HL-LHC: Cryogenic BLMs

M. R. Bartosik, B. Dehning,
C. Kurfuerst, M. Sapinski and A. Alexopoulos;
Beam Loss Monitoring section

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**
- **Future**
  - **TCT and next cryogenic tests**
  - **Installations in LHC**
- **Conclusions**

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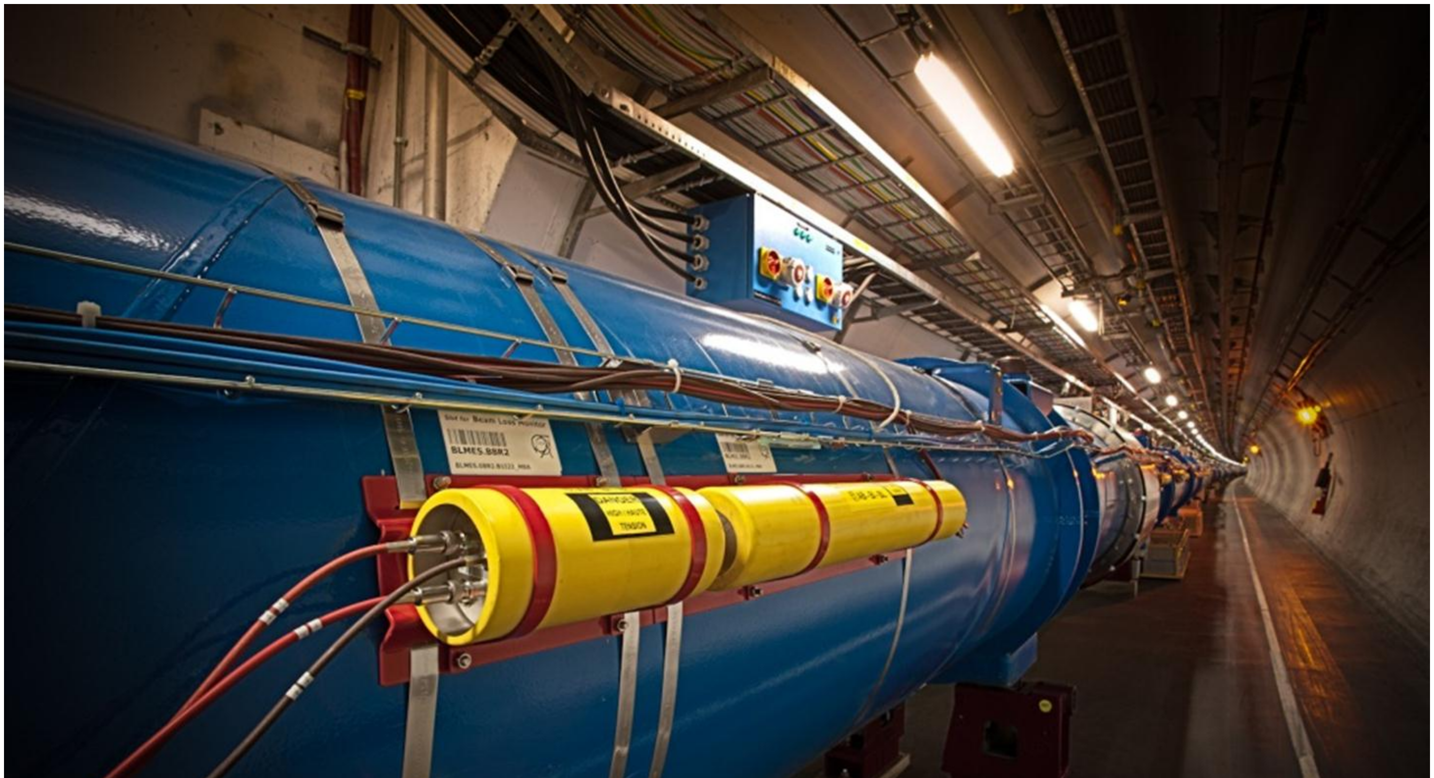
Beam Loss Monitoring system for the LHC



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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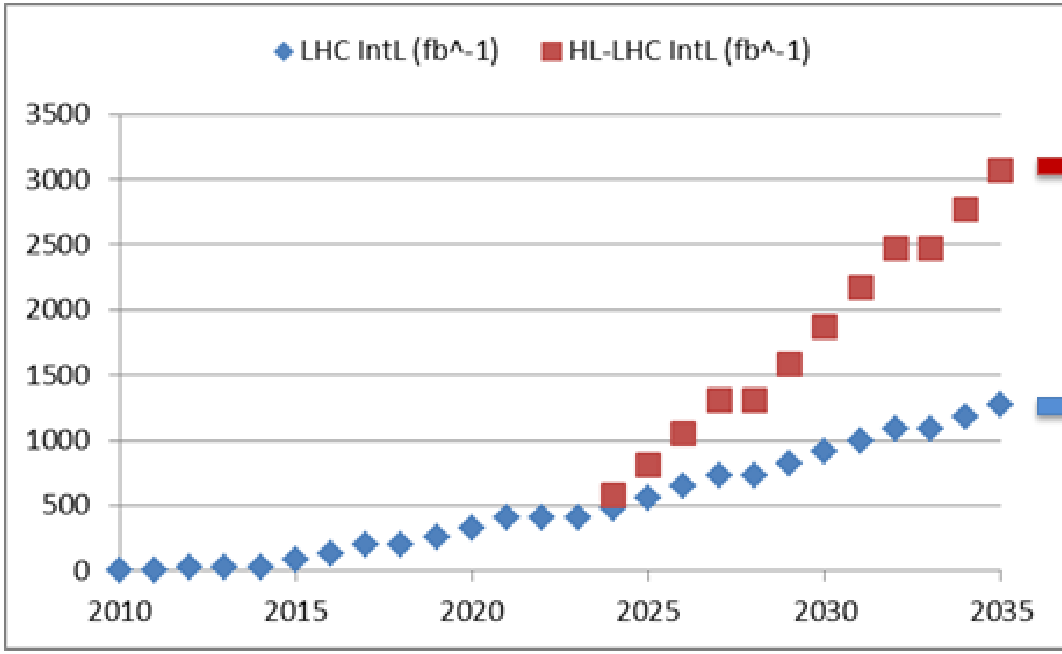
Cryogenic BLMs for HL-LHC



By implementing HL-LHC

Almost a factor 3

By continuous performance improvement and consolidation

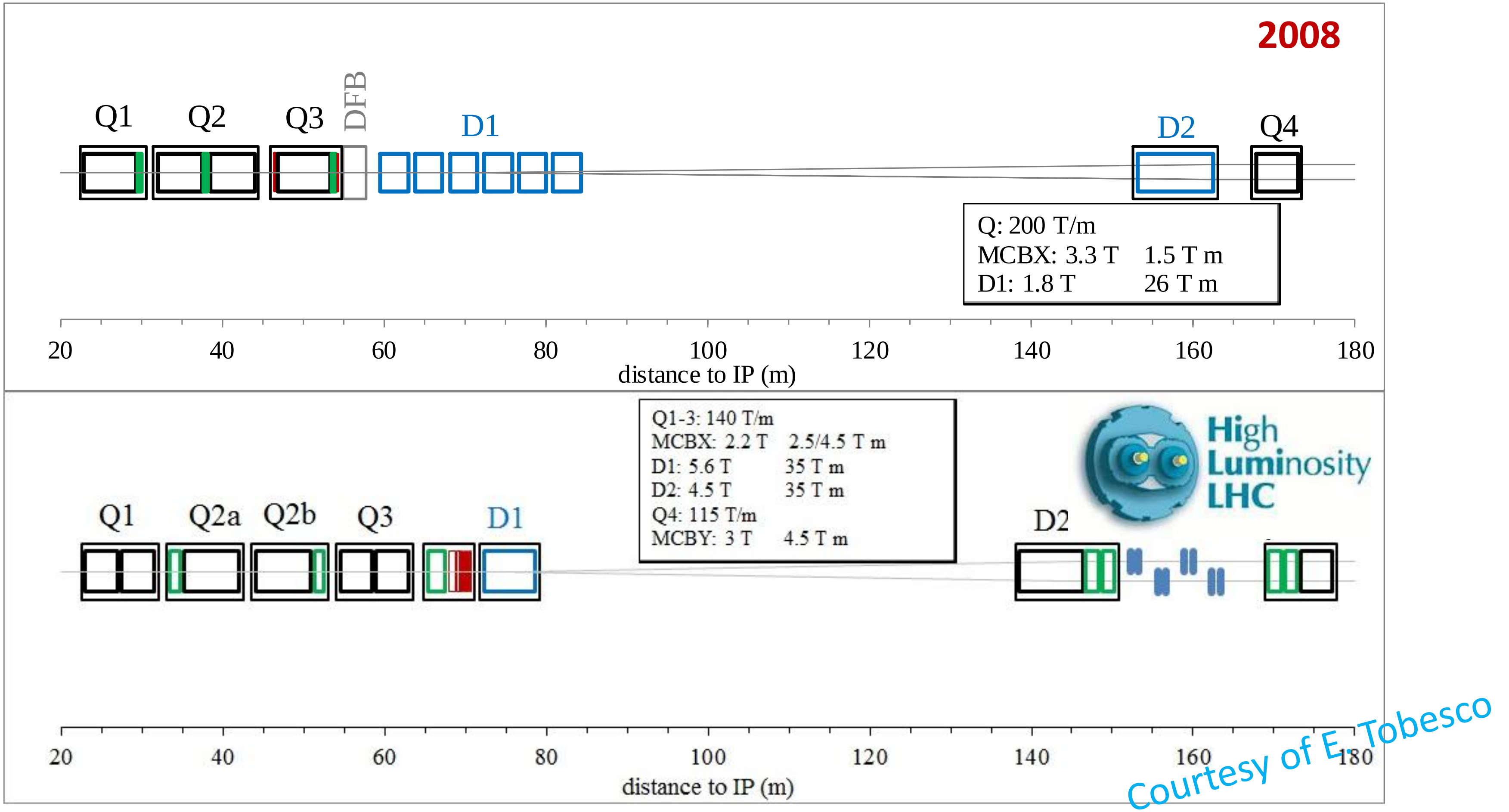
Courtesy of F. Bordry

Goal of the HL-LHC project:

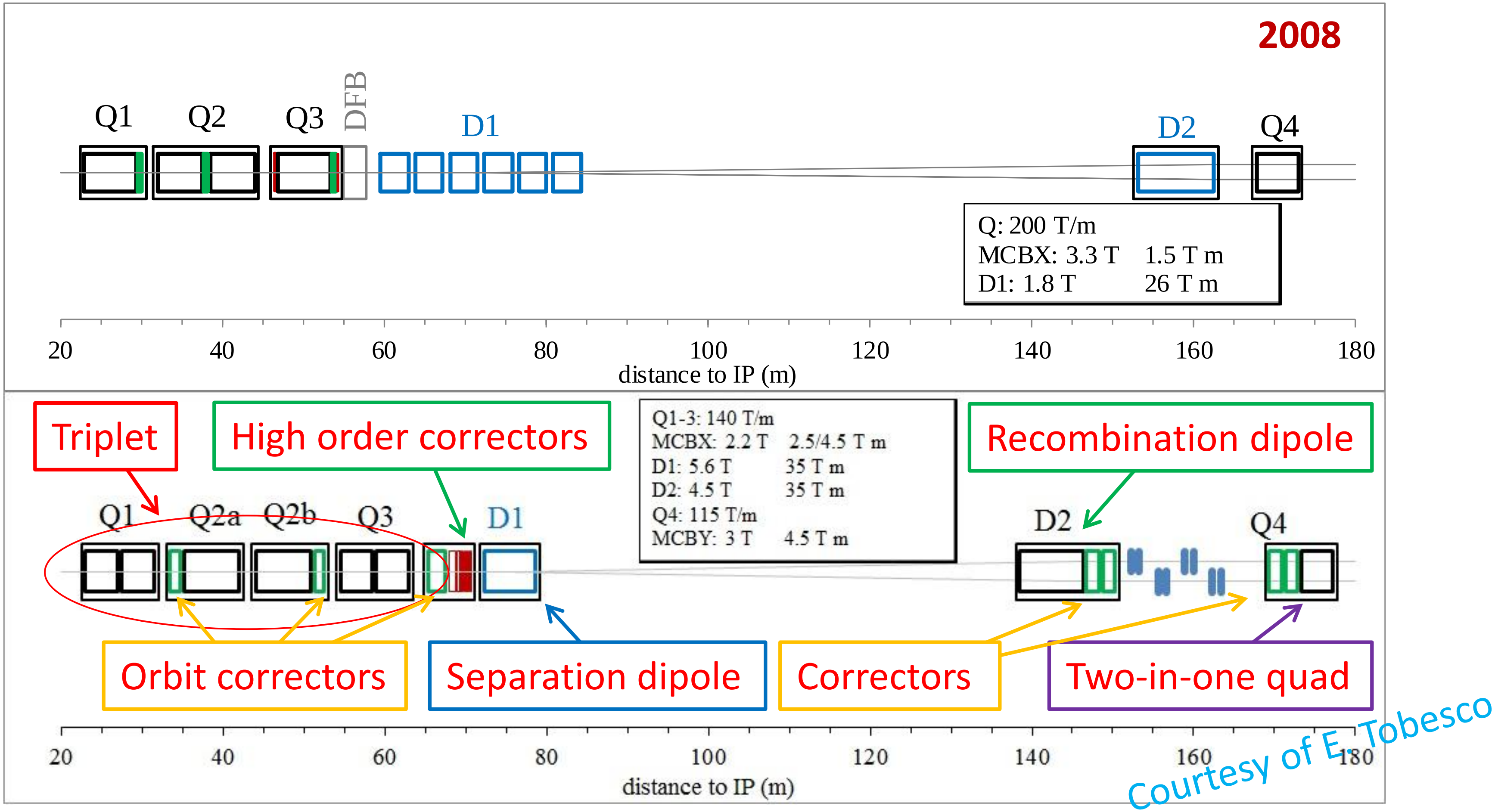
- 250 – 300 fb^{-1} integrated luminosity per year
- 3000 fb^{-1} integrated luminosity in about 10 years

