V3.5

"Finding New Dynamics by *Judgments*"

Motto: Impact of Non-perturbative QCD on CP Violation in Many-Body Final States of Flavor Transitions

Ikaros Bigi, Notre Dame du Lac

Victoria, May 2019

`Gods' (= Symmetries) speak in Riddles

Fitting the data vs. *Information* inside the data

1st step: models

2nd step: model-independent analyses – indeed, true progress

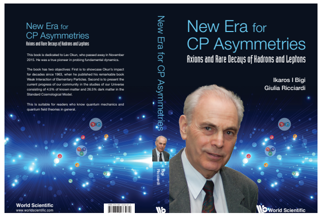
3rd step: best fitted analyses often do *not* give the best information about the dynamics;data are the referees in the end!

crucial: *collaborations* of experimenters & theorists with *correlations* & judgments !

Goal for this century (& this conference): establish the existence of New Dynamics & their features

Tools: -- probe *many-body* non-leptonic FS

-- collaboration of HEP & Hadrodynamics from different `cultures'



My Plan (much less the minutes than the `items'):

(I) Introduct: *Wilsonian* OPE, *broken* U- & V-spin symmetries

(II a) *Quark Masses* in Quantum Field Theories (QFT)
(II b) *Consistent* Parameterization of the CKM Matrix

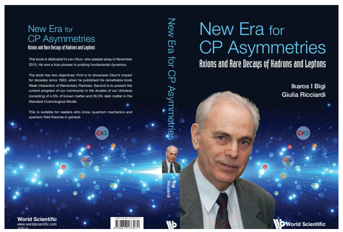
(III) April 2019: *Direct CP asymmetry* in D^0 -> K+K- vs. π+π- !

(IV) *3- & 4-body* Final States in Beauty & Charm Mesons

(V) Challenges for Beauty & Charm & Strange *Baryons*

(VI) Summary:Need *Collaboration* of HEP & MEP/Hadrodynamics

On the slides I think there are important items, see this symbol *



number of * is 19

(I) Introduction: *Wilsonian* OPE, *broken* U- & V-spin symmetries

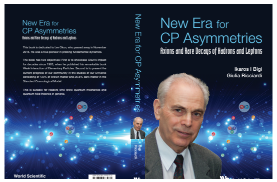
(I.1) *Wilsonian* Operator Product Expansion (OPE)

Almost all invoke OPE -- often *without* using *Wilsonian* prescription!
Shifman & collaborators had emphasized applying OPE is subtle:

> the *Wilsonian* OPE *stops* at ~ 1 GeV, not sizably lower *

arXiv: hep-ph/9703290 (BSU):
effective Lagrangian $T(H \to f) = \cdots \Sigma_i\, c_i(\mu) \langle f|O_i(\mu)|H\rangle$
with "soft" < μ < "hard"; μ demarcation between long- & short-distance forces

-- *broken* $SU(3)_{flavor}$ can be described by 3 SU(2) with I-, U- & V-spin symmetries
-- (u,d) are obviously combined for Iso-spin symmetry
-- broken U-spin symmetry *without* V-spin is okay for *strong spectroscopy*, where (s,d) are combined.



-- *weak* decays?

- $A_{CP}(B^0 \to K^+\pi^-) = -\,0.082 \pm 0.006$

  [$\tau(B^0) = 1.52 \times 10^{-12}$ s, $BR(B^0 \to K^+\pi^-) = (1.96 \pm 0.05) \times 10^{-5}$]

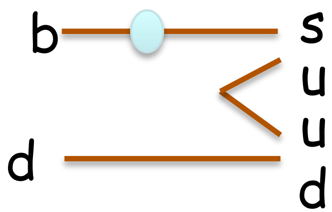
  1987 prediction by Uraltsev, IIB, ...: $A_{CP}(B^0 \to K^+\pi^-) \sim -\,0.1$

  it shows the impact of Penguin diagrams, but semi-quantitatively ??
- $A_{CP}(B_s^0 \to \pi^+K^-) = +\,0.26 \pm 0.04$

  [$\tau(B_s^0) = 1.51 \times 10^{-12}$ s, $BR(B_s^0 \to \pi^+K^-) = (0.56 \pm 0.06) \times 10^{-5}$]
- Can we predict this connection with the 2018 data from run-1?

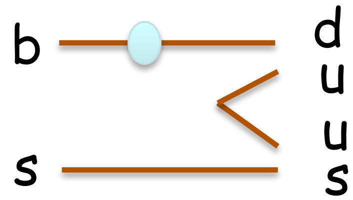
-- it had been suggested by Lipkin in 2005 to use *U-spin symmetry*

$B^0 \to K^+\pi^-$



$B_s^0 \to \pi^+K^-$

d ⟷ s

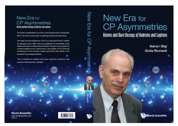


\`Popes' know \`our' world is *not* perfect; in this case of Lipkin:

$\tau(B_d) \approx \tau(B_s)$: $A_{CP}(B_d \to K^+\pi^-)/A_{CP}(B_s \to \pi^+K^-) \neq 1$, $\Gamma(B_s \to \pi^+K^-)/\Gamma(B_d \to K^+\pi^-) \neq 1$

$$\Delta = A_{CP}(B_d \to K^+\pi^-)/A_{CP}(B_s \to \pi^+K^-) + \Gamma(B_s \to \pi^+K^-)/\Gamma(B_d \to K^+\pi^-) = 0$$

- to get the opposite sign in the SM is obvious



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LHCb Collab. PRD 98 (2018) 032004 (all data from the run-1):

$A_{CP}(B_s \to \pi^+K^-) = +\,0.213 \pm 0.015 \pm 0.007$, $A_{CP}(B_d \to K^+\pi^-) = -\,0.084 \pm 0.004 \pm 0.003$

2018: $\Delta_{LHCb} = -\,0.11 \pm 0.04 \pm 0.03$

-- Δ_{LHCb} is still consistent with zero

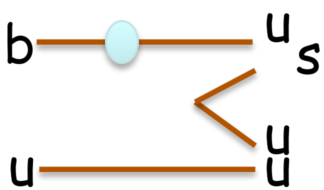
-- Δ_{LHCb} is consistent with ~ 0.1 as expected for direct CPV for *2-body* FS

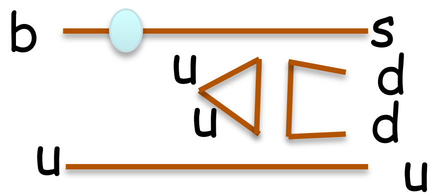
-- *re-scattering* ! d ⟷ s

- U-spin is sizable broken
- correlations of U-spin with V-spin due to *re-scattering*

? u ⟷ s ?

