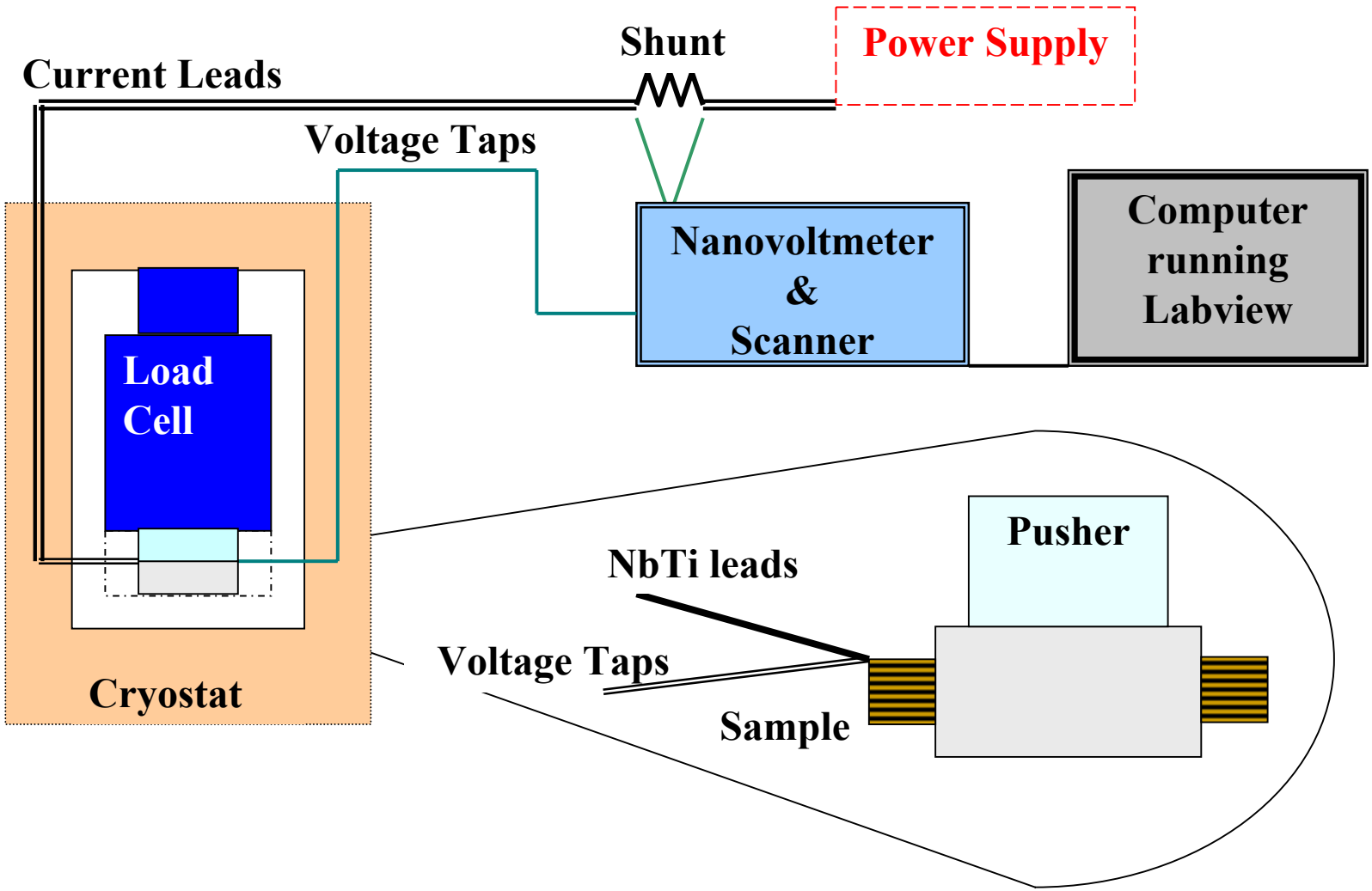
Inter-strand Contact Resistance measurement

GOALS

Measure ICR in our magnets “as built” and in cable stacks in order to:

- *Know the range of values with present technology (W&R and R&W)*
- *Understand most effecting parameters (reaction and impregnation pressure, binder and oil amount…)*
- *Modify fabrication technology in order to obtain acceptable values*

