A study of high gradient 201 MHz cavities in strong magnetic fields for the MICE experiment

A study of high gradient 201 MHz cavities in strong magnetic fields for the MICE experiment[1]

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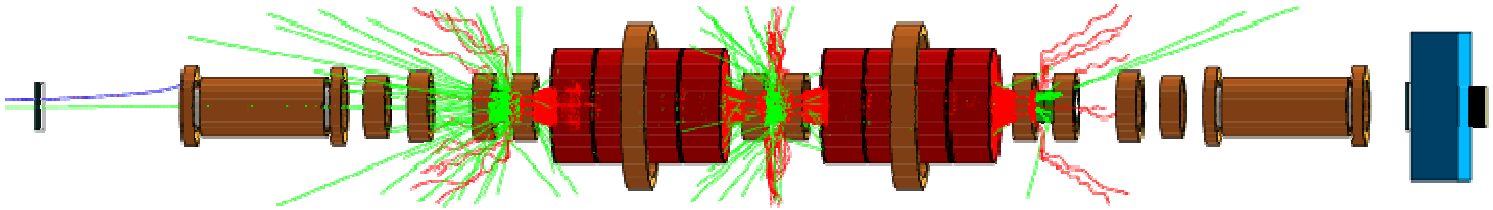
Motivation

1. RF gradient achievable in B field = critical component for Neutrino Factory (NF) (and Muon Collider MC) design → cost and performance (squared for MC) understanding the effect requires statistics and varied conditions

2. level of RF-generated background is critical for MICE
   -- may affect performance of even prevent running
   -- two effects :
      -1- effect of E-M 200MHz wave on PMTs and electronics this was tested for trqcker but not for TOF, KL, EMR
      -2- dark current electrons -> photons -> noise in detector



3. MICE will have 8 RF cavities which need to be individually tested
   -- this is clumsy both at RAL and at MTA

HISTORY by GERSENDE PRIOR

In 2009, following a discussion in the muon front-end group, G.Prior started to look for a large bore (R > 60 cm) magnet able to provide a 2 T solenoid field on axis, which could be either shipped to the MTA at FNAL or used at CERN for an RF R&D experiment in support of the MTA.

The M1 CERN magnet is a ~40 years old Helmholtz-type magnet composed of two SC coils mounted on squared Fe plates held apart by four cylindrical bars. Provides 3 T on axis in the center. The distance between the coil is 82 cm and the coil inner/outer diameter is 140 cm/210 cm.

Shipping would turn to be more than difficult and we are not even sure it would fit in the MTA.

MICE EB (May 21st 2010) gave a positive response (and stated some of the limitations) to the idea of using the magnet in support of MICE RF activities.

MICE EB received idea very positively

-- stressed need to have a CERN CHAMPION

-- stressed scope creep and need to find extra resources

PHILOSOPHY

First step:
The program will be concentrated on the test of MICE RF cavities

MICE is a CERN recognized experiment and request is legitimate.
(also SPC and UK delegation have been pressing for CERN to help MICE more)

The request is formulated as coming from MICE
CERN management's responsibility is to find -- the RF-Champion
-- the additional resources needed

the needed resources are spelled out

This first step can lead to further developments

possible synergies with other warm RF developments are mentioned. (CLIC etc..)

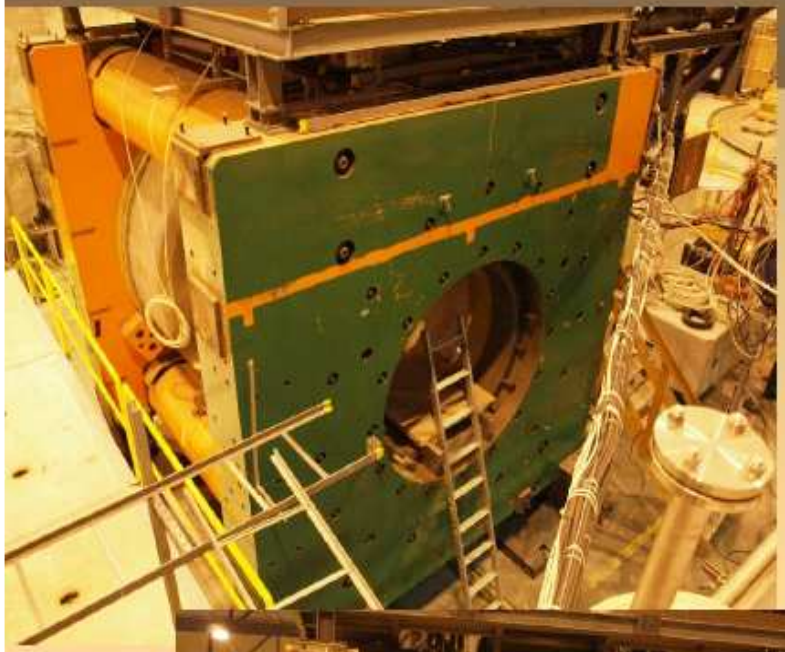
A MICE RF cavity test area?

