:: CN1/Spoke2/WP1/b.2 ::

b) Theoretical Research Projects
2) Collider Phenomenology

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Università degli Studi di Padova

HPC Kick-off Meeting
October 13, 2022

Outline

WP1.b2.nodes

WP1.b2.goals

WP1.b2.usecases

Conclusions and Next Steps

WP1.b2.nodes

NODES

U. Bologna
U. della Calabria
U. Milano Bicocca
U. Napoli
U. Padova

PARTICIPANTS

Staff	RTDA	PhD students
14	0 **+ 2**	5 **+ 3**

WP1.b2.goals :: Precision Physics in Collider Phenomenology (and beyond)

APPLICATIONS	TOOLS	STRATEGIES
Standard Model Beyond Standard Model Parton Distributions Higgs and Heavy Particles g-2 Effective Field Theory Particles-Gravitation-Universe Scattering Amplitudes	Event Generations Numerical Simulations Data Fits Integrals/Special f'ns Evaluation Differential Equations Reconstruction Algorithms Linear Algebra Number Theory Computational Algebraic Geometry	Smart combination of existing software packages Improvement of existing algorithms Development of novel computational strategies Development of novel mathematical methods

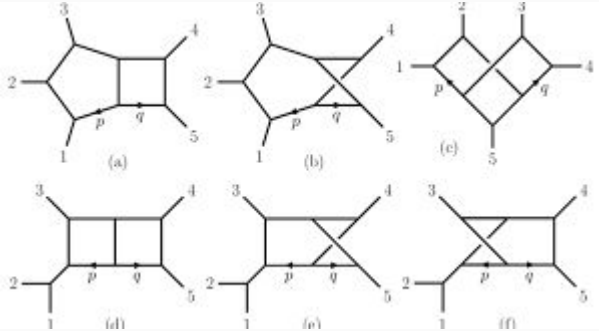
@ UNIBO

Participants: Maltoni, Peraro

Recruitment: 1 PhD

Task 1: Fast and accurate predictions for Collider Phenomenology

Description: We would like to explore analytical, numerical methods and new computational architectures to bring predictions for collider phenomenology up to the challenges of future experiments, in terms of accuracy (two-loop) and speed. At the loop level, we apply new mathematical methods for integrand reduction implemented over finite fields. For order of magnitude improvements in speed we work on the parallelization of MadGraph on GPU's also using Maching Learning methods.



Links: WP 2|(3)|4 ; **timing:** 0,5 - 1 MCore-hours/yr

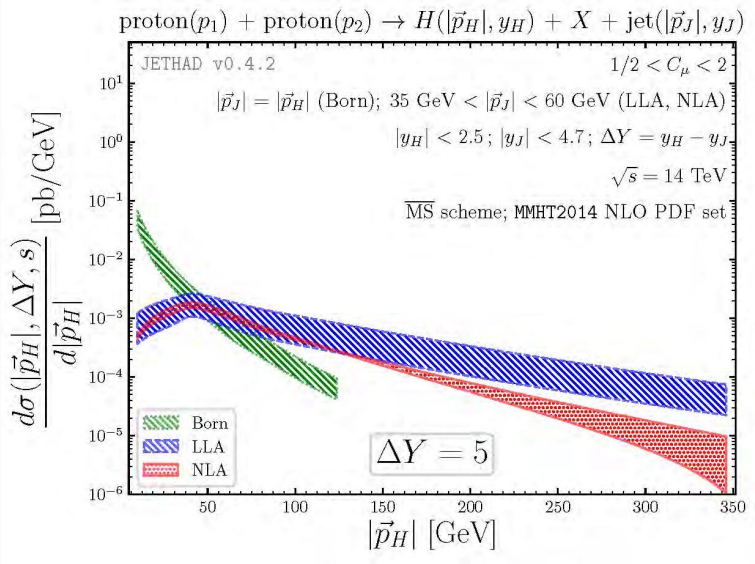
@ UNICAL

Participants: Papa

Recruitment: 1 RTDA (or 1 PhD)

Task 2: Cross Sections and Partonic Distributions

Description: Implementation of numerical techniques for the evaluation of integrals entering the cross section of elementary particle collisions; implementation of global fits of collision data for the extraction of partonic distributions within hadrons.
Deliverables: Fortran and/or Python codes for (1) numerical evaluation of hadronic cross sections in hadronic processes (2) global fits of partonic distributions in hadrons, with special reference to the (unintegrated in the transverse momentum) gluon distribution (UGD) in the proton.



