Υ and J/Ψ production in $p\bar{p}$ collisions

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Summer Internship at Fermilab National Accelerator Laboratory - CDF experiment

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The measure

Υ and J/Ψ are reconstructed using their μ^+ μ^- decay modes.

$$\Upsilon \rightarrow \mu^+\mu^-$$

$$J/\Psi \rightarrow \mu^+\mu^-$$

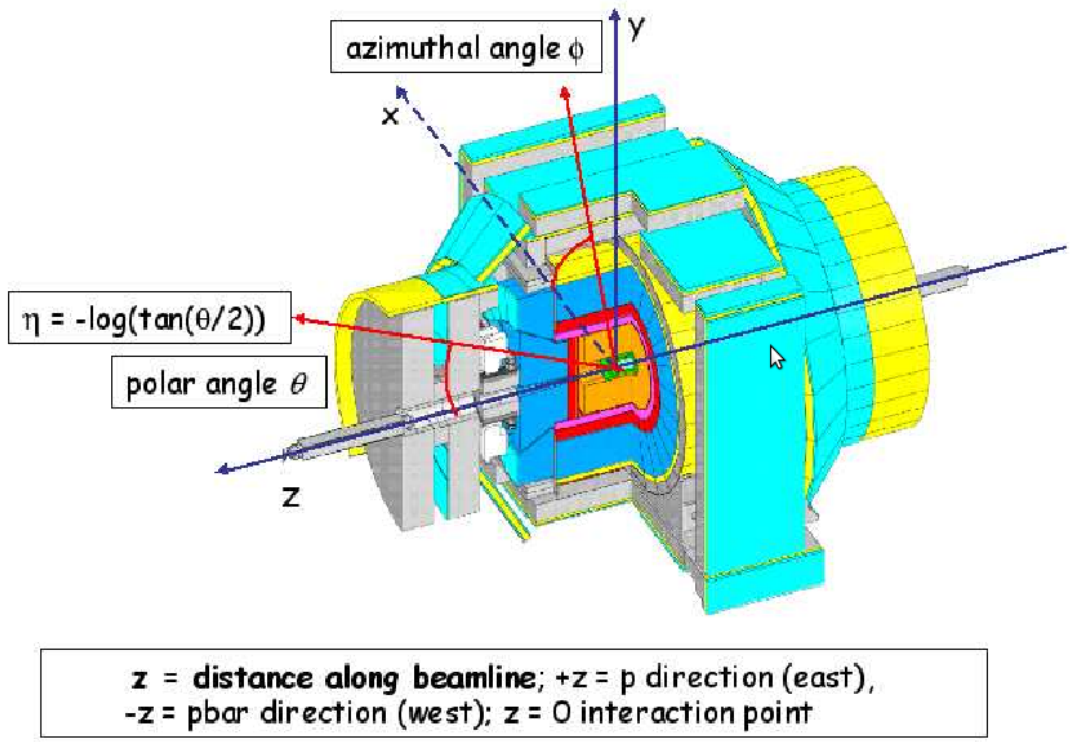
Why is this measure important?

- Test of theoretical models of direct bottomonium and charmonium production
- Investigation on $b\bar{b}$ bound state production mechanisms in $p\bar{p}$ collisions.

CDF detector

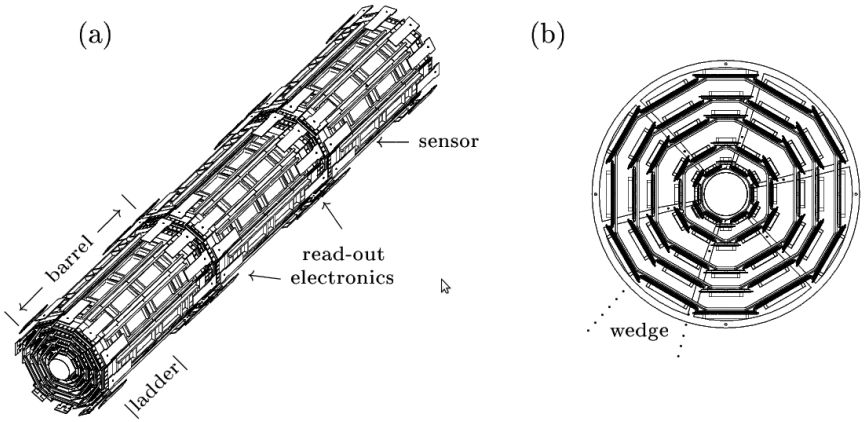
Collider **D**etector at **F**ermilab

- Solenoidal magnetic spectrometer surrounded by 4π calorimeters and muon detectors.
- 5000-ton assembly of subdetectors
- $\sim 16m$ in lenght by $\sim 12m$ in diameter.
- Approximately cylindrically symmetric layout both in the azimutal plane and in the forward-backward directions $\rightarrow$ cylindrical coordinate system



