Quarkonium production, offline monitoring, alignment & calibration

Darren Price, Vato Kartvelishvili
LANCASTER UNIVERSITY

ATLAS UK Physics Meeting '08

Quarkonium as a physics and detector probe

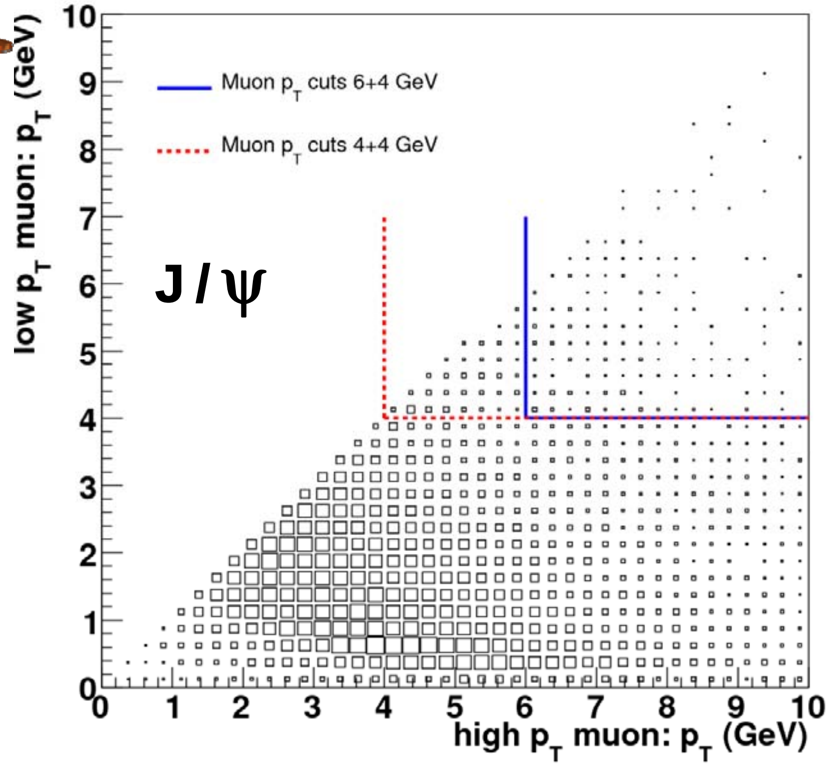
- One of the earliest physics studies that can be undertaken with early data is analysis of charmonium and bottomonium production models, leading to a better understanding of QCD

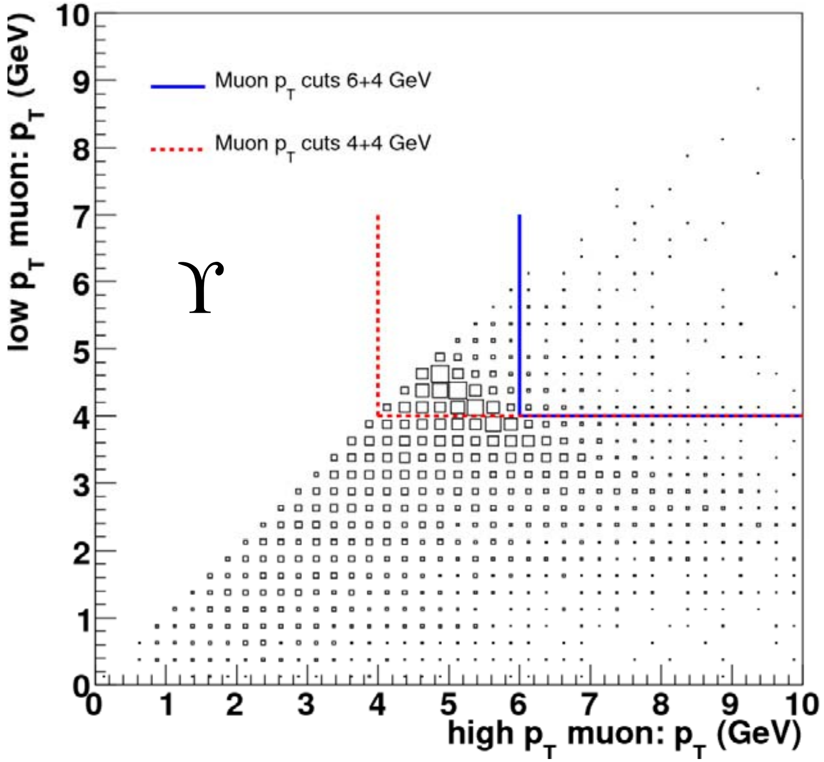
- Ongoing studies include:
  - Spin polarisation analysis
  - Associated hadronic/jet activity
  - Reconstruction of χ_c and χ_b states
  - Hadroproduction of quarkonium in association with heavy quark pair

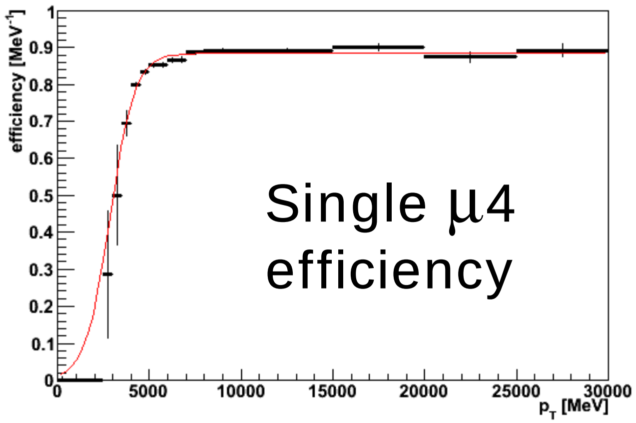
See ATL-PHYS-INT-2007-001, ATL-SLIDE-2007-055 and CSC Note BPHYS-9

- The high production rate and well-understood kinematics of quarkonia into di-leptons lend themselves to detector monitoring, alignment and calibration in early data
  - Provide additional low-mass, low transverse momenta points for detector studies generally conducted with the W/Z

Rates with lower p_T triggers







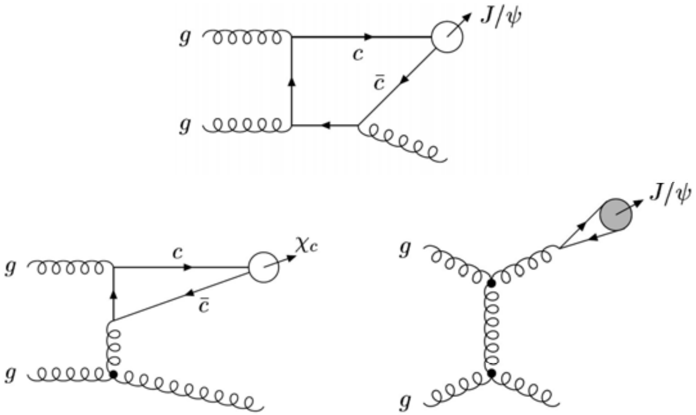
Trigger cuts	6+4 GeV	4+4 GeV
Prompt J/ψ	22 nb	27 nb
Prompt ϒ	4.6 nb	43 nb

Expected quarkonium rates at μ4μ4

- Sources of quarkonium production can be separated into two groups: prompt and non-prompt.

