B Physics potential of CMS

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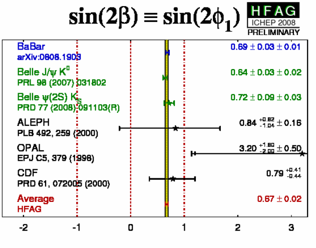
Outline

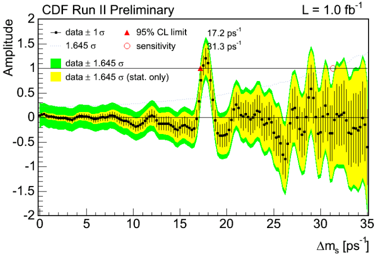
- Introduction: experimental B Physics today
- CMS detector: key subsystems
- Trigger strategy: L1 trigger and HLT
- Physics channels: overview and detailed example: $B_s^0 \to \mu^+\mu^-$
- Conclusions

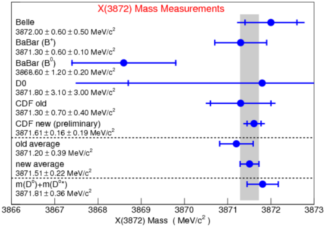
Experimental B Physics today

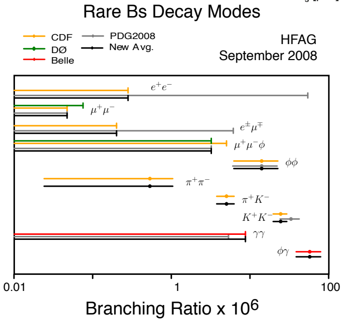
- Existing facilities (B factories)
  - *BABAR* (SLAC PEP-II, USA) and Belle (KEK, Japan) experiments
  - Proper energy (Υ(4S), 10.58GeV), specialized detectors: dE/dx (DCH), DIRC, TOF etc
  - Huge statistics: many $\mathcal{B}$ measured, rare decays, CP violation etc
- CMS at LHC (hadron collider)
  - High energy: 14TeV, not necessary for BPhysics
  - General purpose detector: no dE/dx, TOF, performance not so outstanding for soft physics
  - Main goals: Higgs, SUSY, Exotica $\Rightarrow$ limited trigger bandwidth for BPhysics
- B Physics at hadron collider: CDF and D0 at Tevatron (Fermilab)
  - properties of B_u and B_d: lifetime, mass, CP, rare decays
  - B_s: $B_s^0 - \bar{B}_s^0$ oscillations, lifetime, mass, limit on $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$
  - properties of B_c, Λ_b: lifetime, mass, $\mathcal{A_{CP}}$
  - Σ_b, Σ_b^* discovery: m(Σ_b^-)=5815.2$\pm$1.0(stat)$\pm$1.7(sys) MeV/c^2

B Physics results (examples)









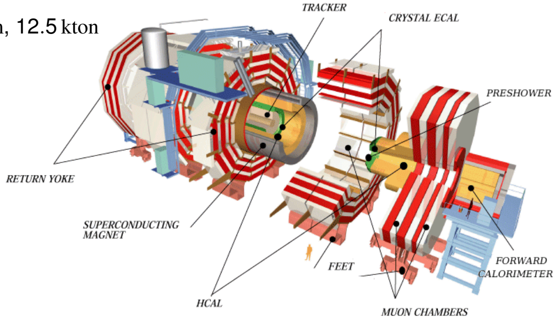
Motivations

- Physics:
  - $b\bar{b}$ x-section at 14(10) TeV $\simeq 500\mu$b
  - 'New' flavors produced: B_s^0 ($\simeq$ 20%) and $B_c^{\pm}$ ($\simeq$ 0.2%)
  - NP search in decay rate: mainly $B_s^0 \to \mu^+\mu^-$
  - NP search in $\mathcal{A}_{FB}$, $\mathcal{A}_{CP}$, $M_{\mu^+\mu^-}$, $P_{L(T)}$: $B \to X_s\mu^+\mu^-$ and $\Lambda_b \to \Lambda\mu^+\mu^-$
- Detector:
  - (di-)muon low p_T trigger, precise vertex detector, efficient tracker system
  - B and quarkonia (J/Psi, Υ) decays provide excellent calibration
- Collider:
  - at low luminosity phase no Higgs, but already plenty of $b\bar{b}$
  - at high luminosity, thanks to efficient (di)-muon trigger, continue BPhysics

The CMS Detector

for details see talk G.Tonelli

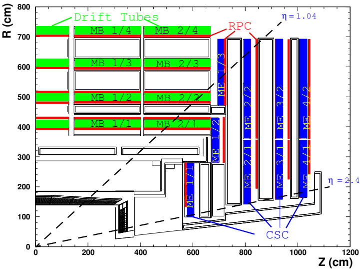
- The Compact Muon Solenoid
  - Length 22 m , diameter 15 m, 12.5 kton
  - Magnetic field 3.8 Tesla
- Muon system
  - DT, CSC, RPC
  - $p_T > 3$ GeV/c
- All-silicon tracker (220 m^2)
  - $|\eta| < 2.5$
  - pixel: 3 layers, 2 disks, 100x150 μm^2 pixels
  - strip tracker: 10 layers, 9 disks



