

# Program of **Statistics and Data Analysis**

PhD course 2018/19

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## **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.
- Use of the Feldman-Cousins method for exclusion plots.

## **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: monopole, 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.