

# Cryogenic Beam Loss Monitors for the Superconducting Magnets of the LHC

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

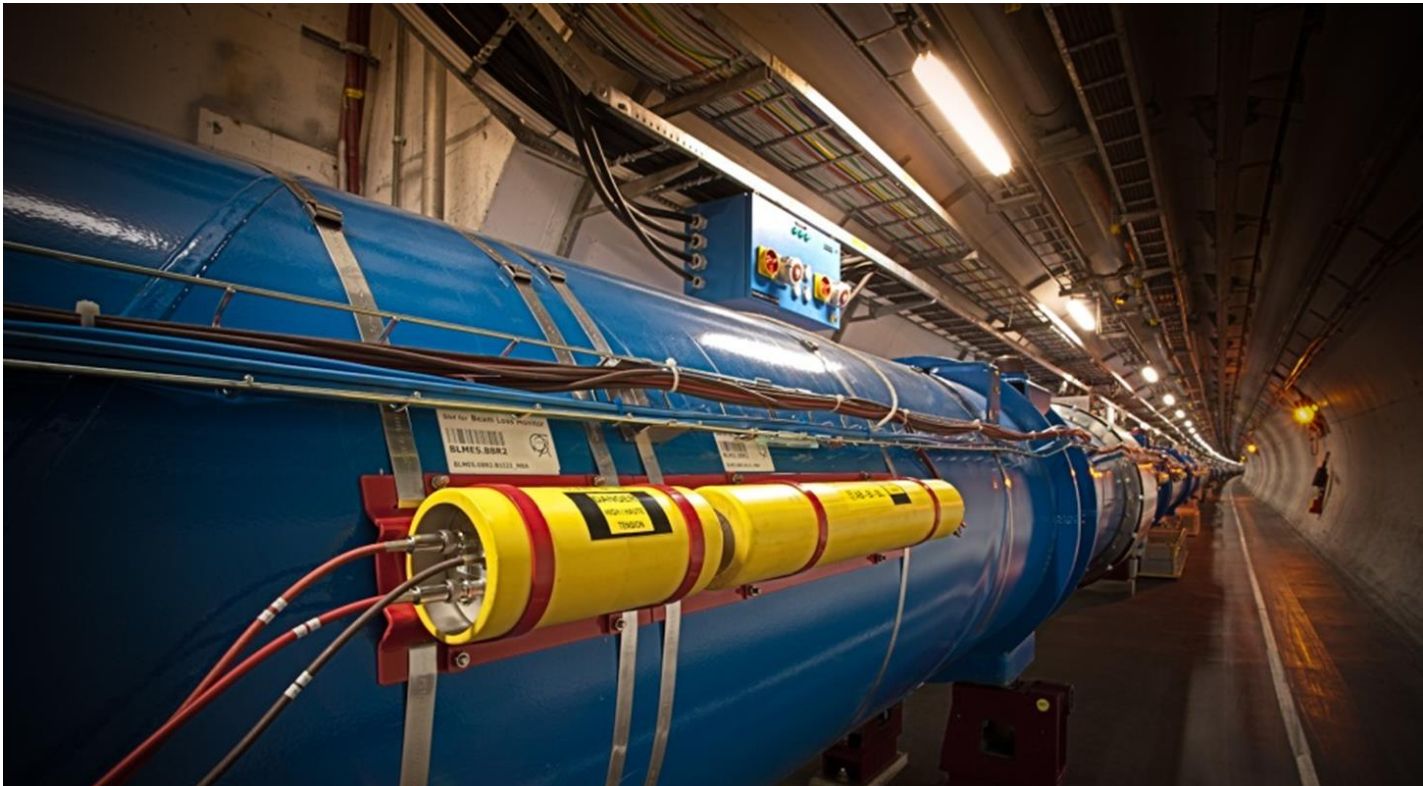
# Plan of the presentation

- **Introduction:**
  - BLM system for the LHC
  - Cryogenic BLMs for HL-LHC
- **Cryogenic BLM project up to now**
  - Irradiation tests
  - BLMs in LHC ring
- **Future**
  - Next cryogenic tests
  - Installations in LHC
- **Conclusions**

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# Beam Loss Monitoring system for the LHC

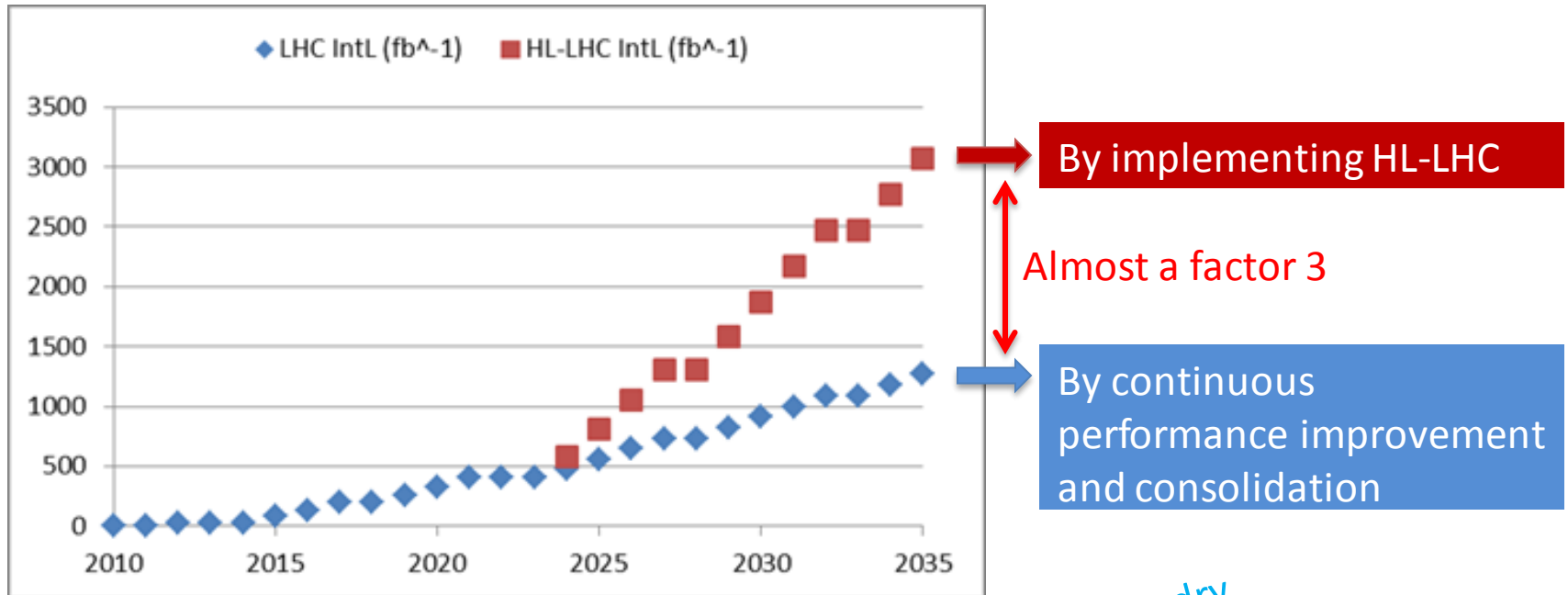


**Damage and quench protection of the sensitive superconductive elements by measurement of secondary shower particles from beam losses by Ionisation chambers, secondary emissions monitors and diamond detectors.**

