Onium polarisation and the $\mu 10$ trigger

V. Kartvelishvili, D.Price

Lancaster University, UK

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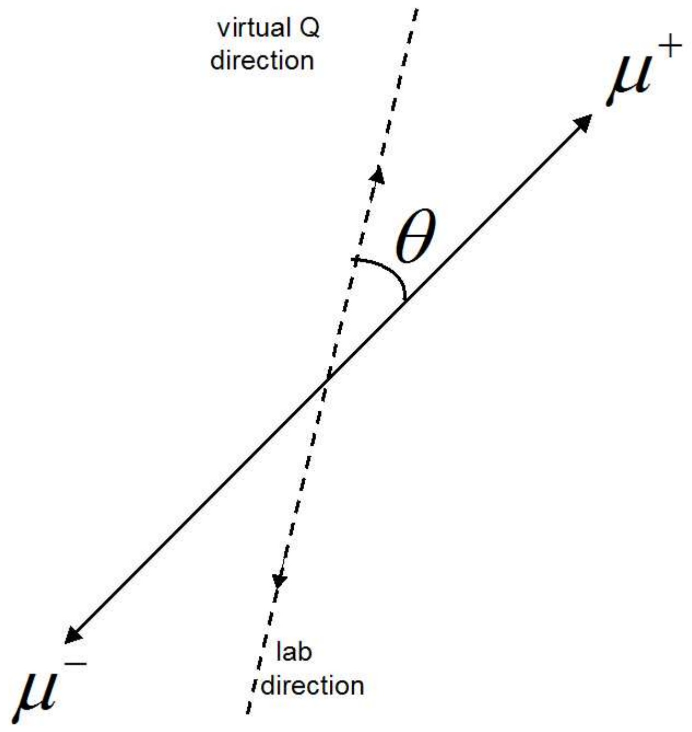
Introduction

J/ψ and Υ polarisation measurement — a crucial test of production models

$$\frac{dN}{d\cos\theta^*} \sim 1 + \alpha\cos^2\theta^*$$

- $\alpha = \;\; 0$ — unpolarised
- $\alpha = +1$ — transversely polarised (helicity ± 1)
- $\alpha = -1$ — longitudinally polarised (helicity 0)



Decay angle θ^*:

angle between the direction of μ^+ in onium decay frame and the direction of onium in lab frame

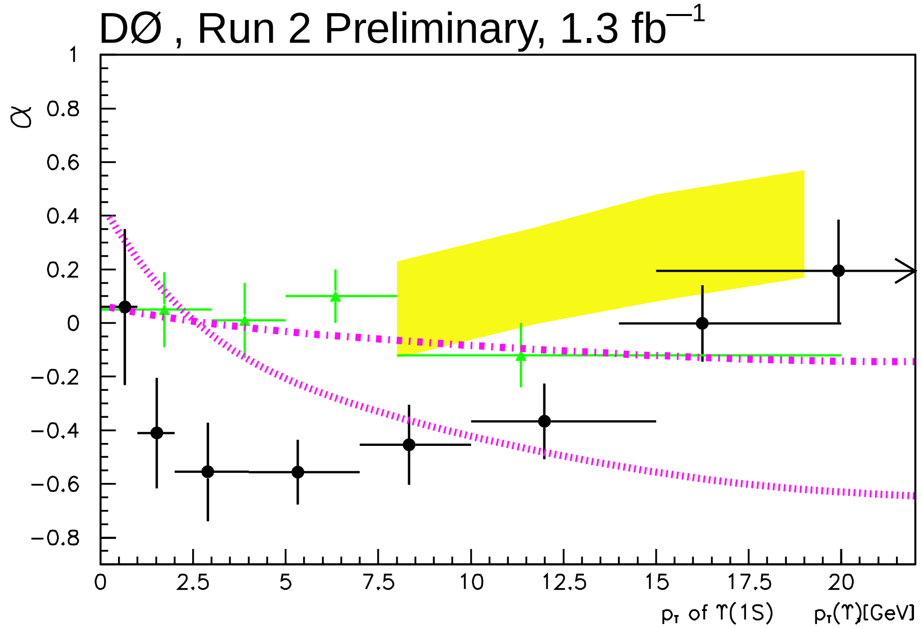
Problem?

