Non-linearities in MICE

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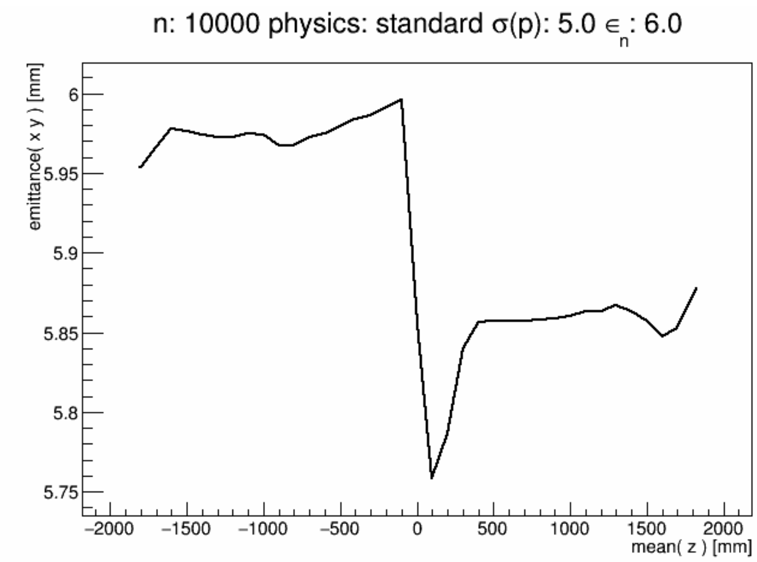
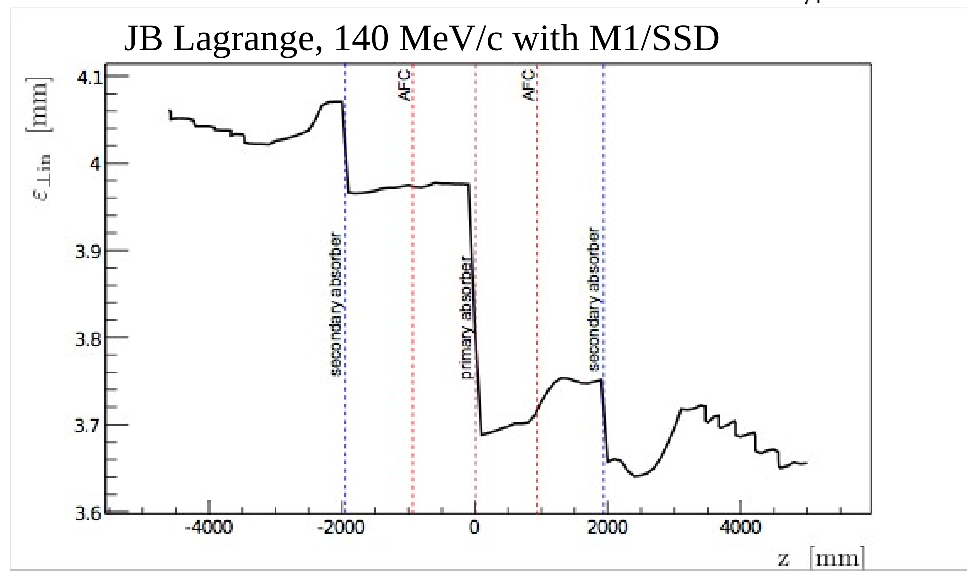
Non-linearities in MICE



