



Laboratoire de
Supraconductivité et
Magnétisme

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Quench detection and protection of REBCO magnets: can the CFD concept help?

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SMP Technical Meeting, December 13th, 2022



TIMELINE OF C. LACROIX AND F. SIROIS AT LBL



Christian Lacroix: **from Dec. 1st to Dec. 23rd**

Main topics of interest (jointly with F. Sirois):

- Discuss and learn about quench protection techniques for future HTS magnets (X. Wang, M. Marchevsky, ...)
- Learn about experimental capabilities of LBL regarding quench protection and cable fabrication
- Plan joint projects about testing the **current flow diverter** (CFD) concept for DC cable quench protection



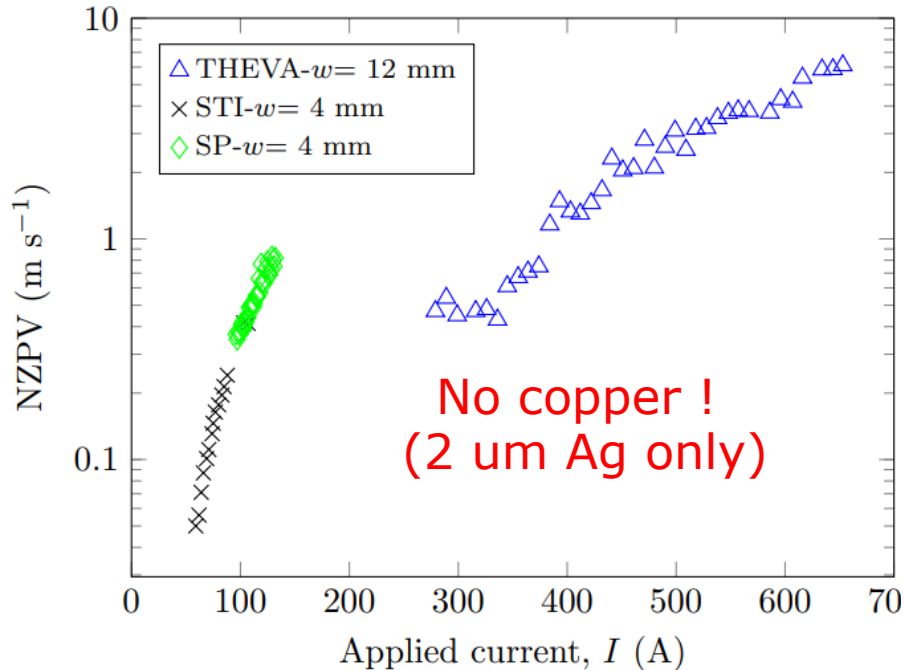
Frédéric Sirois: **from Nov. 28th to Feb. 7th**

Main topics of interest (in addition to above):

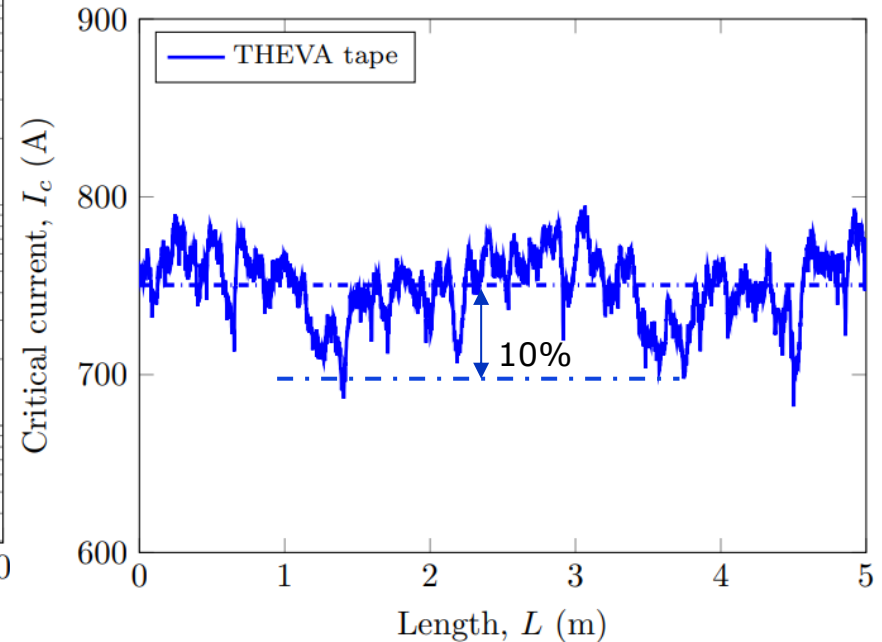
- Discuss and learn about internal modeling efforts and tools at LBL (C. Messe, L. Brouwer, ...)
- Jointly develop code and algorithms specialized for HTS magnets
- Prepare the hosting of a Canadian Ph.D. student (Gregory Giard) next January

