



Compatibility of the ALICE beam pipe with HL-LHC parameters

Riccardo De Maria and Massimo Giovannozzi

Acknowledgements: A. Tauro

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Outline

- Situation for nominal LHC
 - Nominal beam pipe
 - New beam pipe
- HL-LHC
 - New parameters for aperture computation
- HL-LHC: injection
- HL-LHC: collision

History of proposal - I

- Initial activities carried out in the framework of LEB WG.
- 19th LEB meeting (April '12): OD 3.6 cm cylindrical beam pipe (5.5m long) was submitted to LEB
- 20th LEB meeting (June '12): Conclusion from aperture study: too small aperture at injection beyond -2 m from IP!
- 25th LEB (December '13): New layout submitted to LEB. OD 3.6 cm only around IP.
- Spring 2014: Increase central section OD to 3.8 cm to relax alignment tolerance.

	Present	New
Outer diameter	6 cm	3.8 cm (only central part)
Wall thickness	800 μm	800 μm
Length	482 cm	550 cm
Length beryllium	395 cm	88.8 cm
Bellows/flanges	SS	Al
Nb of supports	3	3

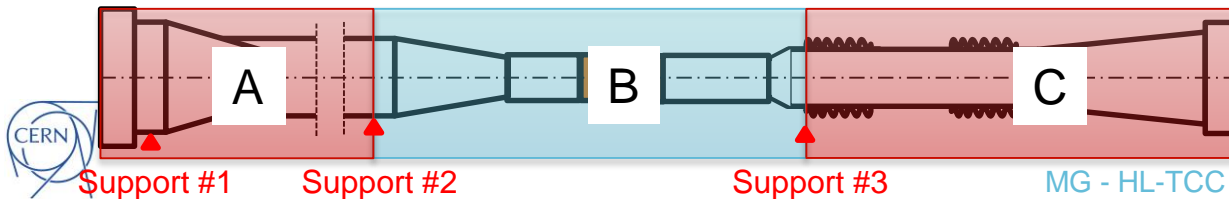
History of proposal - II

■ Mechanical tolerances

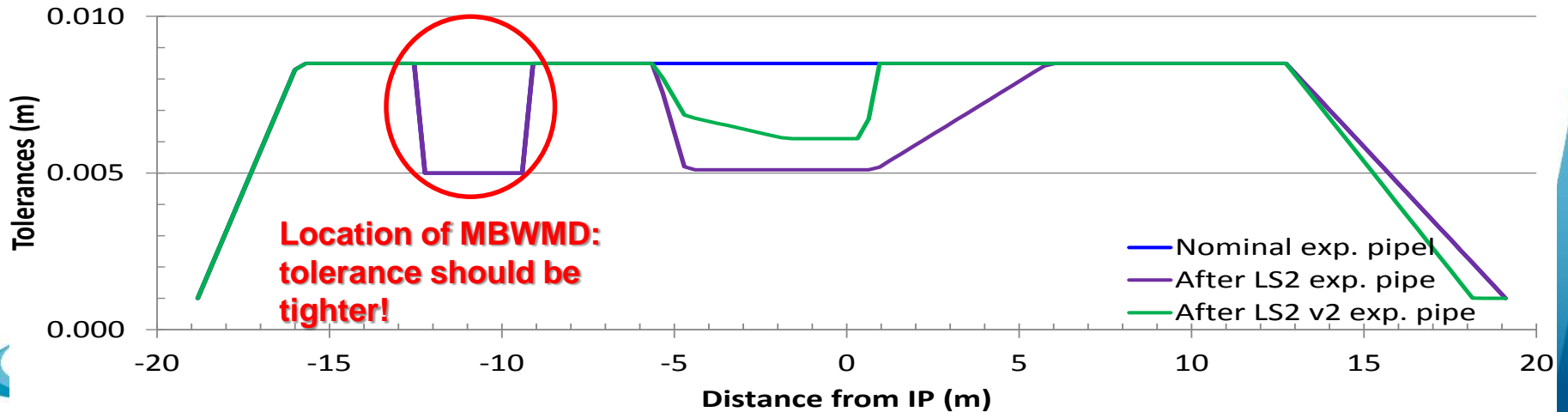
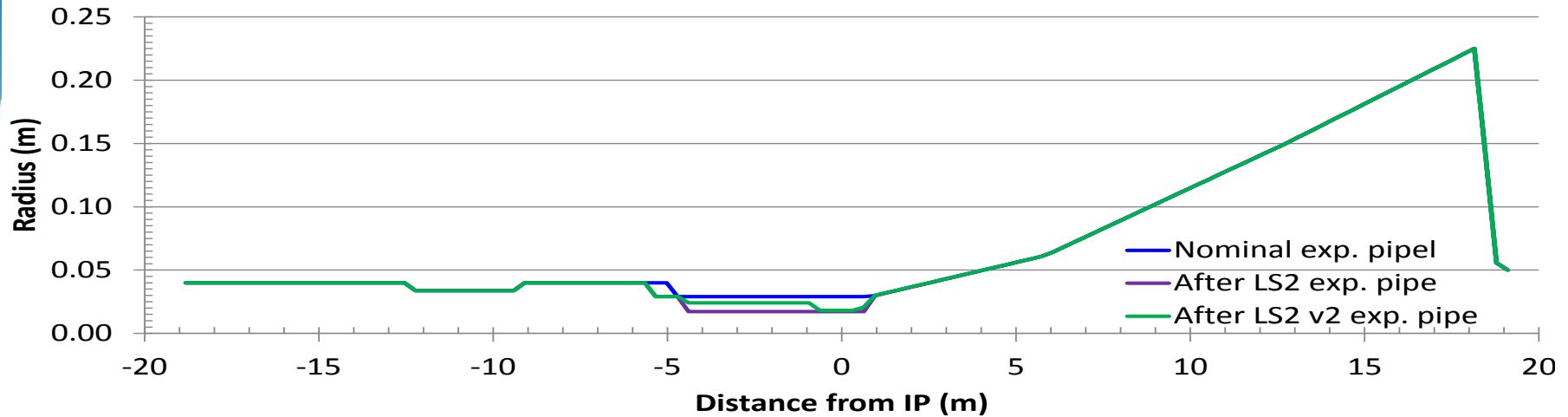
Courtesy A. Tauro

