The Cockcroft Institute
of Accelerator Science and Technology

UNIVERSITY OF LIVERPOOL

PROGRESS ON THE SUPERSONIC GAS JET BEAM PROFILE MONITOR

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QUASAR

HiLumi HL-LHC PROJECT

Outline

- Gas-jet project update
  - Motivation
  - Diagnostic development in CI
    - Supersonic gas jet curtain
    - Beam induced fluorescent monitoring
    - Improve integration time and resolution
    - Jet density measurement
  - Design of the second test monitor

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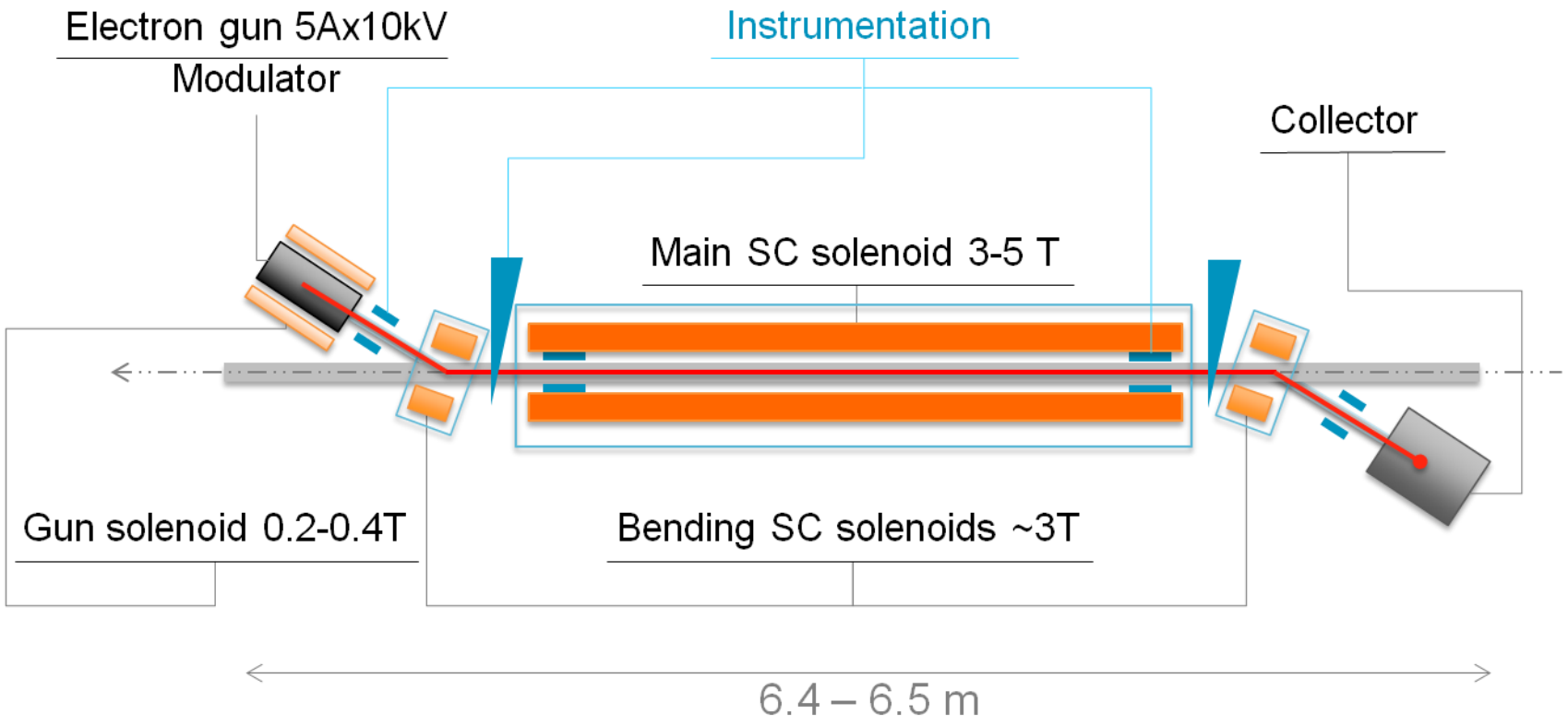
Motivation

- Serve as beam profile monitor for electron lens project



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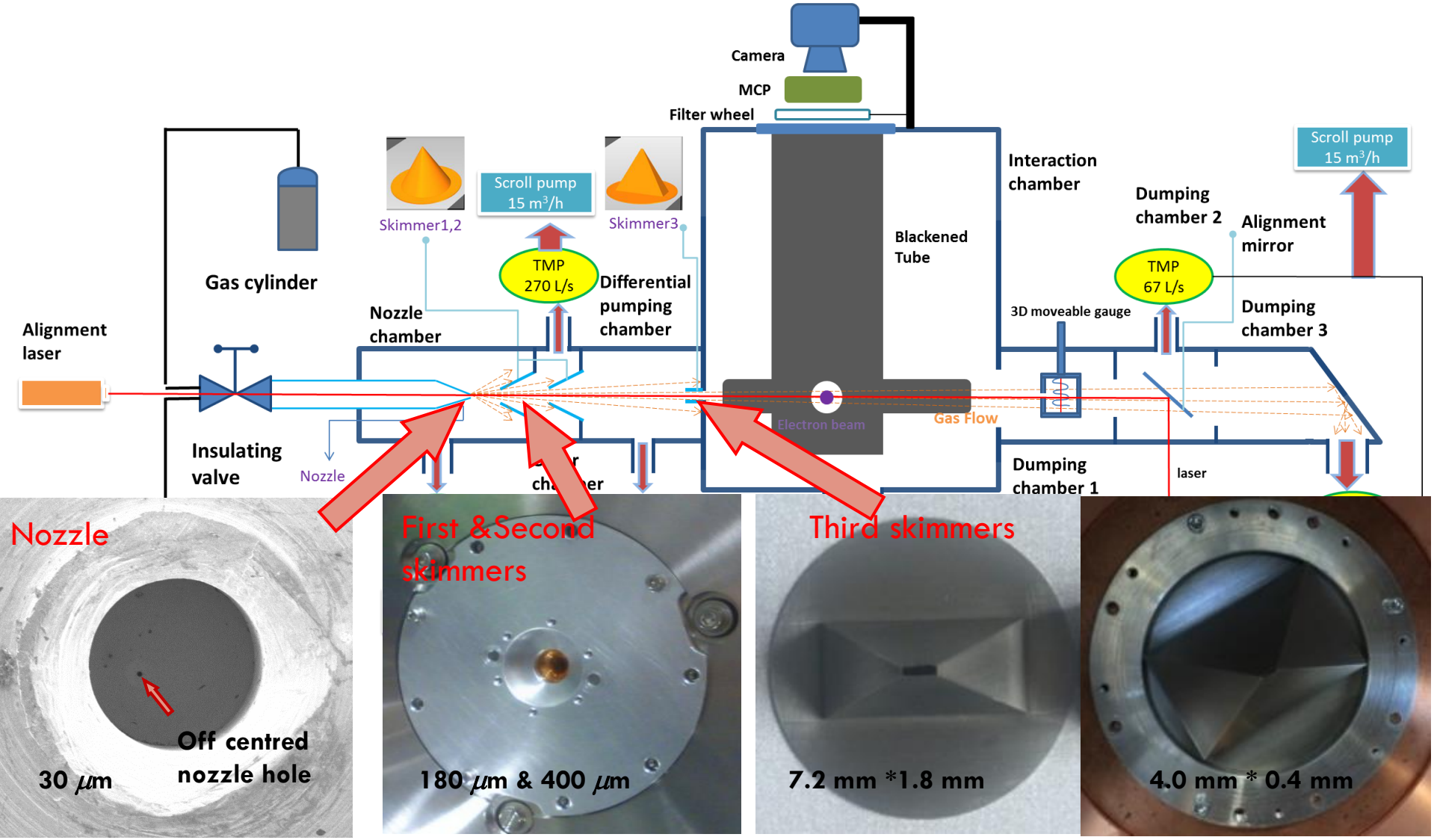
BIF monitor based on supersonic gas jet



