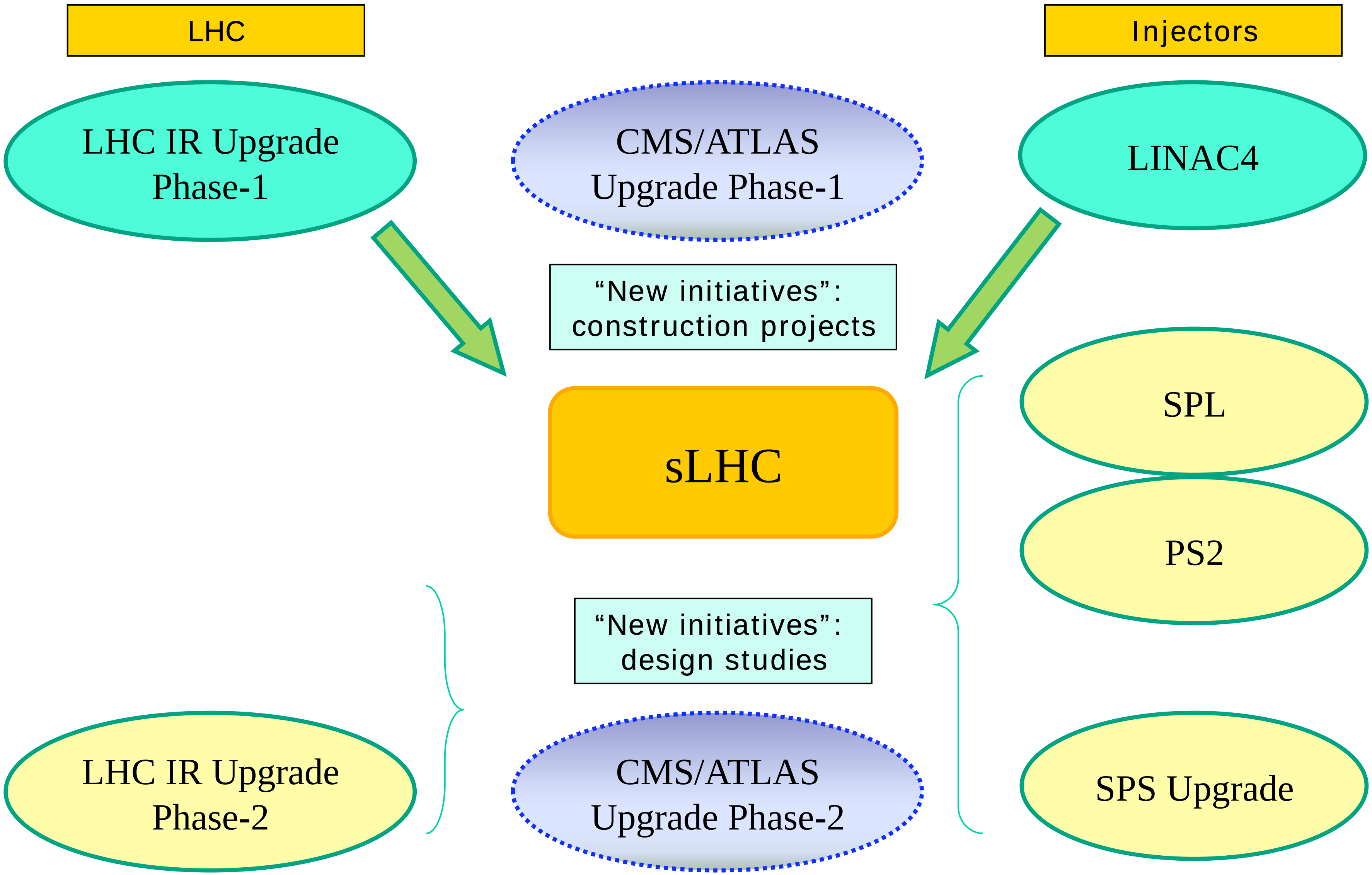
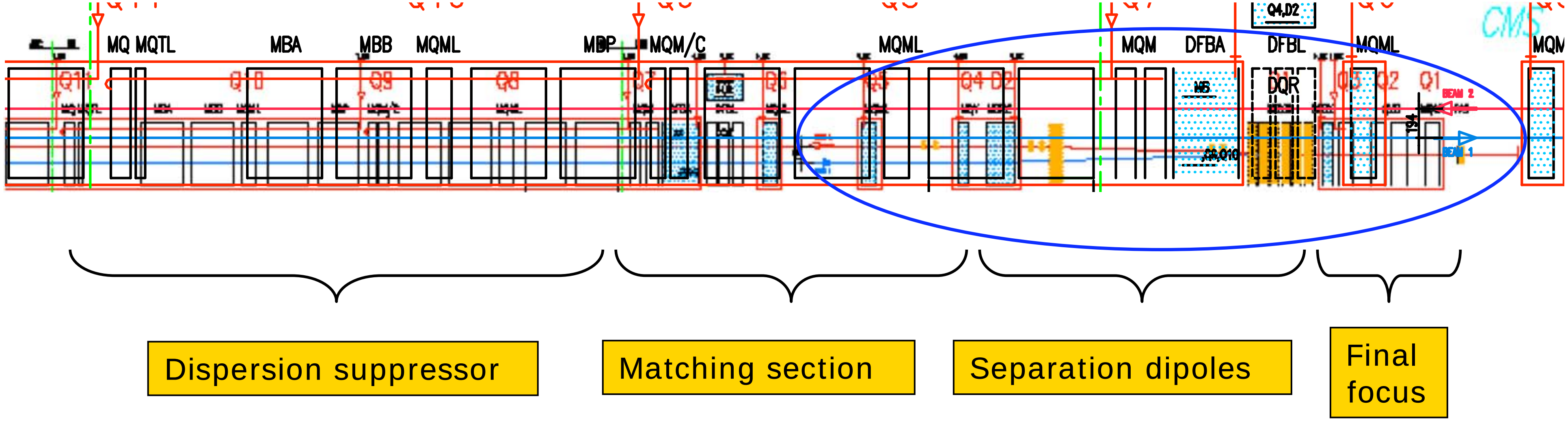
LHC IR Upgrade Phase-1

