Development of gas-jet based diagnostics at the CI

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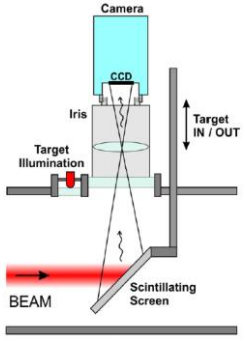
Diagnostics: Beam profile monitors

Intercepting method

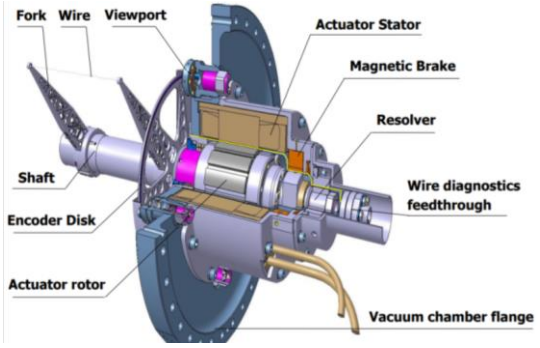
- **Scintillating screen**



phosphor
YAG, etc.

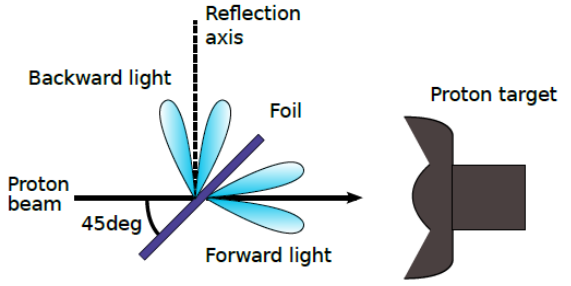
Credit: B. Walasek-Höhne, GSI and G. Kube, DESY

- **Wire scanner or slits**



Credit: B. Dehning et al., CERN

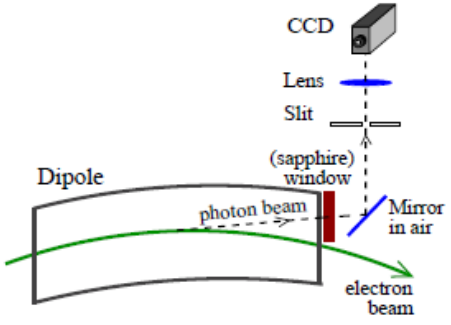
- **OTR**



Credit: D. Morris, et al., TRIUMF

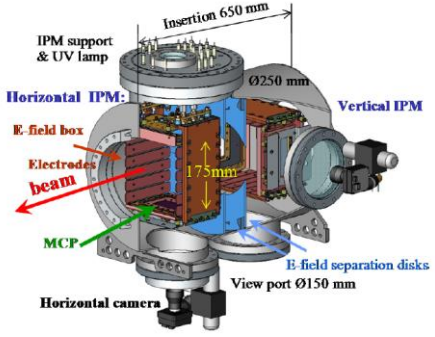
Non-Invasive method

- **SR**



Credit: U. Iriso and F. P´erez, ALBA

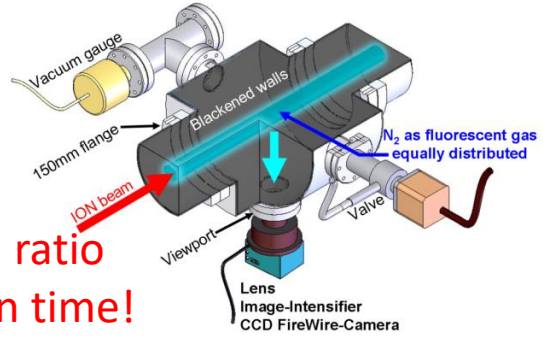
- **Residual gas based IPM monitor**



Credit: P. Fork, GSI

Resolution, S/N ratio
Long integration time!