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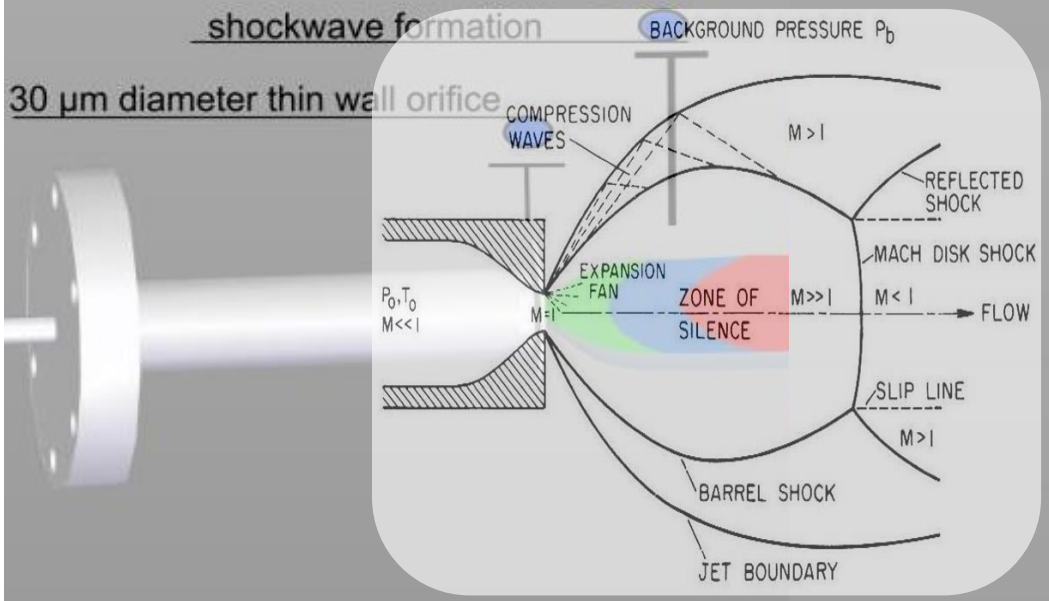
Generation of supersonic gas jet



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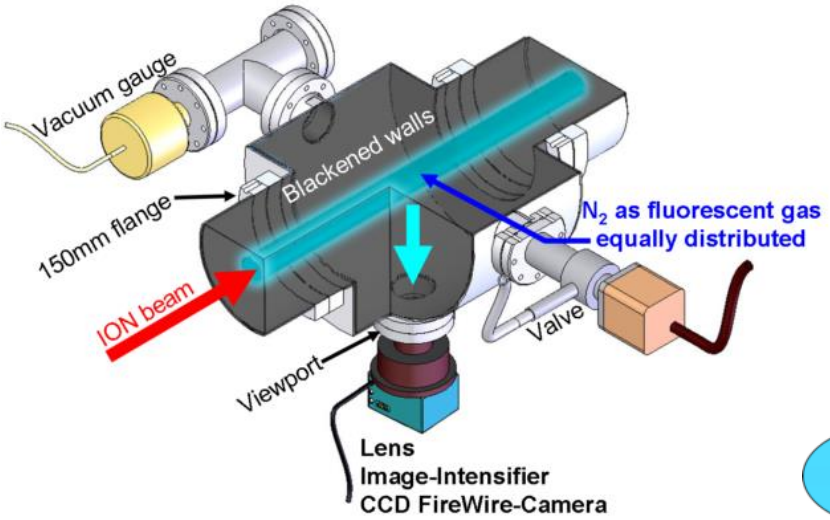
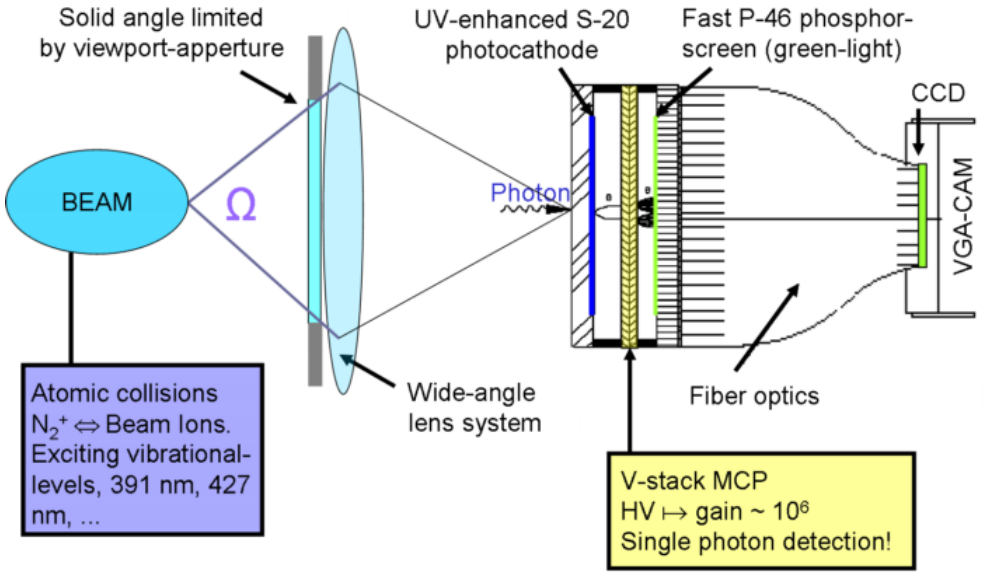
Beam induced fluorescence mode



Schematic drawing of the BIF-monitor as installed at GSI UNILAC. *



BIF detection principle - How the beam induced fluorescence light is imaged, intensified and detected.*

Advantage of using gas jet: No need to use leaking valve to increase the chamber pressure.

