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Development of a Least-Interceptive Beam Profile Monitor Based on a Supersonic Gas-Jet Screen

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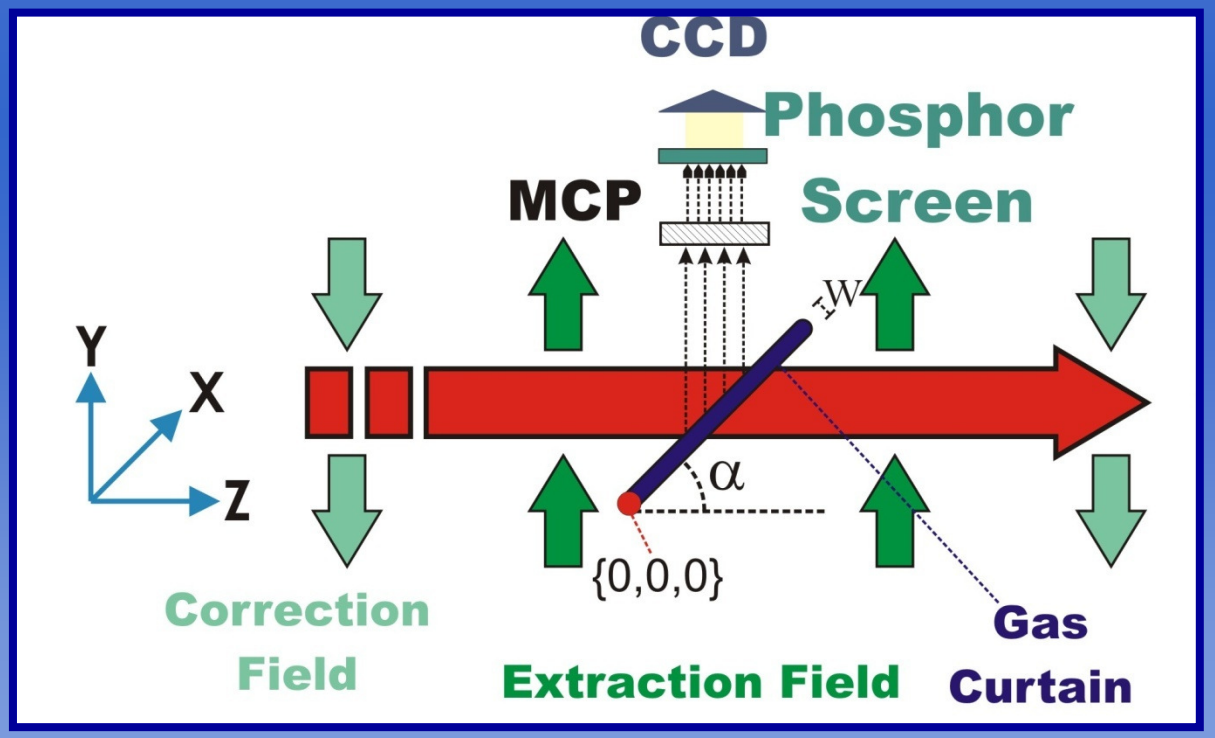
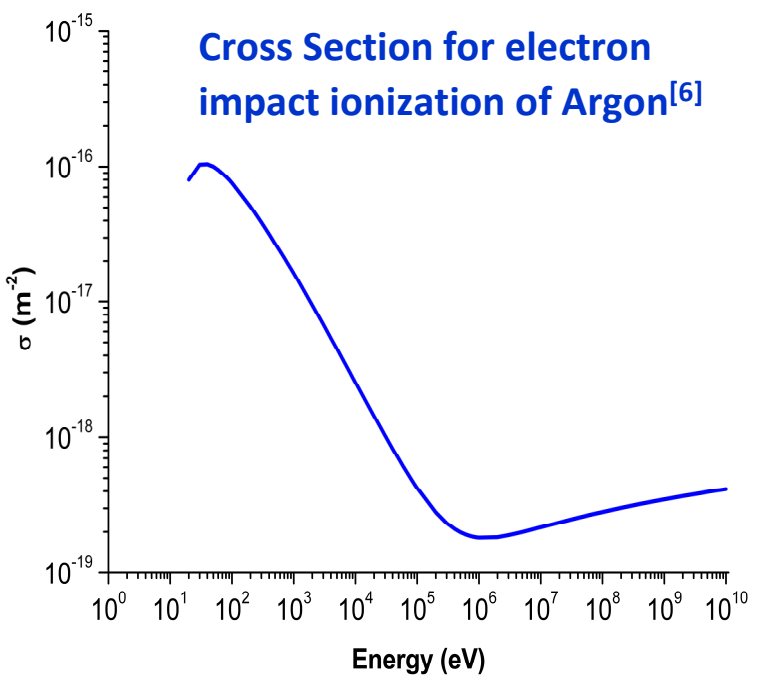
- Operation Principle
- Numerical Studies
- Experimental status

- Gas Curtain Monitor[1,2,4,5]
  - Non-perturbing to both vacuum and beam
  - High Count Rate



Count rate estimation

$$R = \frac{\sigma(E_{proj}) \cdot \rho_{curtain} \cdot d_{curtain}}{e} \cdot I$$



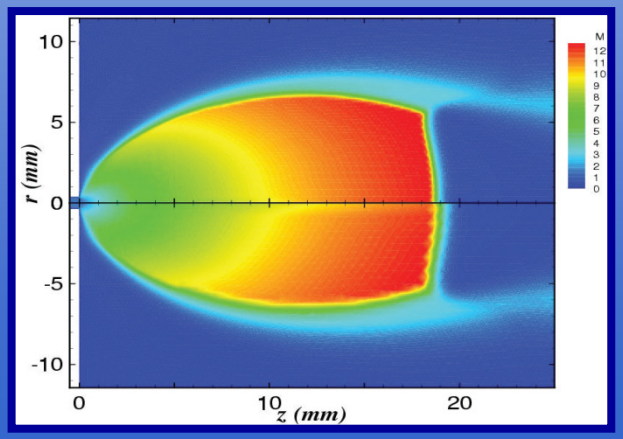
- About **2000 events** needed for a profile
  ⇔ error on estimate (5% confidence)
  μ < 1%
  σ < 5%

