THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Heavy Flavour Measurements with CMS

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Hot Quarks 2008

Outline

CMS Heavy Ions Programme

Quarkonia – motivation and results

b and c quarks – motivation and results

Heavy quark R_{AA} and v_2 - motivation

Summary

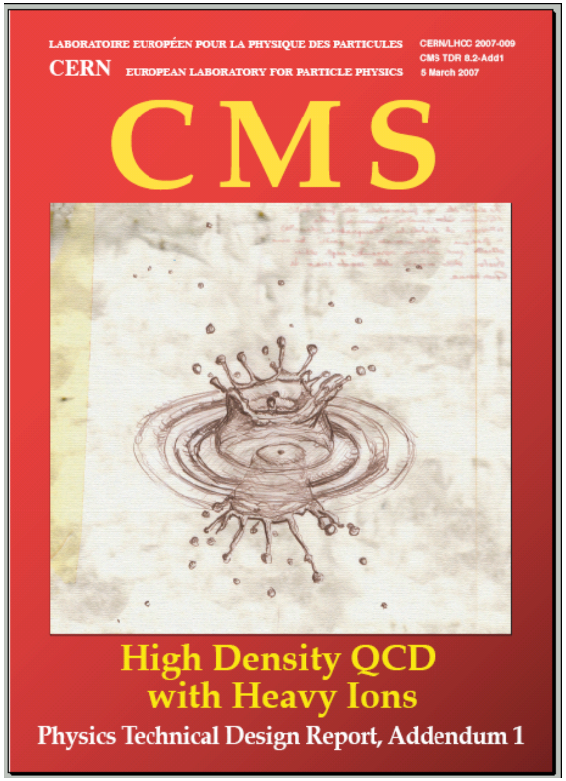
CMS Heavy Ions Programme

WHO?

Athens, Auckland, Budapest, CERN, Chongbuk, Colorado, Cukurova, Ioannina, Iowa, Kansas, Korea, Lisbon, Los Alamos, Lyon, Maryland, Minnesota, MIT, Moscow, Mumbai, Seoul, Vanderbilt, UC Davis, UI Chicago, Vilnius, Zagreb

WHAT?

- Multiplicity
- Low p_T spectra
- Elliptic flow
- Quarkonia
- Heavy Flavours
- Jets
- High p_T hadrons
- Ultraperipheral collisions
- ...



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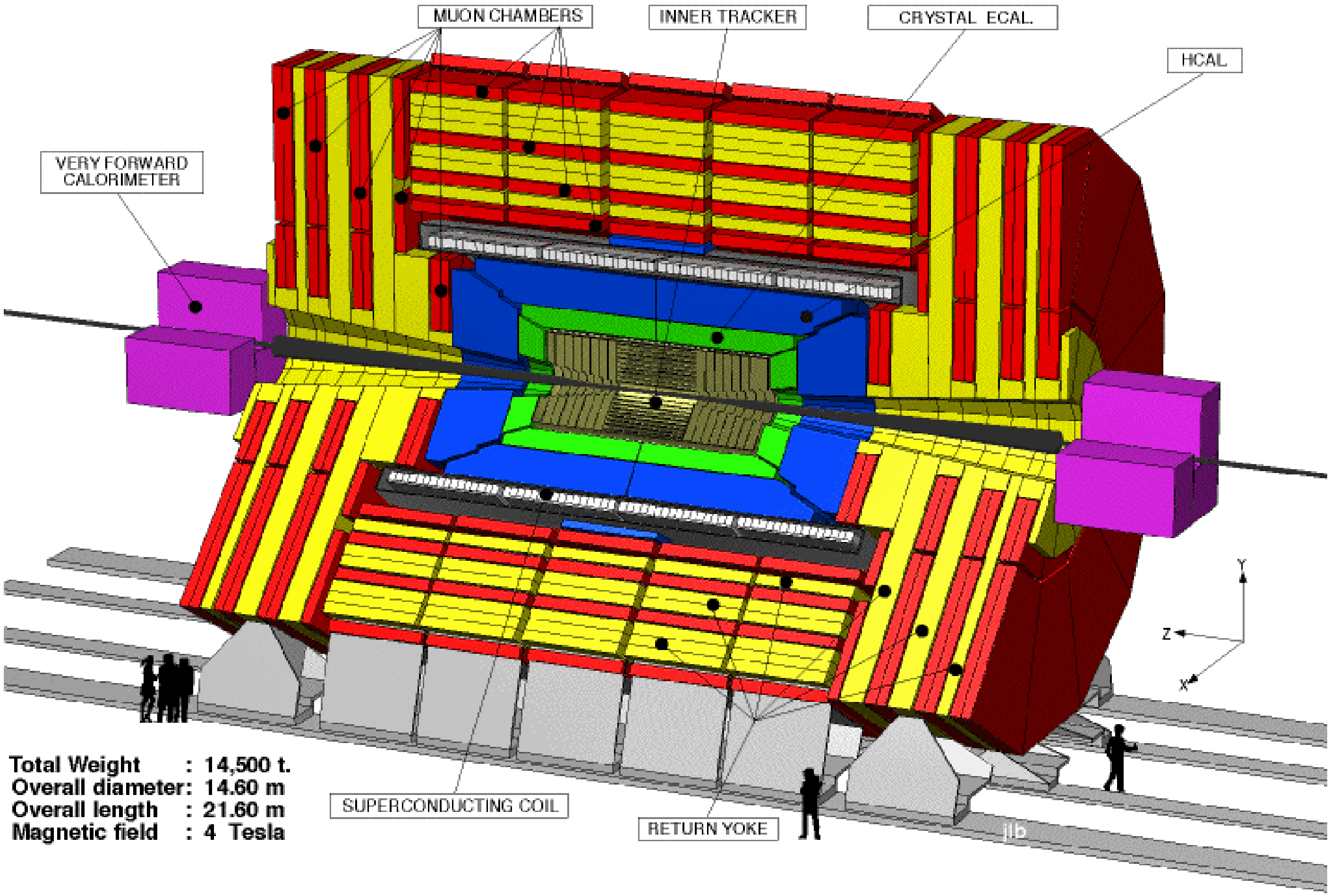
HOW?

