Upsilon Production at D0

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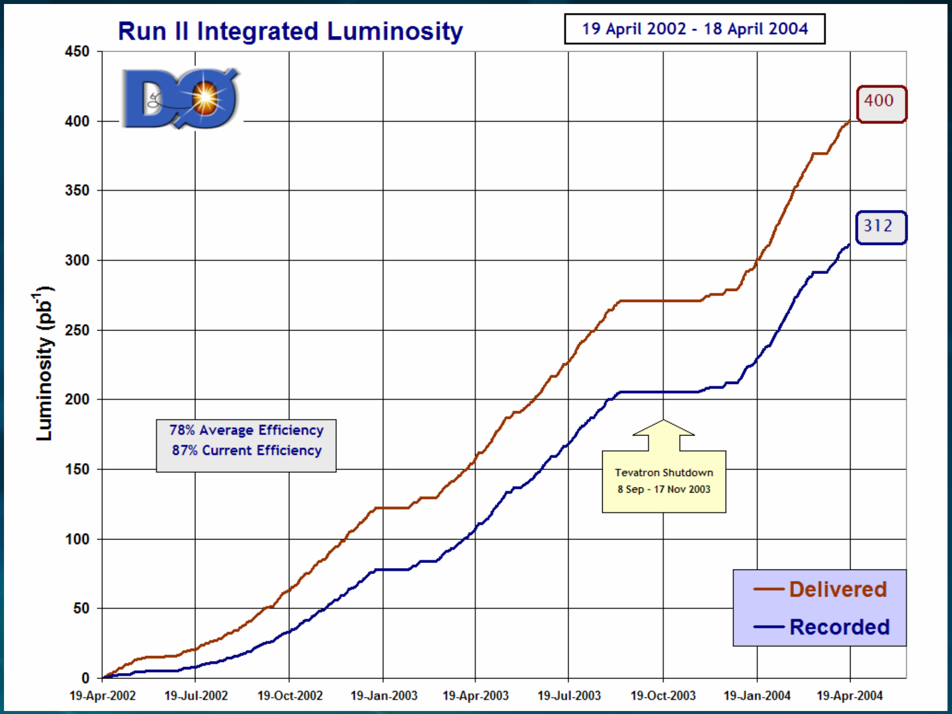
Quick Overview of the Tevatron – The 8am Slide

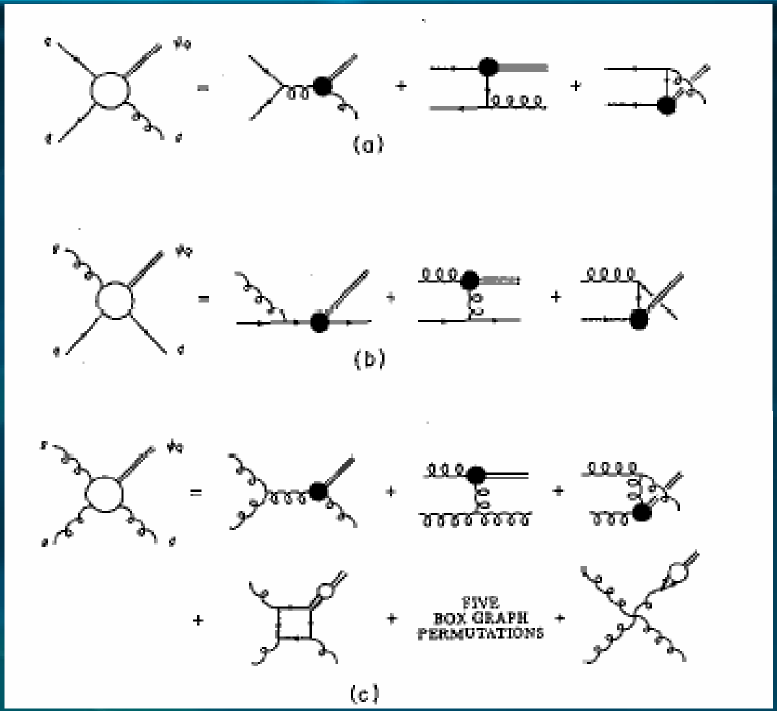


- Upgraded Tevatron is a 1.96 TeV proton anti-proton collider
- A more accurate description would be a multi-bandwidth parton collider

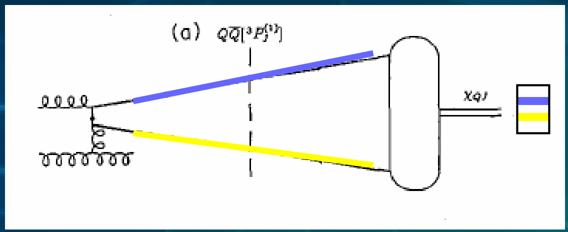
Theoretical Modeling of Upsilon Production – The 8.01 Slide

All production mechanisms are based on factorised (HQET) QCD calculations to order (α_s^3).

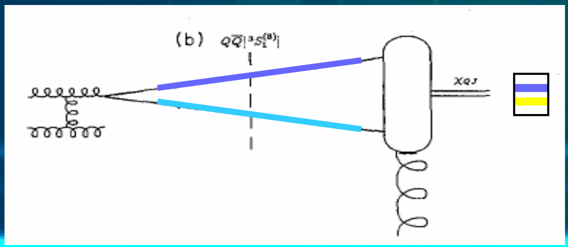
This is what is currently employed in Pythia to model heavy quark production.



