NPS Fringe Field Impact on HMS

Question:

- What is the fringe field of the NPS sweeping magnet at the front of the HMS when NPS and HMS are at small separation; and
- what is the potential impact on the HMS optics.

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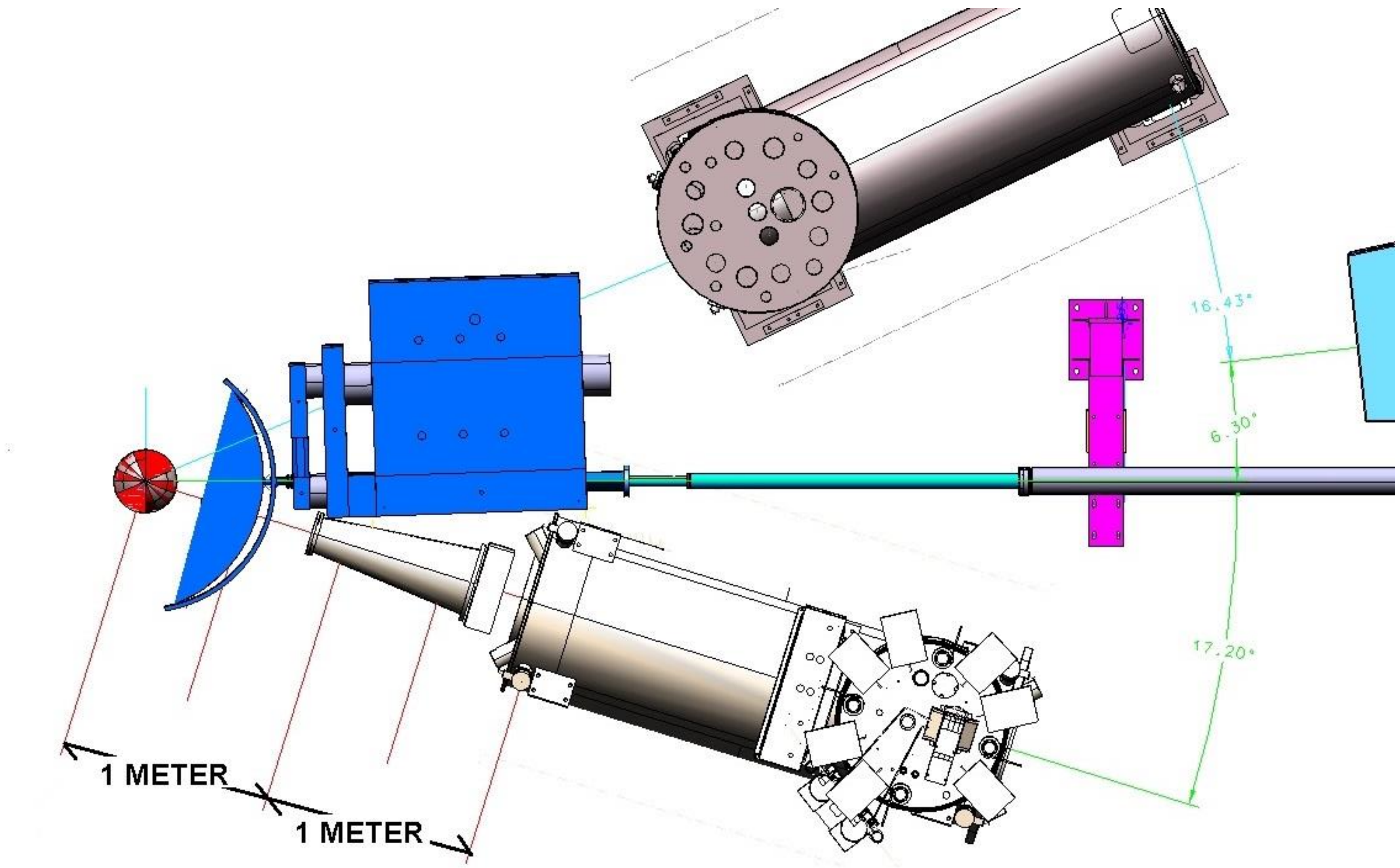
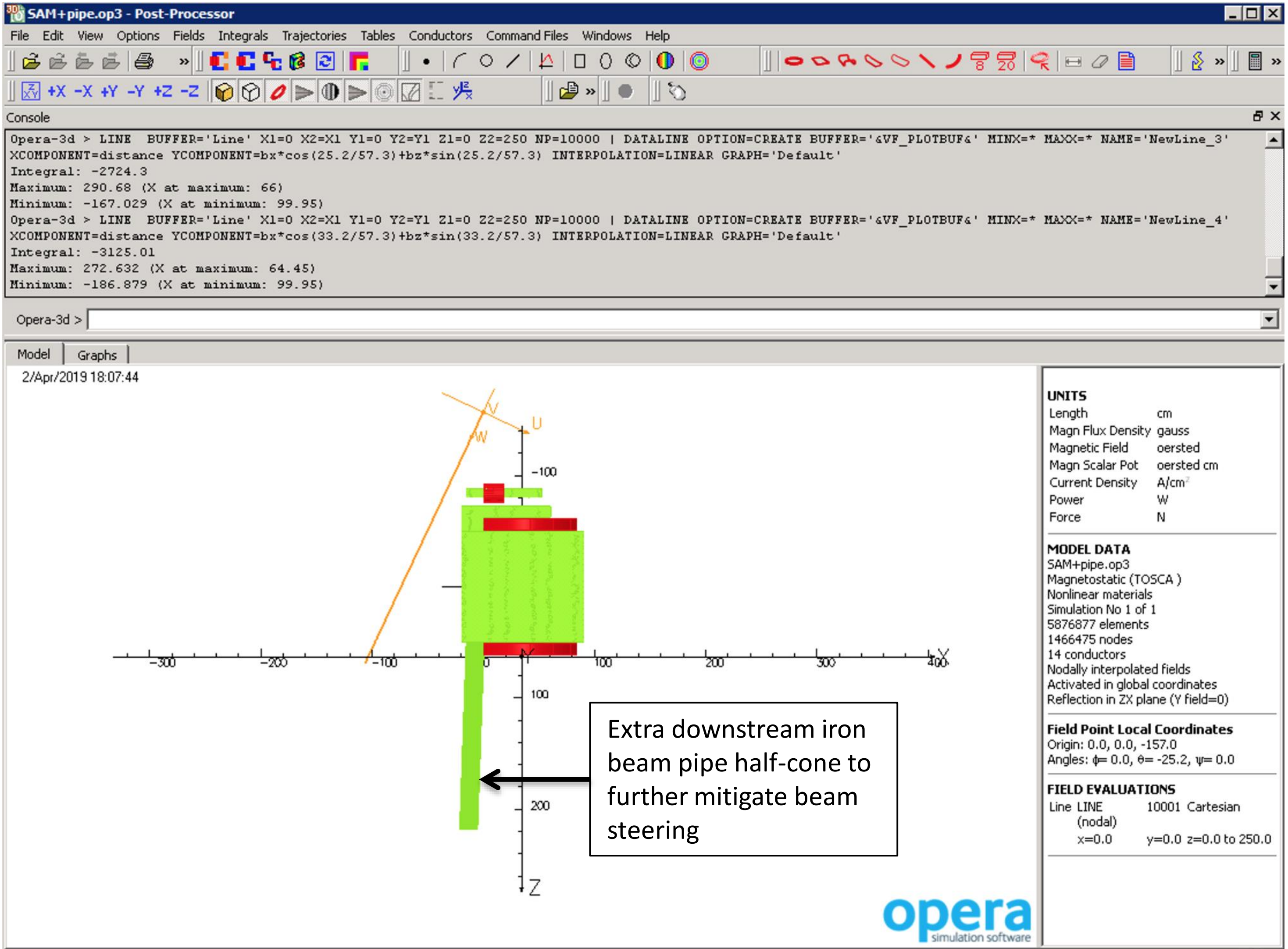
