Characterizing MICROMEGAS Atom Detection Capabilities at the INFN Pisa Ion Beam Facility

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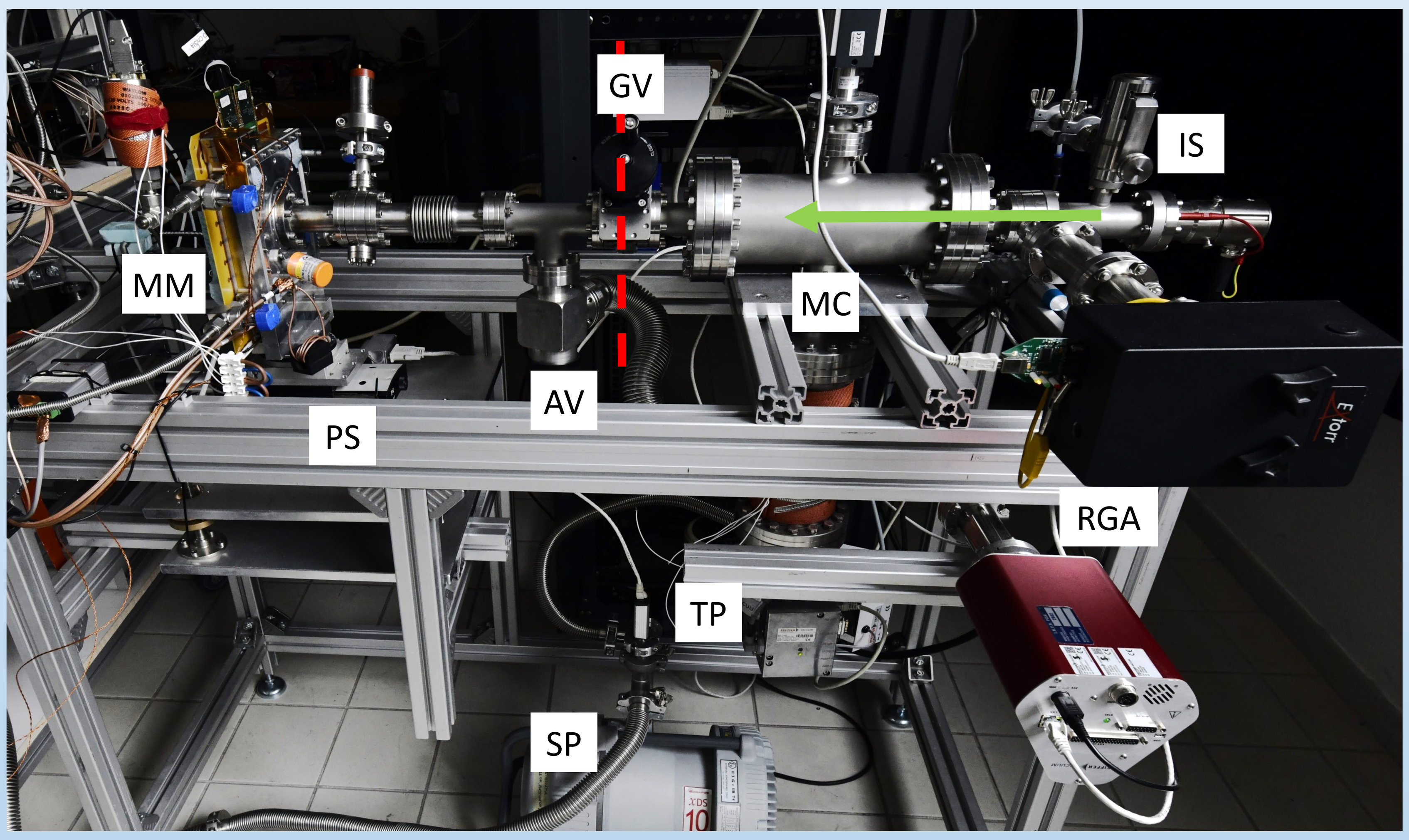
INTRODUCTION

An Ion Beam Facility (IBF) has been set-up at the INFN Pisa laboratory with the specific intent of having a test bench for developing gas detectors sensitive to low-energy ionizing radiation under low-pressure conditions (100 mbar and below). The IBF is currently being used to highlight the sensitivity of a MICROMEGAS (MM) detector operating at low pressure for the observation and study of light ions (H, He, O) with energy below 5 keV [1].



