Online Particle Physics Information

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1 Introduction

The collection of online information resources in particle physics and related areas presented in this chapter is of necessity incomplete. An expanded and regularly updated online version can be found at:

`http://library.cern/particle_physics_information`

Suggestions for additions and updates are very welcome.[1]

[1] Please send comments and corrections to micha.moshe.moskovic@cern.ch

2 Particle Data Group (PDG) resources

- **Review of Particle Physics (RPP):** A comprehensive report on the fields of particle physics and related areas of cosmology and astrophysics, including both review articles and a compilation/evaluation of data on particle properties. The review section includes articles, tables and plots on a wide variety of theoretical and experimental topics of interest to particle physicists and astrophysicists. The particle properties section provides tables of published measurements as well as the Particle Data Group's best values and limits for particle properties such as masses, widths, lifetimes, and branching fractions, as well as an extensive summary of searches for hypothetical particles. RPP is published as a large book every two years, with partial updates made available once each year on the web.

  All the contents of the book version of RPP are available online:

  `http://pdg.lbl.gov`

  The printed book can be ordered:

  `http://pdg.lbl.gov/2019/html/receive_our_products.html`

  Of historical interest is the complete RPP collection which can be found online:

  `http://pdg.lbl.gov/rpp-archive/`

  `http://library.cern/PDG_publications/review_particle_physics`

- **Particle Physics booklet:** An abridged version of the Review of Particle Physics, available as a pocket-sized 250-page booklet. It is one of the most useful summaries of physics data. The booklet contains an abbreviated set of reviews and the summary tables from the most recent edition of the Review of Particle Physics.

  The PDF file of the booklet can be downloaded:

  `http://pdg.lbl.gov/current/booklet.pdf`

  The printed booklet can be ordered:

  `http://pdg.lbl.gov/2019/html/receive_our_products.html`

- **PDGLive:** A web application for browsing the contents of the PDG database that contains the information published in the Review of Particle Physics. It allows one to navigate to a particle of interest, see a summary of the information available, and then proceed to the detailed information published in the Review of Particle Physics. Data entries are directly linked to the corresponding bibliographic information in INSPIRE.

  `http://pdglive.lbl.gov`

- **Computer-readable files:** Data files that can be downloaded from the PDG include tables of particle masses and widths, PDG Monte Carlo particle numbers, and cross-section data. The files are updated with each new edition of the Review of Particle Physics.

  `http://pdg.lbl.gov/current/html/computer_read.html`

3 Particle Physics Information Platforms

- **INSPIRE:** INSPIRE serves as a one-stop information platform for the particle physics community, comprising 8 interlinked databases on literature, conferences, institutions, journals, researchers, experiments, jobs and data. Run in collaboration by CERN, DESY, Fermilab, IHEP, IN2P3, and SLAC, it has been serving the scientific community for almost 50 years. Previously known as SPIRES, it was the first website outside Europe and the first database on the web. Close interaction with the user community and with arXiv, ADS, HEPData, ORCID, PDG and publishers is the backbone of INSPIRE's evolution.

  `http://inspirehep.net/`

  In 2019, INSPIRE launched INSPIRE beta, featuring all-new literature search, author profiles and job postings. INSPIRE beta is running in parallel with the current platform and it will

fully replace it in the future. The INSPIRE beta site is available at:

`http://beta.inspirehep.net`

- Blog: `http://blog.inspirehep.net/`
- Twitter: `@inspirehep`

4 Literature Databases

- **ADS:** The SAO/NASA Astrophysics Data System is a Digital Library portal offering access to 13 million bibliographic records in Astronomy and Physics. The ADS search engine also indexes the full-text for approximately four million publications in this collection and tracks citations, which now amount to over 80 million links. The system also provides access and links to a wealth of external resources, including electronic articles hosted by publishers and arXiv, data catalogs and a variety of data products hosted by the astronomy archives worldwide. The ADS can be accessed at:

  `http://ads.harvard.edu/`

- **arXiv.org:** A repository of full-text articles in physics, astronomy, mathematics, computer science, statistics, nonlinear sciences, quantitative finance, quantitative biology, electrical engineering and systems science, and economics. Papers are submitted by registered authors to arXiv, often as preprints in advance of submission to a journal for publication; includes postprints, working papers, and other relevant material. Established in 1991, the repository is interlinked with ADS and INSPIRE, among others. Readers can browse subject categories or search by author, title, abstract, date, and other fields. Receive daily update alerts for subfields by email or RSS.

  `https://arXiv.org`

  - Blog: `https://blogs.cornell.edu/arXiv`
  - Twitter: `@arxiv`

- **CDS:** The CERN Document Server contains records of about 700,000 CERN and non-CERN articles, preprints, theses. It includes records for internal and technical notes, official CERN committee documents, and multimedia objects. CDS is planning to focus on its role as an institutional repository covering all CERN material from the early 50s and reflecting the holdings of the CERN library. Non-CERN particle and accelerator physics content is in the process of being exported to INSPIRE.

  `http://cds.cern.ch`

- **INSPIRE HEP:** The HEP collection, the flagship of the INSPIRE suite, serves more than 1.3 million bibliographic records with a growing number of full-text articles attached and metadata including author affiliations, abstracts, references, experiments, keywords as well as links to arXiv, ADS, PDG, HEPData, publisher platforms and other servers. It provides fast metadata and full-text searches, plots extracted from full text, author disambiguation, author profile pages and citation analysis and is expanding its content to, e.g., experimental notes.

  `http://inspirehep.net`

- **JACoW:** The Joint Accelerator Conference Website publishes the proceedings of several accelerator conferences held around the world. A custom interface allows searching based on keywords, titles, authors, and in the full text.

  `http://www.jacow.org/`

- **KEK Library Preprints and Reports Database:** This database contains bibliographic records of preprints and technical reports held in the KEK library, with links to the full-

text images of more than 100,000 papers scanned from their worldwide preprint collection. Particularly useful for older scanned preprints. Links to it are included in INSPIRE HEP.

