IV Characterisation for the VELO Upgrade

Vinícius Franco Lima[1] - On Behalf of the LHCb Collaboration

The LHCb Upgrade

LHCb is a dedicated heavy flavour physics experiment that operates at the LHC. The current experiment runs at a typical luminosity of $4x10^{32}cm^{-2}s^{-1}$ and is expected to accumulate 9 fb^{-1} by the end of Run II. The LHCb collaboration plans to change key features of the present detectors for Run III, moving to a full detector readout at 40MHz and operating at a luminosity of $1\text{-}2x10^{33}cm^{-2}s^{-1}$ (Figure 2)[1]. The new readout scheme and operation conditions will require replacing many of the detectors to be completely replaced, including the VELO.

VELO Upgrade

The new Vertex Locator (VELO) detector (Figure 1) will replace the silicon micro-strip detector currently operating around the interaction point. It will use hybrid pixel detectors composed of silicon sensors bump-bonded to new VeloPix CMOS readout chips designed for the new 40MHz readout rate. Each VELO module will have 12 readout chips attached to 4 different sensors (Figure 3), mounted in a mechanical frame capable of moving the sensors away from the beams when LHC is not in stable colliding beam mode [2].

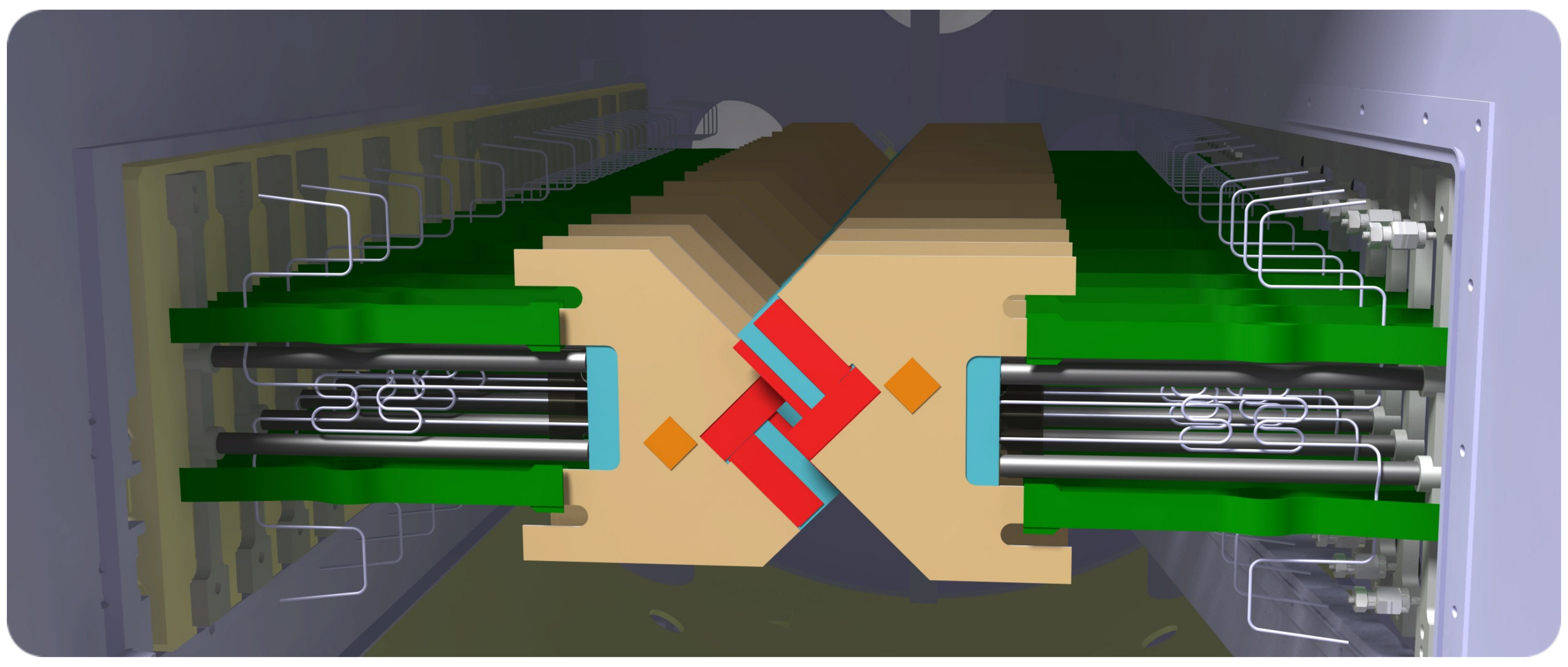

Figure1: The VELO Upgrade. Each module has four sensors (in red) on a microchannel cooling silicon substrate(blue).