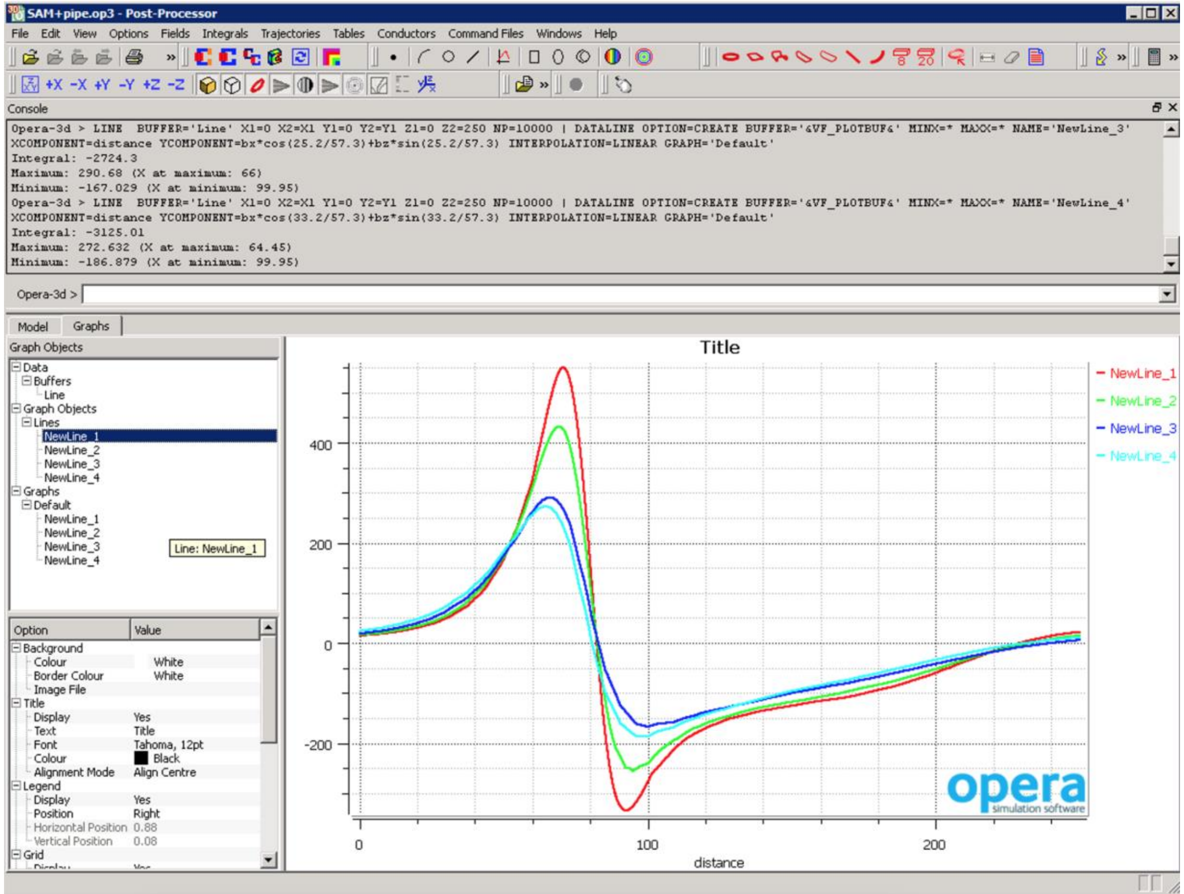


Basic geometry of NPS and HMS at small angles *(courtesy Paulo Medeiros)*

- Minimum separation angle = 23.5 degrees
- Effect of the NPS fringe field is around the location of the HMS vacuum snout, before Q1



The model of the NPS magnet. Top view. The downstream pipe is included in this analysis.