High Luminosity LHC

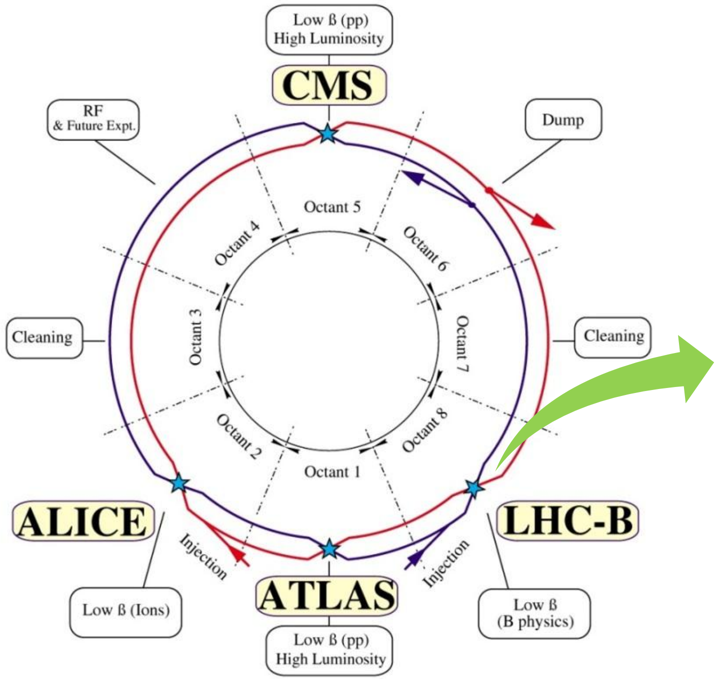
Cryogenic BLMs for HL-LHC



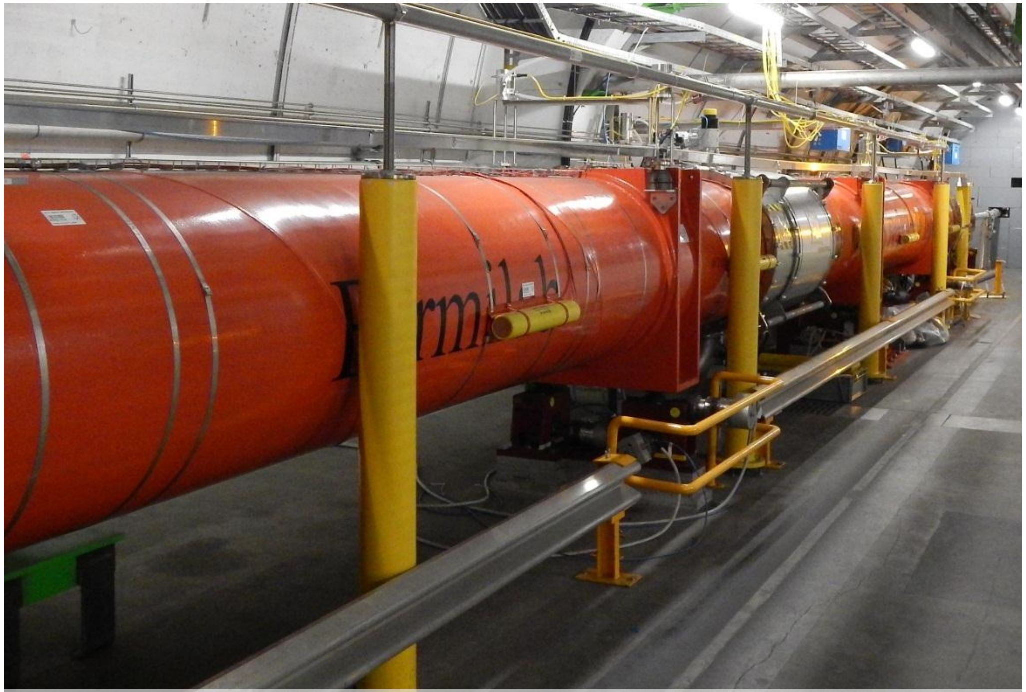
Cryogenic BLMs for HL-LHC



Cryogenic BLMs for HL-LHC



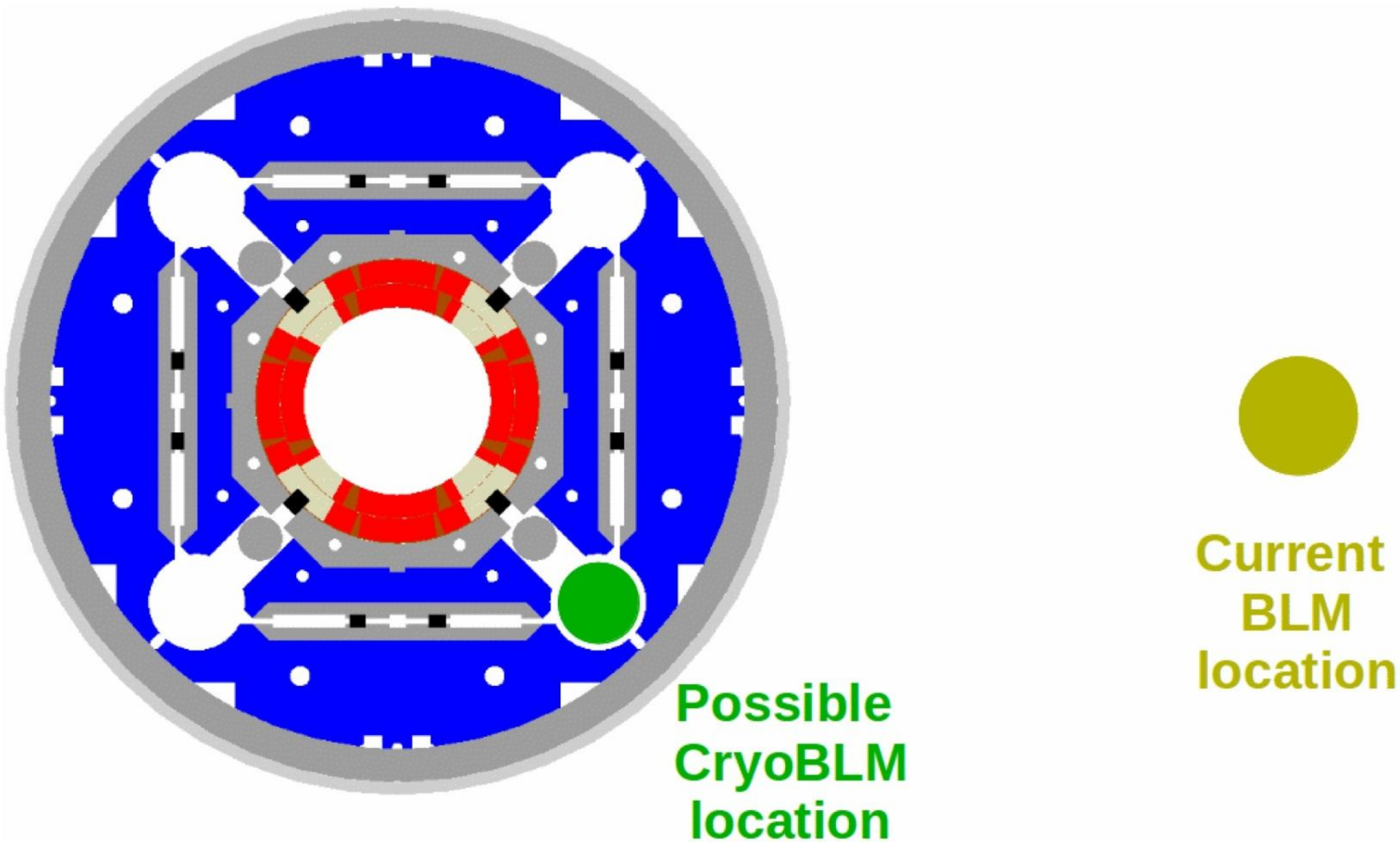
Overview of LHC ring with four main experiments



LHC triplet magnets left of LHC-b experiment at CERN

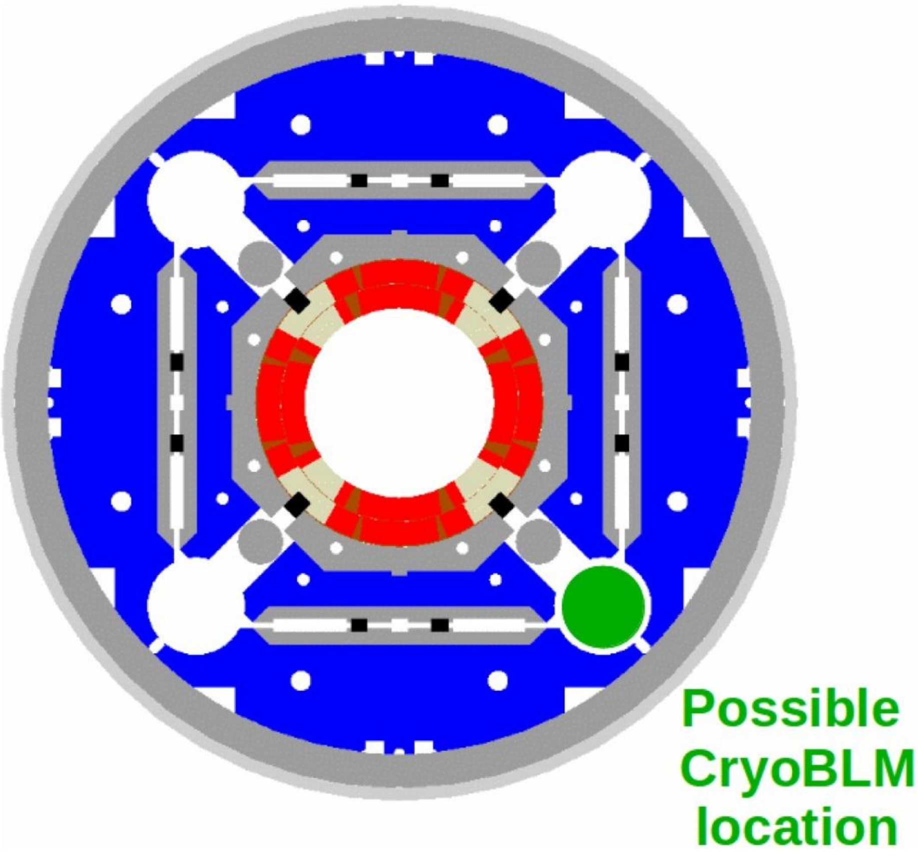
Presently: 16 ionization chambers.
HL-LHC: about 20 ionization chambers and **20 cryogenic BLMs**.

