

## Characterization of HTS bulks

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## Outline

**Introduction**  
**Theoretical considerations**  
**Measurements**  
**Conclusion**

## New HTS bulk characterization method

- Characterization of **complete** HTS bulks

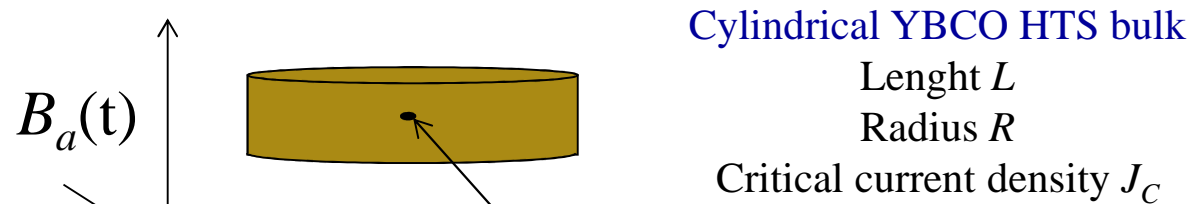
- Determination of  $J_c$  and  **$n$ -value**

$$E = E_C \left( \frac{J}{J_C} \right)^n = \frac{E_C}{J_C} \left( \frac{J}{J_C} \right)^{n-1} J$$

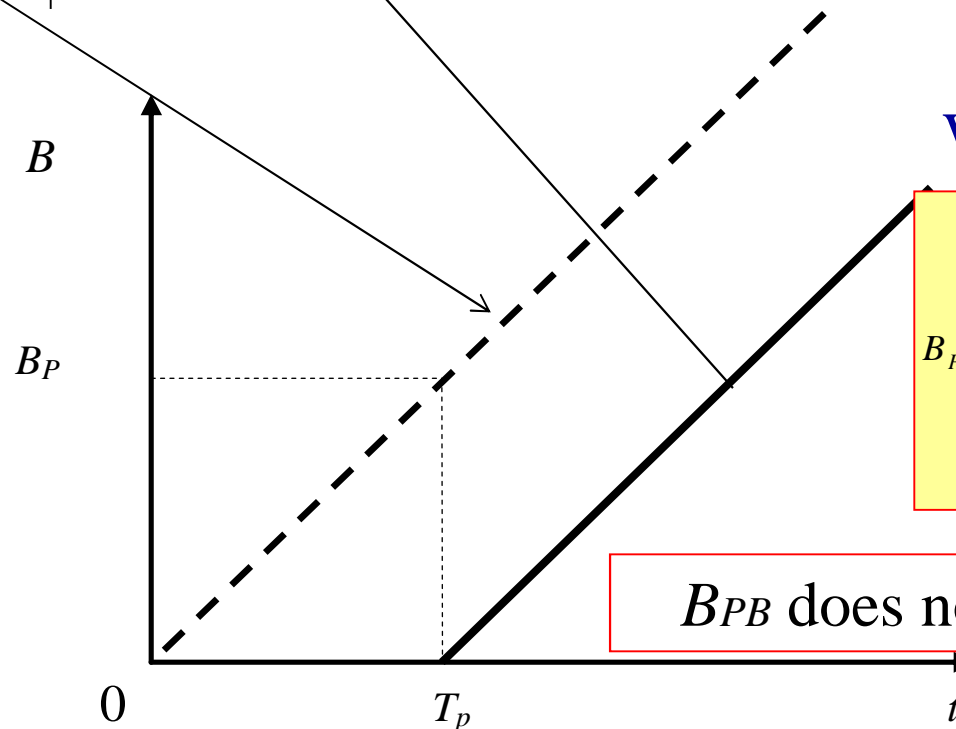
- Need for **modelling** and applications (motors, levitation...)

**=> Method using measurements and simulations**

## Complete penetration magnetic field



$$B_a(t) = V_b \cdot t$$



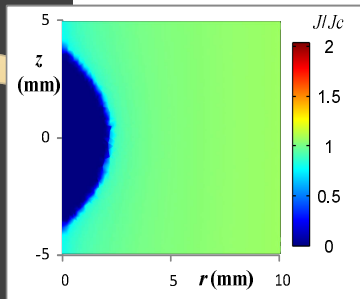
With Bean model

$$B_{PB} = \frac{\mu_0 J_C L}{4} \ln \frac{1 + \frac{R}{\sqrt{R^2 + \frac{L^2}{4}}}}{1 - \frac{R}{\sqrt{R^2 + \frac{L^2}{4}}}}$$