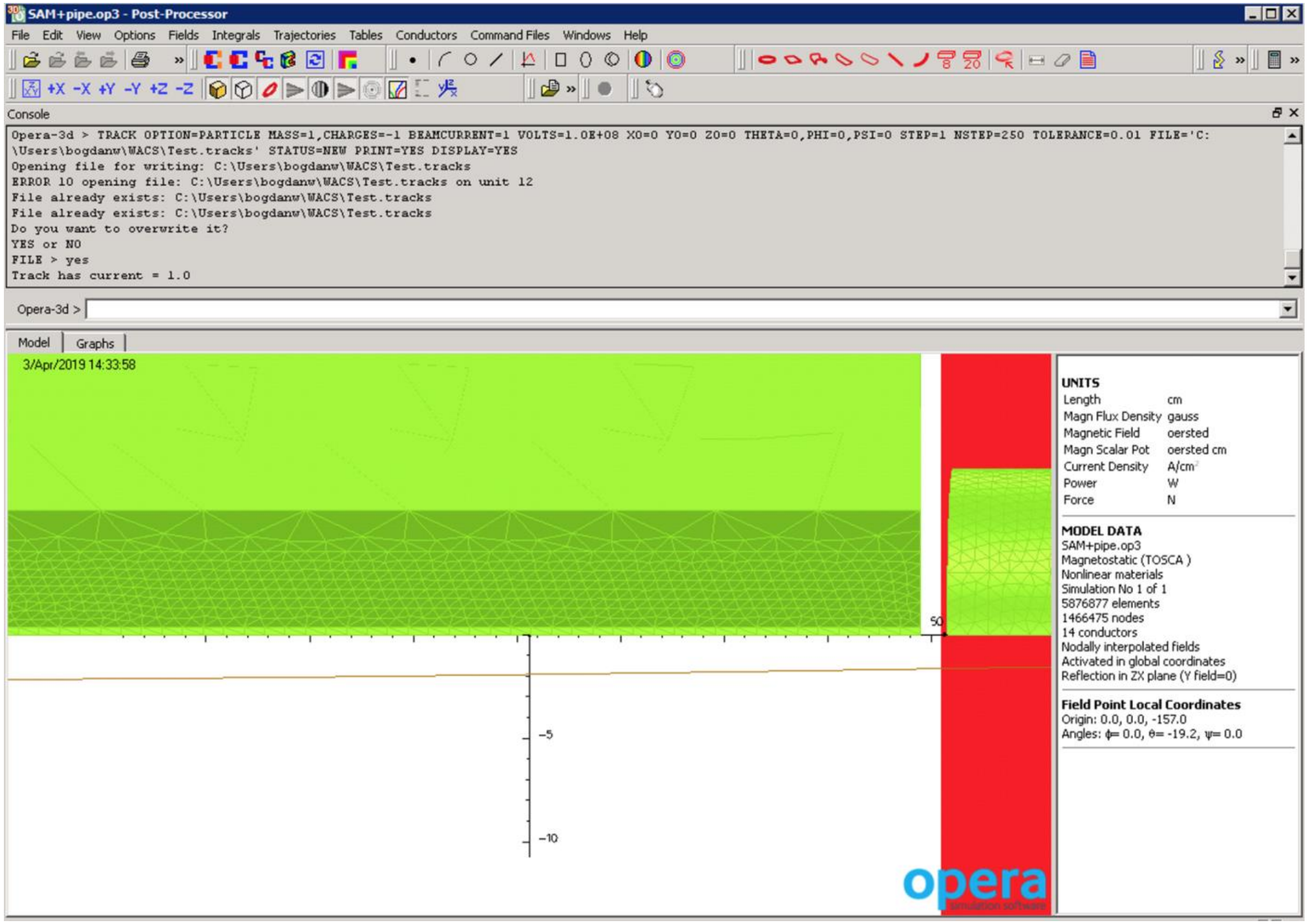


The field perpendicular to the central trajectories at angles of 19.2 (red), 21.2 (green), 25.2 and 33.2 degrees versus the distance from the target. The beam angle is 2 degrees. These settings correspond to the angle separation of NPS and HMS of 23.5, 25.5, 29.5 and 37.5 degrees, respectively, with HMS initially at 17.2 degrees with beam and then rotating outward.