$B^+ \to K\pi / K^+\eta / K^+\eta'$

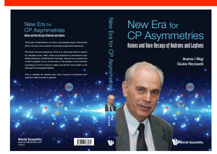




Iso-spin symmetry

$A_{CP}(B^+ \to K_S\pi^+) = -\,0.017 \pm 0.016$, $A_{CP}(B^+ \to K^+\pi^0) = +\,0.037 \pm 0.021$

$A_{CP}(B^+ \to K^+\eta) = -\,0.37 \pm 0.08$, $A_{CP}(B^+ \to K^+\eta') = +\,0.004 \pm 0.011$



1st lesson: difference between U- & V-spin is \`fuzzy'
2nd lesson: we have to go *well beyond 2-body* FS

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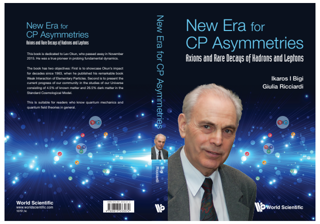
(IIa) Quark Masses in Quantum Field Theories (QFT)

-- Pole mass is gauge independent; furthermore, it is *perturbative* infrared in QCD. However, it is *not* infrared stable *non-perturbatively*.

-- It is easy to apply pole mass in Feynman diagrams.
Yet pole mass depend on long distance dynamics, for what we have little control. One can*not* ignore the impact of IR renormalons;
I just mention that.

For a Reference:
M. Shifman, in "QCD & Heavy Quarks, In Memoriam Nikolai Uraltsev",
World Scientific; arXiv:1310.1966 [hep-th]



(IIa) Quark Masses in Quantum Field Theories (QFT)

(IIa.1) Definitions of Quark Masses:"$\overline{\text{MS}}$","kinetic", "PS"; `1S',`pole mass'

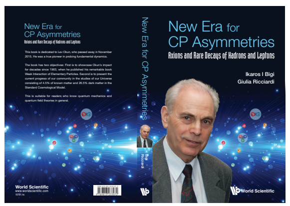
-- "MS" (`modified minimal subtraction scheme'): for $\mu > m_Q$ basically coincides with the running mass to describe their *production*. However, it *diverges logarithmically* for $\mu \to 0$.

The `landscape' is very different from the *weak decays* of H_Q.

-- The "kinetic scheme" regular in the IR region is the best

$$dm^{kin}_Q(\mu)/d\mu = -(16\alpha_S/9\pi) - (4\alpha_S/3\pi)(\mu/m_Q) + \mathcal{O}(\alpha_S^2)$$

-- The "PS (= potential-subtracted) scheme" is different in the conceptual level; [technical problems of "PS" arise at $\mathcal{O}(\alpha_S^4)$;] still "PS" is in the same `division' of fundamental physics.



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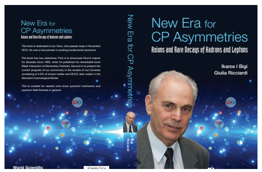
-- 2018 PDG review basically ignores "kinetic" & "PS" schemes, while focus in the `1S scheme' with $m_b^{1S} \approx M_{\Upsilon(1S)}/2$ by

It claims these schemes give us the same information about underlying dynamics -- however, I quite disagree !

Uraltsev pointed out: $m_b^{1S}=m_b^{pole}[1-C_F^2(\alpha_S^2/\pi)+/-\mathcal{O}(\alpha_S^3, \beta_0\alpha_S^3 \log \alpha_S)]$;

$m_b^{1S} \approx M_{\Upsilon(1S)}/2$ is a `easy scheme',



yet it is *not* well-defined at the *non-perturb.* level !

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(IIb) Parameterization of the CKM Matrix

(IIb.1) Wolfenstein's parameterization

Wolfenstein's parameterization was very smart, easily usable, well-known & used all the time. The SM with 3 families of quarks describes the CKM matrix with 4 parameters: λ, A, ρ, η;

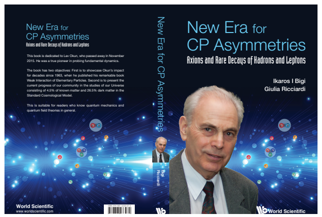
expansion of $\lambda = 0.223$, while A, ρ, η are $\mathcal{O}(1)$.

`Real' world

Measured values:

$A \approx 0.82$; however: $\eta \approx 0.35$, $\rho \approx 0.14$ not close to unity;

-- thus not real control over *systematic* uncertainties.



(IIb.2) *Consistent* parameterization

Need *consistent* parameterization of CKM matrix with more precision [Y.H. Ahn, H-Y. Cheng, S. Oh (2011)] *through* $\mathcal{O}(\lambda^6)$!

$$\begin{pmatrix} 1-\lambda^2/2-\lambda^4/8-\lambda^6/16 & \lambda & h\lambda^4 \exp(-i\delta_{QM}) \\ -\lambda+\lambda^5 f^2/2 & 1-\lambda^2/2-\lambda^4/8(1+4f^2)-fh\lambda^5\exp(-i\delta_{QM})+\dots & f\lambda^2+h\lambda^3\exp(-i\delta_{QM})+\dots \\ f\lambda^3 & -f\lambda^2-h\lambda^3\exp(-i\delta_{QM})+\dots & 1-\lambda^4/2\, f^2 - fh\lambda^5\exp(-i\delta_{QM})+\dots \end{pmatrix}$$

with $f \sim 0.75$, $h \sim 1.35$, $\delta_{QM} \sim 90^o$

Pattern is not so obvious as before: *

correlations between 4 triangles, not focus \`golden one'

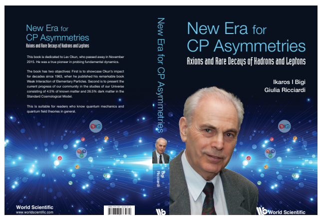
-- maximal SM value for $S(B^0 \to \psi K_S) \sim 0.74$ for indirect CPV

-- SM value $S(B_s^0 \to \psi\phi) \sim 0.03 - 0.05$

-- basically zero CPV for *double Cabibbo suppressed* decays

- *hunting region for ND*!

-- ...



(III) April 2019: *Direct CP asymmetry* in $D^0 \to K^+K^-$ vs. $\pi^+\pi^-$!

Now we are just entering a new era:

for the first time CP violation has been established in $\Delta C \neq 0$!

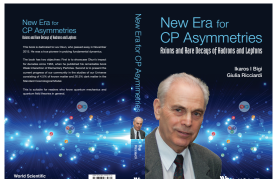
LHCb collaboration has shown its data from the run-1 & run-2:

! $\Delta A_{CP} = A_{CP}(D^0 \to K^+K^-) - A_{CP}(D^0 \to \pi^+\pi^-) = (-15.4 \pm 2.9) \times 10^{-4}$!

indirect CPV was found first in $\Delta S \neq 0 \neq \Delta B$, but not yet for $\Delta C \neq 0$;
SM `paints' the `landscape' for indirect CPV ~ $10^{-4} - 10^{-3}$.
Here I talk about SCS rates [below I will discuss DCS ones]:

-- $BR(D^0 \to K^+K^-) \sim 4 \times 10^{-3}$ vs. $BR(D^0 \to \pi^+\pi^-) \sim 1.4 \times 10^{-3}$;
-- $BR(D^+ \to K^+K_S) \sim 2.8 \times 10^{-3}$;
-- $BR(D_s^+ \to \pi^+K_S) \sim 1.2 \times 10^{-3}$;

three comments:
-- first one probes direct CP asymmetries in 2-body FS;
-- present data show the impact of FSI ?
-- it is crucial to probe 3- & 4-body FS; I will come back below. *



(IV) 3- & 4-body Final States in Beauty & Charm Mesons

(1) For experimenters it is easier to measure 2-body FS
(& narrow resonances), for suppressed transitions;
for theorists to predict those & to analyze the data.

