Rare B decays in ATLAS and CMS

CKM2006 at Nagoya University

Dec. 14th 2006

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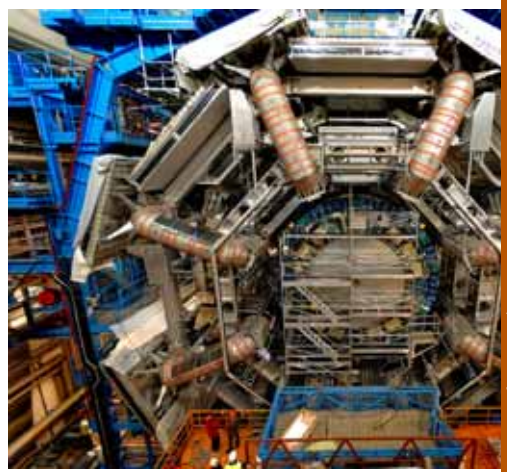
Nagoya University

on behalf of CMS and ATLAS collaborations



Outline

B physics in ATLAS and CMS

ATLAS and CMS detectors

$B \rightarrow \mu\mu$

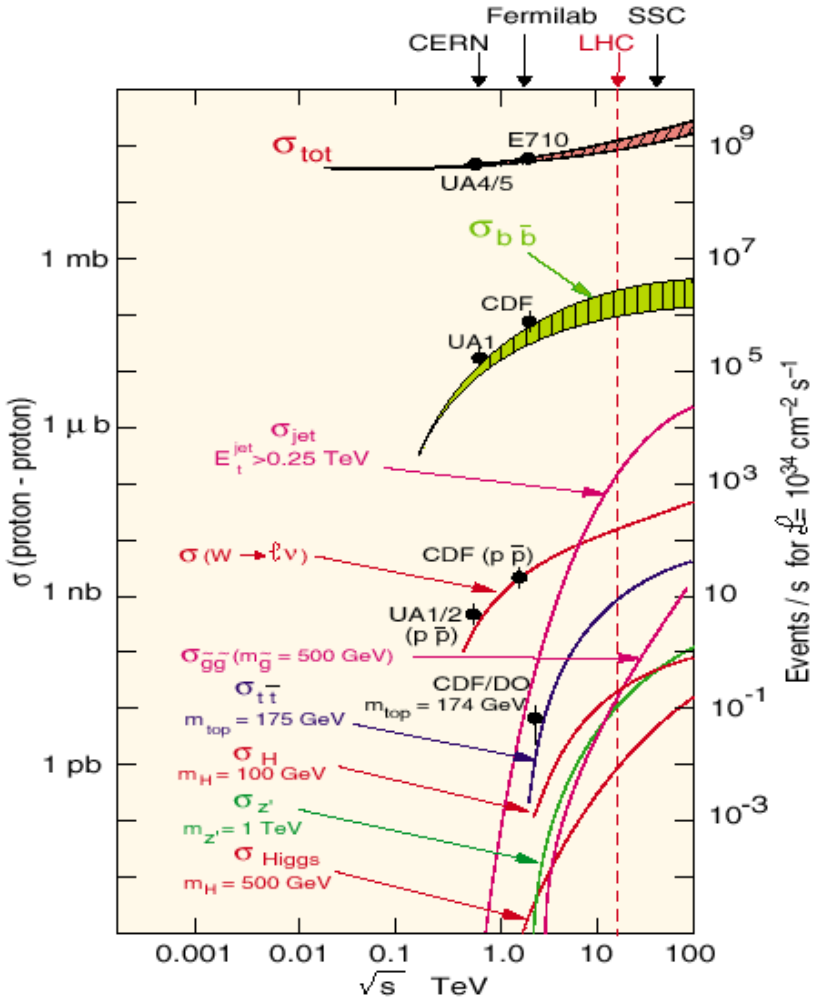
$B \rightarrow X\mu\mu$

Conclusion

B physics in ATLAS and CMS

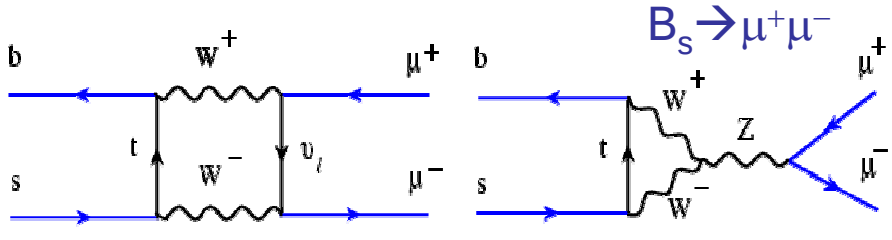
- ATLAS and CMS
  - p-p collision at $\sqrt{s}$ = 14TeV
- $\sigma(b\bar{b})$ = 500 μb
  - $B_d\bar{B}_d$: B^+B^- : $B_s\bar{B}_s$: b-barions = 4:4:1:1
  - 10^5 bb pairs/s @ L=10^{33} $cm^{-2}s^{-1}$
    - "B-factory" as well as "New particle-factory"
- Detector design is dedicated high-p_T physics
  - Majority of B-events is low-p_T particles
    - Trigger and analysis are a challenge

  → B-decays to μ's are promising
- Strategy on B-physics in ATLAS and CMS
  - CP violation (Low luminosity run)
  - B_s oscillation (Low luminosity run)
  - Rare B decay (Even in High lumi.)
    (B→$\mu\mu$, B→K*$\mu\mu$, Λ_b→$\Lambda\mu\mu$)

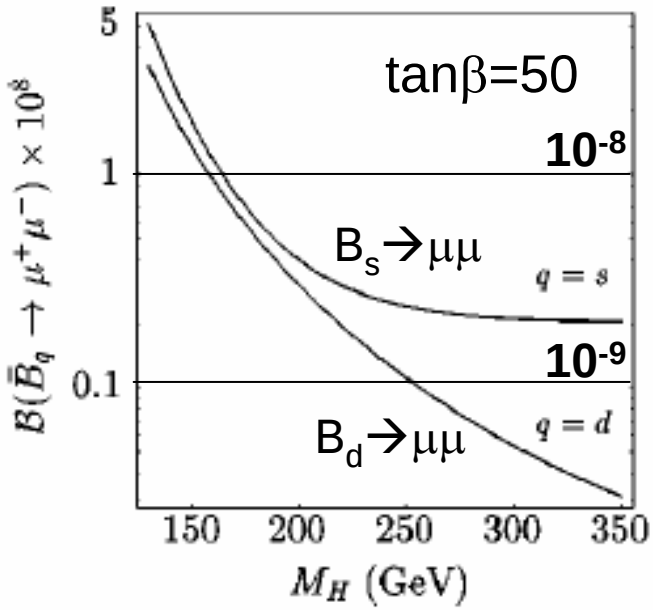


Rare B decays

- $B \to \mu^+\mu^-$ and $b \to sll$
  - Sensitive to new physics
    - SUSY, Higgs etc.
  - FCNC transition
    - Forbidden at tree diagram



Br(B→μμ)	$B_s \to \mu\mu$	$B_d \to \mu\mu$
SM	3.5×10^{-9}	0.9×10^{-10}
CDF (780 pb^{-1})	1.0×10^{-7} 95%CL	3.0×10^{-7} 95%CL
DØ (700 pb^{-1})	2.0×10^{-7} 95%CL	11.1×10^{-7} 95%CL
Belle 78 fb^{-1}	-	1.6×10^{-7} 90% CL
BaBar 111 fb^{-1}	-	0.6×10^{-7} 90% CL

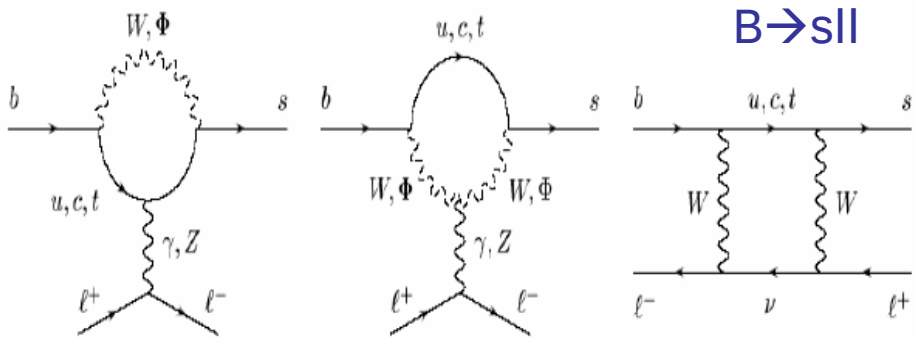


- SM: Br(b→sll) ~ 10^{-6} ~ 10^{-7}

  Br(B_d→K*μμ) measurements

  Belle : $1.33\ ^{+0.42}_{-0.37} \pm 0.10 \times 10^{-6}$

  Babar : $0.86\ ^{+0.79}_{-0.58} \pm 0.16 \times 10^{-6}$
- $|V_{ts}|$ and $|V_{td}|$ determination
- Wilson coefficient C_7, C_9, C_{10}



