

BBC asymmetry

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Outline

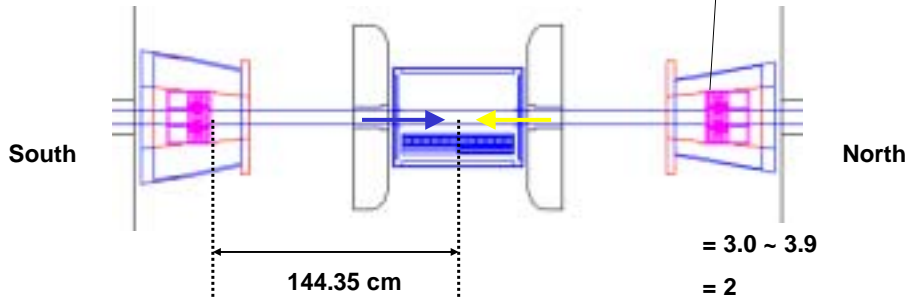
- Introduction
- Event selection
- Bunch fitting method
- Results
- Discussion
- Summary and prospects

Introduction

- **FNAL E704**: observed large single spin asymmetry (A_N) of pions in forward region with transversely polarized pp reaction at $\sqrt{s} = 20$ GeV.
- BBC: most forward detector in PHENIX that can measure asymmetry.
 - Measure A_N of inclusive (charged) particles by BBC.
- STAR observed finite $A_N \sim 0.005$ in their preliminary analysis.

PHENIX BBC

- 2 identical parts (BBC-north and -south)
- Quartz Cherenkov counter, 64 segments each.



Event selection

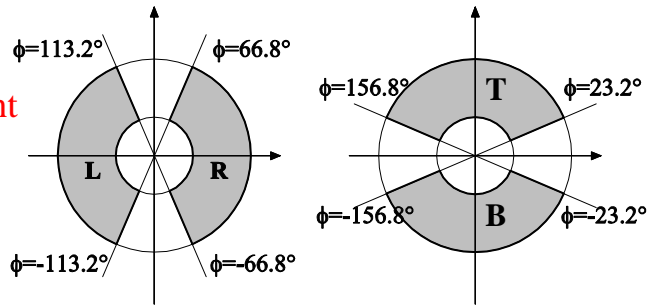
- Data from 11 fills (2257, 2258, 2265, 2266, 2275, 2277, 2281, 2289, 2290, 2301, 2304) after 01/18/02 were analyzed.
 - earlier fills are severely contaminated by beam-gas backgrounds.
- Trigger: BBC LL1
- Beam gas contamination:
 - events in abort gaps $< 10^{-3}$ of normal bunch
 - three fills (2257, 2265, 2266) rejected
- Bad bunches:
 - unpol: 0, 20, 40
 - abort gaps: 15-19, 55-59
 - other bad bunches: 10, 30

Definition of left-right

- View from collision point (BBC-south)



