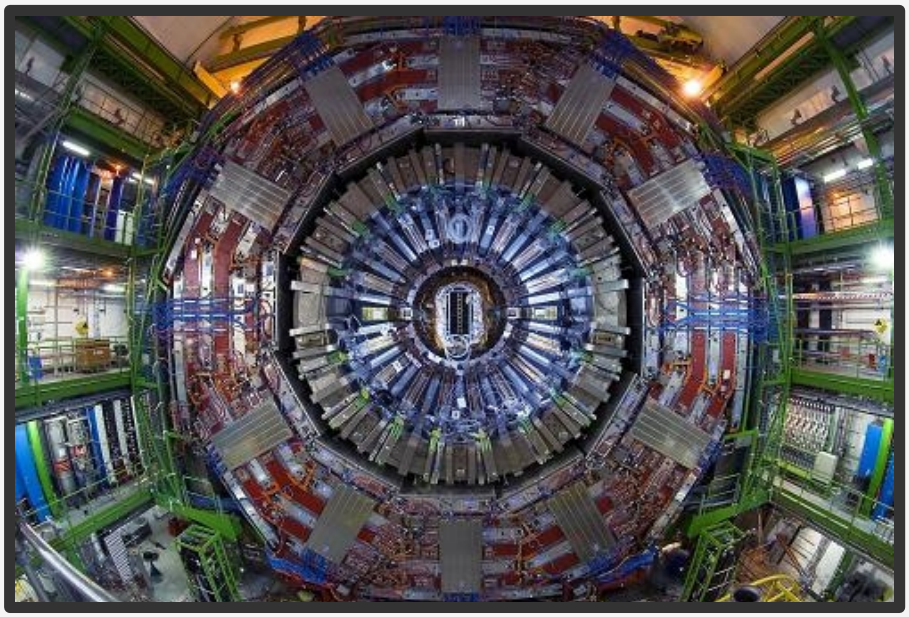
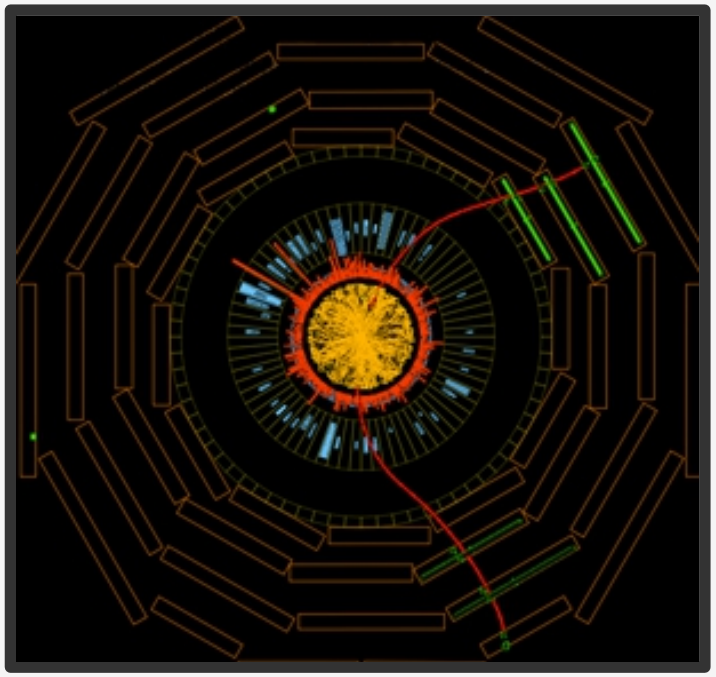
Polarization Systematic Uncertainty at CMS



Compact Muon Solenoid (CMS)



Upsilon Event at CMS

Physics Motivation

Early universe was in Quark-Gluon Plasma (QGP) state.

↓

Upsilon meson is a temperature probe and indicator of deconfinement in the QGP.

