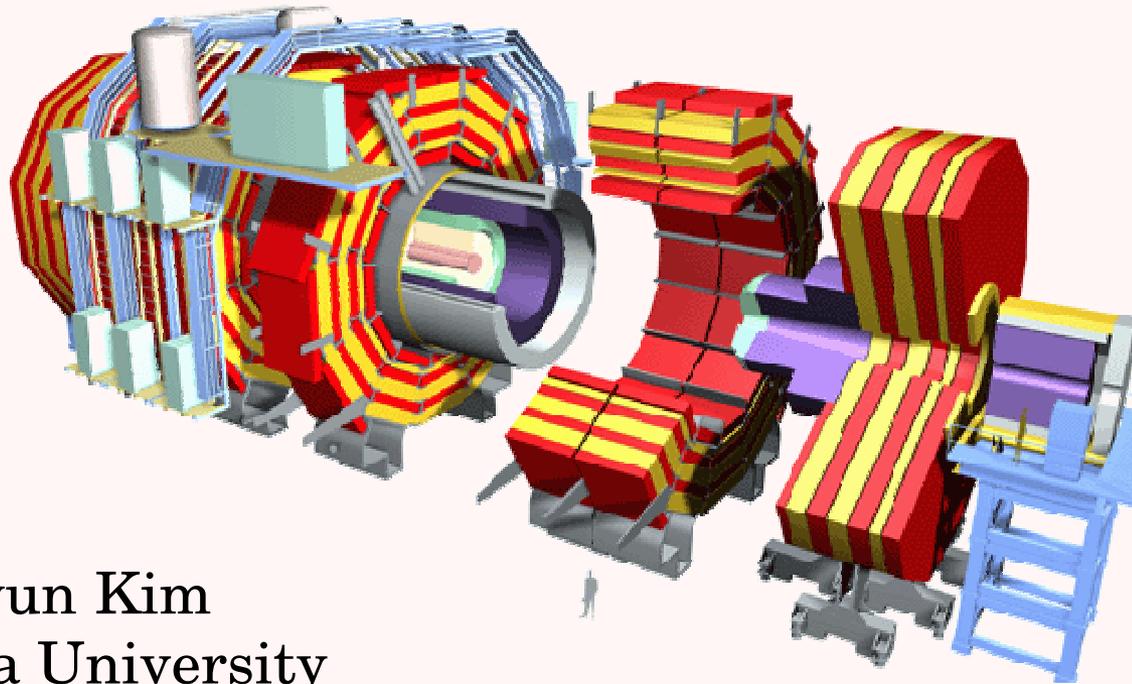# J/ψ production cross section measurement with early p+p data in CMS
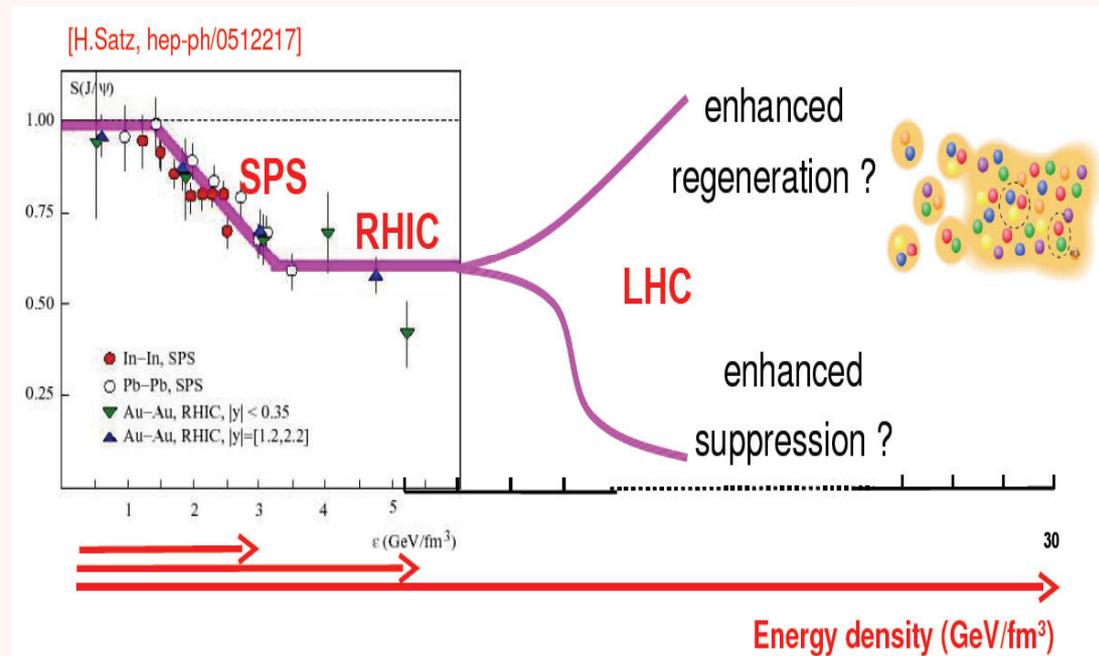
Ji Hyun Kim
Korea University