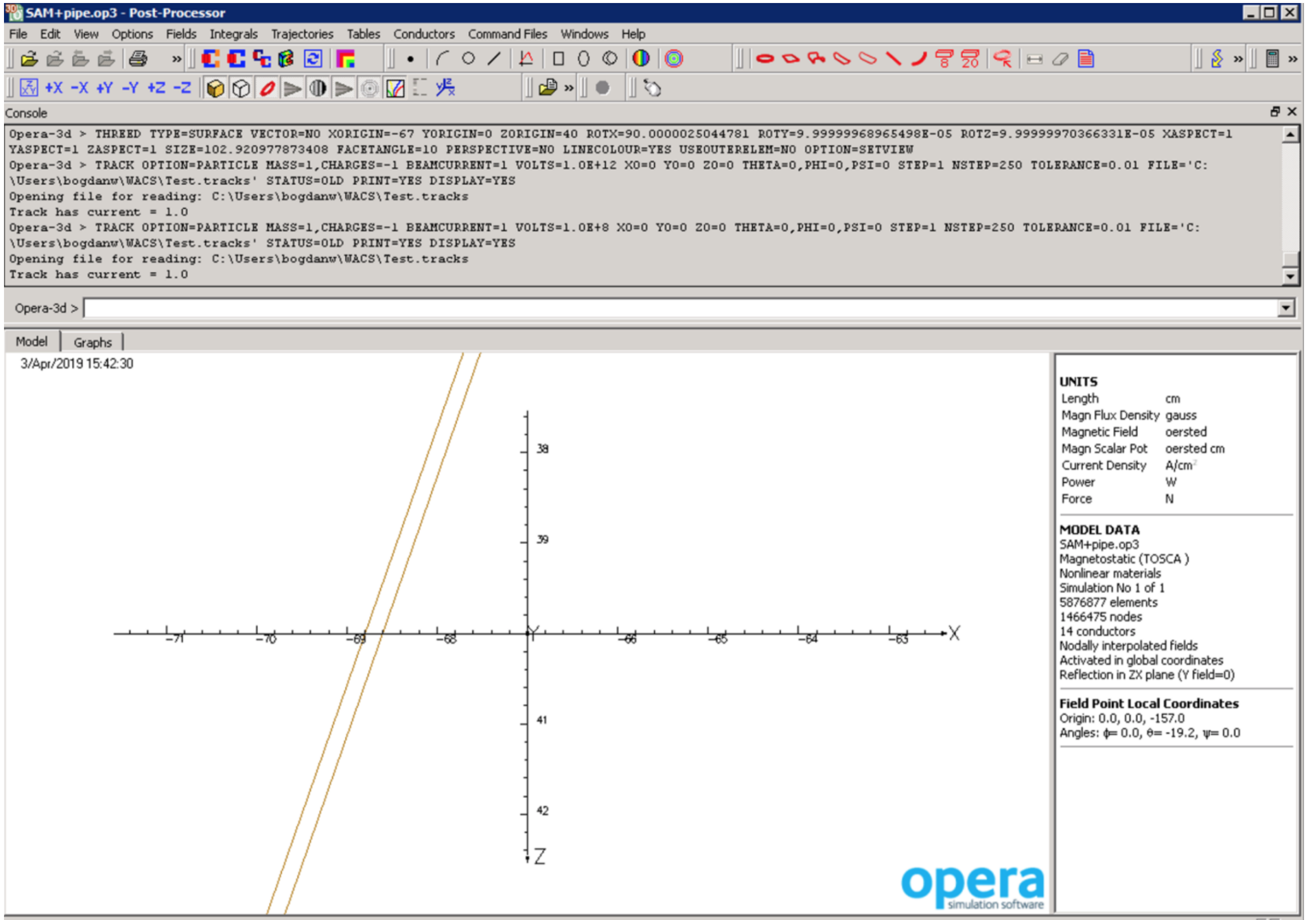
Field integral ~ -4650 Gauss-cm for 23.5^o (red);

Field integral ~ -3960 Gauss-cm for 25.5^o (green);

Field integral ~ -2720 Gauss-cm for 29.5^o (blue) (near-identical for 37.5^o (light-blue).



The 19.2 deg. angle of HMS (17.2 relative beam line, NPS at 6.3 degrees).
Trajectory for a 100 MeV/c electron.
Vertical displacement ~ 1-2 cm. Note that it is near-parallel the axis.
For typical HMS momentum (3 GeV/c) shift is 0.5 mm.



The 19.2 deg. angle of HMS (17.2 relative beam line, NPS at 6.3 degrees).

Trajectory for a 100 MeV/c electron.

Horizontal displacement ~ 0.2 cm at Q1 → negligible for typical HMS momenta (> 1 GeV/c)

Impact on HMS Optics

As can be seen, the impact of the NPS fringe field corresponds to a small vertical deflection of the rays entering the HMS spectrometer optics, and parallel to the axis.

HMS is a vertical bending spectrometer, so such a vertical offset has an optics effect similar as a vertical beam position offset would have. This is minor.

