

Bunch Recombiner for a $\mu^+\mu^-$ Collider Cooling Scenario

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FNAL

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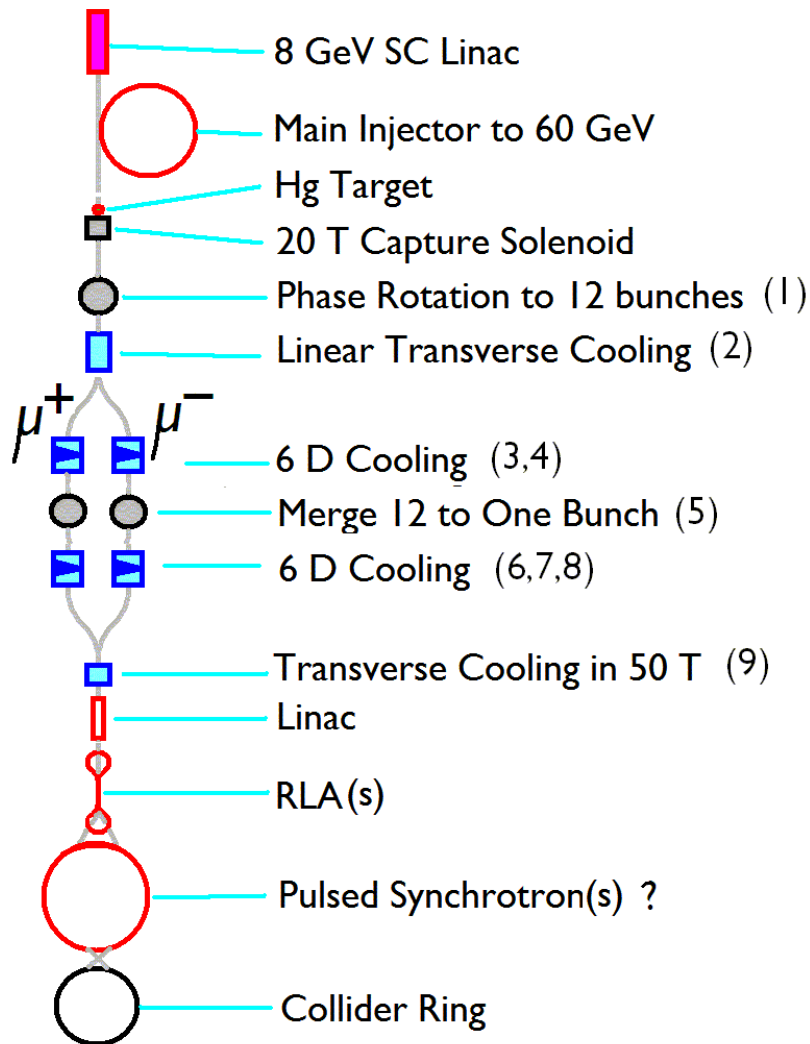
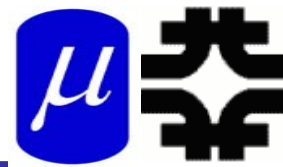
- **Front End for the Neutrino Factory/MC**
 - Concepts developed during study 2A

