

Diffusion in Hadron Storage Rings

S. Peggs, Snowmass, July 2001

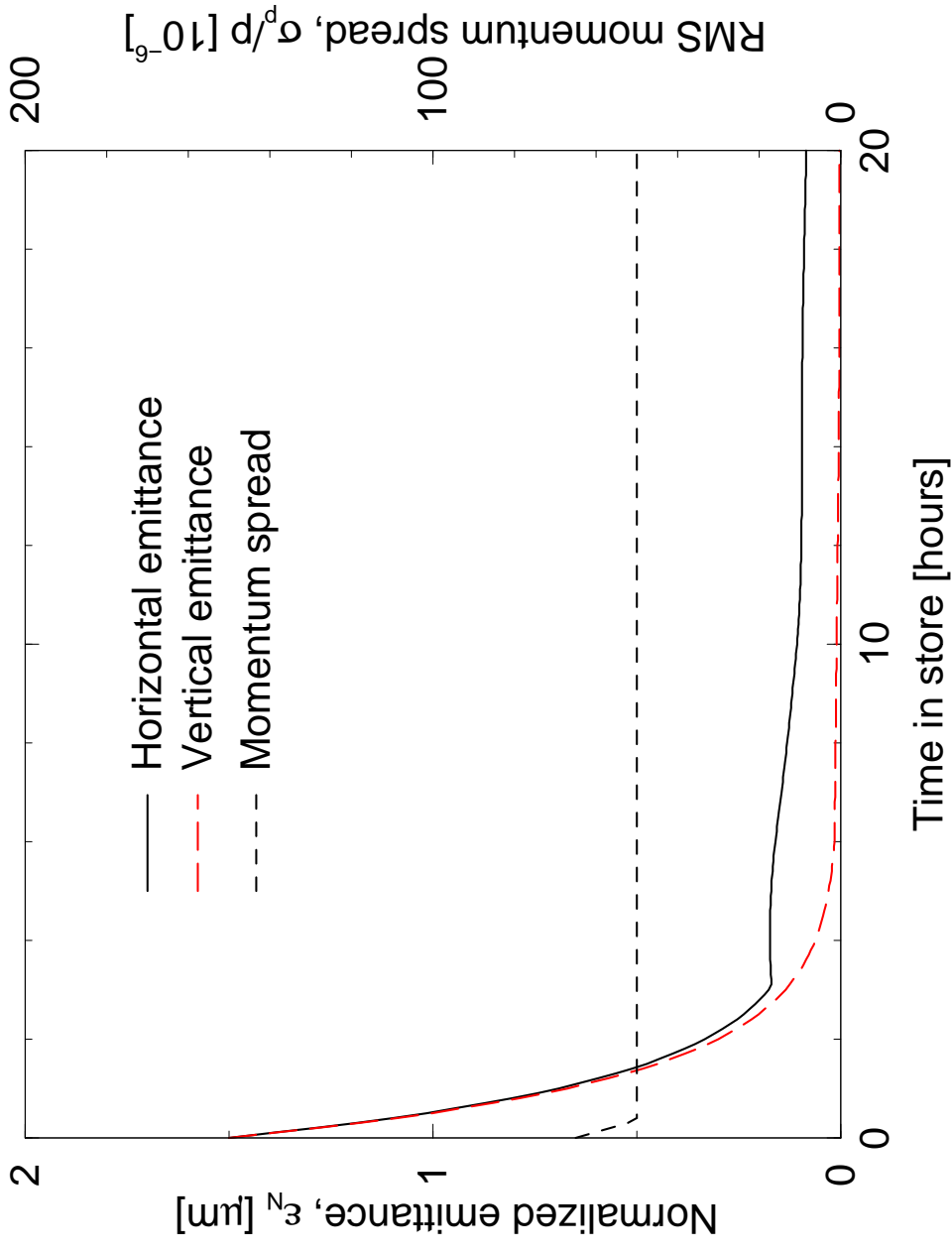
With particular reference to a High Field VLHC

- How little we know !
- Store evolution in a high field VLHC
- Tune modulation in 1.5 D
- Modulation diffusion
- Conclusions

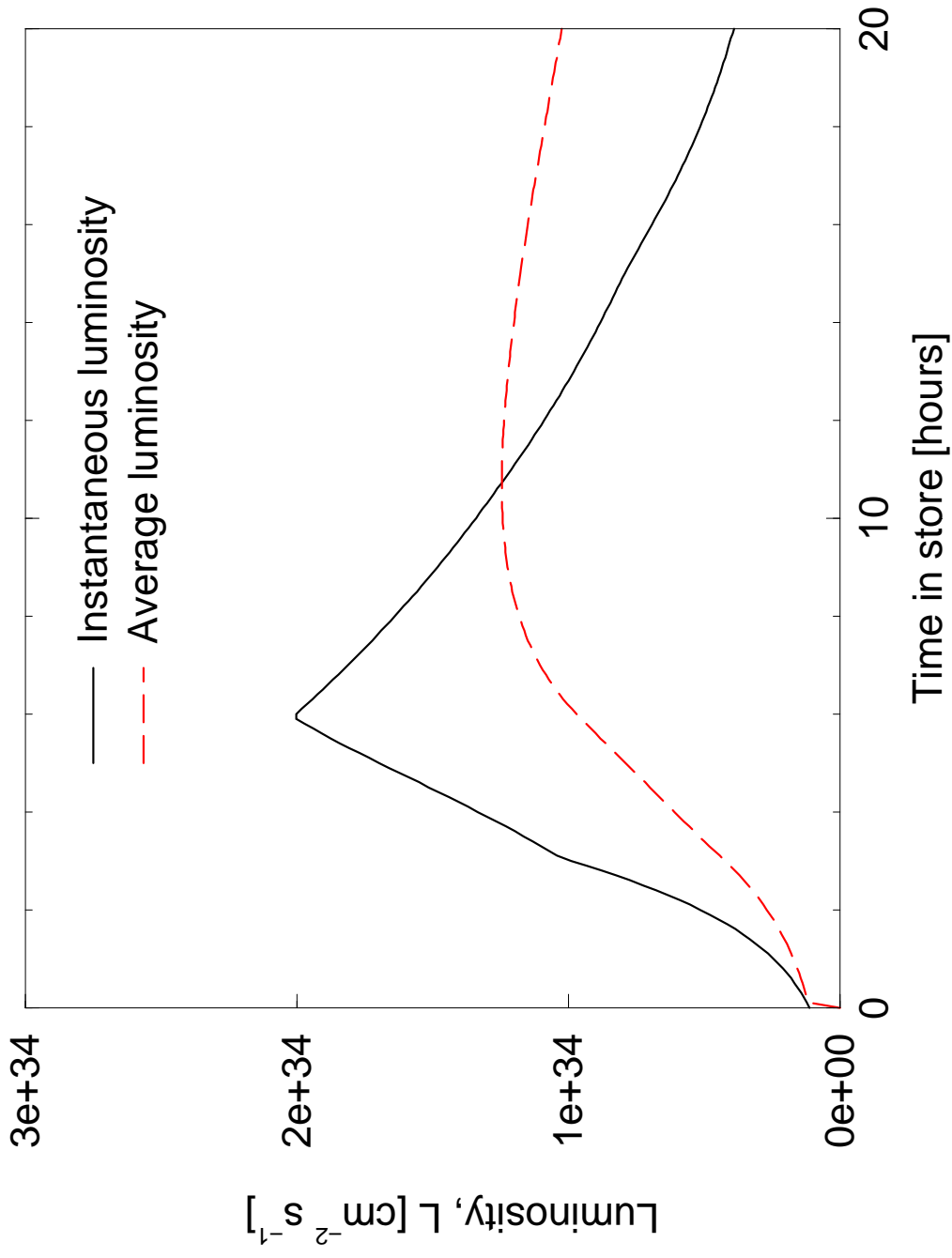
How little we know !

