New gas target design for the HL-LHC Beam Gas Vertex profile monitor

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HiLumi HL-LHC PROJECT

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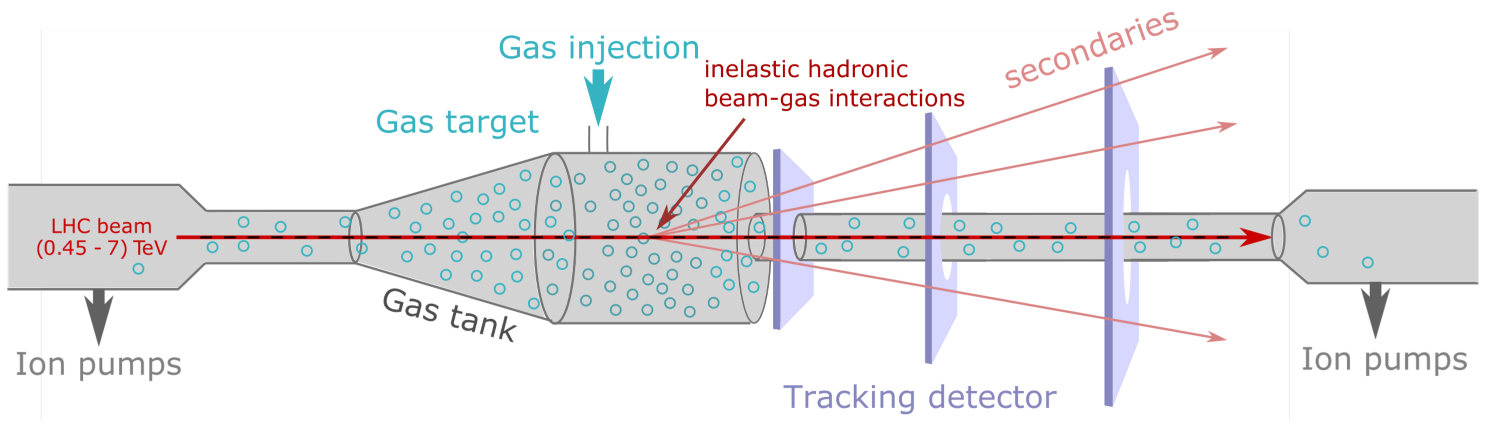
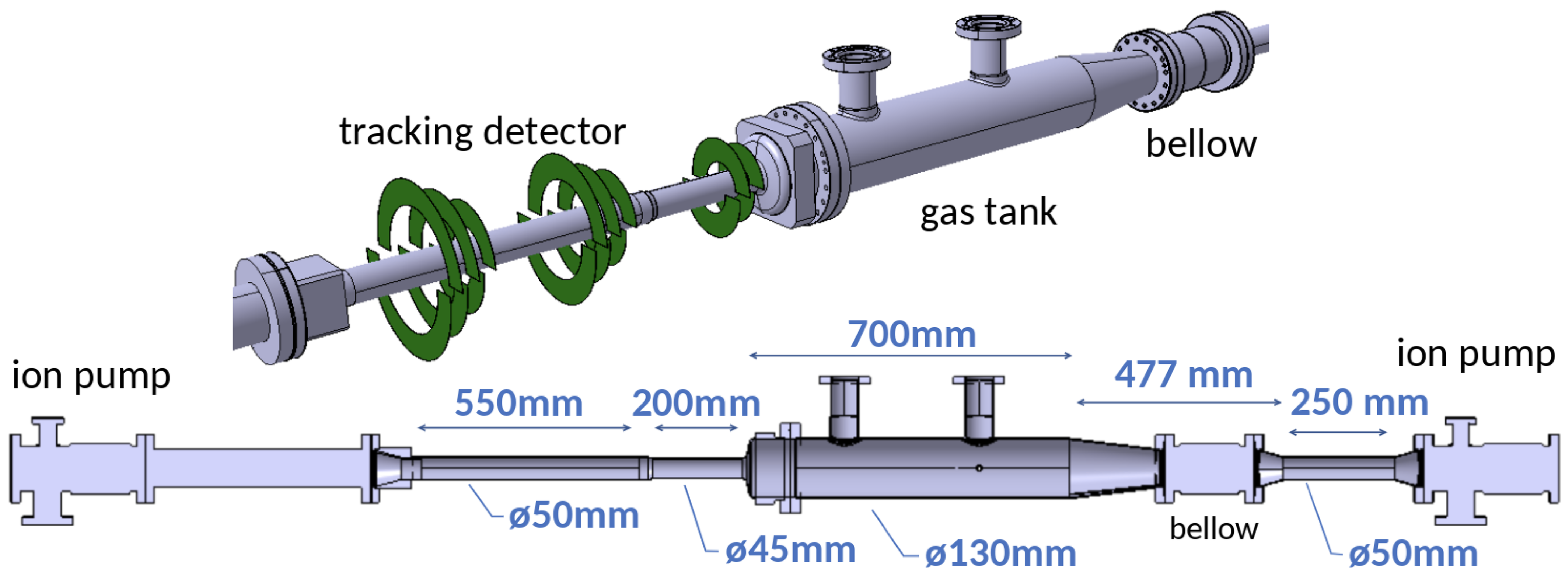
Concept

