$\Upsilon(1S)$ Production at DØ

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Why measure $\Upsilon(1S)$ at DØ ?

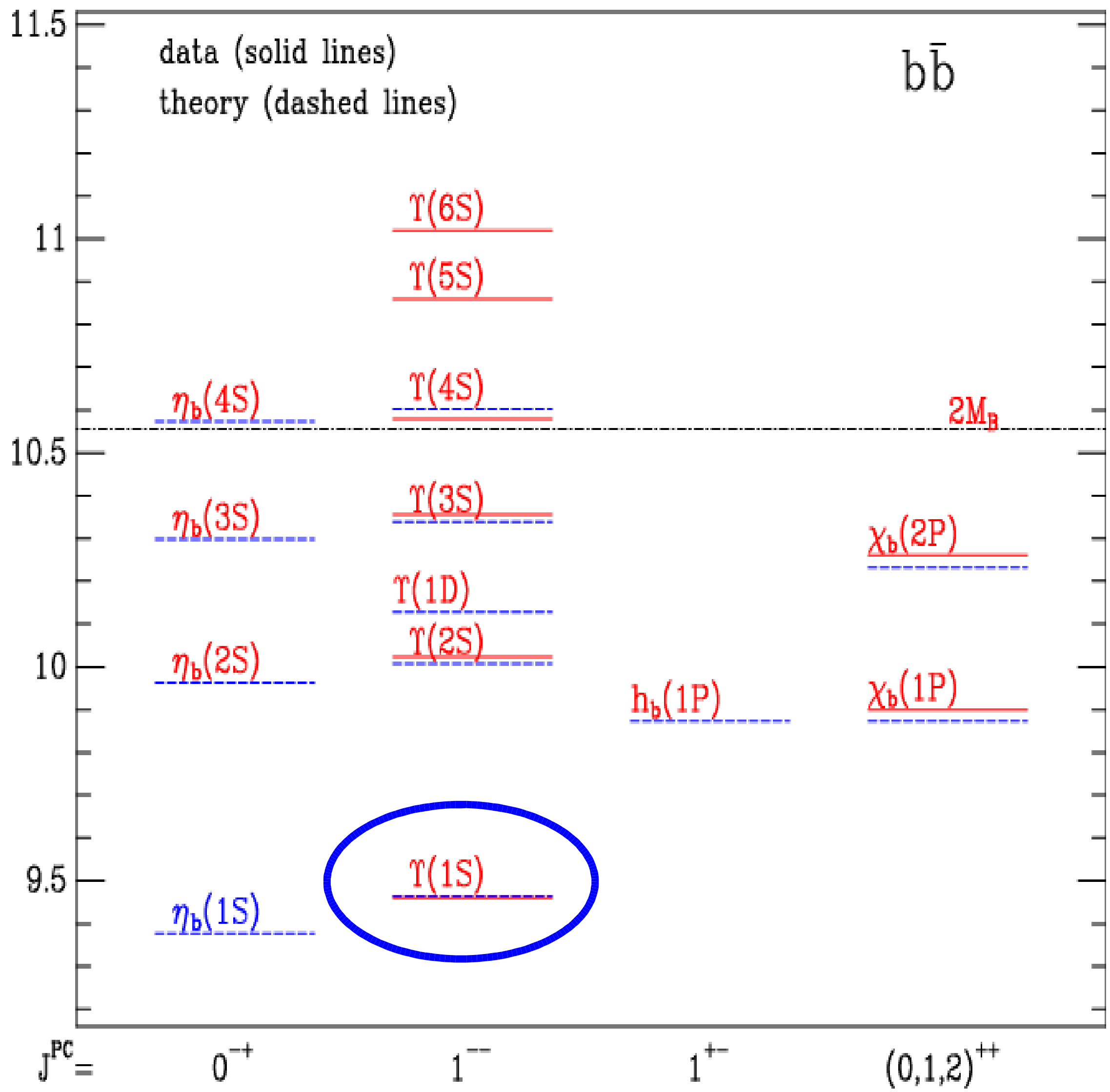
- Measuring the $\Upsilon(1S)$ production cross-section provides an ideal testing ground for our understanding of the production mechanisms of heavy quarks.

- The $\Upsilon(1S)$ cross-section had been measured at the Tevatron (Run I measurement by CDF) up to a rapidity of 0.4.
  DØ aims to measure this cross-section up to a rapidity of 1.8.

- The color octet model predicts an increase in transverse polarization with increasing p_t.
  Measurements so far have been inconclusive.

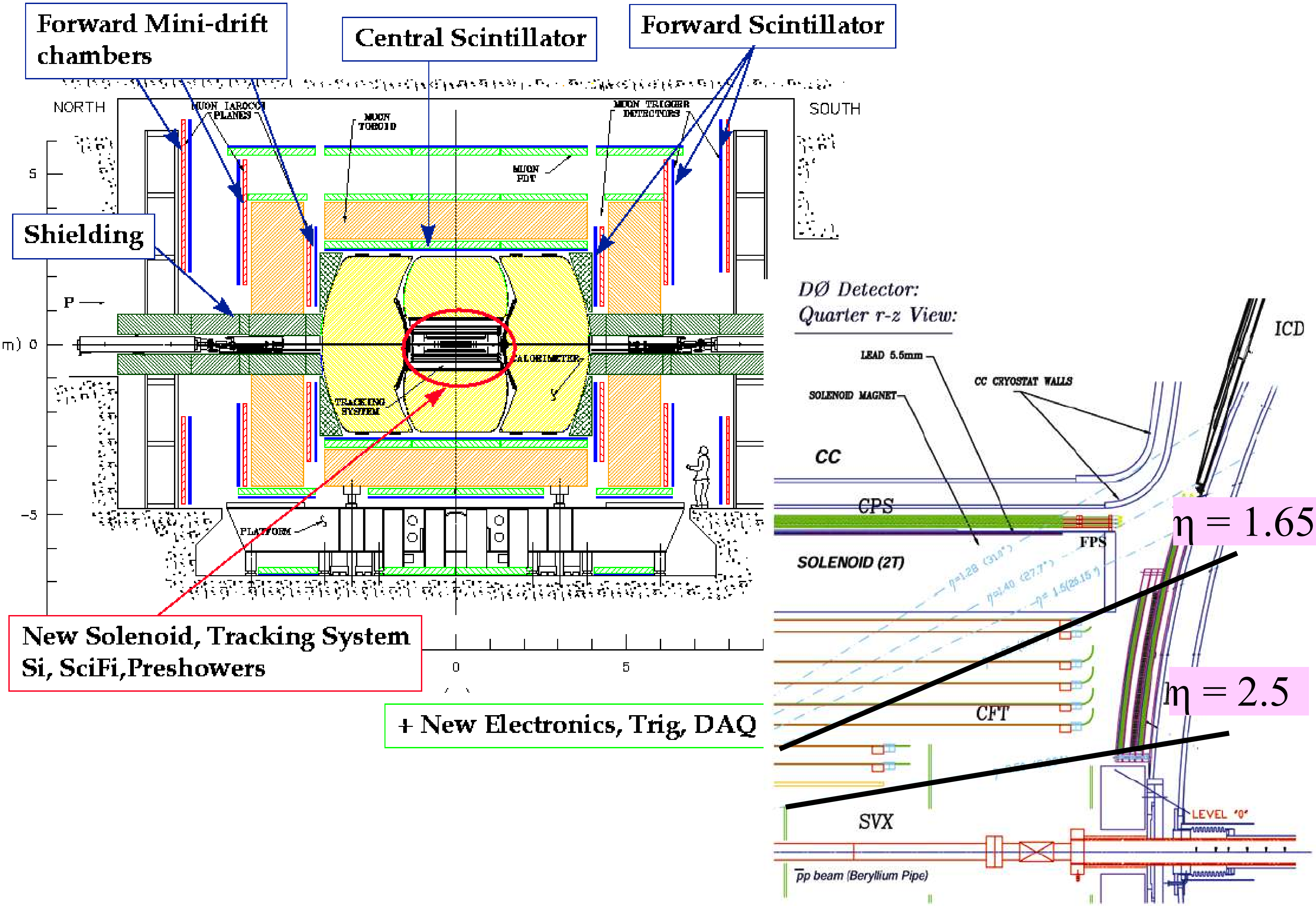
Where do the $\Upsilon(1S)$ come from ?

