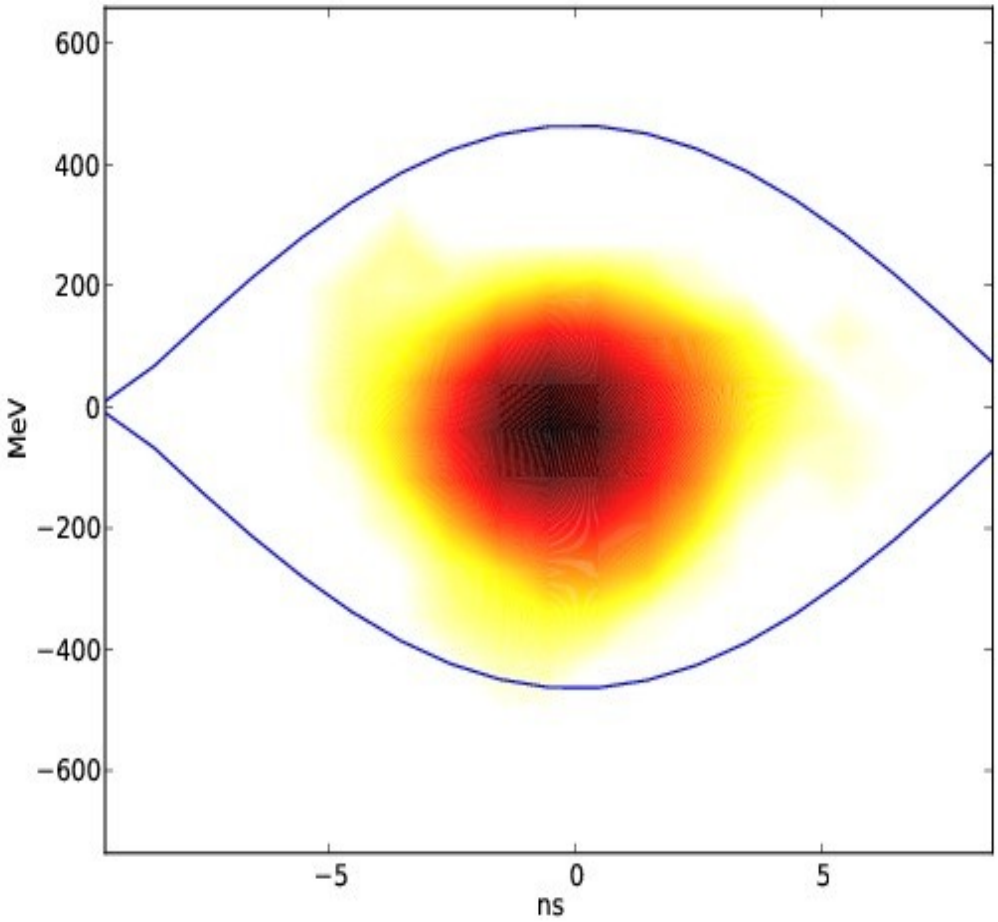
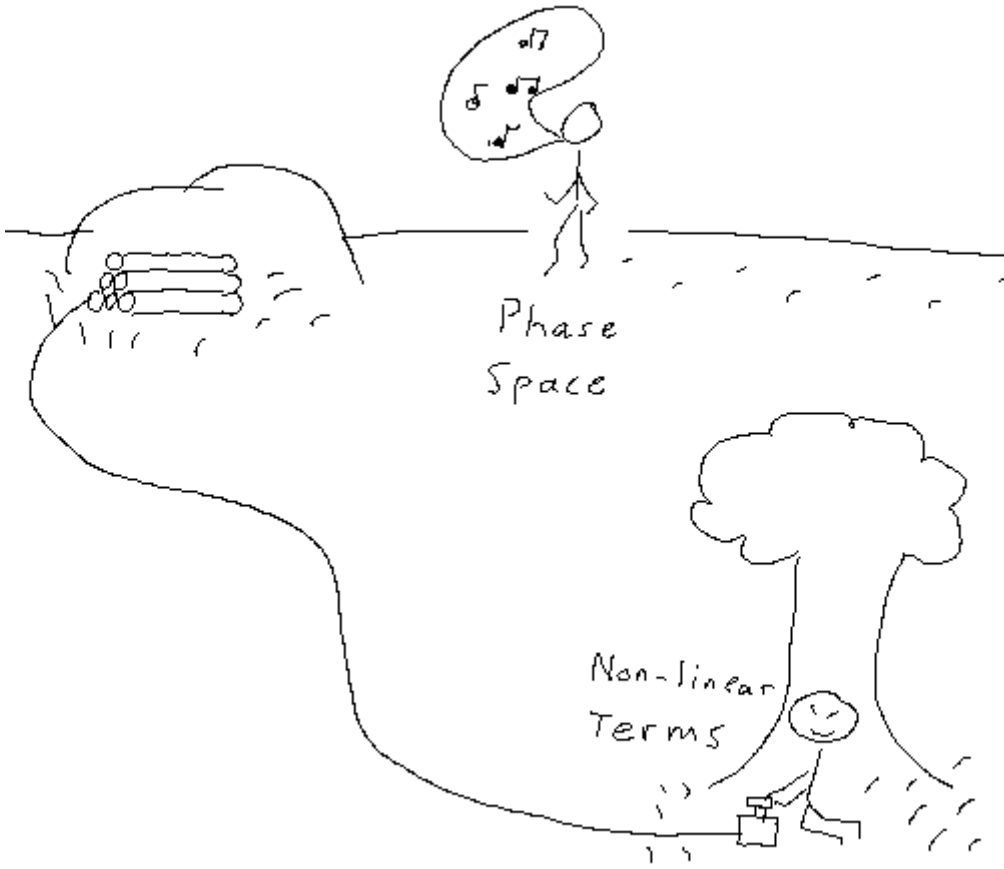
Longitudinal Dynamics in the Tevatron

