

Cooling

Tom Roberts

Muons, Inc.

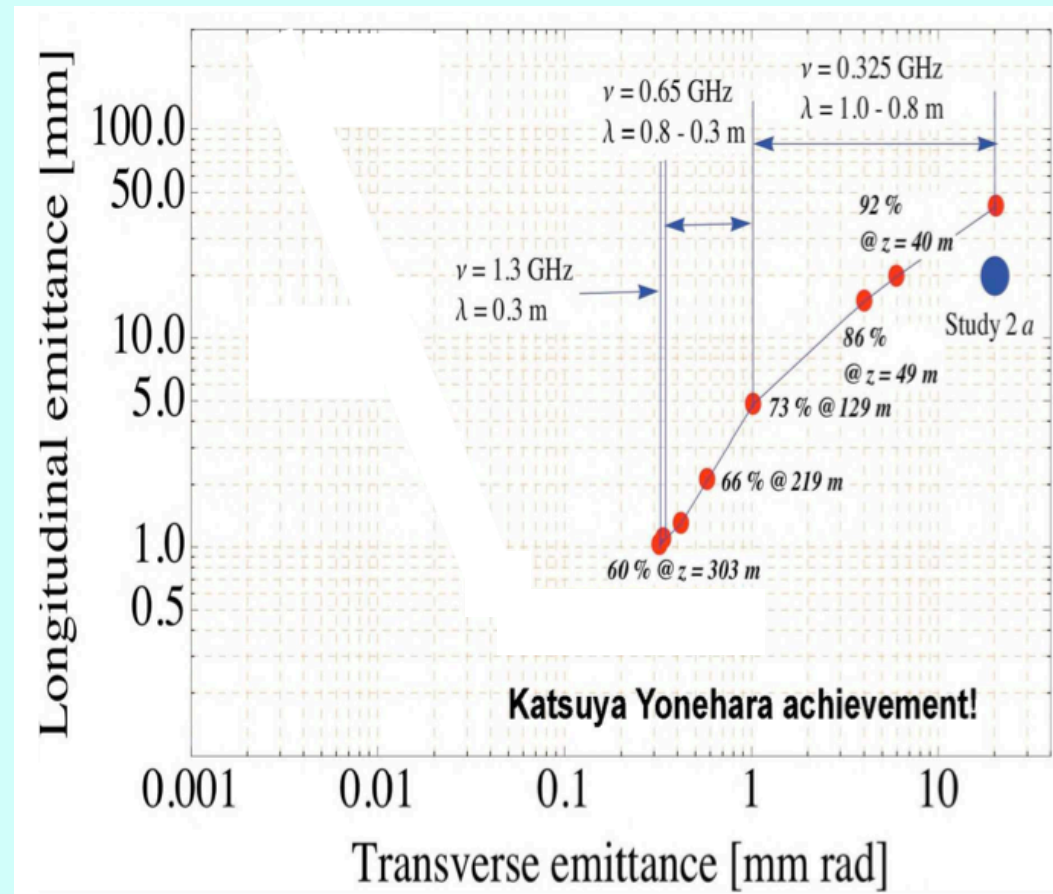
Outline



- Recent Progress
 - 6-D: Helical Cooling Channel
 - 6-D: Guggenheim Cooling Channel
 - 6-D: FOFO Snake Cooling Channel
 - Final Cooling
 - Auxiliary Components
 - New Ideas
 - Rectilinear snake, Half-Flip lattice(s), Planar Snake
 - Missing Physics Processes
- Future Work
 - Simulations: Front-end to Acceleration
 - Engineering Studies
 - Missing Physics Processes
 - Selecting a Baseline
- Summary

6-D: Helical Cooling Channel

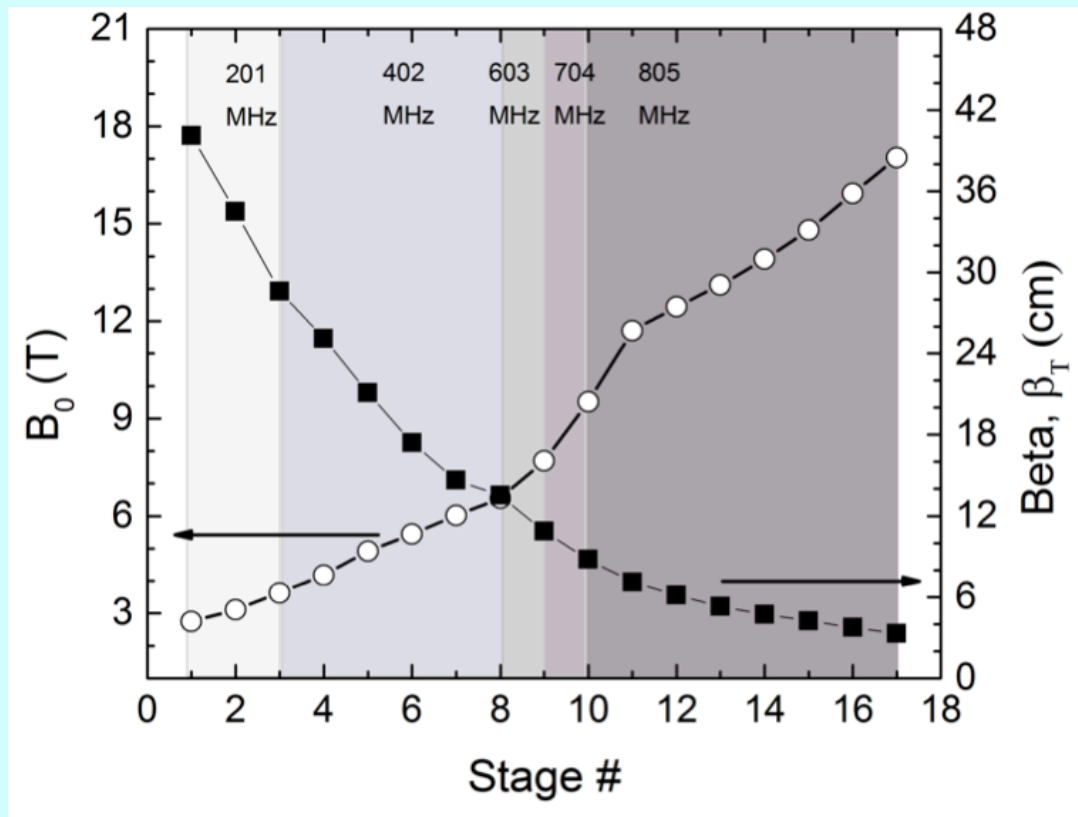
- Improved matching between segments
- See Cary's talk tomorrow