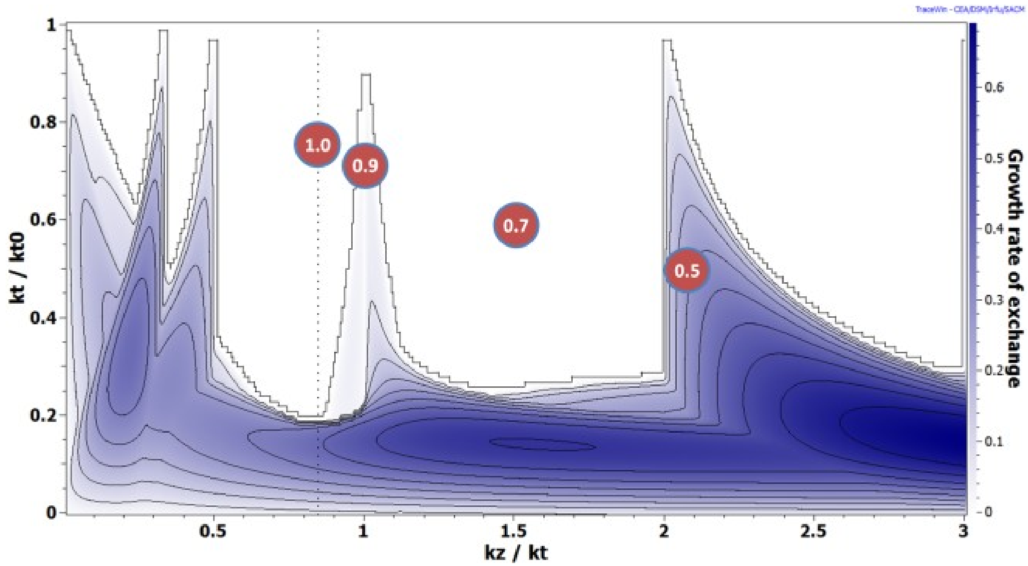


- Non-linear effects are topical for two reasons
  - Emittance non-conservation in MICE Demonstration of Ionisation Cooling lattice
    - At 140 MeV/c
    - Without M1
  - Emittance non-conservation in Step IV without M1
- Here I outline the problem; not the solution!

Non-linearities in MICE

- We don't quite have a crisp explanation for why these effects occur in MICE
  - Rob Ryne and C. Rogers, MICE Note 461 “The issue of greatest concern appears to be mismatch”
  - What does “mismatch” mean in a non-repeating linac?
- Matching a beam means “make a beam whose envelope is periodic with lattice period”
  - Not-periodic beams tend to filament out until they are periodic
- There is no matching
  - Without a repeating structure, we can't talk about “matching”
  - We can hack it for “old” step IV
  - It is an outright lie for e.g. asymmetric fields
- Many accelerator physics tools are predicated on having a repeating structure
  - Beta function

Non-linearities in proton linac



C. Plostinar et al, Measurement of Resonant Space Charge Effects In The J-PARC Linac, IPAC 13

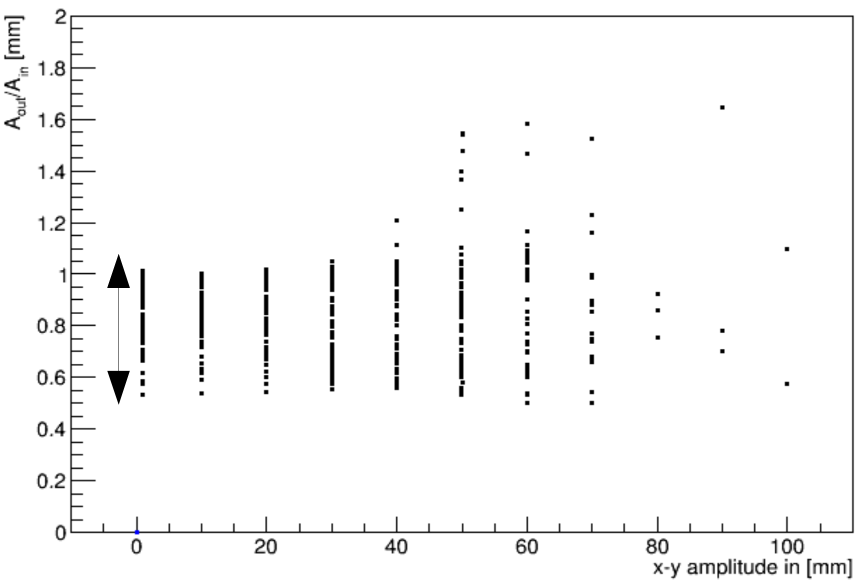
- E.g. proton linac (repeating structure)
  - Tune shift driven by space charge
  - Pushes particles onto resonances
  - Resonance stability “Hofmann charts”
- Can the analogy be take to MICE?
  - Tune shift driven by non-linear beam optics in solenoids
  - We do not have a repeating structure