- **Extend to Collider**
 - need bunch recombiner

- **Use**

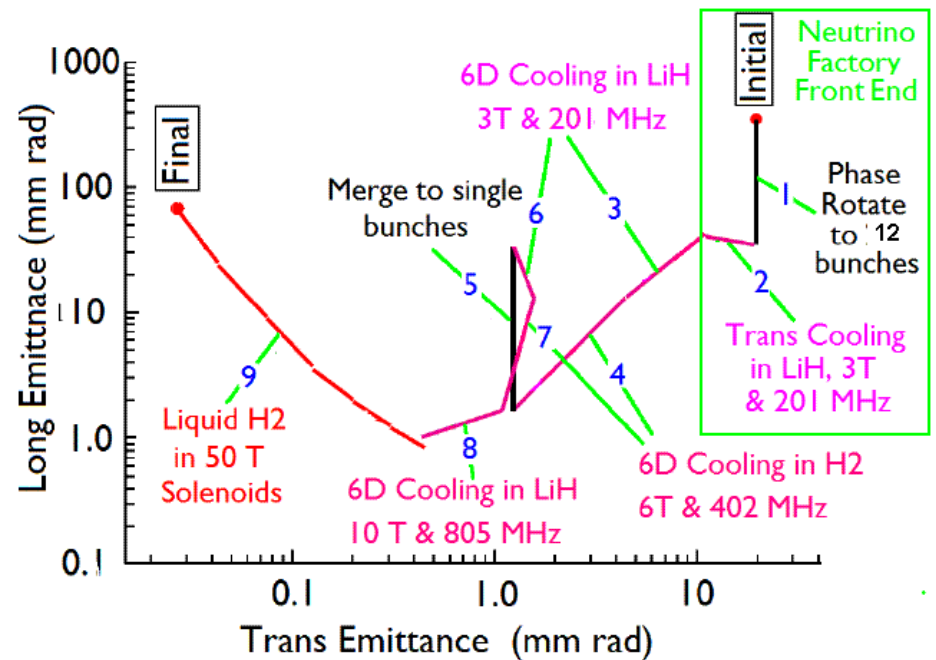
- **See MuCOOL Note 548**
 - (March 2010)