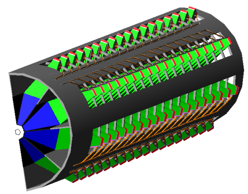
- High precision tracking over $|\eta|<2.5$
- Muon identification over $|\eta|<2.5$
- High resolution calorimetry over $|\eta|<5$
- Forward coverage
- Large trigger bandwidth

CMS Detector



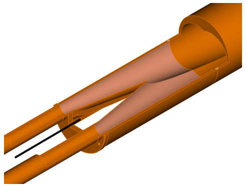
CASTOR

$5.32 < \eta < 6.86$

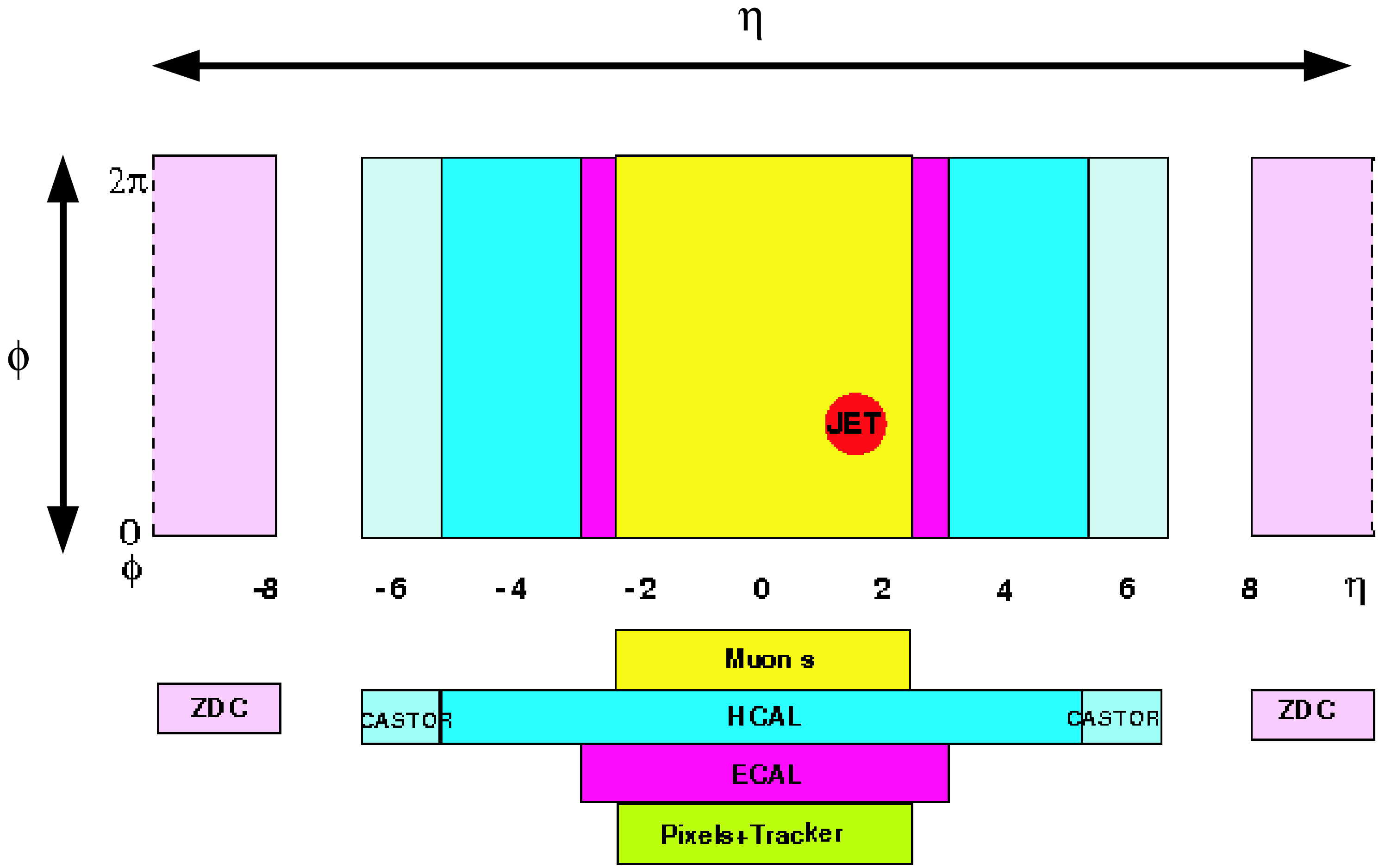


ZDC

$z = \pm 140\text{m}$



CMS Detector η-ϕ coverage



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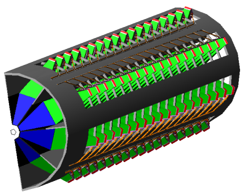

