Aspects of QCD studies at LAPTh

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QCD activities in a nutshell

Three axes of research

- Loop calculations in QCD
  - GOLEM project
- QCD phenomenology
  - Photon production in deep inelastic scattering and hadronic collisions
- QCD under extreme conditions
  - Study of quark-gluon plasma in heavy-ion collisions

About us

- Permanent staff
  - F. Arleo, P. Aurenche, J.-Ph. Guillet, É. Pilon
- Ph.D. students
  - C. L. Nguyen, M. Zidi Sadok
- External collaborators
  - M. Fontannaz, G. Heinrich, S. Peigné, **I. Schienbein**, **T. Stavreva**, M. Werlen, B. Zakharov, . . .

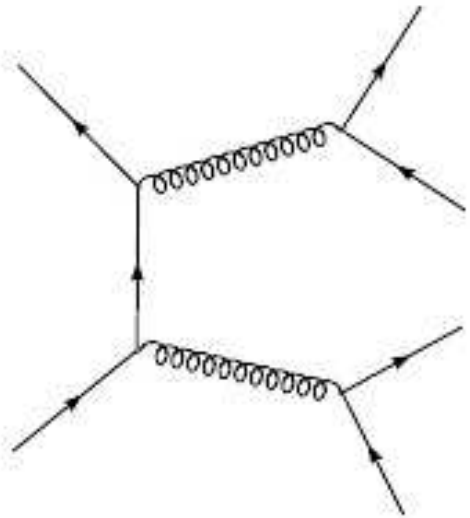
Part I

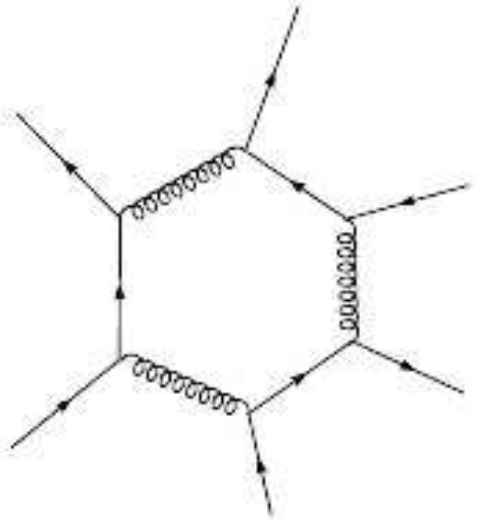
Loop calculations in QCD

Why multileg loop calculation

QCD precision studies at the LHC

- NLO accuracy in order to
  - reduce the (arbitrary) scale dependence of the calculations
  - test the convergence of the perturbative series
- One-loop multi-leg processes to investigate multiparticle production
  - n jets, Z/W's + jets, . . .





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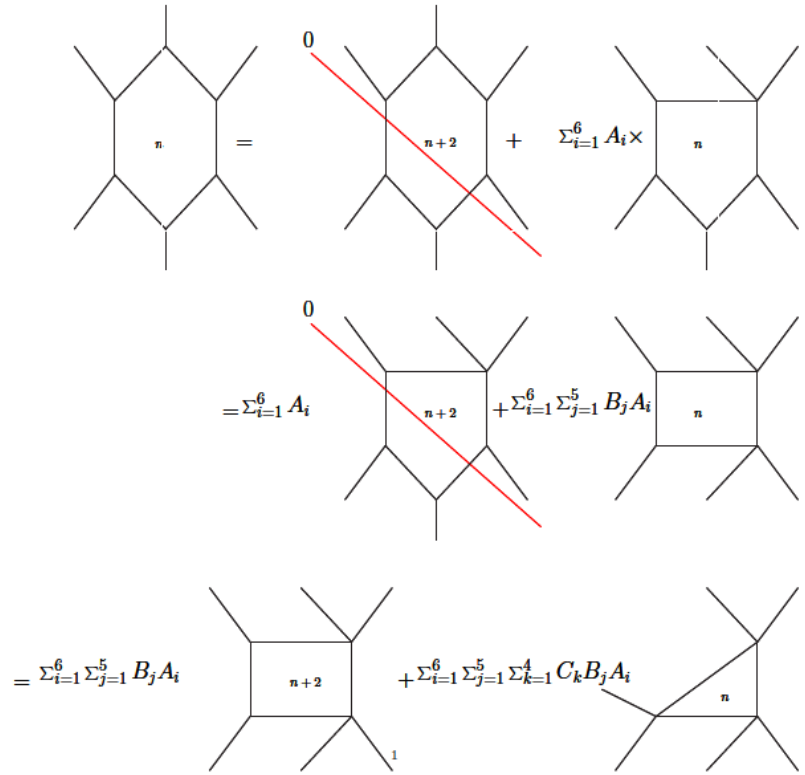
Status of NLO calculations

