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Status of LHCb

&

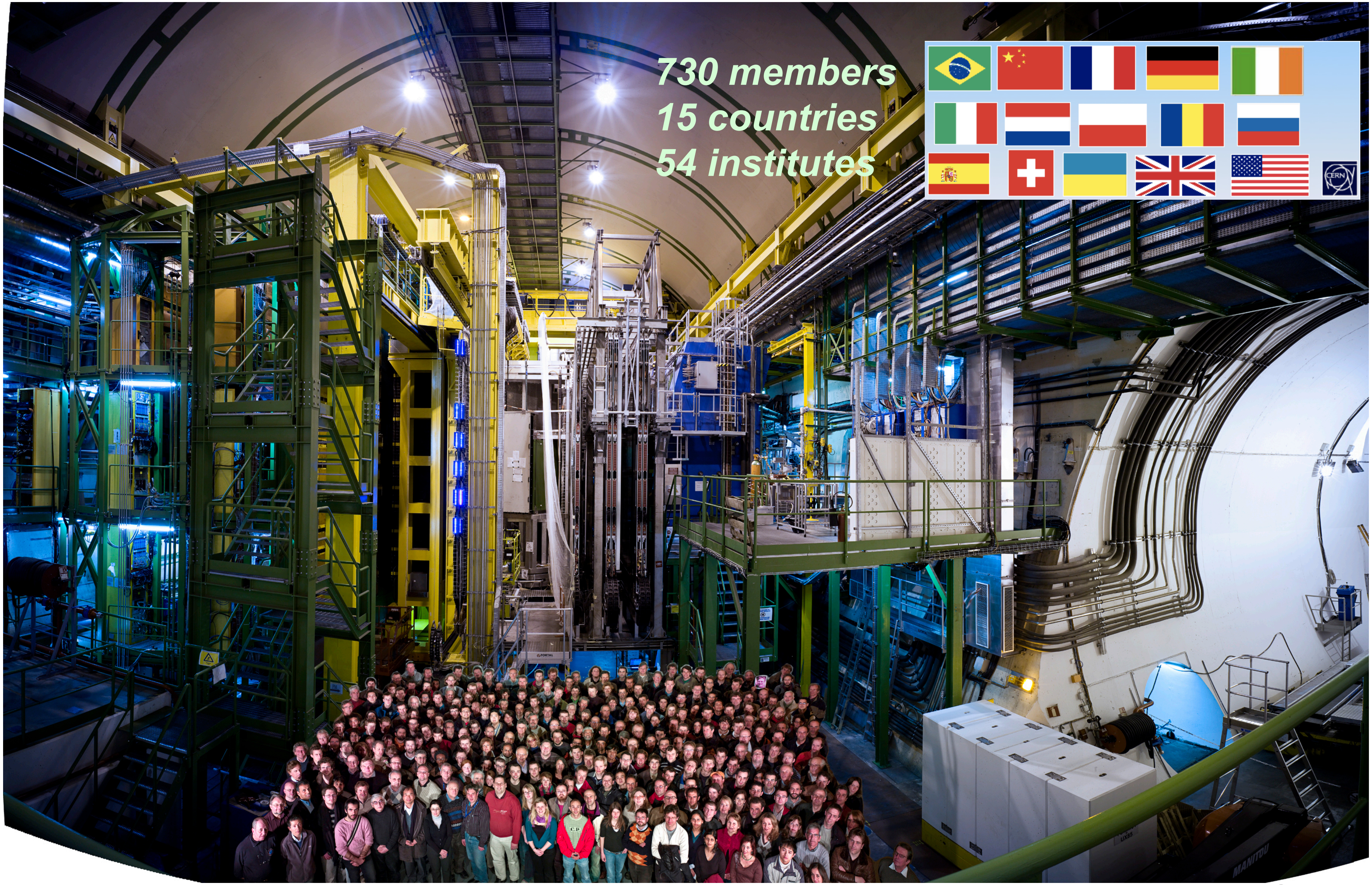
expected physics production in next several years

(CERN-LHCb-PUB-2009-029)

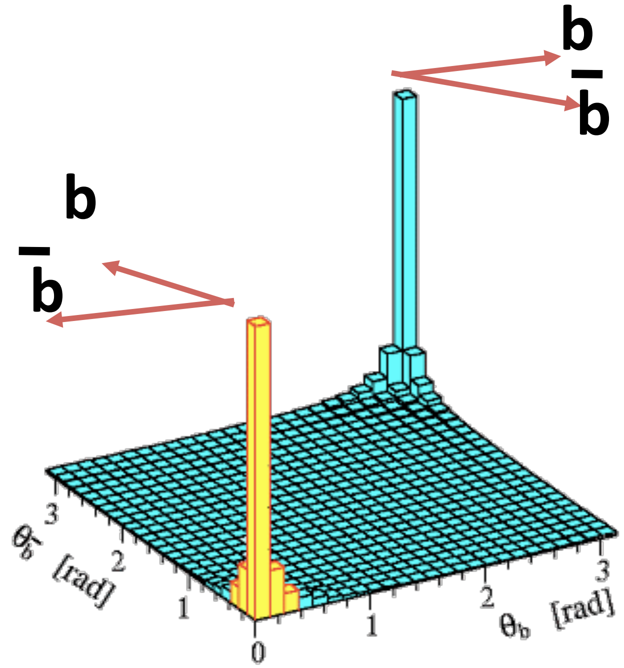
Integrated luminosity for 1 nominal LHCb year: 2 fb^{-1}
Expected for 2010 – 2011 : 1 fb^{-1}
LHCb physics programme needs 10 fb^{-1}
LHCb upgrade to collect ~100 fb^{-1} is under discussion