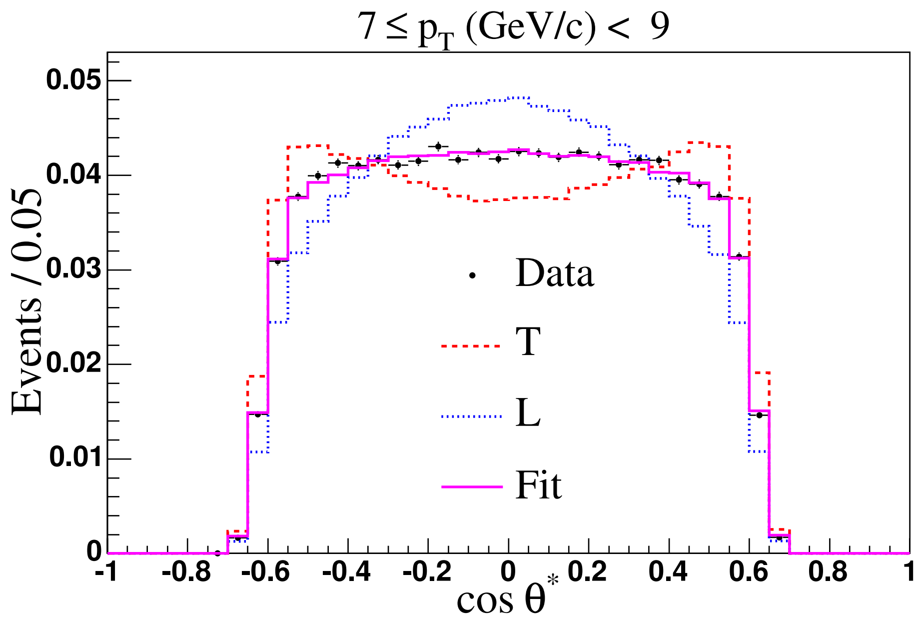
So far, major disagreements between theoretical models

- Colour Octet Model — yellow band
- k_T factorisation model — red lines

and different experiments

- D0 — black points
- CDF — green points



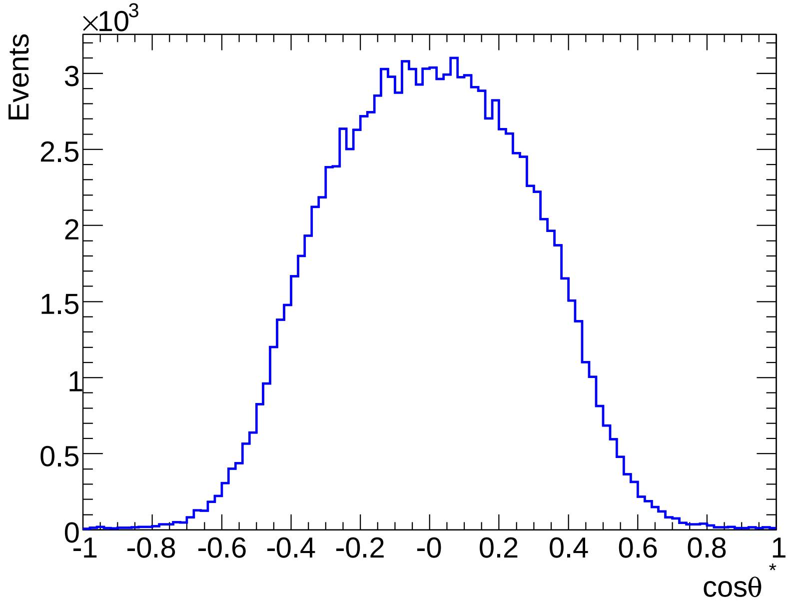


Main reason: large $|\cos\theta^*|$ not easily accessible

as trigger requires both muons to have high p_T

Dimuon kinematics in ATLAS case

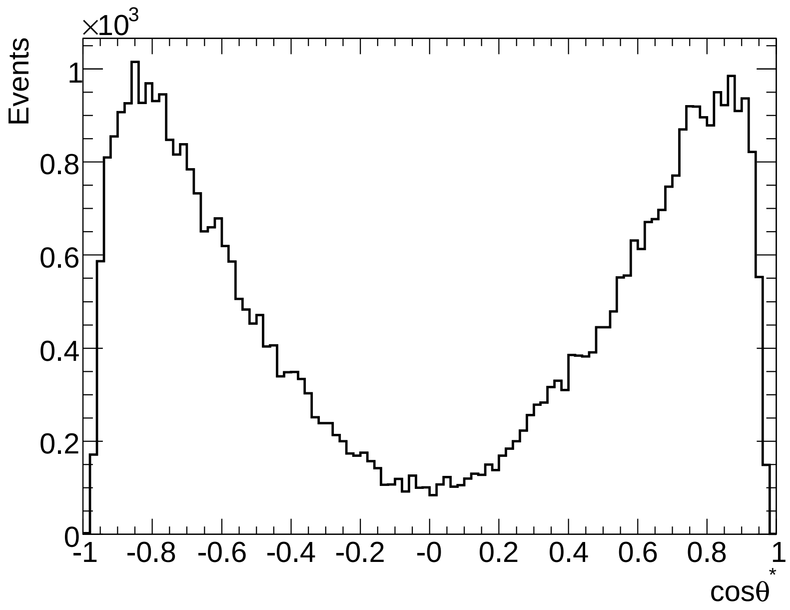
- With a $\mu 6 \mu 4$ trigger, P_T distribution of the J/ψ starts at about $6 + 4 = 10$ GeV
- Both muons from J/ψ decays have rather large P_T
- Allows for both muons to be identified
- BUT: restricts acceptance in polarization angle $\cos\theta^*$:



- At a fixed P_T of the J/ψ, a big fraction of the cross section is lost (up to 60 %)
- $|\cos\theta^*| = 1$ exactly means $p_1/p_2 \simeq (M_\psi/m_\mu)^2 \simeq 900$ (not very likely!)

