Lattice Weak Matrix Elements: A diagnostic tool for New Physics in the LHC era

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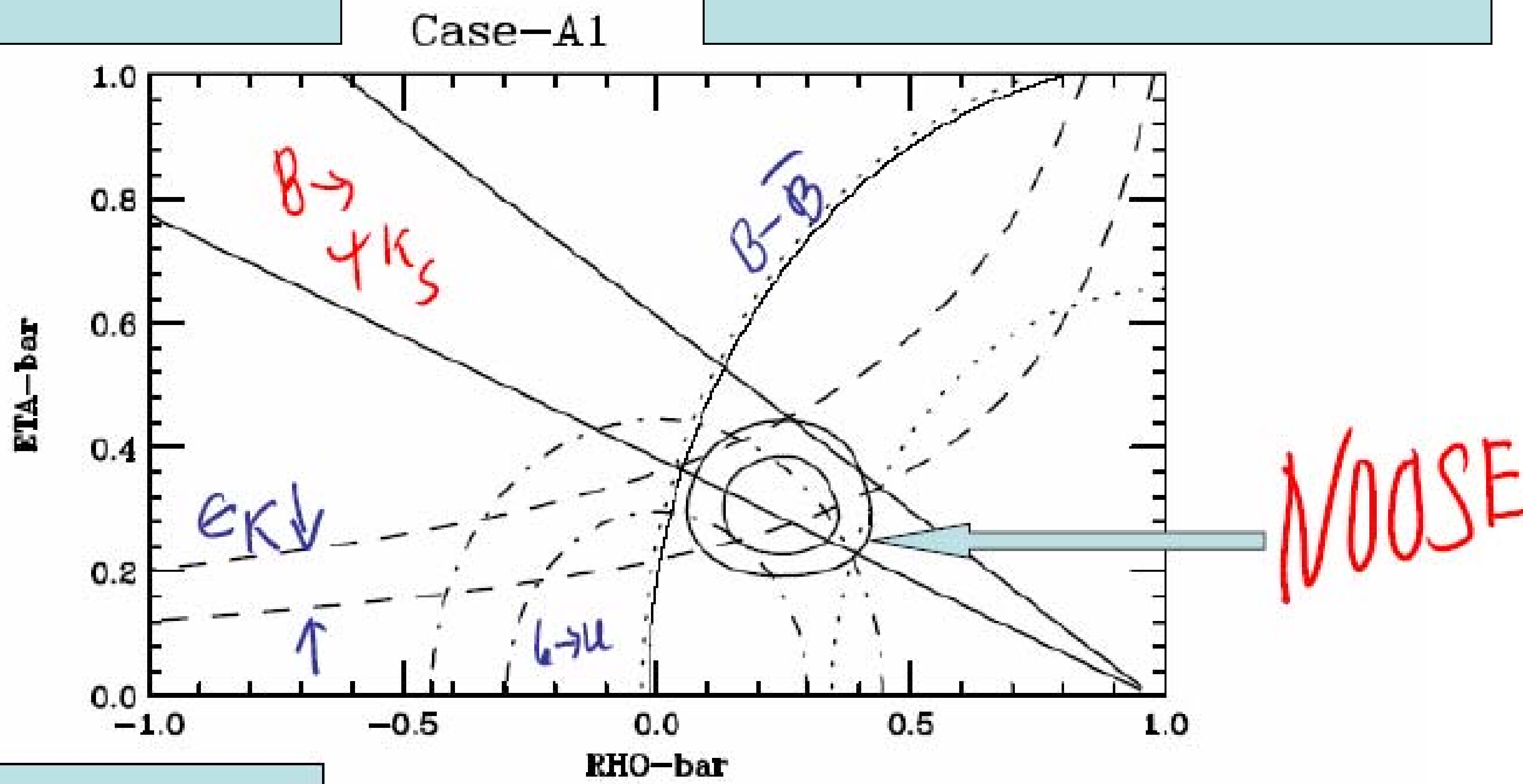
Main point

Increase in accuracy in B_K allows separately to test the SM against input from "loop" versus input from "trees" yielding possibly important result

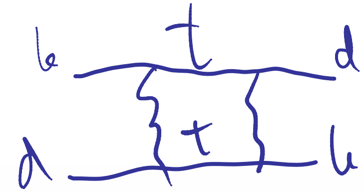
1st Hint of confirmation of KM CP description

