A Wire-Based Methodology to Directly Analyse the Nanometric Resolution of an RF Cavity BPM

S. Zorzetti*, K. Artoos, F. N. Morel, P. Novotny, D. Tshilumba, M. Wendt, CERN, Geneva, Switzerland
L. Fanucci, Universitá di Pisa, Pisa, Italy

*silvia.zorzetti@cern.ch

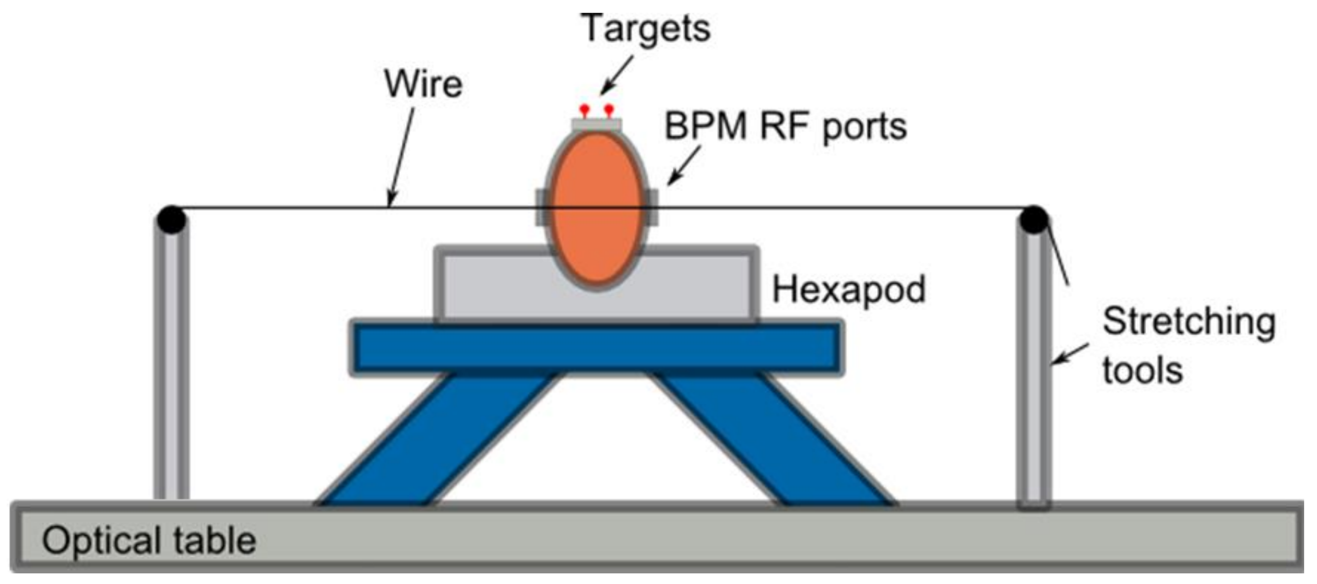
ABSTRACT

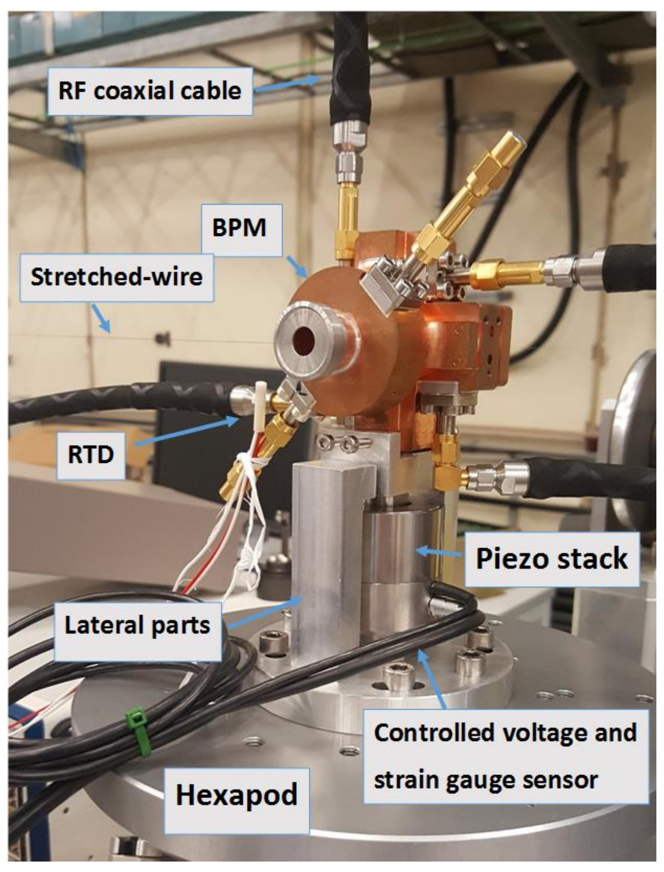
Resonant Cavity Beam Position Monitors (RF-BPMs) are diagnostic instruments capable of achieving beam position resolutions down to the nanometre scale. To date, their nanometric resolution capabilities have been predicted by simulation and verified through beam-based measurements with particle beams. **In the frame of the PACMAN project at CERN, an innovative methodology has been developed to directly observe signal variations corresponding to nanometric displacements of the BPM cavity with respect to a conductive stretched wire**. The cavity BPM of this R&D study operates