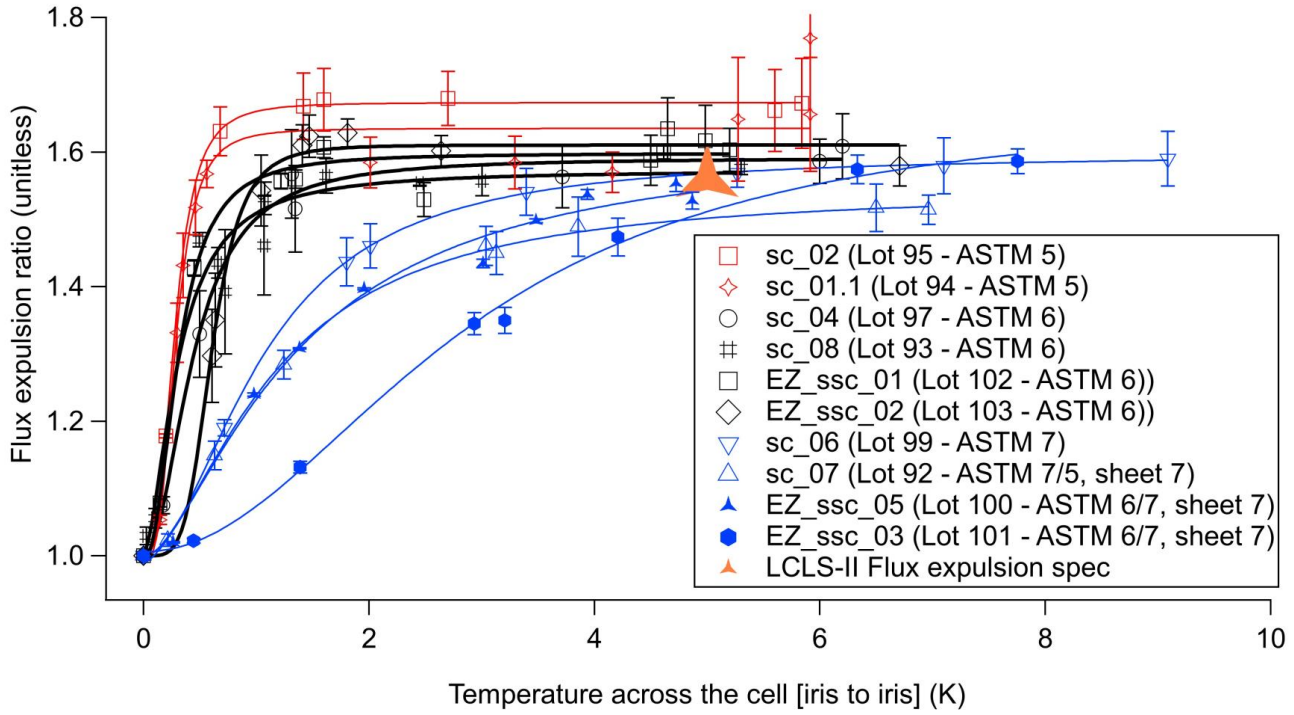
LCLS-II materials studies: flux expulsion of Tokyo Denkai Co., Ltd. niobium

Ari D. Palczewski

SRF Staff Scientist

ari@jlab.org



TTC/ARIES topical workshop on flux trapping and magnetic shielding

November 8 – 9, 2018

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

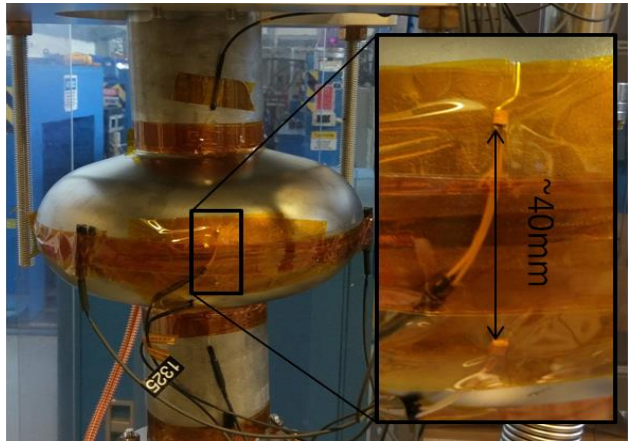
JSA

Outline

- Flux expulsion setup JLab
- History
- LCLS-II material batch sorting
- Flux expulsion results
- Summary

