Experimental Study of Flux Expulsion and Cold Work

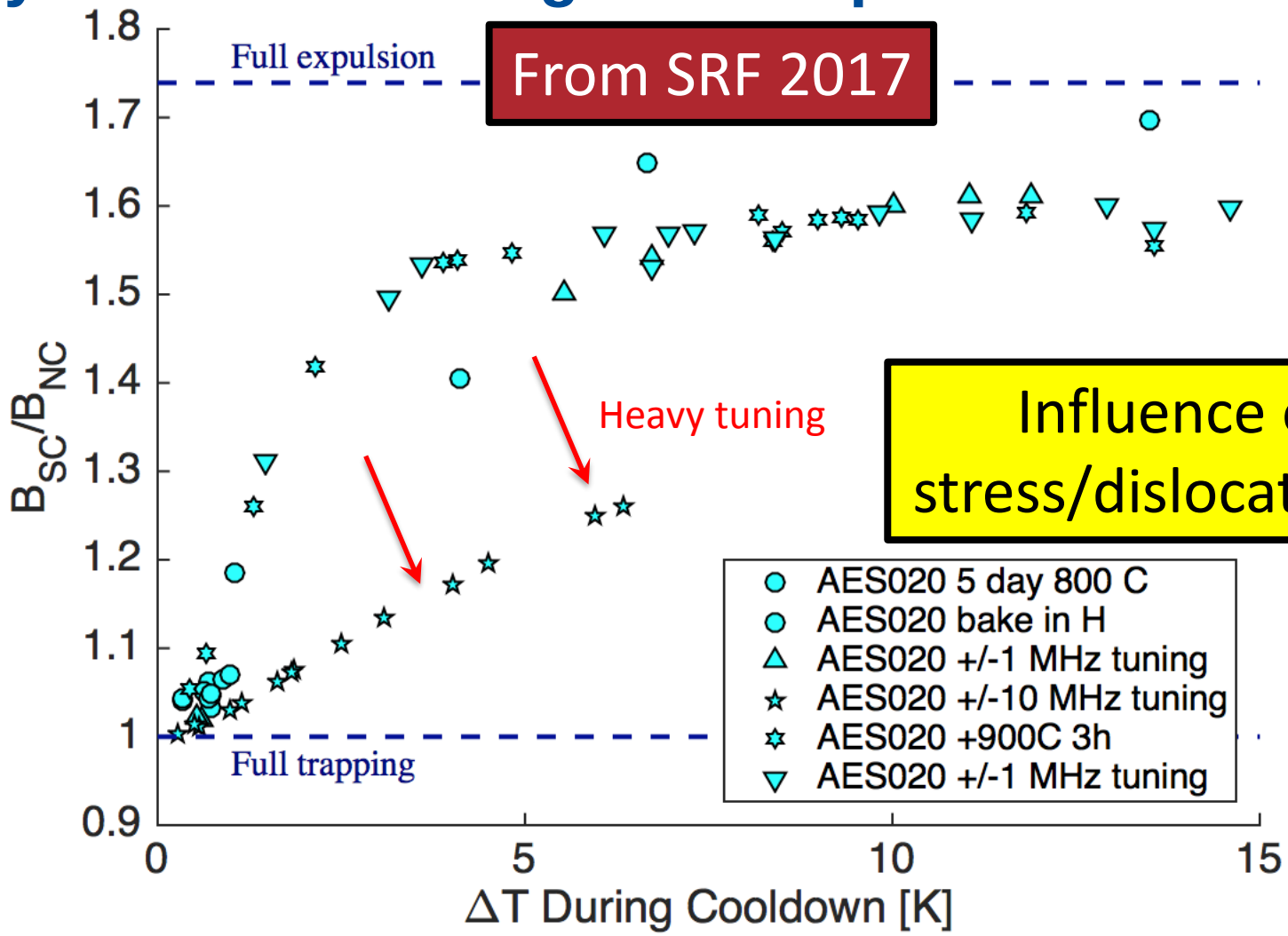
Sam Posen, Fermilab SRF Team

TTC Topical Workshop on Flux

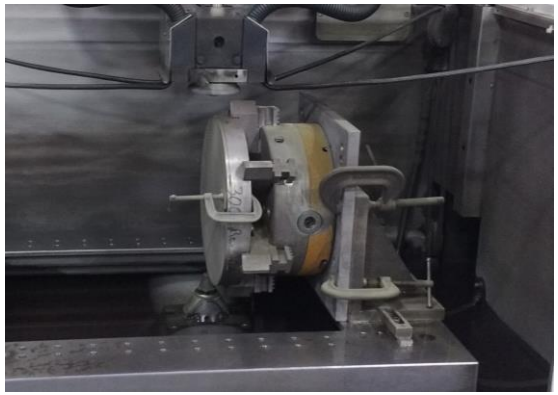
9 November 2018

CERN

Heavy deformation degrades expulsion behavior



- Tantalizing hint that cold work plays a major role in flux expulsion
- This presentation presents new results from an experiment to follow up on influence of cold work



Large Grain Experiment

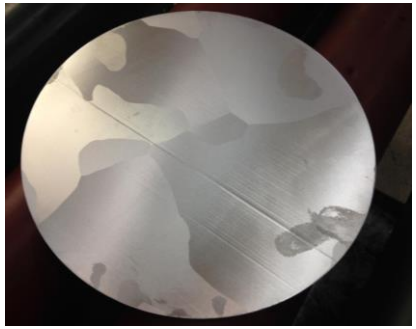