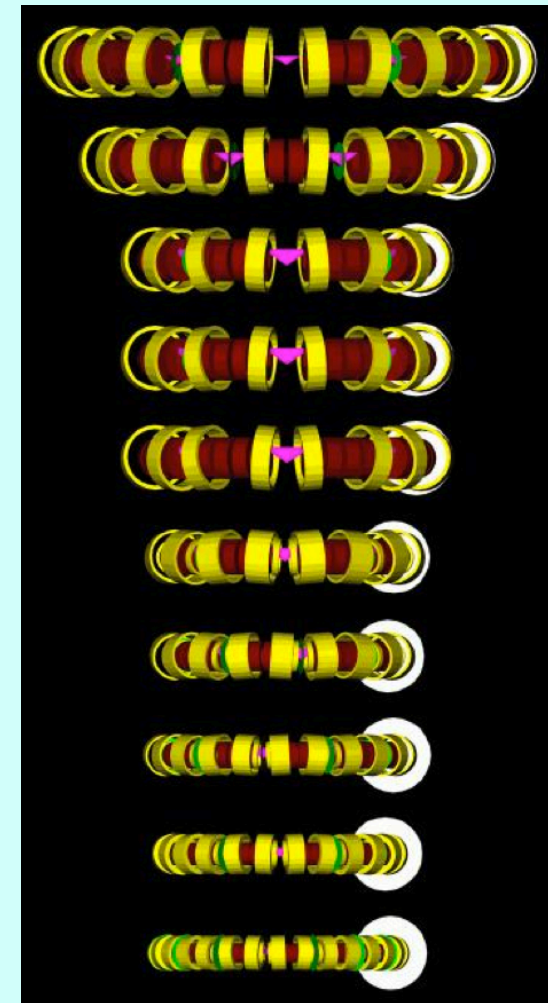
K. Yonehara

6-D: Guggenheim Cooling Channel

- Simulated as 17 rings.
- See Diktys's talk tomorrow.



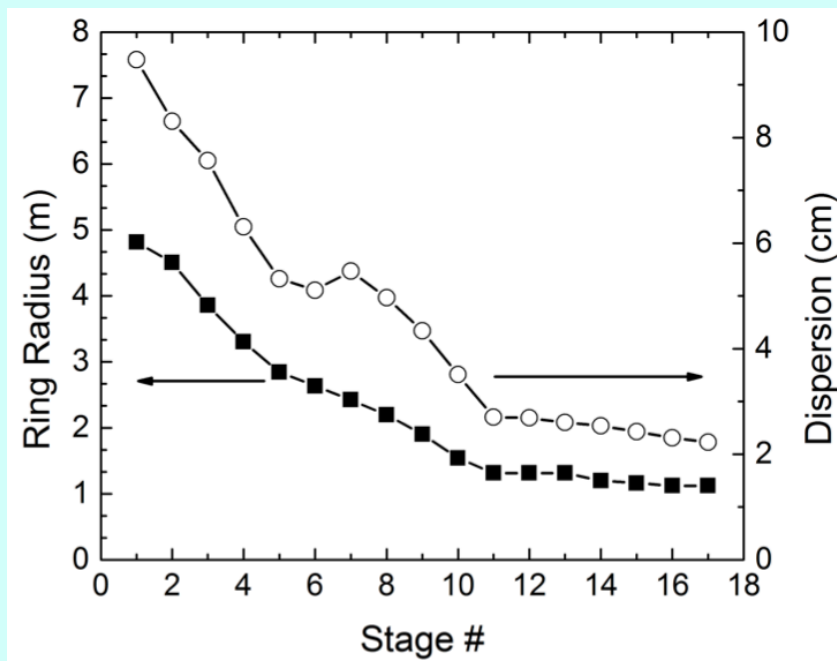
D. Stratakis



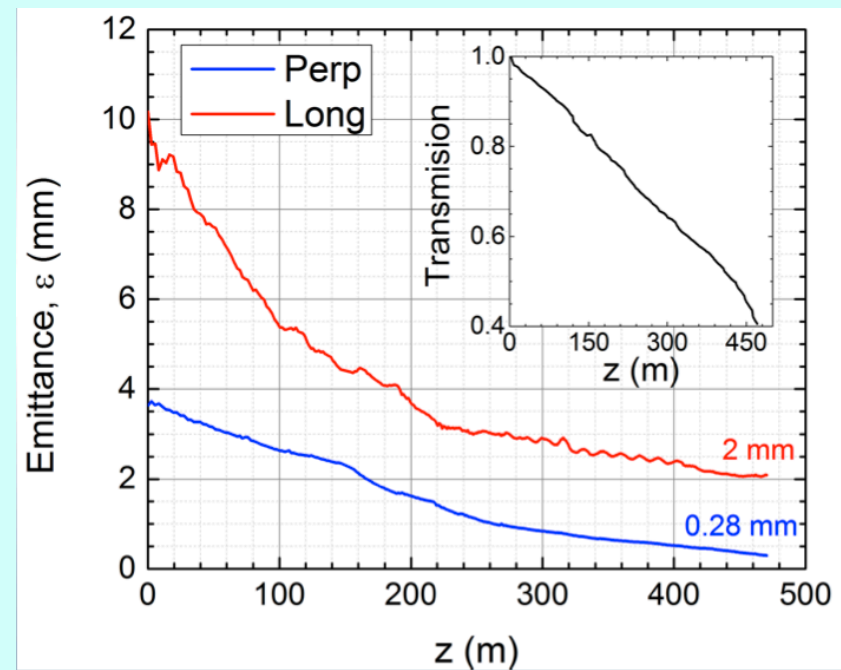
P. Snopok

6-D: Guggenheim Cooling Channel

- 17 Ring details and tracking results.



