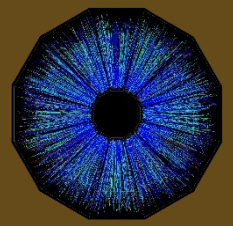
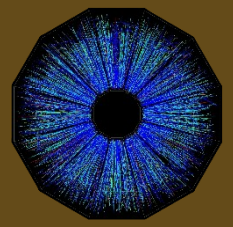


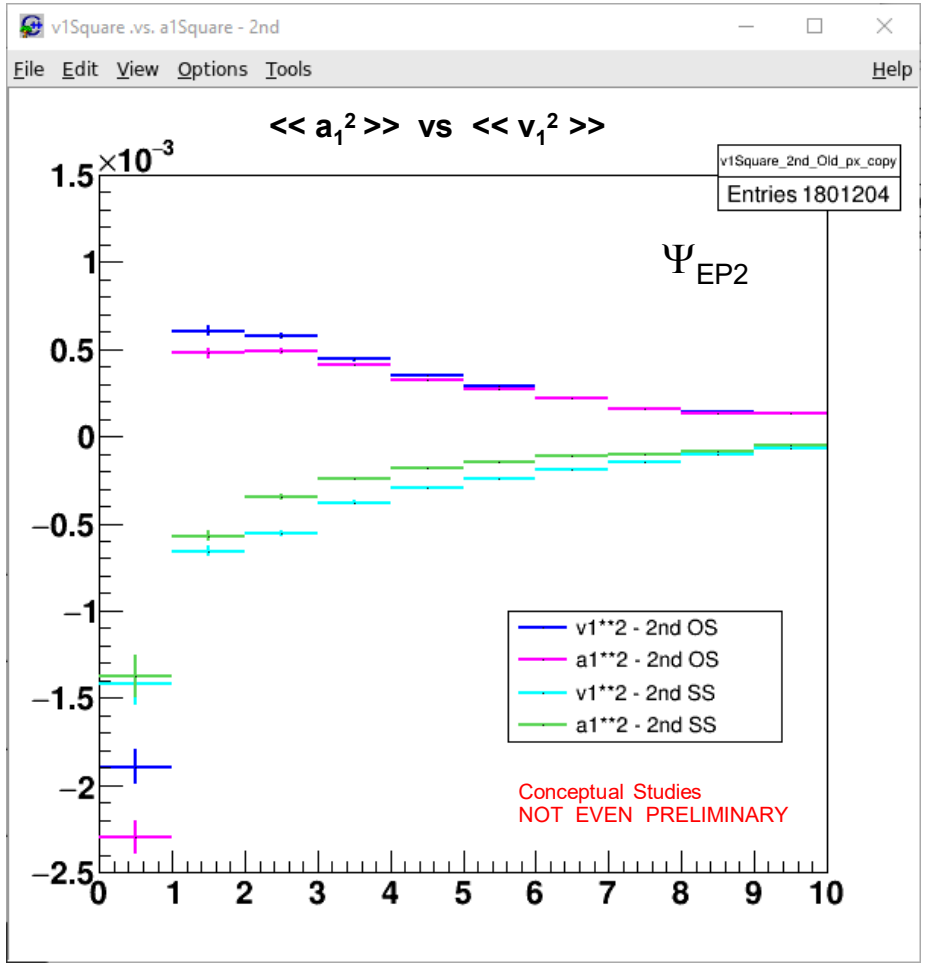
CME Focus Studies

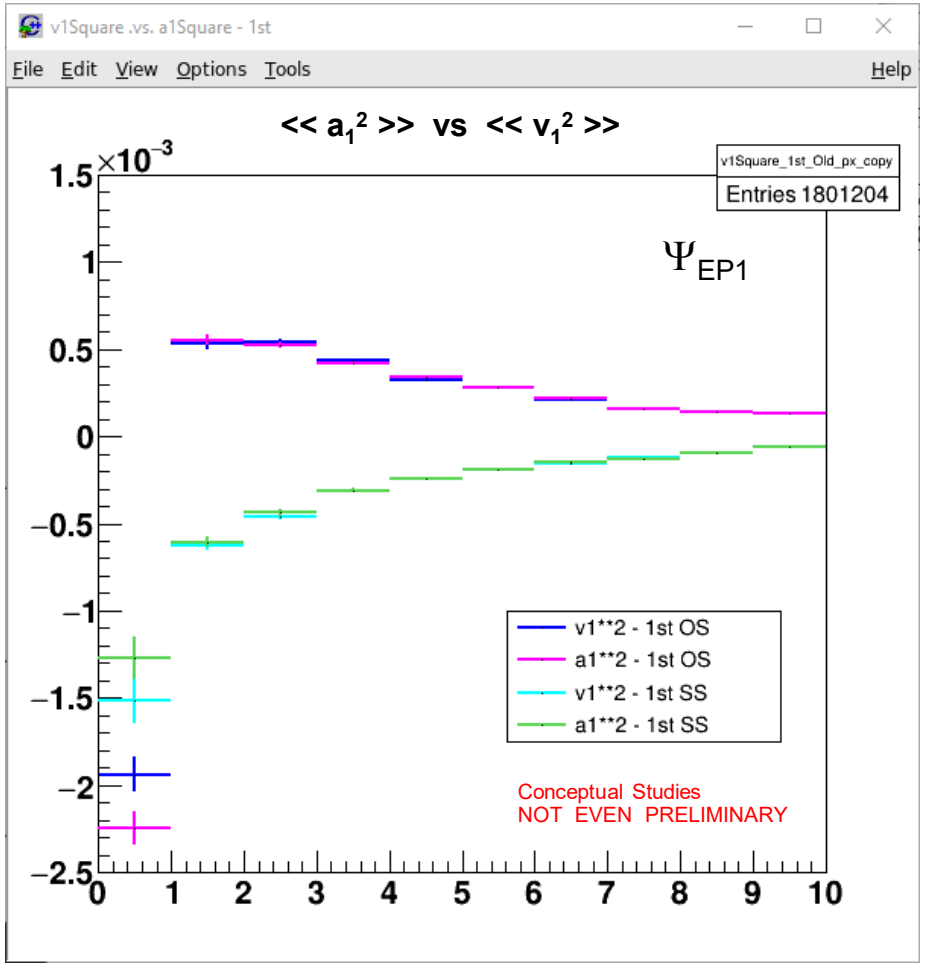
Jim Thomas
Winter 2023



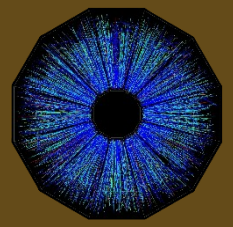
The Chiral Magnetic Effect

a_1^2 and v_1^2 from the 200 GeV Au-Au Run 19



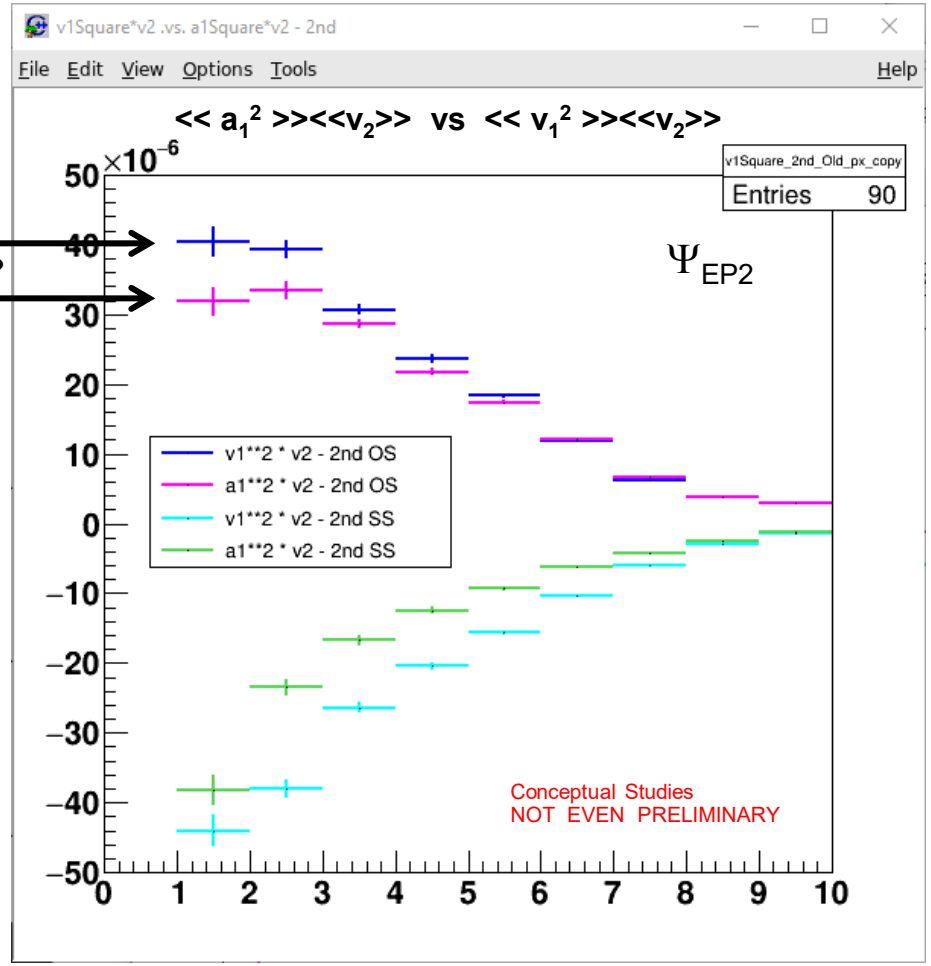


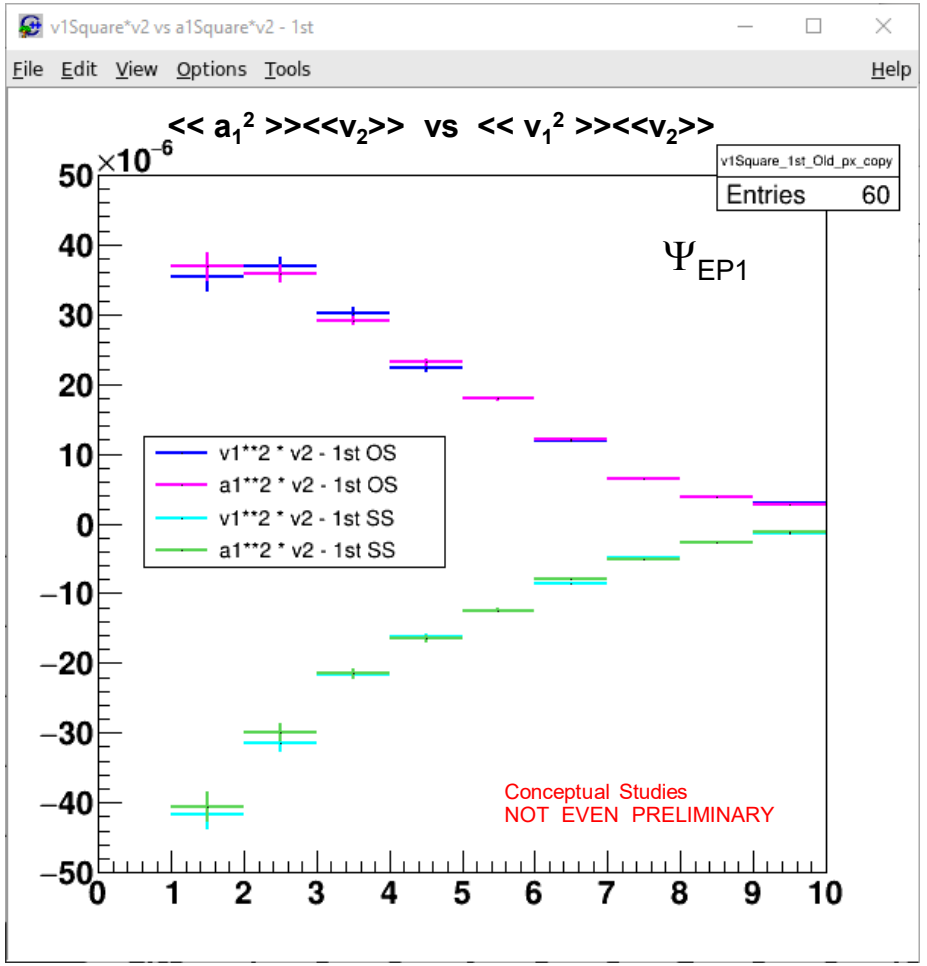
- The notation a_1^2 denotes the EbyE quantity $\Sigma\,(a_{1\_p1}{*}a_{1\_p2})$ with p1≠ p2
- a_1^2 is similar in shape and magnitude to v_1^2 , independent of which EP is used in the study
- a_1^2 shows charge separation … but so does v_1^2 … I didn't expect to see that



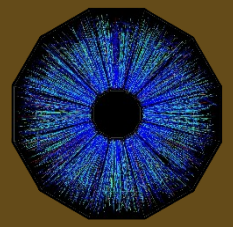
Compare $\langle\langle a_1^2 \rangle\rangle$ and $\langle\langle v_1^2 \rangle\rangle$ [times $\langle\langle v_2 \rangle\rangle$]

CME signal?