1. Project goals and constraints
2. Elements of the conceptual design
3. Cost estimate
4. Procurement structure
5. Perspectives

sLHC projects and design studies



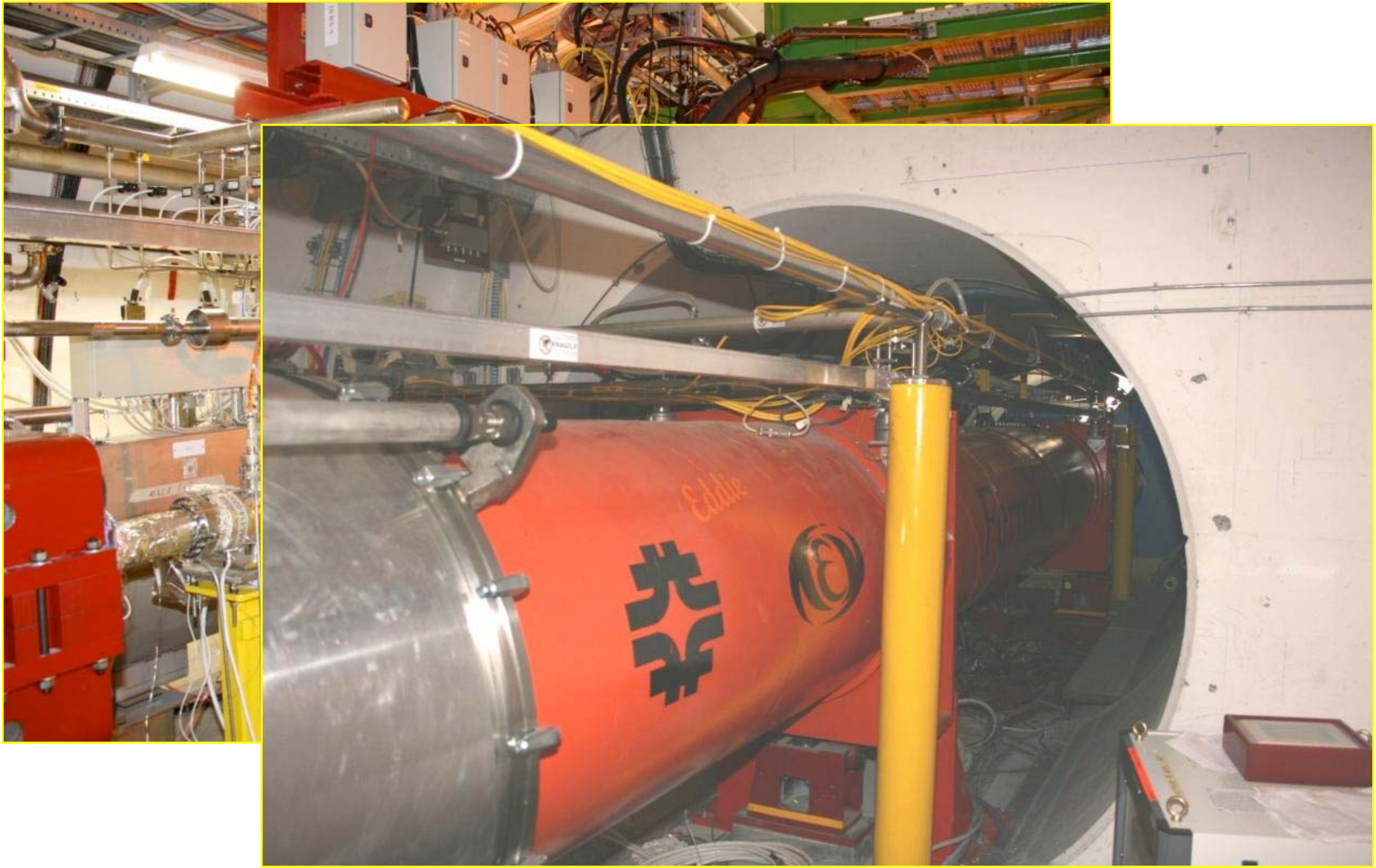
The ATLAS and CMS interaction regions



- Triplet position L* = 23 m
- Triplet gradient 205 T/m
- Triplet aperture
  - Coil 70 mm
  - Beam screen 60 mm ⇒ b* = 0.55 m

  ⇒ **L** = 10^{34}
- Power in triplet ~ 180 W @ 1.9 K

The low-b triplet in IR1



The low-b triplet in IR5

The Matching Sections

LHC IR Upgrade – Phase-1

Goal of the upgrade:

Enable focusing of the beams to b*=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 2014.

