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Probing 3-Body Final States in B, D & τ Decays about Existence & Features of New Dynamics with Precision including CPT Invariance

Ikaros Bigi (Notre Dame du Lac & CBPF)

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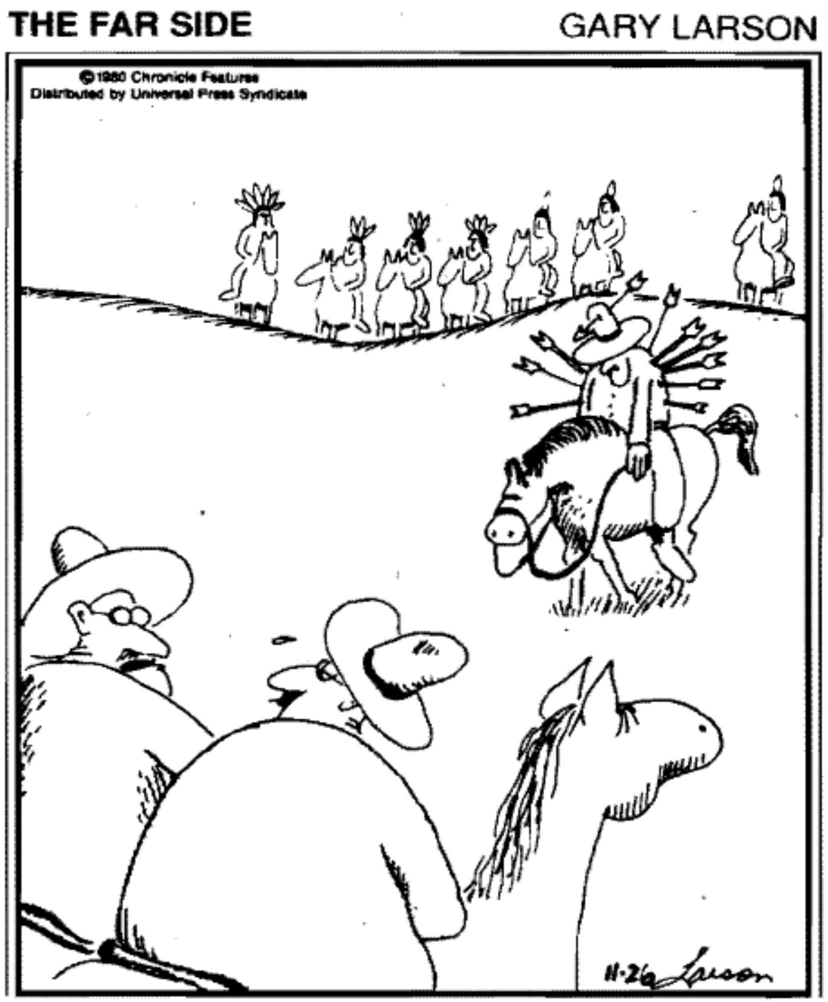
or

"The Achaeans outside Troy"