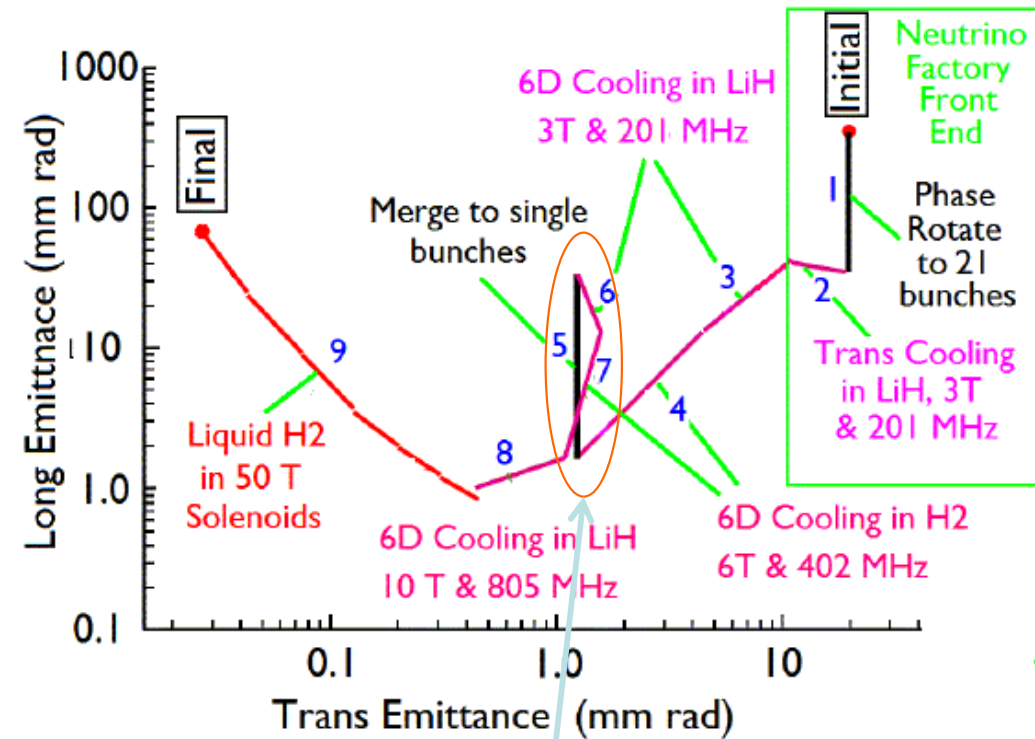
Collider Scenario



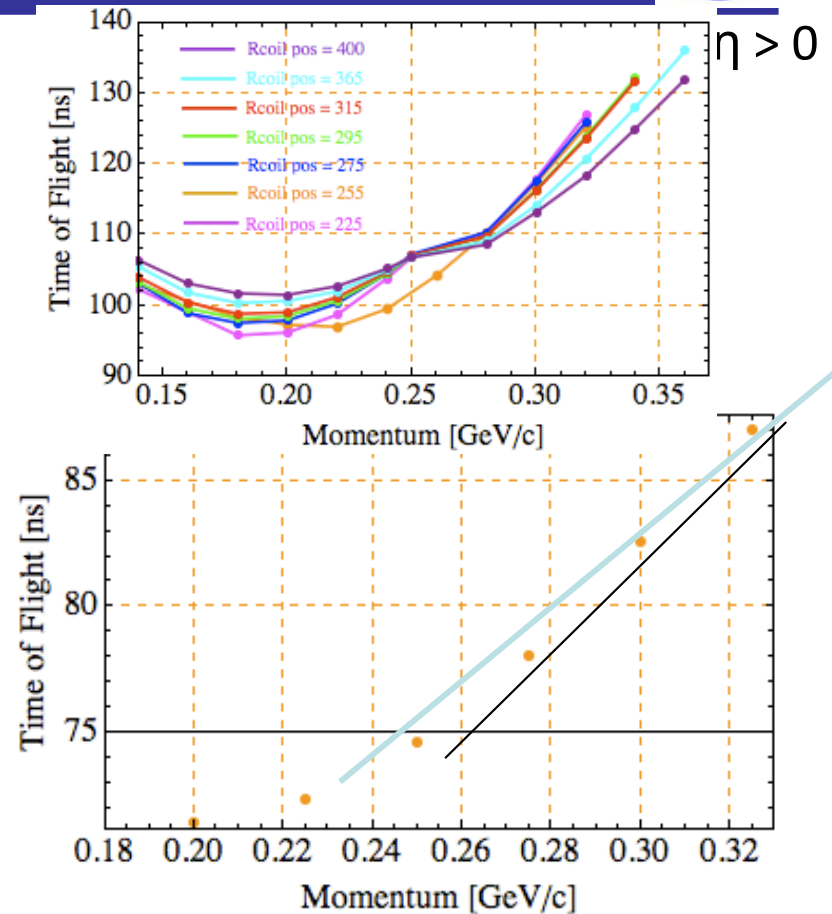
➤ Scenario requires bunch recombiner half-way through cooling

➤ Could also be needed after final cooling



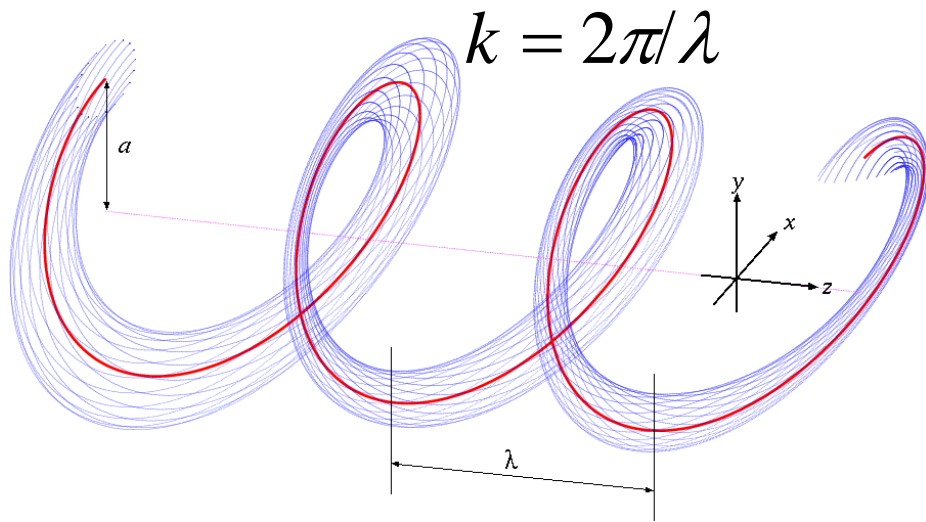


Rebunching process is required in Cooling schemes



Helical transport channel:
 Relatively large dependence
 Of time of flight on momentum.
 Linear over large ΔE range.

