Muon Chicane

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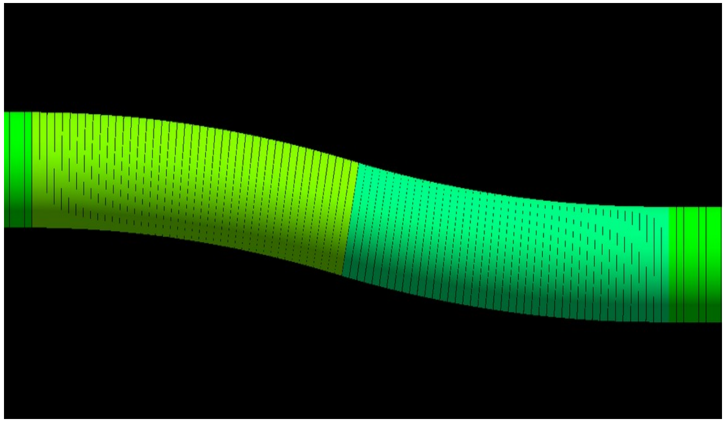
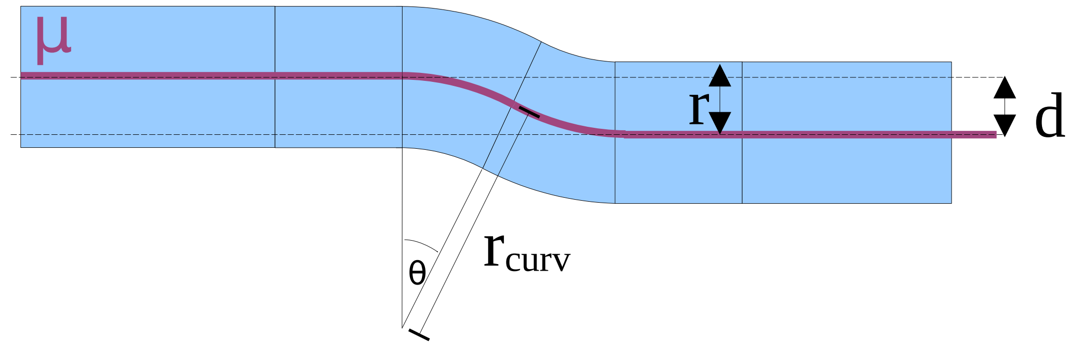
Chicane Revisited

- Chicane is needed to protect the longitudinal capture/cooling
  - Spallation protons would irradiate downstream equipment
    - Feasibility issue
  - Electrons would cause extra heating
    - Cost/technology issue
- Conventional chicane does not have sufficient acceptance
  - Typical pion/muon beam emittance 10-20 mm
  - Need to transport both sign muons
- Solenoid chicane does have a good acceptance
  - Pure solenoids, no dipoles
  - Induce vertical dispersion
  - MAP baseline design includes solenoid chicane
- MAP assumed a solenoid chicane for charge separation
  - +/- has vertical dispersion in opposite direction
- Considering chicane as an option to remove primary protons
  - MAP assumed they would be absorbed in solenoid shielding

Chicane concept





- Characterise chicane by
  - (Field in chicane) – determined by acceptance vs RF cavity radius
  - (Coil aperture) – never really studied
  - Radius of curvature r_{curv}
  - Bending angle θ
  - Nb at this point I am not concerned with realistic coils
    - I use 1 metre full aperture to better understand dynamics