Cryogenic BLMs for HL-LHC



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

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**,
- the mechanical resistance to a fast pressure rise from 1.1 to about **20 bar**, in the case of the quench of a magnet,
- the time response faster than **1 ms**.

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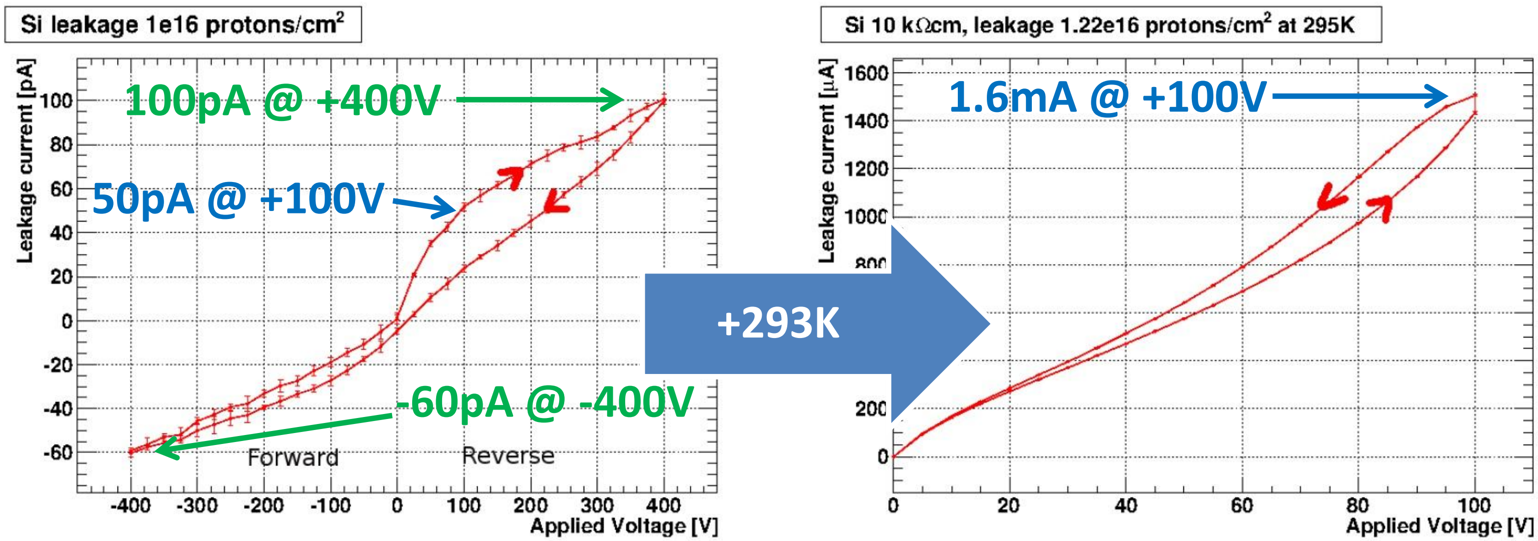
Cryogenic irradiation test – results – leakage current

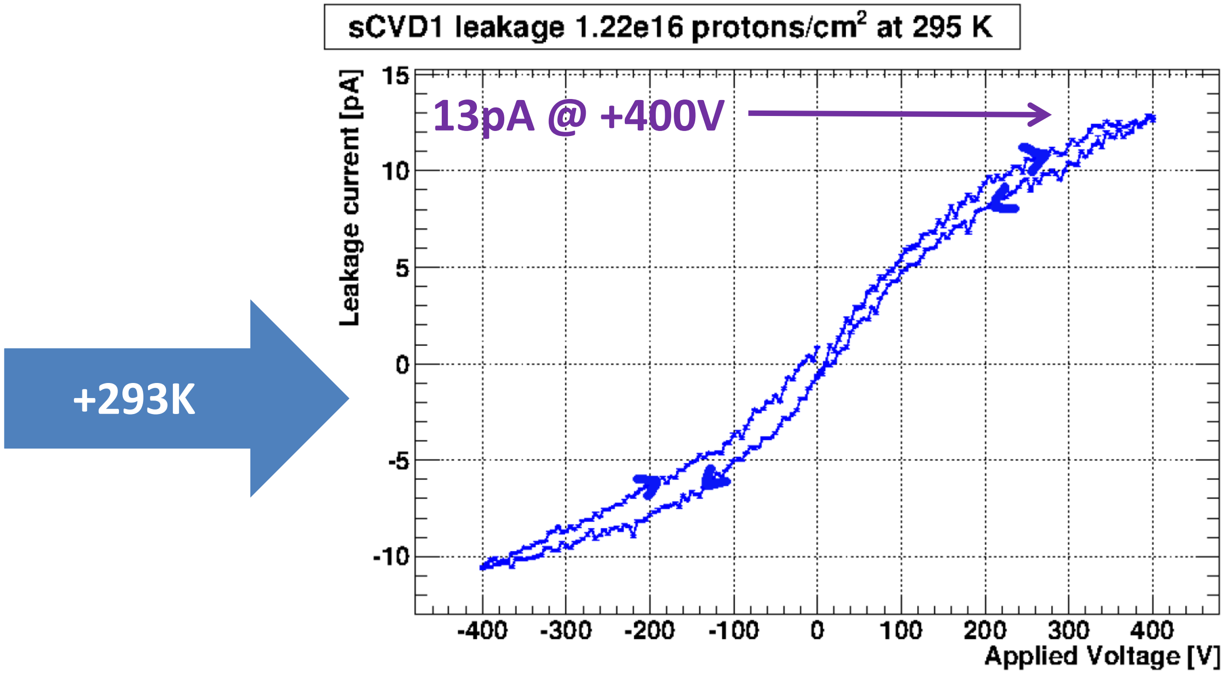
By the end of the irradiation a total integrated fluence of $1.22 \cdot 10^{16}$ protons/cm^2 was reached, corresponding to an integrated dose of **3.26 MGy** for **silicon**.



Silicon leakage curves (after irradiation) in liquid helium (left) and room temperature (right).

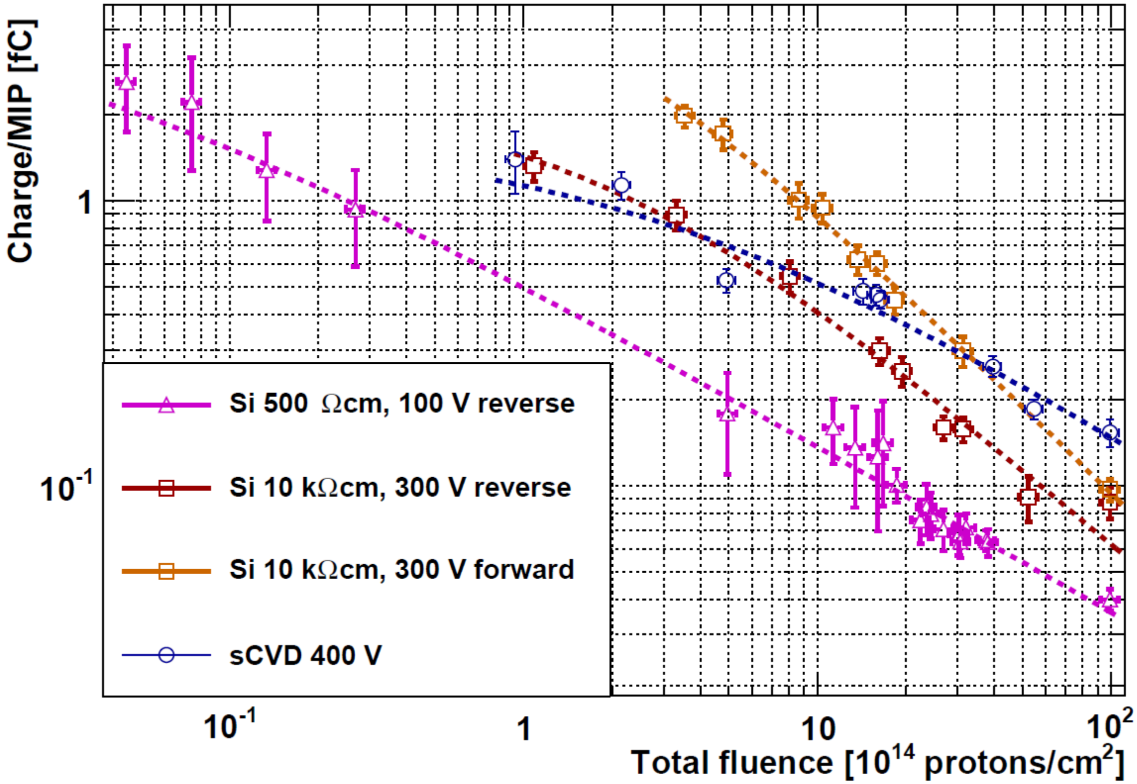
Cryogenic irradiation test – results – leakage current

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**.



Diamond leakage curve (after irradiation) in room temperature.

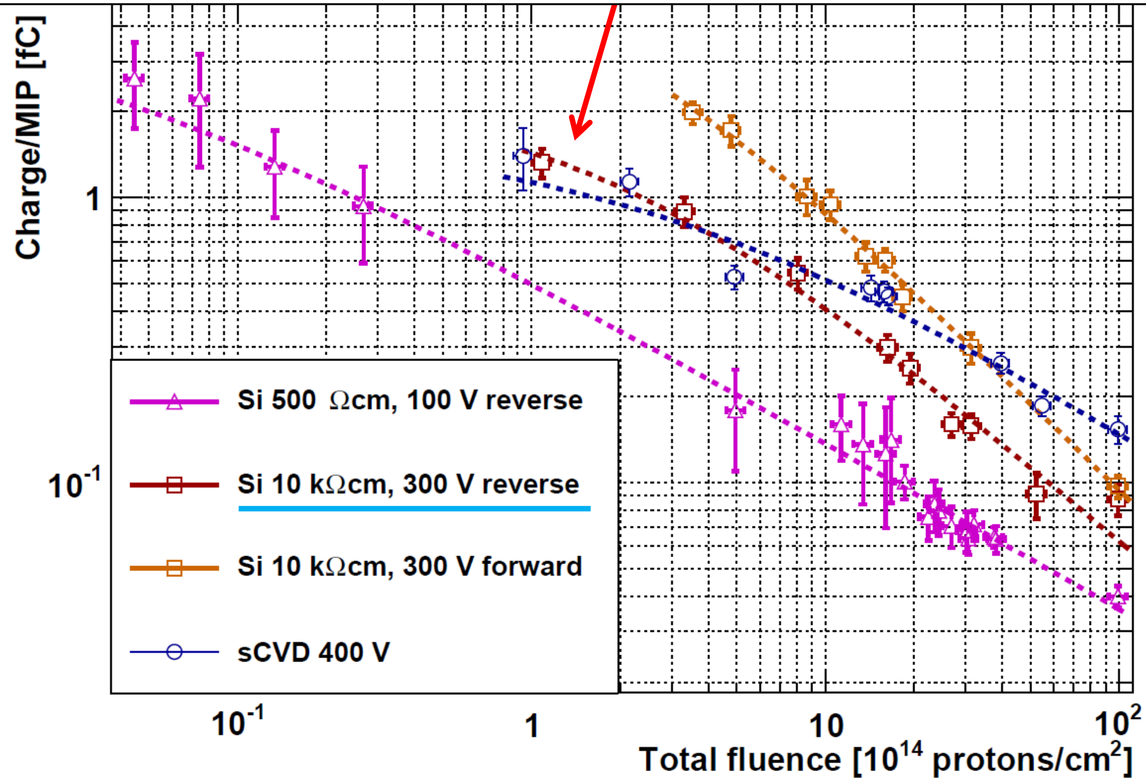
Cryogenic irradiation test – results – degradation



