MCTF EXPERIMENTAL ACTIVITES

- towards demonstrating 6D cooling

MCTF Experimental Goals

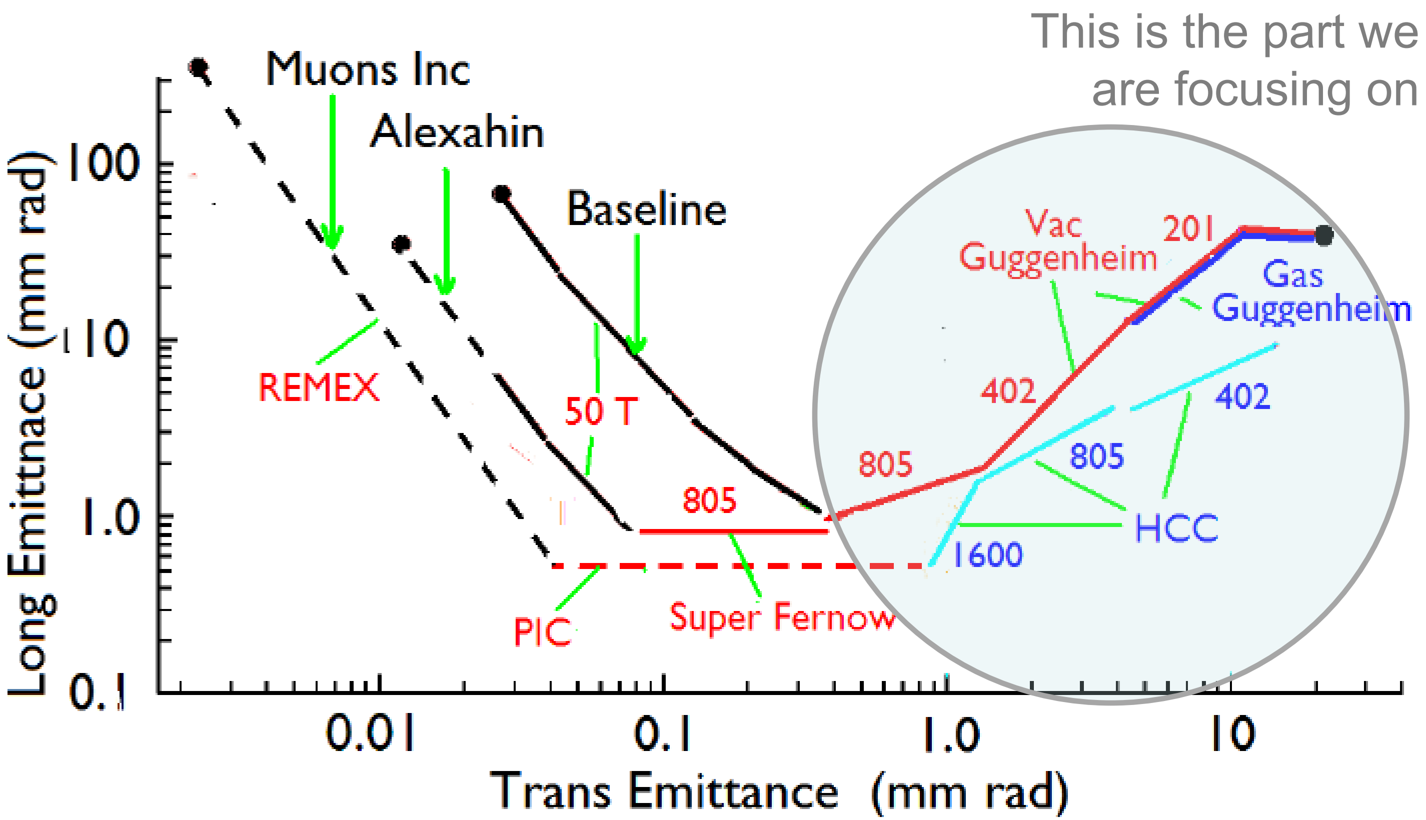
- **Goal: Establish feasibility of 6D muon cooling required for collider.**

- Want to bring (at least) one cooling channel technology to the point where
  - Enough engineering has been done that we are confident it can be built.
  - Simulations show that what we can build would actually cool.
- We would then like to build a suitable section as an engineering demonstration, eventually followed by a 6D cooling experiment.
  - Cost estimate for engineering demo is $3-5M.
- As an initial goal: Investigate the Helical Cooling Channel (HCC) proposed by Derbenev & Johnson (Muons Inc):
  - Investigate HPRF behavior in beam.
  - Find a realistic way to incorporate RF into the HCC

