MEBT studies for IsoDAR
Work in progress

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Initial Beam Properties

"These are my principles and if you don't like them, well, I have others." – Groucho Marx

From Luciano: transverse emittances 18.1π mm mrad as one-sigma
This appears as 6.03 mm in position and 3 mrad in angle.
Assume uncorrelated at start
Assume same for horizontal and vertical
$\alpha = 0 \qquad \beta = 1.42 \qquad \gamma = 0.70$
I have no information on longitudinal emittance - assume $\sigma_L = \sigma_t$ and no energy spread. Probably not important.

Assume (for now) 5 cm radius (10 cm diameter) circular aperture

Ignore the spread produced by the stripping foil.

Beam losses

Assume limit of 1W/metre (except at collimators)
A 60 MeV, 10 mA beam is 600 kW, so should not lose more than 1 particle in 600,000 per metre
1 in 600,000 is around 5 sigma, for 2-D

Obvious conclusion

Keeping losses low for radiation protection is much more challenging than not losing protons-on-target

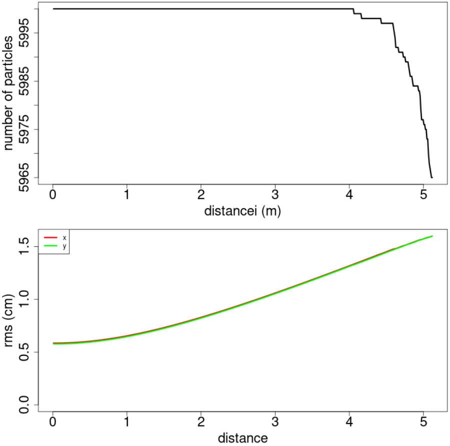
Tools:

- Focussing. But convergence becoms divergence
- Collimation. But angular spread means effect is not permanent

Estimate beam losses from particles lost in simulation - but need 600,000 particles for good statistics. Or get rms from simulation and require rms $<$ aperture/5. But that doesn't handle non-Gaussian tails.

Where is the first problem?

$\sigma_T(s) = \sqrt{0.603^2 + 0.003^2 s^2} \approx 0.003s$ cm
So no trouble till $\sigma_T = R/5$, which happens at $s = 3.33$ m



Conclusion: No need to focus until after the first 45 degree bend

The first bend

Do we need one? Yes. To remove the remaining H_2^+ and H^0
How much? 45 degrees seems reasonable
Allow 1 m for stripping foil, collimation, etc.
How long? 1 metre end to end seems reasonable
That gives $R = \frac{0.5}{sin(\pi/8)} = 1.3$ m, and with $p = 0.34$ GeV/c we have $B = 0.86T$ which is OK

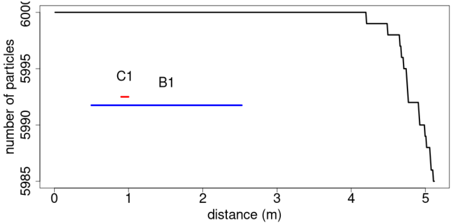
Gap size

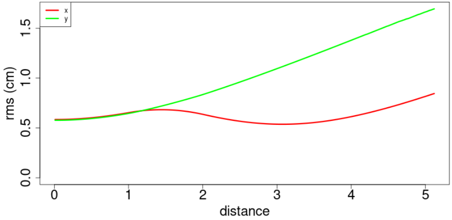
But a 10 cm gap seems large. Try about 5 cm?
This will give losses - need a protective collimator
With a 5 cm gap, lose 0.3% of the beam. That's 1800 W. Not good.

Use 10 cm magnet gap. But include protective collimator set at 10 cm to catch any nasty surprises.