1. Measured and predicted dynamic apertures agree to a factor of 2, at best.
2. Diffusion experiments (eg profile evolution) are empirical, not predictive.
3. Exception: white noise in crystal extraction studies?
4. IBS controversies persist: very little world wide data ... yet
5. Modulational diffusion is neglected – as too difficult?

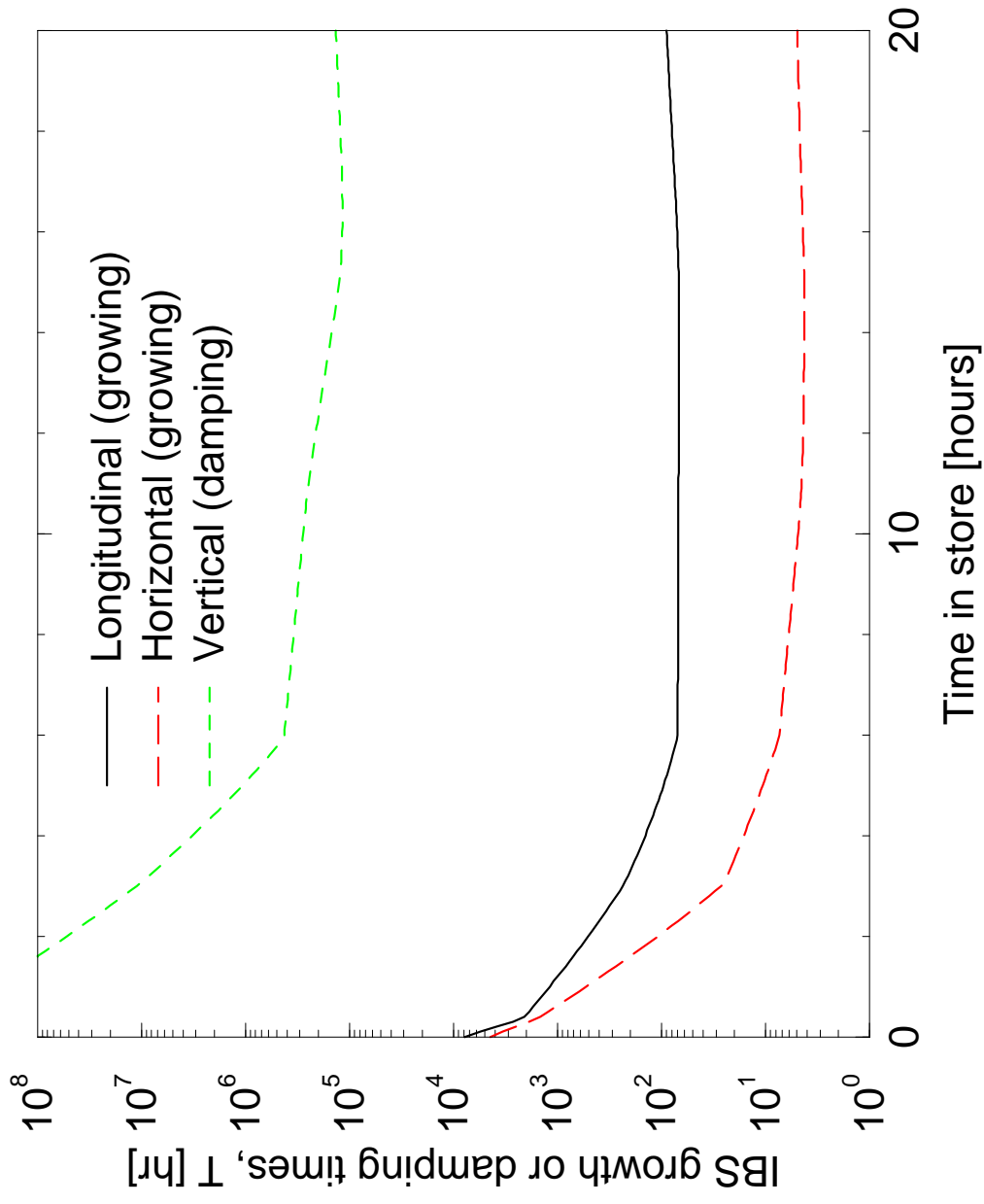
Store evolution in a high field VLHC



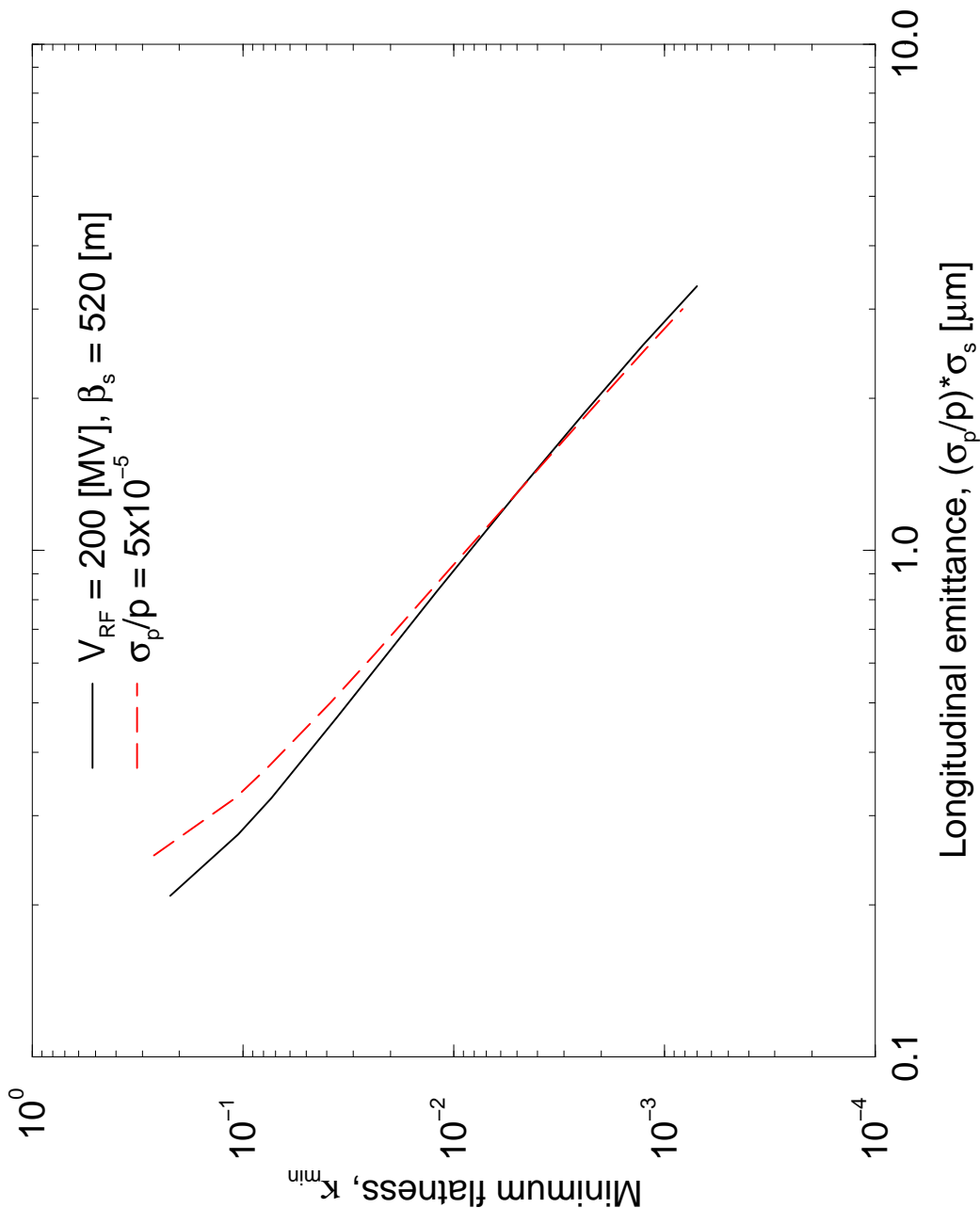
Emittance evolution during a store in the synchrotron radiation dominated VLHC ($B = 10 \text{ T}$).



Evolution of instantaneous and average luminosities.

