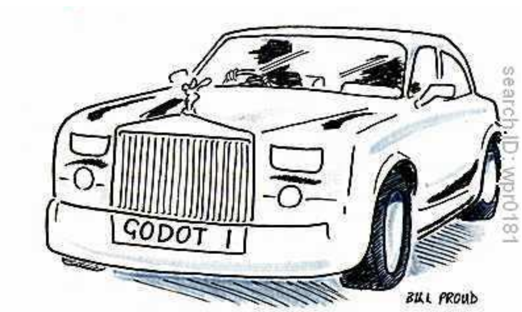
Godot and the New Physics

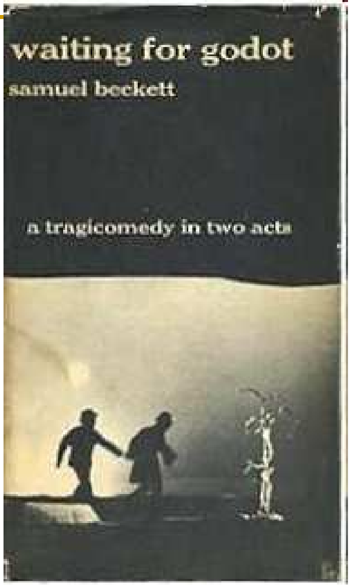
(or conference highlights: FPCP 2011 … FPCP 2014)



"Are we there yet?"

Guy Wilkinson
University of Oxford

Waiting for Godot – a parable for the flavour physics community ?



Samuel Beckett's play (1949) a landmark of modern theatre.

Two tramps, Vladimir and Estragon, await the arrival of the mysterious Godot. He does not come, although other sinister characters pass through whom they mistake for Mr G. They pass their time in meaningless activities and talk.

A play of existentialist angst focused on the futility of the human condition…

…or a parable of the search for new physics in the flavour sector ?

(which in turn could be seen as a tale of existentialist angst focused on the futility of the human condition)

Why are we here? Godot as the New Physics

Like Vladimir and Estragon, we hope we know what we are doing here

"But that is not the question. Why are we here,

that is the question. And we are blessed in this,

that we happen to know the answer. Yes, in this

immense confusion one thing alone is clear.

We are waiting for Godot to come."

We know why we are doing what we're doing.

We are awaiting the arrival of the New Physics.

All we know tells us that if there is New Physics it must affect the flavour sector !

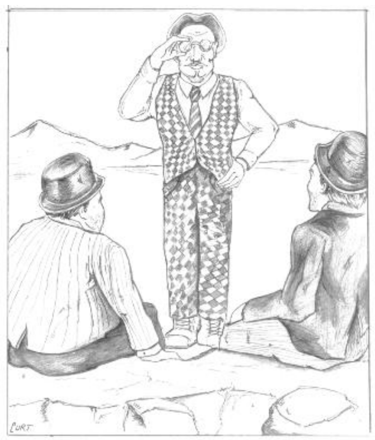
This can sometimes make us a little too enthusiastic…

It’s Godot, we’re saved!

In our excitement we are eager to acclaim interesting deviations as New Physics

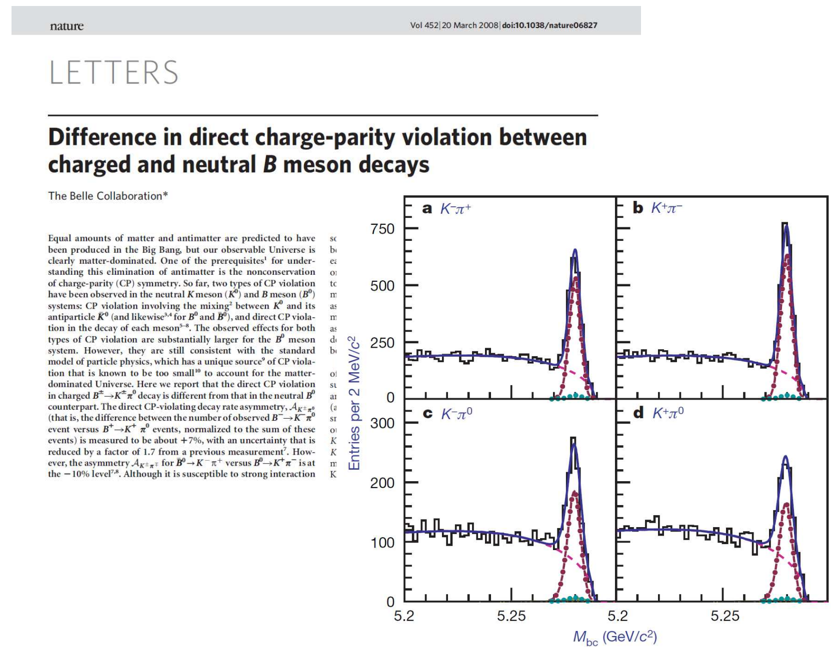
POZZO:

“You took me for him?”



ESTRAGON:

“That's to say . . .
you understand . . .
the dusk . . . the strain . . .
waiting . . . I confess . . .
I imagined . . . for a second . .”



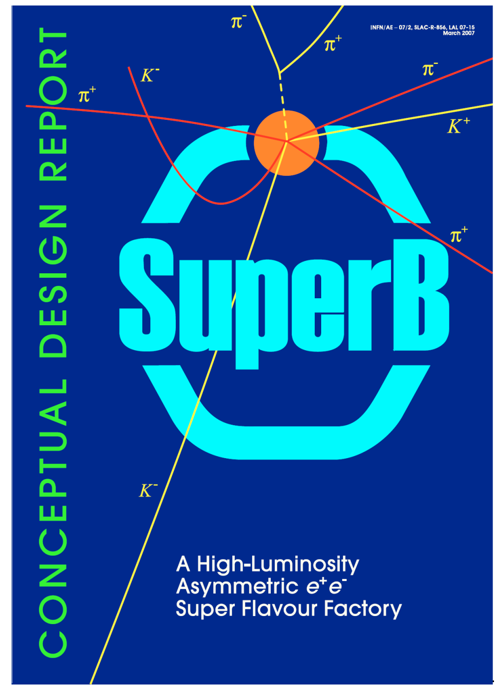
$$\Delta\mathcal{A} \equiv \mathcal{A}_{K^\pm\pi^0} - \mathcal{A}_{K^\pm\pi^\mp} = +0.164 \pm 0.037$$

?!?

But we don’t give up

VLADIMIR:
“What are you insinuating? That we've come to the wrong place?”
ESTRAGON:
“He should be here.”
VLADIMIR:
“He didn't say for sure he'd come.”
ESTRAGON:
“And if he doesn't come?”
VLADIMIR:
“We'll come back tomorrow. “
ESTRAGON:
“And then the day after tomorrow.”
VLADIMIR:
“Possibly.” (ie, subject to funding body support)

‘the day after tomorrow’ ?



Aims of this talk

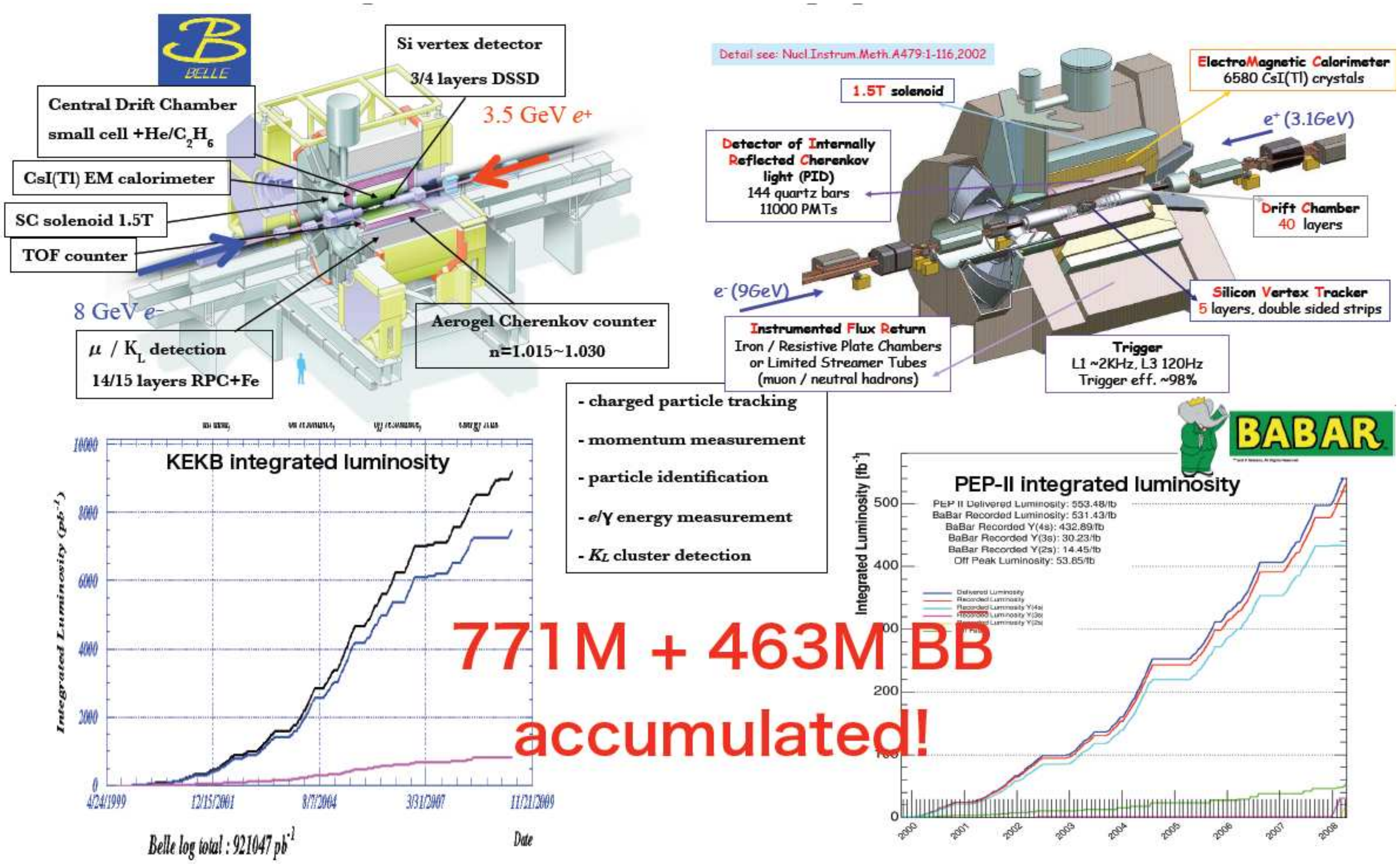
Will present a highly selective and personal view of opportunities where we have the possibility to find New Physics in the coming 5 years (‘tomorrow’) – or at least the areas where advances necessary for this end will occur.

