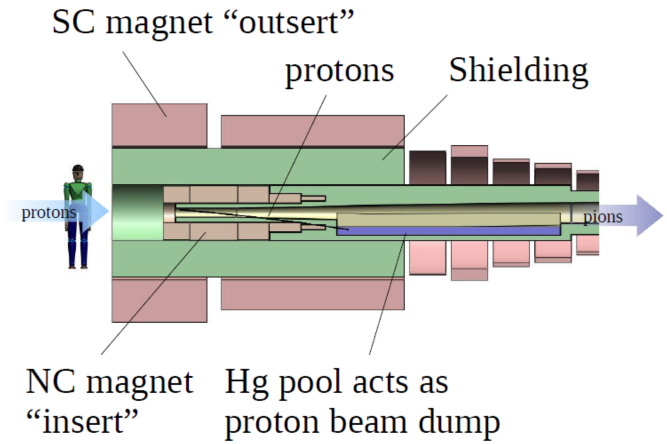
International
MUON Collider
Collaboration

Collider magnets

3 February 2022

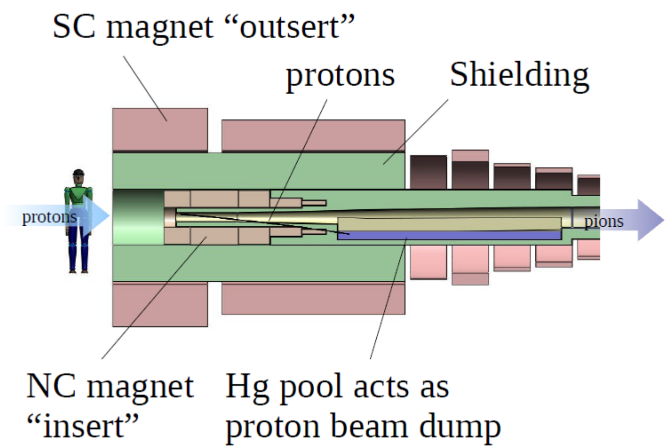
Target end solenoid



Hybrid design
(superconducting + conventionnal magnets)

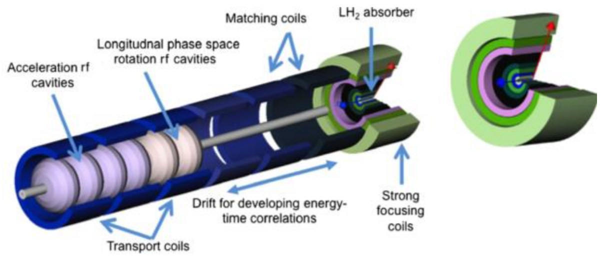
- Target field from 15T to 20T, SC coil inner diameter up to 1.2m
- For now, one could achieve 10T, 1m ID (independently from the cost) ?
- Strong effort needed to optimize the design;
- Balance to be found between radiation loads, operating temperature, magnetic forces, stray field shielding…

Target end solenoid

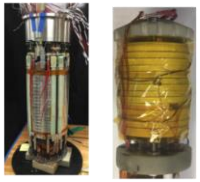


1 Priority :	Target end solenoid	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
1	Define magnet specification	1x0,5	1x3		
1	Evaluate realistic parameters (conductor mechanical performances, radiation loads, material radiation tolerance…)	1x3			
1	Assess the nominal cooling operation from the physics; evaluate the required cooling power and the cooling mode	0,5x3			
3	Conceptual design of a +15T large bore solenoid and of the ancillaries (cryoplant, quench protection system, DAQ…)	3	1		

Cooling

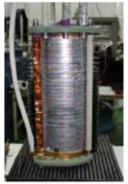


- **Field target >30T, SC coil inner diameter of 50mm for the final cooling, as short as possible**
- **So far, achieved performances are still very far**



