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Status of ATLAS Preparations for B-physics Measurements

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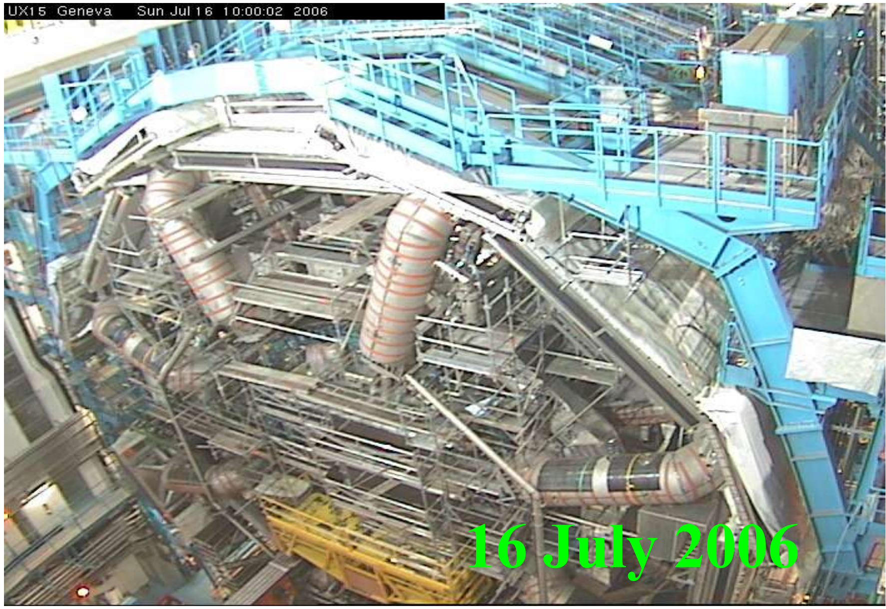
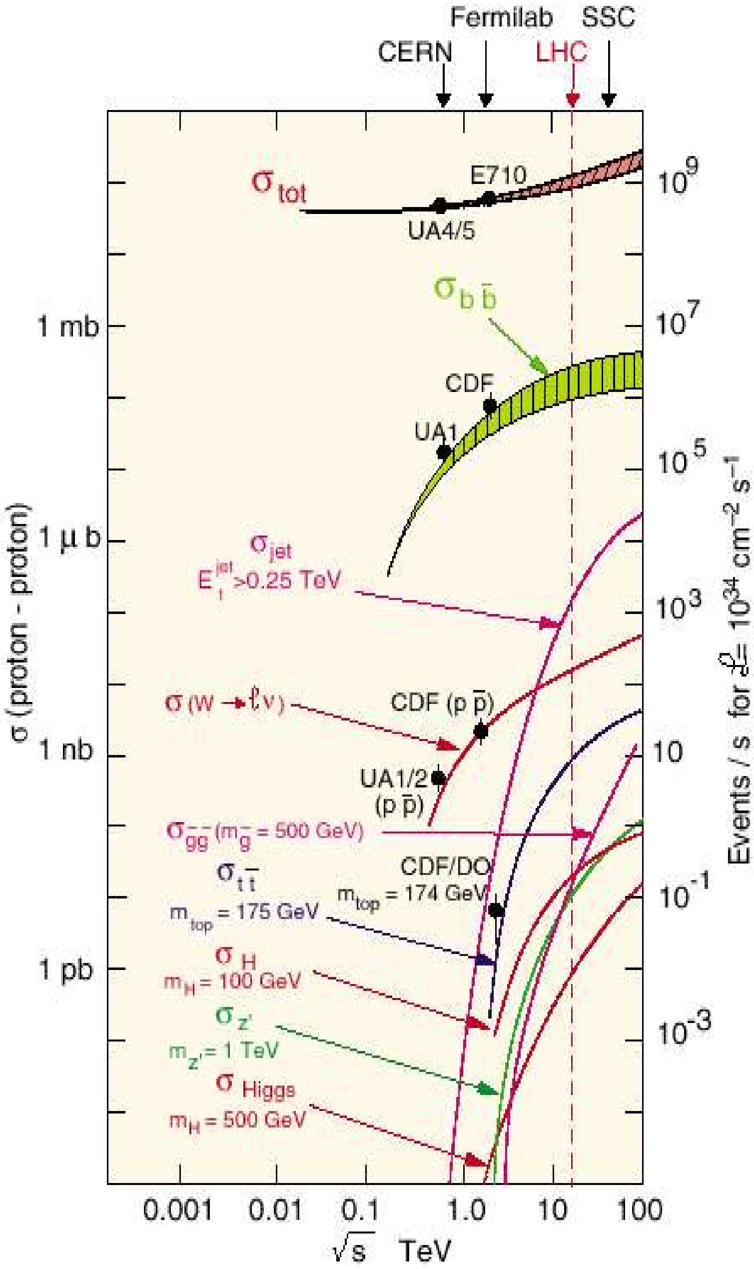
On behalf of the ATLAS Collaboration



