Afterburner with BeAGLE Sample

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Approach – Afterburner Comparison

- Observed something strange in nuclear remnants distribution after “afterburner” when comparing to before “afterburner”. Needs to investigate further this problem

- Kong generated **BeAGLE v1.03.02** 1M events (**ePb 18×110** J/ψ diffractive)
- Passed events through “afterburner” with **different configurations**

- Compare **before “afterburner”** sample to **after “afterburner”** sample with two settings
  - Default ***ip8_eau_110x18*** (crossing angle **with beam effect**)
  - Additional ***ip8_eau_110x18_ca*** (crossing angle **without beam effect**)
  - Additional ***ip8_eau_110x18_bdiv0*** (crossing angle **with beam effect, but zeros divergence**)

Afterburner Configuration

```
ab::AfterburnerConfig ab::EicConfigurator::preset_ip8_eau_110x18() {
    ab::AfterburnerConfig cfg;

    cfg.crossing_angle_hor = -35e-3;            // Crossing angle in horizontal plane [rad]
    cfg.crossing_angle_ver = 0;              // Crossing angle in vertical plane [rad]

    cfg.hadron_beam.beta_crab_hor = 500000.0;
    cfg.lepton_beam.beta_crab_hor = 150000.0;

    // Beam divergence
    cfg.hadron_beam.divergence_hor = 218e-6;
    cfg.hadron_beam.divergence_ver = 379e-6;
    cfg.lepton_beam.divergence_hor = 101e-6;
    cfg.lepton_beam.divergence_ver = 37e-6;

    // Beam beta star [mm]
    cfg.hadron_beam.beta_star_hor = 910;
    cfg.hadron_beam.beta_star_ver = 40;
    cfg.lepton_beam.beta_star_hor = 1960;
    cfg.lepton_beam.beta_star_ver = 410;

    // RMS emittance
    cfg.hadron_beam.rms_emittance_hor = 43.2 * nm;
    cfg.hadron_beam.rms_emittance_ver = 5.8 * nm;
    cfg.lepton_beam.rms_emittance_hor = 20 * nm;
    cfg.lepton_beam.rms_emittance_ver = 0.6 * nm;

    // RMS bunch length
    cfg.hadron_beam.rms_bunch_length = 7 * cm;
    cfg.lepton_beam.rms_bunch_length = 0.9 * cm;

    return cfg;
}
```

- In configuration card (afterburner/cpp/afterburner/EicConfigurator.cc)
  - Crossing angle
  - Beam beta function at crab cavity
  - Beam divergence
  - Beam beta function at IP
  - Beam RMS emittance
  - Beam RMS bunch length
  - Beam momentum spread missing?

(afterburner/cpp/afterburner/AfterburnerConfig.hh)

  - use_beam_bunch_sim = true/false

Afterburner Configuration Details

```
ab::AfterburnerConfig ab::EicConfigurator::preset_ip8_eau_110x18_ca() {
    ab::AfterburnerConfig cfg;

    cfg.crossing_angle_hor = -35e-3;            // Crossing angle in horizontal plane [rad]
    cfg.crossing_angle_ver = 1e-30;             // Crossing angle in vertical plane [rad]

    cfg.hadron_beam.beta_crab_hor = 1.;
    cfg.lepton_beam.beta_crab_hor = 1.;

    // Beam divergence
    cfg.hadron_beam.divergence_hor = 0;
    cfg.hadron_beam.divergence_ver = 0;
    cfg.lepton_beam.divergence_hor = 0;
    cfg.lepton_beam.divergence_ver = 0;

    // Beam beta star [mm]
    cfg.hadron_beam.beta_star_hor = 1e-30;
    cfg.hadron_beam.beta_star_ver = 1e-30;
    cfg.lepton_beam.beta_star_hor = 1e-30;
    cfg.lepton_beam.beta_star_ver = 1e-30;

    // RMS emittance
    cfg.hadron_beam.rms_emittance_hor = 1e-30 * nm;
    cfg.hadron_beam.rms_emittance_ver = 1e-30 * nm;
    cfg.lepton_beam.rms_emittance_hor = 1e-30 * nm;
    cfg.lepton_beam.rms_emittance_ver = 1e-30 * nm;

    // RMS bunch length
    cfg.hadron_beam.rms_bunch_length = 1e-30 * cm;
    cfg.lepton_beam.rms_bunch_length = 1e-30 * cm;

    return cfg;
}
```

- Created *ip8_eau_110x18_ca* setting
- In order to get rid of beam effects

afterburner/cpp/afterburner/EicConfigurator.cc

to remove any beam effect related constants

  - Beta function at crab cavity H = 1
  - Beam divergence H/V = 0
  - Beta function at IP H/V = 0
  - Beam RMS emittance H/V = 0
  - Beam RMS bunch length = 0

afterburner/cpp/afterburner/AfterburnerConfig.hh

(*L47 and L52*) to turn off bunch simulation

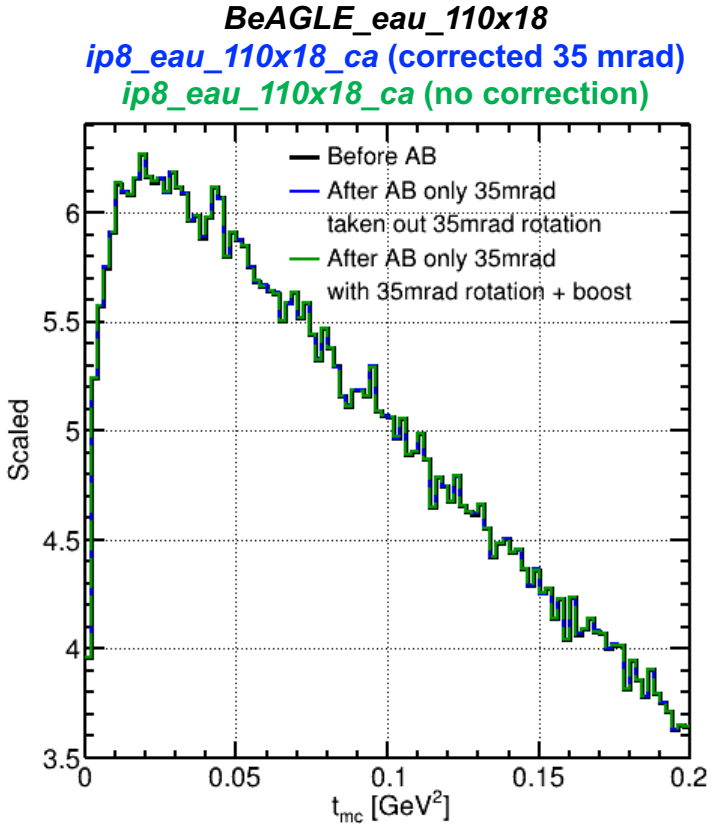
  - Beam bunch simulation = false
  - SmearFuncs:: Uniform

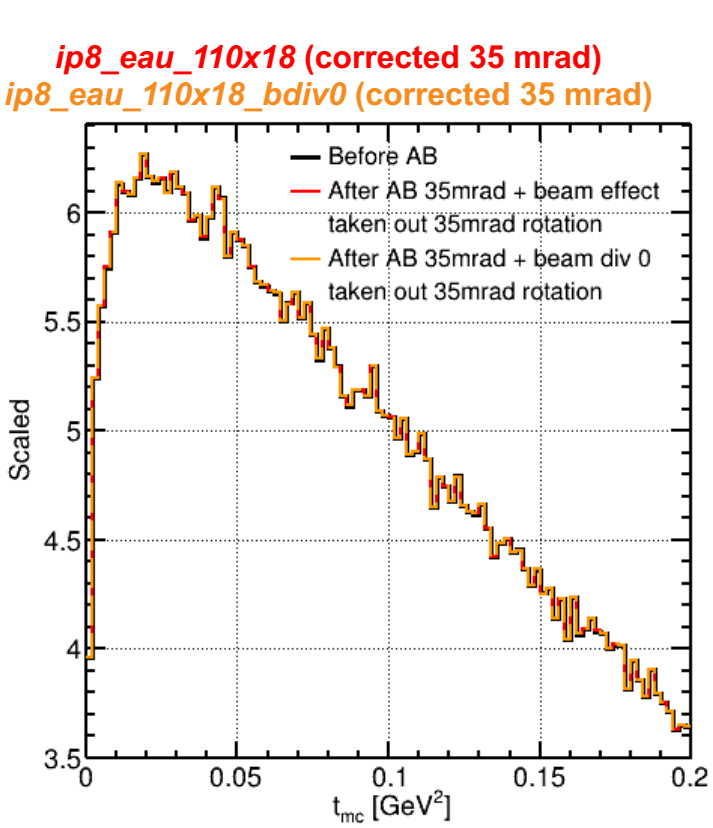
afterburner/cpp/afterburner/Afterburner.cc

(*L310 and L311*) to remove beam angular deflection

  - Real_hadron_dir = ideal_hadron_dir
  - Real_lepton_dir = ideal_lepton_dir

t: Before/After "afterburner"





- **Normalized histograms by scaling by 1/integral and taking width into account**
- Four different "afterburner" samples:
  - Only Boost, Crossing angle + Boost, Boost + All Beam Effects, Boost + Beam effects, but No Beam divergence
- Observed that "t invariant" in reconstruction using particles in central region

Blue taken out rotation + boost

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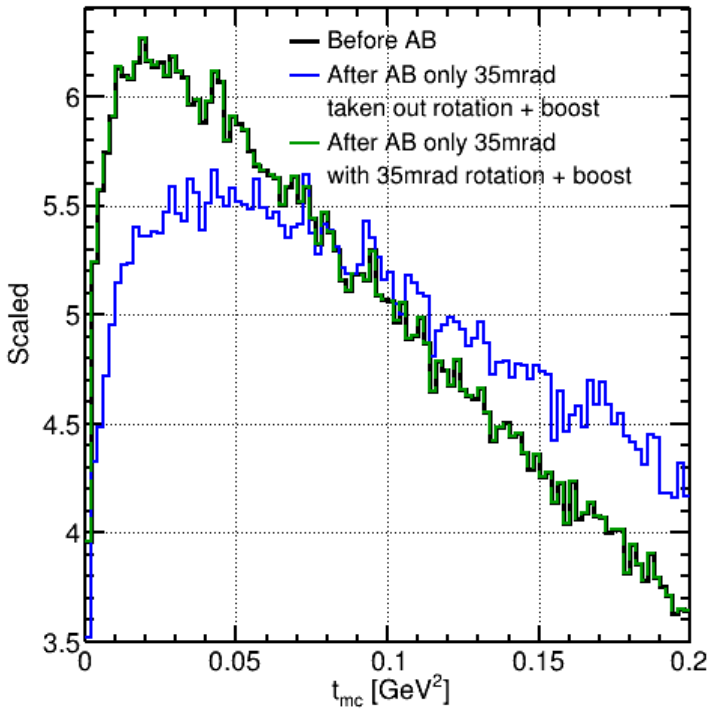
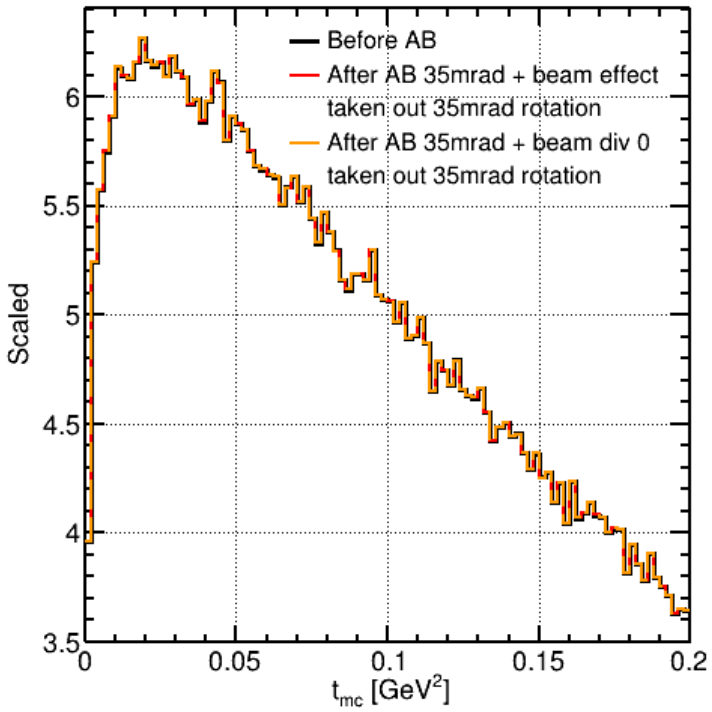


***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**



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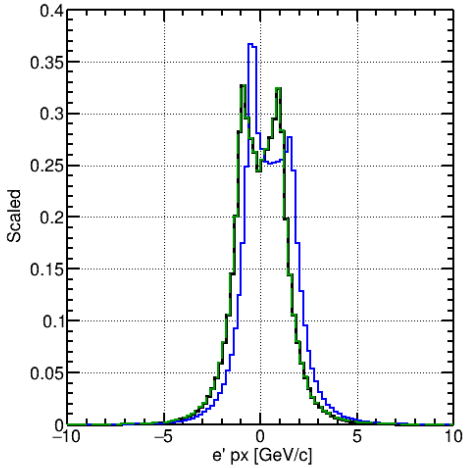
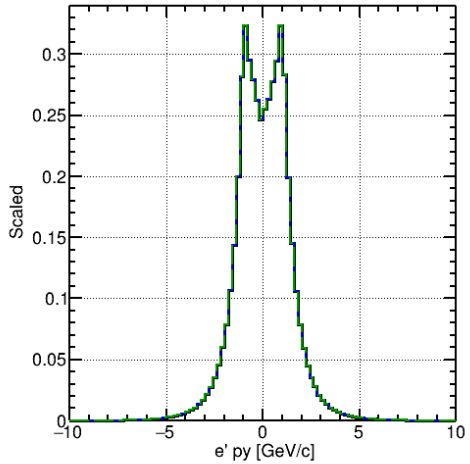
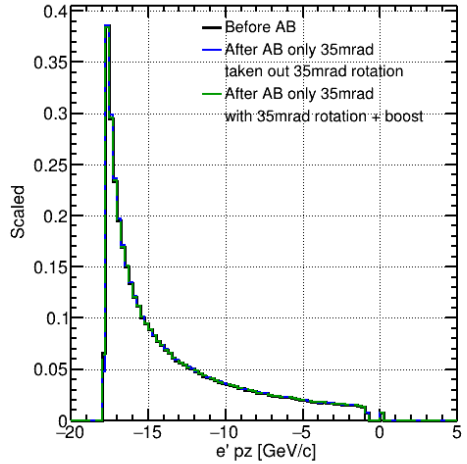
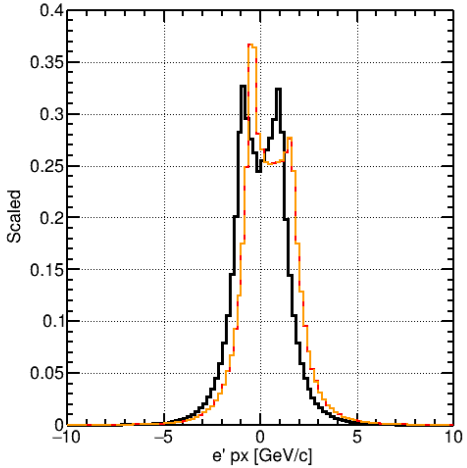
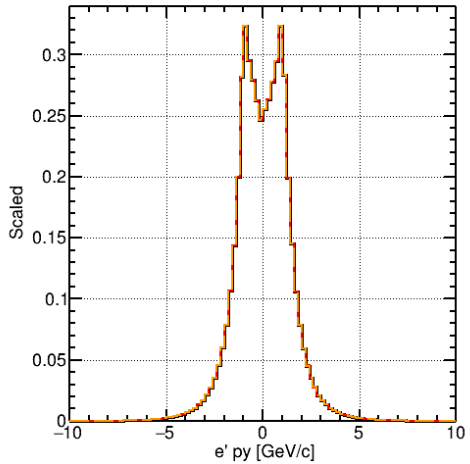
- From comparing to blue and green distributions, **boost and rotation reflects on original distribution for particles in central region.**
- From comparing to red and orange distributions, they are very similar, and smeared by beam effects. **Beam divergence doesn’t affect too much for particles in central region.**

