Cooling Studies in the UK

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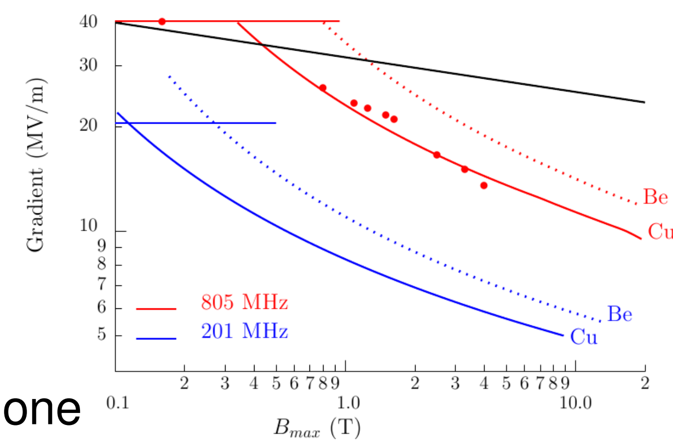
Cooling in the UK

- UK cooling studies focus on Neutrino Factory
  - This is muon collider front end
- I won't talk about MICE
- Aim is to have a practical, costed, engineered solution ready in ~3-4 years
  - Ready for IDR in 2010
  - Ready for CDR in 2012
- Study ISS/FS2A cooling channel design
  - Effect of reduced gradient
- Look at ways to mitigate the effect of RF in high B-field
  - Even if MTA produces a good result with 200 MHz cavity in B-fields, should we believe it?
    - A statistic of 1
  - If MTA produces a bad result we need to be ready to manage it

Cooling with Reduced Gradient

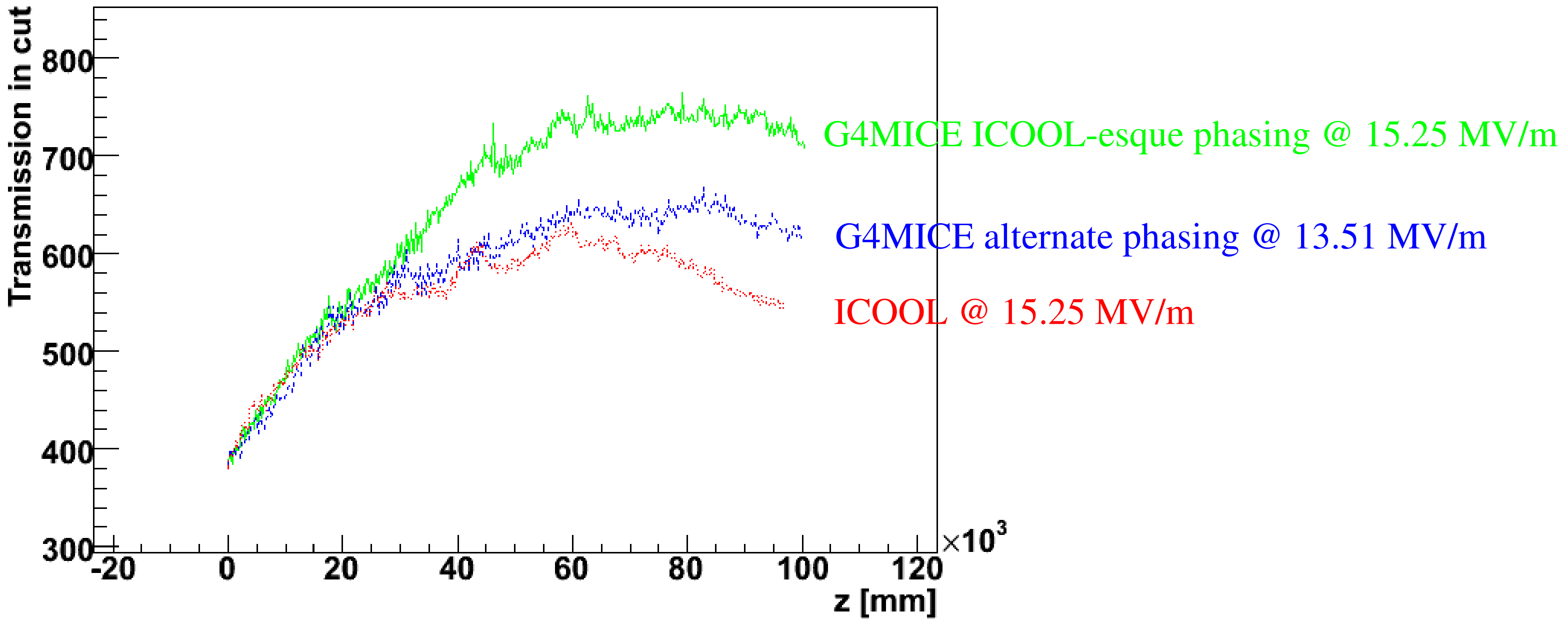
- NF cooling channel RF is
  - 15.25 MV/m @ 200 MHz
  - Sitting in ~2.4 T field
- It looks like this is tough to achieve
  - Kilpatrick Limit is at 17 MV/m
  - But 2.4T field limits what can really be done
  - Palmer's simulations indicate might only get ~7 MV/m
    - Many caveats, esp that FS2A coils sit on a field flip
- First: what is the difference in cooling performance between G4MICE and ICOOL?
- Second: How well can the FS2A cooling channel cope with a reduced gradient?
- Third: Scheme(s) to mitigate this problem



