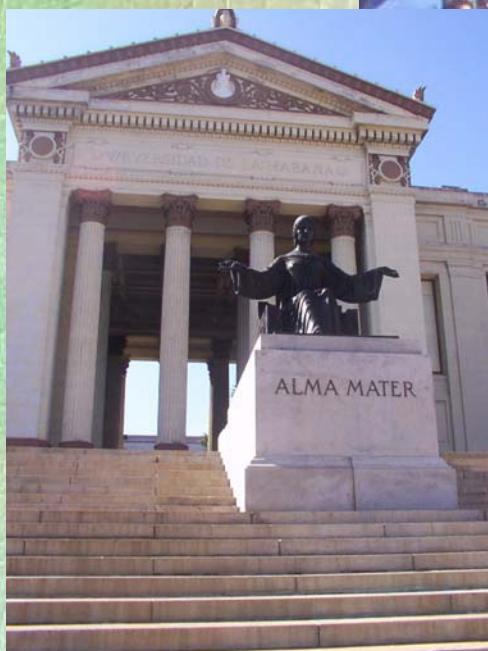
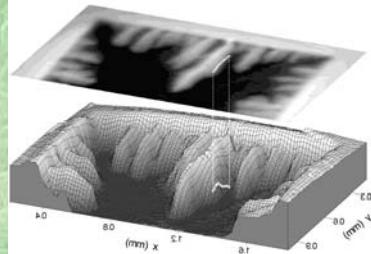


Experiments in superconducting vortex avalanches

Ernesto Altshuler
University of Havana
Texas Center for
Superconductivity



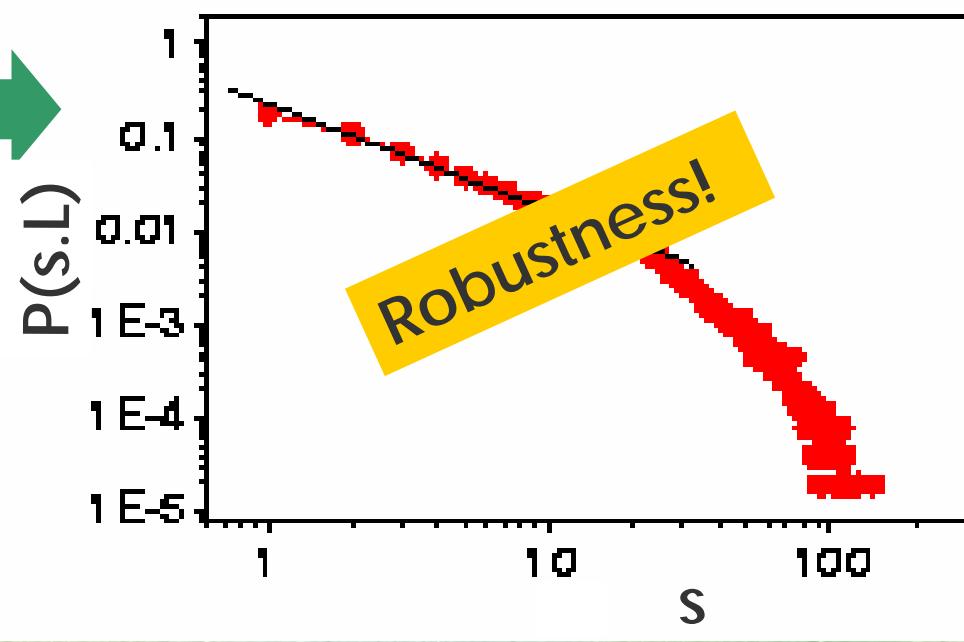
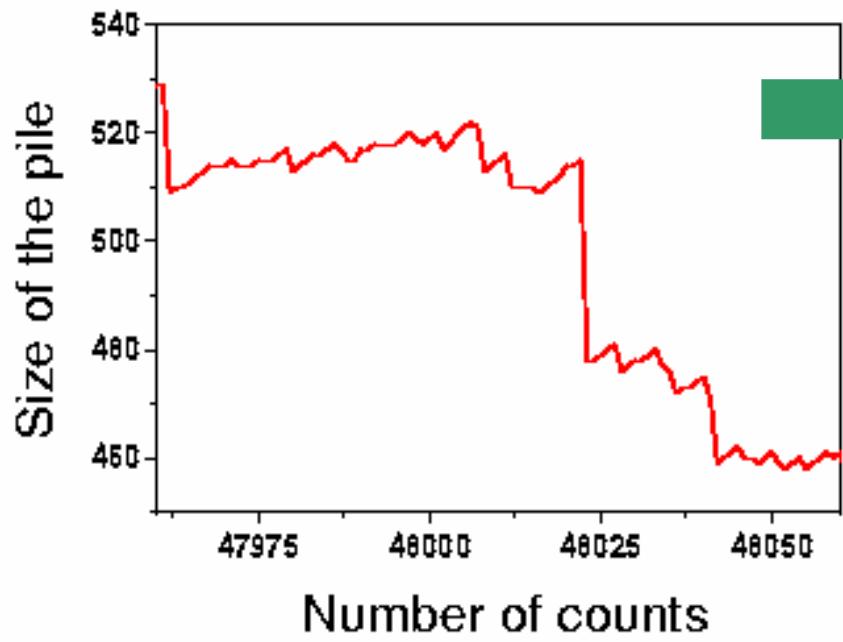


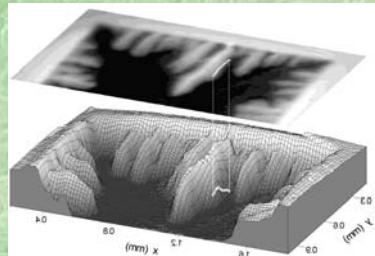
Avalanches in a sandpile: a paradigm for SOC?

47970

This was a real
experiment!

(Ramos & Altshuler, 2003)





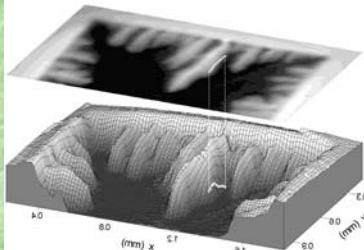
Goals

To improve the relatively poor statistics
in avalanche size distributions
previously reported

To determine how much
vortex avalanches depend
on the flux penetration
“landscape” where they take place

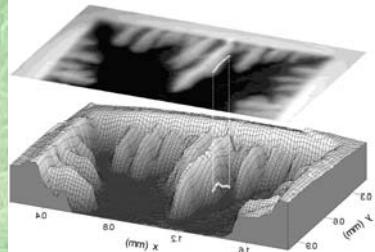
To determine avalanche correlations
along x , y and z

Are vortex avalanches an SOC phenomenon?



Previous reports (those including avalanche statistics)

Reference	Geometry	Material	Sensor	Avalanche type	Avalanche distribution
Heiden & Rochlin PRL (1968)	Hollow cylinder	Pb-In	Coil	Off the edge	Exponential
Field et al PRL (1995)	Hollow cylinder	Nb-Ti	Coil	Off the edge	Power law (slow ramps)
Zieve et al PRB (1996)	Planar	YBCO crystal	1 Hall probe	Internal	Peaked
Nowak et al PRB (1997)	Ring	Nb film	2 Hall probes	Off the edge & internal	Peaked or Power law (dep. on T)
Aegerter PRE (1998)	Planar	BSCCO crystal	SQUID	Off the edge	Exp or Power law (dep. on T & t)
Behnia et al PRB (2000)	Planar	Nb film	Hall probe arrang.	Internal	Peaked or Power Law (dep. on H & T)



