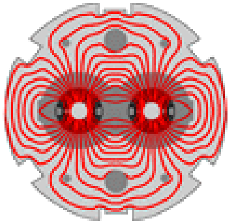
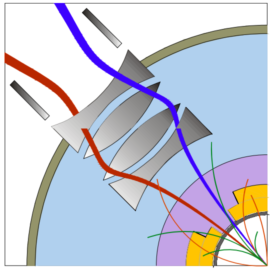
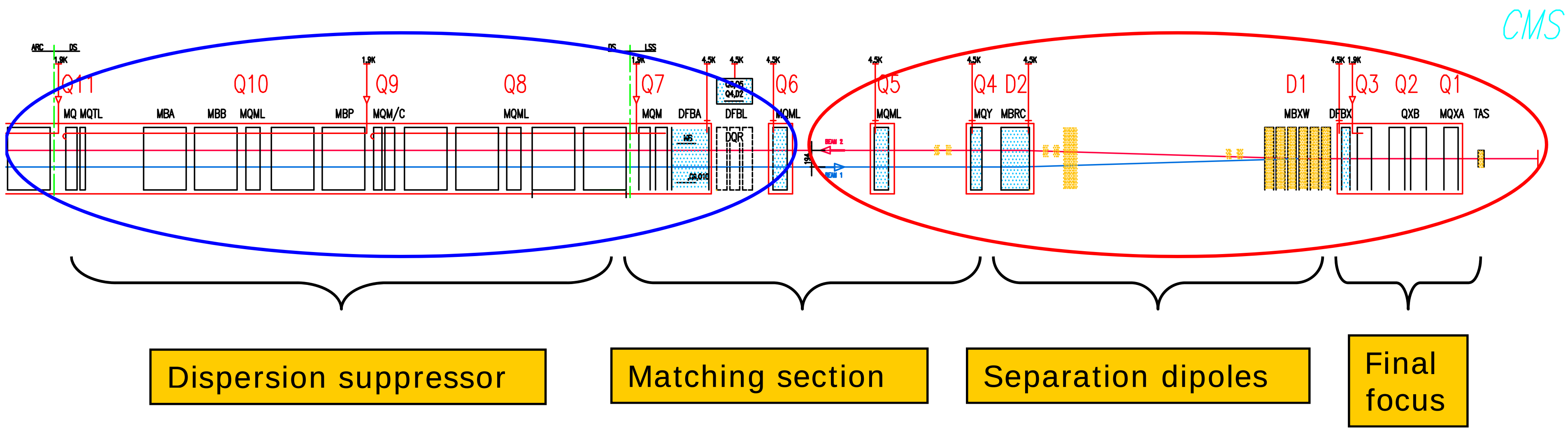


