Summary of LEB Discussions for the LHCB VELO Upgrade for LS2

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for the LHC Experimental Beampipes (LEB) Working Group

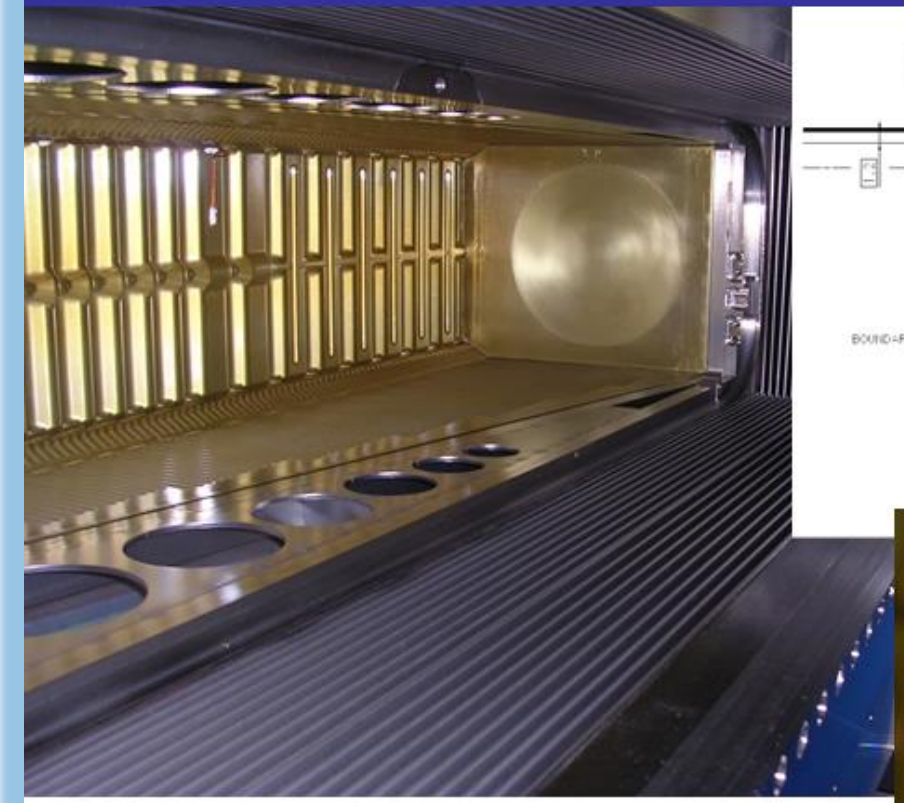
Acknowledgements: V Baglin, R Bruce, H Burkhardt, G Corti, M Ferro-Luzzi, M Giovannozzi, B Holzer, G Lanza, E Metral, S Redaelli, B Salvant, K Vatansever (Tech. Secretary), J Wenninger + LEB Working Group