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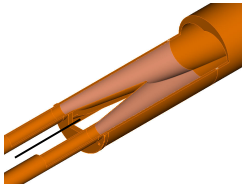
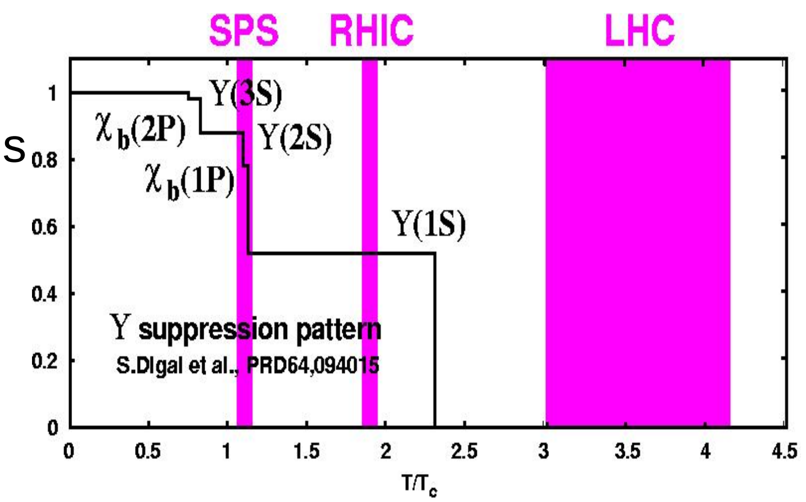


J/ψ and Υ: Motivation

Colour charge screening in QGP depends on temperature

Quarkonia dissociate when screening length < binding radius

Excited states larger radius, dissociate first
+ feed down
= stepwise suppression of J/ψ and Υ

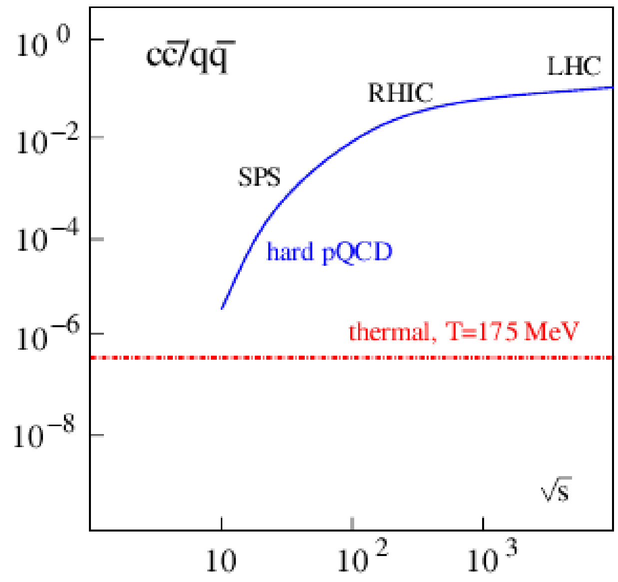


Quarkonia suppression acts as thermometer for QGP

This assumes Q and Qbar don't recombine due to low concentration

QQbar cross-section increases faster than qqbar, so assumption not necessarily valid

Get regeneration of quarkonia with Q and Qbar from different parents



Regeneration can enhance quarkonia production rate

J/ψ and Υ: Motivation (II)

Need to separate contributions from suppression and regeneration

LHC allows studies of Υ family for first time

Υ' dissociates at ~1.2Tc, comparable to J/ψ but little regeneration expected

Υ' should help disentangle suppression and regeneration

J/ψ and Υ: At CMS

1 month (10^6 s) LHC PbPb running: L_{int}~0.5 nb^{-1}

Production cross-sections PbPb, 5.5 TeV (μb)