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.

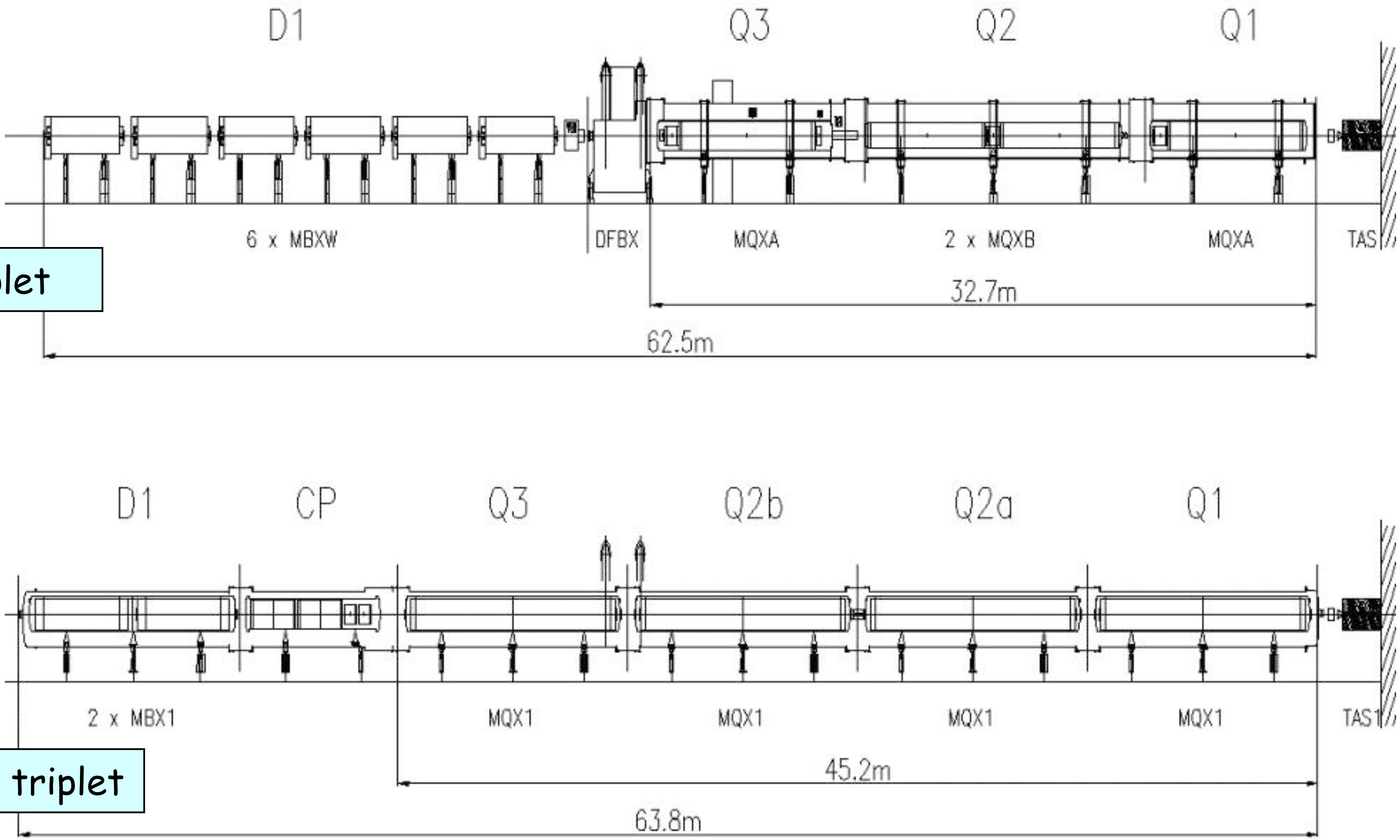
Project milestones

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 b* 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-1 upgrade of the experiments).