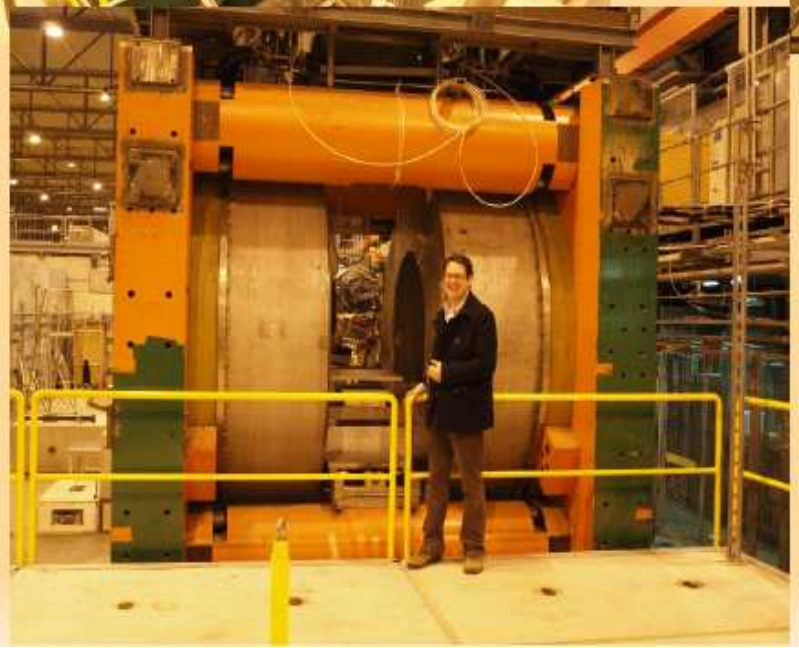
needed :

-- large magnet with up to 2T
-- easy access, shielding, interlocks, power, water etc…
-- RF cavities
-- RF power
-- people

M1 Magnet

Bravo Gersende!





M1 Magnet

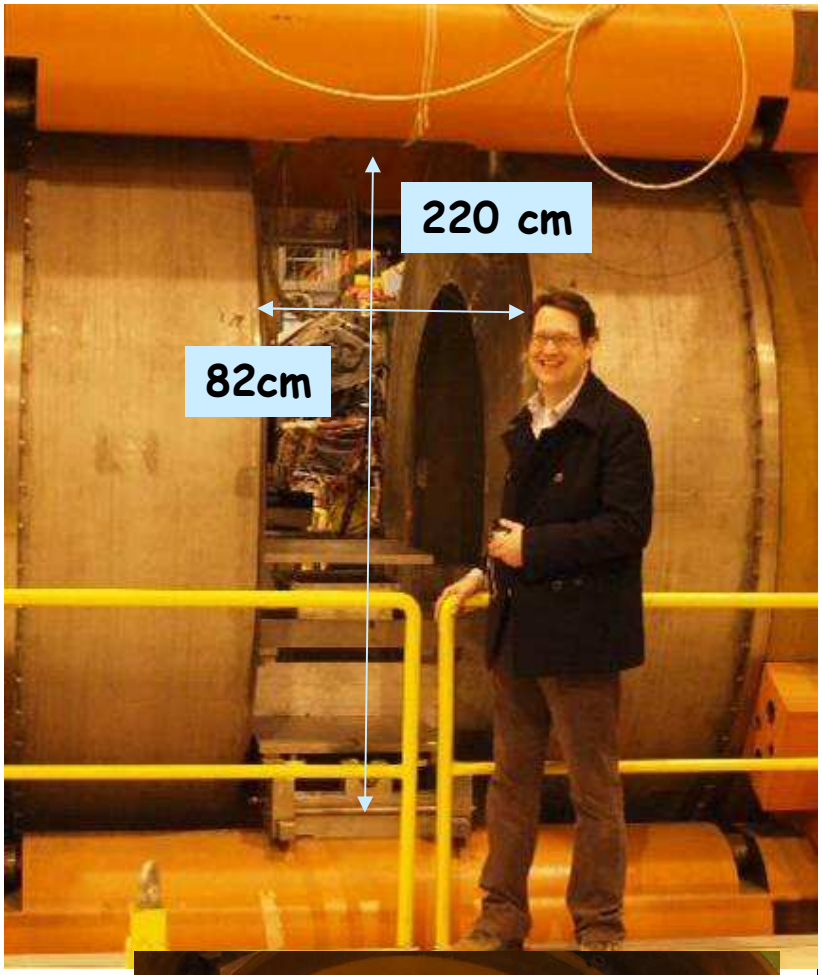
B max = 3T

B field direction can be inverted.
Has always worked in Helmolz mode **(~uniform)**
other configurations *a priori* not allowed (not tried)
no proper return yoke, stray field quite important.