Atwood &AS, hepph/0103197

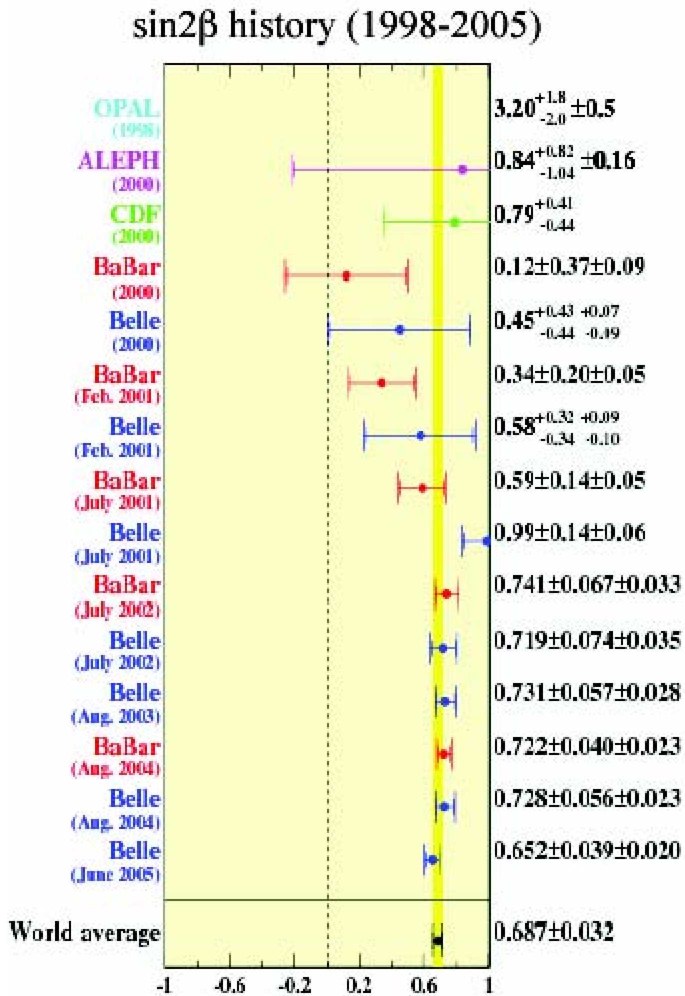


Most bands due
To theory errors

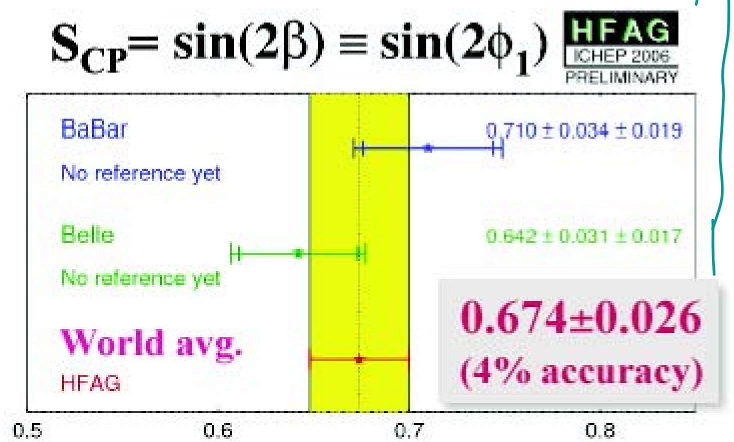
MEASUREMENT of $\beta(\phi_1)$

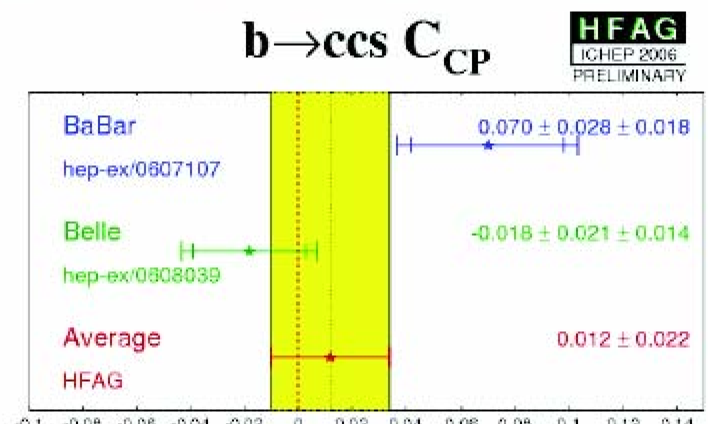


$10+5K
M-Y



2006 BaBar + Belle



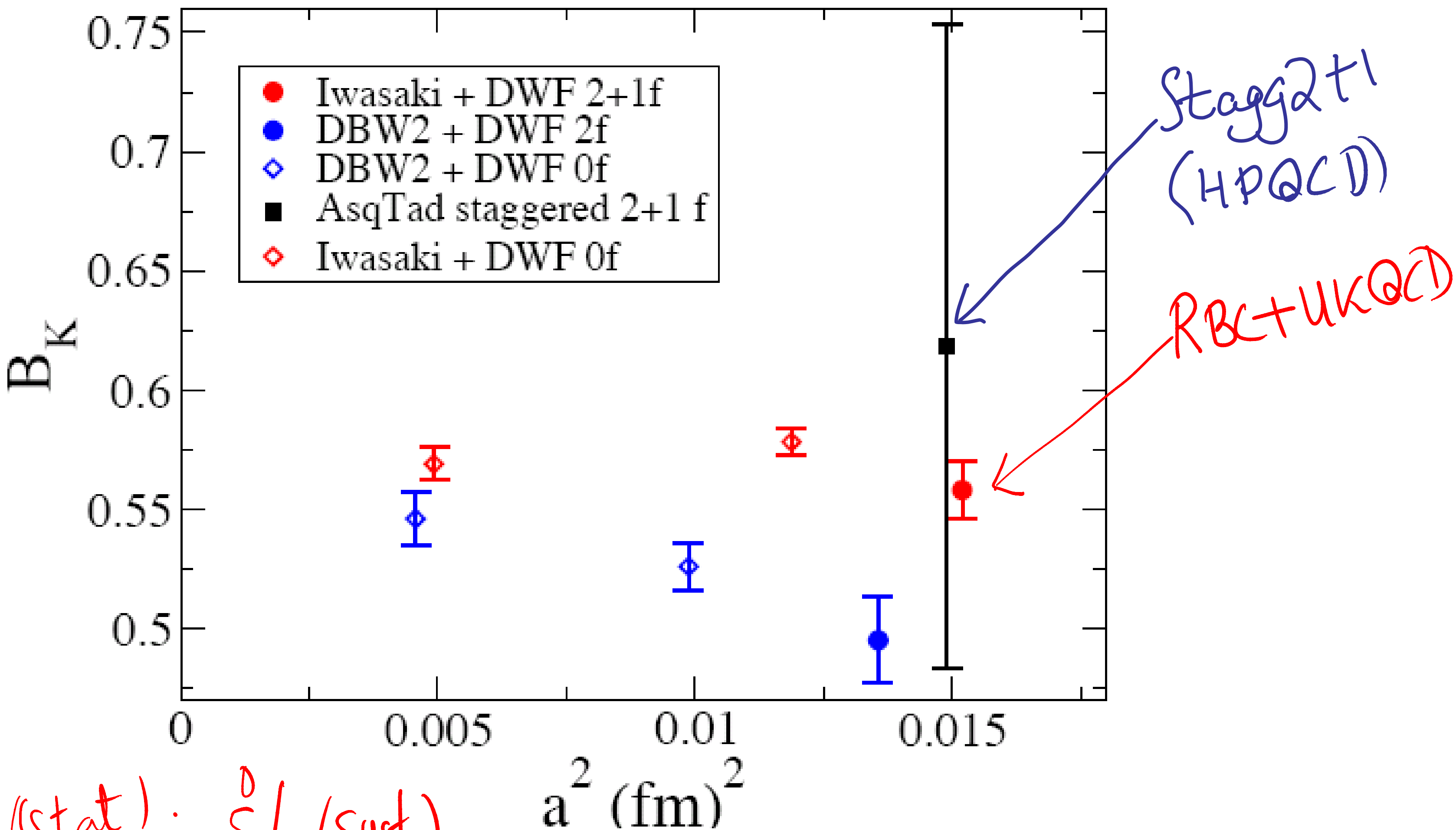


PRIMARILY with LATTICE INPUT (CKMFIT+UTFIT) ~ SM $\sin 2\beta = .78 \pm .10$

RBC-UKQCD 2+1 dynamical DWQ,hep-ph/0702042

$$B_K^{\overline{\mathrm{MS}}}(2\ \mathrm{GeV}) = 0.524(10)(28)$$

PRL Jan25,08



~2% (stat); 5% (syst)

BROOKHAVEN NATIONAL LABORATORY

HEP office of high energy physics

Brief (~25 years) History of B_K

, ~'83 DGH use K^+ lifetime + LOChPT + SU(3)->
B_K ~0.33… no error estimate, no scale dependence… UNCONTROLLABLE APPROXIMATION

~'84 Lattice method for WME born…many attempts & improvements for B_K evaluations

~'98 JLQCDstaggered B_K (2GeV)= 0.628(42)quenched(~110).

