Crab Crossing: History and some Uses

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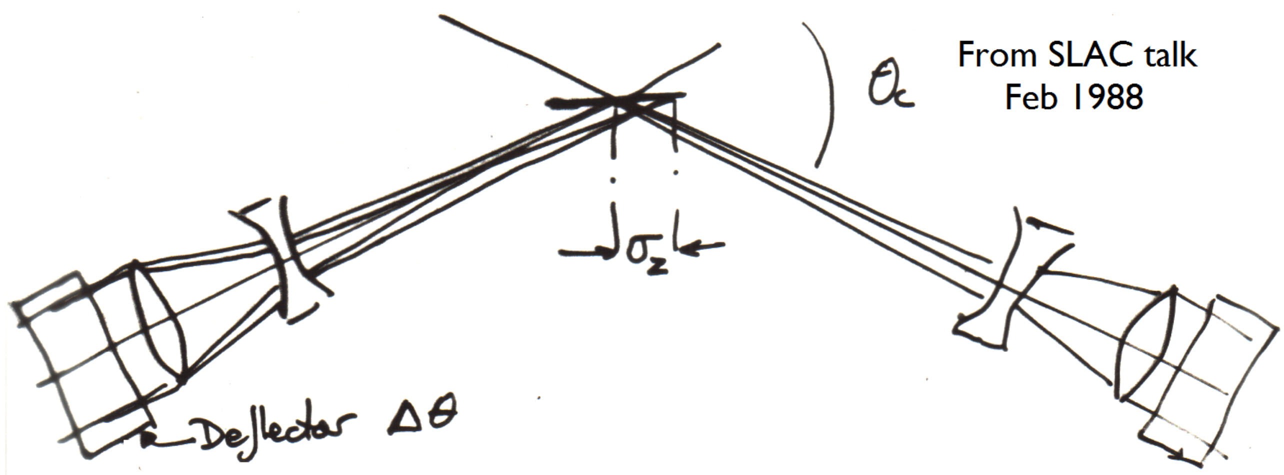
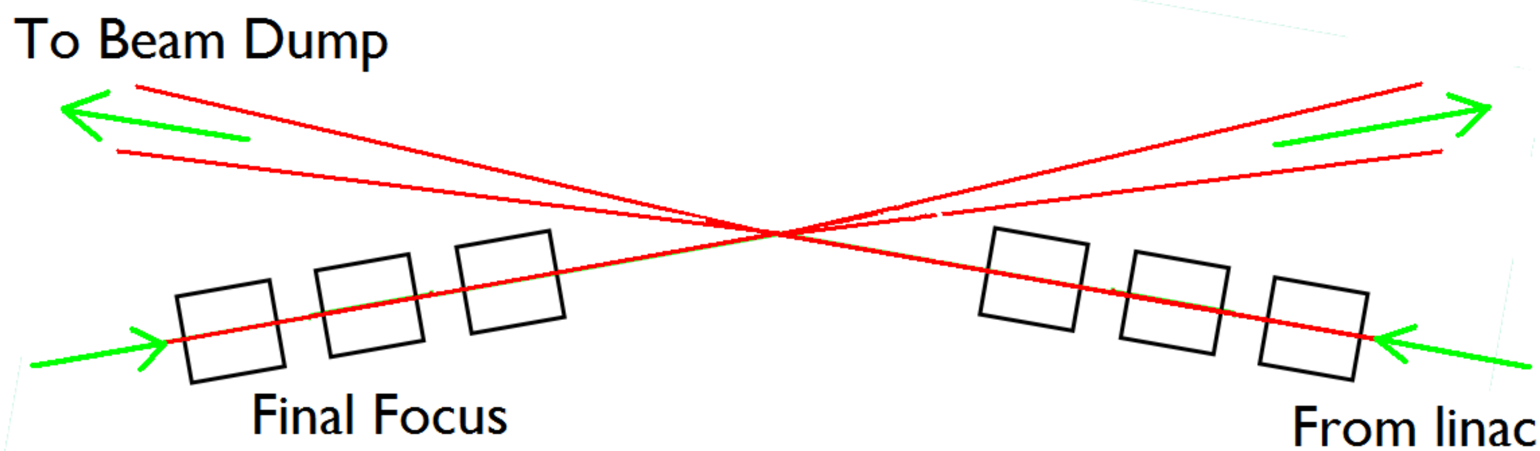
Feb 08

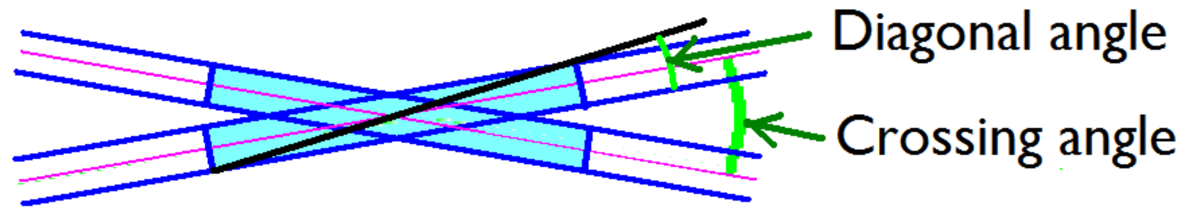
- Linear collider motivation
- Crab Crossing
- Super-Disruption
- Crab-Super-Disruption



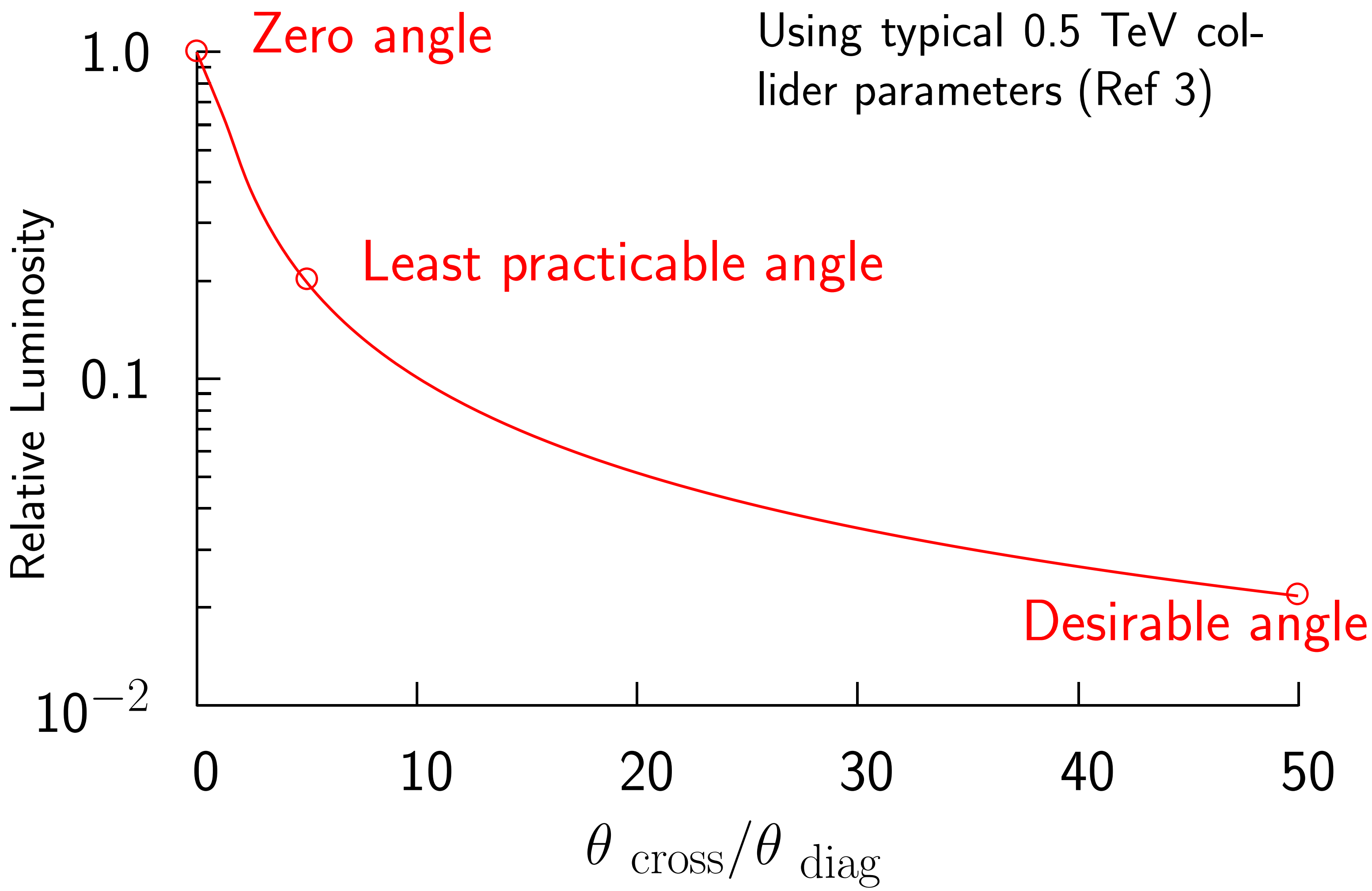
The Linear Collider Problem

- If head on then 'debris' from the collisions will pass up the opposing linac
- Bending does not separate beams of opposite charge
- One MUST have a crossing angle 50 mrad easily 5 mrad with difficulty