`https://www.i-repository.net/il/meta_pub/engG0000128Lib`

- **MathSciNet:** This database of almost 3 million items provides reviews, abstracts and bibliographic information for much of the mathematical sciences literature. Over 100,000 new items, most of them classified according to the Mathematics Subject Classification, and more than 80,000 reviews of the current published literature are added each year. Author identification allows users to search for publications by author and citation data allows users to track the history and influence of research publications.

`http://www.ams.org/mathscinet`

- **OSTI.GOV:** A portal to free, publicly available DOE-sponsored R&D results including technical reports, bibliographic citations, journal articles, conference papers, books, multimedia and data information. It consolidates OSTI's home page and the now-retired primary search tool SciTech Connect. It contains over 3 million records, including citations to 1.5 million journal articles, 1 million of which have digital object identifiers (DOIs) linking to full-text articles on publishers' websites.

`https://www.osti.gov`

5 Particle Physics Journals and Conference Proceedings Series

- **CERN Journal List:** This list of journals and conference series publishing particle physics content provides information on Open Access, copyright policies and terms of use.

`http://library.cern/oa/where-publish`

- **INSPIRE Journals:** The database contains over 3,600 journals publishing HEP-related articles.

`http://inspirehep.net/collection/journals`

6 Conference Databases

- **INSPIRE Conferences:** The database of more than 23,000 past, present, and future conferences, schools, and meetings relevant to high-energy physics and related fields is searchable by title, acronym, series, date and location. Included are information about published proceedings, links to conference contributions in the INSPIRE HEP database, and links to the conference website when available. New conferences can be submitted from the entry page.

`http://inspirehep.net/conferences`

7 Research Institutions

- **INSPIRE Institutions:** INSPIRE Institutions contains over 11,500 institutes, laboratories, and universities, where research on particle physics and astrophysics is led. Every record includes, whenever possible, as detailed information, such as address, web links, experiments, and links to INSPIRE papers authored by people affiliated to that institution. One can search for a particular institution by name, acronym, and location.

`http://inspirehep.net/institutions`

8 People

- **INSPIRE HEPNames:** Searchable worldwide database of over 125,000 active, departed, retired, and deceased people associated with particle physics and related fields. The affiliation history of these researchers, their e-mail addresses, ORCIDs, web pages, experiments they participated in, PhD advisor, information on their graduate students and links to their papers in the INSPIRE HEP, arXiv and ADS databases are provided, as well as a user interface to update this information.

http://inspirehep.net/hepnames

- **ORCID**: Registry providing persistent digital identifiers allowing to unambiguously identify researchers. Through integration in key research workflows such as manuscript and grant submission, it supports automated linkages between scientists and their professional activities ensuring that their work is recognized.

https://orcid.org

9 Experiments

- **INSPIRE Experiments:** Contains more than 3,500 past, present, and future experiments in particle physics. Lists both accelerator and non-accelerator experiments. Includes official experiment name and number, location, and collaboration lists. Simple searches by participant, title, experiment number, institution, date approved, accelerator, or detector, return a description of the experiment, including a complete list of authors, title, overview of the experiment's goals and methods, and a link to the experiment's web page if available. Recently, it has expanded its scope to include particle accelerators besides experiments and to link them together.

http://inspirehep.net/Experiments

- **Cosmic ray/Gamma ray/Neutrino and similar experiments:** This extensive collection of experiment websites is organized by focus of study and by location. Additional sections link to educational materials, organizations, and other useful resources. The site is maintained at the Max Planck Institute for Nuclear Physics, Heidelberg.

http://www.mpi-hd.mpg.de/hfm/CosmicRay/CosmicRaySites.html

10 Jobs

- **AAS Job Register:** The American Astronomical Society publishes once a month graduate, postgraduate, faculty and other positions mainly in astronomy and astrophysics.

http://jobregister.aas.org/

- **Academic Jobs Online**: A full-service online recruiting site for academic institutions worldwide in all disciplines and areas.

https://academicjobsonline.org/ajo

- **APS Careers:** A gateway for physicists, students, and physics enthusiasts to information about physics jobs and careers. It contains Physics job listings, career advice, upcoming workshops and meetings, and career and job-related resources provided by the American Physical Society.

http://www.aps.org/careers/employment

- **brightrecruits.com:** A recruitment service run by IOP Publishing that connects employers from different industry sectors with jobseekers who have a background in physics and engineering.

http://brightrecruits.com/

- **IOP Careers:** Career information and resources primarily aimed at university students are provided by the UK Institute of Physics.

http://www.iop.org/careers/

- **INSPIRE HEPJobs:** Lists academic and research jobs in high energy physics, nuclear physics, accelerator physics and astrophysics with the option to post a job or to receive email notices of new job listings. About 500 jobs are currently listed.

http://inspirehep.net/jobs

- **Physics Today Jobs:** Online recruitment advertising website for Physics Today magazine,

published by the American Institute of Physics. Physics Today Jobs is the managing partner of the AIP Career Network, an online job board network for the physical science, engineering, and computing disciplines. Over 6,000 resumes are currently available, and nearly 5,000 jobs were posted in 2018.

`http://www.physicstoday.org/jobs`

11 Software Packages and Repositories

Most relevant software is hosted by general-purpose repositories like GitHub, GitLab or BitBucket, but here are a few specific repositories focused on astrophysics or HEP. ## Repositories

- **ASCL:** The Astrophysics Source Code Library (ASCL) is a free online registry for source codes of interest to astronomers and astrophysicists. It lists codes that have been used in research that has appeared in, or been submitted to, peer-reviewed publications.

  `http://ascl.net`

- **GenSer:** The Generator Services project collaborates with Monte Carlo (MC) generator authors and with LHC experiments in order to prepare validated LCG compliant code for both theoretical and experimental communities at the LHC, sharing the user support duties, providing assistance for the development of the new object-oriented generators, and guaranteeing the maintenance of the older packages on the LCG supported platforms. The project consists of the generators repository, validation, HepMC record and MCDB event databases.

