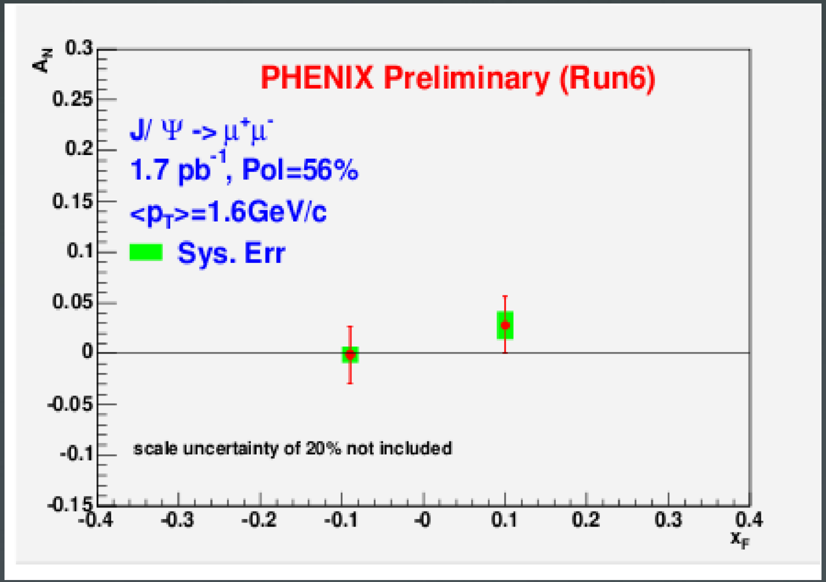
Single Transverse Spin Asymmetry in $J/\psi \rightarrow e^+e^-$ from Run6

Todd Kempel
Iowa State University

Work Done so Far (by others)

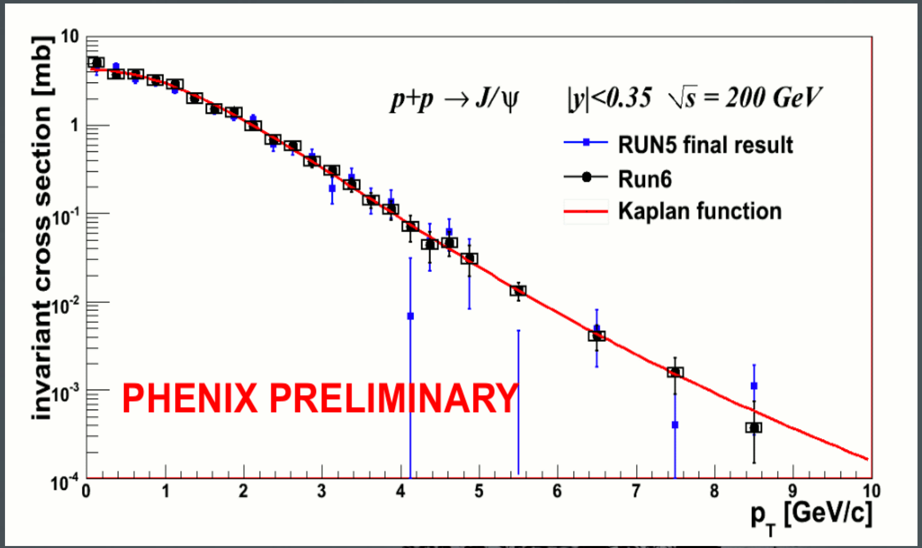
Muon Arm A_N vs. xF (Run6)

Liu Han (LANL)



Central Arm Cross-Section (Run6)

Marisilvia and Cesar



Electron Selection

Use ERT_E && BBC triggered data
ntuples created directly from Marisilvia and Cesar's analysis (thanks Cesar!)

<u>eID (very loose)</u>

n0>=0

dep>-4

|emcsdphi|<3σ

|emcsdz|<3σ

no quality cut

0.5 GeV/c < momentum < 40 GeV/c

prob>0.005

<u>fiducial cuts</u>

remove 0.07<phi<0.15 because of inconsistencies with simulation (done by Marisilvia and Cesar)

<u>Vertex</u>

| BBCz|<30 cm

Run Selection

<u>Same QA requirements as cross-section analysis:</u>

4.3% rejected because of fluctuations in the acceptance

5.8% rejected because of fluctuation in the ERT efficiency

<u>Additional spin-related QA:</u>

Only Transverse Spin runs: 190281 < runnumber < 197795

Remove run with missing GL1P Log files:
197523

Remove runs where the STAR magnet tripped:
192909, 194797, 194799, 194801, 194802, 194803, 194804, 194806

Remove three fills whose polarization information are not consistent between PHENIX and CDEV
7622, 7672, 7745

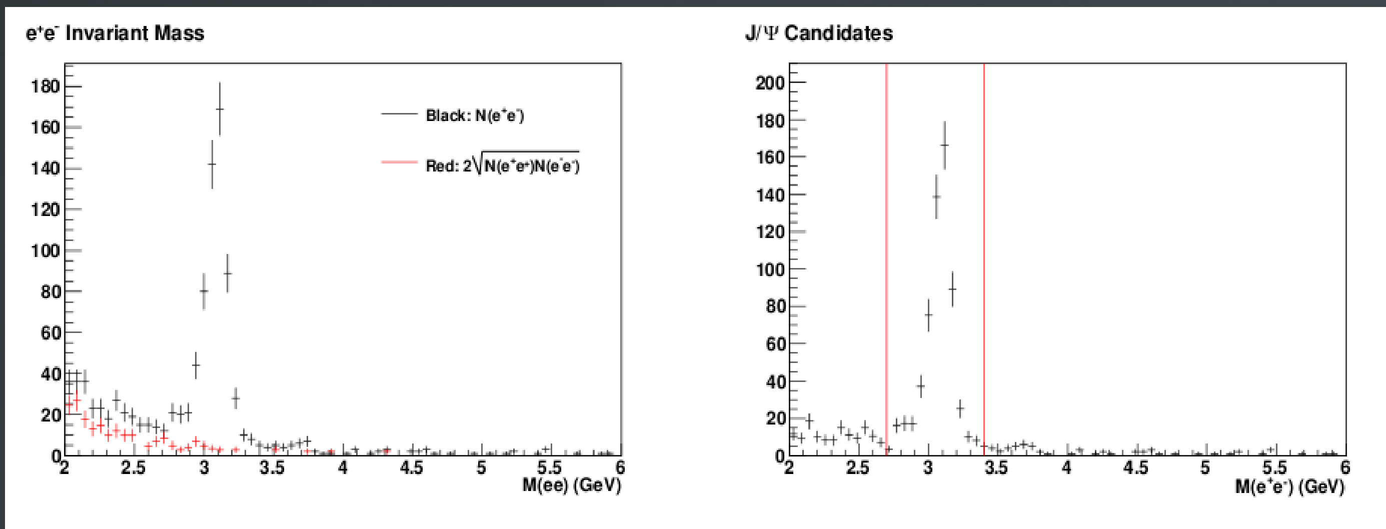
Now included (Han checked these). They're ok for this analysis—still need to fix Spin DB so these are ok for all analyses

remove all runs with ERT_E&&BBC scale downs (to get rid of an explicitly time-dependent efficiency)

What's Left?

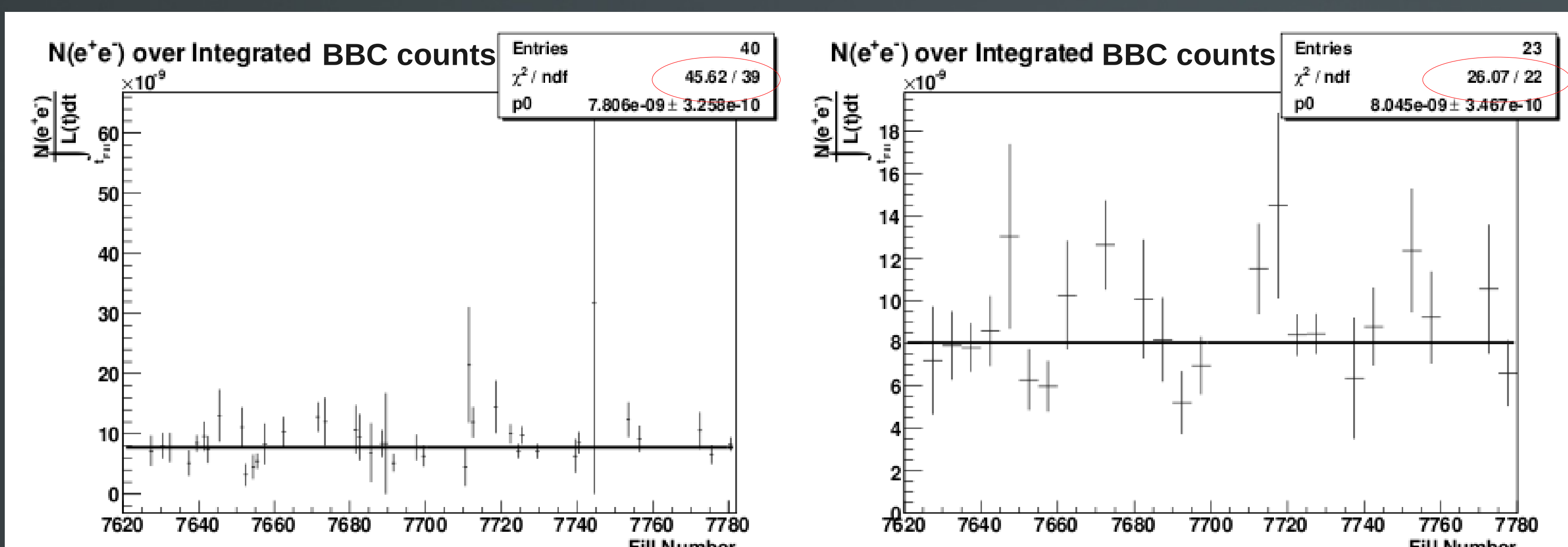
162 runs remaining (2.68 pb^{-1})

