



Atelier "Physique Théorique des deux infinis"

ANR PRC PROJECT PRECISONIUM

HUA-SHENG SHAO

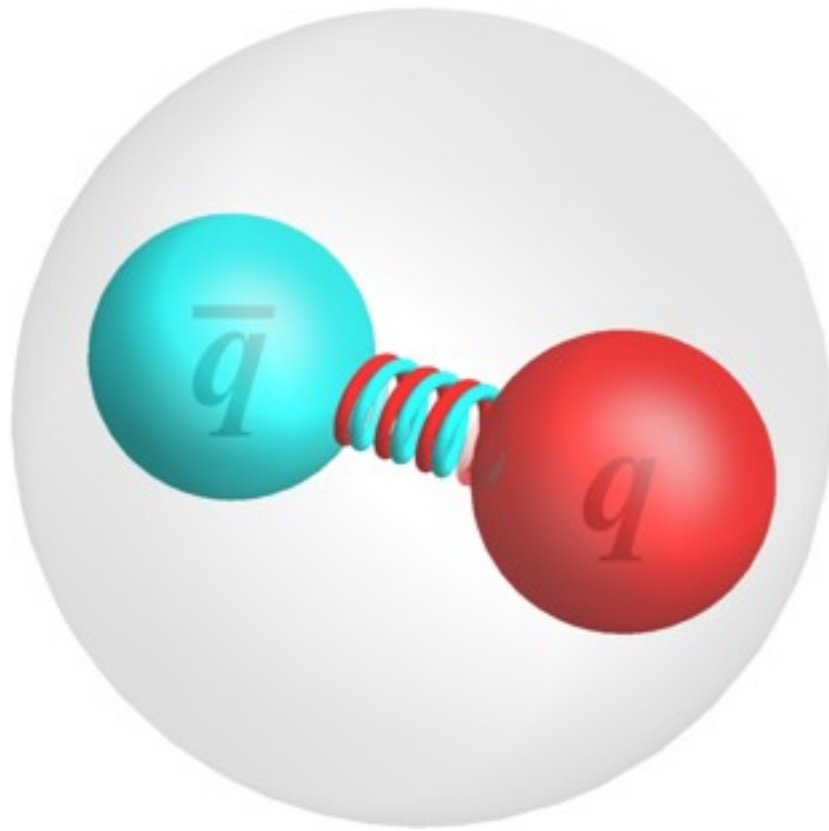


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07-08 JUNE 2021

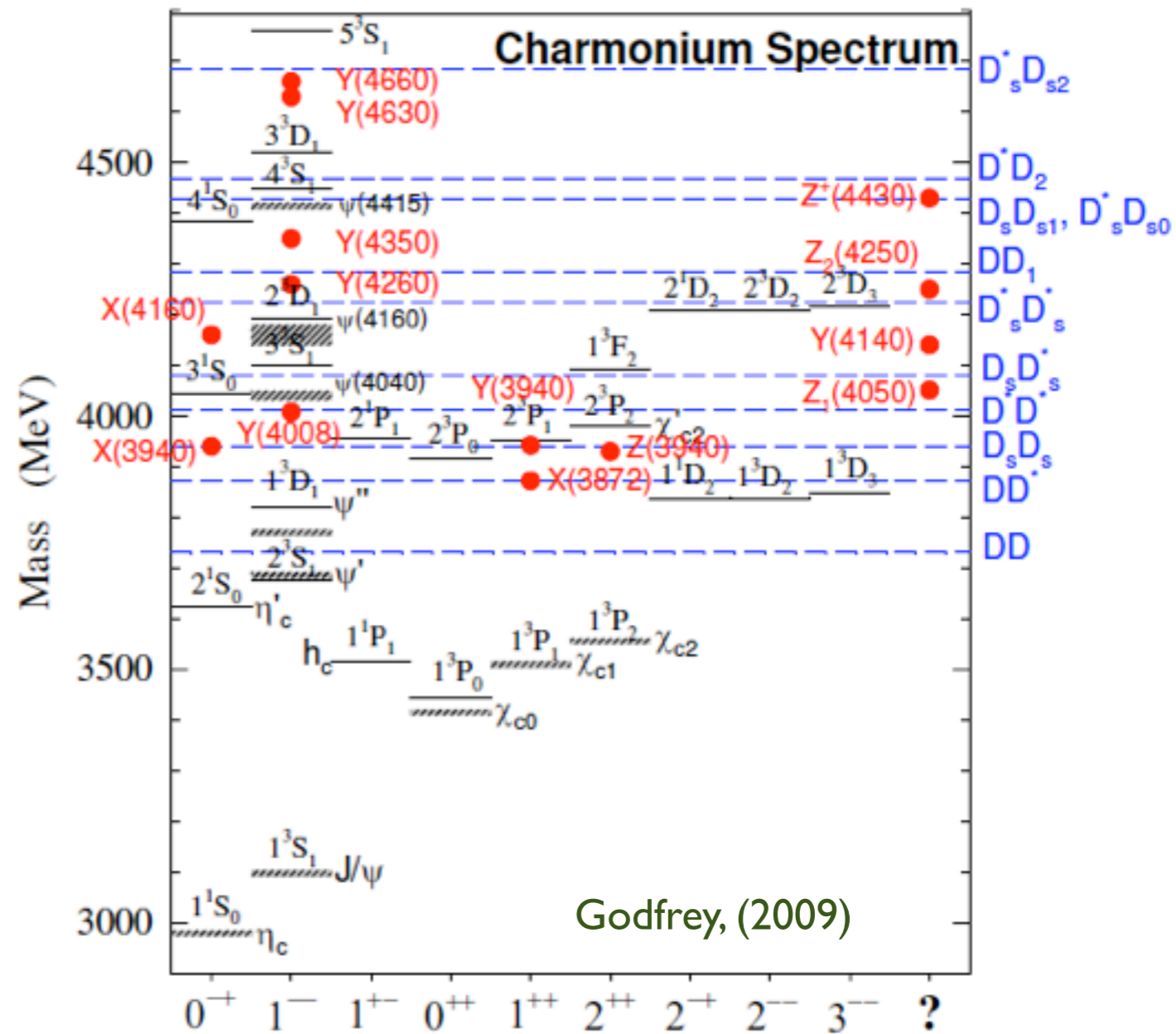
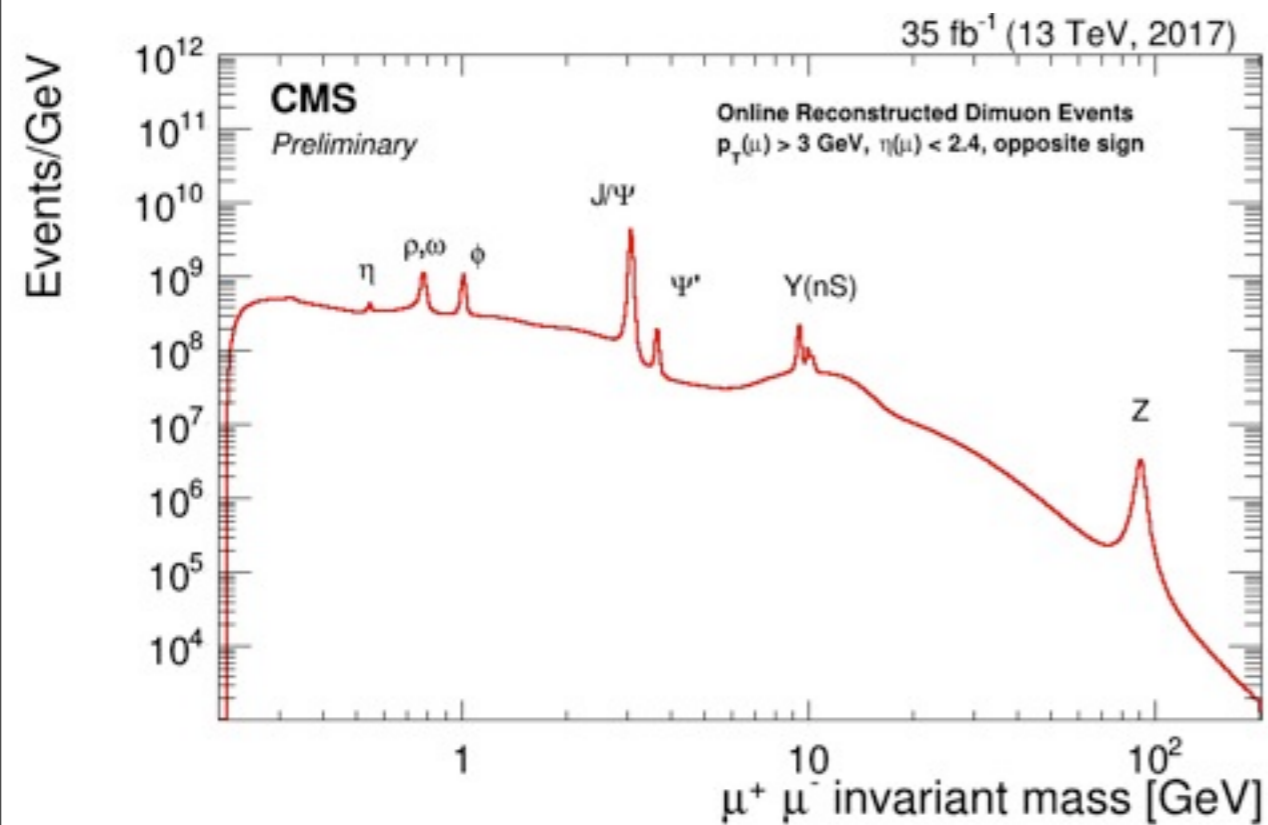
Advancing the Precision of Quarkonium-Production Studies