  } Focus of this talk

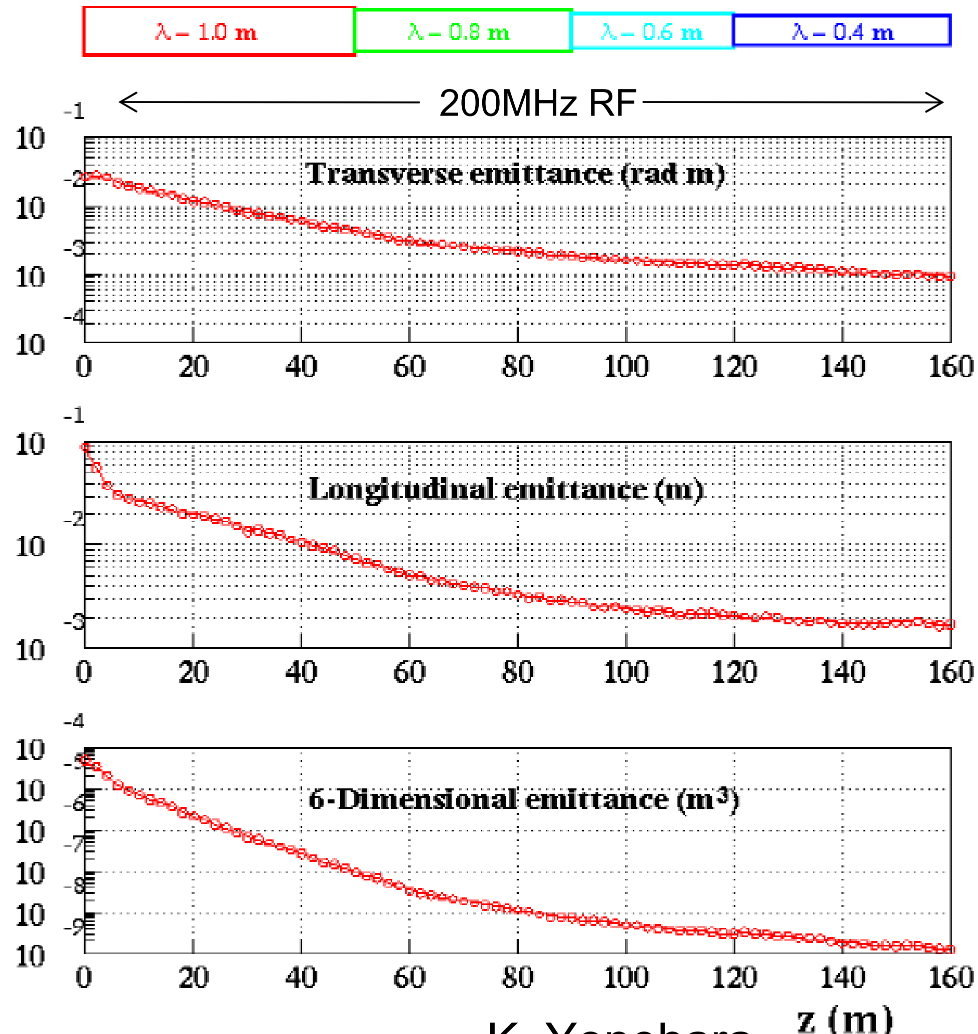
The bigger picture

(See Palmers talk)



Why focus on HCC?

- Possibility of high average gradient yielding fast cooling and less decay losses.
- Concept needed further study.
- Guggenheim already being studied by NFMCC.



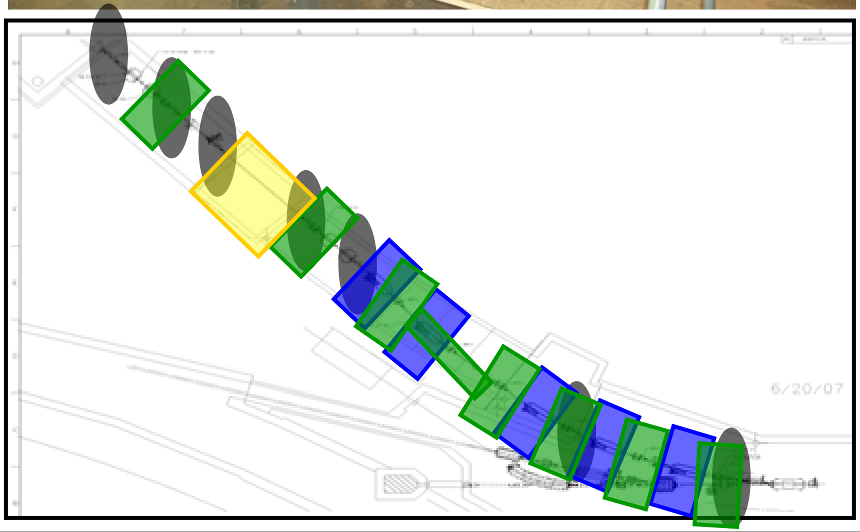
K. Yonehara

Beam tests of

HIGH PRESSURE RF CAVITIES

MTA beamline

- HCC uses high pressure H_2 cavities
- Test with beam critical to understand if HPRF cavities are useful.
- MTA beam line major activity and budget item for MCTF this year.
- See separate talk (Johnstone)



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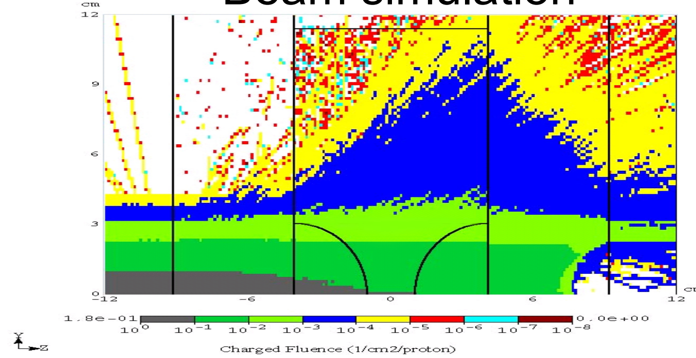
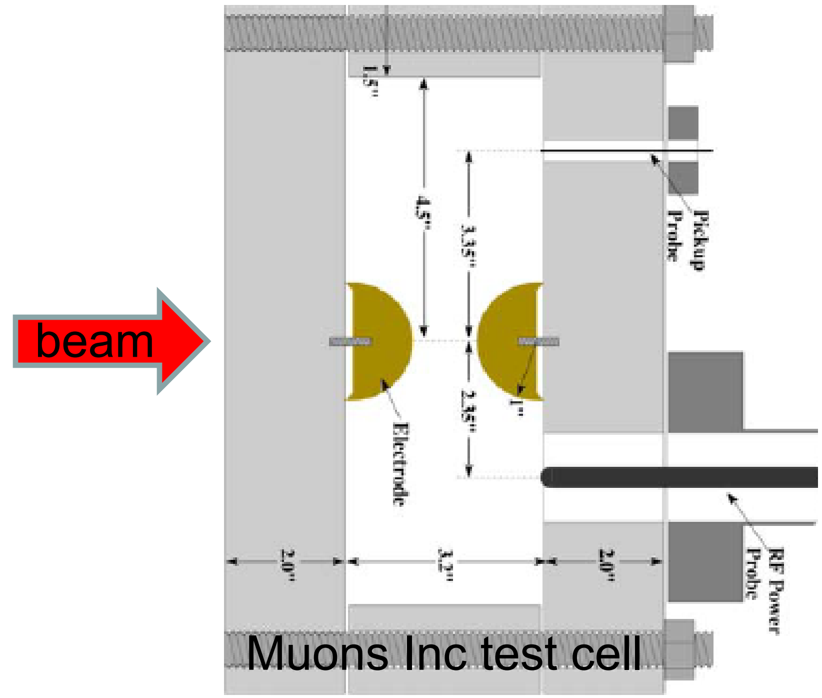
First HPRF experiment