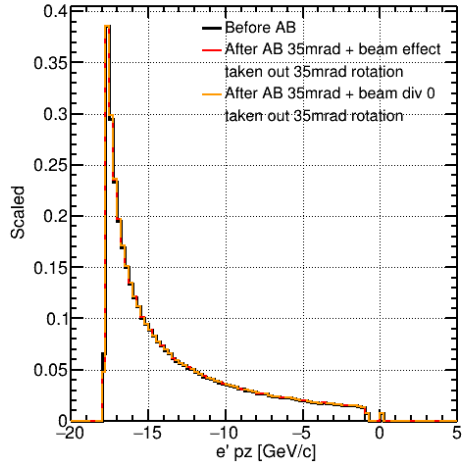












Normalized histograms by scaling by 1/integral and taking width into account

e': Before/After "afterburner"

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***ip8_eau_110x18* (corrected 35 mrad)**
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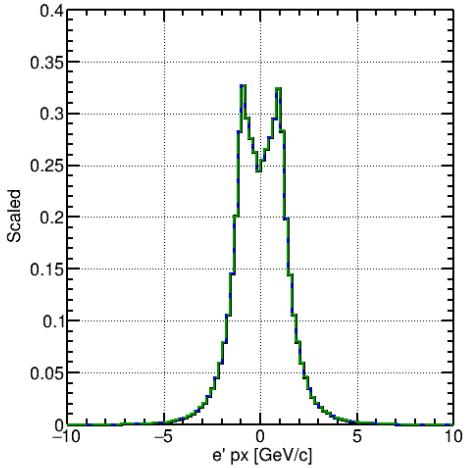

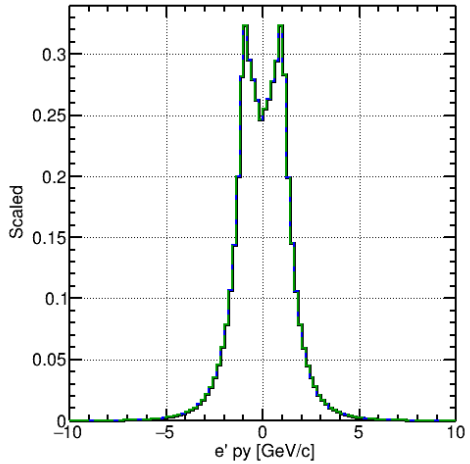

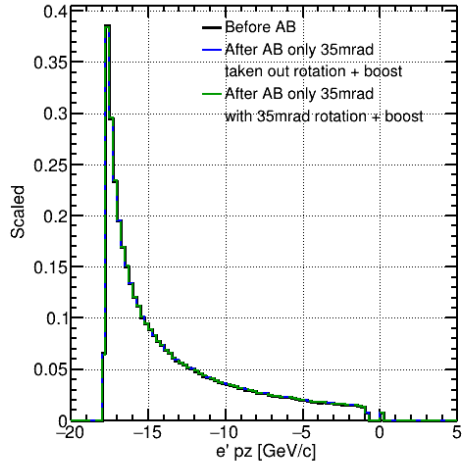

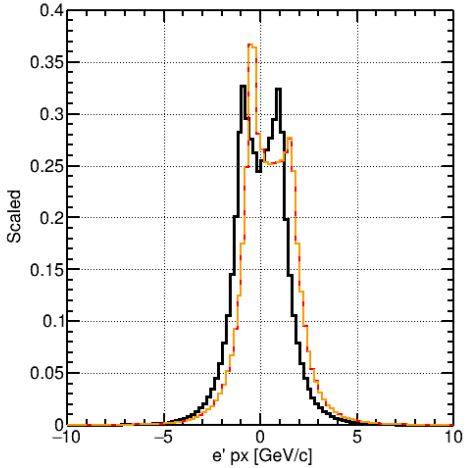

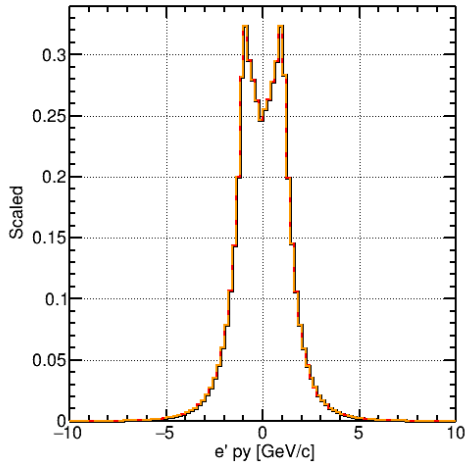

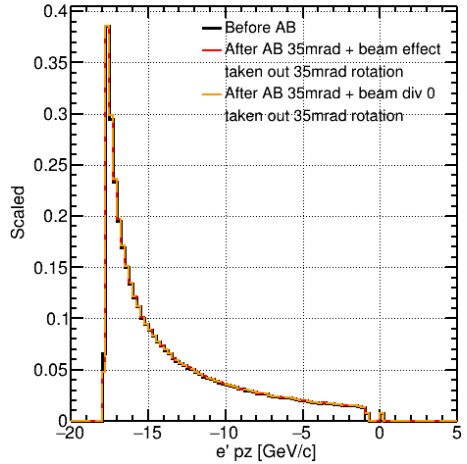

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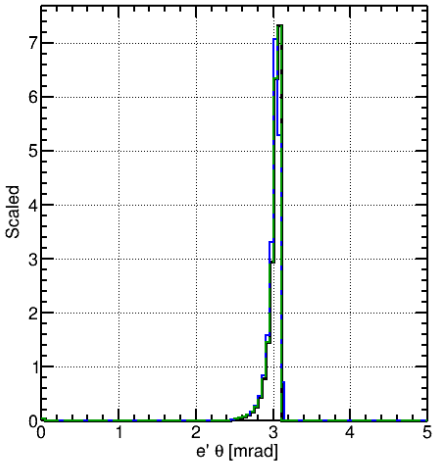

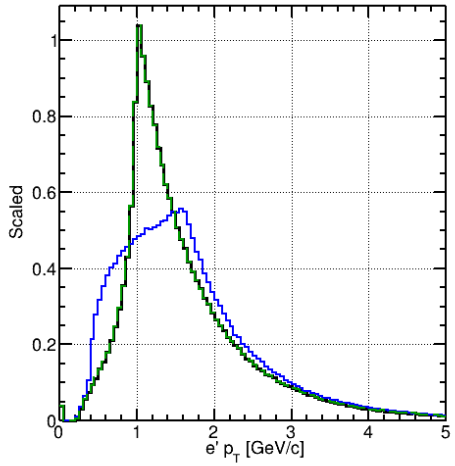

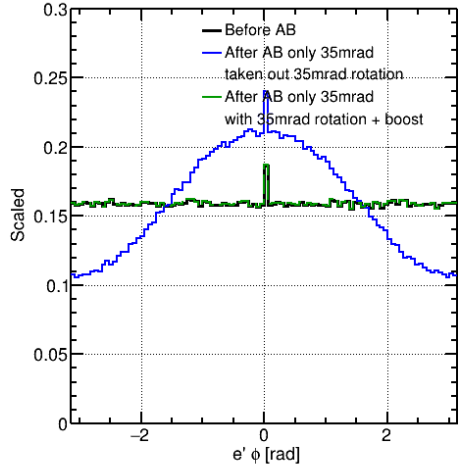

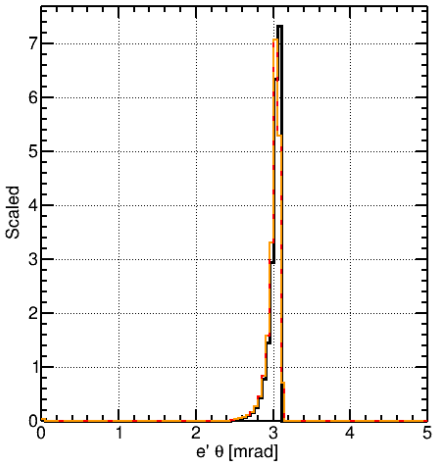

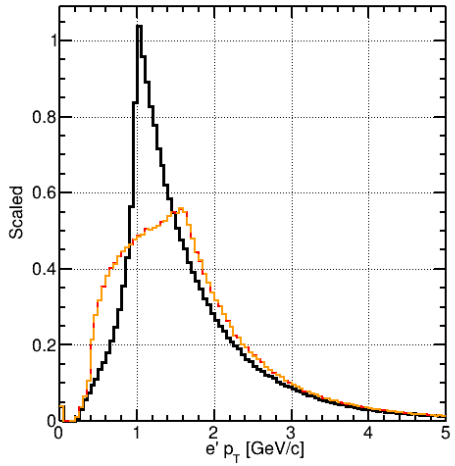

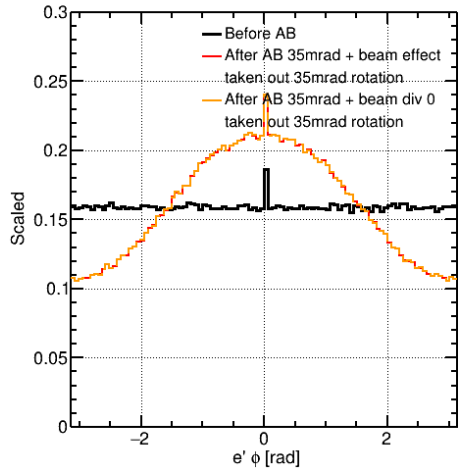

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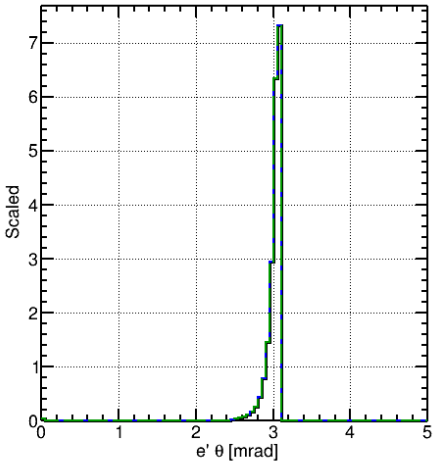

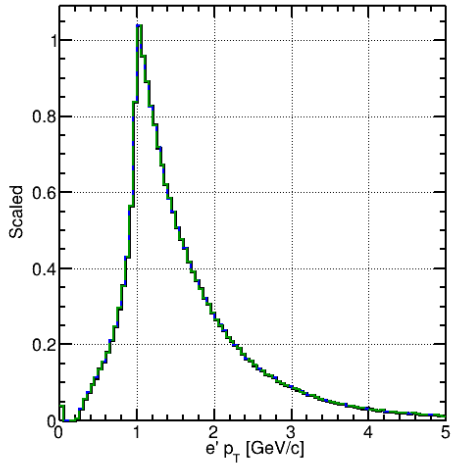

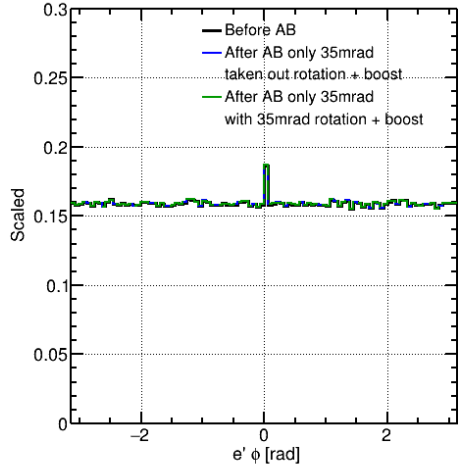

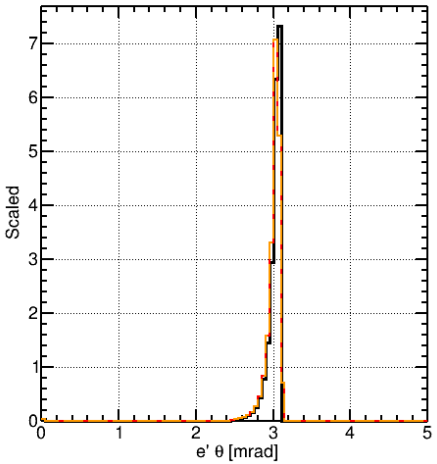

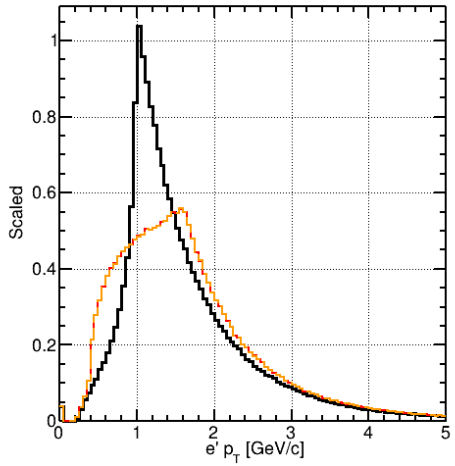

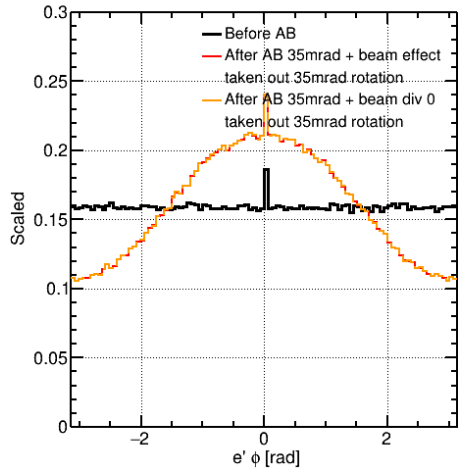

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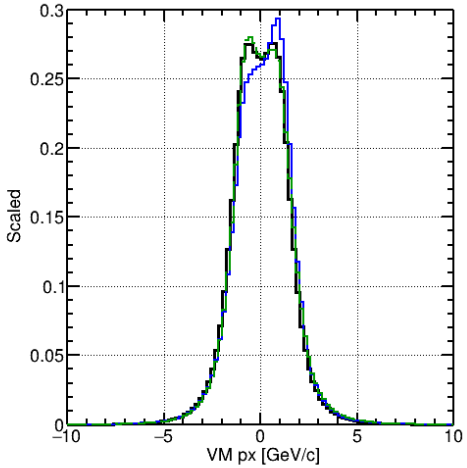