A couple of previous reports

Field et al, 1995

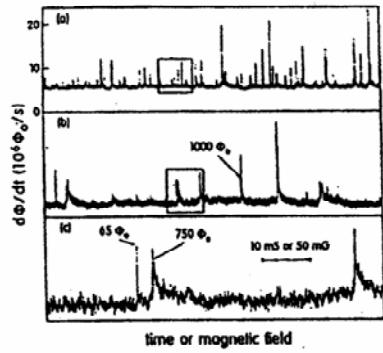
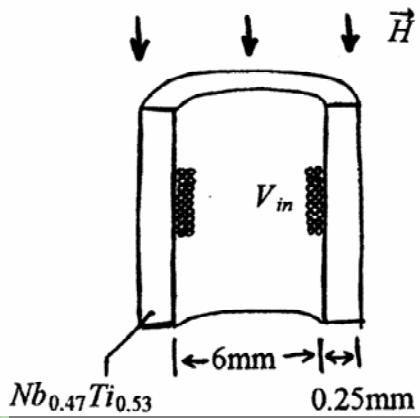
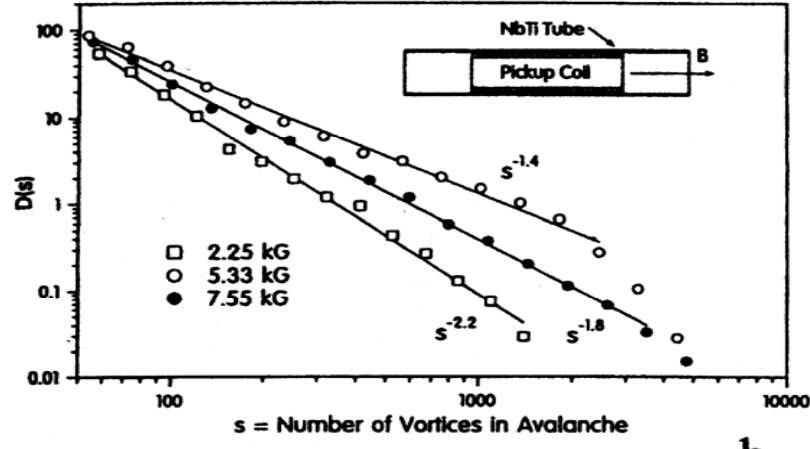
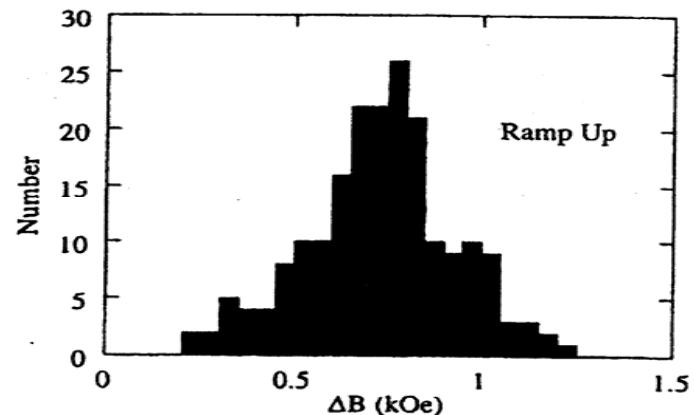
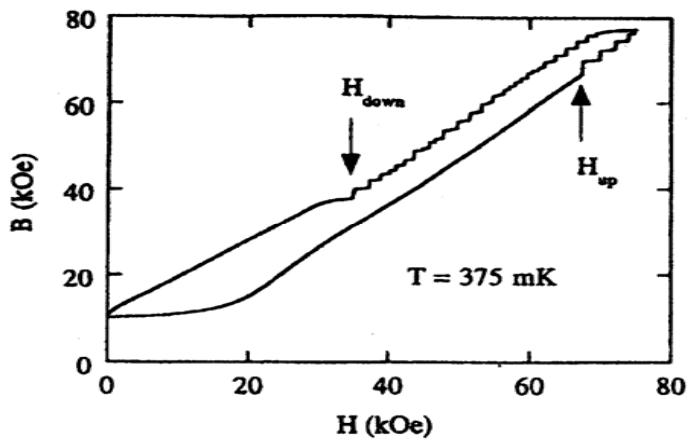
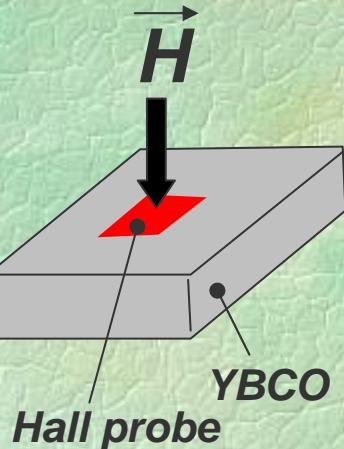
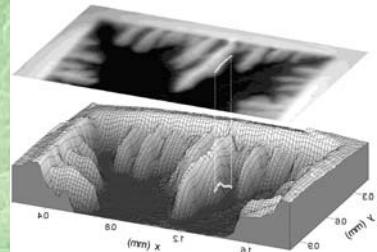


FIG. 1. The voltage measured on the pickup coil as the magnetic field is ramped at 5 G/s. Frame (a) shows a 30 G segment centered at $B = 7.55$ kG. There are 262 144 data points in this segment. The voltage trace consists of a series of many pulses of widely varying sizes. Each pulse represents

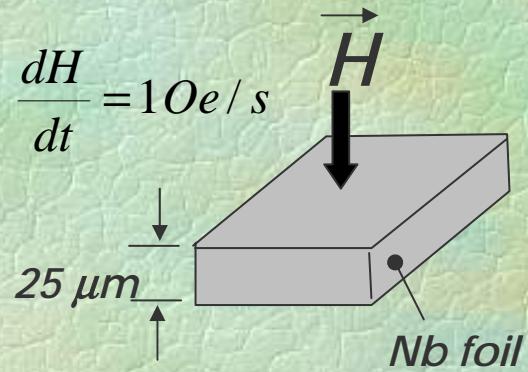


b



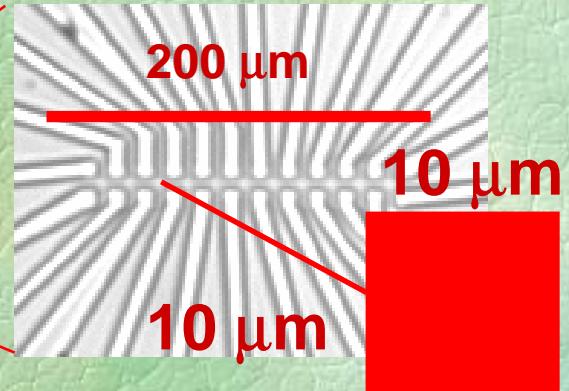
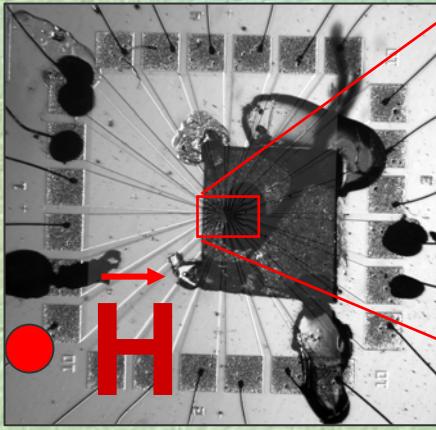
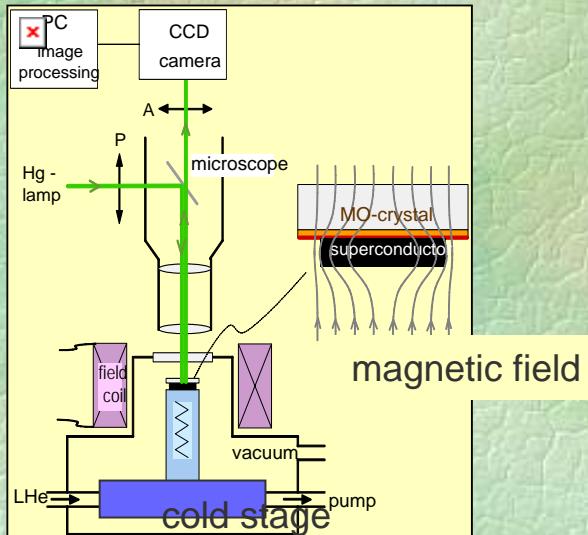