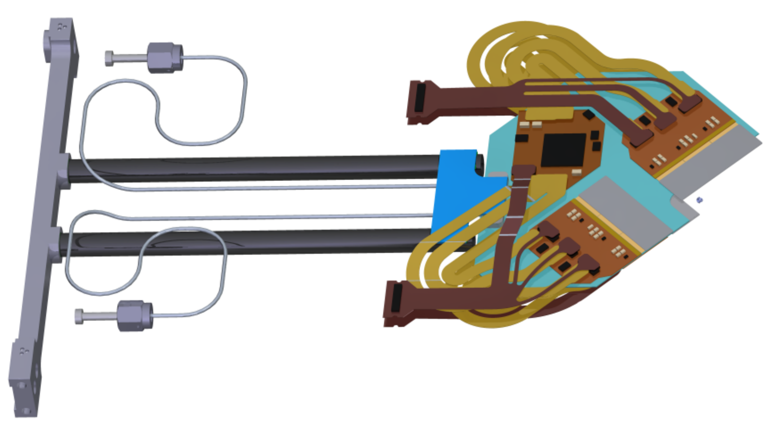

Figure 3: VELO Upgrade module schematic. Two sensors are mounted on each side of the module.

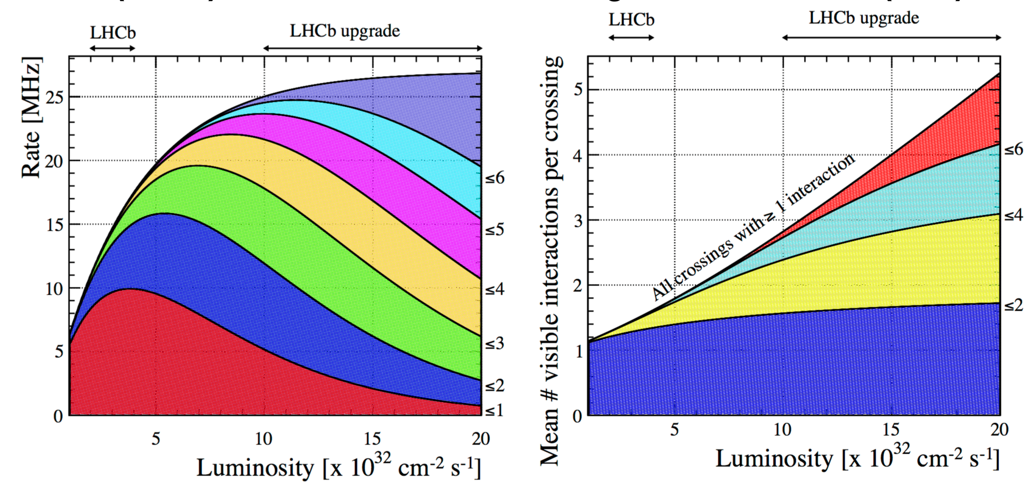

Figure 2: Comparison between LHCb operational luminosity between present and Upgrade.

Probing IV Characteristics

The current versus voltage (IV) behaviour of a silicon sensor is important to qualify the electrical stability and power dissipation of sensors.

- The IVs have to be taken before wire bonding, so sensor quality is assured before module construction.
- To avoid sparks damaging the assembly, the IVs should be performed in vacuum.
- A vacuum setup prevents the use of delicate probing needles.

The intent is to devise a way to reliably bias sensors that can be implemented in vacuum and up to 1000V.

- If the backside surface of the ASIC is conductive, it is possible to **reverse bias the sensor** by grounding the ASIC backside and **forward biasing the ASIC** n-well.
- To test the feasibility of this method a bare ASIC was probed under a microscope to observe the forward bias diode behaviour expected (Figure 4). Then an assembly with a sensor bump-bonded to a VeloPix was used to test the whole chain (**Figure 5**).