Simulation in G4MICE

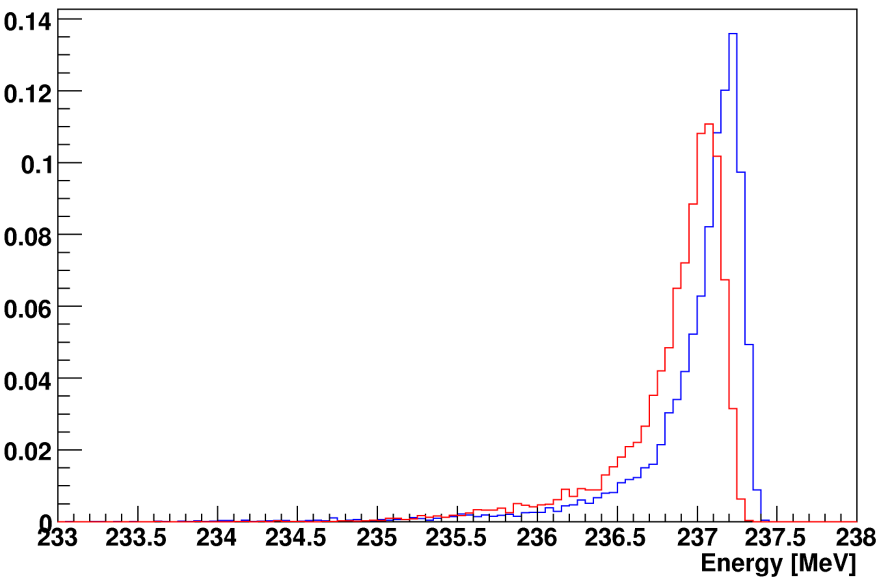
- Movie 1 (generated by G4MICE/povray interface)
  - Simulate using ISS beam

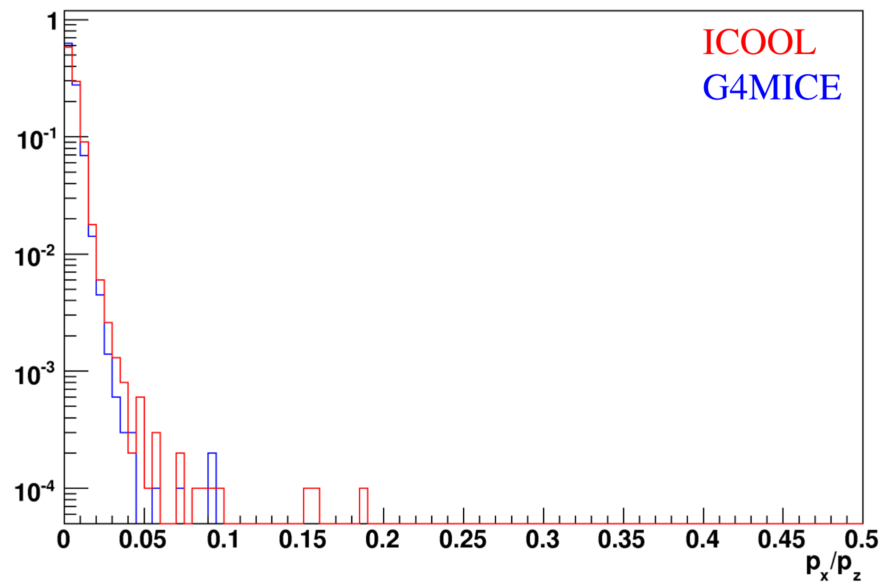
Transmission in Cut



- Plot number of muons in 30 mm acceptance with 150 < E_{tot} < 300 MeV
- Shows number of muons that would make it into an accelerator chain
  - Initially 383 muons in this cut
- G4MICE with the constant energy phasing model does very well
  - Much better than ICOOL
- Why is this?