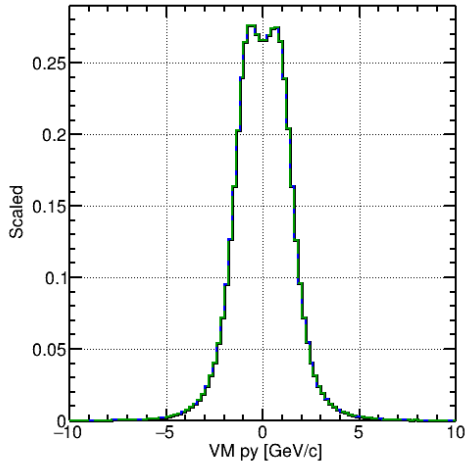

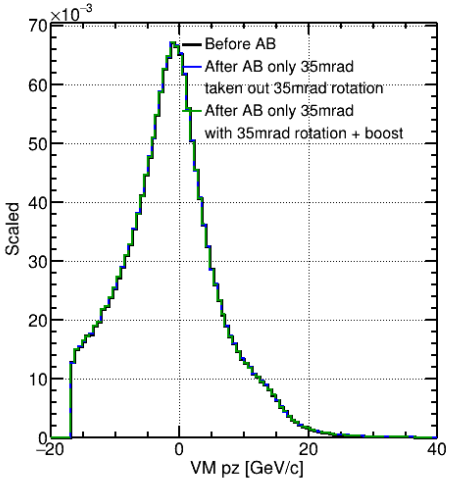

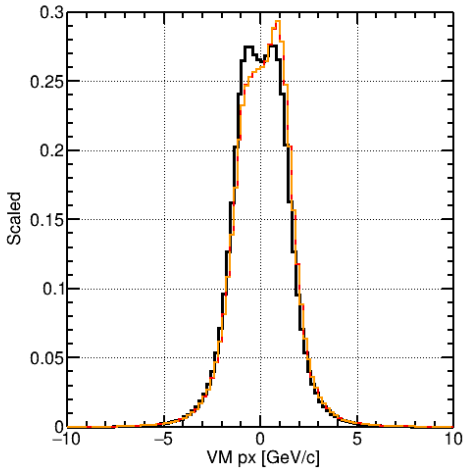

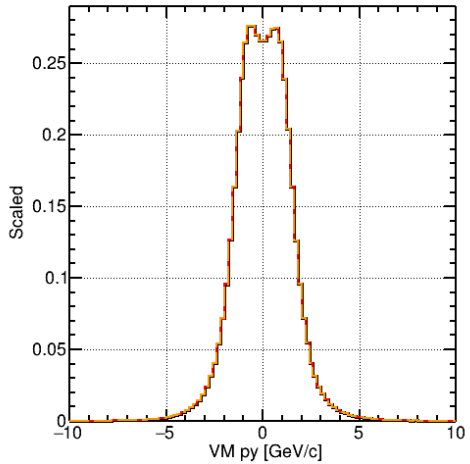

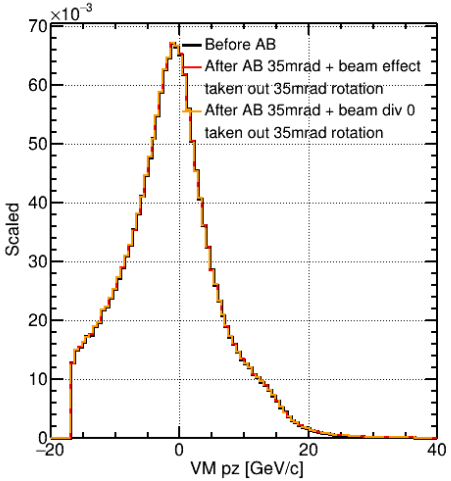

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Blue taken out rotation + boost

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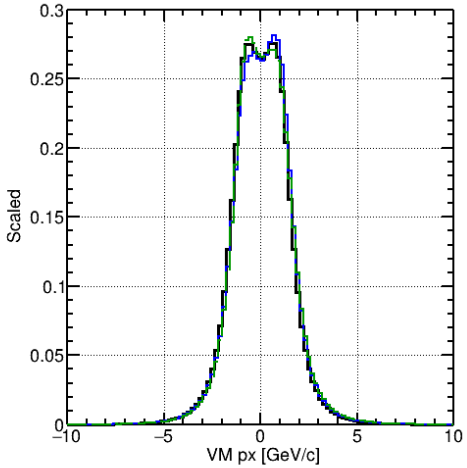

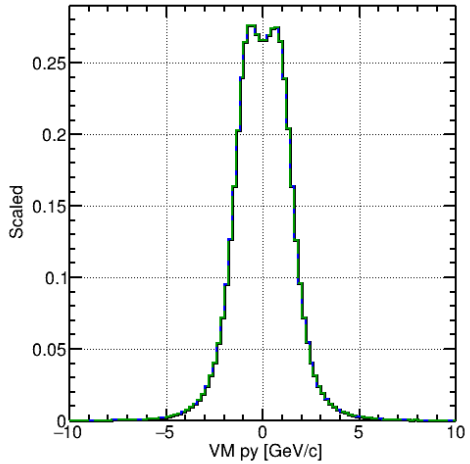

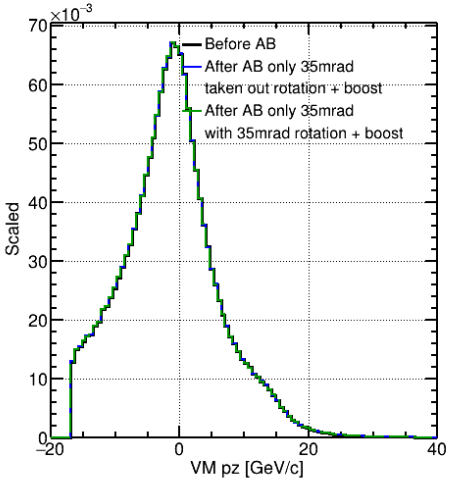

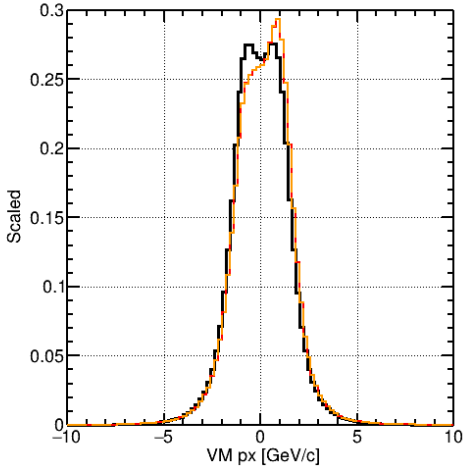

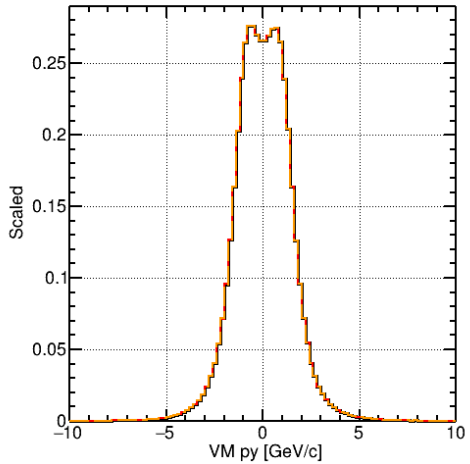

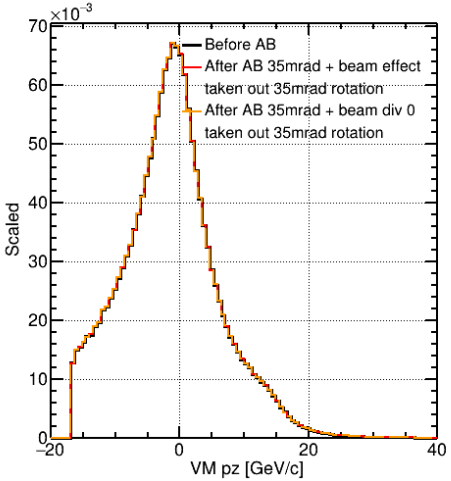

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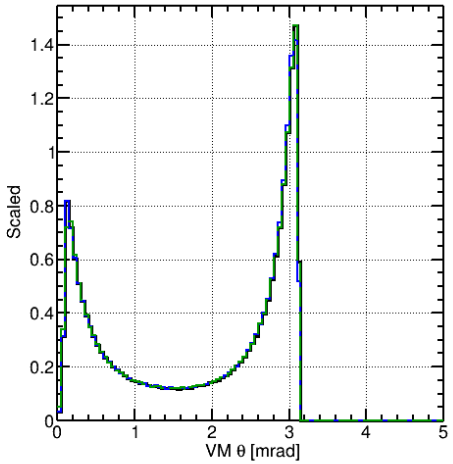
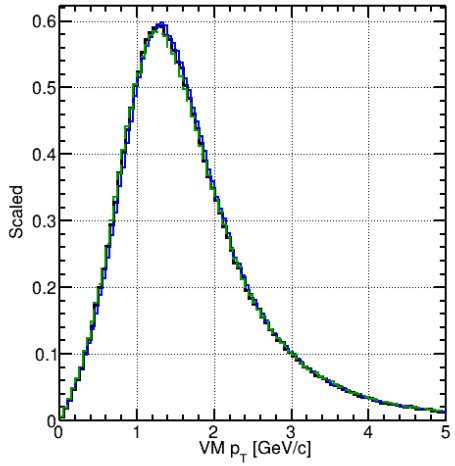
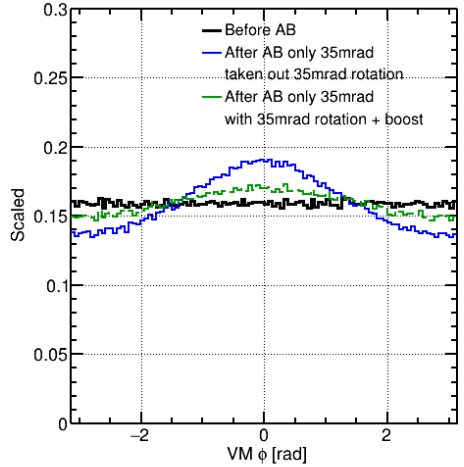
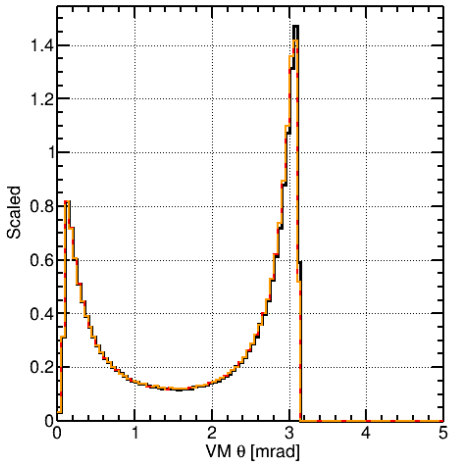
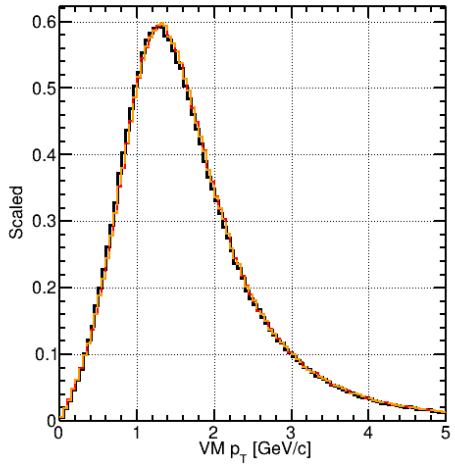
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

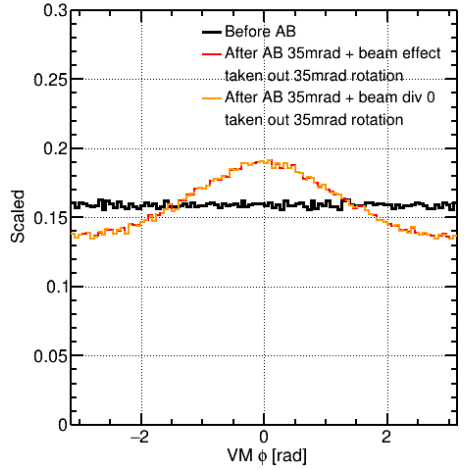










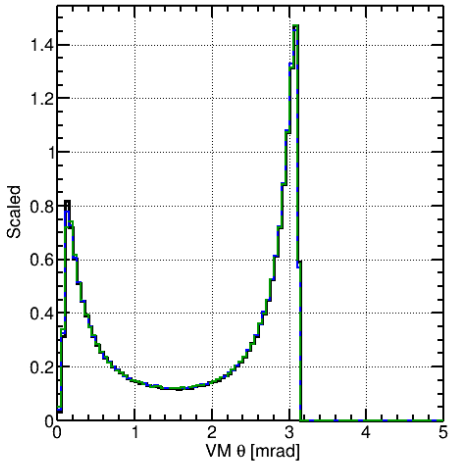


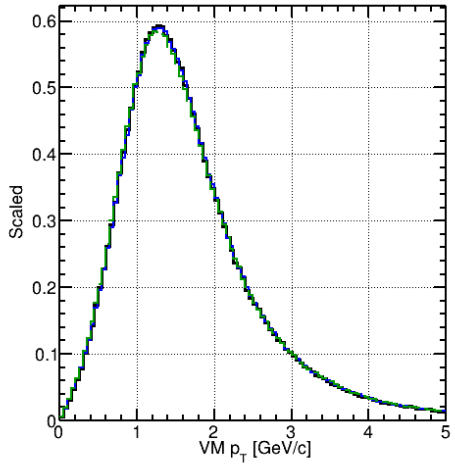
Normalized histograms by scaling by 1/integral and taking width into account

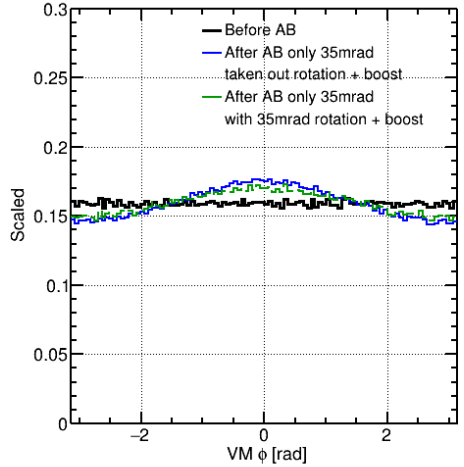
Blue taken out rotation + boost

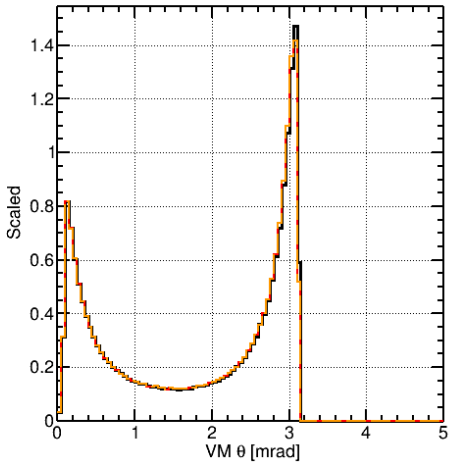
J/ψ: Before/After "afterburner"

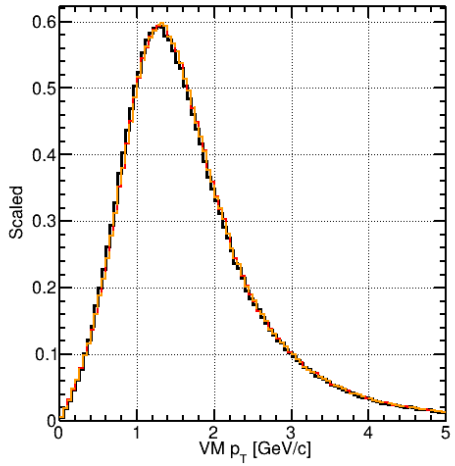
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