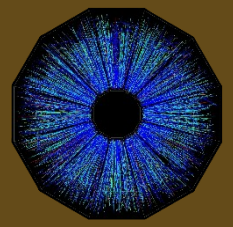


- $\langle\langle a_1^2 \rangle\rangle * \langle\langle v_2 \rangle\rangle$ is similar in shape and magnitude to $\langle\langle v_1^2 \rangle\rangle * \langle\langle v_2 \rangle\rangle$ (note global avg)
- $\langle\langle a_1^2 \rangle\rangle * \langle\langle v_2 \rangle\rangle$ shows charge separation … but so does $\langle\langle v_1^2 \rangle\rangle * \langle\langle v_2 \rangle\rangle$
- I didn't expect to see that …



A few thoughts

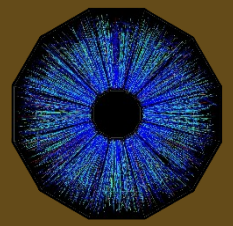
- $\langle\langle a_1^2 \rangle\rangle$ contains a significant amount of 'signal' (i.e. not small)
- $\langle\langle v_1^2 \rangle\rangle$ contains a significant amount of 'signal' (i.e. not small)
  - $\langle\langle v_1^2 \rangle\rangle$ is full of signal and similar in shape and magnitude to $\langle\langle a_1^2 \rangle\rangle$
- Both $\langle\langle a_1^2 \rangle\rangle$ and $\langle\langle v_1^2 \rangle\rangle$ show charge separation with OS > 0, SS < 0
  - Not what I had expected
- The difference between these two curves [times $\langle\langle v_2 \rangle\rangle$] is small and similar in shape and magnitude to the γ correlator (Ψ_{RP2})
  - It could be the CME
- Bottom line:
  $\langle\langle v_2 \rangle\rangle$ inside or outside the sum is not important. The physics is in $\langle\langle a_1^2 \rangle\rangle$.
  - What we are really doing is comparing $\langle\langle a_1^2 \rangle\rangle$ to $\langle\langle v_1^2 \rangle\rangle$ using $\langle\langle v_1^2 \rangle\rangle$ as the reference (i.e. by comparing fluctuations in the vertical direction to fluctuations in the horizontal direction).
  - This is a good start … but an assumption. Since $\langle\langle v_1^2 \rangle\rangle$ is large, the physics in the horizontal direction may contain bits not equal to whatever is going on in the vertical direction. Minor bits may overwhelm the CME. This is obvious to expert observers.



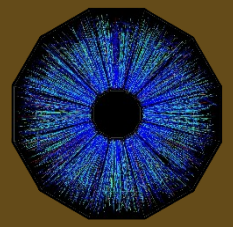
Consider a minor shift in direction …

- If our goal is to isolate a_{1CME} then we could try focusing directly on $\langle\langle a_1^2 \rangle\rangle$ and work to understand its various components.
  - Currently, we are comparing $\langle\langle a_1^2 \rangle\rangle$ to the same quantity calculated with the EP at 90 degrees, it can also be done with a random EP angle
  - Or, use mixed events to create another form of a random EP, or the EP from the previous event

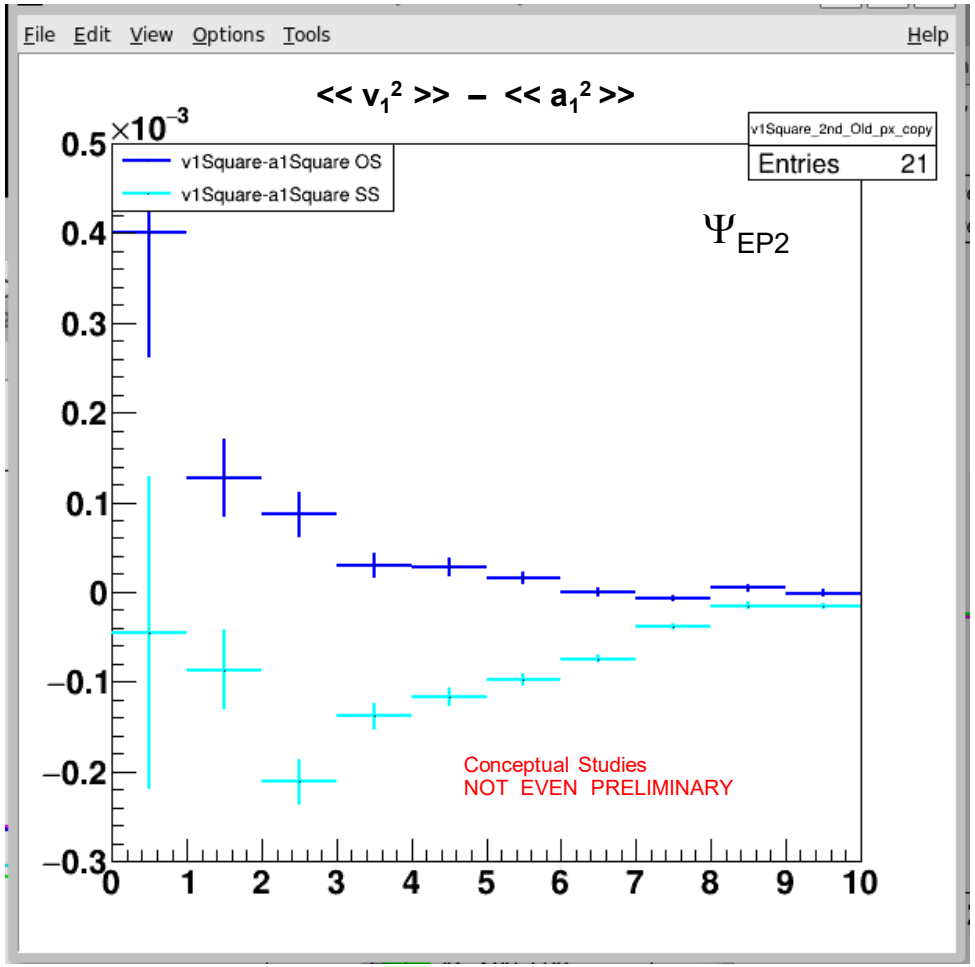
- STAR: we can directly compare the isobar systems $\langle\langle a_1^2 \rangle\rangle_{Ru}$ and $\langle\langle a_1^2 \rangle\rangle_{Zr}$
  - This would avoid background signals introduced by $\langle\langle v_1^2 \rangle\rangle$ and/or $\langle\langle v_2 \rangle\rangle$.
  - It is likely that nuclear shapes, flow & multiplicity fluctuations will play a role but this can be evaluated
  - And, of course, measure the event planes using multiple independent detectors such as the EPD