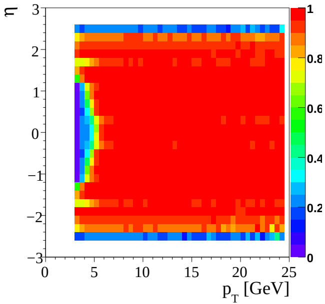
The CMS Muon System

for details see talk S.Marcellini

- Three types of gaseous particle detectors for muon identification
  - Drift Tubes (DT) in the central barrel region: position and momentum measurements
  - Cathode Strip Chambers (CSC) in the end-cap region: position and momentum measurements
  - Resistive Parallel Plate Chambers (RPC) in both the barrel and end-caps: fast information for the Level-1 trigger



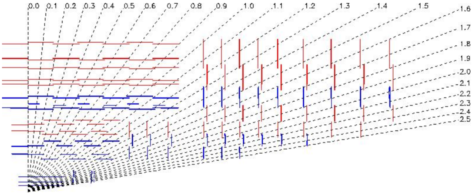
Muon identification efficiency

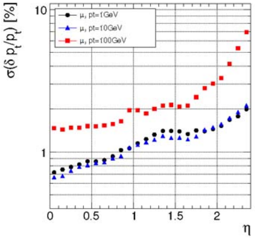


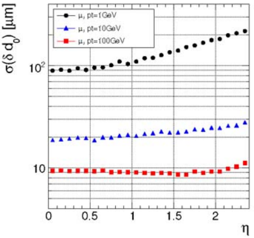
The CMS Tracker

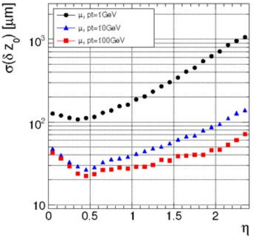
for details see talk M.Krammer

- Silicon Strip Detector
  - $10 \div 14$ points
  - hit resolution: 50/500 μm in $(r - \phi)/z$
- Pixel Detector
  - 3 points
  - hit resolution: 10/17 μm in $(r - \phi)/z$







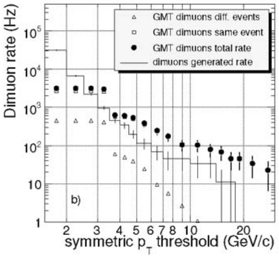


The CMS Trigger Strategy

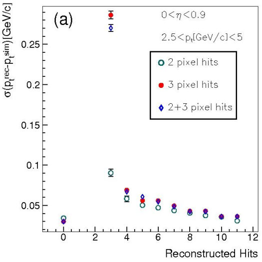
- Level 1 Triggers
  - muons and calorimeters,
    Latency: 3.2μs,
    40 MHz $\rightarrow$ 100 kHz
- High-level Triggers (HLT)
  - fast (local) reconstruction,
    100kHz $\rightarrow$ 100Hz

- B-physics triggers
  - Level 1: single- or di-muon trigger
    1μ: $p_T > 7(14)$ GeV/c,
    2μ: $p_T > 3(7)$ GeV/c
  - HLT: exclusive and inclusive b/c
    triggers at $\sim$ 5Hz
    partial reconstruction,
    displaced di-muons

L1 trigger rate



Partial reconstruction



LHC start-up and CMS objectives

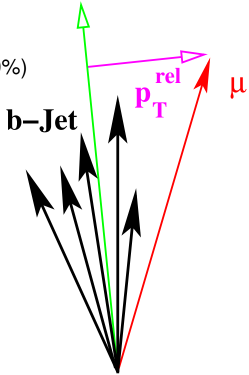
- 2009 - 10TeV Collision:
  - 'Engineering' Run $\rightarrow 1 \div 5\,\mathrm{pb}^{-1}$
  - Nominal luminosity $(10^{28} \rightarrow 10^{31})\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - Detector commissioned, calibration and alignment
- 2010 - 10TeV Collision:
  - Physics Run $\rightarrow 100 \div 300\,\mathrm{pb}^{-1}$
  - Nominal luminosity $(10^{31} \rightarrow 10^{32})\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - Detector calibrated and aligned, physics data taking
- Beauty related information
  - $N_{b\bar{b}} = 5 \times 10^8 / \mathrm{pb}^{-1}$
  - L1 trigger:
    2μ: p_T= 3 GeV/c;
    1μ p_T= 3, 5 GeV/c - (un)prescaled, p_T>7 GeV/c, unprescaled till 10^{32}
- Main BPhysics goals at start-up
  - measure: m_B, τ_B, decay branching ratio for different b-hadron decays
  - measure: $b\bar{b}$ production x-section and production mechanisms
  - search: NP effects in rare B decays branching ratio