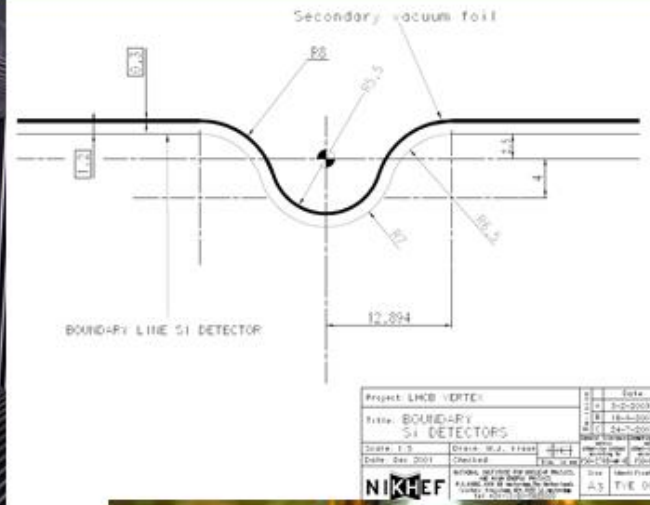
Introduction

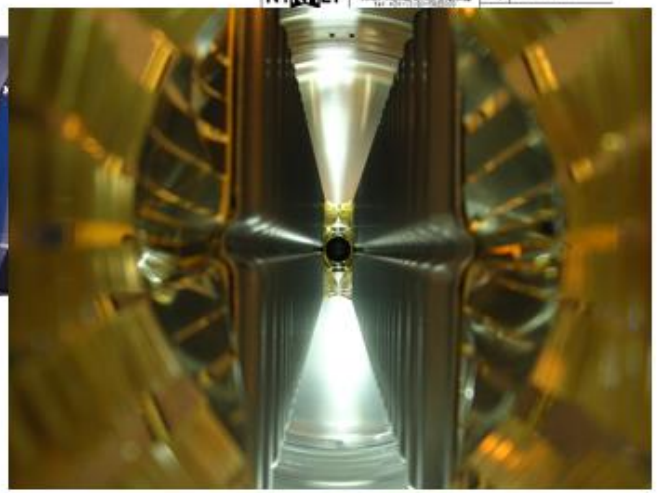
- **Requested Change**
- **Recap LEB Working Group and System**
- **Aperture**
  - Aperture Calculations (M Giovannozzi + B Holzer)
  - Aperture Observations (B Holzer)
- **Other Considerations**
  - Vacuum (G Lanza)
  - Experimental Background (G Corti)
  - Impedance (B Salvant)
  - Machine protection (J Wenninger)
- **Summary**

