Sivers Asymmetry in J/ψ Production in COMPASS 2010 Proton Data

Jan Matoušek
Charles University in Prague
On behalf of COMPASS Collaboration

DSPIN-15, Dubna, Russia

Outline

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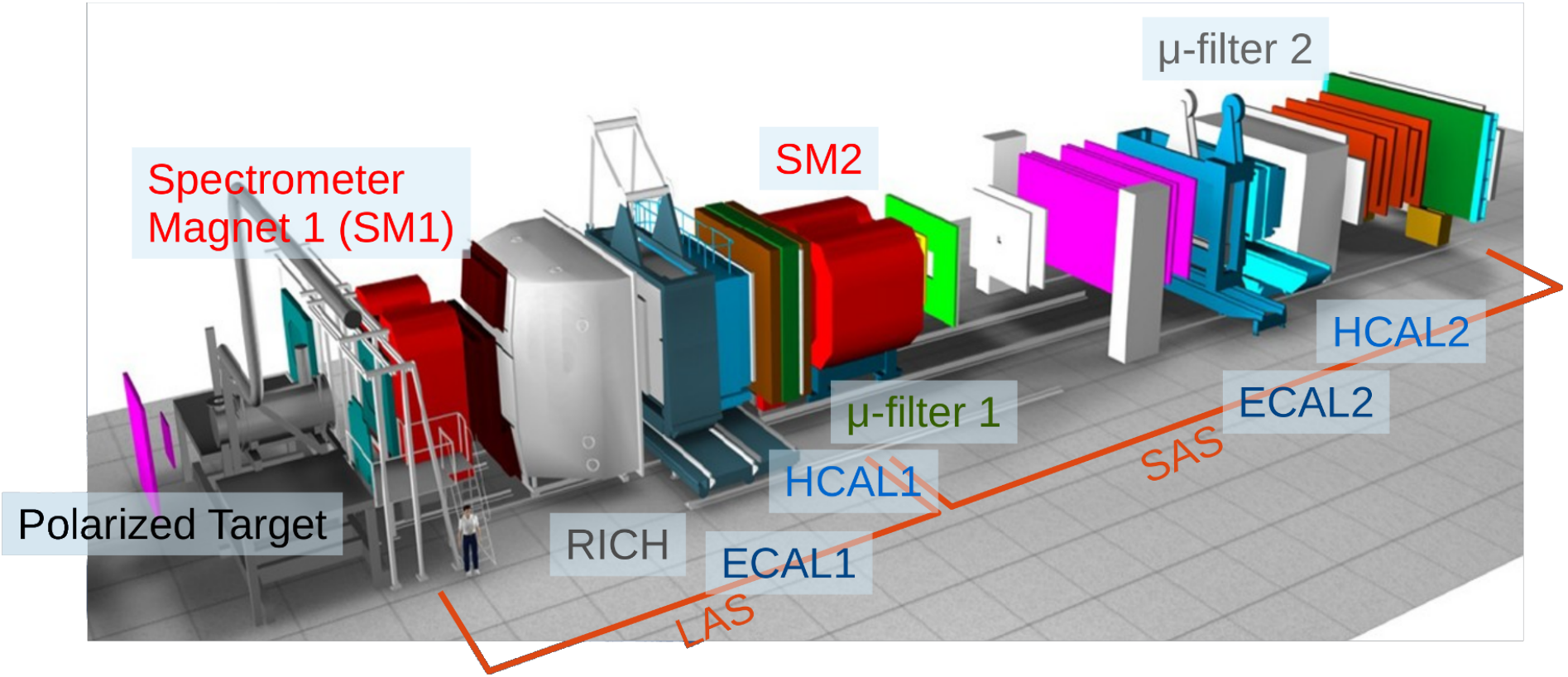
COMPASS Experiment at CERN



- Collaboration: 24 institutions from 13 countries ($\approx$ 220 physicists).
- Experiment: CERN SPS North Area, fixed target, multipurpose.
- $\approx$ 200 GeV/c secondary beams & various targets:
  - Long. polarized μ beam & polarized p/d target—nucleon (spin) structure;
  - hadron beam (π, K, p) & LH_2/nuclear target—meson spectroscopy, π & K polarizabilities, future: GPDs from DVCS;
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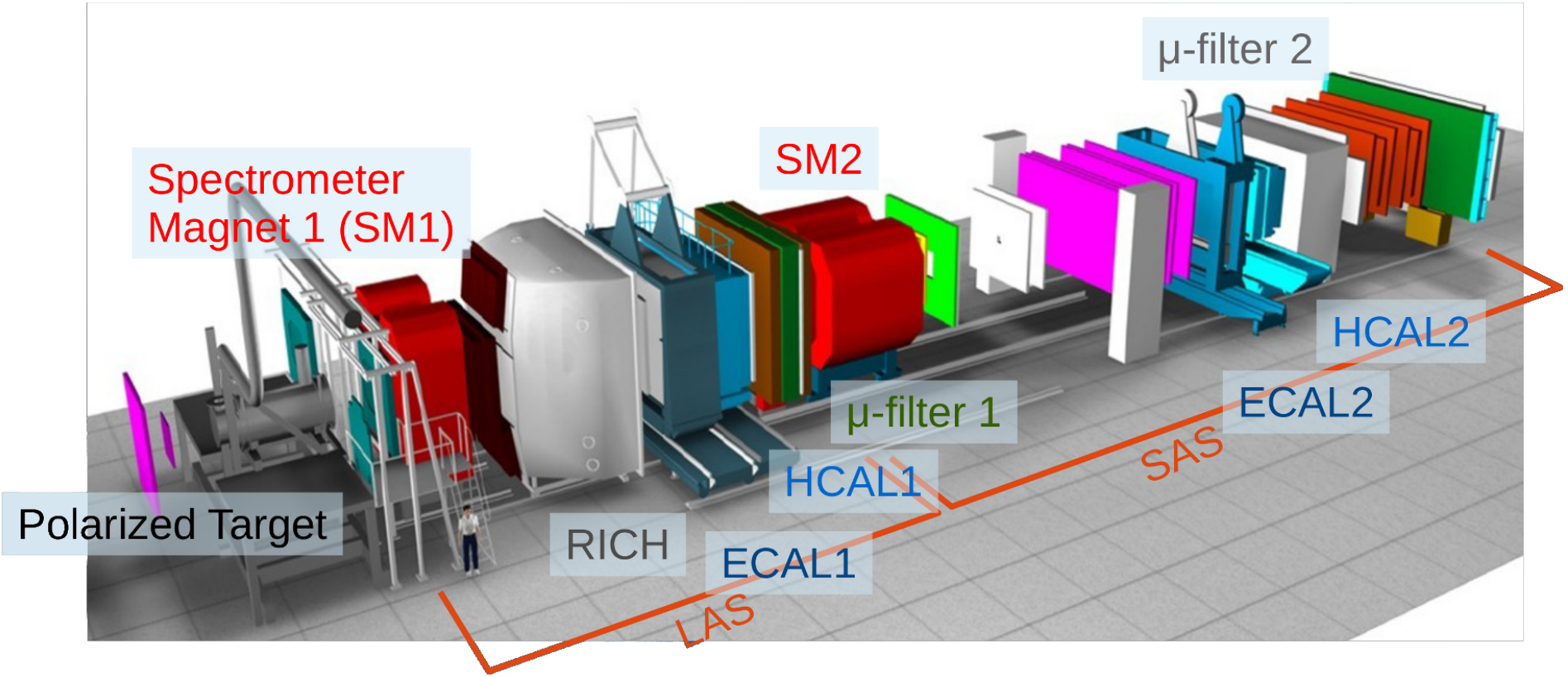

