Course unit English denomination	**Statistical methods for physics analysis**
Teacher in charge (if defined)	**Denis Bastieri, Tommaso Dorigo, Luca Stanco**
Teaching Hours	**24**
Number of ECTS credits allocated	3
Course period	**February - June 2025**
Course delivery method	X In presence ☐ Remotely ☐ Blended
Language of instruction	**English**
Mandatory attendance	x Yes (50% minimum of presence) ☐ No
Course unit contents	The course aims at providing students with a basic understanding of fundamental issues in statistics of relevance for practical data analysis, and a knowledge of the main techniques for statistical inference in experimental science. General Introduction: - Random variables, probability density functions, the Central Limit theorem, cumulative function, properties of estimators, examples and applications. - Methods of minimum squares and maximum likelihood, covariance matrix. Applications and examples. - Error propagation: some examples and practical applications. - Probability theory, Kolmogorov axioms, theorem of Bayes, practical applications. - Lemma of Neyman-Pearson. Probability ordering. - Interval estimation, confidence intervals, hypothesis testing and p-values, goodness of fit and practical applications. Construction of the power-curve. Coverage for the confidence intervals from maximum likelihood. - The problem of the measurement of 0 or very few events. The method of Feldman-Cousins. - Technicalities in the generation of random numbers. Simulations of several functional relations. - Processes of Markov. Sketch of Markov chain. The process of Filtering and Smoothing. The Kalman filter. Statistics in HEP: - Evaluation of p-values for counting experiments, with and without nuisances.

	- Definition and computation of significance for a signal. - Correspondence between p-value and significance in case of non-Gaussian nuisances. - Look-elsewhere effect and approximate methods for its estimation. - The CLS method and its application to the search for signals. - Profile likelihood and statistical tests. - Application to the search for the Higgs boson at LHC. - Asymptotic methods for the evaluation of sensitivity with the profile likelihood. Statistics in Astrophysics: - Applications of statistical inference and test of models: Z-score and T-score - Coefficient of correlation and related test. Bootstrapping. - Non-parametric tests: Spearman's rank. - Kolmogorov-Smirnov: test and related applications, test of Cramér-von Mises - Test of isotropy: monolope, dipole and quadrupole, statistics of Rayleigh, Watson and Bingham. - Correction of Bonferroni or trial factors. - Test of Anderson-Darling. - Statistics of Cash (Poisson) - Application of maximum likelihood: the catalogue. - Errors of type I and type II: screening and testing, technicalities, sensitivity and power of testing. - Data analysis: correlation, auto-correlation, function of angular correlation at 2 points, and applications. - Analysis of images: linear filters and applications, the Gaussian filter.
Learning goals	Enable students to appropriately choose the statistical method for different use cases in data analysis tasks; teach students the importance of reasoning on the sampling distribution of their data, and on its effects on inference; stress the importance of error analysis and uncertainty quantification; make them better scientists by distributing information on what are sound analysis practices and what are incorrect or faulty techniques.
Teaching methods	Frontal lectures; open discussion of software solutions; homework exercises; stimulating students to critically assess topics in open discussion
Course on transversal, interdisciplinary, transdisciplinary skills	x Yes ☐ No
Available for PhD	x Yes

students from other courses	□ No
Prerequisites (not mandatory)	None
Examination methods (in applicable)	Discussion of a topic of interest of the candidate, chosen from the course; or of aspects of the statistical analysis relevant for the research carried out by the candidate
Suggested readings	Lecture notes, slides shown during lectures, software provided by the instructors; book by Glen D. Cowan “Statistical Data Analysis”, Oxford Science Publications 1997.
Additional information	It is advisable to download and install the ROOT program from root.cern.ch to carry out exercises proposed during the course