(2) However, the goal is to probe CPV: it gives only numbers.

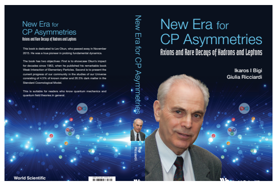
(3) 2-body FS of suppressed non-leptonic weak decays are a small part of charm mesons & tiny ones for beauty mesons;
- data show that;
- it is not surprising.

(4) 3- & 4-body FS are described by two-& more *dimensional* plots.

☹ Price: lots of data & work both for experimenters & theorists

☺ Prize: find existence & *features* of New Dynamics (ND)!

-- the situations are very different for $\Delta S = 1$ & 2
- local operators
- FS with only one & two pions



$$T(P \to a) = \exp(i\delta_a)\,[T_a + \sum_{aj \neq a} T_{aj}\; i\; \boxed{T_{aj,a}^{resc}}\,]$$

$$T(\bar{P} \to \bar{a}) = \exp(i\delta_a)\,[T^*_a + \sum_{aj \neq a} T^*_{aj}\; i\; \boxed{T_{aj,a}^{resc}}\,]$$

$$\Delta\gamma(a) = |T(\bar{P} \to \bar{a})|^2 - |T(P \to a)|^2 = 4\sum_{aj \neq a} \boxed{T_{aj,a}^{resc}}\; \boxed{\mathrm{Im}\, T^*_a T_{aj}} \qquad *$$

With*out* strong re-scattering *direct* CP asymmetries can*not* happen, *even if there are weak phases*.

Misha & Misha & collab.; Wolfenstein

The goal: measuring CP asymmetries probes *existence* & even *features* of New Dynamics (ND):

they can depend only an amplitude.

$$\Delta\gamma(a) = |T(\bar{P} \to \bar{a})|^2 - |T(P \to a)|^2 = 4\sum_{aj \neq a} \boxed{T_{aj,a}^{resc}}\; \boxed{\mathrm{Im}\, T^*_a\, T_{aj}} \qquad *$$

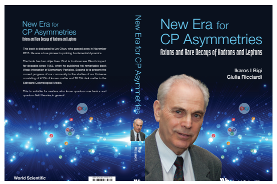
There are tools to deal with much more & `complex' data:

-- fitting the data is the 2nd step, but not the final one!

-- unitary

-- dispersion relations …

-- chiral symmetry: pions [+++], kaons [++/+] ?



(IV.1) 3-body Final States in general

Dalitz plots (with pions, kaons, η & η′) probe the underlying dynamics with two observables: with*out* angular correlations a plot is flat, while resonances & thresholds show their impact from their deviations; excellent record both about strong forces & weak ones.

Four main statements:

(a) The FS are *not* described only by a sum of (semi-)2-body FS & their interferences; true 3-body FS happen in the weak decays of charm & beauty mesons.

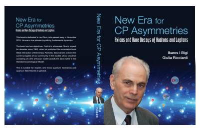
(b) Best fitted analyses often do *not* give us the best information about the underlying dynamics.

(c) We have *broad* resonances in the region of ~ 1 – 3 GeV; scalar ones like *f_0(500)/ sigma, K^*_0(700)/kappa* etc. can*not* been described with Breit-Wigner parameterization.

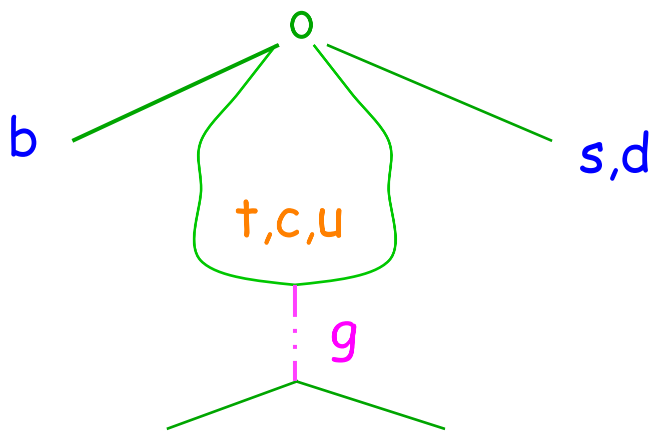
(d) Maybe the centers of the Dalitz plots are somewhat empty?

correlations & judgments !

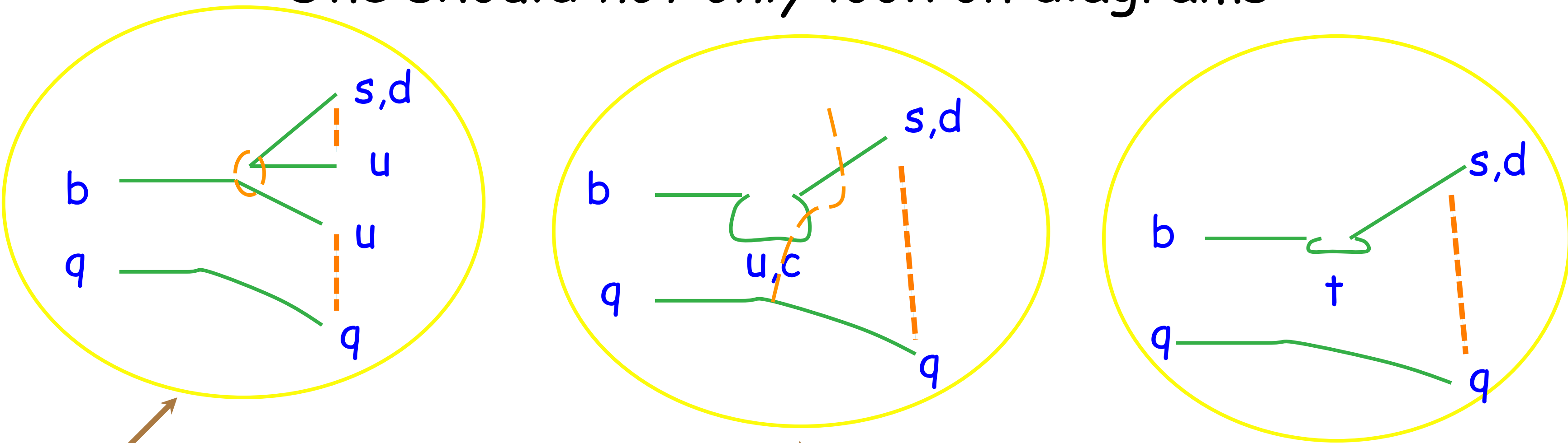
Not trivial to connect the world of hadrons with the diagrams of quarks & gluons. Re-scattering / non-perturbative forces !