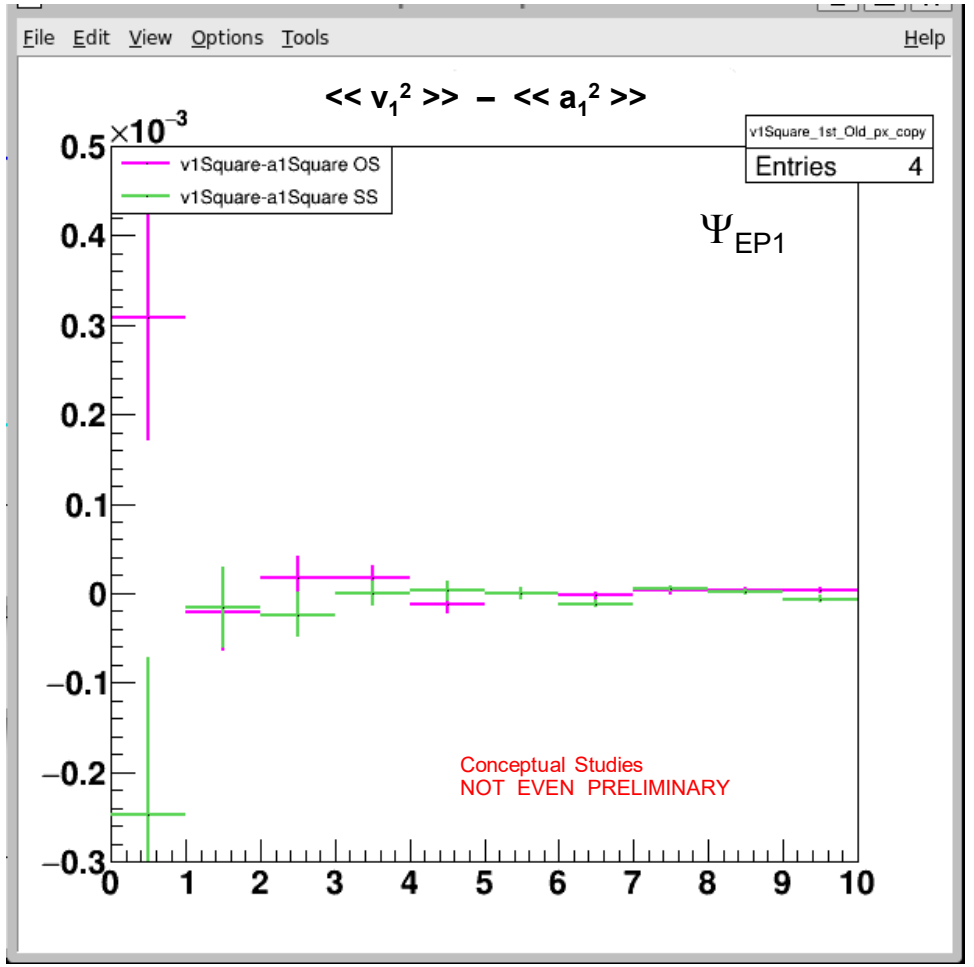


Backup Slides



a_1^2 and v_1^2 from the 200 GeV Au-Au Run 19

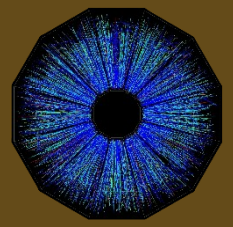




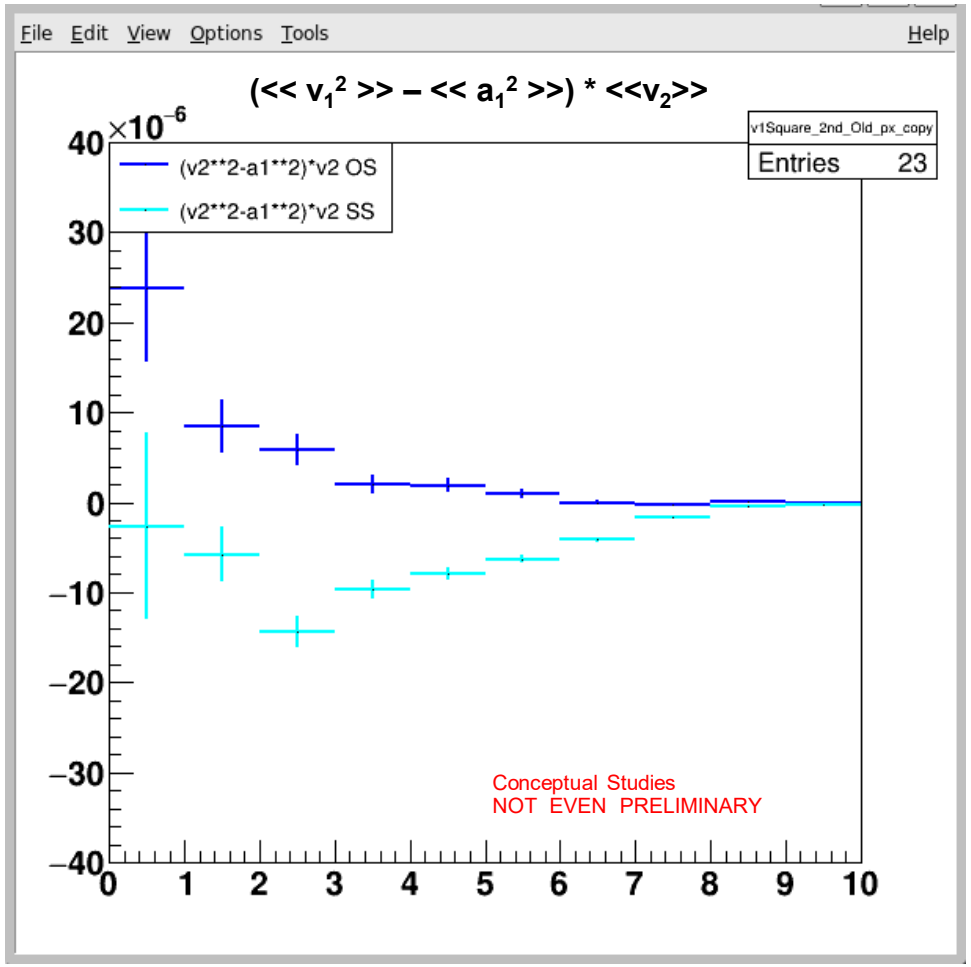
$(v_1^2 - a_1^2)$ with Ψ_{EP2} suggests that SS < 0, OS > 0

