Beam Gas Vertex instrument
Potential integration of a gas jet as target

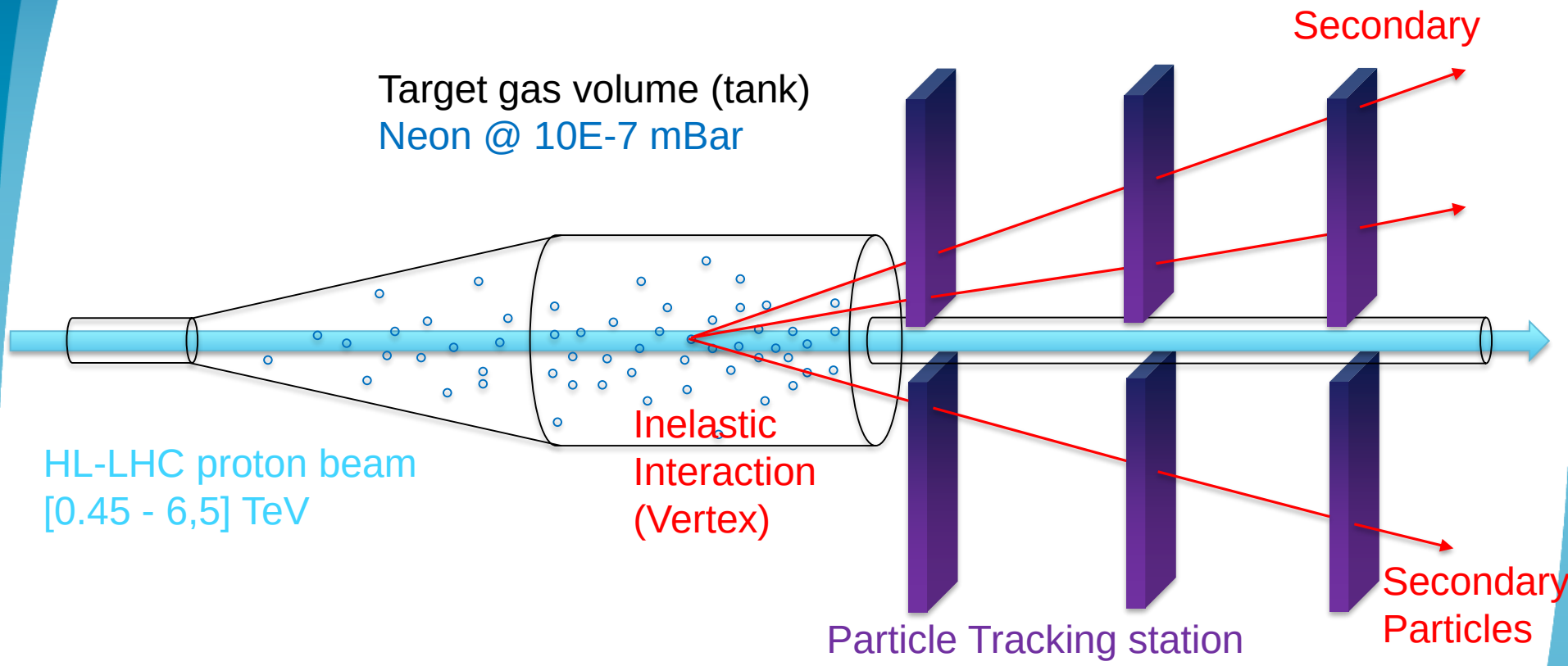
Robert Kieffer
rkieffer@cern.ch

BGC Collaboration Meeting at the Cockcroft Institute June 2019

Overview

- Beam Gas Vertex profile measurement.
- The BGV demonstrator in LHC.
- Gas jet target for the BGV.
- Jet density profile imaging.
- Conclusions