LHC IR Upgrade Phase-I Project: Goals and Status



1. Project goals and constraints
2. Elements of conceptual design
3. Collaborations
4. Perspectives

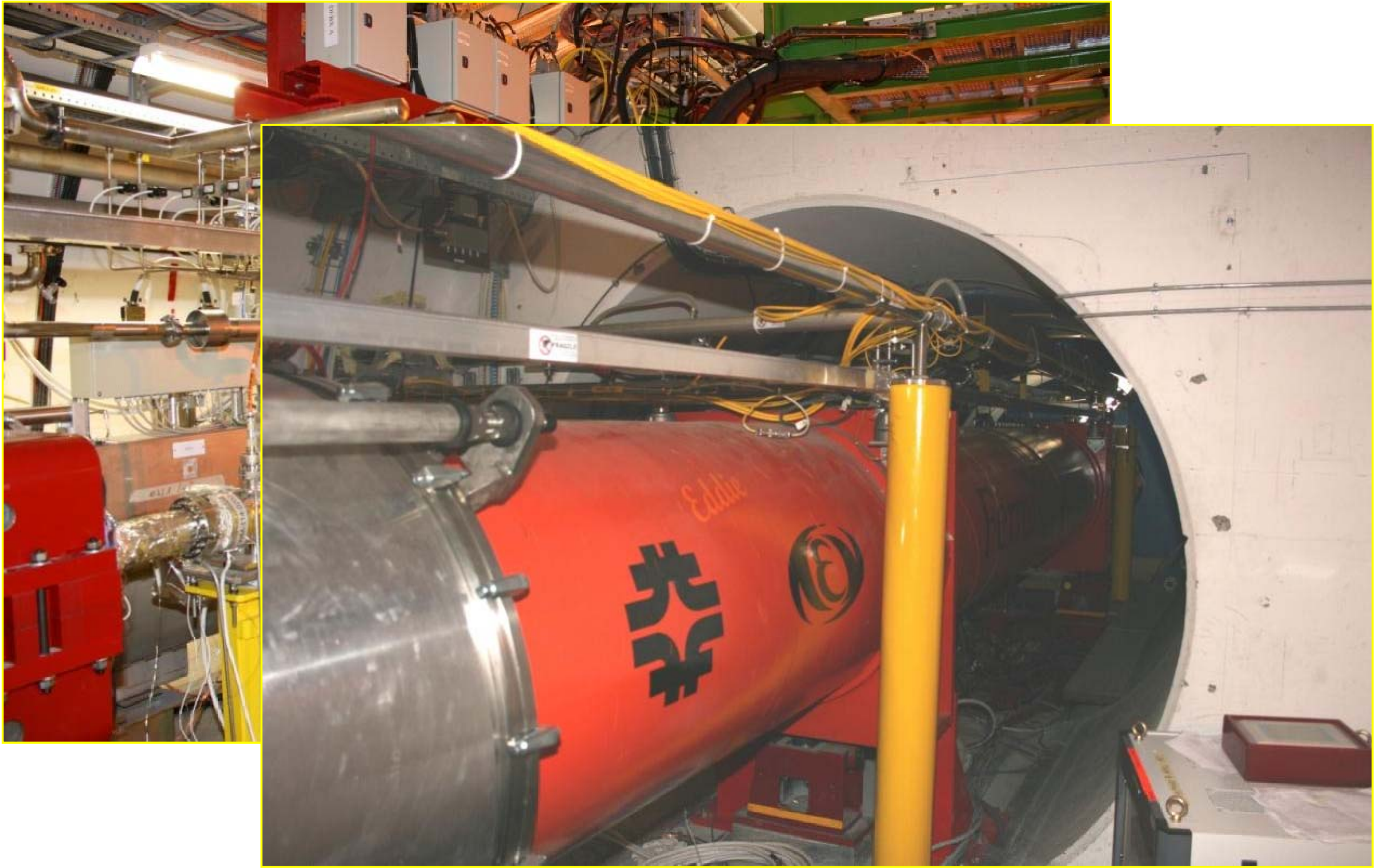
The ATLAS and CMS interaction regions



- Triplet position — L* = 23 m
- Triplet gradient — 205 T/m
- Triplet aperture
  - Coil 70 mm
  - Beam screen 60 mm — $\rightarrow \beta^* = 0.55$ m

    $\rightarrow \mathcal{L} = 10^{34}$
- Power in triplet — ~ 180 W @ 1.9 K

The low-β triplet in IR1



The low-β triplet in IR5

The Matching Sections

LHC IR Upgrade - Phase I

Goal of the upgrade:

Enable focusing of the beams to $\beta^*=0.25$ m in IP1 and IP5, and reliable operation of the LHC at 2 to 3 10^{34} $cm^{-2}s^{-1}$ on the horizon of the physics run in 2013.

Scope of the Project:

1. Upgrade of ATLAS and CMS interaction regions. The interfaces between the LHC and the experiments remain unchanged.
2. The cryogenic cooling capacity and other infrastructure in IR1 and IR5 remain unchanged and will be used to the full potential.
3. Replace the present triplets with wide aperture quadrupoles based on the LHC dipole (Nb-Ti) cables cooled at 1.9 K.
4. Upgrade the D1 separation dipoles, TAS and other beam-line equipment so as to be compatible with the inner triplets.
5. Modify matching sections to improve optics flexibility and machine protection, and introduce other equipment relevant for luminosity increase to the extent of available resources.

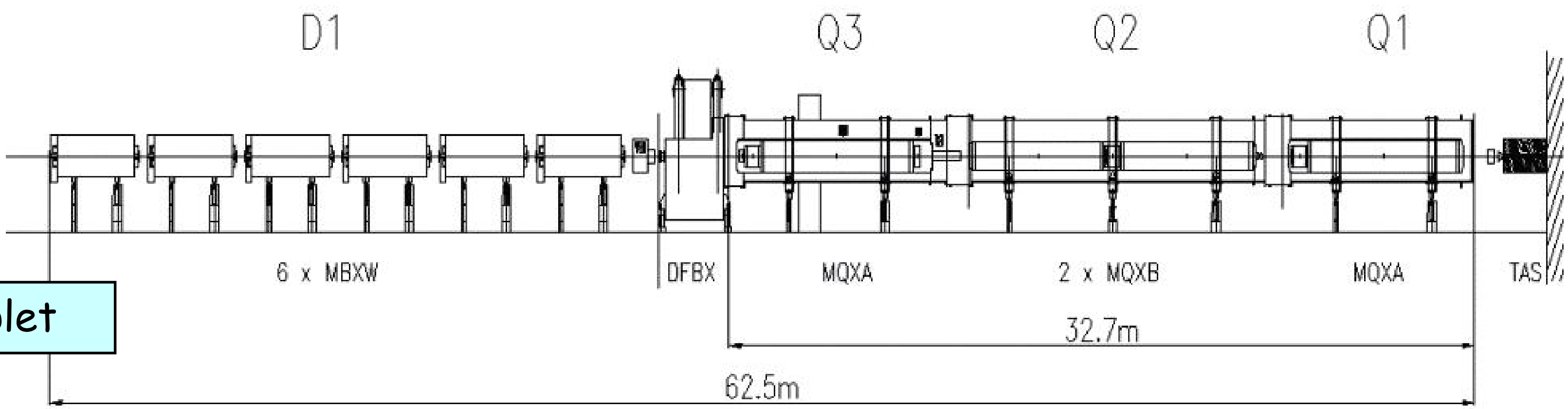
Project milestones

Project Start	**Jan 2008**
CD Report	**Nov 2008**
TD Review	mid 2009
Model magnets	end 2009
Pre-series quadrupole	end 2010
String test	2012 -> 2013
Installation	shutdown 2013 -> 2014