$2 \to 3$	Standard
$2 \to 4$	State-of-the-art
$2 \to 5$	Rare cases

GOLEM method

GOLEM = General One Loop Evaluator of transition Matrix elements

Algorithm for the algebraic reduction of Feynman diagrams into a linear combination of process dependent tensor structures weighted by universal form factors



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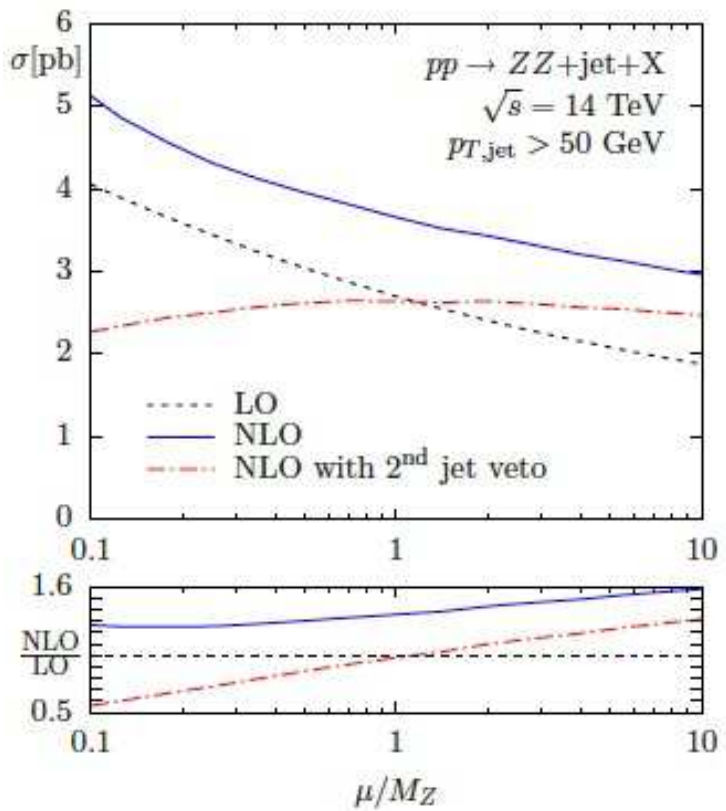
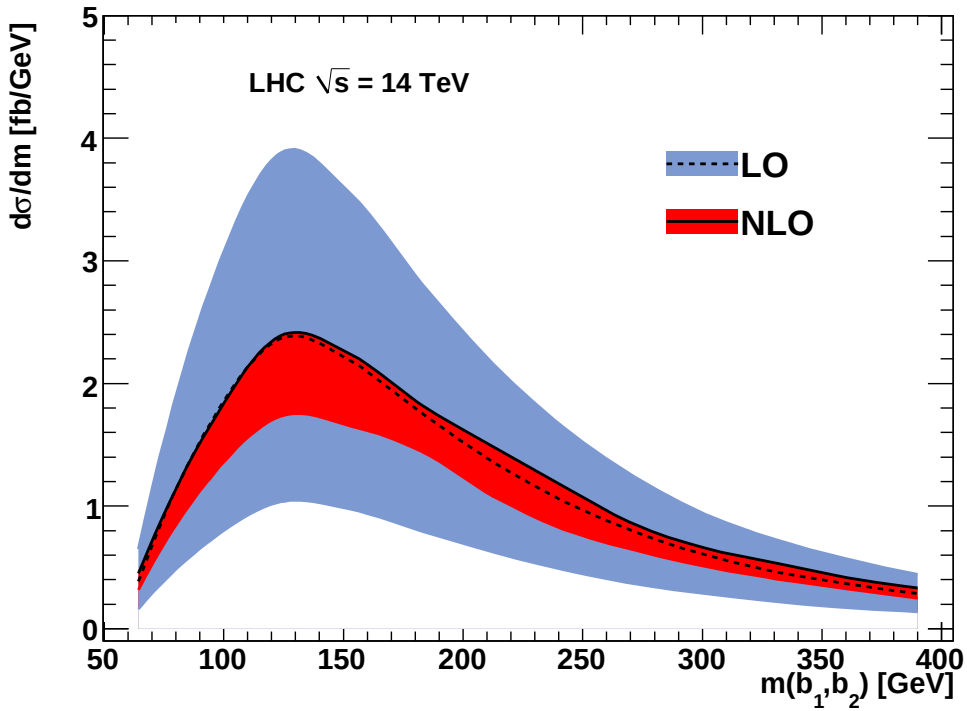
Golem95 numerical library

