# Cryogenic beam loss monitors for the HL-LHC magnets

M. R. Bartosik, B. Dehning,
C. Kurfuerst, M. Sapinski and A. Alexopoulos;
CERN Beam Instrumentation

# Plan of the presentation

- **Introduction:**
  - **BLM system for the LHC**
  - **Cryogenic BLMs for HL-LHC**
- **Cryogenic BLM project up to now**
  - **Irradiation test**
  - **BLMs in LHC ring**
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  - **TCT and next cryogenic tests**
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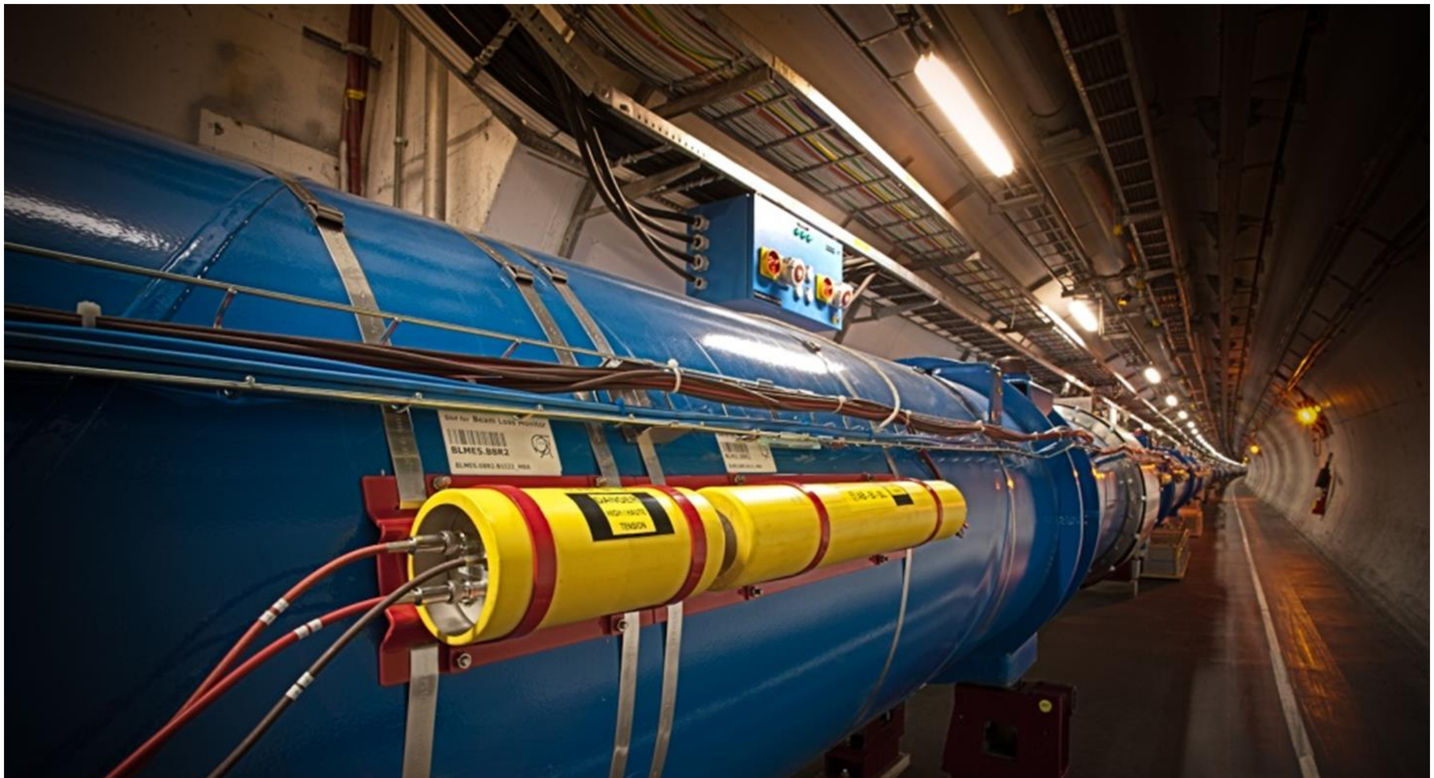
# Beam Loss Monitoring system for the LHC




**Damage and quench protection of the sensitive superconductive elements** by **measurement of secondary shower particles from beam losses** by **Ionisation chambers**, secondary emissions monitors and diamond detectors.

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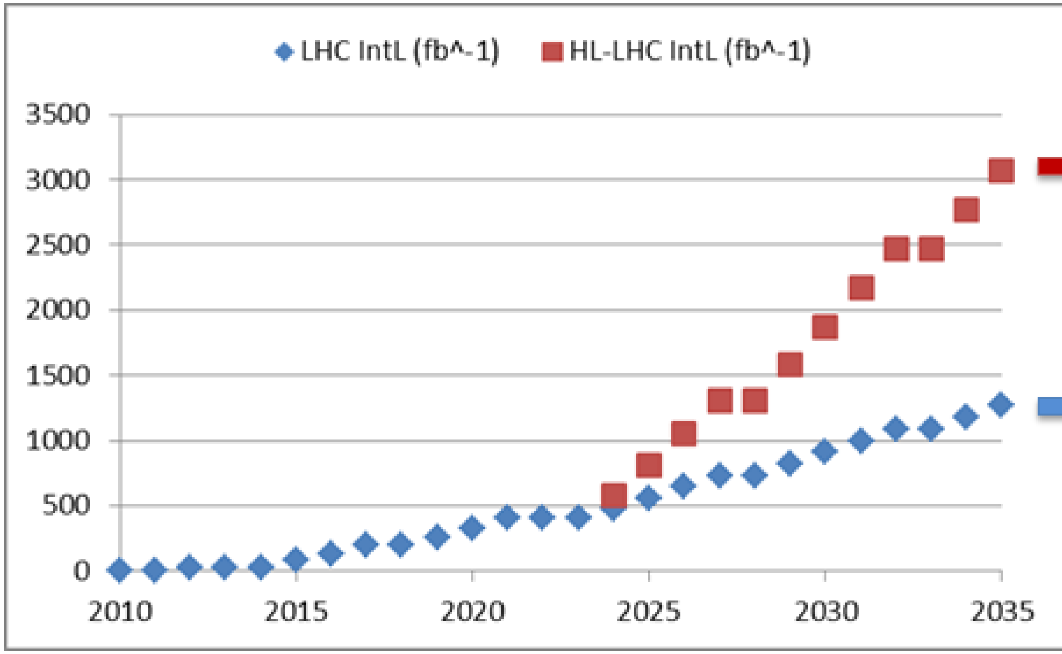
# Cryogenic BLMs for HL-LHC




By implementing HL-LHC

Almost a factor 3

By continuous performance improvement and consolidation

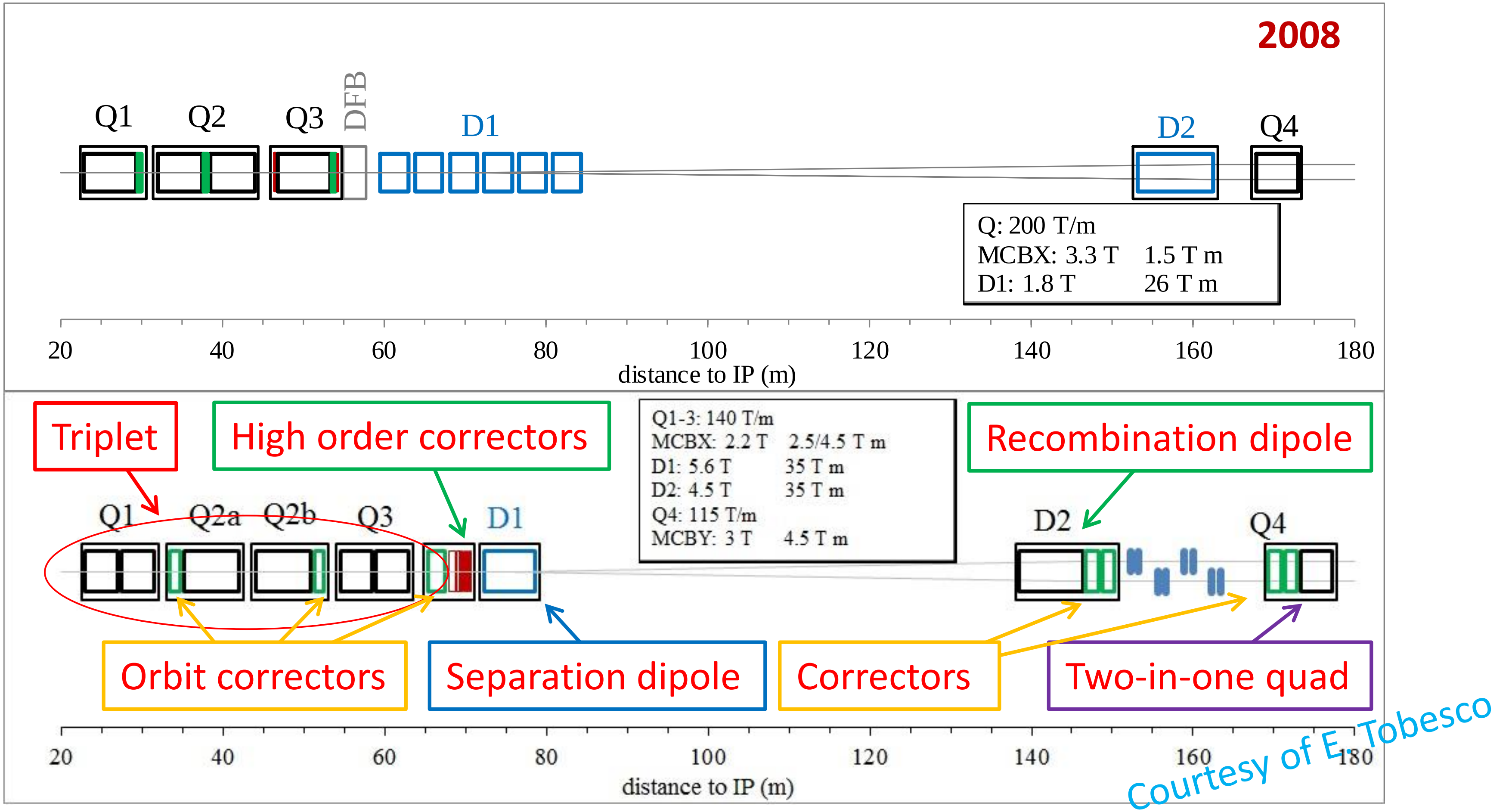
Courtesy of F. Bordry

**Goal of the HL-LHC project**:

- 250 – 300 $fb^{-1}$ integrated luminosity per year
- 3000 $fb^{-1}$ integrated luminosity in about 10 years