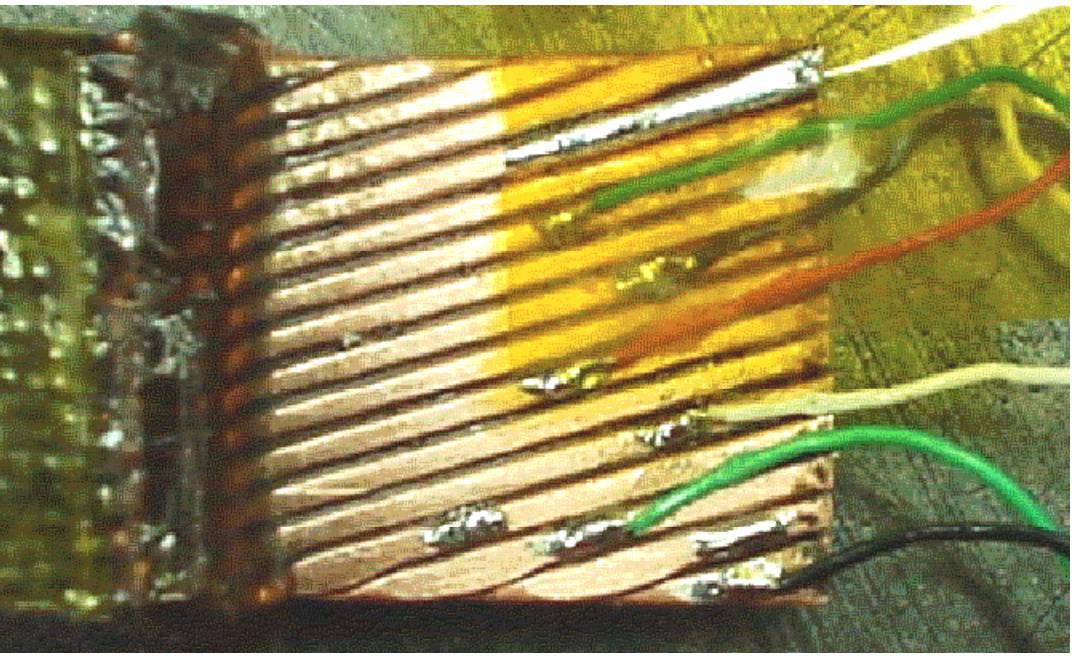
Measurement set-up

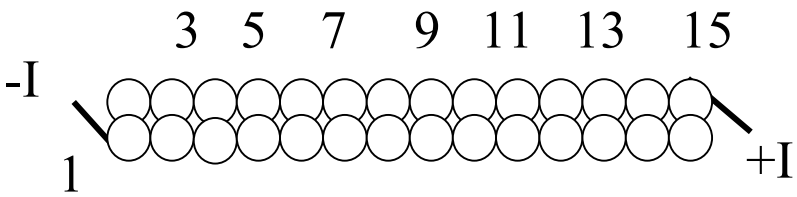


Measurement set-up

- Load cell (~70 MPa)
- Power supply (100 A)
- Nanovoltmeter and scanner (8 channels)
- Labview (~ 1 Hz)

Sample instrumentation





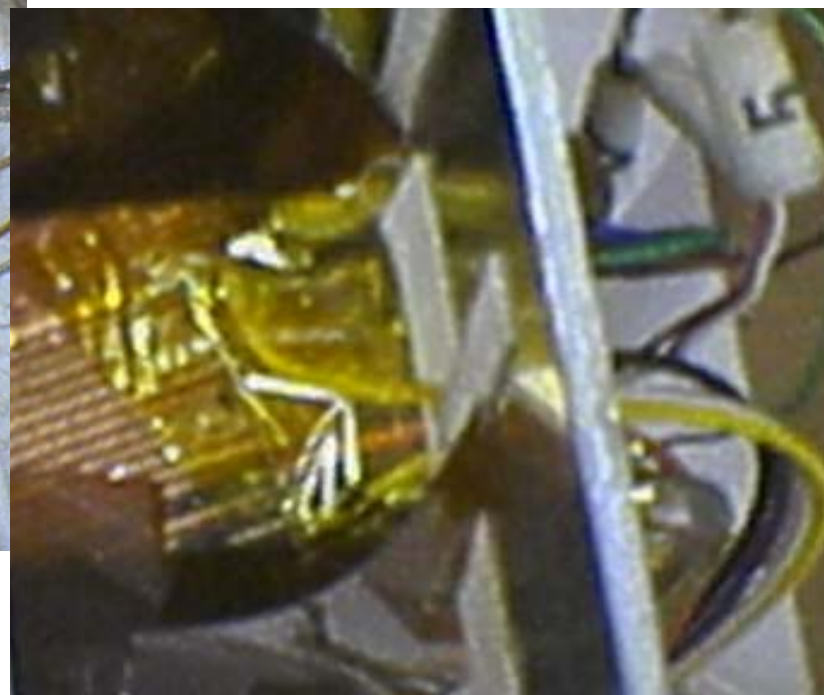
Cos-theta cable

- 28 strands
- 1 mm diameter
- 110 mm (=twist pitch)
- Kapton used to avoid contacts by soldering