Singlet Graph



Octet Graph

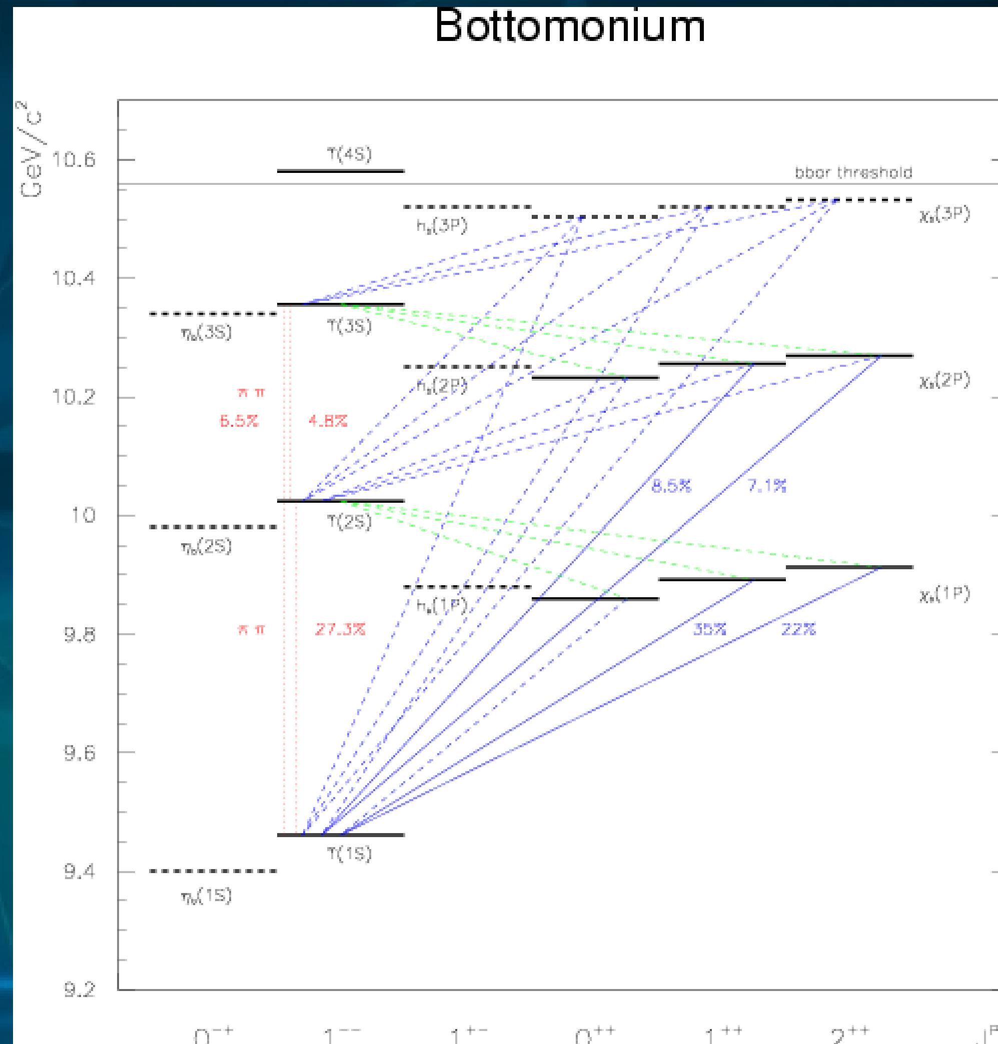


Early modeling of $Q\bar{Q}$ production focused on color singlet $Q\bar{Q}$ production. Drastically unrealistic since soft gluon emission can "de-colour" the quark anti-quark pair. Include Octect interactions !

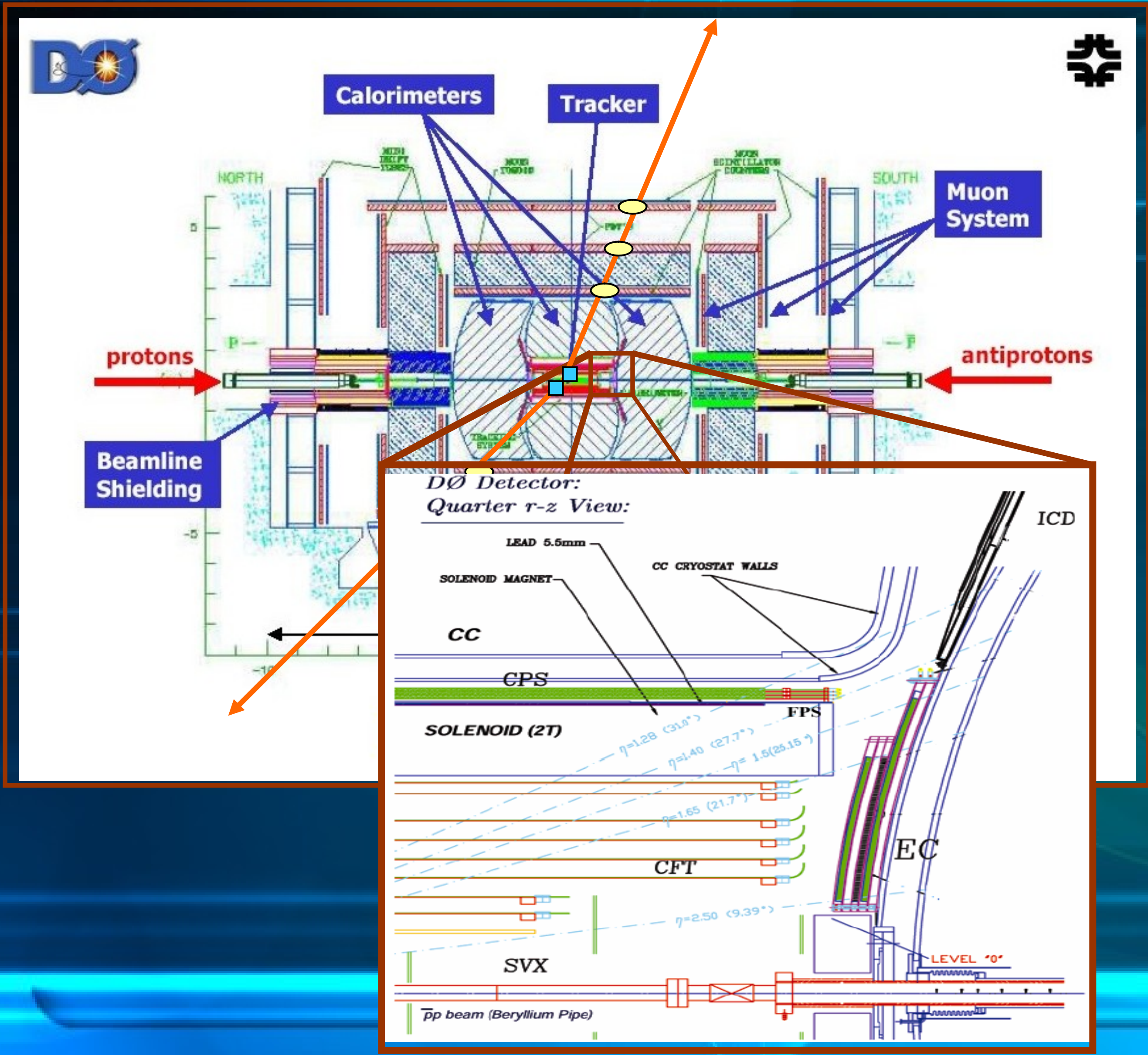
All $b\bar{b}$ states are produced directly at D0, as shown in the previous slide. Virtually none are produced through jet fragmentation.