- Beam tests will be done in collaboration with Muons Inc
- First test will use the existing Muons Inc test cell
  - Will indicate direction of follow-ups experiments
- Linac 400MeV proton beam can generate ionization levels similar to muon beam.
  - 6e12 protons ~1.2e13 muons

Beam simulation

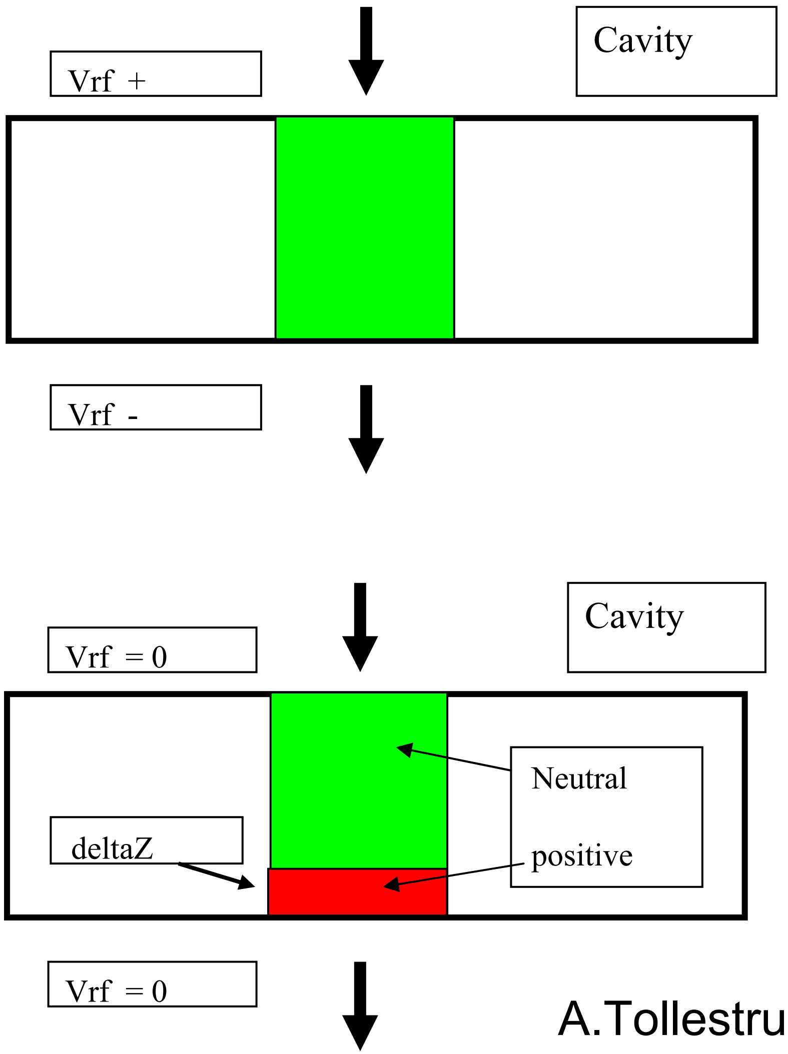




Muons Inc test cell

What we expect to see?

- If re-absorption time is long enough, electrons would load down the cavity.
  - Effect increasing along linac pulse
- Estimates depend on hydrogen purity and vary by orders of magnitude
  - Try adding e.g. SF6
- Limited diagnostics
  - Power probe
  - Field probe



A.Tollestrup

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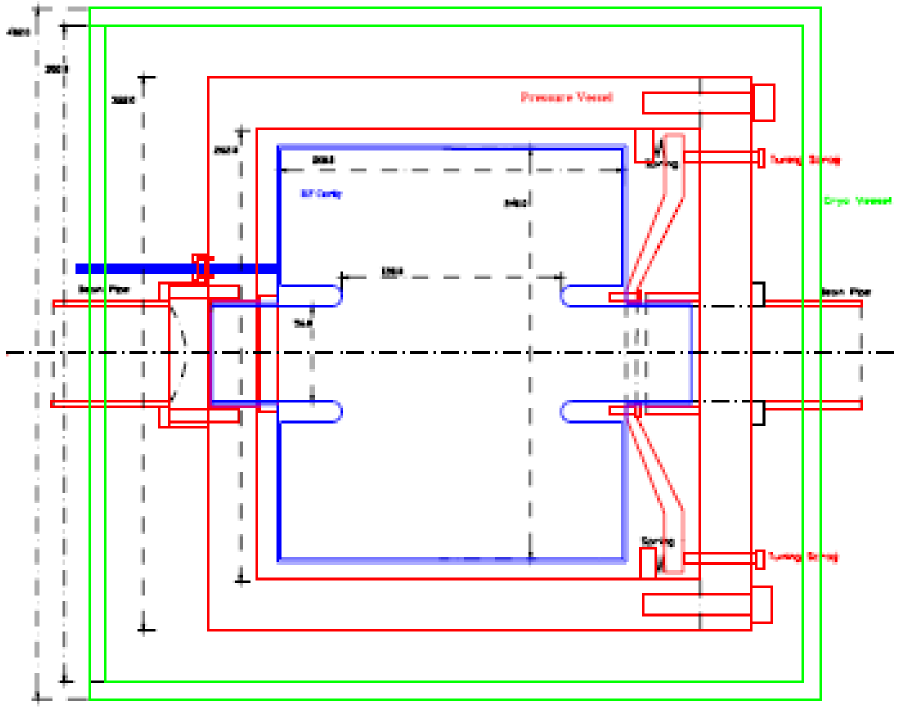
Follow-up cavity

- Test cell is not an accelerating cavity.
- Several effects we will not be able to study
  - Scaling with pressure
  - Are the ions a problem?
- Build dedicated cavity!
- Will require MCTF resources in FY09.
  - Scale ~1 FTE + ~$200k
  - There is also a SBIR Phase I with Muons Inc.