Lithium Hydride Model

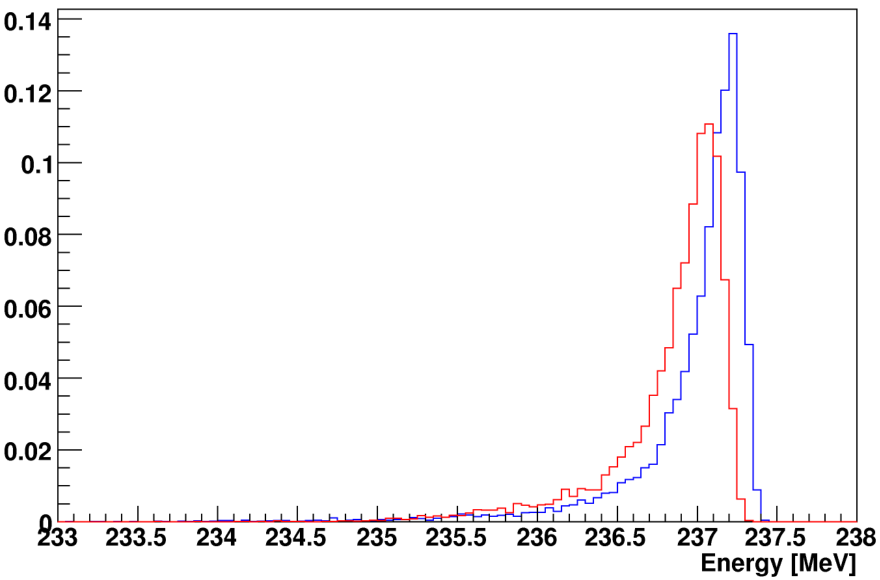


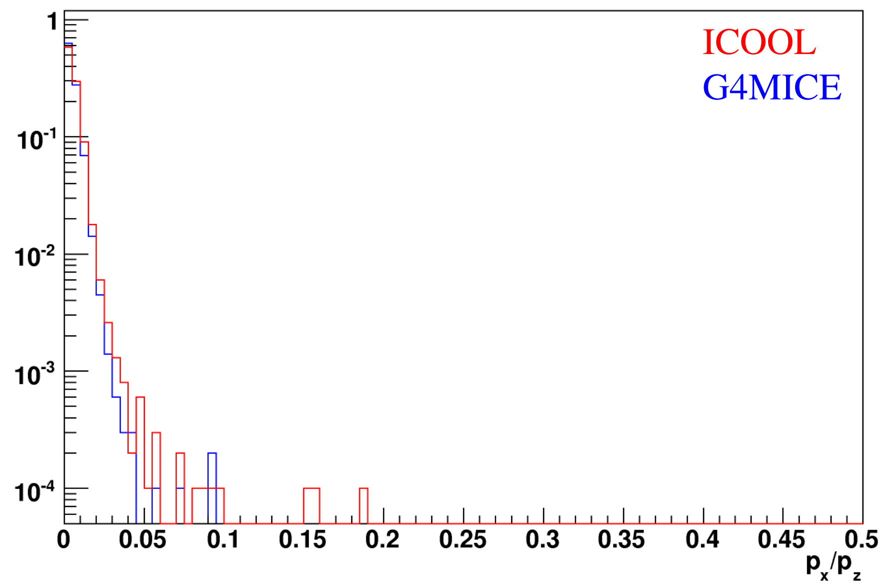


- For 1 cm LiH:

LiH	*ICOOL*	*G4MICE*
Change in E [MeV]	1.823	1.682
Final RMS E [MeV]	0.382	0.424
Final RMS x'	0.00782	0.00633

Lithium Hydride Model





- For 1 cm LiH (PDG = Particle Data Group formulae)