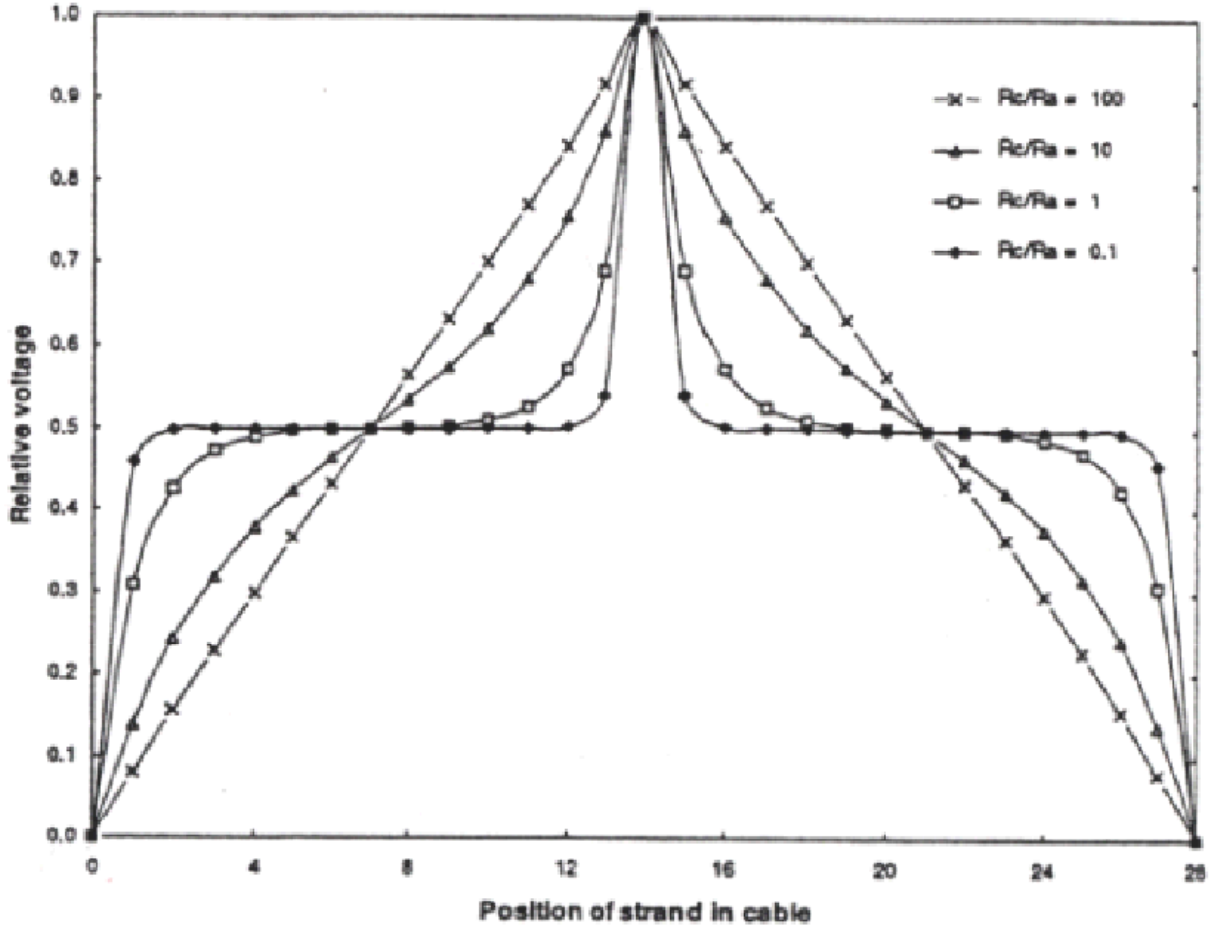
Same technique is used to instrument coil samples after removing the end of a few strands

Coil sample instrumentation

Same technique is used to instrument coil samples after removing the end of a few strands



Voltage distribution vs. Rc/Ra



If Rc>>Ra

uniform contacts

$$R_a \approx \frac{2N^2(V_k - V_i)}{I(k-1)(N-j+i)}$$

$$R_a \approx 8 * \frac{\Delta V_{Max}}{I}$$

Preliminary results

- HFDB-01 sample (41 strands, 0.7 mm, w synthetic oil):

  Ra ~ 20 mΩ << Rc

- 41 strands, 0.7 mm, with synthetic oil:

  Ra ~ 2.4 μΩ << Rc

- 28 strands, 1 mm, with core and ceramic binder:

  Ra ~ 1.8 μΩ << Rc

➔ All samples showed a very small effect of pressure

Warning: sample ends were NOT polished

Study of the effect of the **binder** and the **R&W technology** (pressure during HT)

