$\Psi(2S)$ Production Cross Section at CMS

Muhammad Ahmad
National Center for Physics
Pakistan

Motivation

From Detector point of View

- This channel is important to study due to its large production cross section at LHC energy. So we can analyze this channel on initial data of CMS.
- This channel is important for the calibration of the detector, because it has also studied at CDF detector.
- This channel is also important for the study of detector efficiency for muons. So it is good for us because we can study the efficiency of RPC during this study.

From Physics point of View

- Charmonium production provides a unique laboratory for testing our understanding of quantum chromodynamics (QCD) at the interface of the perturbative and non-pertubative regimes which describe the physics of heavy-quark creation and bound state formation respectivel.
- It will improve the previous measurement at CDF.
- It is also important for the study of transverse polarization.

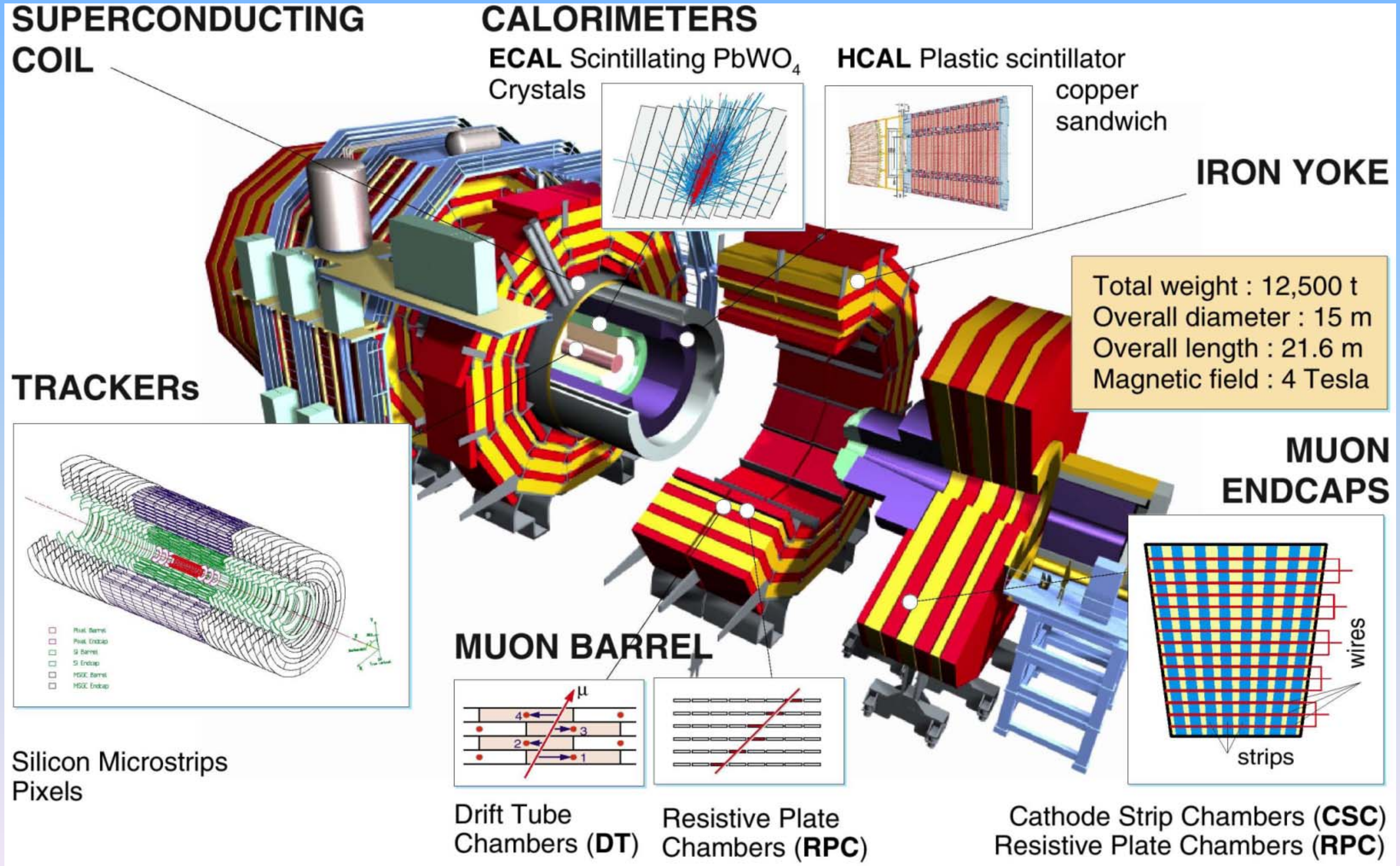
Motivation

- The mechanism for producing heavy vector mesons in pp collisions is not well understood. The experimental measurement of prompt J/ψ and ψ(2S) production cross sections by CDF in Tevatron Run I showed that the measured cross sections were one to two orders of magnitude larger than expected from the leading order (LO) color-singlet models. Theoretical efforts to improve the calculations added color octet contributions that increased the predicted cross sections, e.g., in the non-relativistic QCD model (NRQCD).

- Measurement of quarkonium production cross-section and polarization at LHC is highly recommended as it allows to test theoretical models at high transverse momentum region.

Compact Muon Solinoid

The large muon acceptance and the high precision tracker make the CMS detector ideal for studies of quarkonium states through their dimuon decays.