558 e^+e^- pairs, 20 e^+e^+, 22 e^-e^-
in 2.7 GeV/c < M(pair) < 3.4 GeV/c



2498+/-76 J/ψs in cross-section analysis
(All of Run6)

So, if transverse luminosity is ~1/5 of total run6 luminosity this is about right



Same plot rebinned 5→1

Two Formulae for Calculating Asymmetry

Square Root Formula

$$A_{\mathrm{sqrt}} = \frac{f}{P} \frac{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} - \sqrt{N_L^{\downarrow} N_R^{\uparrow}}}{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} + \sqrt{N_L^{\downarrow} N_R^{\uparrow}}}$$

Luminosity Formula

$$A_{lumi} = \frac{\frac{f_L}{P} \frac{\frac{N_{\mathrm{L}}^{\uparrow} - R N_{\mathrm{L}}^{\downarrow}}{N_{\mathrm{L}}^{\uparrow} + R N_{\mathrm{L}}^{\downarrow}}}{\delta A_{\mathrm{L}}^2} - \frac{f_R}{P} \frac{\frac{N_{\mathrm{R}}^{\uparrow} - R N_{\mathrm{R}}^{\downarrow}}{N_{\mathrm{R}}^{\uparrow} + R N_{\mathrm{R}}^{\downarrow}}}{\delta A_{\mathrm{R}}^2}}{\frac{1}{\delta A_{\mathrm{L}}^2} + \frac{1}{\delta A_{\mathrm{R}}^2}}$$

'Left' : $\vec{S} \times \vec{P} > 0$

pair $p_Y > 0$ (Blue)
pair $p_Y < 0$ (Yellow)

'Right' : $\vec{S} \times \vec{P} < 0$

pair $p_Y < 0$ (Blue)
pair $p_Y > 0$ (Yellow)

R: 'Relative Luminosity' L^+/L^-

'f's: Acceptance Correction Factors
(see AN753 for a derivation of these...)

$$f_L = \frac{1}{<|\sin(\phi)|>_{\mathrm{left}}} \qquad f_R = \frac{1}{<|\sin(\phi)|>_{\mathrm{right}}}$$

$$f = \frac{1}{\frac{1}{2}(<|\sin(\phi)|>_{\mathrm{left}} + <|\sin(\phi)|>_{\mathrm{right}})}$$

Acceptance Correction Factors

Assuming a form of the asymmetry:

$$N_L^{\uparrow} \approx \int_0^{\pi} a(\phi) \frac{N_0}{2} (1 + A \sin\phi) d\phi$$

$$N_L^{\downarrow} \approx \int_0^{\pi} a(\phi) \frac{N_0}{2} (1 - A \sin\phi) d\phi$$

$$N_R^{\uparrow} \approx \int_{-\pi}^{0} a(\phi) \frac{N_0}{2} (1 + A \sin\phi) d\phi$$

$$N_R^{\uparrow} \approx \int_{-\pi}^{0} a(\phi) \frac{N_0}{2} (1 - A \sin\phi) d\phi$$

$$\frac{N_L^{\uparrow} - N_L^{\downarrow}}{N_L^{\uparrow} + N_L^{\downarrow}} = \frac{\int_0^{\pi} a(\phi) A \sin\phi \, d\phi}{\int_0^{\pi} a(\phi) d\phi} = A \langle |\sin\phi| \rangle_{\text{left, in acceptance}}$$

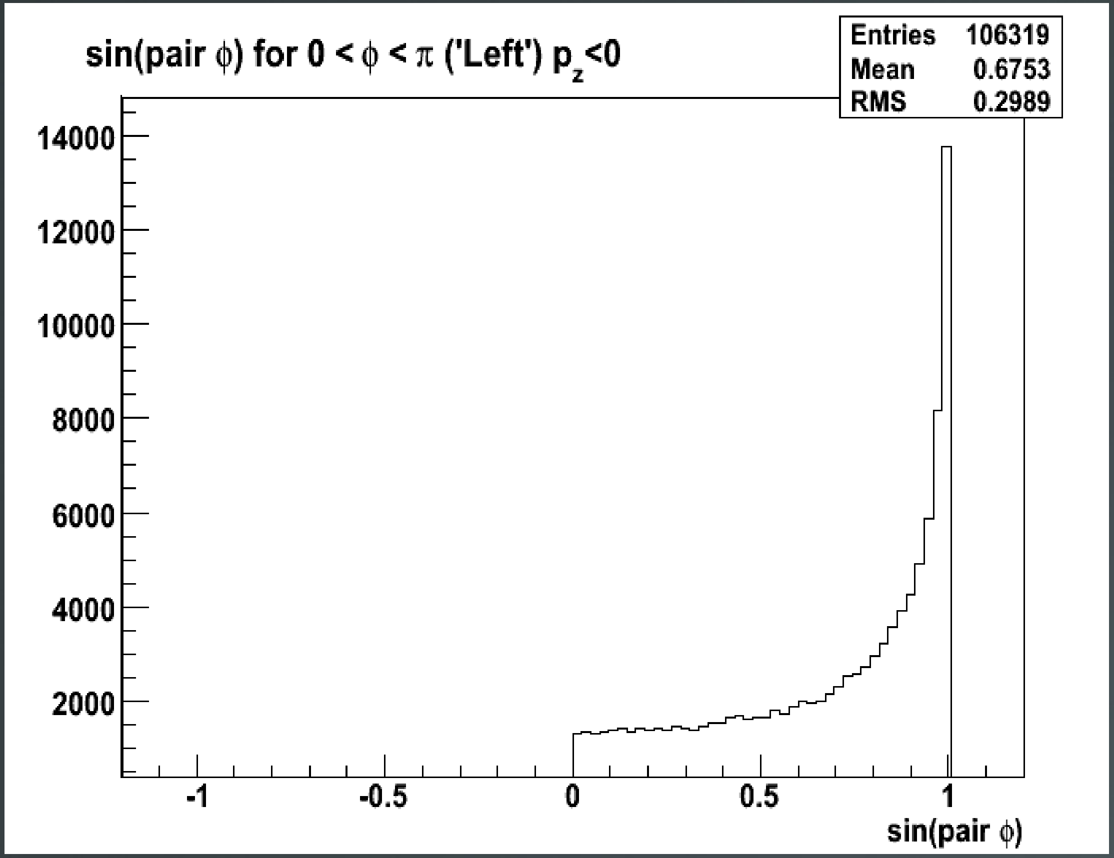
$$A = f_{\mathrm{L}} \, A_{\text{measured, left}}$$

with

$$f_L = \frac{1}{\langle |\sin(\phi)| \rangle_{\text{left}}}$$

See AN753 for more details

Acceptance Correction Factors



$$\langle|\sin\phi|\rangle_{\text{left,in acceptance}} \approx 0.67$$

$$f_L = \frac{1}{\langle|\sin(\phi)|\rangle_{\text{left}}}$$

=> $f_L \approx 1.5$

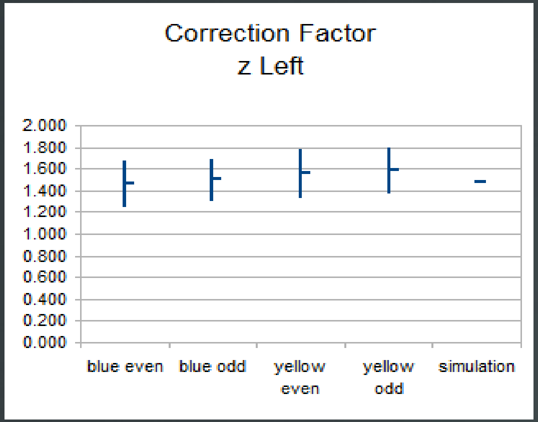
This is, of course, just a quick and dirty example...

