

PhD Course in Physics, Astrophysics, and Applied Physics - Università degli Studi di Milano
PhD cycle 41 (2025-2026)

All lectures will be given in English.

Course title	Advanced topics for precision physics at colliders: higher-order calculations and all-order resummation in QCD
Teacher in charge of the course	Ferrera Giancarlo
List of the teachers of the course	Ferrera Giancarlo, Univ. of Milan, giancarlo.ferrera@unimi.it Röntsch Raoul, Univ. of Milan, raoul.roentsch@unimi.it
Training objectives	This course is designed for PhD students in theoretical and experimental particle physics. It provides a specialized introduction to the advanced theoretical techniques essential for making precision predictions for observables at high-energy colliders, such as the Large Hadron Collider (LHC). The curriculum focuses on two core pillars of modern perturbative Quantum Chromodynamics (QCD): the systematic computation of higher-order corrections and the all-orders resummation of large logarithmic contributions that appear in semi-inclusive regions.
Prerequisites	Master level knowledge of Quantum Field Theory and Quantum Electrodynamics.
Detailed course program	<i>Review of Foundations of Perturbative QCD</i> QCD lagrangian, renormalization and running of α_S. Infrared Safety. Parton densities (PDF) and evolution equations. Factorization. <i>Higher-Order Calculations</i> Anatomy of a Next-to-Leading Order (NLO) calculation. Virtual Corrections: Dimensional regularization, loop integration techniques, and renormalization. Real Emission Corrections: Phase space singularities and subtraction schemes. NLO calculation for the Drell-Yan lepton pair hadroproduction. Overview of Next-to-Next-to-Leading Order (NNLO) techniques. <i>All-Order Resummation</i> The breakdown of fixed-order perturbation theory: Large logarithms. Soft gluons and collinear splitting. Sudakov Form Factors and the universality of infrared radiation. Threshold Resummation: Formalism and application to inclusive cross sections (Higgs, Drell-Yan). Transverse Momentum Resummation for vector boson production. <i>Phenomenology and Modern Applications.</i> Matching resummed and fixed-order calculations. Applications in precision physics: W mass and α_S determination, Higgs characterization. Discussion of theoretical uncertainties: Scale, PDF,

	and model dependence. Future directions and the frontier of precision QCD.
Examination modalities	Oral discussion.
Preliminary schedule	25 May - 5 June 2026 Course enrolment deadline: December 27, 2025.