Luminosity at STAR

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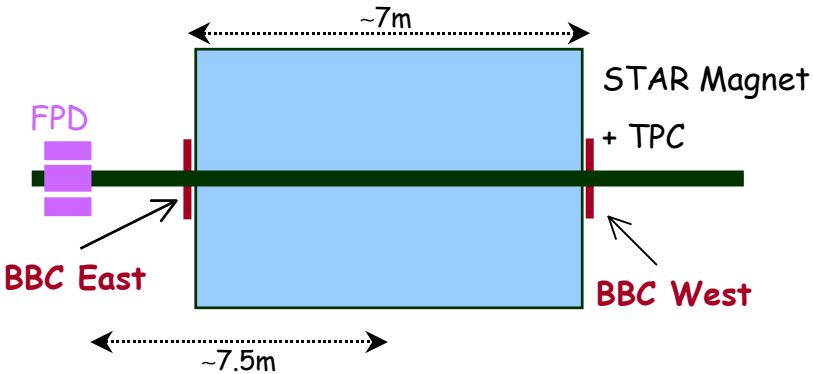
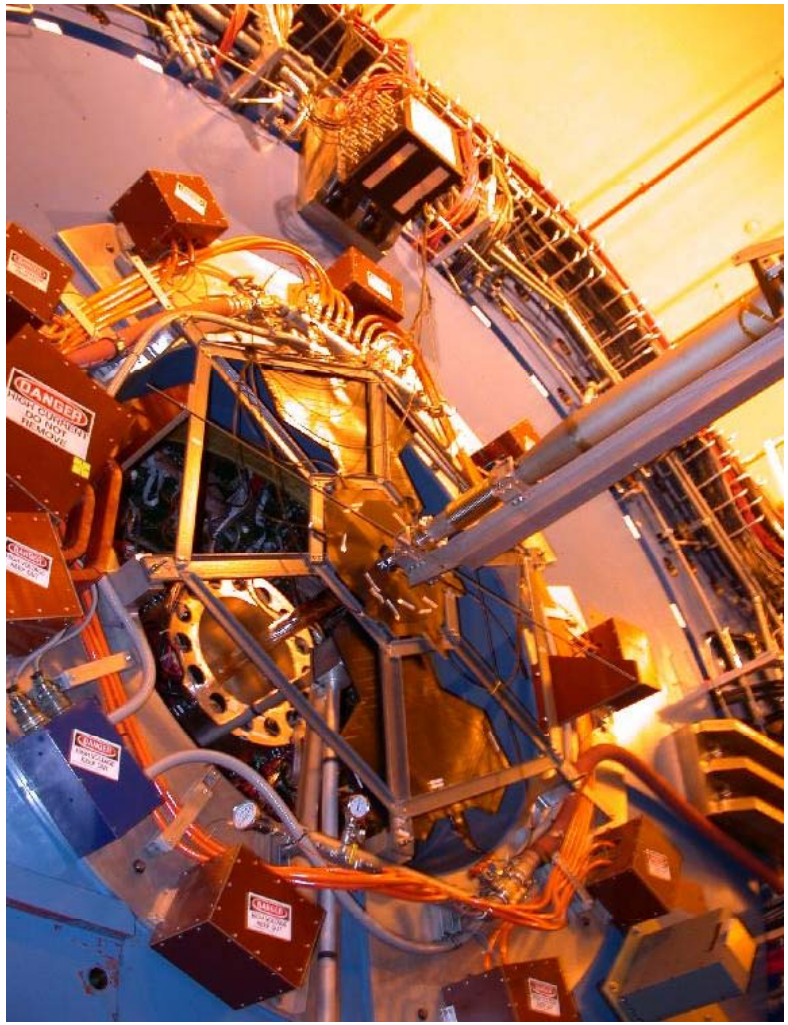
1. STAR detector upgrade (BBC + scaler boards) for luminosity measurement in FY02/FY03
2. Luminosity monitoring
3. Relative luminosity measurement
4. Single spin asymmetries from the BBC scaler data
5. Summary

I Upgrade of STAR detector for luminosity measurement in pp run FY02/FY03

1. Beam-Beam Counters (BBC)
   Scintillator annullus installed around the beam pipe, on the east and west poletips of STAR magnet at ±3.5m from IR
   ($2 < |\eta| < 5$)

2. Scaler Board System



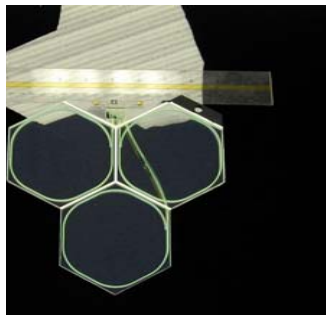


1. Beam-Beam Counters (BBC)

Small hexagonal annulus:

- inner (outer) diameter 9.6cm (48cm); of 18 pixels (6 inner + 12 outer);
- 8PMT: 4 PMT/η ring -> azimuthal segmentation (Top, Bottom, North, South)
- all pixels in place in FY02 covered 3.3 < |η| < 5.0

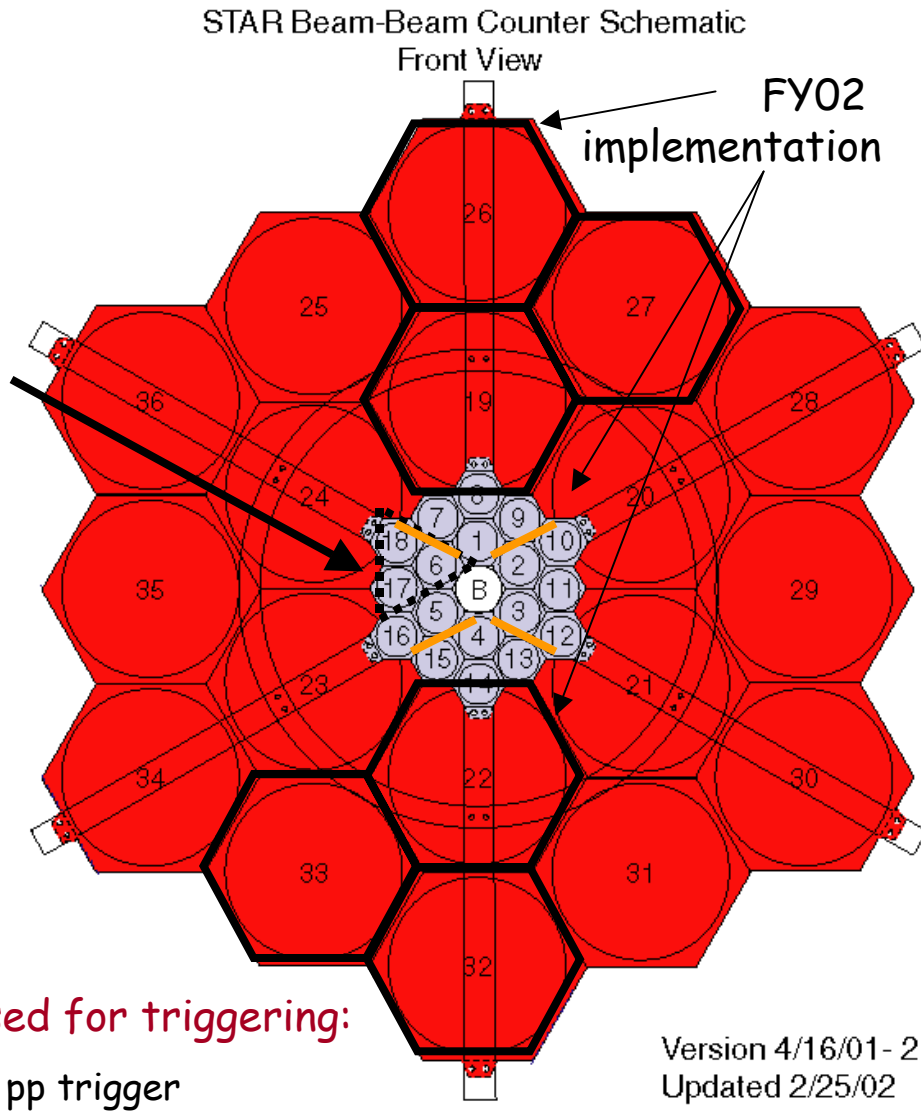
-1 cm thick scintillator SCSN81 (Kuraray)
-4 optical fibers for light collection
- 1,2 or 3 tiles connected to a PMT
-15 photoelectron/MIP



