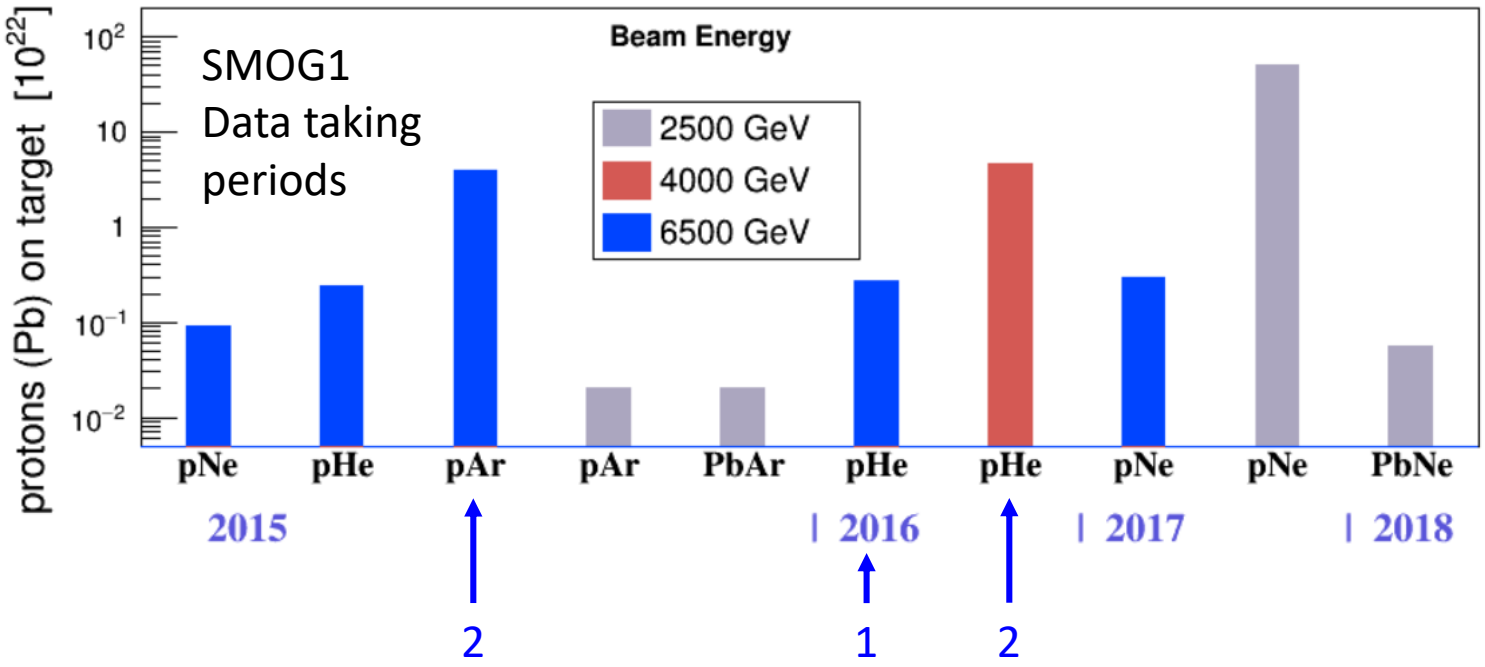
A luminometer for the FT at LHCb

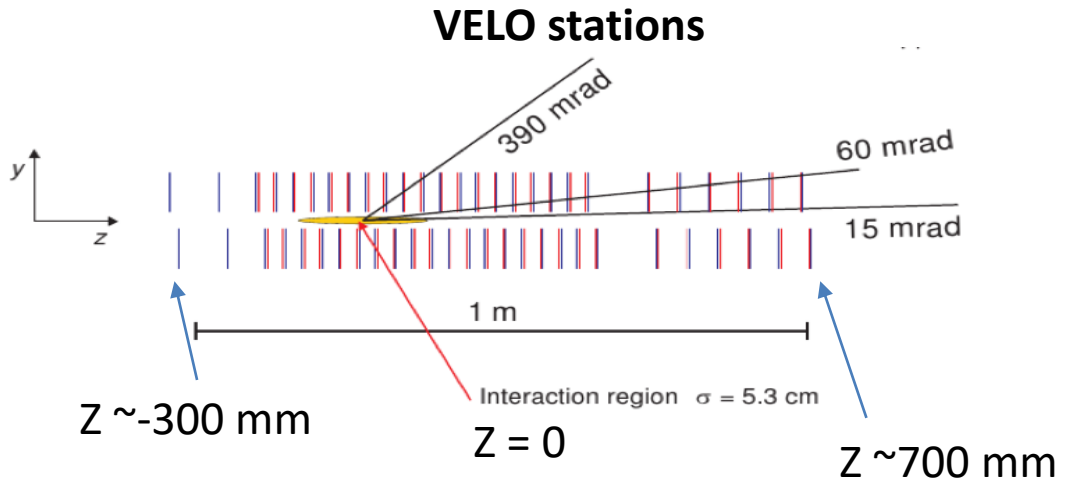
1. **Feedback from SMOG1**
2. **SMOG2**
3. **luminometer**