CDF detector

Collider **D**etector at **F**ermilab

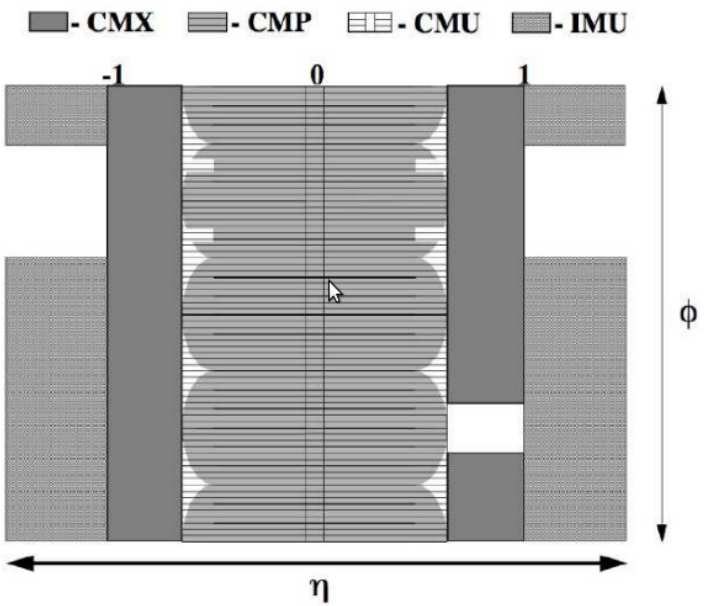


- Silicon detector
  - Layer 00 (L00)
  - Silicon Vertex Detector
  - Intermediate Silicon Layers (ISL)
- Central Outer Tracker (COT)
- Muon chambers
  - Central Muon Detector (CMU)
  - Central Muon Upgrade (CMP)
  - Central Muon Extension (CMX)
  - Intermediate Muon System (IMU)
- Calorimeters

Muons

How to identify muons

Muons traverse CDF detector and leave hits in the outer muon chambers.
Physics objects: tracks.
Reconstruction: adding track segments *(stubs)* to a track formed with hits in the muon drift chamber.
Muon candidate $\rightarrow$ corresponding momentum measured in the tracker.



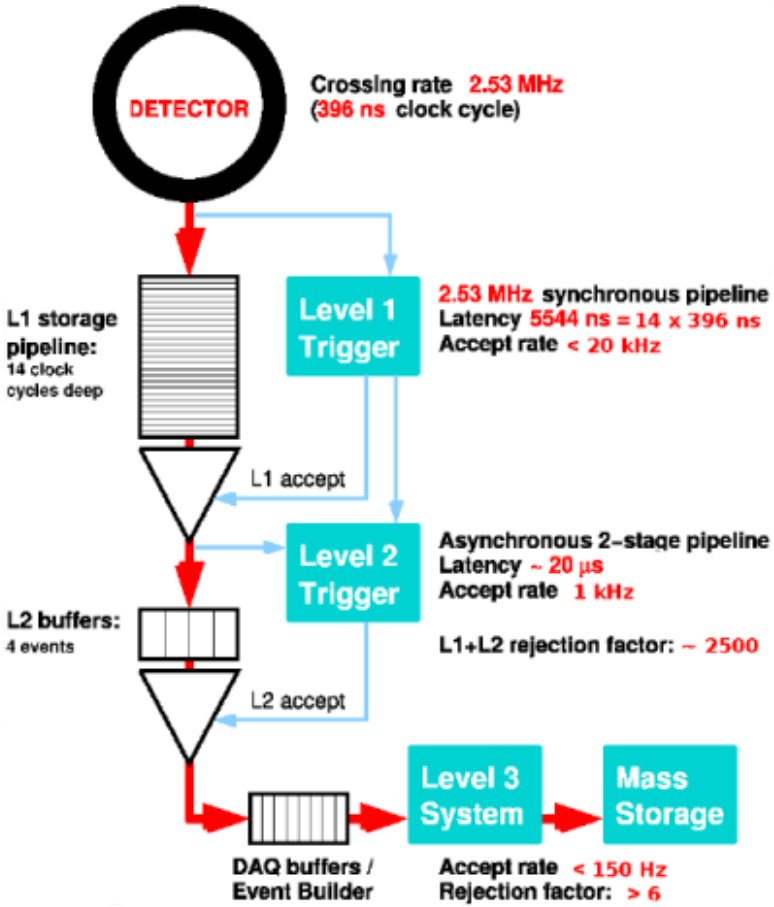
Muon chambers

- Single wire, rectangular drift chambers with azimuthal segmentation
- coupled with scintillator counters which provide timing information
- 50:50 admisture of argon and ethane
- sense wires parallel to the beam axis operating in proportional regime
- 250 μm hit position resolution in the (r, ϕ) view.
- Charge preamplified,shaped,discriminated and digitized

Trigger

A three-level system

Detector crossing rate: 2.53 MHz (396 ns clock cycle).

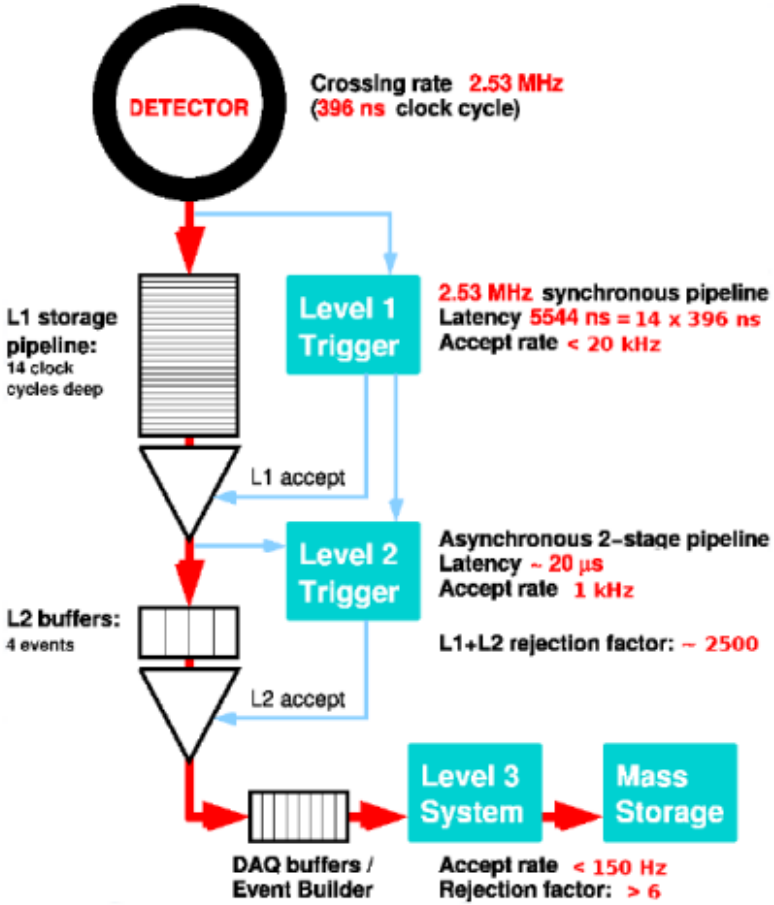


Level 1

Hardware
Takes information from calorimeters, COT, CMU, CMX, CMP chambers.
Makes "primitives" and combines them with muon stubs.
$\rightarrow$ 30 KHz