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

Cryogenic irradiation test – results – degradation

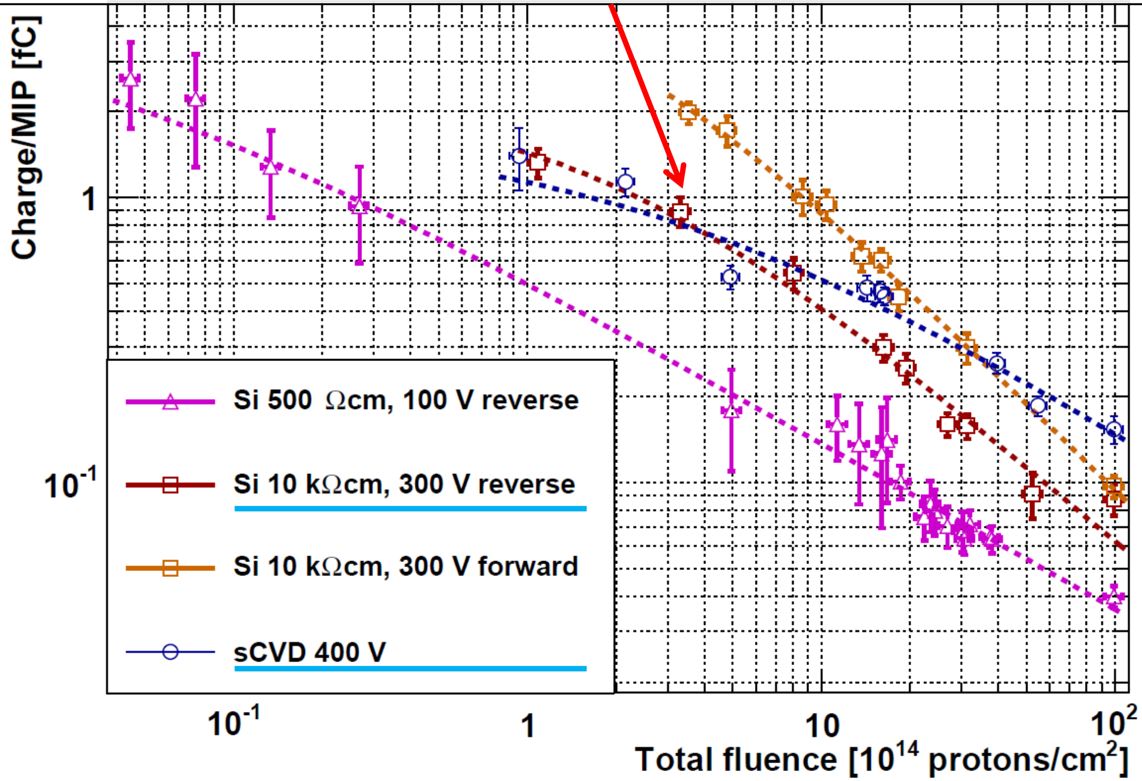
At low irradiation dose, silicon detectors operated at 300 V reverse bias had a larger signal than the diamond detector with 400 V bias.



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

Cryogenic irradiation test – results – degradation

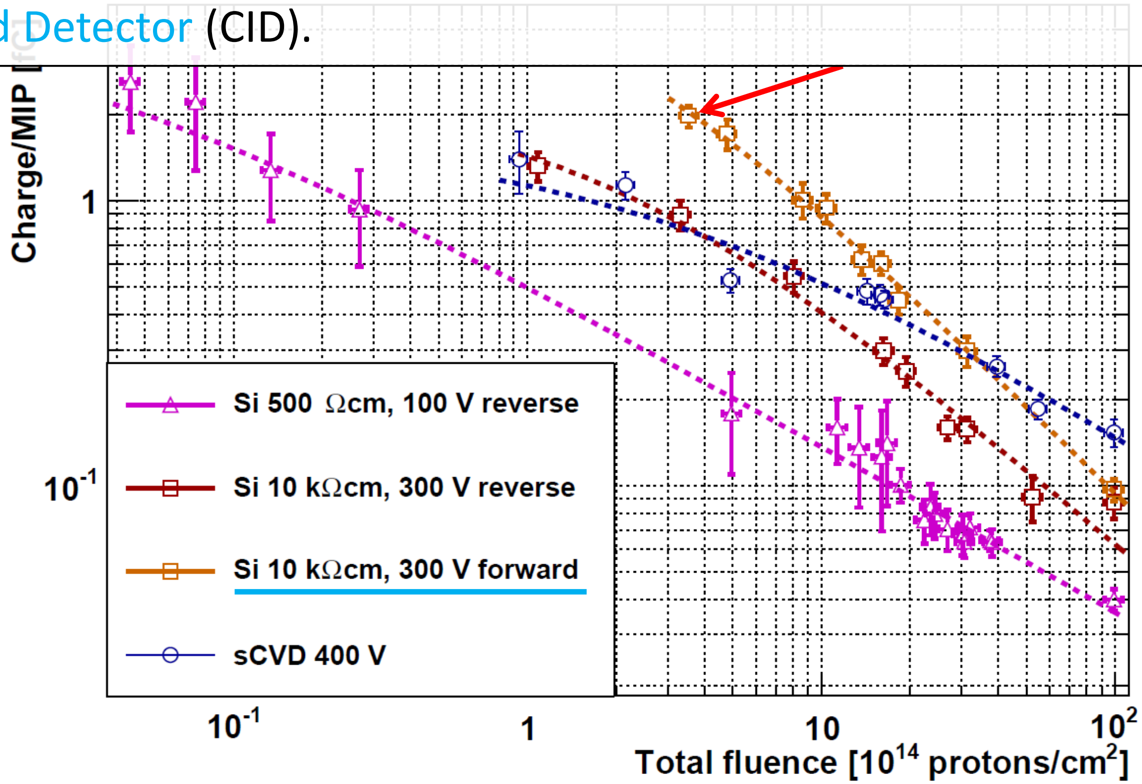
The crossing point was at a fluence of 3.8 · 10^{14} protons/cm^2 (0.1 MGy), from where on sCVD started to have higher signal.



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

Cryogenic irradiation test – results – degradation

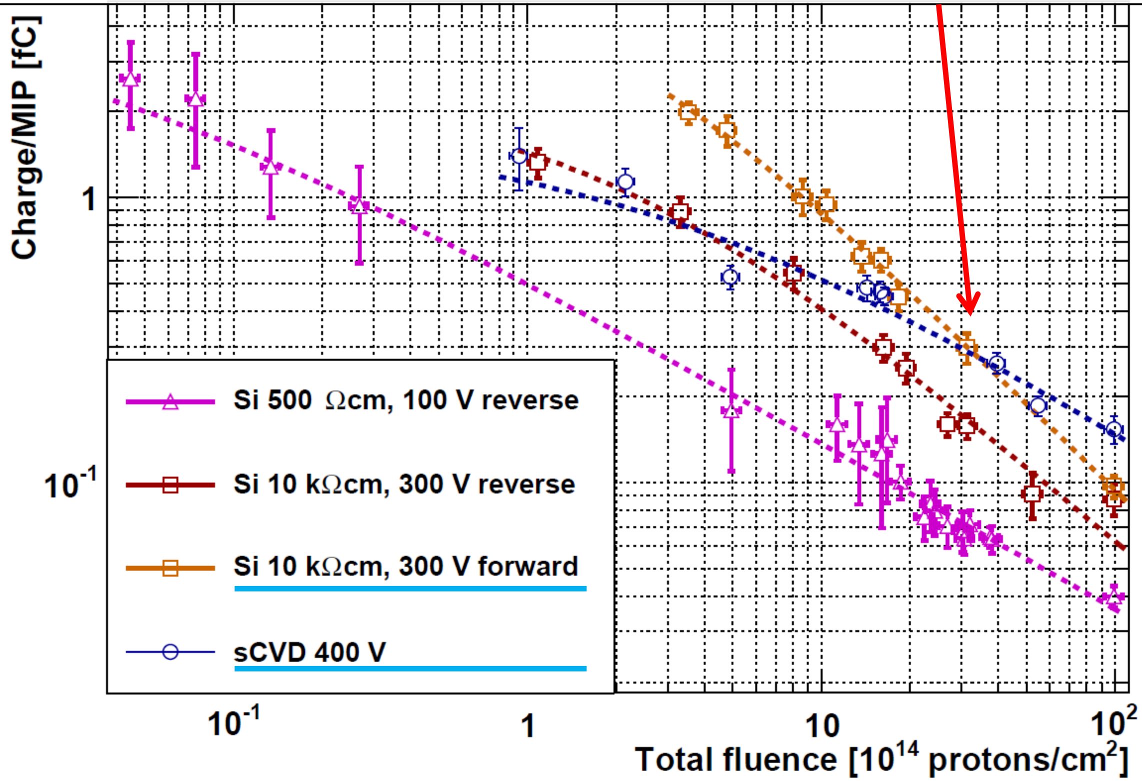
For the silicon detectors at liquid helium temperatures, measurements could be performed under forward bias application, which is known as Current Injected Detector (CID).



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

Cryogenic irradiation test – results – degradation

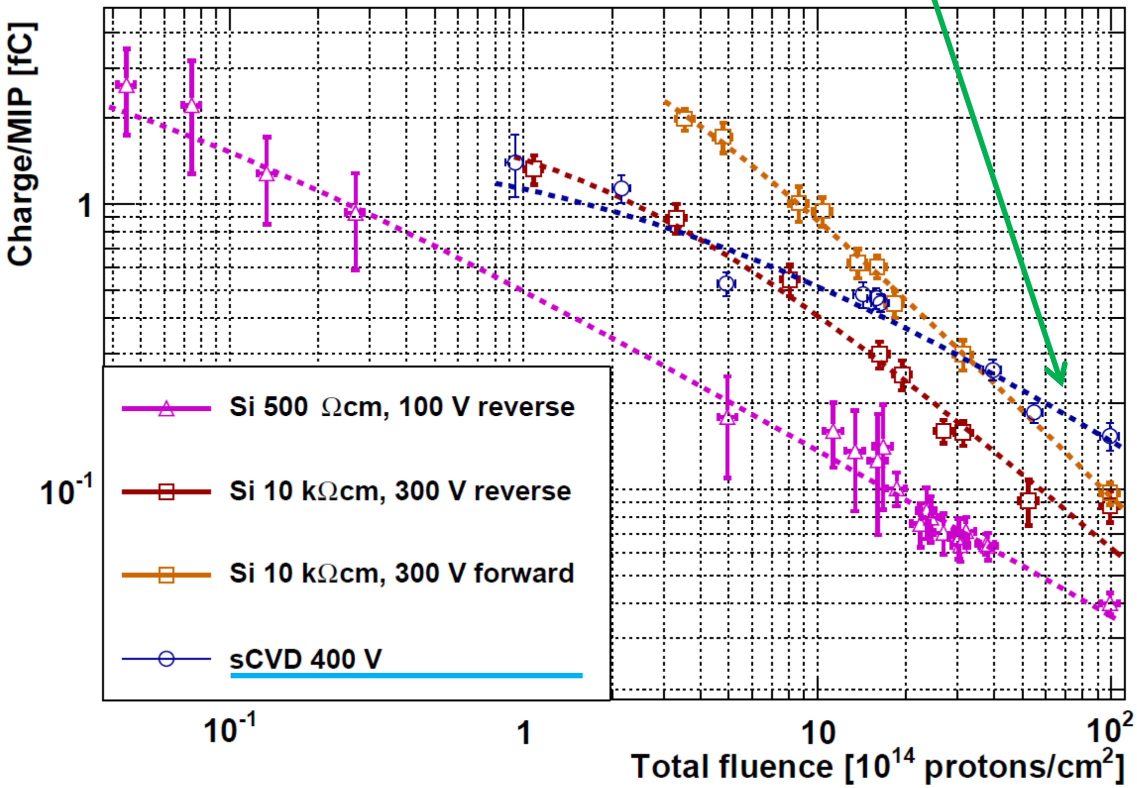
The crossing point between sCVD with 400 V and the silicon detector with 300 V forward bias was at $3.35 \cdot 10^{15}$ protons/cm^2 (0.9 MGy),



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

Cryogenic irradiation test – results – degradation

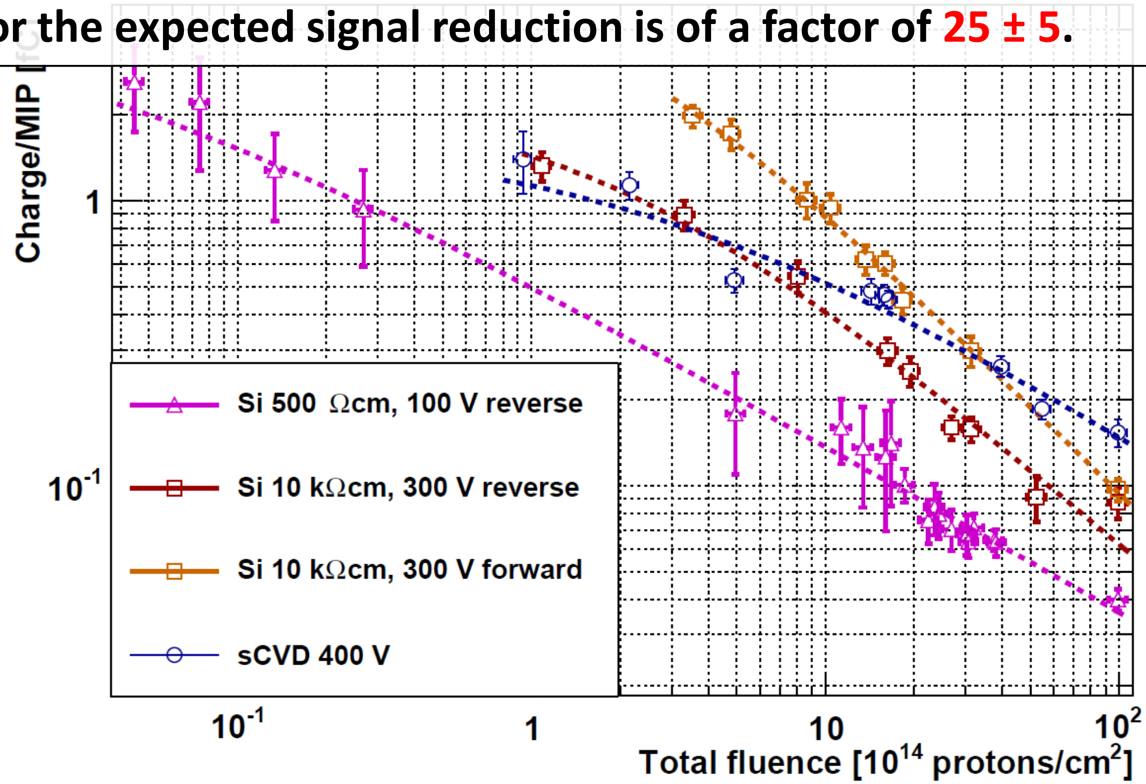
For very high radiations diamond sensors should provide the higher signal.