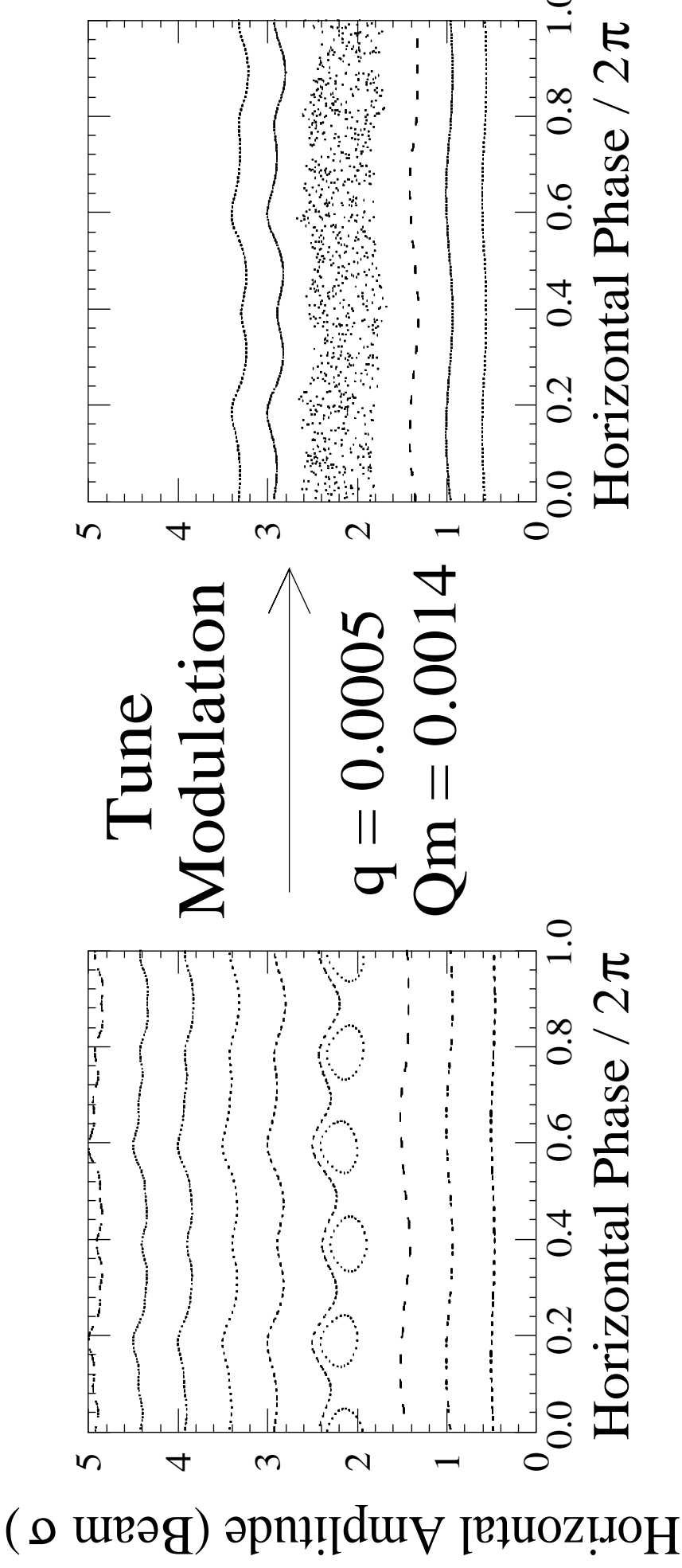


Intra Beam Scattering growth (or damping) times.

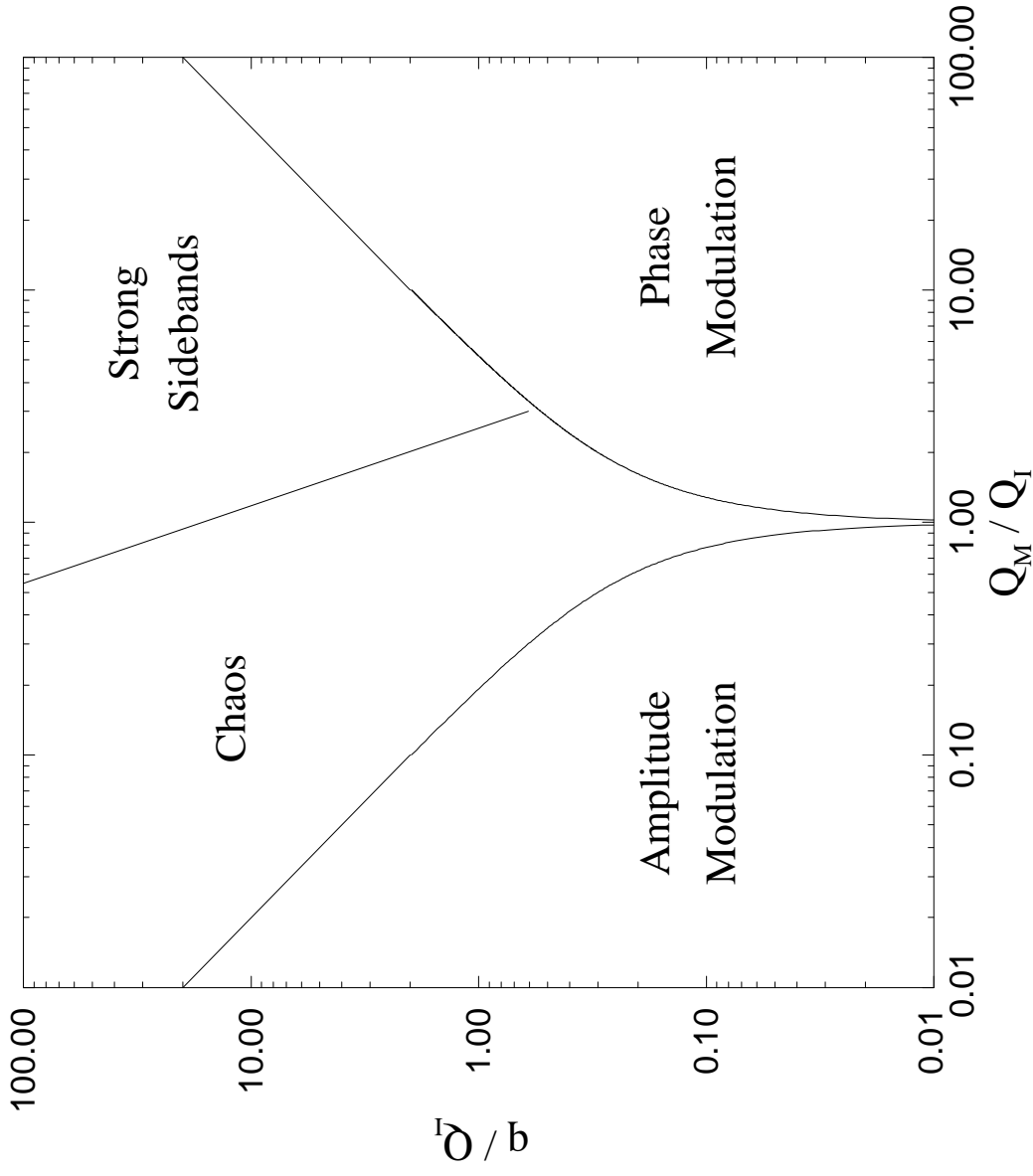


Minimum flatness κ_{min} vs. longit. emittance, $(\sigma_p/p) * \sigma_s$.