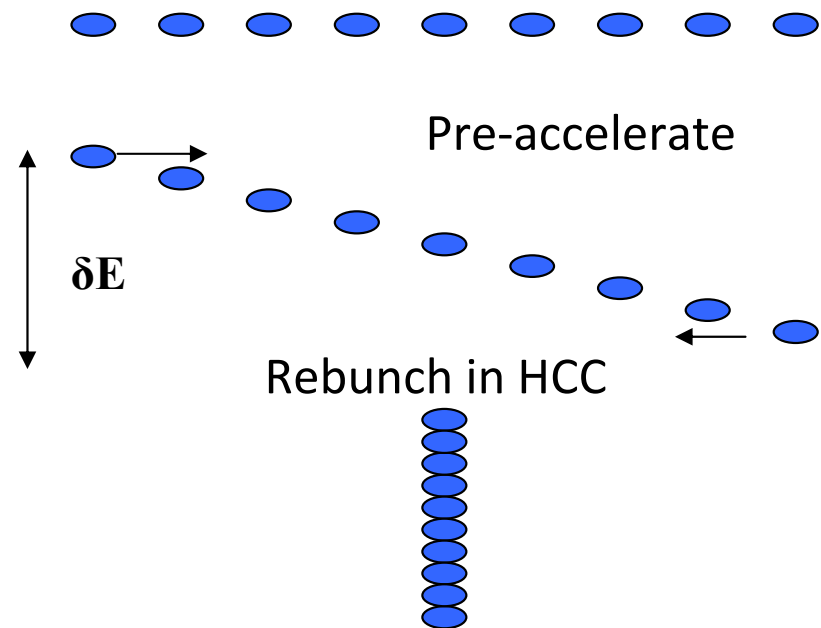
- Overview of rebunching process



$$\kappa = \frac{2\pi a}{\lambda} = \frac{p_\phi}{p_z}$$

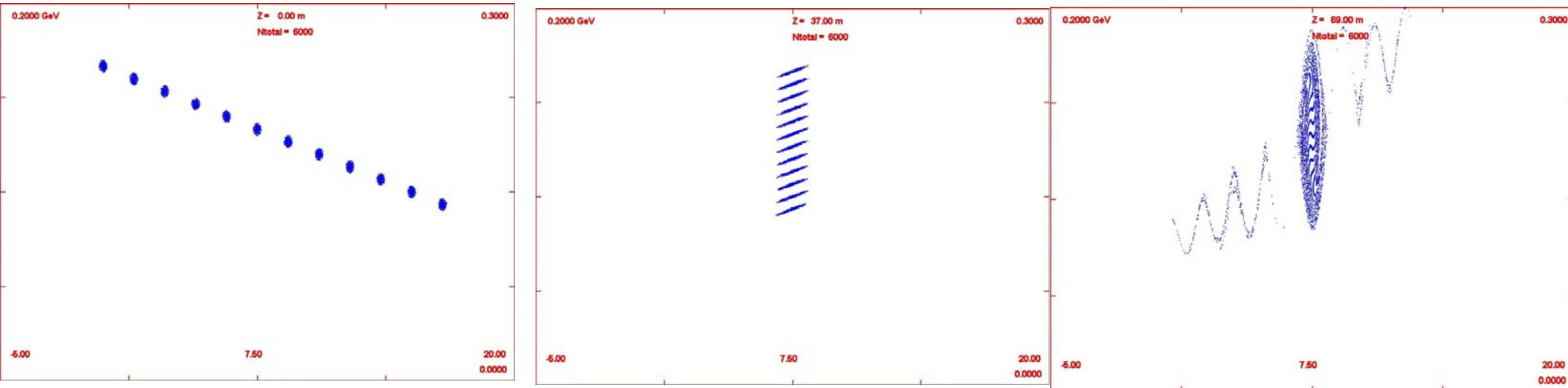
$$p(a) = \frac{\sqrt{1+\kappa^2}}{k} \left[B - \frac{1+\kappa^2}{\kappa} b \right]$$

Initial bunch structure



HCC can have a large phase slip factor and the Bunched beam can be merged with a short HCC ($\sim 20 \lambda$?)