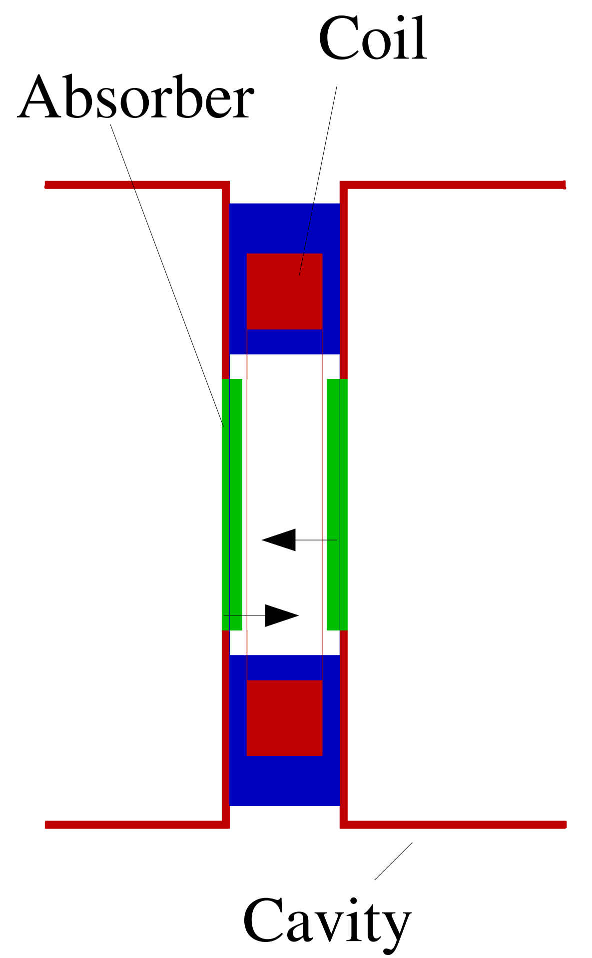
LiH	*ICOOL*	*G4MICE*	*PDG*
Change in E [MeV]	1.823	1.682	1.710
Final RMS E [MeV]	0.382	0.424	N/A
Final RMS x'	0.00782	0.00633	0.00597

Material Model - Comments

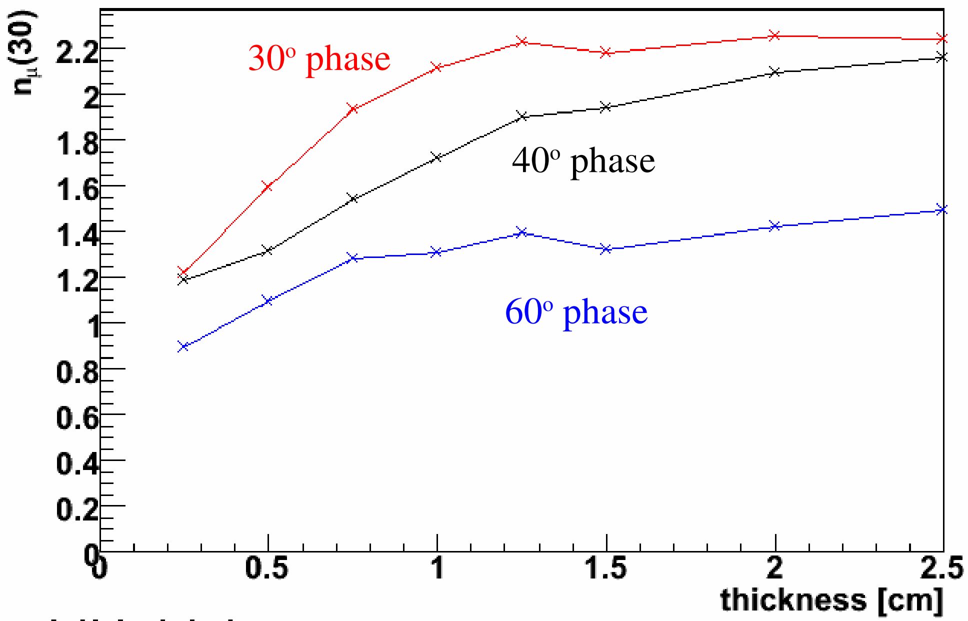
- G4.8.2 estimates significantly less energy loss and multiple scatter compared with ICOOL
  - G4 seems to agree better with PDG values
  - Better models are available in ICOOL
    - For comparison with ISS, I use the ones that came with the deck
      - dE/dx with density effect
      - Bethe version of Moliere scattering with Rutherford limit
      - Vavilov energy straggling
  - ICOOL uses less dense LiH
    - But this should push the physical processes in the opposite direction
  - Both codes compare well with MuScat
    - There was no LiH in MuScat
- Note the discrepancy and push on to look at cooling with reduced RF peak field

Changing RF Voltage

- Study effect of changing the peak RF voltage on the cavity
  - Keep all cavities at same voltage
  - Vary RF phase and Lithium Hydride thickness
    - Aim is to keep the energy loss from material the same as energy gain from cavity
  - Use alternate G4MICE phasing model now
    - Set energy gain independent of RF phase
    - G4MICE figures out the appropriate peak field
- As I change LiH thickness, stretch material into vacuum region
  - Keep material out of RF cavity