CHALLENGES WITH REBCO TAPES

Low NZPV values
 → Measurements at 77 K, self-field



Longitudinal fluctuations of I_c (10-20%)
 → Measurements on Theva tapes



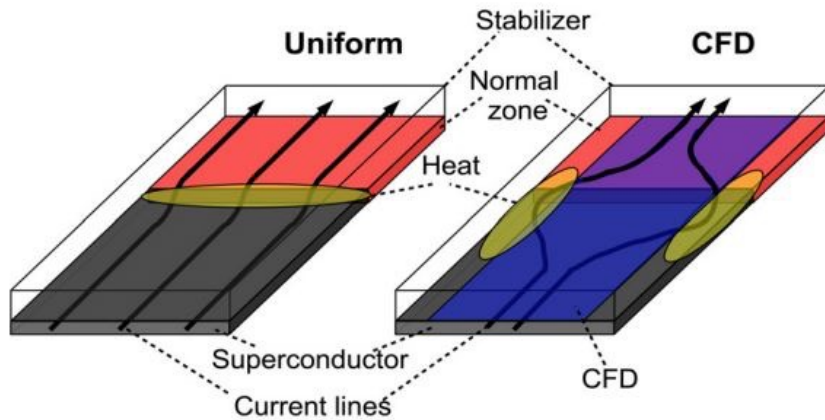
Hot spots can be destructive if quench is not rapidly detected

