High Luminosity LHC

Review HL-LHC triplet layout

G. Arduini, R. De Maria, M. Giovannozzi

Acknowledgment P. Fessia, T. Lefevre, E. Todesco

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Conclusion on triplet lengths

- We took into account the new constraints Ezio set for triplet lengths and gradients:
  - L<=4.2 m for Q1/Q3
  - triplet gradient allowed to exceed 130T/m by ≈1-2%
- We found layout and optics solutions that are compatible with:
  - triplet gradients <132.6 T/m and L* of 23 m or 24 m
  - updated interconnection lengths
  - with degraded (5-10%) β* reach and ≈1-2% integrated luminosity loss

  and with he magnetic lengths of:
  - L=4.2 m for Q1a/Q1b and Q3a/Q3b
  - L=7.15 m for Q2a/Q2b
- Need definition of L* in order to finalize the layout and define new position of the BPM (coordinated by integration, instrumentation and coll./exp. interface).
- The final optics and triplet strengths will be optimized and finalized once the layout is frozen.
- For more information see the following contribution: indico.cern.ch/event/371767/contribution/3/material/slides/1.pptx

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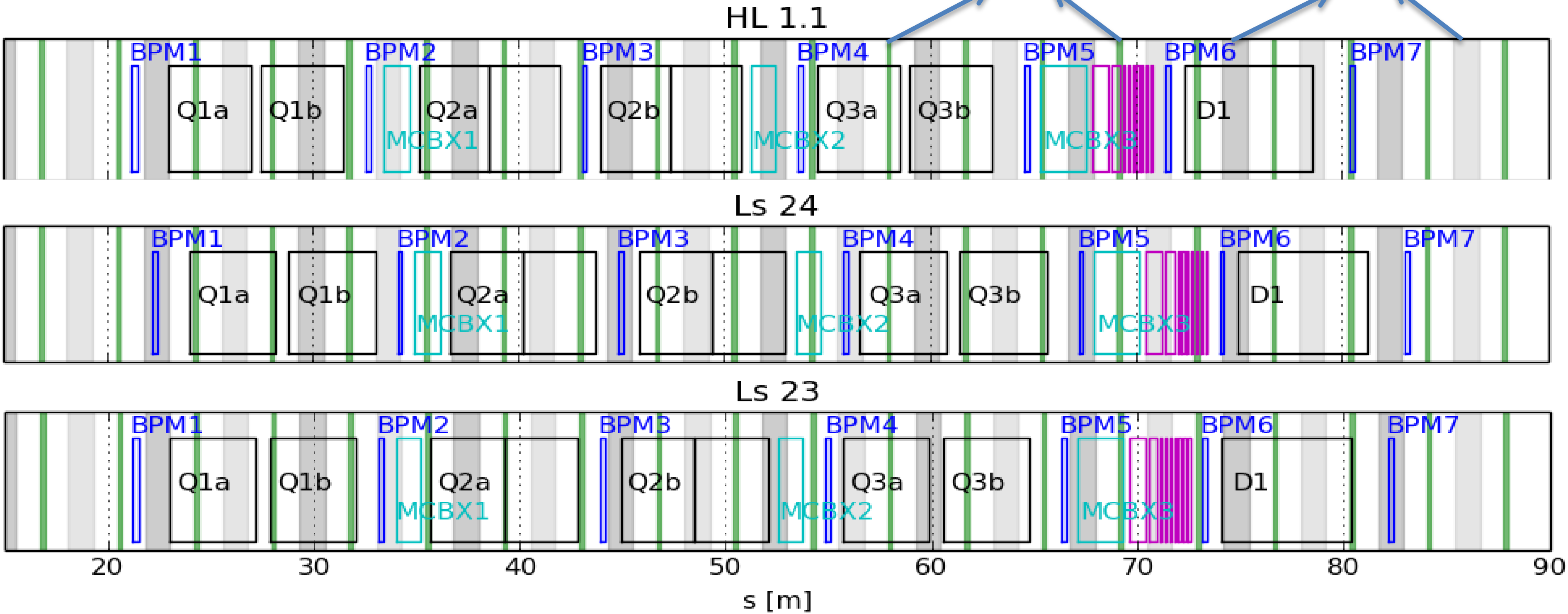
Layouts sketches

Ideal bpm positions

Forbidden areas ±60 cm, assuming best conceivable electronics.