Introduction

- **Quarkonia physics in CMS at LHC**

  - Pb+Pb collisions will create high-density partonic matter at very high temperature where the phase transition to the QGP is expected.

  - Heavy quarkonia (J/ψ, Y) suppression is an ideal signature of the QGP.

  - We need p+p data as a reference.

$$R_{AA} = \frac{N_{AA}}{N_{coll} \, N_{pp}}$$

[H.Satz, hep-ph/0512217]

- In–In, SPS
- Pb–Pb, SPS
- Au–Au, RHIC, |y| < 0.35
- Au–Au, RHIC, |y|=[1.2,2.2]

enhanced regeneration ?

enhanced suppression ?

SPS   RHIC   LHC

Energy density (GeV/fm³)

Expected Statistics in p+p

Month	Comment	Turn around time	Energy [TeV]	Max number bunches	Protons/Bunch	% nom. intensity	Min beta*	Peak Luminosity cm⁻²s⁻¹	Integrated Luminosity
1	Beam commissioning								First collisions
2	Pilot physics, partial squeeze, gentle increase in bunch intensity, availability low	Long	35	43	3×10^{10}		4 m	8.6×10^{29}	100 - 200 nb⁻¹
3		5	35	43	5×10^{10}		4 m	2.4×10^{30}	~1 pb⁻¹
4		5	35	156	5×10^{10}	2.3	2 m	1.7×10^{31}	~9 pb⁻¹
5a	No crossing angle - could at this stage push intensity see 5b	5	35	156	7×10^{10}	3.4	2 m	3.4×10^{31}	~18 pb⁻¹
5b	No crossing angle - squeezing to beta* = 1m at this stage would double these lumi numbers (and the pile-up)	5	35	156	10×10^{10}	4.8	2 m	6.9×10^{31}	~36 pb⁻¹

Expected yields per pb⁻¹ with DoubleMu3 at 10 TeV:

~25000 J/ψ

~6000 b → J/ψ

~10000 Upsilon

~175 B → J/ψK

~100 B → J/ψK*

"With an instantaneous luminosity of just ~1e30, in one month CMS will trigger and reconstruct tens of thousands of quarkonia events and hundreds of exclusive B decays."
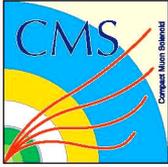
Quarkonia Task Force(QTF)

- Created for first quakonia paper ASAP within B-physics PAG.

- Kick-off meeting was on 8th May.

- Tasks

  - (ideal) MC analyses efforts to a position much closer to the data, keeping track of all the factors needed to extract cross sections.

  - Being aware of any real stuffs : luminosity, HLT bits, data formats, selective readout, zero suppression, DQM efficiency, etc.

- Requiring a good understanding of the **"detector performance and good quality data"**.
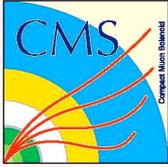
First Papers in QTF

1. "Dimuon production in the J/ψ and Υ mass regions in p+p collisions at 7 TeV with the CMS detector" (~1 pb^{-1})

2. "Measurement of the J/ψ and b-hadron production cross sections in p+p collisions at 7 TeV with the CMS detector" (1~10 pb^{-1})

3. "Measurement of the Upsilon production in p+p collisions at 7 TeV" (~10 pb^{-1})

4. "Upsilon polarization in p+p collisions at 7 TeV" (10~50 pb^{-1})

"Most measurements will be systematics limited with 10pb^{-1}!"
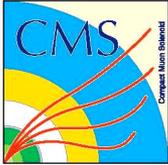
Interest 1

- Physics goals

  – Demonstrate CMS performance in triggering and reconstructing muons at low p_T using dimuons from J/ψ and Υ(nS)