Experiment designed to distinguish effects of dislocations independent of grain size: does LG material inherently expel strongly?

Large Grain Ingot → Cut 2 slices, **3 mm** thick → 1-cell 1.3 GHz cavity fabrication (now)

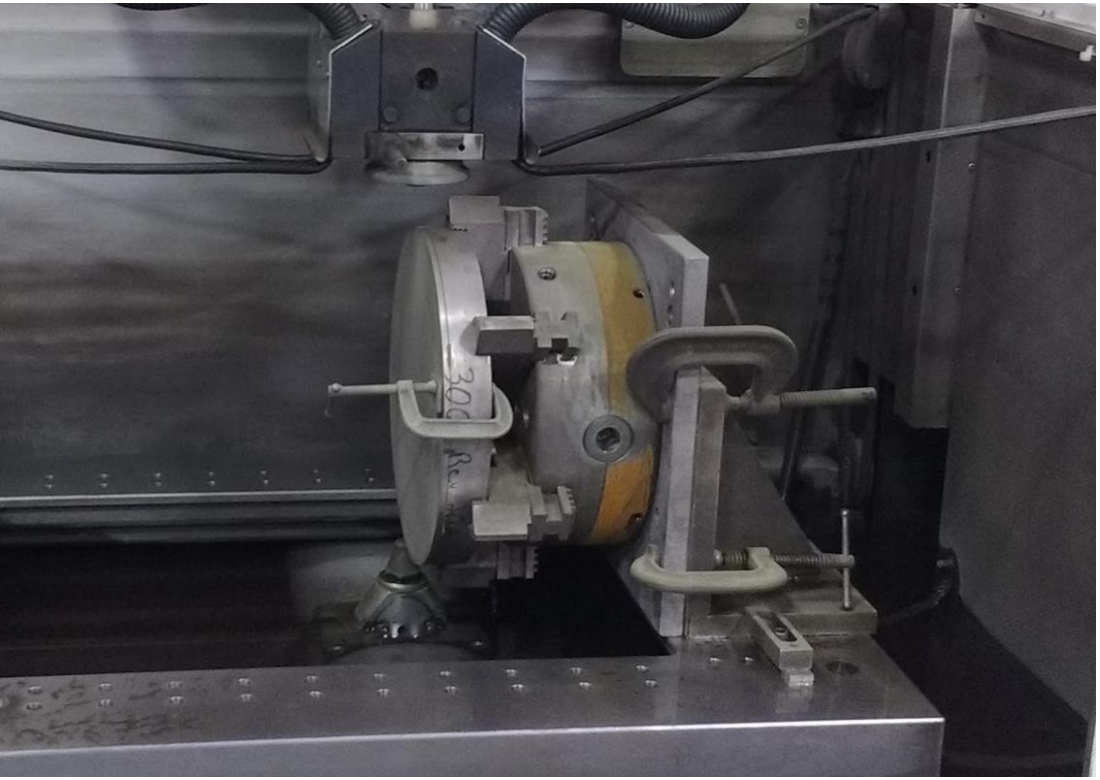
Large grains, low dislocation content

Large grains, high dislocation content

Cut 2 slices, **5 mm** thick → Roll to 3 mm thickness → Cut down to disc size → 1-cell 1.3 GHz cavity fabrication (now)