Flip left-right in BBC-north

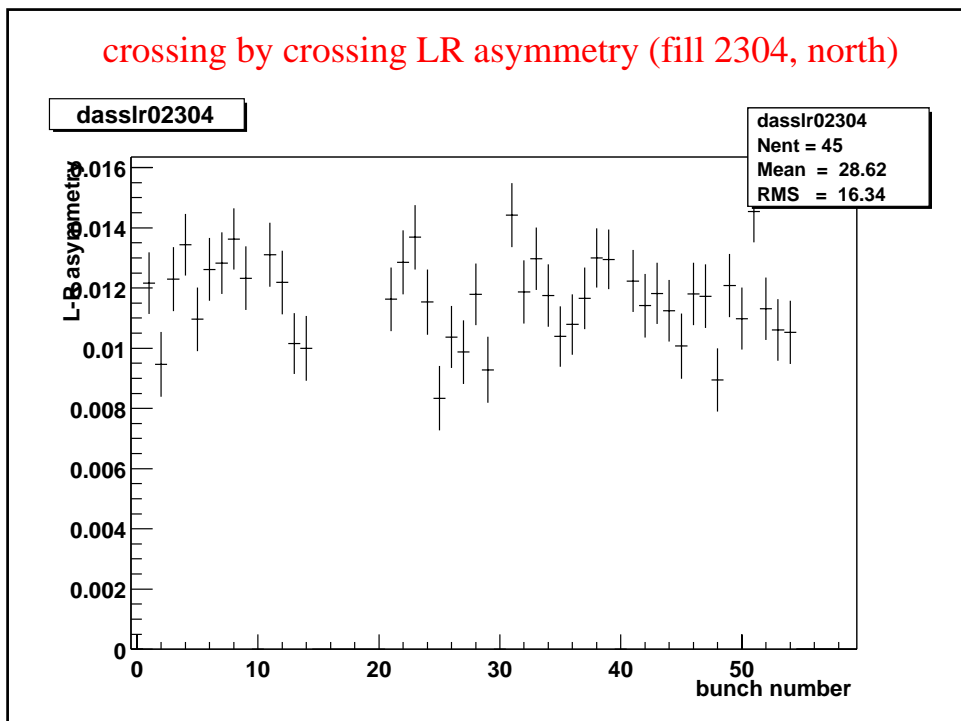


- 66.8 deg ← maximize figure of merit (S^2/N)
- Finite angle correction for $\cos\phi$ dependence
- 0.788

Inclusive and exclusive hit counting

- Left: n_L segments have hit
Right: n_R segments
- Inclusive counting:
left: n_L counts, right n_R counts
 - sensitive for high-multiplicity events, e.g., jets.
 - $\delta N_L > \sqrt{N_L}$ because
 - # one particle can hit two segments
 - # two particle correlation strong
- Exclusive counting:
count one for left only if $n_L > 0$ and $n_R = 0$
 - favors low multiplicity events

crossing by crossing LR asymmetry (fill 2304, north)



Coupling of A_B and A_Y

- M has off-diagonal elements (luminosity asymmetry)
 $\rightarrow A_B$ and A_Y couples
- Effects of off-diagonal elements (at leading order):
 - $\Delta D \sim -(A_B \langle P_B \rangle + A_Y \langle P_Y \rangle) / \langle 1 \rangle$
 - $\Delta A_B \sim -(D \langle P_B \rangle + A_Y \langle P_B P_Y \rangle) / \langle P_B^2 \rangle$
 - $\Delta A_Y \sim -(D \langle P_Y \rangle + A_B \langle P_B P_Y \rangle) / \langle P_Y^2 \rangle$
- second order
- sqrt formula does not cancel terms such as $A_B \langle P_B P_Y \rangle$
- MC simulations tell the fitting method gives correct answers, while the sqrt formula does not.

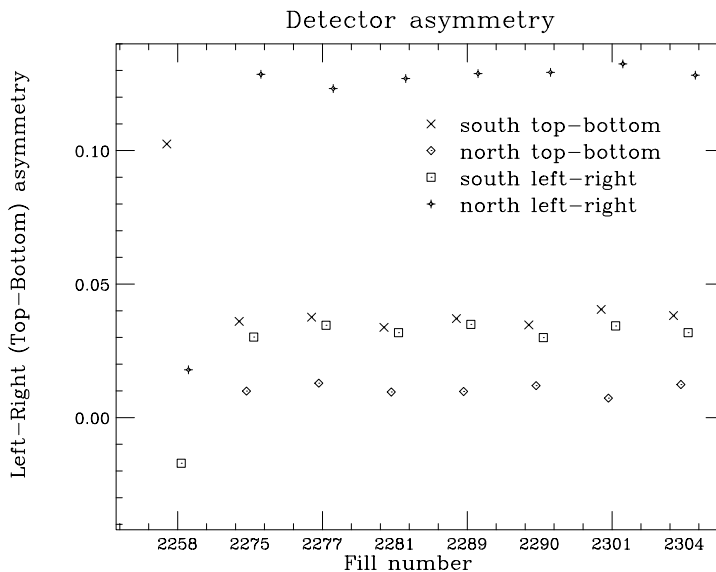
Statistical and systematic errors

- If we neglect the off-diagonal elements of M ,
 $\delta D = \langle 1 \rangle^{-1/2}$, $\delta A_B = \langle P_B^2 \rangle^{-1/2}$, $\delta A_Y = \langle P_Y^2 \rangle^{-1/2}$
- sqrt formula gives approximately the same statistical error.
- Systematic effects: can be checked by fitting χ^2
- Bunch-by-bunch fluctuation of detector asymmetry.
 - independent gaussian of σ_d
 - $\rightarrow D$ fluctuates by σ_d / \sqrt{I} (I : number of bunches)
 - multiplying χ^2 / dof to fitting error gives approximately correct error estimation.
- Sqrt formula equally suffers from this effect, but it gives too small errors because χ^2 check and correction is impossible.