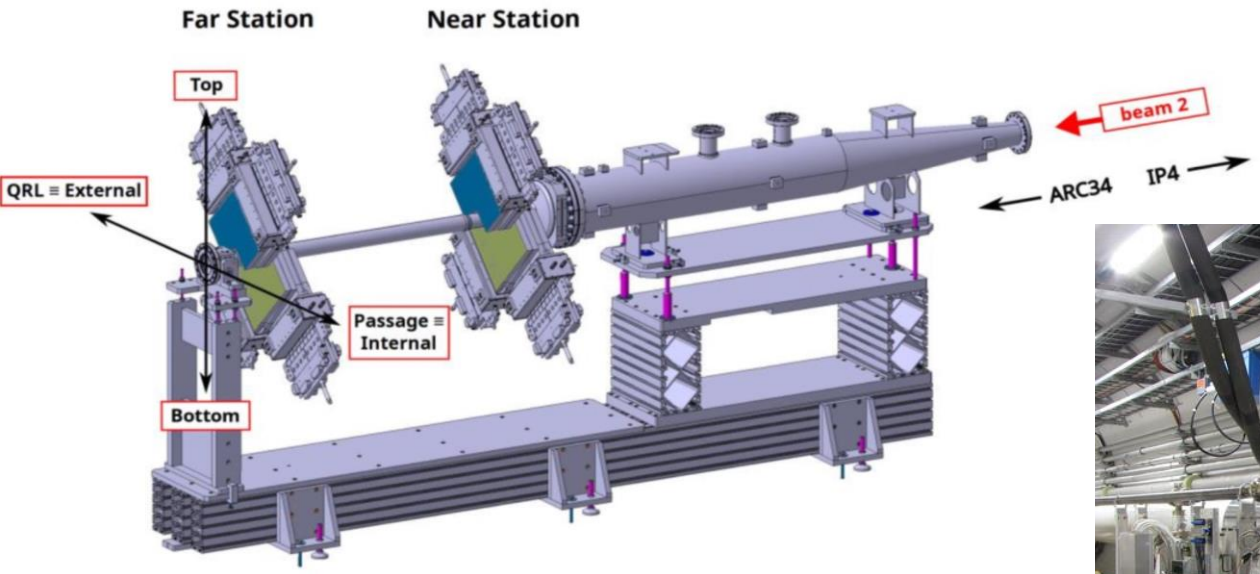
Beam Gas Vertex Profile Monitoring

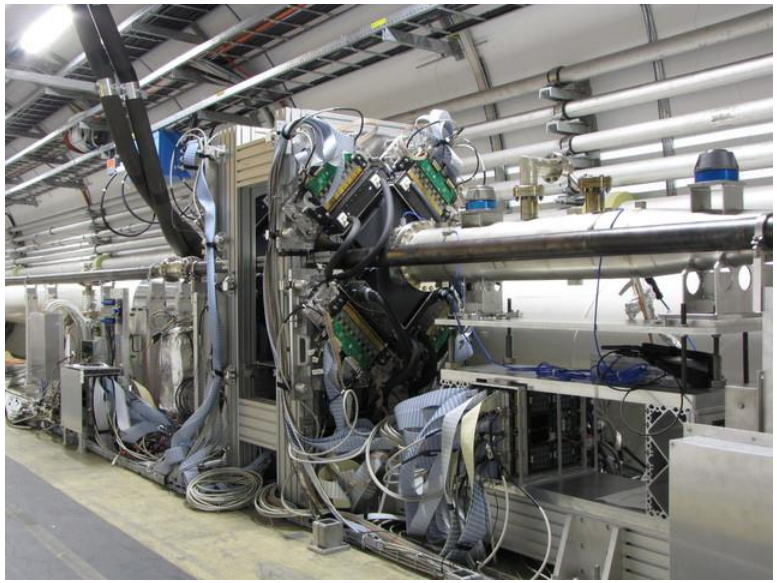


- A set of few thousands **Beam Gas interaction Vertex events** allows to measure the **HL-LHC beam size** within desired accuracy**.**
- This is a fully **non-invasive method** with no visible effects on the beam lifetime.

Ref: **Noninvasive LHC transverse beam size measurement using inelastic beam-gas interactions A. Alexopoulos *et al.* (The BGV Collaboration) Phys. Rev. Accel. Beams 22, 042801 – Published 11 April 2019**

LHC Beam Gas Vertex demonstrator

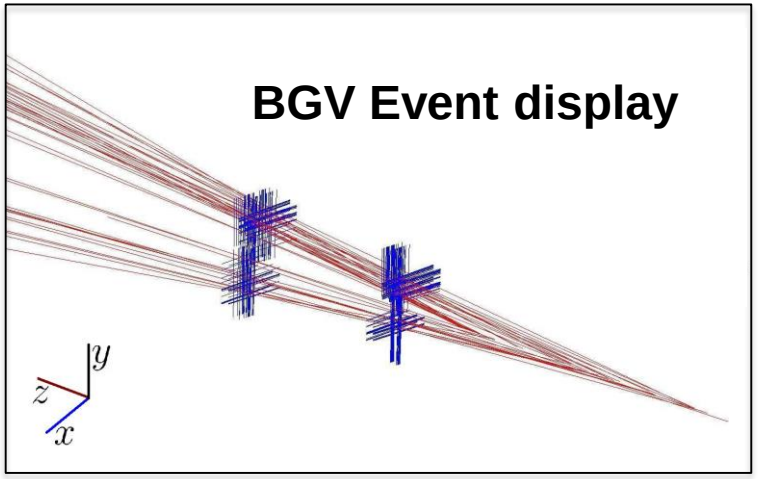




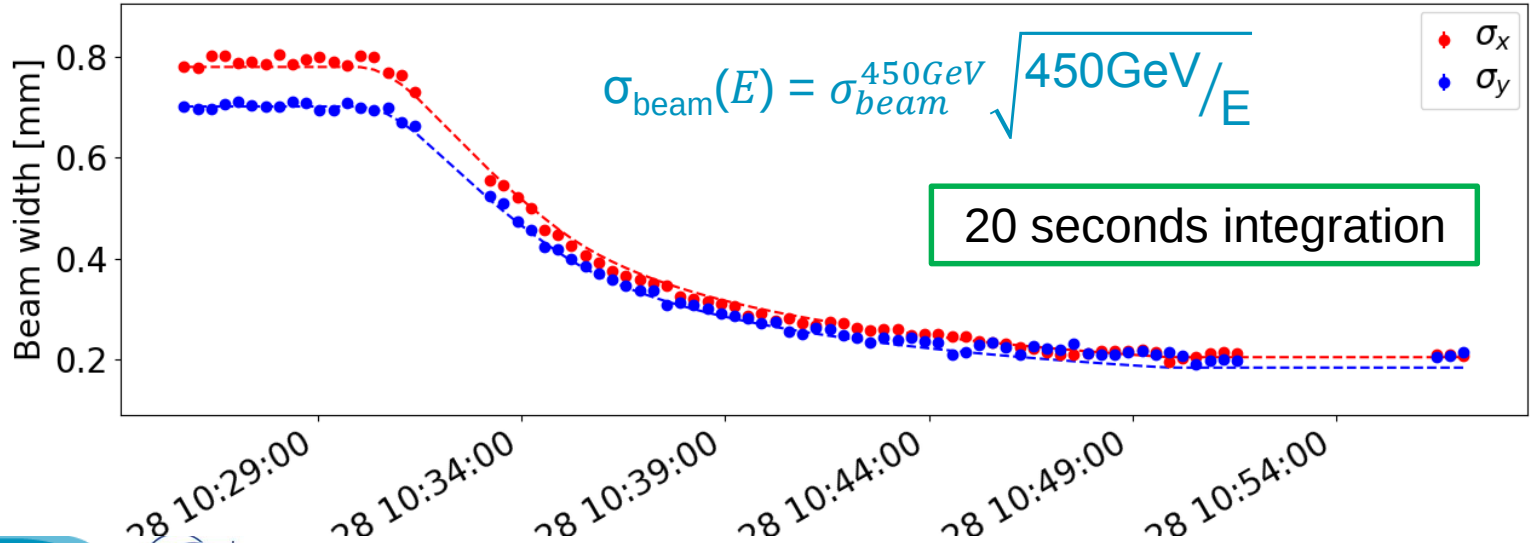
- **BGV Demonstrator** operating in LHC point 4, for full characterization and as a test bench for online processing development.
- Uses **Scintillating Fibers** (SciFi) detector technology from the **LHCb** R&D.

