Simulation studies for gas injection into the SMOG2 storage cell at LHCb

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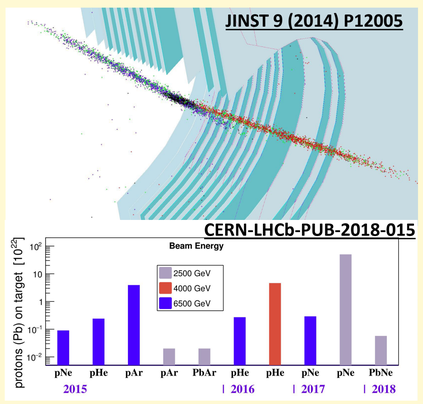
Fixed target programme in LHCb



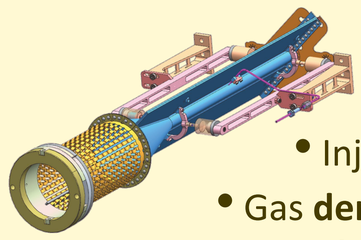
Run 2: SMOG

- Pioneering fixed target programme studying collisions between LHC beams and gas targets
- **LHCb: single arm forward spectrometer**
- Injection of **noble gases (He, Ne, Ar)** in the LHC beam pipe in ± 20 m around the nominal IP point

BUT

- No direct pressure measurement → **Large systematic uncertainty on luminosity**
- Gas flows in a wide vacuum region → **Limited pressure and gas species**
- Overlapped with *pp* luminous region → **Limited data taking time and lower statistic**

Run 3: SMOG2[1]



- **Gas confinement cell** upstream of the nominal IP (*z* in [-541, -341] mm)
  - Injection at the centre of the cylinder
  - Gas **density increased by up to two orders of magnitude** for same gas flow
- **Direct** and precise **pressure** and temperature **measurement**
- More injectable gases: **H_2, D_2**, He, **N_2, O_2**, Ne, Ar, **Kr, Xe**
- SMOG2 and *pp* luminous region separated
  → **Simultaneous *pp* + fixed target data taking**

Simulations with Molflow+[2]

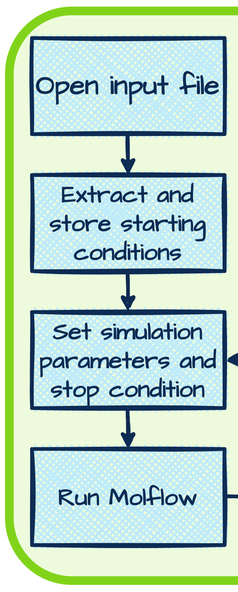
- Ideal cell produces triangular **density profile** BUT real geometry and injection configuration may produce **deviations → What is the impact on the luminosity?**
- The LHC beam pipe and the VELO RF foil are coated with NEG (non evaporable getter)
  - **Sticking coefficient**: probability to capture a molecule hitting the NEG coating
  - Extensive **H_2 load can cause saturation and embrittlement** of the NEG coating