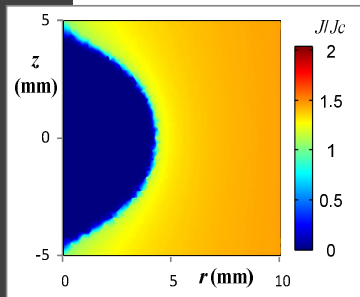
$B_{PB}$  does not depends on  $V_b$



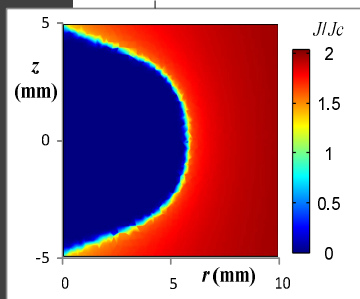
# Numerical simulation with PLM



a)  $V_b = 0.1$  T/s

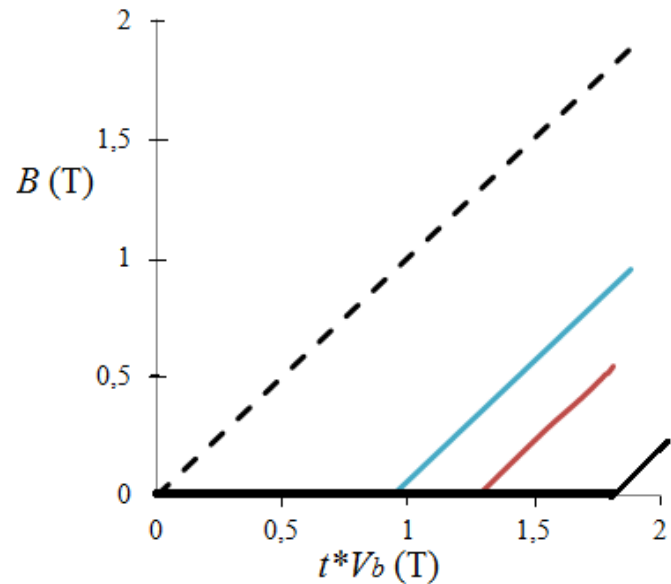


b)  $V_b = 10$  T/s



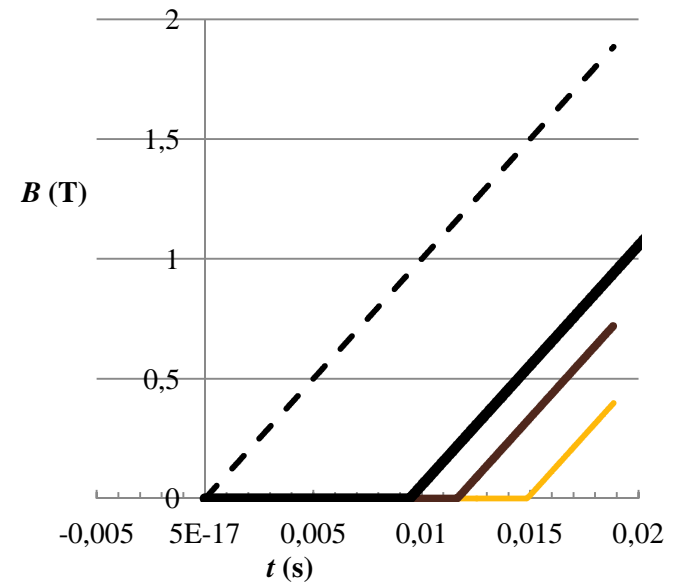
c)  $V_b = 1000$  T/s

$$E = E_C \left( \frac{J}{J_C} \right)^n = \frac{E_C}{J_C} \left( \frac{J}{J_C} \right)^{n-1} J$$



