Atlas direct J/Ψ production studies.

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Agenda

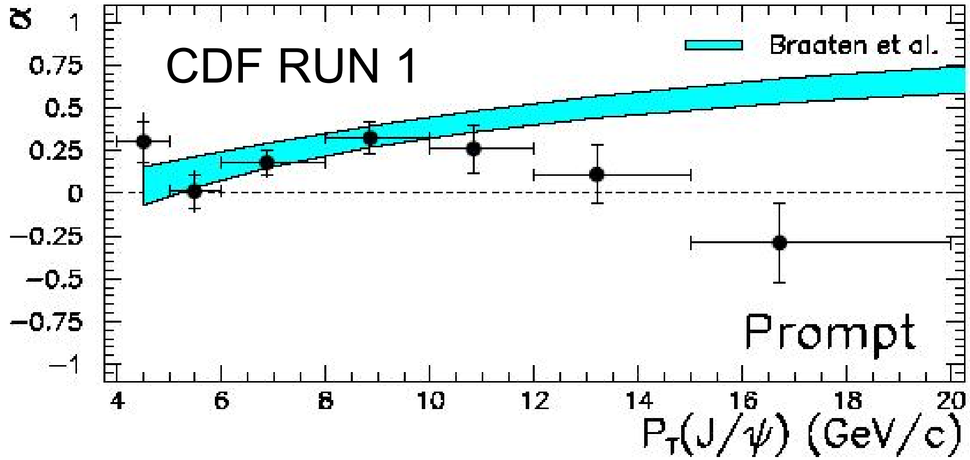
1. Motivation
2. Introduction
3. ATLAS detector at LHC collider
4. Cross Sections
5. New Pythia versions
6. Event Selection
7. Fit Mechanism

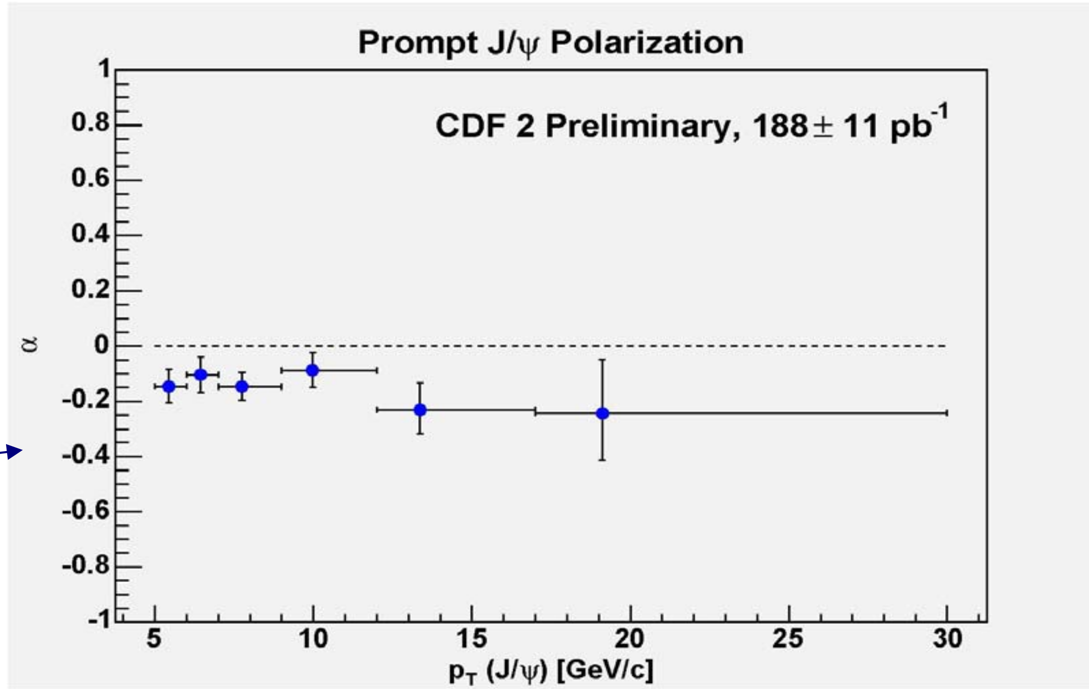
Motivation

- Measurements done at CDF are not consistent with the predictions of the J/ψ polarization P_T dependence. There is a large discrepancy between some theoretical prediction and the CDF measurements mainly at high P_T range.
- *Recent measurements*

  April 28, 2005

  http://www-cdf.fnal.gov/physics/new/bottom/050428.blessed-jpsi-polarization/





Various models in Charmonium Production

- The Color Evaporation Model (CEM)

  It assumes that there is no correlation between the initial $Q\tilde{Q}$ state and the final quarkonium state.

- The Color Singlet Model (CSM)

  It assumes that each quarkonium state can only be produced by a $Q\tilde{Q}$ pair in the same color and angular momentum state as that quarkonium.

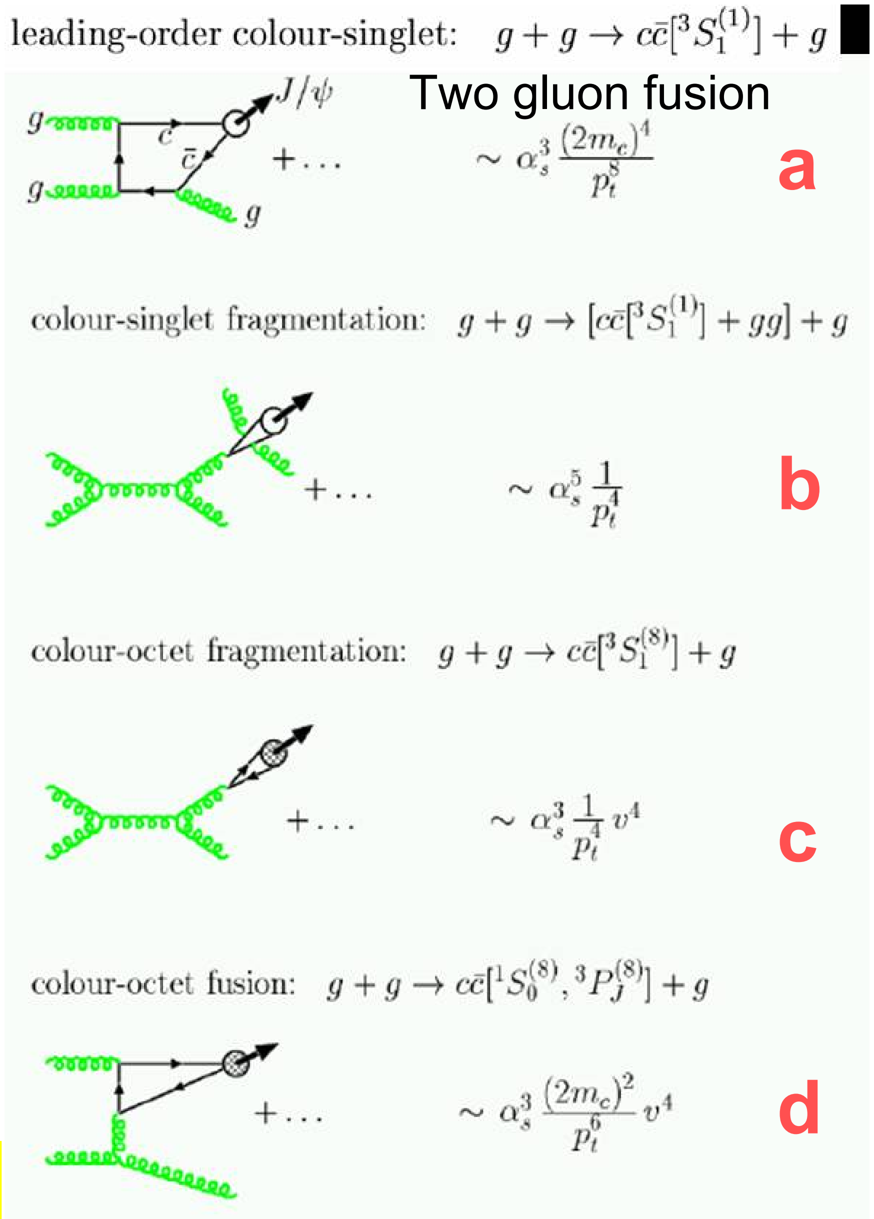
- The Nonrelativistic QCD Model (NRQCD)