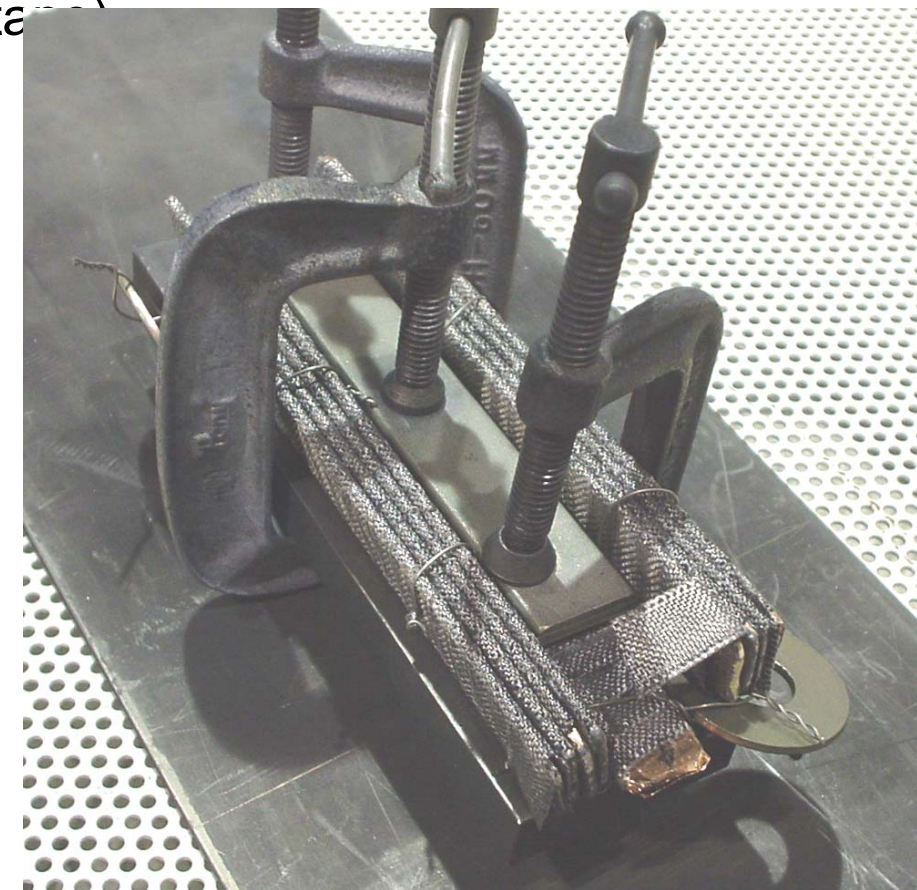
#1: NO binder,
Cables reacted under pressure (clamps)

#2 WITH binder (on cable and ta
Reacted without pressure

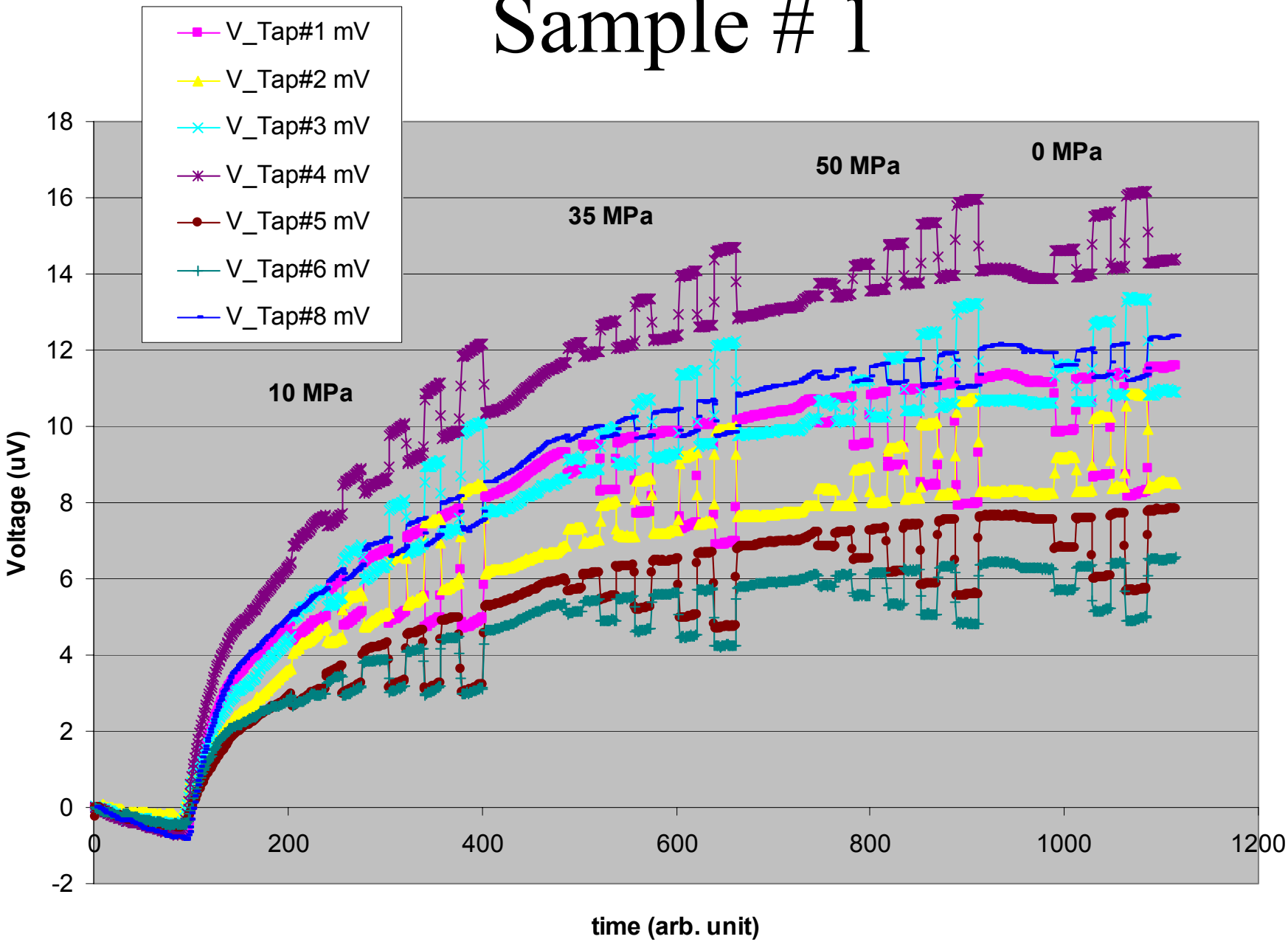
#3: Copper tape (50% overlap)
Ceramic tape (50% overlap)
WITH binder on the ceramic tape
Reacted under pressure