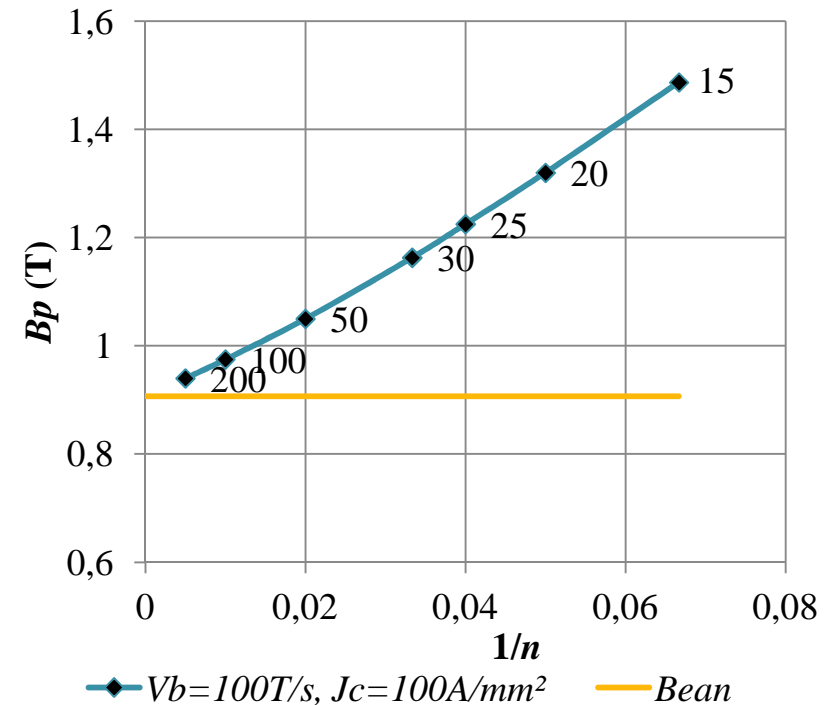
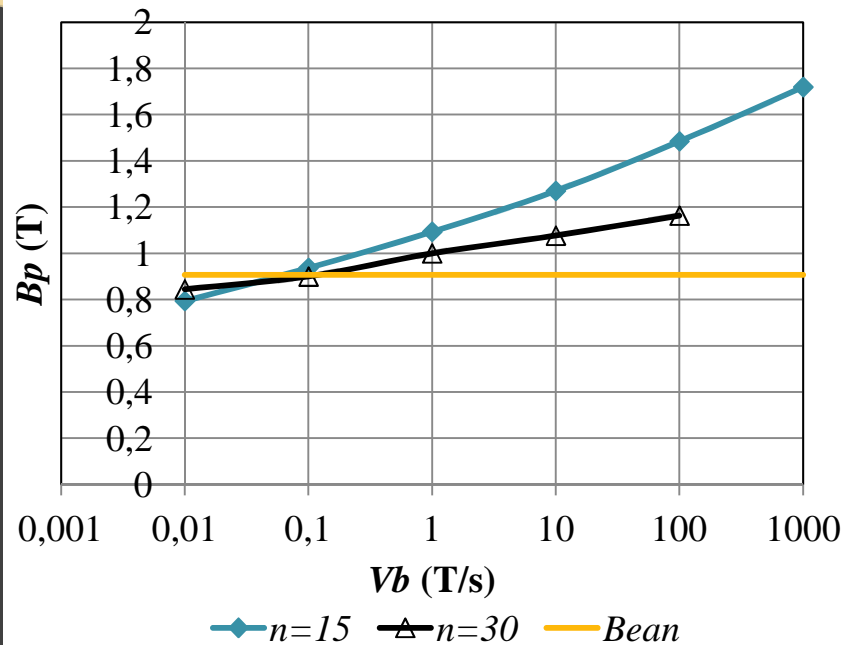
- - -  $B_a$       - - -  $V_b = 0.1$  T/s  
 - - -  $V_b = 10$  T/s      - - -  $V_b = 1000$  T/s