About 50% of the produced heavy b-flavour states are already in their ground state [$\Upsilon(1S)$].

The other 50% are produced in excited states and decay to the ground state via photon or pion emission.



Selecting the Upsilon Events at D0



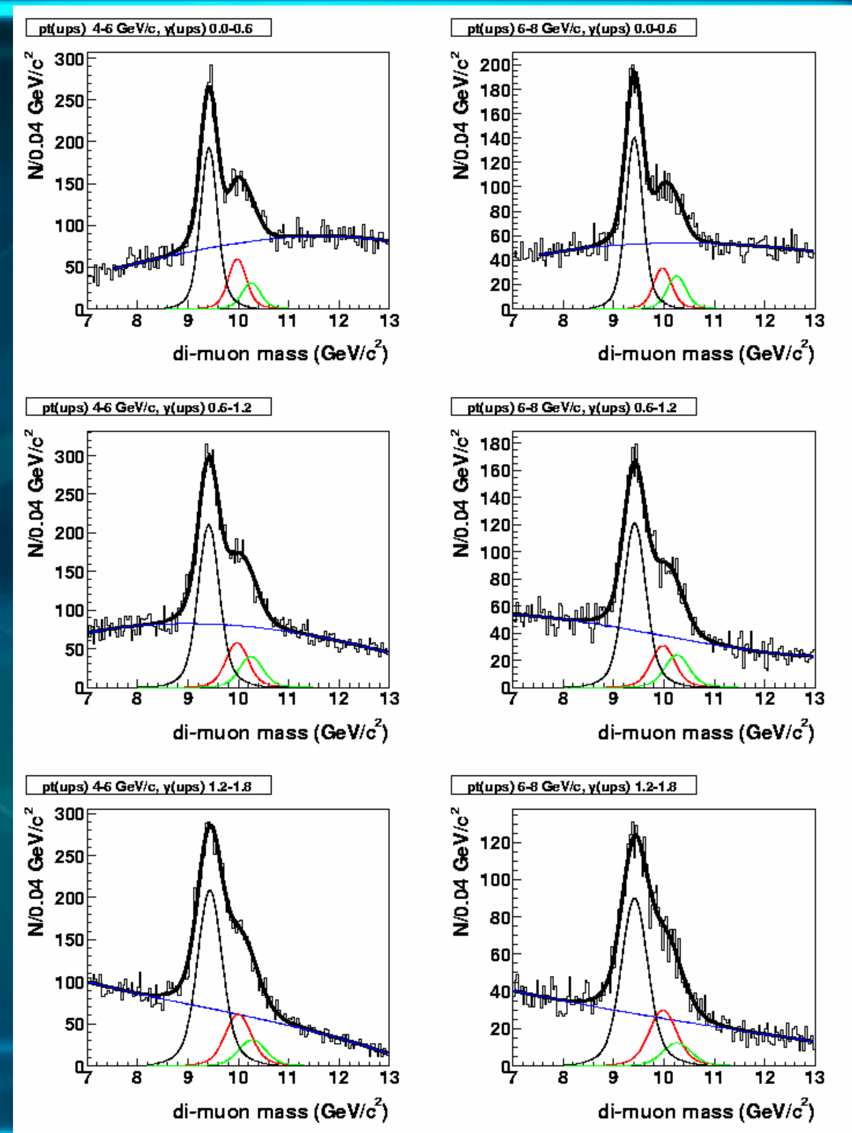
- Muon $p_t > 3$ GeV/c
- $|\eta_{mu}| < 2.2$
- "Loose" isolated muon criteria satisfied.
- Central track match required. Require 1 SMT hit. One isolated.
- Cosmics rejected.

The Upsilon Particle Resonances

In the fits shown, the Upsilon(1,2,3S) resonances are modeled with double gaussians. The second gaussian helps take account of tails where some track has been poorly fit.

The mass of the Upsilon(1S) is a free parameter & the others are fixed relative to it. The width is also free; all other parameters are fixed.

Width of the Gaussians dominated by the central tracking resolution.