*Credit: GSI, http://www-bd.gsi.de/dokuwiki/doku.php

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N_2 as working gas: excitation and emission

$$N_2 + p/e^- \rightarrow (N_2^+)^* + e^- + p/e^- \rightarrow N_2^+ + \gamma + e^- + p/e^-$$

Leads to the electronic transition $B^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+$ of the molecular ion with wavelengths around 391 nm, depending upon involved vibrational and rotational states

$$N_2 + e^- \rightarrow (N_2)^* + e^- \rightarrow N_2 + \gamma + e^-$$

Drives the electronic transition $C^3\Pi_u \rightarrow B^3\Pi_g$ of the neutral molecule with wavelengths around 337 nm. This process cannot be initiated directly by protons because it implies a spin flip mechanism: the upper $C^3\Pi_u$ state is a triplet one, while the ground state of N_2 is a singlet and total spin should stay preserved during excitation.

Credit: Serban Udrea, GSI

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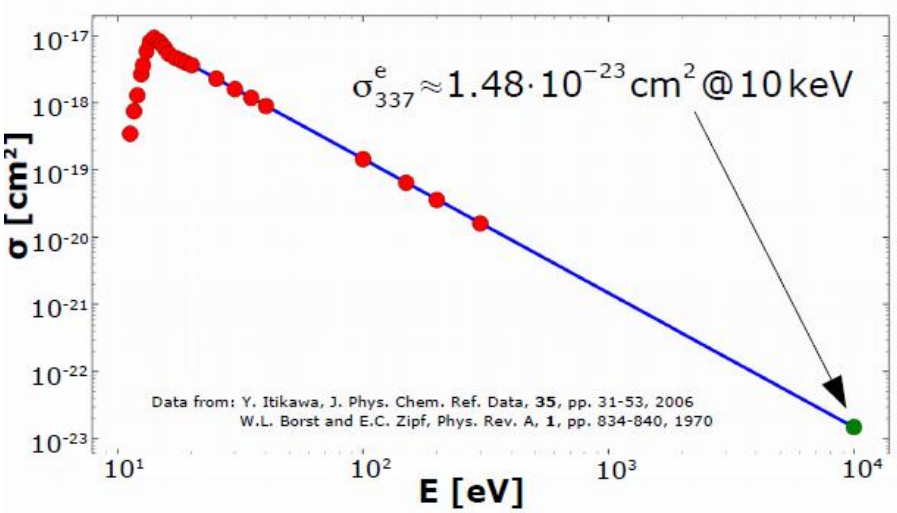
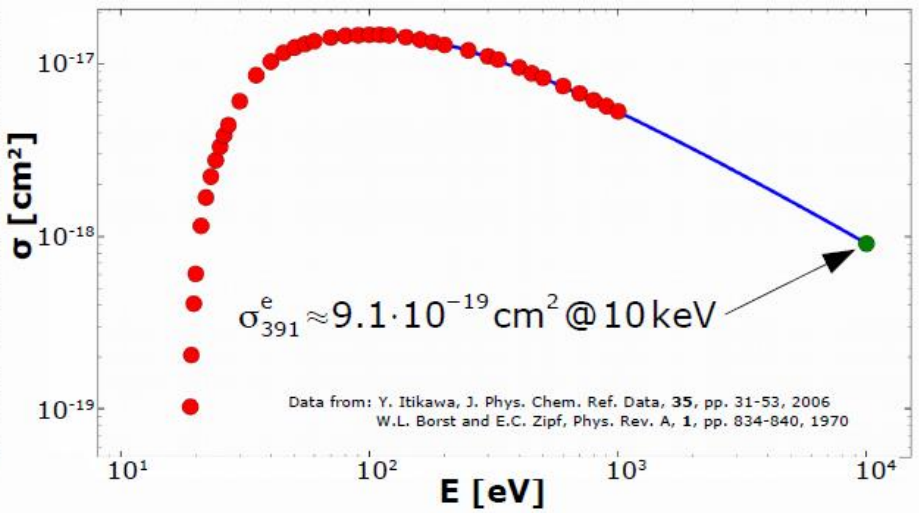
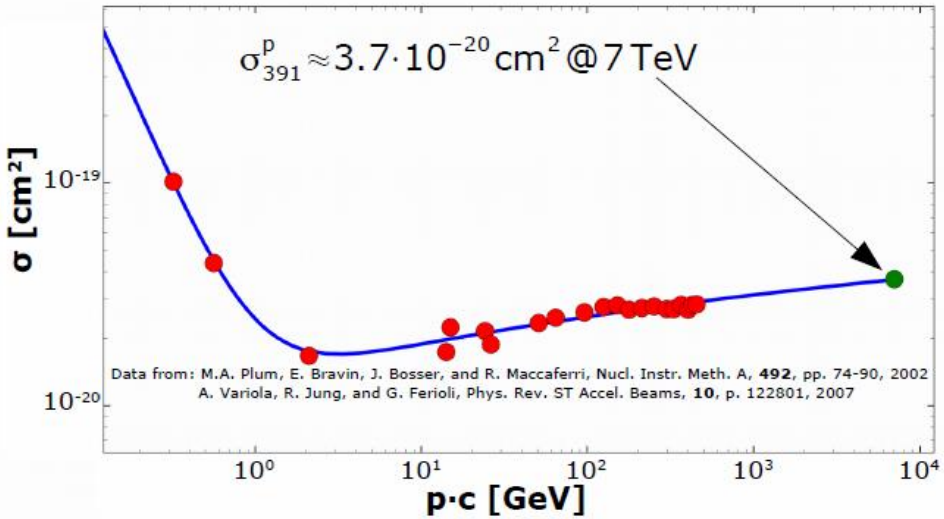
N_2 as working gas: cross sections







Credit: Serban Udrea, GSI

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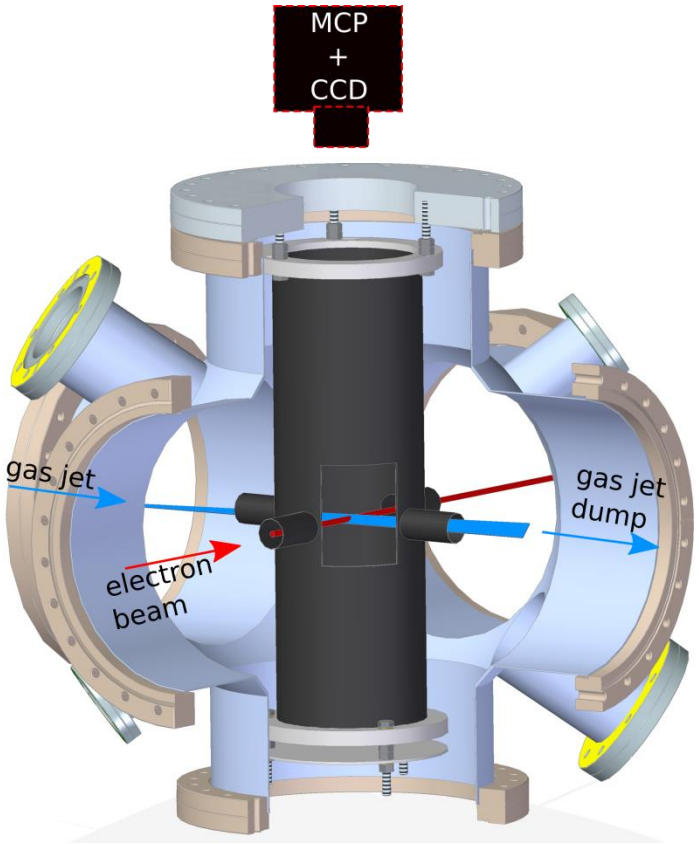
Details on the interaction chamber