Large hexagonal annulus:

-inner (outer) diameter 38cm (193cm) of 18 pixels (6 inner + 12 outer)

-1/3 in place, to be completed for FY03. It will cover 2.1 < |η| < 3.3



Only small annuli have timing information, thus used for triggering:

East*West coincidences condition in each of pp trigger

FY02/FY03 BBC Plans

- Complete construction of large hexagonal tiles
  - purchase/construct wave-length shifting fiber optics
  - assemble/test remaining large hexagonal tile triplets
- Extend PMT readout of hexagonal pixels:
  - 16 PMT for small hexagonal annulus
    - → evaluate/purchase fast, 'green-extended' PMT
    - → purchase/construct clear-fiber optical cables
  - 8 PMT for large hexagonal annulus
    - → design/construct PMT box for mounting atop STAR magnet
- Implement 48-channels of CDB/DSM for pulse-height readout
- Implement 32-channels of CDB/DSM for timing readout (small hexagons only)
- Develop 6U VME time-to-amplitude converter (based on CAMAC design/components)
- Employ LeCroy 1440 HV system / interface to STAR slow controls system

2. Scaler Board System

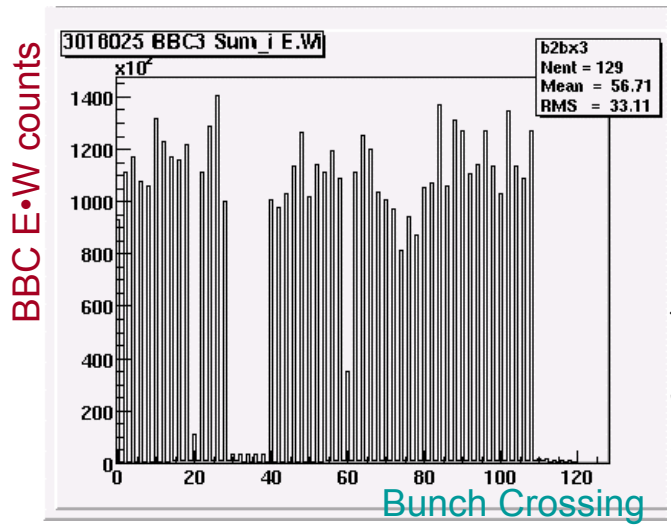
1 BBC E•W
2 BBC E
3 BBC W
4 BBC W.Etop
5 BBC W.Ebot
6 BBC W.Enorth
7 BBC W.Esouth
8 BBC Wtop.Eany
9 BBC Wbot.Eany
10 BBC Wnorth.Eany
11 BBC Wsouth.Eany
12 BBC Enorth
13 BBC Esouth
14 BBC Etop
15 BBC Ebot
16 CTB-M1
17 CTB-M2
18 BX1
19 BX2
20 BX3
21 BX4
22 BX5
23 BX6
24 BX7

- Each scaler board has 24 input bits:
  For pp spin run:
  24 = 7(bunch crossing) + 17(physics inputs) -> $2^{17}=10^5$
  or 24 = 4 (spin index) + 20(physics inputs) -> $2^{20}=10^6$

- Input bit pattern (information from fast detectors like BBC, ZDC, FPD, CTB, EMC) recorded for each RHIC Strobe received

- FY03 - up to 10 scaler boards,
decision which detector(s) to use and bit mapping to be made

example of the BBC scaler bits used in FY02

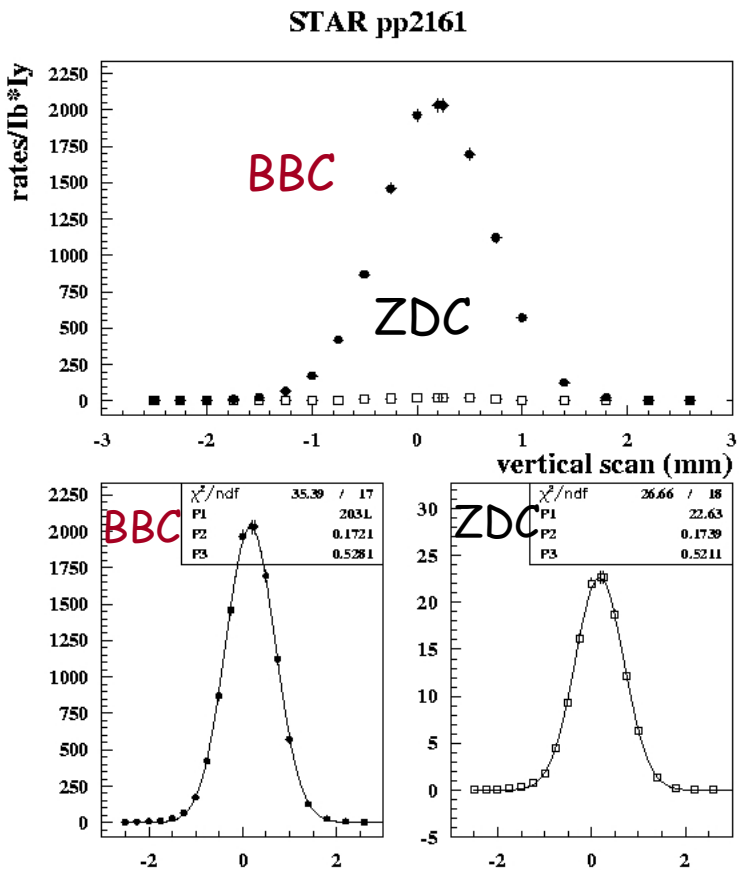


Run 3018025, fill 2251

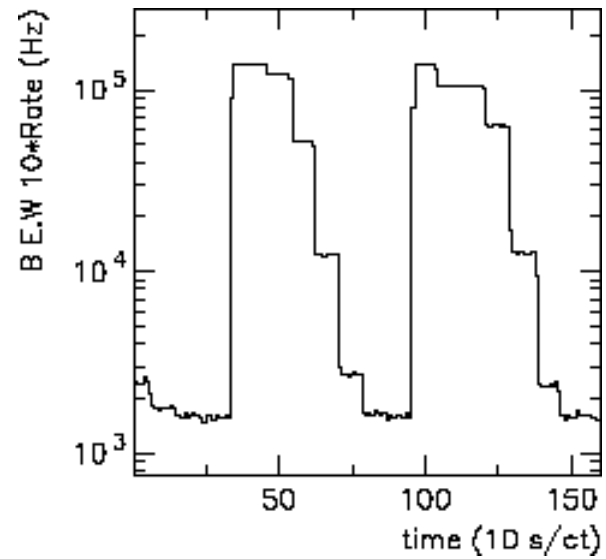
<- To determine the relative luminosity of bunch crossings with different polarization directions.