Heavy Flavor Menu

- ready analysis
  - Inclusive b production: differential x-sections
  - Inclusive and prompt $J/\Psi(\to \mu^+\mu^-)$ production x-section
  - J/Ψ vs μ: $b\bar{b}$ correlation studies, $b\bar{b}$ production mechanisms
  - $B_s^0 \to J/\Psi\phi \to \mu^+\mu^-K^+K^-$: measurement of $\Delta\Gamma_s$
  - $B_s^0 \to \mu^+\mu^-$: FCNC rare decay, possible hint for NP
  - $B_c^\pm \to J/\Psi\pi^\pm \to \mu^+\mu^-\pi^\pm$: mass and lifetime of B_c
  - $\tau \to 3\mu$: search for Lepton Flavor Violation
- analysis in progress
  - $B^\pm \to J/\Psi K^\pm \to \mu^+\mu^-K^\pm$: measurement of $\sigma_{b\bar{b}}$
  - $B \to D_0\mu X$: measurement of $\sigma_{b\bar{b}}$
  - $b \to J/\Psi + X \to \mu^+\mu^- + X$: inclusive b production x-section and lifetime
  - $B^0 \to J/\Psi K^{*0} \to \mu^+\mu^-K^+\pi^-$
  - Quarkonia: Υ and χ_c production x-section, J/Ψ polarization
  - $B \to (\phi, K^*, K_s)\mu^+\mu^-$, $\Lambda_b \to \Lambda\mu^+\mu^-$: search for NP
- parameters assumed in the studies
  - $E_{CM} = 14\ TeV$, $\sigma_{b\bar{b}} = 500\ \mu$b,
  - luminosity from 3 pb^{-1} up to 10 fb^{-1}

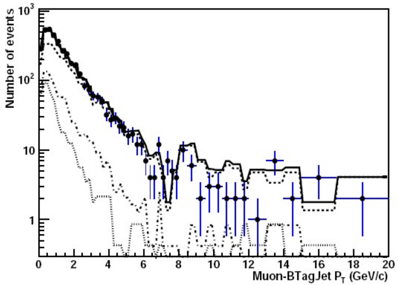
Inclusive b production

- Measure differential *b*-jet x-section: $d\sigma/dp_T$ and $d\sigma/d\eta$
- Experimental signature: μ **+ *b*-jet**
- Trigger
  - L1: single muon with $p_T > 14$ GeV/*c* ($\epsilon = 18\%$)
  - HLT: muon with $p_T > 19$ GeV/*c* + *b*-jet of $E_T > 50$ GeV ($\epsilon = 60\%$)
- Off-line Analysis
  - *b*-jet tagging with CSV (secondary vertex based) algorithm
  - take most energetic *b*-jet in event as B-particle candidate
  - apply muon tag (muon in *b*-jet)
- 1.6M b-events collected @ 1 fb^{-1}
- Key issue is data purity
  - background: *c*-jets, *udsg*-jets with real/fake μ
  - select jets with muon inside (*b*-jet candidates)
  - fit data with MC shapes of muon transverse momentum with respect to jet axis

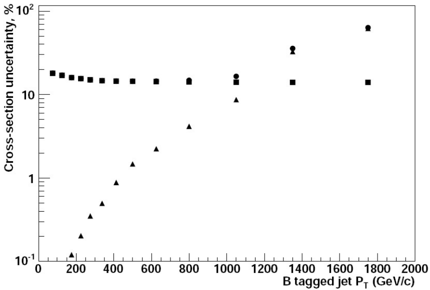


Inclusive b production

muon p_T spectrum fit:
b (dash), c (dot-dash), $udsg$ (dot)



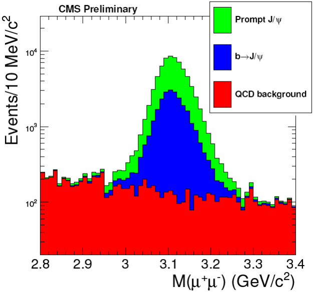
x-section uncertainties:
stat (▲), sys (■), total (●)

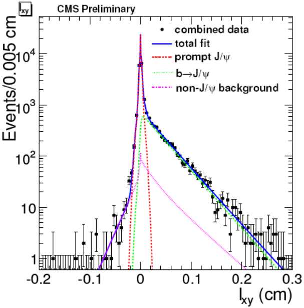


- Dominant source of systematic is Jet Energy Corrections.
- Measurements could be done with 20% error in a range p_T(B)=50 GeV/c ÷ 1.2 TeV/c with 10 fb^{-1} of data