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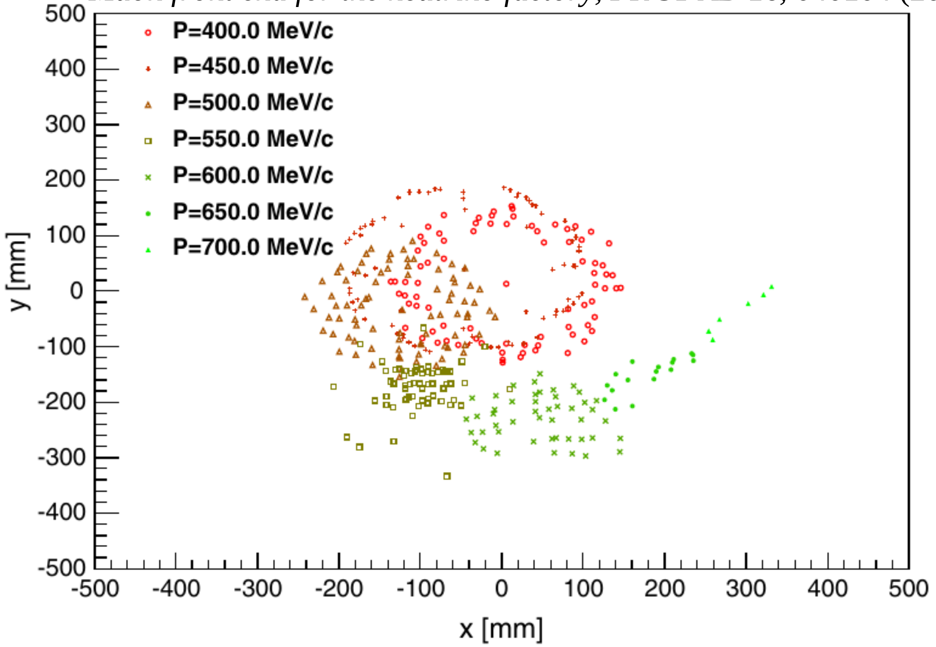
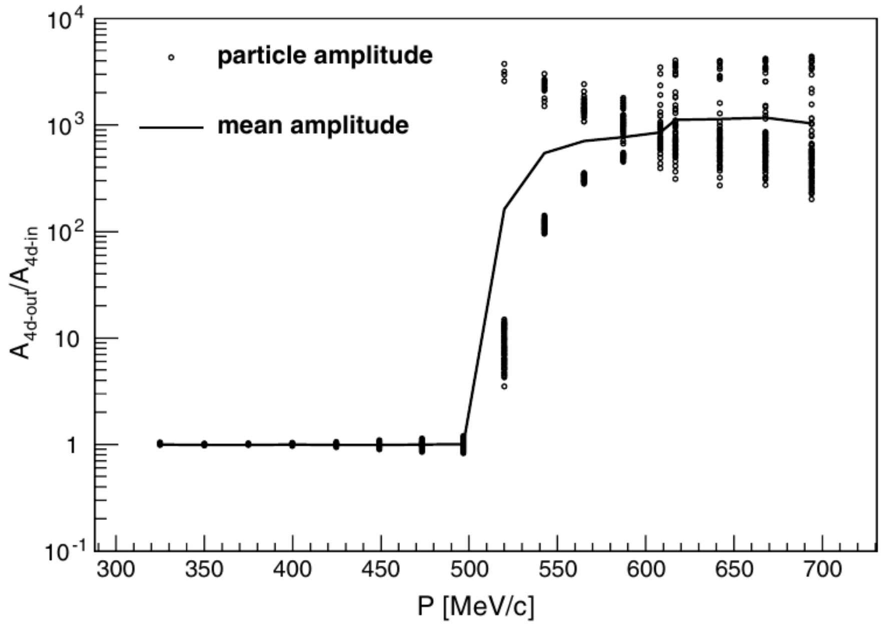
IDS Neutrino Factory concept

Muon front end for the neutrino factory, PR ST AB 16, 040104 (2013)





- Points correspond to a shell at 50 mm A_t
  - A_t is ~ “distance from axis” in position-momentum space
  - Conserved quantity in accelerators
- Reminder, RMS emittance is mean $A_t/4$
- 50 mm corresponds to 1 sigma for 12.5 mm emittance beam

MAP concept

Stratakis and Berg, Design and optimization of a particle selection system for muon based accelerators , IPAC2014

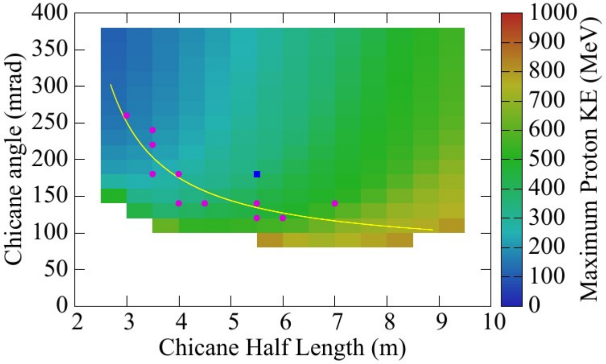


Figure 4: K downstream of the chicane as a function of L and θ. Points correspond to the colored points in Fig. 3. The curve shows the geometric parameters from Eq. 1.

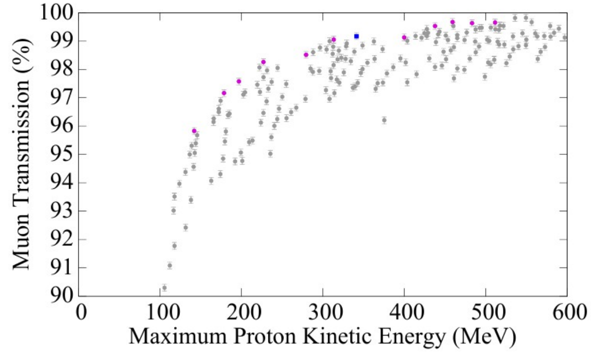


Figure 3: Muon and pion transmission (as defined in text) and K for the chicane parameters we scanned. Magenta points were used to fit the chicane geometry parameters as a function of the K. The square blue point was also originally selected, but was removed from the fit.

