# Mini-BPMs for PRAE

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# PRAE: Platform for Research and Applications with Electrons

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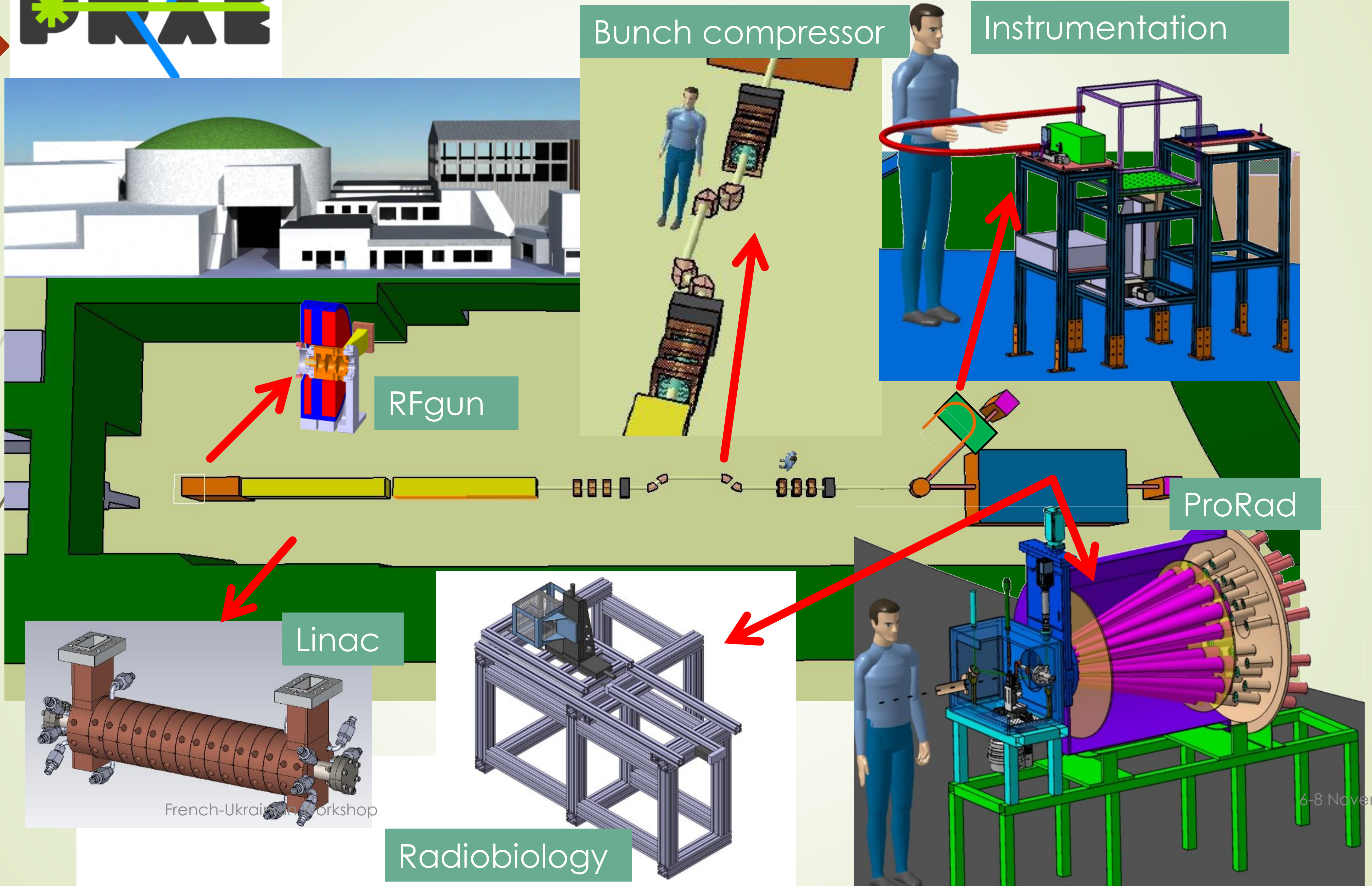
*Laboratoire de l'Accélérateur Linéaire*

The PRAE project aims at creating a **multidisciplinary** R&D facility in the Orsay campus gathering various scientific communities involved in **radiobiology**, **subatomic physic**s, **instrumentation** and **particle accelerators** around an electron accelerator delivering a high-perfomance beam with energy up to 70 MeV and later 140 MeV, in order to perform a series of unique measurements and future challenging R&D.