II Luminosity monitoring

Scalar info sent to RHIC to enable MCR to steer beam at STAR



Absolute normalization from BBC E.W:



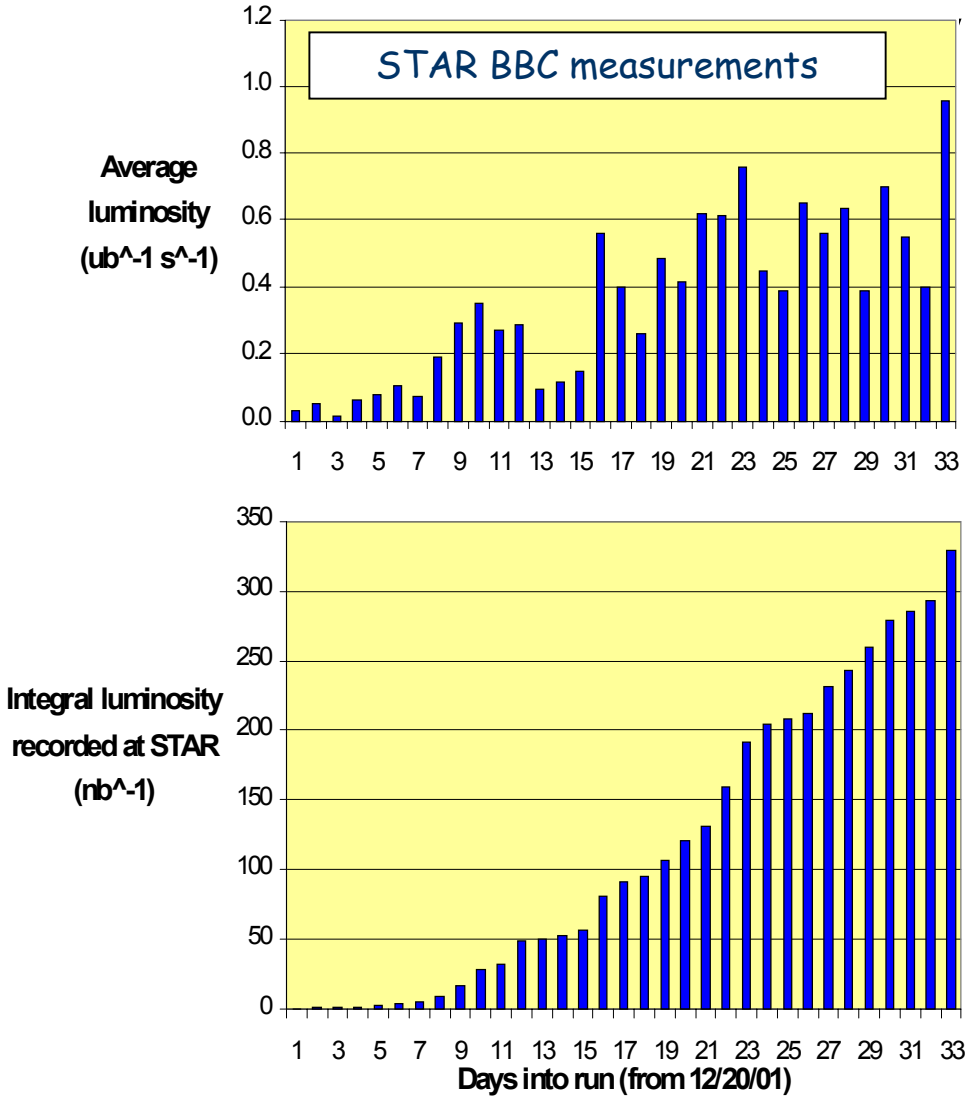
- BBC E•W coincidence rate vs time during a **Van der Meer scan** that determines the beam size, and hence the luminosity, by controlled relative steering of the colliding beams.

From simulations: BBC "sees" 40% of total pp cross section,

Rate of 20 kHz ~ Luminosity of 10^{30} cm^{-2} s^{-1} ; agreement up to 15%

Plot(s) from Angelika Drees

FY02 Polarized Proton Run Luminosity



- RHIC can deliver 10^{30} cm^{-2} s^{-1}
- Integrated luminosity@STAR ~ 325 nb^{-1}

III Relative luminosity measurement

To measure relative luminosity of bunch crossings with different polarization directions with good statistical accuracy, one needs process/detector with

- high rates and
- no (or small) polarization dependence

$$\delta \frac{\mathcal{L}^{\uparrow}}{\mathcal{L}^{\downarrow}} << P \times A_N$$

<u>Transverse Single Spin Asymmetries</u>

1. Left-Right symmetric detector

This method works only with transverse polarization

$$\varepsilon_1 = P_{Y(B)} \times A_N = \frac{\sqrt{L^{\uparrow}R^{\downarrow}} - \sqrt{L^{\downarrow}R^{\uparrow}}}{\sqrt{L^{\uparrow}R^{\downarrow}} + \sqrt{L^{\downarrow}R^{\uparrow}}}$$

$L(R)^i$ – spin dependent yields from Left (Right) detector, where $i = \uparrow, \downarrow$ and $L^i\,(R^i) = N^{i\uparrow} + N^{i\downarrow}$

$P_{Y(B)}$ - beam polarization

2. Non-symmetric detector

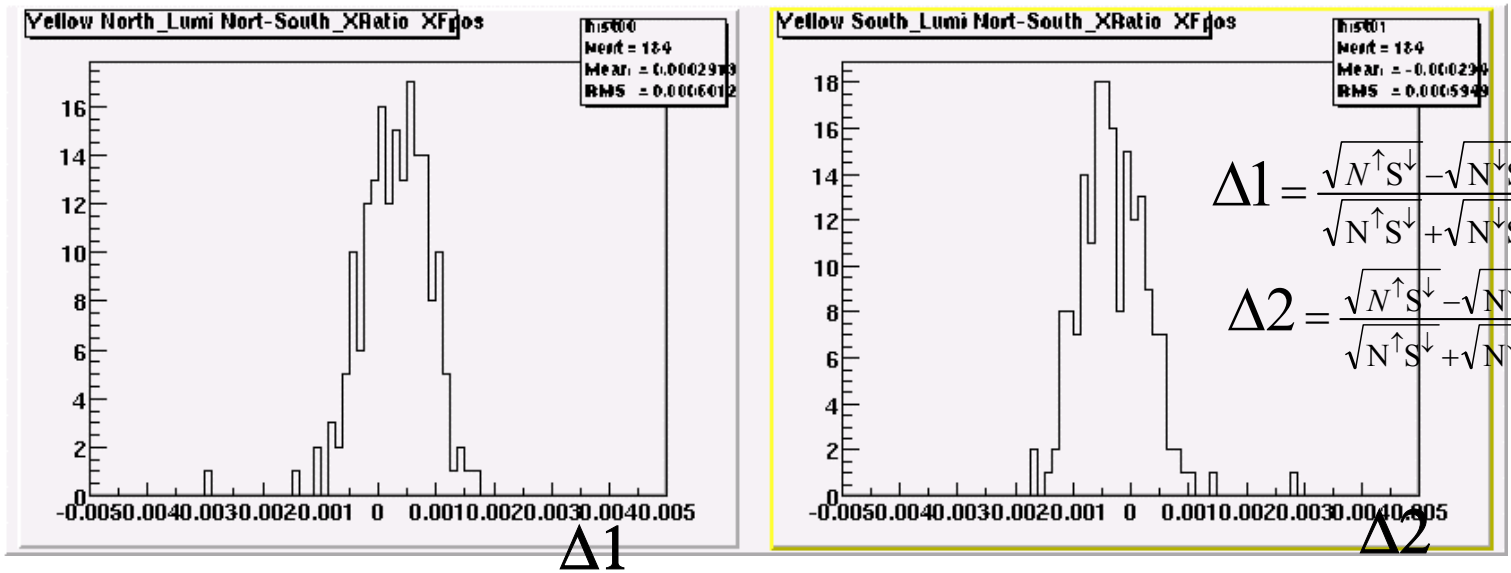
This method will be used when beam(s) are polarized longitudinally (next year) A_{LL}

$$\varepsilon_2 = P_{Y(B)} \times A_N = \frac{N^{\uparrow}/\mathcal{L}^{\uparrow} - N^{\downarrow}/\mathcal{L}^{\downarrow}}{N^{\uparrow}/\mathcal{L}^{\uparrow} + N^{\downarrow}/\mathcal{L}^{\downarrow}}$$

where: N^i – spin dependent yields, requires the $\mathcal{L}^i$ – corresponding luminosity measurements