M. Popovic



Tunable HP cavity

HPRF summary

- MTA beamline installation major activity in FY07-08.
- Plan to complete first HP cavity test by end CY08.
  - Requires MTA beamline completions, which is contingent on LINAC access possibility (shutdown now moved to CY09).
- Follow up with dedicated cavity in FY09.

How to

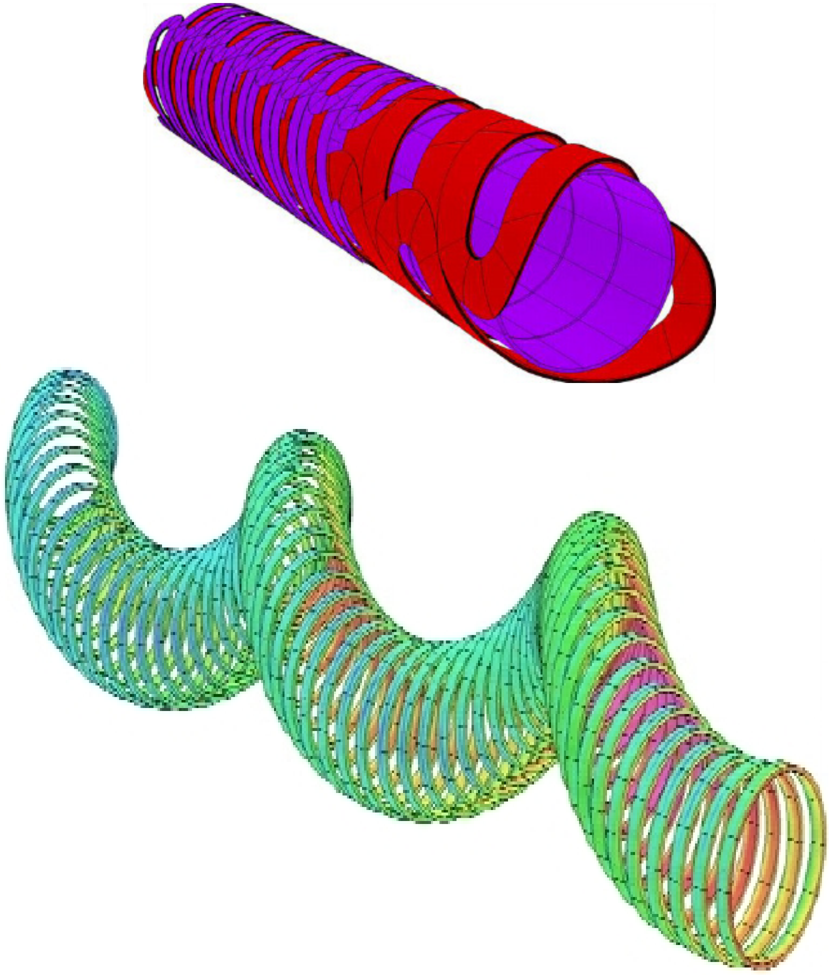
INCORPORATE RF IN HCC

Balbekov's HCC "rules of thumb"

- Independent analysis by Balbekov has confirmed Yonehara's main simulation results, and in addition provided some rules of thumb:
  - Equilibrium emittance is proportional to helix period.
    - 1-2mmrad at 1m helix and 250MeV/c
    - Generally higher in HCC than e.g. Guggenheim for comparable magnetic field because of weaker focusing at absorber
  - There is an optimal RF frequency for each helix period. The cavity size roughly scales with the helix period.
    - 200MHz @ 1m, 400MHz @ 50cm, etc
    - Engineering more challenging than in previously simulated cases.
  - Obtainable 6D cooling factor (ratio of acceptance and equilibrium emittance) with fixed helix period is about 90 in ideal case.
    - Further cooling requires shorter helix (higher B field and RF frequency).

Magnet design

- HCC requires superimposed solenoid, helical dipole and helical quadrupole fields
- Helical solenoid (HS) use smaller coils than a "traditional" design
  - Lower peak field
  - Less stored energy
  - Lower cost
- Field components in HS determined by geometry
  - Over constrained
  - Coil radius is not free parameter



V.Kashikin

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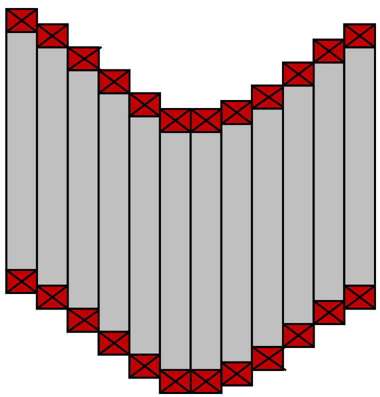
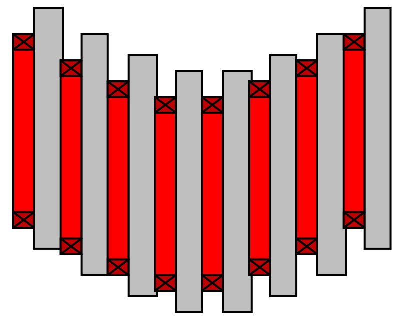
How to implement a real HCC?