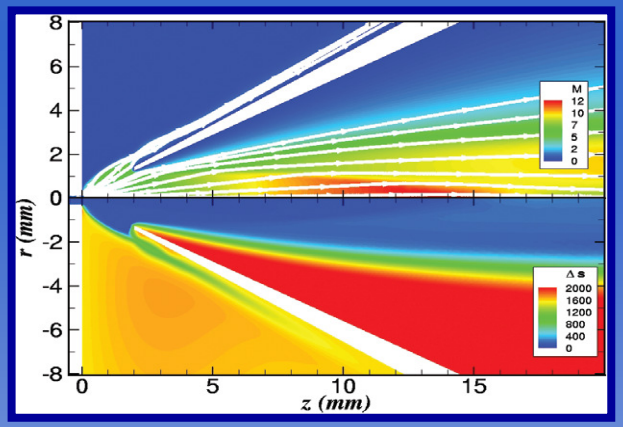
$$R'\left[\frac{Measur}{mA \cdot s}\right] = 10^{10} \cdot P_{[mbar]}$$

⇒

- Down to **1 μs/mA** acquisition time
- Residual gas vacuum pressure can be kept **5 orders of magnitude** lower than jet pressure[5].
- **3 orders of magnitude** faster than residual gas monitors

Study of the gas-jet: state of the art



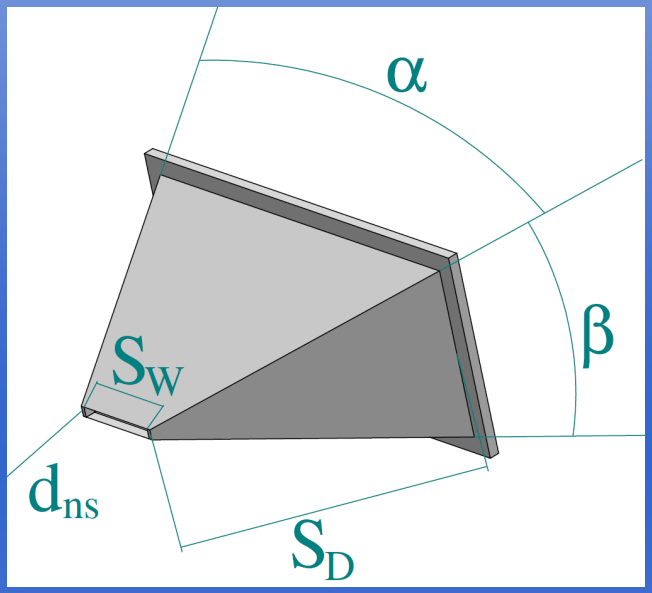


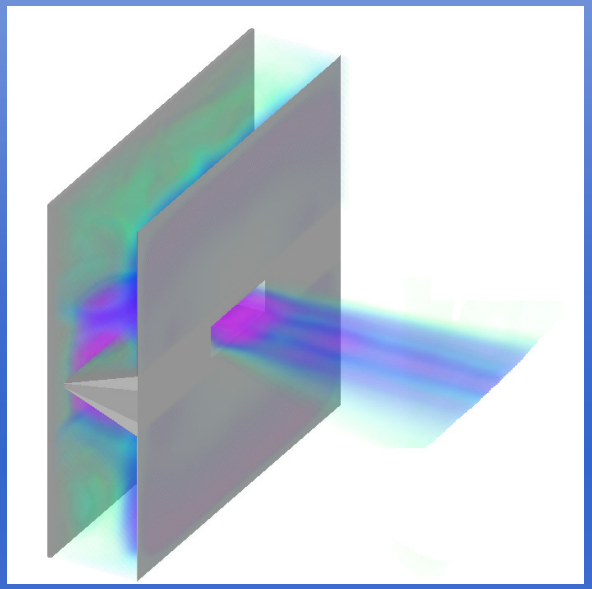
M.Jugroot *et al* [3].

- Detailed study of expansion structure
- Assessment of the impact on jet parameters of:
  - Nozzle-skimmer geometry
  - Stagnation quantities
- Indications on how to optimize the axis-symmetric jet for use as a target.

All optimization studies performed for an axis-symmetric jet.

Variables and Observables





Variables

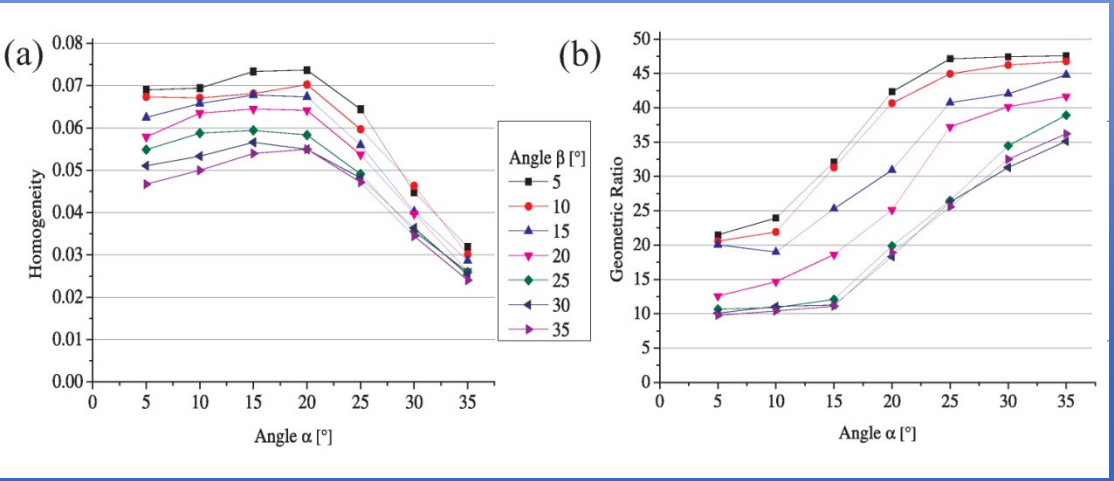
- α – angle of skimmer aperture in the direction of curtain expansion;
- β – angle of skimmer aperture in the direction perpendicular to curtain expansion
- **SW** – skimmer slit width
- **SD** – skimmer depth
- **Dist** – nozzle-skimmer distance