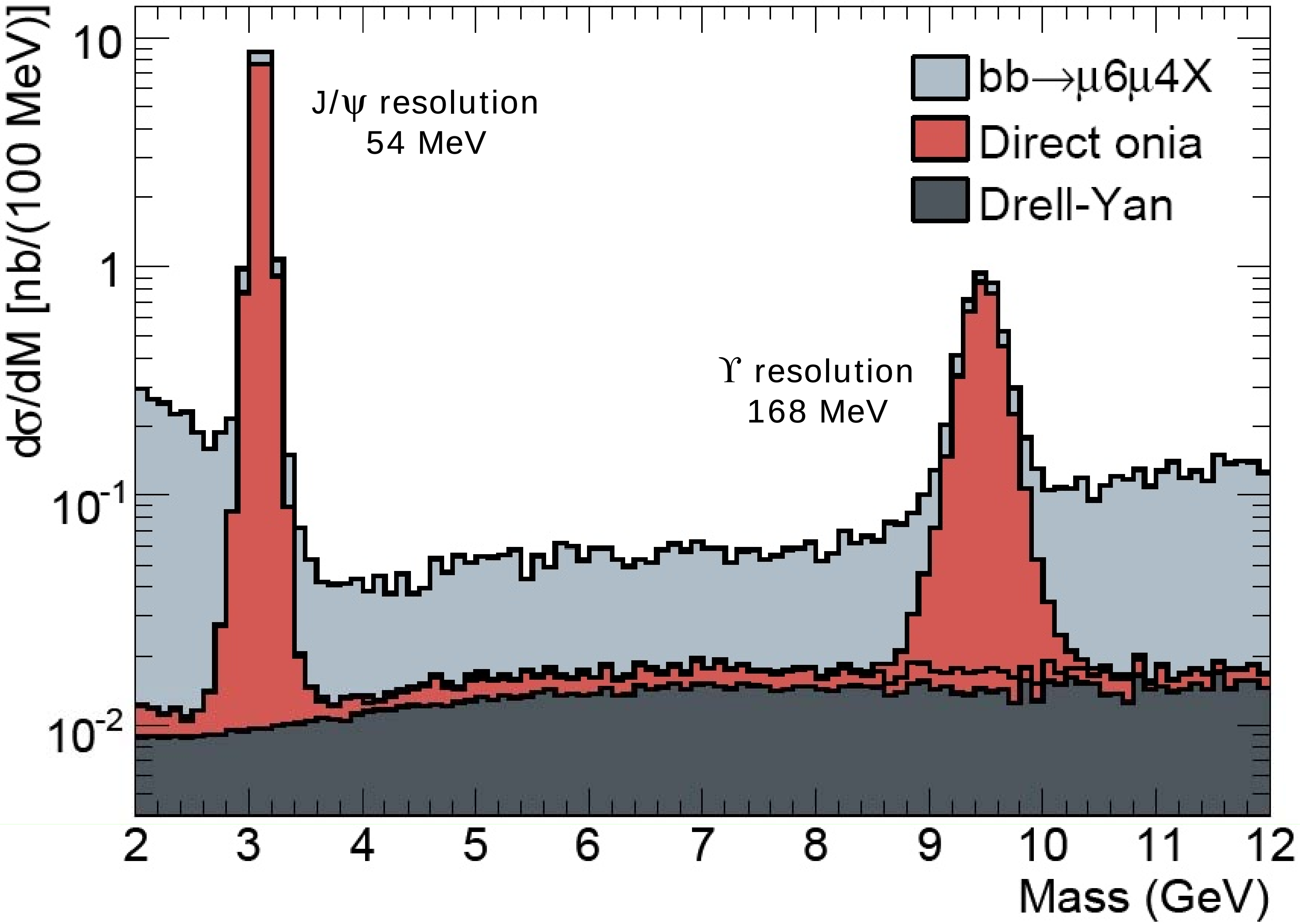
- Non-prompt sources are J/ψ from the decay of B-hadrons (no such sources exist for ϒ)

- Prompt sources comprise direct (from QCD processes such as gluon fragmentation) and indirect production (from feed-down from higher quarkonium states such as the χ states and the ψ' and ϒ(2,3S)).



	J / ψ	ϒ
Direct production	19 nb	22 nb
Indirect χ feed-down	8 nb	21 nb
Higher state feed-down	~ 1 nb	~ 5 nb
Non-prompt sources	14 nb	--
Total rate	42 nb	48 nb

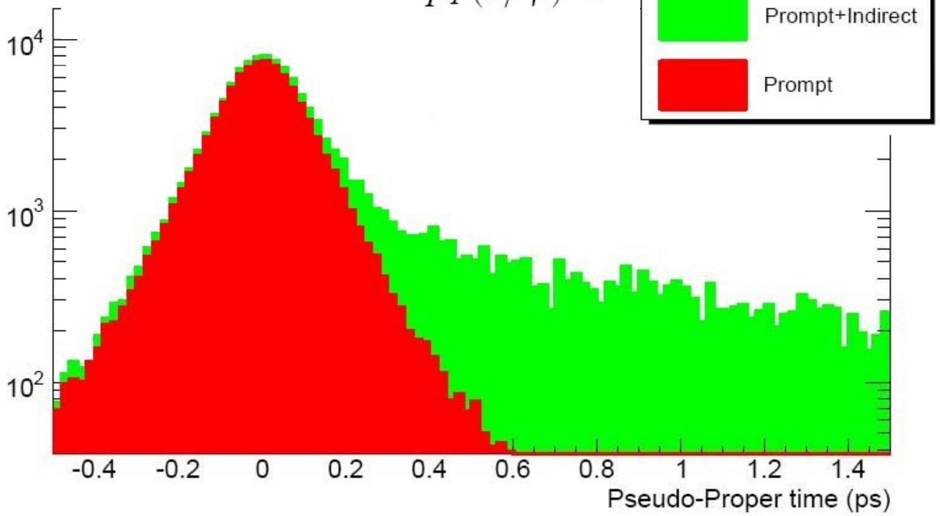
Low mass di-muon sources (μ6μ4)