MAIN FACILITY COMPONENTS

The facility employs a commercial ion source, designed for spattering and sample cleaning, to create a focus, stable, low-current ion beam across the beamline.

Ion Source (IS)
- IG-5-C Staib Instruments
- Generates an ion beam with an energy range of 200 eV to 5 keV

Vacuum System
- Turbo Pump (TP) (Pfeiffer Vacuum, mod: TMU 261 P) with a Scroll Pump (SP) (Edwards, mod: XDS 10) that, when GVs are closed, provides high vacuum conditions in the MC (< 10^{-8} mbar) with minimal mechanical vibration
- Connected to the main chamber (MC) assembled with DN 100 CF components

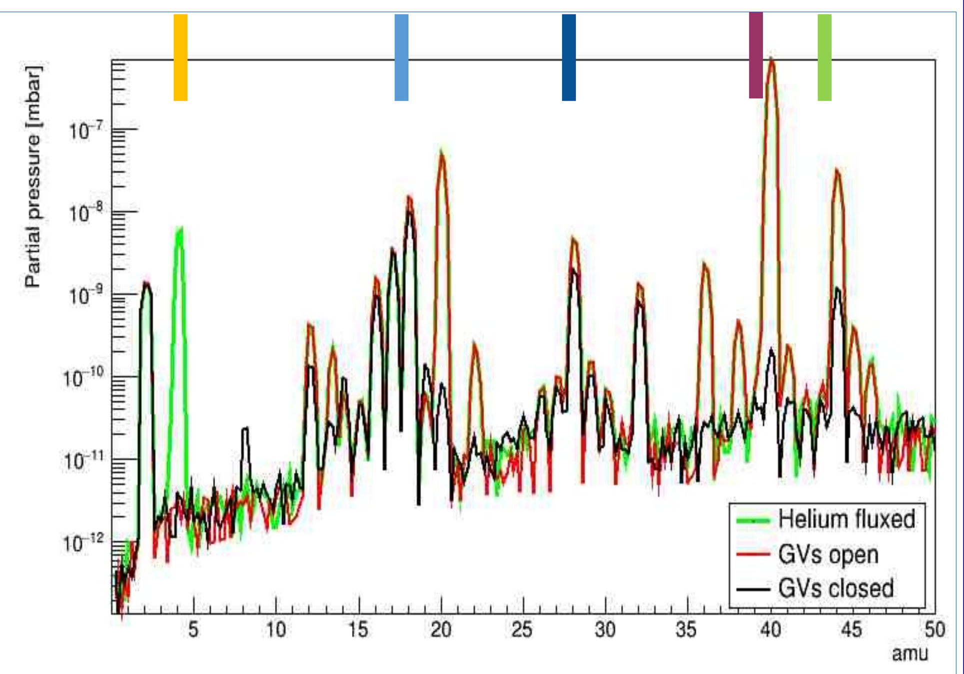
Main Chamber (MC)
- Central hub for auxiliary systems like PIRANI full range pressure gauge (IONIVAC, mod: ITR 90)
- Designed to accommodate future upgrades as a charge exchange cell for neutral beam production and an acceleration stage in front of the IS to increase the ions kinetic energy

Residual Gas Analyzer (RGA) (PFEIFFER VACUUM, QMG 250 PRISMAPRO)
- Connected to the MC to monitor contaminant gases of the vacuum volume that may contribute to the formation of diffuse background and secondary beams that overlap with the main monoenergetic beam signals

The major components of our vacuum in three different conditions are:

1. Ar and CO_2 from the detector gas mixture
2. H_2O (vapor) from components outgassing
3. N_2 from residual leaks
4. He accelerated by the ion source.

Maximum pressure in the MC fluxing gases with the IS $1.3e^{-6}$mbar.