- Fortran 95 library to compute form factor up to six external legs available: http://lappweb.in2p3.fr/lapth/Golem/golem95.html
- No internal mass up to now
  - Almost complete for real masses
  - Work in progress for complex masses

Applications

- $p + p \to Z + Z + \text{jet}$
- $p + p \to b + \bar{b} + b + \bar{b}$ (quark induced case)





Part II

QCD phenomenology

Photon production in QCD

Long-time expertise in the calculation of photon production at NLO in

- e^+e^- collisions at LEP
- ep deep inelastic scattering at HERA
- hadronic collisions at RHIC, Tevatron, and LHC

Numerical programs available (PHOX family)

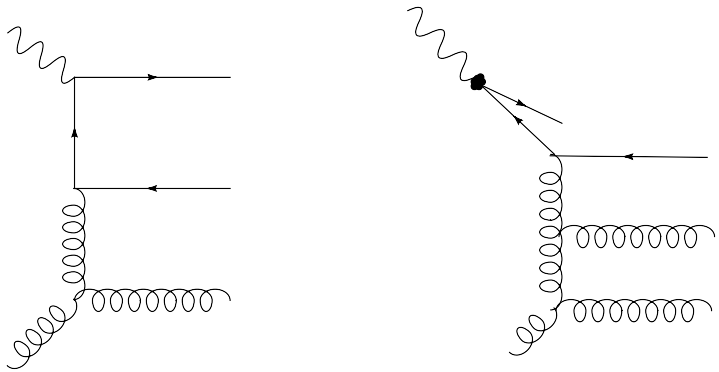
- DIPHOX: $h_1 + h_2 \to \gamma + \gamma + X$
- JETPHOX: $h_1 + h_2 \to \gamma + \text{jet} + X$

