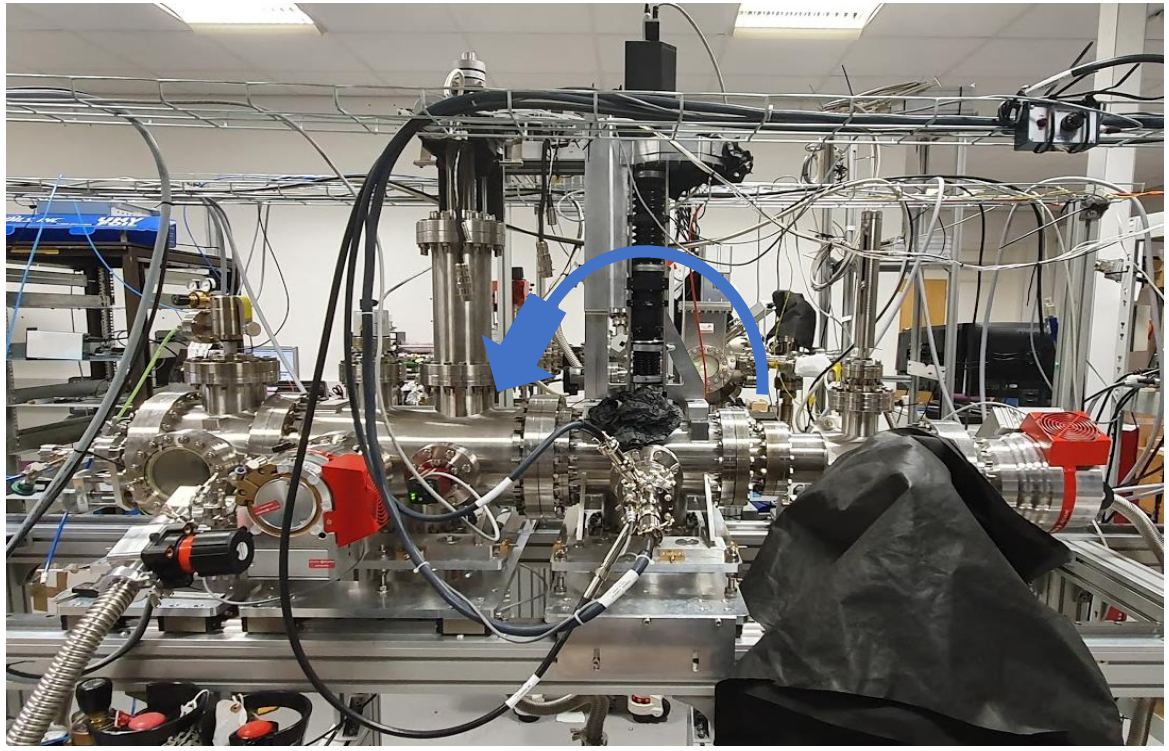
CI Experimental results and plan

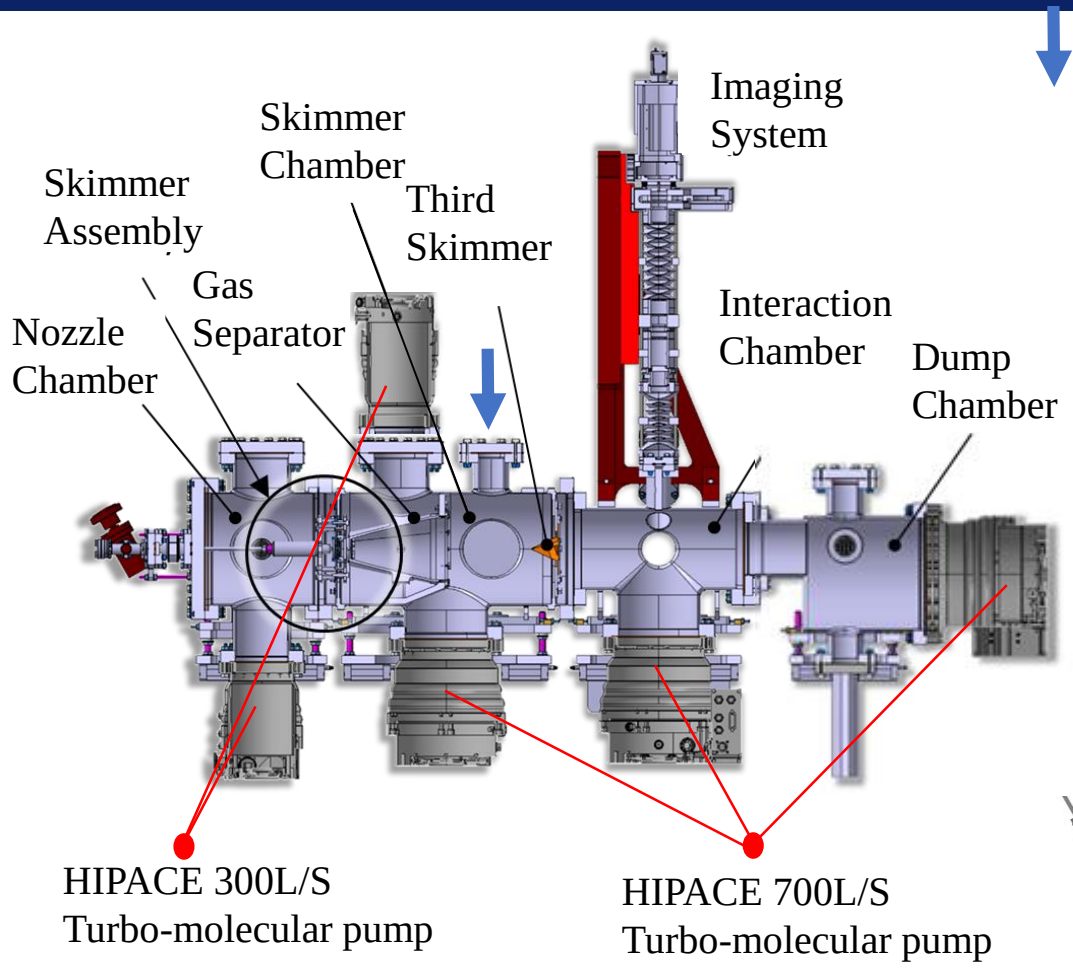
BGC CI team

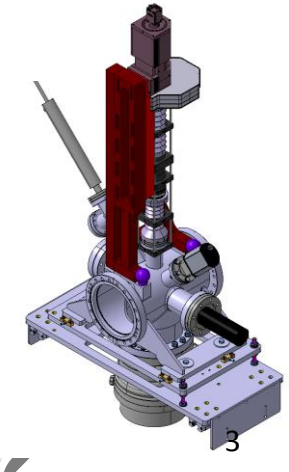
UNIVERSITY OF LIVERPOOL

Experimental result from CI in 2020

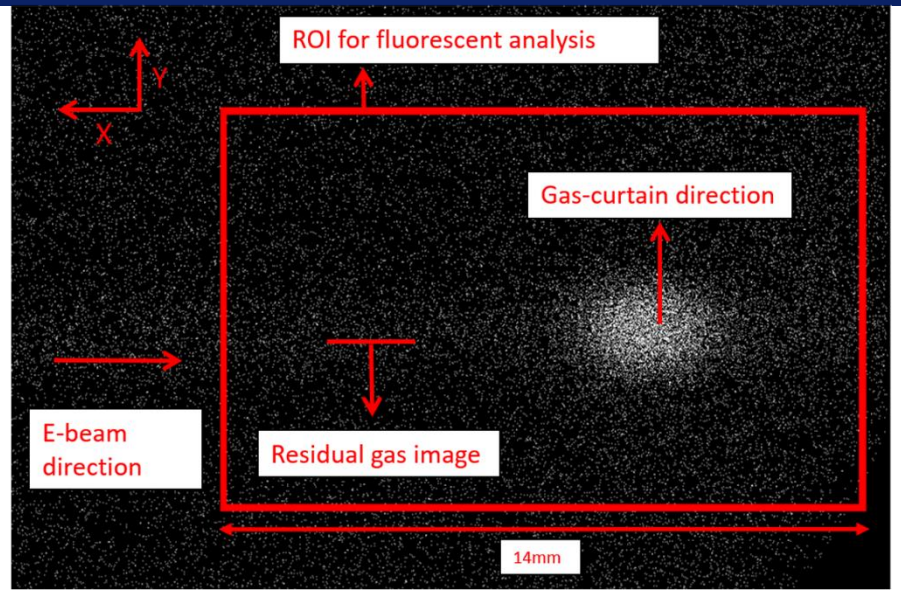
Prototype at the Cockcroft Institute



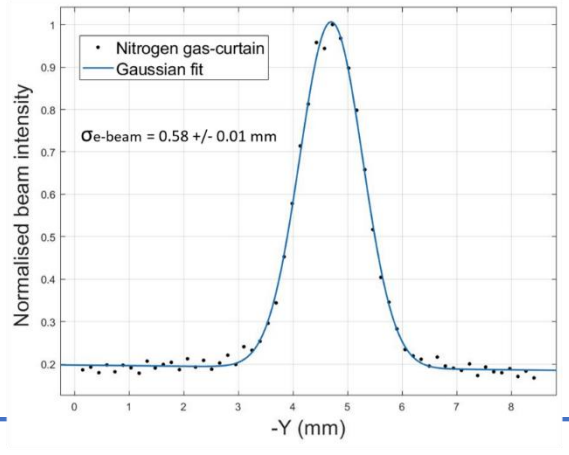




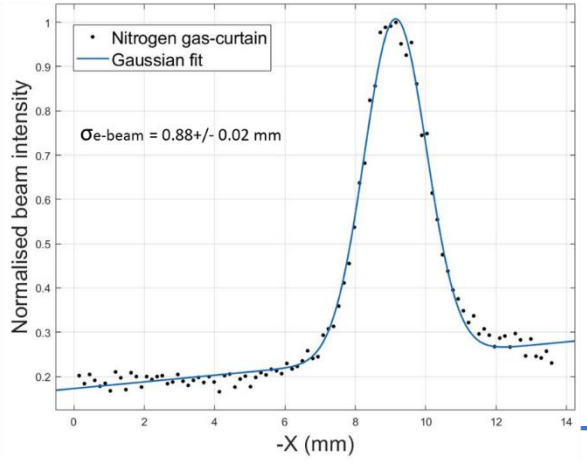
Fluorescence measurements



(a)



(b)

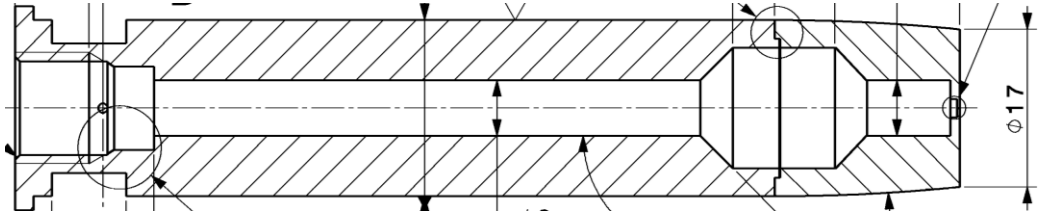


(c)

Brief review on nozzles

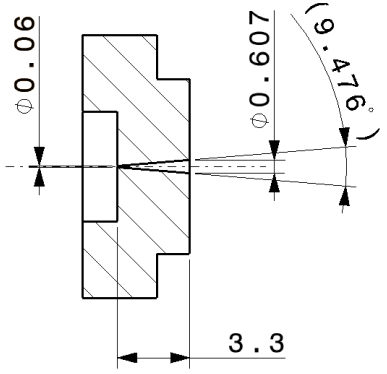
- Three nozzle types were tested at CI.

1. A one piece capillary nozzle (neck length: 100microns, opening diameter: 30microns). [November 2018]
   - This nozzle shows the highest gas-curtain density.
   - This design will be used for V3.