inside dimensions:

between coils: 82cm
access
from side 82 cm x 220 cm.
from bore 140 cm diameter
from the top 82 cm x 155 cm.
from the bottom 82 cm x 220 cm x 0.67cm

Location: CERN North area.
Very Large experimental hall
Availability of power, water, shielding,
interlocked doors and control room



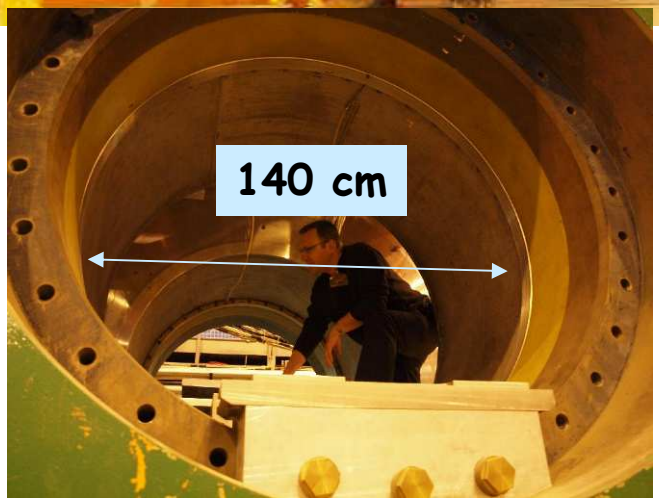


TABLE 1. Estimation of the magnet operation cost.

	Description	Cost
1	liquid He for 6 months of cold (including cooling down) operation	5 kCHF
2	power consumption for 1000 hours of operation	17 kCHF
3	1000 hours of magnet experts	10 kCHF
	Total estimated cost	32 kCHF

