

Collider phenomenology: Standard Model and Beyond

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1. Monte Carlo parton shower generators (HERWIG)
2. QCD higher-order calculations (heavy quarks/hadrons, pdfs, etc.)
3. BSM: SUSY decays of extra Z' bosons
4. Conclusions

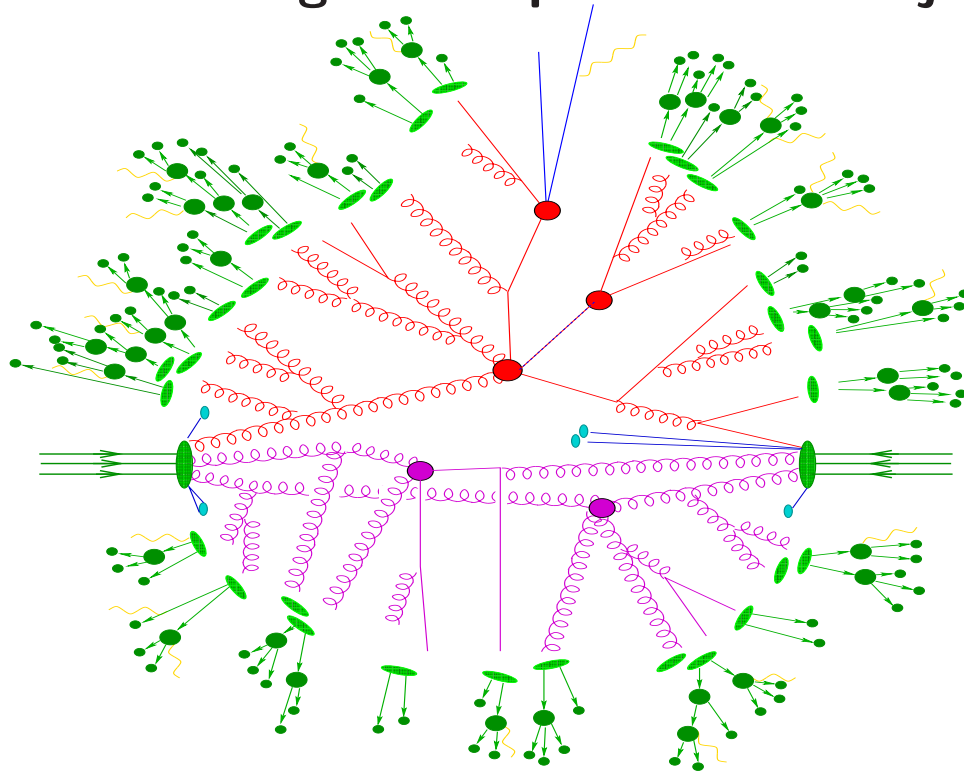
Collaborators:

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Monte Carlo generators are integral part of any experimental analysis: exclusive final states allow the setting of acceptance cuts on jets and leptons



Standard Monte Carlo event generators (HERWIG/PYTHIA):

Hard $2 \rightarrow 2$ subprocess: leading-order (LO) matrix element

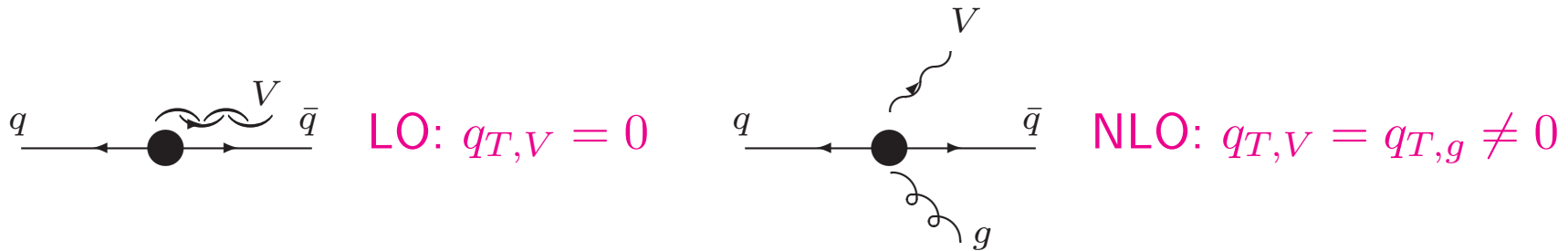
Parton showers in the soft or collinear approximation