Evaluating the Production Cross-Section

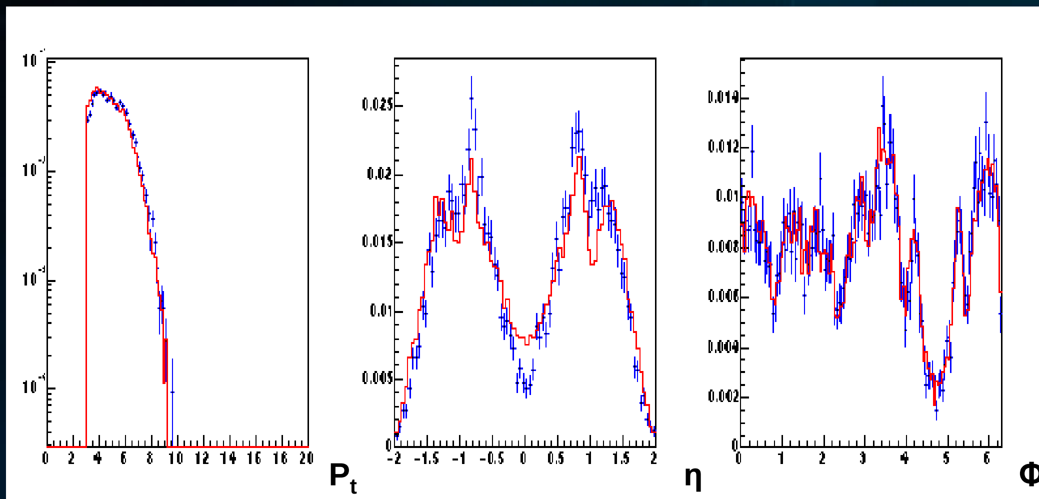
$$\frac{\partial^2\sigma}{\partial p_t \partial y} = \frac{\text{No. of } \Upsilon(1S)}{\mathbf{L} \times \Delta pt \times \Delta y \times \varepsilon_{kin} \times \varepsilon_{acc} \times \varepsilon_{trig} \times \varepsilon^R_{muTrig} \times \varepsilon^R_{isoSMT} \times \varepsilon^R_{trk}}$$

$\varepsilon_{kin} \times \varepsilon_{acc}$ — This is the efficiency after all cuts have been applied (nb. doesn't include trigger efficiency) and is evaluated using the full D0 Monte Carlo simulation.

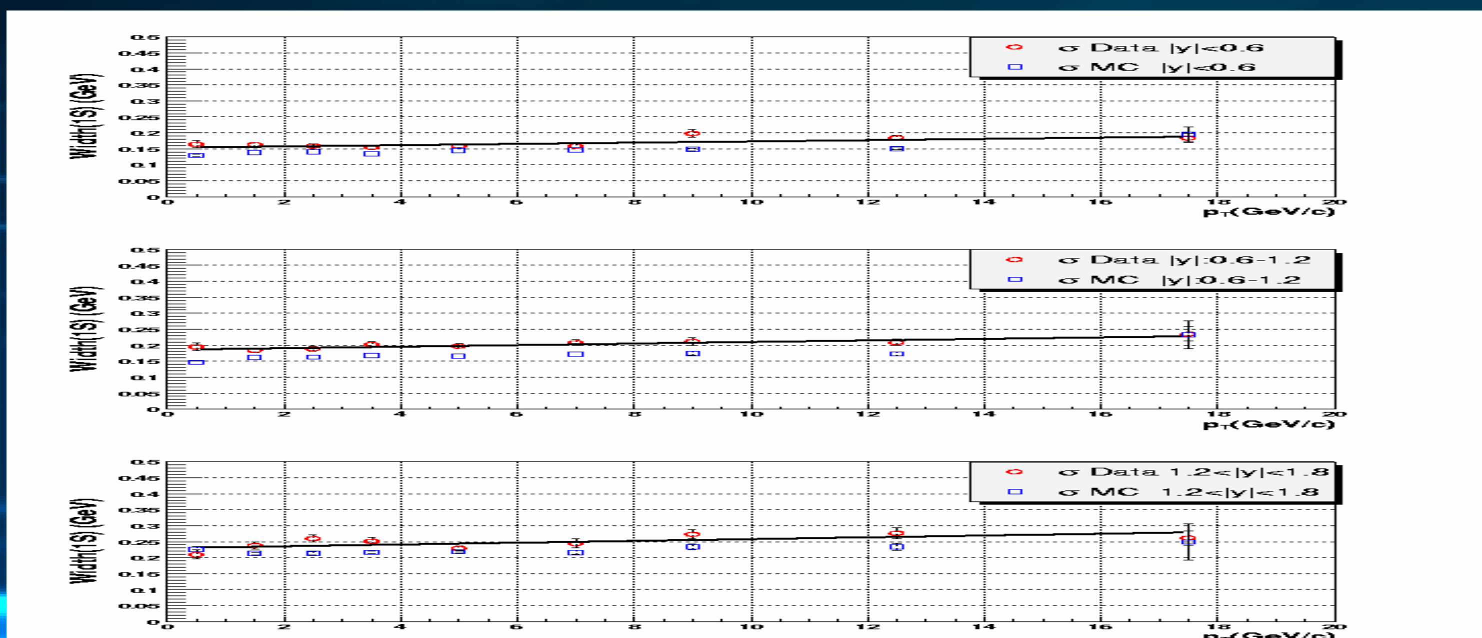
ε_{trig} — The trigger efficiency is evaluated using MC and data as a cross-check and is calculated with respect to the efficiency shown above.

$\varepsilon^R_{muTrig} \times \varepsilon^R_{isoSMT} \times \varepsilon^R_{trk}$ — The last three bits are correction factors and are in effect the ratios of data & MC efficiencies (to account for residual data-MC differences).

