Status of the Beam Gas Vertex (BGV) Profile Monitor

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Acknowledgements:
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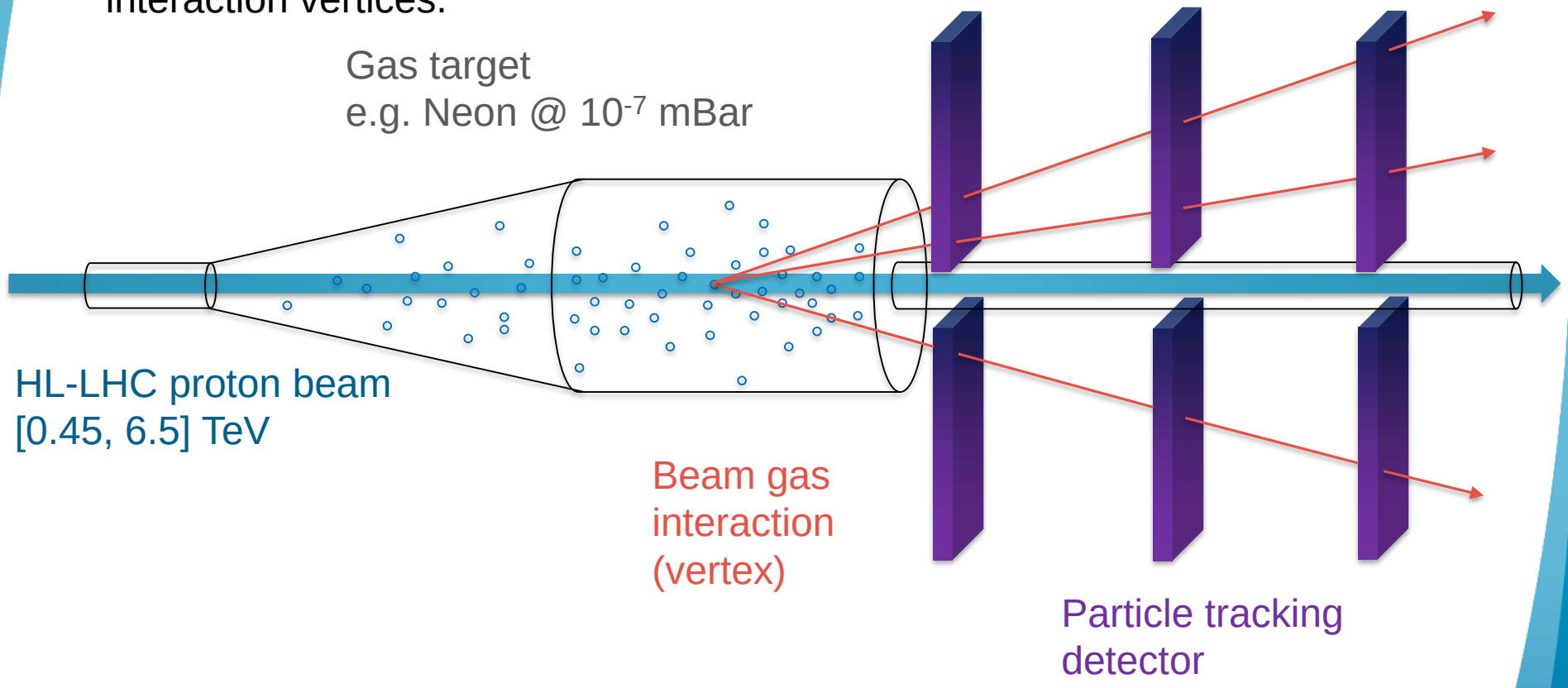
What is the Beam Gas Vertex (BGV) profile monitor?