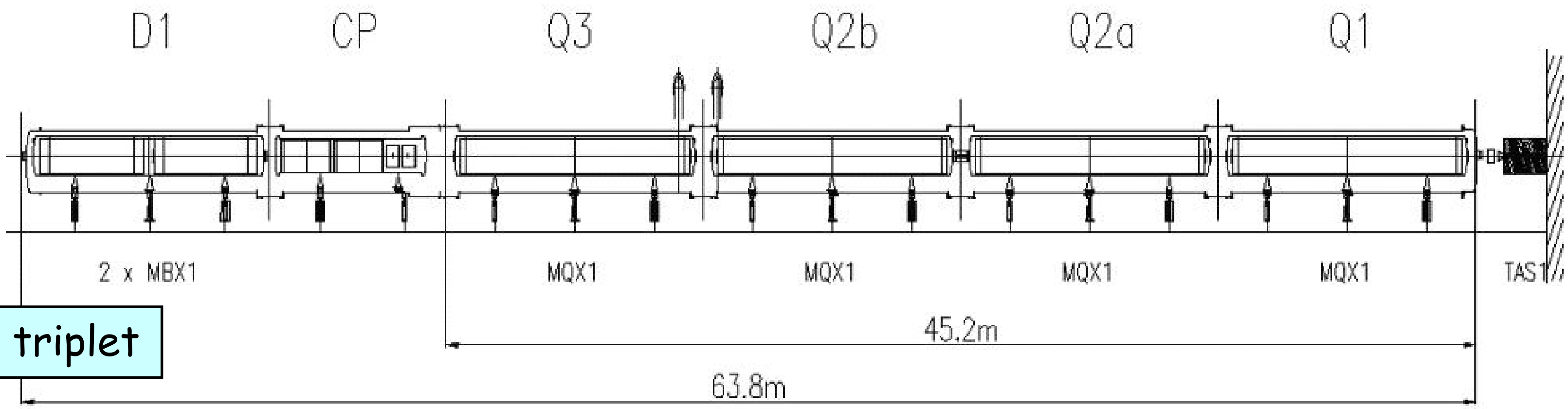
Constraints

- Interfaces with the experiments: Very tight interfaces between the triplet, TAS, shielding, vacuum and survey equipment, and beam instrumentation; no possibility of reducing L* (23m).
- Cryogenics: Ultimate cooling capacity is 500 W@1.9K in each triplet. Replacement of triplets in IR1/5 requires at present warm-up of 4 sectors.
- Chromatic aberrations: Reduction of β^* drives chromatic aberrations all around the LHC. A new optics solution for all arcs and insertions is necessary.
- Accessibility and maintenance: Severe space constraints around IP1 and IP5 for any new equipment. New magnets must be similar in size to the LHC main dipole.
- Upgrade implementation: during the extended shutdown, compatible with CERN-wide planning (Linac4 commissioning, phase-I upgrade of the experiments).

Triplet layout



LHC triplet



Phase-I triplet

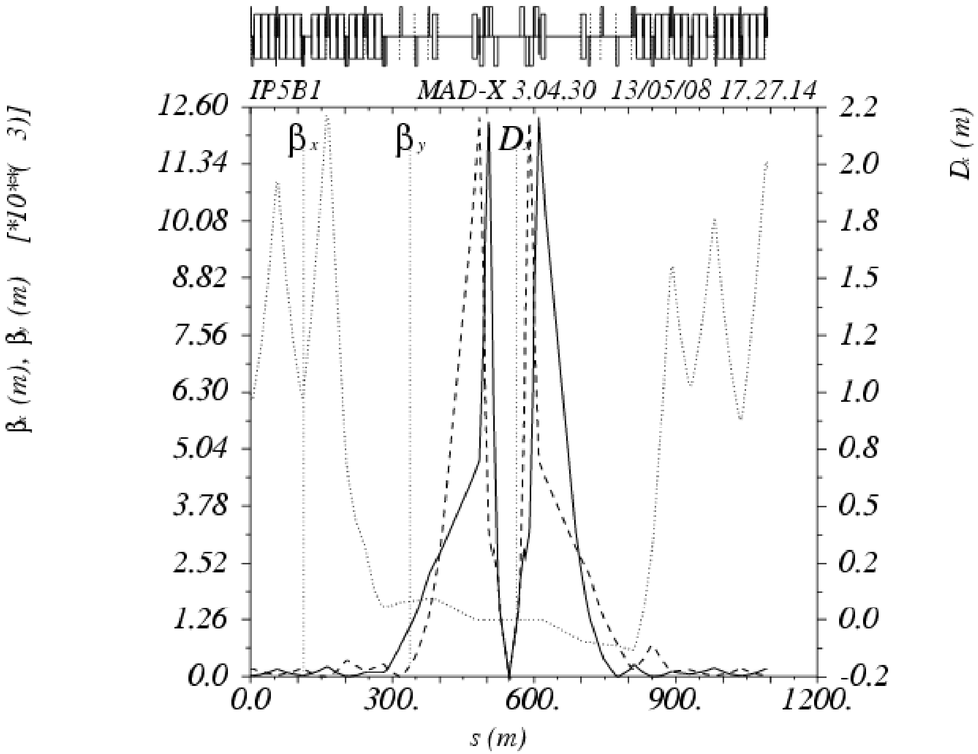
Initial proposal, iterations expected.