With constant  $J_c$  and constant  $n$ -value



- - -  $B_a(t)$       - - -  $n=15$       - - -  $n=30$       - - -  $n=200$

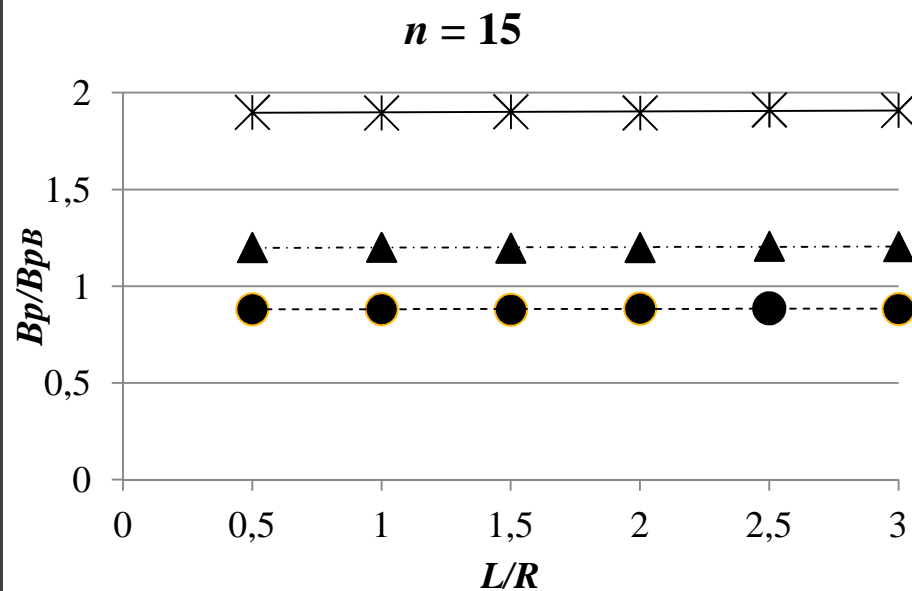
## Complete penetration field with PLM



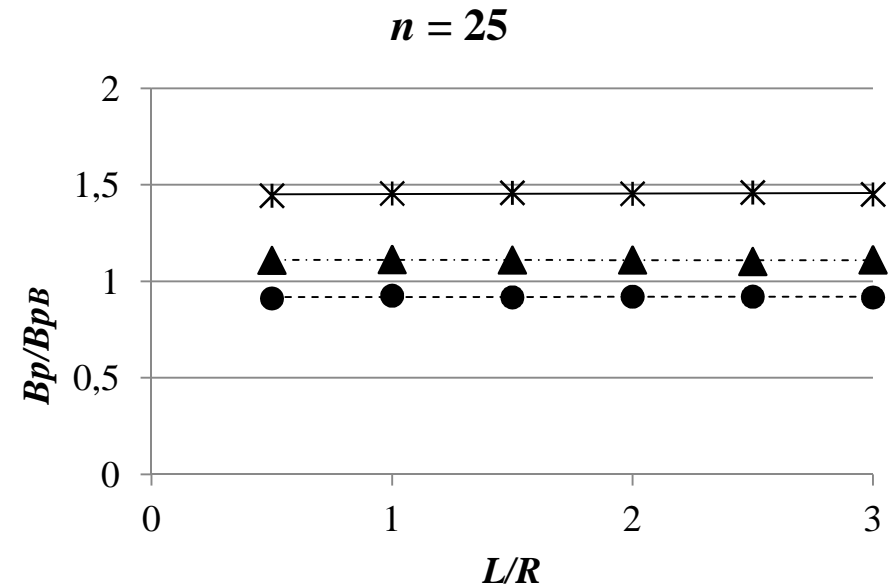
$$B_P = B_{PB} \left( 1 + \frac{\alpha \ln V_b + \beta}{n} \right)$$

For  $R = 10$  mm,  $5$  mm  $< L < 30$  mm  
 $10$  A/mm<sup>2</sup>  $< J_c < 100$  A/mm<sup>2</sup>  
 $0.01$  T/s  $< V_b < 1000$  T/s  
 $\Rightarrow \alpha = 1.2$  and  $\beta = 3.4$

## Complete penetration field with PLM



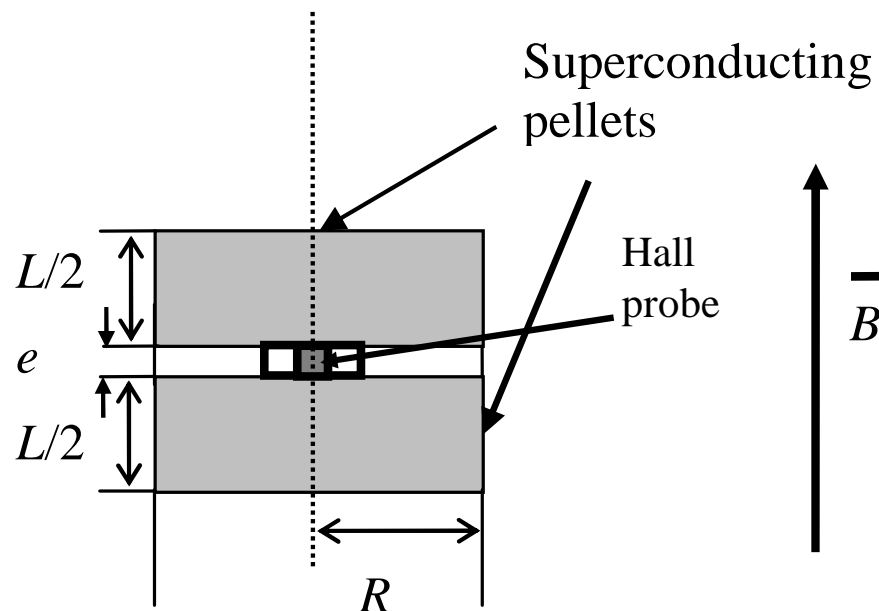
\*  $V_b=1000T/s$     ●  $V_b=0.01T/s$     ▲  $V_b=1T/s$   
 — 1000T/s    - - - - 0.01T/s    - · - · - 1T/s