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# Cryogenic BLMs for HL-LHC



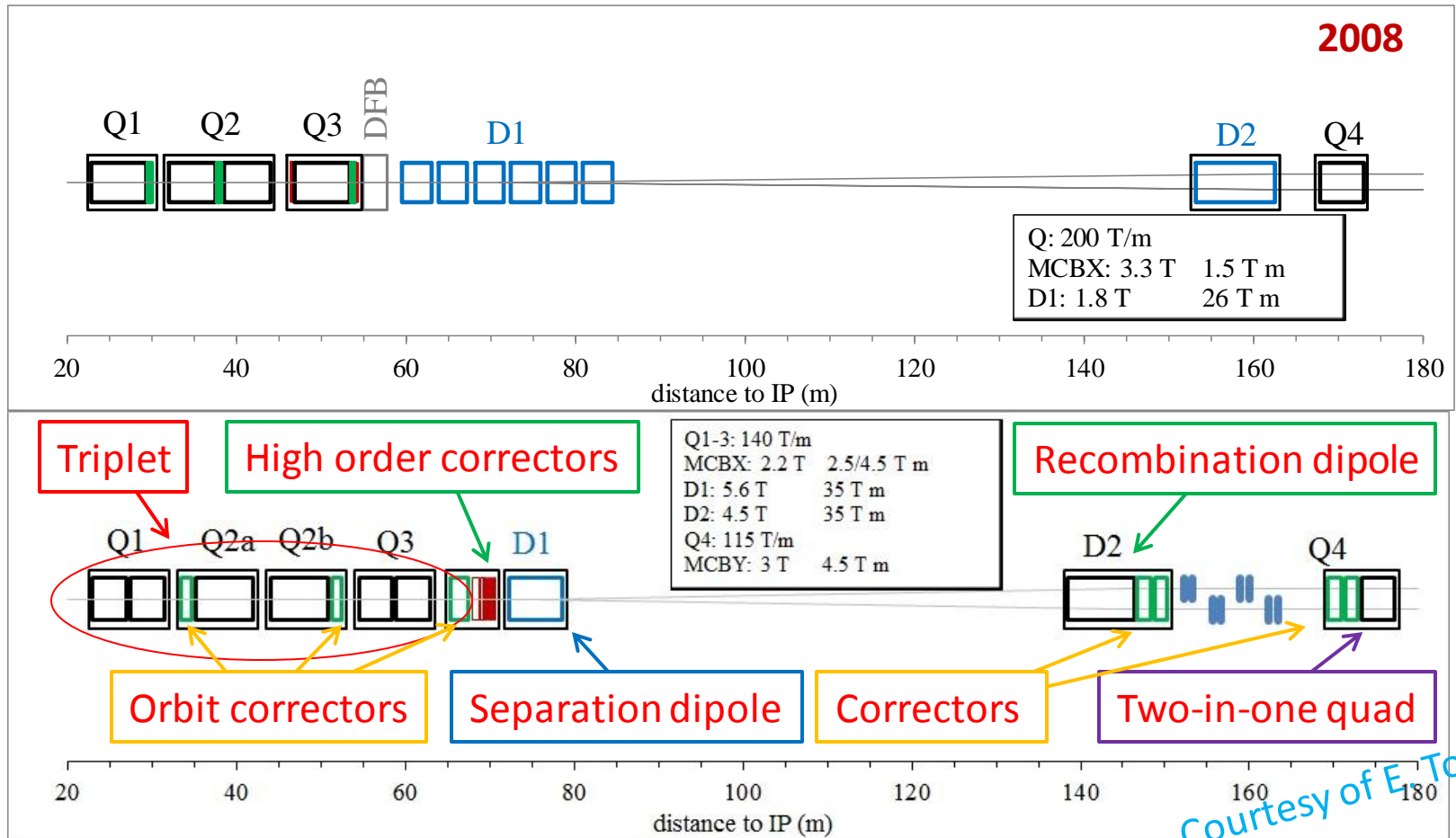
Courtesy of F. Bordry

## Goal of the HL-LHC project:

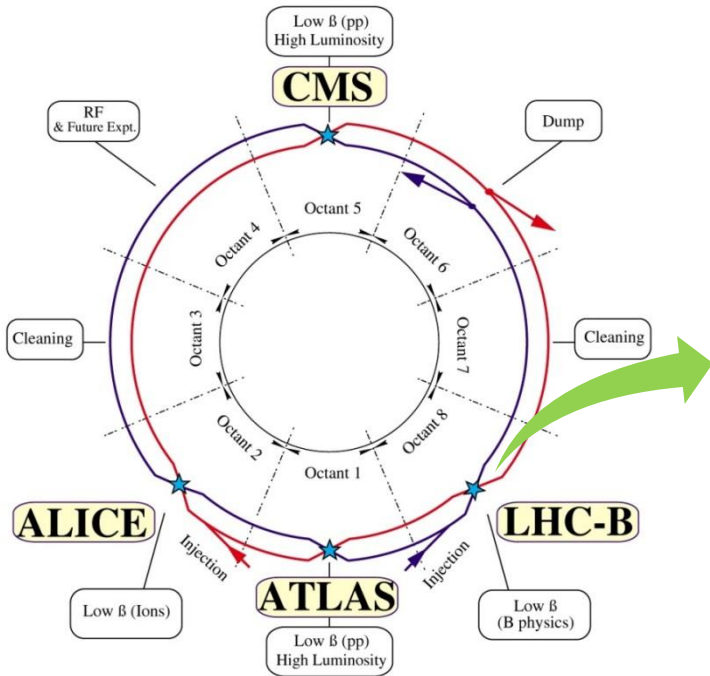
- 250 – 300  $\text{fb}^{-1}$  integrated luminosity per year
- 3000  $\text{fb}^{-1}$  integrated luminosity in about 10 years