Blackened firstly by a Germany Company and then applied another layer of Graphite

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

σ (cross section)	$9.2*10^{-19}$ cm^2
I (electron current)	~10 uA
n (gas jet density)	$2.5*10^{10}$ cm^{-3}
d (jet thickness)	2.8 mm
Ω(acceptance solid angle)	$4\pi \cdot 10^{-5}$ sr
η_{pc}(MCP photocathode efficiency)	0.2
η_{MCP}(MCP detection efficiency)	0.5
T(Transmittance of optics)	0.65
T_f(Transmittance of band pass filter)	0.3

$N_\gamma = 0.08*\Delta t$

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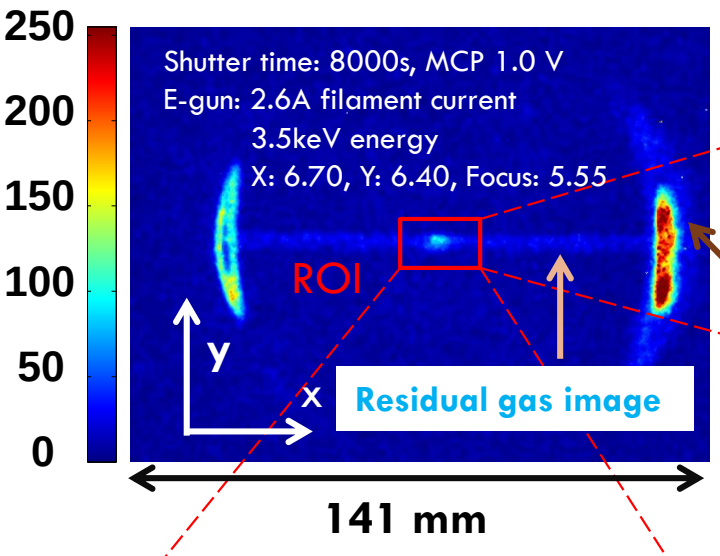
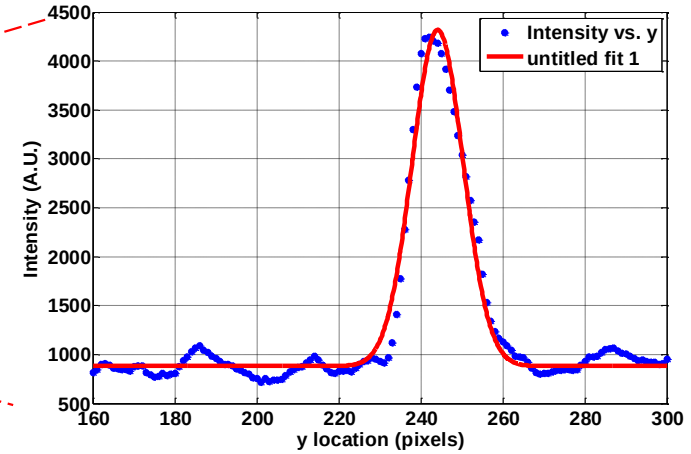
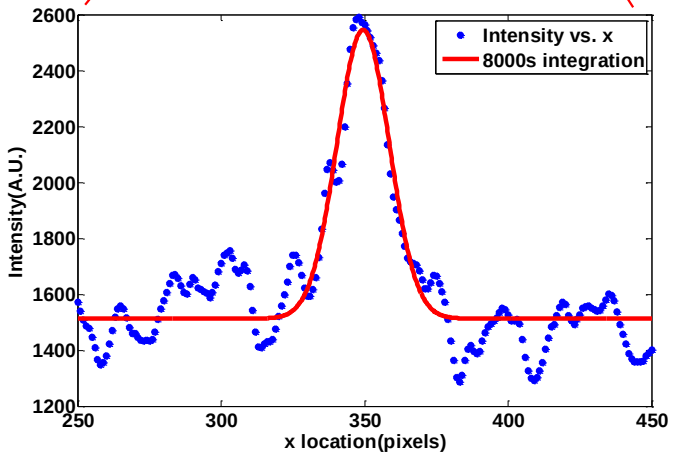
Gas jet image from fluorescent



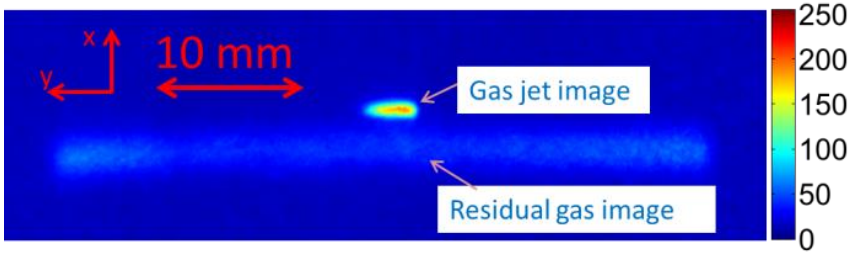
Reflection of the hot cathode or E-beam on the tube joint





Axis	BIF	IPM
Xrms	1.96 mm	1.2 ± 0.2 mm
Yrms	1.33 mm	0.4 ± 0.2 mm

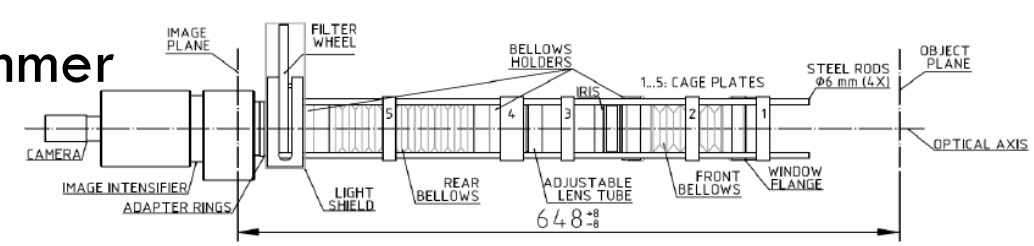
Compared to the Ionization mode



1pixel = 0.215 mm

Future improvement

- Recover from Lab move
- New E-gun parameter
  - I = 100 μA currently
  - Upgradable to 300 μA
- New optical system
  - Increase total transmittance and accepted angle by 5 times
- Integration time can be reduced ~50 times
- Using smaller size 3rd skimmer
  - Smaller jet width, better resolution
  - But increased integration time