Wire EDM from Ingot



- 2 sheets 3 mm thick -> BCP + send direct to cavity vendor
- 2 sheets 5 mm thick -> BCP + send for rolling

Sheets Rolled by ATI

- Thickness reduction from 5 mm to 3 mm (area increase)
- Cold worked so that no longer flat even after roller levelling
- Material sent to cavity vendor

Half Cell Forming

- RI received the sheet material and began deep drawing
- The non-rolled material formed half cells well
- The rolled material tore during the forming process
- This is not entirely unexpected as **the material was not annealed at any point during the manufacturing process**

Repair Developed by RI

- RI used the extra rolled material to plug the holes in the half cells
- Some extra beam welds, but should still be representative!

Photos courte

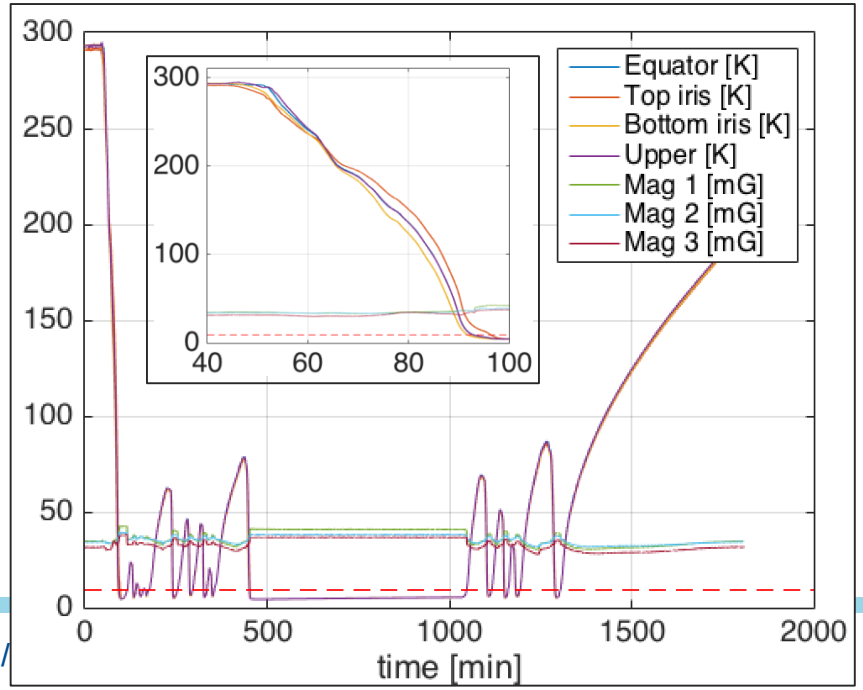
Extra material

Completed Cavities

Photos courtesy RI

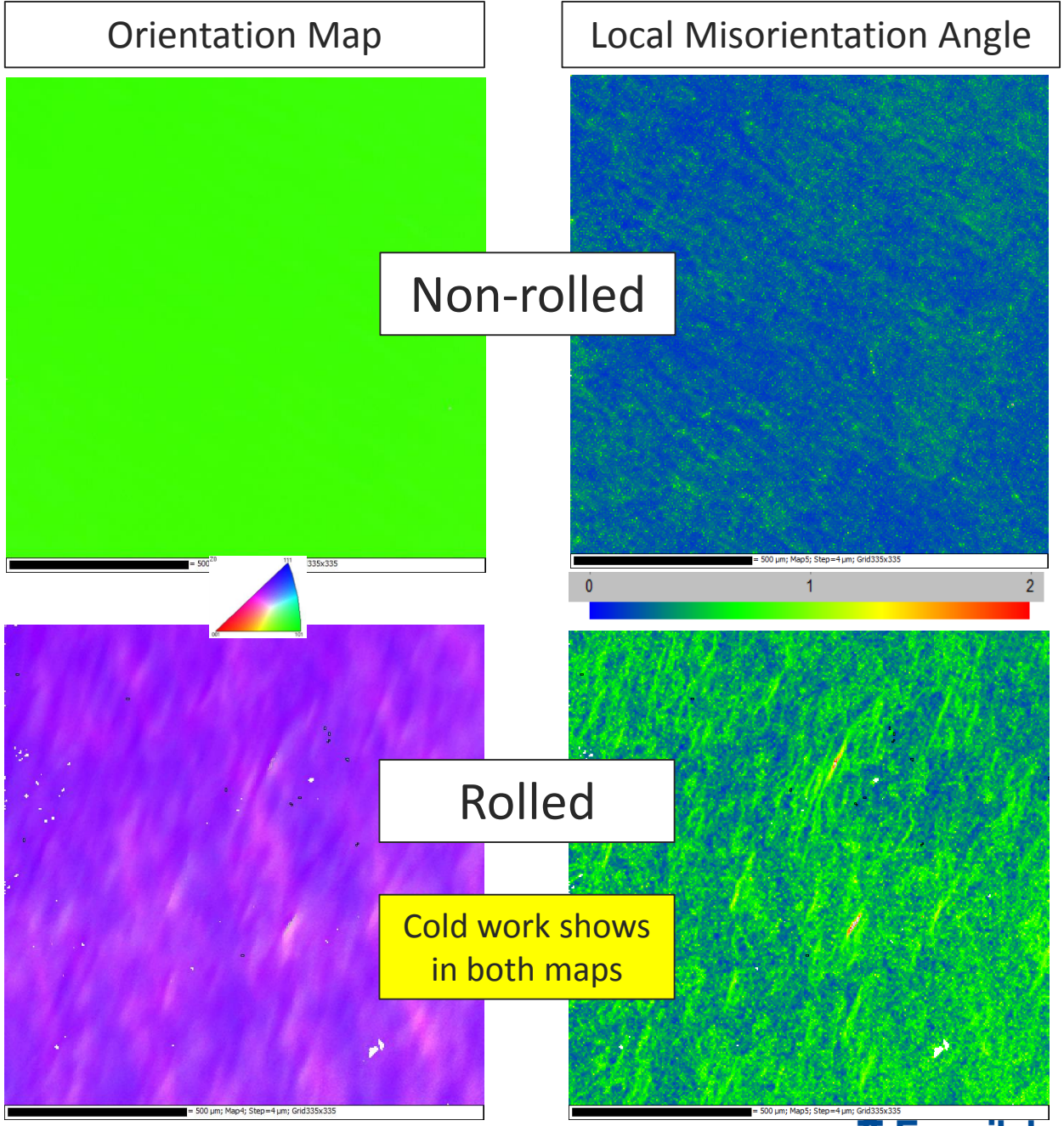
Expulsion Measurement

- Assembled as-received cavities with only vacuum connections (no RF)
- Cavities cooled quickly through range 150-100 K to avoid formation of hydrides
- Thermal cycles to measure expulsion