$J/\Psi(\rightarrow \mu^+\mu^-)$ production x-section

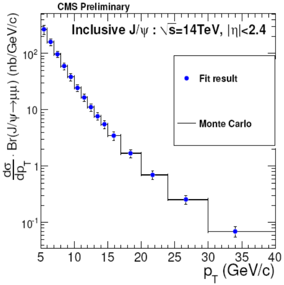
- Measure J/Ψ production x-section: $d\sigma/dp_T$
- Three main production mechanisms:
  - prompt direct production
  - prompt indirect production (via χ_c, $\Psi2$ etc decays)
  - non-prompt production via $b \rightarrow J/\Psi X$
- Goals of the study
  - prompt J/Ψ production mechanism: CSM, COM, else? [Color Singlet/Octet Model]
  - measure B hadron production x-section
- Puzzle in quarkonia production
  - CDF shows 50(!) times higher x-section than CSM
  - NRQCD including COM explains $d\sigma/dp_T$ but not transverse polarization
  - at LHC higher p_T and more luminosity allow for new studies
- 70k J/Ψ events collected @ $3\,\text{pb}^{-1}$

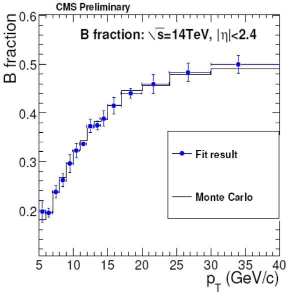


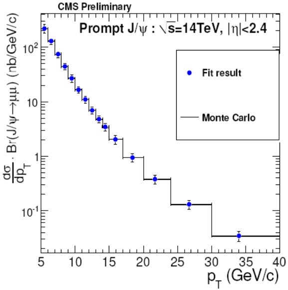


$J/\Psi(\rightarrow \mu^+\mu^-)$ production x-section

- J/Ψ trigger selection and reconstruction:
  - L1: di-muon with $p_T > 3$ GeV/c
  - HTL: muon p_T and $m_{J/\Psi} \pm 0.3$ GeV/c^2
  - off-line: same as trigger + di-muon sec. vert.
- Sample composition:
  - background: QCD with 1 real and 1 fake muons
  - B fraction determined by log-likelihood fit of mass spectrum and transverse flight length l_{xy}
- Systematic uncertainties: $\sim$ 15% (lumi,$\epsilon_{t,r}$)



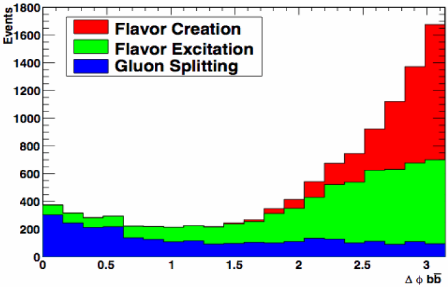




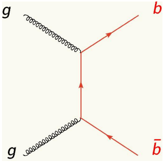
$b\bar{b}$ production mechanisms

- Three production mechanisms:
  - Flavor Creation: both b-quarks in the hard interaction (HI), $\Delta\phi \simeq \pi$, balanced in p_T
  - Flavor Excitation: one b-quark in the HI, asymmetric p_T
  - Gluon Splitting: none b-quark in the HI, small $\Delta\phi$

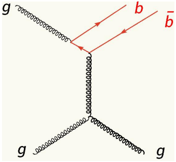
- Goals of the study
  - critical additional test of NLO QCD
  - precise determination of $b\bar{b}$ production topology
  - tune MC generators for more realistic estimation of $b\bar{b}$ background for NP searches



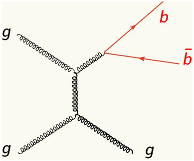
Flavor Creation (50μb)



Flavor Excitation (220μb)

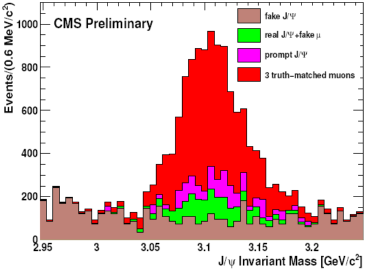


Gluon Splitting (190μb)

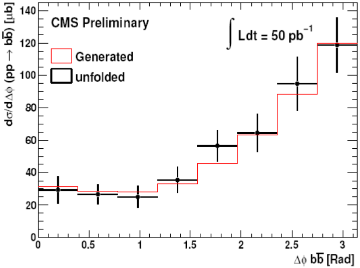


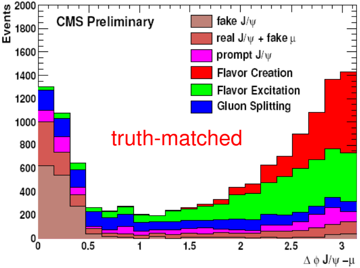
$b\bar{b}$ production mechanisms

- Analysis strategy:
  - Signature: $b\bar{b} \to J/\Psi(\to \mu^+\mu^-)X + \mu^\pm X$
  - L1/HLT triggers: di-muon p_T>3 GeV/c
  - Signal yield measured in $\Delta\phi$ bins through unbinned maximum-likelihood to J/Ψ mass $L_{xy}^{J/\Psi}$ and IP_μ
  - Unfolding $\Delta\phi(J/\Psi - \mu)$ to get $\Delta\phi(b\bar{b})$