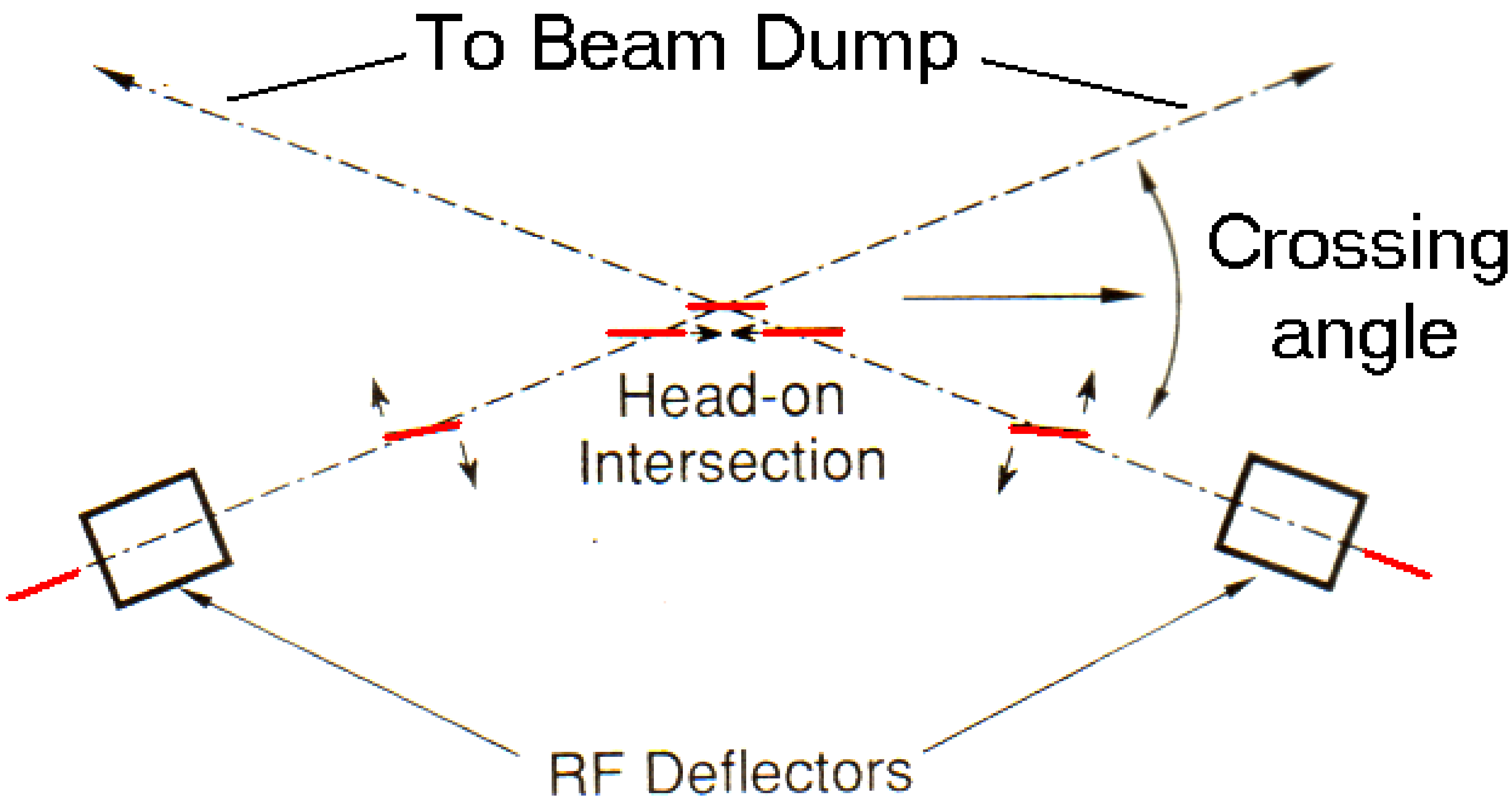


Loss of Luminosity



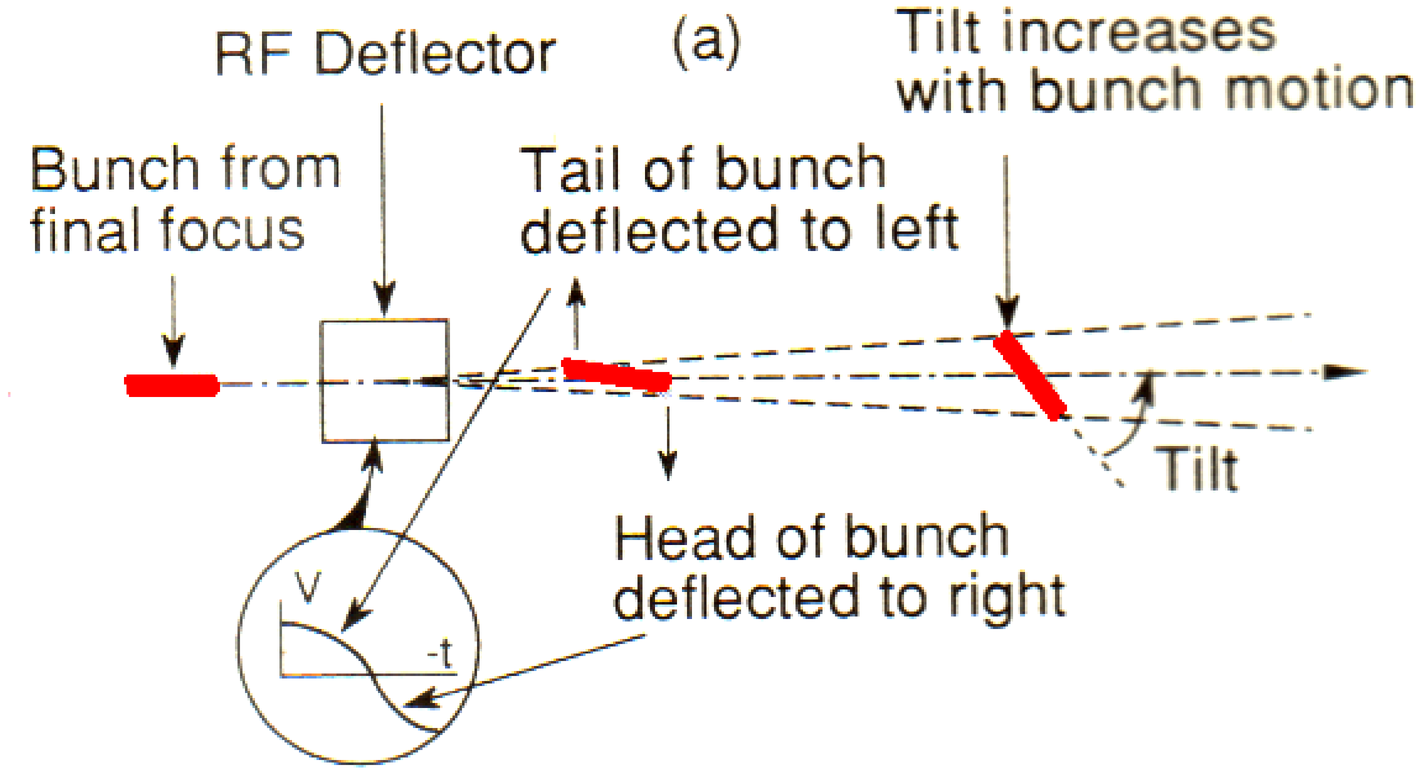
- 80% loss of luminosity even using septa
- 98% loss with desirable angle

Crab Crossing (Ref 1)