~'97 1st B_K with DWQ(T.Blum&A.S),0.628(47) quenched.

~'01 RBC B_K with DWQ, quenched=0.532(11) quenched

~'05 RBC , nf=2, dyn. DWQ, B_K =0.563(21)(39)(30)

~07,RBC-UKQCD DWQ 2+1 …..0.557(12)(29)
DWQ lower B_K -> requiring larger CKM-phase

~'08 Target 2+1 dyn. DWQ, B_K with total error 5%

A. S : Proceedings of LATTICE '85 (FSU)…1st lattice meeting ever attended

time has constrained KM parameters well enough that a knowledge of the B parameter can be used to put a nontrivial bound on the mass of the top quark. Thus, for example, with B = .33 the standard model with three generations requires $m_{top} \gtrsim 40$ GeV for it to successfully account for the experimentally observed value of ϵ.[6)]

Left-right symmetric theories constitute a popular means for extending the standard model. The $K^o\bar{K}^o$ mass difference can be used to learn about the lower bound on the mass scale of such theories. These bounds depend linearly on $M_{LR} \equiv \langle K^o | \bar{s}\gamma_\mu(1-\gamma_5)d\ \bar{s}\gamma^\mu(1+\gamma_5)d | \bar{K}^o \rangle$, and the current bound (1.6 TeV for the mass of the right handed gauge bosons) was deduced by assuming vacuum saturation.[7)] It will therefore be useful to calculate M_{LR} on the lattice.

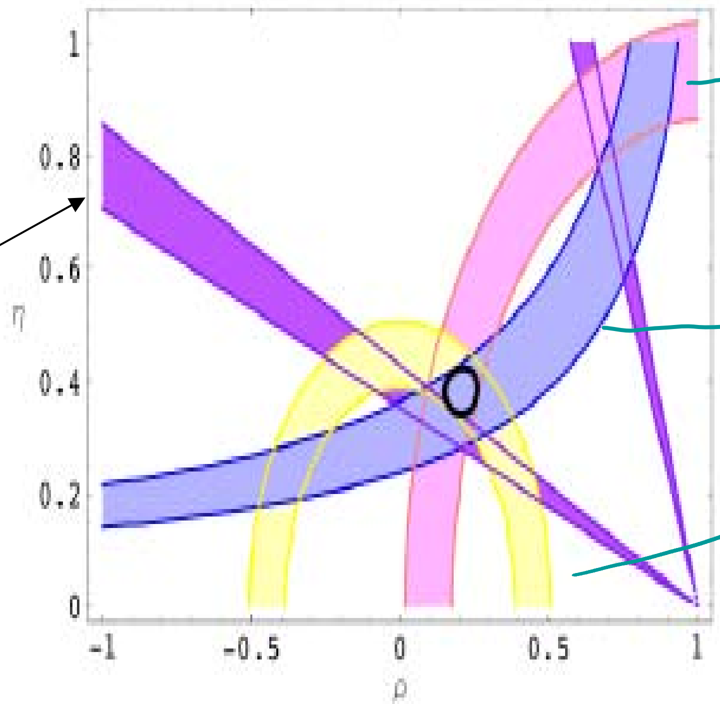
The matrix elements of some penguin operators control in the standard model another CP violation parameter, namely ϵ'/ϵ.[6,8)] Indeed efforts are now underway for an improved measurement of this important parameter.[10)] In the absence of a reliable calculation for these parameters, the experimental measurements, often achieved at tremendous effort, cannot be used effectively for constraining the theory. It is therefore clearly important to see how far one can go with MC techniques in alleviating this old but very difficult

So what does this increased accuracy buy for us?

Lunghi+AS,arXiv.0707.0212

(Sin 2 β = 0.75+-.04)

Directly measured via
(gold-plated)
B->ψ K_S ,,
sin β = 0.68+-.026



$\frac{\Delta m_s}{\Delta m_d}$; ξ_s

ϵ_K ; B_K , V_{cb}

$\frac{V_{ub}}{V_{cb}}$

Figure 1: Unitarity triangle fit in the SM. The constraints from $|V_{ub}/V_{cb}|$, ε_K, $\Delta M_{B_s}/\Delta M_{B_d}$ are included in the fit; the region allowed by $a_{\psi K}$ is superimposed.