- Both layouts, in particular the one for L*=24 m, degrade BPM distance from LR encounters.
- BPMs need more than ±60 cm (up to ±1.5 m with LHC electronics) to cope with bunch trains thus impacting the effectiveness of any IP orbit feedback relying on BPMs.

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Backup

Integrate Luminosity vs β*

β* acts on virtual luminosity and HL-LHC scenarios are most sensitive to levelled luminosity and beam currents (burn-off and levelling times dominates).

E [TeV]	N [10^{11}]	L_{lev} [10^{34} $cm^{-2}s^{-1}$]	$L_{virt\ \beta^*=15cm}$ [10^{34} $cm^{-2}s^{-1}$]	L_{int}/day β^*=15cm [fb^{-1}]	$L_{virt\ \beta^*=18cm}$ (-13.3%) [$10^{34}cm^{-2}s^{-1}$]	L_{int}/day β*=18cm
7	2.2	5	20.1	3.17	17.4	-1.73%
7	2.2	7.5	20.1	4.07	17.4	-2.88%
7	1.9	5	15.0	2.93	13.0	-2.55%
7	1.9	7.5	15.0	3.63	13.0	-4.3%

β* not very sensitive for L_{int} with nominal parameters, at the same time:

- relatively risk free and
- relative impact of β* on L_{int} increases for lower beam current.

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Layout variants and β* reach

Case	L^* [m]	G_{Q1} [T/m]	G_{Q2} [T/m]	G_{Q3} [T/m]	$l_{Q1/3}$ [m]	$l_{Q2a/b}$ [m]	β^*_{pre} [cm]	β^*_{max} at β^*_{15cm}
HL1.1	23	139.8	139.8	139.3	4.0	6.8	44	+0%
L* 24	24	128.9	130.2	130.4	4.2	7.15	48	+8.2%
L* 23	23	132.1	130.5	130.6	4.2	7.15	48	+4.3%
Ls 24 split[1]	24	132.2	129.4	129.6	4.2	7.15/2	49	+12%
Ls 23 split[1]	23	132.3	129.3	129.6	4.2	7.15/2	48	+7.8%

[1] Backup plan for Q2a and Q2b for which 65cm inter-distance is assumed. Not considered to be likely.

The gradient values will be still fine tuned in the range of ±0.3 T/m for the final layout to optimize crab cavities voltage and D2-Q4 aperture.

If needed l_{Q2} can be chosen to 7.2m to approach the old target of 130 T/m at cost <1% in β^*_{max}.