  It treats quarkonium as an approximately nonrelativistic system. When applied to production, this implies that $Q\tilde{Q}$ pairs produced with one set of quantum numbers can evolve into a quarkonium state with different quantum numbers, by emitting low energy gluons.

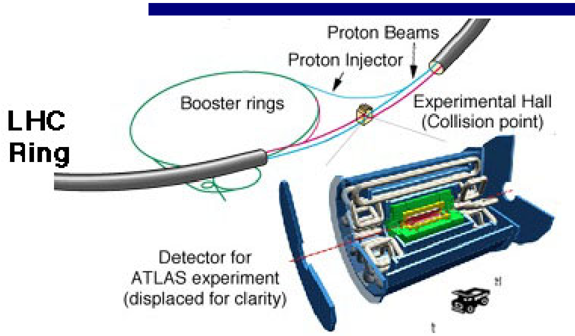
NRQCD

- NRQCD makes systematic nonrelativistic corrections to effective field theory using an expansion series in *v (the velocity of the heavy quark in the quarkonium rest frame)* and α_s.
- At high P_T (P_T >>mc) the dominant process in NRQCD is the fragmentation of a single gluon to a pair in a $[8,{}^3S_1]$ state (c). In comparison to the color singlet fragmentation process in (b) this occurs at a higher order of v_c (v_c^7 versus v_c^3) but at a lower order of α_s (α_s^3 versus α_s^5).
- Taking into account these facts, it is indeed plausible that the color octet process could explain the observed direct cross sections.

fragmentation process – transverse polarization



ATLAS DETECTOR AT LHC



Length of the tunnel is 26.6 km (existing LEP tunnel)

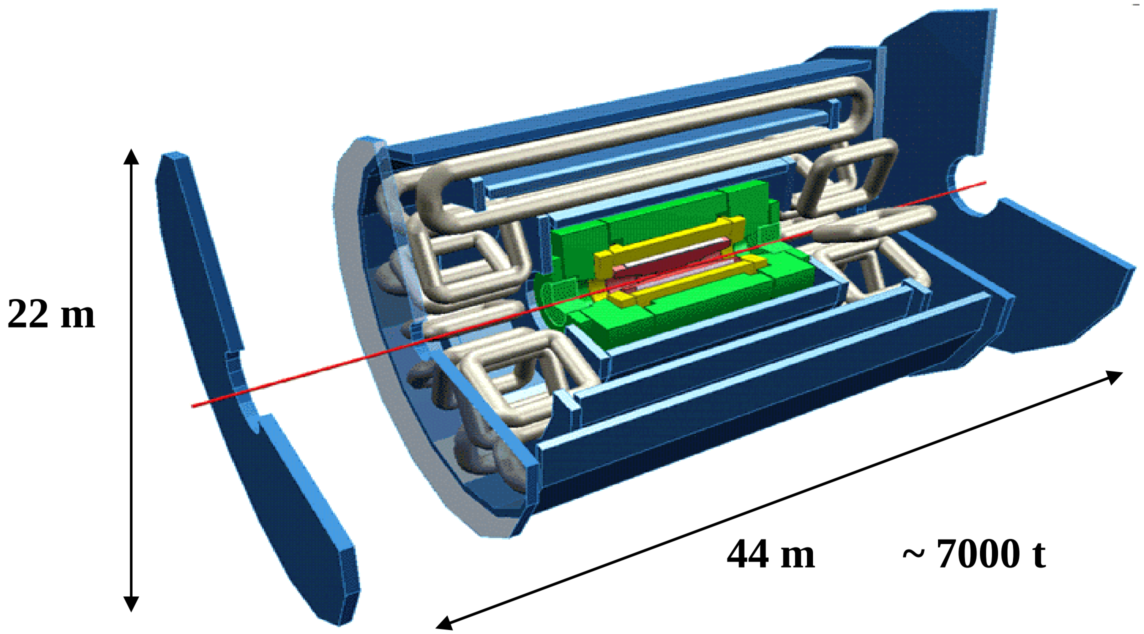
Maximum Energy 14 TeV

Frequency 40 MHz (25nsec)

Low Luminosity-10^{33} $cm^{-2}s^{-1}$

High Luminosity-10^{34} $cm^{-2}s^{-1}$

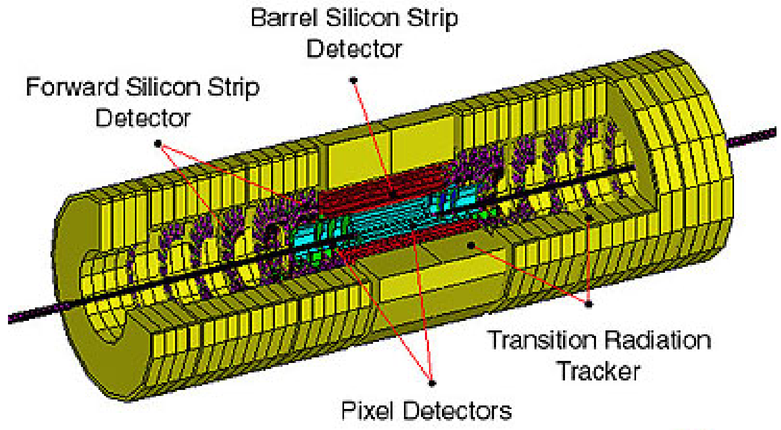
Atlas one of the four LHC experiments that will study p-p collisions



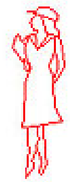
- **Beam pipe.**
- **Tracking detector.**
- **Solenoidal Magnet.**
- **Electromagnetic Calorimeter.**
- **Hadron Calorimeter.**
- **Muon Toroidal Magnets.**
- **Muon Detectors.**

Tracking in Inner Detector

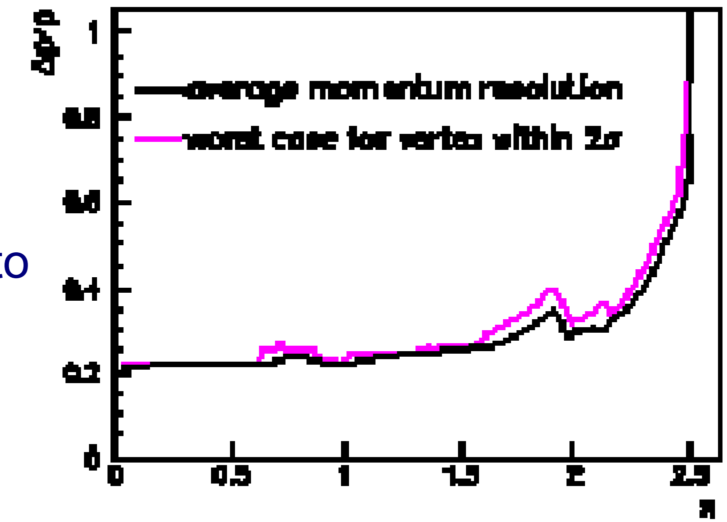
Pixel Detectors -The silicon sensors closest to the collision point. (Resolution: σ_{φ}=12 μm, σ_z=66 μm)
Strip Detectors –The additional layers of silicon narrow strips. additional position measurements (5cm<radii<50cm)
Resolution :σ_{φ}=16μm,σ_z=580μm
Transition Radiation Tracker (TRT)-
gas-wire drift detectors that consist of 4mm-diameter tubes (straws like) with thin wires running through the tube centers. (50<radii<100 cm)
Resolution :σ=170μm per straw .



