Cold Collimator Feasibility Study (CCFS) Working Group:

status report

V.Parma,

CERN, TE-MSC

CERN, 3rd February 2012

Mandate

Scope of the work:

- Verify the feasibility of installing cold collimators, housed in cryo-assemblies, in the continuous cryostat during LHC's LS2, as required by collimation in several machine IR's (pt.1, 2, 3, 5 and 7)

Specific goals:

- Analyze configurations of cold collimators coupled to 11 T magnets;
- Identify potential show stoppers, either related to the implementation of the layout schemes or related to operational aspects of the associated technical systems (vacuum, cryogenics, machine protection, alignment, etc).
- Identify potential needs for R&D with its associated effort and timeline.
- Provide a final recommendation for the opportunity of a cold collimator project, with a draft timeline.

WG composition (by system responsibility):

- Collimators: A.Bertarelli, EN-MME; F.Cerutti, EN-STI
- Vacuum : V.Baglin, TE-VSC
- Cryogenics : R.Van Weelderen, TE-CRG
- 11 T magnets: M.Karpinnen, TE-MSC
- Machine optics, (R.Assmann, BE-OP)
- Machine Layout, Cryostat & Integration: V.Parma (J.Ph.Tock),TE-MSC

And ex-officio participants:

- Collimator project leader (R.Assmann, BE-OP)
- HL LHC project leader (L.Rossi, TE)

Organization

Meetings:

- Chairs: V.Parma (alternate J.Ph.Tock)
- Meetings every 2-3 weeks for an initial period of about 5 months (September 2011-January 2012), *now extended to mid 2012*
- Meeting date/place: *Tuesdays 10:30-12:00, 112-R-028*
- Minutes and workspace: https://espace.cern.ch/CCFS/default.aspx
- *5 meetings to this date, (next meeting planned after Chamonix).*

Reporting:

- Collimation Upgrade Management Meeting

List of topics treated and to come

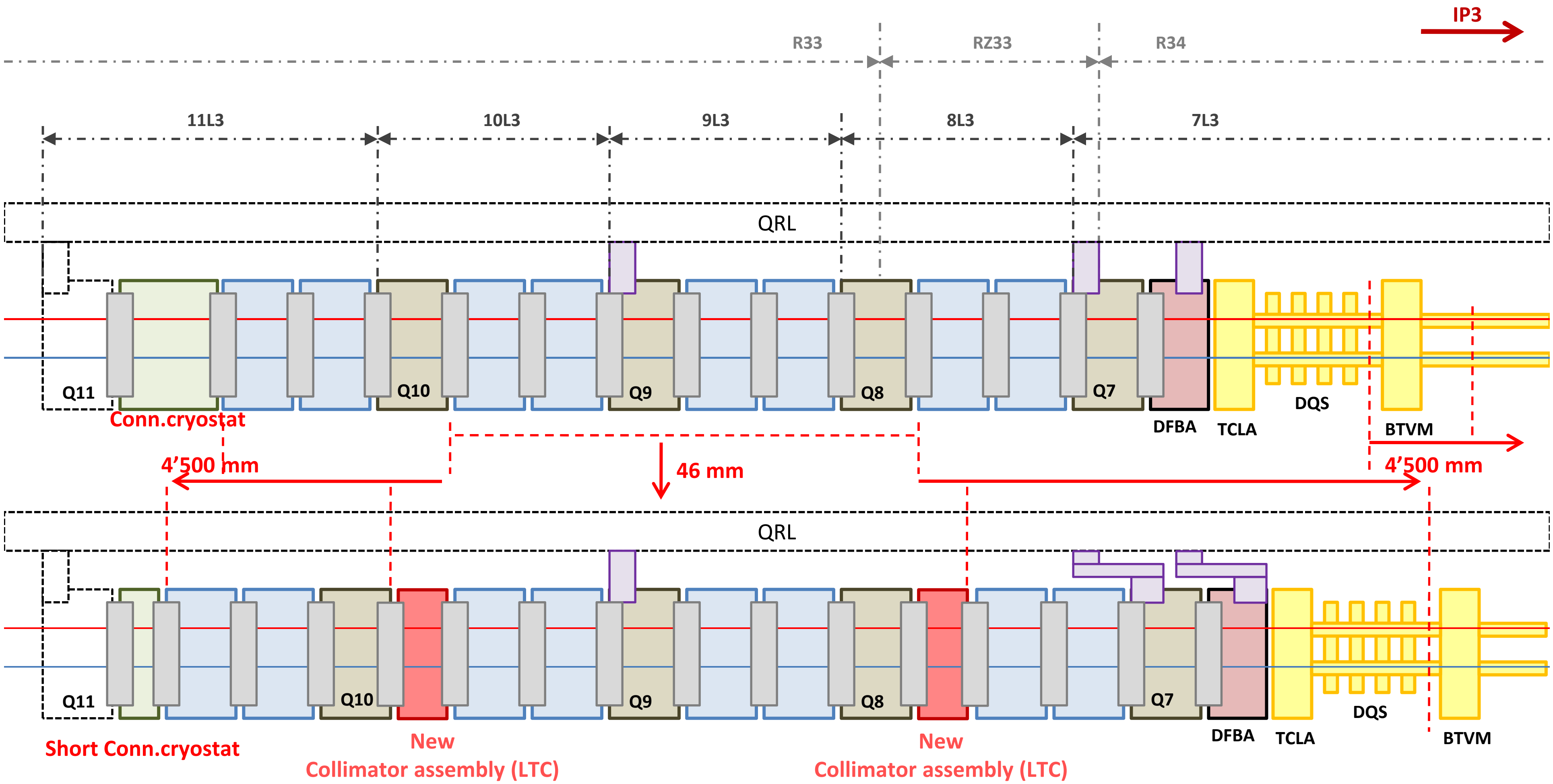
Topic addressed:

- IR Integration specificities (space availability, PC locations,…) *(J.Ph.Tock)*
- 11 T magnet specificities (strength vs.lenght, trim & powering, quench protection,…) *(M.Karpinnen)*
- Possible cryostat layouts (11 T common integration, individual cryostats,…) *(V.Parma+all)*
- Vacuum T and operation aspects *(V.Baglin)*
- Cryogenic aspects (heat capacity margins, operation aspects,…) *(R.Van Weelderen)*

Topic to address :