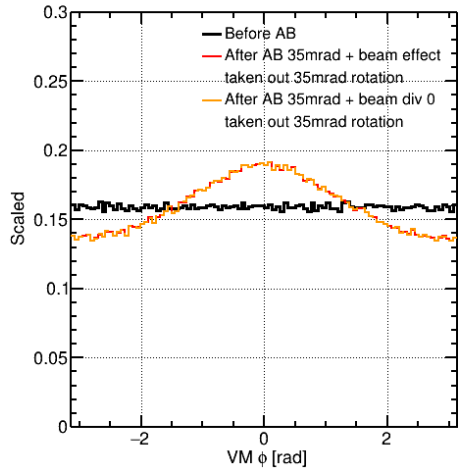










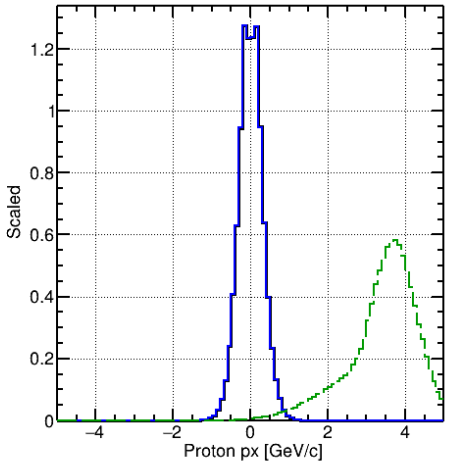


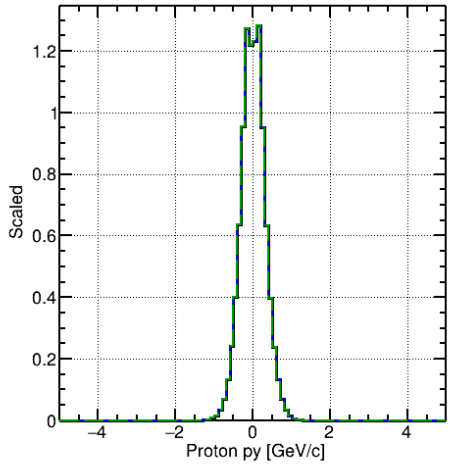
Normalized histograms by scaling by 1/integral and taking width into account

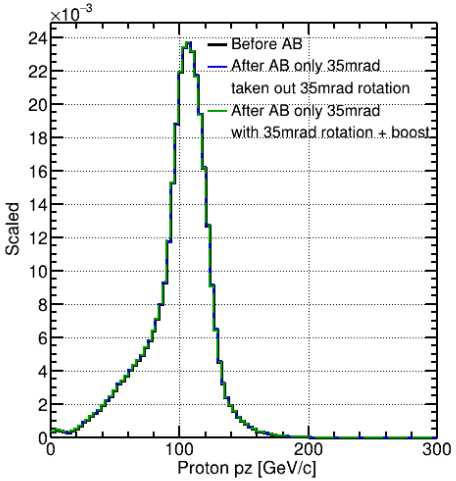
Protons: Before/After “afterburner”

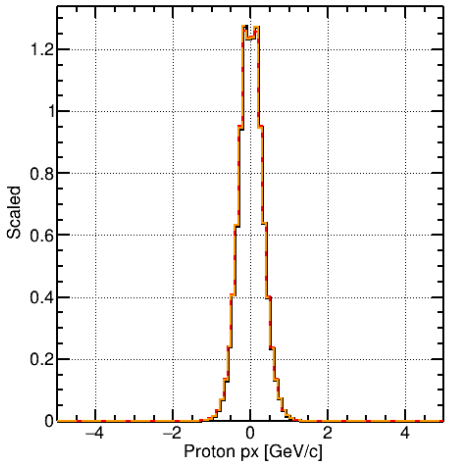
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

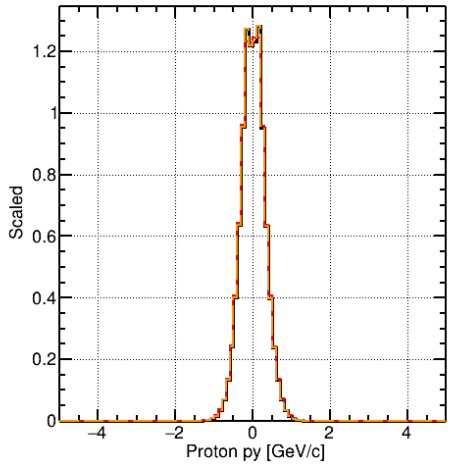
- From blue distribution, **it makes sense.** When protons have only crossing angle effect, it matched with original distribution after removing crossing angle.
- The Green distribution has **boost and crossing angle, but still doesn’t understand smeared distribution in p_x though**.
- From red distribution, **all momentum vectors are smeared by beam effect.**
- The Orange distribution **with no beam divergence has similar to original distribution**

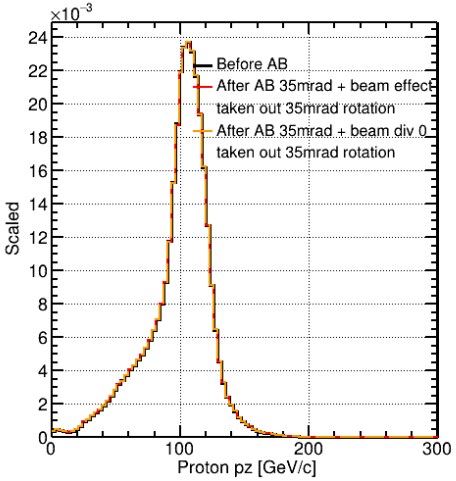










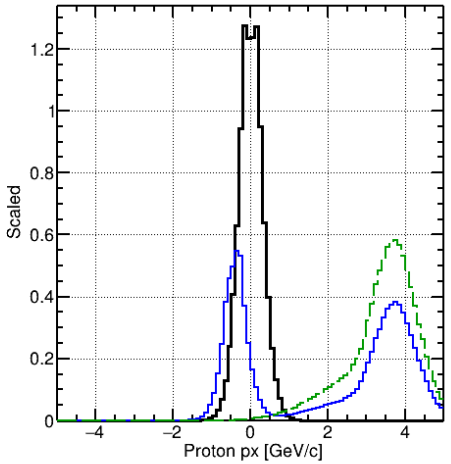


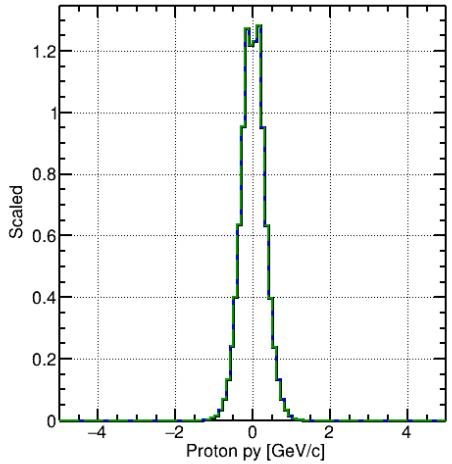
Normalized histograms by scaling by 1/integral and taking width into account

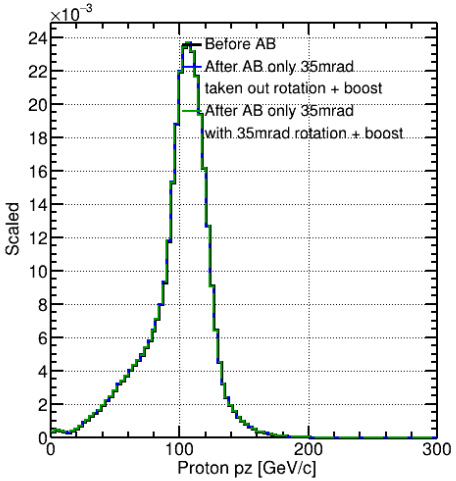
Blue taken out rotation + boost

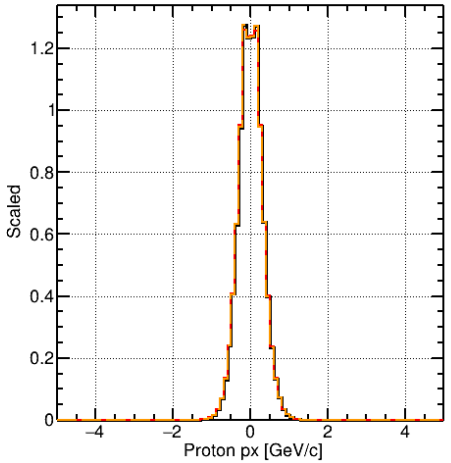
Protons: Before/After “afterburner”

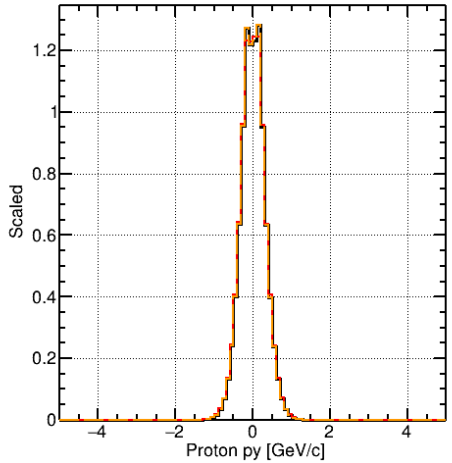
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

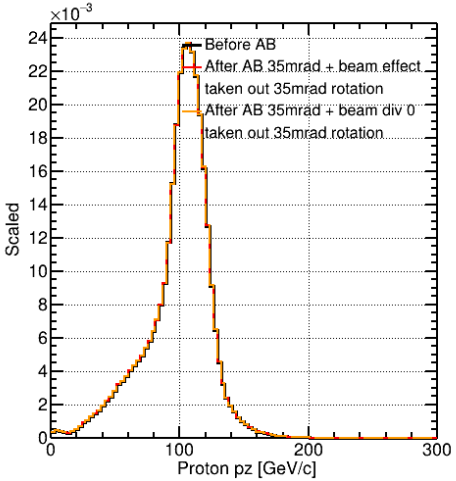








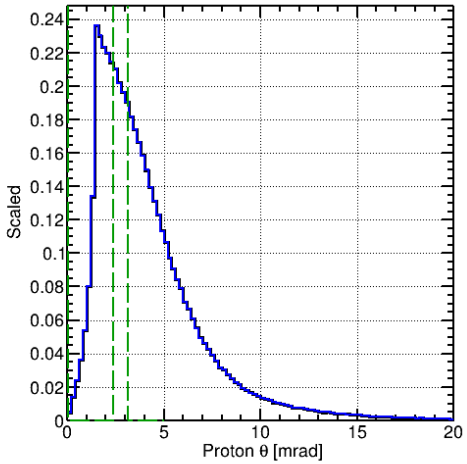


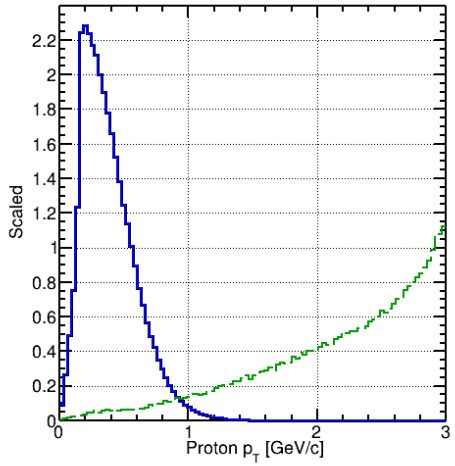


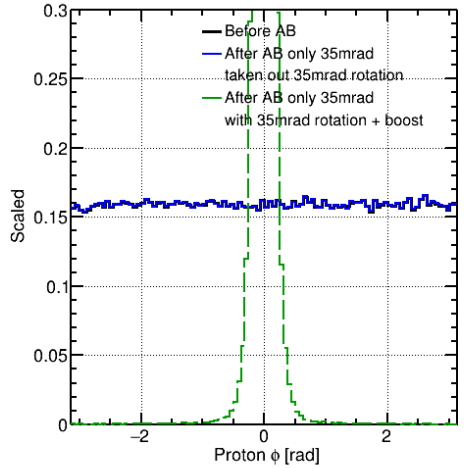
Normalized histograms by scaling by 1/integral and taking width into account

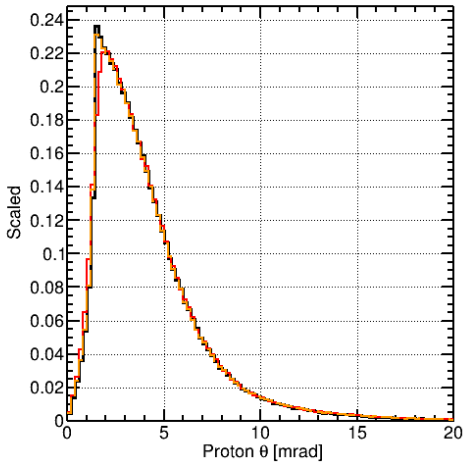
Protons: Before/After “afterburner”

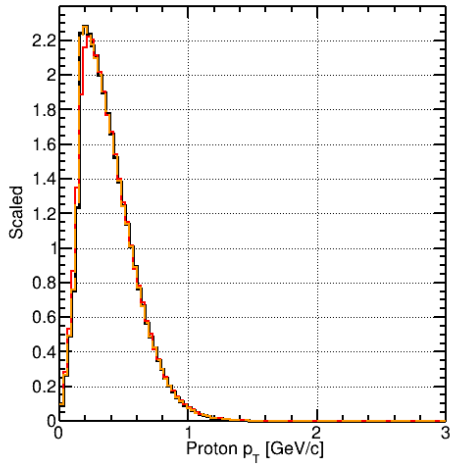
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

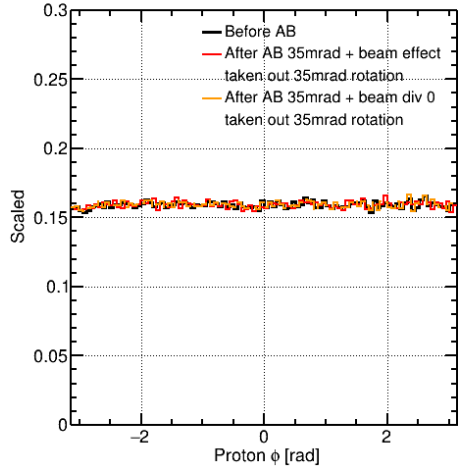










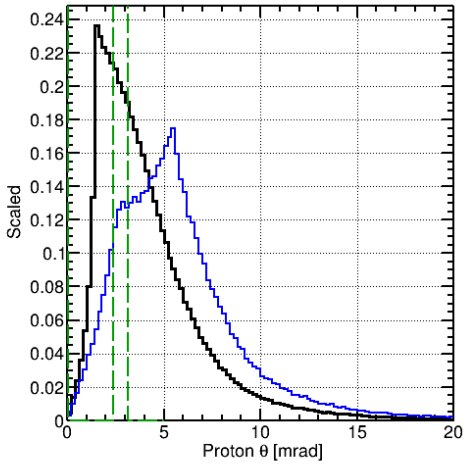


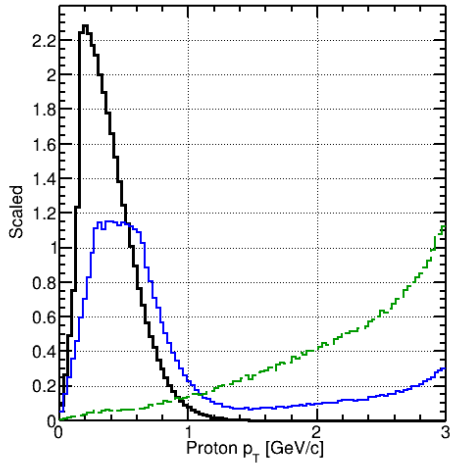
Normalized histograms by scaling by 1/integral and taking width into account

