Outreach modules for new particle searches using the ATLAS Forward Proton detector, Higgs boson physics, and portals for Higgs bosons and SUSY particles

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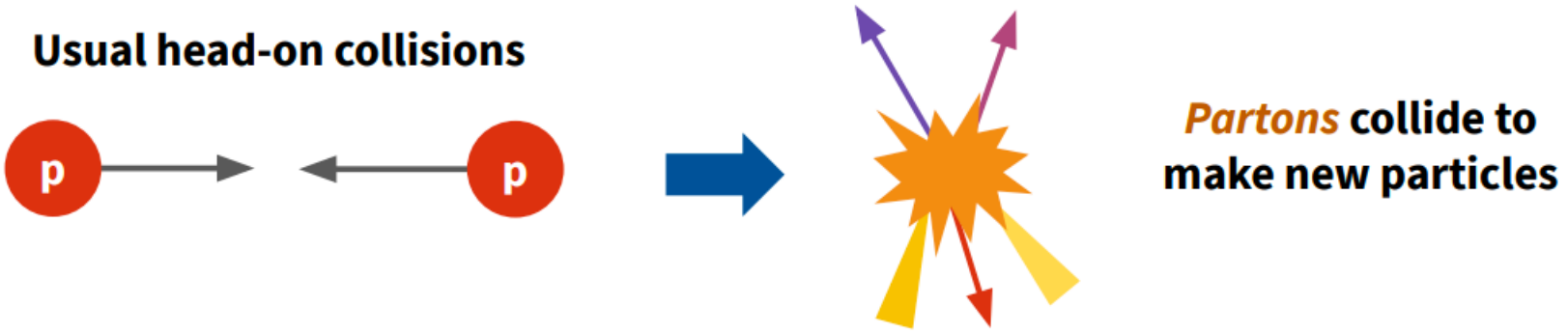
Introduction

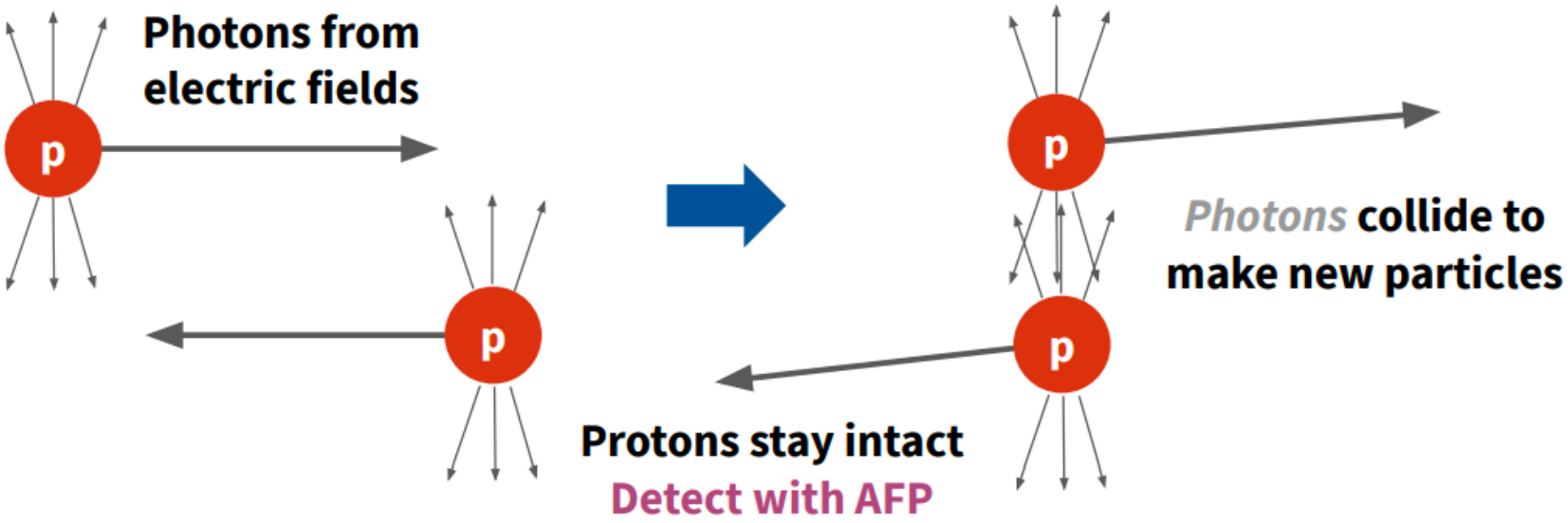
- We present modules as part of the Czech Particle Physics Project (CPPP).
- These are intended as learning tools in masterclasses aimed at high-school students (aged 15 to 18).
- Module dedicated to the detection of an Axion-Like-Particle (ALP) using the ATLAS Forward Proton (AFP) detector.
- Module focuses on the reconstruction of the Higgs boson mass using the Higgs boson golden channel with four leptons in the final state.
- Modules using Natural Learning Processing (NLP) for categorizing Higgs boson and Supersymmetry research publications.
- The modules can be accessed at the following link: http://cern.ch/cppp