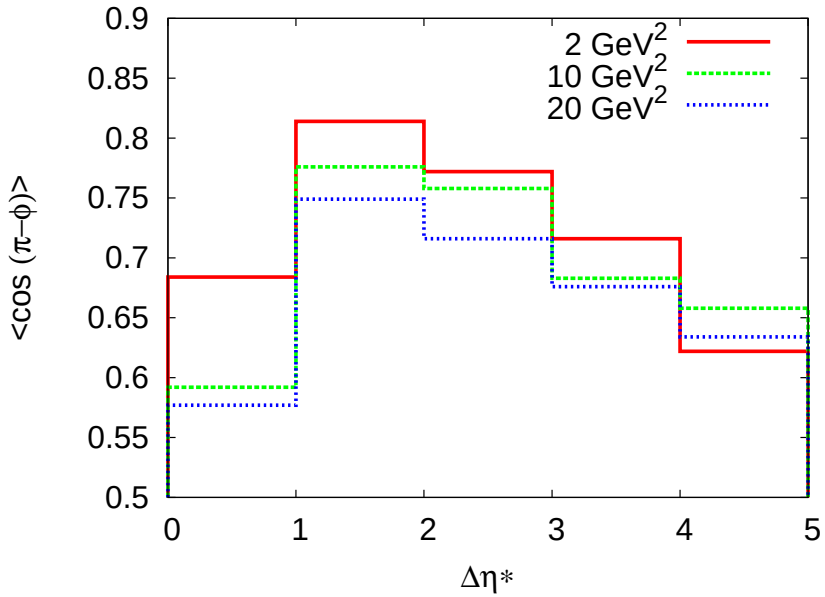
Allows for a variety of phenomenological analyses

involving photons, hadrons and jets in the final state

Jet – hadron correlations in deep inelastic scattering

- Azimuthal decorrelation between hadron and jet in ep scattering
- Sensitive test of QCD radiation dynamics (DGLAP vs BFKL)

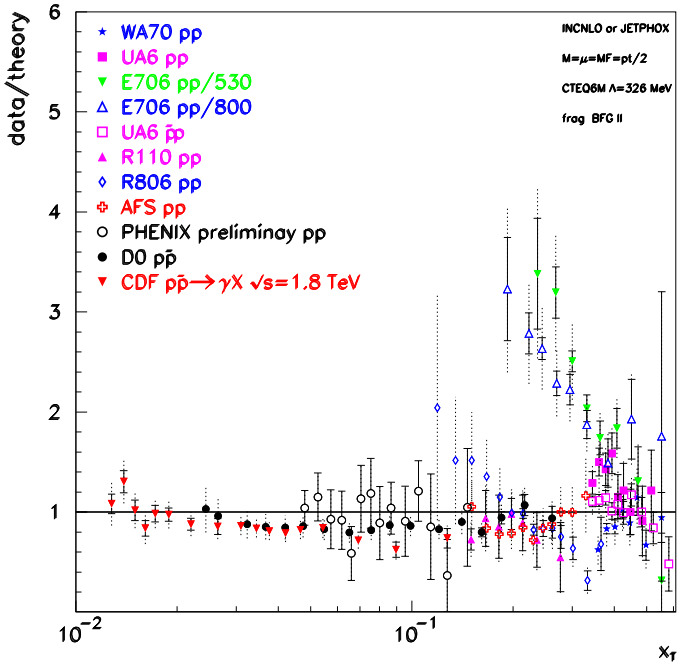


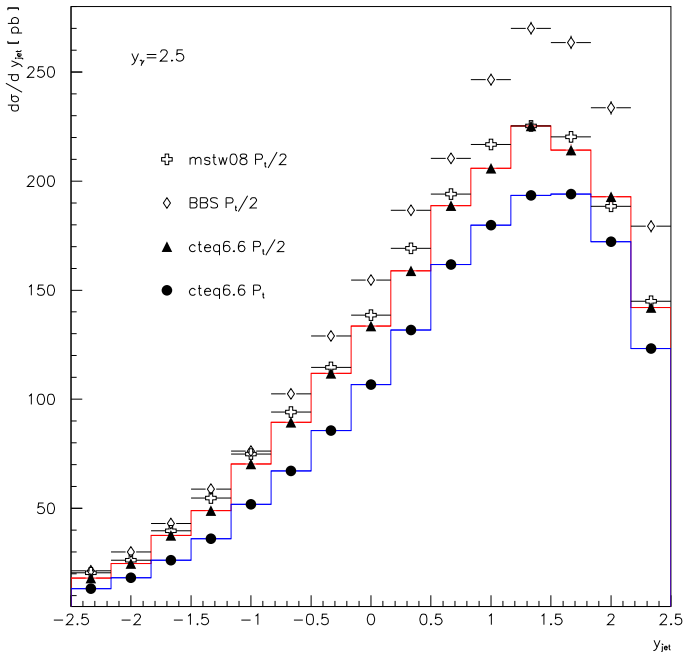


Photon production in hadronic collisions

p p collisions

- Global analysis of inclusive photon production and comparison with world data
- Study of γ – jet correlations from Tevatron to LHC
  - probe of parton distributions and fragmentation into photons