Matrix-element corrections for hard and large-angle parton radiation

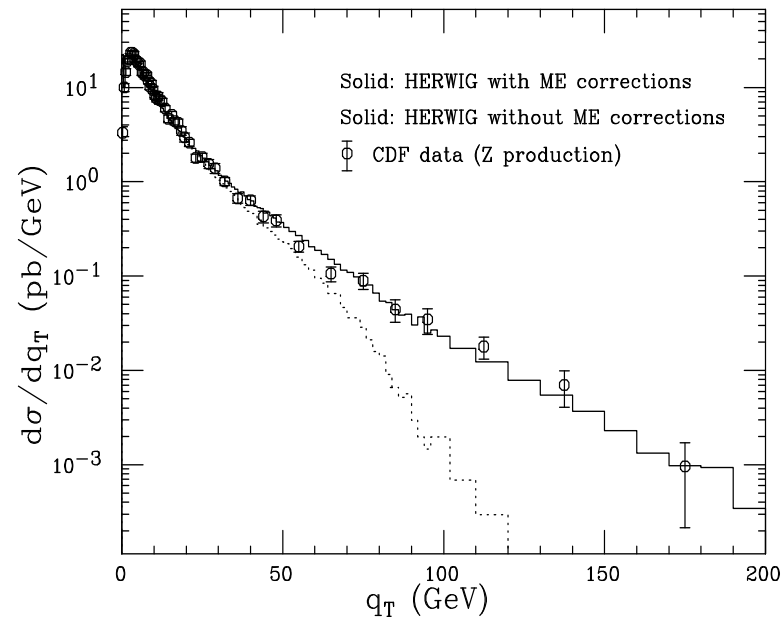
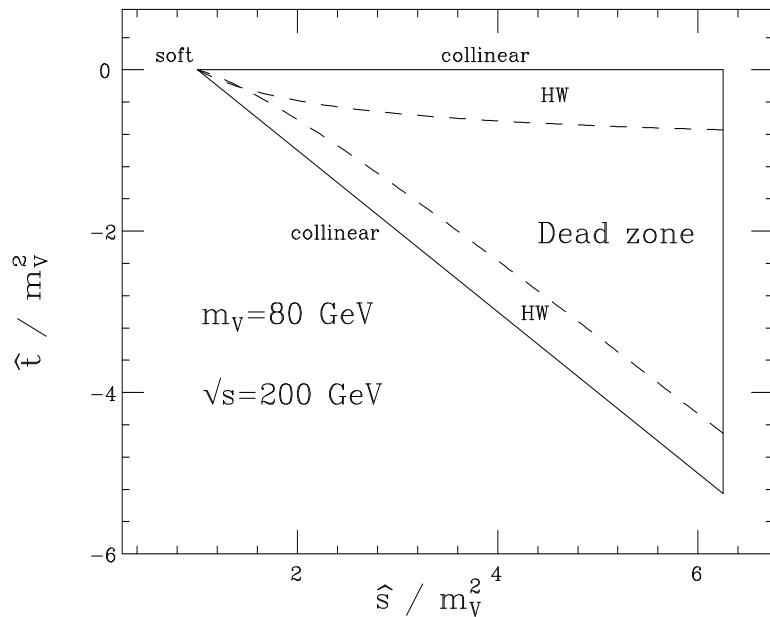
Phenomenological hadronization models

Past work: matrix-element corrections to HERWIG

Vector boson production ($V = W, Z$): $q\bar{q} \rightarrow V$ (LO) $q\bar{q} \rightarrow Vg \dots$ (NLO)