	J/ψ	ψ'	Υ	Υ'	Υ''
σ_{prod} * Br(μ μ)	48900	880	304	80	44

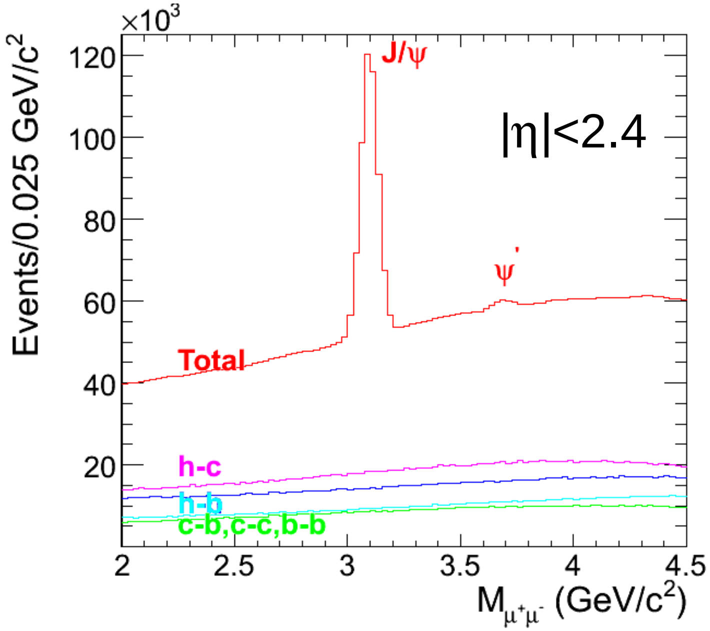
$dN_{ch}/d\eta|_{\eta=0}$: 2500 (assumed)

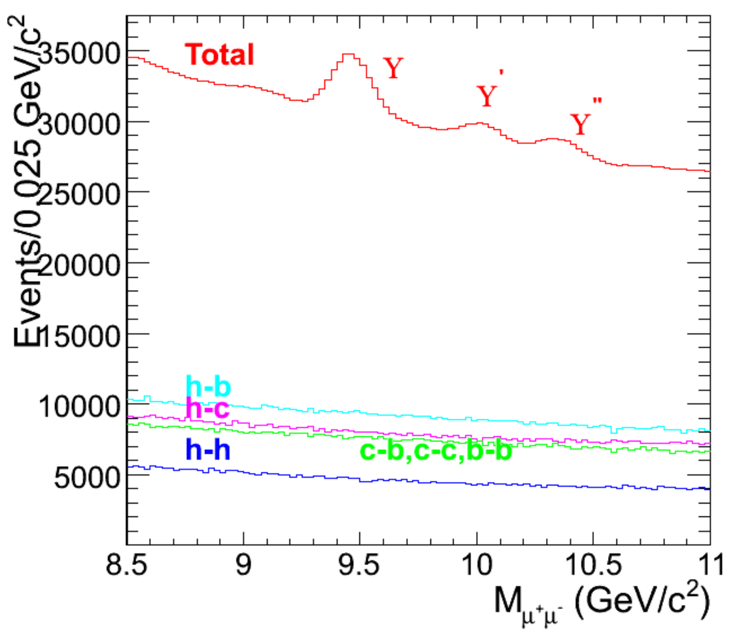
Trigger efficiency: 1% J/ψ
21% Υ

Tracking efficiency: >80% (|η|<1.5),
>65% (|η|<2.4)

Expected yields:

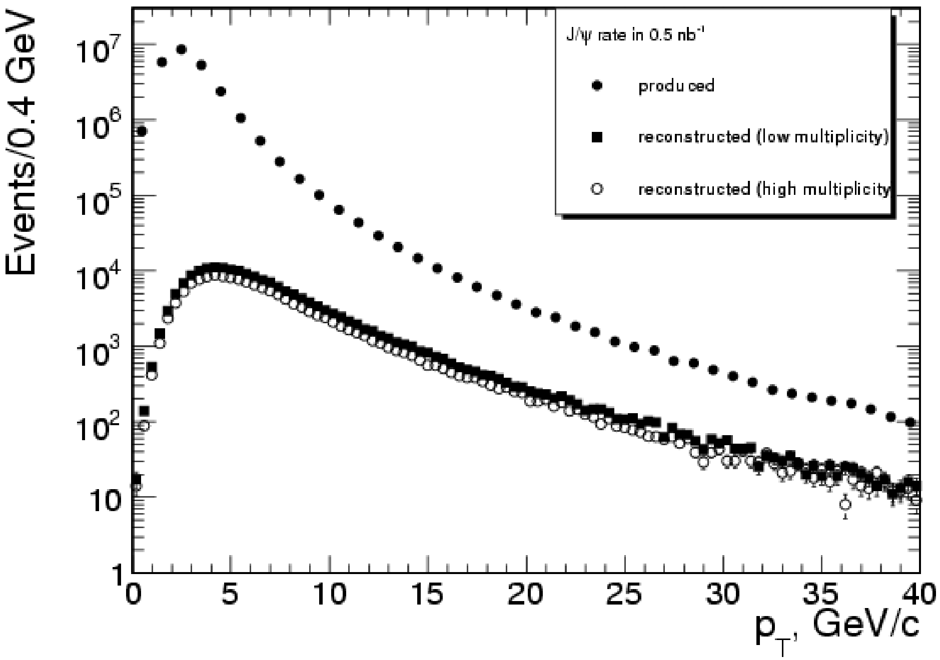
	|η|<0.8	|η|<2.4
J/ψ	11600	184000
Υ	6400	26000
Υ'	2000	7300
Υ''	1200	4400