Trigger

A three-level system

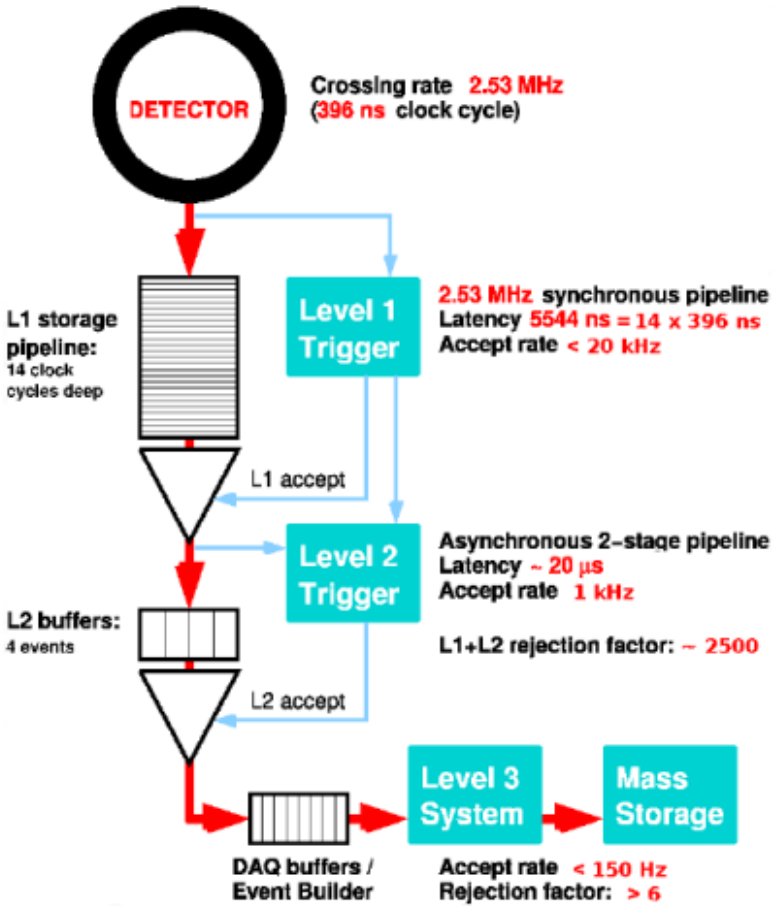


Level 2

Boards and CPU.
New information from SVXII is combined with primitives from Level 1.
Resolution similar to off-line one.
$\rightarrow$ 800 Hz.

Trigger

A three-level system



Level 3

Digitized output from Level 2 accepted events arrives fragmented via optical fibers.
The ordered fragments are assembled in block of data and are ready for the analysis of Level 3 software.
$\rightarrow$ 100 Hz

Trigger

Links across different levels are established by defining trigger paths.

Trigger paths

It identifies a unique combination of a L1, a L2 and a L3 trigger. Data sets are then finally formed by merging the data samples collected via different trigger paths.

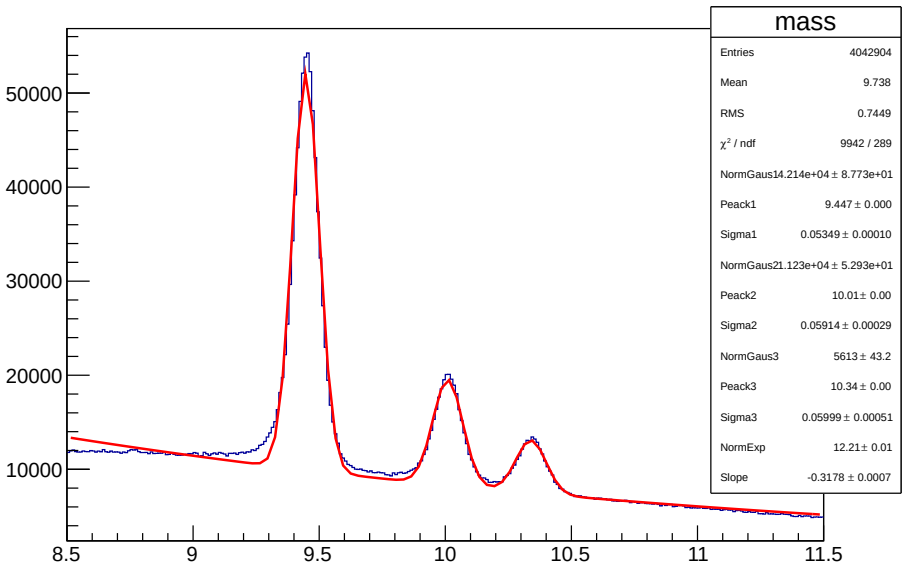
Some trigger paths have output rates that exceed the maximum allowed value → prescaled by a factor N:one event out of N is accepted.

