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B physics prospects of CMS with the first LHC data

On behalf of the CMS Collaboration

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Outline



- The CMS Detector Layout
- B physics prospects with 1 10 50 pb⁻¹
- Summary





2





The CMS Detector Layout





Strengths for B physics

- Single Solenoidal Magnet @ 4T (3.8T), strong and homogeneous B field
- High-precision tracker already aligned with cosmics corresponding close to "100 pb⁻¹" scenario (*see A. Gritsan in this conference*)
- Hermetic coverage of muons up to $|\eta|$ <2.4 and down to low p_T
- Redundant muon trigger with dimuon trigger threshold at $p_T(\mu)>3$ GeV, complemented by single muon triggers at low luminosities start-up with mu_open







B Physics prospects with $\sim 1 - 10 - 50 \text{ pb}^{-1}$



Physics @ 10 TeV vs. integrated luminosity

-		~Few pb ⁻¹ physics					
Month	No. Bunches	Protons per bunch	β* [m]	% Nom	Peak luminosity cm-2s-1	Integrated luminosity	Rec. yield per pb ⁻¹ :
1				~ 25 000 J /ψ			
2	43	3 x 10 ¹⁰	4	0.4	1.2 x 10 ³⁰	100 – 200 nb ⁻¹	~6 000 b →J/ψX
3	43	5 x 10 ¹⁰	4	0.7	3.4 x 10 ³⁰	~2 pb ⁻¹	~ 10 000 Y
4	156	5 x 10 ¹⁰	2	2.5	2.5 x 10 ³¹	~13 pb ⁻¹	10 ph-1 physics
5	156	7 x 10 ¹⁰	2	3.3	4.9 x 10 ³¹	~25 pb ⁻¹	~ 10 pD · physics Dec. viold per 10 pb-1.
6	720	3 x 10 ¹⁰	2	6.7	4.0 x 10 ³¹	~21 pb ⁻¹	
7	720	5 x 10 ¹⁰	2	11.2	1.1 x 10 ³²	~60 pb⁻¹	
8	720	5 x 10 ¹⁰	2	11.2	1.1 x 10 ³²	~60 pb ⁻¹	~ 900 B° 7J/ψK °
9	720	5 x 10 ¹⁰	2	11.2	1.1 x 10 ³²	~60 pb ⁻¹	
10		·		\rightarrow ~50 pb ⁻¹ physics			
Total						200 – 300 pb ⁻¹	b(b) production,
From R.							

From R. Bailey, IOP Oxford April 2009

> CMS trigger 2 muons with $p_T>3$ GeV. Also single muon triggers possible.



PAS BPH-07-002



Few pb⁻¹ measurement example: J/ψ differential cross-section



- Already with a very small statistics, we can measure J/ψ production and separate prompt J/ψ 's from $B \rightarrow J/\psi X$
- Check tracker and muon system performance
- First measurement of J/ ψ production at LHC c.m.s. energy and at p_T(J/ ψ)>20 GeV
- Simulation study performed with sqrt(s)=14 TeV, integrated L=3 pb⁻¹ → reconstructed yield would correspond to ~75 000 events at sqrt(s)=10 TeV, L=3 pb⁻¹
- Trigger: dimuon trigger with p_T>3 GeV, |η|<2.4</p>



PAS BPH-07-002

- Inclusive differential cross-section measured from a fit to the mass distribution
- B- and prompt fractions measured from an unbinned maximum likelihood fit to the mass and the proper decay length



Proper decay length distribution

combined data

non-J/w background

total fit prompt J/ψ

b→J/ψ

E

Events/0.005

 10^{2}

10

PAS BPH-09-001



10 pb⁻¹ measurement example: exclusive B production

- Exclusive B decays $B \rightarrow J/\psi K^{(*)}$ can be used as one of several early checks on the CMS tracker alignment and overall performance
- Well-understood B⁺ and B⁰ decays will be used later on as control samples for new measurements (weak phases and CP violation, rare decays, B_c,...)
- Simulation study performed with sqrt(s)=10 TeV, integrated L=10 pb⁻¹
- Trigger: dimuon trigger with p_T>3 GeV
- About 1 750 triggered and fully reconstructed B⁺ \rightarrow J/ ψ K⁺ and 900 B⁰ \rightarrow J/ ψ K^{*0} (K^{*0} \rightarrow K⁺ π ⁻) events per 10 pb⁻¹
- Proper lifetimes are fitted from a simultaneous fit to the mass distributions and the proper decay lengths for the whole samples with p_T(B)>9 GeV
- Differential cross-sections are then measured by fixing the lifetime and fitting the yields in 7 p_T bins by using a simultaneous fit to the mass distribution and the proper decay length



Upper: $B^+ \rightarrow J/\psi K^+$ mass and proper decay length Lower: $B^0 \rightarrow J/\psi K^{*0}$ mass and proper decay length Both integrated over all p_T

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Upper: B⁺ \rightarrow J/ ψ K⁺ differential cross section Lower: B⁰ \rightarrow J/ ψ K^{*0} differential cross section

Cross section measurements dominated by syst. uncertainty from luminosity

Expect $\sigma(\tau_{+}/\tau_{0}) \sim 5\%$ (stat.) with 10 pb⁻¹ (PDG 1%) Systematic uncertainty ~1%



PAS BPH-08-004



50 pb⁻¹ measurement example: bbbar correlations from $J/\psi - \mu$ angular correlation

- Angular correlations between the 2 b's probe the bbbar production mechanisms and in particular higher order contributions to bbbar production
- QCD test, tuning of Monte Carlo models
- Simulation study performed with sqrt(s)=10 TeV, integrated L=50 pb⁻¹
- Look at the opening angle $\Delta\Phi$ between the J/ ψ and the μ
- Trigger: dimuon trigger with p_T>3 GeV







Fractions of flavour creation, gluon splitting and flavour excitation measured from a simultaneous fit to the J/ ψ mass distribution, transverse flight length of the J/ ψ and the impact parameter of the (third) μ

PAS BPH-08-004







J/ ψ mass, J/ ψ flight length and μ impact parameter distributions





Differential cross section measurement $d\sigma/d\Delta\Phi$ Experimental $\Delta\Phi$ distribution unfolded (singular value decomposition)

PAS BPH-08-004





Error dominated by systematics. Total systematic uncertainty 13-17% per bin. Dominant systematic error from luminosity (10%).