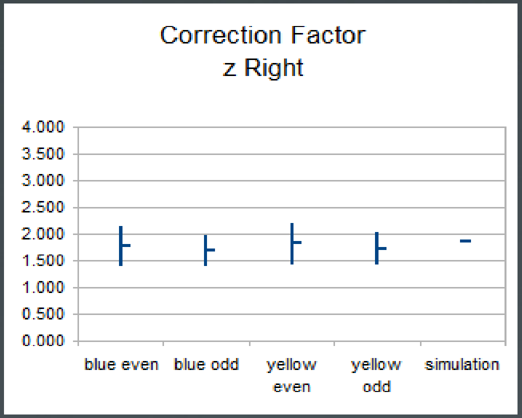
In reality we determine the mean of the histogram ourselves and keep track of statistical errors on the factor (next slide)

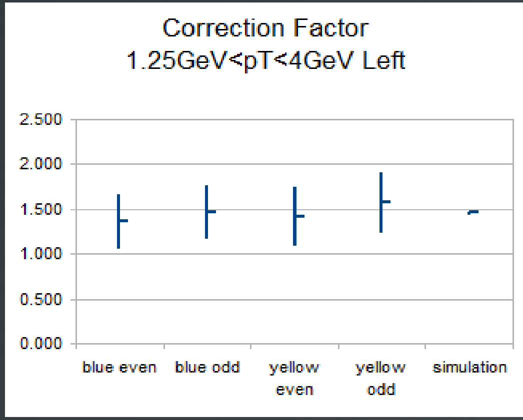
Acceptance Correction Factors

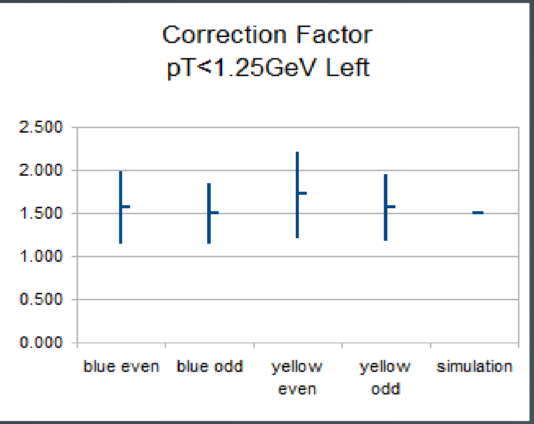
$$f_L = \frac{1}{<|\sin(\phi)|>_{\text{left}}}$$

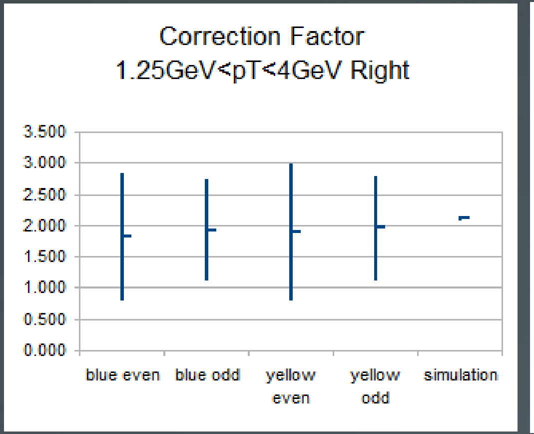
$$f_R = \frac{1}{<|\sin(\phi)|>_{\text{right}}}$$

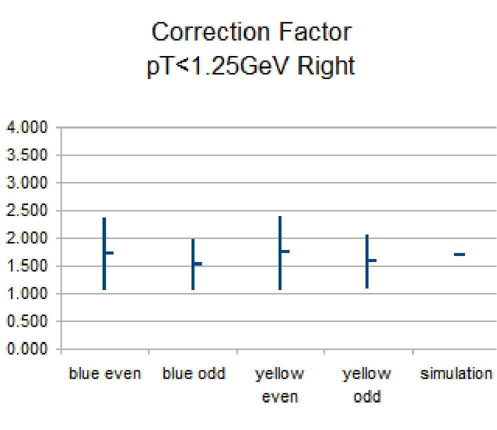












Simulated Correction Factors in Good Agreement with Data.
We use the Simulated Factors in the analysis (smaller error bars)

Note: We still need to include the difference in even /odd efficiencies here—this may bring some of these into better agreement

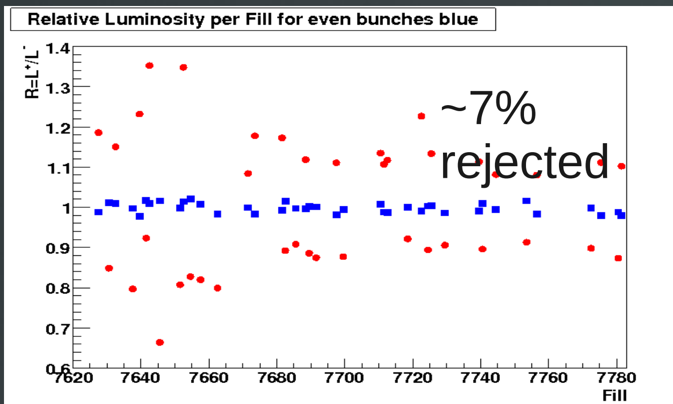
Relative Luminosity Stabilization

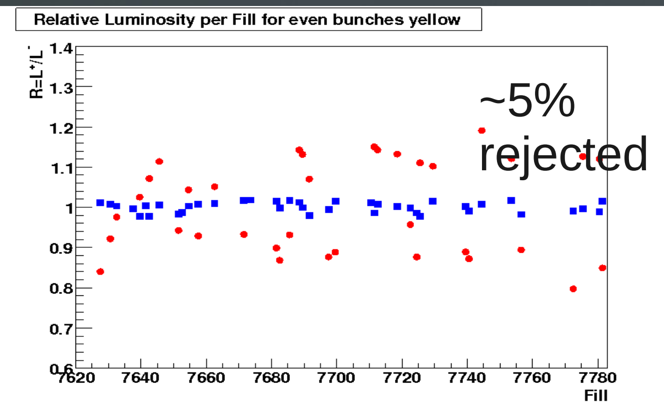
Choose a bunch at Random. Does rejecting this bunch make RL closer to 1? If so, do it if not don't → Go to the next (randomly chosen) bunch

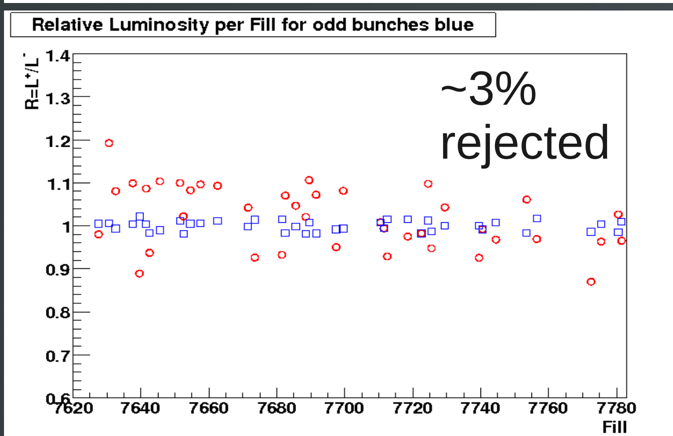
Luminosity	L1	L2	L3	L4	L5	L6	L7
Spin	↑	↓	↑	↓	↑	↓	↑

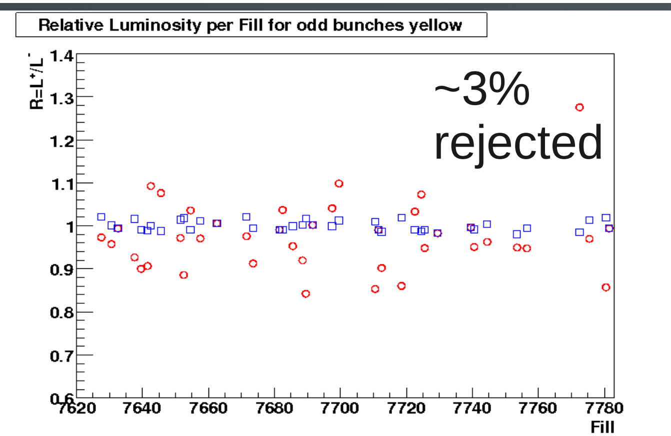
Continue until either RL<1+/-0.01 or you can't do any better