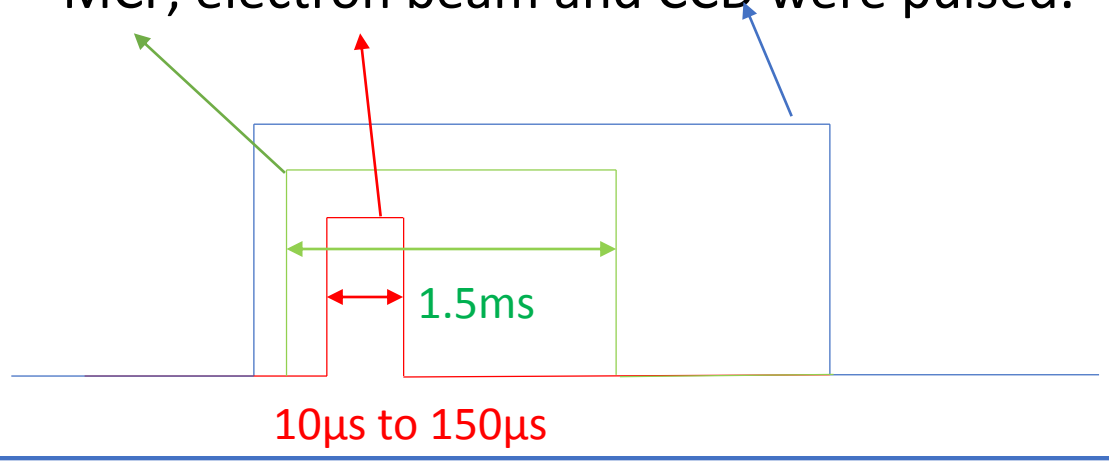
2. Three piece nozzle with interchangeable apertures (neck length: 15microns, opening diameter :20,30 and 50 microns.) [April 2019] [September 2019]
   - Apertures were prone to breaking.
   - Signal strength approximately 3-5 times lower than Nozzle I, at 5bar and optimum distance.

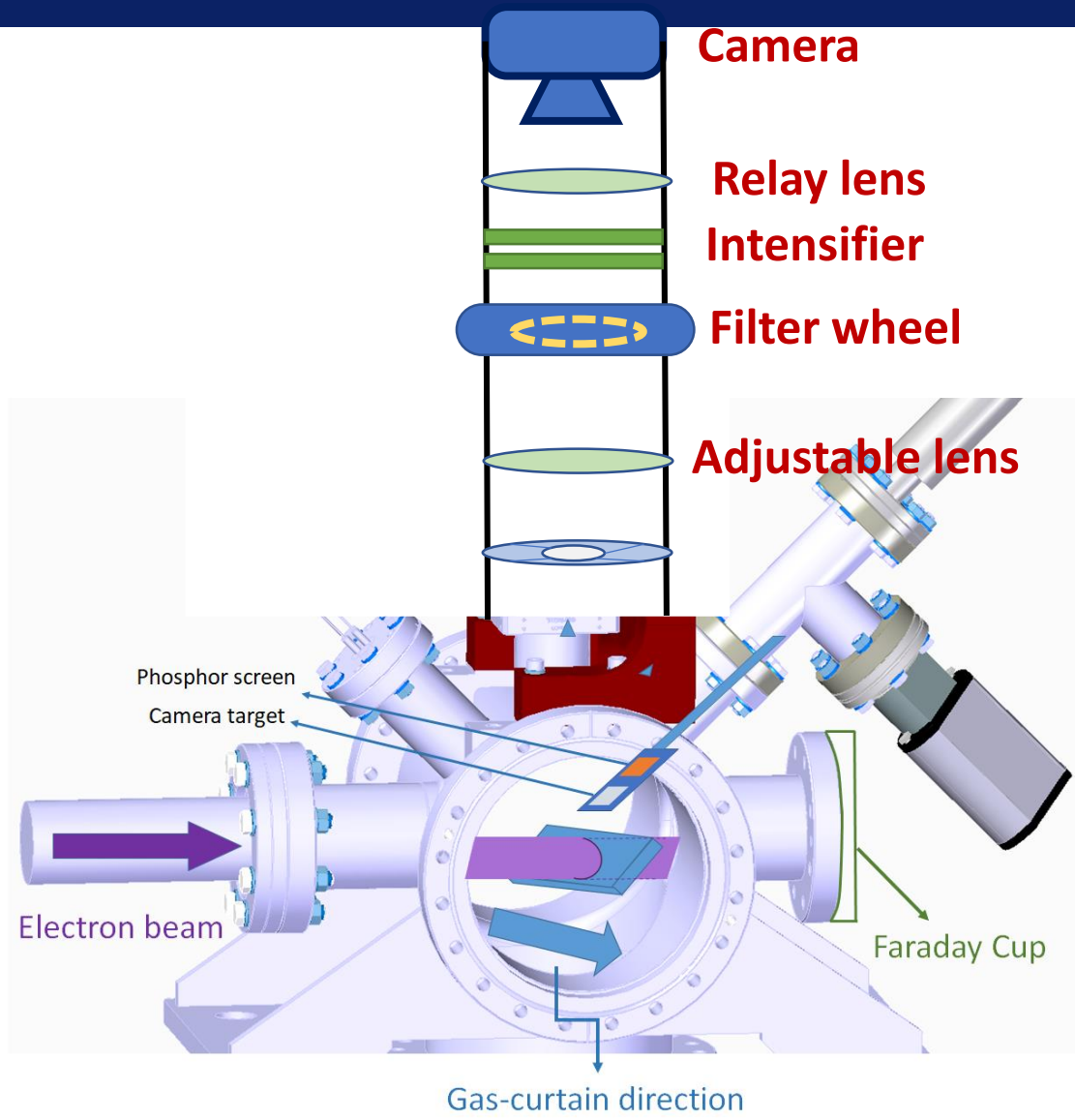
3. A flat-divergent nozzle (Opening diameter : 60micron) [October 2019]
   - High flowrate through the nozzle which results in increased pressure in the nozzle chamber.
   - Highest density observed with an Inlet pressure of 0.5bar, Nozzle skimmer distance : 7mm
   - Gas-curtain density 3 times lower compared to Nozzle I.
4. Convergent-divergent nozzle → to be delivered by CERN and tested by CI.



Phosphor screen measurements

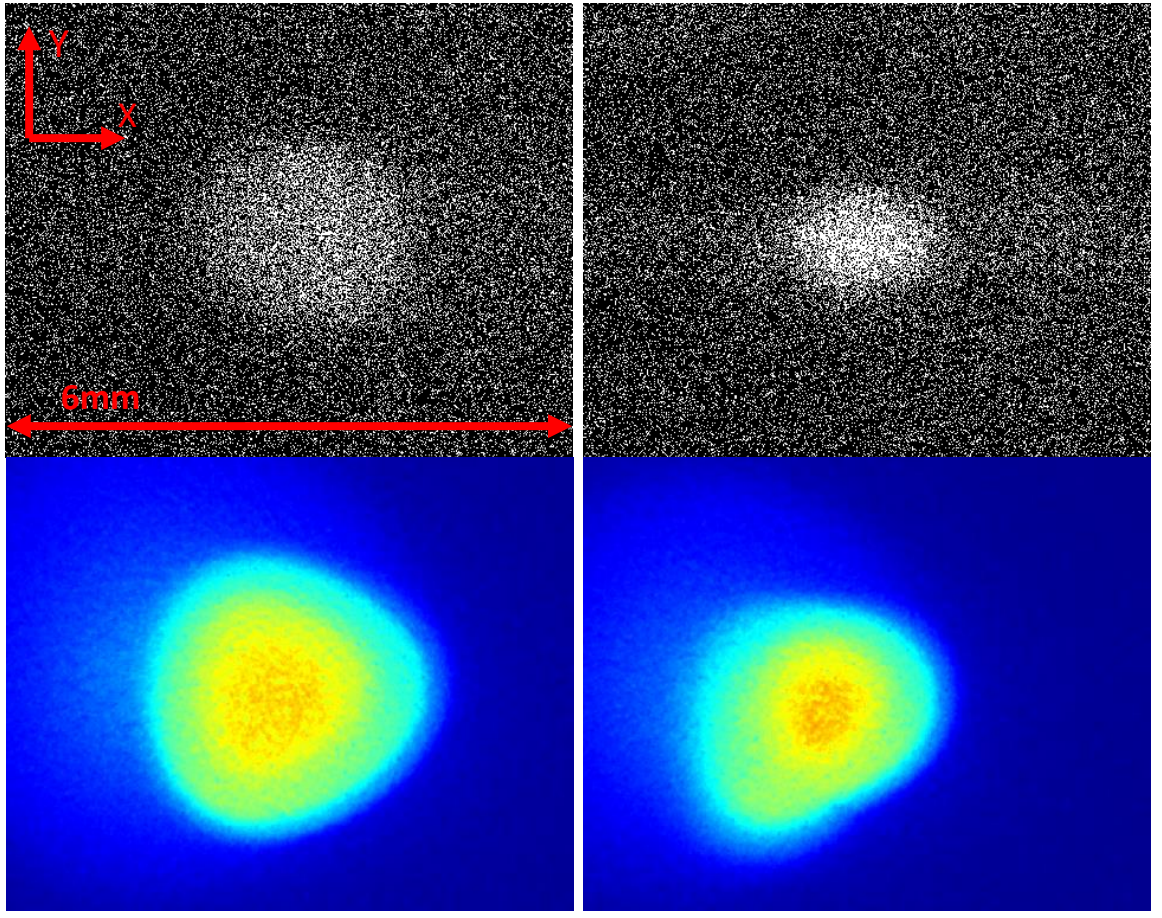
- The profile of the e-beam was also measured with a phosphor screen using the same optical setup.
- E-beam = 0.66mA at 5keV
- For gas-curtain measurements a continuous beam was used.
- For phosphor screen measurements MCP, electron beam and CCD were pulsed.





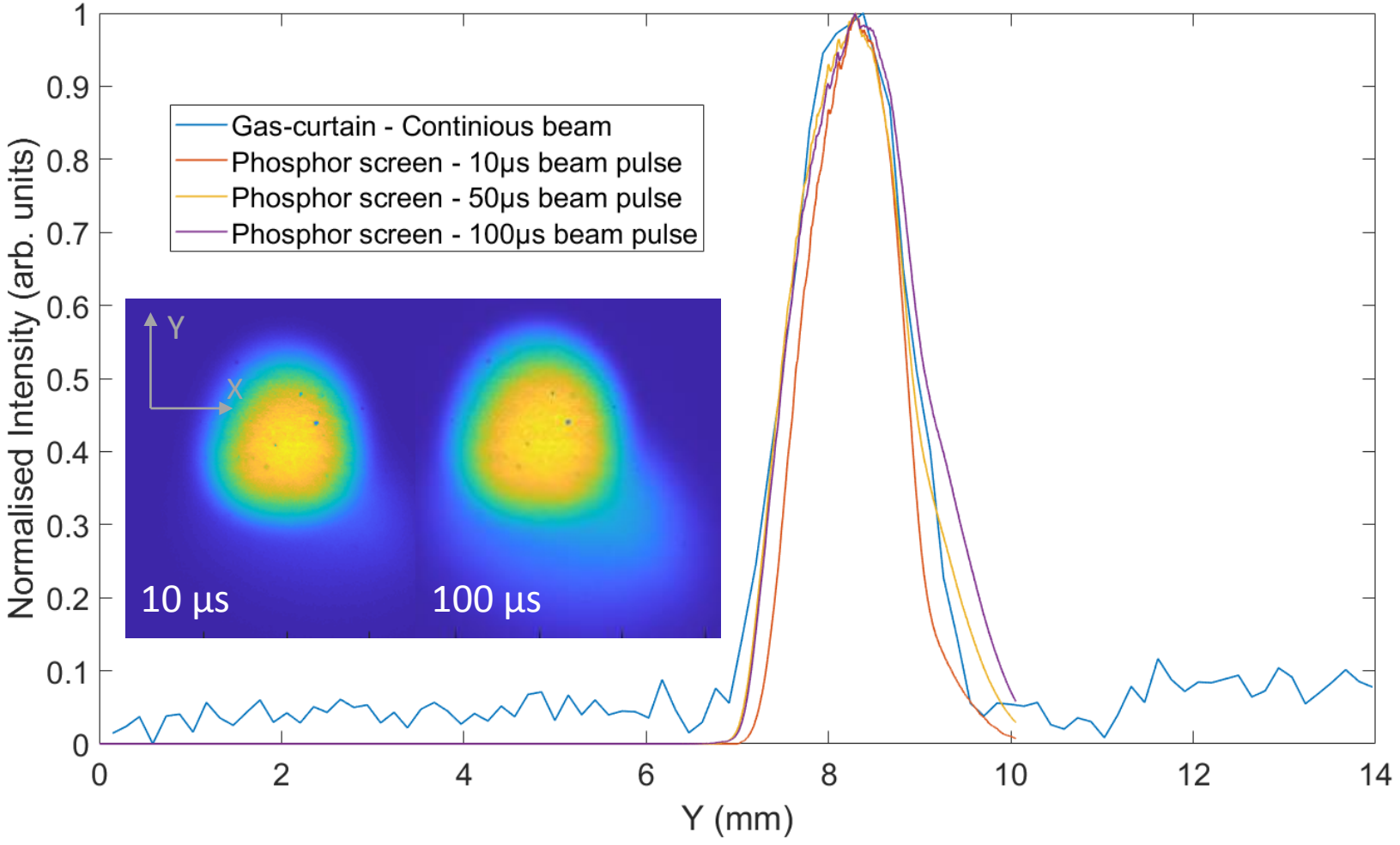
Phosphor screen measurements

- Two sets of measurements were taken for a beam that is focused at the interaction point and one with a larger FWHM.
- Results from a Nitrogen gas-curtain and the Phosphor screen are displayed here.
- We observed that the RMS of the beam, measured by the phosphor screen changes with the pulse-width.
- Even though the CCD was not saturated, it seemed like the MCP was.
- The intensifier was removed and the camera was placed directly on top of the filter wheel.