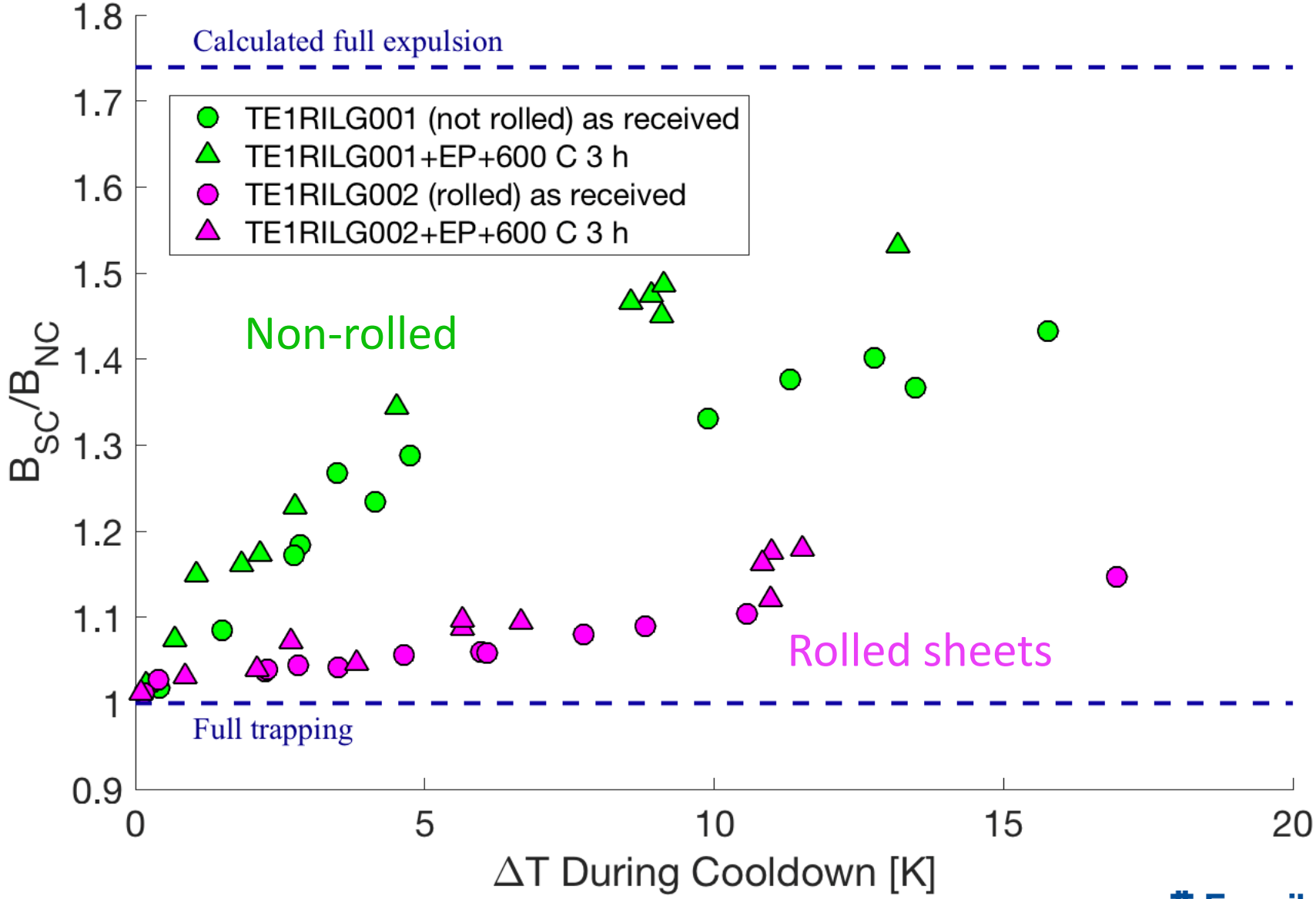


Material

- Cavities are made:
  - From the same ingot
  - By the same vendor
  - And both have large grains
- Key difference:
  - <u>Cold work</u>