Triplet layout



LHC triplet

Phase-I triplet

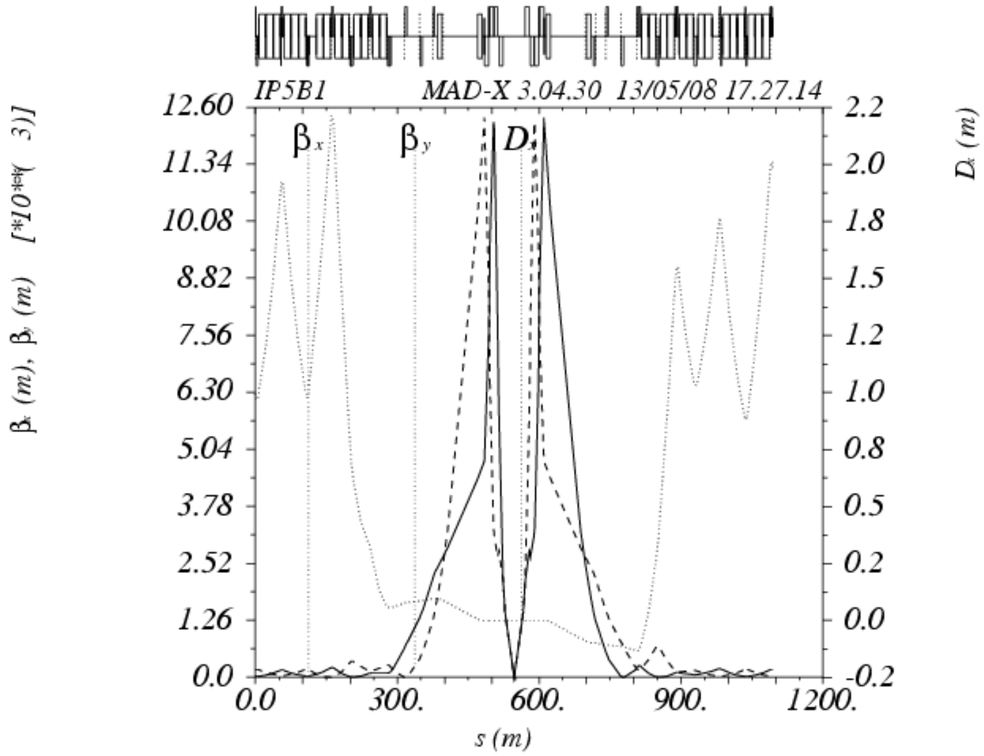
Initial proposal, iterations expected.

Optics issues

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

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



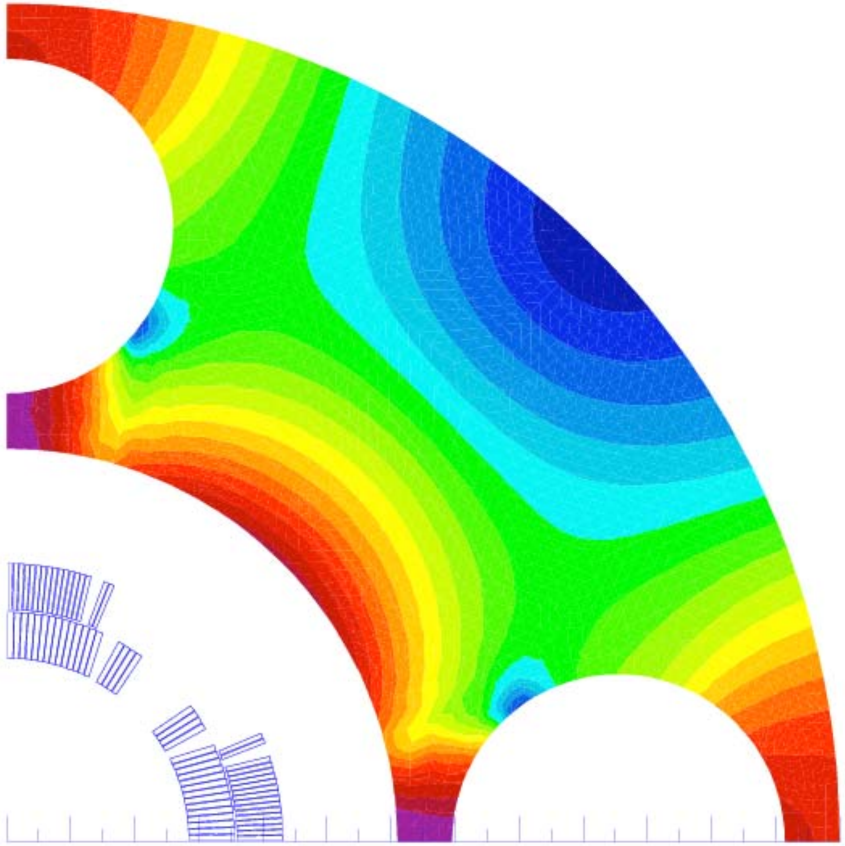
A complete solution for the new LHC collision optics has been developed. Considerable work is required to fully validate the flexibility and robustness of the new optics.

Matching Sections

- The Phase-1 Upgrade assumes that the operating parameters and the position of the matching section magnets (D2-Q6) remain unchanged.
- Reduction of b* 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.