Experimental

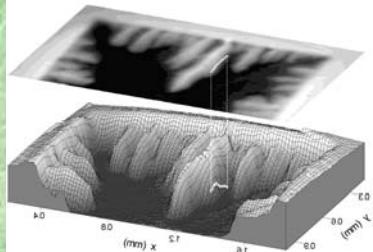


Flux penetration
“topography”:
MO imaging

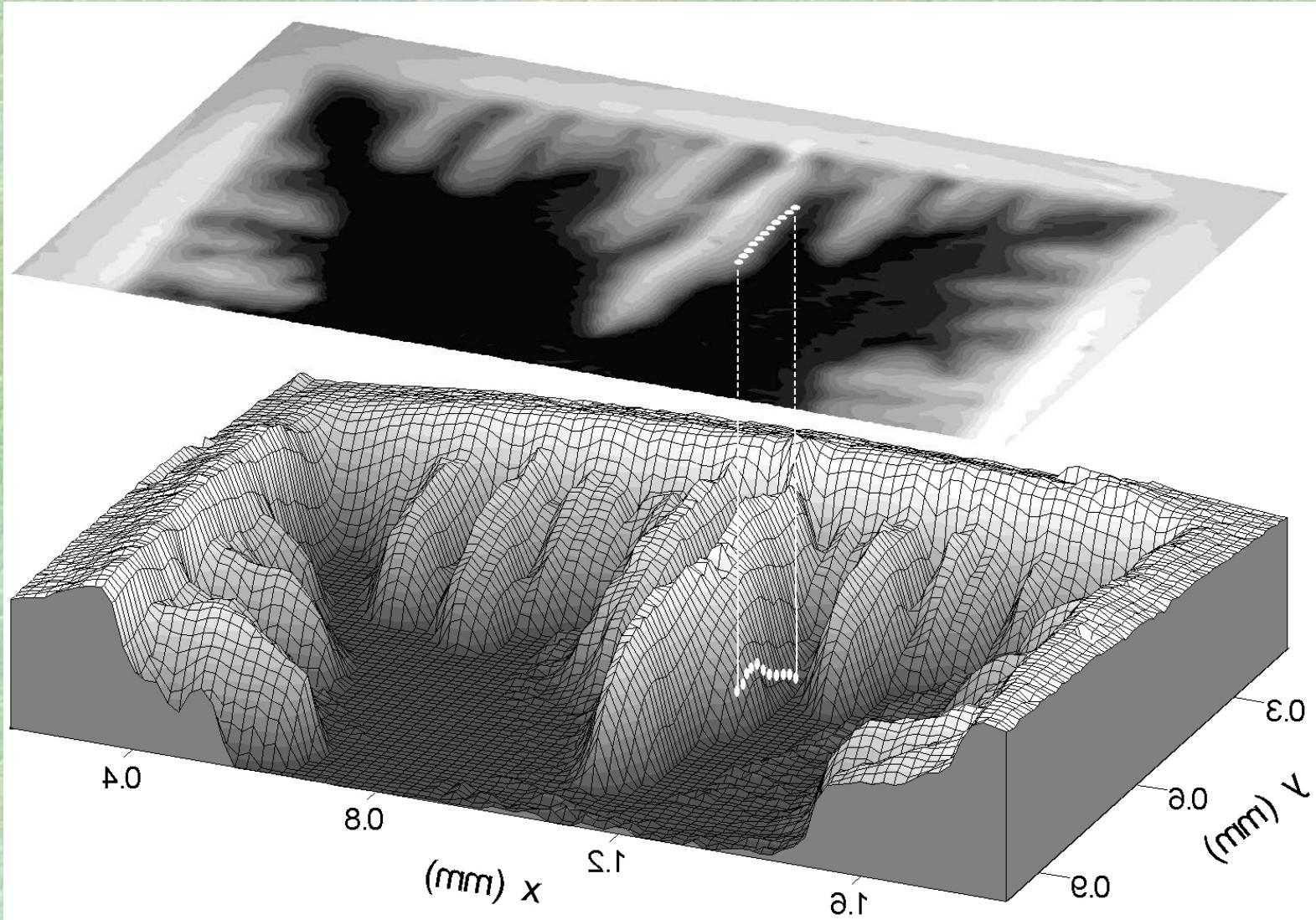
Local avalanche
measurements:
micro Hall probe arrays



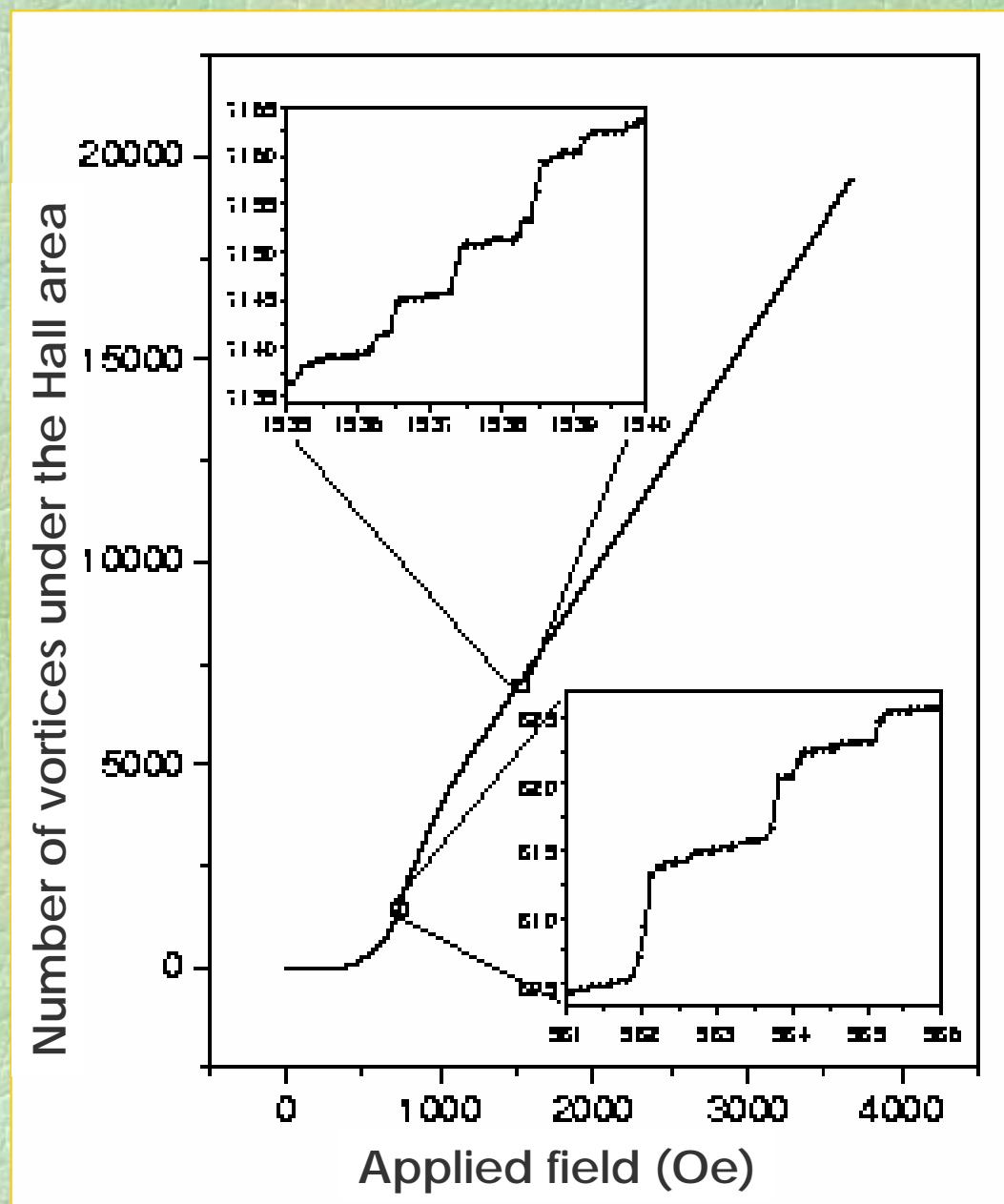
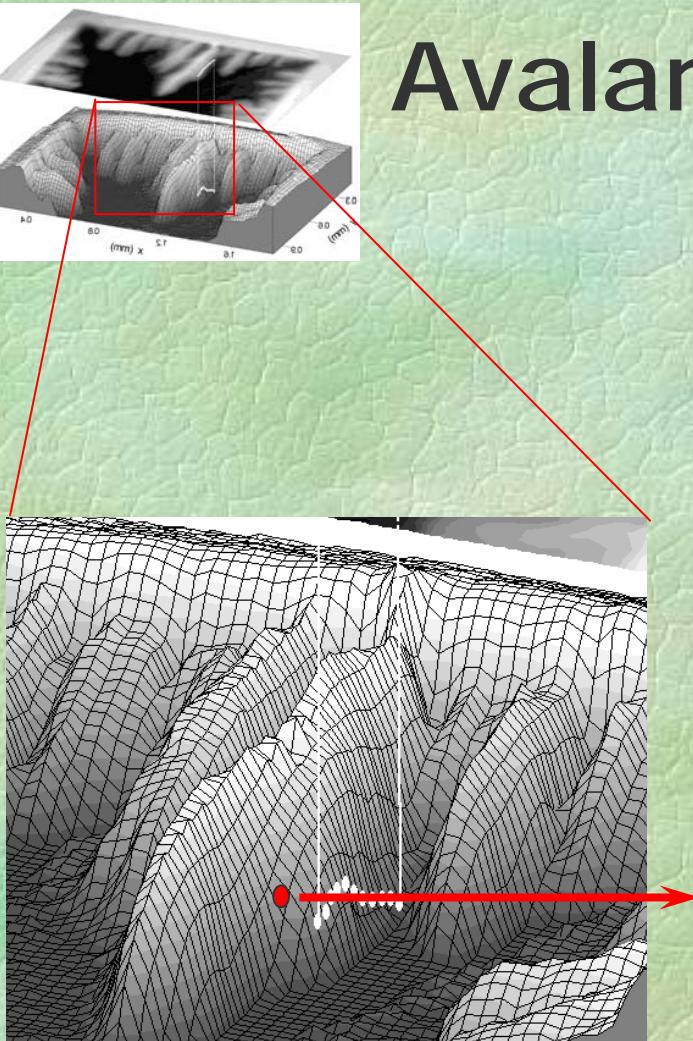
Resolution
 $\Delta H \sim 0.2 \text{ Oe} \Rightarrow \Delta \phi \sim \phi_0$