High Luminosity LHC

# Cryogenic BLMs for HL-LHC



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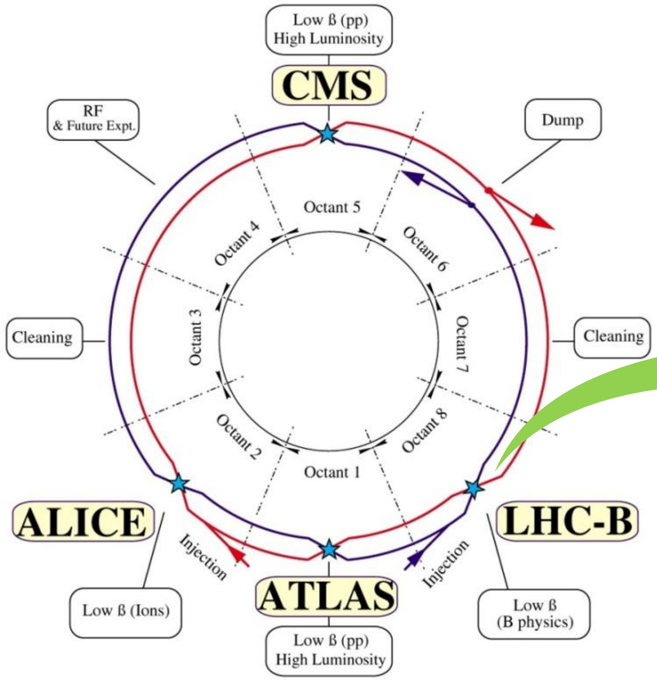
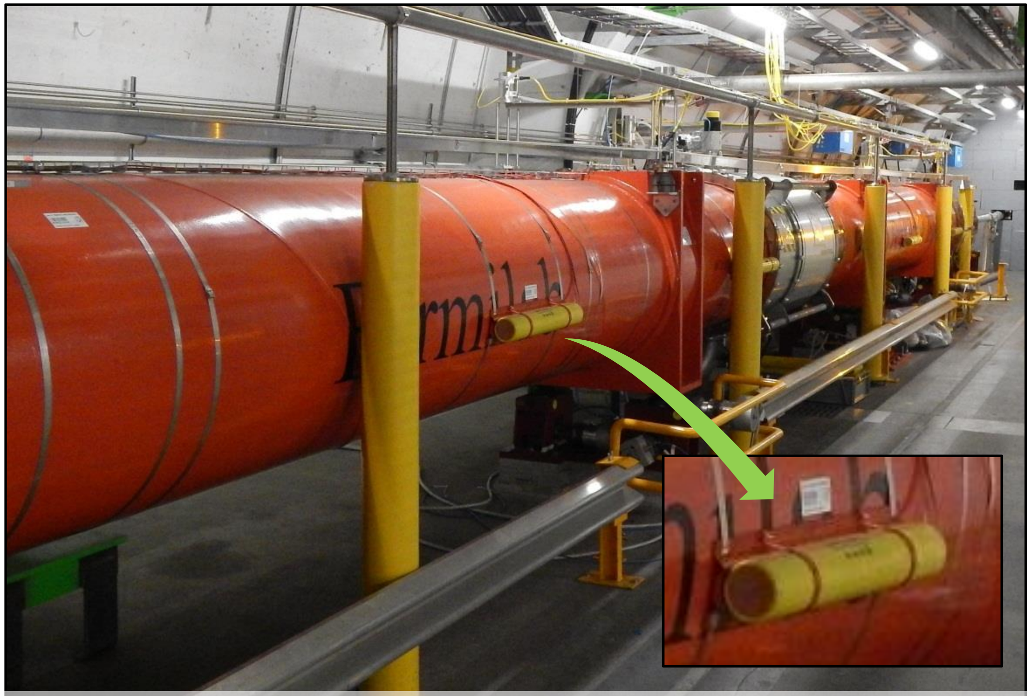



Overview of LHC ring with four main experiments

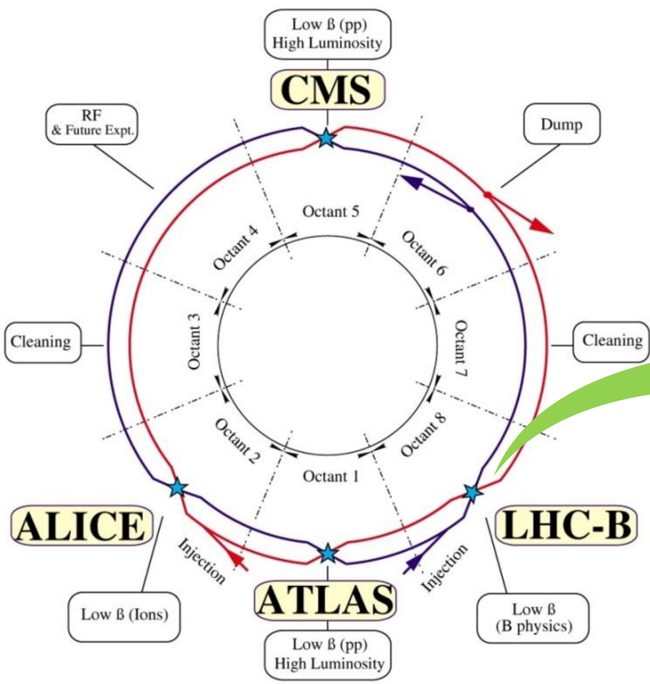


LHC triplet magnets left of LHC-b experiment at CERN

Presently: 16 ionization chambers.

HL-LHC: about 20 ionization chambers and **20 cryogenic BLMs**.

# Cryogenic BLMs for HL-LHC

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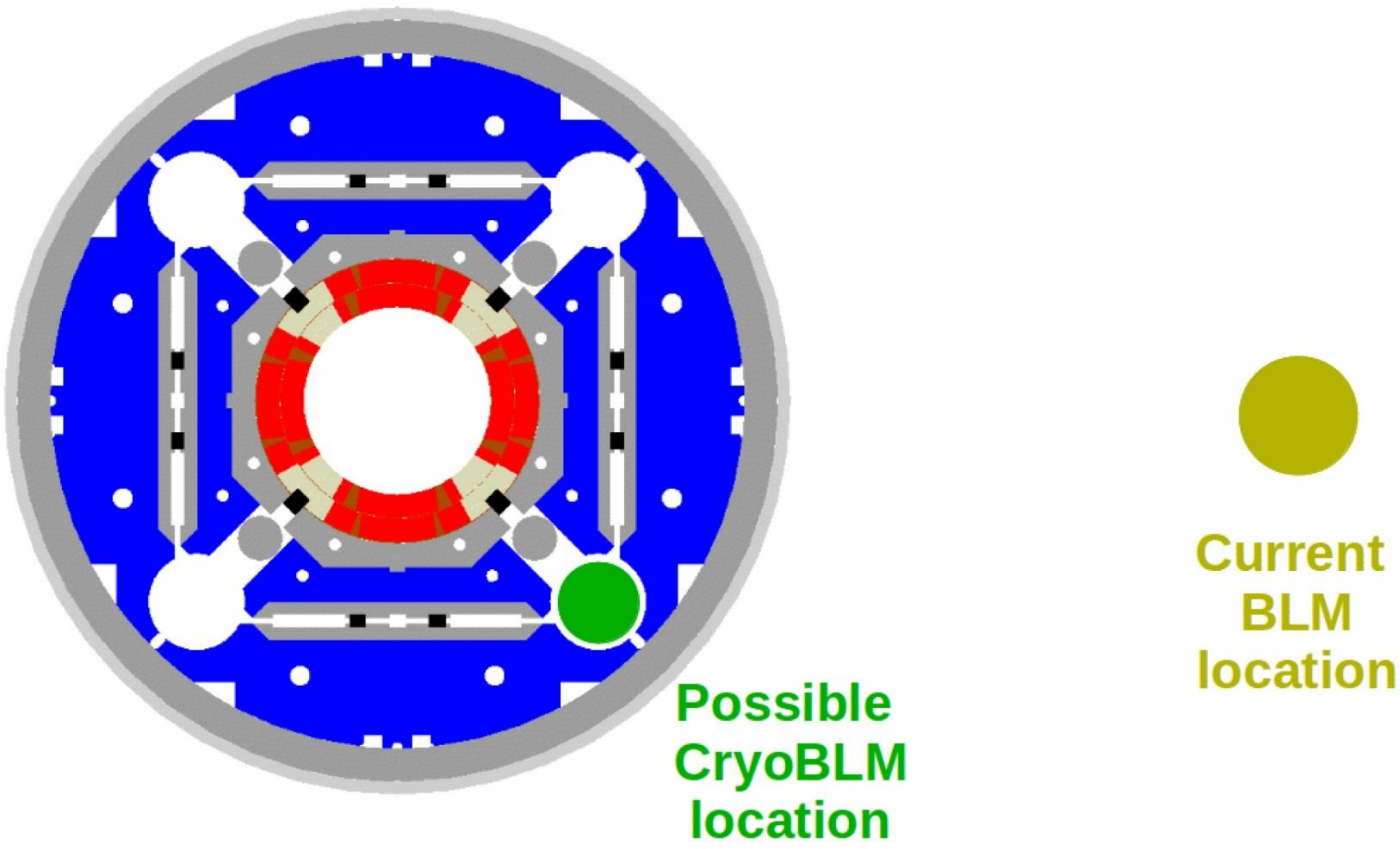
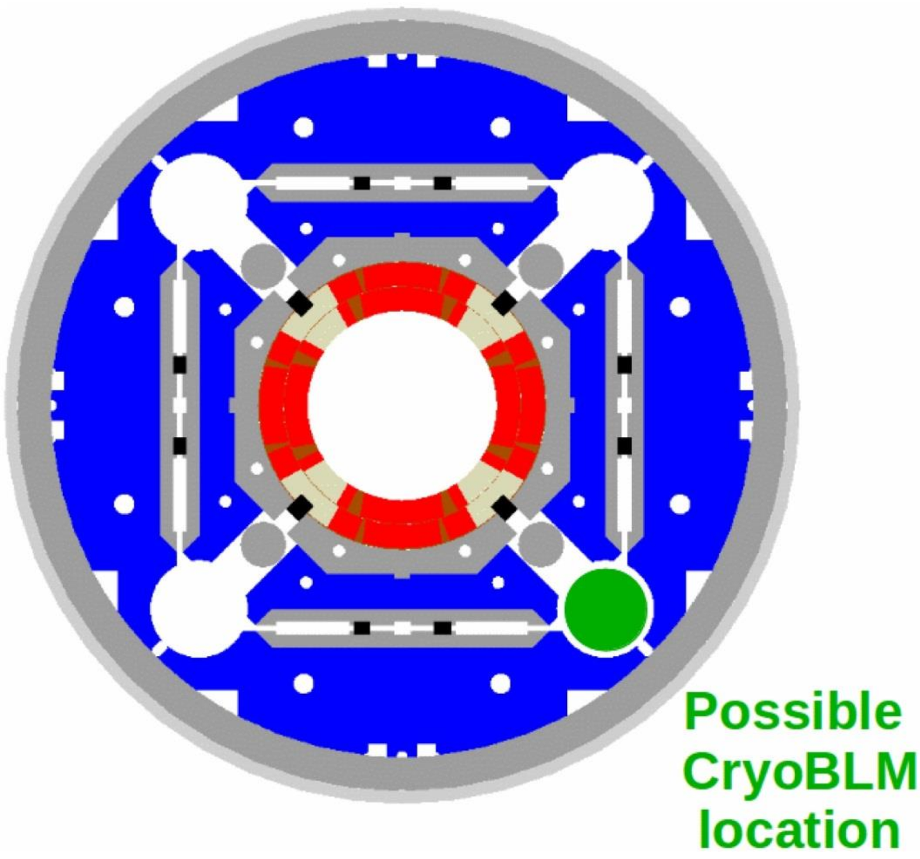



Cross section of the new triplet magnet for the HL-LHC [courtesy of Paolo Ferracin].

