Nonlinear Beam Optics + Wedge Update

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Analysis Meeting

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Fermilab

MICE

Objectives and Method

- Objectives:

– Nonlinear beam optics can lead to apparent emittance growth → Direct phase space volume measurement as a work-around.

– Induce mismatch in the beam and compare the RMS emittance with Kernel-based phase-space density and volume.

- Method:

– Input beam generated using MAUS and handed over to G4beamline.

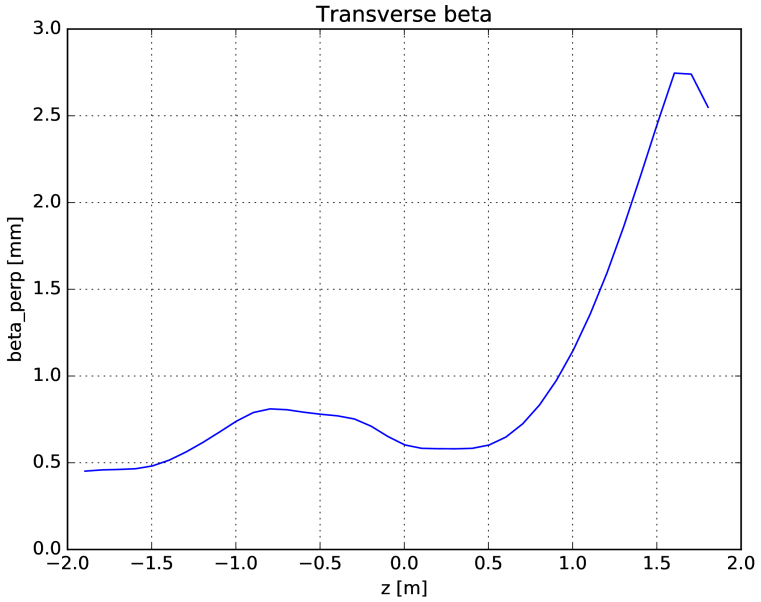
– Initial beam setting is (6, 200) → large initial emittance to ensure emittance growth. Only SSD in ECE setting and all solenoidal fields scaled to 3T.

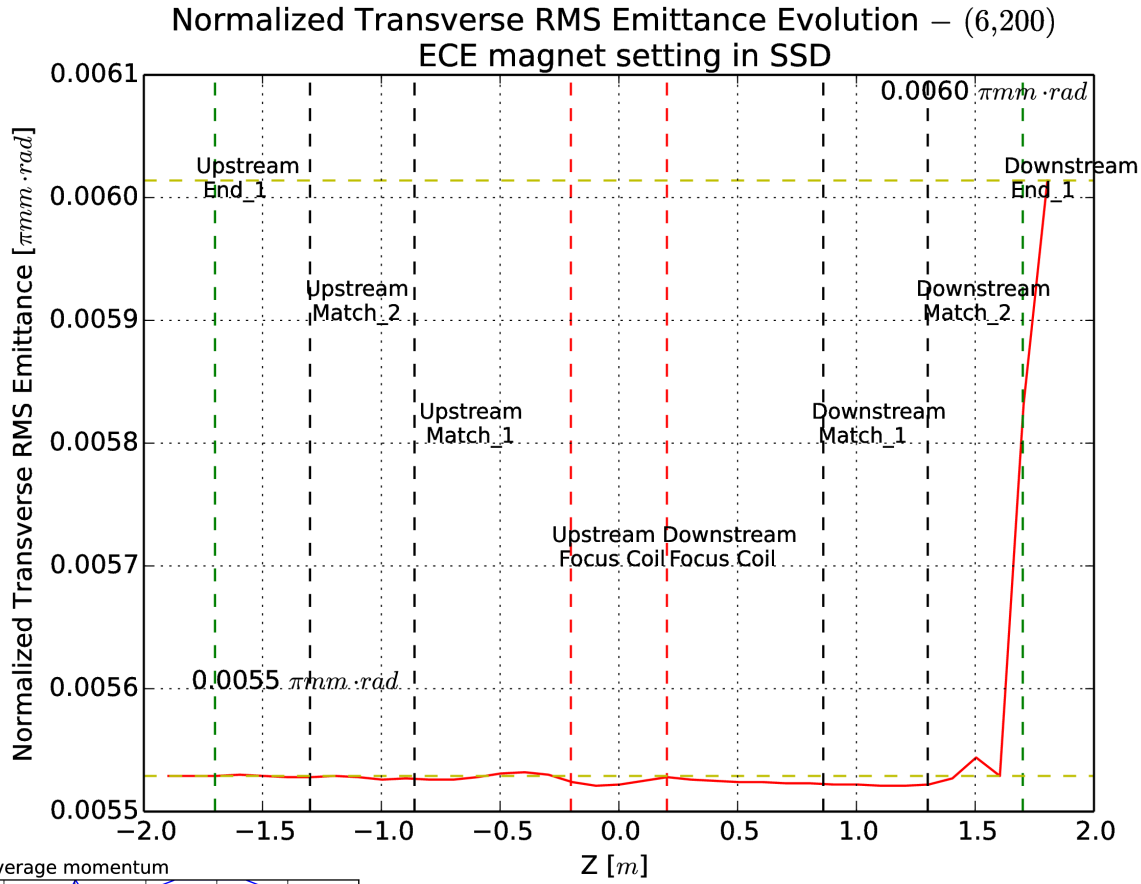
– Empty absorber channel – removed tracker scintillators to avoid energy loss + turned off all energy loss and stochastic processes.

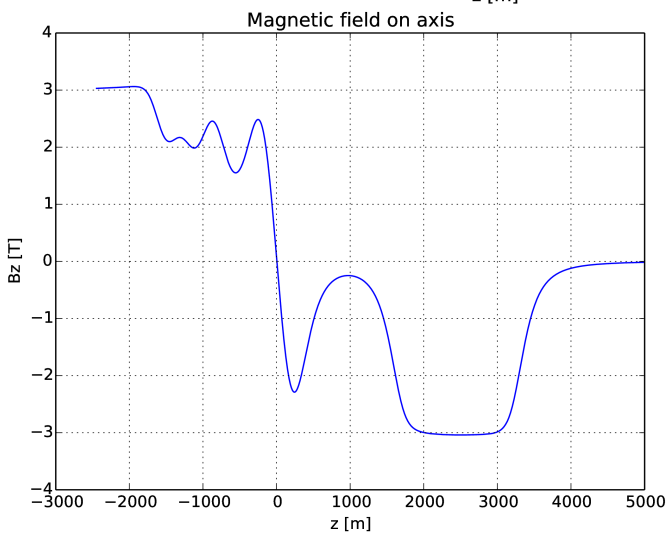
– Computed Kernel-based density and volume one contour at a time and studied their evolutions in the cooling channel → hunted down the different contours by specifying their enclosed number of muons.