- All Bottomonium States are produced directly.
- ~ 50 % of $\Upsilon(1S)$ are produced directly.
- The rest are the result of higher mass states decaying.

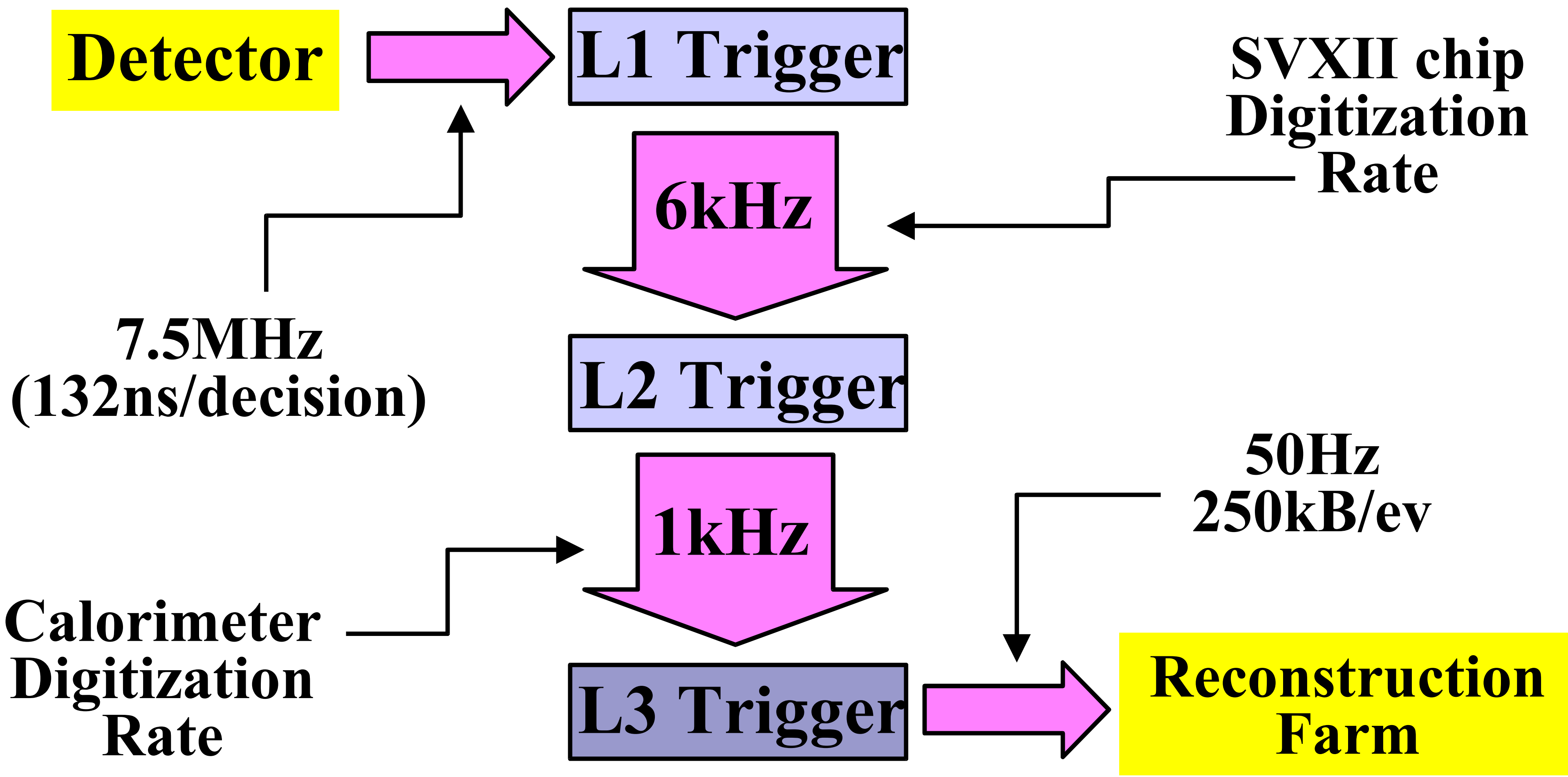


Bottomonium States

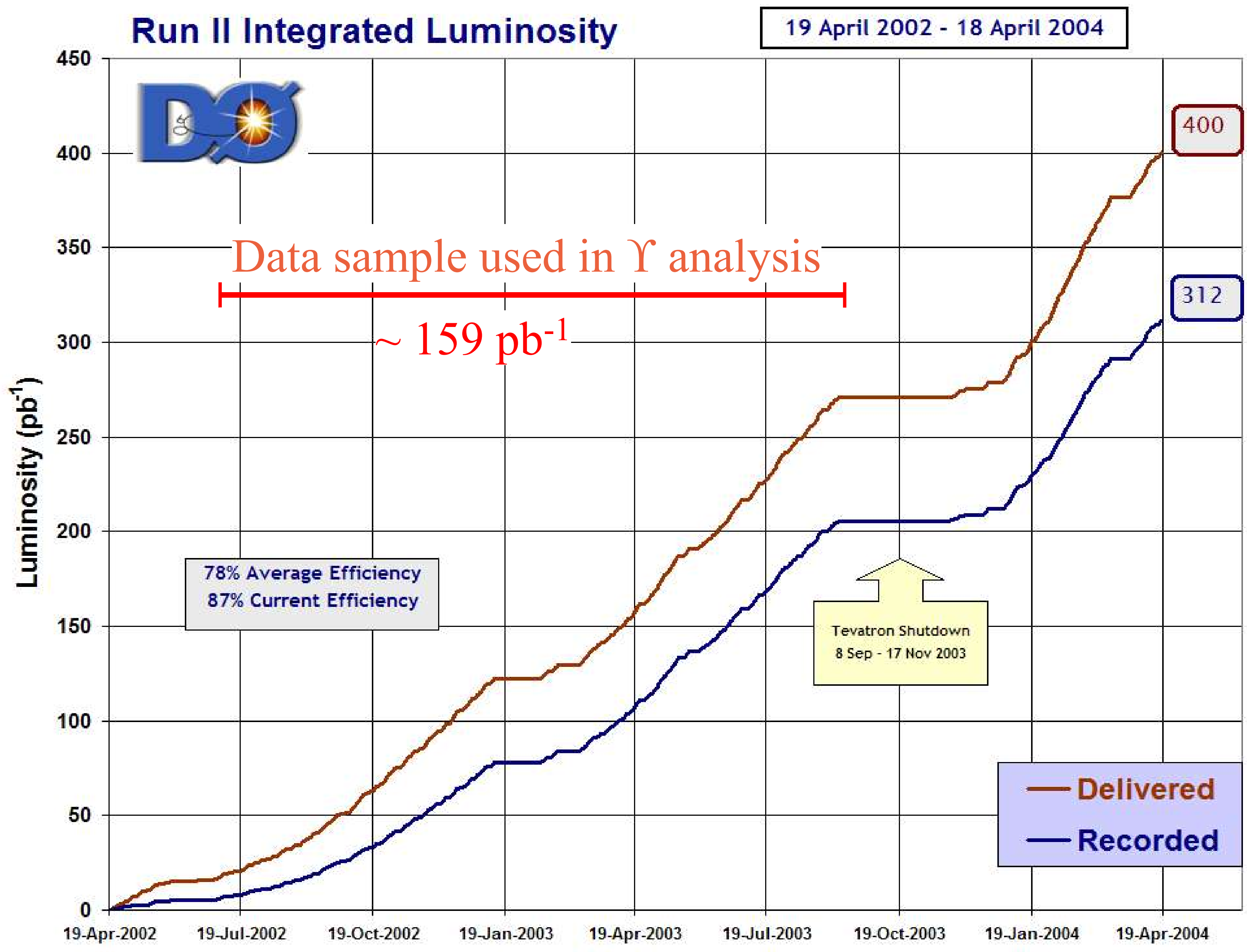
The upgraded DØ Detector



The DØ trigger system



DØ luminosity



The Analysis

Goal:

Measuring the Υ**(1*S*)** cross-section in the channel $\Upsilon(1S) \rightarrow \mu^+\mu^-$ as a function of p_t in three rapidity ranges:

$0 < |\, y^{\Upsilon}| < 0.6$, $0.6 < |\, y^{\Upsilon}| < 1.2$ and $1.2 < |\, y^{\Upsilon}| < 1.8$

Sample selection:

- Opposite sign muons
- Muon have hits in all three layers of the muon system
- Muons are matched to a track in the central tracking system
- $p_t\,(\mu) > 3$ GeV and $|\eta\,(\mu)| < 2.2$
- At least one isolated muon
- Track from central tracking system must have at least one hit in the Silicon Tracker

The signal

Signal: 3 Gaussians: $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$

Background: 3rd order polynomial

Fitting a single Gaussian recovers ~95 % of the signal.

$m(\Upsilon(2/3S)) = m(\Upsilon(1S)) + \Delta m_{PDG}(\Upsilon(2/3S)\text{-}\Upsilon(1S))$

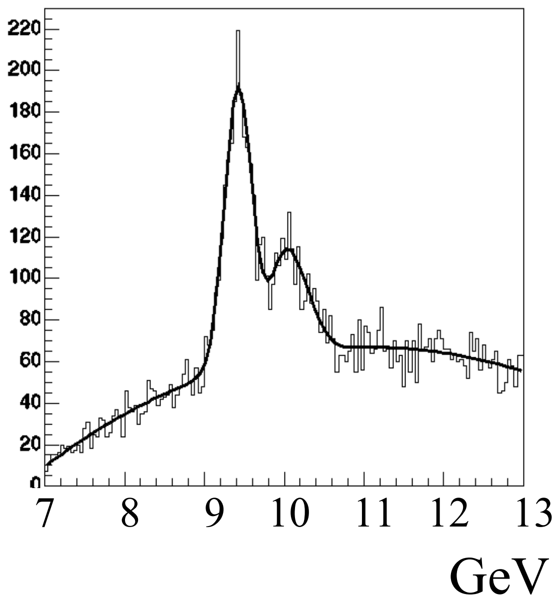
$\sigma(\Upsilon(2/3S)) = \sigma(\Upsilon(1S)) + m\Upsilon(2/3S)/m(\Upsilon(1S)) * \sigma(\Upsilon(1S))$

$\rightarrow$ 5 free parameters in signal fit: **m**$(\Upsilon(1S))$, **σ**$(\Upsilon(1S))$, **c**$(\Upsilon(1S))$, **c**$(\Upsilon(2S))$, **c**$(\Upsilon(3S))$