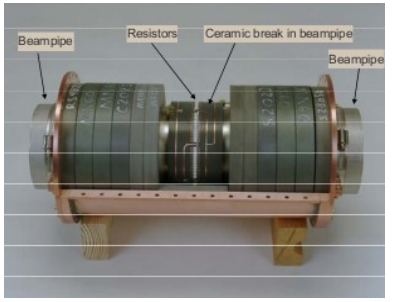
Motivation: To observe the influence of beam-beam interactions on the longitudinal dynamics in the Tevatron

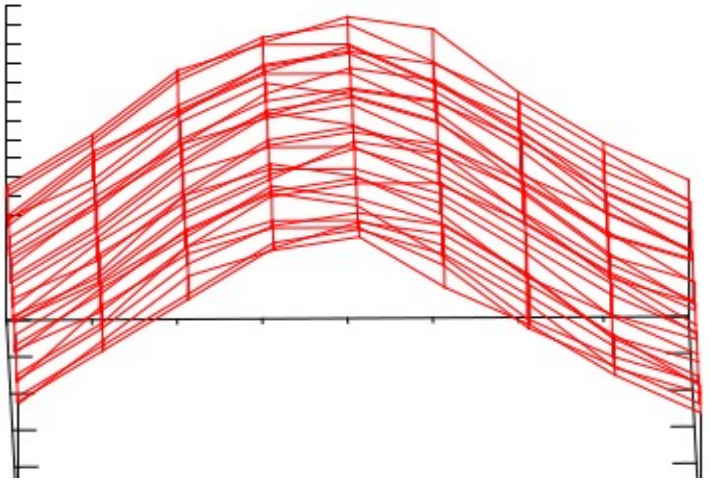




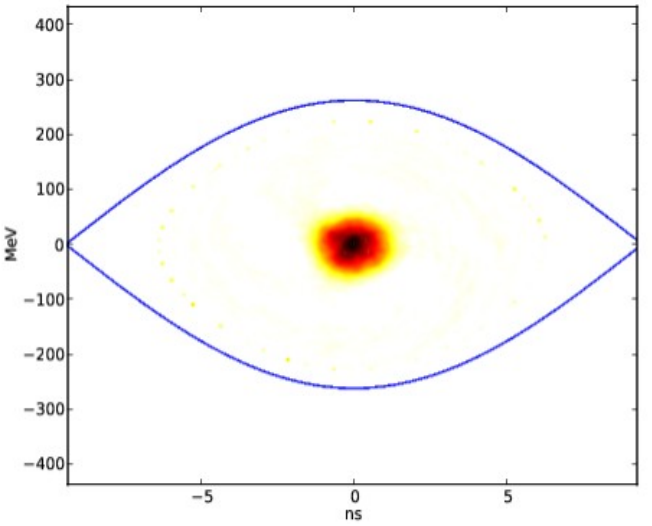
John Stogin
Lee Teng Intern

Remember this?