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

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.



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

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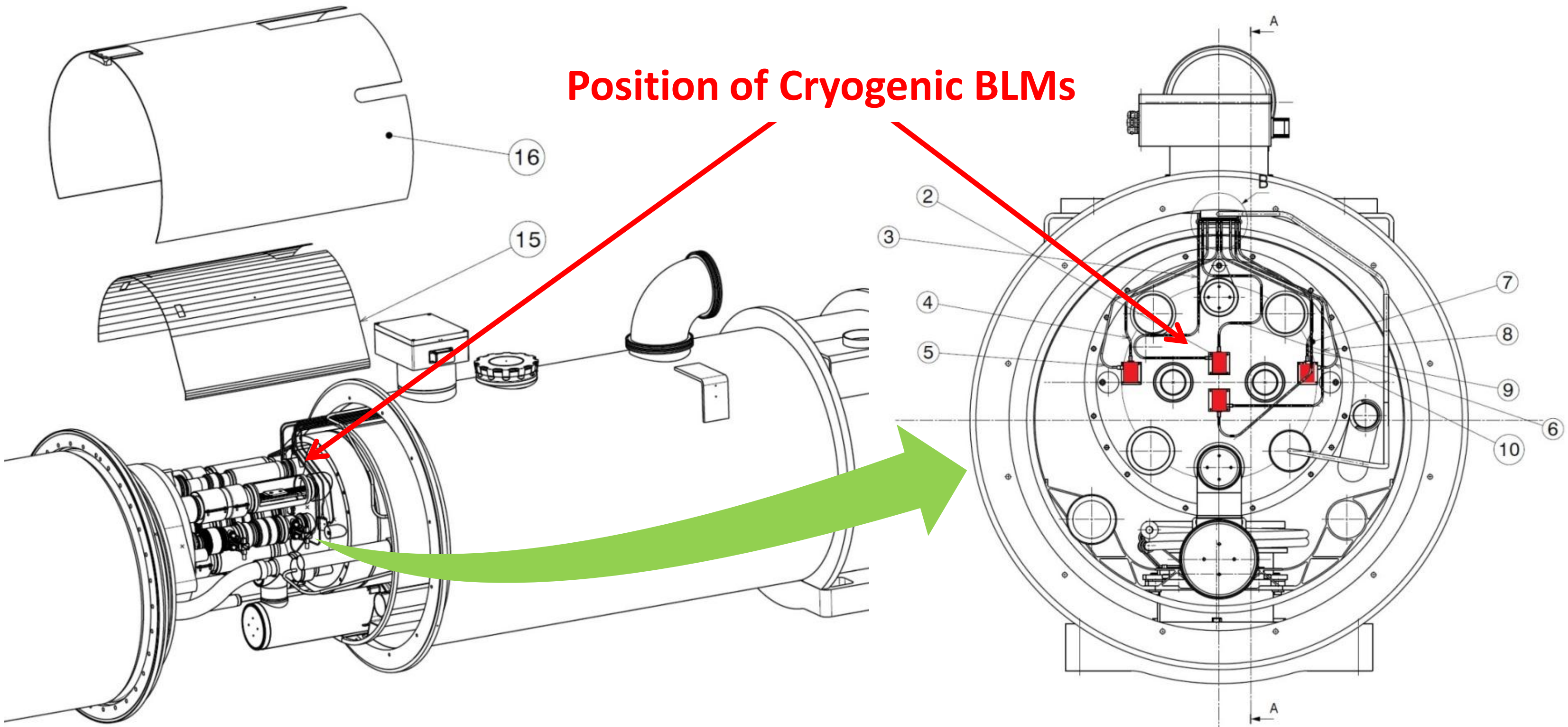
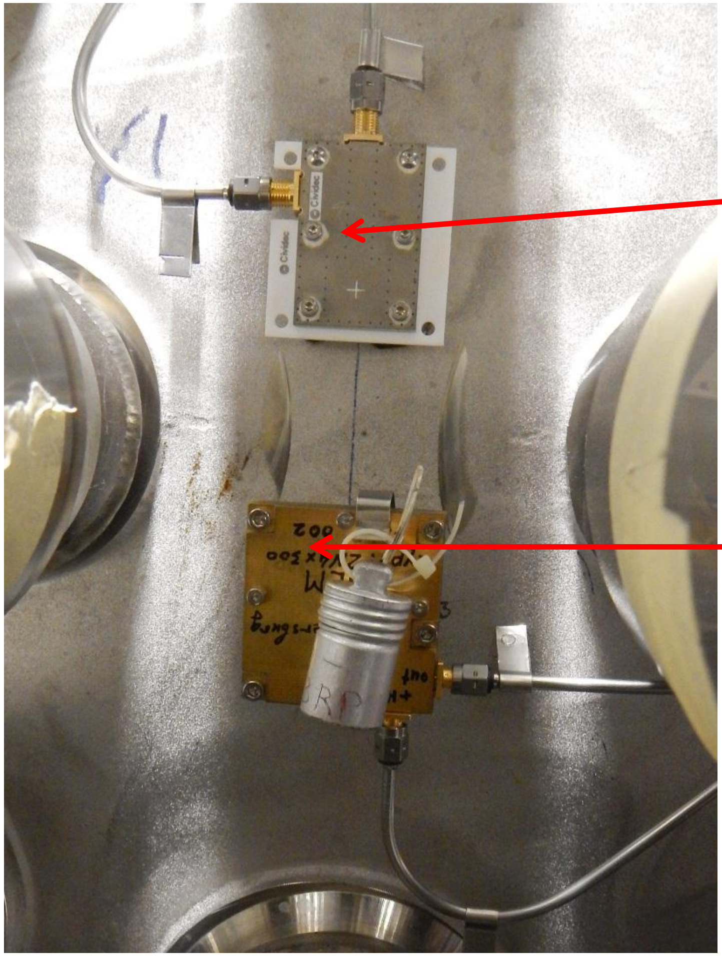
Cryogenic BLMs in LHC ring



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

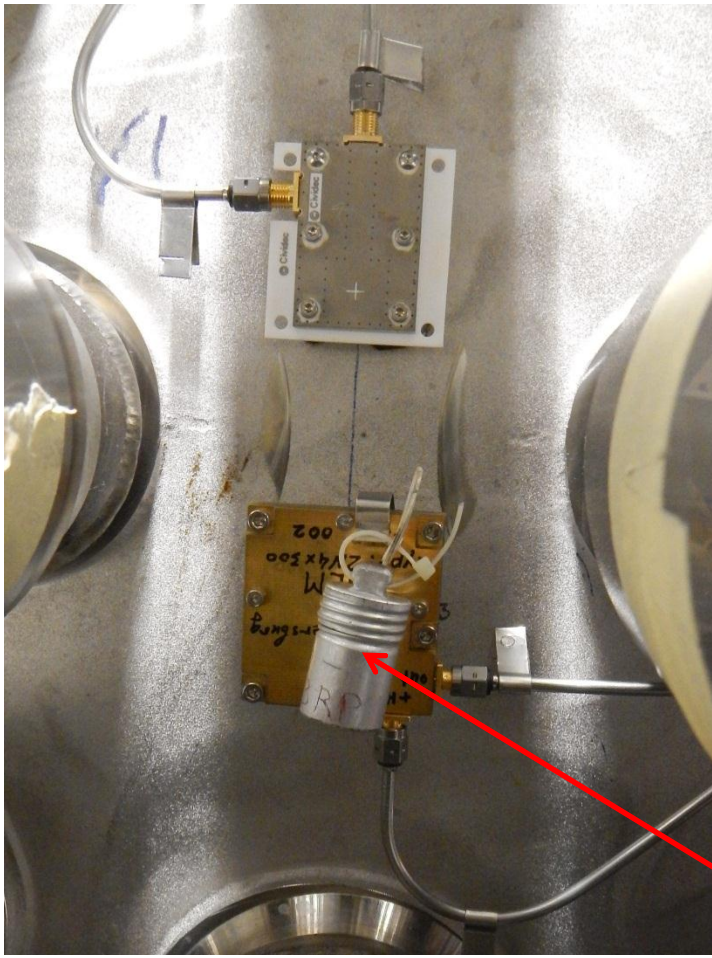


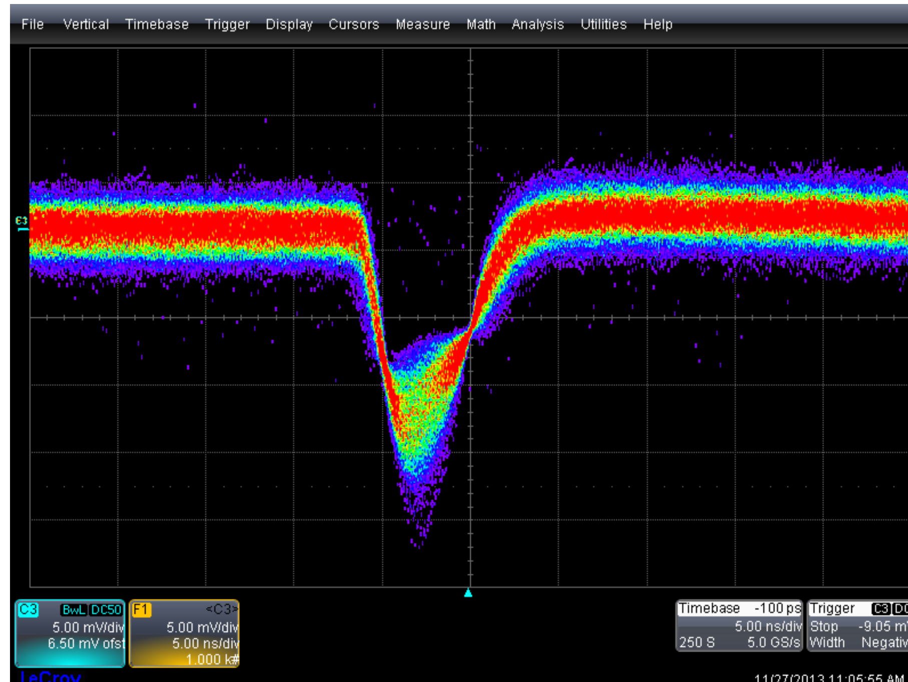
We have installed in the LHC, for example:

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

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

Cryogenic BLMs in LHC ring

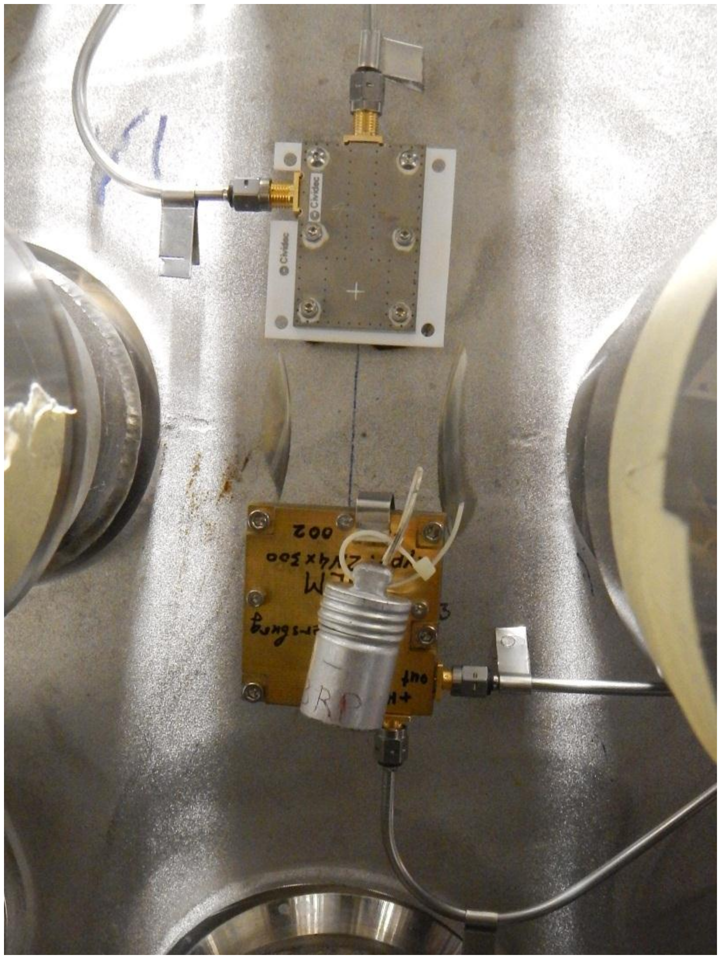




Single photons of γ-radiation recorded by scCVD diamond detector during test in the tunnel with use of Cobalt-60.

γ-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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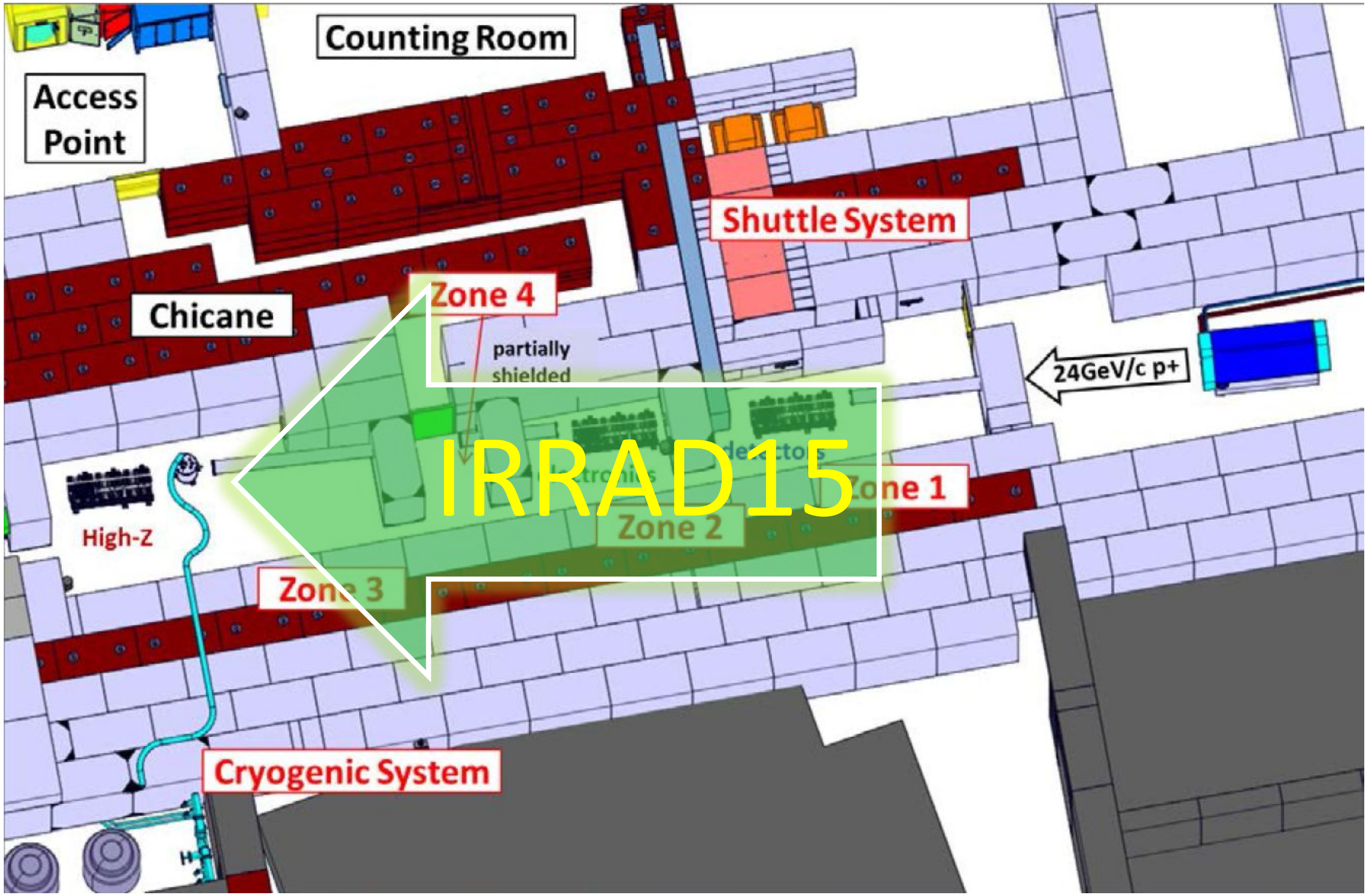
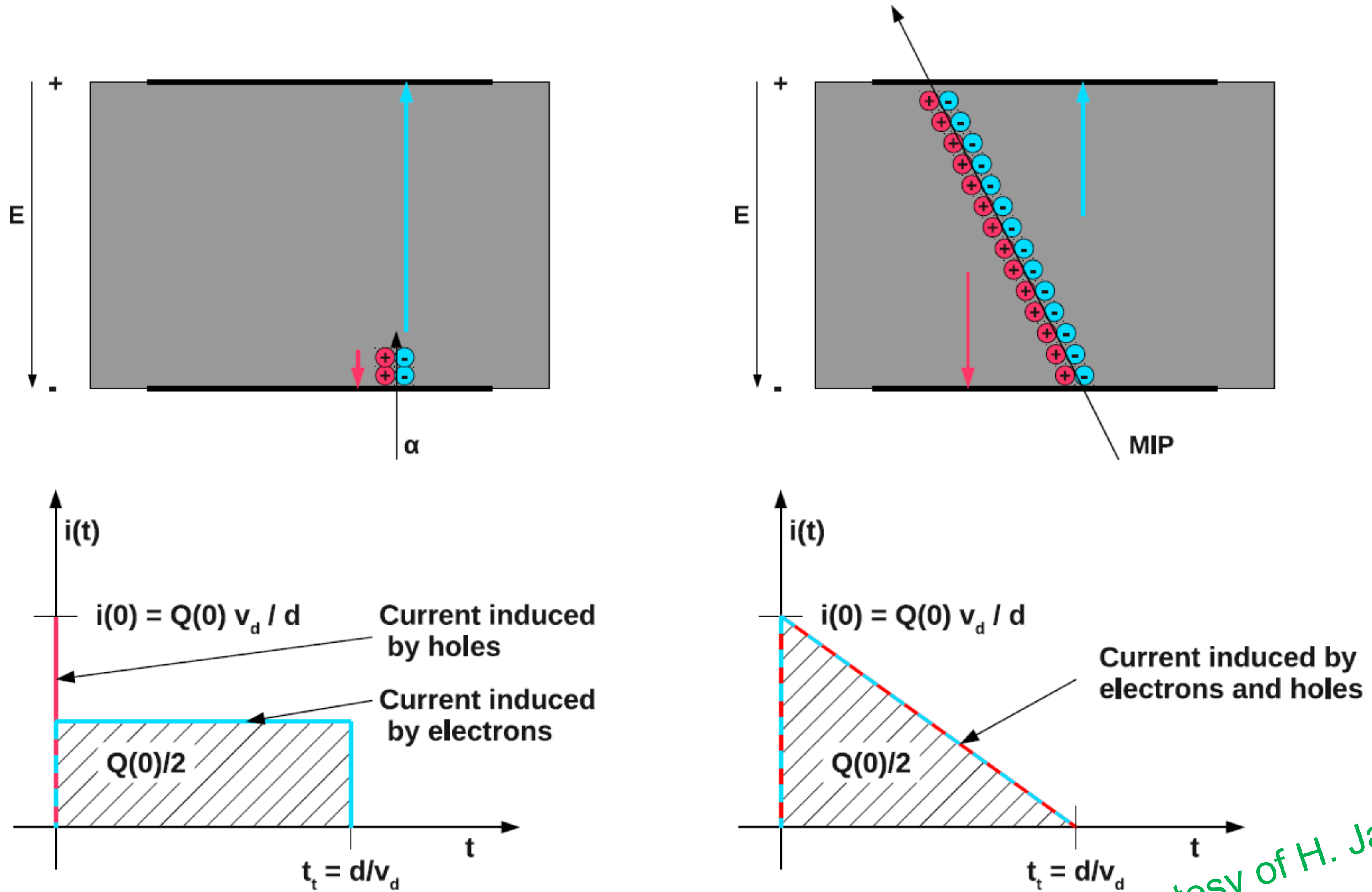
Next cryogenic irradiation tests

