Experimental results in 2018 from Cockcroft

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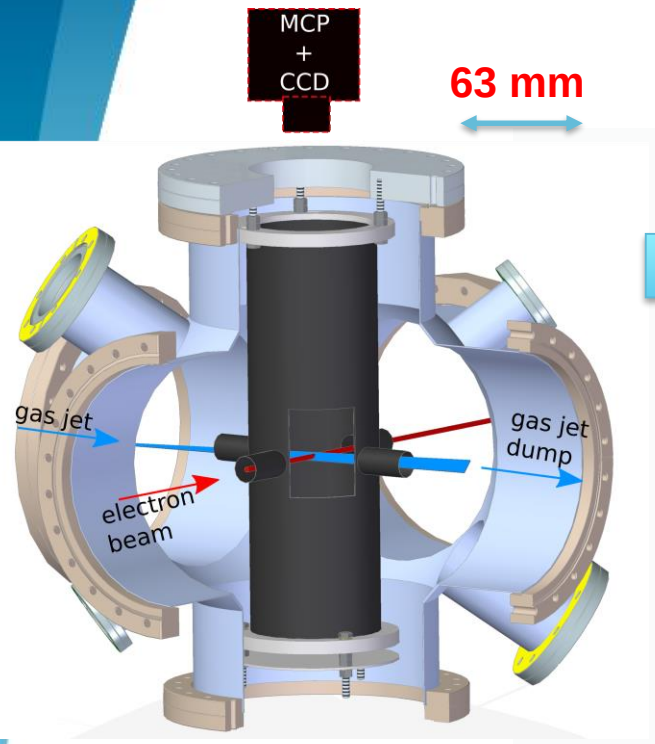
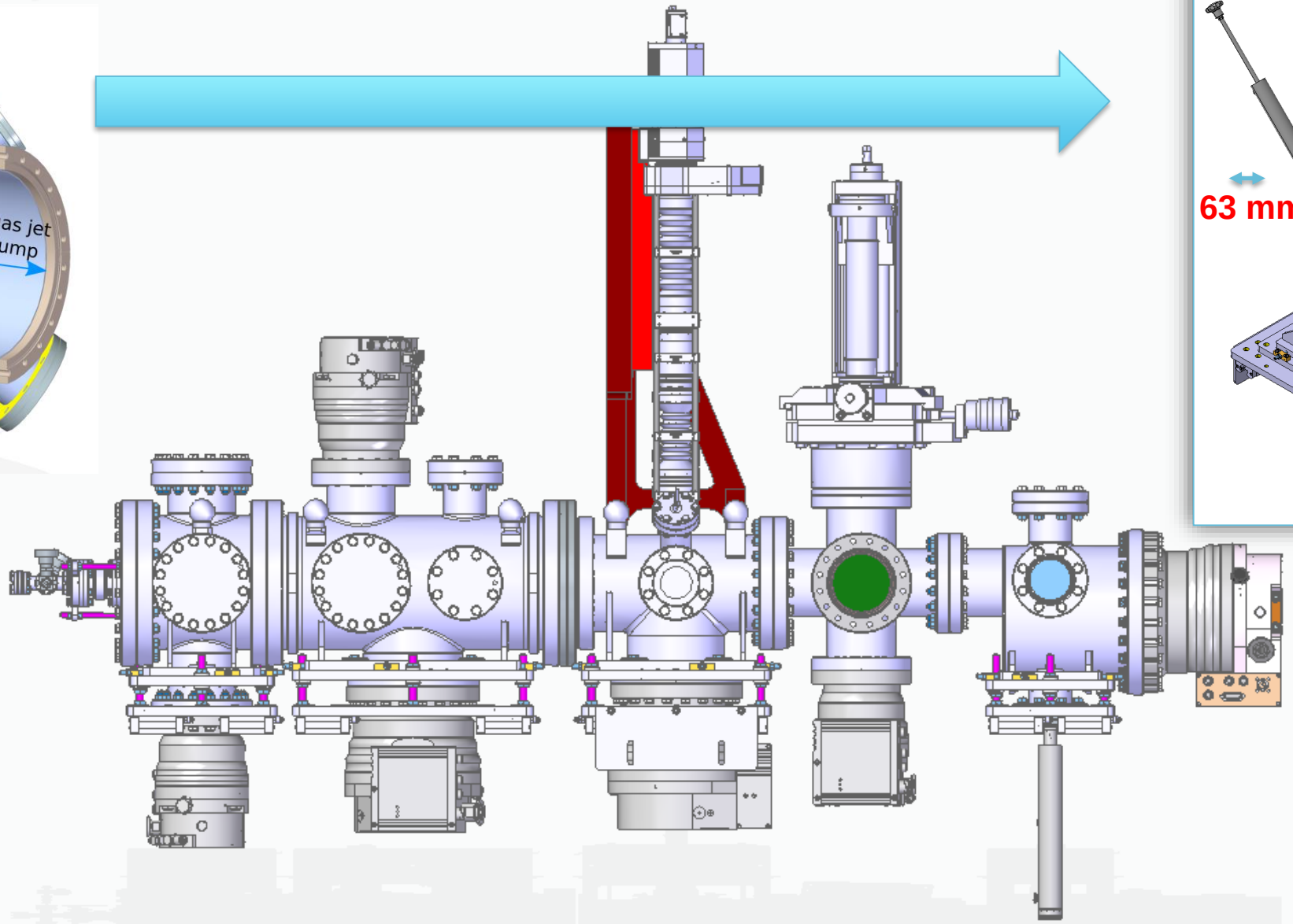
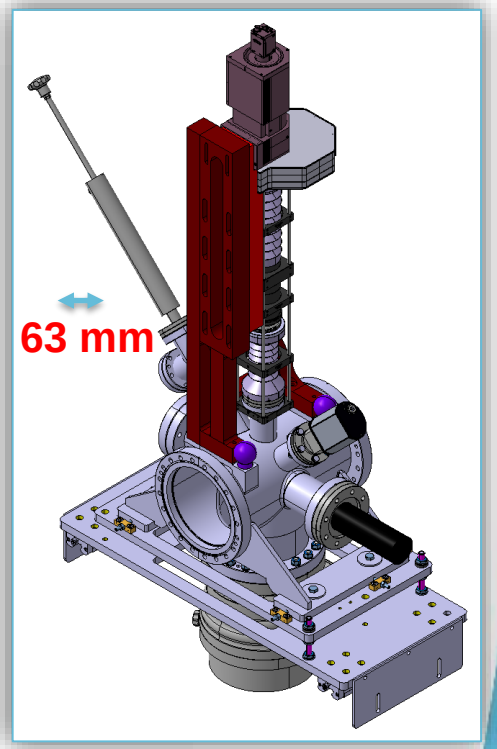
Outline

- Gas jet in fluorescent mode v2
  - System highlights
  - Vacuum condition test
  - Beam imaging using N_2 gas jet and Characterization of N_2 jet.
  - Beam imaging using Neon gas and comparison to Nitrogen
  - Vacuum condition test aiming for LHC installation
- Future plan