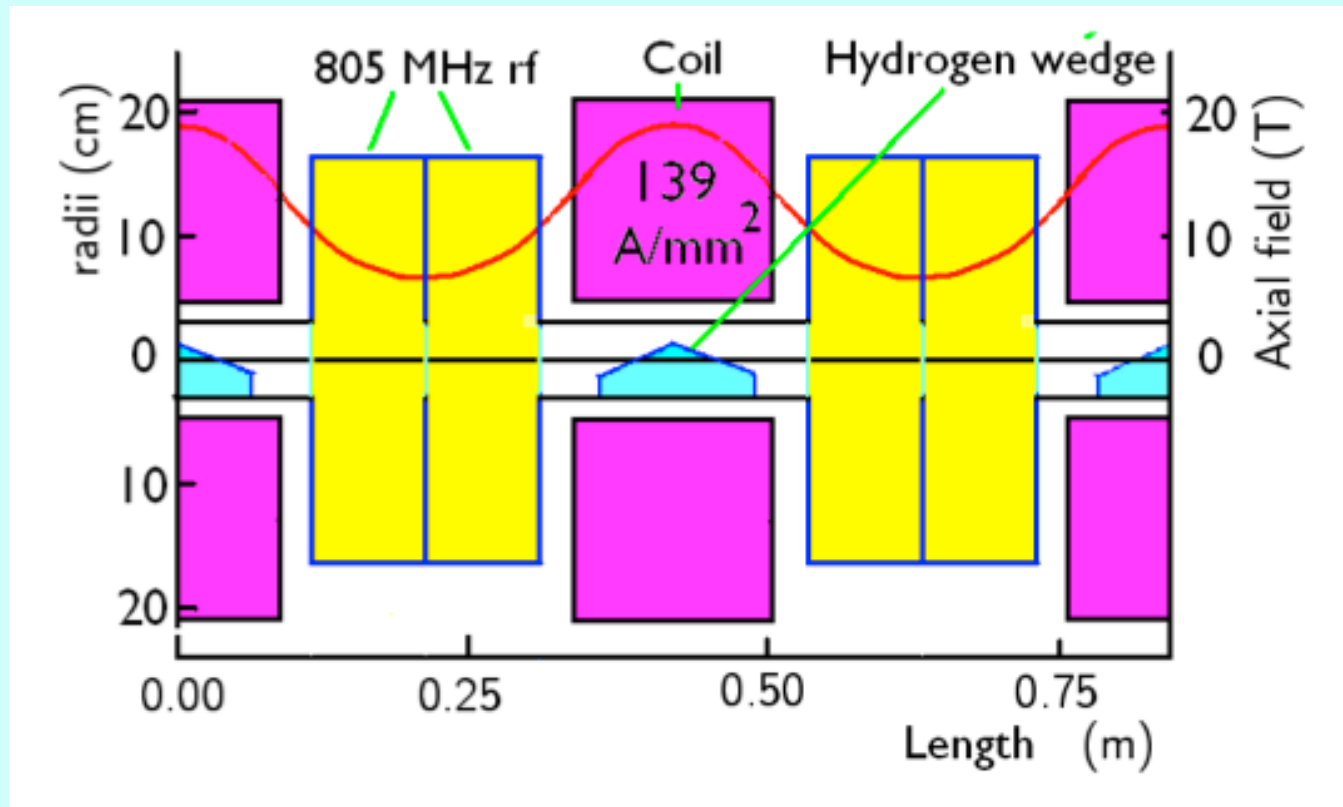
D. Stratakis



D. Stratakis

6-D: Guggenheim Cooling Channel

- Non-Flip (Fernow) Lattice
- Keep longitudinal emittance $> 2\text{mm}$ (space charge)

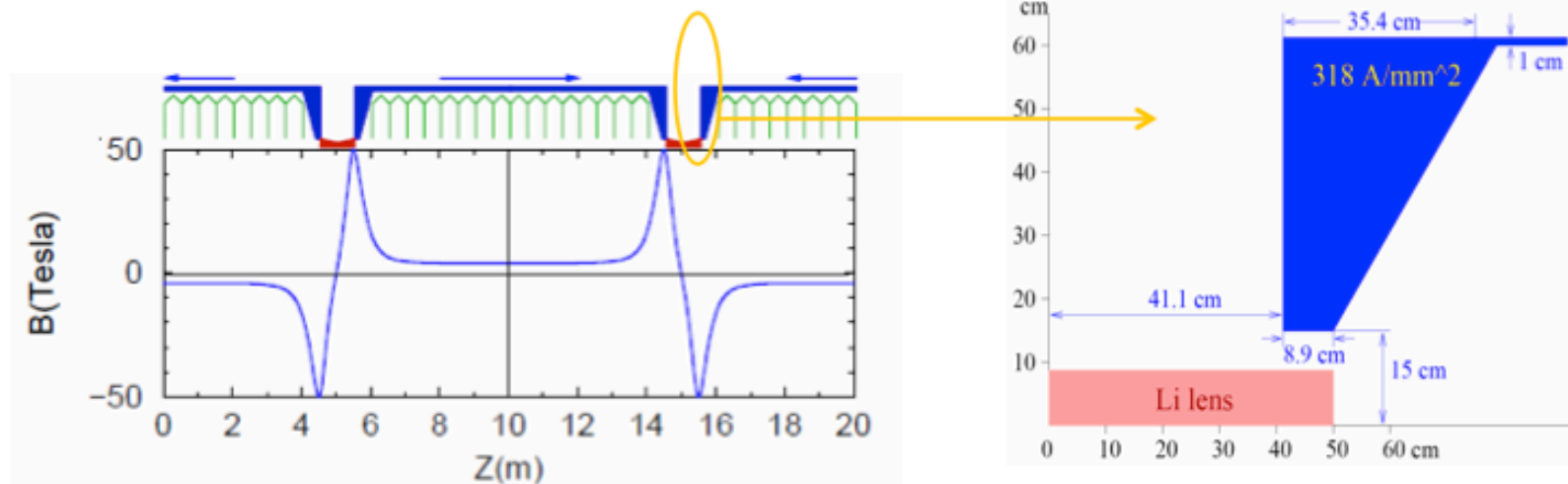


R. Palmer

Final Cooling – Li Lenses

- Li Lenses with Solenoid matching

The channel includes 4-6 cells like this



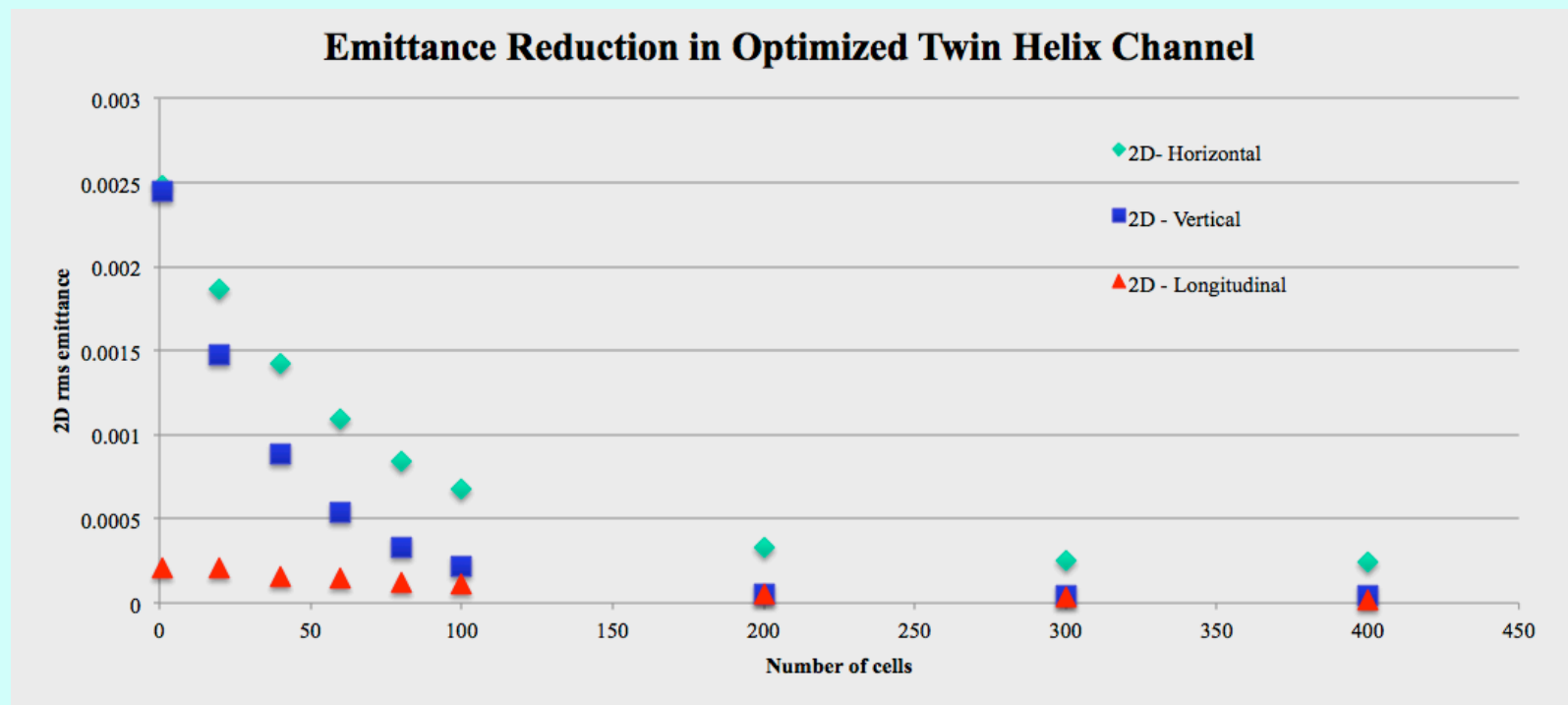
Red -- Li lenses for cooling. All of them differ from each others.