\*  $V_b=1000T/s$     ▲  $V_b=1T/s$     ●  $V_b=0.01T/s$   
 — 1000T/s    - - - - 1T/s    - - - - 0.01T/s

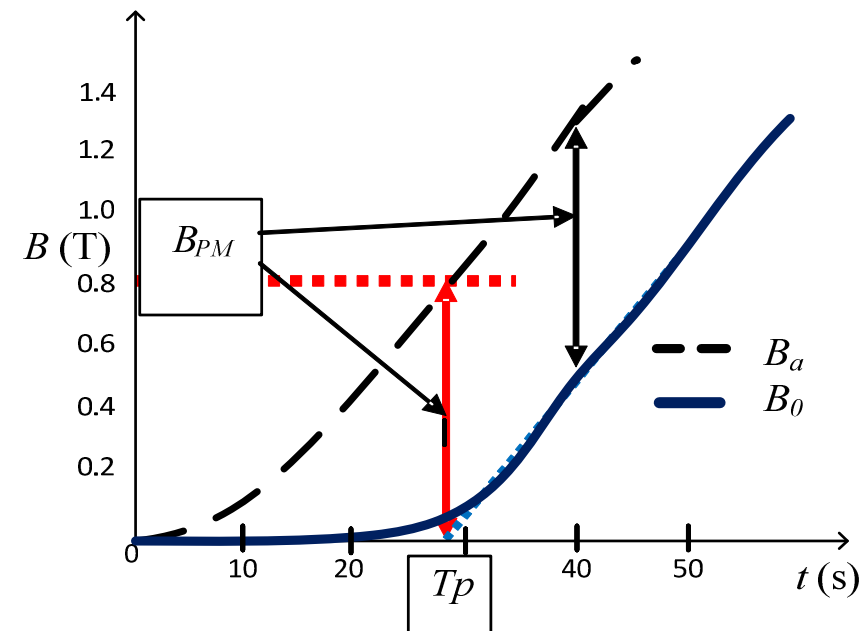
$$\frac{B_P}{B_{PB}} = 1 + \frac{\alpha \ln V_b + \beta}{n}$$