BBC analysis condition

We used

- Linear approximation.
 - very good approximation in this case.
- $\mathbf{P}_B(i) = \mathbf{P}_B \mathbf{S}_B(i)$, $S_B(i) = +1$ (spin up) or -1 (down)
 - RHIC pol. doesn't give bunch-by-bunch polarization
 - average: $P_B, P_Y \sim 0.2$
- Fitting parameter: $\epsilon_B = A_B P_B$ instead of A_B
 - avoid polarization measurement error



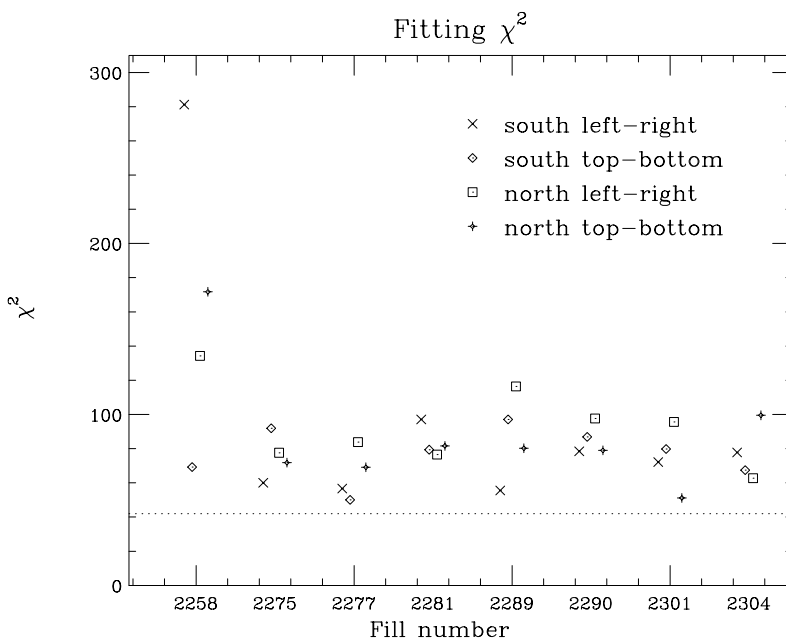
→ Detector asymmetry is reasonably small

3 checks

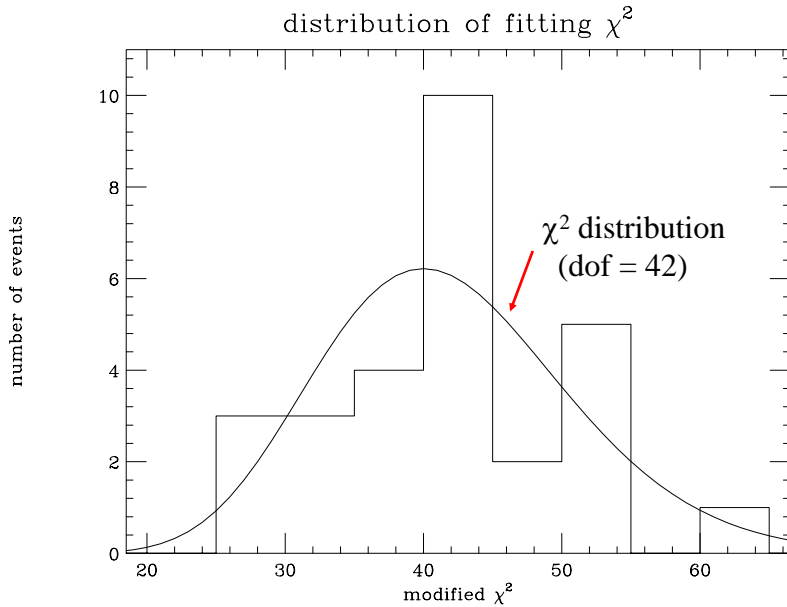
1. $\chi^2/\text{dof}(=42)$ should be near to 1

- All inclusive counting data are rejected
 - probably because δa_{LR} was too small
 - multiplying δa_{LR} by 1.37 makes χ^2 distribution reasonable (except for fill 2258).