Goal

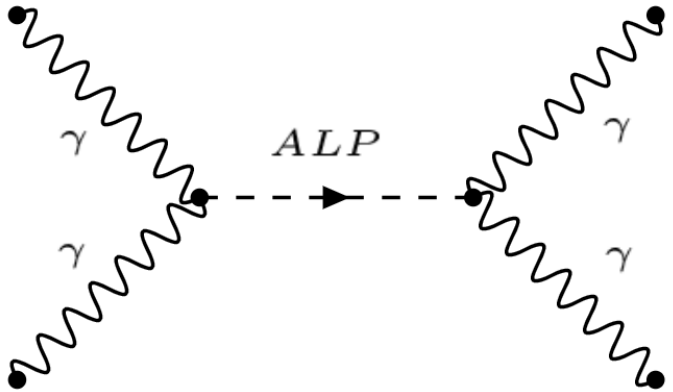
- Interactive web application for master classes.
- Aimed at high school students aged 15-18 years old.
- The aim is to walk students through the process of finding a 1 TeV Axion-Like Particle (ALP) using the ATLAS Forward Proton (AFP) detector.
- The simulation should be realistic but simplified.

Physics Motivation

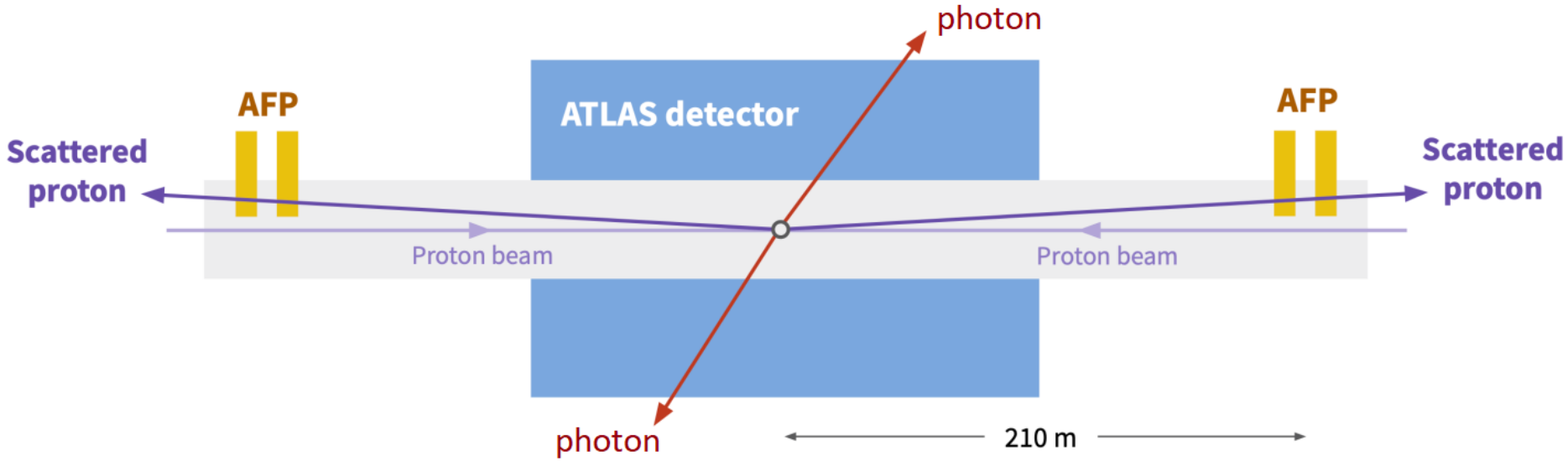




- Axion-Like-Particle (ALP) Production
- Expected signature: two energetic photons in the ATLAS central detector



