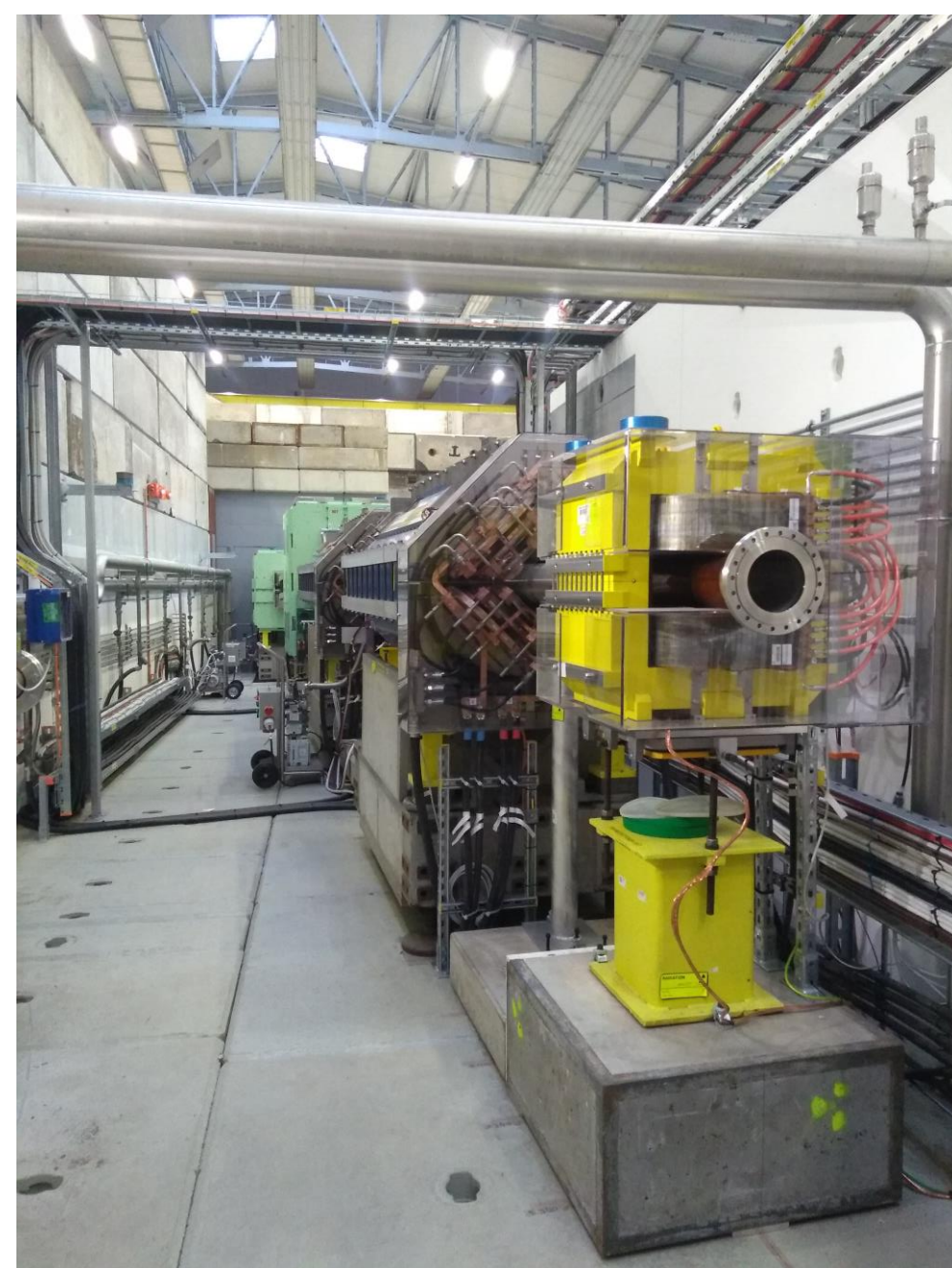
**Find a phenomenon that triggers your curiosity and start to draft your experiment!**