- Instrument : PRC
- Duration of the project : March 2021 - February 2025
- French partners
 - Theory role of IJCLab Orsay (J.-P. Lansberg)
 - LPTHE Paris (H.-S. Shao)
- International partners
 - UCLouvain Belgium
 - CERN
 - Groningen U. Netherland
- Two postdocs + 1 PhD
 - Ajith A.H. (PhD at IMSc Chennai, India and will start this fall) & J. Bor (Co-PhD with Groningen U.)

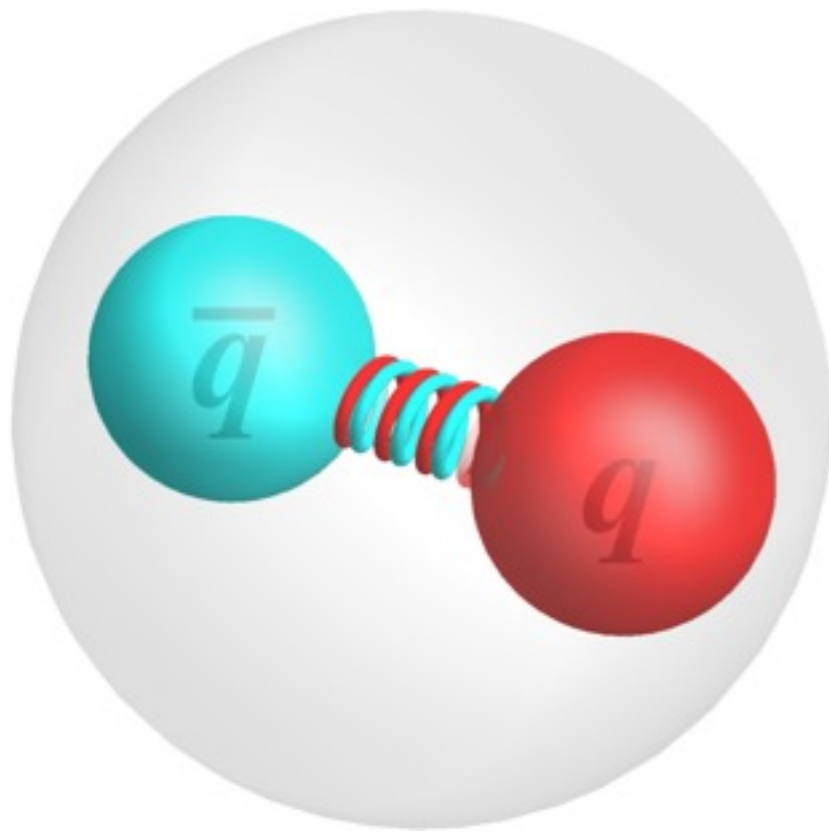
HEAVY QUARKONIUM: WHAT ?