at the TM110 dipole mode frequency of 15GHz. The concepts and details of the RF stretched wire BPM testbench to achieve the best resolution results are presented, along with the required control hardware and software.

STRETCHED-WIRE SETUP

BPM Test Bench

A **conductive wire** is stretched through the BPM cavities. It is fixed on the extremities and behaves as a **passive probe, coupling the E-field**. The BPM is rigidly mounted on a hexapod, which allows **the relative displacement between the center of the position cavity and the wire**. Scattering parameters are acquired by VNA measurements from the 4 lateral waveguides. We found that the **most sensitive information is returned by the phase between adjacent ports** (e.g. $\angle S14$), which demonstrates a linear behaviour around the electrical center of the cavity





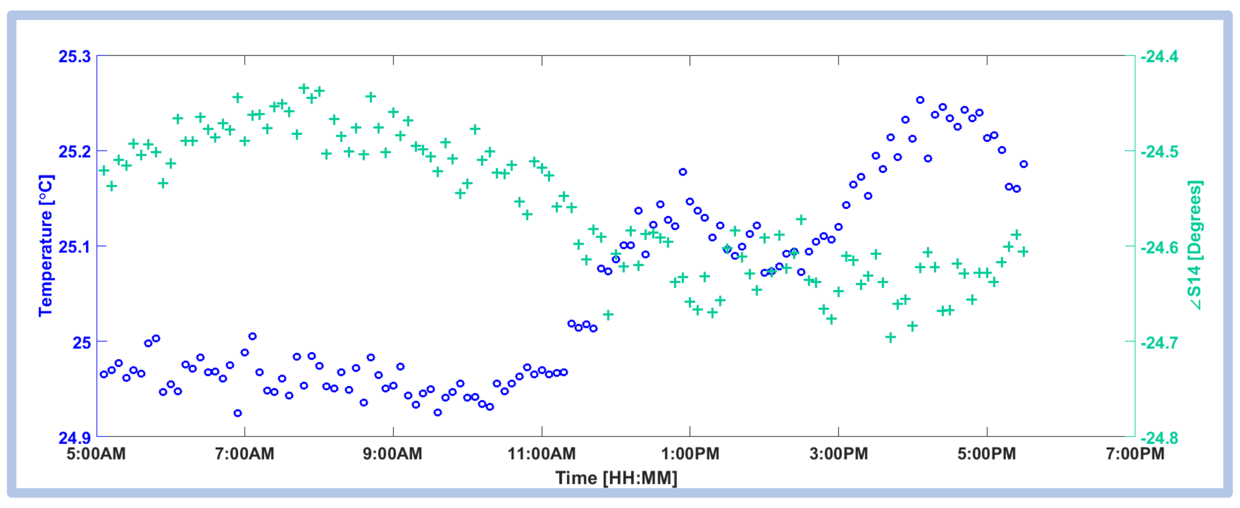
Proving the nanometric resolution of the position cavity