Continuing saga of Vub

- For past 2 years or so exclusive & inclusive ~small discrepancy:
- Exc ~ (3.7 +-.2+-.5)X10^{-3}
- Inc ~ (4.3 +-.2+-.3)X10^{-3}
- More recently (LP'07) Neubert suggests source is m_b extraction from b s gamma; disregarding that m_b shows incl. Vub quite consistent i.e. 3.98+-.15+-.30 X10^{-3}

Furthermore, ***Vub is purely tree, so if we could test the SM w/o it, we should….Observation: Yes, (now) we can***

-> ***Let's try NOT use Vub***

Significance of fit w/o Vub

- Because of reduction of error in B_K

Now non-trivial constraint on sin2beta(SM) obtainable w/o Vub

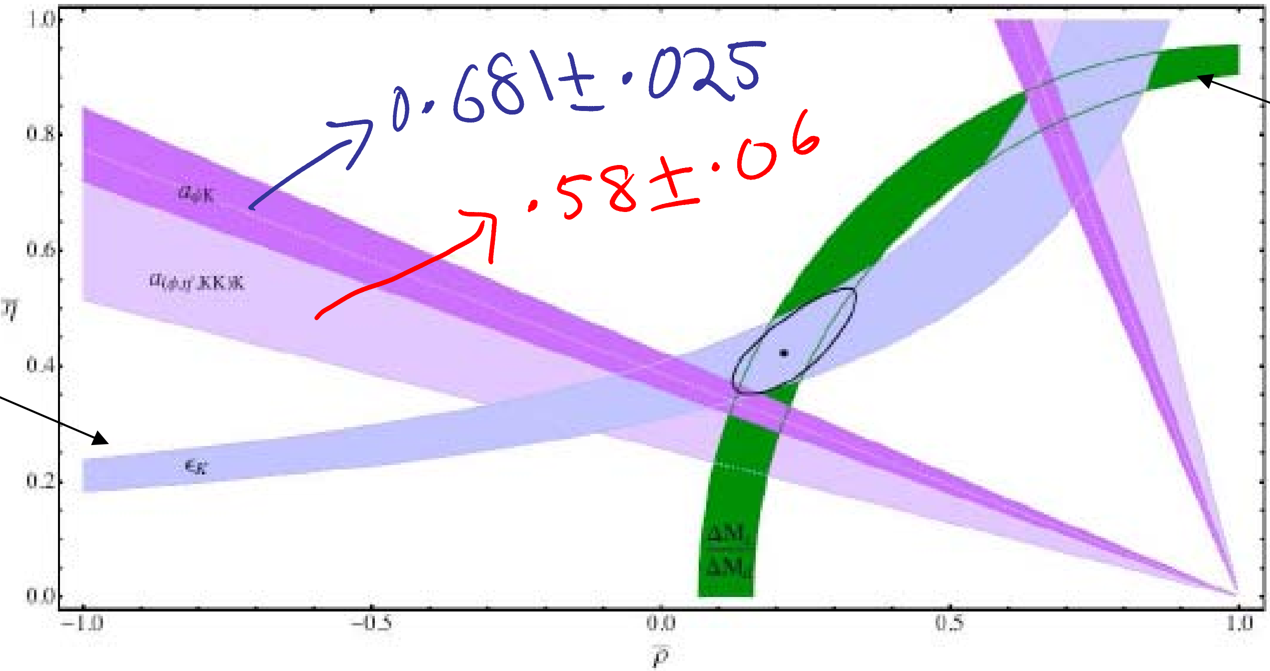
Lattice calculation of B_K and SU3 breaking ratios(are also B's), all involve $\Delta F=2$ mixing matrix elements, do NOT require any momentum injection in sharp contrast to semi-leptonic form factor needed for Vub…

Besides it is very difficult to get Vub from inclusive cleanly (b -> u is NOT protected by HQ symmetry of QCD-> ultimately the lattice will win)

$\Delta F=2$ BOX

Leave out Vub
sin 2 β = 0.87+-.09{Lunghi+AS,hep-ph/08034340}
(became possible only due significantly reduced error in B_K)

Antonio et al (RBC-UKQCD)



Gamiz et al; Becirevic; Tantalo
.

FIG. 1: Unitarity triangle fit in the SM. All constraints are imposed at the 68% C.L.. The solid contour is obtained using the constraints from ε_K and $\Delta M_{B_s}/\Delta M_{B_d}$. The regions allowed by $a_{\psi K}$ and $a_{(\phi+\eta'+2K_s)K_s}$ are superimposed.