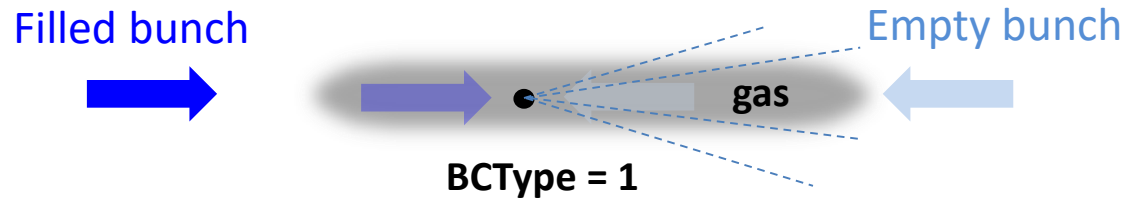


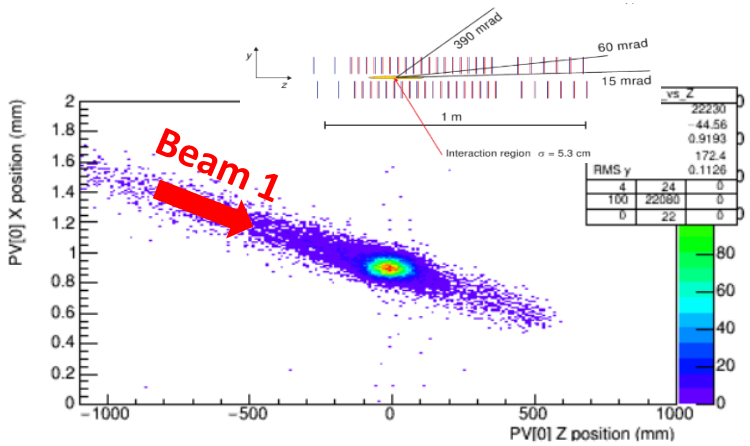
- Since 2015, LHCb started to take data in fixed-target configuration
- Two analyses performed with these data:
  1. Measurement of antiproton production in pHe collisions at $\sqrt{s_{NN}}$=110 GeV, Phys. Rev. Lett. 121 (2018) 222001
  2. First measurement of charm production in fixed-target configuration (pAr+pHe) Phys. Rev. Lett. 122 (2019) 132002
- Ongoing analyses with pNe and PbNe data

1. Feedback from SMOG1 – operations

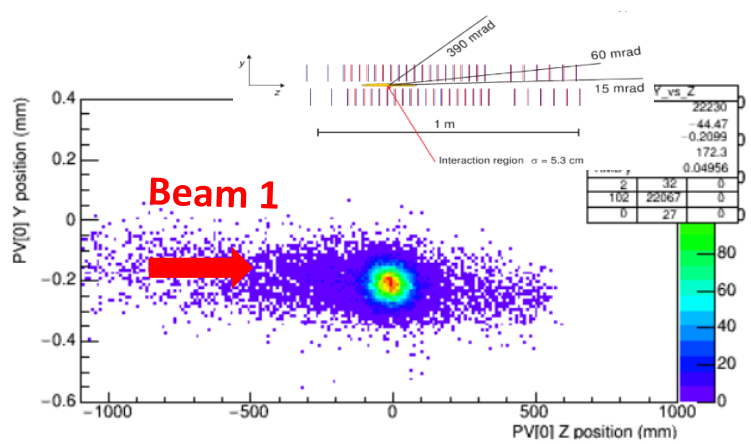
- **Data taking conditions**
  - Plots based on pNe 2017 data
    - ~1100 colliding bunches
    - ~700 non-colliding bunches
  - Gas injected into the VELO tank (VELO pumps switched off)
  - Use BCType=1 ➔ fully filled beam 1 bunch meets empty beam 2 bunch at IP
  - Gas leaks into the LHC tube, pumped 20 m away on both sides ➔ vertices are spread over a large Z range