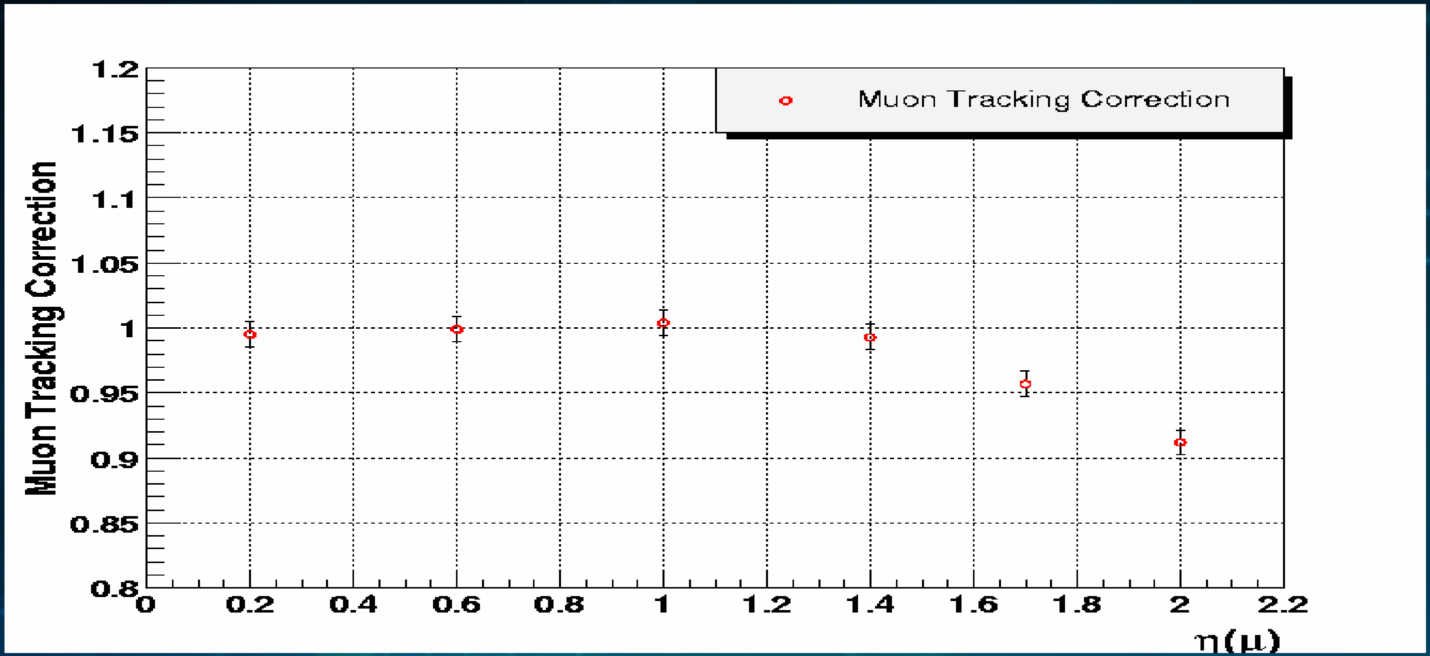
Comparisons Between Simulation & Data



Given that the acceptance and kinematic efficiency is determined by the Monte Carlo it is essential to have a reasonably good agreement between Data and MC.



Corrections Related to the Tracking System



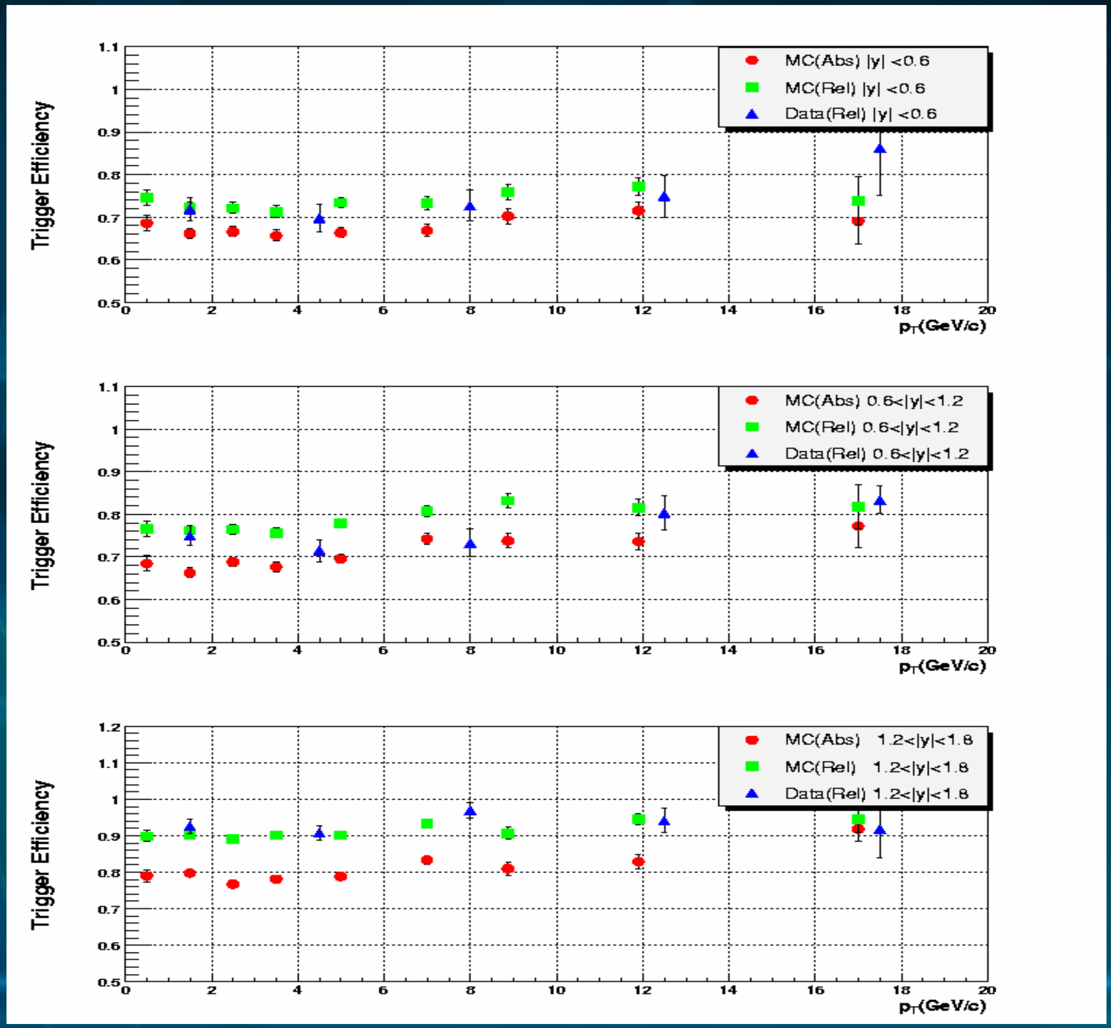
Method:
Reconstruct J/ψ using *global* (i.e. muons matched to a track in the central tracking system) and *local* (i.e. muons that are only reconstructed in the muon system and not matched to a central track) muons.

$$\text{Efficiency} = \frac{N_{J/\psi}(\text{global \& global})}{N_{J/\psi}(\text{global \& local}) + N_{J/\psi}(\text{global \& global})}$$

Corrections Related to the Trigger Efficiency

The absolute trigger efficiency is measured using MC and the integrity of the MC is cross-checked using data.