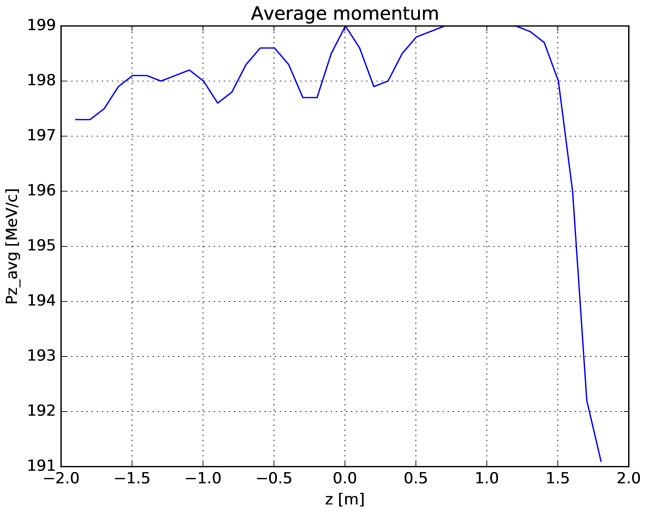
Twiss Parameters + Emittance Evolution

- Substantial beam size growth after beam passes through the disabled match coils in SSD.
- Emittance growth of ~9% from US to DS.





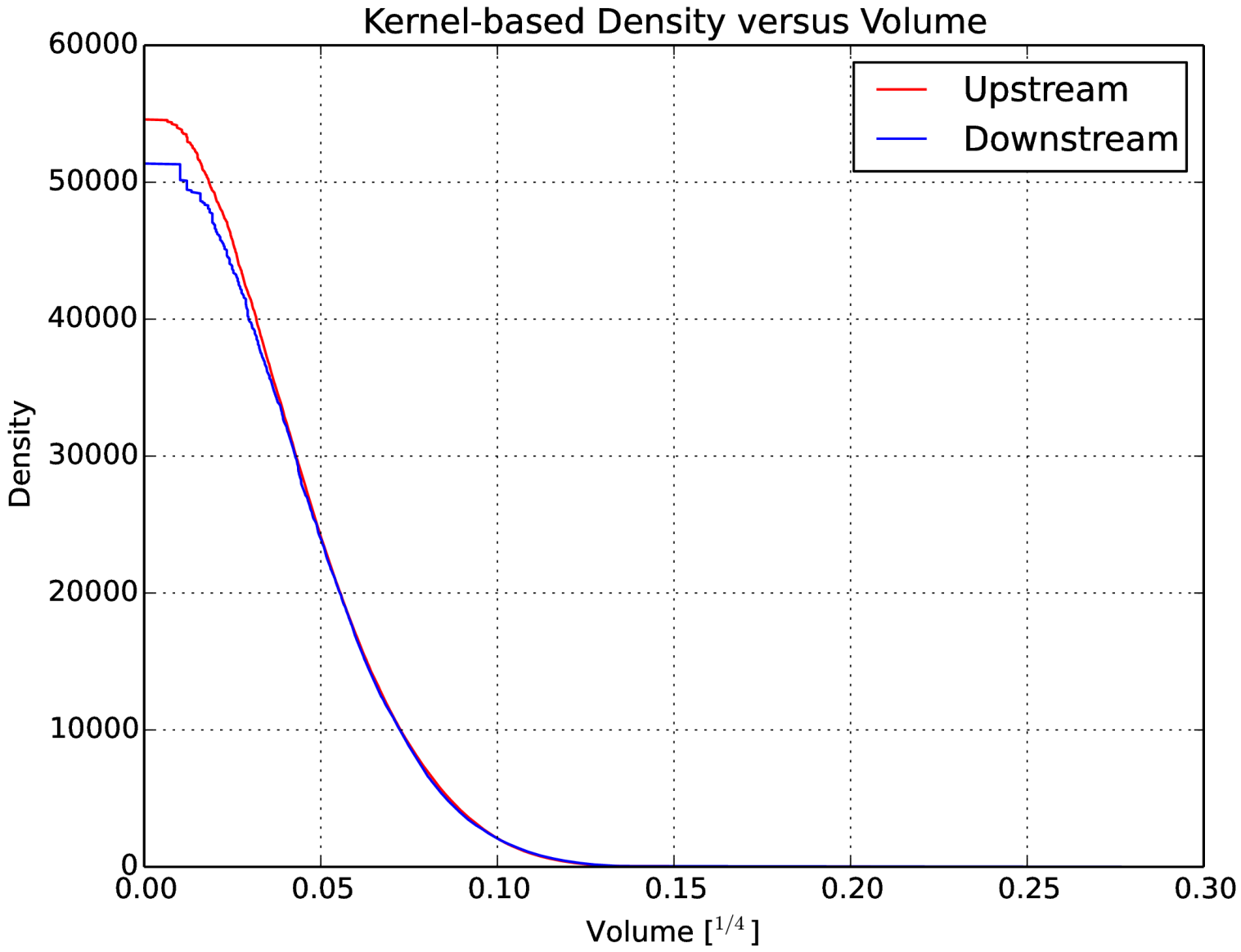




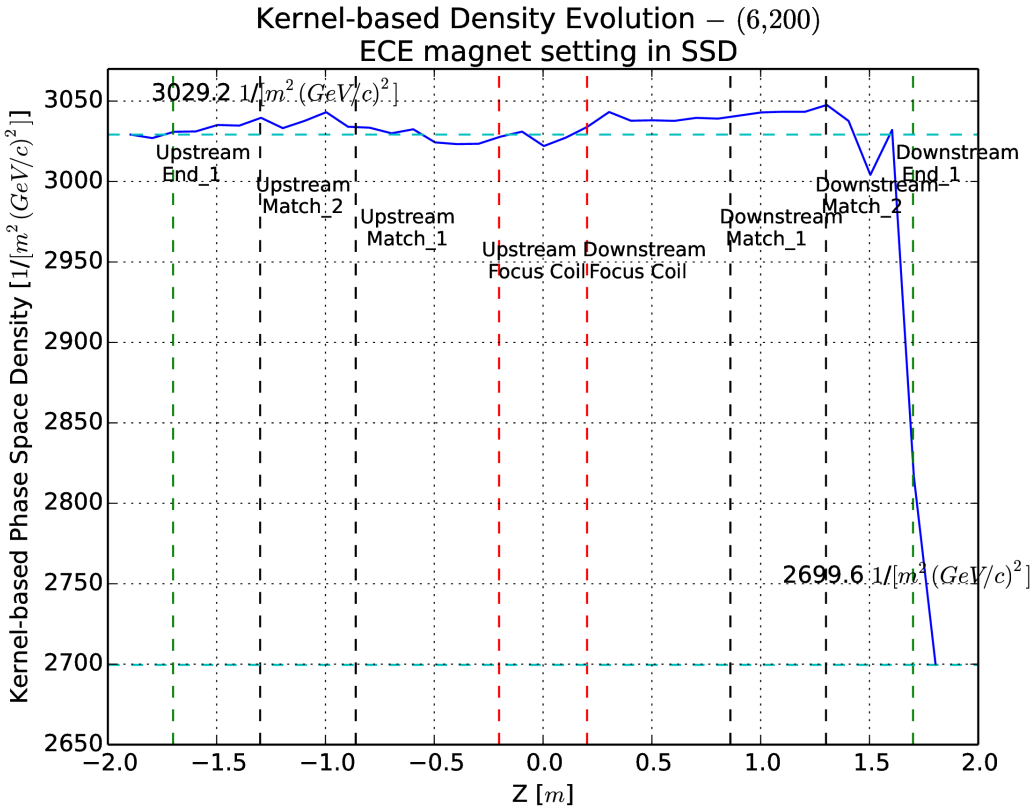
- Applied good muon cut (~500 muons do not make it to DS TRPs).
- Reminder: Only SSD in ECE setting and all solenoidal fields scaled to 3T.