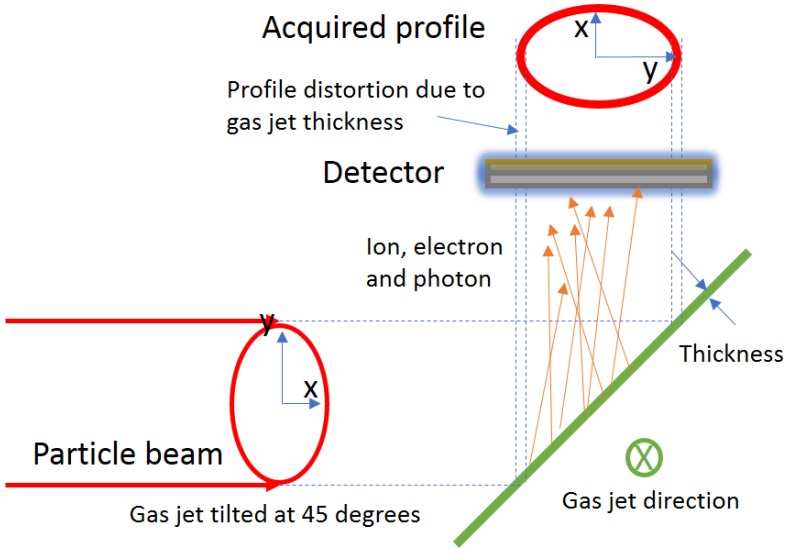
- **BIF monitor**



Credit: P. Fork, GSI

Gas jet based beam profile monitors

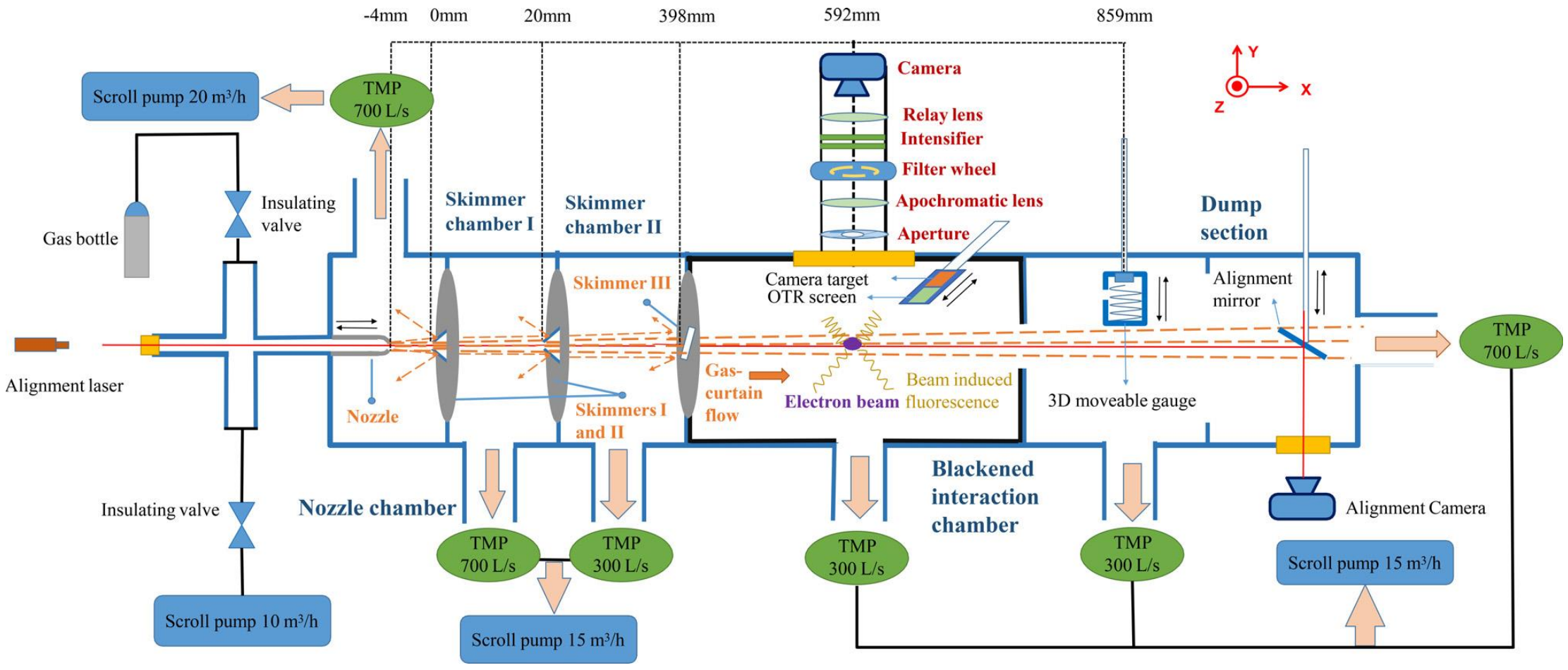
- Principle



Using a supersonic gas jet curtain

- Advantage
  - Non-Invasive
  - Minimum vacuum interference
  - 2D profile with high resolution
  - Versatile
  - Not affected by space charge (Neutral emitter)