`penguin' diagrams:
well-known for
inclusive one --



One should *not only* look on diagrams



local operator
with weak phase

nonlocal operator
with strong phase

local operator not
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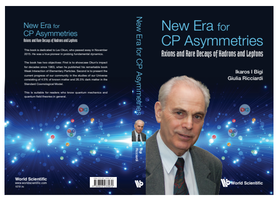

b -> s $\bar{c}$ c & s $\bar{u}$ u `paint' re-scattering

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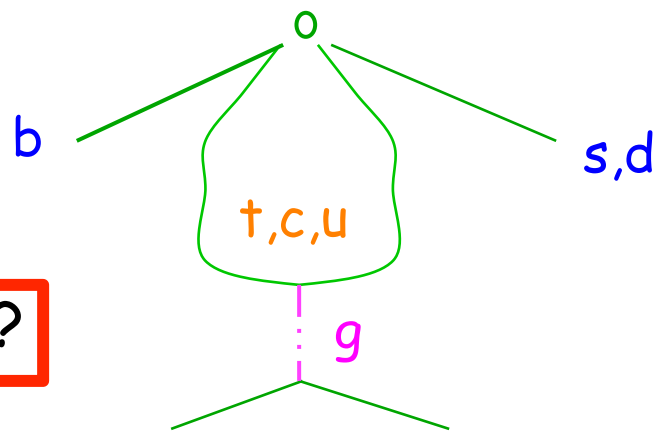

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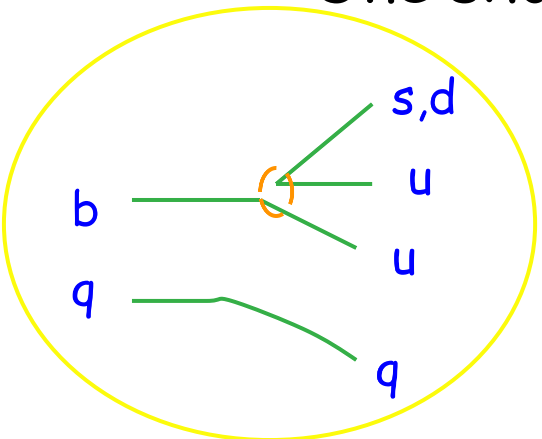

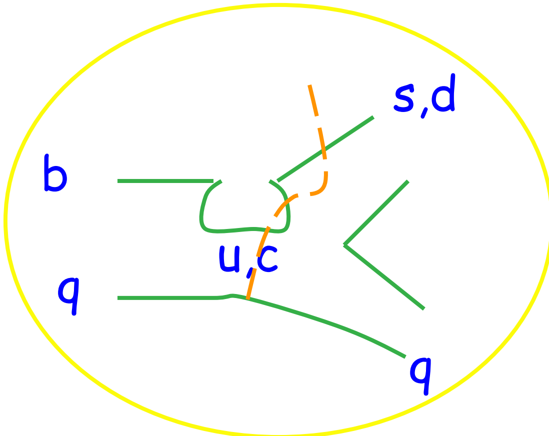

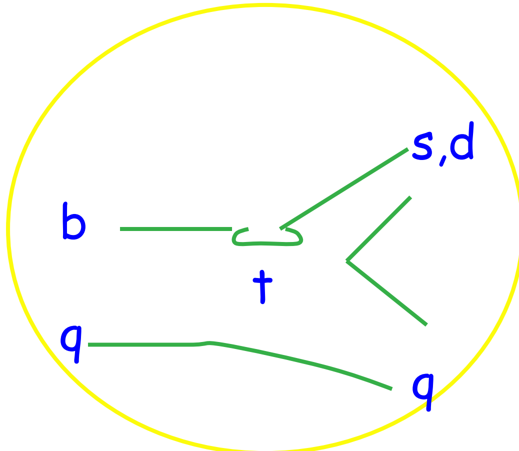

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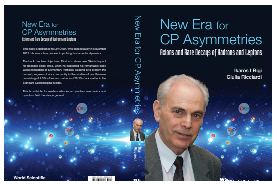

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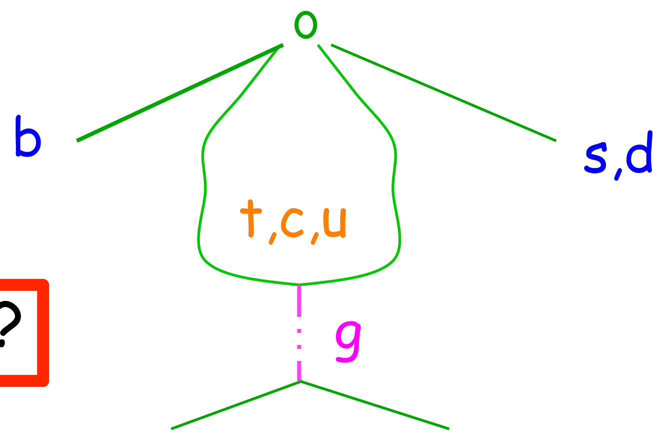

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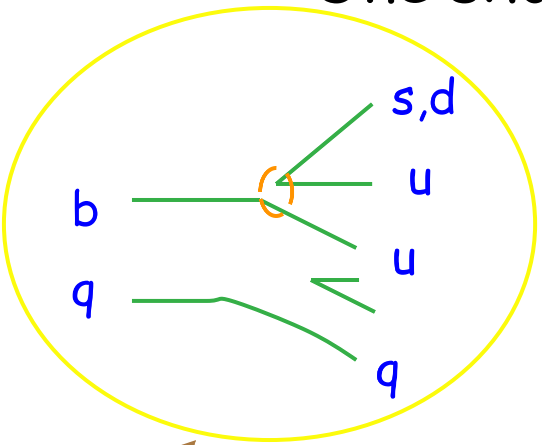

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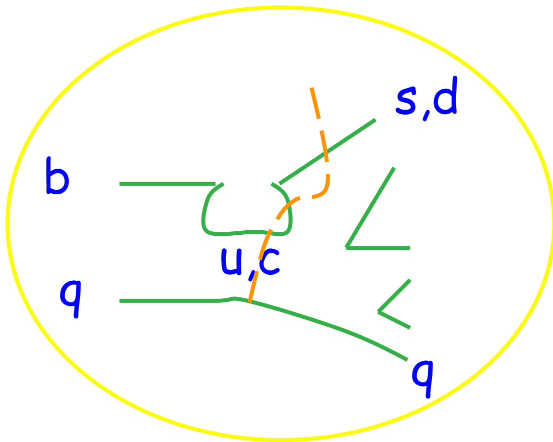

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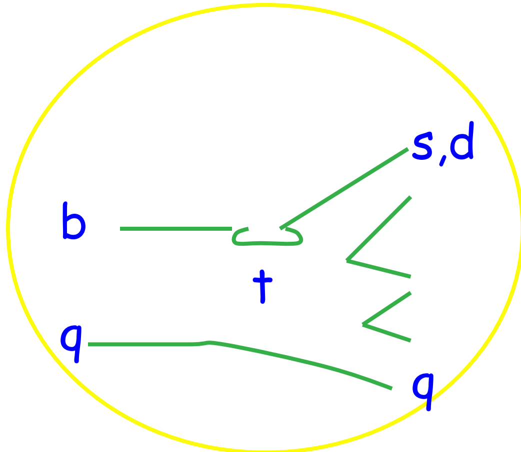

