Laboratoire d’Annecy-le-vieux de Physique Théorique

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LAPTh

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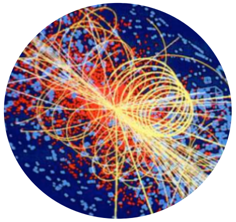
UNIVERSITÉ
SAVOIE
MONT BLANC

Les équipes

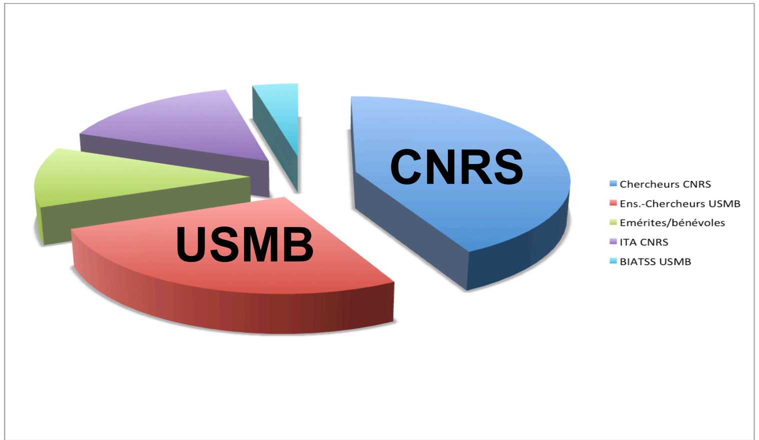
- ✓ **Physique-Mathématique (*les Phys-Maths*)**

