Programma di sviluppo e contributo INFN per i principali dipoli superconduttivi del collider

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RD_MUCOL Riunione di Collaborazione Italiana
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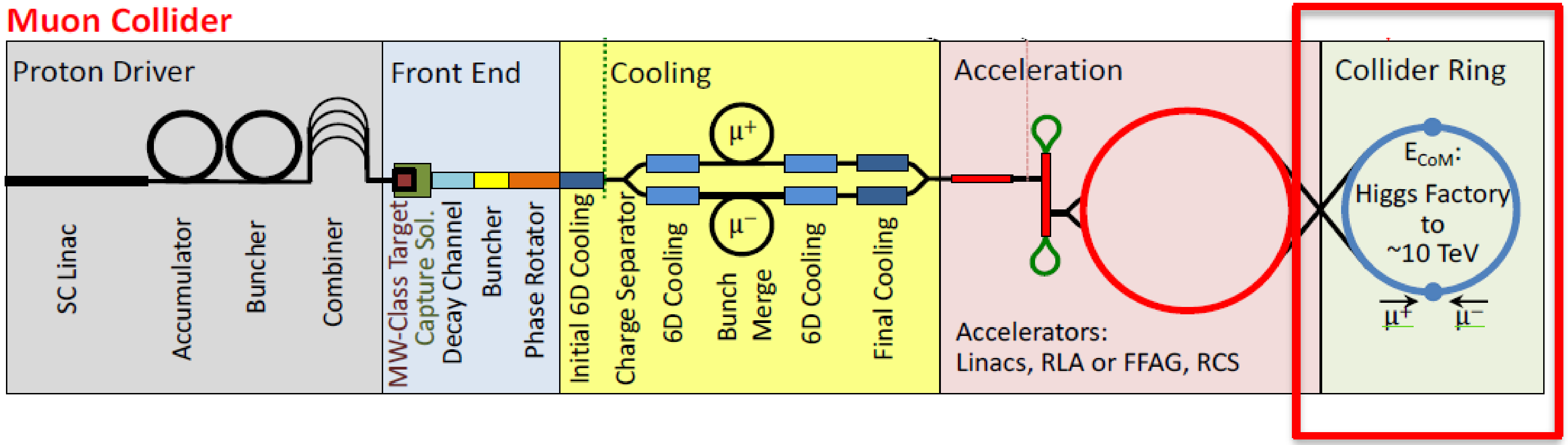
Task 7.4



Scope:

- assessing realistic performance targets for the collider magnets, in close collaboration with beam physics, machine-detector interface, and energy deposition studies

- produce Design Study Credible and Affordable (contain cost, energy efficient, sustainable operation)

Partecipants:

- INFN Milano

M. Statera, M. Prioli, E. De Matteis, R. Valente, S. Sorti, M. Dam

- INFN Genova

B. Caiffi, A. Bersani, A. Pampaloni, F. Levi, S. Farinon, R. Musenich

- UNIMI

L. Rossi, M. Sorbi, S. Mariotto

- CERN

L. Bottura, A. Lechner, P.T.

Tentative proposal

3 TeV machine

- Provide a design study for the 3 TeV machine collider arc magnets
  - *if this is an interesting option for a staged strategy*

NbTi is compatible with required magnetic field

- Are combined function magnets requested also for this options?
- Nb_3Sn can also be considered, if working at 1.9 K is not an option

N.B. This technology is not scalable, magnets for 3 TeV machine or 10 TeV machine are completely different beasts, the studies will be completely different

10 TeV machine

- Provide a design study for the 10 TeV machine collider arc magnets
  - Most likely, the magnetic field required will not be compatible with Nb_3Sn **HTS is more suitable**
  - Working temperature will also constrain this choice: if we want to work @10K to reduce energy consumption, again **HTS is the way**

Magnet requirements

- Define requirements for the combined function collider arc magnets:
  - dipolar magnetic field
  - gradient
  - magnet aperture
  - length

Milestone T_0 + 6 months
Arc Dipole Parameter specifications

This task requires an iterative interaction with beam dynamics teams, loss and radiation teams, vacuum and cryogenics and will lead to the choice of the technology to use (Nb_3Sn, HTS)

