Moriond Highlights: QCD Theory

Séminaire de physique expérimentale
15 mai 2009

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Theory at Moriond QCD

30 talks:

Non-Perturbative QCD & Lattice

Perturbative Methods in QCD

Data - Theory Interface

Beyond the Standard Model

Heavy-Ion Physics

summarized by Gavin Salam (Paris 6 & CNRS)

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Proton mass

Bottomonium ground state mass

One-loop for N external gluons

Higgs → bb

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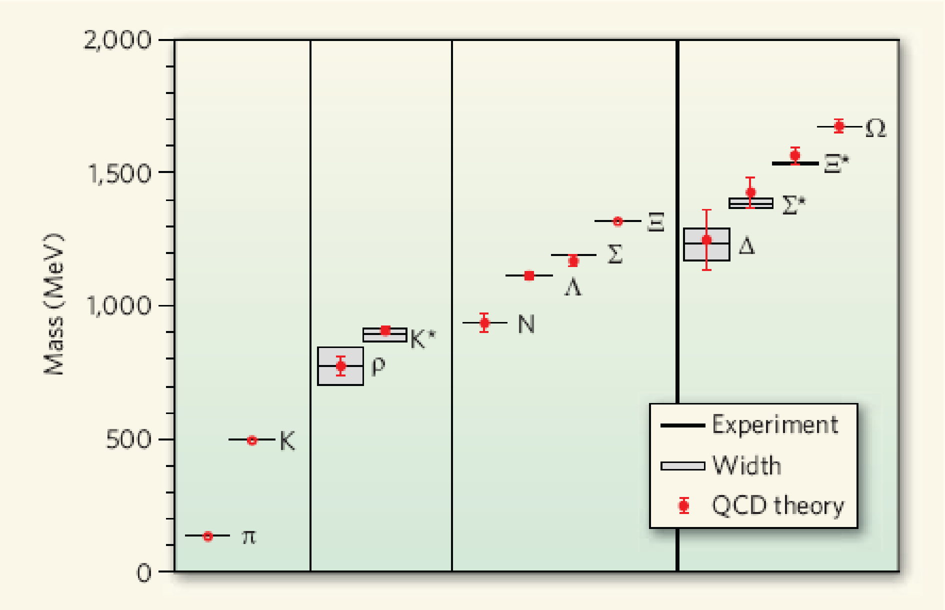
Proton mass from the lattice

Two reports:

Kuramashi (PACS-CS coll.) preliminary; arXiv:0807.1661
try to avoid chiral extrapolation

Fodor (BMW collaboration) published *Science* 322, 1224 (2008)



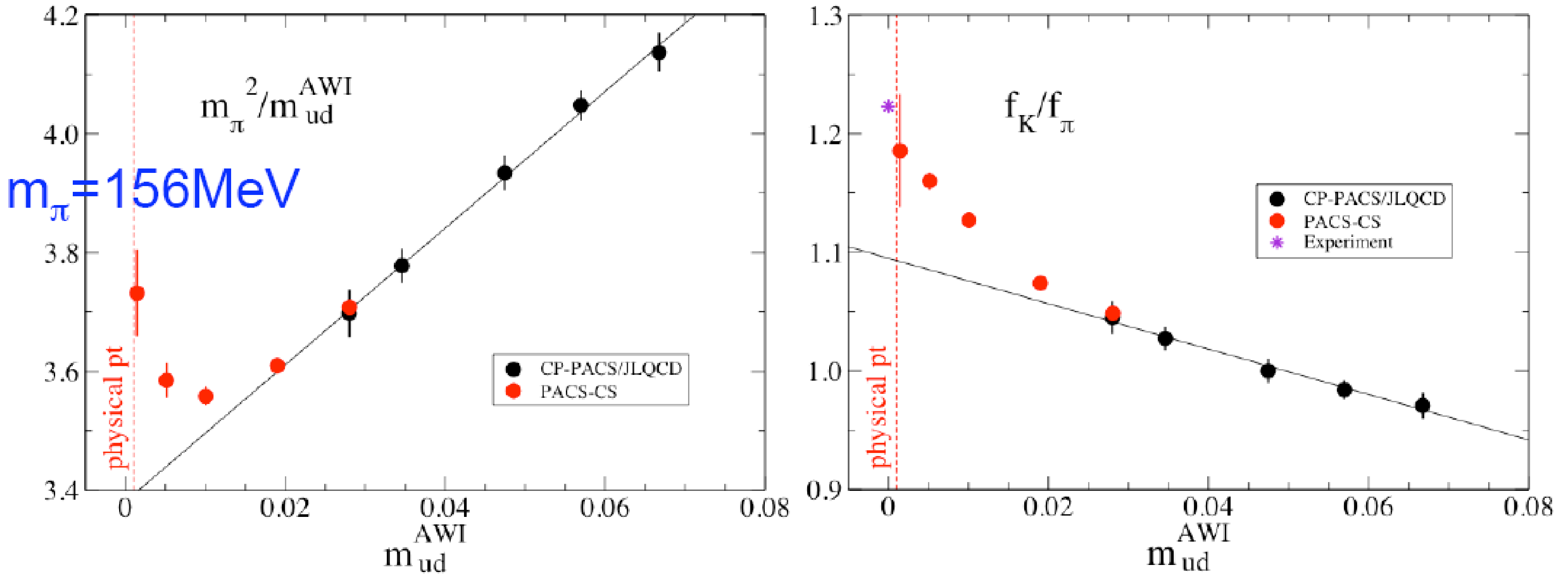
Three parameters fitted:

- up and down mass
- strange mass
- coupling constant

Proton mass from the lattice

Kuramashi

Difficulty of light quark masses: extrapolate from larger values using chiral perturbation theory



$m_{ud}\log(m_{ud})$ behaviors predicted by ChPT

Impact of the proton mass calculation

- scientific: validity of strongly-coupled QCD
- practical: possibility to study other properties of light hardons and nuclei
- philosophical: Wheeler's "its from bits"

$$m_N = 936(25)(22)\ \text{MeV}$$ Ξ set

$$m_N = 953(29)(19)\ \text{MeV}$$ Ω set

statistical (first error), systematic (second error)

Bottomonium ground state and its mass

Heavy quarkonium experiment 2003-2008

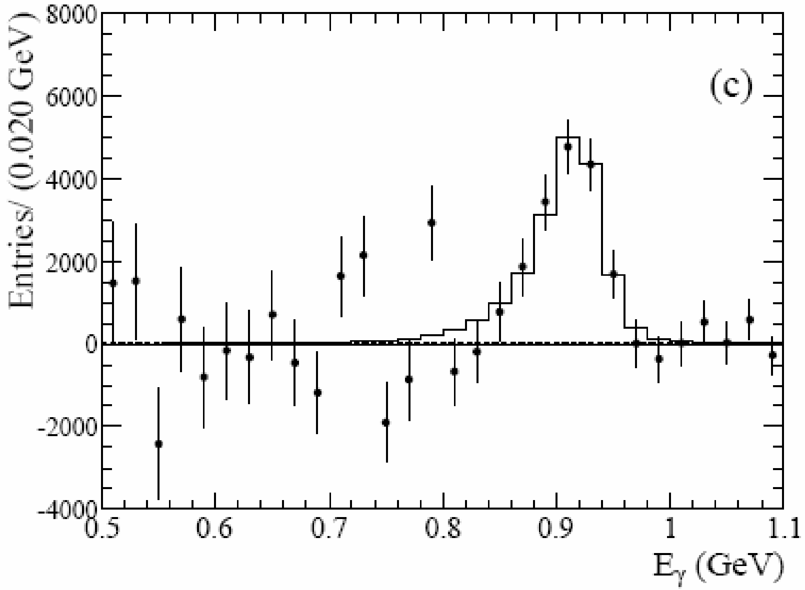
Charmonium	Bottomonium
$X(3872)$, $X(3940)$	
$Y(3940)$, $Y(4260)$	*nothing*
$Z(3930)$	

June 2008: Discovery of η_b

Phys.Rev.Lett. 101, 071801 (2008)

