Beam Effects Task Force Update

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September 16th, 2021

EIC Biweekly Meeting

Crossing Angle Group Goals

1. Verify the Beam Effects Afterburner being developed by Dmitry is consistent with the Pythia-8 implementation
   - Afterburner code from Jin was extensively tested against Pythia-8 implementation and found to agree very well
   - Jin’s code is dependent on fun4all framework and can’t be ported directly to ATHENA
   - Need to verify all is still consistent after the transfer
   - Add automatic benchmarks into the CI pipeline to verify simulation has correct beam effects applied

2. Agree on procedure to move from laboratory frame (with crossing angle) to a head-on frame and possibly others, such as Breit frame
   - No unique axis in the lab frame – how do we define pT, pseudorapidity, etc. for physics quantities
   - Kinematic calculations taking into account the hadronic final state will be distorted by the crossing angle
   - Boost procedure is relatively simple, we just need to agree on a method and make the rest of the collaboration aware – possibly develop a small library / utility people can use

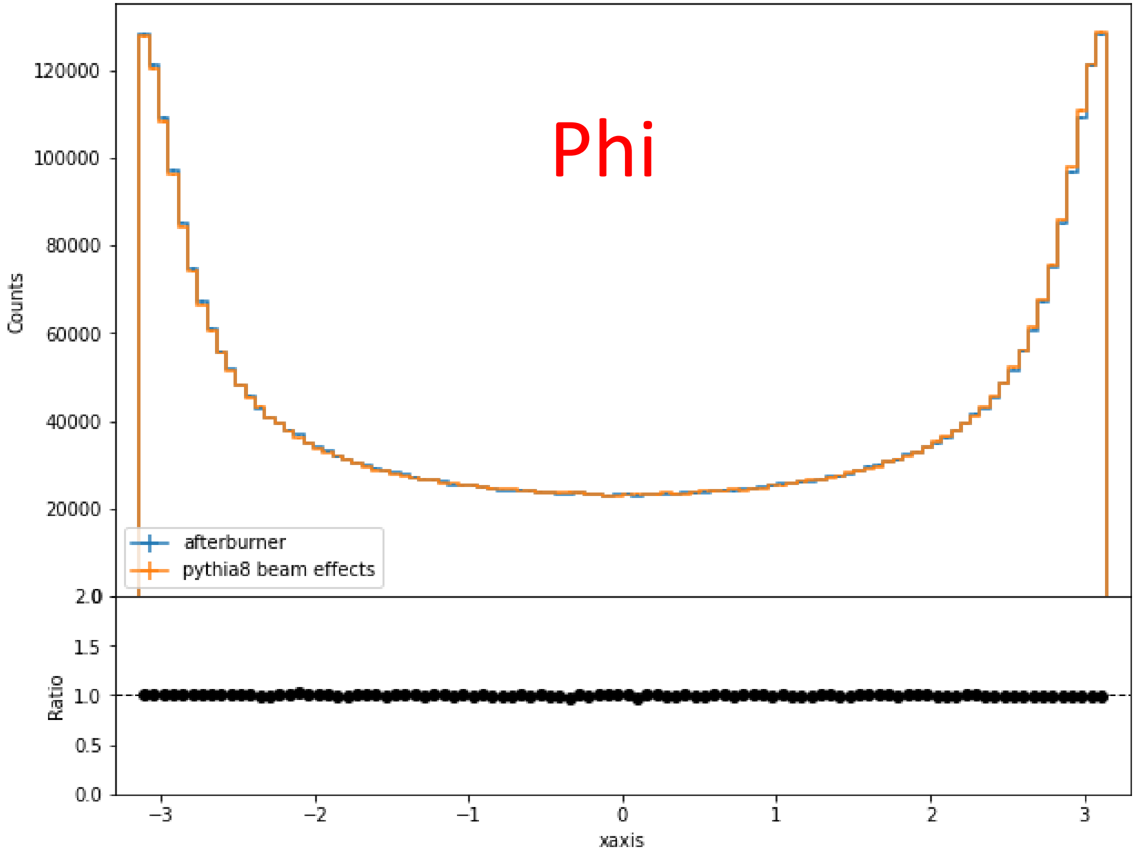
3. Generate a short document or wiki entry with our findings