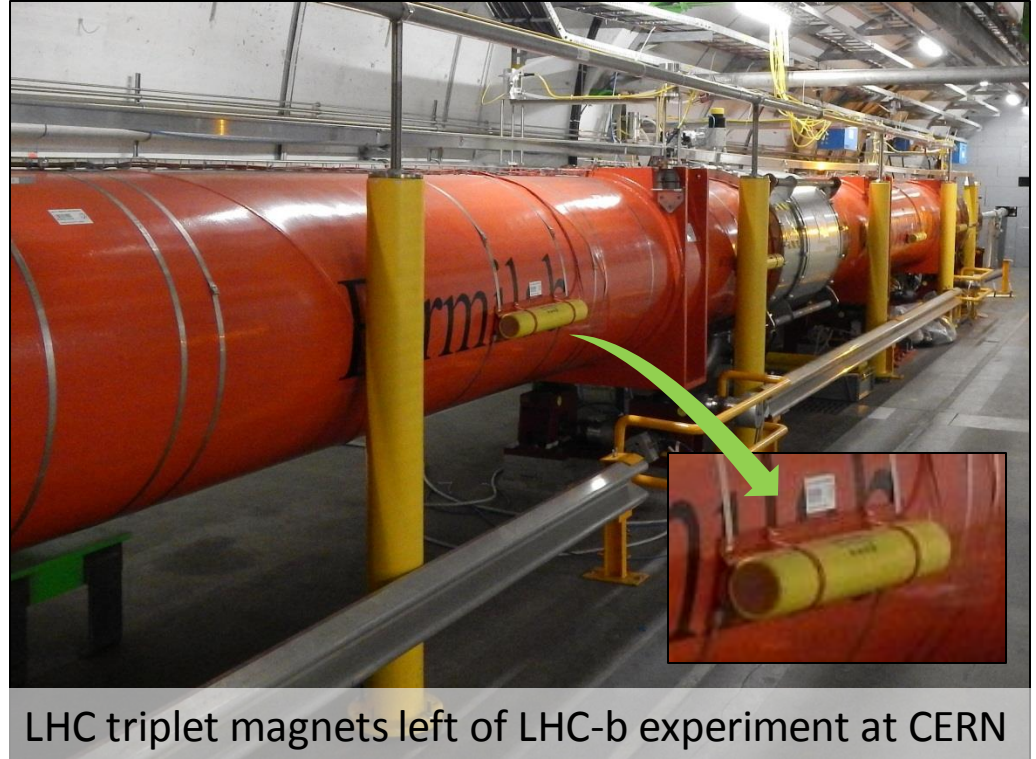
# Cryogenic BLMs for HL-LHC



# Cryogenic BLMs for HL-LHC



Overview of LHC ring with four main experiments



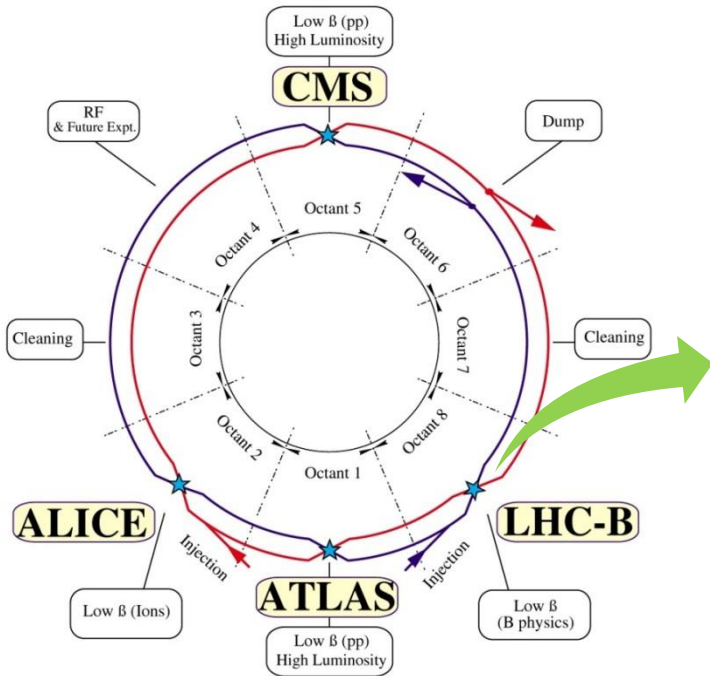
LHC triplet magnets left of LHC-b experiment at CERN

Presently: 16 ionization chambers.

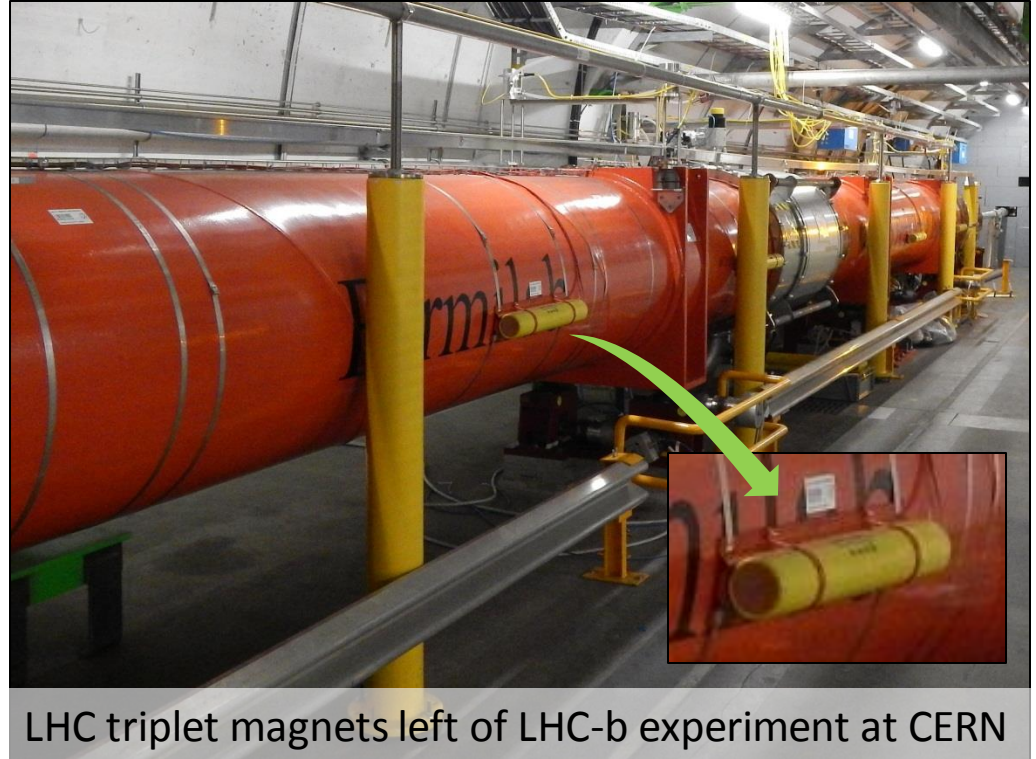
HL-LHC: about 20 ionization chambers and **20 cryogenic BLMs**.