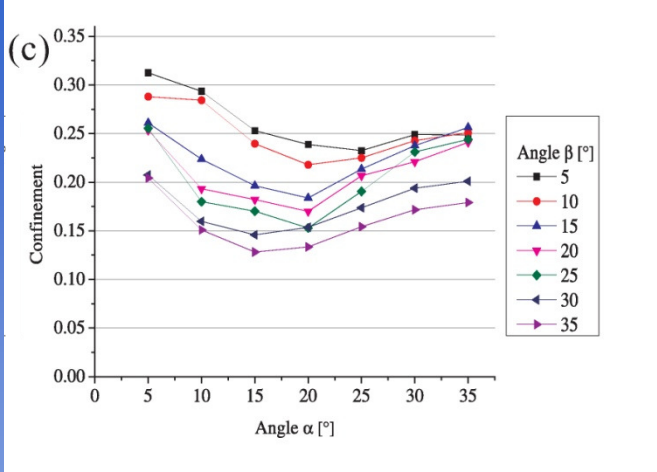
Observables

- H_ρ – Homogeneity of curtain density
- G_R – Geometric Ratio (Resolution)
- **K** – Confinement (% gas enclosed in curtain)

- **T** – Gas Reservoir Temperature
- **P** – Gas Reservoir Pressure

Parameter Optimization





	H_ρ	G_R	K
α	↘	↗	↗
β	↗	↘	↘
SW	↗	↗	↗
SD	↘	→	↗
Dist	→	↗	α, β

M.Putignano *et al* [7]

Parameter Optimization

- System can be optimized through nozzle-skimmer geometry.
- Slit nozzle (instead of circular nozzle)
- Nozzle and skimmer slits have to be perpendicular
- Shaping of the gas curtain is feasible.

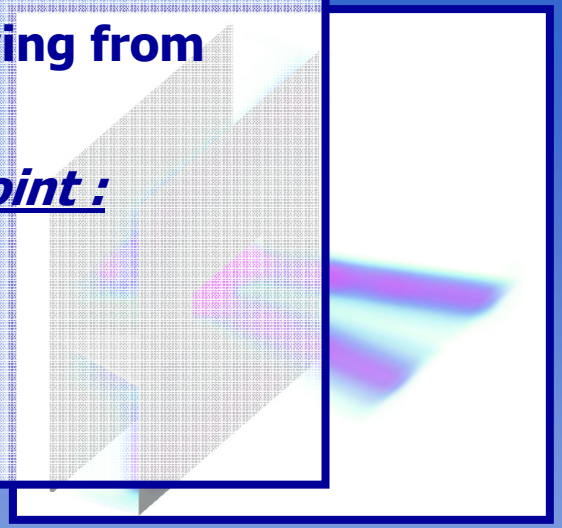
Geometric ratio: G_R :

Decreases of a factor of 2-3 moving from *Slit nozzle to Circular nozzle.*

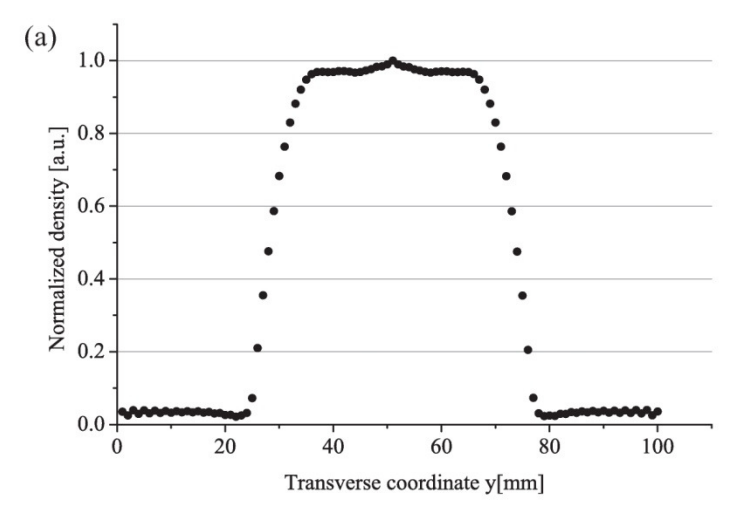
Homogeneity of curtain at interaction point :

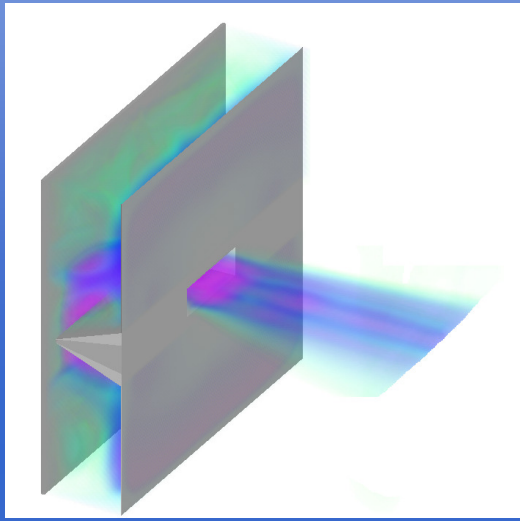
Nozzle-Skimmer system:

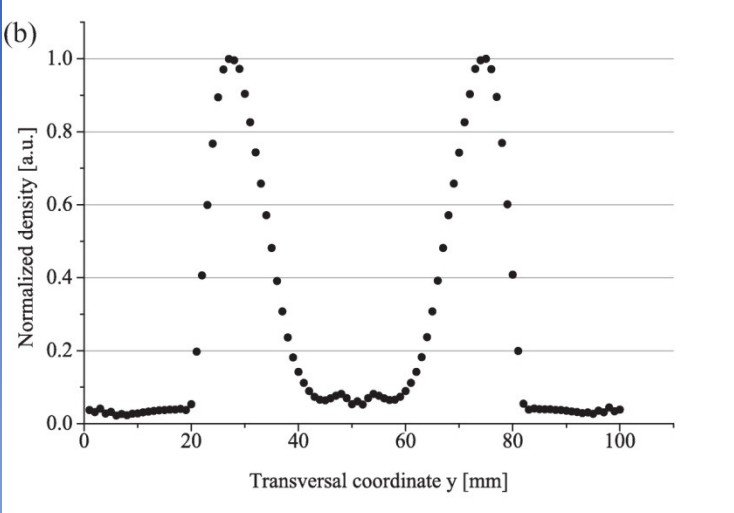
Perpendicular	Parallel
7%	26%

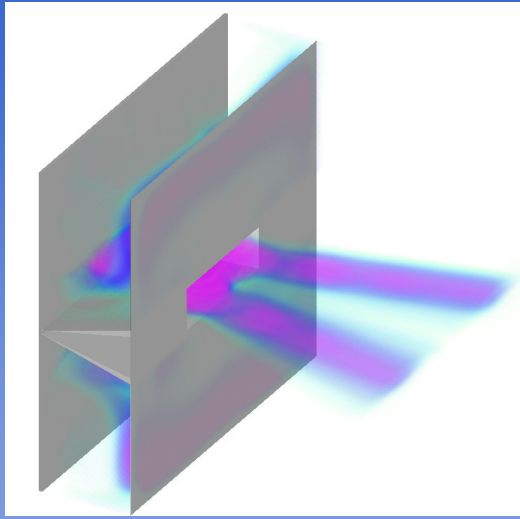


Gas Curtain Shaping



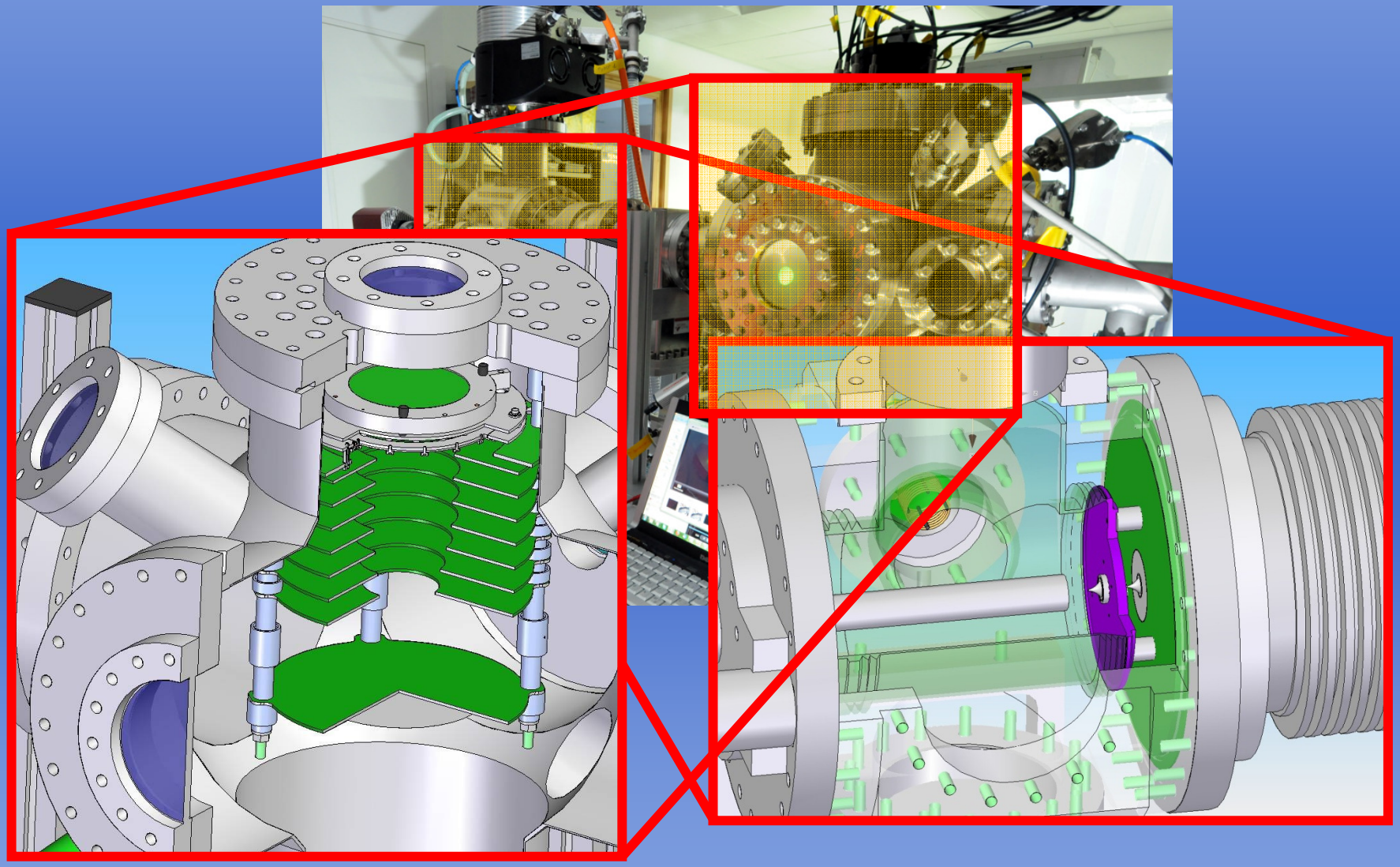




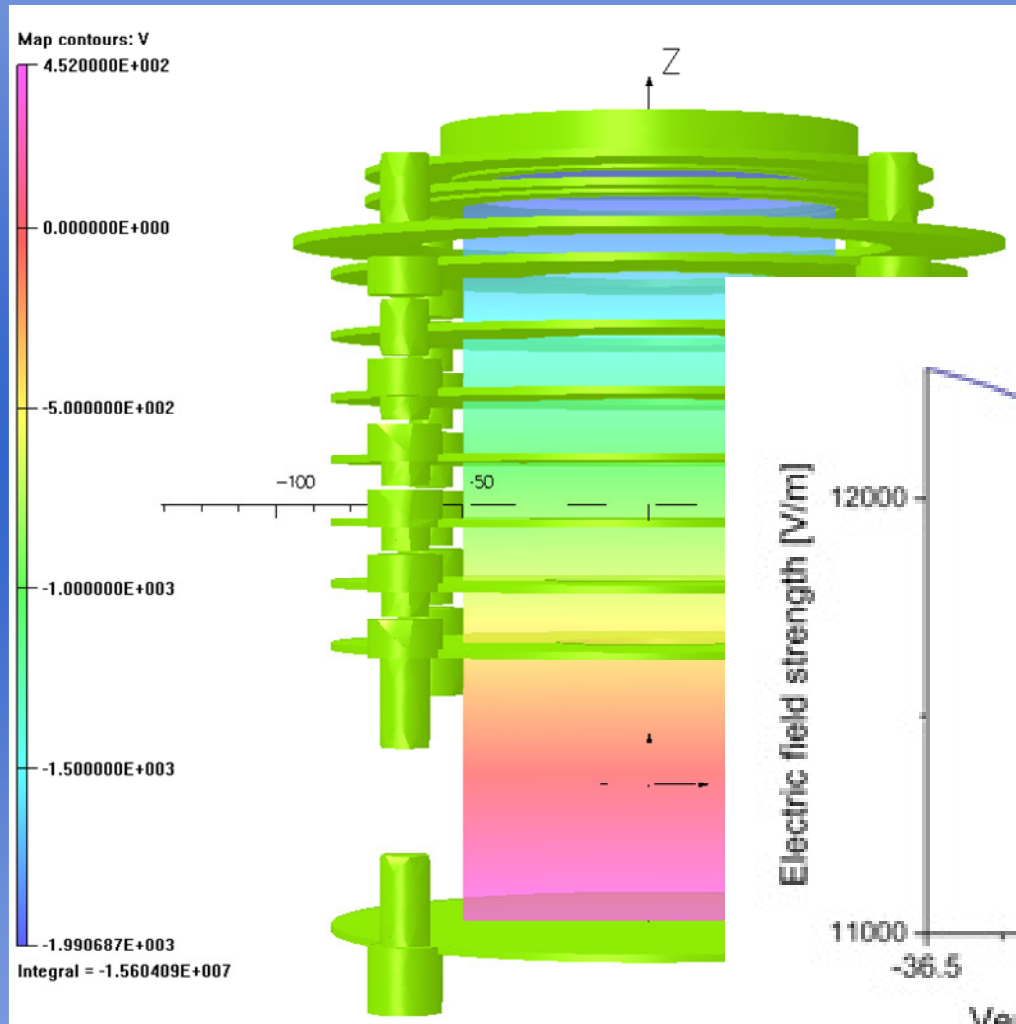


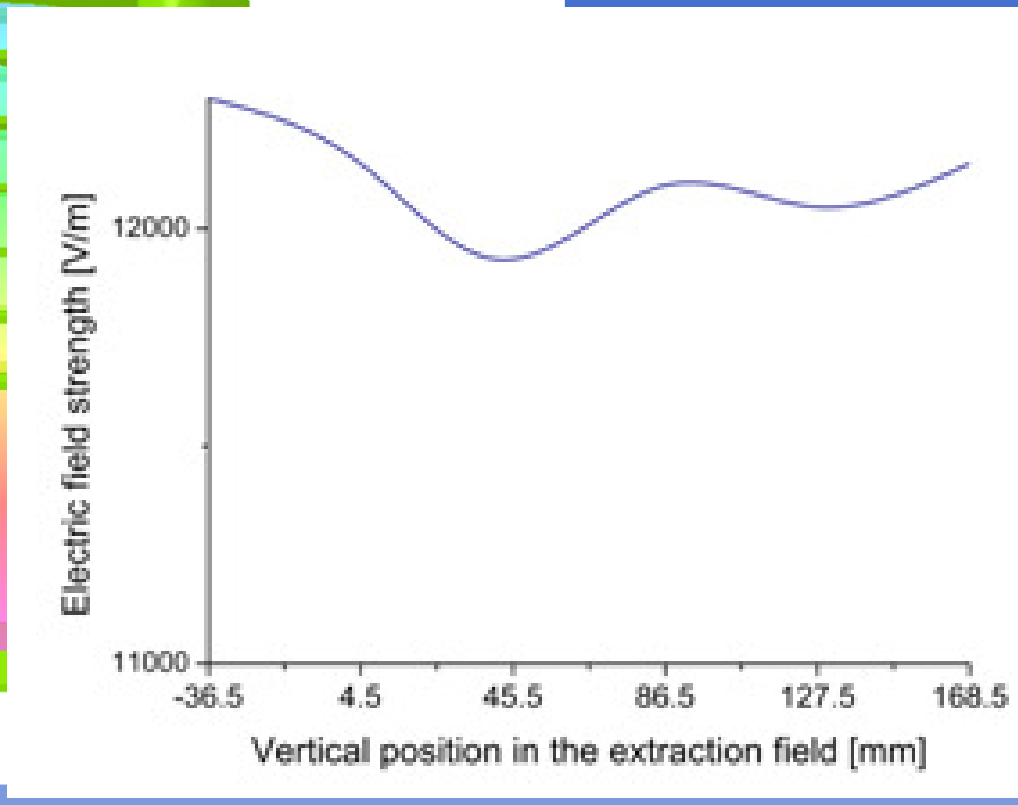
- Shaping of gas curtain possible through sole manipulation of **Pressure and Temperature** of Gas Reservoir.
- **1 order of magnitude** density difference between core and side strands
- **Factor 2.5 in peak intensity** between full and split jet

