PANEL#2

1. How significantly are the currently observed values of T_1 and T_2 affected by the following four issues:
    a. materials imperfections?
    b. readout scheme?
    c. qubit coupling scheme?
    d. environmental noise?

2. In your opinion, what directions should future research take in addressing these issues?

3. What specific challenges should be overcome to improve qubit coherence?

sub-gap conductance

- New way to make barrier – oxidize Al during deposition (Paul Welander)
- Compare this to conventional diffused oxide.

Common starting point in **A**/**B** comparision test

Grow single crystal niobium (110) orientation

Grow single crystal aluminum (111) on top

Then either…

A **Grow** amorphous Al_2O_3 at $PO_2=10^{-6}$T d~1.5 nm

Grow 100 nm polycrystalline niobium (new)

or

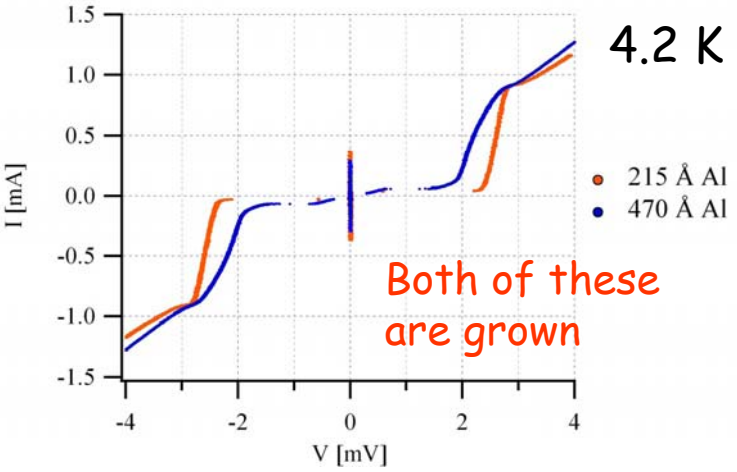
B **Diffuse** amorphous Al_2O_3 at $PO_2=10$T 1 hr

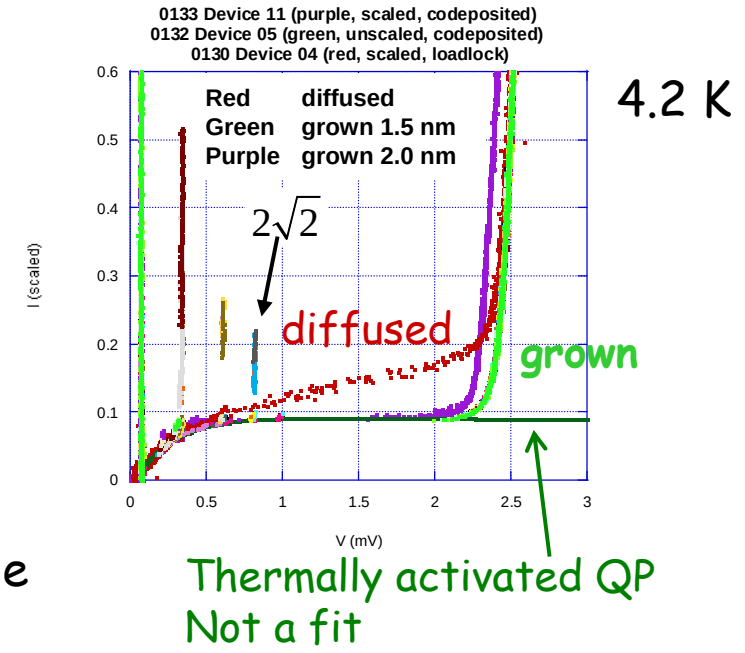
Grow 100 nm polycrystalline niobium (old)

Grown layer has "zero" shunt conductance

For a 100x100 nm^2 junction barrier has 10^6 Al atoms

Oxidation driven by exp(volts/kT) which can be very large. Not kinetically limited,





Microscopic origin

• *charge noise*
- controllable

• FLUX NOISE
- microscopic mechanism whose energy is greater that 10 MHz and less than 100 mK

- good candidate: paramagnetic spins on the surface of superconductor **?**
? (RKKY interaction - surface effect) **?**

- is low frequency noise in high Q superconducting resonator (MKID) related to this complicate surface effect physics **?**
[Mazin, Zmuidzinas et al.]

• **CRITICAL CURRENT**
- very little is known: upper cutoff?
Temperature dependence?