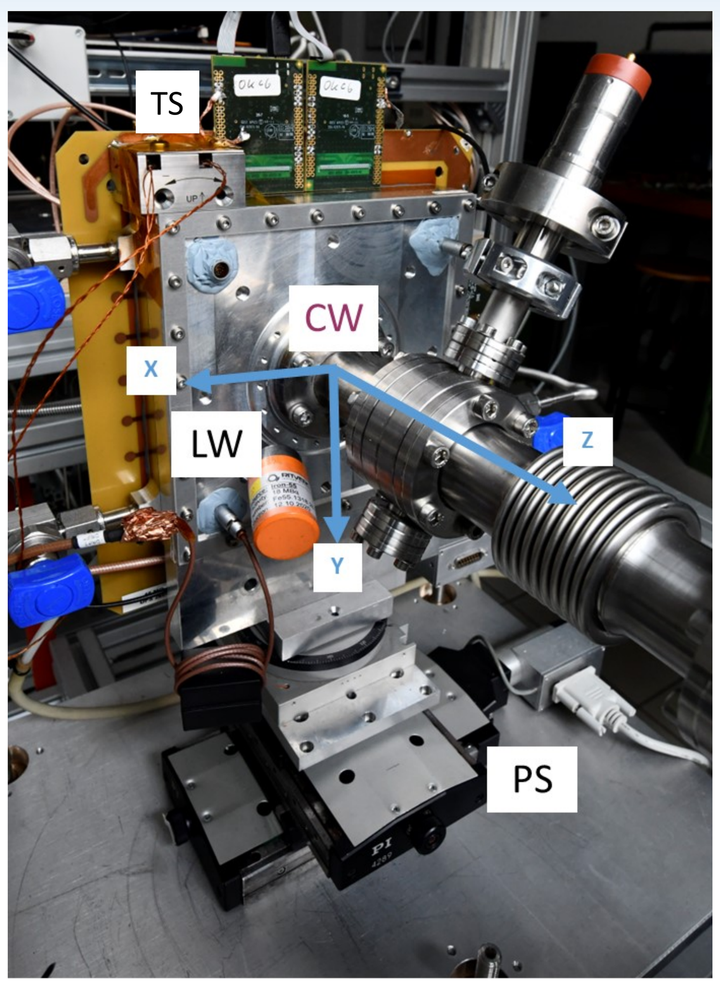


Gate Valves (GVs)
- Separates the upstream region (ion source and vacuum system) from the downstream region (detector under test and experimental setups)
- Allows for system isolation, facilitating maintenance and future upgrades
- A DN 40 CF blank gasket modified with a nominal 0.5 mm central hole is installed downstream of the gate valve (GV) to reduce backflow of residual gases toward the IS causing background signals
- An Angle Valve (AV) is installed along the beam pipe in the downstream region for a better pressure control during vacuum creation

BEAM PIPE AND MICROMEGAS INTEGRATION

Along the beamline, differential pressure technique and detector gas tightness allow low-energy ions to enter the detector for the study of atom-molecule-gas interaction.

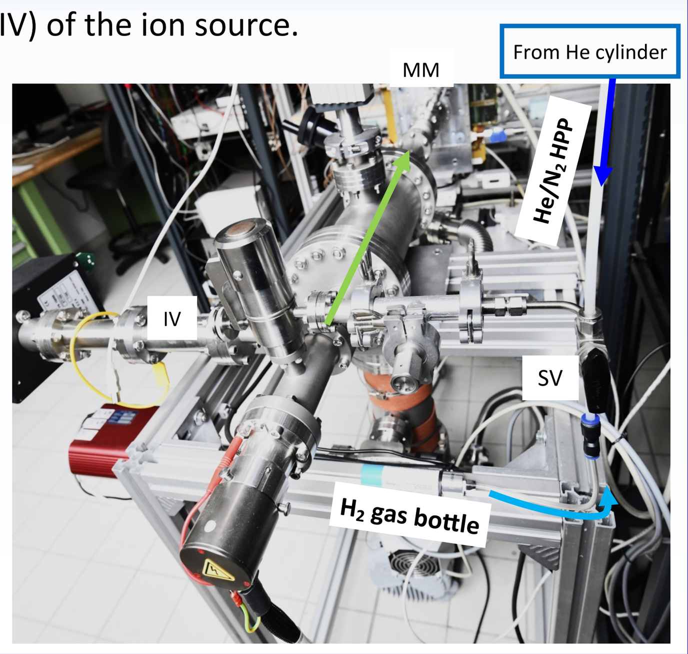
- The beam pipe connects to the MM top cover using a CF 40 nipple with indium sealing
- The top cover has two holes:
  - Central Window (CW): The ions enter the MM drift region through a 5 μm pinhole glued to the detector cathode. This setup maintains stable low-pressure levels within the MM; leak rate < 0.05 mbar/min with gas pressure < 150 mbar
  - Lateral Window (LW): Sealed from the detector side by a 50 μm thick PEEK layer, which is almost transparent to ^{55}Fe X-rays (90%). This window allows online calibration of the detector without removing the tube
- The detector is installed on a precision positioning system (PS) that allows movement in all six degrees of freedom using a combination of manual and motorized stages
- The MM position is monitored with a tilt sensor (TS) with a total range capability of 0.5° and resolution <0.1μrad