Introduction

- b-production at LHC ($\sqrt{s}$ = 14 TeV)
  - σ_{tot} = 100 mb **σ_{bb} = 500 μb** (2×10^{12} bb pairs/year @ lumi $L=10^{33} cm^{-2}s^{-1}$
  - about $2x10^{10}$ b-quark pairs selected after trigger selections for analysis
  - luminosity periods: *early <10^{33}* , low $2x10^{33}$ **, nominal 10^{34} $cm^{-2}s^{-1}$ (100 fb^{-1}/Year)**
- The startup period in 2007 may contain a comissioning run at $\sqrt{s}$=900 GeV followed by 14TeV physics run with the aim of few fb^{-1} integral luminosity to the end of 2008
- ATLAS is a general-purpose experiment with emphasis on high-Pt physics beyond the Standard Model
- Nevertheless the ATLAS B-physics program is rich and exploiting the strong points of the detector (precise tracking and vertexing, calorimetry and muon detection) expected to extend the ATLAS discovery potential in physics beyond the SM:
  - measurements the CP-violation parameters (small in SM)
  - very rare decays (b->(s,d)l^+l^-) (BR, A_{FB},possible enhancement)
  - topics, not accessible for B-factories (B_s, b-baryons etc.)
- ATLAS has a well defined program for all LHC operation stages – from startup to the nominal luminocity



Measurements overview

CP Violation	$B_d \to J/\psi K_s^0(\pi\pi)$ $J/\psi \to \mu\mu/ee$ $B^+ \to J/\psi(\mu\mu)K^+$ $B_d^0 \to J/\psi(\mu\mu)K^{*0}(K^+\pi^-)$	sin(2β)
	$B_s \to J/\psi(\mu\mu)\varphi(KK)$	$\Delta\Gamma_s = \Gamma_H - \Gamma_L$, Γ_s, the weak phase ϕ_s
Measurement of B_s oscillations:	$B_s \to D_s\pi\,;\, B_{s,d} \to D_s a_1$ $D_s^- \to \varphi\pi^-\,;\, \varphi \to K^+K^-$	$\Delta m_s = m_H - m_L$
Rare decays	$B_{s,d} \to \mu^+\mu^-\,;\, B_d^0 \to K^{*0}\mu\mu$ $\Lambda_b \to \Lambda\mu\mu\,;\, B_s^0 \to \varphi^0\mu\mu$	Precise measurements of the branching ratios and asymmetries
	radiative rare decays	
Λ_b polarization measurements	$\Lambda_b \to J/\psi(\mu\mu)\Lambda(p\pi)$	Asymmetry parameter α_b, P_b, life time measurements
B_c mesons	$B_c \to J/\psi\pi\,;\, B_c \to J/\psi\mu\nu$	Precise determination of B_c mass, B_c life time

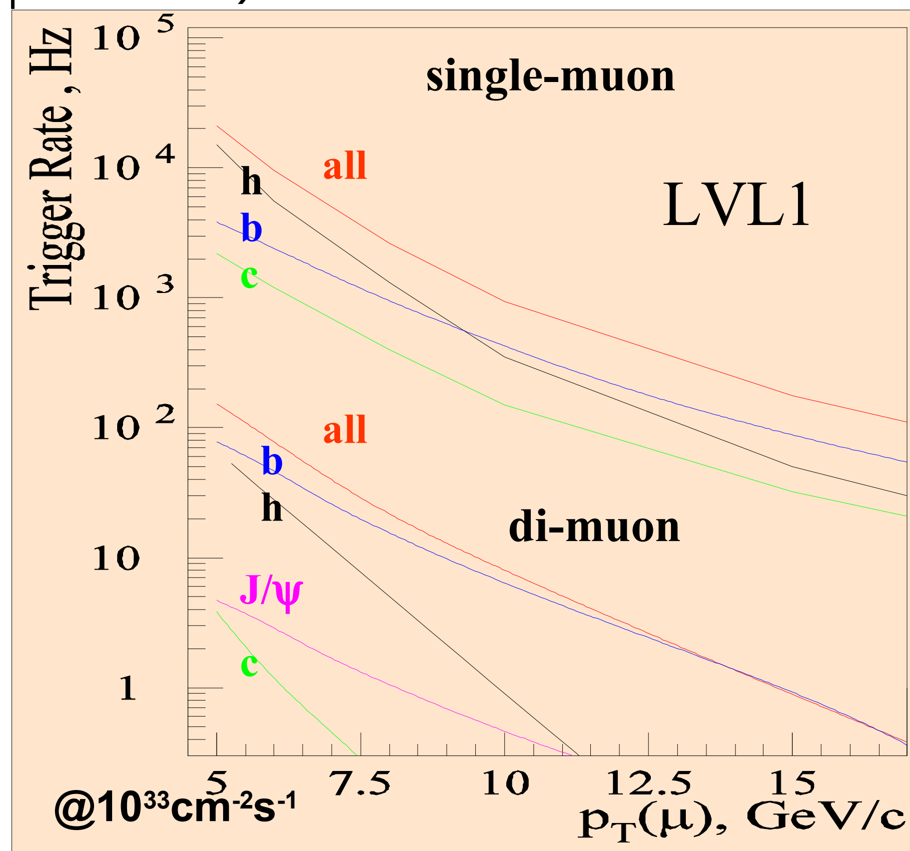
not covered by this talk

Trigger issues

- Key issue is muons – can be identified cleanly and give a clean flavour tag
- Level 1 trigger: based on Calorimeter and Muon Trigger Chambers ($|\eta|<2.4$) Decrease data flow from 40 Mhz to 75 kHz.
- Use LVL1 Dimuon Trigger (p_T>6GeV (4-3 at lower L)) from first running up to higher luminosities
- For lower luminosities, can also use LVL1 MU+EM or MU+JET

  (MU p^T_μ>~6-8GeV, EM E_T >~2GeV, Jet E_T> ~5GeV)

- High Level Trigger based on general purpose processors. Further decrease rate to ~1kHz (LVL2) and then to ~200Hz (Event Filter)
- Reconstruction mostly inside Region of Interests identified from LVL1
- Reconstruction of full volume of Inner Detector (tracker) also possible for events with LVL1 muon (where resources and luminosity allow)



CP violation in $B_d \to J/\psi K_s$ [sin(2β)]

- Maximum likelihood fit using event by event tag and decay time information
- Experimental inputs: proper time resolution, tag probability, wrong-tag fraction, background composition.