Experimental area

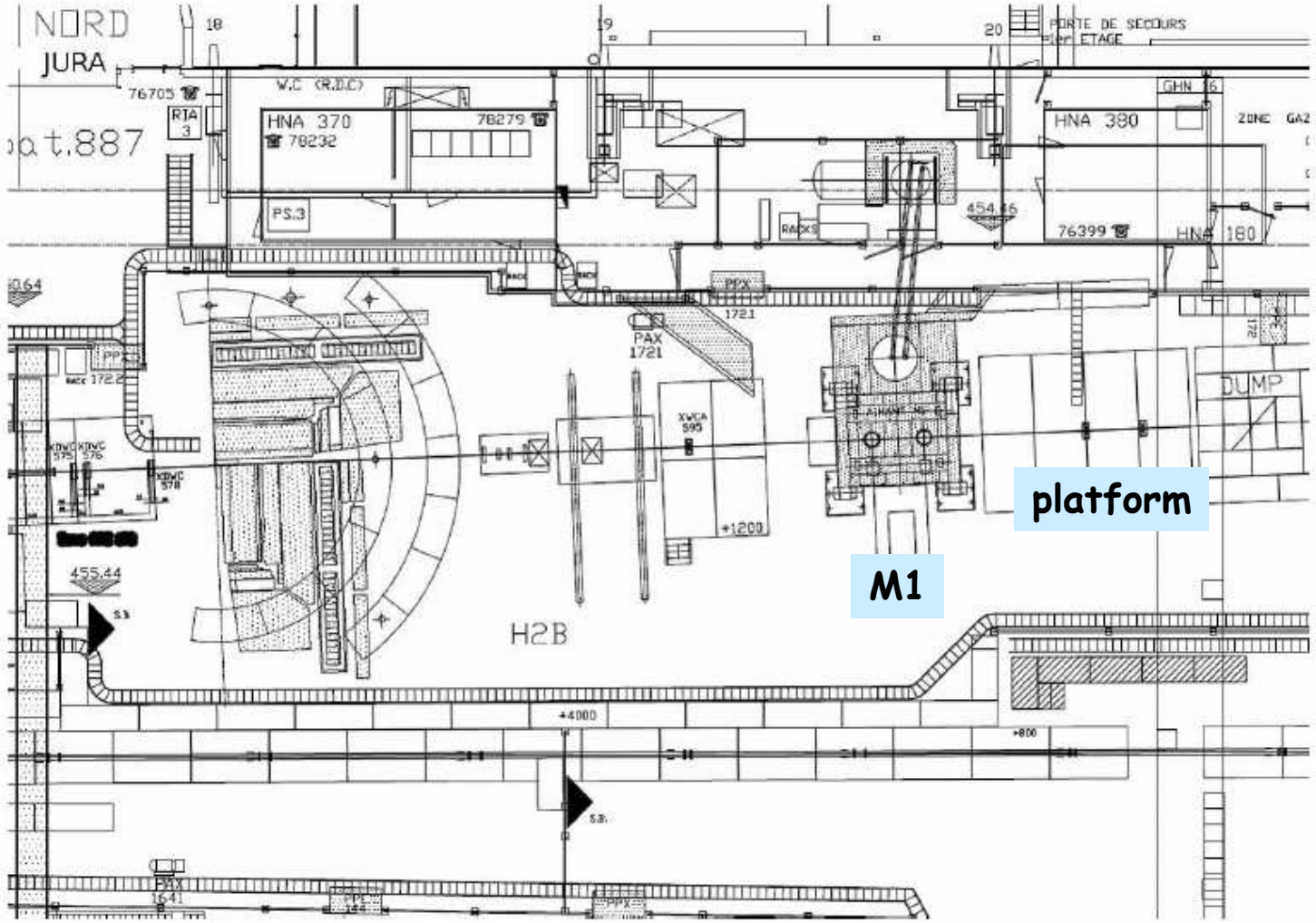


FIGURE 1. Layout of H2 Test Beam Area (courtesy D. Lazic), the beam direction is from left to right.

TABLE 3. Estimated cost (preliminary) for experimental area shielding

	Description	Cost
4	electron shielding with plastic + x-ray shielding with lead	1 kCHF
5	test area infrastructure	20 kCHF
	Total estimated cost	21 kCHF

Moving shielding blocks etc…is not usually billed to experiments.

Experimental area

H2 Test Beam Area:
-- upstream of the magnet area is occupied by NA61 experiment.
No interference with NA61 running (beam stopper upstream)
-- in the magnet area, 2010 occupancy was for CMS hardware R&D pixels (need the magnet) + others (magnet field off)
NB they really don't need such a big magnet for what they are doing!
-- no experiment downstream of the magnet area in 2010
-- need to enter scheduling process with other users of the area.

Services:
electrical power available.
water (demineralized, chilled, normal) available.
concrete blocks for shielding available.
empty control rooms on first floor available.

additional shielding for RF electrons/xrays will have to be worked out (not just concrete also some polyethylene probably).
Need to give spectrum of electrons and photons

RF cavities

The RF cavities are presently built under responsibility of LBNL (Derun Li)

10 cavities being built of which 8 will be MICE cavities + 2 spares

In MICE the cavities appear inside a vacuum vessel by modules of four (RFCC module) integrating the coupling coil (CC)

For testing purposes a single-cavity vacuum vessel has been designed and will be constructed by LBNL

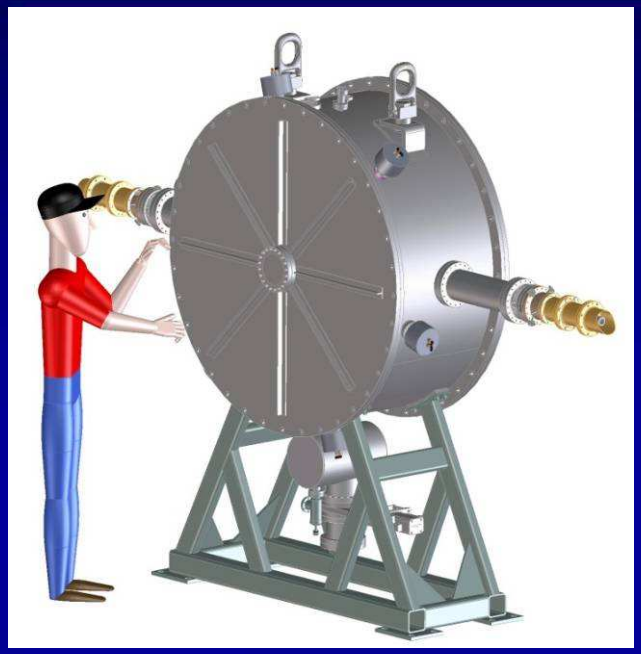
- it fits within the M1 magnet.