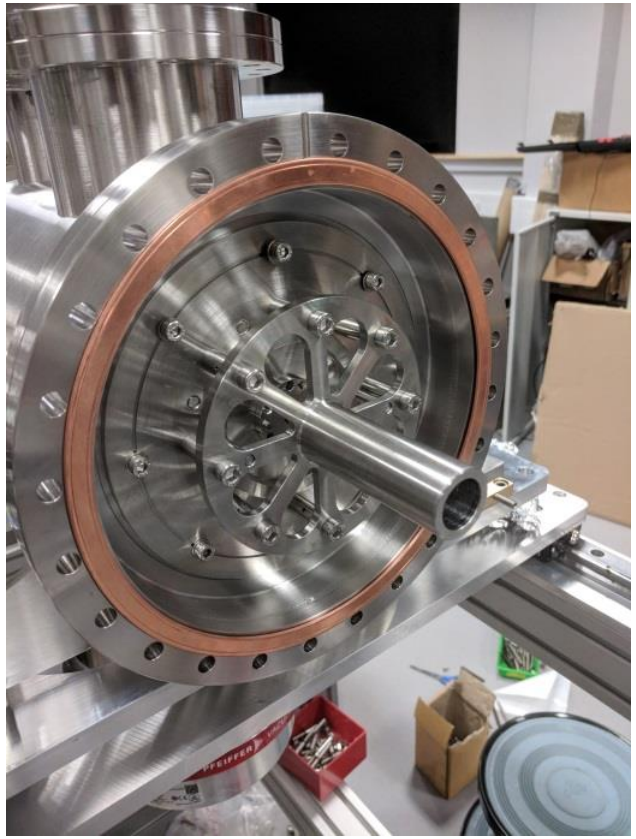
Building a prototype in CI

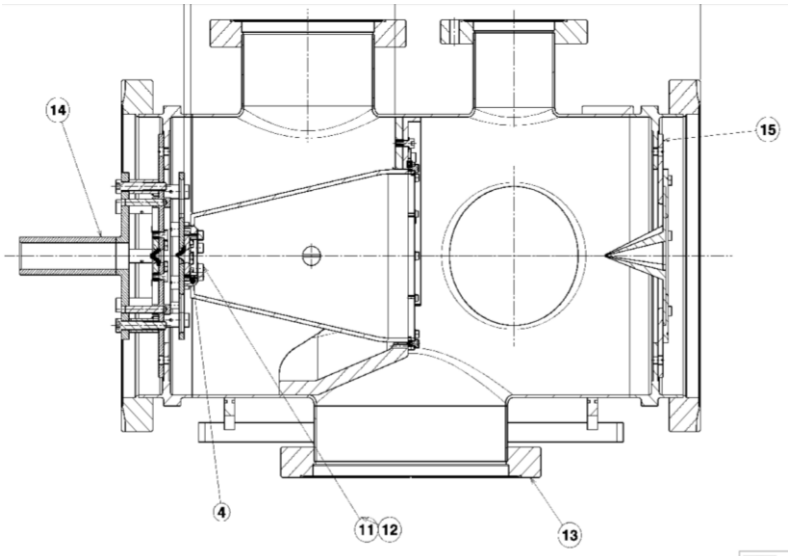


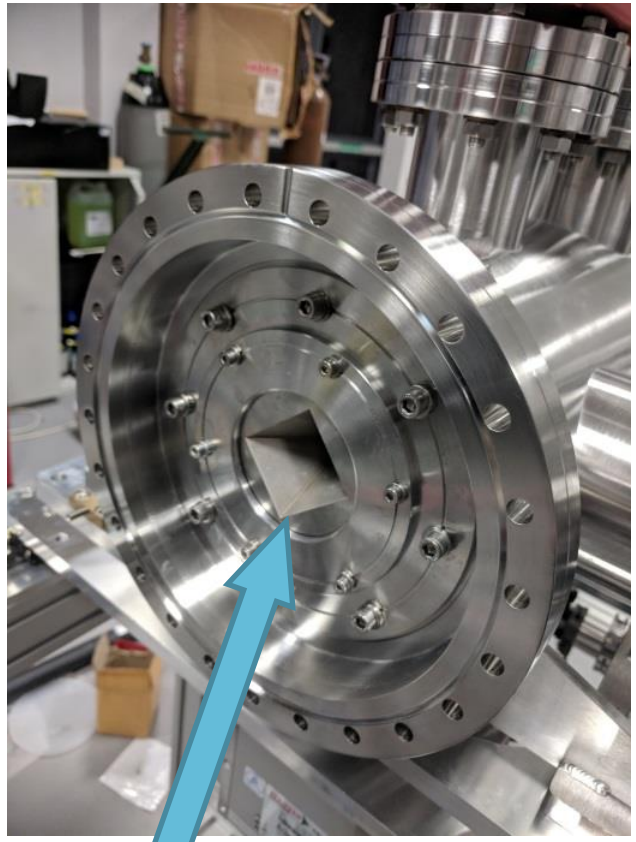




Nozzle and skimmers

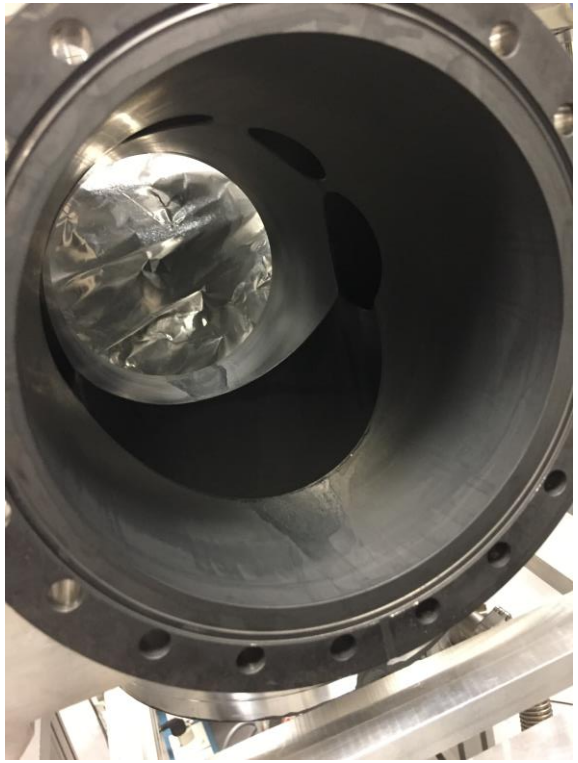


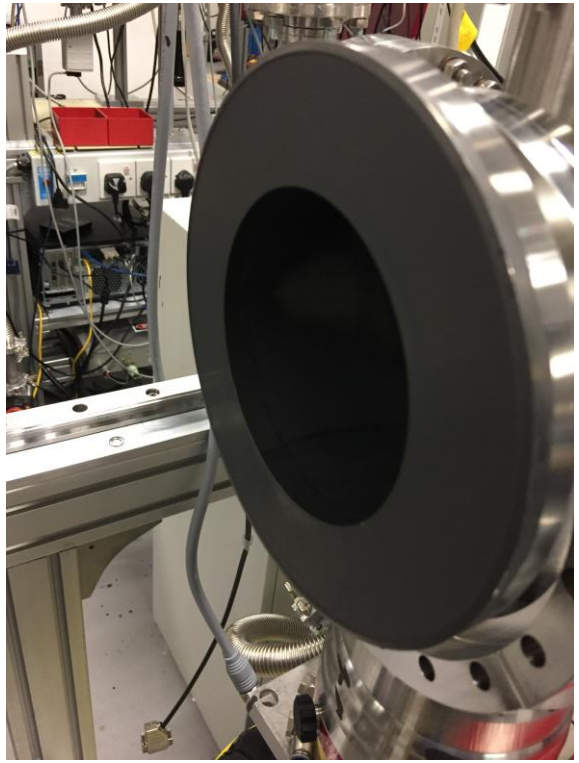


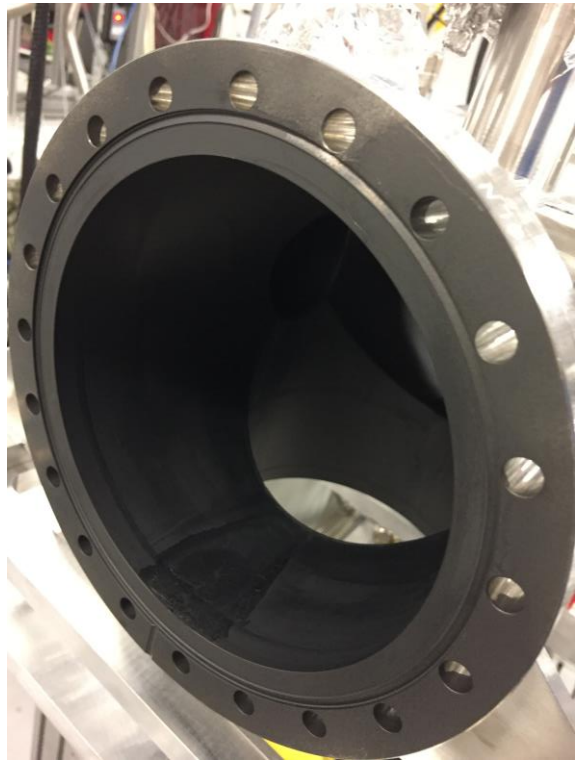


~45 degree tilted

Blackening of the interaction chamber

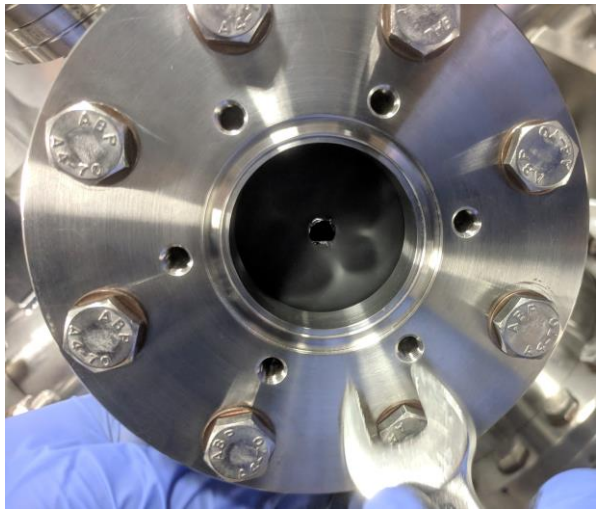


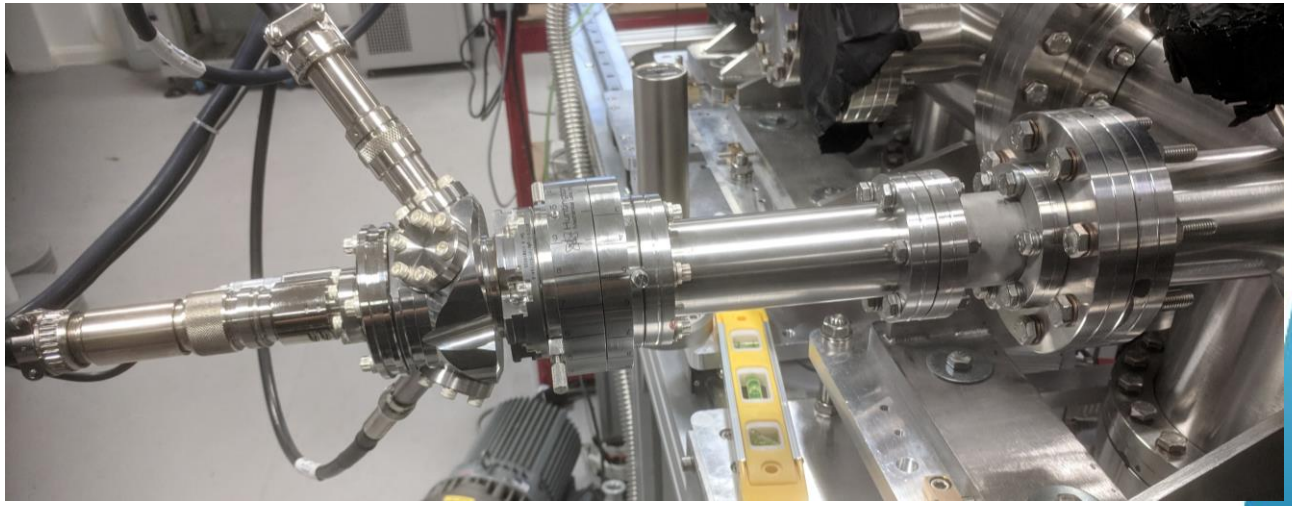




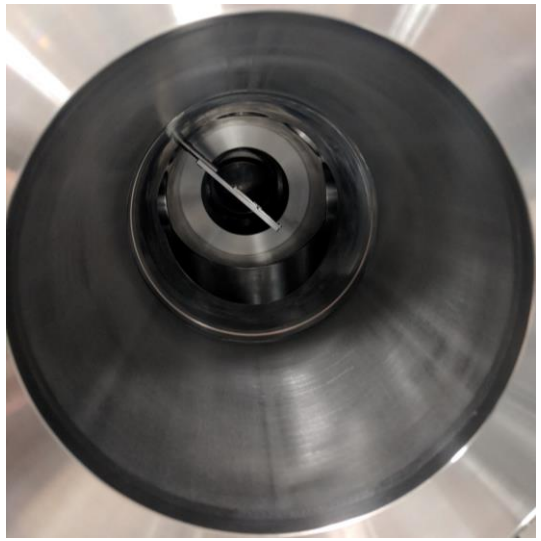
Electron gun

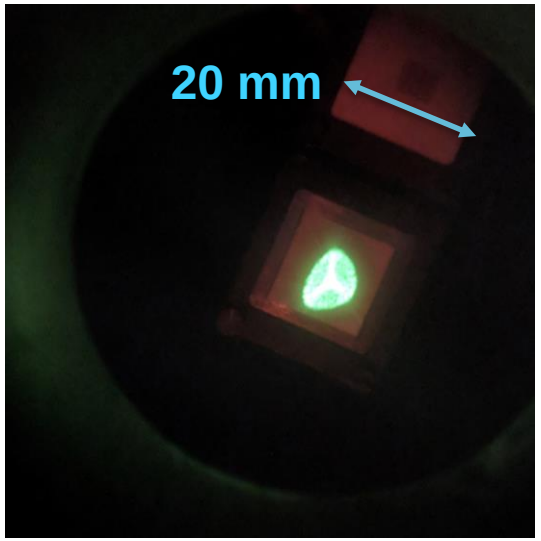
- Energy: 100 eV to 10 keV
- Current: 200uA to 10mA
- Spot size: 1.5mm to 20 mm