# PRAE in one image

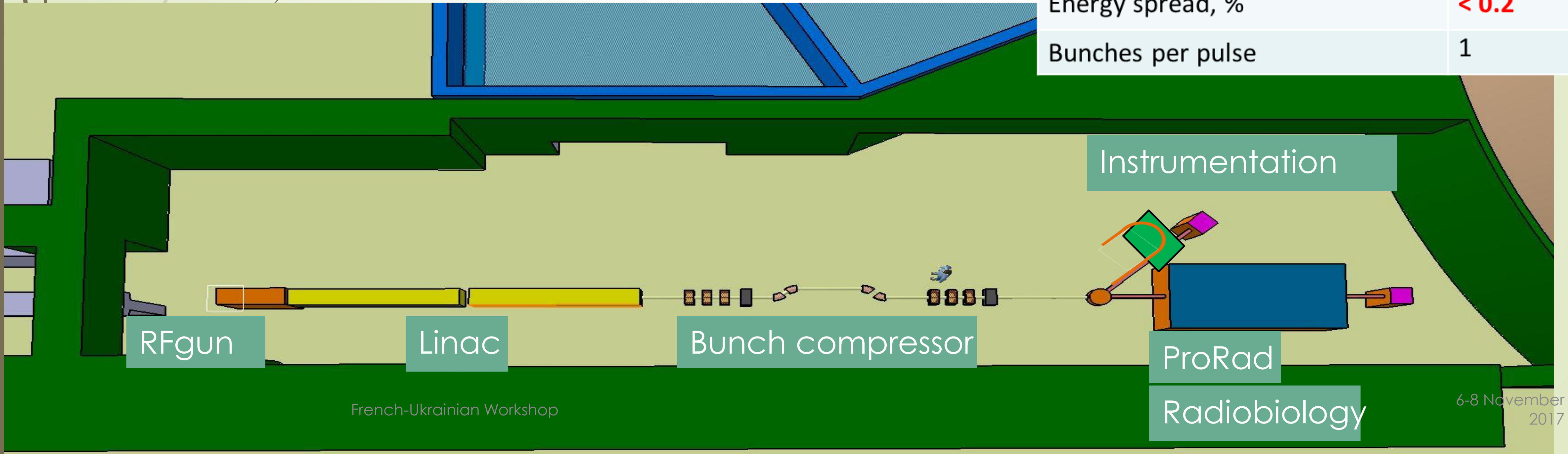


# PRAE accelerator parameters



The PRAE accelerator consists of a photo-injector, an acceleration section and two lines with the corresponding experimental setups: the subatomic physics and radiobiology research axes share the direct line and the instrumentation platform is located the deviated line.

| Beam parameters | Phase A-B |
|---|---|
| Energy, MeV | 50-70 (100-140) |
| Charge (variable), nC | 0.00005 – 2 |
| Normalized emittance, mm.mrad | 3-10 |
| RF frequency, GHz | 3.0 |
| Repetition rate, Hz | 50 |
| Transverse size, mm | 0.5 |
| Bunch length, ps | < 10 |
| Energy spread, % | < 0.2 |
| Bunches per pulse | 1 |

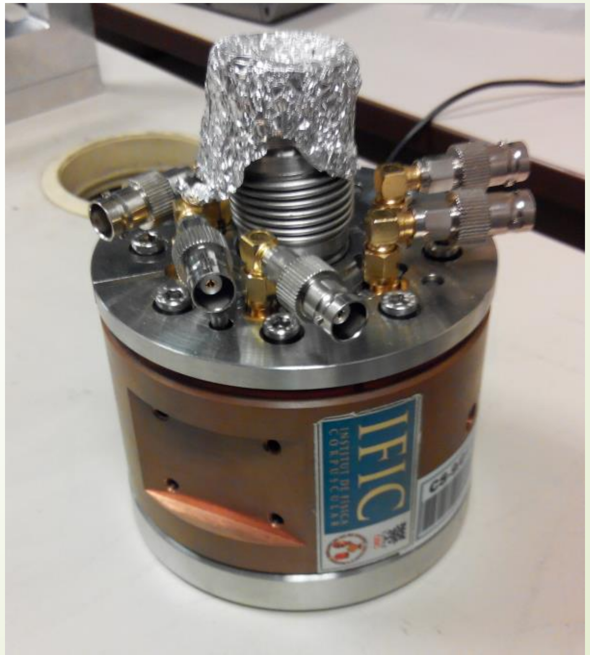


# Beam Diagnostics in Particle Accelerators

- The ***beam instrumentation*** or *beam diagnostics* deals with the design and development of the great diversity of instrumentation devices and technology needed for **monitoring** the **beam properties** in *particle accelerators*.
- Particle **accelerator performance** depends critically on the **measurement** and **contro**l of the beam properties, so **beam diagnostics** becomes an essential constituent of any accelerator. Generally the beam is very sensitive to imperfections or deviations from the ideal accelerator design produced in any real machine, and without adequate diagnostics one would **“blindly grope around in the dark”** for optimum accelerator operation.