- Dramatis Personae
- Time dependent CPV measurements
- The least well known angle
- Rare decays
- The lepton sector: Θ_{13}
- Conclusions

Dramatis Personae

B-factories

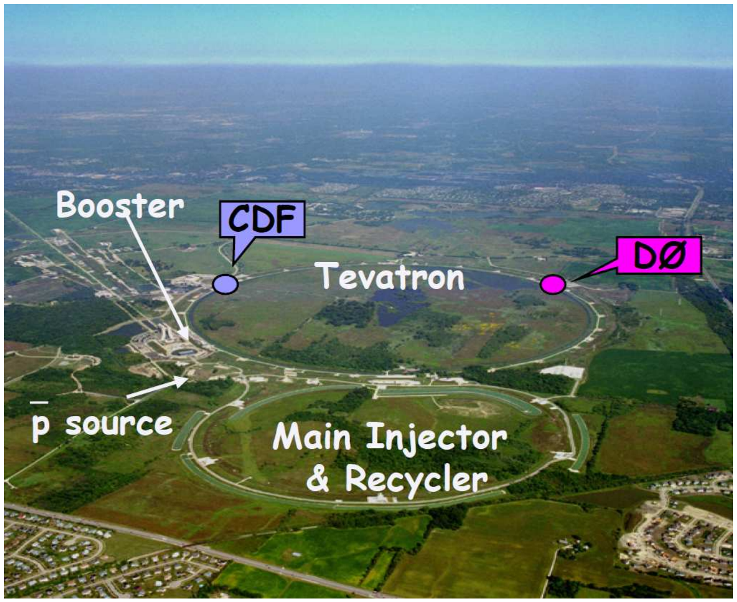
Yusa

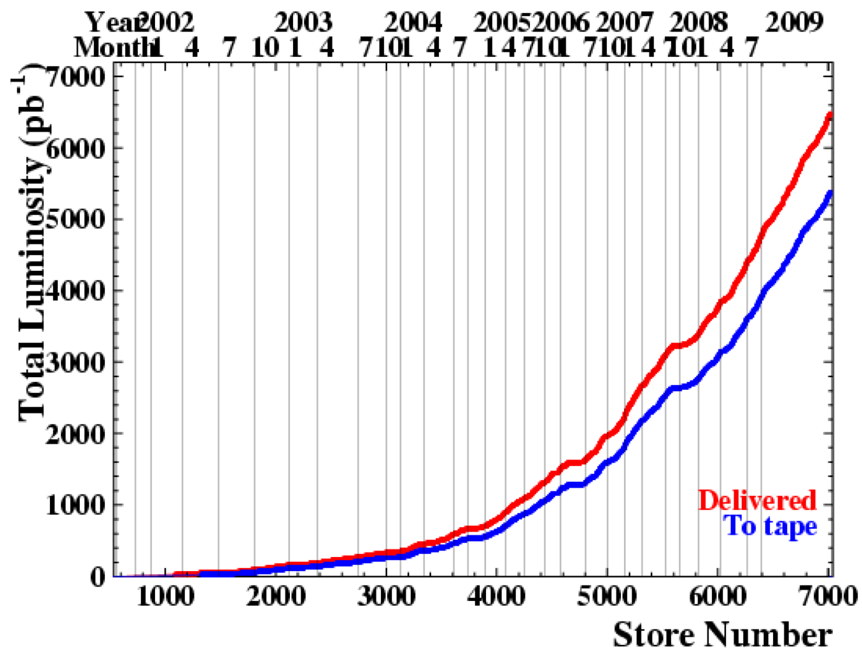


Truly *astounding* achievement ! Bulk of data analysed in bulk of analyses.
Still much *vital* work to be done. But low likelihood of real surprises (?)

Prospects at the Tevatron

Donati, Giurgi et al.





Most analyses seen this conference with 1-3 fb^{-1}. Already > 5 fb^{-1} on tape per experiment, and prospect of significantly more (x 2?) to come

Tevatron harvest is only just beginning – CDF & D0 still have their best years are still ahead of them! (but do they retain the manpower to exploit the data?)

LHC prospects 2009-2010

Lopes-Pegna, Deschamps

Machine running scenario and corresponding luminosity projections still evolving

Provided this week from Mike Lamont:
many caveats and assumptions – use with care!

LHCb 2009 - 2010 luminosity performance - rough estimate

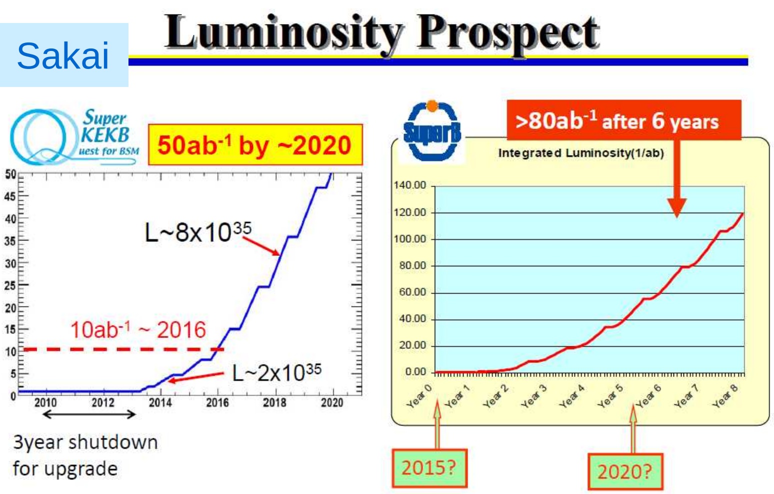
Month	Comment	Turn around time	Availability	Max number colliding bunches	Protons/Bunch	Min beta*	Peak Luminosity $cm^{-2}s^{-1}$	Integrated Luminosity
1	Beam commissioning							First collsions
2	Pilot physics, no squeeze, gentle increase in bunch intensity, max 19 displaced bunches	Long	Low	19	3×10^{10}	10 m	2.4×10^{29}	~50 nb^{-1}
3	No squeeze	5	40%	19	5×10^{10}	10 m	6×10^{29}	~ 0.3 pb^{-1}
4	Partial squeeze	5	40%	72	5×10^{10}	6 m	3.8×10^{30}	~2 pb^{-1}
5		5	40%	72	7×10^{10}	4 m	1.1×10^{31}	~6 pb^{-1}
6	50 ns	5	40%	138	7×10^{10}	4 m	2.1×10^{31}	~11 pb^{-1}
7	50 ns	5	40%	276	7×10^{10}	4 m	4.2×10^{31}	~22 pb^{-1}
8	50 ns*	5	40%	414	7×10^{10}	4 m	6.3×10^{31}	~34 pb^{-1}
9	50 ns*	5	40%	414	9×10^{10}	4 m	1.0×10^{32}	~55 pb^{-1}
10	50 ns*	5	40%	414	9×10^{10}	4 m	1.0×10^{32}	~55 pb^{-1}
							TOTAL	**~200 pb^{-1}**

Similar / slightly higher luminosities to be delivered to ATLAS/CMS

The 3rd generation experiments: 2015→

Super B-factories:
two options under consideration

Sakai



50-100x increase in statistics w.r.t.BaBar/Belle

Very exciting prospects particularly for inclusive rare processes and LFV

LHCb upgrade

Campana

TDR being written
Upgraded trigger and detector; 10x higher luminosity. Overall yield increases w.r.t. LHCb:

→10x for leptonic modes
→20x for hadronic modes

Compelling & complementary programmes – but today I am focussing on <2015…

Time dependent CPV

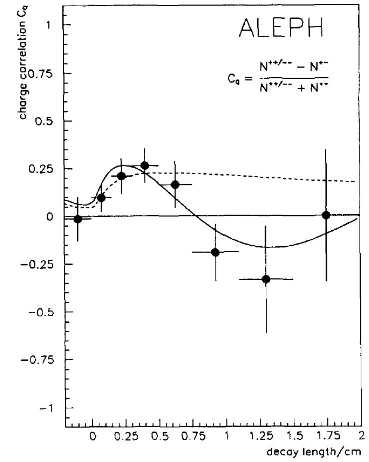
The Long and Wiggling Road to CP Violation

Observation of mixing in (B^0+B_s) and B^0 system

UA1, PLB 186 (1987) 247

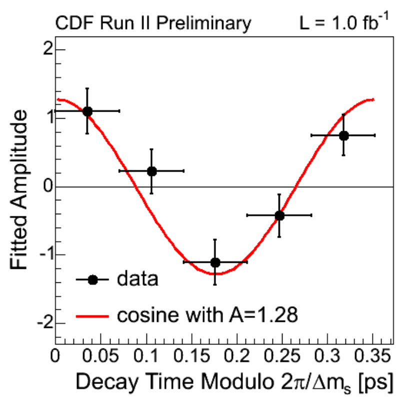
Argus, PLB 192 (1987) 245

Resolution of B^0 oscillations



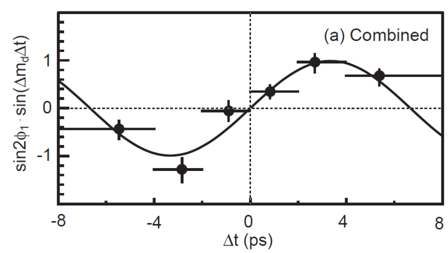
ALEPH, PLB 313 (1993) 498

Resolution of B_s oscillations

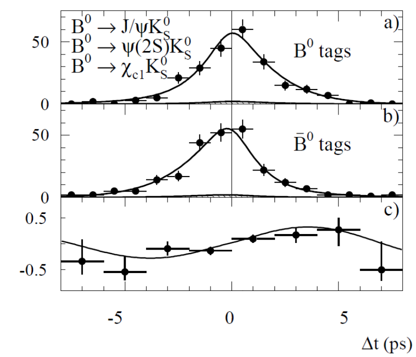


CDF, PRL 97 (2006) 242003

Observation of CPV in interference between B^0 mixing and decay



BELLE, PRL 87 (2001) 091802



BaBar, PRL 87 (2001) 091801

Which in turn has led to…

It's Godot, we're saved!

…`observation' of anomalously high CPV in B_s system by UTfit collaboration

FIRST EVIDENCE OF NEW PHYSICS IN b ↔ s TRANSITIONS

(UT*fit* Collaboration)

M. Bona,[1] M. Ciuchini,[2] E. Franco,[3] V. Lubicz,[2,4] G. Martinelli,[3,5] F. Parodi,[6] M. Pierini,[1]
P. Roudeau,[7] C. Schiavi,[6] L. Silvestrini,[3] V. Sordini,[7] A. Stocchi,[7] and V. Vagnoni[8]

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[3]*INFN, Sezione di Roma, I-00185 Roma, Italy*
[4]*Dipartimento di Fisica, Università di Roma Tre, I-00146 Roma, Italy*
[5]*Dipartimento di Fisica, Università di Roma "La Sapienza", I-00185 Roma, Italy*
[6]*Dipartimento di Fisica, Università di Genova and INFN, I-16146 Genova, Italy*
[7]*Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université de Paris-Sud, BP 34, F-91898 Orsay Cedex, France*
[8]*INFN, Sezione di Bologna, I-40126 Bologna, Italy*

We combine all the available experimental information on B_s mixing, including the very recent tagged analyses of $B_s \to J/\Psi\phi$ by the CDF and DØ collaborations. We find that the phase of the B_s mixing amplitude deviates more than 3σ from the Standard Model prediction. While no single measurement has a 3σ significance yet, all the constraints show a remarkable agreement with the combined result. This is a first evidence of physics beyond the Standard Model. This result disfavours New Physics models with Minimal Flavour Violation with the same significance.