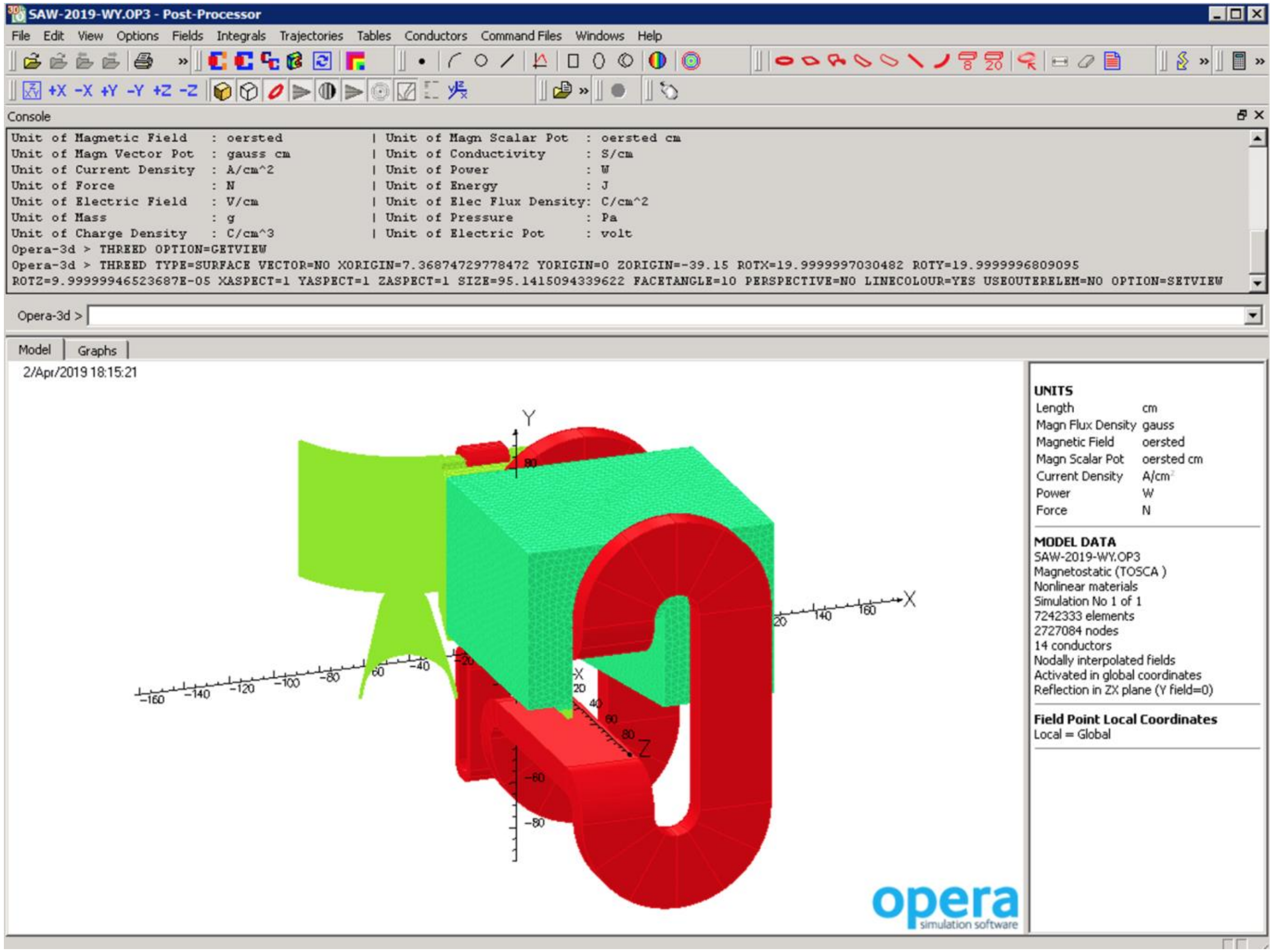
For HMS, a 1 mm vertical offset corresponds to a 0.08% apparent momentum offset. The momentum offset of such particles is taken into account by using the special aberration matrix elements that also take into account a vertical beam offset by the target.

So all one would need to do is calculate the minor vertical deflection imposed by the NPS fringe field, as calculated for the HMS central momentum setting, and treat it as a vertical beam offset, and this NPS fringe field effect automatically gets taken into account in the particle optics reconstruction.