LHC

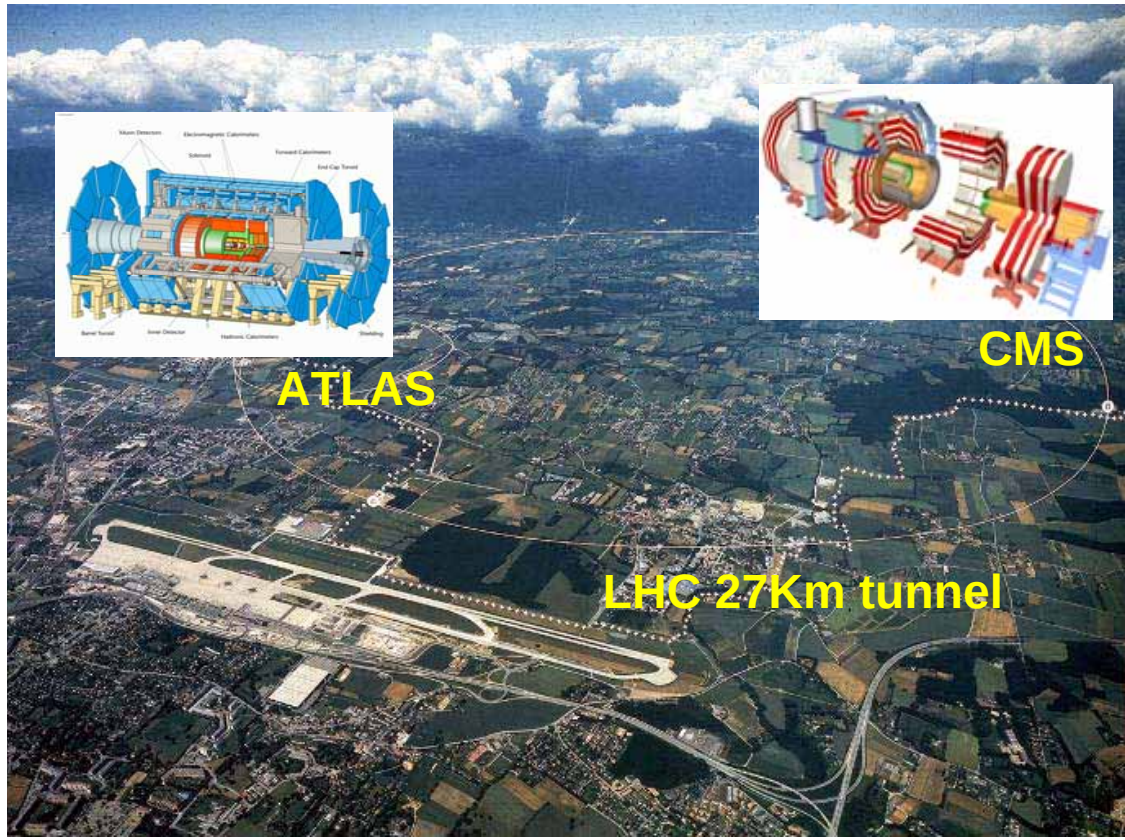
- 27Km ring, proton-proton collider, $\sqrt{s}$=14TeV

- 4 experiments in LHC
  LHCb dedicated B-physics
  ALICE dedicated heavy ion
  Two general purpose detectors: CMS and ATLAS

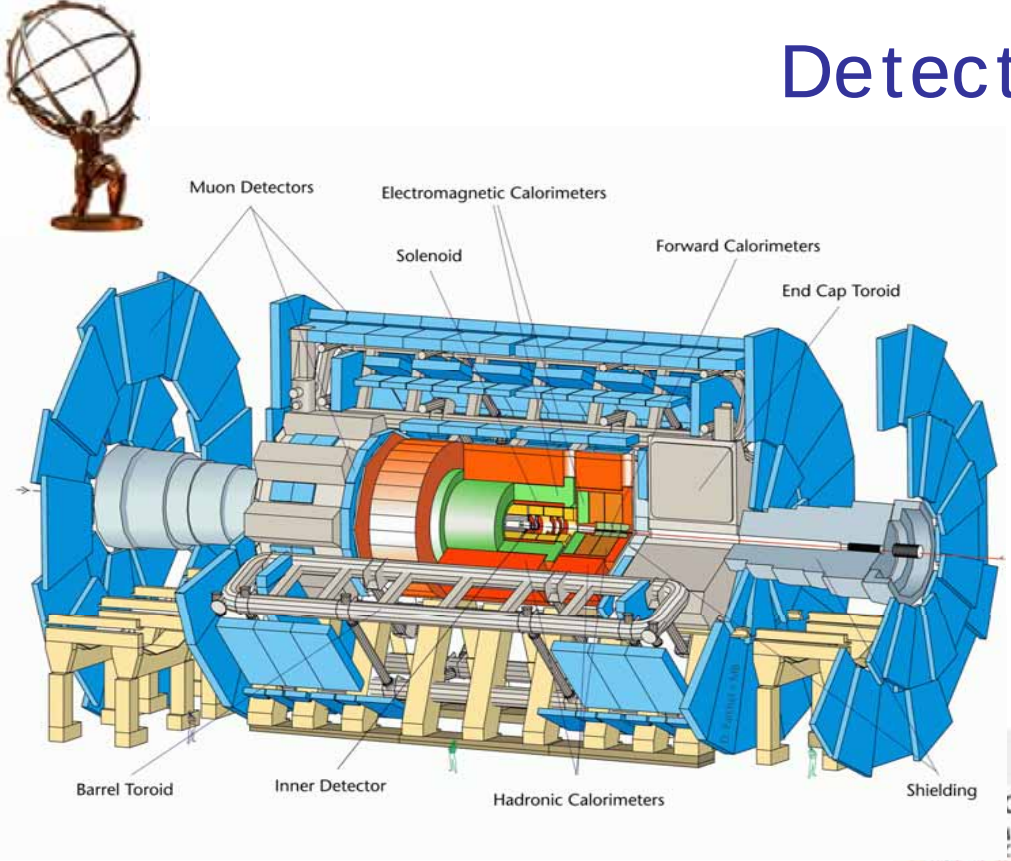
- Operation plan
  - End of 2007:
    900 GeV
    commissioning run

  - After summer 2008:
    14TeV, Low luminosity run
    ($L = 10^{33}cm^{-2}s^{-1}$)

  - Design:
    14TeV, High luminosity run
    ($L = 10^{34}cm^{-2}s^{-1}$)



Detectors

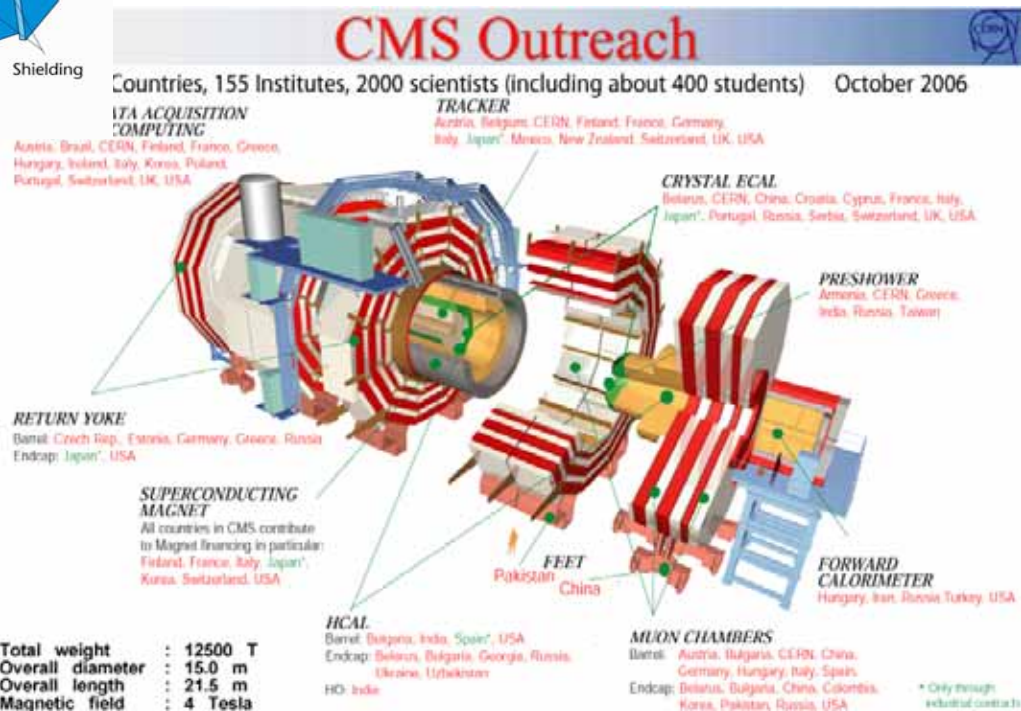


Compact Muon Solenoid

Total weight : 12500 T
Overall diameter : 15.0 m
Overall length : 21.5 m
Magnetic Field : 4 Tesla

