Solenoids

Luca Bottura and Lionel Quettier

IMCC Annual Meeting

Questions

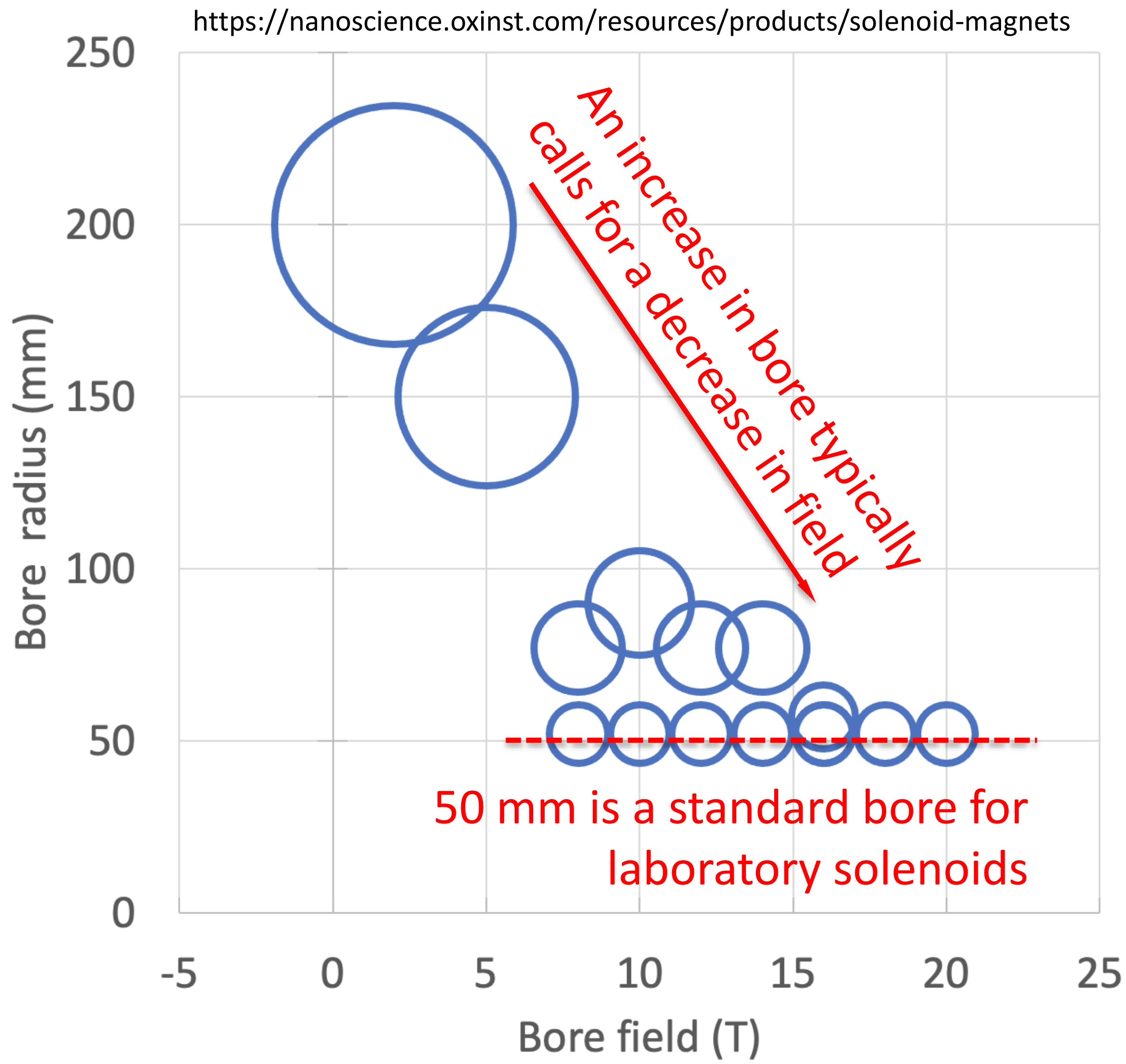
- What solenoids can be used for testing RF ?
- Where to find them ?
- What is their cost ?