# Cryogenic BLMs for HL-LHC



Overview of LHC ring with four main experiments



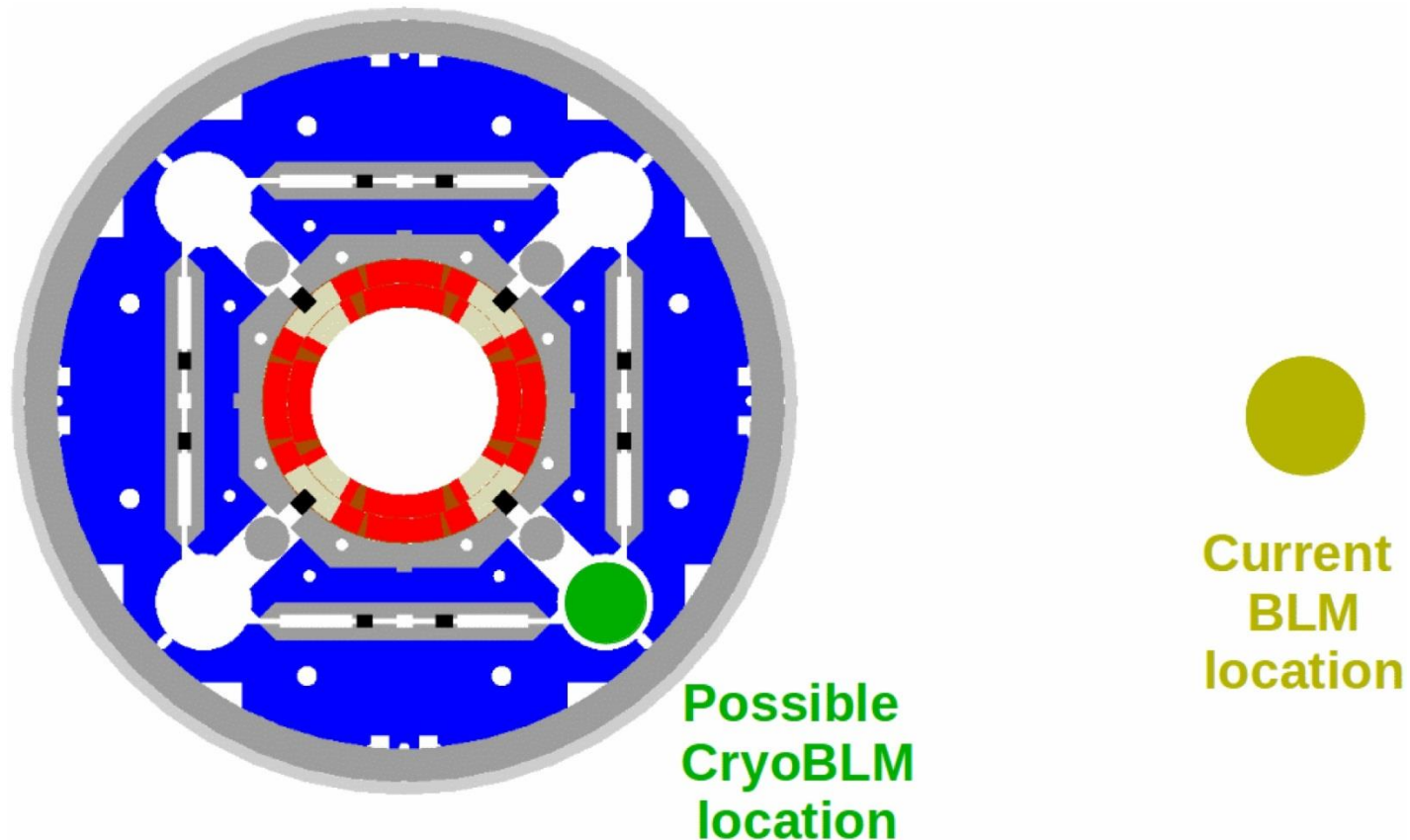
LHC triplet magnets left of LHC-b experiment at CERN

Presently: 16 ionization chambers.

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

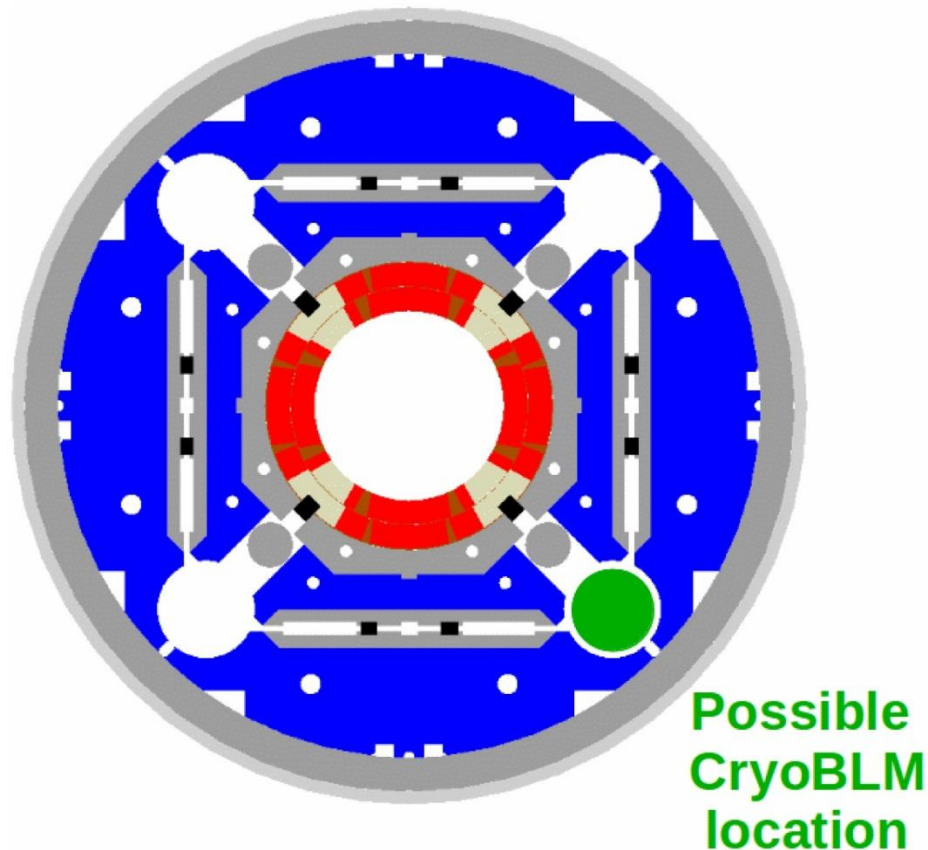


# Cryogenic BLMs for HL-LHC



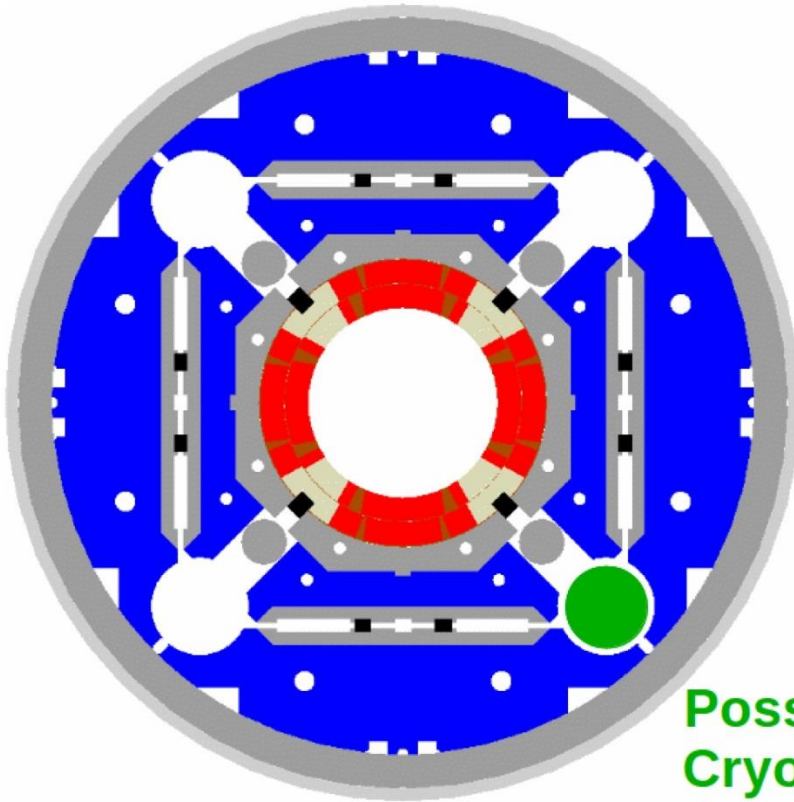
Cross section of the new triplet magnet for the HL-LHC [courtesy of Paolo Ferracin].