Inner Tracker

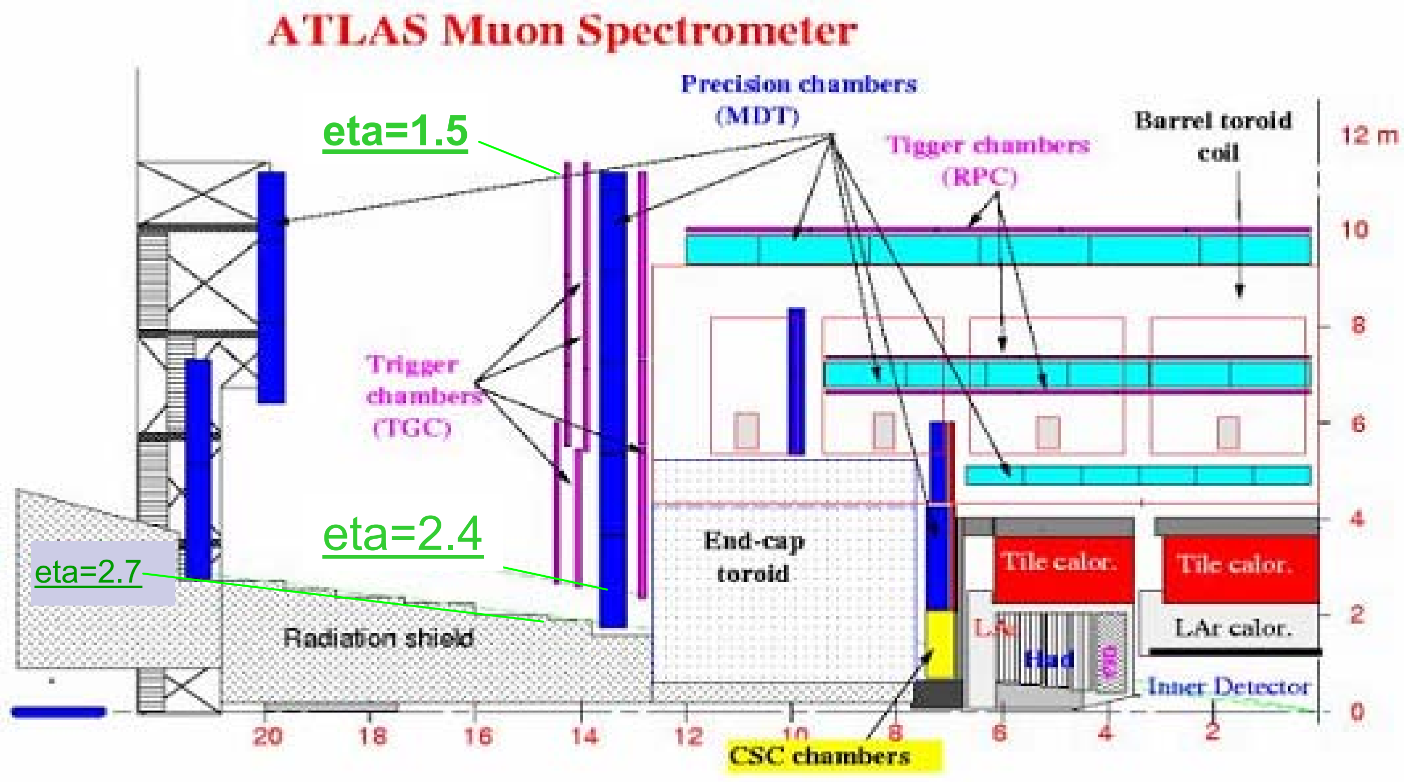


- The silicon pixel and strip detectors - 10 azimuthal position measurements (σ~ 10 - 20 microns.)
- The TRT - 36 azimuthal position measurements, (σ~ 150 microns each).
- The directions, momenta and charge corresponding to all the trajectories, can be determine.



Muon Spectrometer

- The momentum of the muons is determined from the curvatures of their tracks in a toroidal magnetic field.
- Muon tracks are identified and measured after their passage through ~2m of material.



- Track measurement with σ=60μm intrinsic resolution in three precision measurement stations (MDT).

10^9

Atlas Trigger

- The information of one event is approximately 1MB.
- Block diagram shows a simplified functional view of the Trigger system.
- The goal of the first level trigger is to select from 10^9 to $75*10^6$ events within the time interval of the 25 nsec.

Interaction rate ~1GHz

Bunch crossing rate 40 MHz (25 nsec)