Status of the BGV demonstrator

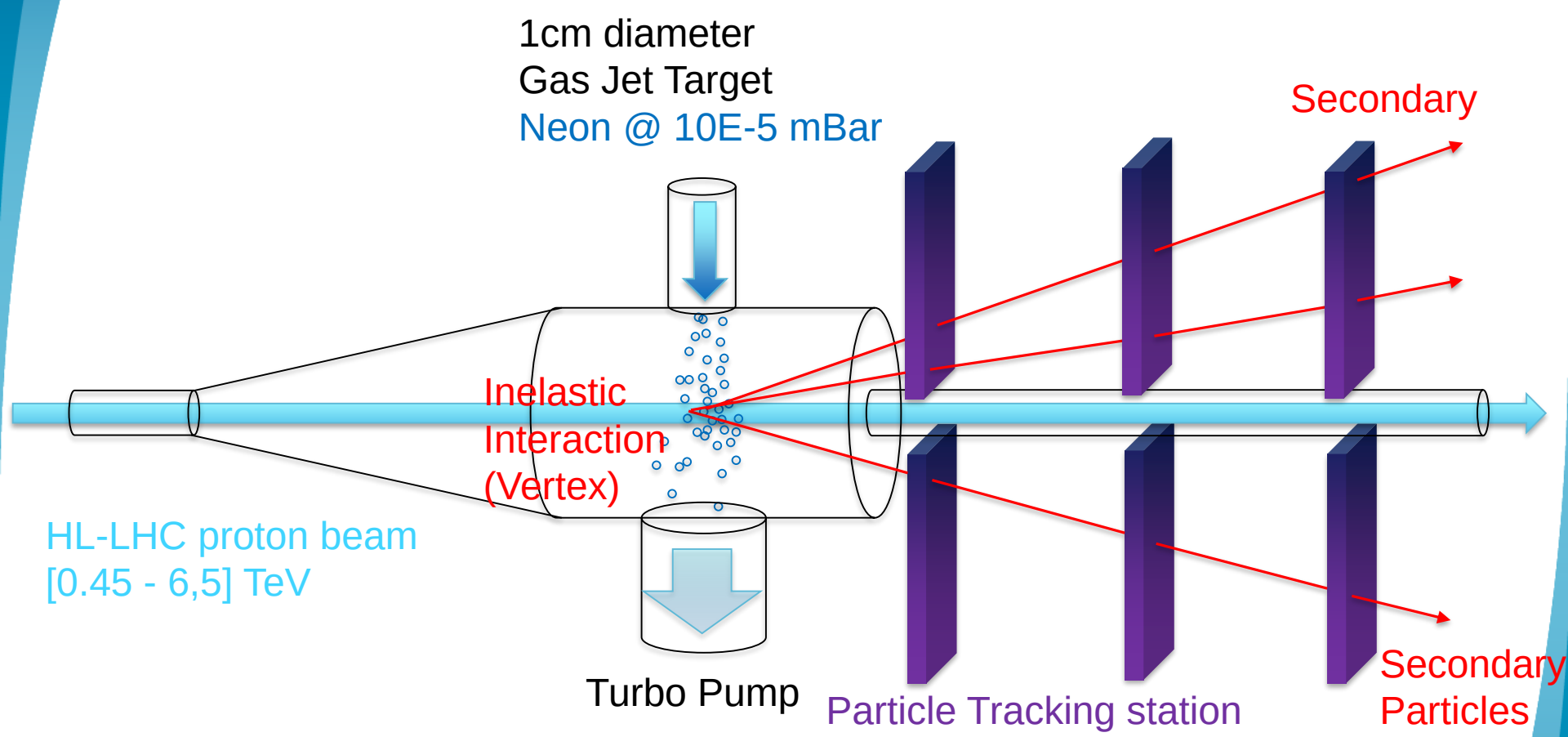
The BGV demonstrator already provided **beam size measurement** **in specifications**.