Quantity	A-side part (A)	Central part (B)	C-side part (C)
Construction and deflection	1.3mm	0.6mm ⁽¹⁾	0.5mm
Mechanical adjustment precision	2.5mm		
Survey to beamline uncertainty	1.5mm ⁽²⁾		
Quad fiducial to beamline uncertainty	0.5mm ⁽²⁾		
L3 movement	<0.5mm ⁽³⁾		
B field movement	<0.5mm		<2.5mm
Linear sum	6.8mm	6.1mm	8.5mm

- 1) LEB 21.3.12
- 2) LEB 22.2.12
- 3) LEB 23.3.12

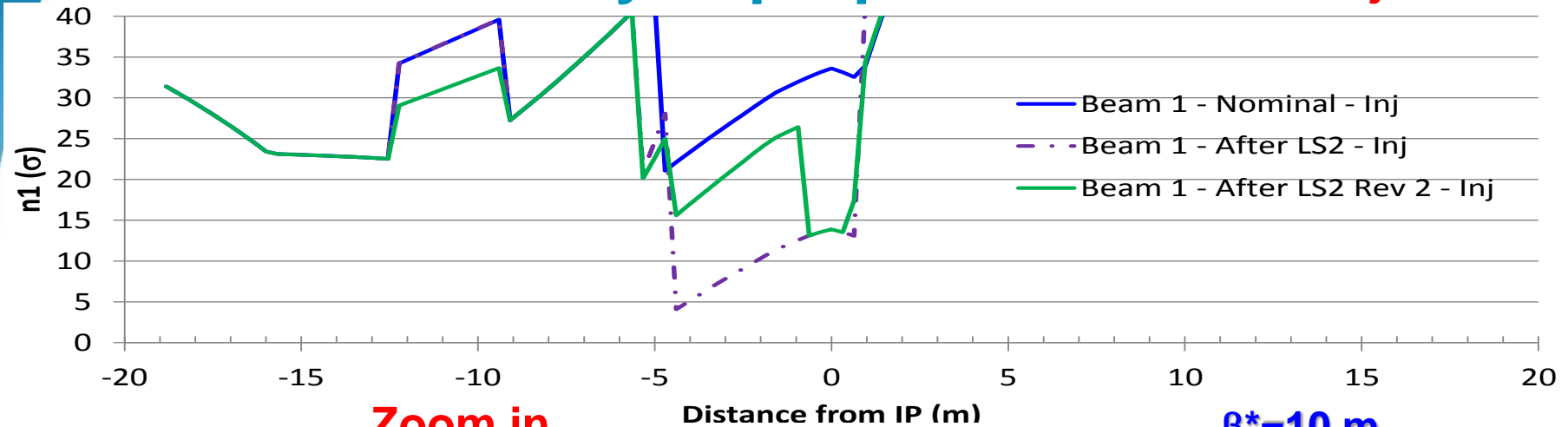


History of proposal - III



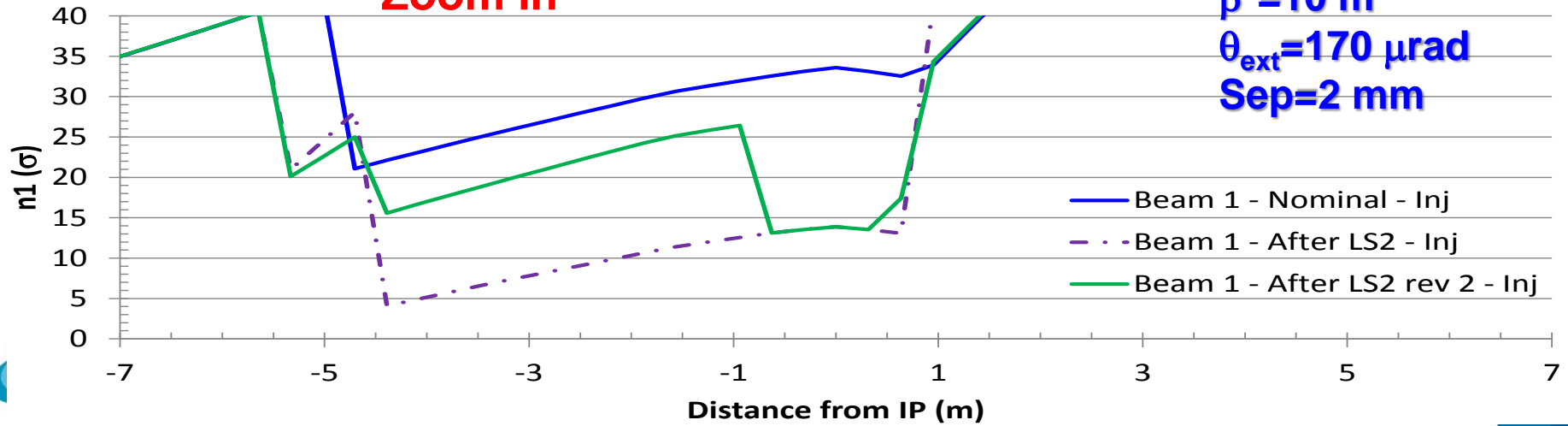
History of proposal - IV

Injection



Zoom in

$\beta^* = 10$ m
 $\theta_{ext} = 170$ μ rad
Sep = 2 mm



Alice aperture: results - II

- Currently, a vertical shift by -2 mm of the IP is performed in physics:
 - This has implications in terms of aperture
 - Correctors' strength
- In the following it is assumed that Alice will be re-aligned during LS2 so that the IP shift will not be needed anymore.
- Impact on n1
 - Collision (protons, $\beta^*=10$ m): $> 73 \sigma$
 - Collision (ions, $\beta^*=0.6$ m): $> 300 \sigma$

New facts for the nominal LHC

- Change of crossing angle philosophy
 - To allow quick polarity reversal the external crossing angle is kept fixed (à la LHCb). This implies
 - Injection: increased parallel separation (2 mm -> 3.5 mm) and an angle in the separation plane of $-40 \mu\text{rad}$.
 - Collision (protons): the external crossing angle is increased to $200 \mu\text{rad}$.
 - Impact on n_1
 - Injection: 10.2σ
 - Collision (protons, $\beta^* = 10 \text{ m}$): $> 72 \sigma$

HL-LHC: new parameters for aperture computations

- Based on the experience from Run 1, the parameters used for aperture computations have been reviewed.
 - Collision: R. Bruce et al, “Parameters for HL-LHC aperture calculations and comparison with aperture measurements”, CERN-ACC-2014-0044.