UTFIT, arXiv:0803.0659 [hep-ph]

(Recall in SM phase ≡ $-2\beta_s = -0.037 \approx 0$, so any significant CPV observed within present experimental precision is a clear sign on new physics)

Not so fast! UTfit performed a valuable service to the community by highlighting this intriguing hint, but combinations are best left to the experiments themselves

Combinations of $2\beta_s^{J/\psi\Phi}$ results

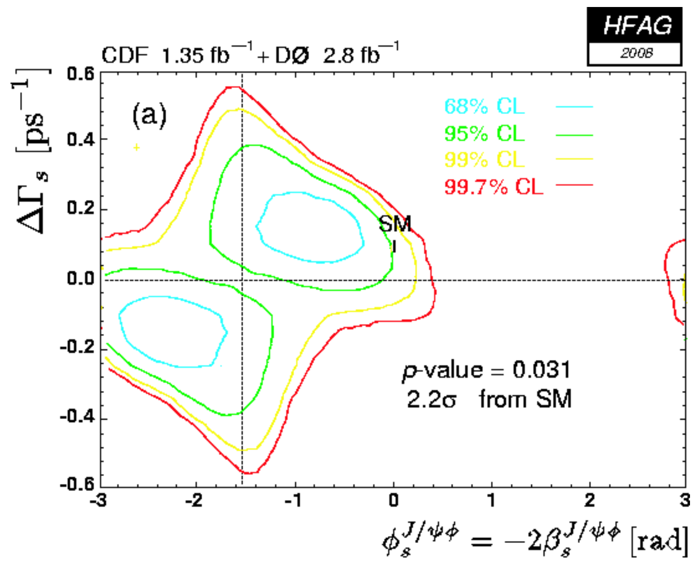
Giurgiu

Beale

When making *common* assumptions (including none about strong phase values)

Expt	Int lumi	From SM
CDF:	1.35 fb^{-1}	1.5 sigma
D0:	2.8 fb^{-1}	1.8 sigma
Combined		2.2 sigma

Summer '08

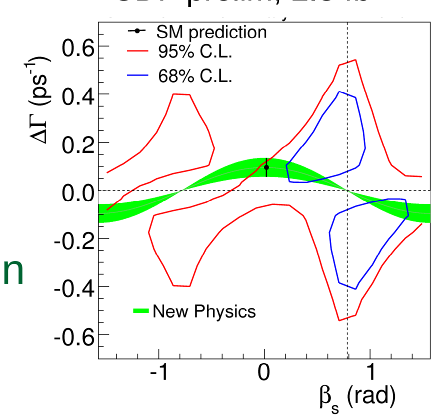


Updates from both CDF (2.8 fb^{-1}) & D0 (systematics revisited for 2.8 fb^{-1} sample):

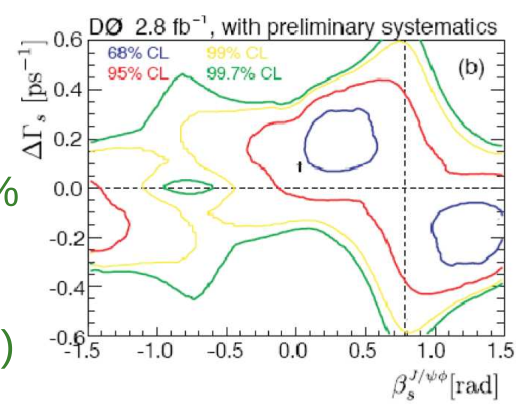
CDF-SM consistency degraded from 1.5 to 1.8 sigma

Precision of these data will improve with inclusion of SS kaon tagger

CDF prelim, 2.8 fb^{-1}



D0-SM p-value improves: 8.5%→24% (10% with external constraints)



New Tevatron combination promised soon !

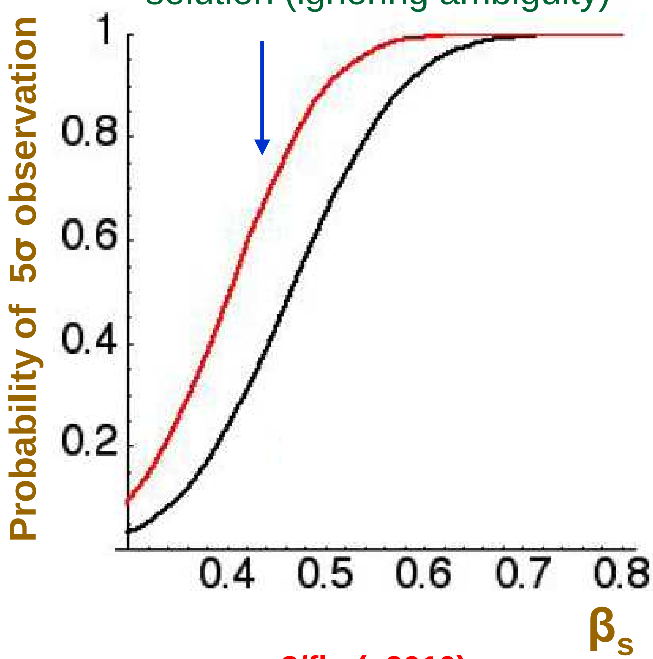
How long must we wait?

Deschamps Giurgiu

Conti (poster)

CDF and D0 extrapolation

Approx location of favoured solution (ignoring ambiguity)

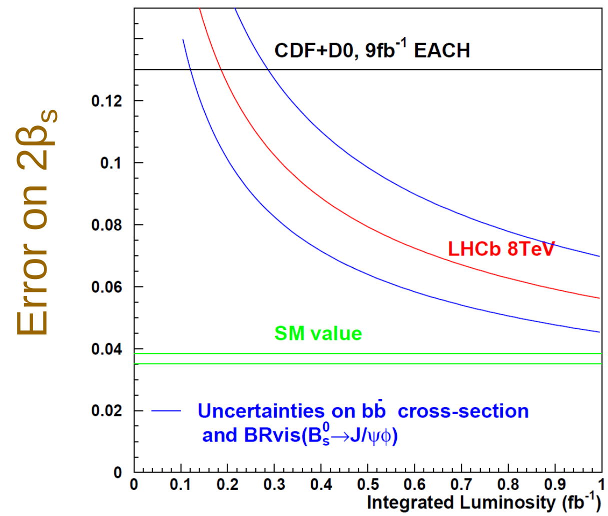


--- 8/fb (~2010)

--- 6/fb (~2009)

$B_s \rightarrow J/\psi\Phi$ a golden channel for LHCb

- high x-sec
- dedicated trigger
- excellent proper time res
- RICH



LHCb should have similar sensitivity after 2010 (100-200 pb^{-1} ?) to combined CDF/D0 (9 fb^{-1}?)
Significant sensitivity from ATLAS/CMS too.

If present preferred value is a fact of nature, we will know soon! If instead $2\beta_s$ is closer to SM-value, then LHC is also prepared – but will take longer

$B_s \rightarrow J/\psi\Phi$: a closer look

Giurgiu

Analysis which yields these results is very non-trivial:

P→VV transition (hence mixture of + & - CP states) with significant width ($\Delta\Gamma_s$) and mass splitting (Δm_s)

So β_s sensitivity has angular dependence, rapidly oscillating in proper time

- $B_s \rightarrow J/\Psi\Phi$ decay rate as function of time, decay angles and initial B_s flavor:

$$\frac{d^4P(t,\vec{\rho})}{dt\,d\vec{\rho}} \propto |A_0|^2\mathcal{T}_+ f_1(\vec{\rho}) + |A_\parallel|^2\mathcal{T}_+ f_2(\vec{\rho}) + |A_\perp|^2\mathcal{T}_- f_3(\vec{\rho}) + |A_\parallel||A_\perp|\mathcal{U}_+ f_4(\vec{\rho}) + |A_0||A_\parallel|\cos(\delta_\parallel)\mathcal{T}_+ f_5(\vec{\rho}) + |A_0||A_\perp|\mathcal{V}_+ f_6(\vec{\rho}),$$

time dependence terms

angular dependence terms

terms with β_s dependence

$$\mathcal{T}_\pm = e^{-\Gamma t} \times [\cosh(\Delta\Gamma t/2) \mp \cos(2\beta_s)\sinh(\Delta\Gamma t/2) \mp \eta\sin(2\beta_s)\sin(\Delta m_s t)],$$

terms with Δm_s dependence present if initial state of B meson (B vs anti-B) is determined (flavor tagged)

$$\mathcal{U}_\pm = \pm e^{-\Gamma t} \times [\sin(\delta_- - \delta_\parallel)\cos(\Delta m_s t) - \cos(\delta_\perp - \delta_\parallel)\cos(2\beta_s)\sin(\Delta m_s t) \pm \cos(\delta_\perp - \delta_\parallel)\sin(2\beta_s)\sinh(\Delta\Gamma t/2)]$$

$$\mathcal{V}_\pm = \pm e^{-\Gamma t} \times [\sin(\delta_\perp)\cos(\Delta m_s t) - \cos(\delta_\perp)\cos(2\beta_s)\sin(\Delta m_s t) \pm \cos(\delta_\perp)\sin(2\beta_s)\sinh(\Delta\Gamma t/2)].$$

'strong' phases:

$$\delta_\parallel \equiv \mathrm{Arg}(A_\parallel(0)A_0^*(0))$$
$$\delta_\perp \equiv \mathrm{Arg}(A_\perp(0)A_0^*(0))$$

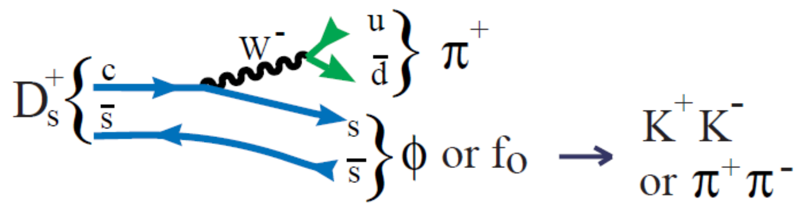
Further issues: does KK system has a S-wave component buried under Φ ? Stone & Zhang [PRD 79 (2009) 074024] estimate 5-10% possible. Not a worry right now but a headache in future. But this points way to another possibility…

…we can use $B_s \rightarrow J/\Psi\ f_0(980)[\rightarrow\pi\pi]$. P→VS so no angular analysis required !

$B_s \to J/\psi f_0(980)[\to \pi\pi]$

Xin Zhang (poster)

Advantage of this mode clear – and doesn't have problem of other channels with neutrals &/or high multiplicity in final state, eg. $B_s \to J/\psi\eta$, $J/\psi\eta'$, $\eta_c\Phi$, $D_s^+D_s^-$



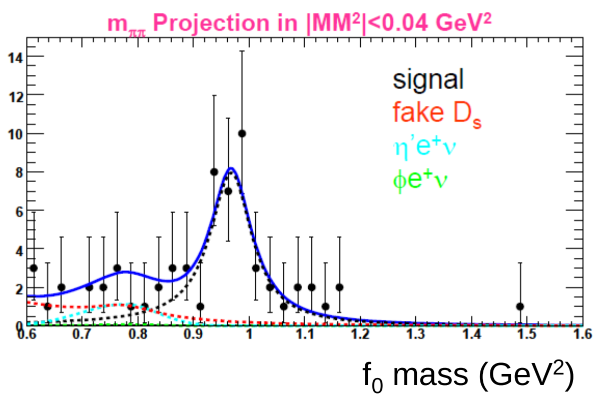
But what is relative rate w.r.t $J/\psi\Phi[\to KK]$? One estimate:

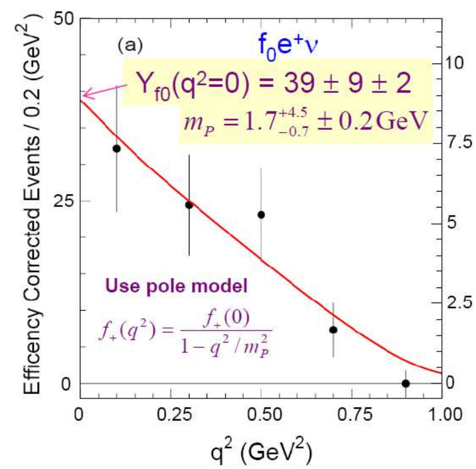
$$\frac{B_s \to J/\psi f_0[\to \pi\pi]}{B_s \to J/\psi\Phi[\to KK]} = \left.\frac{D_s \to f_0[\to \pi\pi]e^+\nu}{D_s \to \Phi[\to KK]e^+\nu}\right|_{q^2=0}$$

