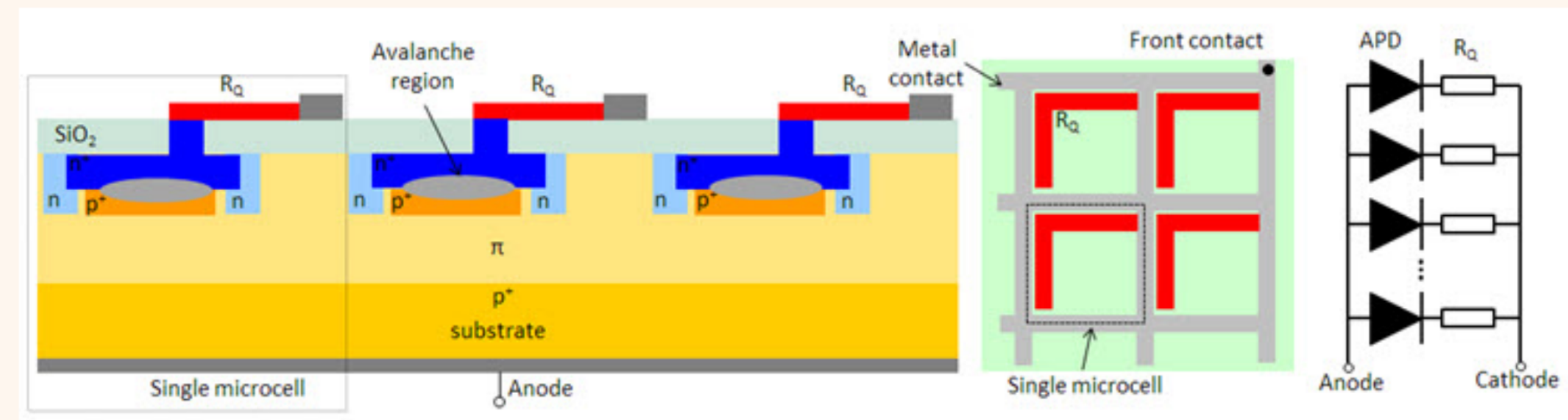


Marco Guarise on behalf of the DUNE collaboration

University of Ferrara and INFN

## General characteristics of SiPM:

- large matrix of single-photon avalanche diodes (SPADs);
- each SPAD is a p-n junction in reverse polarization above breakdown voltage;
- each SPAD produces a macroscopic current when hit by a photon due to the avalanche effect;
- important parameters: breakdown voltage (set the SiPM operation) ( $V_{bd}$ ) and the quenching resistor ( $R_q$ ) (related to the recharge time constant);
- dark signals: thermal generation of carriers + tunnel effect. At room T dominates the former while the latter becomes dominant at cryogenic temperature. These signal contributes to the dark count rate (DCR). In addition after pulses (AP) and cross-talk (CT) can happened.

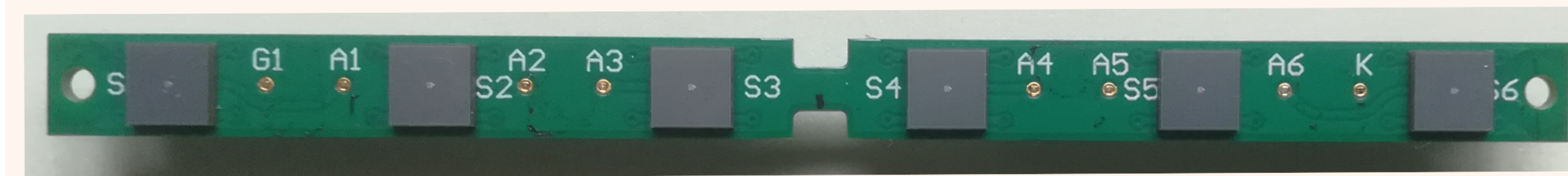


### Features:

- good robustness;
- high sensitivity;
- high dynamic range;
- reduced costs;
- scalability and granularity.