# Cryogenic BLMs for HL-LHC



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# Cryogenic BLMs for HL-LHC

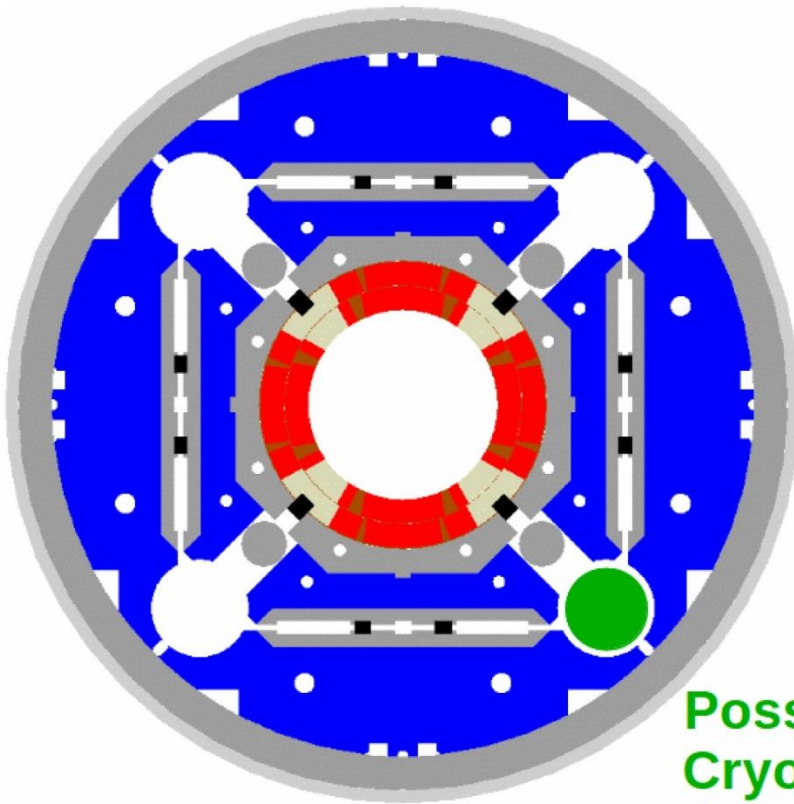


Possible  
CryoBLM  
location

The main challenges for cryogenic BLMs are:

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

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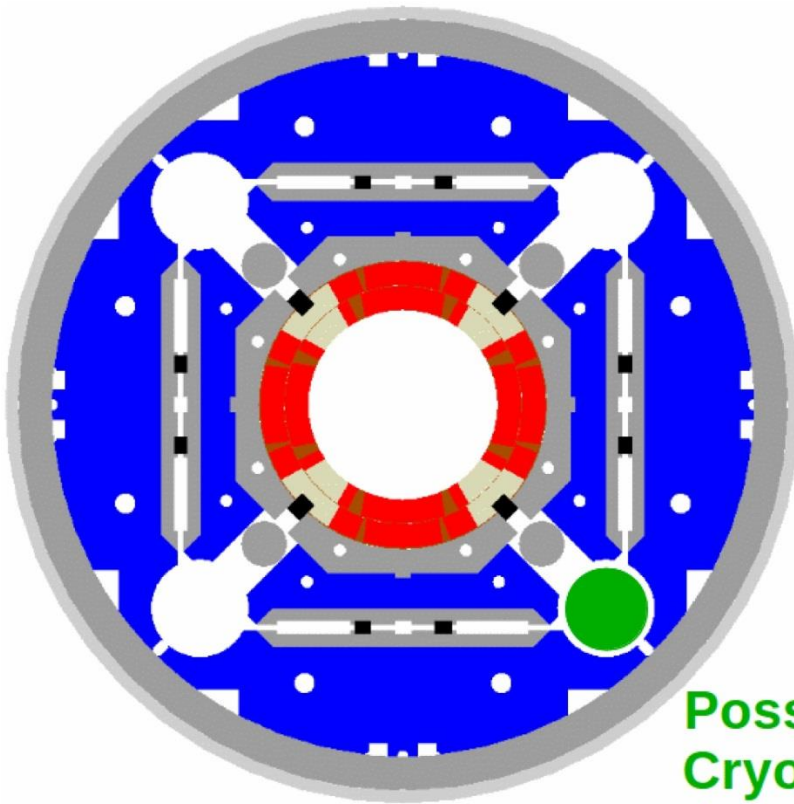


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The main challenges for cryogenic BLMs are:

- the superfluid helium environment (**1.9 K**),
- the integrated dose of about **2 MGy** in 20 years,
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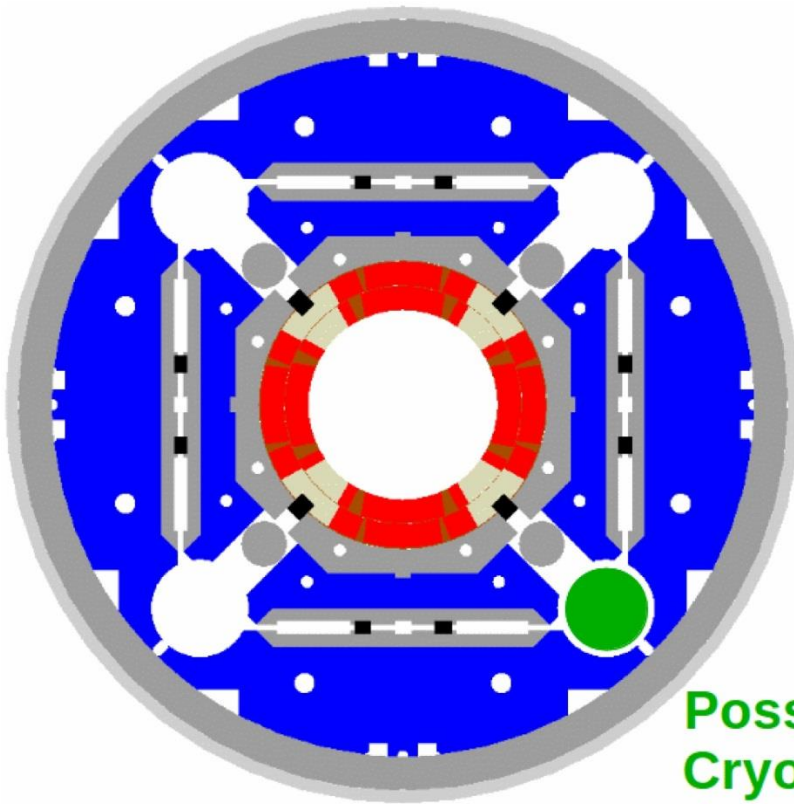


