First measurement of the parity-violating spin asymmetry A_L for W at mid-rapidity at STAR

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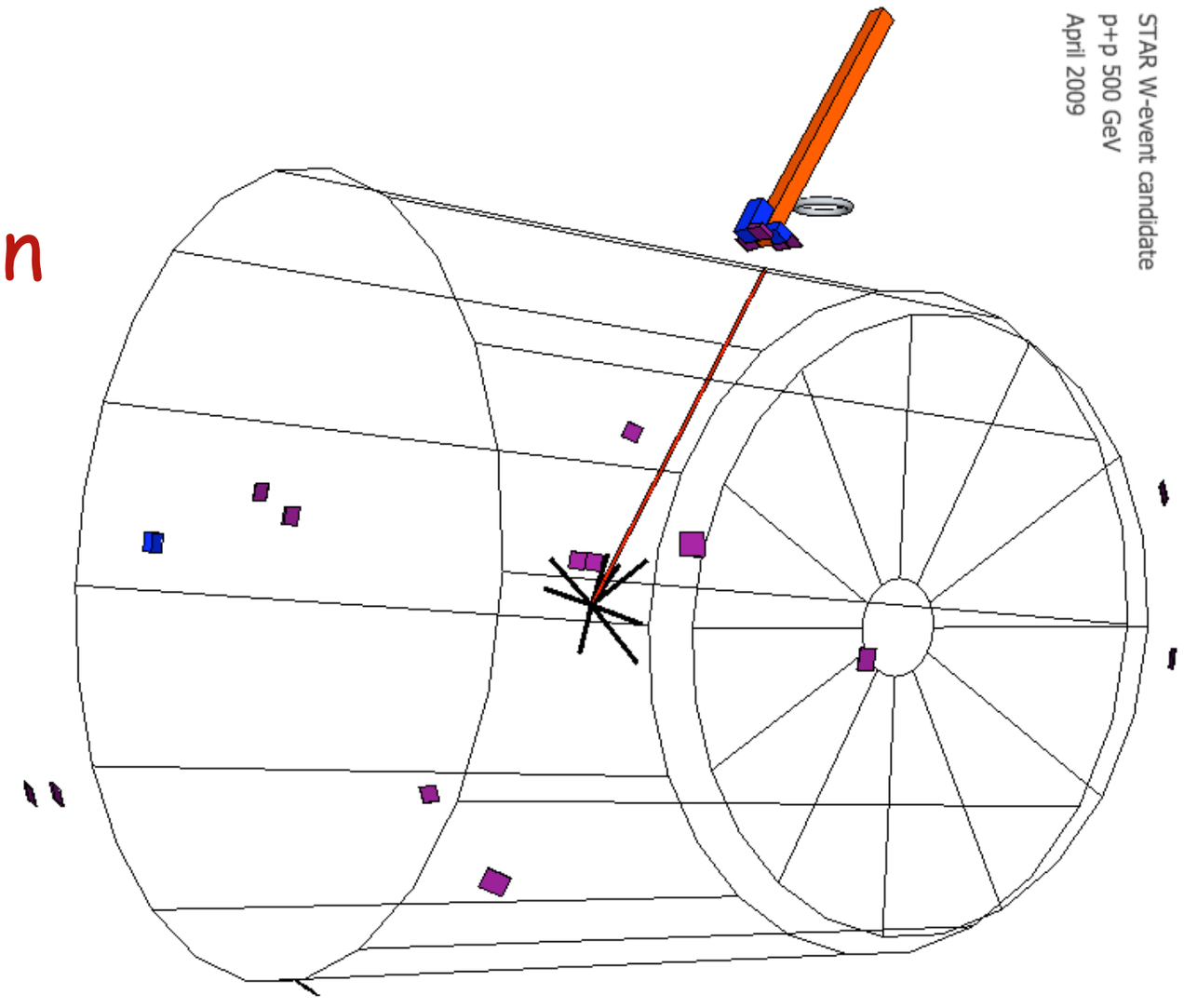
for the STAR Collaboration



APS April Meeting 2010
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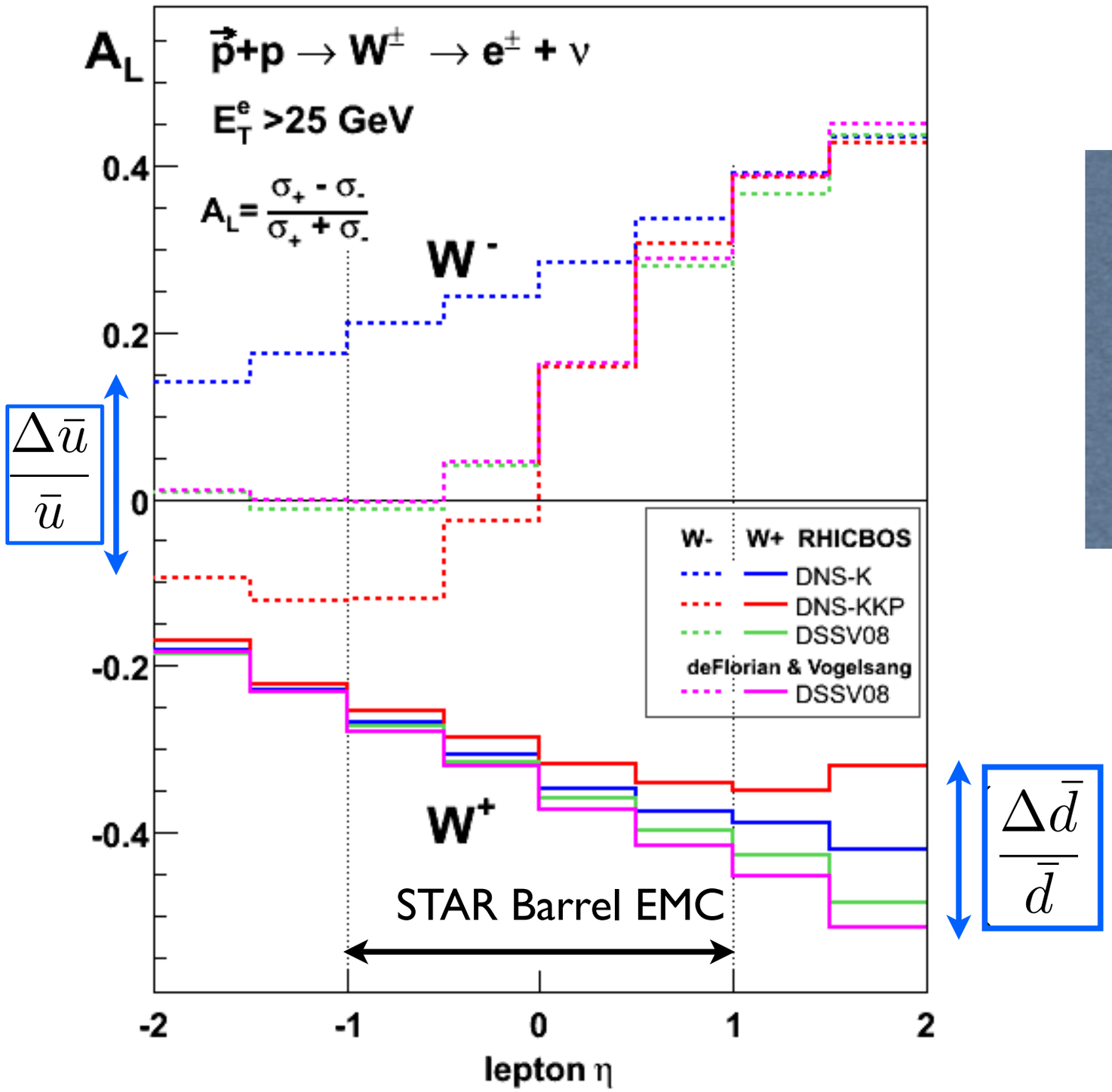
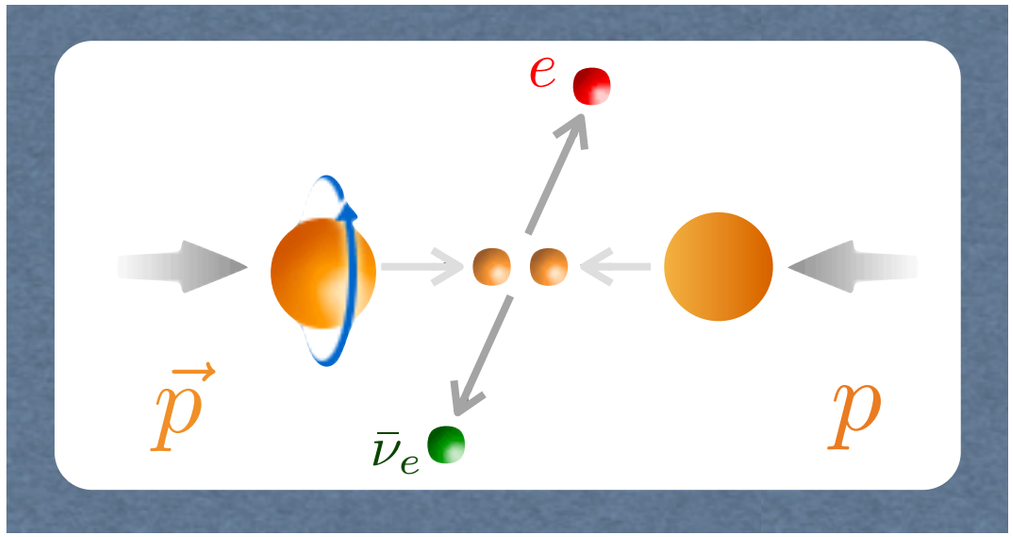
Washington, DC

Predictions for W A_L



$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

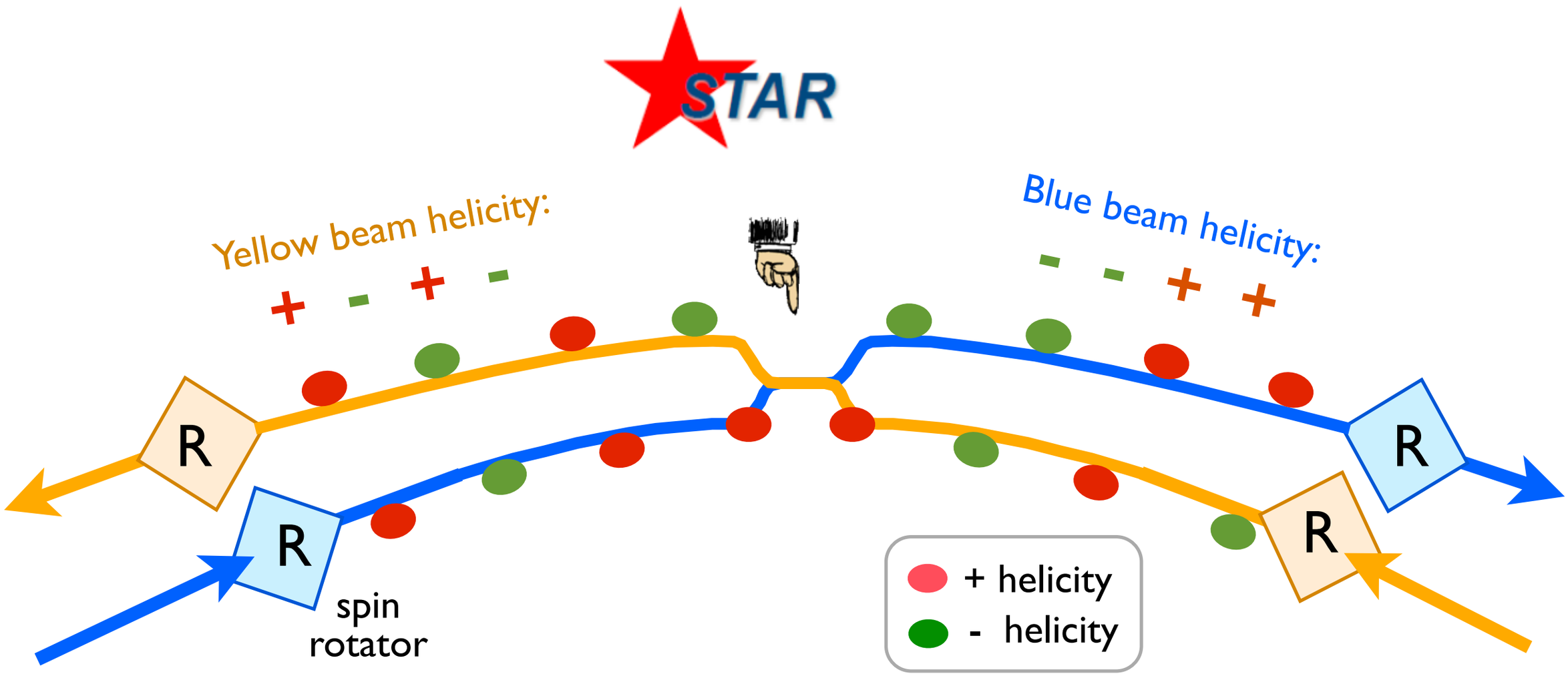


$$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta\bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right)$$

$$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$

LO interpretation for x1=x2

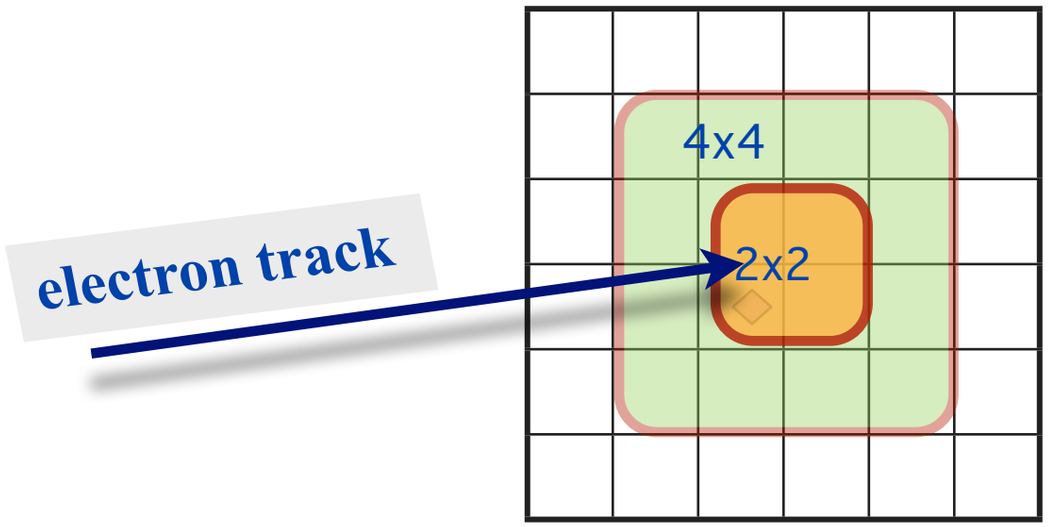
Helicity of beams colliding at STAR

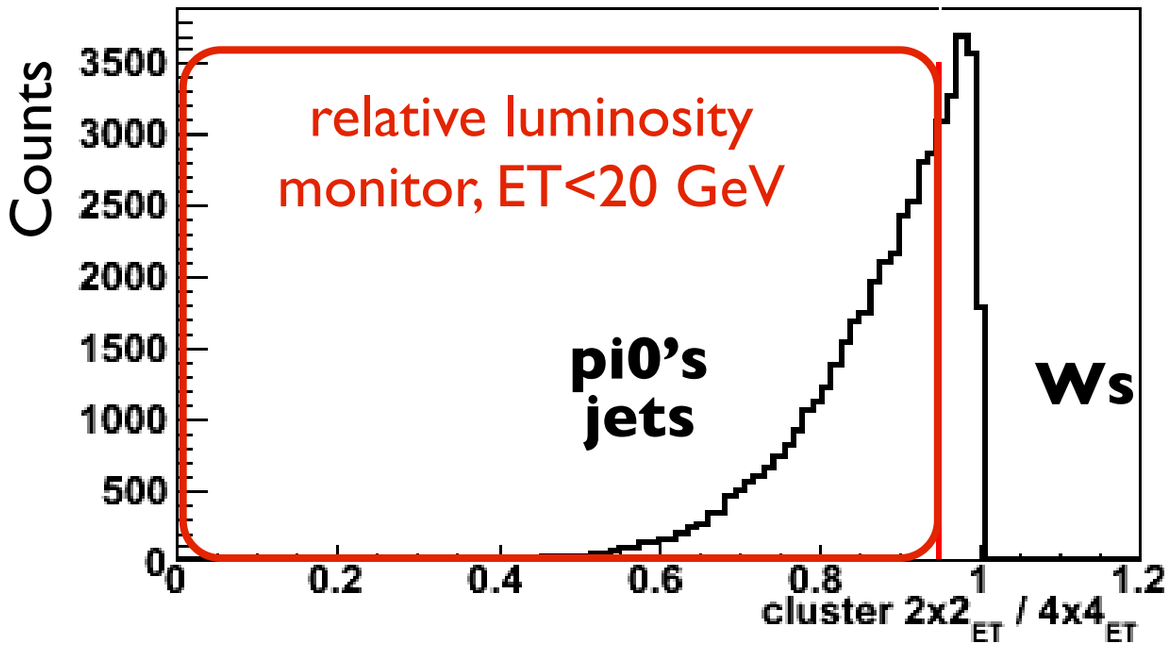


STAR sees 4 helicity configurations
STAR runs 4 parallel measurements

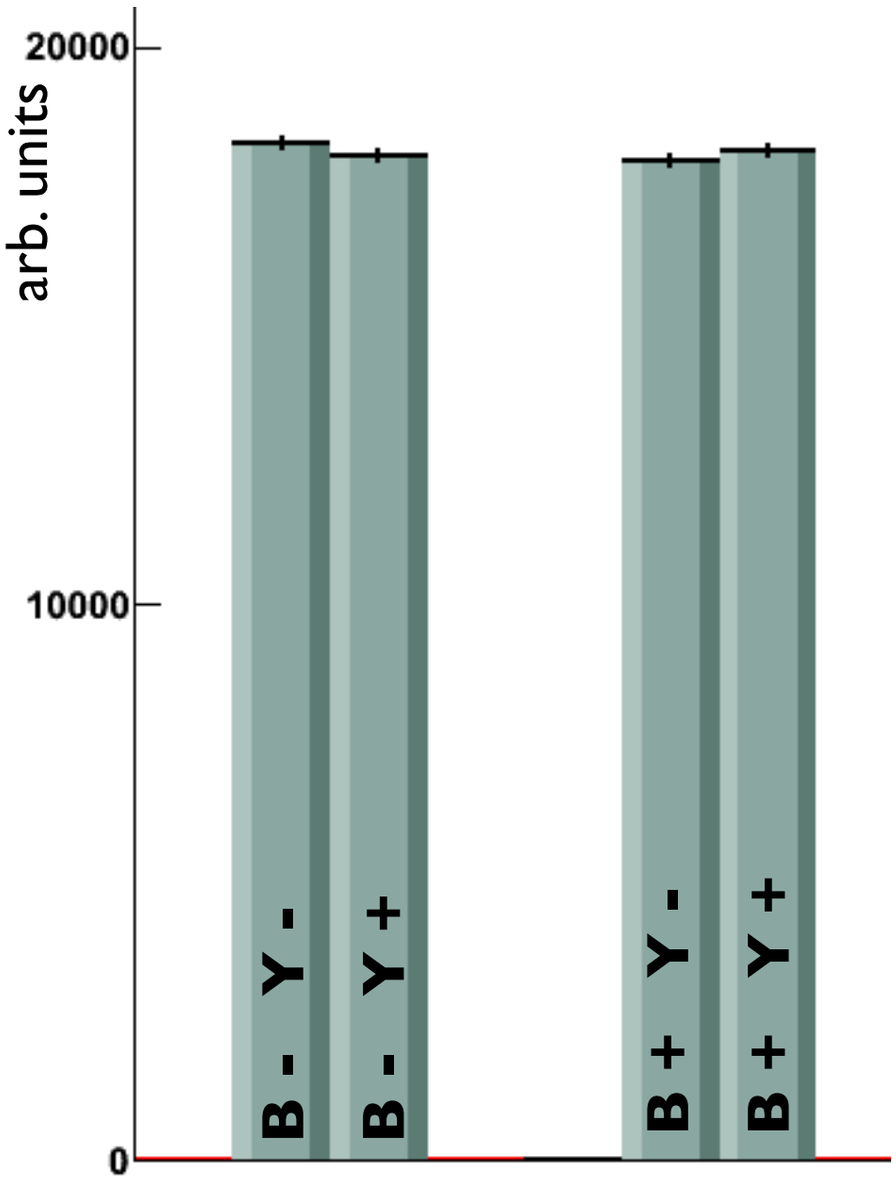
RHIC measured polarization
Run 9 @ 2x250 GeV
Pol yellow 0.40
Pol blue 0.38
syst. pol (blue+yellow)=9.2%

Spin dependent luminosity monitoring





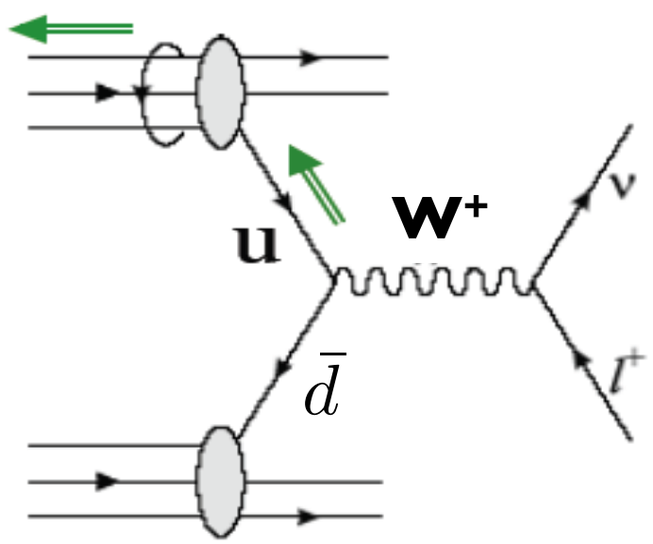
spin dependent luminosity of
4 states monitored to ~1%



helicities of
beams colliding at STAR

u-quark polarization seen with 'naked eye'

negative helicity

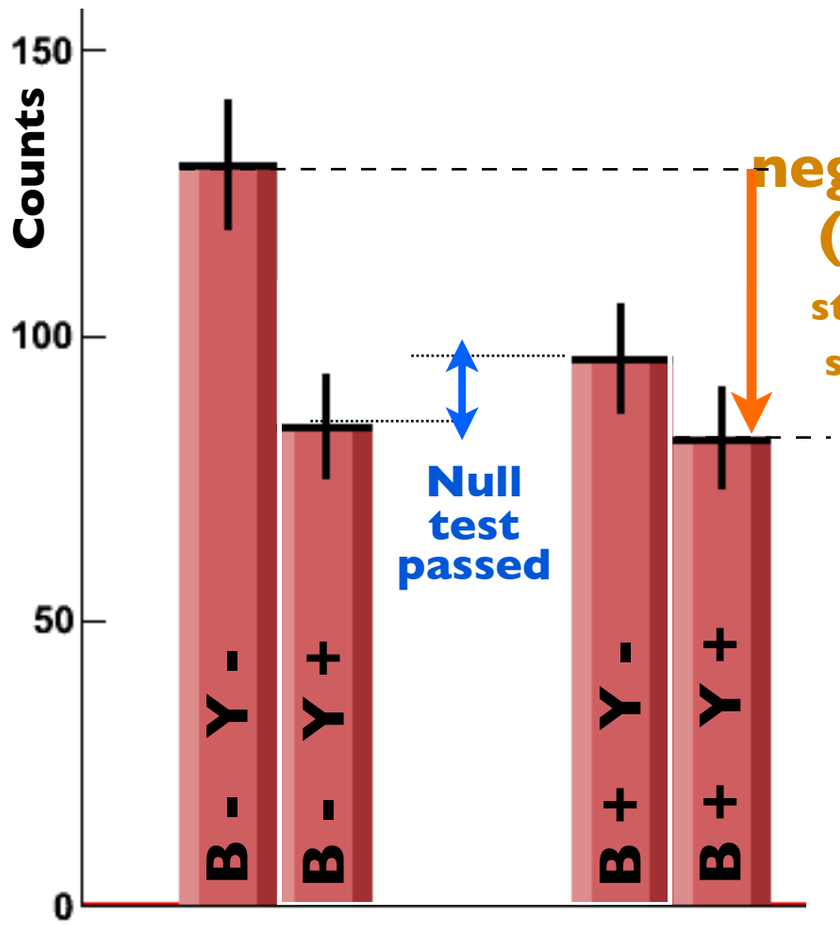


unpolarized proton

W+ yields integrated over |eta|<1

$$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$

$$\begin{aligned}
\mathcal{N}_{++} &\simeq \sigma_0\,\mathcal{L}_{++}\,[\,1 + A_L P_1 + A_L P_2\,] \\
\mathcal{N}_{--} &\simeq \sigma_0\,\mathcal{L}_{--}\,[\,1 - A_L P_1 - A_L P_2\,] \\
\mathrm{eps} &= \frac{\mathcal{N}_{++} - \mathcal{N}_{--}}{\mathcal{N}_{++} + \mathcal{N}_{--}} \\
&\simeq A_L \cdot (P_1 + P_2) \simeq -0.3 \cdot 0.8 = -0.24
\end{aligned}$$



$$\mathrm{eps} = \frac{82 - 130}{212} = -0.23$$

$$\sigma(\mathrm{eps}) \simeq \frac{1}{\sqrt{212}} = 0.07$$

$$\frac{\mathrm{eps}}{\sigma(\mathrm{eps})} = 3.3$$

'naked eye' means big detector + 2 counters + a hand calculator

Spin dependent x-section for longitudinal polarization

yields integrated over |eta|<1

P-V A_L (the goal)

A_N x residual transverse pol Q

A_{LL}

$$\frac{\mathcal{N}_{++}}{L_{++}} = \sigma_0 \left[1 + A_L(P_1 + P_2) + A_N(Q_1 - Q_2)\delta + A_{LL}P_1P_2 \right]$$

$$\frac{\mathcal{N}_{+-}}{L_{+-}} = \sigma_0 \left[1 + A_L(P_1 - P_2) + A_N(Q_1 + Q_2)\delta - A_{LL}P_1P_2 \right]$$

$$\frac{\mathcal{N}_{-+}}{L_{-+}} = \sigma_0 \left[1 - A_L(P_1 - P_2) - A_N(Q_1 + Q_2)\delta - A_{LL}P_1P_2 \right]$$

$$\frac{\mathcal{N}_{--}}{L_{--}} = \sigma_0 \left[1 - A_L(P_1 + P_2) - A_N(Q_1 - Q_2)\delta + A_{LL}P_1P_2 \right]$$

neglected because STAR is phi-symmetric

$$\delta \simeq \int_{2\pi} d\phi_e \ \mathrm{Effi}(\phi_e) sin(\phi_e) \simeq 0.02$$

Longitudinal spin asymmetries for Ws

STAR has measured 4 independent yields for the physics process
selected 3 asymmetries are independent (6 were investigated)

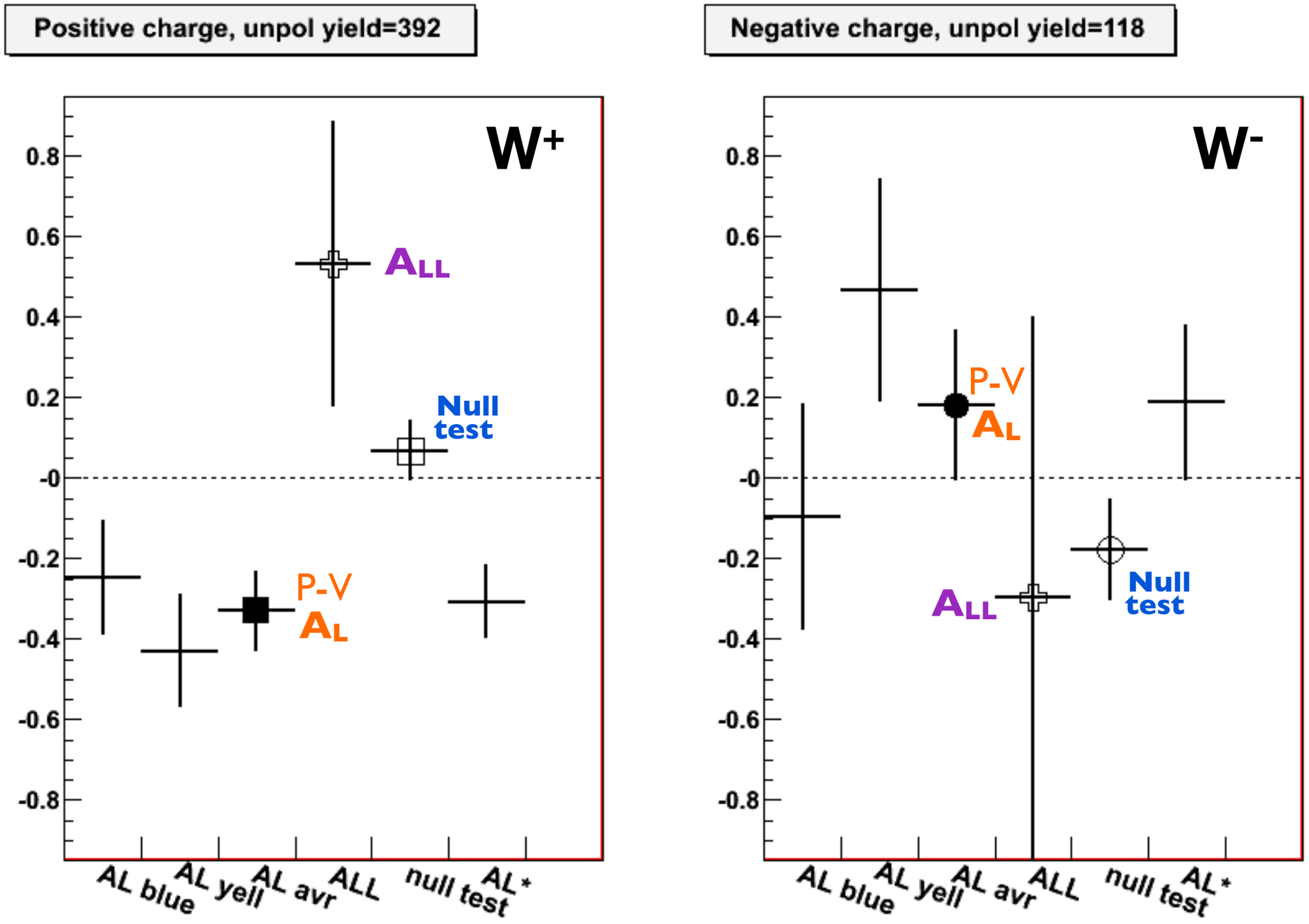
yields integrated over |eta|<1

Leading physics asymmetry	cross section dependence	raw asymmetry
A_L (blue)	$(\sigma_{++} + \sigma_{+-} - \sigma_{--} - \sigma_{-+})/sum4$	$A_L P_1$
A_L (yellow)	$(\sigma_{++} + \sigma_{-+} - \sigma_{--} - \sigma_{+-})/sum4$	$A_L P_2$
A_L (average)	$(\sigma_{++} - \sigma_{--}) \;/\; sum4$	$A_L \dfrac{P_1 + P_2}{2}$
A_{LL}	$(\sigma_{++} + \sigma_{--} - \sigma_{-+} - \sigma_{+-}) \;/\; sum4$	$A_{LL} P_1 P_2$
Null test $A_L(P_1 - P_2)$	$(\sigma_{+-} - \sigma_{-+}) \;/\; (\sigma_{-+} + \sigma_{+-})$	$\dfrac{A_L(P_1 - P_2)}{1 - A_{LL} P_1 P_2}$
$A_L^* \simeq A_L$	$(\sigma_{++} - \sigma_{--}) \;/\; (\sigma_{++} + \sigma_{--})$	$\dfrac{A_L(P_1 + P_2)}{1 + A_{LL} P_1 P_2}$

where $sum4 = \sigma_{++} + \sigma_{+-} + \sigma_{-+} + \sigma_{--}$

6 measured spin asymmetries for W+ and W-

STAR Run 9 data integrated over |eta|<1



Physics asymmetries corrected for unpolarized background

Systematic errors for A_L

Full list of accounted systematic errors in Run 9

W^+		W^-		
high	low	high	low	
0.09	**0.09**	0.09	0.09	**absolute polarization magnitude of both beams (P1+P2)**
0.07	0.02	0.13	0.03	QCD unpolarized background
0.07	0.07	**0.14**	**0.14**	**QCD pol. bckg. ~0: use 1/2 stat error of this test**
0.01	0.00	0.01	0.00	decay of pol. within fill
0.13	**0.11**	**0.21**	**0.17**	**total syst. in fraction of measured A_L**

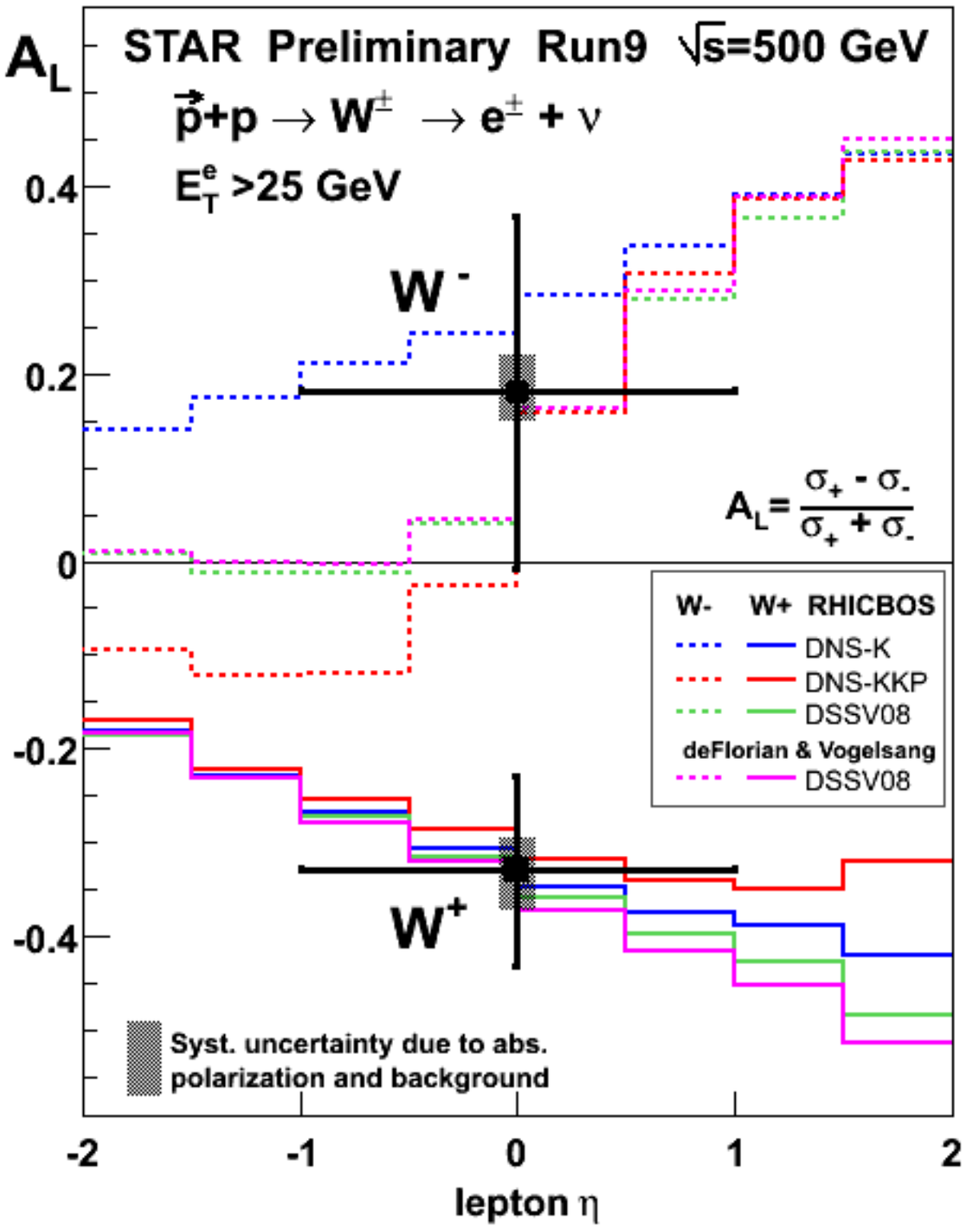
Following effects were considered and their contribution **found negligible**

* dilution of A_L due to swap of W+/W- charge: tracks with too small to measure curvature were removed (discussed by Justin S. during previous talk)

* $A_{LL}P_1P_2$ term cancels out ,

* $A_N(Q_1 - Q_2)\delta < 1/1000$ since: $\delta \simeq \int_{2\pi} d\phi_e \ \mathrm{Effi}(\phi_e) sin(\phi_e) \simeq 0.02$ and $Q_1 \sim Q_2 < 0.1$

A_L for Ws measured in Run 9



$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

STAR Preliminary Run 9

$$A_L(W^+) = -0.33 \pm 0.10(\text{stat.}) \pm 0.04(\text{syst.})$$

$$A_L(W^-) = 0.18 \pm 0.19(\text{stat.}) \; ^{+0.04}_{-0.03}(\text{syst.})$$

Summary
(for mid rapidity leptons)

- $A_L(W^+)$ negative, as predicted, **3.3 sigma <0**
- $A_L(W^-)$ central value positive, as expected
- systematic errors of A_L under control
- TPC charge separation works up to ET~50 GeV