All plots: 3 GeV < $p_t(\Upsilon)$ < 4 GeV

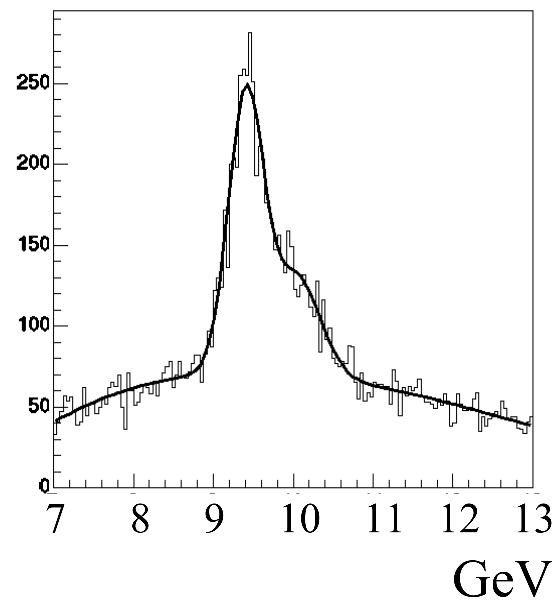
PDG: $m(\Upsilon(1S))$ = 9.46 GeV

$m(\Upsilon)$ = 9.423 ± 0.008 GeV



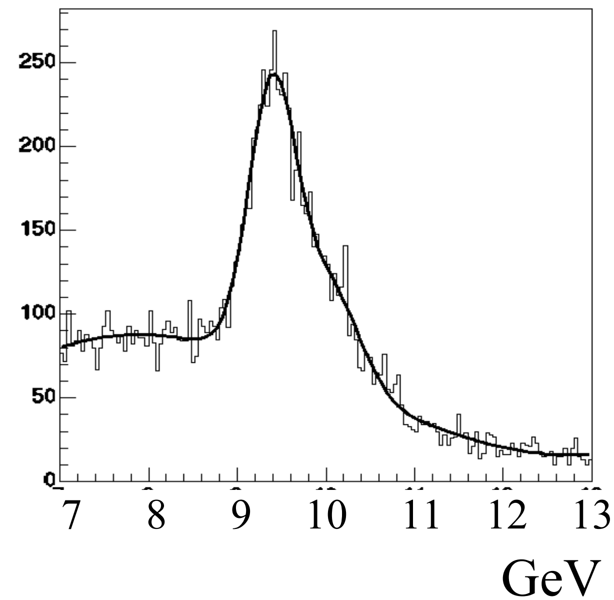
$0 < |y^{\Upsilon}| < 0.6$

$m(\Upsilon)$ = 9.415± 0.009 GeV



$0.6 < |y^{\Upsilon}| < 1.2$

$m(\Upsilon)$ = 9.403 ± 0.013 GeV

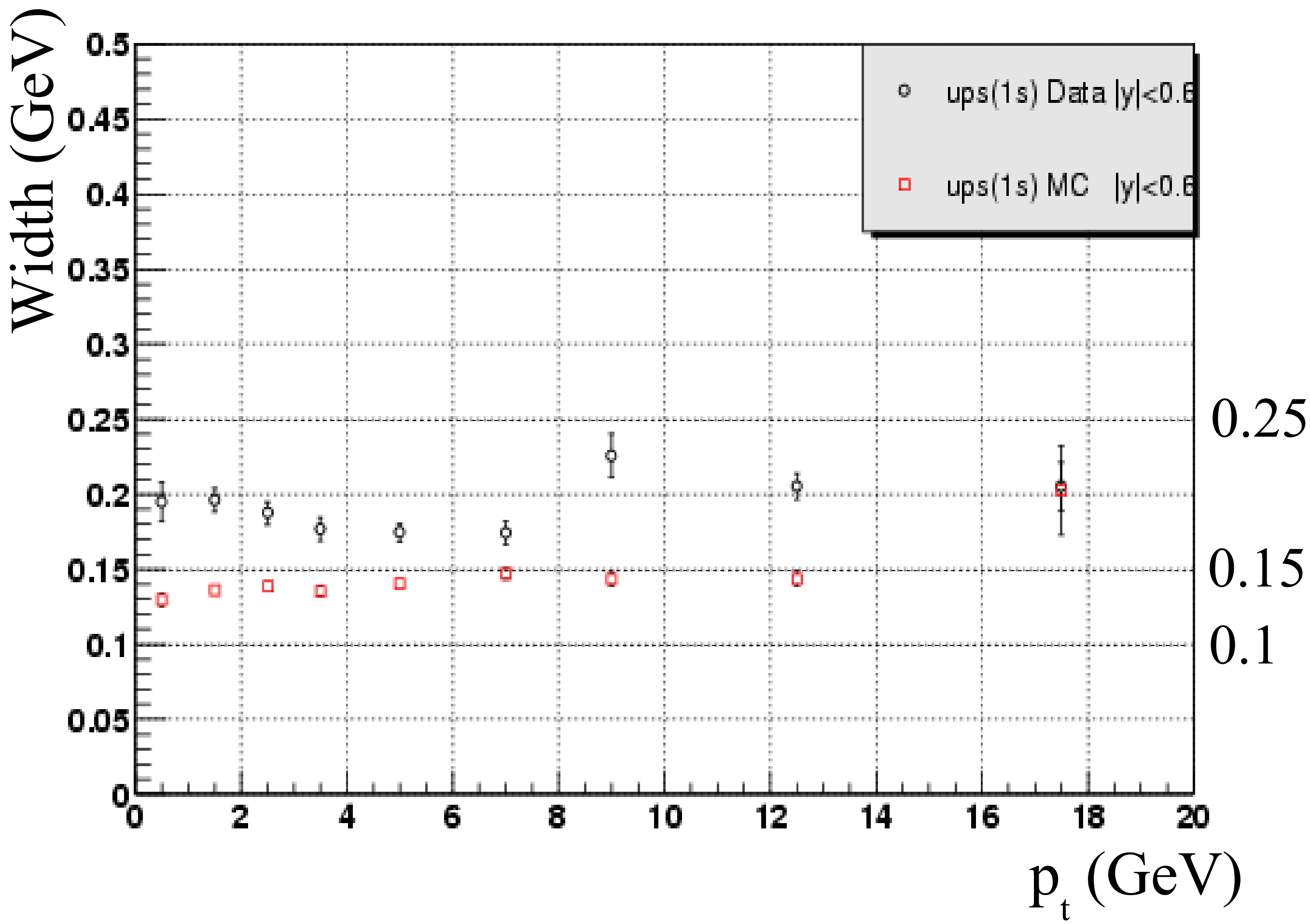


$1.2 < |y^{\Upsilon}| < 1.8$

Width from fit for $\Upsilon(1S)$ with $|y^{\Upsilon}| < 0.6$

○ Data

□ MC



$\sim$ 43000 $\Upsilon(1S)$ candidates

$\Upsilon(1S)$ Cross-section

$$\frac{d^2\sigma(\Upsilon(1S))}{dp_t \times dy} = \frac{N(\Upsilon)}{L \times \Delta p_t \times \Delta y \times \varepsilon_{kinem} \times \varepsilon_{acc} \times \varepsilon_{trig} \times \varepsilon_{muid} \times \varepsilon_{trk} \times \varepsilon_{fit} \times \varepsilon_{iso\text{-}smt}}$$

luminosity L

rapidity $y = \frac{1}{2} \ln [(E+p_z)/(E-p_z)]$

ε_{kinem} Muons that will not reach the muon system are removed after the generator stage ($p_t(\mu) > 1.8$ GeV and $|y(\mu)| < 2.2$). Determined from Monte Carlo without trigger condition.