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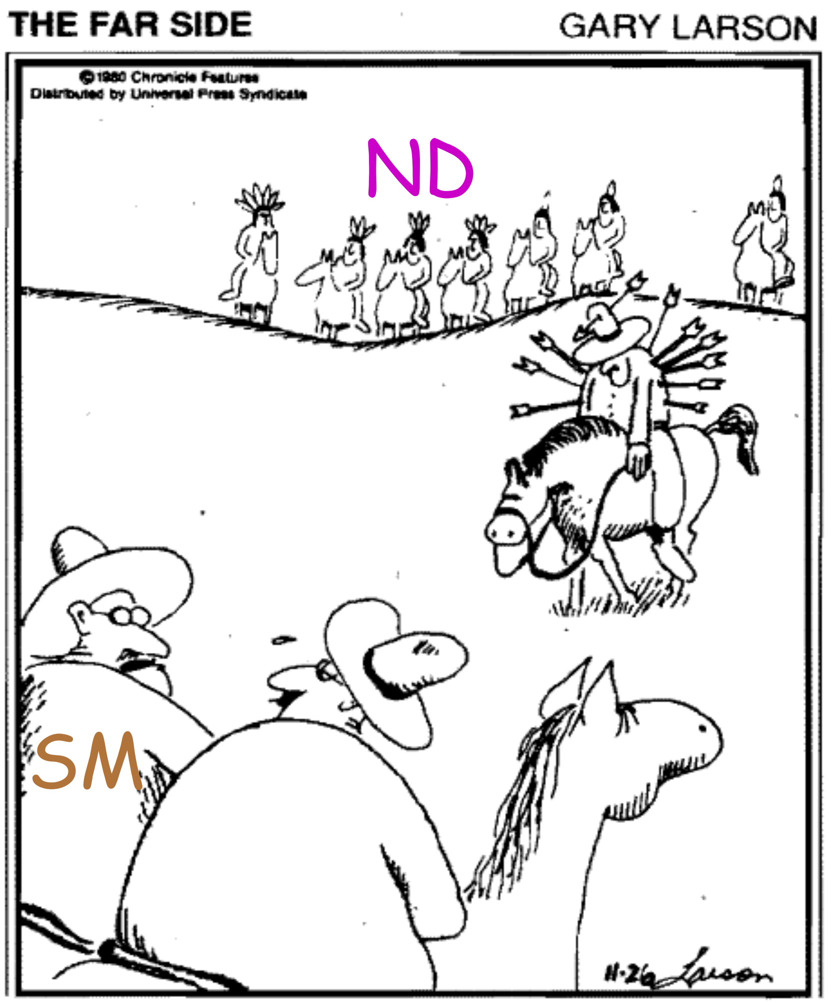

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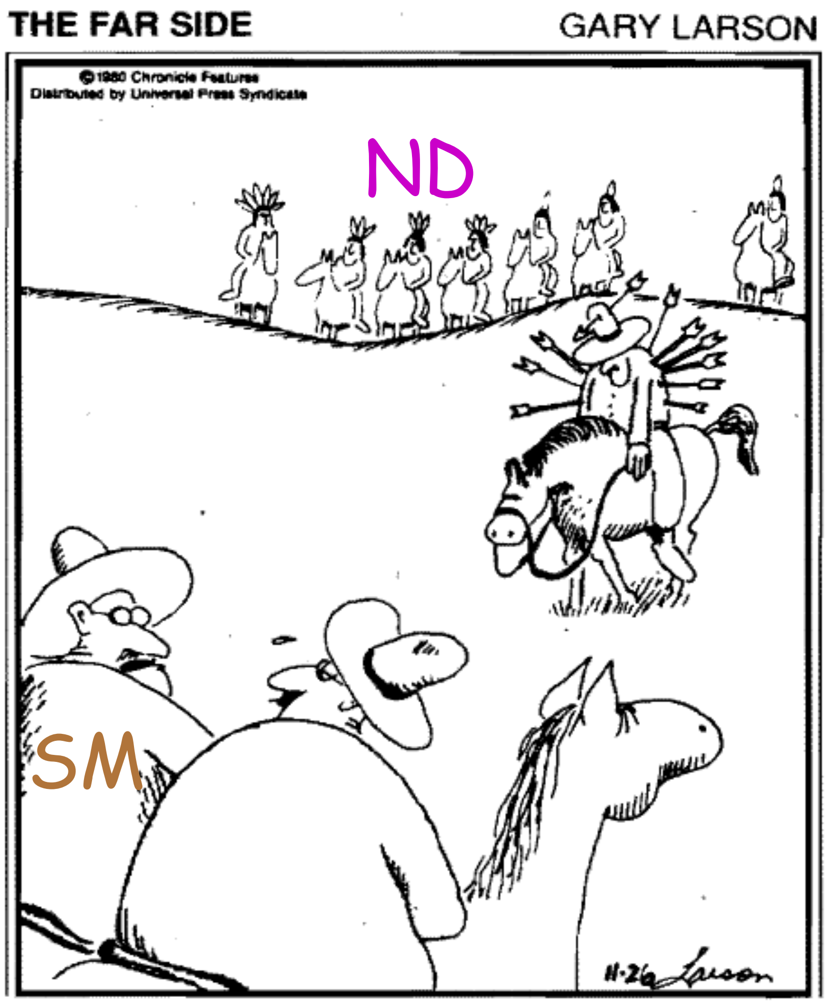