Statistical significance: $P^2 \cdot \int \mathcal{L} dt$

- Single spin asymmetry calculated using counts from North/South BBC East detector, Yellow beam polarized (example)
- Comparison of 2 methods of single spin asymmetry calculation : ε_1 and ε_2 (North/South)



$$\Delta 1 = \frac{\sqrt{N^{\uparrow}S^{\downarrow}} - \sqrt{N^{\downarrow}S^{\uparrow}}}{\sqrt{N^{\uparrow}S^{\downarrow}} + \sqrt{N^{\downarrow}S^{\uparrow}}} - \left(\frac{N^{\uparrow}/\mathcal{L}^{\uparrow} - N^{\downarrow}/\mathcal{L}^{\downarrow}}{N^{\uparrow}/\mathcal{L}^{\uparrow} + N^{\downarrow}/\mathcal{L}^{\downarrow}} \right)$$

$$\Delta 2 = \frac{\sqrt{N^{\uparrow}S^{\downarrow}} - \sqrt{N^{\downarrow}S^{\uparrow}}}{\sqrt{N^{\uparrow}S^{\downarrow}} + \sqrt{N^{\downarrow}S^{\uparrow}}} - \left(\frac{S^{\uparrow}/\mathcal{L}^{\uparrow} - S^{\downarrow}/\mathcal{L}^{\downarrow}}{S^{\uparrow}/\mathcal{L}^{\uparrow} + S^{\downarrow}/\mathcal{L}^{\downarrow}} \right)$$

Conclusion: Relative luminosity known up to 10^{-3}

Results from the charged leading particle analysis (midrapidity, TPC) supports this conclusion - no spin effects observed in pp-> h + X up tp 10^{-3}

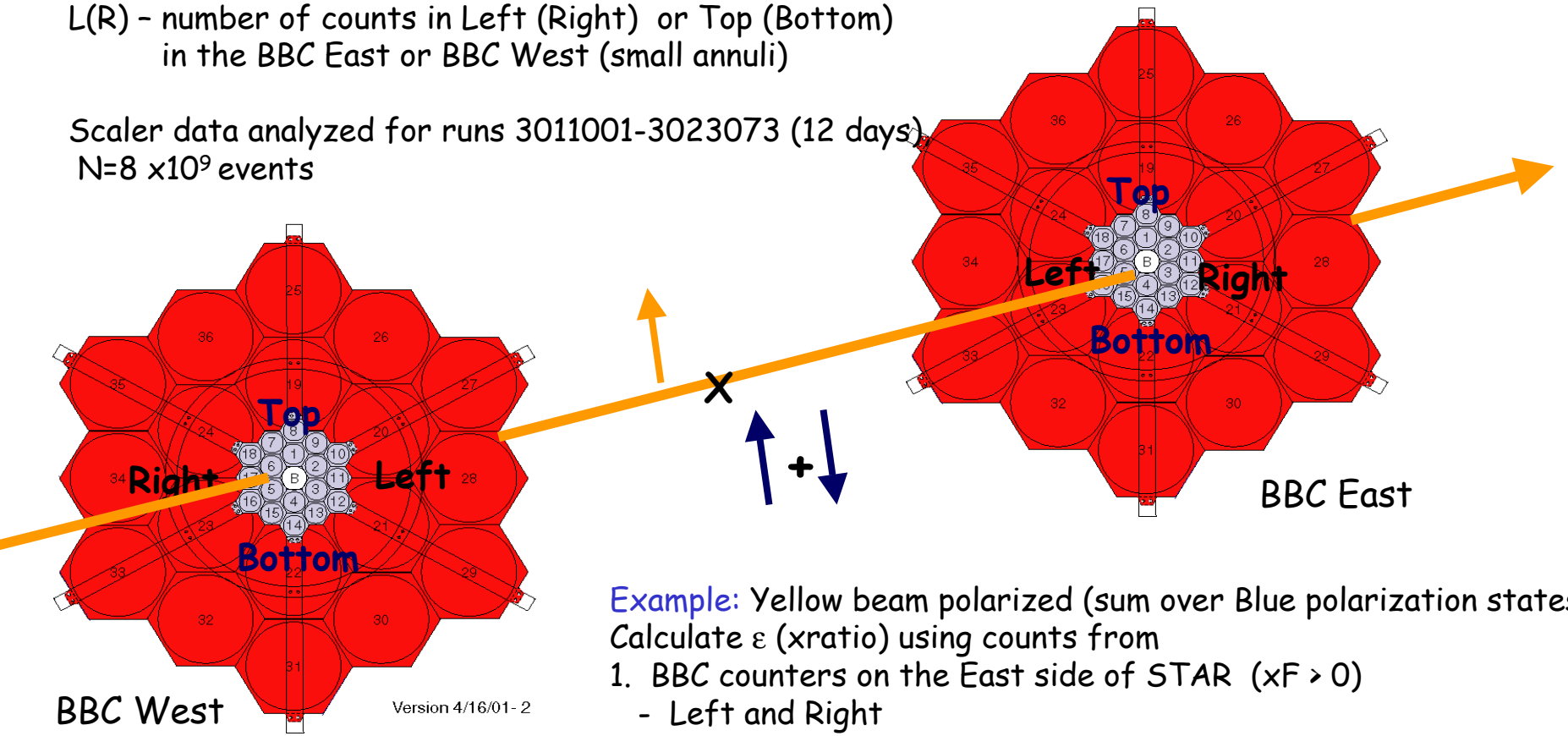
Now we want to check if there is any spin dependence in the process(es) for which we measure the relative luminosity with the BBC:

Transverse single spin asymmetries calculation with BBC counters (possible Due to an azimuthal segmentation: left-right-top-bottom)

IV Transverse Single Spin Asymmetries from the BBC scaler data

L(R) – number of counts in Left (Right) or Top (Bottom)
in the BBC East or BBC West (small annuli)

Scaler data analyzed for runs 3011001-3023073 (12 days)
N=8 x10^9 events

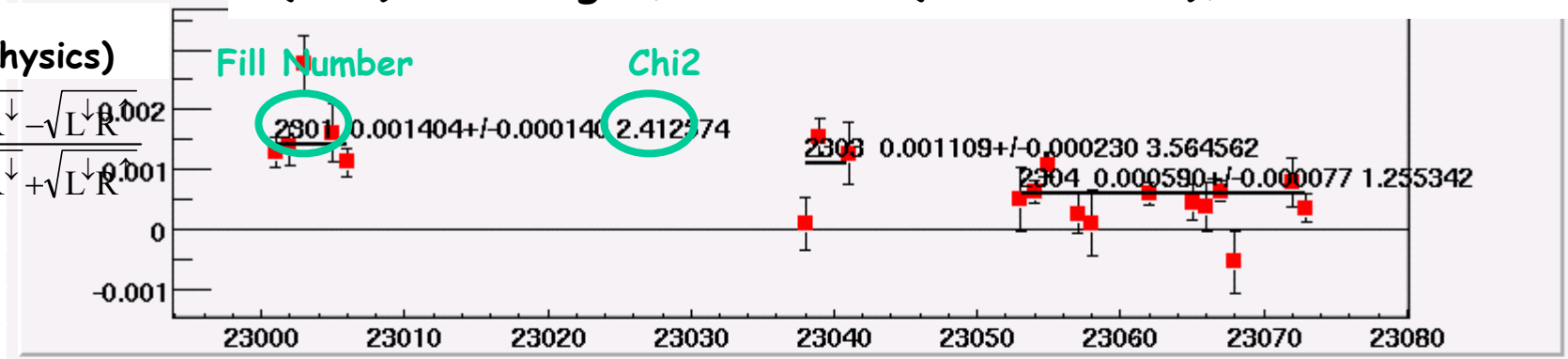


Example: Yellow beam polarized (sum over Blue polarization states).
Calculate ε (xratio) using counts from