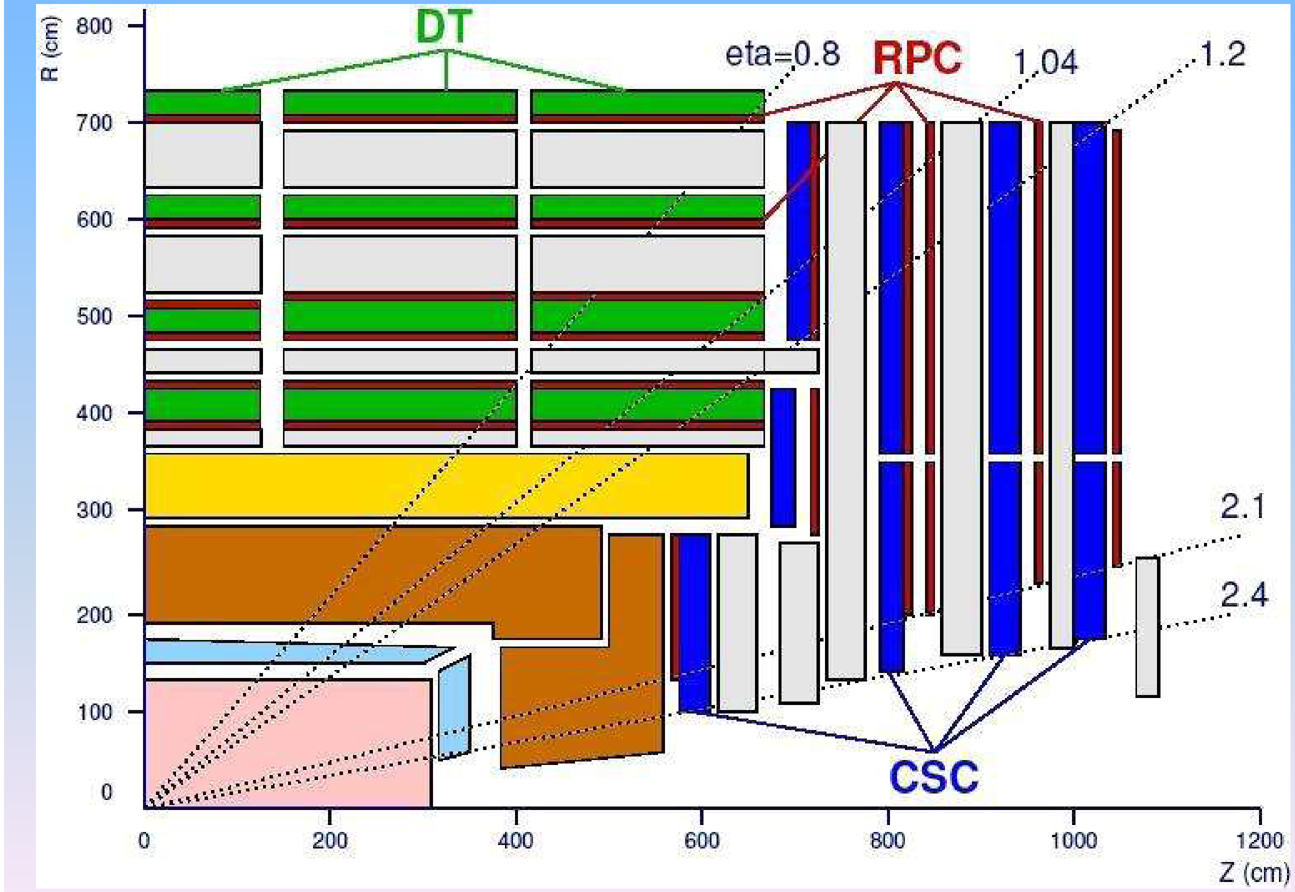


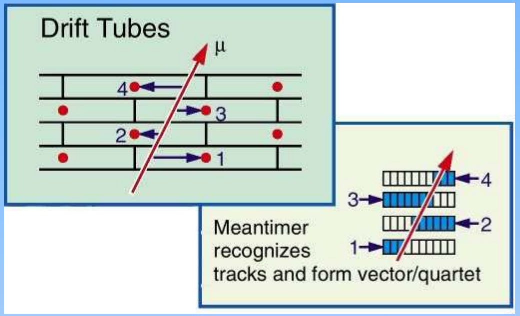
CMS Muon System

3 types of gaseous particle detectors for muon identification:

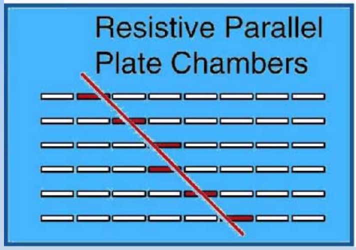
Drift Tubes (DT) in central barrel region

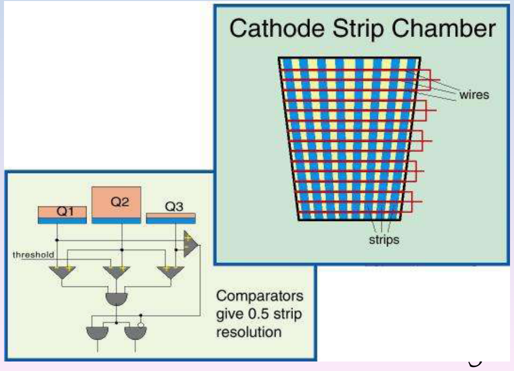
- Cathode Strip Chambers (CSC) in endcap region
- Resistive Plate Chambers (RPC) in barrel & endcaps