This is a partial and preliminary view

What solenoids for testing RF ?

- Superconducting solenoid in the range of 2 T to 20 T and bore in the range of 50 mm to 200 mm are commonplace industrial products
- Higher field/large bore is possible, but these are custom realizations (time, cost)
- Split systems add complexity and reduce performance
- In general, industry has excellent experience in solenoid engineering and construction

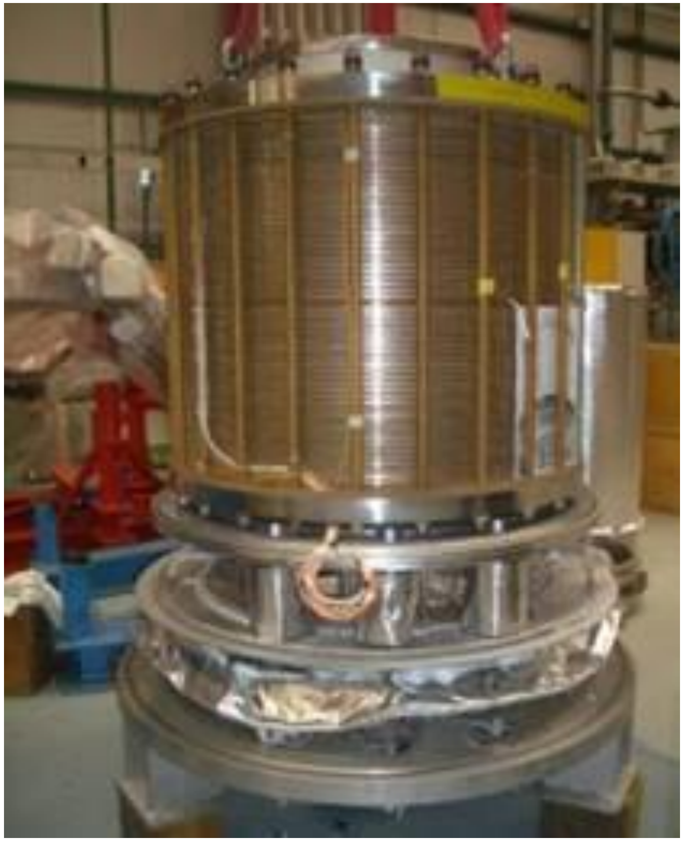
”Standard” solenoids



This is just one example !