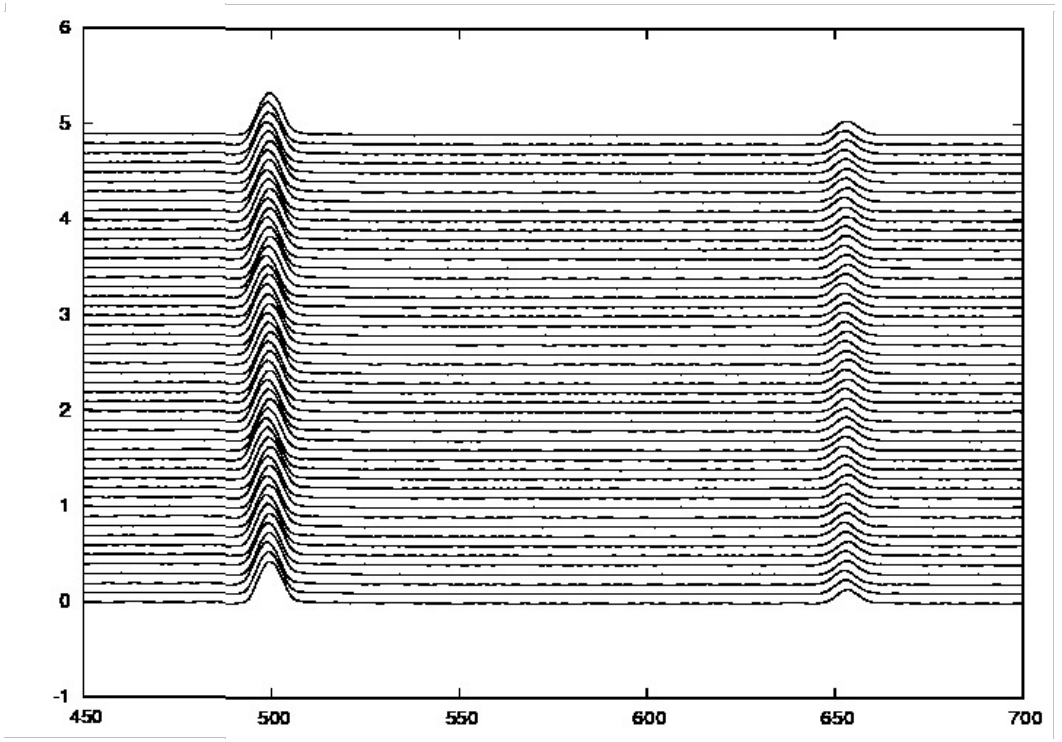
Mathematics



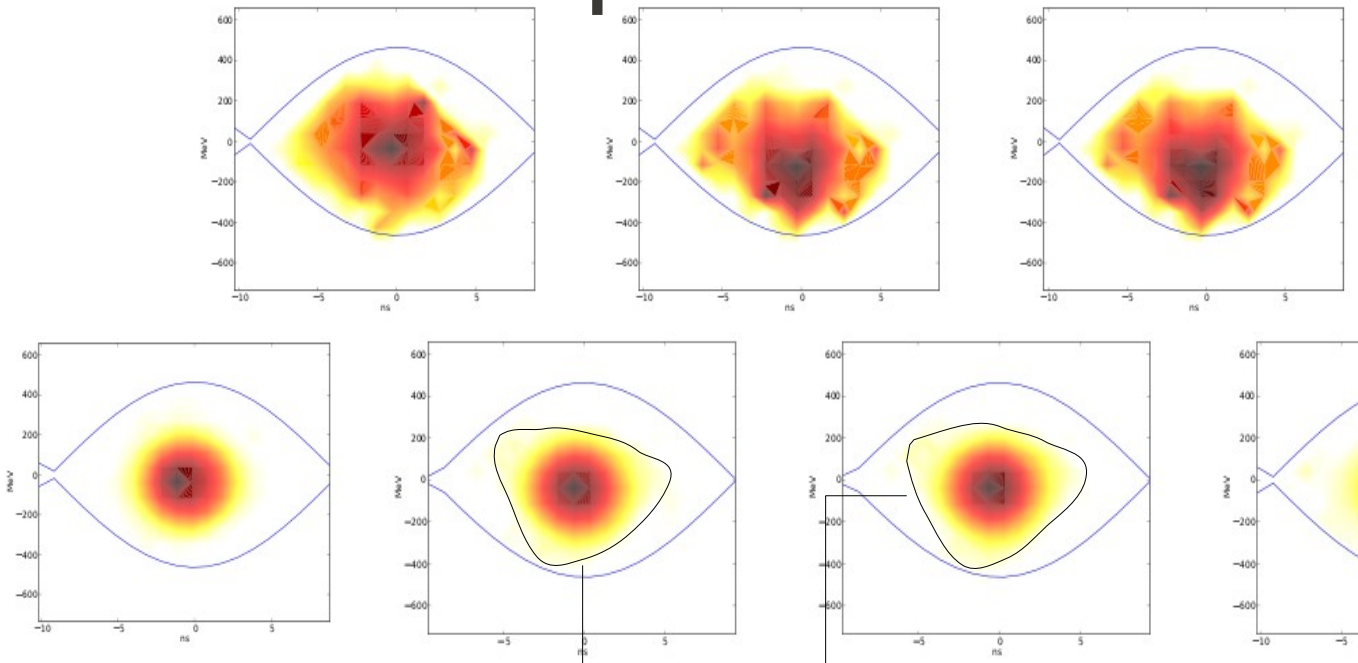
- Each time the bunch passes by the wall current sensor, we get a longitudinal density profile.
- The mountain-range plot (above left) is an accumulation of these profiles, and can be used to construct a phase space diagram.

The Data