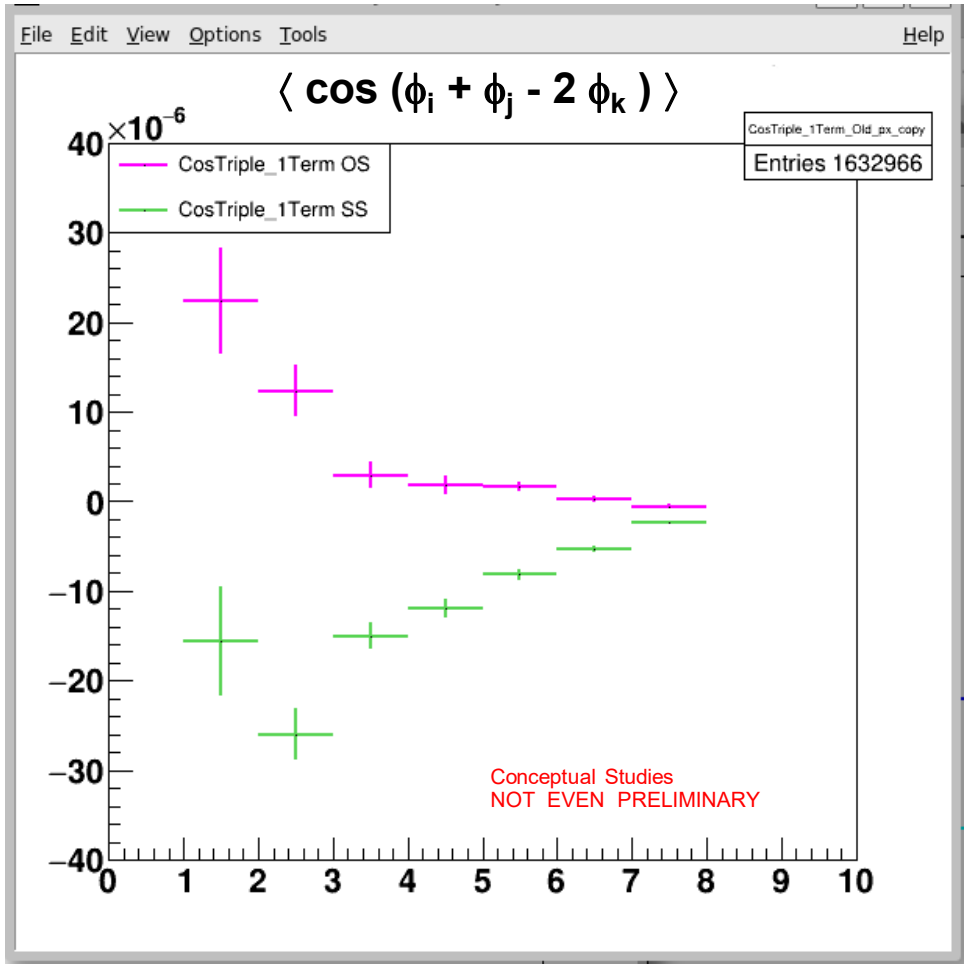
while $(v_1^2 - a_1^2)$ with Ψ_{EP1} is ~zero

Jim Thomas

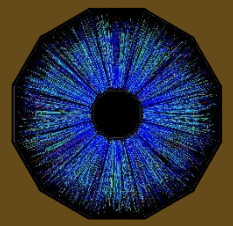


$(v_1^2 - a_1^2) * v_2$ using Ψ_{EP2} in 200 GeV Au-Au (Run 19)



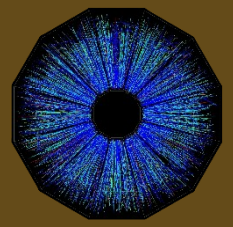


- Note that $\langle \cos(\phi_i + \phi_j - 2\phi_k) \rangle$ was calculated on an EbyE basis, $\Sigma (v_1^2 - a_1^2) * v_2$
- But, on this page, we are comparing it to $(\langle\langle v_1^2 \rangle\rangle - \langle\langle a_1^2 \rangle\rangle) * \langle\langle v_2 \rangle\rangle$
- The similarity of the curves suggests that the separation of variables is a good approximation and we can focus on $\langle\langle v_1^2 \rangle\rangle - \langle\langle a_1^2 \rangle\rangle$ or simply $\langle\langle a_1^2 \rangle\rangle$ to gather the essential physics