Red: Before Correction , Blue: After Correction





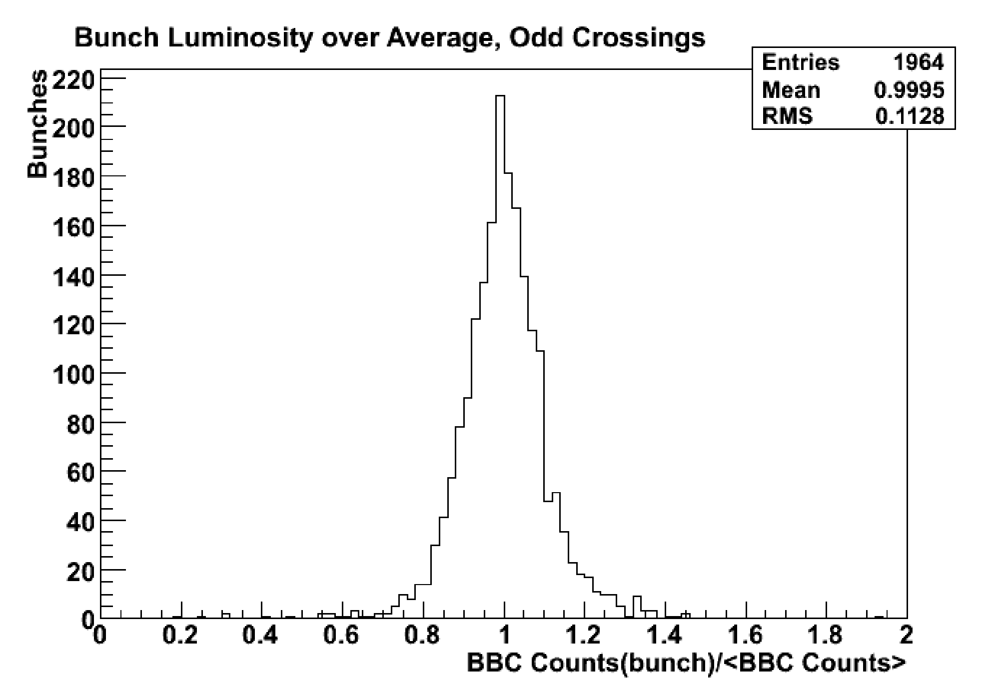


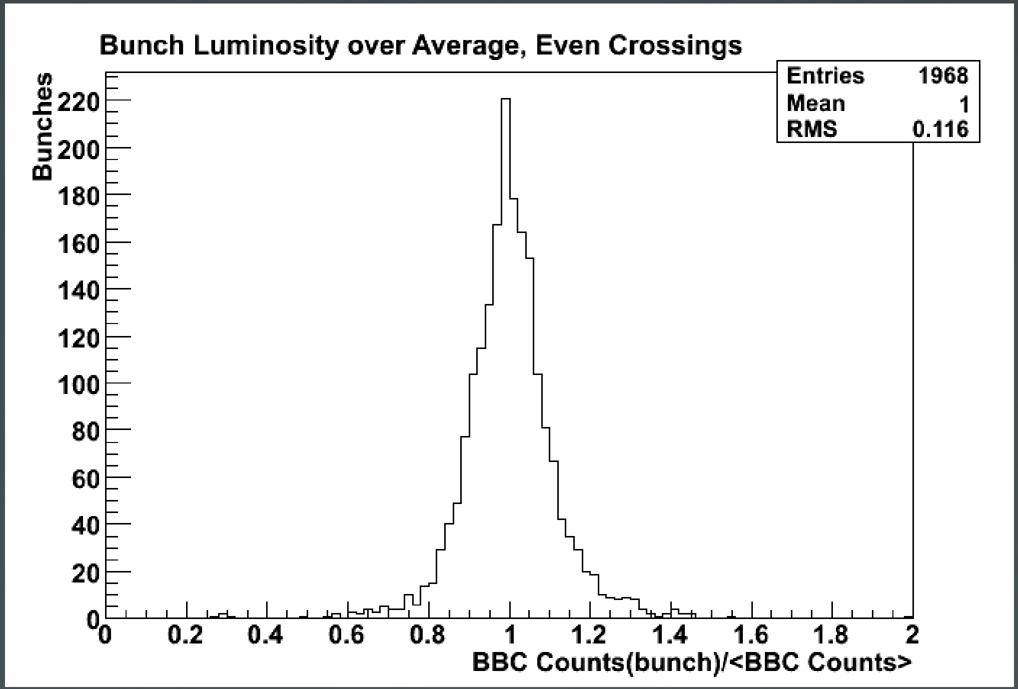


Patricia Liebing's relative luminosity correction.

Also considering 'prejecting' some bunches if the luminosity is considerably different in that bunch

Possible 'prejection' based on luminosity in a bunch

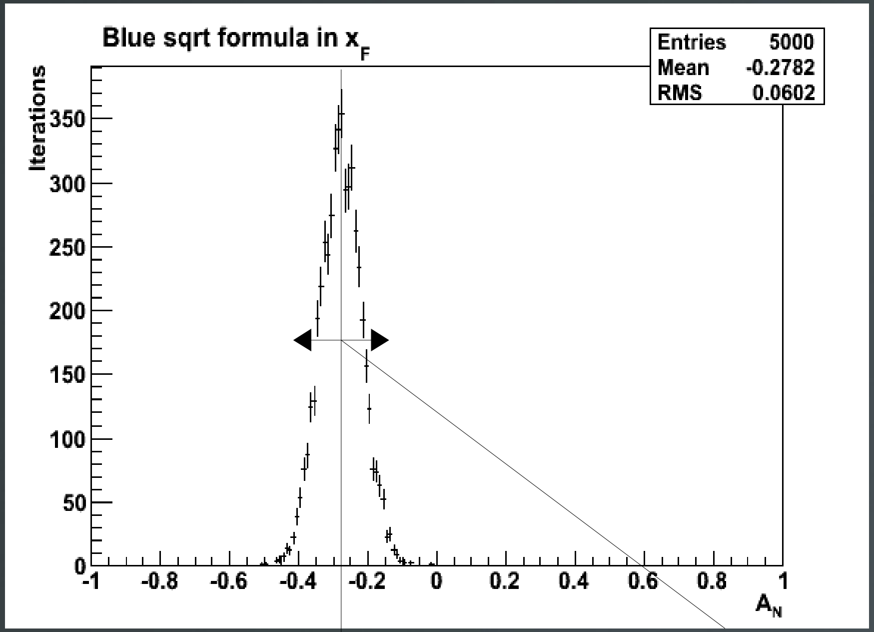


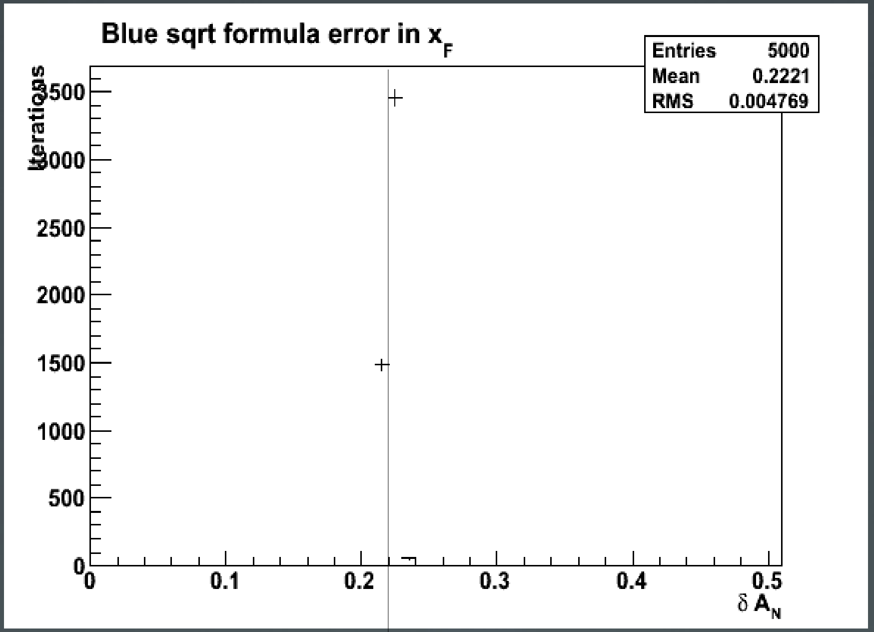


A bunch quality cut like this is currently not included...