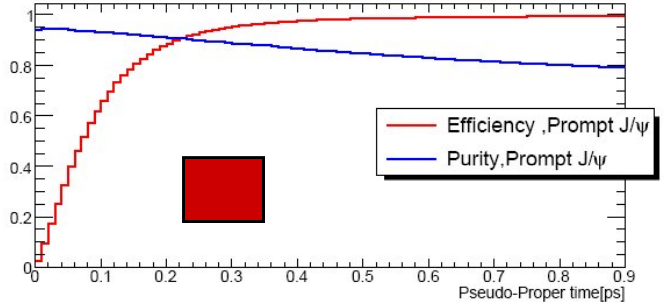


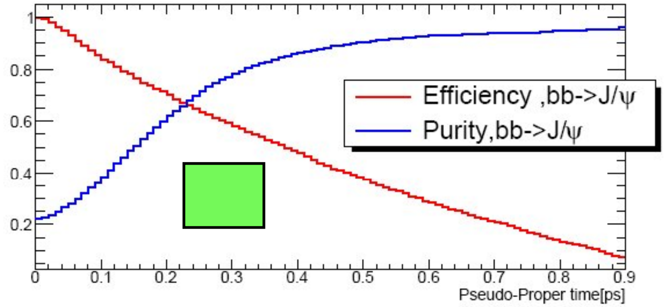
Vertex separation of prompt J/ψ

Pseudo-proper time is used to distinguish prompt J/ψ

$$\text{Pseudo-proper time} = \frac{L_{xy} \cdot M_{J/\psi}}{p_T(J/\psi) \cdot c},$$

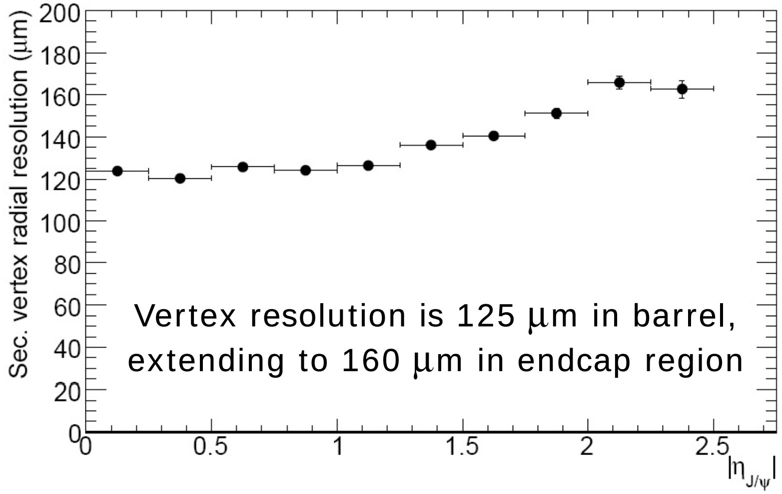






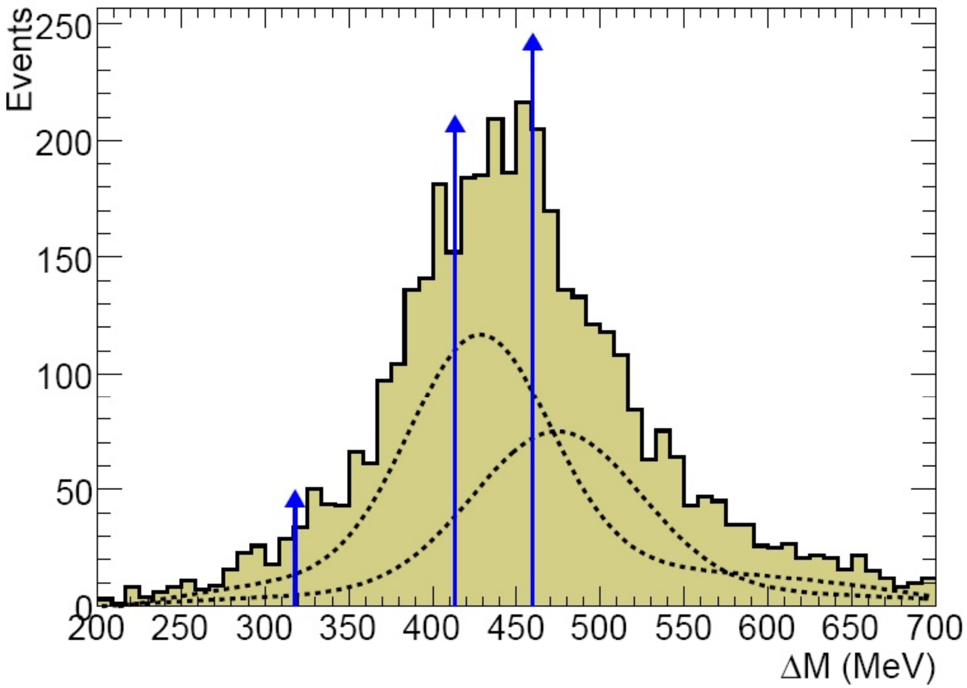
Cut of 0.2 ps gives 90% efficiency and 95% purity in prompt sample

Cut of 0.15 ps gives 80% efficiency and 60% purity in non-prompt sample



χ reconstruction

- Prompt J/ψ candidates are combined with all photon candidates reconstructed in the event to form χ_c candidates
- By looking at $\Delta M = M(\mu^+\mu^-\gamma) - M(\mu^+\mu^-)$ can identify χ_{c0}, χ_{c1}, and χ_{c2} signals
    - Blue lines show means of true signal peaks
    - Dotted lines show fits to χ_{c1} and χ_{c2} signals
- Reconstruction efficiency is 4% for χ_c and just 0.03% for χ_b (smaller photon boost)
- χ_c signals show systematic shift of $\Delta M = +15$ MeV
- Resolution of peaks: 50 MeV



Detector monitoring

The J/ψ and Υ useful as calibration and monitoring tools for detector alignment, material and field tests

STATISTICS:

Express stream: (10 hours)

~15,000 J/ψ, ~25,000 Υ

Physics stream:

50k-1M J/ψ's and Υ's

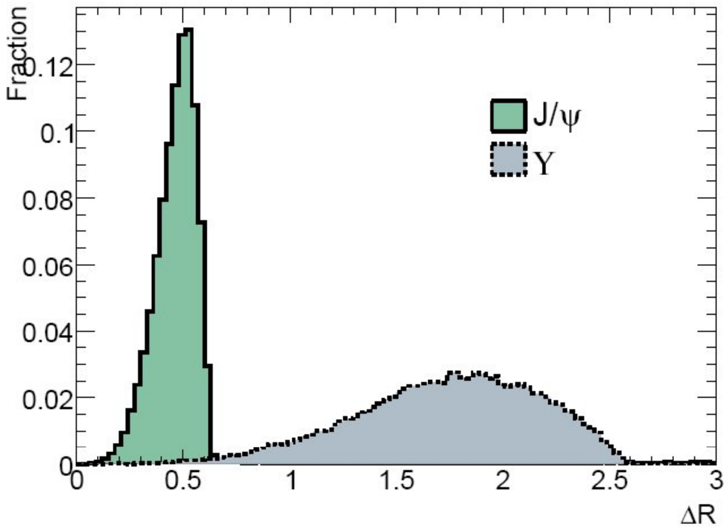
Express stream processing at Tier 0

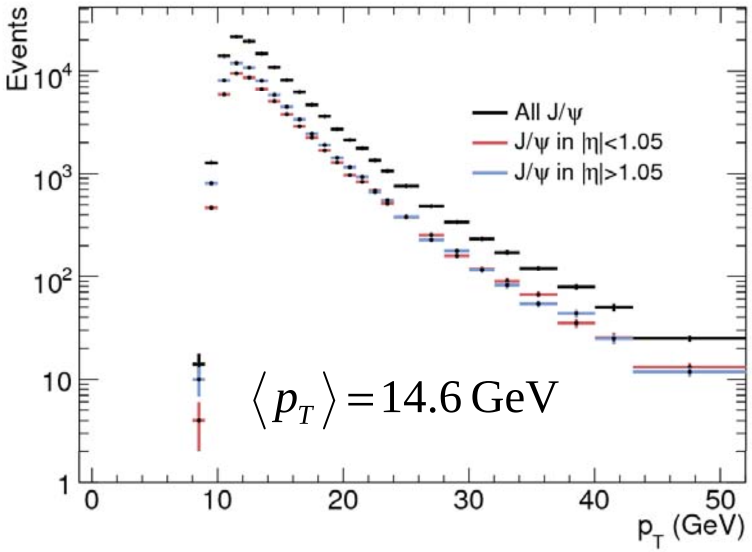
Idea is to reconstruct these events in real-time and identify problems before main reco begins (24 hour turn-over)

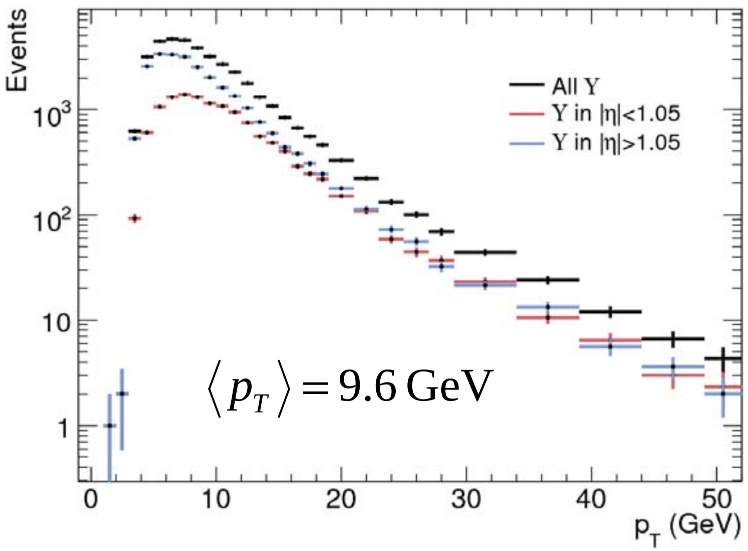
Detector monitoring

By looking at mass shifts in onia with a number of variables, can disentangle various causes of detector effects

Important to use both J/ψ and ϒ to remove systematics when moving to different kinematic regime and decay topologies



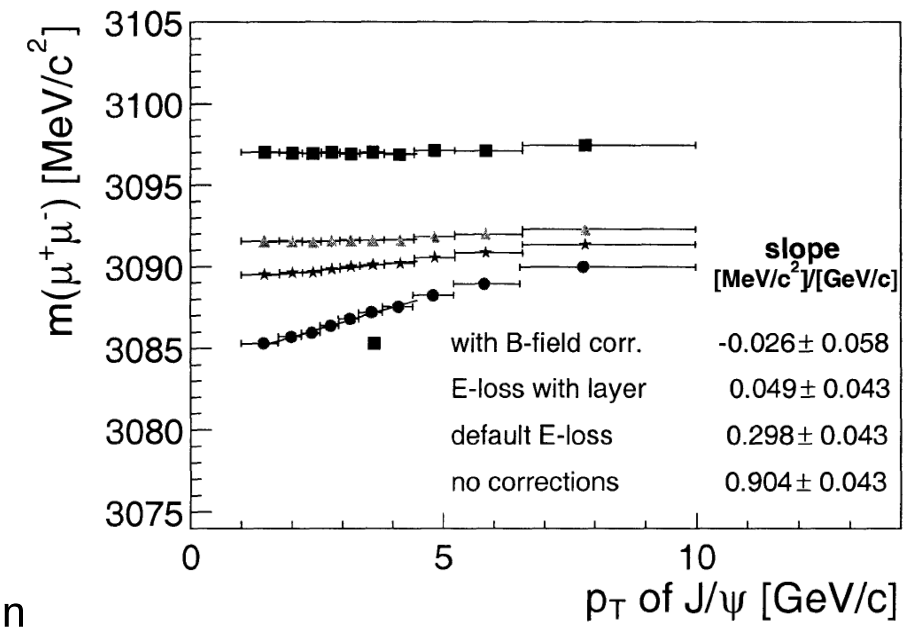




Onia offline monitoring at CDF

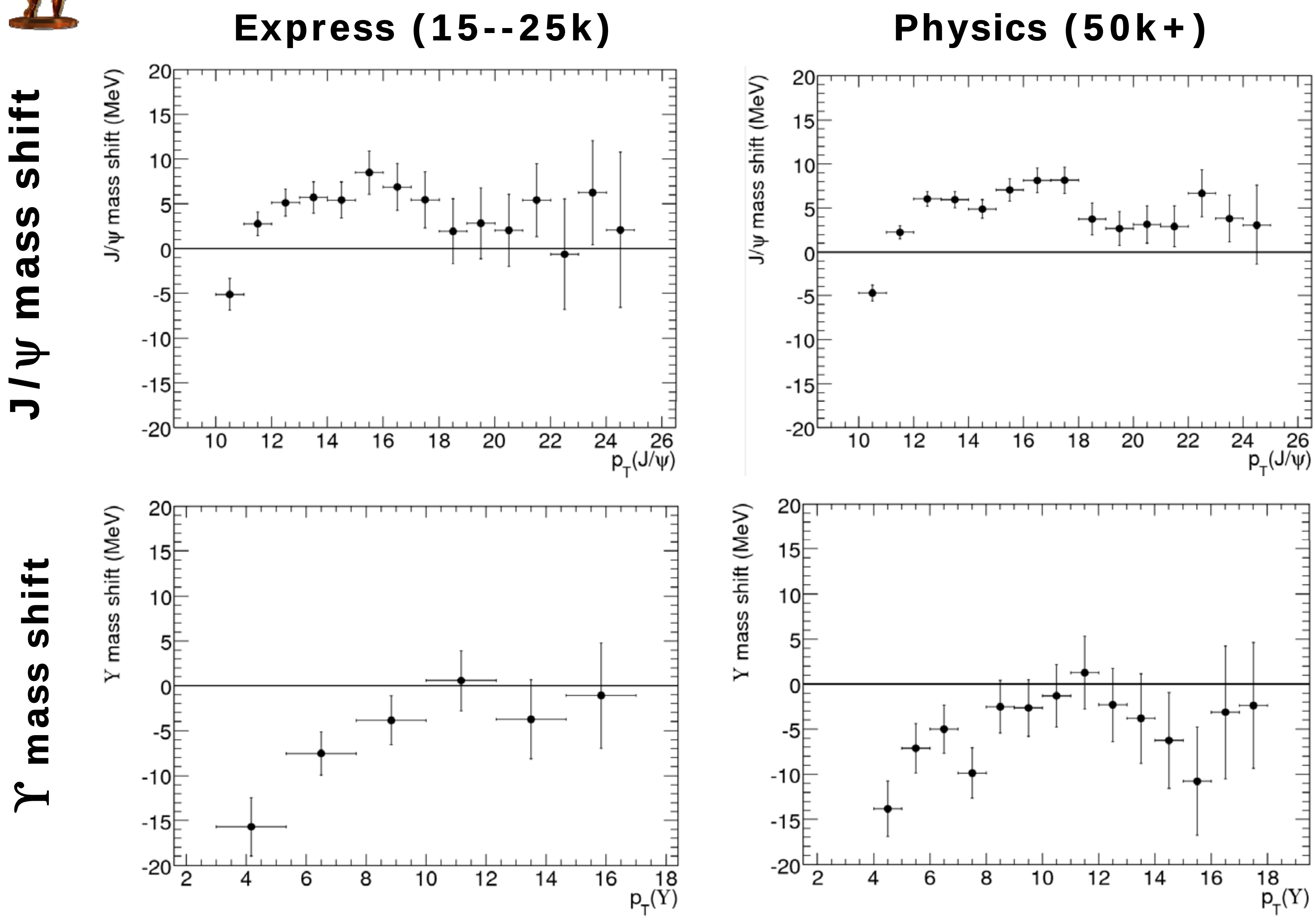
J/ψ were used extensively at CDF for various aspects of detector monitoring and calibration