J/ψ with a $\mu 10$ trigger

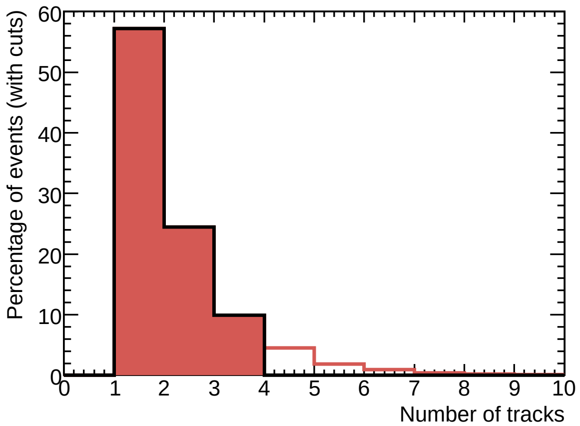
- In order to recover these "lost" J/ψ's, one needs one muon to be fast and the other to be slow.
- In order to complement the dimuon-triggered J/ψ sample, one could use the $\mu 10$ single muon trigger.
- The other muon is not identified - "just" a track with certain requirements.
- $J/\psi \to \mu 10$+track cross section comparable to the $\mu 6 \mu 4$ one, with similar P_T dependence.
- Picks up configurations with large $\cos\theta^*$:



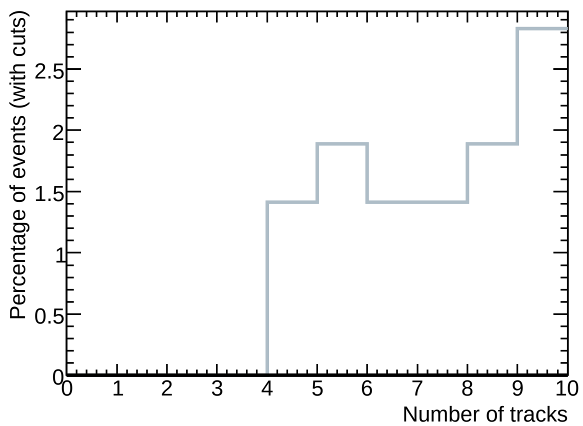
Background

- Background: decays in flight, $cc \to \mu X$, $bb \to \mu X$.
- The last one seems to be the biggest: $bb \to \mu 6 + X$ is 6.14 μb
  - cross section for $bb \to \mu 10 + X$ + at least one track in cone 0.8 is 1.06 μb
  - ...and $M_{\rm inv}(\mu + \rm track) > 2.5$ GeV and ($n_{\rm track} = 1, 2$ or 3) is 40 nb
  - Down to few nb if both tracks are required to come from primary vertex
- Signal ($J/\psi \to \mu 10 + \rm tracks$) raw cross section with the same cuts is about 11 nb.
- Compared to ($J/\psi \to \mu 6 \mu 4$) raw cross section of about 14 nb.