Primary Vertex X .vs. Z position



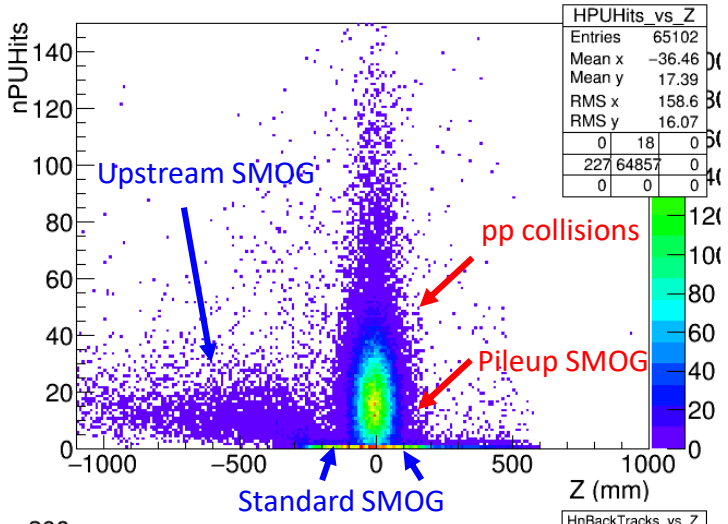
Primary Vertex Y .vs. Z position

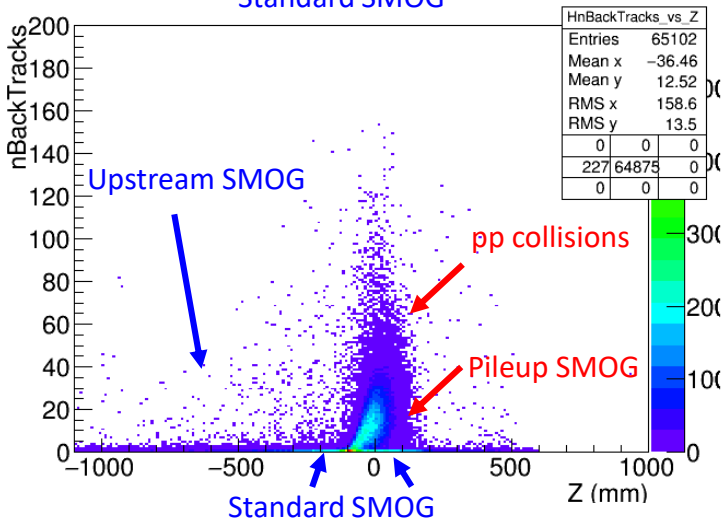
1. Feedback from SMOG1 – event topology

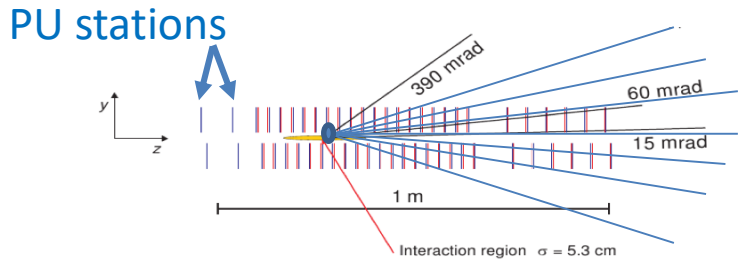
- **Based on backward information**

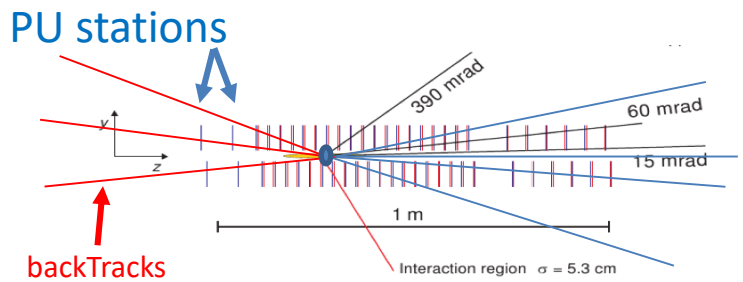
nPUHits = number of hits in PileUp stations

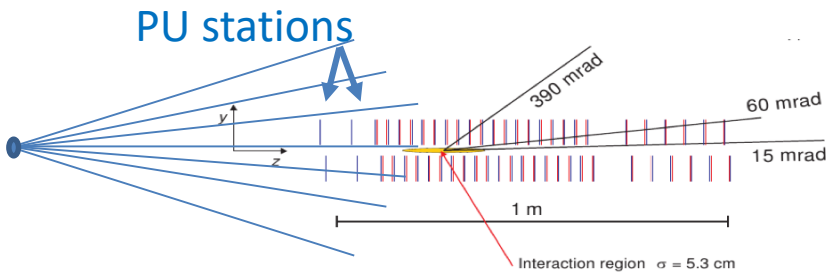
nBackTracks = number of VeloTracks going backward

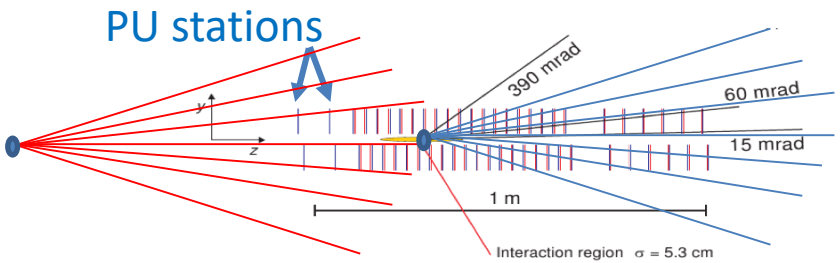












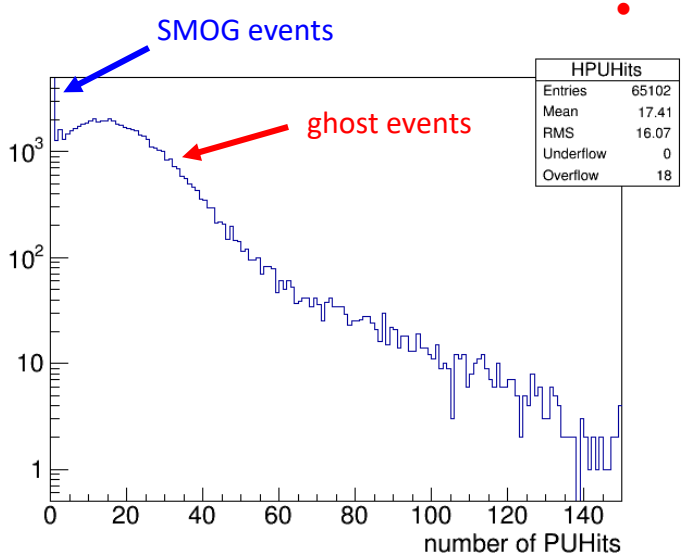
1. Standard SMOG events
Number of hits in PU ~ 0
Number of backTracks ~ 0
➡ IP ⬅