A Toroidal LHC ApparatuS

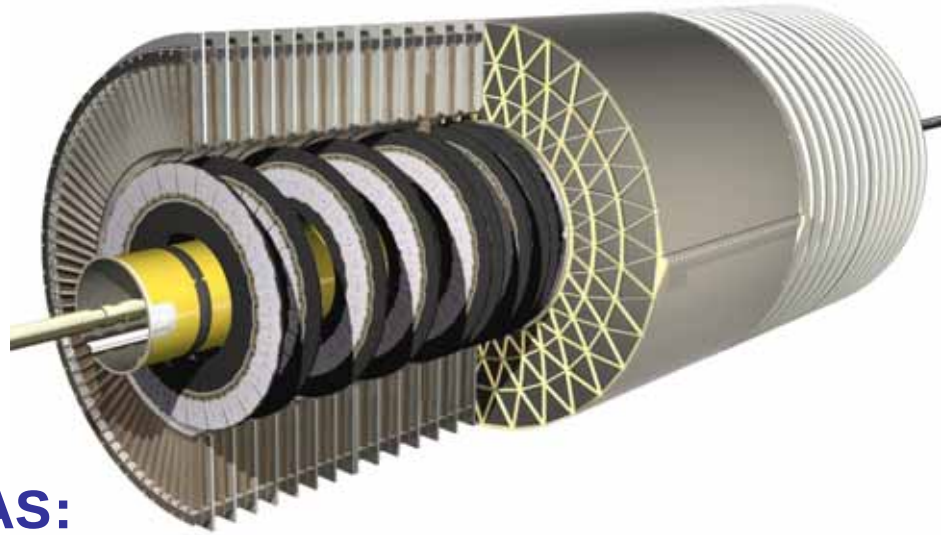
Total weight : 7000 T
Overall diameter : 22.0 m
Overall length : 46.0 m
Magnetic Field : 2 Tesla (solenoid)
0.5 Tesla (toroid)



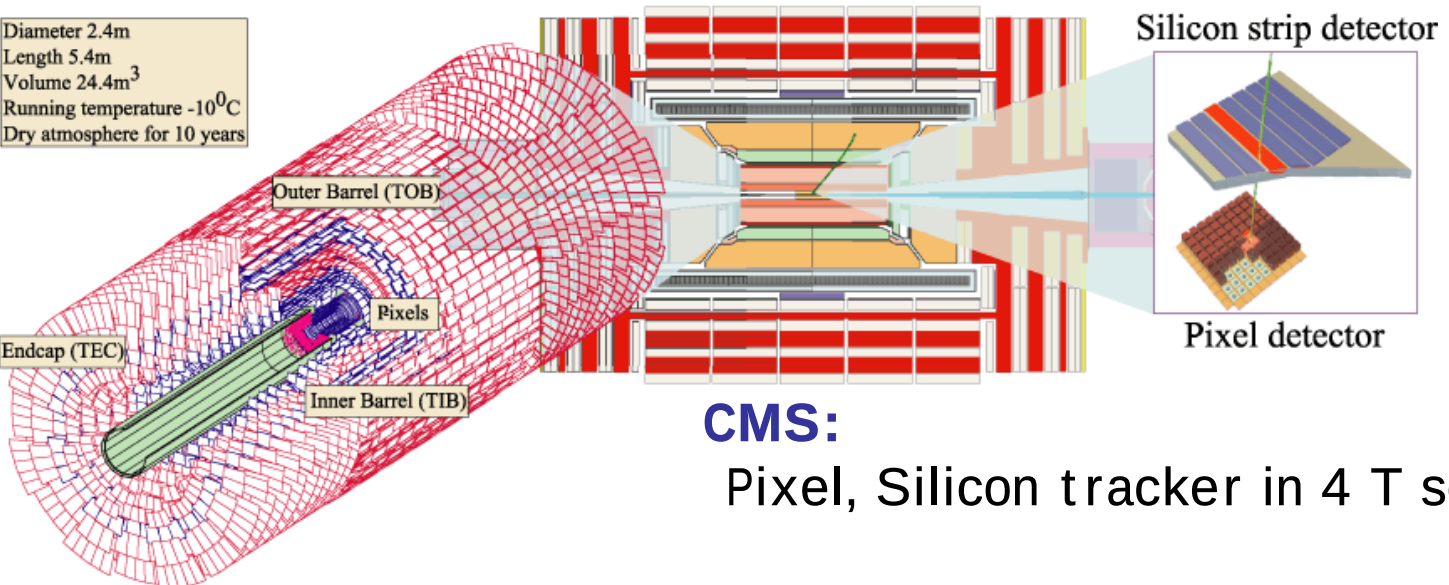
Makoto Tomoto (Nagoya University)

Inner Detectors

To reconstruct vertex of B decays
Used in HLT, better ID of B events
→ Impact parameter significance



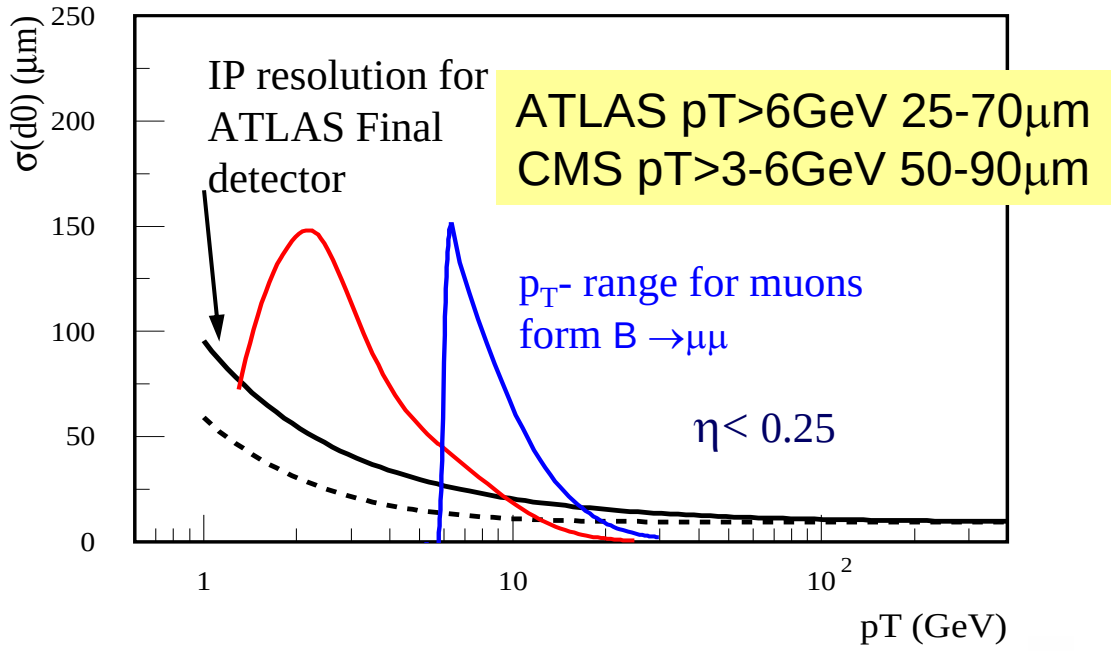
ATLAS:
Pixel, SCT, TRT in 2 T solenoid field