- In their center of mass the bunches collide head on
- Luminosity is as for zero crossing angle

Generation of Crab Walk



- The higher the frequency, the less the Voltage needed
- But if too high, harmonics required to keep bunch straight

"Super Disruption" Another idea from the same time

I will assume round beams for simplicity

$$\mathcal{L} \; \propto \; n_{\text{bunches}} \, f_{\text{turns}} \, \frac{N_\mu^2}{\sigma_\perp^2} \qquad \Delta\nu \propto \frac{N_\mu}{\epsilon_\perp}$$

$$\mathcal{L} \; \propto \; P_{\text{circulating beam}} \;\; \Delta\nu \, \frac{1}{\beta^*}$$

So it is very desirable to lower β^*

"Disruption" - the focusing effect from the opposing beam - is a poor man's way of lowering β^*

Disruption (Ref 3)

D defined (for round beams) by

$$D = \frac{\sigma_z}{f} = \frac{r_o\ N\ \sigma_z}{\gamma\ \sigma_\perp^2} = \frac{r_o\ N\ \sigma_z}{\beta_*\ \epsilon_\perp}$$

remembering that

$$\Delta\nu = \frac{N}{4\pi\ \epsilon_\perp}$$

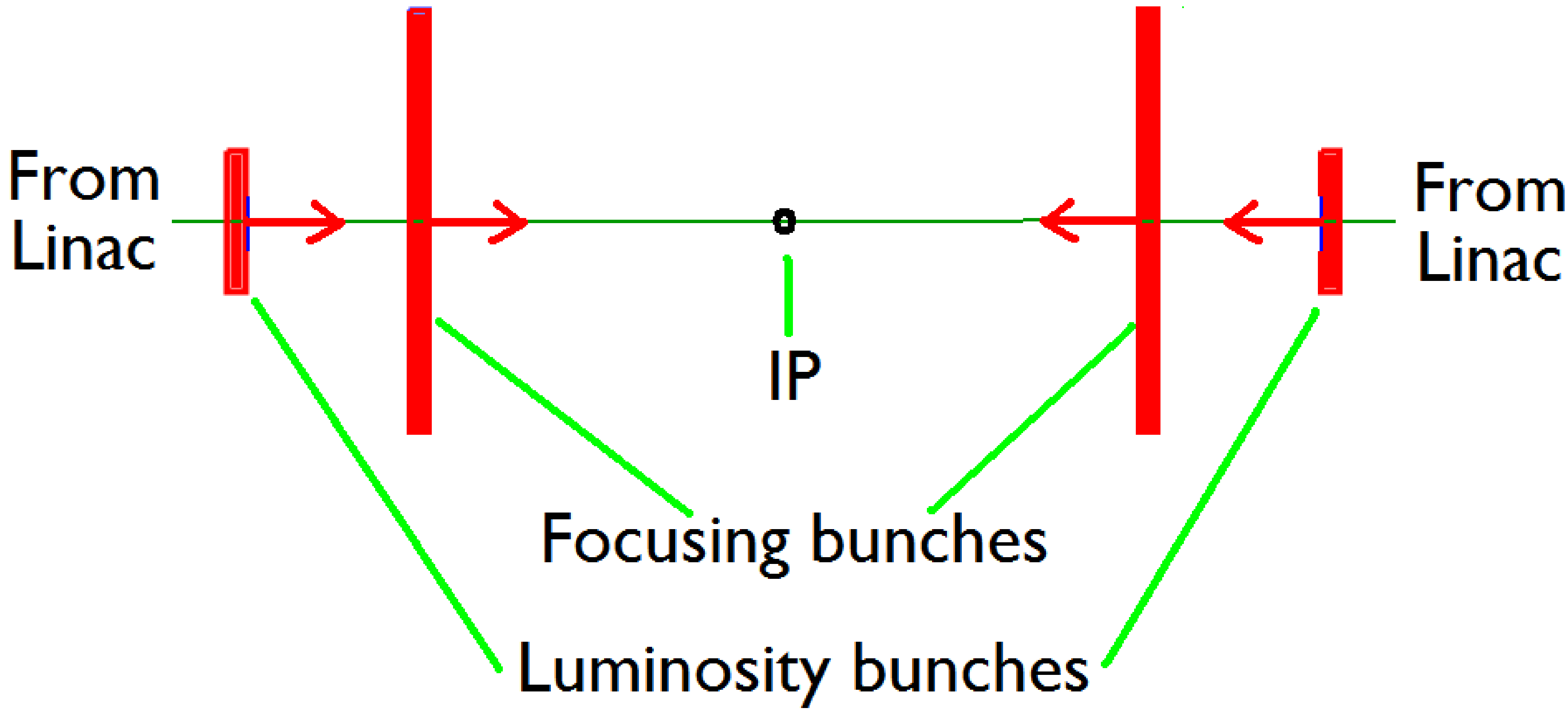
$$D = \Delta\nu\ \frac{4\pi\ \sigma_z}{\beta_*}$$

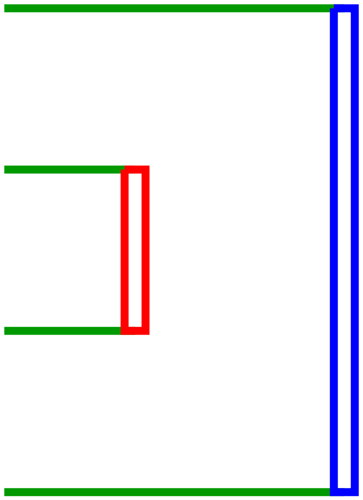
e.g. for $\sigma_z/\beta^* = 0.2$ and D=10: luminosity gain = 2

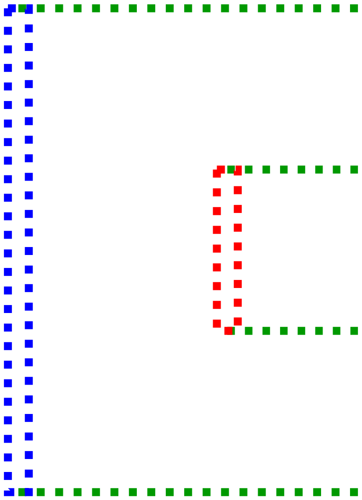
With D>10 there are theoretically greater gains, but a severe kink instability requires impossible alignment tolerances

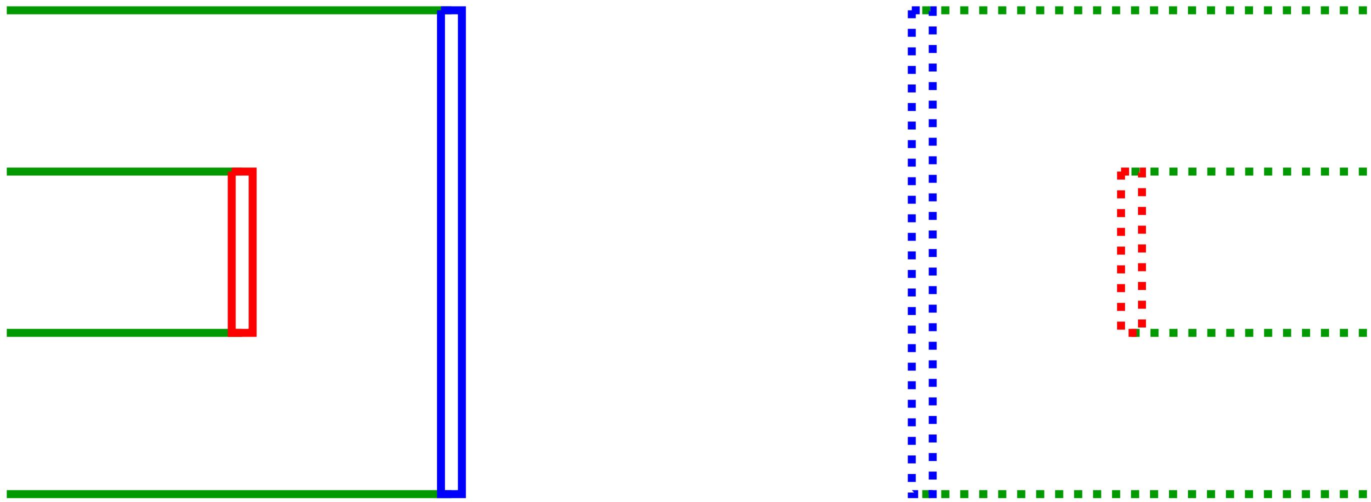
But D=10 and $\sigma_z/\beta^* = 0.2$ corresponds to a $\Delta\nu \approx 5$!
OK for a linear collider, but not for a ring

