

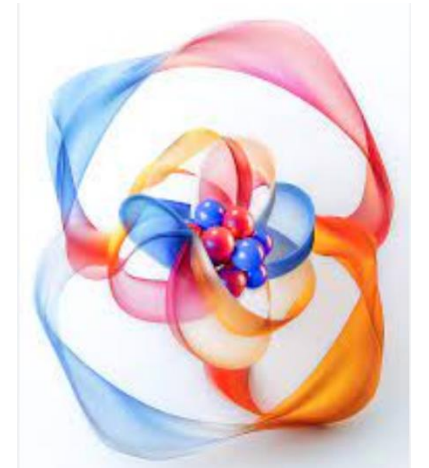
Outreach and Science Education in the European Physics Community



Alessandra Fantoni
INFN Laboratori Nazionali di Frascati



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Introduction

- **Outreach** and **Science Education** are not secondary to research
=> they are vital components in the long-term sustainability and public legitimacy of large-scale physics projects.
- In nuclear, astroparticle, and particle physics, Outreach enhances awareness of scientific goals, technological innovation, and societal relevance (e.g., medical imaging, data science, energy policy).
- Education is central to skill development in frontier science, ensuring the continuity of expertise across generations.
- Europe's model combines institution-led initiatives, transnational networks, and project-specific outreach.

- **NuPECC LRP2024**: dedicated chapter on «People & Society» with Outreach & Education (together with Early Career and Diversity, Equity & Inclusion)
- **ESPPU 2026**: contributions from different communities (HEP via [IPPOG](#), [NuPECC](#), [APPEC](#), [ECR](#))

Key European Institutions Leading Outreach and Education



- **CERN (Switzerland):** Largest particle physics lab; leader in global outreach with Science Gateway, guided visits, teacher and student programs, collaboration with IPPOG
- **INFN (Italy):** Strong national outreach model with local sections, events like “*ScienzaPerTutti*”, and partnerships with schools. School-focused initiatives include “*Lab2Go*”, a program providing schools with experimental kits and training for nuclear and particle physics, and “*Incontri di Fisica*”, an annual event for secondary school teachers featuring lectures and hands-on activities on modern physics
- **DESY (Germany):** Outreach labs (e.g., “*Schülerlabore*”), teacher training, and deep involvement in early-career education via Helmholtz programmes
- **APPEC:** Coordinates European astroparticle physics; promotes coherent communication strategies, support for educational kits, and outreach alignment with major experiments (KM3NeT, CTA, LIGO-Virgo)
- **JRC / Euratom (EU Commission):** Focus on nuclear safety, societal perception of radiation and waste, and school-level curriculum development



Science Shows

Shows are interactive and have a strong education content with impressive experiments.

CERN science and technology on stage ...

... turned educational for all age groups.