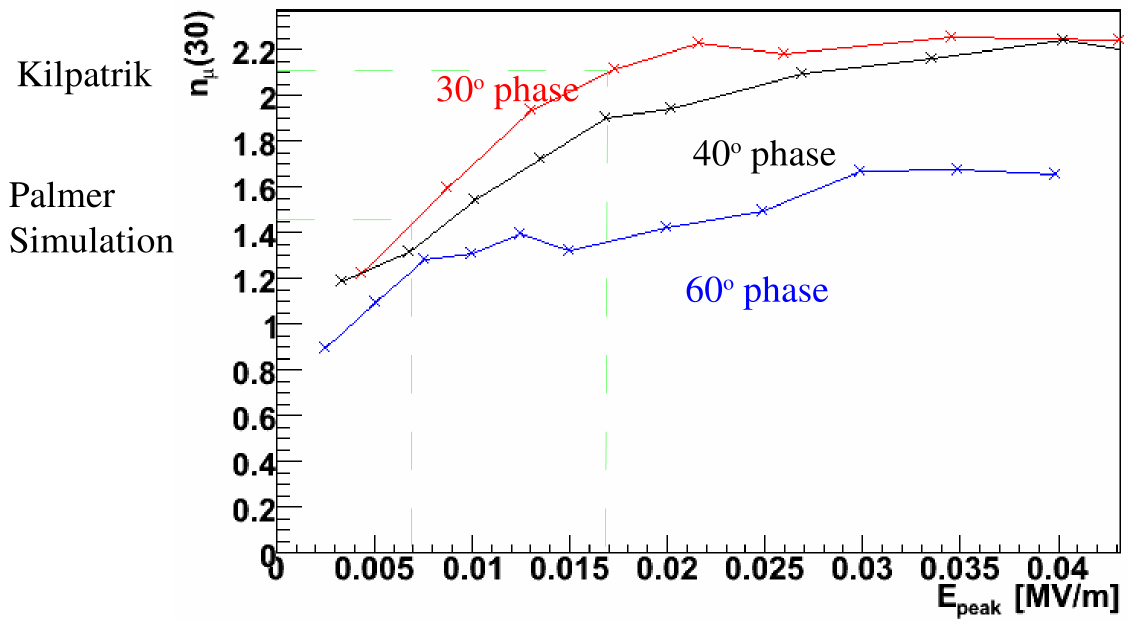


Transmission vs Thickness



- First I adjust LiH thickness
  - Set peak field to give reference particle constant energy
  - Plot *(peak number of muons in cut)/(input number in cut)*
    - Cut is on 150 < E < 300 MeV and Amp < 30 mm (excluding tails)
  - Cooling performance vs LiH thickness
- Improved transmission at lower phase
  - RF bucket is larger
  - Peak field is greater to keep energy gain the same