Conventional voltage detection schemes in magnets: **50-500 mV¹**

Potential solution: increase the NZPV of REBCO tapes

¹Marchevsky, M. *3rd Workshop Accelerator Magnets HTS(2015)*

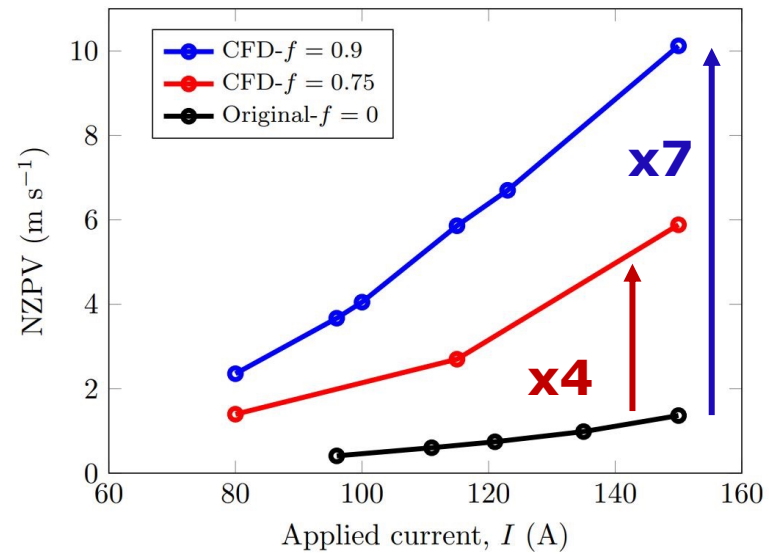
CURRENT FLOW DIVERTER (CFD) CONCEPT



Lacroix et al. SUST 27, 035003 (2014)
 US Patent: Lacroix et al. US9029296B2

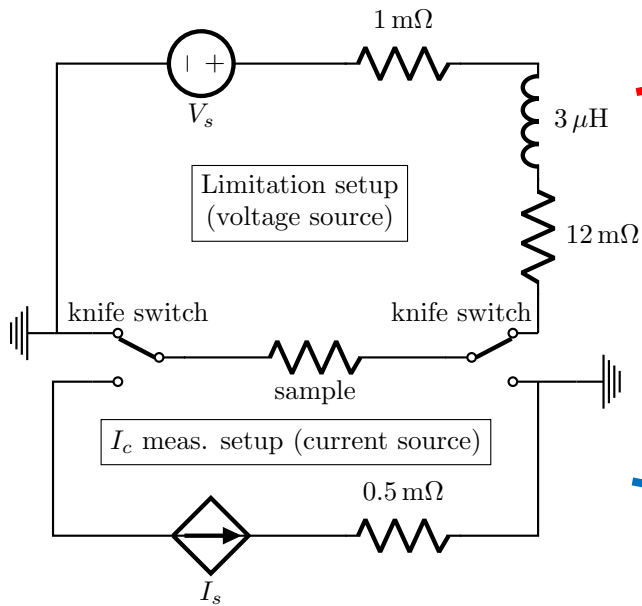
$$f = \frac{\text{Width of the CFD layer}}{\text{Width of the tape}}$$

NZPV obtained at 77 K and in self field

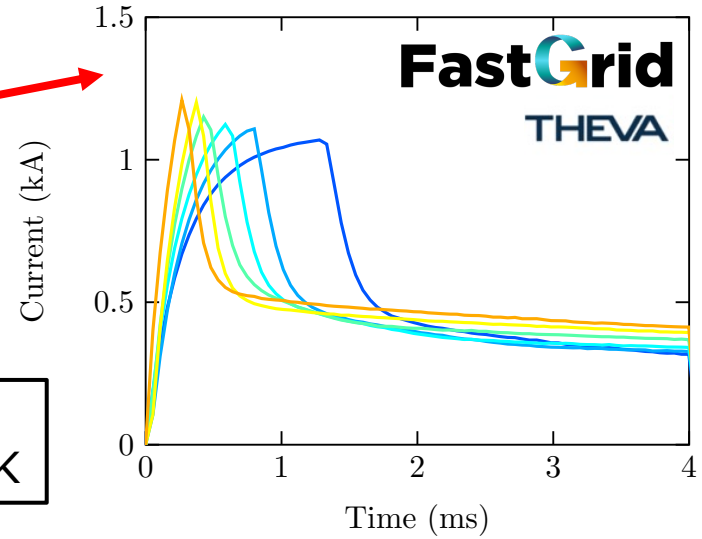


UNIQUE MEASUREMENT SYSTEMS FOR HTS TAPES

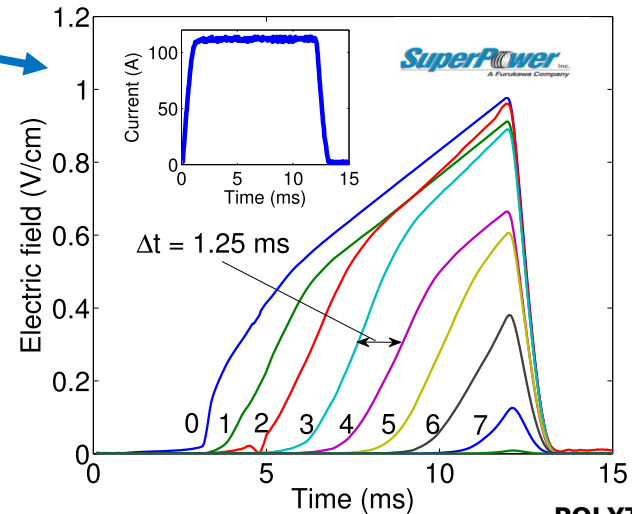
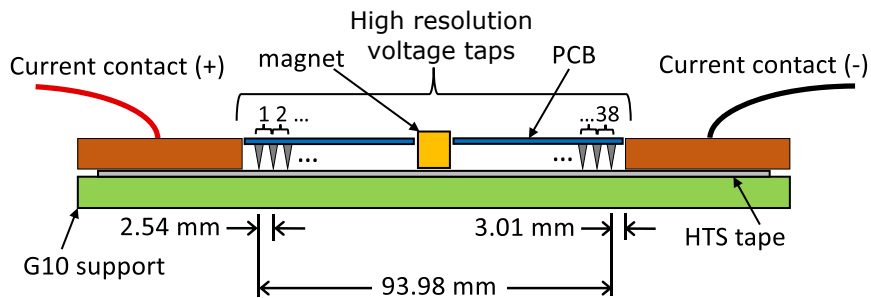
Circuit for current limitation tests



Temperature range = 63-77 K



Circuit for I_c and NZPV meas.