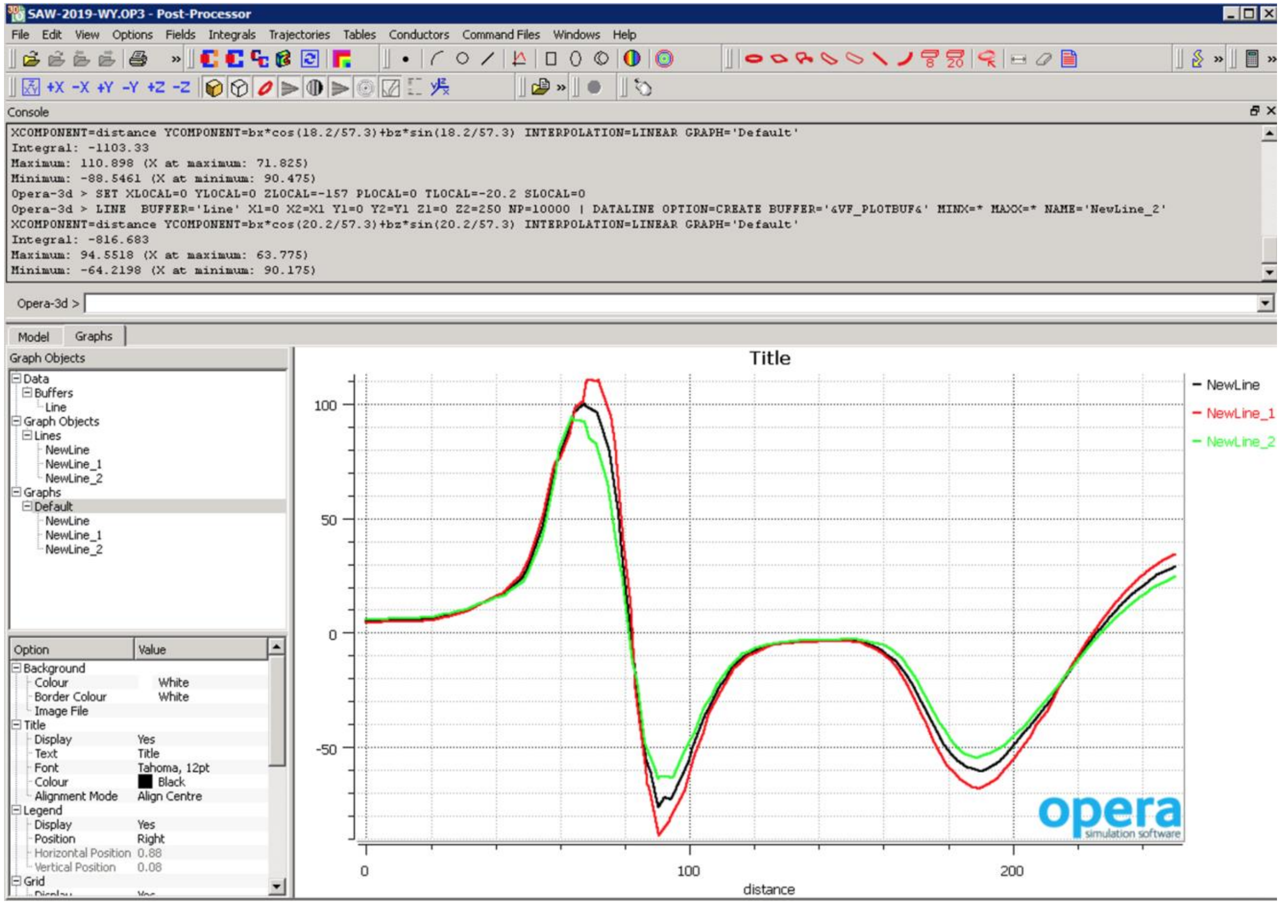
Further mitigation

The impact of the NPS sweeping magnet fringe field is shown to be minimal for the HMS optics in the previous slides, and can easily be taken into account by calculating the vertical deflection imposed by the fringe field at the entrance of HMS-Q1, and treating it as a vertical beam offset.

But, might experiments need further mitigation a recipe is given in the next slides.



Might further mitigation be needed:
A model of the NPS magnet, an iron plate around the scattering chamber, and an iron-walled snout (7 mm wall thickness).

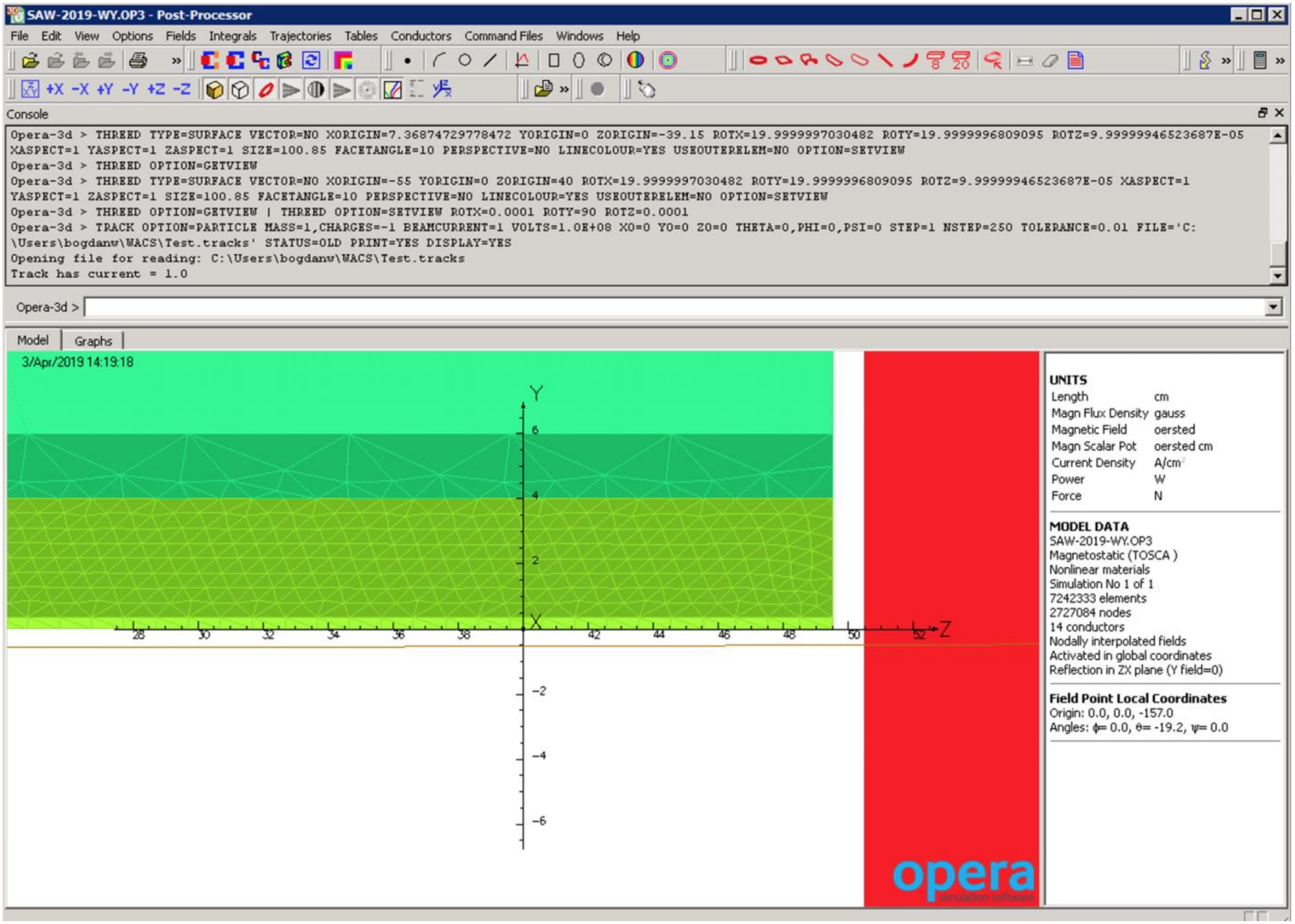


Iron-walled vacuum snout effect on the field in HMS direction:

The field perpendicular to the 19.2 (black), 18.2, and 20.2 deg. central trajectories versus the distance from the target (i.e., no variation over the angles of the particles).

The field drops by a factor of 5 as well as integrals (~<1000 Gauss-cm).

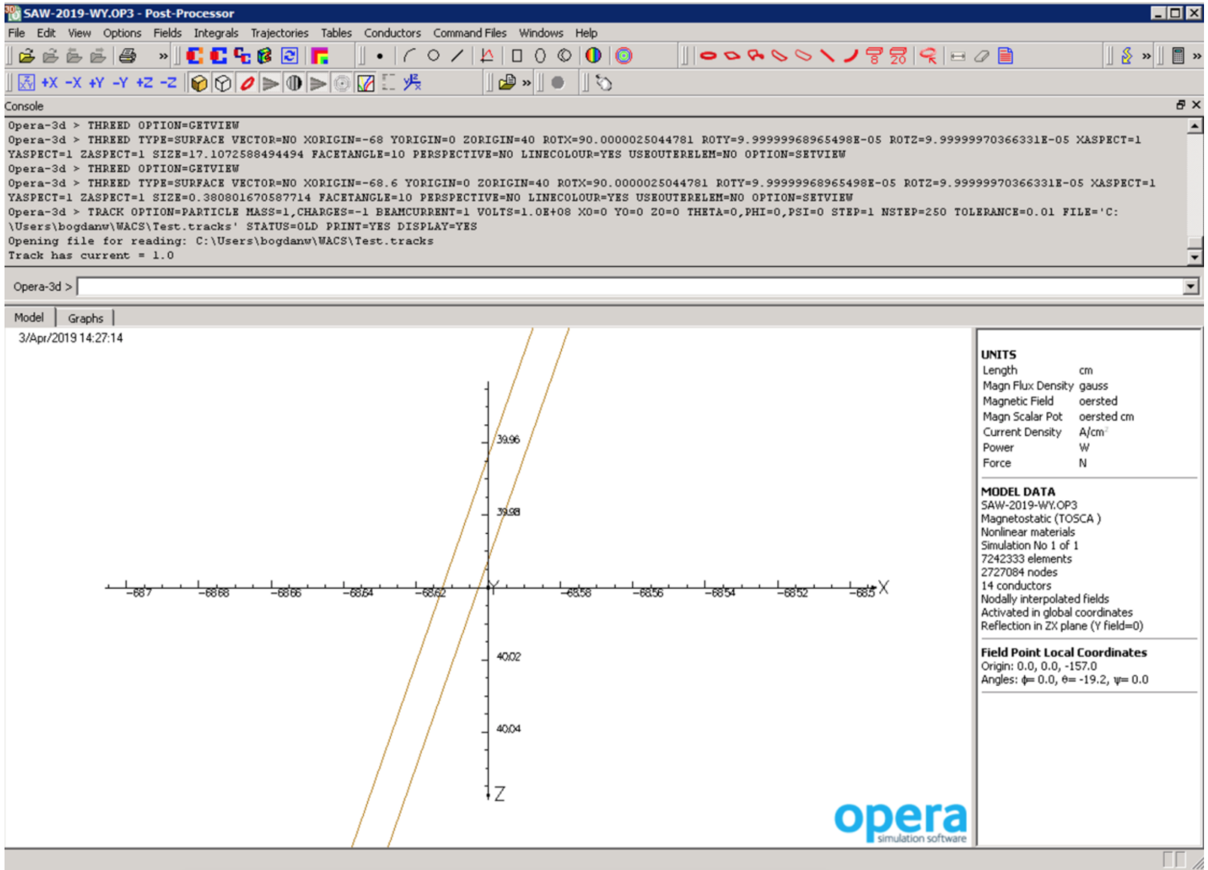
For such small field integrals the impact on the angles of the particles (assuming a 3 GeV momentum) is less than 0.1 mr.



Mitigated effect on the trajectory displacement by iron plate and iron-walled snout for an HMS angle of 17.2 degrees and an NPS angle of 6.3 degrees (i.e., a 19.2 deg. angle of HMS w.r.t. the minimum angle detected)

The trajectory is for a 100 MeV/c electron.

Vertical displacement ~ 0.5 cm → 0.1-0.2 mm for a 3 GeV/c particle



Mitigated effect on the trajectory displacement by iron plate and iron-walled snout for an HMS angle of 17.2 degrees and an NPS angle of 6.3 degrees (i.e., a 19.2 deg. angle of HMS w.r.t. the minimum angle detected)

The trajectory is for a 100 MeV/c electron.