The testing will allow test of operation of RF cavity with Liquid N2 cooling

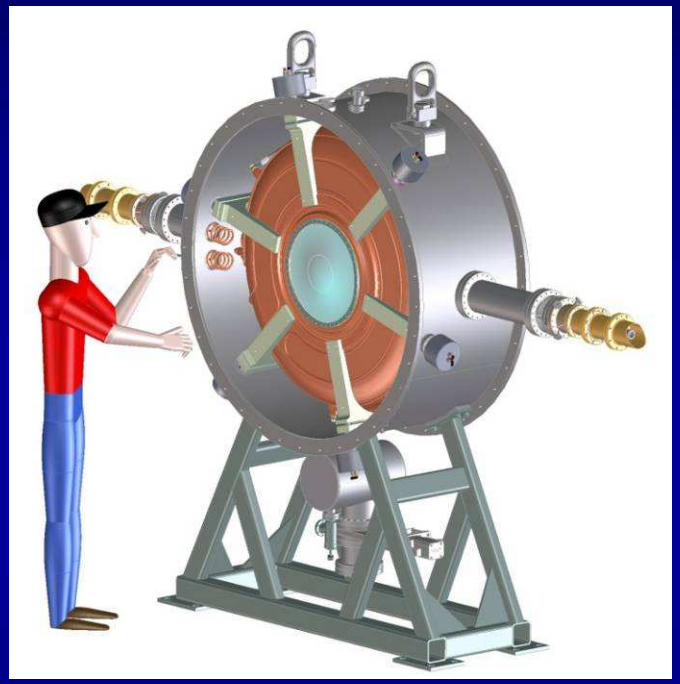
The RF cavities and the testing plan/supervision are responsibility of LBNL /MAP

It is reasonable to consider periods of a few <3 months at a time
The signatories of the proposal understand that they will man the testing

