Cooling in 50T solenoids

R. B. Palmer, J. S. Berg, R. Fernow, J. Gallardo (BNL)
S. Kahn

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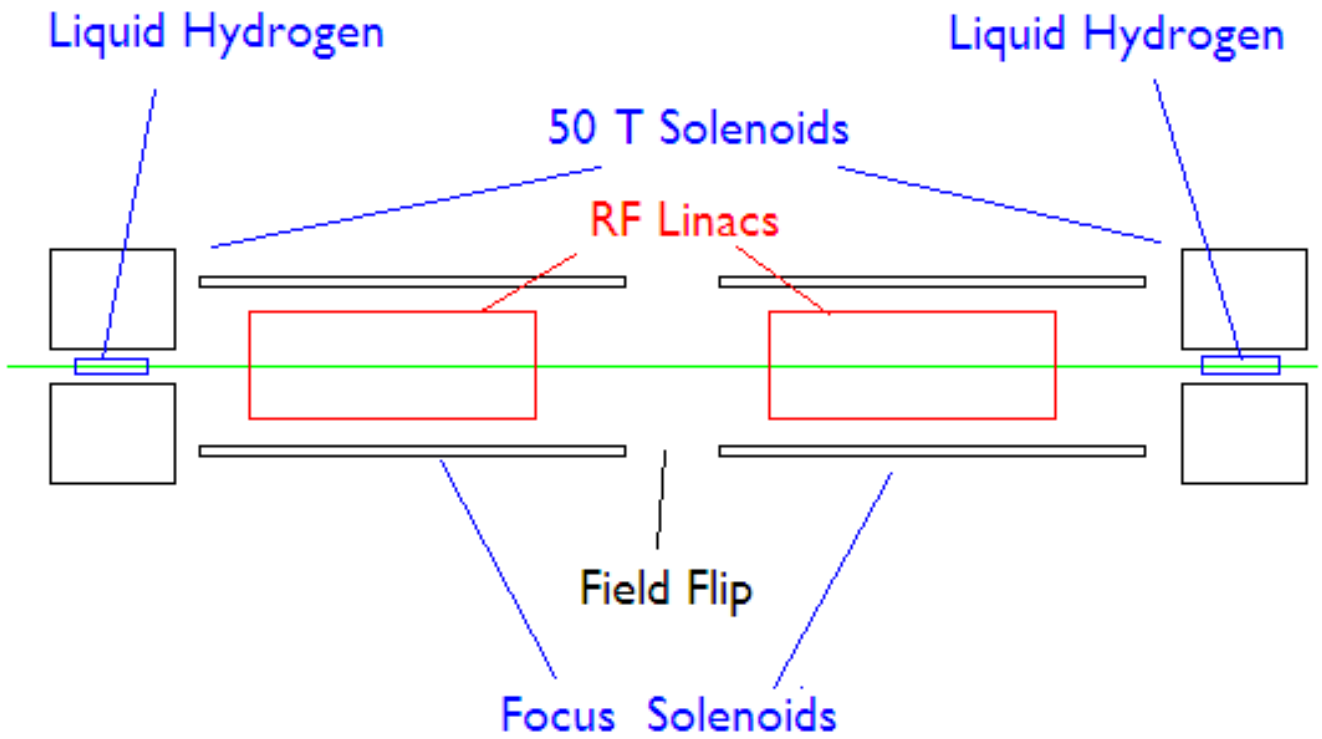
- Introduction
- Example stage #7
- Parameters of many stages
- Improvement if Landau tails removed ?
- Decay losses in matching and re-acceleration
- Longitudinal problem in early stages
- Conclusion

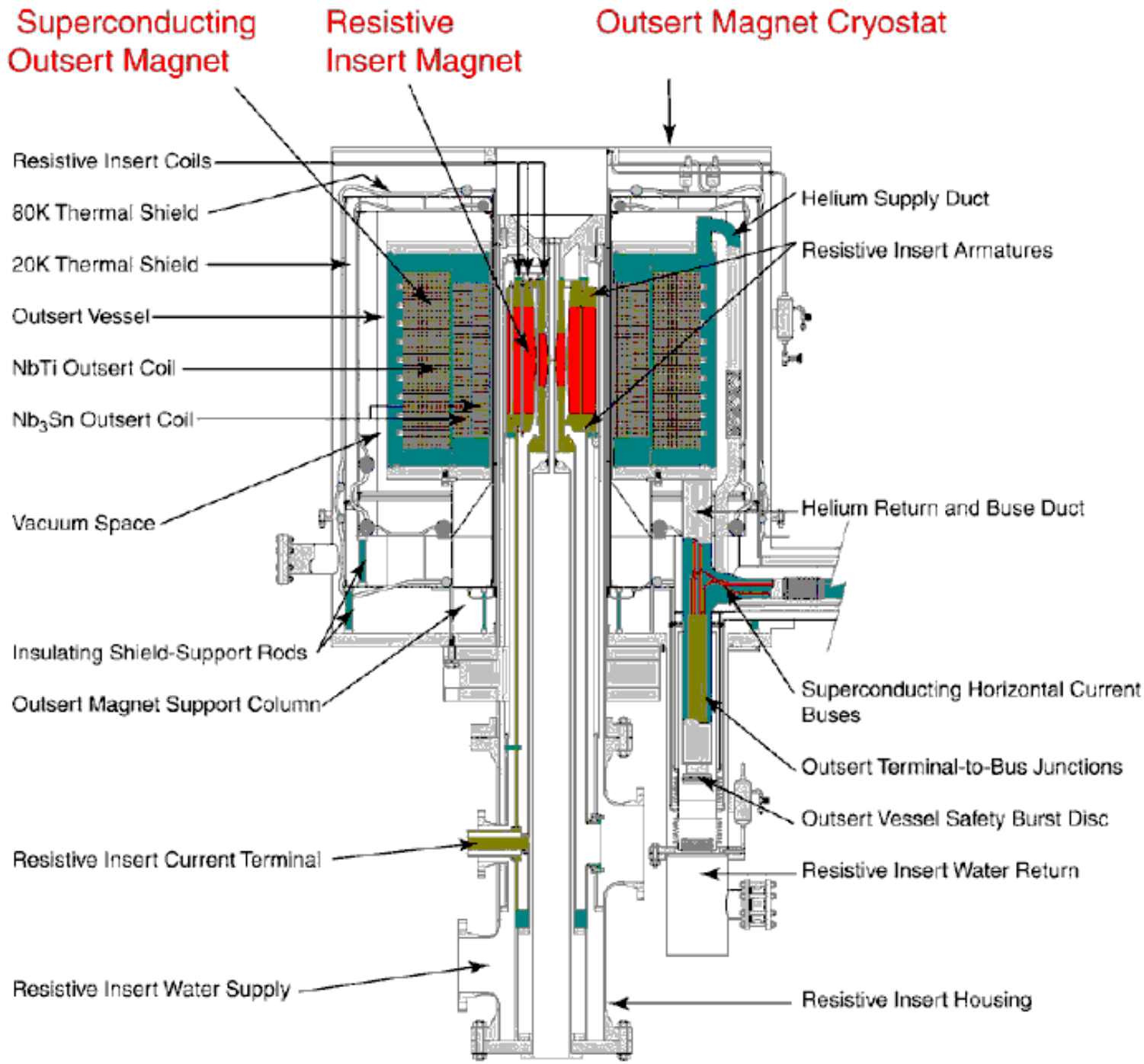
#9 Transverse Cooling in Very High Field Solenoids

- Lower momenta allow strong transverse cooling, but long emittance rises:
- Effectively reverse emittance exchange