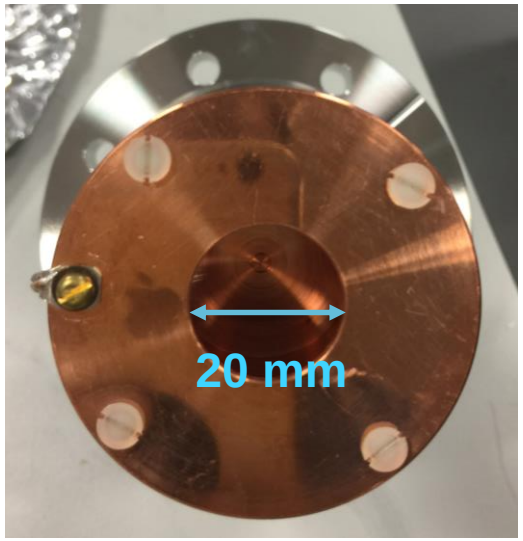


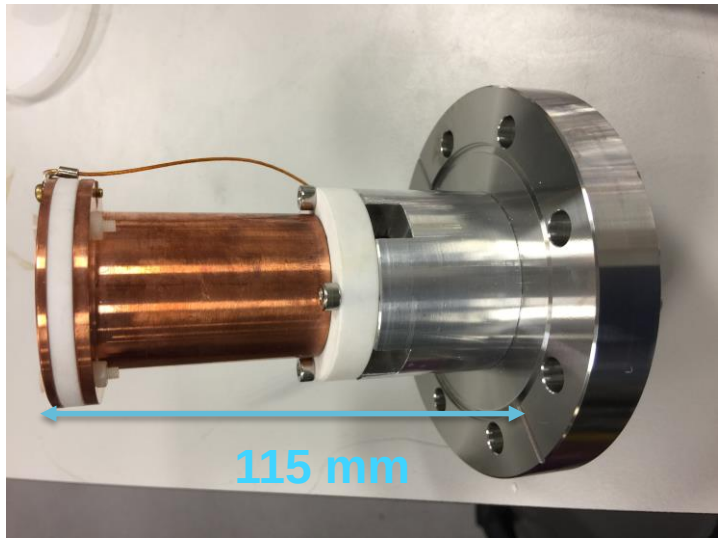
Electron beam diagnostics





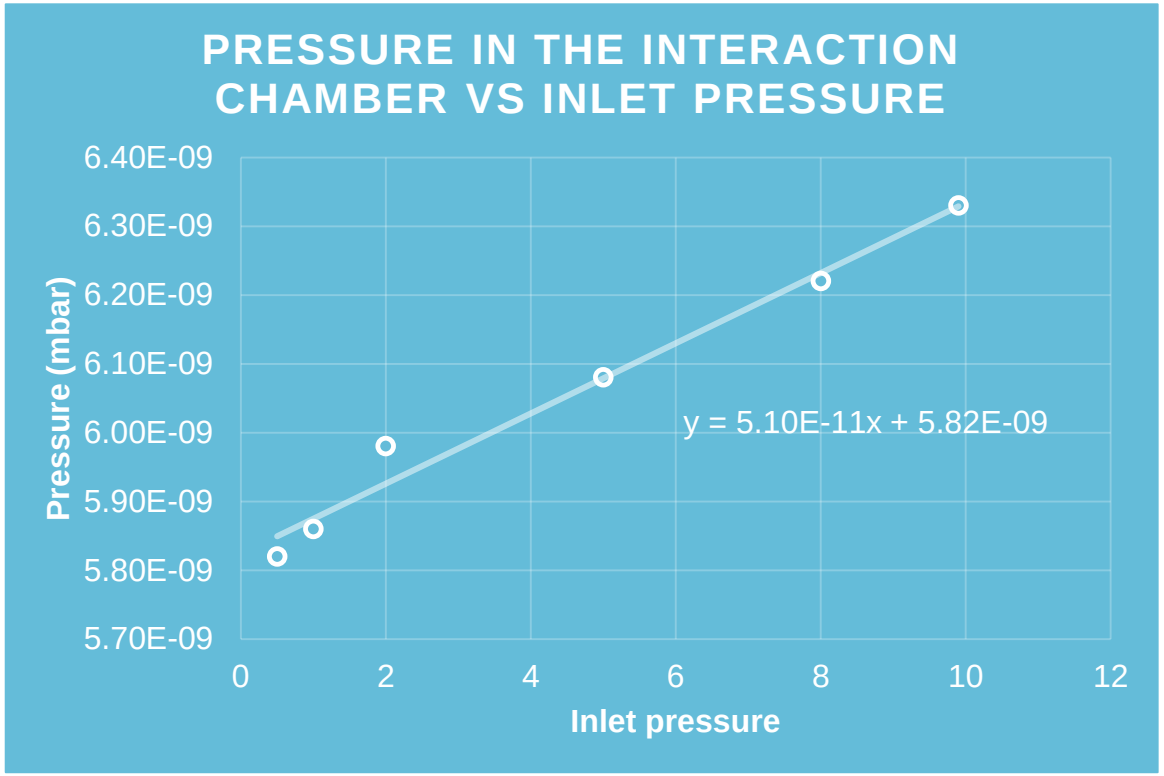
Phosphor screen



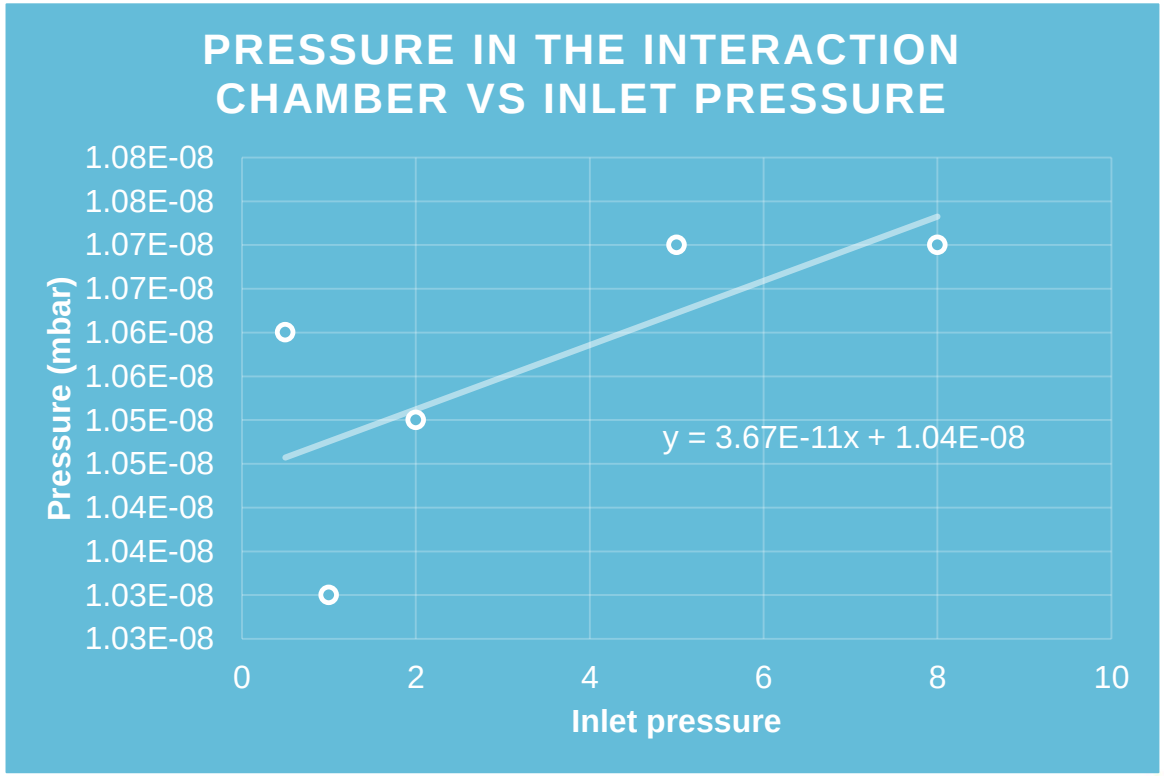


Faraday Cup

Vacuum test of current system

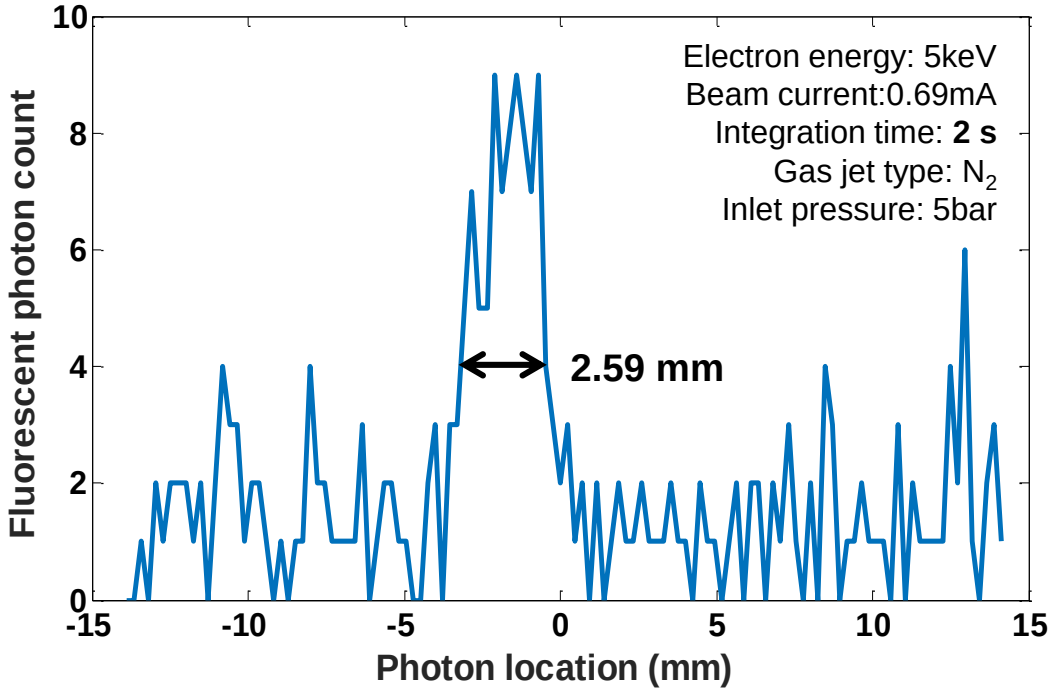


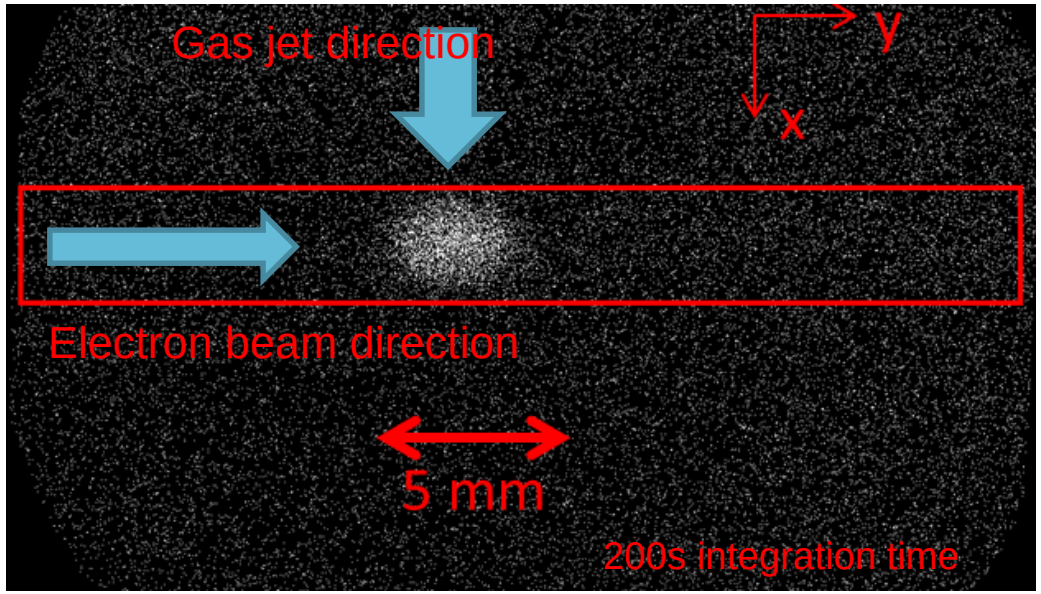
E-gun off



E-gun on

Nitrogen gas jet test



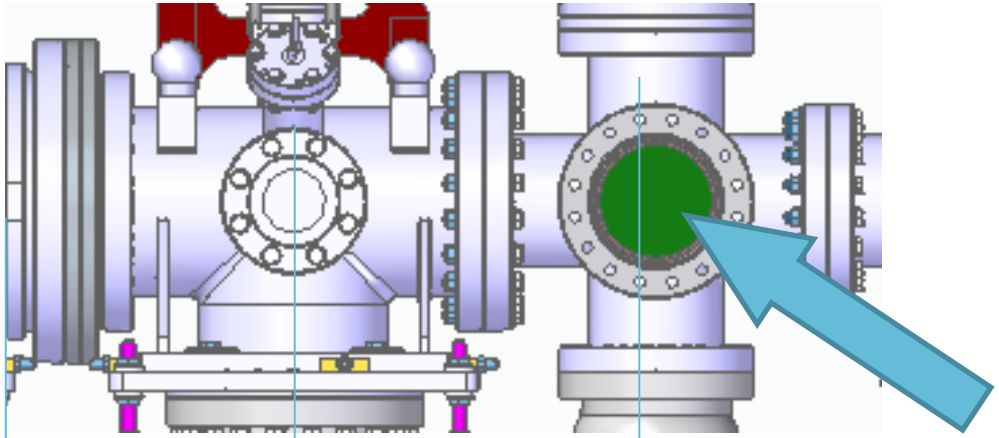


2s integration time to give a profile

More time to give a 2D detailed image

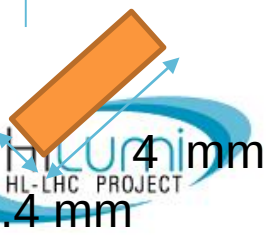
Background pressure: 1.56E-08mbar

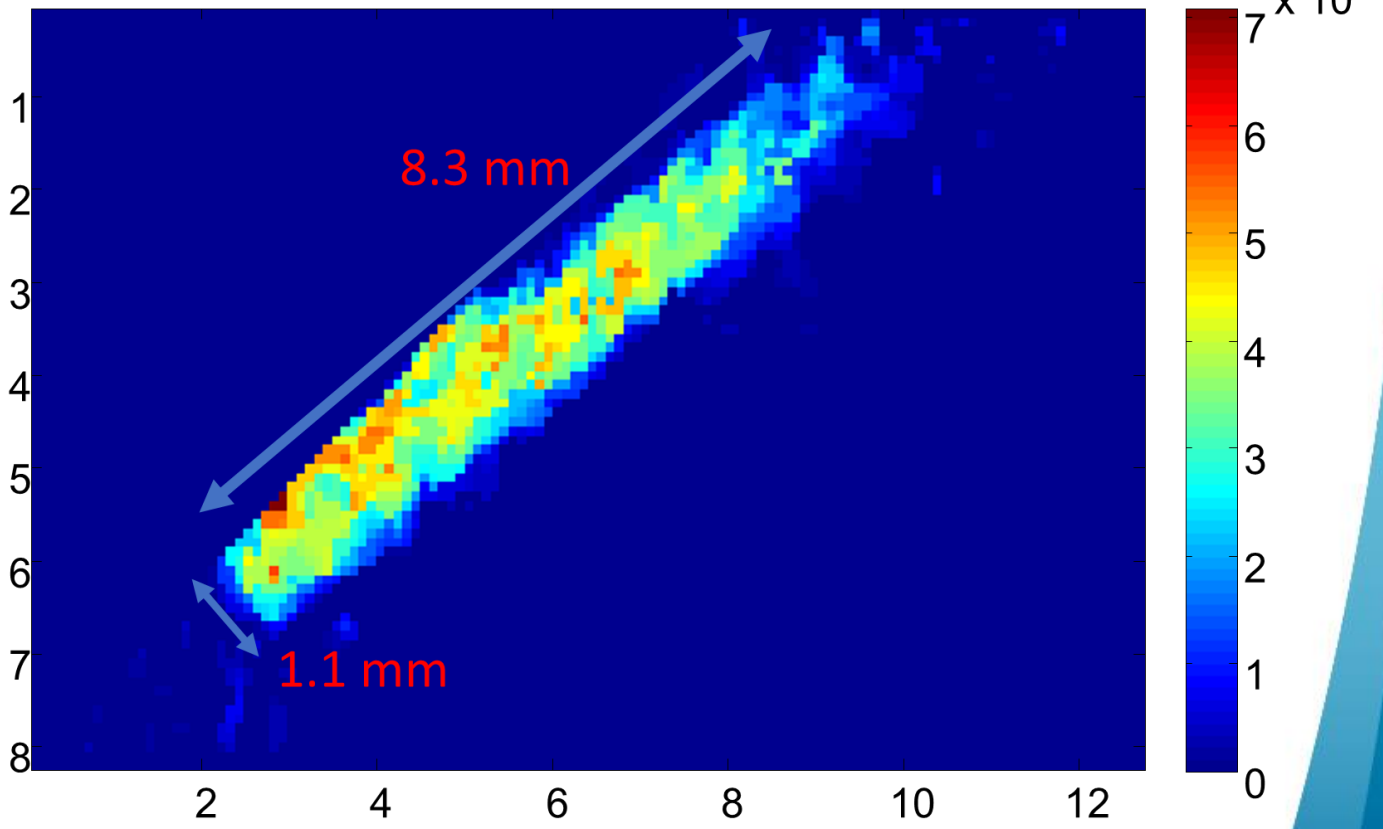
Moveable gauge chamber



224 mm

265 mm