		Number of events after trigger + offline rec. 3y@$10^{33}cm^{-2}s^{-1}$	
		Signal	S/B
$B_d \to J/\psi(\mu6\mu3)$	sin(2β)	490k	28
$B_d \to J/\psi(\mu6\mu5)$		250k	32
$B_d \to J/\psi(ee) + b \to \mu6$		15k	16

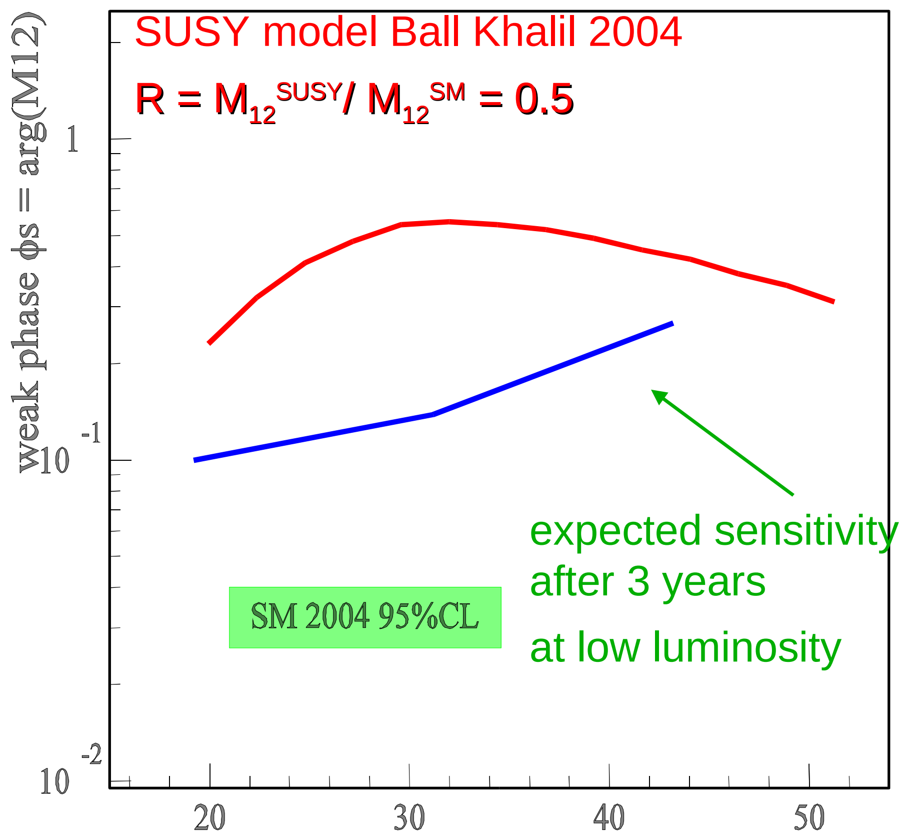
- Systematics controlled via $B^+ \to J/\psi(\mu\mu)K^+$
- Physics Technical Design Report layout results
  - σ sin2β stat : J/ψ(μ6μ3) + J/ψ(ee) : 0.010, for J/ψ(μ6μ5) + J/ψ(ee) : 0.012
  - σ sin2β syst : prod. asym, tagging, background : 0.005

WorldAverage: sin(2β) = 0.685 ± 0.032

CP-violation study. $B_s \to J/\psi(\mu\mu)\phi(KK)$

- B^0_s decay proper time and the angular distribution of secondaries carry information about 8 parameters ($A_{\parallel}, A_{\perp}, \delta_1, \delta_2, \Delta\Gamma, \Gamma, \Delta M_s\ \phi_s$)
- Monte Carlo study performed with a full detector simulation and reconstruction to assess detector performance (decay time resolution, flavour tagging, background rejection). The angular distributions obtained fitted to the theoretical ones.
- The expected precisions (after 30 fb^{-1} = 3Y@$10^{33}cm^{-2}s^{-1}$)