ε_{acc} Fraction of Υ that pass the kinematic cuts and are reconstructed. Determined from Monte Carlo.

ε_{trig} Trigger efficiency (Level1 and Level2). From data and Monte Carlo.

Upsilon cross-section continued

$$\frac{d^2\sigma(\Upsilon(1S))}{dp_t \times dy} = \frac{N(\Upsilon)}{L \times \Delta p_t \times \Delta y \times \varepsilon_{kinem} \times \varepsilon_{acc} \times \varepsilon_{trig} \times \varepsilon_{muid} \times \varepsilon_{trk} \times \varepsilon_{fit} \times \varepsilon_{iso\text{-}smt}}$$

ε_{muid} Correction to account for differences between data and MC in the *local* (i.e. muon system only) muon reconstruction.

ε_{trk} Correction to account for differences between data and MC in the efficiency to match *local* tracks in the muon system to tracks in the *central* tracking system. This includes the tracking efficiency for muons in the central tracking system.

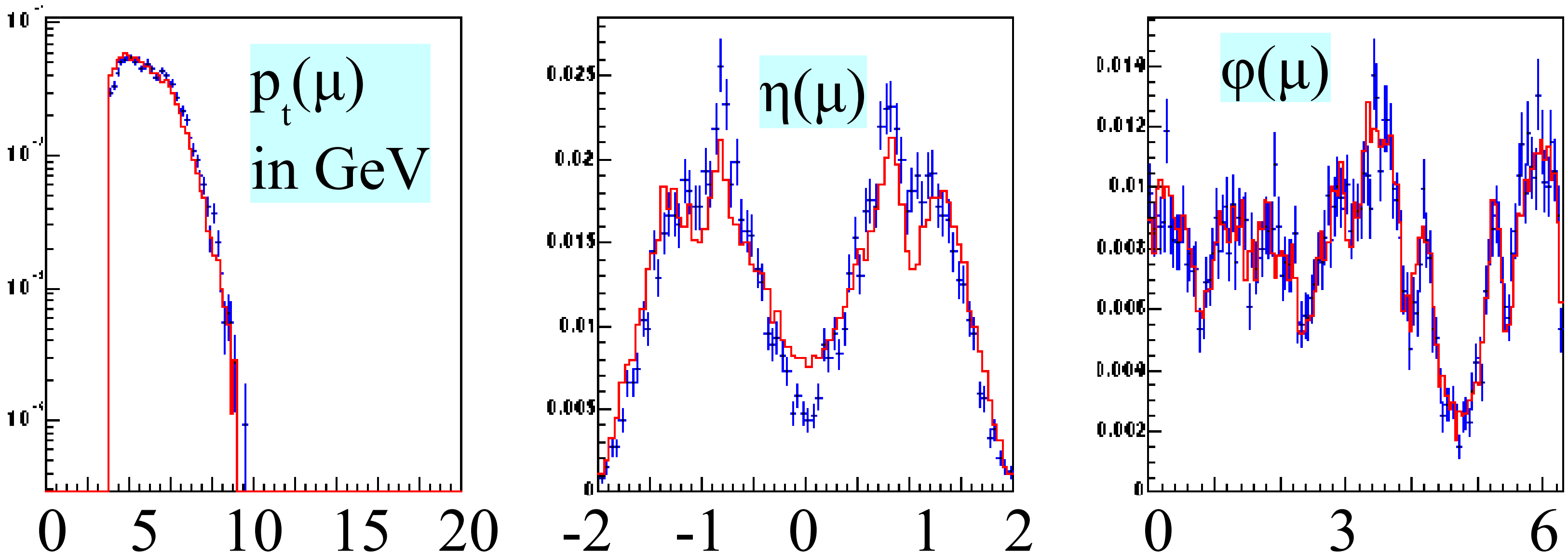
$\varepsilon_{iso\text{-}smt}$ Correction to account for differences between data and MC regarding track isolation and Silicon hit requirement.