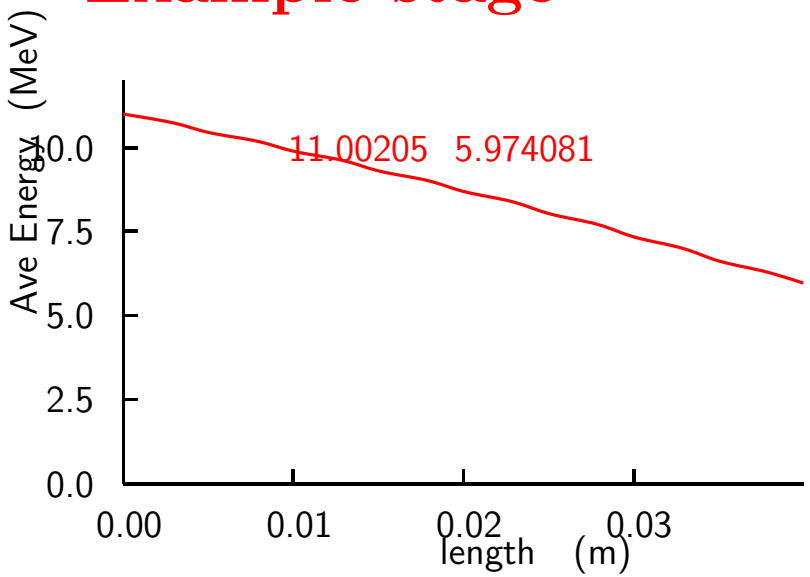


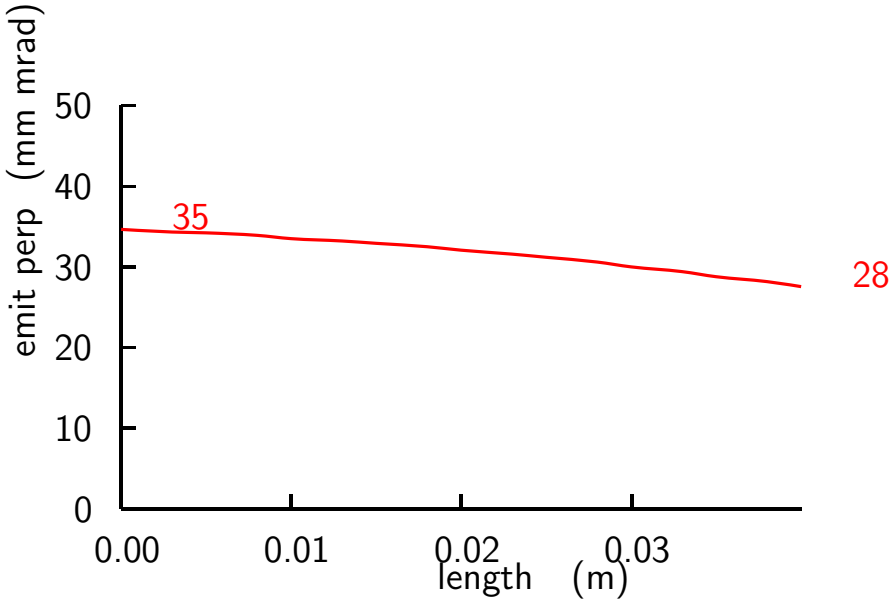
- 50 T HTS Solenoids
  - Current and ss support varied with radius to keep strain constant
  - Design using existing HTS tape at 4.2 deg. gave 50 T with rad=57 cm
  - 45 T hybrid with Cu exists at NHFML, but uses 30 MW
  - 30 T all HTS under construction