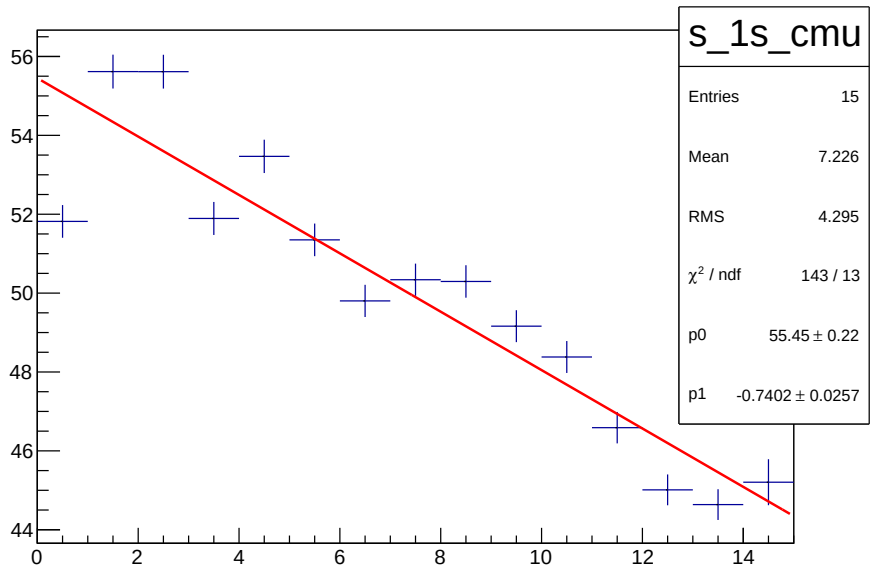
Static prescale:prescale factor is fixed.
Dynamic prescale:prescale factor is varied during the data taking to exploit at the most the available bandwith.

The measure

The $\Upsilon \rightarrow \mu^+ \mu^-$ cross section is calculated by

$$\frac{dN}{dt} = \sigma L_{ist} \rightarrow \sigma = \frac{\frac{dN}{dt}}{L_{ist}}$$



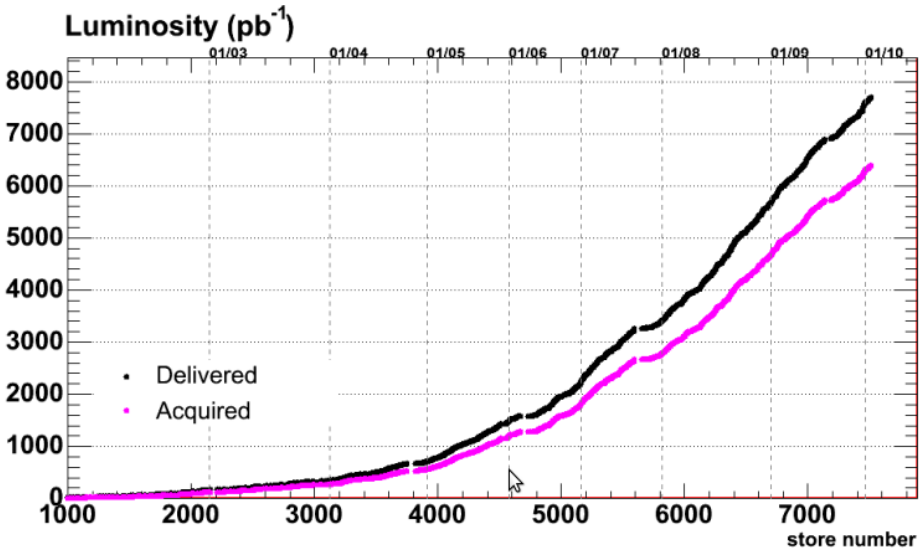


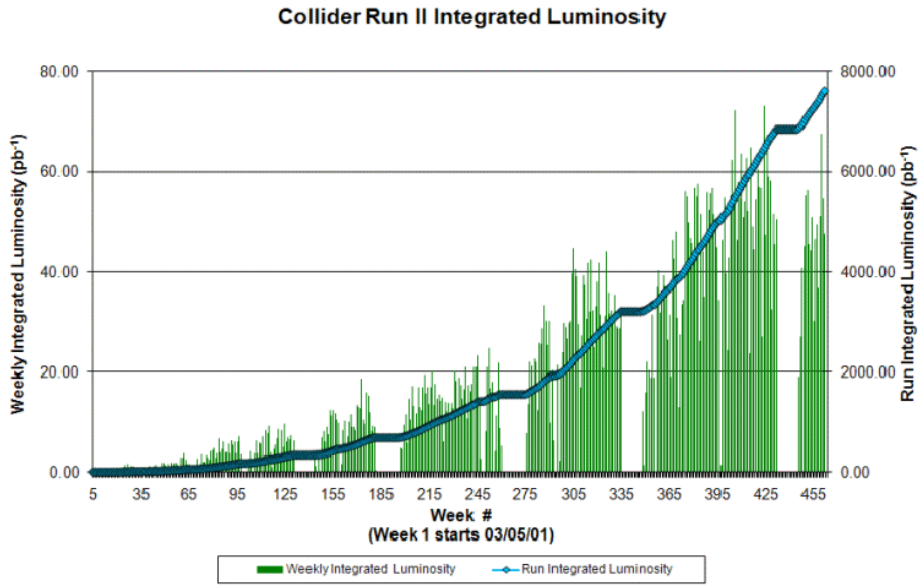
PROBLEM: the Yield/pb^{-1} decreases with time.