- Electrical powering schemes for correctors/trims of 11T magnet
- Collimators @ cryo T (materials, RF heat deposition,…)
- Collimator length (as function of material, efficiency,…)
- Collimator mechanisms @ cryo T (jaws alignment, precision,…)
- Reliability & Maintainability (failure scenarios, down-time,…)
- Comparison between cold and warm options
- Definition of R&D program, and project phases with a timeline aimed at LS2 (R2E) and LS3 (Hi Lumi)

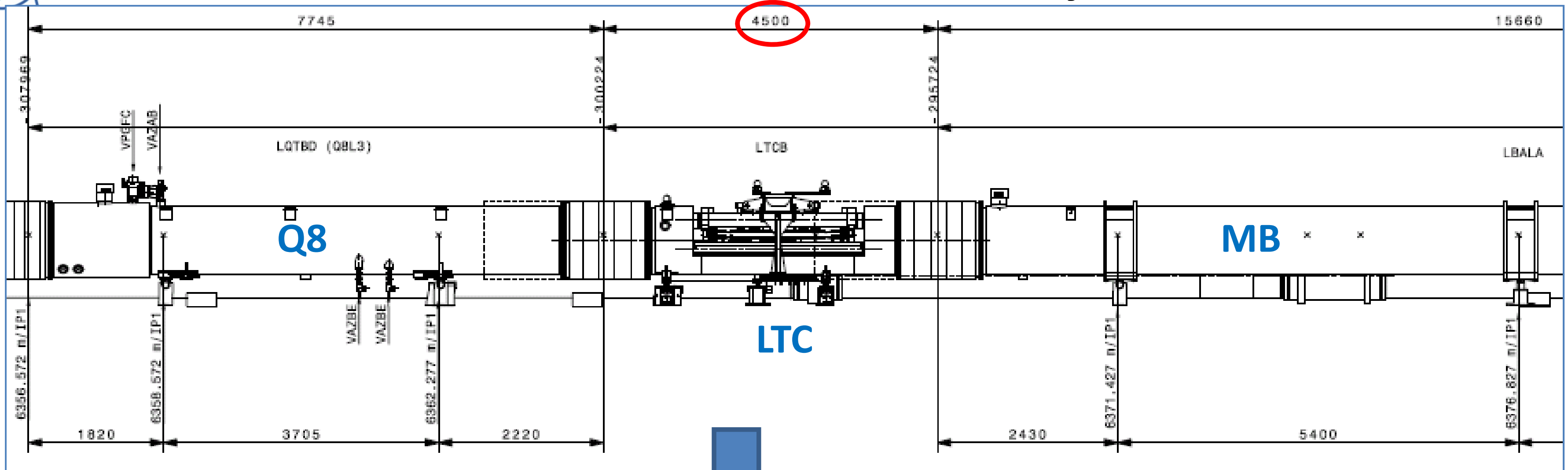
Warm collimators in the DS of IR3: our baseline



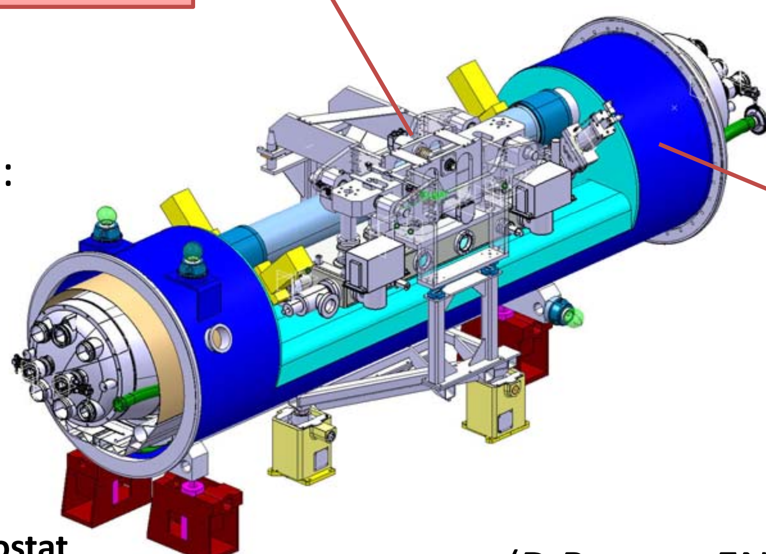
- was aimed at Shut-Down 2012-2013 (no time for 11 T magnets!)
- move 24 existing magnets and DFBAs (considered critical but feasible)

→ not needed for LS1 anymore, project postponed, more time for study/design

DS Collimator Assembly (LTC)



(Y.Muttoni, EN-MEF)