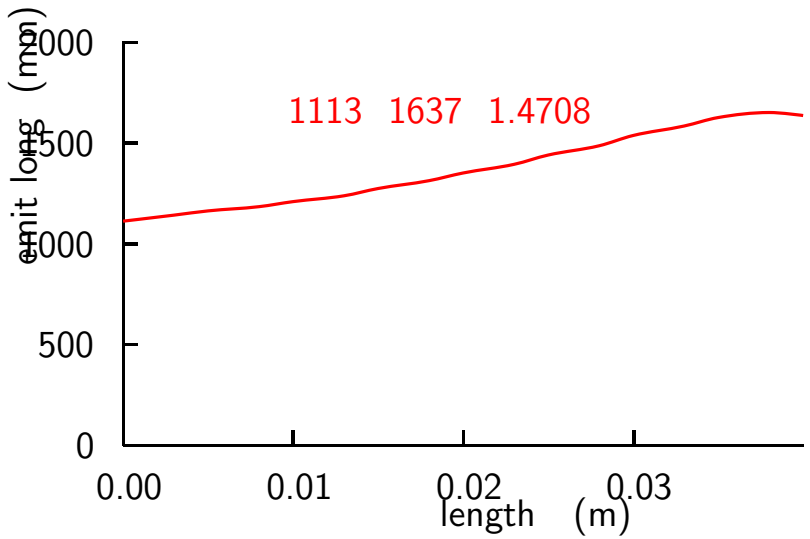
NHFML 45T Solenoid

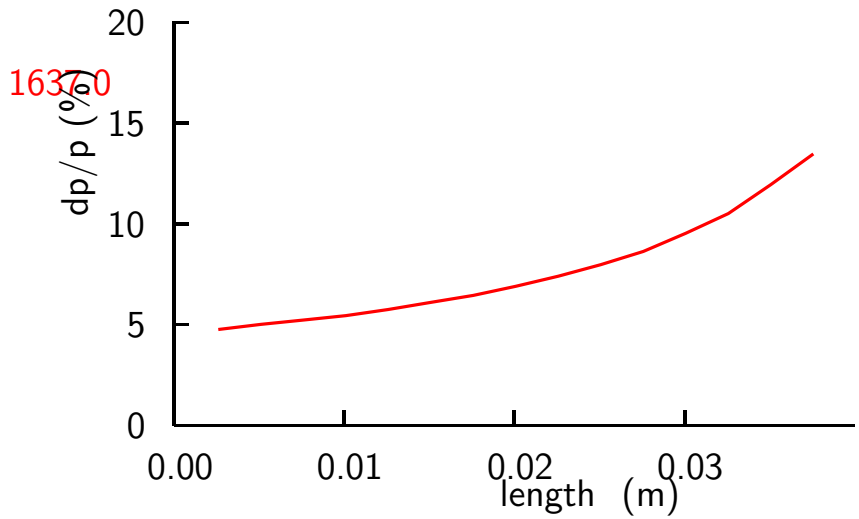


Example stage

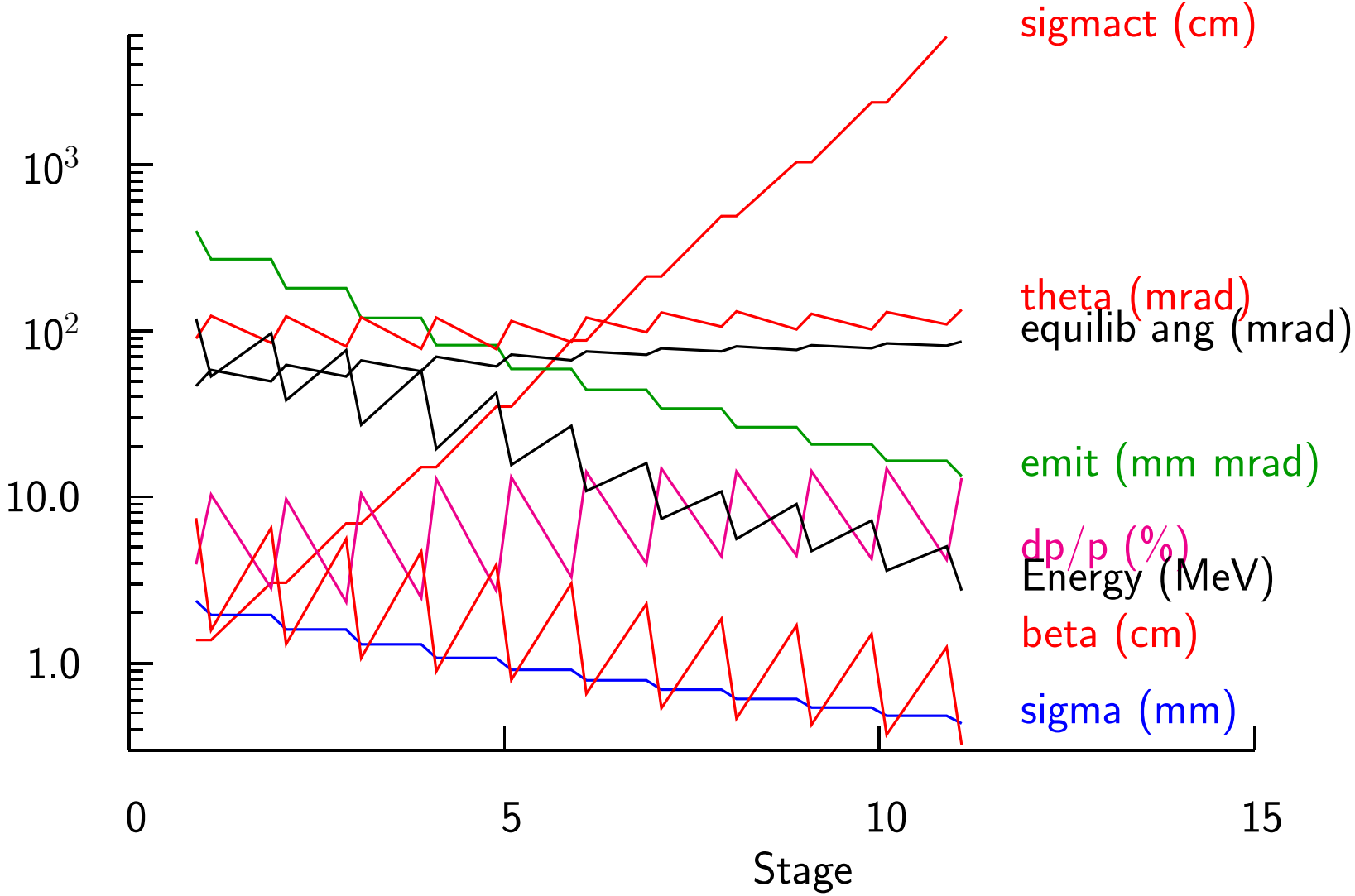






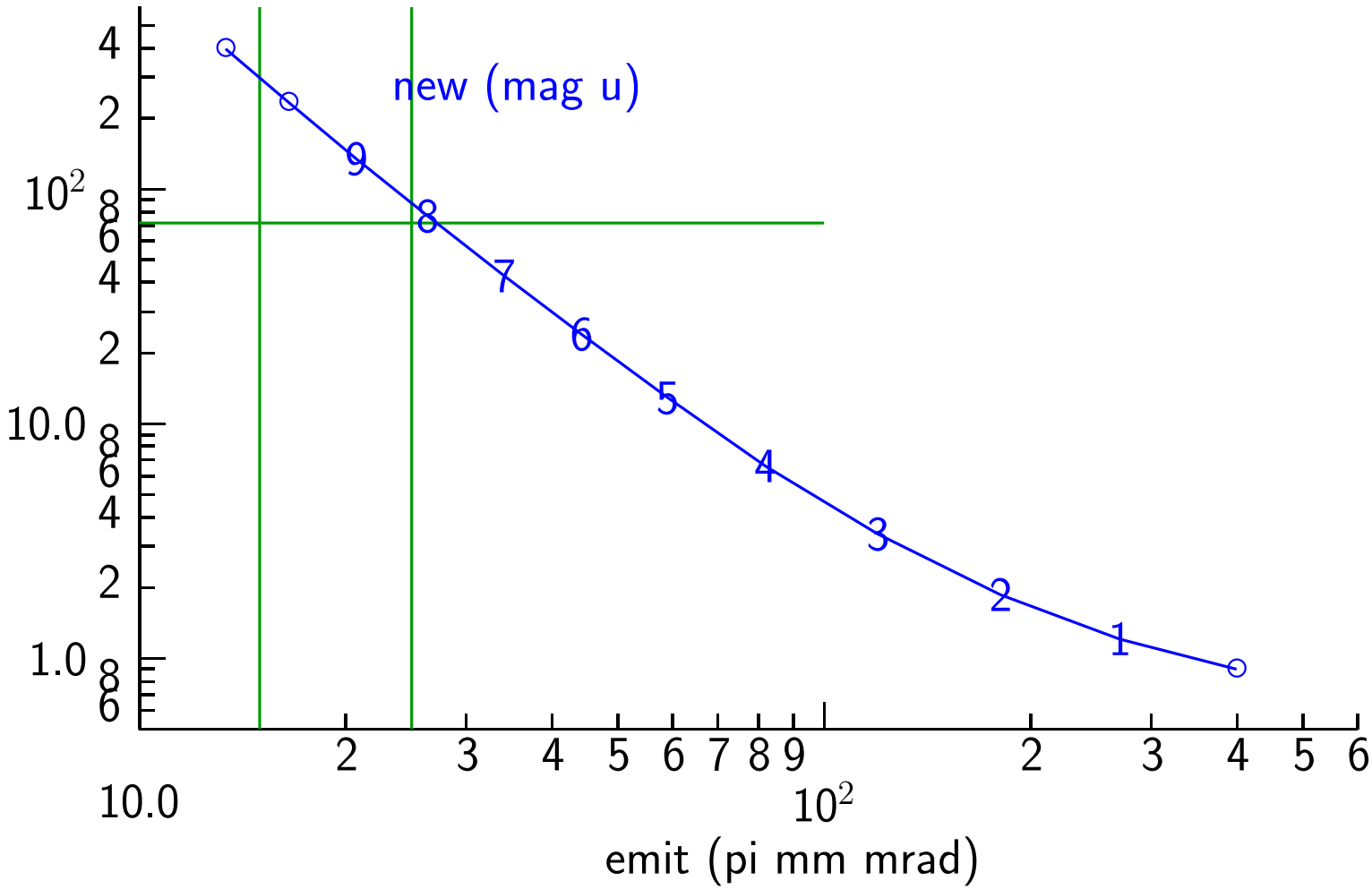


Parameters of many stages



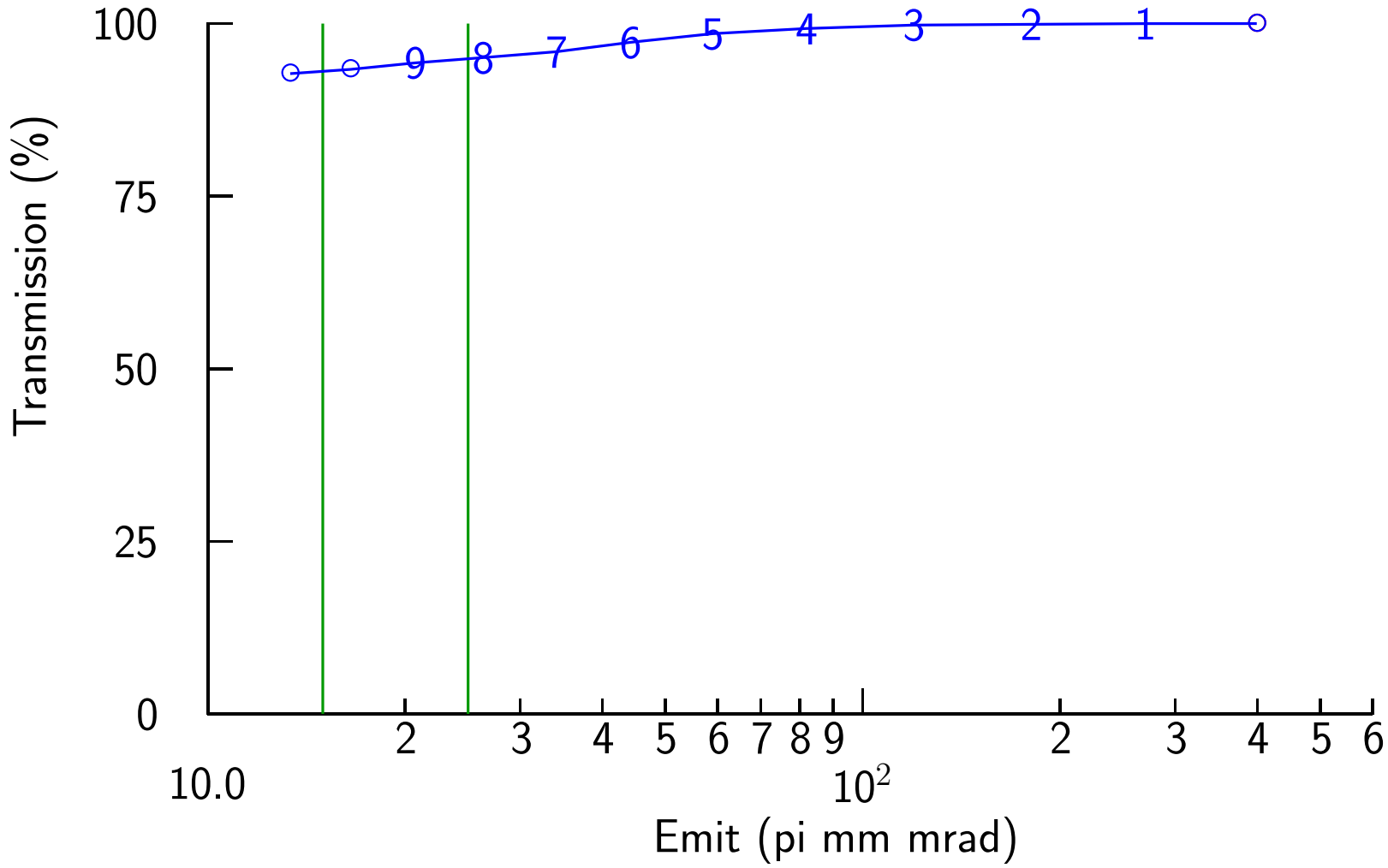
- between stages Energy increased dp/p reduced sigma ct increased
- each stage has lower frequency rf
- sigma theta well above equilibrium at start less so at end