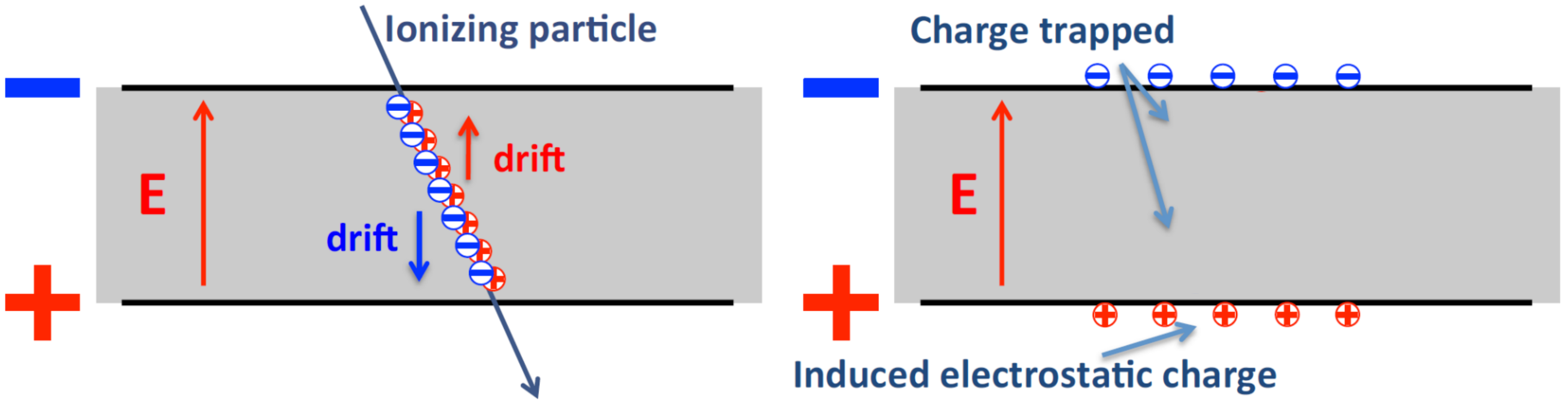


Transient Current Technique



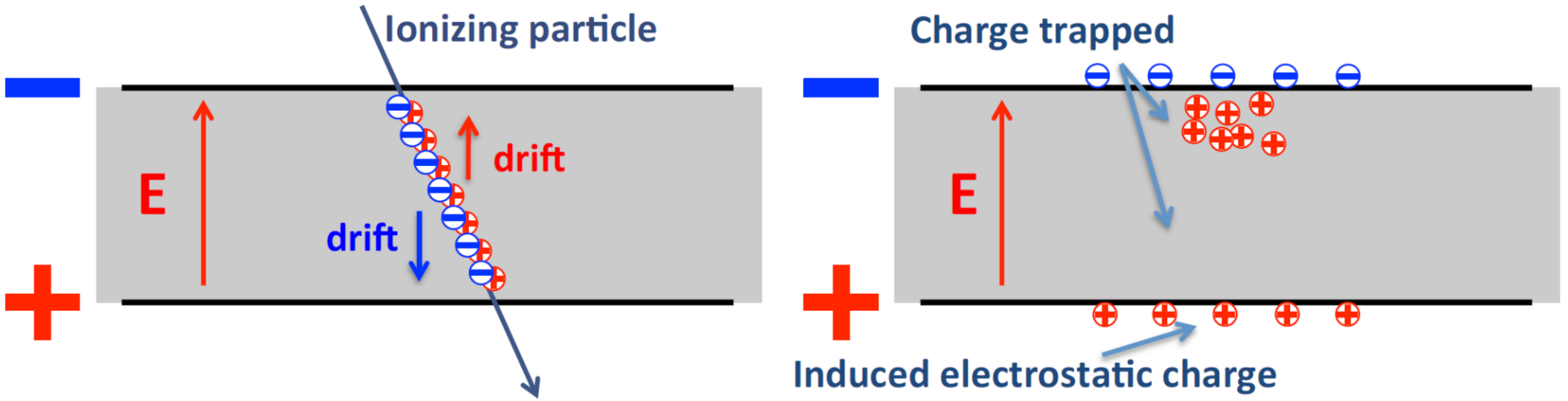
courtesy of H. Jansen

Transient Current Technique



courtesy of M. Guthoff

Transient Current Technique



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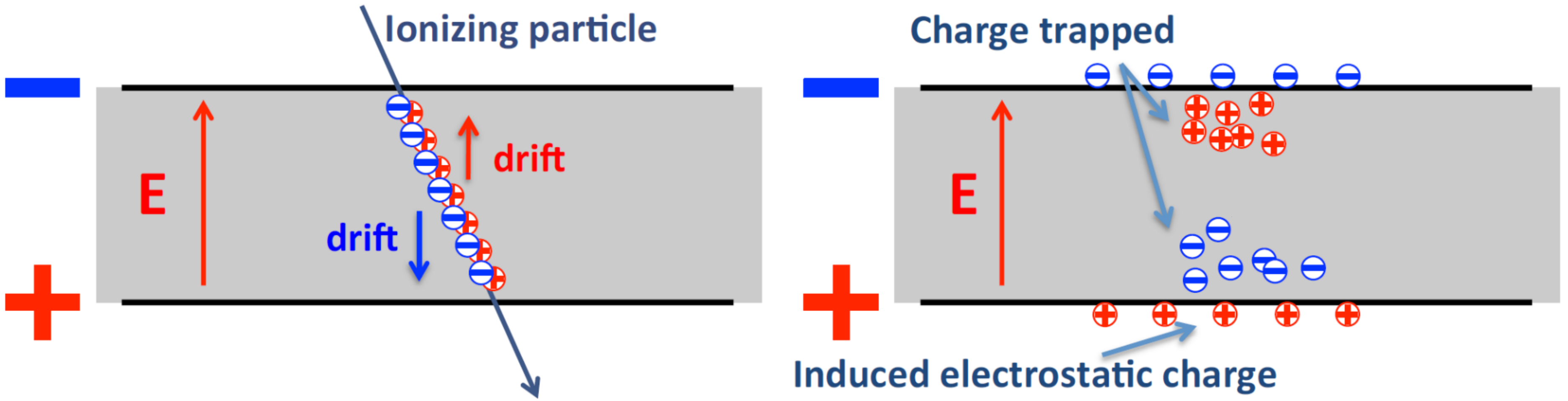

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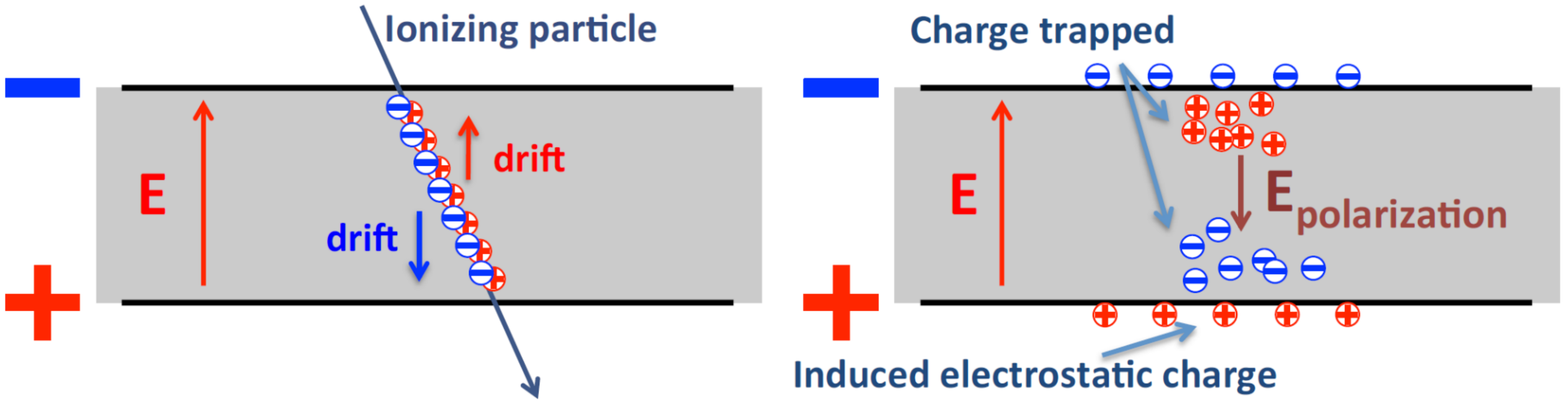

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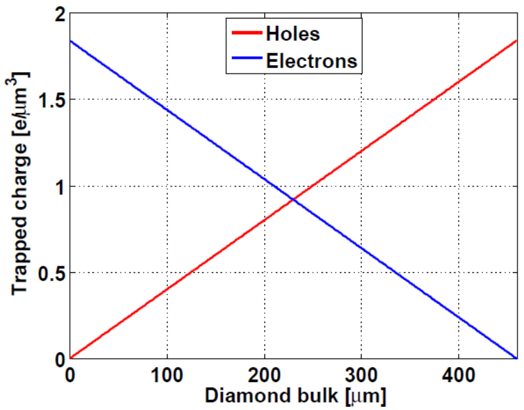

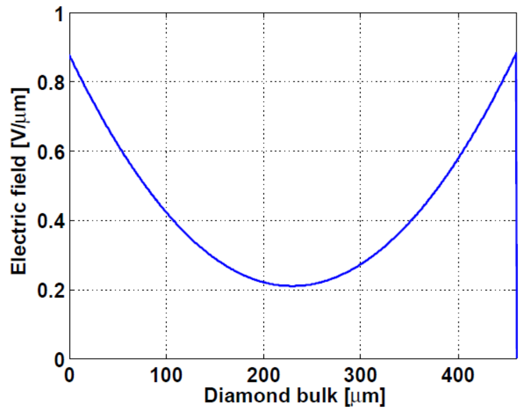

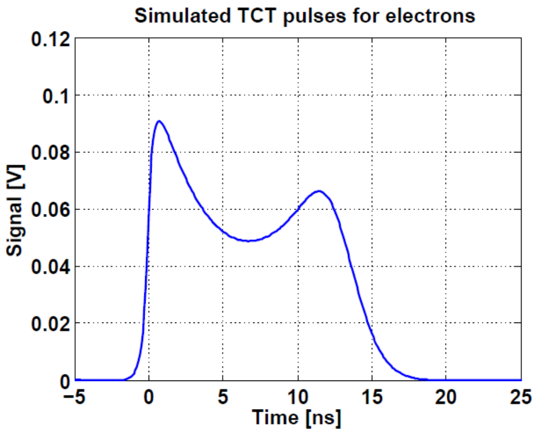

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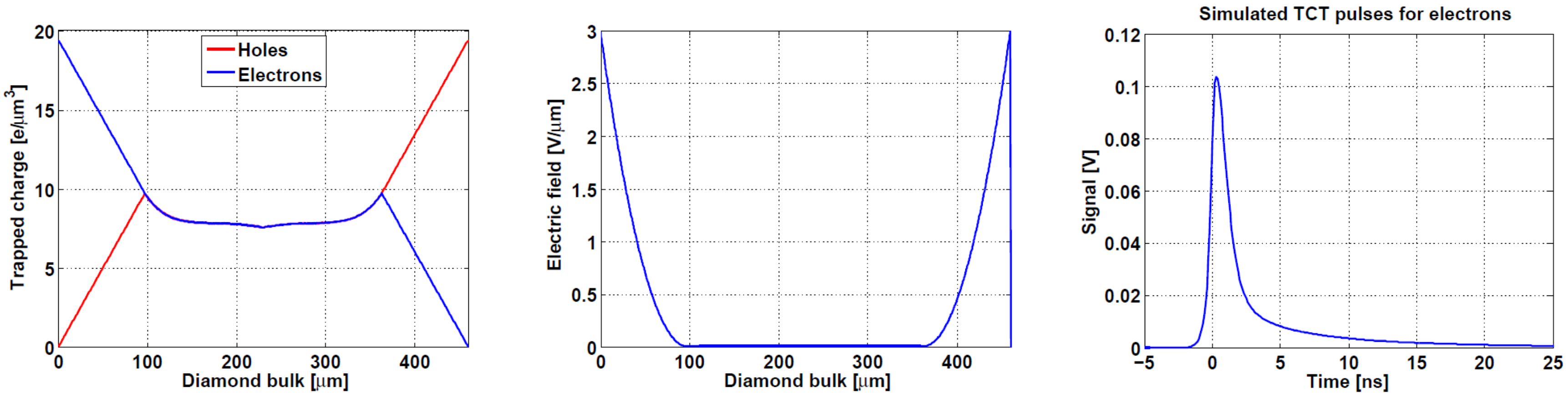


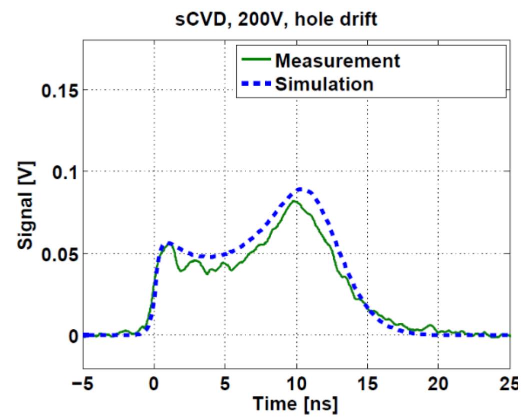
courtesy of M. Guthoff

Transient Current Technique

(a) Charge distribution

(b) Electric field

(c) TCT pulse, electron drift



(d) TCT pulse, hole drift

courtesy of M. Guthoff

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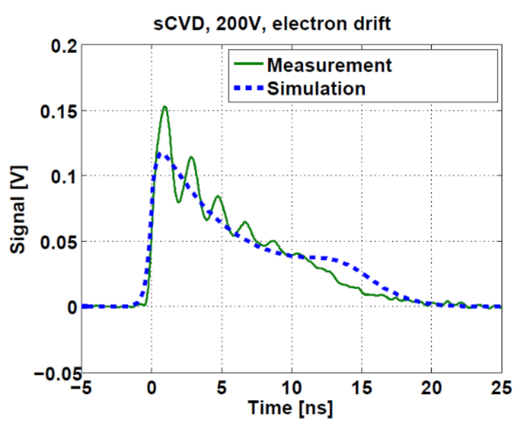
(a) Charge distribution

(b) Electric field



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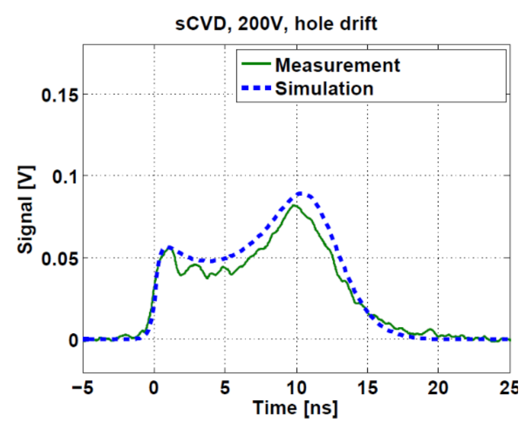