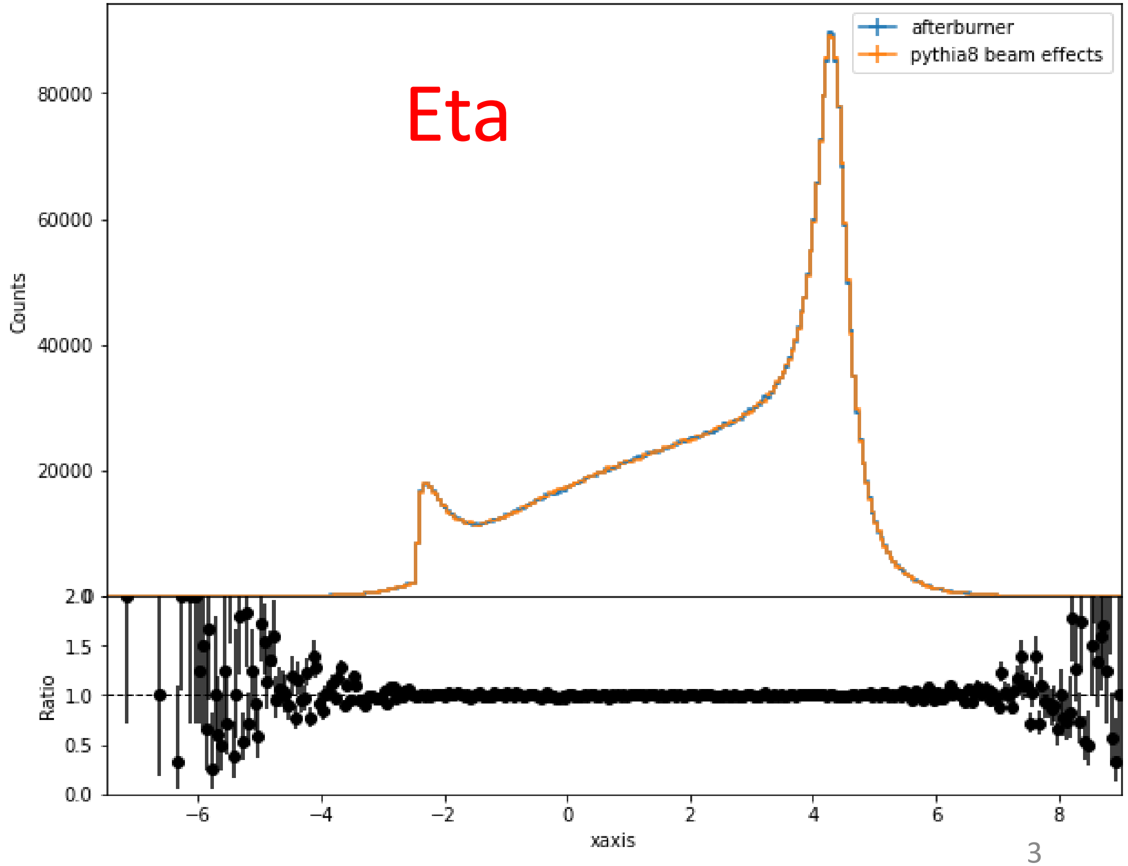
Develop common code to calculate kinematic variables and make them available via the output trees so all is consistent across working groups

Afterburner Validation

- Compare Pythia8 without beam effects included and passed through the afterburner to Pythia8 with beam effects included natively

- See excellent agreement – afterburner reproduces final state particle distributions

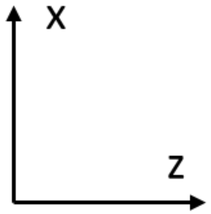




- Still need to verify initial beam distributions and vertex position / time distributions

- Big thanks to Dmitry!