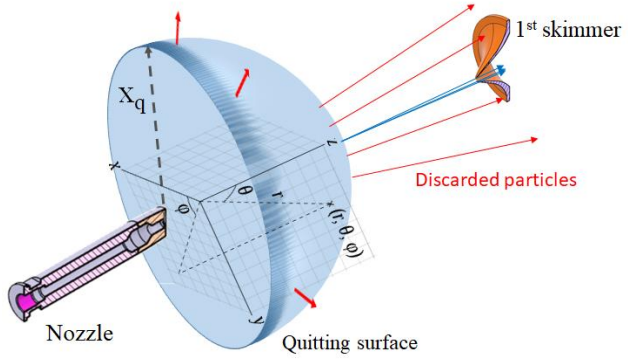
Gas jet monitor setup



Curtain simulation and verification

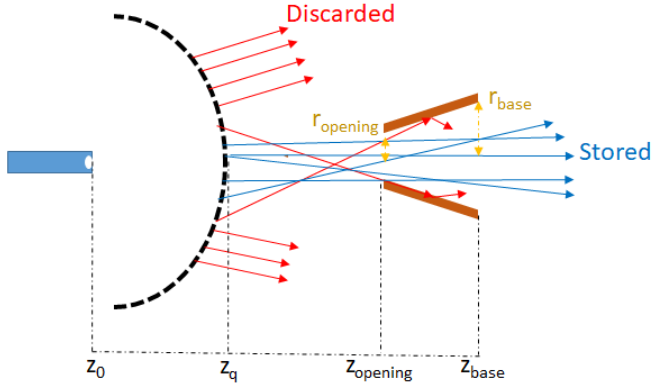
Continuous flow:

Quitting surface + analytical formular

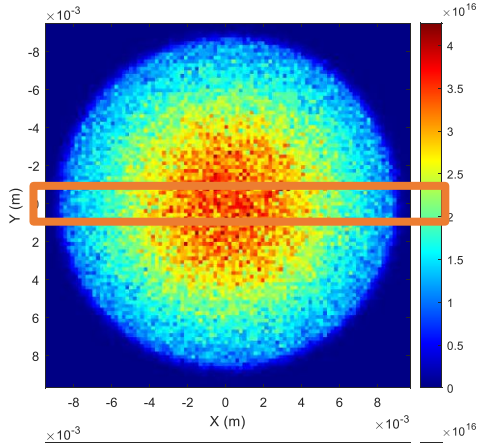


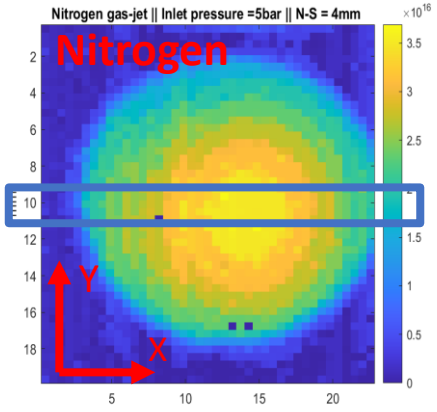
Molecular flow:

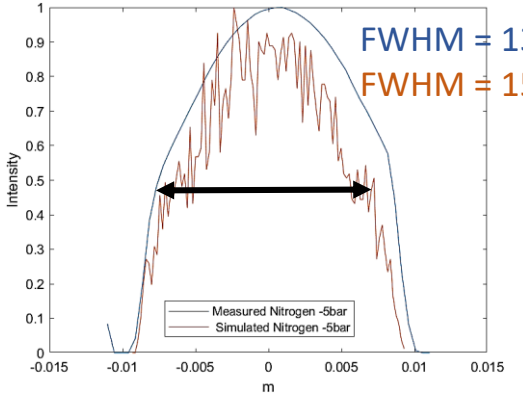
Particle ray tracing



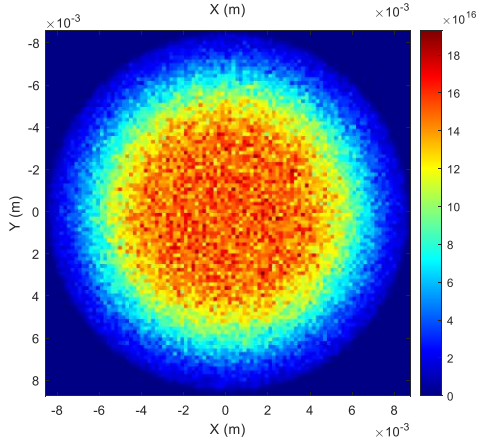
- ***Gas jet density distribution*** verified at 264 mm from nozzle:
  - **Nozzle : 30 µm; 1st Skimmer I : 180 µm; 2nd Skimmer: 2mm**