Blue – Solenoid coils for adiabatic matching (can differ from each other).
Maximal field up to 50 T, transport solenoid 4 T.

V. Balbekov

Final Cooling - PIC

- Progress in simulating Parametric-resonance Ionization Cooling (PIC)



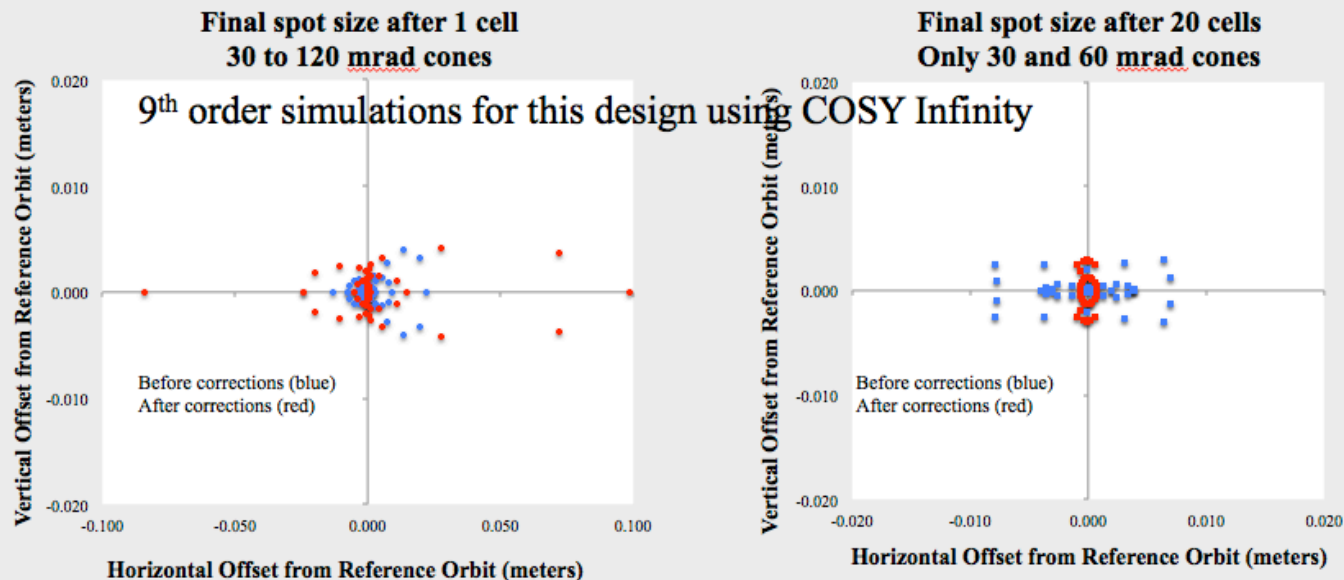
J. Maloney et al

Final Cooling - PIC

Aberration Compensation

- design uses a helical sextupole pair, and 3 pairs of helical octupoles for aberration correction
- 2 helical quadrupoles pairs maintain correlated optics
- Minimizes all major aberrations through 9th order but angular acceptance limited to ~80 mrad

COSY Infinity simulations using 250 MeV/c muon cone (+/- 100 mrad) from point source

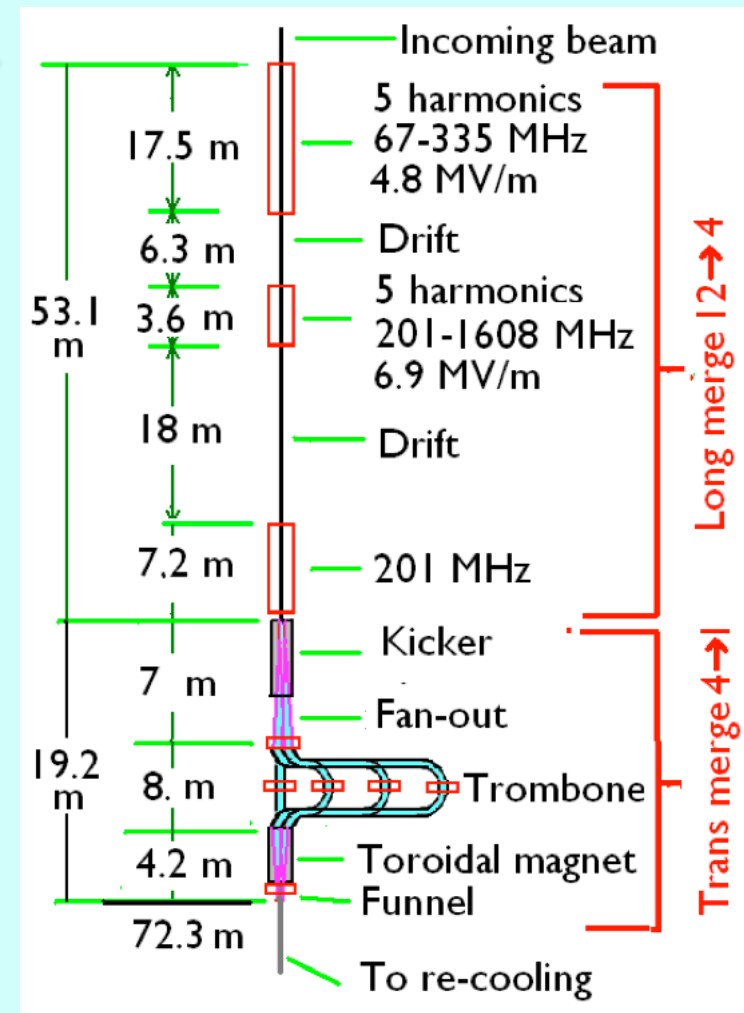


(Note
different
horizontal
scales.)