Meantimer recognizes tracks and form vector/quartet





Comparators give 0.5 strip resolution

The CDF Detector @ Fermilab

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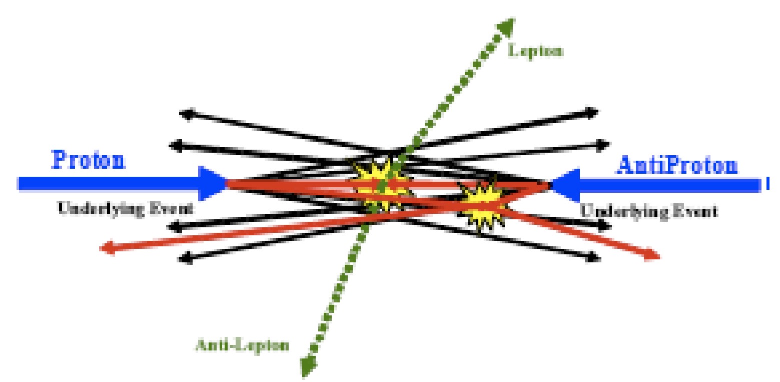
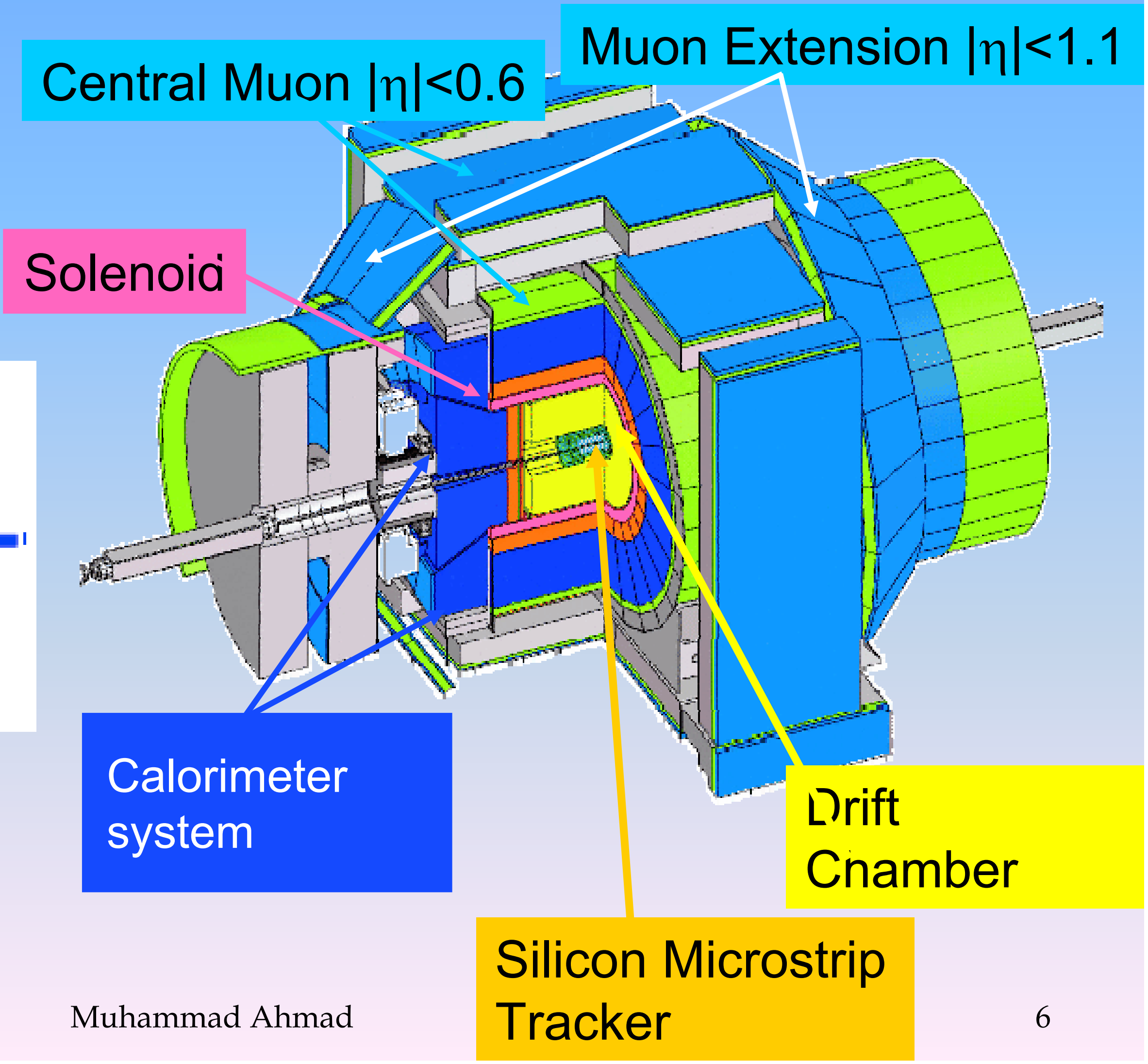
p pbar □1.96□eV





Central Muon |η|<0.6

Muon Extension |η|<1.1

Solenoid

Calorimeter system

Drift Chamber

Silicon Microstrip Tracker

Properties of $\psi(2S)$

- $\psi(2S)$ is an Exited state of J/ψ $(c\bar{c})$ Vector Meson.
- Mass = 3686.09 ± 0.04 MeV
- $\Gamma(\psi(2S)) = (317 \pm 9)$ keV
- $I^G(J^{PC}) = 0^-(1^{--})$
- **Br**$(\psi(2S) \dashrightarrow \mu^+ \mu^-) = (75 \pm 8) \times 10^{-4}$

CDF Measurement

$\sigma(pp \rightarrow \psi(2S)X) \cdot Br(\psi(2S) \rightarrow \mu+\ \mu-)$
pT (ψ(2S)) > 5 GeV/c | ή |< 0.6

Run I (August 2006)   CM Energy = 1.8 TeV
Sample Size = 15.4 pb^{-1}
Production Cross Section = 0.57 ± 0.04(stat.) nb.

Run II (November 2007) CM Energy = 1.96 TeV
Sample Size = 1.1 fb^{-1}
Production Cross Section = 0.645 ± 0.006(stat.) ± 0.044(syst.) nb.

Run II (August 2009), This is measured by Psi(2s) and Jpsi ratio method
Sample Size = 1.1 fb^{-1}
Production Cross Section = 0.69 ± 0.01(stat.) ± 0.06(syst.) nb.

Result:
In Run II measurement Integrated cross section has increased by 13%, but it increased to 21% when measured by Psi(2s) and Jpsi ratio method.