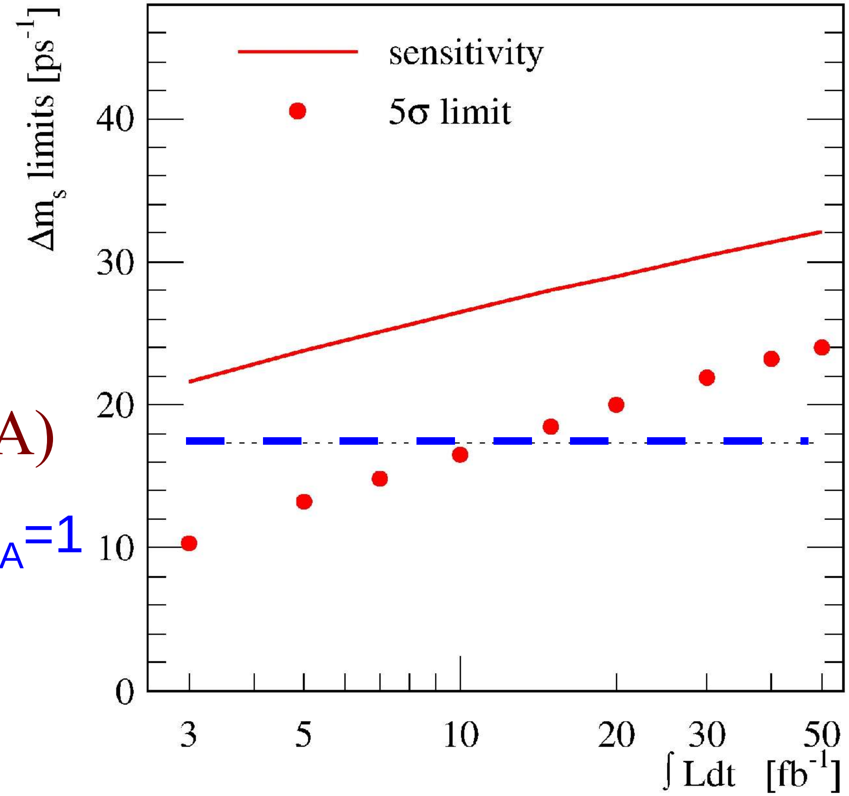
	ATLAS after $30fb^{-1}$ (270 000 events)
$\sigma_{\Delta\Gamma}/\Delta\Gamma$	13%
σ_{Γ}/Γ	1%
$\sigma_{\phi s}$	0.046 for Δms=20ps-1



SM value -0.036 ±.003 (CKMfitter)

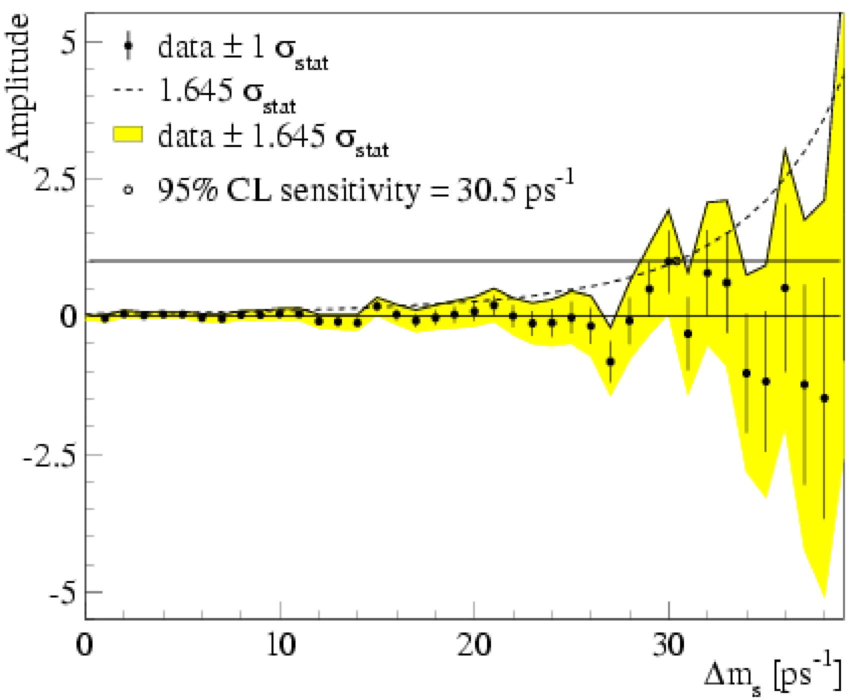
Δm_s with $B_s \to D_s \pi$

		Number of events after trigger + offline rec. 3y@$10^{33}cm^{-2}s^{-1}$	
		Signal	Backgr
$B_s \to D^-_s \pi^+$ $B_s \to D^-_s a_1^+$	Δm_s	8250 4060	<100% <100%



Amplitude-fit method. Minimize $-\ln L(\Delta m_s, \Delta\Gamma_s, A)$

(A=1 if Δm_s= true) 95% C.L. limit: data+1.645σ_A=1



Given the value measured by CDF, ATLAS will be able to measure Δm_s with ~10 fb^{-1} (one year at $10^{33}cm^{-2}s^{-1}$)

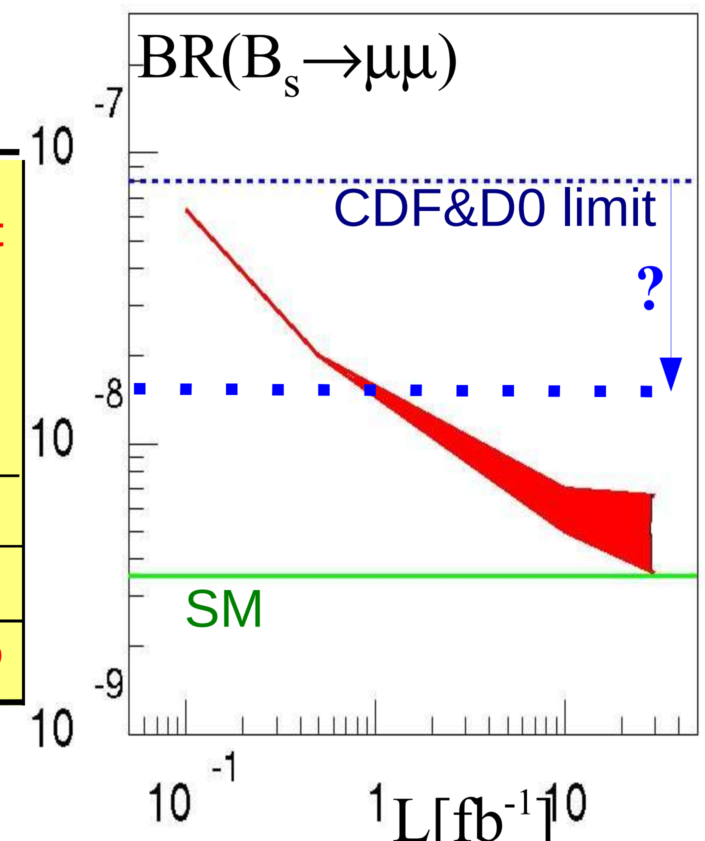
$$\mathrm{CDF}: \Delta m_s = 17.31^{+0.33}_{-0.18} \pm 0.07\ ps^{-1}$$