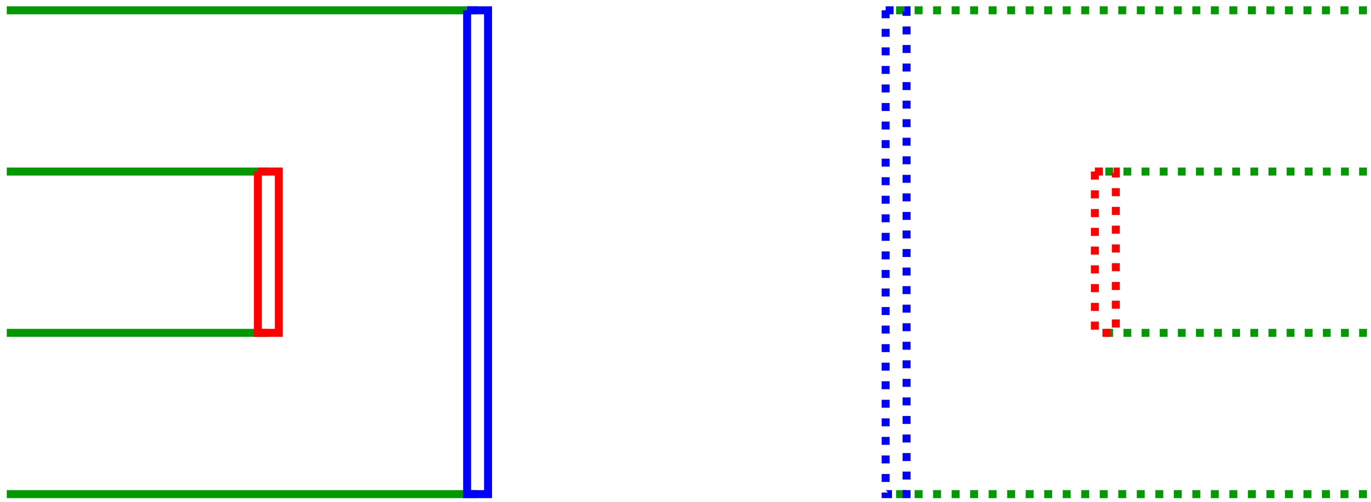
Original Super Disruption (Ref 2)