Technique

1. We want to measure the $\psi(2S) \rightarrow \mu^+ \mu^-$ production cross section
2. From a physics (theory) perspective, the information content is almost the same in the ratio $\psi(2S)$/Jpsi as in the absolute $\psi(2S)$
3. Experimentally, we can measure the ratio with a much higher accuracy, exactly because most of the parameters needed to go from the number of measured events to the production cross section are identical, or very similar, for the two charmonium states
4. The trigger efficiency should be almost identical for the psi' and Jpsi dimuons. The higher mass of the psi' will give it a slightly higher detection efficiency at identical meson pT, at low pT, since the two decay muons will have a bit more energy to reach the muon stations

Measurement

Expression for measuring the ψ(2S) / J/ψ cross section ratio:

$$\frac{\sigma(\psi')\,Br(\psi'\rightarrow\mu\mu)}{\sigma(\psi)\,Br(\psi\rightarrow\mu\mu)} = \frac{N_{\psi'}\,A_{\psi}\,\varepsilon_{\psi}\int L\,dt}{N_{\psi}\,A_{\psi'}\,\varepsilon_{\psi'}\int L\,dt} = \frac{N_{\psi'}}{N_{\psi}}$$

The last step assumes that the acceptances and efficiencies are approximately equal for the ψ(2S) and the J/ψ dimuons.

Procedure

1. We use three data sets for this analysis:

/Psi2S/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO	(for Psi2S)
/JPsi/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO	(for Jpsi)
/InclusivePPmuX/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO	(for Background)

2. The available background has integrated luminosity 0.03/pb; to scale it to other luminosity values, we fitted the shape of the background dimuon mass distribution to a polynomial and randomly generated more Bg events
3. We use global-global muon pairs with momentum from tracker information
4. We only use opposite-sign muon pairs, of mass in the range 2.5—4 GeV/c2
5. We merge the three invariant mass histograms (Psi2S, Jpsi and Backg) ensuring that the same integrated luminosity is used in each of them
6. This analysis is done for several int. luminosities (from 1 to 15 pb-1) to see how the uncertainty on the Psi2S/Jpsi ratio decreases with statistics

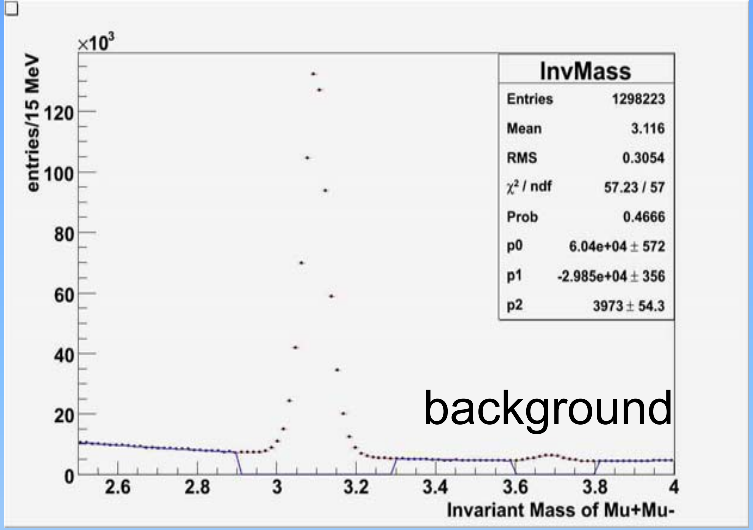
Procedure Cont.

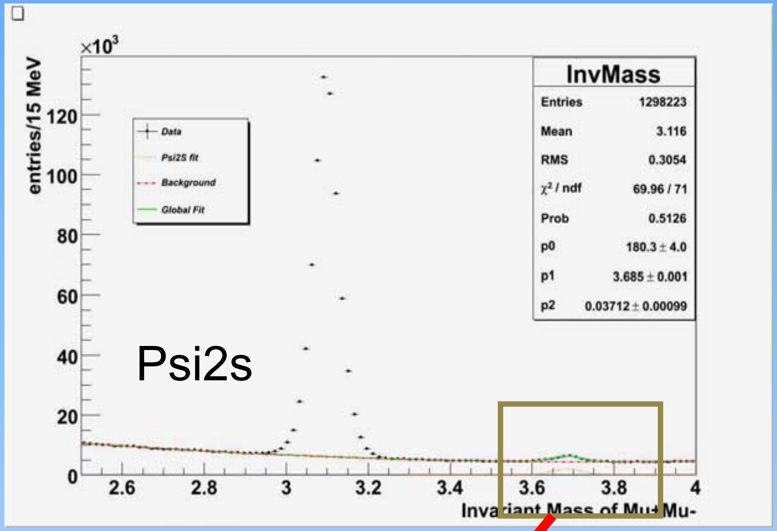
7. We consider 5 dimuon mass regions:
    i. 2.5 - 2.9
    ii. 2.9 - 3.2
    iii. 3.2 - 3.6
    iv. 3.6 - 3.8
    v. 3.8 - 4.0

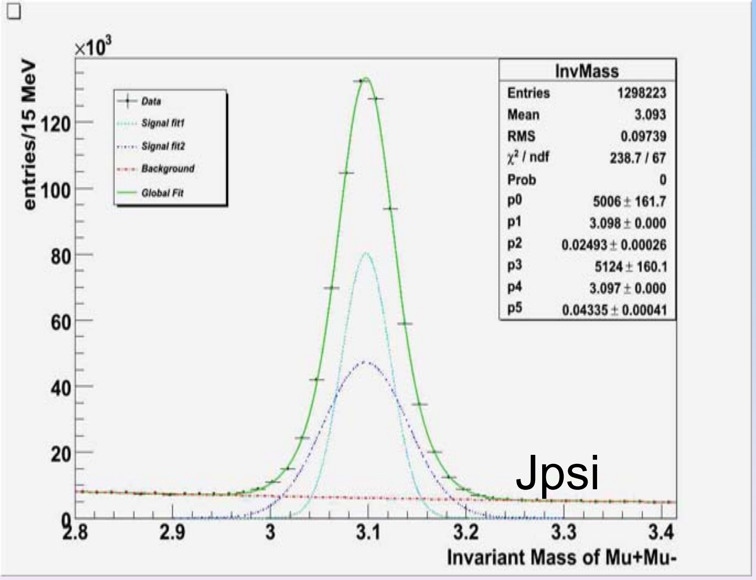
8. We obtain the three parameters of the 2nd degree polynomial Bg function excluding the ranges (ii) and (iv), dominated by the Jpsi and Psi2S peaks. These fitted Bg parameters are then fixed.