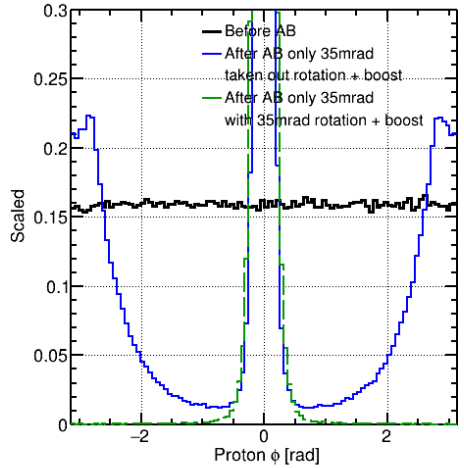
Blue taken out rotation + boost

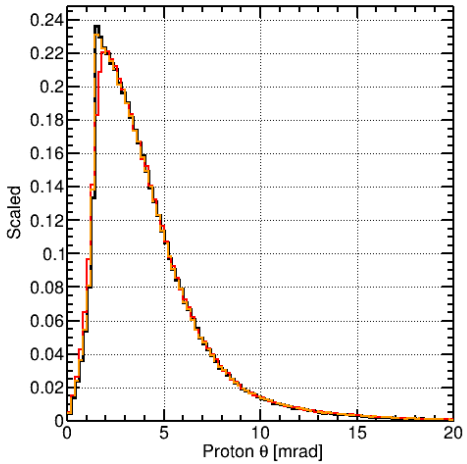
Protons: Before/After “afterburner”

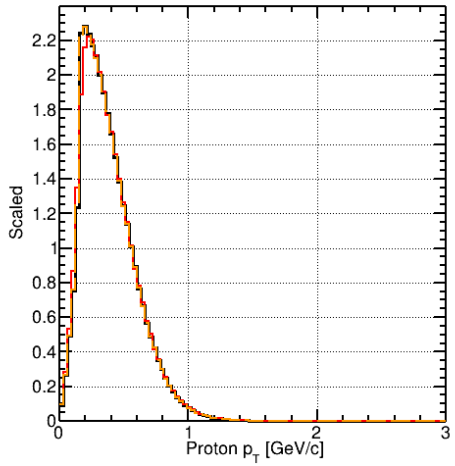
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

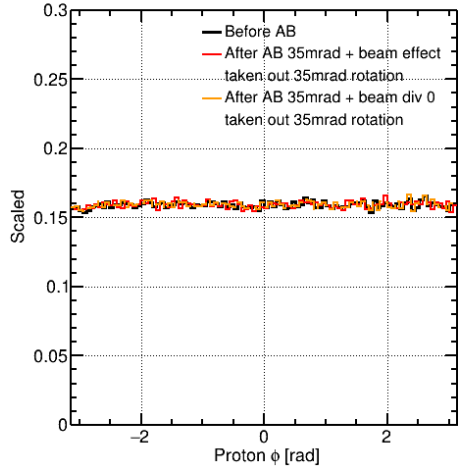








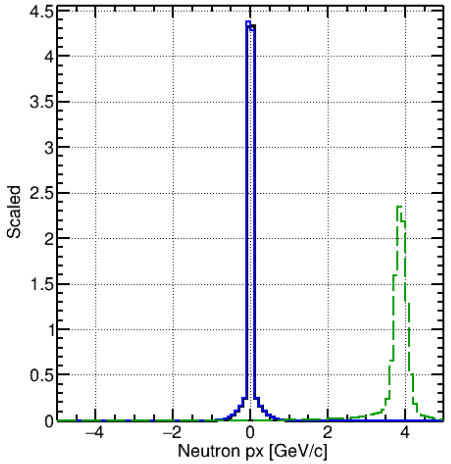


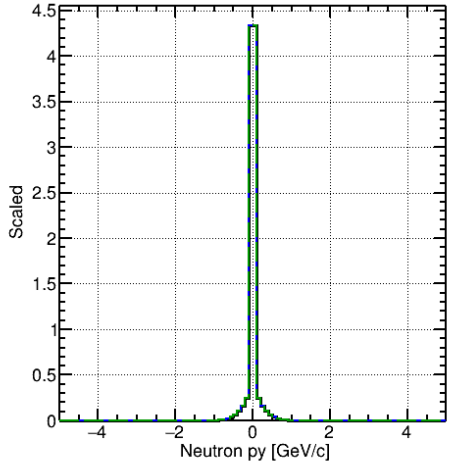


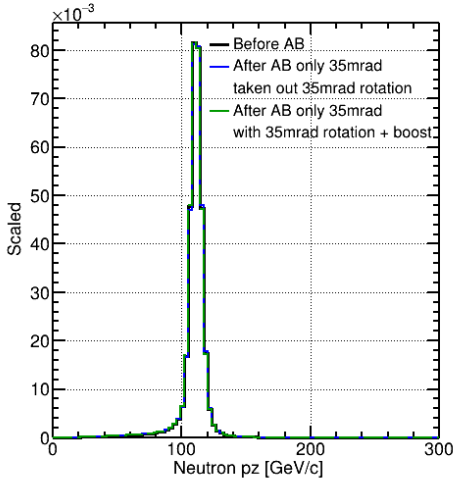
Normalized histograms by scaling by 1/integral and taking width into account

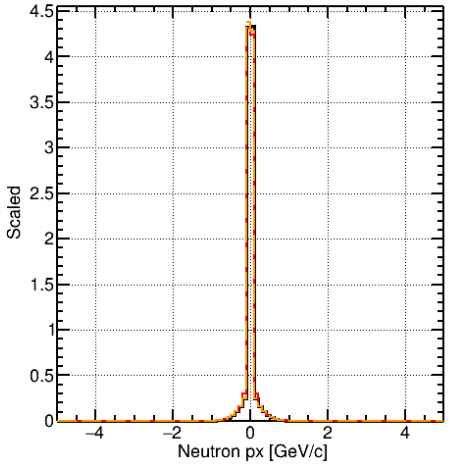
Neutrons: Before/After “afterburner”

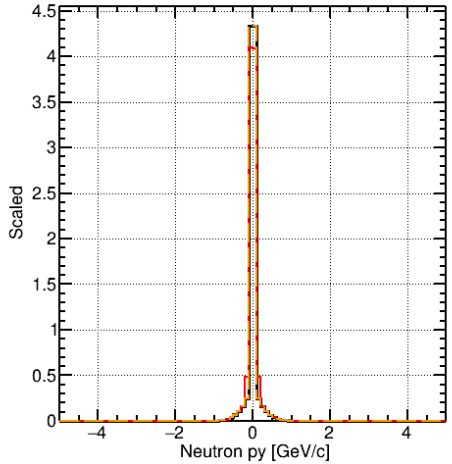
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

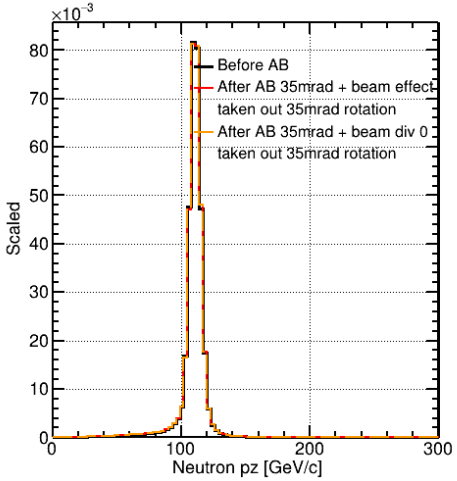










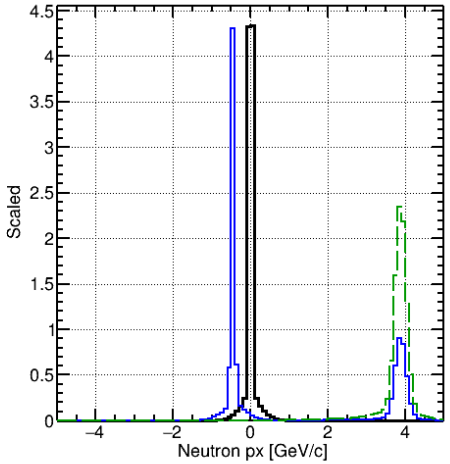


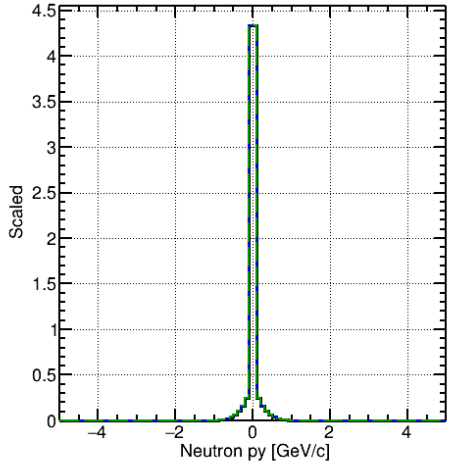
Normalized histograms by scaling by 1/integral and taking width into account

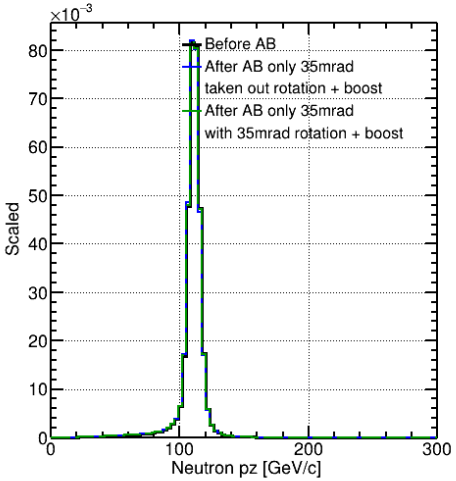
Blue taken out rotation + boost

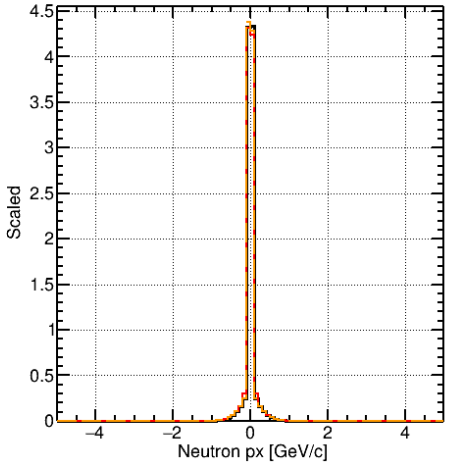
Neutrons: Before/After “afterburner”

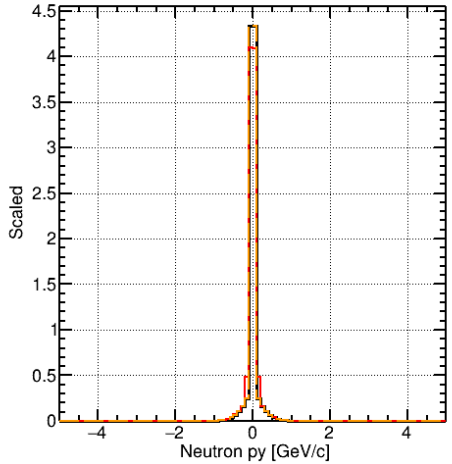
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

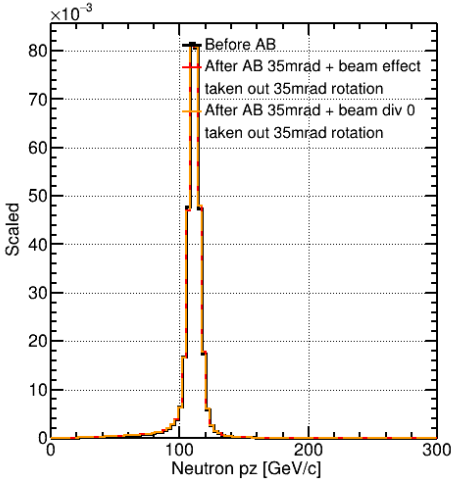








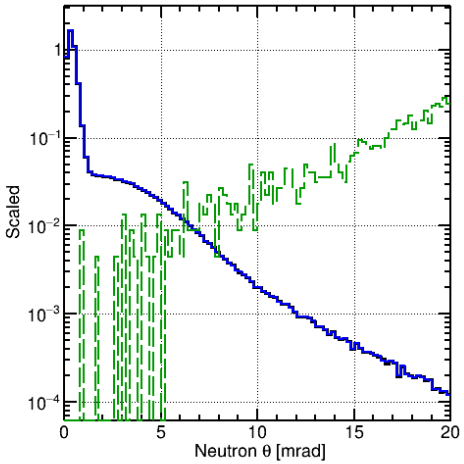


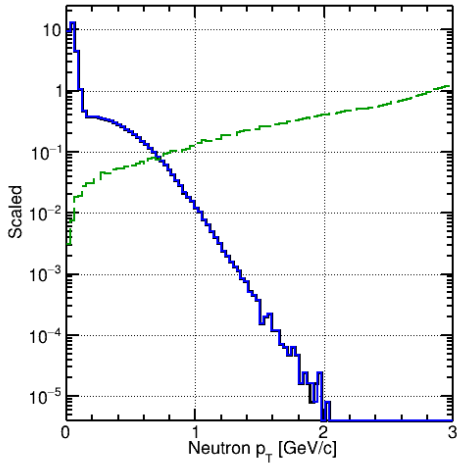


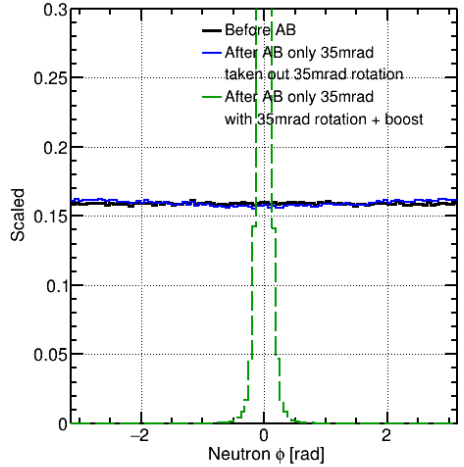
Normalized histograms by scaling by 1/integral and taking width into account

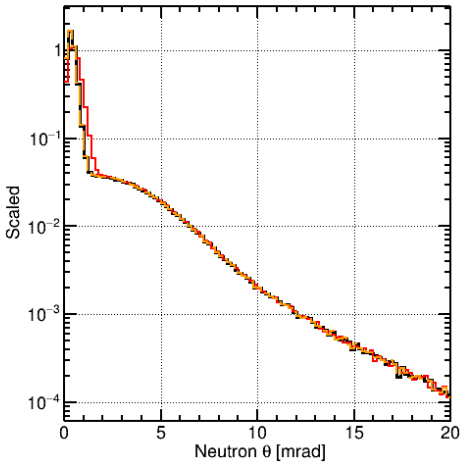
Neutrons: Before/After “afterburner”