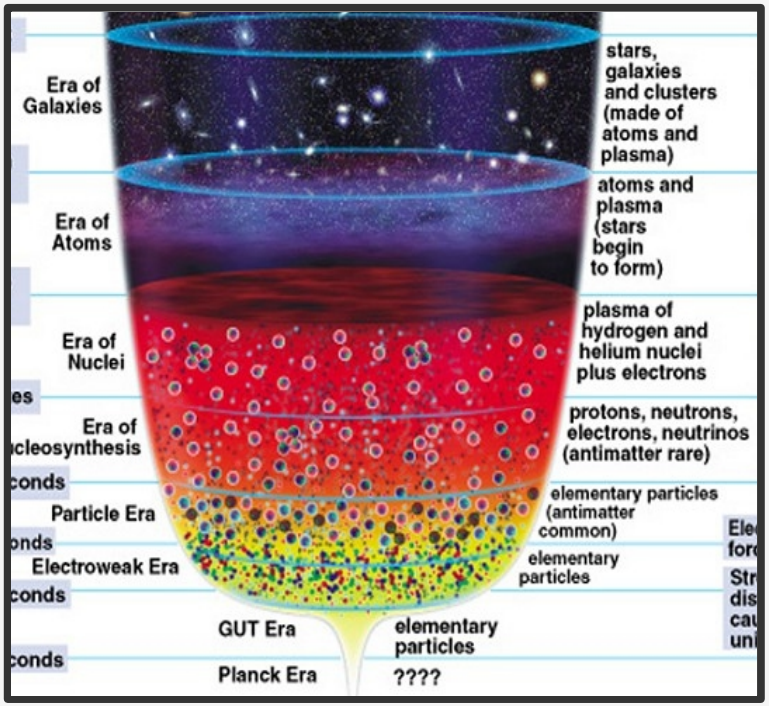
↓

Need to understand Upsilon.