long vs trans



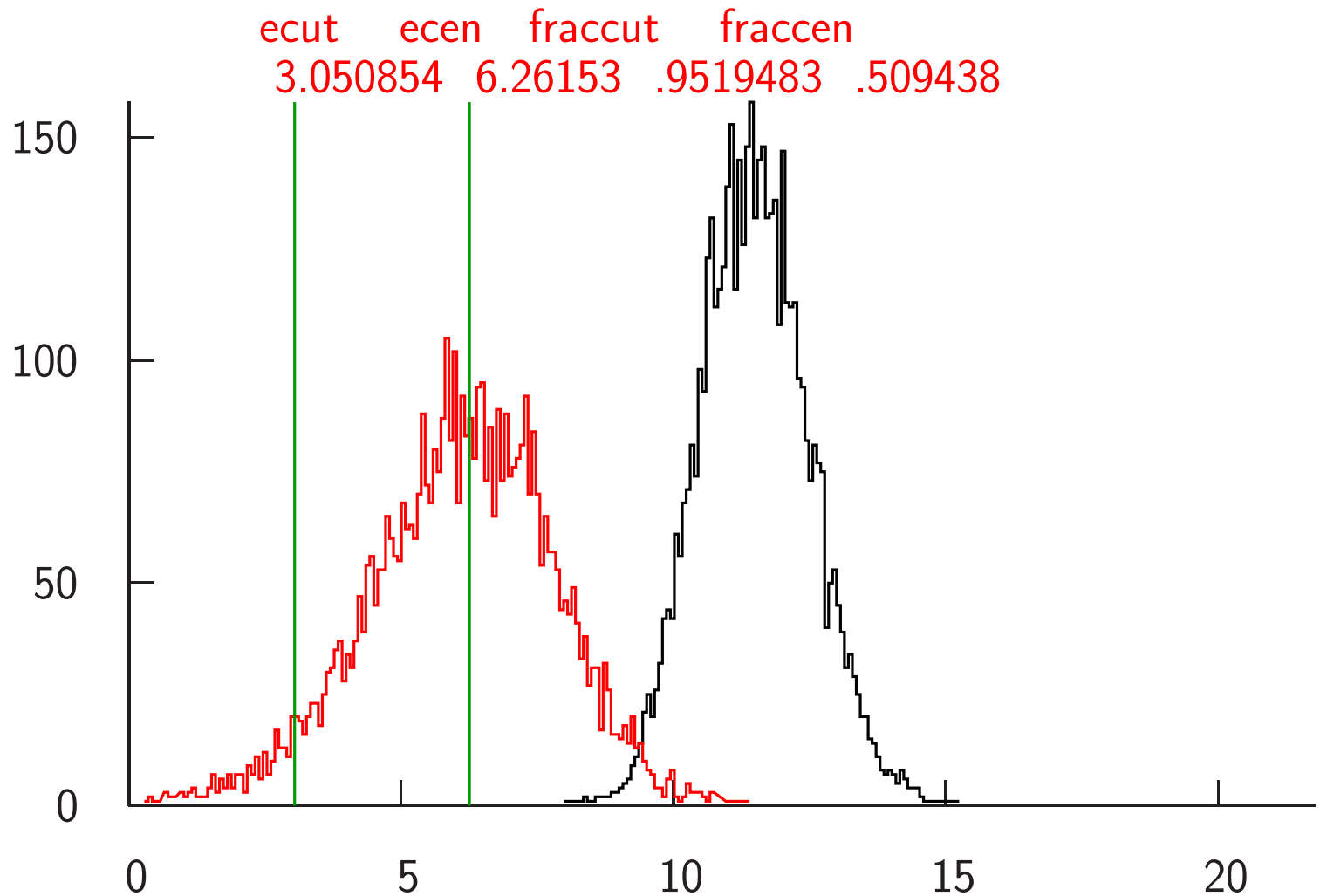
Transmission

No losses in matching or re-acceleration

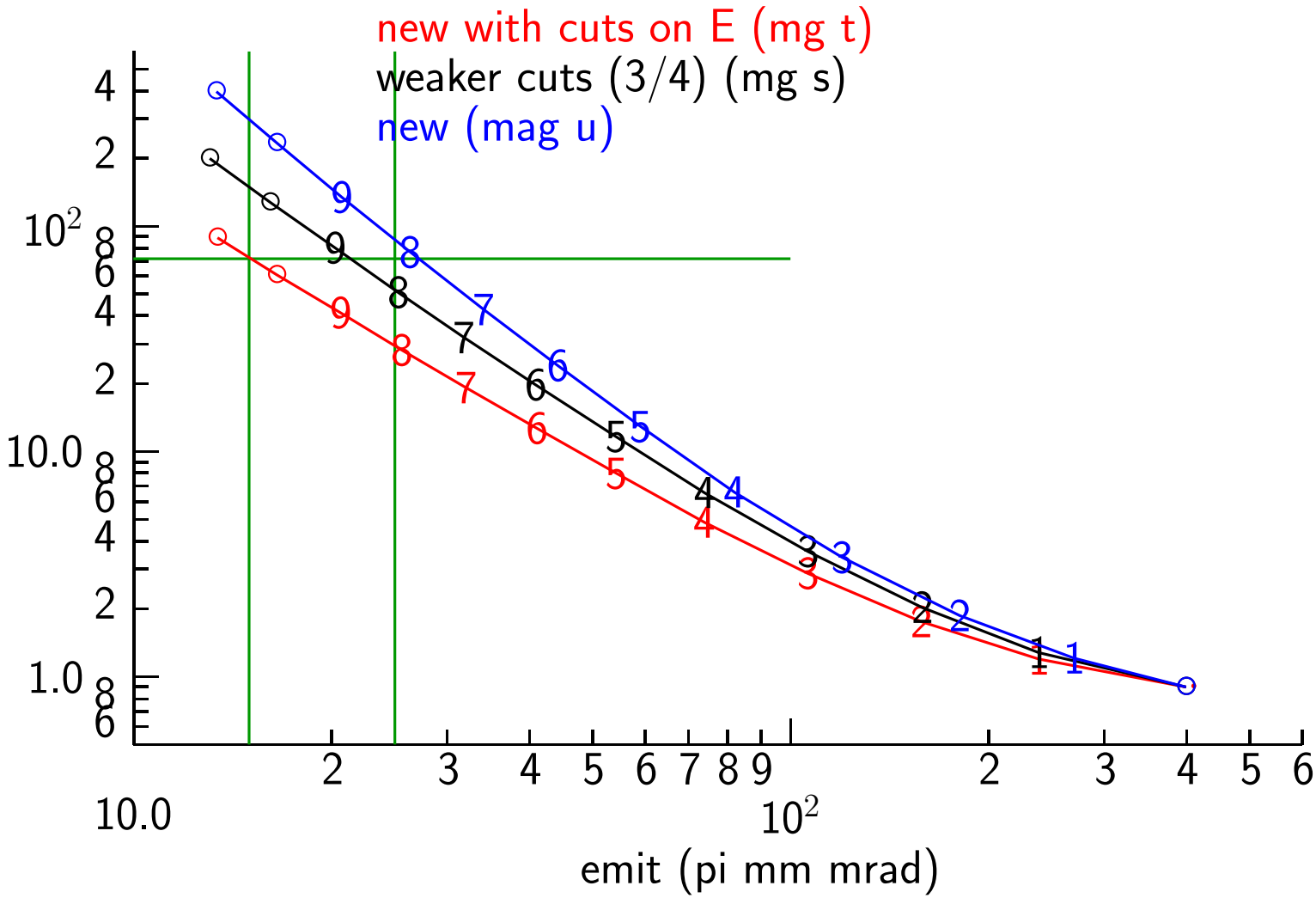


Can we do better with emin cut

Landau tail on energy loss increases longitudinal emittance
what if we though them away?