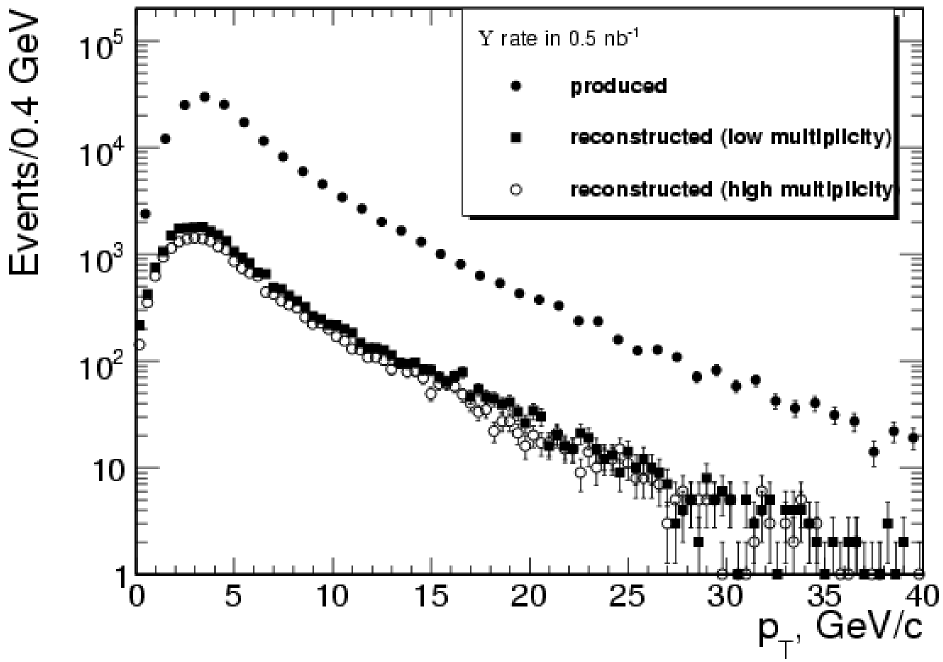


J/ψ and Υ: p_T distribution

J/ψ



Υ



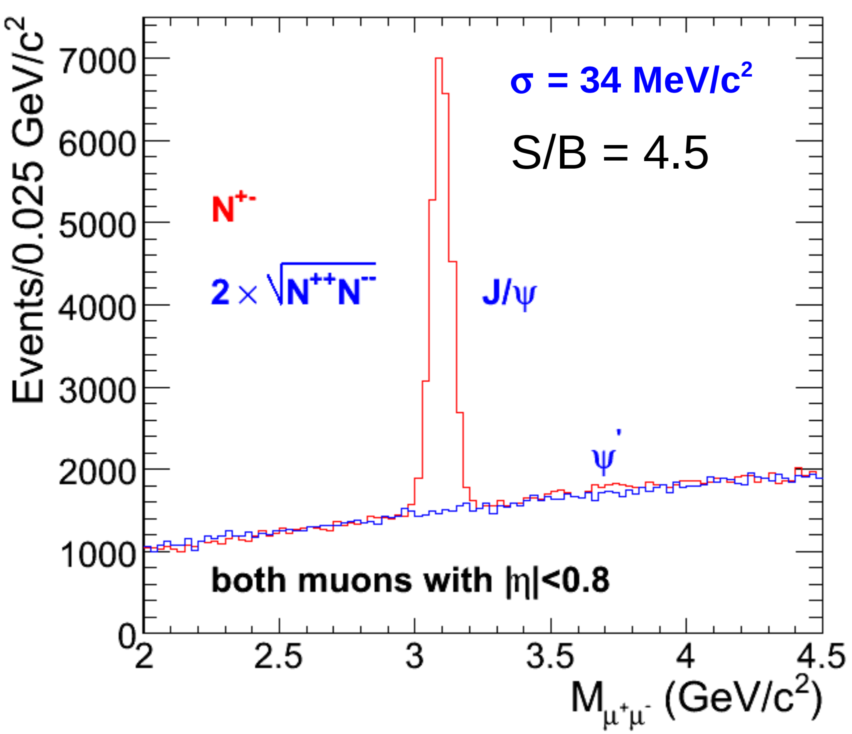
Acceptance goes up to ~40 GeV

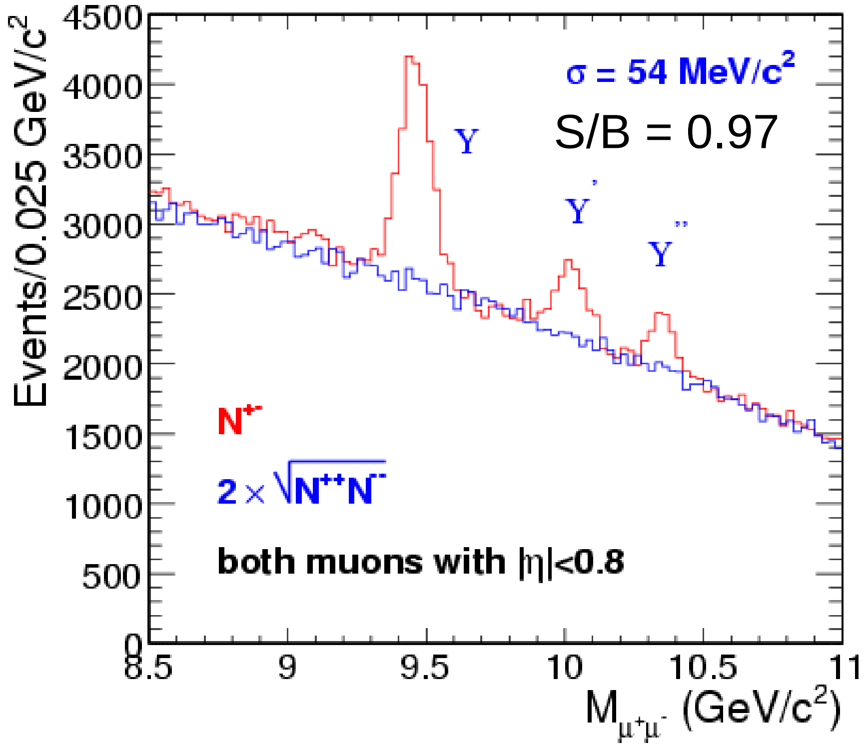
For J/ψ , drop at low pT because muons don't have enough energy to penetrate calorimeter