Defocused case | Normal settings

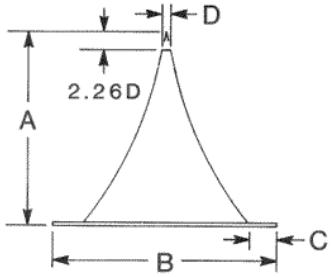
Phosphor screen measurements

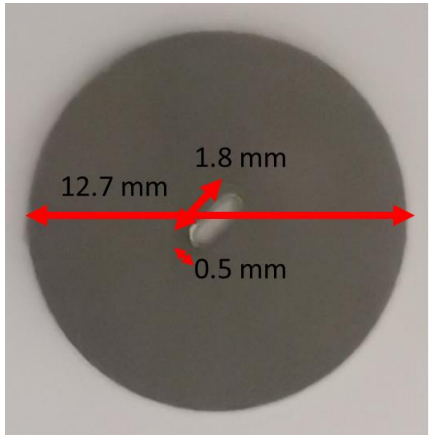


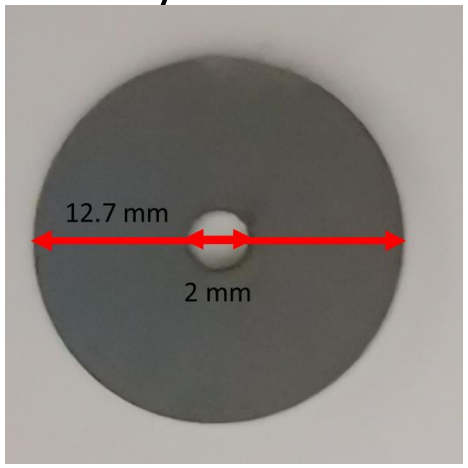
- Vertical profile of the e-beam measured by the gas-curtain and the phosphor screen are compared.
- Increasing the pulse duration of the e-beam increases the width measured by the phosphor screen. This is not yet fully understood. Possibly caused by gating the e-beam.

New 2nd skimmers

- Old 2nd skimmer: Conical with a diameter of 400microns.
- New set of 2nd skimmers:
  - Flat skimmers with circular or slit opening.
  - 1st skimmer to 2nd skimmer distance increased by 6mm.





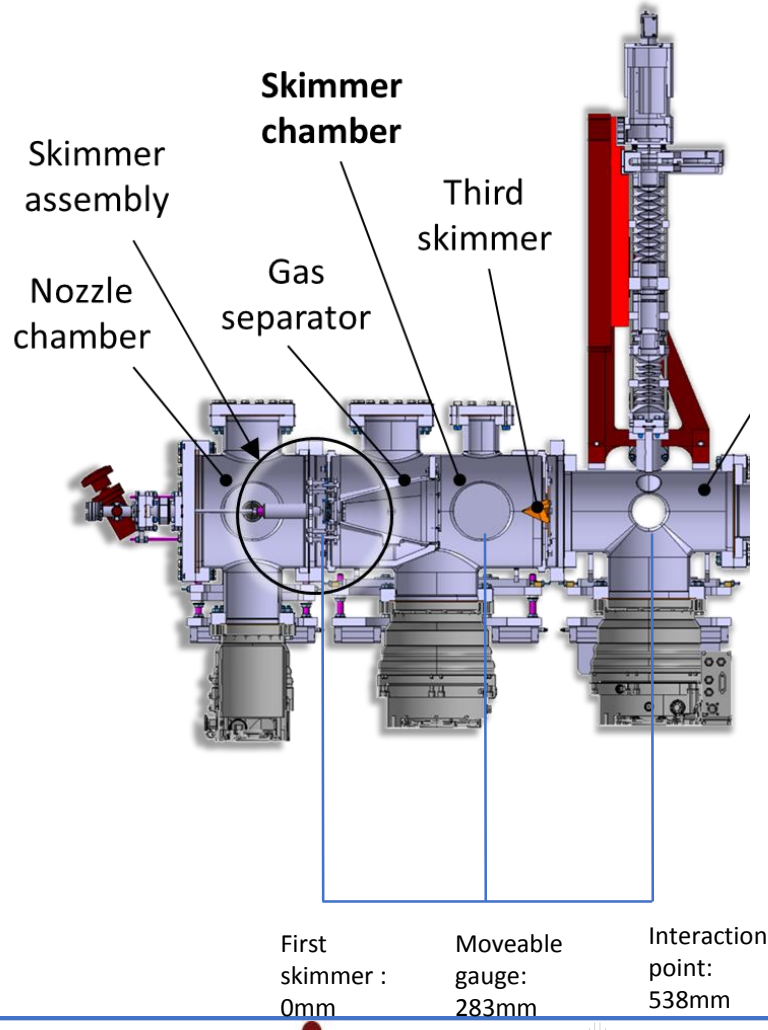


Pressure in (mbar)	Nozzle chamber	Skimmer chamber I	Skimmer chamber II
5bar Inlet (old skimmer)	6.03e-3	1.69e-05	5.33e-07
5bar inlet (new skimmer-circular)	6.18e-3	1.35e-05	1.04e-06

Nitrogen pressure, but Neon is in similar range

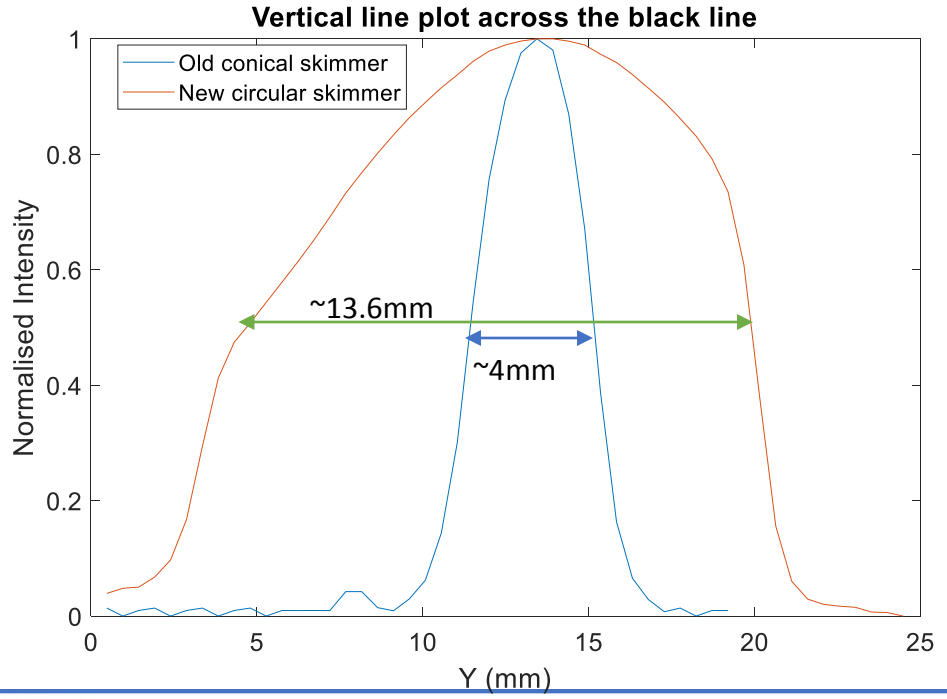
Test details

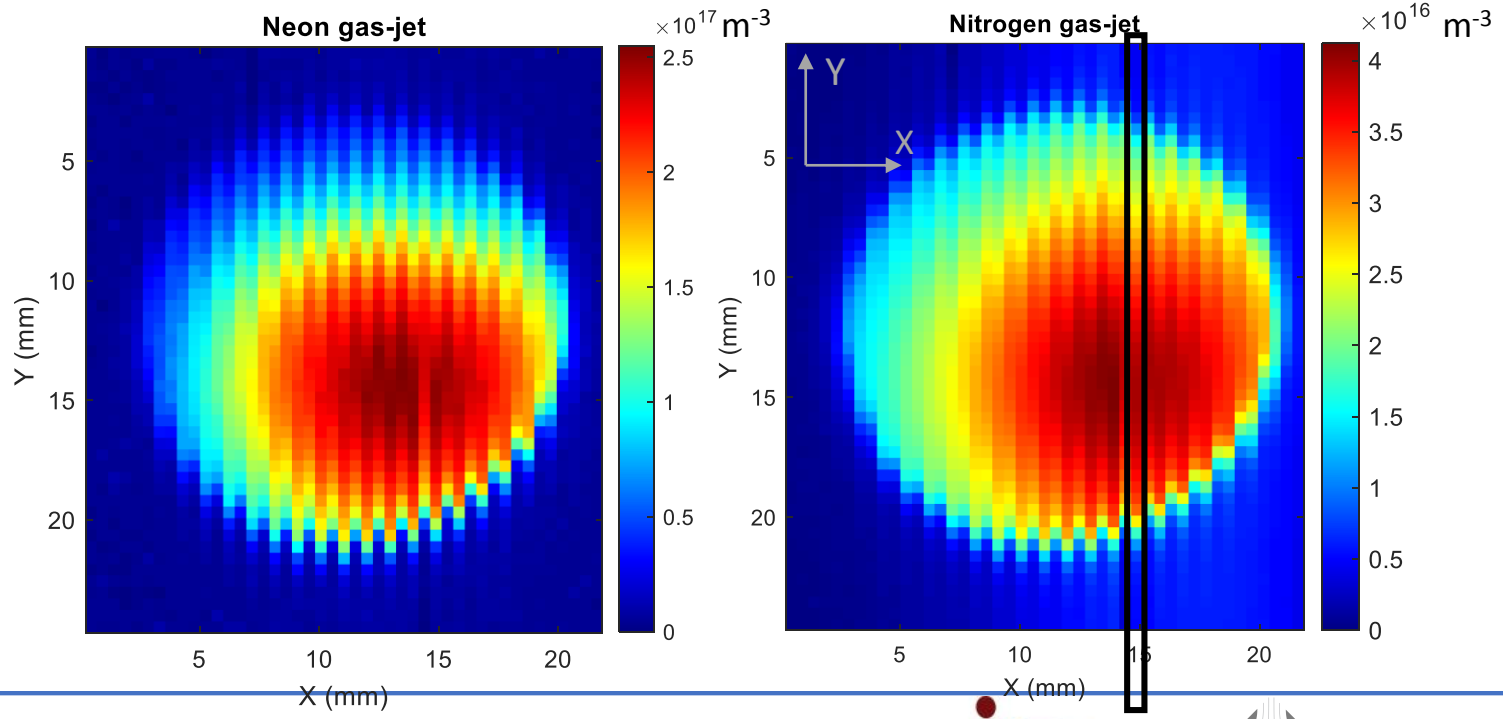
- The density was measured 283mm away from the first skimmer using the moveable gauge.
- The intensity of the jet was also measured at the interaction point, 538mm from the first skimmer.
- Parameters:
  - Nozzle-1st skimmer distance: 4mm
  - Inlet pressure: 5bar
  - Nozzle diameter: 30micron
  - For fluorescent measurements: E-beam = 0.66mA at 5keV
  - Gas : Neon and Nitrogen