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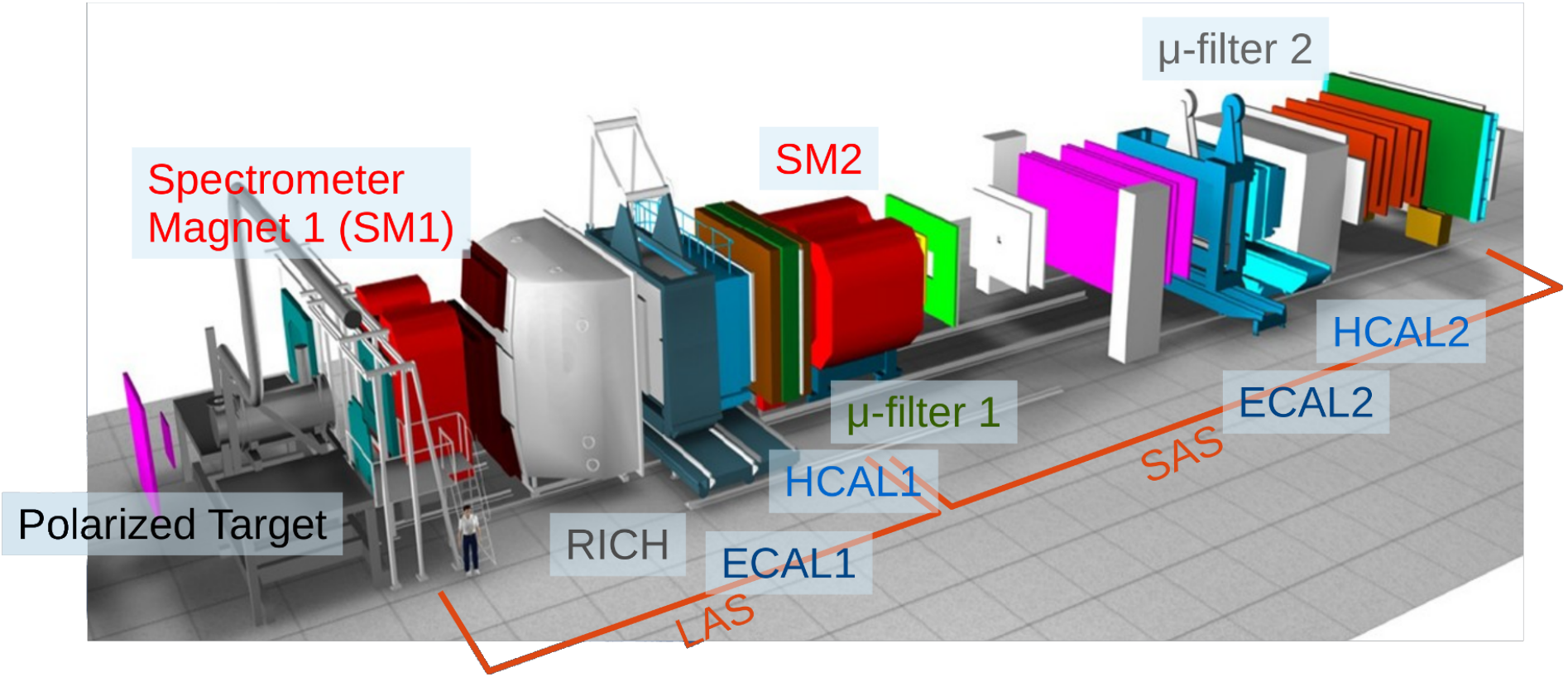

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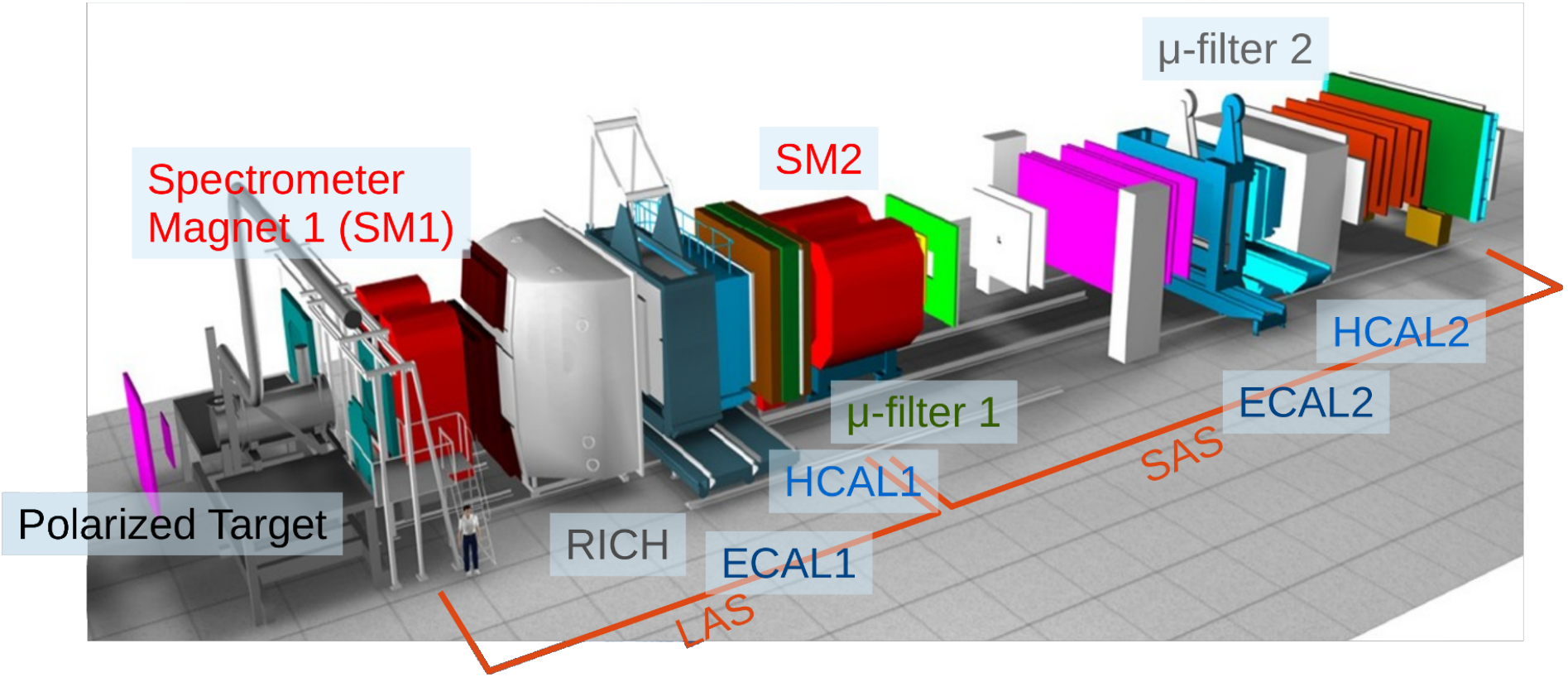

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Spin Structure of the Nucleon

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

- $\Delta\Sigma$—quark spins contribution—measured[1] $\Delta\Sigma \approx 0.3$
- ΔG—gluon spins contribution—RHIC data suggest small contribution[2] (+ x-check: COMPASS[3] $\Delta g/g$).
- L_q and L_g—quark and gluon orbital motion—experimentally challenging.

Gluon Sivers function

- Nonzero gluon Sivers f. is related to its orbital motion in a polarized nucleon.
- In COMPASS "transverse SIDIS mode" (μ^+ scat. on $p^\uparrow / d^\uparrow$):
  - can be accessed via Sivers asymmetry in Photon-Gluon Fusion (PGF) $\gamma + g \to q + \bar{q}$,
  - but there are competing processes: DIS & QCD Compton scattering.
  - Talk of Krzysztof Kurek at this conference.
  - Any other channel?

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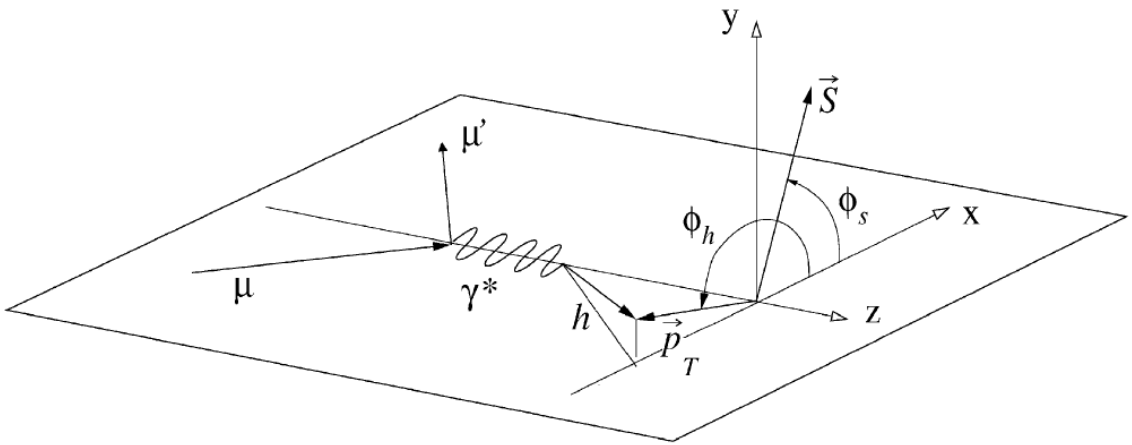

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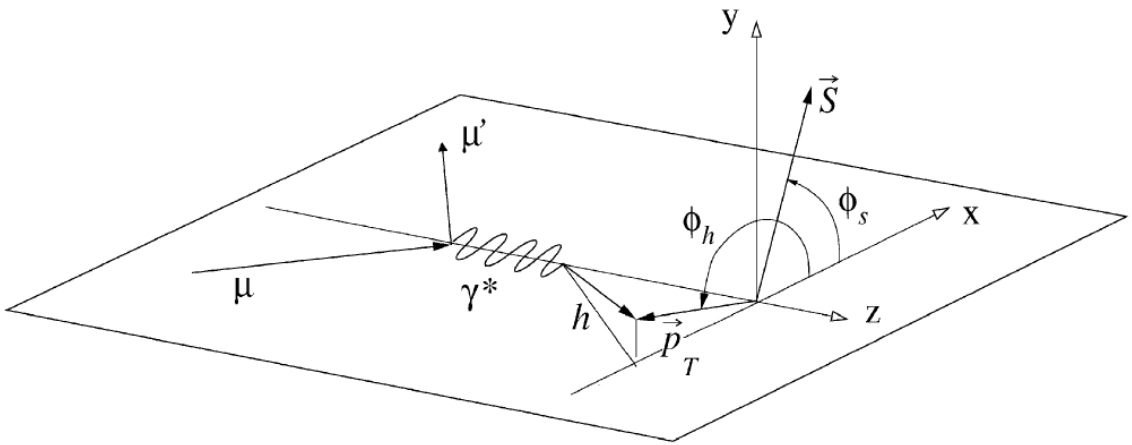

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- J/ψ production in $e^- + p^\uparrow \to e^- + J/\psi + X$.
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- Apart from proposal of the measurement, also an estimate of possible asymmetry for JLab, COMPASS and eRHIC energies is given (up to 25%, depending on model parameters).

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Sivers asymmetry in J/ψ production in scattering of μ off transversely polarized p

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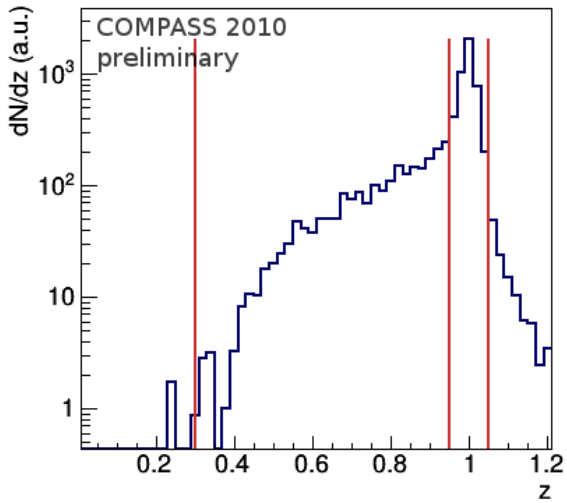

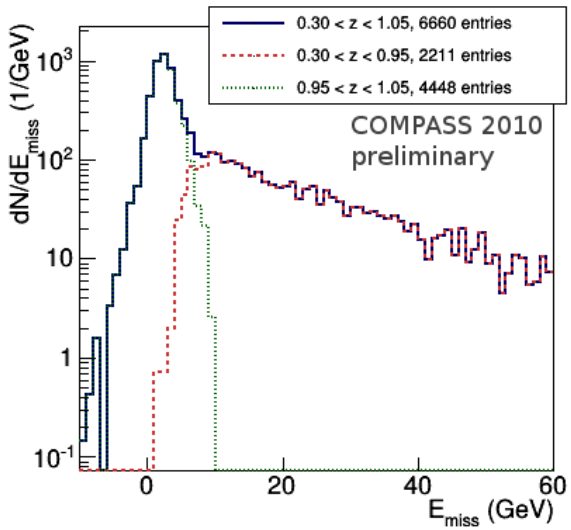

Left: The variable z. Right: The missing energy $E_{\text{miss}} \overset{\text{lab}}{=} E - E' - E_{J/\psi} + \frac{t}{2M_p}$.

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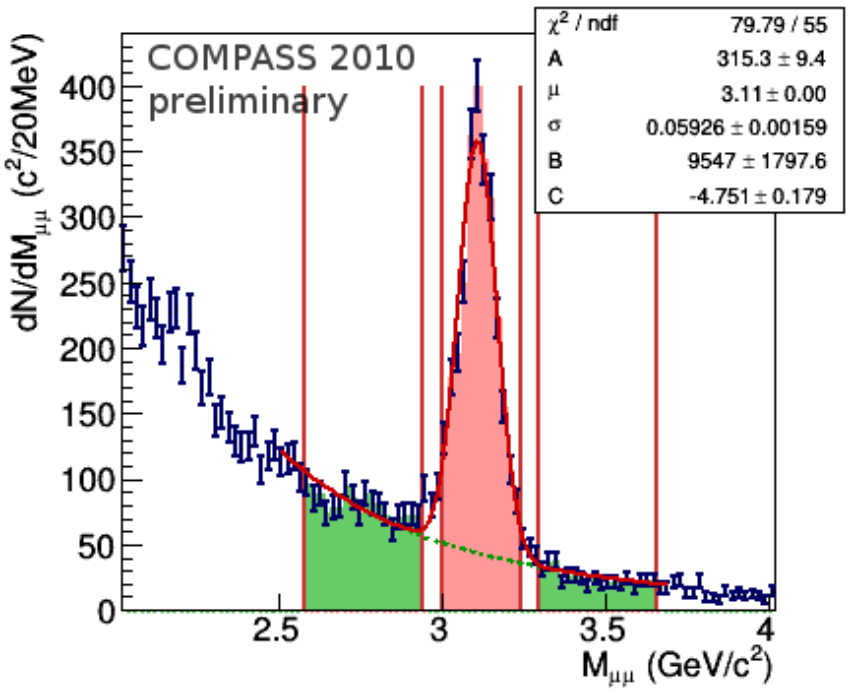
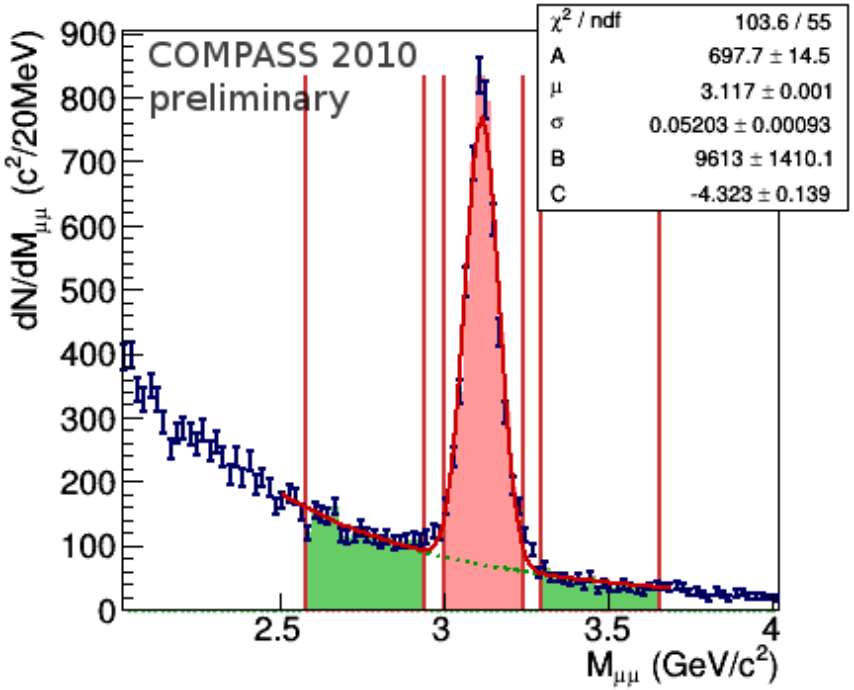
J/ψ selection by invariant mass





Dimuon invariant mass in the 2 z-bins.

- Signal band (in red): 8 026 events in total.
- 2 side-bands (in green) for background asymmetry measurement.
- The red fit: normal dist. + exponential background $A\,N\left(M_{\mu\mu},\mu,\sigma\right) + B\,M_{\mu\mu}^{C}$.

From the fit:

6 600 J/ψ events in total (2 211 inclusive, 4 448 exclusive).

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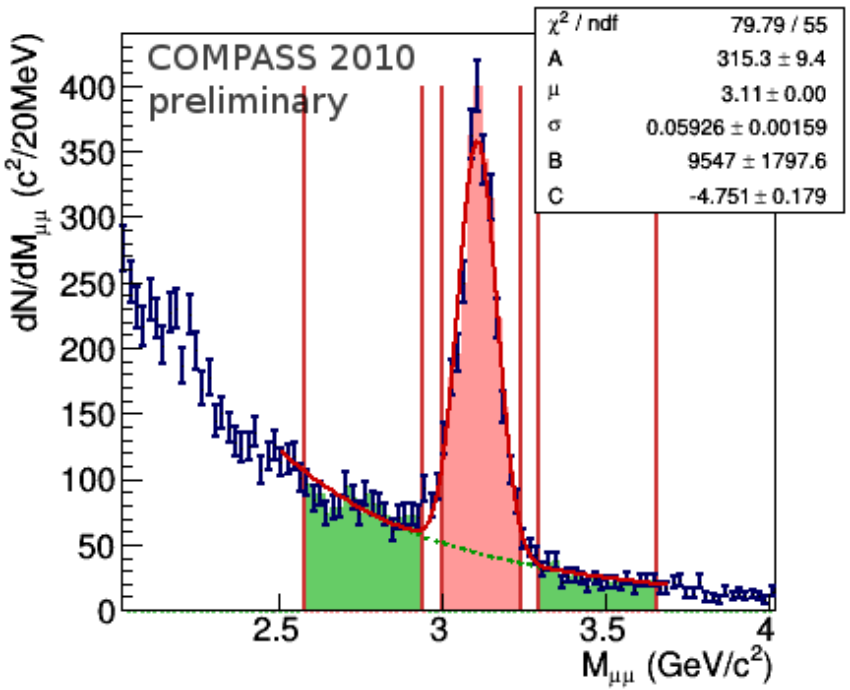

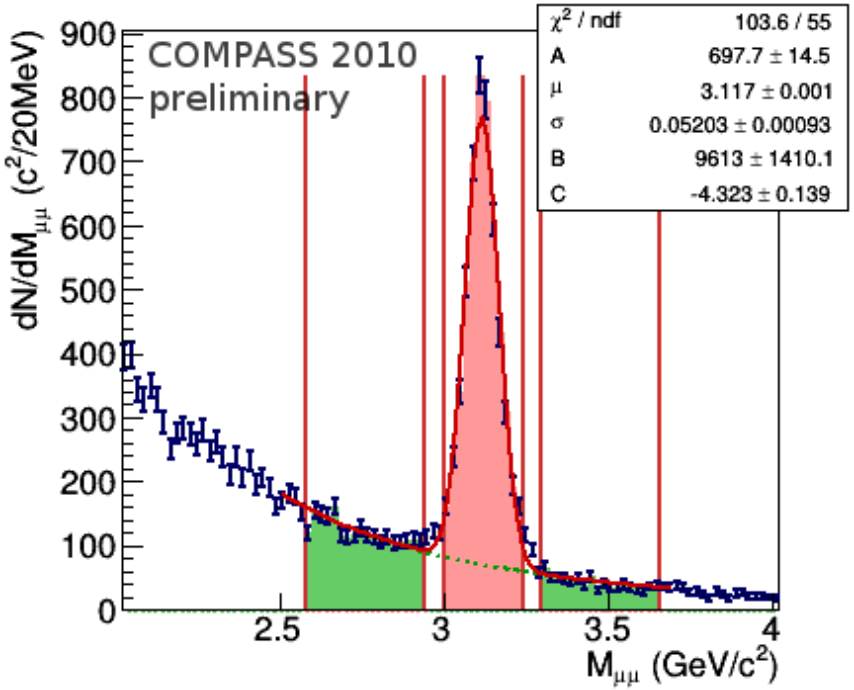

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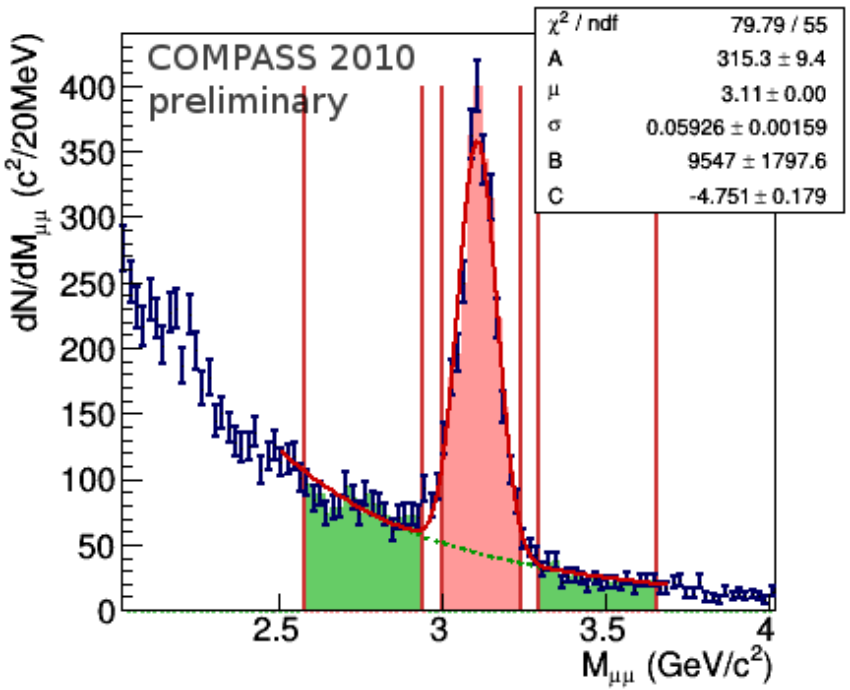

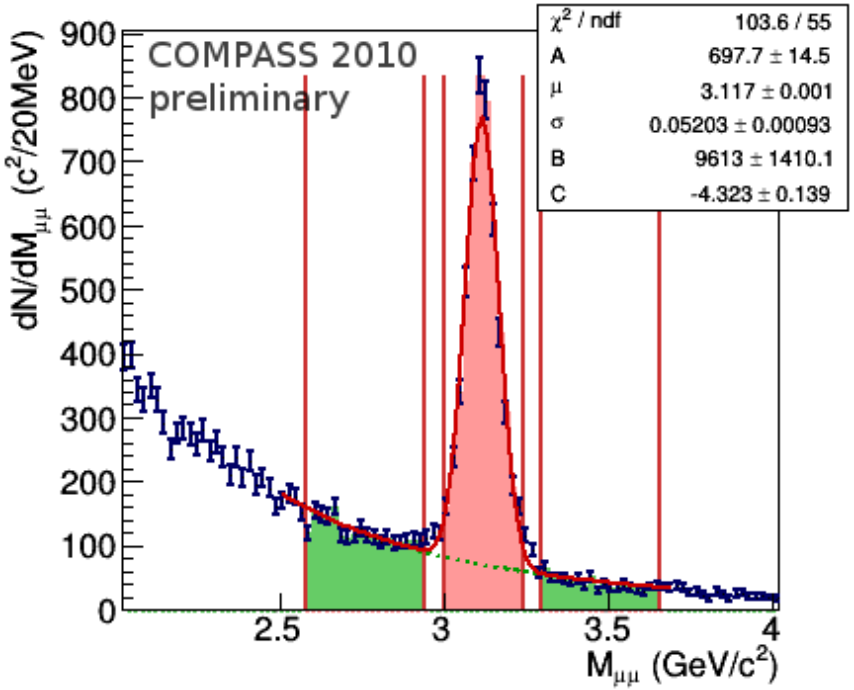

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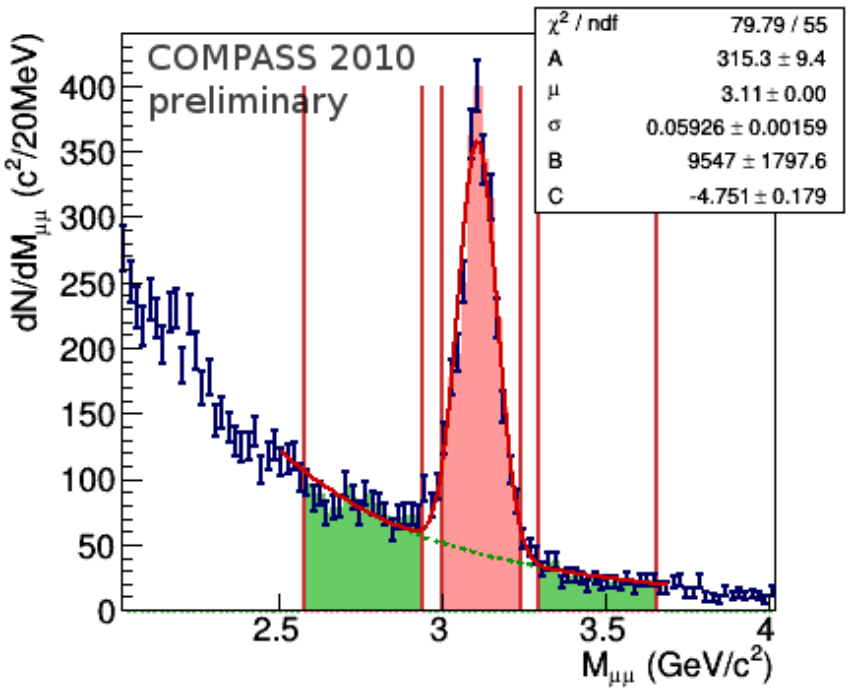

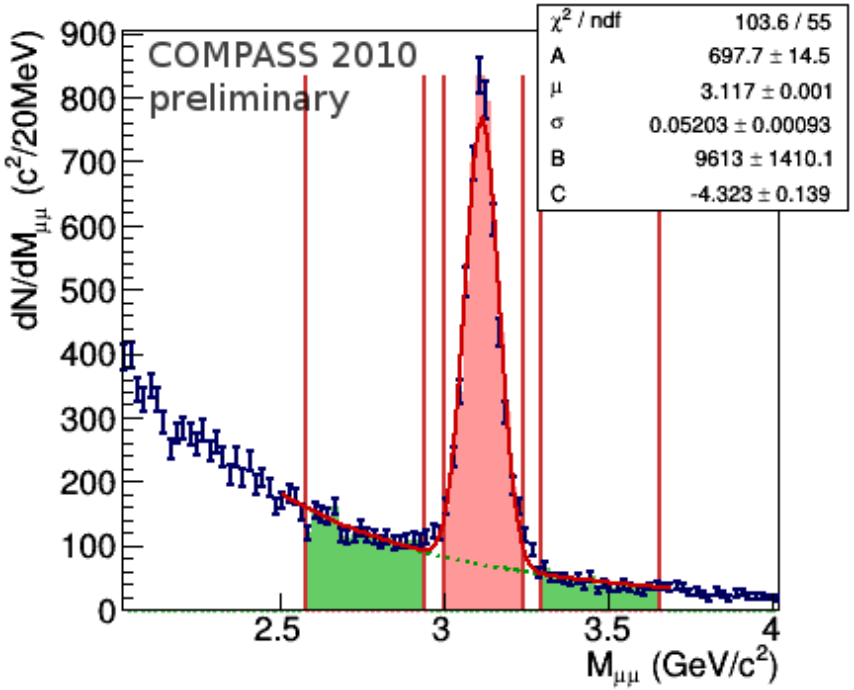

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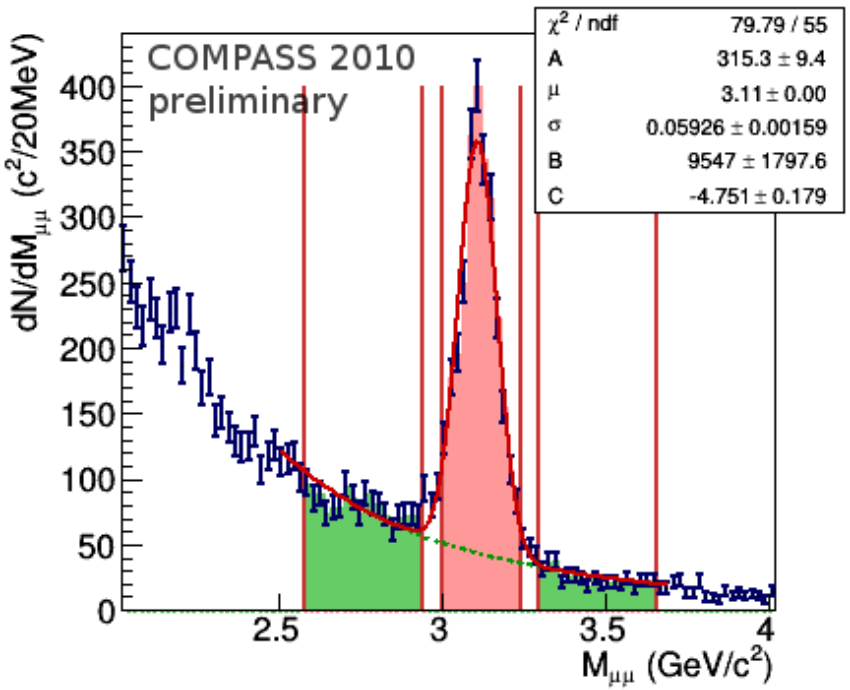

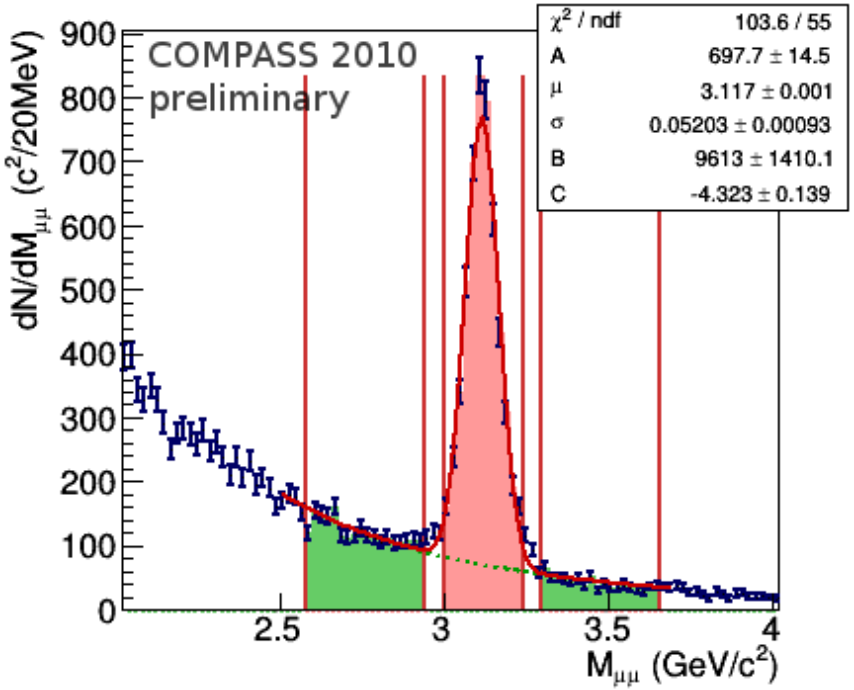

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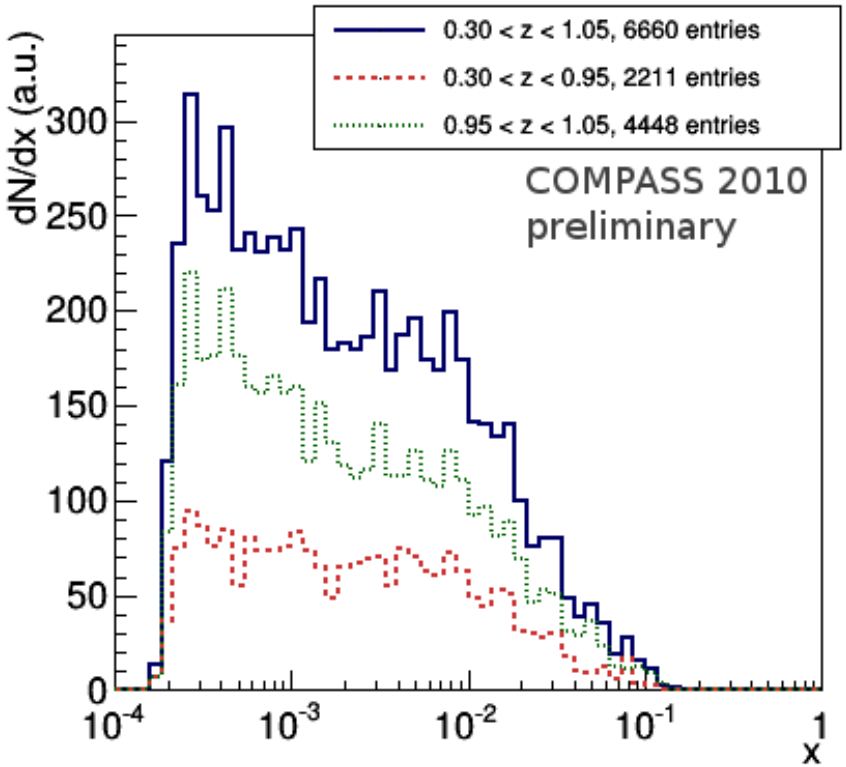
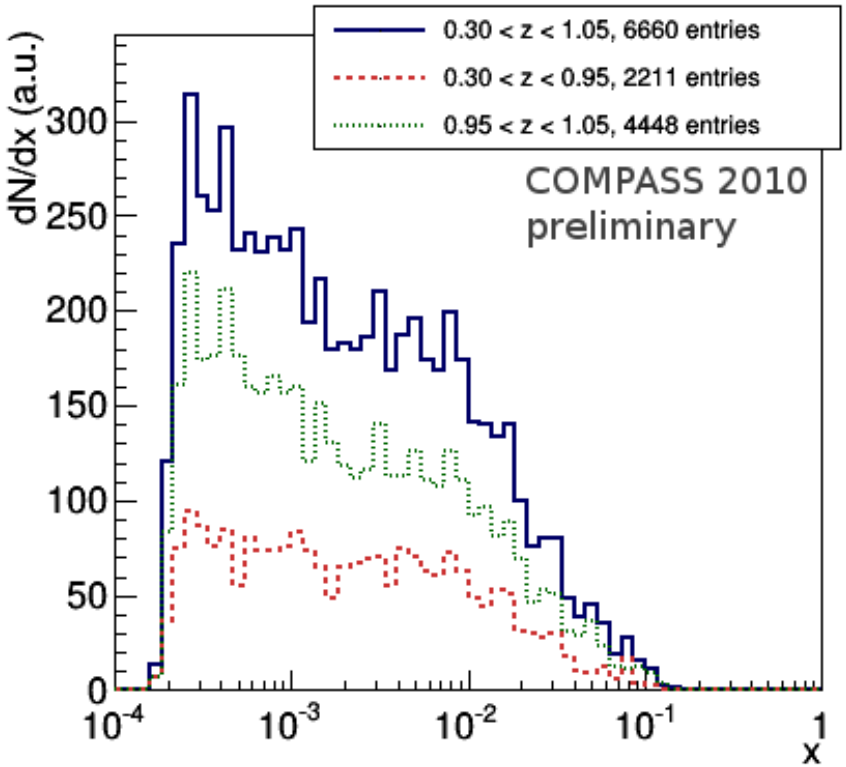
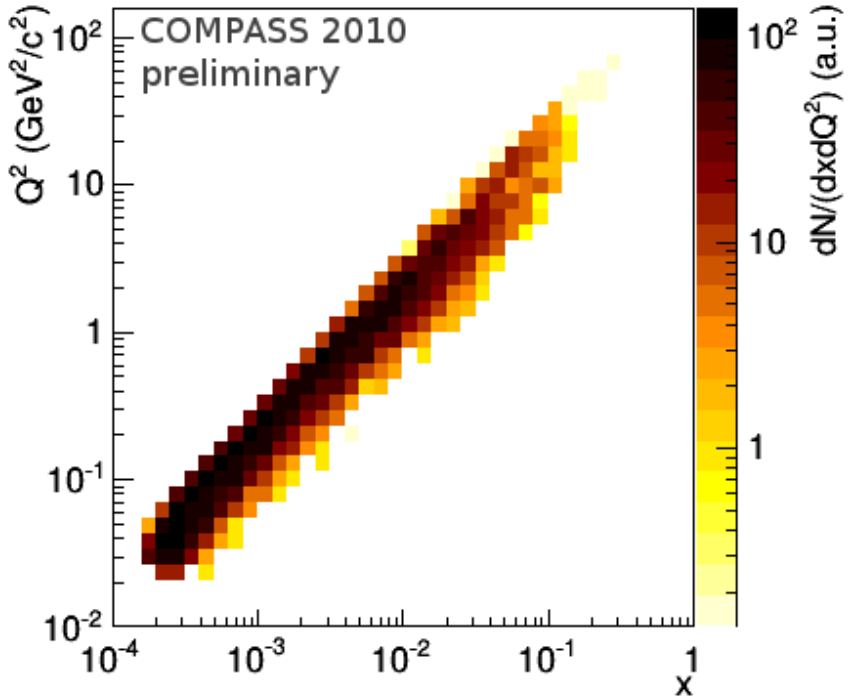


Left: Bjorken x distribution. Right: Bjorken x wrt. Q^2.

- The blue line—all J/ψ events,
- the other two—the two bins in z.
- Low x and Q^2.

Bjorken x and Q^2

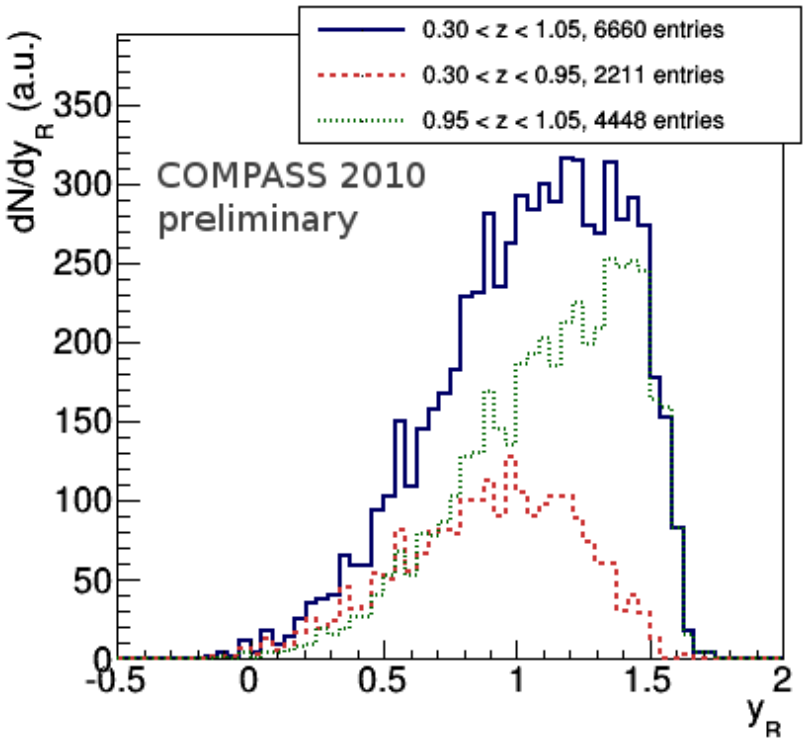




Left: Bjorken x distribution. Right: Bjorken x wrt. Q^2.

- The blue line—all J/ψ events,
- the other two—the two bins in z.
- Low x and Q^2.

J/ψ Rapidity and x-Gluon



Left: The rapidity of the J/ψ in μp CMS. Right: x-gluon (from the rapidity).

- Formula from R. M. Godbole *et al.*: PRD 85, 094013 (2012): $x_g = \frac{M_{J/\psi}}{\sqrt{s}} e^{y_R}$.
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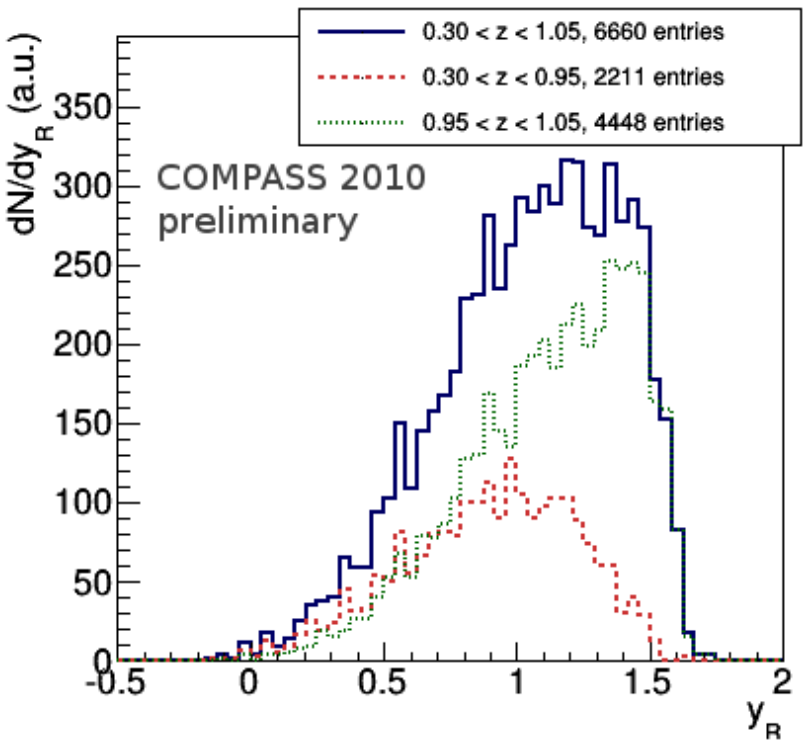

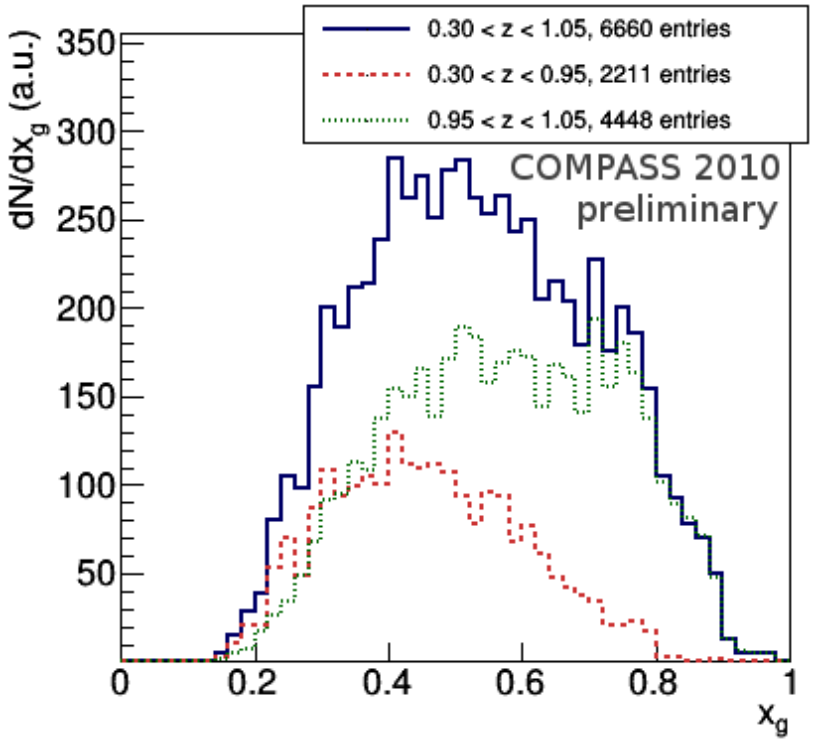

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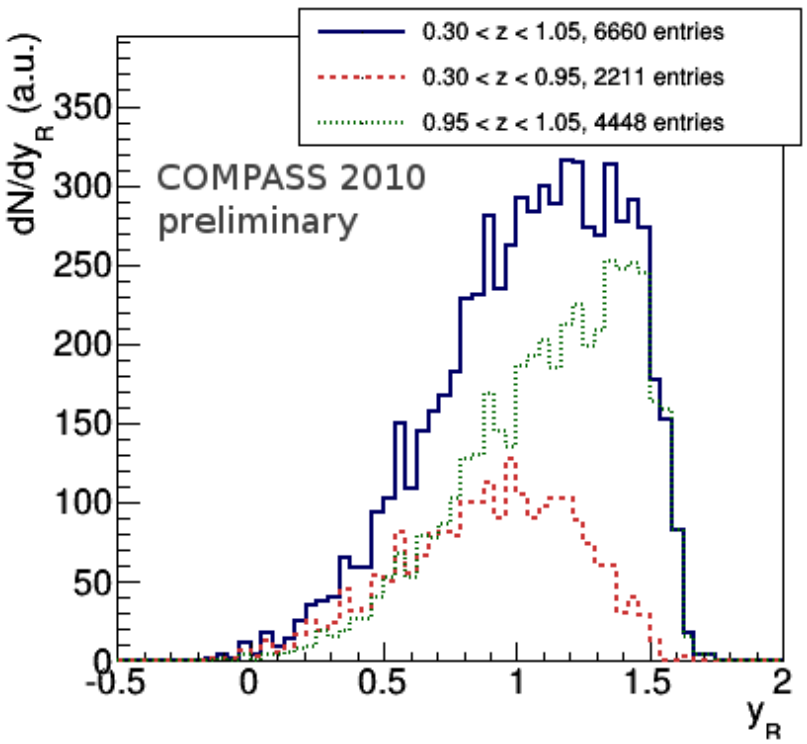

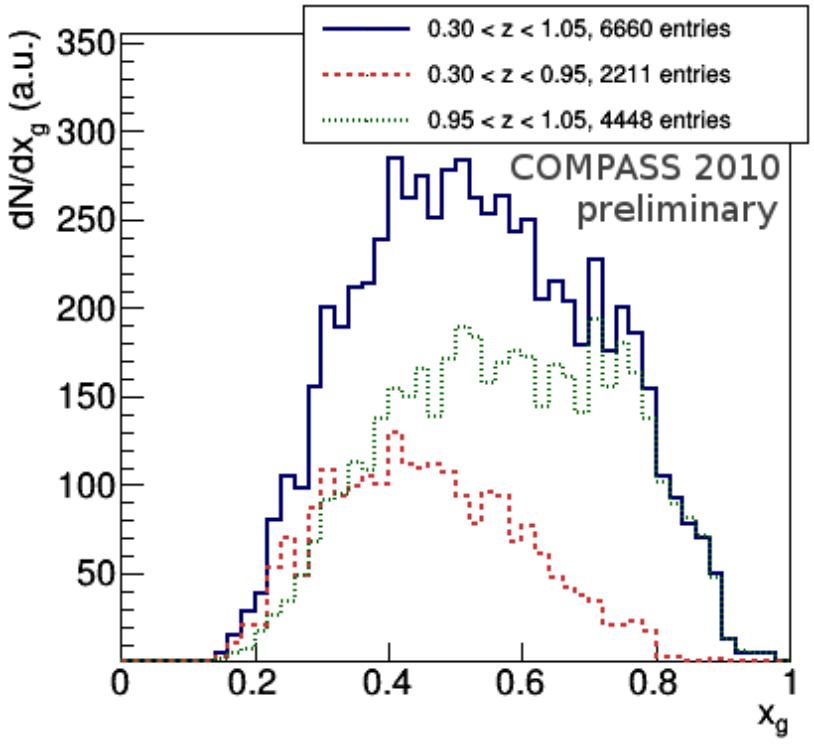

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Outline

Double Ratio Method

- Simple method of asymmetry evaluation.
- Upstream and downstream cell are combined ("outer cell").
- The double ratio:

$$A_{\mathrm{Siv}}(\phi_{\mathrm{Siv}}) = \frac{N^{\uparrow\downarrow\uparrow}_{\mathrm{out}}(\phi_{\mathrm{Siv}})N^{\downarrow\uparrow\downarrow}_{\mathrm{cent}}(\phi_{\mathrm{Siv}})}{N^{\downarrow\uparrow\downarrow}_{\mathrm{out}}(\phi_{\mathrm{Siv}})N^{\uparrow\downarrow\uparrow}_{\mathrm{cent}}(\phi_{\mathrm{Siv}})},$$

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$$A_{\mathrm{Siv}}(\phi) = C\left[1 + 4A^{\mathrm{raw}}_{\mathrm{Siv}}\sin(\phi_{\mathrm{Siv}})\right],$$

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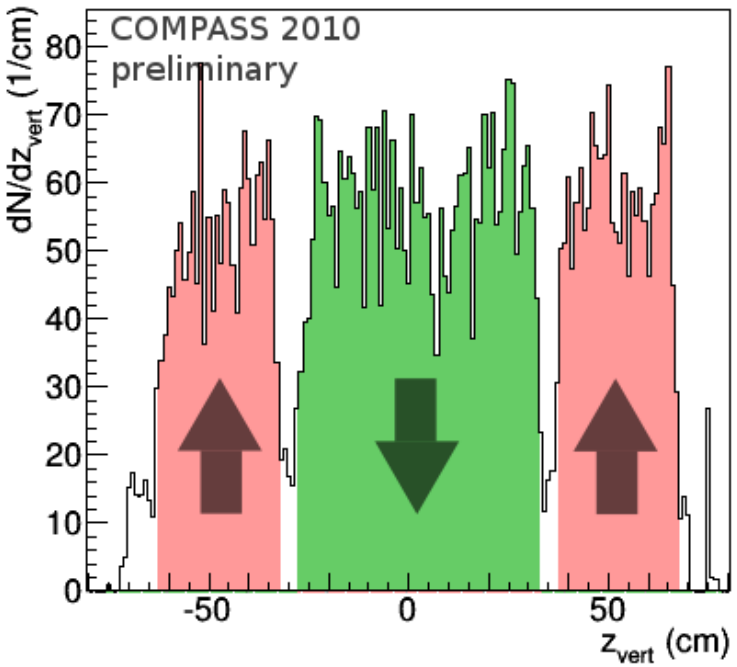

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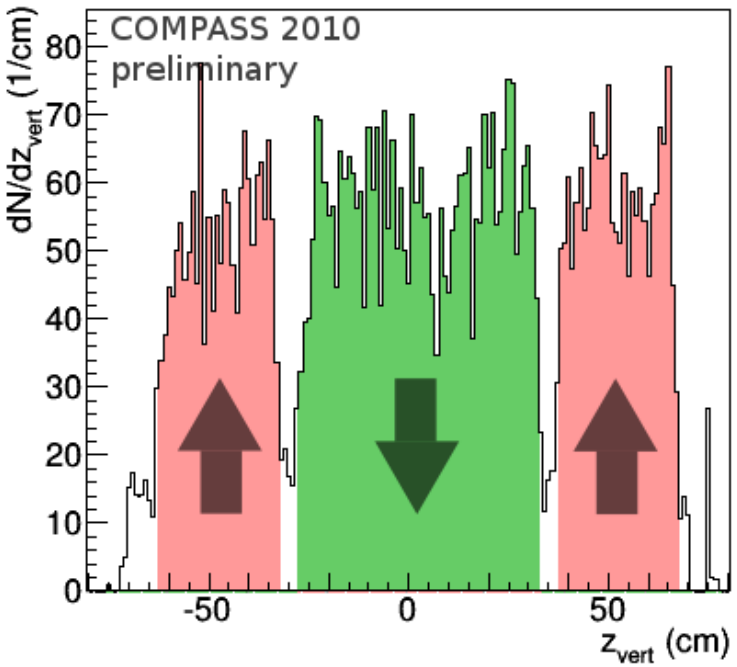

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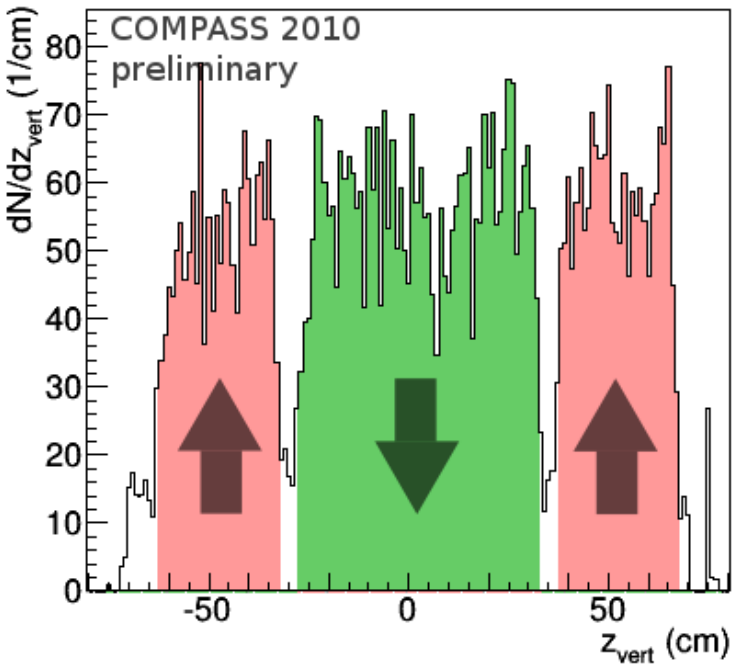

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- $A_{\mathrm{Siv}}^{\mathrm{raw}}$ evaluated in each of the 12 data-taking periods. Weighted mean was taken.
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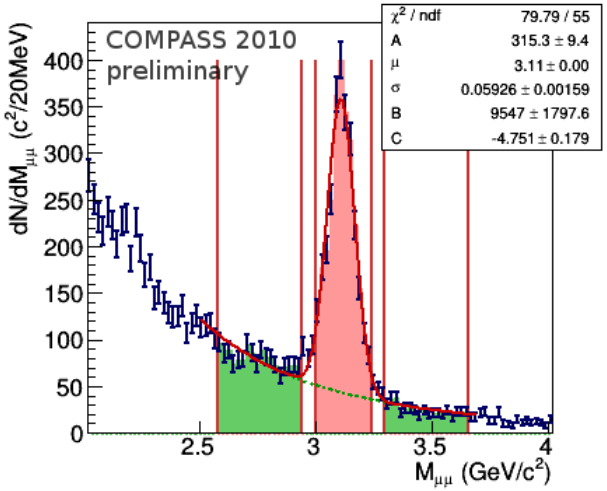

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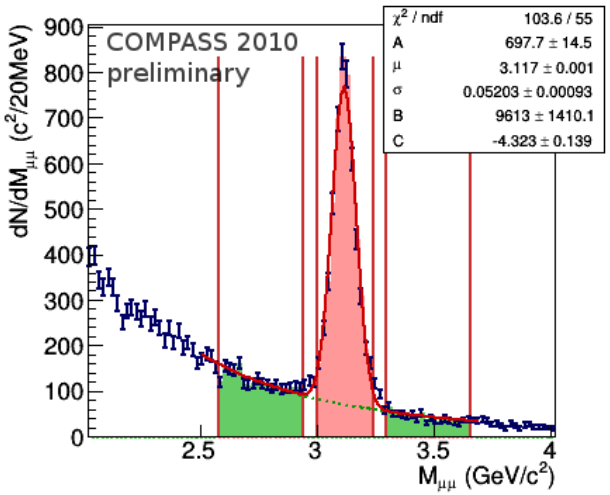

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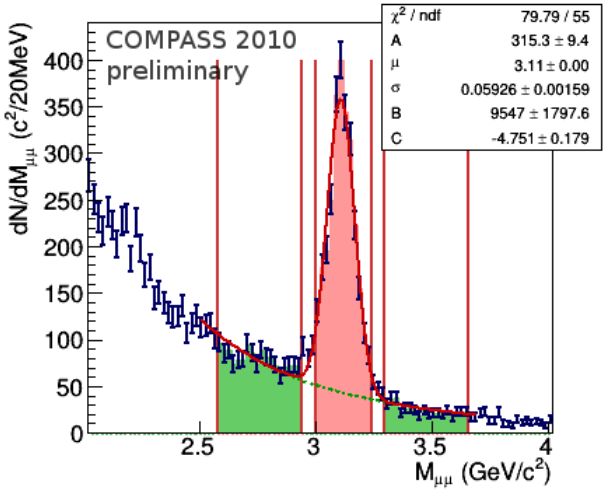

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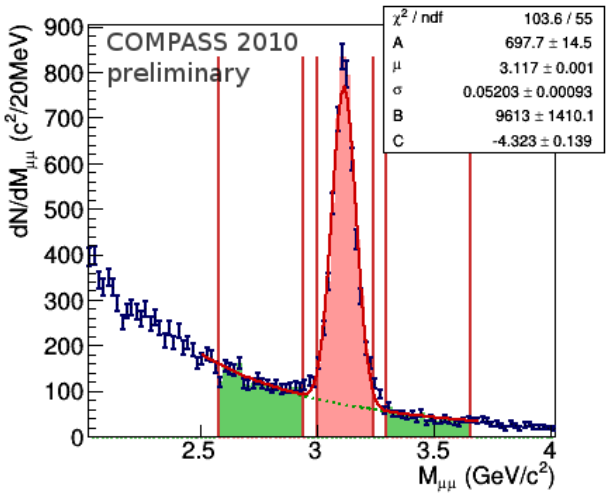

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Sivers Asymmetry

- From raw asymmetry to the final one:
  - Polarization $\langle P \rangle = 80\%$.
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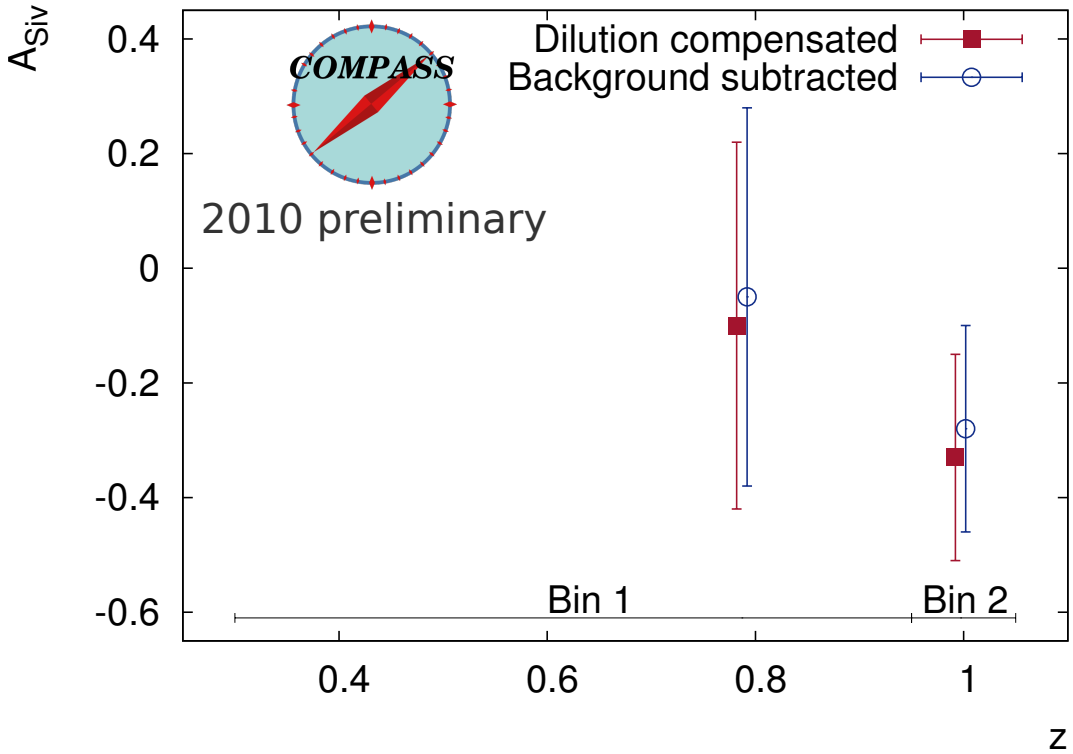

The final Sivers asymmetry (2 methods of BG treatment).
The z coord. were shifted by ± 0.005 not to overlap.

Outline

Conclusion

- The process of interest is rare (2 211 inclusive, 4 448 exclusive J/ψ from 2010).
- The relative uncertainty is too large to give a hint for the theory.
- A_{Siv} found compatible with 0.
- Room for possible improvement:
  - Unbinned maximum-likelihood method.
  - "New production"—max. 10% events more.
  - All COMPASS transverse data (p + d)—better, but still not an order of magnitude in the error...

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