The relative efficiency is measured in data by comparing complementary triggers (ie. comparing L1-only monitor triggers, single to double muon triggers).



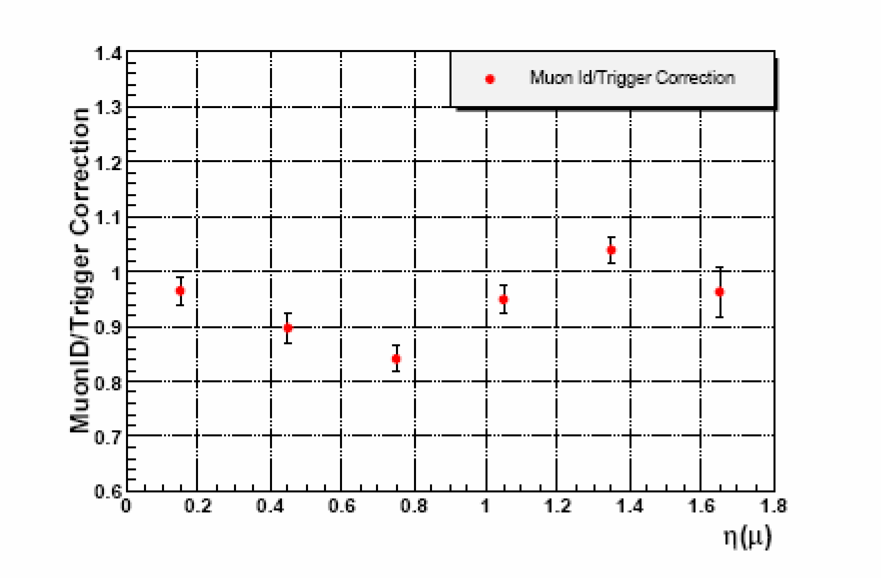
Corrections Related to the Local Muon ID

Use a sample selected using a single muon + di-track trigger to minimise the bias.

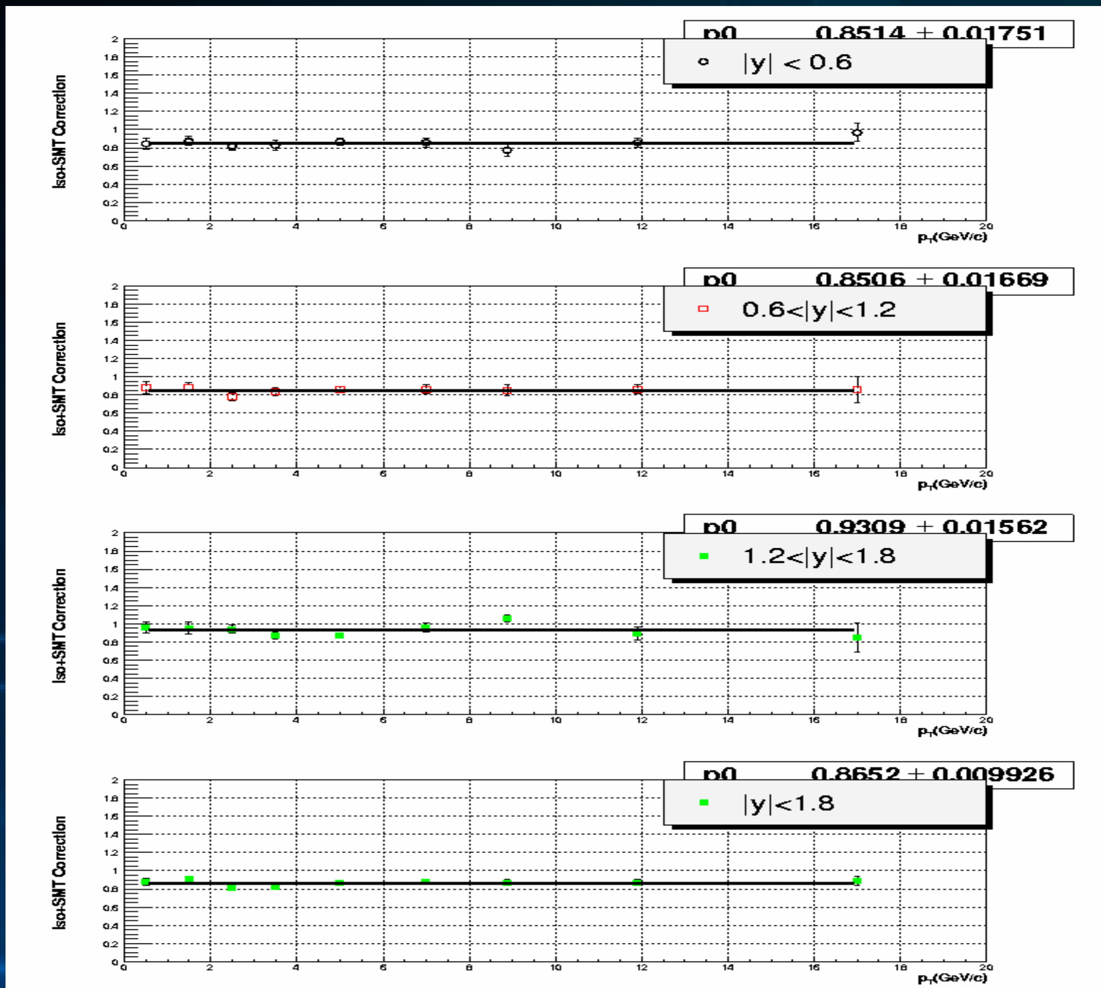
The relative local muon id efficiency for this sample was evaluated :-