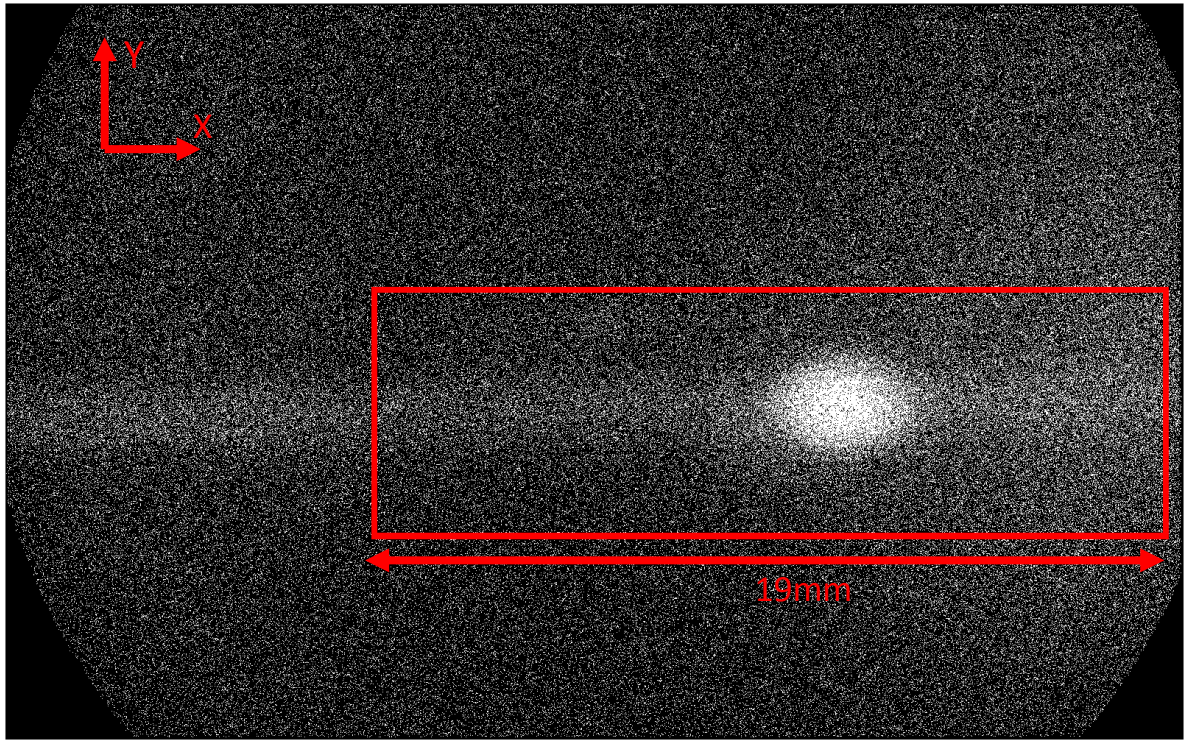
Circular 2nd skimmer –moveable gauge

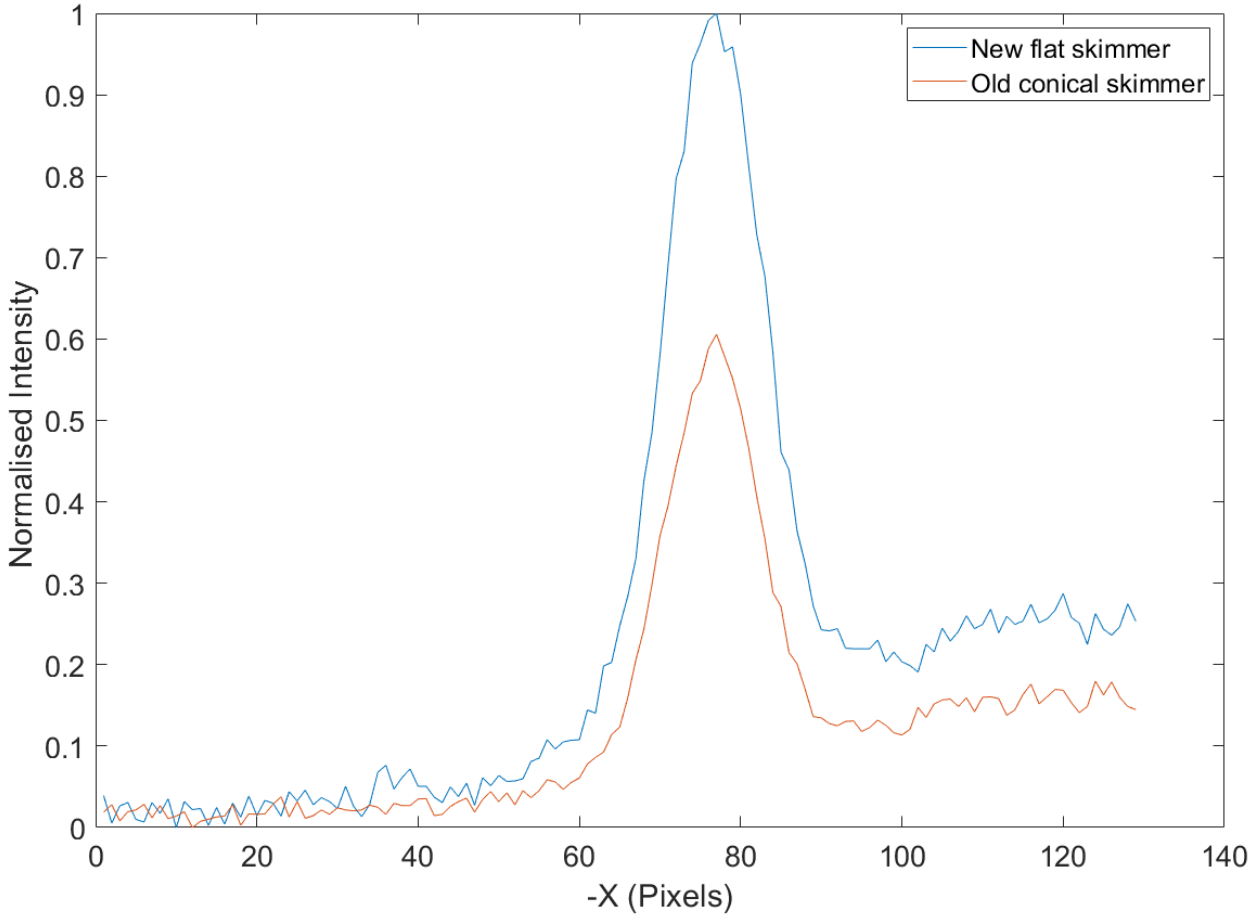
- Jet does not pass through the centre of the 2nd skimmer- an alignment issue that will be corrected in the future.
- Neon gas-jet has a higher density compared to Nitrogen-as expected.
- For Nitrogen and Neon, peak density has increased by a factor of 2 compared to the old conical skimmer.





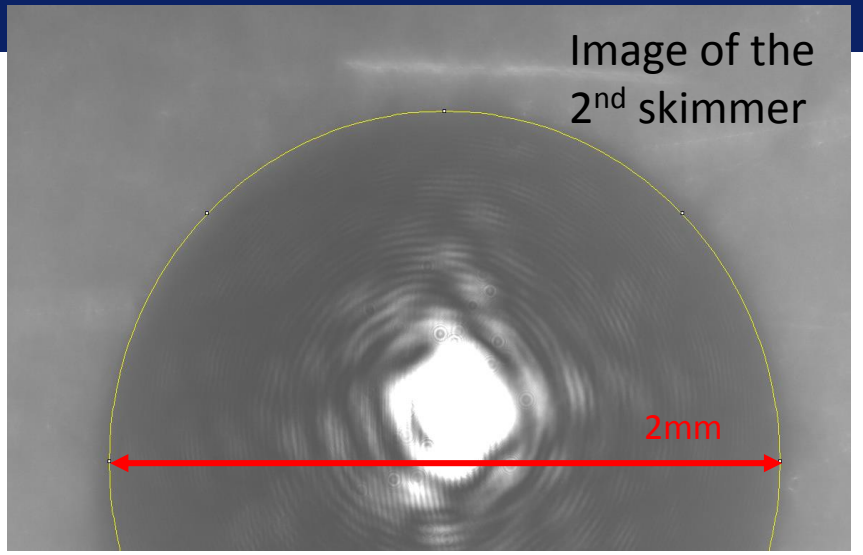
Circular 2nd skimmer- electron gun



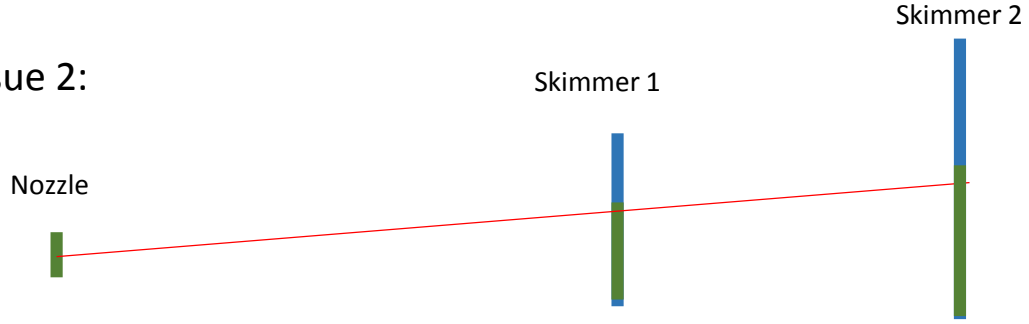


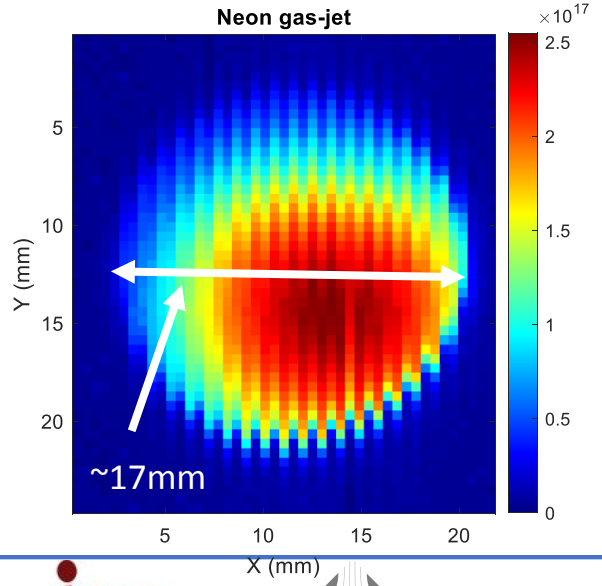
Alignment of the 2nd skimmer

- Issue 1: The diameter of the 2nd skimmer is larger than the field of the view of the alignment camera.
- → Not a showstopper, the centre of the 2nd skimmer can still be found.