- One train of 12 protons and 12 pbars
- First three stages during injection of pbars
- Four more stages at 980GeV
  - Just after ramp
  - Start of collisions
  - Start of HEP (data taking)
  - After 1hr 47min of collisions



Phase Space Reconstruction



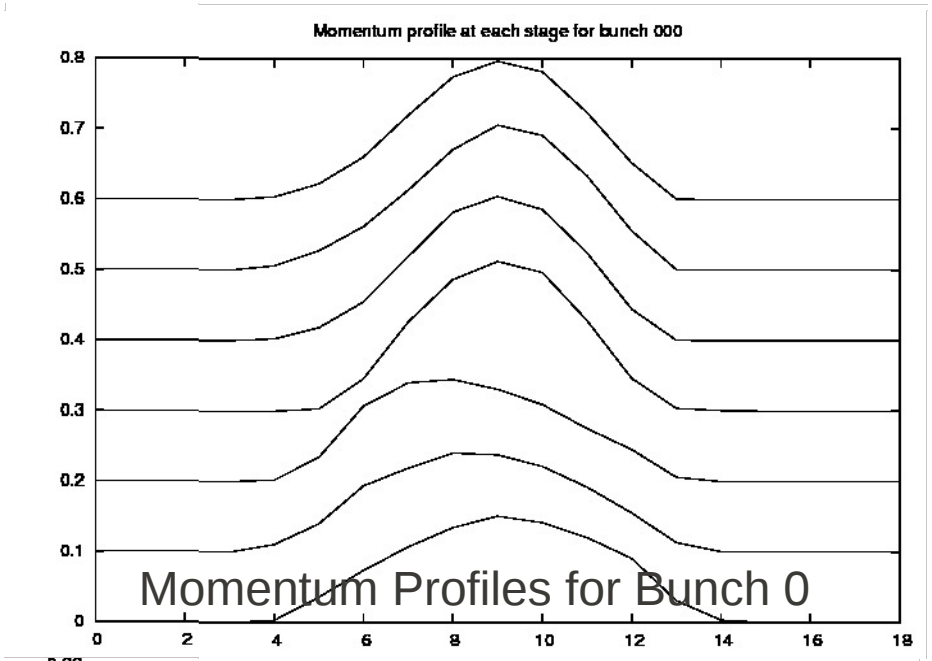
Phase Space Distribution for 12th proton bunch at each stage