Head-On Frame Definition



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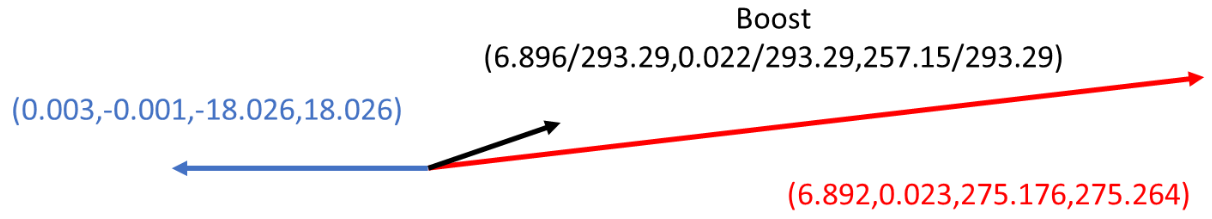
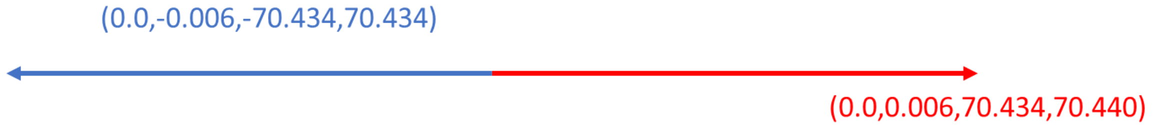


Initial configuration and boost vector

2

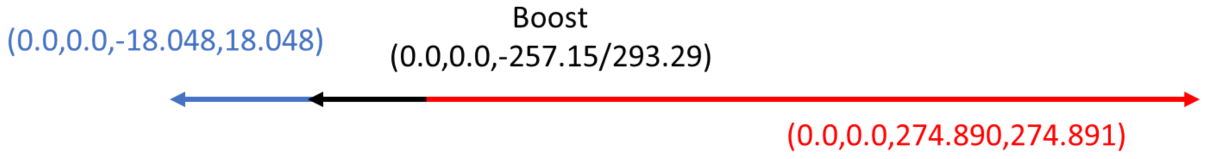
Boost to center of momentum frame

3



Rotate to eliminate x and y components

4



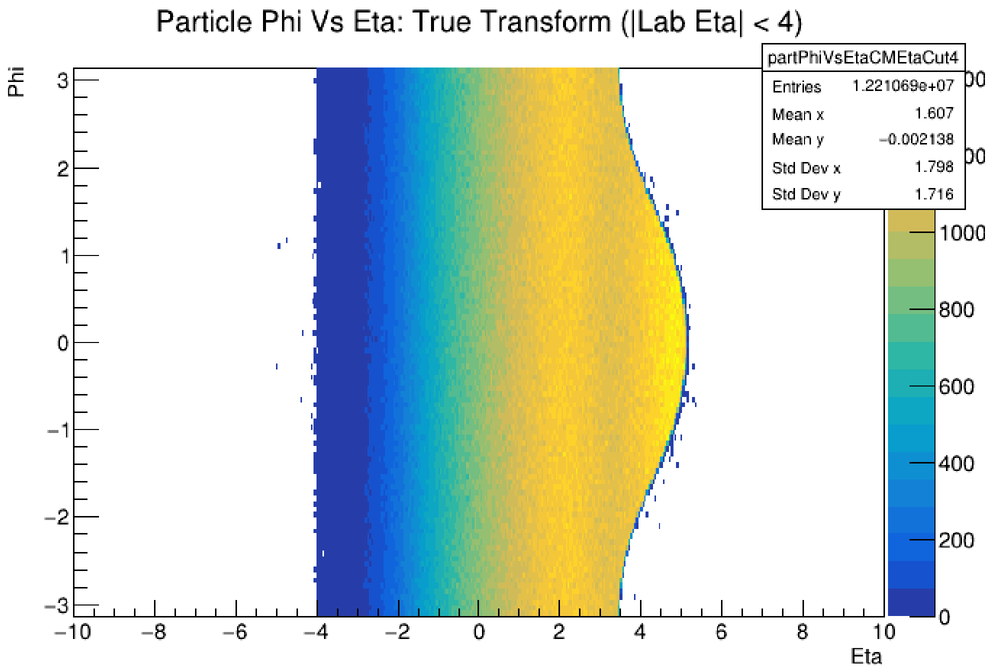
Boost back to restore (nearly) original beam energy