ION SOURCE INLET GAS SUPPLY

Various monoatomic and molecular gases can be supplied to the ion source through a dedicated high-pressure pipe (HPP) connected to ultra-pure gas bottles and the inlet leak valve (IV) of the ion source.

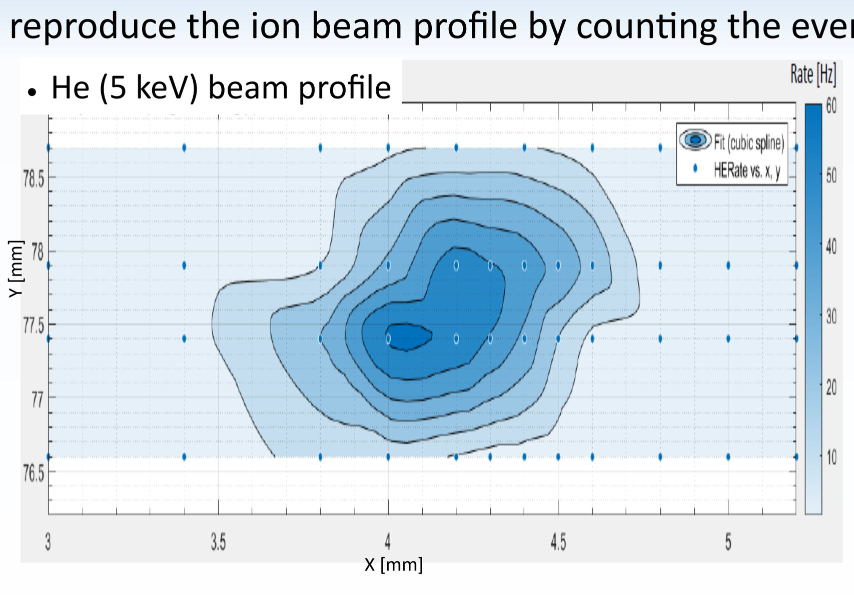
- For hydrogen, small (10 standard liter capacity) refillable metal hydride small bottle containing 4.0 pure H_2 are used for enhanced safety
- A Switch Valve (SV) allow the choice of the beam type



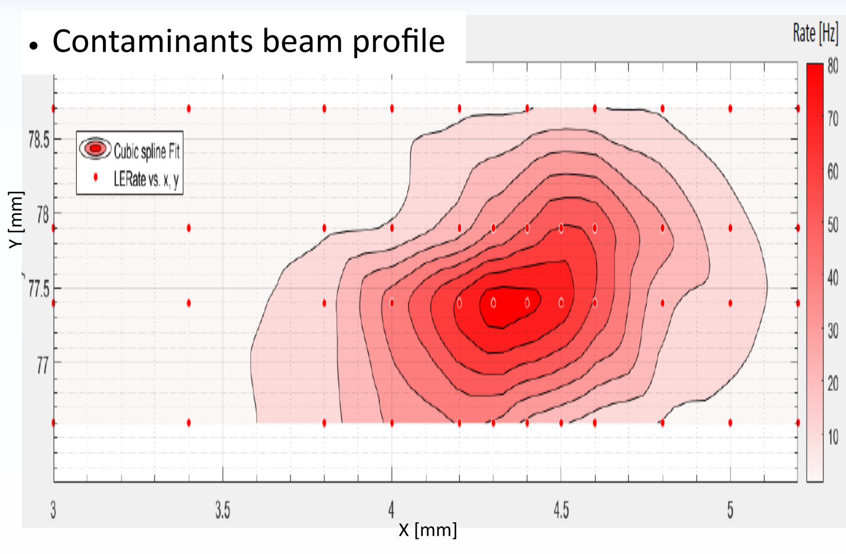
BEAM PROFILE

The small 5 μm MM pinhole entrance is utilized for scanning the beam profile. With the precision positioning system (PS), it becomes feasible to reproduce the ion beam profile by counting the event rate.