  – Momentum/mass scale and resolution; muon reconstruction, trigger, and tracking efficiencies; dimuon vertex resolution

- Status

  – Steady progress on tools for measuring momentum/mass scale, T&P for efficiencies, vertex resolution

CMS PAPER BPH-09-002

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CMS Paper

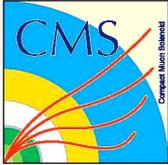*The content of this note is intended for CMS internal use and distribution only*

2009/08/31
Archive Id: 1.9
Archive Date: 2009/08/31 16:29:59

Dimuon production in the J/ψ and Υ mass regions in pp collisions at 7 TeV

The CMS Collaboration

Abstract

The performance of the CMS detector for studies of dimuon production in the invariant mass regions of the J/ψ and Υ resonances has been evaluated from data collected in the first few days of LHC operation, from proton-proton collisions at $\sqrt{s} = 7$ TeV and compared with Monte Carlo simulations. The average J/ψ and Υ masses, obtained from the peaks in the dimuon mass distribution, are in very good agreement with the well-known reference mass values, irrespectively of the muon rapidity and momentum. The good dimuon mass resolution allowed us to use these quarkonium resonances to determine the efficiencies of the muon trigger, of the tracking, and of the muon identification. Finally, by requiring the two muons to have a common production point, the vertex resolution function could also be determined.

Interest 2

- Physics goals
    - Measurement of production cross sections for prompt and non-prompt J/ψ

- Status
    - Approved public result last year, updating to 3.1.x and working on low level tools (ct resolution, fitting, etc)

CMS PAPER BPH-07-002

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CMS Paper

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2009/09/01
Archive Id: 1.7
Archive Date: 2009/08/31 16:09:34

Measurement of the J/ψ and b-hadron production cross sections in pp collisions at 7 TeV with the CMS detector

The CMS Collaboration

Abstract

We present the first CMS measurement of the inclusive total and differential production cross sections of J/ψ mesons and b-hadrons in proton-proton collisions at $\sqrt{s} = 7$ TeV. The data correspond to an integrated luminosity of 4 pb^{-1} and were collected during the first month of LHC operation. The fraction of J/ψ events from decays of long-lived b-hadrons has been determined exploiting their typical decay length distributions. For events with the J/ψ in the p_T range from 5 to 25 GeV/c and in the rapidity range $|y| <2.4$, the total cross sections for inclusive and prompt J/ψ production have been determined to be, respectively, xx± xx(stat)± xx(syst) μb and xx± xx(stat)± xx(syst) μb. The total cross section for the production of B-hadrons, including antihadrons, decaying to J/ψ mesons with transverse momenta greater than 5 GeV/c and in the rapidity range $|y| <2.4$, is measured to be xx± xx(stat)± xx(syst) μb.