Current status of beam dynamics requirements

10 TeV machine

	Dipolar field [T]	Quadrupolar field [T/m]	Aperture (diameter) 2*(5σ+2cm) [mm]	Minimum Coil Bore Aperture [mm]
AQF1	12.3	87.2	82.3	132.3
AQD1	12.3	-120.3	59.7	109.7
AQF2	8	266.9	57.1	107.1
AQD2	6.5	-366.9	51.5	101.5

Beam Screen +50 mm (diameter) →

- Beam screen still to be defined

Reasonable coil aperture $\emptyset_{bore}$=150 mm

- Magnetic field on the conductor can be higher than 20 T -> Nb_3Sn is no more an option
- Parameters must be revised considering the magnet feasibility
  - The Stress on the coil is a critical aspect
  - Combined Function design is not "trivial" (see also later)

Magnet requirements

- Tentative specs for first feasibility evaluation (to be revised)

On-axis peak field(1)	10 T
On-axis peak gradient(1)	300 T/m
Bore(2)	150 mm
Magnetic length	15 m
Field Quality	10 units
Technology	LTS/HTS
Temperature range(2)	1.9/4.2 K (LTS) or 10 to 20 K (HTS)

Combination NOT Possible At the same Time

(1) Field and gradient are evolving with optics

(2) Muon decay shield integration may modify bore and operating temperature

(3) Some of the technology choices are limited by the values of peak field and temperature

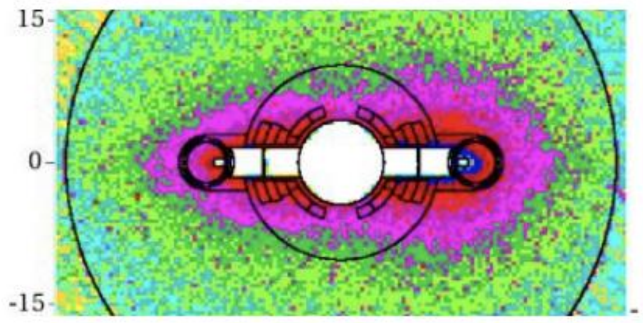
Magnet requirements

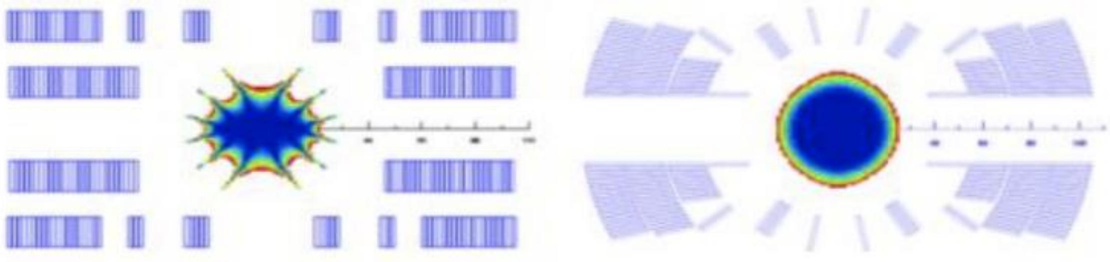
- Radiation map and dose estimate to design the beam screen
- Cryogenic system design
  - ➢ Which cooling rate should be considered affordable?
  - ➢ Working temperature? 1.9 K? 10 K?

CERN in charge for these tasks

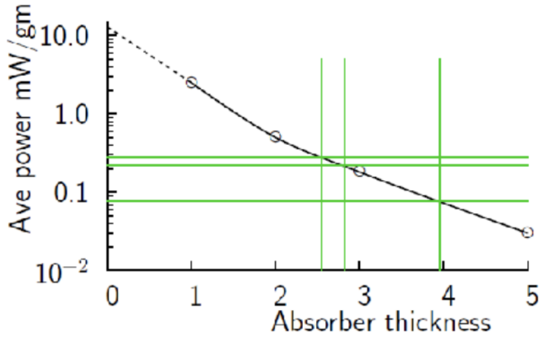
Also in this case iterative interactions between radiation team and magnet design team will lead to the best compromise in terms of magnet requirements

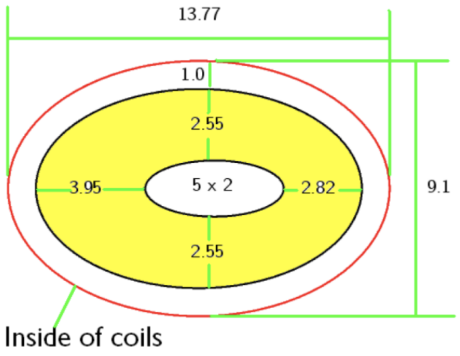
Due to the muon decays, the dose induced by the neutrino beams will be huge in the midplane region