“Other” solenoids

3 T field, 350 mm warm bore
350 ppm in a 300 mm sphere
Operating cost: 15 k€ plus 6 k€/day



8 T field, 587 mm warm bore
Facility set-up: 1.2 M€
Operating cost: 10 k€/day

Available at CEA-IRFU

“Other” solenoids

MAY 22, 2015

Used MRI magnets get a second chance at life in high-energy physics experiments

by Jared Sagoff, Argonne National Laboratory

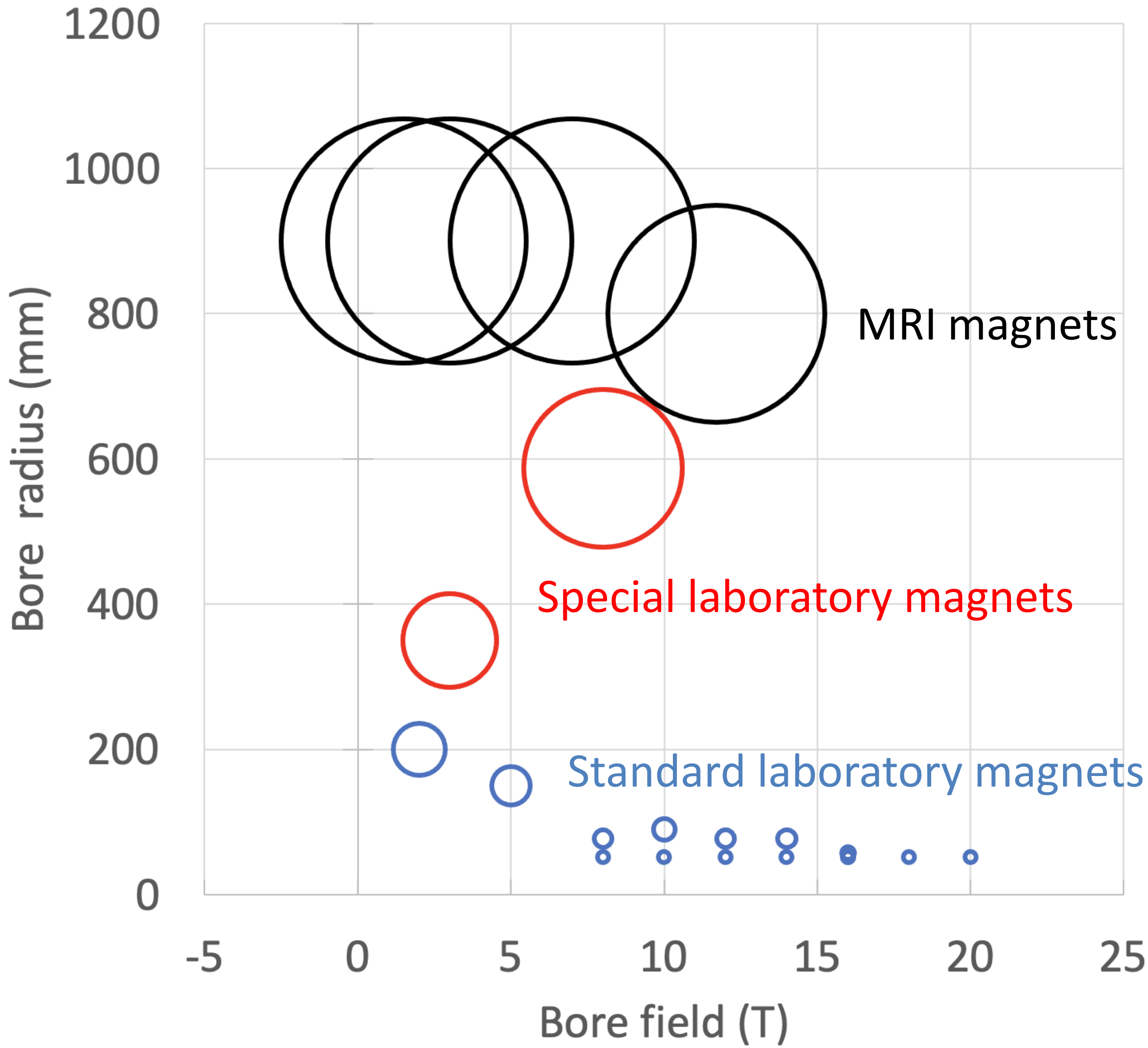
Argonne high-energy physicist Peter Winter, who recently won a DOE Early Ca…

The two new magnets have a strength of 4 Tesla, not as strong as the newest generation of MRI magnets but ideal for benchmarking experiments that test instruments for the g minus 2 ("g-2") muon experiment currently being assembled at the DOE's Fermi National Accelerator Laboratory. The Muon g-2 experiment will use Fermilab's powerful accelerators to explore the interactions of muons, which are short-lived particles, with a strong magnetic field in "empty" space.

4 T, 900 mm bore MRI solenoid

Value 1 MUSD

Wider overview



"Split" solenoids

7 to 15 T systems

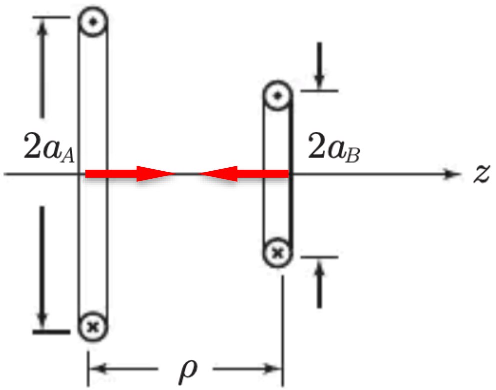
Y. Iwasa, Case Studies in Superconducting Magnets