Experimental Apparatus



Extraction System Design



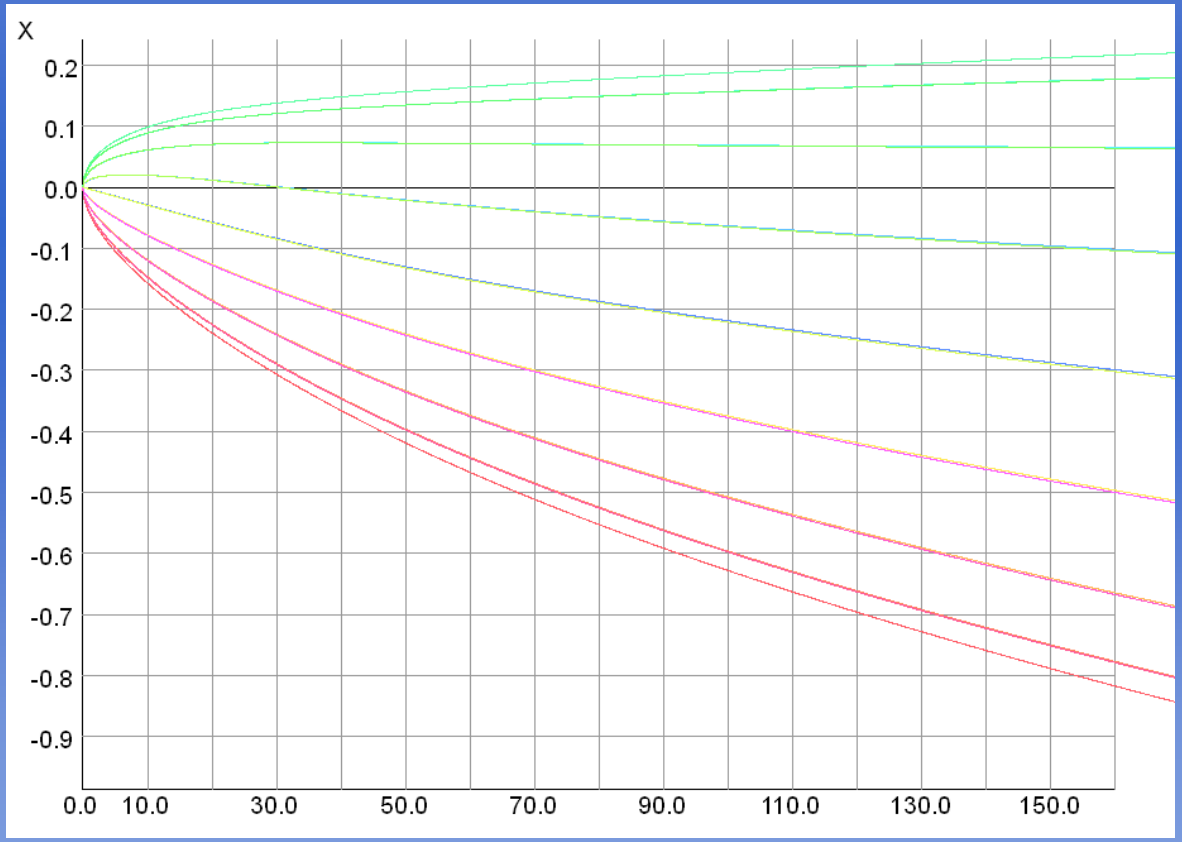


Particle tracking Simulations

- Resolution is limited by target ion initial momentum (ignoring space charge).
  - Temperature
  - Impact recoil