Cooling vs Peak Field

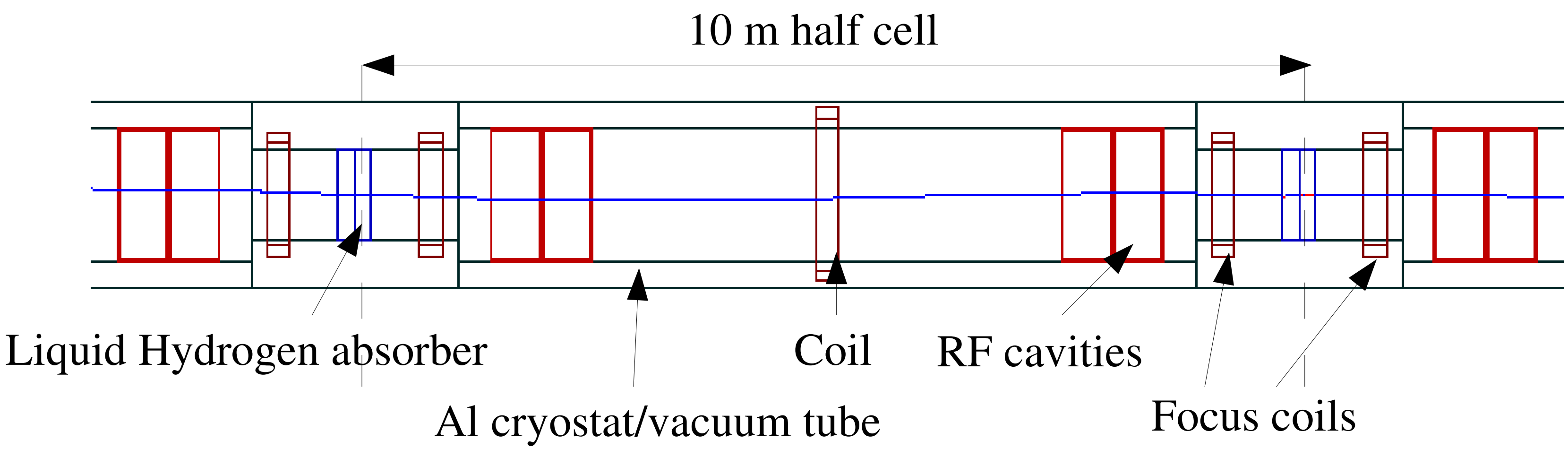


- The same plot but now x-axis is the peak field required to get the appropriate thickness
  - Phasing RF at 30° gives a superior performance than RF at 40°
  - Difference is quite significant
    - 20% on the number of muons i.e. 2 years of running for a Neutrino Factory
  - At 17 MV/m best performance is ~ factor 2.1 in number of muons
  - At 7 MV/m best performance is ~ factor 1.45 in number of muons

Alternate Lattices

- Trying some alternate lattices to mitigate the problem of RF in B-field
- Also worry about maintainability of the system
  - For NF, a cooling channel that gives ~ factor 2 increase in number of muons but is broken half the time is a waste of money
- Three lattices:
  - (i) Stretched SFoFo lattice
  - (ii) Stretched SFoFo lattice with recirculators on the end
  - (iii) Stretched SFoFo lattice with tilted solenoids for bends => ring

Stretched SFoFo Lattice



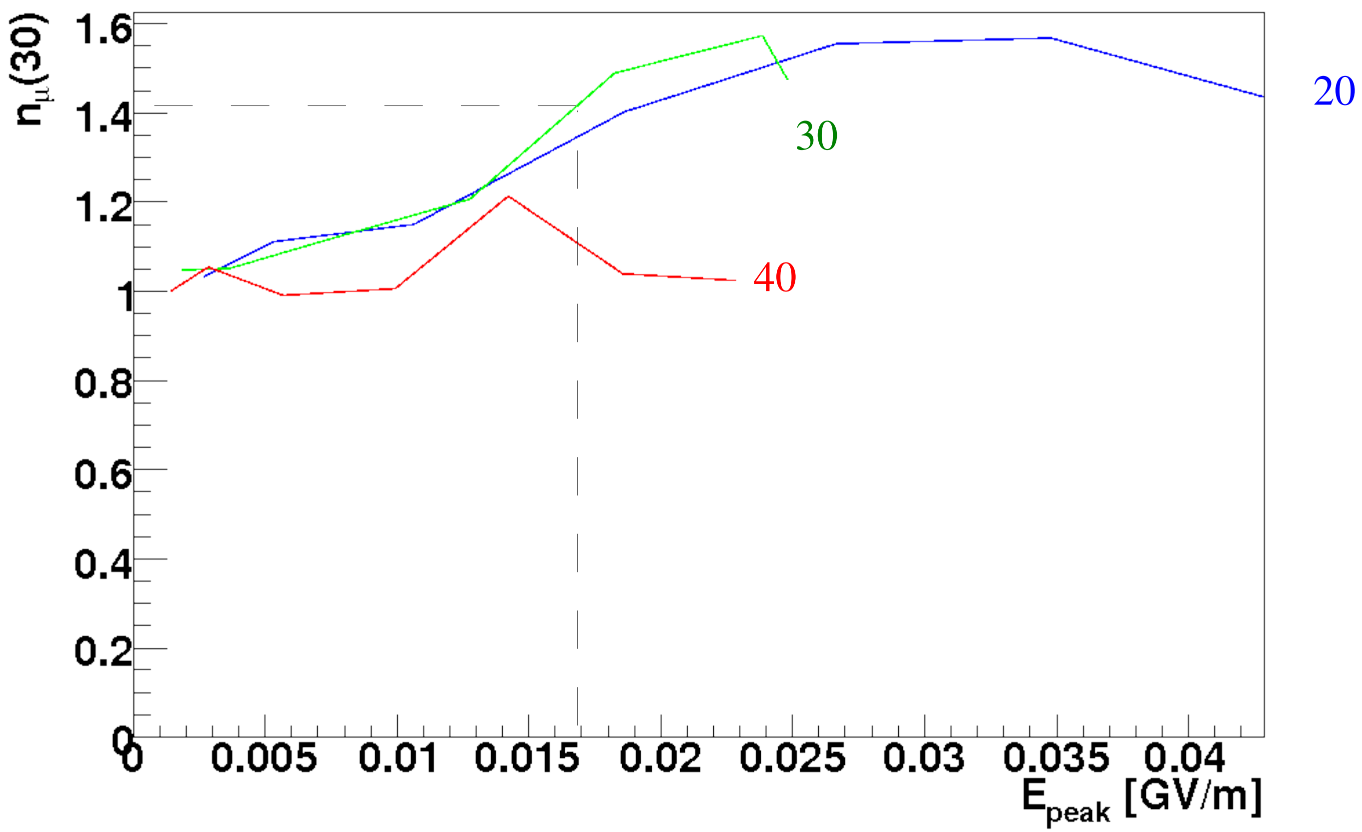
- Much more space to move around
  - RF cavities can be taken away from magnetic fields
- Achromatic over ~ 50 MeV/c
- Limited by dynamic aperture of ~ 80 mm amplitude
  - Need to bring this up a bit