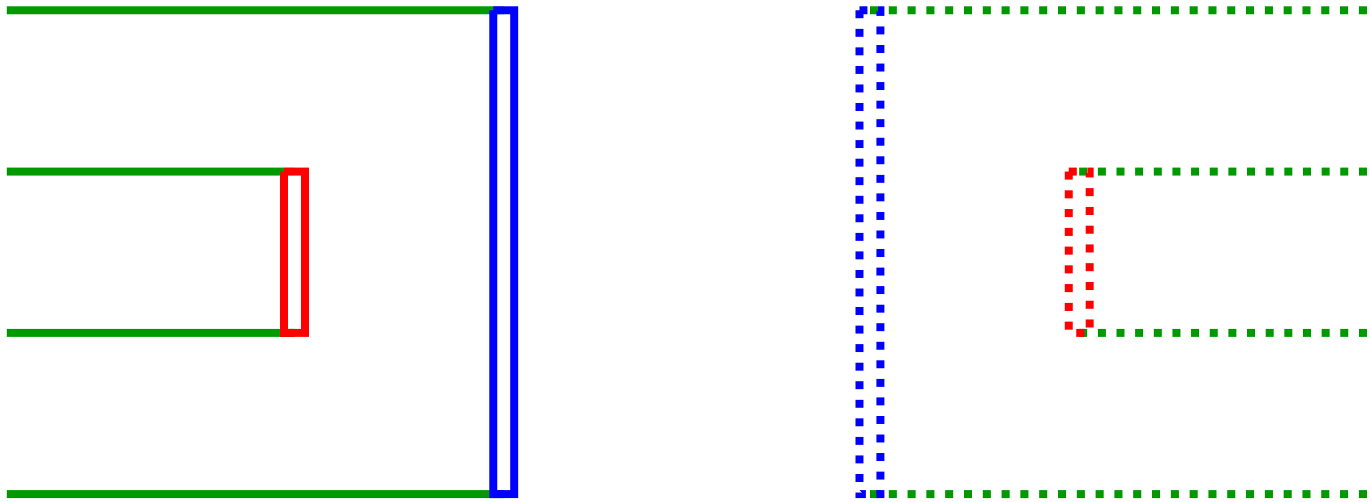


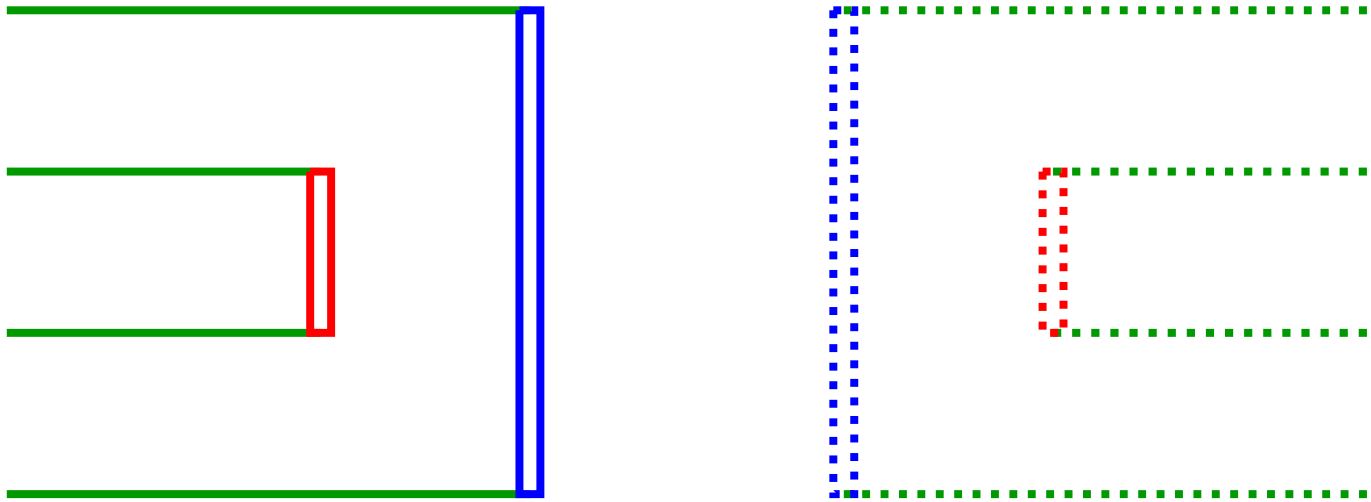


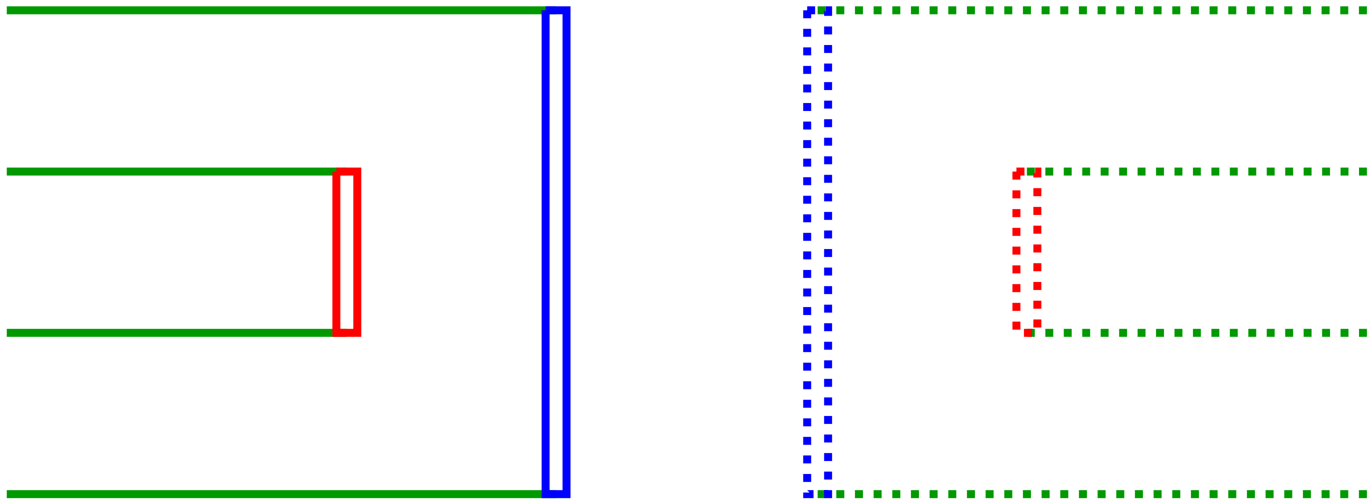


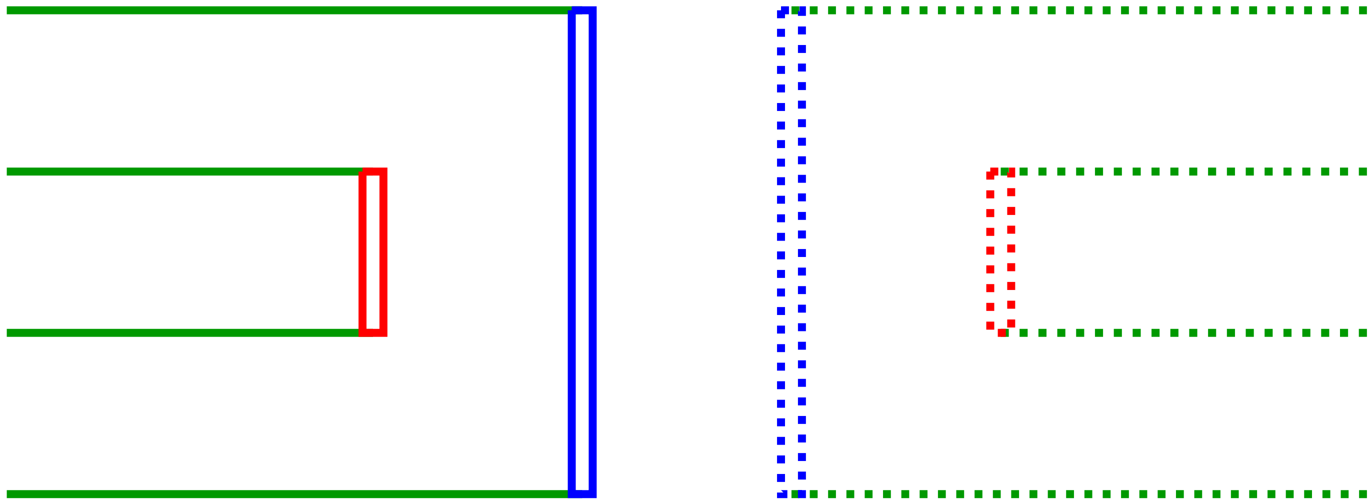


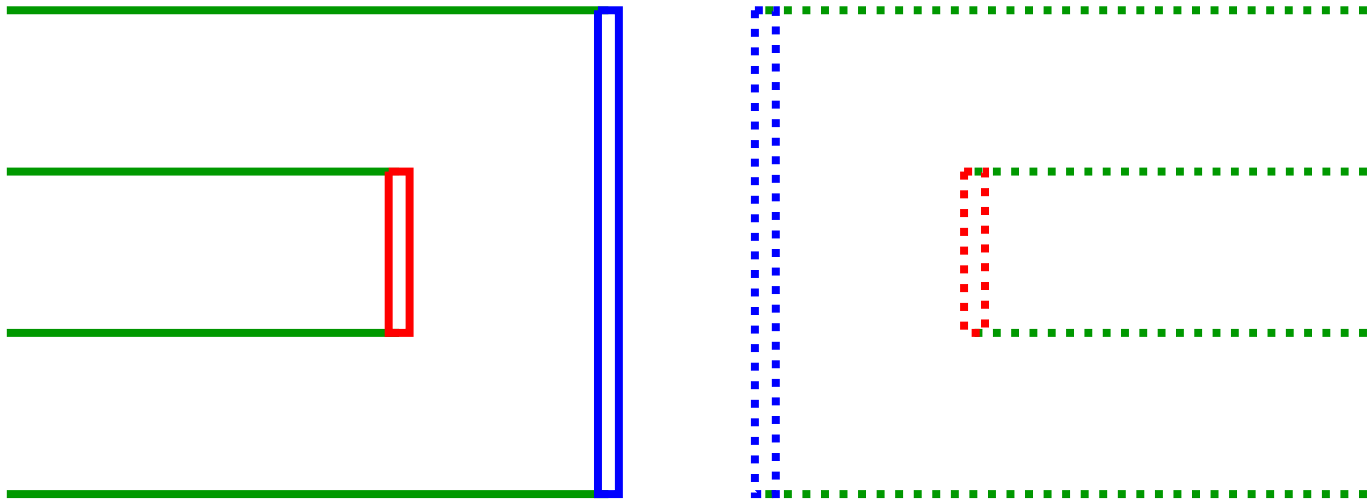


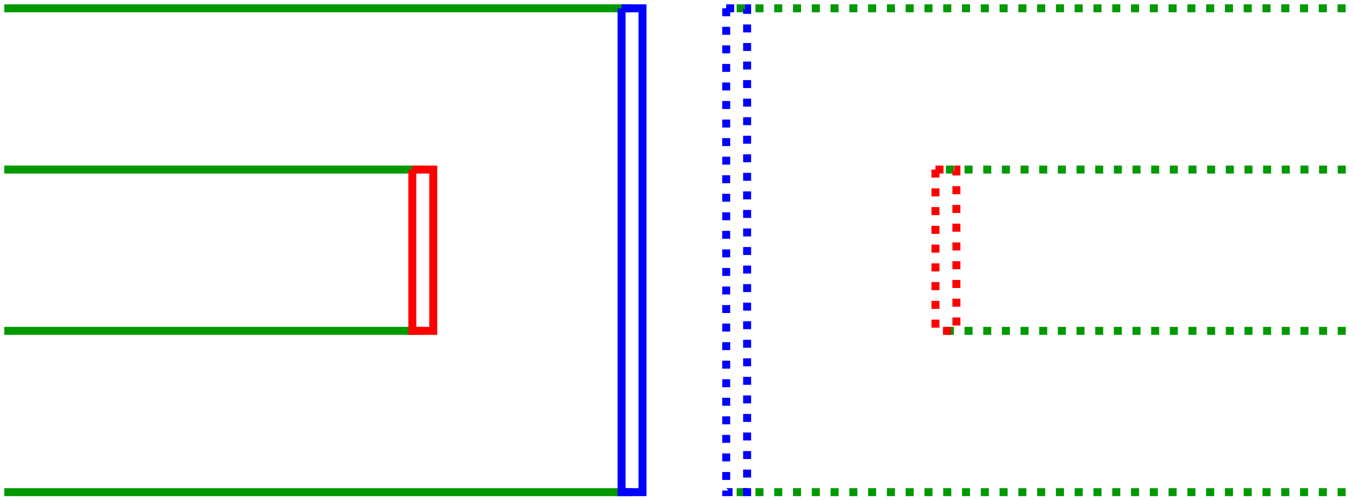


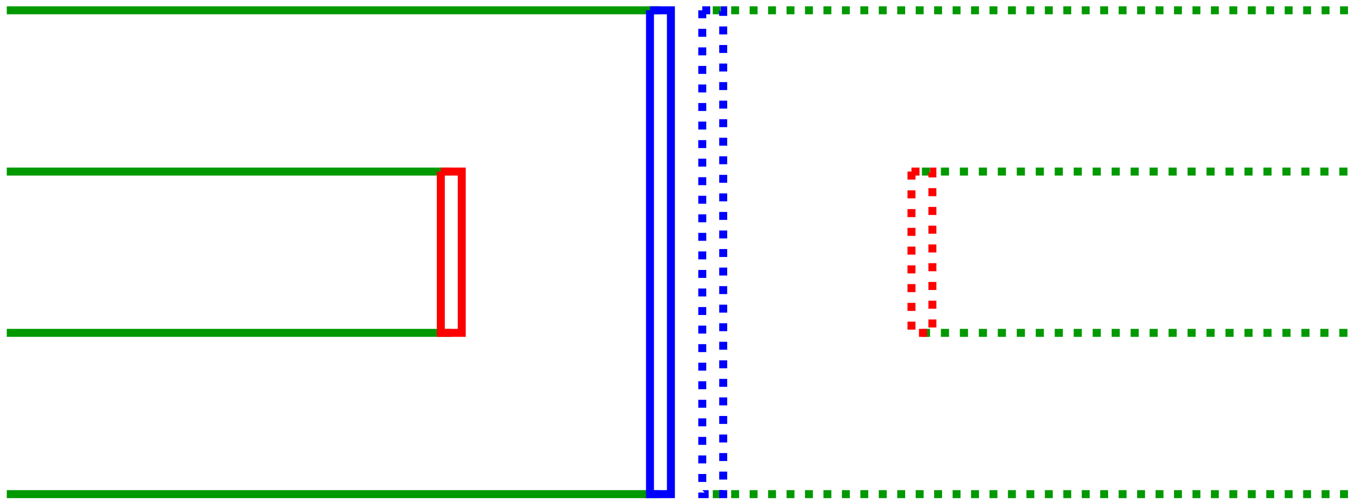


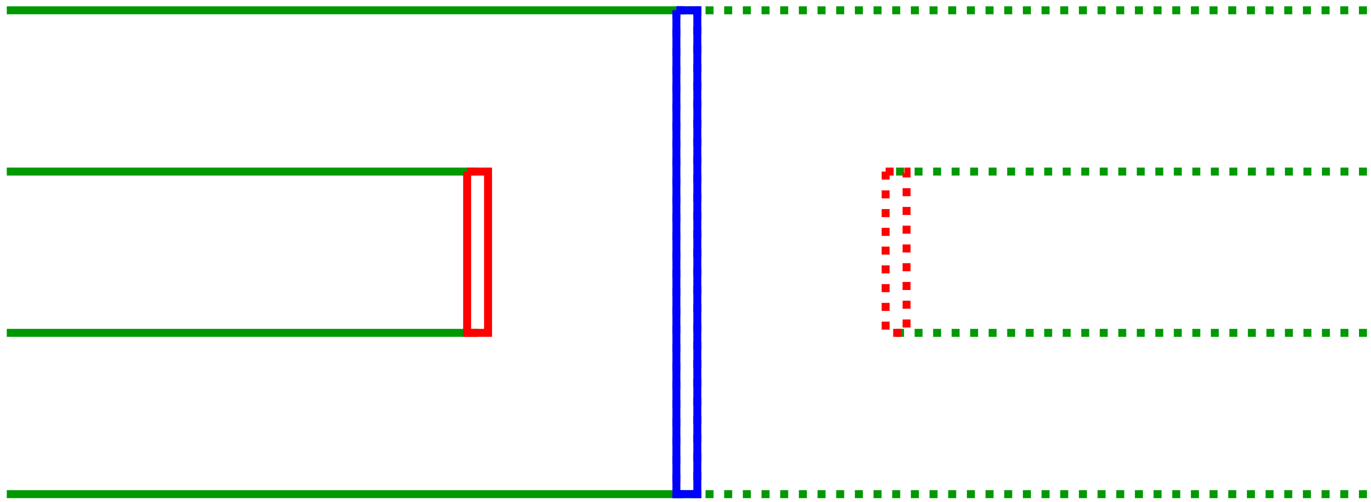


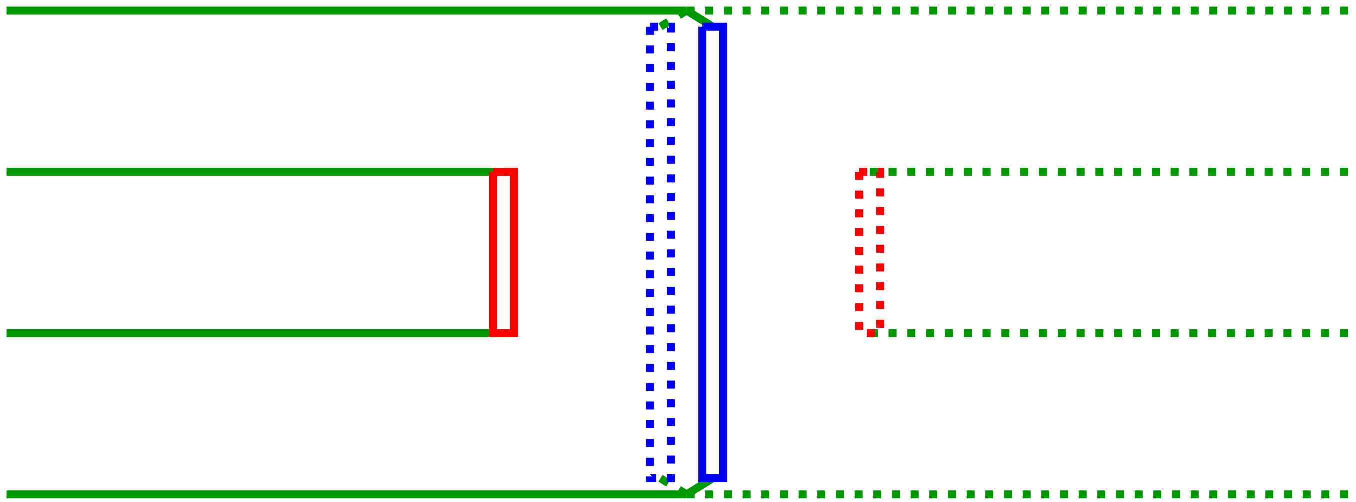


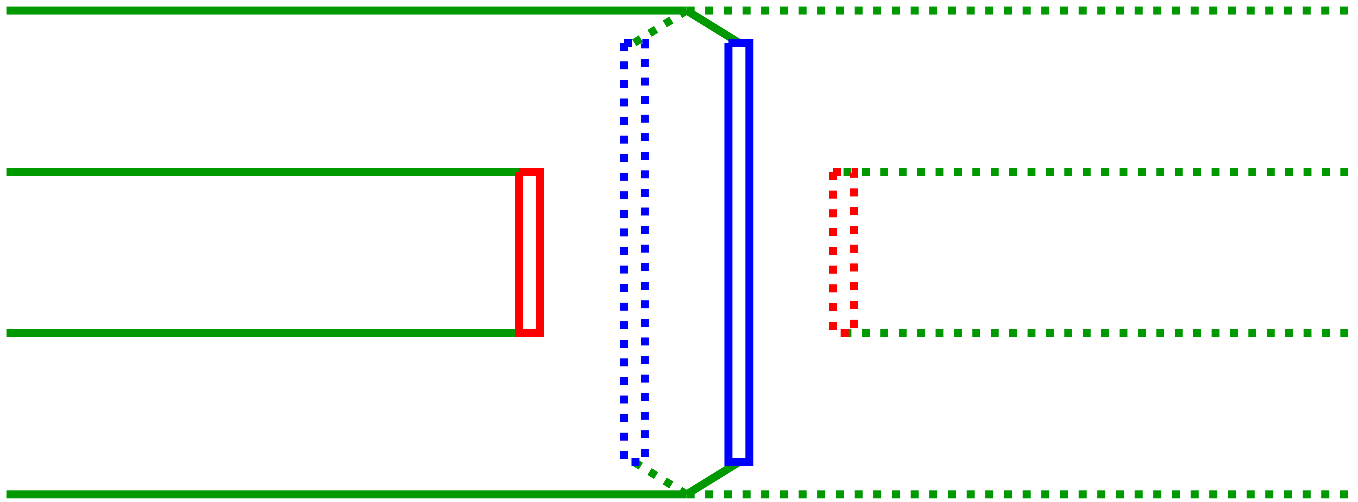


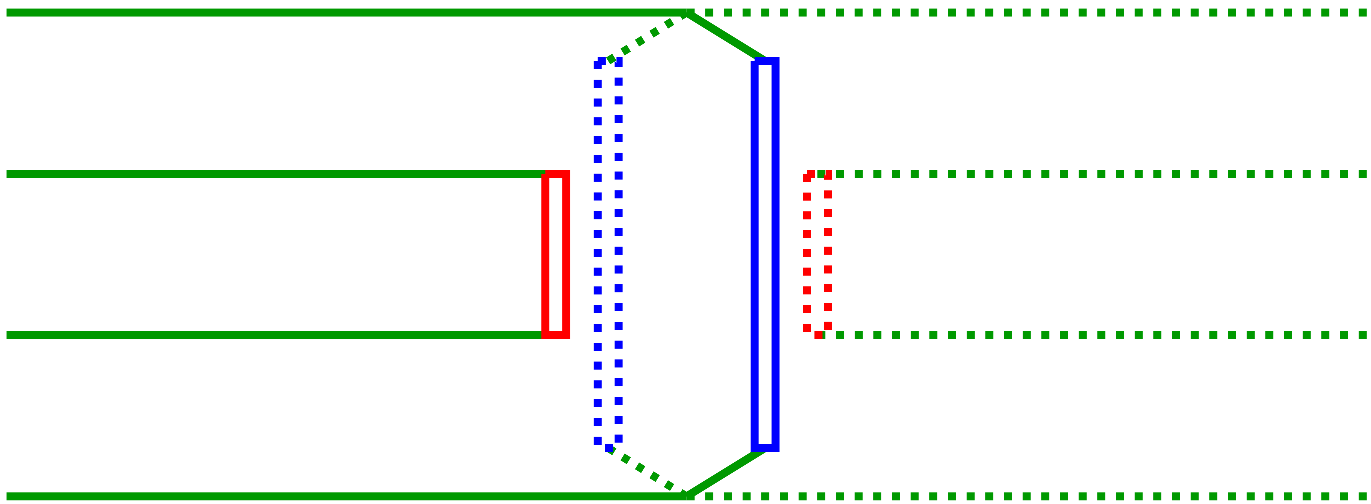