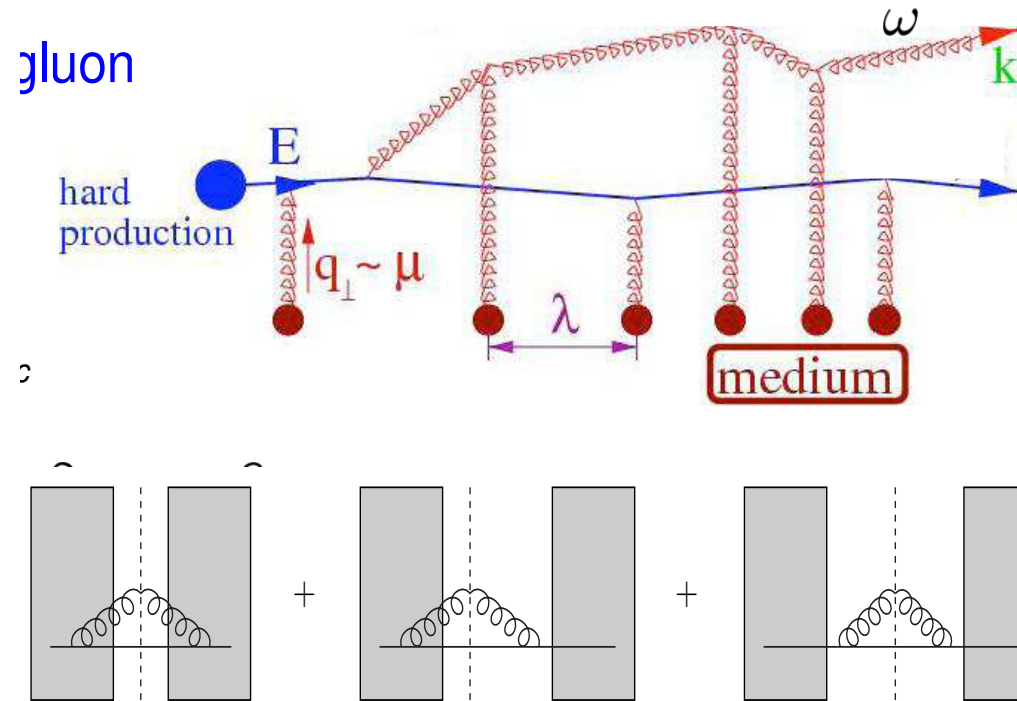


Soft or collinear radiation: small q_T ; hard and large-angle emission: large q_T



Implemented for $e^+e^- \rightarrow q\bar{q}, W/Z/H+\text{jets}, \text{DIS}, \text{top decays}$ ($\Delta m_t \simeq 1.5 \text{ GeV}$)

Recent work: medium-modified parton showers (heavy ions)



Three cases according to whether the gluon is emitted inside or outside the medium in the matrix element and its complex conjugate