New CLEO-c preliminary result from 600 pb^{-1} at 4170 MeV:

$$\frac{\Gamma(D_s^+ \to f_0 e^+\nu, f_0 \to \pi^+\pi^-, q^2=0)}{\Gamma(D_s^+ \to \phi e^+\nu, \phi_0 \to K^+K^-, q^2=0)} = (42 \pm 11)\%$$

(from ~44 signal events)





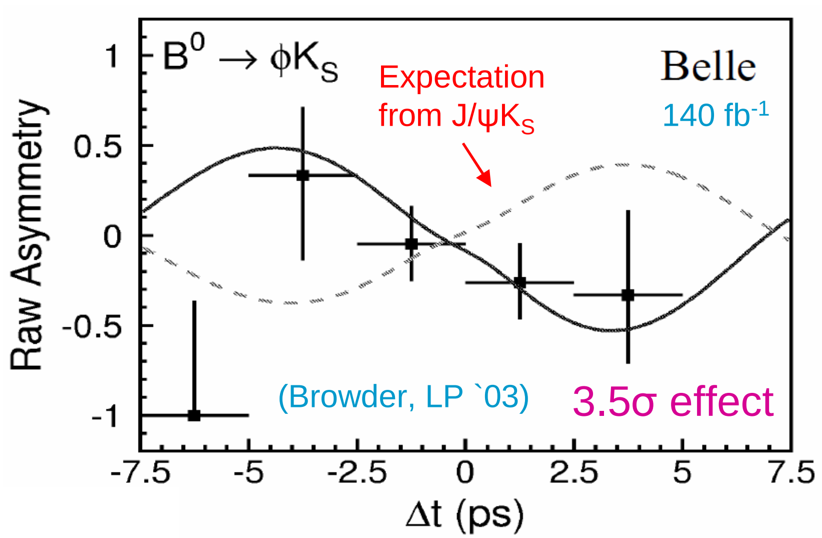
Very encouraging! Can the Tevatron have a look?

With this central value, mode would have β_s sensitivity approaching that of $J/\psi\Phi$

$\sin 2\beta_{eff}$ in $b \to s q \bar{q}$

Yusa | Dutta (poster)

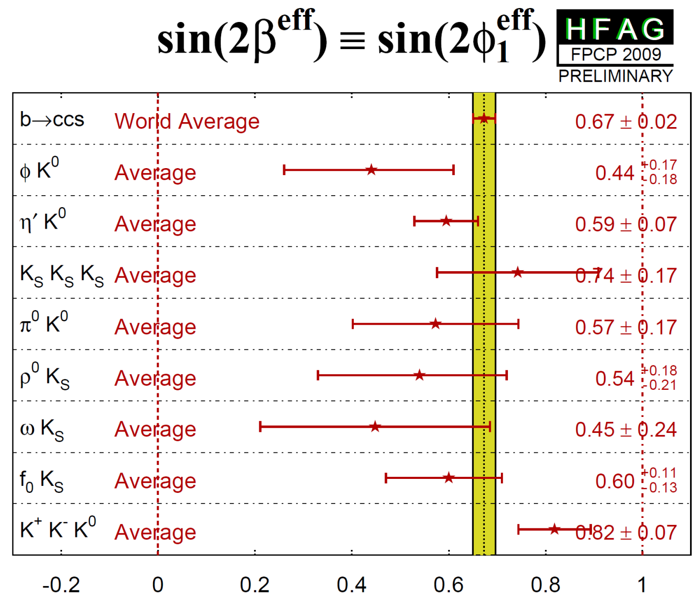
A true "It's Godot, we're saved!" moment



Since then:

- more data
- more modes
- more sophisticated analyses (eg. complete Dalitz treatments)

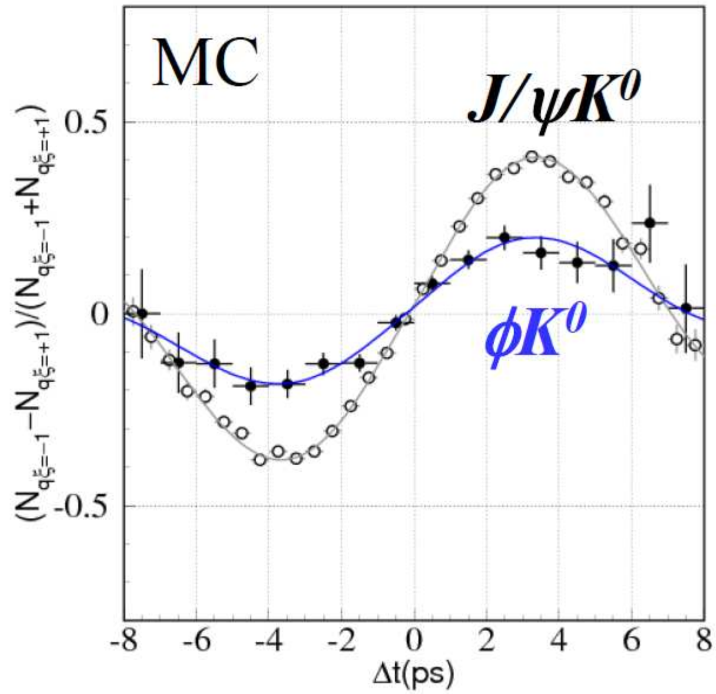
Present status not so encouraging.
ΦK_S now 1.3 σ away from b→ccs, and no other clear discrepancies



But overall tendency is intriguing, and recall that in general 'corrections' will accentuate discrepancy

Nil desperandum!

Superflavor: 50 ab^{-1} with present WA central values



T-dep asymmetries in b→sqq remain an ideal way to look for NP effects

Initial size of effect was way out of line with expectations. It has faded (but not disappeared)

We should not be discouraged from continuing with a precision programme (a salutary lesson for $B_s \to J/\psi\Phi$ perhaps?)

But further progess will not be immediate:

- LHCb will measure ΦK_S asymmetry to ~0.10 (10 fb^{-1}) but other modes difficult. However $B_s \to \Phi\Phi$ is a very promising alternative (σ_{Asymm} ~ 0.05 in 10 fb^{-1})
- Real precision era must await Superflavor Factory and LHCb upgrade (a ‘day after tomorrow’ prospect)

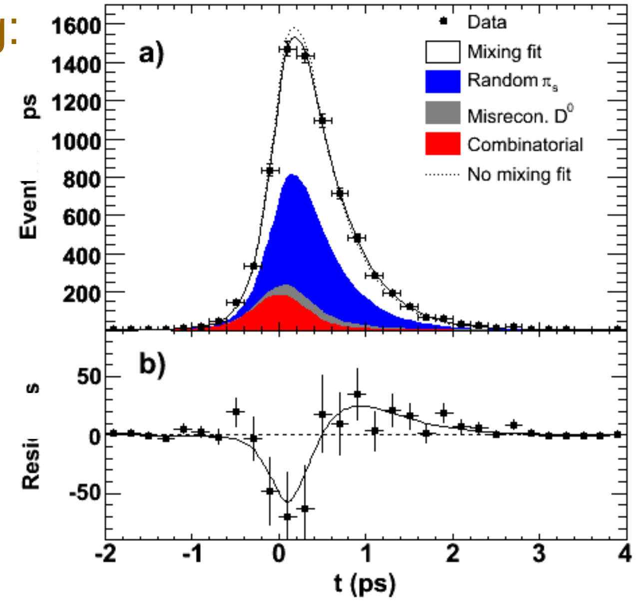
D^0-$\overline{D}^0$ Mixing: Observation

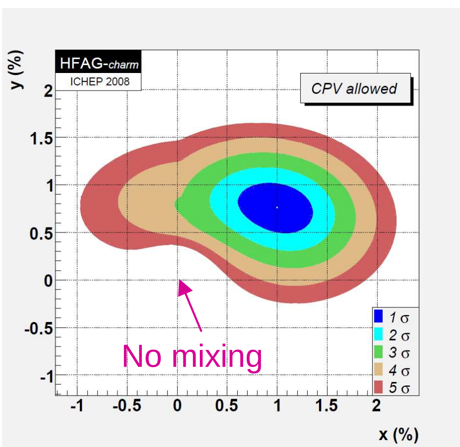
Golob (Sakai)

Numerous recent, exciting results on charm mixing:

The most interesting…

- 'Wrong sign' $K\pi$ (x'^2, y')
  - BELLE PRL 96 (2006) 151801
  - BaBar PRL 98 (2007) 211802
  - CDF PRL 100 (2008) 121802
- Eigenstate lifetime analyses: y_{CP}
  - BaBar arXiv:0712.2249
  - BELLE PRL 98 (2007) 211803
- $K_S\pi^+\pi^-$ Dalitz analyses: x,y
  - BELLE PRL 99 (2007) 131803





A whole armada of complementary analyses

Taken *together*, no doubt now that mixing exists…

$$x = 1.00 \pm^{0.24}_{0.26}\ \%$$

$$y = 0.76 \pm^{0.17}_{0.18}\ \%$$

(HFAG Aug 08, CPV allowed)

…but what does it mean?

Grossman, Neubert

D^0-$\overline{D}^0$ oscillations – the next step

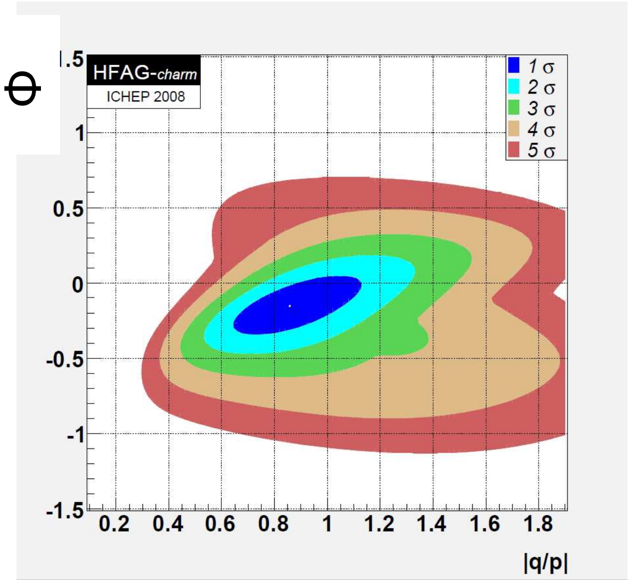
Values of x & y at top end of SM expectation – but *not* inconsistent. Use results to constrain many NP models. See, for example, Golowich et al. PRL 98 (2007) 181801.

'High' values of x & y encourage us to follow lessons of B sector - look for CPV !

In SM Φ=0 and |q/p|=1 is an almost perfect approximation. Looking for deviations from this a powerful NP probe, and one complementary to B / K-sector searches.