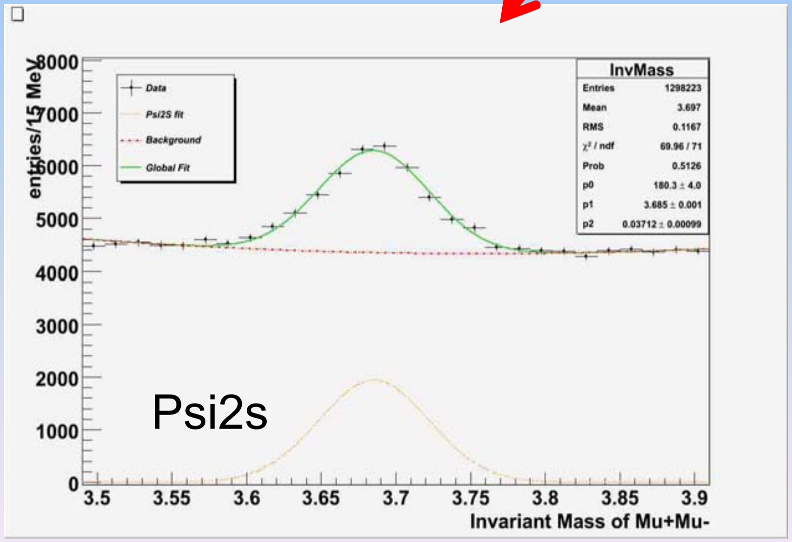
9. Then we fitted the Jpsi region with 2 Gaussians and the Psi2S region with 1 Gaussian, to extract the Jpsi and Psi2S yields

Fits in three steps

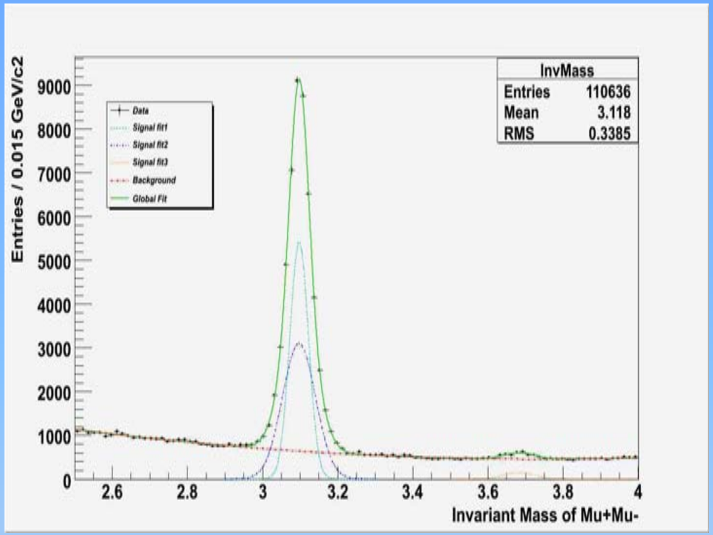


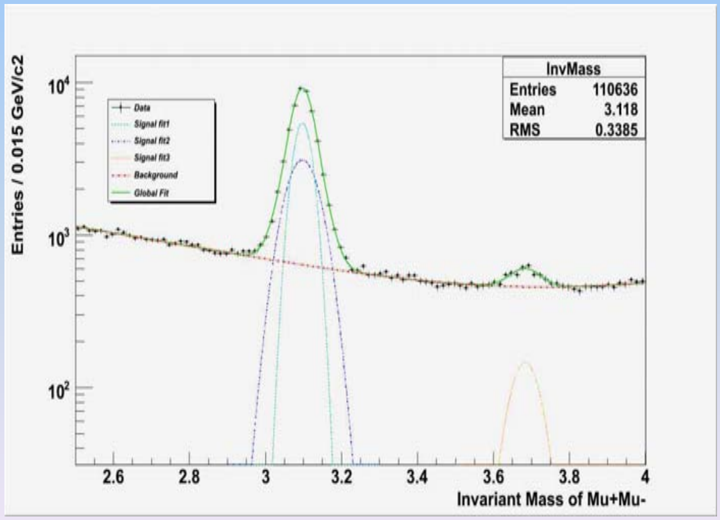






Results





Results of the 1 pb^{-1} integrated luminosity fits

Number of “generated” J/ψ = 45360
Number of fitted J/ψ = 45033 ± 4187

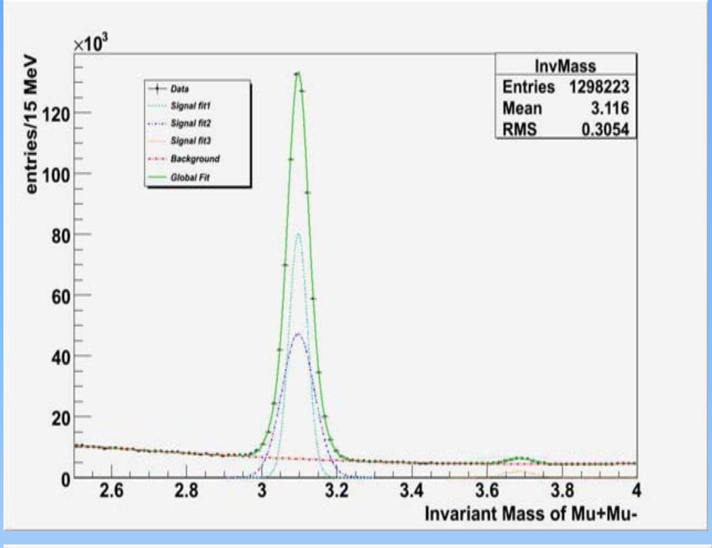
Number of “generated” $\psi(2S)$ = 812
Number of fitted $\psi(2s)$ = 961 ± 87