  `http://ep-dep-sft.web.cern.ch/project/generator-service-project-genser`

- **Hepforge:** A development environment for high-energy physics software projects, in particular housing many event-generator related projects, that offers a ready-made, easy-to-use set of web-based tools, including shell account with up-to-date development tools, web page hosting, subversion, git and Mercurial code management systems, mailing lists, bug tracker and wiki system.

  `http://www.hepforge.org/`

11.1 *Particle Physics Software*

- **FastJet:** This is a software package for jet finding in pp and e^+e^- collisions. It includes fast native implementations of many sequential recombination clustering algorithms, plugins for access to a range of cone jet finders and tools for advanced jet manipulation.

  `http://fastjet.fr/`

- **GAMBIT:** A global fitting code for generic Beyond the Standard Model theories, designed to allow fast and easy definition of new models, observables, likelihoods, scanners and backend physics codes.

  `http://gambit.hepforge.org`

- **Geant4:** This is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science.

  `http://geant4.web.cern.ch/geant4/`

- **LHAPDF:** HEP community standard library for parton distribution function interpolation, including official collection of PDF data sets.

  `http://lhapdf.hepforge.org/`

- **QUDA:** Library for performing calculations in lattice QCD on GPUs using NVIDIA's CUDA platform. The current release includes optimized solvers for Wilson, Clover-improved Wilson,Twisted mass, Staggered, Improved staggered, Domain wall and Mobius fermion actions.

  `http://lattice.github.io/quda/`

- **Rivet:** The Rivet toolkit, a system for validation of Monte Carlo event generators, provides a large set of experimental analyses useful for MC generator development, validation, and tuning.

  `http://rivet.hepforge.org/`

- **ROOT:** This framework for data processing in high-energy physics, born at CERN, offers applications to store, access, process, analyze and represent data or perform simulations.

  `http://root.cern.ch`

- **Scikit-HEP:** This is a community-driven and community-oriented project with the aim of providing Particle Physics at large with an ecosystem for data analysis in Python. The project started in Autumn 2016 and is under active development. It focuses on providing core and common tools for the community but also on improving the interoperability between HEP tools and the scientific ecosystem in Python as well as the discoverability of utility packages and projects.

  `http://scikit-hep.org`

- **tmLQCD:** This freely available software suite provides a set of tools to be used in lattice QCD simulations, mainly a HMC implementation for Wilson and Wilson twisted mass fermions and inverter for different versions of the Dirac operator.

  `https://github.com/etmc/tmLQCD`

- **USQCD:** The software suite enables lattice QCD computations to be performed with high performance across a variety of architectures. The page contains links to the project web pages of the individual software modules, as well as to complete lattice QCD application packages which use them.

  `http://usqcd-software.github.io`

- **Software lists:** A list of Monte Carlo generators may be found at:

  `http://cmsdoc.cern.ch/cms/PRS/gentools/www/geners/collection/`

  The homepage of the SUSY Les Houches Accord contains links to codes relevant for supersymmetry calculations and phenomenology.

  `http://skands.physics.monash.edu/slha/`

  A variety of codes and algorithmic tools for analysing supersymmetric phenomenology is described in

  `http://arxiv.org/abs/0805.2088`

  G. Cowan's list provides links to HEP software, general statistics and data analysis links.

  `http://www.pp.rhul.ac.uk/~cowan/sda/statlinks.html`

  An extended list of more specialized HEP-related software can be found in the online version of this review:

  `http://library.cern/particle_physics_information#sof`

11.2 *Astrophysics Software*

- **Astropy:** The Astropy Project is a community effort to develop a single core package for Astronomy in Python and foster interoperability between Python astronomy packages.

  `http://www.astropy.org`

- **Starlink:** Starlink was a UK Project supporting astronomical data processing. It was shut down in 2005 but its open-source software continued to be developed at the Joint Astronomy Centre until March 2015. It is currently maintained by the East Asian Observatory. The open-source software products are a collection of applications and libraries, usually focused on a specific aspect of data reduction or analysis.

`http://starlink.eao.hawaii.edu/starlink`

- Links to a large number of astronomy software archives are listed at:
  `http://heasarc.nasa.gov/docs/heasarc/astro-update/`

11.3 *Web Apps*

- **APFEL Web:** This online parton density function plotter allows to compare predictions for different PDF fits.
  `https://apfel.mi.infn.it/`
- **ColliderReach:** A tool to give a simple estimate of the relation between the mass reaches of different proton-proton collider configurations.
  `http://collider-reach.web.cern.ch/`
- **TMDplotter:** Allows to plot TMDs and PDFs as a function of different variables.
  `http://tmdplotter.desy.de/`

11.4 *Mobile Apps*

- **arXiv eXplorer:** Android app for browsing and searching arXiv.org, and for reading, saving and sharing articles.
  `https://play.google.com/store/apps/details?id=com.gbeatty.arxiv`
- **Collider:** This mobile app allows users to see data from the ATLAS experiment at the LHC.
  `http://collider.physics.ox.ac.uk/`
- **LHSee:** This smartphone app allows users to see collisions from the Large Hadron Collider.
  `http://www2.physics.ox.ac.uk/about-us/outreach/public/lhsee`
- **The Particles:** App for Apple iPad, Windows 8 and Microsoft Surface. Allows users to browse a wealth of real "event" images and videos, read popular "biographies" of each of the particles and explore the A-Z of particle physics with its details and definitions of key concepts, laboratories and physicists. Developed by Science Photo Library in partnership with Prof. Frank Close.
  `http://www.sciencephoto.com/apps/particles.html`

12 Data repositories

Data is increasingly deposited in general-purpose repositories like Zenodo (https://zenodo.org/), figshare (https://figshare.com/) or the Open Science Framework (https://osf.io/), but here are a few specific repositories focused on physics.