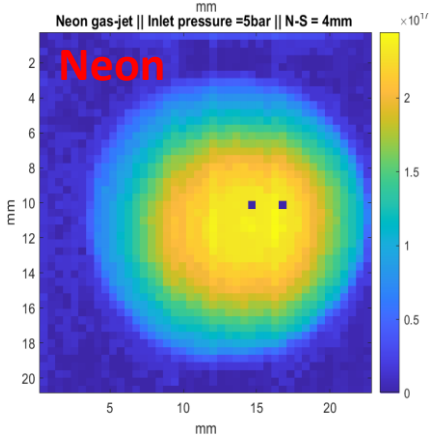


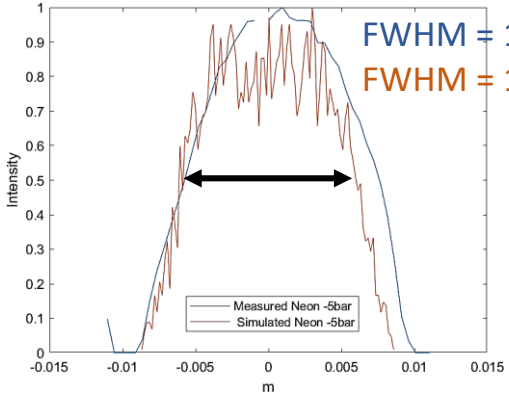




FWHM = 13.6 mm
FWHM = 15.8 mm







FWHM = 12.5 mm
FWHM = 13.3 mm

Beam profile Measurement

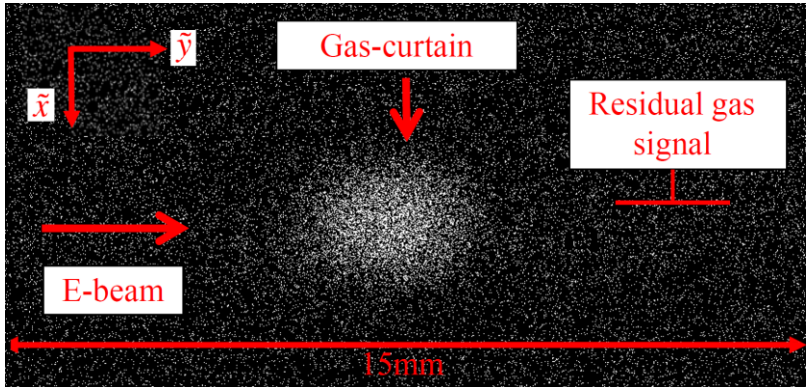
- IPM mode (See Narender's talk)
- BIF mode

Photon number

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

σ(cross section, N_2, 391 nm)	$9.2*10^{-19}$ cm^2
I (electron current)	0.66 mA
n (gas jet density)	4×10^{15} m^{-3}
d (jet thickness)	0.7 mm
Optical parameter	2.9×10^{-4}
Photon rate estimation	**49 ± 39 s^{-1}**
Photon rate measured	**18.0 ± 0.3 s^{-1}**