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METER-SCALE CFD REBCO TAPES

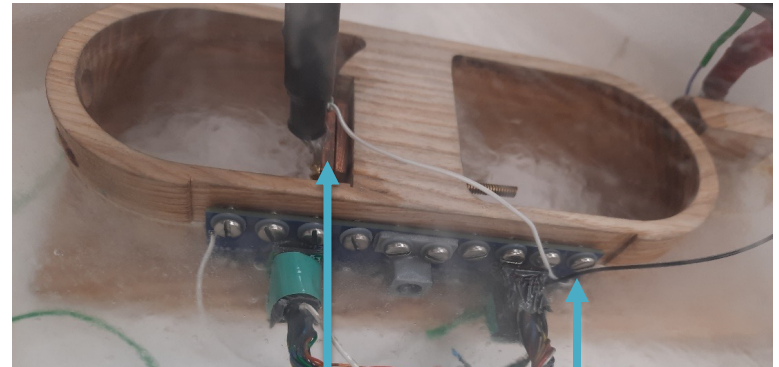
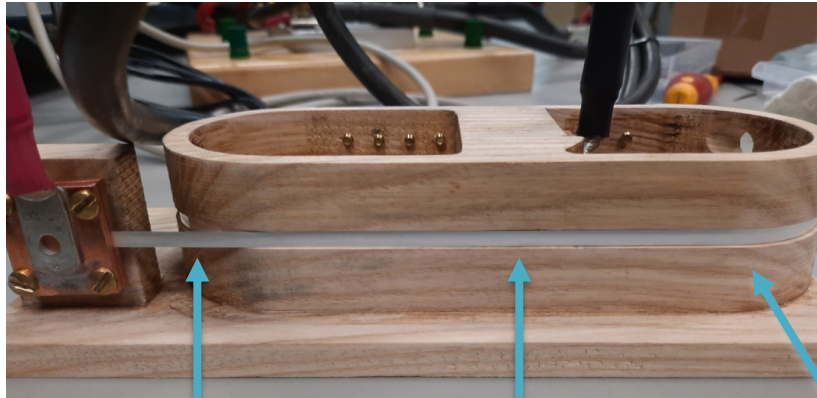


Manufacturer	THEVA	STI	SP
Substrate thickness (μm)	97	50	50
Buffer layers thickness (μm)	3.1	0.58-0.78	1.5
REBCO thickness (μm)	3.1	0.8	1
Silver thickness (μm)	2 surrounding	2 on top	2 surrounding
Width (cm)	1.2	0.4	0.4
Length (cm)	74	74	50
Critical current (A)	756	94	160

Actual fabrication capabilities: CFD tapes up to 5 m (4 mm wide)



VERY SIMPLE ONE-TURN COIL WITH CFD TAPE



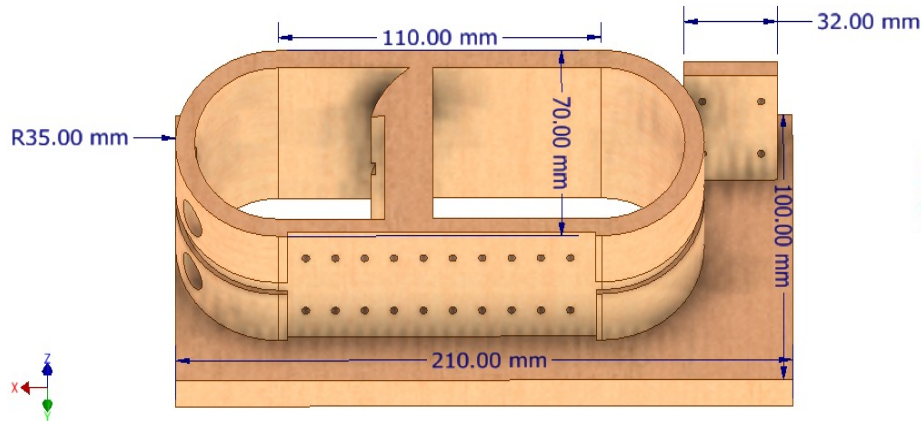
Current contact (+)

REBCO tape

Coil support

Current contact (-)