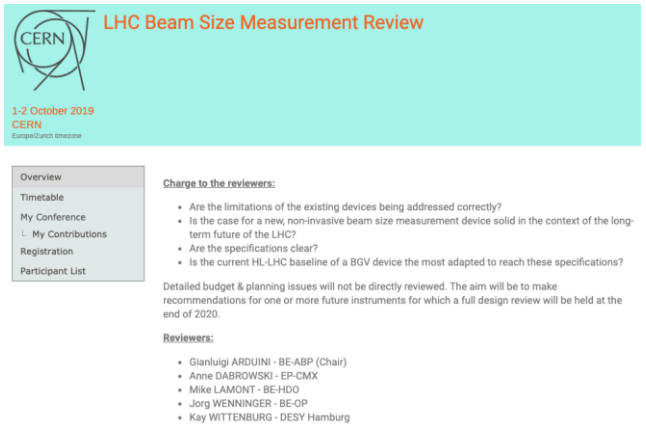
Non-invasive beam profile monitor based on the reconstruction of beam-gas interaction vertices.



Transverse beam profiles inferred from density of beam gas interactions.

Context : The case for a new non-invasive beam profile monitor for the LHC

[LHC Beam Size Measurement Review held on 1st October 2020]



Charge to the reviewers related to the BGV:

1. Is the case for a new, non-invasive beam size measurement device solid in the context of the long-term future of the LHC?

2. Is the current HL-LHC baseline of a BGV device the most adapted to reach these specifications?

Recommendations of LHC Beam Size Review

Review summary & recommendations

1. Is the case for a new, non-invasive beam size measurement device solid in the context of the long-term future of the LHC?
   - ”Yes the case is solid.”
2. Is the current HL-LHC baseline of a BGV device the most adapted to reach these specifications?
   - Recommendation to provide a technical design for the BGV in time for a final decision on the solution to be taken for HL-LHC.

Specification for new non-invasive beam profile monitor

Throughout the HL-LHC cycle [0.45 – 6.5 TeV] :

1. Beam size measurement accuracy < 5 % (emittance measurement accuracy < 10%).

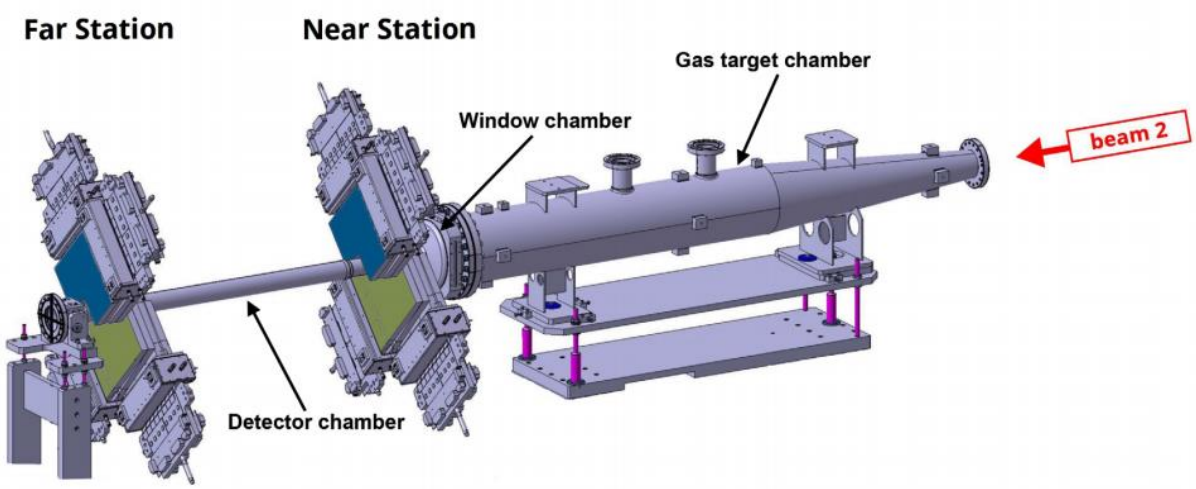
2. Beam size measurement precision ~1% for relative changes over time & bunch-by-bunch measurements.

3. Integration time ~1 minute for bunch-by-bunch measurements.

4. Measure the beam profile.

BGV Demonstrator

Demonstrator device based on a gas target extending ~1m longitudinally & a particle tracking detector based on scintillating fiber stations.



Installed, commissioned & operated in LHC Run 2.

BGV-Demonstrator: What was learnt?