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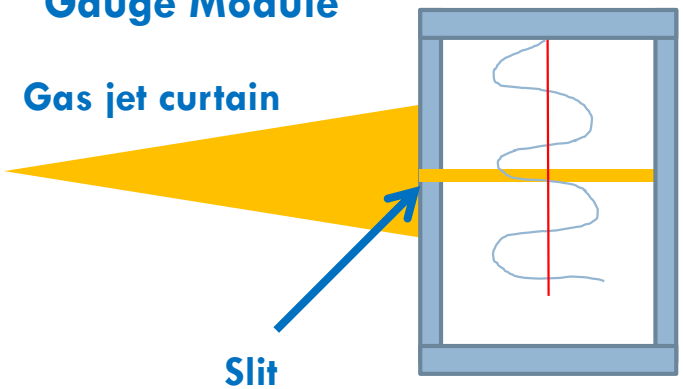
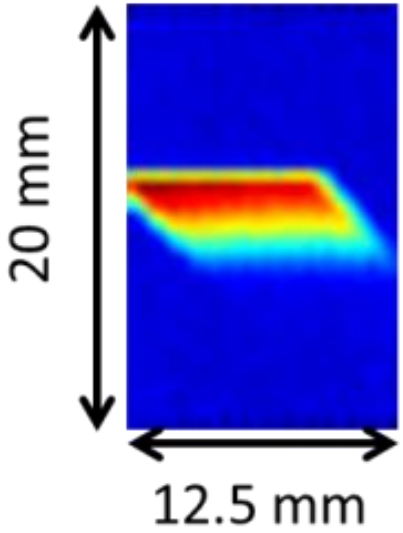
Gas density measurement

Compression Gauge Module

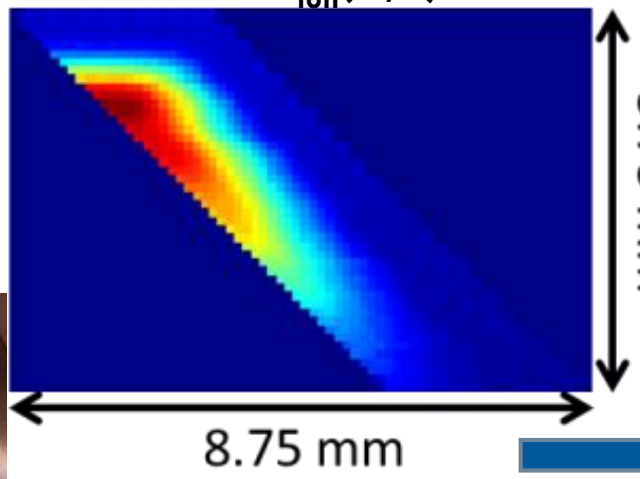




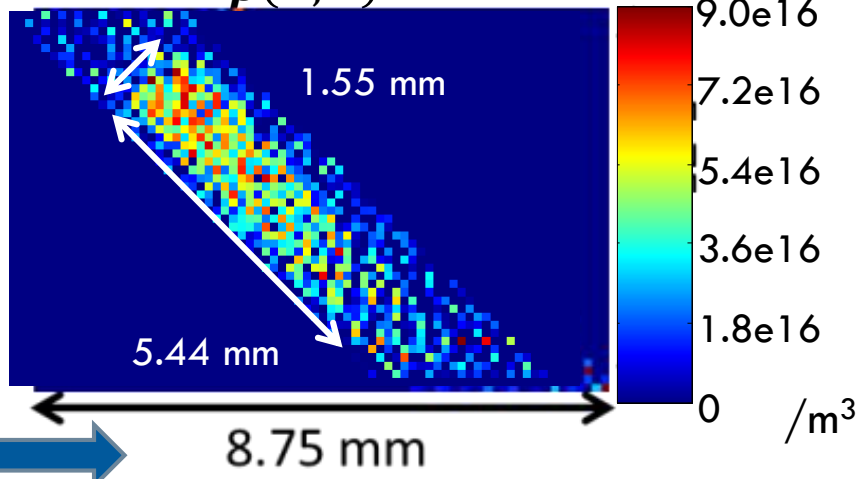
Current reading I_{ion} from ion gauge
By 41*26 pixel (pixel size is 0.5 mm)

$$\rho(X,Y) = -\frac{1}{I_e S v L_y}\frac{V}{k_B T}\frac{d}{dX}\frac{dI_{ion}}{dt}(X,Y)$$

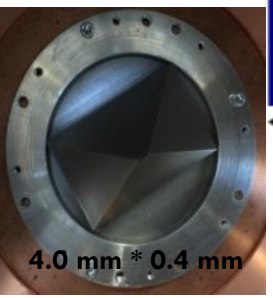
$I_{ion}(X,Y)$



$\rho(X,Y)$



46*25 edge pixel (pixel size is 0.125 mm)



Differentiate the data in horizontal axis

Jet size in interaction point is estimated as : 4.66 mm *0.92 mm

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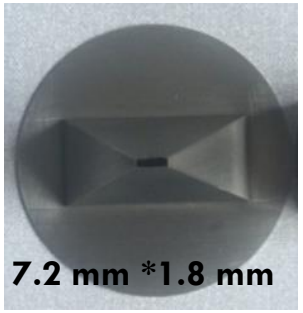
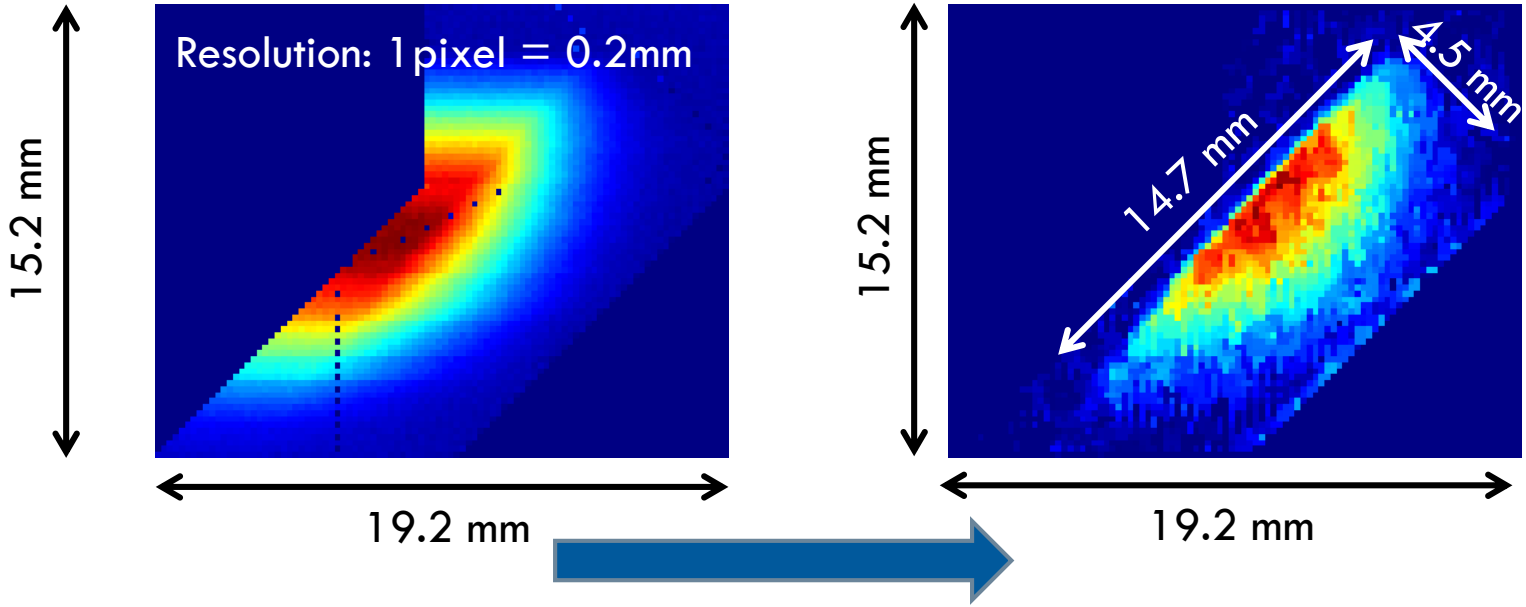
Edge scan (large skimmer)