# Cryogenic BLMs for HL-LHC

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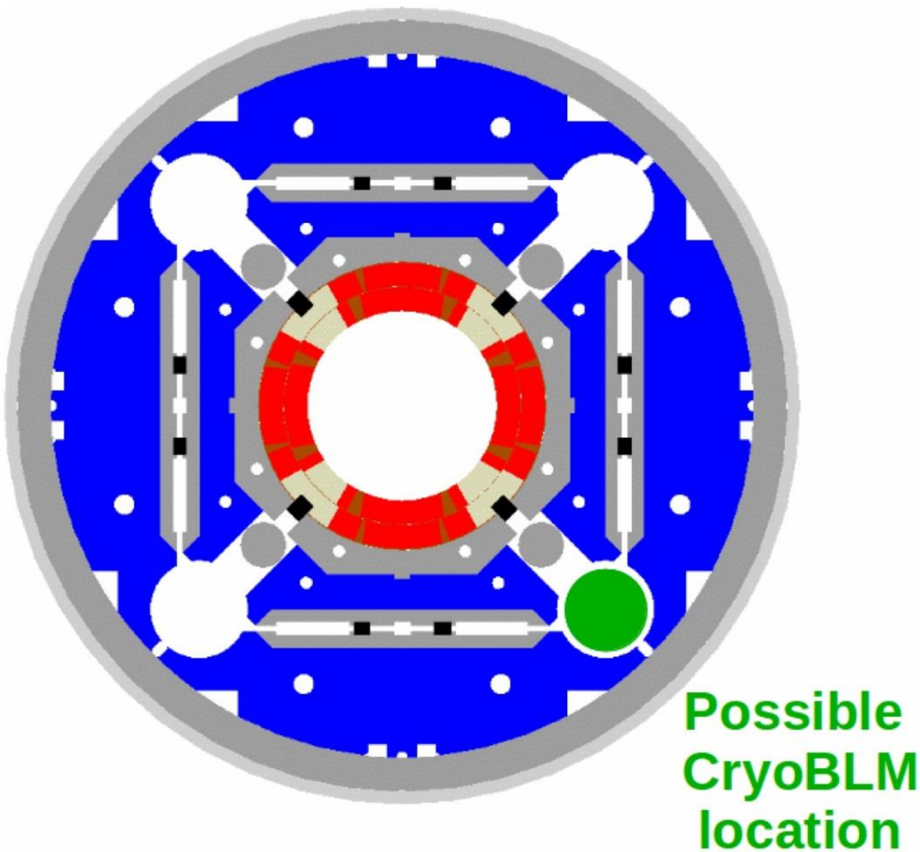
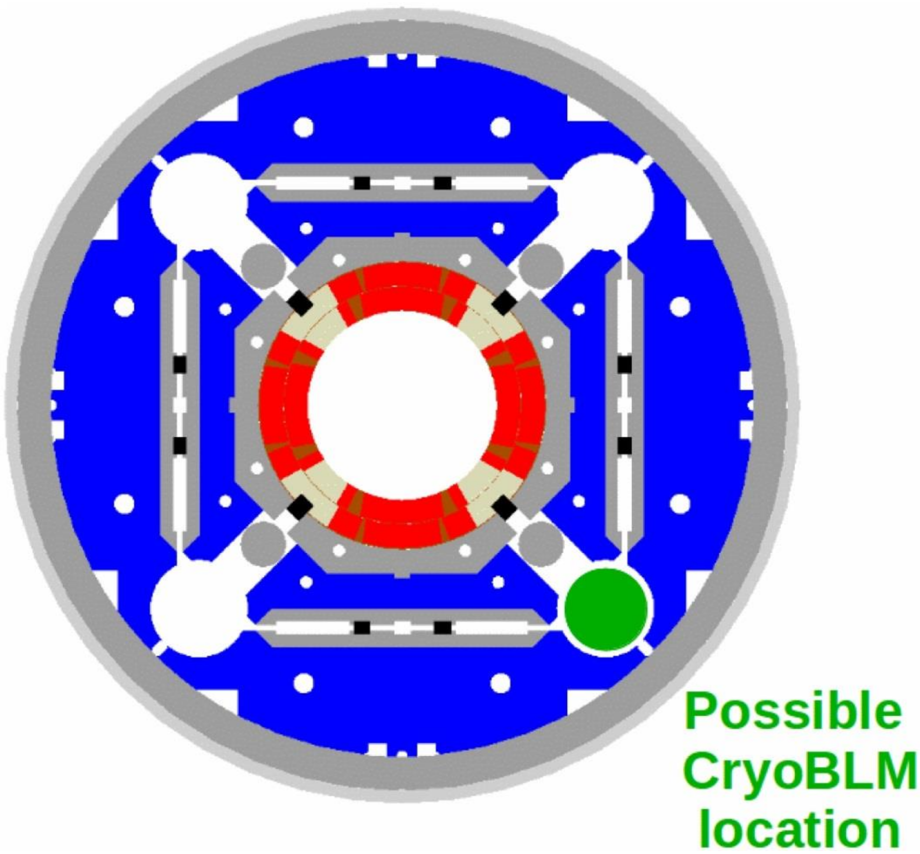



The main challenges for cryogenic BLMs are:

- the superfluid helium environment (**1.9 K**),

# Cryogenic BLMs for HL-LHC




The main challenges for cryogenic BLMs are:

- the superfluid helium environment (**1.9 K**),
- the integrated dose of about **2 MGy** in 20 years,
- the reliable operation in a magnetic field of **2 T**,
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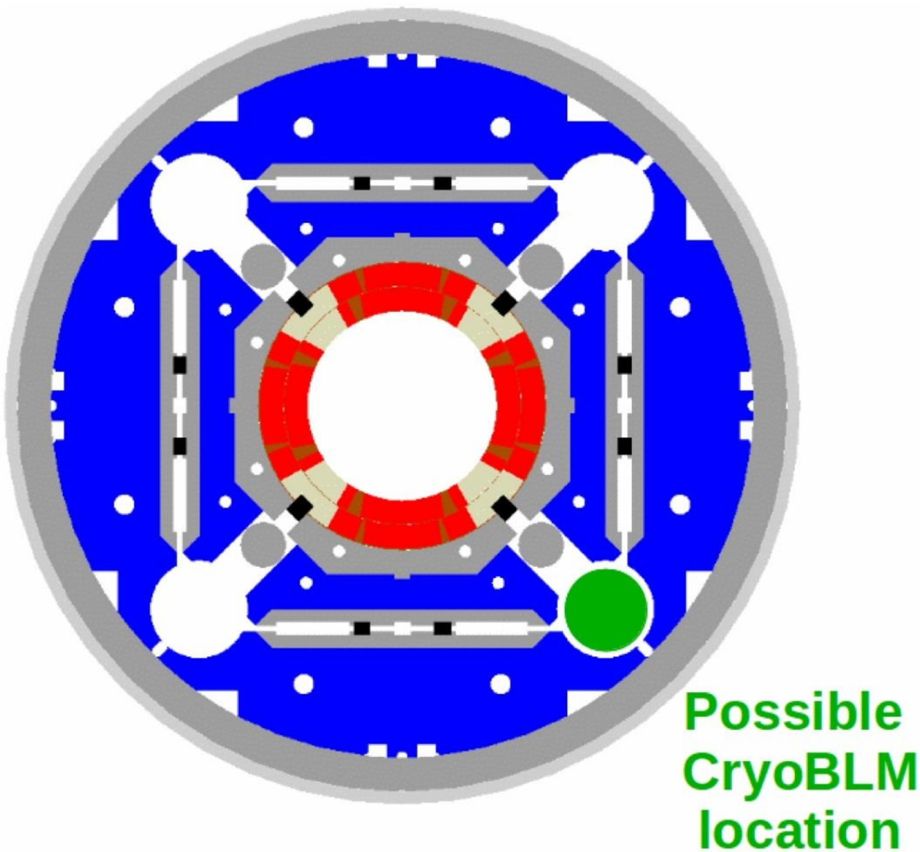


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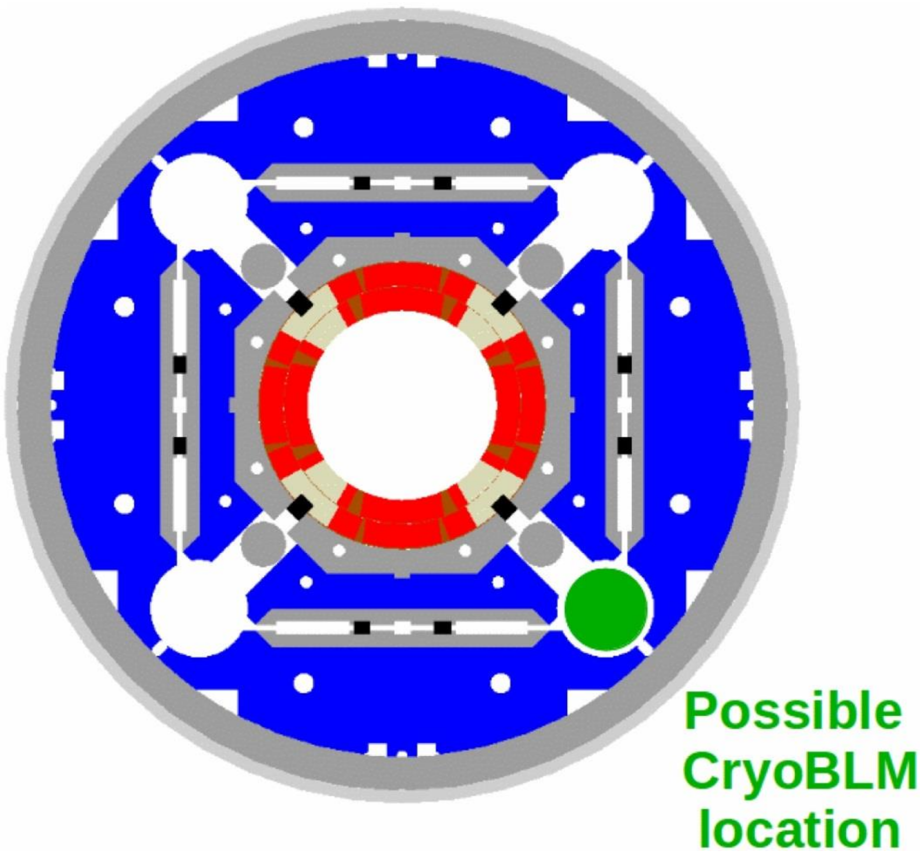
# Cryogenic BLMs for HL-LHC