Possible solutions

Idea:luminosity increasing is the problem

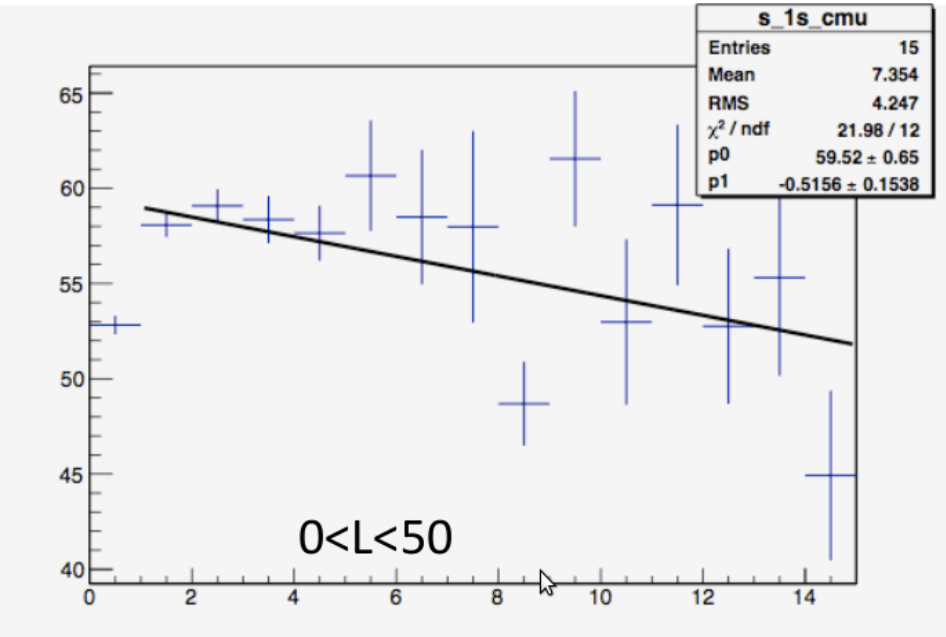
Tevatron has been developed during the years of running: if L_{ist} increases with time, events become less clear and not easy to identify.

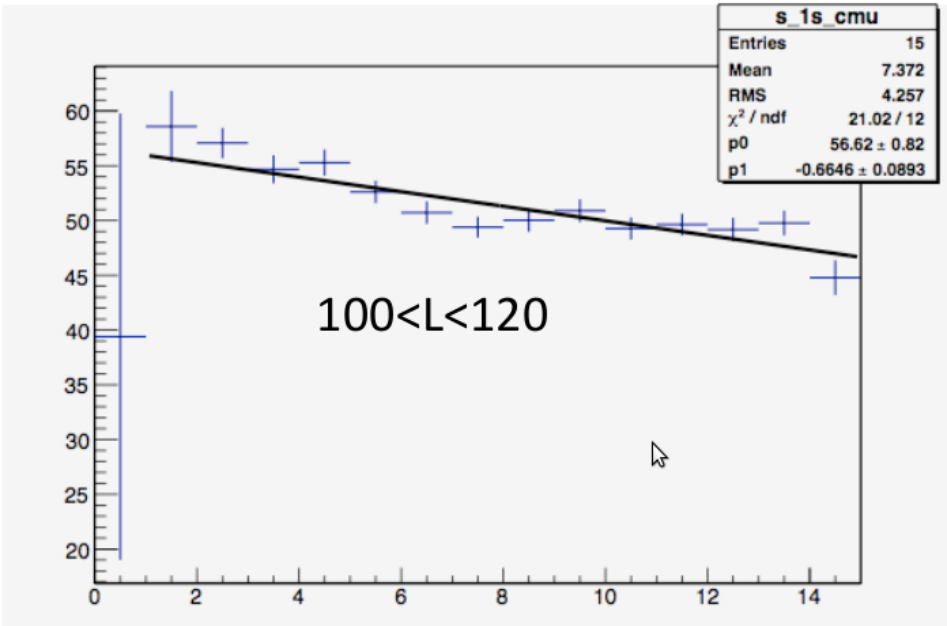




Possible solutions

Plots of Yield/pb^{-1} at fixed luminosity ranges should have had a constant trend
$\rightarrow$ time false variable.
There is residual dependence on time:Yield/pb^{-1} still decreases.