J. Maloney et al

Auxiliary Components

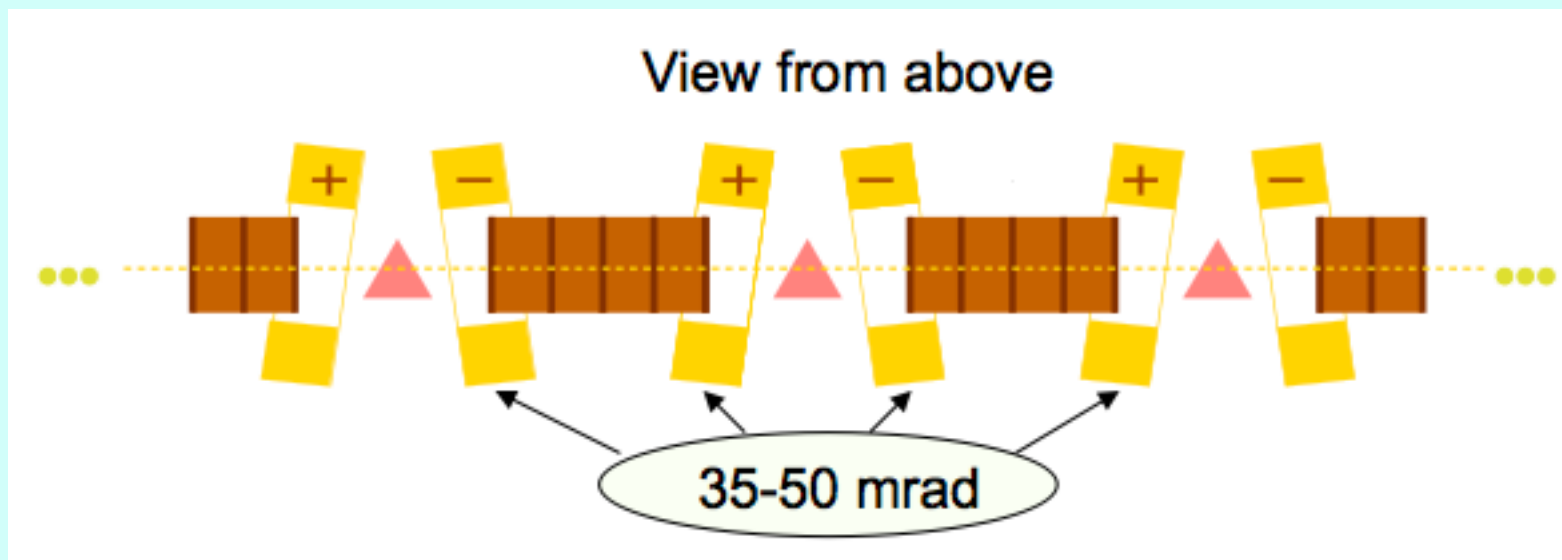
- 6-D Bunch Merge
- Charge Separation
(see Cary's talk tomorrow)



R. Palmer

New Ideas

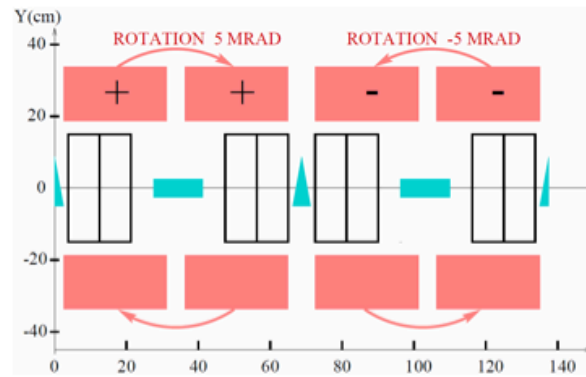
- Rectilinear Snake



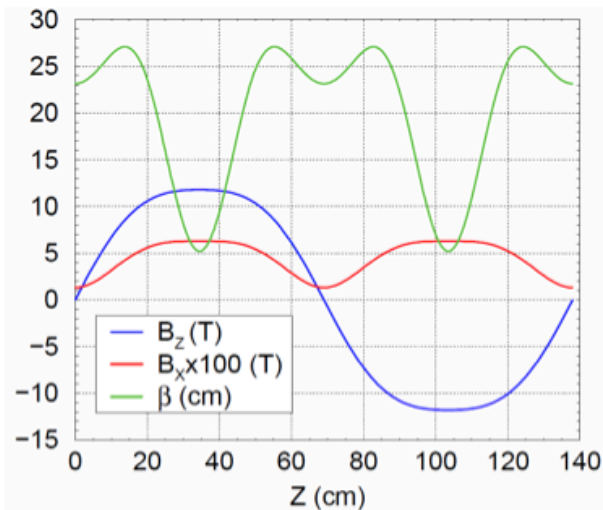
V. Balbekov

New Ideas

Schematic of the transformation
Solenoids are tilted ± 5 mrad horizontally



Field and beta-function with tilt



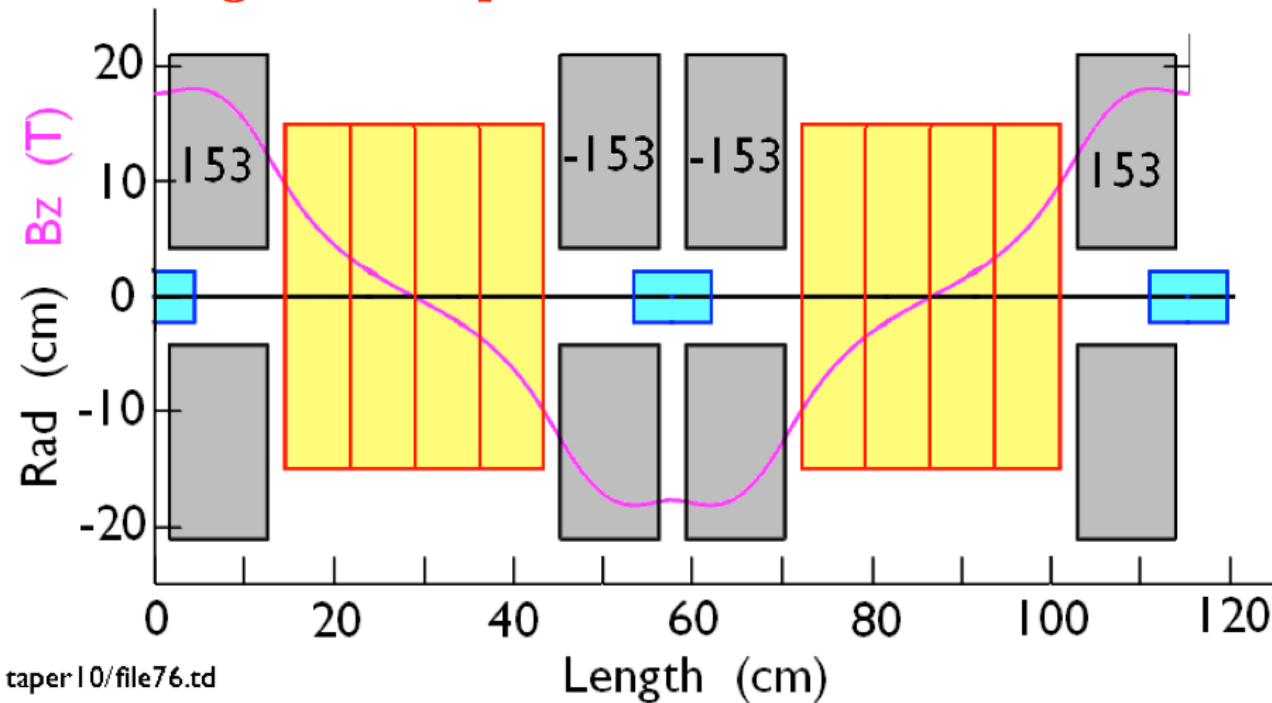
- Rectilinear Snake
- High dispersion occurs at different place than low beta
- Use short wedges at high-dispersion points to provide emittance exchange; longer absorbers at low-beta points for cooling.