Optics issues

Insertions. The strength and aperture of the magnets are the limiting factors for reducing β*.

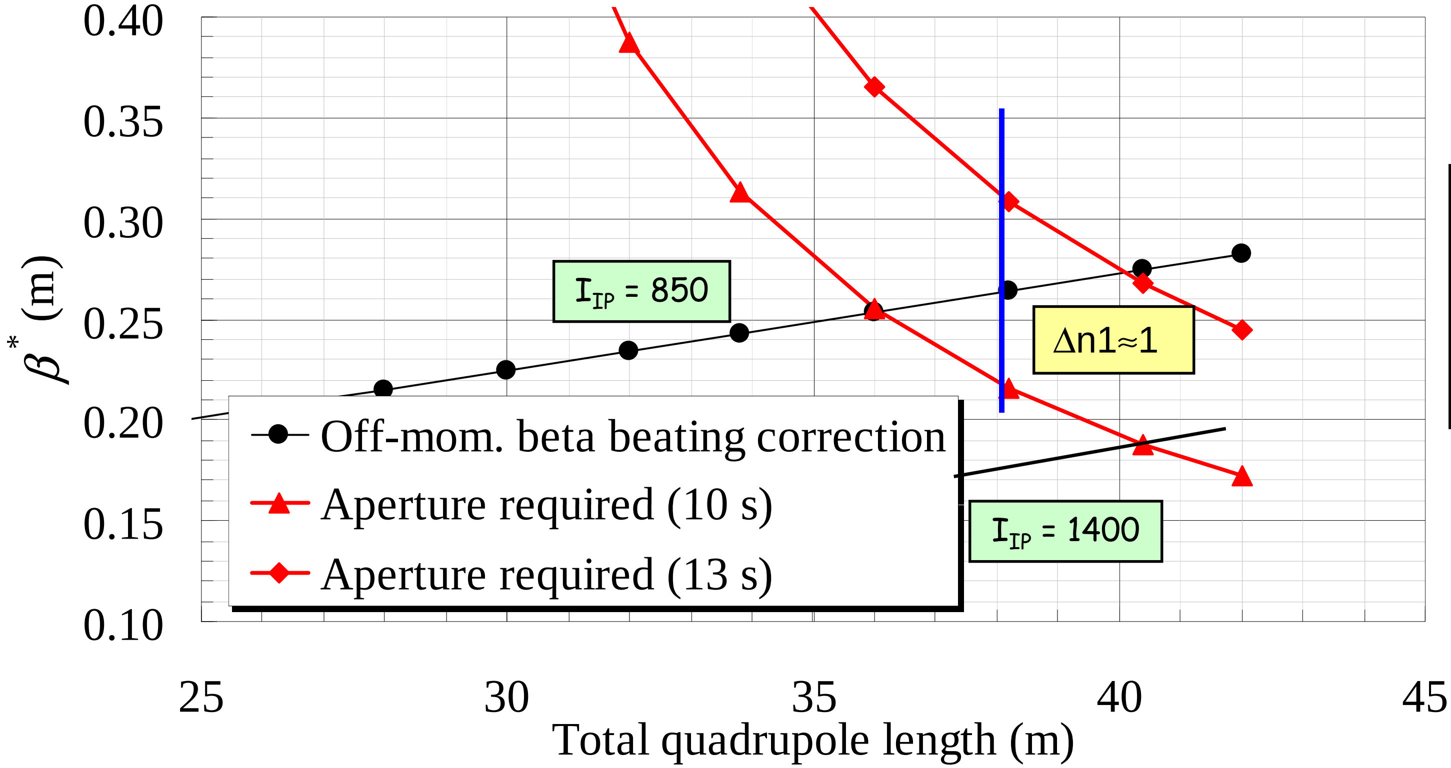
Arcs. Correction of chromatic aberrations requires re-phasing of all the arcs and insertions for β* < 0.5 m.