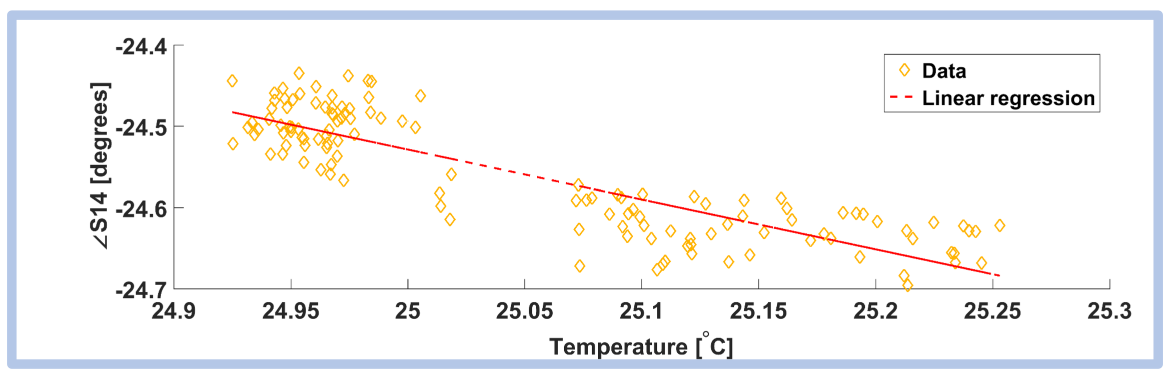
The test bench is improved by adding a **piezo stage** between the hexapod and the BPM to apply nanometric displacements. The piezo is operated in a **closed loop, to cancel hysteresis and improve linearity**. Due to the small mass of the BPM (0.7 kg) with respect to the high load actuator (12.5 kN), no external linear guideline was used for this simple setup. This is considered sufficient as **the measurement campaign consist of a rather static process.**

Environmental tests

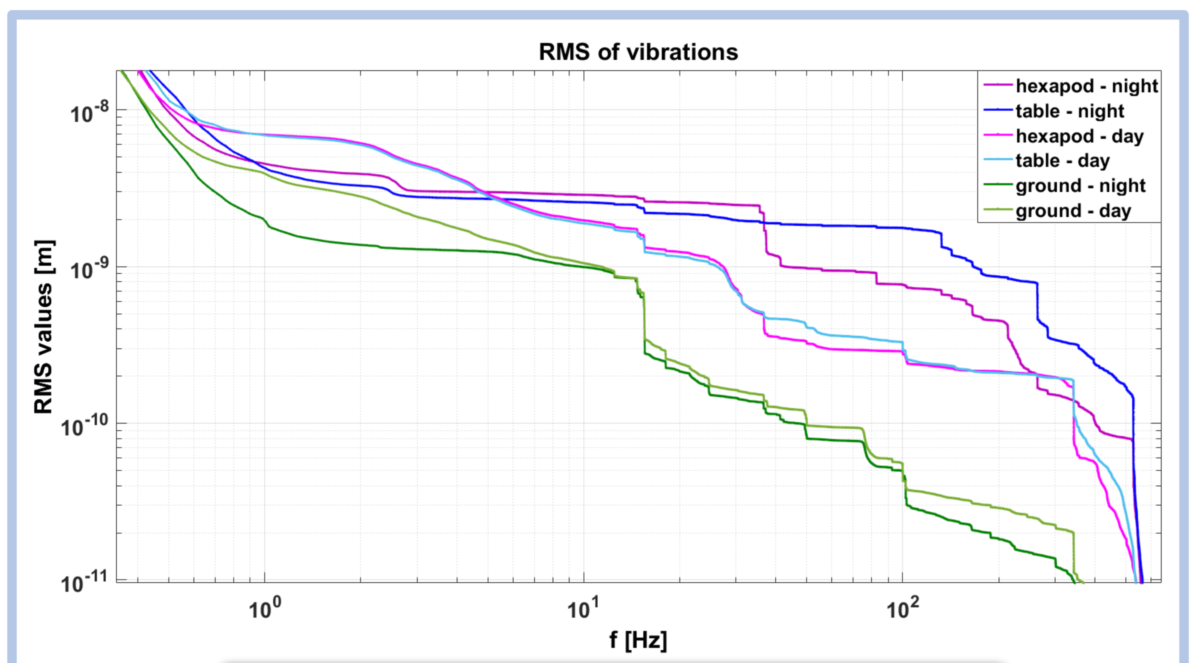
Environmental tests were carried out to **verify the stability of the laboratory** in terms of temperatures and vibrations