High School Education Programs

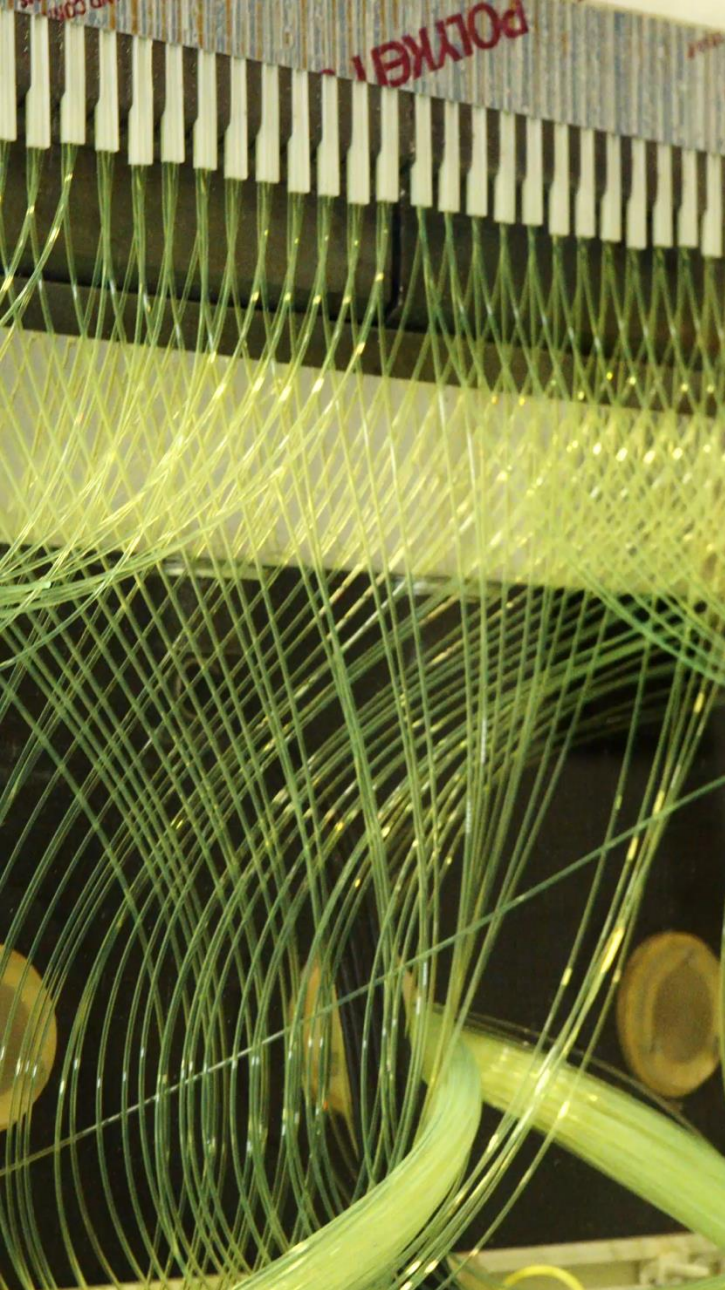


Outreach at the high school level is a cornerstone for early scientific literacy and long-term recruitment in nuclear, particle, and astroparticle physics

Many European institutions have established **structured programs**, providing direct access to real data, tools, and researchers

see D. Hatzifotiadou's talk

- **IPPOG International Masterclasses (CERN):** Students analyze LHC event displays with ROOT, interpret collision types, and participate in mock CERN videoconferences
- **CERN Solvay:** Project partnering with a foundation to make STEM attractive
- **BL4S (CERN+DESY):** Teams of high school students from all around the world can propose an experiment that they want to perform at a particle accelerator
- **INSPIRE (INFN):** School to introduce the students to the hot topics of Modern Physics
- **Lab2Go (INFN):** Kit-based experiments designed for school use, bridging theoretical and practical physics education
- **LHC Experiments Virtual Visits:** Allow remote engagement with the major LHC experiments, fostering early exposure to real data and scientific reasoning
- **Teacher Programs ([CERN HST](#), [Science on Stage Europe](#), [INFN Incontri di Fisica](#)):** Empower educators with content knowledge, resources, and international networking



High School Education Programs – CERN Solvay



A project partnering with a foundation (Solvay) to make STEM attractive for young people around the world:



SOLVAY

- collection of short videos for own experiments related to CERN science and technology to be posted on social media
- high-school level online course based on CERN topics
- on-site camps for the immersion of the school students (1 week, 30 students from all over the world after completion online course)



High School Education Programs – BL4S



Beamline for Schools ([BL4S](https://cern.ch/bl4s)) => physics competition for worldwide high school students

- started in 2014, 3000+ students from 50 countries, 292 proposals
- organized by CERN in collaboration with DESY
- teams with 5-9 students + teacher
- proposal of experiment to perform at a fully equipped beamline
- winner's teams: 2 weeks @CERN / DESY
- huge ↗ participation : 119 => 508 proposals, 50 => 78 countries, 1000 => 3600+ students
- 2025: from 2-3 => 5 winners, 2 @CERN, 2 @DESY, 1 @ELSA (new)



Other winners:

- best video
- best Outreach proposal

High School Education Programs – INSPYRE, LAB2GO & HEPSCAPE (INFN)



INSPYRE = International School on modern PhYsics and REsearch

- started in 2000, always in Frascati National Labs (INFN-LNF)
- 1w school focusing on the topics of modern physics and INFN research
- 30-40 high school students from all over the world
- since 2025, both in LNF and LNL
- Lectures on modern physics, discussions with researchers, hands-on with interactive activities and experiments

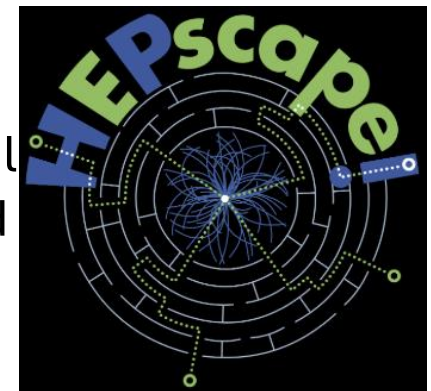


Lab2Go = Kit-based experiments designed for school use, bridging theoretical and practical physics education:

- promote hands-on (laboratory-based) teaching methods in schools
- share best teaching practices via materials and public/school community events
- provide teacher training focused on practical, lab-based methodologies

HEPSCAPE = High-energy physics escape room

Project born at INFN in 2021 to bring the field of high-energy physics closer to the general public, made up of kids, young students and adults. A map with many clues, riddles and questions to be solved within a limited amount of time. Journey through time & space

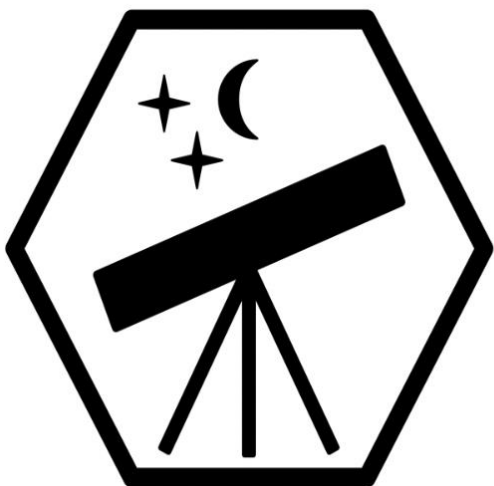


High School Education Programs – other competitions & offers



SSVI = Sterren Schitteren Voor Iedereen (Stars Shine For Everyone)
Project aiming at bringing kids with disabilities and coming from underserved communities in contact with science , astronomy in particular

- Belgium
- annual contest with significant number of Bresser telescopes + accessories and extra educational material



IACC = International Astronomy and Astrophysics Competition
Competition for worldwide students to test their skills in astronomy and astrophysics by solving problems in 3 rounds

- since 2019, 28000+ participants
- 3 categories for students (<16y & 16<y<19 high school, >19y university)
- teachers
- awards: small cash, medals, telescopes for school/university/country

University-level Education Programs

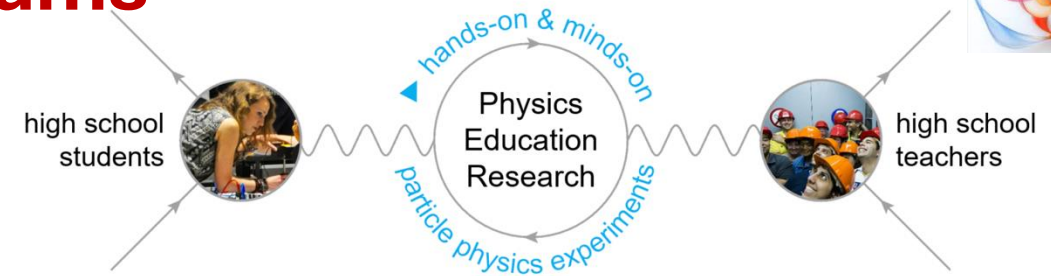


University-level education across Europe is deeply integrated with ongoing research in nuclear, astroparticle, and particle physics. Institutions collaborate across borders to offer advanced training through summer schools, international MSc programs, and immersive internships directly at laboratories

- **CERN Summer Student Programme:** ~300 students annually from all over the world; includes lectures, project work, and participation in detector shifts
<https://home.cern/summer-student-programme>
- **Joint Schools (e.g., ESI, GGI, ESHEP, ISAPP):** Offer cross-disciplinary courses in high-energy and astroparticle physics with hands-on sessions, detector tutorials, and coding workshops
- **Integration in Curricula:** Specialized MScs in Subatomic Physics, often supported by ERASMUS+ mobility and research-stage internships
- **Open Learning Platforms:** CERN Moodle, Coursera collaborations, and use of real datasets for course assignments promote access to advanced content