ε_{fit} To account for losses due to a single Gaussian fit to model the $\Upsilon(1S)$ mass resolution.

Efficiencies from Monte Carlo

$0.6 < |y(\Upsilon)| < 1.2$

— MC
— Data*



*9.0 GeV $< m(\mu\mu) <$ 9.8 GeV

$\lvert y^{\Upsilon}\rvert$	ε_{kinem}	ε_{acc}
0.0 – 0.6	0.8 – 0.9	0.25 – 0.4
0.6 – 1.2	0.8 – 0.9	0.25 – 0.4
1.2 – 1.8	0.7 – 0.75	0.25 – 0.4

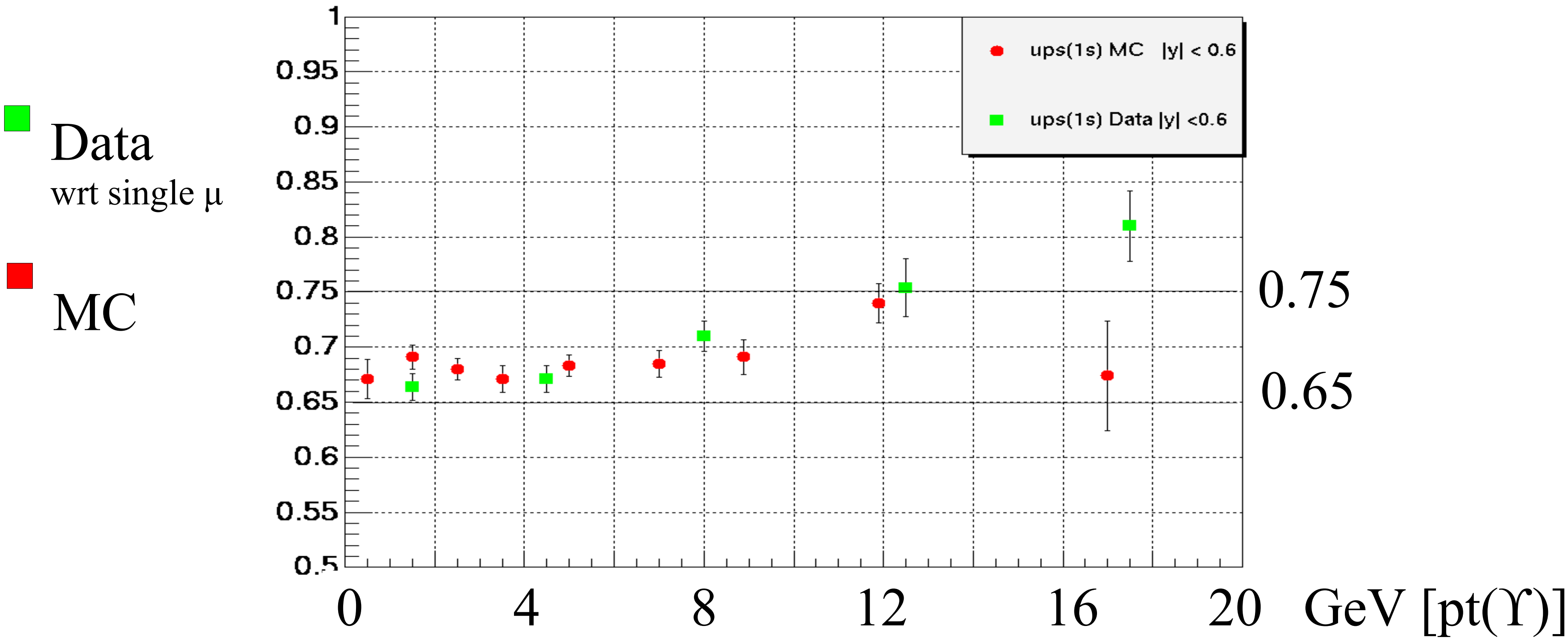
Trigger

Level 1: di-muon trigger, scintillator only
Level 2: one medium muon (early runs)
two muons, at least one medium, separated in eta and phi (later runs)

Both triggers at Level 2 are ~ 97 % efficient wrt Level 1 condition.

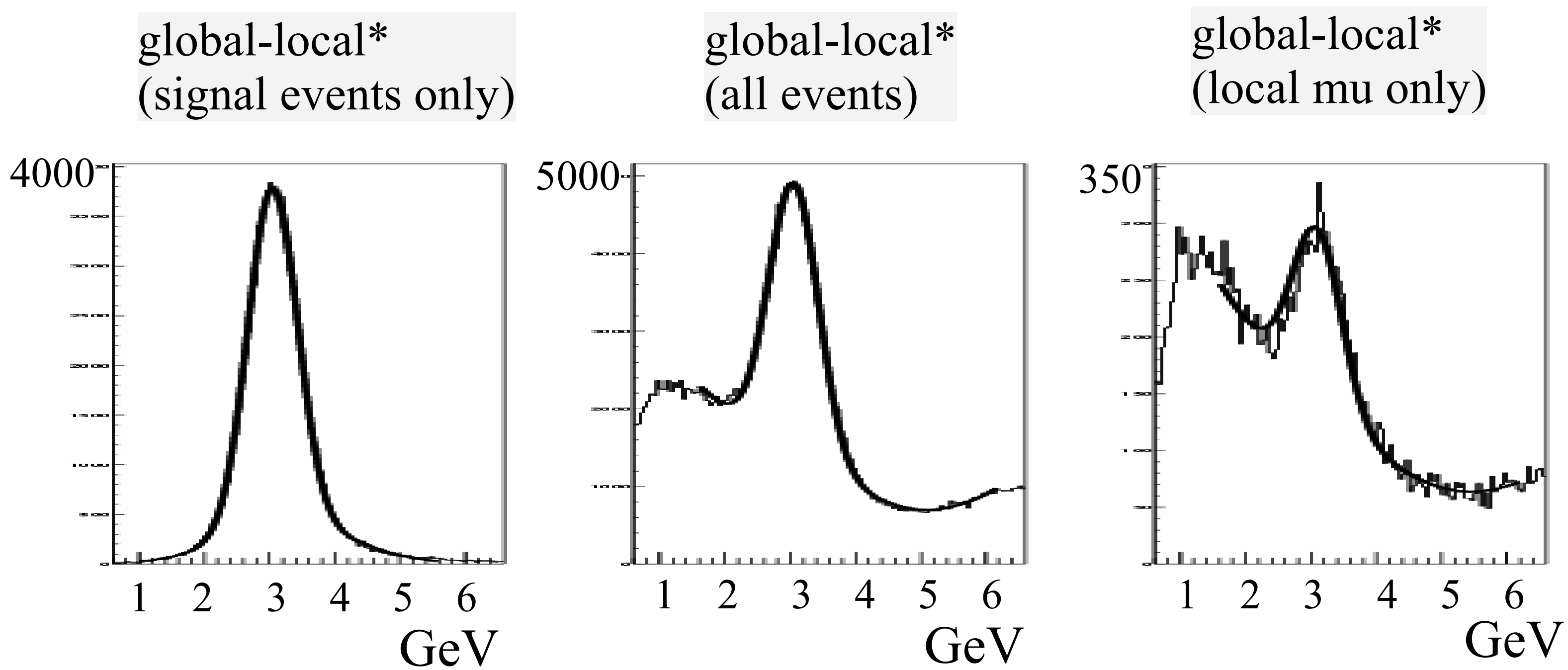
Trigger efficiency for fully reconstructed di-muon events:
central region: 65 %
forward region: 80 %