- **Temperature**: the resonant frequency of the position cavity changes in function of the temperature
- **Vibrations**: the relative motion between the table and the hexapod is in the order of 4 nm





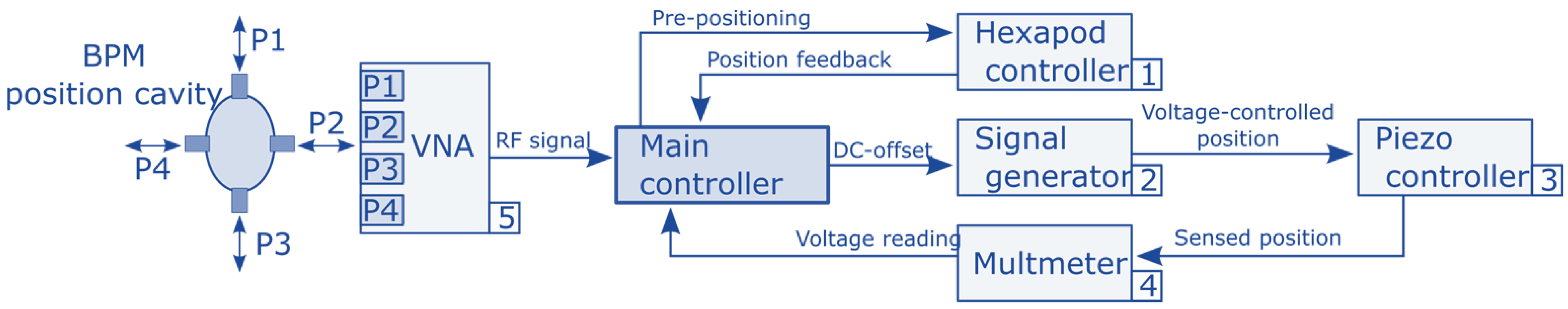
Adjacent ports phase Vs. Ambient temperature