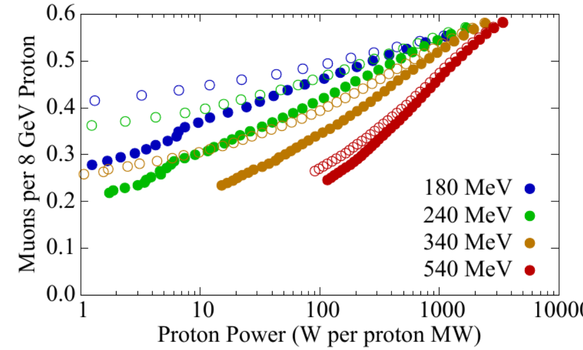


Figure 5: Each point shows, for a given chicane geometry and absorber position and thickness, the muons with kinetic energies in the range of 20 to 390 MeV and the proton power at a position 31 m from the beginning of the chicane. Each color is for a different chicane geometry, as defined by K (shown in the figure key) and Eq. 1. The absorber is positioned at the end of the chicane for filled circles, and with its upstream face 30 m from the beginning of the chicane for open circles. For each symbol, points for different absorber thicknesses in 1 cm, starting at 1 cm in the top right.

- Optimised in terms of pareto front
  - Extra pion decays → better to put proton absorber 30 m downstream of chicane

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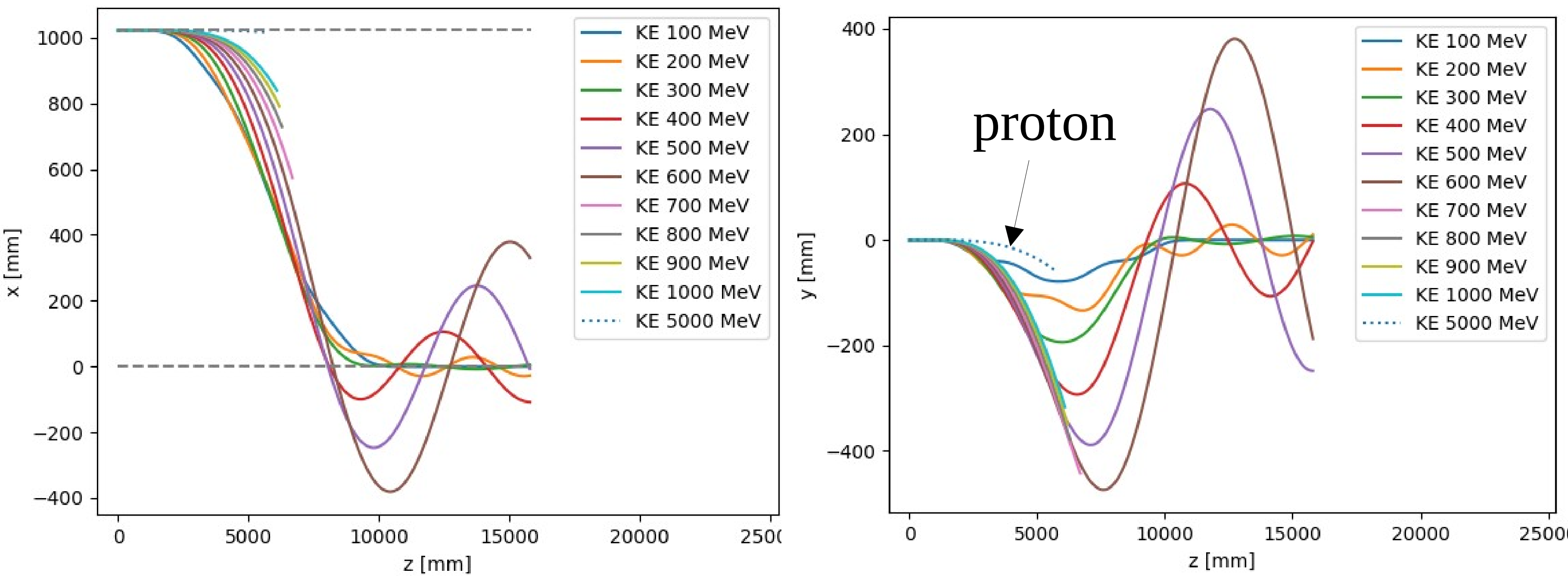
Trajectory in the chicane