## DUNE splits SiPMs:

- provided by 2 vendors: Hamamatsu Photonics K.K. and Fondazione Bruno Kessler;
- requests: large area, high gain, single p.e. sensitivity, UV detection, cryo operation and resistant to thermal stresses, low temperature DCR < 100 mHz/mm<sup>2</sup>;
- before downselections we tested six types of sensors from HPK and FBK, customized for cryogenic operation and matched with the optical parameters of the X-ARAPUCA module.



### Array features:

- 6 SiPMs 6mm<sup>2</sup> area;
- common cathode;
- (120x8)mm;
- detection part of the X-ARAPUCA module.

## Characterization tests:

- IV curve at room and liquid nitrogen temperature;
- thermal stresses (20 cycles between room and LN2 temperature);
- DCR measurements.

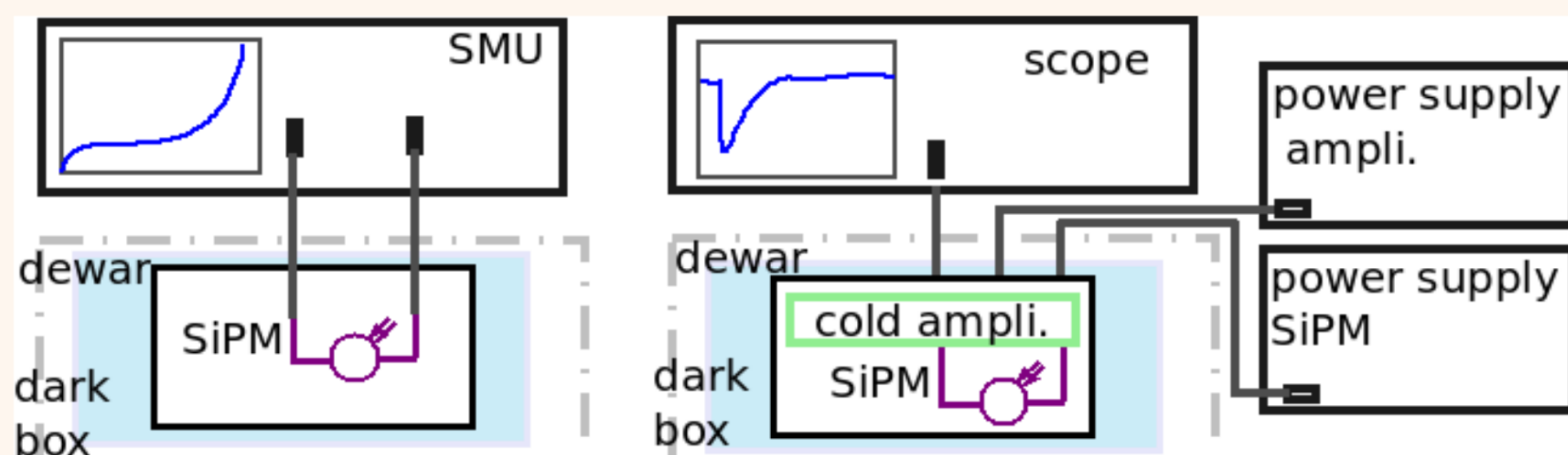


## Status and prospects:

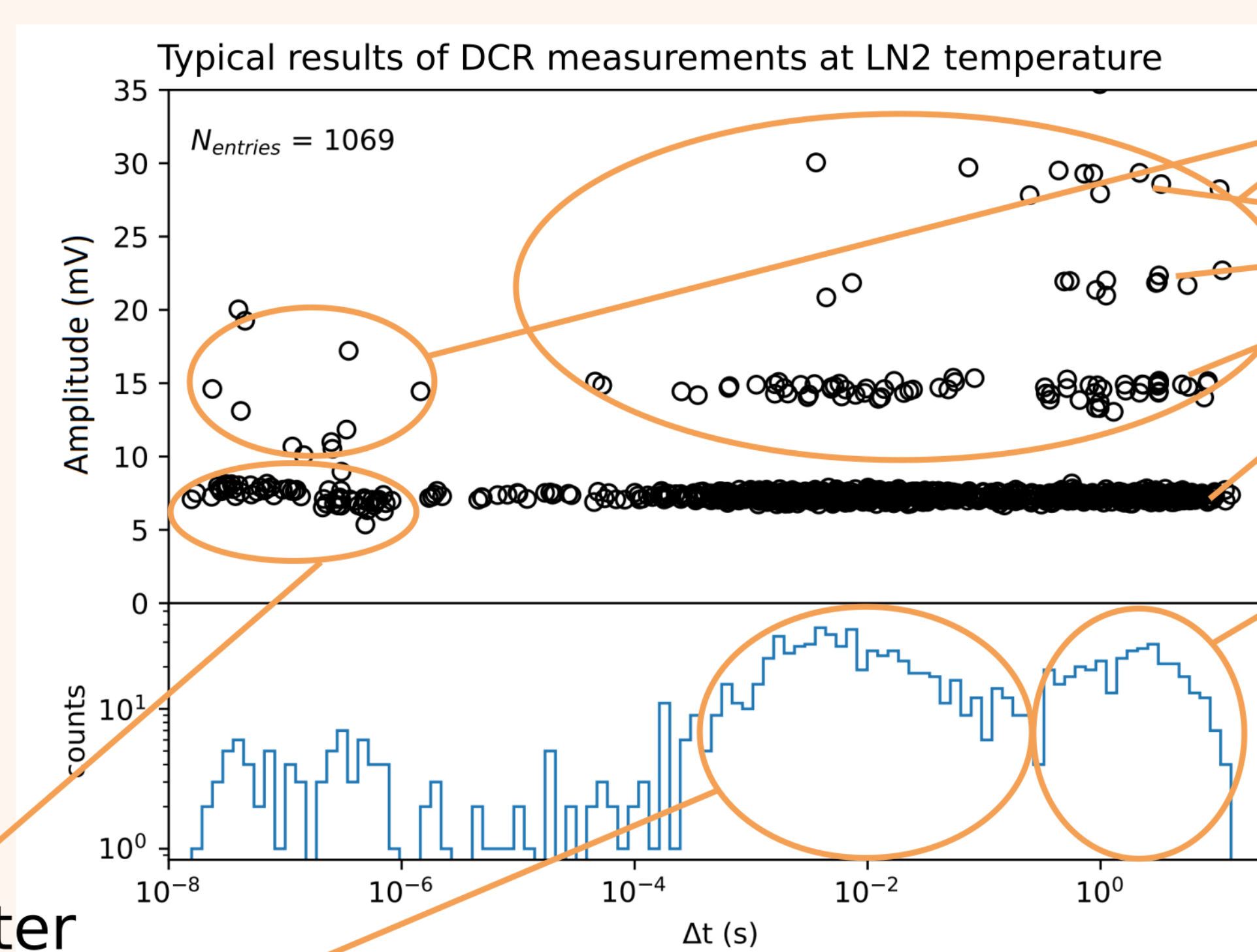
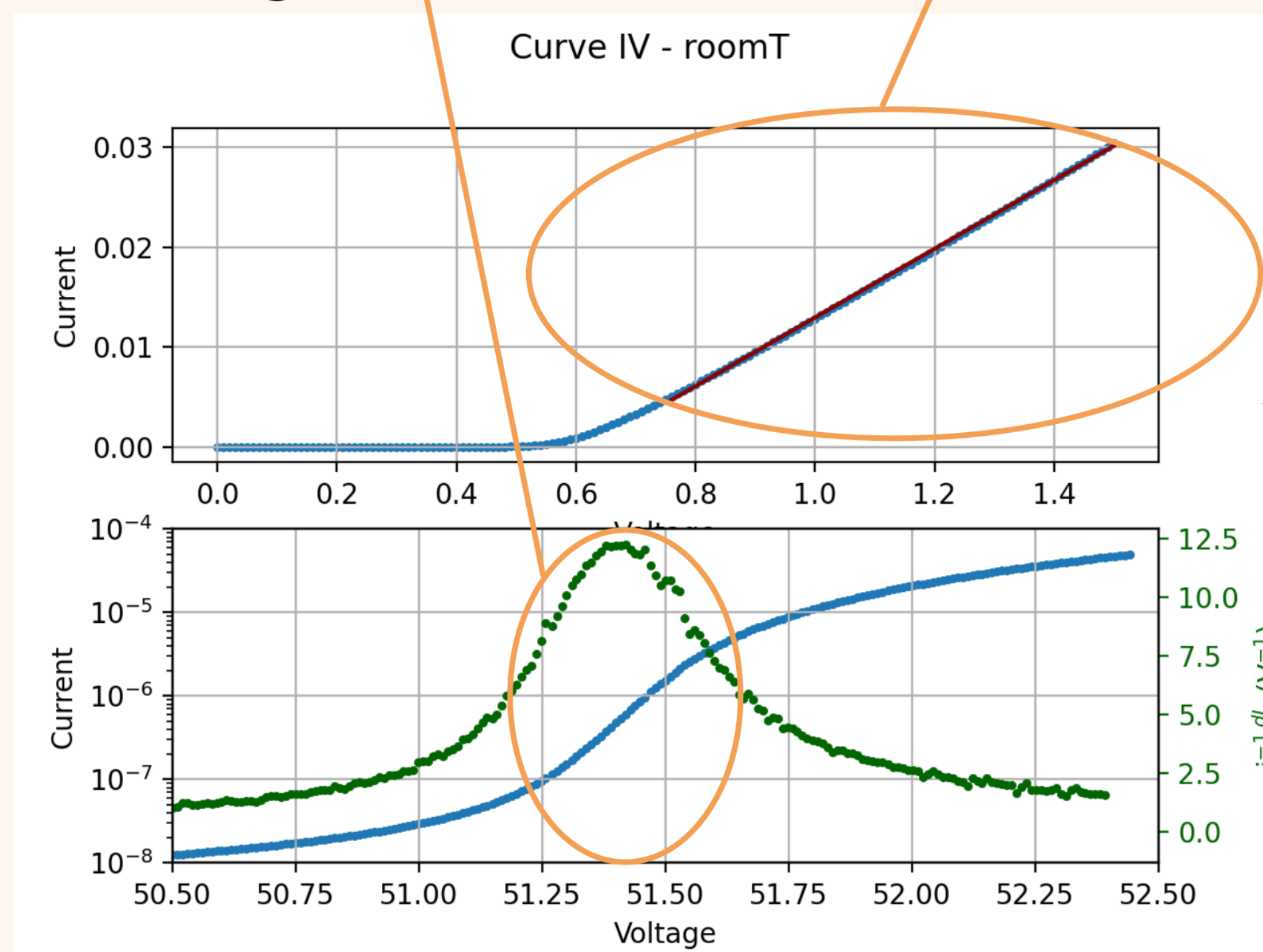
- downselection of 1 model HPK and 1 model FBK;
- mass tests of the selected SiPM (8000 samples);
- installation in ProtoDUNE-SP.

## Set-up and results:

- cryogenic environment: liquid-nitrogen dewar;
- light shield: dark box;
- characteristic IV-curve: source meter unit;
- dark signals: power supply, cryo-amplifier, oscilloscope.



- $R_q$  from the linear fit in the forward region of the IV curve (mA range);
- $V_{bd}$  calculated from the maximum of the curve  $i^{-1} di/dV$  measured in the inverse region.



prompt and delayed cross talk clusters  
Clusters of signals at 1, 2, 3, and 4 photoelectrons.

Primary dark signals cluster.  
At LN2 temperature we found a DCR of the order of tens mHz/mm<sup>2</sup> (we measured Hz rate considering the entire SiPM).

### Burst events cluster:

- unexpected behavior;
- correlated events;
- last for a few tenths of a second;
- separated by [0.1 – 10] ms;
- average number of events in a burst is ~ 100;
- typically triggered by a high-amplitude event;
- observed in all DUNE split SiPMs;
- further investigations are underway.