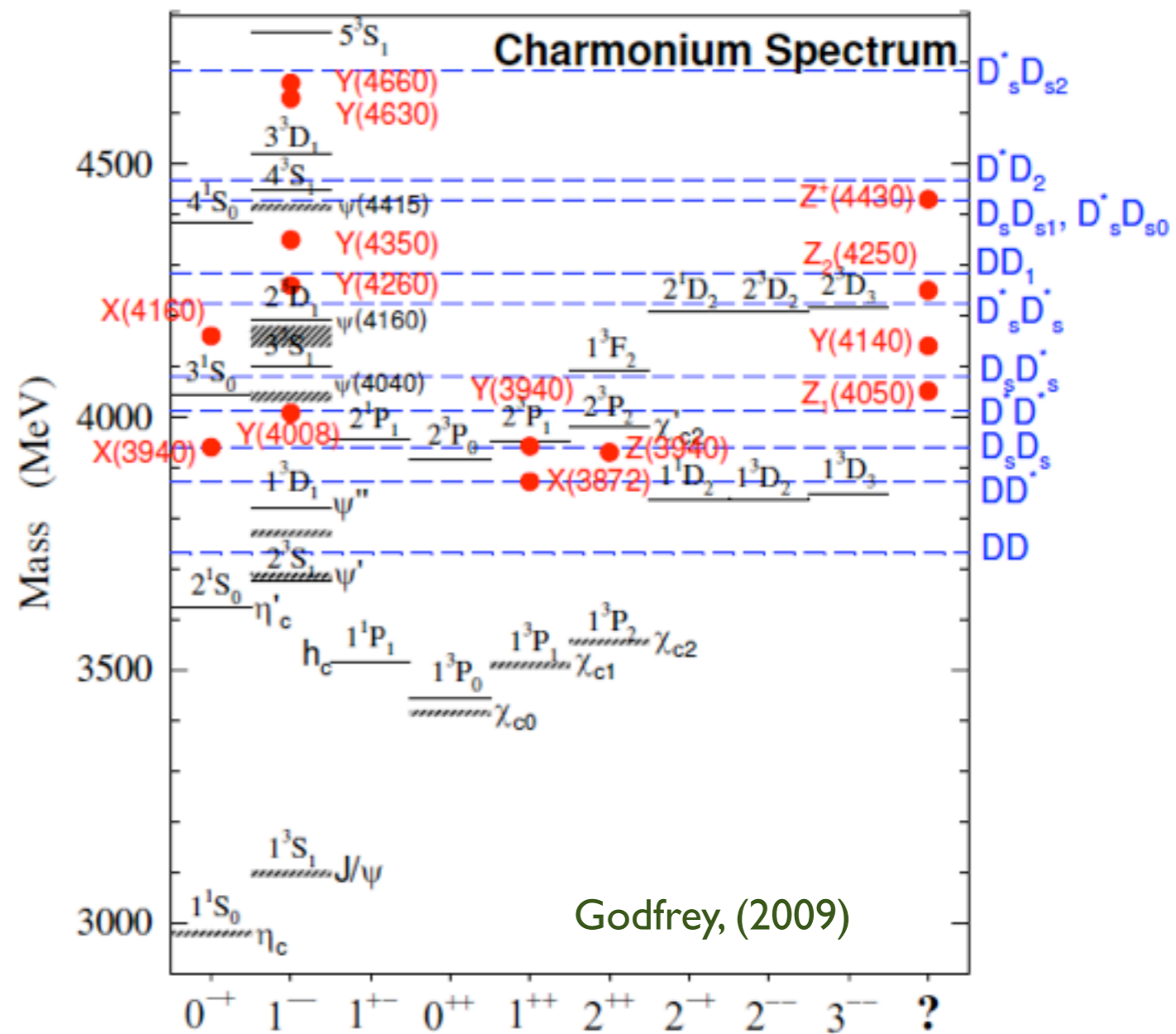
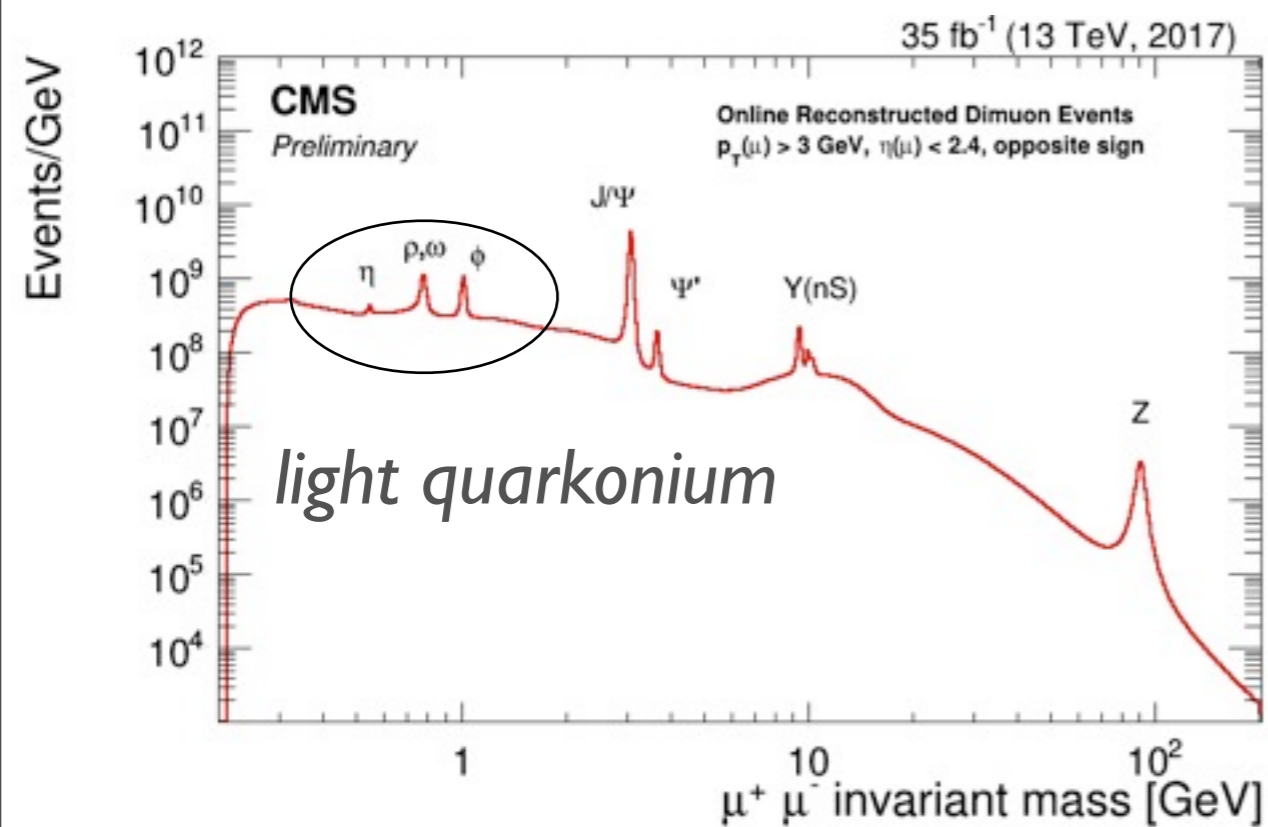
- A class of mesons composed of two (same or diff.-flavor) heavy quarks