RMS vibrations of the bench

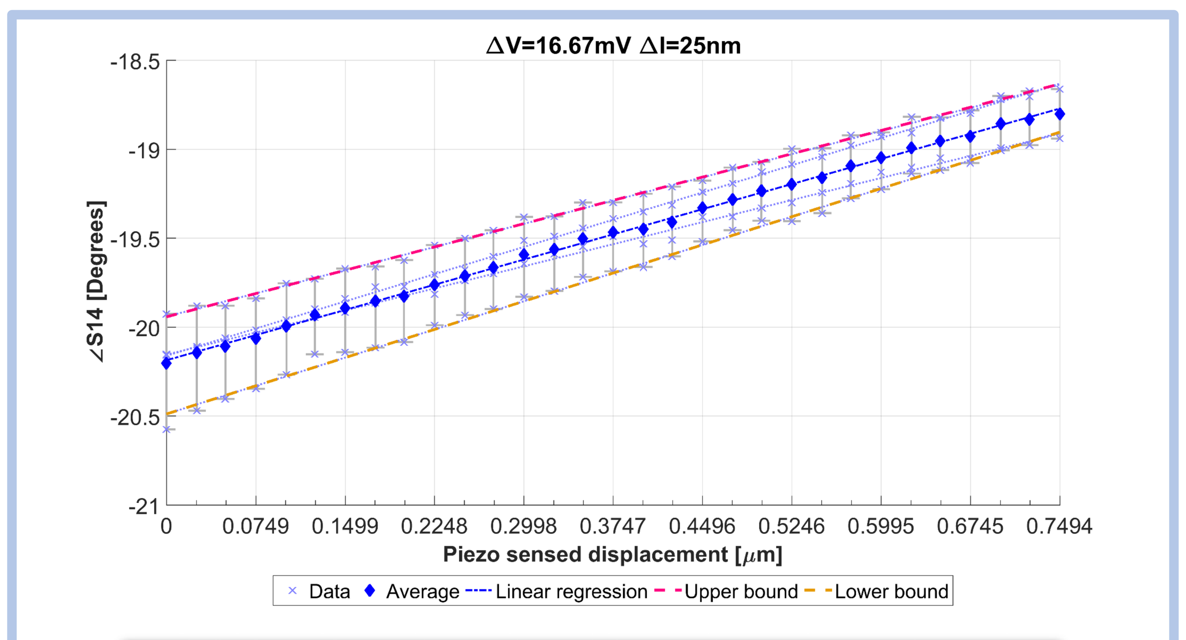
Methodology

1. The **hexapod** is moved to prepositioned coordinates. This predetermined point is close to the electrical center and has high sensitivity;
2. The **main controller** provides the voltage value to the *signal generator*;
3. The **piezo actuator** is controlled by **DC voltage offsets** from the signal generator's output;
4. After the movement of the piezo, a **sensed position** is sent in closed loop for voltage reading to the **multimeter**;
5. The **VNA**, connected to the four BPM ports, performs RF magnitude and **phase measurements** in frequency sweep