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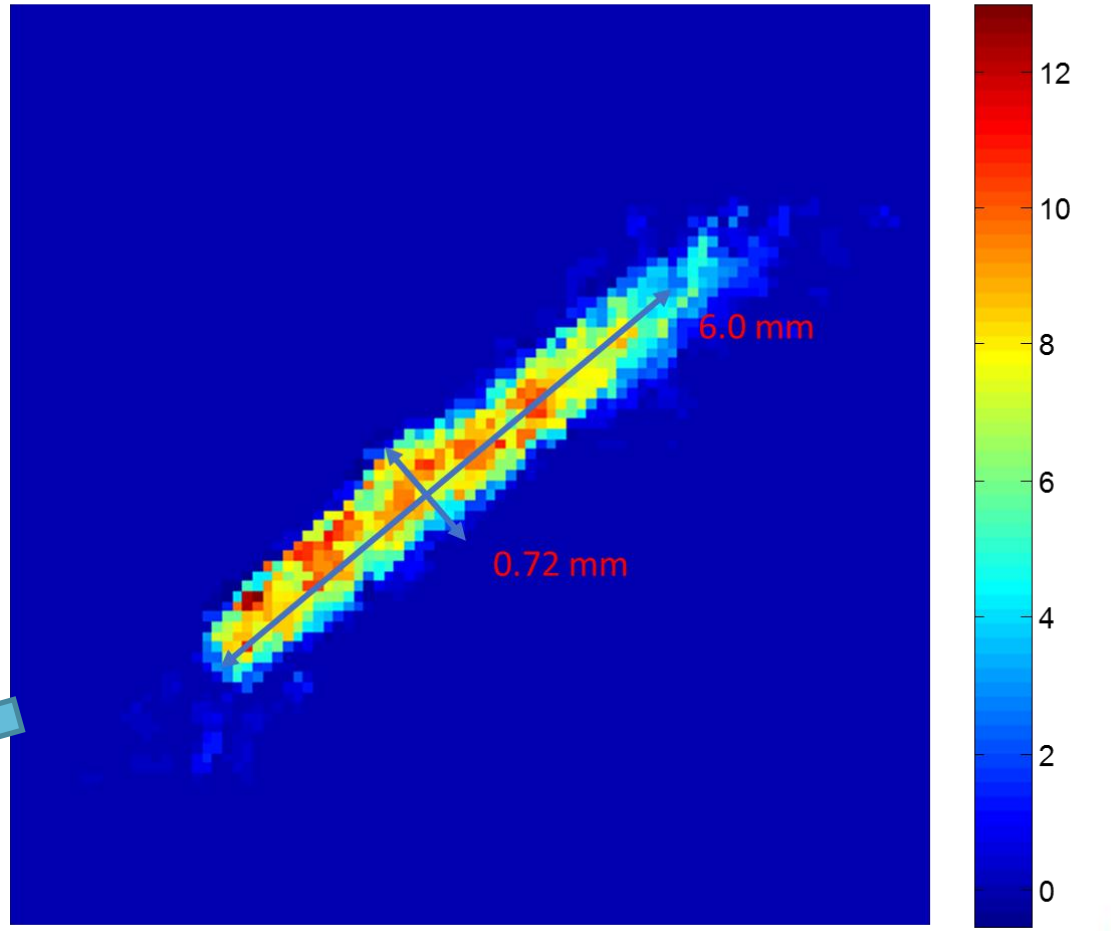
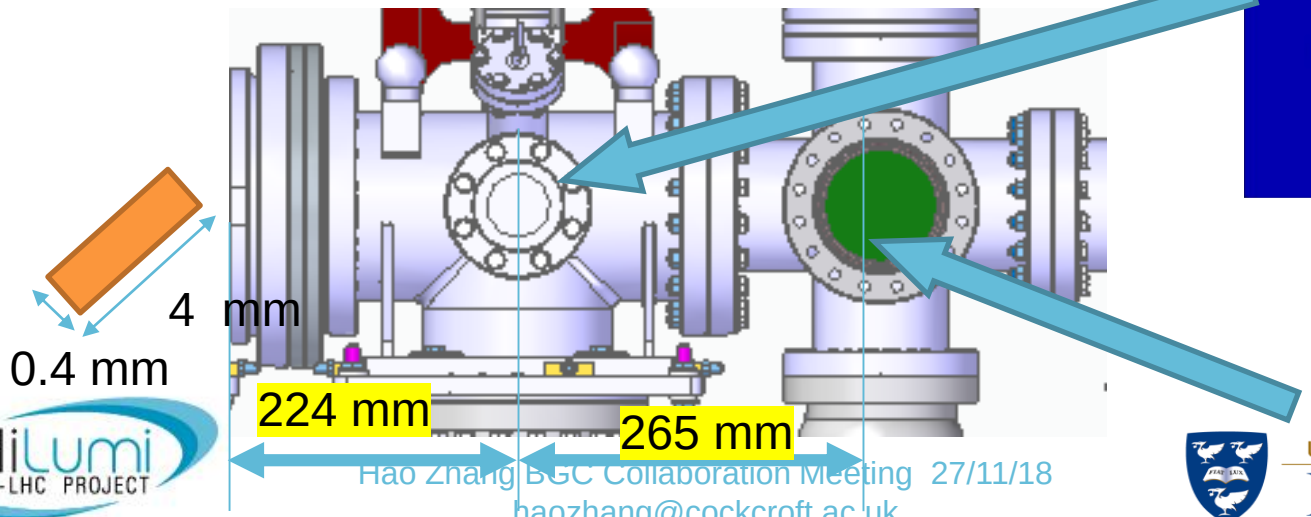
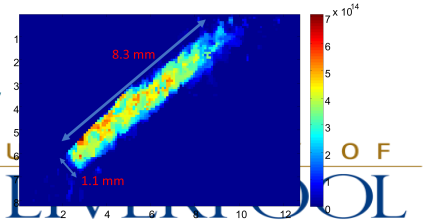
Interaction chamber

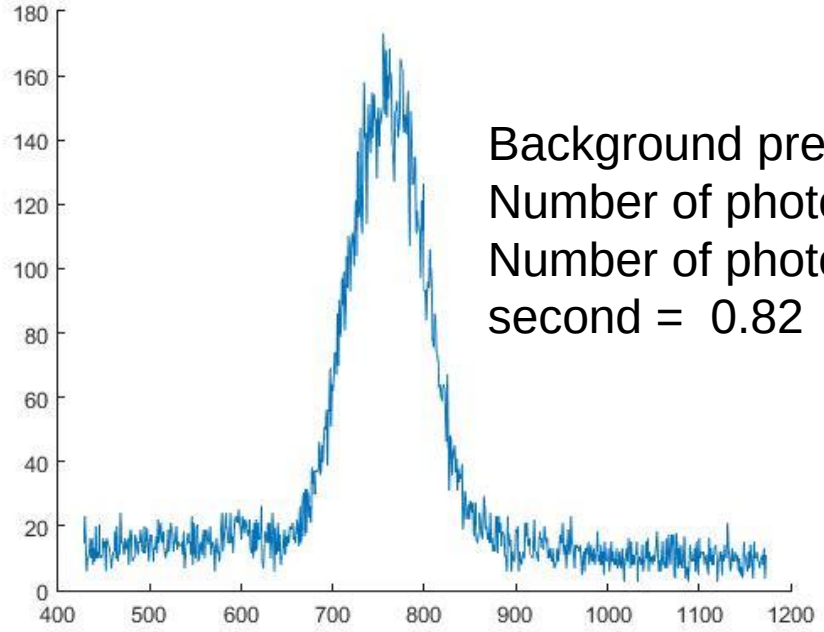
- Assume linear expansion from the 3rd skimmer
- The expansion is decoupled in both transverse direction
- Average density = 9.0 e14 m^{-3}



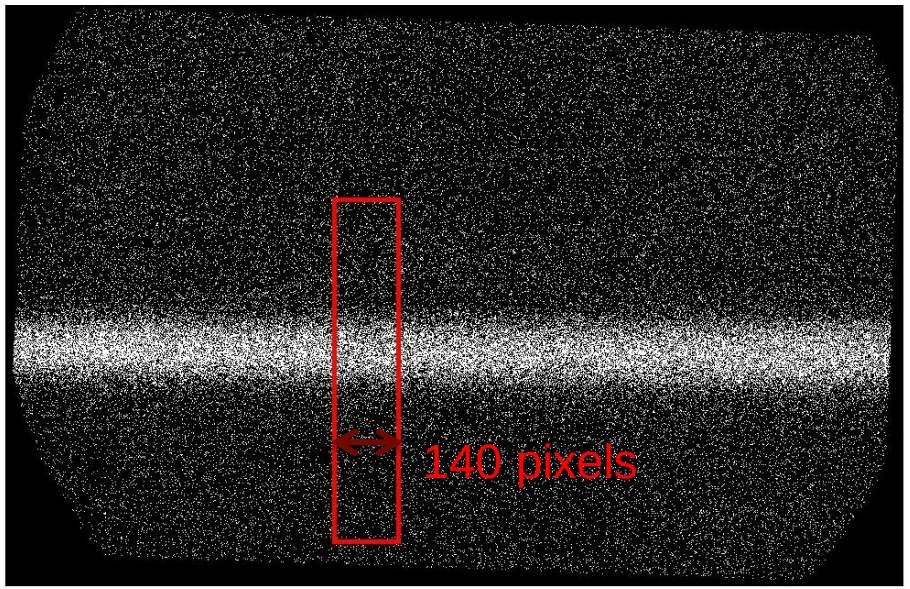




Residual gas calibration



Background pressure 2.5e-7mbar
Number of photons = 4.60E4
Number of photons per pixel per second = 0.82



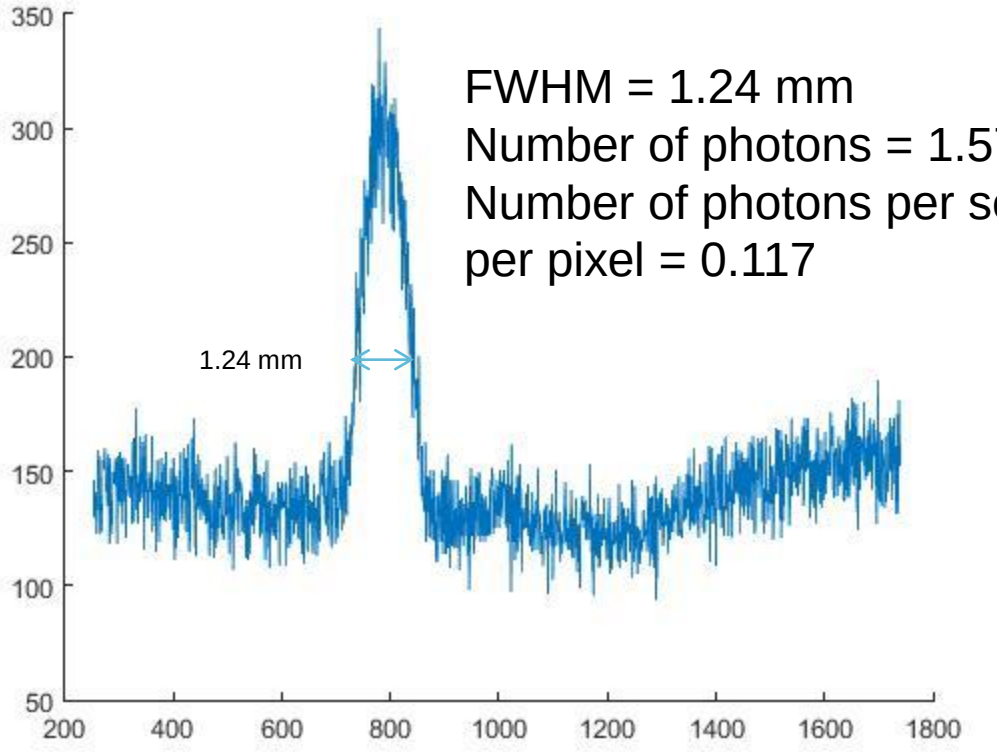
Fitting equation: $F(x) = \frac{N}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(x-b)^2}{2\sigma^2}\right) + Ax + B$