Systematics of Relative Luminosity Stabilization

Asymmetry from the analysis then depends on a random number-- this isn't good! So, we histogram 5000 runs



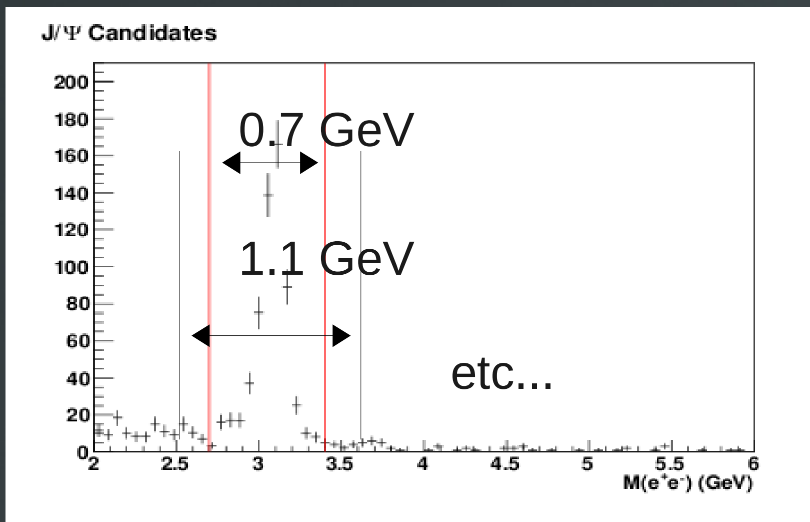


Central Value of Data Point

Systematic Error from Bunch Correction

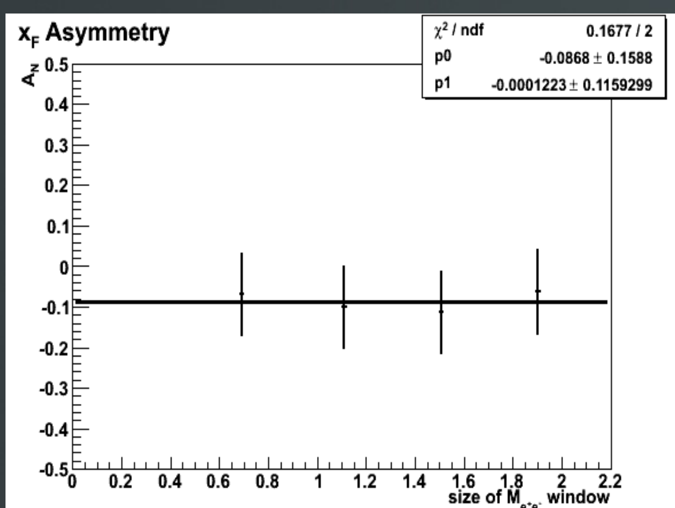
Statistical Error

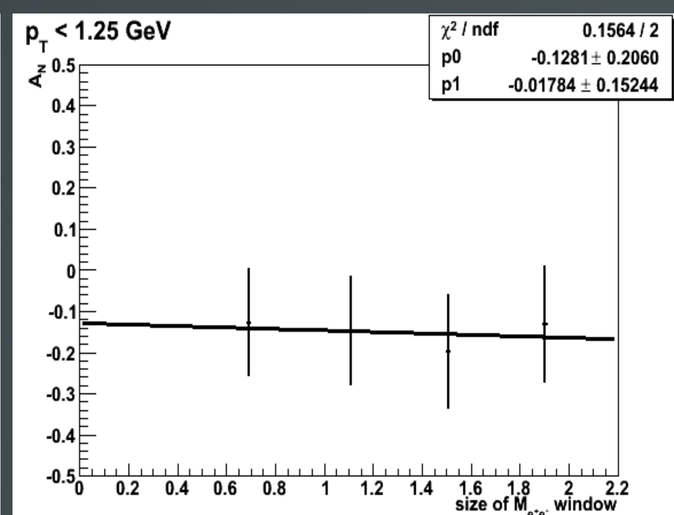
Systematics of Continuum Background

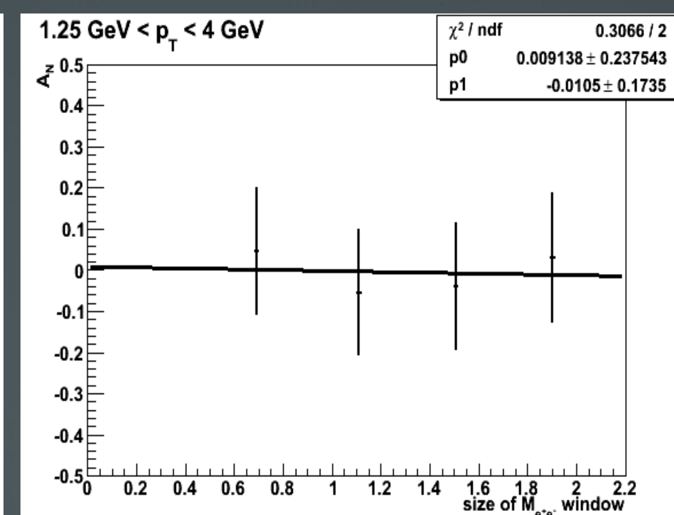


Increase included mass window then project to '0' to get asymmetry with zero continuum contribution.

Data points are not shifted—This is just included as a systematic error.

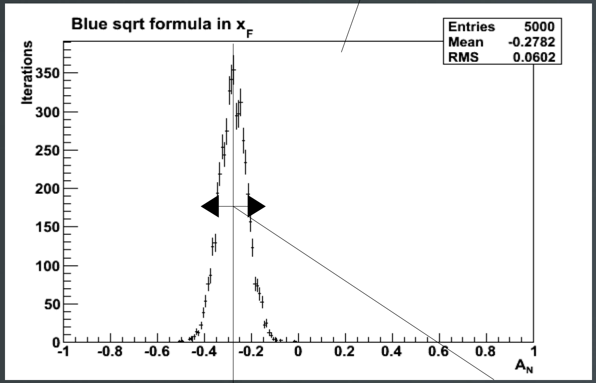




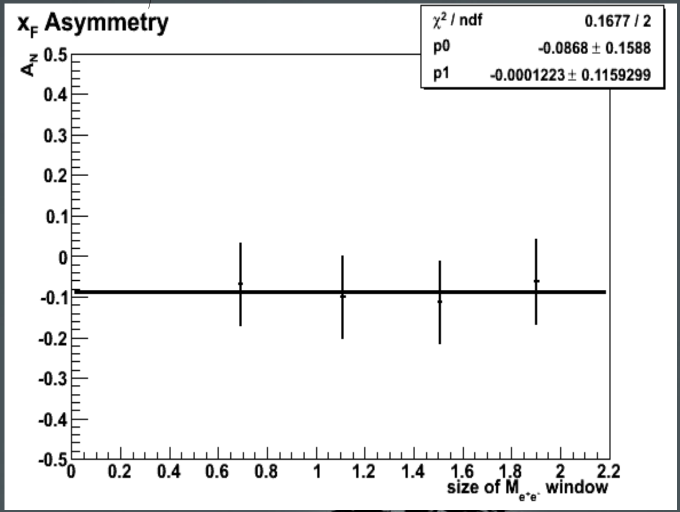


Systematics Errors

	Bunch Correction Width	Difference with Mass Projection	Total
x_F	0.026	0.0178	0.0315
p_T<1.25 GeV	0.032	0.0001	0.0320
1.25 GeV < p_T < 4 GeV	0.040	0.0369	0.0544