- Mass shift of onia with a number of different variables were studied at CDF to remove biases, correct for alignment and material effects
- Looking at one or two variables is not enough, as many different effects are convolved to create the mass shifts
- Proper correction for material and alignment took years at CDF to accumulate statistics for precise correction

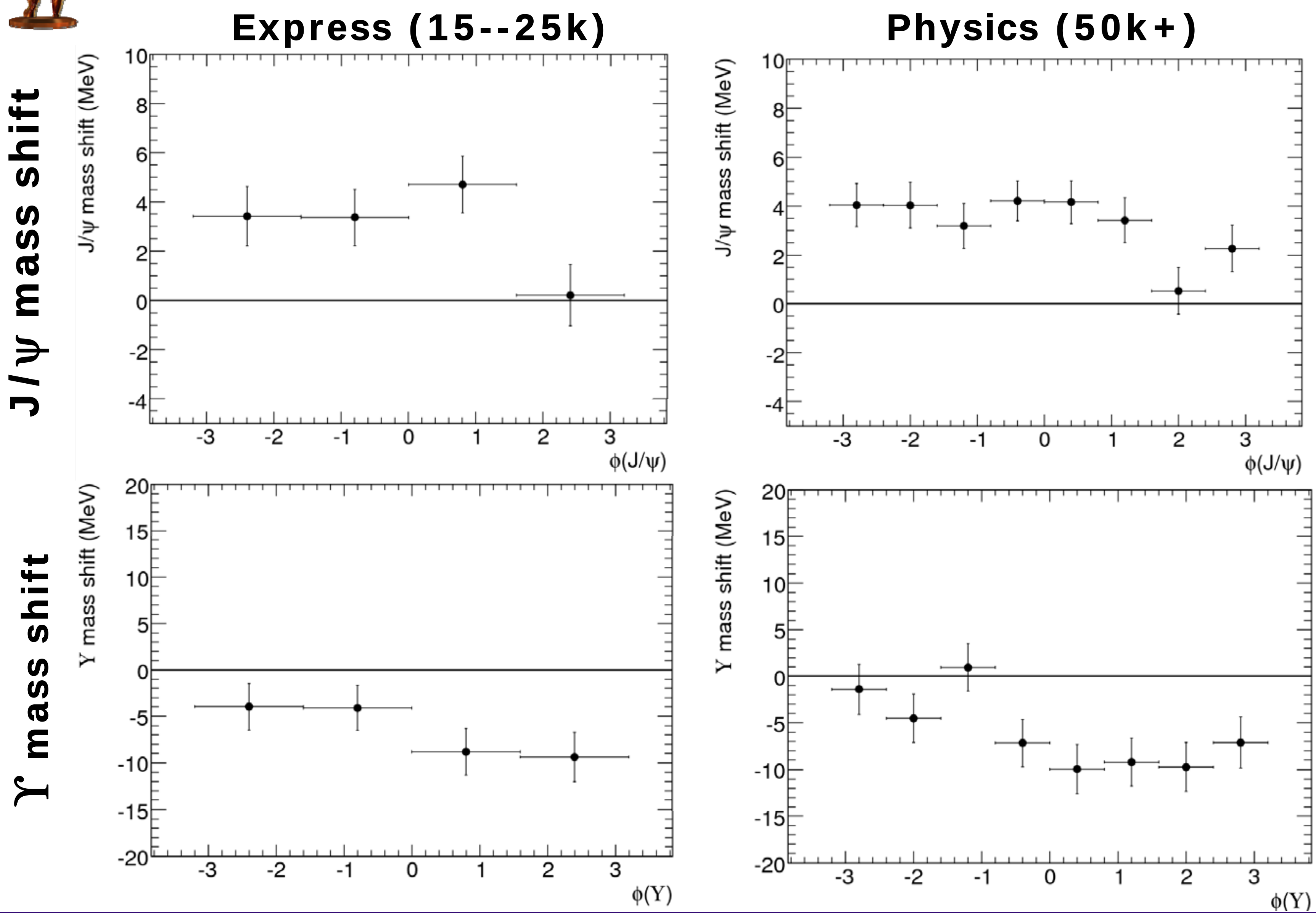


At ATLAS, will have similar statistics in weeks/months to total yield from Tevatron

Mass shift with onia p_T



Mass shift with onia φ



+/- muon p_T difference (alignment)

- Horizontal misalignments in detector planes result in constant curvature offset, leading to charge-dependent tracking effects

- The effect of these charge-dependent tracking effects can be significant, and were seen at CDF