Trigger efficiency $|y(\Upsilon)| < 0.6$



Corrections: Tracking efficiency

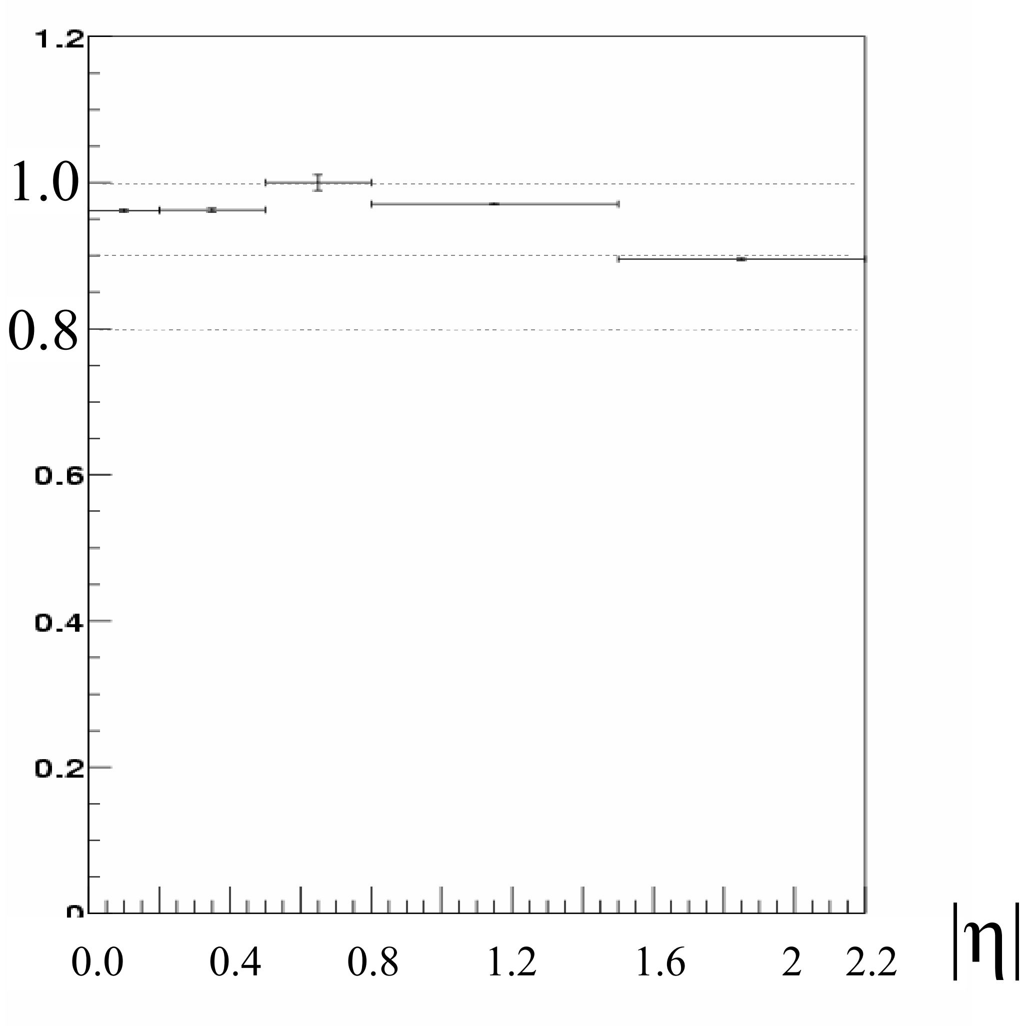
Method:
Reconstruct J/ψ using *global* (i.e. muons matched to a track in the central tracking system) and *local* (i.e. muons that are only reconstructed in the muon system and not matched to a central track) muons.



* i.e. the local momentum of the test muon is used, whether is was matched or not.