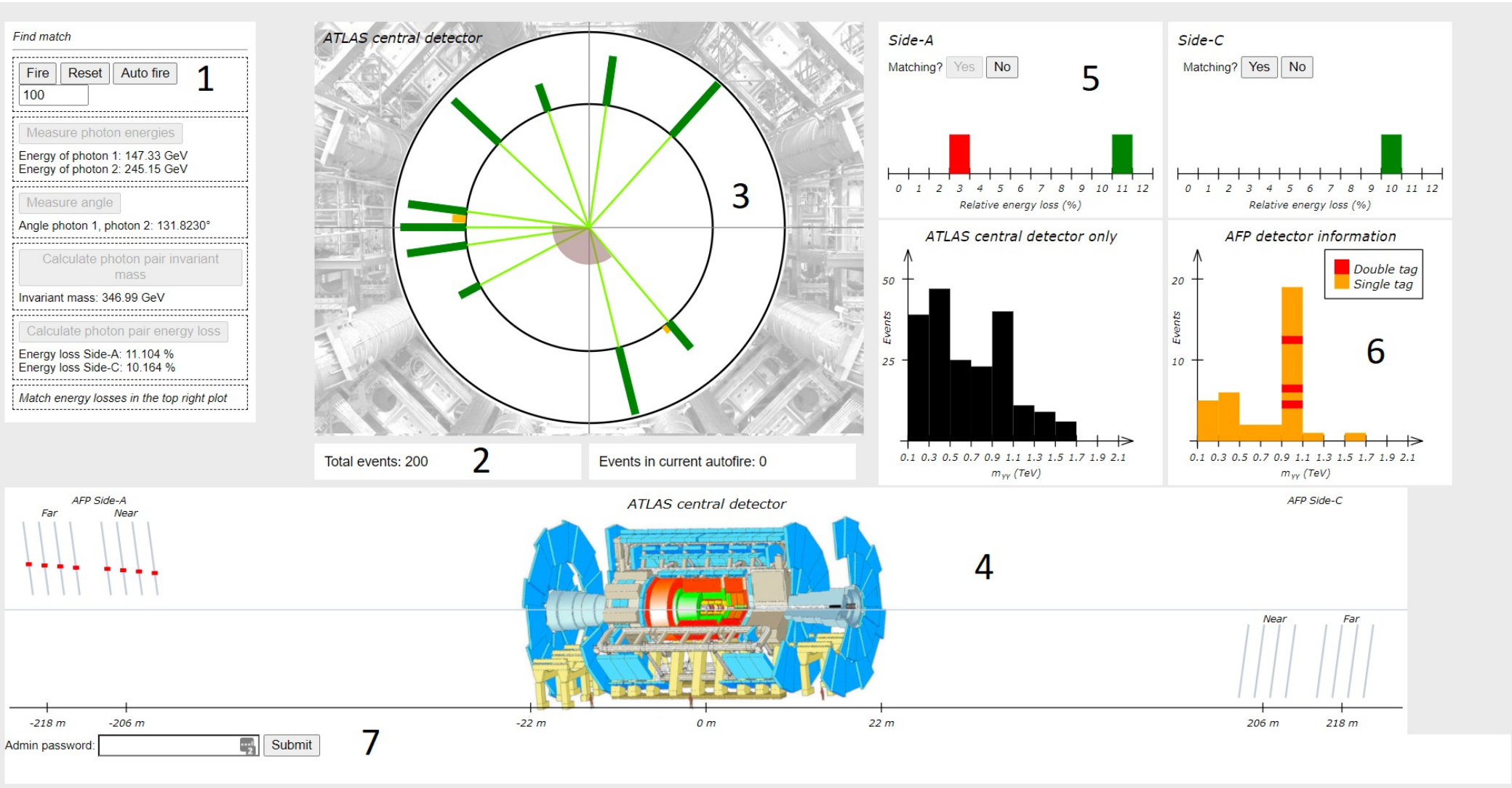
Background Reduction



In order to reduce the background of the AFP signal:

- ❑ Two ways of calculating energy loss: photons in central detector and deflected protons in AFP detectors.
- ❑ Di-photon events, where the energy loss does not match, are considered background events and are removed.
- ❑ In this way the AFP detector contributes to separate signal from background events.