A. Korn

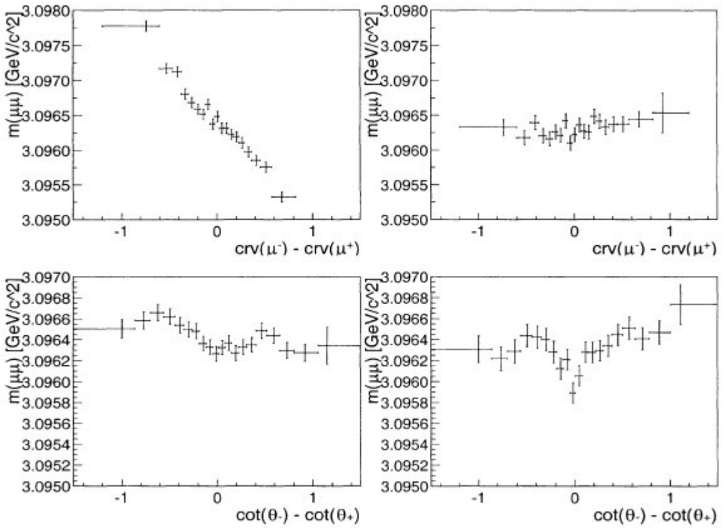
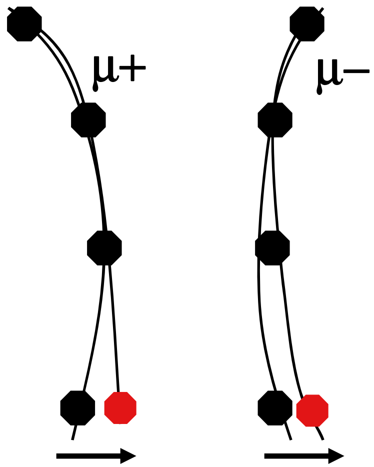


Figure 4-44: The di-muon mass variation as a function of the curvature difference (top), and the cot θ difference (bottom), between the positive and negative muon in Run II. The left two plots are using default tracks while the right plots use COT only

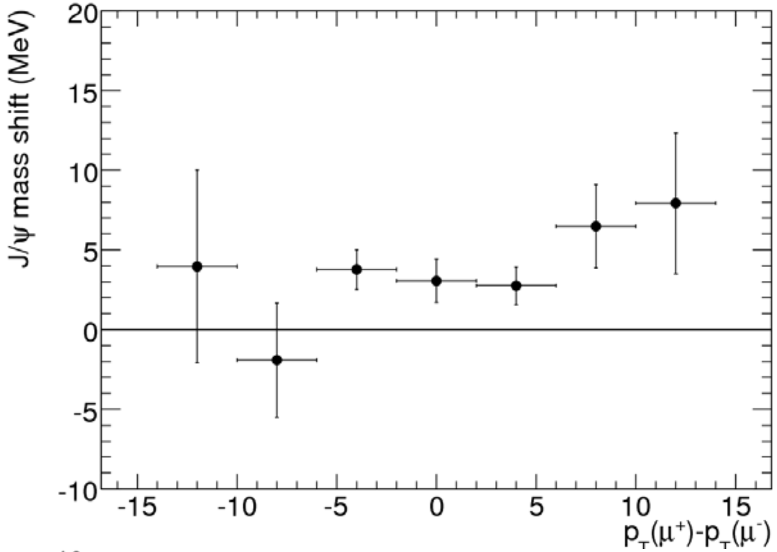
In this example, a misalignment means a negative track has a higher assigned curvature, whilst a positive track has a lower asssigned curvature

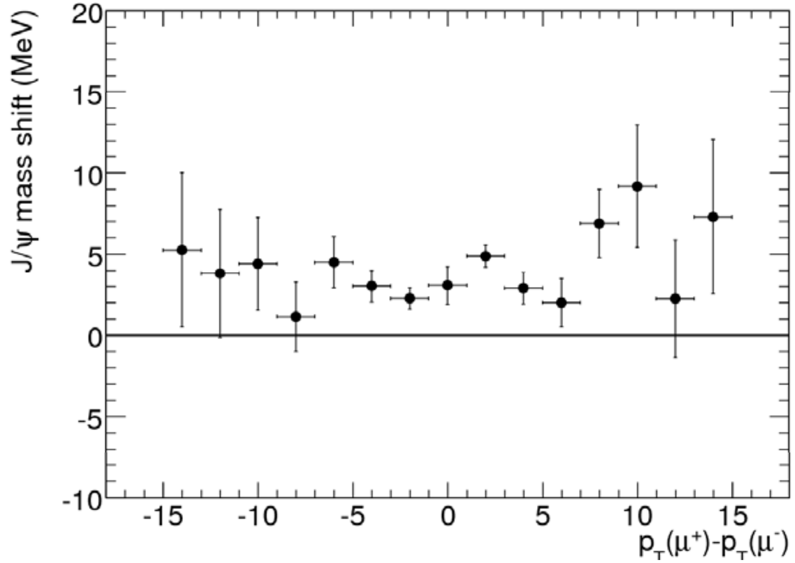


Mass shift with +/- muon p_T difference

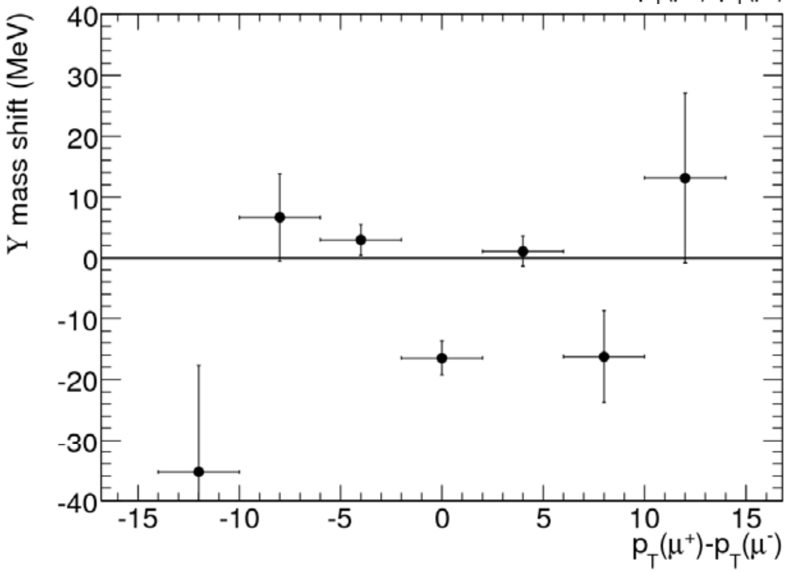
Express (15--25k) | Physics (50k+)