- Consider IDS-NF chicane design
  - Beam returns to axis for KE <~300 MeV

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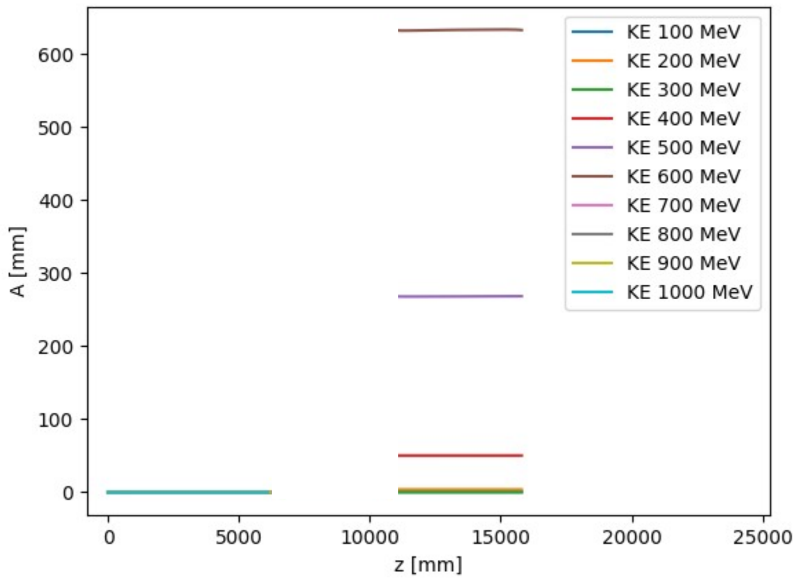
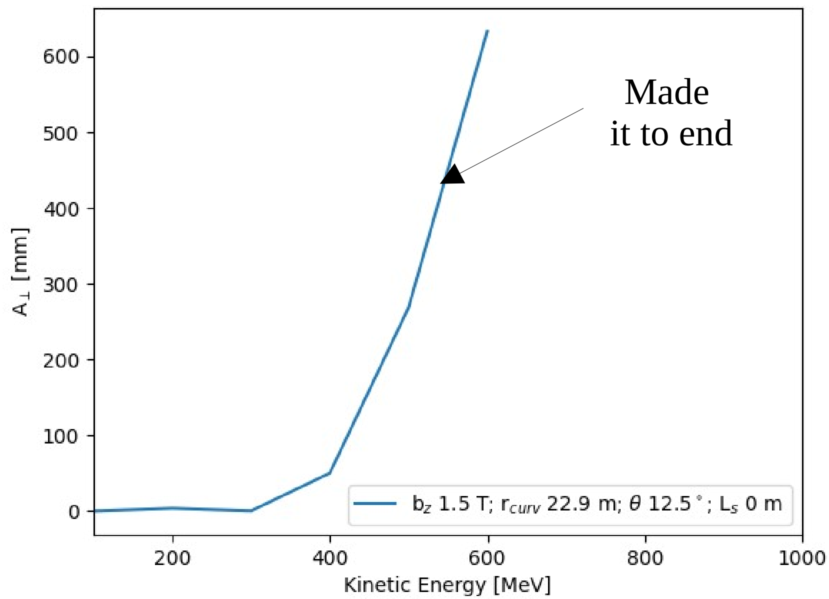
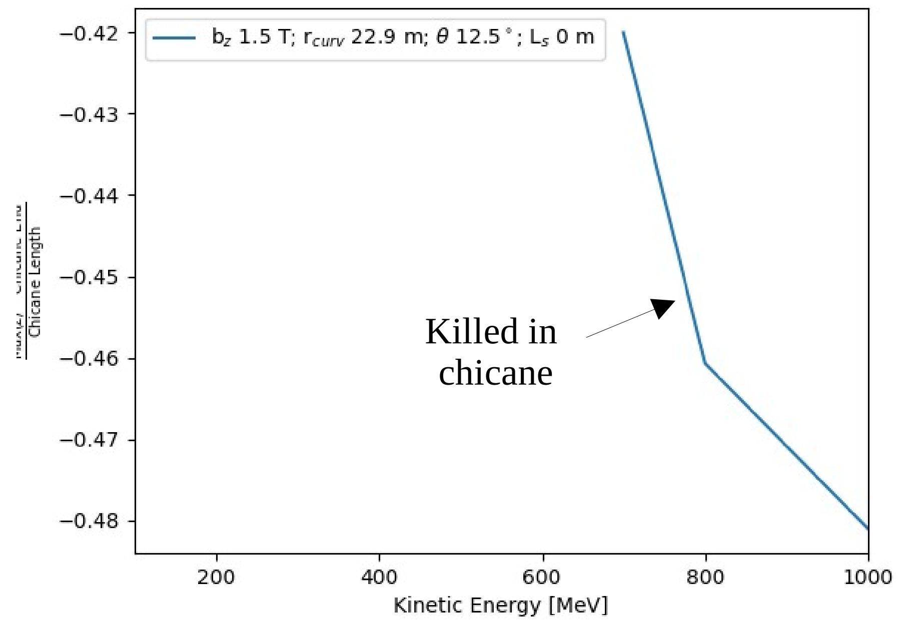
Amplitude in the chicane