Interactive Application



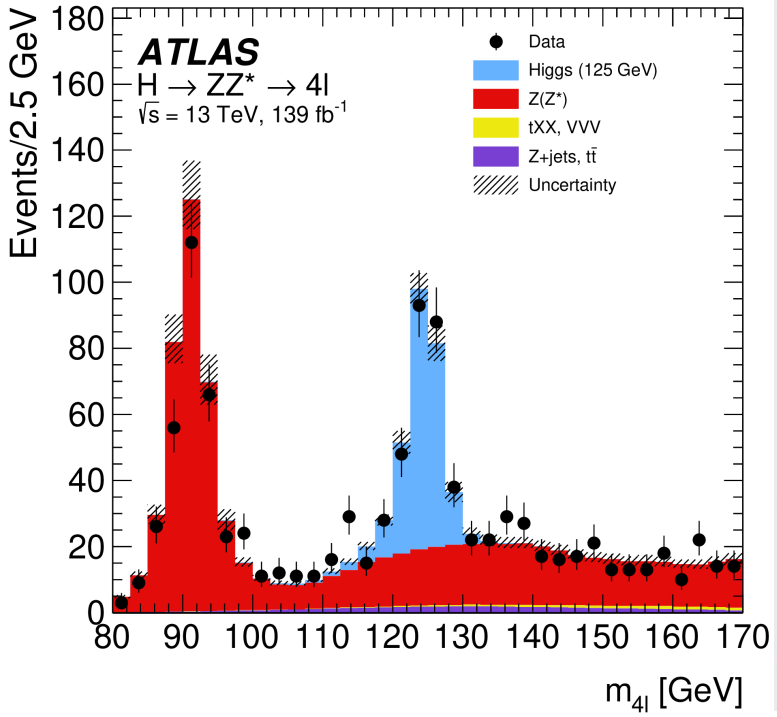
The visualisation page contains:

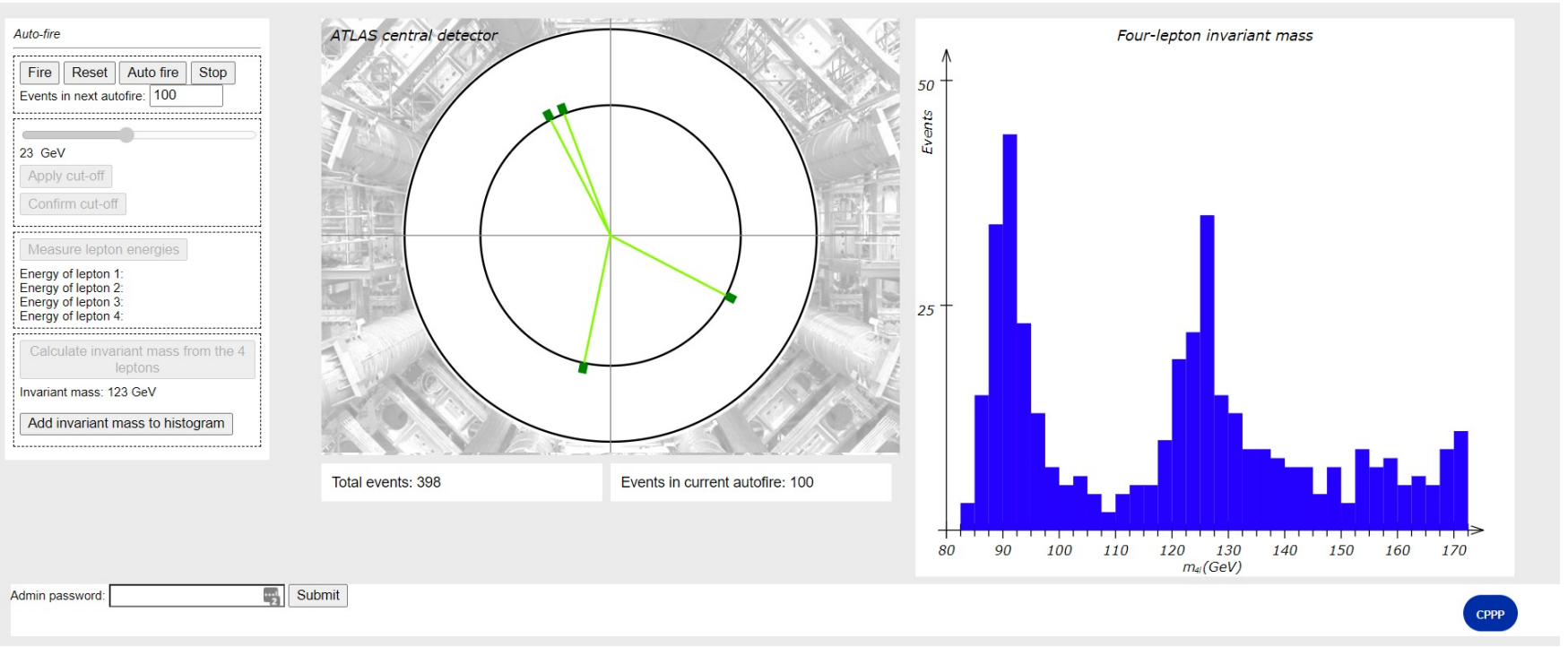
1. Control panel
2. Event counter
3. ATLAS central detector
4. ATLAS central detector side view with AFP on either side
5. Energy loss matching histograms
6. Invariant mass histograms
7. Access to admin page