(For the Status of LHCb see the talk of Ulrich Kerzel)

LHCb Collaboration

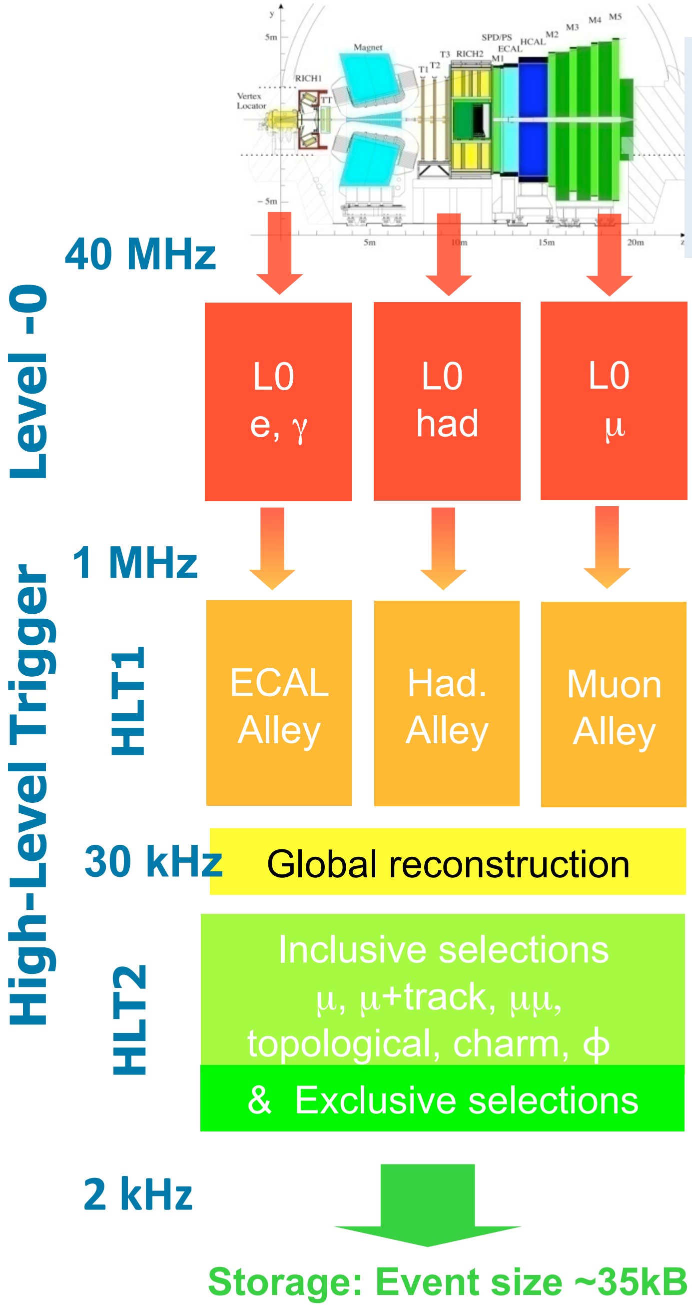


The LHCb Experiment



- *Advantages of beauty physics at hadron colliders:*
  - *High value of bb cross section at LHC:*
    σ_{bb} ~ 300 - 500 μb at 10 - 14 TeV
    (e+e- cross section at Y(4s) is 1 nb)
  - *Access to all quasi-stable b-flavoured hadrons*
- *The challenge*
  - *Multiplicity of tracks (~30 tracks per rapidity unit)*
  - *Rate of background events: σ_{inel}~ 100 mb*
- *LHCb running conditions:*
  - *Luminosity limited to ~2×10^{32} cm^{-2} s^{-1} by not focusing the beam as much as ATLAS and CMS*
    - *Maximize the probability of single interaction per bunch crossing*
      At LHC design luminosity pile-up of >20 pp interactions/bunch crossing while at LHCb ~ 0.7 pp interaction/bunch
    - *LHCb will reach nominal luminosity soon after start-up*
  - ***2fb^{-1} per nominal year (10^7s), ~ 10^{12} bb pairs produced per year***

LHCb Trigger



Trigger is crucial as σ_{bb} is less than 1% of total inelastic cross section and B decays of interest typically have BR < 10^{-5}

- ☐ ***Hardware level (L0)***

  Search for high-p_T μ, e, γ and hadron candidates

- ☐ ***Software level (High Level Trigger, HLT)***

  *Farm with **O**(2000) multi-core processors*

  HLT1: Confirm L0 candidate with more complete info, add impact parameter and lifetime cuts

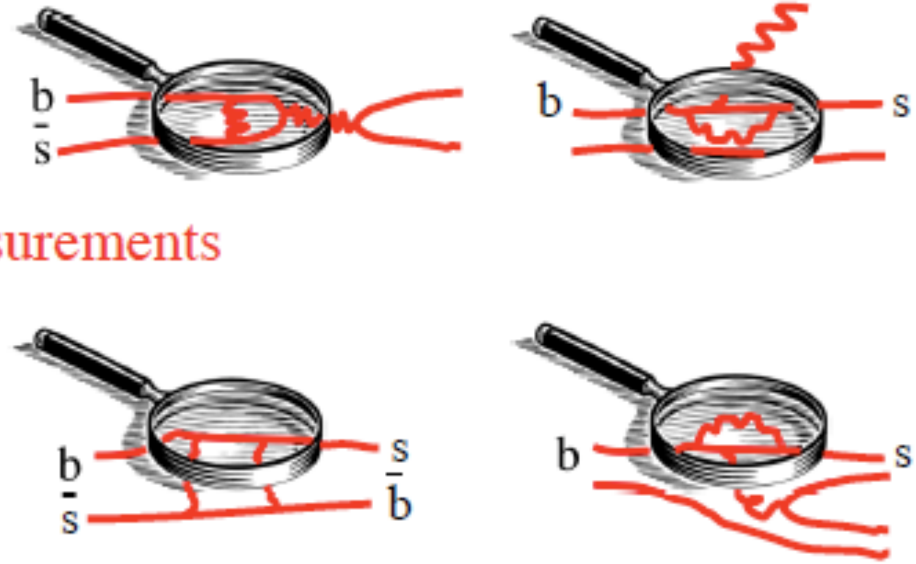
  HLT2: B reconstruction + selections

	ε(L0)	ε(HLT1)	ε(HLT2)
Electromagnetic	70 %	> ~80 %	> ~90 %
Hadronic	50 %		
Muon	90 %		