32T
17T HTS+
15T LTS
ID 34mm

45,5T
14,5T HTS+
31T résistif
ID 14mm



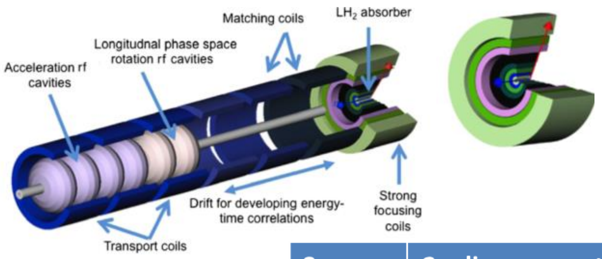
26,4T
(HTS only)
ID 35mm

32,5T: 14,5T HTS+ 18T résistif
ID 38mm

Bruker ASCEND 1.2 GHz 28.2T
(LTS/HTS @ 1,9K)
54 mm bore
Strongest commercial NMR

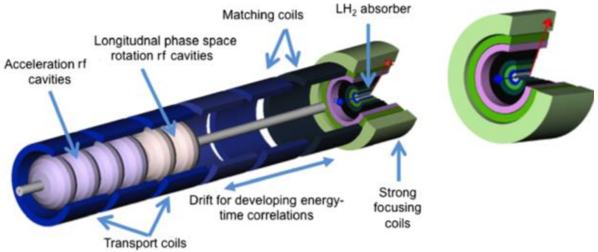
- **For all projects, magnetic field is in the vertical direction**, **while we need horizontal magnet**
- **Several demonstrators needed to address all the technical issues** (winding, joints, quench protection and detection of HTS magnets, radiation loads management, cooling management due to stagnant “Helium bubble”)
- **Short term plan may have to concentrate on realistic values** (**ID 50mm but only 15T to 20T or 30T but only ID 40mm to 45mm**)

Cooling magnet



2	Cooling magnet	Resource estimate			
		staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
2	Engineering design of a 30T horizontal cooling solenoid	2x3	1x3	1	
3	Prototype and mock-up fabrication to demonstrate winding techniques, mechanical design, quench protection strategy	1x3	1x3	1	300
3	Components procurement and 30T magnet fabrication	2x3	1x3	1	1100
3	Cryo tests of the 30T solenoid	0.5x3	1x3	1	50
1	Feasibility studies of a 50T solenoid	1x3	1x3	1	
1	Conceptual design of a rectlinear cooling channel, and of the associated magnets	1x3	1x3	1	

Cooling module



3 Priority	Muon cooling module	Resource estimate			
		staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
1	HTS magnet design based on a existing design (20T-25T with proven technologies), and interface definition with the RF WG	1.0x3	1x3	1	
2	Magnet components procurement and magnet fabrication	0.5x3	1x3	1	800
2	Integration and tests (In collaboration with the RF WG)	0.5x3	0,5x3	1	200

Acceleration

Need of fast ramped magnets (+/- 1.8T @ 400Hk)

- AC losses management, large stored energy -> protection?
- Power converters (link with existing R&D at CERN)
- Continue the R&D existing at Fermilab (HTS magnet, 0.6T @ 20Hz)
- Discussion on a new demonstrator perrmances

Vertical excursion FFA for muon acceleration (option not discussed in MAP)

- Feasibility of magnets for vFFA as well as vFFA concept itself has to be demonstrated.
- At STFC/RAL, feasibility study on vFFA is going on and normal conducting prototype magnet is being designed.
- Magnets for vFFA muon accelerator may be realised as an extrapolation of the activity.
- R&D on vFFA magnets to build a scale down model of superconducting vFFA magnet.

Acceleration

4	Accelerator ring	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
2	VFFA cost scaling model	0.5x3			
3	VFFA engineering design based on ISIS upgrade model	1.5x3			
1	Fast ramped magnet (to be added here ?)				

Collider ring

- High field magnets (up to 10T) and high gradient (200T/m) with large apertures (80 mm to 160mm)
  - Combined functions
  - Geometry of combined function magnets (curved magnet such that dipolar field constant?)
  - Field quality requirements to be discussed, understood and defined
  - Open mid-plane magnets?

- Technical issues: mechanical forces, magnet protection (radiation losses management)

Collider ring

5	Collider ring	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Define magnet specification, and radiation level	0,5x3		1	
	Evaluate available options for combined function magnet (nested coils *vs.* L/R asymmetric coils)	2x3	1x3	1	
	Conceptual design of mid-plane magnets	2x3	1x3	1	

R&D NEEDED

- Renforced NbTi/Nb3Sn conductors for large high field magnets,
- HTS conductor performances
- Magnet protection again radiation heat loads, specially for HTS magnets, and accelerator magnets
- Material aging against radiation
- Material aging, power converter performances, AC losses for fast cycled magnets

- Synergies with other R&D programs?