Admin and Back-end

- A password protected page enables an admin to change the parameters of the simulation (eg. making signal more visible, accelerating the animations).
- Any changes made on this page are sent to the server and are applied globally.
- Website hosted using CERN webservices and deployed with OpenShift connected to a GitLab.

Higgs Boson Golden Channel H → ZZ → 4μ





Measurements of the Higgs boson inclusive and differential fiducial cross sections in the 4ℓ decay channel at √s = 13 TeV

Eur. Phys. J. C 80 (2020) 942

- Goal: the student/user shall reproduce this mass spectrum and learn how to perform a simple analysis and reconstruct the Higgs boson mass peak with sufficient statistics
- For the outreach project, the events are generated using MadGraph but the invariant mass is picked from the ATLAS mass spectrum. Some low transverse momentum particles are added to illustrate the analysis in a simple form.
- The student/user should choose a momentum cut-off such as to keep only 4 muons, and reconstruct the invariant mass.

Portal Dedicated to Higgs Bosons

- Web portal dedicated to Higgs boson research.
- A database is created with more than 1000 relevant articles using CERN Document Server API and web scraping methods.
- The database is automatically updated when new results on the Higgs boson become available.
- Using natural language processing (NLP), the articles are categorised according to properties of the Higgs boson and other criteria.
- The process of designing and implementing the Higgs Boson Portal (HBP) is described in detail.
- The components of the HBP are deployed to CERN Web Services using the OpenShift cloud platform.

Higgs Boson Research

- 1989 – 2000: CERN – Large Electron-Positron Collider
  - ALEPH
  - DELPHI
  - L3
  - OPAL
- 1987 – 2011: Fermilab – Tevatron Collider
  - CDF
  - D0
- 2010 – present: CERN – Large Hadron Collider
  - ATLAS
  - CMS

Research Resources

- 1000+ scientific publications (experimental results)
- Various types of experiments
- Various publishing methods
- New results each week/day
- Large number of articles – important to create a categorisation system

Goals

- ❑ Easy access to publications
- ❑ Collection and categorization
- ❑ Visualisation of development precisions
- ❑ Bringing the research closer to the public

Collecting data

- Publications –
  title, abstract, tables, graphs.
- Measured values –
  masses, production modes, decay modes. . .
- Fermilab (old websites) – web scraping
- CERN – CERN Document Server API
- Measured values – extract from text

Categorisation

- Goal of the publication
  - Experimental measurement
  - Search for “new physics”

- Observed events
  - Higgs boson production
  - Higgs boson decay

- Other properties
  - Number of collisions (luminosity)
  - Collision energy
  - Experiment
  - Current stage
    (preliminary, submitted, published)

Natural Language Processing

Categorization results

- ❑ True Positives: TP
- ❑ False Positives: FP
- ❑ False Negatives: FN
- ❑ Precision = TP/(TP+FP)
- ❑ Recall = TP/(TP+FN)
- ❑ F1 score = 2 P*R/(P+R)