- Slight triangular shape during initial collisions
- More concentrated at 980GeV as expected

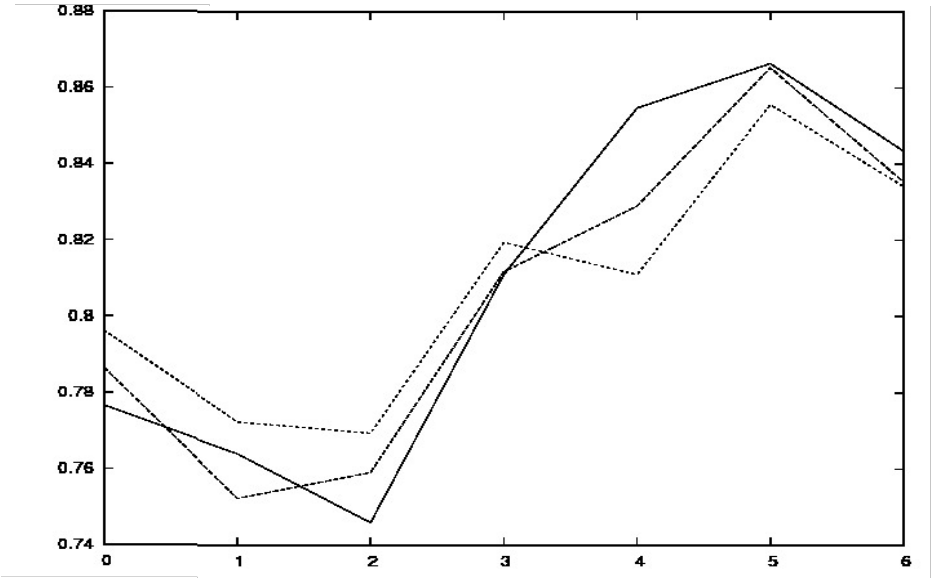
- Nothing unexpected (this is a good thing)
- Phase space does not differ greatly between bunches.

Momentum Profile

- Momentum profile constructed by projecting phase space onto vertical axis
- Profiles become less Gaussian as Pbars are injected and over time during collisions



Momentum Profiles for Bunch 0



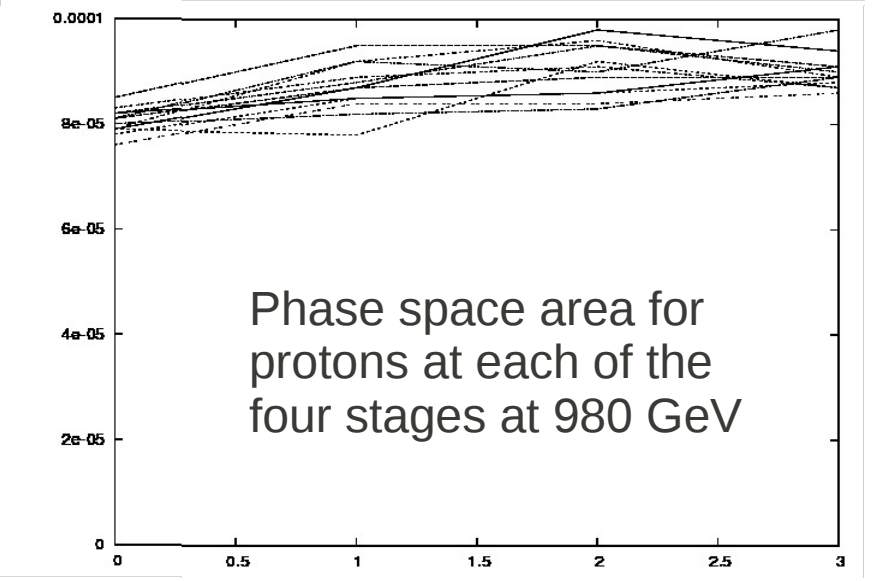
Gaussianity of Momentum Profiles at each stage