LHCb Physics Programme

- *Main LHCb objective is to search for the effects induced by New Physics in CP violation and Rare decays using the FCNC processes mediated by loop (box and penguin) diagrams*

- Promising rare decay measurements
  - $B_s \rightarrow \mu\mu$
  - $B^0 \rightarrow K^* l^+ l^-$
  - $B_s \rightarrow \phi\gamma$
- Promising CP violation measurements
  - $B_s \rightarrow J/\psi\phi$
  - $B_s \rightarrow \phi\phi$



- *NP effects could be different in boxes and penguins*
  → *study different topologies separately !*

Sensitivity to masses, couplings, spins and phases of New Particles

New Physics Search Strategy

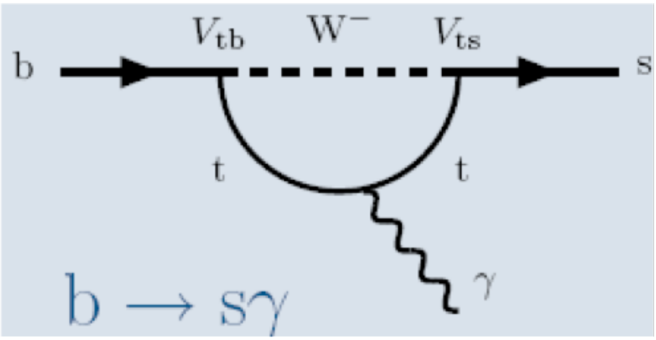
- **Phases**

  CPV processes are sensitive to the phases of New Physics e.g. measurements of **β , β_s & γ**

- **Masses and magnitude of the couplings of new particles**

  Look at specific cases with enhanced sensitivity e.g. helicity suppression in **$B_s \rightarrow \mu\mu$** decay gives increased sensitivity to SUSY with extended Higgs sector

- **Helicity structure of the couplings**



- Photon polarization in $b \rightarrow s\gamma$

  $b \rightarrow \gamma_L + (m_s/m_b) \times \gamma_R$

  $\phi\gamma$ produced in B_s and B_s decays do not interfere

  → corresponding CP asymmetry vanishes

  Significantly non-zero A_{CP} indicates a presence of right-handed current in the penguin loop

- $B \rightarrow K^*\mu\mu$ & $B \rightarrow K^*ee$ decays

CPV measurements: phase of B_s mixing

- ***Box diagrams***

*$\phi_s^{J/\psi\phi}$ = **$-2\beta_S$** in SM is the B_s meson counterpart of 2β*

penguin contribution ≤ 10^{-3}

$\phi_s^{J/\psi\phi}$ is not presently well measured (indication of large value from CDF/D0)

Theoretical uncertainty is very small

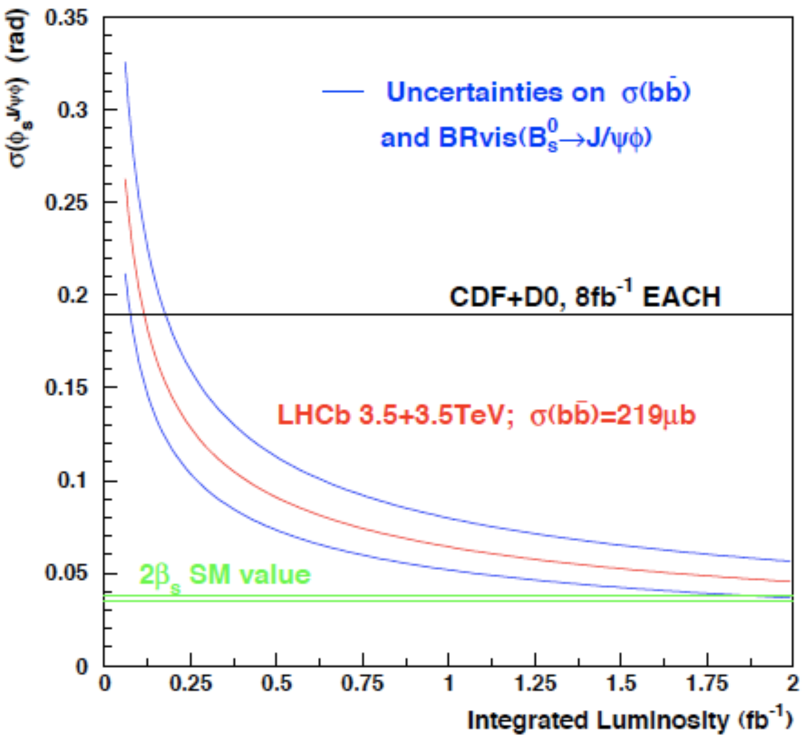
$-2\beta_s$ = - 0.0368±0.0017 (CKMfitter 2007)

LHCb prospects (2 fb^{-1} sample)