#4: Copper tape (50% overlap)
Ceramic tape (50% overlap)
WITH binder on the ceramic tape
Reacted without pressure

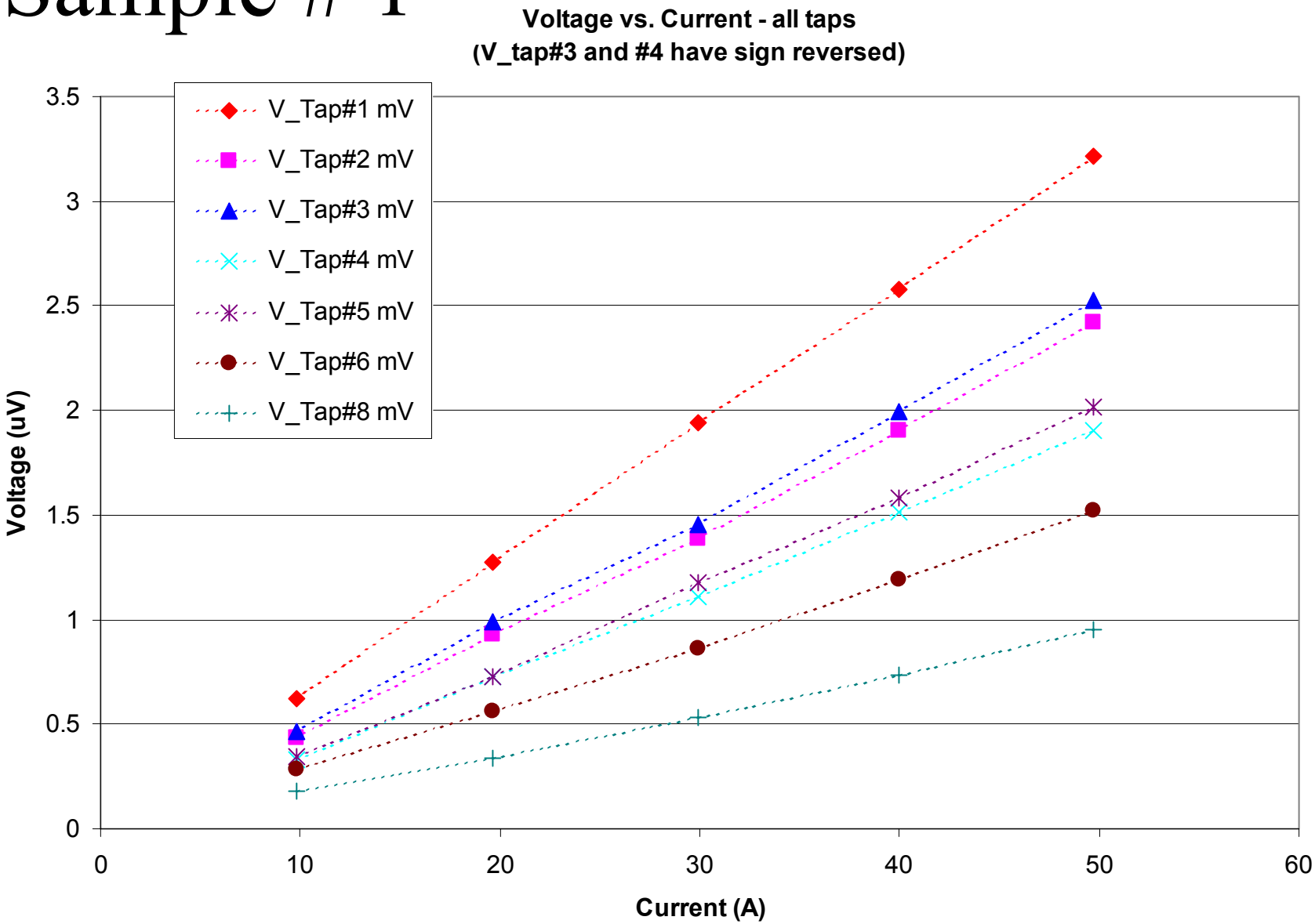
Cables: 28 strands
1 mm diameter
NO core