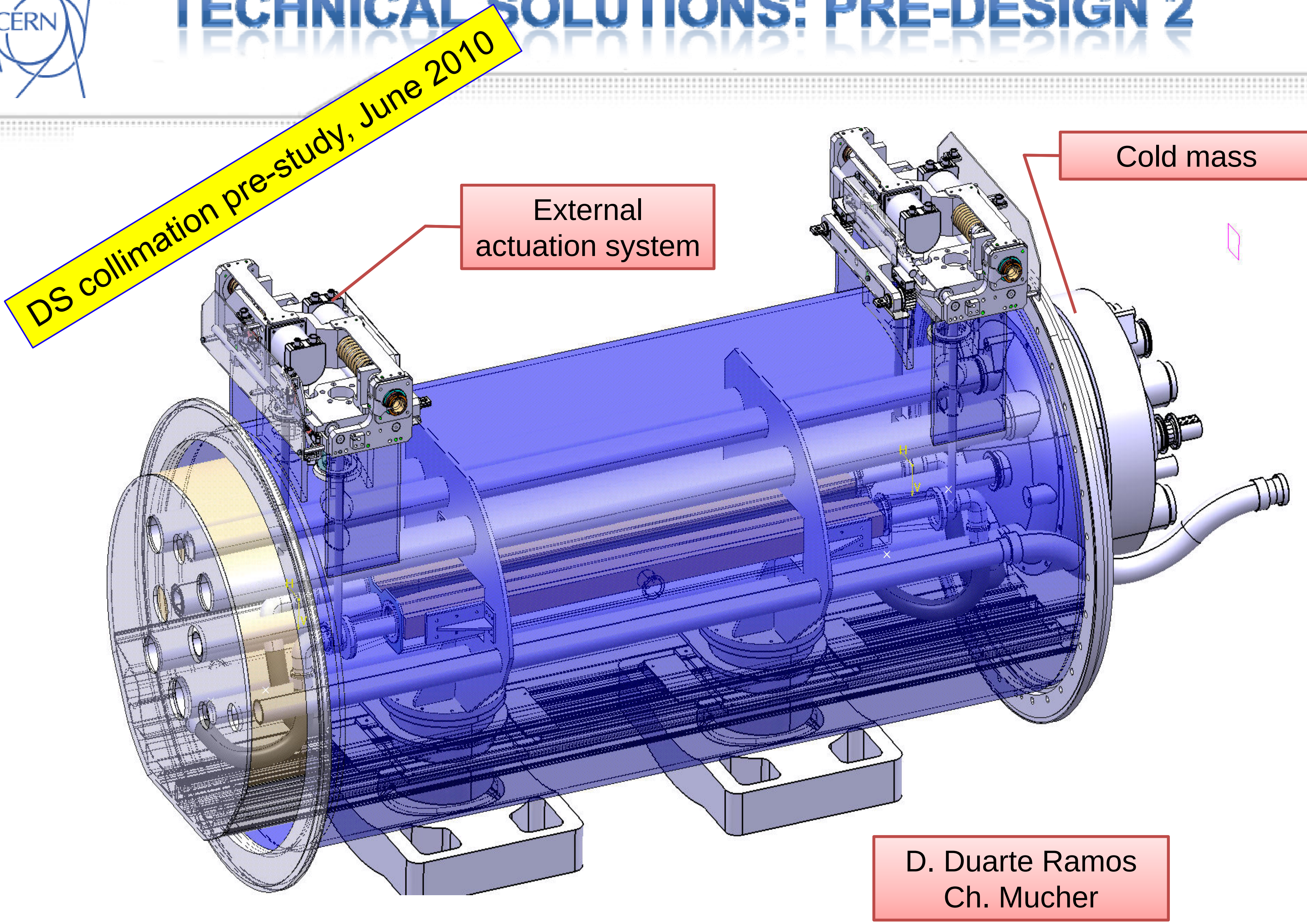


- W jaw length → 1 m
- overall length 4.5 m
- ineffective length due to:
  - Bus bars routing
  - Cold-Warm transitions

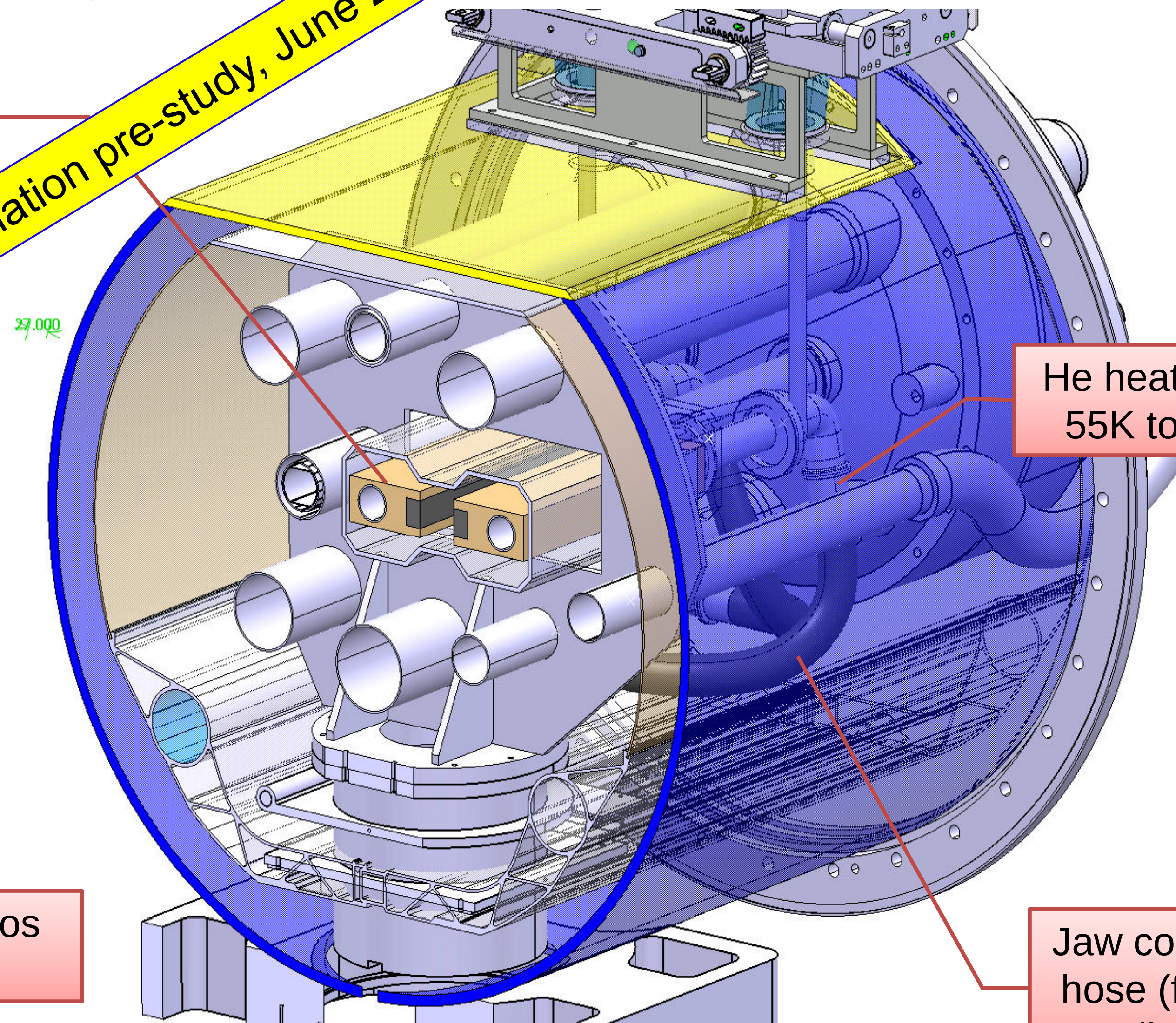
1 prototype cryostat is under construction

(D.Ramos, EN-MME)

TECHNICAL SOLUTIONS: PRE-DESIGN 2



TECHNICAL SOLUTIONS: PRE-DESIGN 2



D. Duarte Ramos
Ch. Mucher

TECHNICAL SOLUTIONS: PROS AND CONS

Warm pre-design

Pros:

1. Design inspired by FP420 project (TR).
2. Mainly standard and known solutions.
3. Warm collimators decoupled from cryogenic by-pass (can be independently installed/removed)

Cons:

1. Dimensions (up to 4.5 m).
2. Intricate cryo-lines rerouting
3. More complex manufacturing (two separate objects): higher costs and times
4. Harder to accommodate in IR7 and IR2 (lack of space): new cold design required in 1,5 yrs?