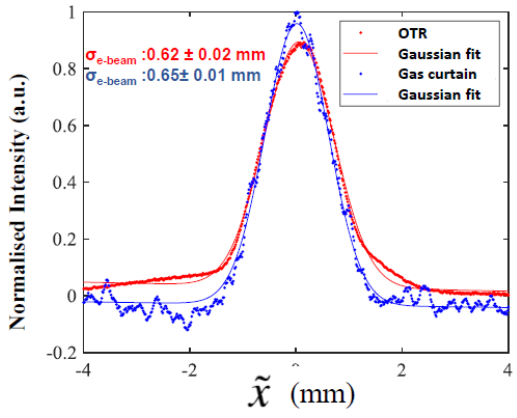
Measurement

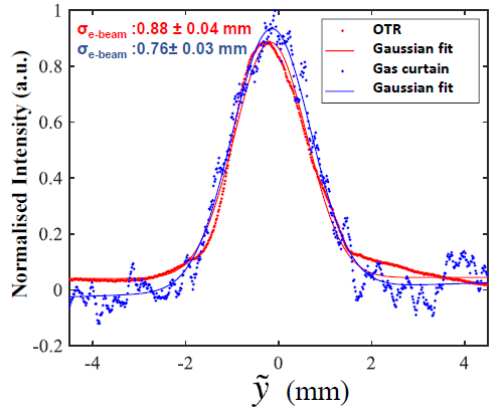


E-beam:
0.66mA, 5keV

Image:
200 frames with
2s exposure time each

Verified with OTR



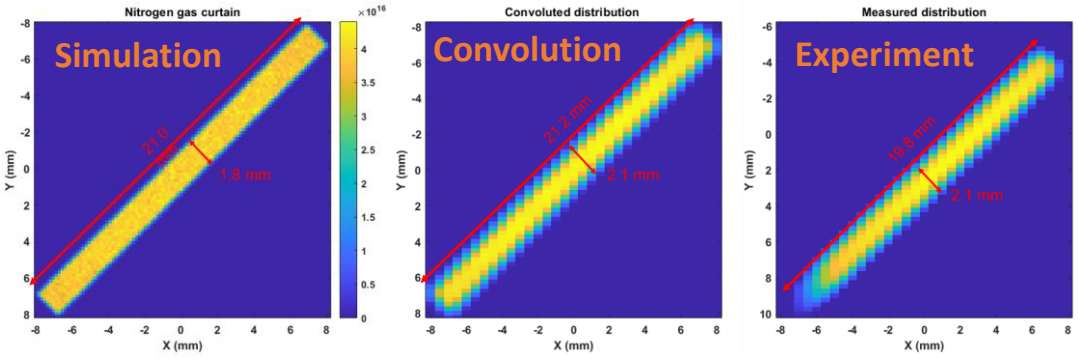


A. Salehilashkajani, H. D. Zhang, et al. Appl. Phys. Lett. 120, 174101

Design a monitor for LHC

Generate a uniform gas jet with 20 mm

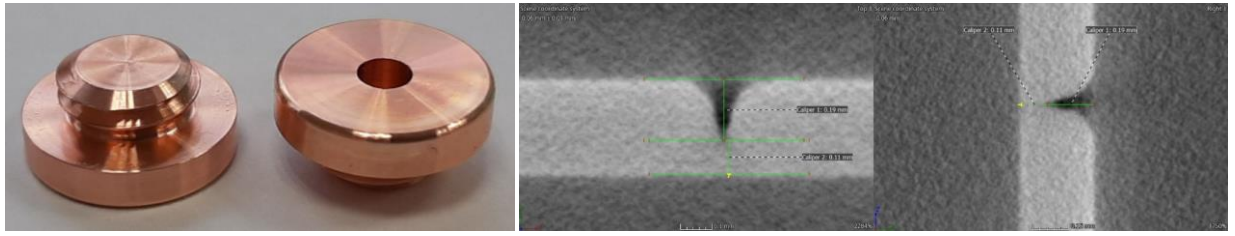
- Old configuration
  30 µm nozzle
  180 µm 1st skimmer
  2 mm 2nd skimmer
  9*0.7 mm² 3rd skimmer
- New configuration
  30 µm nozzle
  400 µm 1st skimmer
  2 mm 2nd skimmer
  9*0.7 mm² 3rd skimmer



Vacuum behaviour (when jet in on)

Nozzle chamber	Skimmer chamber I	Skimmer chamber II	Interaction chamber
5.56×10^{-3} mbar	1.13×10^{-5} mbar	1.52×10^{-6} mbar	$<5\times10^{-9}$ mbar

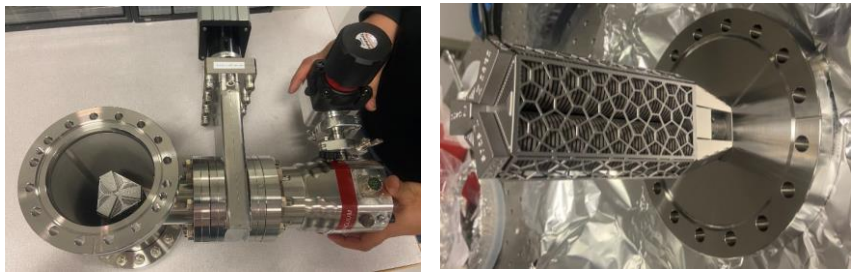
Nozzles testing



Credit: A. Cherif

Convergent-Divergent (CD) Nozzles

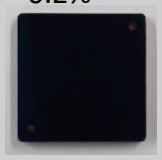
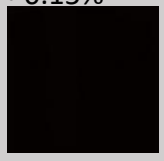
Replace TMP with NEG



For high B-field applications

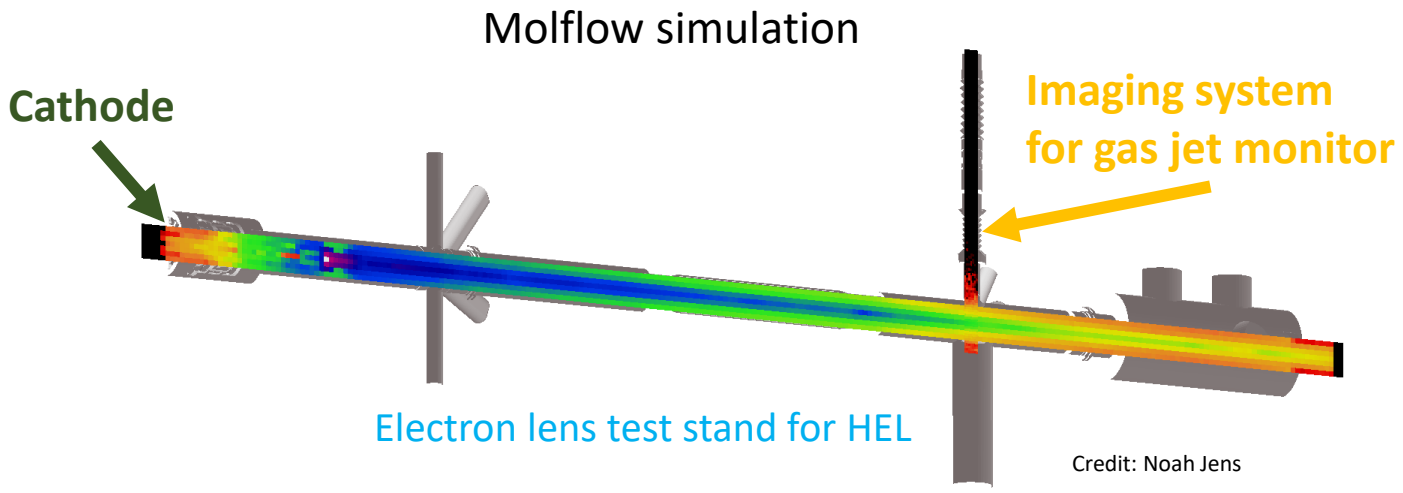
Noise reduction and stray photon estimation