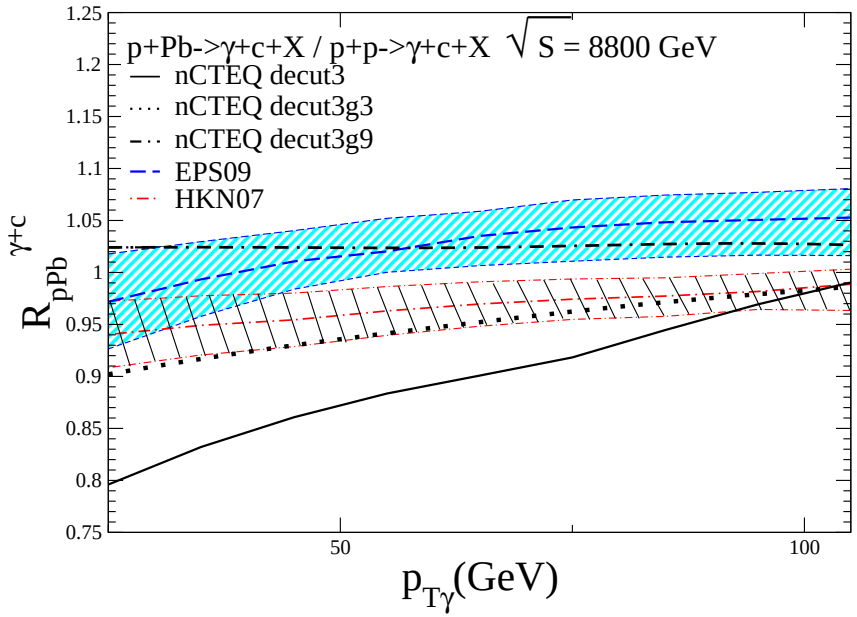




Photon production in hadronic collisions

p A collisions

- Predictions of photon + Q production from RHIC to LHC
  - constraints on the gluon distribution in nuclei