PCB

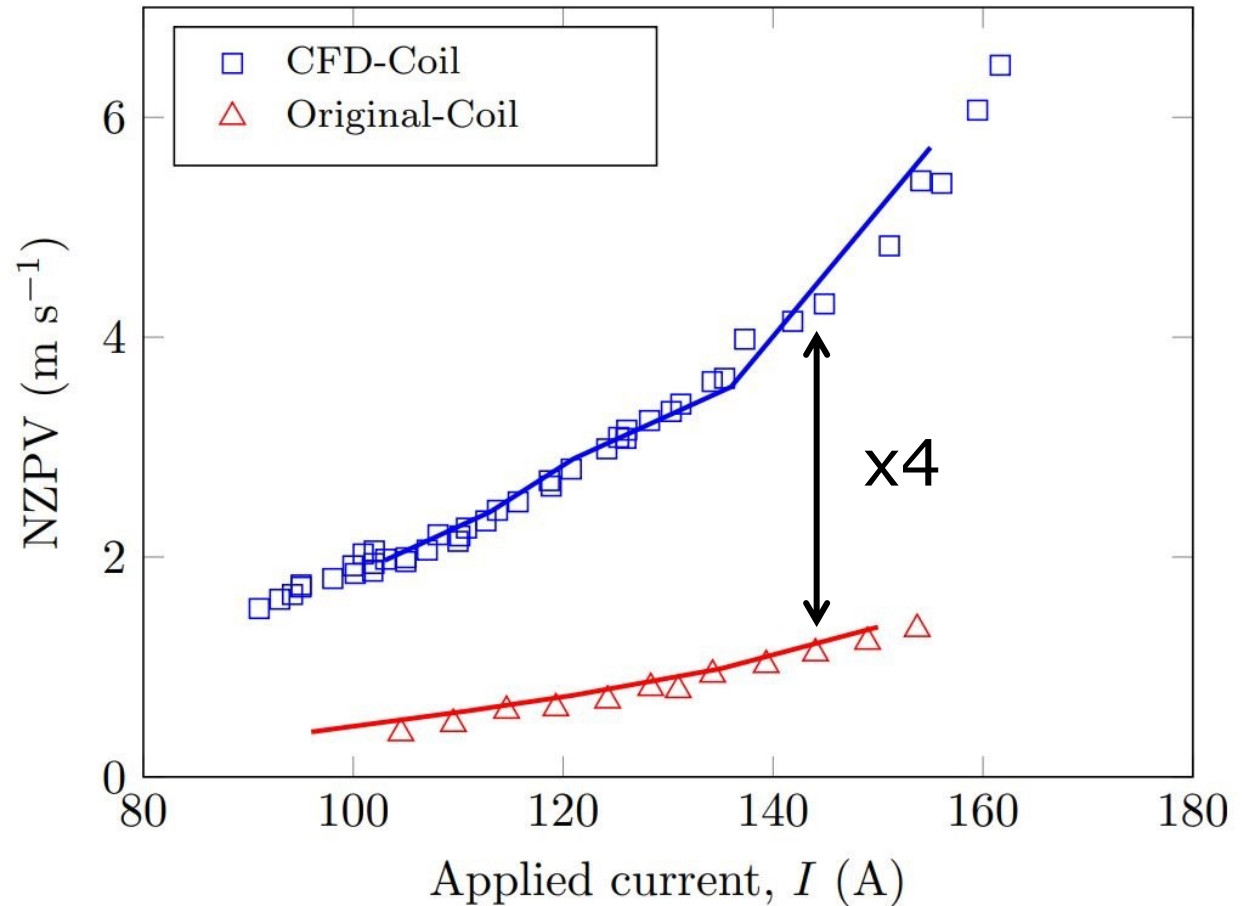


NZPV MEASUREMENTS (77 K, SELF-FIELD)