Chamber blackening to reduce stray photons

	Amorphous carbon	LESS (Dundee)	Multilayer sputtering (Polyteknik)	Carbon nanotubes (Vantablack)
Copper	≈ 13% 	≈ 2% 	≈ 0.2% 	
Steel	≈ 14% 	≈ 2% 	≈ 0.2% 	≈ 0.15% 

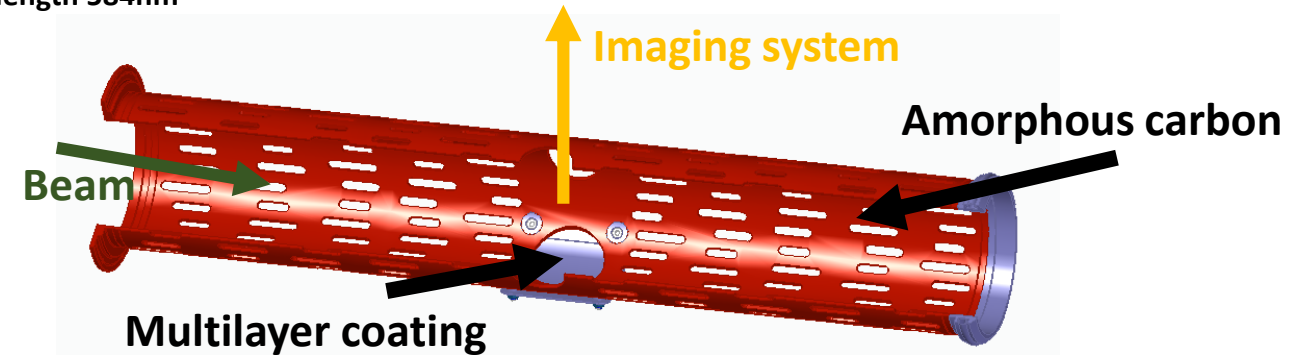
Reflectivity test at neon wavelength 584nm

Stray photons from cathode and Synchrotron light

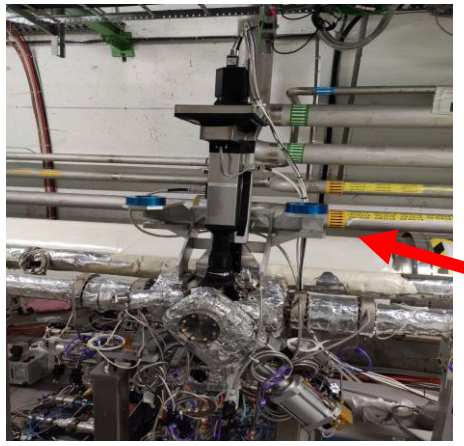


Conclusion:

- α-C coating used in the copper liner and the vacuum chamber with reflection of 10-15%
- Multi-layer optimized coating used under the interaction point with reflection of < 0.2%

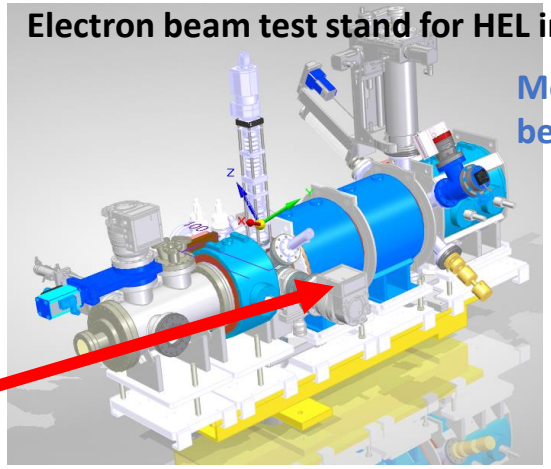


Gas jet monitor delivered to CERN

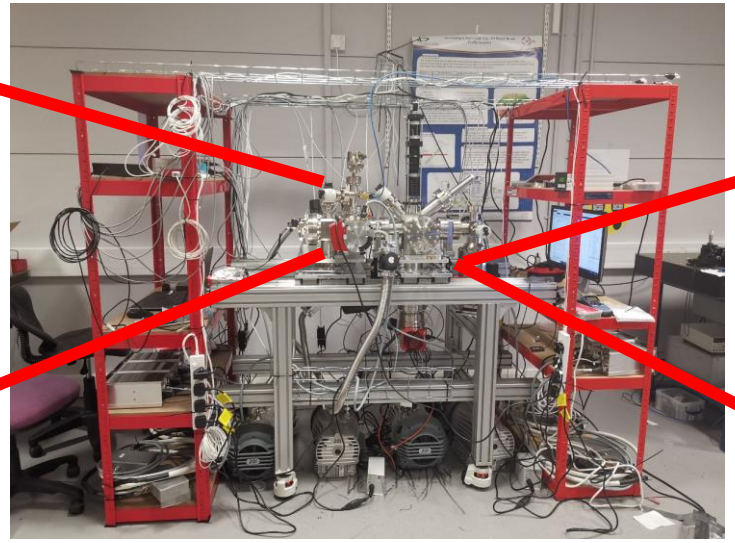


LHC installation during LS2
(interaction chamber and optics)
Measure beam profile using residual gas
& fluorescence cross section with 6.8 TeV beam

Electron beam test stand for HEL in Sep.