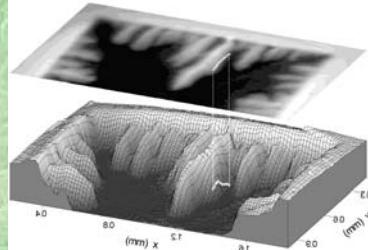


Experimental: hiking in vortex piles



Avalanches from a single probe

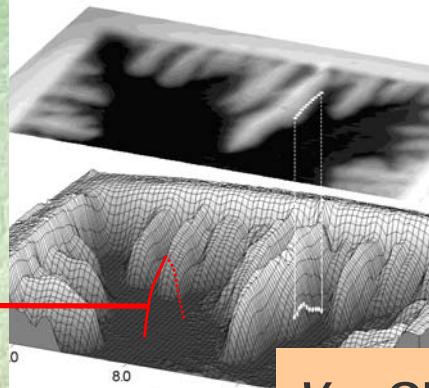
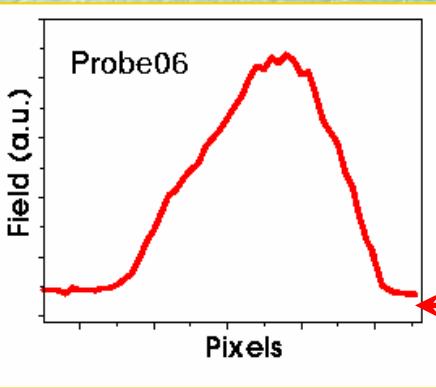




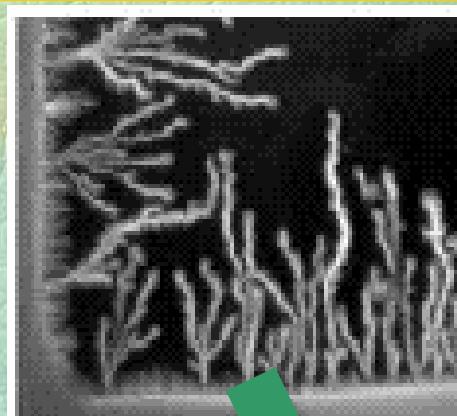
Fingers vs. dendrites ⇒ avalanches vs. flux jumps?

Repeatable fingers

non-repeatable dendrites

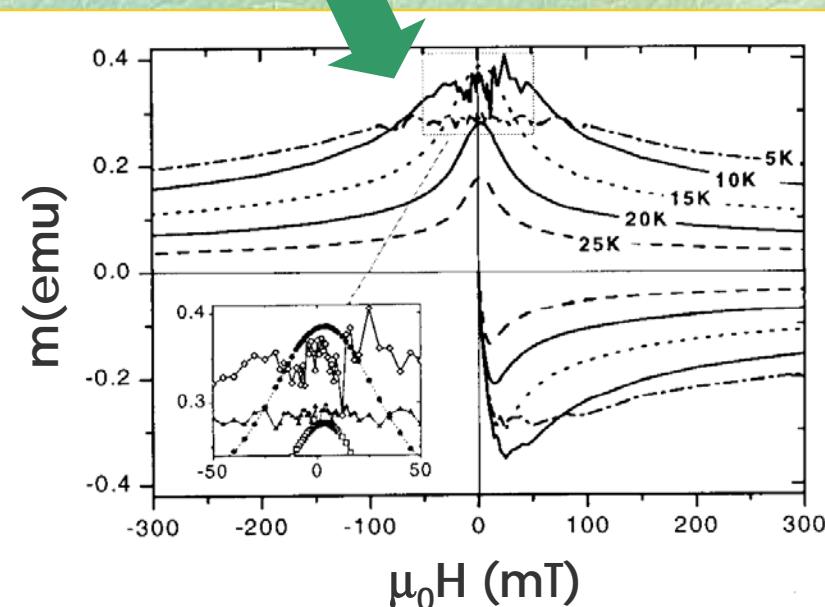
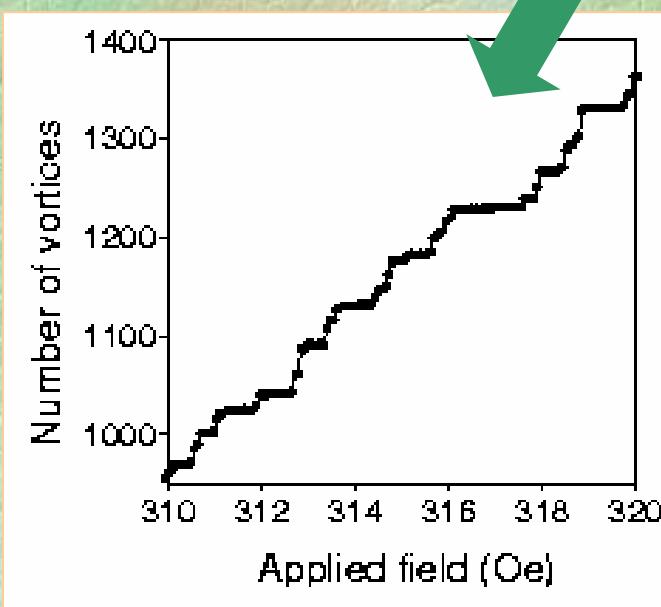