Flux expulsion – Definition and Example

Niobium cavity sensors



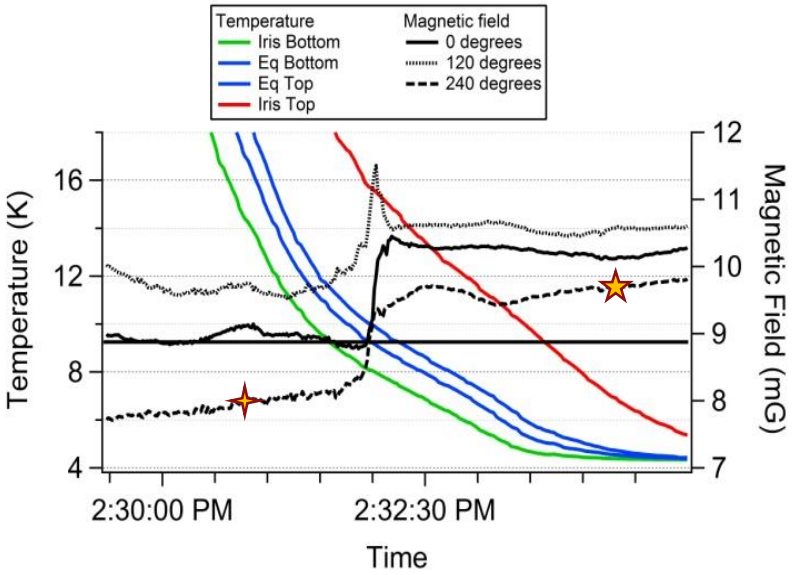
4 calibrated Cernox

- Upper iris
- 20mm above the equator
- 20mm below the equator
- Lower iris

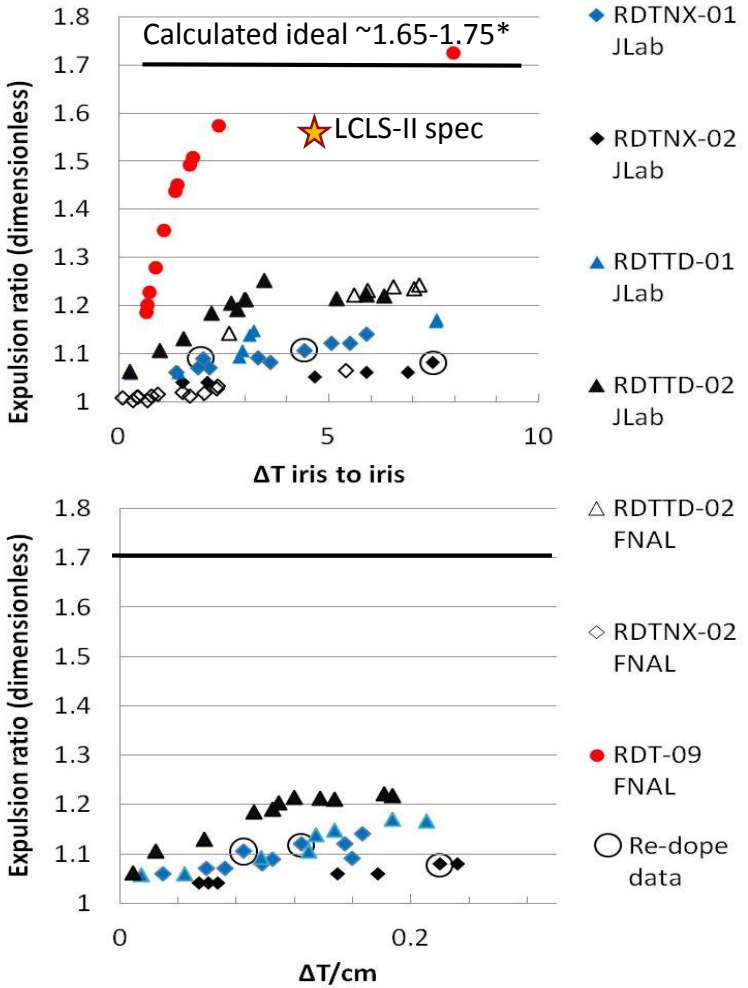
3 calibrated fluxgate magnetometers

- All on equator
- All aligned axially to the cavity
- Each 120 degrees apart

Cool down curve



$$Flux\ expulsion\ rato = \frac{magetic\ field\ above\ Tc}{magnetic\ field\ below\ Tc}$$