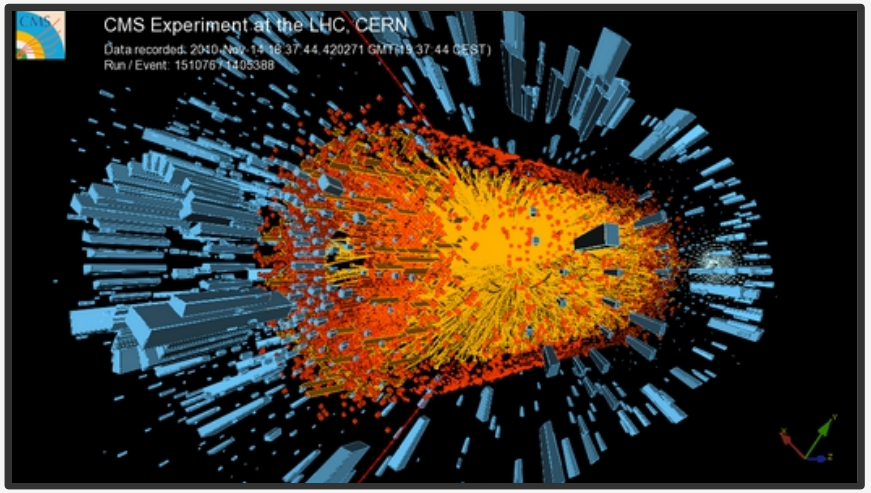
↓

Unknown:
Degree of Upsilon Polarization

Time Evolution of Universe



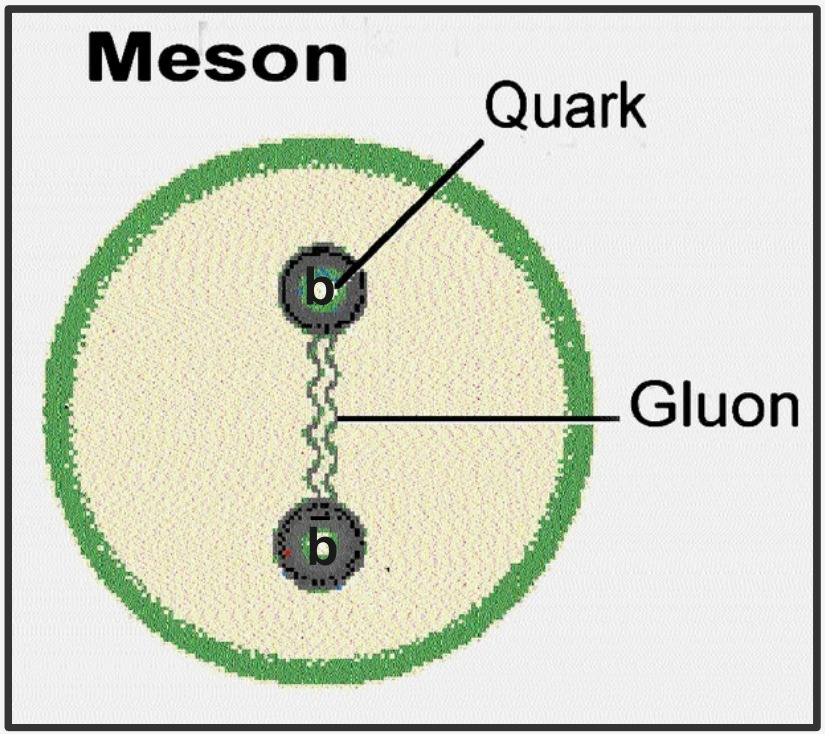
Upsilon Event in CMS



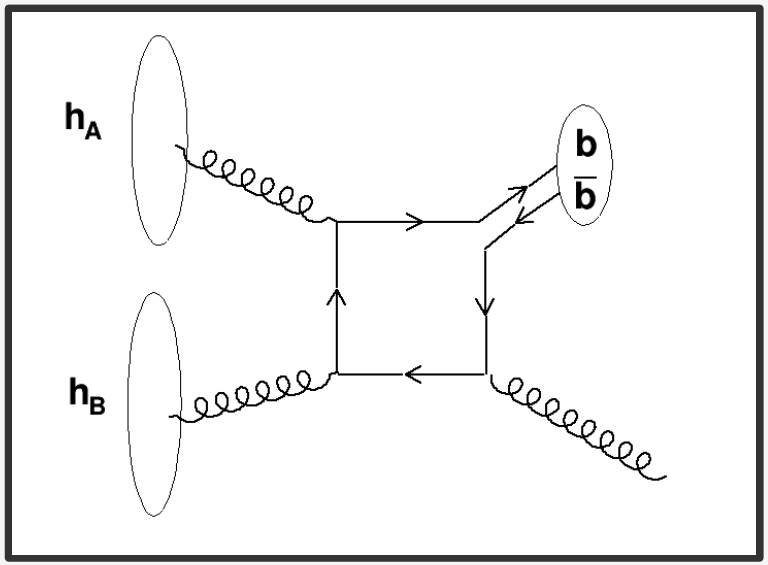
The Upsilon Meson

- What is it?
  - More Specifically:

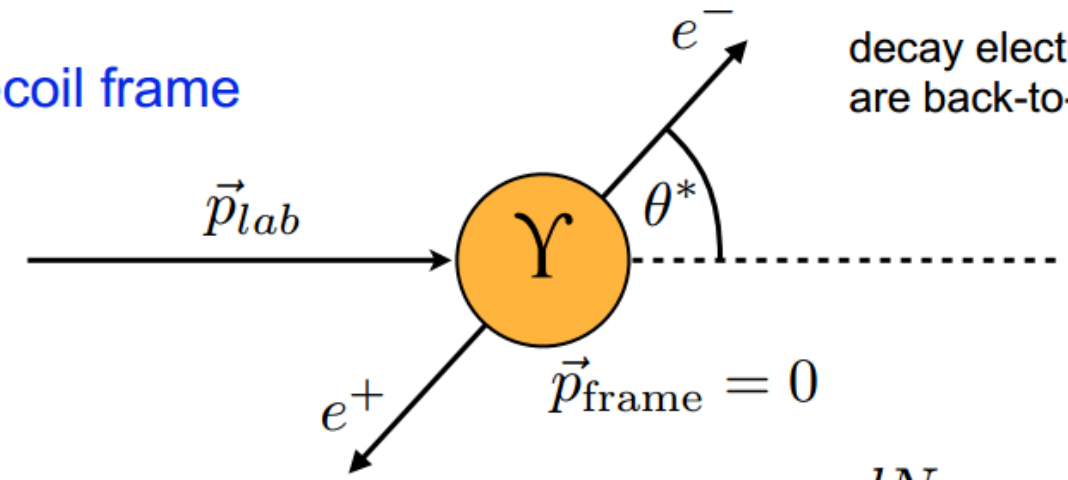
mean lifetime	1.2×10^{-20} seconds
half-life	8.4×10^{-21} seconds
width	54 keV (kiloelectronvolts)



* Masses of different energy states:
→ Y(1S) : 9.46 GeV/c^2
→ Y(2S) : 10.02 GeV/c^2
→ Y(3S) : 10.36 GeV/c^2
* Discovered in 1977
* First observation of the bottom quark



Upsilon Polarization



Polarization is measured through: $\frac{dN}{d\cos\theta^*} \propto 1 + \alpha\cos^2\theta^*$

where $\alpha = \frac{\sigma_T - 2\sigma_L}{\sigma_T + 2\sigma_L}$

σ_T and σ_L are the transverse and longitudinal polarized components of the production cross-sections

Using this definition, simulate millions of proton-proton collisions.