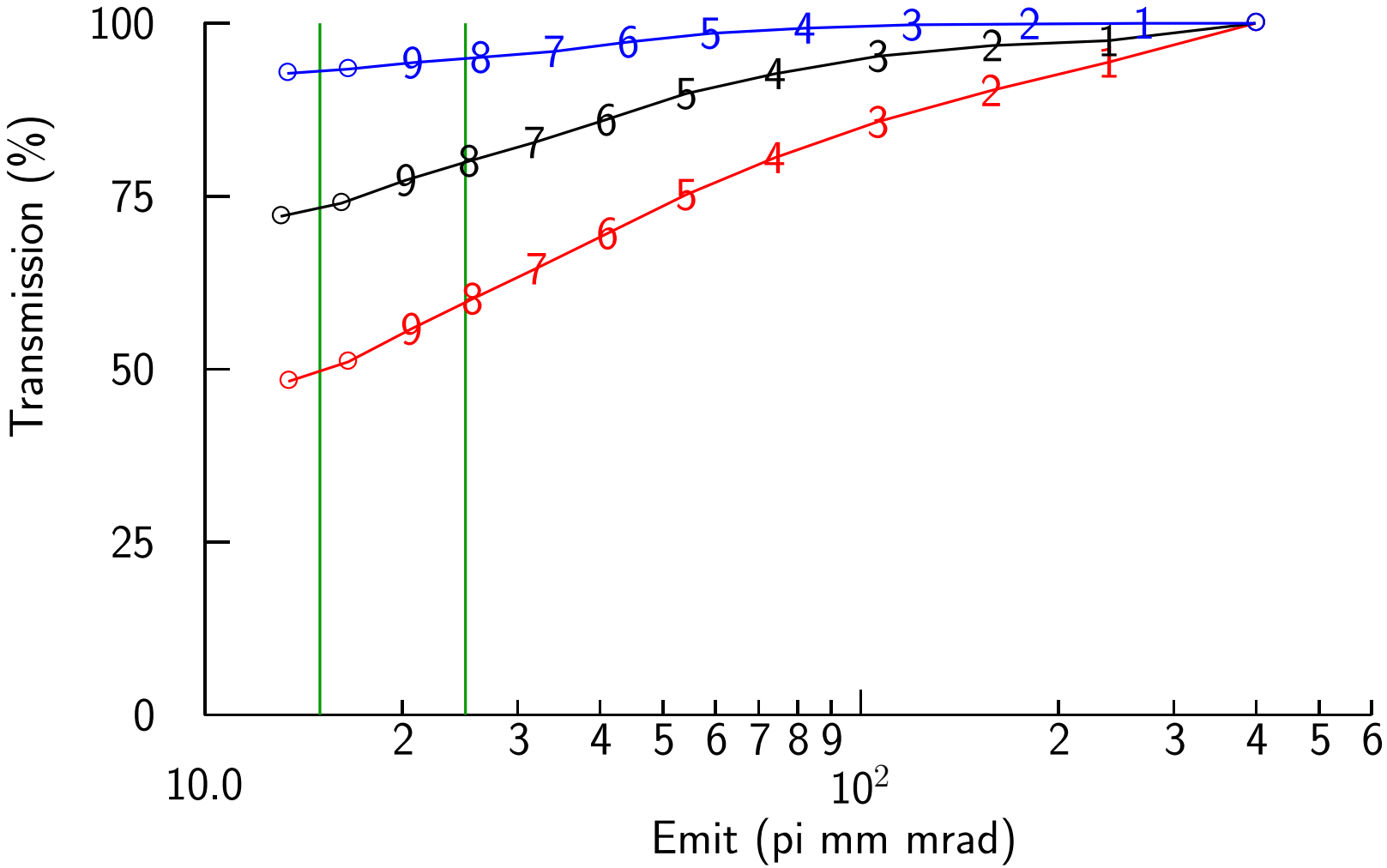


long vs trans



Looks good

But accumulated losses are serious



But losses are serious, though probably less than this procedure imposed

Needed drift to increase σ_{ct}

checked with an ICOOL simulation of stage 7

$$d(ct) \;=\; \sqrt{\sigma_{ct}^2(\text{after drift}) \;-\; \sigma_{\text{ct}}^2(\text{before drift})}$$

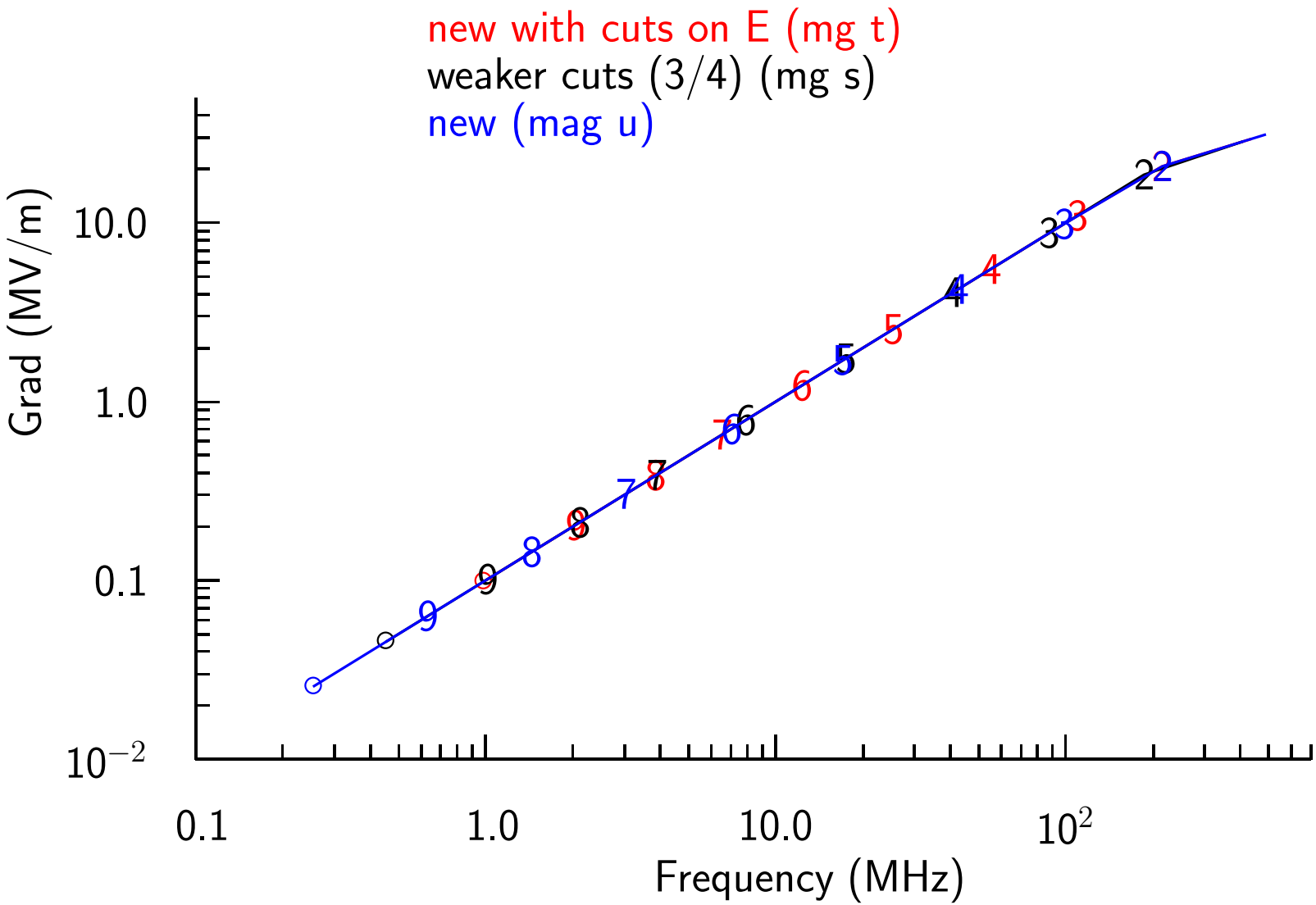
$$\begin{aligned} d(ct) \;&=\; \left(\frac{L_{\text{drift}}}{\beta_v^2}\right)\, d(\beta) \\ &=\; \left(\frac{L_{\text{drift}}}{\beta_v}\right)\, \left(\frac{d\beta}{\beta_v}\right) \\ &=\; \left(\frac{L_{\text{drift}}}{\beta_v}\right)\, \frac{1}{\gamma^2}\, \left(\frac{dp}{p}\right) \\ &=\; \left(\frac{L_{\text{drift}}}{\beta_v^3}\right)\, \frac{1}{\gamma^2}\, \left(\frac{dE}{E}\right) \end{aligned}$$