The first bend - focussing

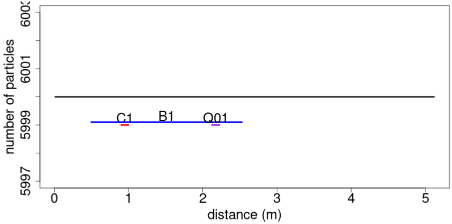
The edge focussing affects vertical and horizontal differently

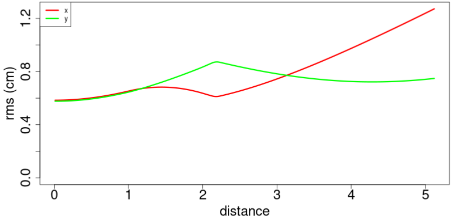




Deploy a quadrupole

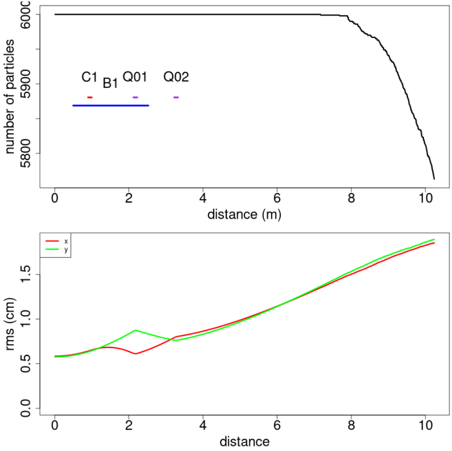
Stop the vertical growth with a well-placed quadrupole





Deploy a quadrupole

Balance the horizontal and vertical with another quad



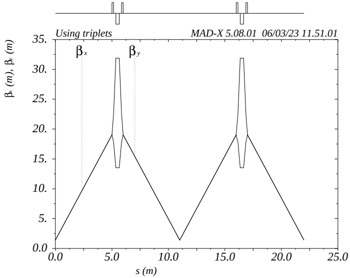
Note the shrinking axis.

Moving on

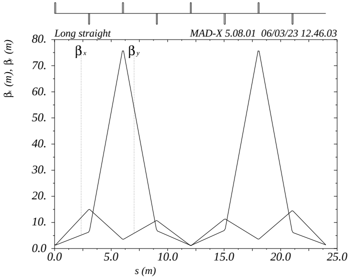
Switch to using MADX instead of OPAL. For now

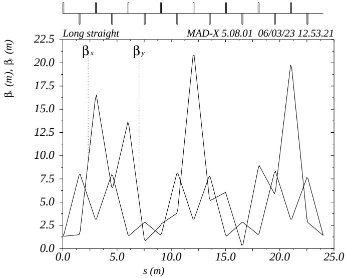
Can keep beam together either by doublets (FODO cells) or triplets
Triplets involve fewer magnets but radius varies from small to large
Not good (?) because of space charge and losses
Keeping within 5 sigma means rms radius below 1 cm
Transverse size scales like $\sqrt{\beta}$
Start at 6 mm, $\beta = 1.42$. Require $\beta < 1.42(10/6)^2 = 5.6$

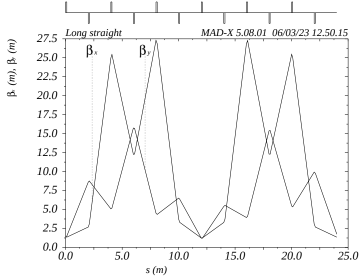
Triplet design (plagiarised from Luciano)
Elegant, but beam gets large.
We lose a few percent of the beam
A few percent of 600kW is a lot

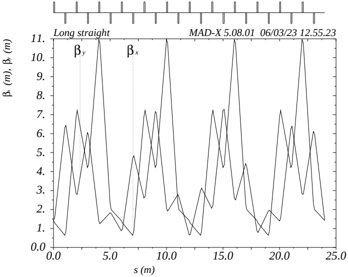


Using doublets





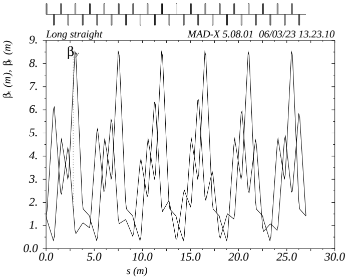


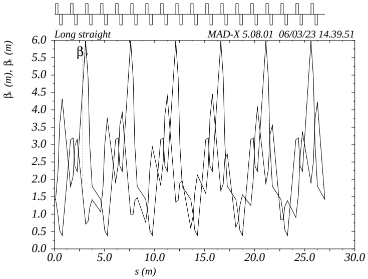


Using doublets(continued)

With 1.5m length cells, we get close to the desired β_{max}

With additional tweaks (increase length of quads, move D quads a little forwards, small drift at the start) we get down to $\beta_{max} = 6$.
Let's leave it at that for now.