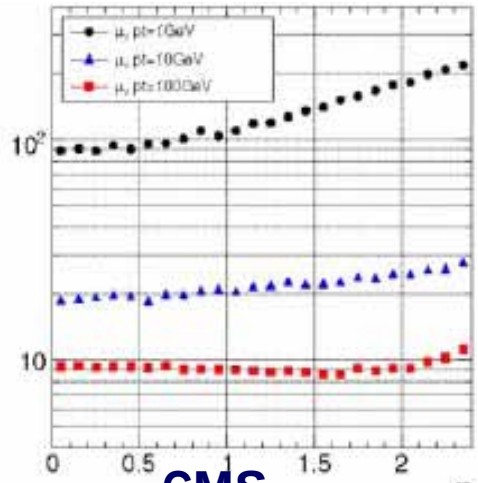


CMS:
Pixel, Silicon tracker in 4 T solenoid field

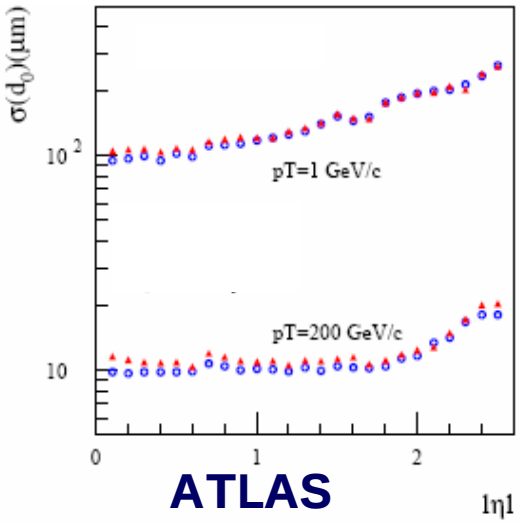
Impact Parameter Resolution

Impact parameter



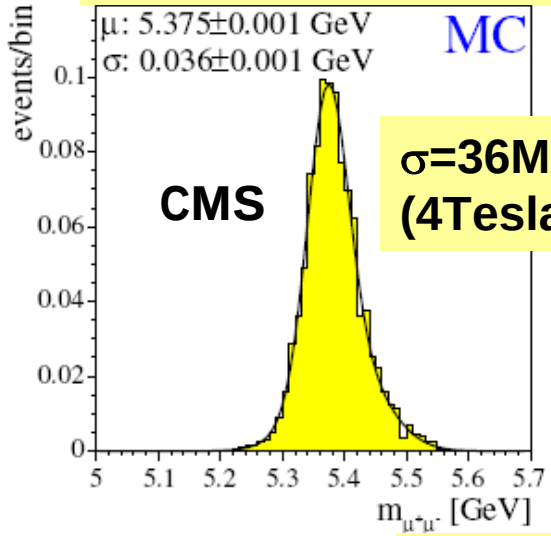


CMS



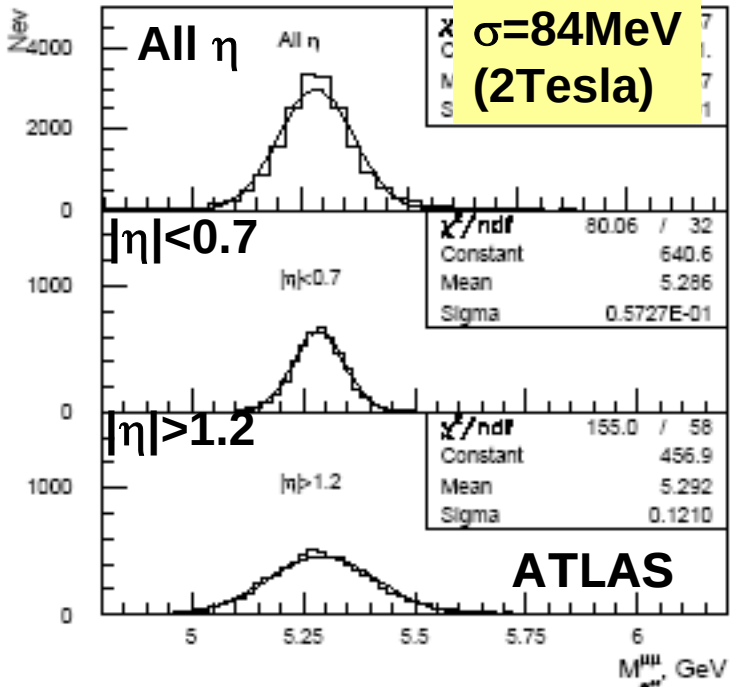
ATLAS

Mμμ Mass Resolution



CMS

σ=36MeV (4Tesla)



σ=84MeV (2Tesla)

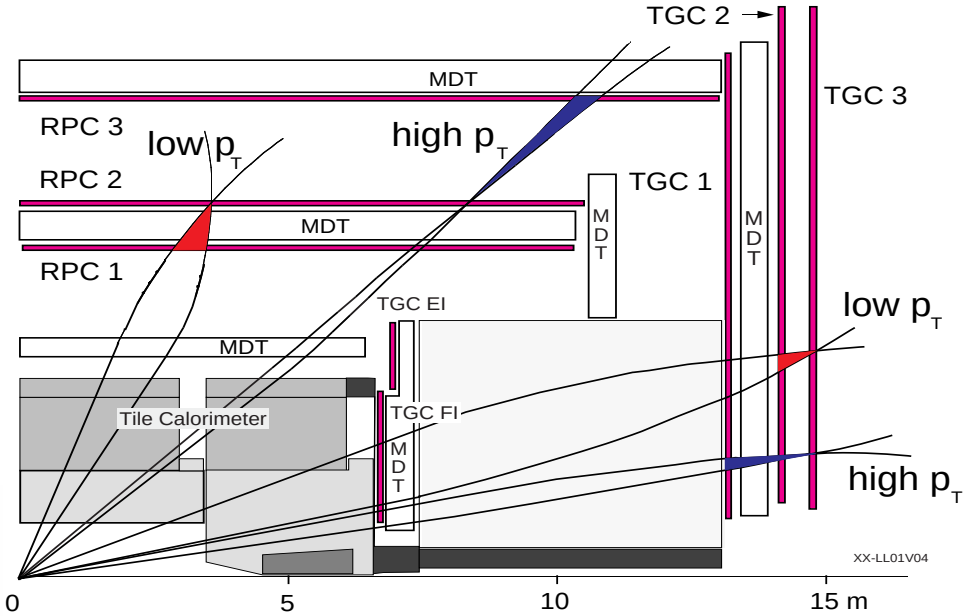
ATLAS

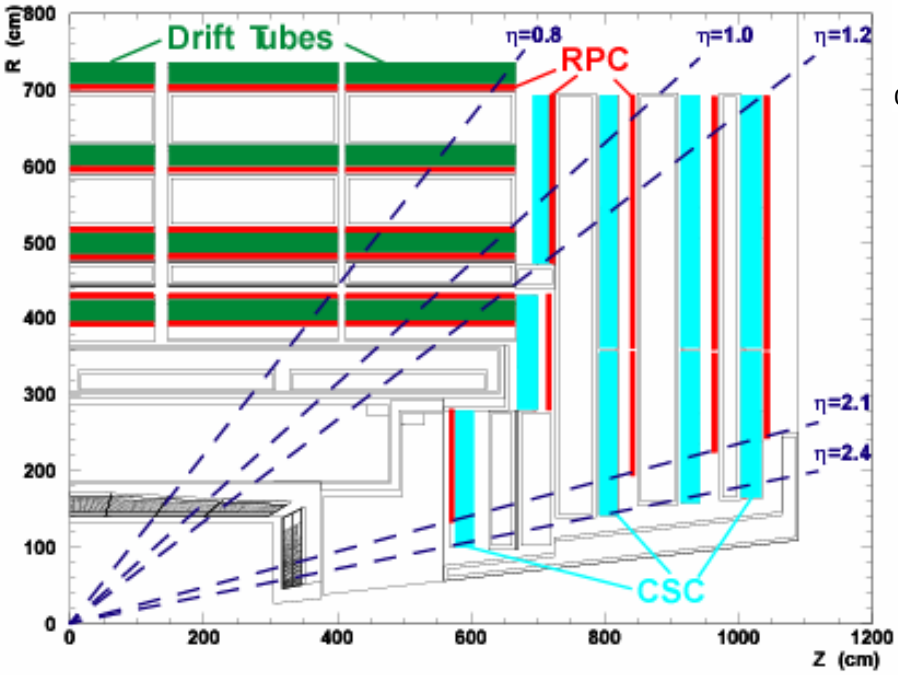
Muon detectors

For trigger and offline selection to get pure rare B-decay samples

ATLAS:

- RPC (barrel) and TGC (endcap) for LVL1 trigger
- CSC and MDT for precise tracking in 0.5 T toroid field