Goal: Obtain estimate for polarization systematic uncertainty at CMS.

Contradiction in Data!

*proton-antiproton collisions

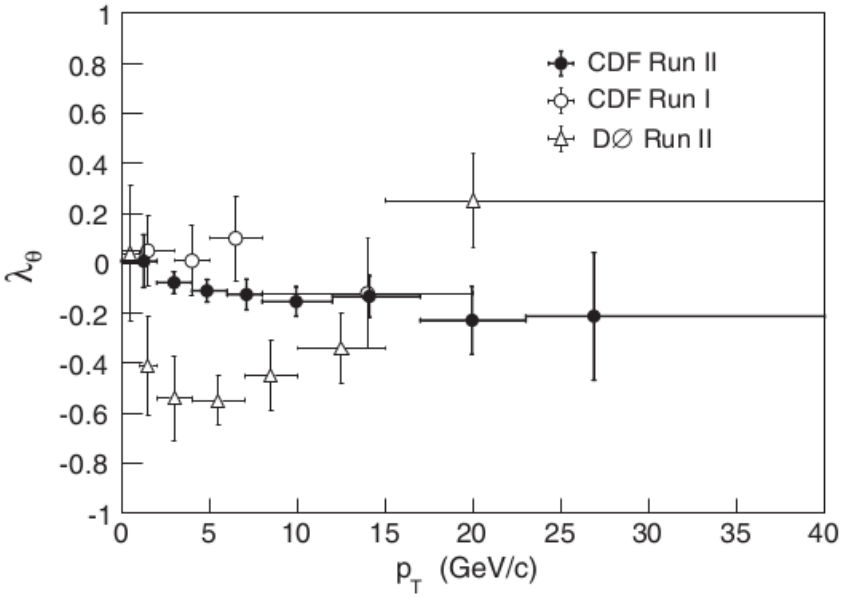
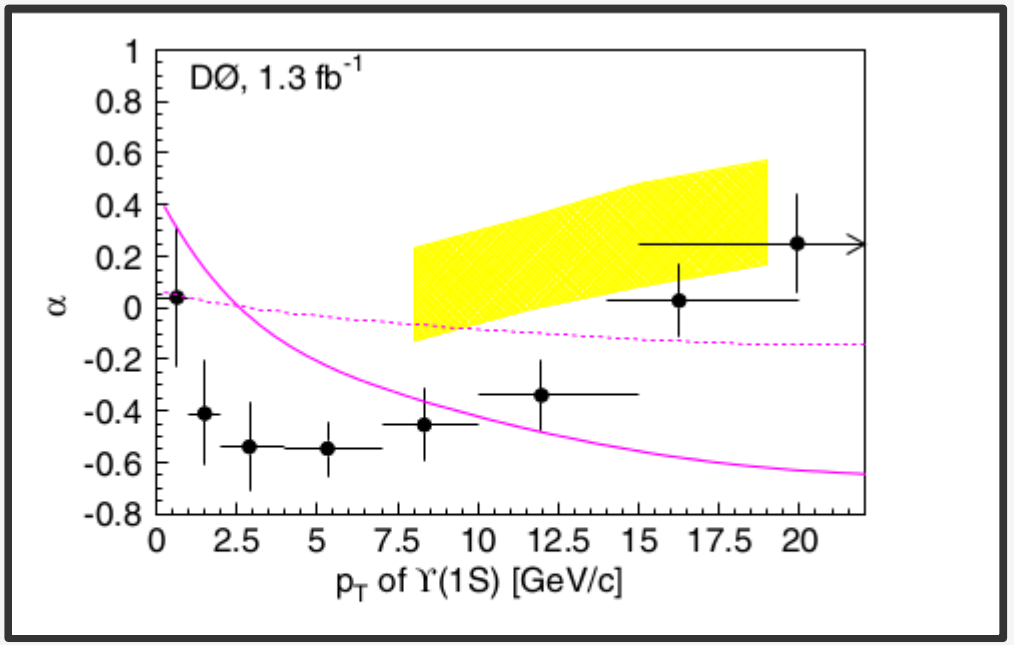


FIG. 5. Comparison of the λ_θ parameter measured for $\Upsilon(1S)$ decays in the s-channel helicity frame (solid symbols) with previous measurements from the CDF [4] (open circles) and the D0 [18] (open triangles) experiments.