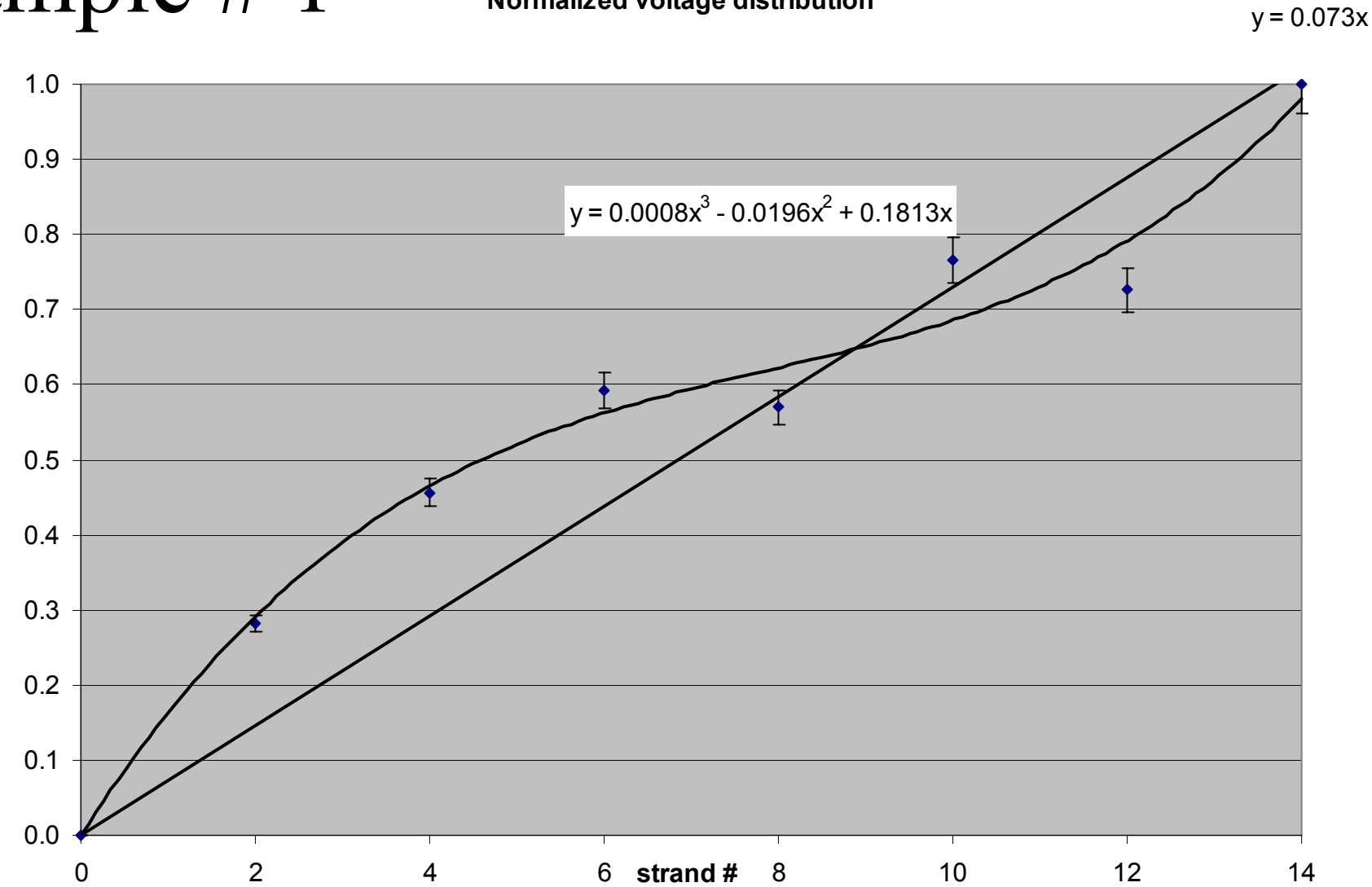
Sample # 1


V_Tap#1 mV
V_Tap#2 mV
V_Tap#3 mV
V_Tap#4 mV
V_Tap#5 mV
V_Tap#6 mV
V_Tap#8 mV
10 MPa
35 MPa
50 MPa
0 MPa
Voltage (uV)
time (arb. unit)
18
16
14
12
10
8
6
4
2
0
-2
0
200
400
600
800
1000
1200

