



# **US LHC Accelerator Research Program**

***bnl - fnal- lbnl - slac***

LARP Collaboration Meeting 13

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## **Cable Insulation**

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## Outline

- FNAL Investigations
  - ICMC 2007 Paper
- BNL-NEWC insulation trials
- LBNL alternatives

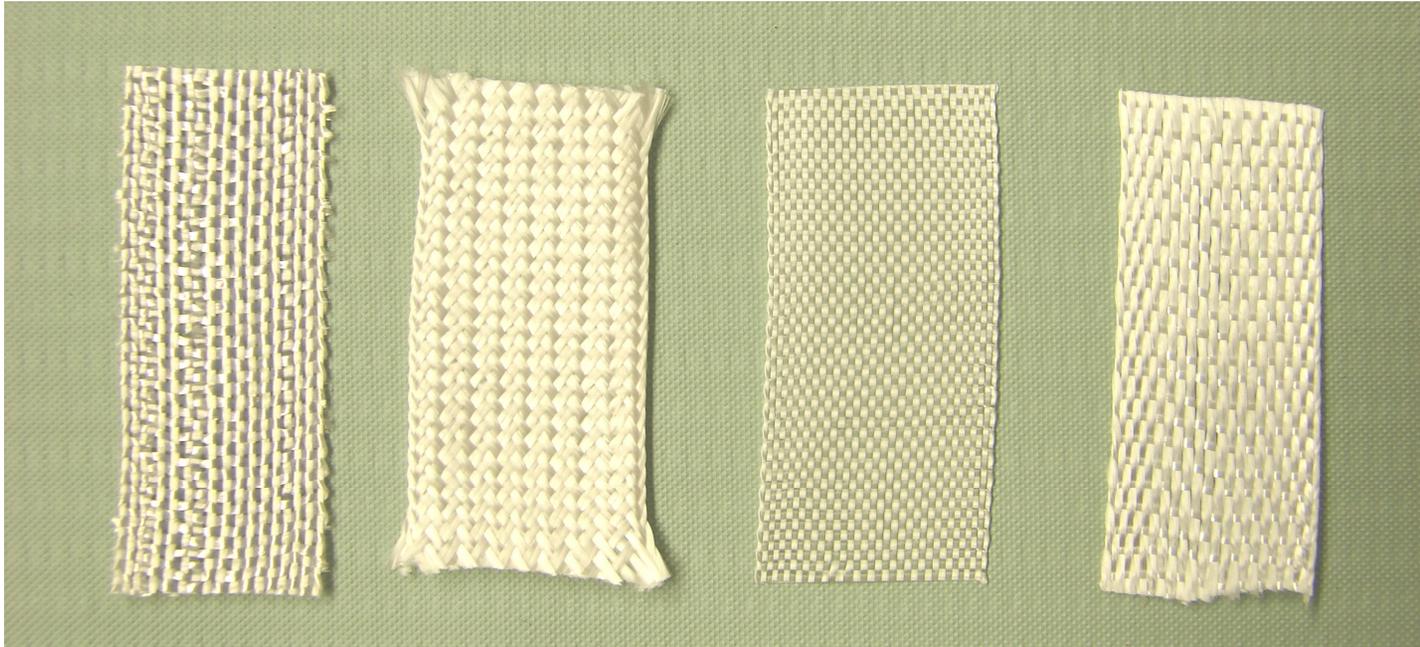


## R. Bossert et al. 2007

<b>Material</b>	<b>Insulation</b>	<b>Cost per meter of insulation</b>	<b>Cost per meter of cable assuming 50% overlap for tape</b>
Ceramic	125 $\mu$ m thick x 13mm wide tape	\$20.00	\$72.00
S-2 glass	125 $\mu$ m thick sleeve	\$10.50	\$10.50
E-glass	75 $\mu$ m thick x 13mm wide tape.	\$0.20	\$0.72
E-glass	125 $\mu$ m thick x 13mm wide tape.	\$0.20	\$0.72
S-2/E-glass combination	125 $\mu$ m thick x 13mm wide tape.	\$6.00	\$21.60