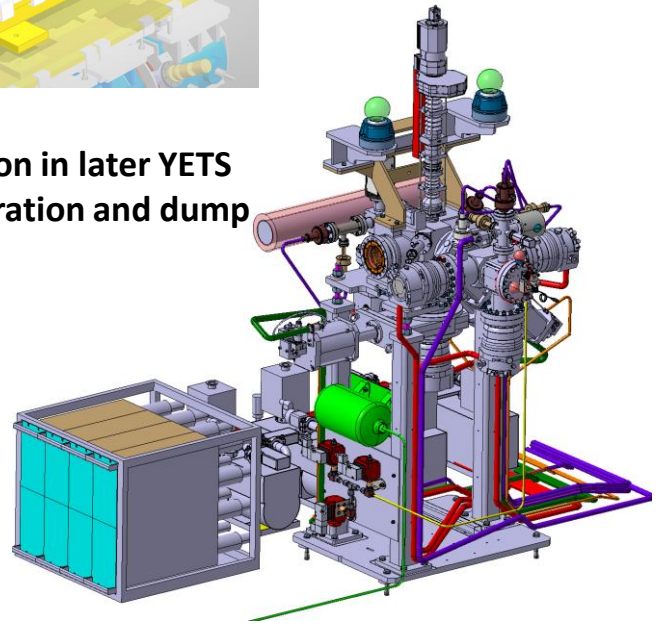
Measure hollow electron beam (test v4 concept)



V3 gas jet monitor in CI
See Oliver's poster for more details.

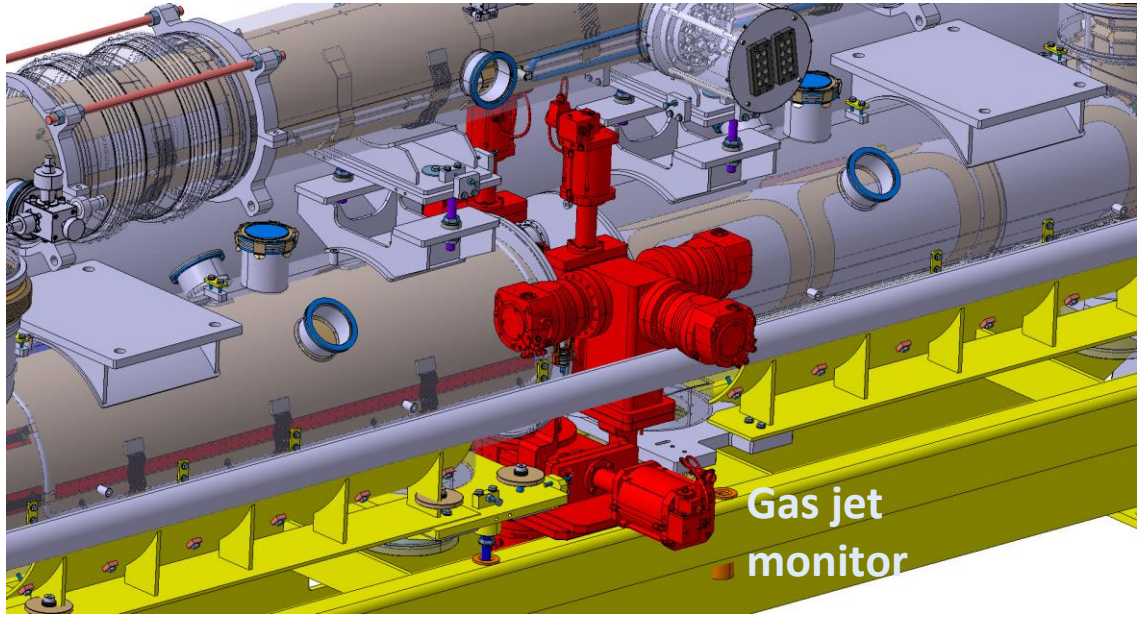
Standalone lab space in CERN
Validate CI result and vacuum compatibility test

LHC installation in later YETS
(Gas jet generation and dump chambers)

