`Duality'

This item is used very often, when one does not understand what happens. This `duality' talks about how to connect the worlds of quarks & gluons with those with hadrons.

The landscape is `complex'. Can we `paint' that?

`Duality'

This item is used very often, when one does not understand what happens. This `duality' talks about how to connect the worlds of quarks & gluons with those with hadrons.

The landscape is `complex'. Can we `paint' that?

ibi: "duality"

In this case we know a lot about underlying dynamics – we are in the middle.

For good reasons we focus on semi-leptonic decays of beauty mesons & baryons (charm hadrons ??)

-- Misha, Kolya & me agreed there all the time;

-- for non-leptonic ones the situation was less clear

-- the situations are clearer for inclusive vs. exclusive decays

-- V_{xb}: V_{ub} vs. V_{cb} ;

ibi: "duality"

Basics of O(perator)P(roduct)E(xpansion)

$$\Gamma(H_Q \to f) = \Sigma_i\, c_i^{(f)}(KM, M_W, m_Q, \alpha_s, \mu) \langle H_Q \mid O_i \mid H_Q \rangle_{(\mu)}$$

- *short distance* dynamics → coeff. $c_i^{(f)}$
- universal cast of local operators O_i
- $\langle H_Q|O_i|H_Q\rangle$ inferred from other observables or LQCD!
- expansion parameter

$$1/E_{release} \sim \begin{cases} 1/(m_b - m_c) & b \to c \\ 1/m_b & b \to u \end{cases} \quad \text{for}$$

- Wilson(ial) OPE: auxiliary scale μ s.t.

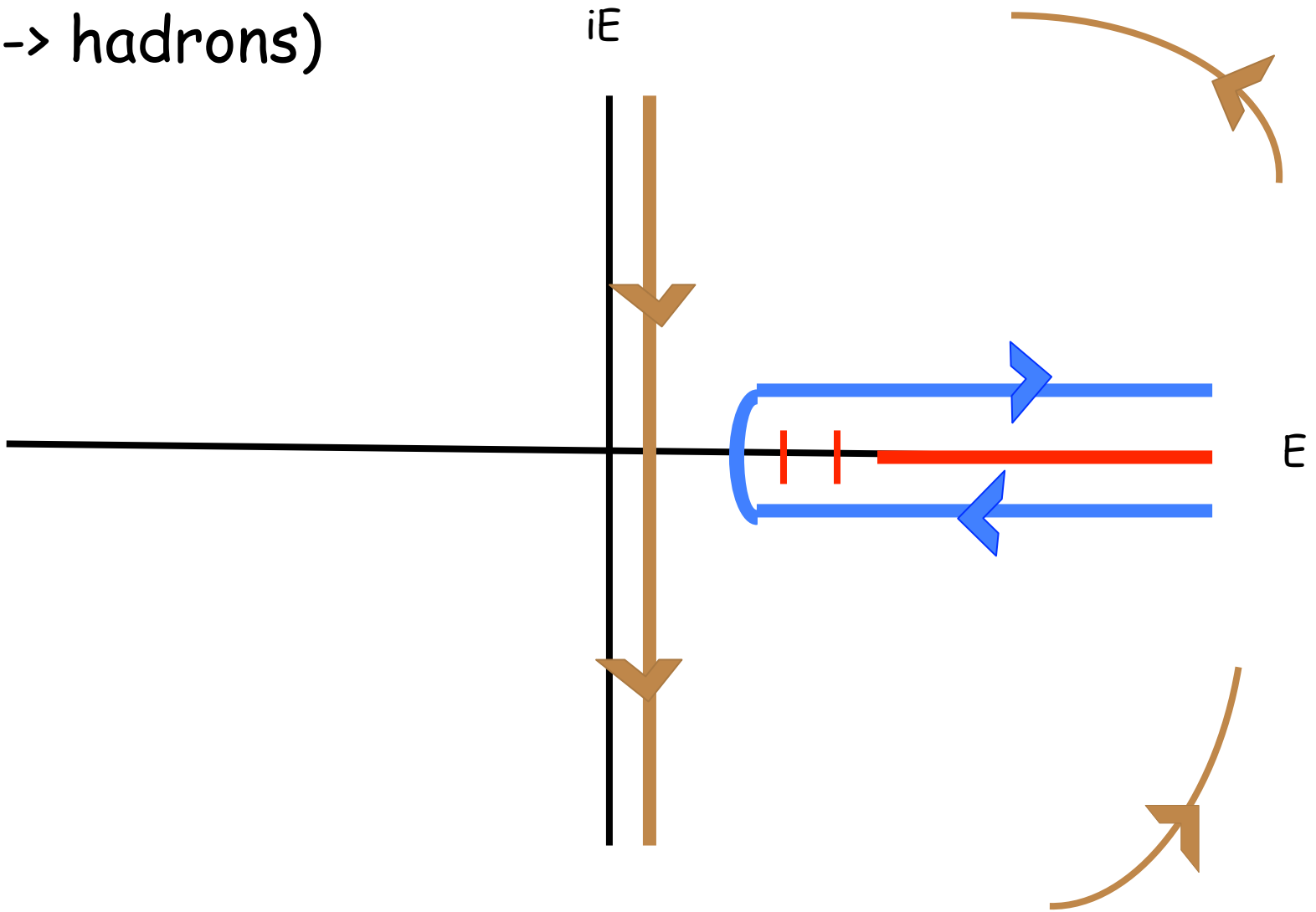
  short distance < μ^{-1} < long distance