For Υ acceptance goes down to 0 GeV

J/ψ and Υ: Resolution

For |η|<0.8





For |η|<2.4

σ = 34 MeV/c^2 | σ = 90 MeV/c^2

S/B = 1.2 | S/B = 0.12

b and c Hadrons: Motivation

Open heavy flavour measurements provide information on dynamical response of dense QCD medium to massive colour charges

Equivalent to info from high pT jets, for light quarks/gluons

Puzzle from RHIC: e± from semileptonic b,c decays suppressed at ~same level as light quarks

Either charm electrons dominate, or b quarks lose lots of energy

b (c) quark cross section at LHC is 100 (10) x RHIC, so can investigate in more detail

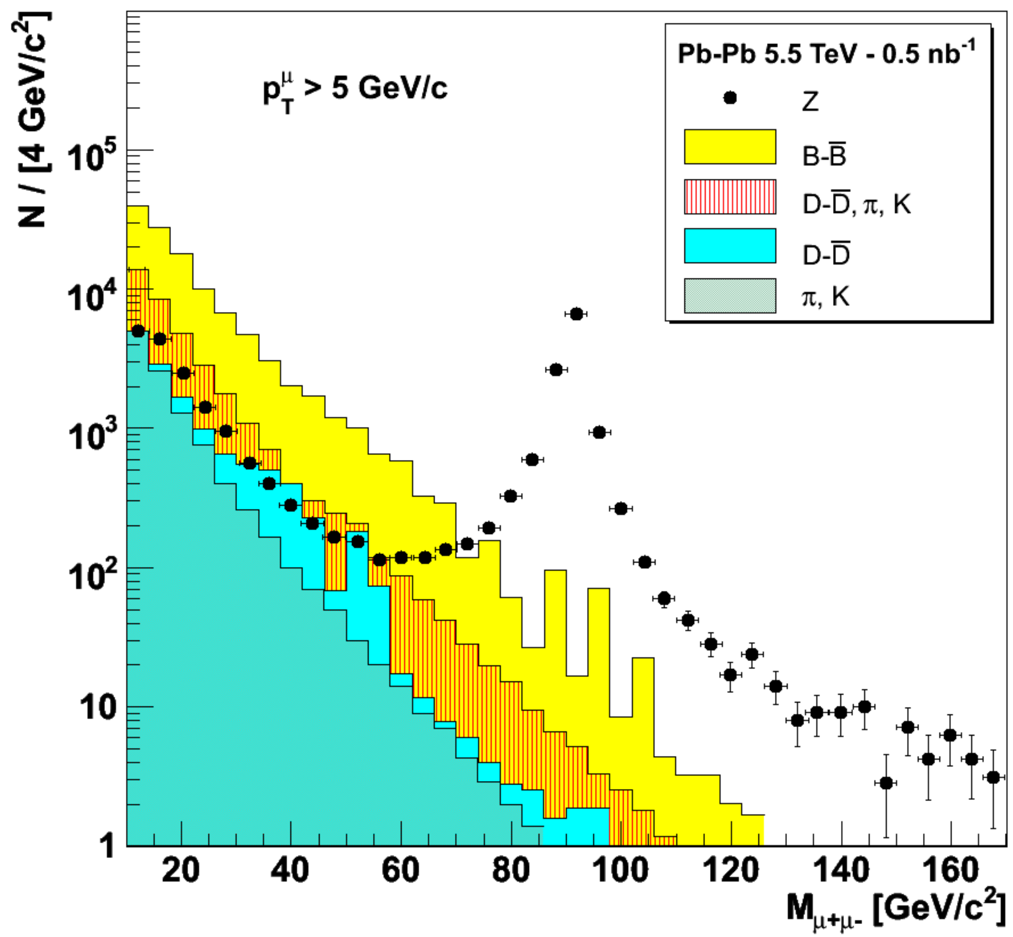
Can provide benchmark for quarkonia suppression (no dissociation/regeneration)

Also need to separate e.g. J/ψ from B decay from primary J/ψ

b and c Hadrons: Dimuons

Dimuon spectrum between 10 and 70 GeV dominated by bbar decays

Yield sensitive to b quark in-medium energy loss



Clear Z^0 peak, not affected by in-medium interactions

Could be used to normalise yield relative to pp collisions
(e.g. to check quarkonia, b suppression...)