  → **What impact can be expected for a given flow + time injection?**

Molecular flow simulations in ultra-vacuum conditions

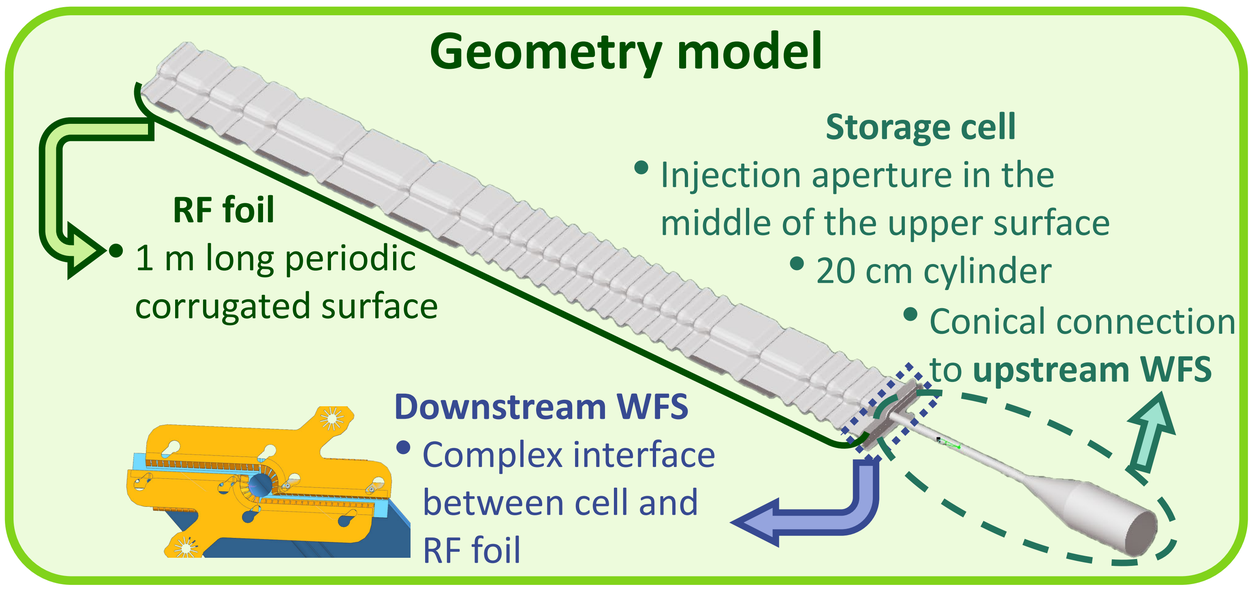
- **Geometry manipulation** for complex configurations
  → Model for wakefield suppressors (WFS)+cell+RF foil
- Automated control of simulation parameters
  → Implementing **time dependent** sticking coefficient evolution **simulation**

Time dependent simulation

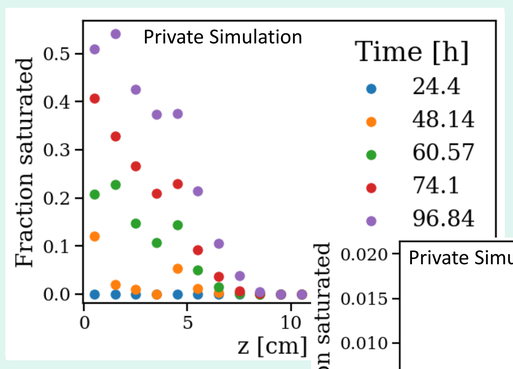


- **Iterative simulation**
  - Total time divided into steps
  - Sticking coefficient updated after each steps
- Sticking coefficient evolution **model from fit to experimental data**