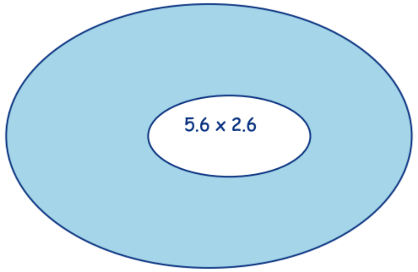




B. Palmer, MCSR Magnet workshop, 2011

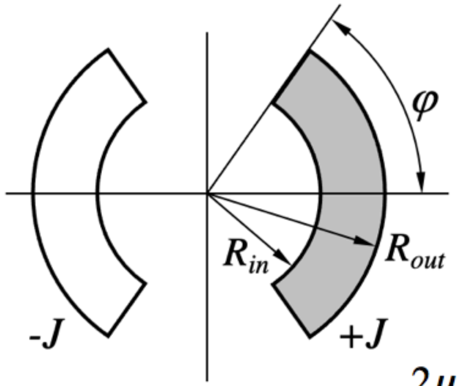




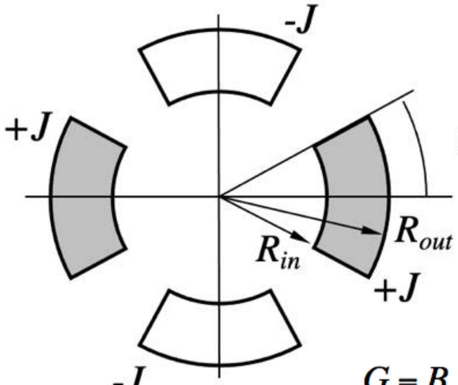


Fast evaluation of magnet parameters

In order to provide fast feedback on the magnet requirements provided by beam optics, MDI, radiation and cryogenics teams, a set of analytic expressions will be setup at least for the main parameters (Main Component, Peak Field, Field Errors, Forces).



$$B_1 = \frac{2\mu_0}{\pi} J \left(R_{out} - R_{in}\right) \sin(\varphi)$$



$$G = B_2 = \frac{2\mu_0}{\pi} J \ln\left(\frac{R_{out}}{R_{in}}\right) \sin(2\varphi)$$

Analytical expressions for NbTi and Nb3Sn type dipoles and quadrupoles already exists: field, error, forces and energy

- Scalable laws can be extensively used for simplified cos(nθ) configurations

Points to be addressed

- Equivalent expressions for block coil design?
- Peak Field to be evaluated numerically

HTS magnet are different from LTS configurations

- Limiting parameters and optimal configuration of the design can be different

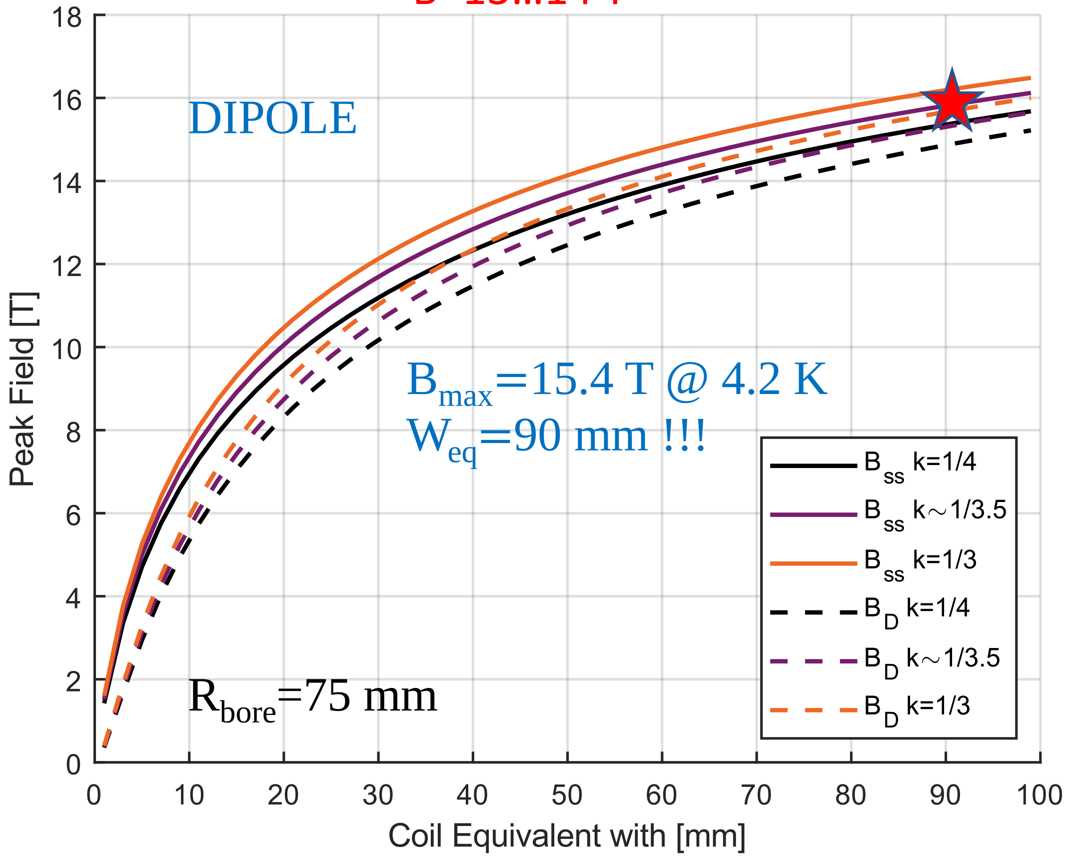
Milestone T_0 + 12/14 months
Analytical Magnet Cross-section