Inclusive J/ψ Cross Section
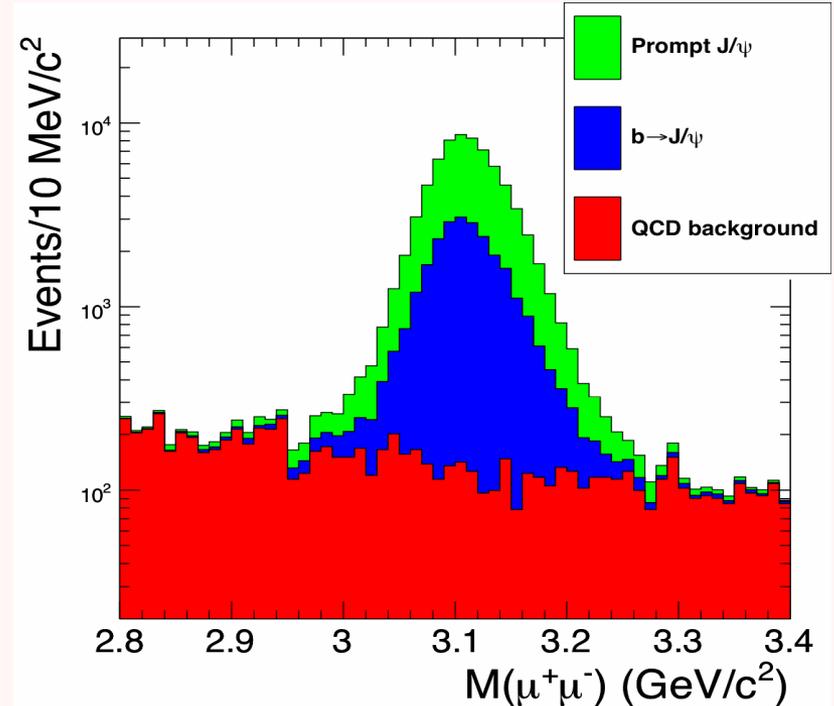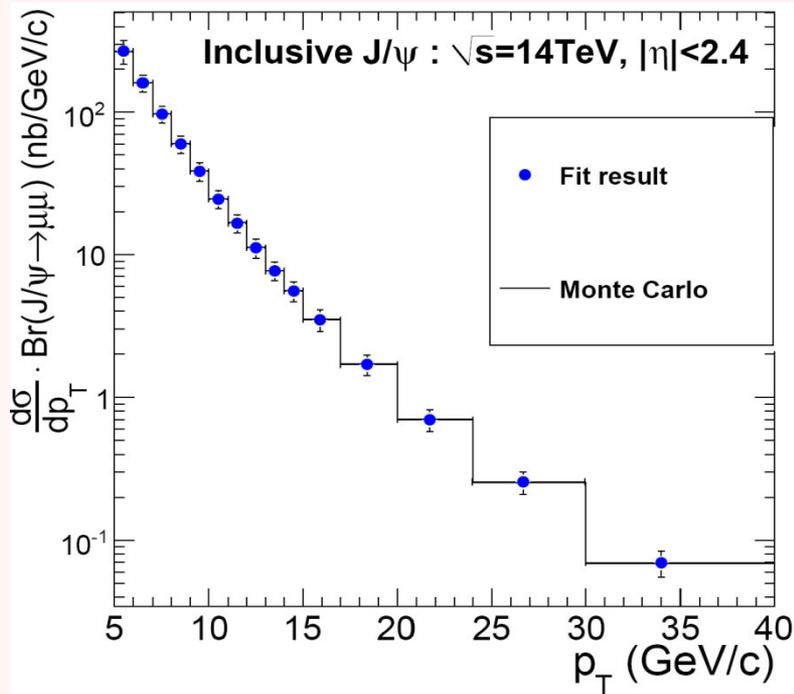
$$\frac{d\sigma}{dp_T^{J/\psi}} \cdot Br(J/\psi \rightarrow \mu^+\mu^-) = \frac{N_{J/\psi}^{fit}}{\int L dt \cdot \Delta p_T^{J/\psi} \cdot A \cdot \lambda^{corr}}$$

Muon Efficiency correction by T&P
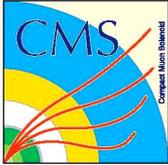
Tag & Probe in General

- Well established data-driven approach to measure particle efficiencies.

- Assuming no efficiency correlation between the two decay products of the resonance(e.g. J/ψ, Y, Z).

  – Tag : Object that passed a set of very tight selection criteria

  – Probe : Selected by pairing with tags such that invariant mass of the combination is consistent with that of resonance