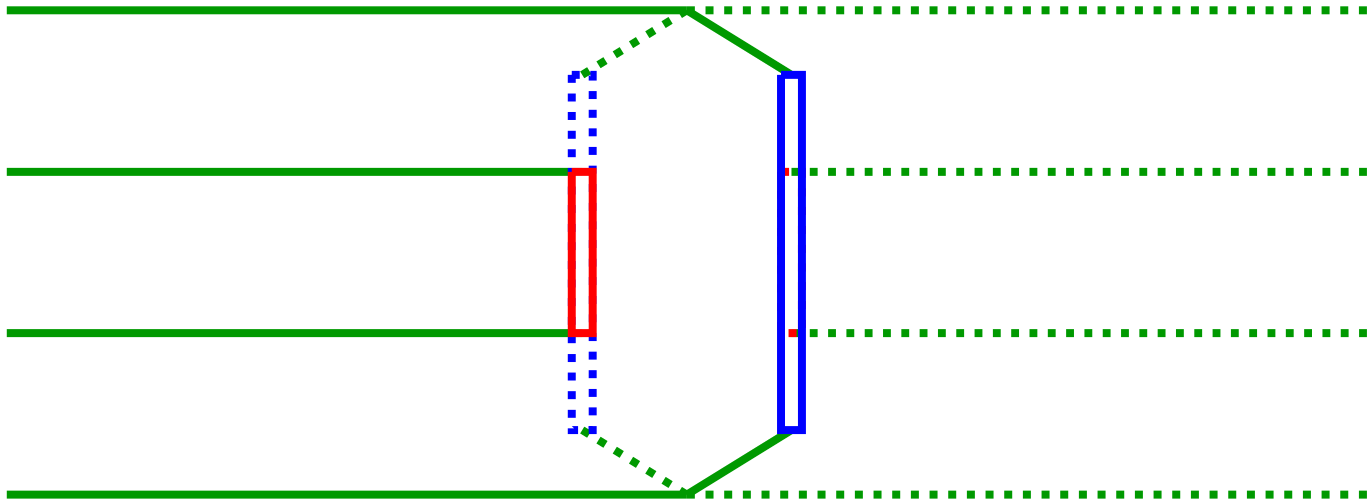


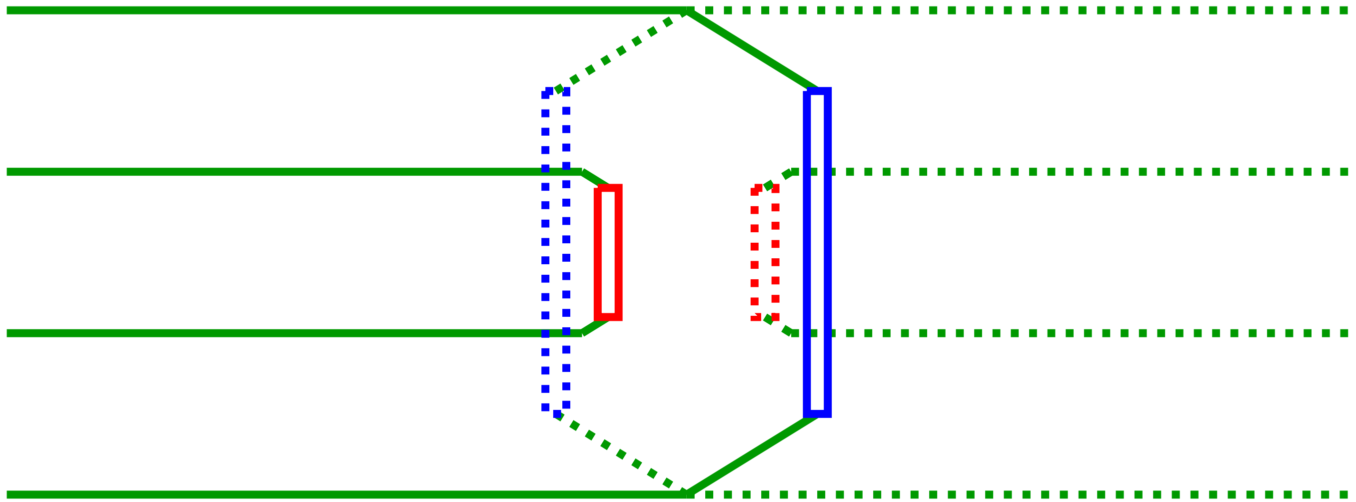


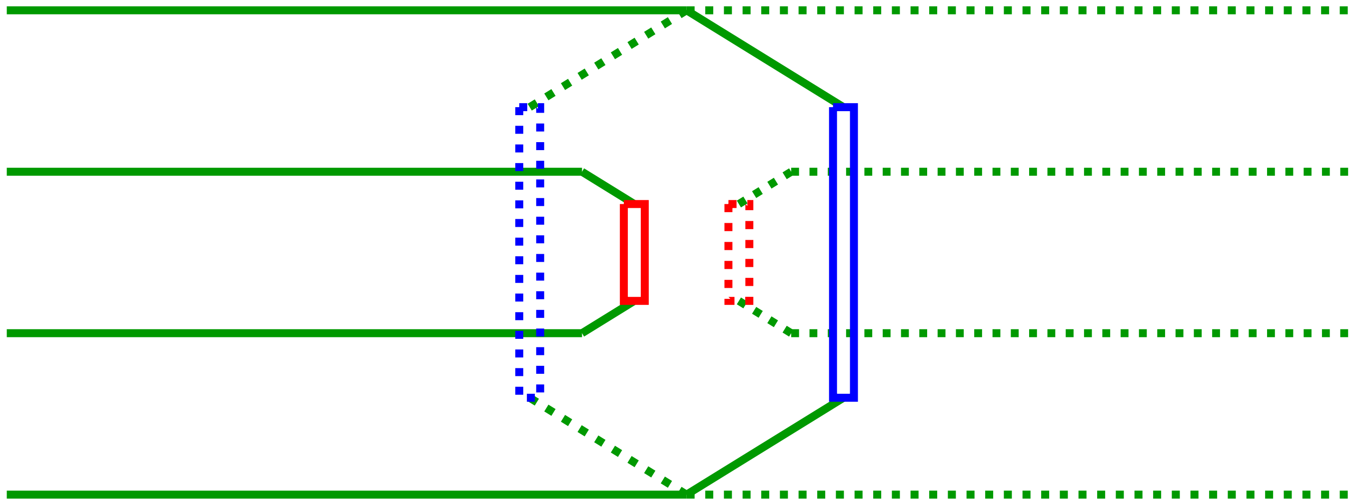


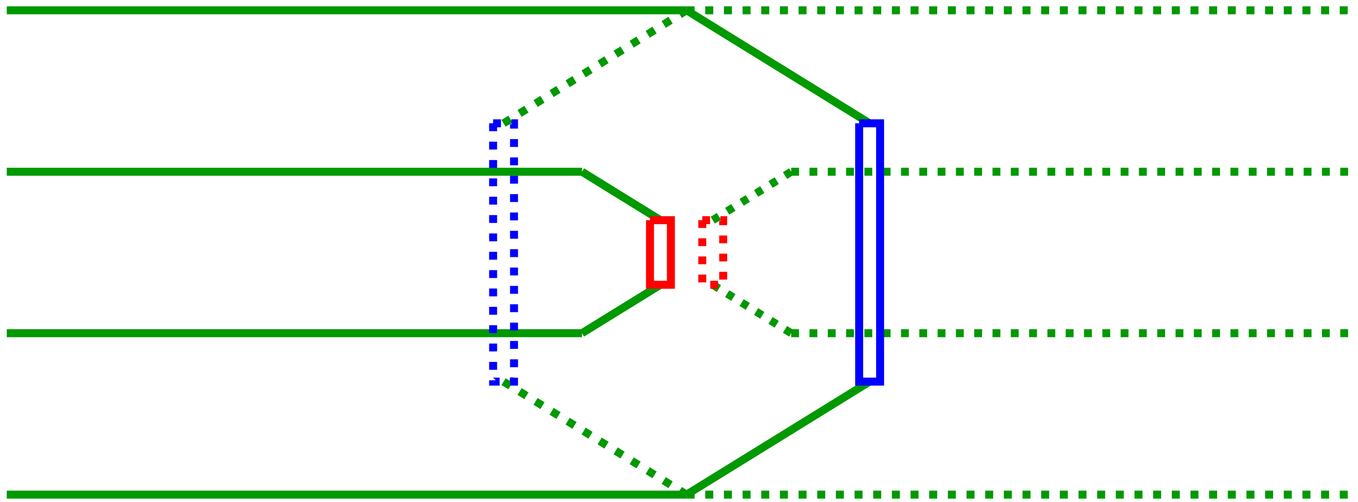


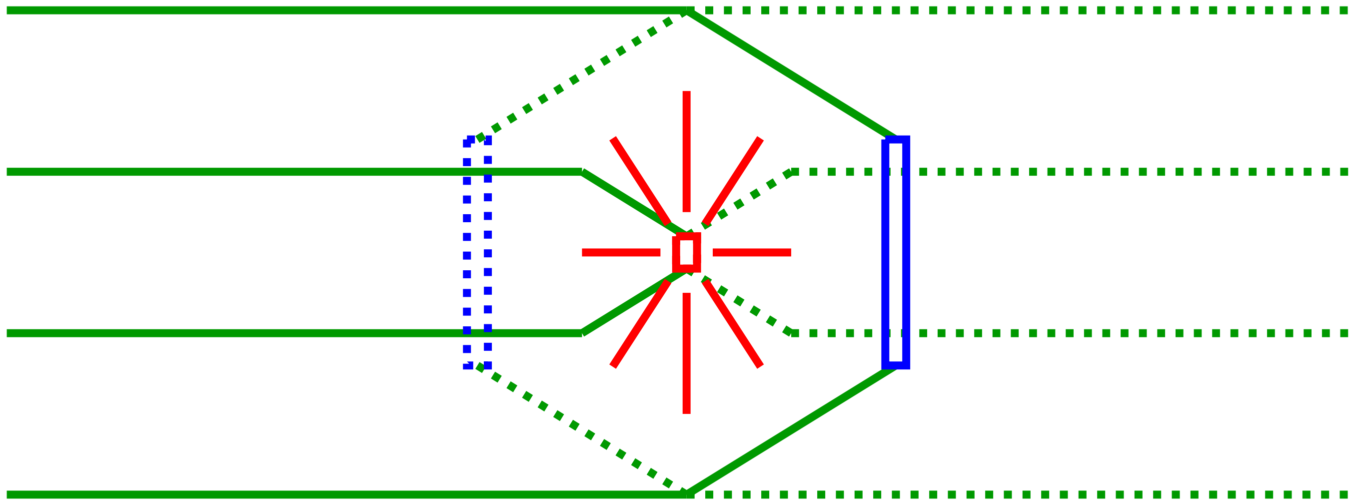












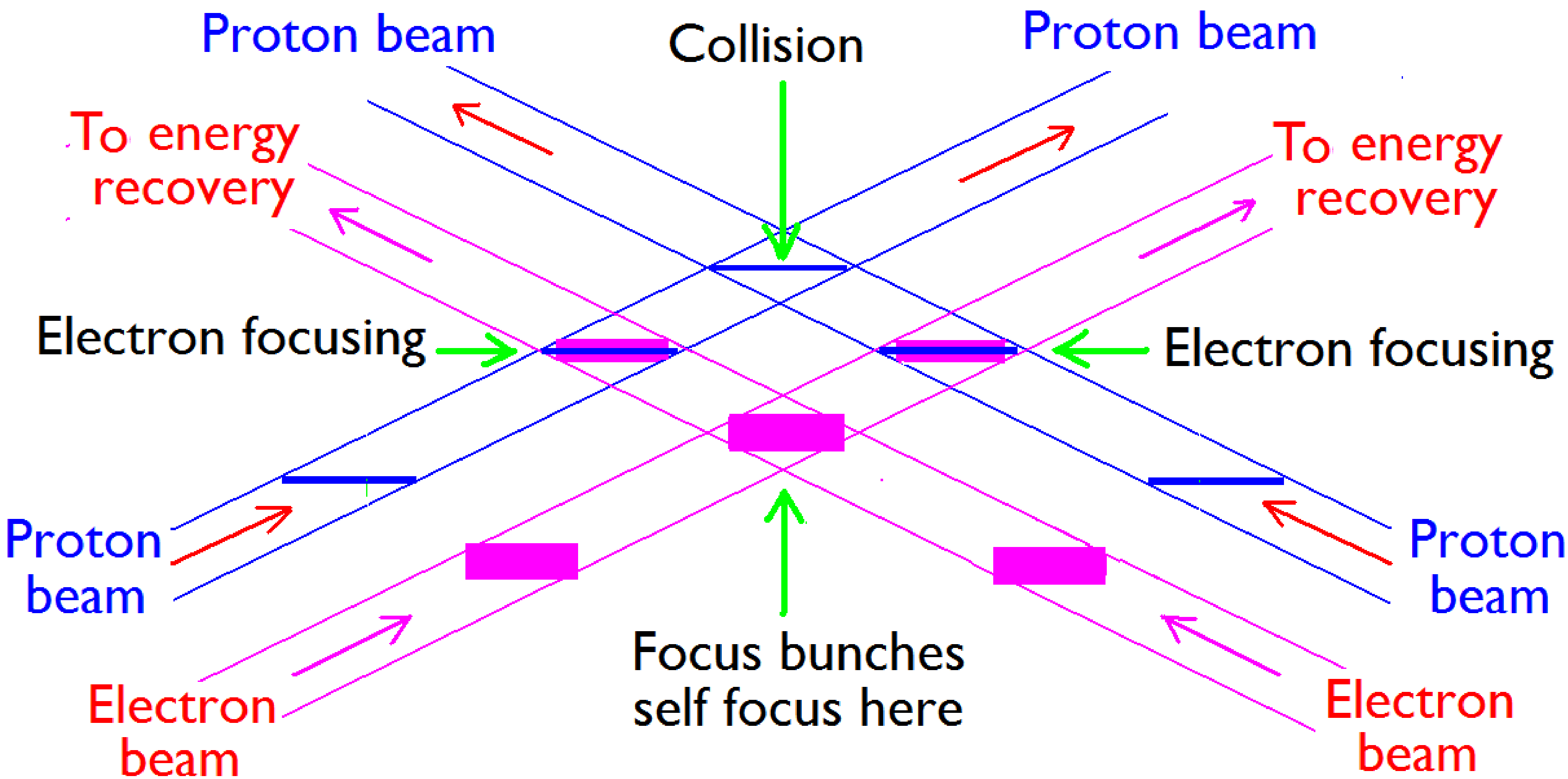
Application to a ring collider

- Cannot work in a ring collider because focus bunches are heavily disrupted ($\Delta\nu > 1$) and would be lost
- But plausible particle bunches could significantly focus a beam

Note:

- The focusing bunch does NOT need to have high energy
- It does NOT need to have very small emittance - we want linear focusing
- It should have the opposite charge - e.g. electrons for a proton-proton collider
- The crab idea allows the focus beams to be in separate channels

Crab-Super-Disruption



One needs two more electron lenses after the IP to match back into the ring. Not shown here for simplicity. But you get the idea.

Conclusion

- Crab crossing was invented for linear colliders
- I never thought it would work in a ring

- Super-disruption was also invented for linear colliders
- I never thought it would work in a ring

- Perhaps I could be wrong twice
- Anyway, I wanted to say something you probably did not know

References

1. Crab Crossing: R.B.Palmer; Snowmass Proceedings p 631 (1988), and SLAC-PUB 4708 Dec 1988
2. Super Disruption: R.B.Palmer; SLAC-PUB 3688 (1985)
3. Linear Colliders: R.B.Palmer; Annual Rev. Nuclear Science (1990) 40: p529