Possible showstoppers:

1. No showstoppers found so far …

Cold pre-design

Pros:

1. Compact and simpler cryostat (~3.2m vs. 4.5m), not affecting cryo-lines (no re-routing)
2. Less components, shorter manufacturing times(?), less expensive construction (??).
3. Synergy possible with GSI/FAIR project???

Cons:

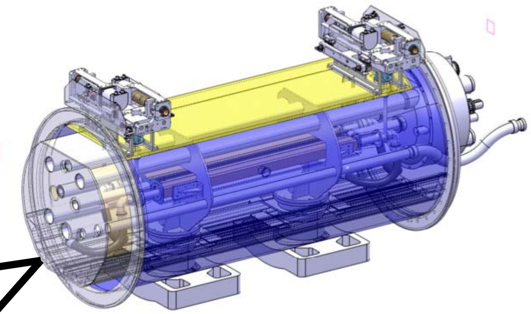
1. New concept (Cu jaw at >~80K?), requiring cryo-cooling.
2. New design validation requires lot of testing.
3. More engineering resources needed.
4. Non-accessible collimator jaws (no in-situ repair or easy replacement).
5. Additional constraints to cryogenic operation.
6. Cooling circuit derived from E-line with active controls in cold and vacuum: reliability?

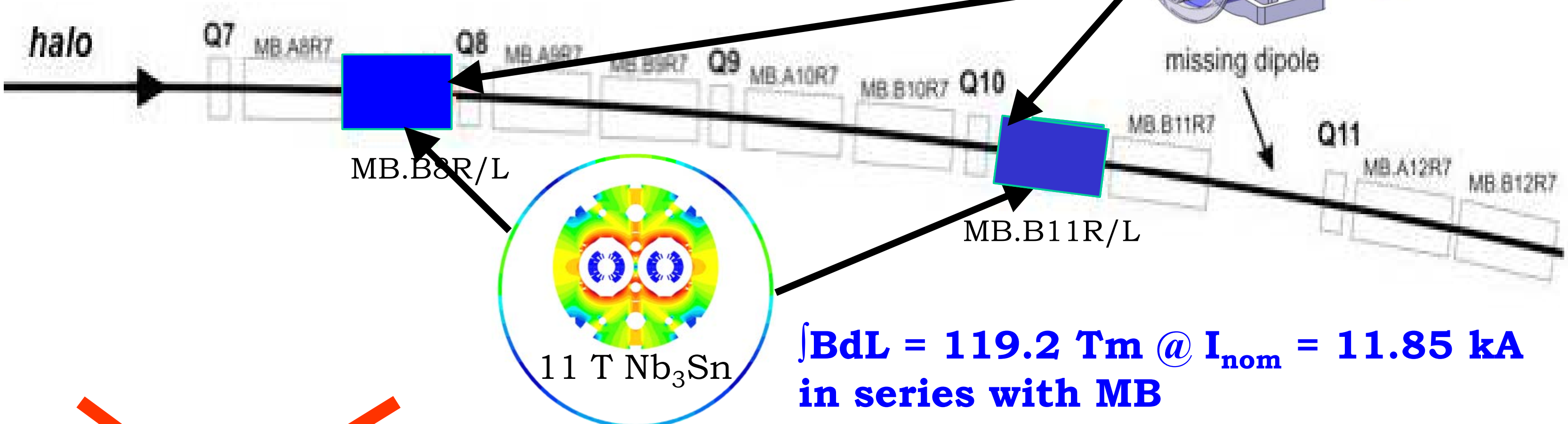
Possible showstoppers:

1. Beam vacuum operation at 100K.
2. Tungsten brittleness at low temperature.
3. Possible additional heat from RF heating.