prompt J/ψ

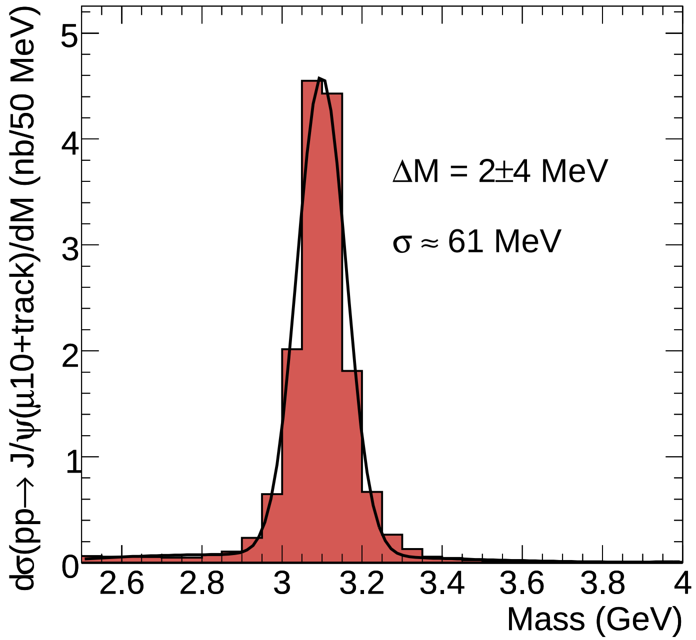


$bb \to \mu 10 X$



J/ψ mass peak

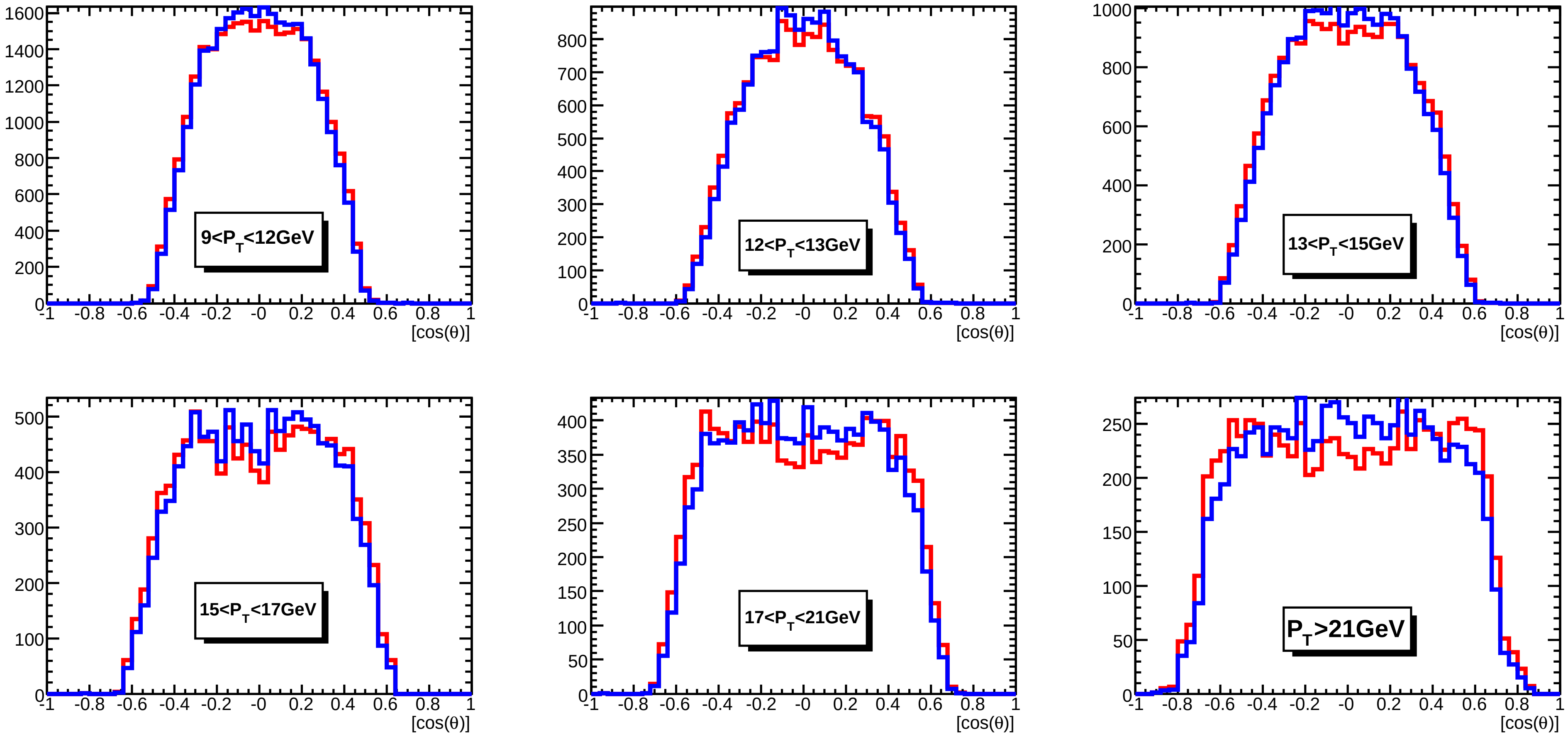
Invariant mass of $\mu 10$+opposite sign track within $R < 0.8$ cone, both from primary vtx:



So, with the trigger "$\mu 10$+tracks":