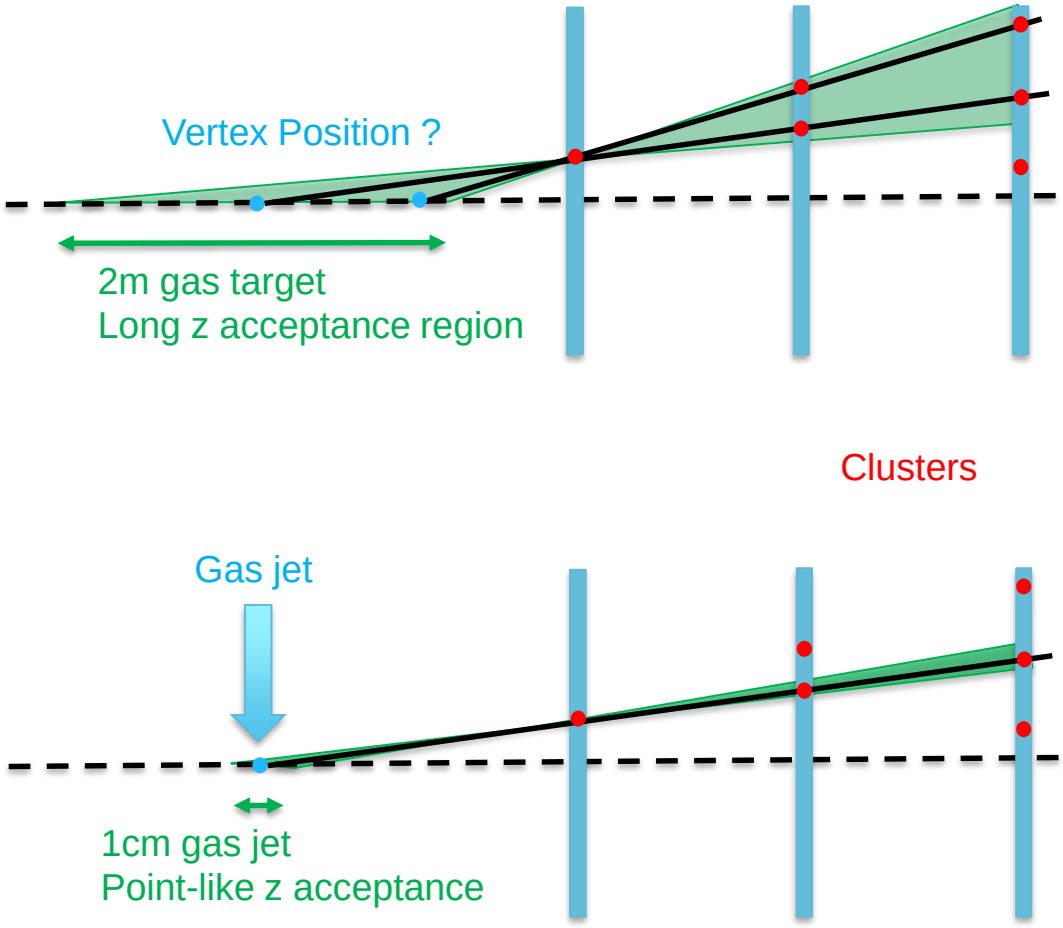
Recent Measurement during LHC ramp



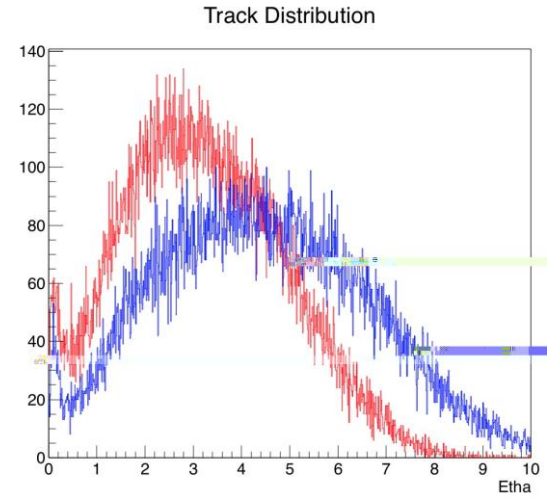
Beam Gas Vertex using Gas jet Target

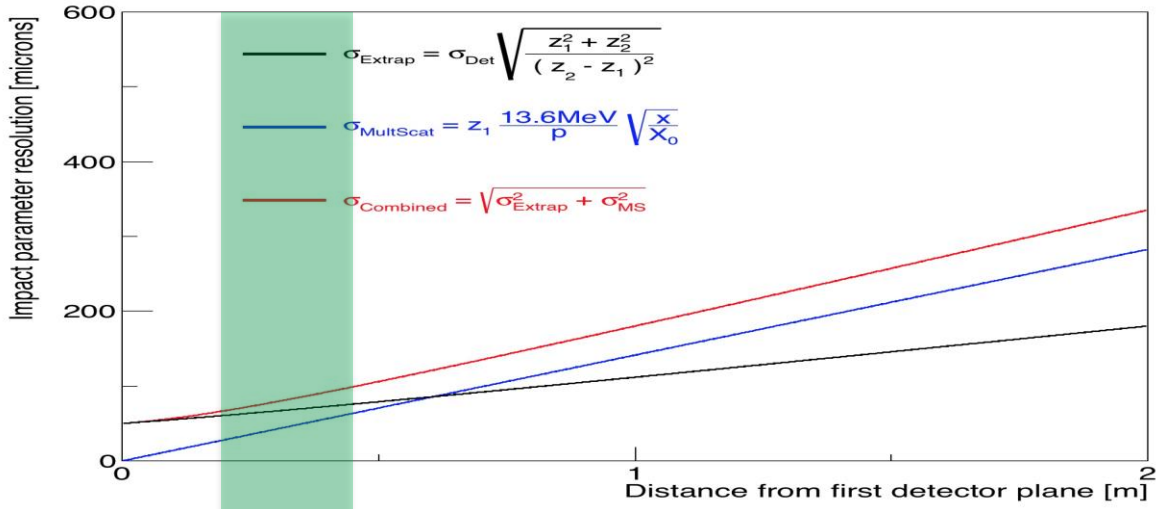


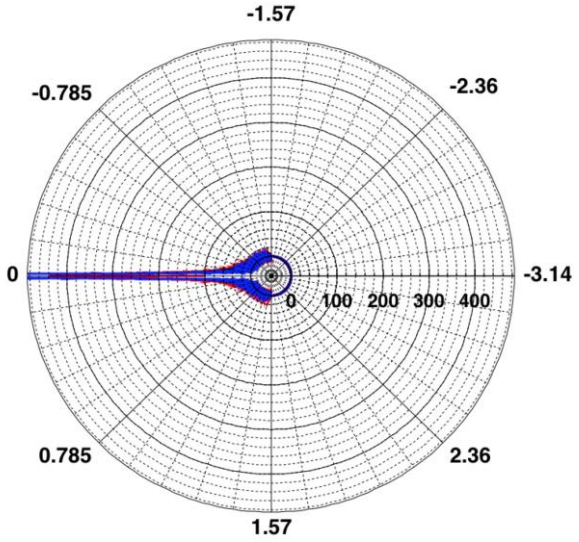
Gas jet benefits for the cluster association