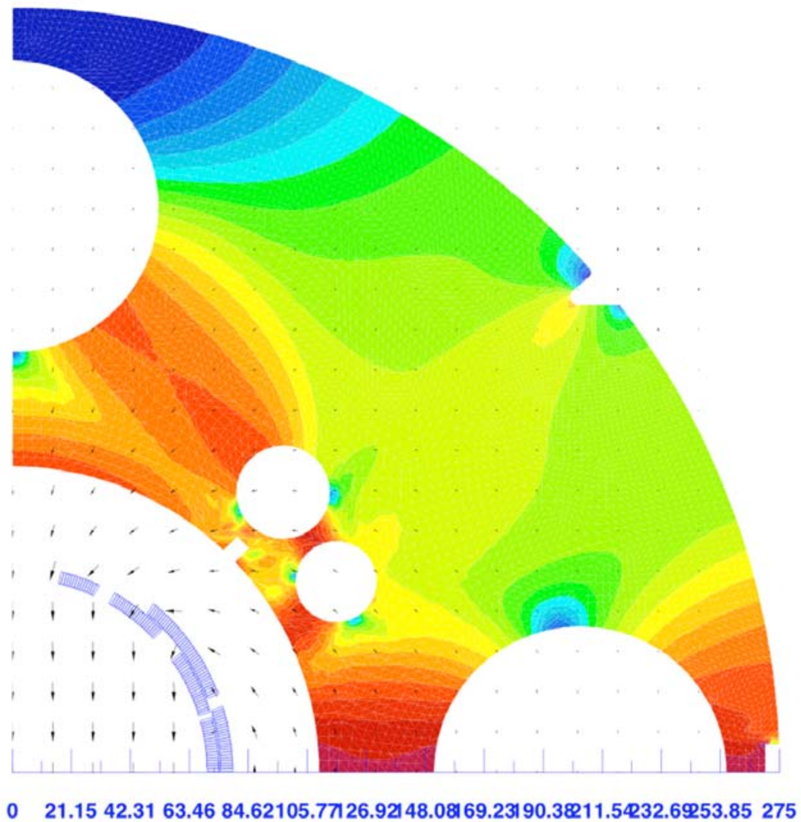
Low-b quadrupole



- 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

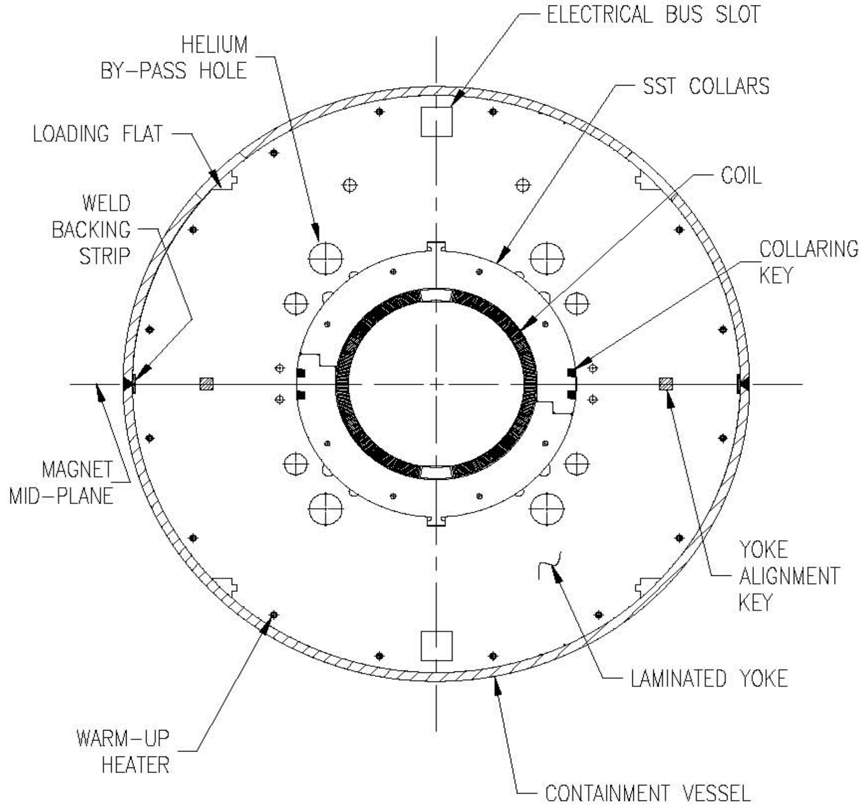
- Coil aperture 140 mm
- Field strength 6 Tm
- Operating temp 1.9 K
- Current 2.5 kA
- Inductance 55 mH/m
- Yoke ID 260 mm
- Yoke OD 550 mm