12.1 *Particle Physics*

- **HEPData:** The HEPData project, funded by the STFC (UK) and based at Durham University, has been built up over the past four decades as a unique repository for scattering data from experimental particle physics papers. It currently comprises the data points from plots and tables related to several thousand publications including those from the LHC. The data from HEPData can also be accessed through INSPIRE. A new enhanced service was recently developed in collaboration with CERN.
  `https://hepdata.net`
- **CERN Open Data:** The CERN Open Data portal provides data from real collision events, as well as simulated and simplified datasets, produced by the experiments at the LHC, virtual machines to reproduce the analysis environment, and software to process the data. It serves over 2 PB of data in total and encourages their use for both educational and research purposes.
  `http://opendata.cern.ch`
- **HepSim:** A repository with Monte Carlo simulations for particle-collision experiments. It

contains predictions from parton shower models and includes Monte Carlo events after fast and full detector simulations and event reconstruction.

`http://atlaswww.hep.anl.gov/hepsim/`

- **ILDG:** The International Lattice Data Grid is an international organization which provides standards, services, methods and tools that facilitate the sharing and interchange of lattice QCD gauge configurations among scientific collaborations by uniting their regional data grids. It offers semantic access with local tools to worldwide distributed data.

  `http://www.usqcd.org/ildg/`

- **MCDB - Monte Carlo Database:** This central database of MC events aims to facilitate communication between Monte-Carlo experts and users of event samples in LHC collaborations. Having these events stored in a public place along with the corresponding documentation allows for direct cross checks of the performances on reference samples.

  `http://mcdb.cern.ch/`

- **MCPLOTS:** MCPLOTS is a repository of Monte Carlo plots comparing High Energy Physics event generators to a wide variety of available experimental data. The website is supported by the LHC Physics Centre at CERN.

  `http://mcplots.cern.ch/`

12.2 *Astrophysics*

- **CfA Dataverse:** This astronomy data repository at Harvard is open to all scientific data from astronomical institutions worldwide.

  `https://dataverse.harvard.edu/dataverse/cfa`

- **NASA's HEASARC:** The High Energy Astrophysics Science Archive Research Center (HEASARC) is the primary archive for NASA's (and other space agencies') missions dealing with electromagnetic radiation from extremely energetic phenomena ranging from black holes to the Big Bang.

  `http://heasarc.gsfc.nasa.gov/`

- **NASA archives:** The NASA archives provide access to raw and processed datasets from numerous NASA missions.

  Mikulski Archive for Space Telescopes (MAST): Hubble telescope, other missions (UV, optical):

  `http://archive.stsci.edu/`

  NASA/IPAC Infrared Science Archive: Spitzer, Herschel, Planck telescope, other missions:

  `http://irsa.ipac.caltech.edu/`

- **NASA/IPAC Extragalactic Database (NED):** An astronomical database that collates and cross-correlates information on extragalactic objects. It contains their positions, basic data, and names as well as bibliographic references to published papers, and notes from catalogs and other publications. NED supports searches for objects and references, and offers browsing capabilities for abstracts of articles of extragalactic interest.

  `http://ned.ipac.caltech.edu/`

- **SIMBAD:** The SIMBAD astronomical database provides basic data, cross-identifications, bibliography and measurements for astronomical objects outside the solar system. It can be queried by object name, coordinates and various criteria. Lists of objects and scripts can be submitted.

  `http://simbad.u-strasbg.fr/simbad/`

- **VizieR:** VizieR provides access to the most complete library of published astronomical cat-

alogues and data tables, available online organized in a self-documented database. Query tools allow users to select relevant data tables and extract and format records matching given criteria. Currently, more than 19,000 catalogues are available.

`http://vizier.u-strasbg.fr/`

12.3 *General Physics*

- **NIST Physical Measurement Laboratory:** The National Institute of Standards and Technology provides access to physical reference data (physical constants, atomic spectroscopy data, x-ray and gamma-ray data, radiation dosimetry data, nuclear physics data and more) and measurements and calibrations data (dimensional and electromagnetic measurements).

  `https://www.nist.gov/pml/`

- **Springer Materials - The Landolt-Börnstein Database:** Landolt-Börnstein is a data collection covering all areas of physical sciences and engineering, such as particle physics, electronic structure and transport, magnetism, superconductivity. International experts scan the primary literature in more than 8,000 peer-reviewed journals and evaluate and select the most valid information to be included in the database. It includes more than 130,000 online documents, 1,2 million references, and covers 250,000 chemical substances. SpringerMaterials Interactive allows to visualise and analyse data. The search functionality is freely accessible and the search results are displayed in their context, whereas the full text is secured to subscribers.

  `http://materials.springer.com`

13 Data preservation activities

13.1 *Particle Physics*

- **CERN Analysis Preservation:** CERN Analysis Preservation is a platform for preserving knowledge and assets of individual physics analyses in LHC collaborations. Its aim is to capture and document all the elements needed to understand and rerun an analysis even several years later: data, software, environment, workflow, context, and documentation. This platform is currently in a pilot stage. It is accessible by LHC experimental groups (standard collaboration access restrictions are applied).

  `https://analysispreservation.cern.ch`

- **DASPOS:** A collective effort to explore the realisation of a viable data, software and algorithm preservation architecture in High Energy Physics

  `https://daspos.crc.nd.edu`

- **DPHEP:** DPHEP coordinates the efforts to define and implement Data Preservation and Long Term Analysis in HEP. DPHEP, which was initiated as a study group in 2008-2009, includes all major HEP experiments and labs. In 2014, it has become a Collaboration through the signature of a Collaboration Agreement by a number of large funding agencies. The group is endorsed by the International Committee for Future Accelerators (ICFA).

  DPHEP regularly organizes workshops, creates status reports, and maintains links with similar activities in other disciplines. Details of the organizational structure, the objectives, workshops and publications can be found on the website.

  `http://dphep.org`

- **REANA:** REANA (REusable ANAlyses) is a system for instantiating research data analyses on the cloud using container-based solutions. It complements CERN Analysis Preservation permitting the reuse and revalidation of preserved analyses. It is being developed in close collaboration with DASPOS and RECAST.