Special Case 2: Two Adjacent Ring Coils of the Same Diameter

When two ring coils have the same diameter $a_A = a_B = a$ and are very close to each other, i.e., $\rho \ll 2a$, hence $k^2 \to 1$ and $K(k) \to \infty$ and $E(k) \to 1$, then Eq. 3.34 may be transformed to an expression much simpler than Eq. 3.34:

$$F_{zA}(\rho) \simeq \mu_\circ (N_A I_A)(N_B I_B) \left(\frac{a}{\rho}\right) \qquad (3.39d)$$

Split coils tend to attract(repel) each other with significant force

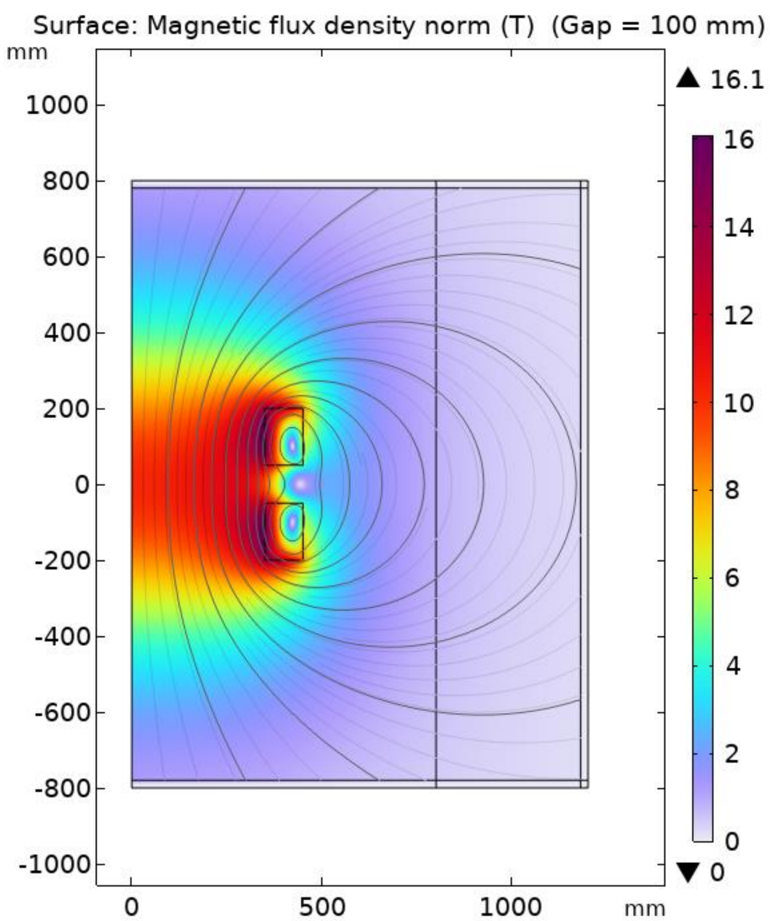


Example:
10 T split solenoid
150 mm x 100 mm coil
700 mm bore (2a)
100 mm gap (ρ = 250 mm)
Fz ≈ 25 MN (2500 tons)