V. Balbekov

New Ideas

- Half-Flip Planar Snake
- See Bob's and Diktys's talks tomorrow

A late stage Half Flip



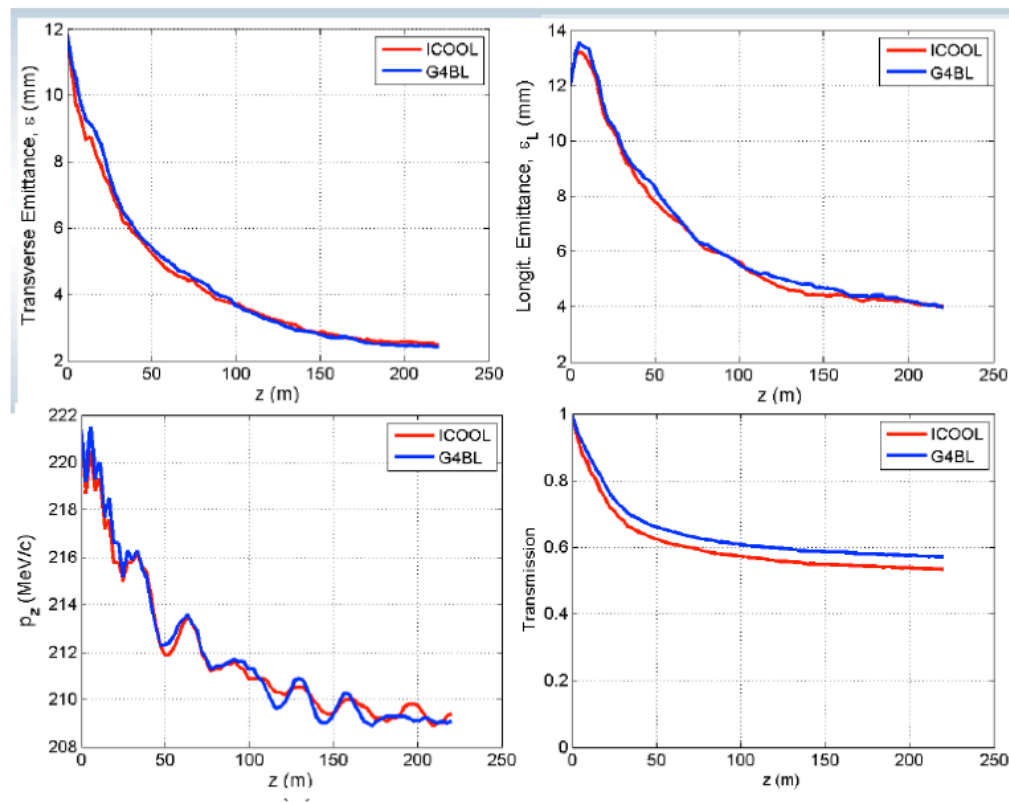
- All cells no longer identical: must operate between 3π and 4π

R. Palmer et al

New Ideas

- Half-Flip Planar Snake

Simulations with real field maps

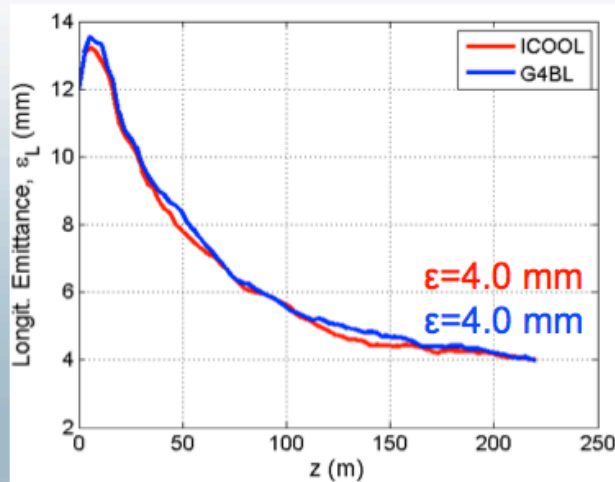
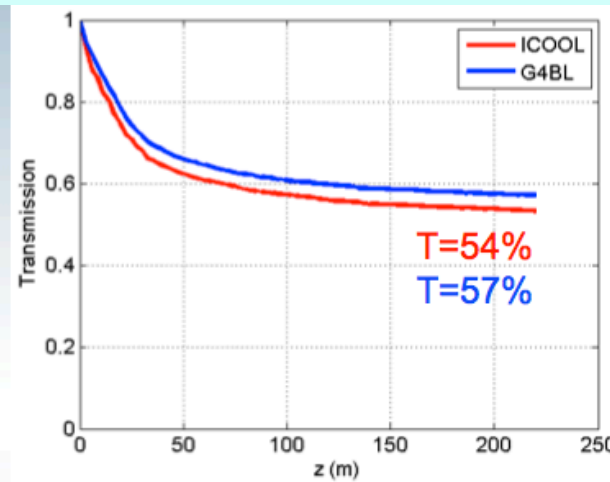
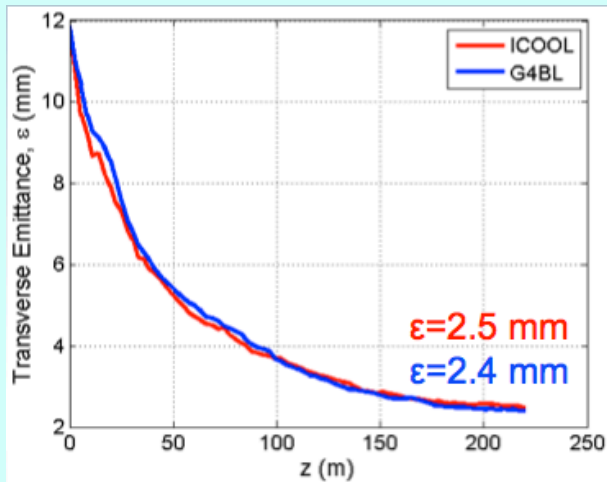


• Good agreements: Fourier, G4BeamLine, ICOOL

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New Ideas

- Half-Flip Planar Snake (early stage)