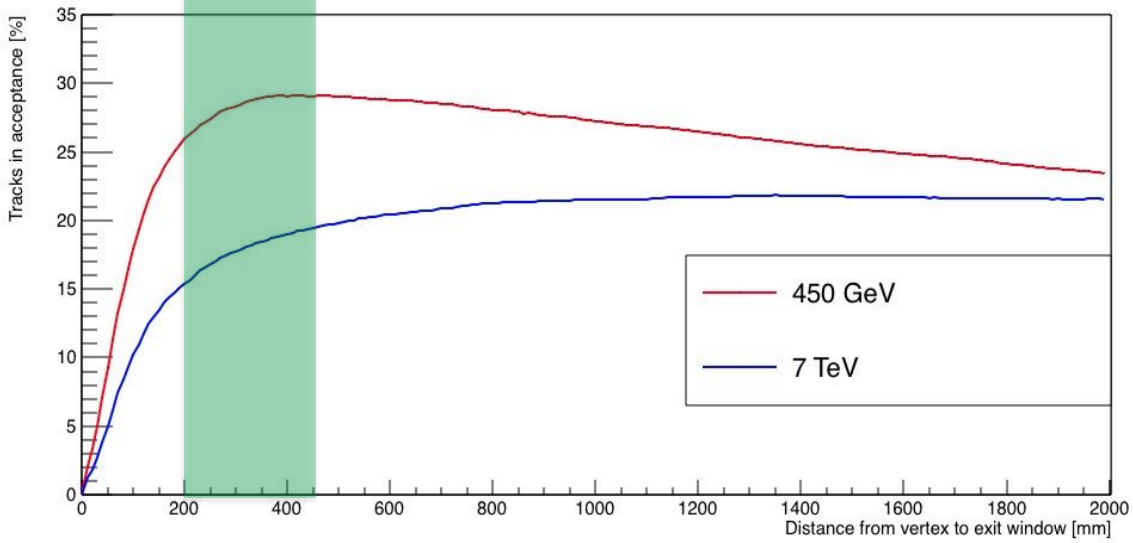


Gas jet open the path for vertexing capability

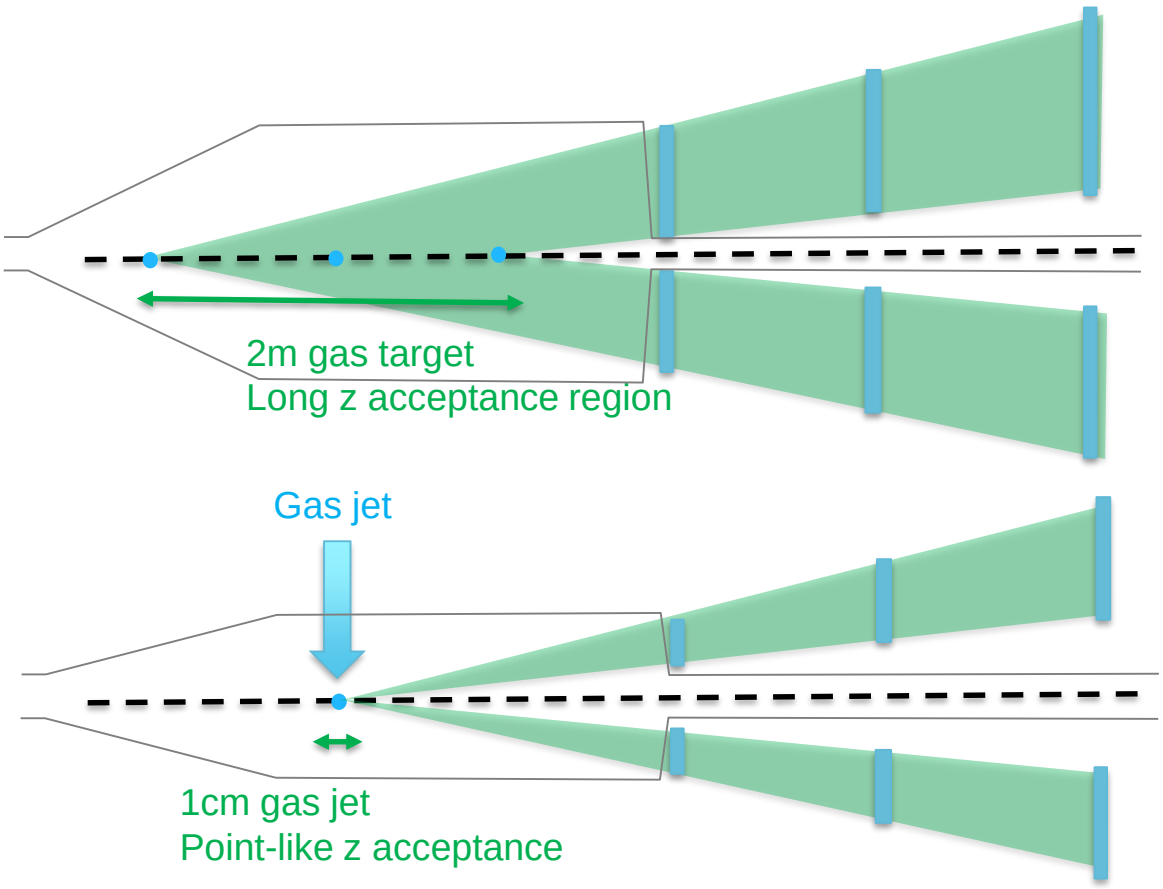






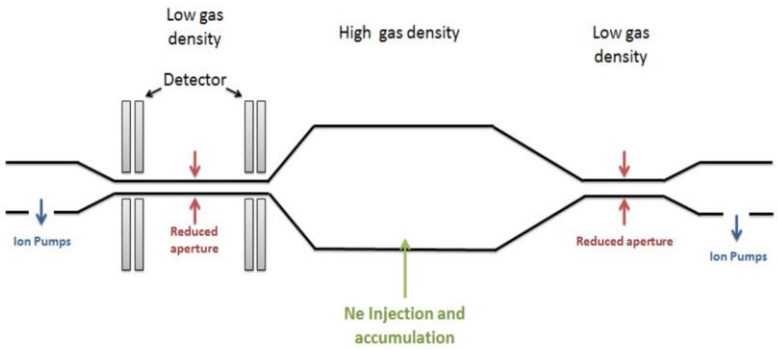


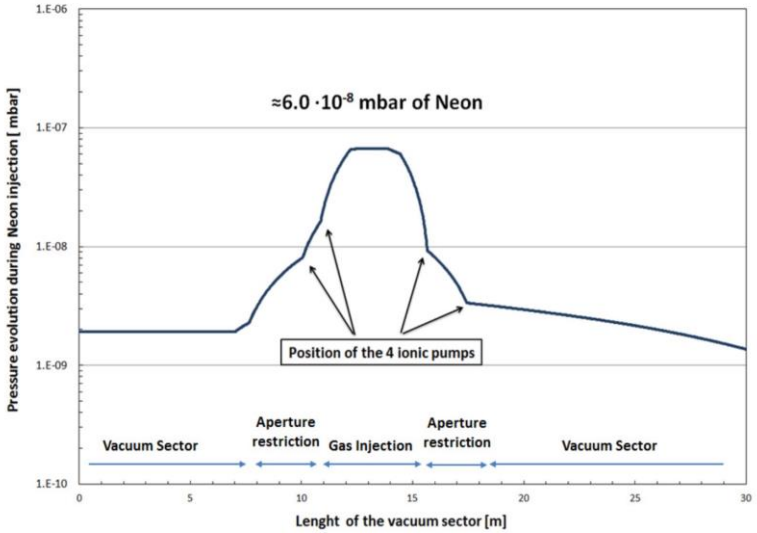
Gas jet reduces necessary tracker sensor surface and Exit window dimensions



- Impact on Cost: **smaller sensor** dimensions and less electronic **channels**.
- Impact on Multiple scattering error if the **exit window can be made thinner**.

Pressure profile in the BGV demonstrator





P = **1E-7** [mBar] = 1E-6 [kg/m^2]
T =293 [K]
K_b=1.38E-23 [m^{2}kg . s^{-2} . K^{-1}]

Density = 2.47E15 [Ne/m^3] = 2.47E9 [Ne/cm^3]
Integrated density along the gas target of 200 cm : 4.94E11 [Ne/cm^2]

Gas jet target case

P = **2E-5** [mBar] = 2E-4 [kg/m^2]
T =293 [K]
K_b=1.38E-23 [m^{2}kg . s^{-2} . K^{-1}]