First level trigger

↓ Events rate ~75 kHz

Second level trigger

↓ Events rate ~ 2 kHz

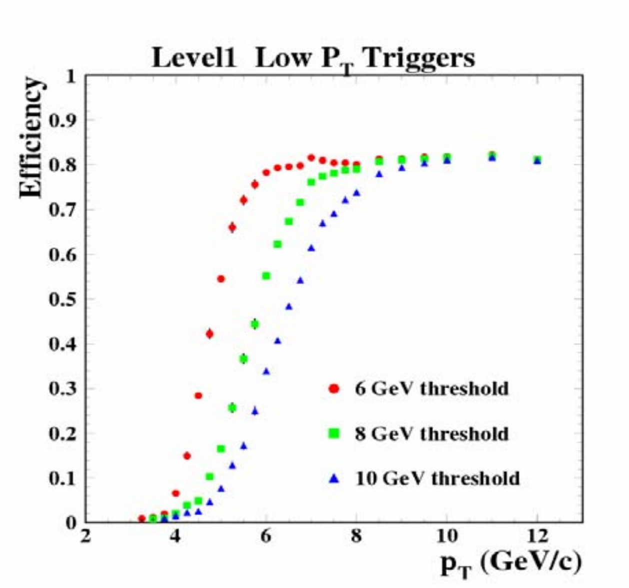
Third level trigger

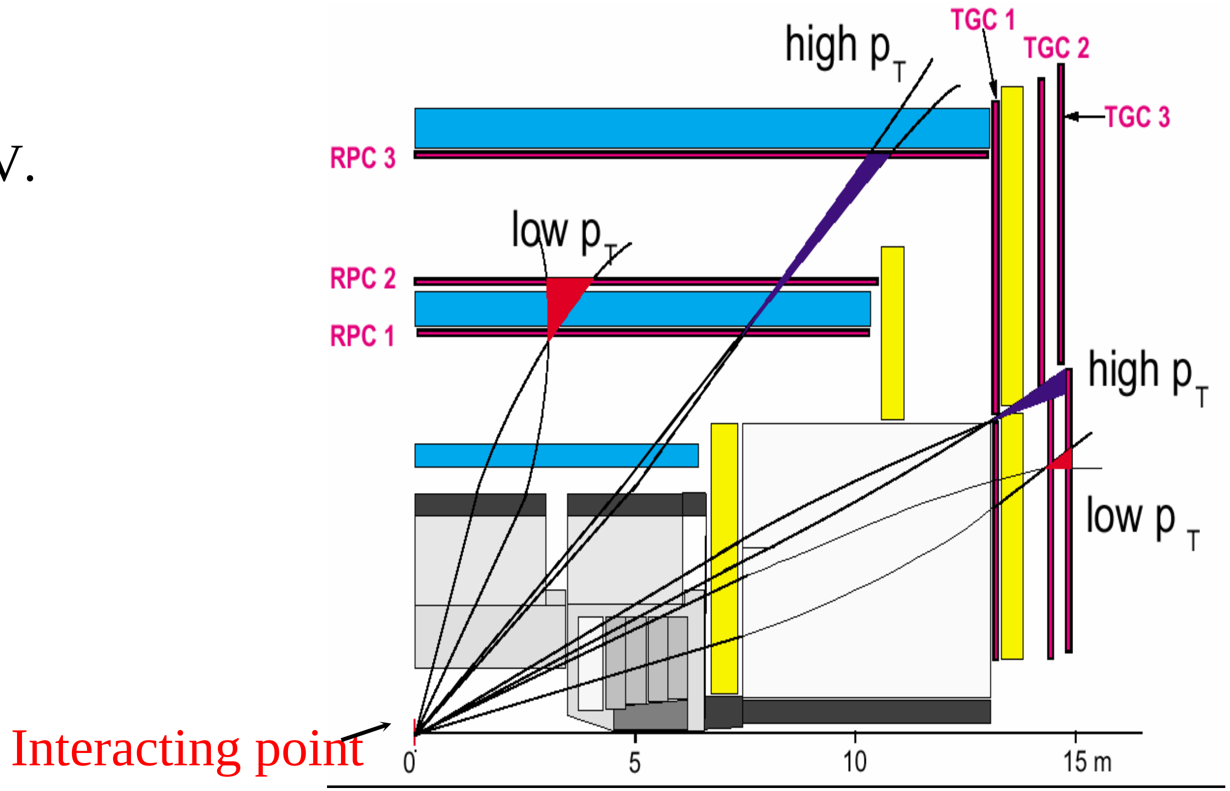
↓

Events rate ~200 Hz

Trigger System

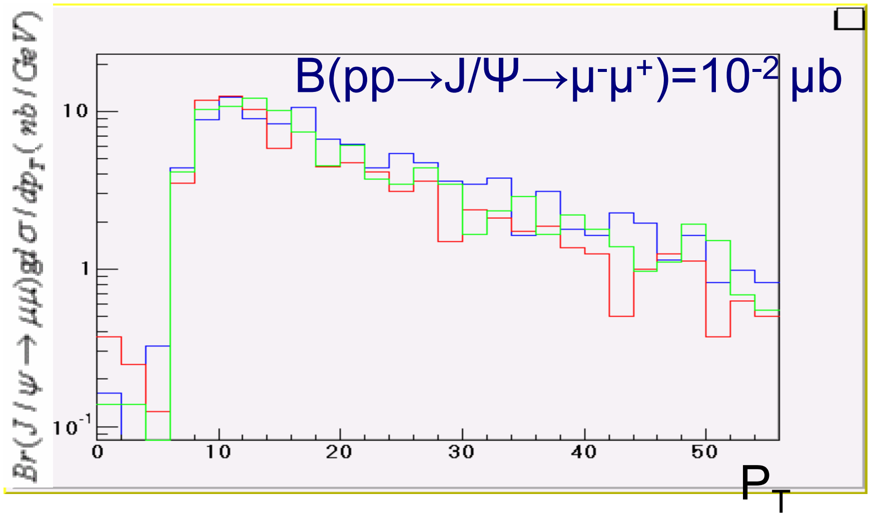
- The first level muon trigger is derived from three trigger stations formed of Resistive Plate Chambers (RPC) in the barrel and Thin Gap Chambers (TGC) in the end-caps.
- Each station is made of 2 (or 3) planes of strips (or/and wires) with x or y readout .
- The trigger is based on a coincidence between a strip(or wire) hit in the 1st station and a range of strips(or wires) in the 2nd or 3rd station. Typical momentum resolution is 20%.
- Low p_T trigger: $p_\mu > 6GeV$
- High p_T trigger: $p_\mu > 20GeV$.





Cross Sections (g+g→J/Ψ +g)

The prompt J/Ψ direct production using 3 different parton distribution functions.
CTEQ3L-Green
CTEQ5L-Red
CTEQ6M-Blue



- Trigger efficiency (low luminosity) to select pp→ J/Ψ → μ(6GeV)μ(3GeV) is~10%
- Reconstruction algorithm efficiency **~60%**
- First year run ~ 100 days

$$10^{33}[bar^{-1}\sec^{-1}]\bullet 10^{-24}[particles/cm^2]\bullet 10^{-8}[bar]\bullet 10^{7}[\sec/run\_year]=10^{8}[events/year]$$

$$10^{8}[events/year]\times 0.1\times 0.6\approx 6\times 10^{6}[events/year]$$

After one year we expect 6 million events of pp→J/Ψ→μ⁻μ⁺

Background

- The main background for our process is $pp \to B \to J/\Psi + X$ .The cross-section for this process is :

$$\sigma(pp \to B \to J/\Psi \to \mu(6GeV) + \mu(3GeV)) \approx 10^{-2} \mu b \ .$$

Signal / Background of O(1)

Monte Carlo Study

- Generation was done with Pythia 6.221
- Parton distribution function - CTEQ6M
- The Octet model was implemented in Pythia 6.221 software (adding two extra differential cross-sections for the process $pp \rightarrow J/\Psi + X$ corresponding to the colored $^3S_1$ and $^1S_0 + ^3P_0$ states)
- Di-muon filter on P_T of more than 3 and 6 GeV was applied in the event production.
- All the generated events were processed with Geant-4 Simulation, Digitization, Reconstruction and "My Analysis" algorithms.
- We are currently moving to new Pythia 6.326 version

New Pythia versions

- Implementation of Non Relativistic QCD model (NRQCD) original code (by Stefan Wolf) within the new PYTHIA versions.
  - This PYTHIA implementation was already in use via external code in our previous studies.
  - PYTHIA 6.326 enables a full **charmonia** and **bottomonia** production.
  - The new PYTHIA code is under validation;
  - Realistic parameter values (e.g. NRQCD MEs) have to be fixed.
- The default parameters are incorrect:

New Corresponding Matrix elements

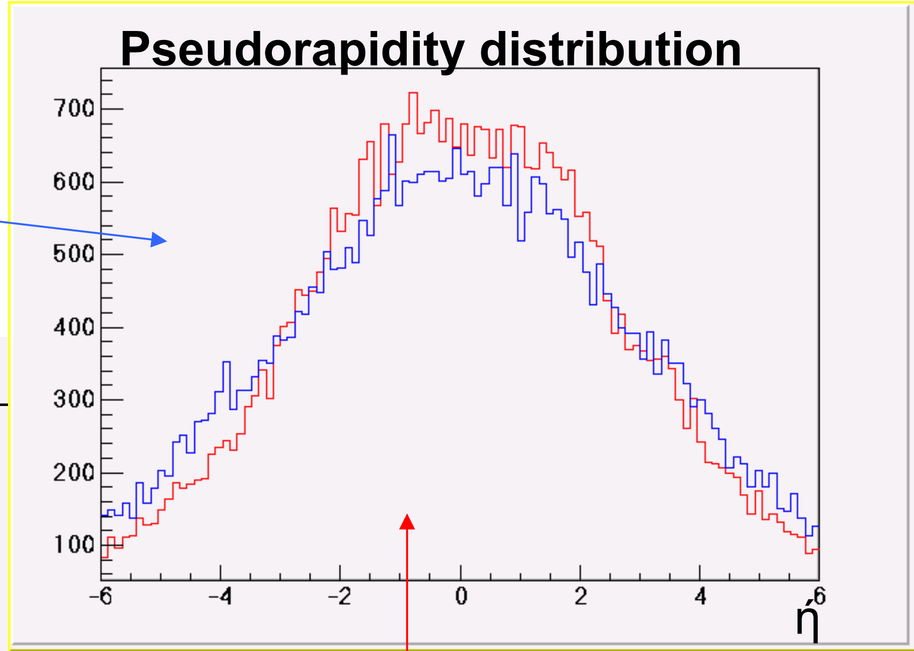
- 10 new values for NRQCD matrix elements inserted based on values extracted from: hep-ph/0003142

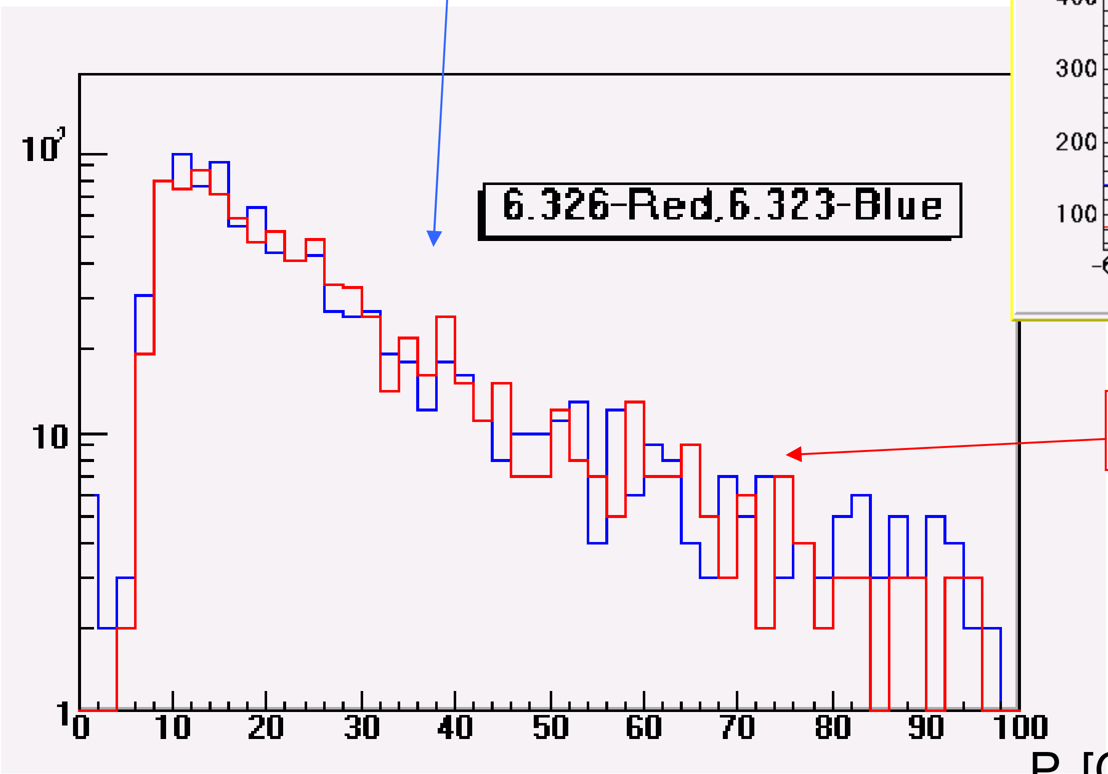
PARP(141)	$\langle O^{J/\psi}[^3S_1^{(1)}]\rangle$	1.16
PARP(142)	$\langle O^{J/\psi}[^3S_1^{(8)}]\rangle$	0.0119
PARP(143)	$\langle O^{J/\psi}[^1S_0^{(8)}]\rangle$	0.01
PARP(144)	$\langle O^{J/\psi}[^3P_0^{(8)}]\rangle / m_c^2$	0.01
PARP(145)	$\langle O^{\chi_{c0}}[^3P_0^{(1)}]\rangle / m_c^2$	0.05
PARP(146)	$\langle O^{\Upsilon}[^3S_1^{(1)}]\rangle$	9.28
PARP(147)	$\langle O^{\Upsilon}[^3S_1^{(8)}]\rangle$	0.15
PARP(148)	$\langle O^{\Upsilon}[^1S_0^{(8)}]\rangle$	0.02
PARP(149)	$\langle O^{\Upsilon}[^3P_0^{(8)}]\rangle / m_b^2$	0.48
PARP(150)	$\langle O^{\chi_{b0}}[^3P_0^{(1)}]\rangle / m_b^2$	0.09

Events Kinematics

Normalized to the total number of events

In Blue Pythia version 6.323 with external Color Octet implementation(11.0.4)