$$D0: 17 < \Delta m_s < 21\ ps^{-1} @ 90\, c.l.$$

ATLAS Performance for $B_{d,s}\to\mu\mu$

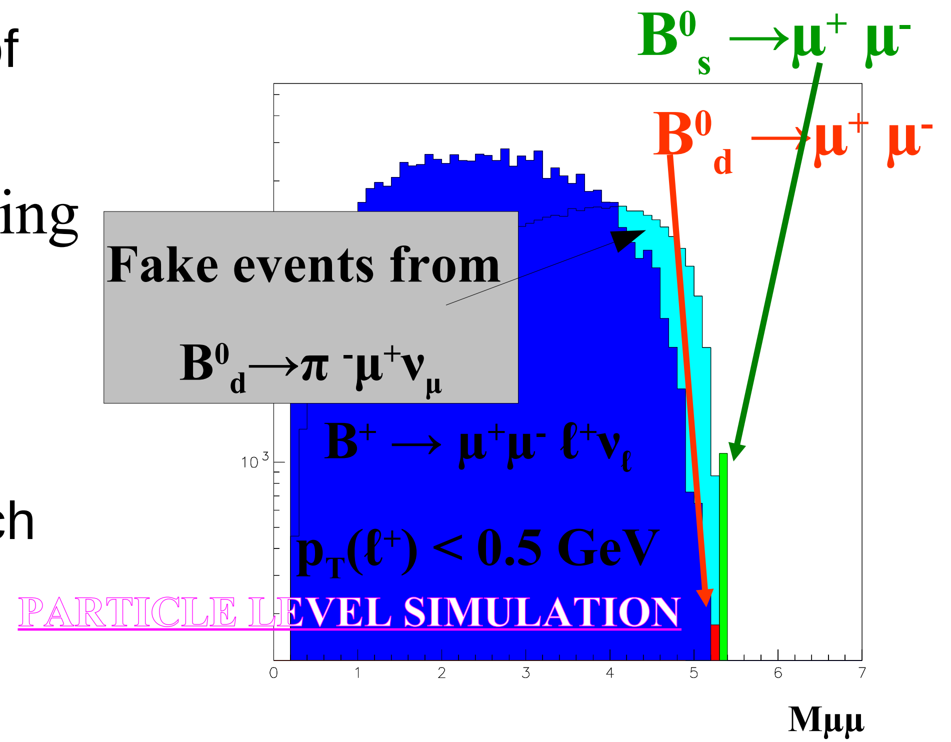
- Clear theoretical picture for SM and for BR predictions.
  - $BR(B_s\to\mu\mu) \approx 3.5\times10^{-9}$ (Tevatron limit: $<8\times10^{-8}$)
  - $BR(B_d\to\mu\mu) \approx 0.9\times10^{-10}$ (BaBar(111 fb^{-1}) $<8.3\times10^{-8}$ Belle(78fb^{-1}: $<1.6\times10^{-7}$)
- Good potential sensitivity for the SUSY (for example: in MSSM Br ~ $\tan^6\beta$).
- Simple experimental signature
- Preliminary (TDR layout) study shows a possibility to continue $B_{d,s}\to\mu\mu$ program at nominal luminosity ($10^{34}\,cm^{-2}s^{-1}$)

Integral LHC Luminosity	$B_s\to\mu\mu$ Signal ev. after cuts	BG ev. after cuts	ATLAS upper limit at 90% CL
100 pb^{-1}	~ 0	~ 0.2	6.4×10^{-8}
10 fb^{-1}	~ 7	~ 20	$5\div7.0\times10^{-9}$
30 fb^{-1}	~ 21	~ 60	$3.4\div6.6\times10^{-9}$



Backgrounds for $B_{d,s} \to \mu\mu$

- Extremely small branching ratio, so many possible BG sources
  - combinatorial di-muon background. Main source is bb(cc)$\to\mu\mu$ processes with muons from semileptonic b(c) decays
  - exclusive decays with small BR, but kinemtically contributed to signal $\mu\mu$ mass region
    - example: $Br(B^0_d \to \pi^- \mu^+ \nu_\mu) \sim 10^{-4}$ but if π misidentified as μ the contribution to $B_{d(s)}$ mass region could be substansial!
    - B->hh (h=π,K) with typical probability of misidentification of 0.1-0.5% is a potential problem
    - 4-lepton decays with 2ℓ missing