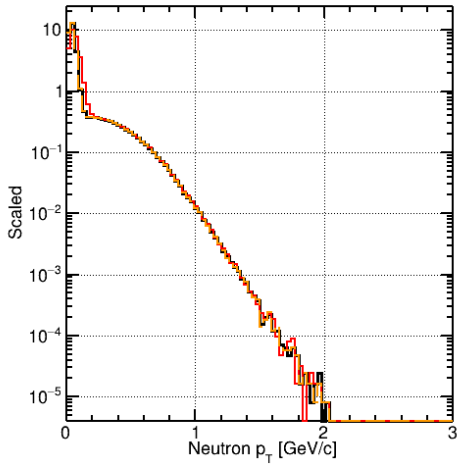
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

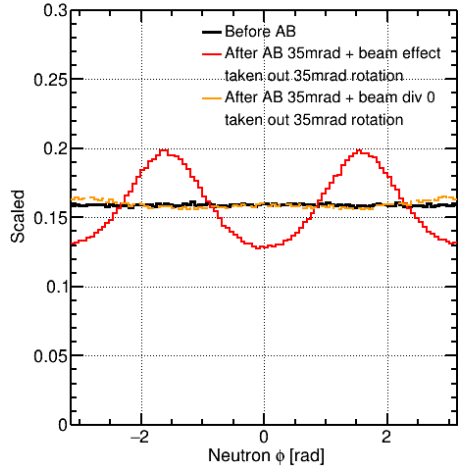












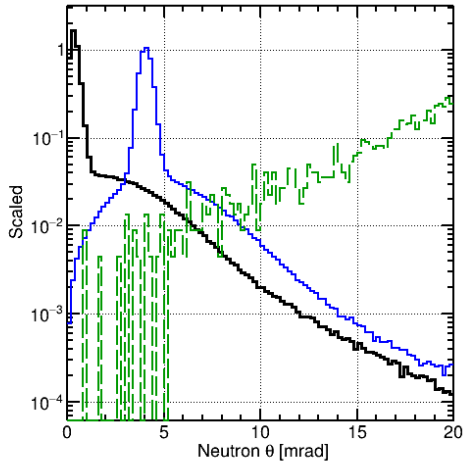
- Unlike proton distribution, **with beam divergence ON** (red distribution comparing to orange) **neutron azimuthal angle has some modulation.**

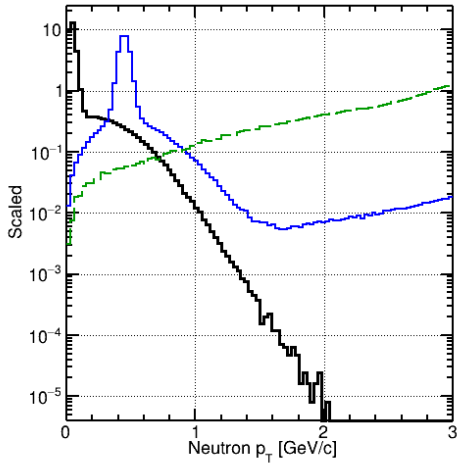
Normalized histograms by scaling by 1/integral and taking width into account

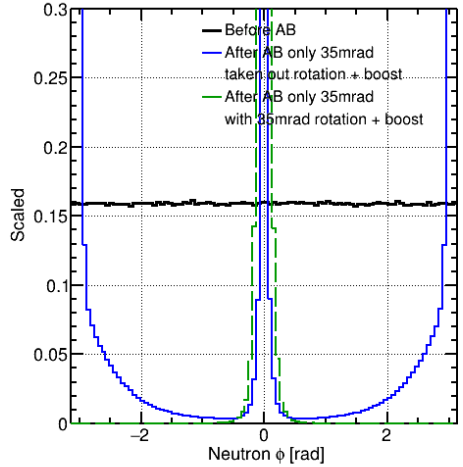
Blue taken out rotation + boost

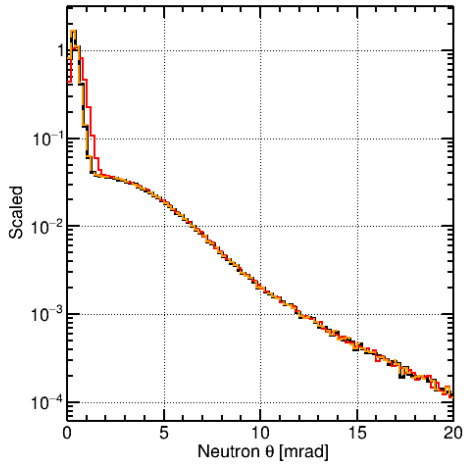
Neutrons: Before/After “afterburner”

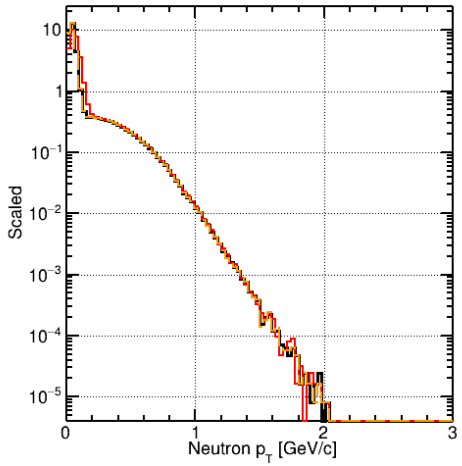
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

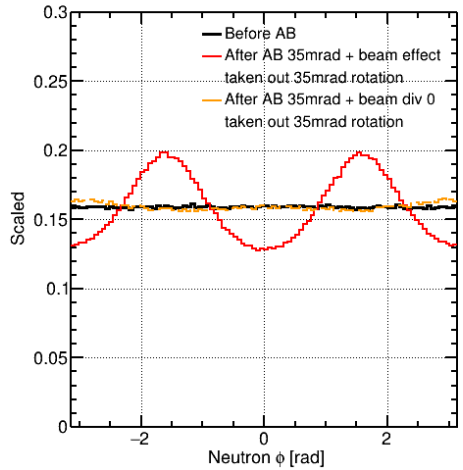








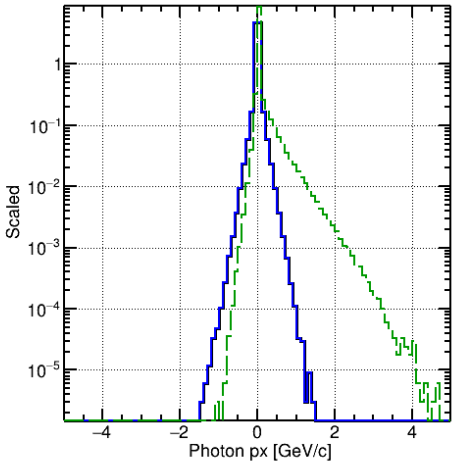


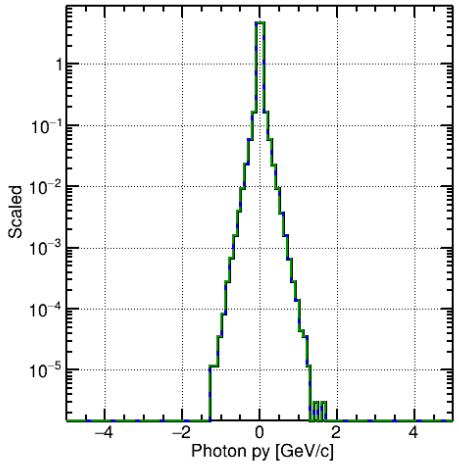


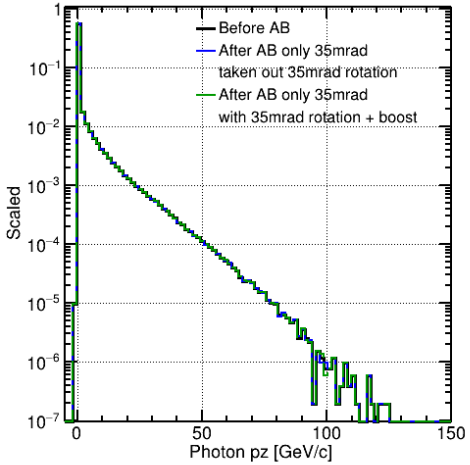
Normalized histograms by scaling by 1/integral and taking width into account

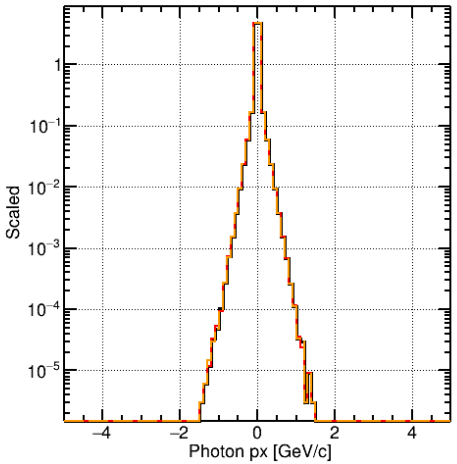
Photons: Before/After “afterburner”

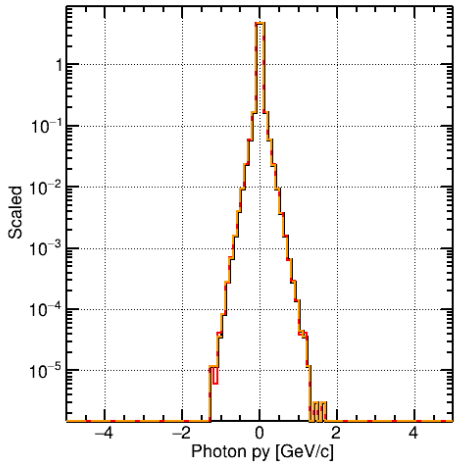
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

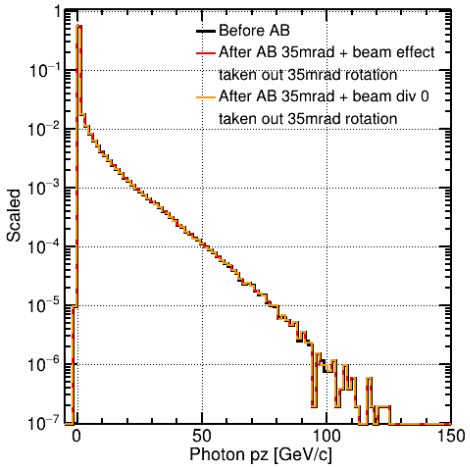










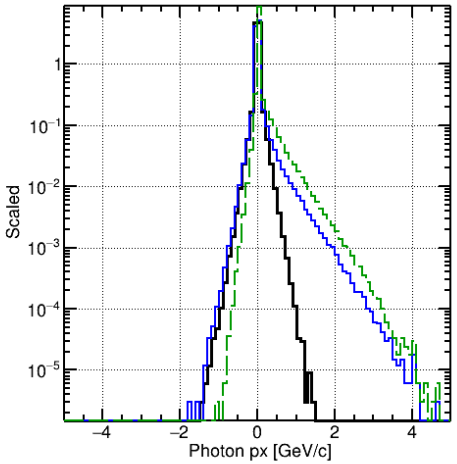


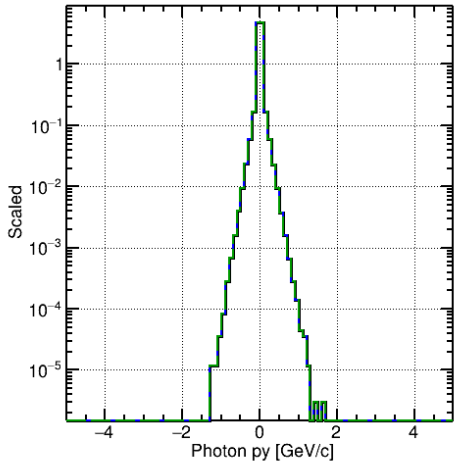
Normalized histograms by scaling by 1/integral and taking width into account

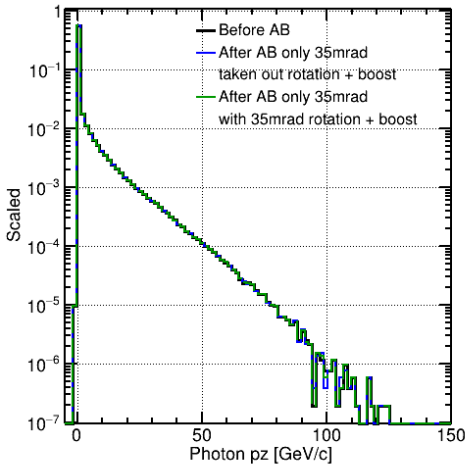
Blue taken out rotation + boost

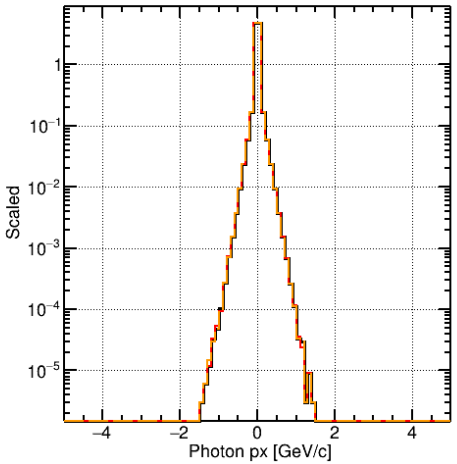
Photons: Before/After “afterburner”

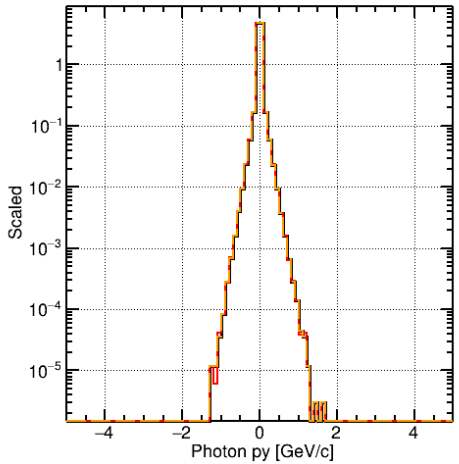
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