Sample # 1

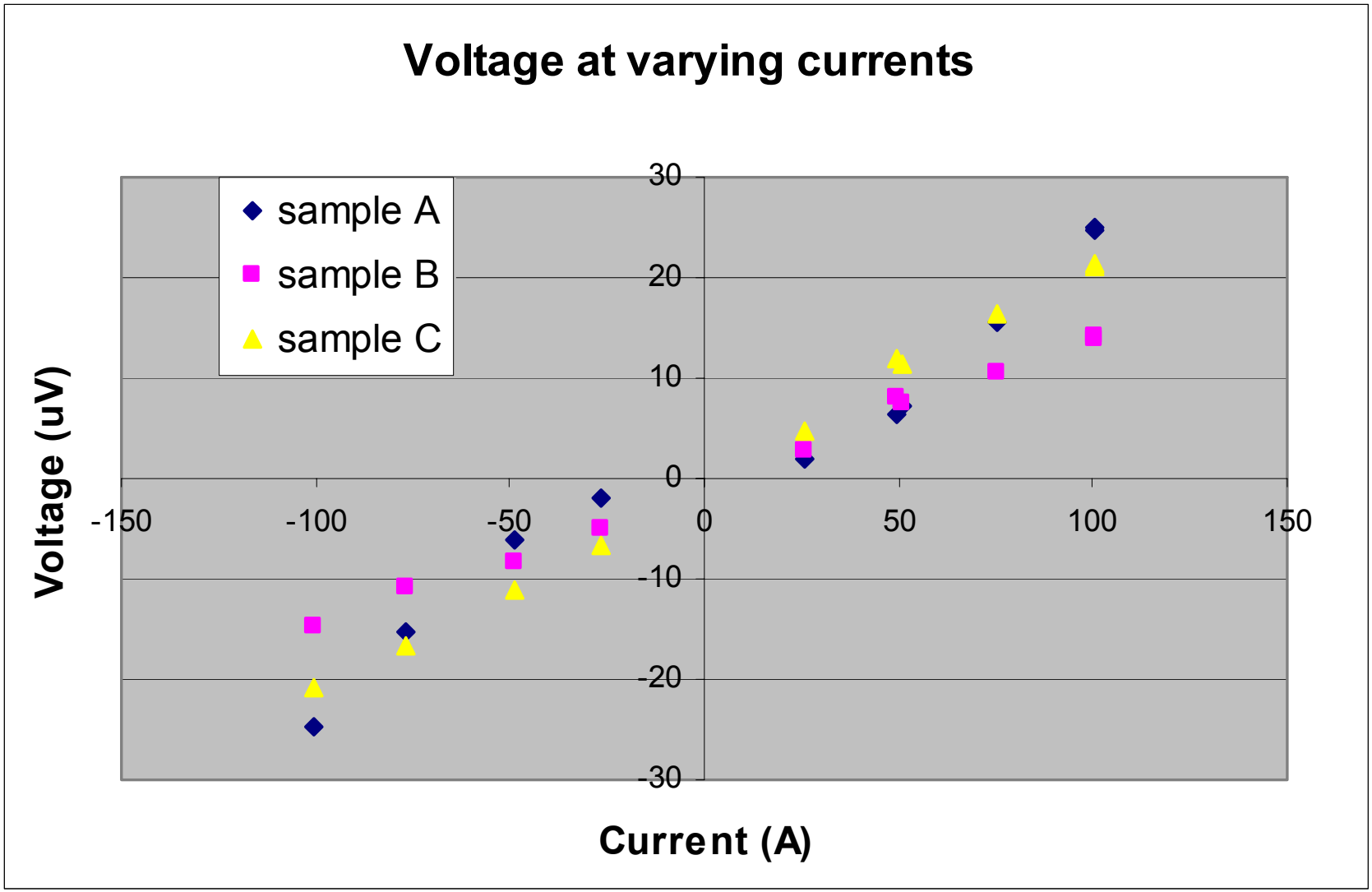

Voltage vs. Current - all taps
(V_tap#3 and #4 have sign reversed)
V_Tap#1 mV
V_Tap#2 mV
V_Tap#3 mV
V_Tap#4 mV
V_Tap#5 mV
V_Tap#6 mV
V_Tap#8 mV
Voltage (uV)
Current (A)
0
0.5
1
1.5
2
2.5
3
3.5
0
10
20
30
40
50
60

Sample # 1



- Ra is slightly smaller than Rc
- Ra is in the range 0.5 –1.5 μΩ

Samples # 2,3,4


Voltage at varying currents
sample A
sample B
sample C
Voltage (uV)
Current (A)
30
20
10
0
-10
-20
-30
-150
-100
-50
0
50
100
150

Samples # 2,3,4

- All samples gave Ra:
  - 1 – 2 uV (if Rc >> Ra)
  - 3 – 6 uV (if Rc slightly larger than Ra)

Next

- Samples with different pressure during impregnation
- Four samples HFDA-04 (cos-theta coil)
- Four samples HFDB-02 (racetrack coil)
- Samples with different amount of synthetic oil

- Improvement of the apparatus in order to measure 4 samples each time with 8 voltage taps each

Test in background field ???