Requested change

The foil now







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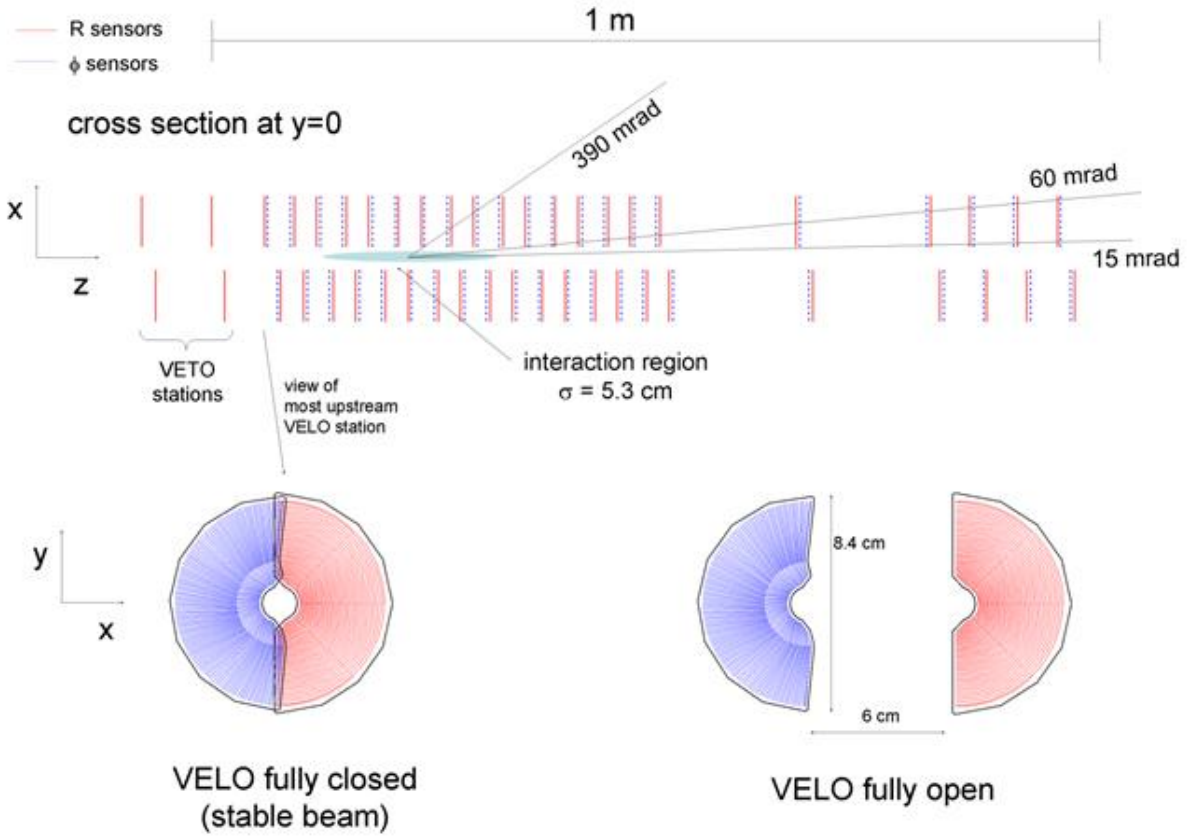
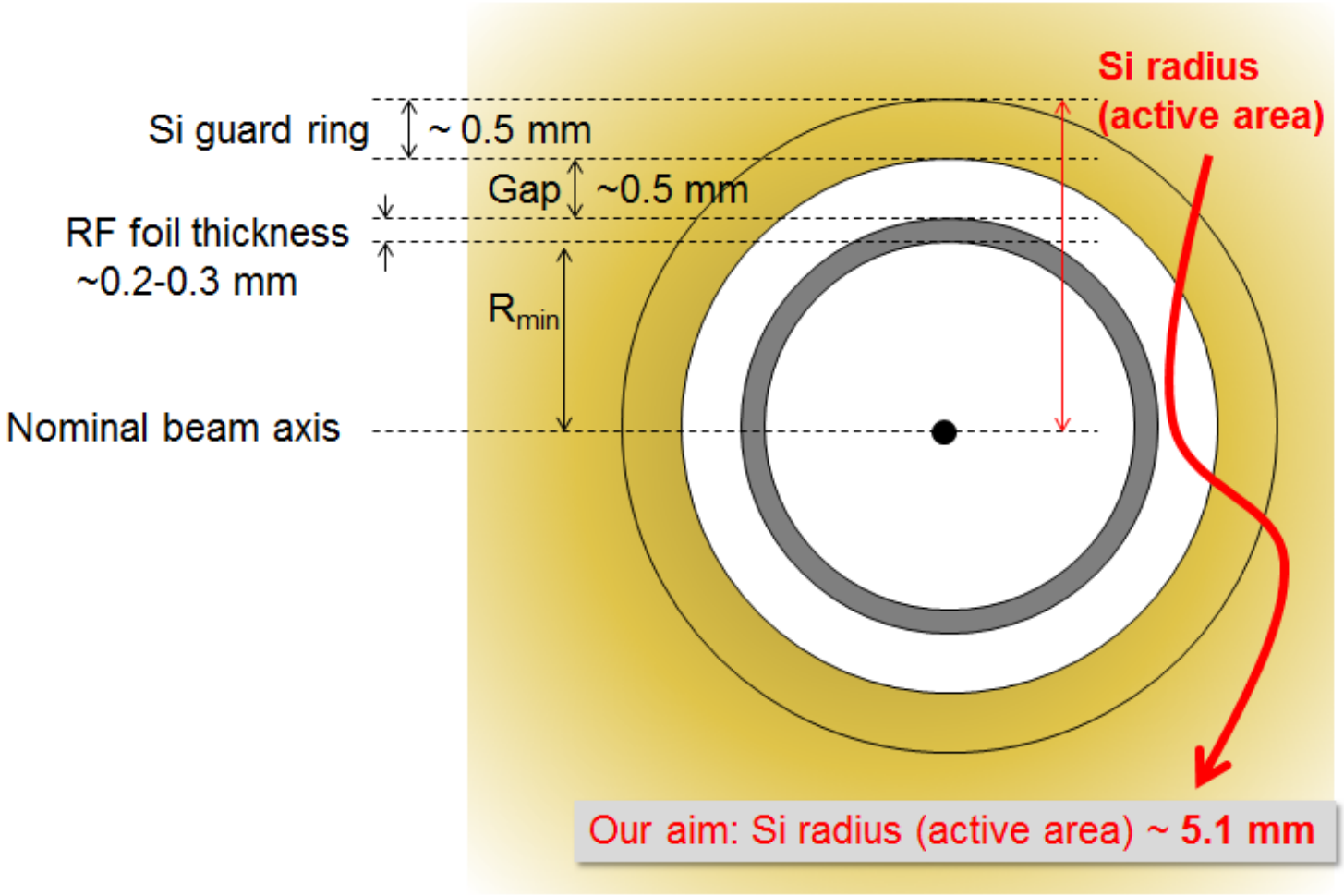
Requested change