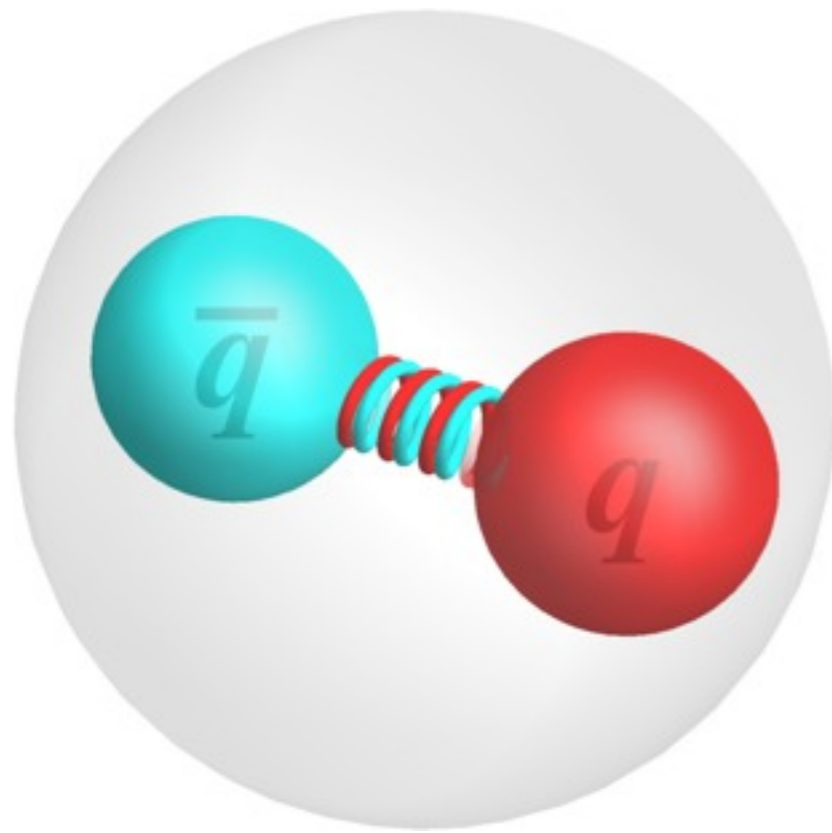
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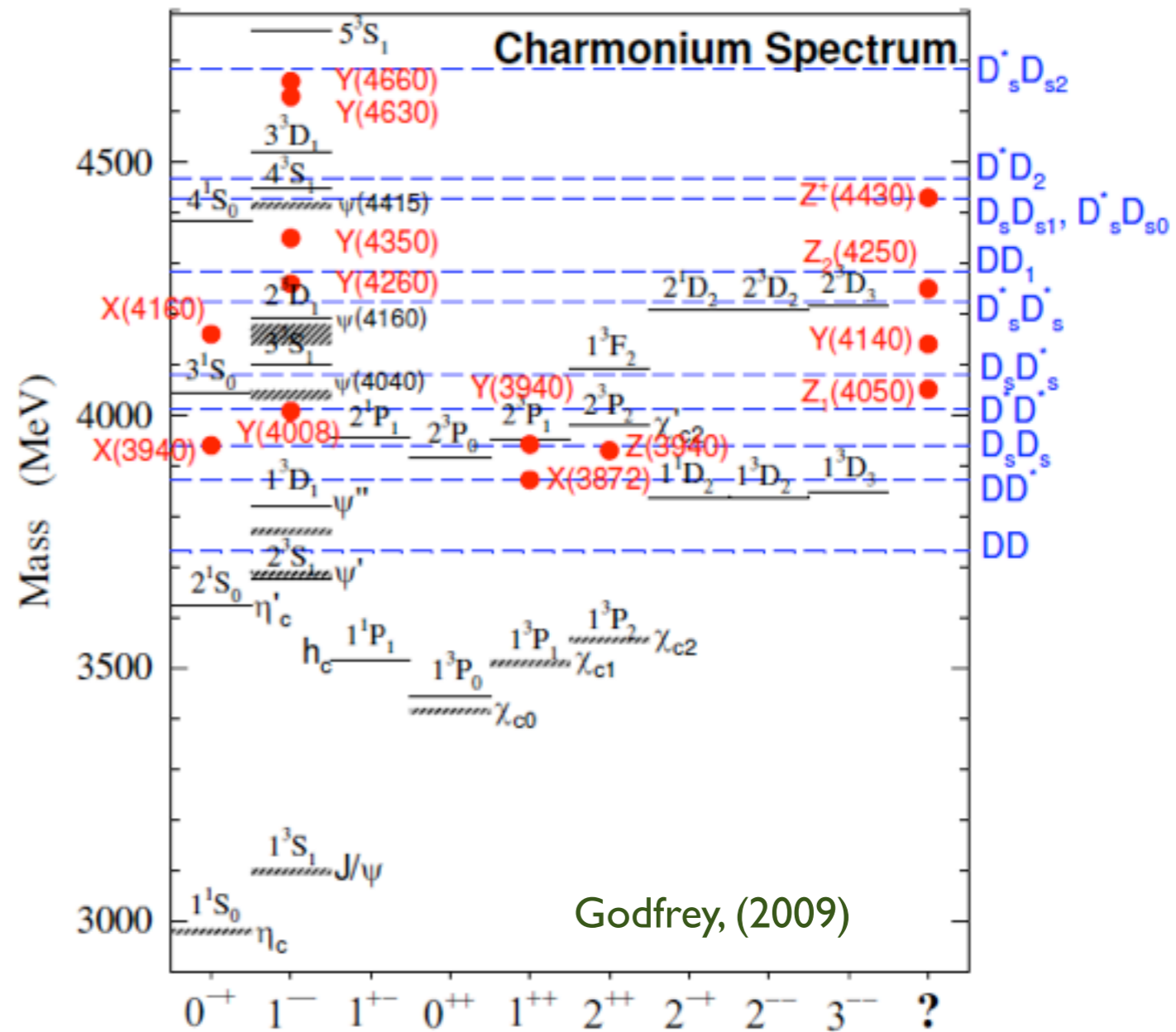