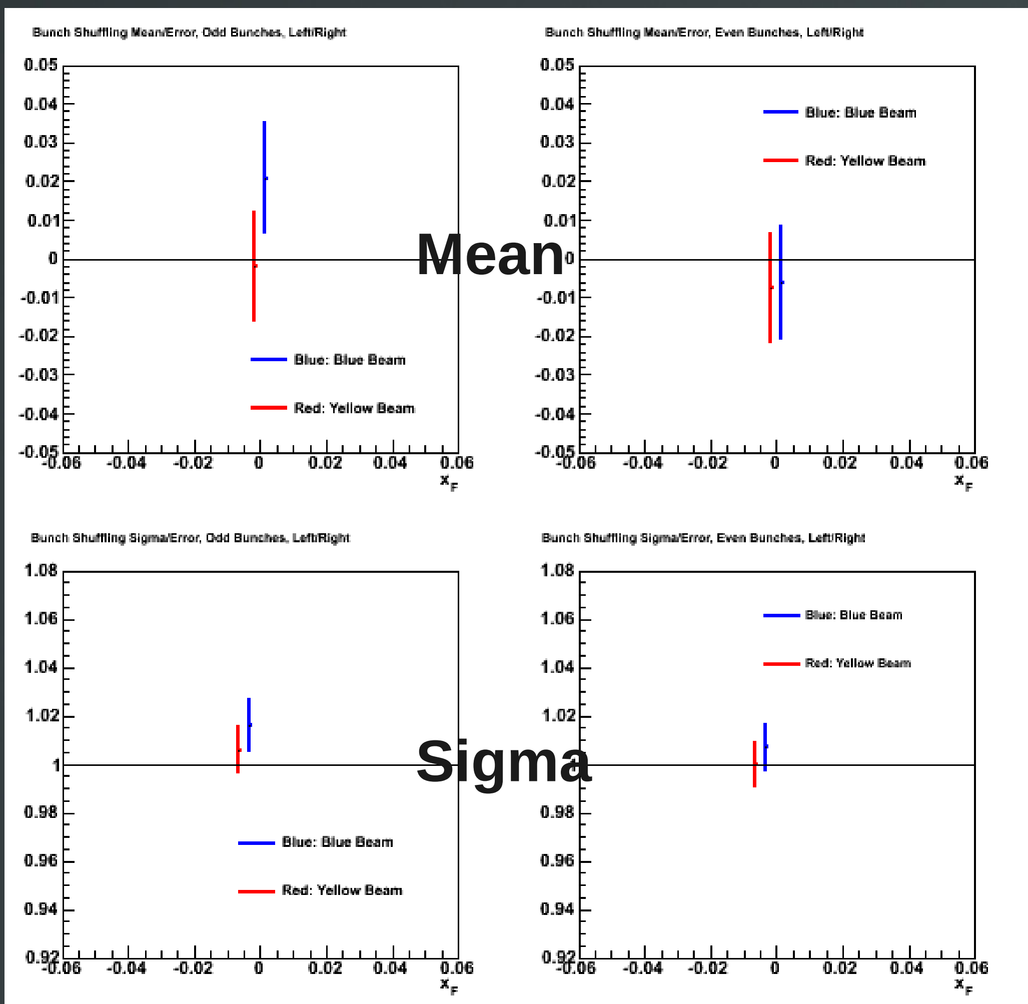


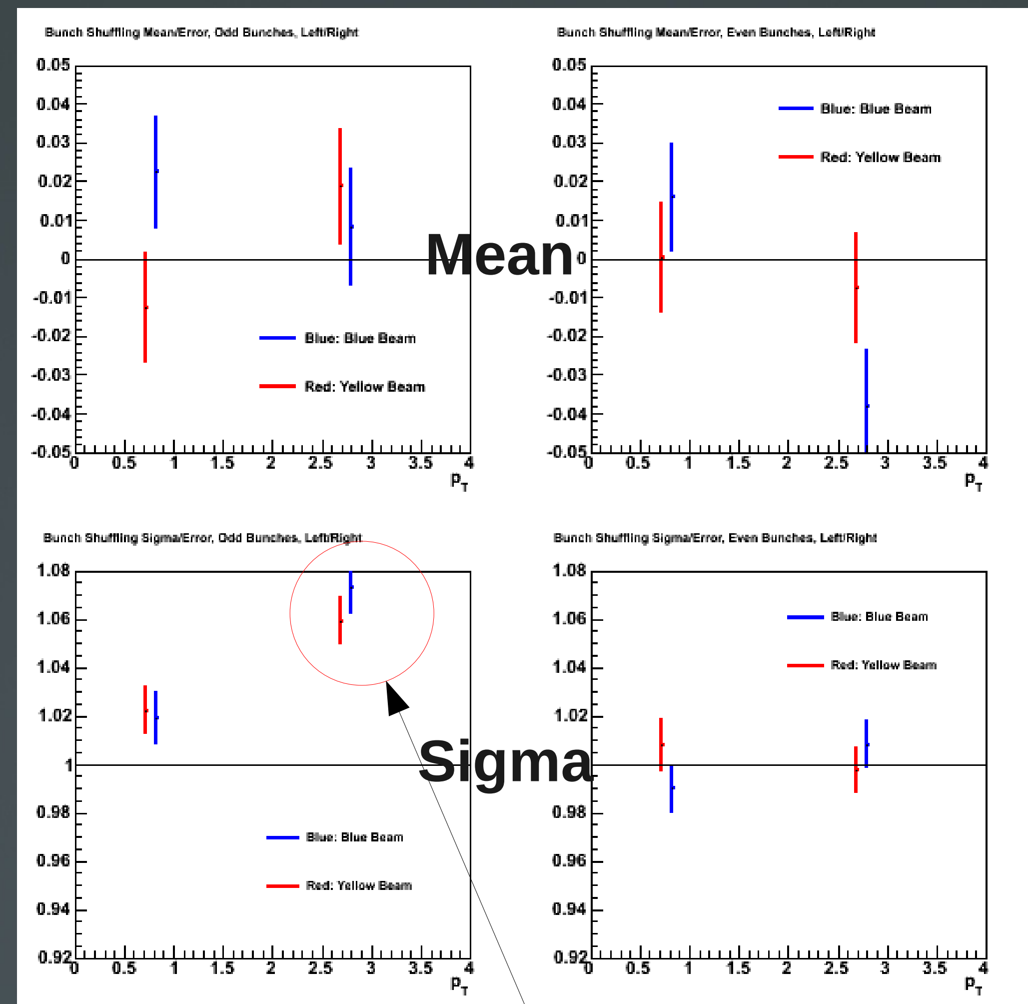
Systematic Error from Bunch Correction



Bunch Shuffling

Randomize Spin Pattern every Fill

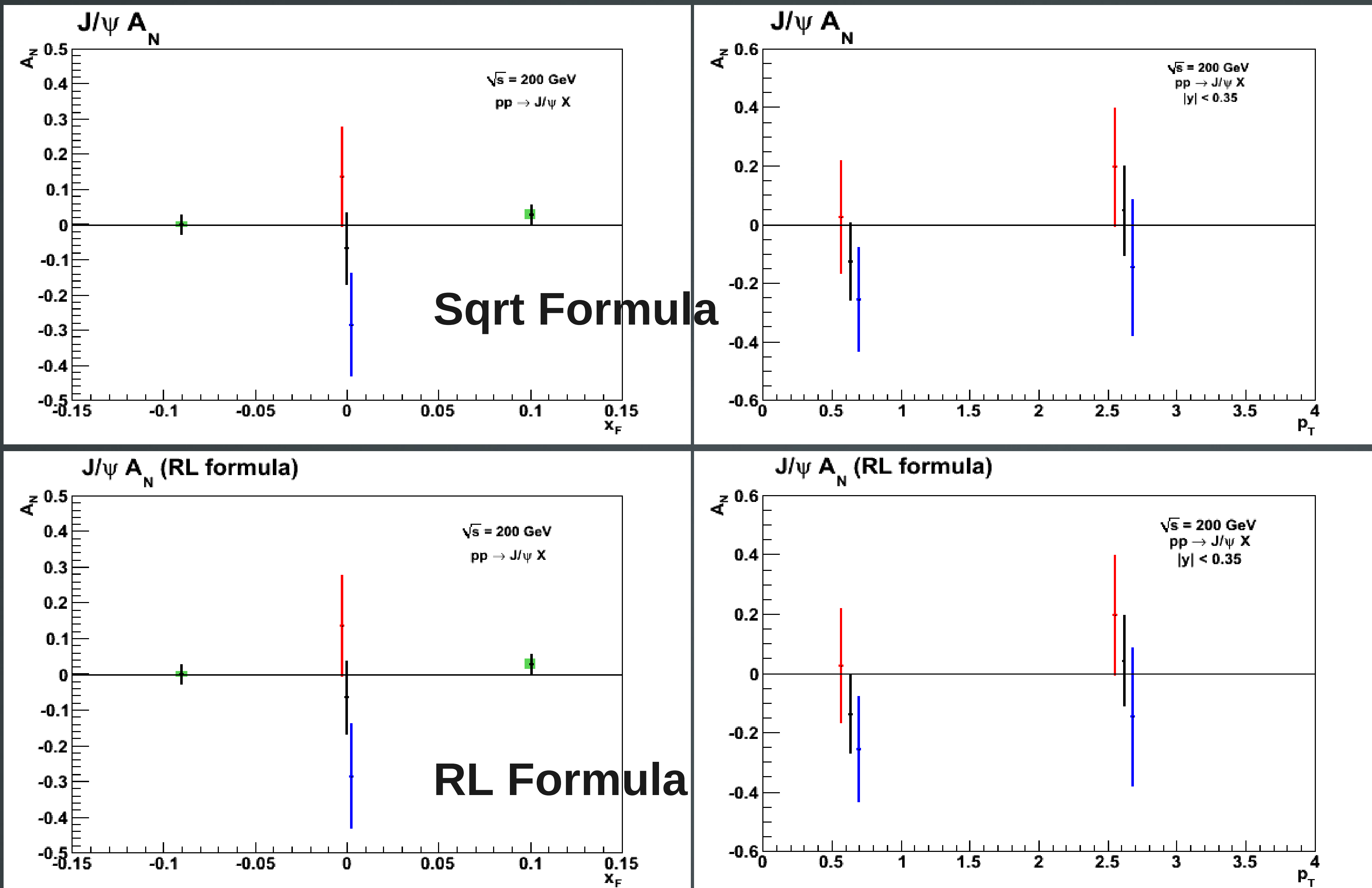




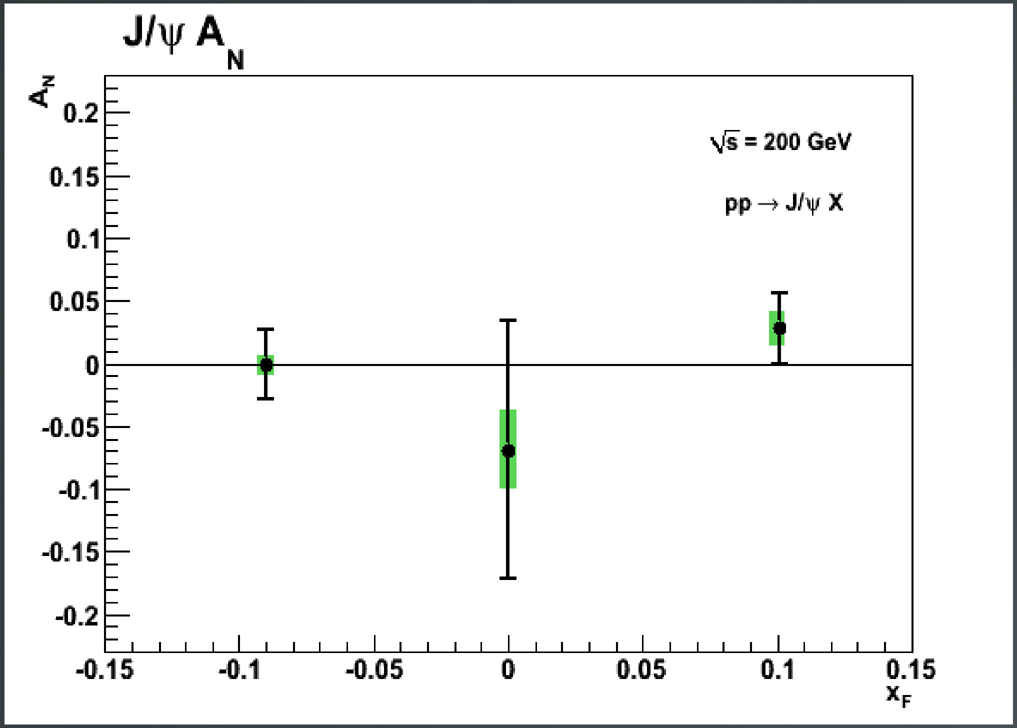
A bit worrisome-- may be helped by including trigger effects in acceptance factors

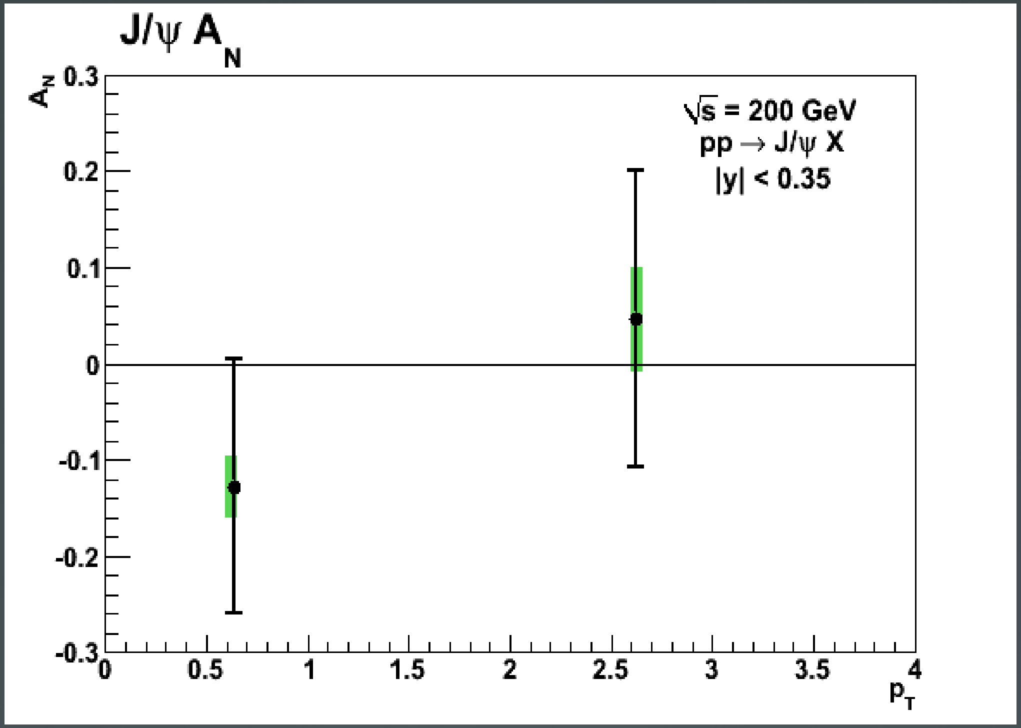
Results (by beam—for 2 different formulae)

The agreement is almost scary...



Results





Using Han's preliminary data points