Dynamic aperture

- Movie 2 (generated by G4MICE/analysis interface)

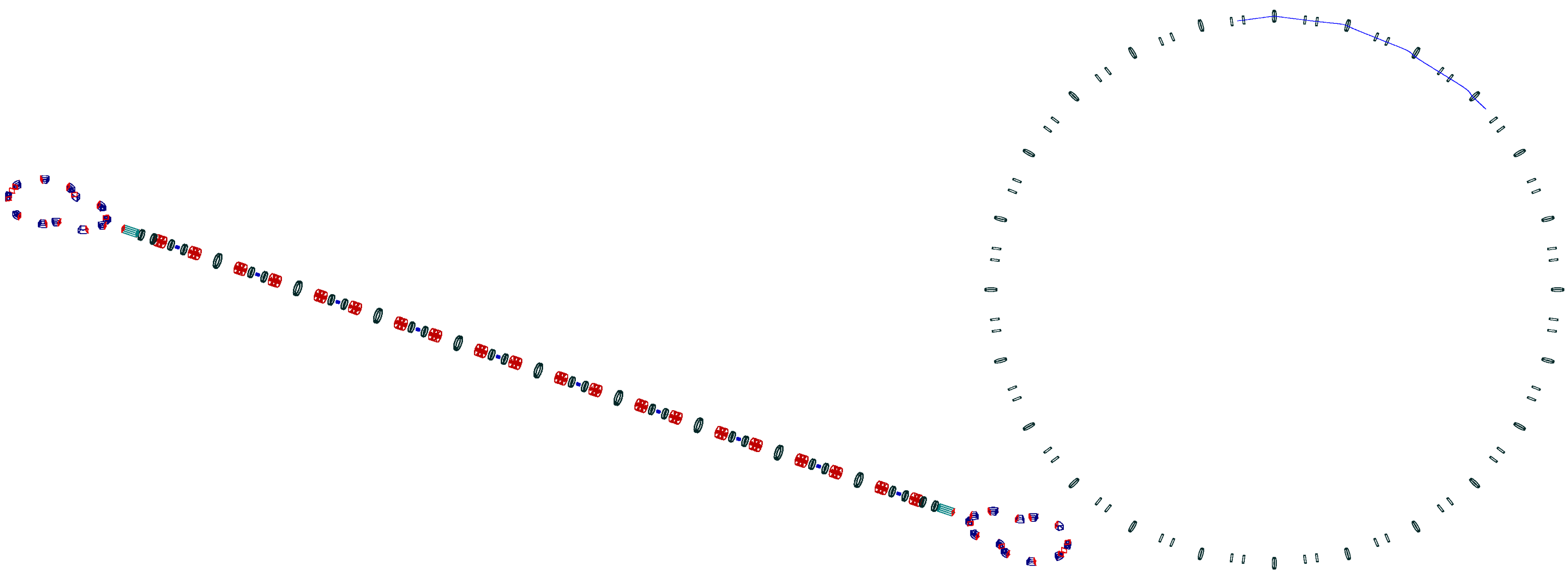
Stretched SFoFo Lattice

- At the Kilpatrik limit, I get < 45% increase in number of muons
  - ~Same as FS2A with limited RF



Recirculating Lattices

- Recirculation is plausible (but not easy)
  - Longer lattice => time for kickers
  - More vacuum => space for kickers
  - But tricksy solenoid fringe fields to navigate
- Problem - getting dynamic aperture high enough