Tune modulation in 1.5 D

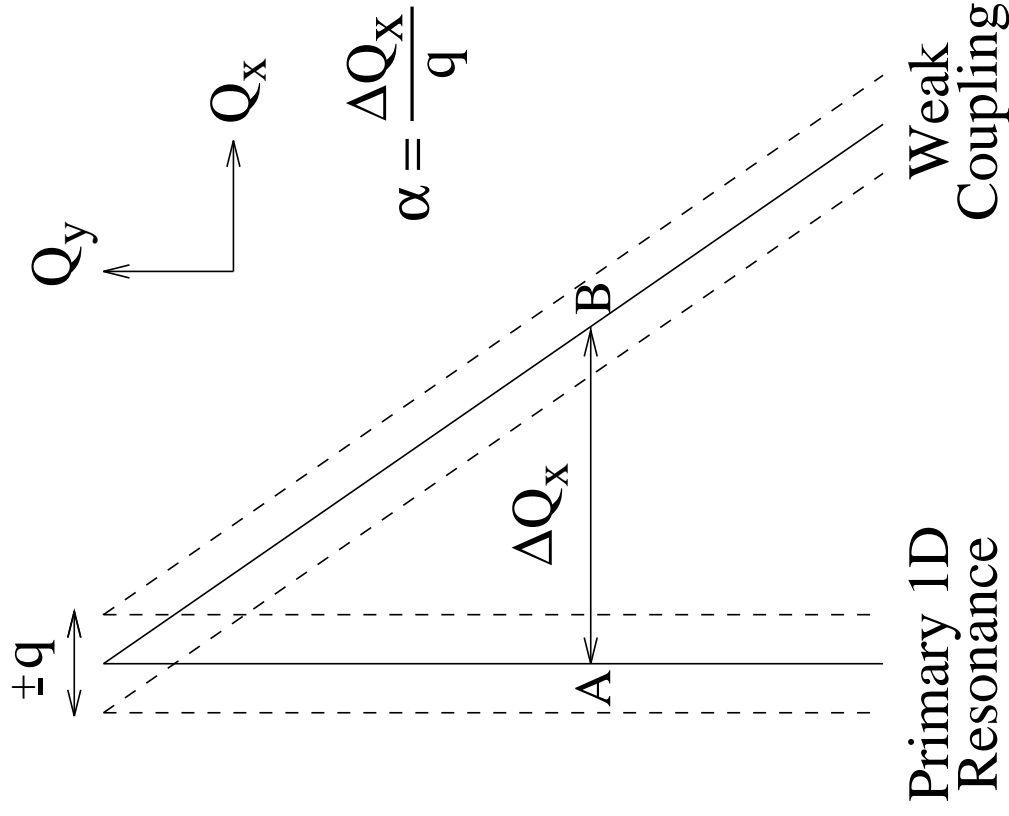


Chaos in 1.5 D through tune modulation, with a typical timescale of 10 to 100 modulation periods, $T_m = 1/Q_m \approx 1,000$ turns

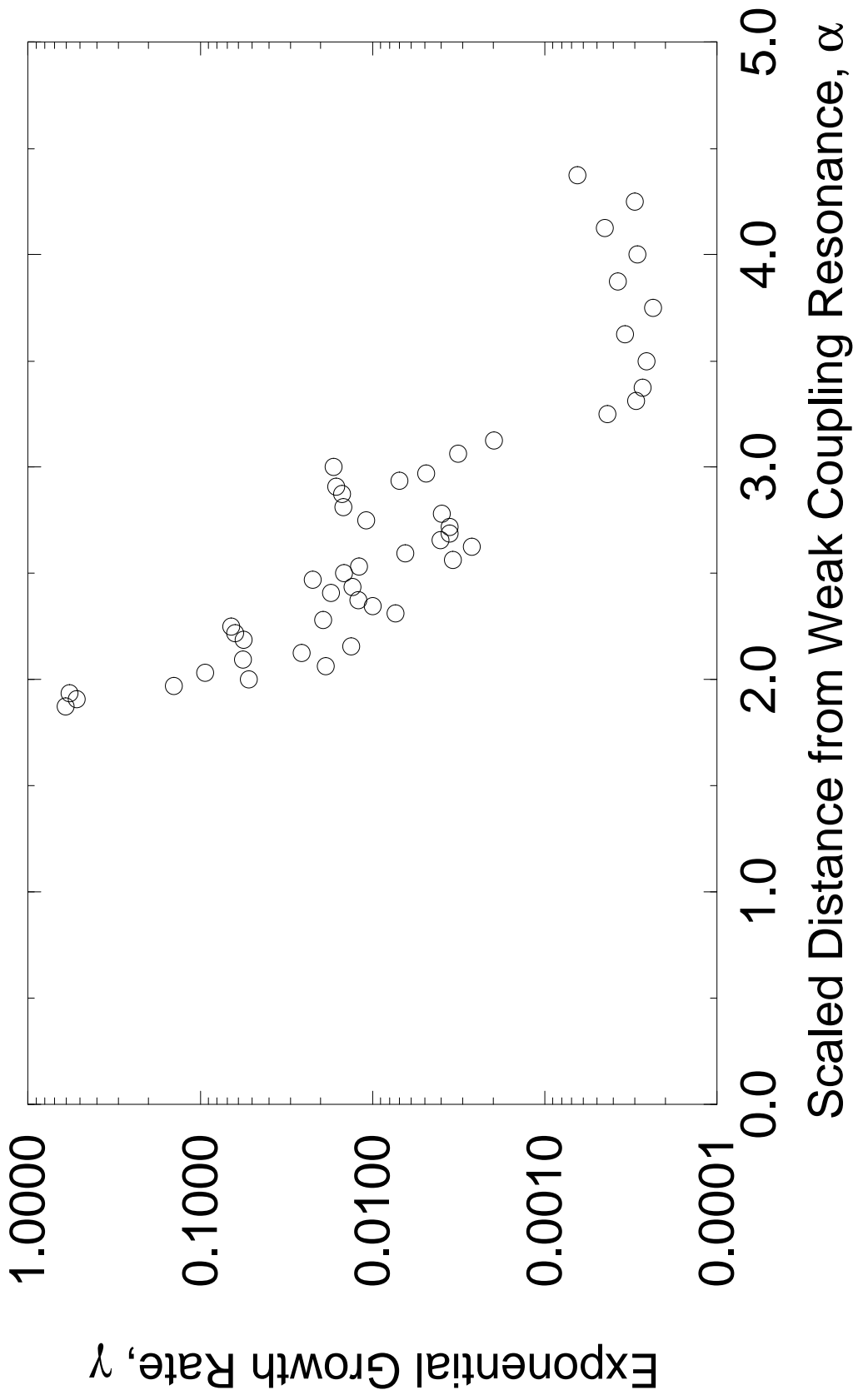


This is well understood in terms of synchrotron sideband overlap and adiabatic trapping. **What about more dimensions?**