Photon number

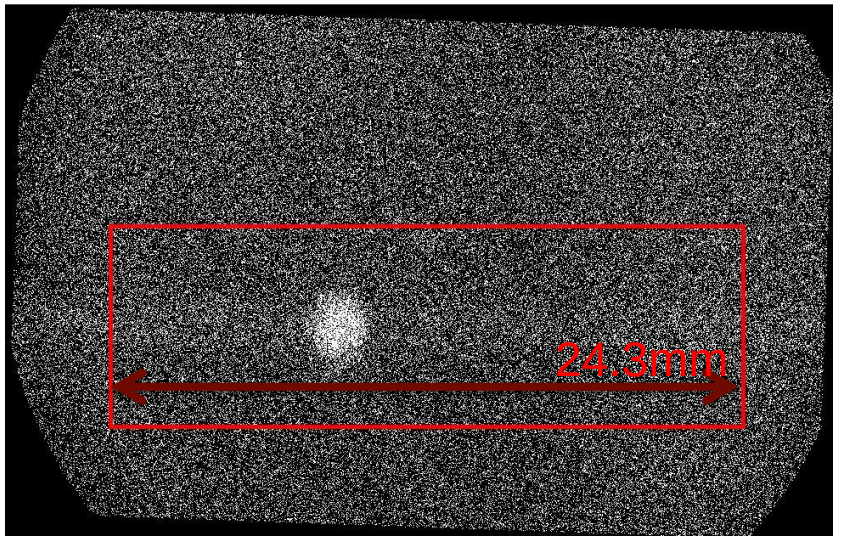
Beam size

Gaussian equation + linear background

Gas jet image of a vertical 3rd skimmer



FWHM = 1.24 mm
Number of photons = 1.57e4
Number of photons per second per pixel = 0.117



Gas jet image with Inlet pressure of 5bar
Integration time = 1600seconds
Electron beam energy = 5kev
electron beam current = 0.66mA
Third skimmer = vertical

~0 degree tilted

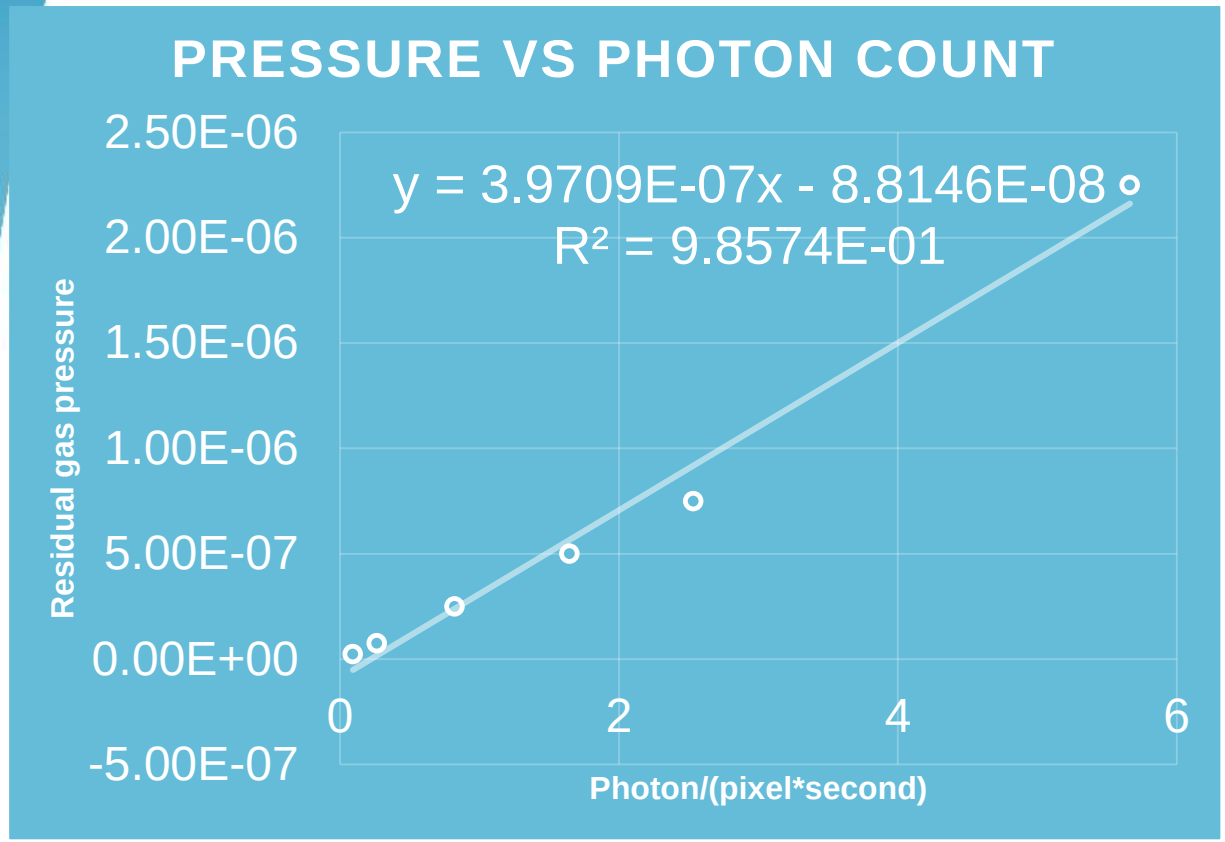
Fitting equation: $F(x) = \frac{N}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(x-b)^2}{2\sigma^2}\right) + Ax + B$

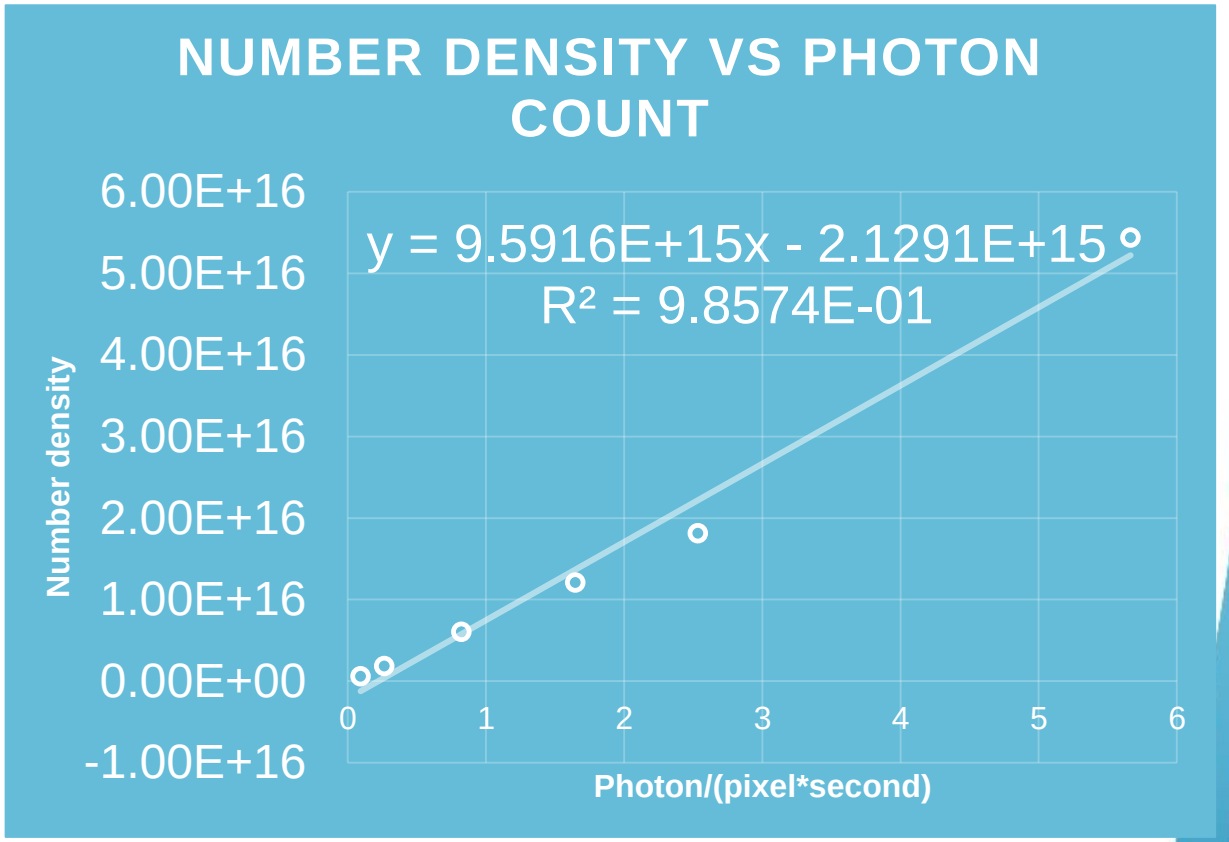
Photon number

Beam size

Gaussian equation + linear background

Photon Gauge test





For gas jet image: The photon rate per pixel = 0.117

Gas jet average number density = 1.12e15 m^{-3} or 4.62e-8 mbar

Cross section measurement

$$N_\gamma = \sigma \cdot \frac{I \cdot \Delta t}{e} \cdot n \cdot d \cdot \frac{\Omega}{4\pi} \cdot T \cdot T_f \cdot \eta_{pc} \cdot \eta_{MCP}$$

n = 0.96e15 ± 0.2e15 m^{-3}
d = 0.98e-3 ± 0.2e-3 m
Ω = 0.0059
T = 0.75 ± 0.05
T_f = 0.45 ± 0.05
η_{MCP} = 0.75 ± 0.15

η_{PC} = 0.19 ± 0.02
N = 15700 ± 100
Δt = 1600 s

N_γ	= average number of photons detected during time Δt
σ	= cross section of the photon generation process
I	= electron or proton current (electrical)
e	= elementary charge
n	= gas density
d	= distance traveled through gas (curtain thickness)
Ω	= solid angle of the optics
T	= transmittance of the optical system
T_f	= transmittance of the optical filter
η_{pc}	= quatum efficiency of the photocathode
η_{MCP}	= detection efficiency of the MCP