## Types of Insulation



**125 µm ceramic tape, S-2 glass sleeve, 50 µm E-glass tape,  
and 125 µm S-2/E-glass combination tape.**



## Types of insulation tested

Material	Insulation	Wrap	Total thickness between turns
Ceramic	125 $\mu\text{m}$ thick x 13mm wide tape	50% overlap	500 $\mu\text{m}$
S-2 glass	125 $\mu\text{m}$ thick sleeve	Pulled over cable	250 $\mu\text{m}$
E-glass	50 $\mu\text{m}$ thick x 13mm wide tape.	66% overlap	300 $\mu\text{m}$
E-glass	50 $\mu\text{m}$ thick x 13mm wide tape.	50% overlap surrounded by another 50% overlap	400 $\mu\text{m}$
S-2/E-glass	125 $\mu\text{m}$ thick x 13mm wide tape.	50% overlap	500 $\mu\text{m}$



# Hi-Pot Test of 6-stack reacted/potted CDT101

Insulation system	Maximum Leakage (nA)			Mean Leakage (nA)		
	100V	200V	500V	100V	200V	500V
<b>Ceramic 50% overlap</b>	3	4	8	1	1	3
<b>S-2 glass sleeve</b>	2	6	36	2	4	15
<b>E-glass 66% overlap</b>	8	18	64	6	12	38
<b>E-glass 50% x 2 overlap</b>	7	17	52	1	4	12
<b>S-2/E-glass 50% overlap</b>	10	20	74	6	11	34



## Braiding Trial at NEWC

- ECG type FG
  - Sized with 636 binder - the binder is 60-70% starch, balance vegetable oil
  - “coning” lubrication applied when FG is packaged
    - ~90% “Severely hydro-treated naphthanic oil (cyclo-paraffin) (petroleum oil)” and ~10% “Nitrogen containing surfactant/emulsifier”
  - S2 type fiberglass without the coning oil applied during packaging, however it would have the 636 binder as well.