Something more on Education Programs

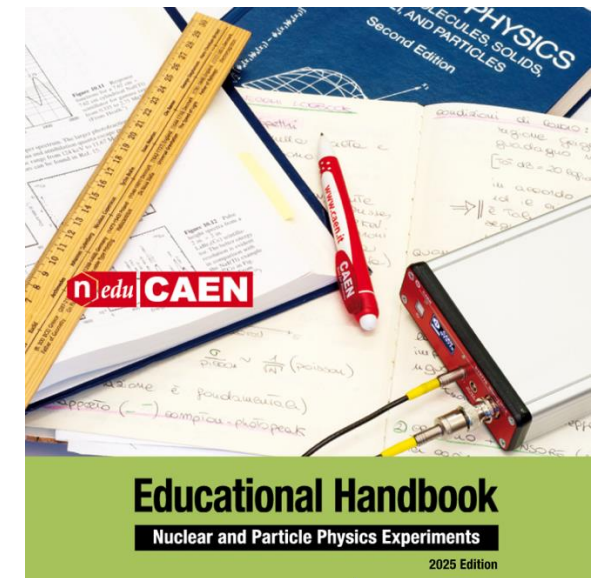
- **S’Cool LAB** (2014-2022) hands-on & minds-on particle physics experiment sessions on-site at CERN. From 2023 => Labs at CERN Gateway



- **Virtual Laboratory** Course on experimental nuclear physics and nuclear electronics or university students & young specialists. Laboratory of nuclear fission, γ -spectroscopy, data analysis in ROOT, detectors & data processing, hands-on practicum

INTRODUCTION TO EXPERIMENTAL NUCLEAR PHYSICS AND NUCLEAR ELECTRONICS

- **CAEN Educational Handbook** Nuclear and Particle Physics Experiments: Several Educational Notes are provided and continuously developed for covering different Physics topics and helping the tutor in exploiting the advanced capabilities of the CAEN Educational kits



Support for Early Career Researchers (ECR) - Programs



Early career researchers (ECRs) in physics (PhD students, postdocs and junior scientists) are essential to the sustainability of large-scale research programs. In Europe, a variety of structured initiatives provide **funding, mentoring, technical training, and career development** opportunities within a research-rich ecosystem

- **Marie Skłodowska-Curie Actions (MSCA) - Doctoral Networks (DNs):** Create structured, interdisciplinary PhD programs with strong outreach components
- **GÉANT and ESCAPE:** Provide computing and data science training for young researchers working on large-scale experiments (e.g., LHC, CTA, SKA)
- **Career Development Events:** Career orientation days at CERN, GSSI, and DESY promote alternate career pathways beyond academia => help researchers transition toward roles in software, education, consultancy, and science diplomacy
- **Mentoring Schemes:** EU-funded initiatives for women in STEM and underrepresented groups in physics

Outreach Activities and Public Events



Public-facing activities are essential in building scientific trust, increasing awareness of fundamental research, and ensuring the social license for large-scale experiments.

In Europe, major labs and collaborations invest in **interactive science communication**, **cultural events**, and **immersive experiences** to make invisible physics tangible

- **CERN Science Gateway:** Opened in 2023 with immersive exhibitions, explorable simulations, hands-on workshops, a state-of-the-art visitor center designed by Renzo Piano with a 900 seats auditorium

Outreach Activities and Public Events – CERN gateway



<https://sciencegateway.cern>



- Labs
(Re-) Discover your inner scientist

- Science Shows
Explore the stories of discoveries

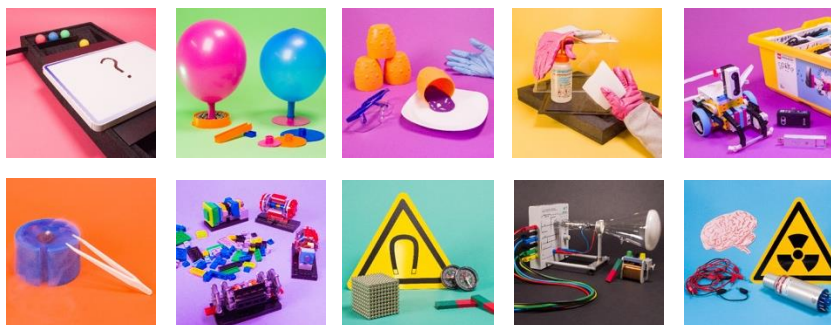
- Online Learning
Engage online to find out more





Outreach Activities and Public Events – CERN gateway

LAB Workshops



- 10 different lab workshops, 45-90 min, 24p
- First 9 months: 785 workshops, 17k visitors

Age group	% Visitors
5 to 7	4%
8 to 12	7%
13 to 15	5%
16 to 19	35%
20 to 29	1%
30+	5%
Open workshops	42%