Skimmer size	7.2×1.8 mm²
Oriental angle	45°



$I_{ion}(X,Y)$ $\rho(X,Y)$



Differentiate the data in horizontal axis

Jet size in interaction point is estimated as : 10.03 mm * 2.81 mm

$\sigma_{jet} = 0.99$ mm

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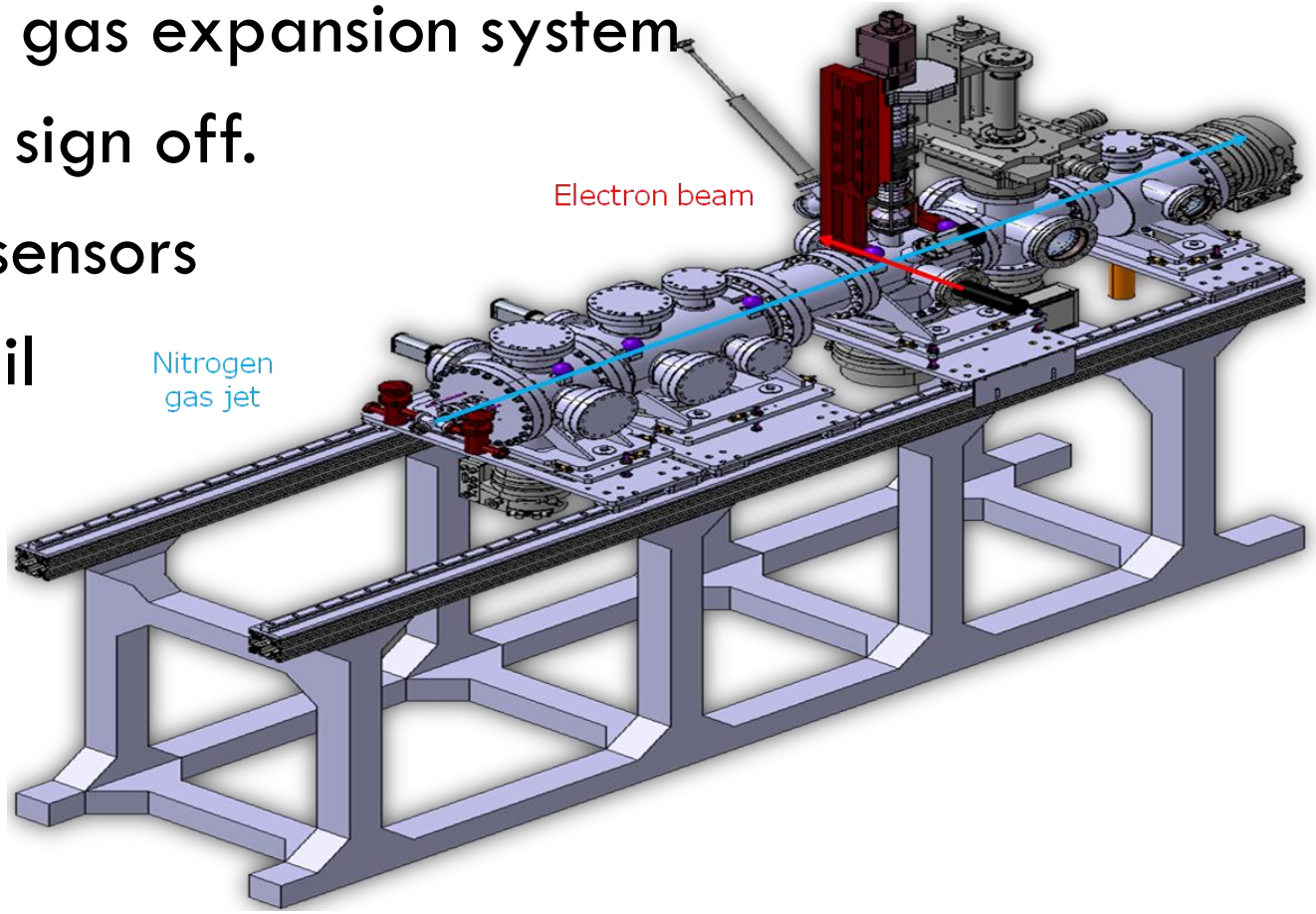
Design of the new gas jet monitor

- Optical system is ready.
- Vacuum chambers are under manufacturing.
- Drawing for gas expansion system is about to sign off.
- Pumps and sensors
- Rack and rail