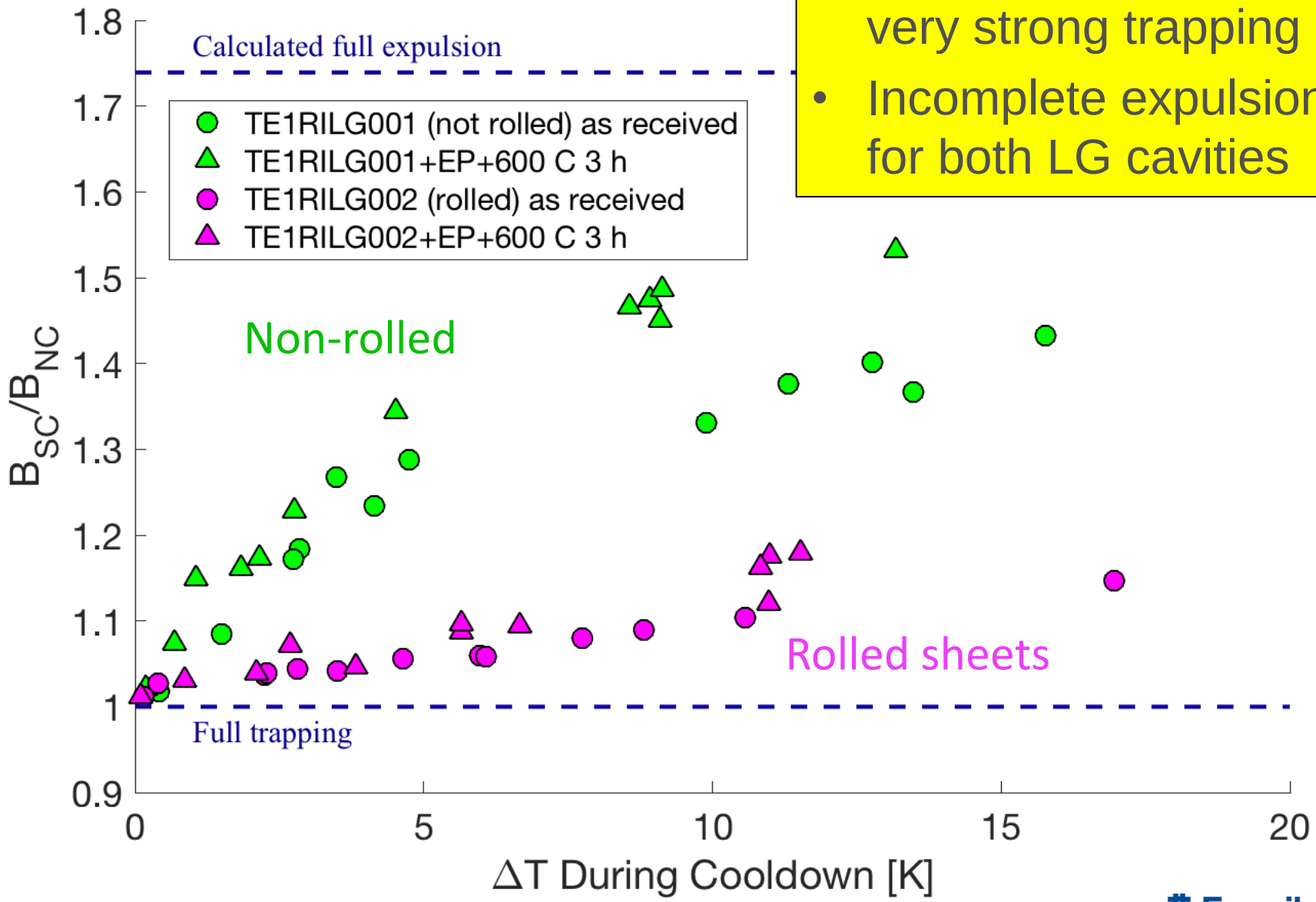


Expulsion Measurement

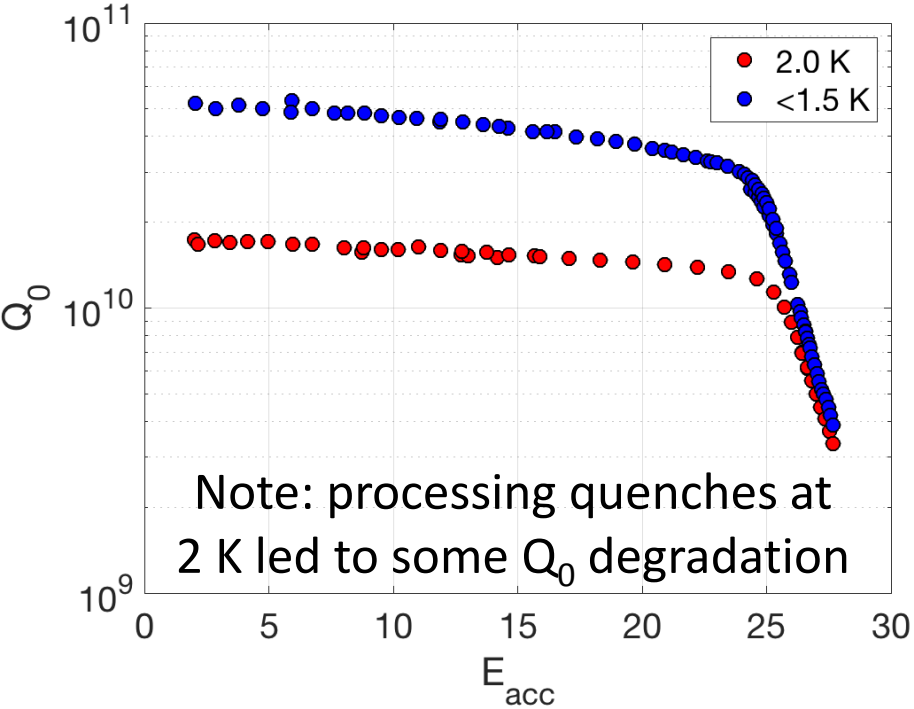


Expulsion Measurement