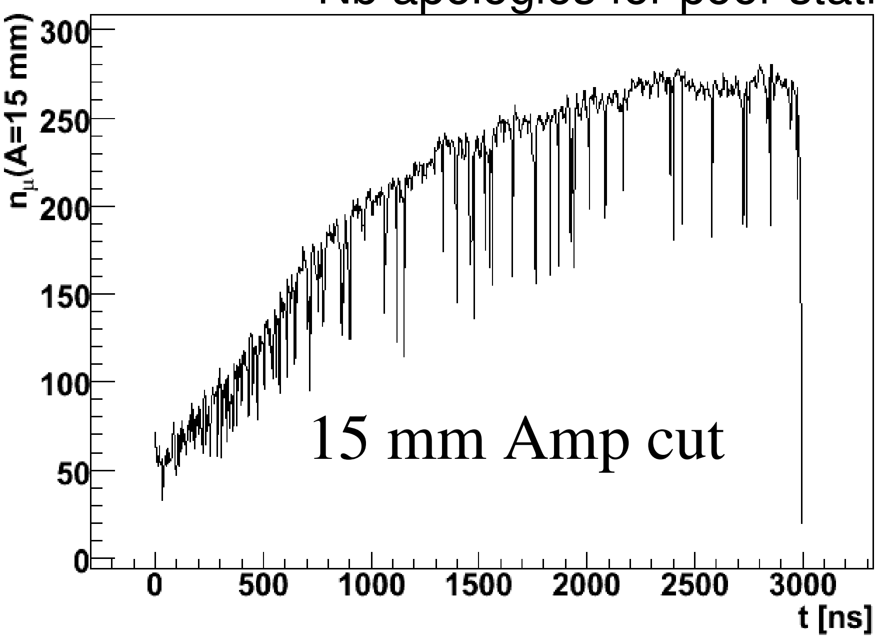


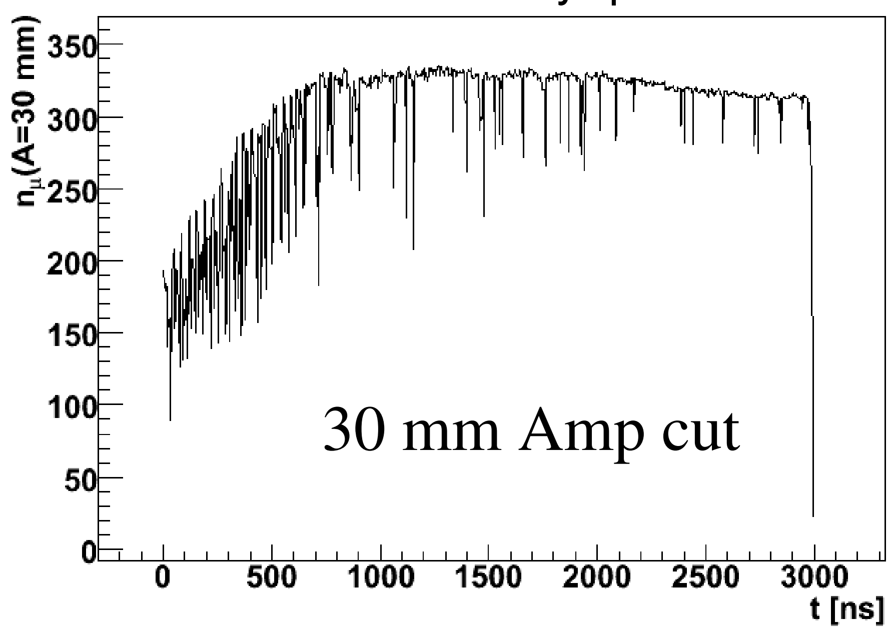
SFoFo Ring

- Movie 3

SFoFo Ring

- With idealistic beam...
  - 0 longitudinal emittance
  - ~20 mm initial transverse emittance
- ...Cooling channel shows reasonable performance over 3 turns
- Difficult to get polychromatic beam through
  - Would allow us to take advantage of emittance exchange
  - Nb apologies for poor statistics & effect of tails => “fuzzy” plots





Schedule

- Aim for Neutrino Factory Interim Design Report 2010
- Conceptual Design Report 2012
- This dictates schedule
  - Need to start engineering design work ~2010
  - Might want to start ramping the activity now/soon
- After 2010, conceptual work has to be upgrade or fallback for NF
  - A lot to do in 1 or 2 years
- Some hard work to be done!
- Dedicated NF Front End & Acceleration workshop on Sunday and Monday
  - Here at J-Lab
  - For detailed and free flowing discussion
  - All welcome - no registration fee
  - Feel free to sign up