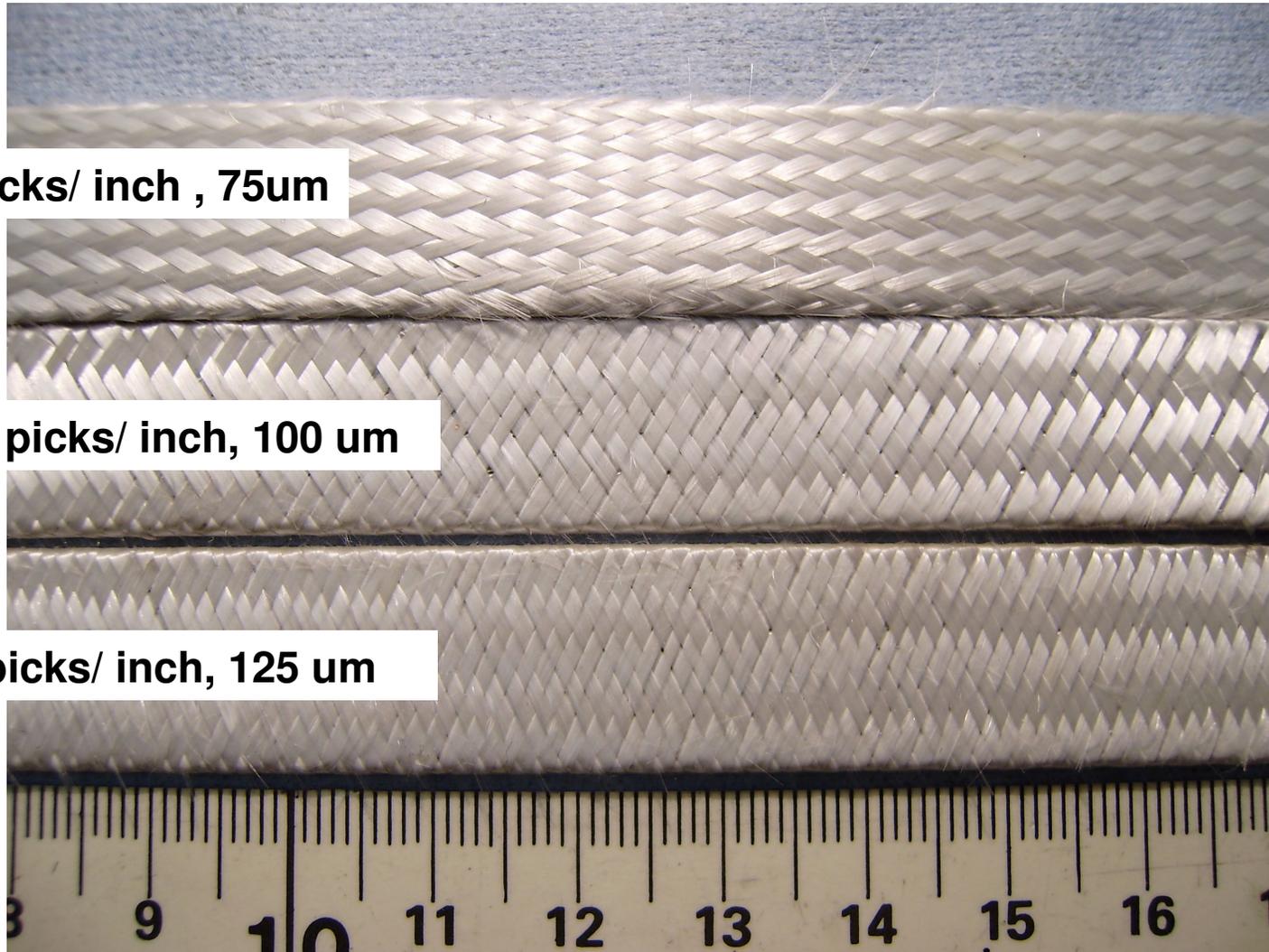


# NEWC Braiding Trials

**48 carrier, 7 picks/ inch , 75um**

**24 carrier, 15 picks/ inch, 100 um**

**24 carrier, 20 picks/ inch, 125 um**





## Follow-up of Trial run

- 12" cable samples are being reacted
- Evaluated for integrity
- Cost being developed by NEWC
- Braiding with S-2 glass



## LBL Braiding Trial

- AP Technology , Cincinnati OH
- S-2 glass with 493 sizing
- Target 100 um /side



# Braided Ceramic-Fiber Reinforcements

Proposed substitute for S2 glass

## Minimizing cost

Lower-cost fiber reinforcements for ceramic-based insulation (CTD-CF-200)

CTD-1202 ceramic binder is 70% less than previous inorganic resin system

## Improving magnet fabrication efficiency

Textiles braided directly onto Rutherford cable (eliminates taping process)

Wind-and-react, ceramic-based insulation system

## Enhancing magnet performance

Insulation thickness reduced by 50%

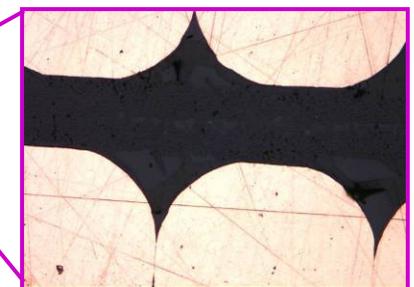
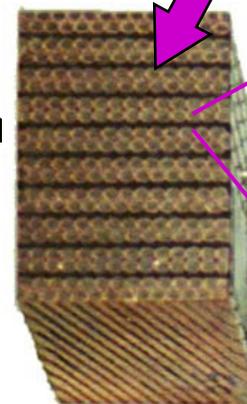
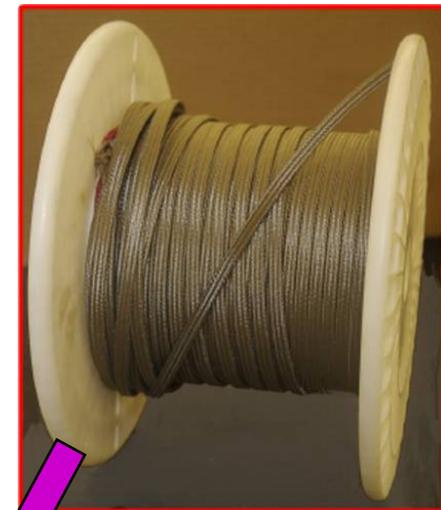
Closer spacing of conductors enables high magnetic fields

## Robust, reliable insulation

Mechanical strength and stiffness

High dielectric strength

Radiation resistance





# Enhanced Strain in Ceramic-Composite Insulation