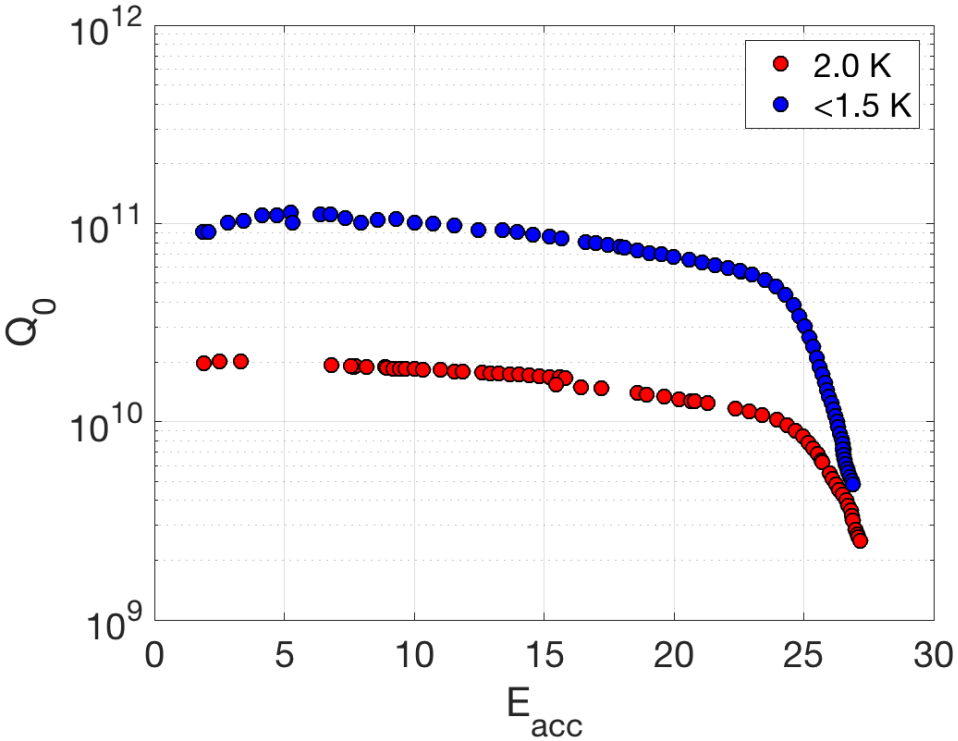
- Cold worked material very strong trapping
- Incomplete expulsion for both LG cavities