Category	Precision (%)	Recall (%)	F_1-score (%)
Luminosity	96	88	92
Energy	100	85	92
Production mode	87	85	86
Decay mode	81	79	80

HIGGS BOSON PORTAL

HOME | ARTICLES | HISTORY | ABOUT | FEEDBACK

Search

DATE

All of time

EXPERIMENTS

ATLAS ALEPH
CMS DELPHI
CDF L3
DØ OPAL

LUMINOSITY

Any

CENTRE-OF-MASS ENERGY

Any

DECAY PRODUCTS

Any

CMS SUBMITTED BEYOND SM

Search for charged Higgs bosons produced in vector boson fusion processes and decaying into vector boson pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV

A search for charged Higgs bosons produced in vector boson fusion processes and decaying into vector bosons, using proton-proton collisions at $\sqrt{s} = 13$ TeV at the LHC, is reported. The data sa... See more

SAT APR 10 2021

PDF DETAILS

ATLAS PRELIMINARY BEYOND SM

Search for Higgs boson pair production in the two bottom quarks plus two photons final state in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

Searches are performed for non-resonant and resonant di-Higgs boson production in the $b\bar{b}\gamma\gamma$ final state. The data set used corresponds to an integrated luminosity of 139 fb^{-1} of ... See more

WED MAR 31 2021

PDF DETAILS

ATLAS PRELIMINARY SM

Measurements of gluon fusion and vector-boson-fusion production of the Higgs boson in $H \to WW^* \to e\nu\mu\nu$ decays using pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The gluon fusion and vector-boson-fusion Higgs boson production modes are measured using proton--proton collisions in the $H \to WW^* \to e\nu\mu\nu$ decay channel. The Large Hadron C... See more

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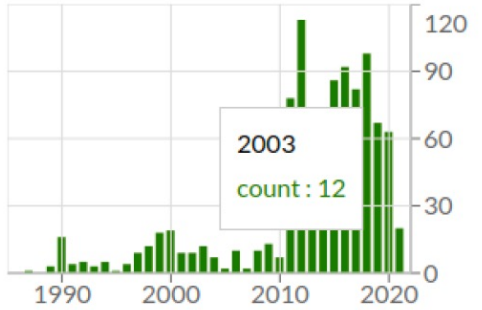
PDF DETAILS

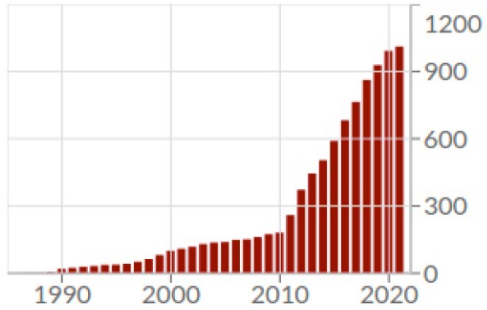
STATISTICS

Displaying 1012 articles.