- Non-invasive **transverse beam profile monitor** for HL-LHC.
- Reconstruction of **vertices** from **beam-gas inelastic hadronic interaction**.
- Beam profile image inferred from spatial distribution of reconstructed vertices.
- Beam **profile** and **bunch-by-bunch beam size** measurement throughout the **full energy cycle** and independently of the beam **intensity**.



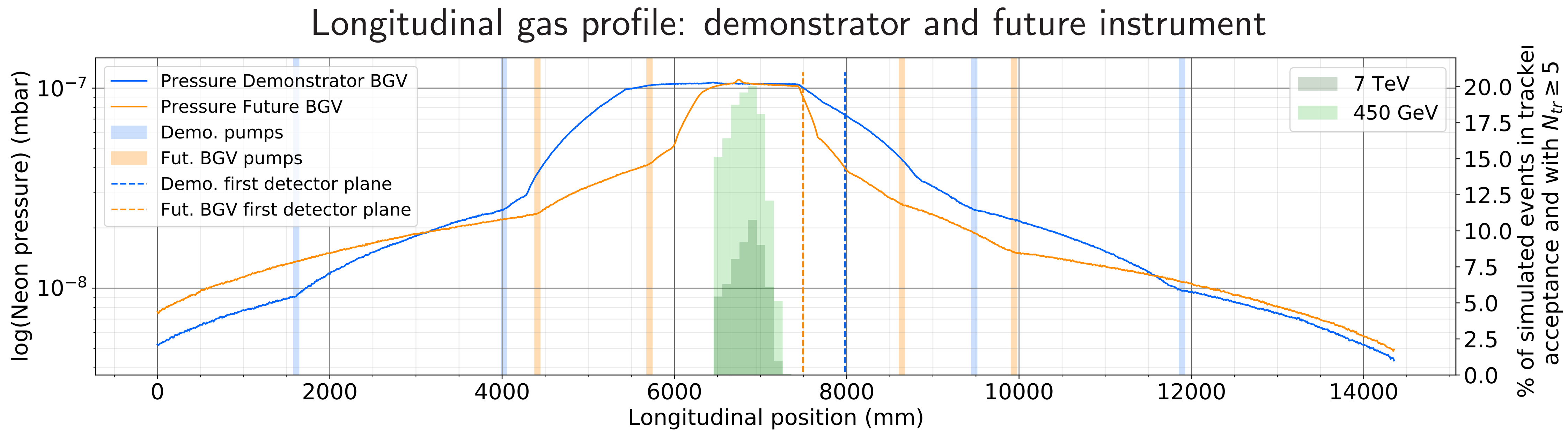
Gas tank design

Gas target and tank design **optimised** with longitudinal gas profile and structure impedance simulations (resp. Molflow+ [1] and CST Particle Studio [2] wakefield solver).