# Beam Position Monitors (BPM)

- The devices designed specifically to measure the **beam position** as the beam centroid are called **Beam Position Monitors (BPM**) which are also commonly known as Pick-Ups (PU)
- In our case we use **Inductive Pick-Up (IPU)** which was developed for the Diagnostics of the Test Beam Line in the CTF3 at CERN

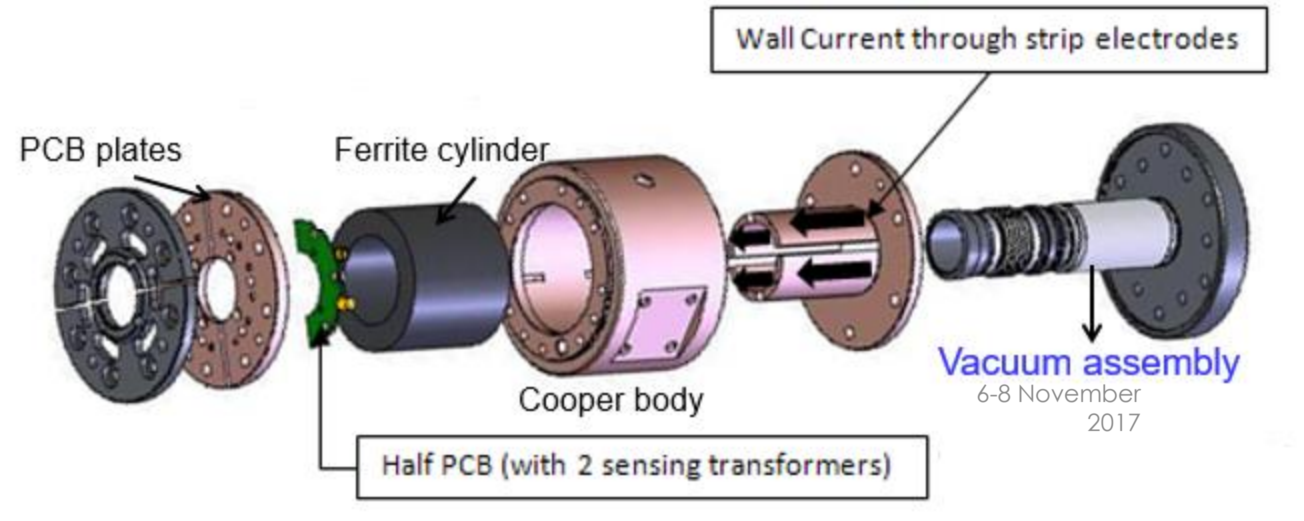


# Main features of the Inductive Pick-Up (IPU) type of BPM:

- **Less** perturbed by the **high losses experienced** in linacs;
- It generates **high output voltages** for typical beam currents in the range of amperes;
- Calibration **wire** inputs allow testing with current once installed;
- Broadband but better for **bunched beams** with **short bunch** duration or pulse

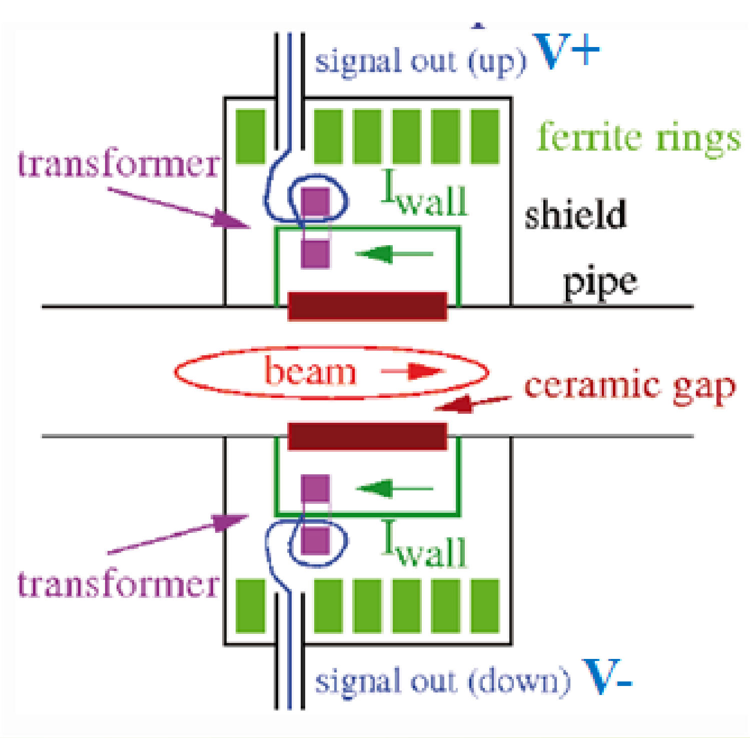
# BPM basic mechanism

The IPU wall is devided longitudinally into four independent strip electrods which are placed outside and surrounding a ceramic gap tube of the same electrodes length replacing a vacuum pipe section inside the device. Therefore the wall current is forced to follow the electrodes path instead of the non-conducting inner path corresponding to the ceramic gap pipeline section. The four strip electrodes are orthogonally spread over the pipe circular cross section so that the beam position horisontal and vertical coordinates is determined just by measuring the wall current intensity flowing through them.