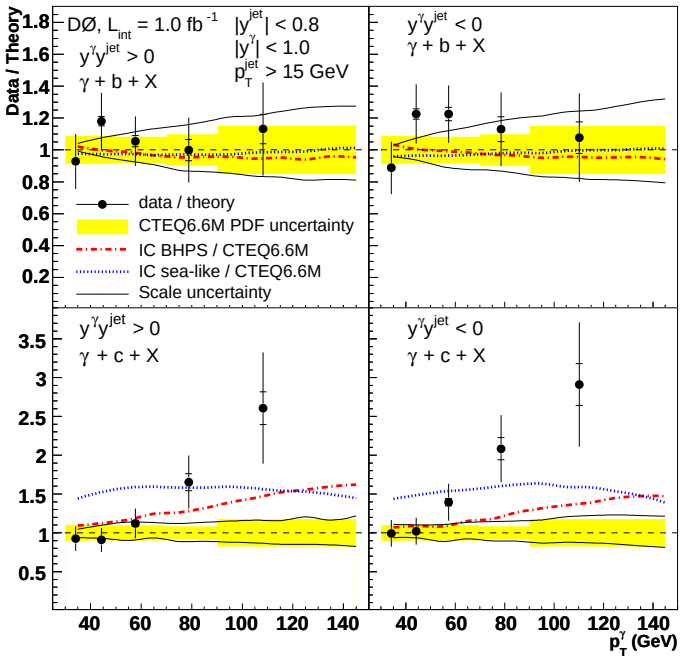


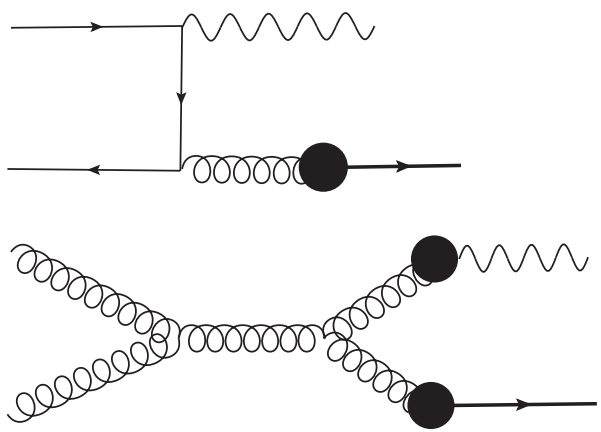
$$\frac{\sigma(p\,A \to \gamma\,Q\,X)}{\sigma(p\,p \to \gamma\,Q\,X)} \simeq \frac{G^A(x_\perp e^{-y})}{G^p(x_\perp e^{-y})}$$

Photon production in hadronic collisions

Work in progress

- Improving the calculation of photon + heavy-quark production by including fragmentation of partons into heavy-quarks





Part III

QCD under extreme conditions

Introduction

Confinement

Quarks and gluons are confined into hadrons (pions, protons, ...) and can't propagate over "large" distances as compared to $\Lambda_{\mathrm{QCD}}^{-1} \simeq 1\ \mathrm{fm} = 10^{-15}$ m

The origin of confinement is still unknown !

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Confinement

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A new state of matter

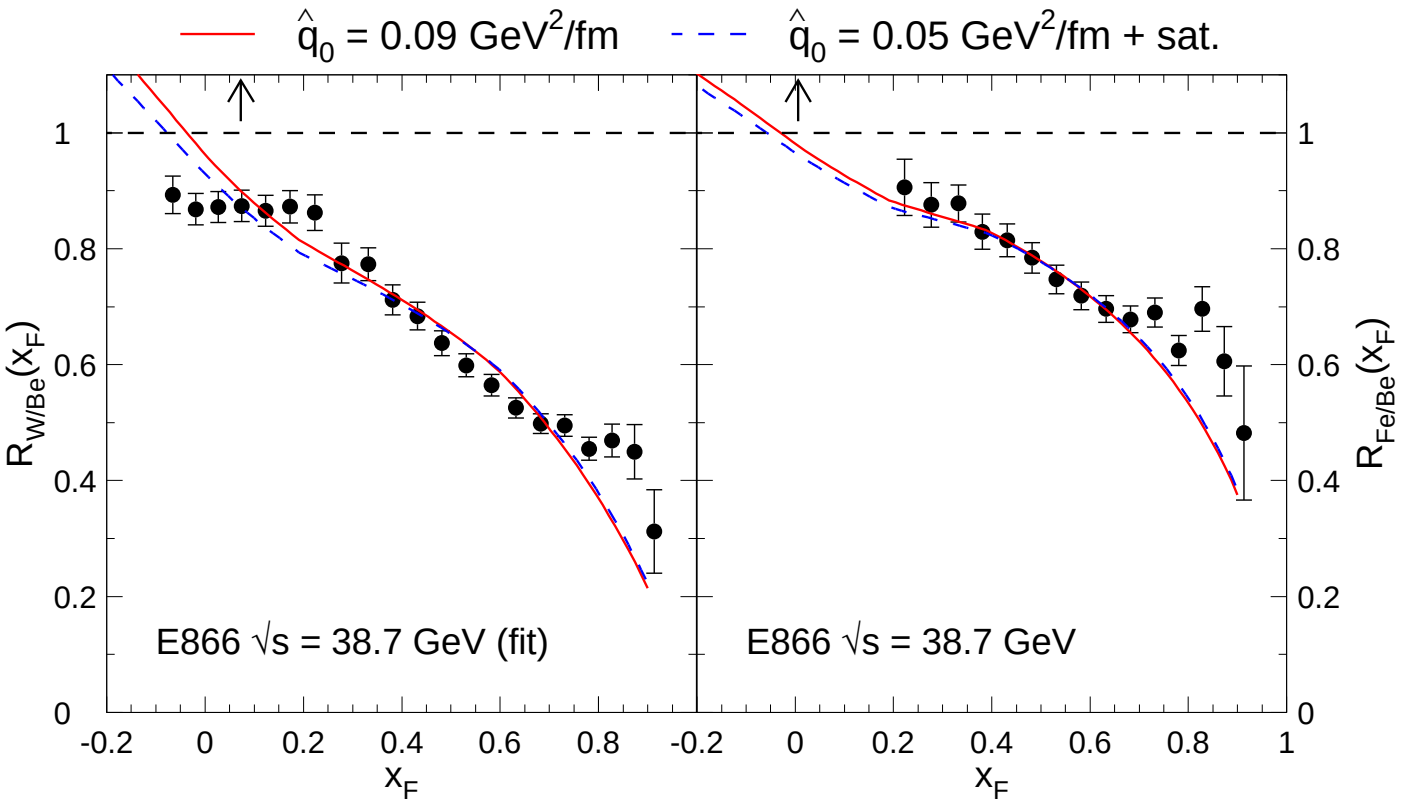
At high temperature ($T \simeq 200\ \mathrm{MeV} \simeq 2 \times 10^{12}\ \mathrm{K}$) transition from confined matter towards quark-gluon plasma