2. pp Collisions
Number of hits in PU > 0
Number of backTracks > 0
➡ IP ⬅

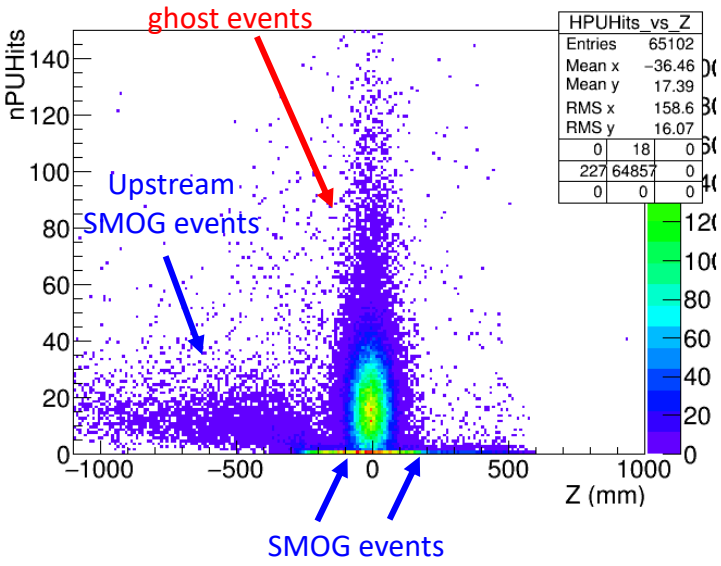
3. Upstream SMOG events (PVZ < -200 mm)
Number of hits in PU > 0
Number of backTracks ~ 0
➡ IP

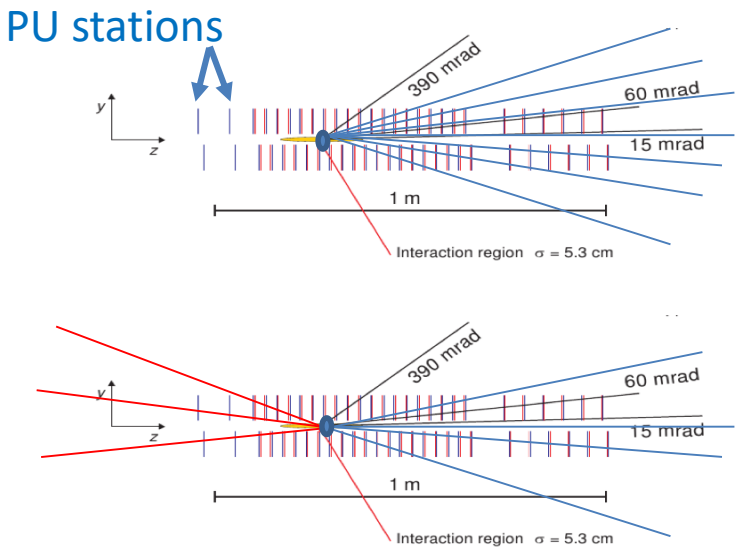
4. Pileup SMOG events
Number of hits in PU > 0
Number of backTracks > 0
➡ IP

1. Feedback from SMOG1 – main source of background



- **pp collisions in BCType=1 due to Ghost charge contamination**
  - **BCType = 1 ➔** fully filled beam1 bunch meets empty beam2 bunch at IP
  - In principle, beam2 bunch is empty, but some protons from previous fully filled beam2 bunch can migrate to downstream empty beam2 bunches → empty bunches may not be fully empty. Debunched protons are called « ghost charges ».
  - Those **« ghost charges »** may interact with fully filled beam1 bunches at IP, producing a **proton-proton collision at 5 TeV**





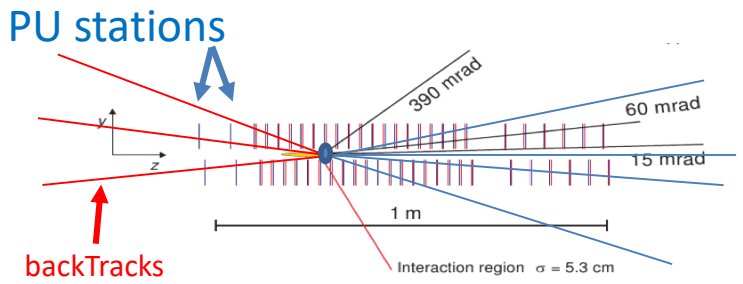
« regular » SMOG events
Number of hits in PU ~ 0
Number of backtracks ~ 0