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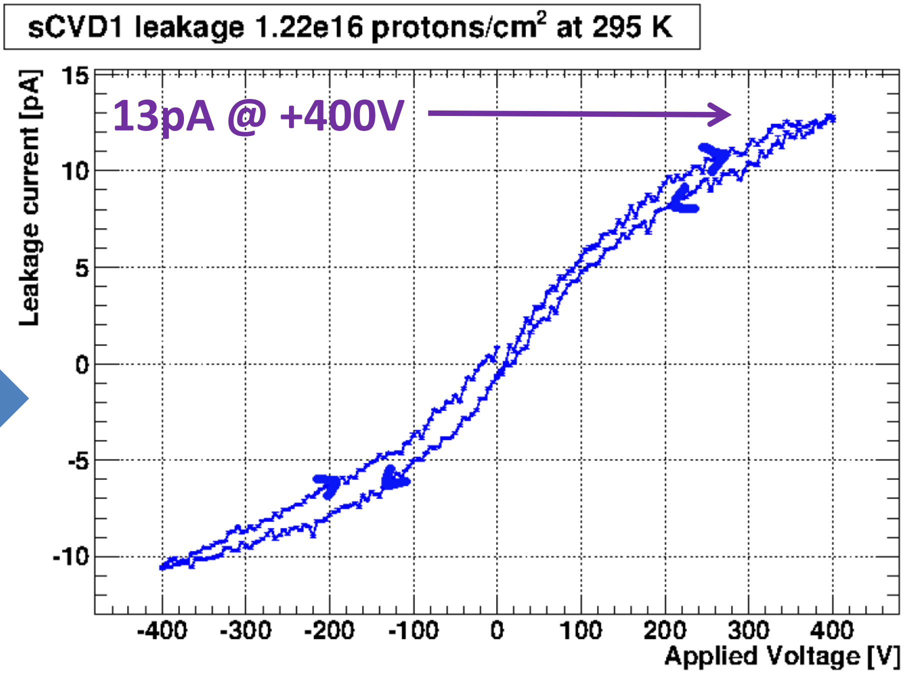
# Cryogenic irradiation test – results – leakage current

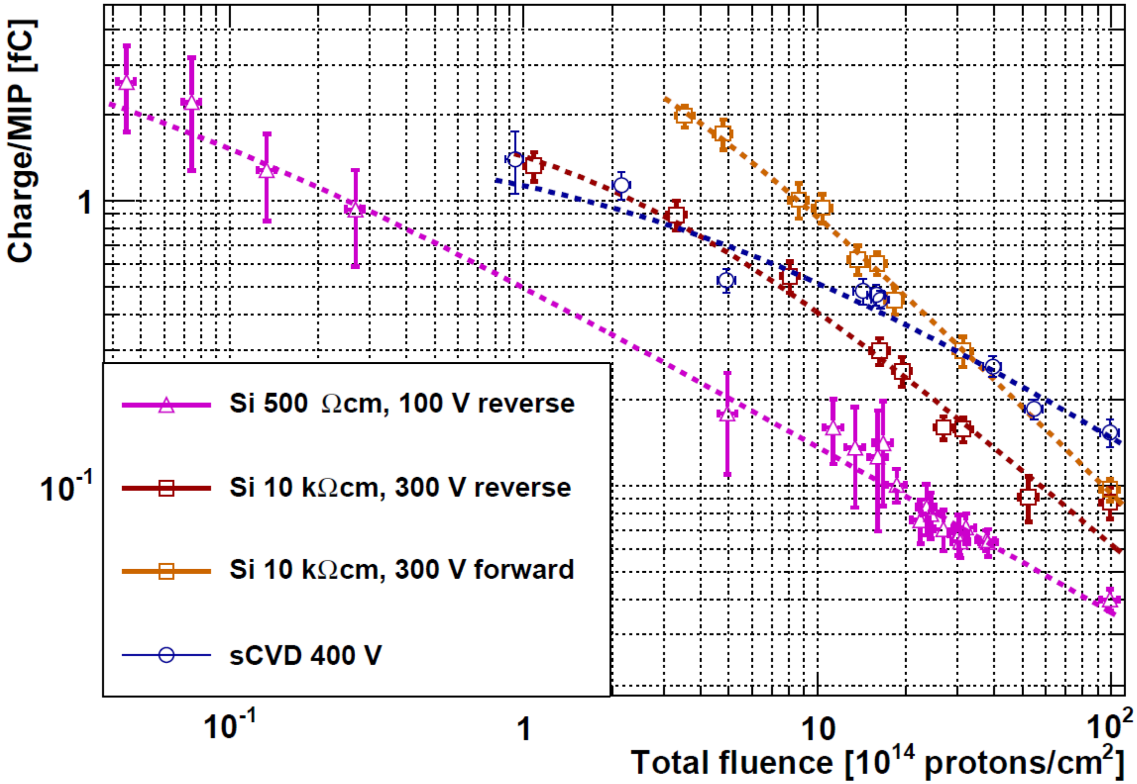
**By the end of the irradiation** a total integrated fluence of $1.22 \cdot 10^{16}$ protons/cm$^2$ was reached, corresponding to an integrated dose of **3.42 MGy** for **diamond**.

+293K




Diamond leakage curve (after irradiation) in room temperature.

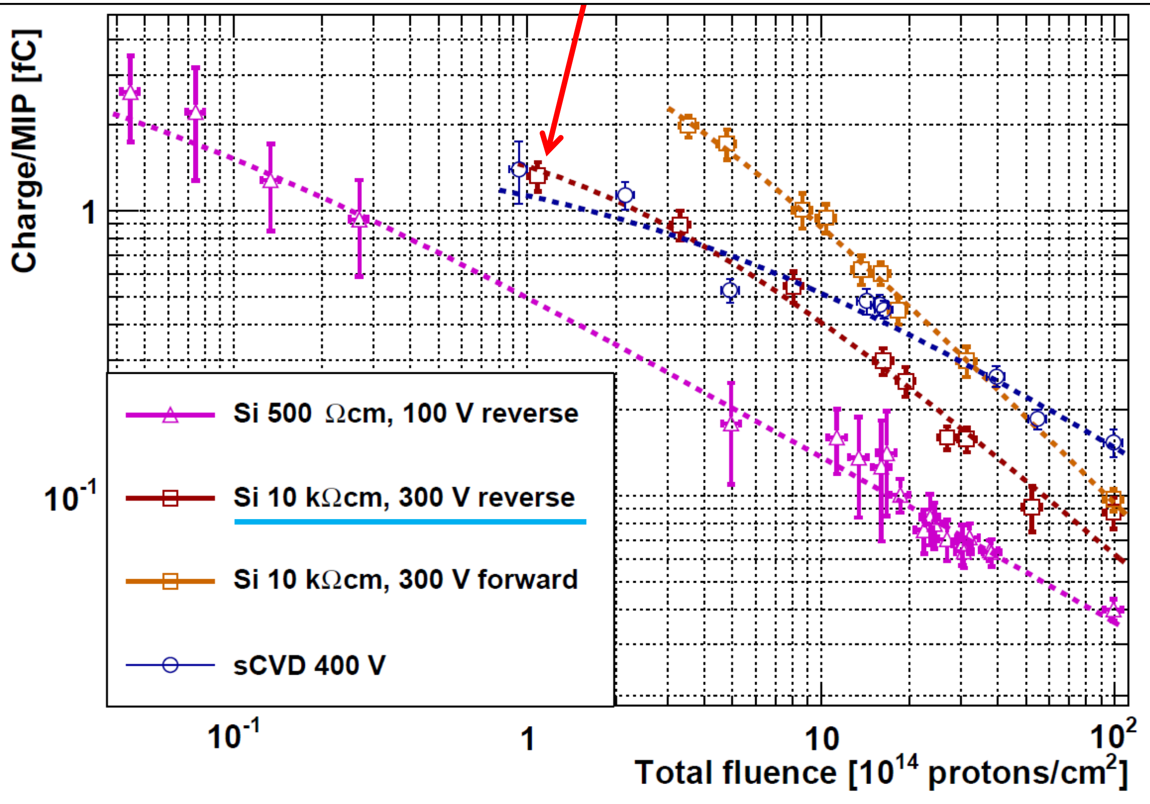
# Cryogenic irradiation test – results – degradation




Comparison of scCVD diamond with 10 kΩcm silicon in two modes and 500 Ωcm silicon as reference.

# Cryogenic irradiation test – results – degradation

At low irradiation dose, silicon had a larger signal than the diamond detector.

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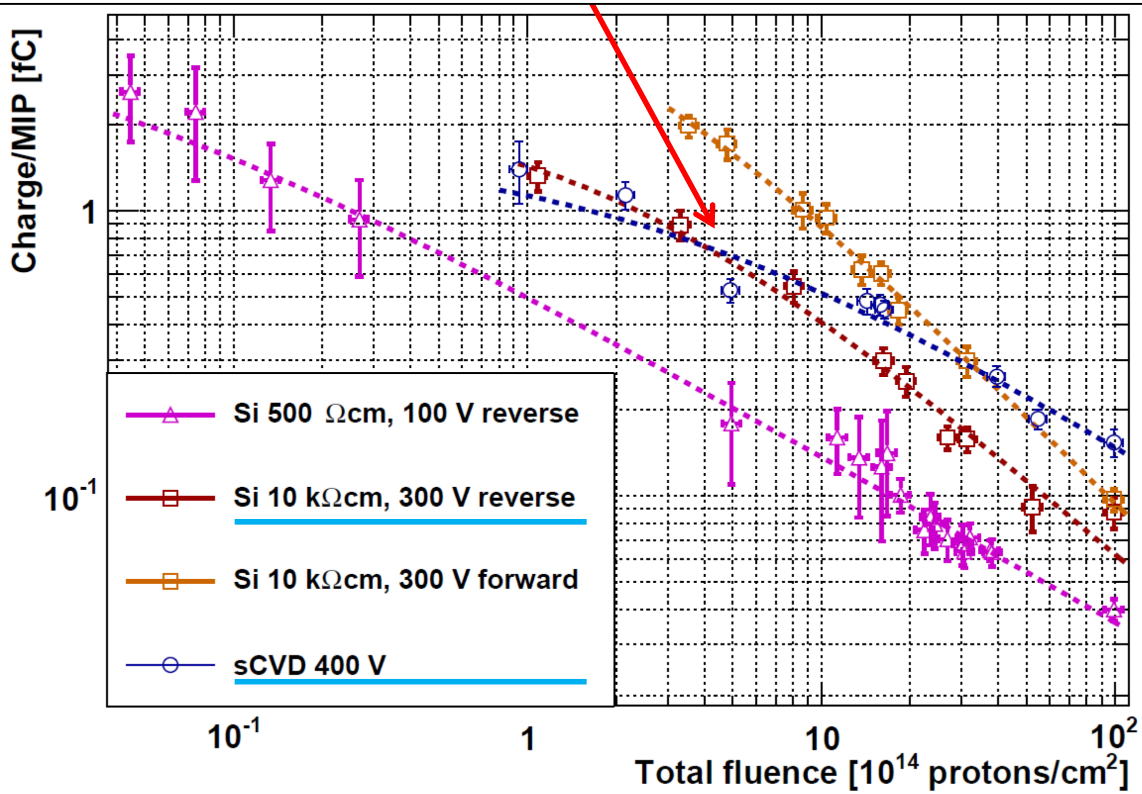
# Cryogenic irradiation test – results – degradation

The crossing point (0.1 MGy) - diamond started to have higher signal.