- Issue 2:

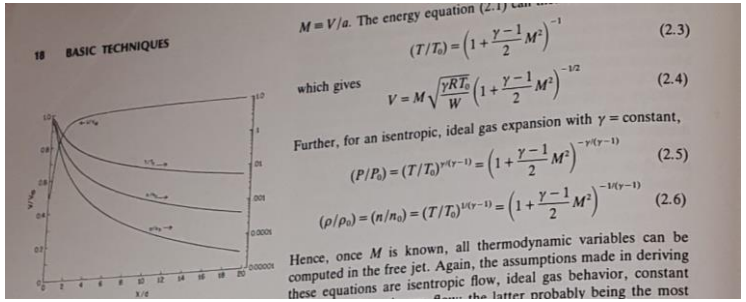




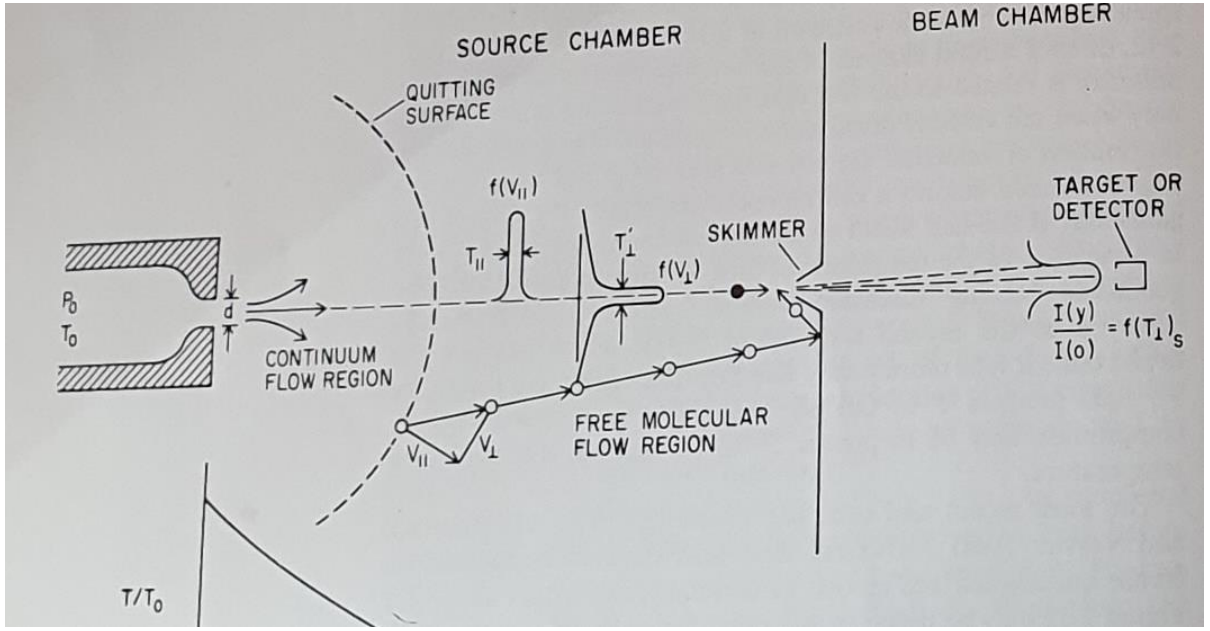
- We suspect that the issue is the misalignment of the laser to the nozzle, during the last alignment. The nozzle and the laser will be realigned and a 2D scan will be taken in the future.

Gas distribution simulation

- Continuum flow region (adiabatic expansion)

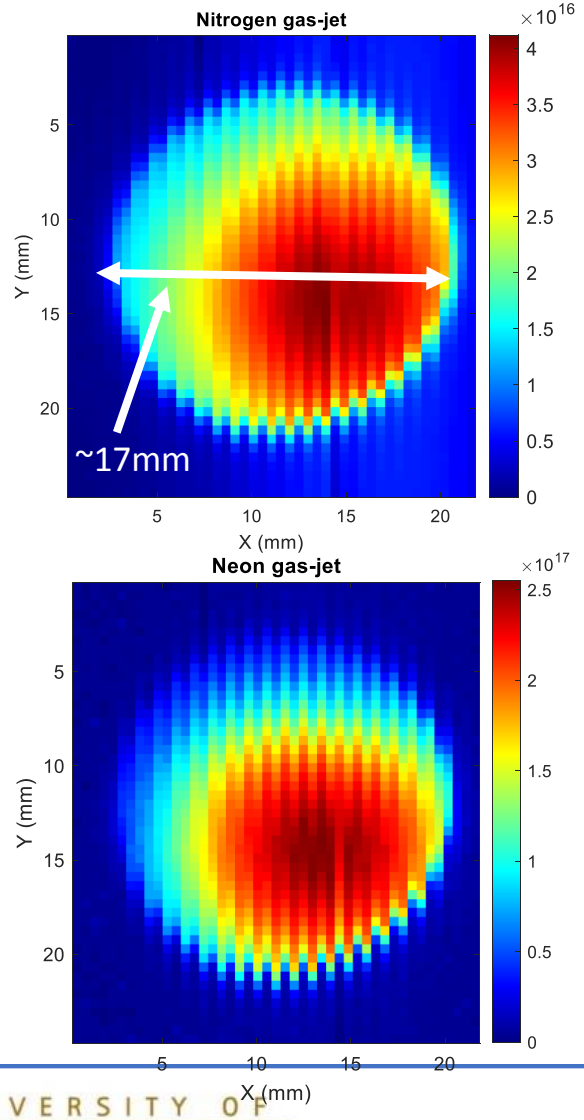


- Quitting surface model
  - Generate random number based on uniform distribution on quitting surface.
  - Gaussian distribution on velocity
- Molecular Flow region
  - Single particle tracking
  - remove particles outside of each skimmer



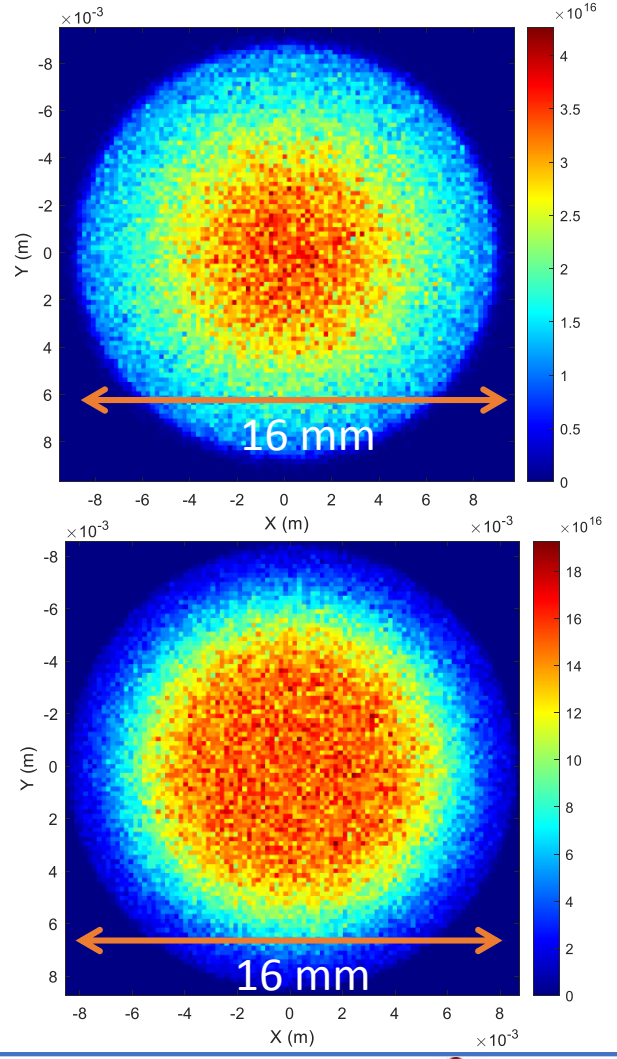
- Density
  - Distribution is calculated statistically
  - skimmer attenuation (mostly first skimmer)
  - background attenuation (mostly nozzle chamber and first skimmer chamber)

Experiment vs Preliminary simulation



- **Density and its distribution match very well.**
- **Nitrogen has a slightly higher spread than Neon, which is showing in both cases.**
- **5-time higher density for neon showed in both cases.**
- **Clearly there is a misalignment in experimental data.**

Need to carefully examinate the simulation code. Master student Bethany is dedicatedly working one this.



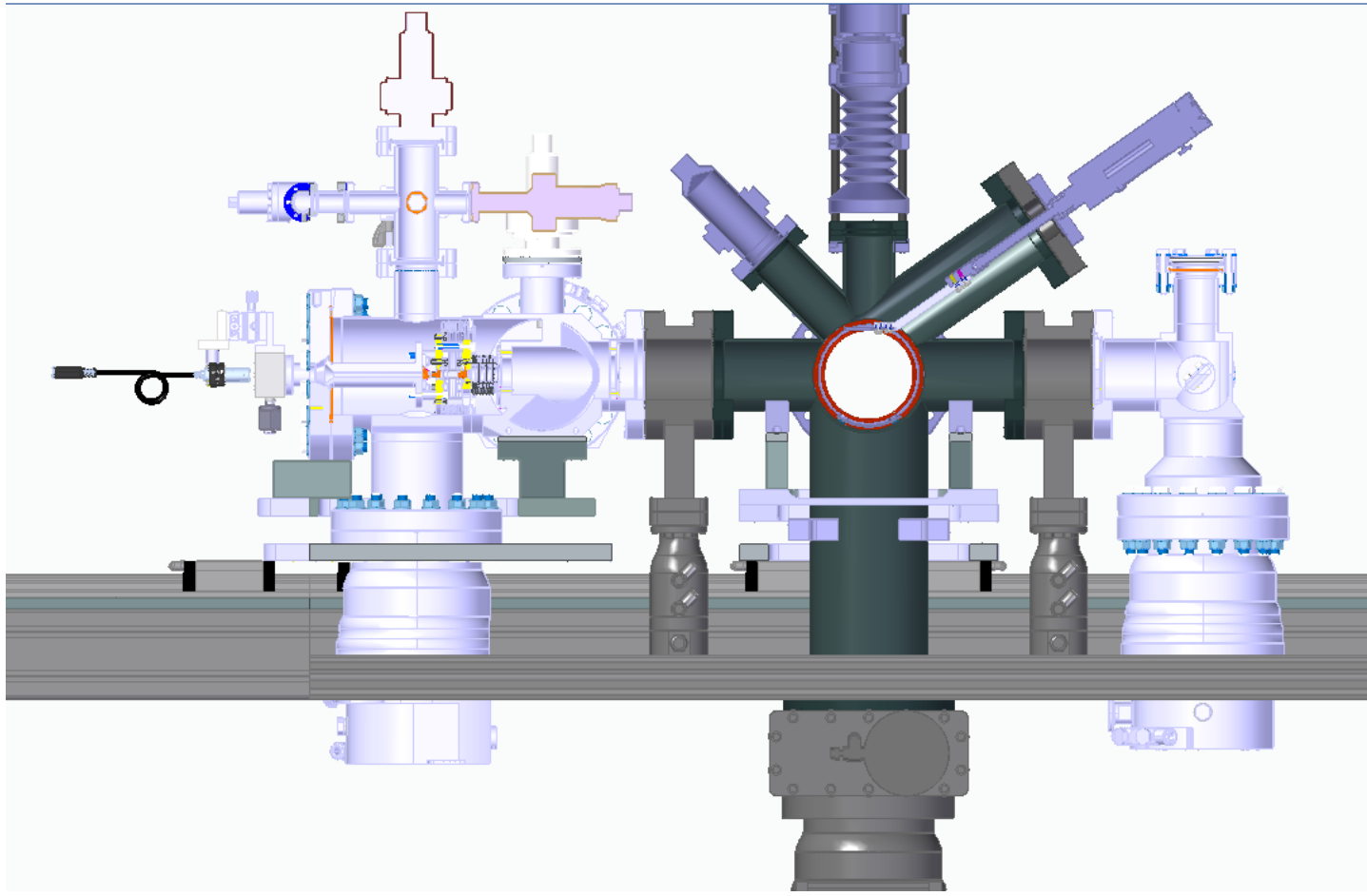
Experimental plan

- Continue the simulation validation
  - Different nozzle skimmer distance
  - misalignment
  - Multi-location density check (if the second moveable gauge is available)
- Develop a interferometry method for measure the gas jet density at nozzle chamber.