**Example experiments:** [https://beamline-for-schools.web.cern.ch/sites/default/files/Experiment\\_examples\\_2024.pdf](https://beamline-for-schools.web.cern.ch/sites/default/files/Experiment_examples_2024.pdf)

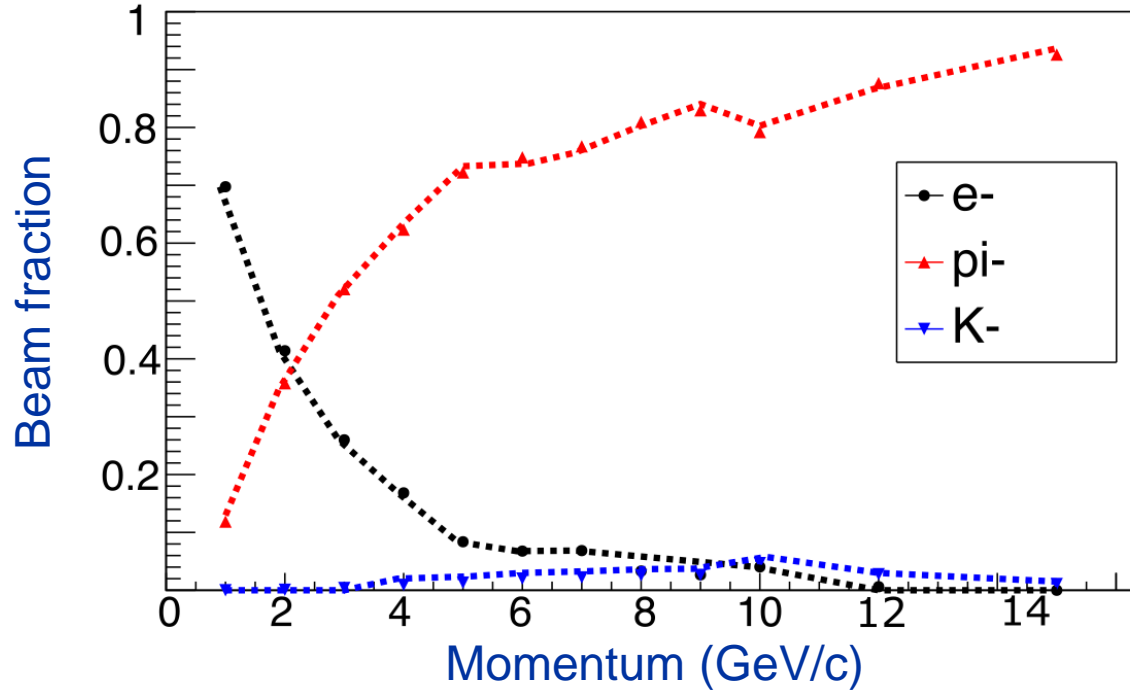
# Beam properties at CERN

- ❖ 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), their energies, and the opening of collimator (i.e. the beam diameter).
- ❖ **Beam diameter:** ~ 2 cm