1-D simulation model



➤ Anisochronous HC transport

- HC - B= 4.2T $b_d=0.75$, $b_q=0.4$
- $\kappa=1$, $\lambda=1.6\text{m}$, $P_0=290\text{MeV}/c$
- $\eta=0.43$, $\hat{D}=1.7$, $D=0.44\text{m}$

$$\eta = \frac{\sqrt{1+\kappa^2}}{\gamma\beta^3} \left[\frac{\hat{D}\kappa^2}{1+\kappa^2} - \frac{1}{\gamma^2} \right]$$

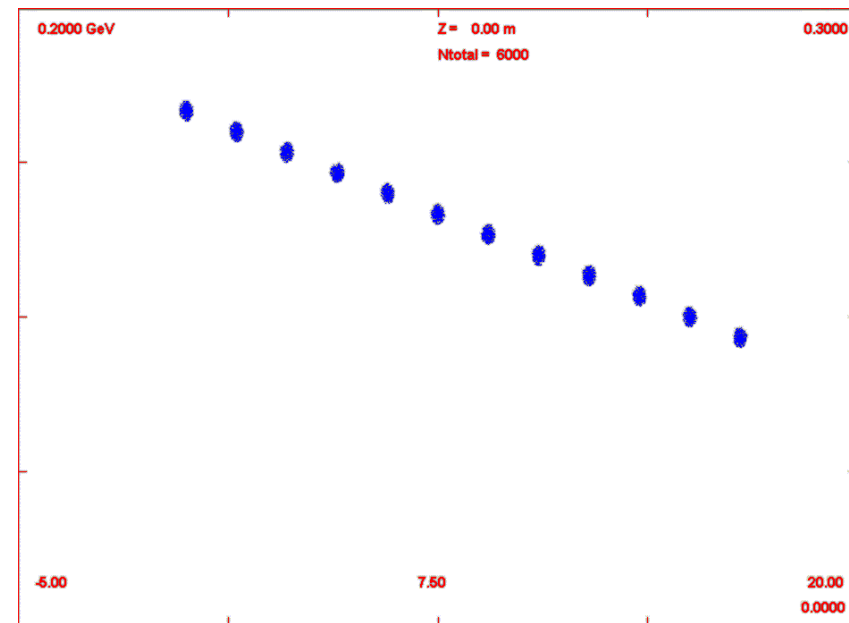
➤ Bunching transport

- $V' = 10 \text{ MV}/\text{m}$
- $\eta=0.1$
- $\sim 95\%$ capture

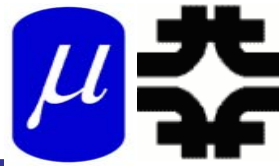
- **Need to form beam into string of bunches of different energies**
 - $\sim 10\text{cm}$, $\delta E = 2.5\text{MeV}$
 - 10 MeV, 1.5m bunch spacing
 - 12 bunches