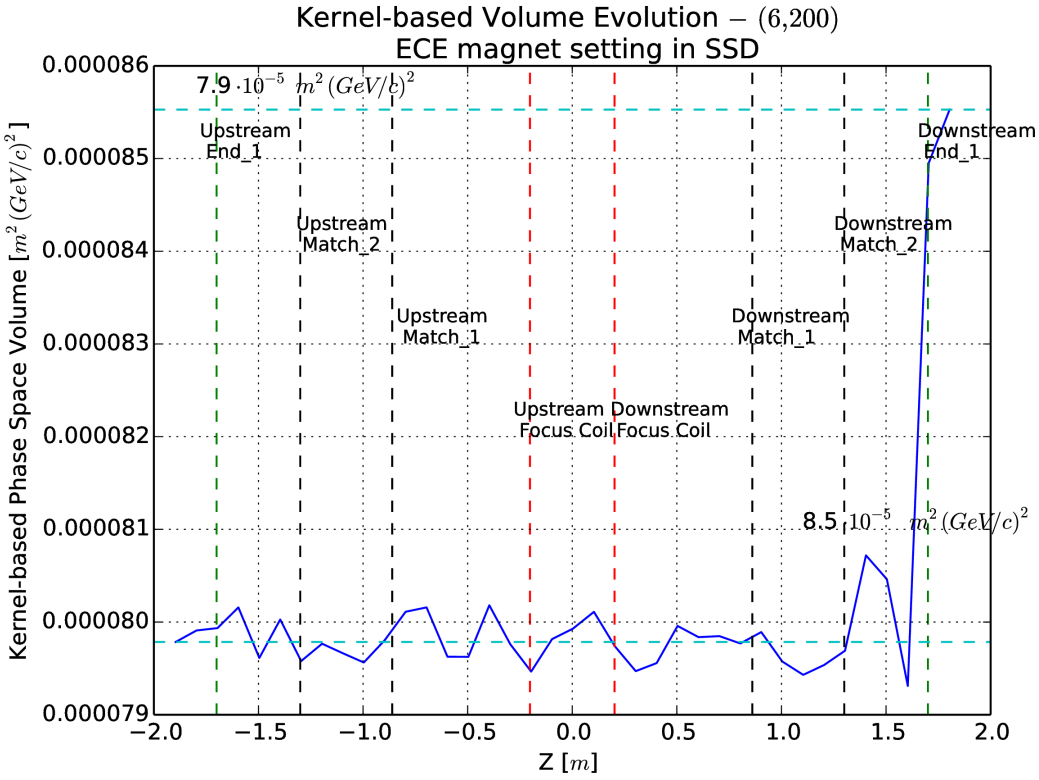
Routine Check – Kernel-based Density Vs. Volume

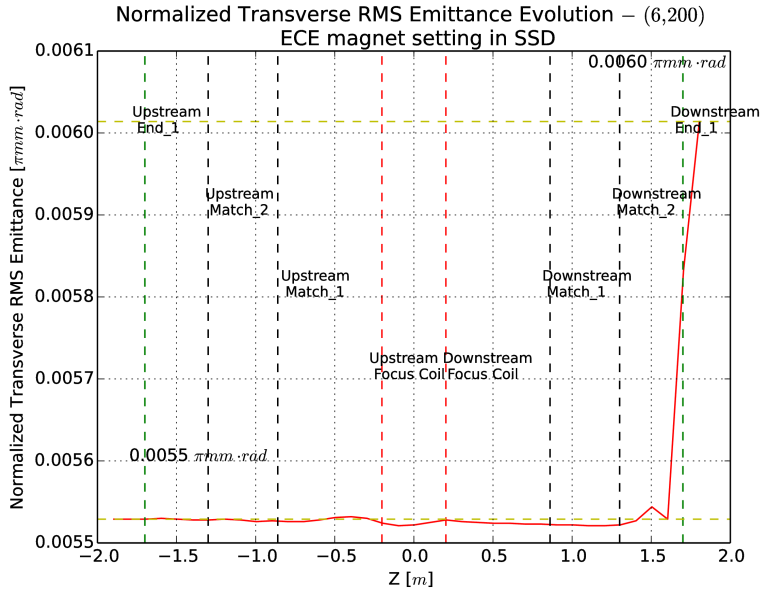
- Checking density versus volume at the US and DS TRPs. Same run settings as slides 2 and 3.
- Previous analysis was always on contour enclosing 9% of all muons – slides that follow look at density and volume of three different contours.
- For the same volume, the density should not change → but there is apparent heating closer to the core of the beam.