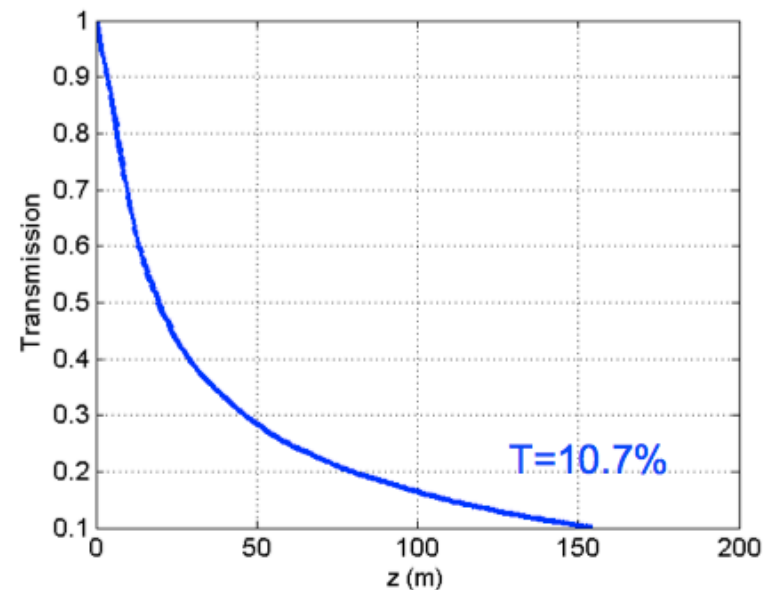
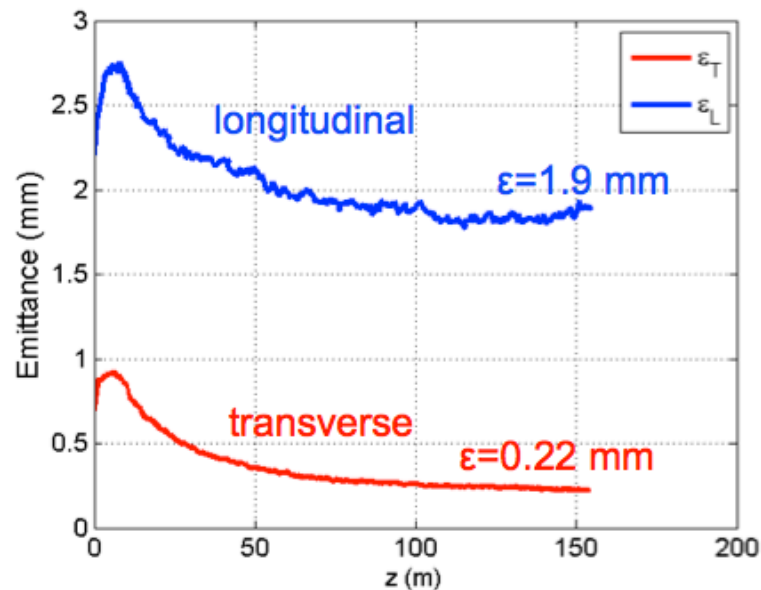


- Stochastics included
- Without muon decay
- No cavity windows
- 500 μm absorber AL windows

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New Ideas

- Half-Flip Planar Snake (late stage)



- Stochastics included but no muon decay
- No cavity windows, 100 μm absorber AL windows
- Achieve baseline MC parameters but poor transmission

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New Ideas



Remember, none of these new ideas have been optimized, or even fully simulated.

All are still works in progress.

Missing Physics Processes

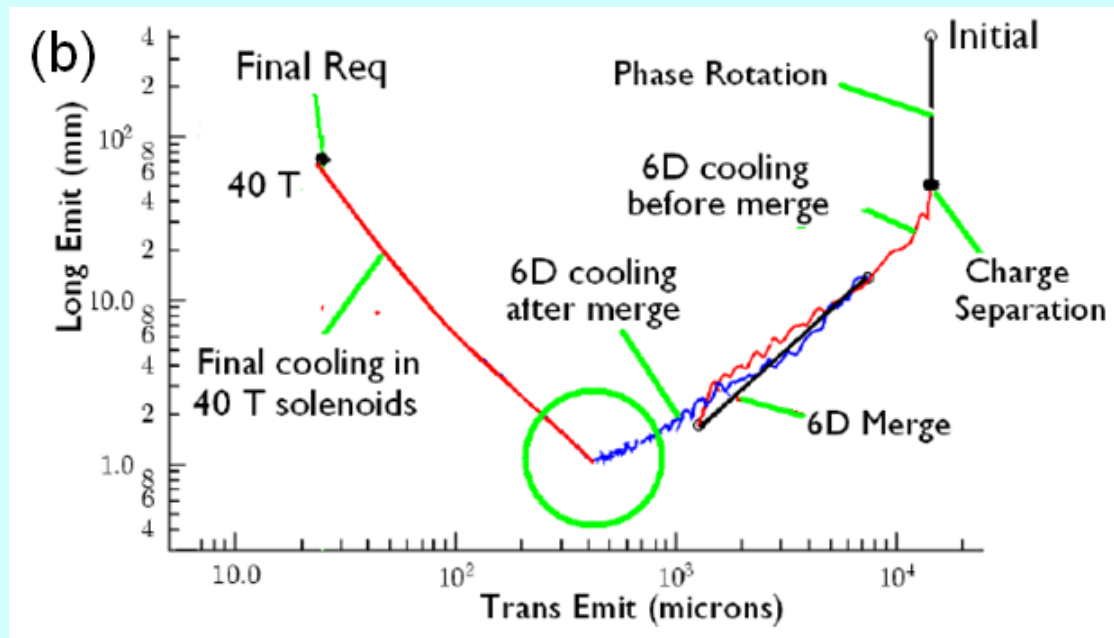


- Space charge (next few slides)
- Multiple Scattering in high-field solenoid magnets
 - G4beamline code to limit step length to improve accuracy

The list of missing physics processes is large and diverse.

**This effort needs more funding and more people
(we need to involve non-MAP experts).**

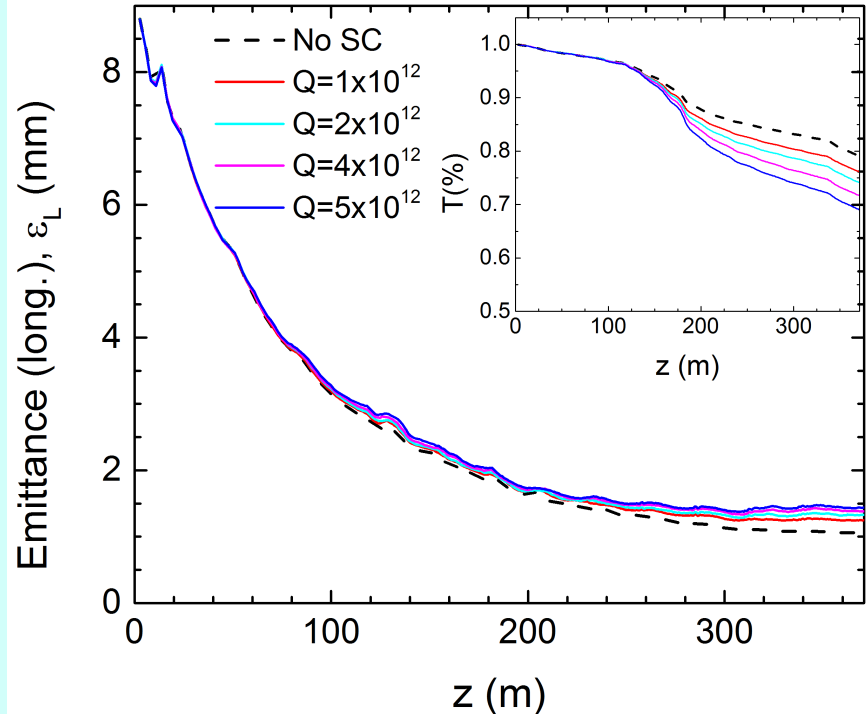
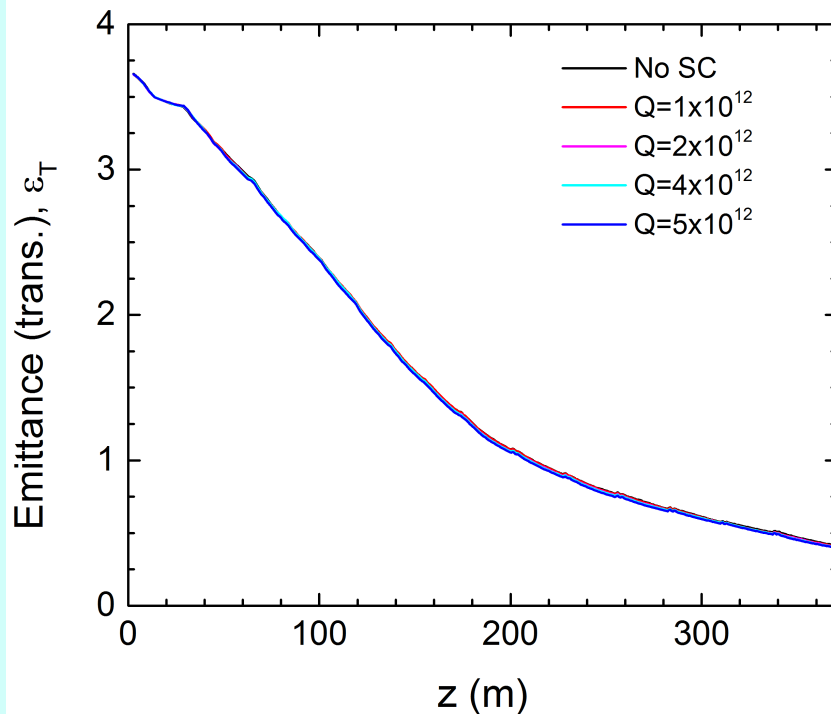
Missing Physics Processes: Space Charge (Warp)