Phase Space Area at 980 Gev

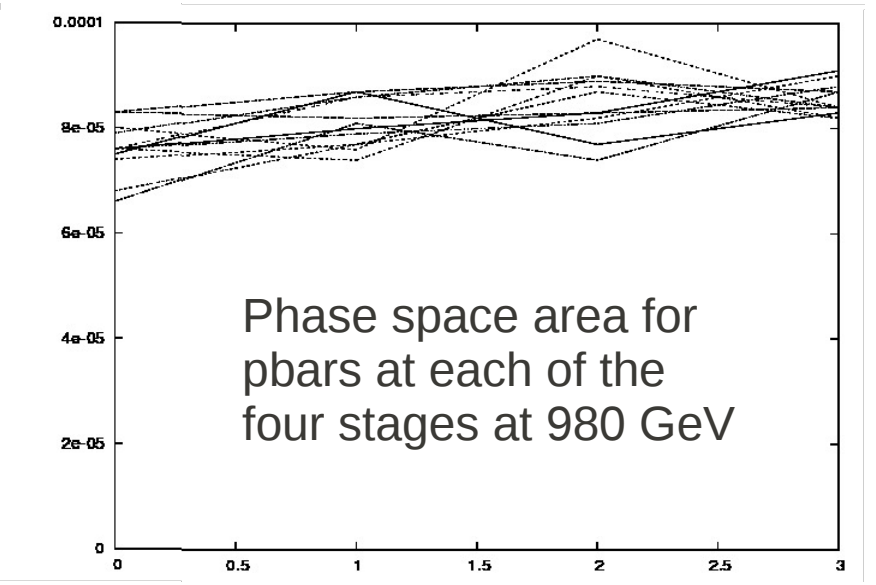
- Measure of area calculated by taking product of standard deviations along horizontal and vertical axes in phase space plot
- No significant increase in phase space area between stages (although slight increasing trend)

Average percent increase in area

Transition	Protons	Pbars
1	8.2	6.6
2	3.9	5
3	-0.6	0.5



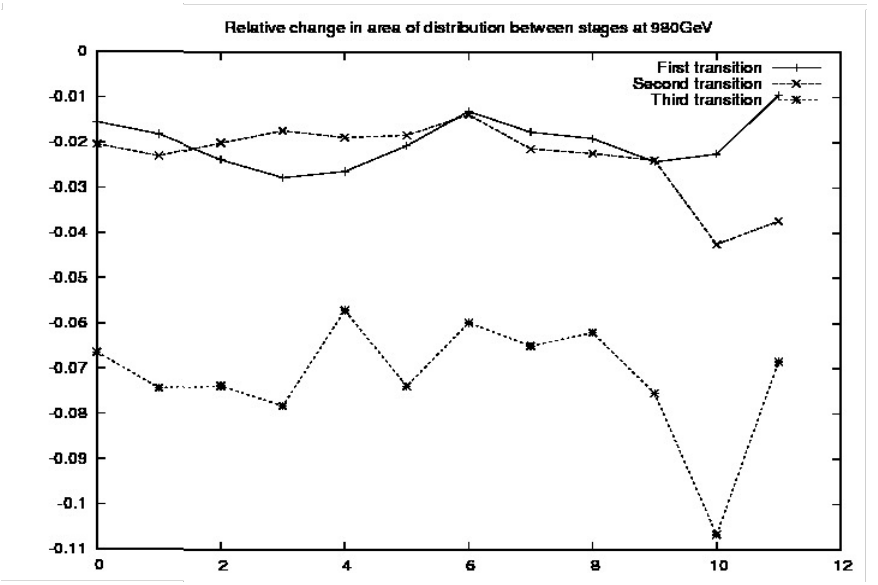
Phase space area for protons at each of the four stages at 980 GeV