- Is the current flowing in the Nb barrier?

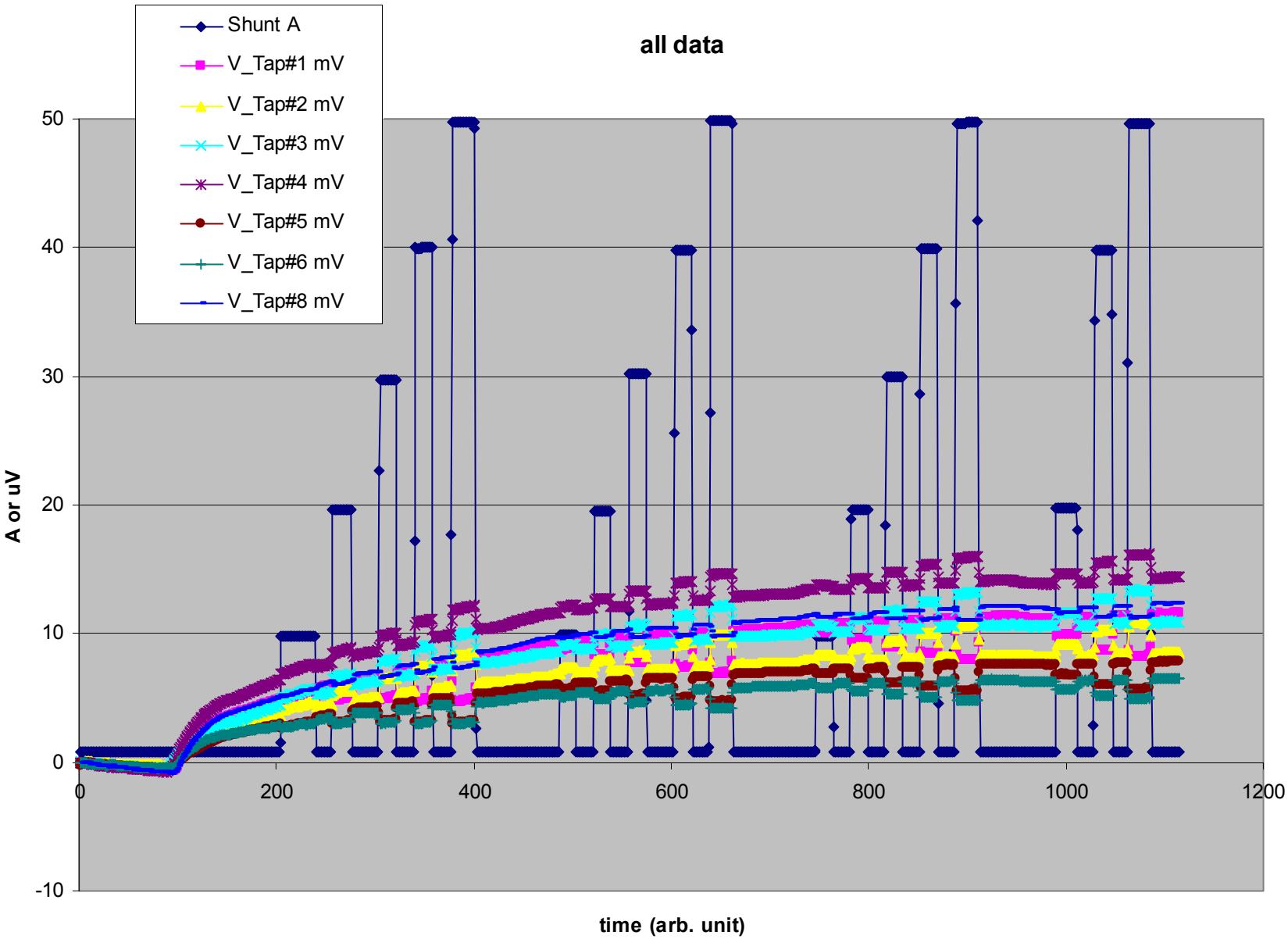
- Test in background field inside the ss test facility
  - I = 0 -100 A
  - B = 0 – 0.4 T (B_{c2} of Nb is 0.27 T)

Appendix

ICR measurement WW

CERN	BNL	Saclay	Twente OSU
D. Richter	R. Soika	A. Devred	A. Verweij
VI	VI	VI	Calorim.
Saw tooth	Ramp	Ramp	
NbTi	NbTi	Nb_3Sn	Nb_3Sn ?

Sample # 1


all data
Shunt A
V_Tap#1 mV
V_Tap#2 mV
V_Tap#3 mV
V_Tap#4 mV
V_Tap#5 mV
V_Tap#6 mV
V_Tap#8 mV
A or uV
50
40
30
20
10
0
-10
0
200
400
600
800
1000
1200
time (arb. unit)