“PROGRESS on QD0 QUADRUPOLE”

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CLIC09 Workshop 12-16 October 2009

*… Studies (new) for a CLIC FF conceptual design has started in **June 2009** within the scope of the newly created "Machine Detector Interface "(MDI) Working Group*

"Nominal" Requirements for CLIC FF Quad: *(from Specifications by D. Schulte, R. Tomas, and from discussions with L. Gatignon, D. Swoboda et al. at the "MDI WG Monday Meetings":*

- **Gradient:** highest possible towards a nominal value of: **575 T/m**)
- **Required Length**: **2.73 m** *(but the real FF Quad will be cut in different longitudinal sections…)*
- **Magnet Bore Radius:** 3.8 mm + 0.3mm estimated for a vacuum chamber thickness *(as proposed with TE Vacuum Group)* + 0.025(tolerance) = **4.125mm**
- **Field Quality:** a 1st specification exist, but needs and requirements to be further discussed with CLIC Beam Physic Group
- **Geometric (layout) boundary conditions**:

  Major one is: presence of the "**spent beam pipe**": conical shape (10 mrad aperture), min. distance from the FF (at the front end for a L* = 3.5 m): **35 mm**

- *Other boundary conditions like:*
  - *Anti-solenoid presence*
  - *Stabilization requirements*
  - *Detector design and its interfaces*

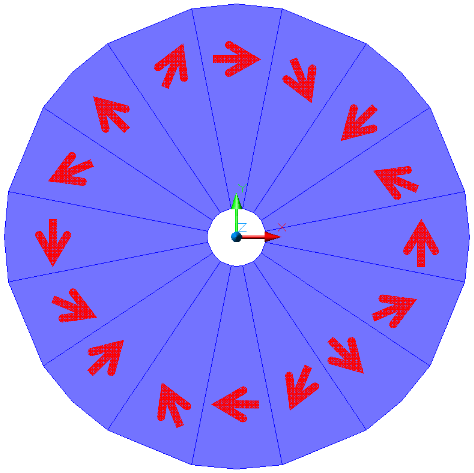
  Were recently put also on the table for discussion.

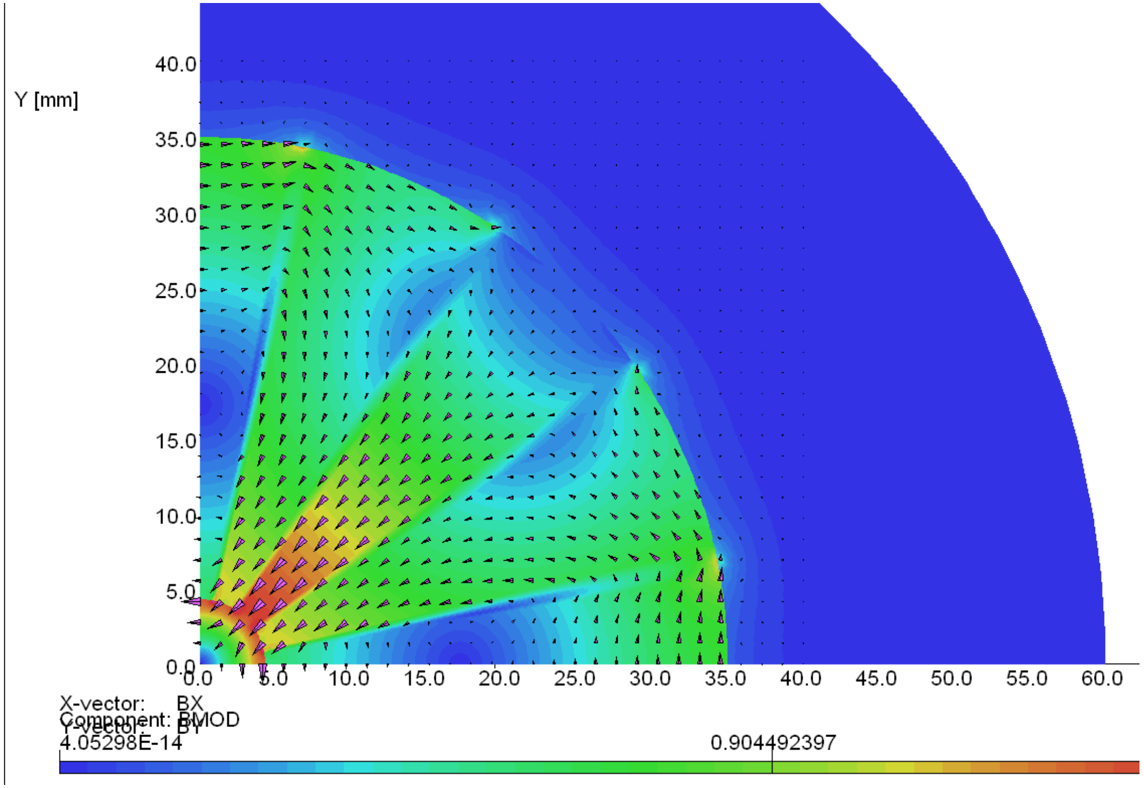
As CERN "Magnet Group" we propose to go on ASAP with the construction of a **1st short prototype.** We see several advantages in this.

A FF quadrupole prototype (short model!) will be useful for :

- *for CLIC*: To **check the feasibility of** a possible FF design approach.
- *for CERN*: To let CERN-TE/MSC **starting activities in PM magnet domain** and more specifically:
  - **Validation** of a possible FF cross-section design
  - To **investigate the difficulties** for the high precision machining of the Permendur poles, the PM wedges, achievable tolerances, etc.
  - To investigates the role of **tolerances** between poles and PM wedges in terms of Gradient and Field Quality
  - Eventually, to **tests different PM materials**
- *for CERN/CLIC*: Provide a magnet with a **minimum bore aperture** to develop and test **miniaturized magnetic measurement** systems.
- …

