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| Course unit English denomination | Advanced particle detection techniques and methods: from physics requirements to detector design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Teacher in charge (if defined)   | <ul style="list-style-type: none"><li>• Garfagnini Alberto (Physics and Astronomy Department, University of Padova)</li><li>• Mattiazzo Serena (Physics and Astronomy Department, University of Padova)</li><li>• Sestini Lorenzo (INFN, Firenze Section)</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Teaching Hours                   | 24                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Number of ECTS credits allocated | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Course period                    | February/May 2025                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Course delivery method           | <input checked="" type="checkbox"/> In presence<br><input type="checkbox"/> Remotely<br><input type="checkbox"/> Blended                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Language of instruction          | English                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Mandatory attendance             | <input checked="" type="checkbox"/> Yes (50% minimum of presence)<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Course unit contents             | <p>The course will present and review the current and innovative detection technologies used in the design of complex detector concepts for colliders. Examples of running detectors will be given, and several R&amp;D cases for the next generation of detectors will be presented. In addition, a specific discussion of the various experimental conditions and detector requirements from physics in the case of different colliding particles and energies (pp, heavy ions, e+e-, muons) will be discussed using concrete examples of running experiments or ongoing projects (CMS, ALICE, LHCb, BELLE2, and more). In addition, a section of the course will be devoted to detectors and techniques for the detection of neutrinos of different origin (accelerators, cosmic, reactors).</p> <p><b>Part 1: Detectors and techniques for physics at colliders (16h)</b></p> <ul style="list-style-type: none"><li>• Tracking and particle identification (8h)<ul style="list-style-type: none"><li>◦ Vertex detectors</li><li>◦ Tracking detectors</li><li>◦ Detectors for particle identification</li><li>◦ Muon detectors</li></ul></li><li>• Calorimetry, timing and global considerations (8h)<ul style="list-style-type: none"><li>◦ Electromagnetic Calorimeters</li><li>◦ Hadronic Calorimeters</li><li>◦ Timing detectors</li><li>◦ Trigger and data acquisition</li><li>◦ Physics requirements for detectors at different colliders (ee vs pp vs muon)</li></ul></li></ul> <p><b>Part 2: Detectors and techniques applied to neutrino physics (8h)</b></p> <ul style="list-style-type: none"><li>• Neutrino Oscillation detectors:<ul style="list-style-type: none"><li>◦ Large Cherenkov Detectors (photo sensors and particle identification techniques). Threshold counters. Ring Imaging detectors. Askaryan radiation.</li><li>◦ Large Cryogenic liquids detectors (LAr and LXe): properties and techniques.</li><li>◦ Large Liquid Scintillator Detectors: performances and techniques</li></ul></li><li>• Double beta decay<ul style="list-style-type: none"><li>◦ material selections for high radiopurity detectors</li><li>◦ active techniques for background suppression (PSD e active veto systems)</li></ul></li></ul> |
| Learning goals                   | <p>At the end of the course, students will learn the operating principles of some of the most used particle detectors. They will also have acquired knowledge of the physical quantities that can be obtained from these.</p> <p>Students will learn how the physical working principles of detectors might fit the needs of specific and varied experimental contexts of collider and neutrino physics.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |



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|                                                                    | Finally, they would also learn to deal with the balance between physics needs and practical constraints that drive the ultimate design choices of real experiments.                                                                                                                                                                                   |
| Teaching methods                                                   | Frontal teaching, case studies (example from running experiments or ongoing projects)                                                                                                                                                                                                                                                                 |
| Course on transversal, interdisciplinary, transdisciplinary skills | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                |
| Available for PhD students from other courses                      | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                |
| Prerequisites (not mandatory)                                      | This course might be taken by students already having some preliminary knowledge of detector technology from their Master or as a follow-up to the Course of “Modern Detectors: Physics, Techniques and Technologies” also offered as part of the PhD school                                                                                          |
| Examination methods (in applicable)                                | The exam will consist of an in-depth study on a topic chosen from those presented in the course (and agreed with the teachers beforehand), in the form of an oral presentation of about 20 minutes (slides) and its discussion, followed by an additional interrogation to verify the acquisition of the knowledge of the rest of the course content. |
| Suggested readings                                                 | Material suggested by the teachers                                                                                                                                                                                                                                                                                                                    |
| Additional information                                             |                                                                                                                                                                                                                                                                                                                                                       |