$$v \sim \text{cm/s}$$

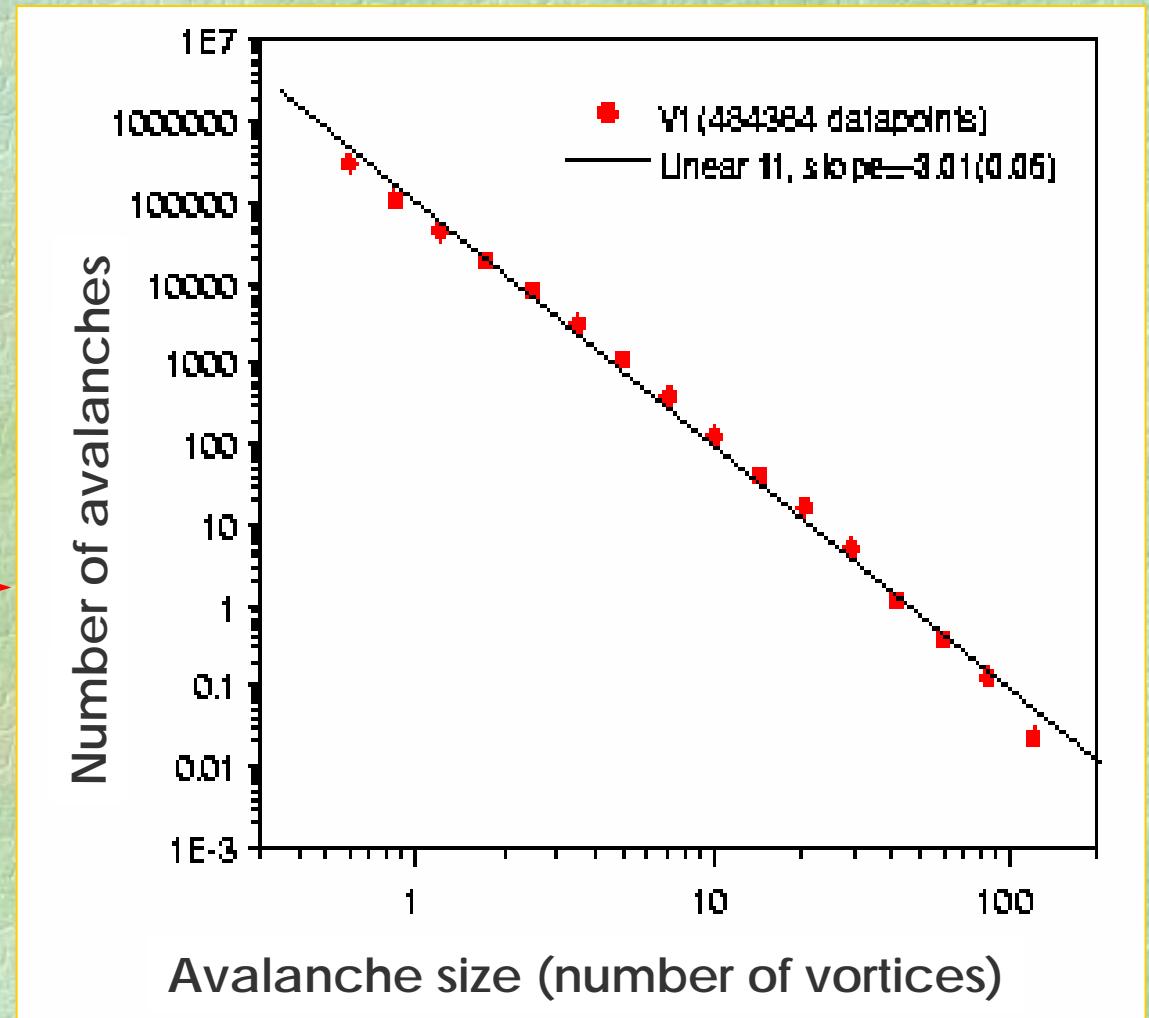
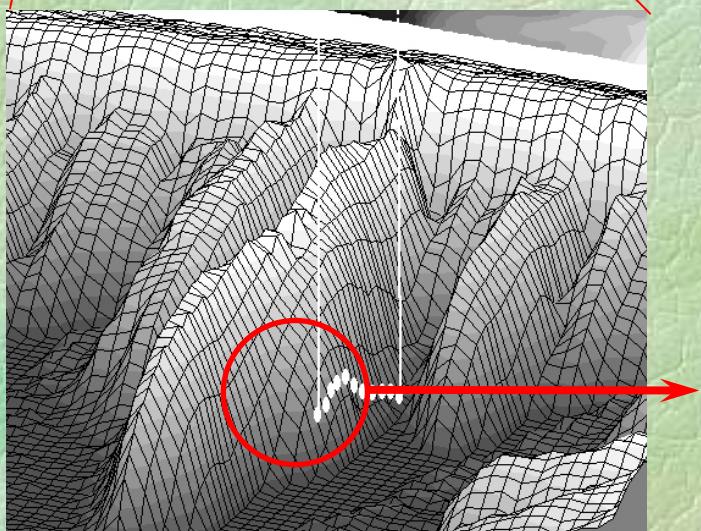
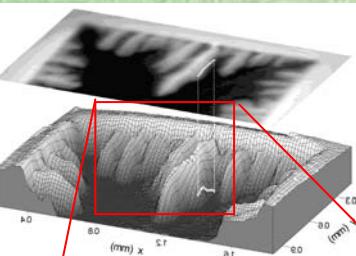


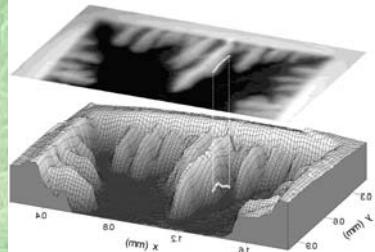
$$v \sim \text{km/s}$$

Johansen et al. Europhys. Lett. (2002)