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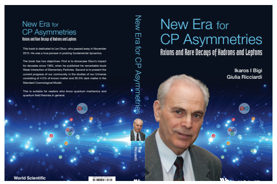

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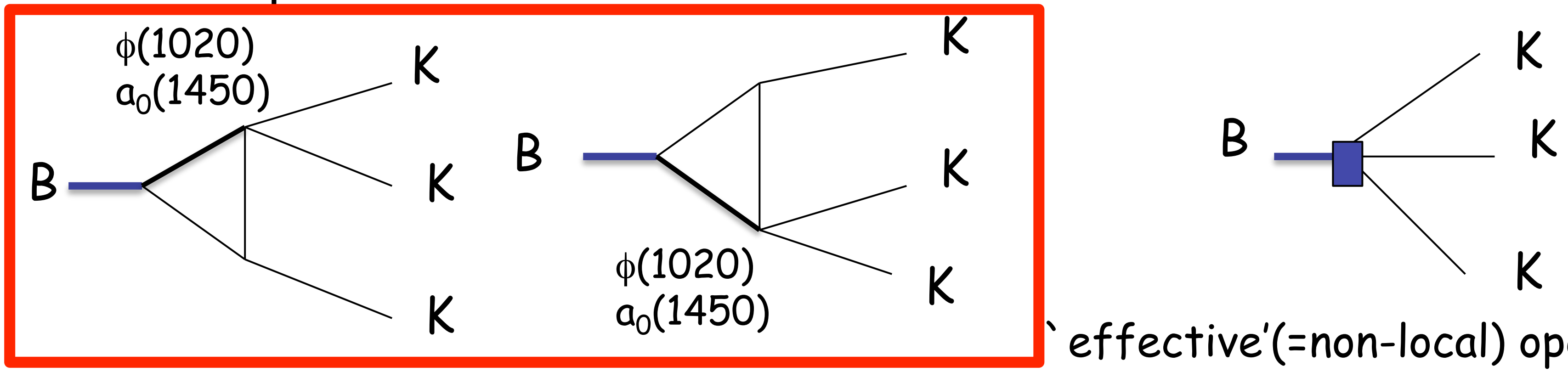
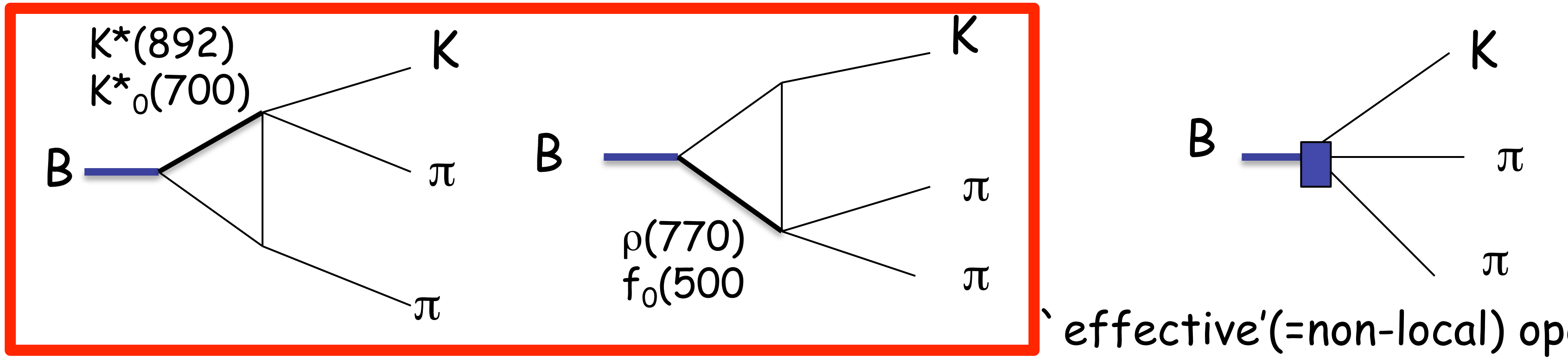
The landscapes of hadrons



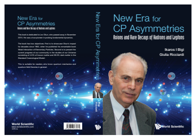
`effective'(=non-local) operators

Re-scattering is crucial to understand the underlying dynamics !



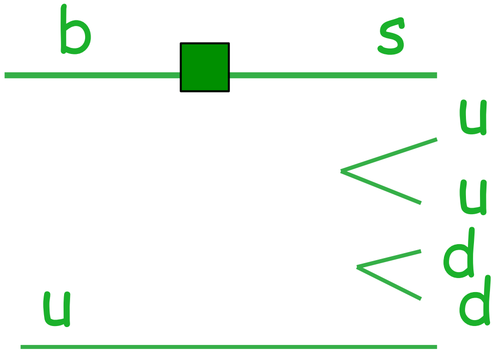
`effective'(=non-local) operators

One needs `judgment' about applying *resonances*, *threshold enhancements* etc. with tools like *dispersion relations*
[LHCb for *DCS* decays,arXiv:1902.05884v3[hep-ex] about 8 TeV
`Dalitz plot analysis of the D+ -> K-K+K+ decay' with the Figure 9(a) on p. 12 only the top diagram, but *not* the bottom one; I disagree which I will explain below.]

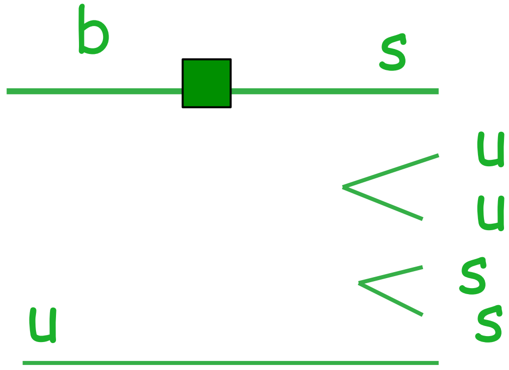


Look at quark diagrams:

b -> s -- impact of Penguin diagrams in the SM

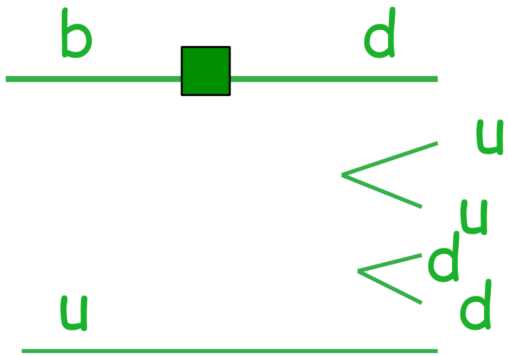


$B+ \to K^+\pi^+\pi^-$

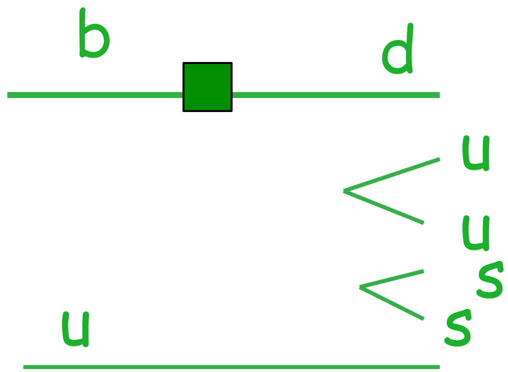


$B+ \to K^+K^+K^-$

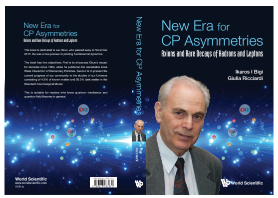
b -> d -- less impact of Penguin diagrams in the SM