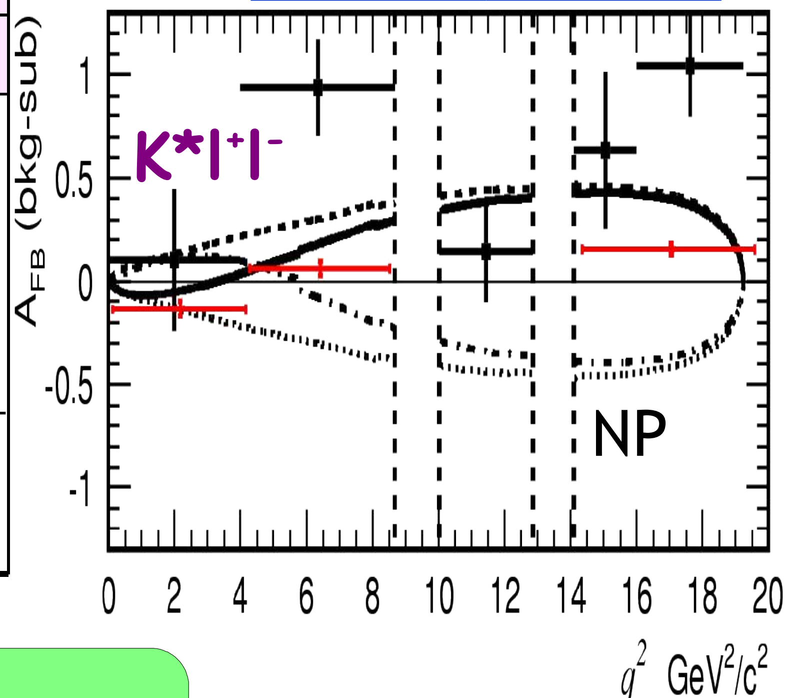
- Careful estimation of all possible BG sources contributions is an important part of very rare decays search program in ATLAS

Semi-muonic rare decays

- di-muon mass spectra and Forward-Backward asymmetry (A_{FB})show significant sensitivity to new physics effects

BR used in the MC			Signature after trigger +offline reconstruction 3y@$10^{33}cm^{-2}s^{-1}$	
			Signal	Backgr
1.3×10^{-6}	$B_d \rightarrow K^{0*}\mu\mu$	Br.fraction $\mu\mu$-mass A_{FB}	2500	<7000
3.5×10^{-7}	$B^+ \rightarrow K^+ \mu\mu$		1500	<50000
1.0×10^{-6}	$B_s \rightarrow \phi \mu\mu$		900	<7000
2.0×10^{-6}	$\Lambda_b \rightarrow \Lambda\mu\mu$		800	< 4000

A. Ishikawa et al., hep-ex/0603018 (2006)



More details: Poster Session 8,
ATLAS Preparation for precise measurements in semi-muonic rare B-decays by K.Toms

+ ATLAS 30 fb^{-1} (3y@$10^{33}cm^{-2}s^{-1}$)

Beauty with 100 pb^{-1}, first measurements, preparations (“week One”)

Inclusive B and Onia	Direct $J/\psi(\mu6\mu3)$	1000 k	R = $bb \to J/\psi$ / $pp \to J/\psi$ R = $pp \to \Upsilon$ / $pp \to J/\psi$
	$bb \to J/\psi(\mu6\mu3)$ X	400 k	
	Υ $(\mu6\mu3)$	100 k	
	$B \to J/\psi(\mu6\mu3)$ X $b \to \mu5$ X	25 k	b-b correlations
Exclusive B Tree decay	$B^+ \to J/\psi K^+$	17000	Important reference channel. New channels ($B \to \mu\mu$) relative to this
	$B^0 \to J/\psi K^{0*}$	8700	Masses, Lifetimes Sensitive checks for understanding Inner Detector
	$B^0 \to J/\psi K_s$	1300	
	$B_s \to J/\psi \phi$	900	
	$\Lambda_b \to J/\psi \Lambda$	260	
	$B_s \to D_s \pi$	25	Hadronic channels – only prepare methods for later measurements
Rare exclusive B Sensitivity limits	$B^+ \to \mu\mu K^+$	23	Belle today 80
	$B^0 \to \mu\mu K^{0*}$	12	
	$B_s \to \mu\mu \phi$	9	
	$\Lambda_b \to \mu\mu\Lambda$	3	
	$B \to \mu\mu$	$1 * 10^{-7}$ 90%CL	Tevatron today 8 10^{-8}