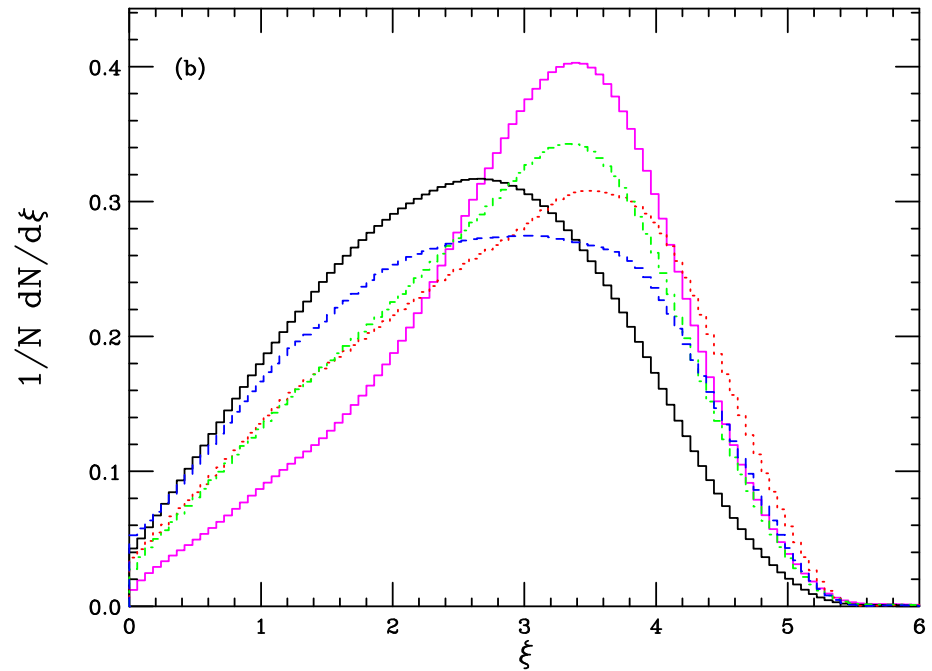
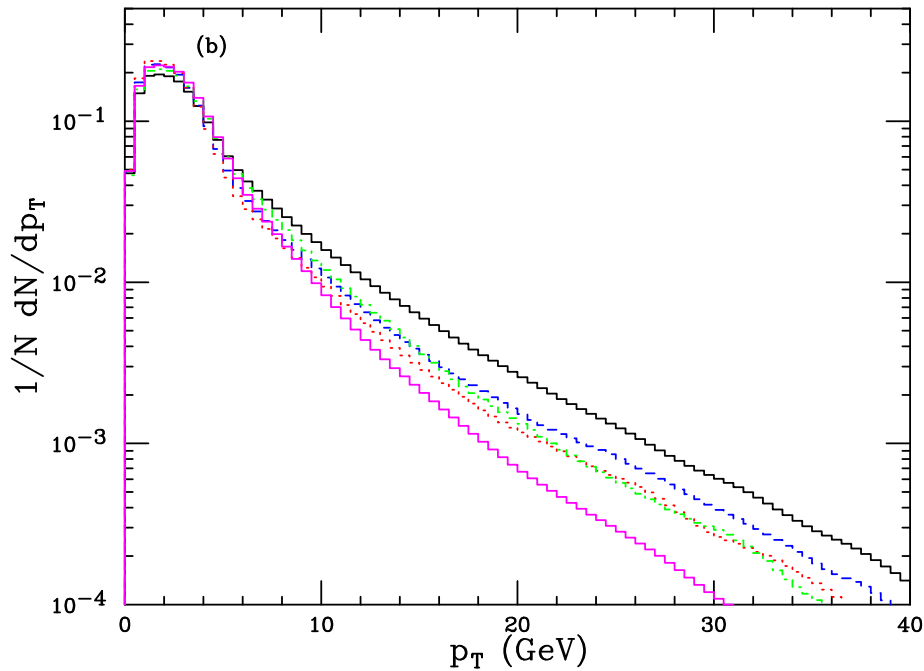
Medium contribution by means of the BDMPS approximation (static scattering centres, independent scatterings, hadronization outside the medium) in the Altarelli–Parisi splitting function:

$$P(z) \rightarrow P(z) + \Delta P(z, E, p^2, \hat{q}, L)$$

Showers initiated by gluons of 10 and 100 GeV - average parton multiplicities:

E	$\hat{q}L = 0$	$\hat{q}L = 2 \text{ GeV}^2$	$\hat{q}L = 5 \text{ GeV}^2$	$\hat{q}L = 20 \text{ GeV}^2$	$\hat{q}L = 50 \text{ GeV}^2$
10 GeV	2.56	3.05	4.14	3.60	4.56
100 GeV	6.95	7.41	8.79	8.93	11.70

Transverse momentum and $\xi = \ln(E_g/|p|)$ distributions (jet quenching)



Solid: vacuum; Dashes: $\hat{q}L_0 = 2 \text{ GeV}^2$; Dots: $\hat{q}L = 5 \text{ GeV}^2$; Dot-dashes: $\hat{q}L = 20 \text{ GeV}^2$ Solid: $\hat{q}L = 50 \text{ GeV}^2$