Current VELO layout



Requested change

The various bits we would liketo minimize

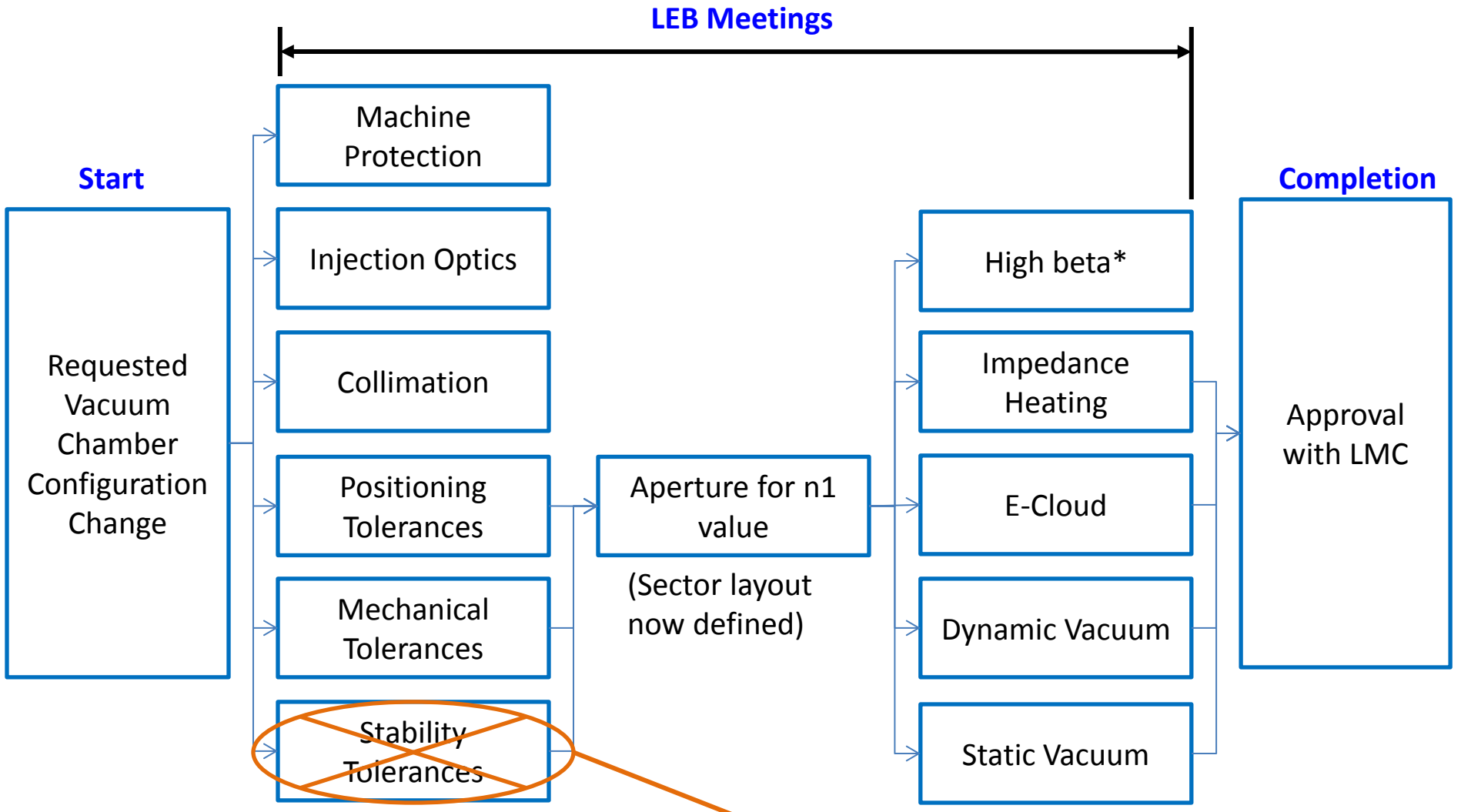


LEB - Working Group

- **LHC Experimental Beampipes(LEB) Working Group**
  - Forum for discussing changes to layouts in experimental vacuum sectors
  - Representatives from all experiments and relevant machine groups
  - LEB website on sharepoint [http://cern.ch/leb]
  - Presentations and minutes are recorded on INDICO[1]

[1] http://indico.cern.ch/categoryDisplay.py?categId=2261

LEB - System



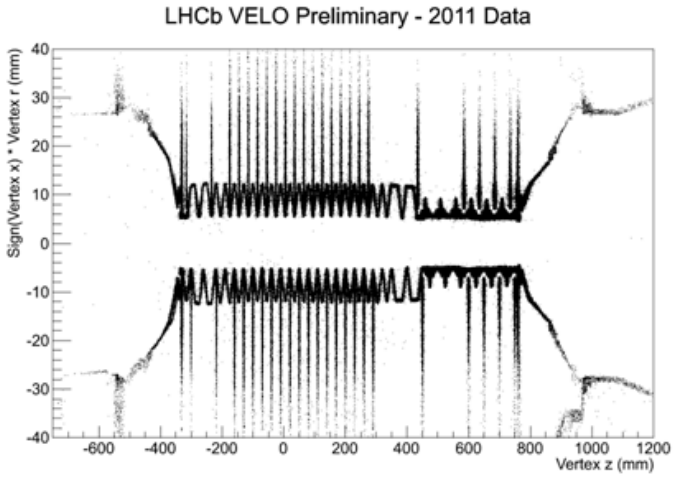
Movable system centred around beam-beam interactions therefore cavern stability not considered for study