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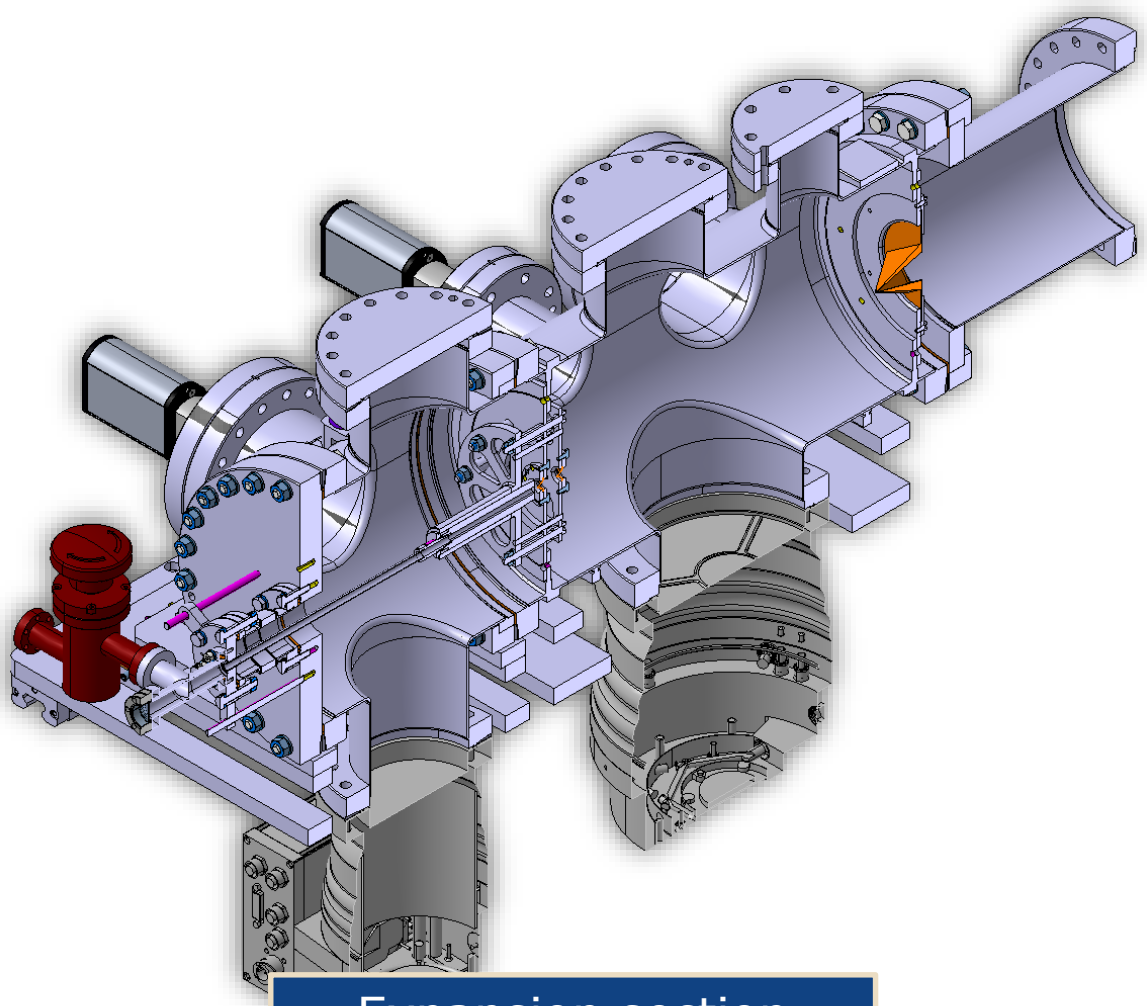
Elements of the BGC system



Expansion section

Credit: Elena Barrios Diaz, CERN

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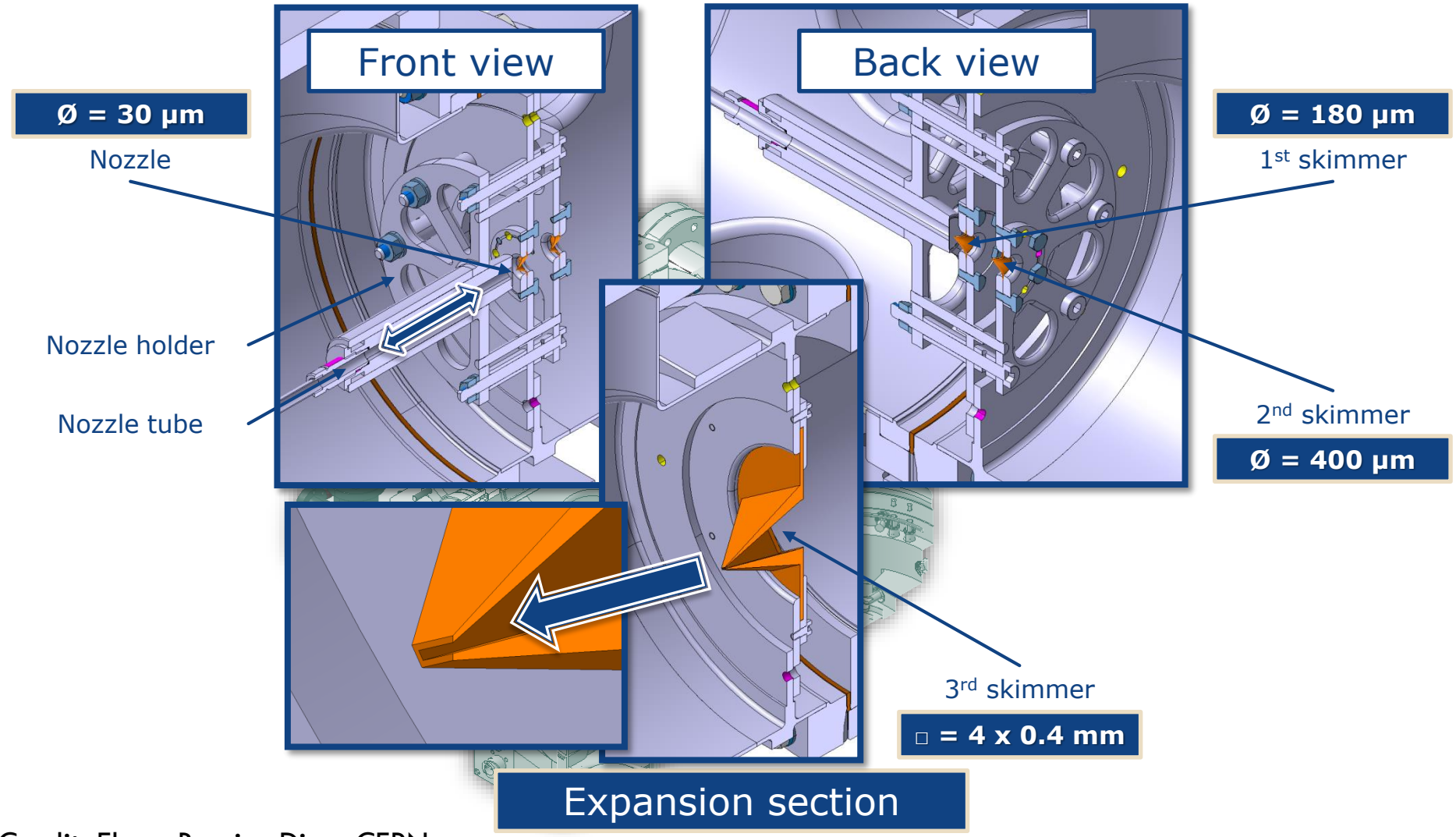