Extended pressure bump

Longitudinal gas profile: demonstrator and future instrument



Green bars: percentage of events which can be reconstructed with the future instrument tracker (Monte Carlo simulations [3]).

Impact on LHC beam and operation

BGV **operation time**:

- min. 2 h/fill for beam size and profile measurement at key phases of the energy cycle.
- max. limited by radiations to downstream equipment. Radiation studies ongoing [4].

Emittance growth due to **elastic scattering** on the gas target [5]: $\Delta\epsilon = \frac{1}{2} q_p^2 \left(\frac{13.6\,\mathrm{MeV}}{p\beta_r}\right)^2 \bar{\beta}_x \frac{L}{L_{\mathrm{rad}}}$

Beam and Energy	$\Delta\epsilon_n$ (µm h^{-1})
Beam 1, 450 MeV	3.2×10^{-3}
Beam 1, 7000 MeV	2.0×10^{-4}
Beam 2, 450 MeV	1.6×10^{-3}
Beam 2, 7000 MeV	1.0×10^{-4}

1 h BGV operation at injection + 1 h at collision energy:
$\frac{\Delta\epsilon_n}{\epsilon_n} \simeq$ **0.17 %** for Beam 1 and **0.085 %** for Beam 2
($\ll$ 10%-15% emittance growth budget proposed for the beam size measurement [6])

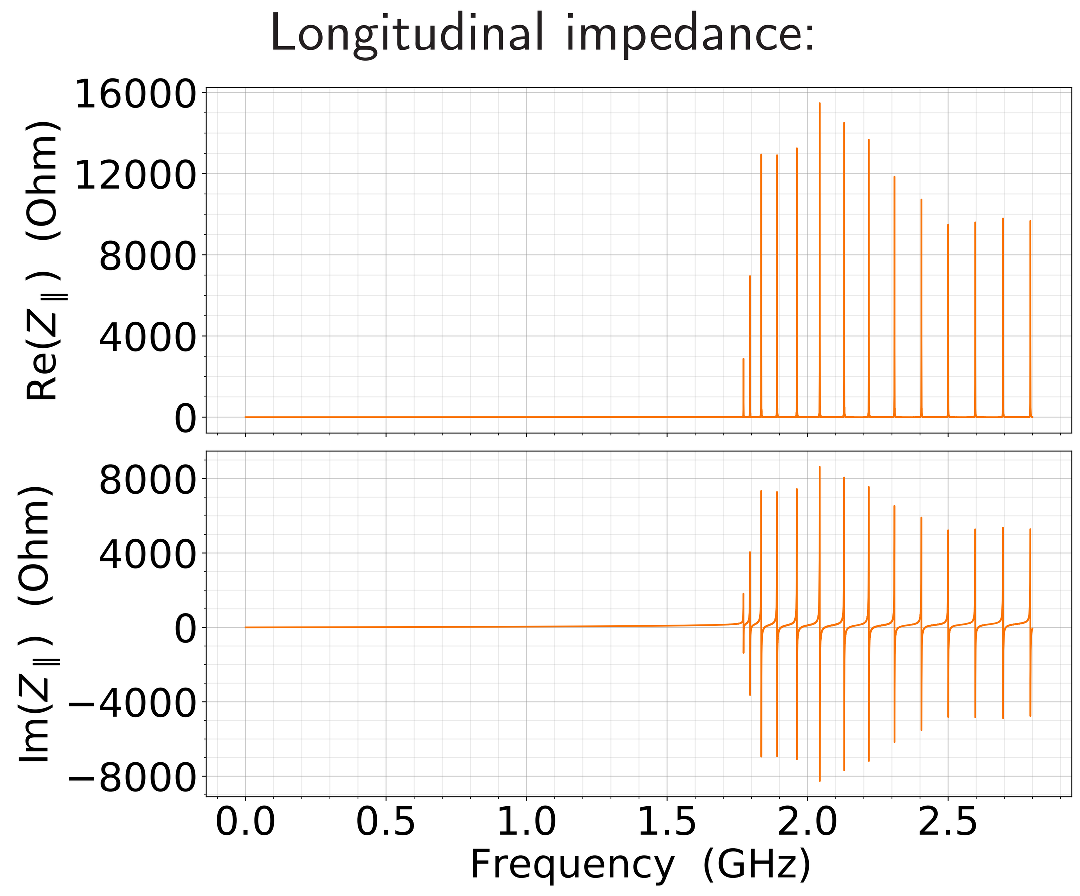
Beam life-time (HL-LHC proton beam):
Foreseen total (elastic + inelastic) interaction rate of 1.0 kHz at injection and 1.2 kHz at collision energies, which translates into beam **half-life times** in the order of **3 years**.