$|q/p| = 0.86 \pm^{0.17}_{0.15}$

$\phi = -8.8 \pm^{7.6}_{7.2}$ degrees



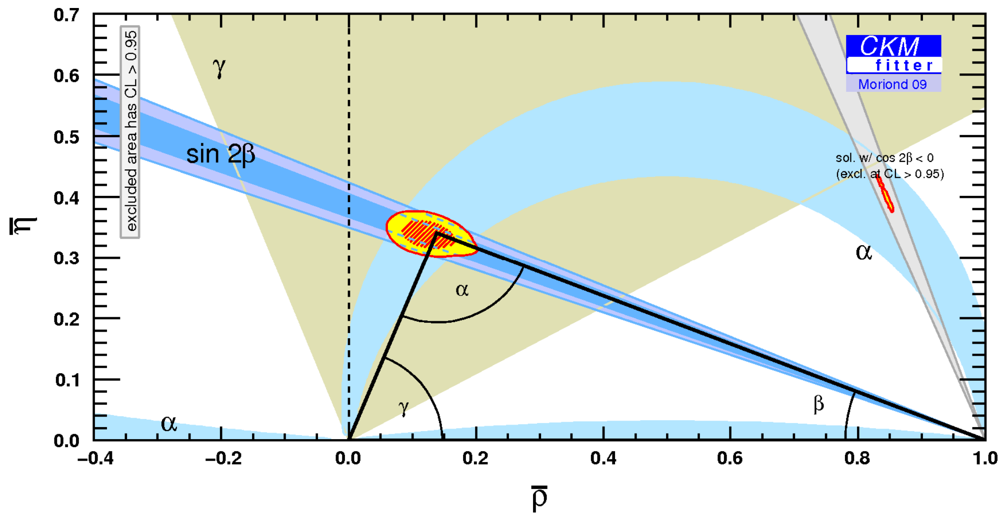
More results expected from B-factory and CDF.
With these, and LHCb order of magnitude improvement possible? Going still further is a strong argument for LHCb upgrade / project-X / superflavor factory

(For similar reasons, we must intensify the hunt for direct CPV in charm)

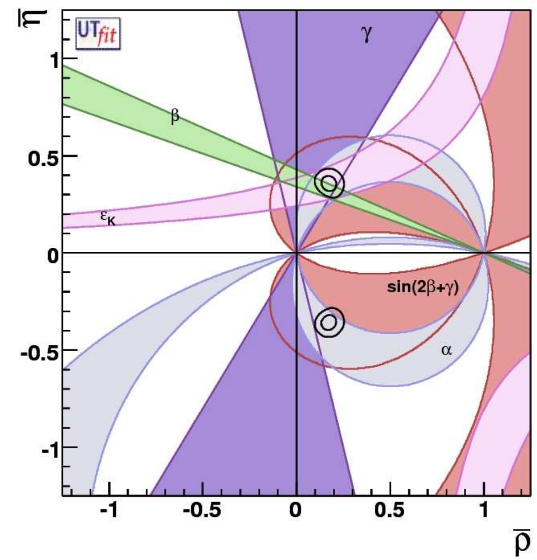
The Unitarity triangle: what is γ/Φ_3 ?

The least well known angle: γ / Φ_3

But how badly known is badly known ? Frequentists (CKMfitter) and Bayesians (UTfit) cannot agree, which is surely an indication that our knowledge is too fuzzy.



$\gamma = (70^{+27}_{-30})^o$



$\gamma = (78 \pm 12)^o$

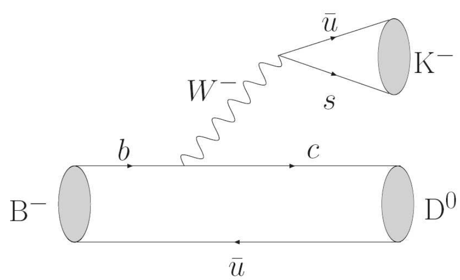
Furthermore γ is the only CP-violating observable that can be measured at tree level – a benchmark quantity to be measured as well as we possibly can.

γ from $B^\pm \rightarrow DK^\pm$

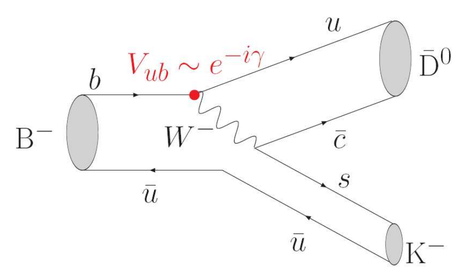
Rama

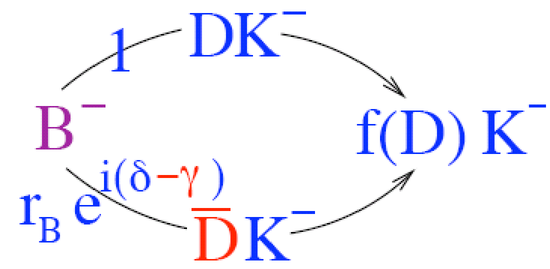
Most powerful way to measure γ is through 'B→DK' strategy:

$$B^- \longrightarrow D^0K^-$$



$$B^- \longrightarrow \overline{D}^0K^-$$





$$\frac{< B^- \longrightarrow \overline{D}^0K^- >}{< B^- \longrightarrow D^0K^- >} = r_B e^{i(\delta_B-\gamma)}$$

Here D final state is common to both D^0 and $\overline{D}^0$ – many, many possibilities:

$K^0_S\pi\pi$, K^0_SKK, $K\pi$, KK, $\pi\pi$, $K^0_S\pi^0$, $K\pi\pi\pi$, $K\pi\pi^0$ …

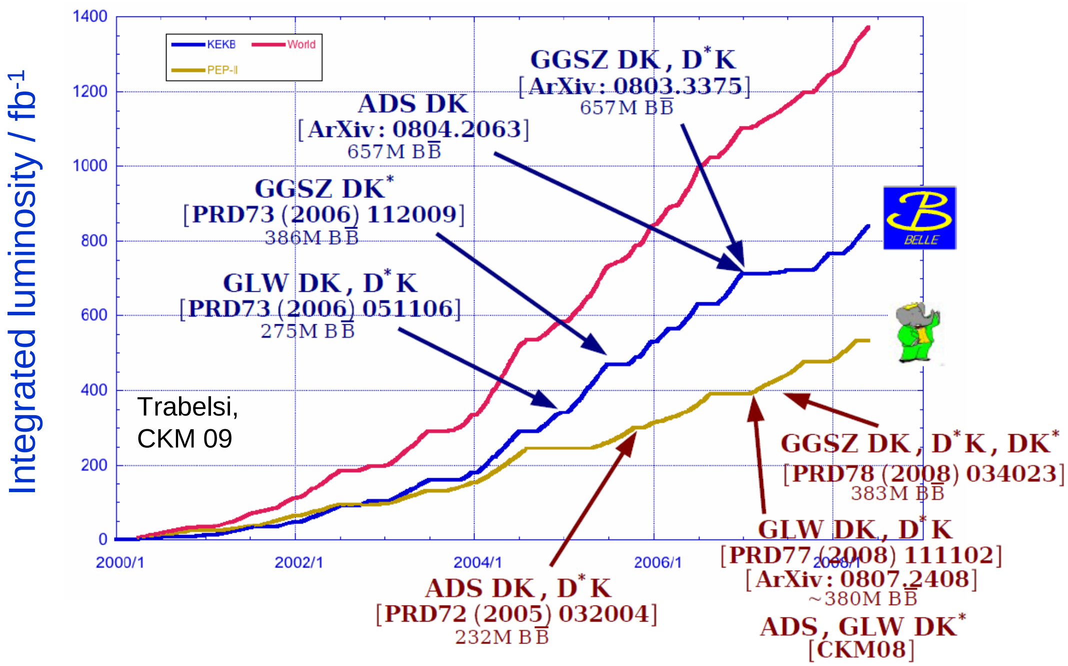
'whole is greater than the sum of the parts'

All B decay parameters in common – so important to exploit as many modes as possible. Beware, however, as each D/$\overline{D}$ decay (if not a CP-eigenstate) brings its own strong phase difference which needs to be known

γ prospects

Deschamps | Rama

B-factories have plenty more gas in the tank (see figure) and Tevatron also can contribute (see ‘GLW’ measurement with 1 fb^{-1}: CDF note 9109) :



Much unfinished business for the B-factories!

Hope for updates for FPCP 2010, 2011

Approach very suited to LHCb:

- self-tagging – full statistics can be used
- lots of kaons – RICH system invaluable

Precision of 2-3° with 10 fb^{-1} ?

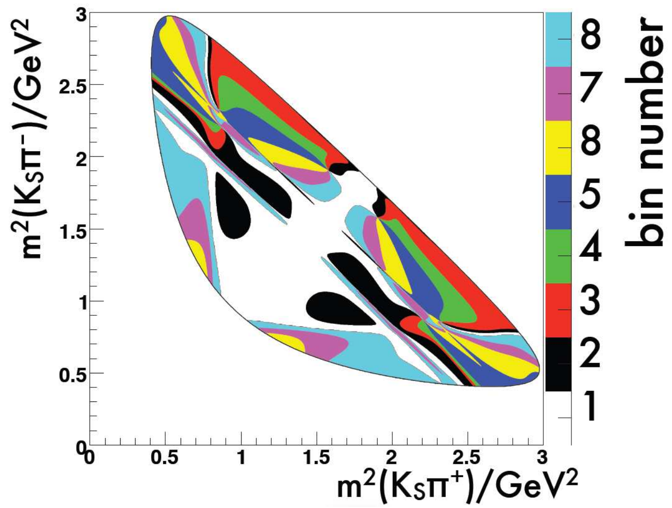
Rademacker | Briere

Brisbane (poster)

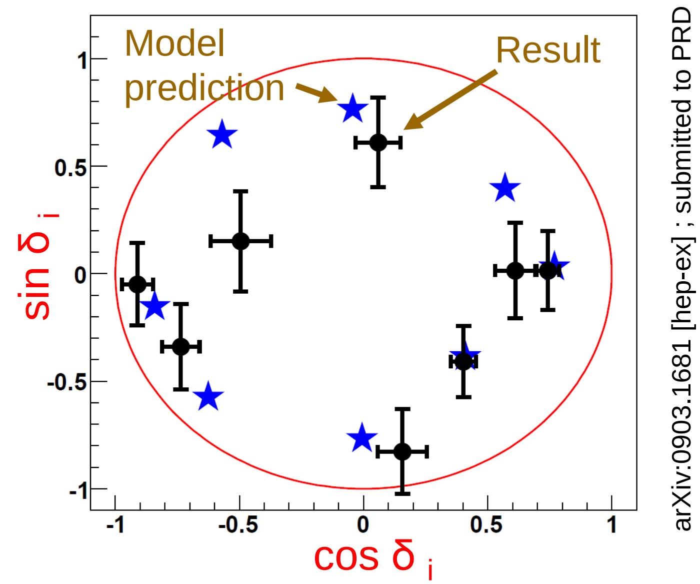
Synergy between facilities

B→DK analyses require knowledge of strong phase differences in D-decays. These can be measured in 'CP-tagged' Dalitz plot analyses at ψ(3770)

Eight bins of strong phase differences according to model developed in flavour-tagged $D^0 \to K_S\pi\pi$ decays



CLEO-c measurements of cosine and sine of these strong phase differences

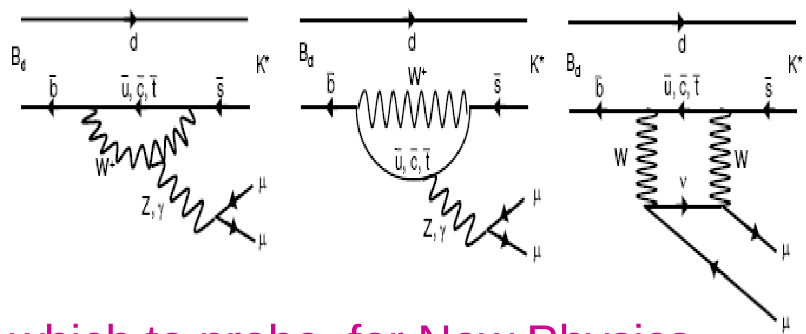


Such measurements will eliminate all model dependence from γ determination (pioneering measurements at CLEO-c to be augmented by high stats at BES-III)