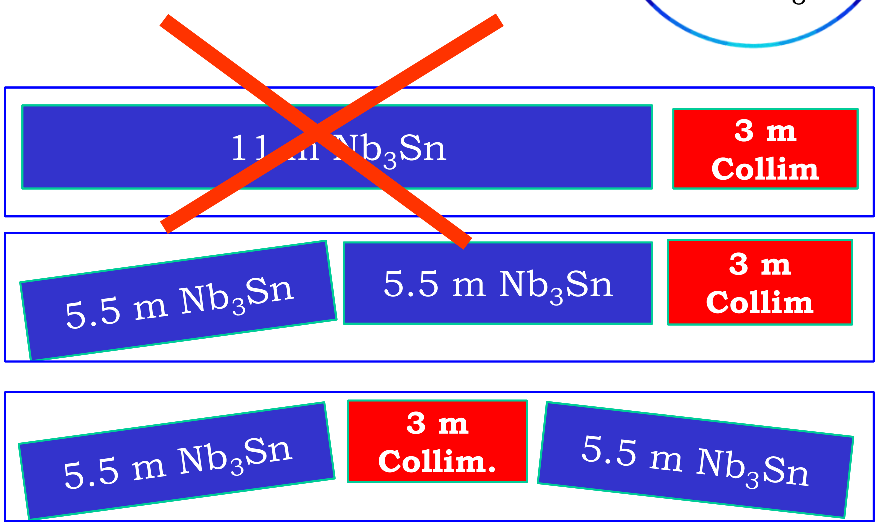
DS Upgrade

- **2017-18: Point-3,7 & IR-2**
- **2020: IR1,5 as part of HL-LHC**





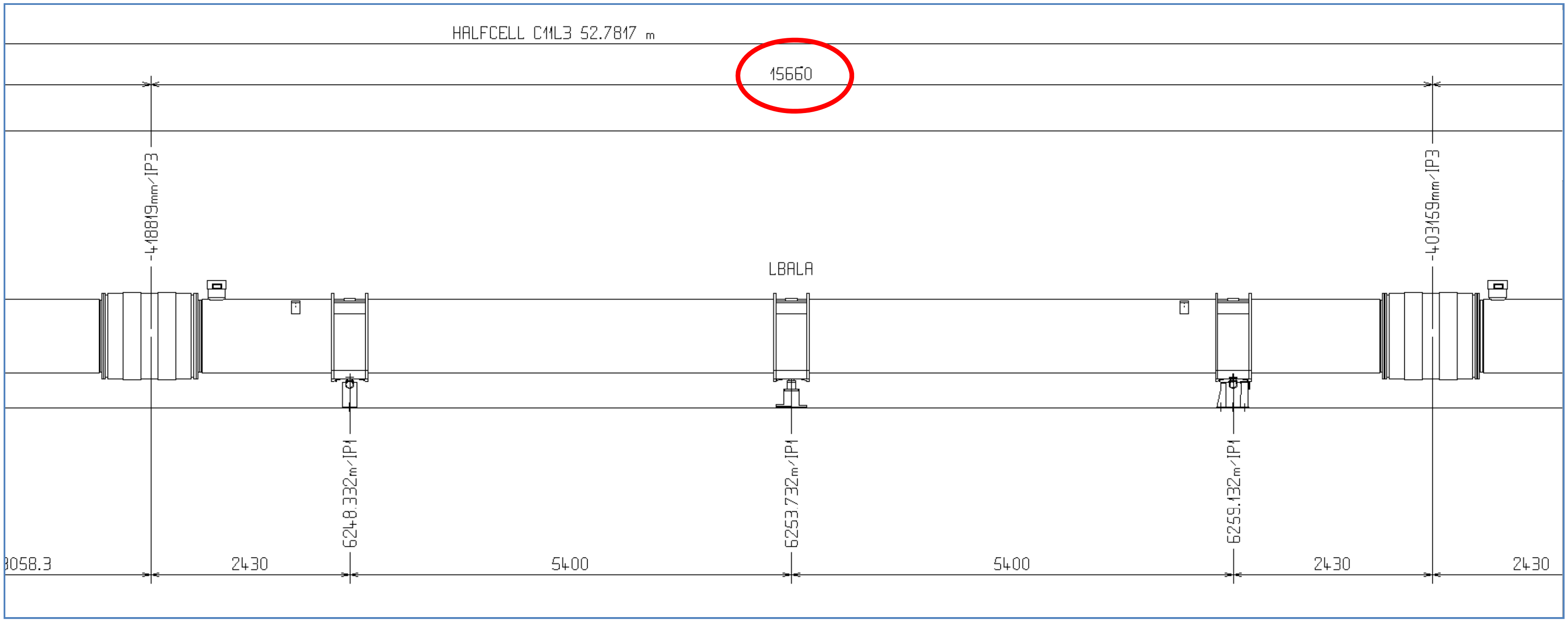
$\int BdL$ = 119.2 Tm @ I_{nom} = 11.85 kA
in series with MB



(11.2 T x 10.6 m), L_{CM} ≈ 11 m, (MB -4.2 m)
=> 12 coldmass + 2 spares = 14 CM

2 x (11.2 T x 5.3 m), L_{CM} ≈ 11.5 m, (MB -3.7 m)
=> 24 coldmass + 4 spares = 28 CM

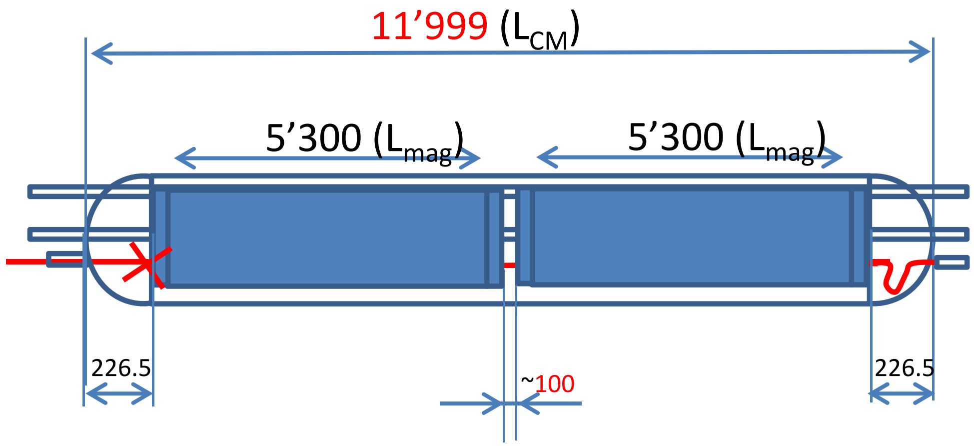
Dipole integration layout



- Remove and replace MB
- Preserve standard interconnect (i.e. standard interfaces)

→ 15’660 mm (IC plane to IC plane) space constraint

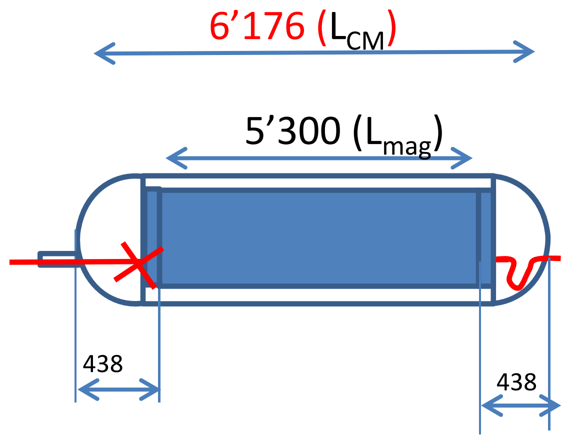
“2x5.3m 11T magnet” option



$L_{CM} = 2 \times L_{mag} + 2 \times 226.5 + 2 \times 423 + 100$

Note: One pair of standard MCS and MCDO can be included.