CDF and DØ Collaborations



DØ Collaboration and NRQCD Prediction

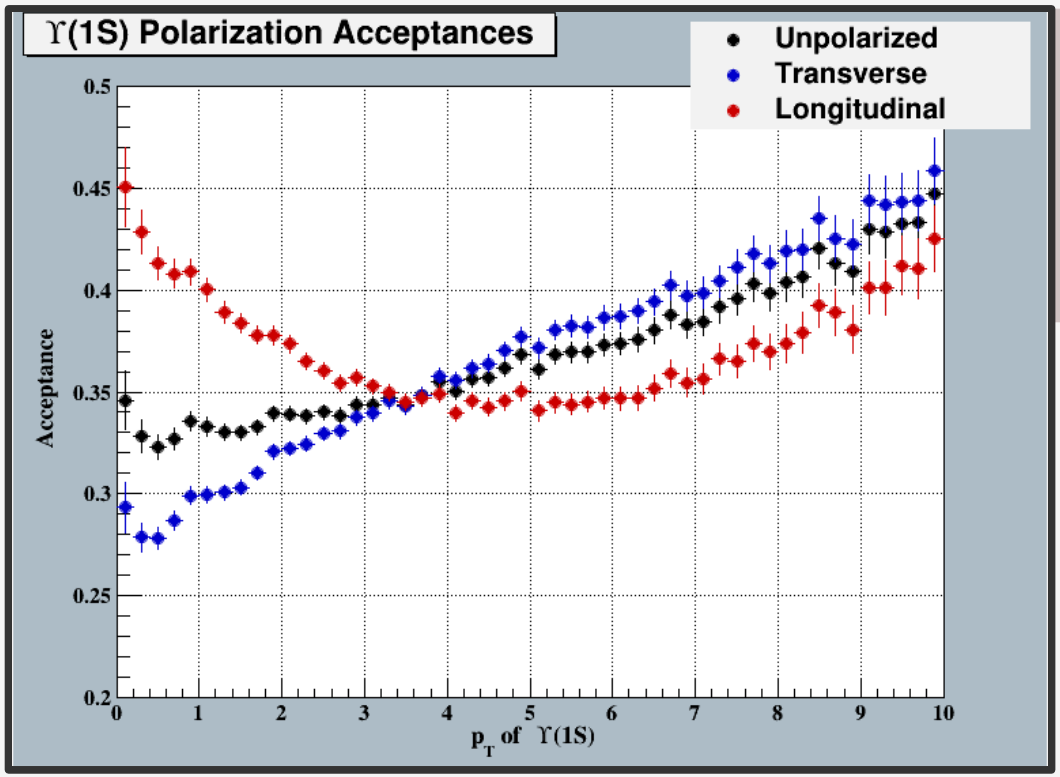
We expect the CDF and D0 results to be similar,
and we have no explanation for the observed difference.
- DØ Collaboration

Methodology

1) Simulate millions of p-p collisions in PYTHIA.
   - Require $\Upsilon \rightarrow \mu^+\mu^-$ in each event
2) Upsilon p_T is plotted for each polarization case.
   - Polarization modeled by applying α weights (see slide 4).
3) Cuts are applied to each polarization case to model detector acceptance and online event selection.
4) Systematic Uncertainty is estimated by differences in acceptance magnitudes for polarized vs. unpolarized cases.