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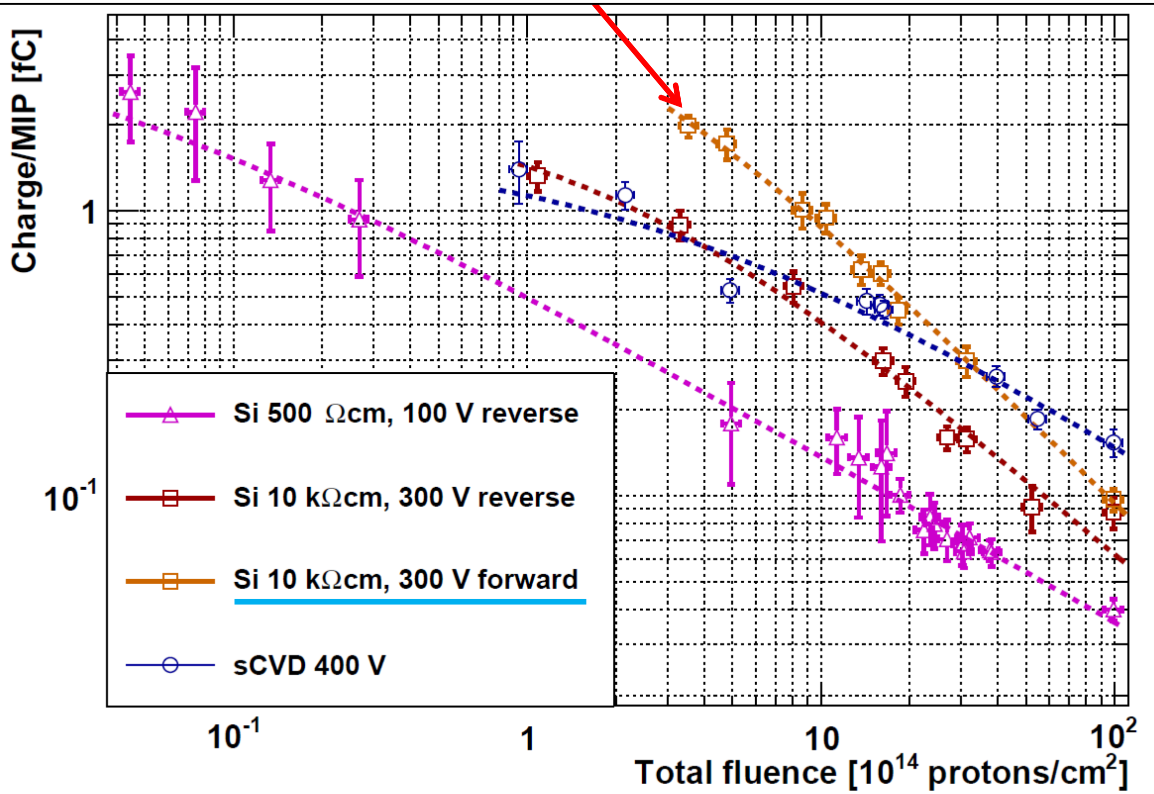
# Cryogenic irradiation test – results – degradation

Current Injected Detector (CID) after absorption of 0.1 MGy dose.

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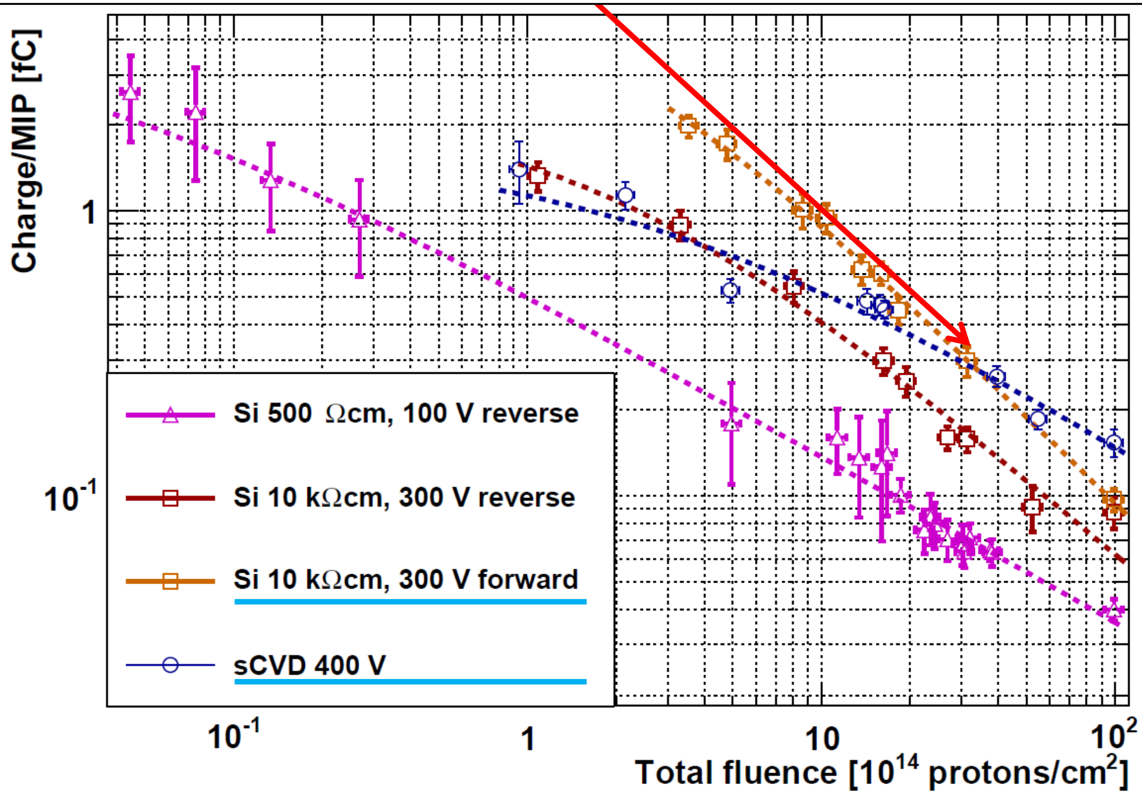
# Cryogenic irradiation test – results – degradation

The crossing point (0.9 MGy), at which diamond and CID.

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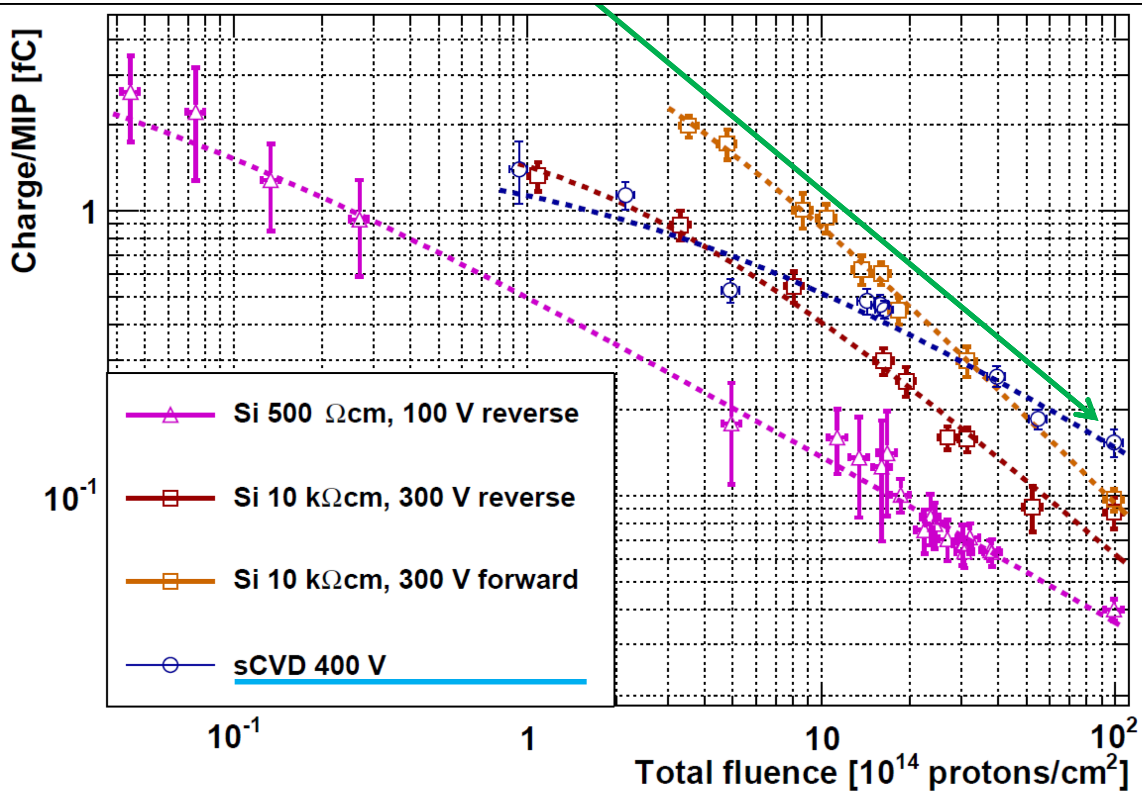
# Cryogenic irradiation test – results – degradation