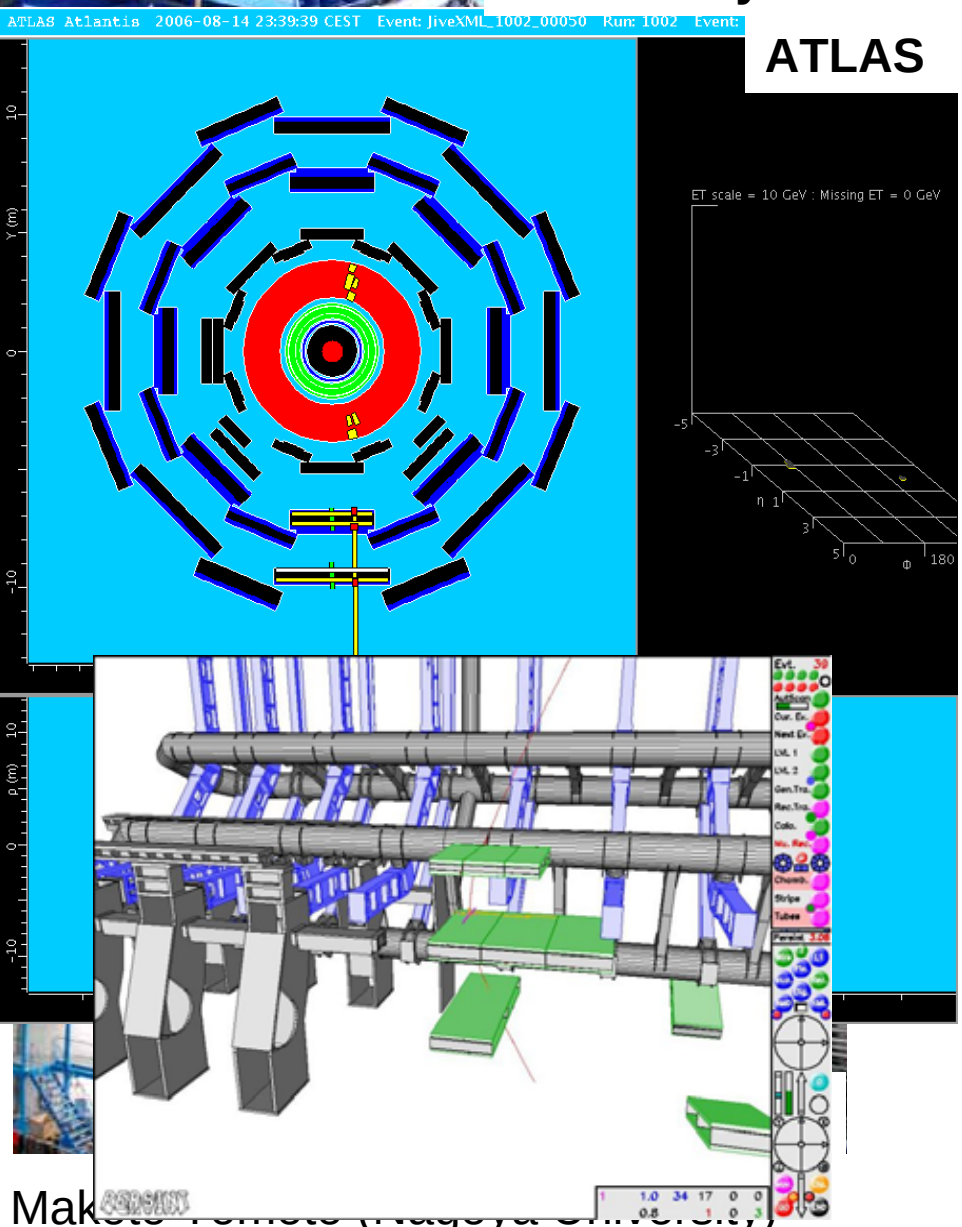


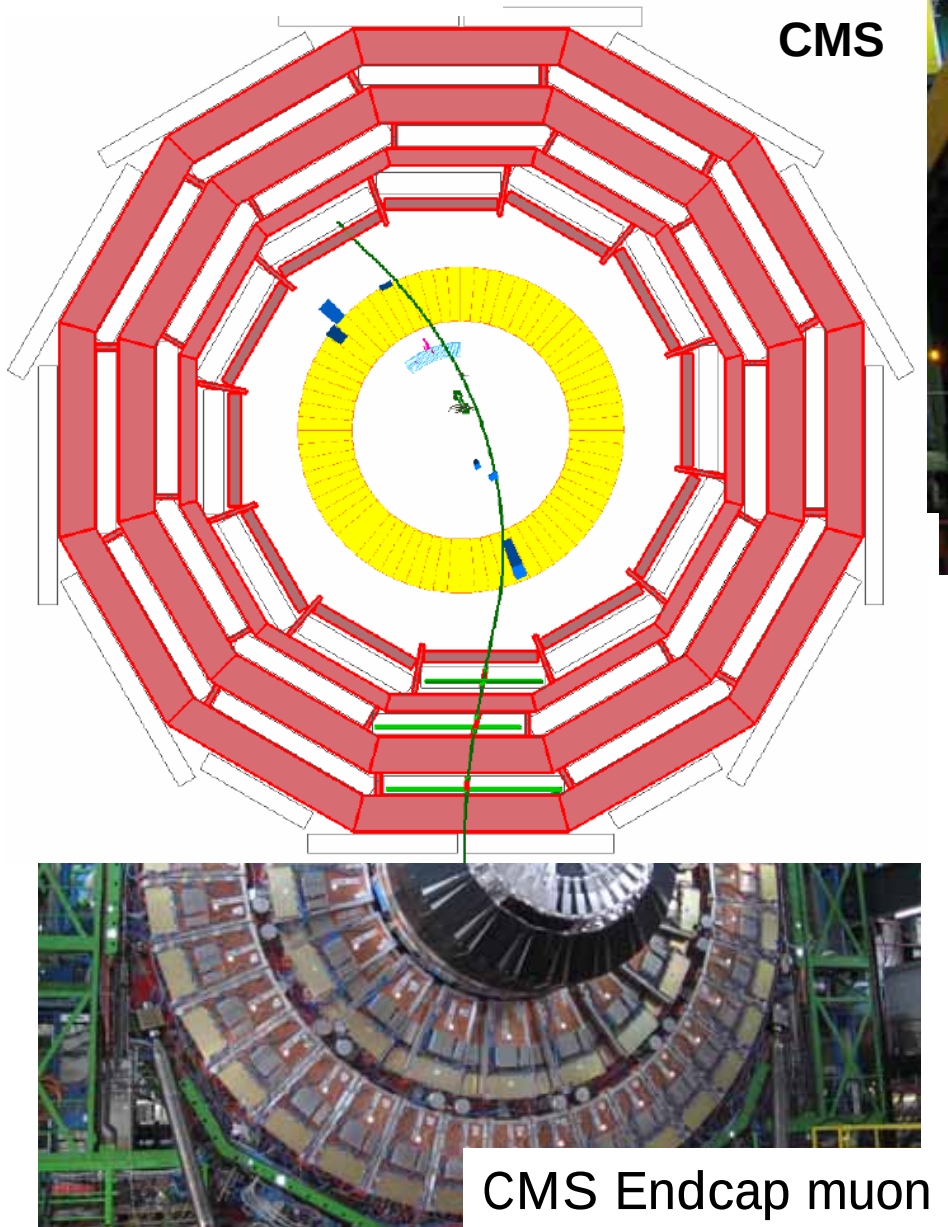
CMS:

- RPC (barrel) for LVL1 trigger
- CSC and DT for precise tracking in 2 T solenoid field

Muon detectors

Cosmic ray run with real muon detectors!



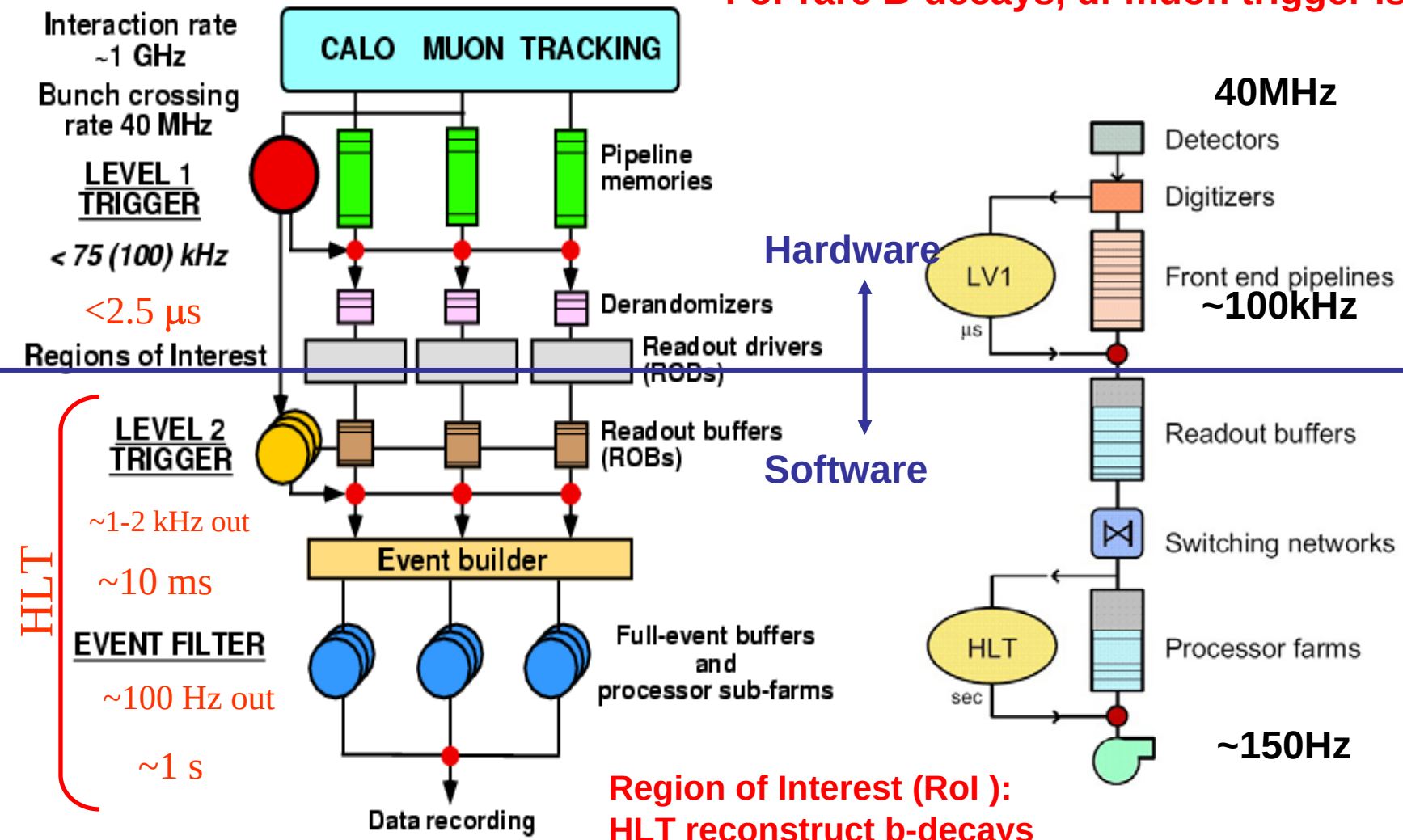


CMS Endcap muon

Makete remote (Nagoya University)