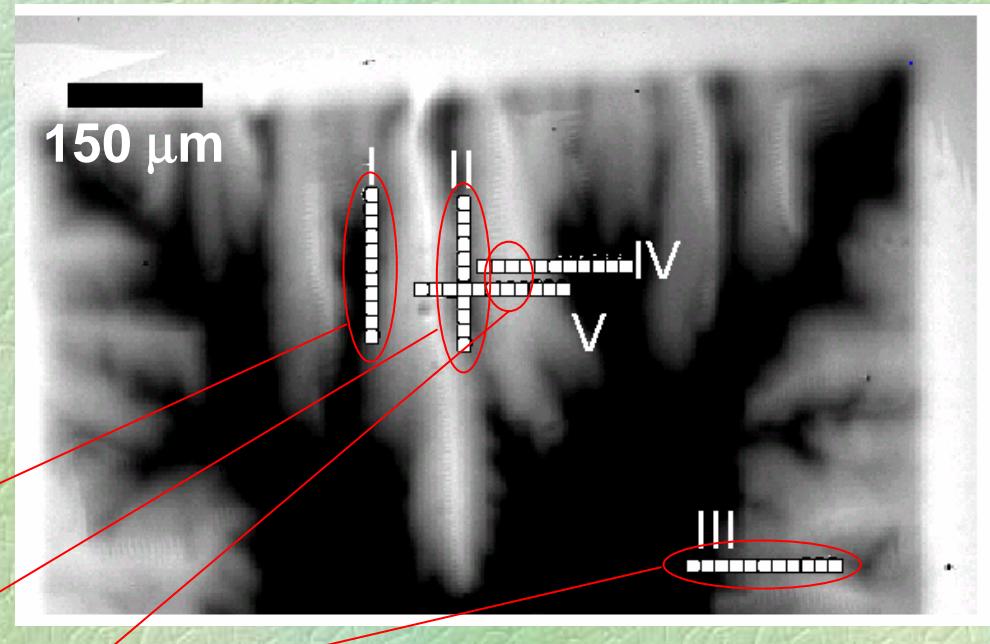


Avalanche statistics from a set of probes

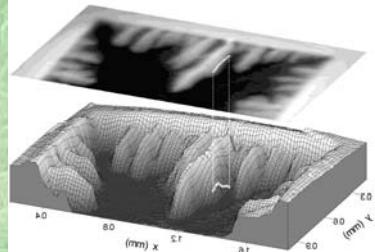




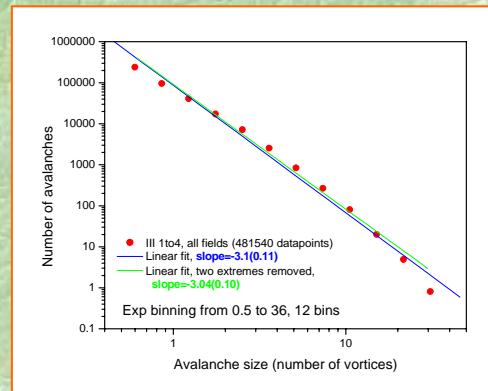
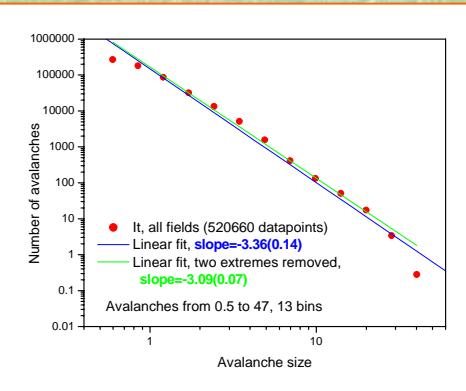
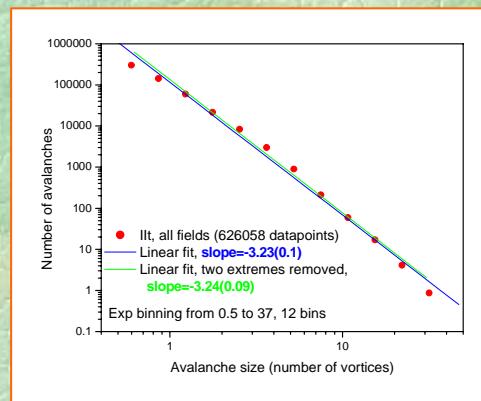
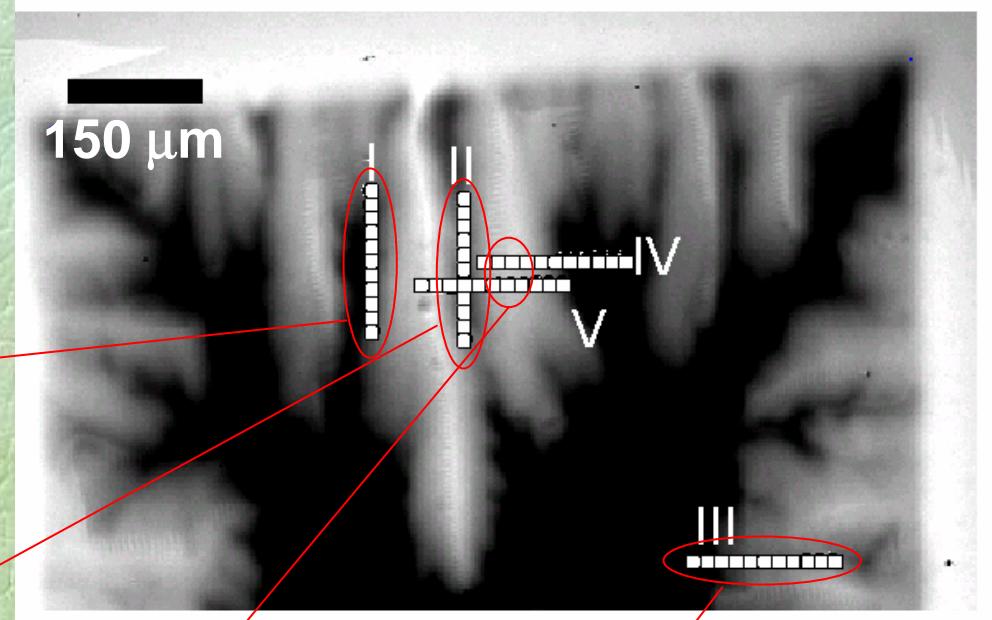
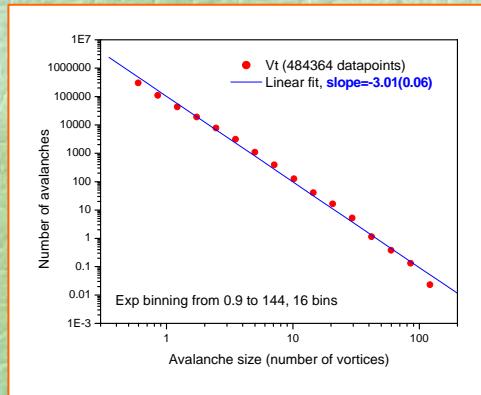
Robustness in the avalanche statistics

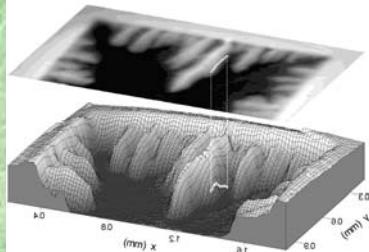


Location	Between thin dendrites	Also between thin dendrites	ON a thin dendrite	Between short dendrites	Average	SOC?
Slope	-3.0	-3.2	-3.1	-3.1	-3.1	