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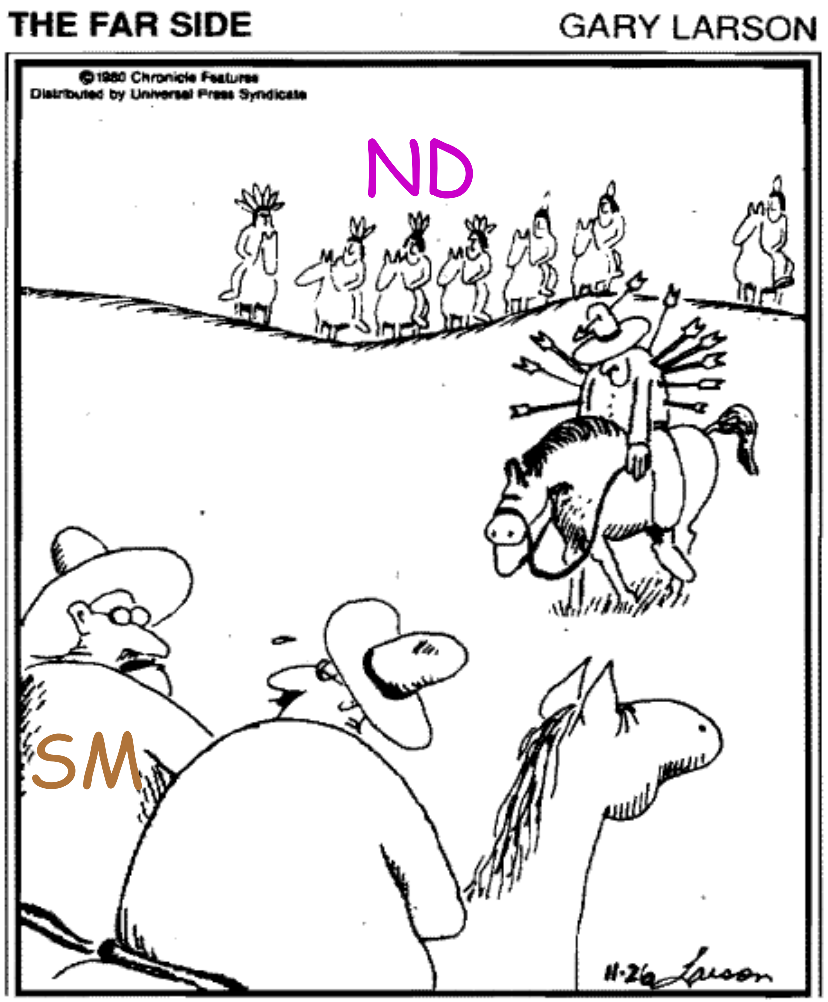

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-- neutrino oscillations
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Come back to `known' matter
-- CP asymmetries
-- correlations of quarks & leptons
-- probe 3- & 4-body final states
-- need more accuracies

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-- at least leading source of *measured* ~~CP~~ in B decays

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New era:

\`Accuracy' → \`Precision'

also about CPT invariance
whether it can be really used
or
gives us at least directions

Outline/Plans

I: 3-& 4-Body FS of CP Asymmetries in B,D & τ

II: Impact of CPT Invariance

III: Parameterization of CKM Matrix through $\mathcal{O}(\lambda^6)$

IV: Theoretical Tools for Treating Final States Interactions – `Nabis Project'

V: Summary of Indirect Searching for New Dynamics (ND) in 3- & 4-Body Final States

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😐 need more data with *more accuracy*

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-- Collaboration of Hadronic Dynamics/MEP & HEP!

-- direct ~~CP~~ in leptonic dynamics

- $A_{CP}(\tau^+ \to \nu K_S \pi^+)|_{SM}$ = (0.36 ± 0.01) %

  $A_{CP}(\tau^+ \to \nu K_S \pi^+)|_{BaBar'12}$ = (- 0.36 ± 0.23 ± 0.11)%

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  - need precision
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◆ accuracy on different CKM levels & *correlations* !