so

$$L_{\text{drift}} \;=\; d(ct)\, \frac{\gamma^2 \beta_v^3}{dE/E}$$

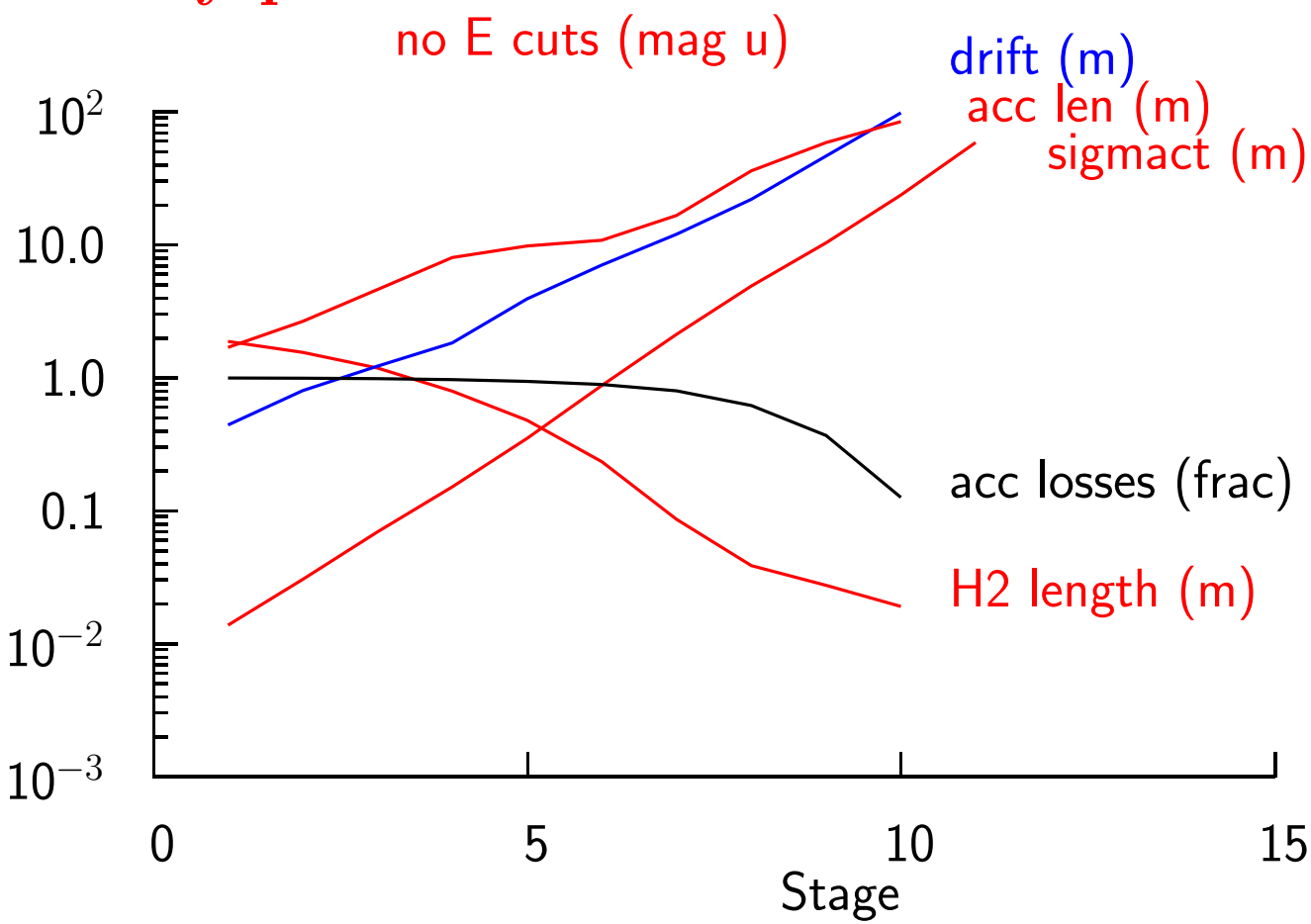
βs, γs, E , dE and σ_{ct}(before drift) are after the hydrogen in one stage
σ_{ct}(after drift) is taken as the before hydrogen value for the following stage .