Expected yield 117k B_s → $J/\psi\phi$ events

$\sigma(\phi_s)$ ~ 0.03

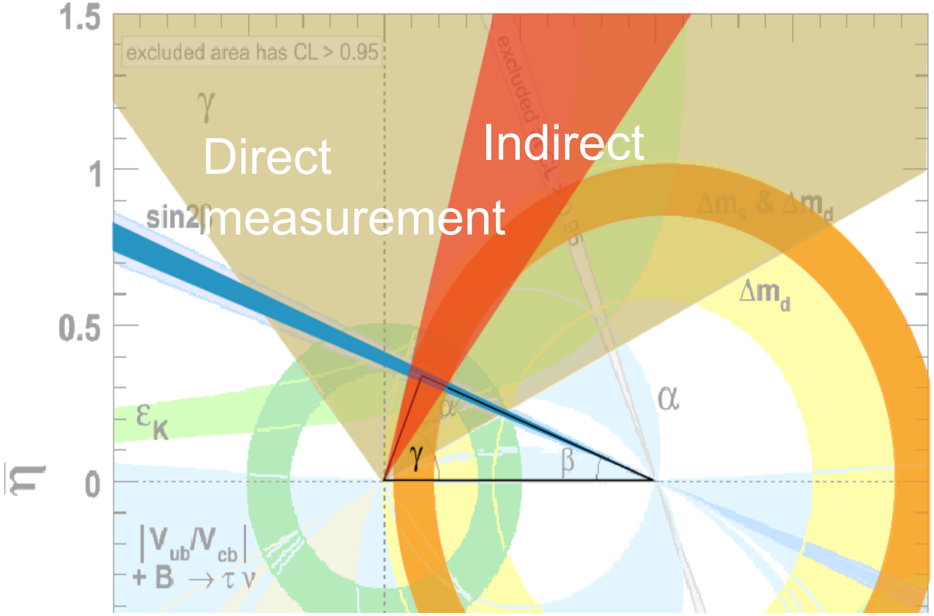
Other channels are under study e.g.
$B_s \rightarrow J/\psi f^0$, $f^0 \rightarrow \pi^+\pi^-$. Looks promising
if this CP-eigenstate mode has BR indicated
by CLEO



With 0.3 fb^{-1} ~8k signal events → $\sigma(\phi_s)$ = 0.12

CPV measurements: UT angles

❑ Box diagrams



Indirectly, γ is determined to be (68±5)° from processes involving boxes

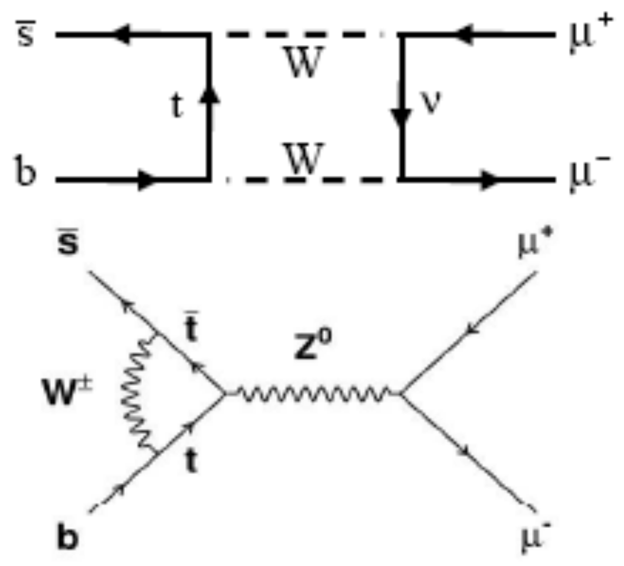
LHCb will measure γ directly in tree decays using the global fit to the rates of $B \to D^0K$, D^0K^* decays and time-dependent measurements with $B_s \to D_sK$ and $B^0 \to D\pi$ decays

Expected $\sigma(\gamma_{trees}) \approx 4°$ with 2 fb^{-1}

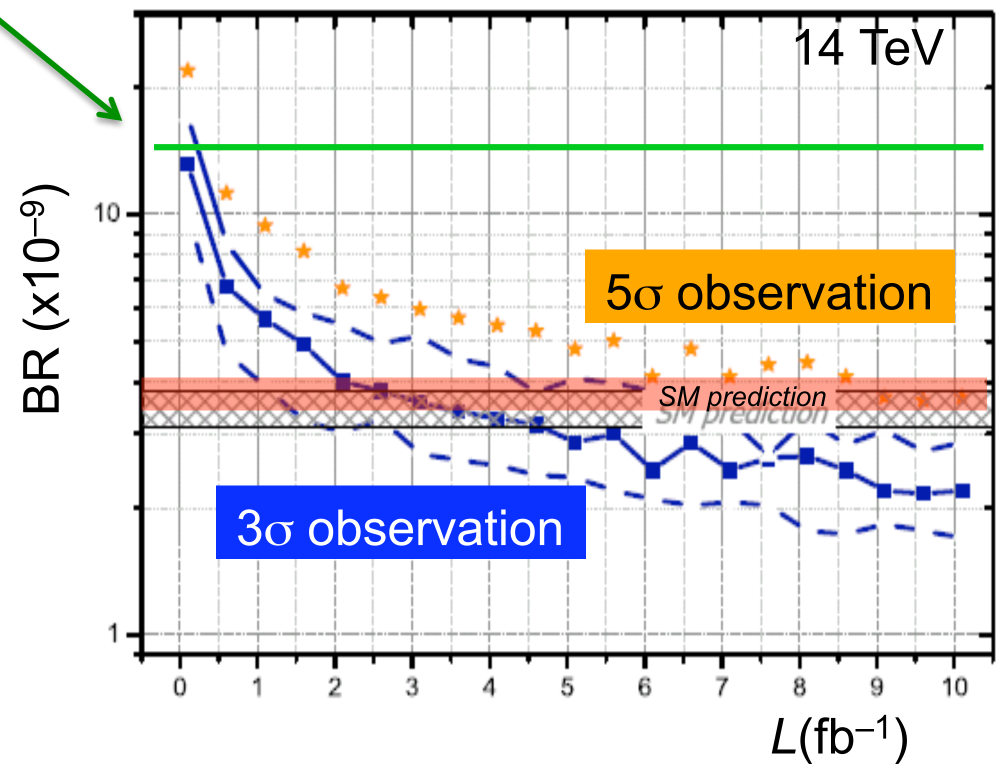
- *Quoted errors do not include experimental systematics*
- *Statistical errors expected to dominate*