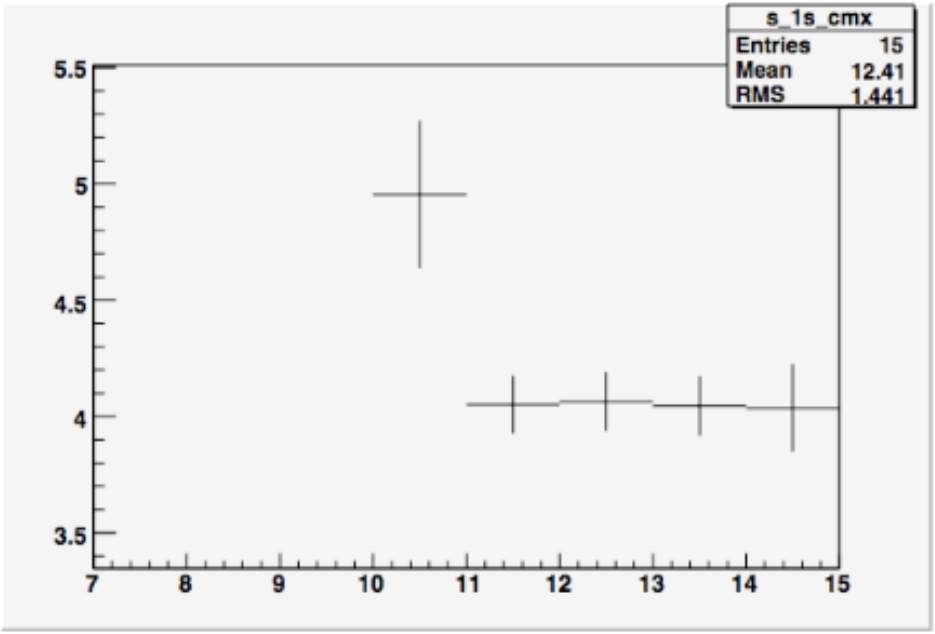


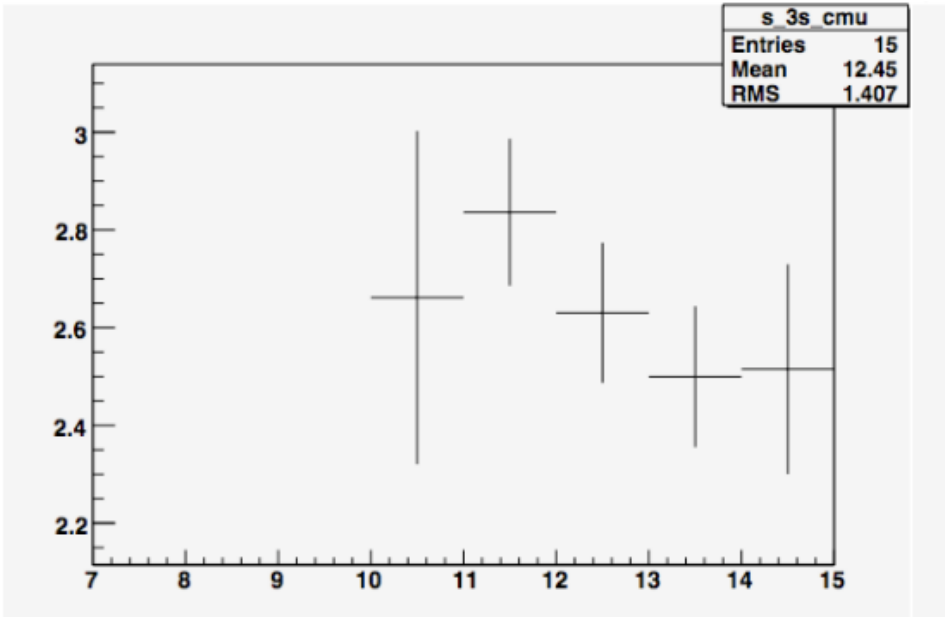
Possible solutions

Idea:the trigger system is the problem

One trigger muon of high p_t
1 CMUP muon: $p_t > 8 GeV/c$ (at L1/L2/L3)
1 L3 muon: $p_t > 1.5 GeV/c$ (at L3 - no L1/L2 requests)

Only one muon is affected by the trigger selection : the influence of the trigger selection decreases and also the time-dependence.



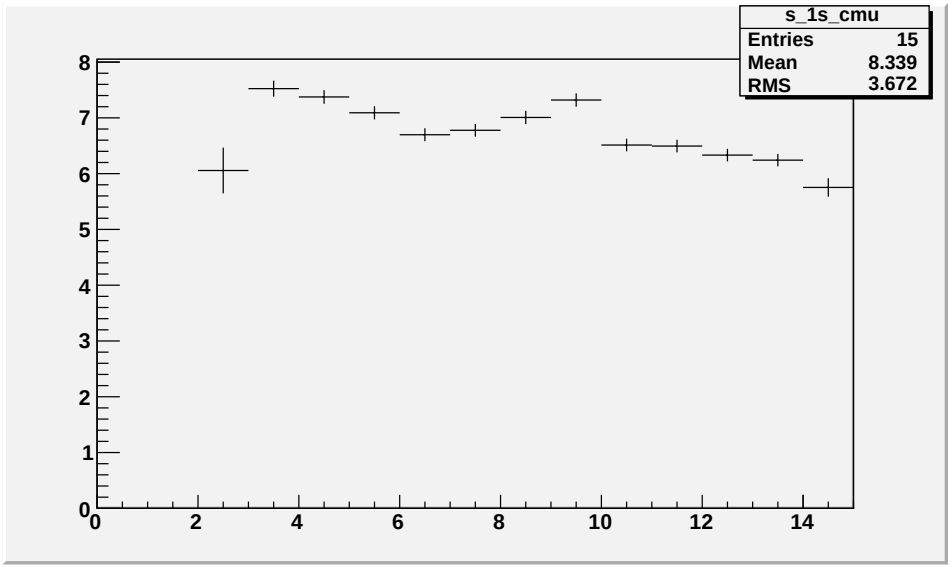


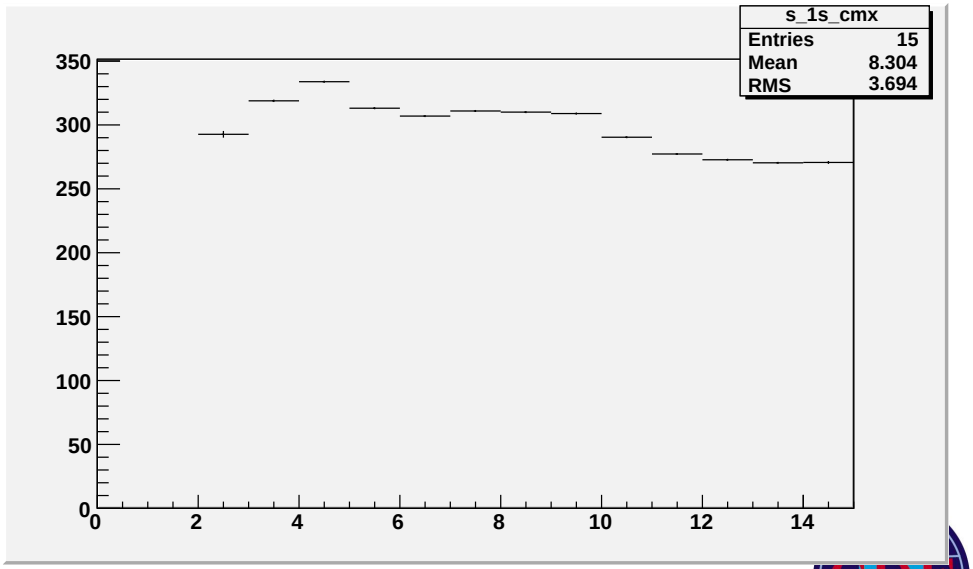
An interesting comparison: J/Ψ

A similar analysis has been performed for the J/Ψ data sample.