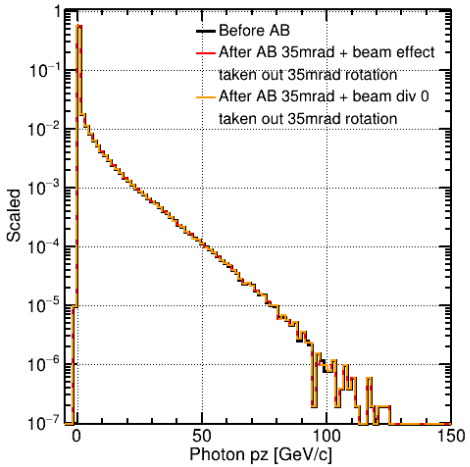








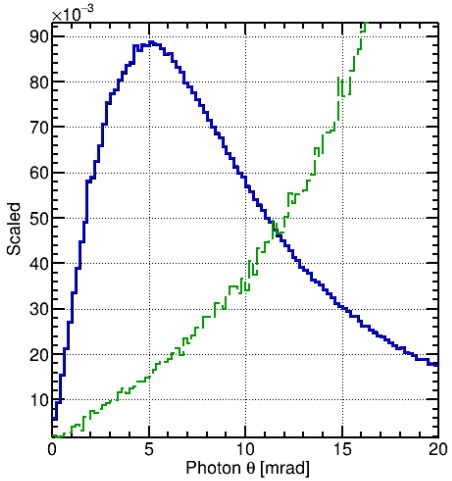


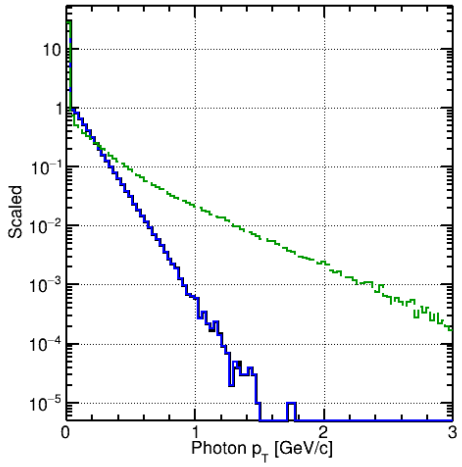


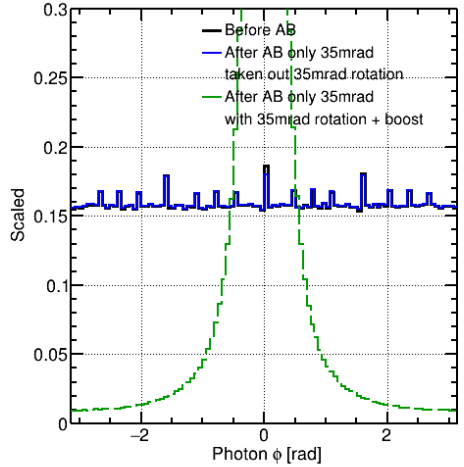
Normalized histograms by scaling by 1/integral and taking width into account

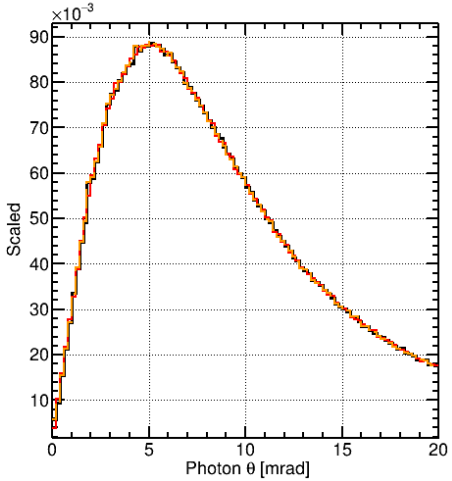
Photons: Before/After “afterburner”

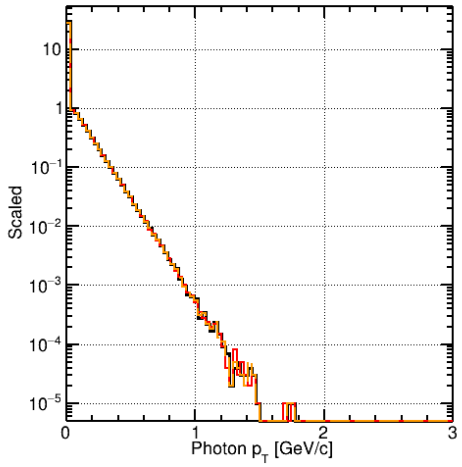
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

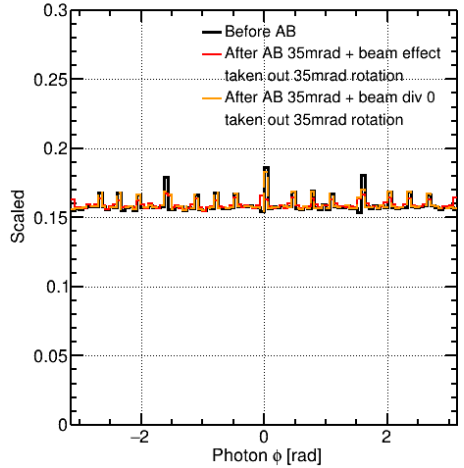










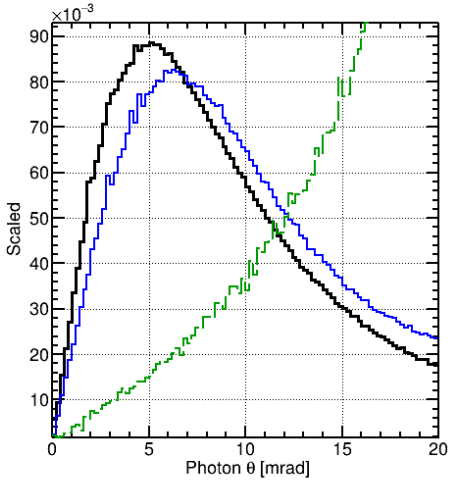


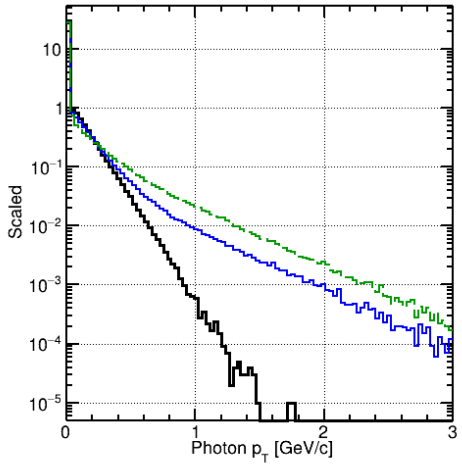
Normalized histograms by scaling by 1/integral and taking width into account

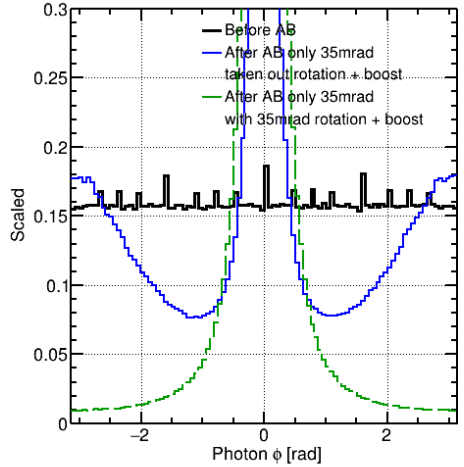
Blue taken out rotation + boost

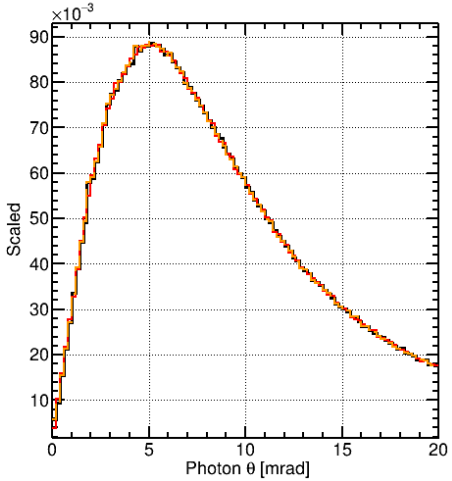
Photons: Before/After “afterburner”

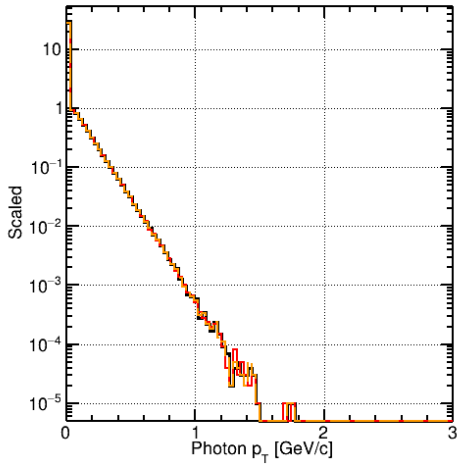
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

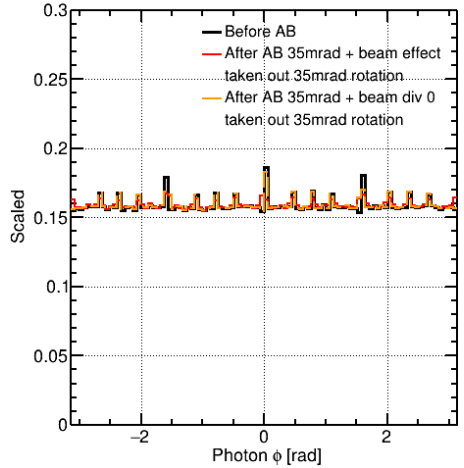










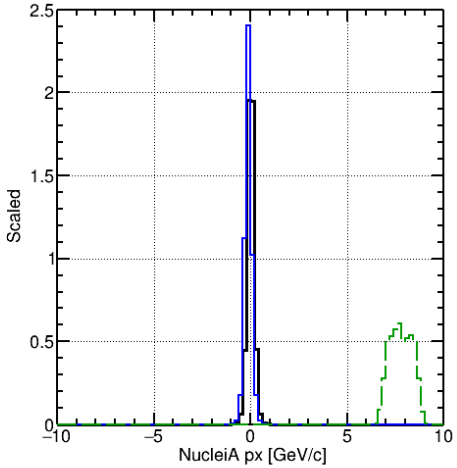


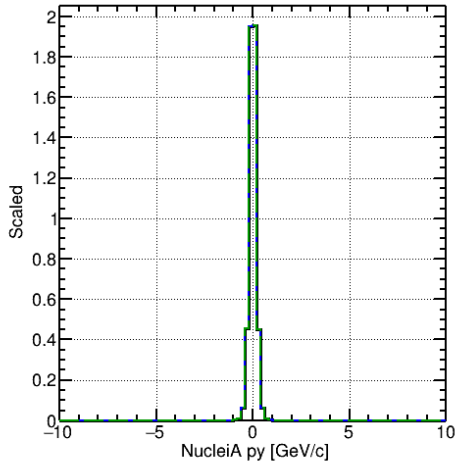
Normalized histograms by scaling by 1/integral and taking width into account

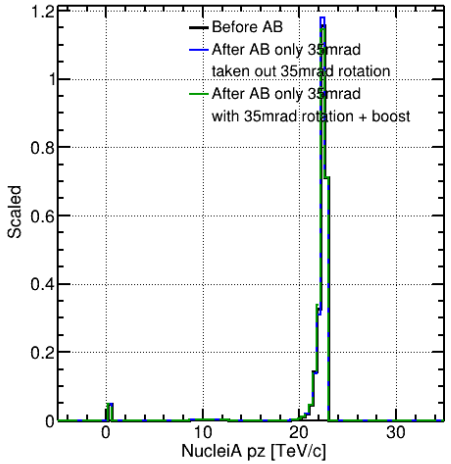
Fragments: Before/After “afterburner”

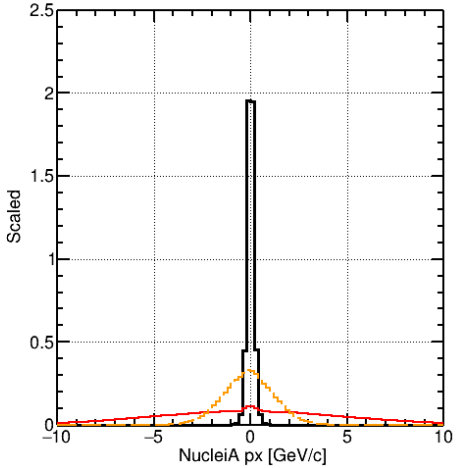
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

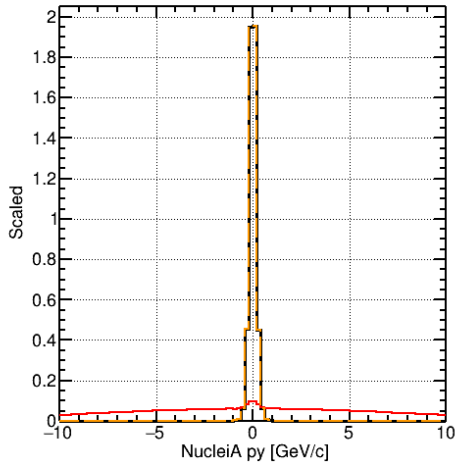
- From blue and green distributions, **p_x distribution has been smeared, but only they supposedly have boost (and rotation) effect(s).**
- From red distribution, **p_x and p_y are smeared a lot when all beam effect On. When turn OFF beam divergence** (orange distribution), **less smeared in p_x and matched to original in p_y.**

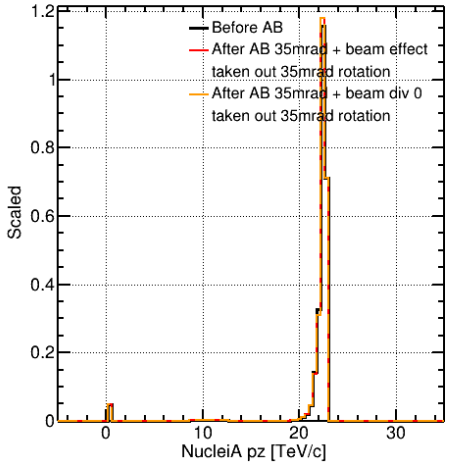










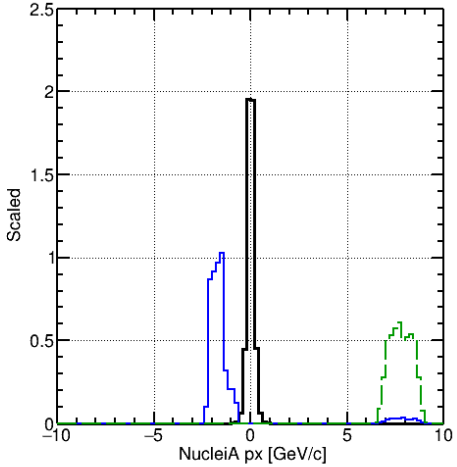


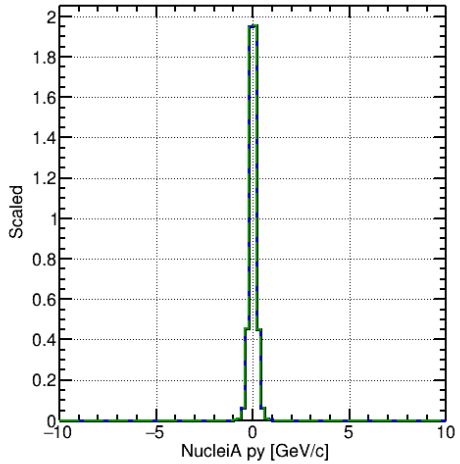
Normalized histograms by scaling by 1/integral and taking width into account

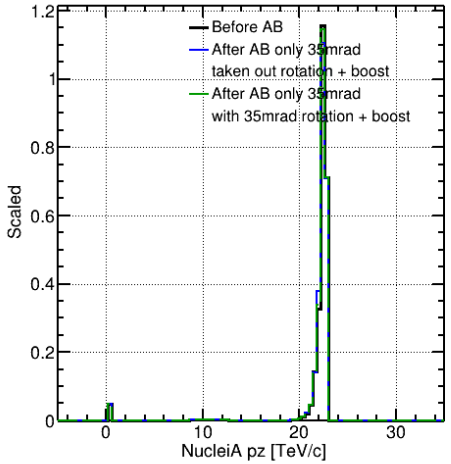
Blue taken out rotation + boost

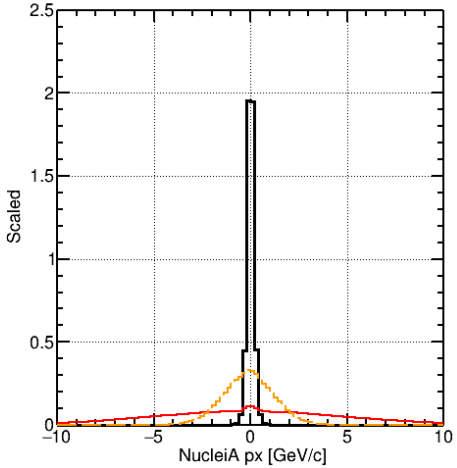
Fragments: Before/After “afterburner”