Performances of Nb3Sn

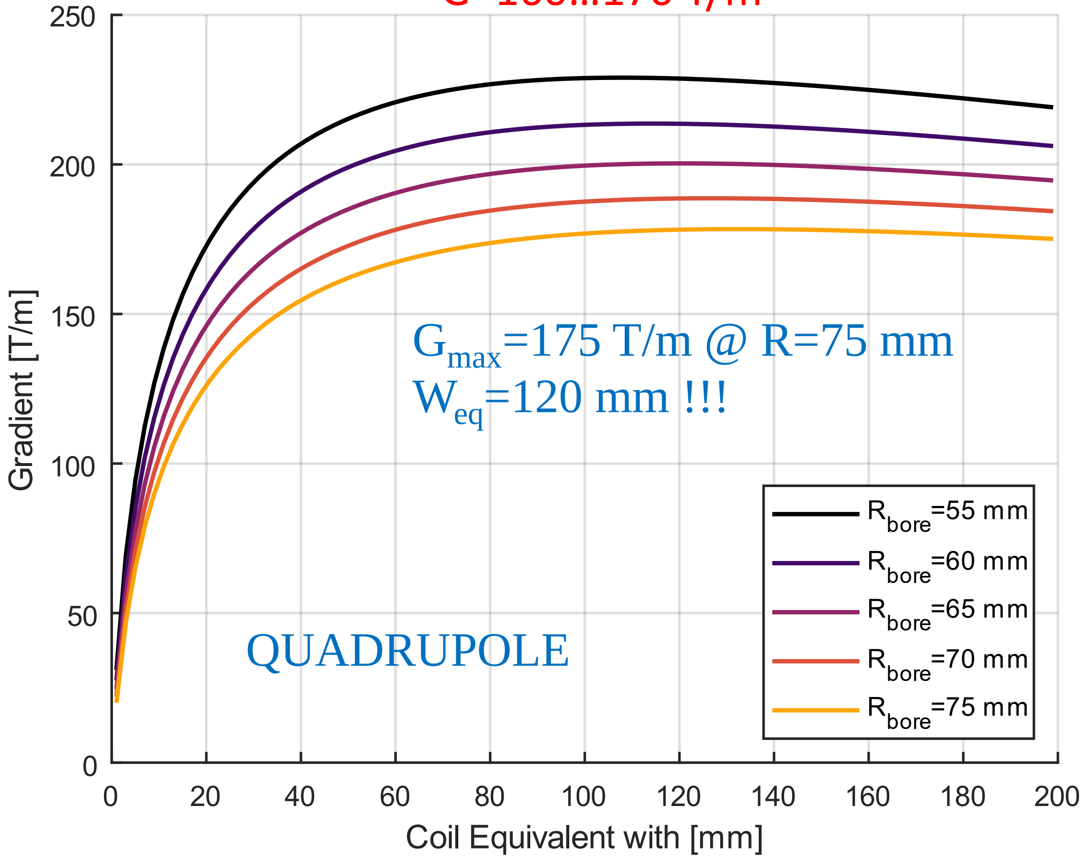
Dipole and Quadrupole Gradient – Maximum Values obtainable as function of the coil equivalent width