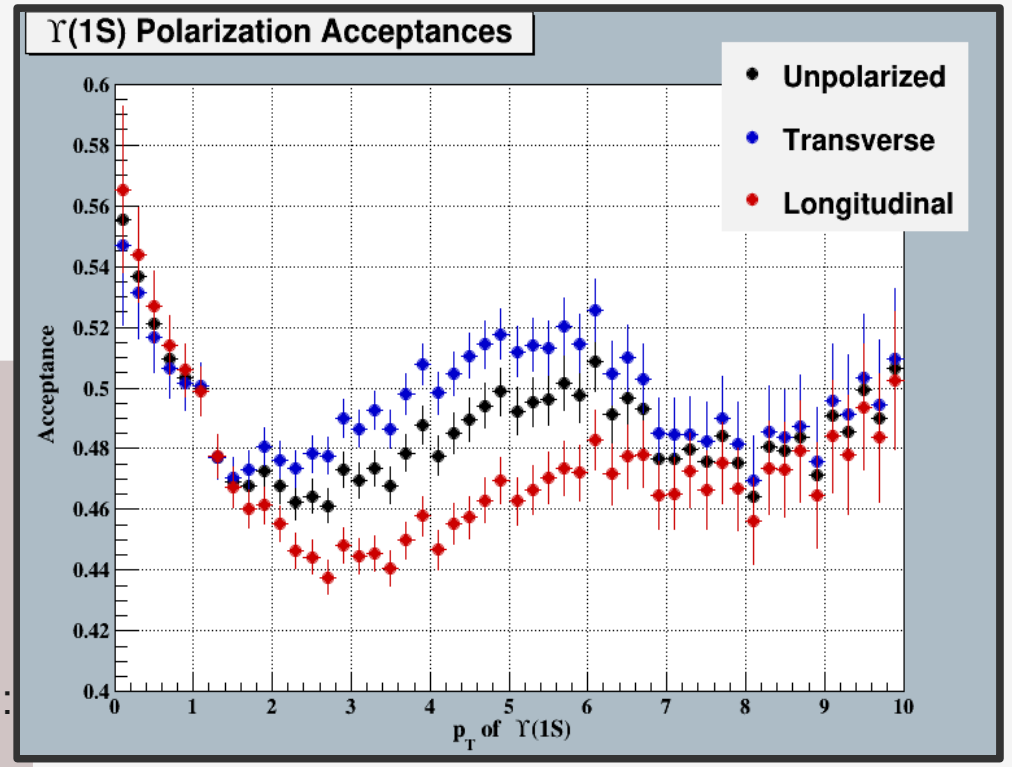
Polarization at STAR

For the **STAR** detector at RHIC.
200 GeV of energy per-nucleon pair.



Begin with all dimuons produced in 1 million proton-proton collisions.

And *then* allow only those dimuons within region of detector acceptance:
$|\eta_\mu| < 1$