Kernel-based Density and Volume - 90% Contour Evolution

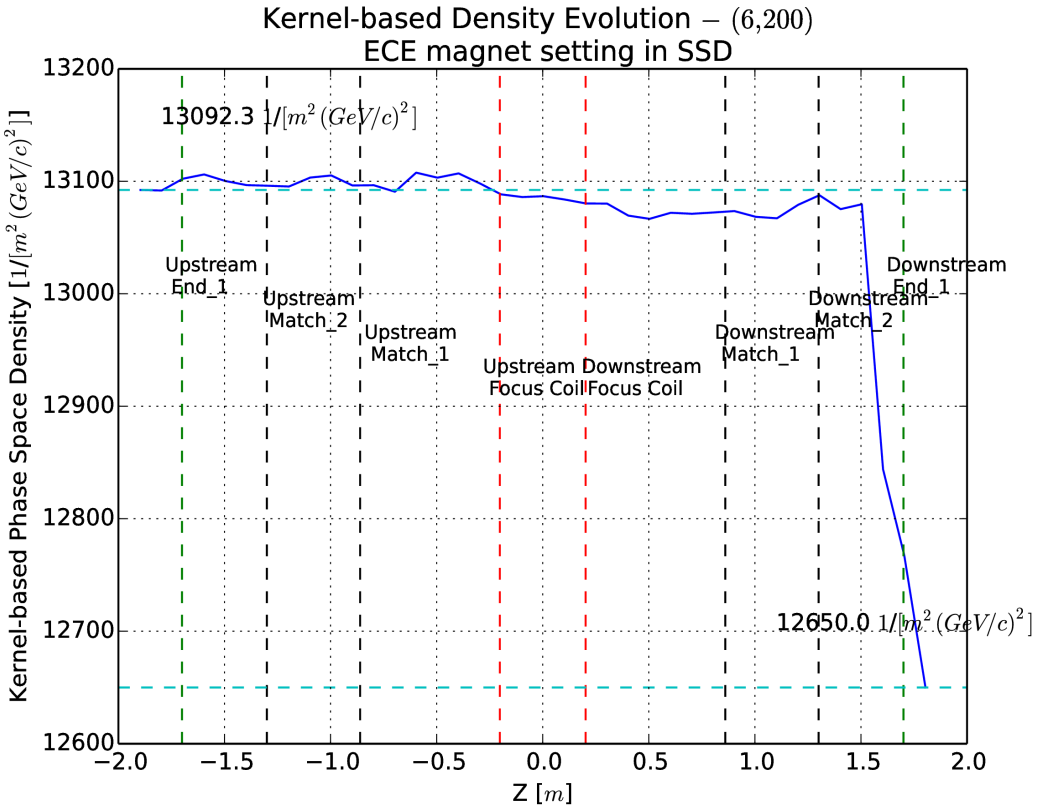


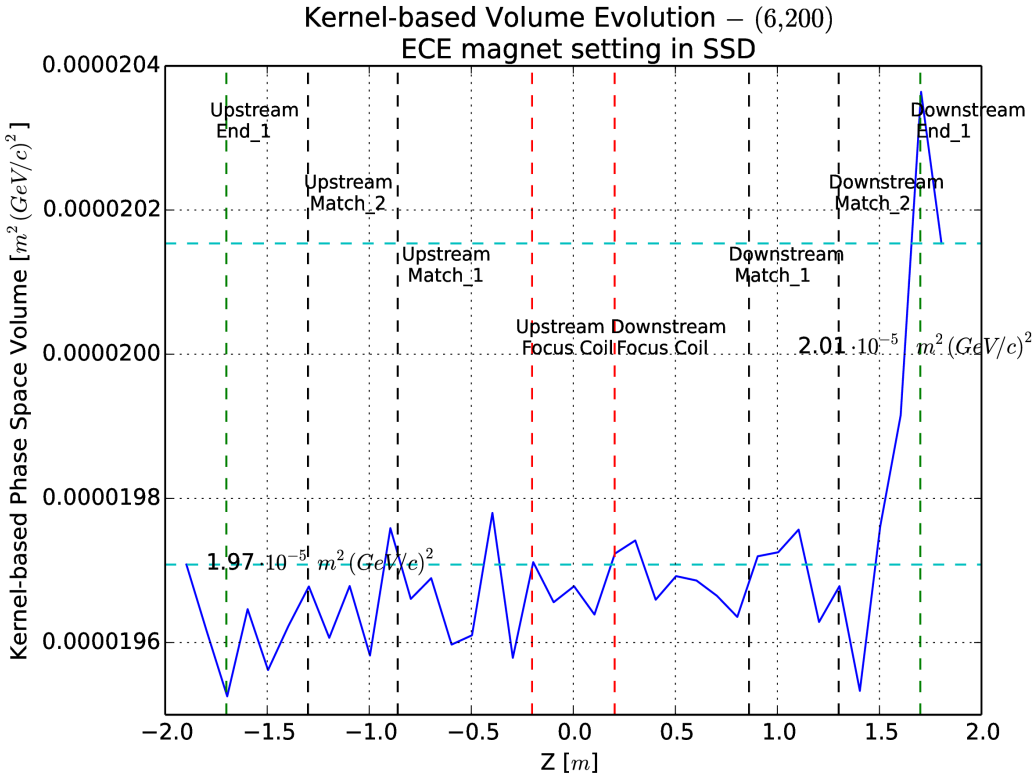


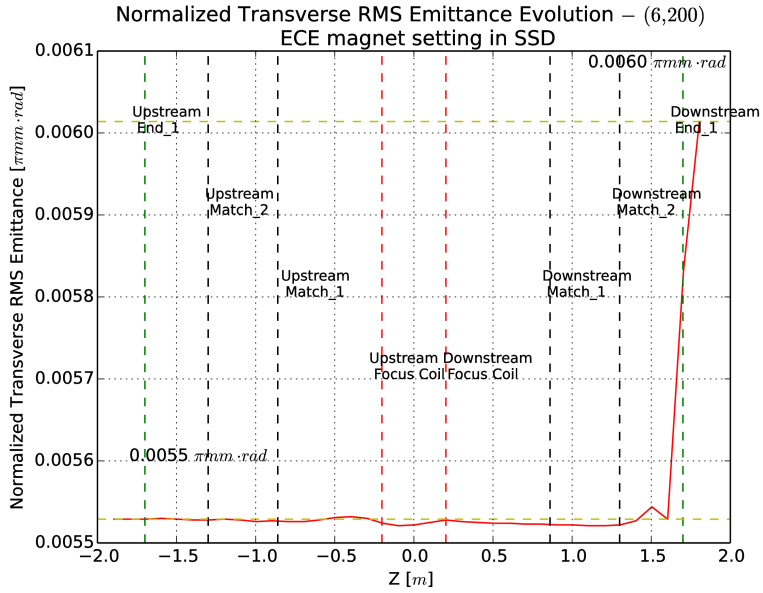


- Computed Kernel-based density and volume for the contour enclosing 90% of total muon.
- Density drops by ~12% and volume grows by ~7.5%.
- Measurement fluctuations are present. Expected for volume as its measurement relies on MC approach.
- Standard deviations in density and volume: 89 and 1.4e-06.