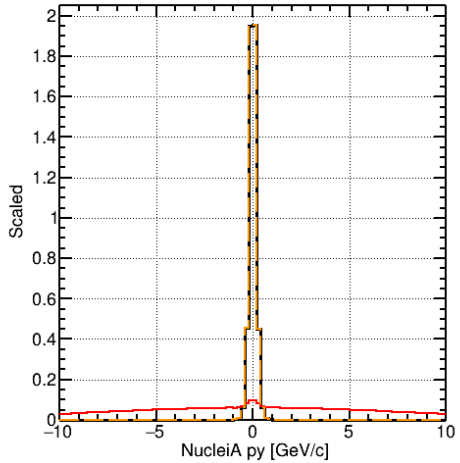
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

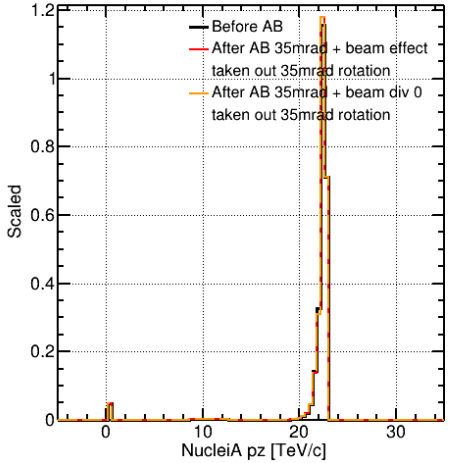








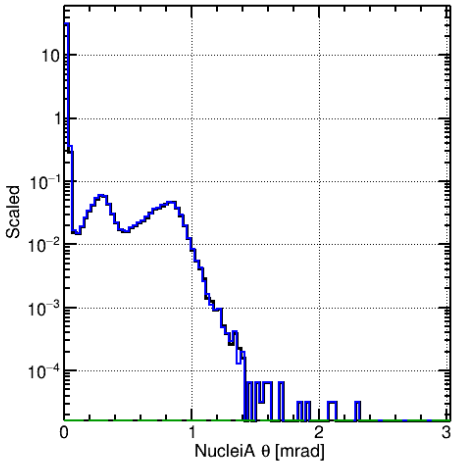


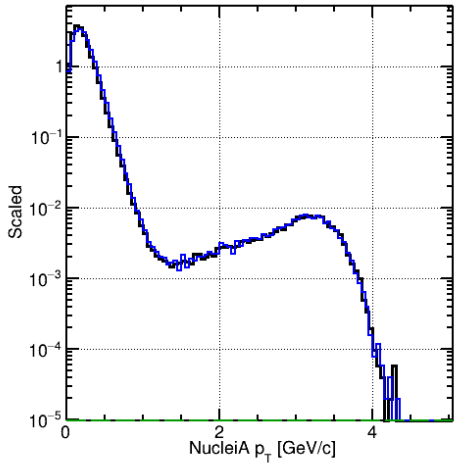


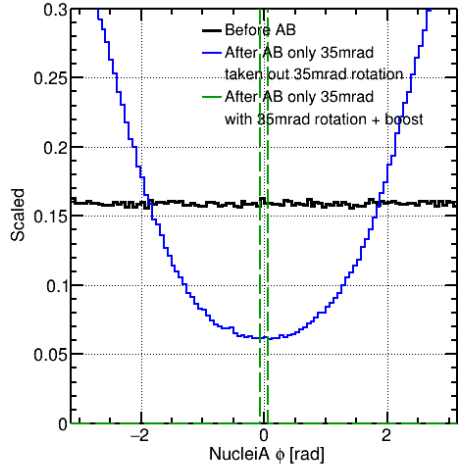
Normalized histograms by scaling by 1/integral and taking width into account

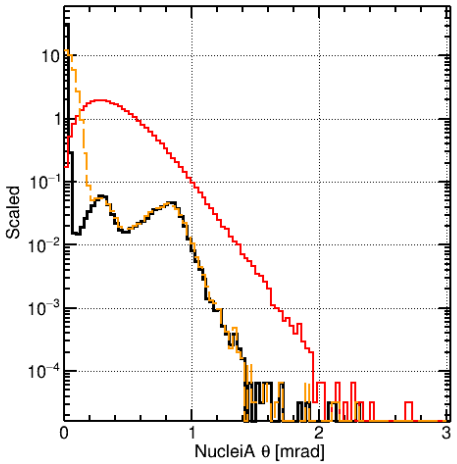
Fragments: Before/After “afterburner”

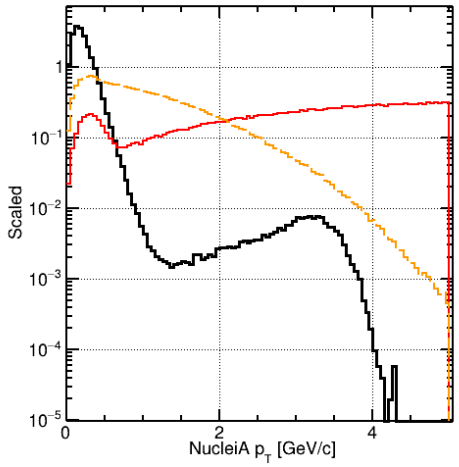
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

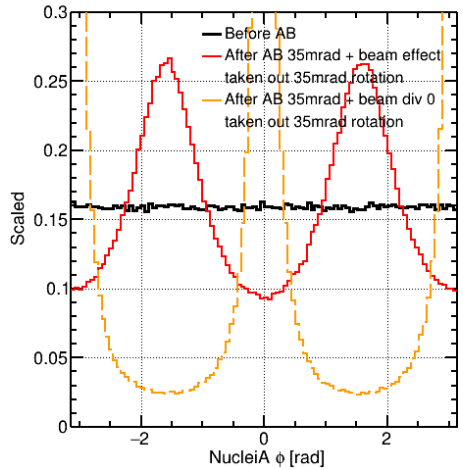










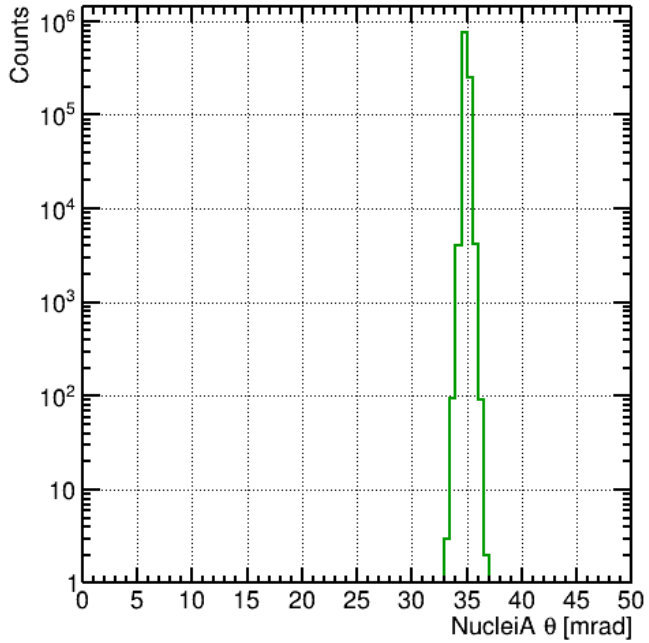


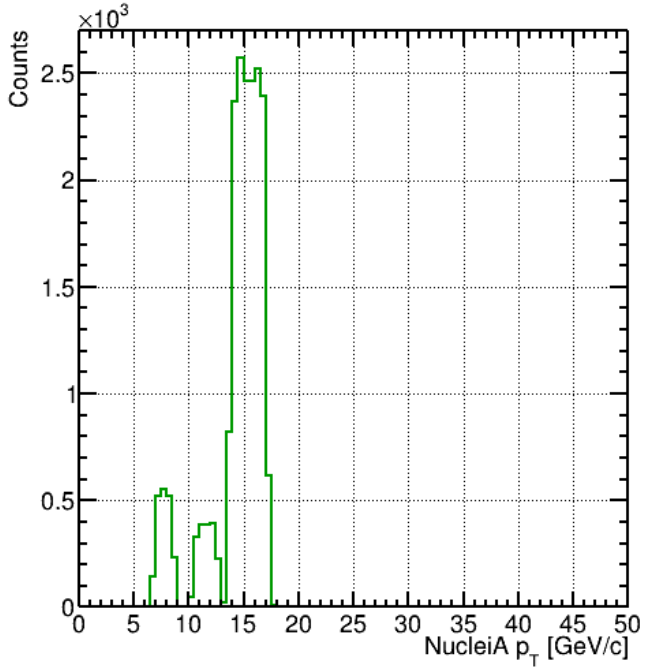
Normalized histograms by scaling by 1/integral and taking width into account

Fragments: Before/After “afterburner”

BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected 35 mrad)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

For sample with boost + crossing angle (green)
Out of scale in polar angle and transverse momentum

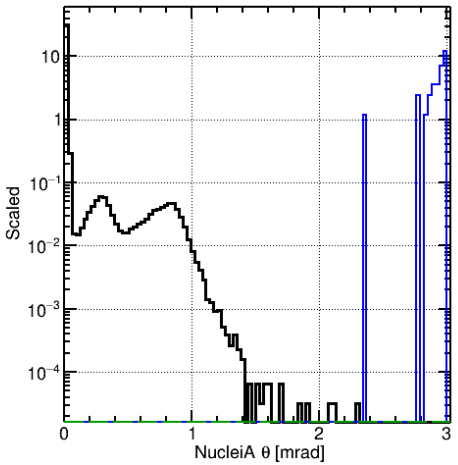


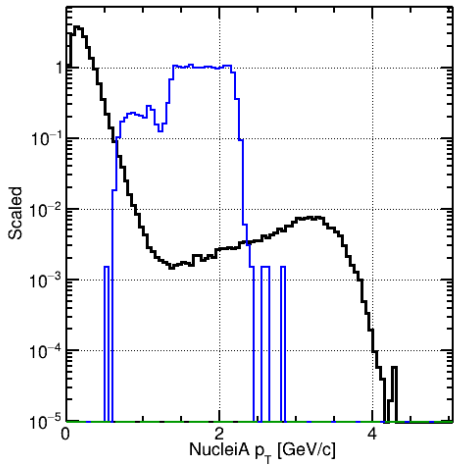


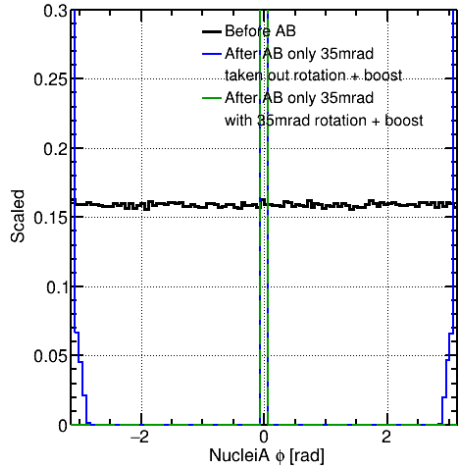
Blue taken out rotation + boost

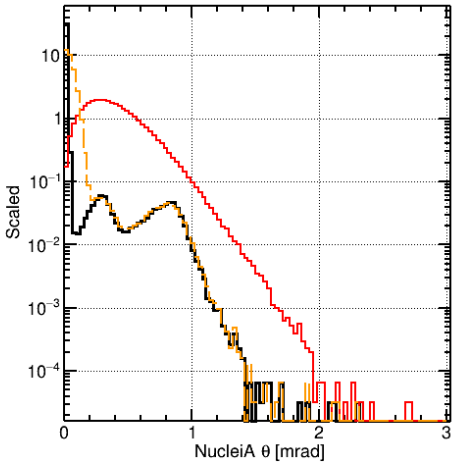
Fragments: Before/After “afterburner”

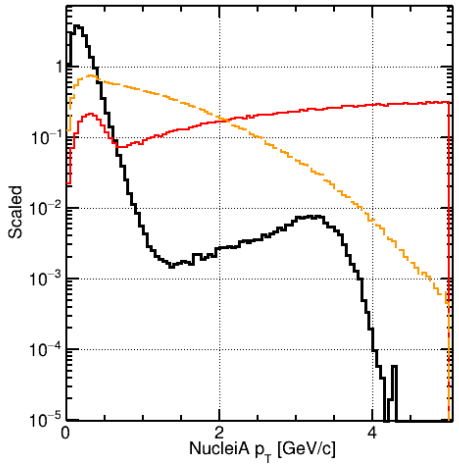
BeAGLE_eau_110x18
***ip8_eau_110x18_ca* (corrected rotation + boost)**
***ip8_eau_110x18_ca* (no correction)**
***ip8_eau_110x18* (corrected 35 mrad)**
***ip8_eau_110x18_bdiv0* (corrected 35 mrad)**

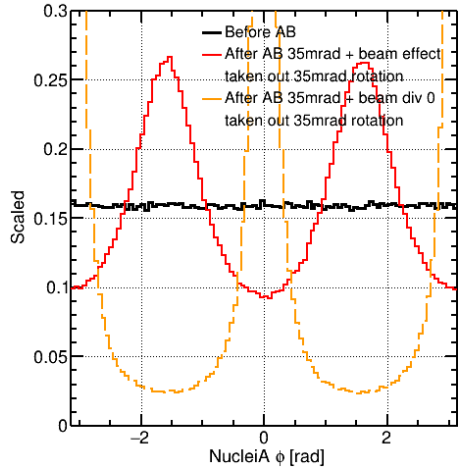












Normalized histograms by scaling by 1/integral and taking width into account

Summary

- Created a couple of configurations in afterburner to test
- Shown that t distribution matched after removing crossing angle for two samples (crossing angle only and crossing angle + beam effect)
  - Observed that “t invariant” in reconstruction using particles in central region
- Regarding each particle distribution
  - For scattered electron and vector meson, boost and rotation effects together (taken out) reflect on original particle distribution in central region
  - For final-state protons, neutrons, and photons, their distributions make sense except for some modulation in azimuthal angle for 35 mrad correction, however, with rotation and boost, then their distributions doesn’t make sense at all
  - For final-state nuclear remnants
    - For sample of only crossing angle effect, observed some smeared p_x and p_z and azimuthal angle became strange. Other than that, it looks reasonable
    - For crossing angle + beam effect, observed that too large smearing happens in p_x and p_y after beam effect and it relates to beam divergence at some level, but it cannot be entirely explained by that

Next Steps

- Take default ip8 setting (crossing angle + all beam effect: red distribution) and do correction on rotation and boost to see if red distribution reflects back to BeAGLE (before “afterburner”: black distribution) distribution
- For sample with correction on rotation and boost (final-state fragments)
  - Check why there are two grouping in and what makes correction is applied or not in terms of kinematics
- Regarding nuclear remnants
  - Varying other configuration variables from default setting (crossing angle + beam effect)
    - For instance, beam divergence only turn OFF, beam bunch turn OFF, …
  - However, it is hard to turn off all throughout ”afterburner” code (can be missing some)
  - Some toy model to understand each piece (with Alex and Brian)
  - Run PYTHIA8 with heavy-ion collisions (ex. ^{208}Pb incoming beams) would help?

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