Channel	Analysis method	Signal Events (2 fb^{-1})	B/S	$\sigma(\gamma)$(°)
$B^\pm \to D^0(K\pi)K^\pm$ fav	2-body ADS	84k	0.6	10-11
$B^\pm \to D^0(K\pi)K^\pm$ sup	2-body ADS	1.6k	0.6	
$B^\pm \to D^0(hh)K^\pm$	2-body GLW	11.5k	0.93	
$B^\pm \to D^0(K3\pi)K^\pm$ fav	4-body ADS	53k	0.2	Improves the above
$B^\pm \to D^0(K3\pi)K^\pm$ sup	4-body ADS	554	3.1	
$B^0 \to D^0(K\pi)K^{*0}$ fav	B0 ADS	3.2k	0.2	15-25
$B^0 \to D^0(K\pi)K^{*0}$ sup	B0 ADS	291	<10	
$B^0 \to D^0(hh)K^{*0}$	B0 GLW	274	<6	
$B^\pm \to D^0(K_S\pi\pi)K^\pm$	GGSZ	6.8k	<1.6	12.5
$B_s \to D_s^\mp K^\pm$	TD	14k	0.22	9-12
$B_d \to D^\mp \pi^\pm$	TD	1,240k	0.16	≥22

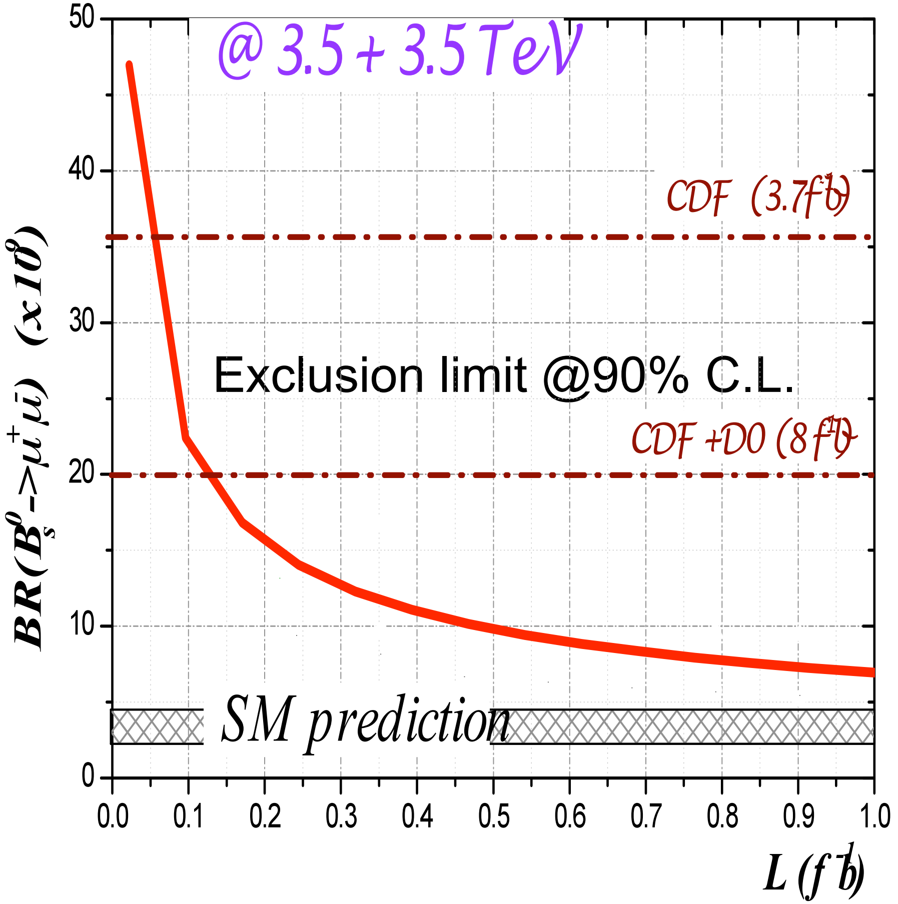
$B_s \rightarrow \mu\mu$

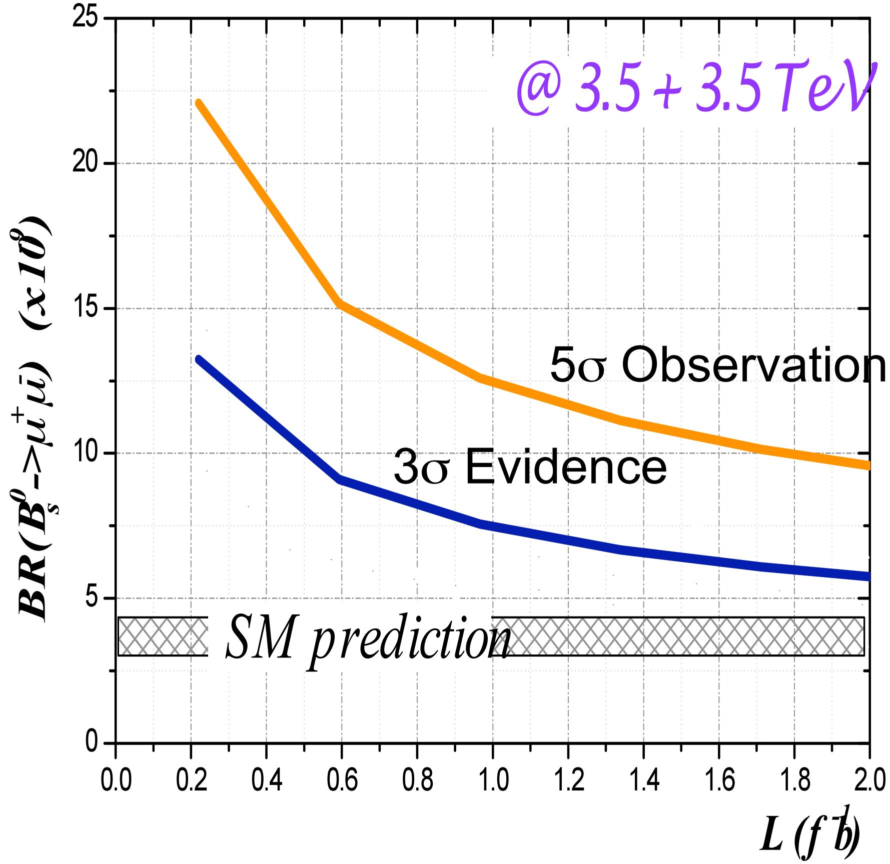


- Super rare decay in SM with well predicted $BR(B_s \rightarrow \mu\mu) = (3.55\pm0.33)\times10^{-9}$
- Sensitive to NP, in particular new scalars
  In MSSM: $BR \propto \tan^6\beta / M^4_A$
- Present best limit is from Tevatron:
  $BR(B_s \rightarrow \mu\mu) < 4.3\times10^{-8}$ @ 90% CL
- For the SM prediction
  LHCb expects 21 signal and 180 background events with 2 fb^{-1}.
  Background is dominated by muons from two different semileptonic b-decays
- LHCb sensitivity for the SM BR:
  3σ evidence with 3 fb^{-1}
  5σ observation with 10 fb^{-1}



Running at 3.5 TeV per beam:





Measurement of the photon polarization

- BaBar & BELLE used CPV analysis in $B \rightarrow K^*(K^0\pi^0)\gamma$ decay
  σ (A ($B \rightarrow f^{CP}\ \gamma_R$) / A ($B \rightarrow f^{CP}\ \gamma_L$) ~ 0.16 (HFAG)
  (~0.03 within SM due to m_s/m_b and gluon effects)

- CPV analysis in the $B_s \rightarrow \phi\gamma$ decay can be performed without flavour tagging

$$\Gamma(\mathrm{B}_q(\bar{\mathrm{B}}_q) \to f^{CP}\gamma) \propto e^{-\Gamma_q t}\left(\cosh\frac{\Delta\Gamma_q t}{2} - \mathcal{A}^{\Delta}\sinh\frac{\Delta\Gamma_q t}{2} \pm \right.$$
$$\left. \pm\mathcal{C}\cos\Delta m_q t \mp \mathcal{S}\sin\Delta m_q t\right)$$

SM:

- C = 0 direct CP-violation
- S = **sin2ψ** sinϕ_s
- A^{Δ} = **sin2ψ** cosϕ_s

$$\tan\psi \equiv \left|\frac{A(\bar{\mathrm{B}}\to f^{CP}\gamma_R)}{A(\bar{\mathrm{B}}\to f^{CP}\gamma_L)}\right|$$

- Expected signal yield at LHCb for $B_s \rightarrow \phi\gamma$ decay is 11k for 2 fb^{-1}
  Sensitivity: σ (A ($B \rightarrow f^{CP}\ \gamma_R$) / A ($B \rightarrow f^{CP}\ \gamma_L$) = 0.11

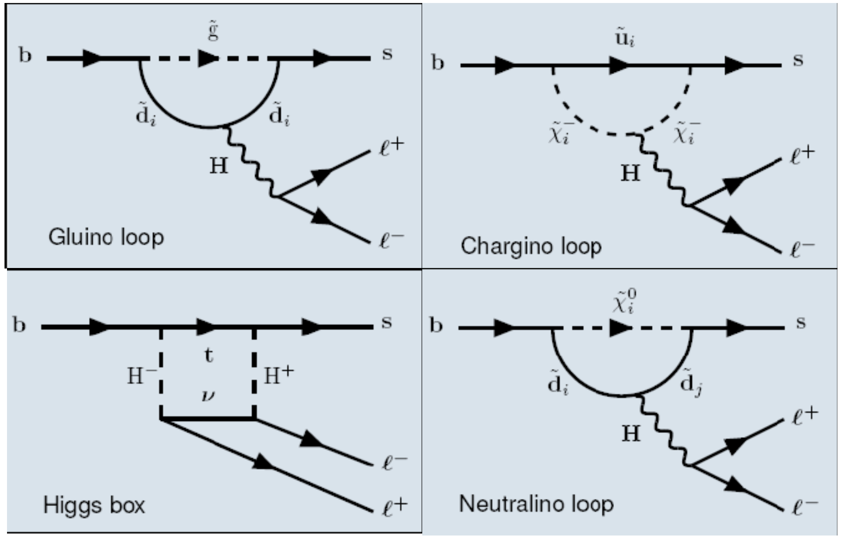
- Contribution not coming from virtual photons can be neglected at low $q^2 < (1\ GeV)^2$
  → $B_d \rightarrow K^{*0}e^+e^-$ with electrons in the final state can be used to measure photon polarization complementary to $B_s \rightarrow \phi\gamma$