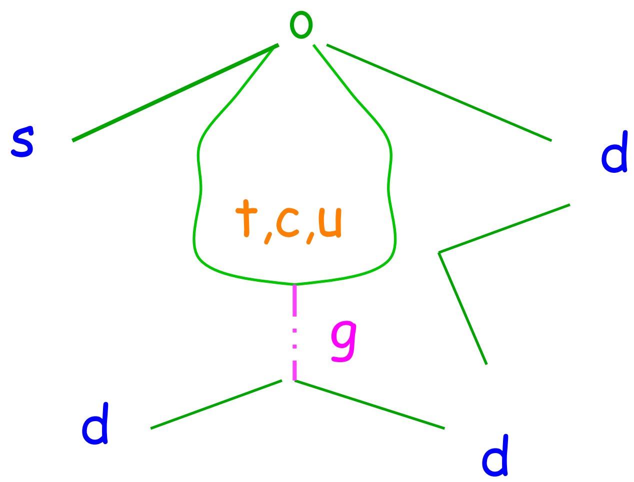
$B+ \to \pi^+\pi^+\pi^-$



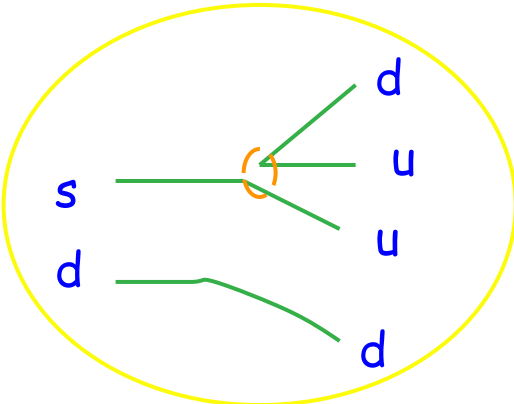
$B+ \to \pi^+K^+K^-$

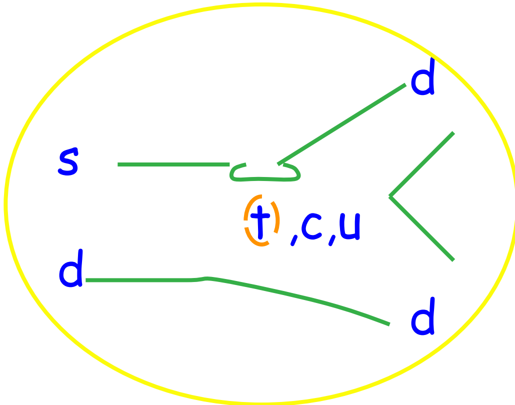


History:
`penguin' diagrams



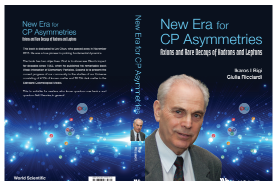
One should *not only* look on diagrams





local operator

local penguin *operator* for $K^0 \to 2\pi$
-- with weak phase



(IV.2) $B^{+/-} \to K^{+/-}\pi^+\pi^-$ vs. $B^{+/-} \to K^{+/-}K^+K^-$

LHCb data *run-1* about rates:

$BR(B^+ \to K^+\pi^+\pi^-) = (5.10 \pm 0.29) \times 10^{-5}$;

$BR(B^+ \to K^+K^+K^-) = (3.37 \pm 0.22) \times 10^{-5}$;

not surprising at all

averaged CP asymmetries

$\Delta A_{CP}(B^+ \to K^+\pi^+\pi^-) = +\, 0.032 \pm 0.008 \pm 0.004 \pm 0.007$;

$\Delta A_{CP}(B^+ \to K^+K^+K^-) = -\, 0.043 \pm 0.009 \pm 0.003 \pm 0.007$;

it is okay

\`regional' CP asymmetries

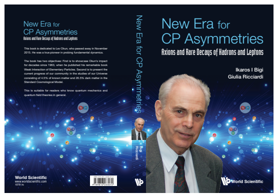
$\Delta A_{CP}(B^+ \to K^+\pi^+\pi^-)|_{\text{`regional'}} = +\, 0.678 \pm 0.078 \pm 0.032 \pm 0.007$; *

$\Delta A_{CP}(B^+ \to K^+K^+K^-)|_{\text{`regional'}} = -\, 0.226 \pm 0.020 \pm 0.004 \pm 0.007$;

Very surprising due to two connected points:

-- the centers of the Dalitz plots are somewhat empty

-- the differences are so huge!



(IV.3) $B^{+/-} \to \pi^{+/-}\pi^+\pi^-$ vs. $B^{+/-} \to \pi^{+/-}K^+K^-$

LHCb data *run-1* about rates:

BR($B^+ \to \pi^+\pi^+\pi^-$) = $(1.52 \pm 0.14) \times 10^{-5}$;

BR($B^+ \to \pi^+K^+K^-$) = $(0.50 \pm 0.07) \times 10^{-5}$;

not surprising

averaged CP asymmetries

$\Delta A_{CP}(B^+ \to \pi^+\pi^+\pi^-) = +0.117 \pm 0.021 \pm 0.009 \pm 0.007$;

$\Delta A_{CP}(B^+ \to \pi^+K^+K^-) = -0.141 \pm 0.040 \pm 0.018 \pm 0.007$;

maybe surprising

`regional' CP asymmetries

$\Delta A_{CP}(B^+ \to \pi^+\pi^+\pi^-)|_{\text{`regional'}} = +0.584 \pm 0.082 \pm 0.027 \pm 0.007$; *

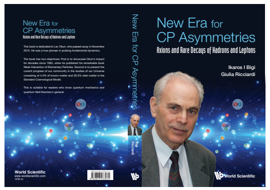
$\Delta A_{CP}(B^+ \to \pi^+K^+K^-)|_{\text{`regional'}} = -0.648 \pm 0.070 \pm 0.013 \pm 0.007$;

Very surprising due to two connected points:

-- the centers of the Dalitz plots are somewhat empty

-- the differences are so huge!

underlying dynamics are not obvious



(IV.4) CP asymmetries with $\Delta C \neq 0$

April 2019: LHCb Collaboration has established *direct* CP asymmetry

Next steps:

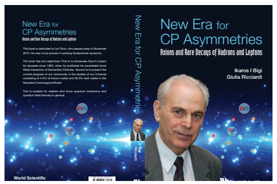
-- Indirect CP violation

-- *SCS* decays: $D^0 \to 2\pi^+2\pi^-/K^+K^-\pi^+\pi^-$:

- Averaged CPV:
  SM ~ 0.001
- Regional CPV:
  large impact of re-scattering like ~ 0.01 or more

-- *DCS* decays: : $D^0 \to K^+\pi^-\pi^+\pi^-/2K^+K^-\pi^-$:

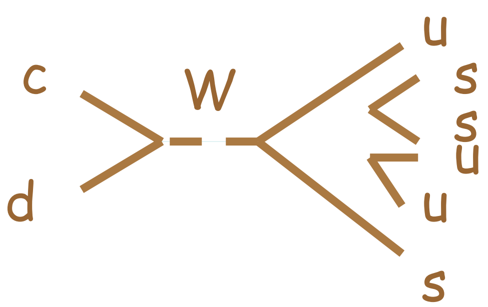
- Averaged CPV:
  basically zero for the SM
- Regional CPV:
  hunting region for ND with no SM background if one has large data;
  at least novel lessons about non-perturbative QCD



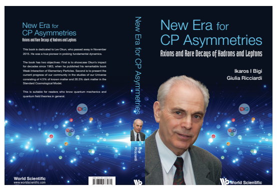
(IV.5) $\Delta C \neq 0$ with 3-body FS

LHCb for *DCS* decays, arXiv:1810.03138 [hep-ex] about 8 TeV (not run-2)
(1a) BR(D+ -> K+K+K-) = (0.587 +/- 0.002 +/- 0.004 +/- 0.018) x 10^{-4}
(1b) BR(D+ -> K+π+π-) = (4.70 +/- 0.01 +/- 0.02 +/- 0.15) x 10^{-4}
(1c) BR(D_s^+ -> K+π-K+) = (1.293 +/- 0.013 +/- 0.014 +/- 0.040) x 10^{-4}
Look at Feynman diagrams in Figs. 1(a), 1(b) & 1(c) on page 1 of this article:
-- Figs. 1(b) & 1(c) are okay, but incomplete.
-- however, my main problem comes from Fig. 1(a) [to put it politely].

LHCb for *DCS* decays, arXiv:1902.05884v3[hep-ex] about 8 TeV (not run-2)
published in JHEP 04 (2019) 063
\`Dalitz plot analysis of the D+ -> K-K+K+ decay'
p. 12, \`Figure 9 (a) is assumed to be the dominant mechanism …'



-- \`WA' no chance to be the leading source !
-- \`WA' <-> re-scattering (FSI) is *misleading* !



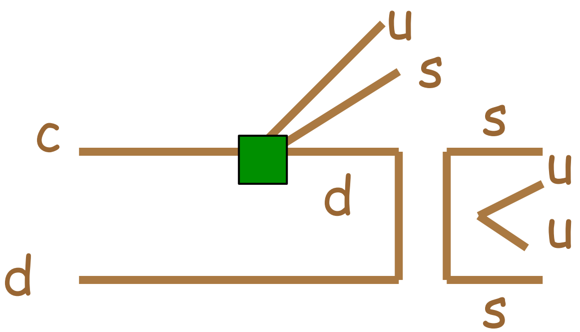
(IV.5) $\Delta C \neq 0$ with 3-body FS

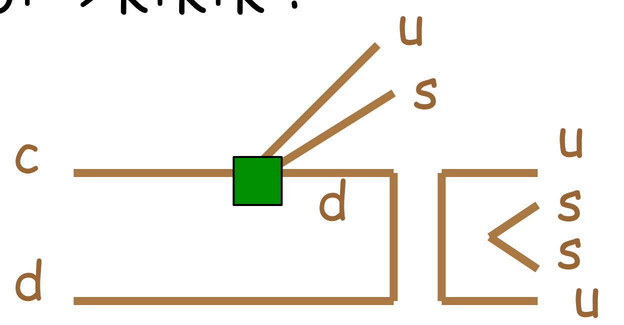
LHCb for *DCS* decays, arXiv:1810.03138 [hep-ex] from 8 TeV;
arXiv:1902.05884v3 [hep-ex] from 8 TeV:

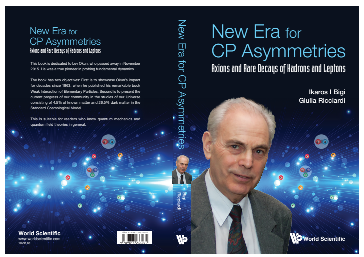
BR(D+ -> K+K+K-) = (0.587 +/- 0.002 +/- 0.004 +/- 0.018) x 10^{-4}

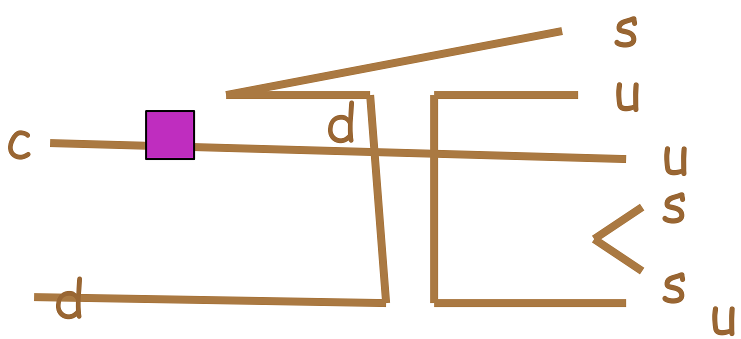
[BR(D+ -> K+π+π-) = (4.70+/-0.01+/-0.02+/-0.15) x 10^{-4}
[BR(D_s^+ -> K+π-K+) = (1.293+/-0.013+/-0.014+/-0.040) x 10^{-4}]

My `painting' of the amplitudes for D+ -> K+K+K-:









--`WA' <-> re-scattering (FSI)
is *misleading* !
-- effective chiral Lagrangian ?

(V) Challenges for Beauty & Charm & Strange *Baryons*

(V.1) CP asymmetries in the decays of Λ_b^0

-- First step: probe Λ_b^0 -> p π-/p K- ;
no sign, but it is beyond realistic scale

-- I had suggested before to probe Dalitz plots
Λ_b^0 -> $\Lambda\pi$+π-/ΛK+K-

-- LHCb came by with a novel idea: probe Λ_b^0 -> p π-π+π-
between two planes

- Its result: CPV with 3.3 σ uncertainties with
- *regional* asymmetries ~ 20 % due to [p π^-_{fast}][$\pi^+\pi^-_{slow}$] !
- *Present* data & analyses about [p π^-_{slow}][$\pi^+\pi^-_{fast}$] ?
  No predictions – we have to learn from the (re-fined) data !

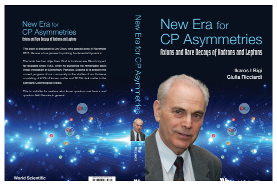
-- probe Λ_b^0 -> p π-K+K- where 3 mesons are different

-- likewise Λ_b^0 -> p K-π+π-[different]/pK-K+K- [complex]

-- application of QFT are subtle due to non-local interferences

-- thus decays of Λ_b^0 are excellent cases of underlying dynamics

-- *no* information from *run-2* yet.



(V.2) Present and future lessons $\Delta C \neq 0$

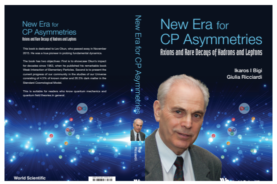
-- When one goes for CPV, one can*not* stop at 2-body FS: crucial to probe 3- & 4-body FS including regional CPV.