Conclusion

- **New gas target and tank designs** are proposed for the future HL-LHC BGV instrument, based on experience gained with the demonstrator instrument and **optimised** with **simulation studies**.
- The BGV target **impact on LHC beam and operation** expected smaller than the demonstrator based on simulations, and **not worrying for machine operation**. BGV operation time will be limited by its **radiation impact**.
- The full design of the HL-LHC BGV will be detailed in a **conceptual design report** and presented in a review in October 2022.

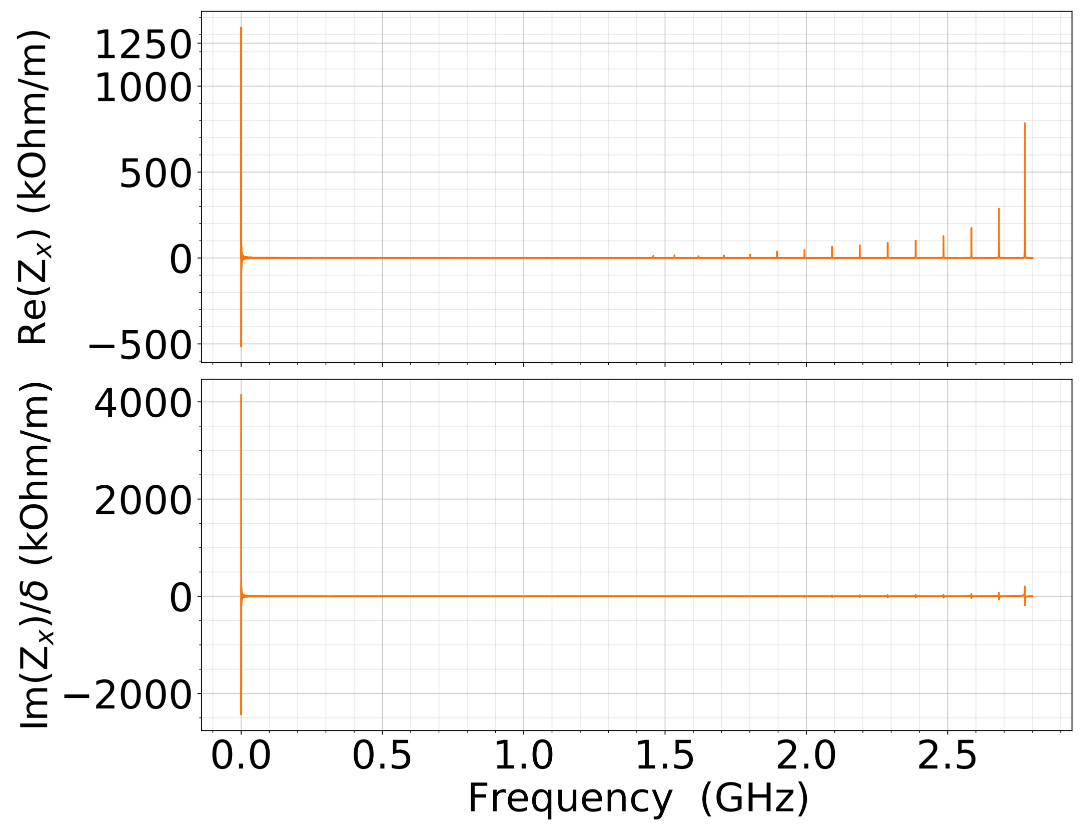
Beam-coupling impedance

Longitudinal impedance:



Transverse impedance:

$$Z_x(\omega) \simeq Z_x^0(\omega) + x_s Z_x^{\mathrm{dip}}(\omega) + x_t Z_x^{\mathrm{quad}}(\omega)$$

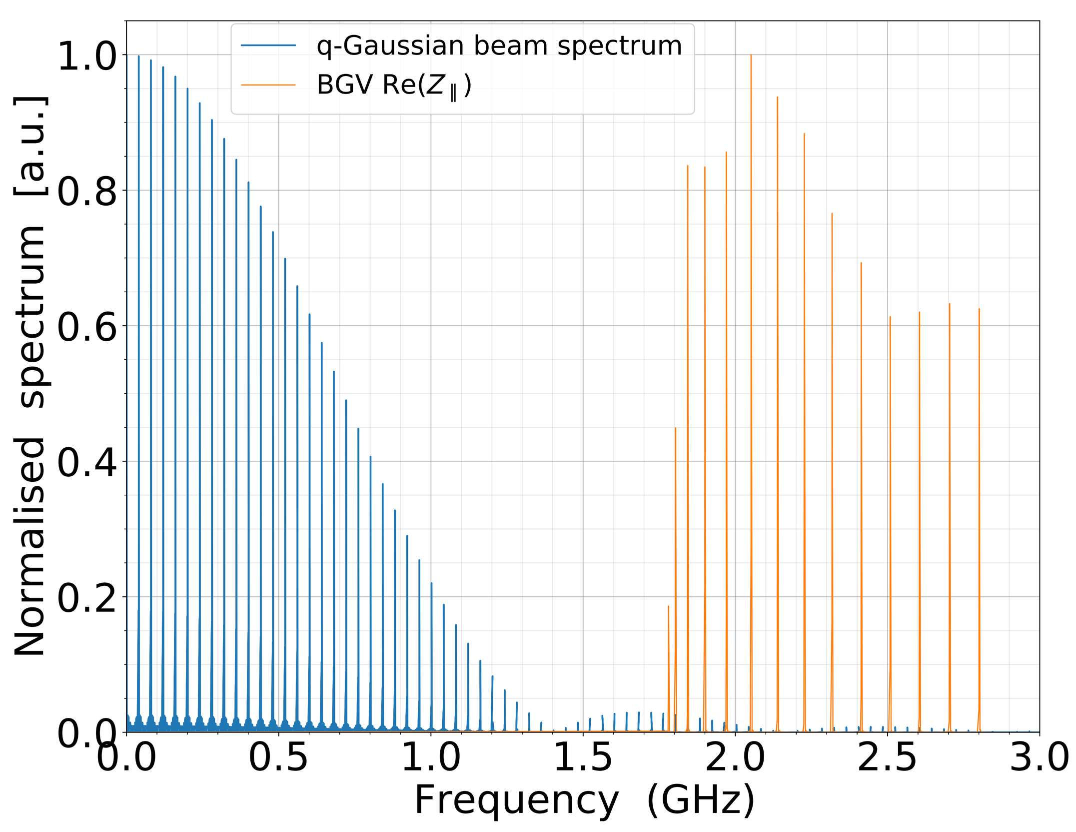


Dissipated power:

$$P_{\mathrm{loss}} = 2 I_{\mathrm{beam}}^2 \sum_{i=0}^{n} |\Lambda(\omega_i)|^2 \Re[Z_\parallel(\omega_i)]$$

Bunch shape	$P_{\mathrm{loss,\,av}}$	$P_{\mathrm{loss,\,max}}$
q-Gaussian	14 W	40 W
Gaussian	11 W	12 W
$\cos^2$	10 W	12 W

worst case configuration ($P_{\mathrm{loss}} = 40$ W):



References

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[2] CST Microwave Studio. http://www.cst.com.

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