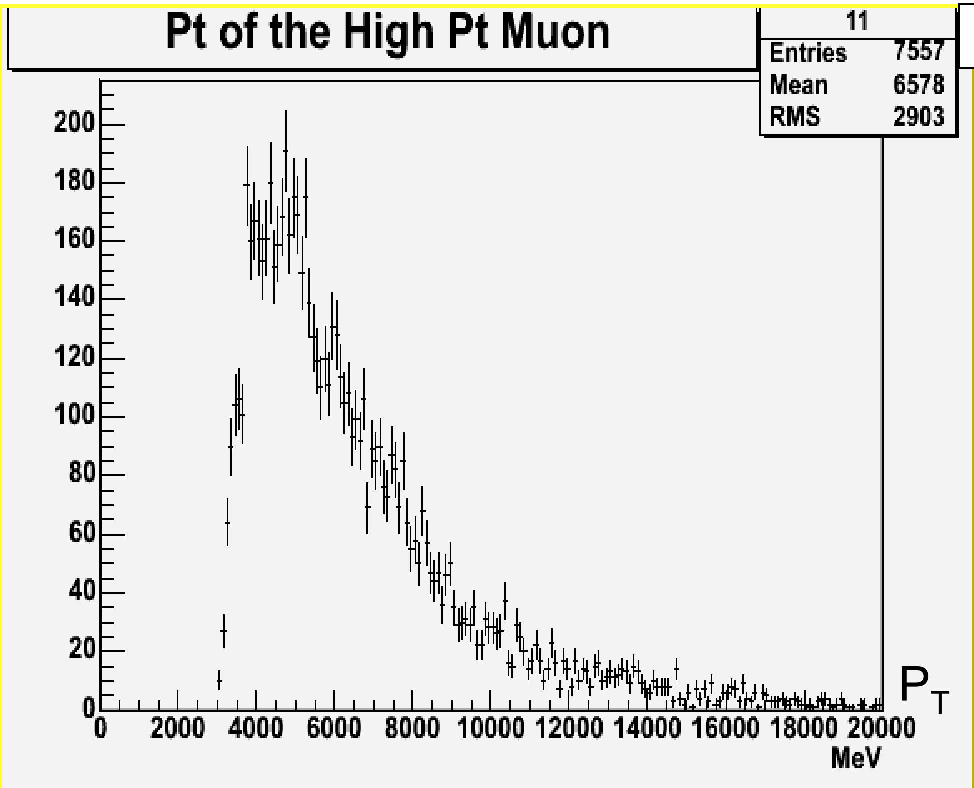


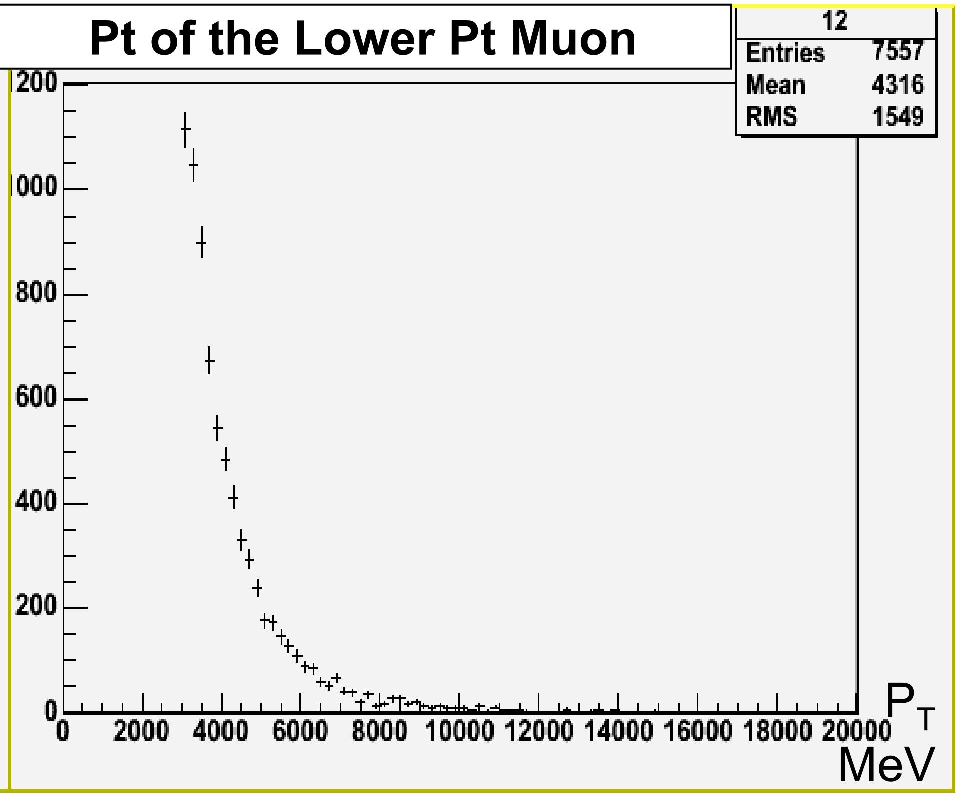
P_T[GeV]

In Red Pythia version 6.326 (11.5.0)

Selection of J/Ψ to Muon pair

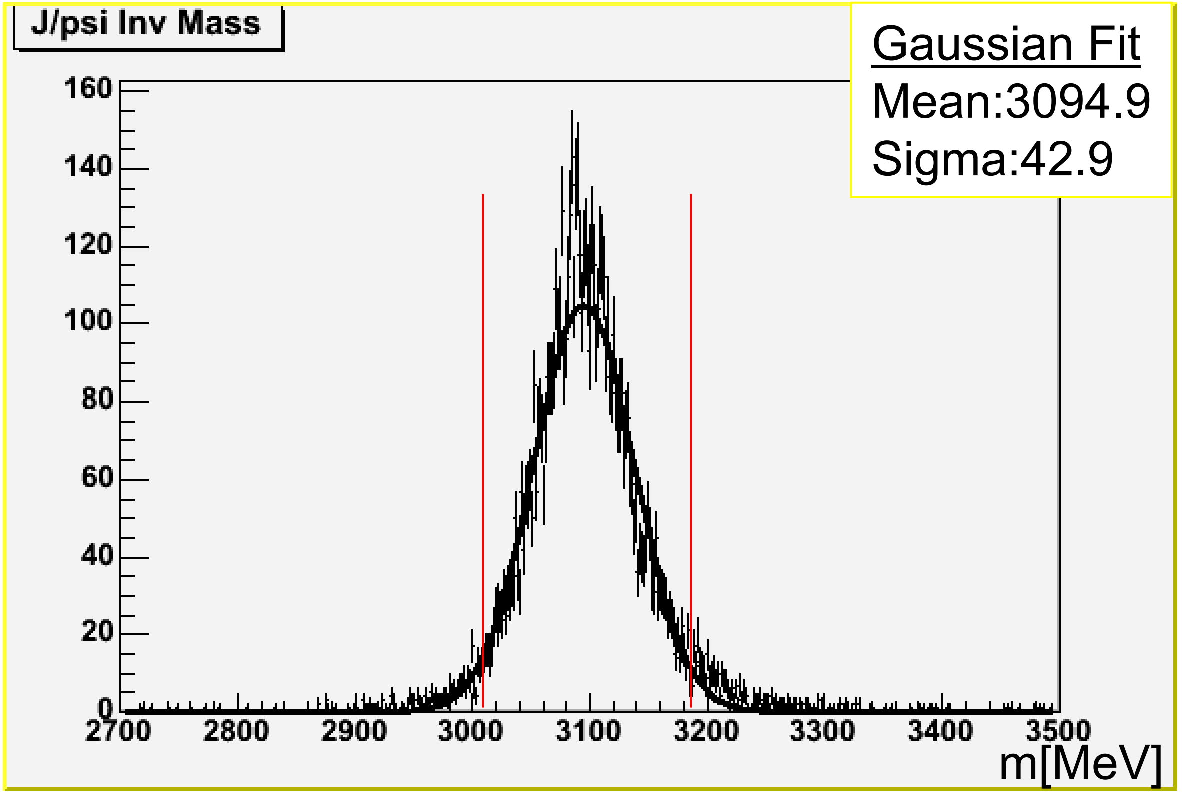
- To properly select J/Ψ events, pairs of differently charged muons are chosen.





Selection II

- The selection is based on the dimuon invariant mass reconstruction.