Q vs E Curves after Bulk EP + 600 C 3 hr + Light EP

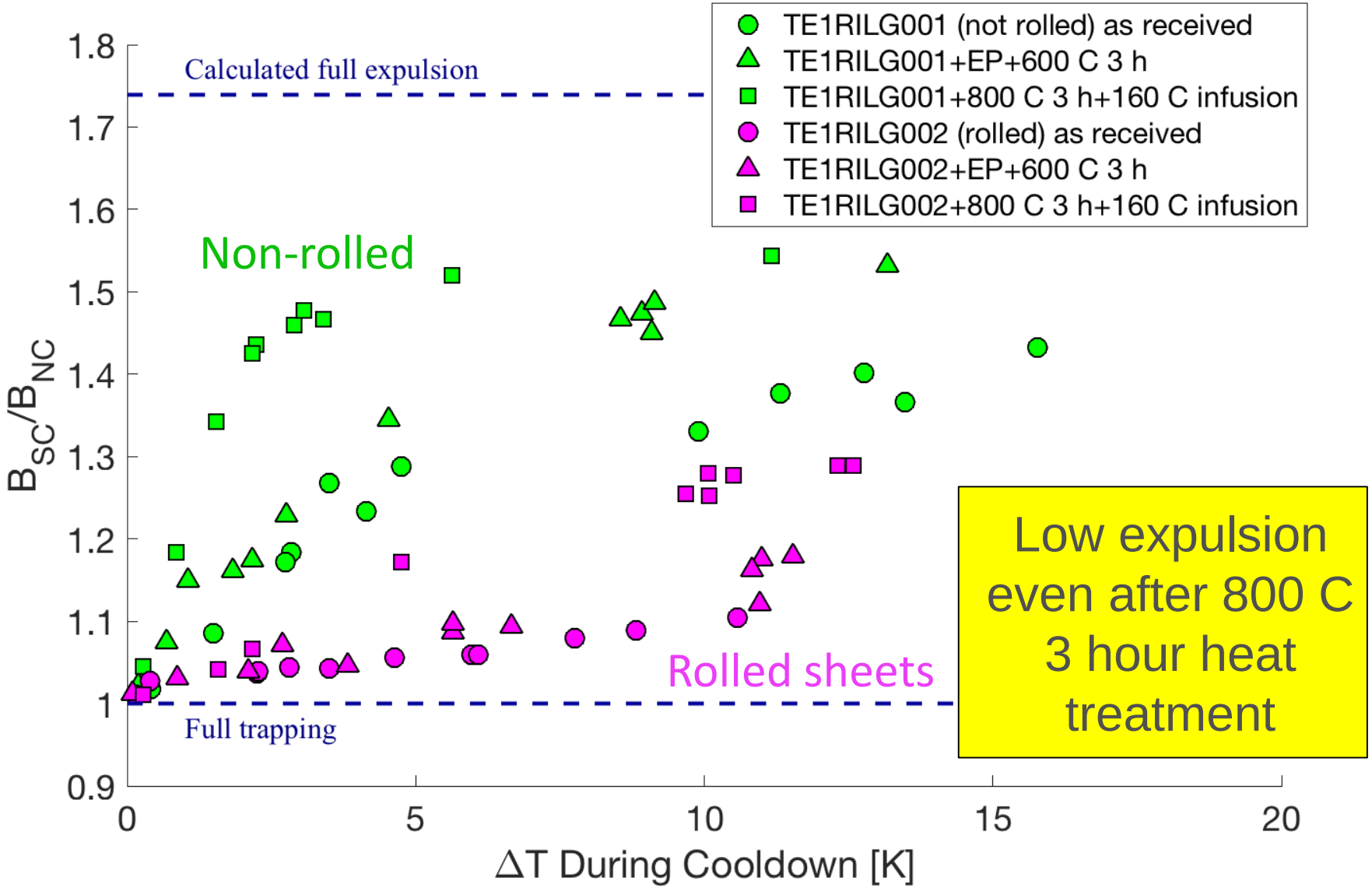


TE1RILG001
(non rolled)



TE1RILG002
(rolled)

Expulsion Measurement



Conclusions

See also P. Dhakal (JLab), TTC Topical 2017

- **Strong trapping behavior** is possible with **large grain material even after 800 C 3 hour** heat treatment, especially for rolled material
- These results contribute to a body of evidence that **cold work** in SRF-grade niobium is **crucially important to determining the flux trapping behavior**
- Implicates rolling steps in producing material that requires very high temperature heat treatment to have acceptable flux expulsion
- Further motivate studies of dislocations in strongly trapping material