‘Rare decays’: looking for Godot in CP-conserving processes

$B \to K^{(*)}l^+l^-$

Lunghi



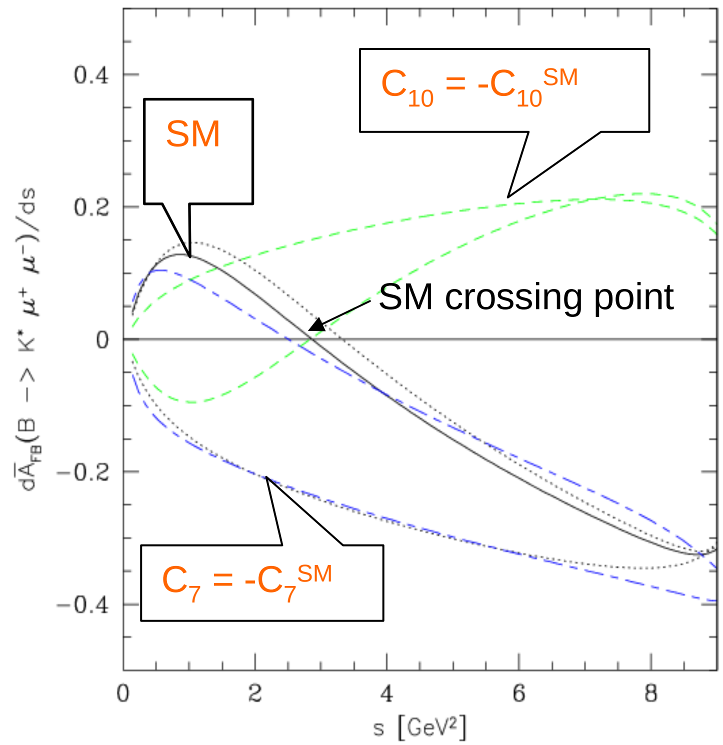
One of the most powerful laboratories in which to probe for New Physics effects in B decays is $B \to K^{(*)}l^+l^-$.

Host of interesting observables

Most promising in $K^*l^+l^-$ are angular distributions, eg. forward-backward asymmetry of the angle between lepton and B in the dilepton rest frame

sensitive to effective Wilson coefficients C_7, C_9 and C_{10}

Position of zero-asymmetry 'crossing-point' rather cleanly predicted in SM, but also sensitive to new physics effects



Ali *et al.* PR D61 (2000) 074024

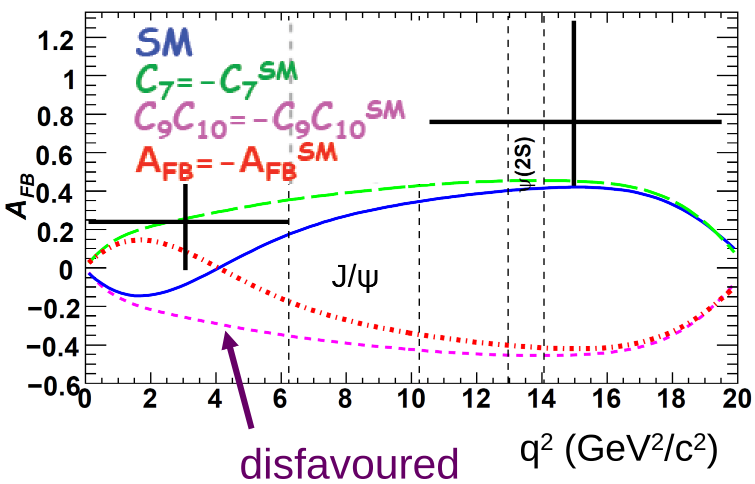
$B \rightarrow K^{(*)} l^+ l^-$: state of play

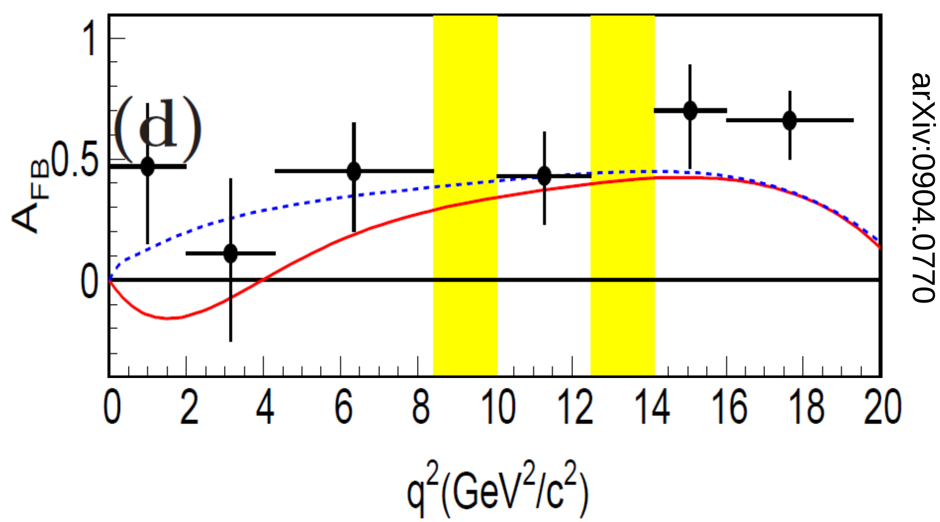
Salvati

BaBar: 384 million BBbars analysed
~100 $K^* l^+ l^-$ events

Belle: 657million BBbars analysed
~250 $K^* l^+ l^-$ events

PRL 102 091803 ; PRD 79 031102





arXiv:0904.0770

Intriguing shape perhaps emerging, but poor precision – need much higher statistics!

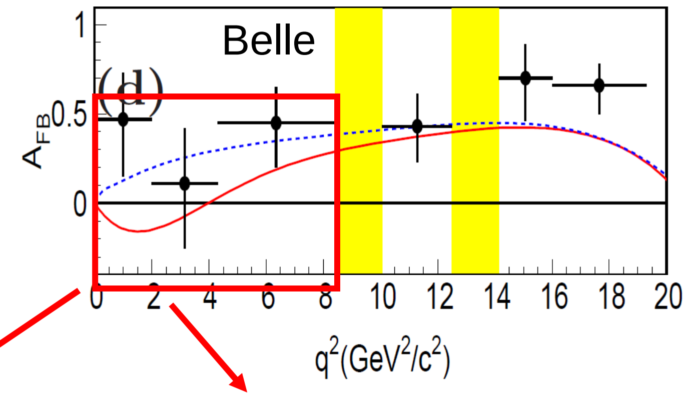
(Also interesting behaviour in isospin asymmetry at low q^2. BaBar see 3.9σ excursion from zero, Belle a 2.4σ effect)

CDF have ~20 $K^*\mu\mu$ events in 1 fb^{-1} (PRD 79 011104)

B→K*l⁺l⁻ at the LHC

Deschamps

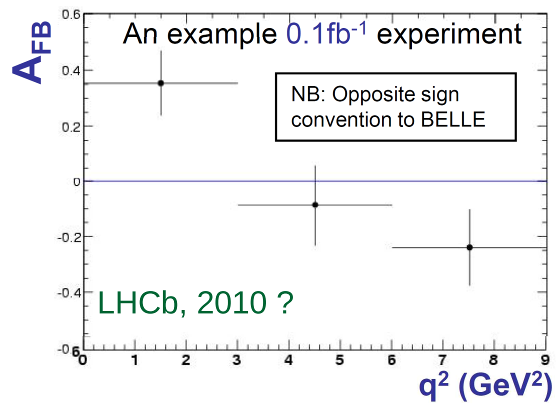
In 0.1 fb^{-1} LHCb will accumulate in K*μμ similar statistics to present Belle analysis (e^+e^- + $\mu^+\mu^-$)
(Ergo, no new physics discovery here in 2010 ?)

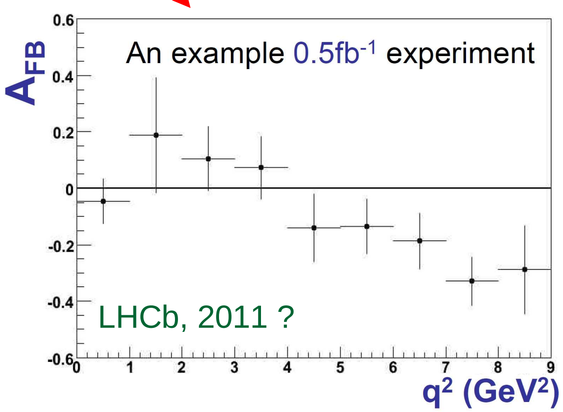


Initial asymmetry determination will proceed through counting analysis

LHCb precision on
q^2 of crossing-point

0.5 fb^{-1}	0.8 GeV^2
2 fb^{-1}	0.5 GeV^2
10 fb^{-1}	0.3 GeV^2





Better than present theory
error on prediction ~ 0.32. Improved precision (~0.12) exists in inclusive prediction – SuperB !

Full angular analysis will allow amplitudes to be extracted and other asymmetries to be Formed [Egede et al., JHEP 0811:0322,2008] – will benefit from upgrade statistics.

Neubert, Grinstein

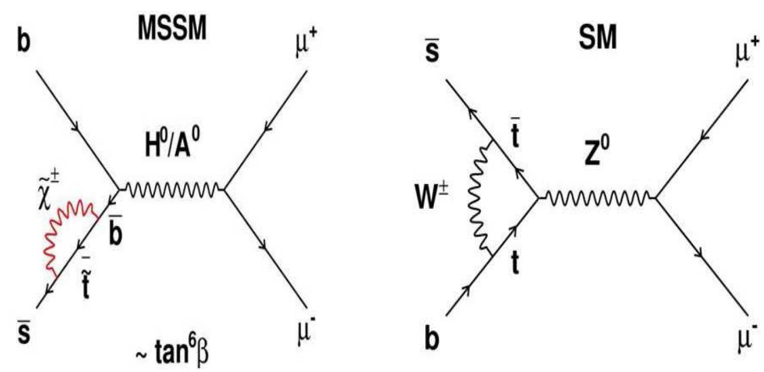
Godot will come tomorrow: $B_s \to \mu\mu$

B physics rare decay par excellence:

$BR(B_s \to \mu\mu)_{SM} = (3.35 \pm 0.32) \times 10^{-9}$

(Blanke et al., JHEP 0610:003,2006)

Precise prediction (which will improve) !