Kernel-based Density and Volume - 50% Contour Evolution

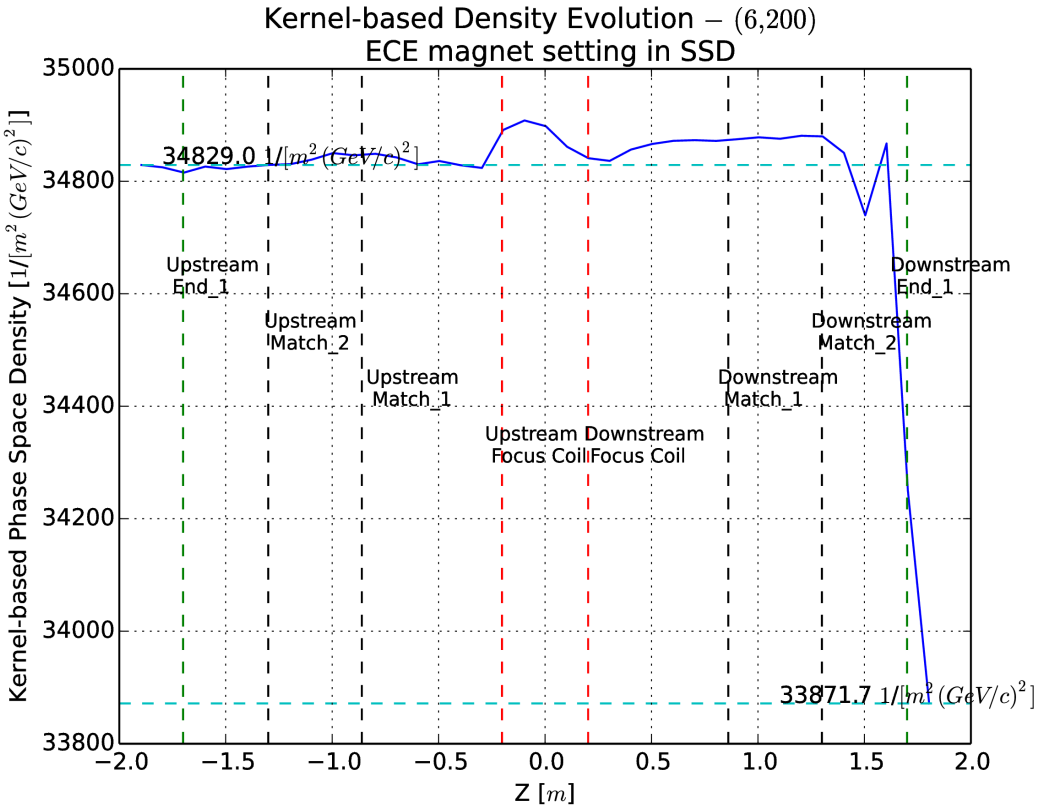


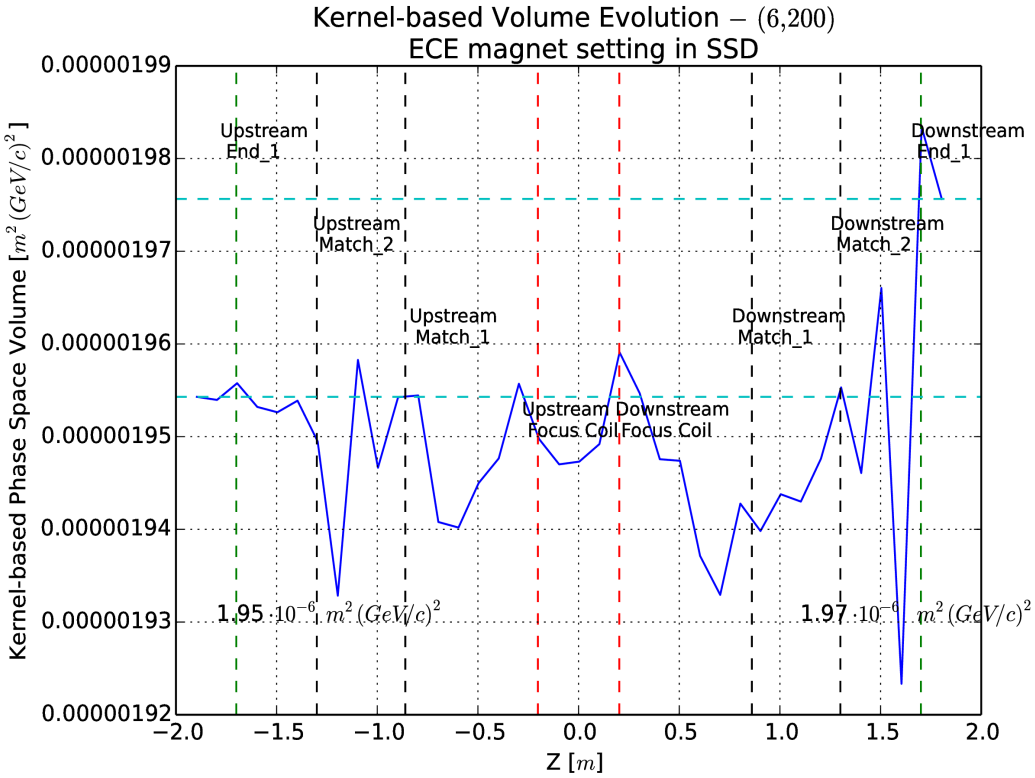


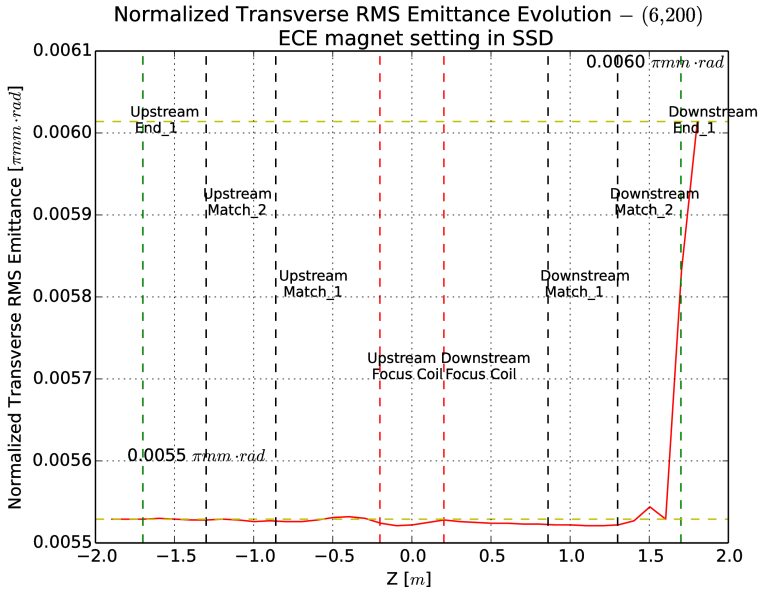


- Computed Kernel-based density and volume for the contour enclosing 50% of total muon.
- Density drops by ~3% and volume grows by ~2.0%.
- Measurement fluctuations are present. Expected for volume as its measurement relies on MC approach.
- Standard deviations in density and volume: 93.6 and 1.5e-07.