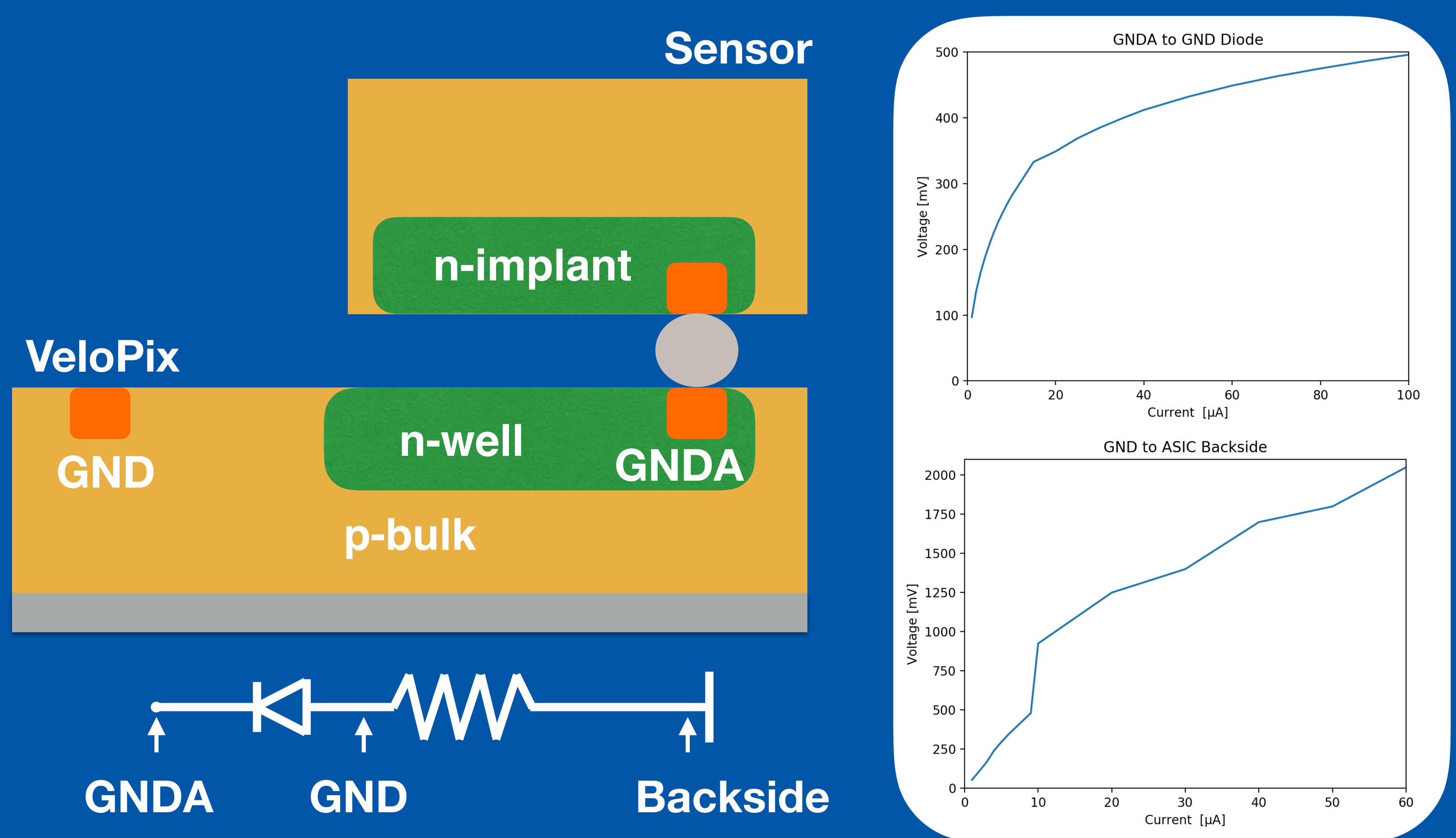

Figure 4: A scheme of the ASIC and the expected behaviour of the current transversing the ASIC (left). Together measured behaviour between terminals on a bare ASIC (right).