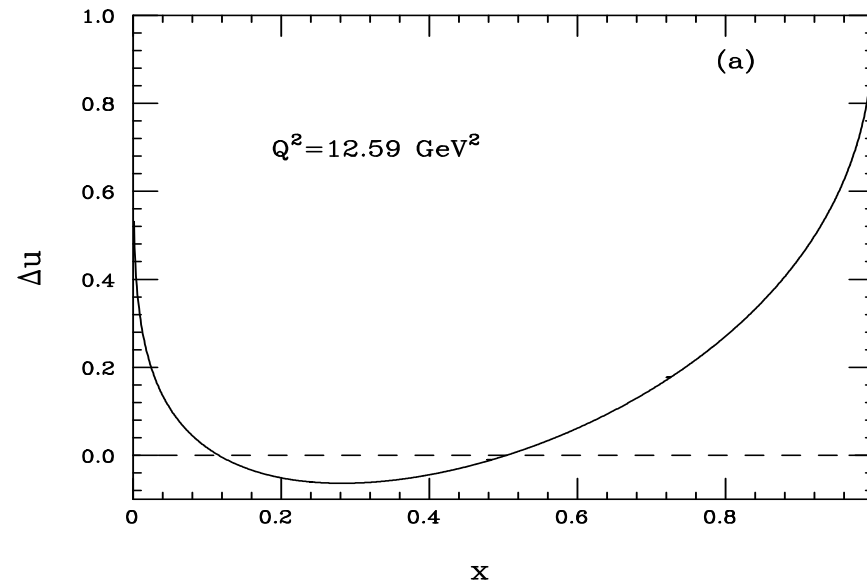
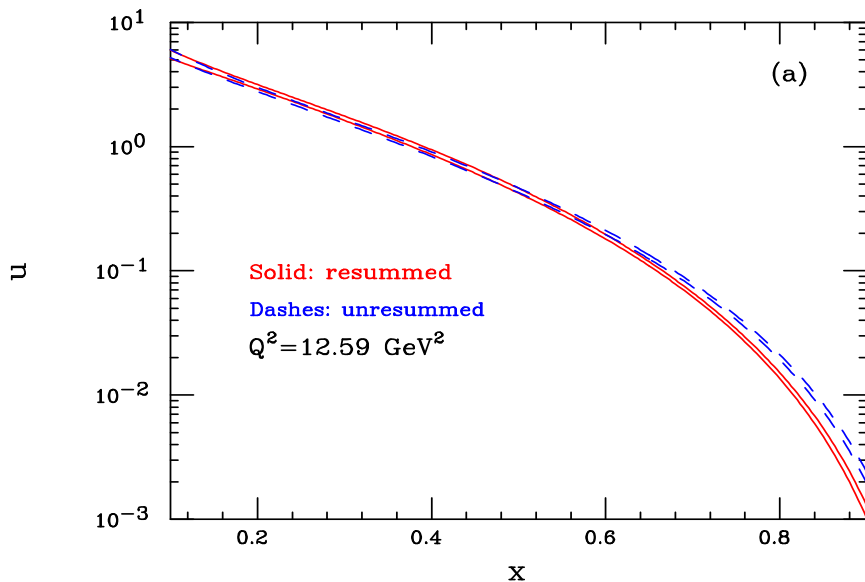
In progress: release of the Q-HERWIG code and comparison with heavy-ion data

Higher-order QCD calculations: fixed-order computations (NLO, NNLO, etc.) are reliable to describe inclusive quantities, e.g. total cross sections

Differential distributions exhibit contributions like $\alpha_S^n [\ln^k(1-x)/(1-x)]_+$, $\alpha_S^n \ln^k(s/m^2)$ (structure functions or heavy quark spectra) \implies all order resummation

Valence quark distributions from NuTeV, NMC and BCDMS data

$$F(x, Q^2) = x \int_x^1 \frac{d\xi}{\xi} f(\xi, Q^2) \hat{\sigma}\left(\frac{x}{\xi}, Q^2\right)$$



Impact of soft resummation: 5 – 25% for $0.55 < x < 0.75$

In perspective: fully-resummed cross sections at the LHC, i.e. both pdfs and $\hat{\sigma}$ (global fits?)