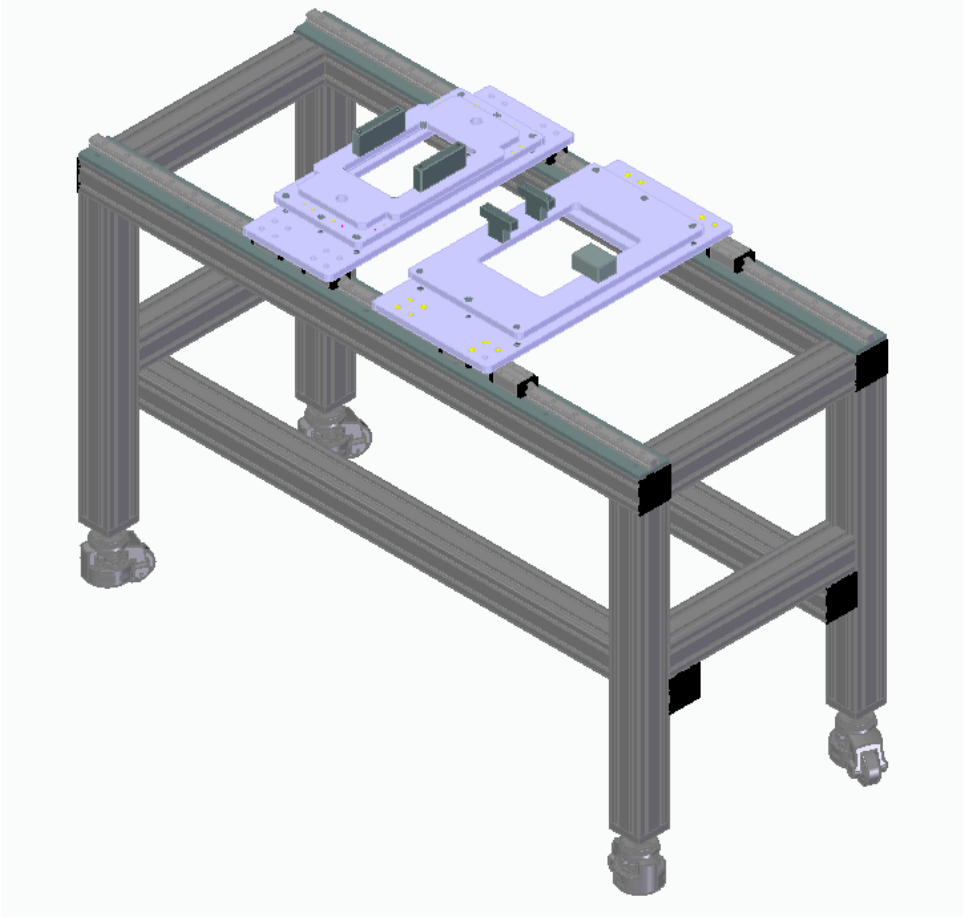
Design and procurement of BGC V3 by CI

Design for v3 HEL test stand

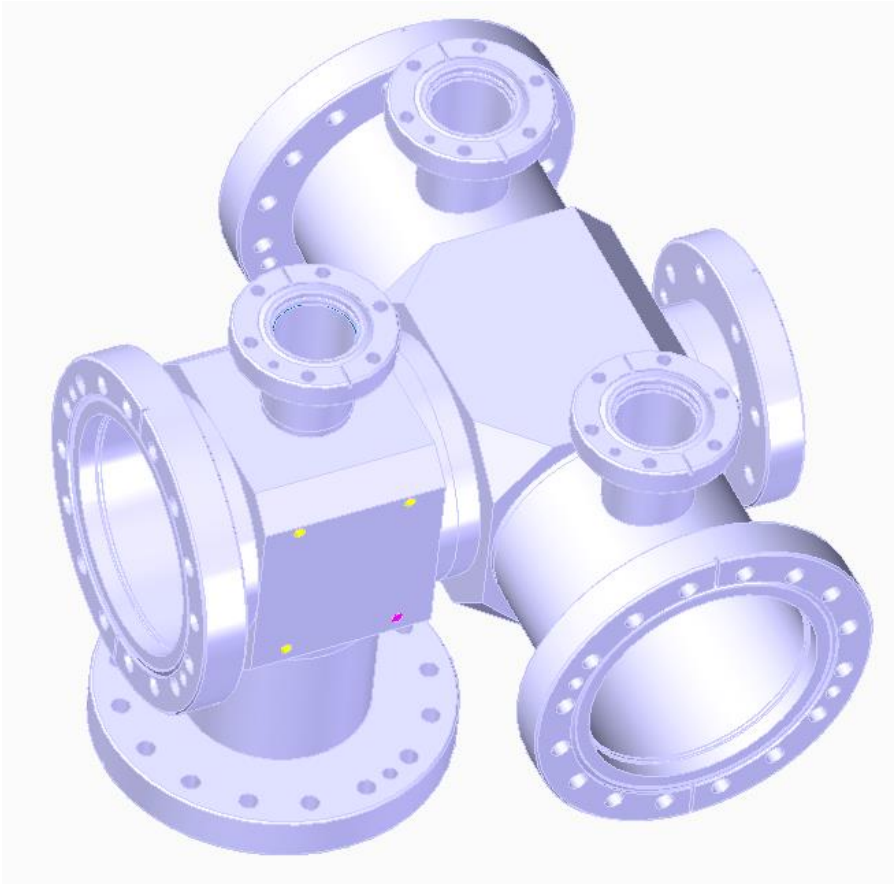
- Interaction chamber
  - Fit to HEL test stand 2
  - Main tube: Longitudinal length is the same as LHC one (500 mm)
- Gas injection and dump
  - The same as LHC
  - Vacuum gauge will be different in CI test, which will be changed after arriving at CERN.
- Gate valve
  - Slim design



Frame and support

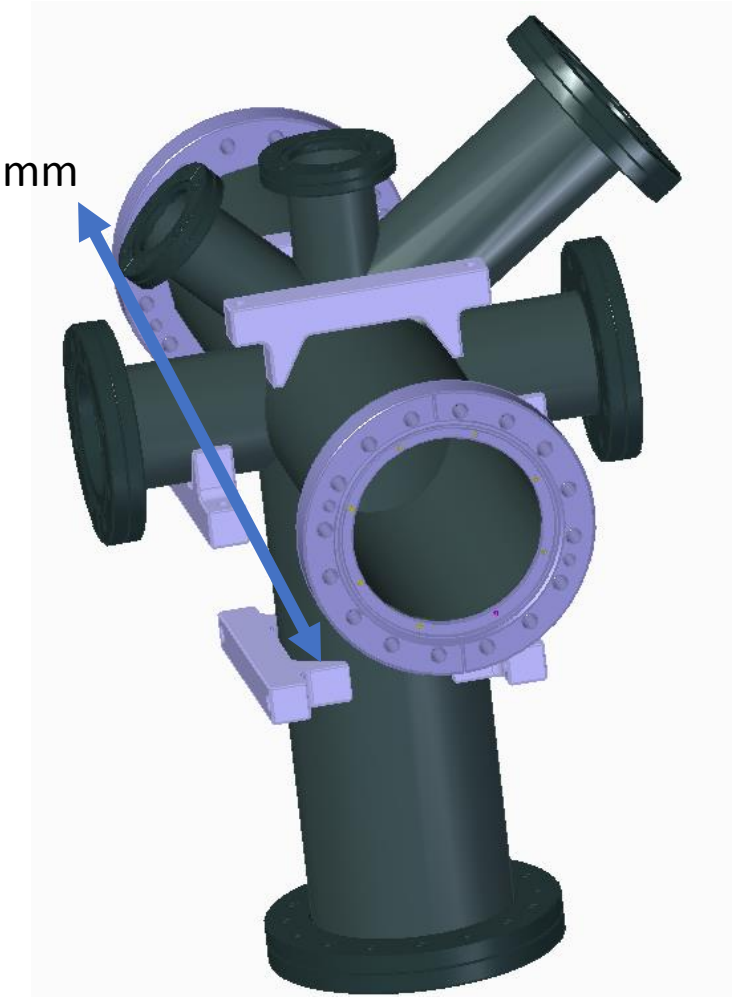


Gas injection chamber

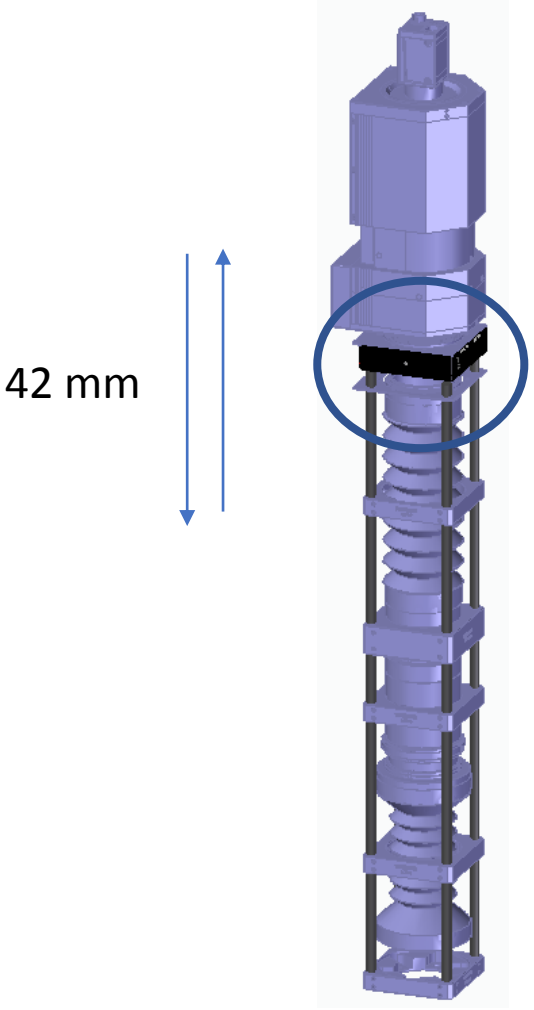


https://www.linkedin.com/company/scanwel-ltd/videos/

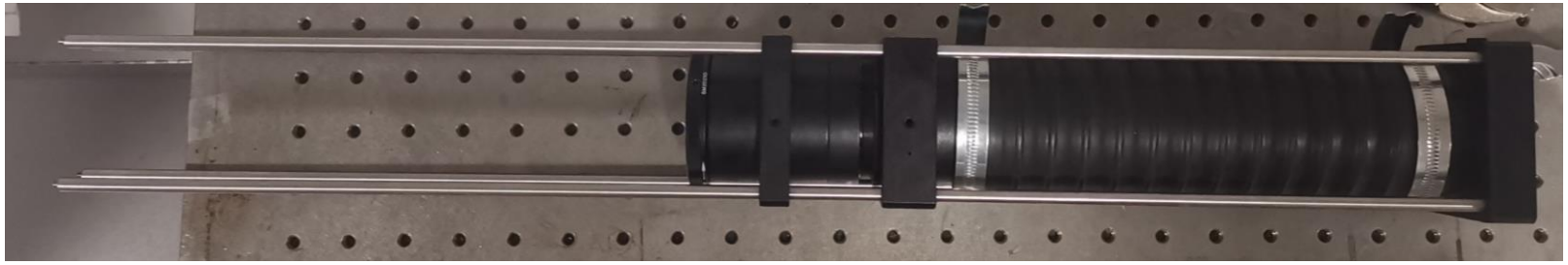
Interaction chamber



Imaging system

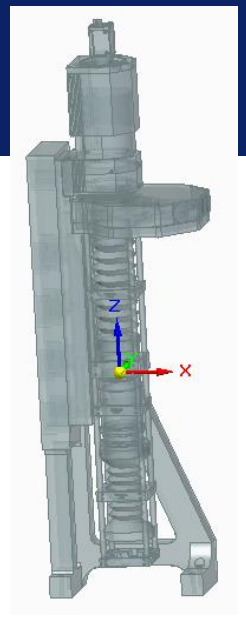


- Removable filter for CI test
- Motorized filter needed for CERN (New action)
- Motorize the whole imaging system for ~42 mm movement (from target location to the interaction point) (New action)

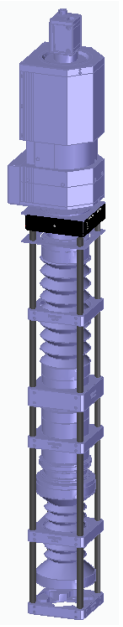


List of imaging system

- 1. Current system for v2
  - In use and will be kept in CI for future tests.
  - Focus is adjusted manually.
  - Intensifier has a 25 us minimum gate time.



- 2. System for v3 (HEL test stand 2)
  - In hand and will be used for the v3 commissioning.
  - No support yet, suppose there will be a motor to adjust the focusing.
  - Intensifier is the same with 1.
  - Will be shipped with v3 setup to CERN.



- 3. System in for v4
  - In discussion.
  - Will use new cathodes (see meeting 23/10/2020). But whether to use fast gating of 3ns is not decided.
  - Can be purchased for v3 LHC test in case LHC residual gas experiment require an imaging system.