Kernel-based Density and Volume - 10% Contour Evolution



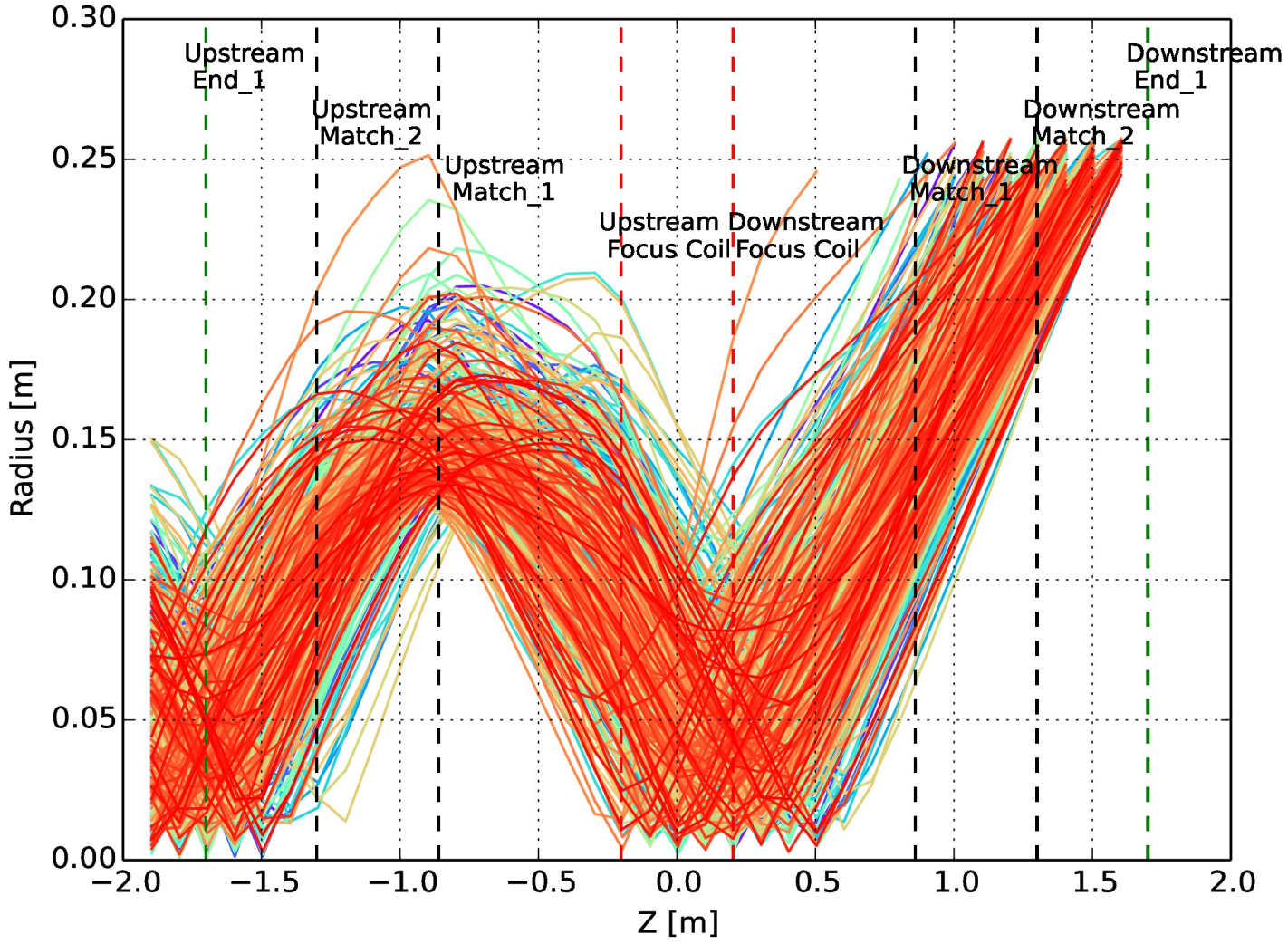




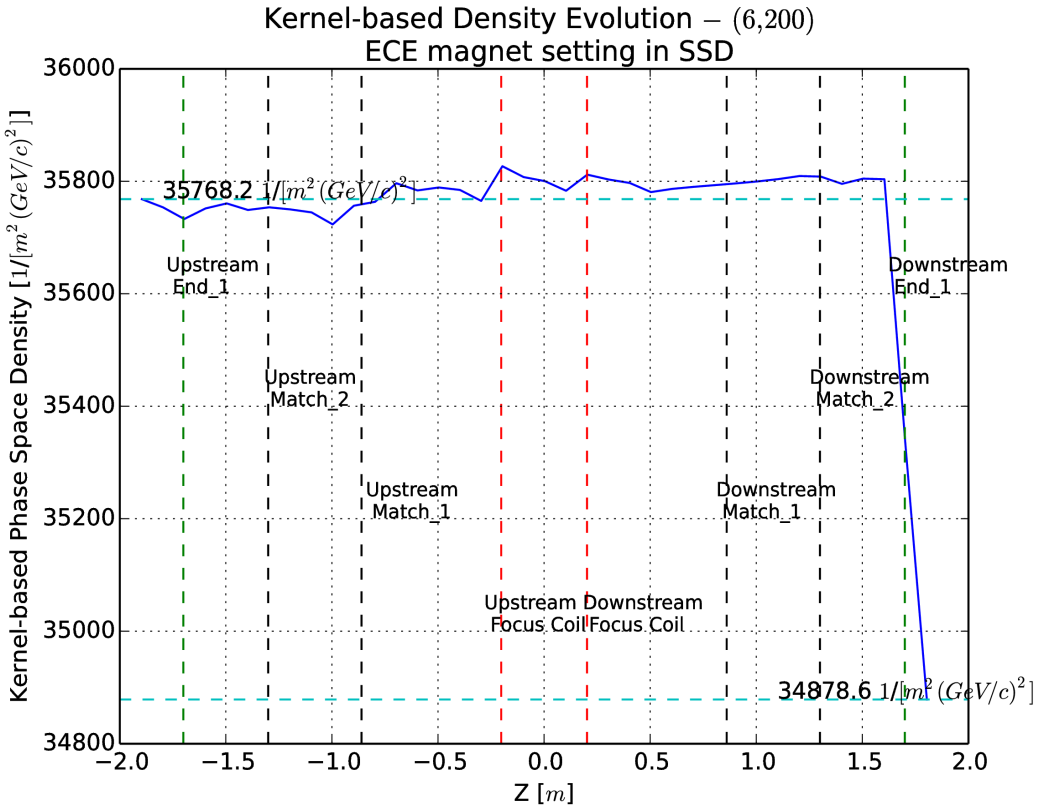
- Computed Kernel-based density and volume for the contour enclosing 10% of total muon.
- Density drops by ~2.7% and volume grows by ~1.0%.
- Measurement fluctuations are present. Expected for volume as its measurement relies on MC approach.
- Standard deviations in density and volume: 295.2 and 1.31e-08.

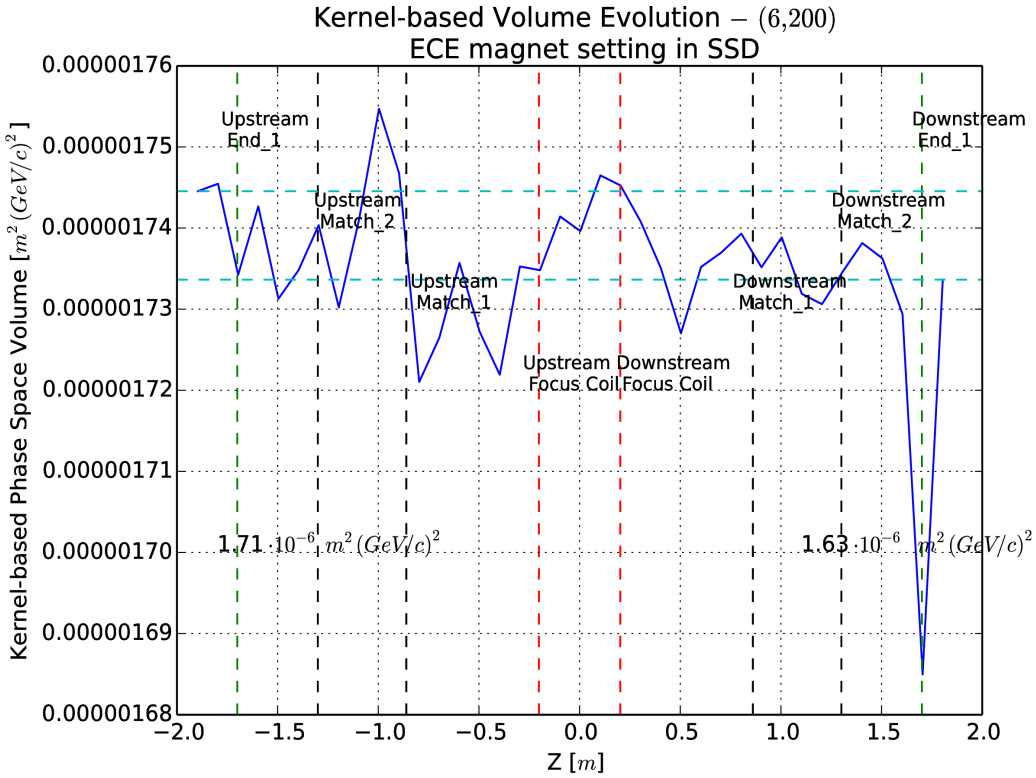
On-going Studies - Good Muons Cut Bias

- Cuts applied to discard muons lost from US to DS TRPs may introduce biases on KDE measurements. The idea is to compare the current setting's volume and density with a perfect transmission case.
- Radial profile of lost muons vs. z below → suggests that lost muons are scraping muons.