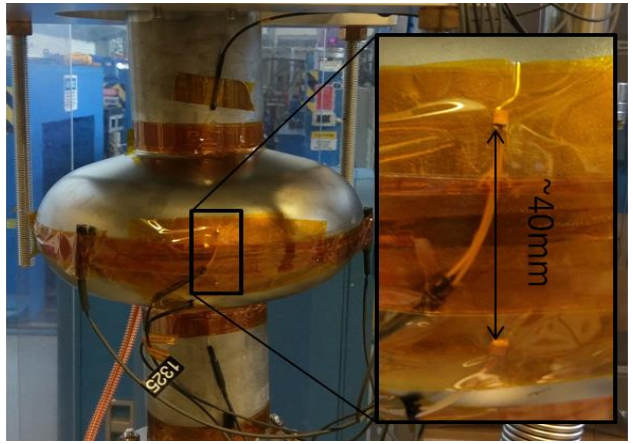


*S. Posen http://lss.fnal.gov/archive/2016/conf/fermilab-conf-16-367-td.pdf

Jefferson Lab

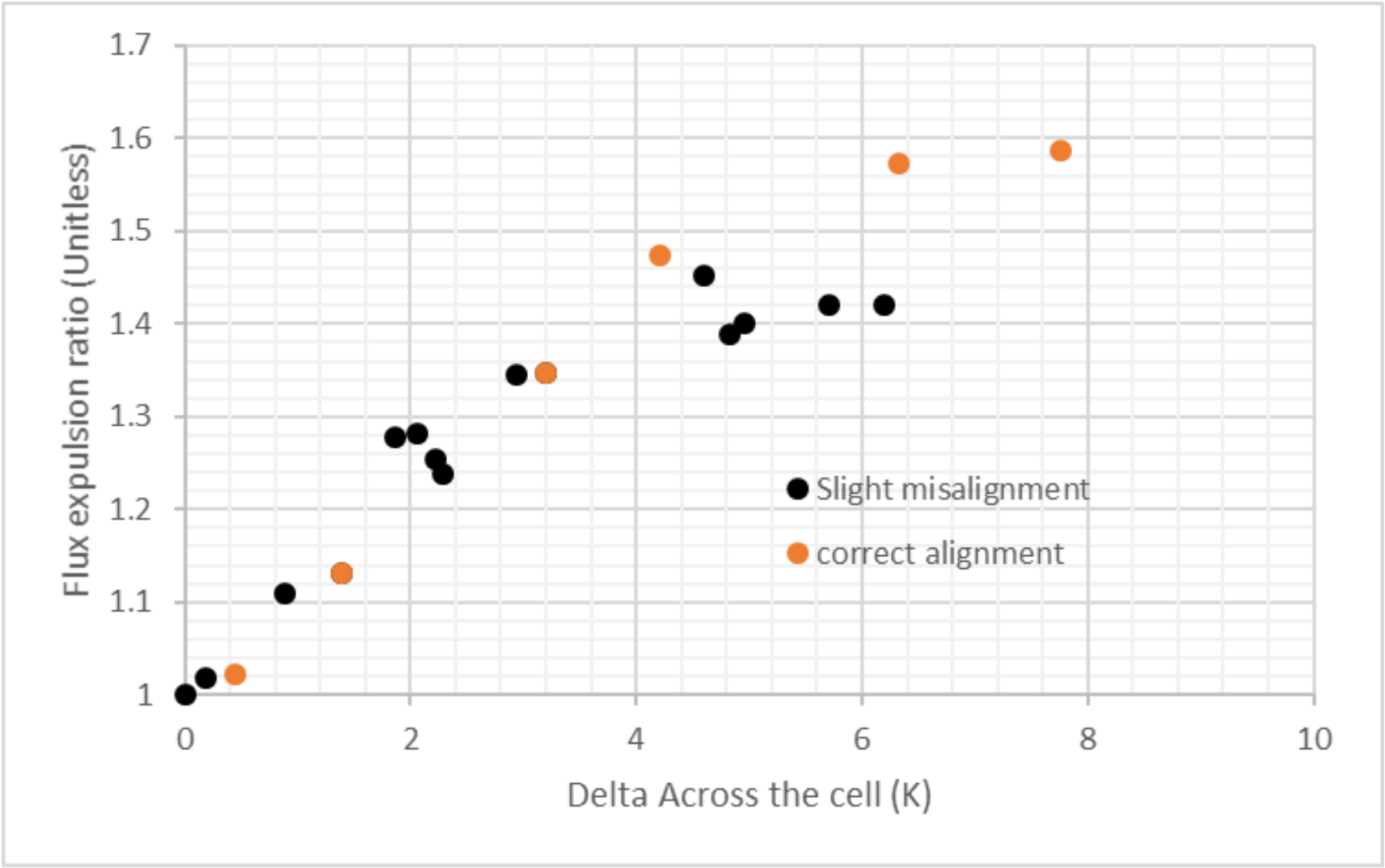
Issues with thermal currents and misalignment with our setup