- **Old scenario**
 - Induction linac or 5MHz rf

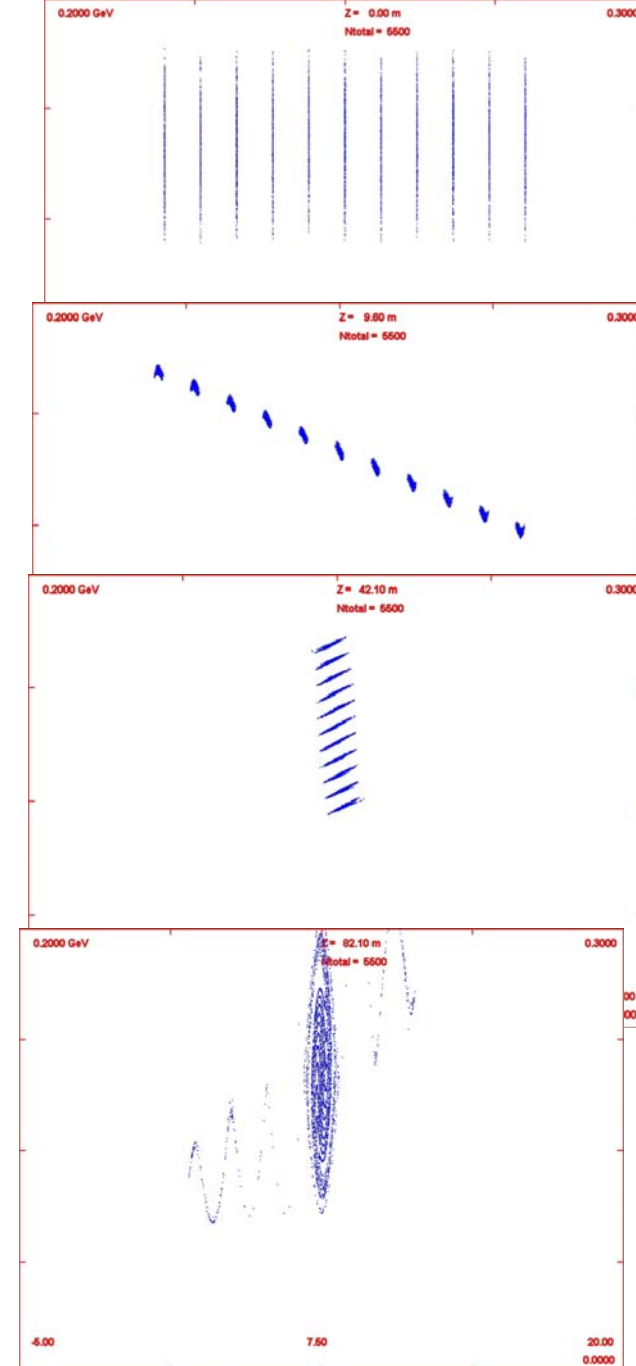
- **Attempt to reverse front end buncher**
 - Different system



Form Beam into bunches



- **Start with cooled bunches**
 - $\sim 0.6\text{cm}$, $\delta E = 33\text{MeV}$ $\varepsilon_L = 0.002\text{m/bunch}$
 - 200MHz 11 bunches
 - 200MeV kinetic energy
- **Bunch and Tilt with off-frequency rf**
 - 204.8MHz, -15MV/m , 9.6m
 - Quasiisochronous: $\eta = M_{56} = 0.05$
 - $\frac{1}{4}$ synchrotron period
- **Drift in anisochronous Helical Transport**
 - $\eta = 0.43$, 34m
- **Beam in single bunch**
 - Rebunch at 200MHz
 - Modest rf if quasiisochronous
 - $\eta = 0.1?$