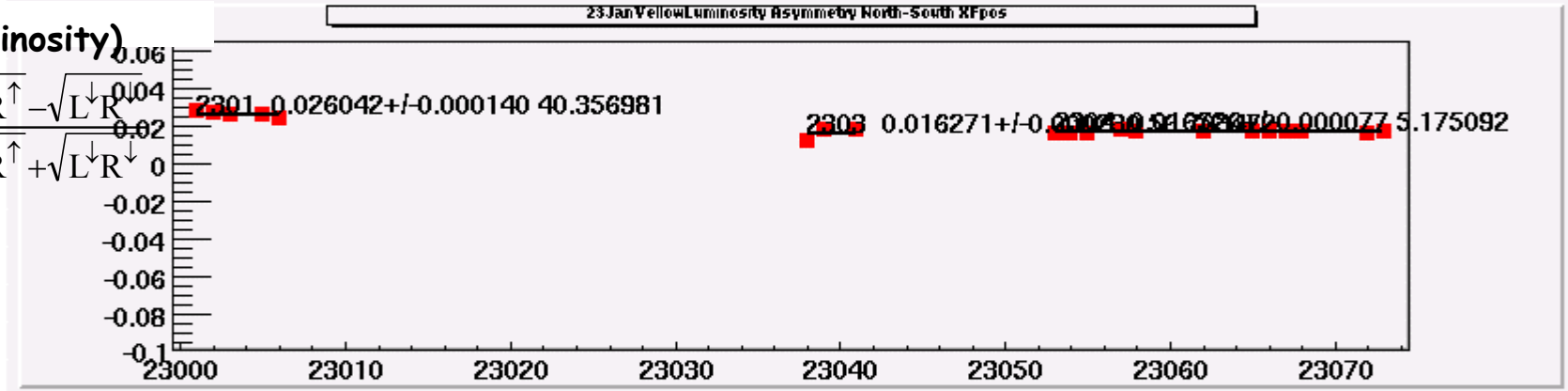
1. BBC counters on the East side of STAR (xF > 0)
   - Left and Right
   - Top and Bottom
2. BBC counters on the West side of STAR (xF < 0)
   - Left and Right
   - Top and Bottom

ε(BBC) Left-Right, BBC East (Yellow xF>0), vs RunNumber

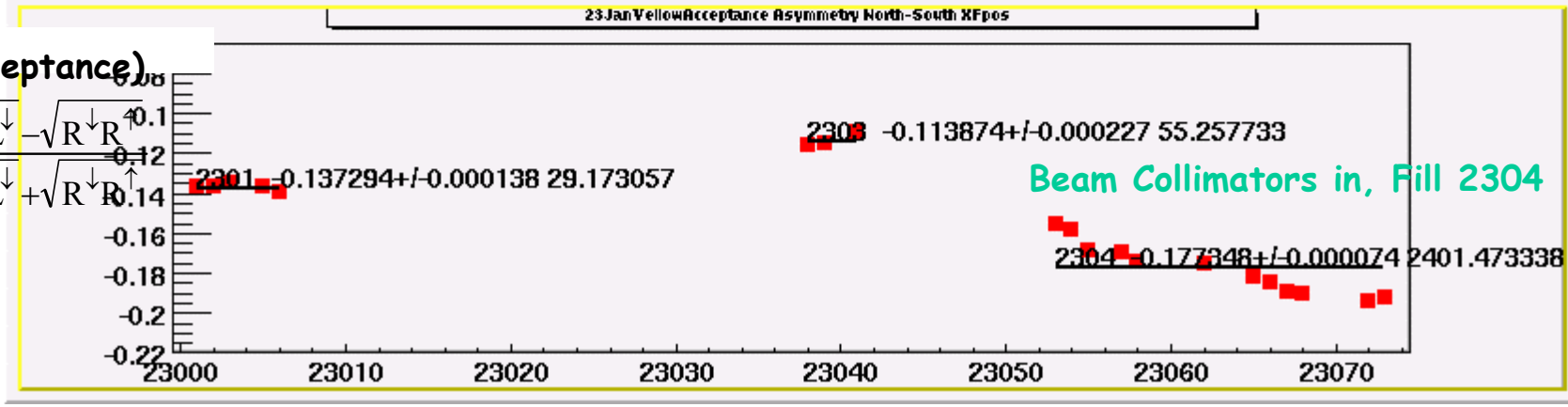
$$\varepsilon(\text{physics}) \approx \frac{\sqrt{L^{\uparrow}R^{\downarrow}}-\sqrt{L^{\downarrow}R^{\uparrow}}}{\sqrt{L^{\uparrow}R^{\downarrow}}+\sqrt{L^{\downarrow}R^{\uparrow}}}$$



$$\varepsilon(\text{luminosity}) = \frac{\sqrt{L^{\uparrow}R^{\uparrow}}-\sqrt{L^{\downarrow}R^{\downarrow}}}{\sqrt{L^{\uparrow}R^{\uparrow}}+\sqrt{L^{\downarrow}R^{\downarrow}}}$$

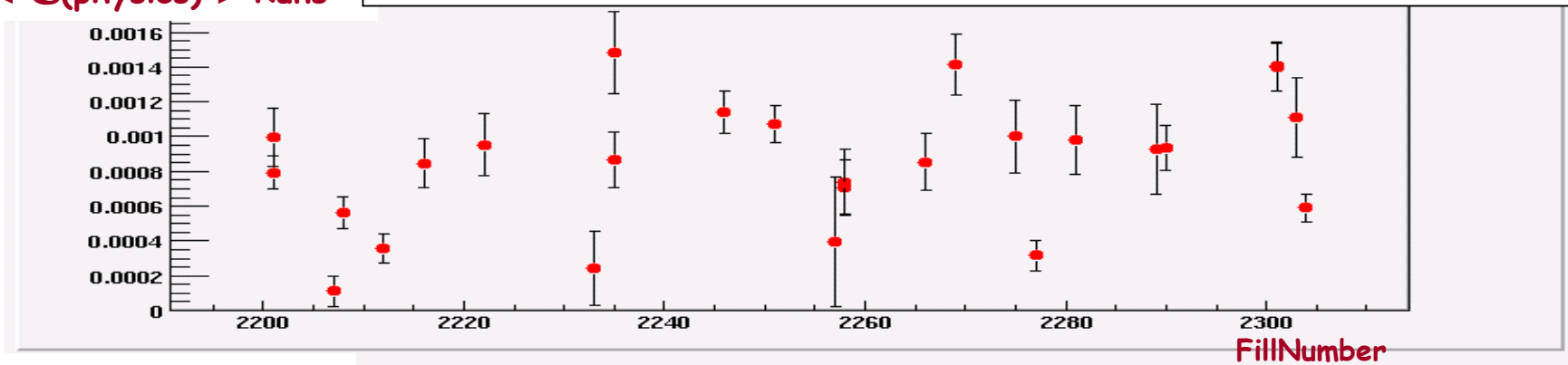


$$\varepsilon(\text{acceptance}) = \frac{\sqrt{L^{\uparrow}L^{\downarrow}}-\sqrt{R^{\downarrow}R^{\uparrow}}}{\sqrt{L^{\uparrow}L^{\downarrow}}+\sqrt{R^{\downarrow}R^{\uparrow}}}$$