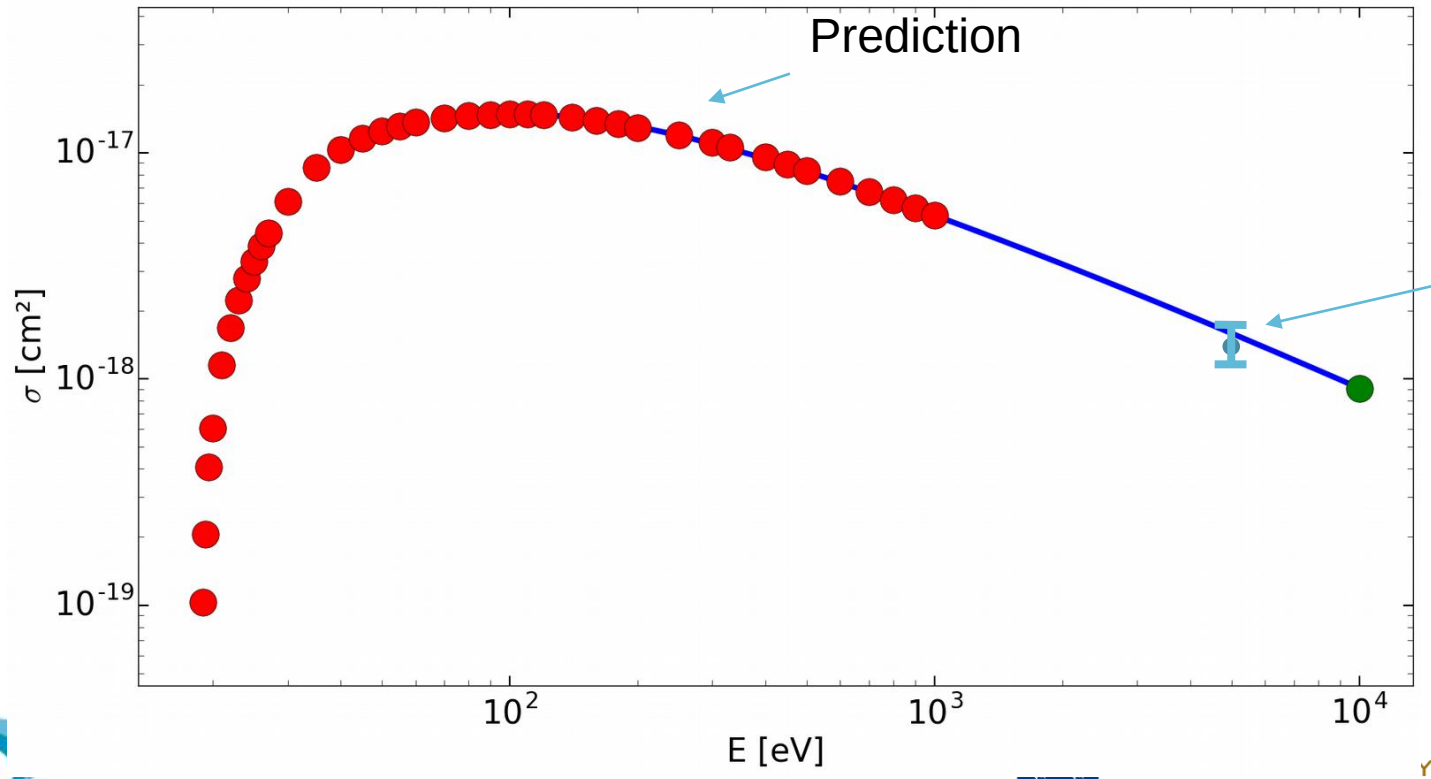
Cross section: 1.07±0.55 e-18 cm^{-2}

Comparison to the theory

$$\sigma^{e}_{391} = A_3 \cdot E^{-1} \cdot \ln(B_3 \cdot E)$$

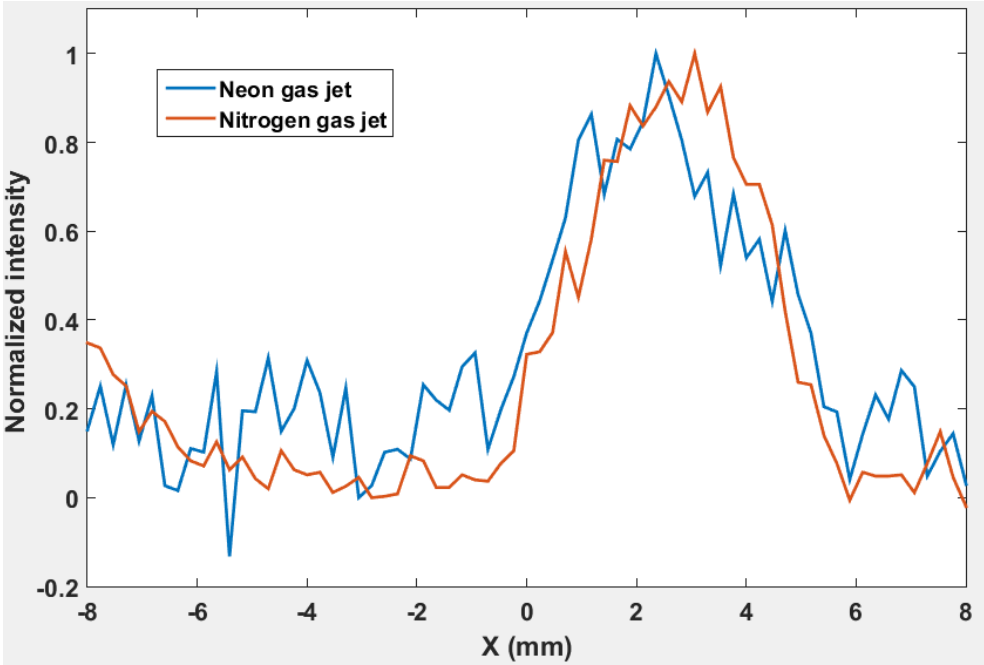
with $A_3 = 1.66 \cdot 10^{-15}$ cm^2·eV and $B_3 = 2.4 \cdot 10^{-2}$ eV^{-1}. Hence $\sigma^{e}_{391} \approx 9.1 \cdot 10^{-19}$ cm^2 at 10 keV,

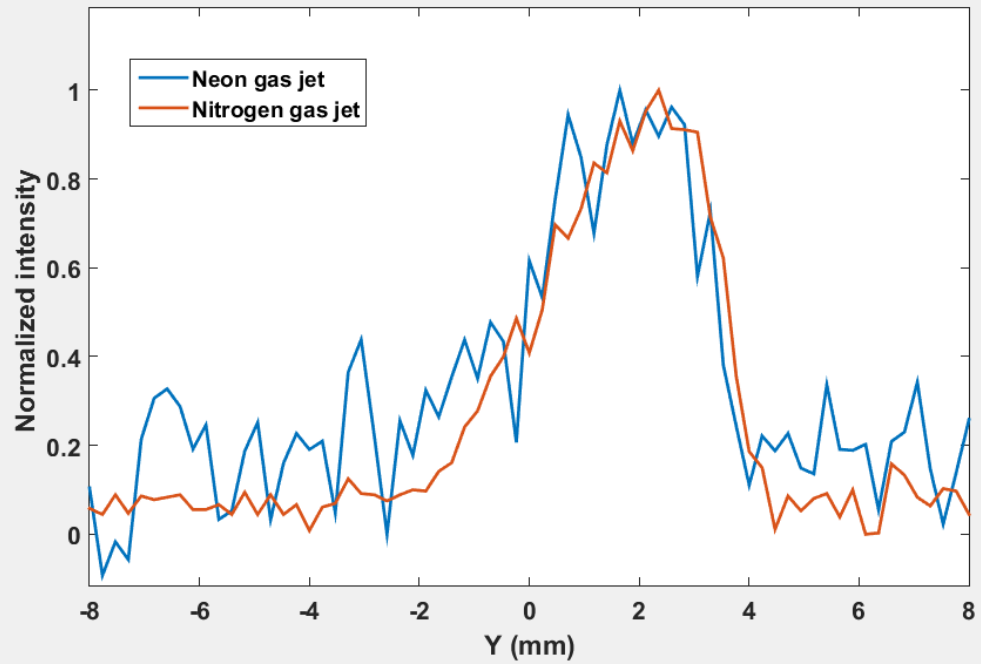
1.59e-18 cm^{-2} for 5keV electron beam



Experiment: 1.07±0.55 e-18

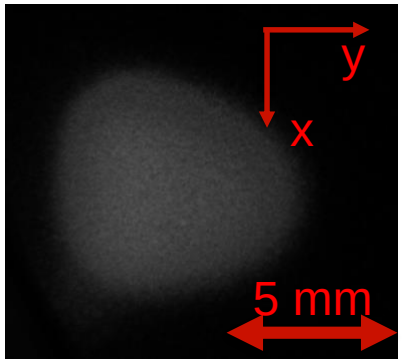
Preliminary results of Neon gas jet





Electron energy: 3 keV
Beam current: 0.50mA
Integration time: 200 s for N_2, 4000 s for Neon
Inlet pressure: 5bar

Image from the phosphor screen



Comparison between N_2 and Neon

- Gas jet condition: inlet 5 bar
- Photon number per second
  - Nitrogen: 5.63
  - Neon: 0.77
- Ratio of Nitrogen/Neon: 7.32

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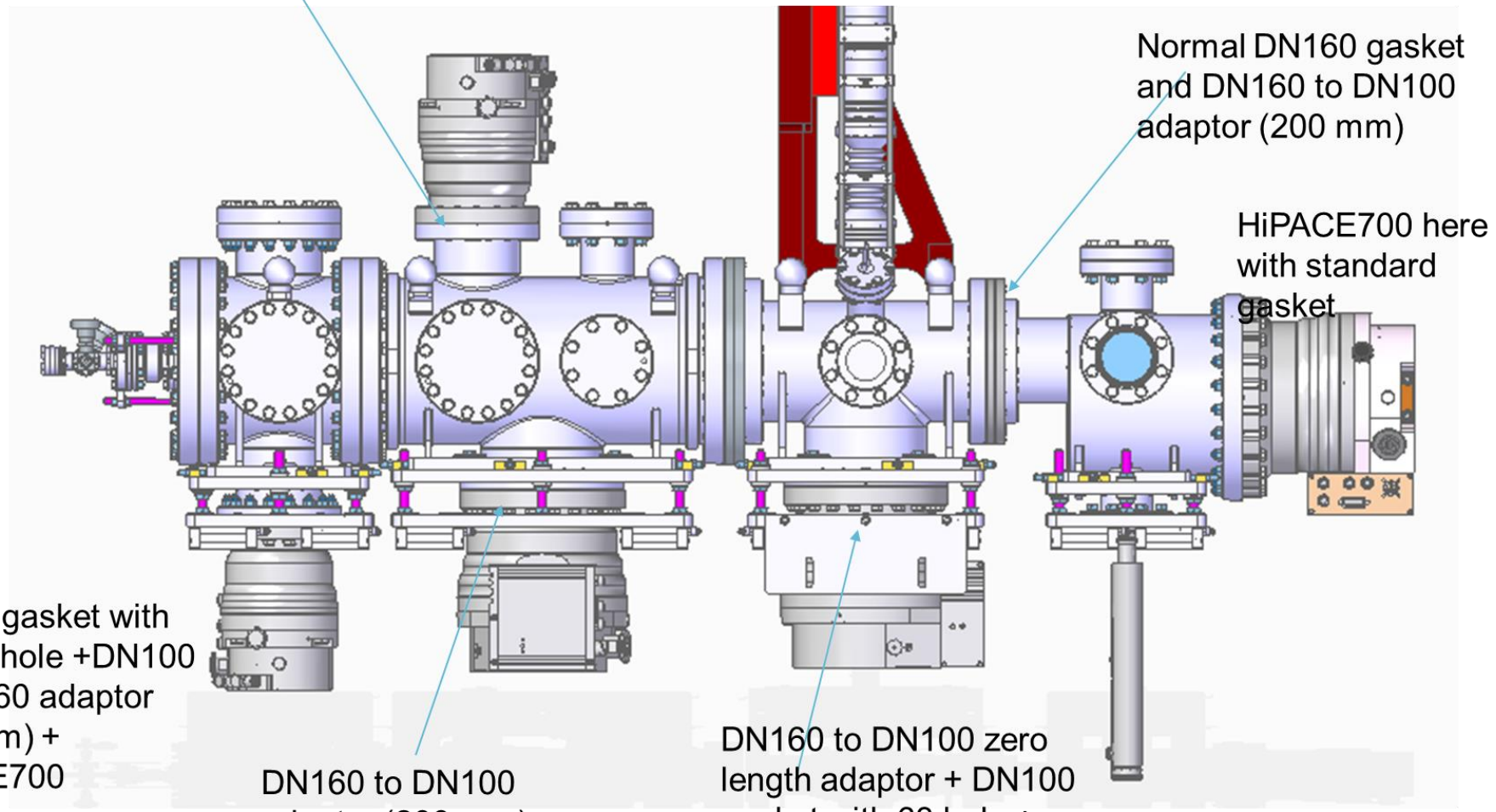
Possible reason

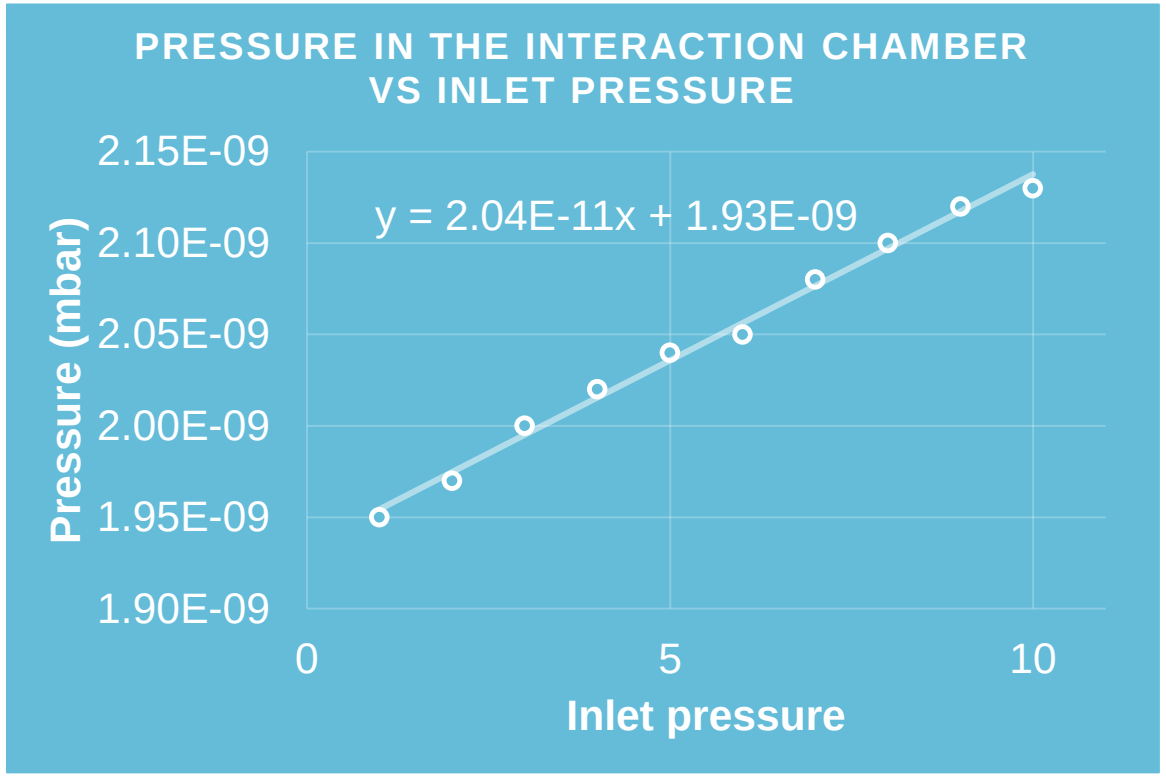
$$N_\gamma = \sigma \cdot \frac{I \cdot \Delta t}{e} \cdot n \cdot d \cdot \frac{\Omega}{4\pi} \cdot T \cdot T_f \cdot \eta_{pc} \cdot \eta_{MCP}$$