Discovery of η_b by BABAR

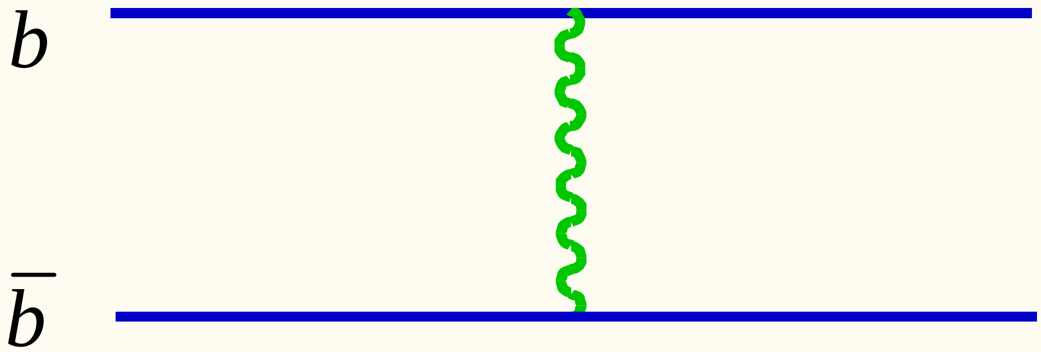
Single photon spectrum at $s = M(\Upsilon(3S))$



Peak at $E_\gamma = 921.2^{+2.1}_{-2.8}\text{stat} \pm 2.4_{\text{syst}}\ MeV$ ⇨ $\Upsilon(3S) \to \gamma\eta_b$

Phys.Rev.Lett. 101, 071801 (2008)

Mass of η_b vs. $\Upsilon(1S)$: Hyperfine splitting



very sensitive to the strong coupling constant, $\sim \alpha_s^4$

Measured:

$$E_{\mathrm{hfs}}^{\mathrm{exp}} = 71.4 \pm 2.7\,(\mathrm{syst})\,^{+2.3}_{-3.1}\,(\mathrm{stat})\ \mathrm{MeV}$$

QCD NLL prediction:

$$E_{\mathrm{hfs}}^{\mathrm{th}} = 39 \pm 11\,(\mathrm{th})\,^{+9}_{-8}\,(\delta\alpha_s)\ \mathrm{MeV}$$

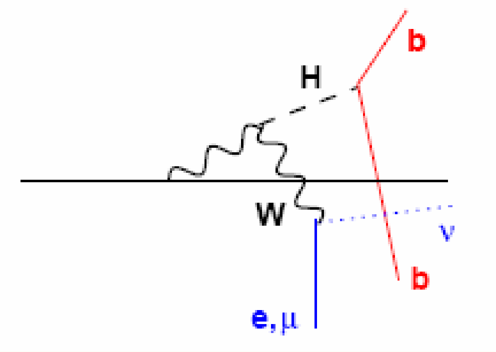
Published lattice prediction much closer to exp. but Penin suggests a missing -20 MeV correction.
Further theoretical cross checks in the works.
Experimental problem?

Renaissance of H→bb

Light Higgs search at LHC: combination of several channels
- gluon fusion → H → $\gamma\gamma$
- gauge boson fusion
- production with top pairs

What about pp → WH, ZH ?

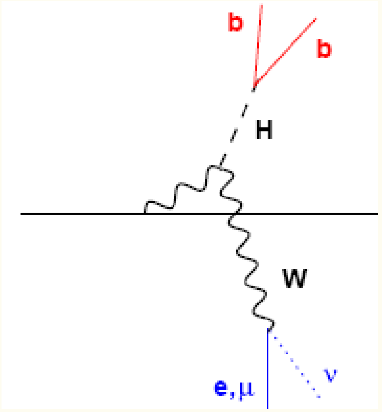
Challenges:
- acceptance limited if too large rapidity
- $H \to b\bar{b}$ – dominant decay channel swamped by QCD bkgd



Renaissance of H→bb

Suggested solution: special high-p_T kinematics

Butterworth, Davison, Rubin, Salam
PRL 100, 242001 (2008)



- larger S/B
- better detector acceptance
- backgrounds lose cut-induced shape
- $Z(\to \nu\bar{\nu})H$ channel more easily visible

Key: special jet-finding algorithm; identify characteristic structure of boosted H → two b jets

NLO QCD calculations with many gluons

Beyond Madgraph, Comphep, ALPGEN:
one-loop corrections; extra gluon emission

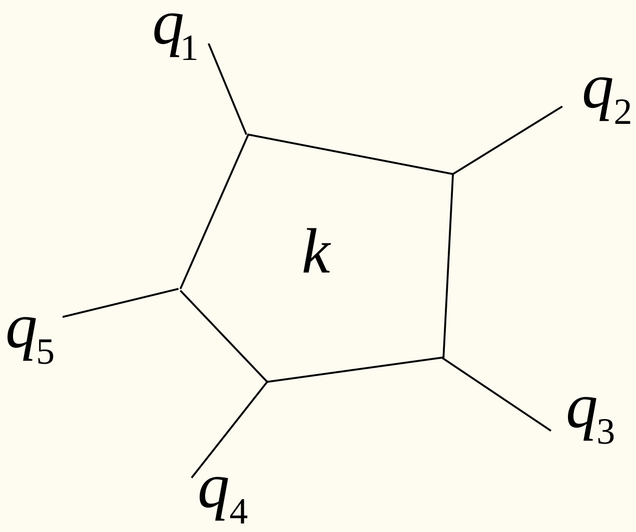
NLO especially important for multi-parton final states
because of scale dependences;
but then particularly difficult