- Want a quick metric for where the momentum cut-off is
  - Plot A_t for central trajectory, relative to solenoid centre
    - Reminder At is normalised “distance” from solenoid centre in phase space, and is conserved
    - Difficult to calculate in chicane and I have not done so
  - Assume “matched” beam in upstream/downstream solenoids
  - KE >= 400 MeV → significant amplitude growth
  - KE <= 300 MeV → see little or no amplitude growth
  - Almost consistent with IDS-NF result

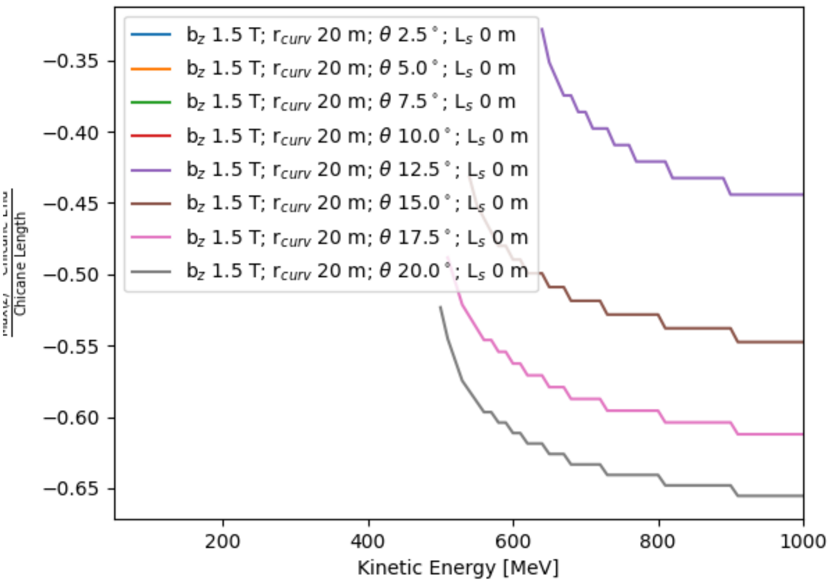
Another metric

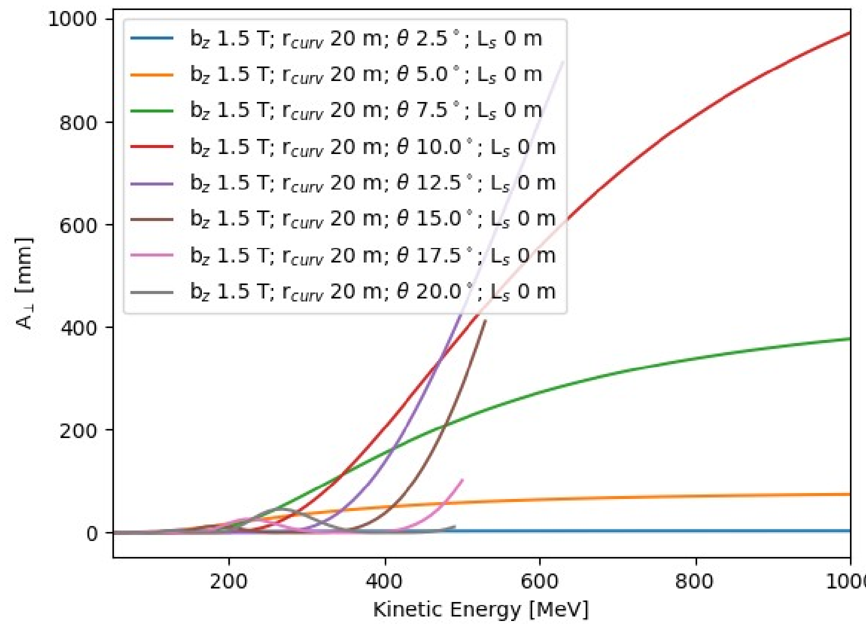




- Concerned with end point of particles having different energy
  - In particular protons with energy 5 GeV or more
- Aim to kick protons → exit window downstream of a chicane
- Look at "z position of particles that hit the walls"
  - Relative to chicane end, normalised to chicane length
- Also use "A_t for particles that survived to the end"

Scalings - θ





- Concerned with end point of particles having different energy
  - In particular protons with energy 5 GeV or more
- Aim to kick protons → exit window downstream of a chicane
- Introduce metric
  - “z position of particles that hit the walls”