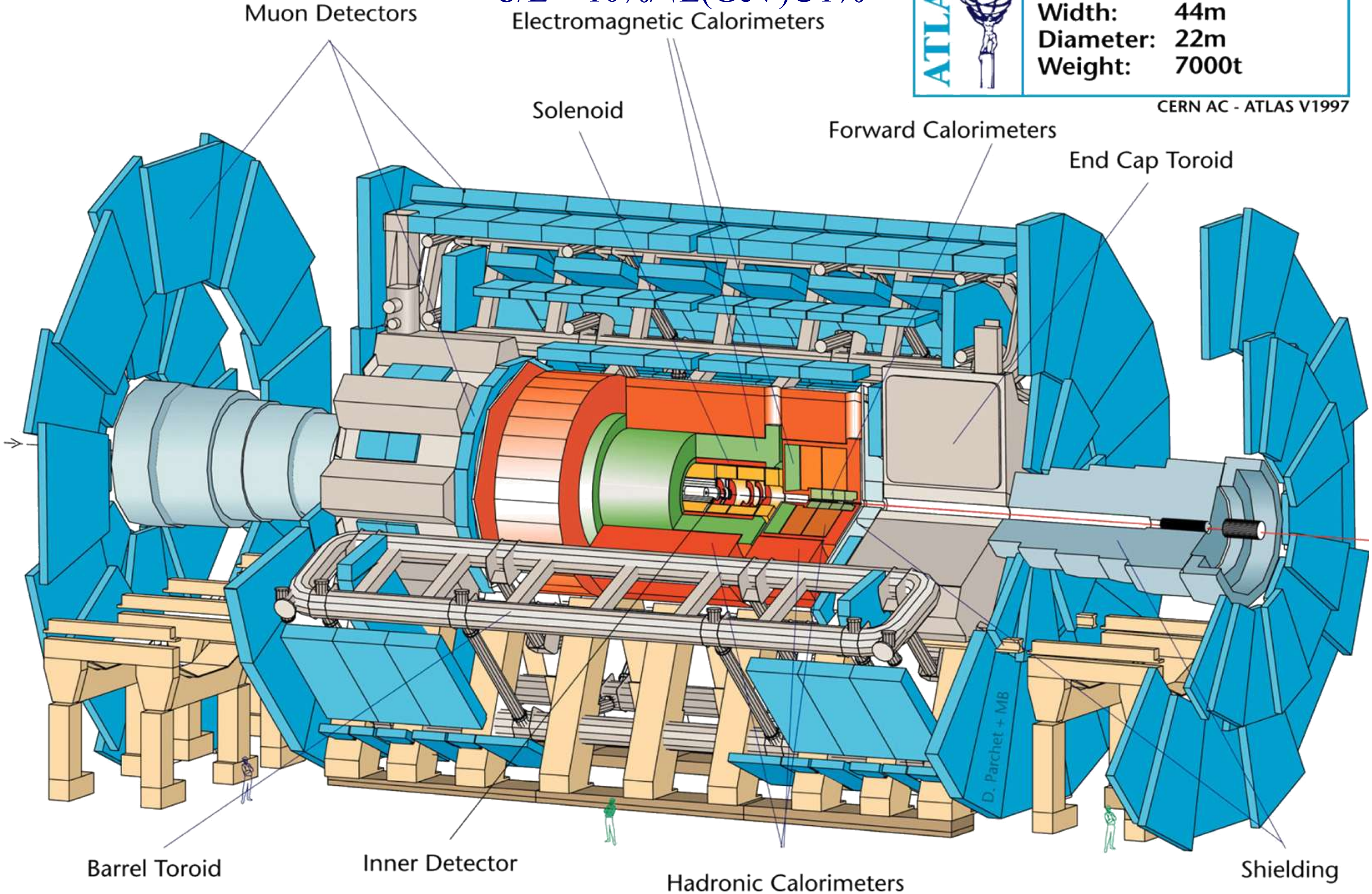
Conclusions

- ATLAS B-physics programme is concentrated on measurements that are sensitive to New Physics or set strong constraints on extensions of the Standard Model
- ATLAS has been demonstrated to be capable of extracting signals of all most important rare B-decays of interest at LHC
- With possible achieved sensitivity a detailed study of non-combinatorial background sources (mis-identification, other decays with small BR) is of great importance.
- Some channels with di-muon final states can be followed up to nominal LHC luminocity
- CDF&D0 limits for $B_{d,s} \to \mu\mu$ will be reached in one week measurements (after the luminosity $2*10^{33}$ will be achieved) and SM BR will be reached
- ATLAS statistics will allow angular analysis in semileptonic decays that can show evidence for new physics and, in some cases distinguish between different models

Backup slides

$\sigma/p_T \sim$ 2-7 % $|\eta| < 2.7$

$\sigma/E \sim 10\%/\sqrt{E(GeV)} \oplus 1\%$



$\sigma/p_T \sim 0.05\%$

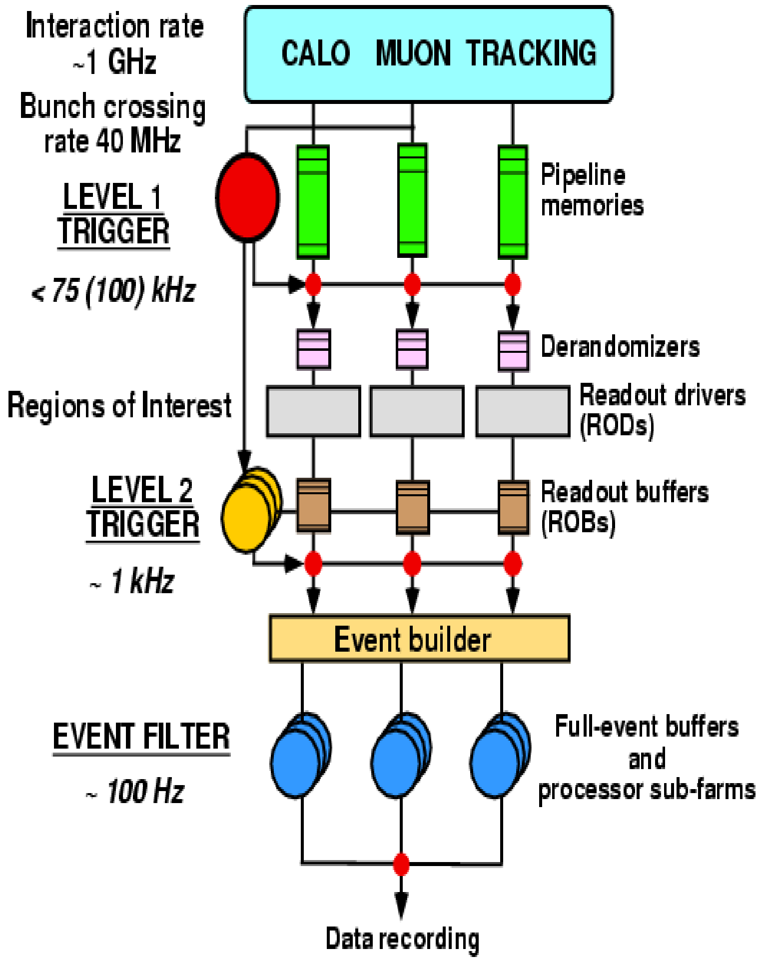
$p_T(GeV) \oplus 0.1\%$

in $|\eta| < 2.5$

$\sigma/E \sim 50\%/\sqrt{E(GeV)} \oplus 3\%$

in $|\eta|<3$

The ATLAS trigger system



Level 1 (Hardware based):

Defines the Region-of-Interest (ROI)

Uses Calorimeters and Muon chambers with coarse granularity.