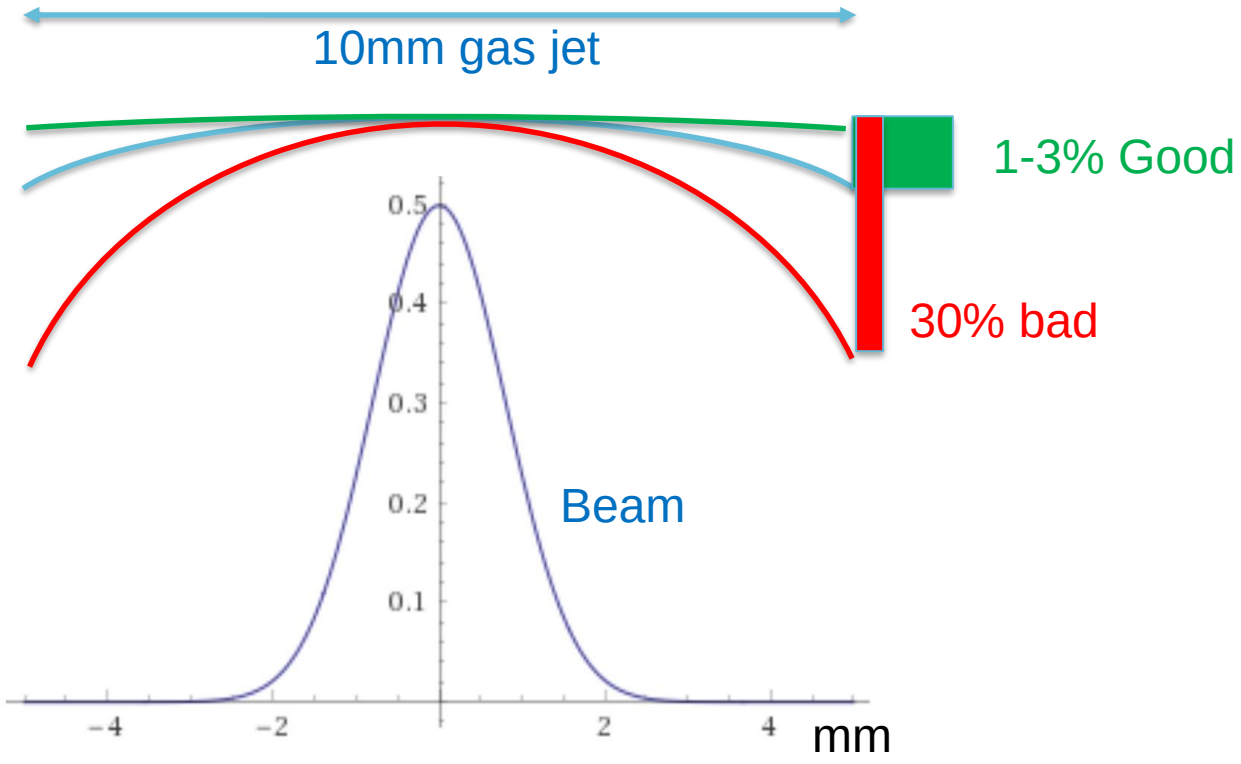
$$pV = n k_B T \quad \Rightarrow \quad \rho = \frac{p}{k_B T}$$

Density = 4.94E17[Ne/m^3] = 4.94E11 [Ne/cm^3]

Integrated density along the gas target of 1 cm : 4.94E11 [Ne/cm^2] SAME AS BGV DEMONSTRATOR

Gas Jet shape and dimensions

- At 450GeV the beam size is around 0.8 mm sigma.



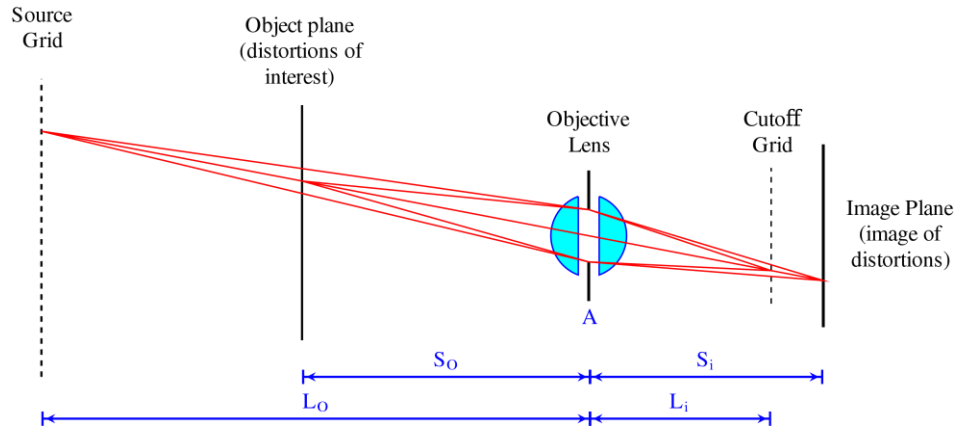
Gas jet profile can have big impact on the reconstructed beam profile !

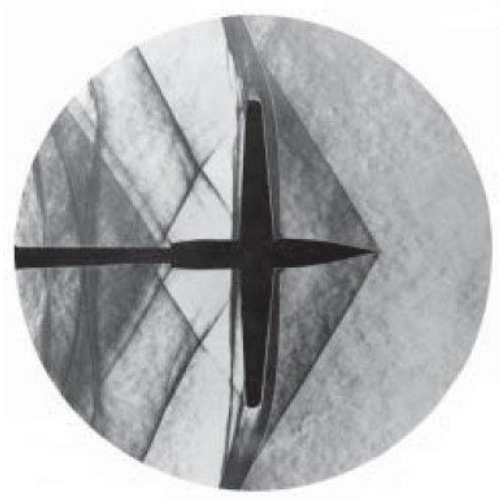
Imaging the gas jet density profile ? WHY

- In order to **correct the BGV beam profile** from gas jet pressure profile (distortion).
- We would need an accurate (within 1%) **mapping of the jet pressure profile**.
- In case the jet is subject to change over time the imaging system will be installed on the BGV station to perform **regular calibration**.