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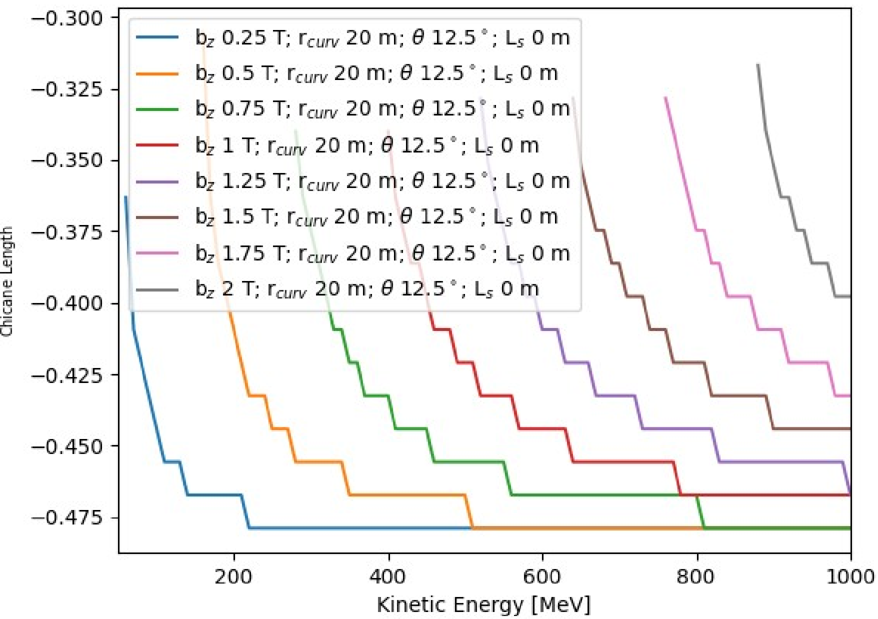
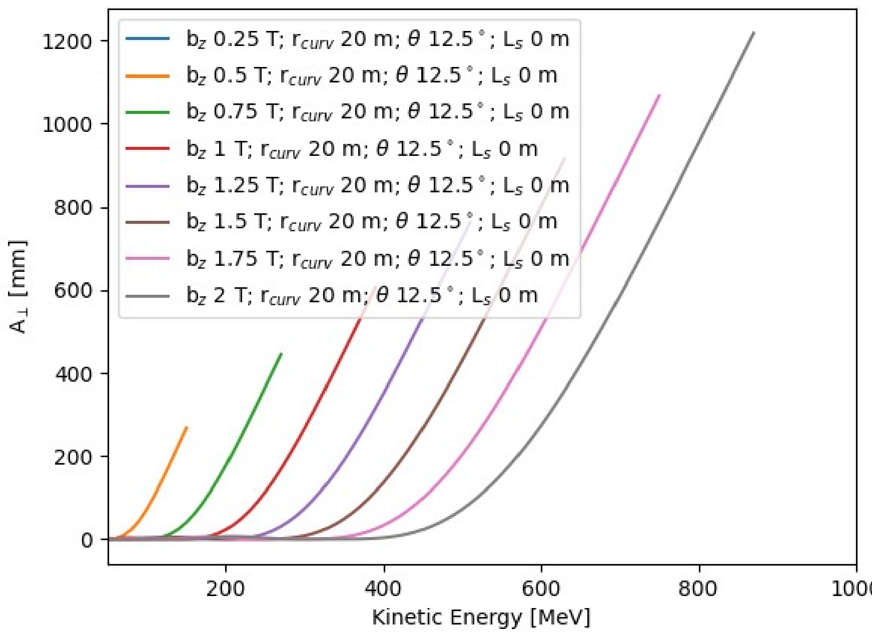
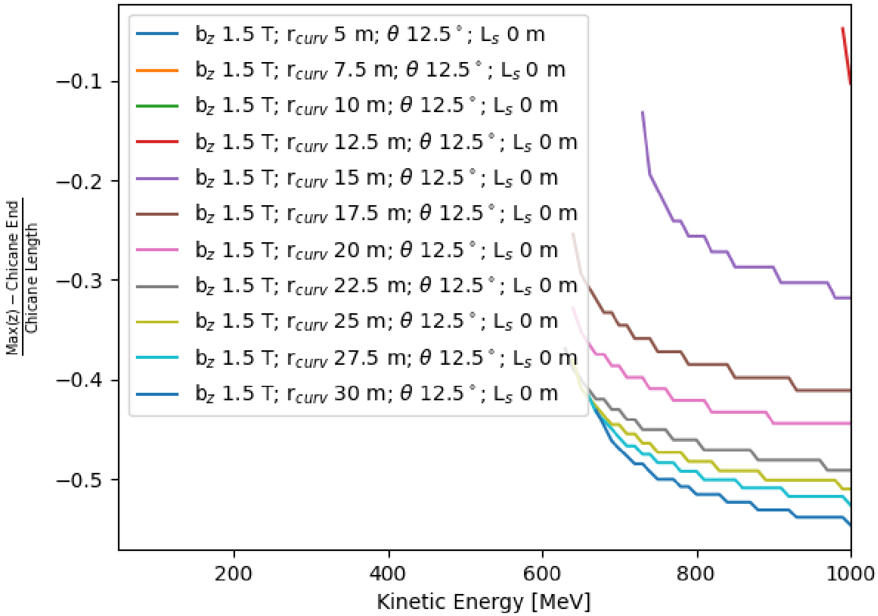
Scalings - B_z