ATLAS/CMS Trigger System

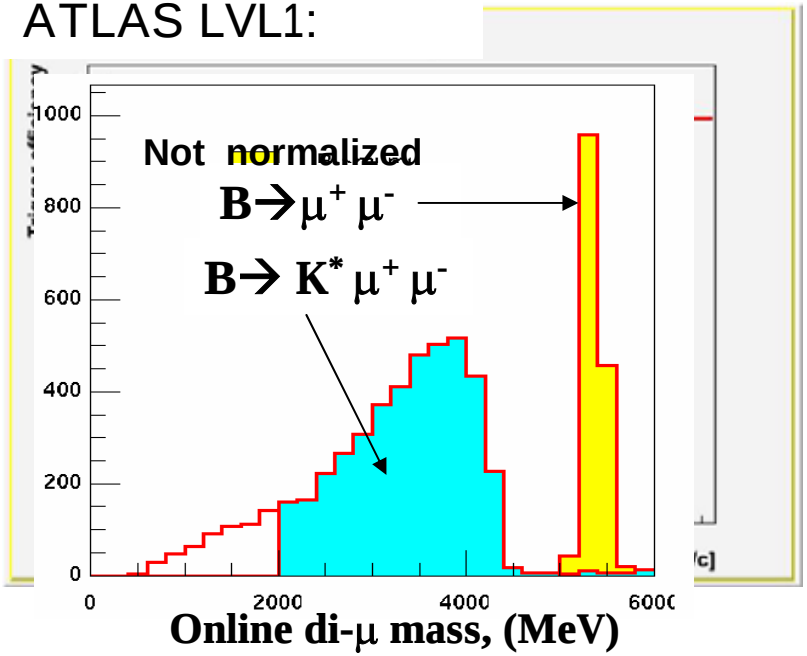
For rare B-decays, di-muon trigger is used



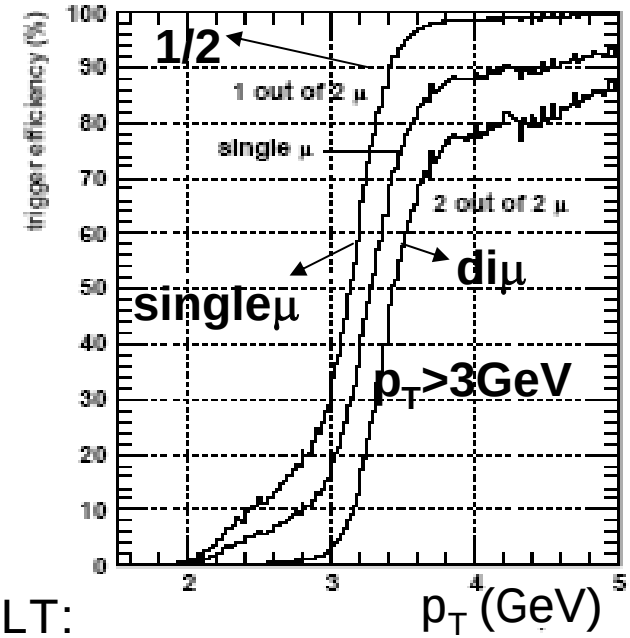
Region of Interest (RoI): HLT reconstruct b-decays using partial reconstruction in RoI around L1 muon

di-muon trigger

ATLAS LVL1:



CMS LV" 1:



CMS HLT:

Primary vertex reconstruction
- use three most probable vertices

Regional track reconstruction
- partial reconstruction with ≤ 6hits
- Pt > 4 GeV

Track pairs
- mass windows for signal
- (un)like sign charge

Vertex fit
- χ^2 <20 & Decay flight length > 150μm

ATLAS LVL2:

Confirm each m RoI from LVL1

Mass cut

B→μμ : 4 GeV < M(μμ)< 6 GeV

ATLAS EF:

Refit ID tracks in Level-2 RoI

Decay vertex reconstruction

Transverse Decay length cut:

L_{xy} > 200μm

CMS offline analysis : B→μμ

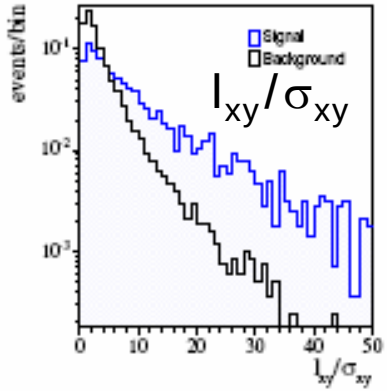
- Decay flight length significance l_{xy}/σ_{xy}
  - transverse plane: $l_{xy}/\sigma_{xy} > 18$
- Muon separation in $\eta\phi$:

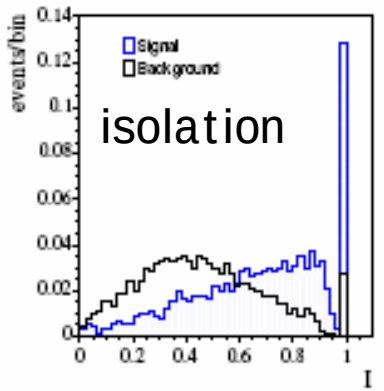
$$\Delta R(\mu\mu) = \sqrt{(\eta_{\mu_1} - \eta_{\mu_2})^2 + (\phi_{\mu_1} - \phi_{\mu_2})^2}$$

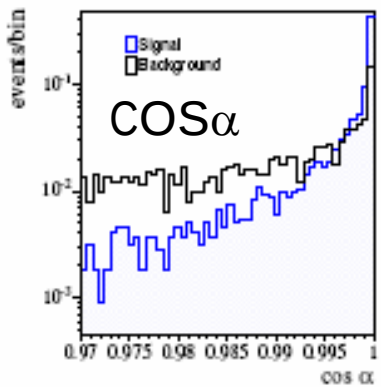
  - $0.3 < \Delta R(\mu\mu) < 1.2$
- Isolation of muon pair

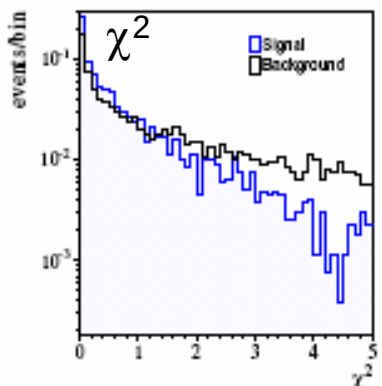
$$I = \frac{p_\perp(B_s)}{p_\perp(B_s) + \sum_{trk} |p_\perp|}$$

  tracks in cone with $r = \sqrt{\eta^2 + \phi^2} < 1.0$ and $p_\perp > 0.9$ GeV
  - $I > 0.85$
- Secondary vertex
  - Pointing angle: $\cos(\alpha) > 0.995$
  - vertex fit $\chi^2 < 1$



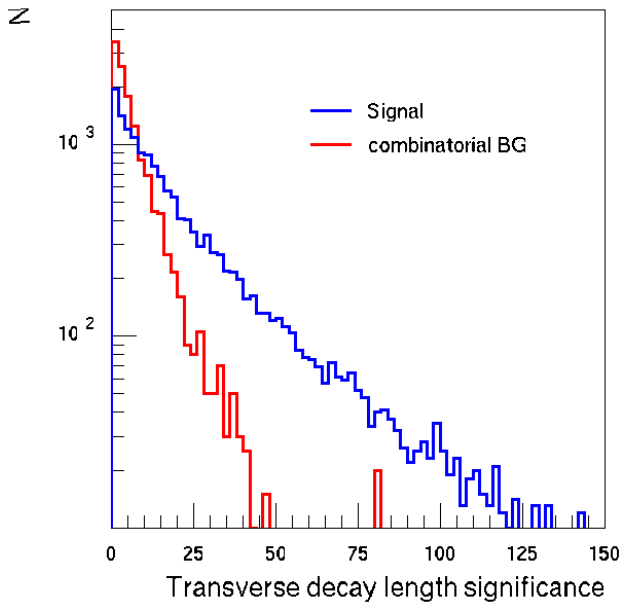






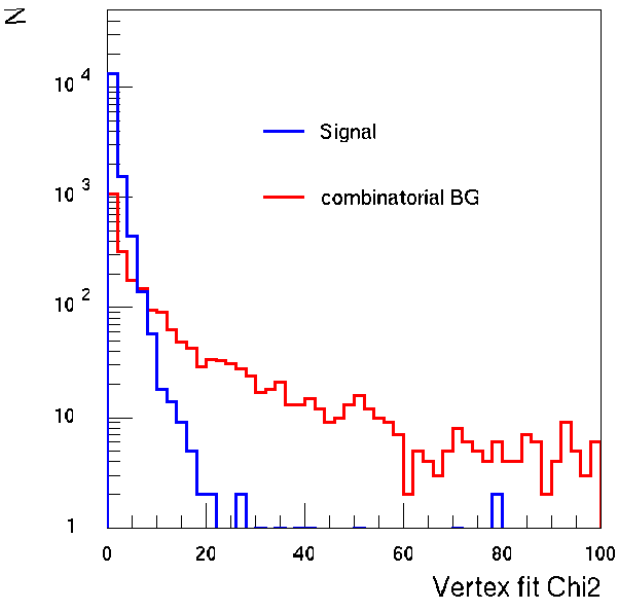
ATLAS offline analysis : $B_s \rightarrow \mu\mu$

- $M_{mm} = M_{Bs}{}^{+140}_{-70}$ MeV
- isolation: no charged tracks with $p_T > 0.8$ GeV in cone $\theta < 15$ degrees
- vertex fit with pointing to primary vertex constraint
- transverse decay length $L_{xy}/s(L_{xy}) > 11$



Exected signal v.s. inclusive $bb \rightarrow \mu\mu X$ bkg

	B^0_s signal	BG ($bb \rightarrow \mu\mu X$)
p_T>6 GeV, $\Delta R_{\mu\mu}$<0.9	50 events	6.0×10^6 events
$M_{\mu\mu}$cut	0.77	2×10^{-2}
Isolation cut	0.36	5×10^{-2}
L_{xy}/σ>11, χ^2<15	0.4	$< 0.7 \times 10^{-4}$
All cuts	7	20 ± 20