- ✓ **Astroparticules et cosmologie (*les Astros-Cosmos*)**

- ✓ **Physique des particules (*les Phénos*)**

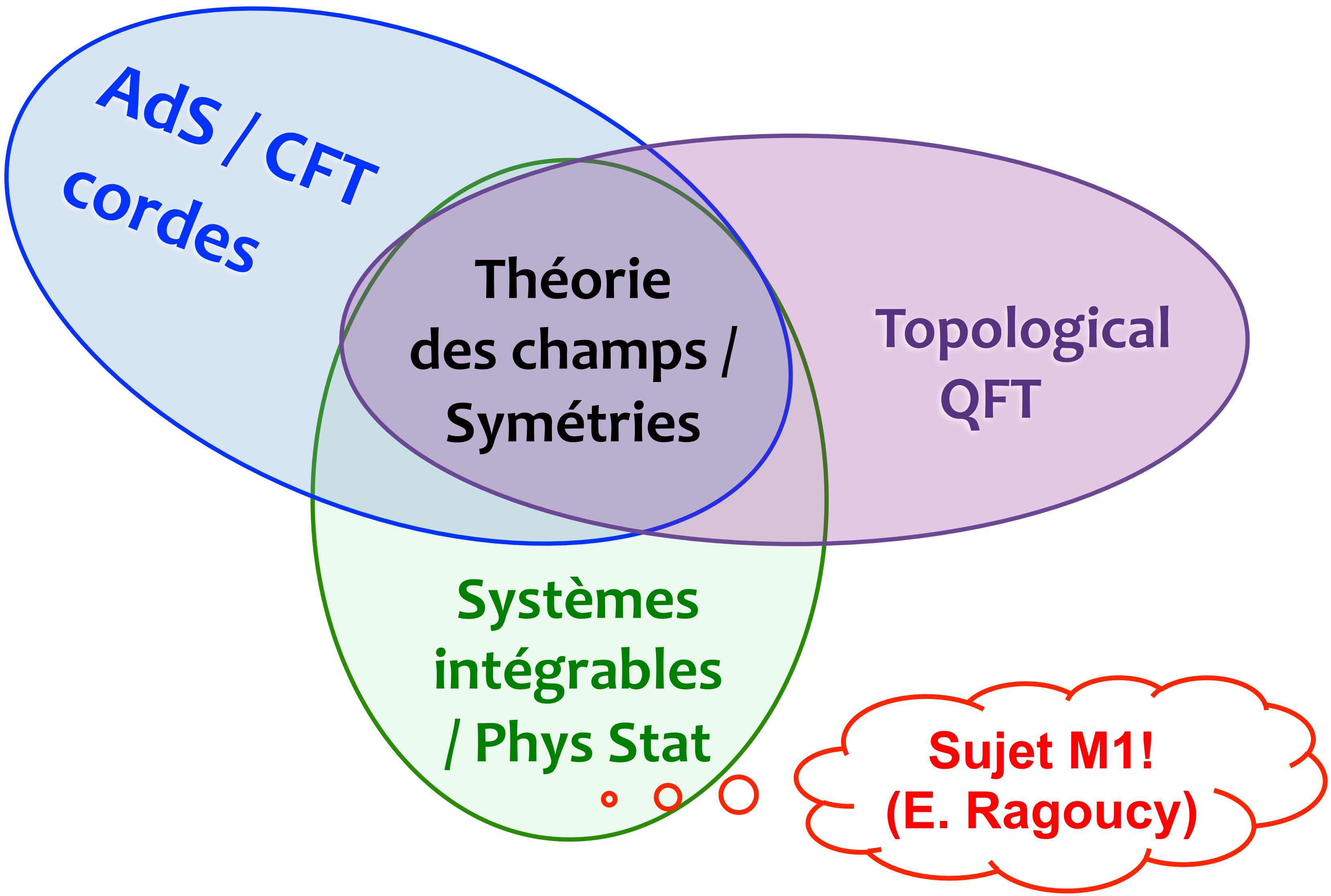


Permanents
+ Doctorants et Post-docs
+ Programme chercheurs invités



~ 40 personnes

Équipe Physique Mathématique



Équipe Astroparticules et cosmologie

Cosmology

Big bang nucleosynthesis
CMB spectra calculation
Test of inflationay models
Standard/non-standard ν
Constraints from data analysis

Energetic astrophysical sources

GRB as a new mode of stellar collapse
ν in dense astrophysical media
Phenomenology at giant underground detectors

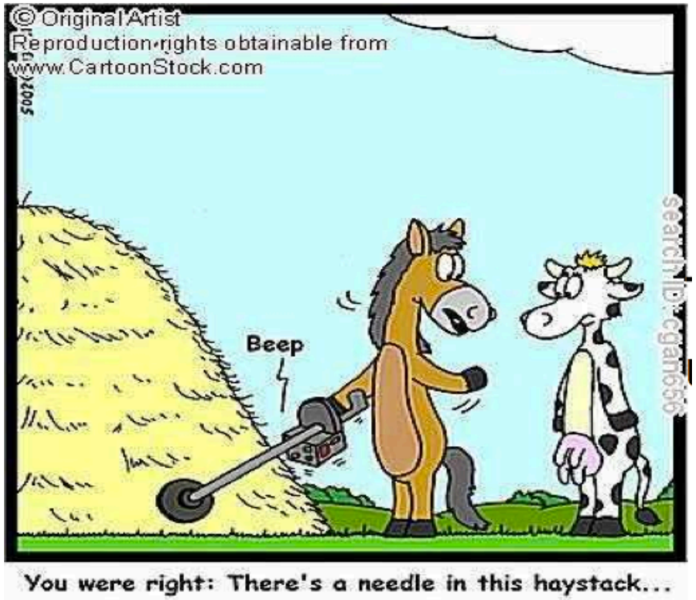
Dark Matter

Indirect DM searches, signals and backgrounds
Cosmic rays, sources and propagation

Sujet M1-M2!
(P. Serpico)

Connection with observational groups: AMS-02, HESS, Planck

Équipe Physique des Particules



Constructions de Modèles de Nouvelle Physique en lien avec la brisure de symétrie électrofaible

Physique du HIGGS, Supersymétrie, Modèle de Matière Noire, Masses des fermions, Problème de la Saveur

Phénoménologie de ces Modèles et recherches aux collisionneurs (en particulier au LHC)

Trouver des signatures particulières, travail en collaboration avec les expérimentateurs, outils et codes

Manifestation de la Nouvelle Physique aux collisionneurs et en astrophysique/cosmologie

Sujet M2+PhD! (C. Delaunay)