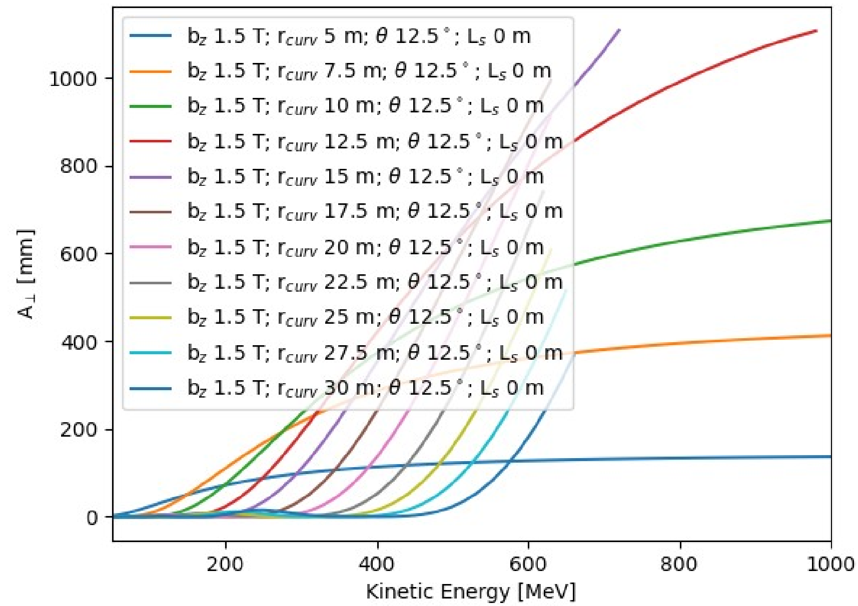




- Try varying B_s

Scalings - r_{curv}





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  - In particular protons with energy 5 GeV or more
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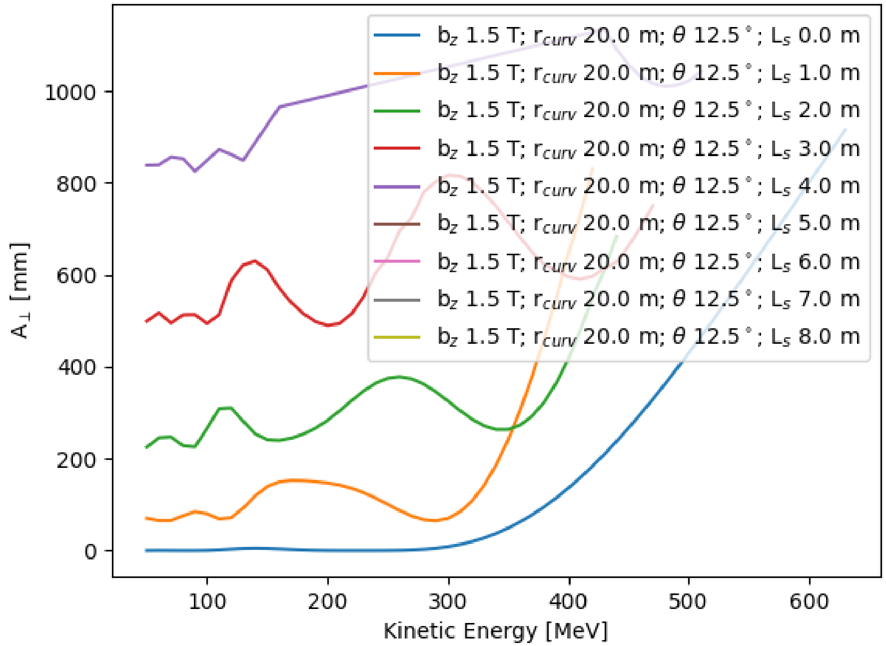
Adding a straight



- Nb: adding a straight in the middle of the chicane makes a mess of everything
  - Dispersion vector rotating with Larmor angle ~ 1/pz
  - Vertical dispersion becomes horizontal for some particles
  - Cancelling horizontal dispersion not possible