Triplets. Parasitic dispersion in the triplets due to large crossing angle has to be controlled. Beam crossing schemes in IP1 and IP5 need to be conform.



A complete solution for the new LHC collision optics has been developed. Considerable work is required to fully validate the flexibility and robustness of the new optics.

Quadrupole aperture and β*



Length vs. aperture:
42 m - 140 mm
40 m - 130 mm
38 m - 120 mm
36 m - 110 mm

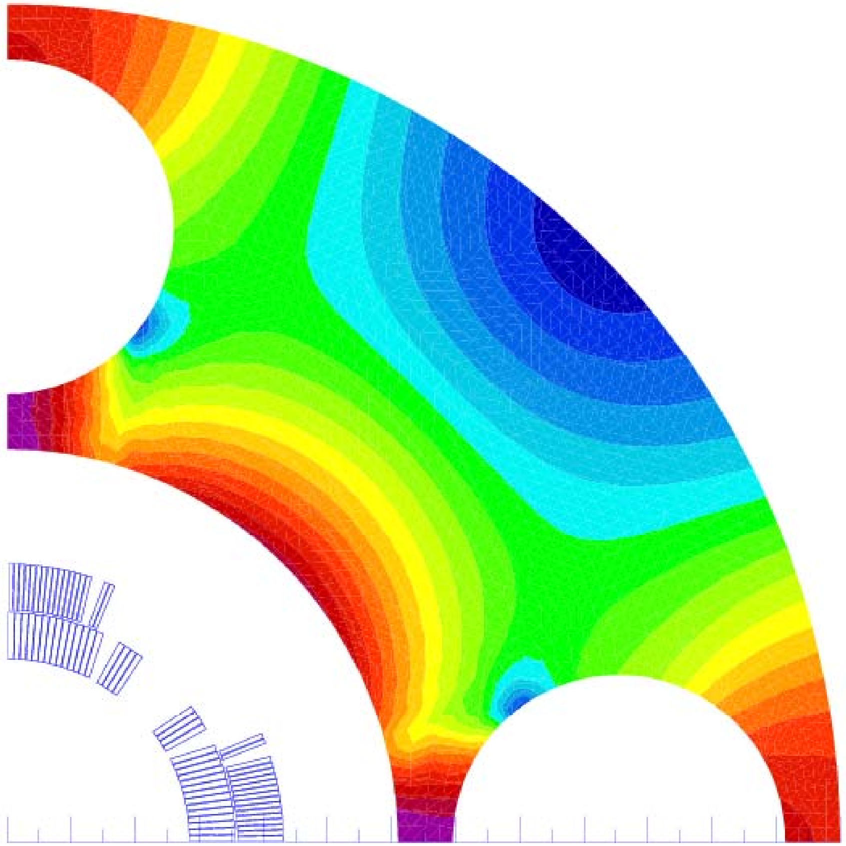
Quadrupole with a 120 mm aperture, 120 T/m chosen for the Phase-I Upgrade

Matching Sections

- The Phase-I Upgrade assumes that the operating parameters and the position of the matching section magnets (D2-Q6) remain unchanged.
- Reduction of β* inevitably reduces the aperture margin in Q4, D2 and Q5 and nearby equipment.
  - TAN vacuum chamber will have to be replaced.
  - Protection against the beam halo (tertiary collimators) will need to be extended to matching section magnets.
  - Protection of the arc magnets against diffractively scattered particles needs to be confirmed.
  - Integration of forward-physics experiments to be confirmed.
  - Background will need special attention.

Interventions on the warm equipment can be done in normal shutdown periods.