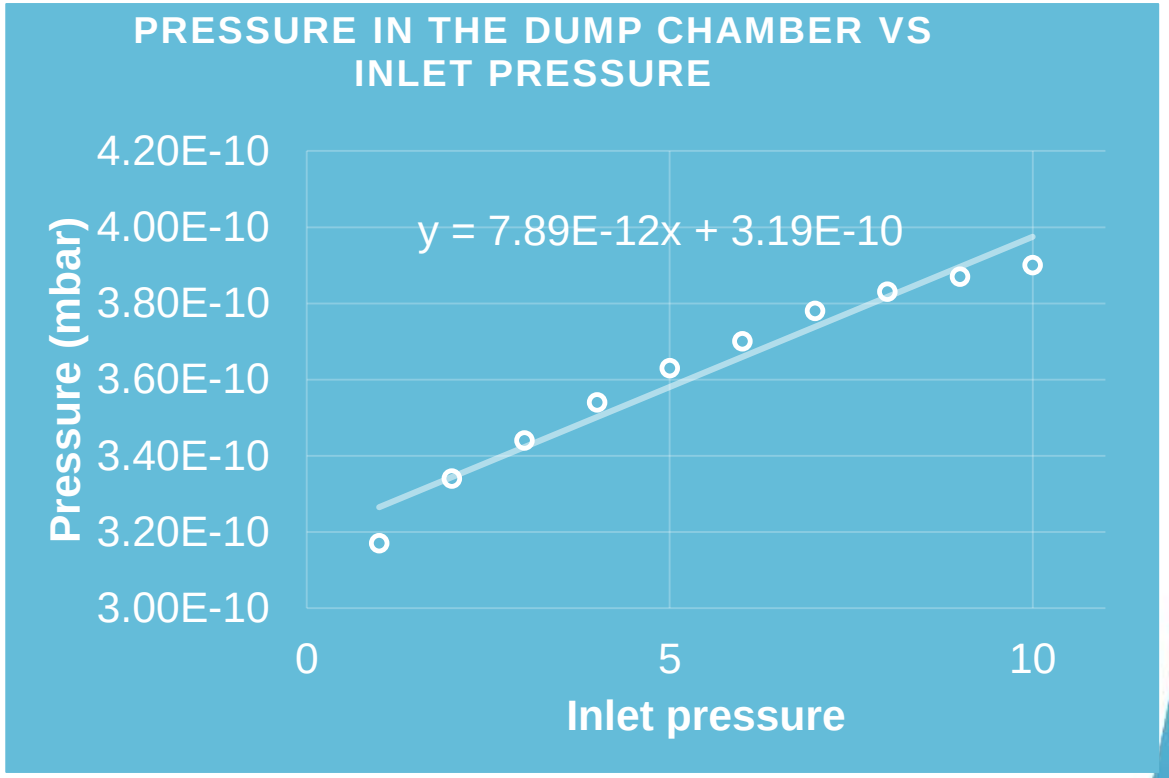
	Neon	Nitrogen		Ratio of Nitrogen and Neon		
	3keV	3keV		3keV		
Degree of freedom	3	5				
Heat capacity ratio	1.4	1.67				
Atomic mass	20	28				
Pressure in the interaction from theory (inlet 5 bar)	3.29E+17	2.62E+16		7.96E-02		
Cross section	4.60E-20	2.37E-18		5.15E+01		
Eff_PC	0.09	0.19		2.111111		
T_filter	9.00E-01	4.50E-01		5.00E-01		
Equal density				5.43E+01		
Take density into consideration				4.32E+00		

Vacuum test of modified system (lower pumping speed)