Other measurements with early data



At least:

- Upsilon production
- J/ψ and Upsilon polarization
- Other exclusive decays
- b production cross-section (several methods) (see talk by A. Grelli in this conference)
- bbbar correlations (several methods)





Summary



- CMS is an outstanding detector for low-p_T physics: strong and homogeneous B-field, efficient set of triggers, precise muon and tracking detectors
- B physics results will be among the first ones CMS will publish
- Already with a very small integrated luminosity
 - $(1 10 50 \text{ pb}^{-1})$ large reconstructed samples of quarkonia, inclusive and exclusive b's
- Measurements are important tests and cross-checks for the detector performance and for Monte Carlo's
 - First glimpses to properties of B hadrons at LHC energies



#Run 66714 #Event 3860732 (176/249) Sat Oct 18 10:13:39 2008





References

- Physics results after TDR: <u>https://twiki.cern.ch/twiki/bin/view/CMS/PhysicsResults</u>
- PAS BPH-07-002: <u>Charmonium production cross section</u> (July 2008)
- PAS BPH-09-001: Measurement of Differential Production Cross Sections and Lifetime Ratio for Exclusive Decays of B+ and B0 Mesons in pp Collisions at 10 TeV (Jun 2009)
- PAS BPH-08-004: <u>Study of b-bbar correlations using J/psi + muon events</u> (Mar 2009)
- Physics TDR: <u>http://cmsdoc.cern.ch/cms/cpt/tdr/</u>
- B production: Vol II pages 189-190, measurement of inclusive b production cross section
- PAS BTV-07-003: Effect of misalignment on b-tagging







Backup slides





LHC planning

Month	Comment	Turn around time	Availability	Max num ber bunches	Protons/Bunch	Min beta*	Peak Luminosity cm ⁻² s ⁻¹	Integrated Luminosity
1	Beam commissioning							First collisions
2	<u>Pilot physics</u> , partial squeeze, gentle increase in bunch intensity, 40%	Long	Low	43	3 x 10 ¹⁰	4 m	1.2 x 10 ³⁰	100 - 200 nb ⁻¹
3		5	40%	43	5 x 10 ¹⁰	4 m	3.4 x 10 ³⁰	~ 2 pb ⁻¹
4	2.5% nominal beam intensity	5	40%	156	5 x 10 ¹⁰	2 m	2.5×10^{31}	~13 pb ⁻¹
5		5	40%	156	7 x 10 ¹⁰	2 m	4.9 x 10 ³¹	~25 pb ⁻¹
6	9% nominal beam intensity, 75 ns	5	40%	936	3 x 10 ¹⁰	2 m	5.1 x 10 ³¹	~30 pb ⁻¹
7	15% nominal beam intensity, 75 ns	5	40%	936	5 x 10 ¹⁰	2 m	1.4 x 10 ³²	~75 pb ⁻¹
8	15% nominal beam intensity, 75 ns*	5	40%	936	5 x 10 ¹⁰	2 m	1.4×10^{32}	~75 pb ⁻¹
9	15% nominal beam intensity, 75 ns*	5	40%	936	5 x 10 ¹⁰	2 m	1.4 x 10 ³²	~75 pb ⁻¹
10	lons							
							TOTAL	~300 pb ⁻¹





CMS Trigger

- Level-1 (L1): custom boards $-40 \text{ MHz} \rightarrow (50-100) \text{ kHz}$
 - L1 primitives: muons, electrons, calorimeter energies
- High Level Trigger (HLT): software based (50-100) kHz \rightarrow 150 Hz
 - HLT confirms/combines/refines L1 triggers, full reconstruction tracking
- Trigger menus selected according to the instantaneous luminosity
- B physics relies on muon triggers. Depending on the luminosity, require:
 - Dimuon: 2 muons with p_T>3 GeV
 - Single muons: 1 muon with p_T>3, 5, 7, 10 GeV (possibly pre-scale low-p_T)
 - In the very beginning, muon_open (basically no threshold)
 - HLT muon objects confirm L1 muons and add Silicon Tracker information to improve p_T resolution
 - Other HLT variables: Displaced dimuon vertex, dimuon mass, opposite charge, ...









PAS BPH-09-001



Upper: invariant mass of main backgrounds for B⁺ (left) and B⁰ (right) Lower: proper decay length of main backgrounds for B⁺ (left) and B⁰ (right)





B-tagging efficiencies with different alignment scenarios. CMS has already been aligned with cosmic data with a precision corresponding to close to the100 pb⁻¹ scenario



Figure 9: b-jet efficiency versus non b-jet efficiency for the various misalignment scenarios for the Combined Secondary Vertex algorithm, presented for light flavor (left) and charm (right) jets.



CMS Physics TDR Vol I (2006)

















Right: transverse impact parameter resolution $\sigma(\delta d_0)$ Left: longitudinal impact parameter resolution $\sigma(\delta z_0)$









From A. Grelli in this conference