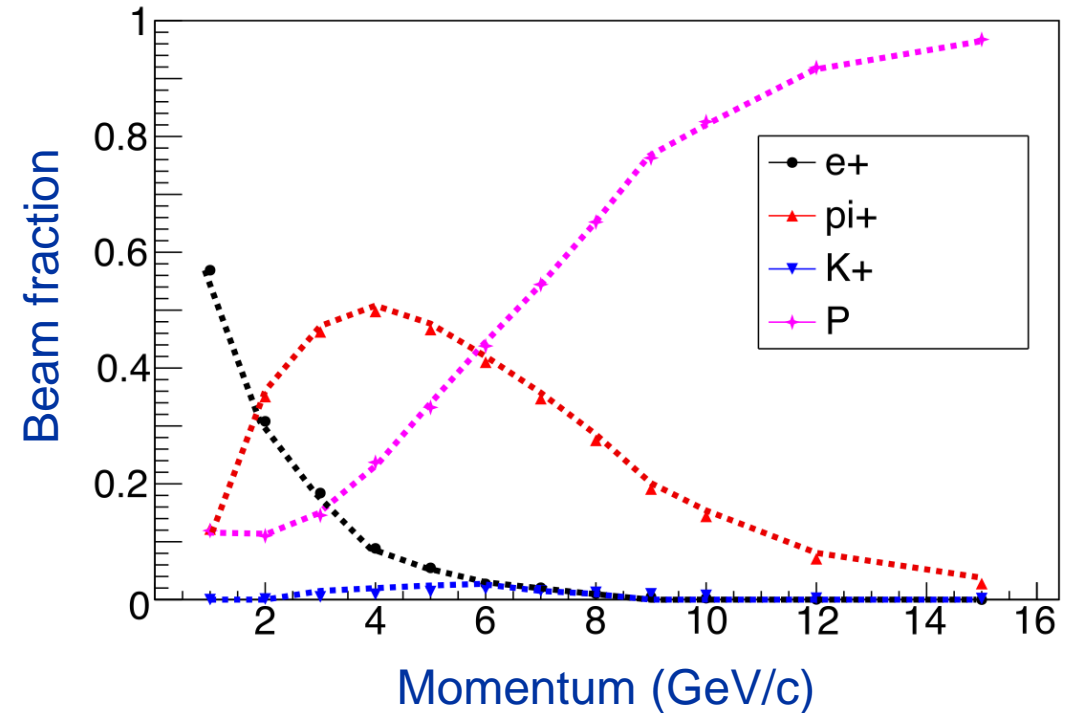


# Beam properties at CERN

Negative beam

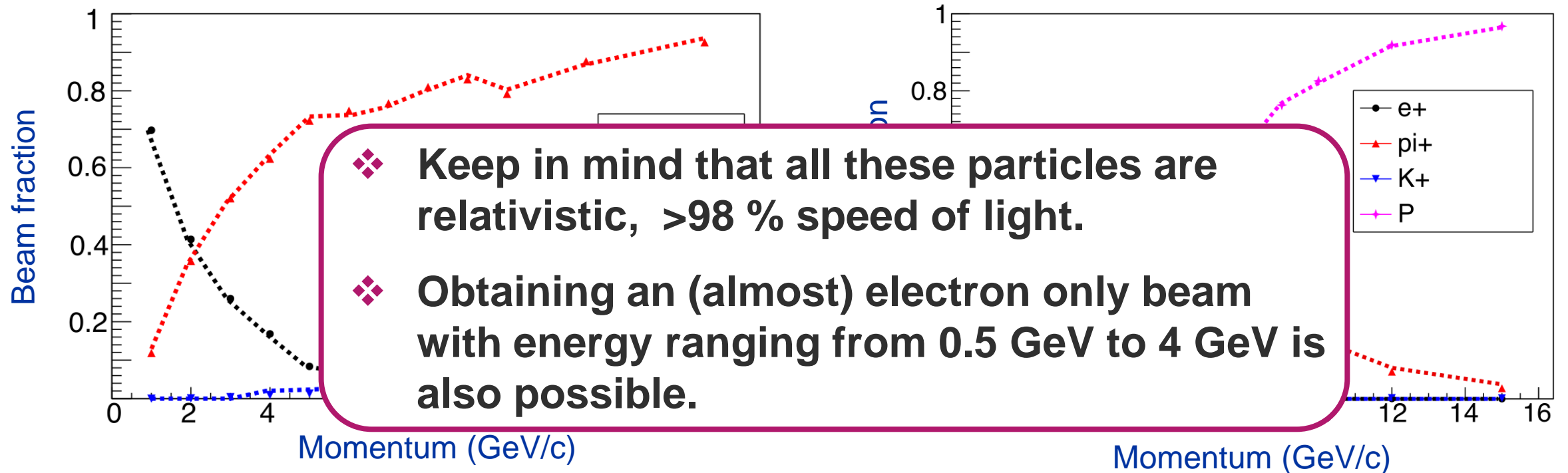


Positive beam



Protons or pions, respectively, make up the highest fraction of particles.  
Energy range: 0.2-15 GeV