Pumping system

no	Part	Amount
1	HiPace 80	2
2	Asset codes HiPace 80	-
3	Air Cooling kit 24V DC	2
4	Air Cooling Kit 230V 50/60 Hz	5
5	Splinter Shield for turbopumps with DN 63 CF-F flange	2
6	Venting Flange, DN 10	7
7	Venting Valva Manually actuated DN 10	7
8	TCP 350 Profibus	7
9	Centering ring DN 100	5
10	Mains Cable 2.5m	7
11	Verbindungskabel TCP 350 - HiPace (M8)	2
12	Connection Cable TCP 350 - Box1	5
13	Connection Cable TCP 350 - Box2	5
14	HiPace 300 - CF	5
15	Asset codes HiPace 300	-
16	Linear Bellow Drive with welded part	1

Edwards NXDS20i

no auto pressure hold

Yes auto start

Will controlled and monitored by RS232 in CI

https://shop.edwardsvacuum.com/products/a73801983/view.aspx

Gauges and valves

K. J. Lesker Pneumatic SS Gate Valves

2X DN63

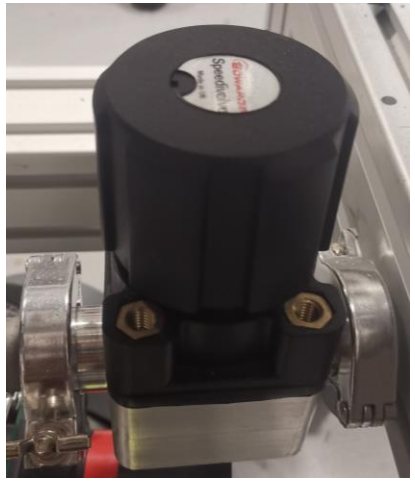
Solenoid valve monitored and controlled by Arduino

https://www.lesker.com/newweb/valves/gatevalves_standard_ss_pneu_copper.cfm?pgid=0

1X DN100

5X SP25K Speedivalve FKM GP Diaphragm

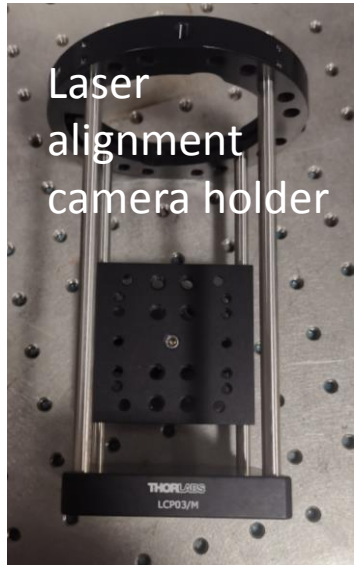
https://shop.edwardsvacuum.com/products/c33355000/view.aspx

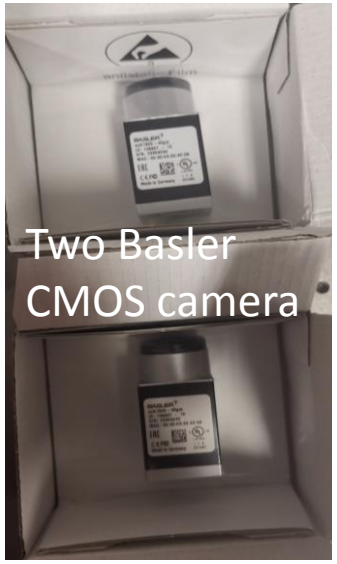


4X IKR 270
Part No.: **PT R21 251**

https://www.pfeiffer-vacuum.com/en/products/measurement-analysis/measurement/activeline/activeline-gauges/?detailPdoId=3866

Skimmers, holders and alignment system



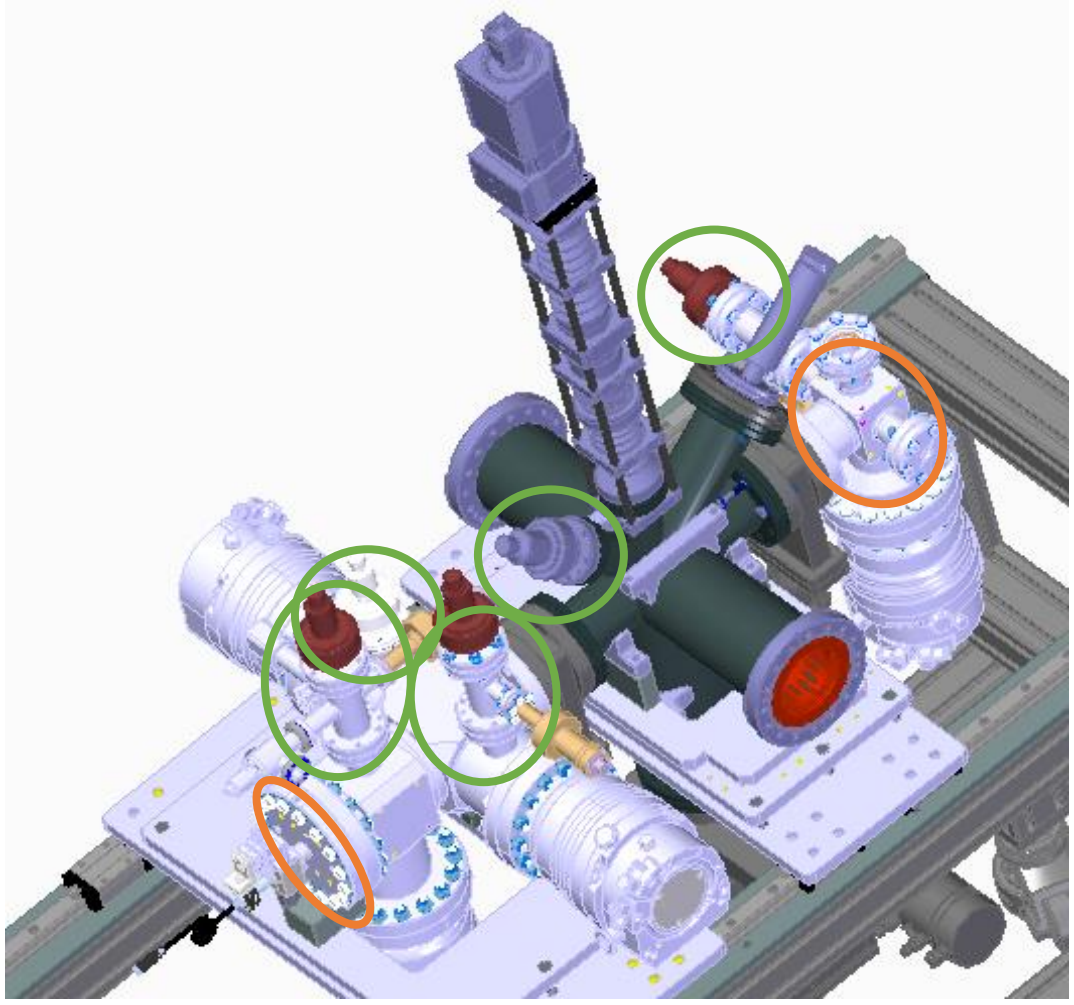


Items for commissioning

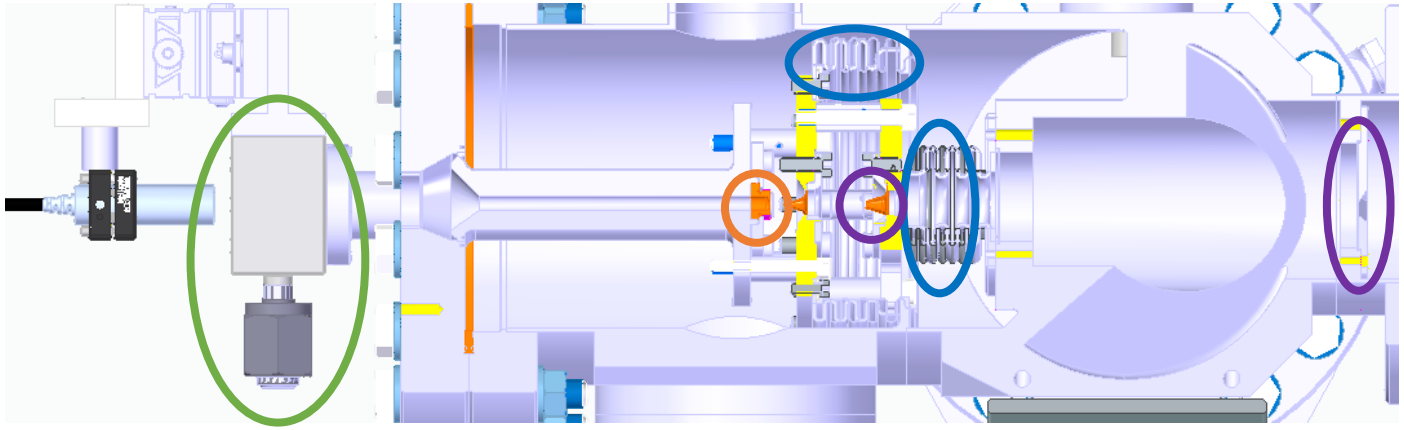
- Electron gun (from v2)
- Faraday cup (from v2)
- Moveable gauge system (from v2, potentially a new one)

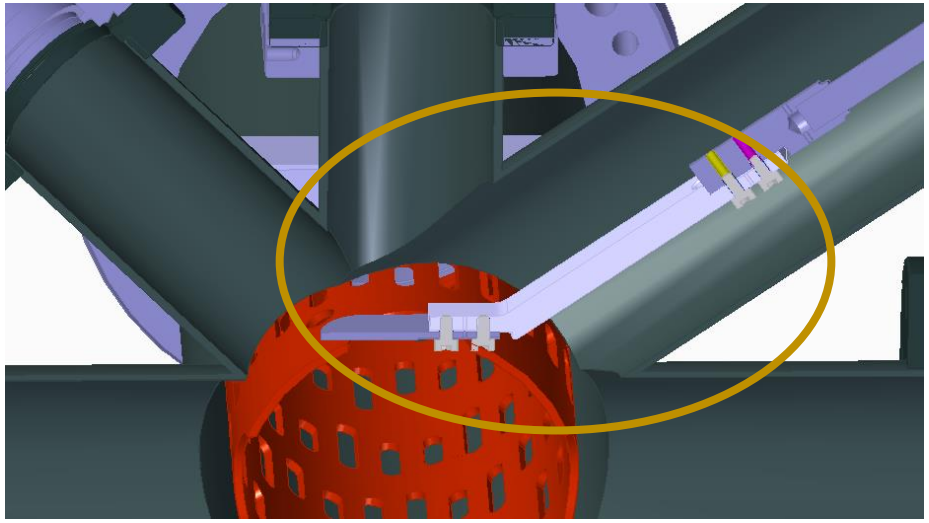
Summary for v3

- Active gauge used in CI, will be changed to modular one after shipping to CERN.
- Dump chamber, injection flange, mirror flange being manufactured (CI, ready in Jan)



- Special gas injection flange: ordered by CERN
- Nozzle: ordered from oxford by CERN
- Bellows: ordered by CERN
- 2nd skimmer and 3rd skimmer (Need to order)
- Target and adaptor: not ordered yet.