Single RF Cavity Vacuum Vessel

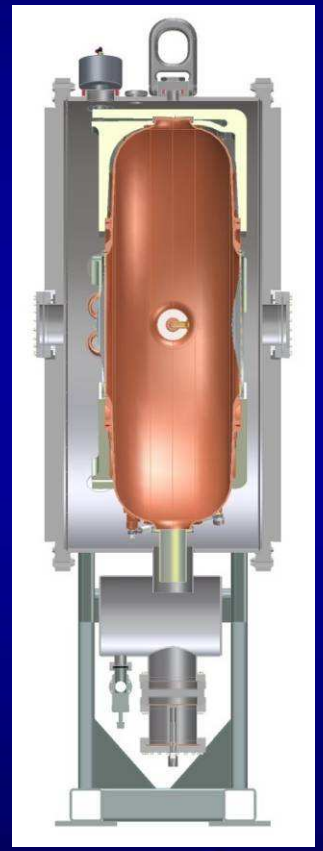


- Complete single cavity assembly

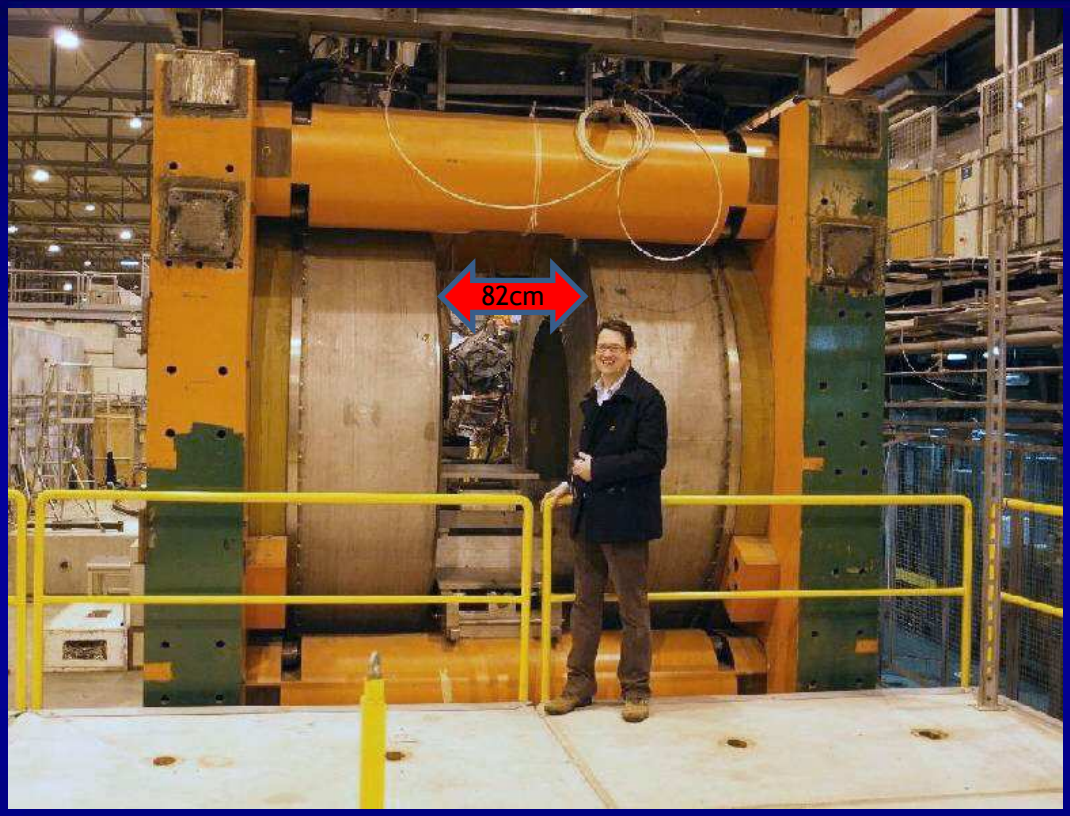


- Vessel front cover removed

- Side section view



Single RF Cavity Vacuum Vessel

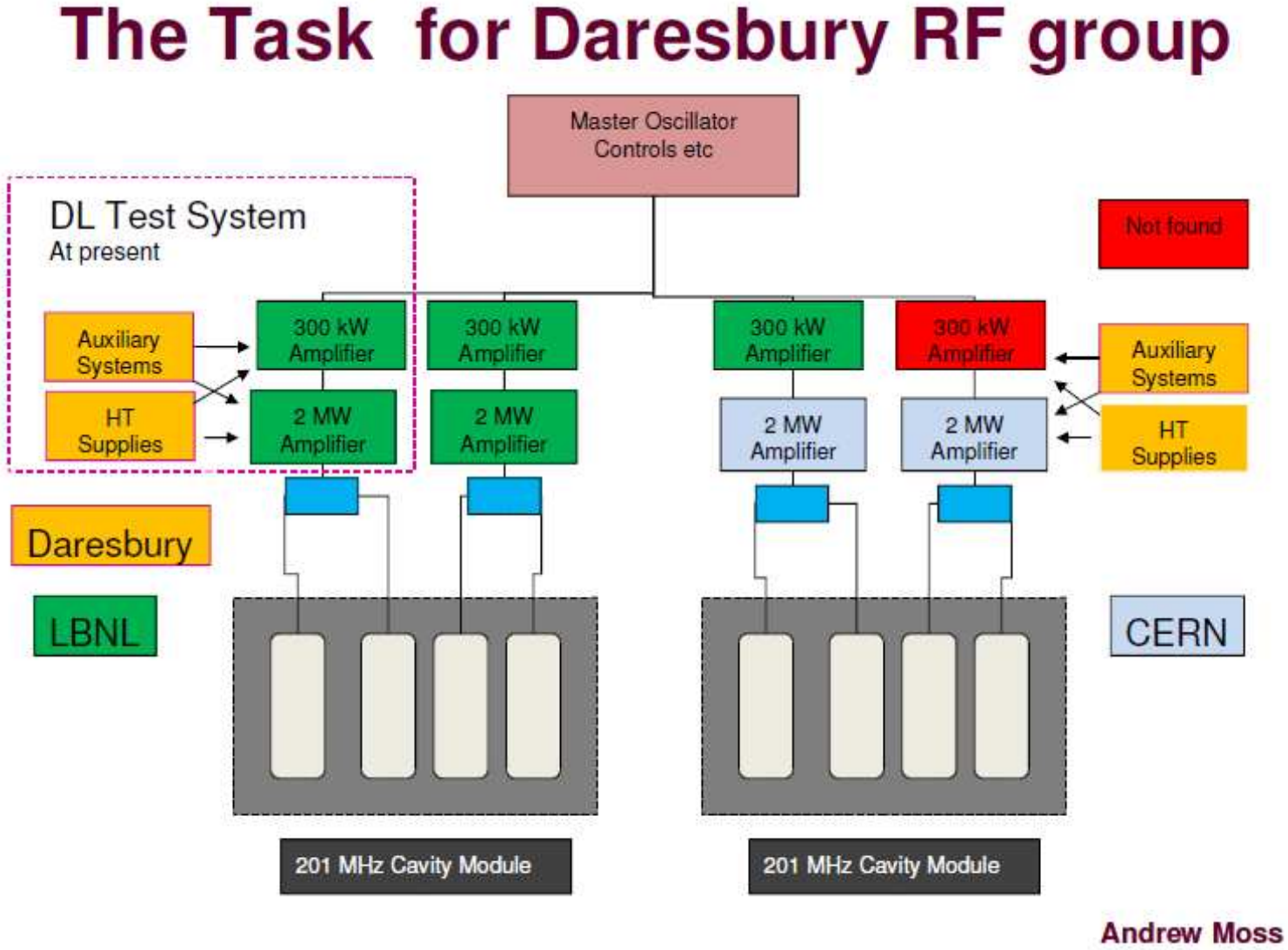


- Single cavity vacuum vessel superimposed between the magnet coils

- Single RF cavity vacuum vessel will potentially be used in a 3 T large bore magnet to perform RF breakdown test measurements in a magnetic field at CERN in support of the MTA at FNAL or in support of MICE