Cuts

CMU_CMU: $p_t > 1.5 GeV/c$ $p_t > 1.5 GeV/c$
CMU_CMX: $p_t > 1 GeV/c$ $p_t > 2 GeV/c$
CMP not used.





The problem is still open

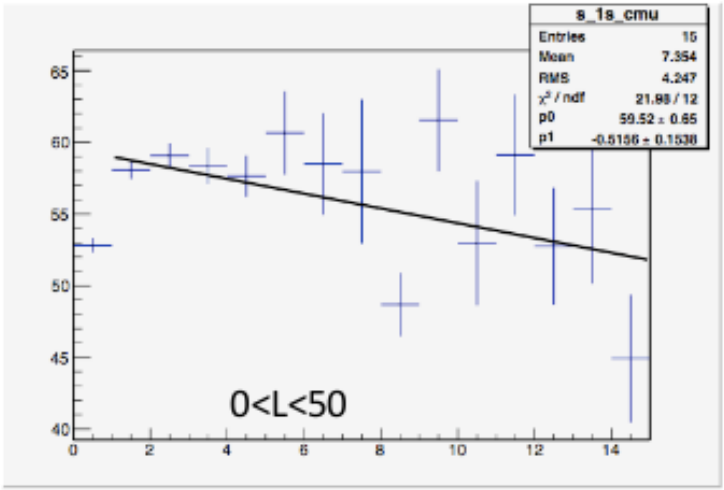
Decreasing of Yield/pb^{-1} was unexpected.

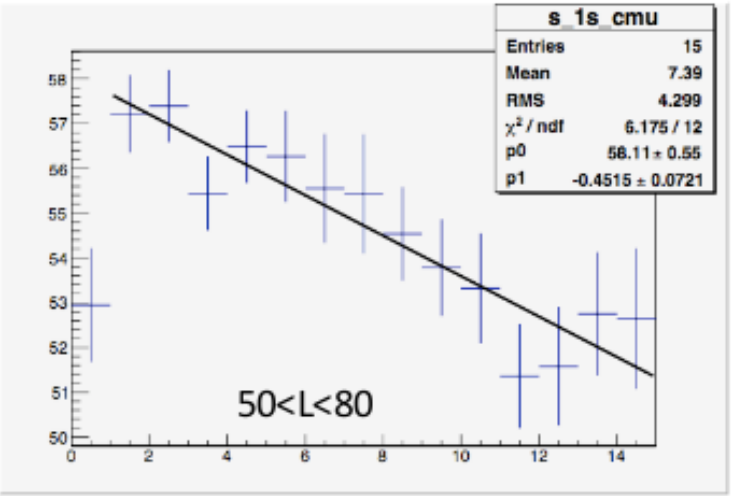
Different data samples L_{ist} dependence analysis:

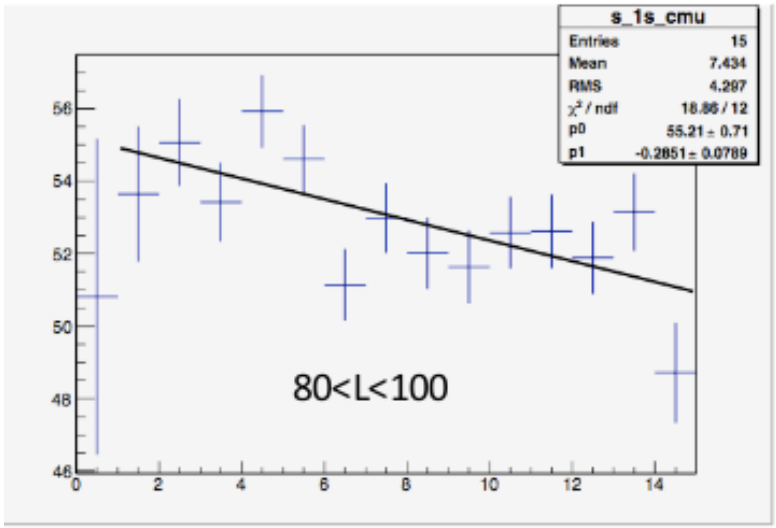
- Upsilon high p_t
- J/Ψ high p_t
- soft J/Ψ

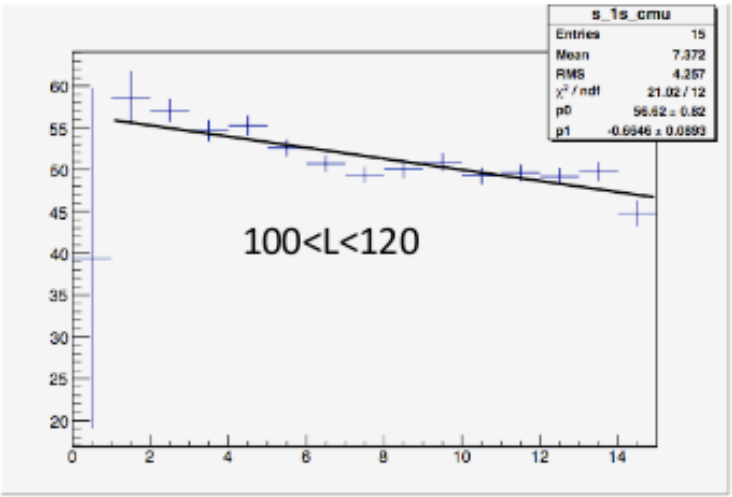
The problem is still open!