Fill-by-fill χ^2 for inclusive counting



χ^2 -- Inclusive case (except fill 2258)



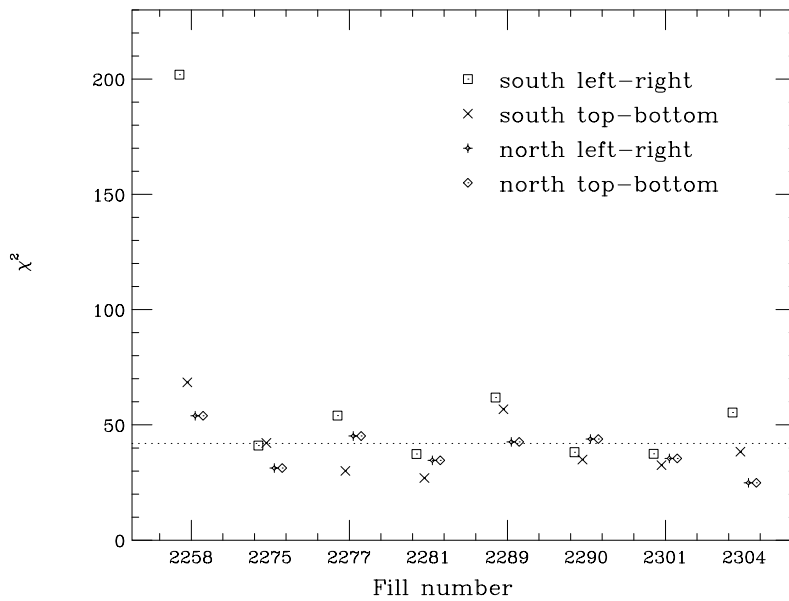
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- only one bad fill (2258) for exclusive counting
 - χ^2 distribution -- OK for the other fills
 - use only exclusive counting data hereafter

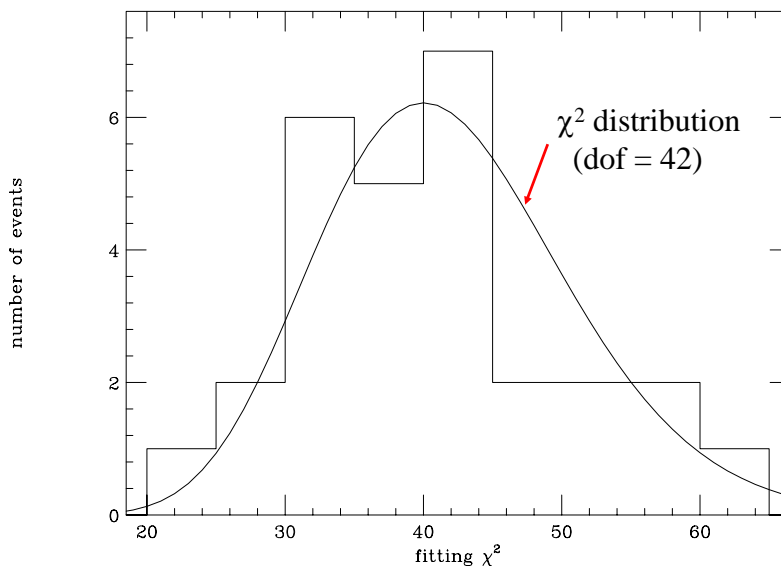
Fill-by-fill χ^2 for exclusive counting

fitting χ^2 (DOF=42)



χ^2 -- Exclusive case (except fill 2258)