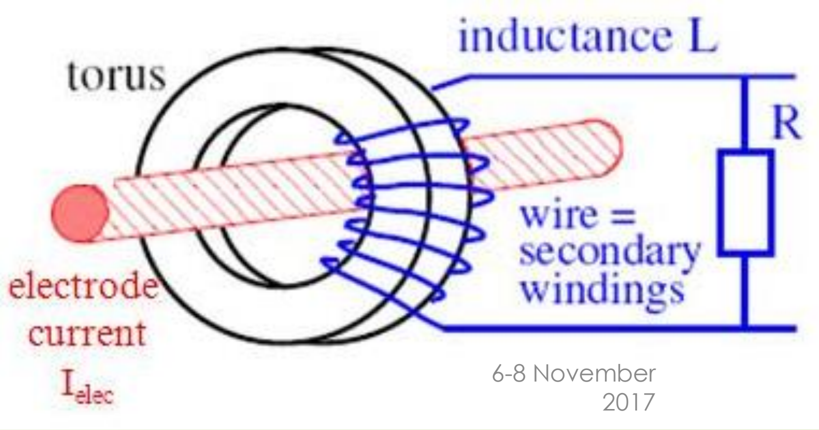


# BPM basic mechanism

The electrode currents are then sensed by converting them into voltage signals and sent to the monitor outputs. Basically in an IPU device this is done at the end of each of four strip electrodes by connecting a narrow conductor that can go through a small toroidal transformer being the responsible for the inductive sensing of electrode wall currents.
A Printed Circuit Board (PCB) will hold the four transformers for each electrode and its wall current component is converted to a voltage signal.