# Beam properties at CERN

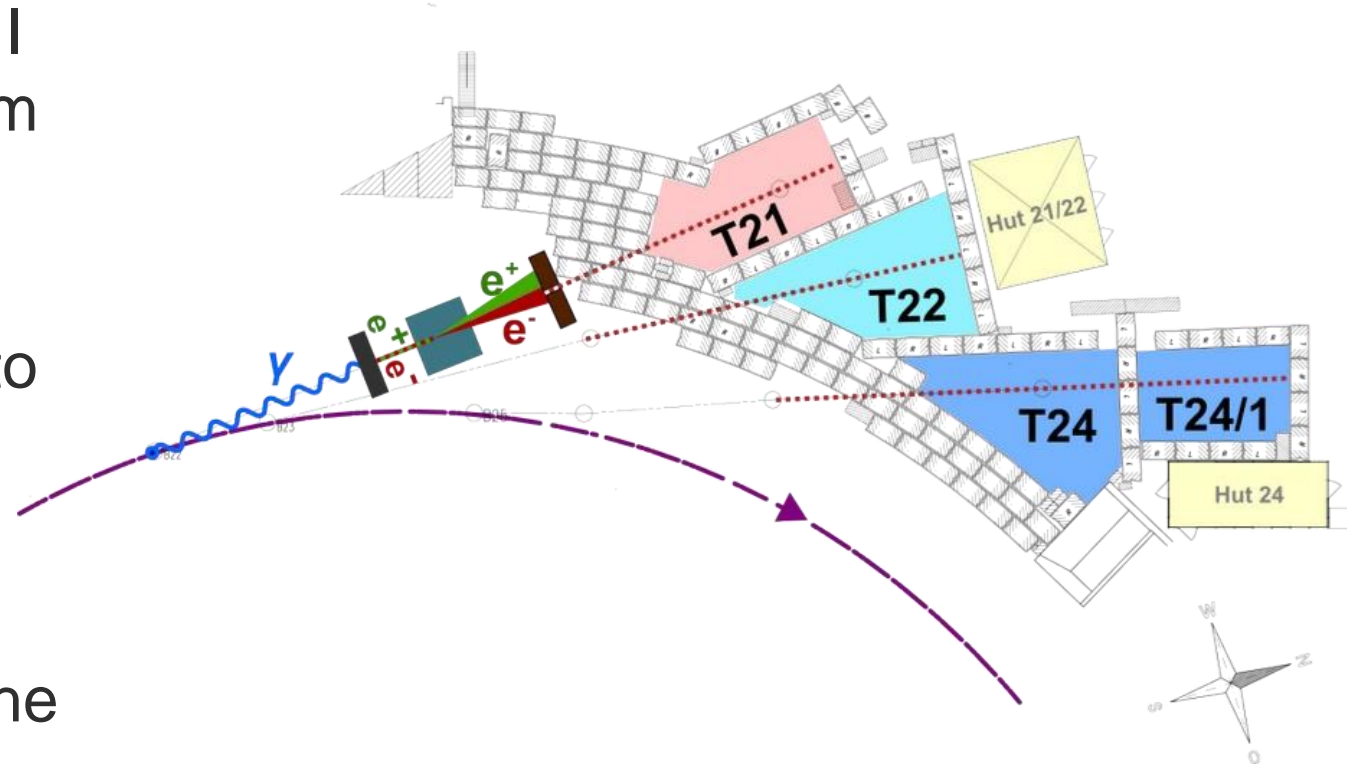


Protons and pions make up the highest fraction of particles.  
**Energy range: 0.2-15 GeV**



# 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), their energy, the opening of collimator (i.e. the beam diameter).
- ❖ **Beam diameter:** ~ 2 cm