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due to CPT symmetry:

$$\sum_a \Delta\gamma(a) = 4\sum_a \sum_{aj\neq a} T_{aj,a}^{resc}\, \mathrm{Im}\, T^*_a T^*_{aj} = 0$$

since $T_{aj,a}^{resc}$ symmetric & $\mathrm{Im}\, T^*_a T^*_{aj}$ anti-symmetry

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-- SM gives ~zero \`background' in τ transitions

- correlations with neutrino oscillations?

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III. Parameterization of CKM Matrix through $\mathcal{O}(\lambda^6)$

In Wolfenstein parameterization it gets 3 classes; however:

- $\eta \approx 0.34$, $\rho \approx 0.13 \ll \mathcal{O}(1)$
- PDG: $|V(ub)/V(cb)| \sim 0.085 - 0.10 < 0.225$

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Need parameterization of CKM matrix with more precision !

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

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

now we get somewhat different 6 classes:

Class I.1:

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Pattern is not so obvious as before,

- but not very different in qualitative ways,
- needs more accuracy &
- deeper insights in flavour dynamics & QCD impacts!

IV. Tools for Treating Final States Interactions

the goal is to find *ND* --

- its existence & its (their ?) nature(s) & shape(s)!

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- it is *non*-perturb. QCD that controls FSI;
- have to probe correlations of ~~CP~~ in K, D & B [&τ] decays
- there are lots of experiences from
  - Hadronic Dynamics/MEP
  - need collab. Hadronic Dynamics/MEP & HEP !

IV.1 `Catholic' Road to ND

- A Catholic Scenario for B/D → PPP:

single path to heaven - asymmetries in the Dalitz plot

- ✧can rely on relative rather than absolute CP asym
  - ✓ much less dependent on production asym.

need

- lots of statistics
  - robust pattern recognition
  - `Miranda' procedure

Bediaga et al.:

-- Phys.Rev.D80(2009)096006;arXiv:0905.4233[hep-ph]

-- Phys.Rev.D86(2012)036005;arXiv:1205.3036[hep-ph]

Jussara M. de Miranda (LHCb coll.);

-- arXiv:1301.0283

IV.2 Theoretical Tools for Treating Final States Interactions – `Nabis Project'

theoretical guidance: $B/D \to PPP$

- chiral dynamics & FSI are not strengths of LQCD

- use great experience from Hadron Physics/MEP about chiral dynam. & FSI – use for profit!

☞ working group of theorists & experimentalists needed

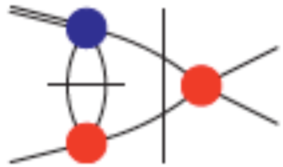
- to deal with CPV in Dalitz studies &
- probe features of ND

`topology' of CPV in Dalitz plots:

3 sources

- with quasi-2-body final states (resonances)
- with interference between quasi-2-body final states
- contributions from true 3-body final states or broad resonances like σ, κ.

One example: B. Kubis, arXiv:1108.5866



$$\mathcal{M}_0(s) = \Omega_0(s)\left\{\alpha_0 + \beta_0 s + \gamma_0 s^2 + \frac{s^3}{\pi}\int_{4M_\pi^2}^{\infty}\frac{ds'}{s'^3}\frac{\sin\delta_0(s')\hat{\mathcal{M}}_0(s')}{|\Omega_0(s')|(s'-s-i\epsilon)}\right\}$$

applied to η, ω, φ -> 3 π

- *refined* dispersion relations
- data driving
- with subtraction constants

…

- with input from theoretical constraints like Kπ & ππ scattering in Kππ final states

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remember SUSY!

the goal is to find ND –

like a criminal case where you did *not* see two witnesses at the crime:

No golden test of flavour dynamics -- you have to rely on a series of several arguments with *correlations*!

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LHCb-PAPER-2013-018:

$A_{CP}(B_s \to K^-\pi^+) = 0.27 \pm 0.04 \pm 0.01$, $A_{CP}(B_d \to K^+\pi^-) = -0.080 \pm 0.007 \pm 0.03$

$$\Delta_{LHCb} = -0.02 \pm 0.05 \pm 0.04$$

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$\Delta_{Lipkin} = \mathcal{O}(10 - 20)\ \%$ vs. $\Delta_{LHCb} = -\ 0.02 \pm 0.05 \pm 0.04$

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-- one should mention that theoretical uncertainties are not included; furthermore Lipkin said in his 2005 paper that

"symmetry breaking which produces effects of the order 10 or 20 per cent ..."

the goal is to find ND –

a criminal case where you did *not* see two witnesses at the crime

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- Need detailed analyses of 3- & 4-body final states, including CPV – despite the large start-up work!