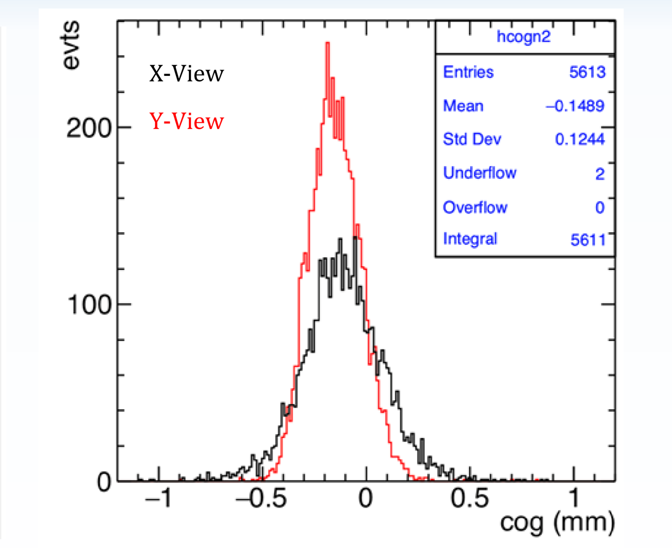
- He (5 keV) beam profile



- Contaminants beam profile



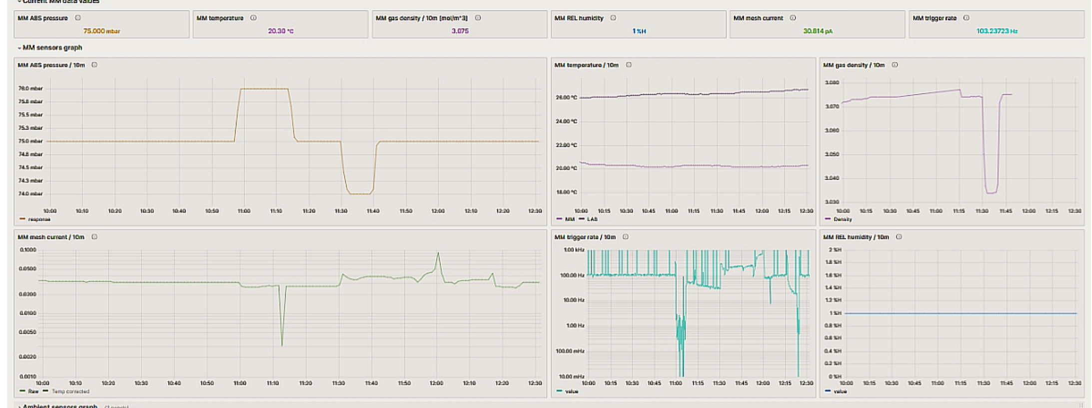
Both beams have a central peak of about 0.8 mm, which is larger than the 0.5 mm diameter pin hole on the copper gasket in front of the GV. This increase is due to the beam divergence specified by the manufacturer.