"Noninvasive LHC transverse beam size measurement using inelastic beam-gas interactions",
A. Alexopoulos *et al.* (The BGV Collaboration)
Phys. Rev. Accel. Beams **22**, 042801

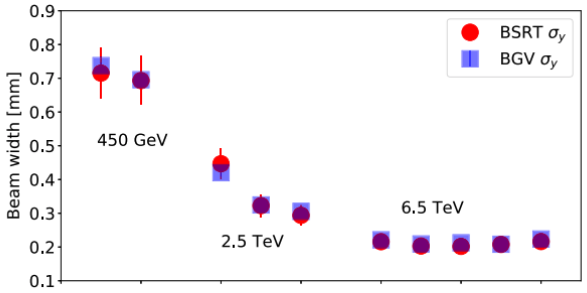


FIG. 15. Transverse beam size measurements for the BGV (blue squares) and BSRT extrapolated to the BGV location (red circles) for three different beam energies.

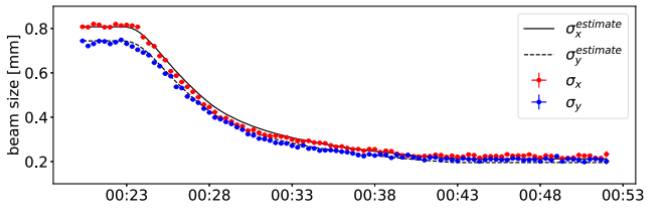


FIG. 16. BGV measurement of transverse beam size during the LHC acceleration phase. The expected beam size evolution given by Eq. (9) is also drawn. For clarity, the symbols used per data point are larger than the error bars of the measurements.

Demonstrated:

- Beam size measurements (200 - 800μm) throughout the LHC cycle.
- Required beam size precision.
- Bunch-by-bunch measurements.
- Consistency with other instrumentation.

Limitations:

- Reconstruction of beam gas interaction vertices not possible (beam size determined via IP correlation method.)
- No beam profile measurements.

BGV-Demonstrator: What was learnt?

Need to improve both the efficiency & purity (quality) of the reconstructed tracks.

How to do this?

- Detailed simulations to optimise instrument design, including: event generation; transport of secondary particles; detector digitization; track finding & vertex reconstruction.

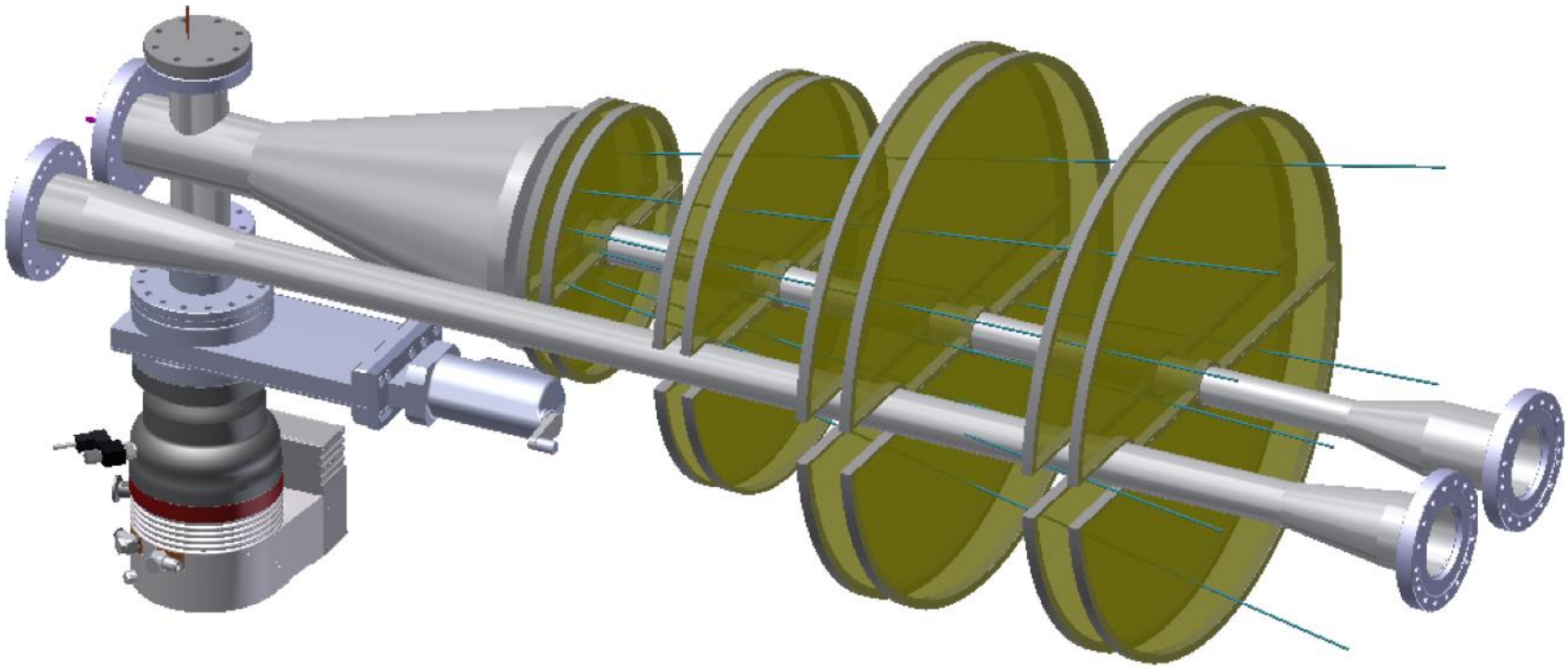
- Most likely the new HL-BGV design will require:

    - Additional tracking detector planes & (better) alignment.
    - Gas curtain to constrain beam gas interactions to a limited region along the beam axis – why?
        - Additional constraint to help match detector hits to tracks.
        - Facilitates smaller tracking detector & thinner exit window.

Towards HL-LHC BGV design

1. Gas target

2. Particle tracking detector

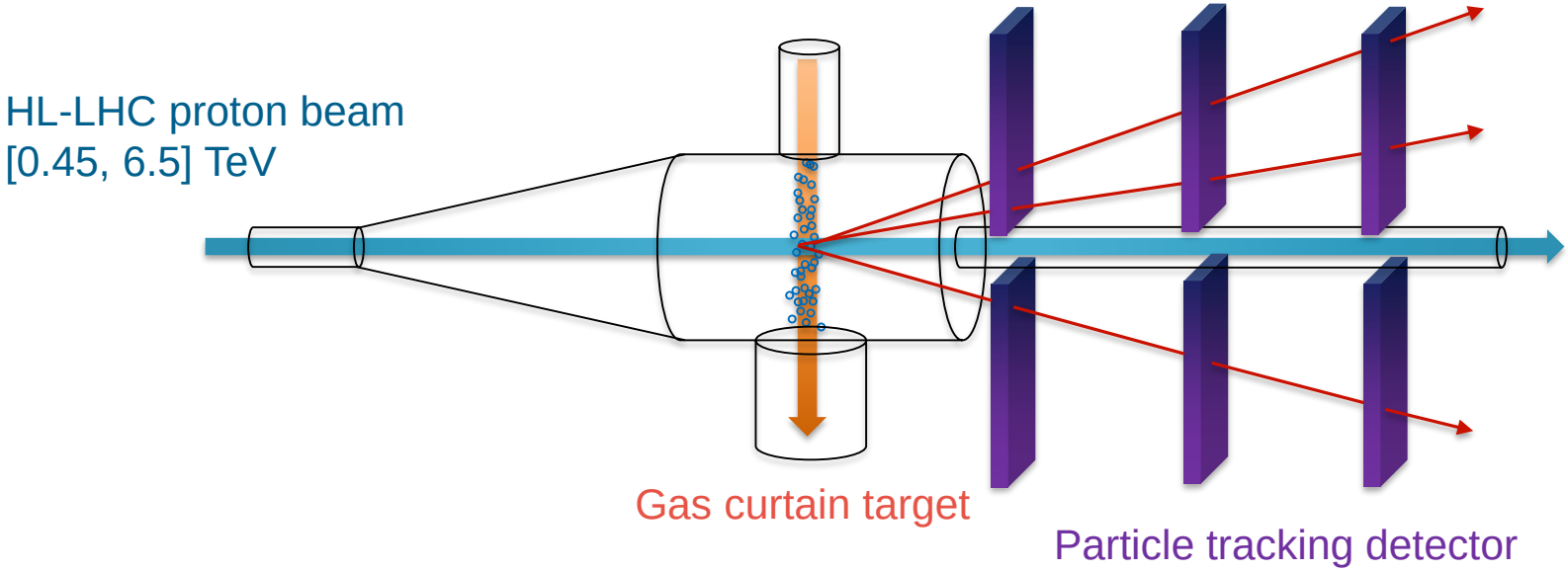


HL-BGV design with gas curtain target &
GEM based tracking detector (R. Kieffer)