Back to basics

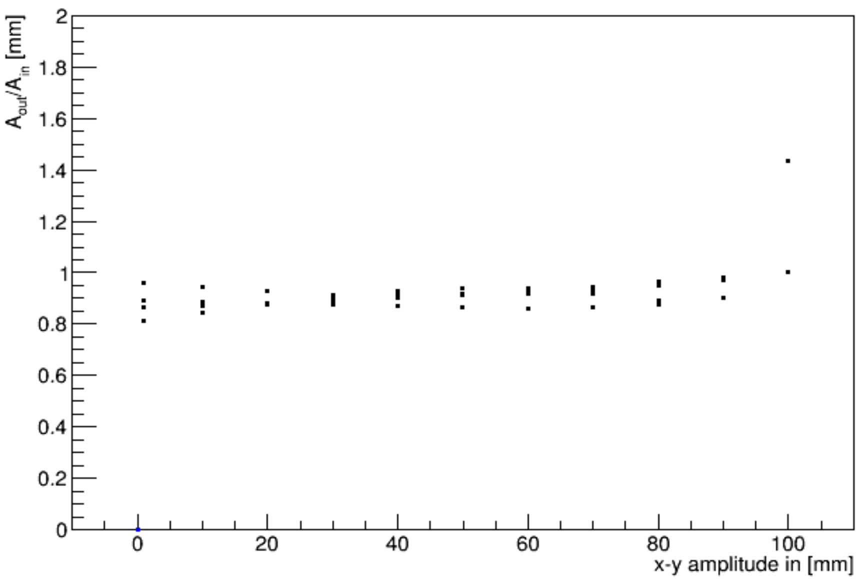
- Transfer map is defined (2D) as a Taylor series, like
  - $x_{out} = m_0 + m_{00}x_{in} + m_{01}x'_{in} + m_{000}x^2_{in} + m_{001}x_{in}\ x'_{in} + \ldots$
  - $x'_{out} = m_1 + m_{10}x_{in} + m_{11}x'_{in} + m_{100}x^2_{in} + m_{101}x_{in}\ x'_{in} + \ldots$
- In the absence of cooling
  - Terms up to m_{ij} conserve emittance (“linear map”)
  - Terms >= m_{ijk} do not conserve emittance
  - Phase space volume is always conserved for canonical coordinates
    - Canonical momentum $p^c_x = p_x + qA_x$
    - A_x is the vector potential, q particle charge
    - A_x is a non-linear function of x, y even in the constant-field spectrometer solenoids
- How strong are the non-linearities in MICE?
  - How much “curvature” is there in the tracking?
  - What are the residuals between “tracking” and “linear map”

Amplitudes

140 MeV/c



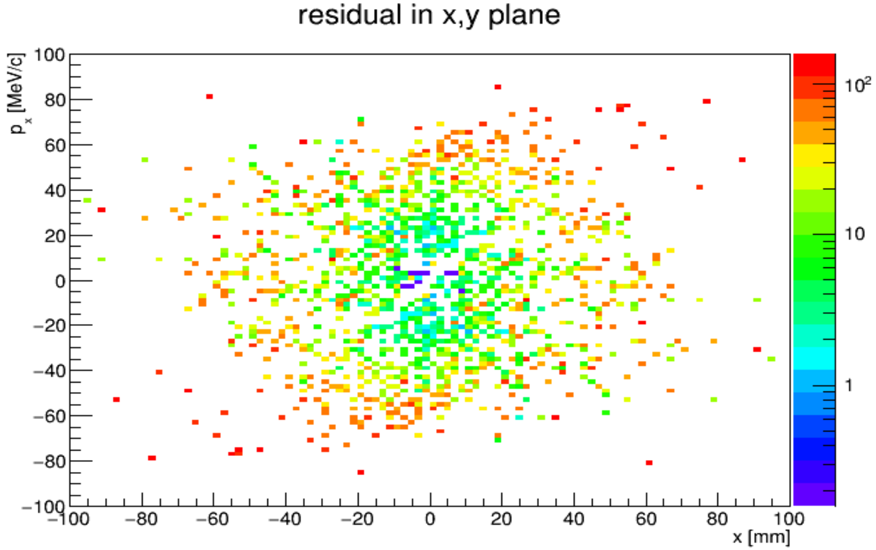
200 MeV/c



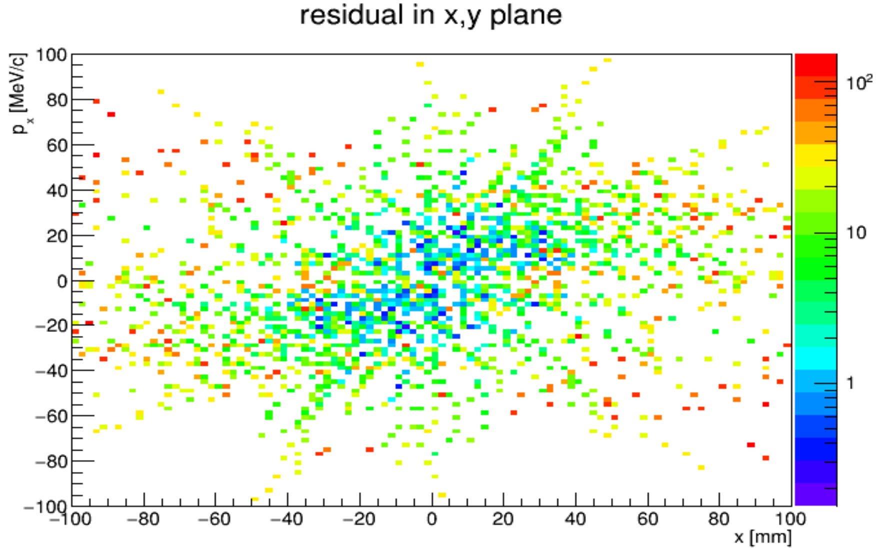
- Why the big spread in A_{out}/A_{in}
- Why is it bigger for 140 MeV/c lattice than 200 MeV/c lattice?
- (Mean reduction in A_{out}/A_{in} is cooling)
- Why the bigger scatter at higher amplitudes?
  - Why not for 200 MeV/c lattice?
- Both beams are “matched”