**For very high radiations diamond sensors should provide the higher signal.**

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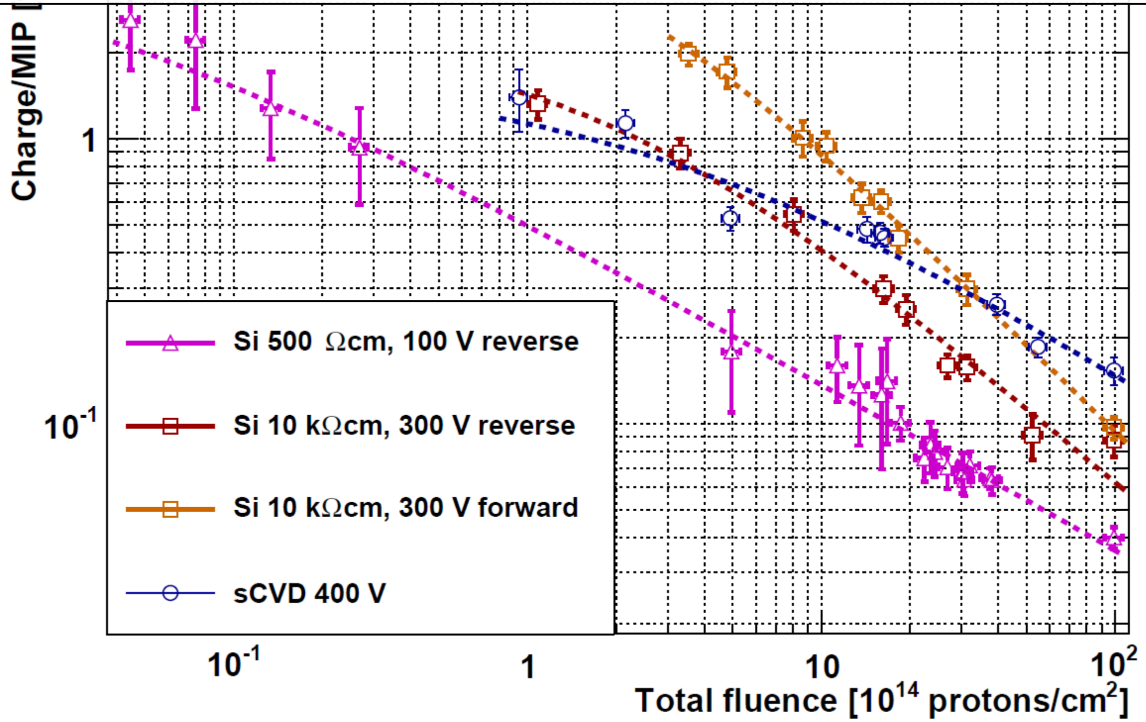
# Cryogenic irradiation test – results – degradation

**The expected reduction in detector sensitivity over 20 years (2 MGy) of LHC operation is of a factor of 14 ± 3 for the diamond detector. For the silicon detector the expected signal reduction is of a factor of 25 ± 5.**

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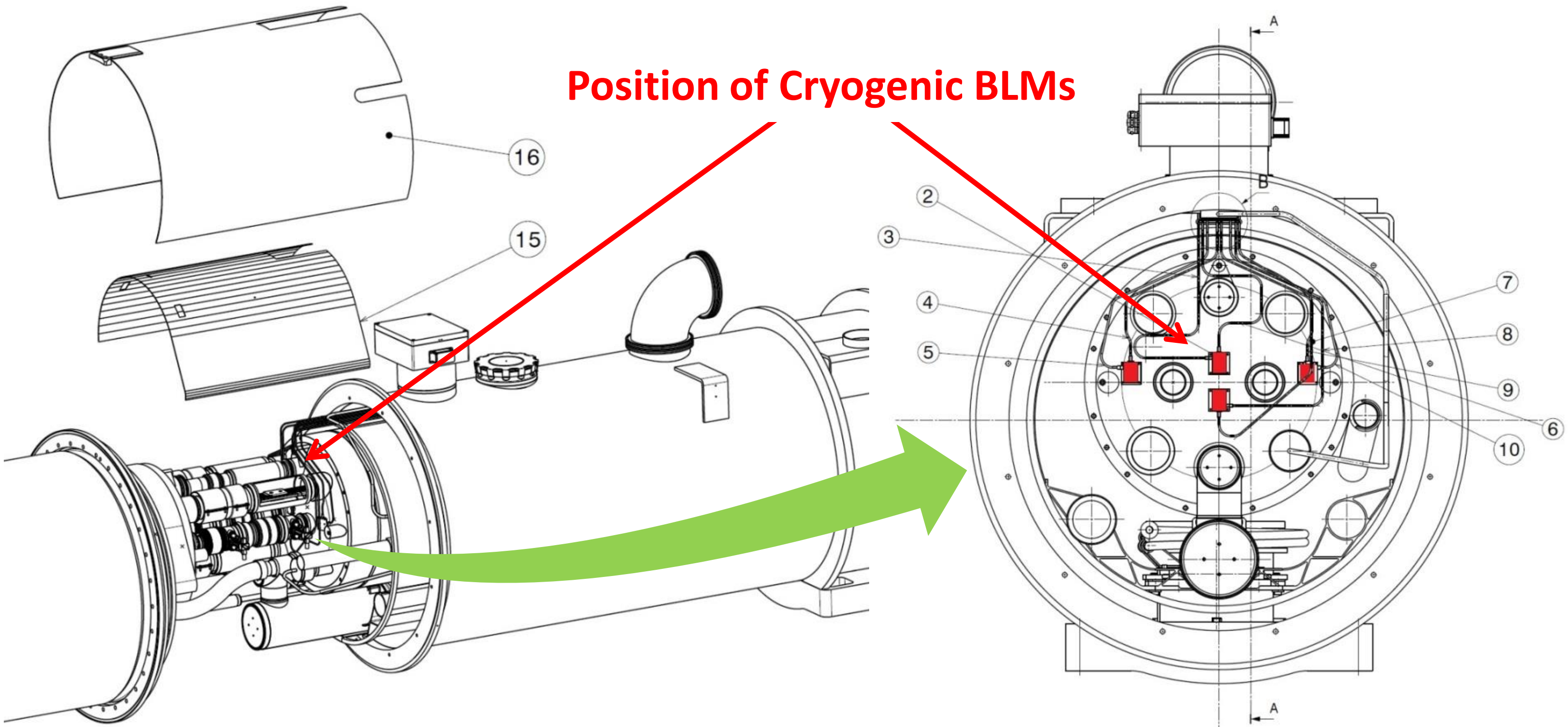
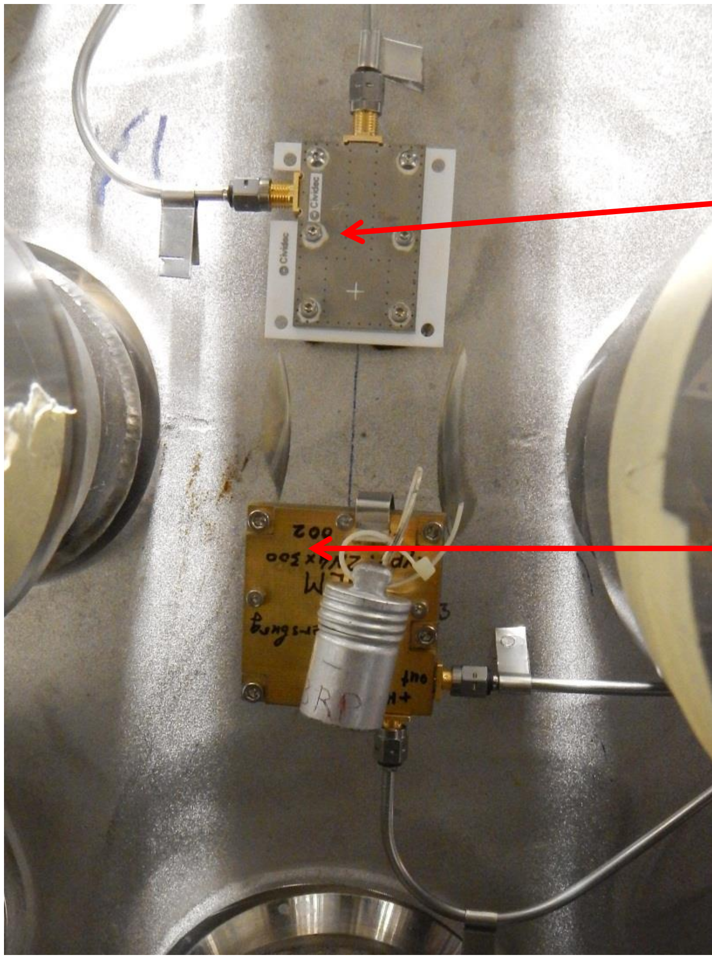
# Cryogenic BLMs in LHC ring




Intersection between LHC bending magnets.

View on a cold mass of bending magnet with places, market in red, for cryogenic BLMs installation

# Cryogenic BLMs in LHC ring



We have installed in the LHC, for example:

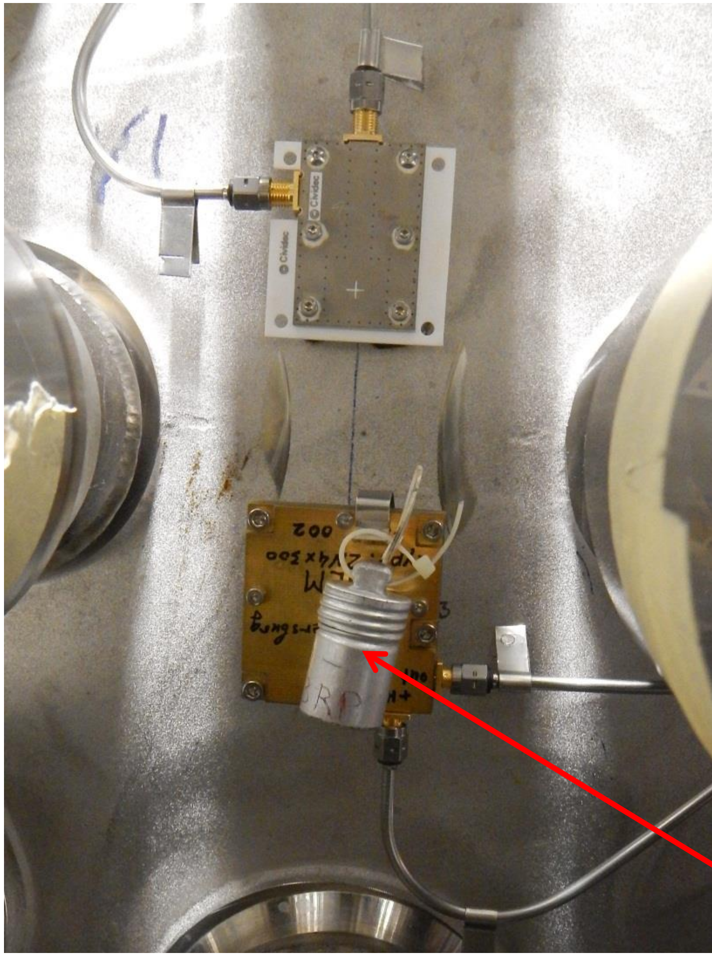
**A 500µm scCVD diamond detector**
(In collaboration with Erich Griesmayer, CEO of CIVIDEC instrumentation GMBH, Vienna).