Symbols: experiments

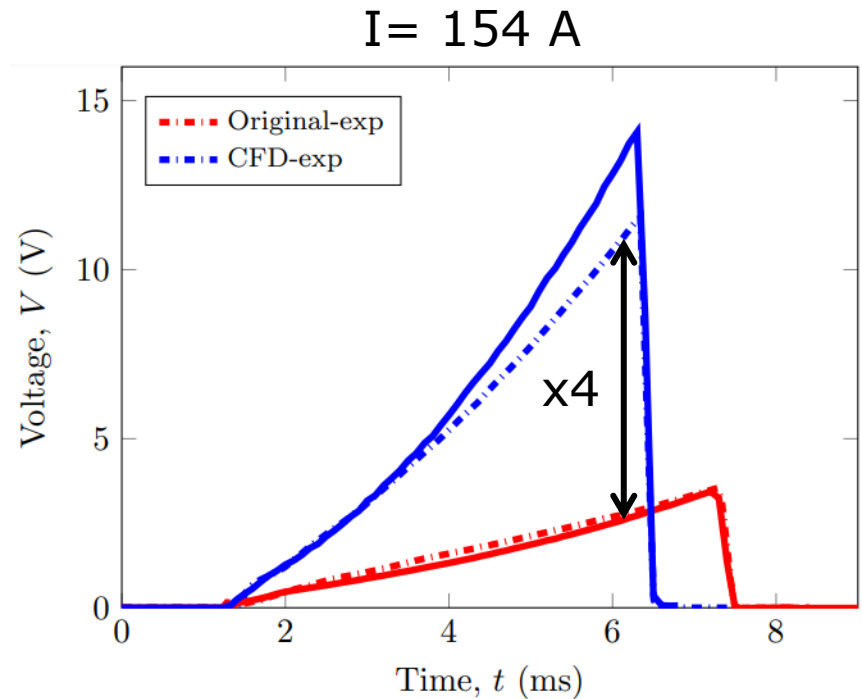
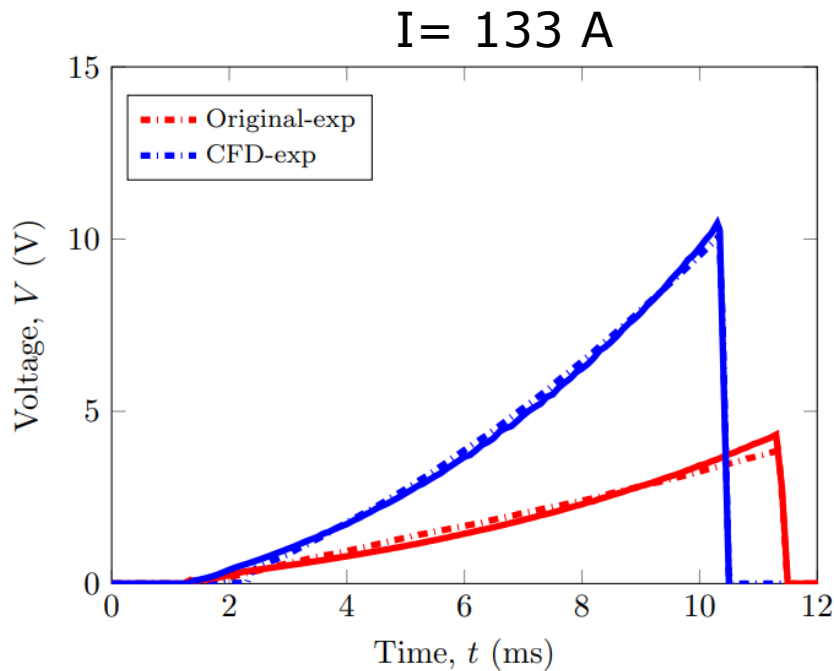
Lines: simulations