- Target aperture: 12σ

- Take minimum over $(-\delta_p, 0, \delta_p)$

Parameter set	LHC design	HL-LHC design	Intermediate	Run I
Primary halo extension	6σ	6σ	6σ	6σ
Secondary halo, hor./ver.	7.3σ	6σ	6σ	6σ
Secondary halo, radial	8.3σ	6σ	6σ	6σ
Normalised emittance ϵ_n	$3.75 \mu\text{m}$	$3.5 \mu\text{m}$	$3.5 \mu\text{m}$	$3.5 \mu\text{m}$
Radial closed orbit excursion x_{co}	3 mm	2 mm	1 mm	0.5 mm
Momentum offset δ_p	8.6×10^{-4}	2×10^{-4}	2×10^{-4}	0
β -beating fractional beam size change k_β	1.1	1.1	1.05	1.025
Relative parasitic dispersion f_{arc}	0.27	0.1	0.1	0.1

HL-LHC: new parameters for aperture computations

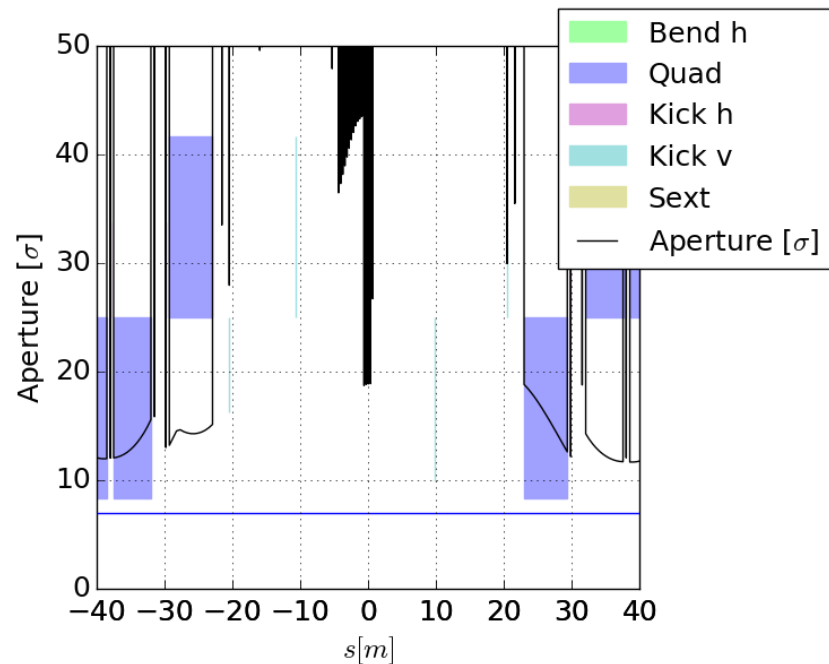
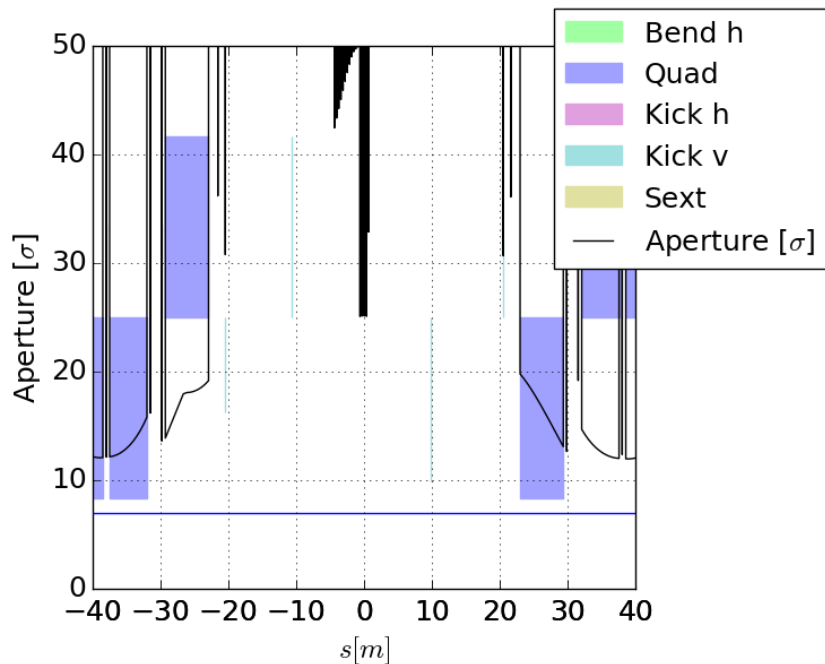
- Based on the experience from Run 1, the parameters used for aperture computations have been reviewed.
 - Injection: discussions on-going and note in preparation.
 - Target aperture: 10.6σ
($\epsilon_n=2.5 \mu\text{m}$)