E = Events with 2 x muon / Events with muon + track

(where all the events were within the Upsilon(1S) fit region)



Corrections Related to the Isolation & Silicon Vertex Cuts



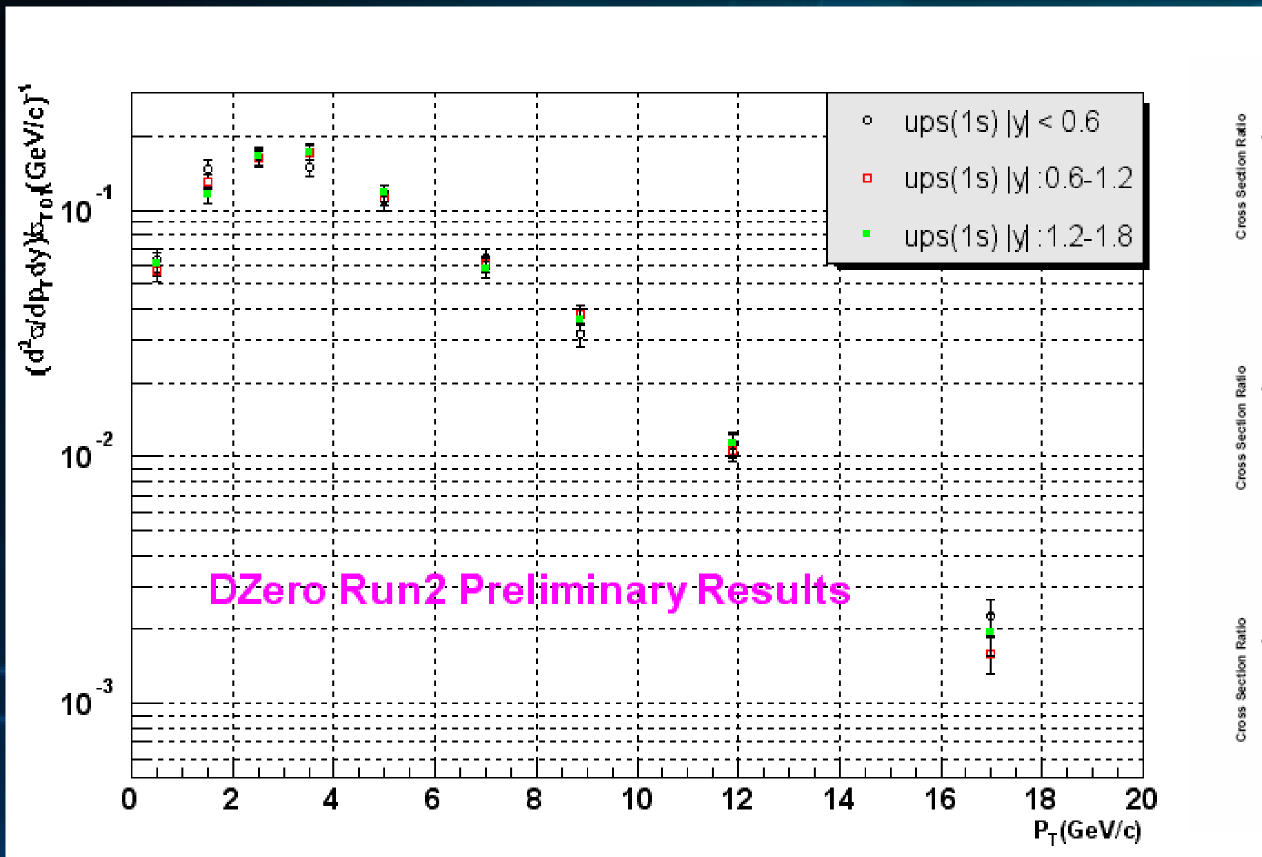
The MC estimates that the efficiency of the combined isolation and SMT cuts is pretty much 100%.

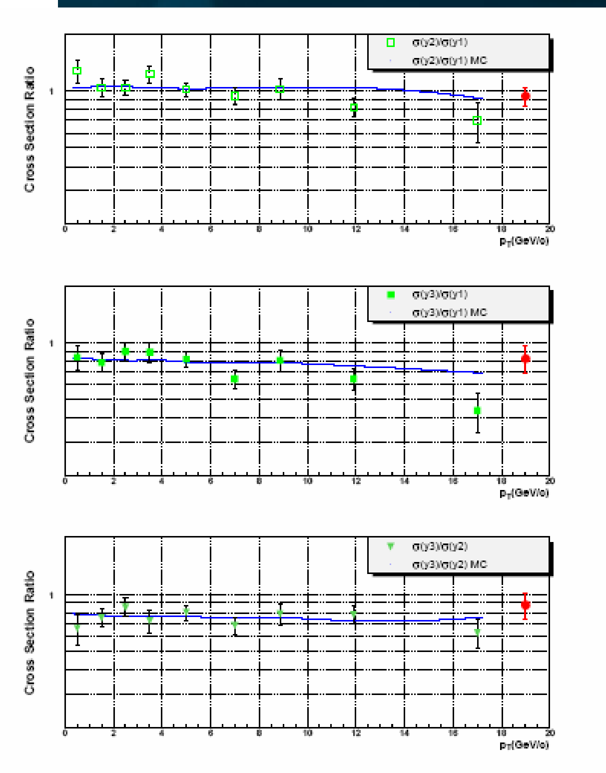
In contrast after taking the ratio in data :-

No. Upsilon(1S) w cuts/
No. Upsilon(1S) w/o cuts

we find these remove some 10% of the signal.