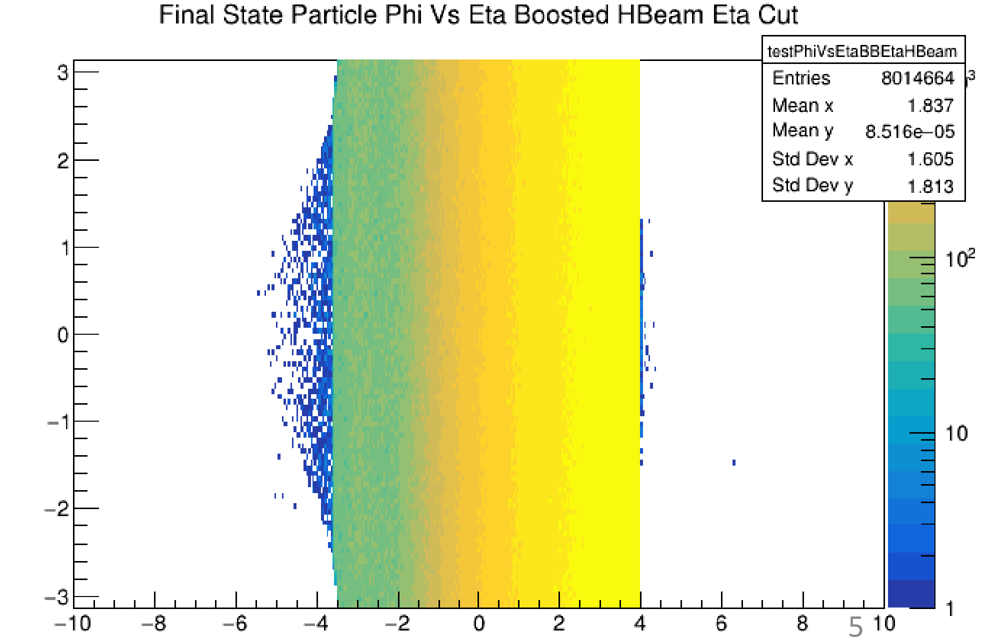
How to Define Acceptance Cuts

- Because it has a single meaningful axis, the head-on frame is still likely the best frame for defining our physics quantities

- However, will our detector acceptance (the limit of HCal or tracking coverage) be symmetric around the electron beam or the hadron beam? If it is symmetric about the hadron beam, we should use eta as defined with respect to the hadron beam to place our cuts

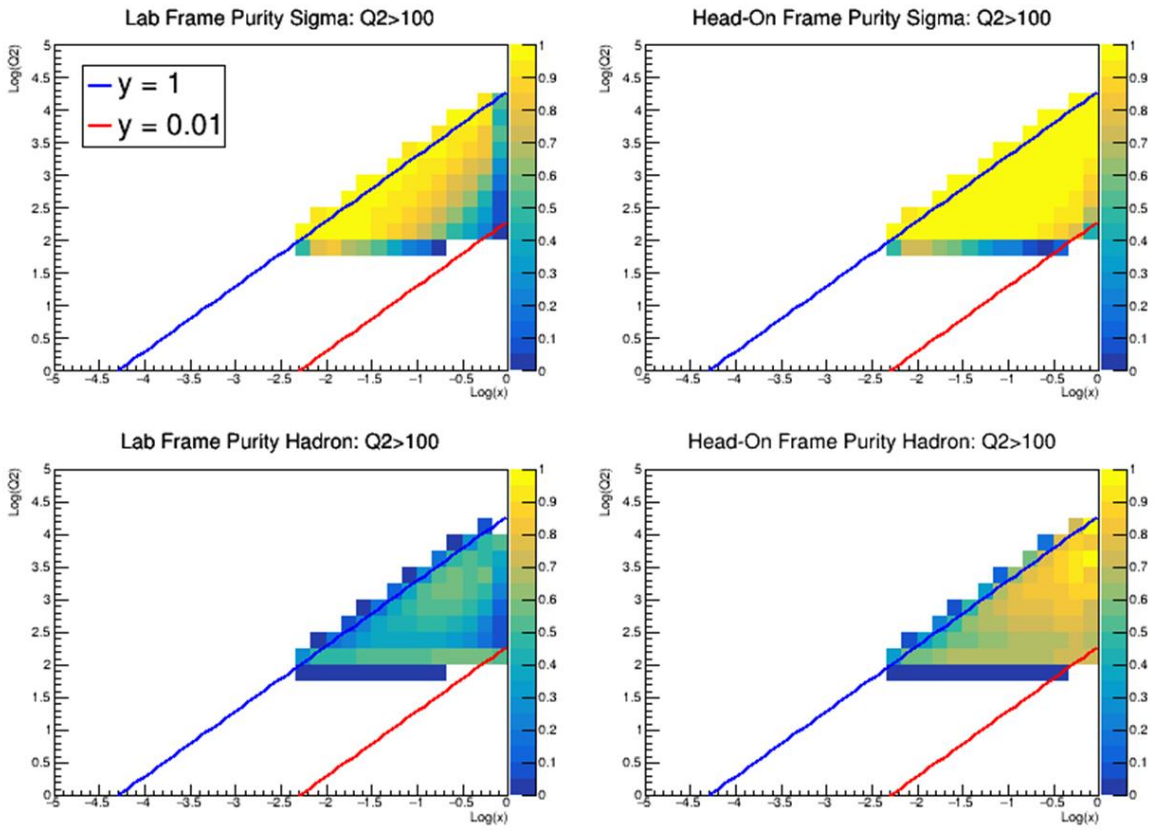
- Both plots show the phi vs eta distribution where these quantities are defined in the head-on frame
  - Top plot applies a cut for |eta| < 4 where eta is defined relative to the electron beam
  - Bottom plot applies a cut for |eta| < 4 where eta is defined relative to the hadron beam
  - At negative eta, can define acceptance relative to the electron beam – this will eliminate distortions in electron going direction