Links: WP2; **timing:** ~1 MCore-hours/yr

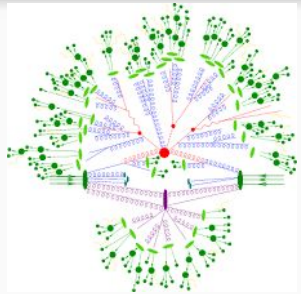
@ UNIMIB

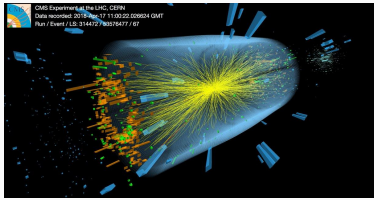
Participants: Alioli, Oleari, Re

Recruitment: 1 PhD

Task 3: Accelerating Event Generation

Description: Improve the parallelization of existing event generators (POWHEG BOX, GENEVA) to take advantage of modern computing infrastructure and accelerators (GPU) and heterogeneous architectures, in preparation for the computing challenges of the LHC high-luminosity upgrade and other future colliders.





Links: WP 2|4 ; **timing:** ~ 3 MCore-hours/yr

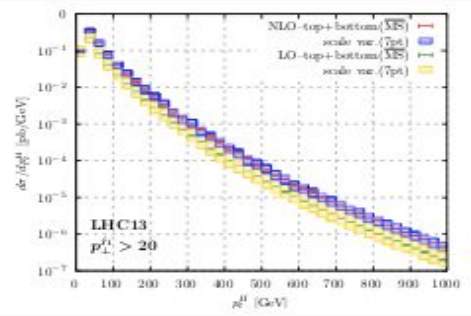
@ UNINA

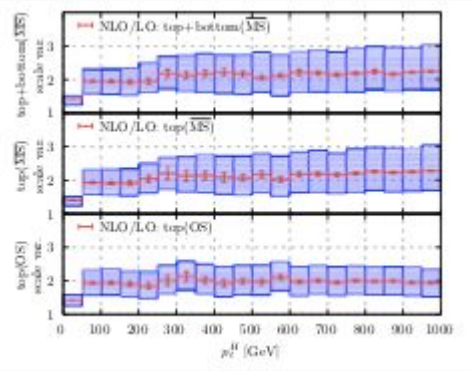
Participants: Tramontano

Recruitment: (1 PhD)

Task 4: Scalable numerical evaluation of Feynman integrals

Description: Convert and optimize algorithms for the numerical evaluation of Feynman integrals, that have been designed and developed to run with a well-known proprietary software. Such a software is an excellent tool for the exploration phase of novel techniques, but is not suitable for the production mode with parallelization and run on clusters of cpu's or gpu's. The target of Task 4 is to deliver public libraries written with a low level language and making use of open source facilities so to make facible any computation at the second order in perturbation theory by means of exploitation of the computer power.

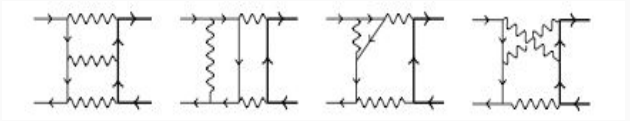




Links: WP 2|(3)|4 ; **timing:** ~ 3 MCore-hours/yr

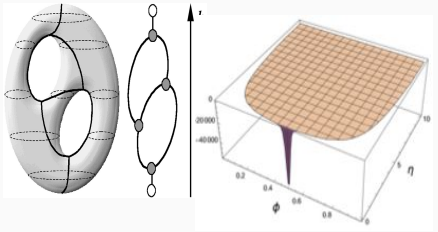
@ UNIPD

Participants: Gröber, Mastrolia, Salvioni, Zanetti
Recruitment: 1 RTDA

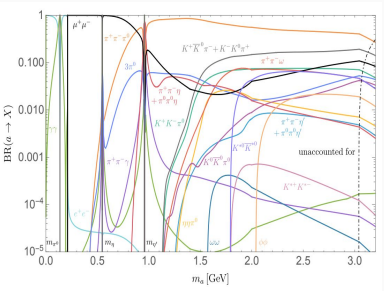


Task 5: Advanced Computational Tools for Scattering Amplitudes

Description: Developments of methods and tools for analytic and numerical calculation of Feynman Diagrams and Scattering Amplitudes, in gauge theories and EFTs, based on innovative mathematical and computer science methods (Integration by parts, Differential Equations, Intersection Theory, Finite Fields Reconstruction, Tropical Monte Carlo Integration, Machine Learning and Neural Networks), for applications to Particle Physics, General Relativity, and Mathematics (Differential and Algebraic Topology, Theory of Special Functions, Statistics)