## Determination of $n$ -value from $B_P$ measurement

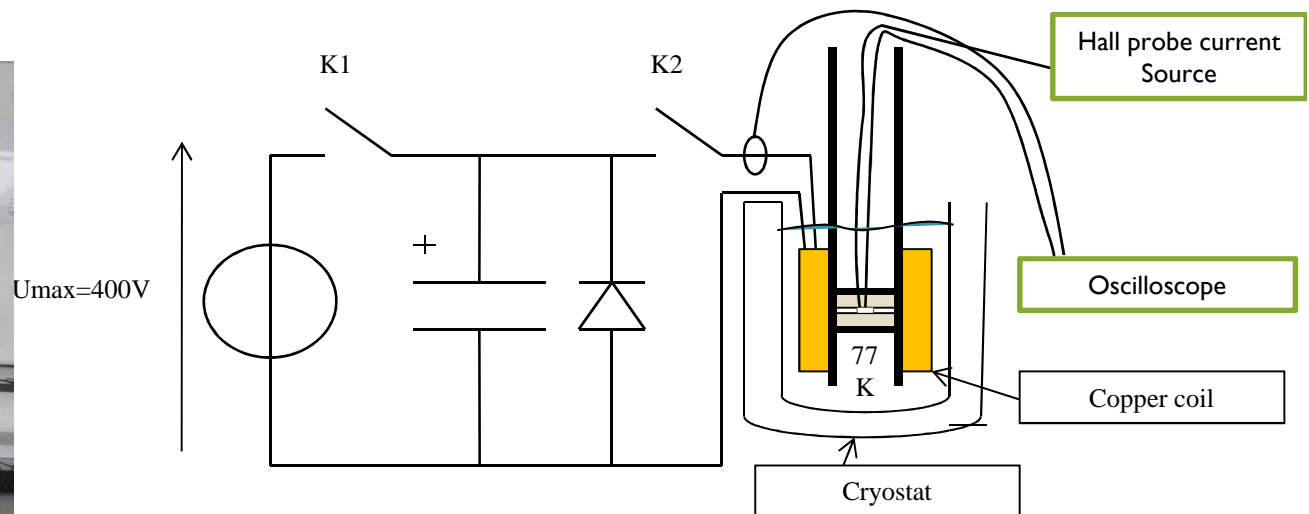




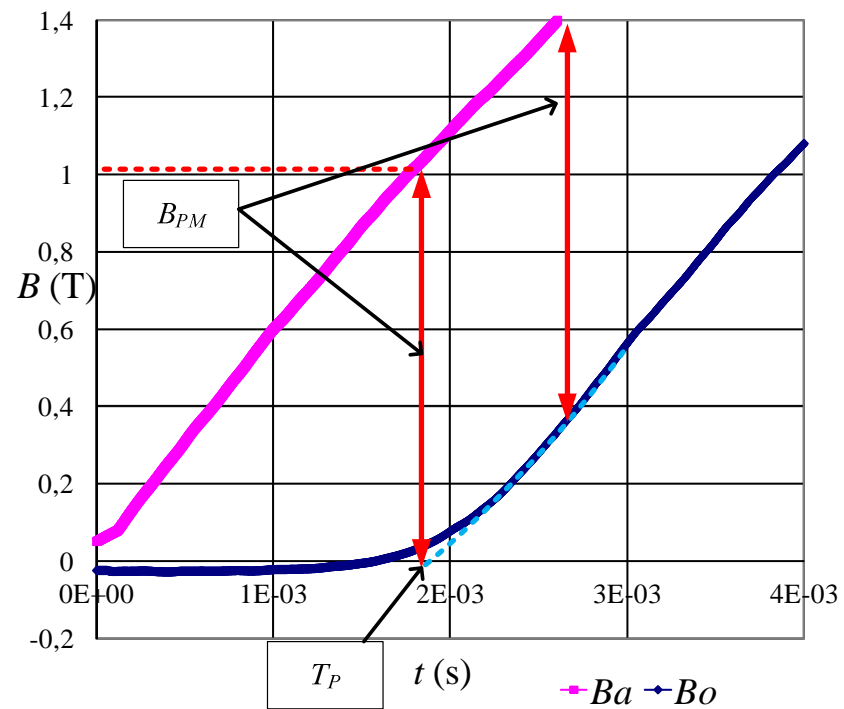
## HTS Bulks in 4T COIL (ZFC)