- We need real collaboration between theorists from HD/MEP & HEP and experimental people from HEP

Remember –
finding the Devil in the Basilica San Francesco in Assisi in Italy painted in the 14^{th} century took till now!

Ikaros Bigi: “ND by Cunning”

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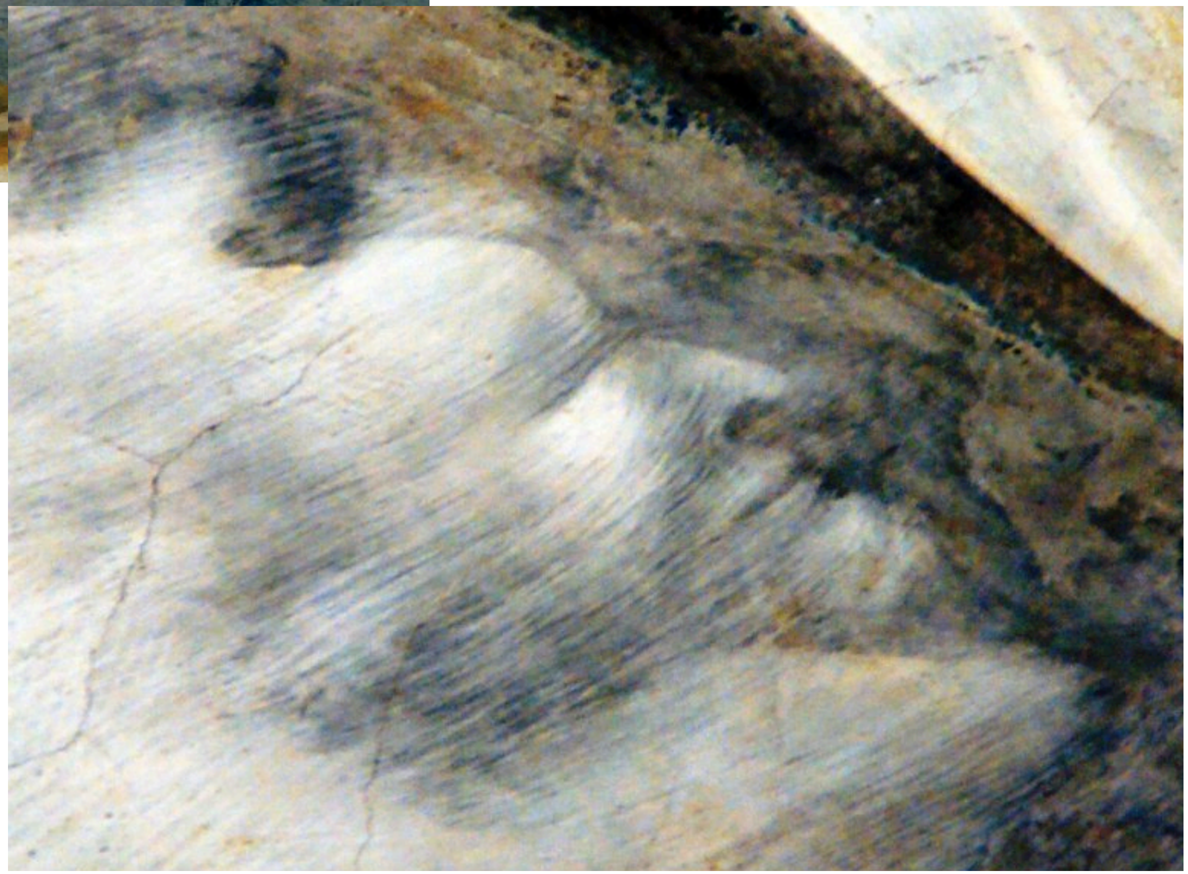

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Odysseus = need force & lots of cunning

Achilles

Aias

Odysseus = need force & lots of cunning of exp. & th.

LHCb!

Achilles
= ATLAS

Aias
= CMS

Ikaros Bigi: "ND by Cunning"