2.1-2.7 σ- deviation from the directly measured values of sin 2 β require careful follow-up

SU(3) breaking ratio ξ_s

- It was noted (Bernard, Blum & AS,heplat/9801039; c also Lellouch et al, hepph/0011086) that once Δm_s gets measured then Δm_s / Δm_d from expt. along with SU(3) breaking ratio from the lattice would provide a powerful constraint on the η,ρ plar

$$\xi_s = \frac{f_{B_s}\sqrt{\hat{B}_s}}{f_{B_d}\sqrt{\hat{B}_d}}$$

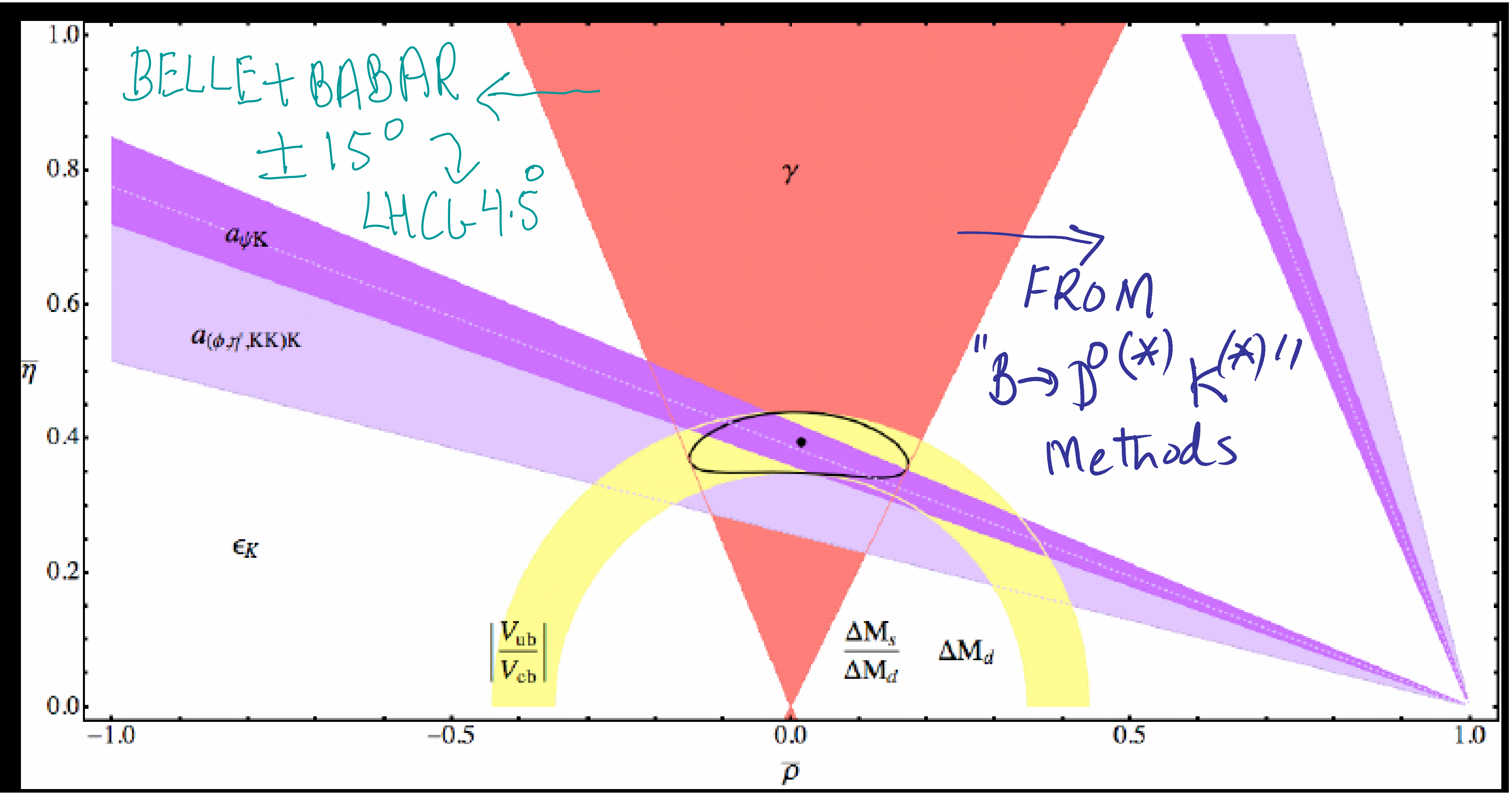
- For now DWQs are quite behind this extremely important quantity and the best lattice numbers (1.20 +-0.06) come from Gamiz,Davies,Lepage, Shigemitsu and Wingate, arXiv:0710.0646; c also, Becirevic, hepph/0310072 and Tantalo, hepph/0703241