- 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



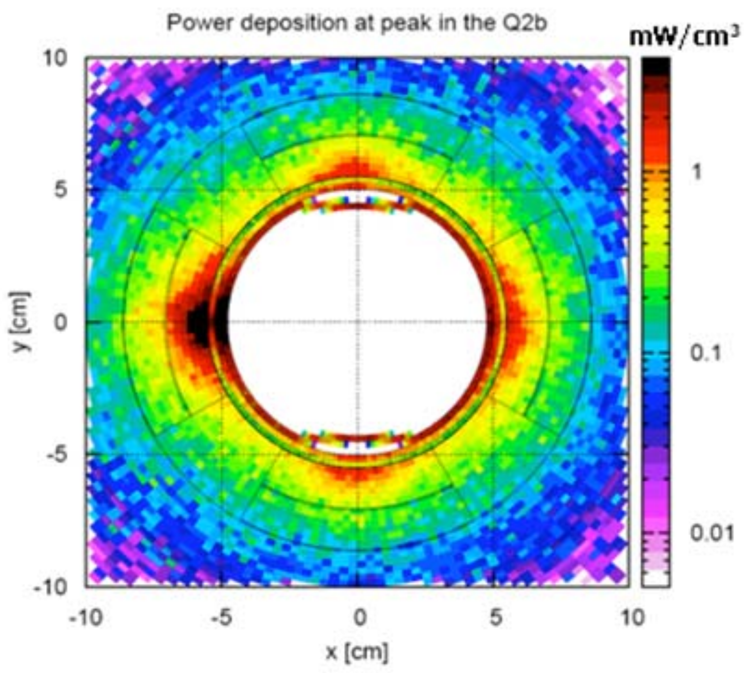
D1 = two DX in one cryostat

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 …

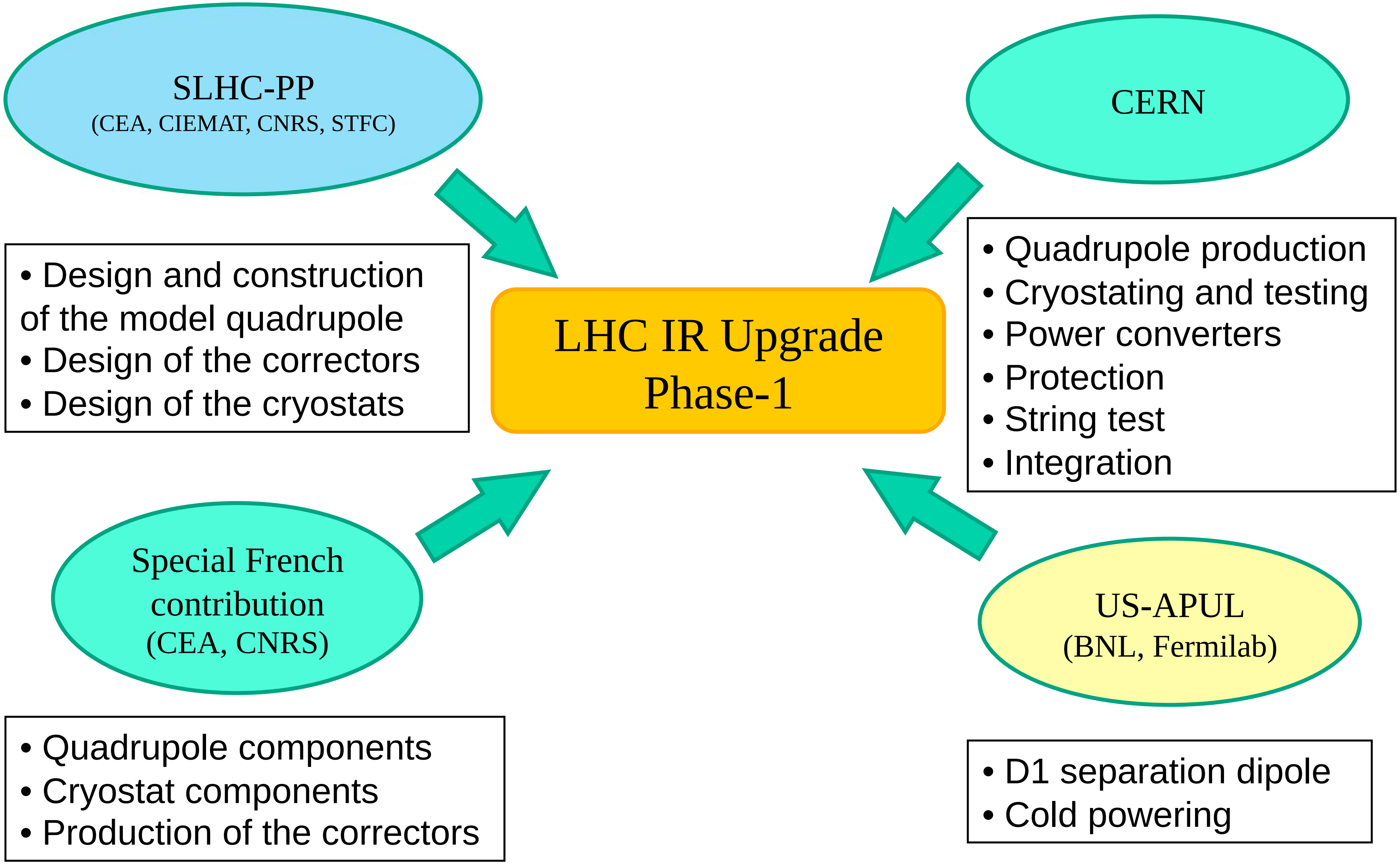
Max power density = 4.3 mW/cm³ (@2.5 10^{34})