## Pulsed Field Magnetization of HTS Bulks

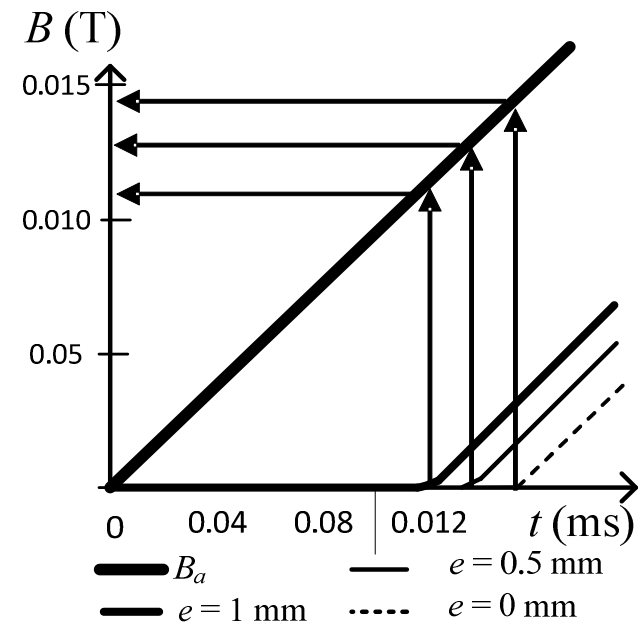
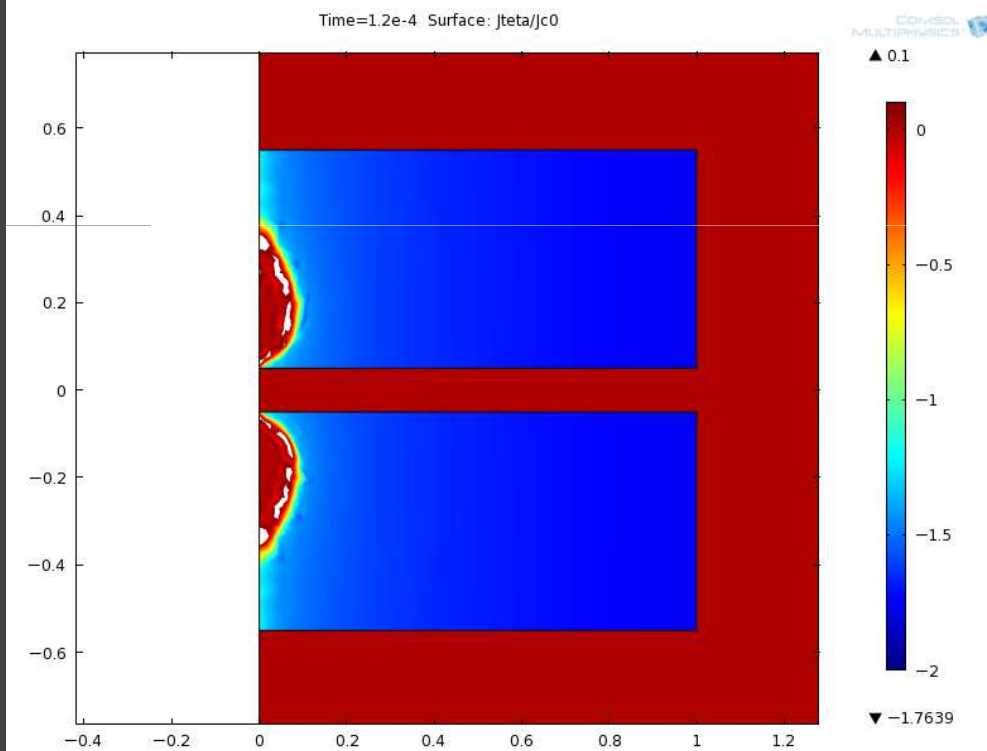


## Experimental determination of n-value



$$n = \frac{\alpha \cdot (B_{PM2} \cdot \ln V_{b1} - B_{PM1} \cdot \ln V_{b2})}{B_{PM1} - B_{PM2}} - \beta$$