Predict sin 2 β only from "trees"

Lunghi + AS

(work in progress)

With input of trees only (γ and V_{ub}), predicted value of sin 2 β = 0.68+-0.065



IMPROVED ACURACY IN LATTICE WME REVEALS POSSIBLY INTERESTING HINTS

- sin 2 β deduced purely from “tree” input 0.68+-0.065 agrees quite well with directly measured value 0.68+-0.026

- However sin 2β = 0.87+-.09 deduced with input from ΔFlavor=2 box contributions of K, B and B_s disagrees by about 2 (2.7) sigma

It is perhaps of some use to extract the values of $\hat{B}_K$, ξ_s and V_{cb} that are required to reduce to the 1-σ level the discrepancy between the prediction given in Eq. (5) and $a_{(\psi+\phi+\eta'+K_S K_S)K_S} = 0.66 \pm 0.024$. We find that one has to choose either $\hat{B}_K^{\rm new} = 0.96 \pm 0.04$, $\xi_s^{\rm new} = 1.37 \pm 0.06$ or $V_{cb} = (44.3 \pm 0.6) \times 10^{-3}$.

[USED $\hat{B}_K = 0.72 \pm .04$; $\xi_s = 1.20 \pm .06$; $V_{cb} = (40.8 \pm .6) \times 10^{-3}$]

Anomalies in $B(B_s)$-CP asymmtries

- Sin 2 β from penguin-dominated modes tends to be systematically below from the value obtained via $B \to \psi K_S$ ~2.5 σ (in addition an intriguing trend of central values of almost all modes are low)
- $ACP(K^+ \pi^-)) - ACP(K^+ \pi^0)$ =14.4+-2.9% & not ~0
- -> these anomalies suggest new CP phase in b->s (Lunghi + AS, arXiV:0707.0212)
- Lattice determined sin2 β now tends to be around 0.87+-0.09 (Lunghi+AS, arXiV:0803.4340)
- $B_s \to \psi \varphi$ (CDF,D0) requires a largish NEW CP phase in b->s (see M. Bona et al, UTFIT arXiV:0803.0659)