Niobium cavity sensors



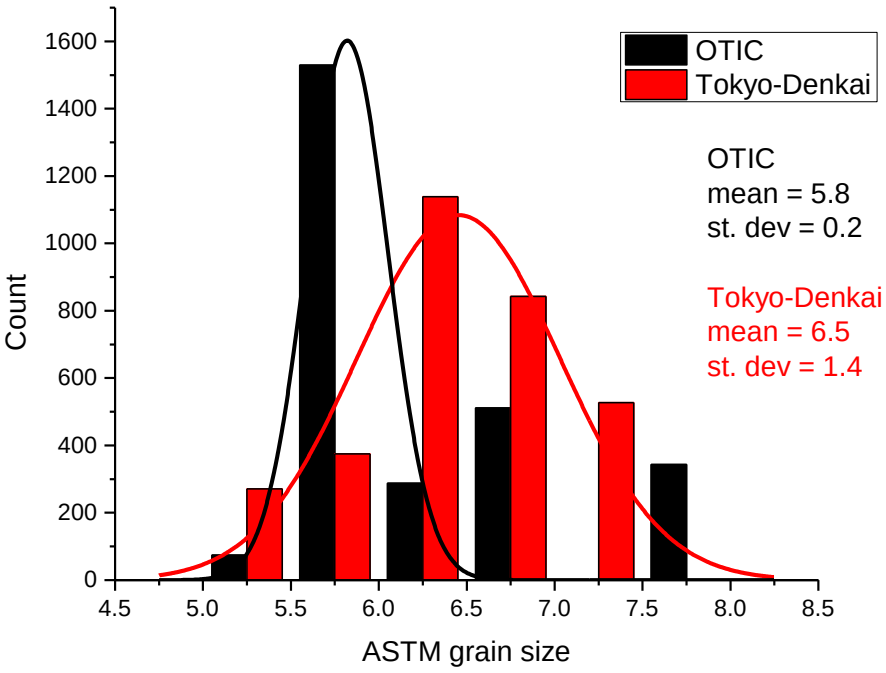
We use full Dewar compensation coils outside the vacuum shield.

If the cavity or sensors are slightly misaligned to the axis of the coils – errors occur especially at high thermal gradients