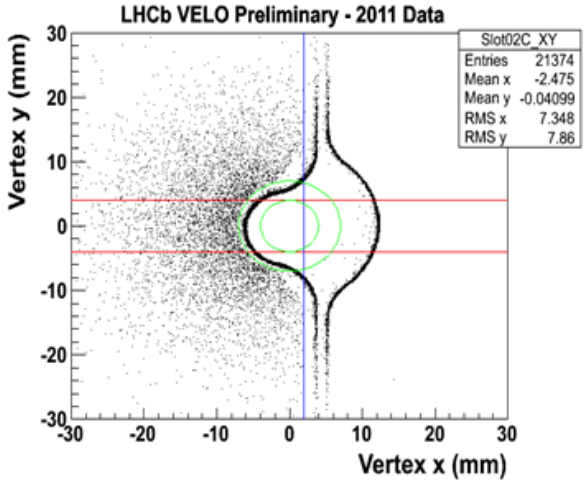
Mechanical tolerances

RF foil tolerances

Measurement on the current VELO RF boxes

- performed before installation can be found here
  - http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/test/secondary_foil/deflection/Metrology_0612updated.pdf
  - Typically, the foils are within +/-0.5 mm of their nominal position over the whole surface.
- from particle interactions are being worked on, preliminary results confirm above tolerances