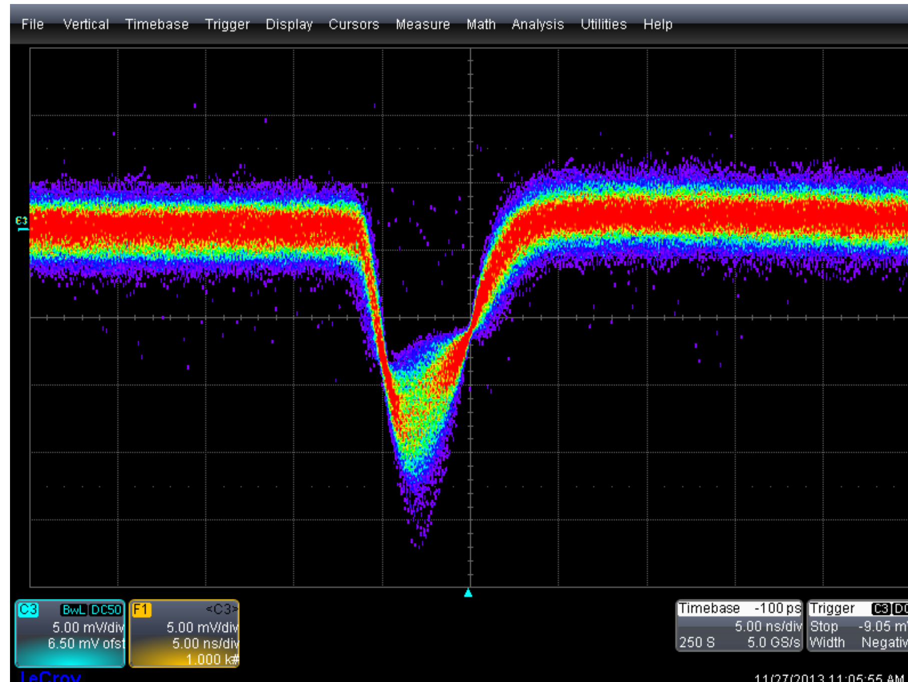
cividec
Instrumentation

**A module with four 300µm Si detectors**
(in collaboration with Vladimir Eremin, IOFFE, St. Petersburg).

Ioffe Physical Technical Institute

# Cryogenic BLMs in LHC ring

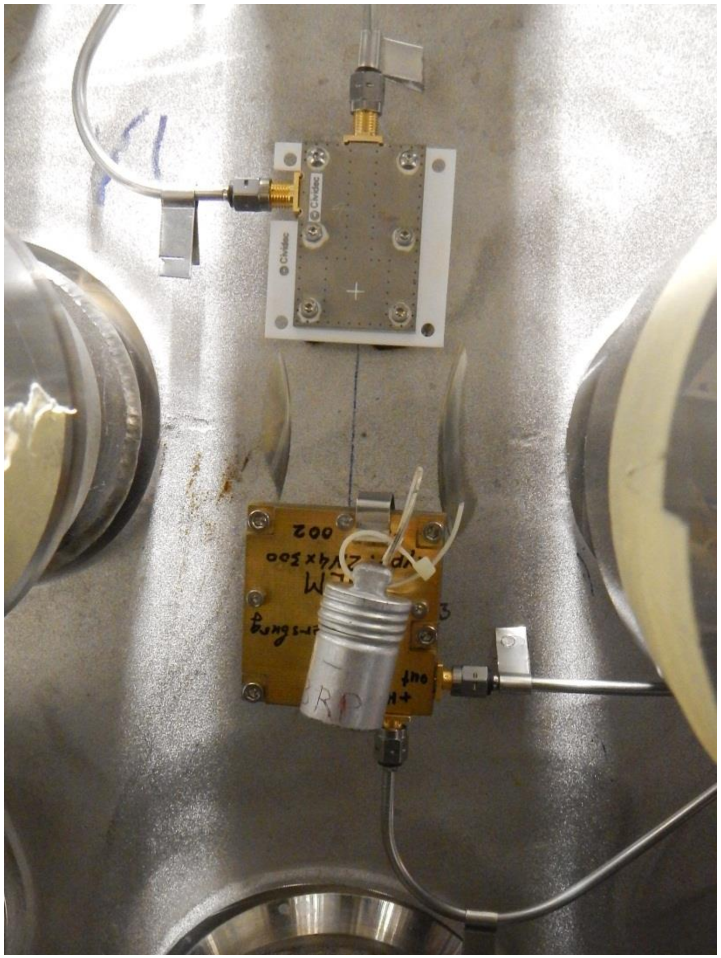





Single photons of $\gamma$-radiation recorded by scCVD diamond detector during test in the tunnel with use of Cobalt-60.

$\gamma$-radiation source

# Cryogenic BLMs in LHC ring



These first cryogenic radiation detectors installed in **operational, superconducting LHC** magnets will not only allow the behaviour of the detectors to be tested in realistic conditions, but also determine the validity of the integration in a setup at **1.9 K**, in a **magnetic field** and under **vacuum**.

First **results** with beam are expected in early **2015**, when the LHC starts its second operational run.

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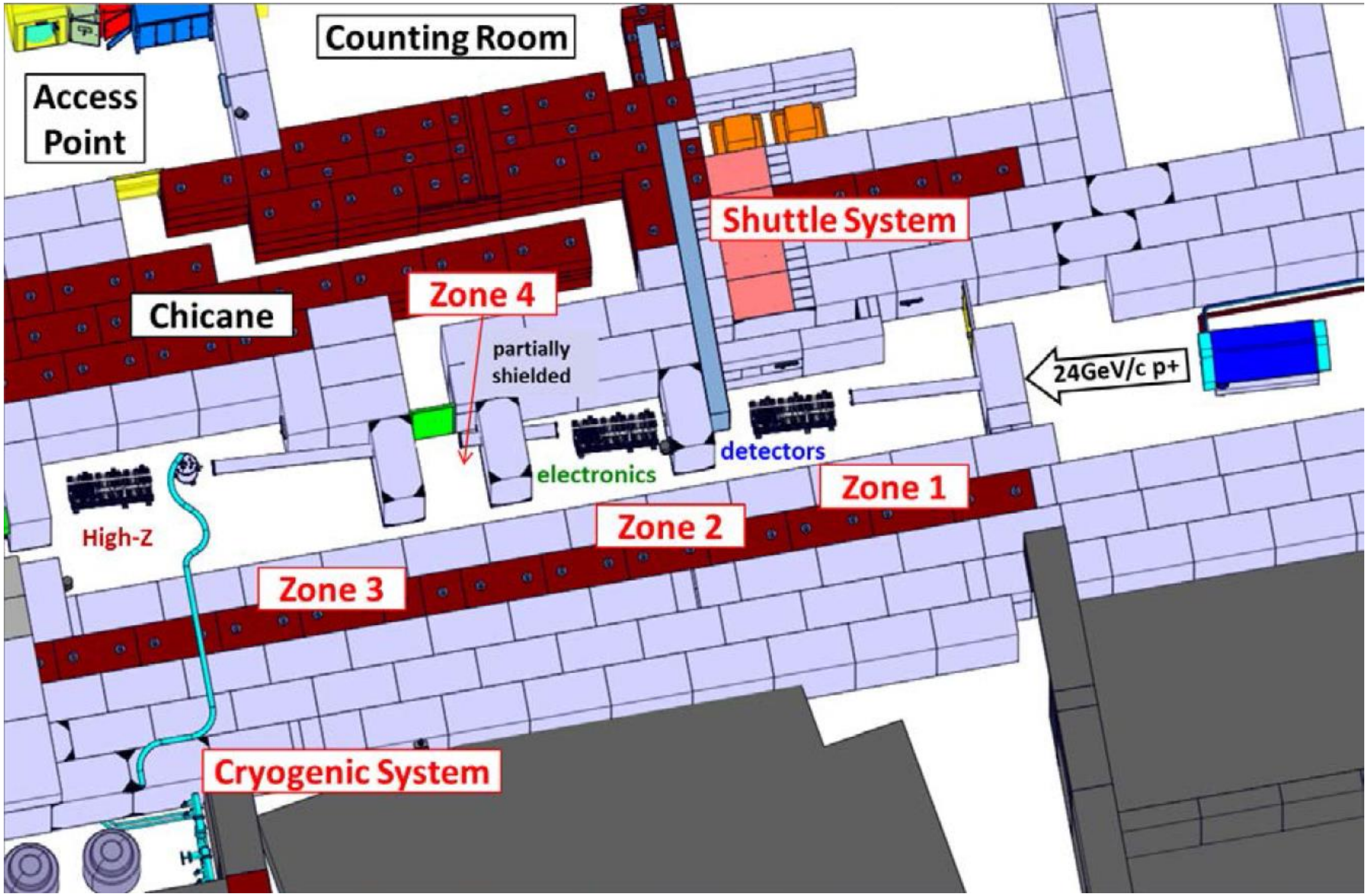
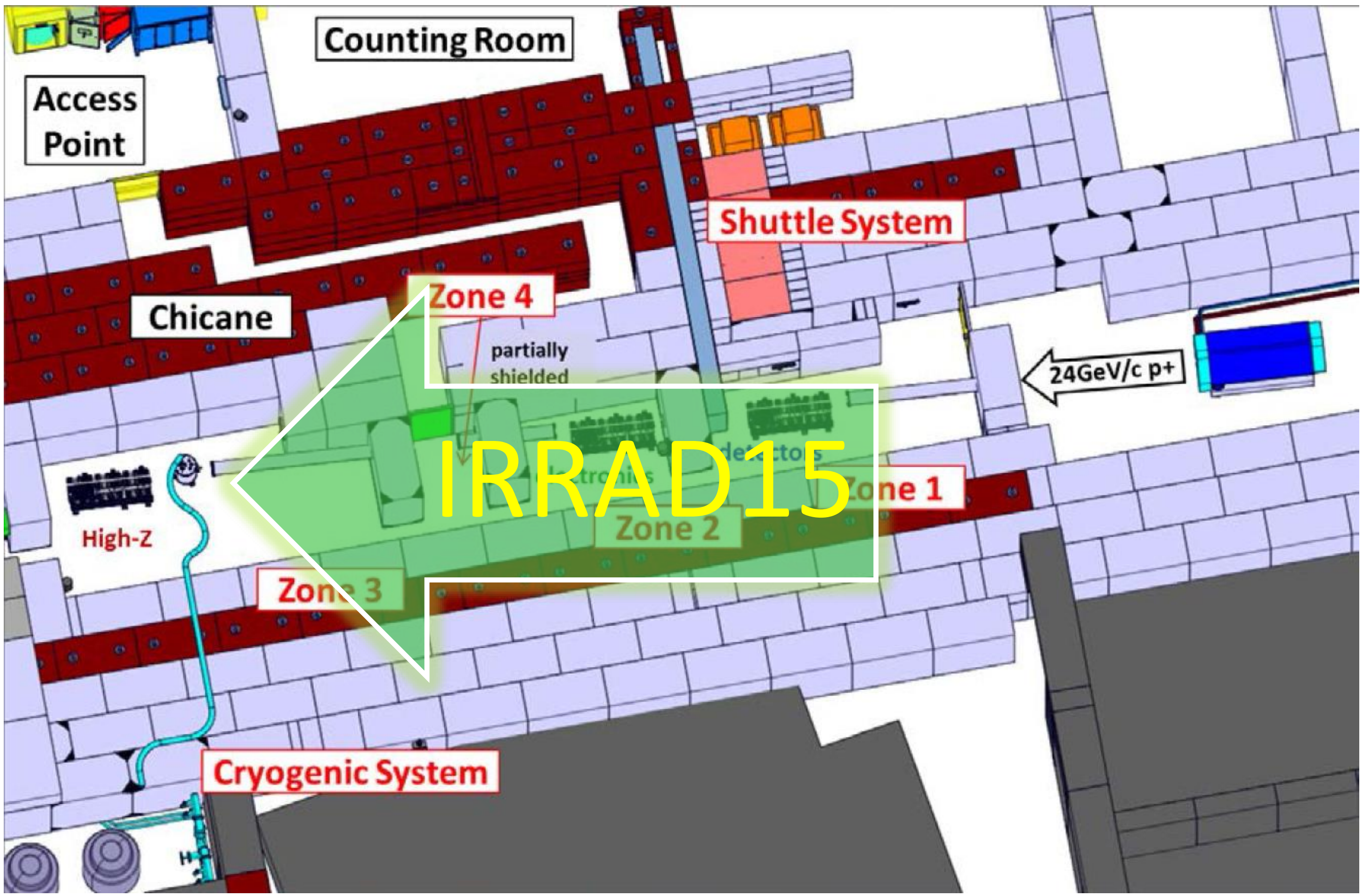
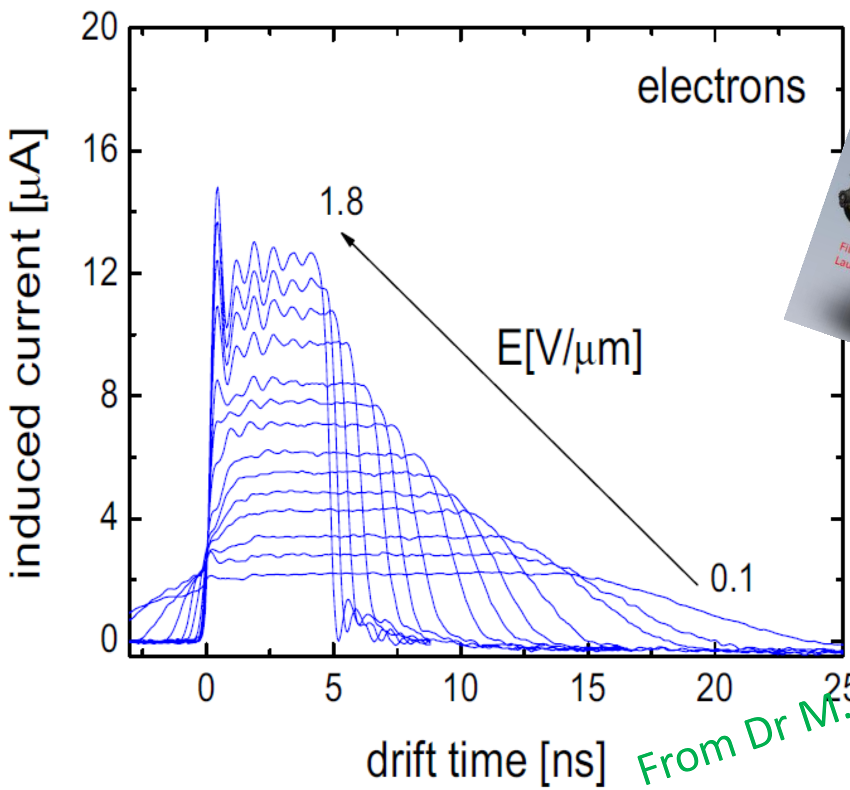
# Next cryogenic irradiation tests