LCLS-II material studies

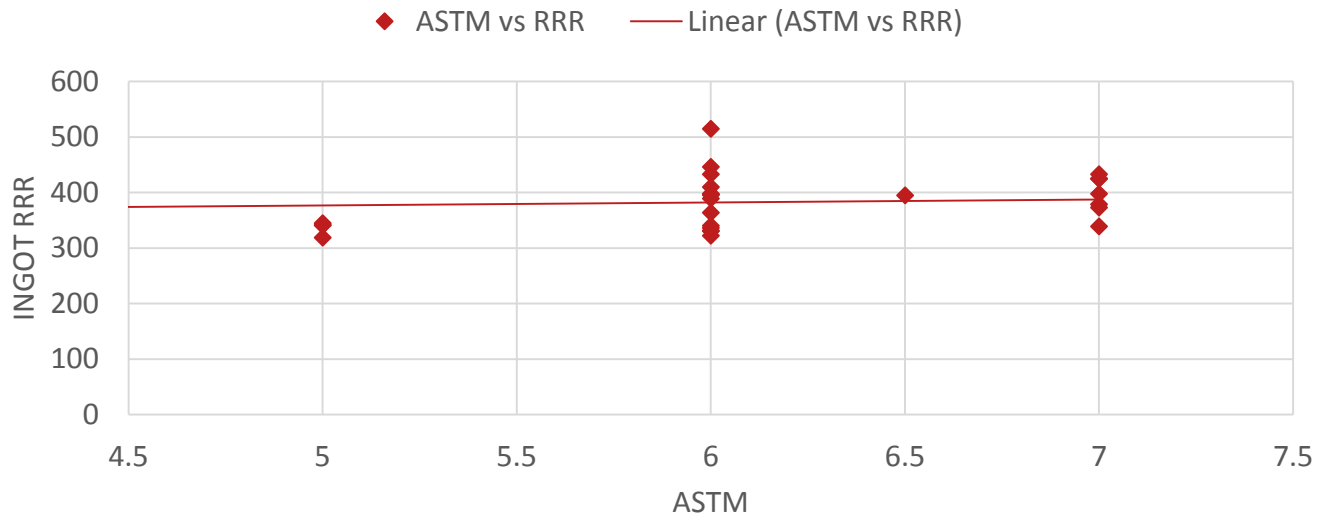
- 2015/2016 – Flux expulsion in niobium cavities began to be investigated after a failure to get high Qo after doping – initial research done at FNAL.
- LCLS-II niobium flux expulsion effort initialed at JLab along with FNAL – rapid manufacturing of 8 single cell initiated at JLab made out of select batches of production niobium in parallel with production of the 9 cells at the two cavity manufactures Zanon (Italy) and Research Instruments (Germany).
- 4 unique recipes developed depending on where the niobium was manufactured and the initial crystal structure.
- Replacement new material from the higher performing niobium supplier (Tokyo Denkai) was ordered as contingency if the recipes above failed.
- 64 new cavities order – to be made from new material.
- A single cell for each ingot lot of the new material produced to validate every batch of 9 cells – 13 single cells needed for 64 - 9 cells - data analysis underway.
- Three single cells were damaged due to a furnace error so undressed 9 cell were RF tested to validate the lot instead (data not shown).



Plot buy Gigi Ciovati - JLab

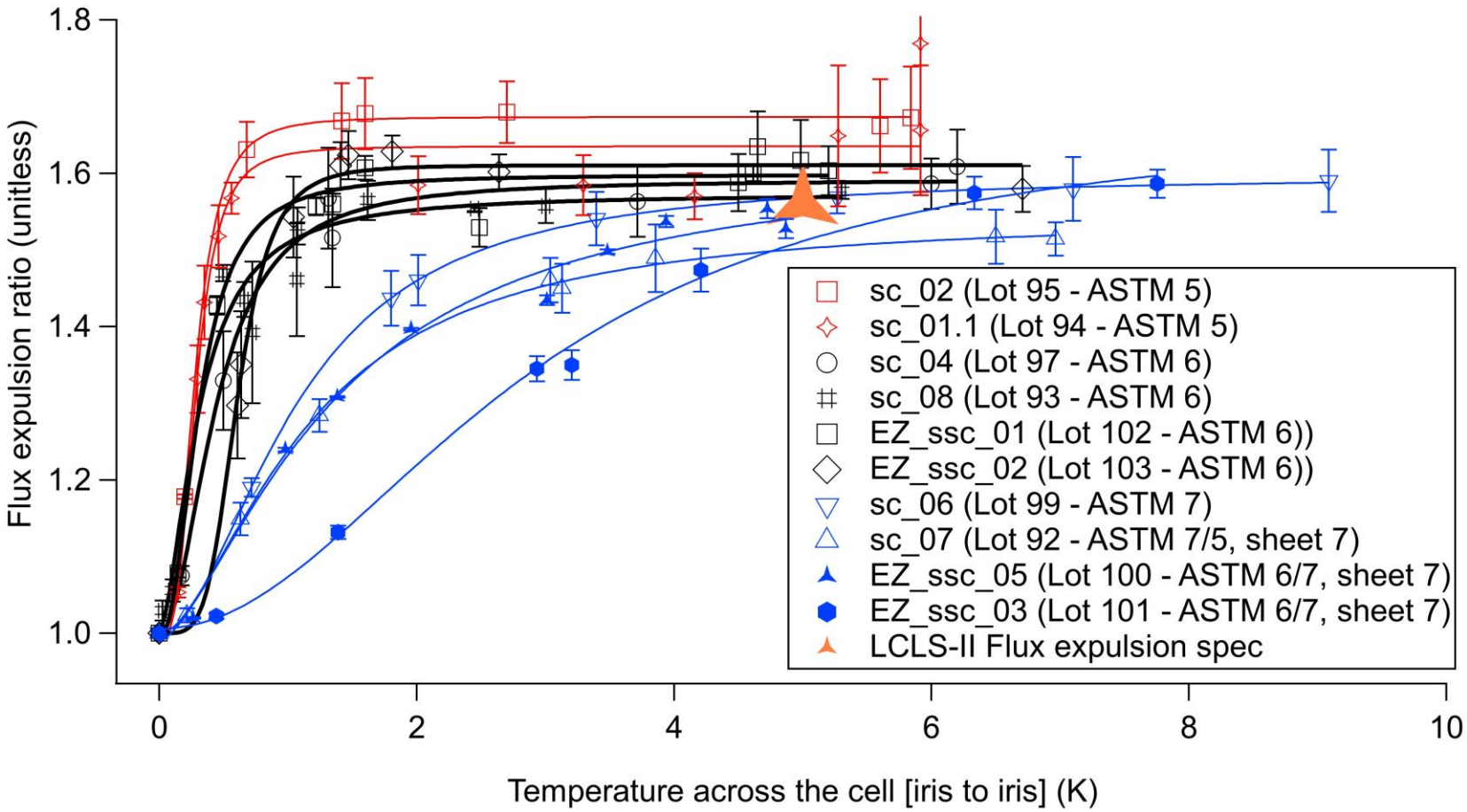
Lot validation single cells for new LCLS-2 - 9 cells