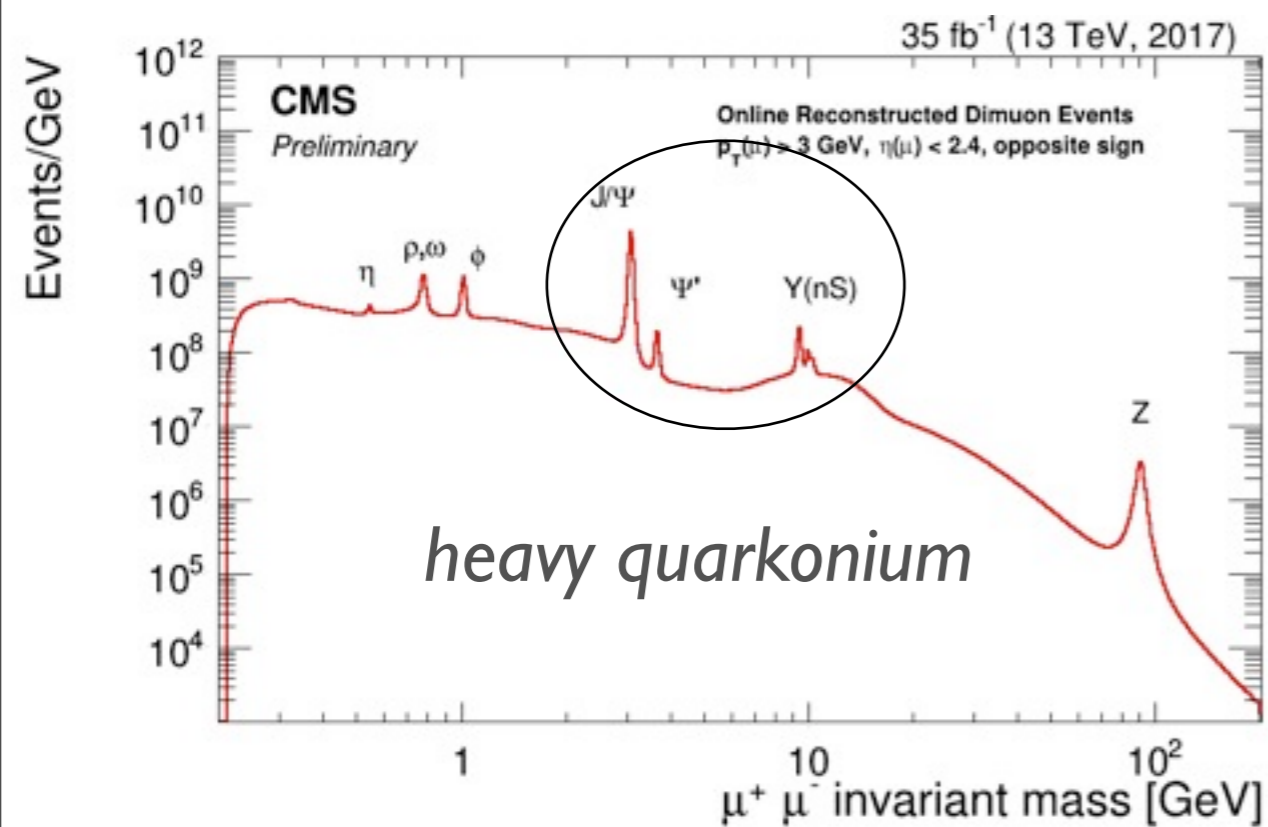
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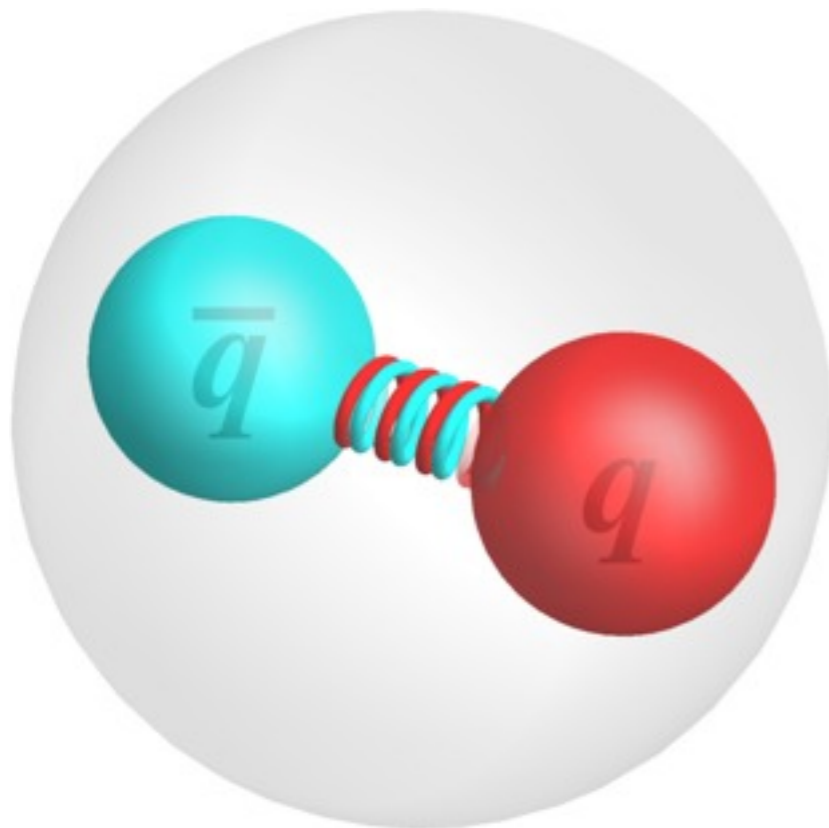
HEAVY QUARKONIUM: WHAT ?