To Do

1) Include Trigger Effects in Simulation

2) Understand bunch shuffling sigma problem in large p_T even crossings

3) Consider 'prejecting' high/low luminosity bunches

3) Finish the Analysis Note

3) Get Preliminary

4) Form the PPG (Jan.)

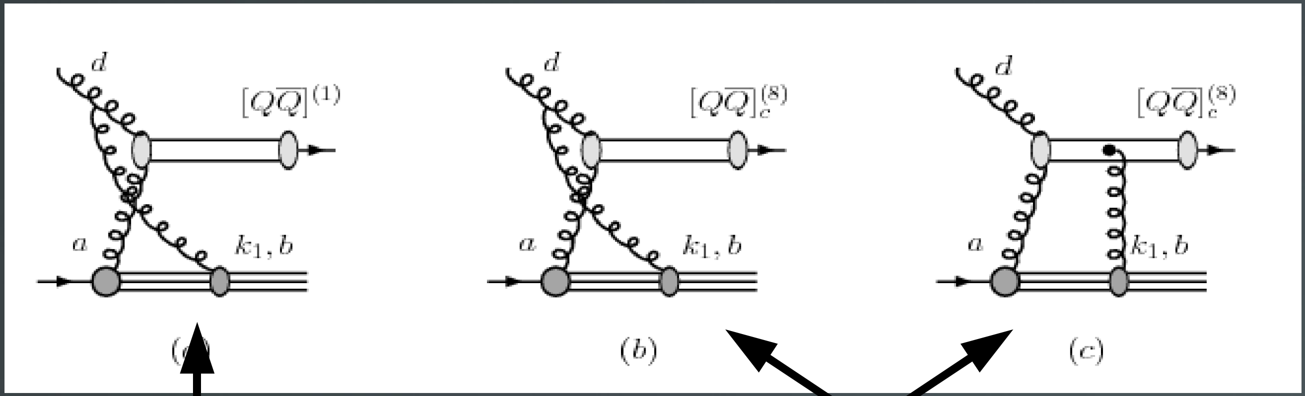
5) Write the Paper

Backup

Physics Motivation

Prediction: $p^{\uparrow}p$ non-zero asymmetry only in color singlet model

from Feng Yuan—
Phys. Rev. D 78, 014024 (2008) (arXiv: 0801.4357)