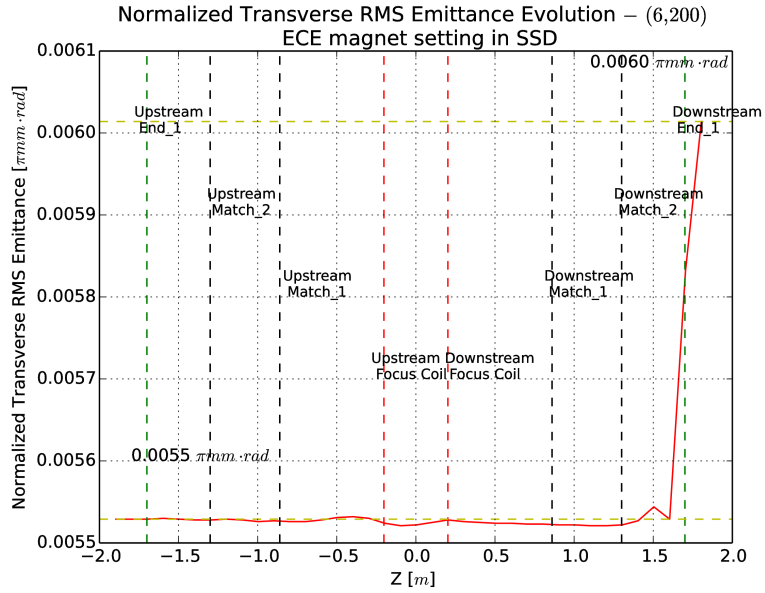


Before - (6, 200) with SSD in ECE – ~95% Transmission

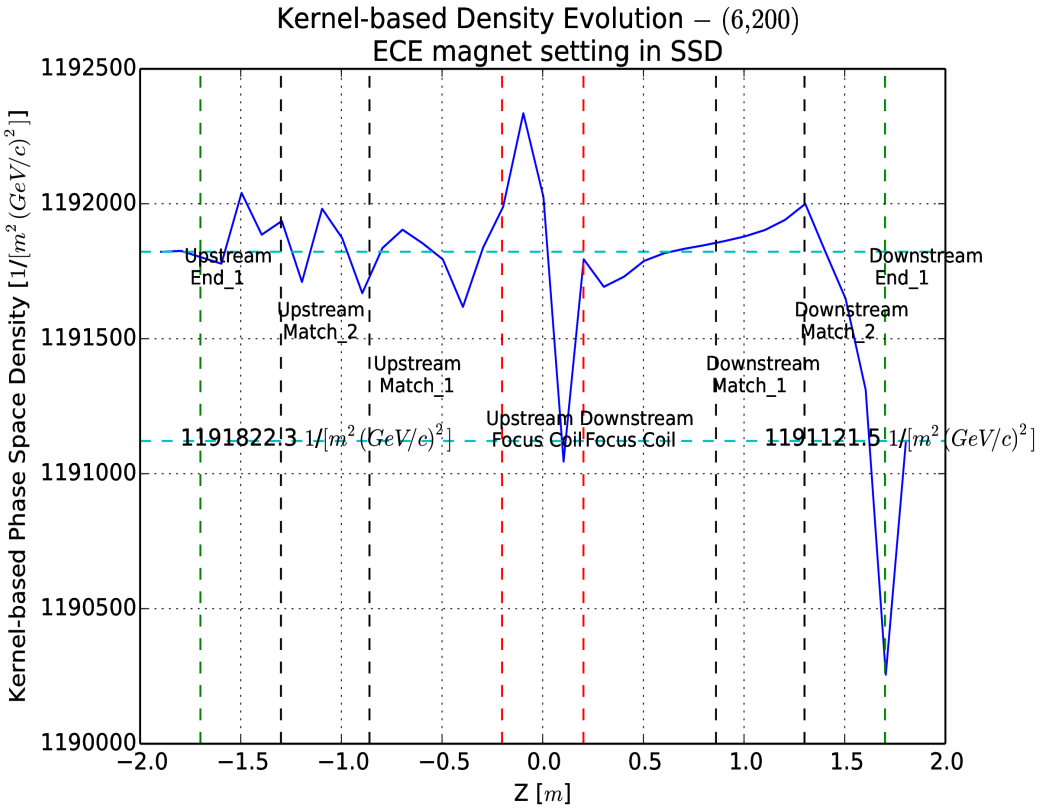


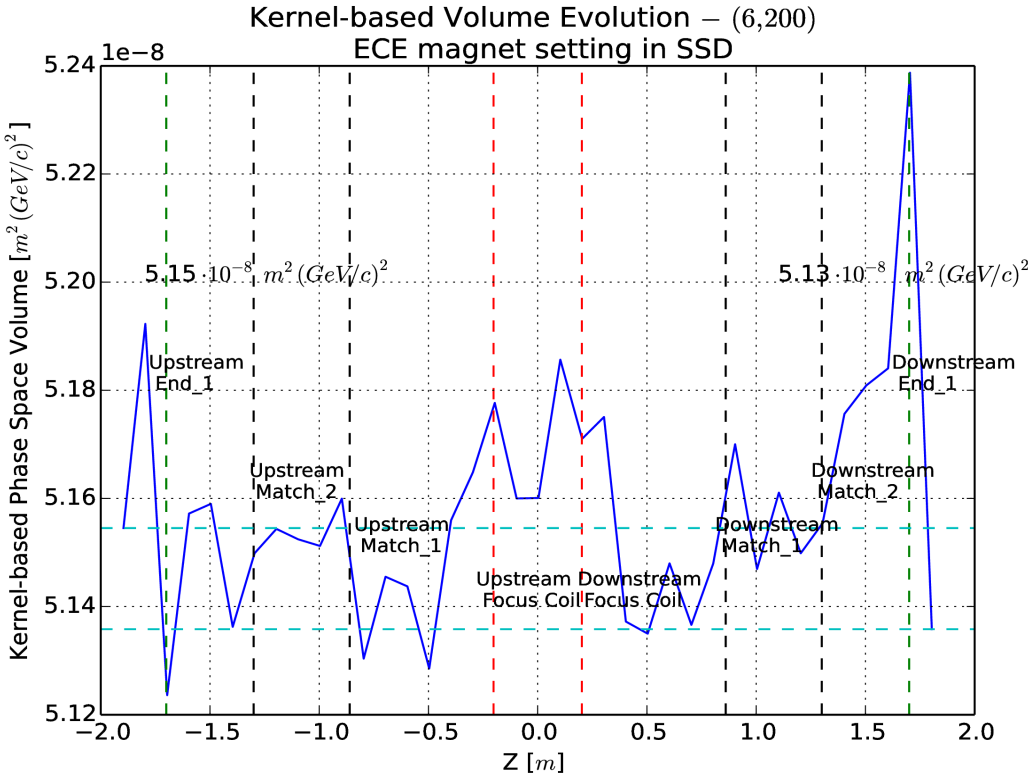


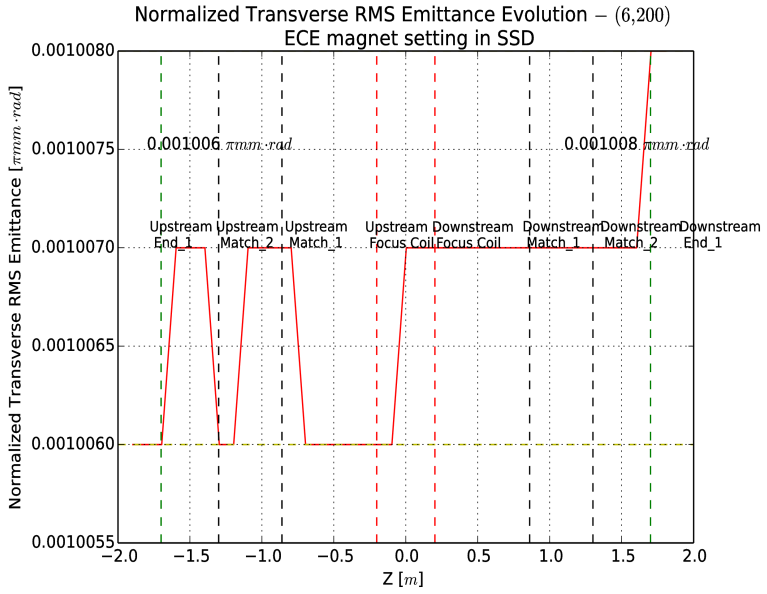
- Computed Kernel-based density and volume for the contour enclosing **9%** of total muon.
- If bias is present, a run with 100% transmission should give 'better' Kernel-based volume and density measurement.
- Density drops by ~2.5% and volume grows by ~5.0%.
- Standard deviations in density and volume: 273.7 and 1.2e-08.