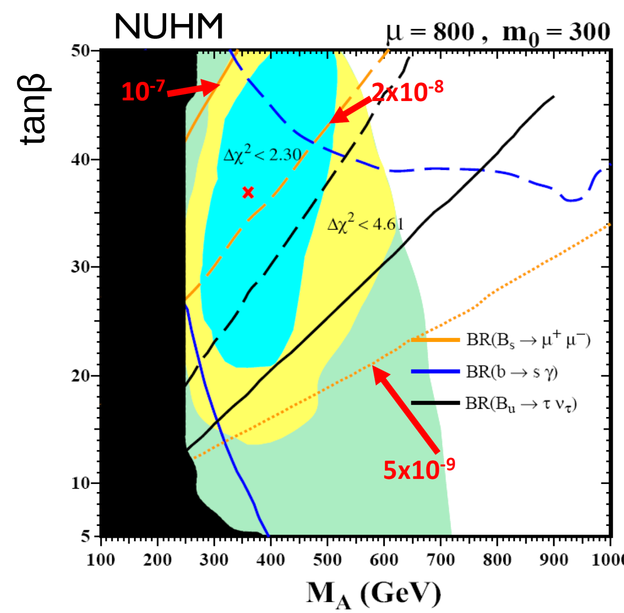
Very high sensitivity to NP, eg. MSSM:

$$Br^{MSSM}(Bq \to l^+l^-) \propto \frac{m_b^2 m_l^2 \tan^6\beta}{M_{A0}^4}$$

One example (Ellis et al., JHEP 0710:092,2007) with NUHM (= generalised version of CMSSM)

- $b \to s\gamma$ and Higgs > 114.4 GeV
  ➡ M_A > ~ 300 GeV & tanβ < ~50
- $(g_\mu$-2) is 3.4σ from SM
  ➡ M_A < ~ 500 GeV & tanβ > ~20

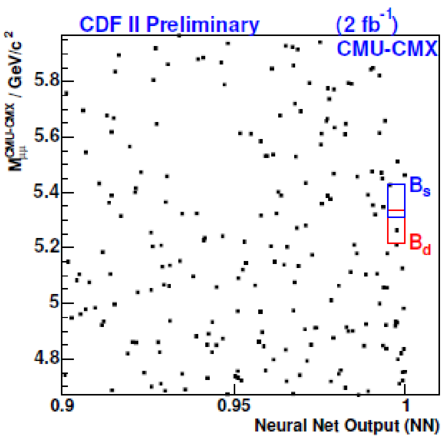
$BR(B_s \to \mu\mu) \approx 2 \times 10^{-8}$

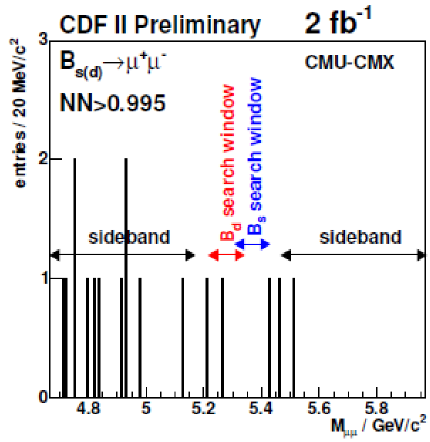


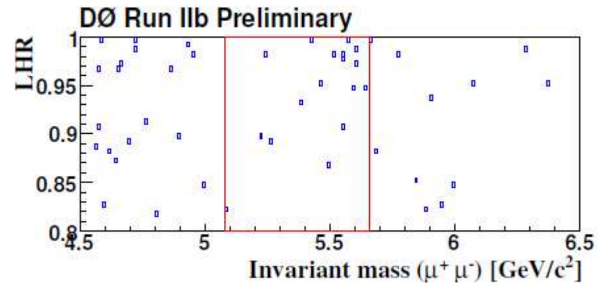
Scuri

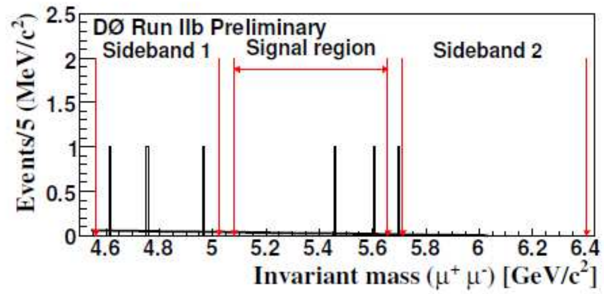
Tevatron $B_s \rightarrow \mu\mu$: status and prospects

Both experiments make a loose preselection and then use a likelihood (D0) or NN (CDF) to isolate signal like events (muon quality, flight distance, isolation etc). Normalise what is seen to $B^+ \rightarrow J/\psi K^+$.









Limit 90% (95%) × 10^8	$B^0_s \rightarrow \mu\mu$	$B^0_d \rightarrow \mu\mu$
Previous best	9.4	3.9
BaBar [PRD 77, 032007 (2008)]	n/a	5.2
DØ (Note 5344)	7.5 (9.3)	n/a
CDF [PRL 100, 101802 (2008)]	4.7 (5.8)	1.5 (1.8)

D0 have improved analysis and expect 90% CL upper limit of 4.3 x 10^{-8} with 5 fb^{-1} (Note 5906)

Still better expected from CDF → Tevatron now entering a very interesting regime!

$B_s \to \mu\mu$ at LHCb

Deschamps

Bettler (poster)

LHCb approach will be philosophically similar to Tevatron's: loose preselection (which is optimised to have similar efficiency for signal and control channels: $B_{(s)} \to h^+h^-$, $B^+ \to J/\psi K^+$, $B \to J/\psi K^*$), and then construction of global likelihood

Global likelihood built from:

- 'Geometrical likelihood' (topology & lifetime info)
- Invariant mass likelihood
- Particle id likelihood

(Signal calibrated on control channels; background from sidebands)

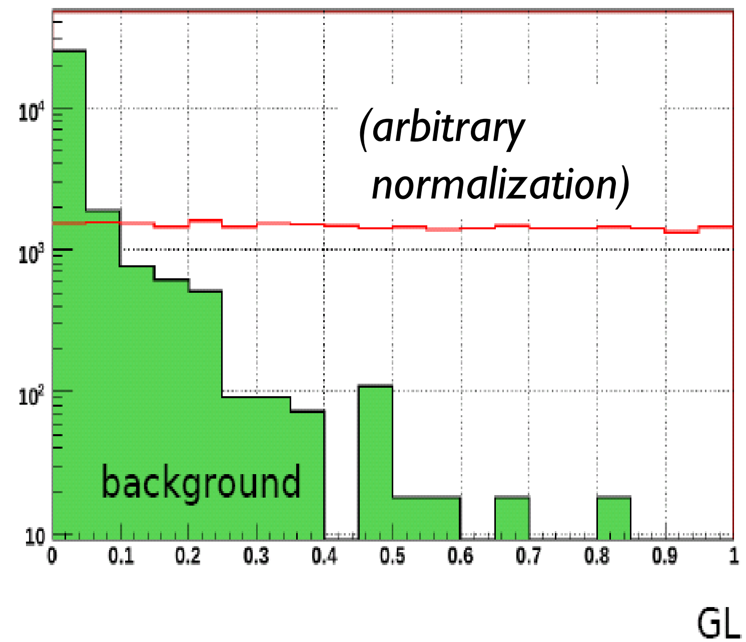
Observation then turned into limit or BR measurement after comparing with known control channel, eg. $B^+ \to J/\psi K^+$

Remark – uncertainty on B_s/B^+ production ratio (~13%) an annoying systematic. Improved measurements of B_s BRs at $\Upsilon(5S)$ from Belle would be interesting.

$$\mathcal{B}(B_s^0 \to D_s^- \pi^+) = (3.67^{+0.35}_{-0.33}(\text{stat})^{+0.43}_{-0.42}(\text{syst}) \pm 0.49(f_s)) \times 10^{-3}$$

~20% with 24 fb^{-1}

[Belle, PRL 102 (2009) 021801]

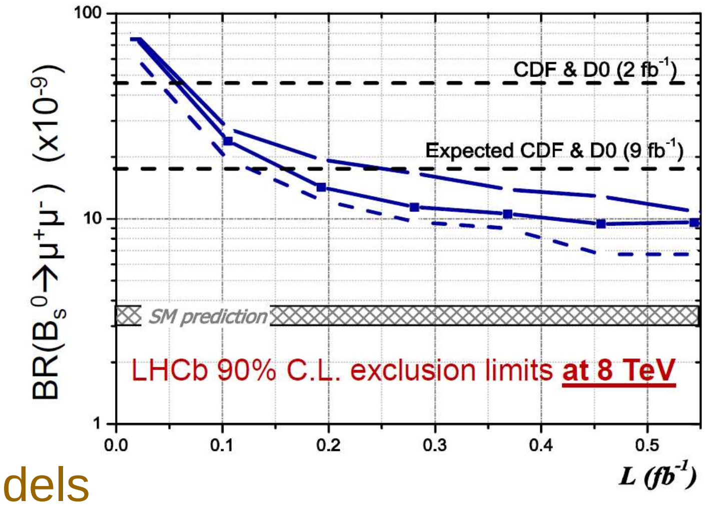


Deschamps, Pegna

Bettler, Grybel (posters)

LHC 2010 prospects for $B_s \to \mu\mu$

For 0.1-0.2 fb^{-1}, limit should be ~ 2×10^{-8} - similar to that of the Tevatron



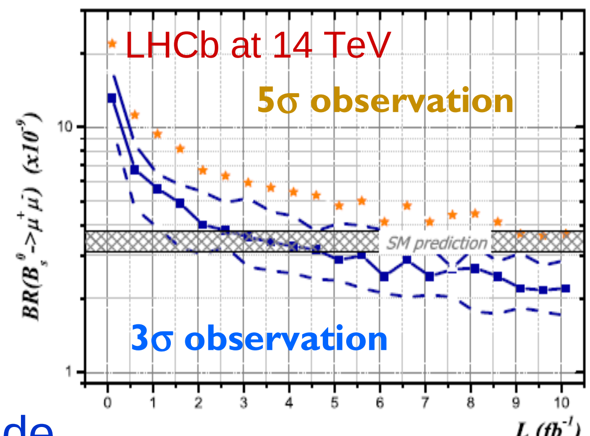
Contributions in this ballpark will also come from ATLAS/CMS

CERN, or indeed worldwide combination could be useful?
Will ask interesting questions of many models

Even better – an observation!

- 2×10^{-8} could be observed at 5σ with ~0.5 fb^{-1}
- SM requires 10 fb^{-1}

} LHCb at 14 TeV



Once observed *need* to measure BR as well as possible. If SM-like this would require upgrade…

The Lepton Sector

- Neutrinos: tracking down Θ_{13}
- LFV: of front-rank importance, but I have no time – apologies!

Dukes Simonetto

Prospects with neutrinos

Dornan

De Gouvea

In the next 5 years we are unlikely (???) to uncover New Physics in neutrinos (but recall $m_\nu \neq 0$ IS a non-SM result). First we need to gain sensitivity to all elements of the PMNS matrix and map out the mass spectrum.

Immediate challenge: measure / better constrain Θ_{13}

Reactor:
ν_e disappearance in ν_e beam

	start	$\sin^2 2\theta_{13}$
Double Chooz	2009-10	>~0.02
Daya Bay	2011	>~0.01
RENO	2011	>~0.02

No matter effects – but small 'signal'

Off-axis superbeam:
ν_e appearance in ν_μ beam

- T2K (~now)

(Kato, Neutrino 08)

Expected number of events at SK (0.75kW beam x 5yr)