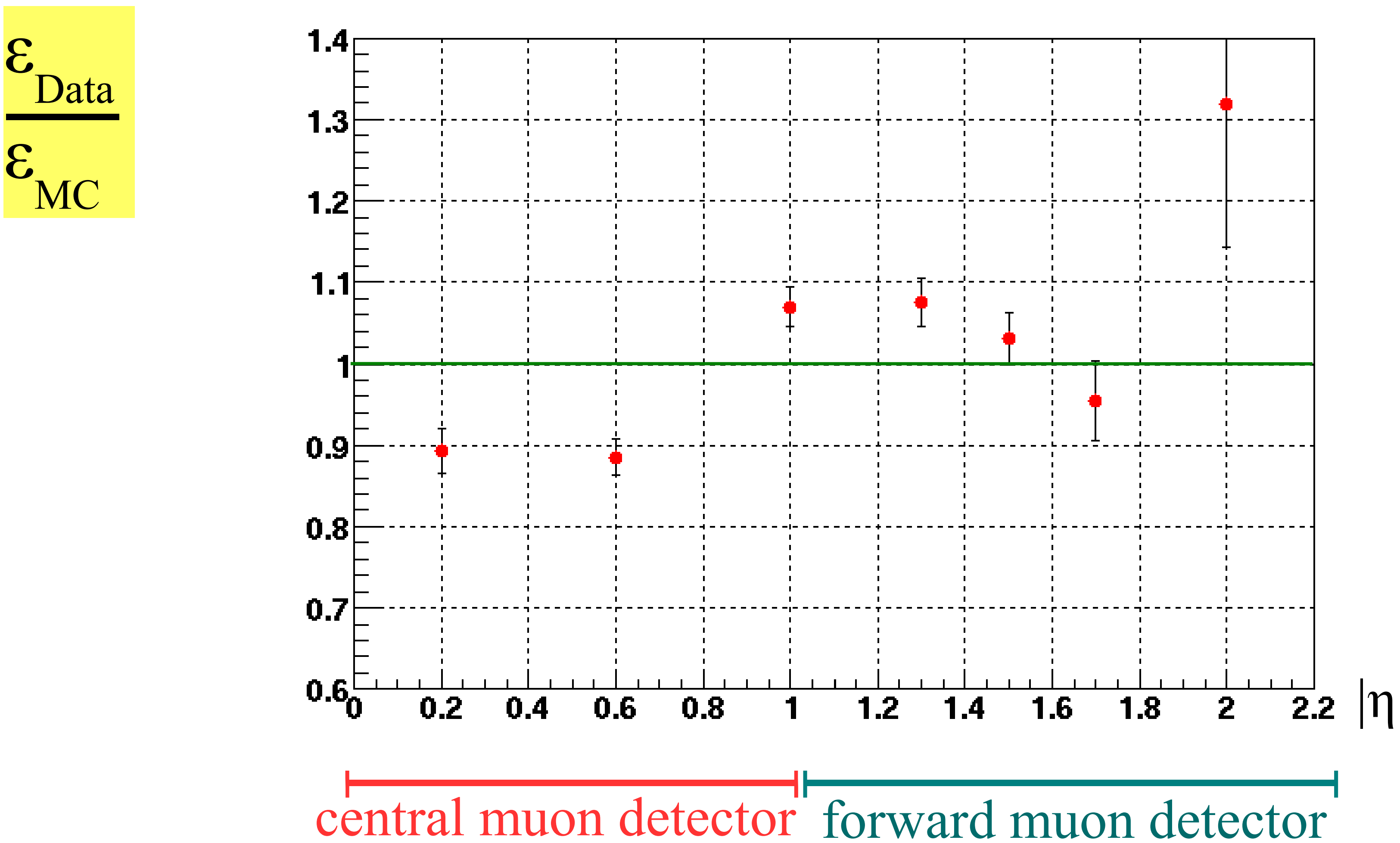
Corrections: Tracking Efficiency

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



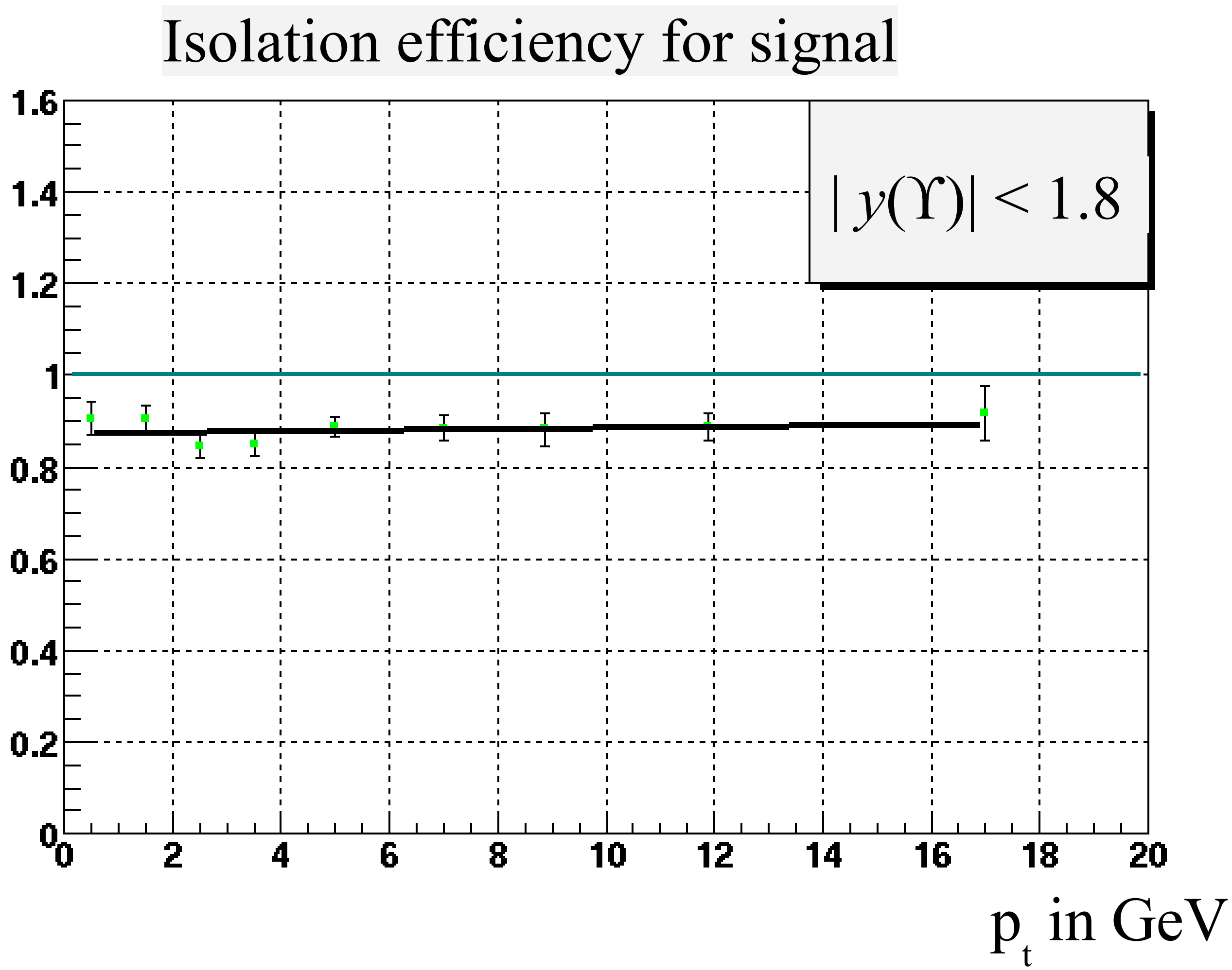
Corrections: Local muon reconstruction efficiency