-- On first & second steps one goes after SCS ones where the SM predicts small CPV on the order of $\mathcal{O}(10^{-3})$.

-- For DCS decays the SM predicts basically zero; hunting regions for ND.

-- One has to probe CPV in charm baryons with Dalitz plots

- SCS: Λ^+_c -> p π+π- / p K+K-
- DCS: Λ^+_c -> p K+π-



(V.3) Present and future lessons $\Delta S \neq 0$

-- We know that CP asymmetries has been found & established in the transitions of neutral strange mesons:

- *indirect* CPV in $K^0 \to 2\pi$ with the scale ~ 2.23 x 10^{-3} data
- *direct* CPV in $K^0 \to 2\pi$ with
  - ~ 3.6 x 10^{-6} data
  - < 2.2 x 10^{-6} SM ?!?
  - ~ 1.1 x 10^{-6} "Buras team[LQCD]"

*

- amazing established of data & analyses
- it *might be beyond* the SM: "Buras team" ["LQCD"].

-- Next step for direct CP asymmetry in strange *baryons*

$e^+e^- \to J/\psi \to \Lambda\,\Lambda \to [p\,\pi^+][p\,\pi^-]$

- BESIII will probe CPV by 2018/19 with below 10^{-3}

-- duality violation enhanced close to thresholds ?

-- A novel `*road*'

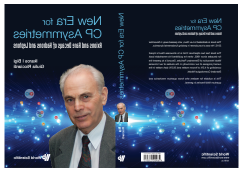
Giovanni Punzi:

LHCb could do much better with *run-3/4 below* 10^{-4} !

$J/\psi \to \Lambda\,\Lambda \to [p\,\pi^+][p\,\pi^-]$

*

- Some details: $J/\psi \to Y\,Y \to [X\,\pi]\,[X\,\pi]$ with a dedicated trigger



"Imagination created reality" – Richard Wagner

or: "dedicated trigger"

(VI) Summary: need Collaboration of HEP & MEP/Hadrodynamics

about fundamental dynamics:

(a) Two-body final states do not *give* `royal insights' in *general*;

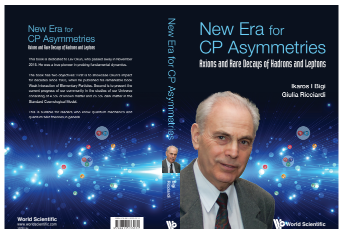
(b) diagrams *give* no `royal ones';

(c) Wolfenstein's parameterization of the CKM matrix is well-known & used all the time, but it is *not* `royal ones' for *this* century;

(d) pole mass *gives* no `royal insights' !

"Goals for *flavor dynamics* of quarks":

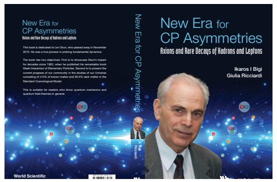
- ☞ Probing CP asymmetries in 3- & 4-body FS of charm & beauty hadrons is crucial to find both existence & features of ND.
  [At least it shows the impact of non-perturbative QCD.]
- ☞ theorists do not like waiting: *results from run-2* !
- ☞ waiting for run-3 & run-4: that is life.



When Gods(Symmetries) speak in Riddles

? Tragic Oracles & Tragic Mis-understanding ?

LHCb & Belle II both as a pioneer about non-pert. QCD & weak dynamics –
as a team of experimenters and HEP (& MEP) theorists
[as before BaBar & Belle]



When Gods(Symmetries) speak in Riddles

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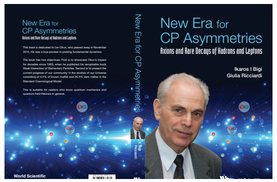
LHCb & Belle II both as a pioneer about non-pert. QCD & weak dynamics – as a team of experimenters and HEP (& MEP) theorists [as before BaBar & Belle]

experimenters

theorists

"On seeing the missile shot by a catapult which had been brought then for the first time from Sicily", the king from Sparta in the fourth century B.C. cried out:
` By Heracles, this is the end of man's valor.' "



Analogy with computers?

Very short summary:

-- `We' need more data, but that is not enough –
thinking & judgments about the impact of *long distance* QCD!

[-- HQET [with μ = 0] ≠ HQE [μ ~ 1 GeV > 0]

HQET: `observables'= perturb. forces + non-perturb. Forces

HQE: "observables" = "long-distance" forces +"short-distance "ones]

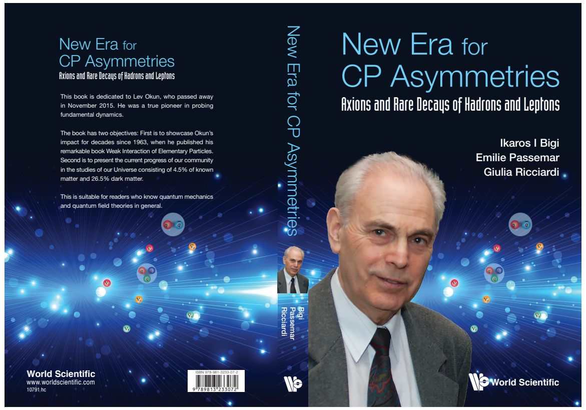
-- best fitted analyses do *not* give the best information about the underlying dynamics

-- CP asymmetries in 3- & 4-FS is crucial to make progress about ND

$$\Delta\gamma(a)=|T(P \to a)|^2-|T(P \to a)|^2=4\sum_{aj\neq a} \boxed{T_{aj,a}^{resc}} \; \boxed{\mathrm{Im}\, T^*_a \, T_{aj}}$$

-- `Challenges between Cultures' of HEP vs. Hadrodynamics
like "current quarks" vs. `pole masses of hadrons'

-- My new book will be published in the Summer/Fall 2019:
dedicated to L. Okun



Back-up slides

Final steps need `judgment' about applying resonances, threshold enhancements etc. with dispersion relations

-- 1st step: models;

-- 2nd step: model-independent

-- 3rd step: best fitted analyses often do *not* give us the best information about the underlying dynamics –

correlations & judgments

Future lessons for LHCb/Belle II

Yes, the data are the referees, but in the end -

theorists should not be the slaves of the data !

One example:

IIB & collab.:

$\tau(\Lambda_b)/\tau(B_d) > 0.9$ 1993; ~ 0.94 & > 0.88 1996

Data: $\tau(\Lambda_b)/\tau(B_d) = 0.77 +/- 0.05$ 1996; 0.81+/-0.05 2004; 0.94+/-0.09 2005

"Imagination created reality" – Richard Wagner

or:

"dedicated trigger"

-- history

→ NP → HEP

flavor dynamics

-- now

→ NP → MEP/Hadrodynamics → HEP

decays of strange/
beauty/charm mesons & baryons
Dalitz plots
dispersion relations
accuracy/precision

jets,
Higgs, top quarks
direct SUSY

different `landscapes' & "cultures": it is not easy, but important

- pions, kaons, ..., N, ... vs. quarks & gluons
  - 3- & 4-body FS and regional CP asymmetries

\`thinking is better than power'

\`dreaming in more dimensions'

Kolya Uraltsev & I had looked at this painting *in person* & realized that it is symbol of collaboration.