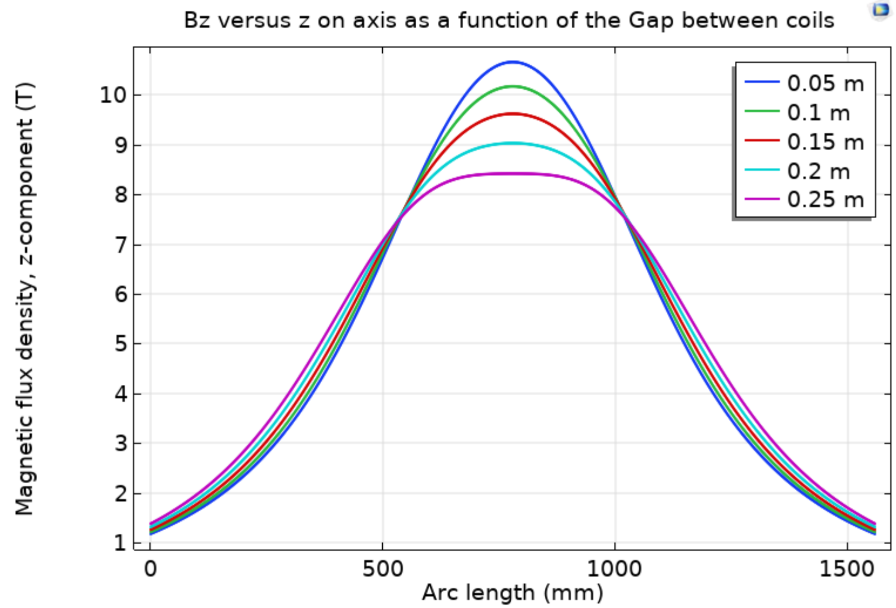
This requires large support structures

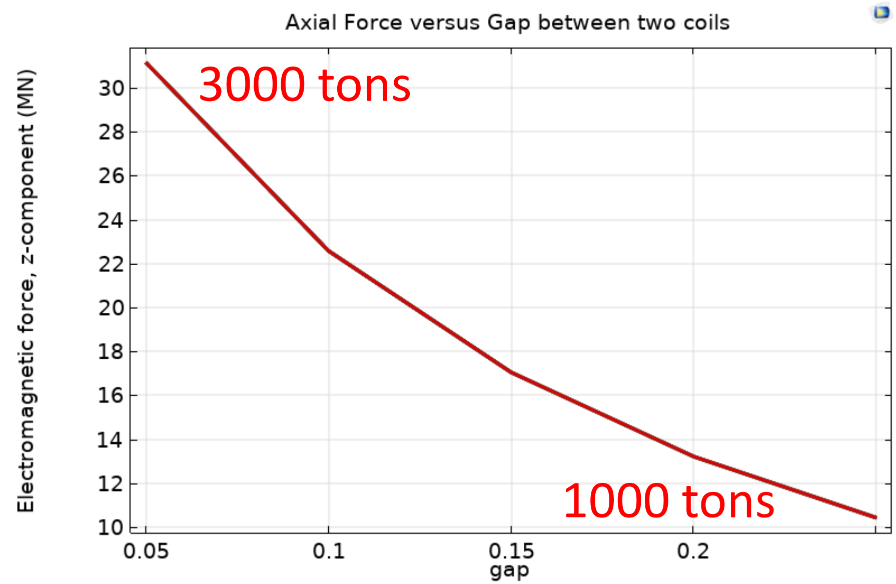
A specific split solenoid

10 T, 700 mm bore



Courtesy of S. Fabbri, CERN





Where to find them ?

- Standard laboratory solenoids (2…20 T, 50…200 mm) are best procured in industry, who has experience in design, engineering and construction
- Custom laboratory solenoids (5..10 T, 500…1000 mm) need to be purpose designed and built – this can be a very time consuming and expensive endeavor. Most effective approach is to use existing facilities
- MRI-class magnets (1.5…7 T, 900 mm) could at best be found (decommissioned) or procured as “stripped” magnetic system

What is their cost ?

- There is a large difference between the cost of the *magnet* and the cost of a *system* (cryostat and test environment, cooling, powering, protection, …)
- Focus on the magnet cost only:

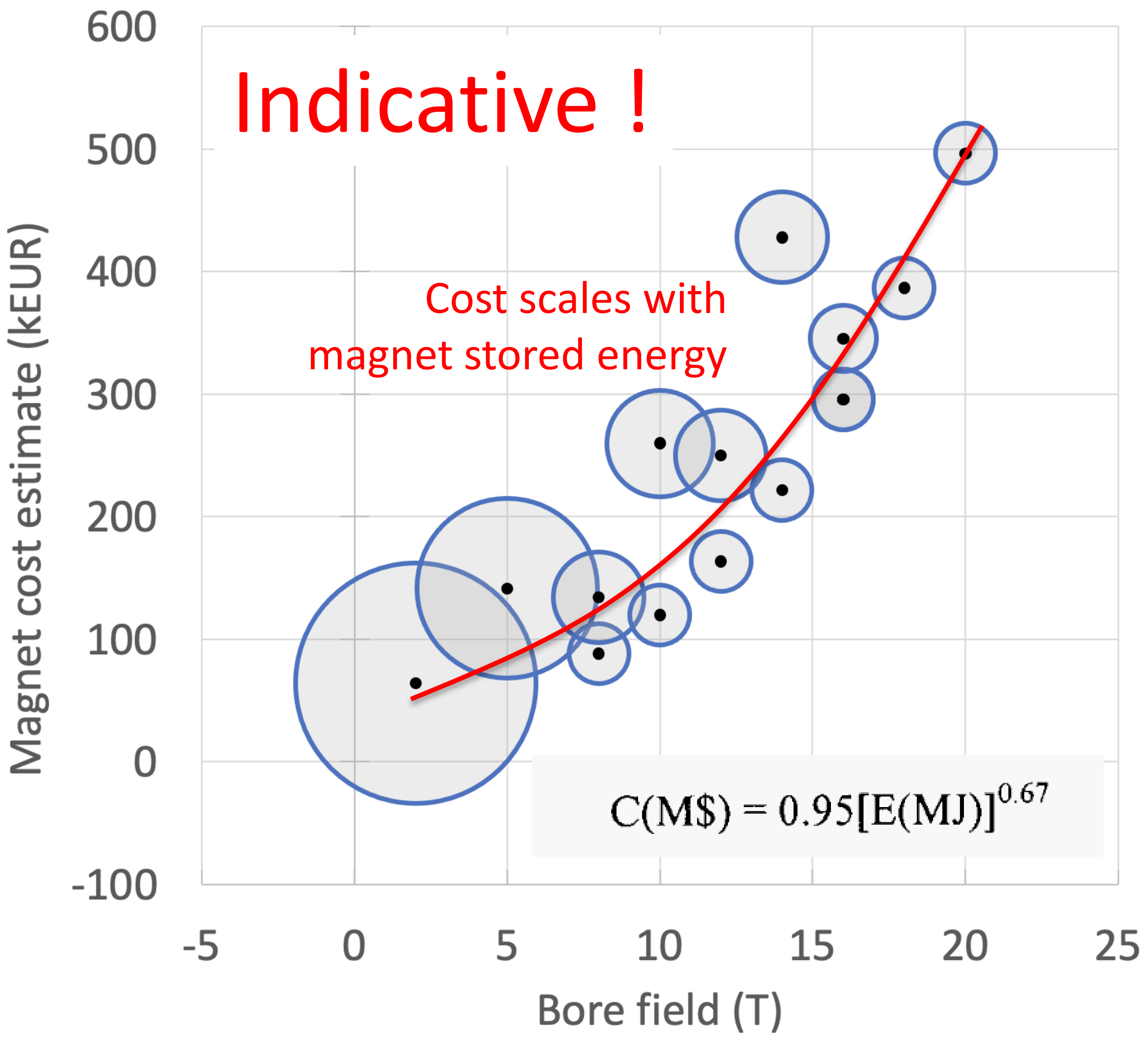
248 IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 18, NO. 2, JUNE 2008

The Cost of Superconducting Magnets as a Function of Stored Energy and Design Magnetic Induction Times the Field Volume

Michael A. Green and Bruce P. Strauss

International MUON Collider Collaboration

Magnet cost scaling



MRI magnet cost

Field (T)	Cost (MEUR)
1.5	0.5
3	1
7	5

Profiting from years of engineering, production scale-up and optimization

Summary questions

- What magnet should we look for, among the above classes (standard laboratory, custom laboratory, recycled MRI) ? Remember:
  - A test station is much more than a magnet
  - *In-house* is generally more expensive than *off-the-shelf*
- Is it possible to split the test demands to reduce magnet requirements ? Material testing at high field/gradient may be possible in existing, small bore test infrastructure (?), while component testing may be done in modest performance, large bore new test infrastructure (?)