“5.3m 11T magnet” option

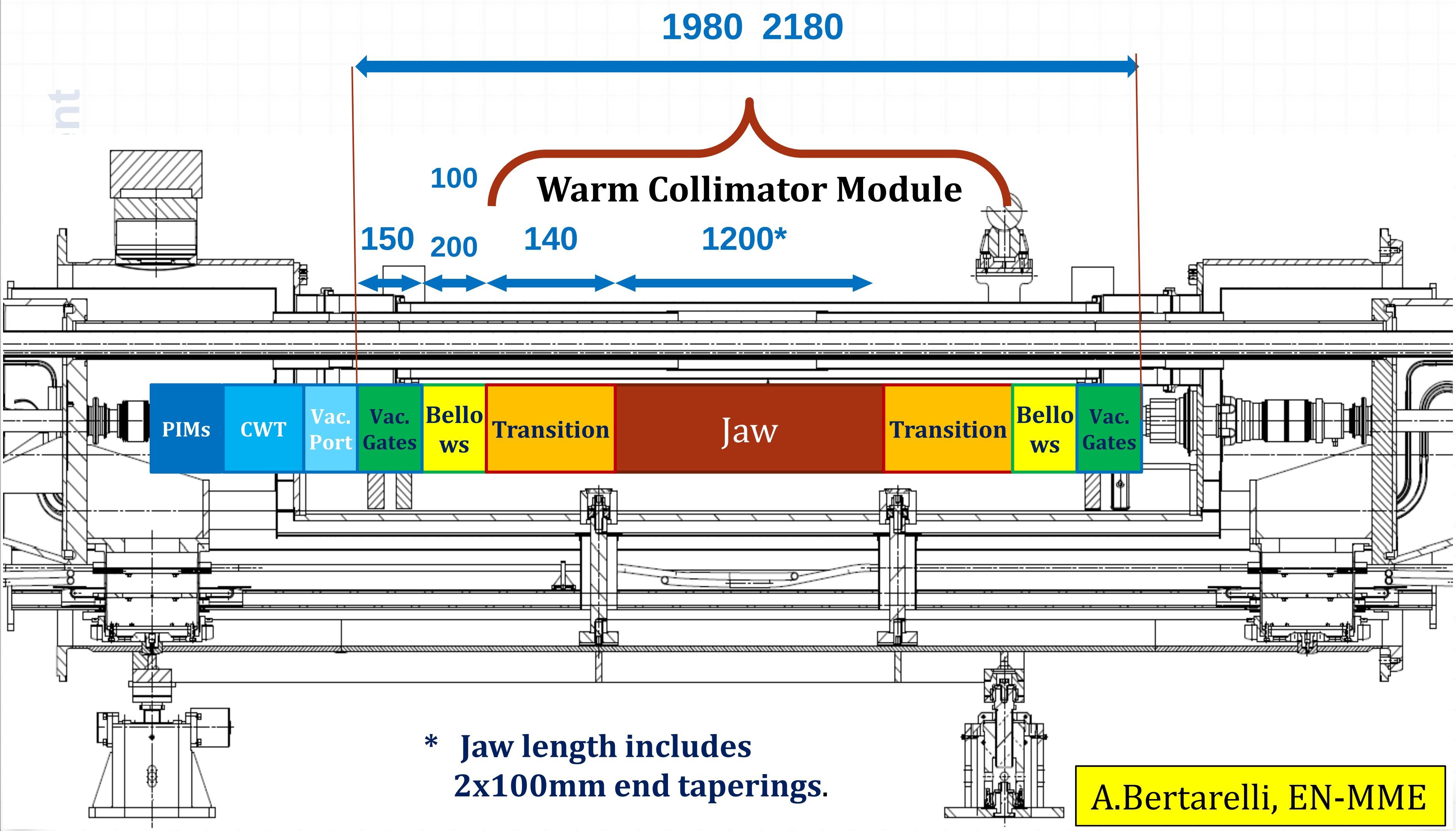


$L_{CM} = L_{mag} + 2 \times 438$

Note: One pair of standard MCS and MCDO can be included.

LAYOUT BREAKDWON

- Warm Solution



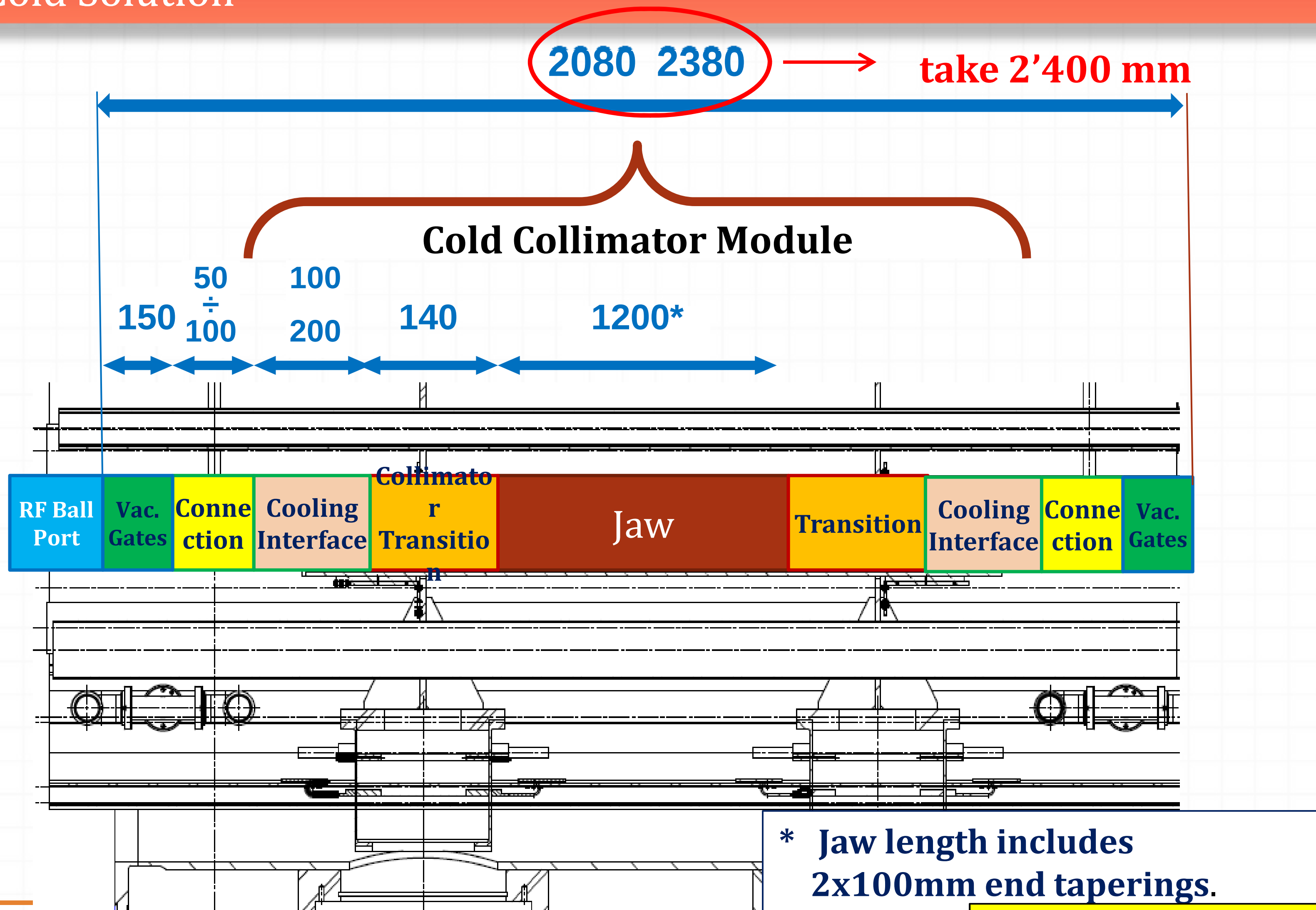
* Jaw length includes 2x100mm end taperings.