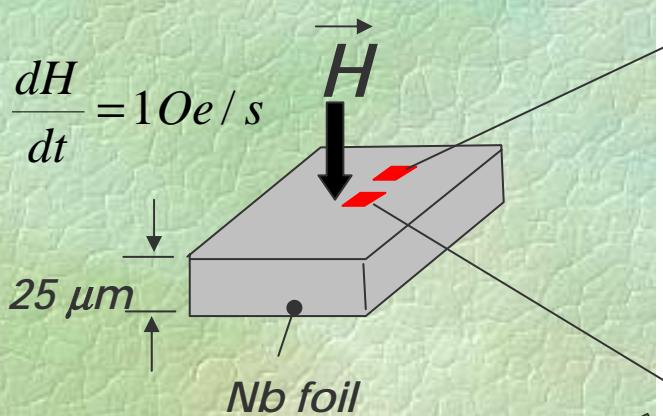


Robustness in the avalanche statistics

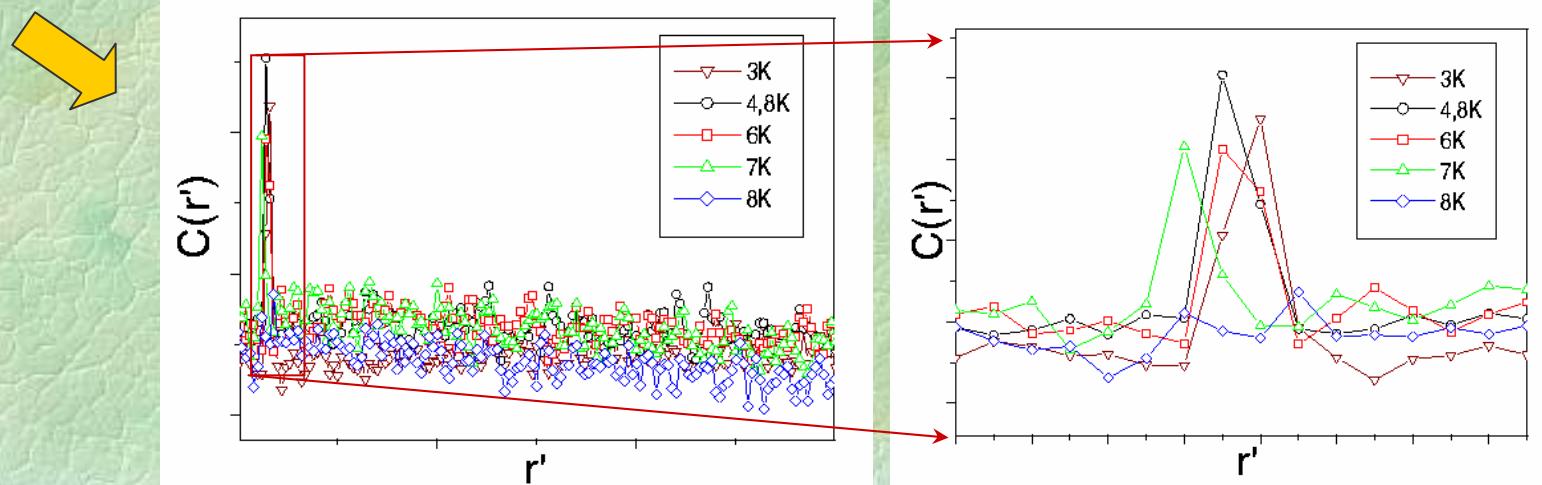
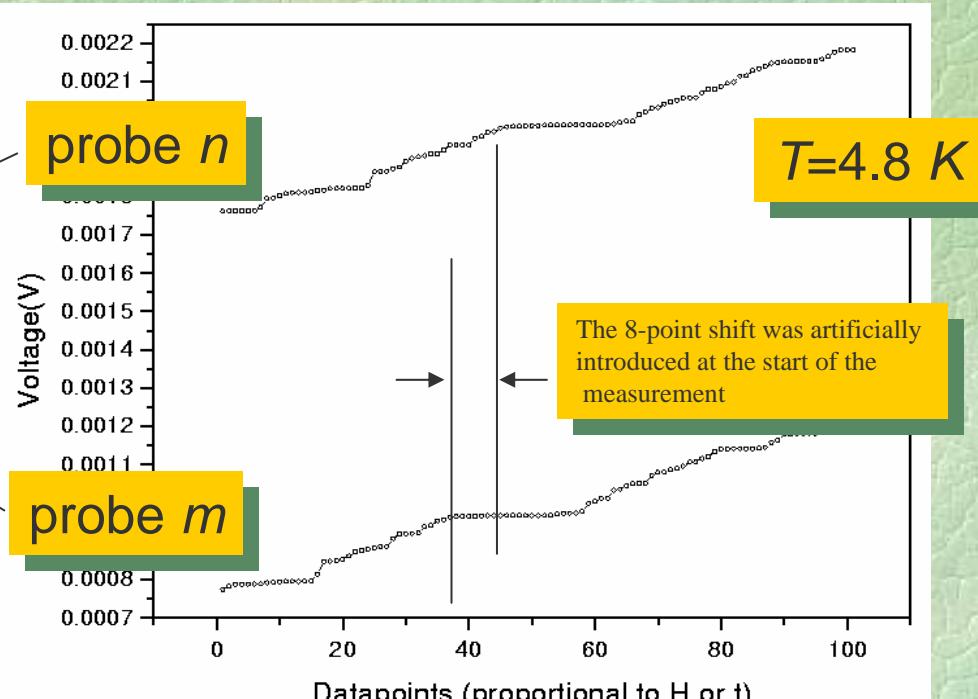




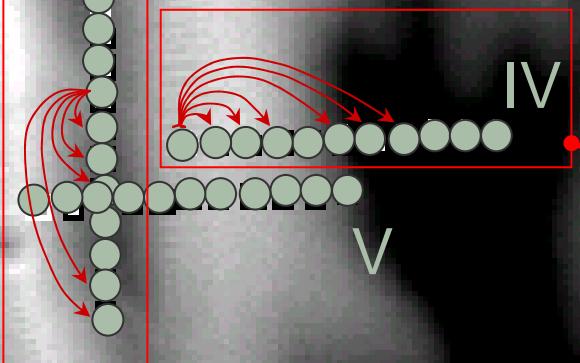
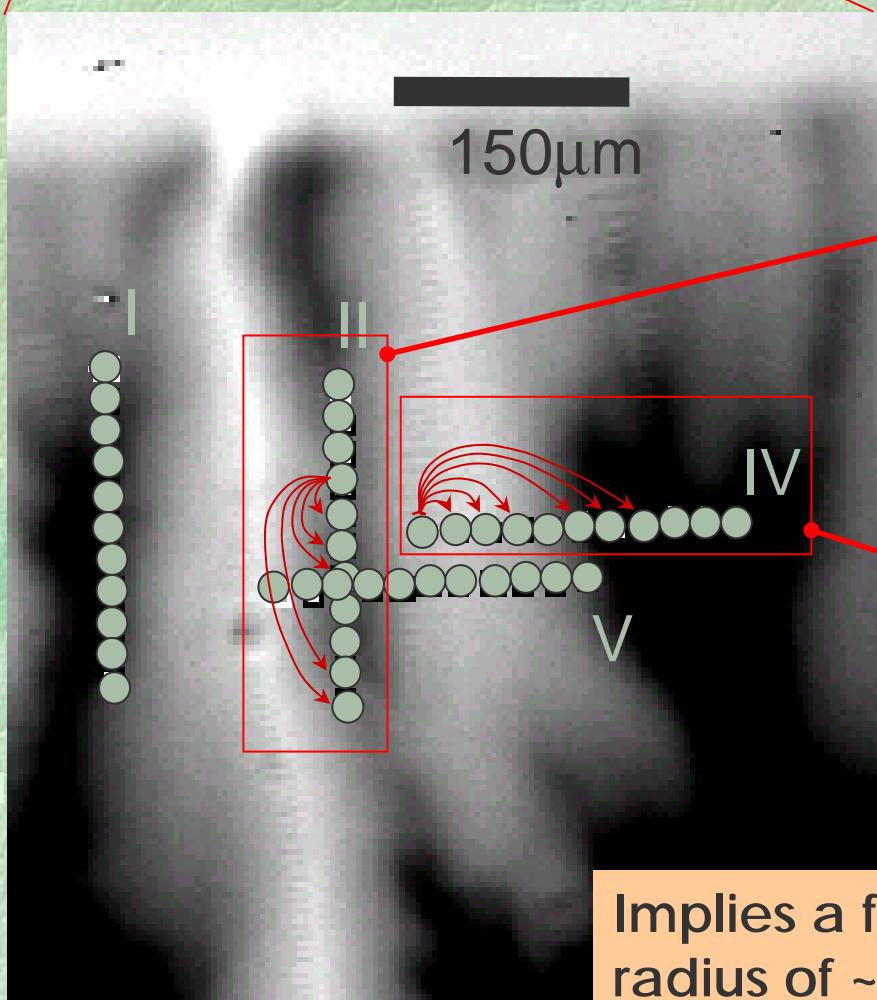
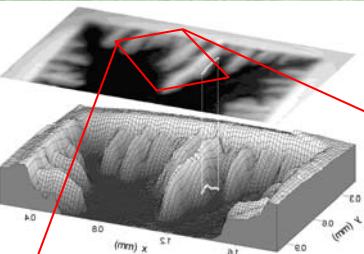
Avalanche correlations