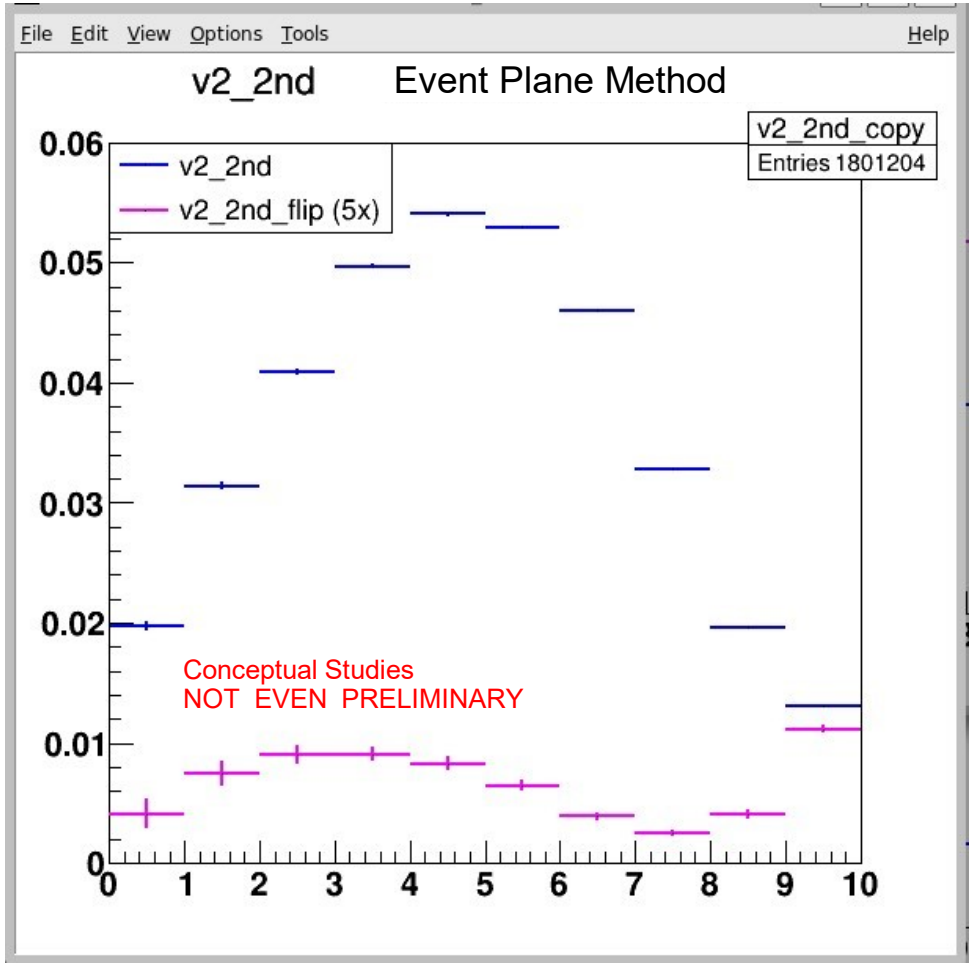


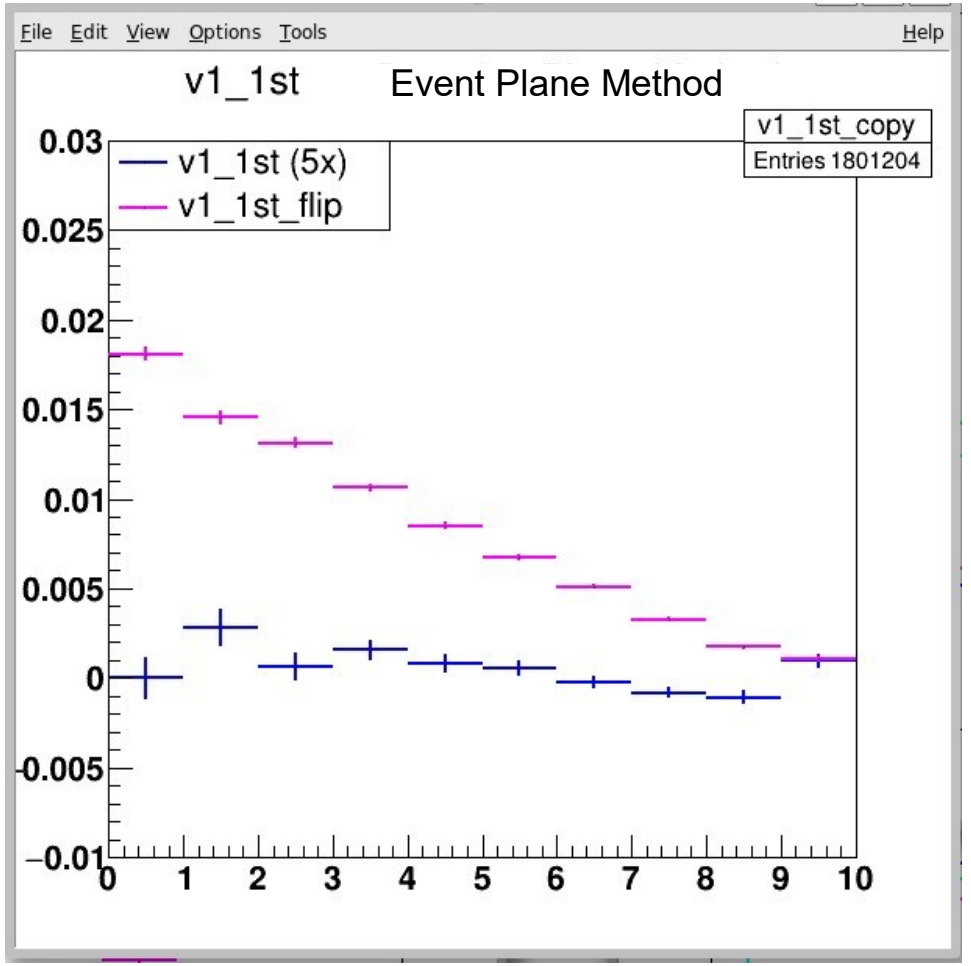
Technical notes

- The event planes were calculated using the TPC data, only.
- Centrality bins are preliminary, not the official Run 19 determination.
- The data for $\langle \cos(\phi_i + \phi_j - 2\phi_k) \rangle$ in the centrality bins 0-5% and 5-10% (pg 8) have been explicitly suppressed because they are expensive to calculate in a triple correlation. These are central events and we expect the result to be zero.
- Data taken from one run (~1.8 M Evts Run 19). This is a curse and a blessing: it makes the acceptance corrections stable but results could be a statistical fluke.
- Pion data, selected by 2σ cut on dE/dx band
- In principle, v_1 and a_1 should be measured wrt the 1st order reaction plane, v_2 should be measured wrt the 2nd order EP. If we take the1st order EP results seriously then the charge separation signal is zero. Would be good to do this again with a high quality measure of the 1st order RP such as the EPD
- It is computationally inefficient to calculate auto-correlations for a three particle correlation (especially when using TPC data). We could use independent 1st and/or 2nd order EP determination (e.g. the EPD) which would simplify the auto-correlation corrections. Food for thought and an obvious next step.

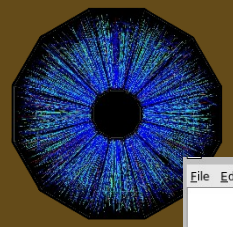


v_1 and v_2 in Au-Au 200 GeV (~1 Million events from Run 19)