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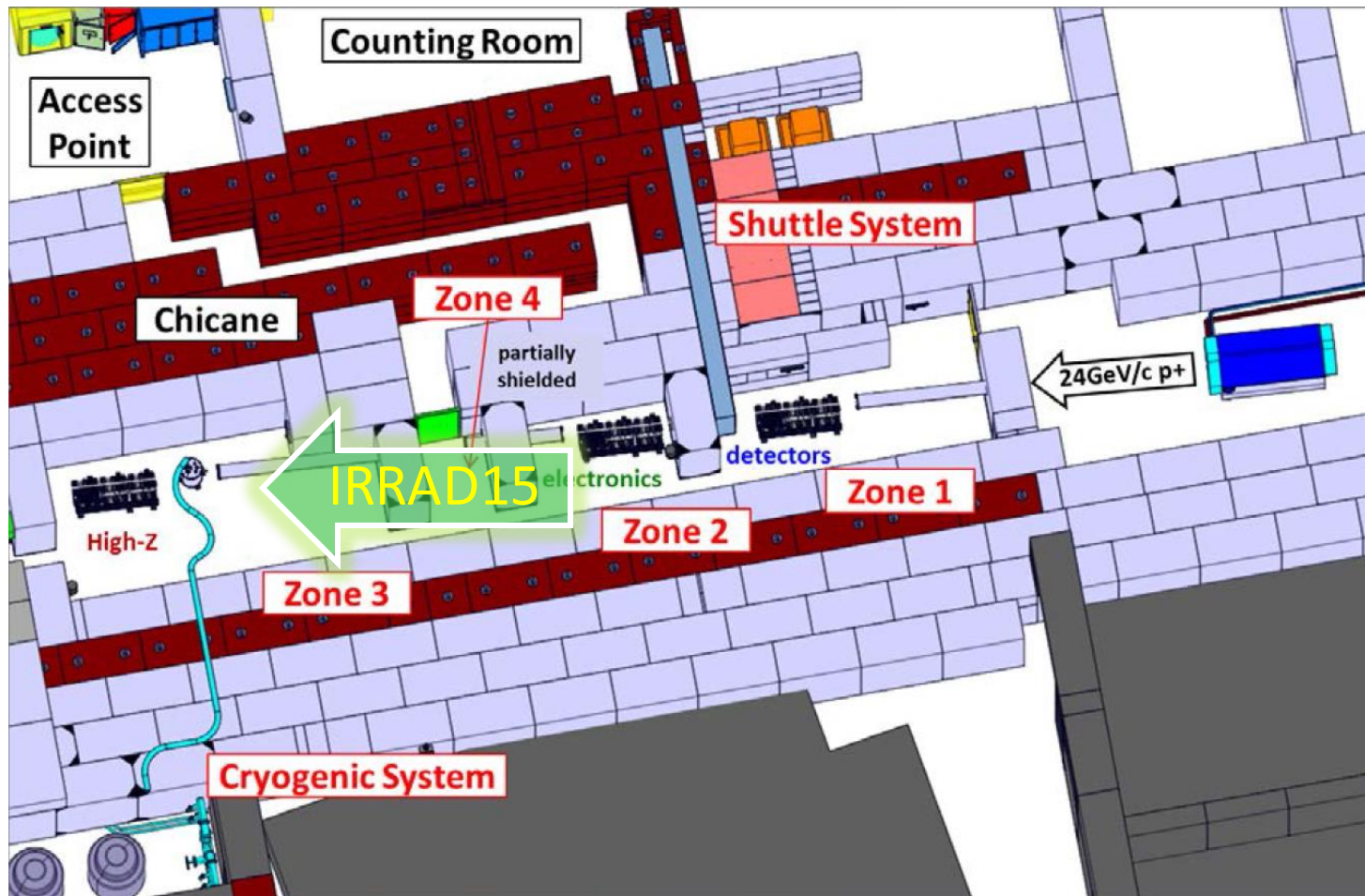
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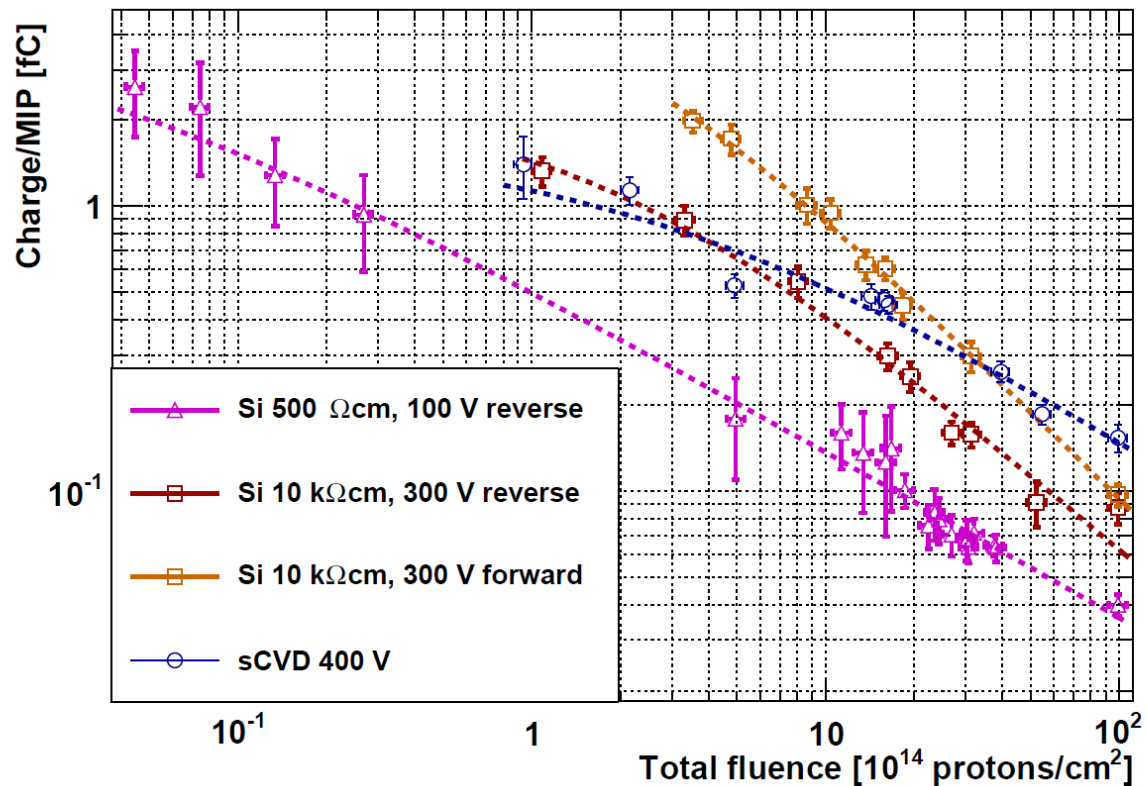
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# Cryogenic irradiation tests