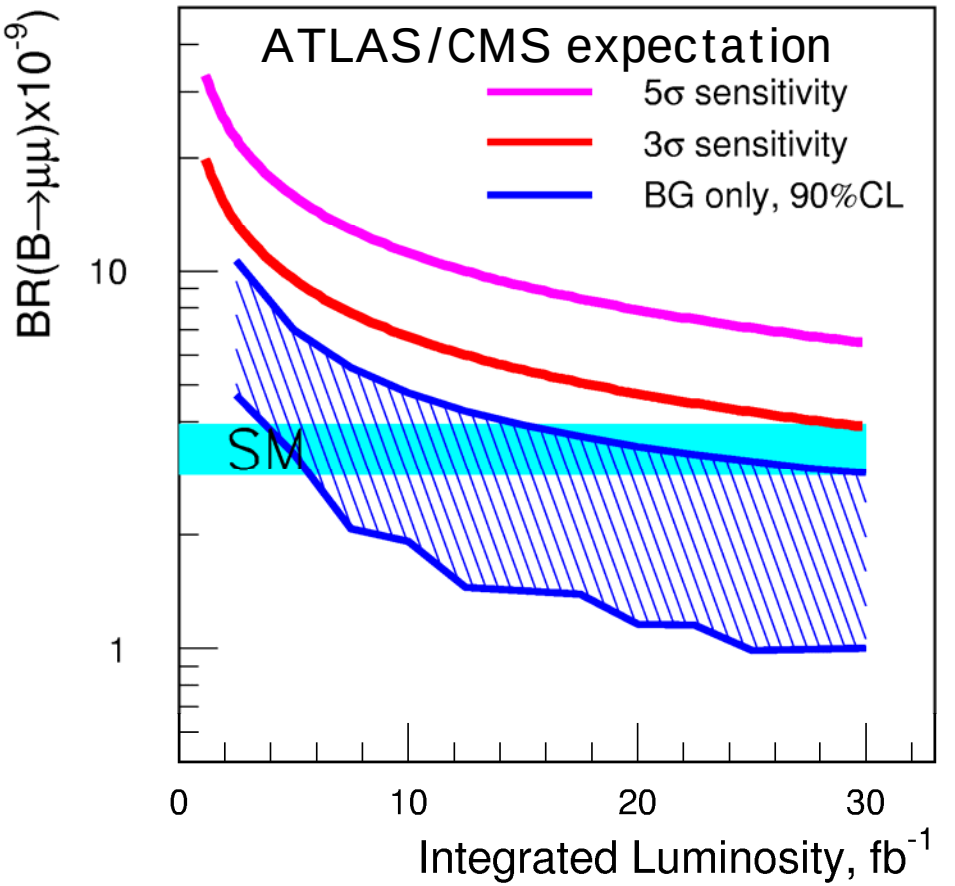
Projected upper limits : $B_s \rightarrow \mu\mu$

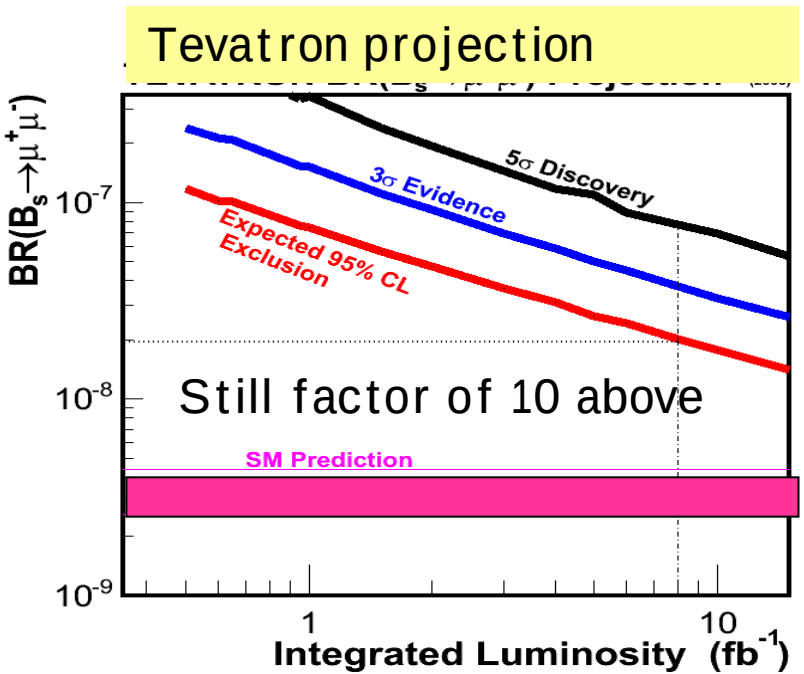
7 signals and 20 backgrounds can expect upper limit on $Br(B_s \rightarrow \mu\mu)$

$$Br\left(B_s^0 \rightarrow \mu^+\mu^-\right) \leq \frac{N\left(n, n_{bg}\right)}{2\sigma_{Bs} L \alpha \varepsilon_{total}}$$

- Single experiment expects to reach the sensitivity of SM prediction

3 years of data taking : L=30fb^{-1}





Both ATLAS and CMS has proven to continue measurement of $B_s \rightarrow \mu\mu$ at nominal LHC luminosity 10^{34}.
This will mean 100 fb^{-1} just in one year.

Specific background study : $B_s \rightarrow \mu\mu$

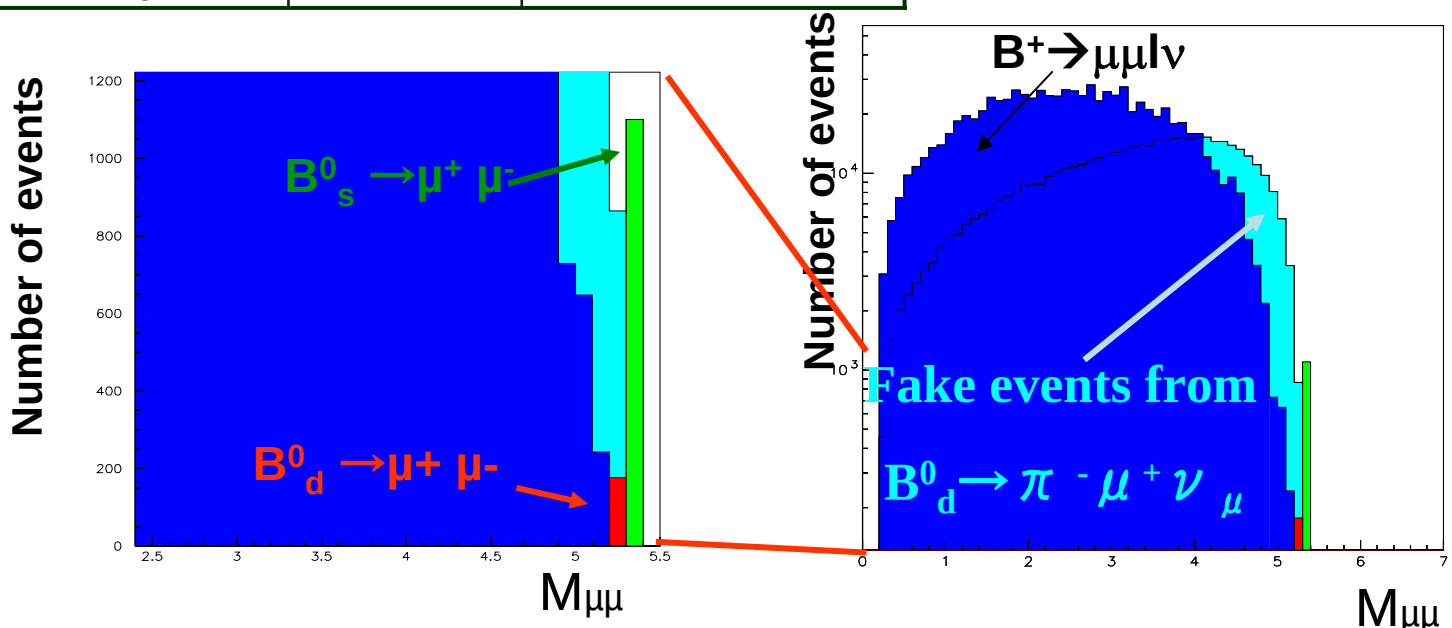
BG process	Br	Effective Br in $B \rightarrow \mu\mu$ signal region
$B^0 \rightarrow \pi^- \mu^+ \nu_\mu$	$\sim 10^{-4}$	$\sim 5 \cdot 10^{-8}$
$B^+ \rightarrow \mu^+\mu^- \ell^+ \nu_\ell$	$< 5 \cdot 10^{-6}$	$< 5 \cdot 10^{-8}$
$B_c \rightarrow \mu^+\mu^- \ell^+ \nu_\ell$	$< 10^{-4}$	$< 10^{-8}$
$B^0_d \rightarrow \pi^0 \mu^+\mu^-$	$\sim 2 \cdot 10^{-8}$	$\sim 10^{-10}$
$B^0_s \rightarrow \mu^+ \mu^- \gamma$	$\sim 2 \cdot 10^{-8}$	$\sim 10^{-10}$
$B_d \rightarrow K\pi$ $B_s \rightarrow KK$	$2 \cdot 10^{-5}$	$< 10^{-9}$