Number of articles published per year



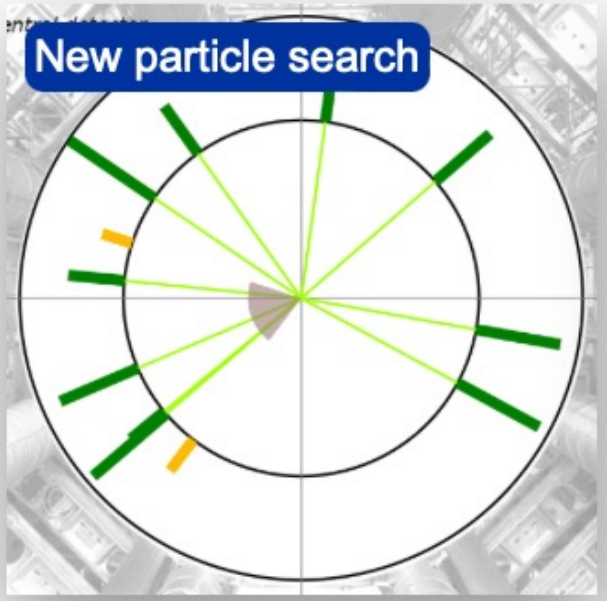
Cumulative article count over the years

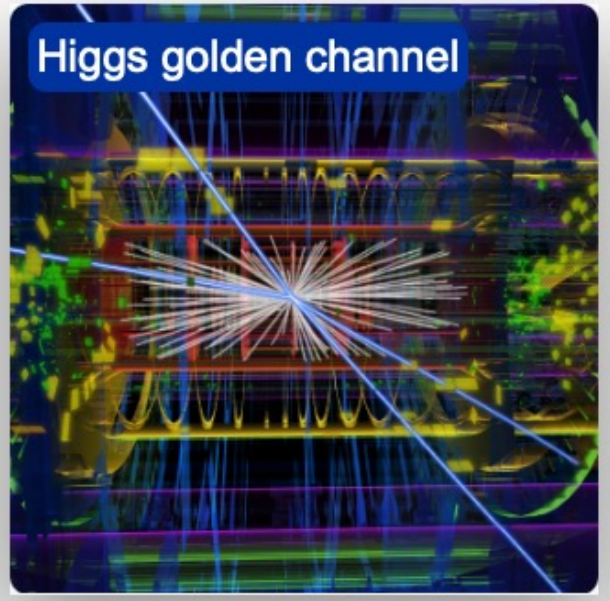


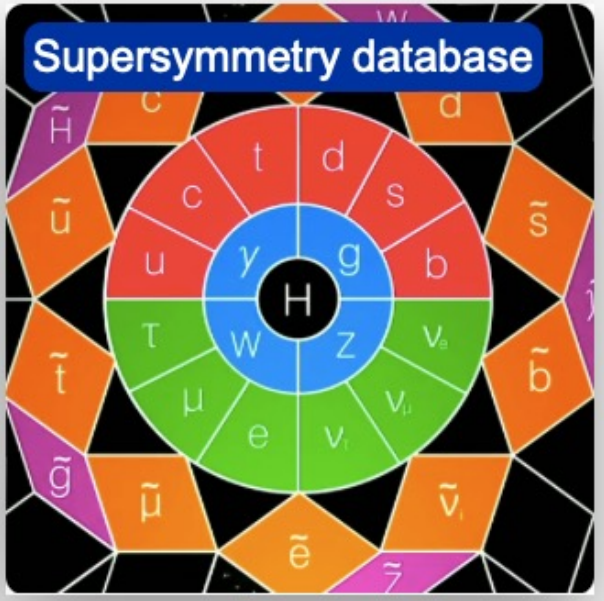
http://cern.ch/cppp

Czech Particle Physics Project

The Czech Particle Physics Project (CPPP) is a collection of learning material related to particle physics. Each box below corresponds to a separate project. Hover over them to get a short description. Click the box to get access to a given project.







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CERN

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Supported by CTU in Prague, grants 2022 and 2023

CERN 2021 summer student Antoine Vauterin
Theses CTU in Prague: Martin Kupka (2020), Ivan Demchenko (2021), Peter Žáčik (2021)

Summary and Outlook for Further Modules

- The Czech Particle Physics Project has outreach and learning tools for masterclasses aimed at high-school students (aged 15 to 18).
- Current Modules:
  - Detection of an Axion-Like-Particle (ALP) using the ATLAS Forward Proton (AFP) detector.
  - Reconstruction of the Higgs boson mass using the Higgs boson golden channel with four leptons in the final state.
- The project includes two further modules for expert information as web portals dedicated to
  - Higgs boson research
  - Searches for Supersymmetry
- The modular structure of the CPPP allows to add new modules for example for educational aspects of astro or neutrino physics.
- The modules are accessible at http://cern.ch/cppp

References and Acknowledgments

- Martin Kupka, CERN-THESIS-2020-053,
  Feasibility Study of a Portal to Provide Knowledge about Higgs Bosons to the General Public and Experts
- Ivan Demchenko, CERN-THESIS-2021-014,
  Feasibility Study of a Portal to Provide Knowledge about Supersymmetry to Experts
- Peter Zacik, CERN-THESIS-2021-080,
  Implementation of a Portal Dedicated to Higgs Bosons for Experts and the General Public
- Antoine Vauterin, André Sopczak,
  22nd IPPOG meeting, 17-19 Nov. 2021,
  https://indico.cern.ch/event/1084892,
  New Web-based Educational Tool for ATLAS

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