- With 50 pb^{-1} of data (few month)
  - 7500 signal events
  - $\sigma(pp \to b\bar{b}X) = 451 \pm 50\mu\text{b}$





$B_s^0 \to J/\Psi\phi \to \mu^+\mu^- K^+ K^-$

- Study properties of B_s system:
  - Width difference of two weak eigenstates $\Delta\Gamma_s = \Gamma_H - \Gamma_L$
    - SM: $\Delta\Gamma_s/\bar{\Gamma}_s \simeq 10\%$, CDF: $(\Delta\Gamma_s/\bar{\Gamma}_s \simeq 3.1 \pm 7.7_{stat})\%$ (2.8 fb^{-1})
  - Mass difference of two weak eigenstates $\Delta m_s = m_{B_s^H} - m_{B_s^L}$
    - CDF: $\Delta m_s = 17.77 \pm 0.10_{stat} \pm 0.07_{sys}$ (1 fb^{-1})
  - height of the Unitarity Triangle (η) and possible hint for NP: $\phi_s^{SM} = -2\lambda^2\eta = (3.12 \pm 0.11)^\circ$ (*CP*-violating weak phase)
- B_s decays into two vector mesons: 3 polarization amplitude
  - *CP*-even: $A_0(t)$ and $A_{||}(t)$ and *CP*-odd: $A_\perp(t)$
  - with constraint $|A|^2 = |A_0|^2 + |A_{||}| + |A_\perp|^2$
- Time dependent angular analysis:
  - simple example: $\frac{d\Gamma(t)}{dcos\theta} \sim (|A_0(t)|^2 + |A_{||}(t)|^2)\frac{3}{8}(1 + cos^2\theta) + |A_\perp(t)|^2\frac{3}{4}sin^2\theta$
  - more information in the full three angles distribution

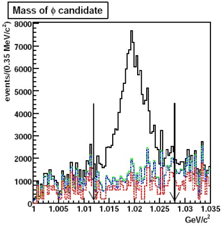
$B_s^0 \to J/\Psi\phi \to \mu^+\mu^-K^+K^-$

- Trigger strategies:
  - L1: di-muon with $p_T > 3\,\mathrm{GeV}/c$
  - HLT 1: partial (∼6hits) track, J/Ψ mass and vertexes reconstruction
  - HLT 2: kinematic (p_T, mass) and topological (L_{xy}, $\Delta\alpha$ etc) selections
  - HLT 3: ϕ and B_s reconstruction and corresponding selections
- Background
  - prompt J/Ψ: important in trigger, negligible after all cuts
  - inclusive $b \to J/\Psi$: after all cuts $n_B/n_S \simeq 33\%$
  - $B_d \to J/\Psi K^*$: after all cuts $n_B/n_S \simeq 7\%$
- Off-line Analysis
  - almost the same as HLT but with full detector information
  - angular analysis to measure $\Delta\Gamma_s$
- ∼14k events collected @ $1.3\,\mathrm{fb}^{-1}$

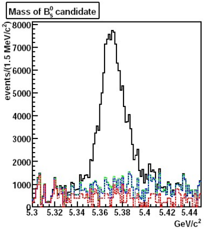
$B_s \to J/\Psi\phi$: results with 1.3 fb^{-1}

Parameter	Input value	Result	Stat. error	Sys. error	Total error	Rel. error
$\|A_0(0)\|^2$	0.57	0.5823	0.0061	0.0152	0.0163	2.8%
$\|A_{\|\|}(0)\|^2$	0.217	0.2130	0.0077	0.0063	0.0099	4.6%
$\|A_\perp(0)\|^2$	0.213	0.2047	0.0065	0.0099	0.0118	5.8%
$\bar{\Gamma}_s$	0.712 ps^{-1}	0.7060 ps^{-1}	0.0080 ps^{-1}	0.0227 ps^{-1}	0.0240 ps^{-1}	3.4%
$\Delta\Gamma_s$	0.142 ps^{-1}	0.1437 ps^{-1}	0.0255 ps^{-1}	0.0113 ps^{-1}	0.0279 ps^{-1}	19%
$\Delta\Gamma_s/\bar{\Gamma}_s$	0.2	0.2036	0.0374	0.0173	0.0412	20%