  - c_i → short distance dynamics
  - O_i active fields - long distance dynamics

4

ibi: "duality"

R(e+e- -> hadrons)



It needs some *judgment* where to apply
-- somewhat above thresholds etc. etc.

ibi: "duality"

☞ choose judiciously!

Scylla & Charybdis: $\Lambda_{QCD} \ll \mu \ll m_Q$ *

- matrix elements calculable
- $\alpha_s \ll 1$

$\mu \sim 1$ GeV okay for Q = b ! yet: Q = c?

leads to `smart' pert. treatment

☞ treat as physical parameter (s. sum rules)

ibi: "duality"

6

Novel symbiosis between different theoretical technologies for heavy flavour nonperturbative dynamics --
in particular between HQE and LQCD

observables = Σ_i $c_i(CKM, m_Q, \alpha_S)$ $\langle H_Q|O_i|H_Q\rangle$

HQE | HQP | LQCD

- it enhances the power of and confidence in both technologies by
  - increasing the range of applications &
  - providing more benchmarks

- duality ≠ additional ad-hoc assumption
- duality violation in $\Gamma_{SL}(B)$ < 0.5 %!

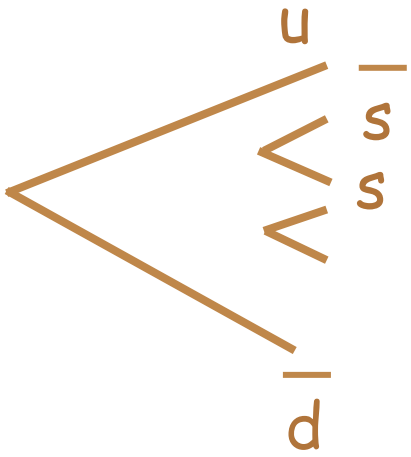
-- IB & N.Uraltsev,Int.J.Mod.Phys.A16(01)5201 (48 p!), arXiv: hep-ph/0106346
-- IB & Th. Mannel: arXiv: hep-ph/0212021v1 (13 p.) [it is easier to read]

ibi: "duality"

-- failure in $|V_{ub}|_{incl.}$ vs. $|V_{ub}|_{excl.}$?

usually probed B -> l ν π's
but *not*
$B^- \to l^- \nu\ K^+K^-$, $l^- \nu\ \overline{K^0K^0}$, $l^- \nu\ \overline{K\,K\,\pi}$
$B^0_d \to l^+ \nu\ K_SK^-$, $l^- \nu\ \overline{K\,K\,\pi}$

Real $|V_{ub}|_{incl.}$ might be smaller than thought before



due re-scattering!

at least novel lessons of non-perturb. QCD

ibi: "duality"