Ghost charges Collisions
Number of hits in PU > 0
Number of backtracks > 0

1. Feedback from SMOG1 – global event selections

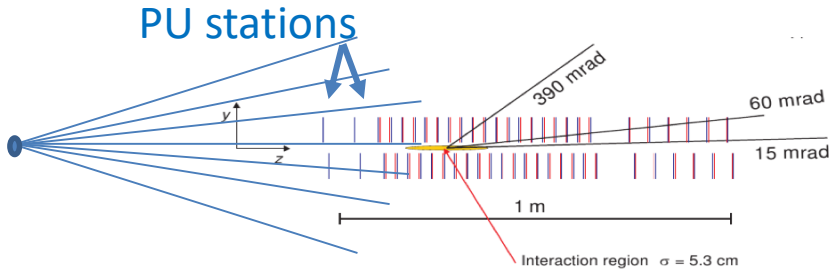
- **Global event selection in antiproton and charm analyses**
  - Backward information is used to remove background; cuts depend on the analysis strategy.

  - Removing **pp collisions**
    - Use nPUHits
    - Use nBackTracks



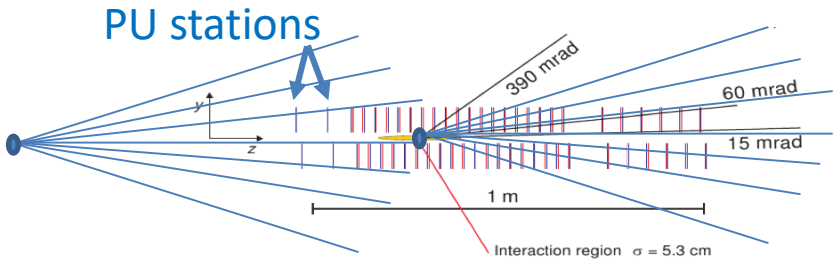
pp Collisions
Number of hits in PU > 0
Number of backTracks > 0
➡ IP ⬅

  - Removing **upstream SMOG**
    - Use nPUHits
    - Use PVZ (Primary Vertex Z position)



Upstream SMOG events (PVZ < -200 mm)
Number of hits in PU > 0
Number of backTracks ~ 0
➡ IP

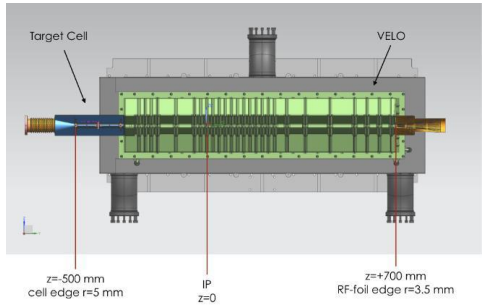
  - Removing **Pileup SMOG**
    - Use nPUHits
    - Use PVZ

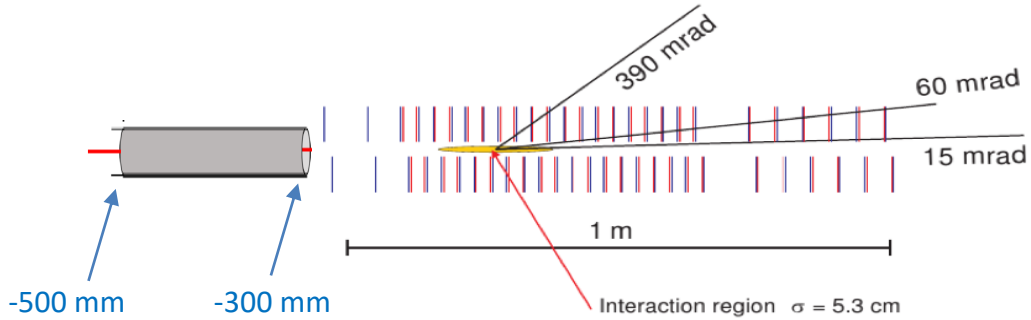


Pileup SMOG events
Number of hits in PU > 0
Number of backTracks > 0
➡ IP

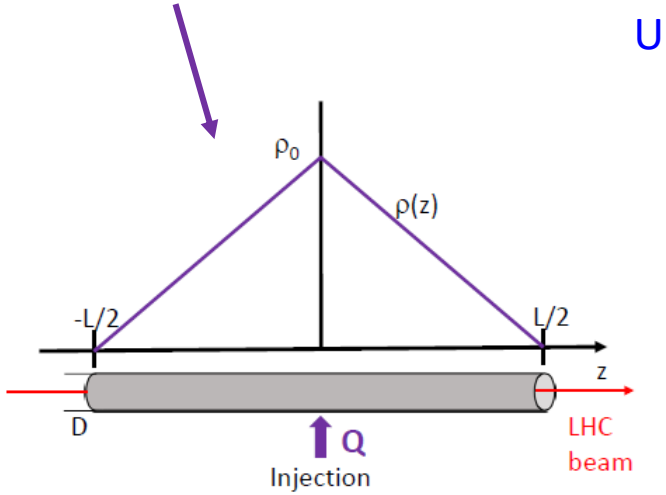
2. SMOG2 - operations

- **Storage cell located upstream of the VELO**
  - Position: -500 < PVZ < -300 mm