- Backgrounds are eliminated by fitting or sideband subtraction.
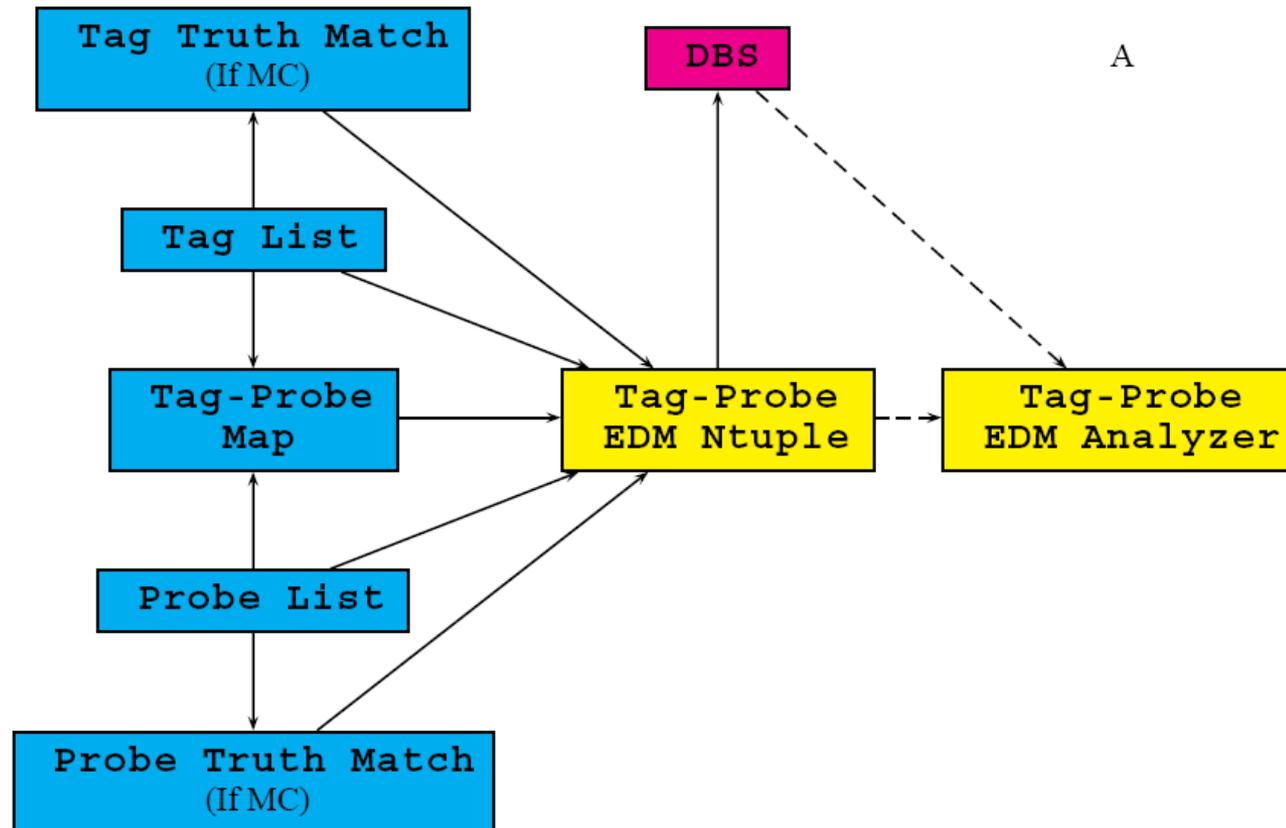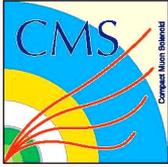
Flow chart of T&P Tool

Figure 1: Flow chart describing the Tag & Probe software at CMS.

Muon Efficiency by T&P

- Efficiency:

$$\varepsilon = \frac{p_{pass}}{p_{all}}$$

P_{pass} : No. of probes passing the selection criteria

P_{all} : Total no. of probes

- Factorization of the Efficiency

$$\varepsilon_{total} = \varepsilon_{trk} \times \varepsilon_{rec} \times \varepsilon_{trig}$$

ε_{trk} : Efficiency that given a generated muon was found as a muon silicon tracker track.

ε_{rec} : Efficiency that given a muon object track was found in the silicon trackers, a global muon track was also found.

ε_{trig} : Total trigger efficiency, muon tracker track matched to HLT_Mu3 trigger object.

Condition of the Trigger

- Descriptions of HLT_DoubleMu0

  – A double muon trigger, based on the Level 3 (combined muon system and tracker) HLT muon reconstruction.

  – At least two L1(L2/L3) muons with $p_T > 0$ GeV/c are required at corresponding higher trigger level.
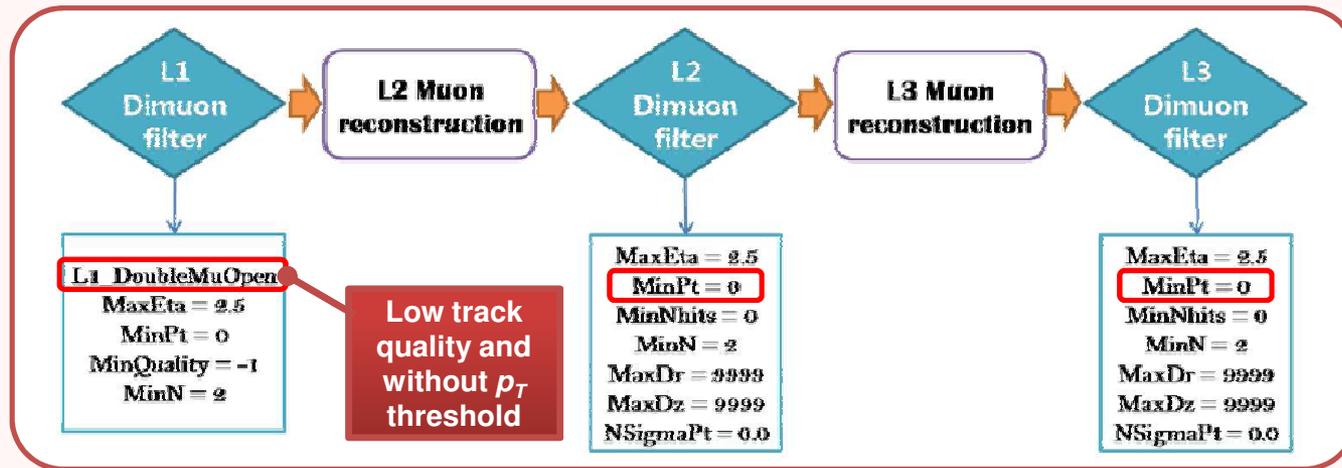
J/ψ Triggger Efficiency