A.Bertarelli, EN-MME

LAYOUT BREAKDOWN

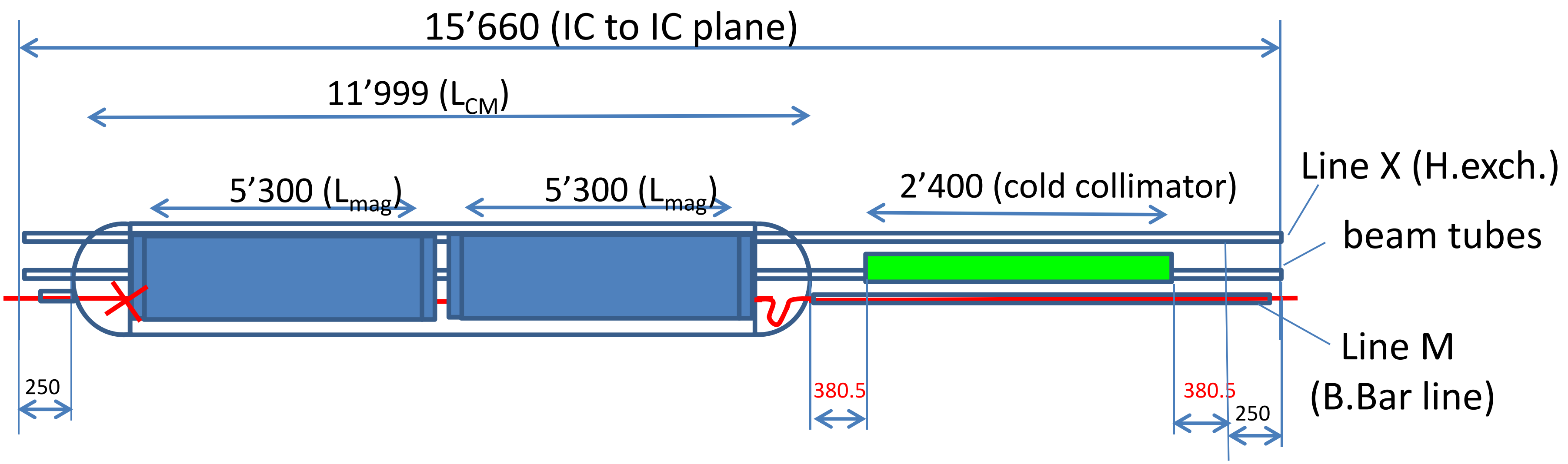
Engineering Department

- Cold Solution



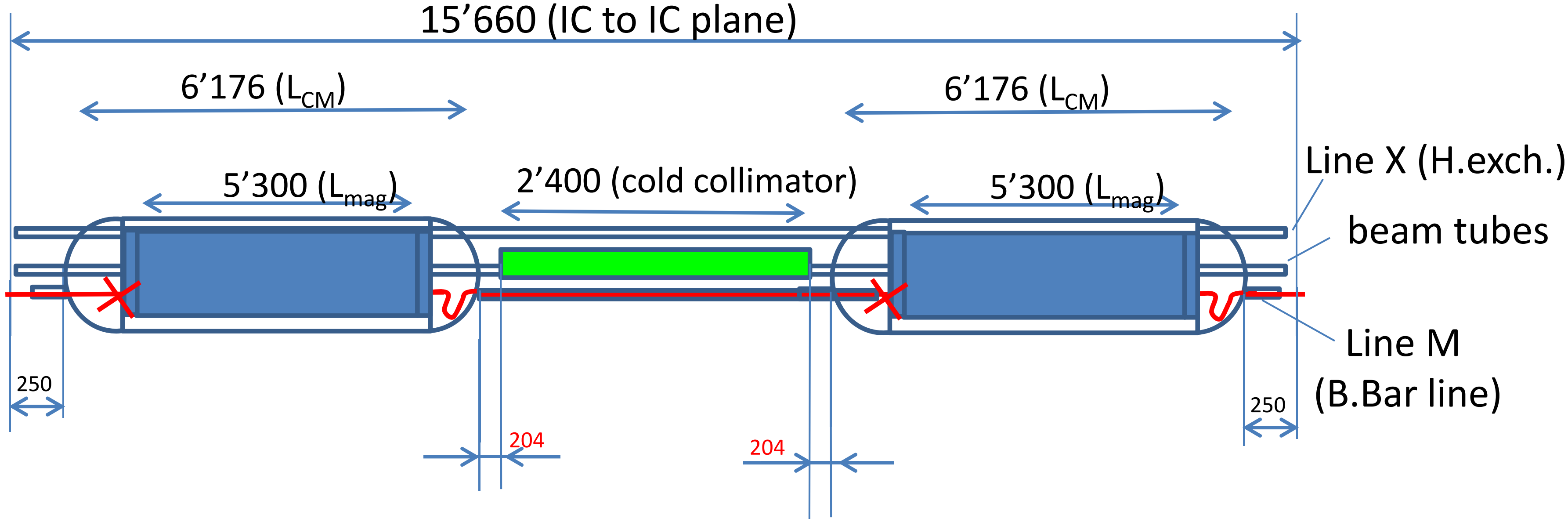
A.Bertarelli, EN-MME

“2x5.3m 11T magnet+collimator” option



Note: One pair of standard MCS and MCDO can be included.

"Collimator in the middle" option



Collimator space reduced (w.r.t *2x5.3m 11T magnet+collimator* option)

Note: 2 pairs of standard MCS and MCDO can be included.