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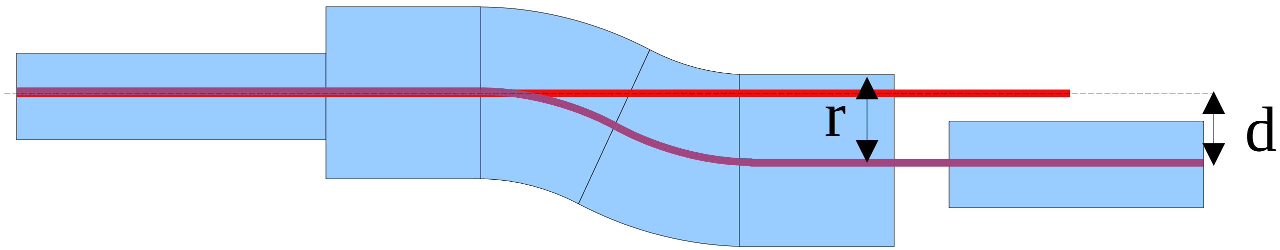
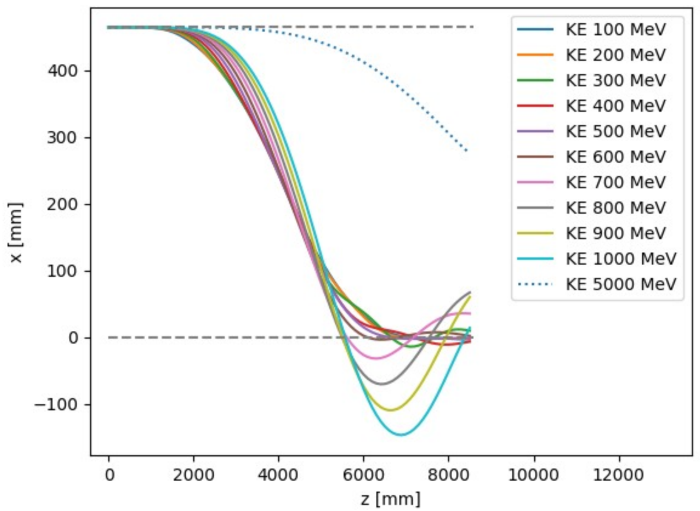
Concept 1



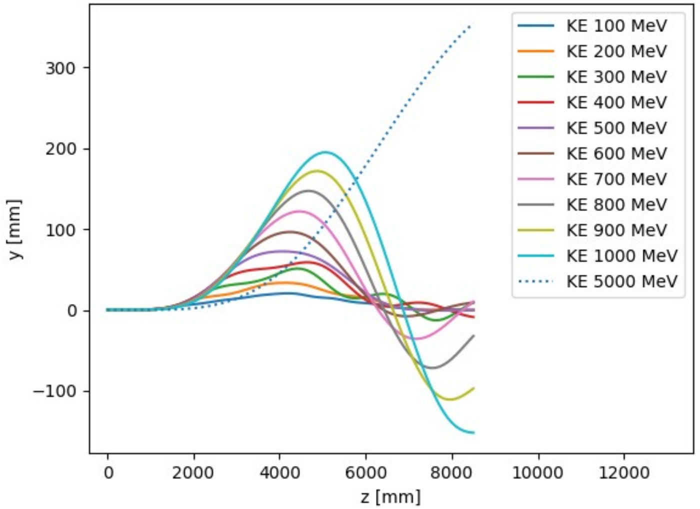
- Schematic of proton dump concept
  - Take 1.0 m pipe diameter as largest "reasonable" chicane aperture
    - What about space for shielding?
  - Seek transverse displacement of beamline by ~ 0.4 m
- Coil radius in the chicane determines maximum proton displacement
- Lower transverse displacement → stronger B_z required

Concept 1

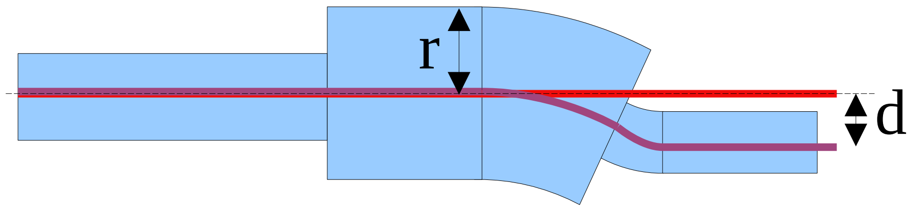
B_z	-4 T
Theta	9 degrees
r_{curv}	20 m



- We can get about 450 mm proton displacement from meson beam
- Does that leave enough space?
  - Superconducting solenoids
  - Radiation shielding
  - Etc



Concept 2



- Take protons out inside chicane
- In principle can get much more separation between proton and muons
  - i.e. some of the chicane bend contributes to separation
- In principle can use lower B-field → normal conducting
- Making gaps in hardware/etc may be easier
  - Fewer forces, cryogenics, support structure concerns
  - But need awkward solenoid juggling inside the chicane

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Concept 2

- To be continued