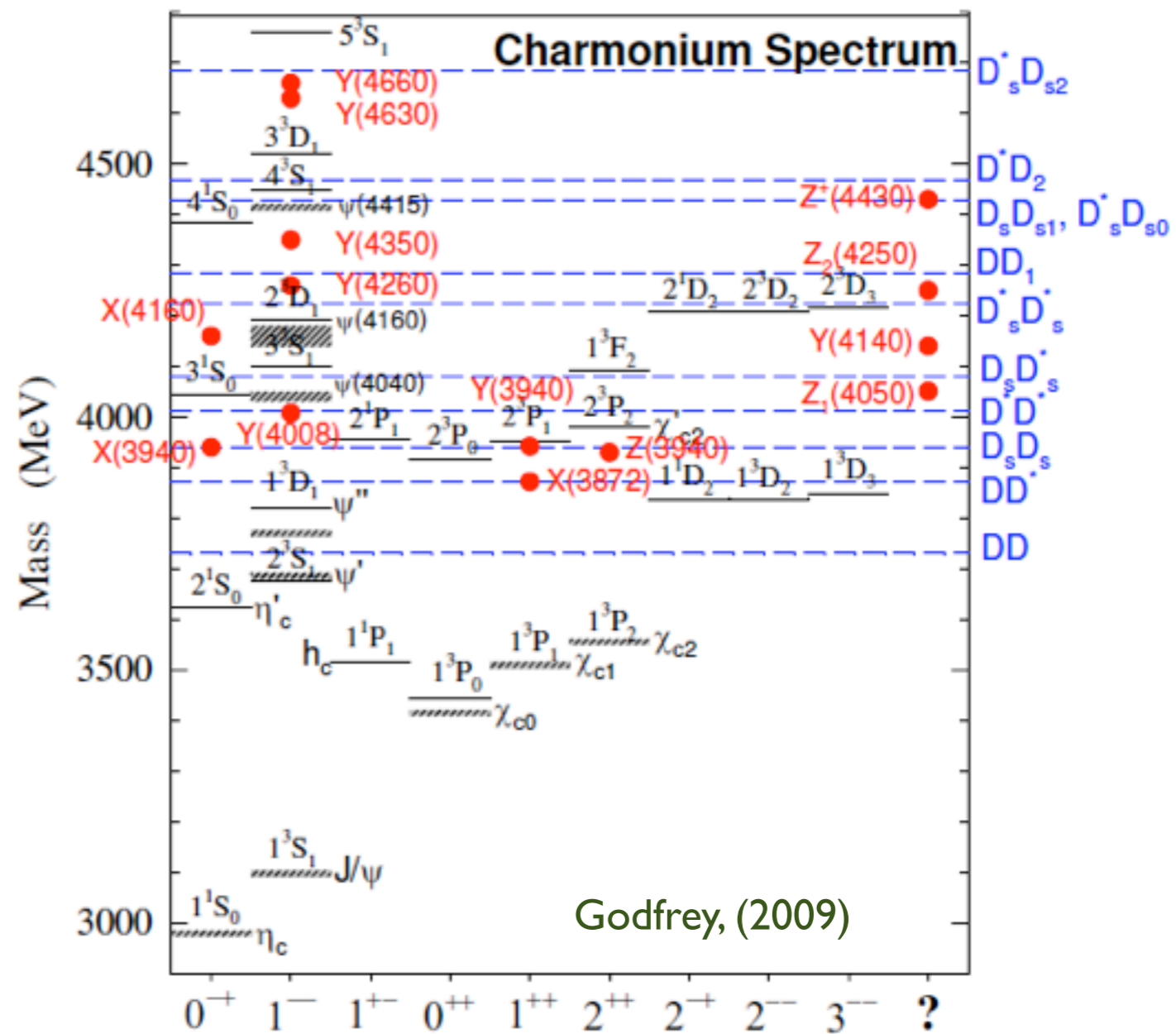
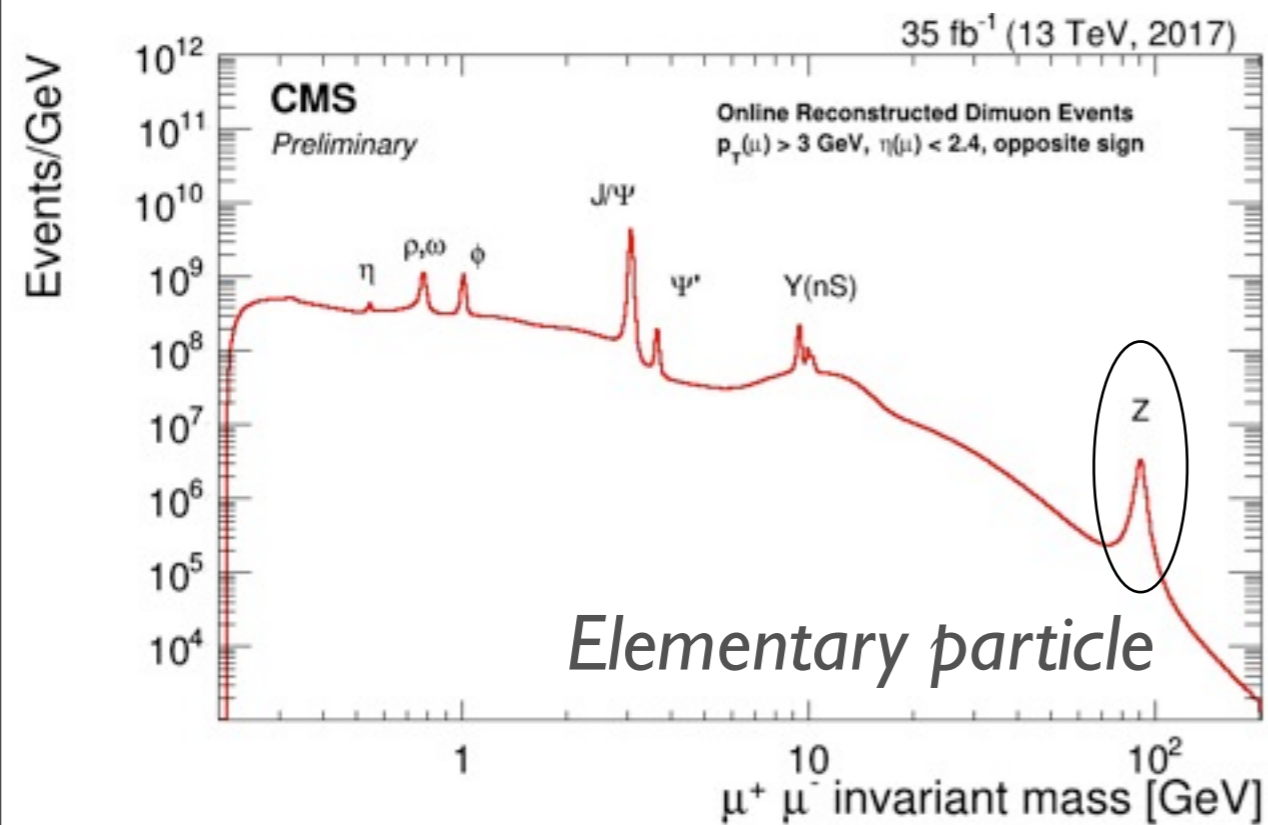
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HEAVY QUARKONIUM: WHAT ?