- Expected LHCb yield with 2 fb^{-1}: ~ 200 – 250 events with B/S ~ 1
  Expected sensitivity σ(A ($B \rightarrow f^{CP}\ \gamma_R$)/A($B \rightarrow f^{CP}\ \gamma_L$) ≈ 0.1
  limited by statistics and comparable to $B_s \rightarrow \phi\gamma$ accuracy

$B \to K^*\mu\mu$

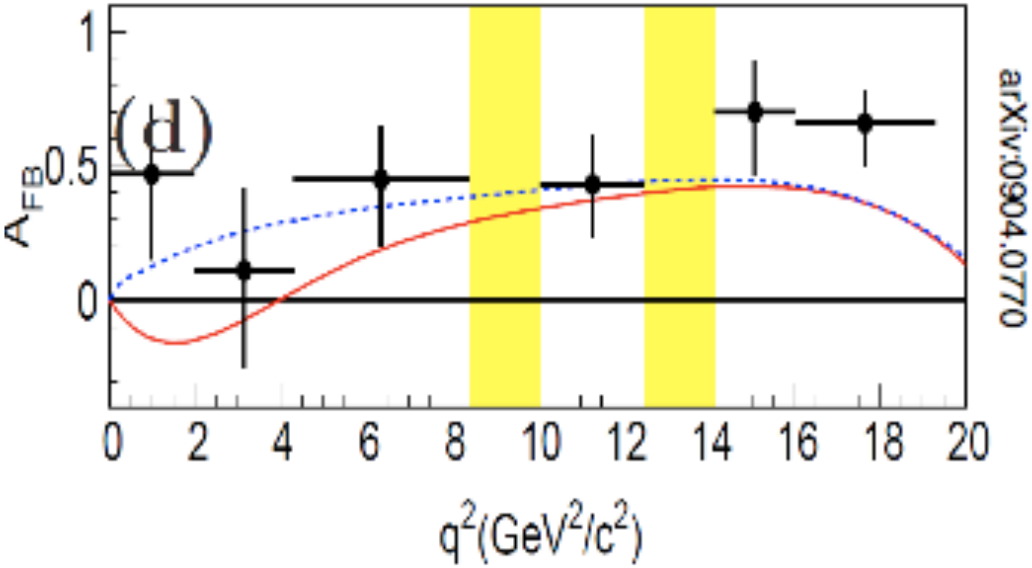
In SM this b→s penguin decay contains well calculable right-handed contribution; corresponding angular distributions could be modified by NP

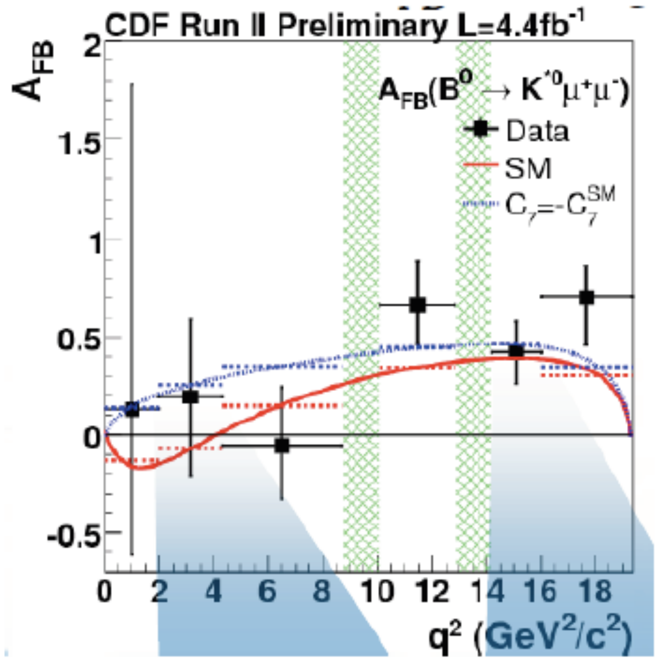
Forward-backward asymmetry A_{FB} (q^2=$m^2_{\mu\mu}$) is of particular interest at zero-point, since dominant theor. uncert. from hadronic form-factors cancels at LO



Intriguing indication from B-factories and CDF :

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



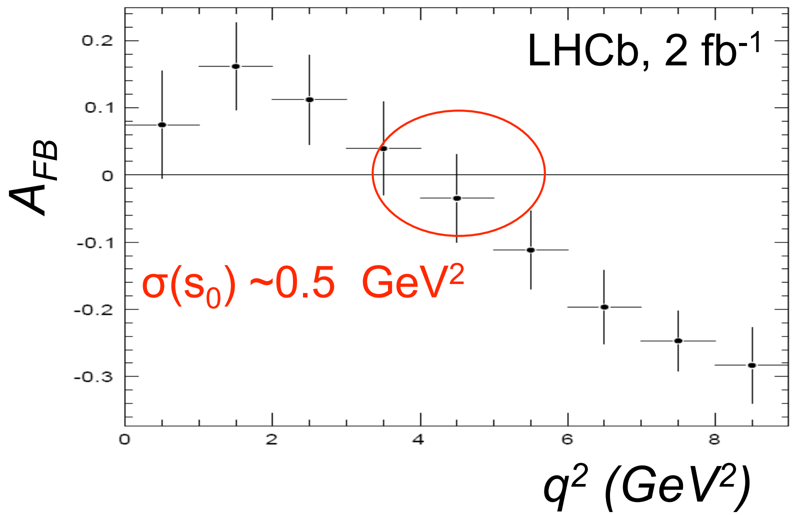


Assuming the central value given by BELLE, LHCb measurement of A_{FB} can exclude SM with 0.5 fb^{-1}.
TEVATRON contribution is important !!!