Many theorists have contributed

Recent breakthrough: “D-dimensional unitarity”

NLO QCD: basic idea

One loop results (with any number of legs) have a known basis of "building blocks", up to four legs.



Propagators expressed by

$$k^2, k \cdot q_1, \ldots, k \cdot q_5$$

but $q_5 = a_1 q_1 + \ldots + a_4 q_4$

so only at most four propagators are linearly independent.

Challenge: find coefficients, quickly and accurately
Solution: cut and compute tree-level amplitudes
Recent breakthrough: work in integer D>4 to fix D-dependence

Melnikov et al.

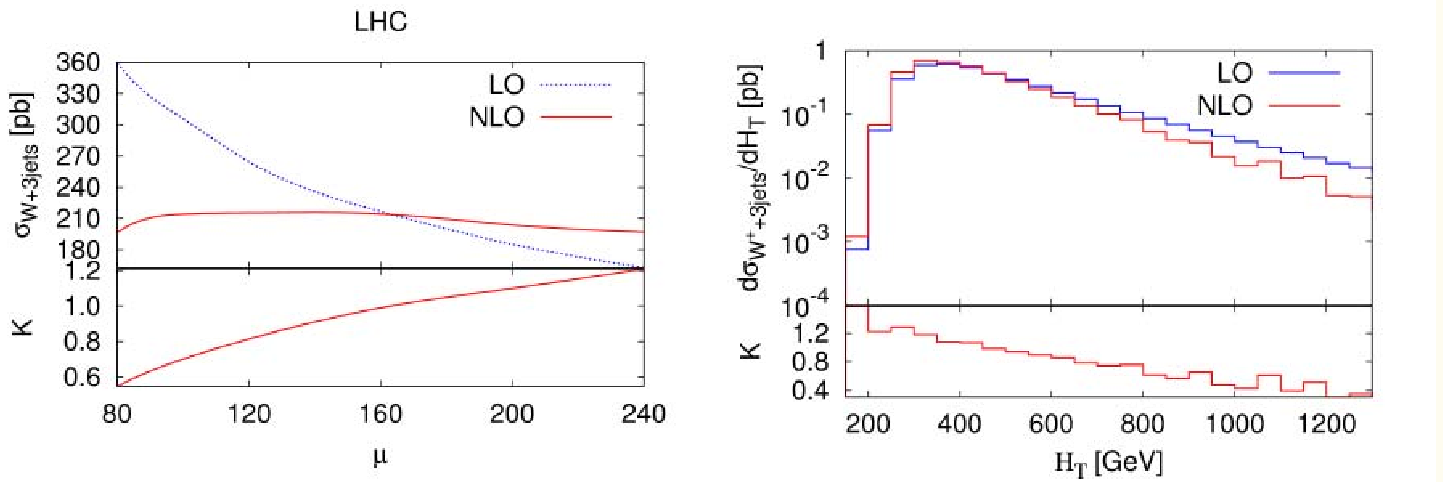
Numerical implementation: ROCKET

Currently, Rocket can compute the following one-loop amplitudes

- N-gluon scattering amplitudes
- two quark (massless and massive)+ N-gluon scattering amplitudes
- W boson + two quarks + N-gluons
- W boson + four quarks + 1 gluon
- tt+Ngluons, ttqq+N gluons (Schulze)

First physics: W+3 jets

- W+ production cross section at the LHC



We simplify the problem by

- working at large Nc
- keeping only two-quark channels (qqW+gluons)

These are 10-30 percent approximations, so phenomenology is rather preliminary

Summary

Important progress on the eve of LHC operations

- Lattice comes to grips with light hadrons
- New tools at NLO – better control of QCD errors
- New perturbative QCD insights into Higgs production
- Interesting disagreement

  QCD NLO/Lattice/Experiment in bottomonium

Many other beautiful results: visit the collection of talks

http://moriond.in2p3.fr/