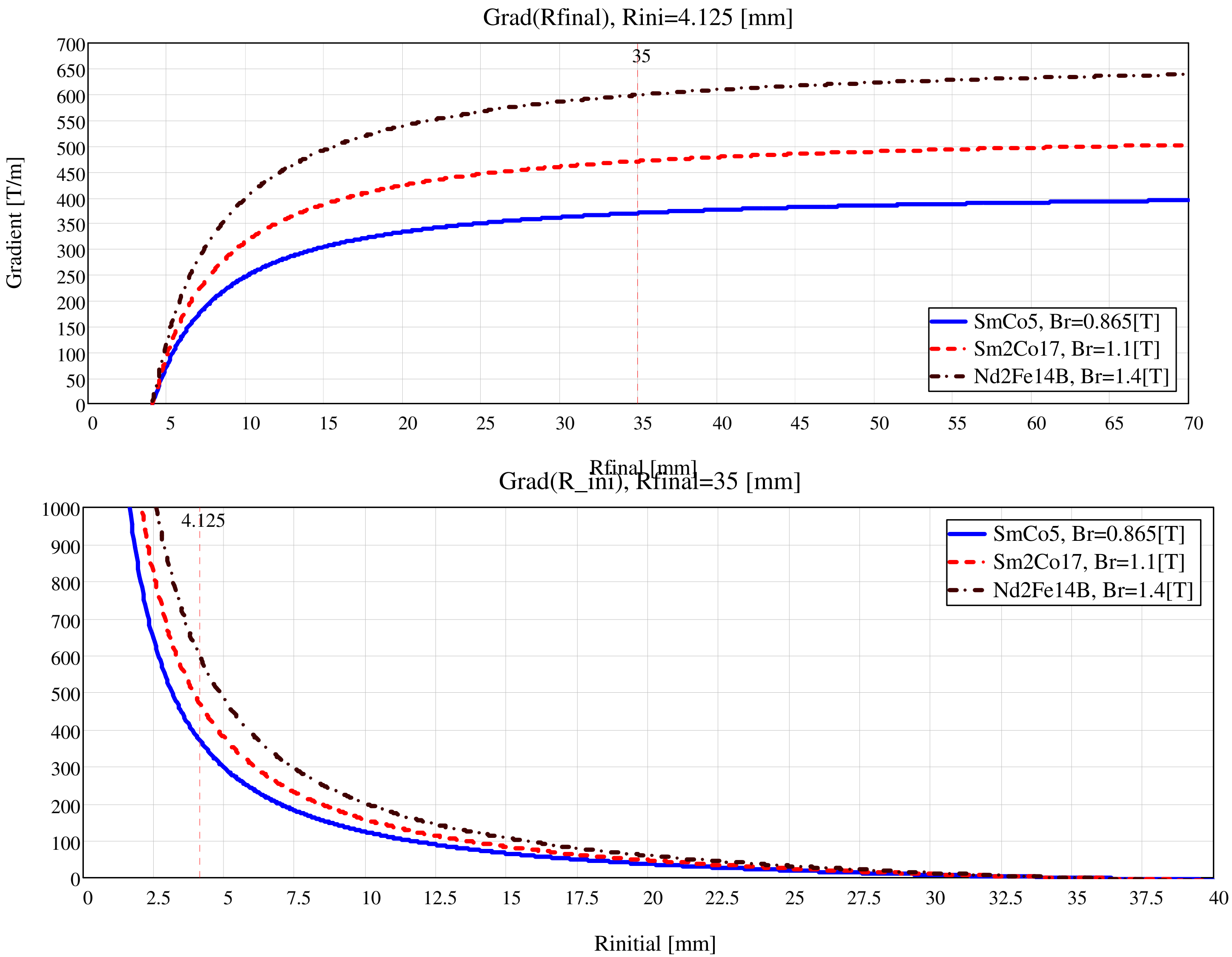
"Halbach type" approach:





(Opera 2D simulation. Courtesy A. Vorozhtsov)

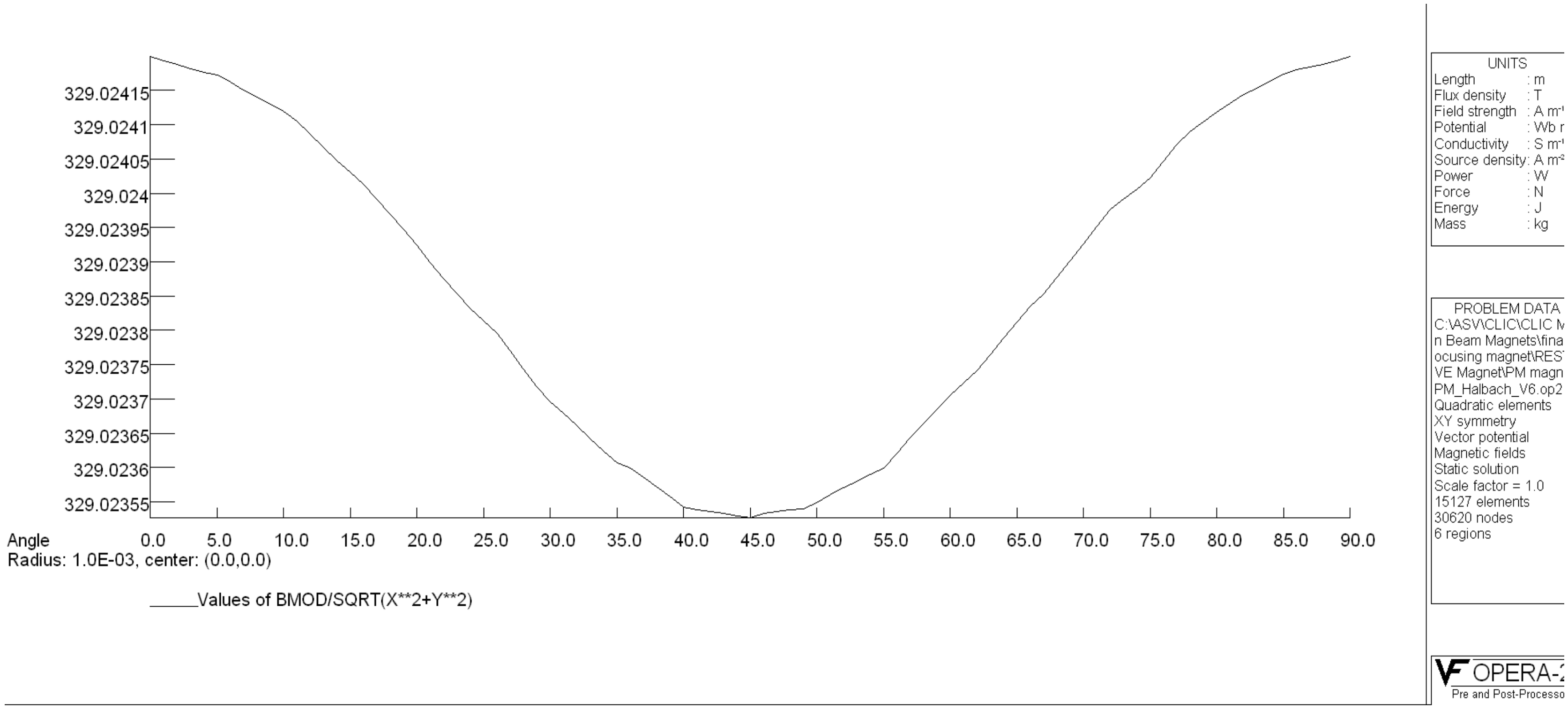
“Halbach type” approach: *achievable gradients*