- Sort every production sheet into heat lot (containing 2 ingots).
- Pull 2 random sheets from each heat lot from the highest ASTM ingot and make into a single cell.
- Pure 9 cell cavities must be made, no mixing of lot sheet until the very end
- No 9 cell can be heat treated until the single cell from the lot is validated to clear to lots.
- Lot that are questionable will be heat treated at 925°C, or 950°C depending on the performance. 950°C heat treatment requires the single cell to fail after an additional heat treatment 925°C



annealing lot	lot	ingot	ingot RRR	astm
HT9-1052	99	NC-2107	425	7
		NC-2108	389	6
HT9-1065	100	NC-2124	399	na
		NC-2125	395	6,7
HT9-1074	101	NC-2126	446	6
		NC-2143	373	7
HT9-1081	102	NC-2150	340	6,6
		NC-2151	339	na
HT9-1093	103	NC-2152	364	6
		NC-2155	336	6
HT9-1101	104	NC-2159	410	6
		NC-2145	433	7
TH9-1002	94	NC-2075	339	7
		NC-2085	345	5
HT9-1012	95	NC-2086	319	5
		NC-2137	341	5
HT9-1013	96	NC-2087	322	6
		NC-2137	341	5
HT9-1025	97	NC-2092	331	6
		NC-2099	396	6
HT9-1046	98	NC-2092	331	6
		NC-2099	396	6
HT9-1052	99	NC-2107	425	7
		NC-2100	398	7
HT9-773	92	NC-2096	379	7
		NC-2100	398	6
HT9-982	93	NC-2060	433	6
		NC-2135	515	6

Flux expulsion of new material – Tokyo Denkai niobium cavities all @ 900°C 3 hours



Red – ASTM 5
Black - ASTM 6
Blue - ASTM 7

LCLS-II specification comes from the cooldown and magnetic field specification for the cryomodules

- Lot 92 ASTM 7 ingot lot temperature raised to 950°C, ASTM 5 ingot left at 900°C Time allowed extra sorting to pure ingots within lots
- Lot 99 left alone with knowledge it will just meet the specification
- Lot 100 raised to 925° as it is a mixed lot
- Lot 101 – EZ_SSC_03 - will be heat treated at 925°C and re-evaluated

Summary

- Unprecedented levels of material analysis through batch test cavities are underway to ensure LCLS-II 9-cells cavities have the highest possible operating Q0, even with non-optimal cryomodule cool downs i.e. 2K delta.
- The data suggests TD material at the ASTM 7 is incompatible with optimal flux expulsion performance with a 900°C heat treatment.
- TD ASTM 5 material gives by far the best performance with almost 100% flux expulsion with almost no thermal gradient.

Work in this presentation finically supported by the DOE and LCLS-II project. All work Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177