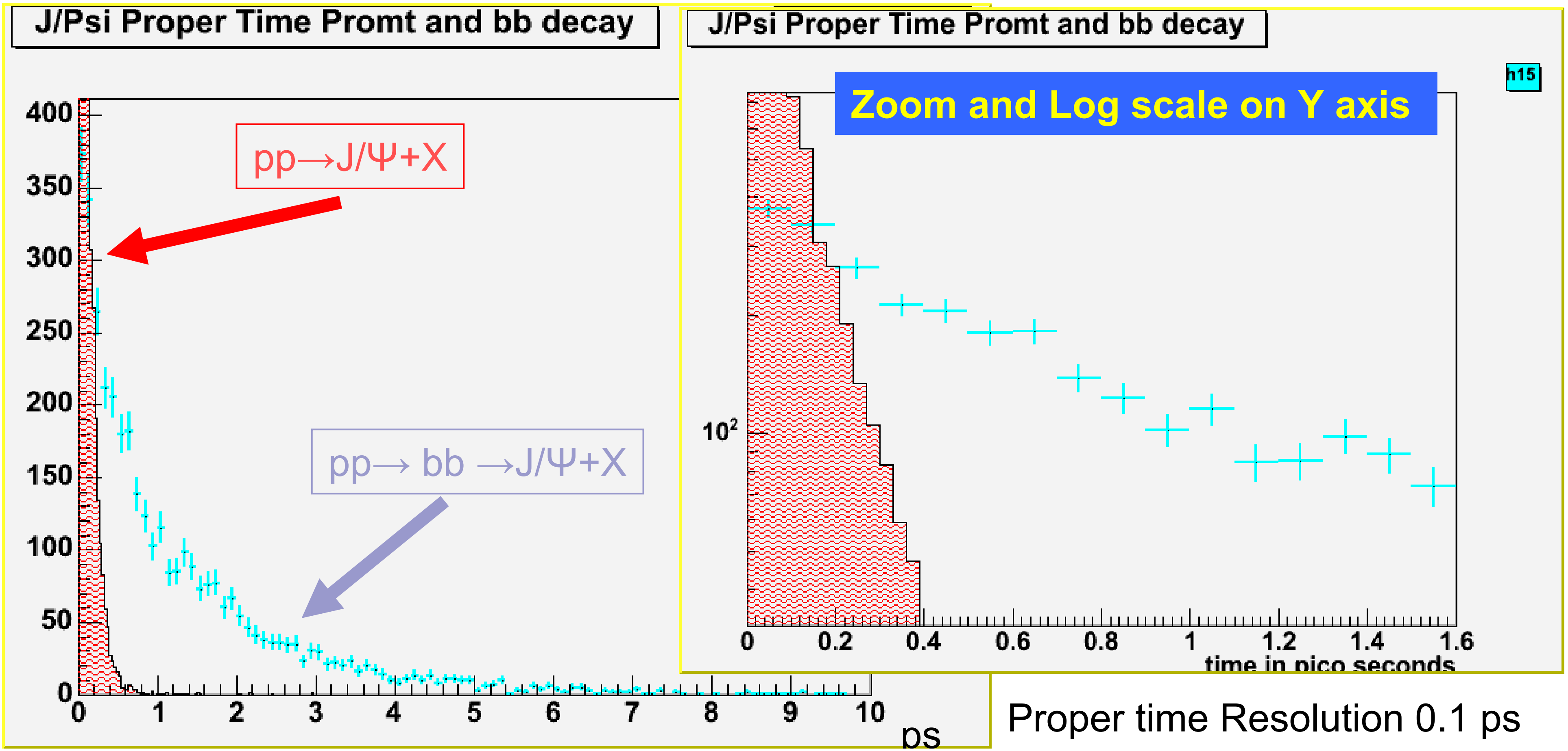


Mass resolution $\sigma(M_{2\mu})$=43MeV

In the tails of the J/Ψ Invariant Mass histogram there are only 5% of the total number of events.

$b\tilde{b}$ events rejection (proper-time cut)

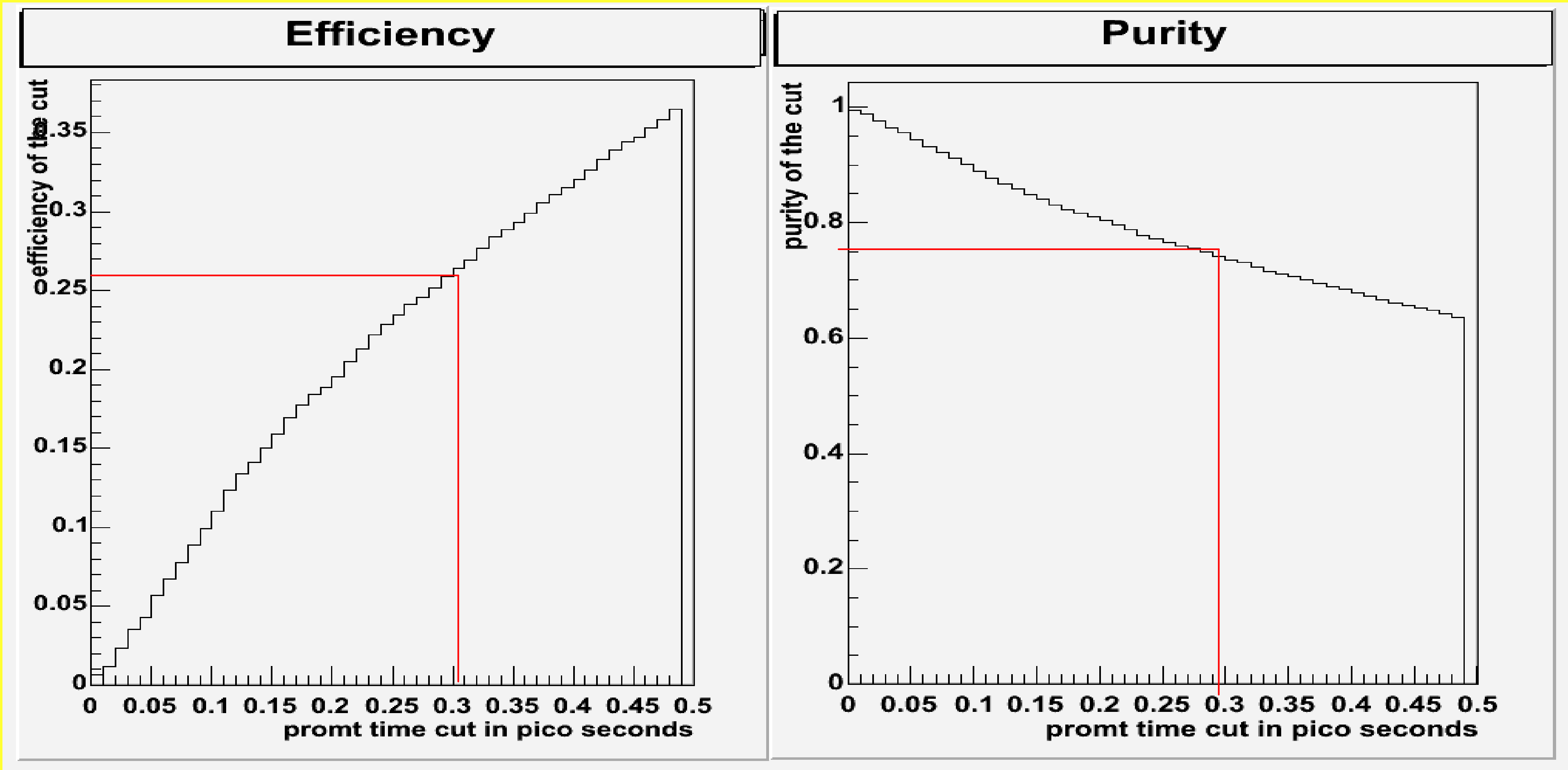
- The displacement of the two-track vertex from the beam line will be used to distinguish between prompt J/Ψ or from B-hadron decays.