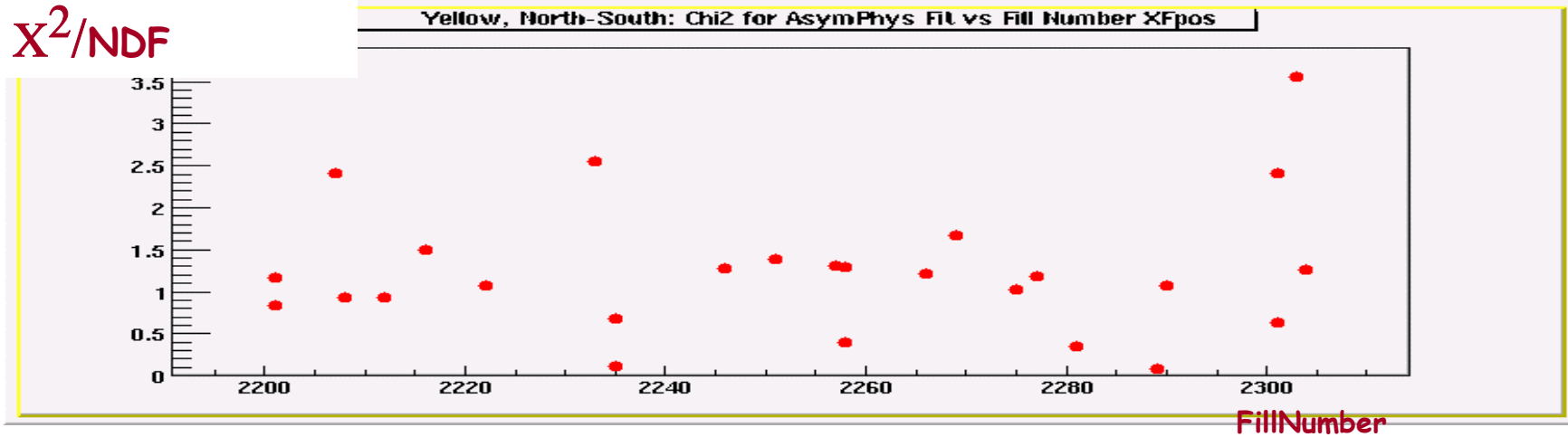


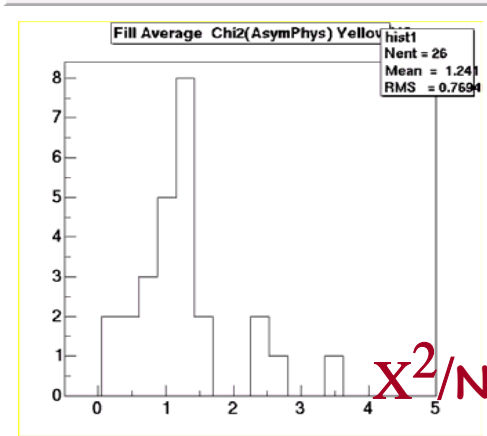
Left-Right, BBC East (Yellow xF>0), vs FillNumber

$< \varepsilon(\text{physics}) >_{\text{Runs}}$



X^2/NDF

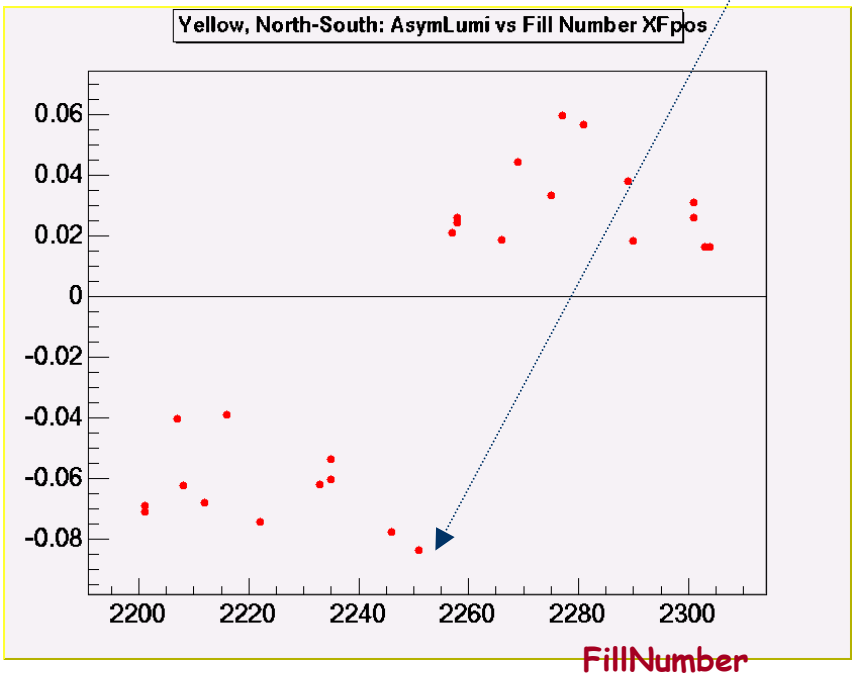


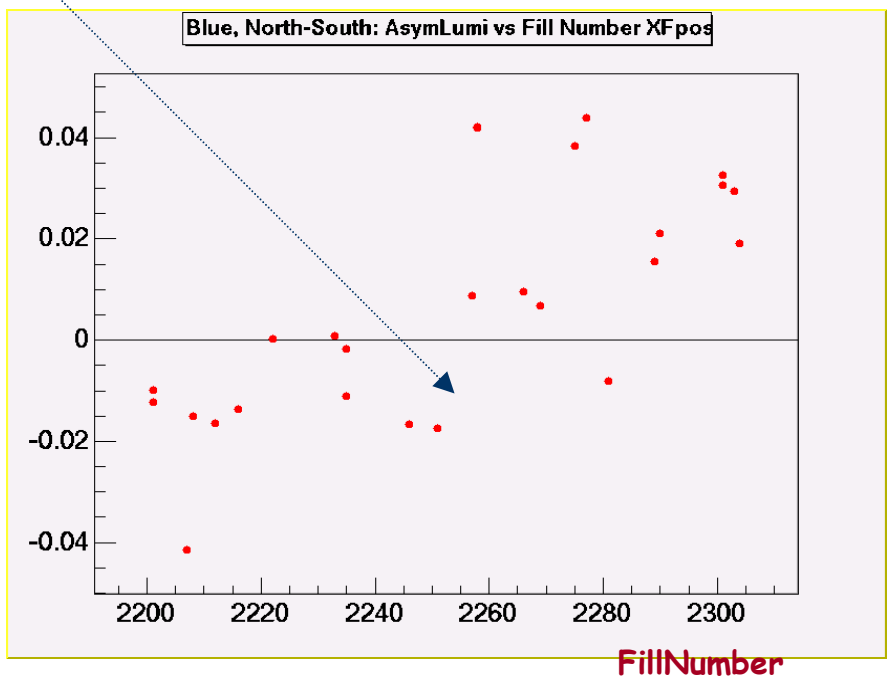


X^2/NDF - consistent with 1 , no evidence for beam depolarization during RHIC fill