After - (1, 200) with SSD in ECE – 100% Transmission

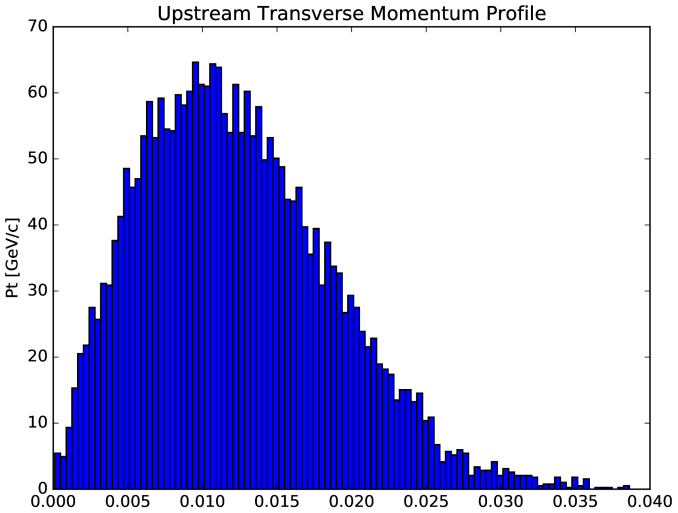


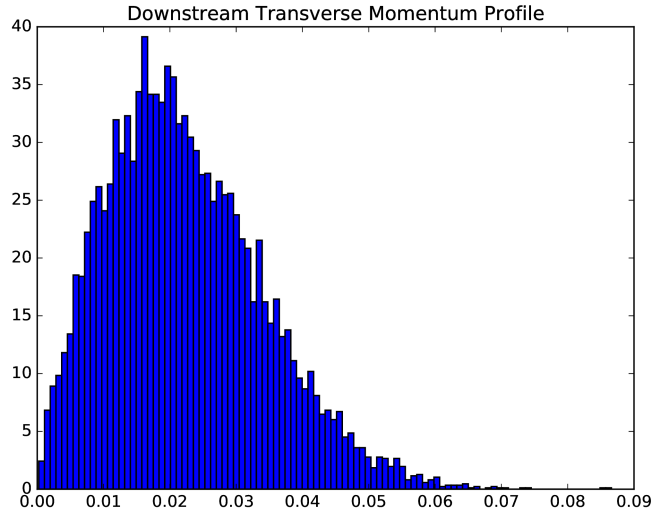


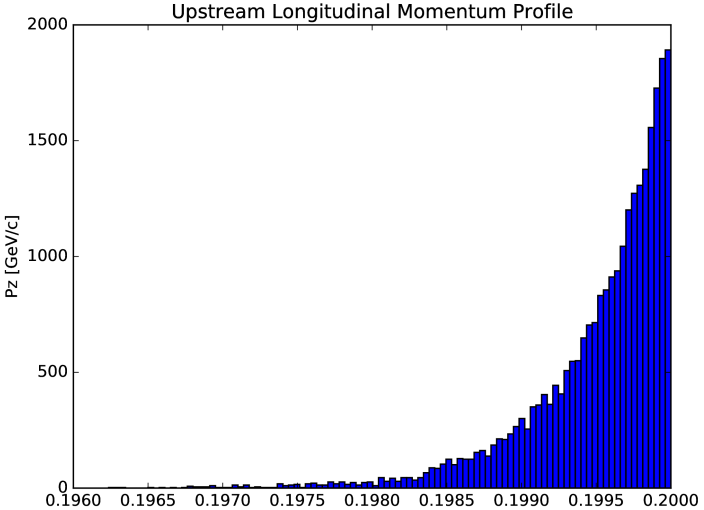


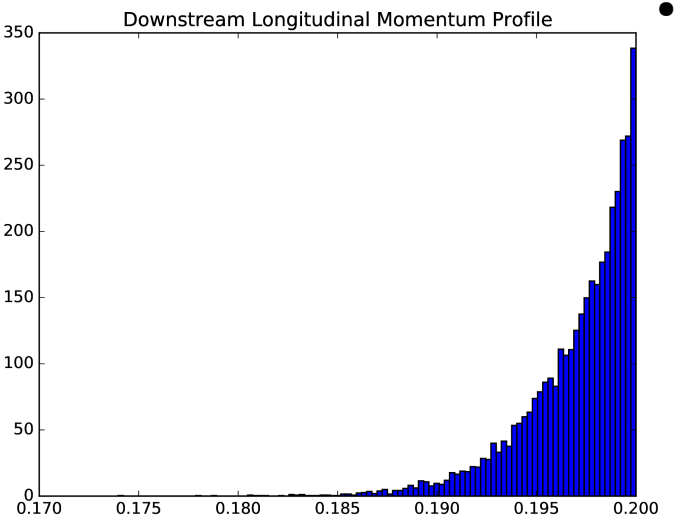
- Computed Kernel-based density and volume for the contour enclosing 9% of total muon.
- Density drops by ~0.06% and volume grows by ~1.0%. Emittance growth is now improved as well ~0.1%
- Standard deviations in density and volume: 395.1 and 2.4e-10. 100% transmission run gives better KDE measurements. But fluctuations in measurement are worst.

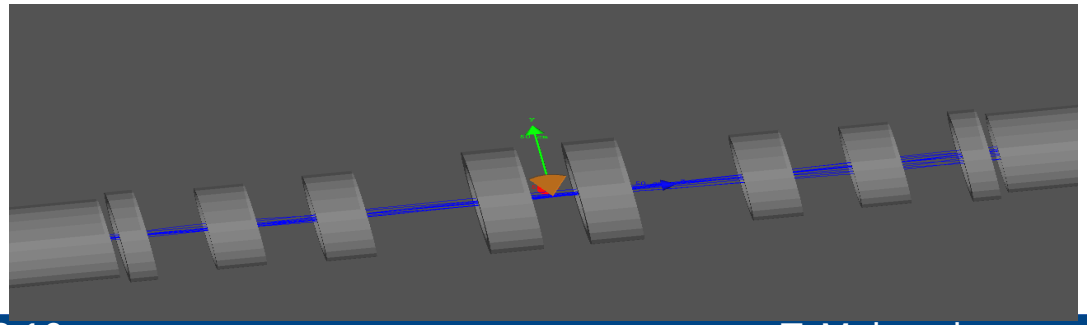
Preliminary Wedge Update











- G4beamline's lattice of initial beam setting (6, 200) + ECE in SSD only and SSU and SSD fields scaled to 3T.
- Compare transverse and longitudinal energy loss at US and DS TRPs. The beam momentum spread is not large and needs to be improved.

Conclusions and To Do's

- The Kernel-based density and volume measurements at different contour levels show consistent trends: the further we are from the beam center, the less the variations in the measurements, and the highest the measurement differences at the TRPs.
- Proposed improvements: increase step sizes in the field measurements + given a nonlinear beam, reduce the bandwidth parameter - the details pertaining to the tail of the beam may be over-smoothed.
- Keep volume constant and count muons – script currently running and takes a long time – need to make it more efficient.
- Possible other improvements: find the weights of each muon and do beam selection for KDE-related measurements.

– As a cross-check, produced phase-space contour plots and compared them from upstream to downstream TRPs.

- Introduce momentum spread into the beam for Wedge studies. Move to MAUS for Wedge simulation studies.