Proper time Resolution 0.1 ps

Efficiency and Purity of the proper-time cut

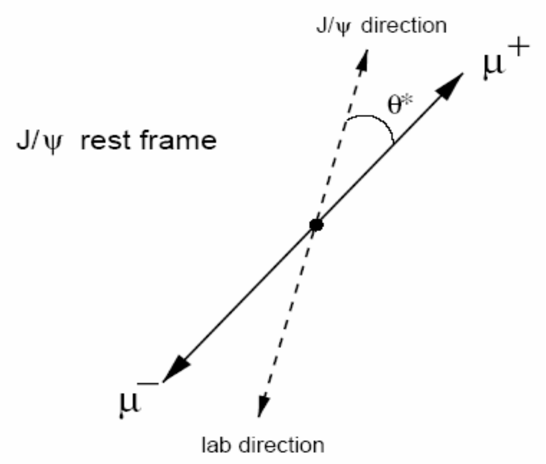
- Selecting events with proper time less than 0.3 ps results in efficiency of 26% and contamination form bb->J/Ψ at a level of 25%.



General method of polarization measurement

- Polarizations can be measured using the angular distribution of the daughter particles produced in the particle decay.
- The decay angle is called θ* and is defined to lie between the direction of muon plus in the J/Ψ rest frame and the J/Ψ direction in the lab frame.

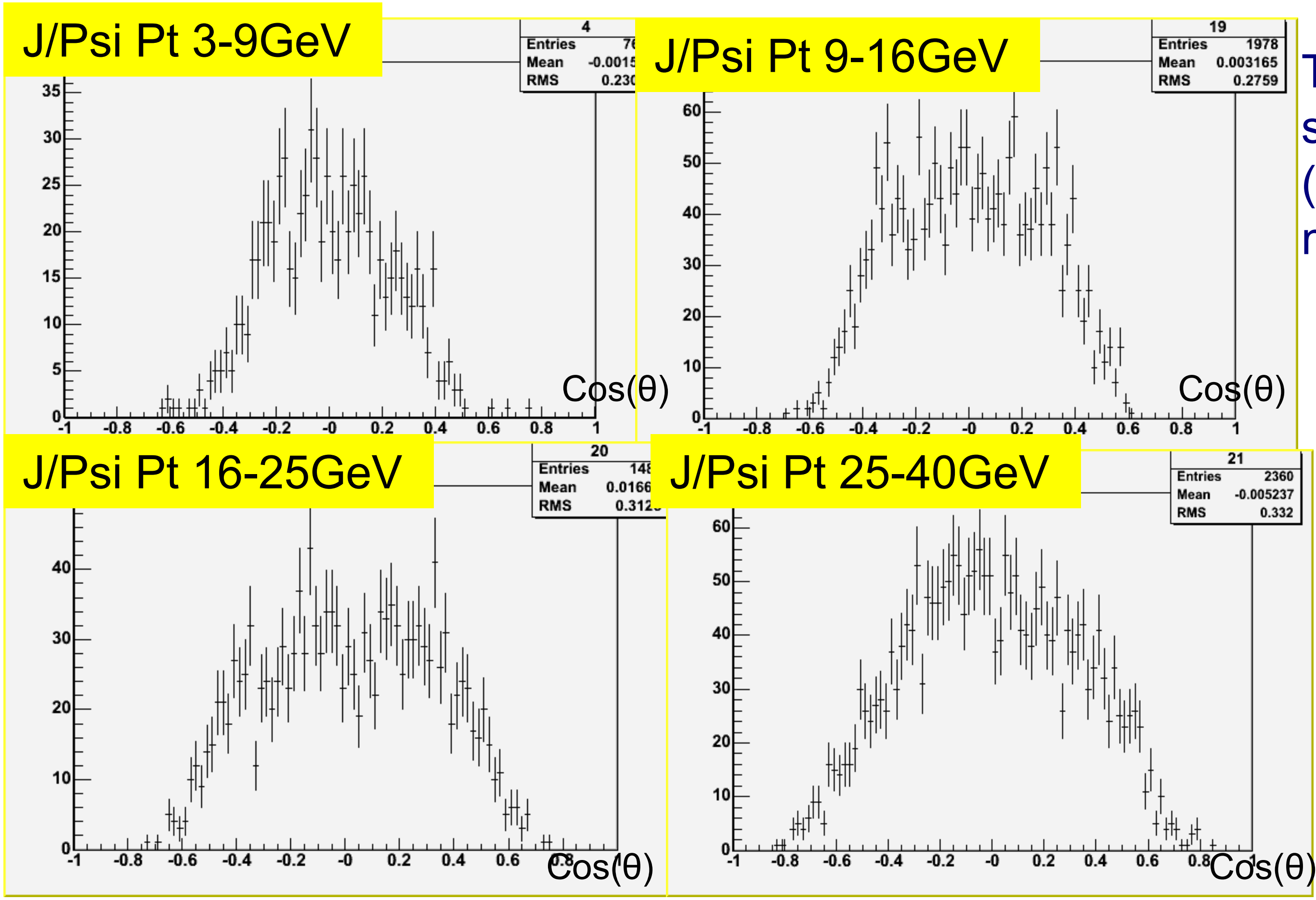
$$d\Gamma / d\cos\theta^* \propto 1 + \alpha\cos^2\theta^*$$



The polarization parameter α, defined as $\alpha = \frac{\sigma_T + 2\sigma_L}{\sigma_T - 2\sigma_L}$, is equal to +1 for transversely polarized production, where transverse polarization refers to helicity ±1. For longitudinal (helicity 0) polarization α is equal to -1. Unpolarized production consists of equal fractions of helicity states +1, 0 and -1, and corresponds to α= 0.

Polarization measurement

- J/Ψ polarizations can be measured applying appropriate fit to the angular distribution of the muons produced in its decay.



The plan is to apply the study in several ranges (bins) of J/Ψ transverse momentum.

Summary

- A simulation study of direct production of J/Ψ in the ATLAS low luminosity runs is shown.
- Although ATLAS is designed to probe the O(1TeV) scale, it can still make some useful measurements in the heavy quarks physics sector.
- The J/Ψ ->di-muons will be one of the main channels in the analysis of the early data to be collected in the experiment.
- The clear signature of this channel enables using it for calibration and alignment of the tracking detectors and algorithms.
- The J/Ψ directly produced at PP collisions will be a main source of background to J/Ψ produced in B hadrons which is a key channel in the B Physics program.
- CDF Run-I and Run-II measurements show some discrepancy between the polarization P_T dependence in the data and theoretical predictions.
- It is shown that ATLAS can improve the precision of this measurement.

END

New Parameters: the NRQCD matrix elements

NRQCD requires **INDIPENDENT** matrix elements: $\left\langle O^{H}[{}^{2S+1}L_J^{(C)}]\right\rangle$

to denote the probability that a $Q\overline{Q}$ pair in a state ${}^{2S+1}L_J^{(C)}$ build up the bound state H.

These matrix elements fullfil the relation due to heavy quark spin symmetry:

$$\left\langle O^{J/\psi}[{}^3S_1^{(1)}]\right\rangle = \frac{3N_C}{2\pi}\left|R(0)\right|^2,$$

$$\left\langle O^{\chi_c}[{}^3P_0^{(1)}]\right\rangle = \frac{3N_C}{2\pi}\left|R'(0)\right|^2.$$

$$\left\langle O^{\chi_{cJ}}[{}^3P_J^{(8)}]\right\rangle = (2J+1)\left\langle O^{J/\psi}[{}^3P_0^{(8)}]\right\rangle,$$

$$\left\langle O^{\chi_{cJ}}[{}^3P_J^{(1)}]\right\rangle = (2J+1)\left\langle O^{\chi_{c0}}[{}^3P_0^{(1)}]\right\rangle.$$