Much high branching ratio compared to $Br(B_s \rightarrow \mu\mu)=10^{-9}$

Generator level study

Taking into account
1. $\pi/K \rightarrow \mu$ fake rate ~ 0.1-0.5%
2. soft ν phase space ~ 10%

Needs further study with full simulation

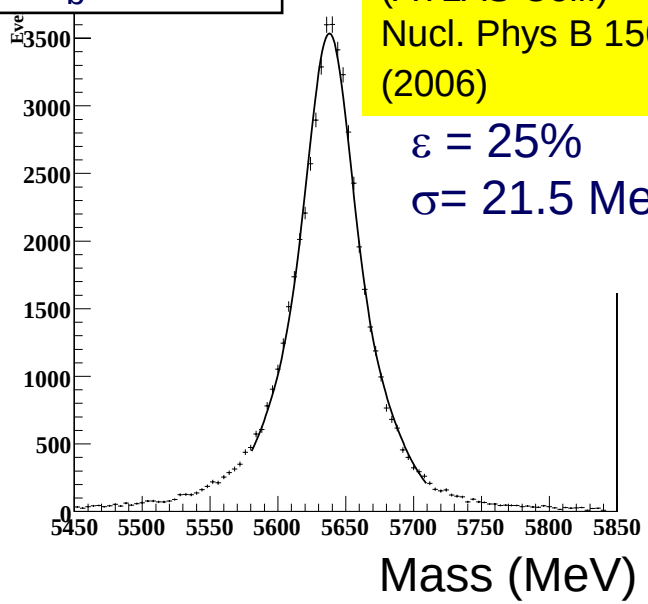


B→Xμμ

BR used in the MC			Signature after trigger + offline reconstruction 30 fb^{-1}		Models used in MC or to confront experimental sensitivities.
			Signal	Bkg	
1.3 ×10^{-6}	$B_d \to K^{0*}\mu\mu$	Br.fraction μμ-mass A_{FB}	2500	<50000	Melikhov, Nikitin, Simula, PRD57,98;
3.5 ×10^{-7}	$B^+ \to K^+ \mu\mu$		1500	<10000	Melikhov, Stech, PRD62, 2000
1.0 ×10^{-6}	$B_s \to \phi \mu\mu$		900	<10000	WC: SM Buras, Munz, PRD52, 95;
					MSSM Cho, Misiak,Wyller, PRD54,96.
2.0 ×10^{-6}	$\Lambda_b \to \Lambda\mu\mu$		800	< 4000	NP: Chen, Geng, PRD64,2001
					Aliev NPB649,2003

Λ_b mass

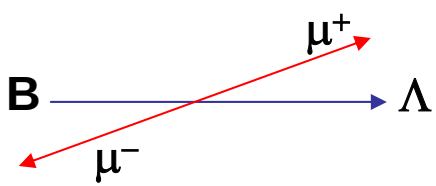
M. Biglietti et al. (ATLAS Coll.) Nucl. Phys B 156 (2006)



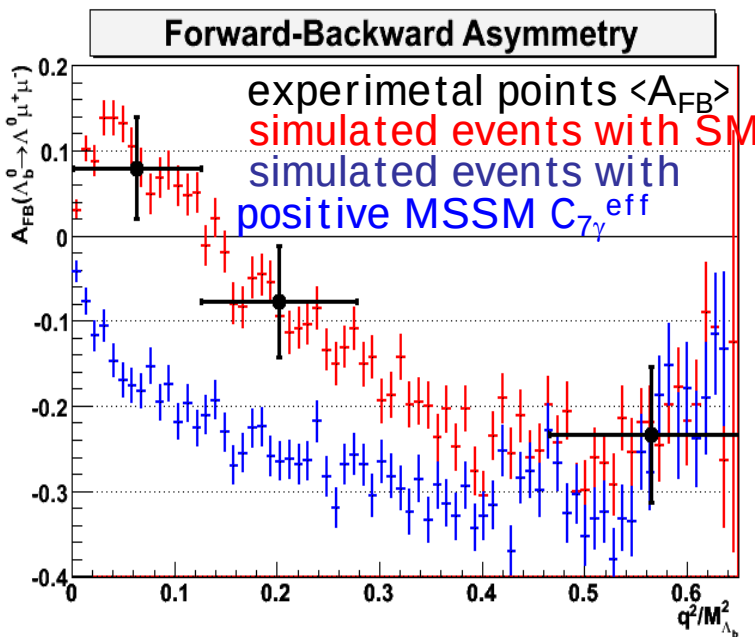
ε = 25%

σ= 21.5 MeV

Forward-backward Asymmetry (A_{FB})



ATLAS statistical error<5%



Conclusion

- ATLAS and CMS sensitivity to rare B-decay is expected to reach the level of SM prediction after 3 years of data taking
  - b→μμs and B→μμ promising for new physics
  - We will directly and indirectly be able to search for new physics at the same place and time
- At LHC nominal luminosity $10^{34}cm^{-2}s^{-1}$, ATLAS and CMS can make a measurement of B_s->μμ branching ratio just after one year.
- More study using full simulation/reconstruction is under way
- The installation and commissioning of the detectors are in good progress

- Everyone is waiting for the data taking …

Backup or Old slides

Rare B-decays

FCNC transition

→Forbidden at tree level

Br(b→sll) ~ 10^{-6} ~ 10^{-7}

Br(B→μμ) ~ 10^{-9} ~ 10^{-10}

Indirect search for new physics

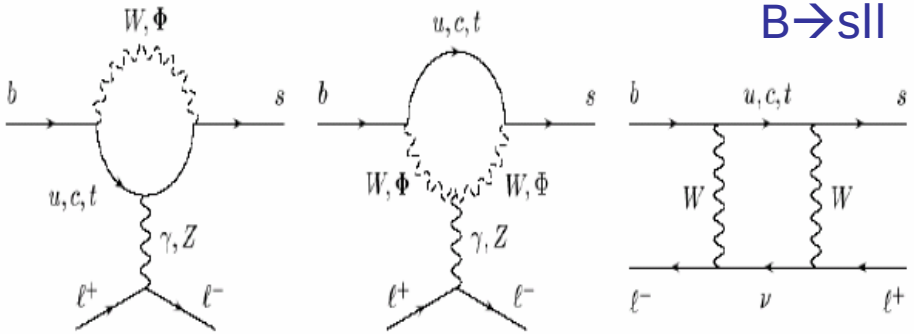
SUSY, Higgs etc

For b→sμμ transitions

$|V_{ts}|$ and $|V_{td}|$ determination

Wilson coefficient C_7, C_9, C_{10}

B→sll



Br(B_d→K*μμ)

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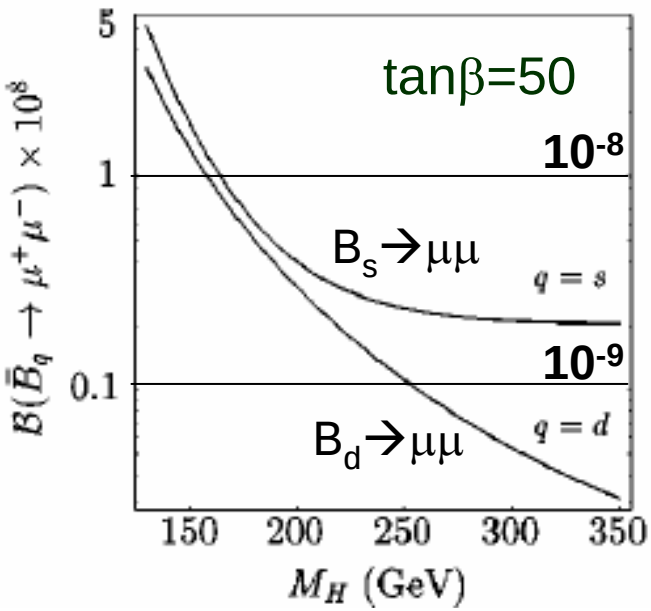
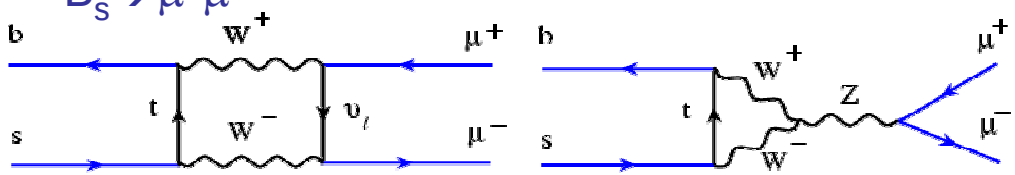
Babar : 0.86 $^{+0.79}_{-0.58} \pm 0.16 \times 10^{-6}$



Bobeth et. al., PRD66 074021 (2002)

B_s→$\mu^+\mu^-$



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CDF (780 pb-1)	1.0×10^{-7} 95%CL	3.0×10^{-7} 95%CL
DØ (700 pb-1)	2.0×10^{-7} 95%CL	11.1×10^{-7} 95%CL
Belle 78 fb-1	-	1.6×10^{-7} 90% CL
BaBar 111 fb-1	-	0.6×10^{-7} 90% CL