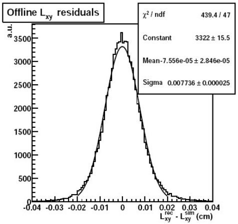
$\Delta m_\phi \sim 3$ MeV/c^2



$\Delta m_{B_s} \sim 14$ MeV/c^2

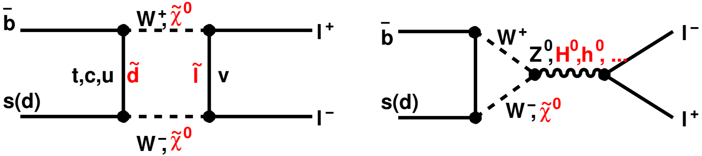


$\sigma_{SV} \sim 77\ \mu$m



- Statistical error on $\Delta\Gamma_s/\bar{\Gamma}_s$ is $\simeq 0.01$ with 10 fb^{-1}
- Measurements of ϕ_s with tagged analysis is under study

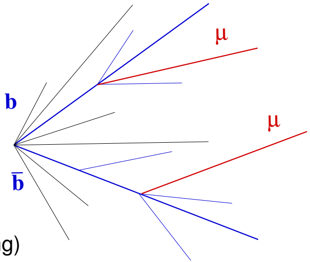
$B_s^0 \to \mu^+\mu^-$



- Highly suppressed in SM: $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.86 \pm 0.15) \times 10^{-9}$
- Sensitive to NP:
  - New particles contribute in decay diagrams
  - MSSM: $\mathcal{B} \propto (\tan\beta)^6$ or 2HDM: $\mathcal{B} \propto (\tan\beta)^4$
  - Constraints on masses (m_0, $m_{1/2}$ etc) and $\tan\beta$
- Current best limit (Tevatron, 2 fb^{-1}):
  - D0: $\mathcal{B} \leq 7.5 \times 10^{-8}$ at 95% C.L.
  - CDF: $\mathcal{B} \leq 4.7 \times 10^{-8}$ at 95% C.L.

$B_s^0 \to \mu^+\mu^-$: analysis overview

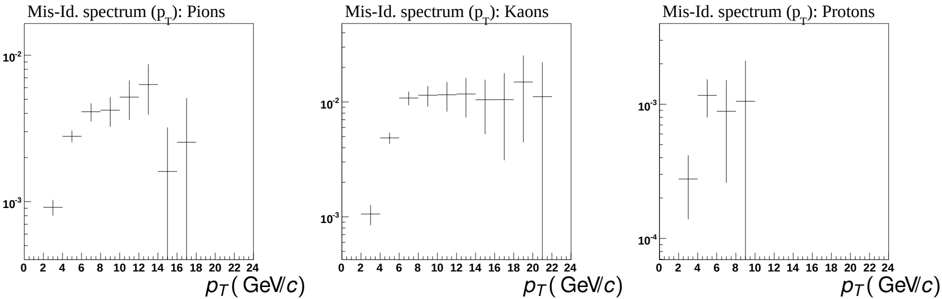
- Search for a very rare decay channel
  - clean experimental signature
  - efficient signal selection
  - strong background reduction
- Background composition
  - $b\bar{b}(c\bar{c}) \to \mu^+\mu^- + X$
  - rare single B decays (peaking and non-peaking)
  - QCD $2 \to 2$ (1 or 2 hadrons identified as muons)
- Background reduction
  - 2 muons consistent with one secondary vertex
  - large flight length
  - isolation of di-muon system
  - mass window