Execution time: 2μs

Level 2 (Software based):

Seeded by the Lvl1 ROIs. Uses full detector granularity.

Confirms the Lvl1 result and refines the physics object position/energy.

Execution time: ~10ms

Event Filter (Software based):

Offline algorithms adapted to online environment. Refinment & calibration

Execution time: ~1s

$B^0_s \to \mu^+\mu^-$ in ATLAS

Signal, BG and efficiencies of selection cuts (10 fb^{-1})

Cuts	BG: $b\bar{b} \to \mu\mu X$		B^0_s - Signal	
Vertexing procedure	CTMVFT	**VKalVrt**	CTMVFT	**VKalVrt**
$p_T(\mu) > 6$ Gev, $\Delta R_{\mu\mu} < 0.9$	**6.0×10^6 events**		**50 events**	
$M(\mu\mu)=M_B{}^{+140}{}_{-70}$ MeV	2×10^{-2}	—	0.77	—
Isolation cut: no ch.tracks $\mathbf{p_T}>0.8$ GeV in cone with $\boldsymbol{\theta} < 15^o$	5×10^{-2}	**5×10^{-2}**	0.36	**0.36**
$\boldsymbol{\sigma} < 90\mu$m, $\mathbf{L_{xy}}/\boldsymbol{\sigma} > 15$, $\boldsymbol{\alpha} < 1^o$	2.8×10^{-3}		0.2	
$\mathbf{L_{xy}}/\boldsymbol{\sigma} > 11$, $\boldsymbol{\chi^2} < 15$		**$< 0.7\times10^{-4}$**		**0.4**
Number of events after cuts	15±10	**20±20**	3	**7**

The basic theoretical description -I

Effective Hamiltonian for b → d,s transition:

$$\mathbf{H_{eff}\,(b \rightarrow q) \sim G_F V^*_{tq} V_{tb} \sum C_i(\mu)\; O_i\,(\mu),}$$

includes the lowest EW-contributions and perturbative QCD corrections for Wilson coefficients $\mathbf{C_i(\mu)}$.

μ - scale parameter ~ **5 GeV** : separates **SD** (perturbative) and **LD** (nonperturbative) contributions of the strong interactions.

SM NLO: A.Buras, M.Munz, ***PRD52, p.182, 1995***

SM NNLO: C.Bobeth et al., ***JHEP 0404, 071, 2004***

MSSM NNLO: C.Bobeth et al., ***NPB713, p522, 2005***

Theoretical description of the $B^0_{d,s} \rightarrow \mu^+\mu^-$ decays

$$\Gamma(B_q^0 \rightarrow \mu^+\mu^-) = \frac{(G_F \cdot \alpha_{em})^2}{16 \cdot \pi^3} \cdot |V_{tq}^{\text{¿}} V_{tb}|^2 \cdot (f_{B_q} \cdot m_\mu \text{¿} C_{10A})^2 \sqrt{M_{B_q^0}^2 - 4 \cdot m_{\mu^2}}$$

1) There is only one, well known, nonperturbative constant $\mathbf{f_{Bq}}$ (~ **5% - 10%** accuracy - one of the best results for nonper-tubative calculations!).

2) The Wilson coefficient C_{10A} in NLO does not depend on scale parameter μ.

3) Main uncertainties are contained in CKM-matrix elements (~ **10%** for $|V_{ts}|$ and greater for $|V_{td}|$).

Misidentification and fake rates

<u>Semileptonic B-decay</u>: $Br(B^0_d \rightarrow \pi^- \mu^+ \nu_\mu) \sim 10^{-4}$.

If we will take into account the <u>π-μ misidentification</u>, we get about one of 200 of pions misidentified as muon. Corresponding fake probability is roughly equal to:

$$Br(B^0_d \rightarrow \mu^- \mu^+ \nu_\mu) \bullet 1/200 \approx 0.5 \bullet 10^{-6}.$$

In order to estimate the fake probability for $B^0_{d,s} \rightarrow \mu^+ \mu^-$ we need to reduce this result by a factor of 10 corresponding to soft-neutrino phase space.

The effective probability rate for this case $\sim 0.5 \bullet 10^{-7}$

can produce a <u>significant BG</u> $Br(B^0_s \rightarrow \mu^+ \mu^-) \approx 3.5 \bullet 10^{-9}$.

Other noncombinatorial BG

Significant:

1) Another fake rates from $B \to h_1 h_2$;

2) Two-body hadronic B-decays;

3) $B^+_c \to \mu^+\mu^-$ (soft $\ell^+\nu_\ell$) + resonant contribution;

4) $B^0_d \to \mu^+\mu^-$ (soft π^0);

Nonsignificant:

1) $B^+ \to \mu^+\mu^-$ (soft $\nu_\mu\nu_\mu$);

2) $B^\pm_d \to \mu^+\mu^-$ (soft $\pi^\pm$) ;

3) $B^0_s \to \mu^+ \mu^-$ (soft γ).