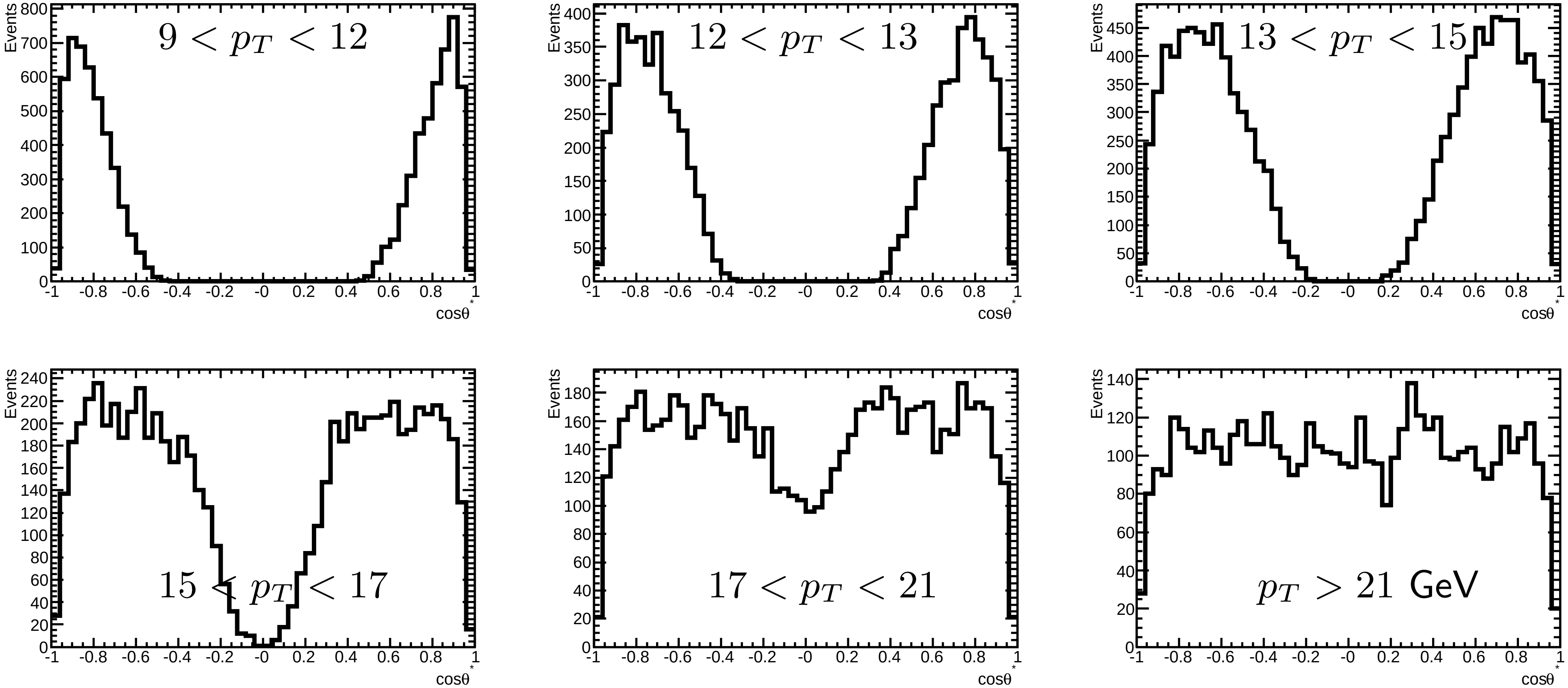
- J/ψ peak is well visible
- Combinatorial background is very low
- Background from beauty decays small (vanished with simulated MC statistics)
- Complements nicely the dimuon-triggered sample
- Broadens the acceptance in $\cos\theta^*$
- Mass resolution almost as good as for $\mu 6 \mu 4$

J/ψ with $\mu6\mu4$: $\cos\theta^*$ distributions in p_T slices



Blue: unpolarised (constant) Red: transversely polarised $(1+\cos^2\theta^*)$

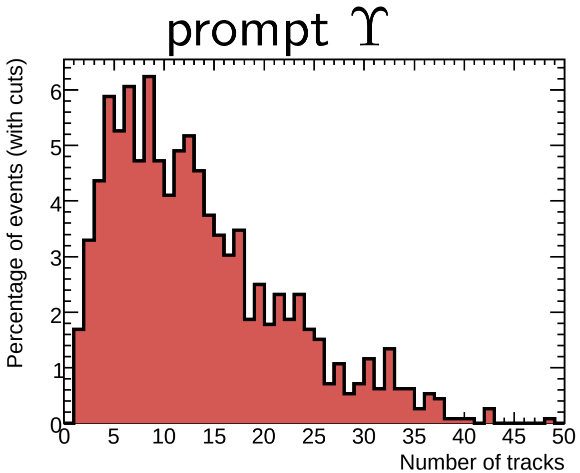
J/ψ with $\mu10$+track: $\cos\theta^*$ distributions in p_T slices

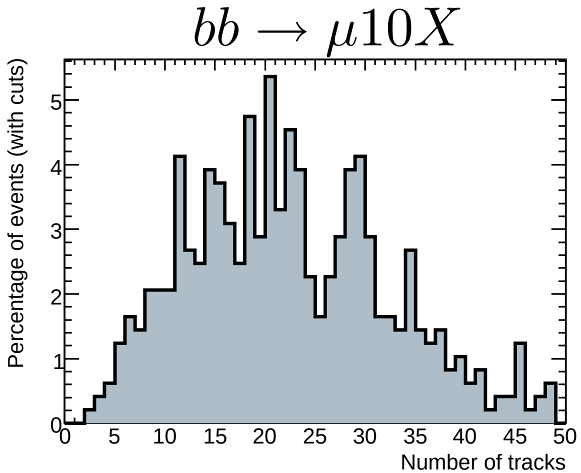


Unpolarised

How about Υ ?