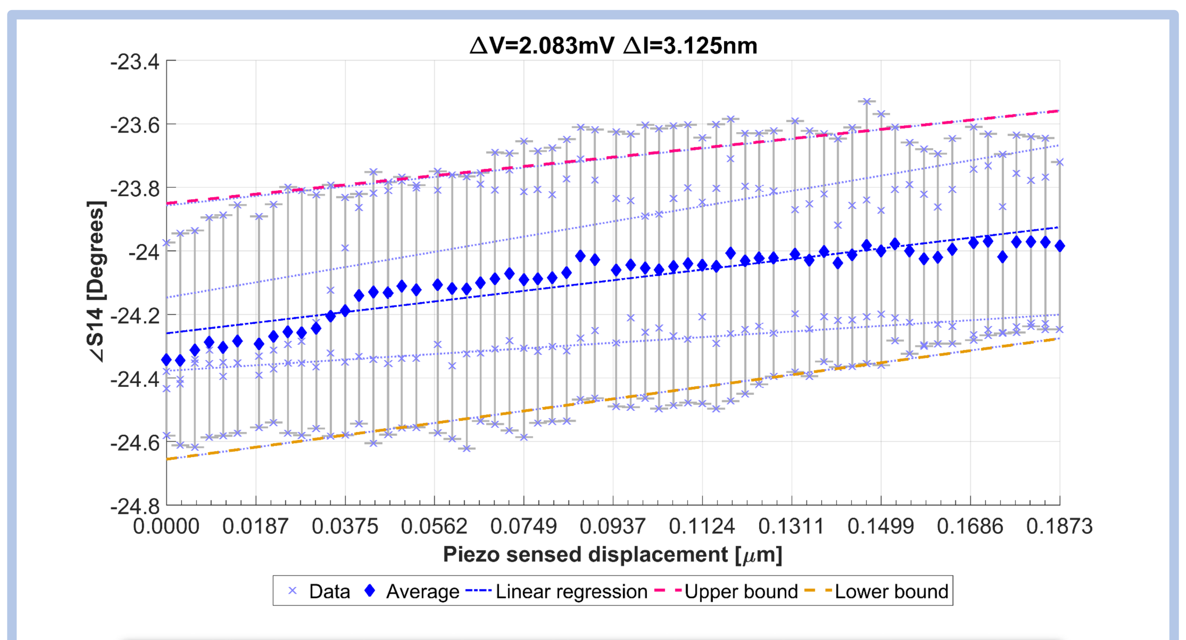


NANOMETRE RESOLUTION RESULTS

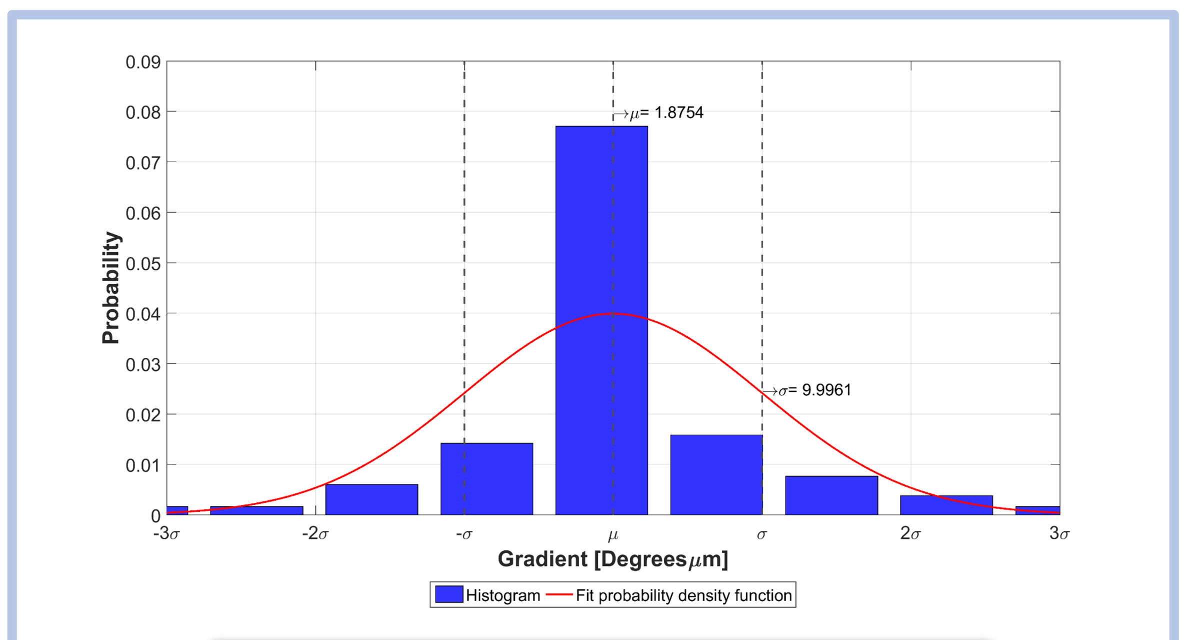
With this experiment we intend to **demonstrate that a few nanometres resolution could be resolved in a static conditions process**. The observed plots show a dependence between the phase and the piezo elongation expressed in a **linear form.** The **gradient distribution** between every couple of samples ($\Delta S14/\Delta l$) is computed. The mean (μ) gradient value has a higher probability of occurrence. The high variance depends mainly on the **impact environmental characteristics drifts at very low frequencies** (much smaller than the sampling frequency).



Sensitivity with 25 nm piezo elongation



Sensitivity with 3 nm piezo elongation



Gradient distribution

PACMAN is founded under the European Union's 7th Framework Program Marie Curie Actions, grant PITN-GA-2013-606839

International Beam Instrumentation Conference IBIC 2016 Barcelona