Vacuum issues

Specs include:

- Include RF ball ports for PIMs inspection
- Beam lifetime is >100 hrs. Needs a pressure ranging between 10^{-8} (H_2) and 10^{-9} (CO_x) mbar. Leads to ~50 mW/m (at 7 TeV) and radiation to materials/electronics to be considered
- Local gas density below quench limit: 10^{-7} (CO_x) to 10^{-6} (H_2) mbar, which is equivalent to about 9 W/m

Design implications:

- Minimise gas reservoir:
  - Clean materials (such as TiZrV coating).
  - Bakeable materials. Bake-out today considered a must. This implies sectorisation (i.e. gate valves, which do not operate @ cryo T!)
- Allow for pumping: H_2, CO, CO_2 and hydrocarbons → pumping capacity
- Control vacuum dynamics in the component and its vicinity:
  - Beam screens needed for cold lengths in excess of 1 m (which is the case)
  - Perforated BS to allow pumping of H_2 vapour pressure onto the cold bore (H_2 sat.pressure from 10^{-6} mbar at 4.2 K down to 10^{-16} mbar at 2 K)
  - Secondary Radiation (saw-tooth design) and Electron Cloud (SEY) imply that an independent warm up of the beam screen must be foreseen (as for LHC)
- T collimator (He cooled 50-75K), > 90 K (avoid CO_2 driven instabilities) and below 150K (avoid H_2O instabilities)

Cryogenics, first thoughts

Design Heat Loads

source: LHC-LT-ES-0001 v.02, page7, section 3.5 Heat Load:

The design heat load for a collimator jaw is 200 W during a 10 s transient (12 minutes beam lifetime) at ultimate intensity (i.e. 1.7x1011 p/bunch).

In steady-state conditions (1 hour beam lifetime), the heat load is a factor 5 lower, i.e. 40 W.

These figures are valid both for protons and lead ion beams.

--> design for ~40 W, and see what the 200W/10s pulse has as consequences.

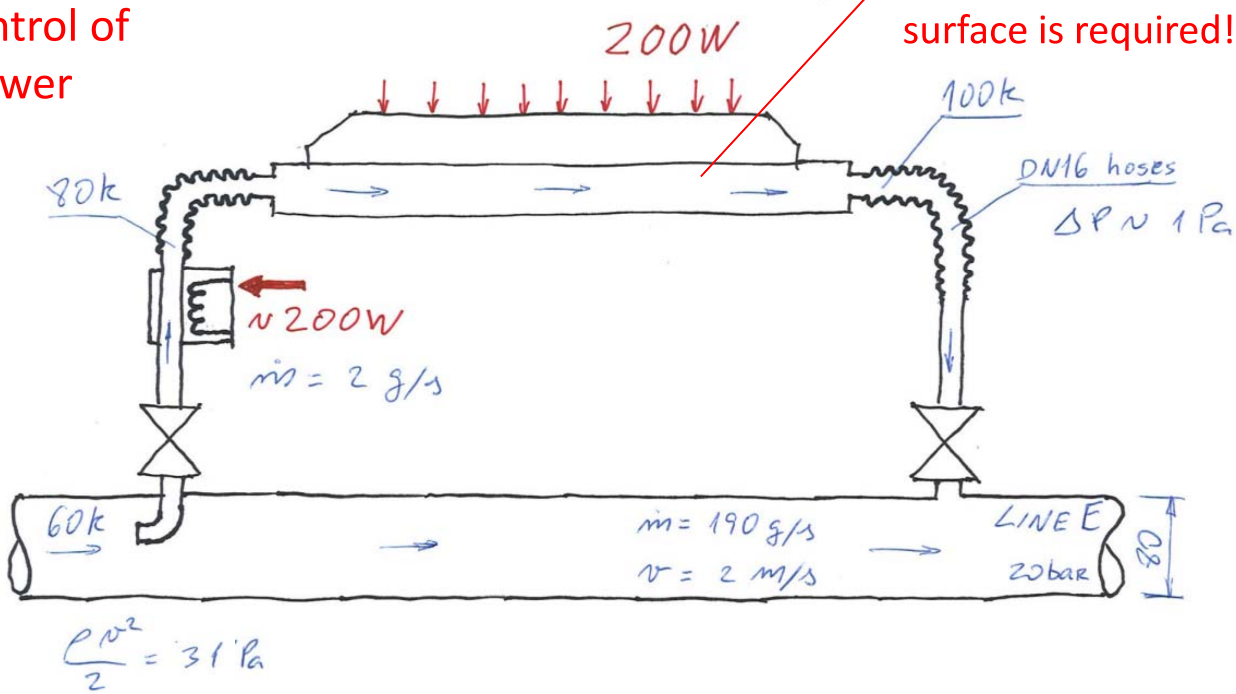
Cryogenics, first thoughts

Cooling at Temperatures > 80 K

- Source: header E, at 55 K - 65 K, depending on particular DS
  - Collimator at 80 K, beam screen at 80
  - Needed: line E bypass, with heater and temperature control

35 mm pipe would result in wall ΔT ~ 36 K (average). Larger surface is required!

Active control of heater power



D.Ramos, EN-MME

Dynamic pressure is sufficiently high; no need to add a restriction in line E

Cryogenics, first thoughts

Cooling at Temperatures 5K - 20 K: a valid option

dynamics:

transit time tau for nominal (150 W): 86 s (1.45 g/s)
transit time tau for ultimate (355 W): 37 s (3.43 g/s)

assuming we handle now as well the dynamic load +/- 40 W:
(515 W, 4.98 g/s), (555 W, 5.37 g/s)

Do we have this mass flow available?
->Yes as long as the e-cloud loads do not interfer!

The 200 W 10 s load will result in a heat wave (> 30 K) of 1 to 2 min over the remaining DS beam screen. For vacuum reasons probably not acceptable.

-> Need dedicated supply split after header C inlet, and dedicated valve at outlet to header D.

Summary

- The CCFS working group aims at analyzing layout configurations, pointing out fundamental show-stoppers, defining need for R&D, and identifying the design/construction effort for LS2 and LS3;
- A comparison between a cold and warm version of collimator will provide the rationale for a choice;
- The CCFS work will be extended until mid of 2012, before moving to the next phase;
- A preliminary layout study of the 11T+collimator assembly, with 2 options, within the space allocation of a standard MB IC-IC space, provides space allocation for the active elements (magnet and collimator), and free space for their connections (beam tubes/screens, cryogenics, etc.);
- Preliminary vacuum considerations suggest a number of design constraints
- Operating temperature between 90 K and 150 K of the collimator jaws; but 5-20 K could be another option
- …still quite some work ahead.

Thank you
for your attention