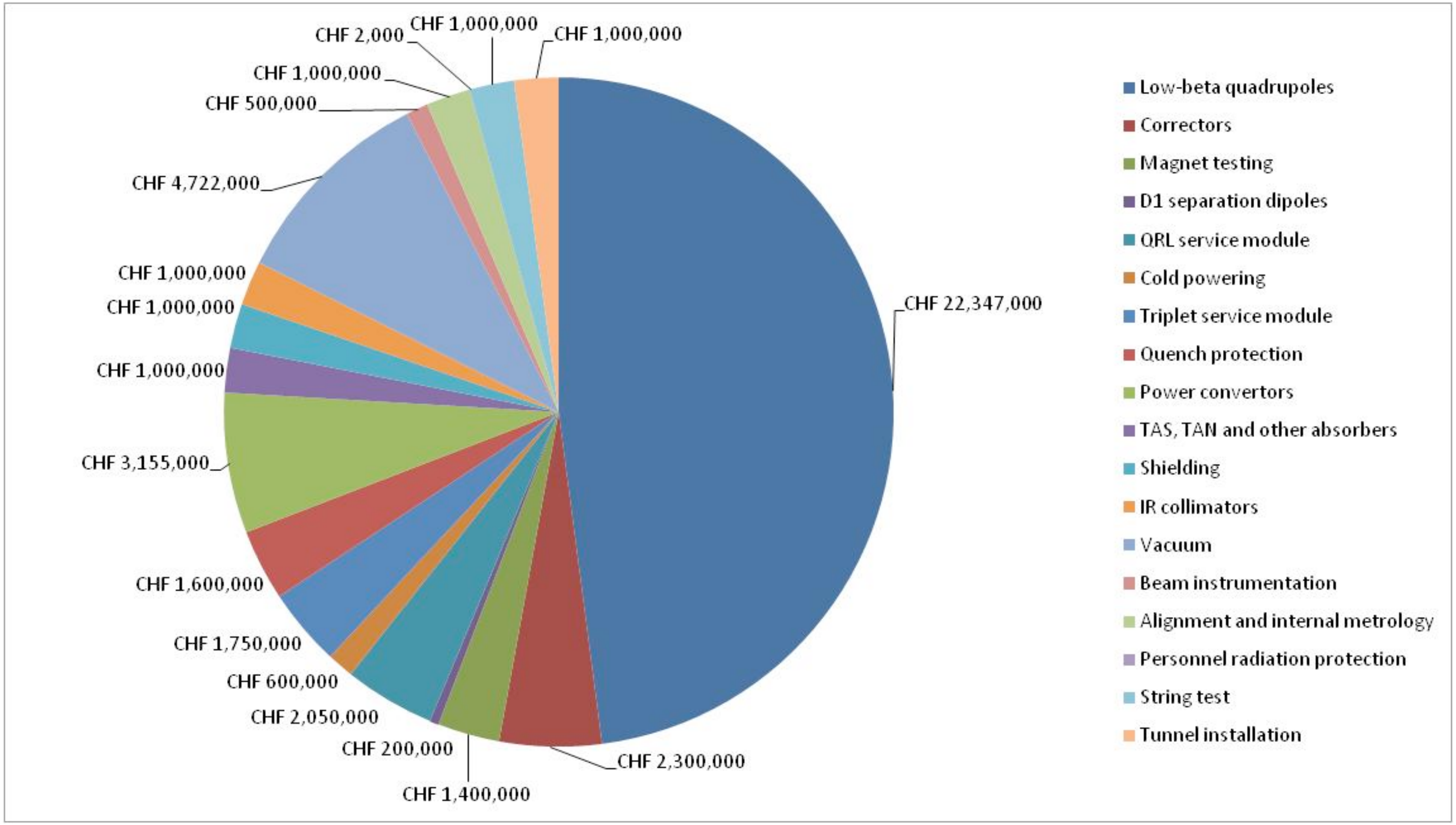
Average dose 1.5 MGy/100 fb^{-1}

All magnets built for a lifetime > 500 fb^{-1}, compatible with the lifetime of ATLAS and CMS before the phase-2 upgrade.