"Halbach type" approach: ***Field quality***

Gradient azimuthal homogeneity at R=1mm

for $SmCo_5$ Br=0.86T

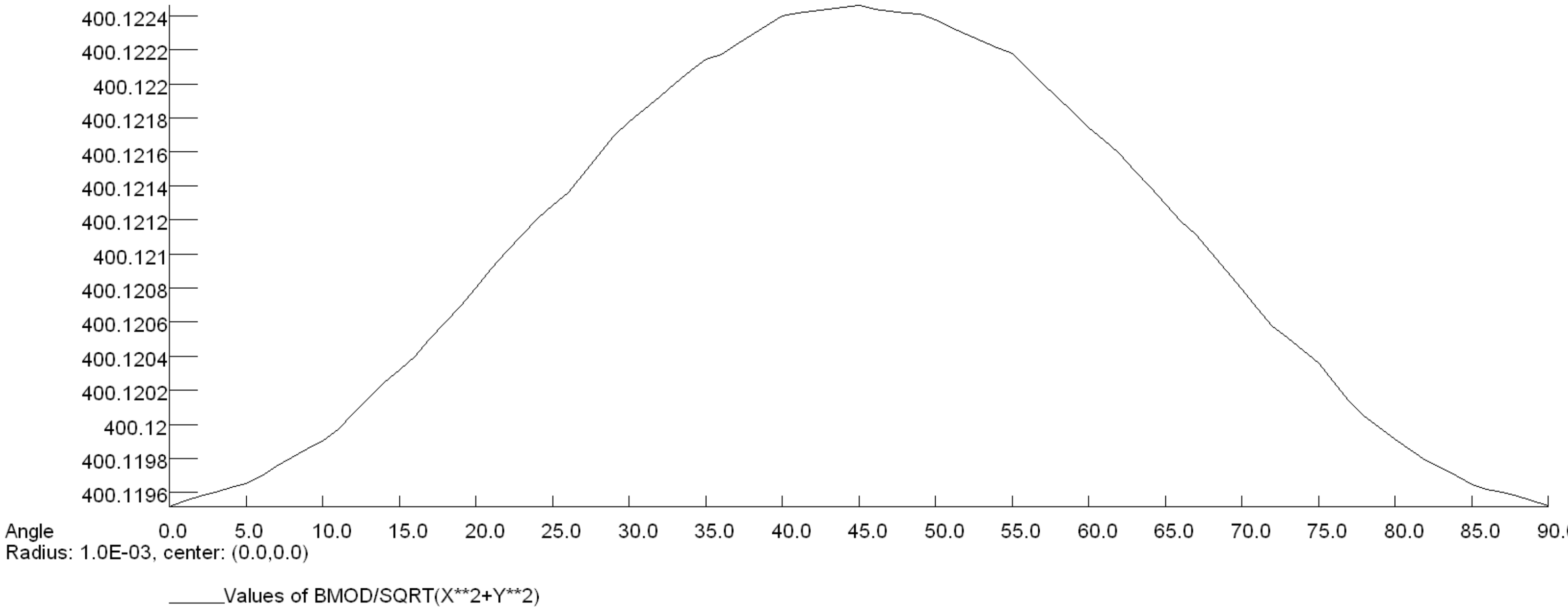


(Opera 2D simulation. Courtesy A. Vorozhtsov)

“Halbach type” approach: *Field quality*

Gradient azimuthal homogeneity at R=1mm

Sm_2Co_{17} Br=1.12T



(Opera 2D simulation. Courtesy A. Vorozhtsov)

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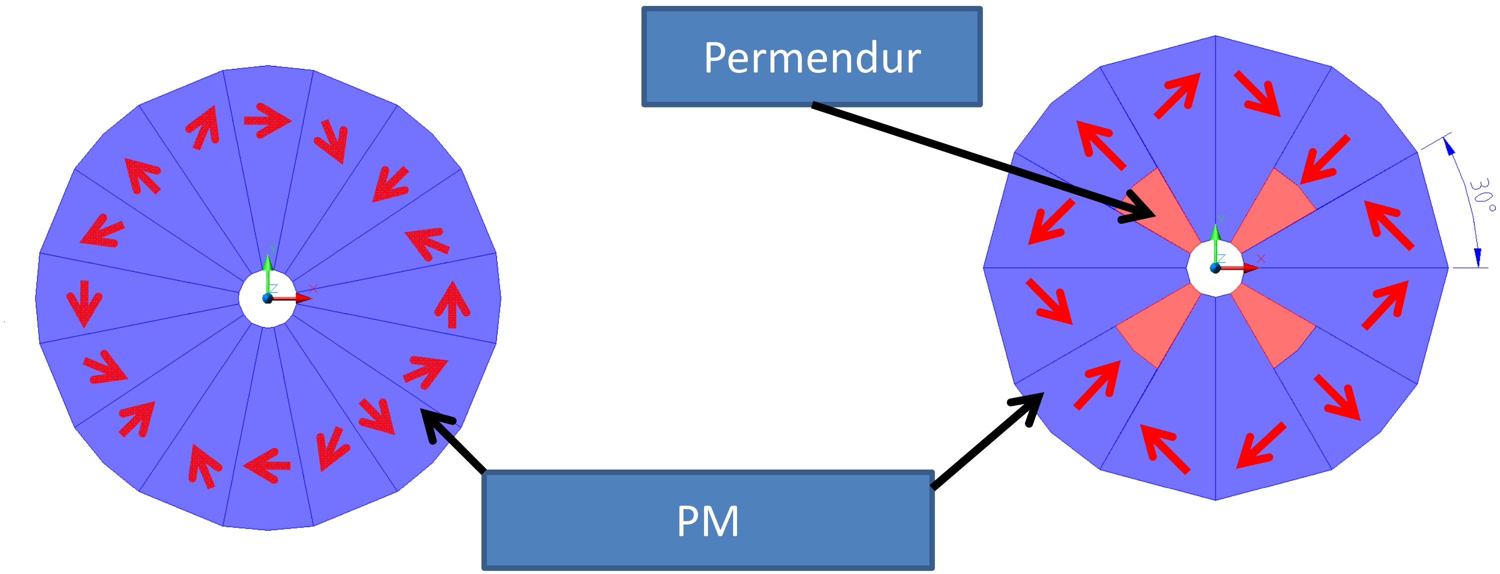
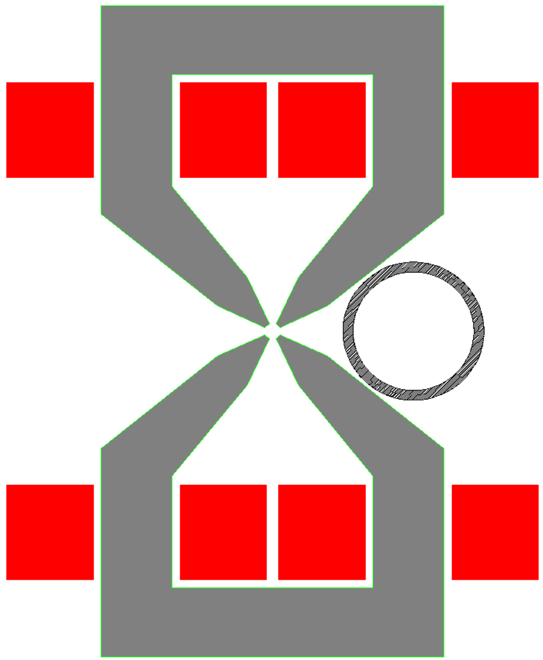
“Halbach” vs. “Super Strong” performances:

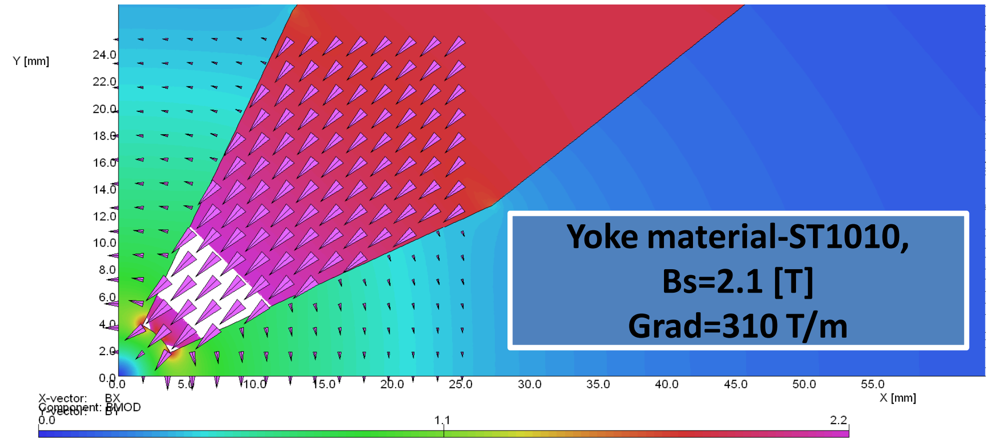


	R=3.8 [mm] (no chamber)		R=4.125 [mm]	
Material	Sm_2Co_{17}	$Nd_2Fe_{14}B$	Sm_2Co_{17}	$Nd_2Fe_{14}B$
Grad [T/m] “Halbach”	450	593	409	540
Grad [T/m] “Super Strong”	564	678	512	615

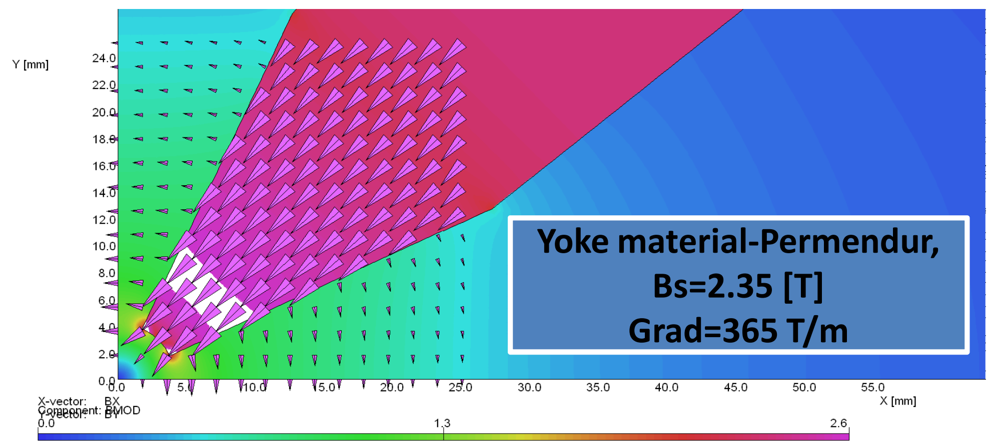
(Courtesy A. Vorozhtsov)

“Pure Electro-Magnetic” approach





(NI= 5000 A)