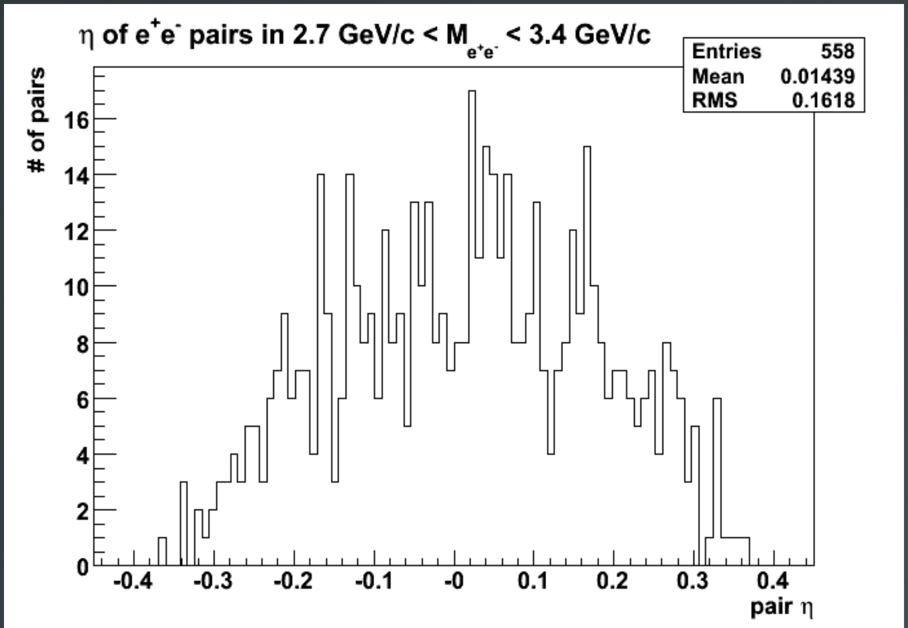
One color-singlet diagram
—no cancellation, only initial state interaction

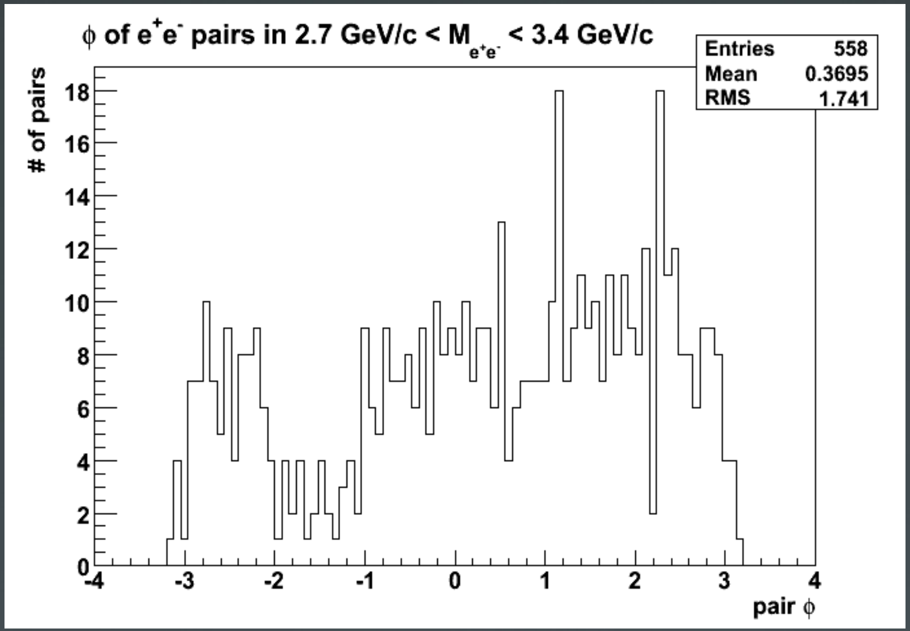
Two color-octet diagrams
—cancellation between initial and final state interactions

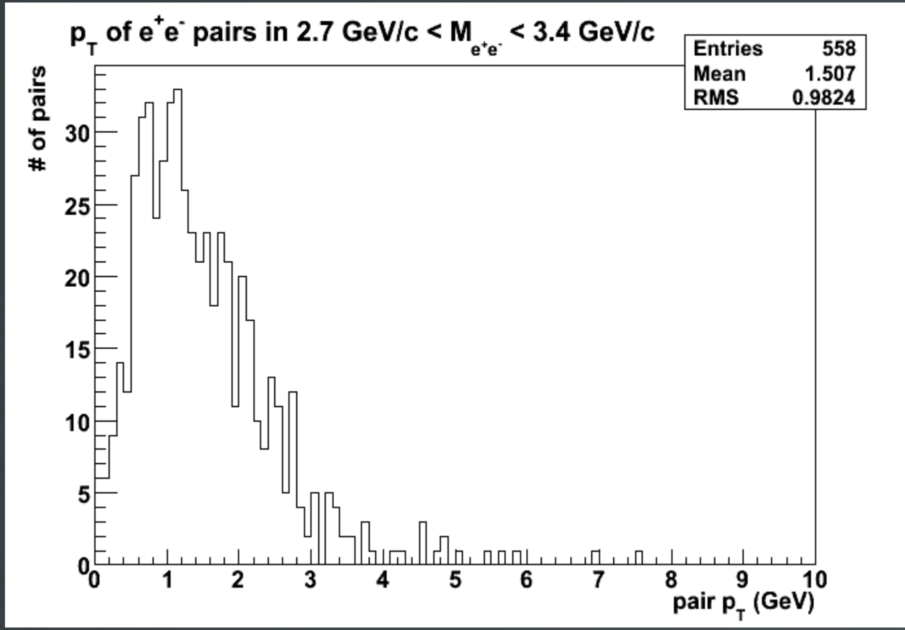
Asymmetry set (essentially) by Gluon orbital angular momentum

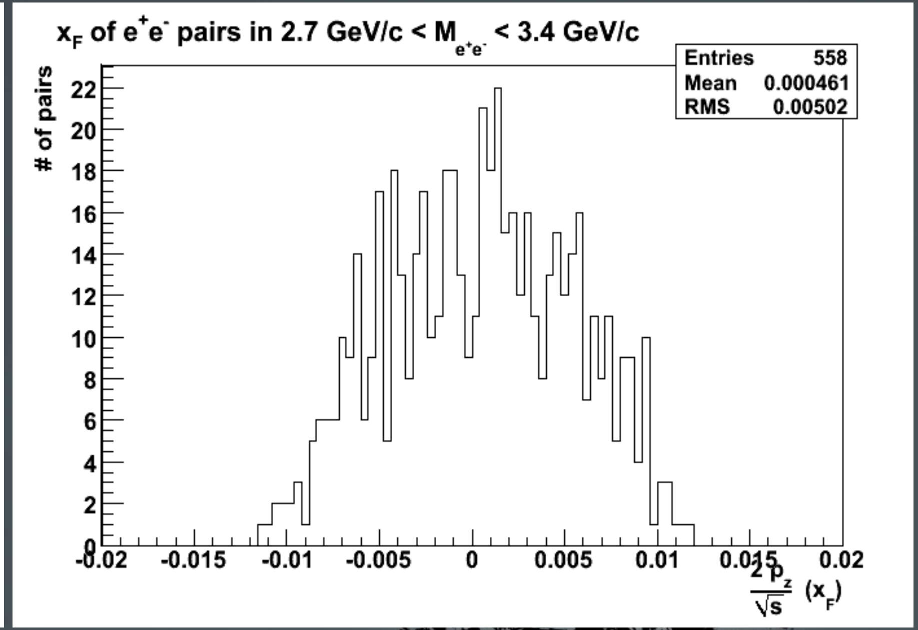
Orbital angular momentum terms cancel

Kinematics of Accepted Pairs







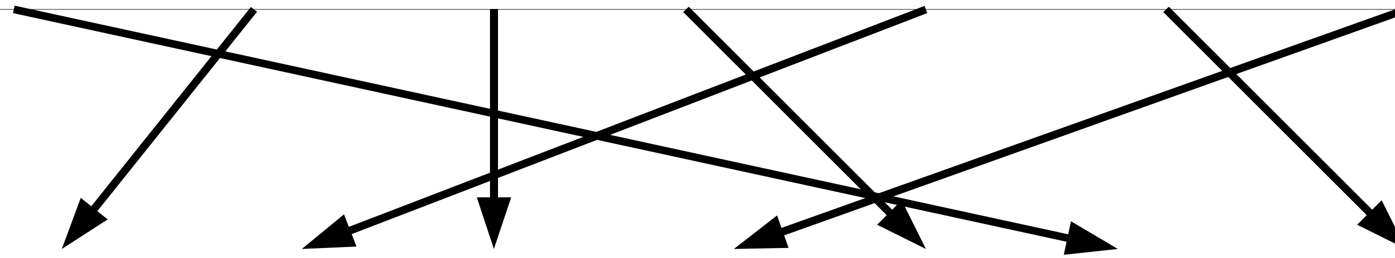


Bunch Shuffling

Not entirely trivial when Patty's correction is included...

Luminosity	L1	L2	L3	L4	L5	L6	L7
Spin	↑	↓	↑	↓	↑	↓	↑

Reassignment based on random number generator



Luminosity	L2	L5	L3	L7	L4	L1	L6
Spin	↓	↑	↑	↑	↓	↑	↓

Do Relative Luminosity Correction on Random Spin Pattern/Luminosities

Calculate Asymmetries

Repeat for every fill
Do analysis 5000 times and histogram A/δA

Gaussian with a mean of 0, sigma of 1

Todd Kempel -- Iowa State University