- Existed less than a micro-second after the Big Bang
- Expected to be produced at the early stage of heavy ion collisions, with short lifetime ($\tau \sim 10$ fm/c $\sim 10^{-21}$ s)
- Quenches the production of jets due to parton energy loss

Probing parton energy loss

Energy loss in (cold) nuclear matter

Might be at the origin of charmonium (J/ψ) suppression in p–A collisions



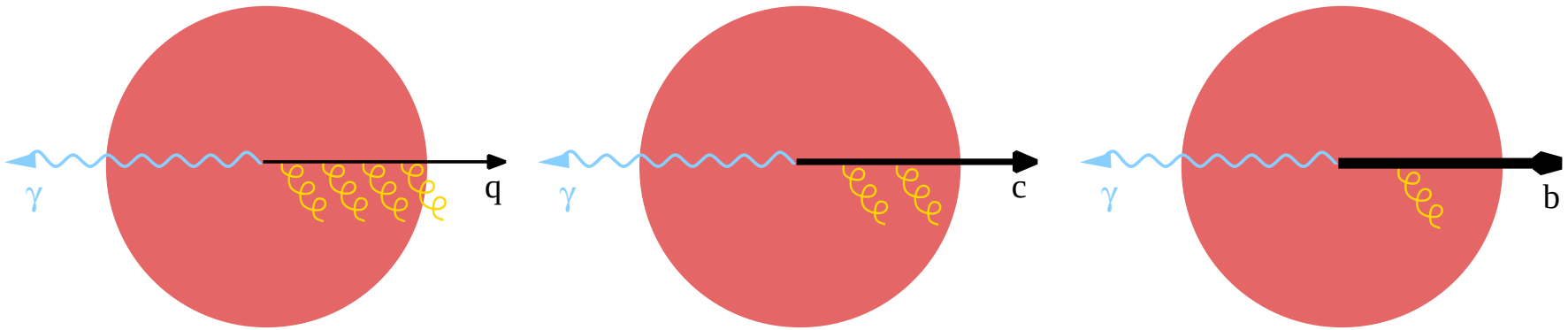
Probing parton energy loss

Energy loss in (hot) quark-gluon plasma

Mass hierarchy

$$\left(\Delta E\big|_g >\right) \Delta E\big|_q > \Delta E\big|_c > \Delta E\big|_b$$

can be studied through the correlations of photons with heavy-quark jets



The End

That’s all, thanks for your attention !