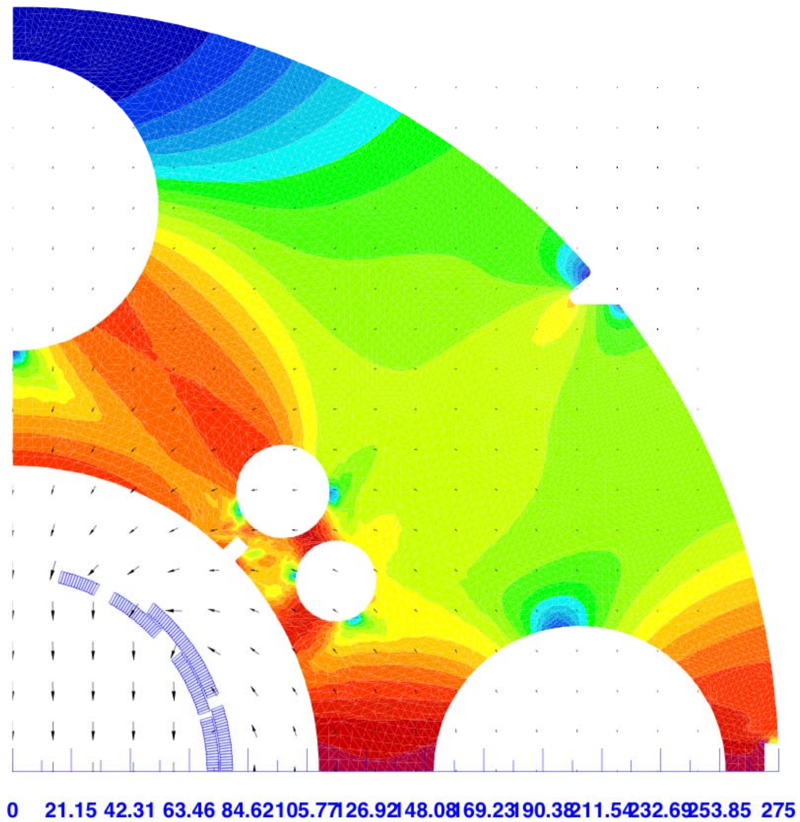
Low-β quadrupole



• Coil aperture	120 mm
• Gradient	120 T/m
• Operating temp	1.9 K
• Current	13 kA
• Inductance	5 mH/m
• Yoke ID	260 mm
• Yoke OD	550 mm

- LHC cables 01 and 02
- Enhanced cable polyimide insulation
- Self-supporting collars
- Single piece yoke
- Welded-shell cold mass

Correctors



MCBX

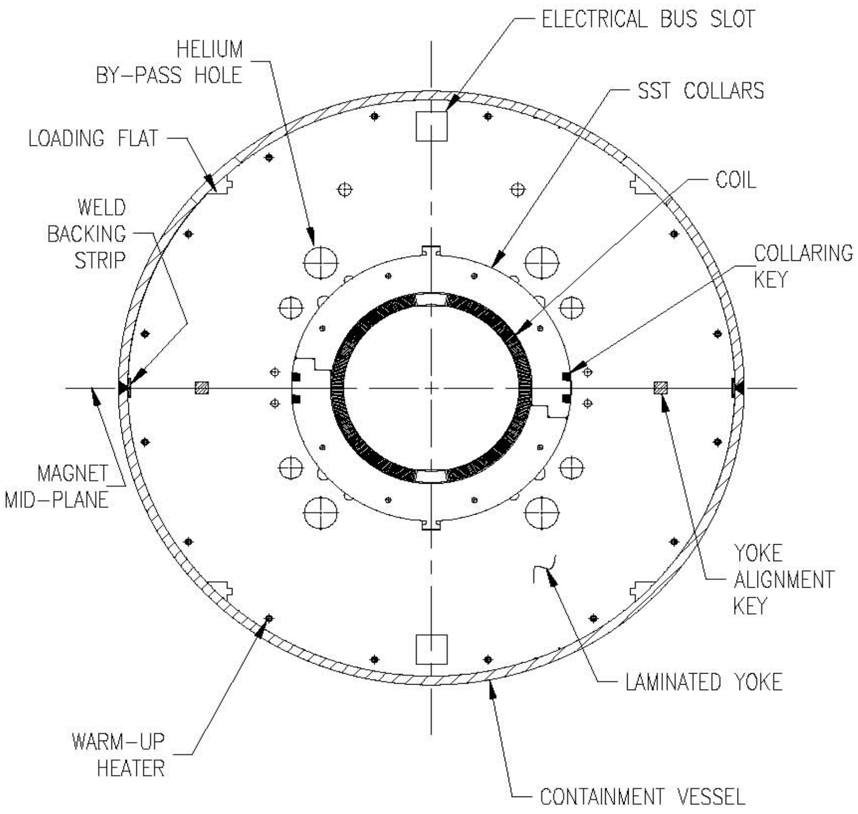
- Coil aperture 140 mm
- Field strength 6 Tm
- Operating temp 1.9 K
- Current 2.5 kA
- Inductance 55 mH/m
- Yoke ID 260 mm
- Yoke OD 550 mm

- New cable design
- Cable polyimide insulation
- Self-supporting collars
- Single piece yoke
- Welded-shell cold mass

D1 separation dipole

RHIC DX magnet	
• Coil aperture	180 mm
• Cold bore	163/174 mm
• Warm bore	140 mm
• Magnetic length	3.7 m
• Operating temp	4.5 K
• Field	4.4 T
• Current	6.8 kA
• Stored energy	1100kJ
• Inductance	49 mH