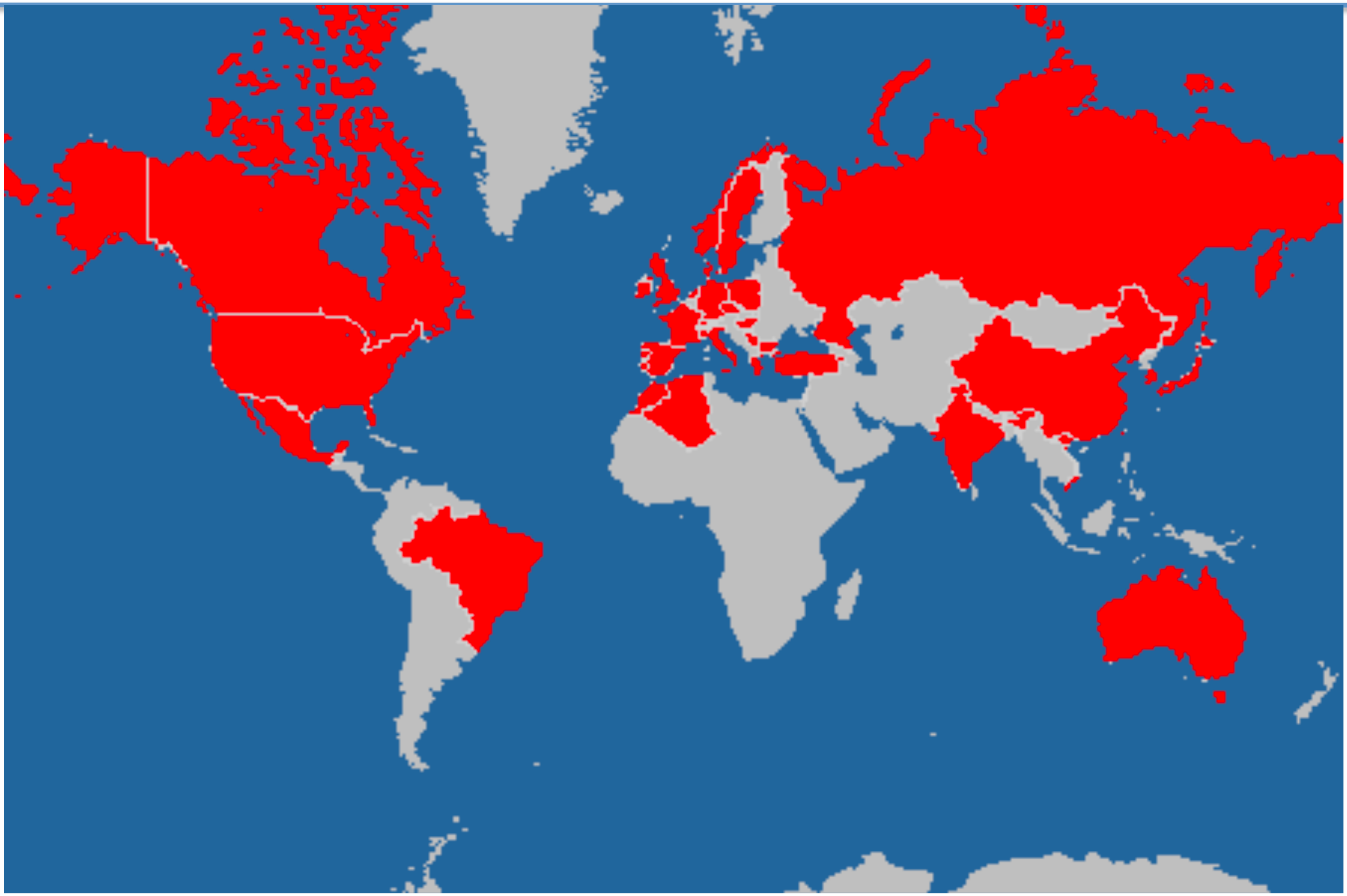
Calculs de Précision dans le Modèle Standard (QCD, EW)

Nouvelles techniques de calculs, calculs au-delà de l'ordre dominant, Calculs de Précision

Transformer nos idées, nos prédictions et nos calculs en OUTILS/Codes Publics

Sujet M2+PhD! (E. Re)

Positionnement à l'international



Recherche :
LIA France-Russie, LIA Inde, Progr. CEFIPRA Inde, nombreux MoU (CERN, Boston, Moscou, DESY, KITP, ISS-Bangalore, Turin, …)

Formation :
M2 Algérie, Liban
Doctorat ERASMUS MUNDUS IRAP
Graspa (M1, ENIGMASS)

Stages / Thèses
Internships / PhD

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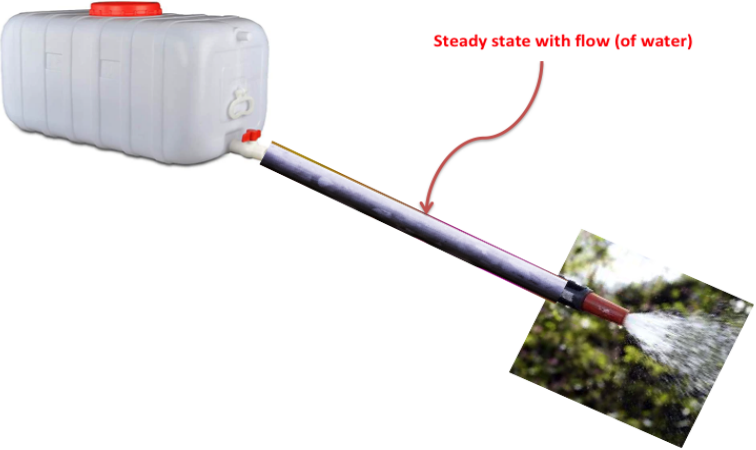
Thank you!