$B \rightarrow K^*\mu\mu$

LHCb expects 6.2k events / 2fb^{-1} with B/S ~ 0.2

After 2 fb^{-1} zero of A_{FB} will be located to ±0.5 GeV^2.



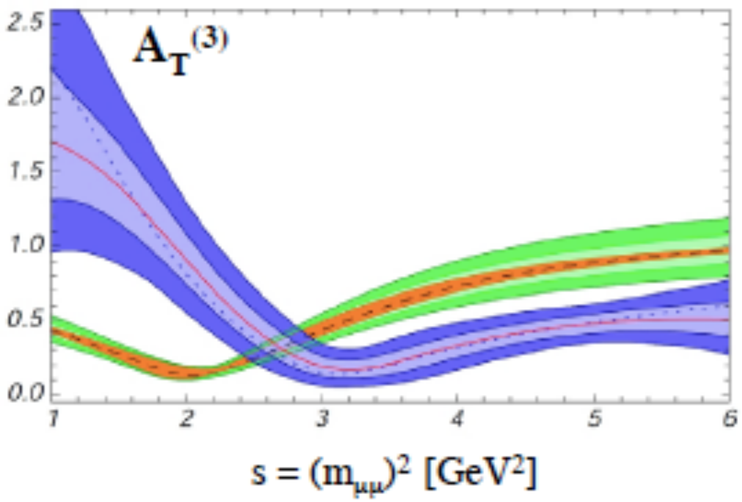
Full angular analysis gives even better discrimination between NP models:

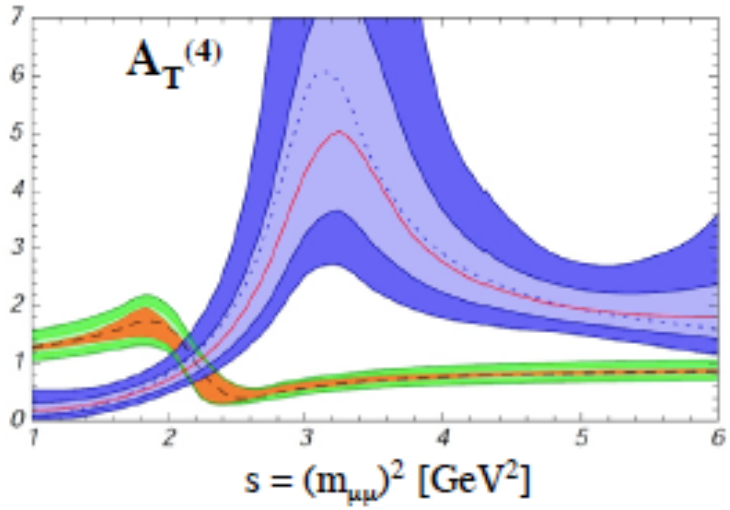
- *Improved precision on A_{FB}*
- *Having extract underlying amplitudes one can construct any observable e.g. $A_T^{(2)}$, $A_T^{(3)}$, $A_T^{(4)}$*

With 10 fb^{-1} of LHCb data

***MSSM** scenario + LHCb errors (1σ and 2σ bands)*

***SM** scenario + theory errors*





LHCb key measurements

(to search for NP in CP violation and Rare Decays)

Key Measurements	**Accuracy in 1 nominal year ($2\ fb^{-1}$)**
❑ *In CP – violation*	
✓ ϕ_s	**0.03**
✓ γ in trees	4°
✓ γ in loops	7°
❑ *In Rare Decays*	
✓ $B_s \to \mu\mu$	**3σ measurement down to SM prediction**
✓ $B \to K^*\mu\mu$	$\sigma(s0) = 0.5\ GeV^2$
✓ Polarization of photon	$\sigma(H_R/H_L) = 0.1$ (in $B_s \to \phi\gamma$) $\sigma(H_R/H_L) = 0.1$ (in $B_d \to K^* e^+ e^-$)

Measurements highlighted in red will become competitive first

LHCb key measurements

(to search for NP in CP violation and Rare Decays)

Key Measurements	Sensitivity with 10 fb^{-1} (few years of data taking)
❑ In CP – violation	
✓ ϕ_s	0.01
✓ γ in trees	~2°
✓ γ in loops	~3°
❑ In Rare Decays	
✓ $B \rightarrow K^*\mu\mu$	$\sigma(s0)$ = 0.28 GeV^2
✓ $B_s \rightarrow \mu\mu$	5σ measurement down to SM prediction
✓ Polarization of photon	$\sigma(H_R/H_L)$ = 0.03 (in $B_s \rightarrow \phi\gamma$ & $B_d \rightarrow K^*e^+e^-$)

Conclusion

- *LHCb is ready for long physics run at close to nominal LHCb conditions already in 2010*

- *First data are being used for calibration of the detector and trigger in particular. First exploration of low Pt physics at LHC energies. High class measurements in the charm sector (In 200 pb^{-1} expect ~10^7 flavour tagged $D^0 \rightarrow KK$ events;* ***Significant improvement of sensitivity for D mixing and CPV)***

- ***With 150 – 200 pb^{-1} data sample LHCb will reach Tevatron sensitivity in a few golden channels in the beauty sector***

- *With 10 fb^{-1} LHCb has an excellent opportunity to both discover New Physics and to elucidate its nature. LHCb have an important role to complement physics programme of ATLAS and CMS*