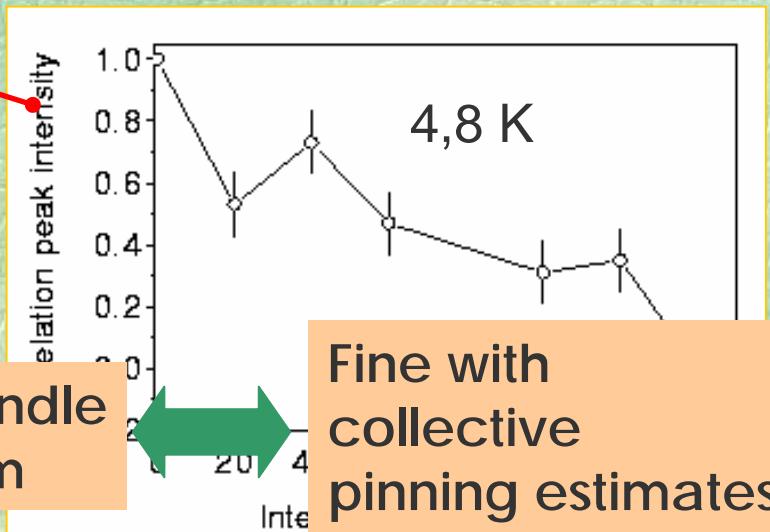
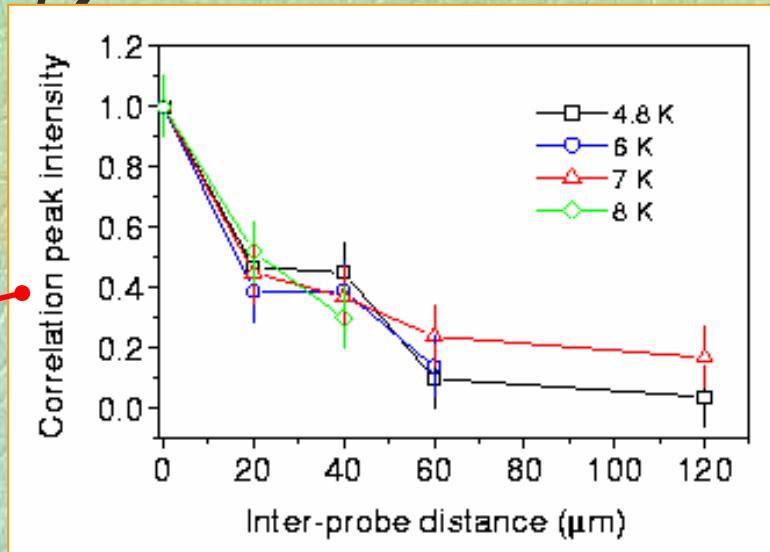
$$C(t') = k \frac{\langle y_n(t)y_m(t+t') \rangle - \langle y_n(t) \rangle \langle y_m(t) \rangle}{\sqrt{\sum [y_n(t) - \langle y_m(t) \rangle]^2 \sum [y_n(t) - \langle y_m(t) \rangle]^2}}$$



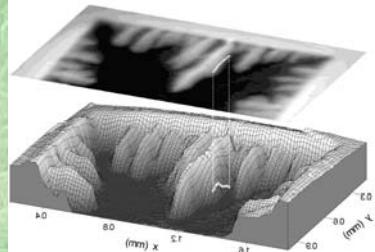
Avalanche correlations: results along x, y



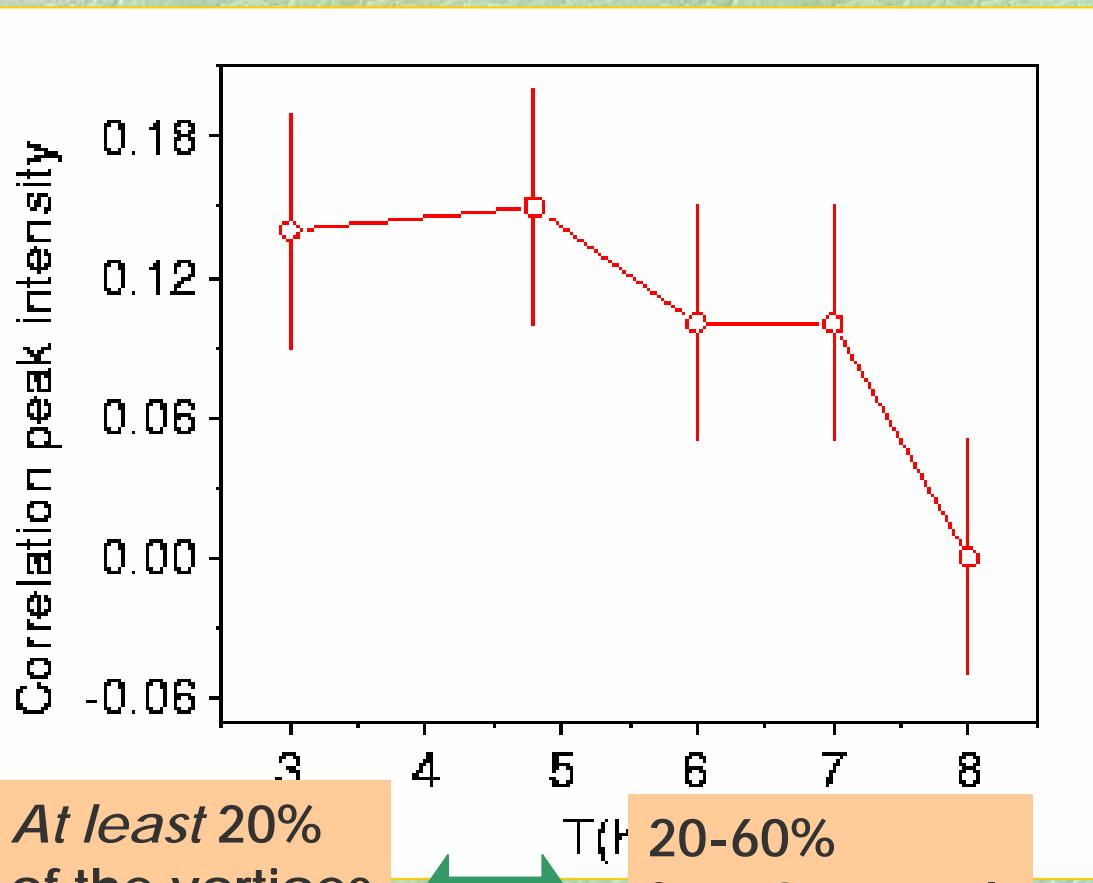
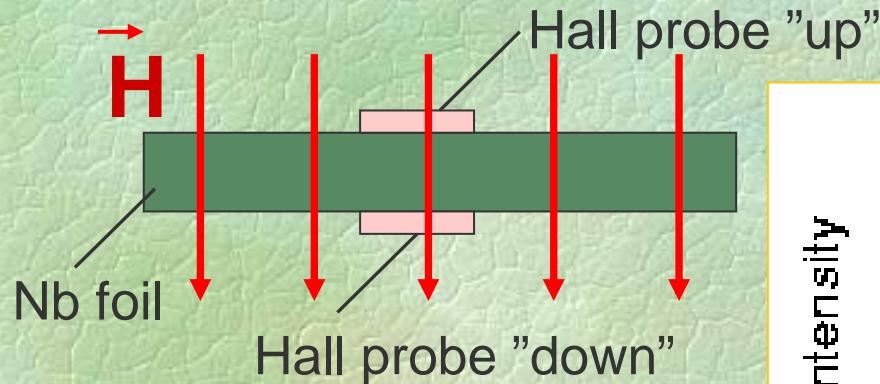
Implies a flux bundle
radius of $\sim 100 \mu\text{m}$



Fine with
collective
pinning estimates

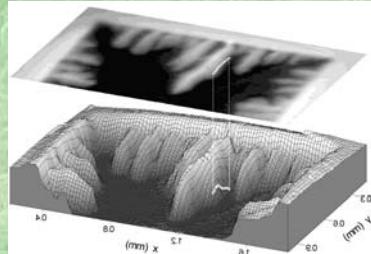


Avalanche correlations: results along z



At least 20%
of the vortices
behave stiff

20-60%
from Lee et al.
PRL (1995)



Conclusions

- 1 Quenched disorder determines the dynamics of the "overall" magnetic landscape, but it does not determine by itself the detailed avalanche behavior
- 2 We have found power laws in the avalanche size distribution for over two orders of magnitude
- 3 The power laws are robust relative to the flux penetration landscape
- 4 Correlations along x , y are not anisotropic, and suggest a vortex bundle size of the order of 100 microns at 4.8 K, which agrees with collective pinning estimates
- 5 At least 20% of the bundles move in a "stiff" fashion when they participate in an avalanche (at 4.8 K)

Suggests
SOC