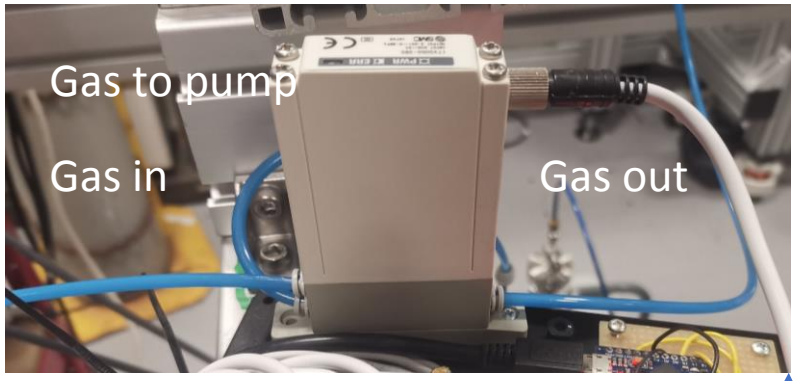
Procurement and manufacturing

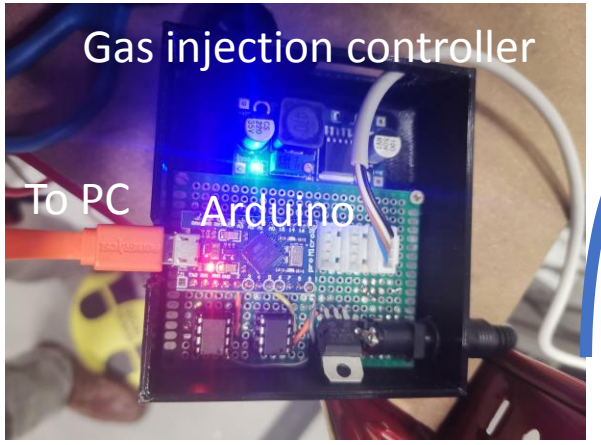
- CI
  - Ready:
    - Frame and support.
    - gas injection chamber, interaction chamber, gate valves, gauges
    - Imaging system(except the motor system and motorized filter wheel)
    - Inner parts such as skimmer assembly, skimmers (not include 3rd skimmer and possible modification to 2nd skimmer)
    - Two alignment system (standalone and attached)
  - Under manufacturing
    - Nozzle flange, dump chamber
  - Still need to order
    - Special vacuum screw, alignment screw
    - Small mechanical jobs for alignment system.
- CERN
  - Nozzle ordered from oxford
  - Bellows for skimmer assembly ordered.
  - Special gas injection flange ordered

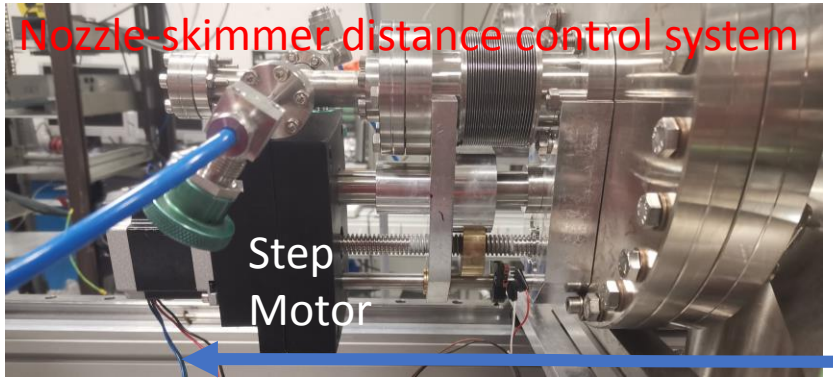
Control system design

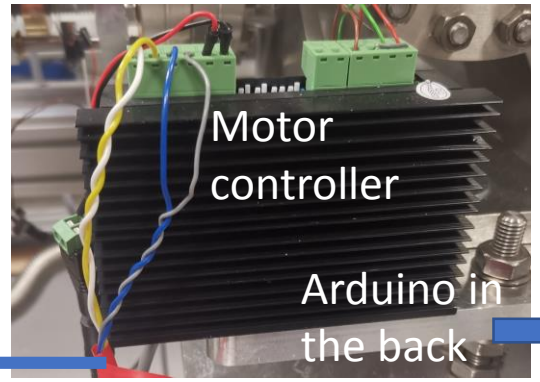
- Based on Arduino and MATLAB.
  - Gas injection
  - Gauge controller
  - Gate valves and TMP
- Test vacuum events (See 05/06/2020)
  - Start
  - Stop and vent
  - Power outage

Gas injection control system









To PC

Commissioning plan for V3 at CI

Milestones

1. Chamber inspection. Dec 2020 – Jan 2021
2. Assemble the system and vacuum test without baking. Jan 2021.
3. Gas jet quantification. Feb 2021.
4. Measurement with Lab electron beam. March 2021.
5. Report the device and preparing to ship. April 2021.
6. Devices arrived at CERN and installed to HEL test stand. May 2021

Performance evaluation

- Chambers
  - Dimension check (Daresbury services)
  - RGA (Daresbury services)
  - Vacuum (Daresbury services)
- Setup
  - Cleaning before assembly (Daresbury services)
  - Vacuum (CI team)
- Jet property
  - Jet density (moveable gauge, electron gun)
  - Jet Profile (moveable gauge)
- Integration time test
  - E-beam with 0.66 mA

Thanks for listening

BGC CI team

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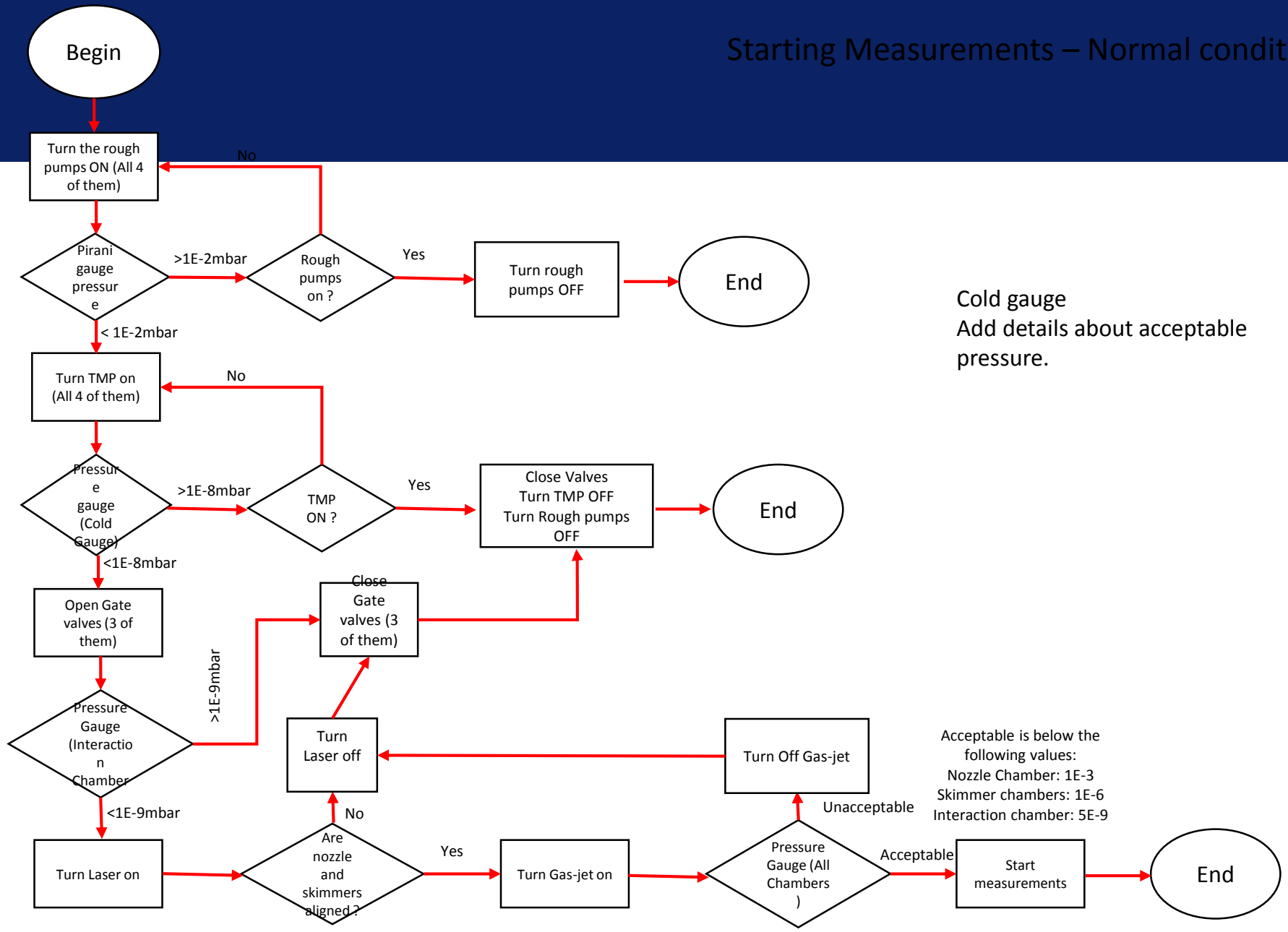
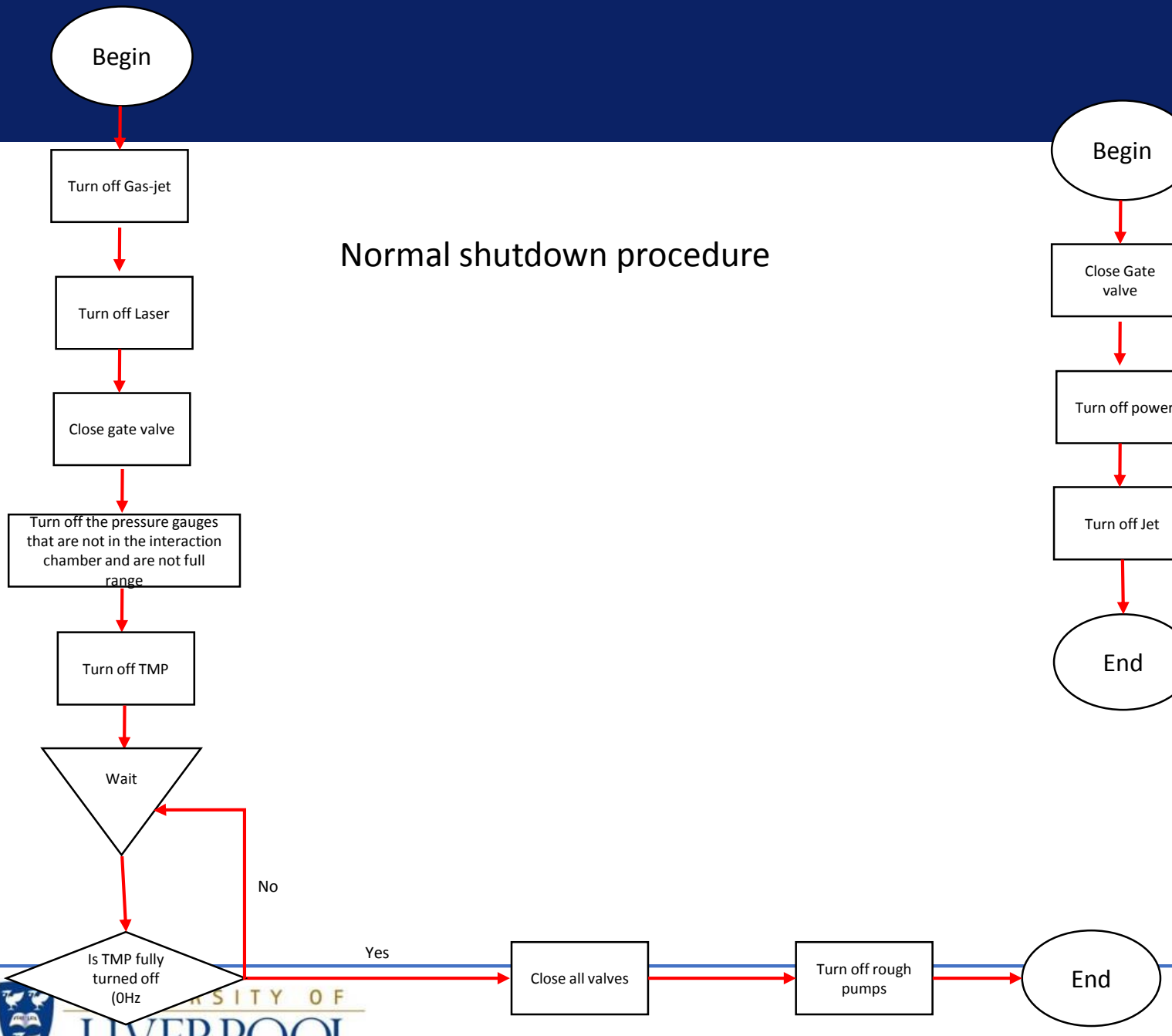
Spare slides

Starting Measurements – Normal conditions



Cold gauge
Add details about acceptable pressure.

Normal shutdown procedure



Emergency shutdown

Pressure drop
Power failure.