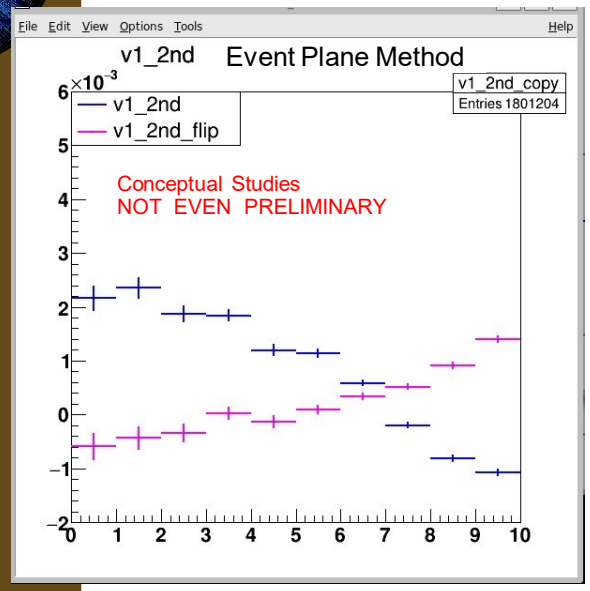


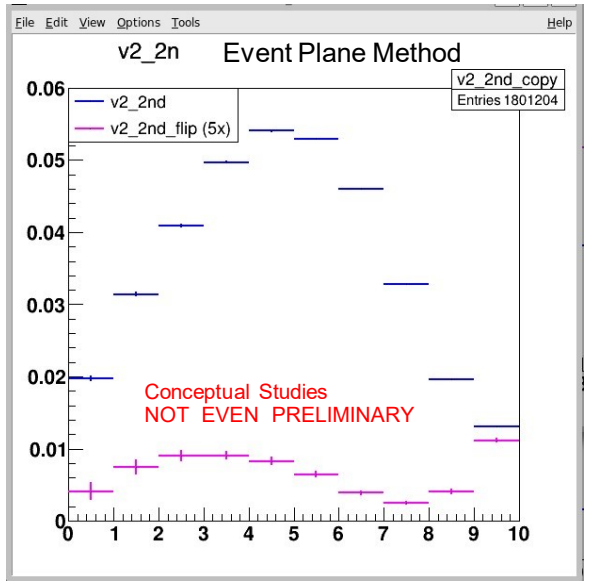


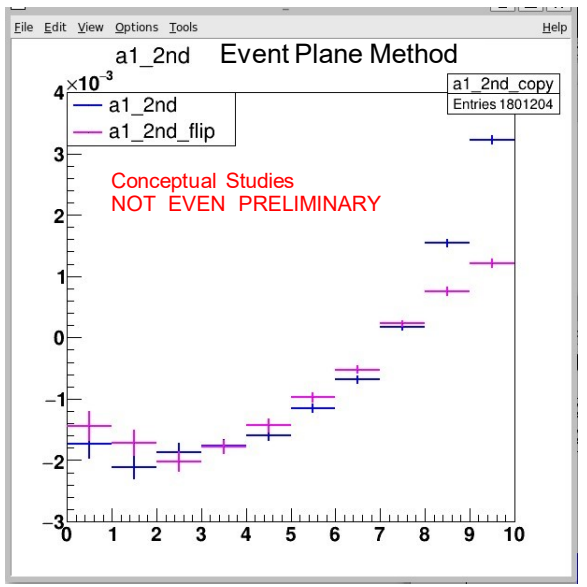
v_1 and v_2 doing familiar things (Note: Ψ_1 & Ψ_2 EPs measured in TPC)