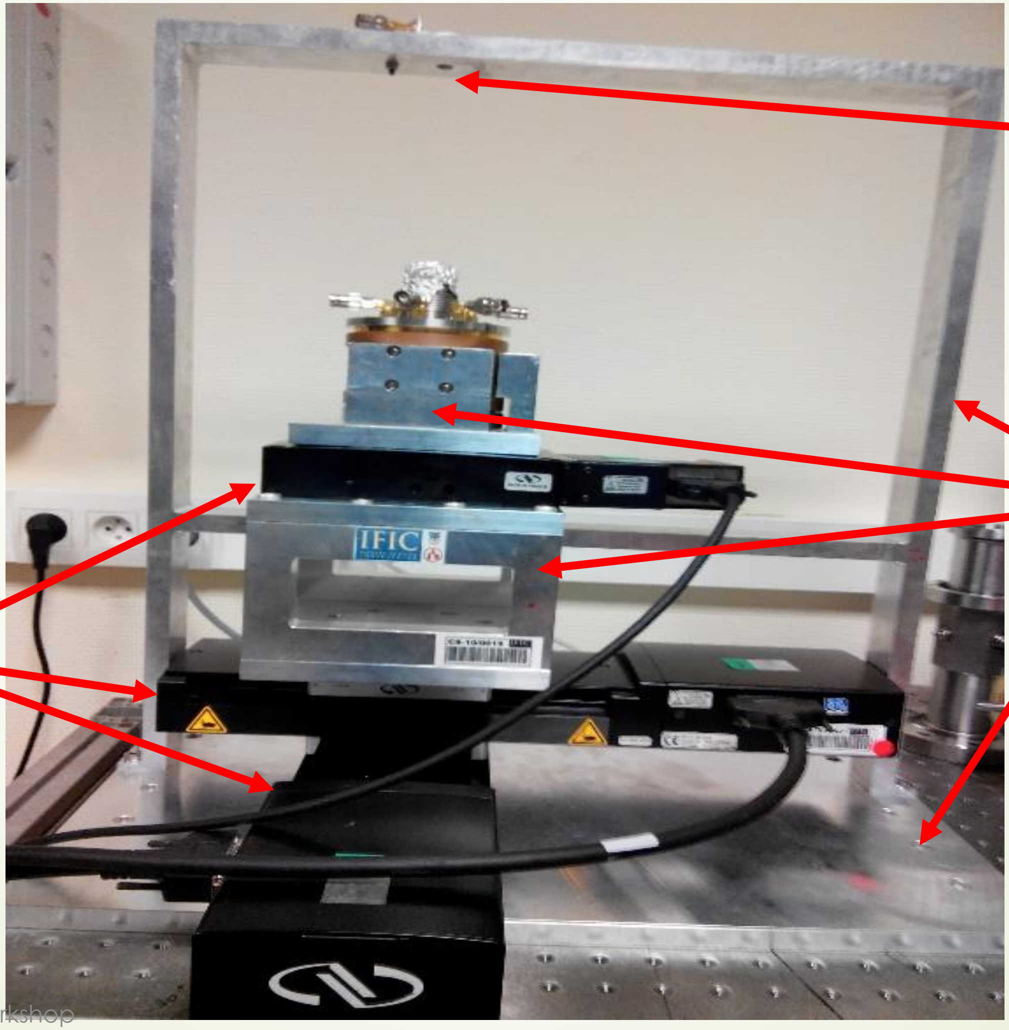

Longitudinal cross-section view




Primary transformer electrode

# The main elements of the BPM test bench:






The wire elements

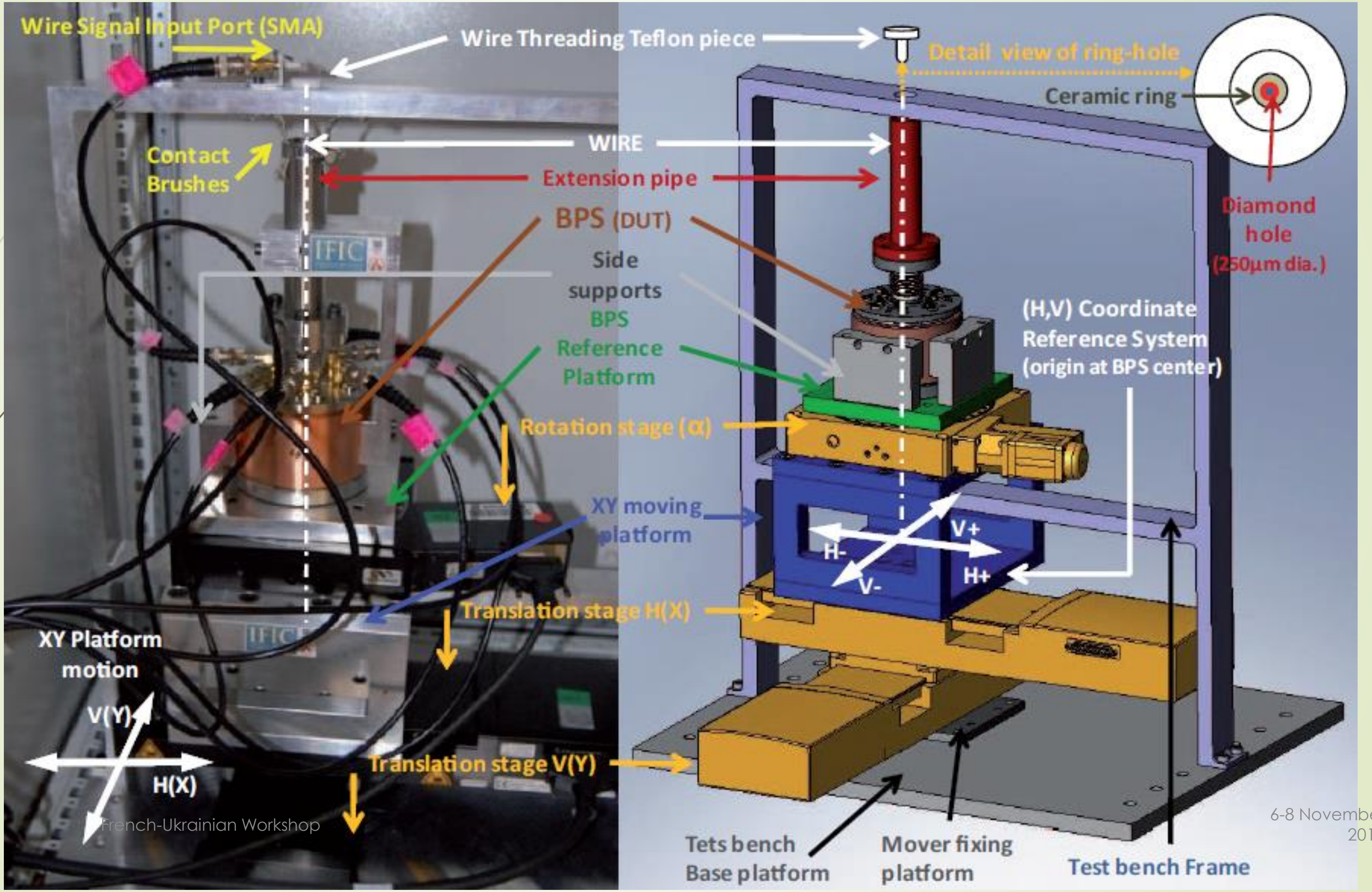
Supporting mechanical elements

Micro-mover stages

Test bench accommodation