Collaborations

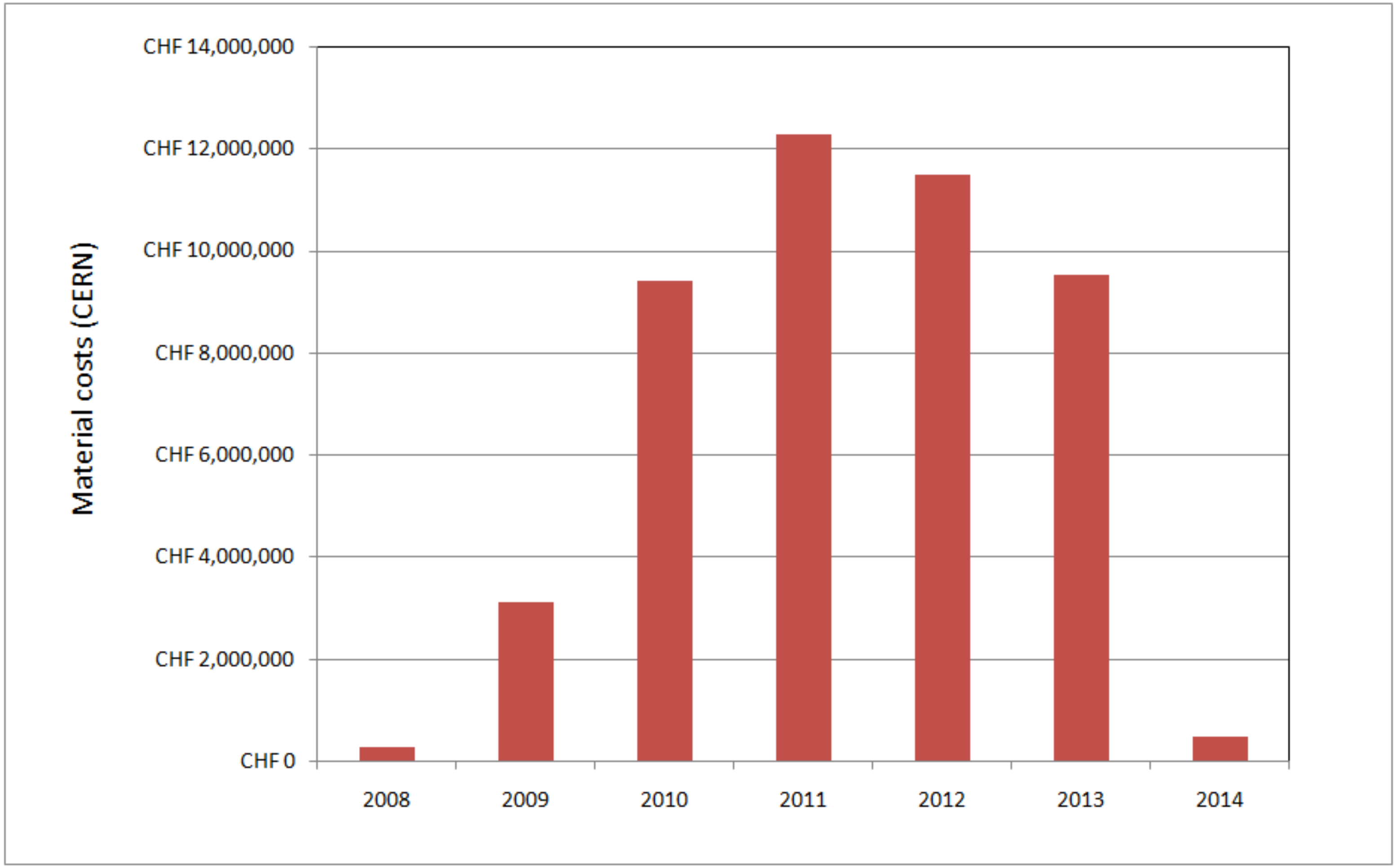


Cost estimate

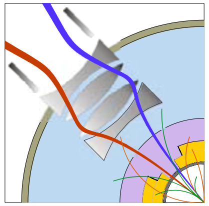


Total estimated material costs: 46.6 MCHF
(excluding US-APUL contribution)

Budget profile



Procurement structure



WP	Title	2009	2010	2011	2012	2013
4	*Low-beta quadrupoles*					
	Low-carbon steel sheets	700,000 CHF				
	Yoke laminations		500,000 CHF			
	End spacers		300,000 CHF			
	Half-shells		1,000,000 CHF			
	Collaring keys	200,000 CHF				
	End supports		400,000 CHF			
	End covers		1,000,000 CHF			
	Heat exchanger tubes		500,000 CHF			
	Vacuum vessels		1,000,000 CHF			
	Curing mold		500,000 CHF			
	Collars		300,000 CHF			
	Quench heaters		200,000 CHF			
	Cold bore tubes	200,000 CHF				
	Cryostat components		1,500,000 CHF			
	Corrector production		2,000,000 CHF			
	FSU	400,000 CHF	450,000 CHF	1,500,000 CHF	3,800,000 CHF	1,700,000 CHF
11	*Quench protection*					
	Energy extraction systems			1,000,000 CHF		
12	*Power convertors*					
	Main 1Q converters			2,000,000 CHF		
	Corrector 4Q converters			1,000,000 CHF		
16	*Vacuum system*					
	Purchase P506 steel	700,000 CHF				
	Co-lamination of P506 steel		600,000 CHF			
	Beam screen tube forming			1,300,000 CHF		

Date of invitation for tender

Estimated cost

Special French Contribution

Contracts > 200 kCHF	= 12.7 MCHF
Production manpower	= 7.8 MCHF
Special French Contribution	= 4.2 MCHF
Orders < 200 kCHF	= 22 MCHF

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-1 Upgrade are subject to this priority.*