Assumed Acceleration Gradient



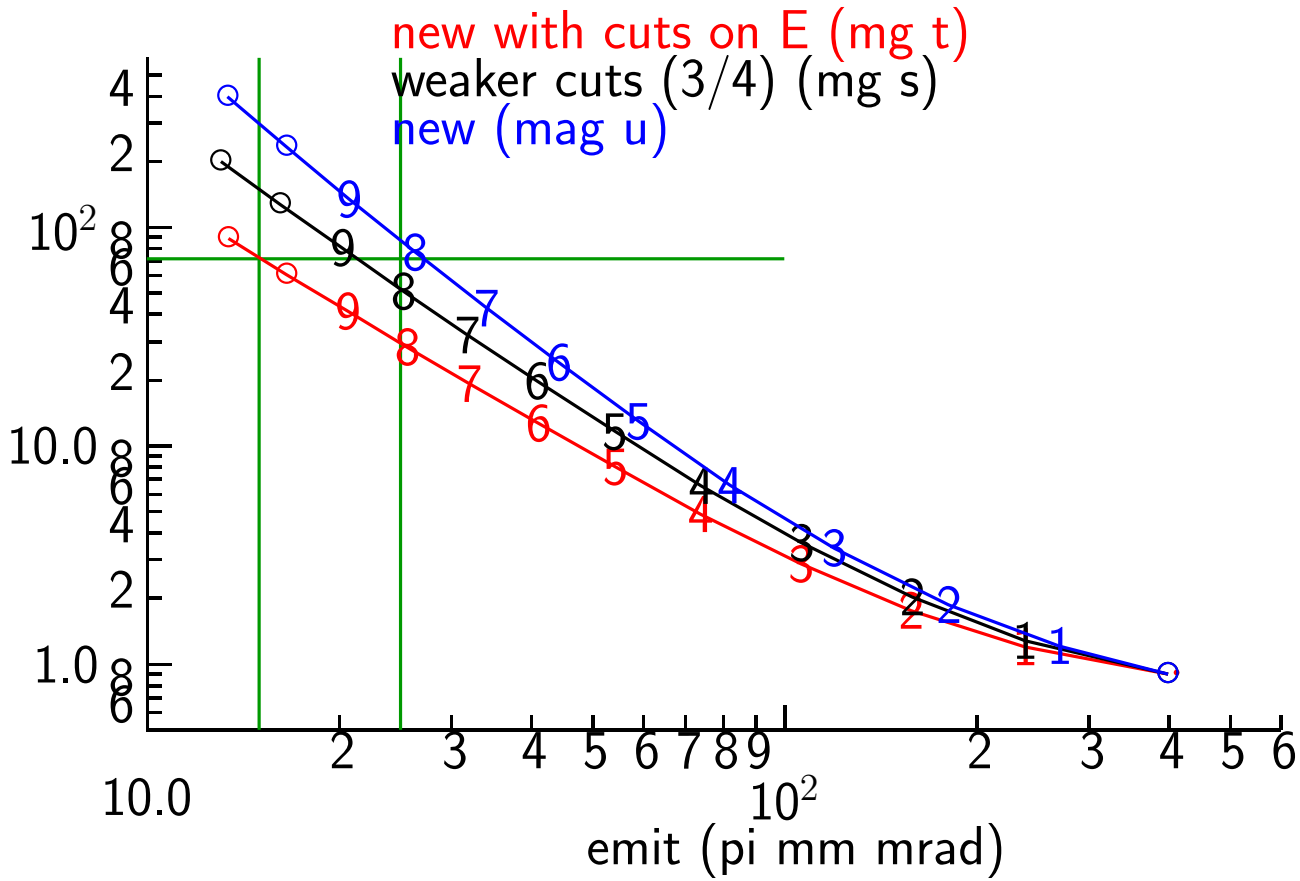
Note very low frequencies at end

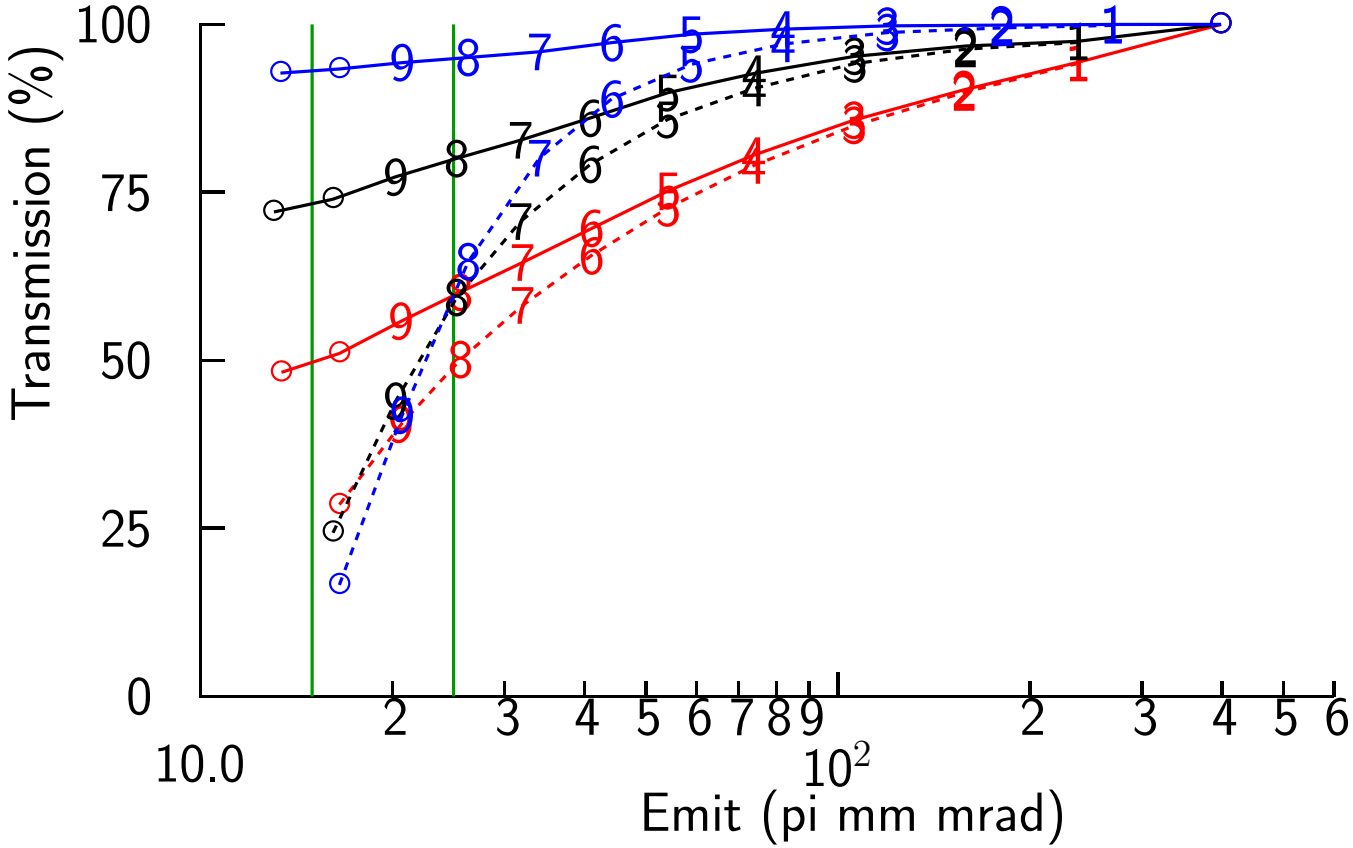
Decay parameters



- sigma ct becomes very long at end
- drift and acc lengths similar and large at end
- severe losses at end

Including decay losses



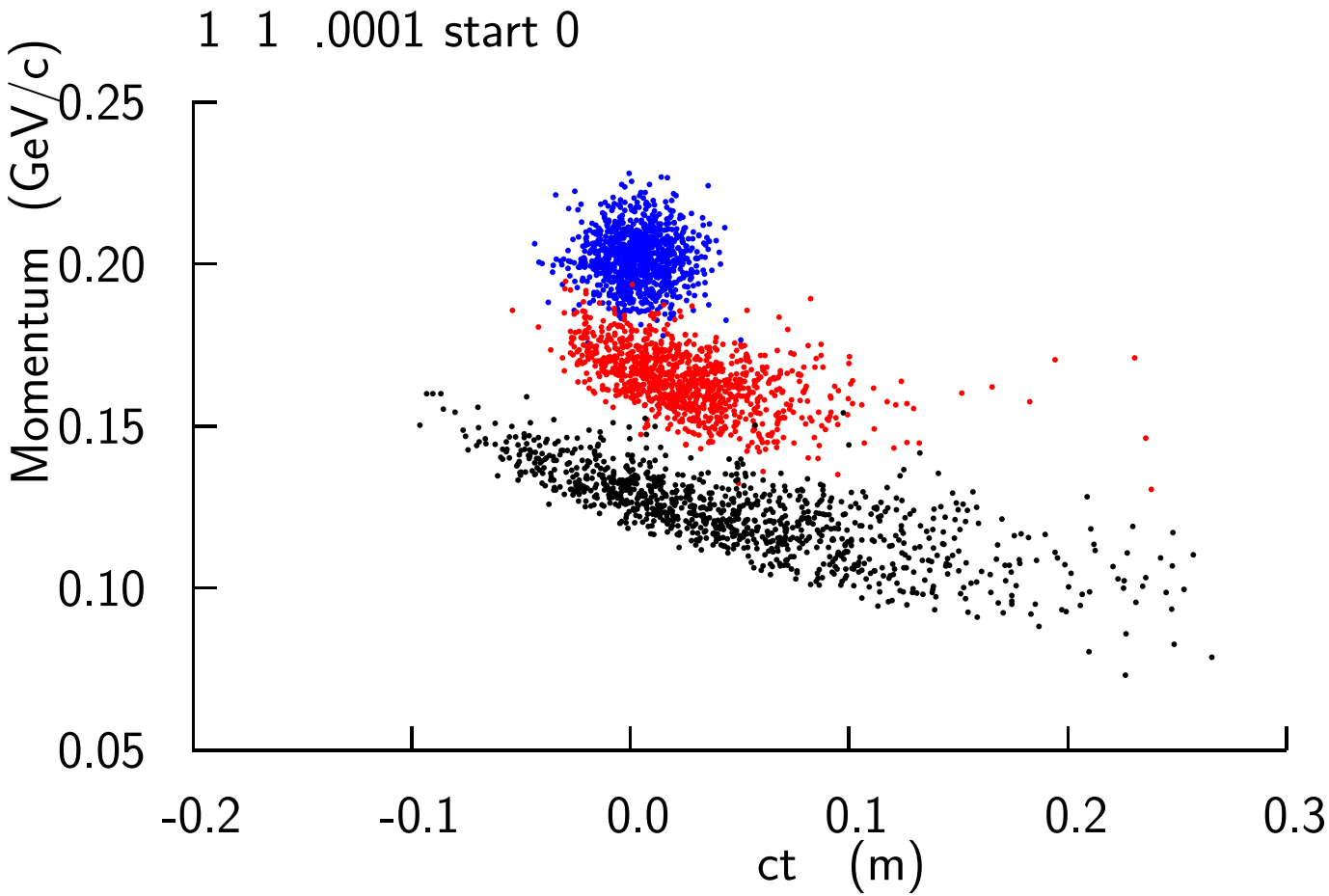

Transmission (%)
100
75
50
25
0
10.0
2
3
4
5
6
7
8
9
10^2
2
3
4
5
6
Emit (pi mm mrad)