"Type I"



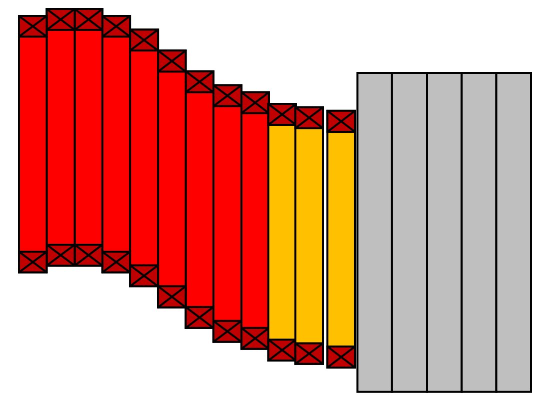
- RF inside coil
- Highest possible RF packing factor
- Cavity must be smaller than the coil → high frequency

"Type 2"



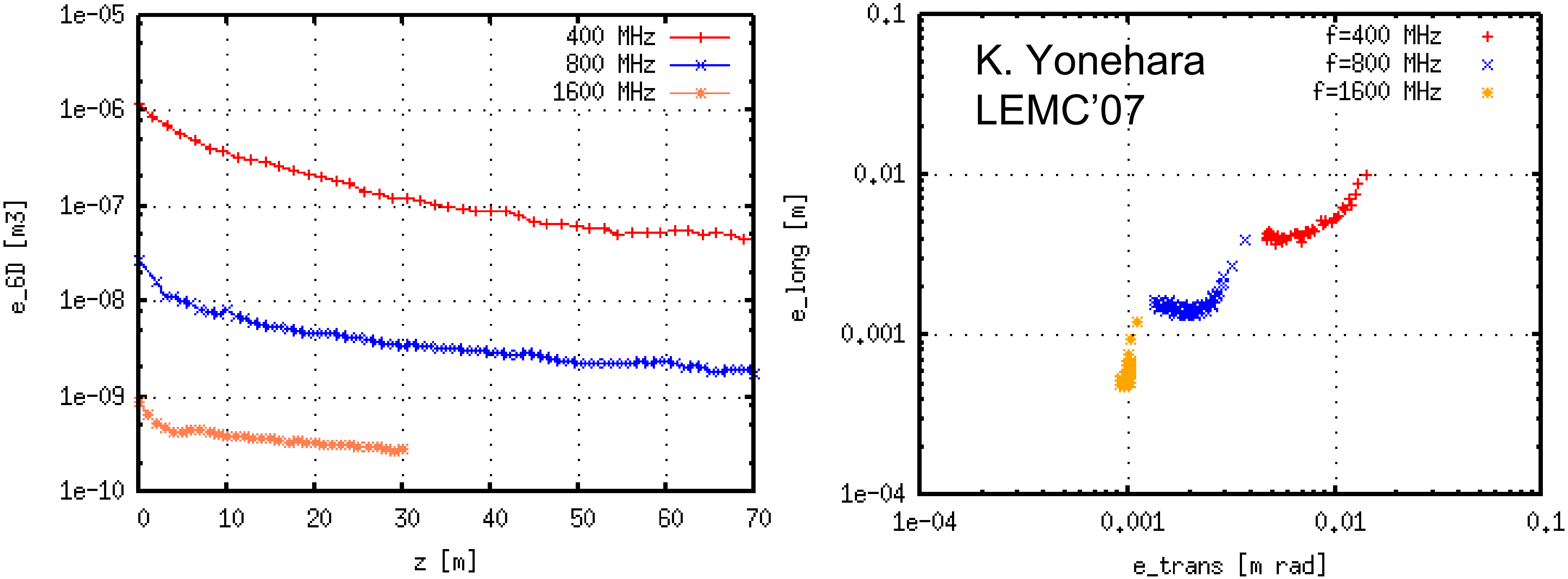
- RF between coils
- Lower RF packing factor.
- Difficult H_2 cryostat design and assembly

"Type 3"



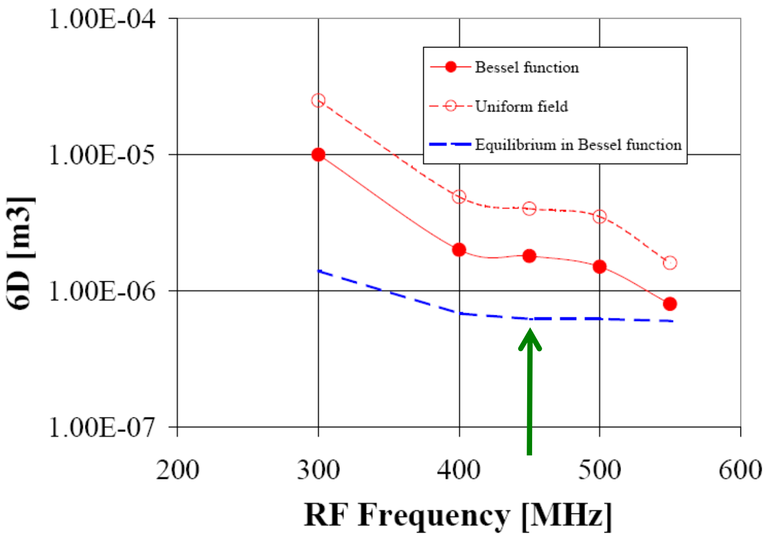
- RF and coils separated
- Lower RF packing factor
- Likely easier to build and maintain.
- Requires good matching between sections