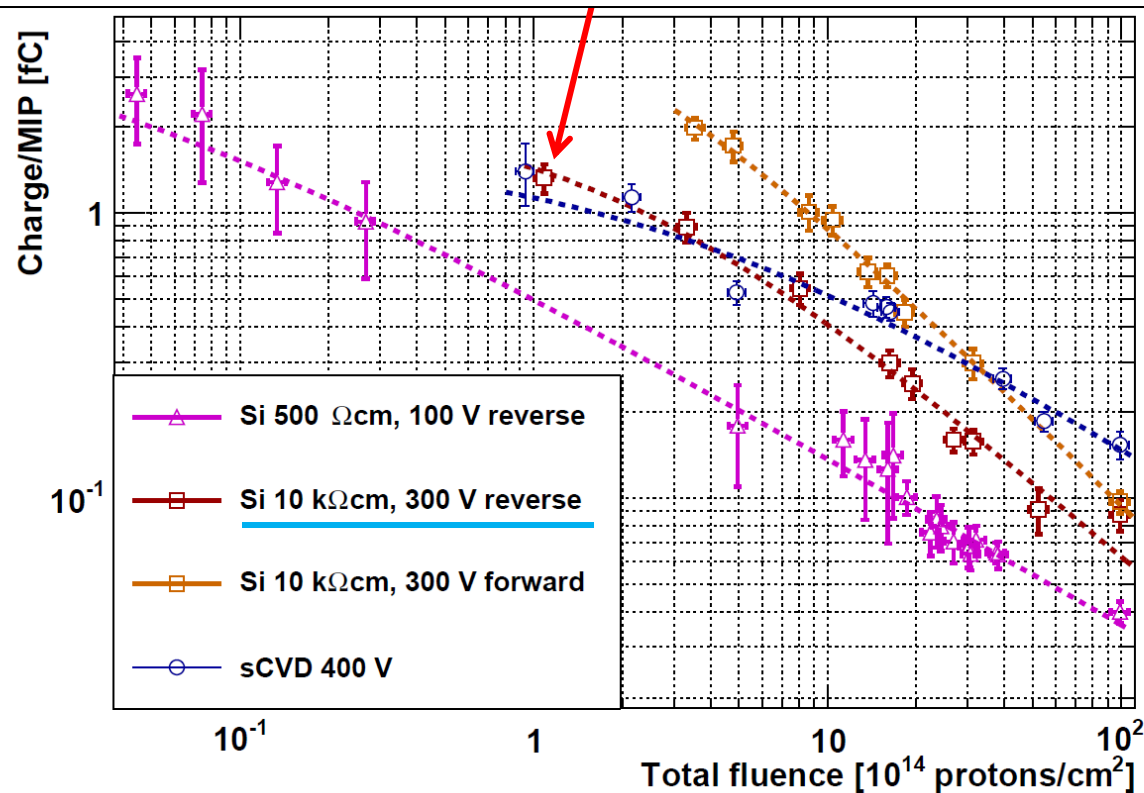
# Results of cryogenic irradiation tests



Comparison of scCVD diamond with 10 k $\Omega$ cm silicon in two modes and 500  $\Omega$ cm silicon as reference.

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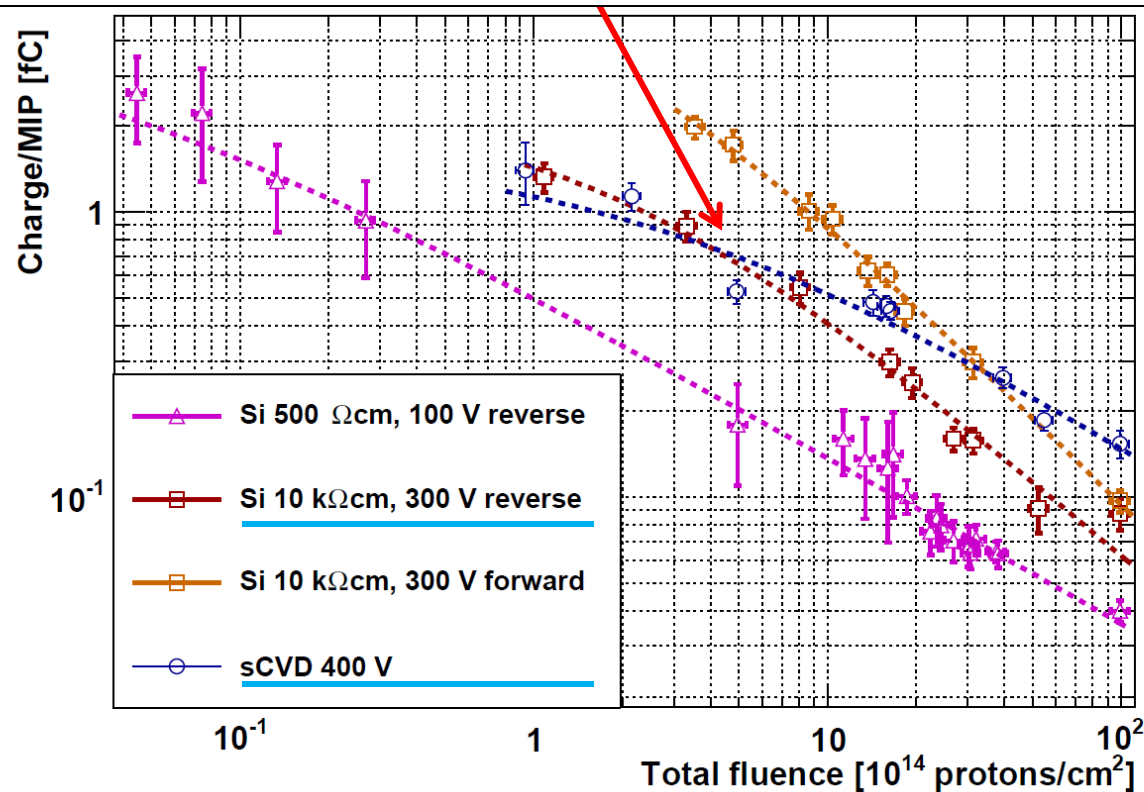
At low irradiation dose, silicon had a larger signal than the diamond detector.



Comparison of sCVD diamond with 10 k $\Omega$ cm silicon in two modes and 500  $\Omega$ cm silicon as reference.

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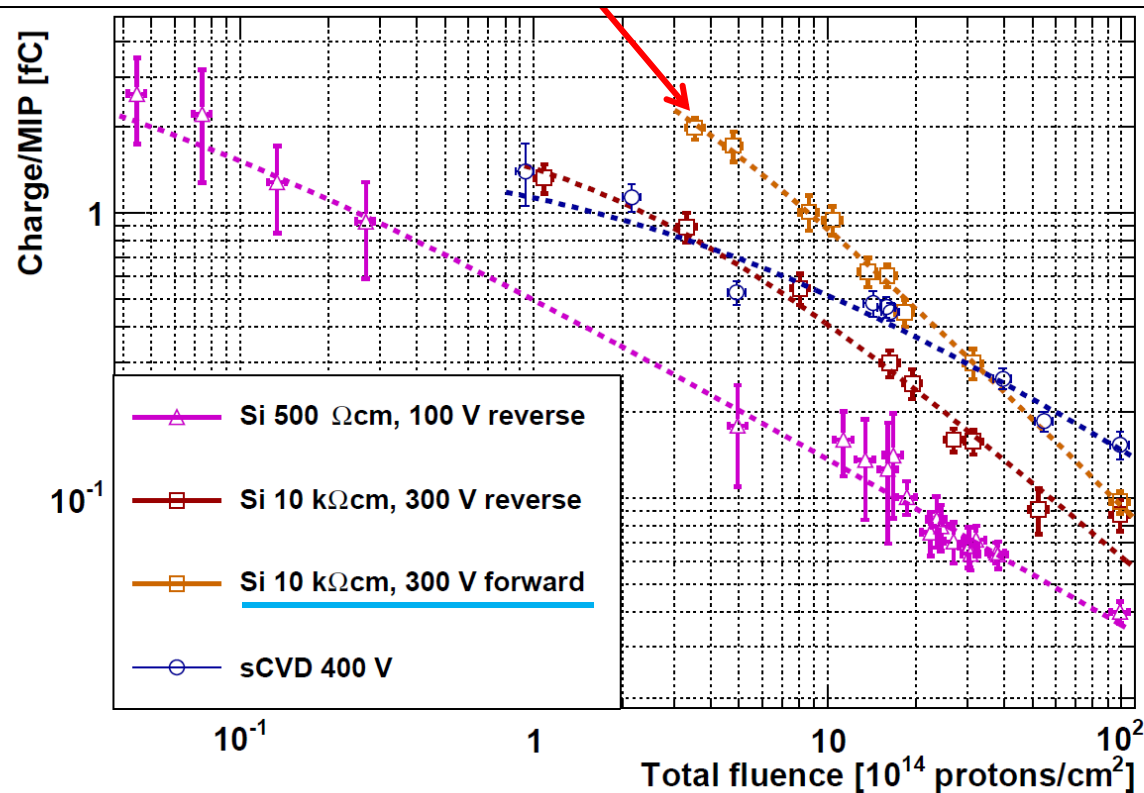
The crossing point (0.1 MGy) - diamond started to have higher signal.