Luminosity ranges

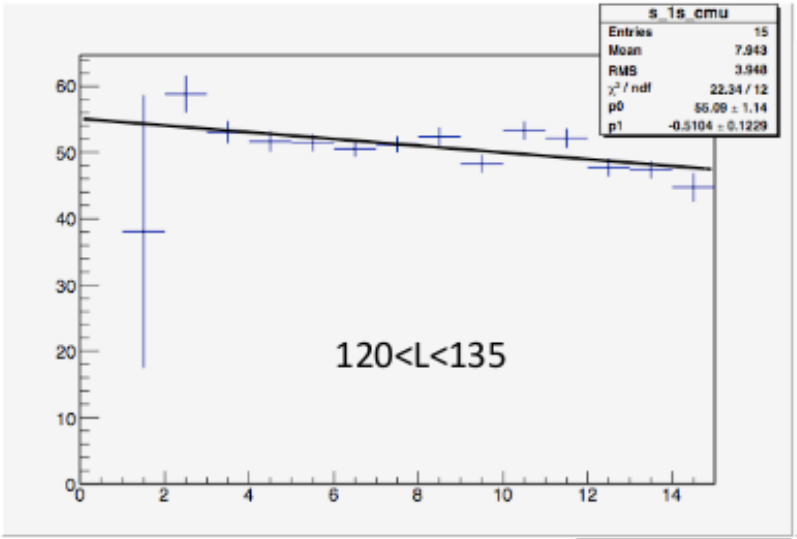


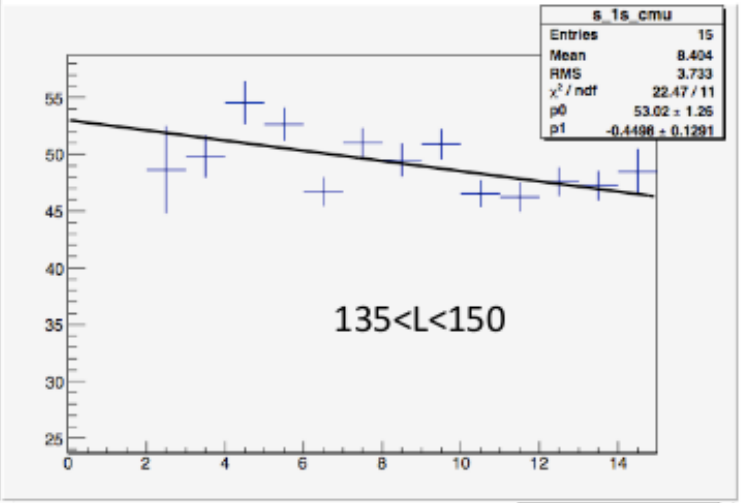


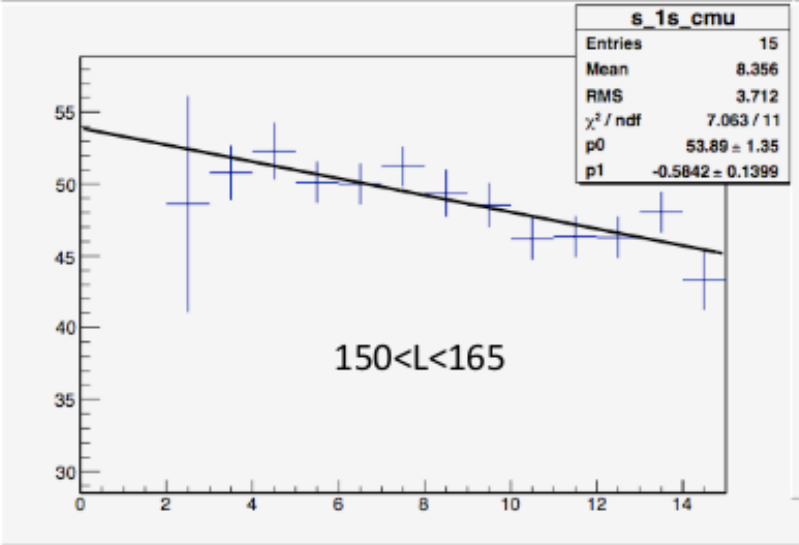


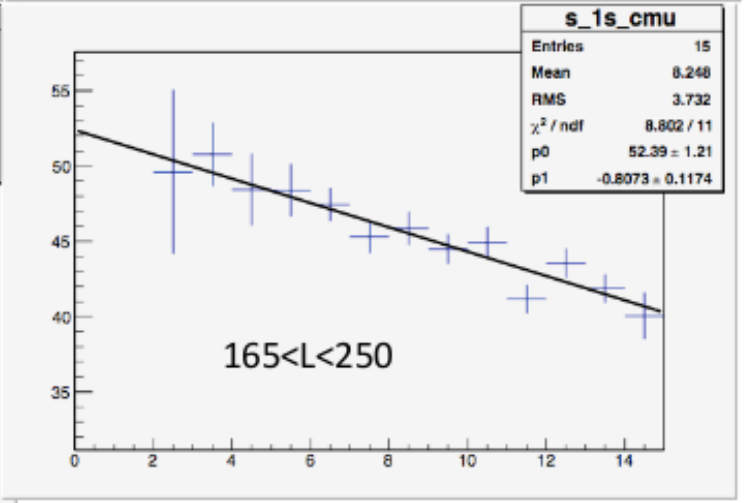


Luminosity ranges









Upsilon High p_t samples