Possible optimizations

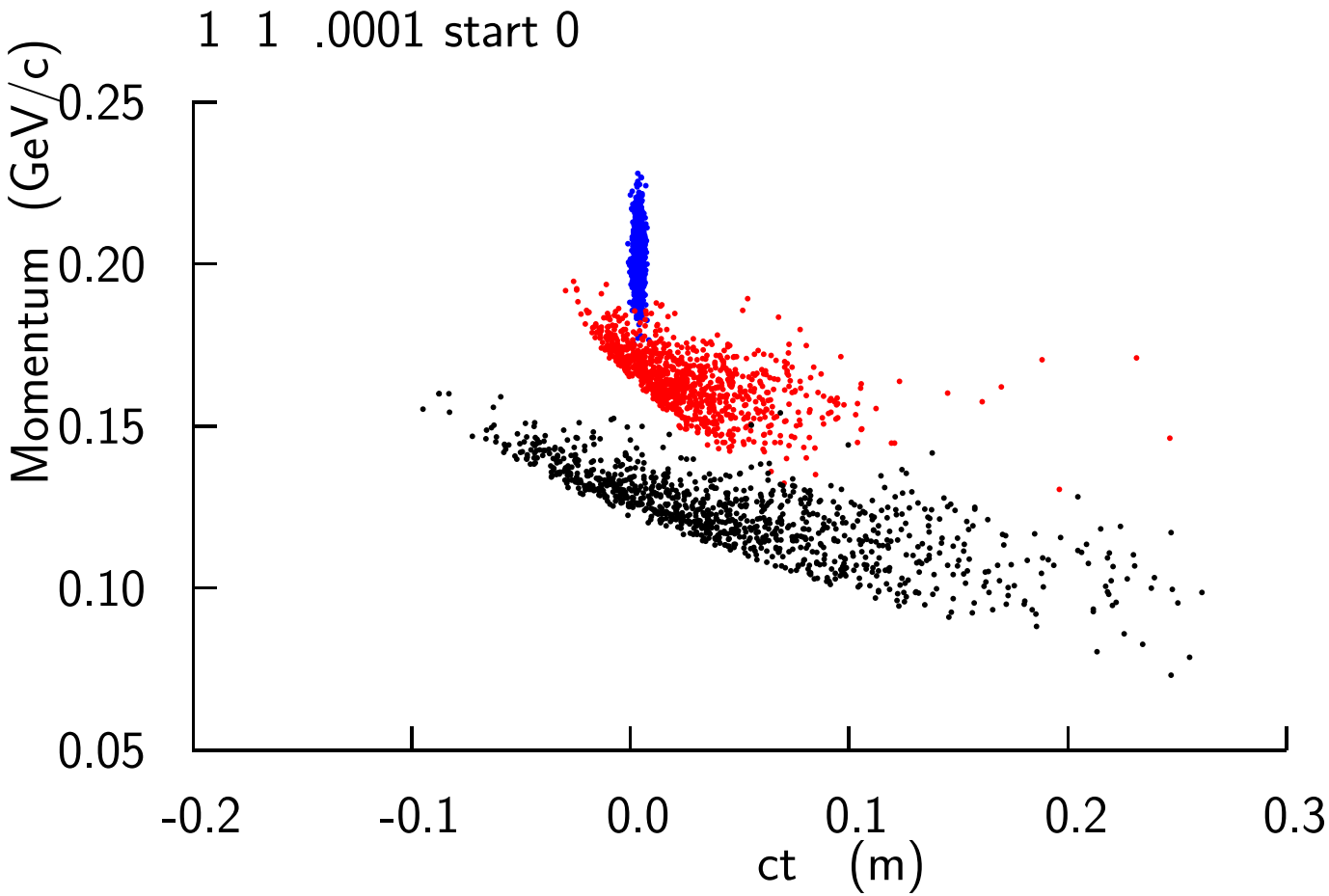
Need to shorten bunches

- increase initial dp/p
- raise energy
  But this will raise the equilibrium emittance, so cannot do too much

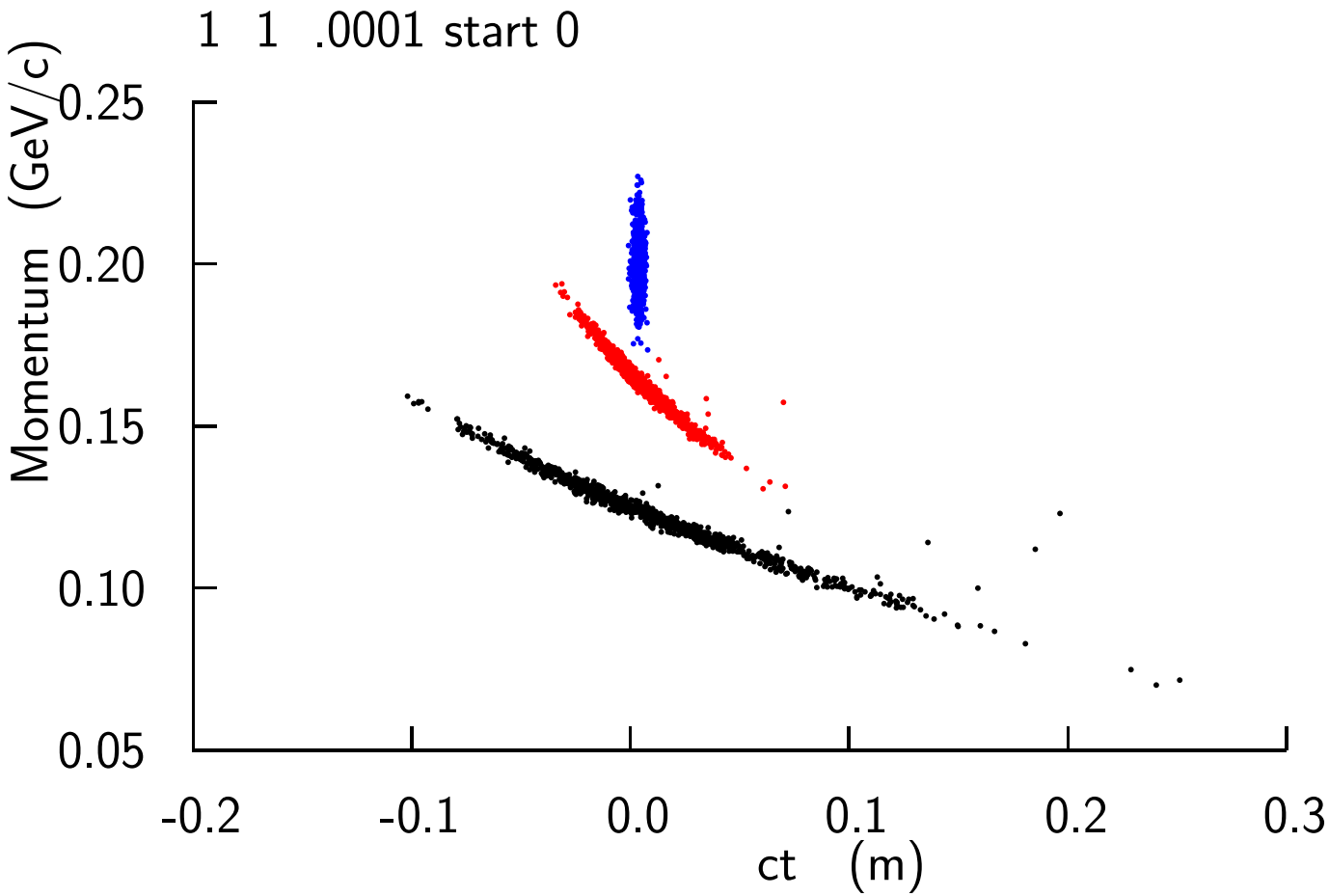
New problem at start



No inital ct spread



No transverse amplitude



So problem is primarily from amplitude dependent motion in solenoid

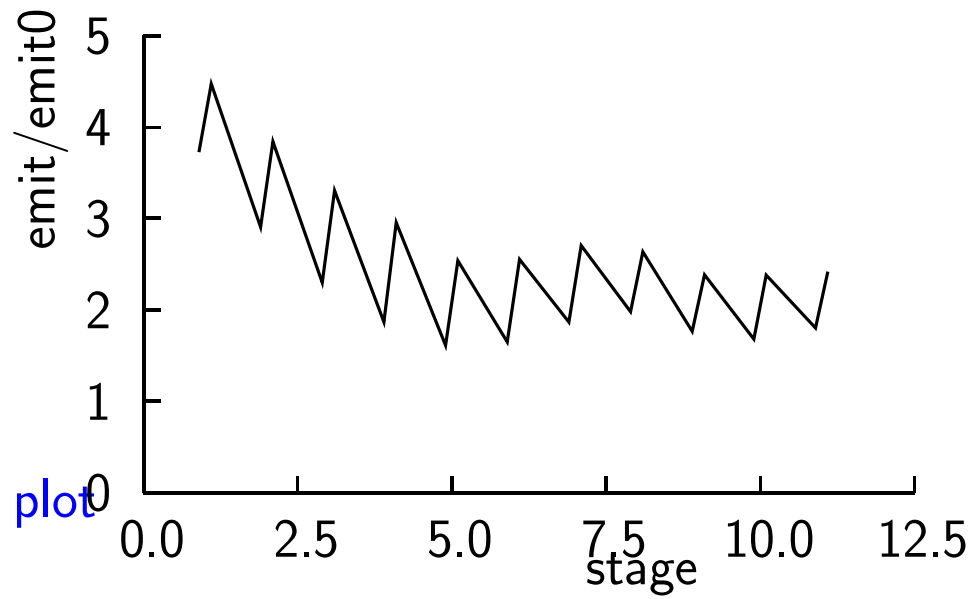
Possible optimizations

Need to lengthen bunches

- decrease initial dp/p
- lower energy

Need to decrease amplitude effect

- lower B field
  The curent B is generous at start - see plot
- add initial correlation
- go several stages with alternating B



Conclusion

- Work needed on parameters
- Then simulation of multiple stages with matrix rotation and acceleration
- Then with real matching transverse and longitudinal
- Much work