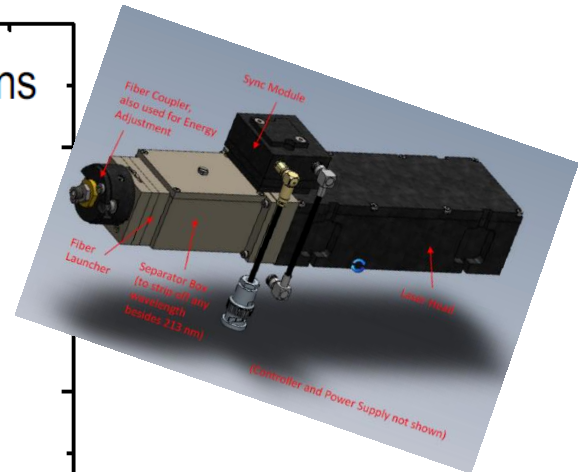


# Next cryogenic irradiation tests



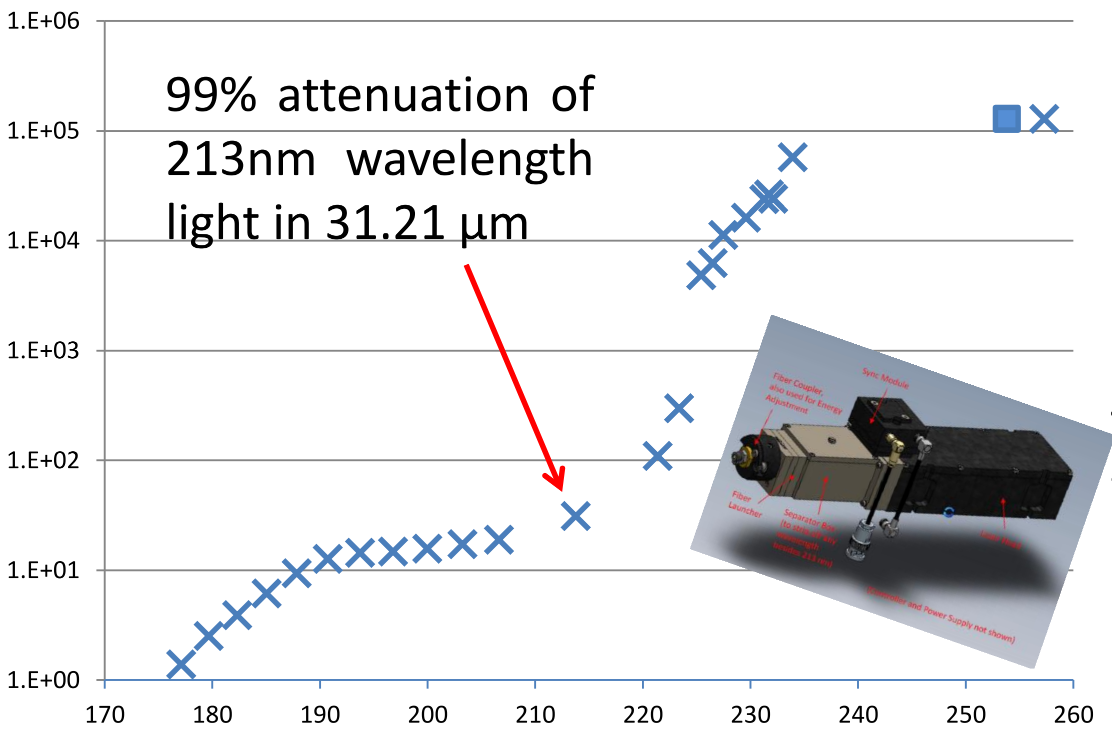
# Transient Current Technique




From Dr M. Pomorski Dissertation

# Transient Current Technique




attenuation constant at **213nm**:

$\alpha = 1.476 \cdot 10^{-1}\ [\mu m^{-1}]$;

99% of light is stop after only **31.21µm** of diamond.

To compare, widely use, in the TCT on silicon, **678nm** wavelength light is in 99% stop after about **35µm** of a silicon bulk.

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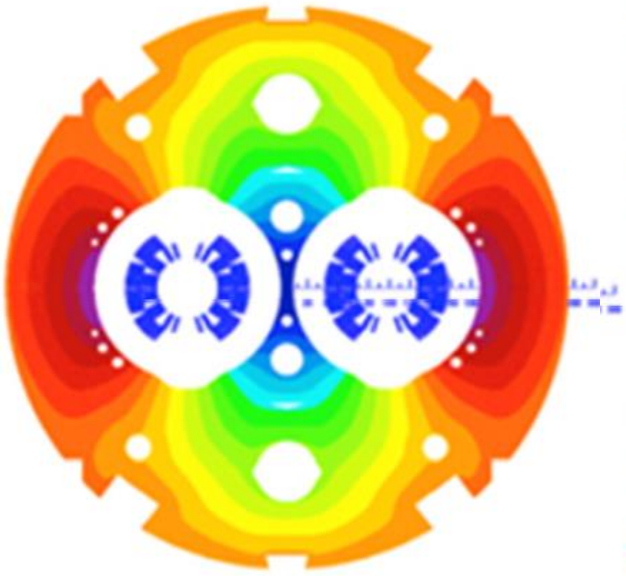
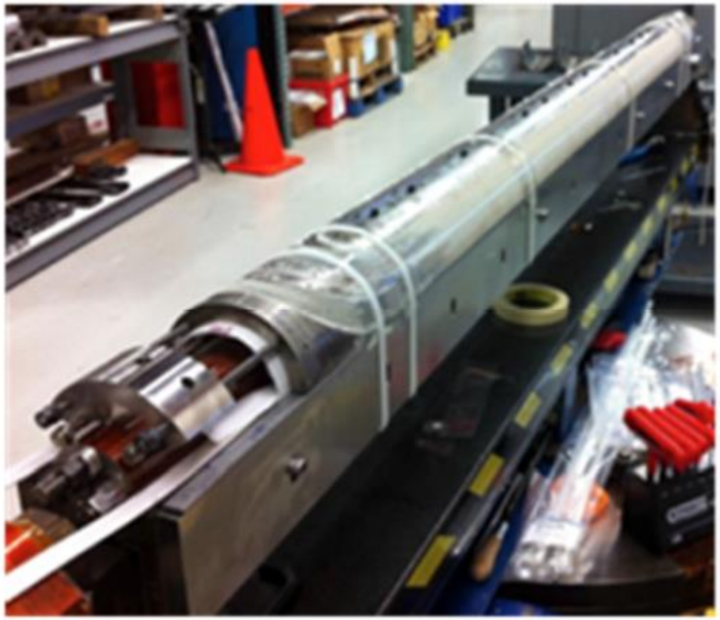
# Future installations in LHC



The twin-aperture, 11 T dispersion suppressor MB cross section.



The first coil of the FNAL demonstrator ready for heat treatment.

[D. Tommasini, et al. Accelerator magnets R&D programme at CERN, Proceedings of IPAC2012, New Orleans, Louisiana, USA (THPPD009)]

# Conclusions

- After the upgrade of LHC, close to the interaction points, the current BLM system will be dominated by the signal from the collisions debris.
- A solution based on placing CryoBLMs inside the cold mass close to the coils will increase the ratio of the proton loss to debris signal.
- Results of cryogenic irradiation were presented and show that for very high radiation doses scCVD diamond detectors should provide a higher signal.
- First results from cryogenic BLMs with beam are expected in early 2015, when the LHC starts its second operational run.
- Results of the future experiments should complement the knowledge of the detector behaviours.

Thank you!