  `http://reanahub.io/`

- **RECAST:** Building on analysis preservation and re-use infrastructure of the LHC experiments, RECAST acts as a science gateway allowing theorists to suggest new reinterpretations of archived analyses of the LHC dataset. Experiments review suggestions and, if approved, simulate the proposed models and re-run the archived analysis to determine their viability. Such reinterpretation results are then appended to the records of the original publication in the relevant digital archives.

  `https://recast.cern.ch`

13.2 *Astrophysics*

More formal and advanced data preservation activity is ongoing in the field of Experimental Astrophysics, including:

- Fermi Data

  `https://fermi.gsfc.nasa.gov/ssc/data`
- IVOA (International Virtual Observatory Alliance)

  `http://www.ivoa.net/astronomers/applications.html`
- GWOSC (Gravitational Wave Open Science Center)

  `https://www.gw-openscience.org/about/`
- PLA (Planck Legacy Archive)

  `http://pla.esac.esa.int/pla/`
- SDSS (Sloan Digital Sky Survey)

  `http://sdss.org`

14 Particle Physics Education and Outreach Sites

A useful list of resources can also be found at

`http://www.stfc.ac.uk/research/particle-physics-and-particle-astrophysics/particle-physics-resources/`

14.1 *Science Educators' Networks*

- **IPPOG:** The International Particle Physics Outreach Group is a network of scientists, science educators and communication specialists working across the globe in informal science education and outreach for particle physics. The IPPOG collaboration comprises 30 members: 24 countries, 5 experiments and CERN as an international laboratory.

  `http://ippog.web.cern.ch`
- **Interactions.org:** Designed to serve as a central resource for communicators of particle physics. The daily updated website provides links to current particle physics news from the world's press, high-resolution photos and graphics from the particle physics laboratories of the world; links to education and outreach programs; information about science policy and funding; a glossary; and links to many educational sites.

  `http://www.interactions.org`
- **QuarkNet:** The QuarkNet Collaboration is a national program that partners high school science teachers with particle physicists working in experiments at CERN or Fermilab. The network consists of over 50 centers at research groups in universities and labs across the United States. About 100,000 students from 500+ U.S. high schools learn fundamental physics as they participate in inquiry-oriented investigations and analyze authentic data online. QuarkNet is supported in part by the National Science Foundation and Fermilab.

  `https://quarknet.org/`
- **Netzwerk Teilchenwelt:** Behind the project are about 200 researchers from 30 institutes

and universities doing research in particle physics, astroparticle physics and hadron and nuclear physics in Germany. Exciting young scientists throughout Germany for particle physics and accompanying them from school to top-level particle physics research—that's what they have set their sights on. https://www.teilchenwelt.de

14.2 *Physics Courses*

- **MIT OpenCourseWare - Physics:** These MIT course materials reflect almost all the undergraduate and graduate subjects taught at MIT. In addition to physics courses, supplementary educational resources are also available.

  `http://ocw.mit.edu/courses/physics/`

- **OnlineCourses.com:** A collection of online tests, video lectures, and related course materials from mostly prestigious universities around the world.

  `http://www.onlinecourses.com/physics/`

14.3 *Masterclasses*

- **Cosmic Ray Studies:** There are more than 12 projects around the world that address young people and teachers giving them an opportunity to explore cosmic particles, collecting, uploading and analyzing data and sharing results. Two annual events include International Cosmic Day and International Muon Week.

  `https://icd.desy.de`

  `https://quarknet.org/content/international-muon-week`

- **Hands-On Universe:** This program enables students to investigate the Universe while applying tools and concepts from science, math and technology.

  `http://handsonuniverse.org/`

- **HYPATIA:** HYPATIA (Hybrid Pupil's Analysis Tool for Interactions in ATLAS) is a tool for high school students to inspect the graphic visualization of particle collision products in the ATLAS detector at CERN.

  `http://hypatia.phys.uoa.gr/`

- **International Masterclasses:** Each year about 13,000 high school students in 55 countries come to one of about 225 nearby universities or research centres for a day to unravel the mysteries of particle physics. Lectures from active scientists give insight in topics and methods of basic research enabling the students to perform measurements on real data from one of seven experiments. At the end of the day, like an international research collaboration, participants join a video conference for discussion and combination of results. The program is coordinated from Institut fur Kern- und Teilchenphysik at TU Dresden and the Notre Dame University QuarkNet Center within the framework of the International Particle Physics Outreach Group (IPPOG). CERN, Fermilab and TRIUMF support videoconferences.

  `https://physicsmasterclasses.org`

  World Wide Data Day is an annual event.

  `https://quarknet.org/content/world-wide-data-day`

- **LHC physics Masterclasses:** Lectures from active scientists give insight into methods of basic research, enabling the students to perform measurements on real data from LHC experiments. Like in a real research collaboration, the participants then discuss their results and compare with expectations.

  `http://cms.web.cern.ch/content/cms-physics-masterclass`

  `http://lhcb-public.web.cern.ch/lhcb-public/en/LHCb-outreach/masterclasses/en`

  `http://alice.physicsmasterclasses.org/MasterClassWebpage.html`

http://atlas-minerva.web.cern.ch/atlas-minerva

- **IceCube Masterclass:** The program is inspired by the International Masterclasses program started by IPPOG and is coordinated by the Wisconsin IceCube Particle Astrophysics Center with support from QuarkNet. https://masterclass.icecube.wisc.edu/

14.4 *General Sites*

- **Contemporary Physics Education Project (CPEP):** Provides charts, brochures, Web links, and classroom activities. Online interactive courses include: Fundamental Particles and Interactions; Plasma Physics and Fusion; History and Fate of the Universe; and Nuclear Science.

http://www.cpepweb.org/

- **PhysicsCentral:** This site maintained by the American Physical Society provides information about current research and people in physics, experiments that can be performed at home or at school and the possibility to get physics questions answered by physicists.