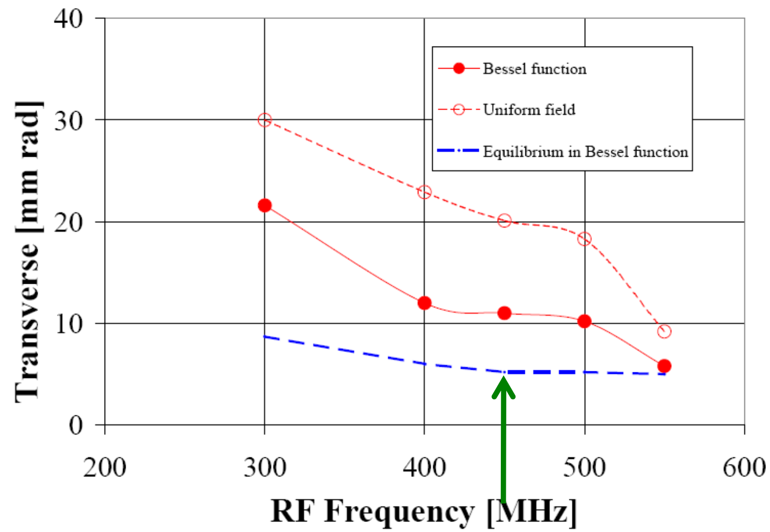
HCC Type I simulations



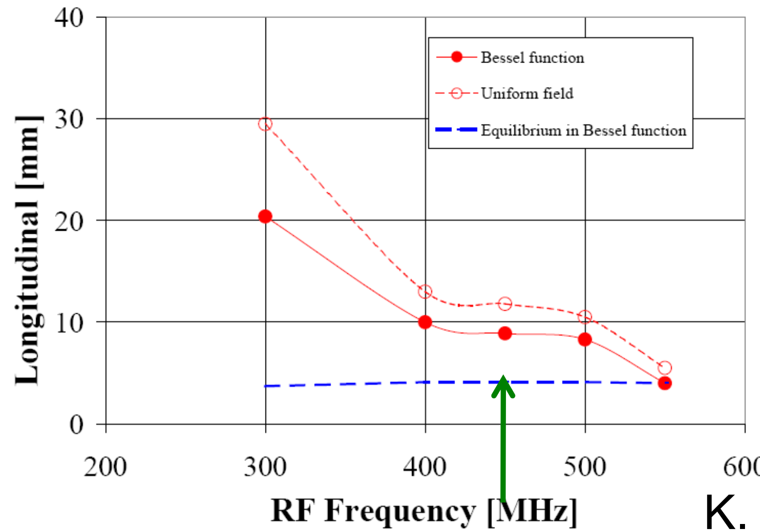
- R_{cavity} =56cm, R_{coil}=50cm, 4000x cooling factor
- More realistic, but still $R_{cavity} > R_{coil}$.
- What happens when reducing the cavity size further?

Reducing cavity size





- Initial and final emittances for different frequency cavities (fixed coil diameter).
- Green arrow indicates where $R_{cavity} = R_{coil}$
- 10% smaller cavity seems OK
- 20% smaller cavity does not cool



K. Yonehara

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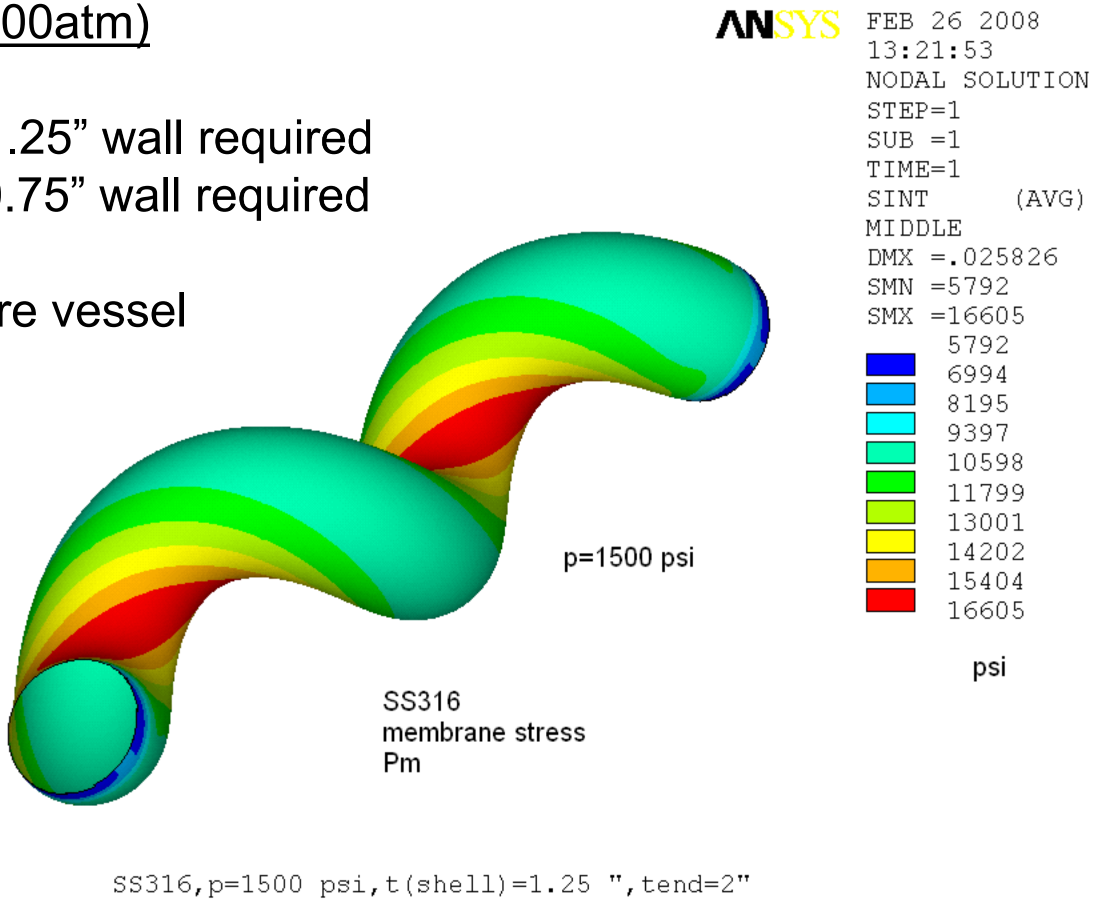
Stress simulation of helical pressure vessel