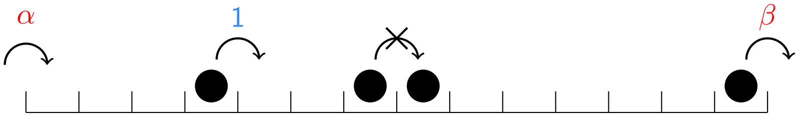
Sujet de stage M1: TASEP and other exclusion processes



Through discretisation...

The TASEP model

(Totally Asymmetric Simple Exclusion Process)



Stochastic process on a one dimensional lattice with boundaries

- In the bulk, particles can jump to the right at the rate 1
- On the left boundary, particles enter at the rate α
- On the right boundary, particles leave at the rate β
- Fermi-like exclusion principle

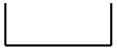
This is an out-of-equilibrium system (there is a particle current)

The model is integrable (rich algebraic structure)

Matrix ansatz (Derrida, Evans, Hakim, Pasquier, 1993):

 $\longrightarrow D$

$\mathcal{S}($  $) = \dfrac{\langle\langle W|EDEDD|V\rangle\rangle}{Z_5}$

 $\longrightarrow E$

$$Z_L = \langle\langle W|(D+E)^L|V\rangle\rangle$$

The goal is to understand why $\dfrac{\langle\langle W|EDEDD|V\rangle\rangle}{Z_5}$ gives the weight of the configuration  in the stationnary state, provided E and D obey these three relations

Algebraic relations (DEHP)

$$DE = D + E \quad ; \quad D|V\rangle\rangle = \frac{1}{\beta}|V\rangle\rangle \quad ; \quad \langle\langle W|E = \frac{1}{\alpha}\langle\langle W|$$

Plan of the internship:

- Study of TASEP model (understanding of the DHEP algebra, links with stationnary state)
- Thermodynamical limit (Number of sites $L \to \infty$): calculation of the current, densities, etc..
- If time allows: study of more models (ASEP, models with evaporation, ...)

Interplay of fixed-order and resummation in perturbative QCD: applications to LHC Physics

Emanuele Re
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LAPTh Annecy

Master 2 internship 2021 at LAPTh

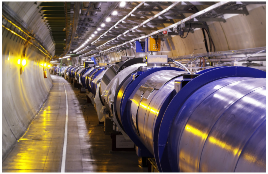
goals of the project

[contact: emanuele.re@lapth.cnrs.fr]

☞ Learn how one goes from the Lagrangian to real data:

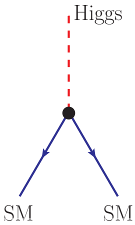
$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \not{D} \psi + h.c. + \bar{\psi}_i y_{ij} \psi_j \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$

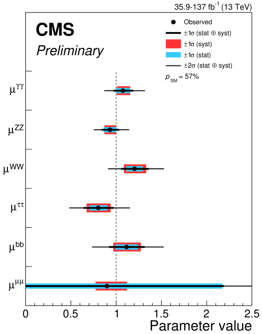
$\longleftrightarrow$ particle phenomenology $\longleftrightarrow$

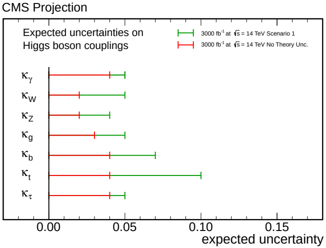


1. understand why nowadays precise theoretical predictions are essential for collider Physics
2. familiarize with fundamental concepts of perturbative QCD in different energy regimes (fixed-order expansion vs all-order resummation)
3. learn technical aspects on how these two different regimes are treated in modern computations $\rightarrow$ improvements are needed!
4. explore new ideas to compute (or estimate) the effects currently neglected
   - *analytic computation*, from first principles
   - implementation into a *numerical* code
   - impact on real distributions that are *measured* at the LHC at CERN

precision (collider) Physics



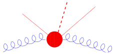




- accurate theory predictions are crucial to study properties of elementary particles

How?

$\Lambda_{\text{QCD}} \simeq 200$ MeV



How?