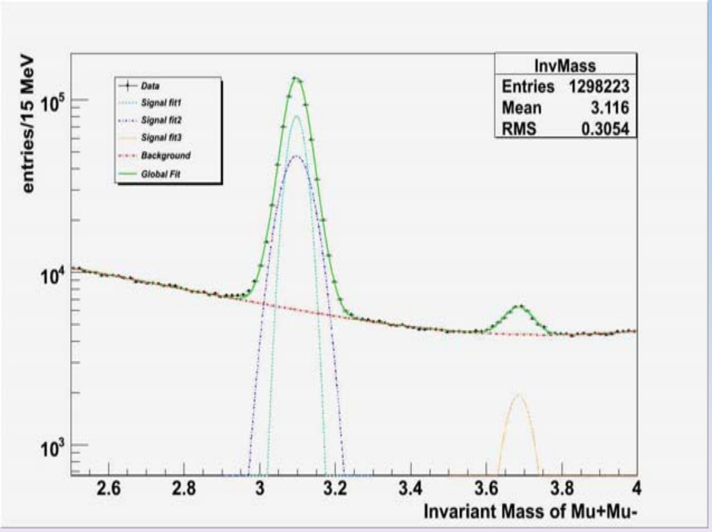
Sig / Bkg (J/ψ) = 5.75
Sig / Bkg ($\psi(2S)$) = 0.19

$\psi(2S) / J/\psi = 0.021 \pm 0.003$

Relative error = 13 %

Results





Results of the 15 pb^{-1} integrated luminosity fits

Number of "generated" J/ψ = 680297
Number of fitted J/ψ = 675333 ± 15466

Number of "generated" $\psi(2S)$= 12303
Number of fitted $\psi(2s)$ = 12018 ± 266

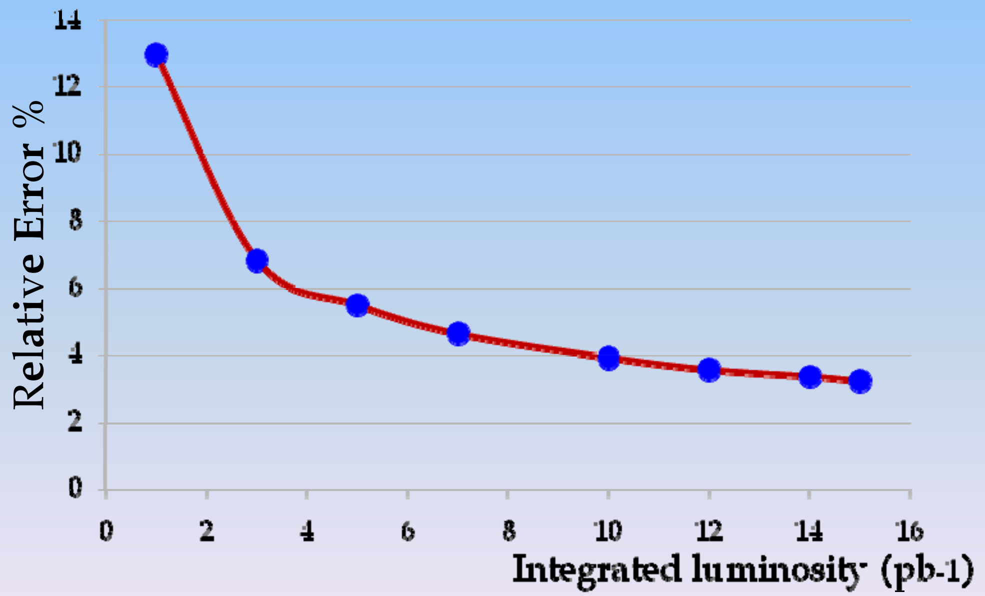
Sig / Bkg (J/ψ) = 9.19
Sig / Bkg ($\psi(2S)$) = 0.27

$\psi(2S) / J/\psi = 0.0178 \pm 0.0006$

Relative error = 3.2 %

	1 pb-1	5 pb-1	15 pb-1
S/B (J/Ψ)	5.75	8.98	9.19
S/B (Ψ(2S))	0.19	0.26	0.27
Psi2S / Jpsi [%]	2.1	1.8	1.8
% Error	13.0 %	5.5 %	3.2 %