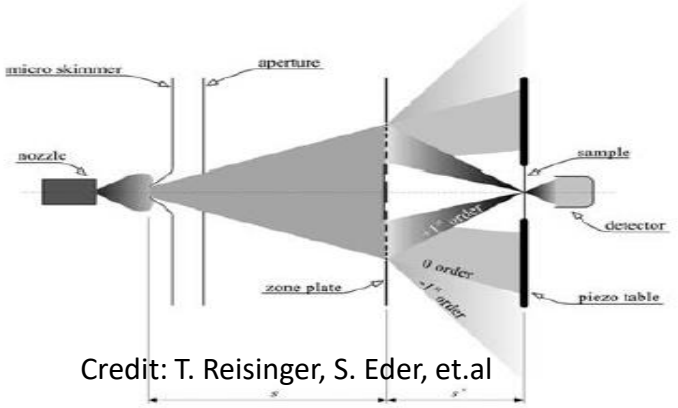


Ongoing work

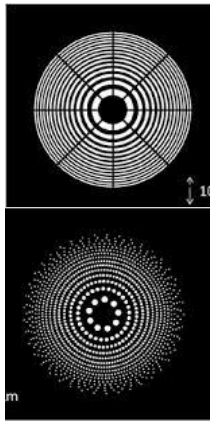
- Gas jet v4 for HLLHC (hollow electron lens)



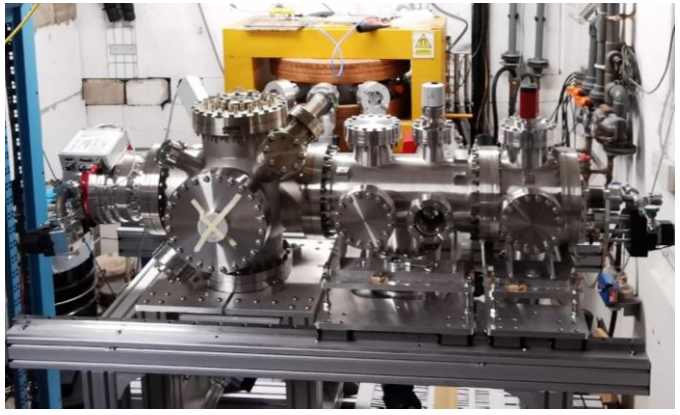
- qHAM & QuantumJet



Credit: T. Reisinger, S. Eder, et.al

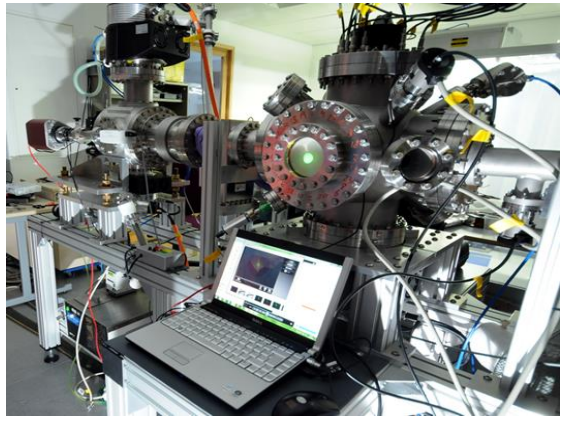


- JetDose (see Narender's talk)

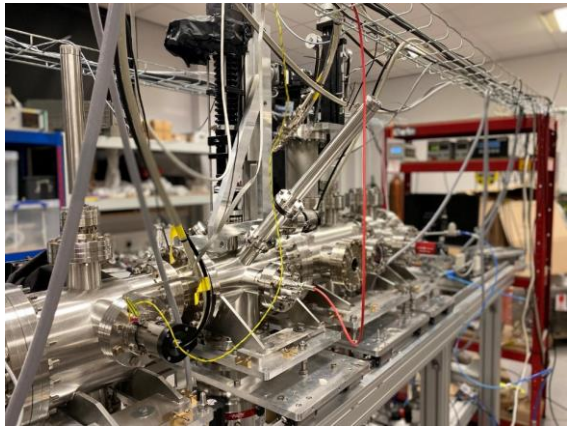


Conclusion

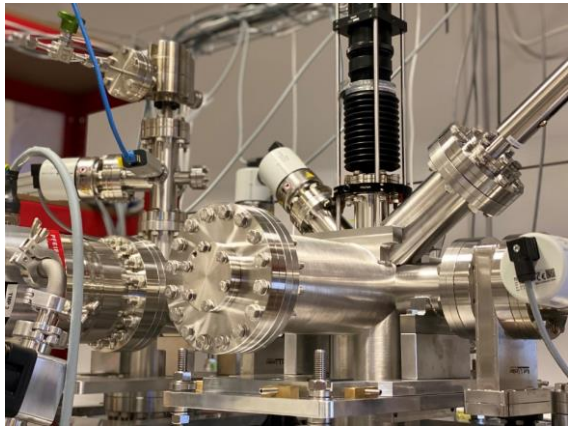
- Gas jet based diagnostics has
  - Developed over a decade at the CI from a lab test equipment to an accelerator module.
  - Been equipped with simulation and experimental tools for versatile design to meet different beam environment.
  - Expanded to wider applications such as Medical and Microscopy.



Monitor for keV beams



HLLHC prototype



HLLHC compatible instrument

Acknowledgment

I would like to thank the whole BGC team.

Any Questions?

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