http://www.physicscentral.com

14.5 *General Physics Activities*

- **HyperPhysics:** An exploration environment for concepts in physics employing concept maps and other linking strategies and providing opportunities for numerical exploration.

http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html

- **PhET Interactive Simulations:** Founded in 2002 by Nobel Laureate Carl Wieman, the PhET Interactive Simulations project at the University of Colorado Boulder creates free interactive math and science simulations. PhET sims are based on extensive education research and engage students through an intuitive, game-like environment where students learn through exploration and discovery.

https://phet.colorado.edu/en/simulations/category/physics

14.6 *Particle Physics Activities*

Citizen Science

- **Higgs Hunters:** A web-based citizen science project to help search for unknown exotic particles in the LHC data.

http://HiggsHunters.org

- **LHC @ home:** Volunteer computing platform to help physicists compare theory with experiment, in the search for new fundamental particles and answers to questions about the Universe.

http://lhcathome.web.cern.ch

Classroom Activities Collections

- **Contemporary Physics Education Project - Fundamental particle and interactions:**

http://www.cpepphysics.org/particles.html

- **Fermilab Physical Science/Physics Resources:**

https://ed.fnal.gov/home/educators1000-physics.shtml

- **IceCube Activities:**

https://icecube.wisc.edu/outreach/activities

- **IPPOG Resources:**

http://ippog.org/resources

- **Jefferson Lab Teacher Resources:**
  https://education.jlab.org/indexpages/teachers.html
- **LIGO Classroom Activities:**
  https://www.ligo.caltech.edu/page/classroom-activities
- **MINERvA Neutrinos in the Classroom:**
  https://neutrino-classroom.org
- **Perimeter Institute Educational Resources:**
  https://resources.perimeterinstitute.ca
- **Quarked Lesson Plans:**
  http://www.quarked.org/parents/lessonplans.html
- **QuarkNet Data Activities Portfolio:**
  https://quarknet.org/data-portfolio
- **Sanford Lab curriculum materials:**
  https://sanfordlab.org/educators/curriculum-modules

Interactive Sites

- **CAMELIA:** CAMELIA (Cross-platform Atlas Multimedia Educational Lab for Interactive Analysis) is a discovery tool for the general public, based on computer gaming technology.
  https://www.atlasexperiment.org/camelia.html
- **CERNland:** With a range of games, multimedia applications and films CERNland is a virtual theme park developed to bring the excitement of CERN's research to a young audience aged between 7 and 12. CERNland is designed to show children what is being done at CERN and inspire them with some physics.
  http://www.cernland.net/
- **In particular:** Podcast and more about physics and the process of discovering physics at the ATLAS experiment.
  https://inparticular.web.cern.ch/
- **Lancaster Particle Physics:** Suitable for 16+ students, this site offers a number of simulations and explanations of particle physics, including a section on the LHC.
  http://www.lppp.lancs.ac.uk/
- **Quarked!** - Adventures in the Subatomic Universe: This project, targeted to kids aged 7-12 (and their families), brings subatomic physics to life through a multimedia project including an interactive website, a facilitated program for museums and schools, and an educational outreach program.
  http://www.quarked.org/

Planetarium Show

- **Phantom of the Universe:** A planetarium show about dark matter that covers astrophysics, an underground experiment, and the LHC. It is distributed to planetariums for free.
  http://phantomoftheuniverse.com/

Video/Film

- **Angels and Demons:** With the aim of looking at the myth versus reality of antimatter and science at CERN this site describes the science behind the story including a set of videos.
  http://angelsanddemons.web.cern.ch/

- **CollidingParticles:** A series of films following a team of physicists involved in research at the LHC.

  http://www.collidingparticles.com/

- **Rewarding Learning videos about CERN:** The three videos based on interviews with scientists and engineers at CERN introduce pupils to CERN and the type of research and work undertaken there and are accompanied by teachers' notes.

  http://www.nicurriculum.org.uk/STEMWorks/resources/cern/index.asp

- **Videos by Don Lincoln:** Short YouTube videos on basic particle physics and cosmology.

  https://www.youtube.com/playlist?list=PLCfRa7MXBEsoJuAM8s6D8oKDPyBepBosS

Websites * **Cambridge Relativity and Cosmology:** Materials for the greater public to learn about the Origins of the Universe, including information on black holes, string theory, M-thoery, the cosmic microwave background and the structure of the Universe.

http://www.damtp.cam.ac.uk/research/gr/public/index.html

* **Imagine the Universe:** This site is for students age 14 and up and for anyone interested in learning about the Universe.

http://imagine.gsfc.nasa.gov/home.html

* **Particle Adventure:** An interactive tour of quarks, neutrinos, antimatter, extra dimensions, dark matter, accelerators and particle detectors from the Particle Data Group of Lawrence Berkeley National Laboratory. Simple elegant graphics and translations into 16 languages.

http://particleadventure.org/

14.7 *Lab Education Offices*

- **Argonne National Laboratory (ANL) Educational Programs:** Connecting today's world-class research to tomorrow's STEM problem solvers.

  http://www.anl.gov/education/

- **Brookhaven National Laboratory (BNL) Educational Programs:** The Office of Educational Programs mission is to design, develop, implement, and facilitate workforce development and education initiatives that support the scientific mission at Brookhaven National Laboratory and the Department of Energy.

  http://www.bnl.gov/education/

- **CERN's education programmes:** CERN's education and outreach programmes cover all ages from high-school students to university students. Specifically, CERN offers the tailor-made High-School Students Internship Programme several times per year and the Beamline for Schools Competition, challenging high-school students from around the world to propose an experiment to carry out at a real research laboratory. The Laboratory also runs residential programmes for high-school teachers from around the world and a summer programme for undergraduate students.

  https://home.cern/about/what-we-do/our-educational-programmes

- **DESY Education:** DESY Hamburg offers a regular series of public lectures and the DESY Science Café for young and old alike.

  https://fortbildung.desy.de/index_eng.html

- **DESY Zeuthen Outreach:** Posters, photos, lectures, videos and blogs. Projects for teachers and students include School Labs, Cosmic@Web, Teilchenwelt and International Cosmic Day.

  https://astro.desy.de/outreach

- **Fermilab Office of Education and Public Outreach:** Provides education resources and

information about activities for 's, physicists, students and visitors to the Lab. In addition to information about 25 programs, the website provides online data-based investigations for high school students, online versions of exhibits in the Lederman Science Center, links to particle physics discovery resources, web-based instructional resources, tips for education and outreach, and links to the Lederman Science Center and the Teacher Resource Center.