$B_s^0 \to \mu^+\mu^-$: background

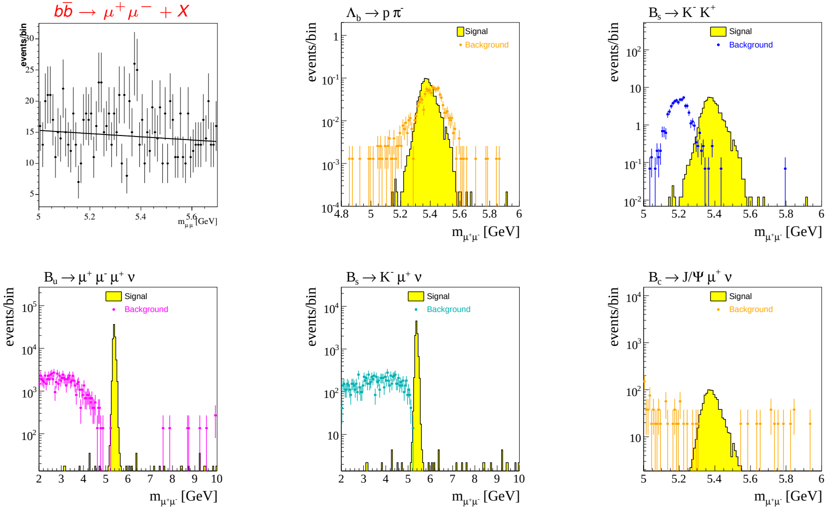
Sample	Generator cuts/channels	σ_{vis} [fb]	$N_{\mu ID}$ (10 fb^{-1})
$b\bar{b} \to \mu^+\mu^- + X$	$p_T^{\mu} > 3$ GeV/c, $\lvert\eta^{\mu}\rvert < 2.4$ $p_T^{\mu\mu} > 5$ GeV/c, $0.3 < \Delta R(\mu\mu) < 1.8$ $5 < m_{\mu\mu} < 6$ GeV/c^2	1.74E + 07	1.74×10^8
B_s decays	$B_s \to K^- K^+$	2.74E + 05	274
	$B_s \to \pi^- \pi^+$	9.45E + 03	3
	$B_s \to K^- \pi^+$	3.08E + 04	16
	$B_s \to K^- \mu^+ \nu$	2.80E + 05	2.80×10^4
	$B_s \to \mu^+ \mu^- \gamma$	1.29E + 01	130
B_d decays	$B_d \to \pi^- \pi^+$	8.34E + 04	21
	$B_d \to \pi^- K^+$	3.74E + 05	187
	$B_d \to \pi^- \mu^+ \nu$	1.25E + 06	6.25×10^4
	$B_d \to \mu^+ \mu^- \pi_0$	3.77E + 01	377
B_u decay	$B_u \to \mu^+ \mu^- \mu^+ \nu$	2.24E + 03	2.24×10^4
B_c decays	$B_c \to \mu^+ \mu^- \mu^+ \nu$	2.01E + 01	201
	$B_c \to J/\Psi \mu^+ \nu$	1.89E + 03	1.89×10^4
Λ_b decays	$\Lambda_b \to p\pi^-$	4.22E + 03	1
	$\Lambda_b \to pK^-$	8.45E + 03	1
QCD hadrons	$5 < M(hh) < 6$ GeV/c^2	2.24E + 11	1.12×10^8

Misidentification of hadron as muon



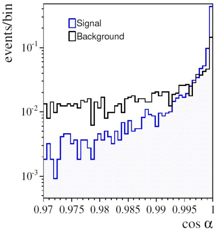
$\epsilon_{mis}(\pi) = 0.5\%$ $\epsilon_{mis}(K) = 1.0\%$ $\epsilon_{mis}(p) = 0.1\%$

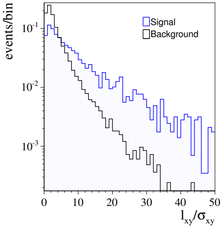
$B_s^0 \to \mu^+\mu^-$: background before cuts

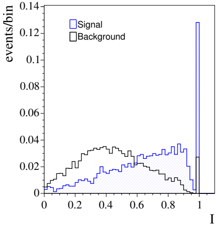


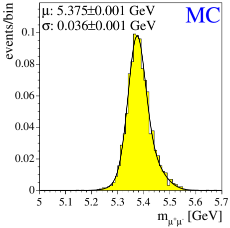
$B_s^0 \to \mu^+\mu^-$: main selections

- Muon separation: $0.3 < R_{\mu\mu} < 1.2$
- Pointing angle: $\alpha(\vec{P}_T, \vec{V}_T) < 5.7^\circ$
- Decay length: $l_{xy}/\sigma_{xy} > 18.0$
- Vertex fit quality: $\chi^2 < 1.0$
- Isolation: $I = \frac{p_T(B_s)}{p_T(B_s)+\sum_{trk}|p_T|} > 0.85$, $R < 1.0$, $p_T > 0.9\,\mathrm{GeV}/c$
- Mass cut: $|m_{\mu\mu} - m_{B_s}| \leq 100\,\mathrm{MeV}/c^2$



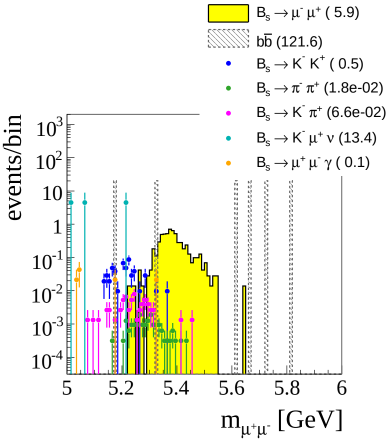


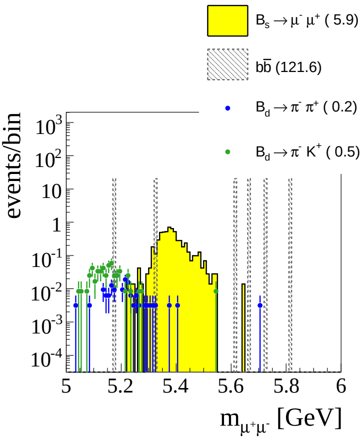




$B_s^0 \to \mu^+\mu^-$: background after cuts

Rare background after selections ($10\,\mathrm{fb}^{-1}$)