D1 = two DX in one cryostat



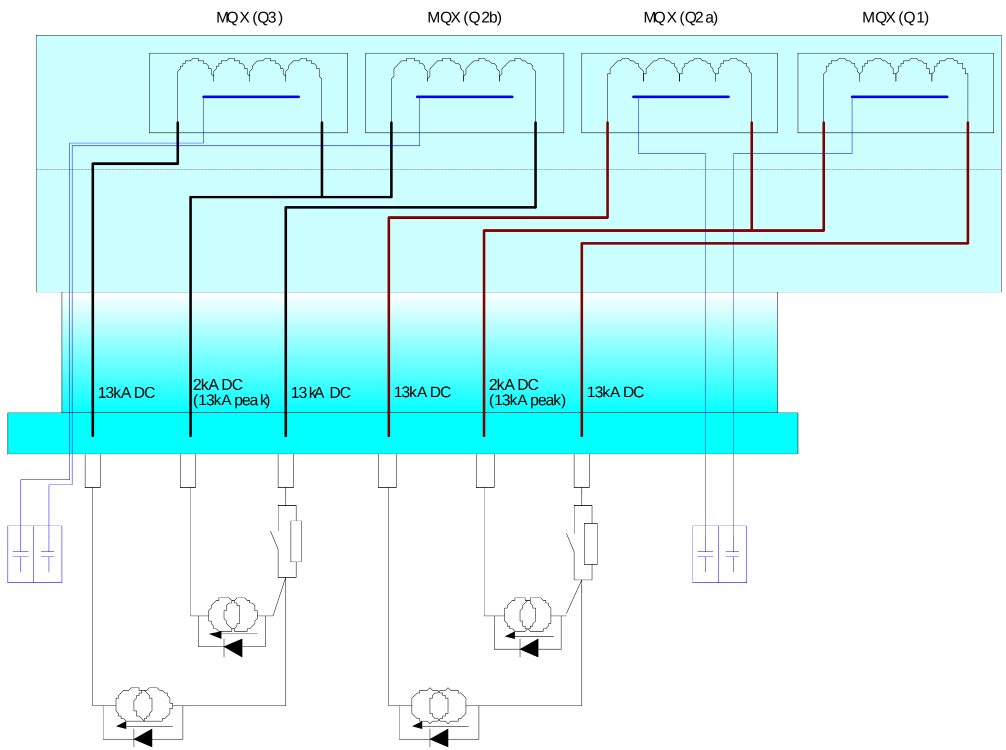
Powering and circuit protection

Individual powering of all quadrupoles required for optics adjustment.

Split powering chosen as a compromise between volume and complexity.

Protection of the magnets ensured by the energy extraction system and by the quench heaters.

Busbars and link integrally protected, leads protected separately. Appropriate signal routing to minimize noise.



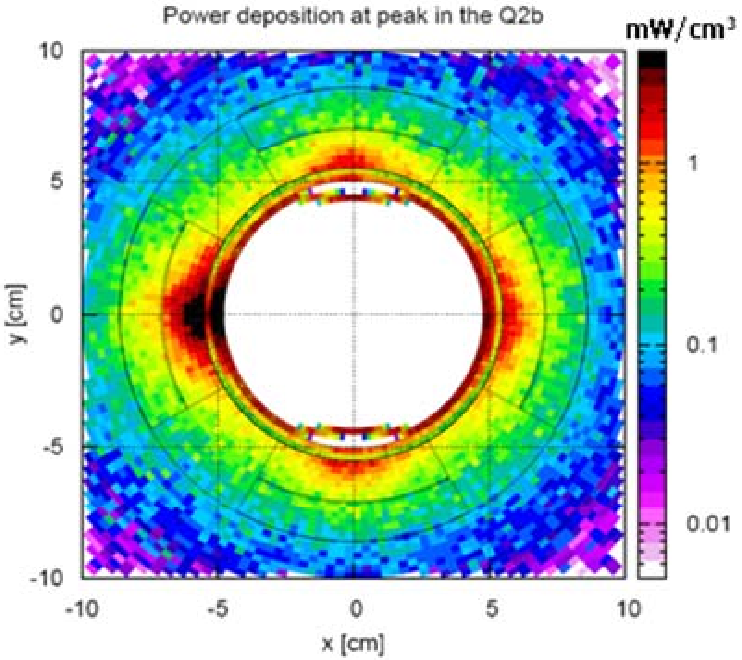
String test to check interfaces and compatibility of all systems.

Protection against particle debris

Protection against particle debris is the single most serious issue of the upgrade.

- Energy deposition in the coils and magnet lifetime.
- Equipment protection in the tunnel (TAS, TAN).
- Protection of electronic equipment in underground areas.
- Maintenance and interventions …