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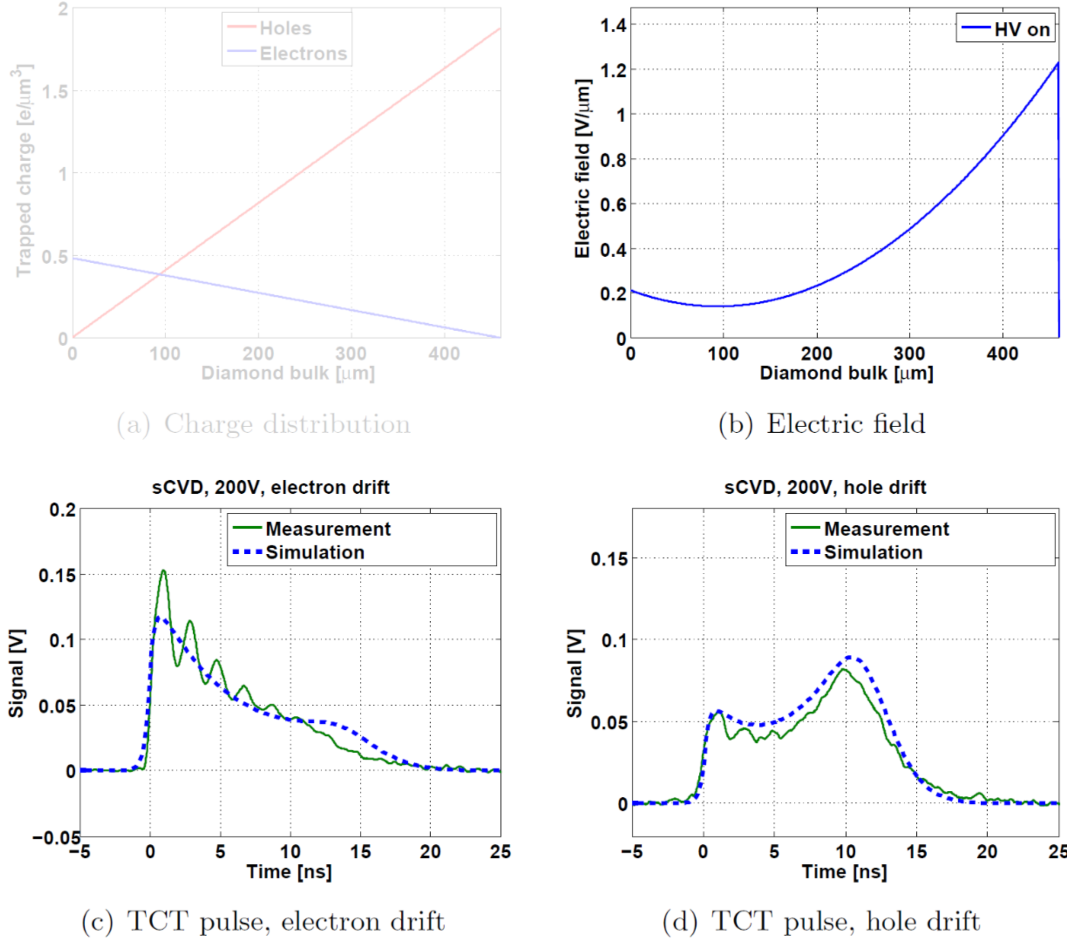

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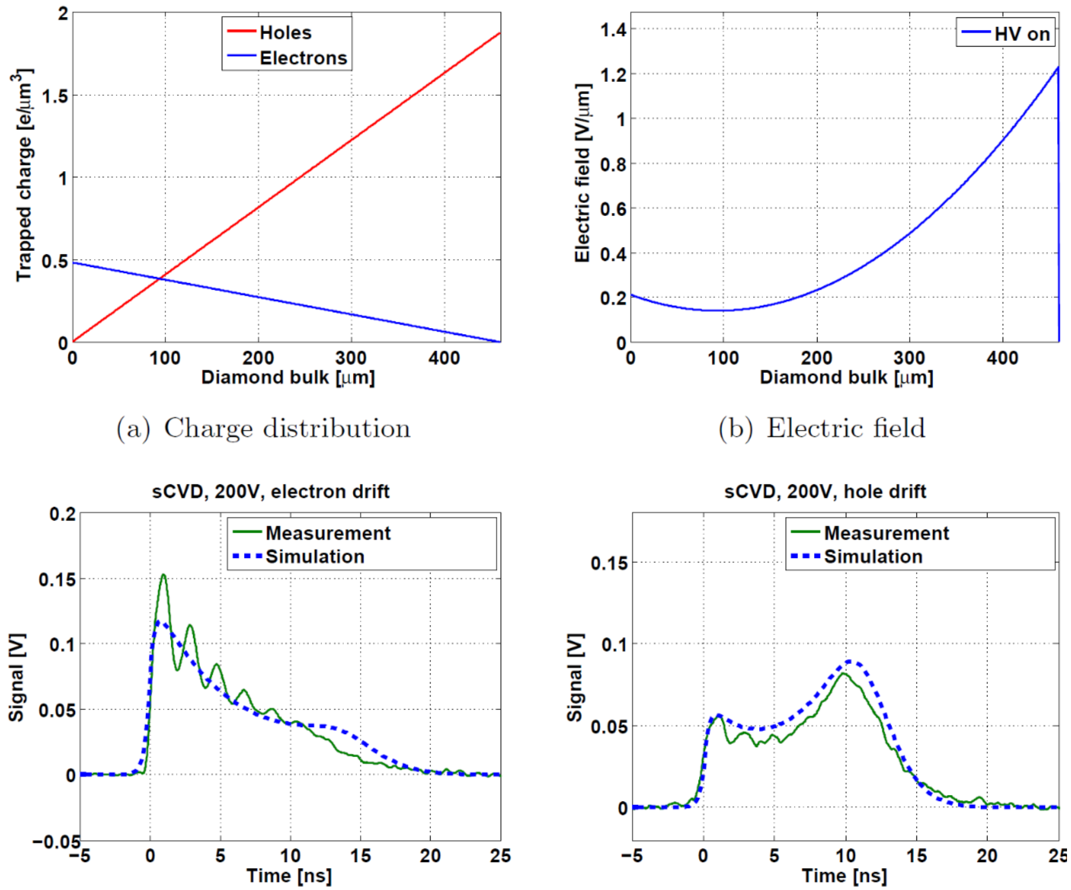

(a) Charge distribution
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courtesy of M. Guthoff

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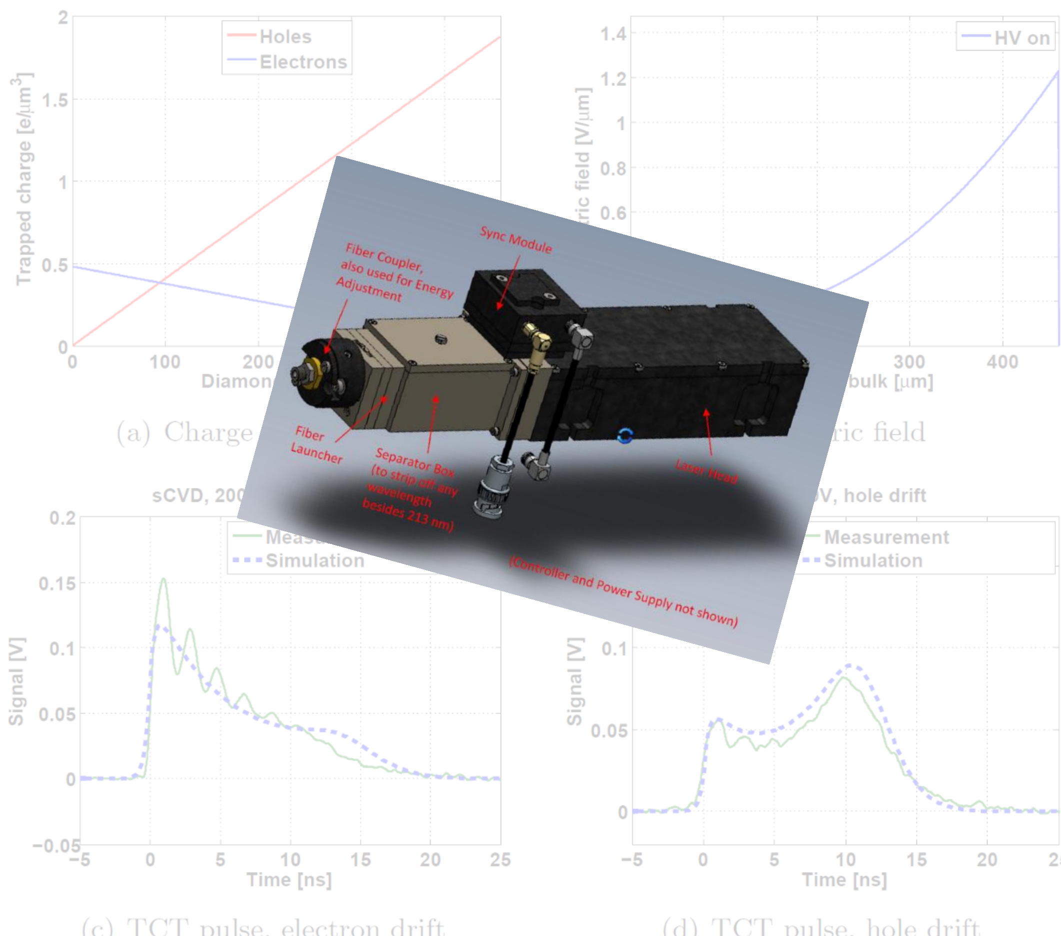

courtesy of M. Guthoff

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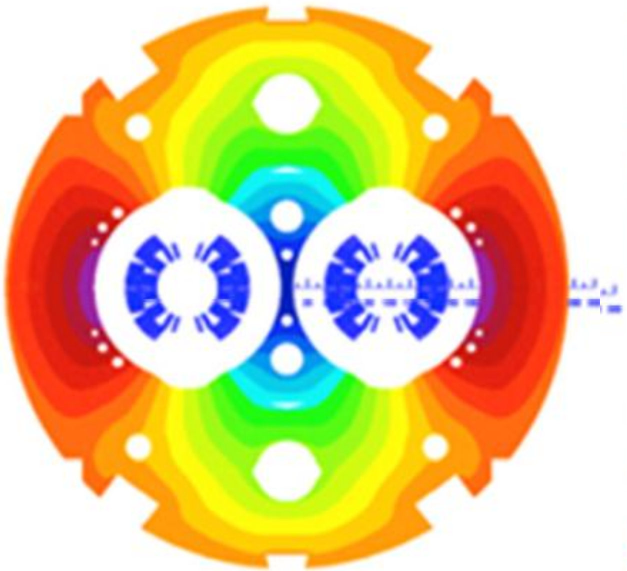
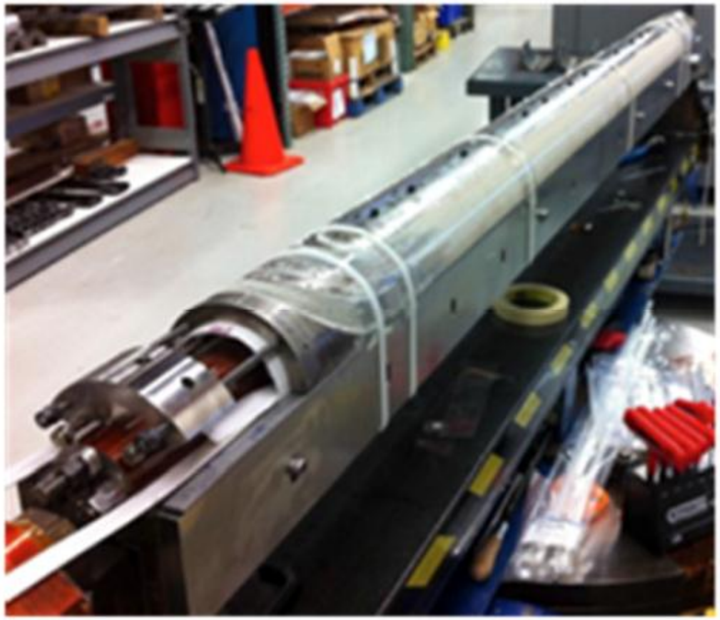
Future installations in LHC





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 to 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.

A lot of fun so far
and
a lot of exciting work to do!

Thank you!