Reproducibility - Rare events [crucial for FTQEC]
Need understanding of noise correlations for error threshold estimate

$$S_\Phi^{1/2}(f) \approx 10^{-6}\Phi_0 Hz^{-1/2}$$

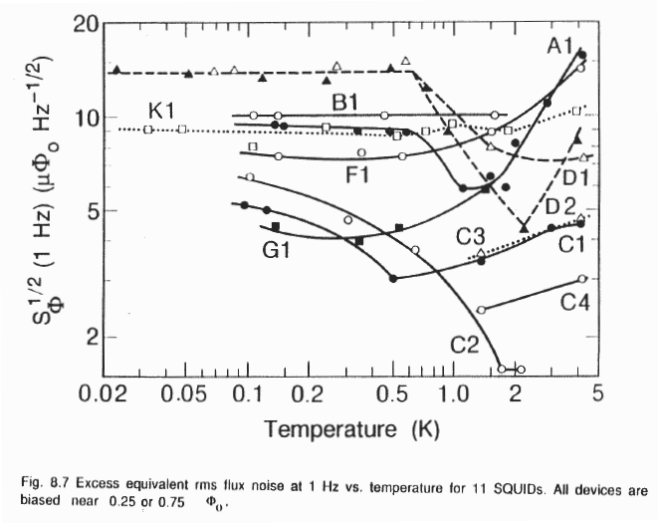
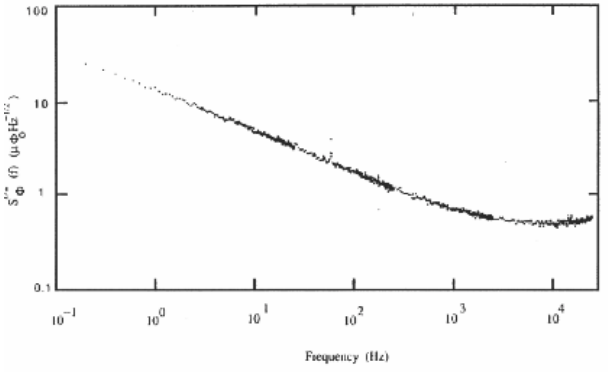


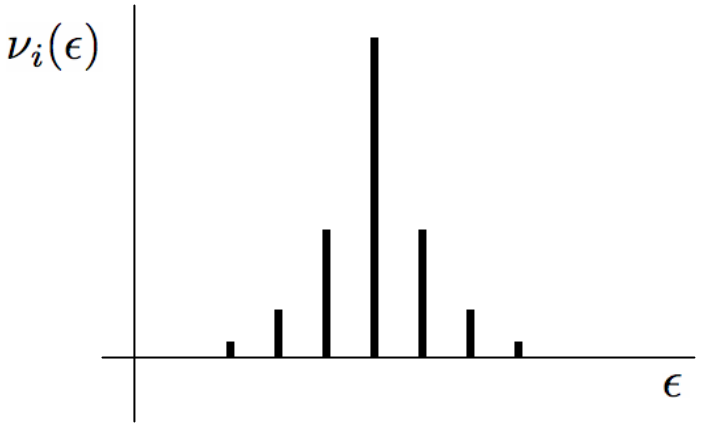
Fig. 8.7 Excess equivalent rms flux noise at 1 Hz vs. temperature for 11 SQUIDs. All devices are biased near 0.25 or 0.75 Φ_0.



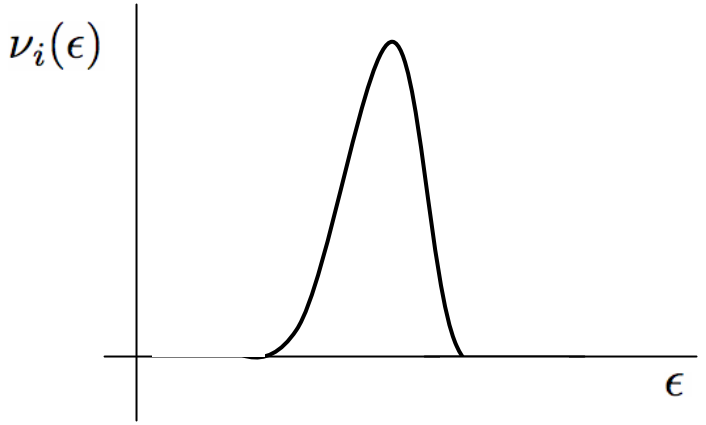
Theoretical challenge

What is the dynamics of collections of spins or TLSs weakly interacting

$$\mathbf{H} = \mathbf{h_i S_i^z} + \mathbf{J}_{\alpha,\beta}^{\mathbf{i,j}} \mathbf{S_i^\alpha S_j^\beta}$$



Quantum?



Classical?

Generation of noise by closed quantum systems
(TLSs dynamics at very low temperature, dilute electron spins with dipole dipole interaction)
Set of problems equivalent to level broadening in closed systems