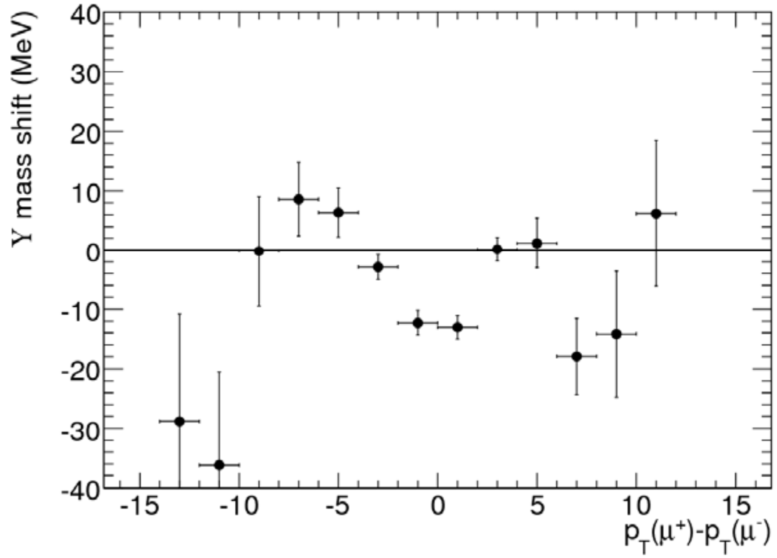
J/ψ mass shift





Υ mass shift

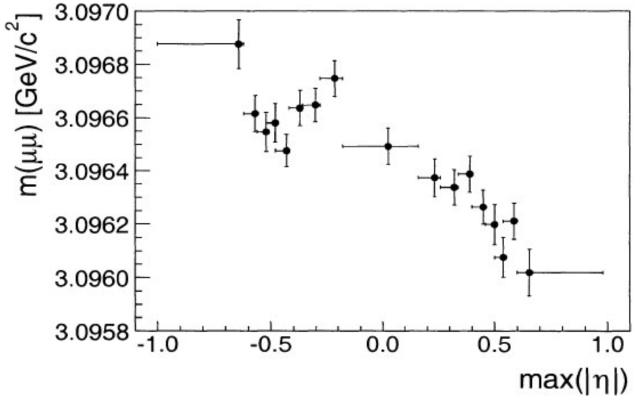




Maximum muon |η| (magnetic field)

- The magnetic field determines the relationship between track curvature and momentum

- Field uniformity: mass shifts vs. maximum absolute pseudorapidity of daughter muons was quantity used at CDF



(A. Korn, CDF)

- Related quantity to study would be mass shift vs. run number, which can serve as indicator of magnetic field stability

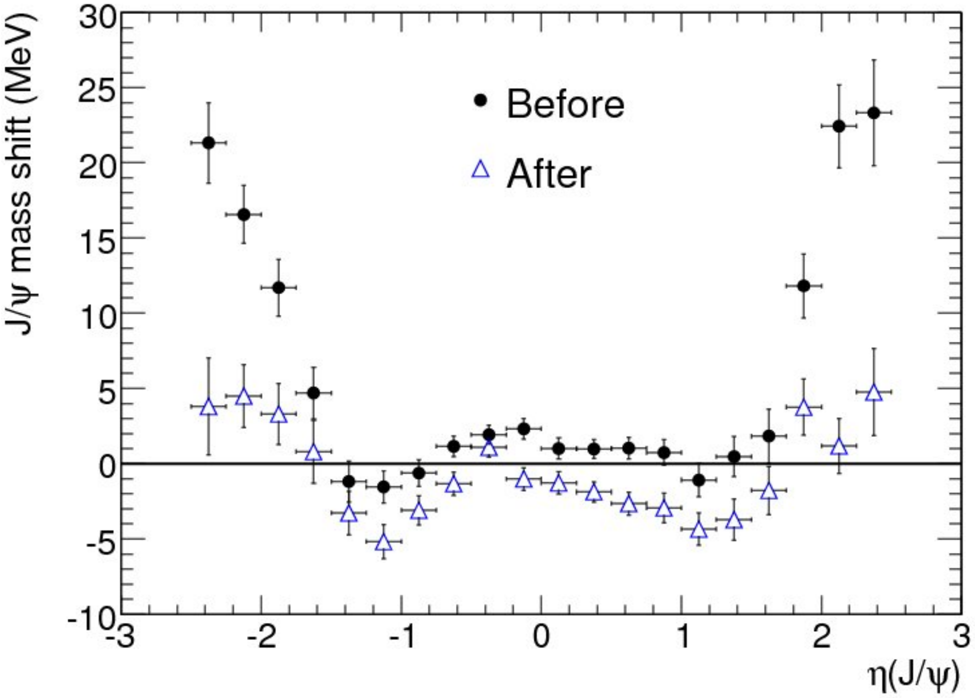
Check of muon reconstruction algorithms

- ❖ With MC generated data, mass shifts can be a good check of muon reconstruction algorithms.

- ❖ This has already been used to solve a previously unseen problem in the Staco reconstruction algorithm

Large mass shifts in release 12 were seen in at high η

Problem found to be overestimation of energy loss in forward regions compared to G4 energy loss



- ❖ Mass shift variables can help to pin down differences between Staco/ MuID reco algorithms – some differences do exist

Summary

- 1 pb^{-1} of data will provide around 30 k of both J/ψ and Υ with μ4μ4 trigger

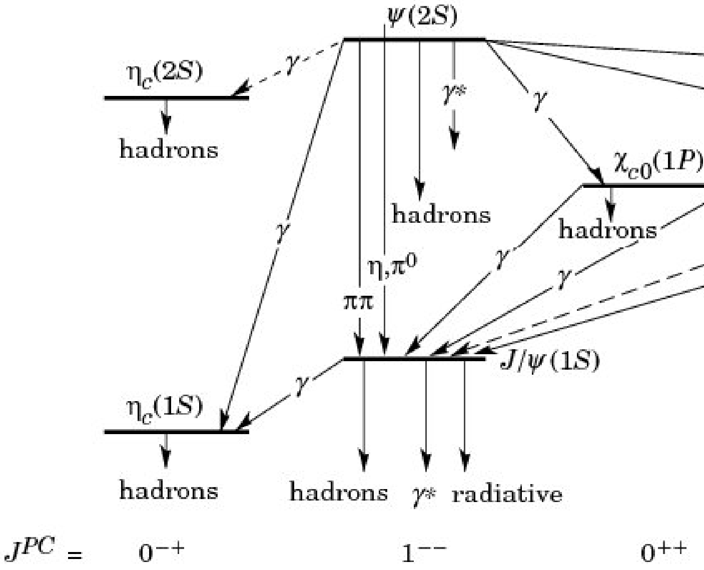
  - first measurement of trigger efficiencies
  - online & offline monitoring for alignment and calibration of detector
  - detector performance measurements
  - measurement of onia differential cross-sections
  - identification and measurement of χ_c signals

- With 10 pb^{-1} will be able to substantially exceed Tevatron reach on spin-alignment analysis for understanding of QCD production mechanisms (more in the next talk)

