Bolometric Measurement of Beam Intensity at Cryogenic Windows

Mark Oreglia
University of Chicago
11 November, 2000

- Study of energy deposition in Al windows
- Mechanical deformation of windows
- Temperature modulation in windows
  - resistance measurements in special coatings
- Program at University of Chicago

•NB: these are very preliminary ideas!

Bolometer (from O.E.D.)

[f. Gr. beam of light + measure.]

An electrical instrument of great sensitiveness for measuring radiant heat. Hence bolometric (blmtrk), a.

1881 Nature XXV. 14 An instrument..capable of indicating a change of temperature as minute as 1-100,000th of a single Centigrade degree ..is termed by its discoverer, Professor S. P. Langley, the bolometer, or actinic balance.

1882 Athenæum 2 Sept.310/1
His 'bolometer', or radiation measureran instrument some twenty times more sensitive than the thermopile.

1881 C. A. YOUNG Sun 306 Shown by the bolometric measures described above.

Deformations of Windows

- Intense muon beam interactions in windows have been considered for secondary particle emission measurements
- However, we are now considering beams with energy deposition large enough to cause measurable mechanical deformation
- Additionally, the liquid hydrogen temperatures could permit novel use of resistance measurements in
  - Superconducting Edge Bolometers
  - other resistive films

Beam Properties

- Assume FNAL design
  - bursts of quadruple-bunches at 15 Hz
  - 2 10^{12} muons in each group
  - roughly 100 ns duration of group

- Beam size
  - I use σ = 5 cm gaussian
  - but results extend to other profiles

- Windows
  - cryostat windows at 10 - 20 K
  - typically 200 - 400 μ thickness
    - I use 300 μ

Properties of Al at 10K

- Density: 2.7 g cm^{-3}
- Minimum dE/dx: 6.9 10^{-13} J cm^{-1}
- Heat capacity: 0.0014 J g^{-1} K^{-1} (6061)
- Thermal diffusion constant:

  $\kappa = 21.7\ cm^2\ s^{-1}$
- Speed of sound: 5000 m s^{-1}
- Expansion coefficient: 2 10^{-5}

- Thus, the relevant time constants are:

  T_{sound} = 100 ns

  $T_{thermal}$ = 40 μs
- Energy deposit per bunch-group: 0.166 J !!!
- Heating per bunch group: > 15K, average
  - same ΔT for any thickness; for 30 micron film, get time constant of 1 μs
  - pulsed temperatures matching hiT_c mat.

Mechanical Deformation

- For uniform illumination of 100 cm^2 (a worst-case!) we obtain window expansions of:
  - 95 nm
- Not practical!
  - marginal magnitudes
  - expensive (?) optics
  - need space for optics

- But… are capacitative measurements feasible?

- On the brighter side:
  - not damaging to surface coatings

Bolometers

- Real calorimetry!
- We would be interested in materials with a high temperature-dependent resistance

- Can deposit on surface in any pattern

- Can get short time constants in thin films
  - easy to sputter onto cryostat windows
  - metal films would be very robust
    - resist mechanical cycling
    - radiation hard
  - exotic materials
    - can be well matched to cold LH temperature
    - can give large signals

Pro and Con

- Thermal time scale
  - no single bunch profiling
  - but might get single-turn profile