$2\sigma \Rightarrow \approx 0.5\text{mm}$

$6\sigma \Rightarrow \approx 1\text{ mm}$



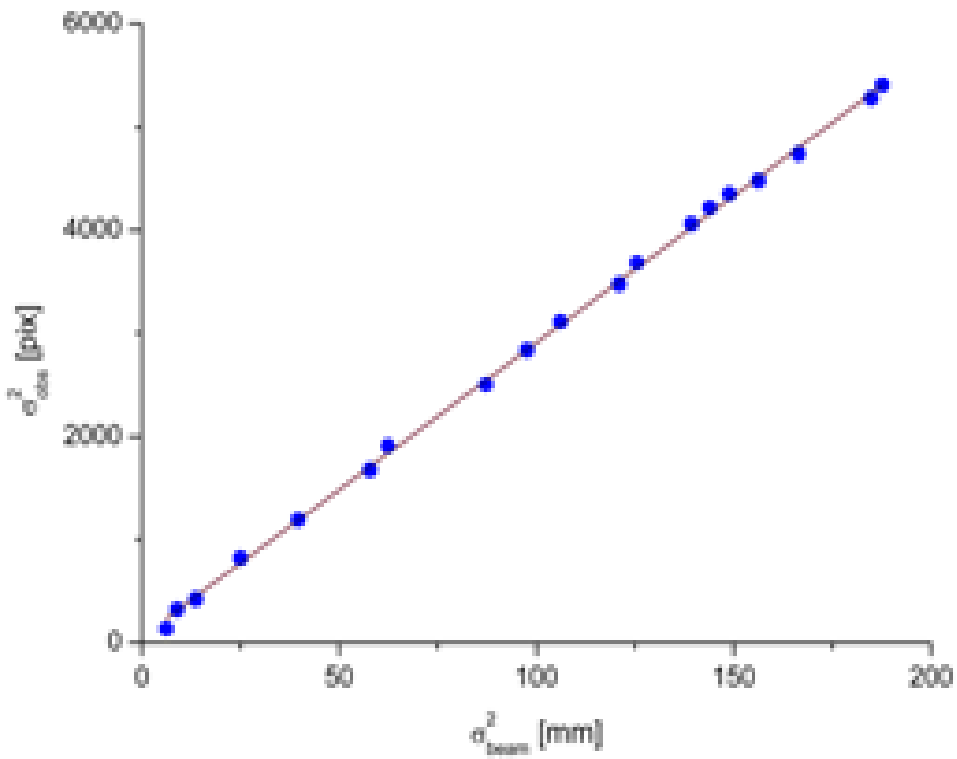
Residual Gas Monitor Calibration

$$\sigma_{obs\,[pix]} = \sqrt{\sigma^2_{beam\,[mm]} + \sigma^2_{drift\,[mm]}} \cdot R_{pix/mm}$$

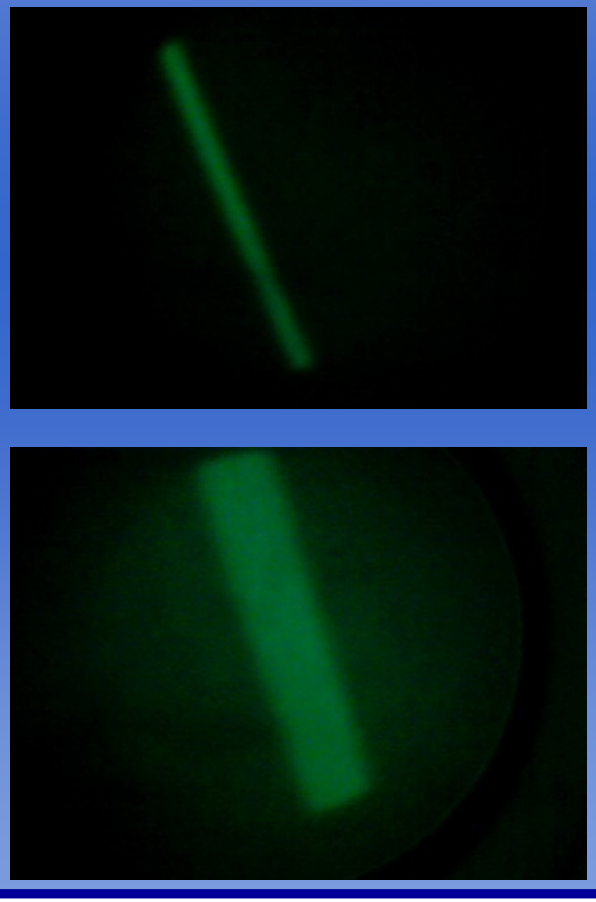
$$\sigma^2_{obs\,[pix]} = \sigma^2_{beam\,[mm]} \cdot R^2_{pix/mm} + \sigma^2_{drift\,[mm]} \cdot R^2_{pix/mm}$$

- Measured ion drift compatible with simulations:

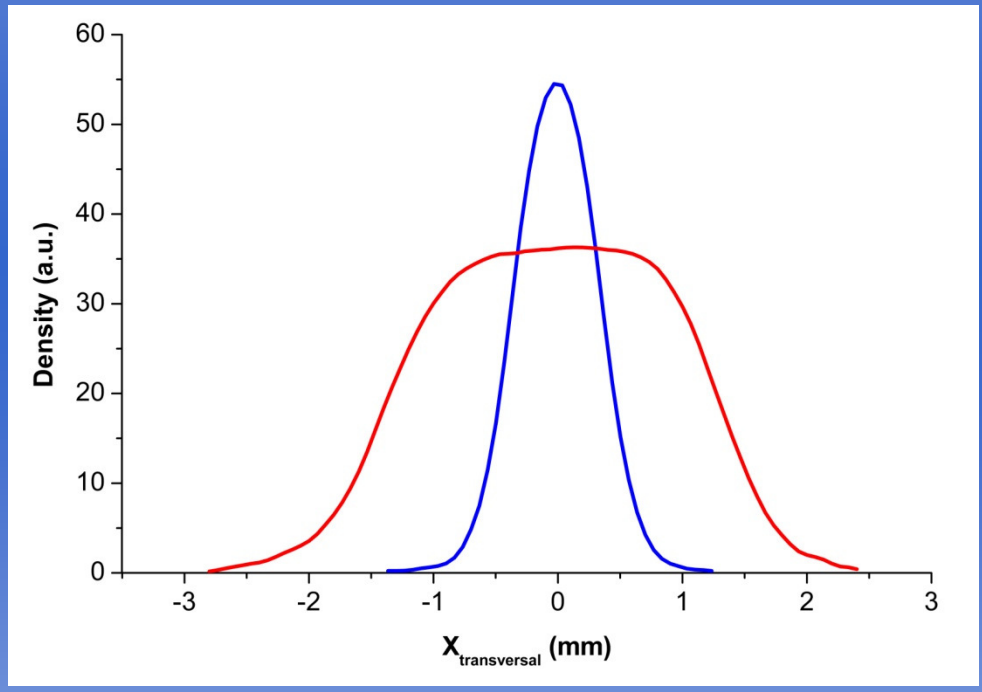
  0.9 ± 0.15 mm



Electron Gun beam (5keV, 10 μA, 10^{-7}mbar)