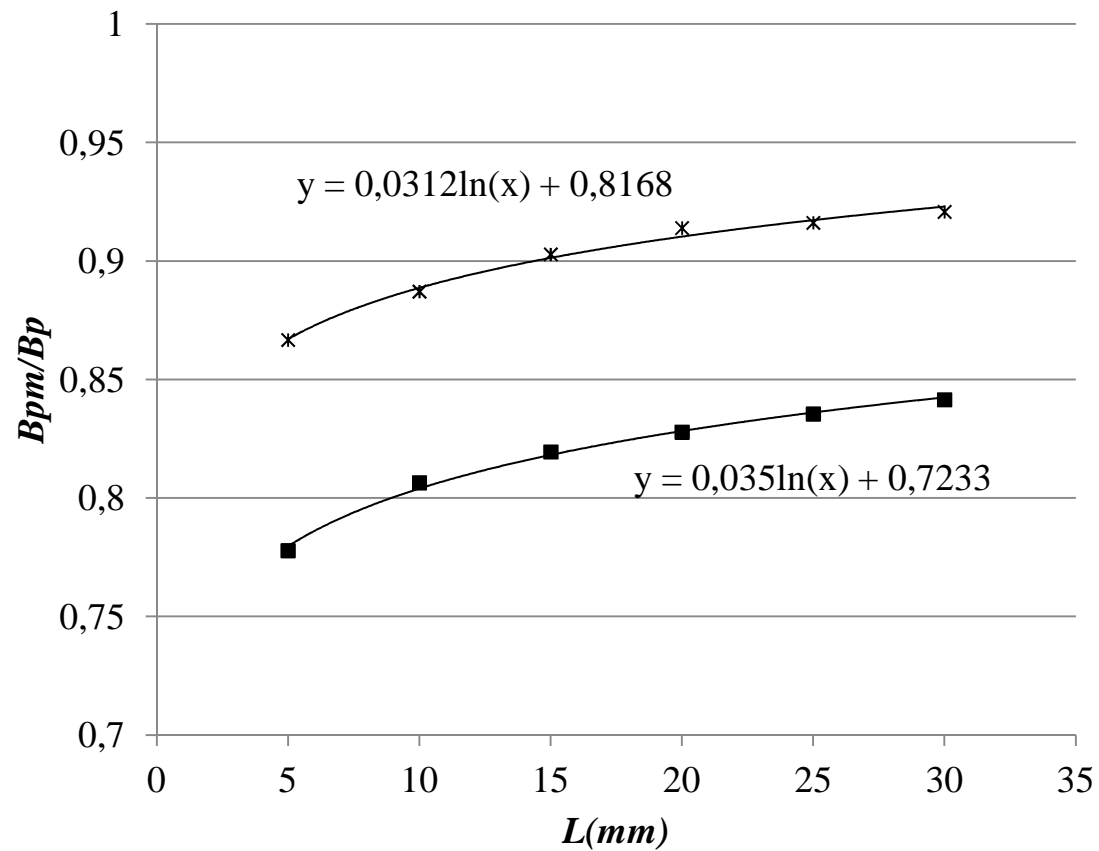
## Influence of sensor thickness



$$\Rightarrow n = 50 \quad J_c = 110 \text{ A/mm}^2$$



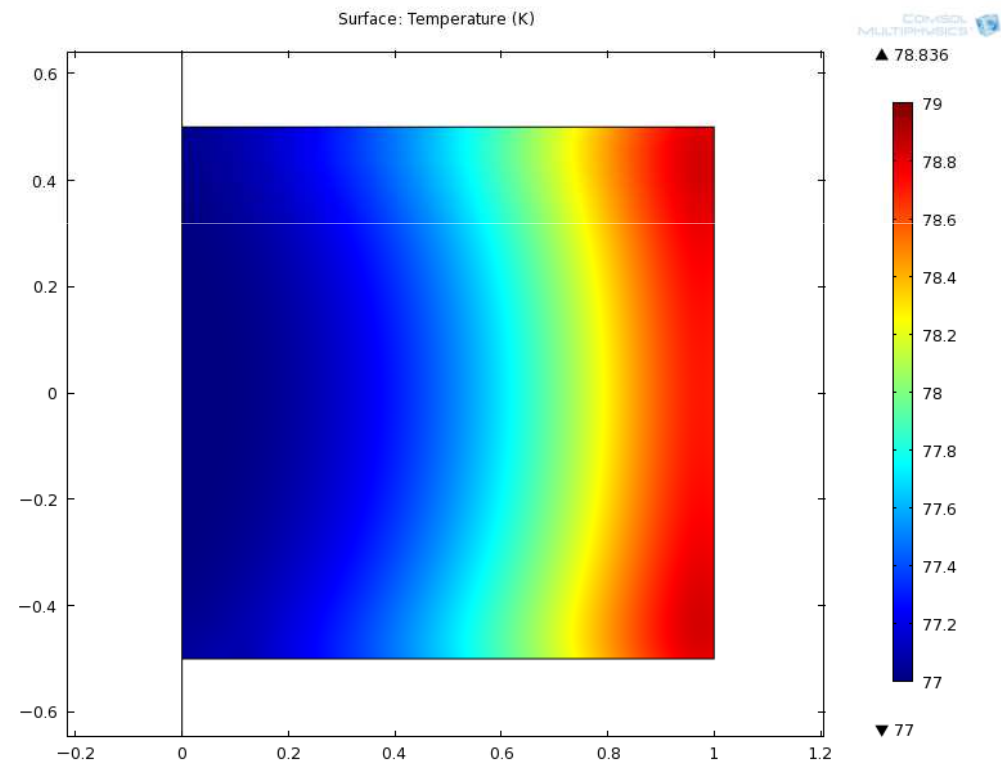
## Influence of sensor thickness



$*$   $e=0.5\text{mm}$     $\blacksquare$   $e=1\text{mm}$    —  $\text{Log. } (e=0.5\text{mm})$    —  $\text{Log. } (e=1\text{mm})$

## Temperature map at high rise rate

$$Vb = 660 \text{ T/s}$$
$$Jc = 100 \text{ A/mm}^2$$



## Conclusion

**Useful new characterization method**  
**Available for pellets with different  $L/R$  ratios**  
**Taking into account sensor thickness**

## Perspectives

**Improving experimental precision**  
**Taking into account  $J_c(B)$ ...**  
**Limits of PLM**



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**Thank you for your attention**