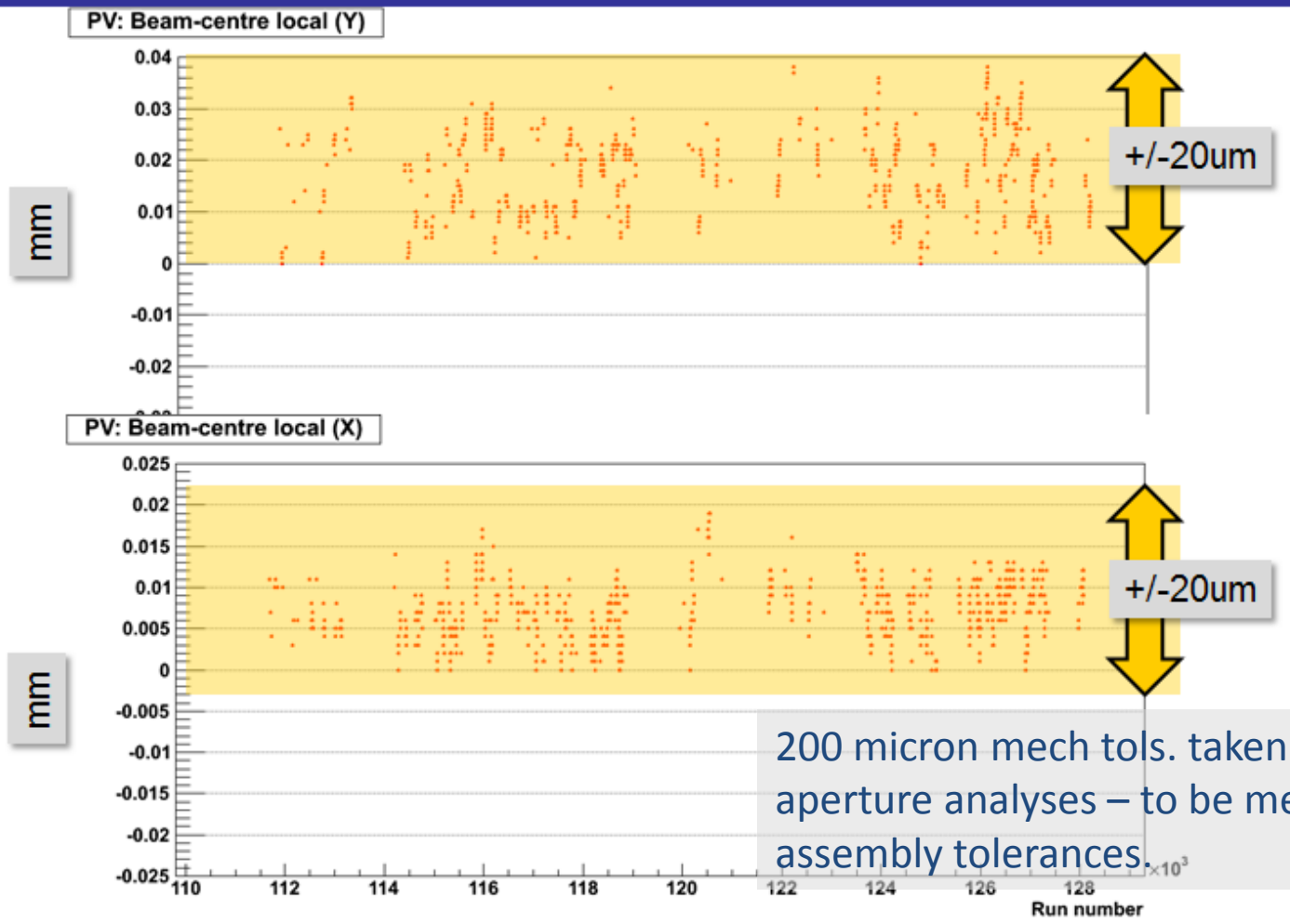




Measurements on the new (upgrade) RF boxes using the milling method are yet to be done, but expect to have better tolerances than the current foils (less stress in foils)

Positioning tolerances

Position of luminous region vs VELO halves



200 micron mech tols. taken for aperture analyses – to be met by final assembly tolerances.

Aperture Calculations

Assumptions - I

- The vertical external crossing angle is the preferred solution by LHCb.
- It restores the symmetry between the configurations with different spectrometer polarities.
- This is the scenario considered as the reference for running after LS2 and with HL-LHC.
- The situation should become clearer after the tests during MD block 3.
- Luminosity levelling could be performed either by
  - Beam-beam separation (routine operation)
  - Beta* variation (tested in MDs)
- Ratio between levelled and virtual luminosity: 5 (this is the general assumption for HL-LHC).
- VELO parameters:
  - Radius: 3.4 mm; Mechanical tolerance: 100 µm; Length: ±800mm around IP.
- Aperture parameters:
  - Beta-beating: 20%; Closed orbit: 100 µm (IP stability during fill is around 50-60 µm).

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200 micron mech + psn tols. Finally taken Based on 3.5 mm Inner radius see paper "VELO Aperture Considerations for the LHCb Upgrade"

Aperture Calculations

Assumptions - II

- Beam parameters (see also Bernhard presentation)

	Nominal		Post LS2		HL-LHC	
	25 ns	50 ns	25 ns	50 ns	25 ns	50 ns
N_b (10^{11})	1.15	1.6	1.7	1.7	2.2	3.5
ε_n (μm)	3.75	2.5	2	1	2.5	3.0

- Post LS2 parameters depend on the performance reach of the injectors. Still to be discussed and unofficial.
- Given the uncertainties, the approach has been to analyse worst case scenarios.

Aperture Calculations

Assumptions - III

- Reference beta*-> 3m
- Beam-beam separation
  - $\lambda \approx 100\ \mu m$ (assuming 25 ns nominal emittance). This value has been added to the closed orbit budget in the aperture estimate (i.e., total closed orbit budget of 200 μm).
- Beta* levelling
  - β^* in the interval 3 m, 15 m
- Vertical external crossing angle (total)
  - Based on saturation of triplet aperture: about 478 μrad (assuming 25 ns nominal emittance). This provides 37 σ of beam-beam separation.

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Aperture Calculations

Results

- Beam-beam separation
  - VELO aperture (beginning of fill): 63 σ (assuming 25 ns nominal emittance).
- Beta* levelling
  - Vertical external crossing angle kept constant while β* is varied.
  - VELO aperture (beginning of fill): ≈31 σ (assuming 25 ns nominal emittance).

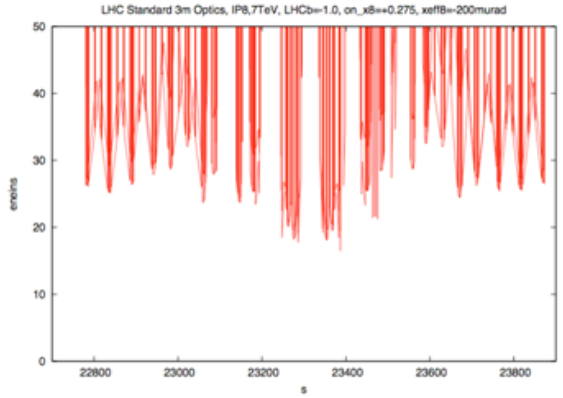
Aperture Observations

LHCb Polarity & Horizontal Crossing Angle

Aperture:

$\beta^*=3.0m$, $\varepsilon_n=3.75\ \mu rad$

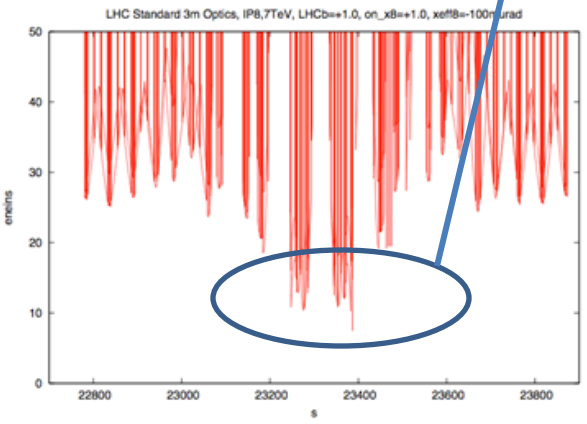
LHCb = "good" (Negative kick on beam 1)



LHCb spectometer polarity could have general aperture implications for LHCb 25 ns running – needs to be addressed

LHCb = "bad"

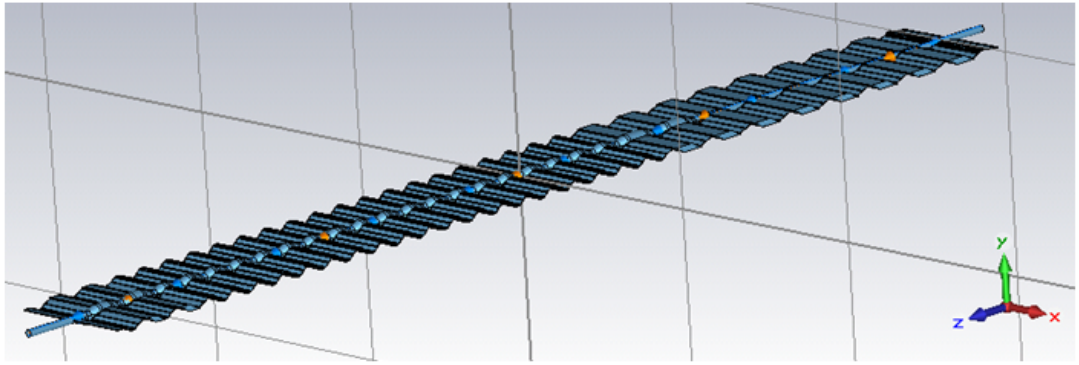
(Positive kick on beam 1)



Presented by B.Holzer at the LEB on 8/10/2012

Impedance

Preliminary results for the LHCb VELO radius reduction (5.5 mm to 3.5 mm)



Final geometry not known → current geometry roughly scaled by 2/3 in both transverse directions.
Very twisted shape → difficult to import 3D model, low accuracy of simulations, convergence issues, far from analytical models

	Im(Zlong/n)	Im(Zeff vertical)	Im(Zeff horizontal)
Current RF box	~ 1.2 mΩ	~0.08 MΩ/m	~0.06 MΩ/m
"New" RF box	~ 1 mΩ	~0.26 MΩ/m	~0.22 MΩ/m
Total LHC (in stable beams)	**90 mΩ**	**25 MΩ/m**	**25 MΩ/m**

Assumes β* up to 15m

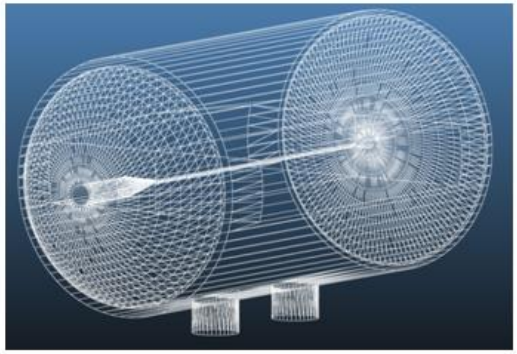
With the current model, the radius decrease is expected to lead to an increase of the transverse impedance estimated to be up to 0.5% of the total transverse LHC impedance, despite the low beta function at the VELO location (up to 15 m). Unexpectedly, the longitudinal impedance in fact decreases with this smaller radius. Actual impedance and power loss with post-LS1 and HL-LHC parameters need to be checked and optimized when the final geometry is known.