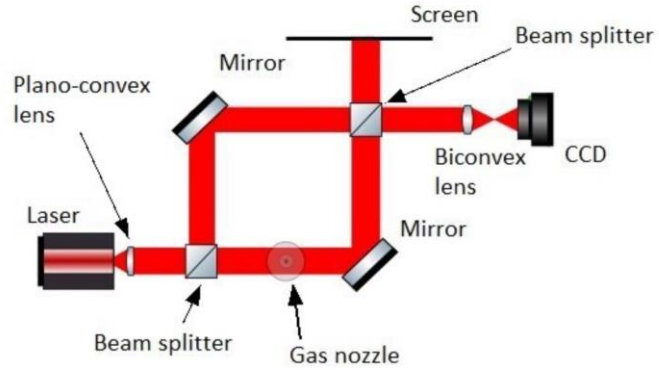
Imaging the gas jet density profile ? HOW

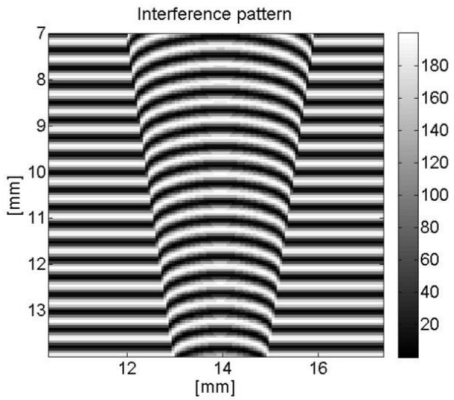
The Schlieren IMAGING

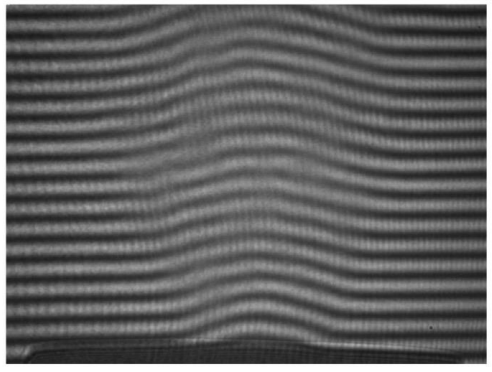




The Mach-Zehnder interferometer







Simulation Measurement

Ref: *Interferometric Characterization od Supersonic Gas-Jet for Laser Wakefield Acceleration*, Jonatan Henriksson Lund University

Index of refraction and phase advance

All optical techniques are using the phase difference created by changes of index of refraction with respect to gas pressure.

Lets assume a 1cm thick jet that is crossed twice by the laser light from an interferometer.

Inside the gas jet:
P = 2E-5 [mBar] T =293 [K]
Density = 4.94E17[Ne/m^3] = 4.94E11 [Ne/cm^3]

$(n-1)= 3.8E^{-4}$

Outside the gas jet:
P = 1E-9 [mBar] T =293 [K]
Density = 2.42E13[Ne/m^3] = 2.42E7[Ne/cm^3]

$(n-1)= 1.E^{-4}$

Phase difference over 2x1cm is 15 radians

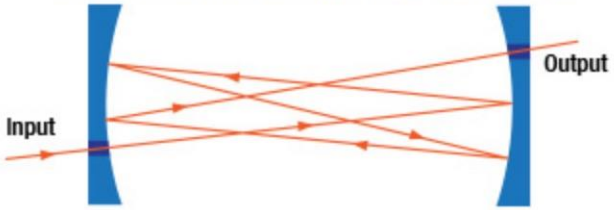
To be confirmed experimentally because the models for computing the index of refraction are numerous and not all working at ultra-high vacuum.

Using multiple pass cell to scan the jet

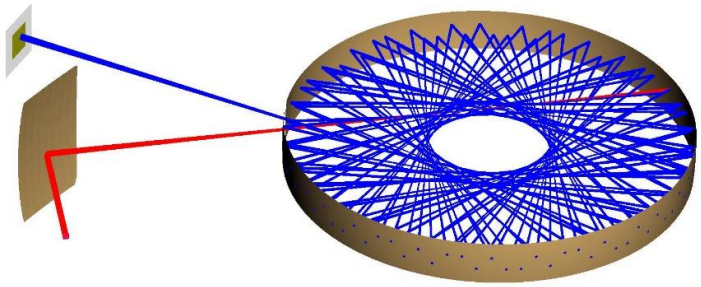
- 10.4 m Optical Path Length in 0.4 m Long Cell
- 600 nm - 8 µm Operating Wavelength Range
- Angled Entry & Exit Ports for Ease of Alignment
- Interfaces Compatible with Thorlabs' Optomechanics

Herriott Cell from Thorlabs

A Herriott cell increases the path length of a beam through the cell.
The HC10L-M02 Herriott Cell has 28 internal reflections.



Circular multi-pass cell can achieve longer path?



Conclusions and outlook

- A gas jet target could be of real advantage for the BGV
- Need to check that a $2e^{-5}$mBar gas jet can be achieved.
- Develop a technique to image the jet profile:
  - To confirm gas jet stability (within 1%)
  - XCheck with the experience of the BGC
  - To allow correction on the BGV beam profile

- Redesign of the BGV gas tank for gas jet compatibility.

- Options: cluster gas jet looks even more complicated.