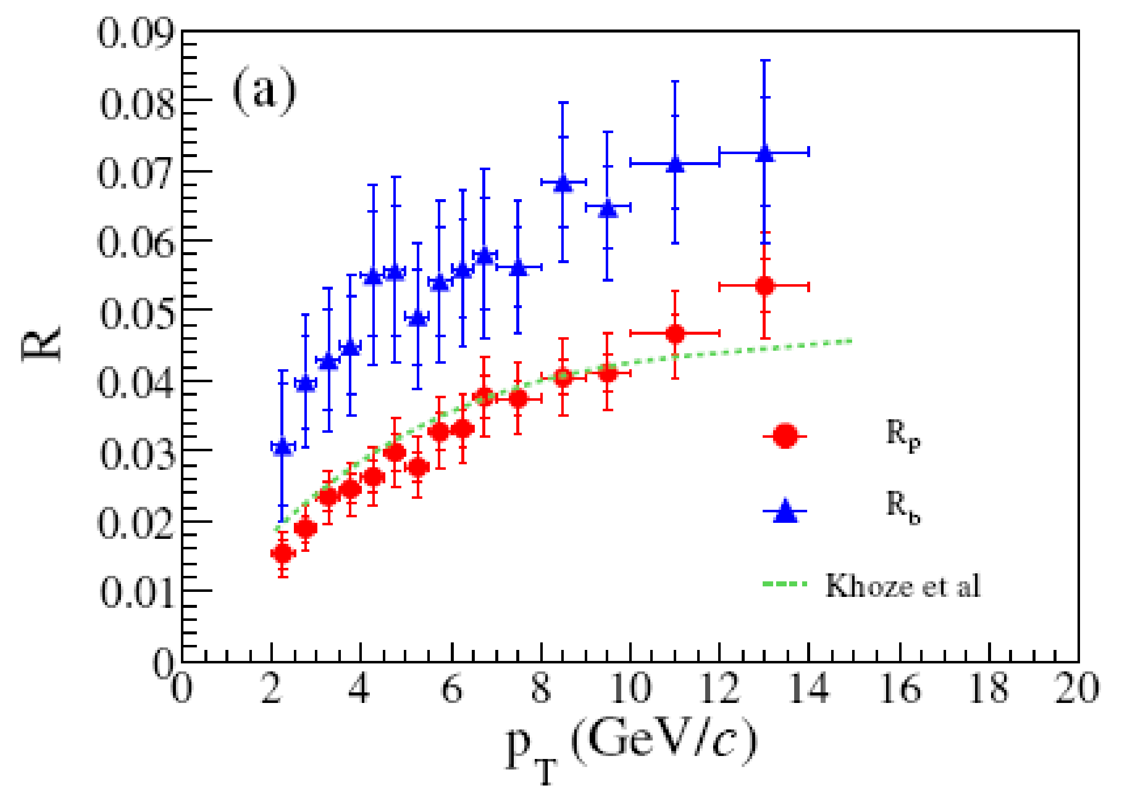
Relative error on the ratio for different luminosities



Summary and outlook

- At the ψ(2S) peak the dimuon mass resolution is ~37 MeV and the S/B is around 0.3
- We extracted the ψ(2S) to J/ψ cross section ratio for different integrated luminosities (inclusive in pT)
- It seems that the relative statistical error on the ψ(2S) / J/ψ ratio saturates at around 3% for L > 15 pb-1
- We will now redo the fit changing the fitting functions and procedure to evaluate the fitting systematic error
- We need to understand the apparent change of S/B with luminosity
- Next step: extract the ψ(2S) / J/ψ cross section ratio as a function of transverse momentum.