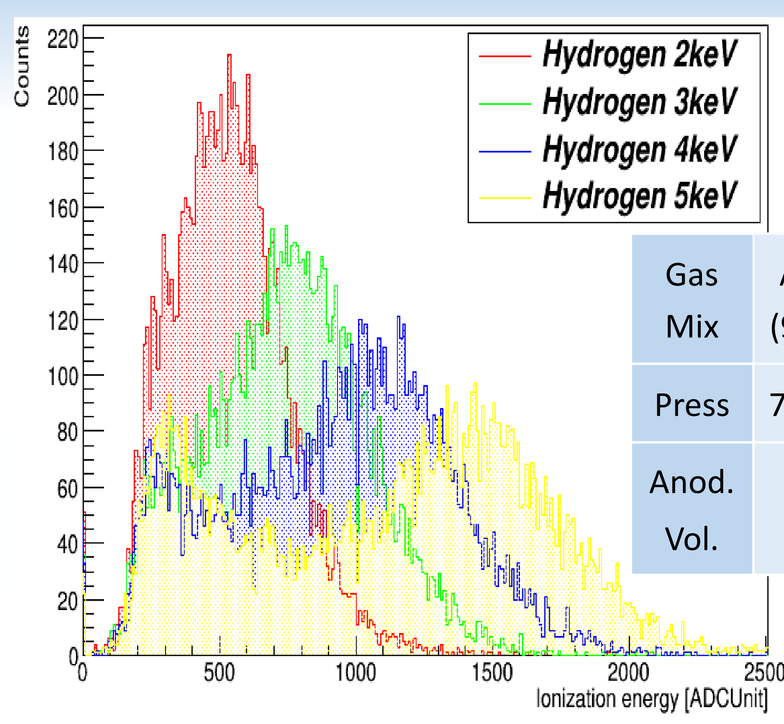
MM Strip signal center-of-gravity (cog); the events are correctly reconstructed as centered in the pin-hole located close to the axis origin

MONITORING AND STABILITY

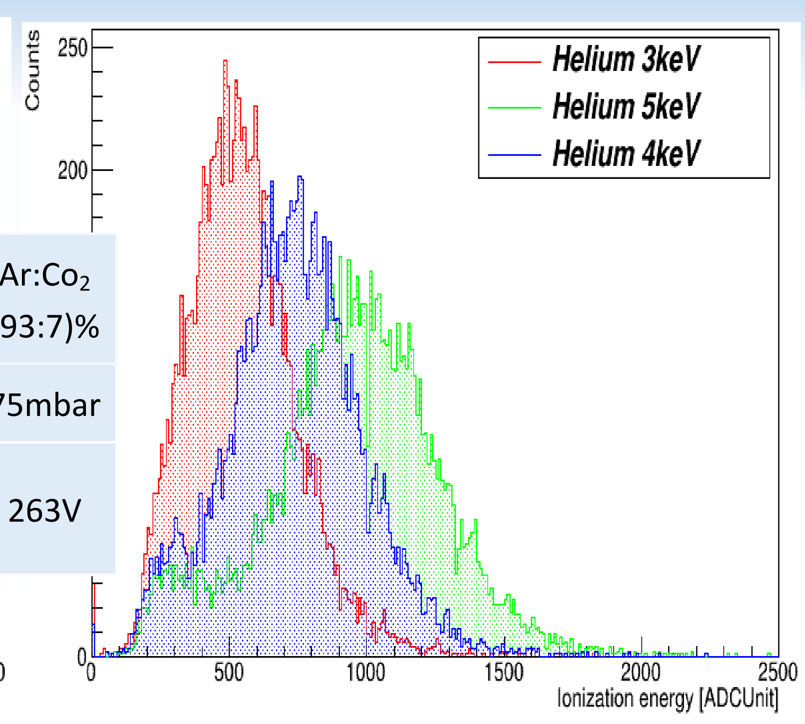
Monitoring parameters affecting IBF performance and detector response is essential for enhancing experimental precision. Key parameters such as pressure, humidity, temperature of the MICROMEGAS (MM) and environment, mesh current, and event rate are continuously recorded to ensure system stability. A dedicated gas system and a sensor-based cooling system are employed to control gas pressure, mixture, flow, and detector temperature.



MONOENERGETIC IONS SPECTRA (H_2, He) WITH THE MICROMEGAS



Gas Mix	Ar:CO_2 (93:7)%
Press	75mbar
Anod. Vol.	263V



- **Ionization energy spectra** are acquired by measuring the signals induced on the MM mesh through a custom front end chain applied [2].
- **Helium signals** are generally lower than hydrogen signals due to helium's lower ionization quenching factor [3].
- **Spectra FWHM** are compatible with the MM expected resolution, indicating that the beam remains nearly monoenergetic up to the detector entrance.
- **Further contaminants** reduction will allow for the detection of lower energy beams, enhancing measurement sensitivity.

CONCLUSION The IBF represents an active playground, at INFN Pisa, for the future developments of gas detectors to be operated in low-pressure regime and for low energy ionization radiation. Thanks to the use of this facility, in the last years a precise characterization of a MICROMEGAS detector was possible and today it represents a cornerstone of a robust and well-established research and development program for future detector technologies.

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