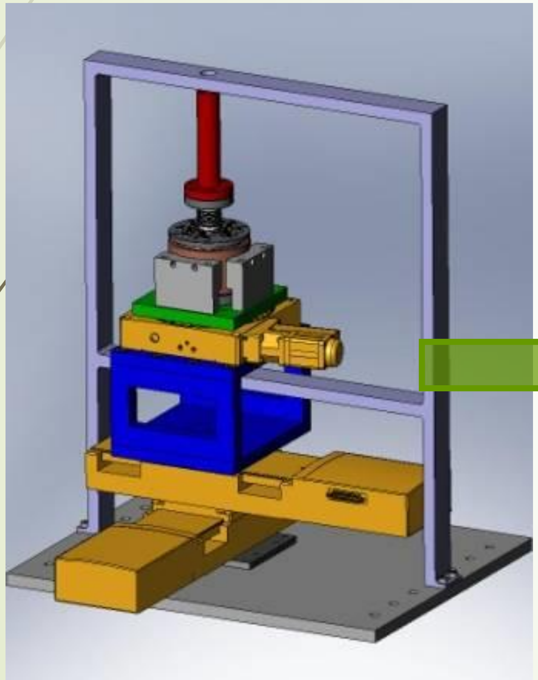
BPM test bench at IPNO lab

# What we want to achieve:

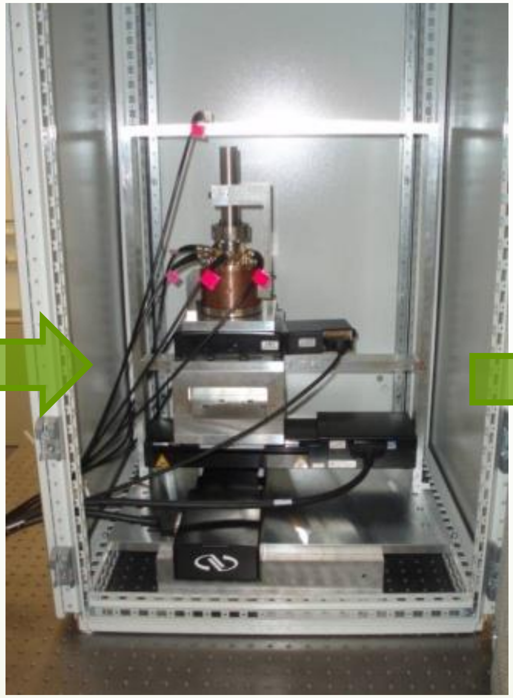


# What we want to achieve:

3D view design



Low-frequency wire set-up



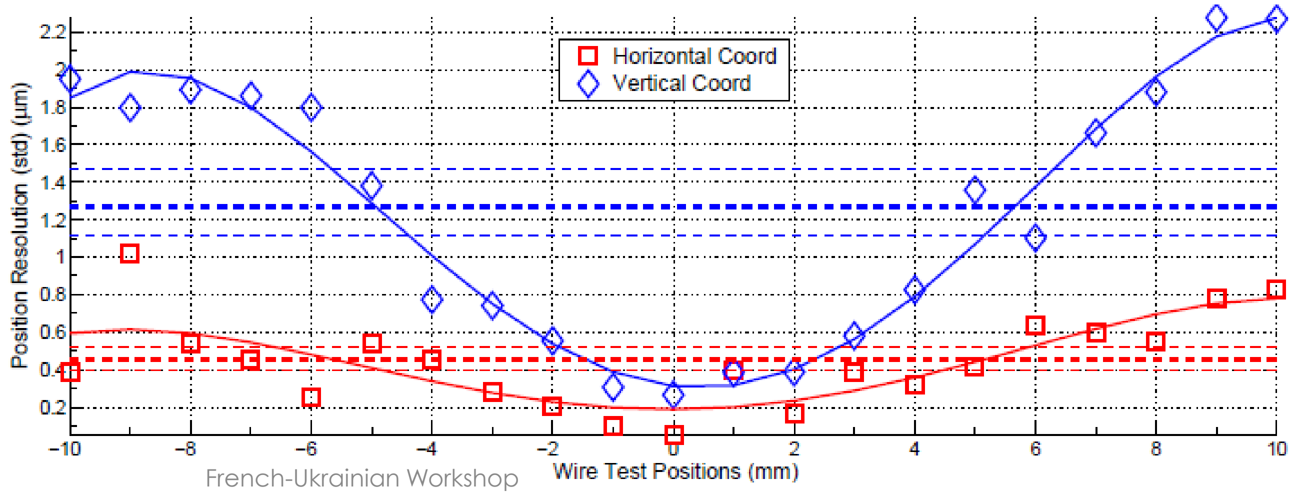
Control and DAQ equipment for all the setup signals