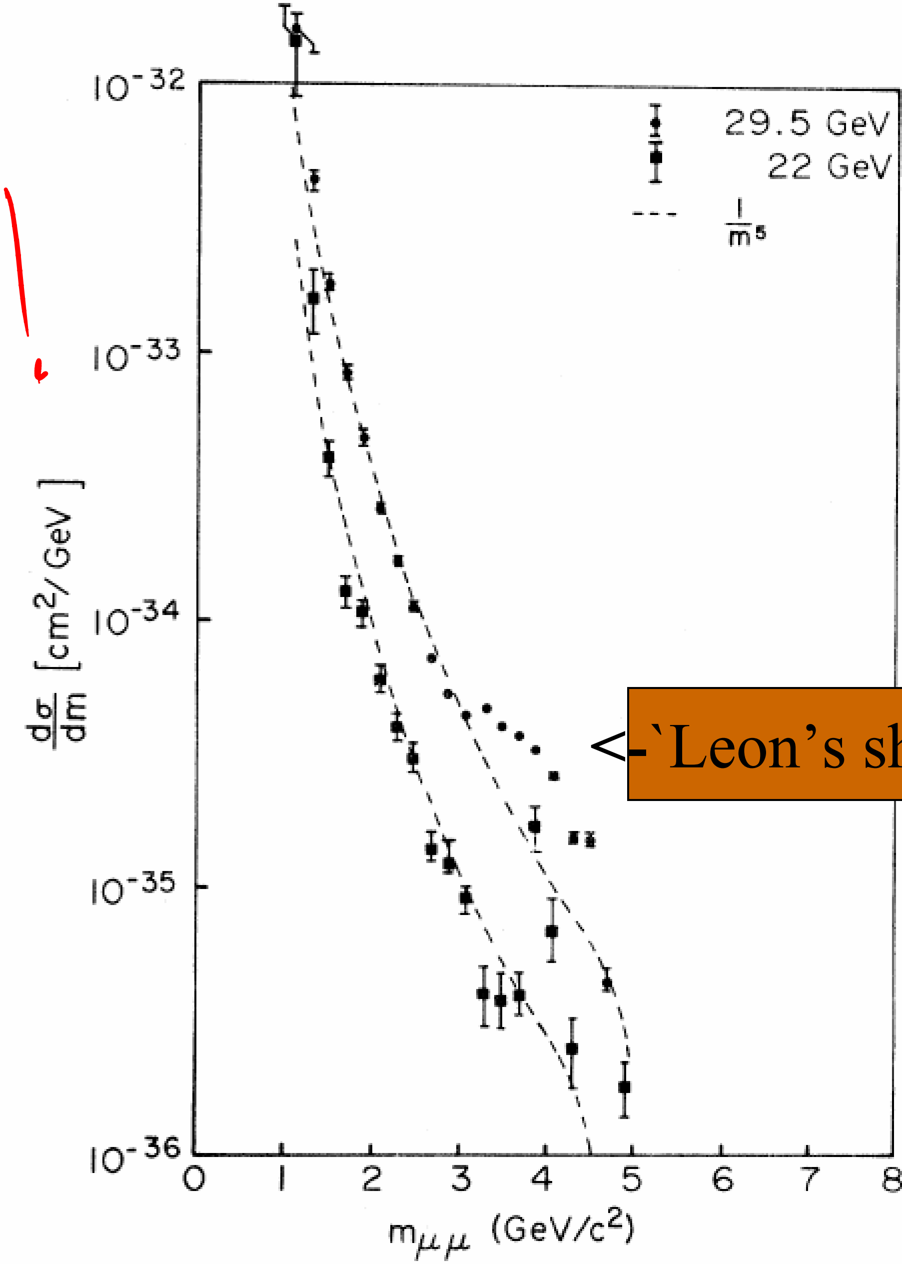
Need to follow-up

- Given especially the fact that several other problems of ~ 2 to ~3.5 σ have been uncovered with SM-CKM, this deviation originating from the lattice should be considered seriously….
- If true provides a very important clue to the nature of underlying new physics (see arXiV:0807.1971)

While one should not chase every 2-3 σ deviation, it is useful to remember that not taking seriously some of them has proven rather costly

[Early agreement to ~15% between CKM prediction and sin 2 β measurement was very likely misinterpreted with serious adverse repercussions for experiments in the US]

DRELL-YAN
@ its
INFANCY!



<-`Leon's shoulder

$pp \rightarrow \mu^+\mu^- X$
@BNL

FIG. 15. Experimental cross sections at two energies compared with a simple $1/m^5$ continuum.

Christenson,Hicks,Lederman,Limon,Pope & Zavattini
PRD 8,2016 ‘72

mass range of 3–5 GeV/c^2, there is a distinct excess of the observed cross section over the reference curve. If this excess is assumed (certainly not required) to be the production of a resolution-broadened resonance, the cross-section–branching-ratio production σB would be approximately 6×10^{-35} cm^2, subject to the cross-section uncertainties discussed above. Alternatively the excess may be interpreted as merely a departure from the overly simplistic (and arbitrarily normalized) $1/m^5$ dependence. In this regard, we should remark that there may be two entirely different processes represented here: a low-Q^2 part which has to do with vector mesons, tail of the ρ, bremsstrahlung, etc., and a core yield with a slower mass dependence, which may be relevant to the scaling argument discussed below.

The “heavy photon” pole that has been postulated[32] to remove divergence difficulties in quan-

cles produced in the initial proton-uranium collision. In principle, these secondary particles could also create muon pairs. In this case, the observed spectrum would represent the inseparable product of the spectrum of the secondary particle and its own yield of muon pairs. In exploratory research of this kind this disadvantage is largely offset by the fact that the variety of initial states provides a more complete exploration of dimuon production in hadron collisions.

2. *Real Photons*

Real photons produced in the target (presumably from the decay of neutral pions) yield muon pairs by Bethe-Heitler or Compton processes. Estimates were made for the photon flux on the basis of pion-production models,[27,28] and this method of calculating the flux was checked against the experimental data of Fidecaro *et al.*[33] The argument

Summary & Outlook

- It is nice that improved accuracy in WME is beginning to allow us additional strategies for testing the SM..
- Vcb, B_K,ξ_s provide a new nontrivial test of SM
  NEED $(Vcb)^4$!
- Gamma (from expt) + |Vub /Vcb| a separate test
- Possibly interesting deviation are appearing
- Clearly very important to further reduce our errors to provide more decisive confrontations