**CFD coverage
fraction = 0.77**



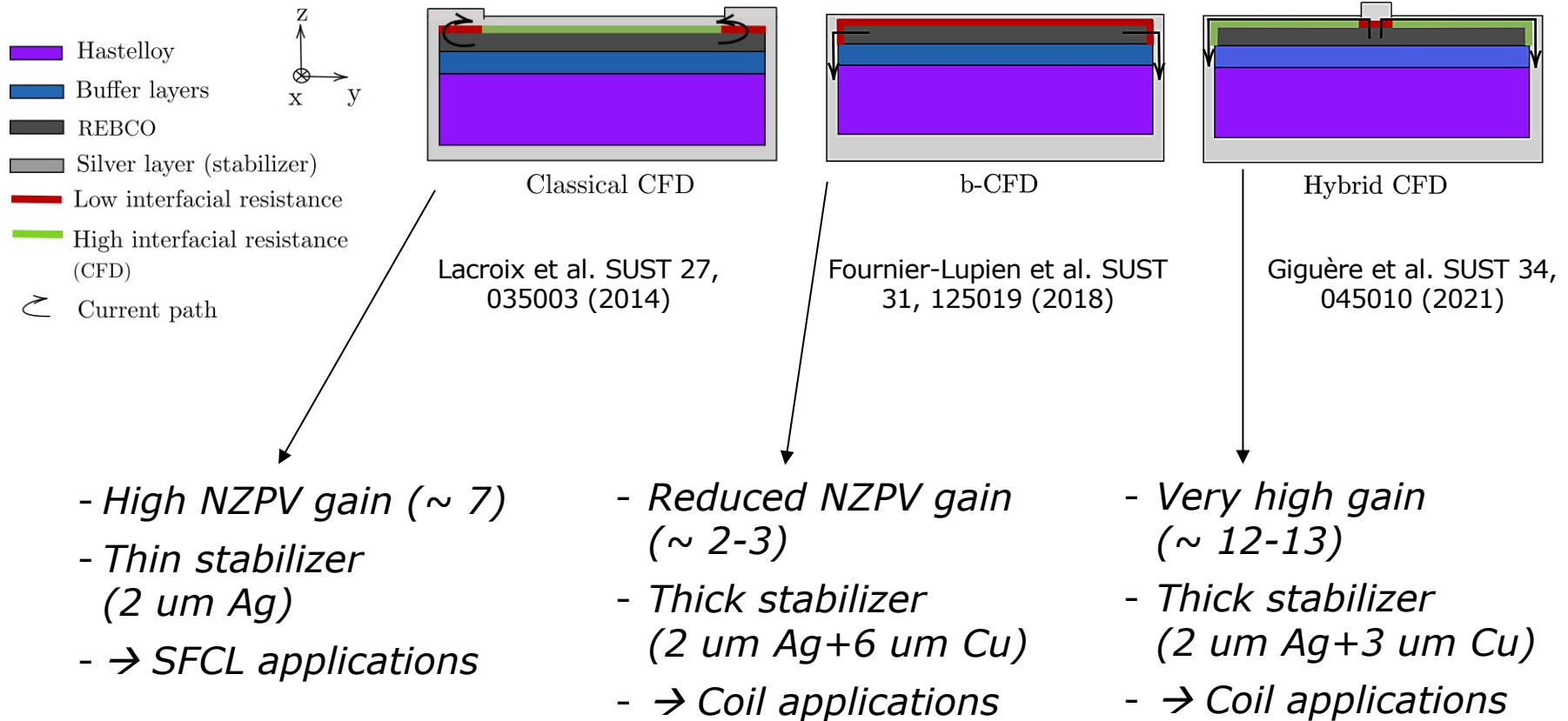
NZPV MEASUREMENTS (77 K, SELF-FIELD)

$I_c = 160 \text{ A}$



$$\frac{\text{NZPV}_{\text{CFD}}}{\text{NZPV}_{\text{Original}}} = \frac{V_{\text{CFD}}}{V_{\text{Original}}}$$

ALTERNATIVE CFD ARCHITECTURES



CFD FOR MAGNET APPLICATIONS: CAN IT HELP FOR QUENCH DETECTION AND PROTECTION ?

- Do cables with CFD tapes have higher NZPV?
- Does CFD help in pre-quench regime?
- Does high NZPV provide benefits with novel detection schemes? (magnetic field / acoustic / fiber optic detection / ...)

Open questions about quench in HTS magnets:

- Quench definition: 1) When voltage rises sharply (thermal instability)? 2) When hot spot reaches T_c ? 3) ...
- Pre-quench regime: voltage rises?
- What temperature elevation would be acceptable after quench?
- What thickness of Cu stabilizer would be needed on REBCO tapes (to sustain magnet discharge)?
- Can we accept a reduction of the minimum quench energy (MQE) in HTS magnets?

EXPERIMENTS PROPOSED TO ANSWER QUESTIONS

- Do cables with CFD tapes have higher NZPV ?
 - dV/dt measured during quench and NZPV measured on CFD CORC cables at 77 K, self-field (Polytechnique)
 - dV/dt measured during quench on CFD CORC cables at 4.2 K in magnetic field (several tesla)? (LBL) **2 mm wide CFD tape required**
- Does CFD help in pre-quench regime?
 - dV/dt measured on single CFD tape at 4.2 K in field (several tesla)? (LBL)
- Benefits of higher NZPV with novel detection schemes?
 - Test some of Maxim's novel quench detection schemes on single CFD tapes and CFD CORC cables (@77 K? In field?)

CORC cables to be fabricated in the short term (ongoing):

- 2 layers, 2 standard tapes (4 mm wide) per layer (insulated and non-insul. core)
- 2 layers, 2 CFD tapes (4 mm wide) per layer (insulated and non-insul. core)