`http://ed.fnal.gov/`

- **Perimeter Institute Outreach:** Perimeter Institute shares ideas with students, teachers, and like-minded people through programs and resources that communicate the power, joy, and mystery of science. Perimeter's award-winning Outreach team brings science to life and raises scientific literacy through classroom resources, public lectures, teacher workshops, an educator network, and a summer school where students interact with Perimeter researchers.

`https://www.perimeterinstitute.ca/outreach`

- **Science Education at Jefferson Lab:** Jefferson Lab's long-term commitment to science education continues to focus on increasing the number of teachers with a substantial background in math and science, strengthening the motivation and preparation of all students, especially minorities and females, and addressing the serious under representation of minorities and females in science, math, engineering and technology careers.

`http://education.jlab.org/`

- **Joint Institute for Nuclear Research Education (JINR):** The JINR educational portal has resources, programs for teachers and school students and lab tours.

`http://www.jinr.ru/schoolstudents-teachers-en/`

- **Laboratori Nazionali di Frescati Educational (INFN):** INFN educational programs are addressed to students, teachers and general audiences of every age, from Italy and abroad. Insights and education about the INFN-LNF research are offered thanks to the organization of guided tours and open days, stages for students, refresher courses for teachers, seminars and divulgation events. The aim is to create a constant exchange between the research world and society, thanks to direct contact and via the internet and other social media.

`http://edu.lnf.infn.it/about/?lang=en`

- **Laboratori Nazionali del Gran Sasso Outreach Activities:** The Lab offers pupils the opportunity to approach the fascinating world of Physics and Science in general through stages, summer schools and training camps. It makes young researchers' skills and competences available to people both in public events, such as the Open Day and the European Researchers' Night, and in guided tours to visit the underground experimental halls.

`https://www.lngs.infn.it/en/outreach-activities`

- **Lawrence Berkeley National Laboratory (LBNL) Workforce Development and Education:** Working with our partners both within and outside Berkeley Lab, LBNL promotes equal access to scientific and technical careers for students from all backgrounds, supports STEM teachers, and build sscientific literacy through innovative education programs. The lab also supports educational outreach efforts from Berkeley Lab's divisions by providing program development assistance, materials, funding, volunteers, project management, marketing, and administrative support.

`https://education.lbl.gov/`

- **Sanford Underground Research Facility Education and Outreach:** Leveraging research being conducted underground at Sanford Lab, staff provide training, teaching tools and materials for teachers so they can inspire and challenge students.

`https://sanfordlab.org/educators`

- **SNOLAB Outreach:** The goal at SNOLAB is to develop new educational material that fosters an appreciation of the field of astroparticle physics. The education team endeavours to facilitate an exchange of knowledge with the public and scientists from around the world to better understand our solar system. The desired outcome of the educational work is to have a network of healthy and resilient community partners with informed and active citizens better equipped to understand the goals here at SNOLAB now and in the future.

  `https://www.snolab.ca/outreach`
- **TRIUMF High School Programs:** TRIUMF offers outreach programs for high-school students, teachers, and the general public with a mission of promoting science and research in the public arena. TRIUMF's outreach activities are also designed to tell Canadian students, teachers, and the public about the excitement of curiosity-driven research and about how a laboratory like TRIUMF adds value to Canada in new technologies, medical applications, and highly qualified people.

  `https://www.triumf.ca/for-public/high-school-programs`
- **LBL Workforce Development and Education:** This group carries out Berkeley Lab's mission to inspire and prepare the next generation of scientists, engineers, and technicians.

  `https://education.lbl.gov/`

14.8 *Educational Programs of Experiments*

- **ATLAS Education:** The ATLAS Experiment has a wide range of educational resources available for students and teachers. Categories include primary and secondary school students, university students, teachers, citizen science, and multimedia and resources.

  `https://atlas.cern/resources/education`
- **CMS Education and Outreach Resources:** Access to 110 resources from Activities and Artworks to Visualizations.

  `https://cds.cern.ch/collection/CMS%20Education%20and%20Outreach%20Resources?ln=en`
- **HiSPARC at UCU:** HiSPARC is an outreach, educational and research experiment on cosmic rays detection, which was initiated in the Netherlands in 2004. It brings together secondary school students and teachers, undergraduate students and university researchers in the quest to understand the origin of the most energetic particles in our universe. HSPARC has stations in the Netherlands, the United Kingdom, Denmark and Namibia.

  `https://www.uu.nl/en/organisation/university-college-utrecht/hisparc-at-ucu`
- **IceCube Education and Outreach:** IceCube is committed to bringing science to a wider audience. Learning opportunities for high school students, research experiences for teachers and undergraduates, learning activities for the classroom or at home, and wecasts.

  `https://icecube.wisc.edu/outreach`
- **KASCADE and KASCADE-Grande KDKC:** The aim of the project KCDC (KASCADE Cosmic Ray Data Centre) is the installation and establishment of a public data centre for high-energy astroparticle physics based on the data of the KASCADE experiment.

  `https://kcdc.ikp.kit.edu`
- **LIGO Education Resources:** Something fun and educational for K-12 educators, parents and interested students.