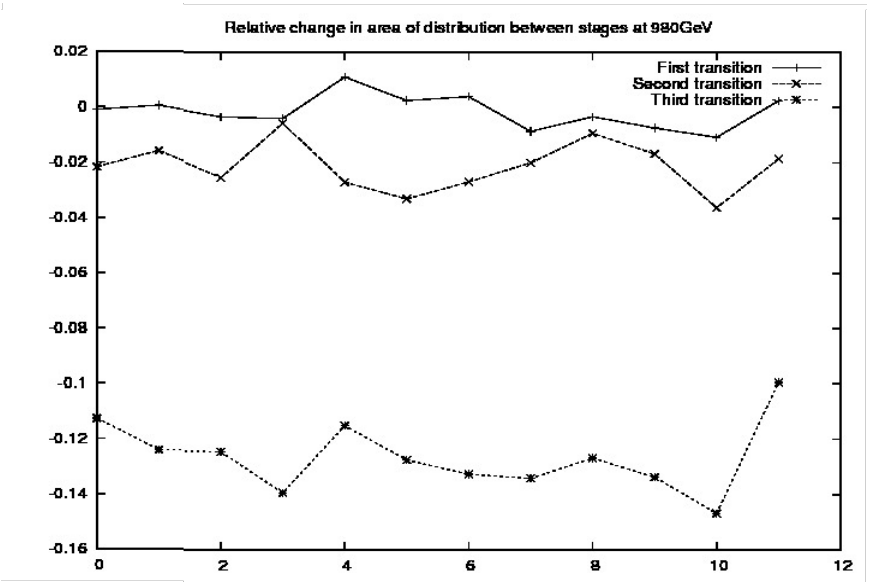


Phase space area for pbars at each of the four stages at 980 GeV

Particle Loss

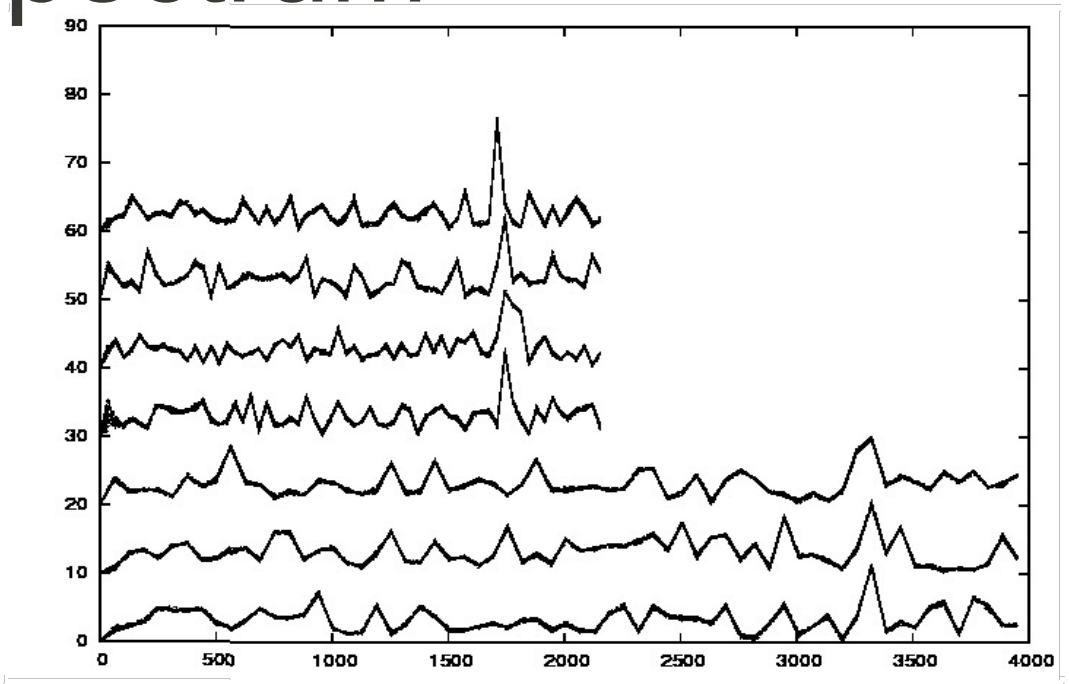
- Low (~1%) loss occurs between the initial stages at 980GeV
- Most proton bunches lose about 7% and most pbar bunches lose about 12% after 1hr 47min of collisions
- The 11th proton bunch seems most sensitive to particle loss, which is seen from the beginning