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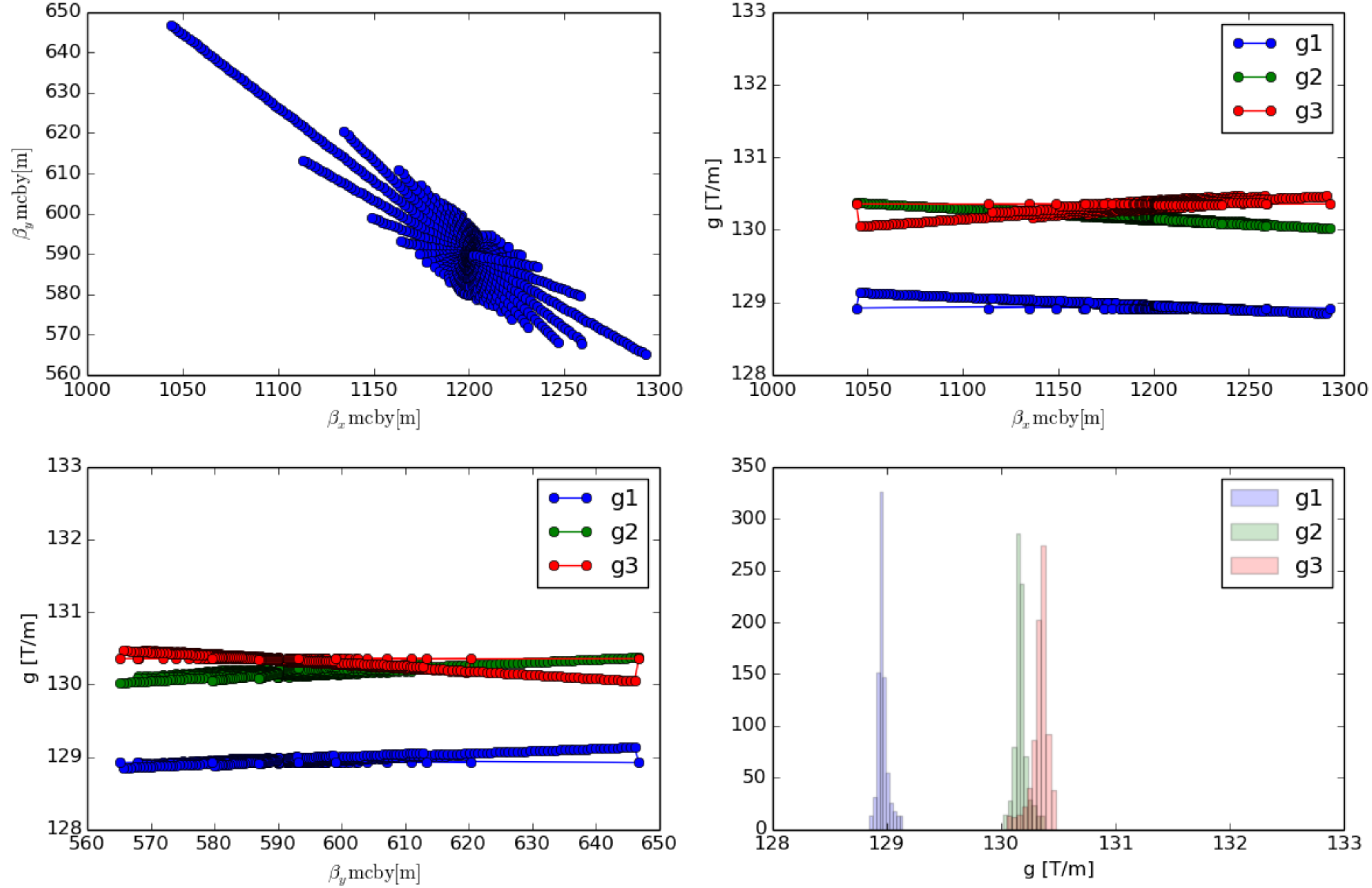
Tunability in Q4: L*=24m option