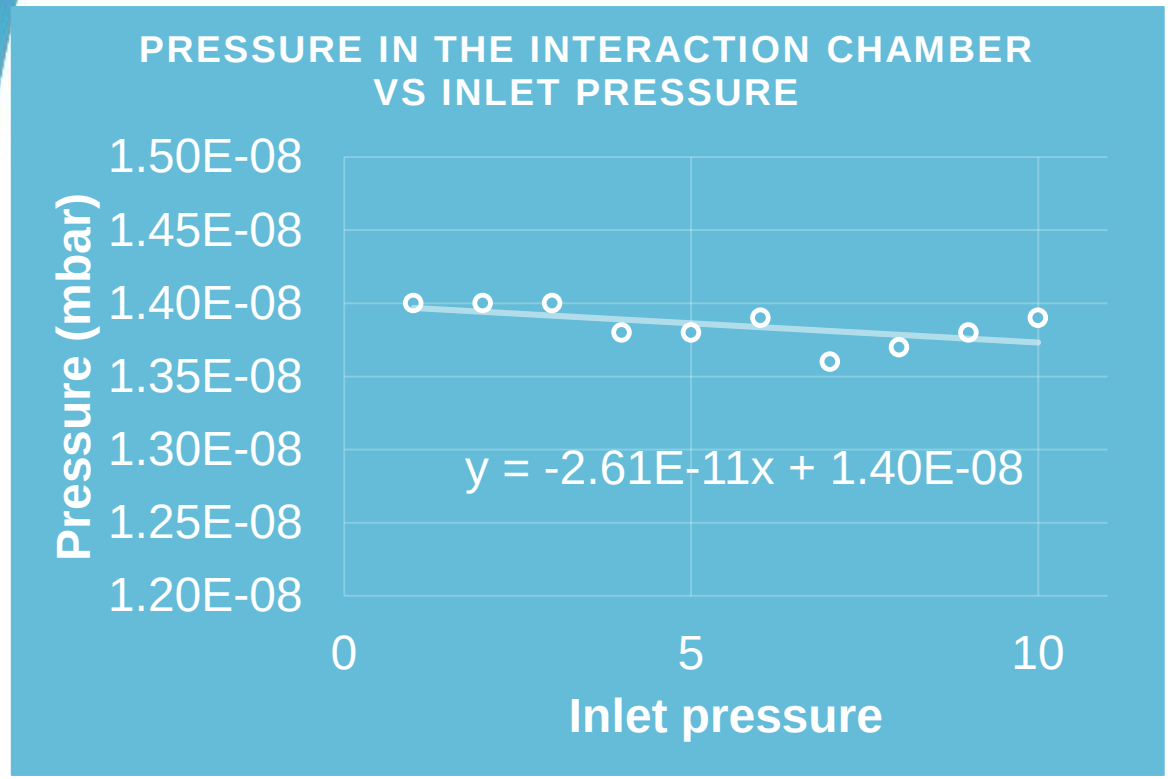
Pressure data when e-gun is off

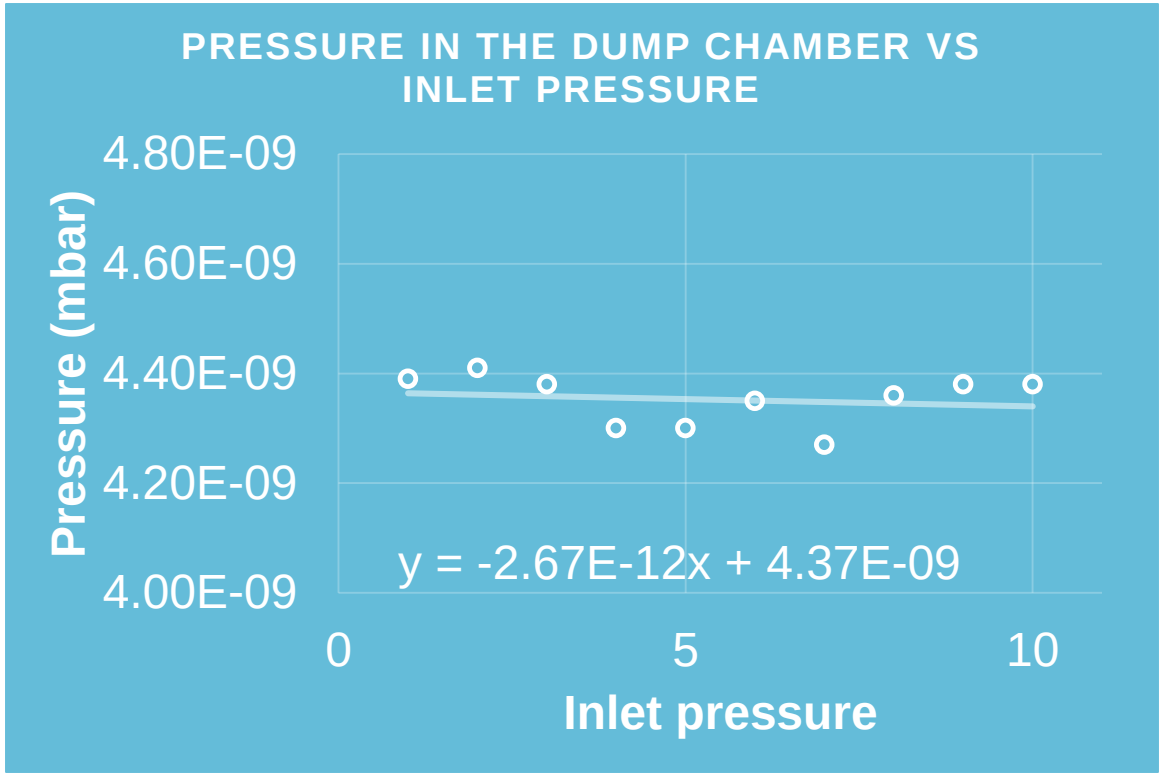




Detailed data for each chamber will be loaded to indico

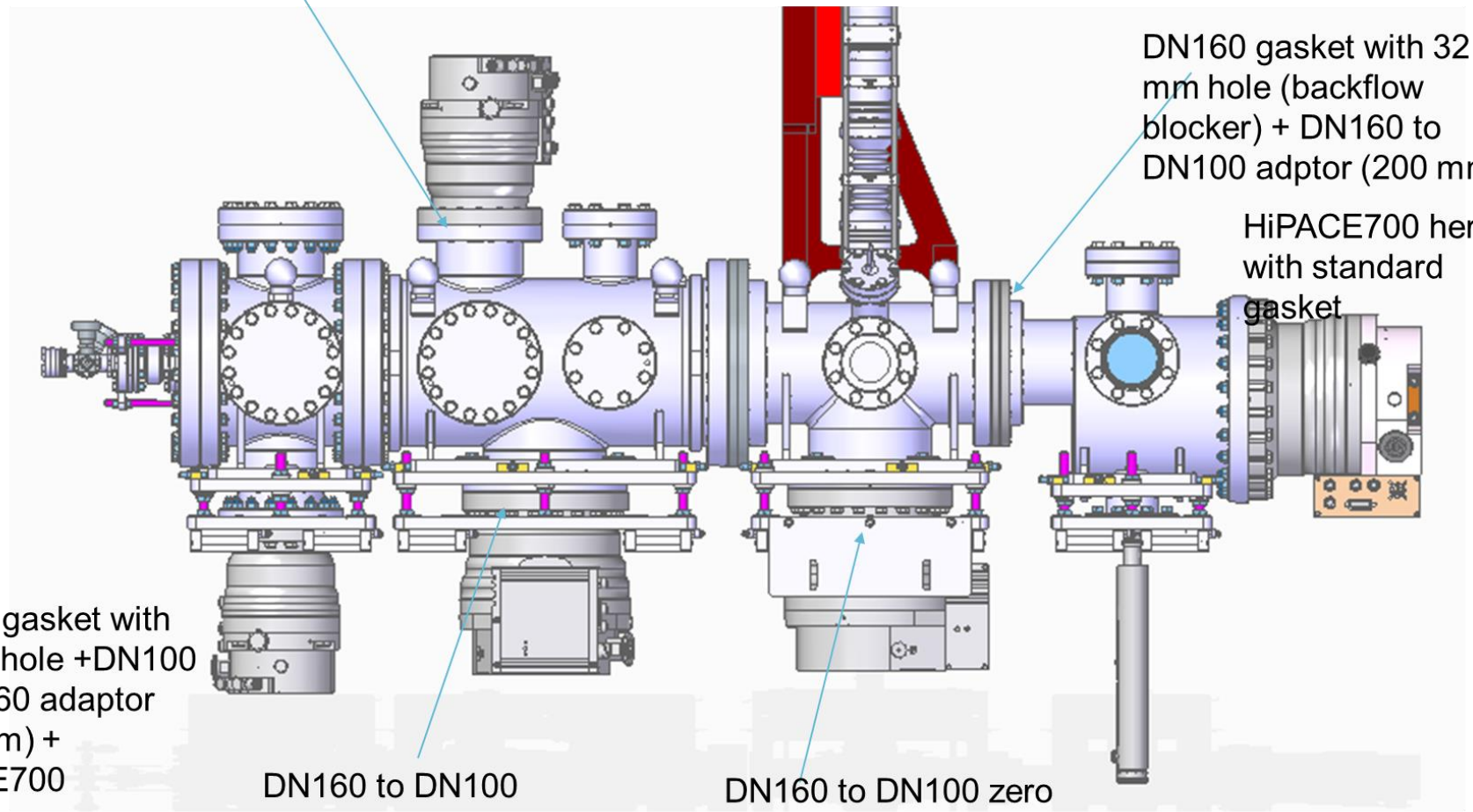
Pressure data when e-gun is on



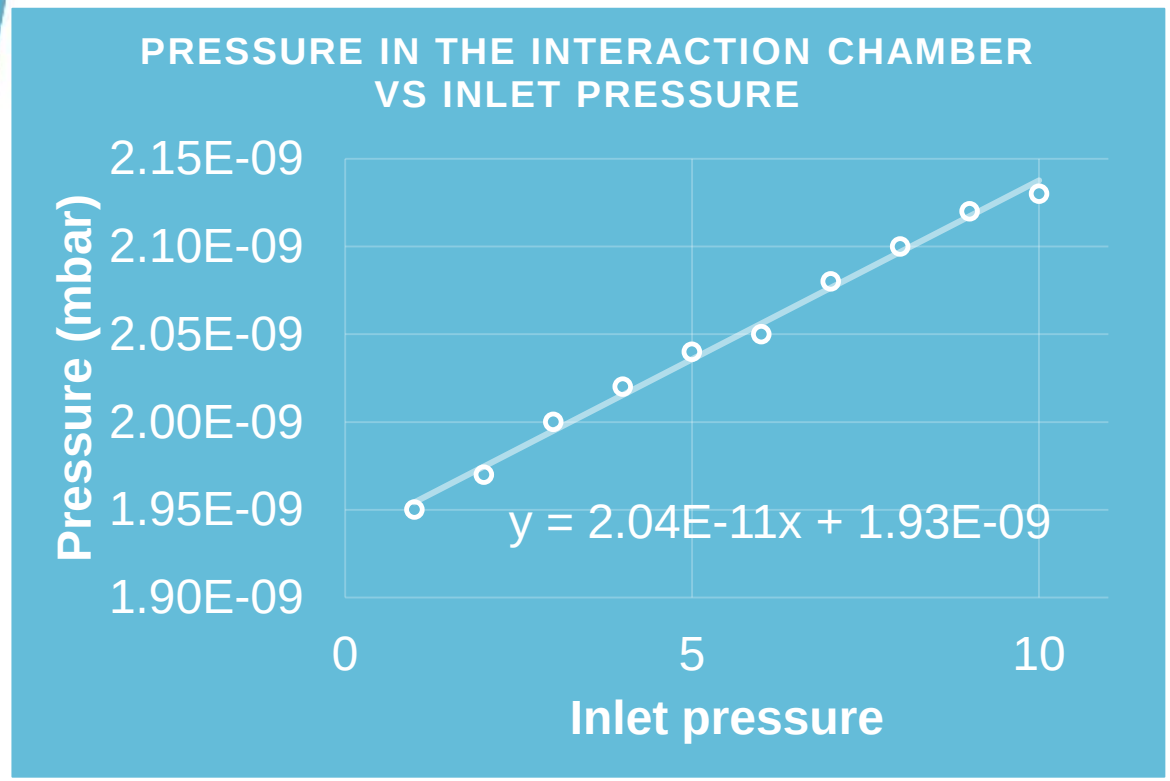


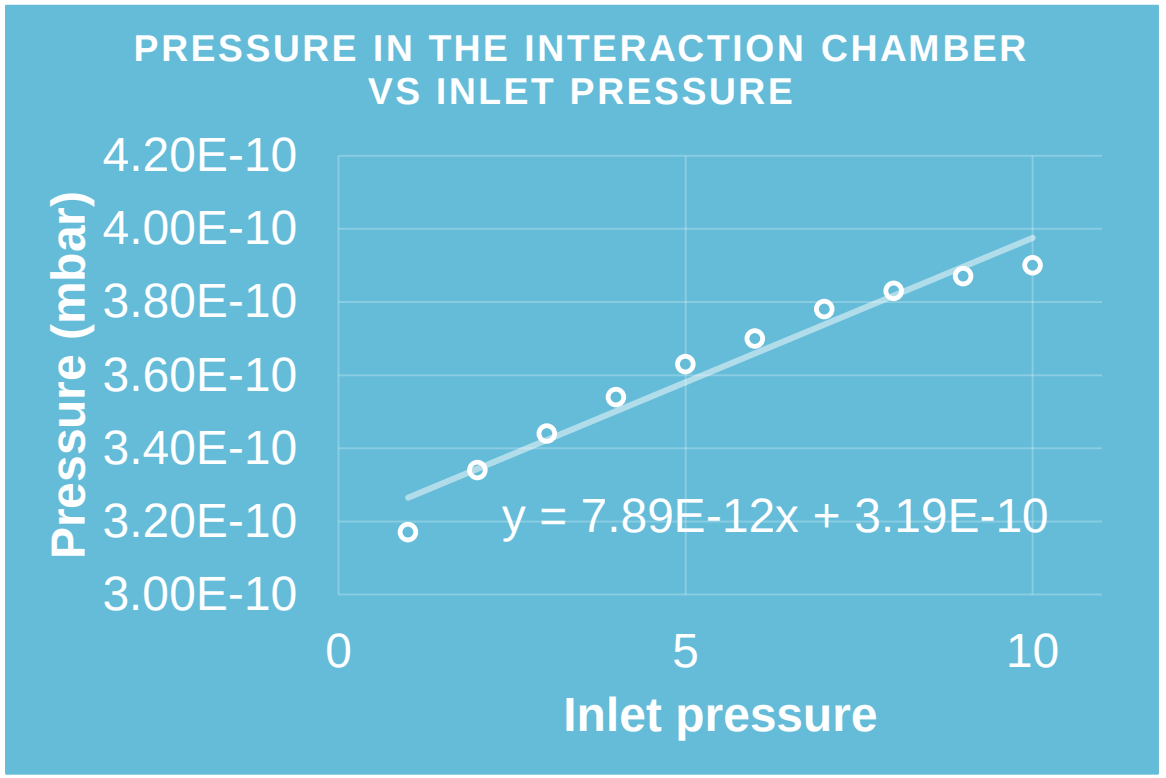
Detailed data for each chamber will be loaded to indico

Vacuum test of modified system (lower pumping speed and back flow blocker)



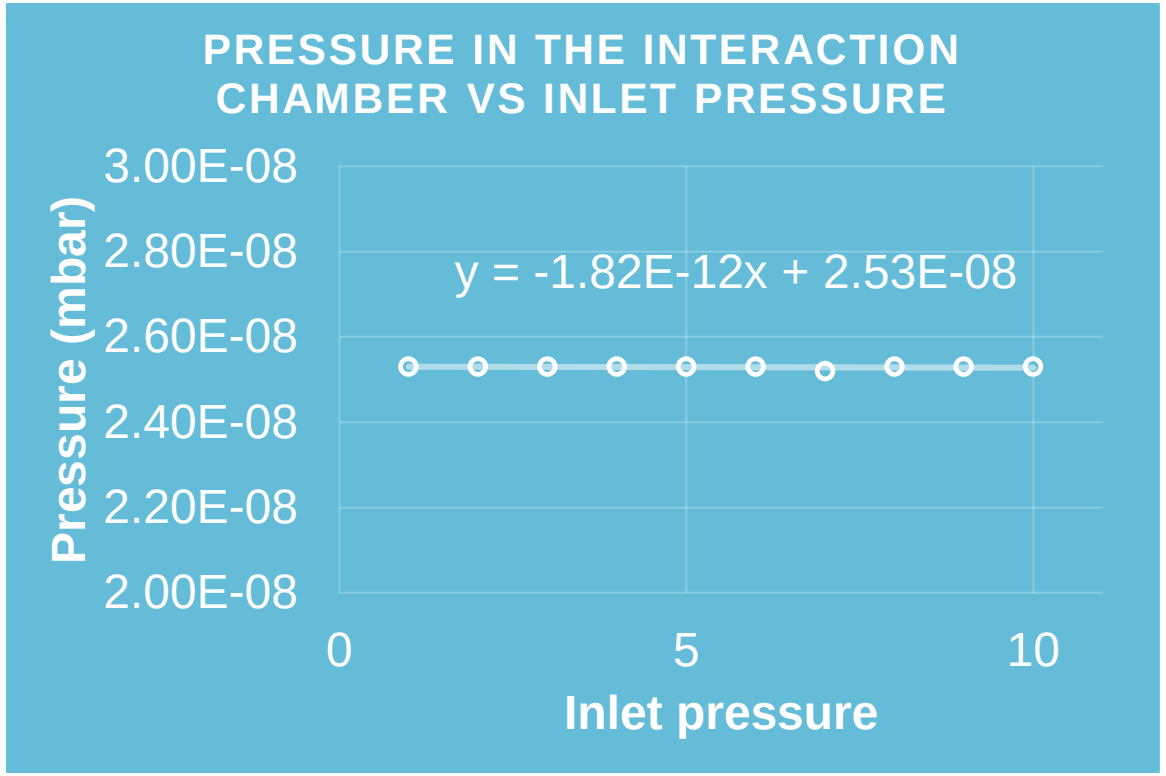
Pressure data when e-gun is off

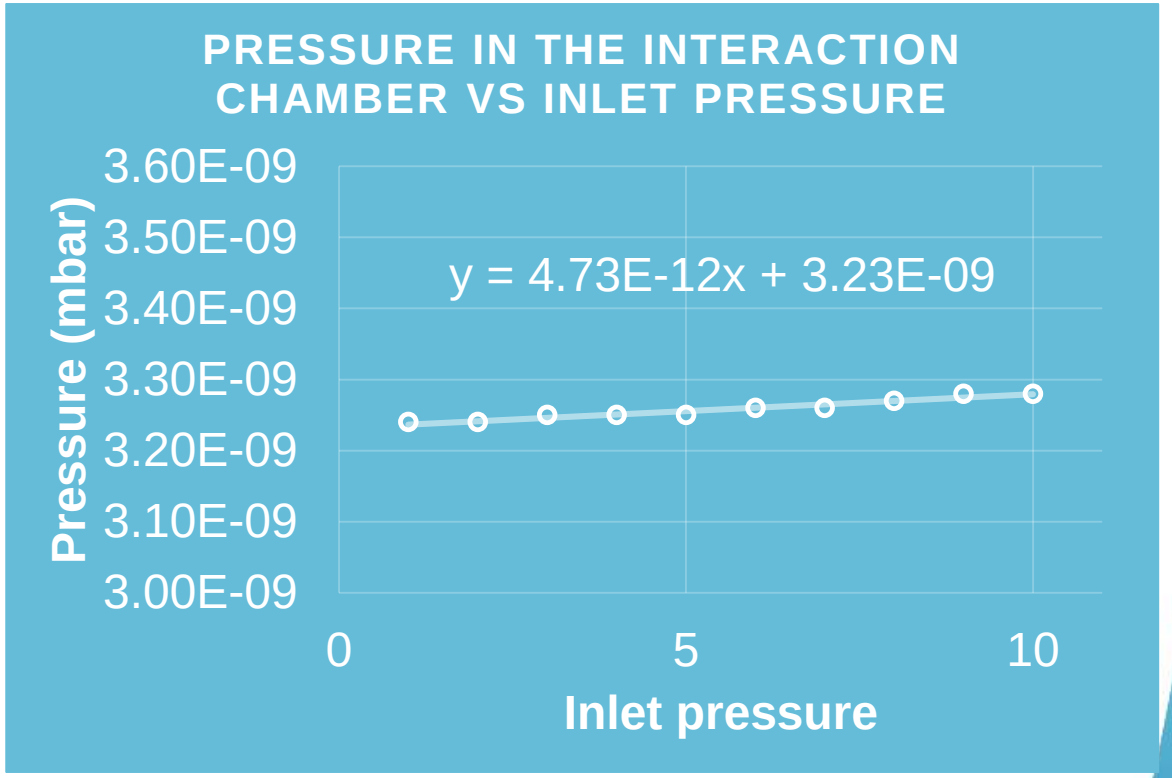




Detailed data for each chamber will be loaded to indico

Pressure data when e-gun is on





Detailed data for each chamber will be loaded to indico

Summary of highlight

- A prototype supersonic gas jet monitor based on BIF mode was designed, built and successfully commissioned;
- N_2 gas jet was carefully measured and has been successfully tested as a working gas using laboratory electron beam source;
- Neon gas jet has been proven as working gas.
- Vacuum test of a modified System in order to design a LHC compatible gas jet system.

Future work

- Continue to optimize the design and geometry
  - Check again the alignment
  - E.g. new De Laval nozzle
  - Change geometry of skimmers.
- Characterize Neon gas jet
- Argon used as a working gas
- Design and building of v3 gas jet system (LHC compatible)
  - Final deliverable for the HL-LHC-UK

Thank you