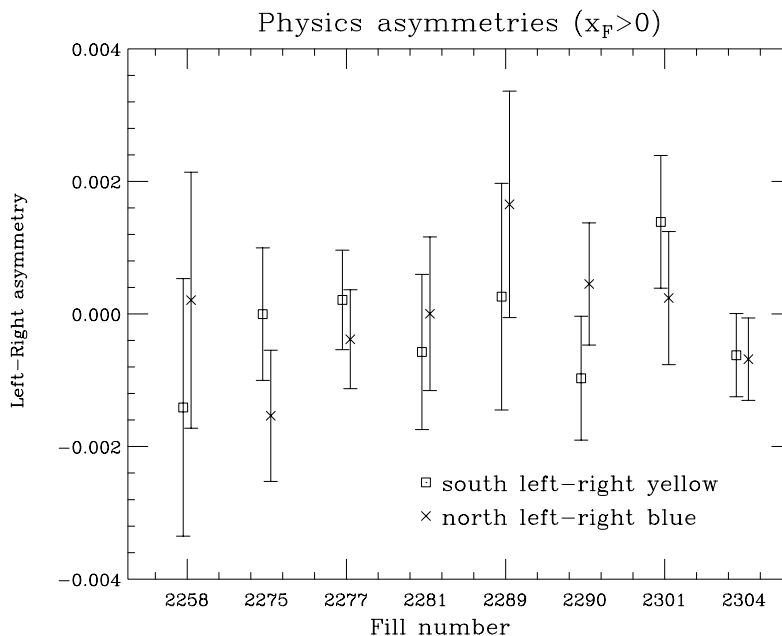
distribution of fitting χ^2



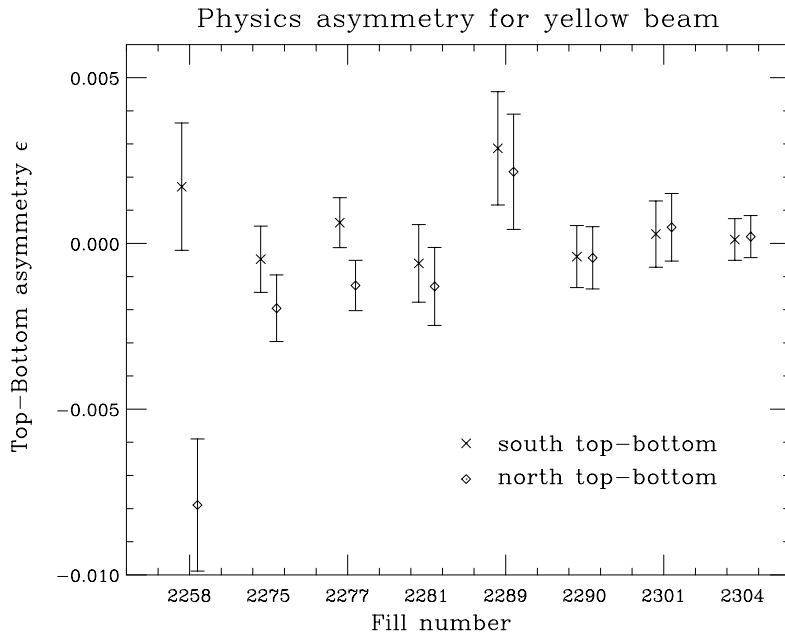
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2. $A_Y(\text{north}) = A_B(\text{south})$ and vice versa
3. Parity-violating top-bottom asymmetry should be 0

Check of $\varepsilon_B(\text{yellow}) = \varepsilon_Y(\text{blue})$



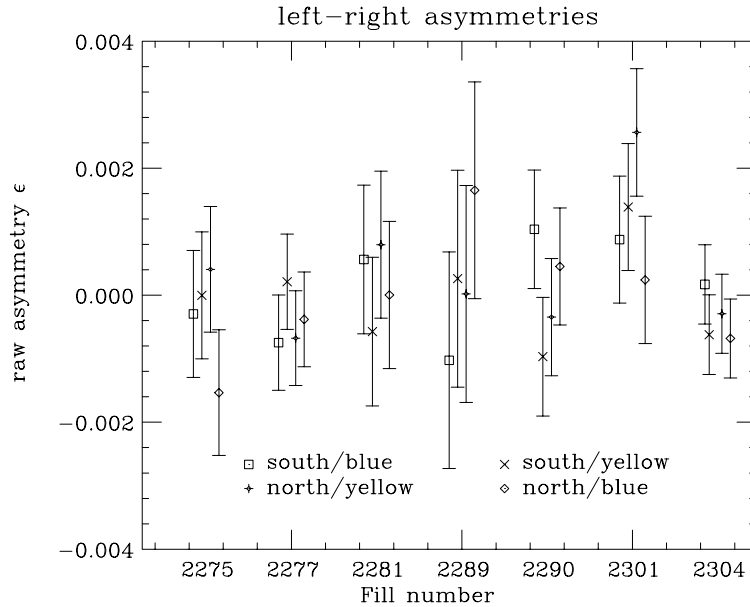
Top-bottom asymmetry for exclusive counting