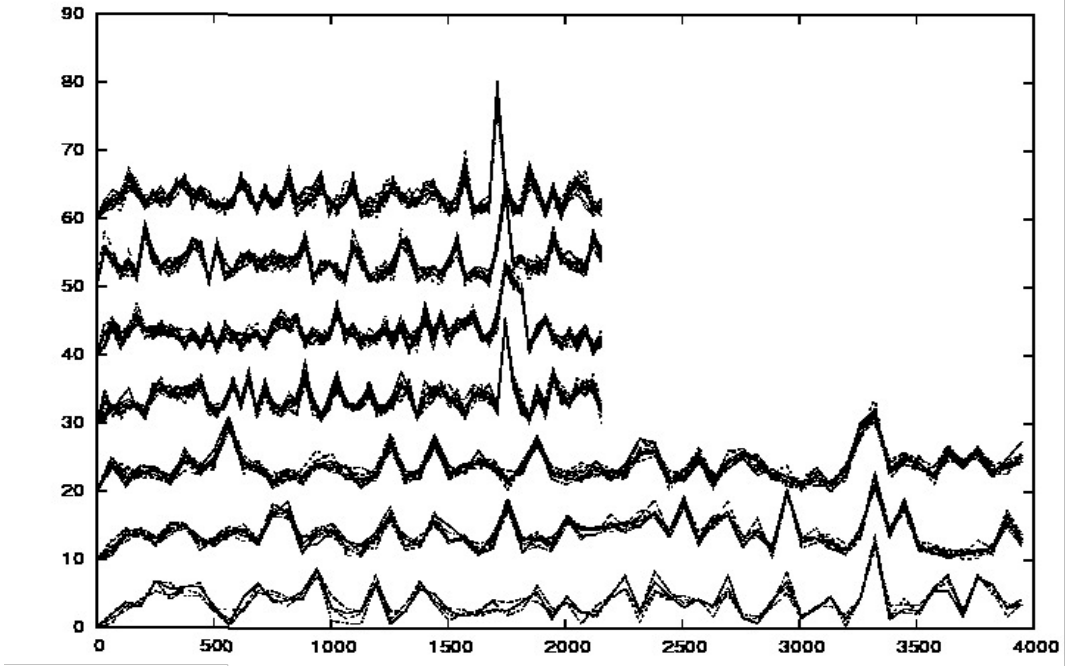




FFT Spectrum

- FFT of bunch mean
- Resolution is 60hz at 150 GeV and 33hz at 980 GeV
- Consistent among bunches (variation is greater among pbars)
- Strongest frequency
  - 3322hz at 150 GeV
  - 1744hz at 980 GeV
  - Peak broadens during initial collisions
  - Drops by 33hz (resolution size) after 1hr 47min of colliding





Conclusions

- The phase space plots do not reveal anything unusual, but it would be nice to have a better resolution. For example, there is a scope that can store 8000 turns, which would yield a resolution on the order of 1hz.
- Proton bunch momentum distributions become less Gaussian while pbars are inserted and over time during collisions.
- Phase Space Area does not significantly change during collisions.
- About 7% of protons are lost in 1hr 47mins of collisions compared to 12% pbars. A bunch may lose significantly more, which can be seen at the beginning of collisions.
- Bunch spectra have the largest peaks at 3322hz at 150GeV and 1744hz at 980GeV. The peak at this frequency widens during initial collisions and the frequency decreases over time. These probably have little impact on the beam, because they are much larger than the synchrotron frequency. (85hz at 150 GeV and 32hz at 980 GeV)
- Smaller peaks seem to appear at odd multiples of 60hz, but a better resolution is needed to confirm this.
- Performing a similar analysis on multiple stores would show whether these findings are consistent.

Thank you

- Tanaji Sen – Advisor
- Ron Moore – Provided Data
- Eric Prebys – Director of Lee Teng program

Questions?