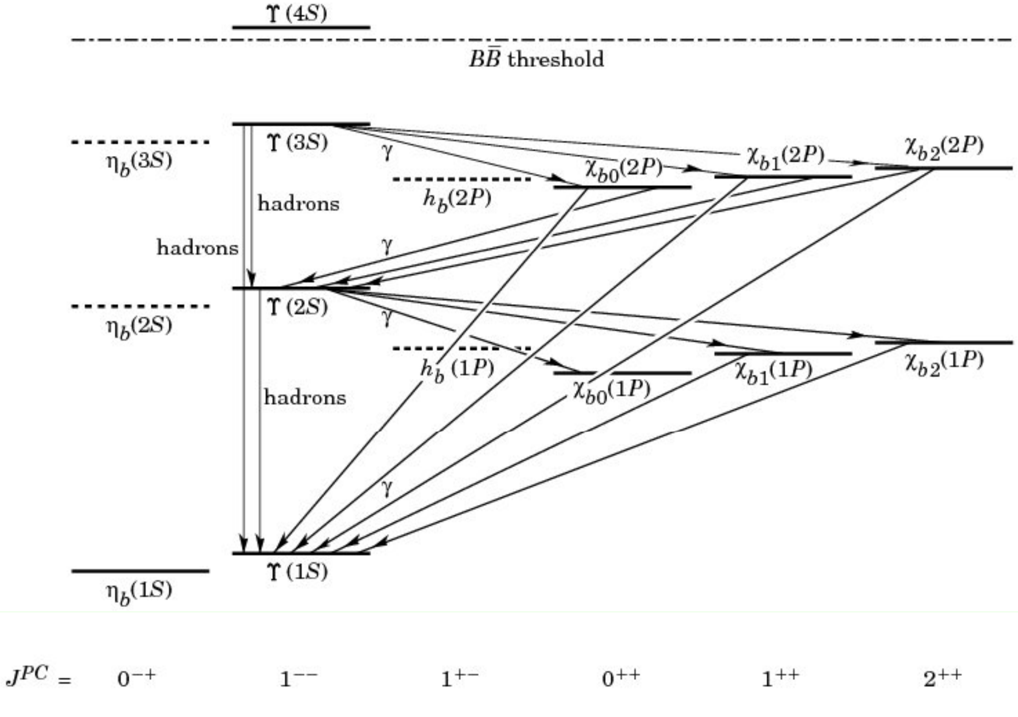
Backup slides

The quarkonium systems

Charmonium

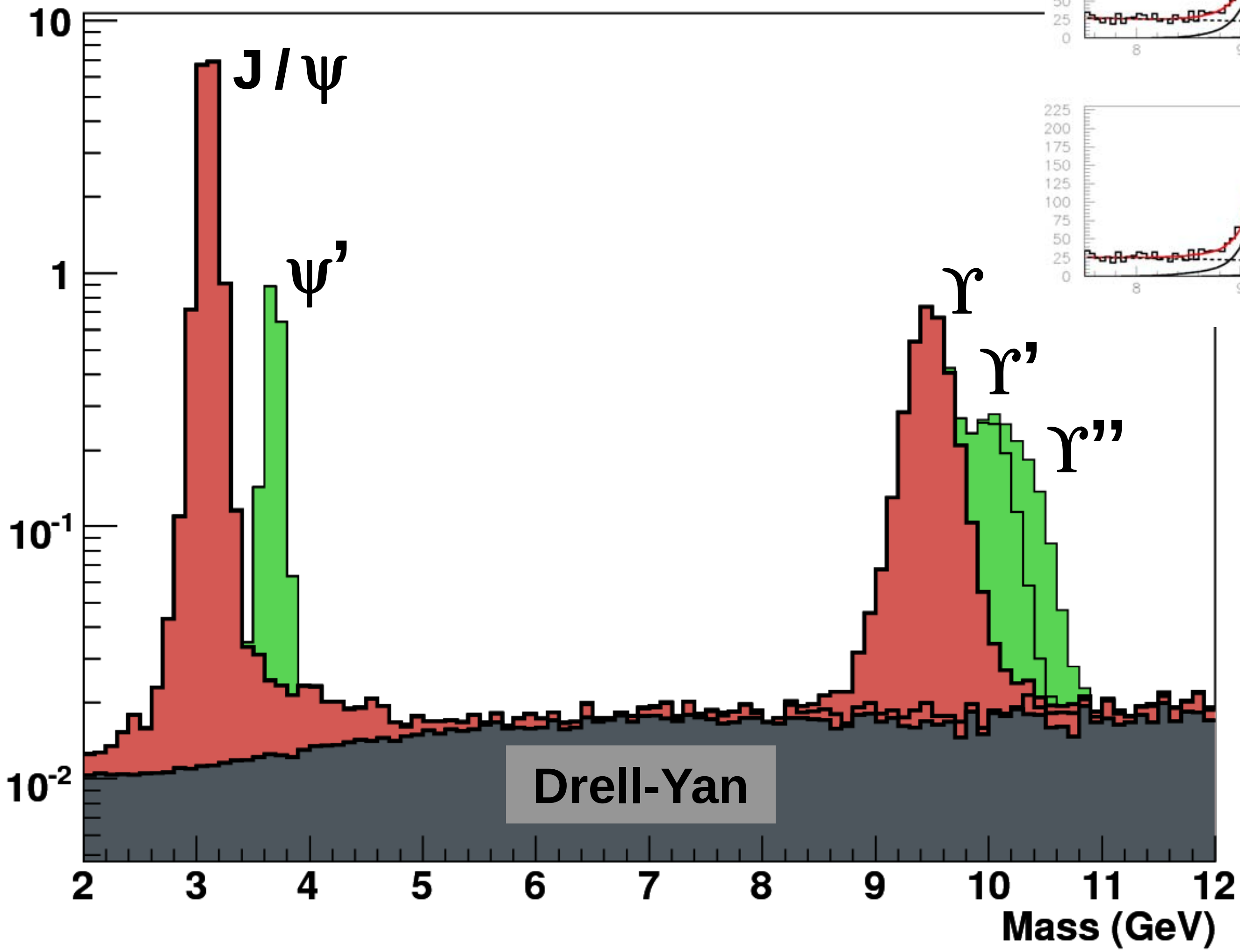


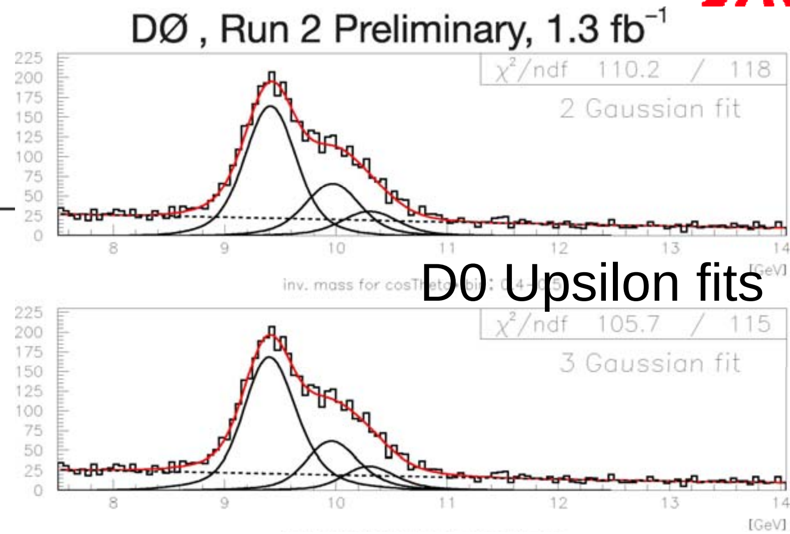
Bottomonium



Di-muon mass plot with higher states

Sources of low invariant mass di-muons





From D0 Note 5089-CONF

(Higher state contributions have been stacked)

Higher state contributions are for illustration only -- correct normalisation and expected resolutions, but are **NOT** fully simulated events!