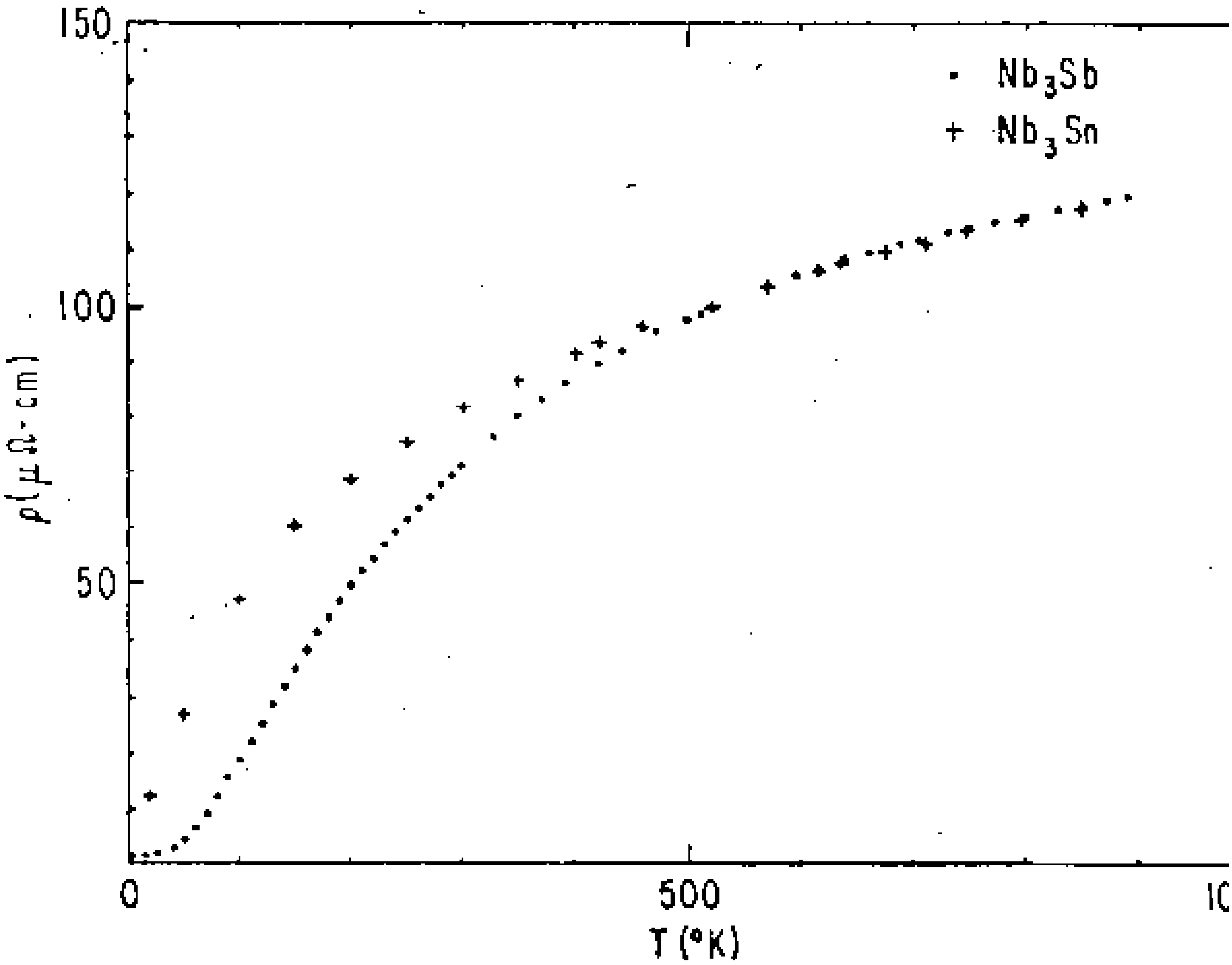
- No separation of X-rays
  - but dual layers of different materials might allow a subtraction

- Easy segmentation (sputter deposition)
  - strip or pixel readout
  - long time-scale resistance measurement should be robust to RF noise
- Radiation hardness varies
  - low amplitude materials are ok
  - … but are the high-sensitivity marterials rad-hard?

A15 Materials

- For windows attached to a LnH thermal batch, get crossing of superconducting “Edge”
  - large class of so-called A15 materials
    - e.g., Nb-Al-Ge
  - can formulate compounds matched to any temperature edge in the 10-30K range
  - resistance goes linear above the edge, so you can measure intensity
  - electrical segmentation possible with deposition by sputtering
  - use insulating substrate … can choose optimal thermal insulation
- Relatively inexpensive
  - robust electronic signals

The General A15 Behavior



Radiation Damage

- This remains an important question
- A15 materials may not survive our beam halo, but this needs to be studied
  - the materials are often “tuned” using ion doses
  - can we establish saturation?
- However, more conventional bolometric materials are radiation-hard
  - can we get enough signal from “simple” resistive strips?

Work In Progress at Chicago

- New postdoc (Kara Hoffman) and Oreglia are setting up a bolometry lab at the EFI
  - materials and sputtering methods under study
  - radiation damage studies
- Finite element model under construction
  - will have thermal diffusion
- Particle backgrounds will be studied
  - sure, the backgrounds are bad, but
    - perhaps dEdx, time constants, profiles can differentiate

- ANL has the world experts on sputter-deposition of A15 materials … talks underway!