Modulational Diffusion

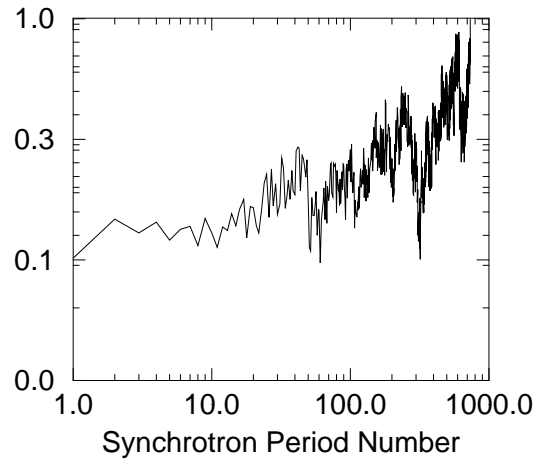
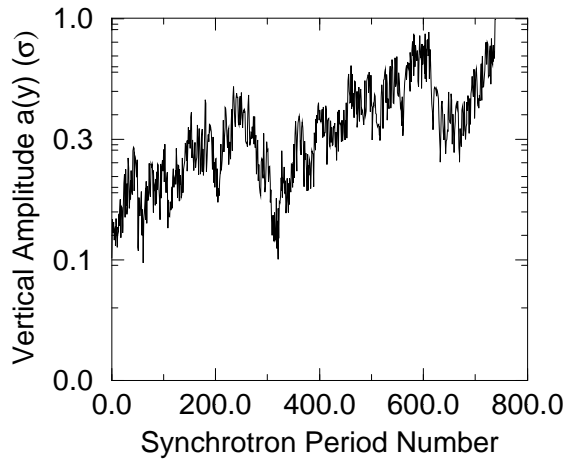


Chirikov, Lieberman, Shepelyanski, and Vivaldi developed a tortuous analysis, parameterized by α

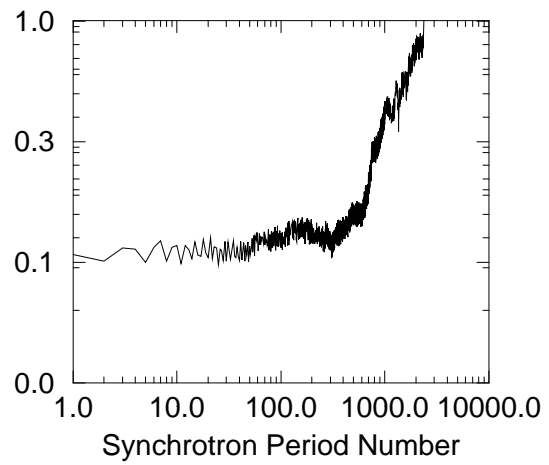
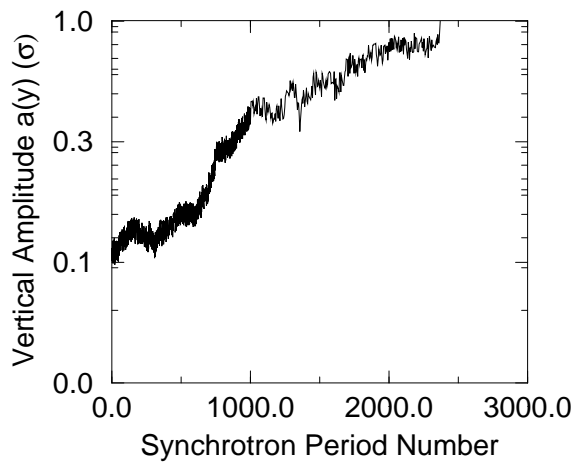


They predicted \sqrt{t} growth, with plateaux in α , over very long time scales. But (beam-beam) simulations show $e^{\gamma t/T^m}$ growth

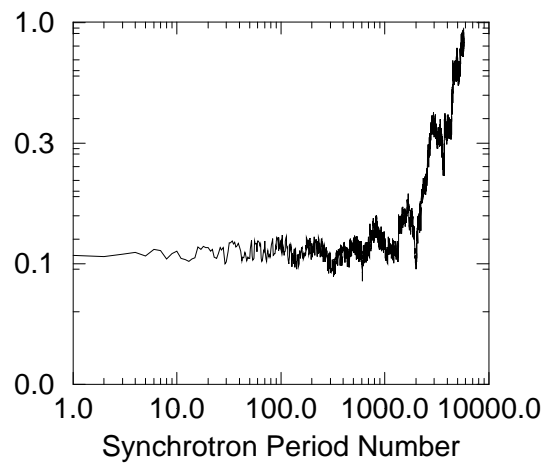
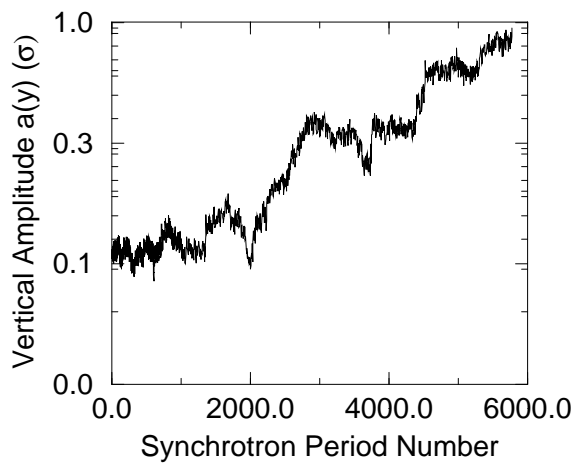
$Q(y_0) = 20.5905 \quad \alpha = 1.90$