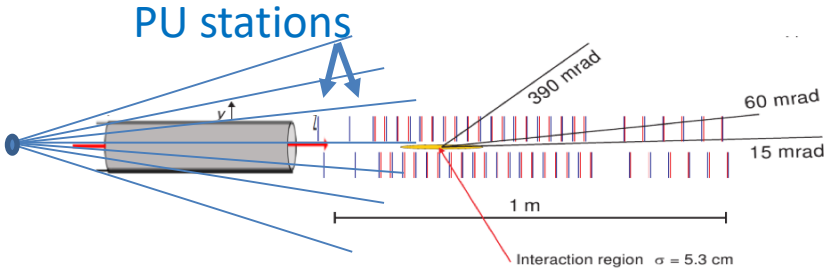




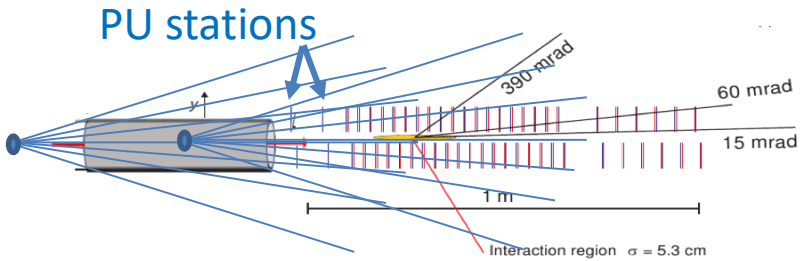
- **Thanks to displaced vertex, ghost charge contamination negligible**
  - Can be estimated with VELO backward information
- **Main source of background: upstream and pileup collisions**
  - No quantitative estimate available, but expect to be small thanks to the **gas density profile**



Upstream SMOG events (PVZ < -500 mm)



Pileup SMOG events



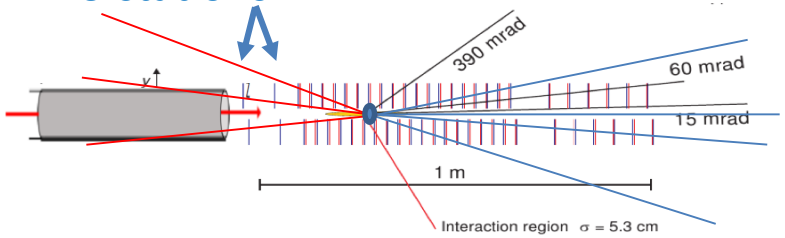
2. SMOG2 - analysis

- **Storage cell located upstream of the VELO**
  - Ghost charge **(pp collisions)** events can be removed with cut on PVZ
  - **Upstream SMOG** events can be removed with cut on PVZ
  - No simple cut to remove **Pileup SMOG** events

- **Analysis**
  - Some analysis depend on event multiplicity
    - **Nucleus-Nucleus collisions:** centrality of the collision is determined with the particle multiplicity and the energy deposited in the CALO.
    - **Proton-Nucleus collisions:** (for instance) the suppression of quarkonia due to their interaction with comoving particles is studied .vs. event multiplicity
    - **Flow analysis:** use particle correlation
  - **Pileup SMOG events** may introduce a biais in event multiplicity determination
  - Although this background is expected to be small, the estimation of the **systematic uncertainty** related to pileup contamination may be tricky.
  - A **detector upstream** of the target would help to remove/estimate pileup contamination

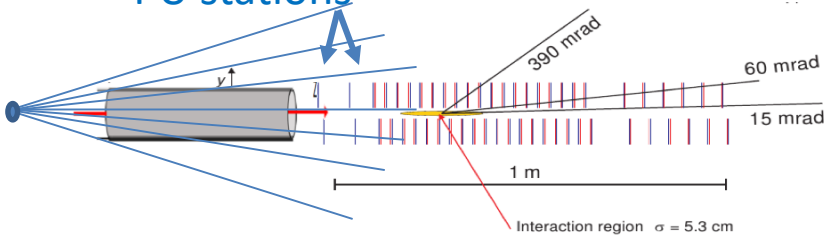
pp Collisions

PU stations



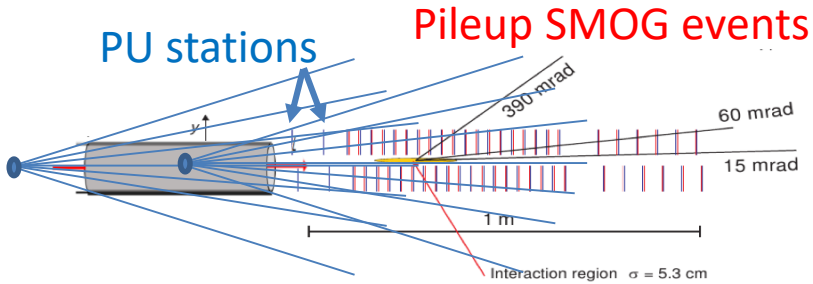
Upstream SMOG events (PVZ < -500 mm)