Simulation Example

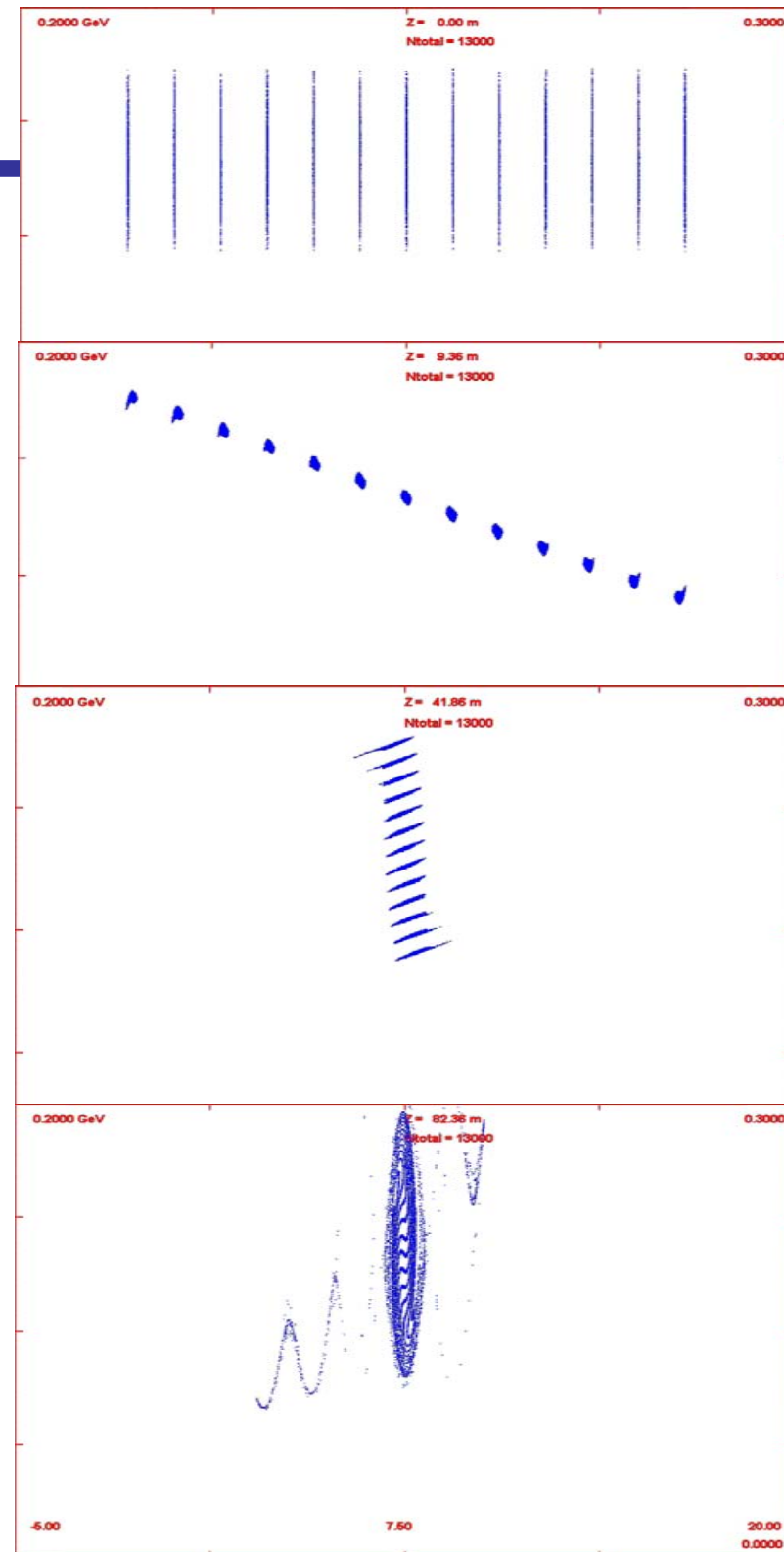
➤ Another example

- Initial beam: $E=200\text{MeV}$, 13 bunches
 - $\delta E=30\text{MeV}$, $\delta z=6\text{mm}$: $P=287\text{MeV}/c$

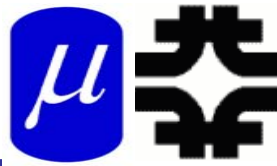
- Rotate: 9.6m , 15 MV/m
 - $\delta E=6\text{MeV}$, $\delta z=3\text{cm}$:

- Drift: $M_{56}=0.43$, 33m

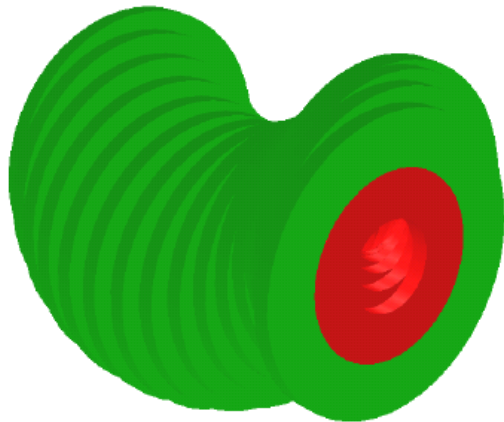
- Capture: 201.25MHz
 - $\delta E=40\text{MeV}$, $\delta z=20\text{cm}$: $P=287\text{MeV}/c$



Too good to be true ??



- **Old scenario**
 - 340m long
 - 5MHz rf , 100m (or 100m + of induction linac)
- **New scenario**
 - $\Delta z=42\text{m}$, $V' = 15\text{MV/m}$ (10m), $\sim 200\text{MHz}$
- **Baseline: ~ 13 bunches $\rightarrow 1$**
- **Works better than it should ..**
 - Probably have to go to adiabatic,
 - longer system ??



"Frankly, I even find it hard to believe some of the things I've been coming up with."