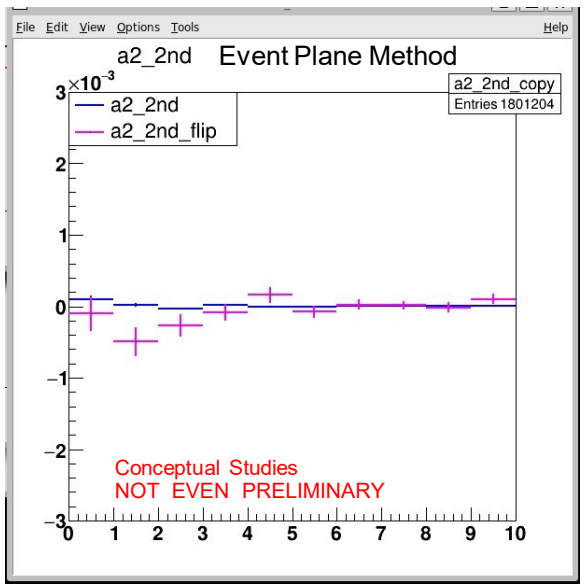


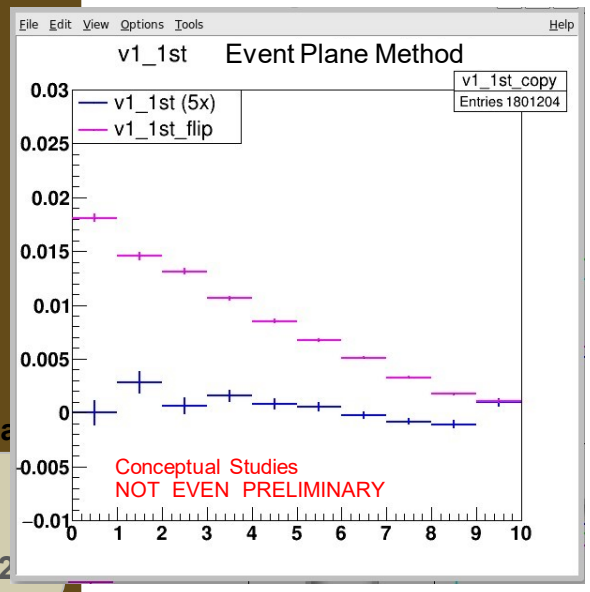
Several more low order terms …

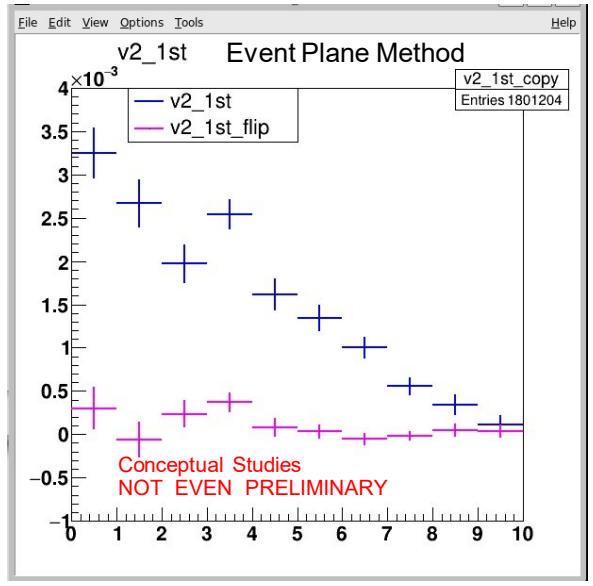


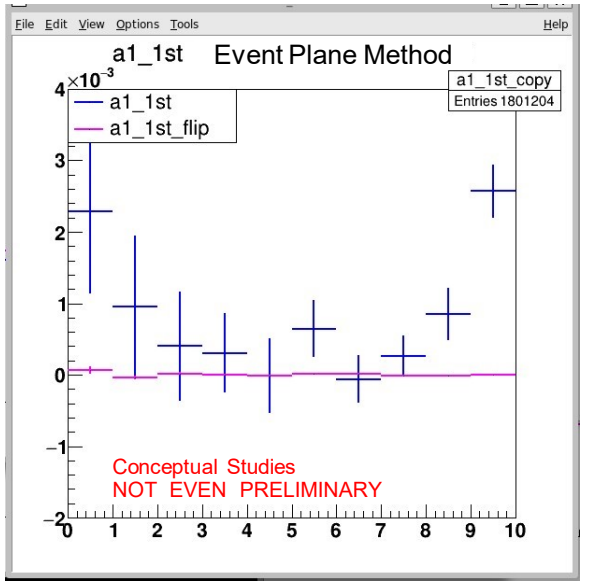


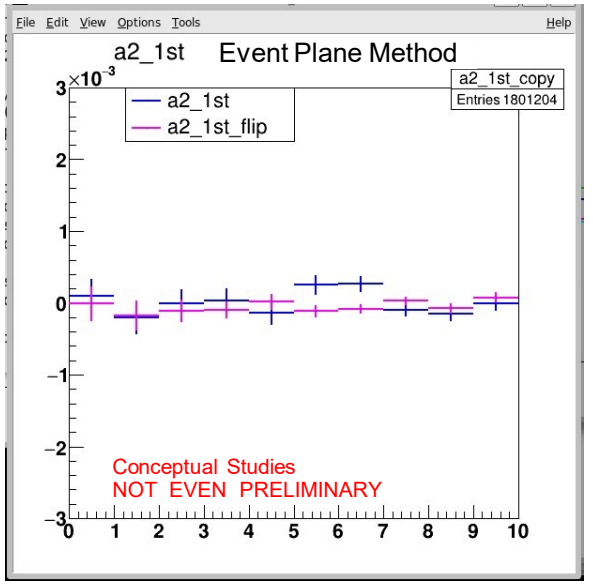


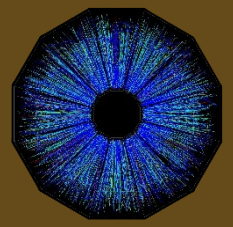




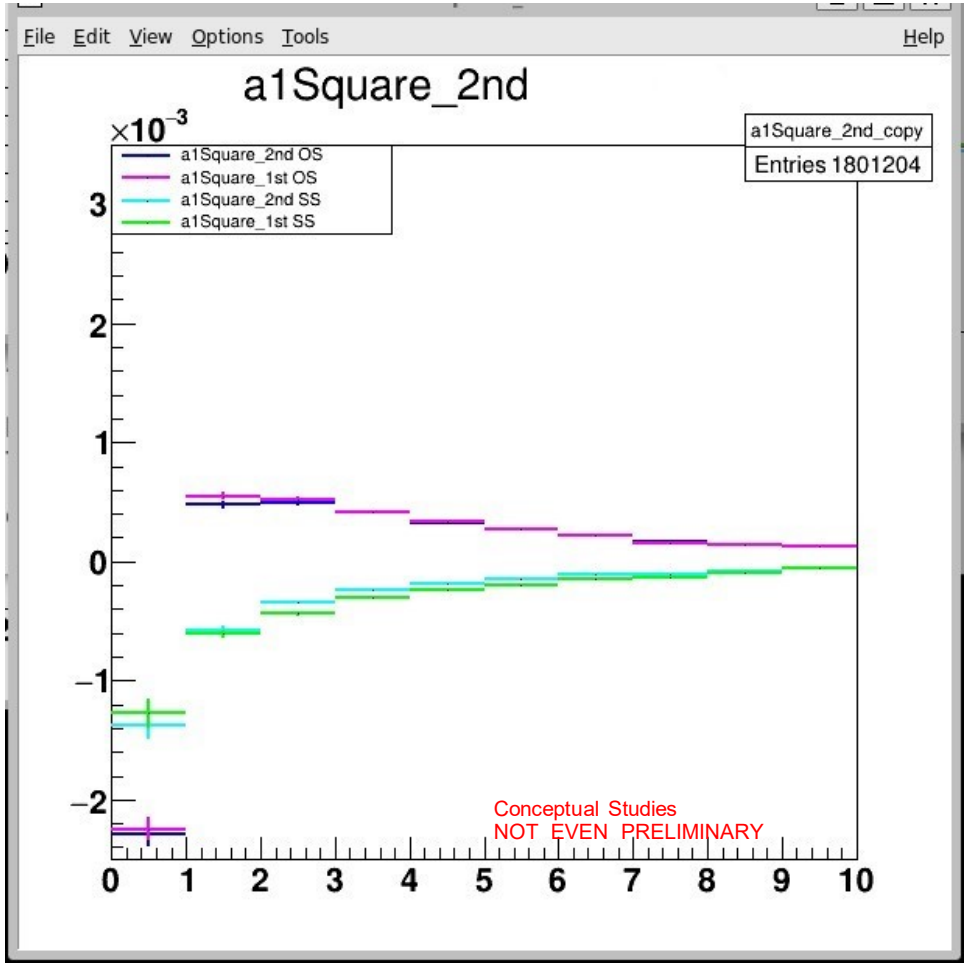


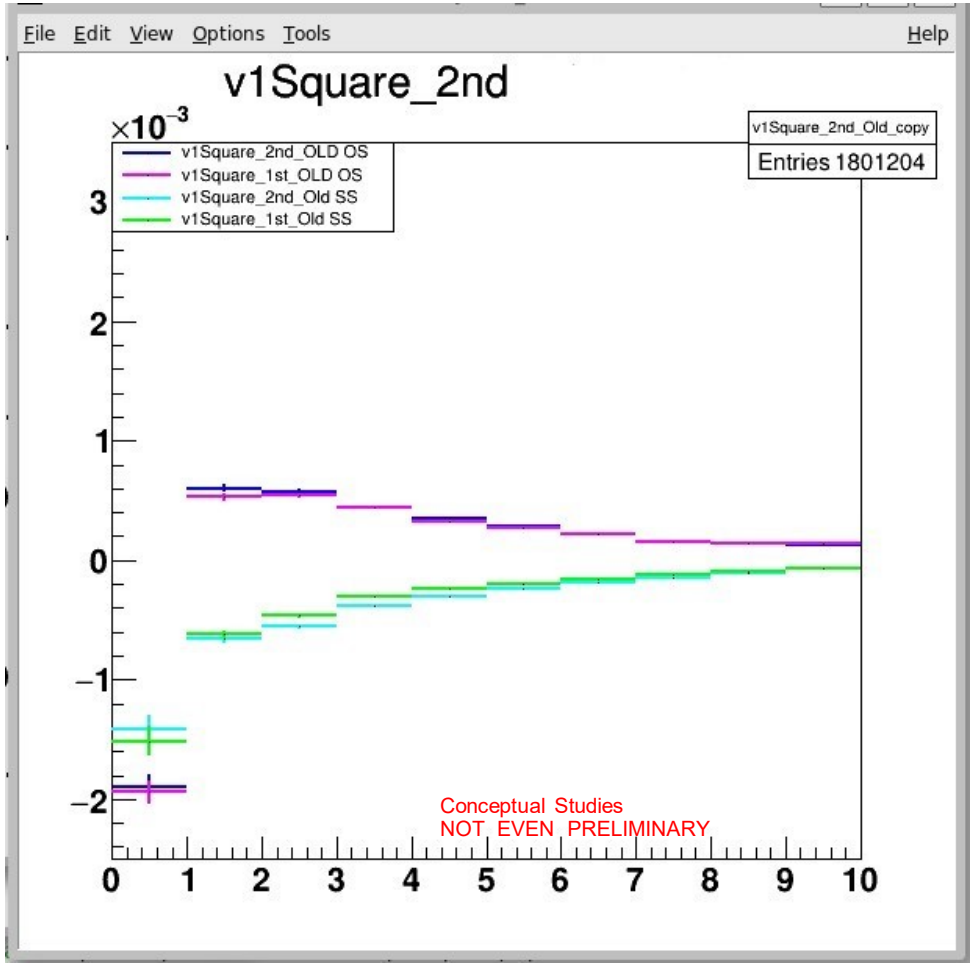






a_1^2 and v_1^2 from the 200 GeV Au-Au Run 19





- The notation a_1Square denotes the EbyE quantity $\Sigma\,(a_{1\_p1}{*}a_{1\_p2})$ with p1≠ p2
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