**Beams and detectors:** [https://beamline-for-schools.web.cern.ch/sites/default/files/Beams\\_Detectors\\_BL4S2024.pdf](https://beamline-for-schools.web.cern.ch/sites/default/files/Beams_Detectors_BL4S2024.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

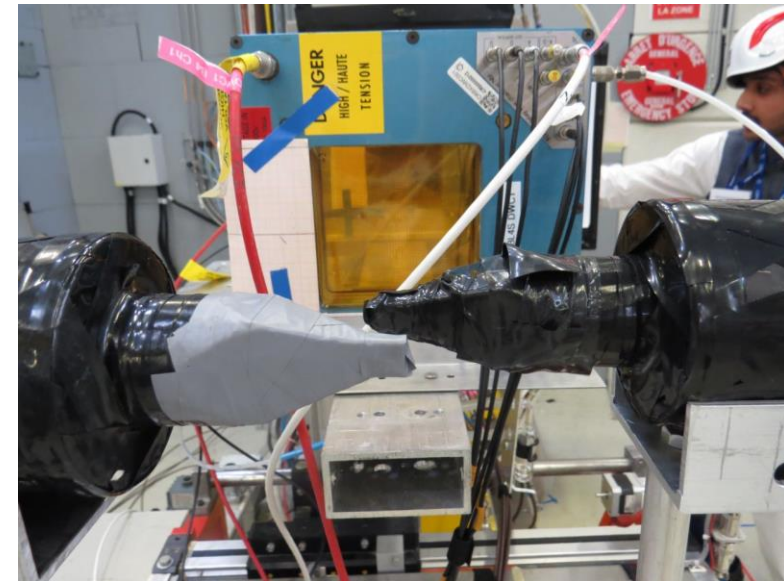
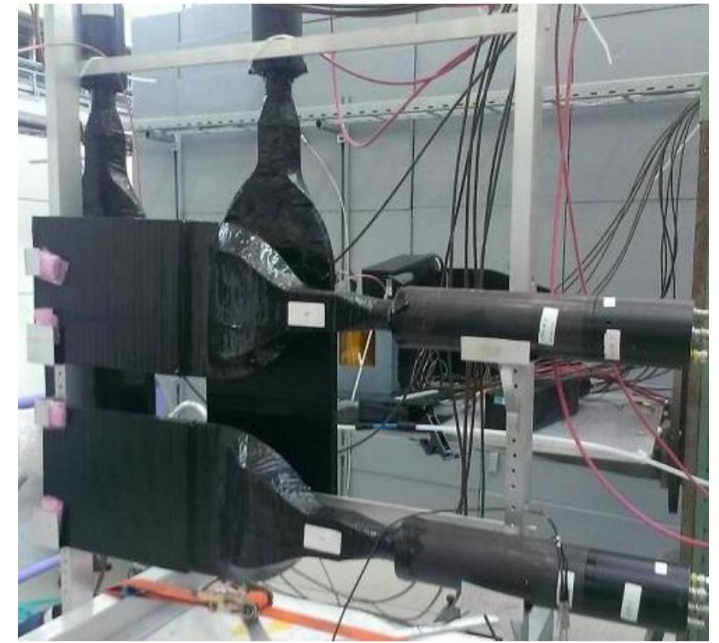
- ❖ Different detectors are available for BL4S
- ❖ The choice depends on the purpose of your experiment
- ❖ Each detector has its own readout system
- ❖ The data-acquisition systems controls all the detectors and the experiment (you don't need to worry about that)



**Beams and detectors:** [https://beamline-for-schools.web.cern.ch/sites/default/files/Beams\\_Detectors\\_BL4S2024.pdf](https://beamline-for-schools.web.cern.ch/sites/default/files/Beams_Detectors_BL4S2024.pdf)

# Detectors

- ❖ Scintillators + photomultipliers – **particle counting, trigger, time-of-flight measurements**  
⇒ How many? When?
- ❖ Delay Wire Chamber – **2D tracker** with an area of 10x10cm and a resolution of 200–300 $\mu\text{m}$  ⇒ Where?
- ❖ MicroMegas detectors – **1D tracker** with an area of 40x40cm, resolution 200 $\mu\text{m}$  ⇒ Where?
- ❖ Silicon pixel detectors – **2D tracker** with an area of 2x2 cm, contact us if interested ⇒ Where?