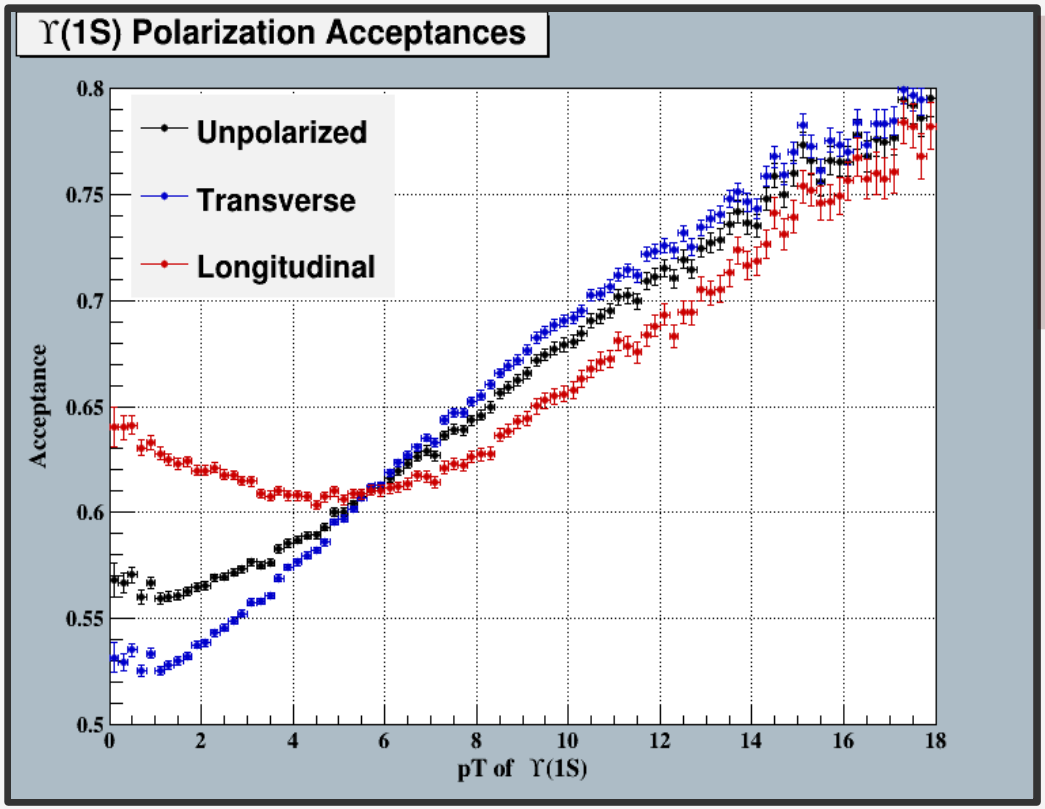


Begin with dimuons that have
→ $p_T^{(1)} > 4$ GeV/c
→ $p_T^{(2)} > 2.5$ GeV/c
→ $\cos(\theta) < 0.5$

And *then* allow only dimuons within detector acceptance region:
$|\eta_\mu| < 1$

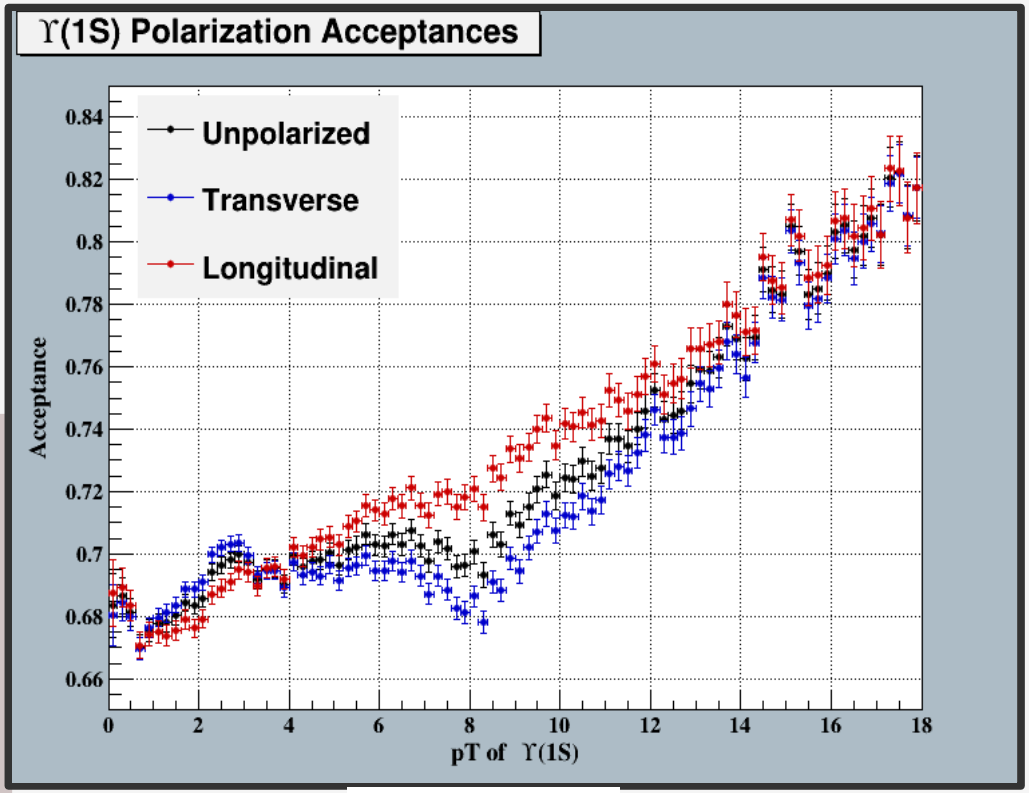
For the **CMS** detector at the LHC.
2.76 TeV of energy per-nucleon pair.

Polarization at CMS



Begin with *all* dimuons produced in 3 million proton-proton collisions.