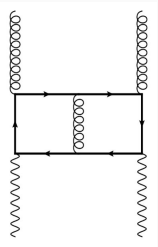


Links: WP 2|3|4|(6) ; **timing:** ~ 0,3 – 1 MCore-hours/yr



Task 6: Optimized Strategies for new Particles and Couplings

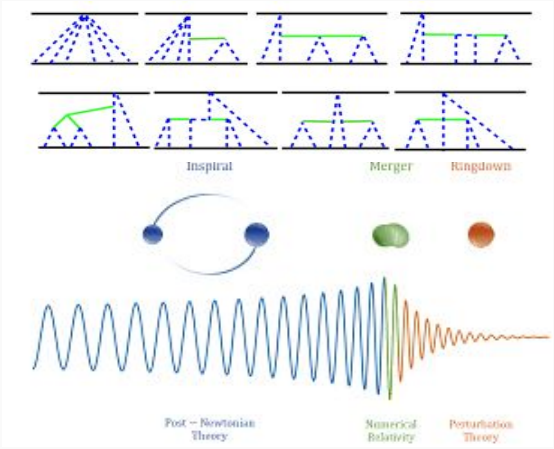
Description: Codes describing hadronic production and decay of new GeV-scale particles at intensity- and energy-frontier experiments, optimized to enable fast evaluation for arbitrary input parameters. Inclusion of higher-order effects as well as SMEFT effects in existing codes for Higgs and top physics, allowing to access less constrained couplings through virtual corrections.



Links: WP 2|3|4; **timing:** ~ 0,3 – 1 MCore-hours/yr

@ UNIPD

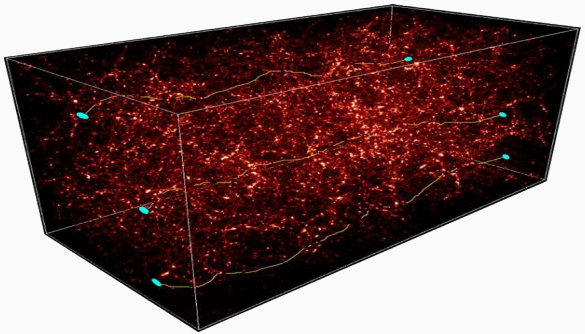
Participants: Bartolo, Mastrolia, Raccanelli, Salvioni
Recruitment: 1 RTDA (same as before)



Task 7: EFT Diagrammatic Approach to Gravitational Wave Physics

Description: Combination of existing tools for analytic and numerical evaluation of Feynman Integrals and Scattering Amplitudes, for applications to Gravitational Wave Physics

Links: WP3; **timing**: ~0,1-0,5 MCore-hours/yr



Task 8: Improved Methods for New Physics from LSS observables

Description: Adaptation of existing codes that calculate Large Scale Structure observables in standard cosmology, to allow for new physics effects, including integration with Markov Chain Monte Carlo packages. Development of user interface taking the linear cosmology evolution as input.

Links: WP3; **timing:** ~ 1 - 2 MCore-hours/yr

@ UNIPD

Participants: Bartolo, Liguori, Raccanelli

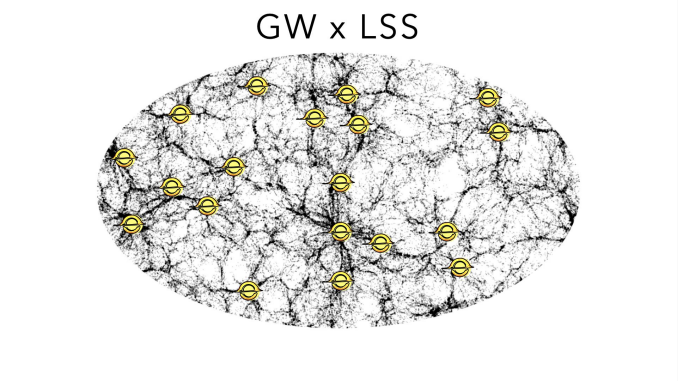
Recruitment: 1 PhD

Task 9: Cross-correlation of gravitational wave with Large Scale Structure and CMB data

Description:

– Numerical and simulation-based analyses of cross-correlations of Large Scale Structure (LSS) with Gravitational Wave (GW) and CMB data

– Development of a machine learning algorithm for the study of relativistic effects in LSS and GW data



Links: WP3 **timing:** ~ 1-2 MCore-hours/yr

CONCLUSIONS and OUTLOOK

Deliverables

Software relevant for Particle Phenomenology (.and. GW Physics .and. Math)
@ LHC upgrade and future colliders and experiments
[c++, phython, fortran, mathematica/maple]-libraries
– multi-purpose/process (broad-brush) tools .and. specific target oriented packages
– publically available in dedicated repository / website
– high-confidence level / feasibility and high-impact for precision physics
– testbed available

Resources Requests

Human resources: 2 RTDA's, 3 (+1) PhD's
CPU timing allocation: O(MCore-hours/yr/use case) in production mode; fewer in R&D and tests
Software Licences: Mathematica, Maple, others.

Cross-links

w/ WP2 + WP3: (R&D) exploit/share common computational techniques
w/ WP4: (R&D.and.Production mode) scalability and GPU/GPU multi-cores clusters
w/ WP5: (R&D.and.Production mode) long-term data preservation
w/ WP6: (R&D) computational topology for Data Science