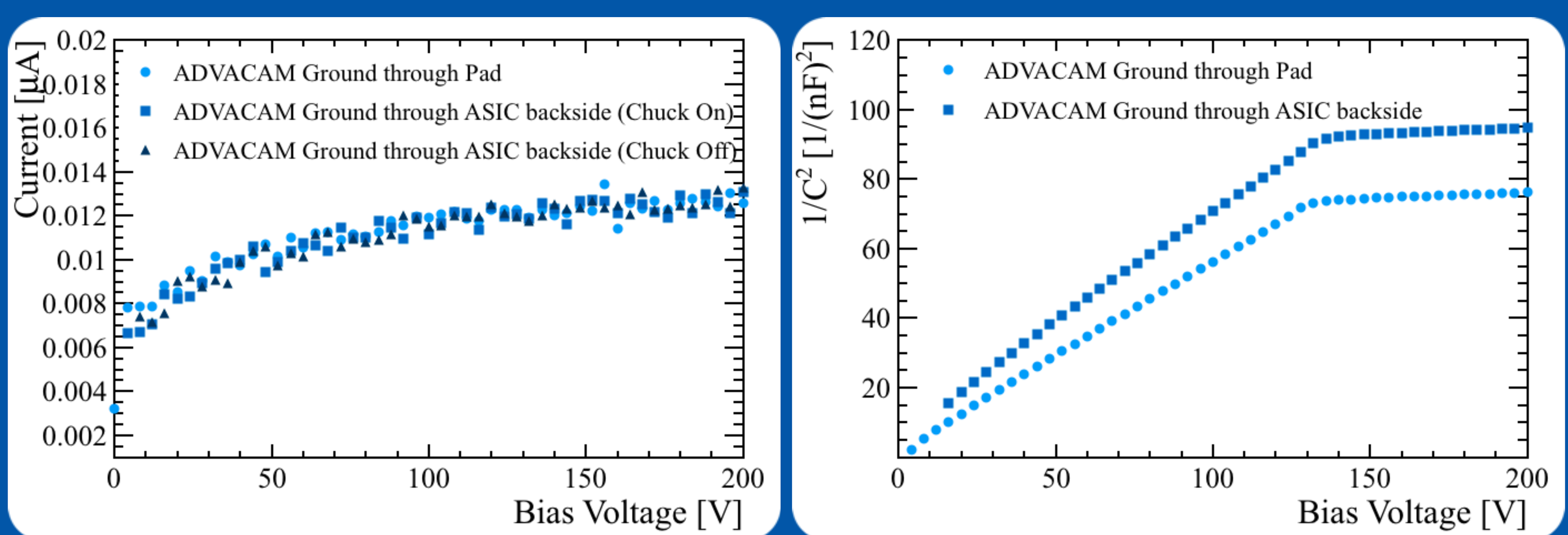

Figure 5: Comparison between normal biasing (light blue) and biasing using the ASIC backside (dark blue).

Vacuum Chuck and Vacuum Hood

A new setup was developed to qualify assemblies in batches of the VELO Upgrade. Due to the vacuum environment, sensors can't be held in position using a vacuum chuck alone. A system using retractable needles was built to carefully deliver bias while holding the sensor down for the ground contact:

- A vacuum chuck that will hold 10 bump-bonded sensors, **positioning them with a precision of 40 μm** using a lithography-made stencil. Used to read out the 3 VeloPix ASICs in a sensor with a probe card.
- A mid-plate that holds all needles and guides the wires to the HV feedthrough.
- A Vacuum chamber encloses the vacuum chuck, **allowing for the IV characterisation to be done up to 1000V**.