- HLT_DoubleMu0 is available since CMSSW_3_X_X:
  - Without p_T requirement on L3 muons.
  - The trigger efficiency is increased by 10%.

- Comparing to DoubleMu3, DoubleMu0 could highly enlarge the statistics at low-p_T.

- No prescale for 8E29 and 1E31.

J/ψ Trigger efficiencies vs. p_T
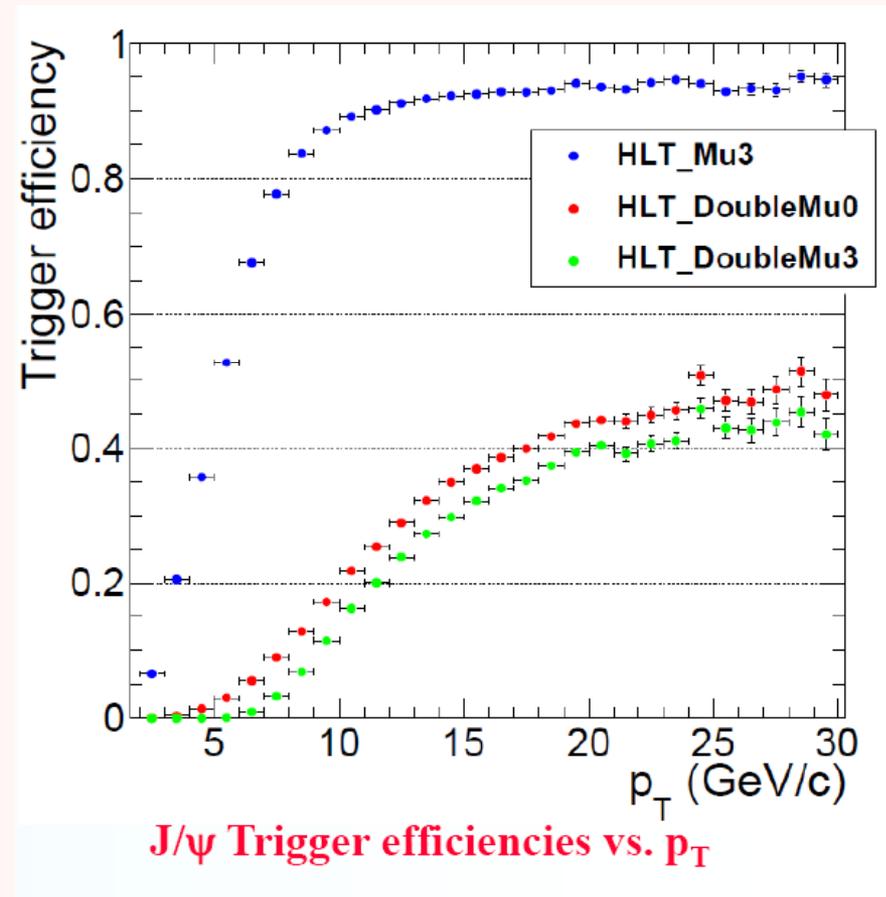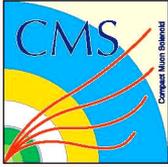
<u>Conclusion</u>

- QTF will serve publishing first CMS quarkonia papers, so, try to find out any necessary works for preparation of the first papers now.

- I am trying to get muon efficiency by using tag and probe tool for J/ψ→$\mu\mu$ sample.

- After obtaining muon efficiency, next step is to get J/ψ production cross section.