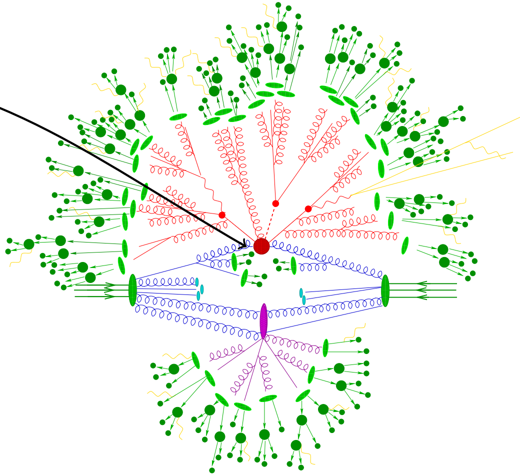
$\Lambda_{\text{QCD}} \simeq 200$ MeV

hard scattering

$\Lambda_{\text{QCD}} \ll \mu \approx Q$

- perturbation theory

$$d\sigma \to d\sigma_0(1 + \alpha_S\delta_1 + \alpha_S^2\delta_2 + \mathcal{O}(\alpha_S^3))$$



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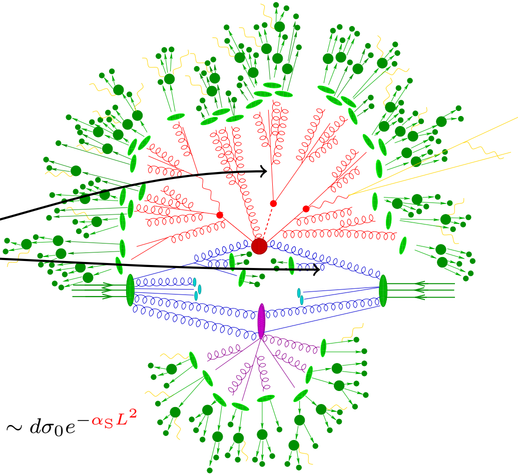
"parton-shower" regime

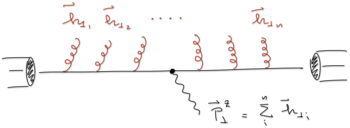
$\Lambda_{\text{QCD}} < \mu < Q$



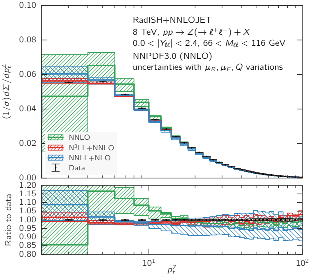
- hierarchy of scales
- all-order resummation of large logarithms (L)

$$d\sigma \to d\sigma_0(1 - \alpha_S L^2 + \frac{1}{2!}(\alpha_S L^2)^2 + \ldots) \sim d\sigma_0 e^{-\alpha_S L^2}$$

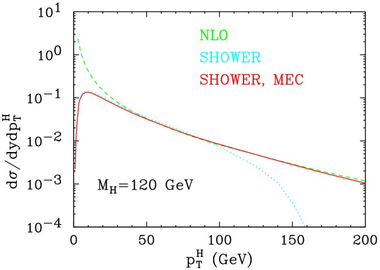
State of the art & bottlenecks



state-of-the-art analytic result [N3LL]



fully-differential result [LL]



$$\sigma \sim \exp\left\{\left[\underbrace{\mathcal{O}(\alpha_S^n L^{n+1})}_{LL} + \underbrace{\mathcal{O}(\alpha_S^n L^n)}_{NLL} + \underbrace{\mathcal{O}(\alpha_S^n L^{n-1})}_{NNLL} + \underbrace{\mathcal{O}(\alpha_S^n L^{n-2})}_{N3LL} + \ldots\right]\right\}$$

Dark Matter Freeze-in Through the Higgs Portal

stage M2 | encadrant : Cédric Delaunay

Motivation: DM interactions and production mechanism of its relic are unknown. Standard scenario (thermal WIMP) is severely challenged by (direct detection) experiments. Time to explore alternative approaches, *eg.* freeze-in through very weak couplings with SM

Proposal: Study such a scenario in a minimal model where fermionic DM interacts with SM only through a (tiny) renormalizable Higgs portal:

Dirac DM → χ; scalar mediator → S

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \bar\chi(i\partial\!\!\!/ - m_\chi)\chi + |\partial_\mu S|^2 - m_S^2|S|^2 - \lambda_S|S|^4$$

$$-\lambda_{SH}|S|^2|H|^2$$

← Higgs portal = only possible renormalizable operator

$$\lambda_{SH} \ll 1$$

Objectives: 1) Get familiarized with the model and DM production in the early universe,
2) Identify processes for freeze-in production & calculate the relic density,
3) Derive prospects for DM detection and signatures at high-energy colliders.