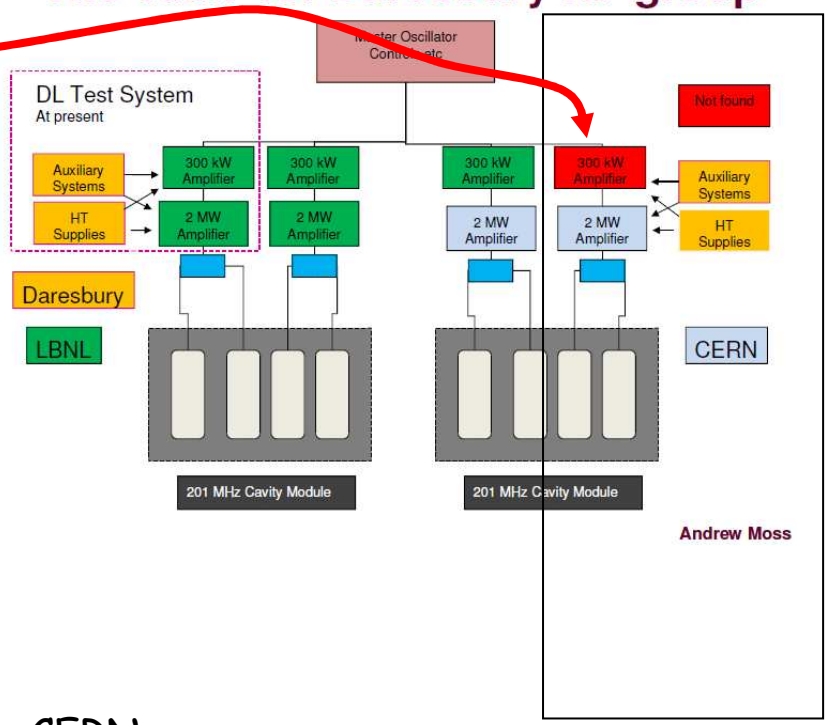
RF Power

The powering of the MICE RF cavities is foreseen as follows



The Task for Daresbury RF group

note the missing 300kW amplifier for MICE step VI



Test needs the equivalent of the DL test system:
300 kW amplifier
2 MW amplifier
auxiliary systems
HT supplies

a 2 MW amplifier can be shipped from DL to CERN.

300 kW amplifier:
can be assembled at CERN using spare SPS parts in 6-8 months
CERN will keep it.
or
using new parts(paid by MICE!) a 300 kW amplifier can be prepared by CERN for MICE use in step VI

auxiliaries and HV needed TBD.

Performance

With 2MW power a single RF cavity can run at 11.2 MV/m

if cooled to Liq N2 we can reach around 16MV/m
more if the tubes can be pushed further assuming low duty cycle

TABLE 4. 300 kW RF amplifier assembly cost.

	Description	Cost
6	components	50 kCHF
7	tubes (4×RS2058 + 1× YL1520)	110 kCHF
8	FSU	25 kCHF
	Total estimated cost	185 kCHF

TABLE 5. Estimated cost for RF shipment, installation and operation.

	Description	Cost
9	2 MW RF power shipment	2.5 kCHF
10	RF amplifier installation	40 kCHF
11	RF cavity installation	76.5 CHF
12	RF additional coax (350 mm diameter - 50 m long)	60 kCHF
13	RF amplifier disconnection work	2 kCHF
	Total estimated cost	181 kCHF

Required Resources

Summary of Estimated cost

32 kCHF magnet operation.
21 kCHF experimental area infrastructure (shielding,interlock...)
185 kCHF 300 kW amplifier assembly
181 kCHF RF installation and operation
50 kCHF instrumentation -- experimental groups (UNIGE et al)

sharing of cost subject to negociation between CERN and MICE members
Instrumentation definitely MICE
300kW amplifier to be paid by MICE if we keep it!
other costs of the order of of 200 kCHF – CERN may charge us part of this depending on how interested they are in hosting such program, but CERN is a member of MICE and can legitimately contribute.

Miscellaneous

manpower costs included above may have to be adjusted CERN-staff vs external.
amplifier HT and auxiliaries was assumed to be available at CERN,
cost may have to be adjusted if need/want to buy those.

Manpower needs

Magnet:
experts available during working hours. Ramp up/down will have to be performed by the person involved in the experiment. Training and procedure to learn not complicated. OK.

Experimental area:
Infrastructure/RP/crane operation. OK.
Services operation. OK.

Amplifier & RF operation:

Presence of a CERN RF expert is a *sine qua non* condition for performing of the experiment
need approx. 6 man-month

Could not be identified in absence of management blessing.

➔ Need to submit proposal to management to obtain OK of principle to break chicken-and-egg problem.

Within MICE:

we need to have a MICE person responsible for these tests who knows something about RF!

Since the cavities are theirs to damage I would suggest that this would be someone from LBNL.

A number of experimental groups have delegations at CERN (for e.g. LHC) and are happy to help with the running of the tests.