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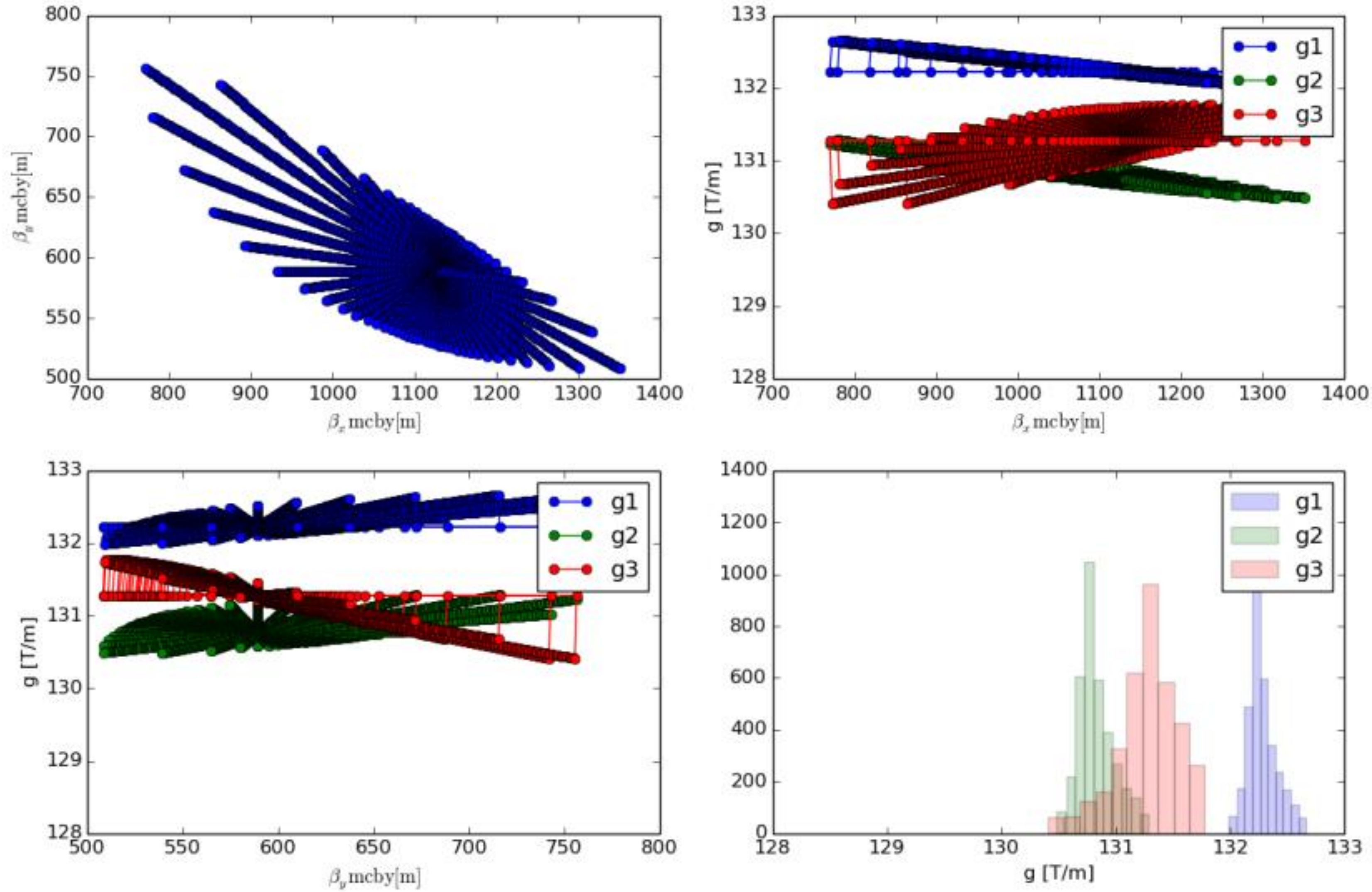
Tunability in Q4: L*=23m option



BPM specifications for orbit and optics

Aperture diameter [mm]	**>98 (Q1) / >118 (others)**
Precision in orbit mode	< 1.5 μm
Accuracy for finding collisions with 1% Luminosity	< 30 μm
Longitudinal alignment accuracy	1 mm
Maximum linearity error after calibration in turn-by-turn mode	<0.5 %
Maximum non-reproducibility of the triplet and correctors transfer functions	$<10^{-4}$
Bunch population range [p/bunch]	$10^{9} – 2.2\times10^{11}$

Optimum position w.r.t. parasitic encounters	**Sensitivity to missing BPM**	**Suggested locations for optics measurements**	**Beta function ($\beta_{x,y}$,$\beta_{y,x}$)[km] (for impendence effects)**
D1downstream (best position)	TAS-Q1a (highest sensitivity)	Q2a-Q2b (most critical)	TAS-Q1a (3.1, 3.1) (smallest beta, smallest effect)
Q1b-Q2a	Q1b-Q2a	Q3b-CP	Q1b-Q2a (4.6, 10)
CP-D1	Q2a-Q2b	TAS-Q1a	Q2b-Q3a (13.5,13.5)
Q2a-Q2b	Q2b-Q3a	Q1b-Q2a	D1 downstream (16.6, 7.1)
TAS-Q1a	Q3b-CP	Q2b-Q3a	CP-D1 (18.8, 7.5)
Q3b-CP	CP-D1	CP-D1	Q2a-Q2b (20.4, 5.3)
Q2b-Q3a (worst position)	D1 downstream (lower sensitivity)	D1 downstream (least critical)	Q3b-CP (20.6, 7.9) (larger beta, largest effect)

See WP2 TL meetings on 23/5/2014 at
https://indico.cern.ch/event/315532/material/minutes/1.docx

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