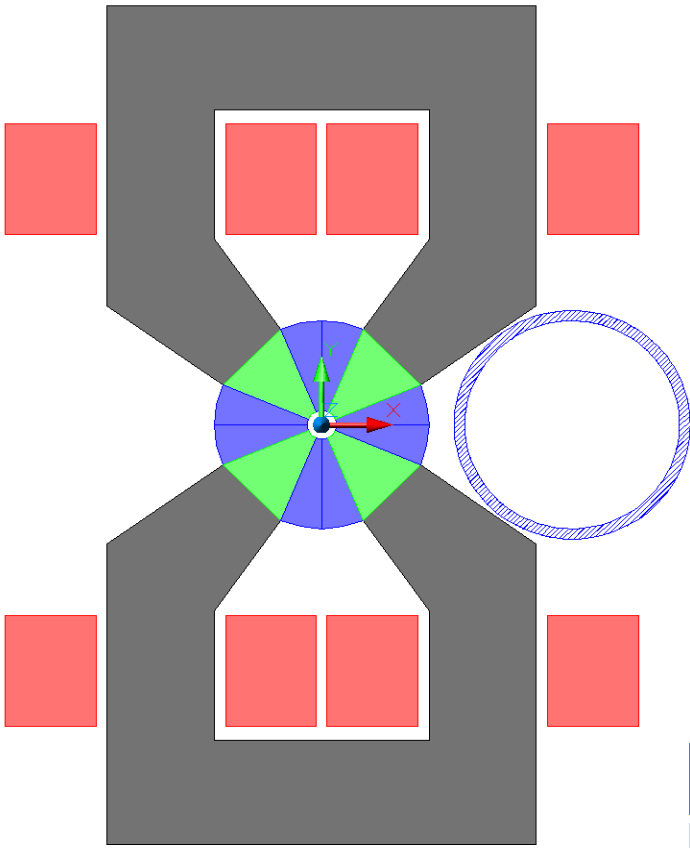


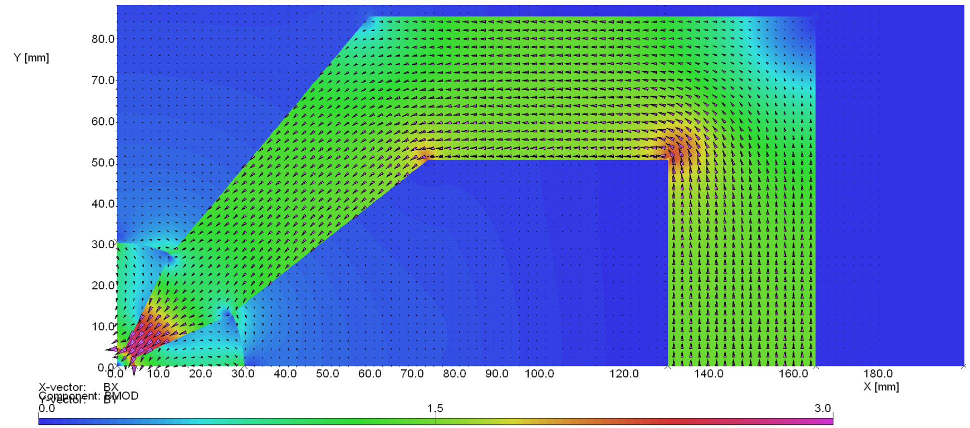
-“8 shape” quad design: (it permits to accommodate the spent beam pipe)

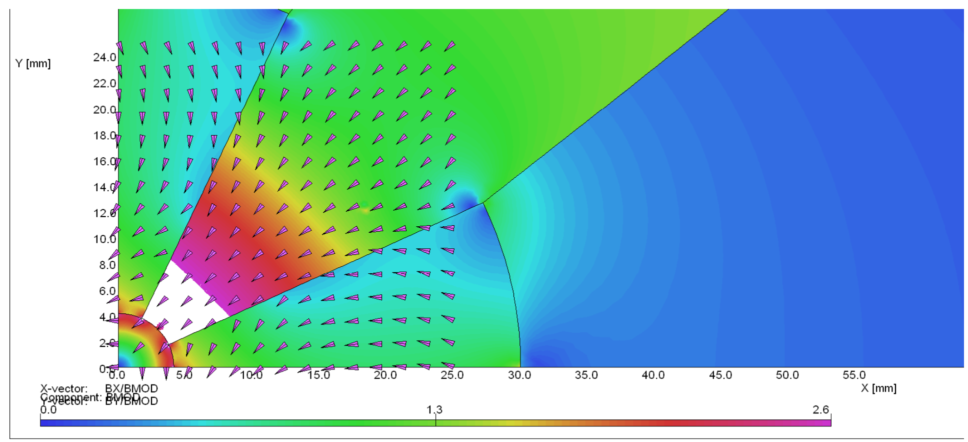
- Saturation appears (with both materials)

(Opera 2D simulation. Courtesy A. Vorozhtsov)

"Hybrid" approach, Version 1:







	Iw=5000 [A]
Grad [T/m] Sm_2Co_{17}	550
Grad [T/m] $Nd_2Fe_{14}B$	615

-Presence of PM wedges reduce strongly saturation in the poles
→ Grad increase of a factor 1.5-1.68

(Opera 2D simulation. Courtesy A. Vorozhtsov)

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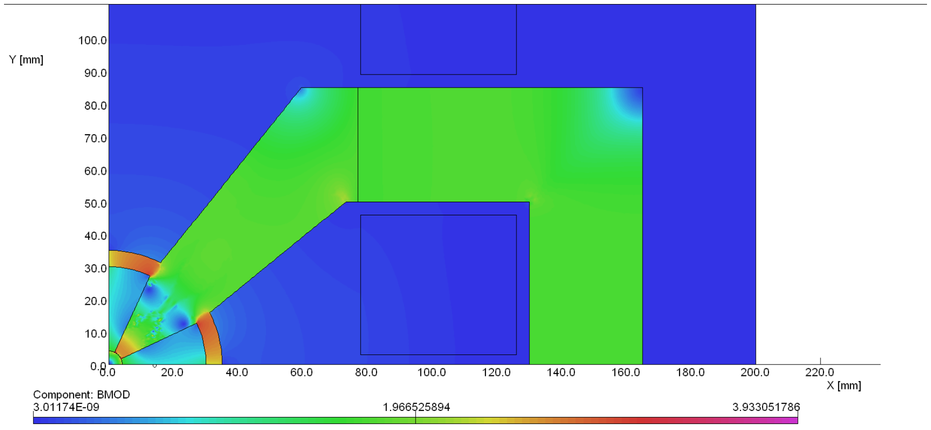
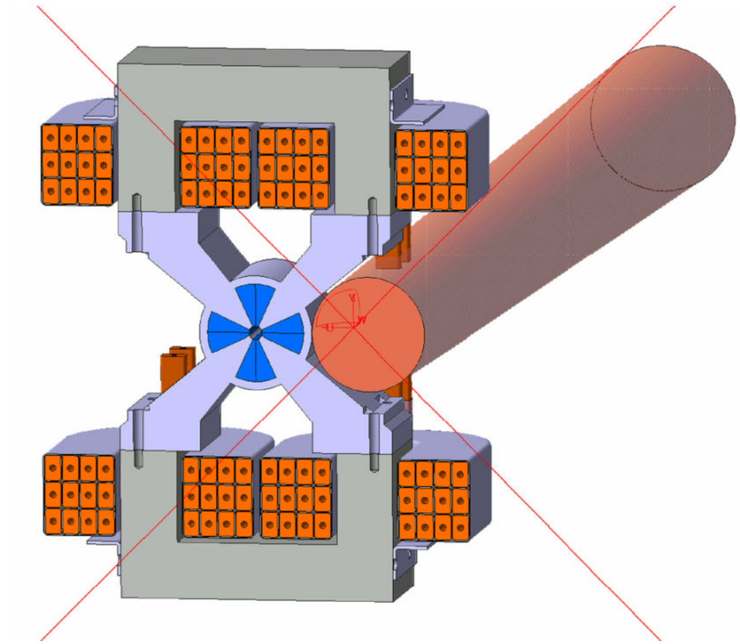
"Hybrid" approach, Version 2:



	Iw=5000 [A]
Grad [T/m] Sm_2Co_{17}	531
Grad [T/m] $Nd_2Fe_{14}B$	599

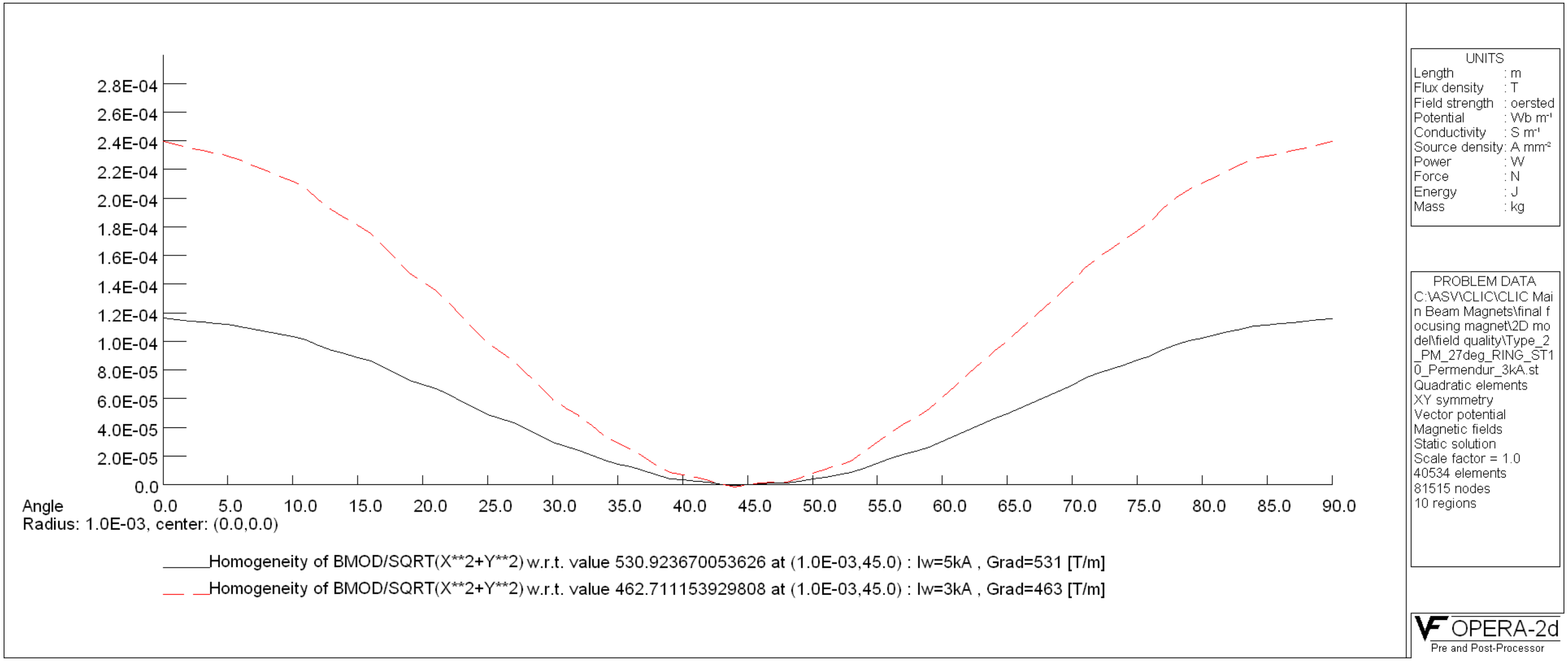


- The presence of the "ring" decrease slightly the Gradient (by 15-20 T/m) but will assure a more precise and stiff assembly

- EM Coils design will permit wide operation conditions (with or without water cooling) that can be critical for performances (ex. stabilization)

“Hybrid” approach, Version 2: *Field quality*

Gradient azimuthal homogeneity at R=1mm



(Opera 2D simulation. Courtesy A. Vorozhtsov)

Resuming :

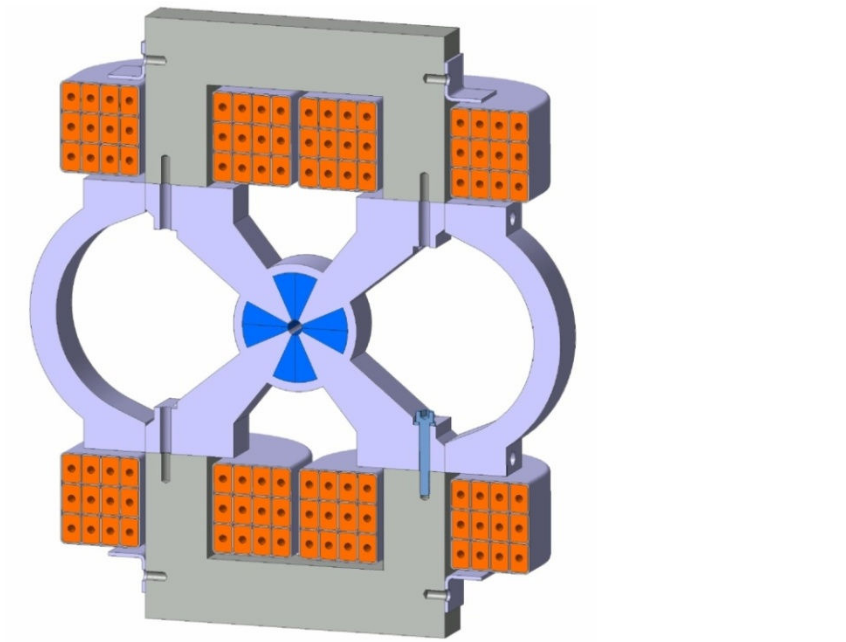
PM magnets (NOT Tunable)	R=4.125 [mm]	
Material	Sm_2Co_{17}	$Nd_2Fe_{14}B$
Grad [T/m] "Halbach"	409	540
Grad [T/m] "SuperStrong"	512	615

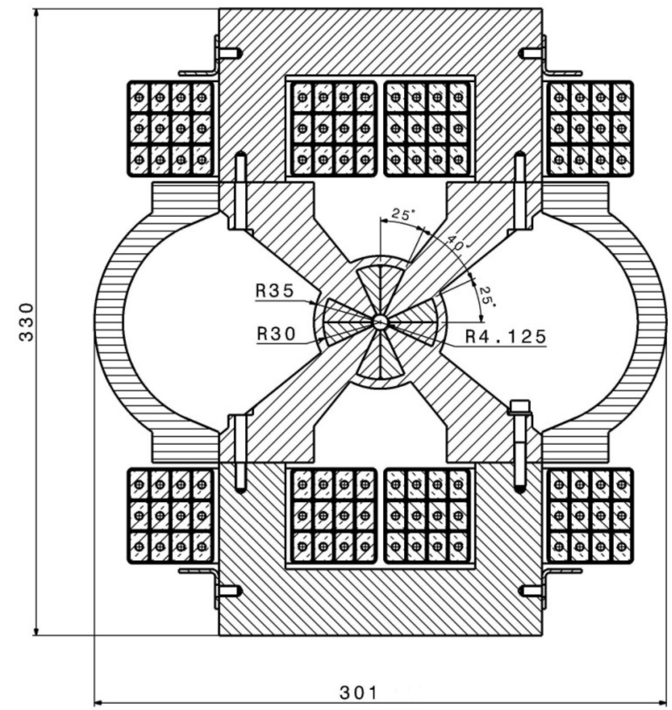
NC magnets Iw=5000 A (Tunable)	R=4.125 [mm]	
Material	ST1010	Permendur
Grad [T/m]	310	366