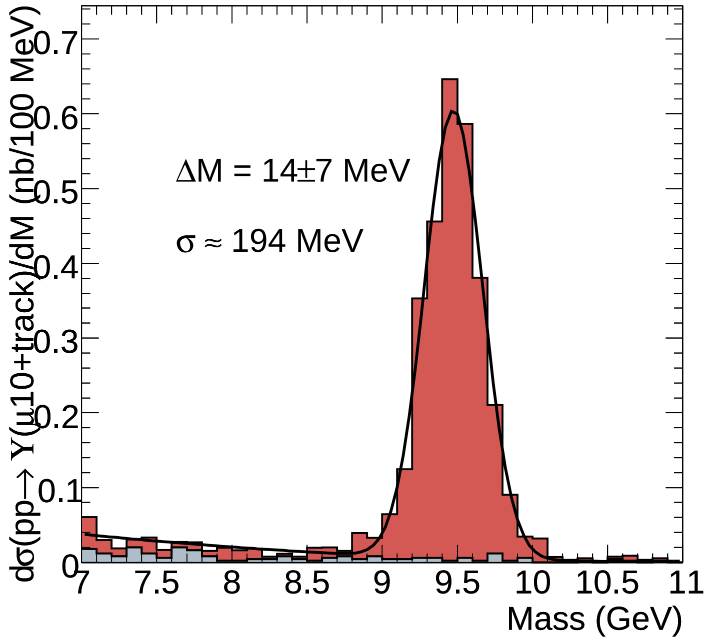
- Same main backgounds: decays in flight, $cc \to \mu X$, $bb \to \mu X$, the latter again expected to be the biggest.
- Higher mass, different decay kinematics: back-to-back now possible (but rare).
- If both $\mu 10$ and the track are required to come from the primary vertex, the background is dramatically reduced.
- Signal ($\Upsilon \to \mu 10 + \mathrm{tracks}$) raw cross section is about 2.5 nb.
- Compared to ($\Upsilon \to \mu 6 \mu 4$) raw cross section of about 3 nb.
- Random combinations tend to have small mass, can survive without the cut on number of associated tracks:





Υ mass peak

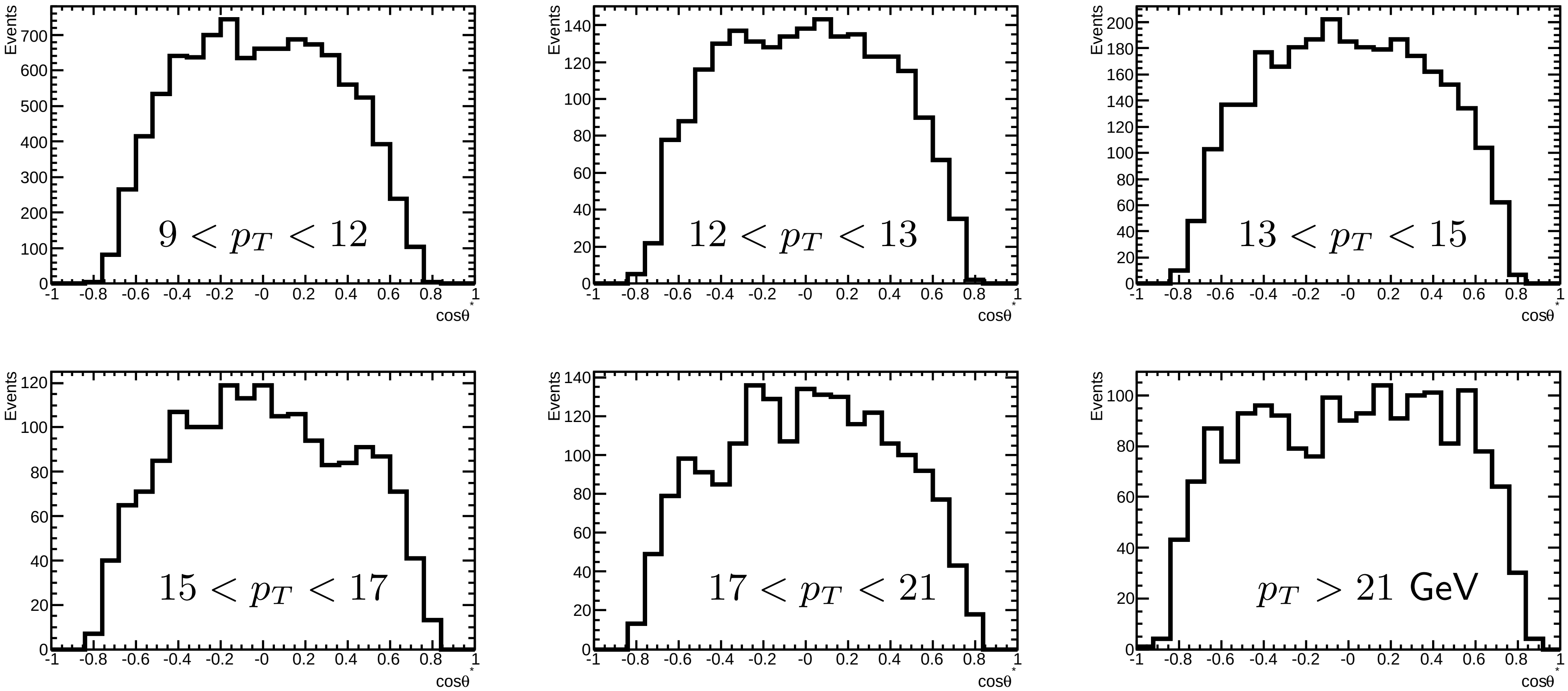
Invariant mass of $\mu10$+opposite sign track within $R < 1.7$, both from primary vtx:



Here too, with the trigger "$\mu10$+tracks":

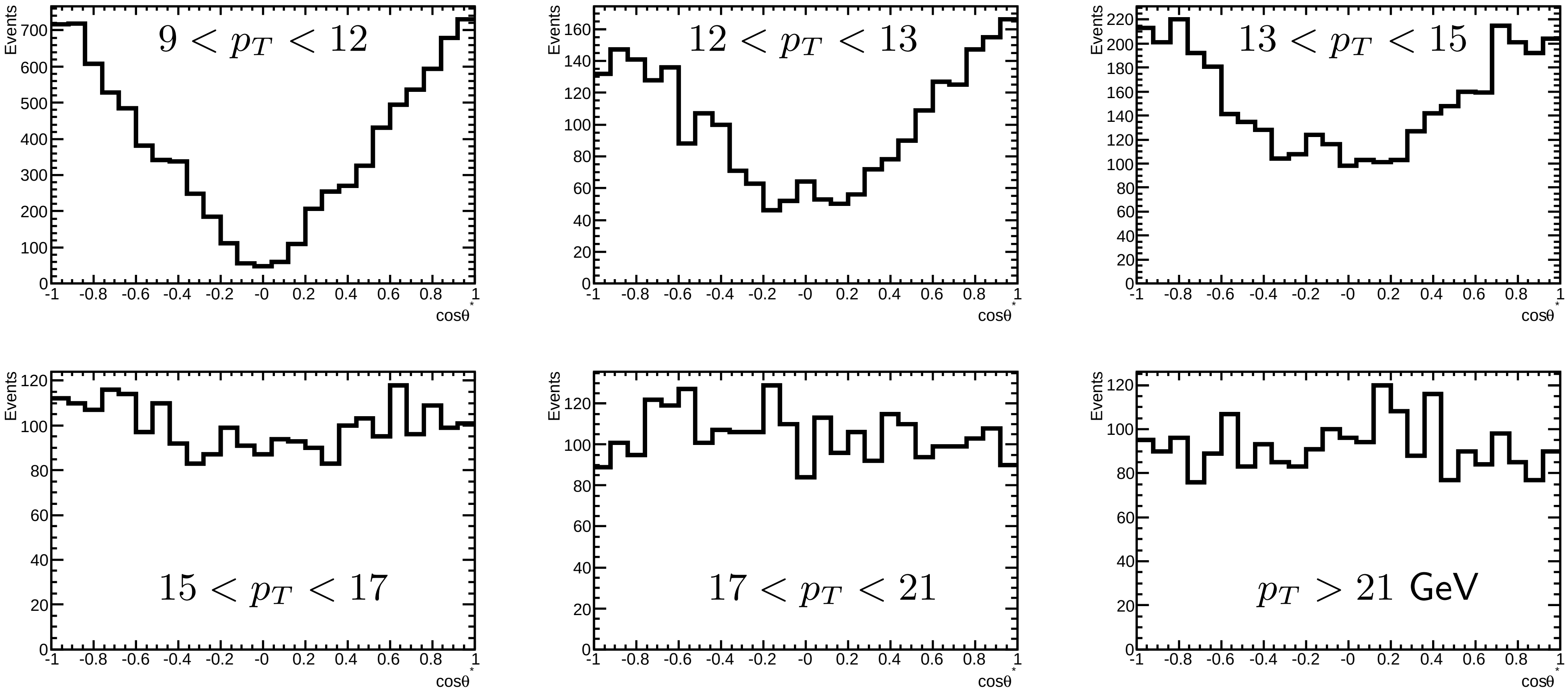
- Υ peak is well visible
- Combinatorial background is very low
- Background from beauty decays also very low
- Complements the dimuon-triggered sample
- Broadens the acceptance in $\cos\theta^*$
- Again, mass resolution almost as good as for the $\mu6\mu4$ sample