$B_s^0 \rightarrow \mu^+\mu^-$: results

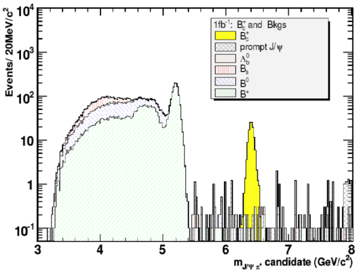
- Results for 10 fb^{-1}
- Signal: $\varepsilon_S = 0.019 \pm 0.002_{stat}$, $n_S = 6.1 \pm 0.6_{stat} \pm 1.5_{sys}$
- Background: $\varepsilon = 2.6 \times 10^{-7}$, $n_B = (13.8 + 0.3)^{+22.3}_{-14.1}$

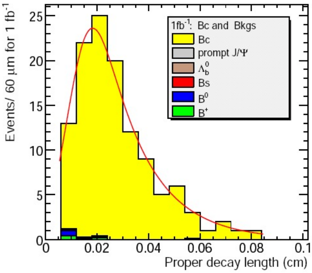
$$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) \leq \frac{N(n_{obs}, n_B, n_S)}{\varepsilon_{\rm gen}\, \varepsilon_{\rm total}\, N_{B_s}} \leq 1.4 \times 10^{-8} \quad (90\%\ \text{C.L.})^*$$

* UL extracted using Bayesian approach (CDF)

$B_c^{\pm} \to J/\Psi\pi^{\pm} \to \mu^+\mu^-\pi^{\pm}$

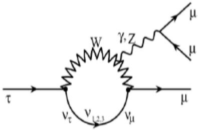
- B_c discovered by CDF (!)
  - $M_{B_c} = (6.40 \pm 0.39 \pm 0.13)\,\mathrm{GeV}/c^2$
  - $\tau_{B_c} = (460 \pm 180 \pm 30) fs$
- M_{B_c} and τ_{B_c} measurements
  - 120 $J/\Psi\pi^{\pm}$ selected in 1 fb^{-1}
  - mass resolution $\sigma_M = 15\,\mathrm{MeV}/c^2$
  - lifetime error $\sigma_\tau = 45 fs$ (stat dominated)



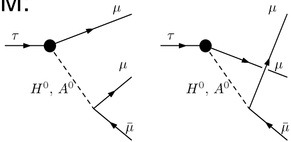


LFV in $\tau \to \mu\mu\mu$

SM:



BSM:



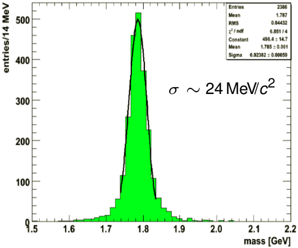
- SM lepton flavor violation is negligible: $\sim (m^2_{\nu_i}/m^2_W)^2$
- Many theories BSM allow $\mathcal{B} \sim O(10^{-10} \div 10^{-7})$
- Current experimental limits:
  - BELLE: $\mathcal{B} \leq 3.2 \times 10^{-8}$, $535\,\mathrm{fb}^{-1}$
  - *BABAR* $\mathcal{B} \leq 5.3 \times 10^{-8}$, $376\,\mathrm{fb}^{-1}$
- CMS can contribute in the measurements:
  - Plenty of τ produced $\sim 10^{11}$ per $1\,\mathrm{fb}^{-1}$
  - Clean experimental signature, suitable triggers

LFV in $\tau \to \mu\mu\mu$

- τ sources at CMS

Channel	$W \to \tau\nu$	$\gamma/Z \to \tau\tau$	$B^0 \to \tau X$	$B^\pm \to \tau X$	$B_s \to \tau X$	$D_s \to \tau X$
$N_\tau/1\,\text{fb}^{-1}$	1.7×10^7	3.2×10^6	4.0×10^{10}	3.8×10^{10}	7.9×10^9	1.5×10^{11}

- Main background sources
  - $c\bar{c} \to D_x D_s \to \mu\nu\phi(\to \mu\mu) + X$
  - $b\bar{b} \to B_x B_s \to \mu\nu D_s(\to h\phi(\to \mu\mu)) + X$
- Trigger strategy
  - L1: single muon with p_T>14 GeV/c, di-muon with p_T>3 GeV/c
  - HLT: single muon with p_T>19 GeV/c, di-muon with p_T>7 GeV/c
- Expected limits for 30 fb^{-1}
  - in $W \to \tau\nu$: 3.8×10^{-8}
  - in $Z \to \tau\tau$: 3.4×10^{-7}
  - in $b \to \tau X$: 2.1×10^{-7}
- Above results from 2002
- Now the study under revision



Conclusions and Outlook

Conclusions

- While designed for high-$p_T$physics, CMS has broad heavy flavor program
- Main features allow this program:
  - high $b\bar{b}$ event rate even at low (10^{32}) initial luminosity
  - efficient low p_T di-muon trigger
  - excellent tracking: momentum, mass, vertex resolution

Outlook

- More heavy flavor topics may come soon
- First results are expected in 2010