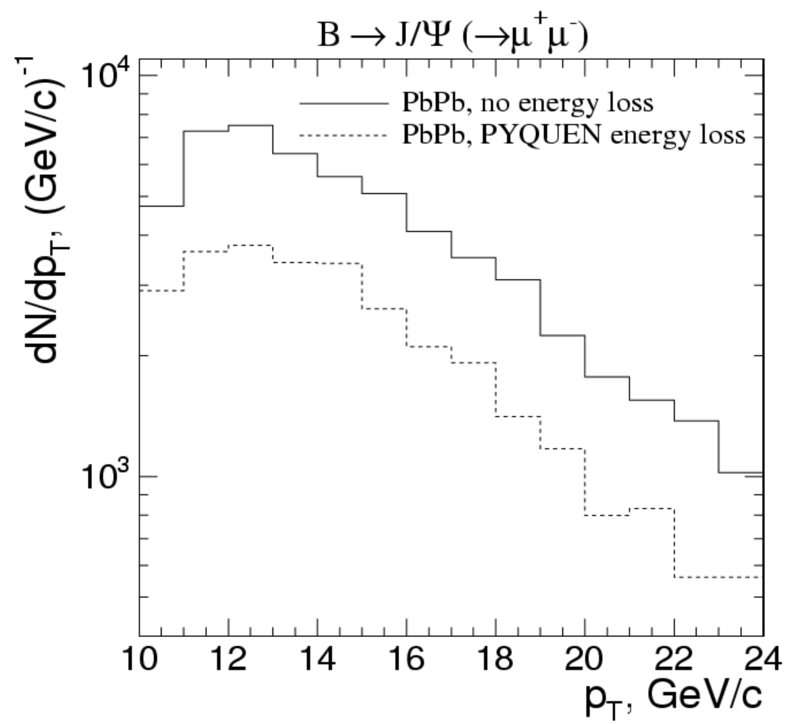
b and c Hadrons: B→ J/ψ X

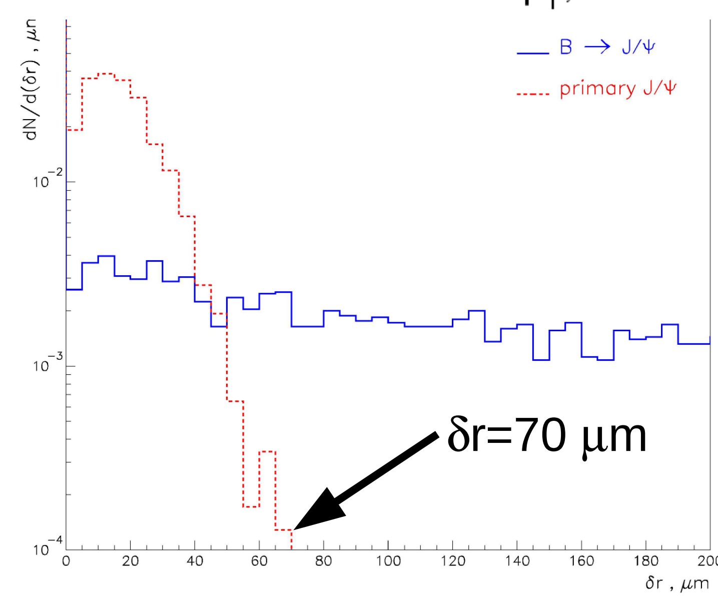
B → J/ψ X → μμ X provides a clean tag for B hadrons

Provides information on b-quark energy loss

Generator level study: PbPb, 5.5 TeV, 0.5nb^{-1}

	B → J/ψ	Primary J/ψ
Cross section	7355 mb	506 mb
# J/ψ	8.6 x 10^7	2.5×10^8
# μμ	5.15×10^6	1.5×10^7
# μμ |η|< 2.4, p_T>5.0 GeV	57000	4.4×10^5
# μμ |η|< 2.4, p_T>3.5 GeV	11300	2.3×10^5





Secondary J/ψ separated from directly produced J/ψ by cut on δr – transverse distance between two muon tracks at closest approach to beamline