TIME SCALE

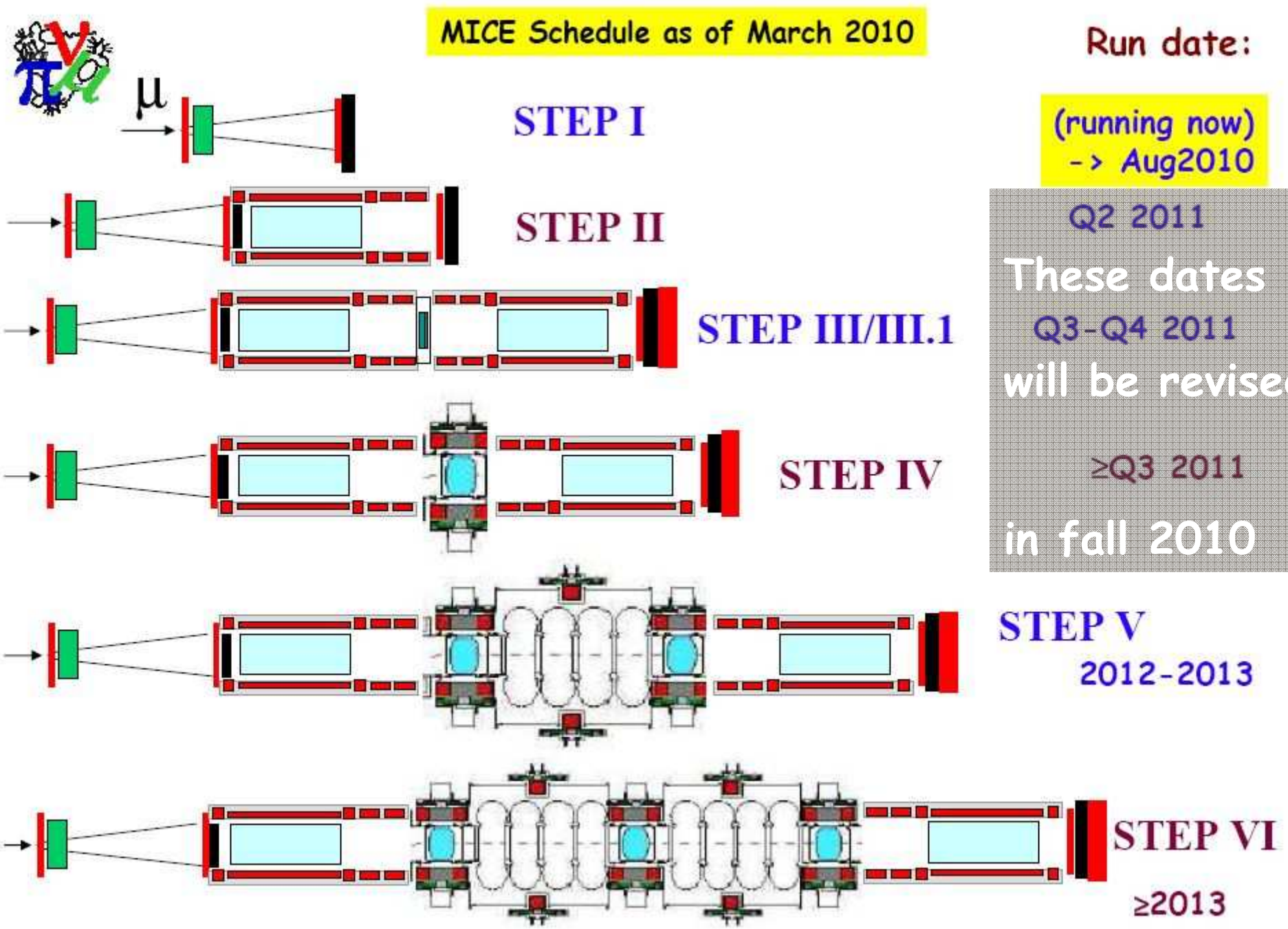
The first RFCC module for MICE is expected in RAL at the second half of 2012.

testing of the step V RF cavities in the second half of 2011-first half of 2012 is required.

second half of 2011 would give an excellent input for the '2012' events and completion of IDS-NF

testing of the step VI RF cavities in the second half of 2012

this timing is quite preliminary and will depend on availability of CERN champion.



see Andy Nichols talk

Conclusions

Gersende has studied the feasibility of a test of 200 MHz RF cavities in magnetic field at CERN.

There is an excellent opportunity in the north area, with the added advantage of CERN potential involvement.

The request to CERN has been written and is 'ready for submission'

Submission is a necessary step before detailed negotiations can take place with CERN on cost and schedule
A detailed plan of tests and procedures will need to be written by MICE RF guru (Derun)