Non-linearity

140 MeV/c



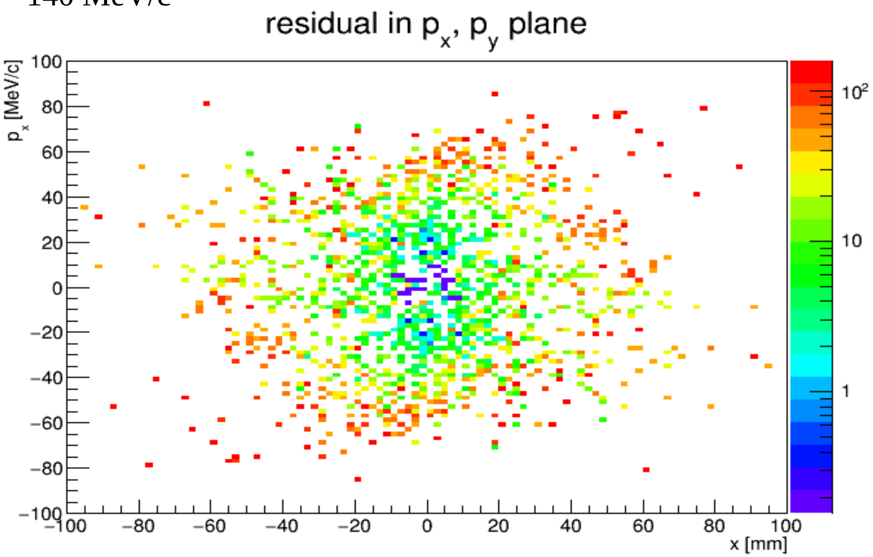
200 MeV/c



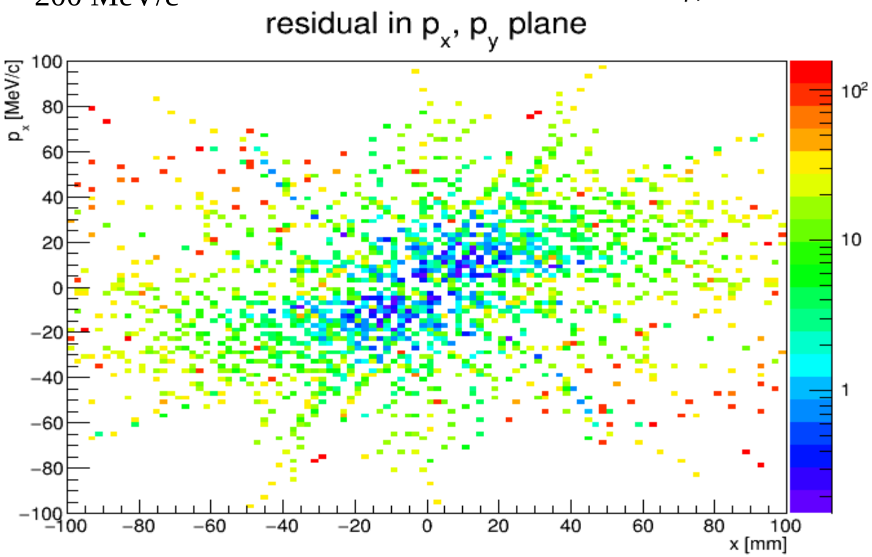
- Project tracks from upstream to downstream using linear map
- Compare with tracking
- Calculate "residual"
  - Position residual is distance in x-y plane from mapped to tracked
  - Momentum residual is distance in px-py plane from mapped to tracked

Non-linearity

140 MeV/c



200 MeV/c



- Residuals are generally worse for 140 MeV/c lattice than 200 MeV/c lattice
- Why?
  - More than just geometric emittance I think

The end

- To be continued...