- Goal 20k in 1y (22k visitors in 11 months)
- Very busy during school holidays and summer
- English, French and many other languages
- 4÷10 workshops/day
- >250 guides trained



Outreach Activities and Public Events - 1



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- **European Researchers' Night (MSCA):** The [ERN](#) is the largest science outreach event in Europe. In 2024 and 2025, 47 projects will run events in 23 countries. Large-scale public event across 300+ cities, showcasing physics experiments and societal applications
- **Astrophysics Planetariums & Documentaries:** Projects like "[Cosmic Light](#)" or "[KM3NeT's VR](#)" installations help make invisible phenomena tangible
- **Public Physics Lectures:** CERN, DESY, INFN, LIP (Portugal) regularly organize public physics lectures on cosmology, quantum physics, climate, and particle discoveries



Outreach Activities and Public Events - 2

- CERN Festival, Festival della Scienza, and Pint of Science bring researchers to cafés, local pubs, squares, and museums
- ⇒ Events often feature artistic collaborations (e.g., music and physics, dance and gravitational waves)
- ⇒ Multi-language accessibility ensures wider social impact



Science Communication Strategies

- Focus on **storytelling**, **emotional engagement**, and **visual explanation** of complex phenomena (e.g., quantum field theory, neutrino oscillations)
- Use of **multilingual resources**, **3D animations**, **social media series**, and **podcasts**
- Training workshops are often offered to young researchers to improve outreach delivery (e.g., “*Meet the Scientist*”, “*Physics Slam*”)

Outreach Tools and Platforms



Effective science outreach requires modern, scalable tools that translate complex physics into understandable, interactive experiences. European institutions have developed **digital platforms**, **open datasets**, and **engaging media** to reach diverse audiences, from students to policymakers

a) IPPOG Repository: Multilingual, peer-reviewed materials for public engagement, ranging from Feynman diagrams to cosmic ray detector activities see D. Hatzifotiadou's talk




b) Multimedia and Social Media Campaigns: High-fidelity visualizations, multilingual explanations (e.g., CERN in 20+ languages), interviews with researchers

c) Data4All / Open Data: Educational datasets allow non-experts and students to perform simplified analyses on real LHC events

d) Interactive Tools: QuarkNet apps, e-Labs, CERN Land, and ROOT tutorials redesigned for browser-based access

Outreach Tools and Platforms – b) Multimedia & Social



- **YouTube Channels:**
 - *CERN, INFN, DESY, and APPEC* share lectures, behind-the-scenes videos, and explainers
- **Podcasts and Documentaries:**
 - *CERN Courier Podcast, LHCb Podcast, KM3NeT Video Diary*
- **TikTok and Instagram Reels:**
 - Experiments like ATLAS and IceCube have dedicated teams posting short physics demos, Q&A with scientists, and real-time updates
- Emphasis on **short-form, multilingual, and mobile-friendly content**
-  CERN YouTube: <https://www.youtube.com/user/CERNTV>
-  INFN Outreach Videos: <https://www.youtube.com/user/INFNChannel>
-  APPEC Podcast: <https://www.appec.org/about/podcasts/>

Outreach Tools and Platforms – c) Open Data Platforms



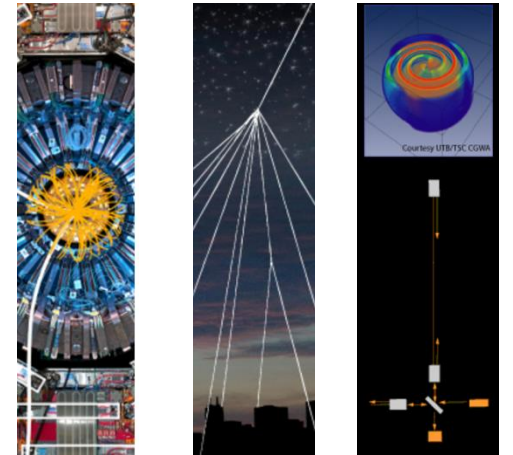
- Public access to simplified datasets from LHC experiments:
 - Particle event data in CSV, JSON, and ROOT formats
 - Jupyter notebooks and analysis scripts for classroom use
 - Interactive visualizations of real LHC events
- Used by both secondary schools and university students in lab courses
 - *ALICE Open Data*: Access to selected pp and Pb-Pb collision datasets from 2010, available in ESD format for educational and demonstration purposes
 - *ATLAS Open Data*: Includes tools to reconstruct event topologies
 - *CMS Open Data*: Offers full 2011 datasets for public analysis
 - *LHCb Open Data*: Provides stripped-down datasets from 2011–2012 runs, including ROOT ntuples for B-physics analysis. Users can explore flavor physics, particle ID, and decay channels using Docker-based environments and Jupyter notebooks designed for education and training