Hybrid magnet Iw=5000 A (Tunable)	R=4.125 [mm]	
PM Material	Sm_2Co_{17}	$Nd_2Fe_{14}B$
Yoke Material	ST1010 and Permendur	
Grad [T/m] Version 1	550	615
Grad [T/m] Version2 (SOLID CENTRAL RING)	531	599

- For our application Sm_2Co_{17} choice could be preferable (Curie temp. higher, higher radiation resistance)

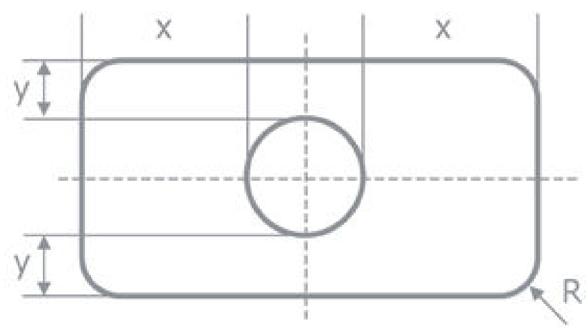
“Hybrid Short Prototype” (Version 2):





(Drawing: courtesy E. Solodko)

Conductor ID (ex. from “LUVATA” Catalogue)	6822
height/width [mm]	15.4/10
hole diameter [mm]	4.0
x/y [mm]	5.70/3.00
R [mm]	1.50
N turns per pole	12
Conductor Length [m] per pole for 1m magnet	28.5
Minimal bending radius [mm]	20
Insulation thickness [mm]	0.5
Mass per m	1.25 kg/m



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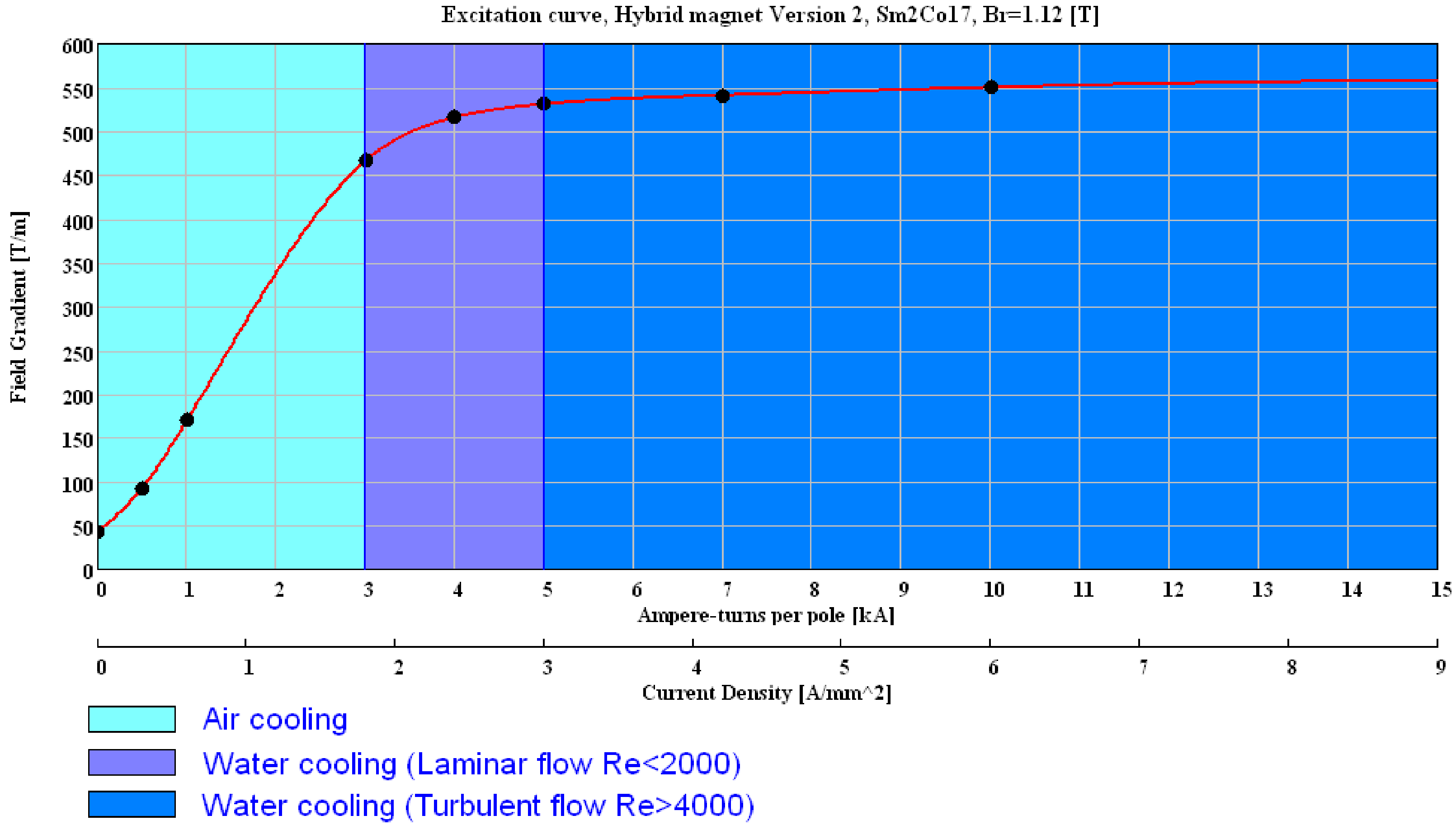
“Hybrid Short Prototype”:



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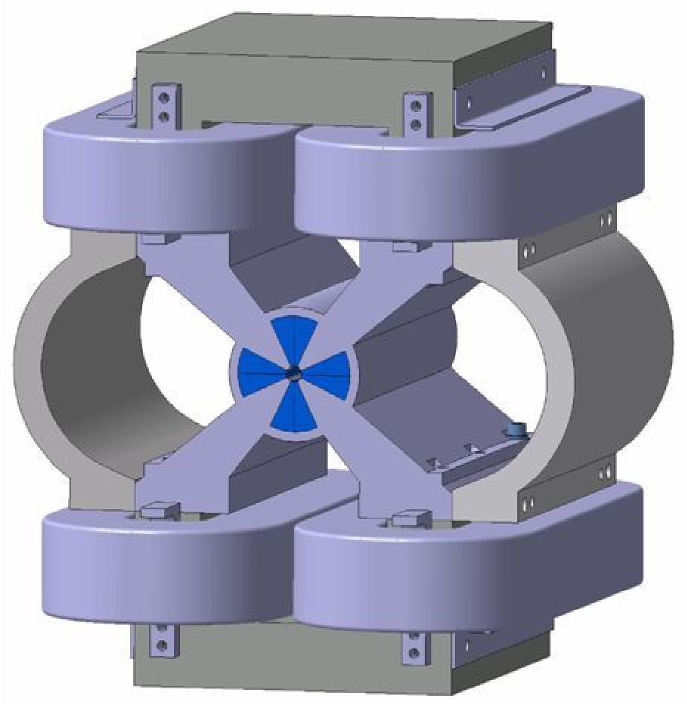
“Hybrid Short Prototype”:



…could be something like this.
Length will be short (it depends by PM wedges length availability), probably between 100 and 200 mm.

STATUS:

-2D and 3D magnetic design mainly completed.
-Simulations about mech. tolerances impact on gradient and field quality ongoing
-Field quality requirements: to be further discussed with Beam Physic Group
-Mechanical checks (simulation) should be done in the next weeks
-Contacts with potential manufacturers and components suppliers started.

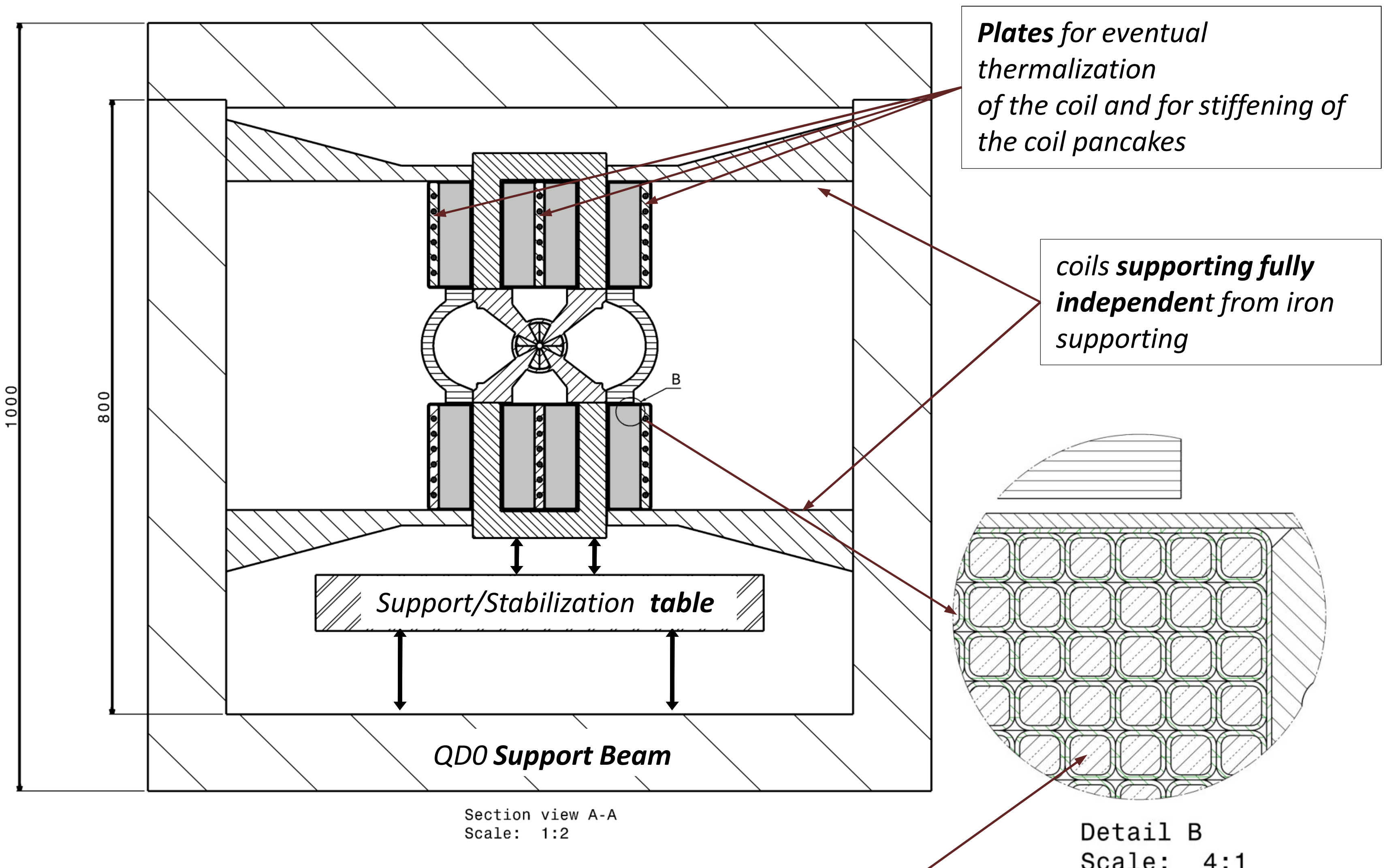
… Towards a more "adapted" design *(…still as CONCEPTUAL design!):*

1) *Reduce the current density in the coil (and consequently the coil cross-section)* ***to be free from cooling water*** *(at least in turbulent regime). The proposed cross section must have* ***J ≤ 1.5 A/mm2****.*

1) *Anyway, the presence of a "cooling circuit" is expected for a* ***"thermalization"*** *more than for a real coil cooling. This will also depends by the design of the support beam.*

1) *The presence of some "thermalization plates" will also provide* ***higher rigidity to the coil assembly*** *(remind that the coils could be quite long in the final magnet(s) since 2.73 m of total length for the QD0 element(s) are required).*

... Towards a more "adapted" design *(...still in CONCEPTUAL phase!):*



Coil copper ***conductor*** *(ex. 4x4mm). Nominal* ***J= 1.5 A/mm2***

(Drawing: courtesy E. Solodko)

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