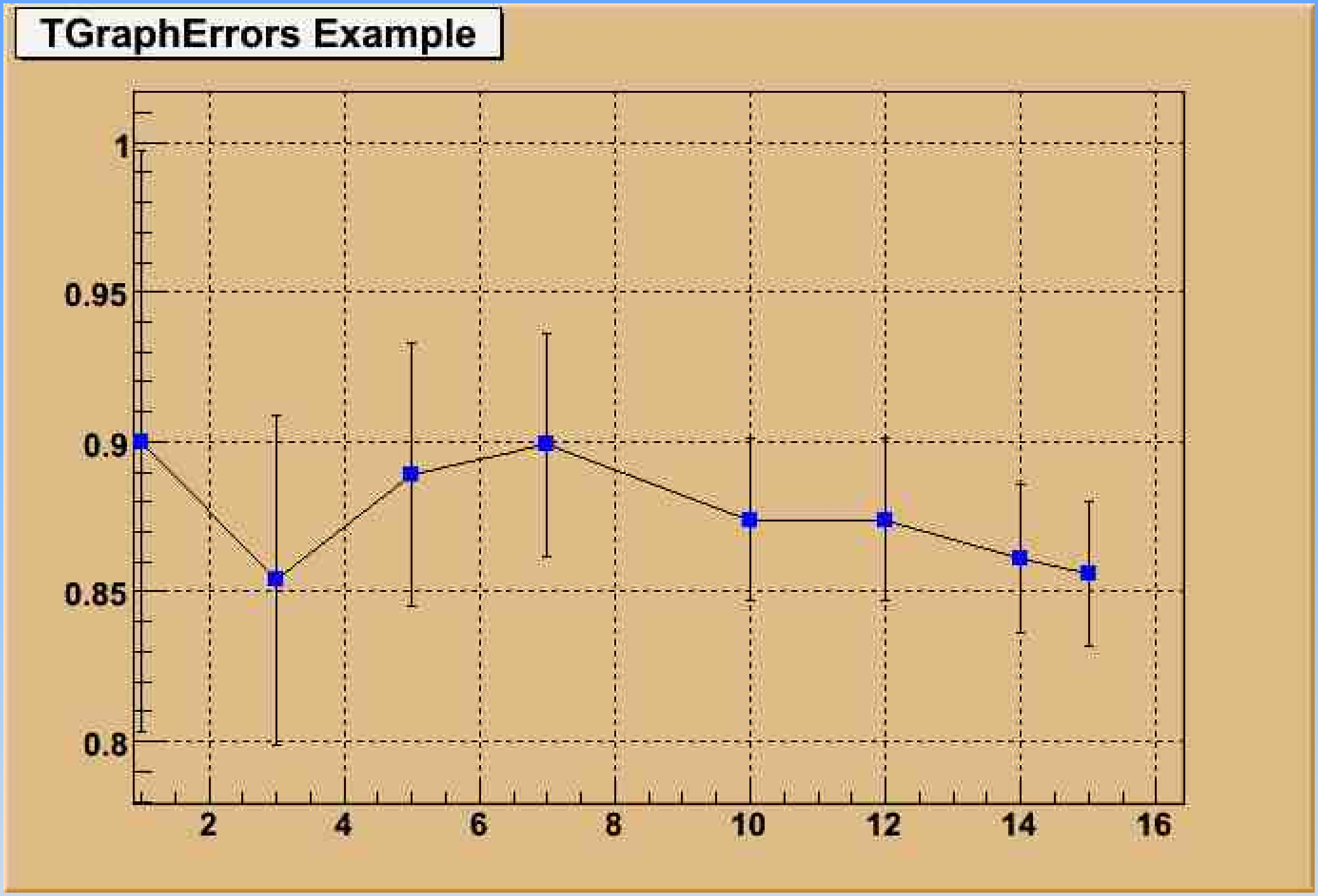
CDF Results



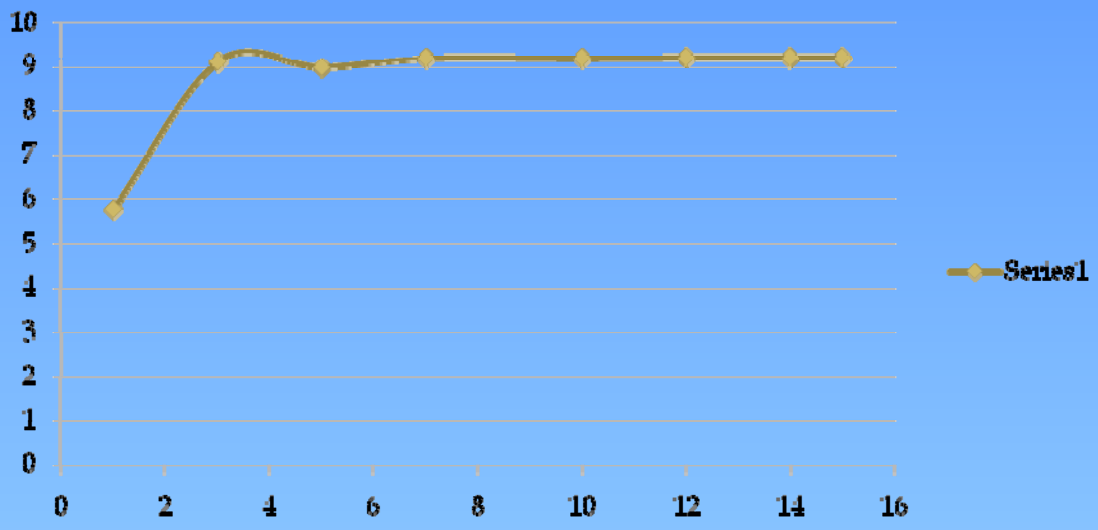
The differential cross section ratio of ψ(2S) to J/ψ as a function of vector meson pT

http://www-cdf.fnal.gov/physics/preprints/cdf9205_psip_rc_revised.pdf

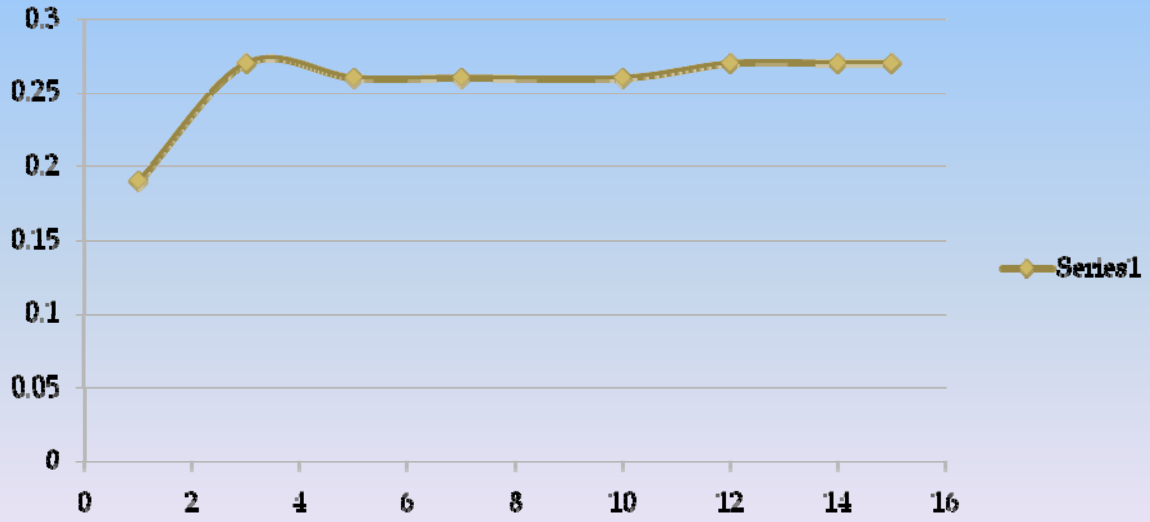
Backup Slides



Wirdth Psi2S / wirdth Jpsi with error bars Vs Int. Luminosities



Jpsi/Bg ratio Vs Int. Luminosity



Psi2S/Bg ratio Vs Int. Luminosity

CDF measurements

- In CDF detector the cross section is measured in its Run I and Run II.

Run I (Aug,2006)

$$\textit{Sample .Size} = 15.4 \pm 0.6\, pb^{-1}$$

$$\text{Production Cross Section} = \left[\sigma(p\bar{p}) \to \psi(2s)\mathrm{X}, |y(\psi(2s))| < 0.6, p_T > 5GeV/c\right]_{\sqrt{s}=1.8TeV} \cdot Br(\psi(2s) \to \mu^+\mu^-)$$

$$= 0.57 \pm 0.04(stat)^{+0.08}_{-0.09}(syst)nb$$

Run II (Nov,2007)

$$\textit{Sample .Size} = 1.1\, fb^{-1}$$

$$\text{Production Cross Section} = \left[\sigma(p\bar{p}) \to \psi(2s)\mathrm{X}, |y(\psi(2s))| < 0.6, p_T > 5GeV/c\right]_{\sqrt{s}=1.96TeV} \cdot Br(\psi(2s) \to \mu^+\mu^-)$$

$$= 0.645 \pm 0.006(stat) \pm 0.044(syst)nb$$

In Run II measuremen t integrated cross section has increased by 13% as compared to Run I.

Calculated cross section at LHC energy 14 TeV is 2.5 ub.

Production Cross Section = 0.69 ± 0.01(stat.) ± 0.06(syst.) nb.