Υ with $\mu6\mu4$: $\cos\theta^*$ distributions in p_T slices



Unpolarised

Υ with $\mu 10$+track: $\cos\theta^*$ distributions in p_T slices



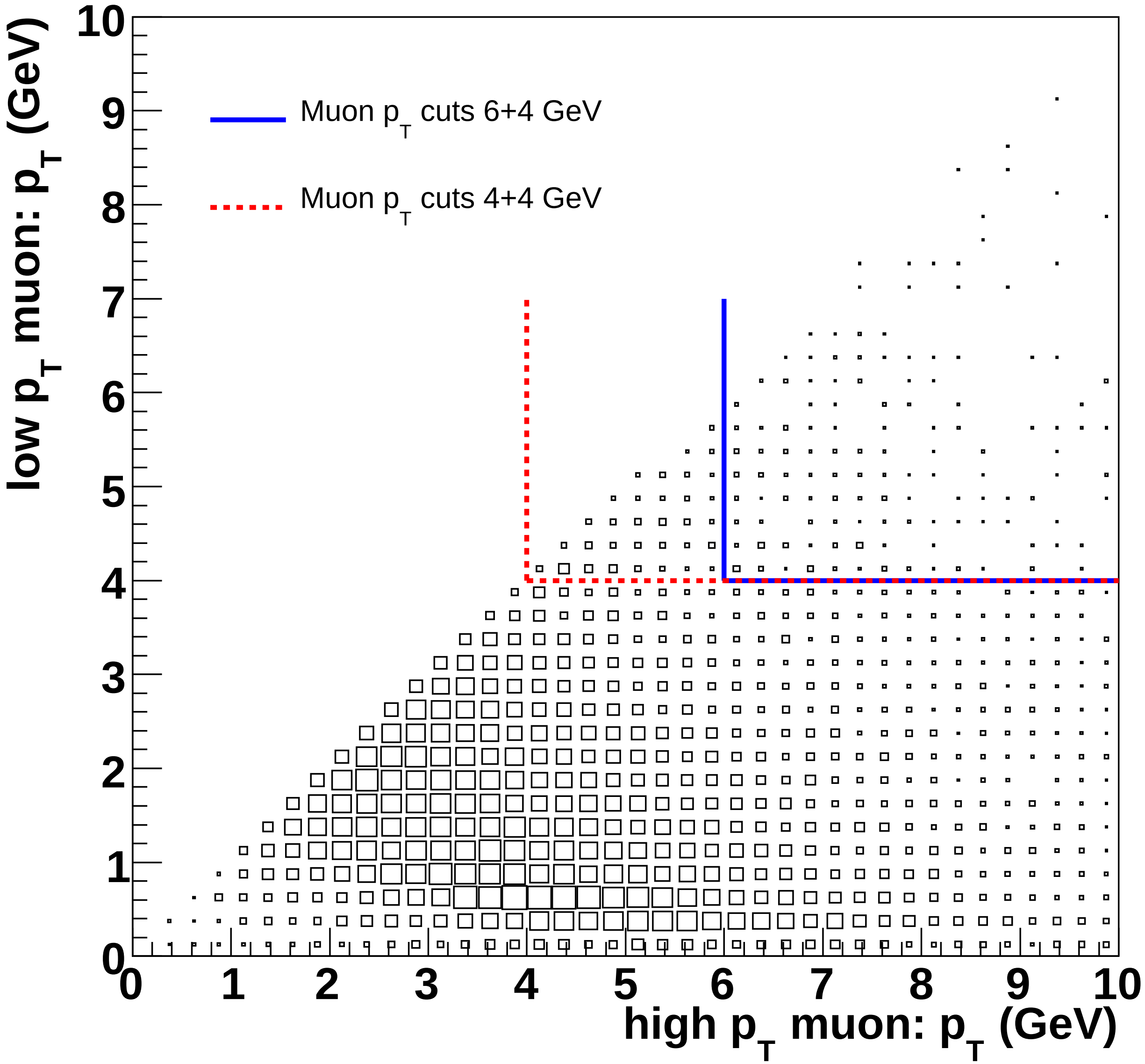
Unpolarised

Conclusions (so far)

- Samples of prompt onia from dimuon and single muon triggers complement each other nicely
- Almost full acceptance in $\cos\theta^*$, at least at high p_T of onia
- In polarisation measurements, same statistics within $|\cos\theta^*| < 0.9$ gives about 4 times smaller stat. errors (and *much* smaller sys. errors), than if made within $|\cos\theta^*| < 0.5$
- $\mu 10$ trigger provides largely independent samples of onia to cross-check efficiencies, cross sections, resolution, alignment etc.
- Onia from single muon triggers is becoming a vital part of mainstream onium analysis, available from day 1
- So far — mostly truth + limited simulations, more studies in progress
- MC statistics cannot possibly compete with real data, when it becomes available

BACKUP SLIDES

J/ψ production, $\mu 1$ vs $\mu 2$, Monte Carlo before trigger



Υ production, $\mu 1$ vs $\mu 2$, Monte Carlo before trigger