# What we want to achieve



| BPS linearity test parameters | |
|---|---|
| **Sensitivity** | |
| Horizontal $S_x$ | $41.5\pm0.6\times10^{-3}\text{mm}^{-1}$ |
| Vertical $S_y$ | $41.1\pm0.5\times10^{-3}\text{mm}^{-1}$ |
| **Position sensitivity** | |
| Horizontal $k_x$ | $24.1\pm0.4\ \text{mm}^{-1}$ |
| Vertical $k_y$ | $24.3\pm0.3\ \text{mm}^{-1}$ |
| **Electric offset** | |
| Horizontal $\delta_x$ | $0.01\pm0.08$ mm |
| Vertical $\delta_y$ | $0.17\pm0.11$ mm |
| **Overall precision** (RMS within ±5 mm) | |
| Horizontal $\sigma_x$ | $32\pm8\ \mu m$ |
| Vertical $\sigma_y$ | $29\pm7\ \mu m$ |
| **Linearity error** (Max. deviation at ±5 mm) | |
| Horizontal $\epsilon_{xdev}$ | $0.9\pm0.4$ % |
| Vertical $\epsilon_{ydev}$ | $0.9\pm0.3$ % |

The resolution parameter at wire current of 57 mA is 0.6 μm and 1.4 μm in the horizontal and vertical coordinates respectively (shown at the plot as dashed lines).
In parallel some tests were made in CLEAR lab at CERN.



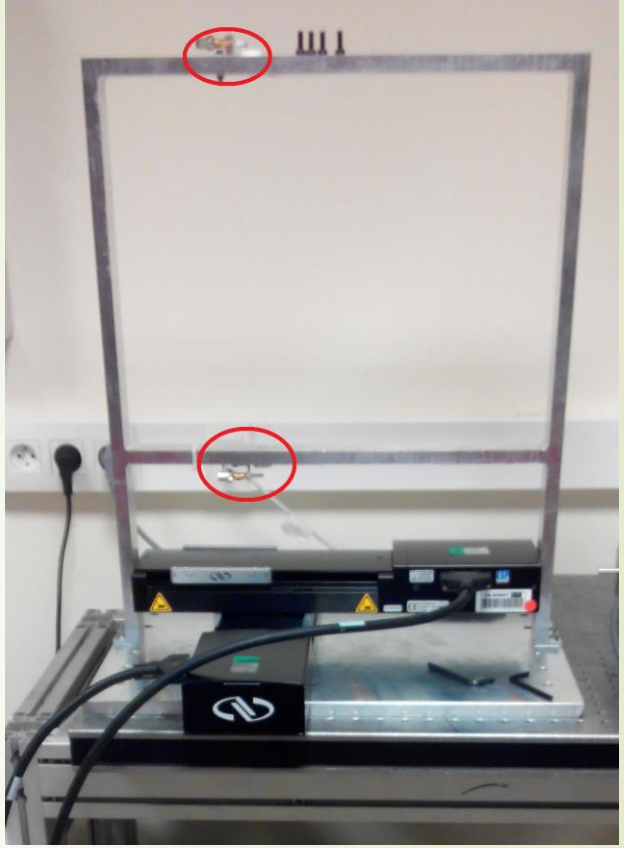

Resolution vs. position for BPS in the ±10 mm range.

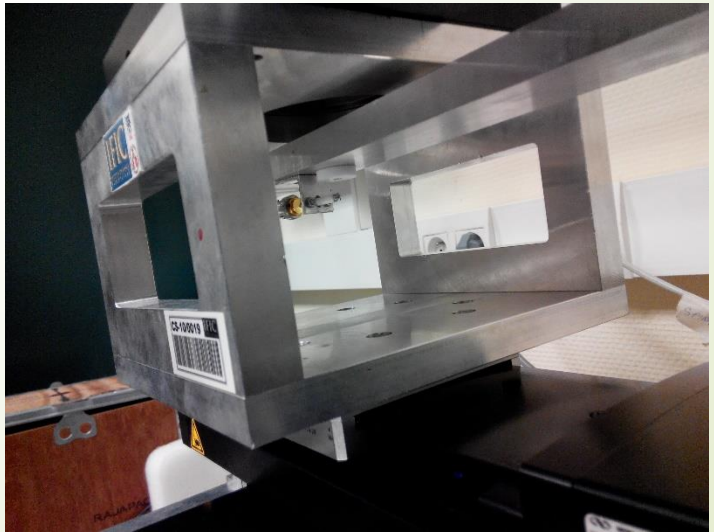
# What we want to achieve:

- To make compensation stages to the wire
- To get results for BPM calibration
- Beam test for the BPM resolution measurement for different currents


# The wire elements

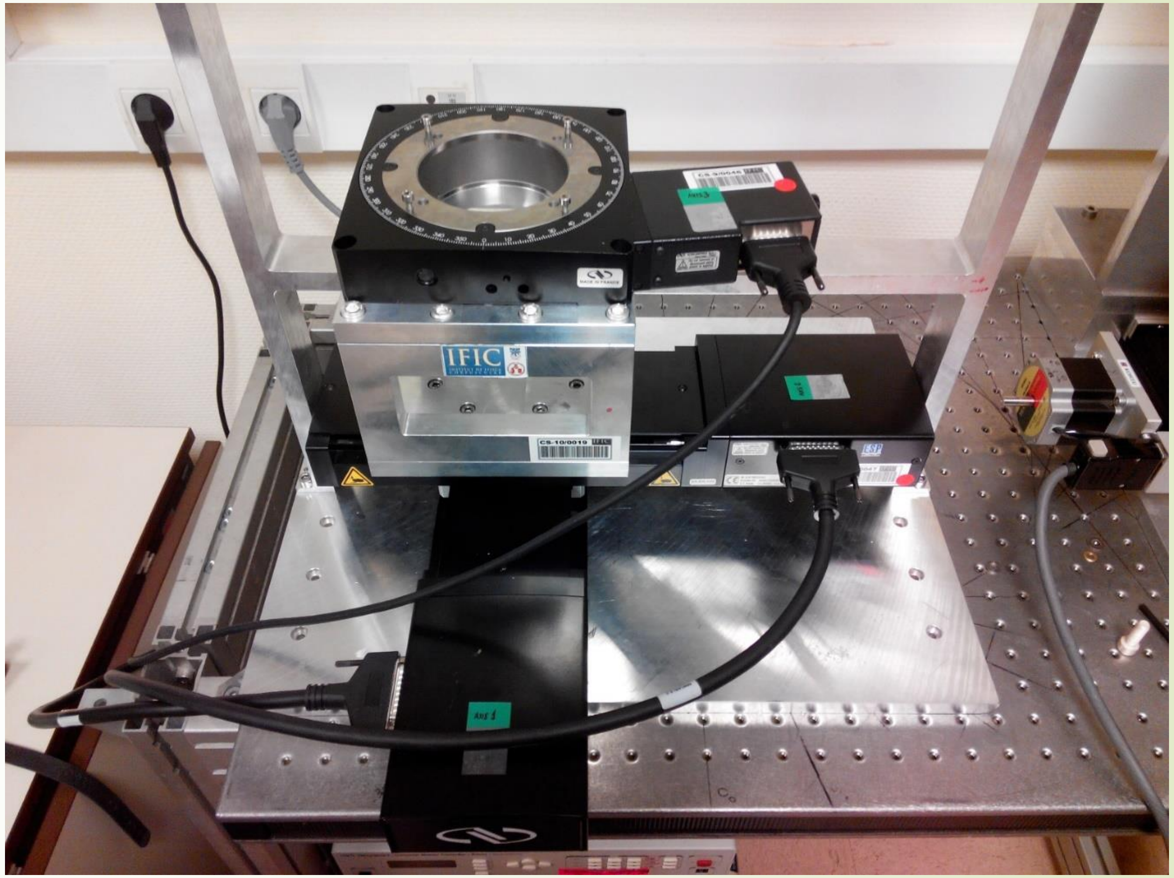
- The wire is stretched between two teflon pieces at the top and bottom of the square frame.





# Micro-mover stages

- The two linear stages are orthogonally mounted providing the BPM displacement relative to the wire in the (x,y) directions.
- On the top of them a metallic platform holds the rotation stage allowing to make BPM-wire relative rotations of a given angle.
- All stages are driven by motors from Newport
- Motion controller ESP300 and LabVIEW are used to controll movers




An encoder providing a resolution of 0.1 μm for the linear stage and a resolution of 0.0005° (8.7 μrad) for the rotation stage

# Where we are:

- Almost all details were mounted and checked
- For the stages control LabVIEW and the Newport's libraries for the motion controller were used
- Special cable was purchased and received

Thank you for attention