OSS: NO IRON considered → +1/1.5 T on Dipole Field with same coil dimension

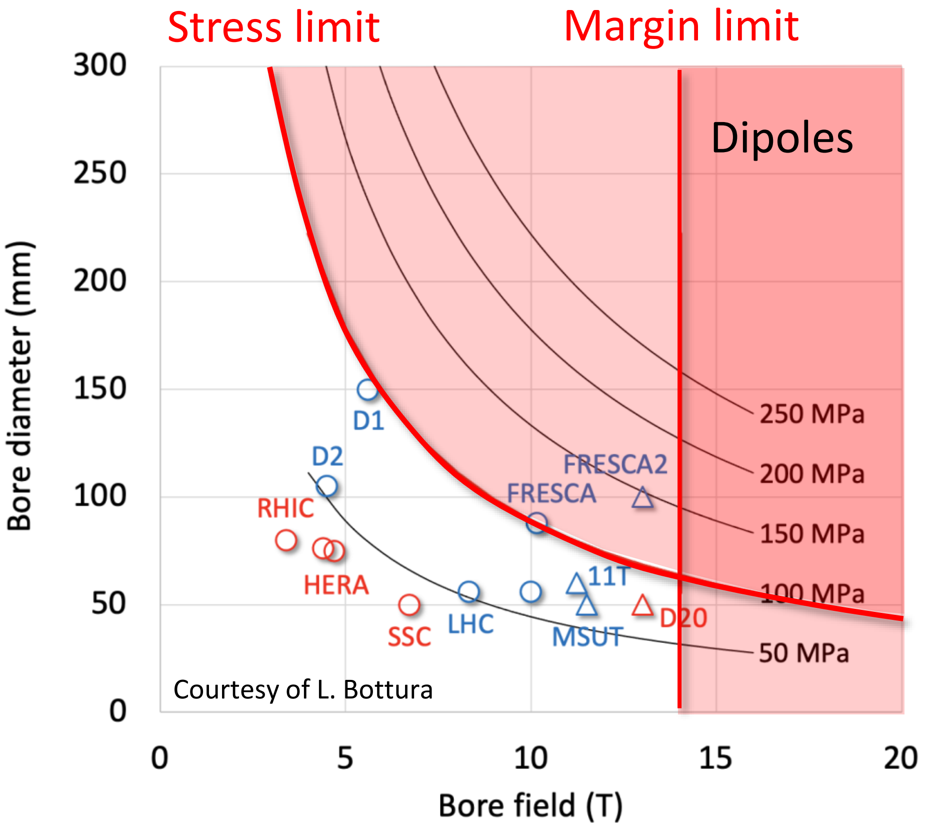
B=13…14 T

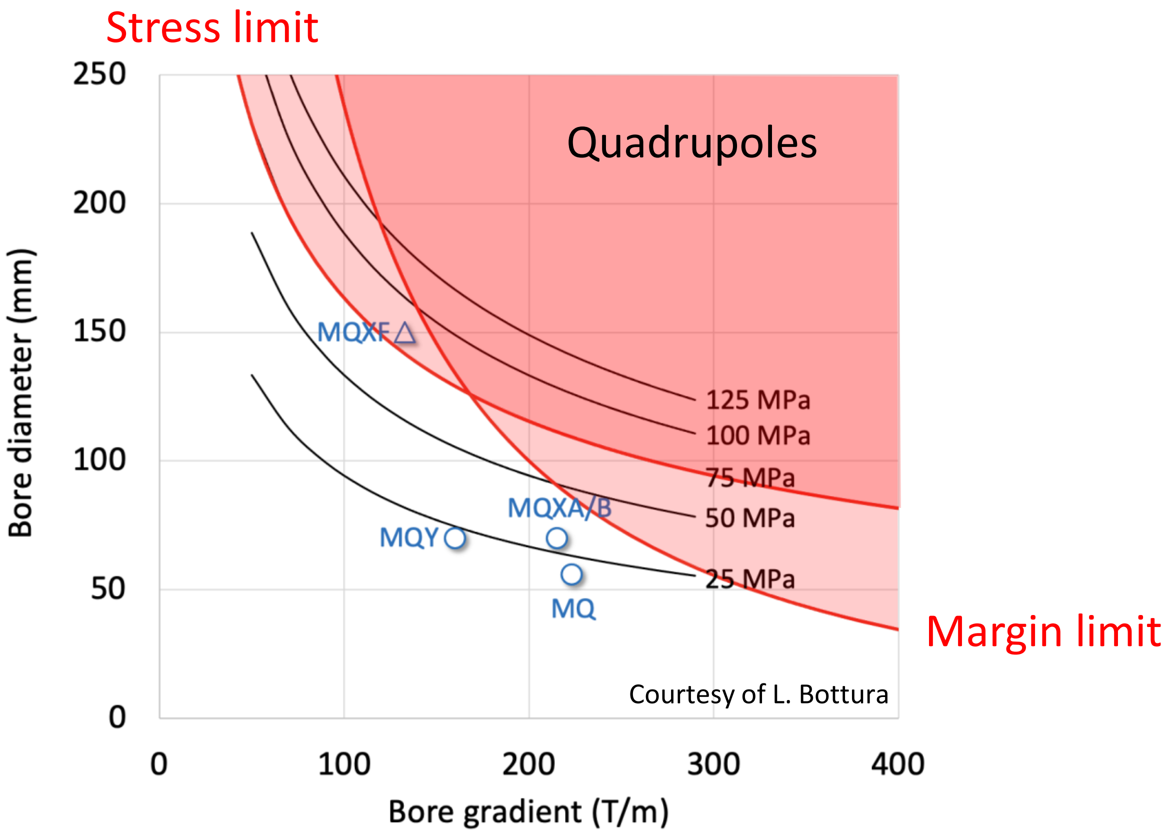


G=160…170 T/m



Fast evaluation of magnet parameters



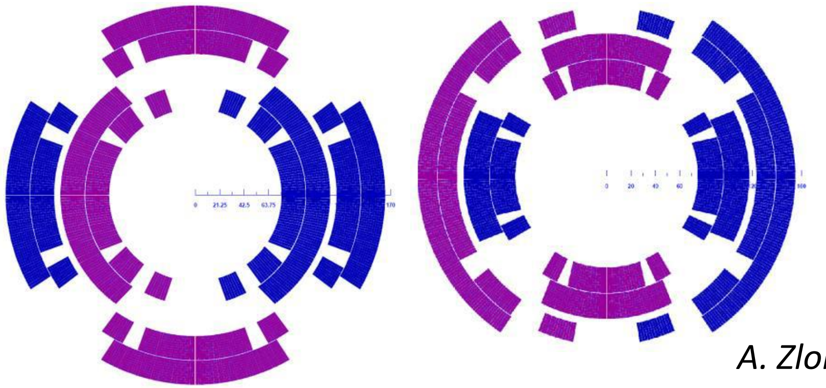


- Scope: provide analytical expression for the magnet design limits
  - Maximum field and gradient vs. magnet aperture in LTS and HTS
  - Combined function limits B+G and B/G

Combined function magnets

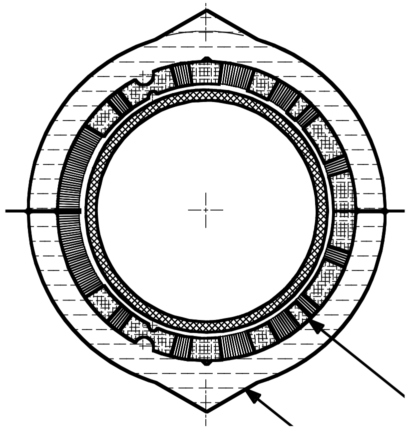
Straight paths generates sharp cones of neutrino beams from muon decays → *COMBINED FUNCTION MAGNETS*

Nested



A. Zlobin

Asymmetric



T. Ogitsu

- **Pros**: Separate Powering Dipole/Quadrupole
- Inherit experience on Nb3Sn magnets for HiLumi and LARP-US development program

- **Cons**: Stress on Coil is critical (large forces where currents are opposite)
- Difficult alignment between the two coils
- Two types of different coil to be produced (Higher Costs)