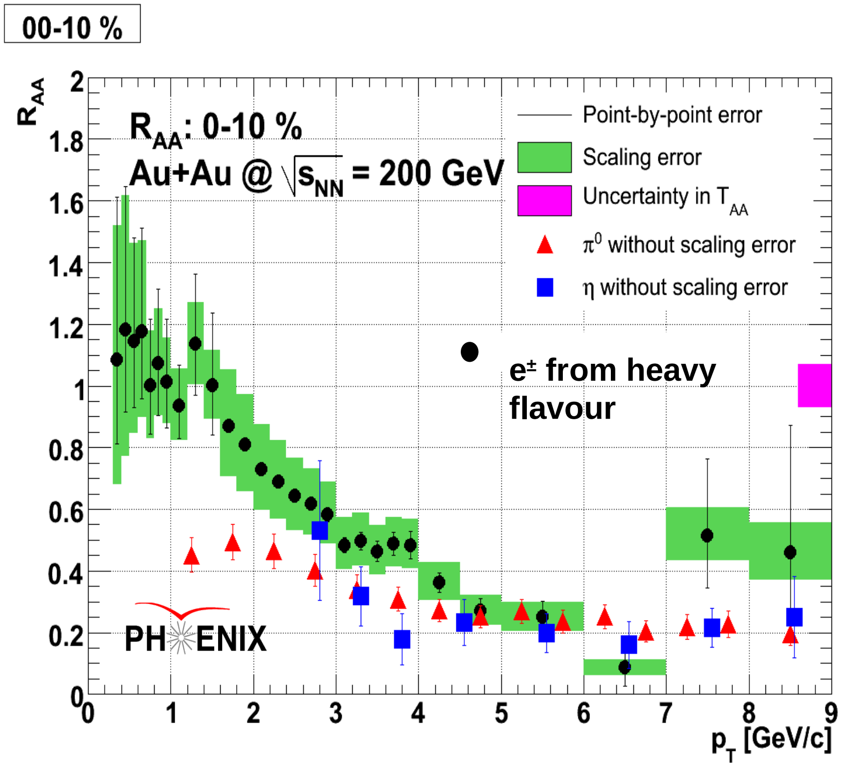
R_{AA}: Motivation

From "dead-cone effect" expect $R_{AA}^{\pi} < R_{AA}^{D} < R_{AA}^{B}$

Not observed at RHIC, e.g. in semileptonic decays

Possible explanations:
- charm dominates measured spectrum,
- bottom quarks lose as much energy as charm
- ...

Need to explicitly reconstruct open heavy-flavour mesons



CMS studies in progress, looking at $D^0 \rightarrow K\pi$, $B \rightarrow J/\psi\ K \rightarrow \mu^+\mu^- K$

Heavy quark v_2: Motivation

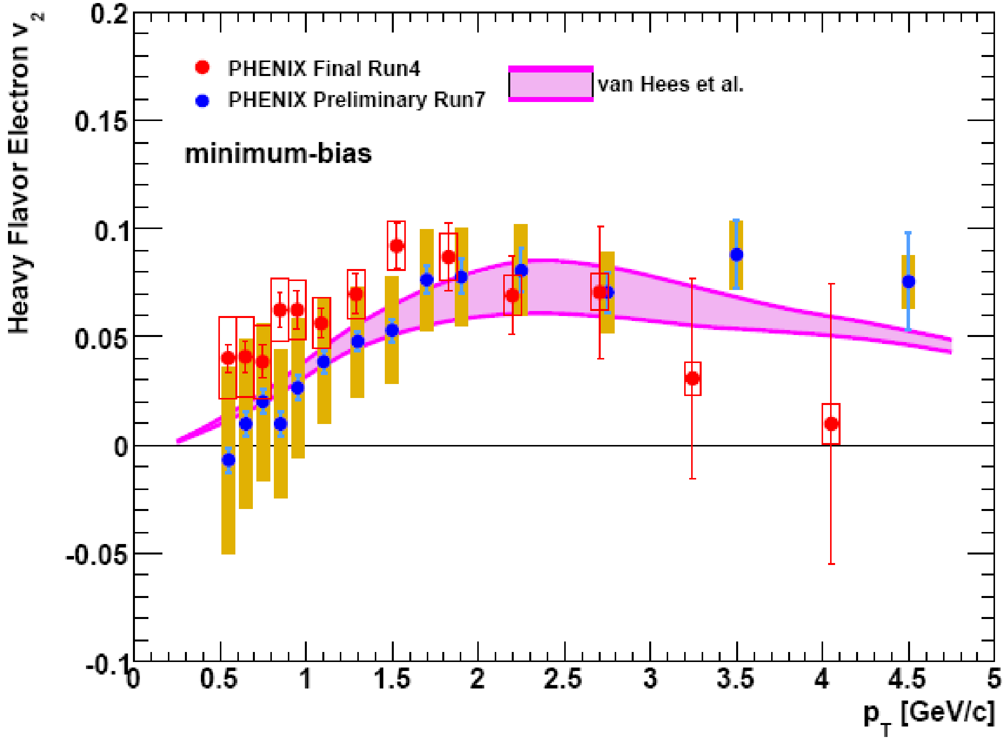
Elliptic flow (v2) gives measure of thermalisation of system

Heavy quarks produced early in collision, traverse partonic medium

Heavy-flavour hadrons sensitive to properties of medium such as viscosity, density

Because of greater mass c and b quarks expected to have less suppression and smaller elliptic flow than light quarks

At RHIC heavy flavours showed non-zero v2, and similar energy loss to light quarks →



At CMS B and D mesons from R_{AA} studies will also be used to determine v_2

Summary

Strong heavy-ions programme within CMS

Excellent muon capabilities for reconstructing quarkonia

Best mass resolution at LHC allows separation of Υ', important in disentangling suppression/regeneration

High-mass dimuons and J/ψ from B decays will provide information about b quark energy loss in partonic medium

Studies ongoing into reconstruction of D and B hadrons to measure R_{AA} and v_2

Looking forward to the world beyond LHC start-up!