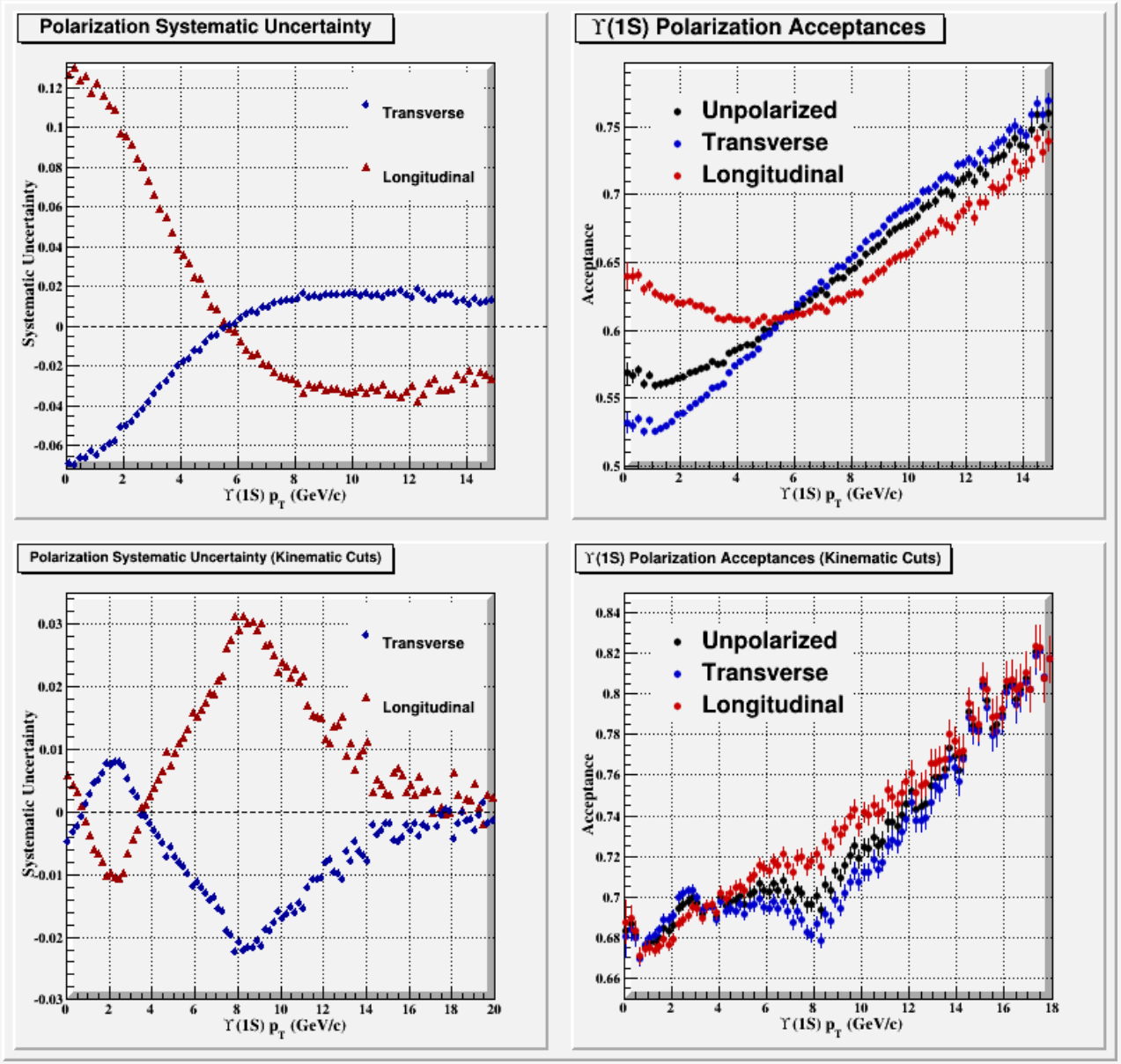
And *then* allow only those dimuons within region of detector acceptance:
$|\eta_\mu| < 2.4$



Begin with dimuons that have
→ $p_T^{(1)} > 4$ GeV/c
→ $p_T^{(2)} > 3.5$ GeV/c

and *then* allow only those within detector acceptance region:
$|\eta_\mu| < 2.4$

Systematic Uncertainty



Conclusions

The systematic error for Upsilon polarization at CMS is similar to what has been found at STAR, but with important differences in momentum crossover values and magnitudes of acceptance.

Although the experimental data is still inconclusive, this uncertainty estimate can provide intuition regarding how results may fluctuate depending on the degree of Upsilon polarization.

Acknowledgements

Advisors: Manuel Calderón de la Barca Sánchez and Daniel Cebra:

The UC Davis Nuclear Physics Group:

The American Physical Society, Far West Section: