Update on flavour facilities

Tim Gershon
University of Warwick

PPAP community meeting
Birmingham University – 5th July 2010

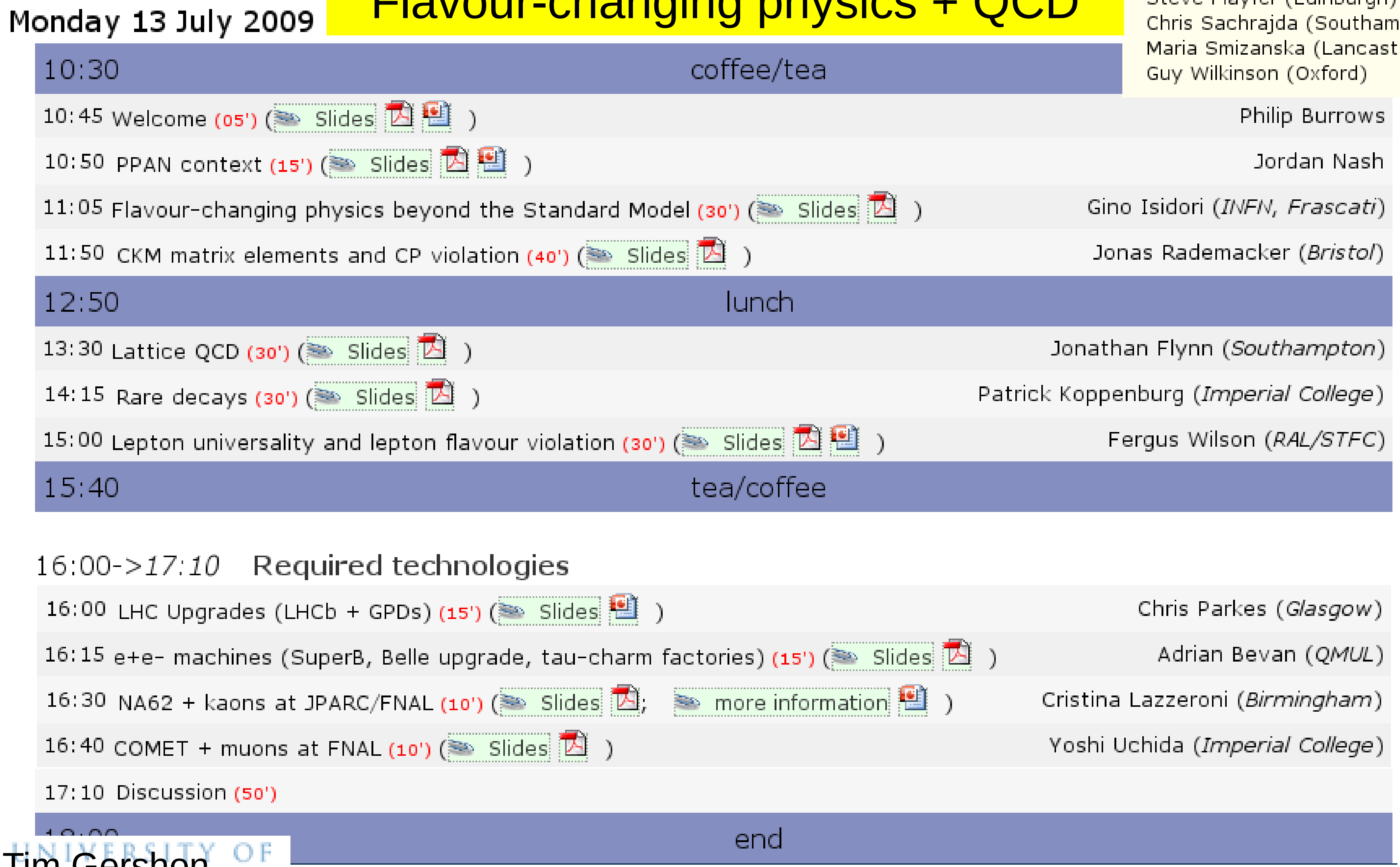
Thanks for input:
Adrian Bevan, Guennadi Borissov, Neville Harnew,
Cristina Lazzeroni, Franz Muheim,
Chris Parkes, Yoshi Uchida, Fergus Wilson

One year ago ...

Programme committee:

Nigel Glover (IPPP) - Chair
Tim Gershon (Warwick) - Deputy
Christine Davies (Glasgow)
Val Gibson (Cambridge)
Cristina Lazzeroni (Birmingham)
Steve Playfer (Edinburgh)
Chris Sachrajda (Southampton)
Maria Smizanska (Lancaster)
Guy Wilkinson (Oxford)

Flavour-changing physics + QCD



Monday 13 July 2009

10:30	coffee/tea	
10:45	Welcome (05') (Slides)	Philip Burrows
10:50	PPAN context (15') (Slides)	Jordan Nash
11:05	Flavour-changing physics beyond the Standard Model (30') (Slides)	Gino Isidori (*INFN, Frascati*)
11:50	CKM matrix elements and CP violation (40') (Slides)	Jonas Rademacker (*Bristol*)
12:50	lunch	
13:30	Lattice QCD (30') (Slides)	Jonathan Flynn (*Southampton*)
14:15	Rare decays (30') (Slides)	Patrick Koppenburg (*Imperial College*)
15:00	Lepton universality and lepton flavour violation (30') (Slides)	Fergus Wilson (*RAL/STFC*)
15:40	tea/coffee	

16:00->*17:10* **Required technologies**

16:00	LHC Upgrades (LHCb + GPDs) (15') (Slides)	Chris Parkes (*Glasgow*)
16:15	e+e- machines (SuperB, Belle upgrade, tau-charm factories) (15') (Slides)	Adrian Bevan (*QMUL*)
16:30	NA62 + kaons at JPARC/FNAL (10') (Slides ; more information)	Cristina Lazzeroni (*Birmingham*)
16:40	COMET + muons at FNAL (10') (Slides)	Yoshi Uchida (*Imperial College*)
17:10	Discussion (50')	
	end	

Update on flavour facilities

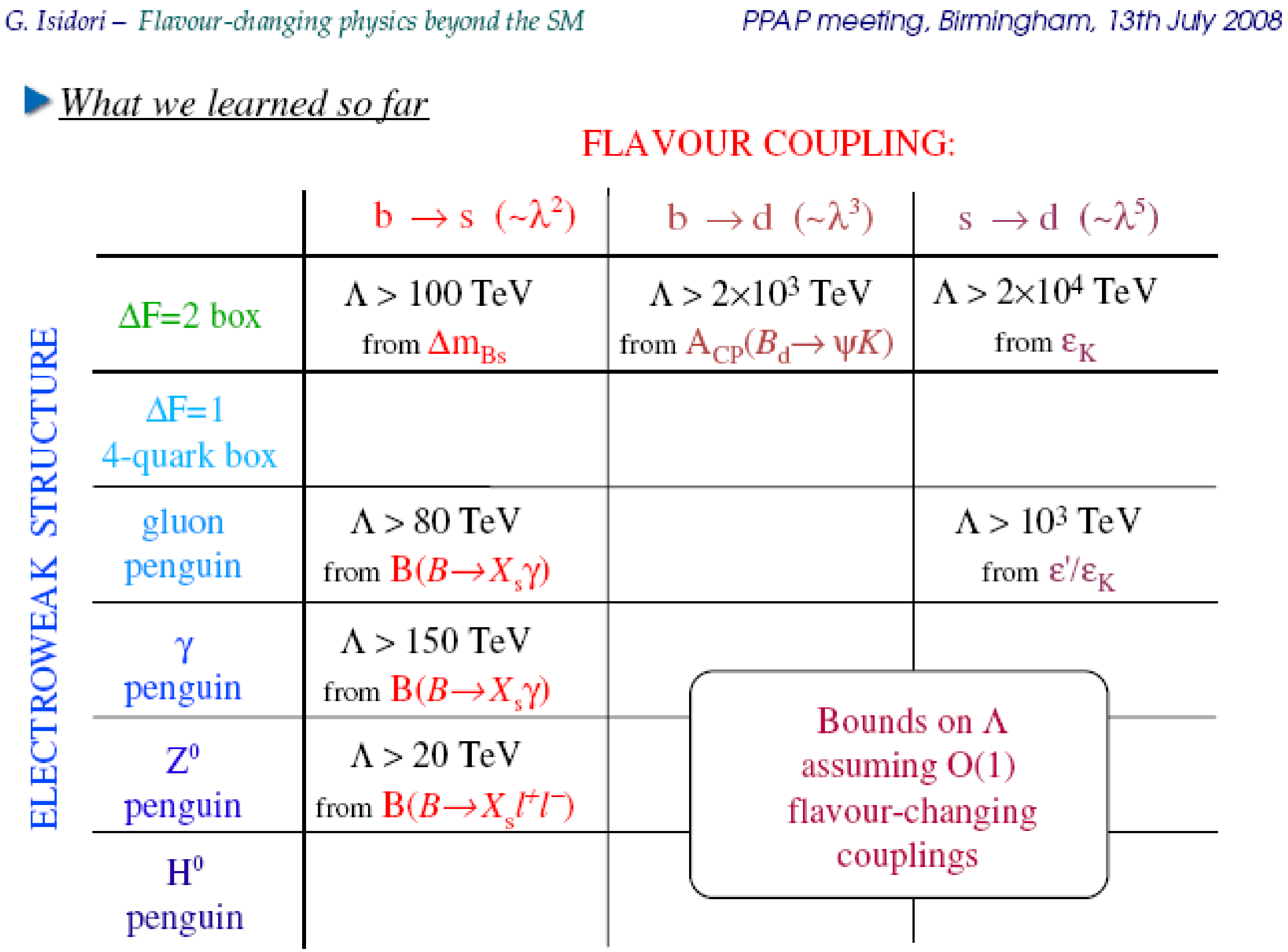
- Will not try to cover everything
  - Please refer to the excellent talks on 13 July 2009
  - Theory covered by Mike Seymour today
  - Apologies for omissions
- Brief recap: why flavour?
- Physics highlights of last 12 months
  - a.k.a. “status of managed withdrawal”
- Update on global status and developments
  - Tevatron, LHC (GPDs & LHCb), LHCb upgrade, e^+e^- flavour factories, kaons, muons

Why flavour?

- New physics usually shows up at precision frontier before energy frontier
  - GIM before discovery of charm
  - CP violation / CKM before discovery of bottom & top
  - Neutral currents before discovery of Z
- Particularly sensitive: loop processes
  - Standard Model contributions suppressed / absent
  - flavour changing neutral currents (rare decays)
  - CP violation
  - lepton flavour / number violation / lepton universality

But we haven't seen new physics yet

More details: Isidori, Nir, Paz http://arxiv.org/abs/1002.0900



G. Isidori – *Flavour-changing physics beyond the SM* PPAP meeting, Birmingham, 13th July 2008

▶ *What we learned so far*

FLAVOUR COUPLING:

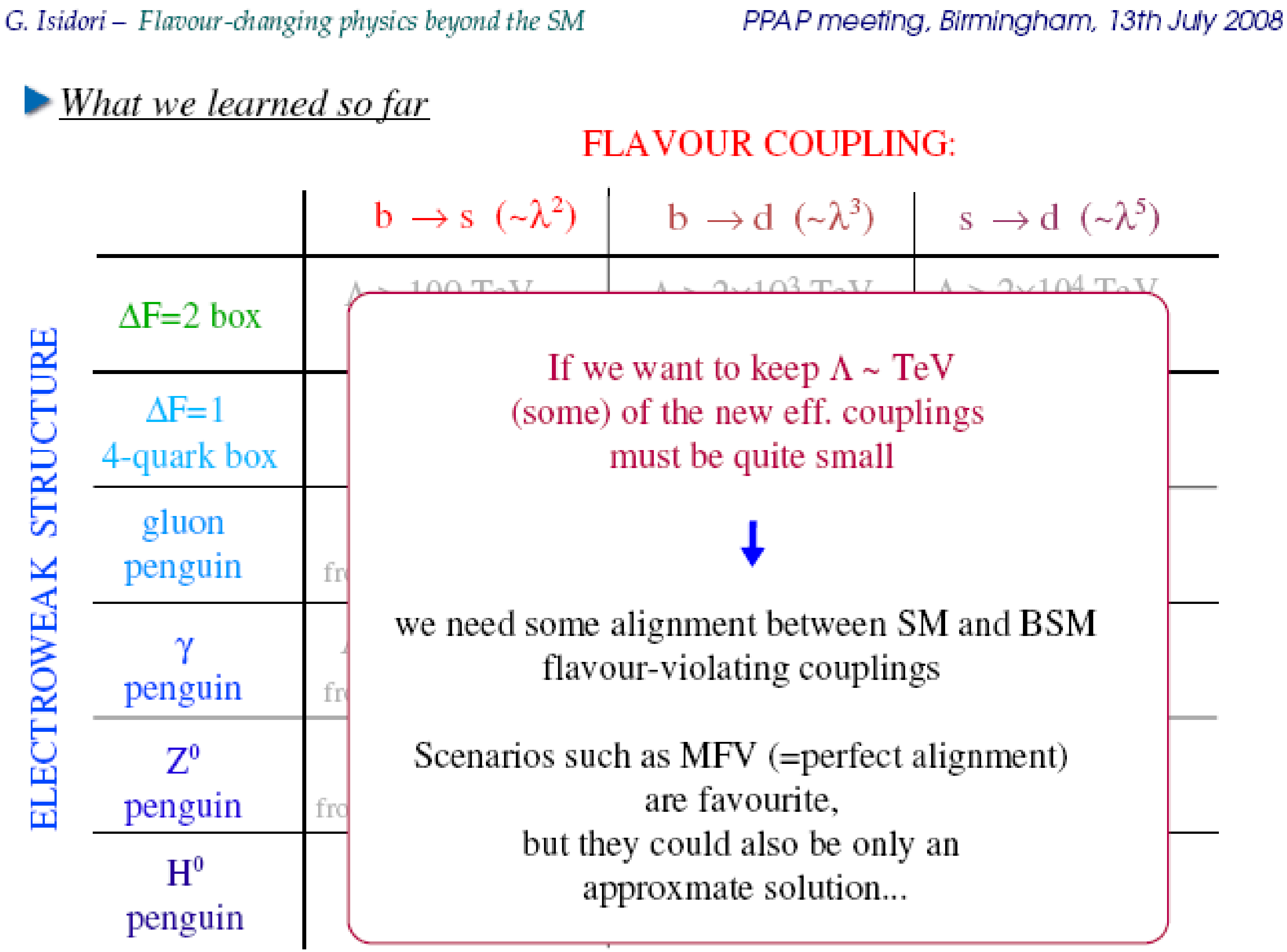
ELECTROWEAK STRUCTURE

	$b \to s$ $(\sim\lambda^2)$	$b \to d$ $(\sim\lambda^3)$	$s \to d$ $(\sim\lambda^5)$
$\Delta F=2$ box	$\Lambda > 100$ TeV from Δm_{B_s}	$\Lambda > 2\times10^3$ TeV from $A_{CP}(B_d \to \psi K)$	$\Lambda > 2\times10^4$ TeV from ε_K
$\Delta F=1$ 4-quark box			
gluon penguin	$\Lambda > 80$ TeV from $B(B \to X_s\gamma)$		$\Lambda > 10^3$ TeV from $\varepsilon'/\varepsilon_K$
γ penguin	$\Lambda > 150$ TeV from $B(B \to X_s\gamma)$		
Z^0 penguin	$\Lambda > 20$ TeV from $B(B \to X_s l^+ l^-)$		
H^0 penguin			

Bounds on Λ assuming O(1) flavour-changing couplings

“New Physics flavour problem”?

But we haven't seen new physics yet



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ΔF=1 4-quark box			
gluon penguin	fr		
γ penguin	fr		
Z^0 penguin	fro		
H^0 penguin			

If we want to keep Λ ~ TeV
(some) of the new eff. couplings
must be quite small

↓

we need some alignment between SM and BSM
flavour-violating couplings

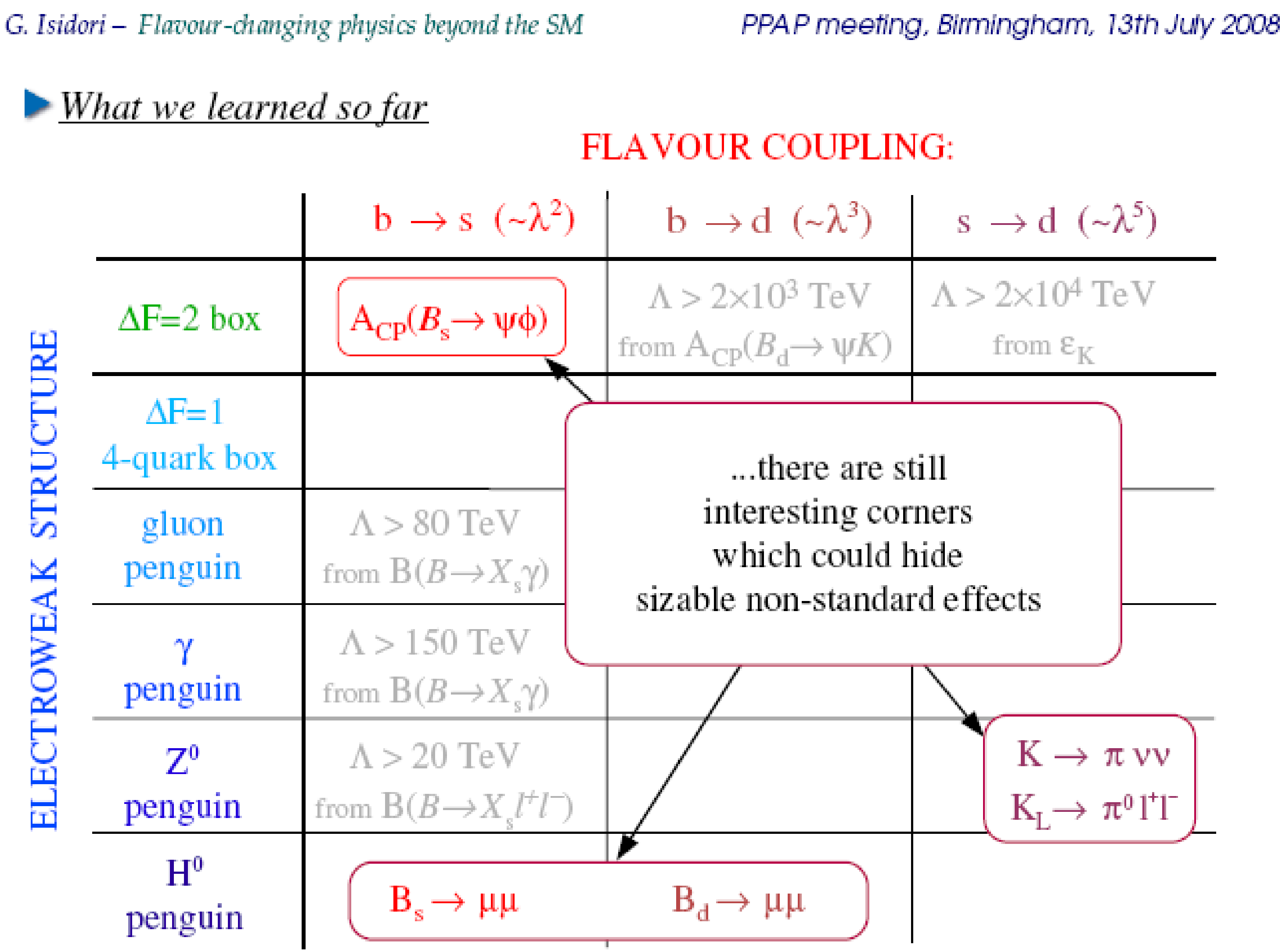
Scenarios such as MFV (=perfect alignment)
are favourite,
but they could also be only an
approxmate solution...

More details: Isidori, Nir, Paz http://arxiv.org/abs/1002.0900

hints of physics at very high scales?

But we haven't seen new physics yet

More details: Isidori, Nir, Paz http://arxiv.org/abs/1002.0900



G. Isidori – *Flavour-changing physics beyond the SM*

PPAP meeting, Birmingham, 13th July 2008

▶ *What we learned so far*

FLAVOUR COUPLING:

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	$b \to s \ (\sim\lambda^2)$	$b \to d \ (\sim\lambda^3)$	$s \to d \ (\sim\lambda^5)$
ΔF=2 box	$A_{CP}(B_s \to \psi\phi)$	$\Lambda > 2\times10^3$ TeV from $A_{CP}(B_d \to \psi K)$	$\Lambda > 2\times10^4$ TeV from ε_K
ΔF=1 4-quark box			
gluon penguin	$\Lambda > 80$ TeV from $B(B \to X_s\gamma)$		
γ penguin	$\Lambda > 150$ TeV from $B(B \to X_s\gamma)$		
Z^0 penguin	$\Lambda > 20$ TeV from $B(B \to X_s l^+ l^-)$		$K \to \pi \nu\nu$ $K_L \to \pi^0 l^+ l^-$
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	

...there are still interesting corners which could hide sizable non-standard effects

but we could see it any time now

Recent highlights

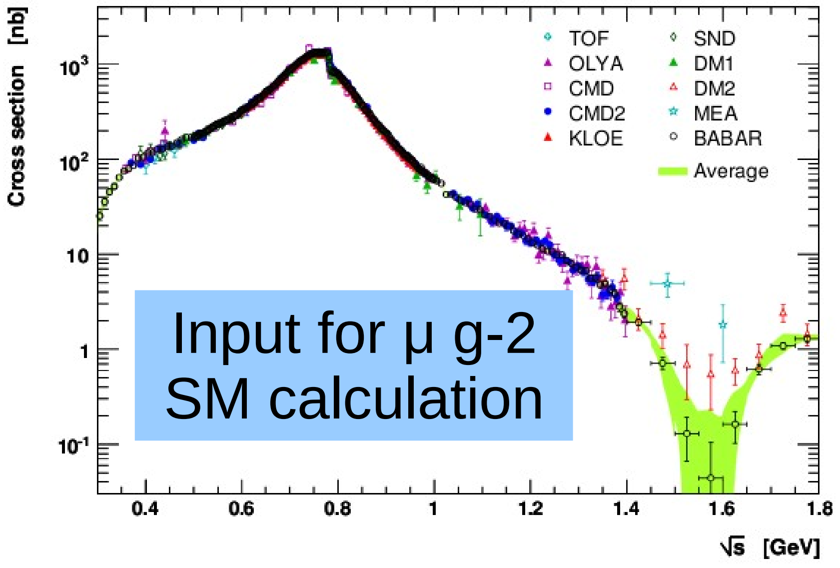
(excepting LHC start-up – discussed later)

- Main players in flavour over last decade
  - B factories, Tevatron, CLEOc, kaon experiments
- UK involvement in
  - BaBar, CDF, D0, CLEOc, NA48/NA62
- All now in ("managed") withdrawal phase
- All continue to produce important and impressive results
  - UK involvement (leadership) highly evident
  - Punching above our weight despite minimal funding

Brunel, Edinburgh, Imperial, Liverpool, Manchester, RHUL, RAL, QMUL, Warwick

BaBar

arXiv:0908.3589 [hep-ex]



Input for μ g-2 SM calculation

$$a_\mu^{had,LO}[e^+e^-] = (695.5 \pm 4.0_{exp} \pm 0.7_{QCD}) \times 10^{-10}$$

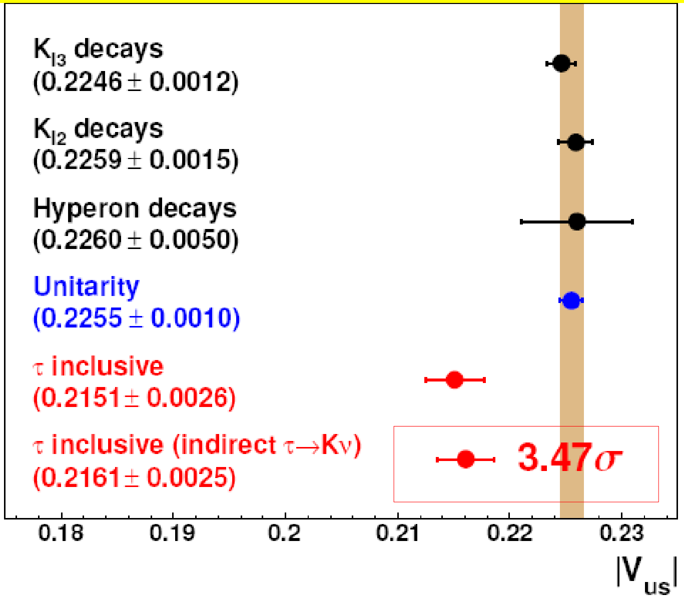
$$a_\mu^{SM} = (11\,659\,183.4 \pm 4.9) \times 10^{-10}$$

$$a_\mu^{exp} - a_\mu^{SM} = (24.6 \pm 8.0) \times 10^{-10}$$

3.1σ

(assuming Gaussian statistics)

S.Paramesvaran @ FPCP 2010



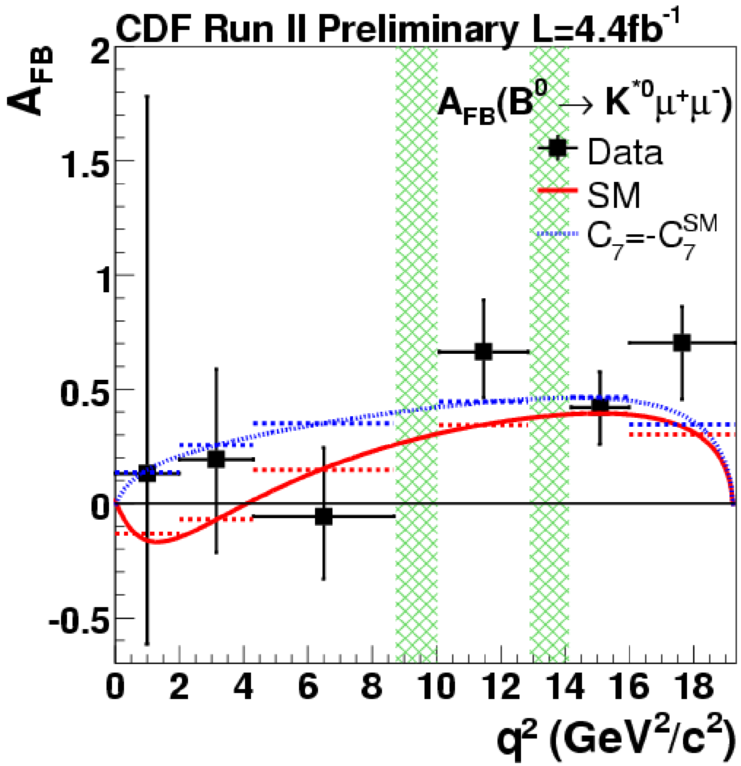
$|V_{us}|$ from inclusive τ → s branching fraction

Many other new results including:
$|V_{ub}|$, γ, rare decays,
charm mixing and CP violation

Glasgow, Oxford, UCL

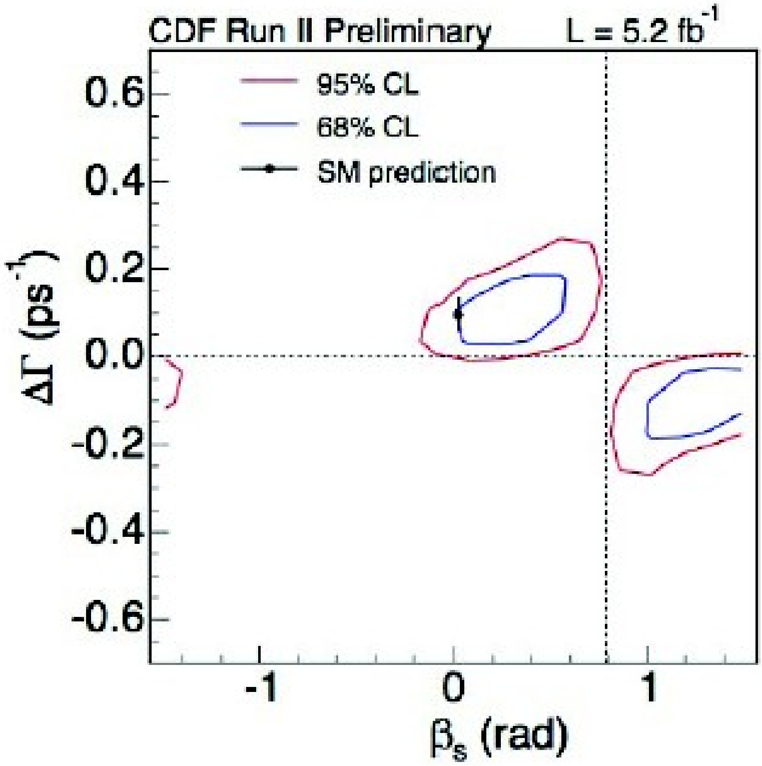
CDF

CDF note 09-11-12



Forward-backward asymmetry in $B \to K^*\mu\mu$

L.Oakes @ FPCP 2010



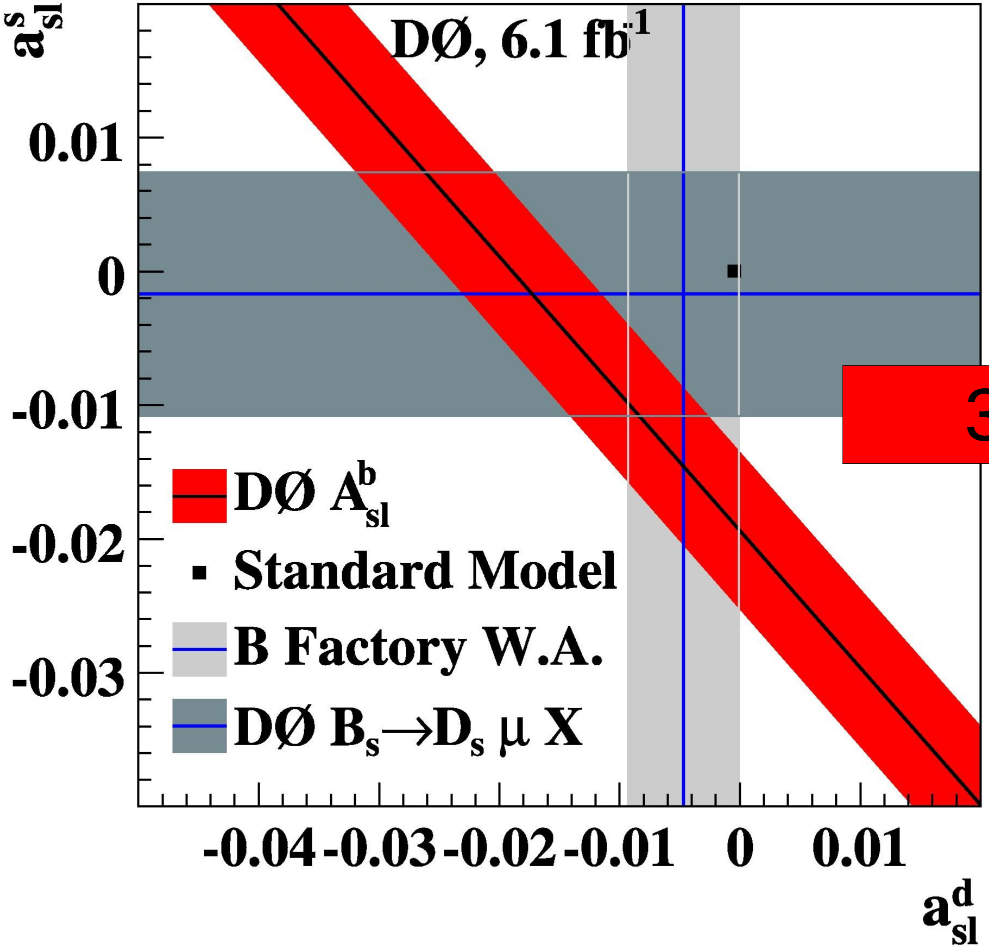
β_s from $B_s \to J/\psi\varphi$

Many other new results including:
$B_s \to \mu\mu$, $B_s \to \varphi\varphi$, B hadron lifetimes

Imperial, Lancaster, Manchester

D0

“ Evidence for an anomalous like-sign dimuon charge asymmetry”
a.k.a. “The most interesting physics result of 2010” (J. Womersley)
arXiv:1005.2757 & arXiv:1007.0395

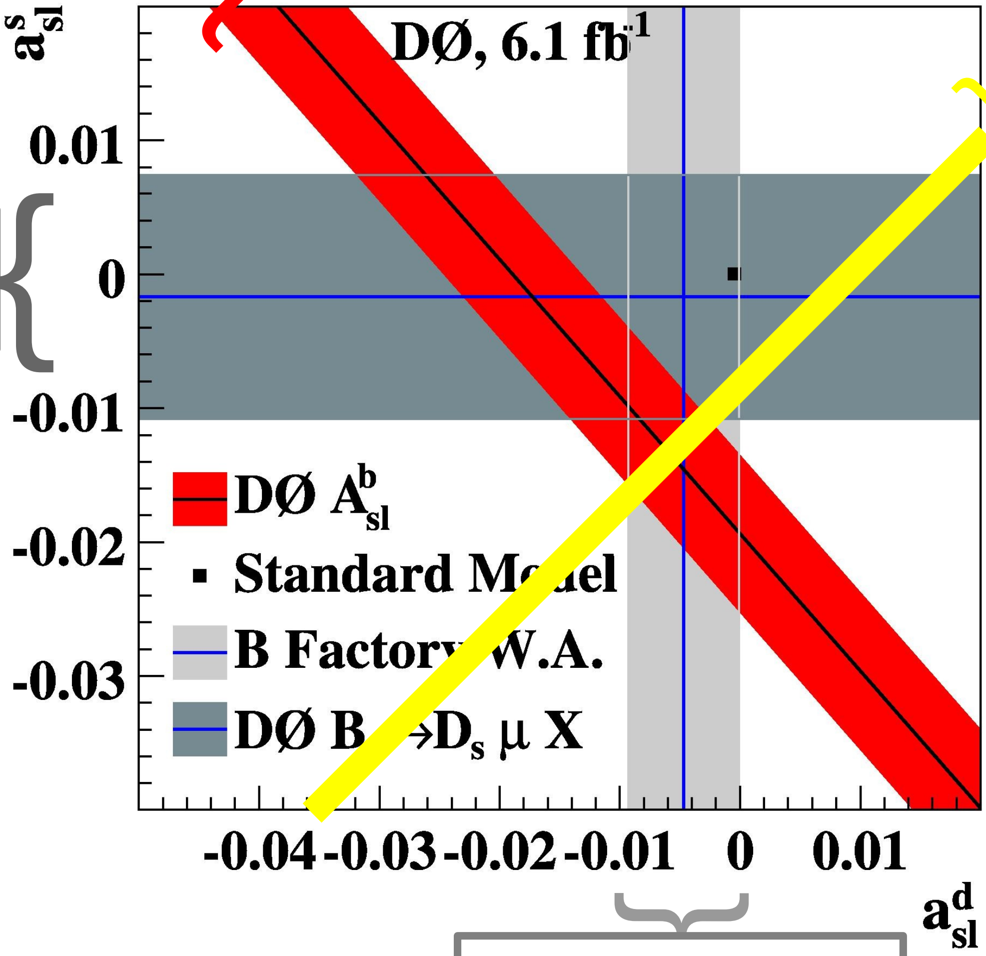


3.2σ

Other new results include $B_s \to \mu\mu$

Future improvements

D0
(maybe Belle2 & SuperB)



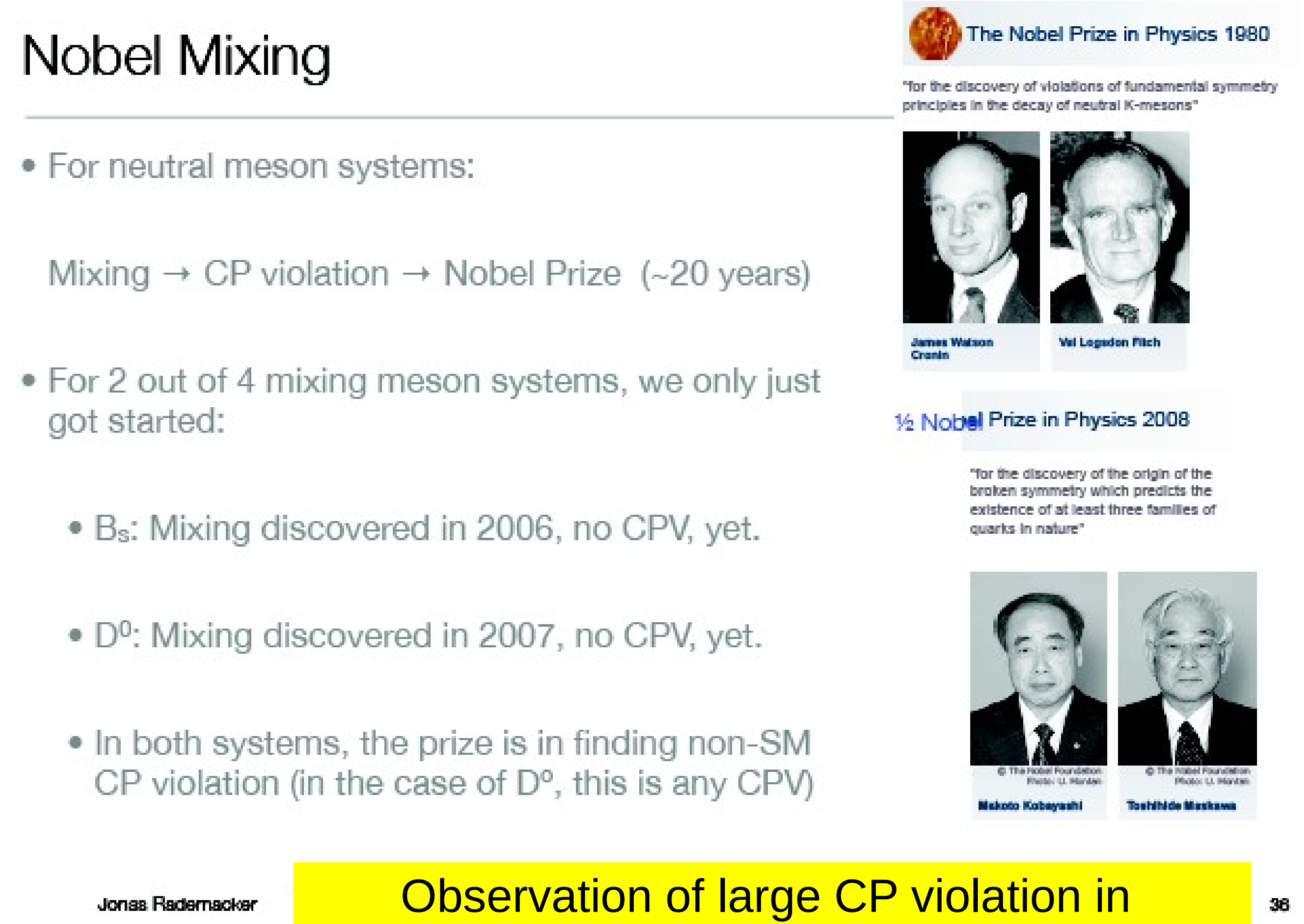
LHCb

R. Lambert, PhD Thesis, Edinburgh, 2009

D0
(maybe CDF & LHCb)

BaBar, Belle
Belle2, SuperB

CP violation and Nobel prizes



Nobel Mixing

- For neutral meson systems:

  Mixing → CP violation → Nobel Prize (~20 years)

- For 2 out of 4 mixing meson systems, we only just got started:
  - B_s: Mixing discovered in 2006, no CPV, yet.
  - D^0: Mixing discovered in 2007, no CPV, yet.
  - In both systems, the prize is in finding non-SM CP violation (in the case of D^0, this is any CPV)

The Nobel Prize in Physics 1980

"for the discovery of violations of fundamental symmetry principles in the decay of neutral K-mesons"

James Watson Cronin

Val Logsdon Fitch

½ Nobel Prize in Physics 2008

"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

© The Nobel Foundation Photo: U. Montan

Makoto Kobayashi

© The Nobel Foundation Photo: U. Montan

Toshihide Maskawa

Jonas Rademacker

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Observation of large CP violation in B_s or D oscillations would be Nobel-worthy

Update on global status and developments

- Tevatron
- LHC (GPDs & LHCb)
- LHCb upgrade
- e^+e^- flavour factories (KEK & Italy)
- kaons (CERN, J-PARC, FNAL)
- muons (J-PARC, FNAL)

Tevatron

Glasgow, Imperial,
Lancaster,
Manchester, Oxford,
UCL

- Proposal to extend running until end 2014
- Arguments for this not based on flavour physics
  - LHCb will overtake Tevatron sensitivity
  - B physics triggers suffer at high luminosity
  - but still some unique potential (e.g. D0 A_{sl})

LHC (GPDs & LHCb)

- LHC operation at √s = 7 TeV, $L \sim 10^{32}/cm^2/s$
  - great news for flavour physics
  - even lower luminosities – opportunity for charm physics
- LHCC:

> "With current luminosity projections LHCb is the only detector capable to achieve almost completely its full physics potential during the 2010-2011 run"

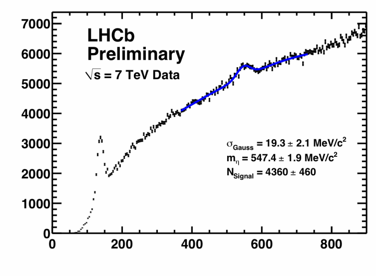
http://indico.cern.ch/getFile.py/access?contribId=20&resId=1&materialId=slides&confId=92525

  - caveat: excellent LHCb potential for an upgraded programme
  - and competition from ATLAS & CMS in a few measurements

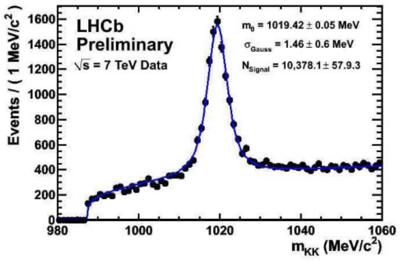
LHCb status

Bristol, Cambridge, Edinburgh, Glasgow, Imperial, Liverpool, Manchester, Oxford, RAL, Warwick

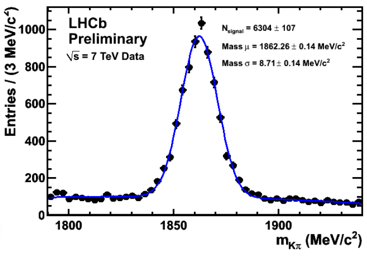
- Building up the ingredients for physics



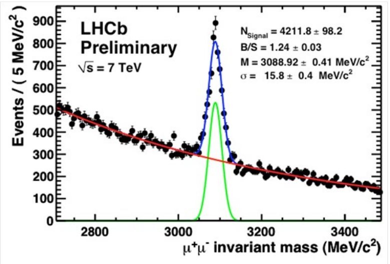
π^0 η



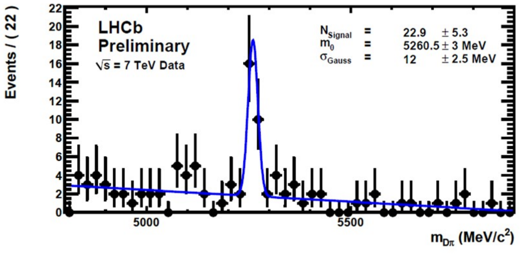
φ



D

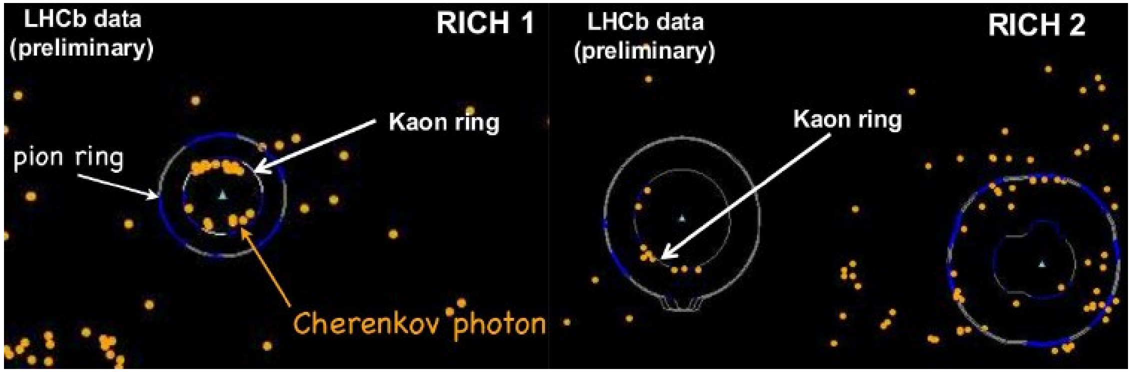


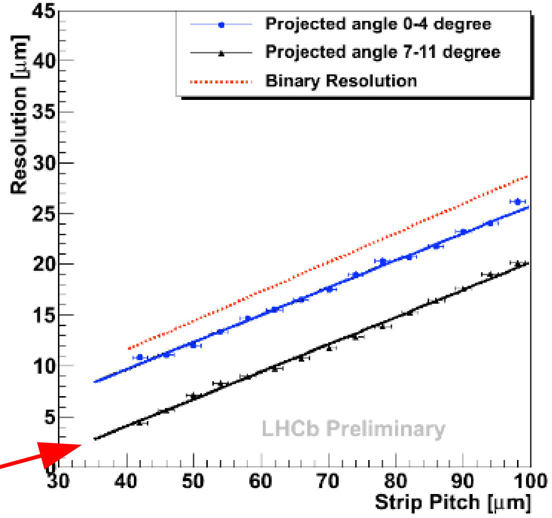
J/ψ



B

- Only possible because the detector works well





VELO: best resolution of any LHC vertex detector

LHCb upgrade

Bristol, Cambridge,
Edinburgh, Glasgow,
Imperial, Liverpool,
Manchester, Oxford,
RAL, Warwick

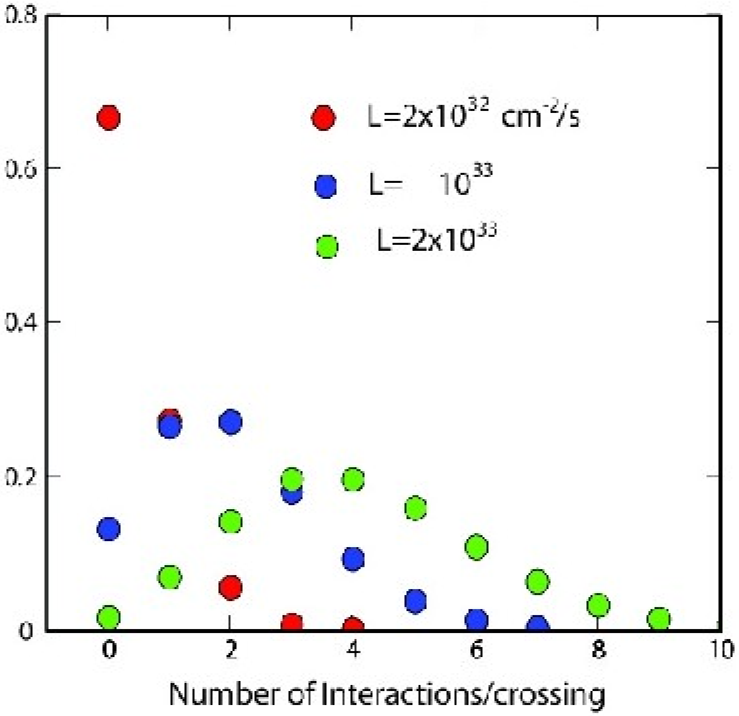
- Upgrade schedule adjusted to fit LHC schedule
  - major upgrade during 2016 shutdown (independent of LHC upgrade)
    - new trigger scheme, new VELO(PIX), new electronics
    - RICH photon detectors replacement, TT & IT replacement
    - peak *L* ~ $10^{32} \rightarrow 10^{33}$ /cm^2/s (integrated *L* ~ 10 → 100/fb)
  - possible second stage upgrade for higher *L* (PID, ECAL)
- UK leadership
  - physics, conceptual design (trigger), VELO(PIX), PID
- LOI in preparation (for LHCC December 2010)
  - cost minimisation exercise in progress – estimate 40 MCHF

exploiting synergies with other experiments

LHCb upgrade – hot news

- At 2×10^{32} $cm^{-2}.s^{-1}$ (nominal conditions)
  - 30 MHz of crossings
  - Most crossings have no interaction
  - L0 reduces data to 1MHz
  - HLT output is 2kHz → on tape
- At 10^{33} $cm^{-2}.s^{-1}$
  - On average 2.3 interactions/crossings

Nominal conditions



Current LHC operation ($\beta^* = 3.5$ m, ~1.5 int./crossing) serves as a test beam for LHCb upgrade

Study effects on hadronic triggers

(precision CKM, charm, $B_s \to \phi\gamma$, $B_s \to \phi\phi$, $K^*\bar{K}^*$)

Confirm performance for leptonic modes

($B_{s,d} \to \mu\mu$, $B_d \to K^*\mu\mu$, $B_s \to J/\psi\phi$)

No UK involvement

e^+e^- flavour factories (I)

- SuperKEKB / Belle2 approved

  http://kek.jp/intra-e/press/2010/KEKBupgrade.html
  - 100 oku-yen (approx $110M) over three years
  - start data taking 2014
  - “nano-beam” scheme, large crossing angle, e^+/e^- 4/7 GeV
  - expected peak luminosity 8 $10^{35}/cm^2/s$
  - accumulate 50/ab by 2020, TDR to be published July 2010
  - main physics goals:

    precision CKM, inclusive rare decays, $B\rightarrow\tau\nu$, τ lepton flavour violation
- BESIII / BEPCII running
  - charm / τ physics near threshold

QMUL, RAL

e^+e^- flavour factories (II)

- SuperB (Italy)
  - more ambitious proposal than SuperKEKB / Belle2
    - higher lumi, polarised beam, flexible CM energy, 700M€
    - timescale: data taking 5-6 years after approval
  - INFN #1 priority, endorsed by the Italian Science and Economy Ministry, support pledged from Lazio regional government, waiting for cabinet approval
  - several international MOUs & agreements signed
  - physics white paper (SLAC-R-952) & TDR coming soon
    - accelerator design reviewed by MAC
  - UK involvement: physics, pixel vertex detector, computing

Birmingham, Bristol, Glasgow, Liverpool

Kaons (I)

- CERN NA62-Phase I
  - preliminary measurement of Ke2/Kμ2 ratio (UK led)
  - 1.5σ tension with the SM prediction

E.Goudzovski @ BEACH'10

- CERN NA62-Phase II ($K^+ \rightarrow \pi^+ \nu\bar{\nu}$ decay in flight)
  - approved at CERN; expect first data end 2012 (possibly with incomplete detector for first 6 months or so)
  - UK involvement
    - on hold until financial situation improves
    - UK progressing with conceptual design of CEDAR detector (very high rate particle id in the beamline)
  - potential for future upgrade (possibility to measure $K^0 \rightarrow \pi^0 \nu\bar{\nu}$)

No UK involvement

Kaons (II)

- J-PARC KOTO ($K^0 \rightarrow \pi^0 \nu \bar{\nu}$)
  - based on KEK E391a detector and experience
  - rebuilding calorimeter with KTeV crystals
  - fully approved; expect first data Autumn 2011
  - will reach SM prediction sensitivity in 3 years
  - possible further upgrade for precision measurement
- FNAL P996
  - proposal for $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ from stopped kaons
  - expecting ~200 events/year

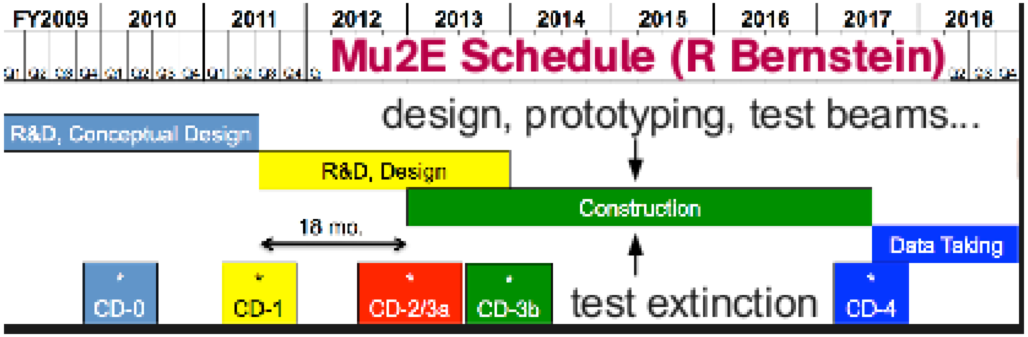
arXiv:0911.4789

No UK involvement

Muons (I)

- PSI MEG experiment ($\mu \rightarrow e\gamma$)
  - first preliminary results < 3 10^{-11}

    arXiv:0908.2594
  - should reach 10^{-13} by 2013
- FNAL mu2e ($\mu \rightarrow$ e conversion; 10^{-16} sensitivity)
  - CD0 granted



  - potential for future improvement using ProjectX

Muons (II)

Cockcroft, DL-ASTeC, Glasgow, Imperial, Liverpool, Manchester, Oxford, RAL, UCL

- J-PARC COMET (μ → e conversion)
  - first (of two) stage approval received
  - schedule similar to mu2e
  - TDR in preparation
    - UK involvement: design studies, software
  - prototype pion capture solenoid (MUSIC, Osaka)
    - UK participation; students present on site
- possible FFAG-based upgrade (PRISM)
  - major synergies with UK programme & UK led

Summary & Discussion

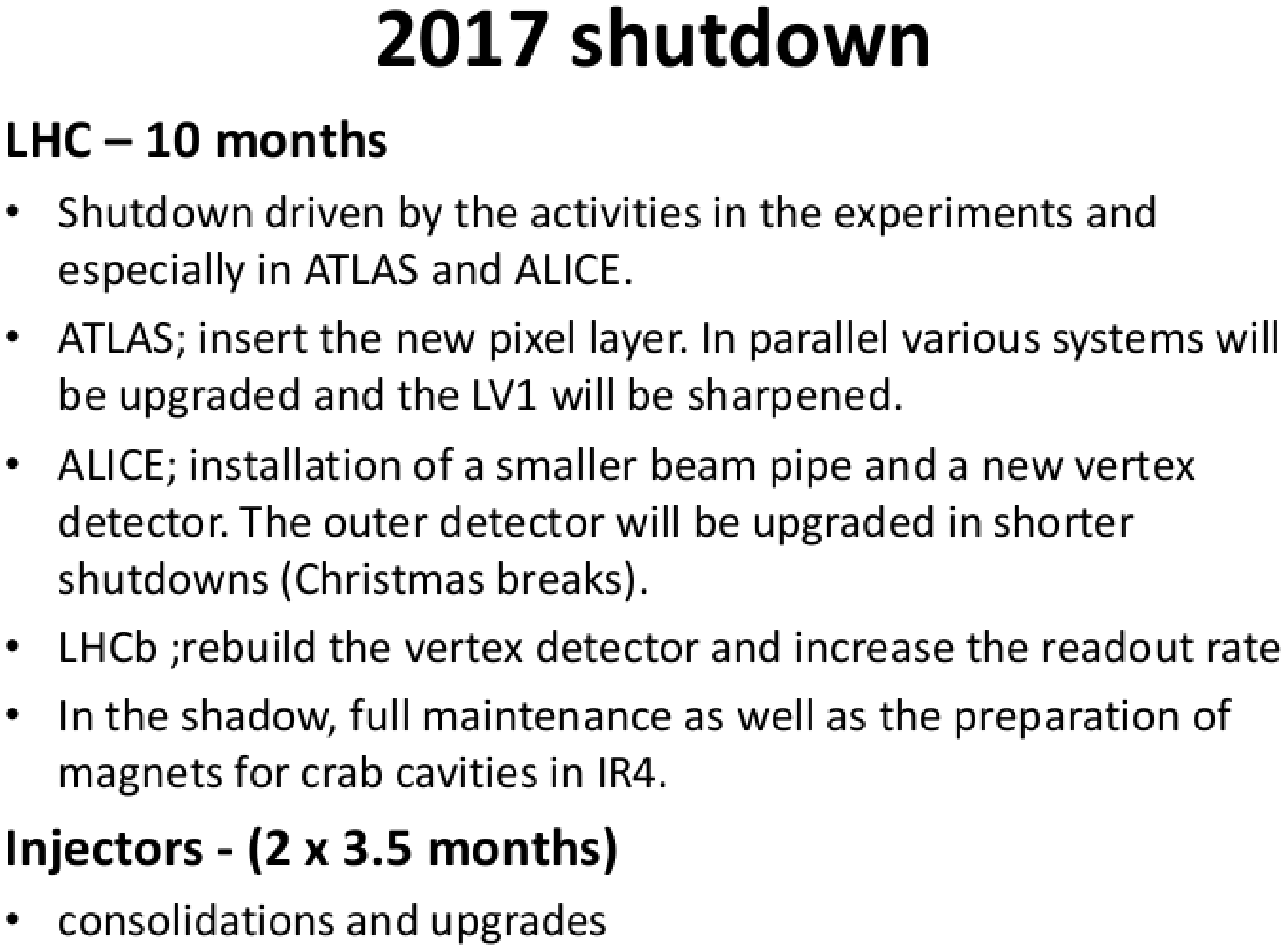
- Flavour physics is a field in which the UK has international leadership (experiment & theory)
- Both volume and breadth drastically reduced
  - excellence undiminished (but not sustainable)
- Physics case for flavour is compelling
  - best chance for NP discovery in next few years
  - long term physics reach beyond energy frontier
- Several positive developments internationally
  - opportunities for UK physics & for UK PLC

Back-up Material

LHC upgrade schedule

http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=95580

LHC upgrade schedule



2017 shutdown

LHC – 10 months

- Shutdown driven by the activities in the experiments and especially in ATLAS and ALICE.
- ATLAS; insert the new pixel layer. In parallel various systems will be upgraded and the LV1 will be sharpened.
- ALICE; installation of a smaller beam pipe and a new vertex detector. The outer detector will be upgraded in shorter shutdowns (Christmas breaks).
- LHCb ;rebuild the vertex detector and increase the readout rate
- In the shadow, full maintenance as well as the preparation of magnets for crab cavities in IR4.

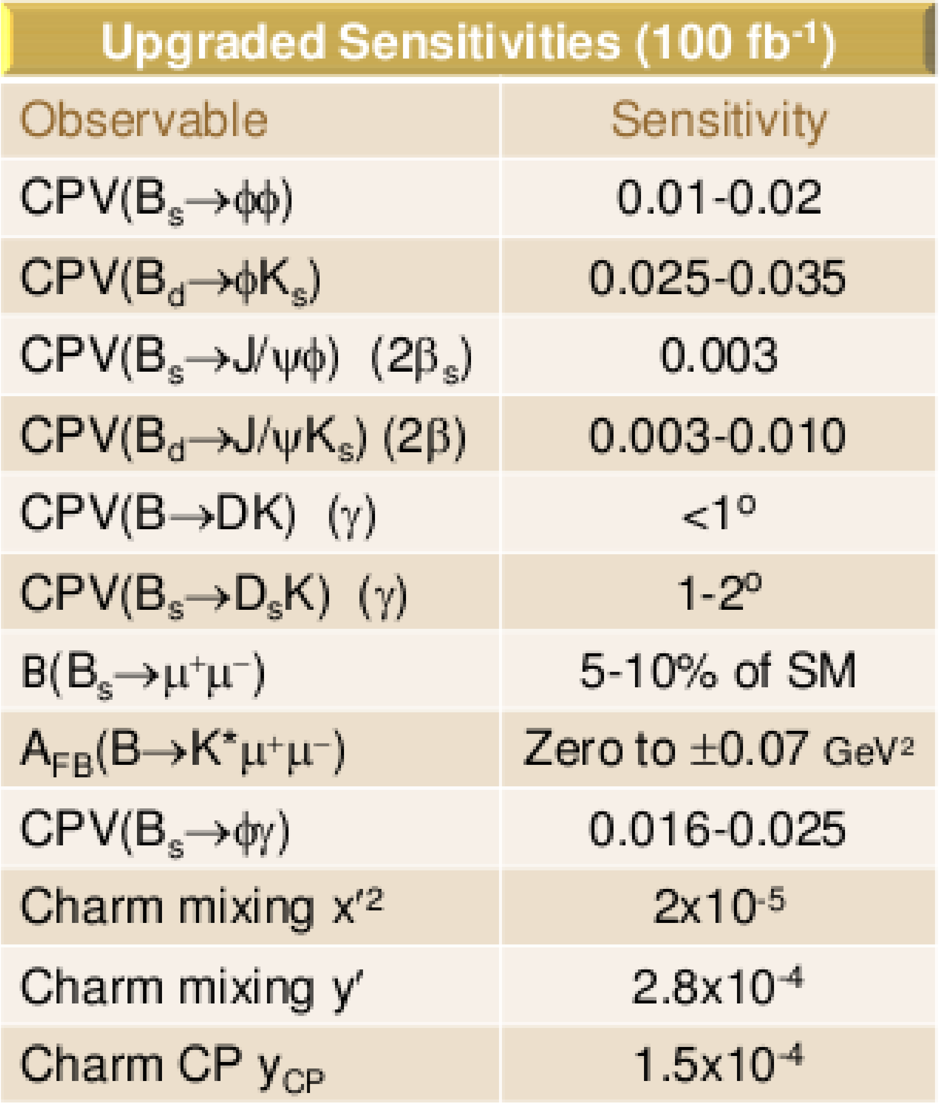
Injectors - (2 x 3.5 months)

- consolidations and upgrades

http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=95580

LHCb Upgrade

- We hope to see the effects of new particles observed by ATLAS & CMS in “flavor” variables in 10 fb^{-1}
- Upgrading will allow us to precisely measure these effects



Upgraded Sensitivities (100 fb^{-1})

Observable	Sensitivity
CPV($B_s \to \phi\phi$)	0.01-0.02
CPV($B_d \to \phi K_s$)	0.025-0.035
CPV($B_s \to J/\psi\phi$) ($2\beta_s$)	0.003
CPV($B_d \to J/\psi K_s$) (2β)	0.003-0.010
CPV($B \to DK$) (γ)	<1°
CPV($B_s \to D_s K$) (γ)	1-2°
$B(B_s \to \mu^+\mu^-)$	5-10% of SM
$A_{FB}(B \to K^*\mu^+\mu^-)$	Zero to ±0.07 GeV^2
CPV($B_s \to \phi\gamma$)	0.016-0.025
Charm mixing x'^2	2x10^{-5}
Charm mixing y'	2.8x10^{-4}
Charm CP y_{CP}	1.5x10^{-4}

Complementary to ATLAS & CMS

- **cover different rapidity region**
- **“direct” discovery potential at high η**

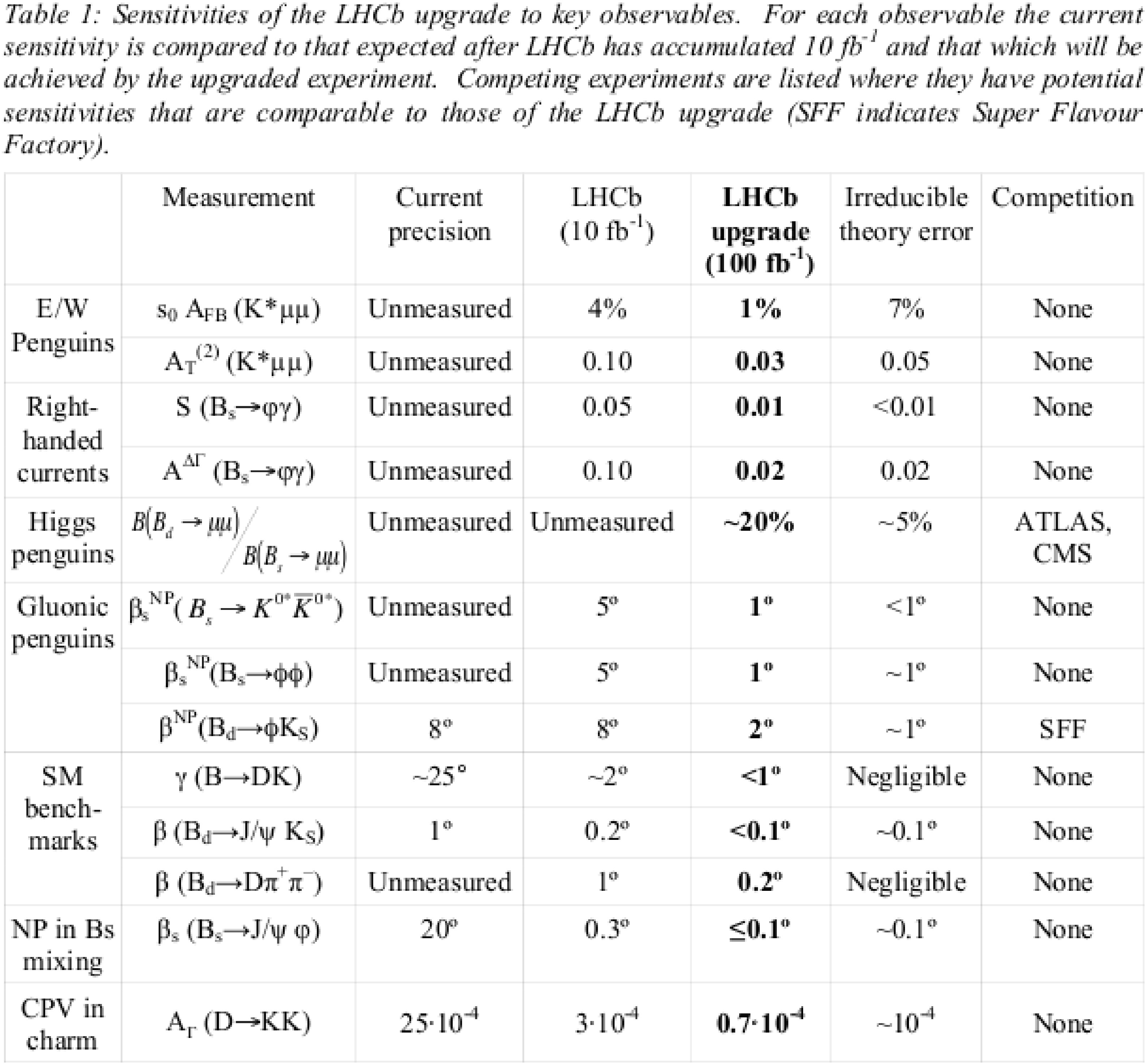
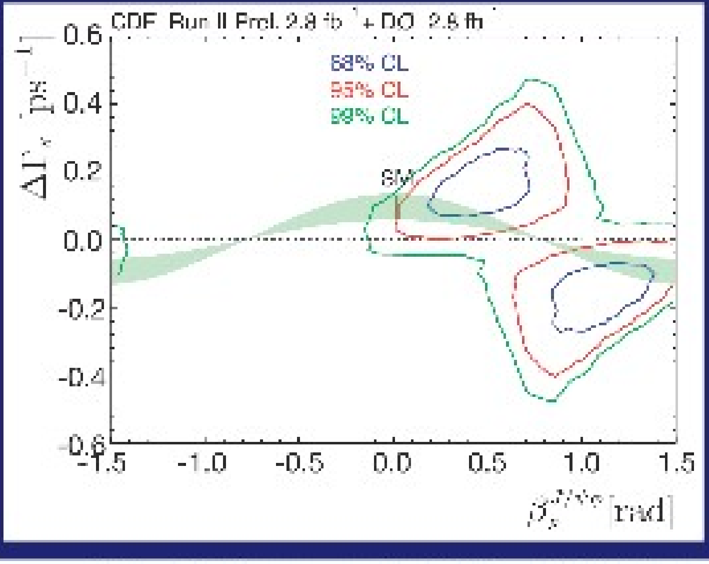


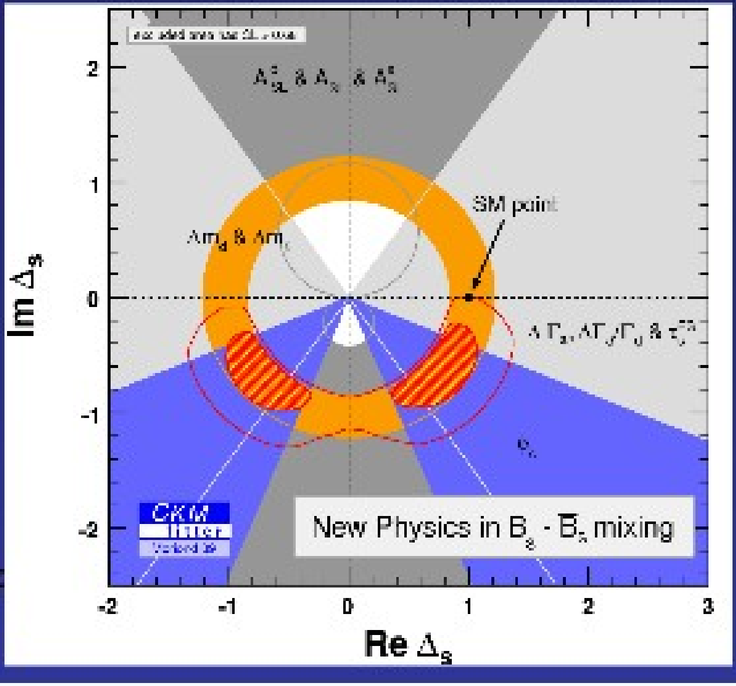
Table 1: Sensitivities of the LHCb upgrade to key observables. For each observable the current sensitivity is compared to that expected after LHCb has accumulated 10 fb^{-1} and that which will be achieved by the upgraded experiment. Competing experiments are listed where they have potential sensitivities that are comparable to those of the LHCb upgrade (SFF indicates Super Flavour Factory).

	Measurement	Current precision	LHCb (10 fb^{-1})	**LHCb upgrade (100 fb^{-1})**	Irreducible theory error	Competition
E/W Penguins	s_0 A_{FB} ($K^*\mu\mu$)	Unmeasured	4%	**1%**	7%	None
	$A_T^{(2)}$ ($K^*\mu\mu$)	Unmeasured	0.10	**0.03**	0.05	None
Right-handed currents	S ($B_s\to\varphi\gamma$)	Unmeasured	0.05	**0.01**	<0.01	None
	$A^{\Delta\Gamma}$ ($B_s\to\varphi\gamma$)	Unmeasured	0.10	**0.02**	0.02	None
Higgs penguins	$B(B_d\to\mu\mu) / B(B_s\to\mu\mu)$	Unmeasured	Unmeasured	**~20%**	~5%	ATLAS, CMS
Gluonic penguins	$\beta_s^{NP}(B_s\to K^{0*}\overline{K}^{0*})$	Unmeasured	5°	**1°**	<1°	None
	$\beta_s^{NP}(B_s\to\phi\phi)$	Unmeasured	5°	**1°**	~1°	None
	$\beta^{NP}(B_d\to\phi K_S)$	8°	8°	**2°**	~1°	SFF
SM bench-marks	γ ($B\to DK$)	~25°	~2°	**<1°**	Negligible	None
	β ($B_d\to J/\psi\ K_S$)	1°	0.2°	**<0.1°**	~0.1°	None
	β ($B_d\to D\pi^+\pi^-$)	Unmeasured	1°	**0.2°**	Negligible	None
NP in Bs mixing	β_s ($B_s\to J/\psi\ \varphi$)	20°	0.3°	**≤0.1°**	~0.1°	None
CPV in charm	A_Γ ($D\to KK$)	$25\cdot10^{-4}$	$3\cdot10^{-4}$	**$0.7\cdot10^{-4}$**	$\sim10^{-4}$	None

Probe New Physics in ~~CP~~

- Is there NP in B_s^o-B_s^o mixing?
  - $B_s \to J/\psi\phi$ is golden mode at hadron colliders
  - Very precise SM prediction for small weak phase $\phi_s = -2\beta_s$
  - $\phi_s(J/\psi\phi) = -0.0368 \pm 0.0017$
- Current Results
  - From CDF and D0
  - Prefer non-zero ϕ_s
- Weak Limits on new physics
  - Weak phase in B_s mixing ϕ_s is not well measured yet
  - New Physics could be around the corner!

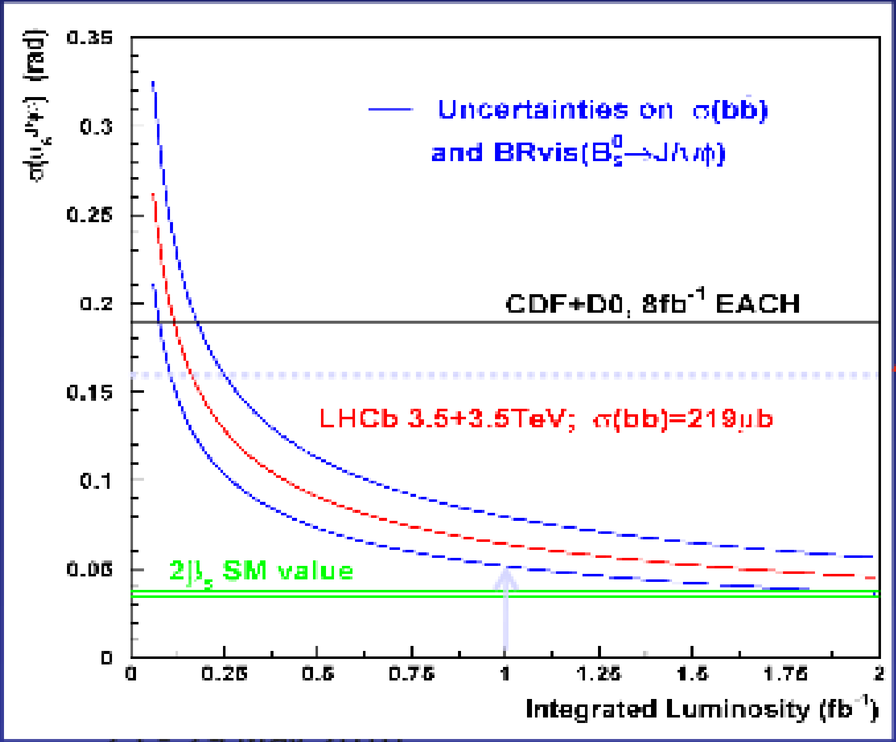




$$\mathrm{Re}(\Delta_q)+i\mathrm{Im}(\Delta_q)=\frac{\langle B^o|H^{full}|\bar{B}^o\rangle}{\langle B^o|H^{SM}|\bar{B}^o\rangle}$$

Prospects with $B_s \rightarrow J/\psi\phi$

- Probe New Physics
  - In box diagrams
- Expected Sensitivity
  - yield: 117k in 2 fb^{-1}
  - $\sigma(\phi_s) \sim 0.07$ with 1 fb^{-1}

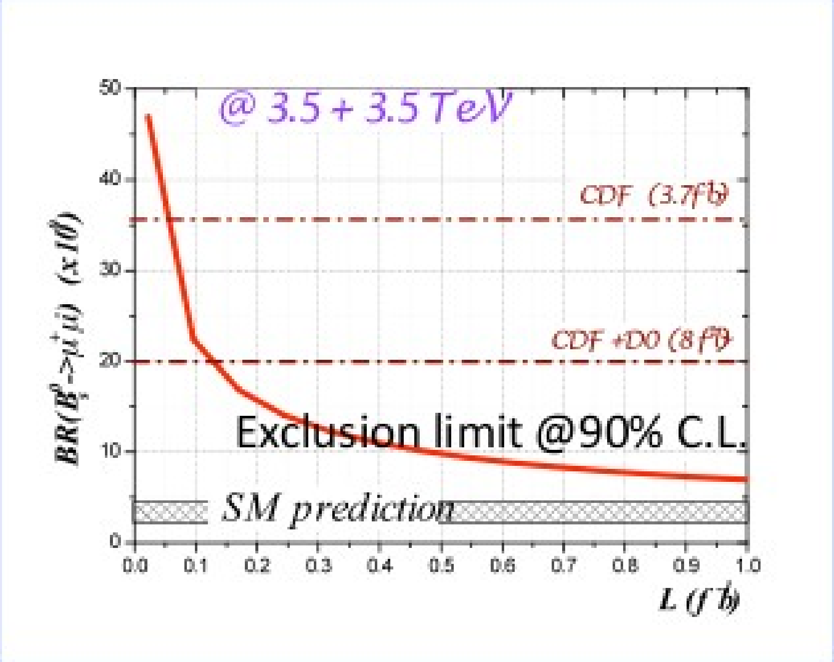


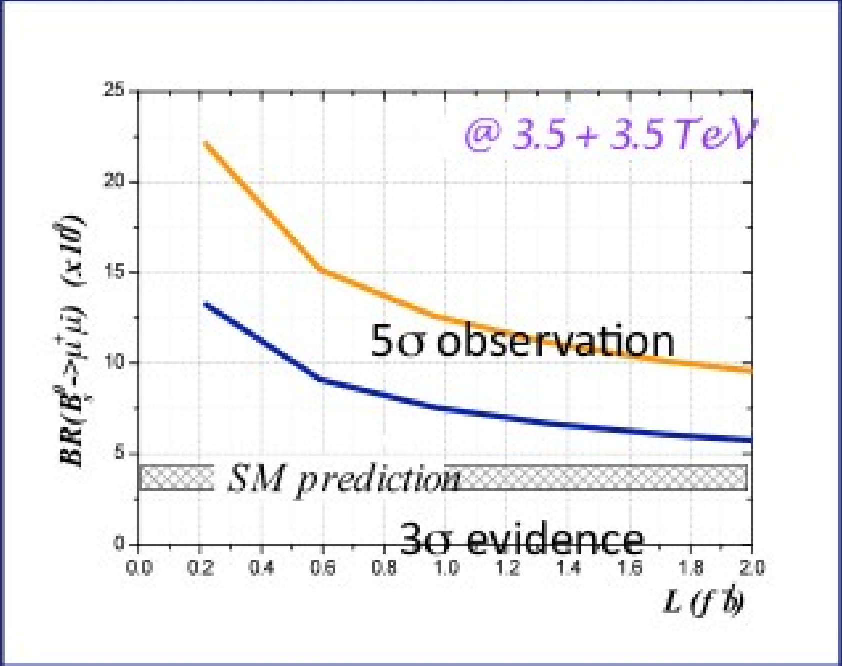
- Exciting Prospects
  - If ϕ_s at Tevatron central value
  - LHCb will make 5σ discovery of new physics in this run
- Additional measurements
  - *CP*-eigenstate $B_s \rightarrow J/\psi f_0(980)$, $f_0(980) \rightarrow \pi^+\pi^-$

Precision required to establish $\phi_s = 0.7$ at 5σ

- Probe New Physics
  - in penguin diagrams
  - Best mode $B_s \rightarrow \phi\phi$

Prospect with $B_s \to \mu^+\mu^-$



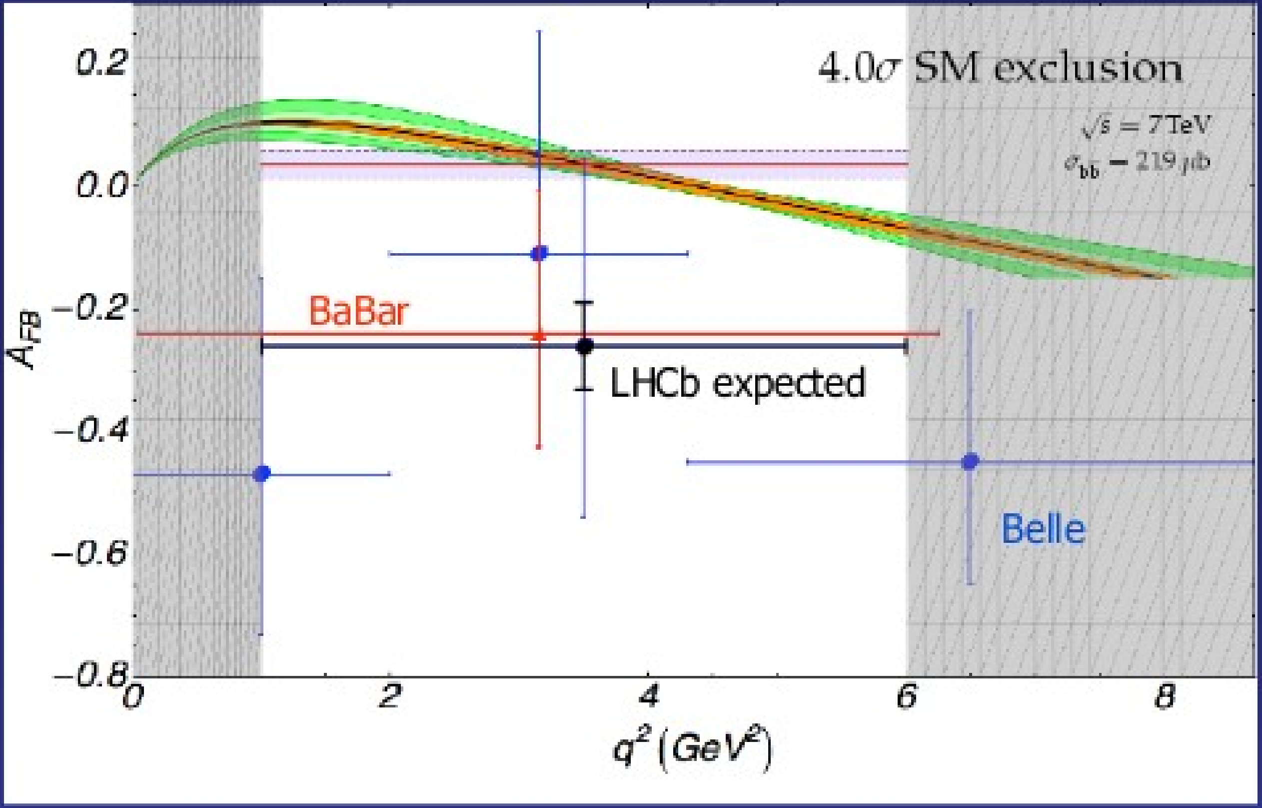


- **Expected Sensitivity**
  - 200 pb^{-1} to improve upon expected Tevatron limit with 8fb^{-1}
  - 3 fb^{-1} for 3σ evidence and
    10 fb^{-1} for 5σ observation of SM value @ 14TeV

Prospects with B→K*μμ

With 1 fb^{-1} LHCb expects 1200 events with $q^2 < 6$ GeV^2

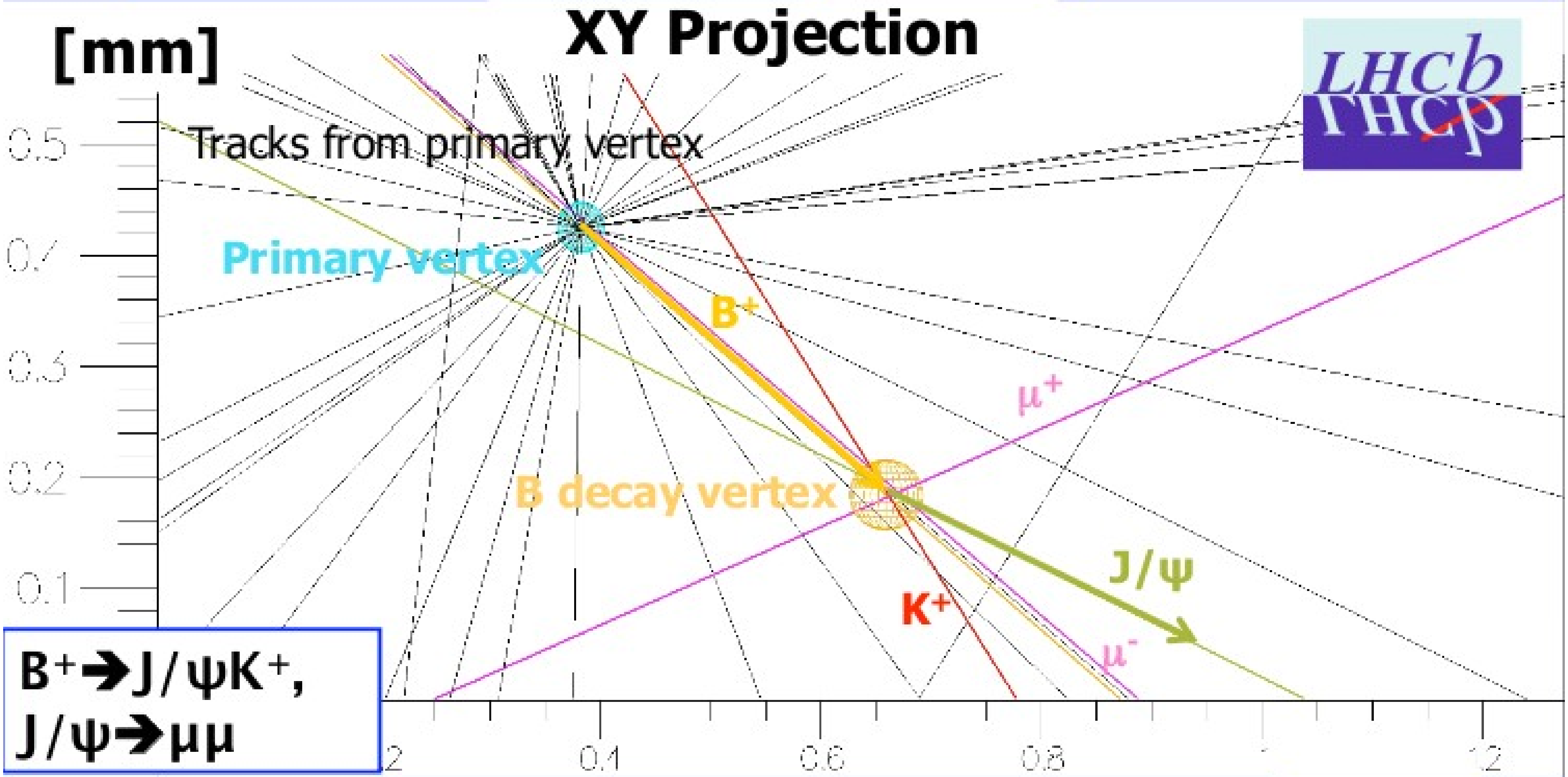
At Belle central value, SM could be excluded at 4σ



$B^+ \to J/\psi K^+$ candidate

21 April 2010: LHCb observes first reconstructed Beauty Particle

All Observables far from cut values



$B^+ \to J/\psi K^+$, $J/\psi \to \mu\mu$

Probe New Physics in $\cancel{CP}$

	Sensitivity with 10 fb^{-1}	Do we need 100 fb^{-1}?
• NP in box diagrams		
– ϕ_s from $B_s \to J/\psi\phi$	$\sigma(\phi_s)$ ~0.010	Yes σ_{theor} ~ 0.002
• NP in hadronic penguins		
– $\Delta S(\phi\phi)$ from $B_s \to \phi\phi$ has best sensitivity	$\sigma(\Delta S(\phi\phi))$ ~ 0.05	Yes
– $\Delta S(\phi K_S)$ from $B_d \to \phi K_S$	$\sigma(\Delta S(\phi K_S))$ ~ 0.10	Yes σ_{theor} ~ 0.01
• NP in radiative penguins		
– Photon polarisation in $B_s \to \phi\gamma$	$\sigma(A^{\Delta\Gamma})$ ~0.09 $\sigma(A^{mix})$ ~0.05	Yes σ_{theor} ~ 0.01

Probe NP in Rare Decays

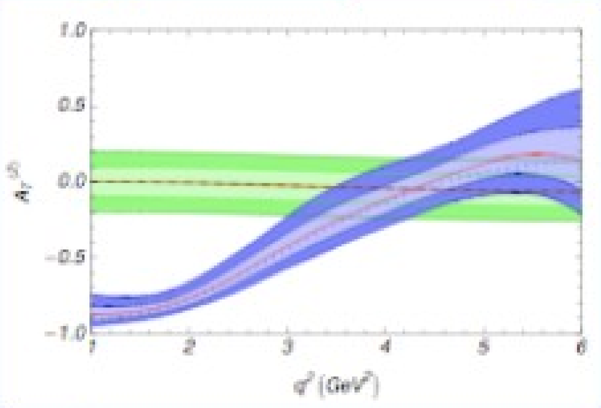
	Sensitivity with 10 fb^{-1}	Do we need 100 fb^{-1} ?
• NP in electroweak penguins		
– $B_s \to K^*\mu\mu$	$\sigma(A_T^{(2)}) \sim 0.16$	Yes
– $B_s \to \mu\mu$	$>5\sigma$ observation if SM	Yes
$B_d \to \mu\mu$	-	Yes
• Charm Physics		
– $D^0 \to K\pi, KK, \pi\pi$	CP asymmetries	Yes
$D^0 \to K\pi\pi\pi, KK\pi\pi$	$A_\Gamma(D^0 \to KK) < 10^{-4}$	Yes
• Lepton Flavour Violation		
– $\tau \to \mu\mu\mu$	BR ~ $O(10^{-8})$	Yes

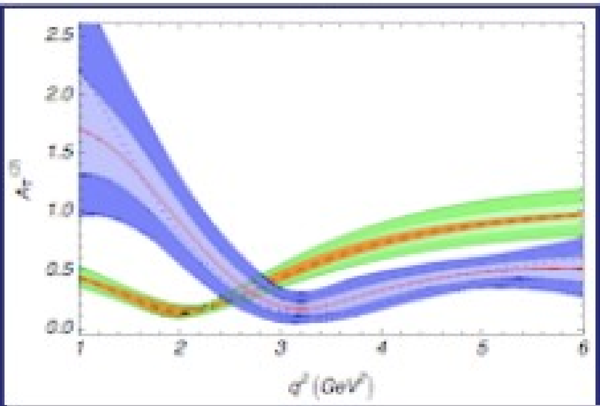
Probe New Physics in B→K*μμ

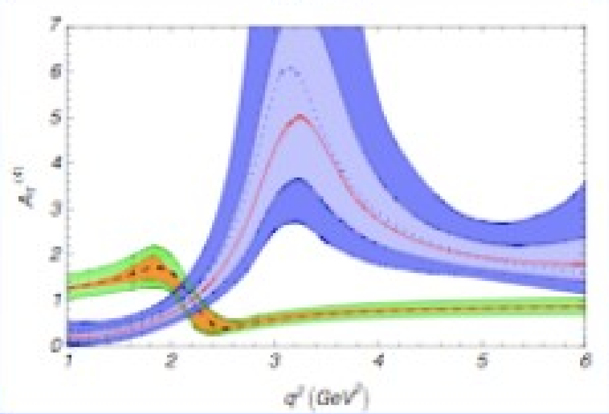
- **Asymmetries**
  - Excellent laboratory to explore NP
  - Sensitive to Wilson Coefficients C7 to C10, SUSY with low tan beta, 4th generation
  - SM predictions have small errors
  - Plots are for 10 fb-1
  - Blue band: SUSY model with large gluino mass, green band: SM

- **LHCb Upgrade**
  - Allows to discriminate between
  - different NP models

F. Muheim



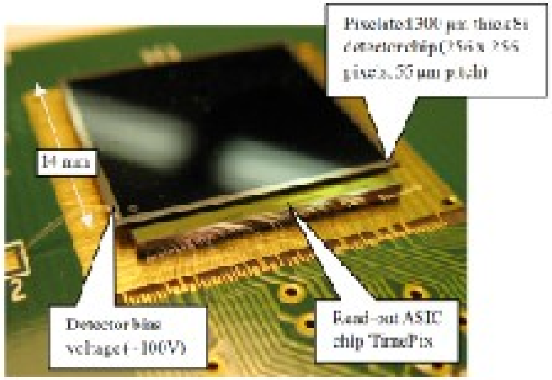


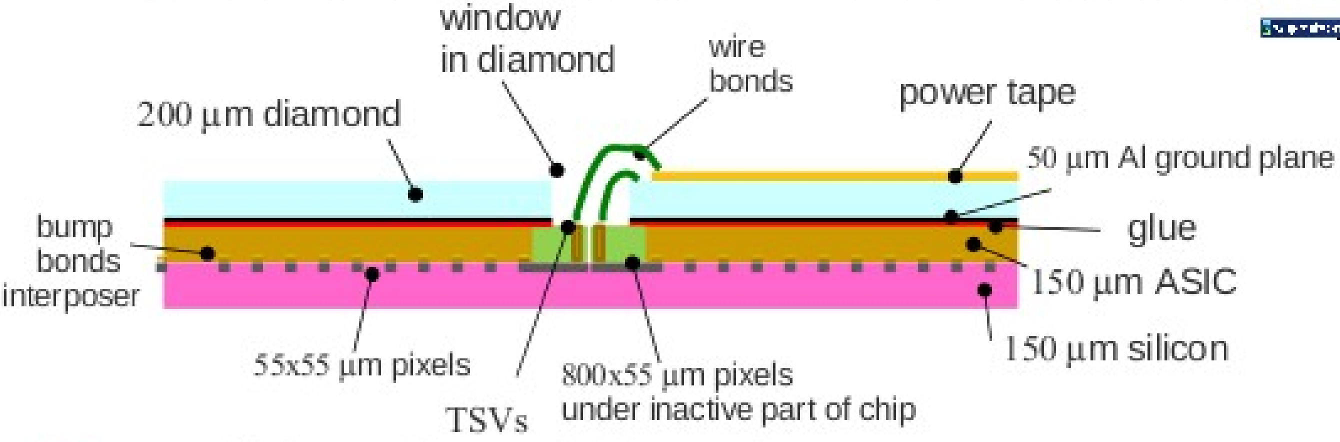


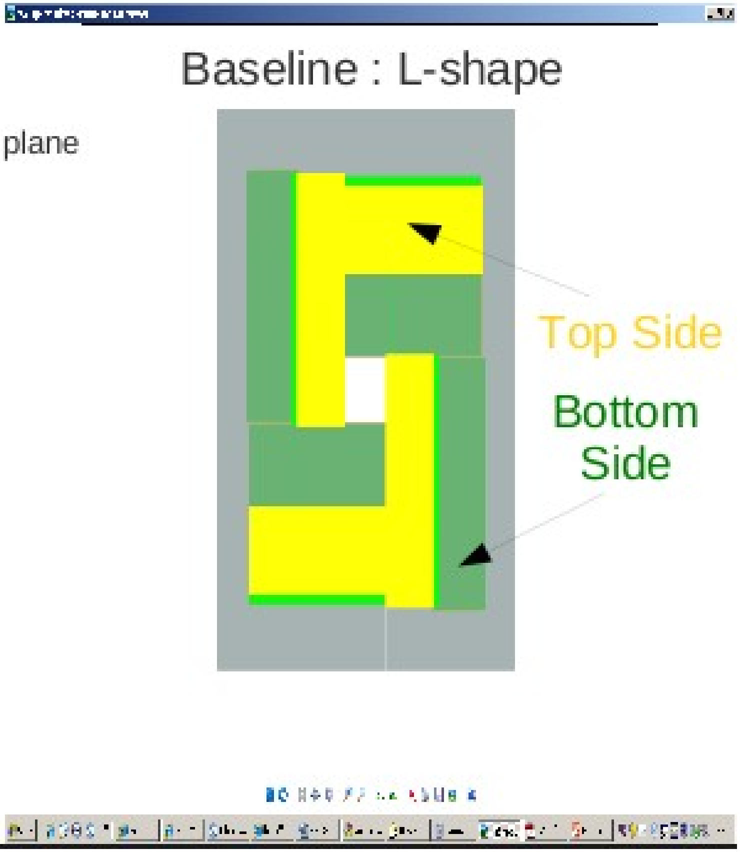
Egede et al., arXiv:0807.2589

The VErtex LOcator

- Present VELO has to be replaced (radiation)
- Precise measurement of the vertices
  - Aim is pattern recognition for the trigger
- The baseline is VELOPix, based on Medipix/TimePix readout chip
  - 256x256 pixels, 55µm square
  - 3 side buttable chip
  - TSV (Through Silicon Via) → dead side may be reduced to 0.8mm (Medipix3)



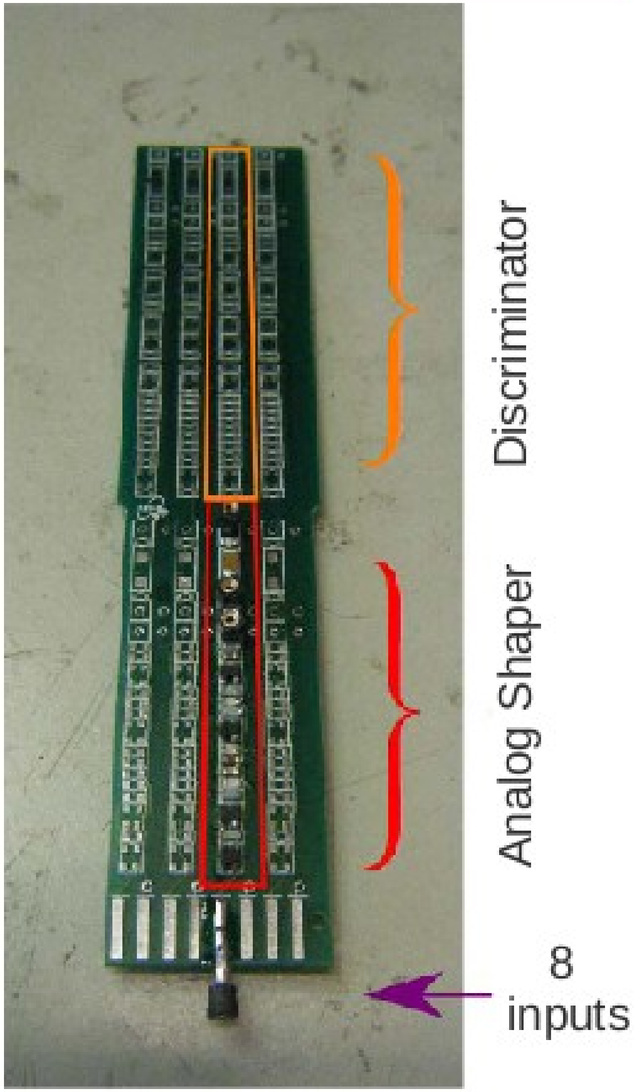



Baseline : L-shape

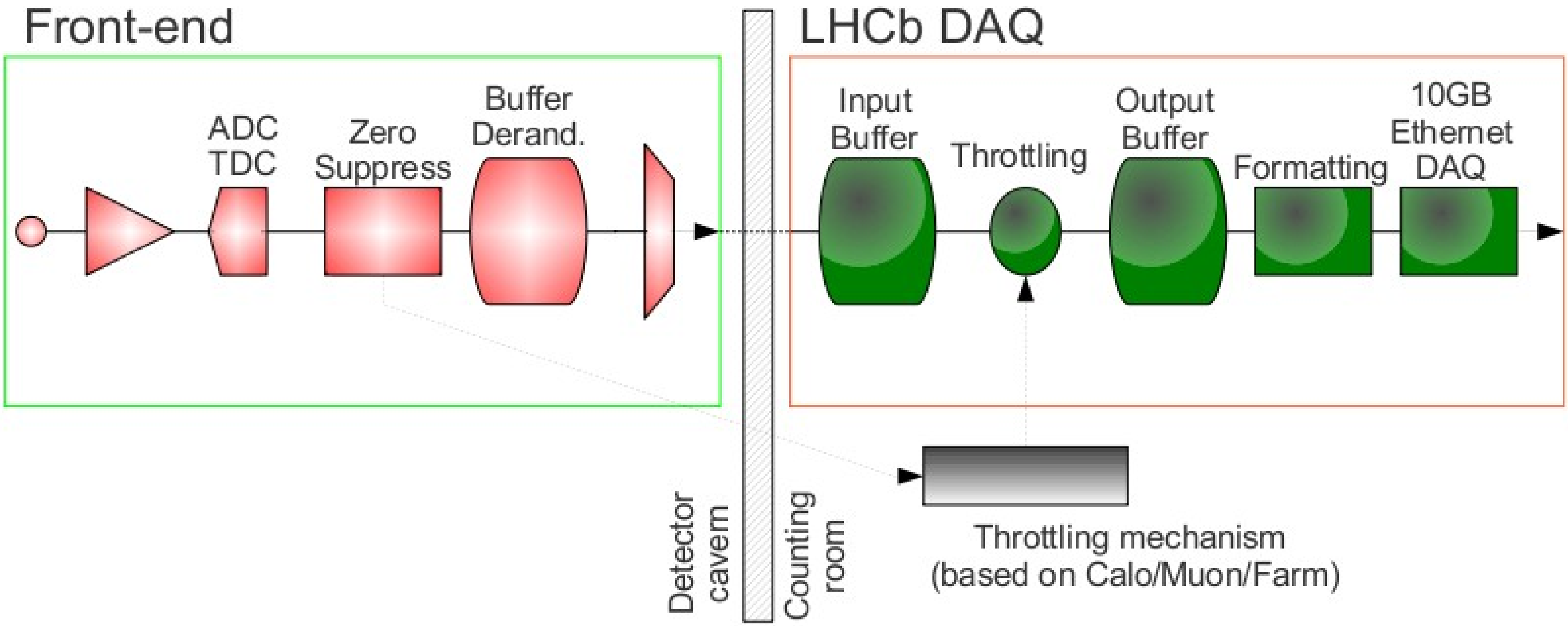
- Benefit from the 3D information
  - Less combinatorial for tracking reconstruction
- Very low occupancy of the detector
- But very high data rate (15Gbit/s/chip)

Rich (+TOF)

- Rich HPD tied to 1MHz readout → must be replaced
- Baseline candidate is the MA-PMT (Hamamatsu)
  - 8x8 pixels (of 2.0x2.0 mm^2)
  - Characterisation of the chip shows good properties
    - Single photon response,
    - Uniformity,
    - Cross-talk,
    - Dark current.
  - Behaviour under magnetic field still to be checked
  - Temperature
- A front-end electronics is being designed
  - Target is
    - no pile-up (25ns)
    - Low consumption
- TOF (Torch)
  - TOF measurement could be coupled to the RICH for PID
  - 1 cm thick quartz plate at z=12m
  - 30ps resolution
  - Probably for the second upgrade phase



Electronics and readout



- Electronics and readout completely re-design to permit readout @ 40MHz
- The events are zero-suppressed / packed at the front-end level
- The GBT technology is used to send the data from the FE to the readout syst.
- The readout boards are common to all the sub-detectors
- A throttling mechanism (Calo/Muon/Farm) is implemented to cope with
  - A staged DAQ which cannot handle the full rate
  - Unexpected high occupancies which prevent a full readout

Tracking

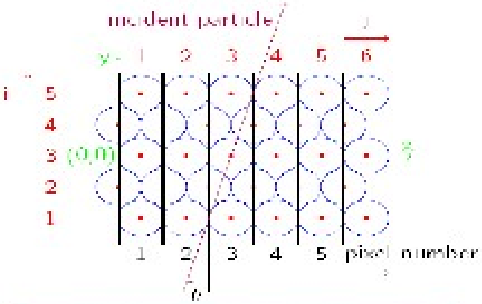
- Running at $2x10^{33}$ is not acceptable for the present Outer tracker
  - Too high occupancy
  - Decide to limit the luminosity to 10^{33} for phase I of upgrade (2016)

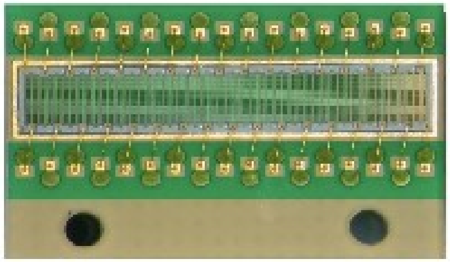
- Still the OT electronics has to be changed to cope with the 40MHz readout
  - First prototypes are being designed

- Two options are still envisaged for the ST (TT and IT)

  (1) Si options
    - Keep the existing modules unchanged
      - Need re-equip them with an upgraded electronics
      - Development of a new rad-hard FE chip @ 40MHz
    - Build new modules identical to the existing ones

  (2) Fiber option
    - Several layers of scintillating fibers
    - Light collections with SiPM
    - Electronics is out of the acceptance (rad. tolerance)
    - First simulations show equivalent performances as Si
    - Requires important R&D but several labs are interested





Calorimeter and Muon system

- The front-end electronics of the calorimeter to be replaced (40MHz readout)
  - The PMT have to be operated at lower gain
  - The electronics will compensate but need to maintain the same noise as before
    - 2 directions : ASIC and discrete components → prototype being delivered
  - The L0 uses calo information (40MHz)
    - Plan is to keep on providing this to the farm to help software trigger (seeds)
- Radiation tolerance of the calorimeter inner modules
  - 2 modules irradiated at Protvino (Russia) and 2 other in the LHC tunnel

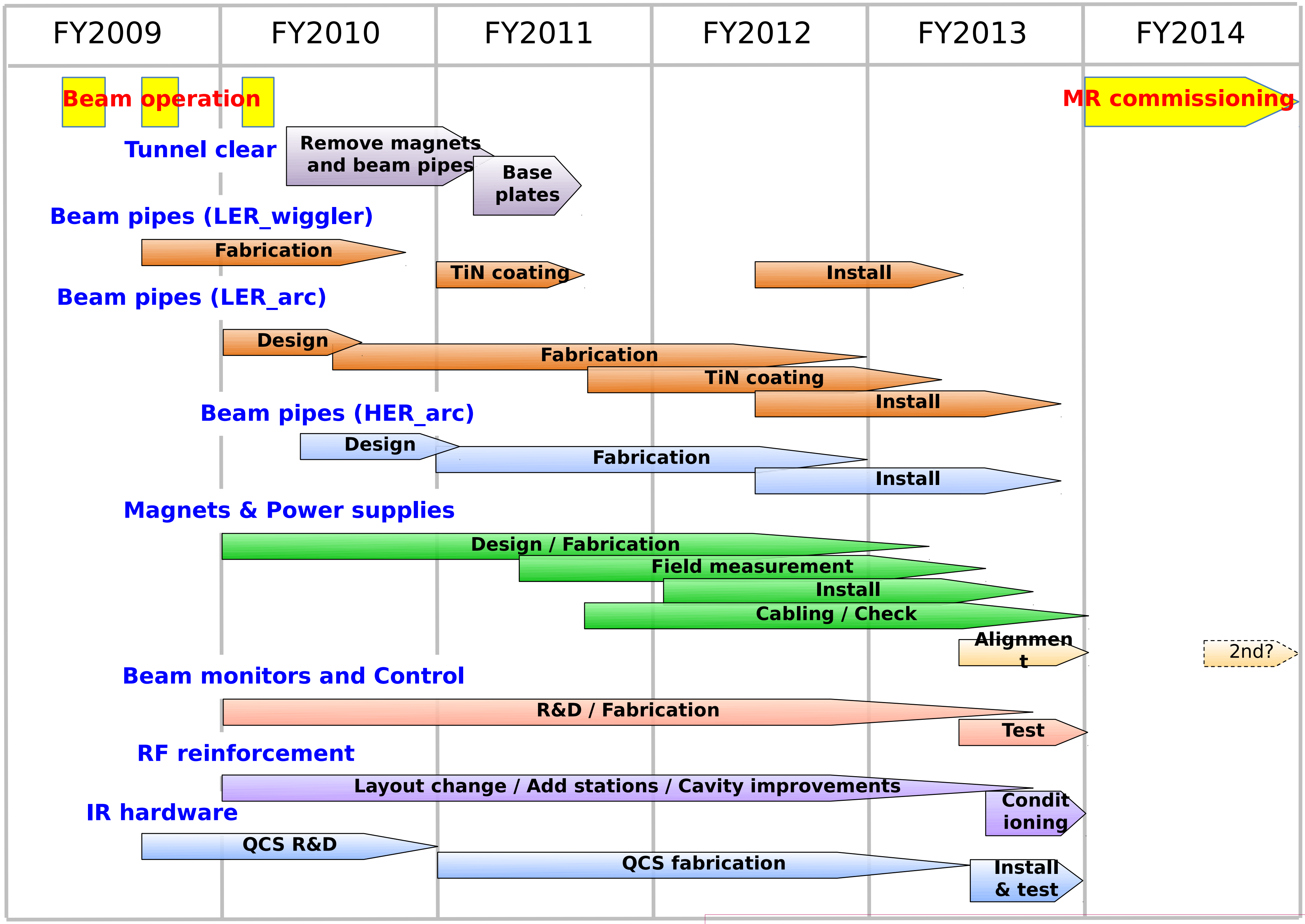
- Muon front-end electronics can basically be kept (already @ 40MHz)
  - The M1 chamber should be removed (background and upgraded L0)
  - The interface to the common readout has most probably to be adapted
  - The muon system should provide information to the throttling mechanism
    - Based on the present L0

SuperKEKB Parameters as of Feb.15, 2010

	KEKB Design	KEKB Achieved : with crab	SuperKEKB
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0
Crossing angle (mrad)	22	0 (crab)	83
βy* (mm)	10/10	5.9/5.9	0.27/0.41
εx (nm)	18/18	18/24	3.2/2.4
σy(μm)	1.9	0.94	0.059
ξy	0.052	0.129/0.090	0.09/0.09
σz (mm)	4	~ 6	6/5
Ibeam (A)	2.6/1.1	1.64/1.19	3.6/2.62
Number of bunches	5000	1584	2503
Luminosity (1034 cm-2 s-1)	1	2.11	80

Parameters presented at KEKB MAC Review Feb.15-17, 2010

SuperKEKB Main Ring schedule



FY2009 FY2010 FY2011 FY2012 FY2013 FY2014

Beam operation

MR commissioning

Tunnel clear
- Remove magnets and beam pipes
- Base plates

Beam pipes (LER_wiggler)
- Fabrication
- TiN coating
- Install

Beam pipes (LER_arc)
- Design
- Fabrication
- TiN coating
- Install

Beam pipes (HER_arc)
- Design
- Fabrication
- Install

Magnets & Power supplies
- Design / Fabrication
- Field measurement
- Install
- Cabling / Check
- Alignment
- 2nd?

Beam monitors and Control
- R&D / Fabrication
- Test

RF reinforcement
- Layout change / Add stations / Cavity improvements
- Conditioning

IR hardware
- QCS R&D
- QCS fabrication
- Install & test

Cost estimation

1 (Oku-Yen) = 1.1 M USD = 0.8 M EUR (as of 12 Feb, 2010)

Components	Cost (Oku-Yen)	Remarks
Linac upgrade and Damping Ring	31	e+ matching and L-band acc., RF-gun and laser system, Damping Ring components
Vacuum System	135	beam pipes (ante-chambers, electrodes, etc), pumps and other vacuum components for 3km x 2 rings
Magnet System	93	magnets,power supplies, cables
IR upgrade	20	QCS and other hardware
RF System	25	add 9 RF stations, improve cavities (coupler, HOM damper)
Beam monitor and control	32	BPM, SRM, feedback, control system, etc.
Belle upgrade	14.7	
Total	350.7	

- Cost for DR tunnel construction is not included in the list. Also cost for buildings and facilities for Linac, DR and MR is not included. These costs are about 30 Oku-Yen in total.
- This list is what went to MEXT last year. According to recent estimation, cost for some components increases, but some others decrease.

SuperB Bullet points

- It is part of the European Strategy Forum on Research Infrastructures (ESFRI) forward look.
- SuperB is the #1 science priority for INFN.
- It is #1 flagship of the Italian National Research Plan.
- It has been endorsed by the Italian Science and Economy Ministry.
- Two possible funding streams: either as part of the Italian National Research Plan or stimulus package.
- Currently waiting for approval from cabinet committee.
- MOU's have been signed between France, Russia and US; letter of support from Canada.
- Berlusconi and Putin signed a joint agreement of mutual financial support of a fusion reactor research in Moscow and the SuperB project in Italy in May.
- Agreement between INFN/IN2P3 to hire people before approval.
- Likely to be one of the first European Research Infrastructure Consortiums, ERIC (no VAT).
- Time-scale: 5-6 years (based on Belle and BaBar experience) from approval.
- Site: Either Roma 2 University Camps at Tor Vergata or Frascati INFN site.
- Cost: ~700M€.
- 15 M€ already pledged by Lazio regional government.
- White Paper and CDR for Physics, Detector, Accelerator and Computing due out this month.

SuperB Bullet points

Accelerator:

- Design already reviewed by Machine Advisory Committee (MAC).
- Copious B, D and tau production (>10^{10} of each type per year).
- 80% polarized e- beam (important for LFV couplings in tau decays).
- Can run at energies from the ψ(3770) to Υ(6S) and energies in between (g-2).
- Can achieve 100 x CLEO-c luminosity in 2 months.
- INFN needs accelerator physicists and has money to pay them.

Detector:

- UK contributing to design for INMAPS pixel silicon vertex detector (NIM paper in preparation).
- Many other possibilities. Highlights:
  - Forward PID: Focusing, TOF RICH.
  - Drift Chamber: Cluster counting could improve dE/dx by factor 2-3.
  - Forward Calorimeter: fast LYSO crystals
  - Trigger and DAQ: new design. Cannot reuse LHC design as some sub-detectors have high latency.
  - Muon Chamber: LSTs

Computing:

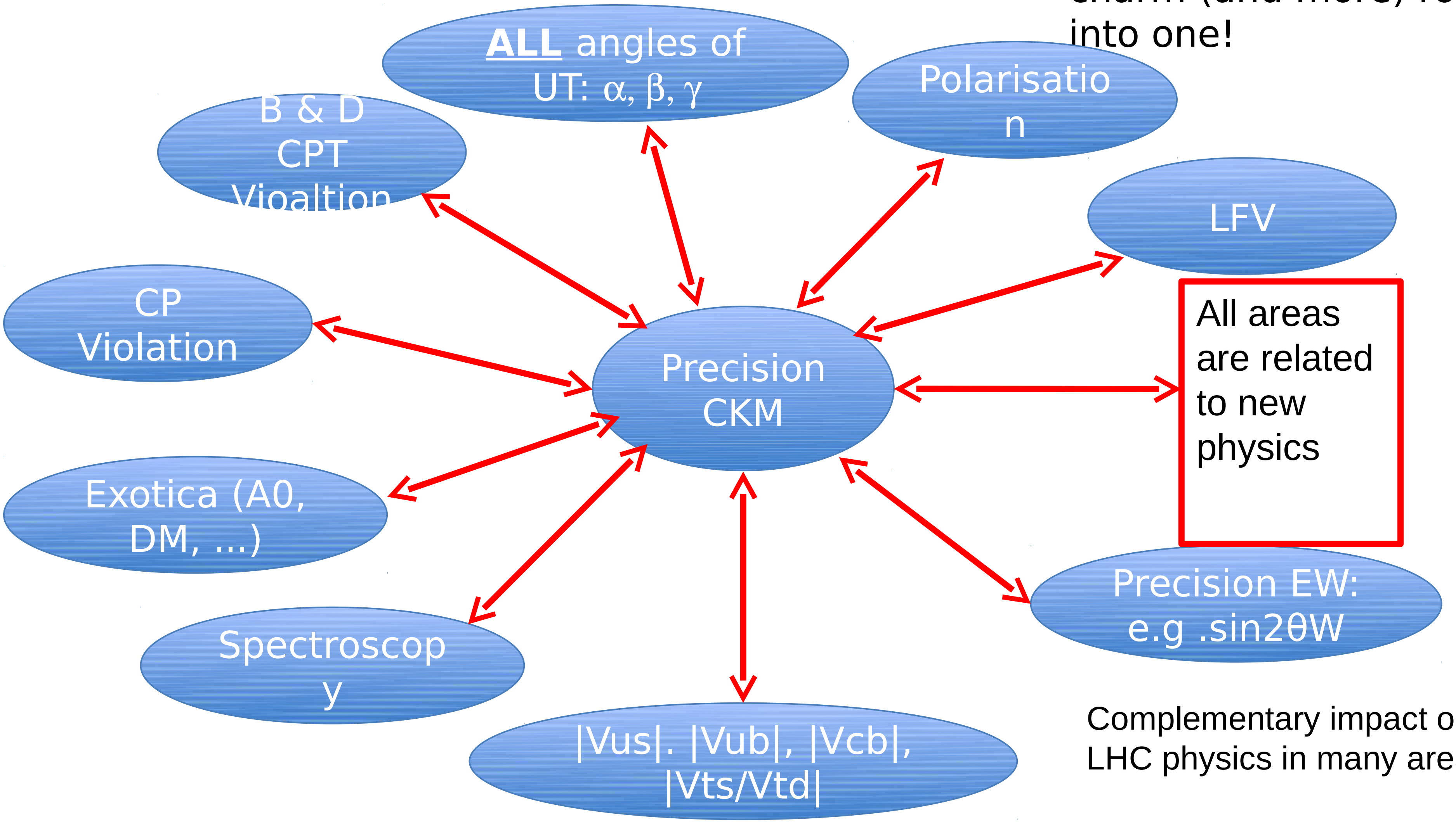
- LHC-like computing requirements. Need to log 25KHz of 75Kbyte events (~3 PetaBytes/year).
- Simulations running on the Grid.
- RAL and QMUL already contributing to production.
- Opportunity to design the complete system.

SuperB: Physics

Operate between Charm threshold and $\Upsilon(6S)$.

- See white paper for details (on archive soon)

Is a Super-CLEO/B/τ-charm (and more) rolled into one!



ALL angles of UT: α, β, γ

Polarisation

B & D CPT Vioaltion

LFV

CP Violation

Precision CKM

All areas are related to new physics

Exotica (A0, DM, ...)

Precision EW: e.g .sin2θW

Spectroscopy

|Vus|. |Vub|, |Vcb|, |Vts/Vtd|

Complementary impact on LHC physics in many areas.

SuperB: Physics

Operate between Charm threshold and Υ(6S).

Is a Super-CLEO/B/τ-charm (and more) rolled into one!

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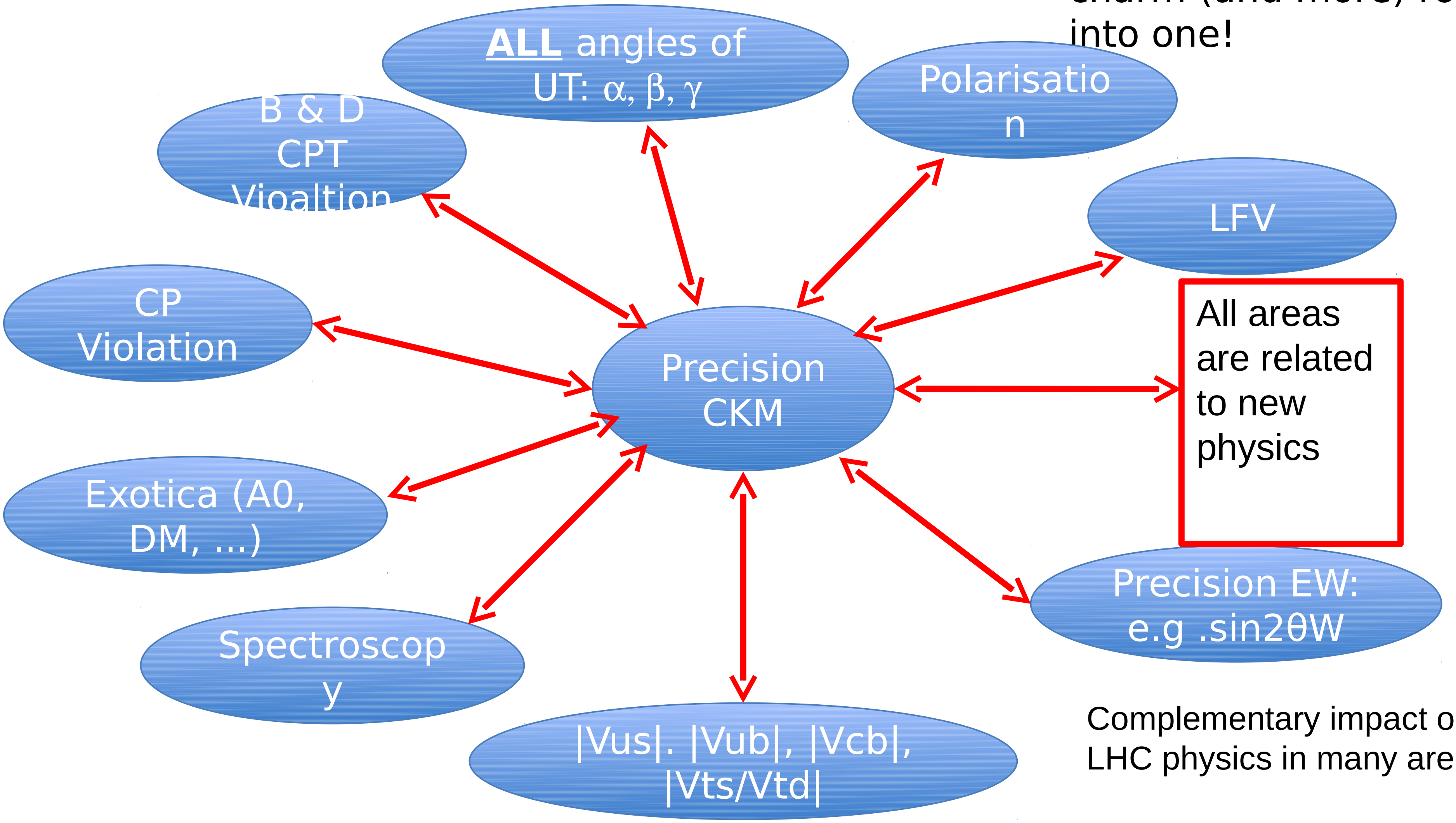

ALL angles of UT: α, β, γ

B & D CPT Vioaltion

Polarisation

LFV

CP Violation

Precision CKM

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Exotica (A0, DM, ...)

Spectroscopy

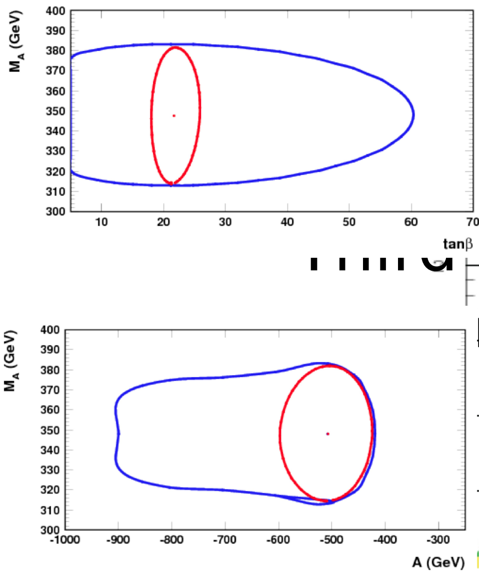
|Vus|. |Vub|, |Vcb|, |Vts/Vtd|

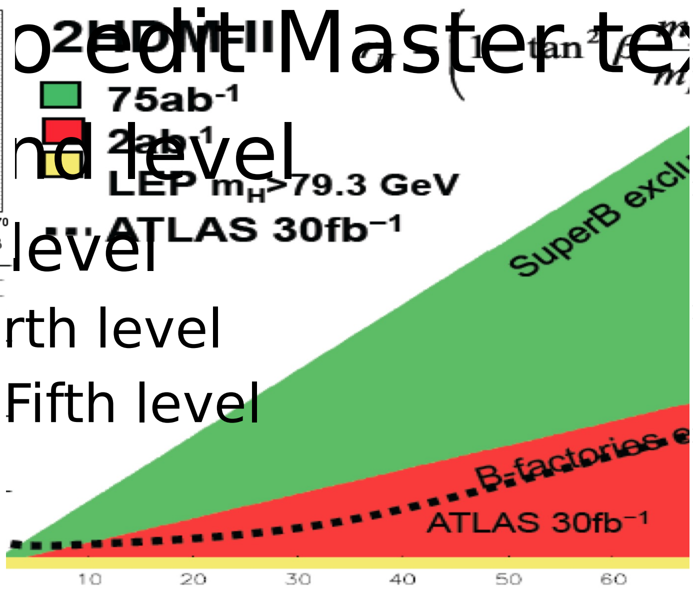
Precision EW: e.g .sin2θW

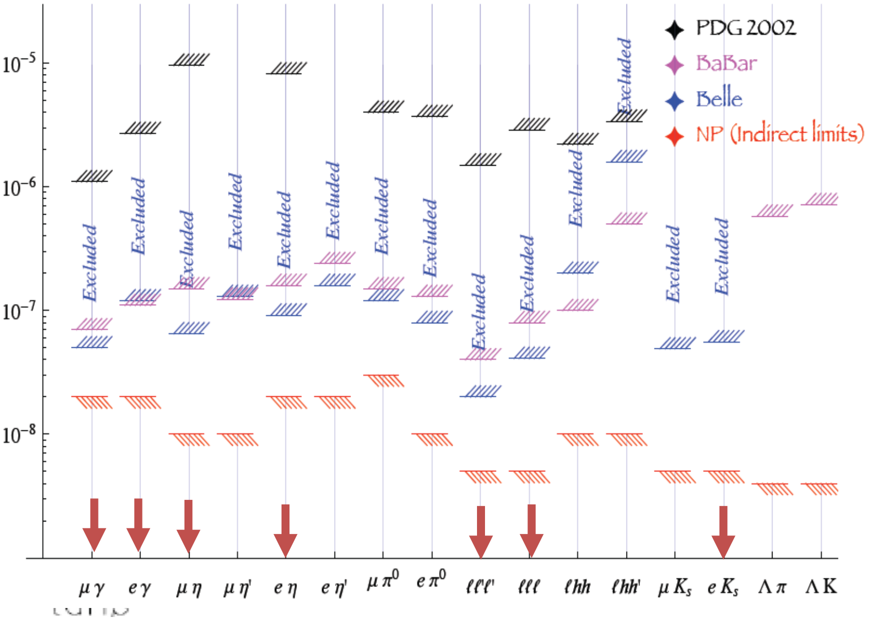
Complementary impact on LHC physics in many areas.

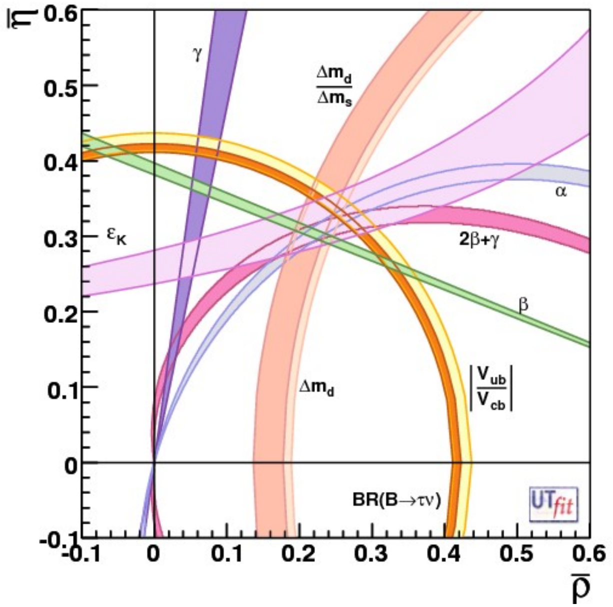
Some examples

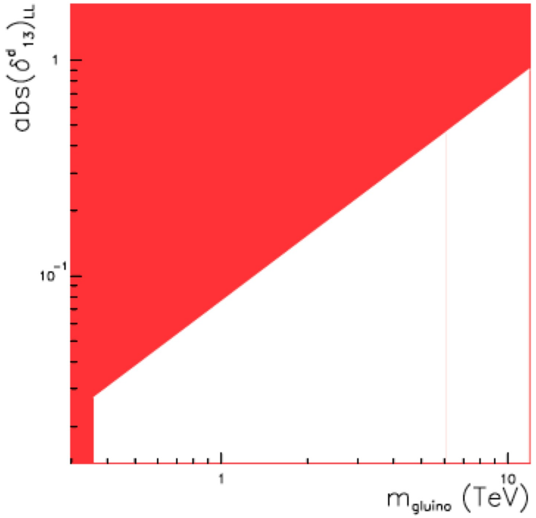
- o edit Master te
  - nd level
    - level
      - rth level
        - Fifth level

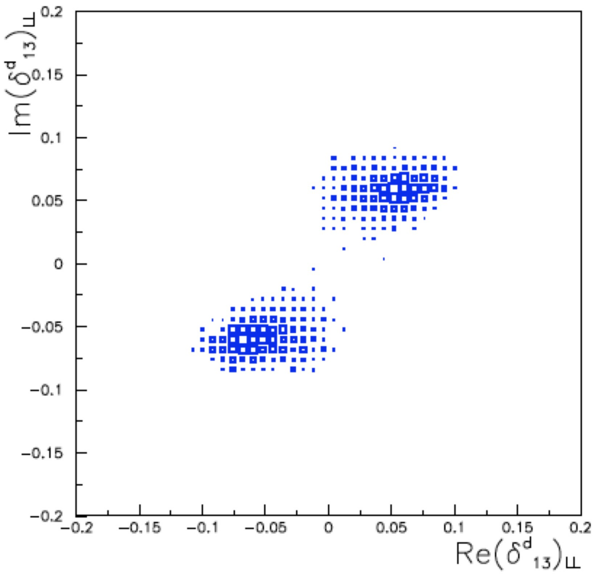










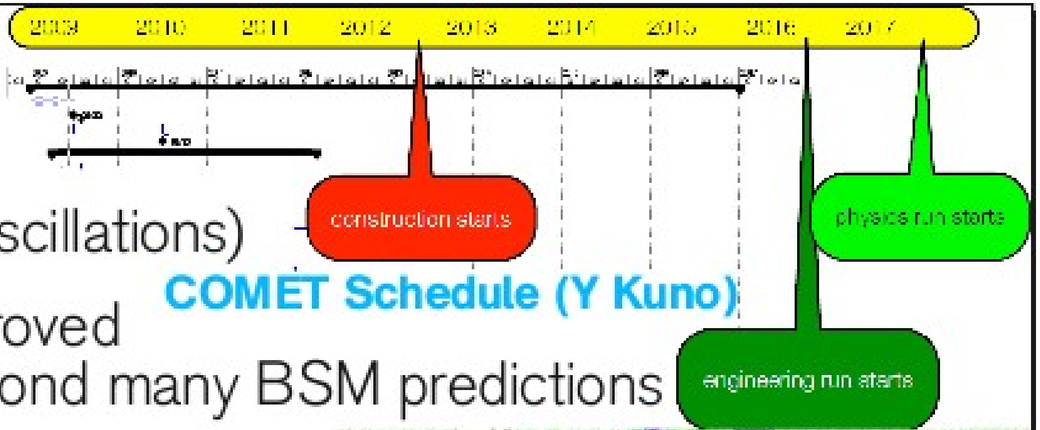


Kaons

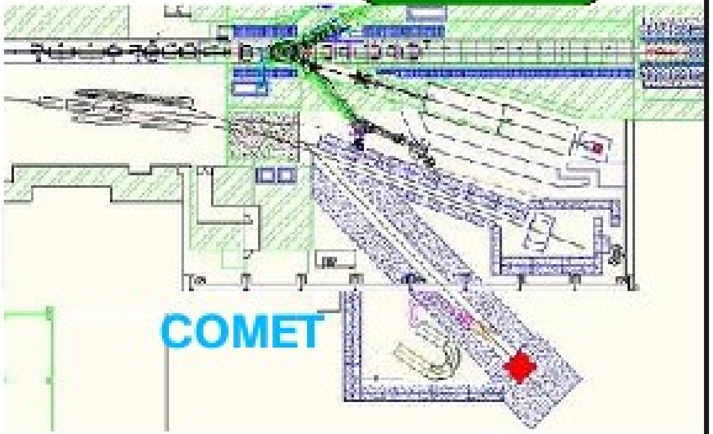
- NA62-Phase I has produced a very precise measurement of Ke2/Kμ2 ratio, which is currently in agreement with SM but shows a 1.5 sigma tension. Birmingham is leading this analysis.
- CERN NA62-Phase II ($K^+ \rightarrow \pi^+ \nu\nu$) is progressing well. The aim is still to take first data at the end of 2012, but possibly with an incomplete detector for the first 6 months or so
- UK (Birmingham, Bristol, Glasgow, Liverpool) involvement is on hold until the financial situation improves. Still, UK is progressing with conceptual design of modifications needed for the CEDAR detector (used to identify kaons in the beam line)
- JPARC KOTO ($K^0 \rightarrow \pi^0 \nu\nu$) is approved & progressing. Expect first data taking Autumn 2011 & reach SM prediction sensitivity in 3 years
- FNAL P996 proposed for $K^+ \rightarrow \pi^+ \nu\nu$ with stopped kaons in target. Expecting ~200 events/year, but not yet approved.

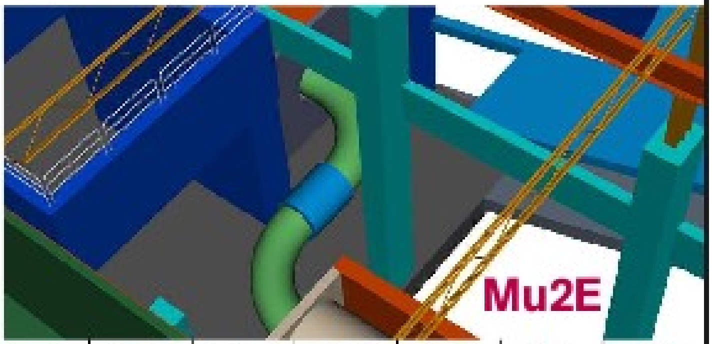
Lepton Flavour Violation

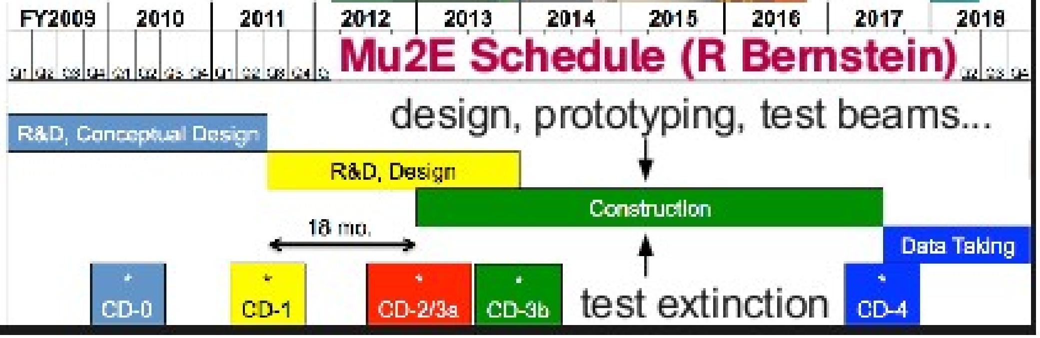
- We know that charged lepton flavour violation *must* occur (from neutrino oscillations)
  - μFV experimental limits can be improved by several orders of magnitude, beyond many BSM predictions
- **MEG** ($\mu \rightarrow e + \gamma$, running since 2008 at PSI)
  - $<3\times10^{-11}$ in 2009; sensitive to 10^{-13} by 2013
- **Muon-to-Electron Conversion** (aim: factor 10,000 improvement, to $<10^{-16}$)
  - **COMET (J-PARC)**
    - **Stage-1 approval** (of 2 stages) July 09
    - J-PARC preparatory work progressing
      - good inter-bunch extinction found in observations at the J-PARC Main Ring beam
  - **Mu2E (Fermilab)**
    - **CD0** at Fermilab in November 09
    - Tracker/Cosmic Veto/ Extinction Monitor R&D this year



COMET Schedule (Y Kuno)







Mu2E Schedule (R Bernstein)

design, prototyping, test beams...

test extinction

COMET/PRISM R&D

- **COMET Prototype (MUSIC)**
  - World's first superconducting pion capture solenoid at Osaka
  - Part of wider programme of study with UK involvement
  - 2 UCL PG students on-site
- **COMET Technical Design Report** (in Preparation)
  - UK contributing design studies, software development, editorial leadership
- **PRISM FFAG Task Force** (Next Generation Muon-to-Electron Conversion)
  - International team (8 UK institutes) led by J Pasternak (Imperial/RAL)
  - Major synergies with UK programme
    - Progress in Injection/extraction, new lattice possibilities for scaling & non-scaling FFAGs, dispersion matching and kicker designs
  - CDR forthcoming