B. Salvant and impedance team; LEB ad hoc meeting10/12/2012

Vacuum

VELO aperture reduction for LS2 and Beam Vacuum Stability

Preliminary Vacuum Stability Code simulations indicates a potential impact of the aperture reduction on the critical current value. Iterations with the mechanical design teams are required to assess the critical current and optimise the VELO design.



The value of the critical current can be upgraded by :

- a full bake out of the entire system
- a full NEG coating of the vacuum system (*e.g.* RF foil included)
- an activation of the NEG coating at temperature equal or better higher than 180°
- an improvement of the VELO tank pumping speed
- a possible recovery of the vacuum performances when required

G.Lanza LEB ad-hoc meeting 10/12/2012

Experiment Background

Background Considerations

- The reduction in the Velo aperture may affect the local vacuum conditions in the experimental beam pipe.
  - Based on the current running experience the background from local beam gas is not expected to become an issue for the experiment unless the vacuum conditions degrade drastically.
- Existing studies with 7 TeV beams shows that the rate of particles from Machine Induced Background(*) is small with respect to those from pp collisions at nominal LHC operation and nominal LHCb $\mathcal{L} = 2 \times 10^{32}$ cm^{-2}s^{-1} ($\mathcal{L}_{upgrade} = 5 - 10 \times \mathcal{L}_{nominal}$)
  - Rates reaching LHCb will depend on machine optics and not VELO aperture
  - Increased rate in VELO due to higher flux at smaller radia not expected to be an issue for low multiplicity showers. Low rate high multiplicity showers illuminate the whole VELO as now.
- Further verification to be carried out with VELO proposed layout

(*) due to beam interactions with machine elements or residual gas far (arcs) and close (LSS) to LHCb

G.Corti private communication 11/12/2012

Machine Protection/Collimation

1. LHCb plan to operate as they have been in terms of detecting and dumping beam. Stefano suggested that LHCb look at a review that was done on the movement system, which suggested some changes/improvements.
2. For the VELO, it is necessary to know how the impedance drives heating in the foils - this information will come from Benoit/Elias.
3. Given the suggested proximity to the beam, it will be useful for LHCb to participate in the "loss maps" along with TOTEM etc...
4. No difference in collimator settings is foreseen between LHC and HL-LHC - see presentation of Roderik Bruce from 16th August in link for LHC settings https://indico.cern.ch/categoryDisplay.py?categId=2582.
5. Jorg mentioned that it is theoretically possible to hit the VELO with the beam by altering some machine settings. A presentation is available on this subject. Jorg has been asked to provide a copy of this presentation.
6. To keep a common approach across the machine, the emittance used in calculations should be 3.5 microns.

Summarised from discussions between J Wenninger/S Redaelli/M Ferro-Luzzi/M Gallilee on 27 Sept 2012 and 05 Sept 2012

Bump @ VELO /5

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One should remark that:
- After LS1 the TCT will move back further from the IP. This changes the situation, but I cannot say in which direction it goes without some further simulation.
- In the talk the TCT was assume to be around 9 sigma, while presently it sits at 12 sigma. This means that it is currently even easier to touch the VELO (+ we are at lower energy , so the correctors have a much larger reach !).
- Bringing the VELO closer to the beam will expose it obviously even more.
- We are currently protected by bringing the beams close to VELO by a redundant interlock on the beam position and on the corrector settings. If they would fail, then it is the LHCb BCM or our BLMs (depending on where the beam touches) that have to spring into action.

No particular worries, but bringing a detector closer to the beams is exposing it more...

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05.09.2005 LEADE / J. Wenninger - AB-OP 33

LEB Summary

- With nominal foil radius of 3.5 mm, assuming 200 μm mech. Tols (to be confirmed with final foils), 200 μm closed orbit tols, minimum aperture at collision would be 31σ, assuming worst case of β* levelling. A summary can be found in the paper "VELO Aperture Considerations for the LHCb Upgrade" By R. Appleby, M. Neat, M. Ferro-Luzzi, M. Giovannozzi, B. Holzer – to be published as an ATS note soon;

- It has been recommended by Machine Protection that an upgraded VELO should participate in the loss maps;

- Require full studies with the final design for vacuum, machine protection and impedance optimisation;

- Preliminary impedance studies expect a worst case increase of 0.5 % on total LHC transverse impedance, longitudinal could actually decrease. An extensive study of impedance will be required to optimise the final design for the machine;

- No show stoppers seen so far based on the presented studies. Further studies needed on the final design and layout.