PU stations



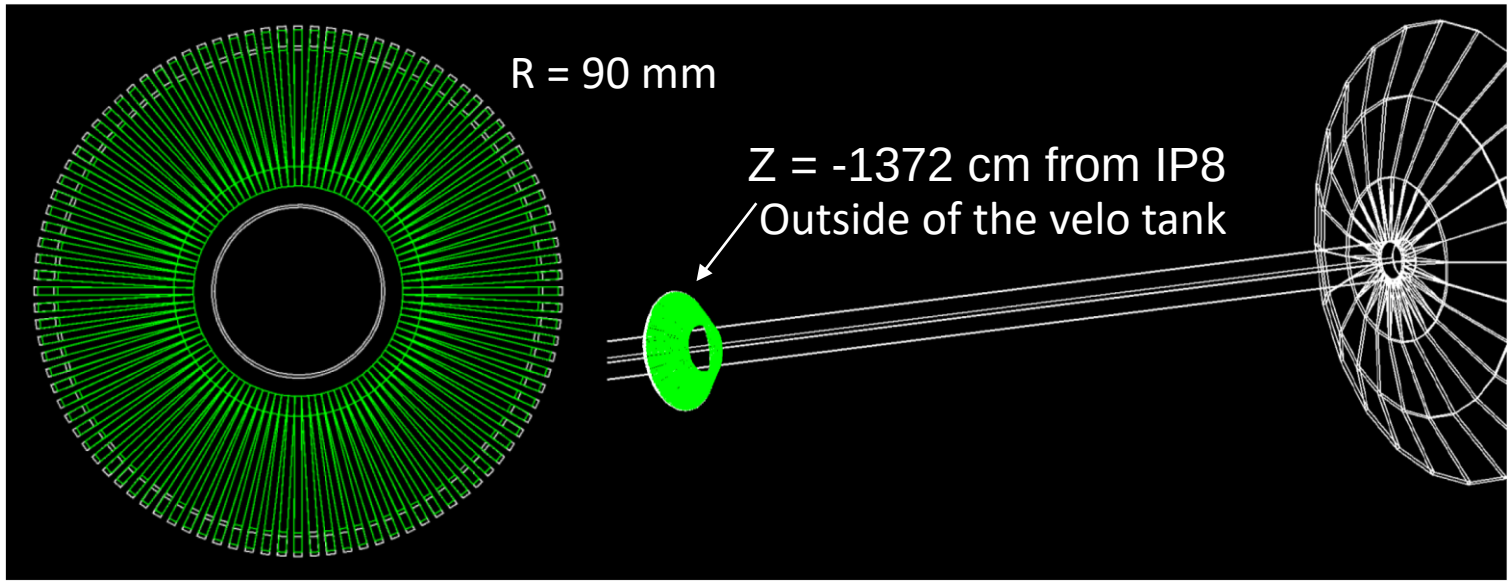
PU stations

Pileup SMOG events

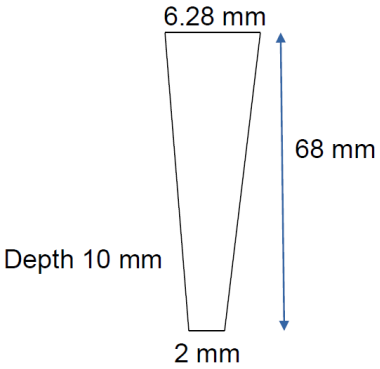


3. Proposal for a luminometer

- **A proposal for a quartz sector counter for luminosity measurement**
  - https://indico.cern.ch/event/824952/contributions/3451280/attachments/1858700/3053920/quartz_lumi.pdf
  - **Main goal:**
    - Alarm for LHC based on single BX ample
    - On(off)line luminosity measurement
    - Veto/monitor PileUp for SMOG2
  - **Proposed technique:**
    - Count fired quartz sectors using Cherenkov light
    - Small-size sectors ➔ yes/no response
    - Count number of BX with no collisions (in addition, count number of collisions), then determine poissonian mean
    - Quartz sector readout: 100 – 400 channels (depending on the chosen option)