- A class of mesons composed of two (same or diff.-flavour) heavy quarks



HEAVY QUARKONIUM: WHY ?

- Heavy quarkonium provides an ideal laboratory to test **perturbative QCD** and to study the underlying **non-perturbative dynamics**.
- Almost all of the high-energy experiments with proton, electron and ion beams have measured them and studied the relevant physics:
 - Fundamental parameters: strong coupling constant, CKM
 - Probe gluon distributions in proton: collinear/transverse dynamics
 - Multiple parton (hard) scatterings
 - Quark-gluon plasma, cold nuclear effects, CP violation etc

A reliable and precise understanding of quarkonium production is fundamental for the high-energy physics community, from searches of new particles to attempts to better understand nucleon structure and the confinement property of QCD or to explore the phase diagram of the nuclear matter. This is what is at stake with PRECISONIUM.

HEAVY QUARKONIUM: HOW ?

The objectives of PRECISONIUM can be summarised as follows

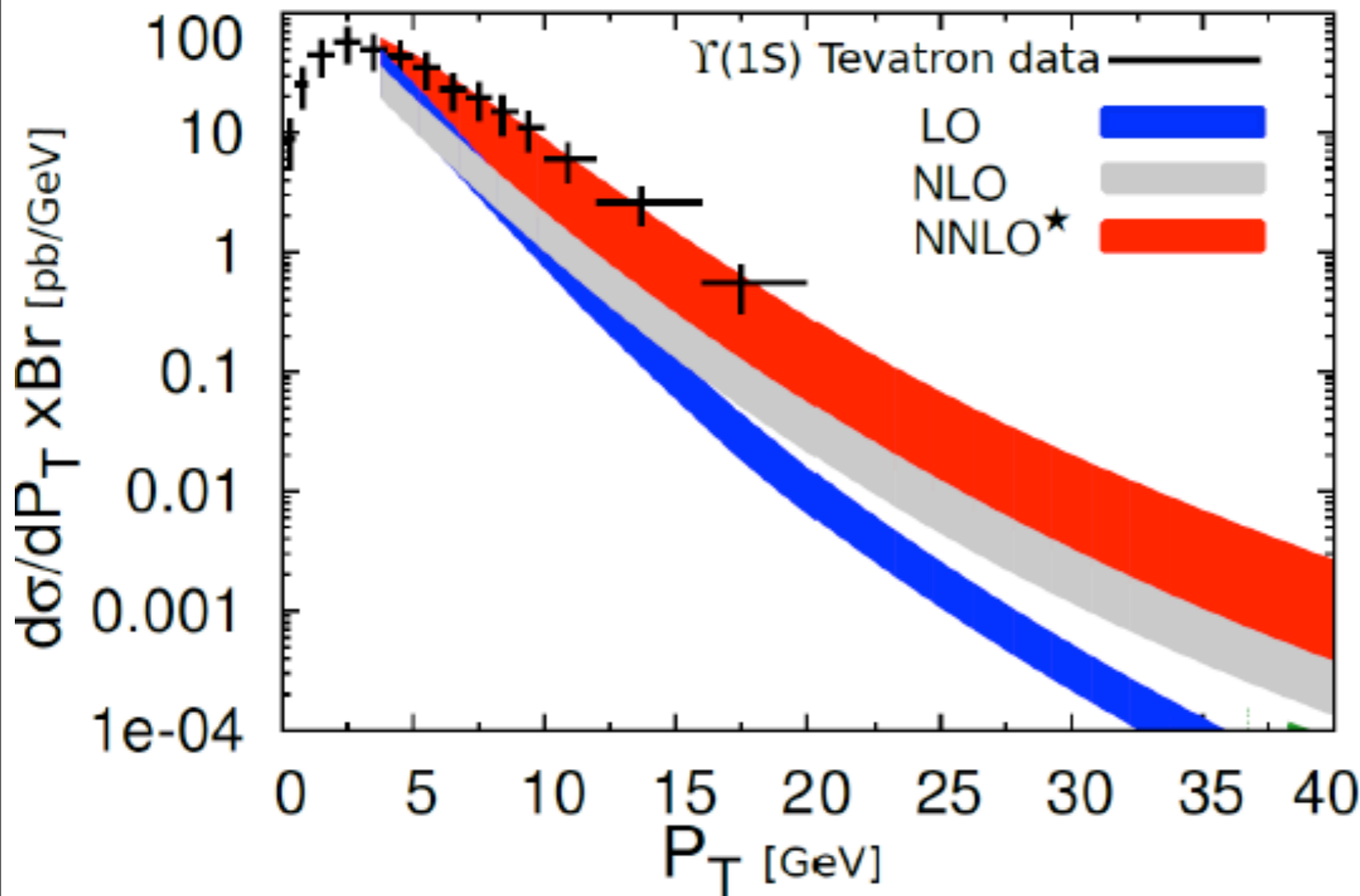
1. Performing the first truly **global NLO analysis** of the NRQCD parameters and thereby significantly **constraining the long-distance** parameters involved in quarkonium production, thank to the first **automated tool** for quarkonium event generation at NLO within NRQCD in collinear factorisation,
2. **Pioneering NNLO computations** for quarkonium production with $2 \rightarrow 1$ then $2 \rightarrow 2$ processes, relevant for the hadron and lepton-hadron machines;
3. Enriching the **virtual access, NLOACCESS**, such it become an **integrated computed framework** for quarkonium production by developing the first TMD tool at NLO+NNLL and putting online our NLO automated tool as well as our NNLO codes.