Integrated profile

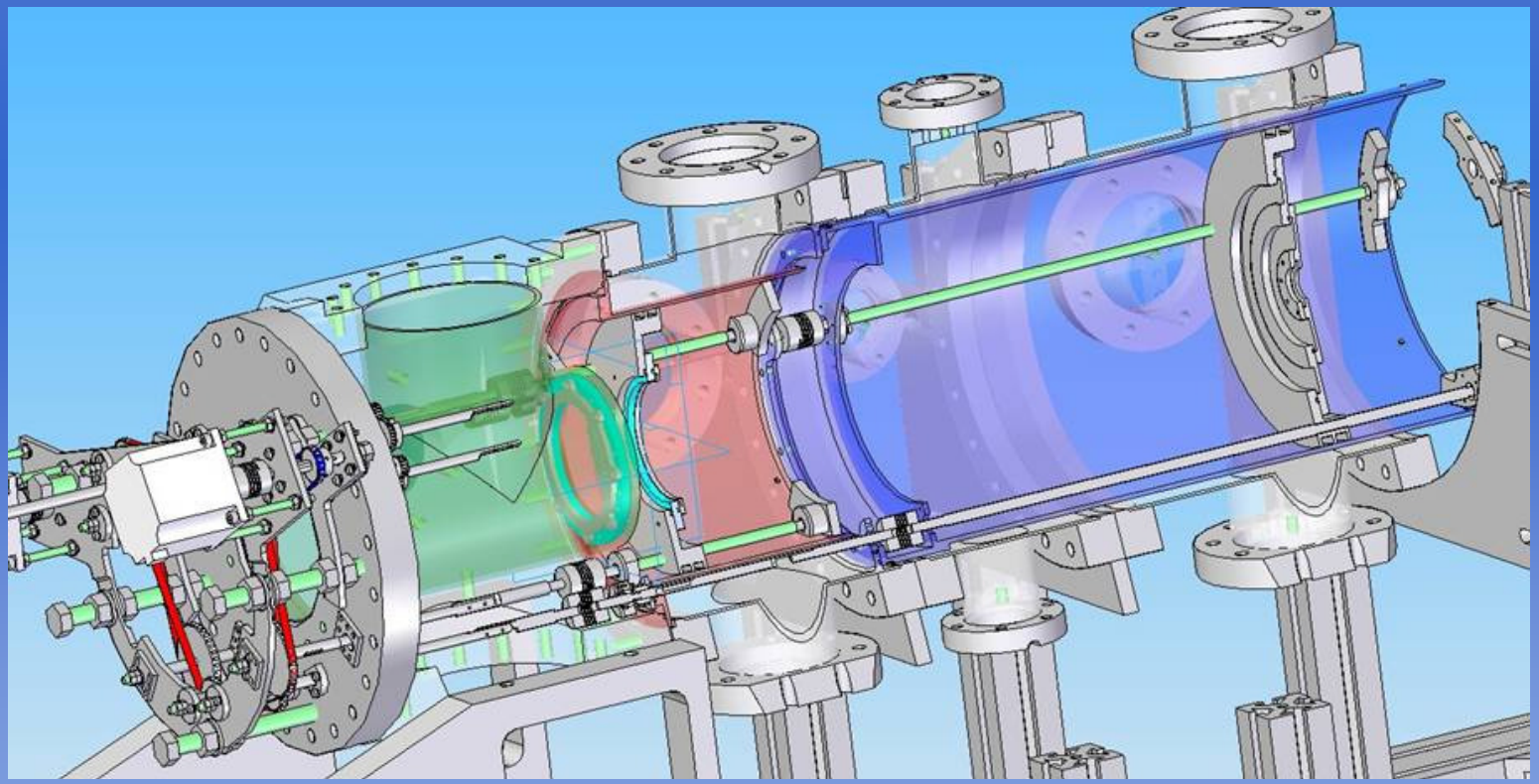


Sub-mm **resolution**

(preliminary result)

Outlook

- Non-Optimized Curtain Jet Operation
- Parameters Optimization



Acknowledgements and References

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Angela Intermite PhD Candidate

Dominic Borrows Undergraduate Researcher

Thank you for your attention

Acknowledgements and References

- References:
  1. M.Putignano *et al*: A Fast, Low Perturbation Ionization Beam Profile Monitor Based on a Gas-jet Curtain for the Ultra Low Energy Storage Ring - Hyperfine Interaction, accepted.
  2. M.Putignano *et al*: Design of a nozzle-skimmer system for a low perturbation ionization beam profile monitor – DIPAC09 Proceedings.
  3. M.Jugroot *et al*: Numerical investigation of interface region flows in mass spectrometers: neutral gas transport – J. Phys. D: Applied Physics, vol. 37 (2004) pp 1289.
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  5. Y. Hashimoto *et al*: Oxygen gas-sheet beam profile monitor for the synchrotron and storage ring - Nucl. Instr. Meth. Phys. Res. A 527 (2004) 289.
  6. F. Riekej and W. Prepejchal: Ionization Cross Sections of Gaseous Atoms and Molecules for High-Energy Electrons and Positrons – Phys. Rev. A Vol. 6 N.4 (1972) 1507.
  7. M. Putignano *et al:* Numerical Study on the Generation of a Planar Supersonic Gas Jet – Nucl. Instr. Meth. Phys. Res. A, *submitted*.