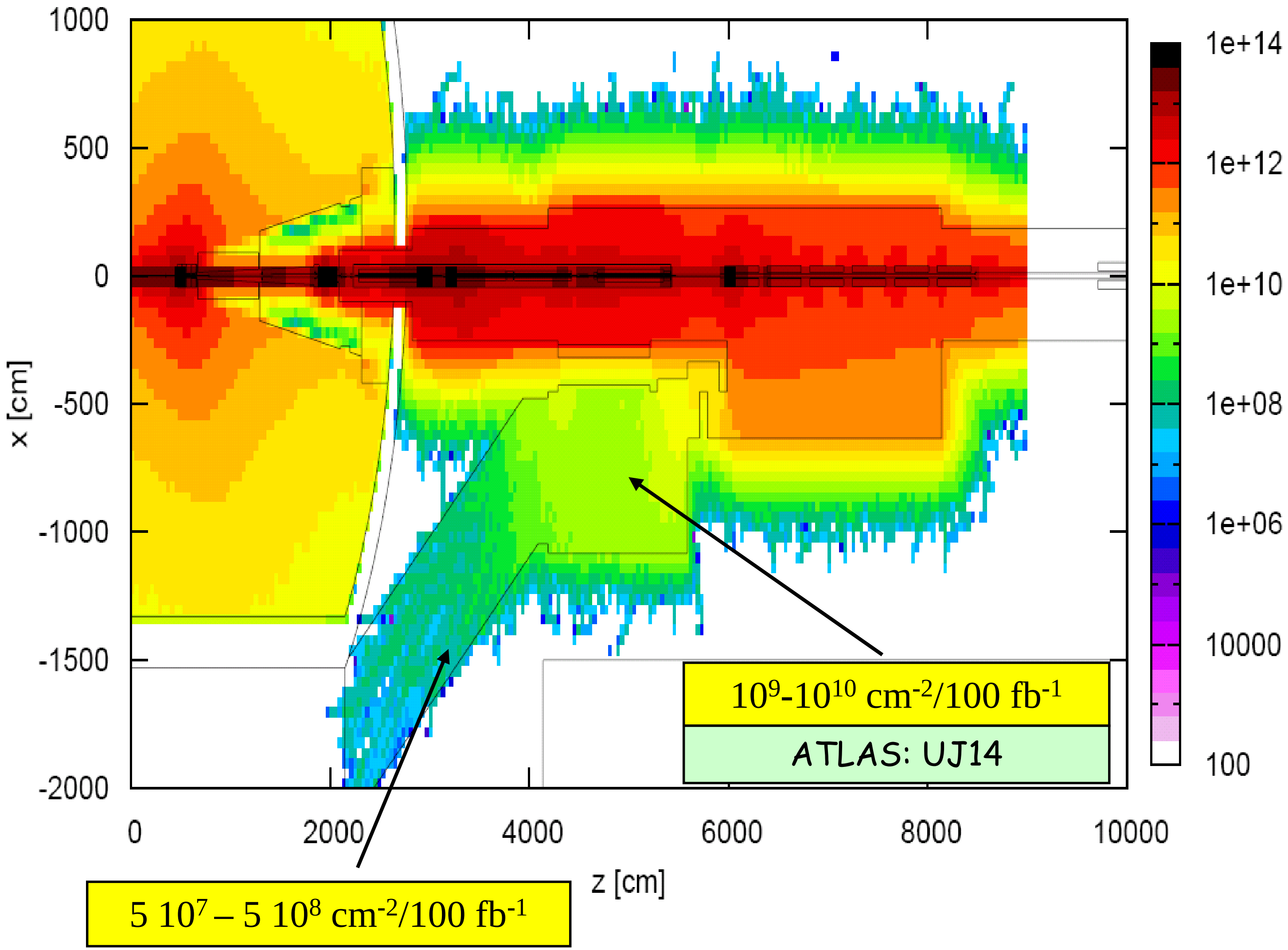
Max power density = 4.3 mW/cm^3 (@2.5 10^{34})



Average dose 1.5 MGy/100 fb^{-1}

All magnets built for a lifetime > 500 fb^{-1}, compatible with the lifetime of ATLAS and CMS before the phase-II upgrade.

Equipment areas (> 20 MeV hadron fluence)



Collaborations

LHC IR Upgrade Phase I

SLHC-PP
(CEA, CIEMAT, CNRS, STFC)

- Design and construction of the model quadrupole
- Design of the correctors
- Design of the cryostats

CERN

- Quadrupole production
- Cryostating and testing
- Power converters
- Protection
- String test
- Integration

Special French contribution
(CEA, CNRS)

- Quadrupole components
- Cryostat components
- Production of the correctors

US-APUL
(BNL, Fermilab)

- D1 separation dipole
- Cold powering

Perspectives

- The first phase of the LHC interaction region upgrade relies on the mature Nb-Ti magnet technology with the target of increasing the LHC luminosity to 2 to 3 10^{34} $cm^{-2}s^{-1}$, *while maximising the use of the existing infrastructure*.

- A solid, reviewed and coherent conceptual design, in line with the general constraints, is at hand. The technical design, including the model work and limited R&D activities, are advancing to a tight schedule.

- Collaborations with European and US laboratories, which bring in their expertise and resources, have been formalised and are in effect.

- Bringing the LHC to nominal performance in the shortest term is the top priority of the CERN management and LHC physics community.
  - *The available resources at CERN for the construction of the magnets and other equipment for the Phase-I Upgrade are subject to this priority.*