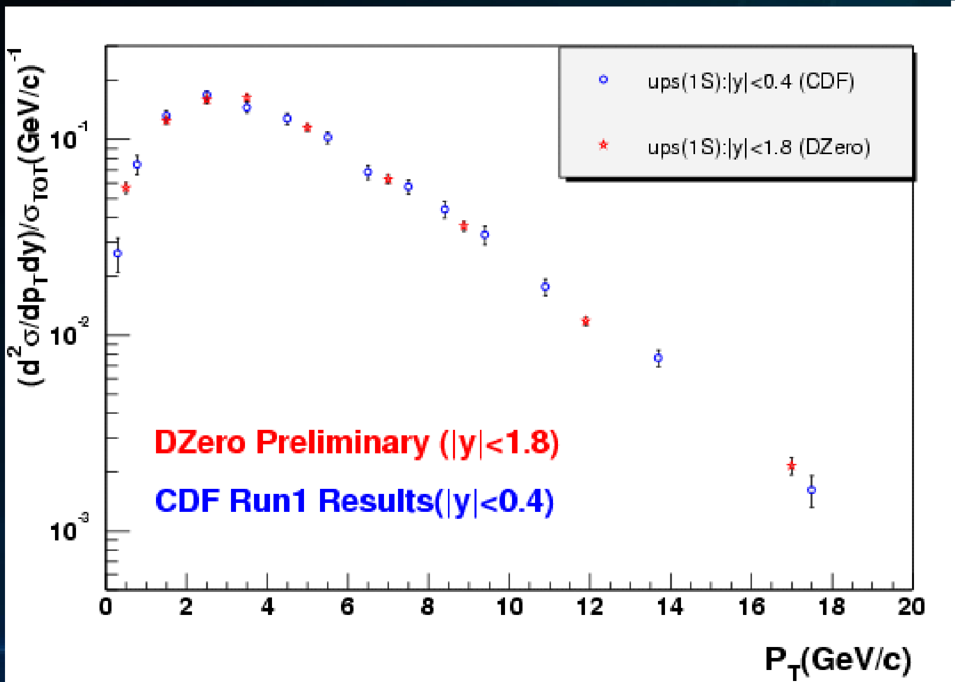
The Production Spectrum and Comparison to Pythia

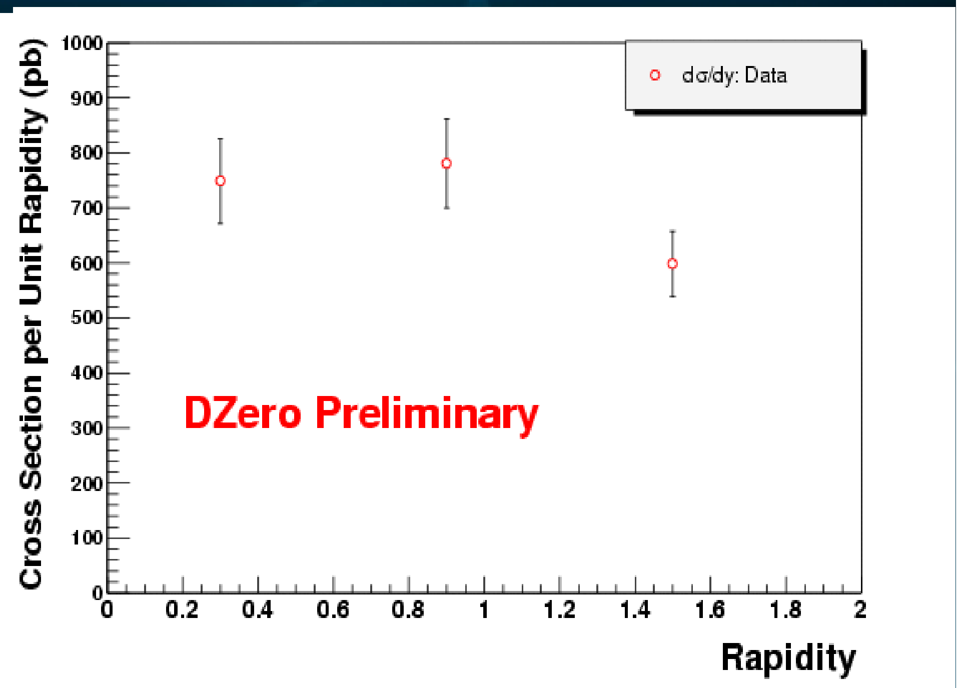




- No strong dependence on rapidity observed.
- Pythia models the production ratios well.

The Absolute Cross-section at D0





- D0 Run II measurement shows similar pt spectrum as the CDF Run I result (would not expect to see strong deviation despite increase in CMS).
- Absolute cross-sections don't show statistically significant deviation with respect to rapidity.

Systematic Errors on the Calculation

$\lvert y^{\Upsilon} \rvert$	0.0-0.6	0.6-1.2	1.2-1.8
Luminosity	6.5	6.5	6.5
Fitting procedure	3.0	4.0	4.0
Isolation+SMT cuts	2.0	2.0	1.7
MC kinematic properties	3.0	3.0	3.0
Momentum resolution	<1.0	<1.0	<1.0
Central Track matching	2.0	2.0	3.0
Muon ID and trigger	8.7	8.2	7.2
Detector performance vs time	2.0	2.0	2.0
Total (no lum, polar)	10.0 %	10.0 %	9.4 %

Summary & Conclusion

These results are based on an integrated Luminosity of 159 pb^{-1} taken during 2003.

These are the first measurements of Upsilon production at D0 and utilise the new tracking & upgraded muon system at D0. Allows a measurement with the Upsilon rapidity range extended to 1.8

The pt spectrum does not show significant difference in the various rapidity regions. The shape is commensurate with CDF's Run-I results.