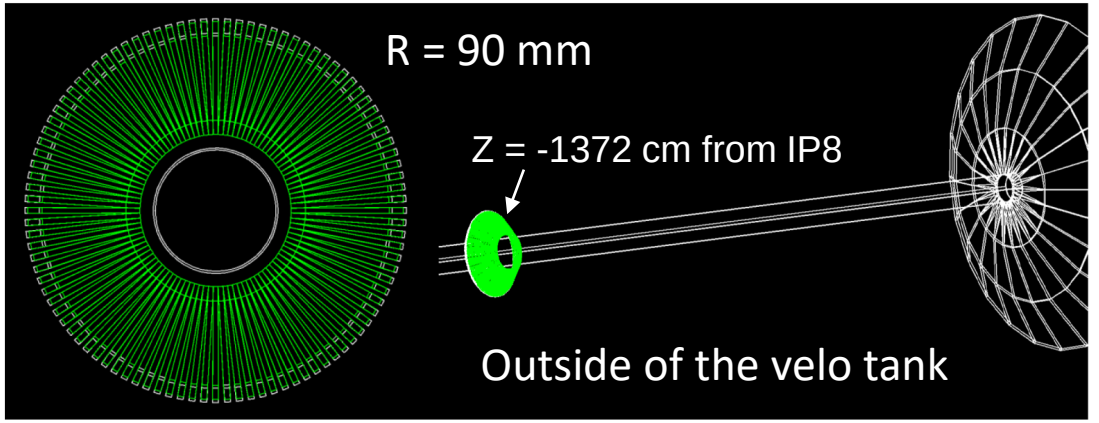


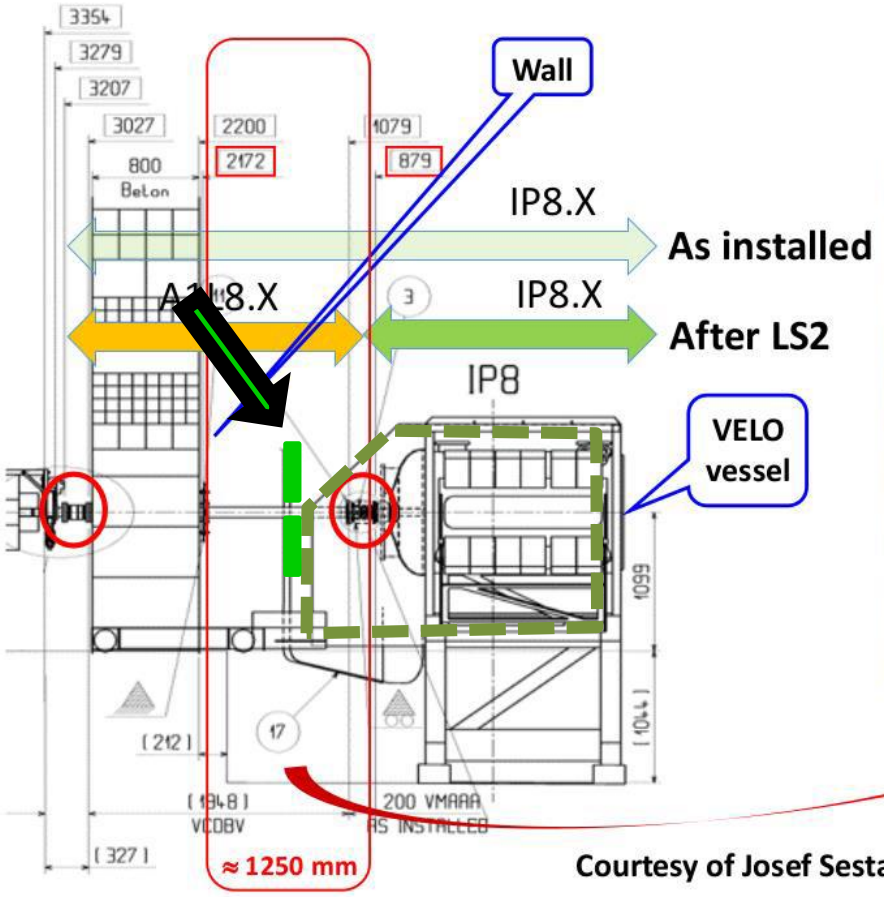
quartz cell

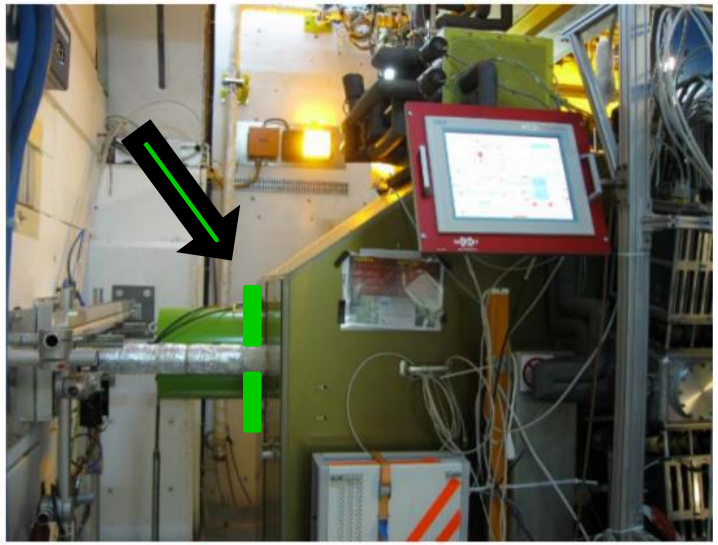


3. Luminometer - position

- **the luminometer would be installed outside the VELO tank**
  - Closest position ~ 80 cm upstream of the target cell







Courtesy of Josef Sestak, CERN

Conclusion

- **Feedback from SMOG1**
  - **Main background** source coming from **ghost charge** contamination
  - Background removed with backward and PVZ information

- **SMOG2:**
  - Thanks to displaced vertex, **ghost charge contamination will be negligible** (can be monitored with VELO information)
  - **Main** source of **background** should come from **pileup SMOG** events
  - The installation of a luminometer upstream of the target would help to veto/monitor pileup SMOG events

- **For SMOG3 (spin): Suggest to consider adding an upstream tracking/veto station in the setup**