- **Pros**: Single type of coil
- Optimized margin and field quality

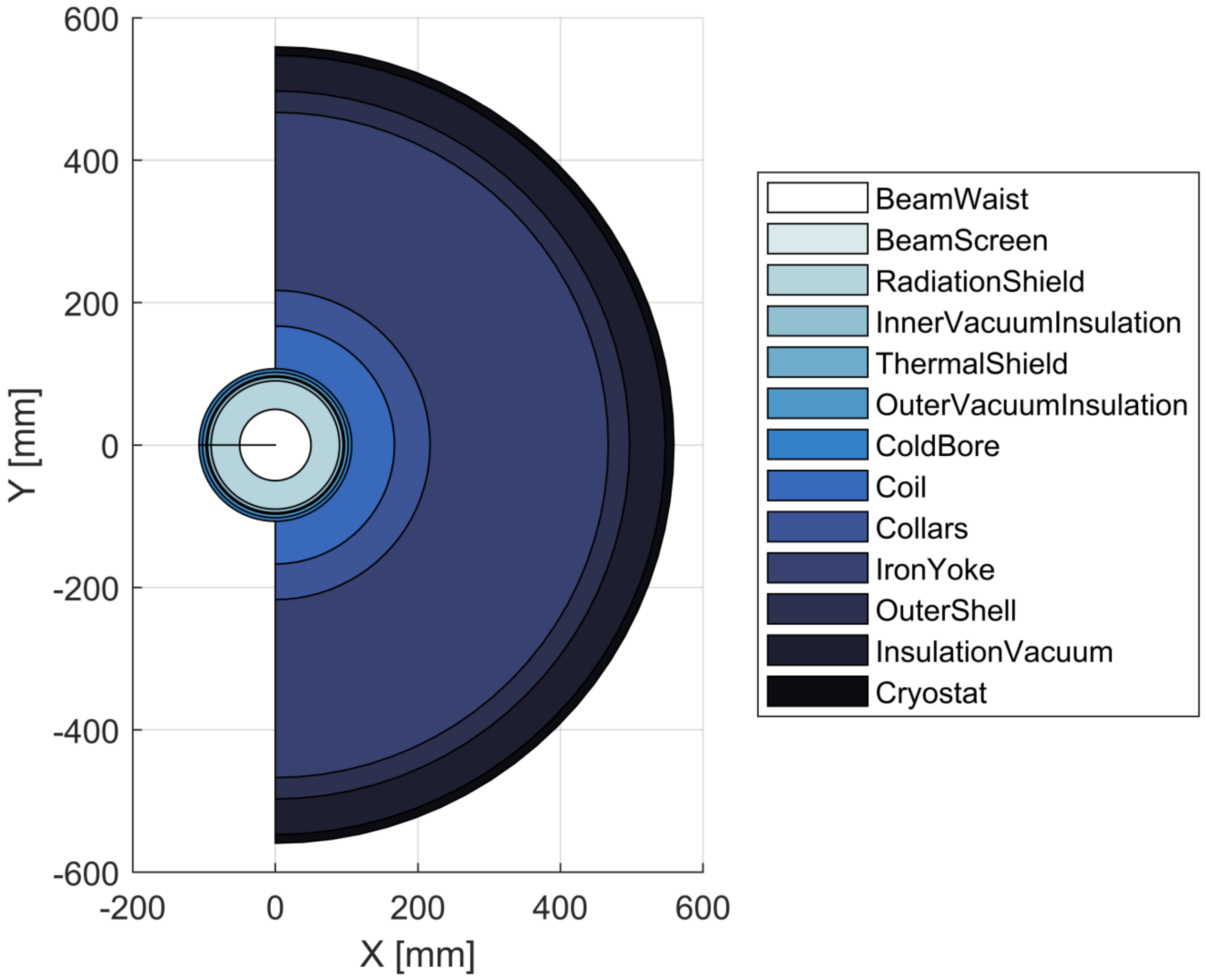
- **Cons**: Fixed Dipole/Quadrupole ratio
- Stress on the supporting structure is not balanced
- Magnet protection more difficult

Radial Build

Different studies to be integrated in a unique design of the dipole layout for the collider

Preliminary Timeline

- T0 +6 months
  Consolidate magnet requirements
- T0 + 12/14 months
  Analytical expressions for cross-section
- T0 +33 months
  D 7.1 Intermediate Report
- T0 +42 months
  M 7.3 Workshop on HFM for collider
- T0 +45 months
  D 7.2 Consolidated report



Thank you
for your attention