- reconstruct J/ψ: muon & muon and muon & track
- ε = muon & muon / muon & track

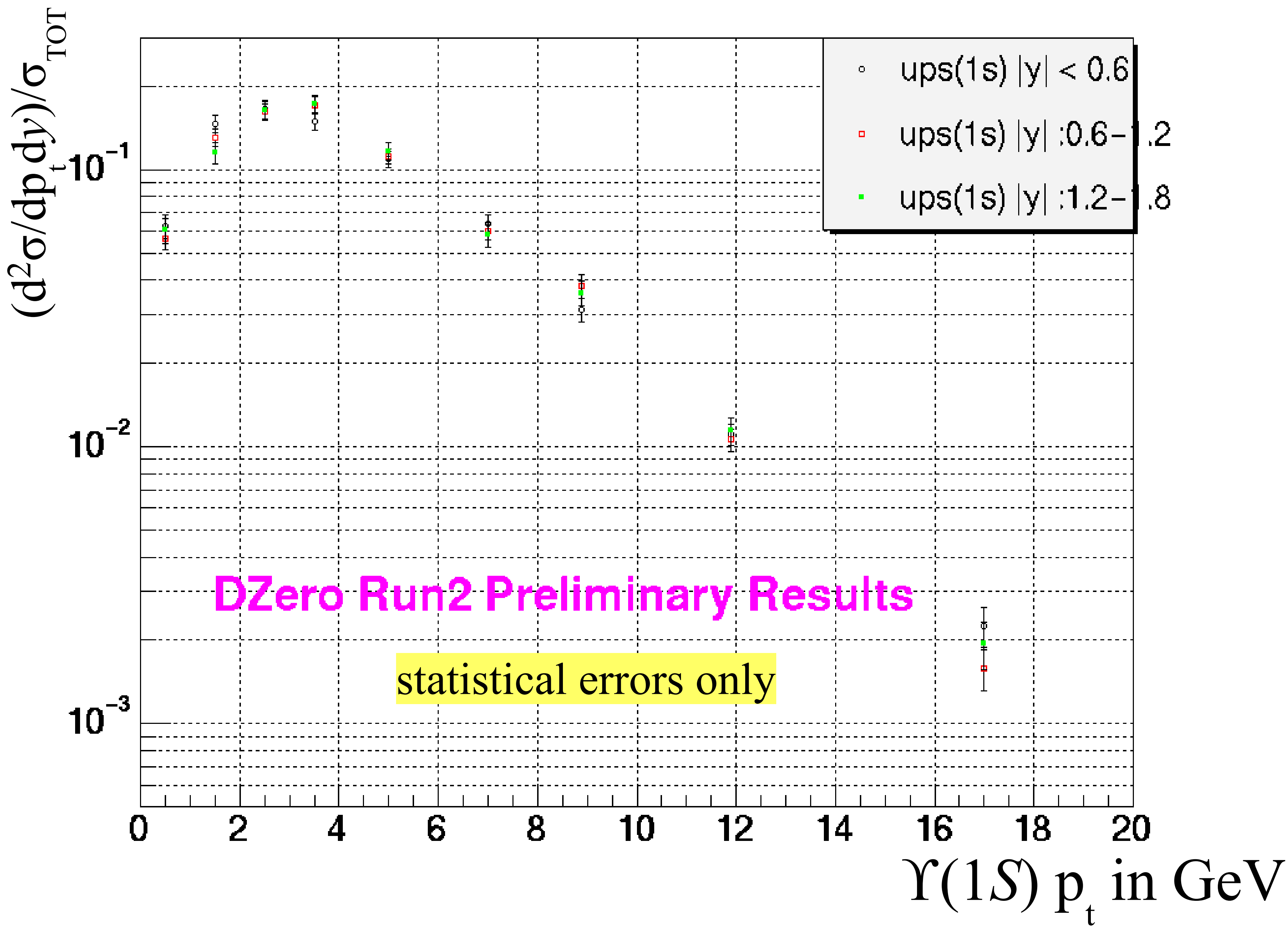


Corrections: Isolation and Silicon Hit Requirement

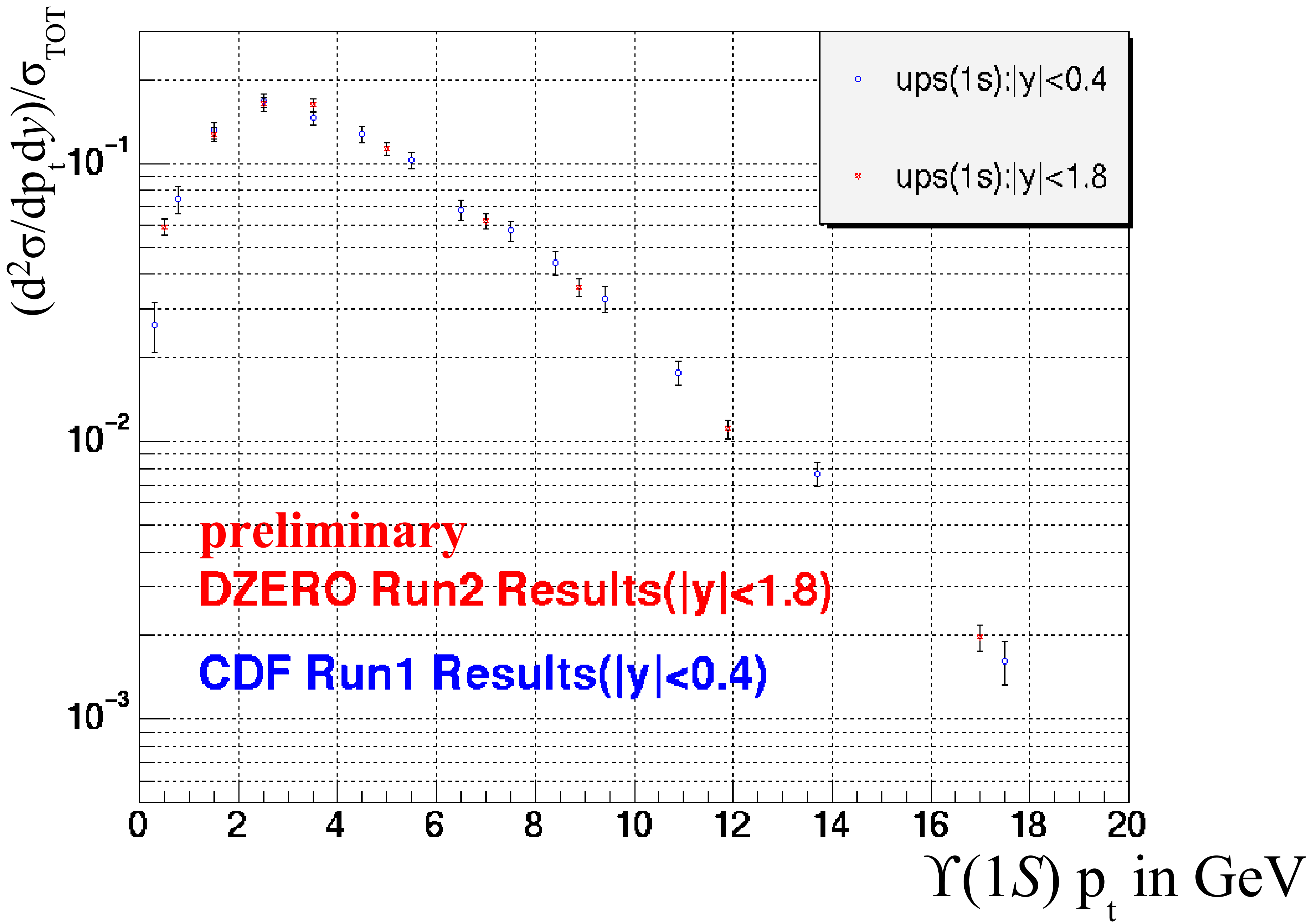
From data – Monte Carlo predicts isolation requirement to be 100% efficient.



Normalized Cross-section for Υ(1S)



Normalized Cross-section



Systematic Errors – very preliminary

local muon ID	6-10 %
trigger	< 10 %
MC modeling of kinematics	2-4 %
fitting procedure	3-5 %
central track matching	2 %
primary vertex requirement	1 %
momentum resolution	1 %
isolation and Silicon hit requirement	1-3 %
Luminosity	6.5 %
Polarization	~20 %

Total (not including polarization): 14-16 %

Conclusions

- $\Upsilon(1S)$ Cross-section measurement extended to $y = 1.8$
- Normalized cross-sections show very little dependence on rapidity.
- Normalized cross-section is in good agreement with published results.
- Absolute cross-section measurement is nearly ready.
- Next step: Polarization measurement.