  `https://www.ligo.caltech.edu/page/educational-resources`
- **MINERvA Neutrinos in the Classroom:** Information and educational materials provide high school physics students with an in-depth hands-on interactive experience with real high-

energy particle physics. The materials should be suitable for a 1-2 weeks module on particle physics as it's done by professional scientists.

https://neutrino-classroom.org

- **VIRGO Educational Resources:** Useful resources (websites, texts, videos) for teachers and students related to gravitational waves and the interferometers like Virgo.

  http://public.virgo-gw.eu/educational-resources/

- **Pierre Auger Observatory's Educational Pages:** The site offers information about cosmic rays and their detection, and provides material for students and teachers.

  https://www.auger.org/index.php/edu-outreach

14.9 *News*

- **Asimmetrie:** Bimonthly magazine about particle physics published by INFN, the Istituto Nazionale di Fisica Nucleare (in Italian).

  http://www.asimmetrie.it/

- **CERN Courier:**
  - Website: https://cernocurier.com
  - Twitter: @cerncourier
- **DESY inForm:**
  - Website: http://www.desy.de/news/desy_inform/index_eng.html
  - Twitter: @desy
- **Fermilab News:**
  - Website: https://news.fnal.gov
  - Twitter: @Fermilab
- **LC Newsline:** The newsletter of the Linear Collider community.

  http://newsline.linearcollider.org/

  - Twitter: @LCnewsline
- **IOP News:**

  http://www.iop.org/news/

- **JINR News:**

  http://www1.jinr.ru/News/Jinrnews_index.html

- **News at Interactions.org:** The Interactions site provides news and press releases on particle physics.

  http://www.interactions.org/news-center

  - Twitter: @particlenews
- **Perimeter Institute News:**
  - Website: https://www.perimeterinstitute.ca/news
  - Twitter: @perimeter
- **Sandford News and Events:**
  - Website: https://sanfordlab.org/news-and-events
  - Twitter: @SanforLab

- **SLAC Signals:** This email newsletter reports about cutting-edge science, major SLAC milestones and other lab information. It has replaced SLAC Today in November 2013. Its signup page can be found at

  `http://eepurl.com/IqPl1`

- **SNOLAB News and Headline:**

  `https://www.snolab.ca/news`

- **Symmetry:** This magazine about particle physics and its connections to other aspects of life and science, from interdisciplinary collaborations to policy to culture is published 6 times per year by Fermilab and SLAC.

  `http://www.symmetrymagazine.org/`

  – Twitter: `@symmetrymag`

- **TRIUMF on NewsWise:**

  `https://www.newswise.com/institutions/newsroom/19528`

14.10 *Art in Physics*

- **Arts@CERN - When Art Meets Science:** Arts at CERN is the leading art and science programme promoting the dialog between artists and particle physicists. Programmes include Art Commissions and Exhibitions, Collide, Accelerate and Guest Artists.

  `https://arts.cern`

  The Collide@CERN residency programme aims to develop expert knowledge in the arts through the connection with fundamental science. Since 2011 the COLLIDE award calls to artists to win a fully funded residency for up to 3 months.

  `https://arts.cern/programme/collide`

  Accelerate@CERN is a country specific one-month research award for artists who have never spent time at a science lab before.

  `https://arts.cern/programme/accelerate`

- **Art of Physics Competition:** The Canadian Association of Physicists organizes this competition, the first was launched in 1992, with the aim of stimulating interest, especially among non-scientists, in some of the captivating imagery associated with physics. The challenge is to capture photographically a beautiful or unusual physics phenomenon and explain it in less than 200 words in terms that everyone can understand.

  `https://www.cap.ca/programs/art-physics/`

- **Fermilab Art Gallery:** The convergence of art and science occurs daily in the Fermilab Art Gallery open to the public. To initiate and stimulate communication and interactions among scientists, artists and the public, the laboratory hosts an artist-in-residence program. The artist-in-residence interacts with scientists to learn about their research and how it connects to society. They use this information to create a body of work, leading to presentations in the community and possibly an exhibition of the artwork at Fermilab.

  `http://events.fnal.gov/art-gallery/`

- **TRIUMF Science through Art:** TRIUMF's Science through Art initiatives explore the space where art and science collide. These programs bring artists and TRIUMF researchers, engineers, technicians, tradespeople, and students together to explore new ways of thinking about science, discovery, creativity, and our universe.

  `https://www.triumf.ca/science-through-art`

14.11 *Blogs and Twitter*

Lists of active blogs and tweets can be found on INSPIRE:

- **Scientist blogs:**
  `http://tinyurl.com/nmku27s`
- **Scientists with twitter accounts:**
  `http://tinyurl.com/nrg5k63`
- **Experiments with twitter accounts:**
  `http://tinyurl.com/q86kma8`
- **Institutions with twitter accounts:**
  `http://tinyurl.com/mzcm3nw`

List of physicists on Twitter at TrueSciPhi:
`http://truesciphi.org/phy.html`
Some selected particle physics related blogs:

- **ATLAS blog:**
  `https://atlas.cern/updates/blog`
- **Life and Physics:** Jon Butterworth's blog in the Guardian.
  `http://www.guardian.co.uk/science/life-and-physics`
- **Of Particular Significance:** Conversations about science, with a current focus on particle physics, with theoretical physicist Matt Strassler.
  `http://profmattstrassler.com/`
- **Particle People:** This interactions.org page highlights a new blogger involved in particle physics research each month.
  `http://www.interactions.org/particle-people`
- **Preposterous Universe:** Theoretical physicist Sean Carroll's blog.
  `https://www.preposterousuniverse.com/blog/`
- **Quantum diaries:** Thoughts on work and life from particle physicists from around the world, from 2005 to 2016.
  `http://www.quantumdiaries.org/`
- **Quantum diaries survivor:** Experimental particle physicist Tommaso Dorigo's blog.
  `https://www.science20.com/quantum_diaries_survivor`
- **Science blogs:** Launched in January 2006, ScienceBlogs features bloggers from a wide array of scientific disciplines, including physics.
  `http://scienceblogs.com/channel/physical-science/`
- **AstroBetter:** Blog with tips and tricks for professional astronomers.
  `https://www.astrobetter.com/`