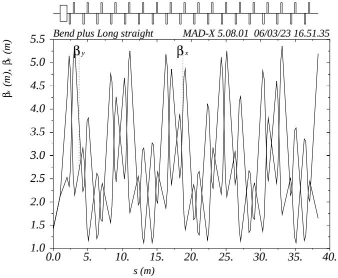




Using doublets(continued)

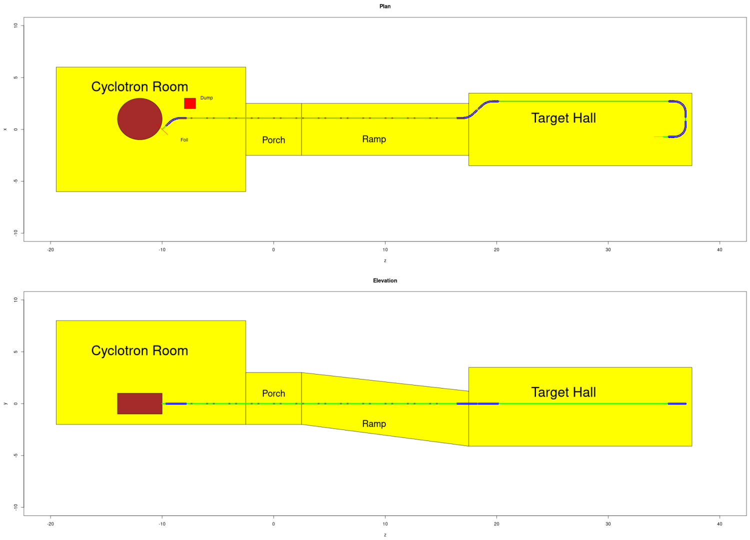
Include the 45 degree bend

Achieve β below 5.5, with 2m cell length



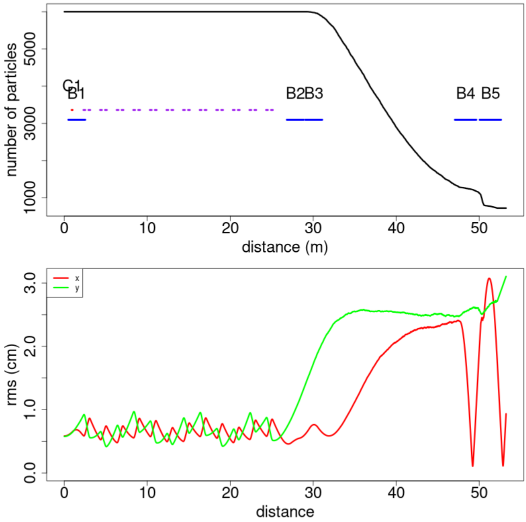
Fields -5.718 and 5.690 T/m

Apply MAD optimised optics in OPAL



Does fine up to the wiggle

Which is as far as I've got



To-do list

1. Put wiggle magnets in MAD and target hall quads. Optimise. (Do we need the wiggle? Maybe not. But easier to take it out later than put it in.)
2. Put MAD target hall quad values into OPAL.
3. Put final bends into MAD and optimise
4. Put final bend MAD values into OPAL
5. Twist wiggle magnets to give vertical offset (if necessary - again, assume the worst)
6. Compare the doublet and triplet options
7. Add foil, wobbler, etc
8. Run long (600K) OPAL job(s) to verify no beam losses

The conclusion

The MEBT design is straightforward.