# Detectors

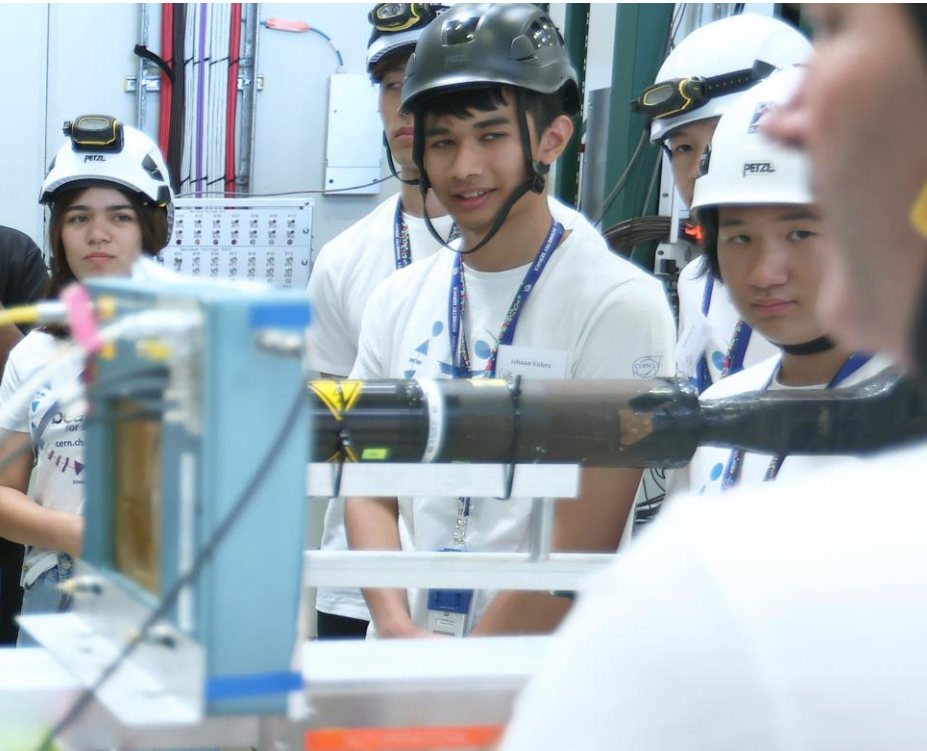
- ❖ Multi-gap resistive plate chambers (MRPC) – **trackers** with an area of 30x30 cm and a time resolution 100 ps ( $10^{-10}$  s), **time-of-flight measurements** ⇒ How many? When?
- ❖ Cherenkov detectors – gas detectors ⇒ What type of particle?
- ❖ Lead crystal calorimeter (scintillator) + photomultipliers – **energy of particles**, with a volume of 10x10x37 cm



**You are free to design and test your own detector!**

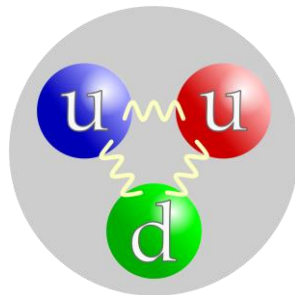
# It's time to design your experiments!

## 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).**



## Leptons

	Electric Charge		Electric Charge
Tau	-1	Tau Neutrino	0
Muon	-1	Muon Neutrino	0
Electron	-1	Electron Neutrino	0

## Quarks

	Electric Charge		Electric Charge
Bottom	-1/3	Top	2/3
Strange	-1/3	Charm	2/3
Down	-1/3	Up	2/3

each quark: ●R, ●B, ●G 3 colors

The particle drawings are simple artistic representations