Horizontal displacement ~ 0.01 cm → zero for a 3 GeV/c particle

Appendix – old slides of two years back when we started to consider this problem, with the NPS sweeping magnet design at that time (i.e., before the fringe field mitigation steps).

NPS Fringe Field Considerations

Deflection = 0.3 x Bdl / E with Bdl in Tm and E in GeV

<u>Impact on beam halo after beam-target interaction</u>

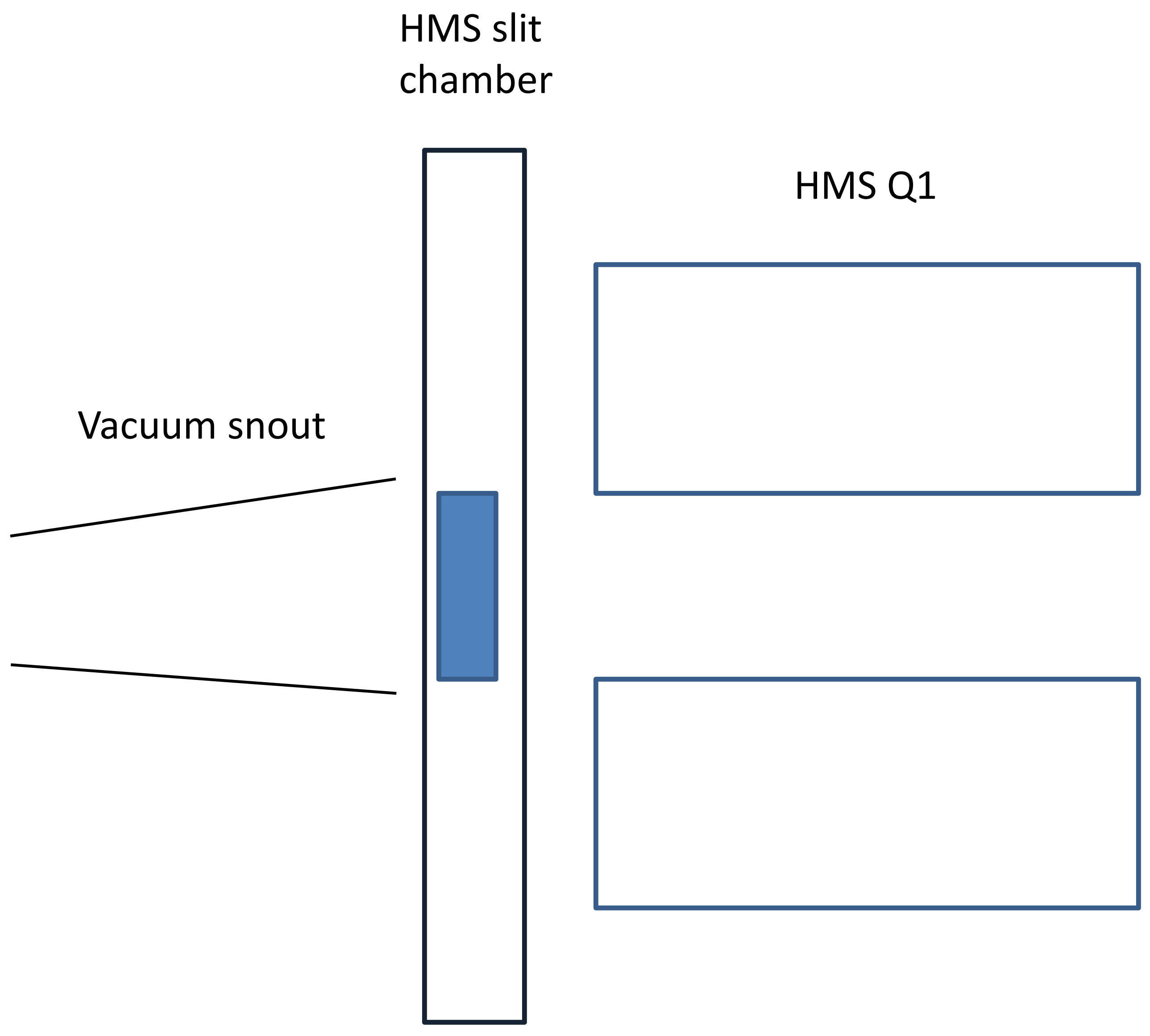
1000 Gcm = 0.001 Tm   0.3 Bdl / E → 0.0003 / E → 0.3 mr / E
Front of dump tunnel @ distance of ~30m → 0.9 cm / E
Assume want to stay in say 8" flange   → +/- 10 cm
→ down to E = 100 MeV stays within flange
Conclusion: 1000 Gcm is safe as fringe field for beam halo after beam-target interaction

<u>Impact on HMS optics</u>

200 G at the HMS vacuum snout   → 0.01 Tm (snout is bout 50 cm long)
→ 1 mr deflection @ 3 GeV/c
This seems too much, need to reduce to say 1000 Gcm → 0.1 mr deflection @ 3 GeV/c.

<u>How close to HMS Q1 can one put iron shell around snout without impacting HMS optics?</u>

Bore of Q1 = 20.5 cm radius = 41 cm diameter
Typical rule of thumb: field dies out at 3 times the bore diameter away from quad entrance
at 2 times the bore diameter away from quad entrance effect a few %
Distance(pivot – Q1 magnetic field edge) = 1.76 m
Distance(pivot – front slits) = 1.26 m, or to front of slit chamber = 1.20 m
→ Would prefer to not have iron "last 30 cm" of vacuum snout


HMS slit chamber
HMS Q1
Vacuum snout