WORK PACKAGE 1: CONSTRAIN THE LONG-DISTANCE PHYSICS VIA GLOBAL NRQCD STUDIES AT NLO

WORK PACKAGE 2: ADVANCE THE PRECISION FOR THE SHORT-DISTANCE PHYSICS WITH FIRST NNLO STUDIES

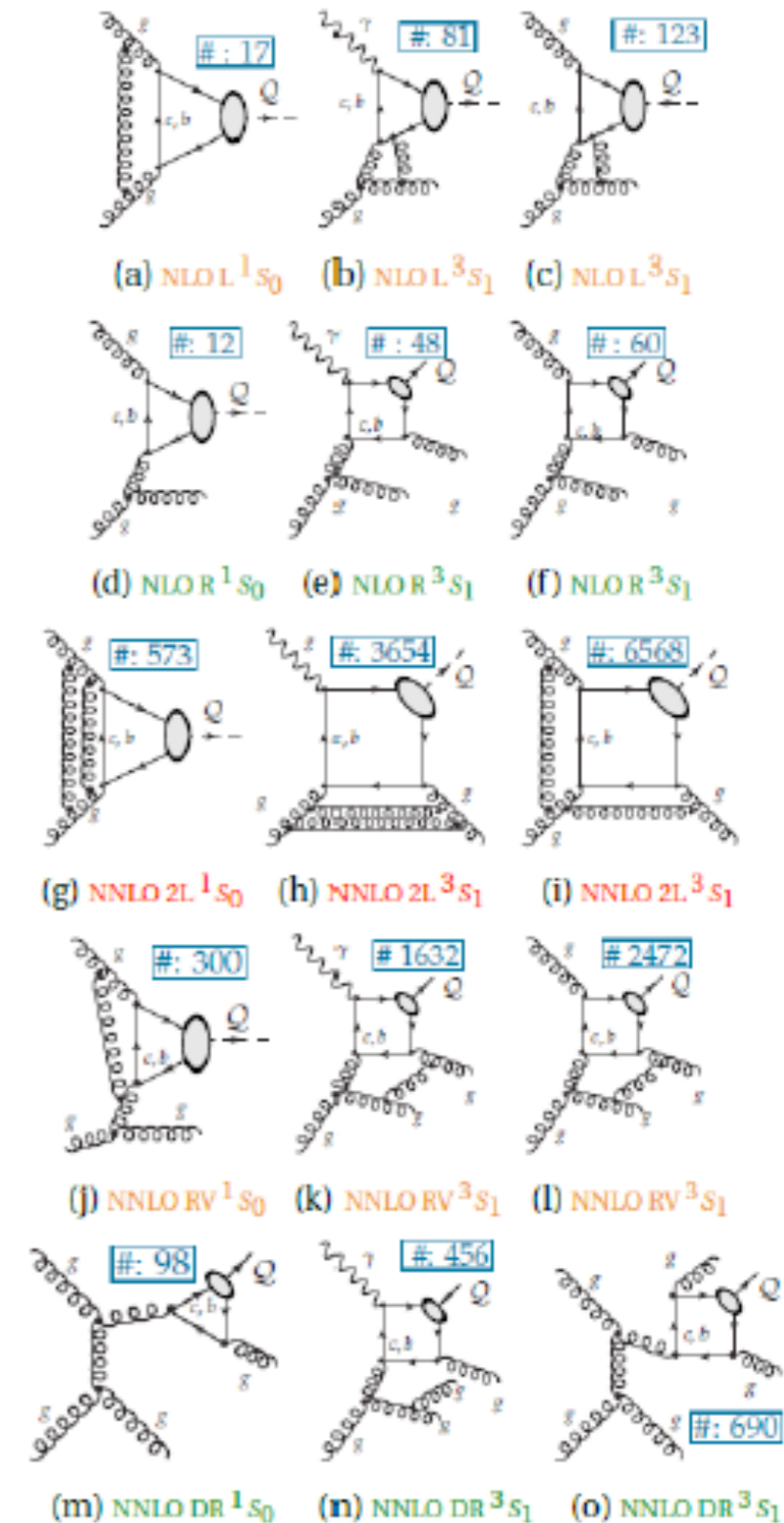
WORK PACKAGE 3: PHENOMENOLOGY WITH TMD FACTORISATION AT NLO+NNLL AND NLOACCESS

HEAVY QUARKONIUM: WHY NNLO ?

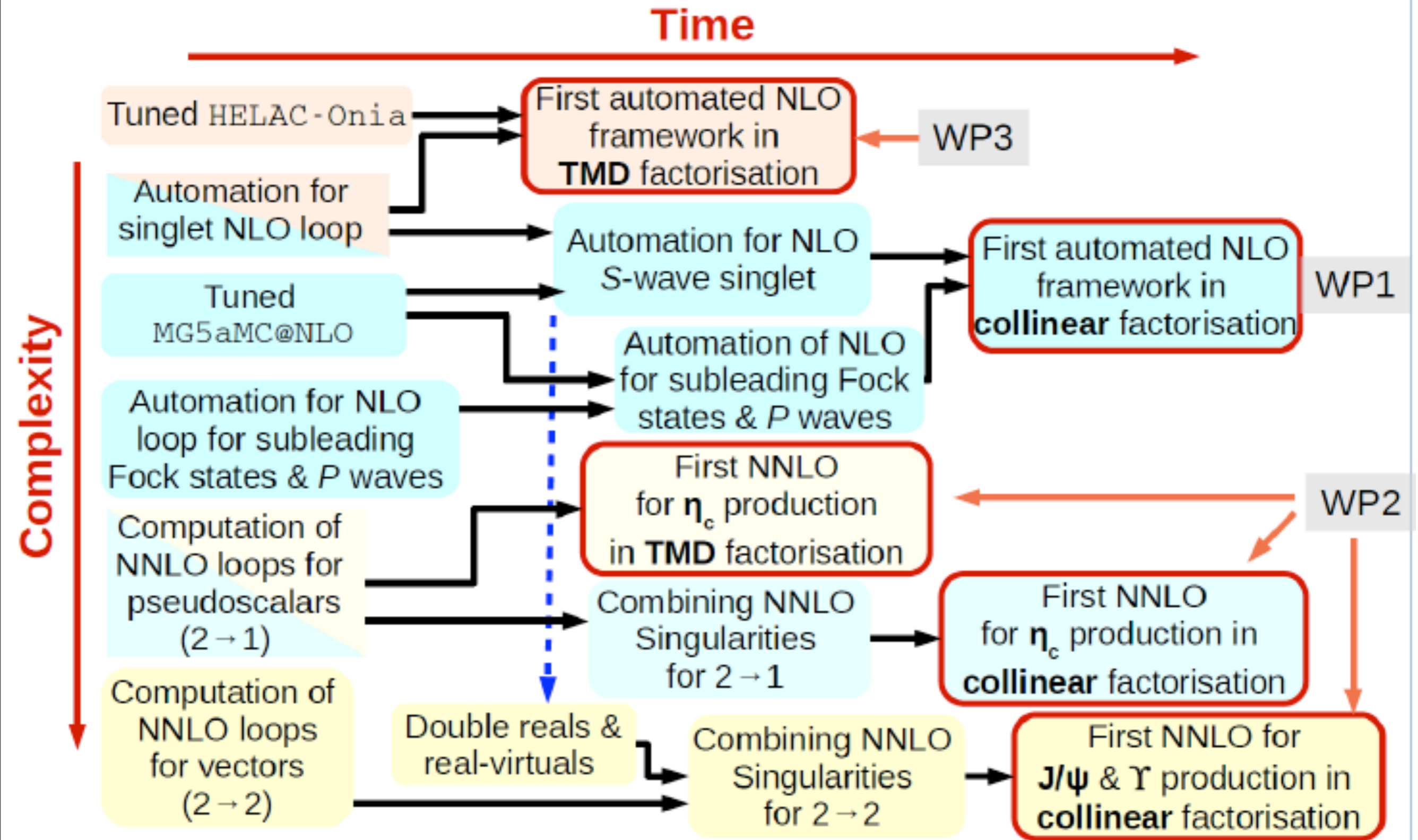


- Partial NNLO* computation done (by us) in 2007 (red band)
- Such QCD corrections are needed to account for the data
- Larger uncertainties since partial
- Alternative method (nnLO, also by us) → different results

→ Complete NNLO computation needed



PRECISIONIUM : TIMELINE



PRECISIONIUM : EXPECTED OUTCOMES

The innovative aspects of PRECISIONIUM comprises : first truly global fits of long-distance matrix elements using a NLO generator to automate data-theory comparisons, first NNLO computations and a Virtual Access to ease the use of quarkonium as tools and improve the relevance of quarkonium data for spin and heavy-ion studies.

PRECISIONIUM : 3 battle fronts – 3 equations

Automated NLO computations + Experimental data = Precision for **Long** distances

First NNLO computations + TMD & collinear factorisation = Precision for **Short** distances

Advances in quarkonium production + Global framework = Precision for **Spin/QGP** physics

Inputs

Deliverables

Impact

NLOAccess

Virtual Access: Automated perturbative NLO calculations for heavy ions and quarkonia (NLOAccess)

Tous les codes résultants de PRECISIONIUM pourront être mis à disposition de la communauté



Thank you for your attention !