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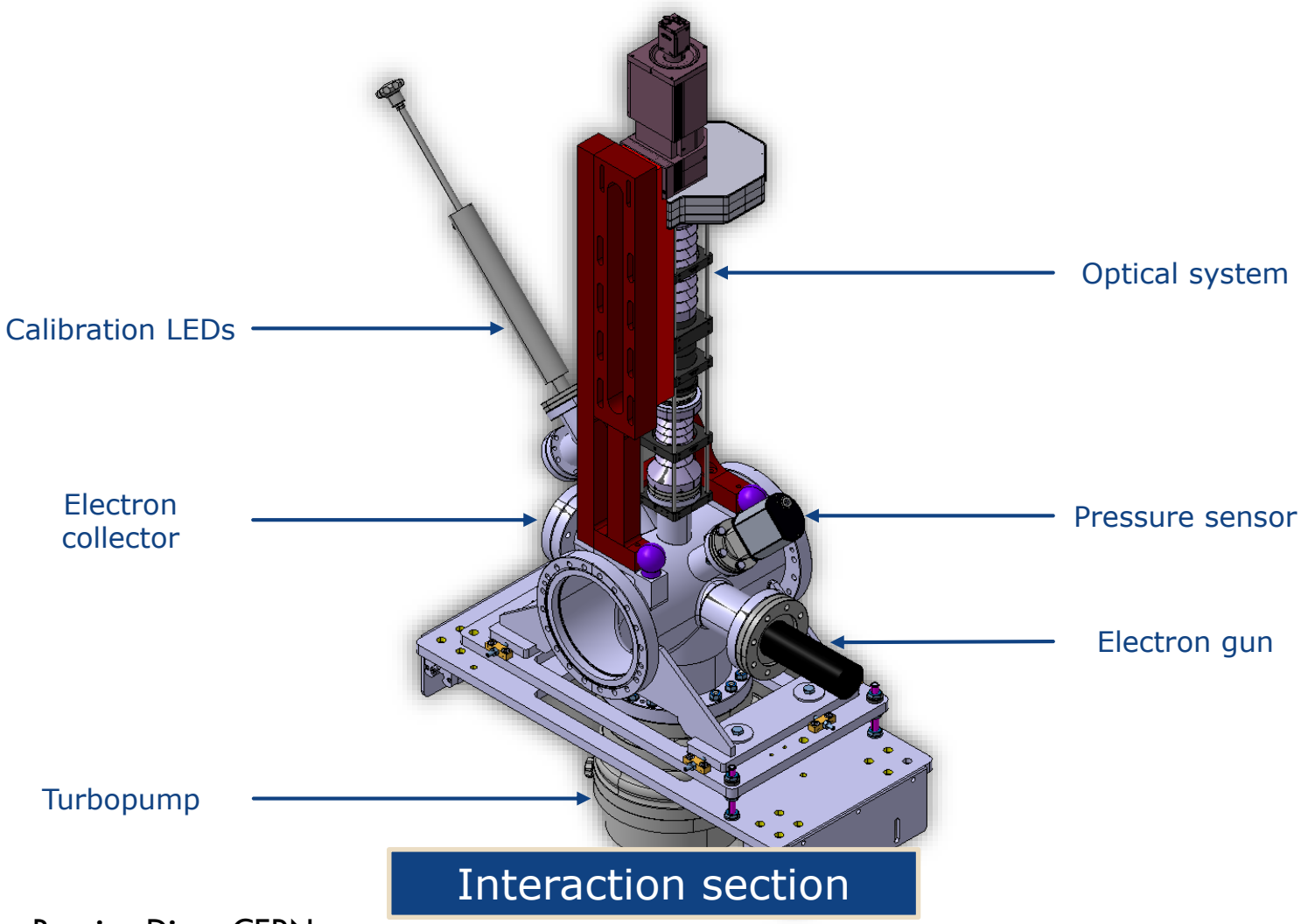

Credit: Elena Barrios Diaz, CERN

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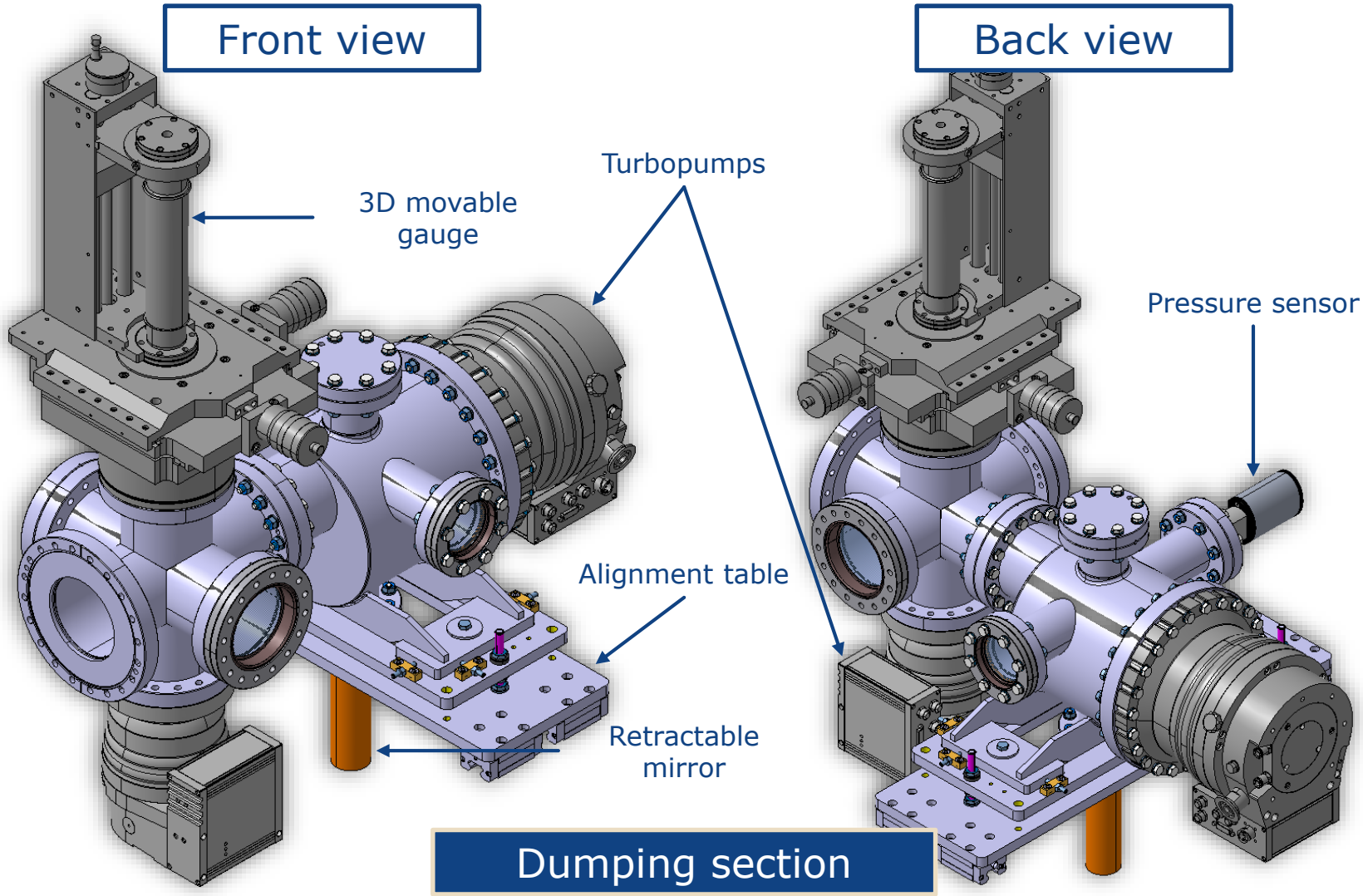

Credit: Elena Barrios Diaz, CERN

Conclusion

- Summary
  - We successfully use the supersonic gas jet to monitor beam profile in fluorescent mode.
  - The design of a second monitor is finished and sent out for manufacture.
  - Future study for improve the integration time and resolution is still undergoing.
  - Simulation about the gas dynamic is still needed to aim for beam requirement of the electron lens project.

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Thank you!

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