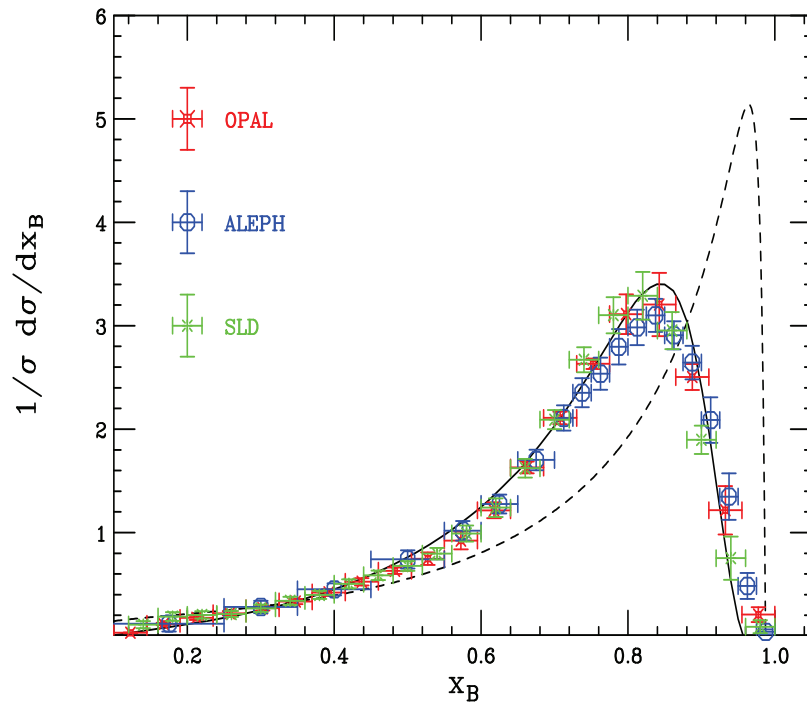
Heavy-quark phenomenology

Heavy-hadron spectrum: heavy-quark production in pQCD, e.g. NLO+N^kLL resummation, non-perturbative effects via an effective coupling constant:

$$\bar{\alpha}_{S,LO}(Q^2) = \frac{1}{\beta_0} \left[\frac{1}{\ln(Q^2/\Lambda^2)} - \frac{\Lambda^2}{\beta_0(Q^2 - \Lambda^2)} \right]$$

B-hadron production at LEP and SLD

$$x_B = \frac{2E_B}{m_Z}$$



In progress: extension of effective-coupling model to DIS and hadron colliders

Z' phenomenology: Sequential Standard Model (same couplings as SM) or Grand Unified Theories (E_6) leading to extra $U(1)'$:

$$Z'(\theta) = Z_\psi \cos \theta - Z_\chi \sin \theta$$

$$Z_\psi \text{ for } E_6 \rightarrow SO(10) \times U(1)_\psi \quad ; \quad Z_\chi \text{ for } SO(10) \rightarrow SU(5) \times U(1)_\chi$$

Latest analyses have focused only SM decays, e.g. high-mass dilepton resonances

CMS: Luminosity of 40 pb^{-1} (dimuons) and 35 pb^{-1} (dielectrons):

$$m(Z'_{SSM}) > 1.14 \text{ TeV} \quad , \quad m(Z'_\psi) > 887 \text{ GeV}$$

ATLAS: Luminosity of 40 pb^{-1} :

$$m(Z'_{SSM}) > 1.05 \text{ TeV} \quad , \quad m(Z'_{E_6}) > 738 - 900 \text{ GeV}$$

Z' production and decay into both SM and MSSM particles:

$$\ell\ell, q\bar{q}, \tilde{q}\tilde{q}^*, \tilde{\ell}\tilde{\ell}, H^+H^-, W^+W^-, ZH_i^0, W^\pm H^\mp, H_i^0 P^0, \tilde{C}_i, \tilde{C}_j, \tilde{N}_i\tilde{N}_j$$

Careful inclusion of extra neutralinos and D -term for sfermion masses, due to the $U(1)'$ breaking, i.e. $\tilde{m}_a^2 = \tilde{m}_{a,0}^2 + \Delta\tilde{m}_a^2$, $\Delta\tilde{m}_a^2 = g'^2 Q'_a \sum_i Q'_i \langle \phi_i \rangle^2$

Implementation into HERWIG event generator of models and branching ratios and benchmarks at the LHC

Conclusions and outlook

Long-term work on collider phenomenology, in particular perturbative QCD, Monte Carlo event generators, heavy-quark physics

Matrix-element corrections to HERWIG parton showers, soft/collinear resummation for heavy quarks and parton densities, effective coupling for non-perturbative effects

In progress:

Q-HERWIG code and comparison with RHIC and ALICE data

Using resummed PDFs to obtain fully-resummed cross sections (e.g. weak boson or heavy-quark production at the LHC)

Extension of effective coupling model to hadron colliders

Phenomenology of new Z' bosons decaying into SM/MSSM particles and implementation in the HERWIG event generator

Looking forward to starting new collaborations at LNF!