Parameter set	LHC design	HL-LHC design
Primary halo extension	6σ	6σ
Secondary halo, hor./ver.	7.3σ	6σ
Secondary halo, radial	8.3σ	6σ
Normalised emittance ϵ_n	$3.75 \mu\text{m}$	$2.5 \mu\text{m}$
Radial closed orbit excursion x_{co}	4 mm	4 mm
Momentum offset δ_p	1.5×10^{-3}	6×10^{-4}
β -beating fractional beam size change k_β	1.1	1.05
Relative parasitic dispersion f_{arc}	0.27	0.14

HL-LHC: results

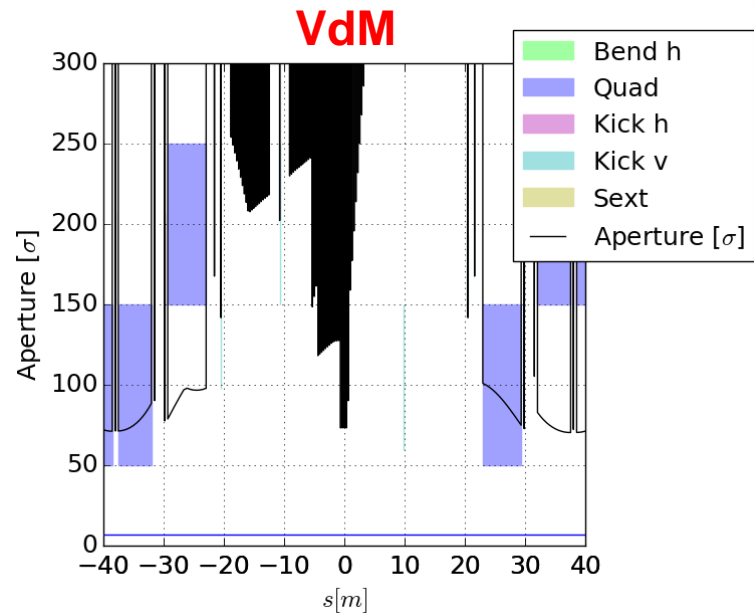
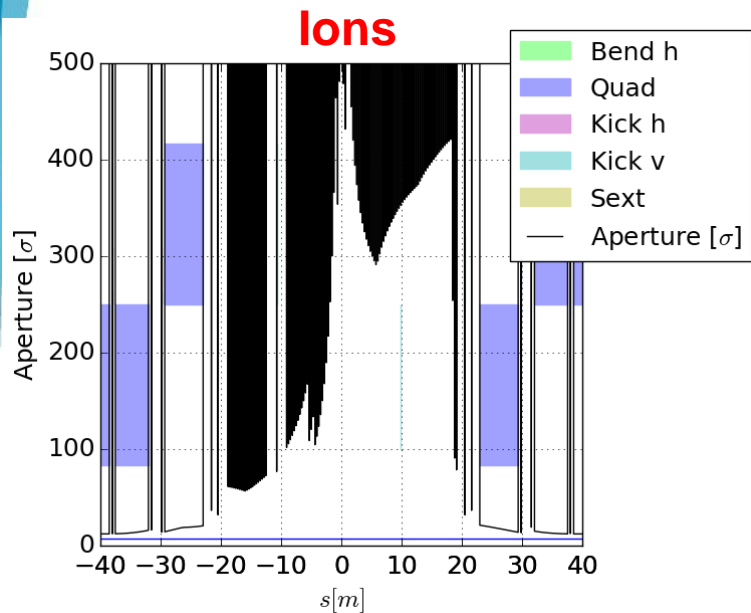
Injection:

- Nominal configuration: aperture is always larger than 24σ ($\varepsilon_n=2.5 \mu\text{m}$)
- Configuration à la LHCb: aperture is always larger than 18σ ($\varepsilon_n=2.5 \mu\text{m}$)



HL-LHC: results

- Collision:
 - Proton ($\beta^*=10$ m): aperture is always larger than 107σ ($\varepsilon_n=3.5 \mu\text{m}$)
 - Ions ($\beta^*=0.5$ m): aperture is always larger than 70σ ($\varepsilon_n=3.5 \mu\text{m}$)
 - VdM ($\beta^*=30$ m): aperture is always larger than 75σ ($\varename{m}=3.5 \mu\text{m}$)



Conclusions

- In spite of the reduction of the diameter of the central pipe the situation in terms of aperture is acceptable, both for LHC as well as HL-LHC.
- The alignment of the whole detector should be carefully monitored as it will be difficult to cope with the current IP offset after LS2.
- The proposed crossing scheme à la LHCb further reduces aperture at injection: the situation might have to be monitored after LS2.
- **Possible impact on background should be evaluated.**