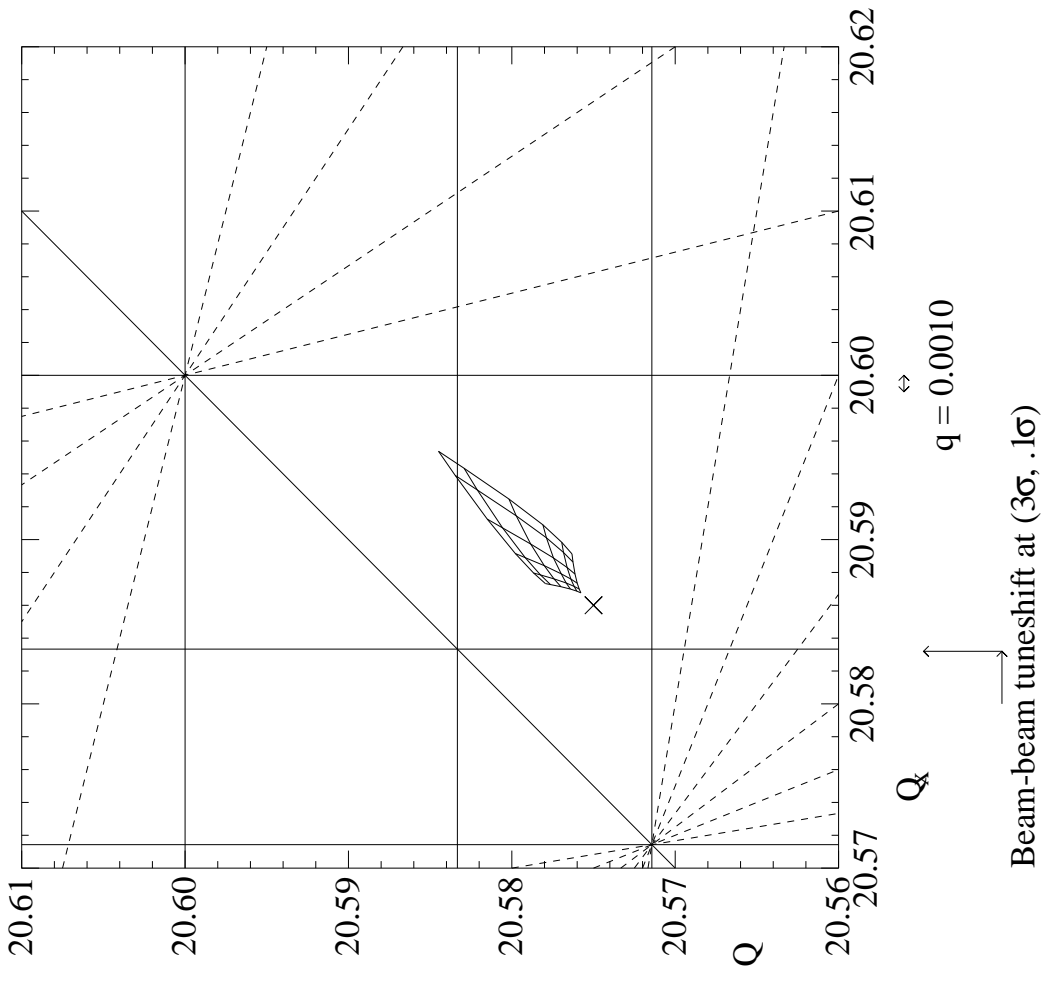


$Q(y_0) = 20.5857 \quad \alpha = 2.86$

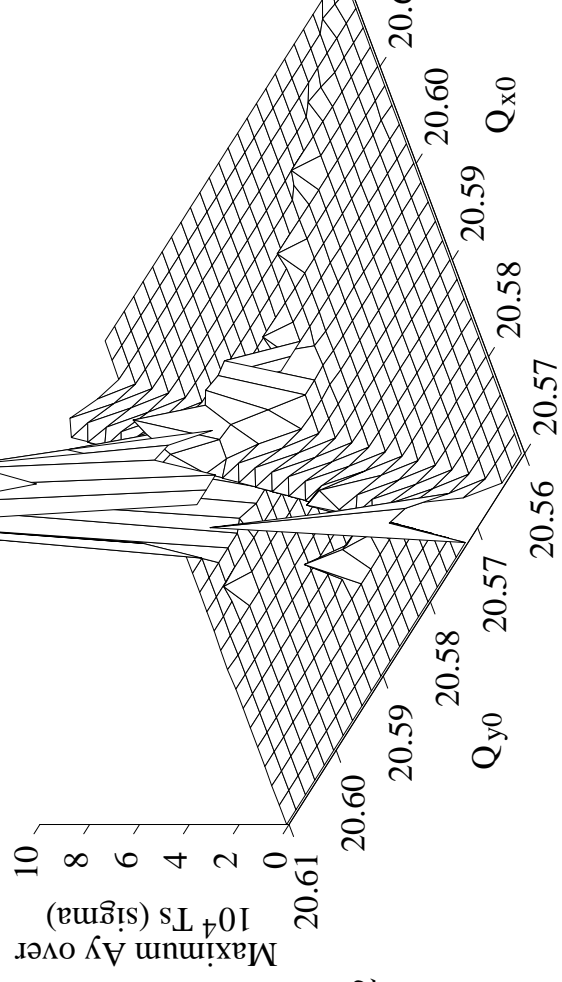
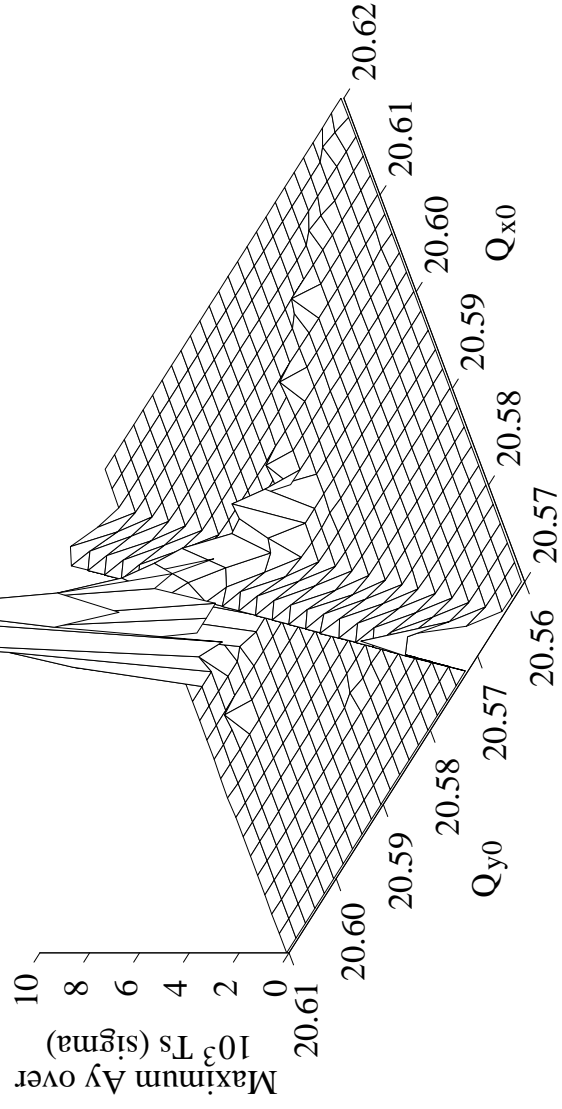
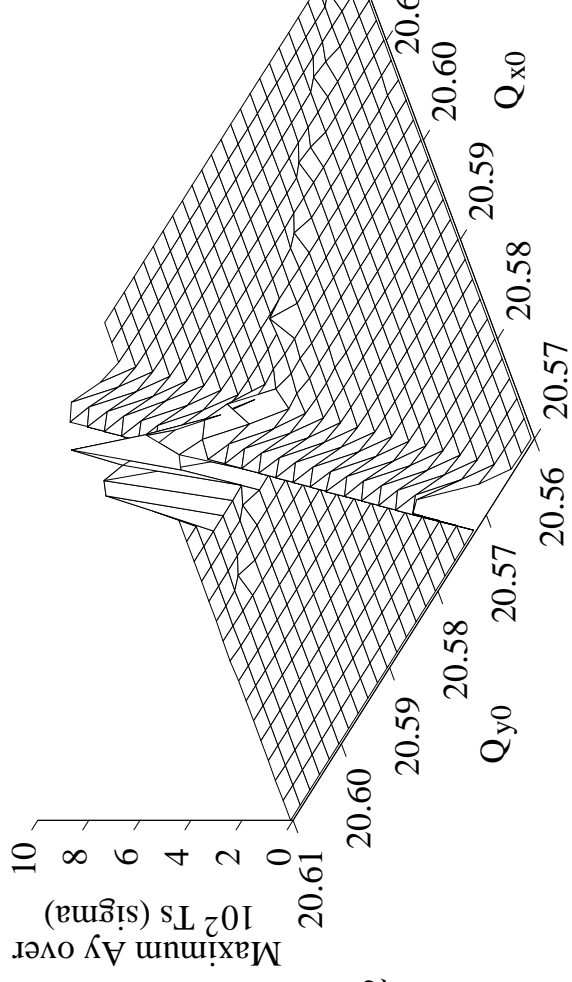
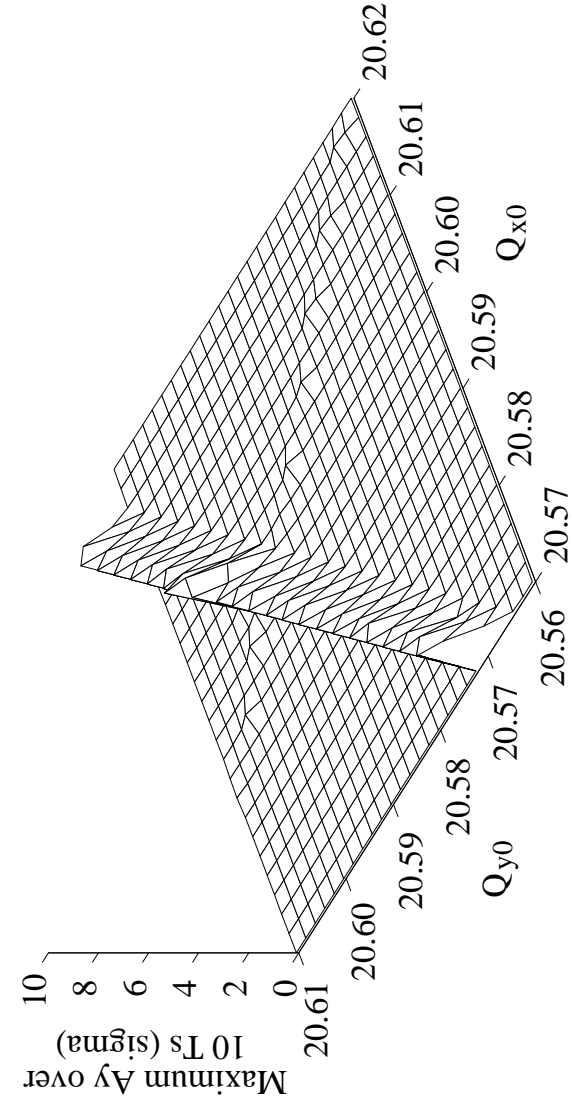


$Q(y_0) = 20.5839 \quad \alpha = 3.22$





Now move the operating point around the tune plane ...



Conclusions

1. New tools became available in the last decade:
 - (a) non-destructive profile monitors
 - (b) crystal angular profile monitors
 - (c) better software and hardware
2. Eagerly await copious IBS data from RHIC.
3. Who picks up the Modulation Diffusion gauntlet?
4. High Field VLHC motivates theoretical work and beam experiments.
5. Can diffusion experiments/studies become predictive?