<u>At 1500PSI (100atm)</u>

SS316: 1.25” wall required
Inconel 625: 0.75” wall required

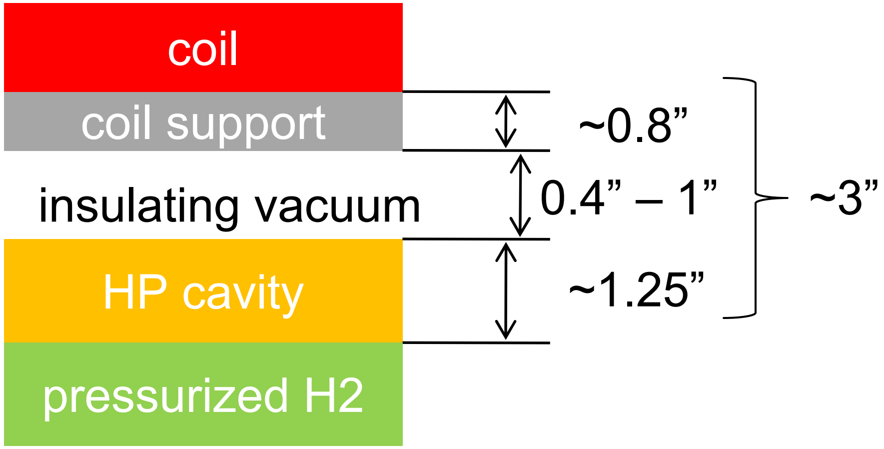
ASME pressure vessel
code used



A.Lee

Required clearance

- Coil and cavity at different temperatures require insulating vacuum gap.
- Estimated required clearance ~3”
  - This does not include any RF feed
- Compare to HP H_2 cavity radius at various frequencies
  - Only 200MHz version appear to be plausible.
  - Balbekovs results imply high equilibrium emittance.

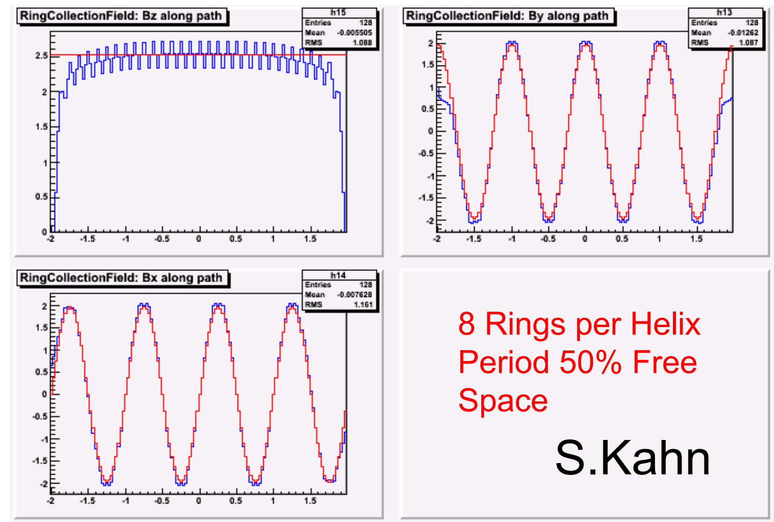


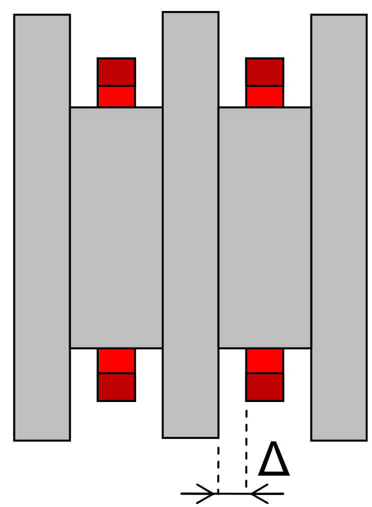
Frequency	Cavity Radius	ratio
200 MHz	55cm (22”)	88%
400 MHz	28cm (11”)	78%
800 MHz	14cm (5.6”)	65%
1600 MHz	7cm (2.8”)	48%

(assuming 200atm H_2)

RF between coils

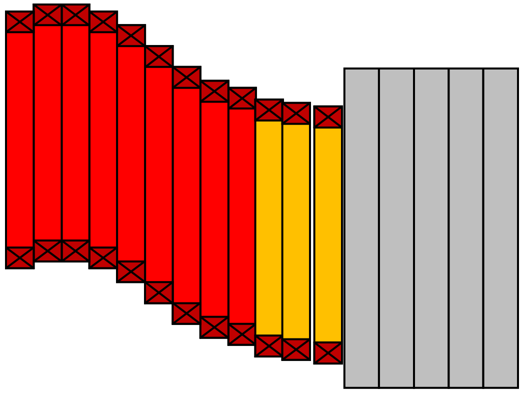
- Coils can be separated to allow space for cavities without compromising field.
- Similar clearance requirements would likely apply longitudinally.
- Very short helix periods appear impractical.
  - Balbekovs results imply high equilibrium emittance.
- Lower RF packing factor implies slower cooling
- Need further study

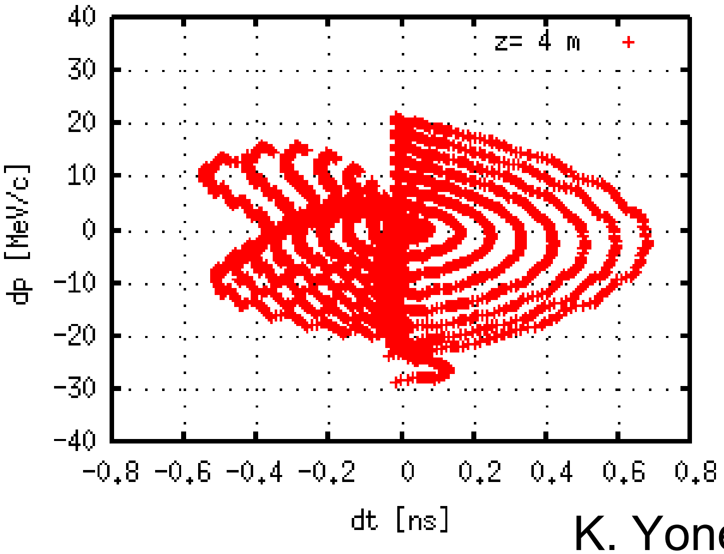




Separate RF and helical solenoid

- Observed problem: time-of-flight spread in helical section too large for longitudinal stability.
- To be efficient, would need a short matching section.
  - Lower RF packing factor implies slower cooling.
  - Current matching design adds significant length.
- Solution may exist, but not found yet.