Outreach Tools and Platforms – d) Interactive Tools



QuarkNet & e-Labs

- [QuarkNet](#) (US/EU collaboration) provides high schools students & teachers with data acquisition kits and access to a shared analysis portal with Masterclasses, Data Activities Portfolio (DAP) and e-Labs
- The [e-labs](#) ([CMS](#), [Cosmic ray](#), [LIGO](#)) allow students to:
 - Organize & conduct authentic research
 - Experience the environment of scientific collaboration
 - Possibility to make real contribution to a burgeoning scientific field
- Interface includes histogram generation, curve fitting, and real-time data access



Educational Games and Simulations

- [CERN Land](#): Interactive games (e.g., “*Save the Higgs Boson*”), virtual labs, and particle quizzes designed for younger audiences and classrooms
 - [CMS Adventure](#): A puzzle-based exploration game about the CMS detector and the discovery of new particles
 - [Particle Clicker](#): A browser-based game where players build detectors, run accelerators, and “discover” particles in a simplified virtual LHC
- => These tools support informal learning and outreach events

Challenges and Strategic Goals



Despite major progress, outreach and education in nuclear, particle, and astroparticle physics still face **systemic, pedagogical, and social challenges**

Addressing these barriers is key to sustaining scientific impact and ensuring equitable participation

- **Communicating Abstract Concepts:** Quantum tunneling, neutrino mass, and hadronization require visual and analogical support without oversimplification
- **Sociopolitical Framing:** Addressing misconceptions about nuclear risks, cost-benefit debates, and ethical concerns of large-scale science
- **Fragmentation of Efforts:** Need for central EU-level frameworks to coordinate and fund long-term outreach and education initiatives
- **Diversity, Equity & Inclusion:** Promote access across rural areas, linguistic minorities, and underrepresented student populations

Conclusions



Outreach & Education => structural components of scientific progress and societal impact

- **Europe is uniquely positioned** to lead this integration, thanks to its collaborative culture, transnational institutions, and commitment to public engagement:
 - Europe is home to the world's most ambitious infrastructures in fundamental physics: CERN, INFN, DESY, KM3NeT, Virgo, CTA, etc.
 - Initiatives like Horizon Europe, Marie Skłodowska-Curie Actions, COST, and Erasmus+ allow mobility, interdisciplinary training, and dissemination.
 - European networks like APPEC, LEAPS, and IPPOG offer unparalleled collaboration models between labs, schools, and policymakers.
- **Early engagement works:** Initiatives like IPPOG Masterclasses, Lab2Go, and open data platforms consistently increase interest in physics and STEM pathways
- **High-quality education sustains innovation:** Through doctoral schools, summer programs, and data training initiatives, Europe develops a scientifically literate, globally mobile research community
- **Outreach is impact:** Public-facing projects (e.g., CERN Science Gateway, KM3NeT VR, Science Festivals) translate abstract concepts into tangible, engaging experiences for all

Conclusions – Core Pillars for the Future



- **Integration**

Outreach and education must be embedded in the life cycle of all major physics projects, from design to post-discovery

- **Openness**

Sharing tools, data, and training ensures transparency and fosters trust in science (aligned with the Open Science movement)

- **Inclusivity**

A just and diverse physics community must be built through equitable access, multilingual resources, and diverse role models

- **Sustainability**

Programs should have long-term funding, policy backing, and measurable outcomes aligned with European goals

“In particle physics, we look for the smallest components of matter.

In education, we plant the smallest seeds of wonder, capable of growing into the next generation of discovery”

Conclusions – Thoughts to be shared



"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science"
- Albert Einstein

- **Messages to young researchers (next generation of physicists):**
 - You are not just researchers - you are translators of the universe
 - Every dataset, every detector, every formula has a story worth telling
 - Outreach is not a distraction. It is a form of leadership
- **Messages to senior researchers => in our career, consider:**
 - Bring science out of the lab and into society, where it belongs
 - Be the mentor you wish you had
 - Champion inclusion, accessibility, and curiosity everywhere you work
 - Advocate for outreach as a scientific duty, not a side project

"What you share today may spark the discovery of tomorrow"