3 checks

1. $\chi^2/\text{dof}(=42)$ should be near to 1
 - All inclusive counting data are rejected
 - probably because δa_{LR} was too small
 - multiplying δa_{LR} by 1.37 makes χ^2 distribution reasonable (except for fill 2258).
 - Only one bad fill (2258) for exclusive counting
 - χ^2 distribution -- OK for the other fills
 - use only exclusive counting data hereafter
2. $A_Y(\text{north}) = A_B(\text{south})$ and vice versa
3. Parity-violating top-bottom asymmetry should be 0
 - OK within 3σ for exclusive data except fill 2258.
 - fill 2258 is discarded.

Results



Averaged asymmetry

- Divide ϵ by raw asymmetry of RHIC pol.
 $\rightarrow A/A^{\text{CNI}}$ (A^{CNI} : effective analyzing power of RHIC pol.)

	A_B/A_B^{CNI}	A_Y/A_Y^{CNI}
South LR	0.15 \pm 0.22	-0.09 \pm 0.17
TB	-0.22 \pm 0.23	0.06 \pm 0.17
North LR	-0.11 \pm 0.22	0.06 \pm 0.17
TB	-0.19 \pm 0.23	-0.16 \pm 0.17

- Errors are statistical only, but include statistical error in polarization measurement.

Analyzing power

- Assume $A_B^{\text{CNI}} = A_Y^{\text{CNI}} = 0.0132$

	$A_B(10^{-3})$	$A_Y(10^{-3})$
South LR	1.9 ± 3.0	-1.2 ± 2.2 ($x_f > 0$)
TB	-2.9 ± 3.0	0.7 ± 2.2
North LR	-1.4 ± 3.0	0.8 ± 2.2 ($x_f < 0$)
TB	-2.6 ± 3.0	-2.1 ± 2.2

- Errors are statistical only, but include statistical error in polarization measurement.
- Systematic error in polarization measurement does not affect the significance of the asymmetry.

Systematic errors

- polarization measurement error:
 - unknown yet, but does not change $A/\delta A$.
 - ε is free from this. So, we show both A and ε .
- bunch-by-bunch polarization fluctuation:
 - effect is negligibly small for $A \sim 0$.
- Other systematic errors:
 - no evidence seen ($\chi^2/\text{dof} \sim 1$)
 - probably negligible compared to statistical error.
 - We don't assign any systematic error other than coming from polarization measurement.

Comparison with sqrt formula

- In the present case, bunch fitting method gave the same result as sqrt formula down to $O(10^{-5})$
- Systematic deviation of sqrt formula
 - $\Delta A_B \sim A_Y \langle P_B P_Y \rangle / \langle P_B^2 \rangle$
 - $A_Y \sim 10^{-3}$
 - $\langle P_B P_Y \rangle / \langle P_B^2 \rangle \sim 10^{-2}$
 - $\Delta A_B \sim 10^{-5}$: small enough
- Systematic deviation of linear approximation.
 - $\Delta A_B / A_B$: $D(A_B P_B + A_Y P_Y) \sim 10^{-4}$
 - i.e., $\Delta A_B \sim 10^{-3} \times 10^{-4} = 10^{-7}$
 - negligible

Discussion

- Our results are consistent with zero.
- E704 result
 - π^+ and π^- have opposite sign of A_N .
 - cancellation in BBC measurement
 - asymmetry is seen at large x_f
 - ⇒ BBC can not measure x_f ,
probably small x_f events dominate
 - not inconsistent with E704 result.
- STAR preliminary result: $\varepsilon \sim 0.001$ ($A_N \sim 0.005$)
 - pseudorapidity is larger
(PHENIX: $3.0 < \eta < 3.9$, STAR $3.4 < \eta < 5.0$)

Summary and prospects

- A_N of inclusive charged particles in a forward region was studied with PHENIX BBC.
- A new method to calculate physics asymmetries was used.
- We saw no evidence of systematic error.
- **Results were consistent with zero.**
- Analysis is still ongoing for various conditions, e.g.,
 - select inner segments of BBC (most forward region)
 - event selection (e.g., ZDC coincidence -- in relation with LocalPol results)
 - Photon (π^0) selection using ADC information.