Gas target

Wish list

- 100Hz(*) of inelastic beam-gas interactions per LHC bunch.
- Homogeneous gas density - $\Delta\rho / \rho < 0.01$(*).
- Limit beam gas interactions to a <10 mm (*) region along beam axis
  → gas curtain target.



→ See "Alternative Gas Jet Creation for the BGV" by Roberto Kersevan.

(*) Numbers to be optimised.

Particle tracking detector

Wish list

- Reconstruct beam gas interaction vertices with a vertex resolution << beam size (and/or well known vertex resolution).
- Reconstruct 1000 beam interaction vertices per bunch per minute → 50 kHz per beam (*).

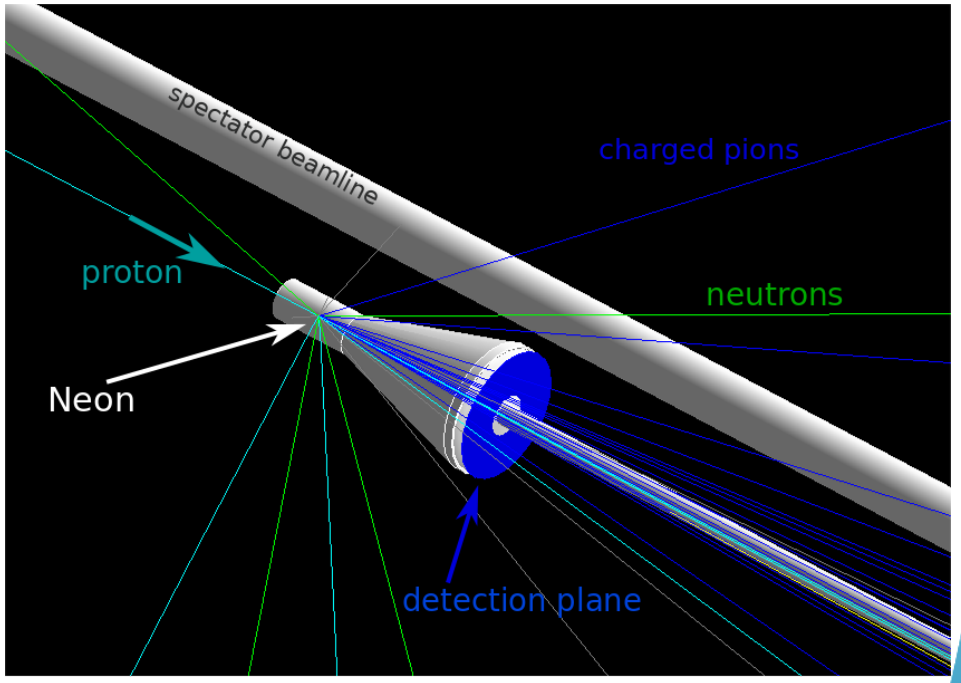
Simulations

- Optimizing tracking detector design by means of Geant4 / FLUKA / Hijing simulations.

Tracking detector technologies

- Considering Gas Electron Multipliers (GEM) & Silicon pixel / strip based technologies.

(*) Numbers to be optimised.



Simulated proton-Neon interaction
(B. Kolbinger, H. Guerin)

Timeline to HL-BGV TDR

Dec. 2021	Technical Design Report (TDR).
Mar. 2021	Decision on gas target & particle tracker technology.
Dec. 2020	Performance evaluation of gas target & tracker options.
Jul. 2020	Fix target & tracker options for performance evaluation.

Conclusion

Feasibility to measure the LHC beam size throughout the LHC cycle using inelastic beam gas interactions has been demonstrated.

Constraining beam gas interactions along the beam axis will be beneficial & could be a necessary condition to meet HL-LHC requirements.

Extensive simulations are currently being done to quantify the requirements for the gas target & tracking detector.

Thanks!