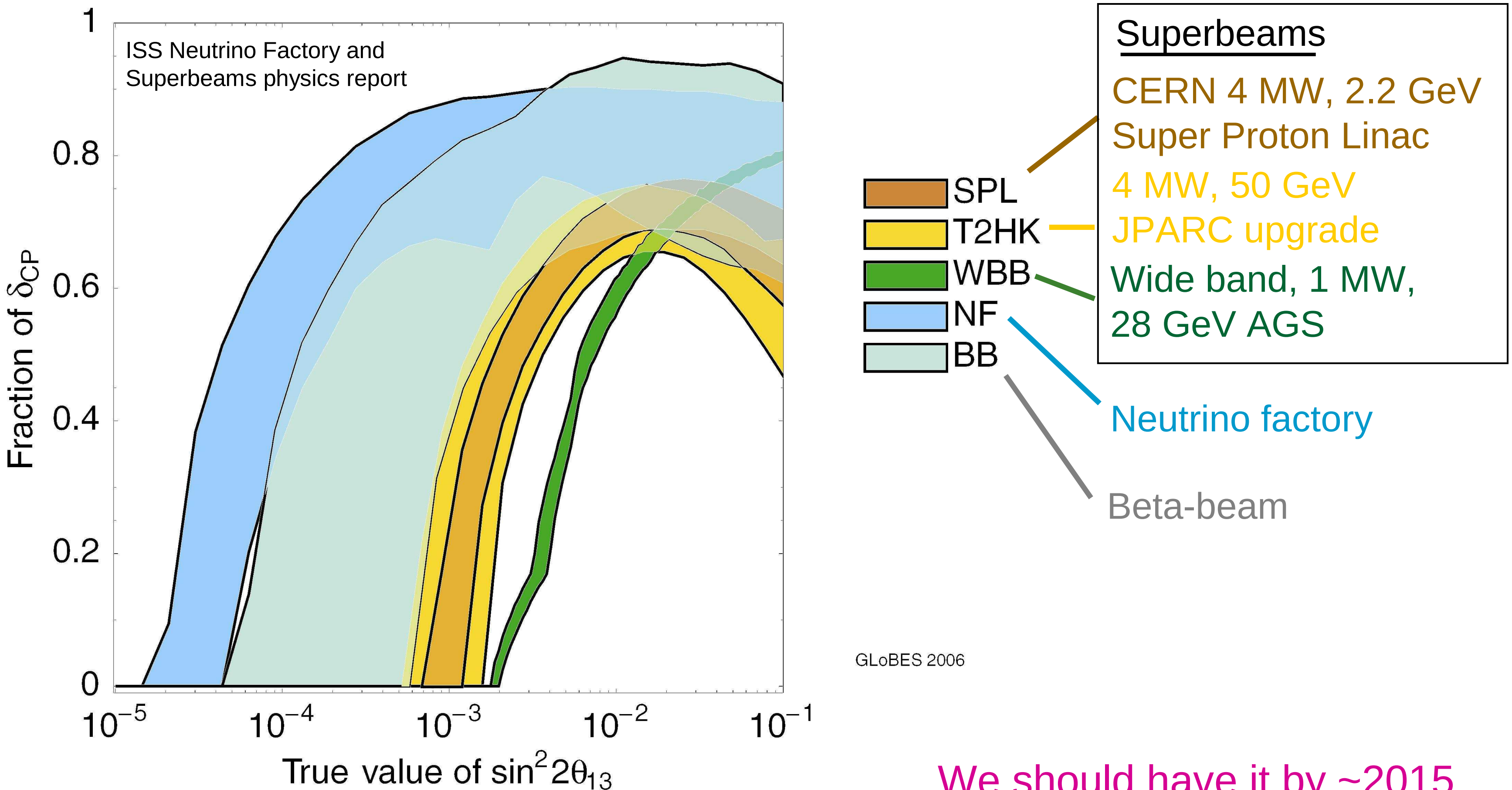
$\sin^2 2\theta_{13}$	Backgrounds			Signal
	ν_μ induced	Beam ν_e	**Total**	
0.1	10	13	**23**	**103**
0.01				**10**

- Nova (2012)

Similar performance – with better sensitivity to mass hierarchy

Neutrino physics: the day after tomorrow

Better knowledge of θ_{13} is essential to decide on next generation of experiments



We should have it by ~2015

Our wait may soon be at an end

The next 5 years hold rich promise

At the least - significant improvements in precision:

- γ / ϕ_3
- A_{FB} in $K^*l^+l^-$
- Charm: mixing and the race for CPV
- Θ_{13}

Real possibilities of NP signals / *fierce* constraints *very* soon:

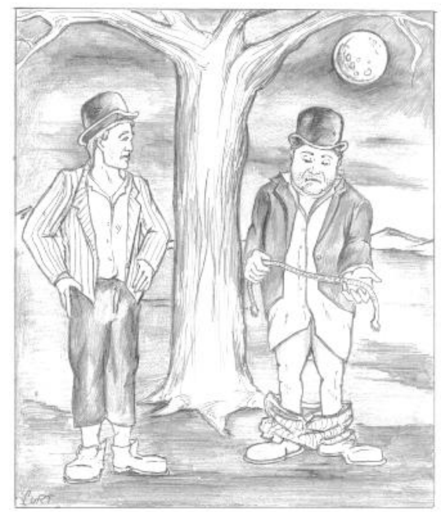
- β_s in $B_s \rightarrow J/\psi\Phi$: we will know soon if the hints are correct, or we are in for the longer haul (if so nil desperandum!)
- $B_s \rightarrow \mu\mu$: this may well be THE result of the first LHC run

A reason to be cheerful – Godot may soon arrive!

But it will take longer to learn who he is.

ie. what *is* the nature of the new physics

VLADIMIR:
We'll hang ourselves tomorrow… Unless Godot comes.



ESTRAGON:
And if he comes?

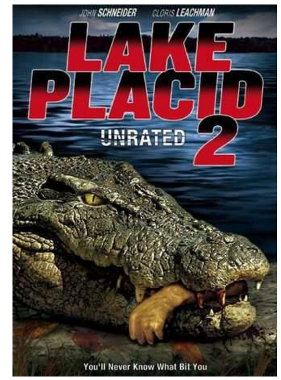
VLADIMIR:
We'll be saved.

Not all sequels live up to the original…

"One of the best-written movies I've ever seen",
Bob Stout, Texas,

"Well, they tried, I guess"
Davidm-14, Seattle

"Worst sequel ever?"
www.imdb.com



"Feed it to the croc"
MartianCreature, Redondo Beach, CA

…but this one did

"Conference of the century!"
Themis Bowcock, Liverpool

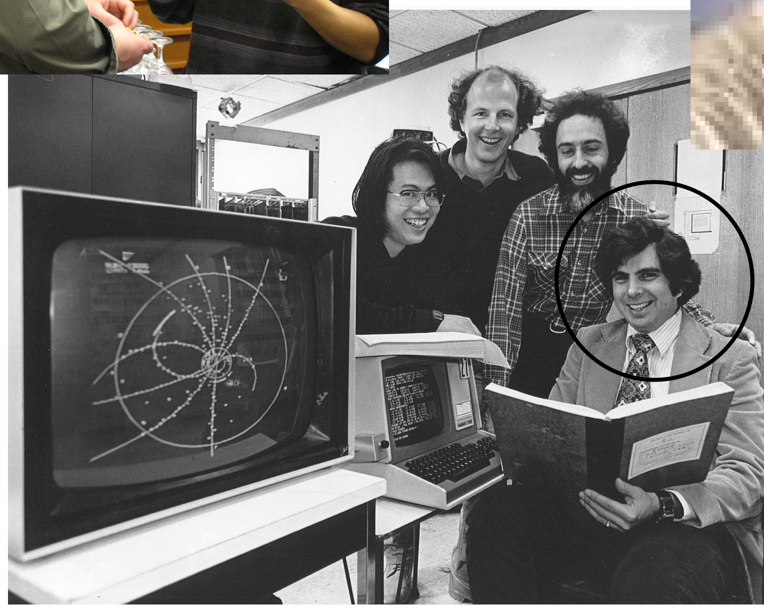
"All perfect (apart from Sheldon's map-reading)"
Paula Collins, CERN

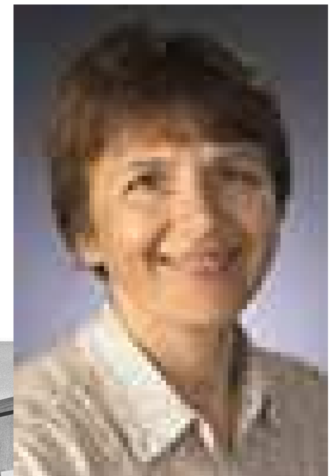
"A joy from start to finish"
Jeff Appel, FNAL

"I learnt so much!"
Peter Dornan, IC

Many thanks to the organisers !

+ Alessandra,
  Victor,
  Sadia, Liming

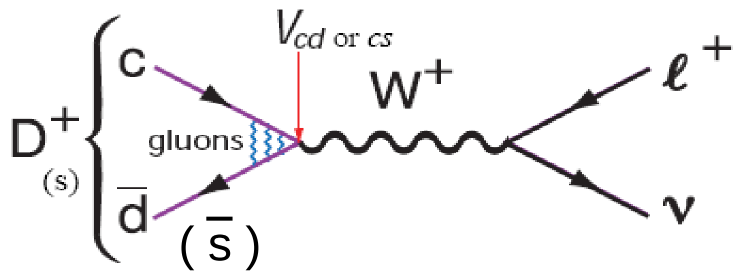




Backups

Leptonic D Decays and Decay Constants

In D^+ and D_s c and spectator quark can annihilate to produce leptonic final state:



In general, for all pseudoscalars:

$$\Gamma(P^+ \to \ell^+\nu) = \frac{1}{8\pi} G_F^2 f_P^2 m_\ell^2 M_P \left(1 - \frac{m_\ell^2}{M_P^2}\right)^2 |V_{Qq}|^2$$

Since V_{cd} and V_{cs} well known, can extract f_D and f_{D_s} and compare with lattice !

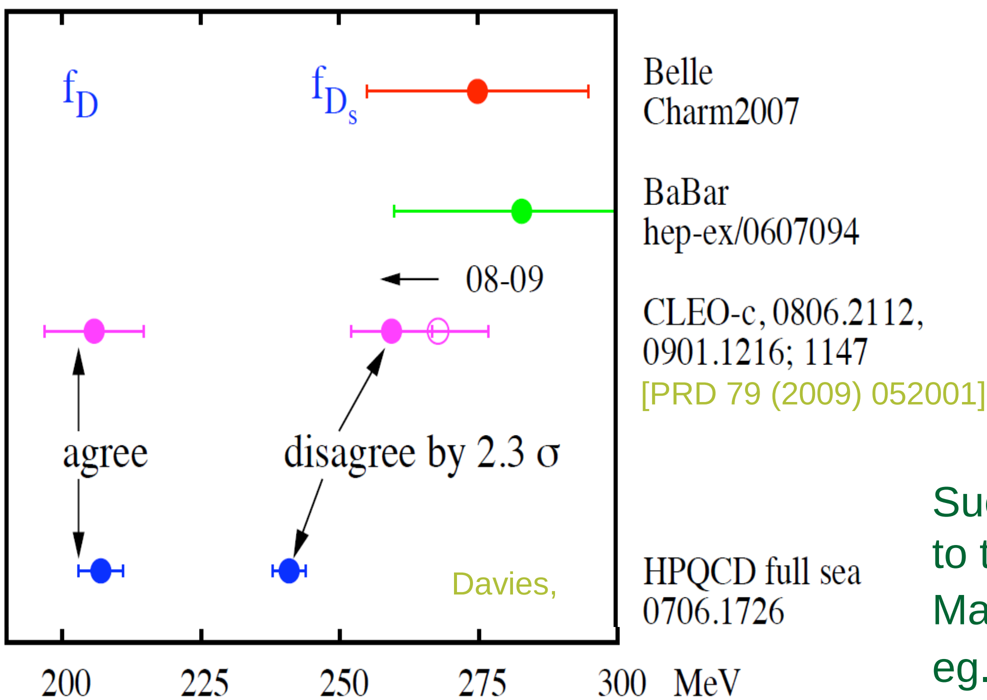
Important confidence building exercise for using lattice calculations in B-sector, which are critical ingredients in unitarity triangle tests

Results for f_{D_s} from BaBar, BELLE and CLEO-c, and for f_D from CLEO-c

Curiouser and curiouser

Briere Davies
Kahlil (poster)

Consistency between measurement and lattice QCD in f_D, but tension for f_{D_s}, although this has eased a little in last year with final CLEO-c results



Preliminary
HFAG average:

f_{D_s} = 263.9 ± 6.7 MeV

disagreement with lattice (HPQCD) is 3.1 sigma

Such a discrepancy is in opposite sense to that expected through a charged Higgs. Maybe something more exotic?

eg. PRD 78 (2008) 015009; PRL 100 (2008) 241802

This needs resolving ! New results on f_{D_s} expected from B-factories, but clarification will probably only come from BES-III when it takes data at 4170 MeV