Luminosity asymmetries: larger for Yellow than for Blue

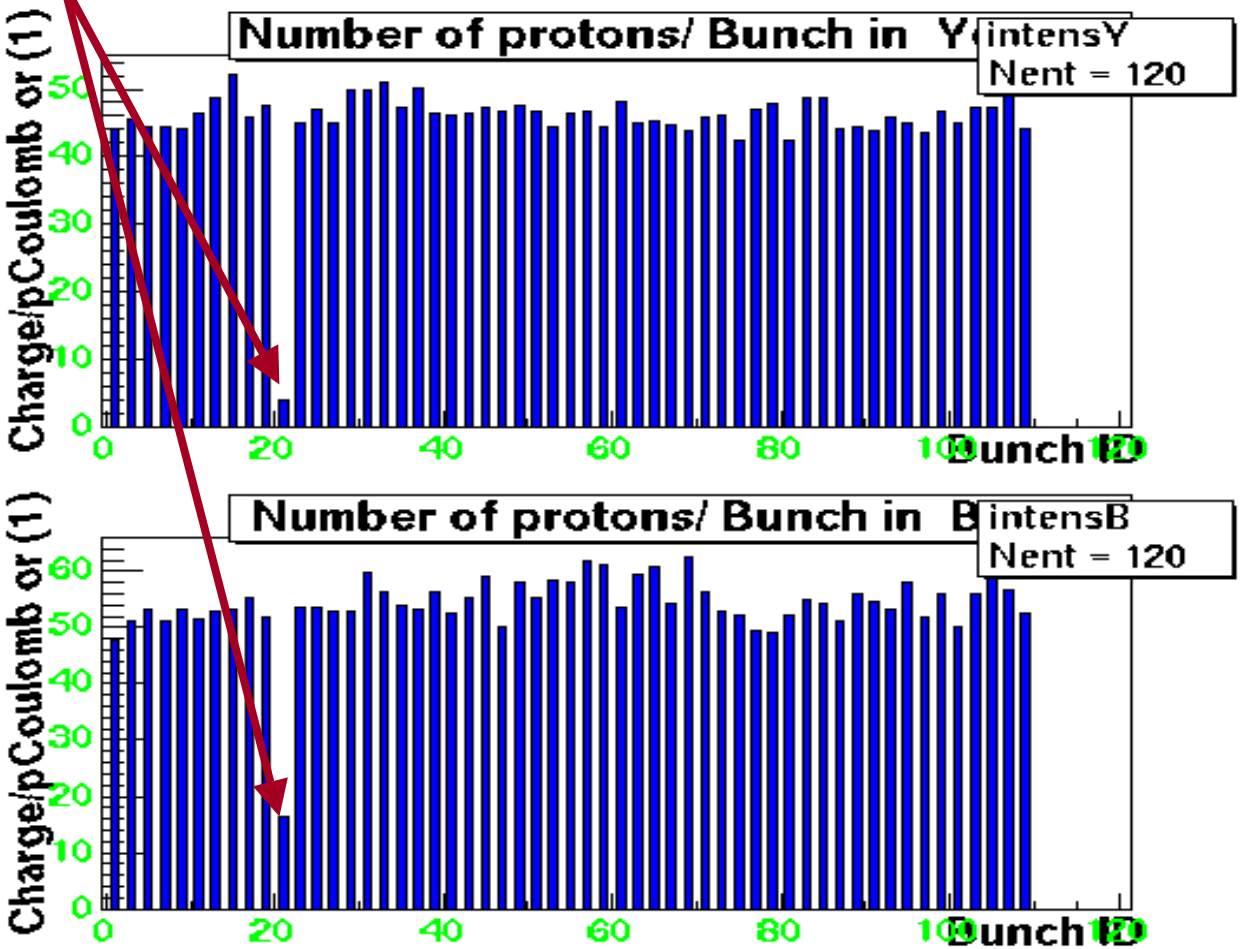
(sign changed when fill pattern changed)





Bunch luminosity:

Weak bunch number 11 in Yellow and in Blue for all RHIC fills ("test" bunches)

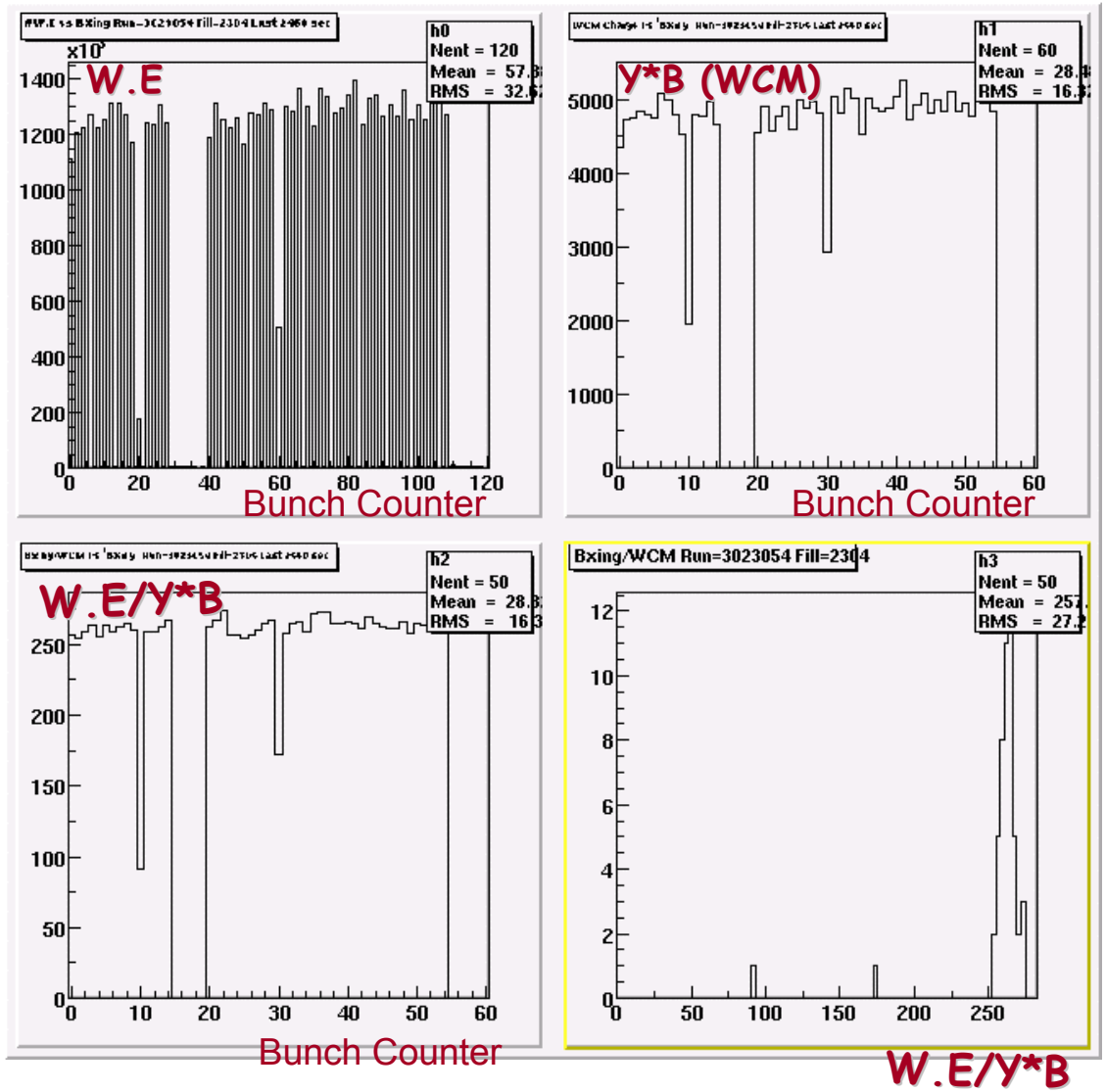


Run 3023039, Fill 2303

Two test bunches result in two weak bunch crossings at STAR with the same spin orientations:
Yellow^Up-Blue^Down -> increase of false asymmetries