Reconstruction of Event Kinematics

- The crossing angle will distort the distribution of the hadronic final state
- Any reconstruction of event kinematics which depends on the hadronic final state will need to correct for this effect in order to return proper values
- As the consistent application of the transformation to a head-on frame is one of the goals of this group, we decided to tackle the problem of creating common kinematic reconstruction methods which can be used by all working groups
- Goal of this effort will be:
  - Determination of true and reconstructed x, y, Q2, etc using various methods
  - Incorporation of these results into the official full simulation output trees so they are available to all users
  - Development of automatic benchmarks which will evaluate if detector changes adversely affect kinematic reconstruction



Reconstruction of Kinematic Variables

- Devil will be in the details: how do we identify scattered electron?, do we incorporate particle flow?, what about PID for energy determination of charged hadrons?, etc…

- These details will evolve as various people/groups refine functionality, how do we keep the determination of the kinematic variables in sync? – strategy will be discussed further tomorrow in the crossing angle task force meeting and the wider convener meeting

- Core group of people willing to work on this problem and do the actual implementation have been identified

- Good news is that we are not starting from scratch – several people have been working on these topics already and we have a very nice analysis framework created by Chris for the SIDIS group that we can poach code from

- Time is short and we have to move fast – hopefully we have something read on a ~2 week timescale

Figure from Owen Long

$$\Sigma = \sum_h (E_h - p_{z,h})$$

$$T = \sqrt{(\sum_h p_{x,h})^2 + (\sum_h p_{y,h})^2}$$

$$\tan\frac{\gamma}{2} = \frac{\Sigma}{T}$$

Appendix: y, Q^2 and x formulae

method	y	Q^2	x	
e	$1-\frac{E}{E^e}\sin^2\frac{\theta}{2}$	$4E^e E\cos^2\frac{\theta}{2}$	Q^2/ys	*Electron*
h	$\frac{\Sigma}{2E^e}$	$\frac{T^2}{1-y_h}$	Q^2/ys	*Hadron*
m	y_h	Q^2_e	Q^2/ys	
DA	$\frac{\tan\gamma/2}{\tan\gamma/2+\tan\theta/2}$	$4E^{e2}\frac{\cot\theta/2}{\tan\gamma/2+\tan\theta/2}$	Q^2/ys	*Double Angle*
Σ	$\frac{\Sigma}{\Sigma+E(1-\cos\theta)}$	$\frac{E^2\sin^2\theta}{1-y_\Sigma}$	Q^2/ys	*Sigma*
IDA	y_{DA}	$E^2\tan\frac{\theta}{2}\frac{\tan\gamma/2+\tan\theta/2}{\cot\theta/2+\tan\theta/2}$	$\frac{E}{E^p}\frac{\cot\gamma/2+\cot\theta/2}{\cot\theta/2+\tan\theta/2}$	
IΣ	y_Σ	Q^2_Σ	$\frac{E}{E^p}\frac{\cos^2\theta/2}{y_\Sigma}$	

From the paper that introduced the Sigma method.
U. Bassler and G. Bernardi, NIM A361 (1995) 197-208.