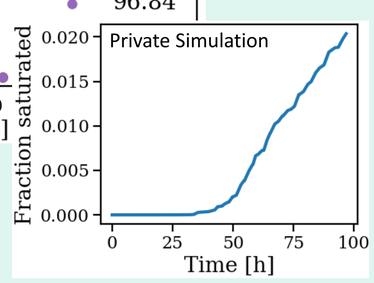
Geometry model

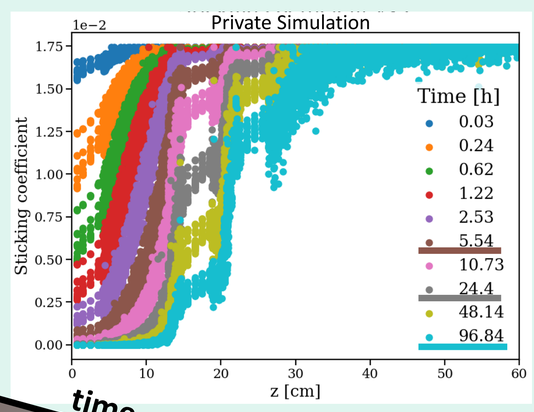


Results: sticking coefficient degradation

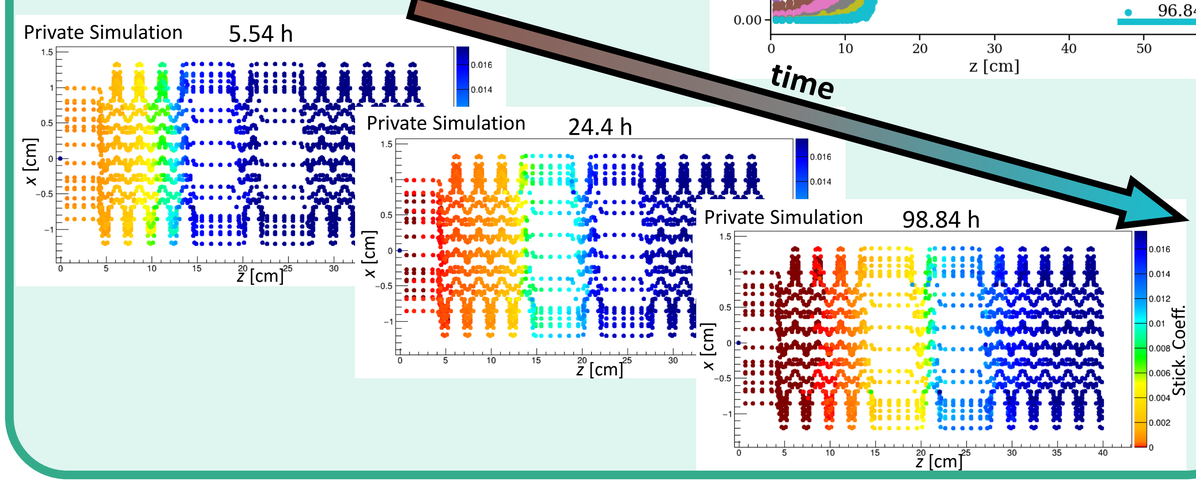


- After **96h** of H_2 injection (**10^{-5} mbar**)
  - Saturation **up to around 7-8 cm**
  - Small fraction of saturated RF foil

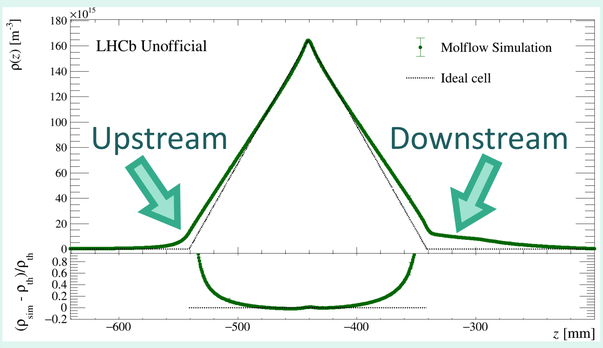




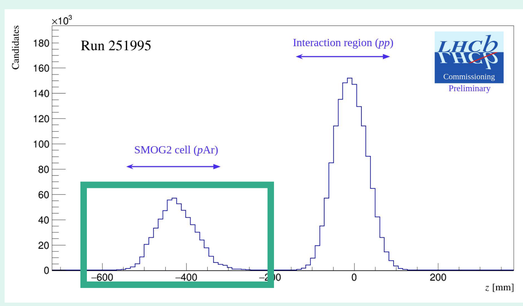
- The **propagation of saturation slows down** with time



Results: gas density profile



- **General agreement** with the ideal profile, with deviations
  - **Upstream: smooth transition to zero** due to the WFS coupling
  - **Downstream: residual density outside the VELO** due to the gas flow in the RF foil



- Useful **input for luminosity measurement**
- The **first data** acquired in SMOG2 configuration present **similar features** as the simulation[3]

Conclusion

- **No showstoppers found for H_2 injection** in SMOG2 during Run 3
- **Experimental studies of NEG coating embrittlement/saturation are ongoing in LHC vacuum group**
- **The simulation predicts the deviations** from the nominal density profile, to be taken into account for the luminosity measurement

References:
[1] LHCb Collaboration, LHCb SMOG Upgrade, LHCb TDR 020
[2] M. Ady, R. Karsevan, Recent developments of Monte-Carlo codes MolFlow+ and Synrad+, JACoW IPAC2019 TUPMP037
[3] L. Pappalardo, First beam-gas events in LHCb using SMOG2, PBC annual Workshop, 2022

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