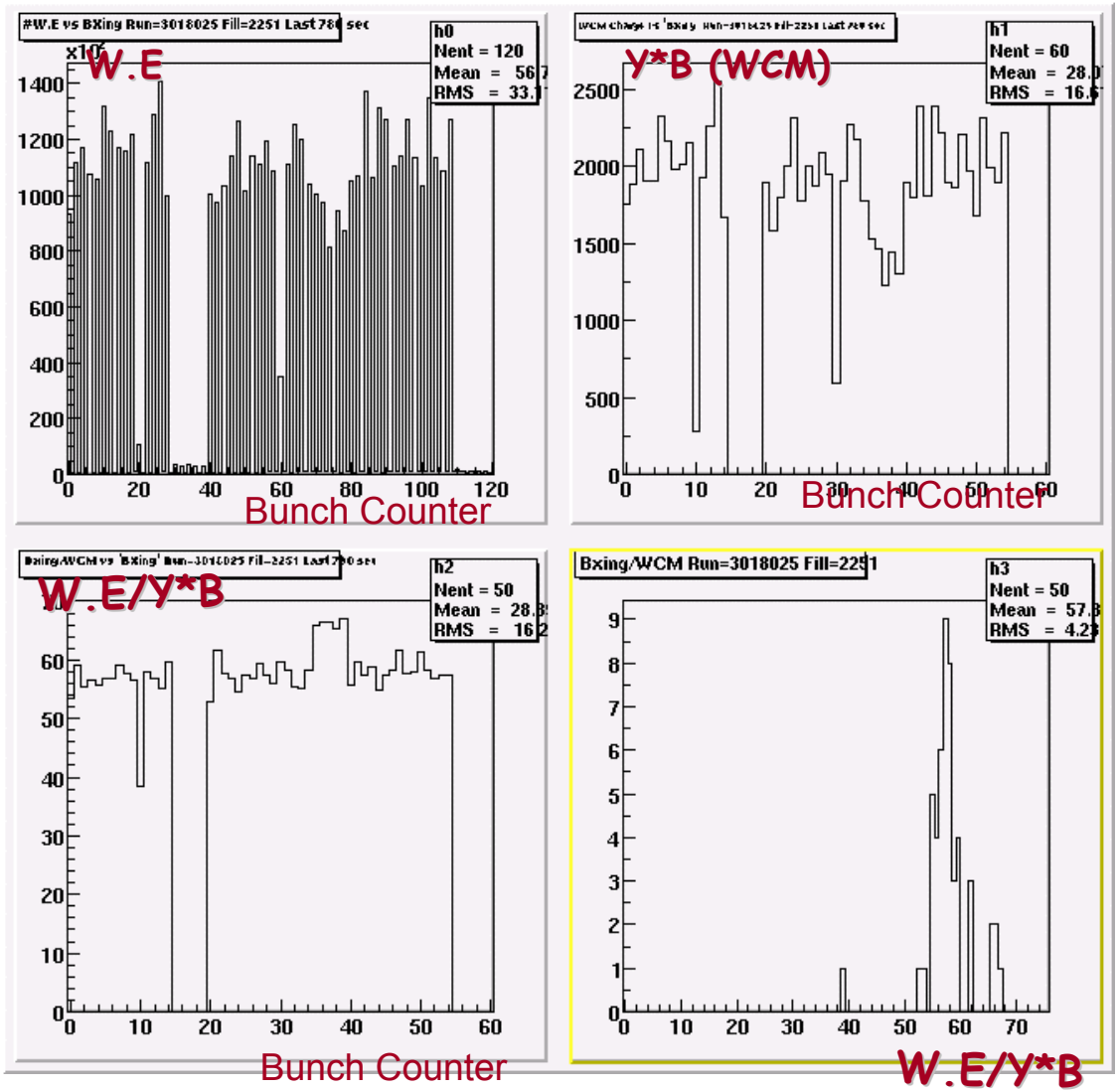
Run 3023039, lasted 2280 sec, Fill 2303

- Time integration for W*E
- Time average for Y*B

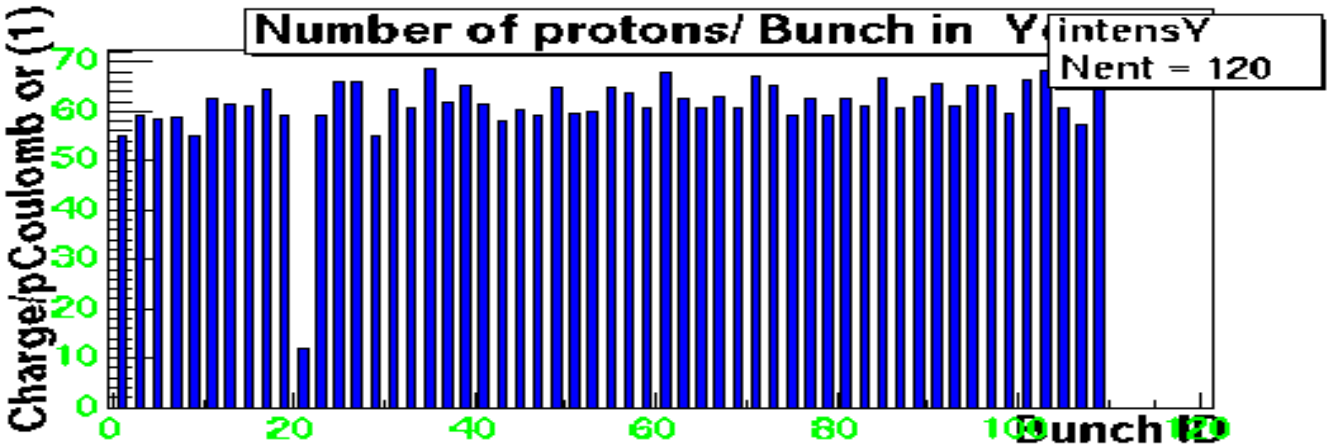


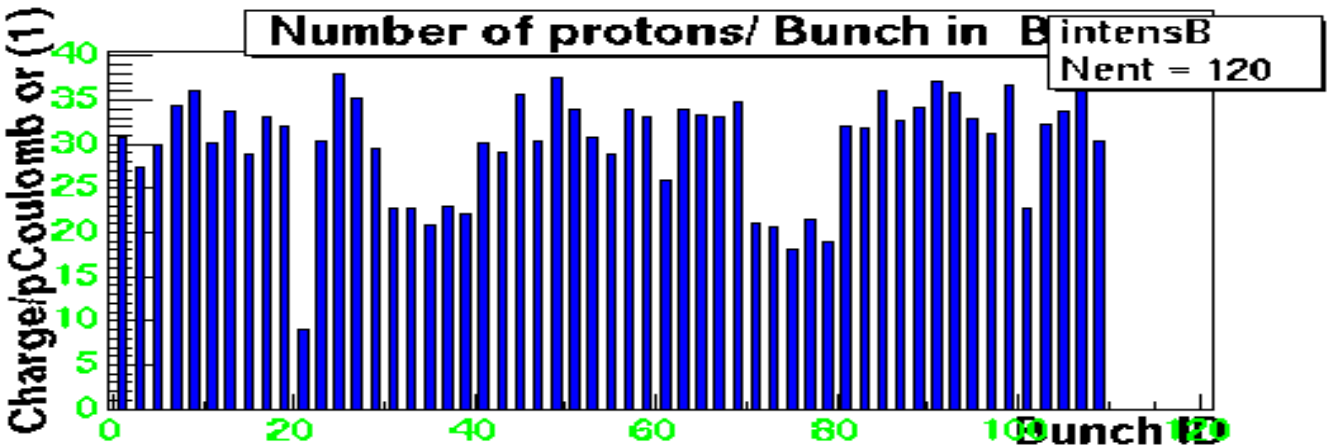
- Specific luminosity looks fine for ~50% fills (Jan11 – Jan23)

Run 3018025, lasted 780 sec,
Fill 2251



A "structure" seen for 5 bunch crossings in ~ 50% fills (Jan11 – Jan23 checked)
- a problem with Blue beam. List of fills:
2233, 2235, 2244, 2246, 2251, 2266, 2269, 2275, 2289, 2301, 2303





Run 3018025, Fill 2251

Summary:

1. Relative luminosity known up to 10^{-3}
2. Spin effects seen in BBC (East) scaler data (if real) are very small, of the order of 10^{-3}, thus suitable for relative luminosity measurements
3. False asymmetries: both detector and accelerator

Further work needed:

- time dependence of false asymmetries,
- beam-gas background,
- bunch selections …