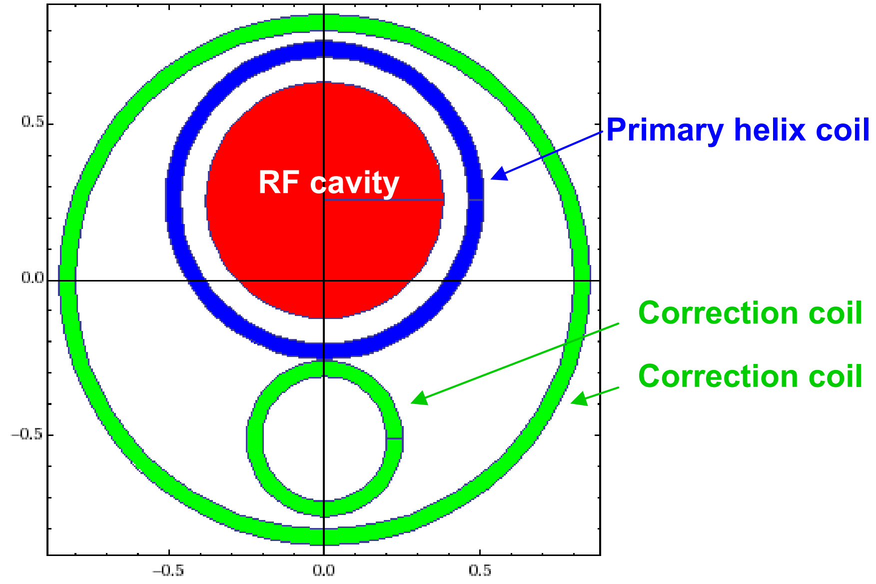
K. Yonehara

HCC Status

- We now have a bottom-up estimate of the engineering clearances required for a HCC based on a Helical Solenoid.
- Simulations of the simplest Type I (cavity inside coil) HCC obeying these constraints indicate loss of cooling
  - Possibly with the exception of 200MHz version, which can not go all the way to the required emittance.
- There are plenty of ideas left, which will be investigated in the near future.

Example of Modified Helical Solenoid HCC

- Adding more coils to the Helical Solenoid could relax the geometrical constraints and allow to widen the primary coil
  - Overall solenoid could allow independent tuning of B_z component
  - Additional helical correction coil(s) could give further tuning range of quad component.
- Dielectrics inside the cavity could reduce cavity size



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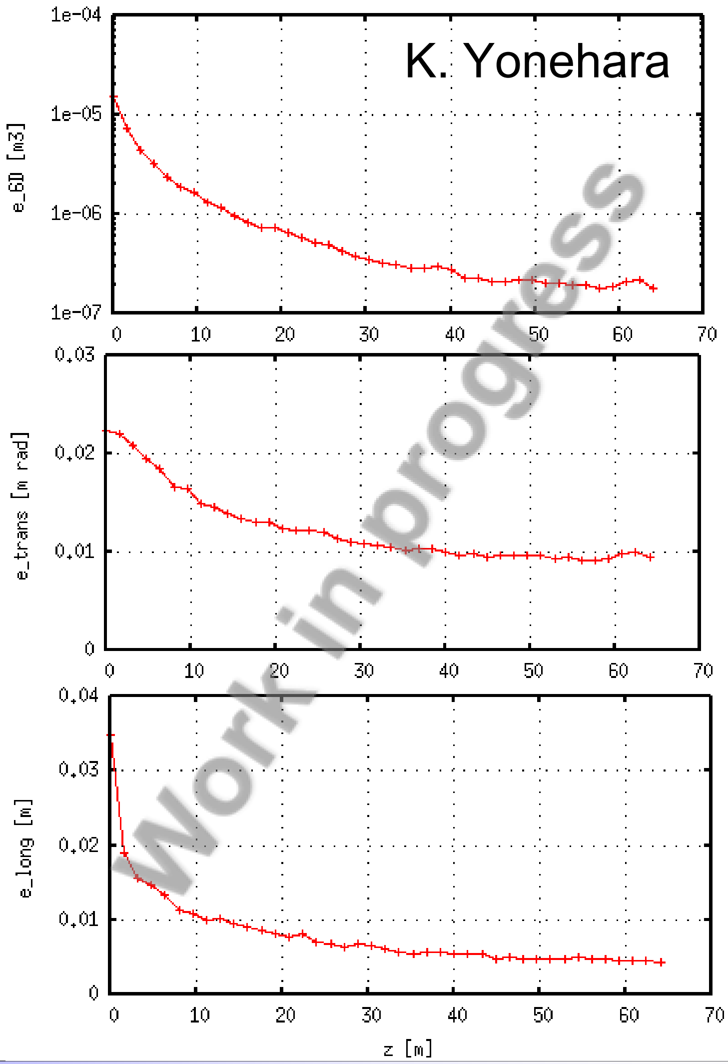
Preliminary result HCC with correction coils

- Preliminary study using
  - 300MHz cavities
  - 1.6m helix period.
  - 8cm radial clearance between cavity and coil
- Seems to work in simulation!
- Need to investigate:
  - extension to higher frequency & shorter periods.
  - optimal correction coil scheme.



Near Term Plans

- Finish MTA beamline and test HPRF cavity with beam.
- Continue efforts on including RF in HCC, looking for solution that can be extended to shorter periods and higher frequencies (=low emittance).
  - If a promising solution is found: proceed to engineer, build and test a section of HCC with RF.
  - If no promising solution can be found, move on to consider e.g. FOFO “snake” or Guggenheim.
- Work out a coordinated NFMCC/MCTF experimental plan between now and August.