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- Last stages of the final 6D cooling:
 - Beam rms bunch length is short (~2 cm)
 - $\sim 4 \times 10^{12}$ muons per bunch \rightarrow large currents
 - Space-charge may harm the beam emittance

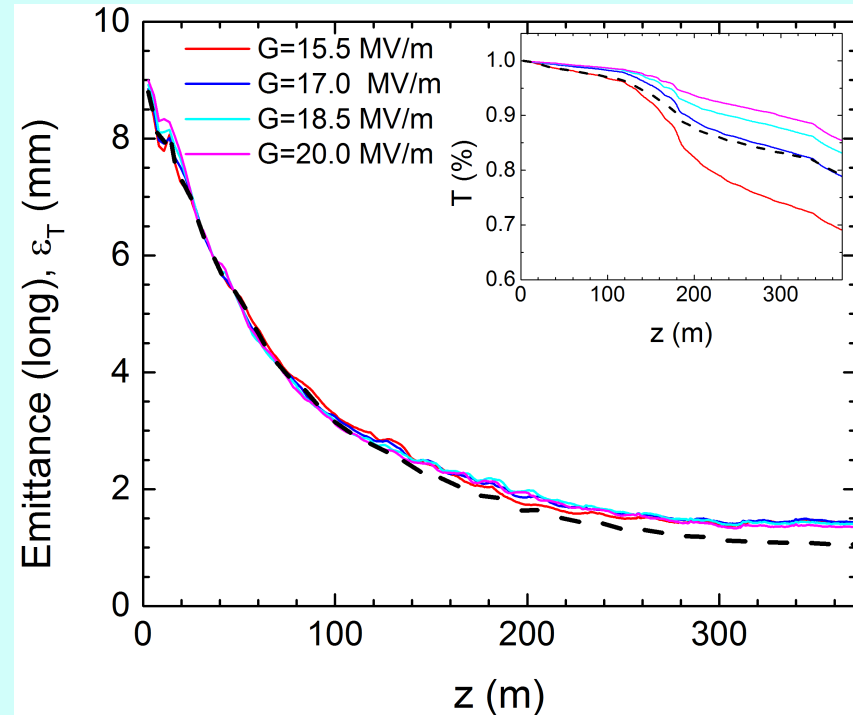
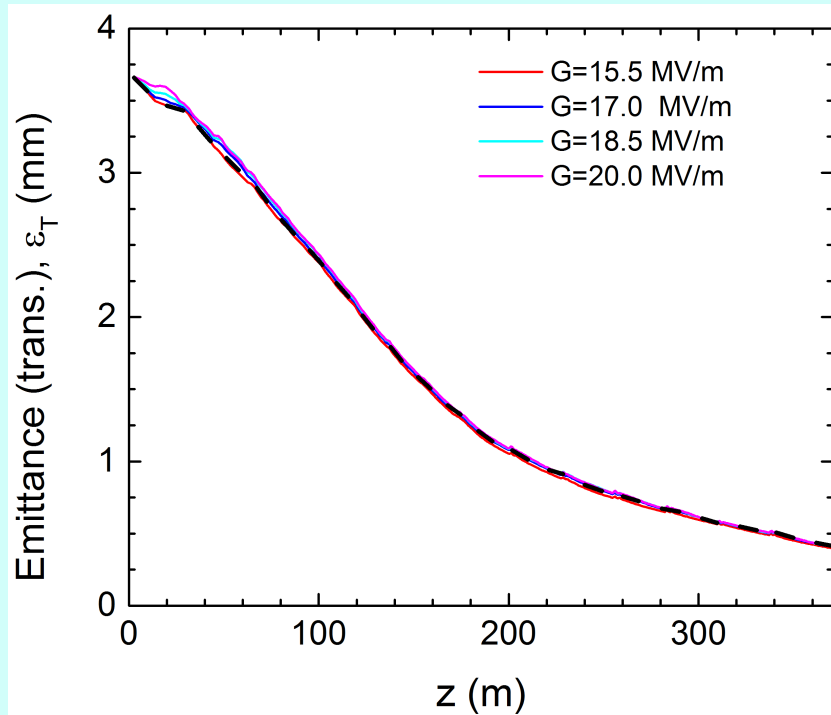
Space-Charge studies with WARP



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- Transverse emittance is not affected by space-charge.
- But SC opposes longitudinal cooling below 1.5 mm
- Transmission drops by ~20%!

Space-Charge studies with WARP



D. Stratakis et al

- Increase of rf gradient may compensate the particle loss
- Longitudinal cooling below 1.5 mm is not possible.

Future Work



- Simulations: Front-end to Acceleration
 - Guggenheim
 - Helical Cooling Channel
 - FOFO Snake may be involved at the start
 - Rectilinear Snake / Planar Snake, ...
- Engineering Studies
 - End of the Guggenheim looks to be more difficult than the HCC
 - HCC
 - Snakes...
- Missing Physics Processes
 - Lots to do...
- Selecting a Baseline
 - Discussion tomorrow, 8am in the Comitium (WH 2SE)
 - Have to deal with staging

Future Work



- Simulations: Front-end to Acceleration
 - Guggenheim
 - Helical Cooling Channel
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 - HCC
 - Snakes...
- Missing Physics Processes
 - Lots to do...
- **Selecting a Baseline** ← Becomes our current primary goal
 - Discussion tomorrow, 8am in the Comitium (WH 2SE)
 - Have to deal with staging

Summary



- There has been considerable progress.
- New ideas are still being generated
- We must focus our effort on preparing for the baseline selection.
- There is much to do...