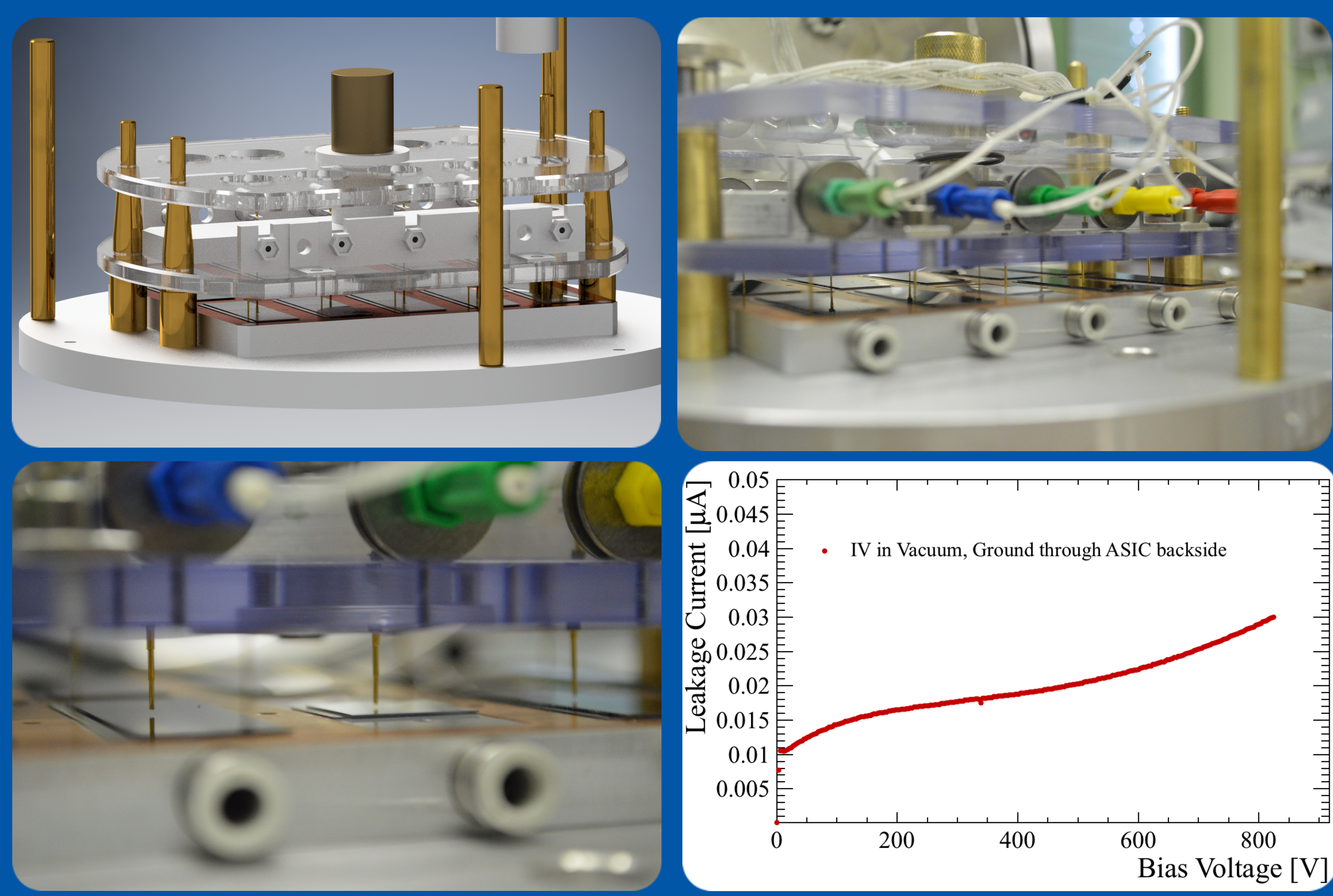

Figure 6: Design (top left) and pictures (top right, bottom left) of the IV vacuum setup. On the bottom right is the IV curve of a test assembly taken in vacuum.

Conclusion

A method for measuring the characteristic IV curve of silicon sensors before wire-bonding was proven to work. We developed a new setup with a vacuum chuck that will precisely position assemblies so the VeloPix ASICs can be readout and the bump bond quality assessed. This new setup will also use the new biasing method to test all sensors IVs up to 1000V bias in vacuum, qualifying them before module construction.

[1] Framework TDR for the LHCb Upgrade : Technical Design Report CERN-LHCC-2012-007 ; LHCb-TDR-12
[2] LHCb VELO Upgrade Technical Design Report; CERN-LHCC-2013-021 ; LHCb-TDR-013

[1]University of Liverpool, Oliver Lodge Laboratory - vinicius.franco.lima@cern.ch

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