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

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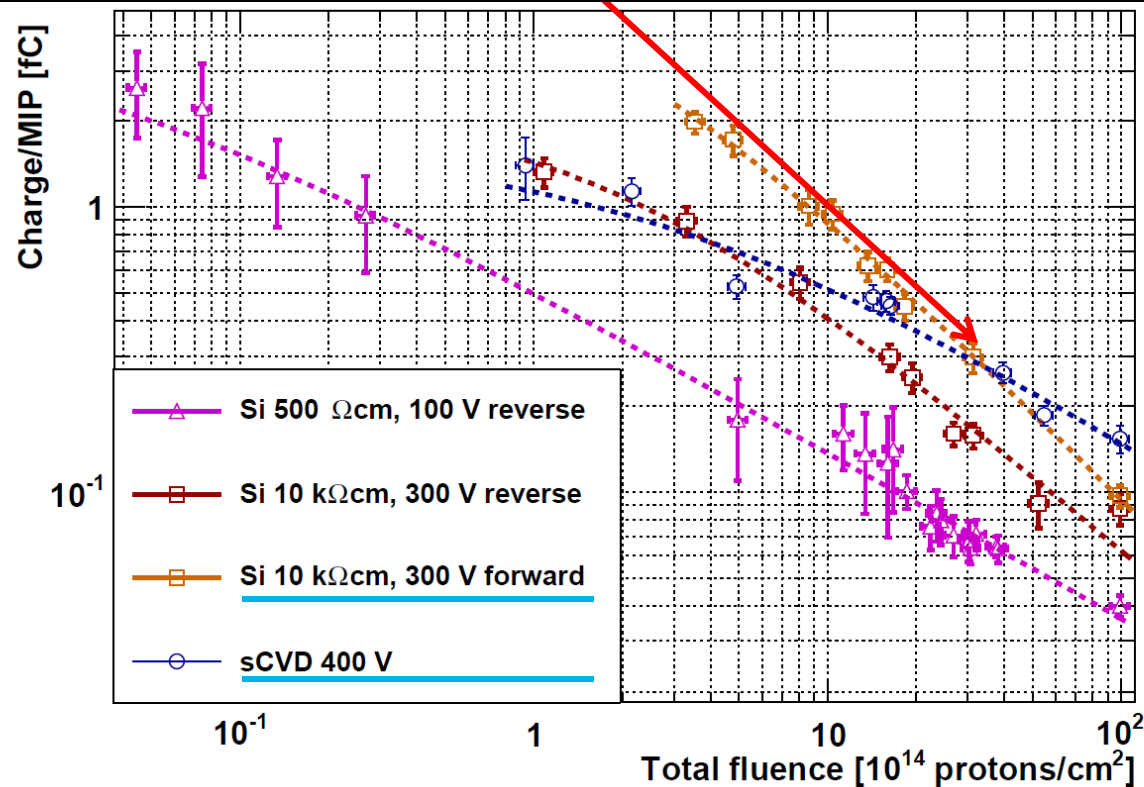
Current Injected Detector (CID) after absorption of 0.1 MGy dose.



Comparison of scCVD diamond with 10 k $\Omega$ cm silicon in two modes and 500  $\Omega$ cm silicon as reference.

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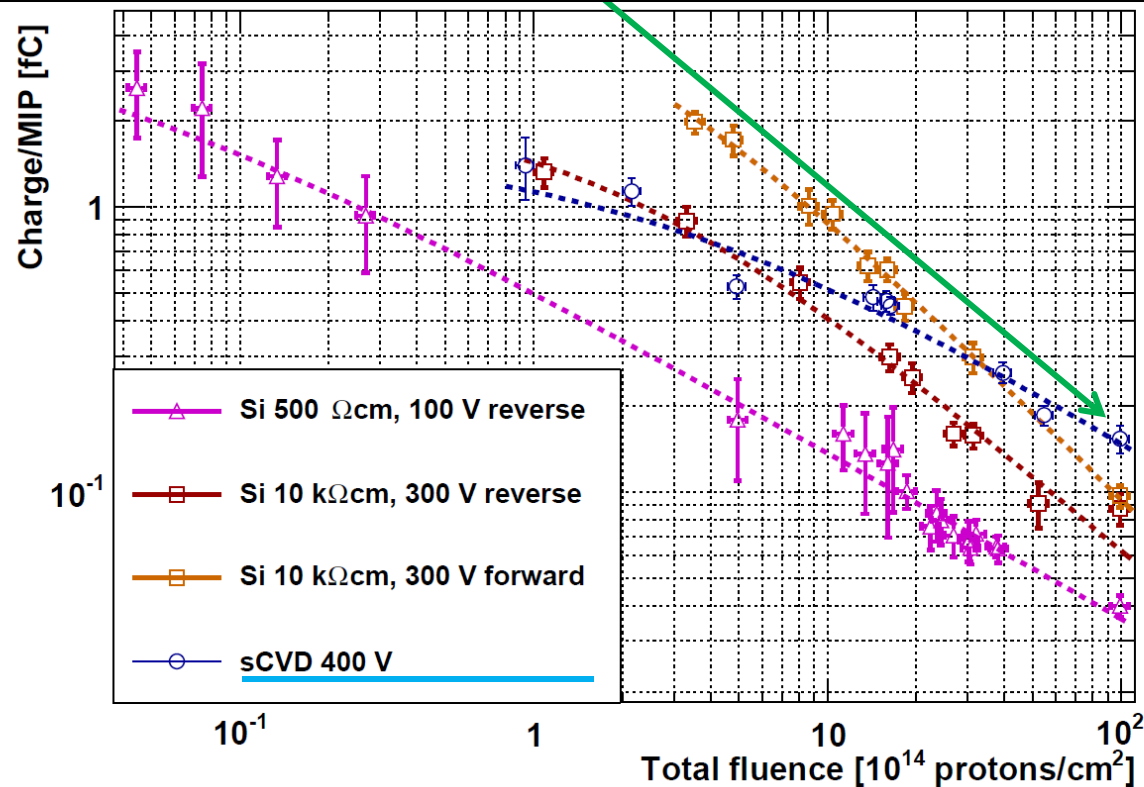
The crossing point (0.9 MGy), at which diamond and CID.



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

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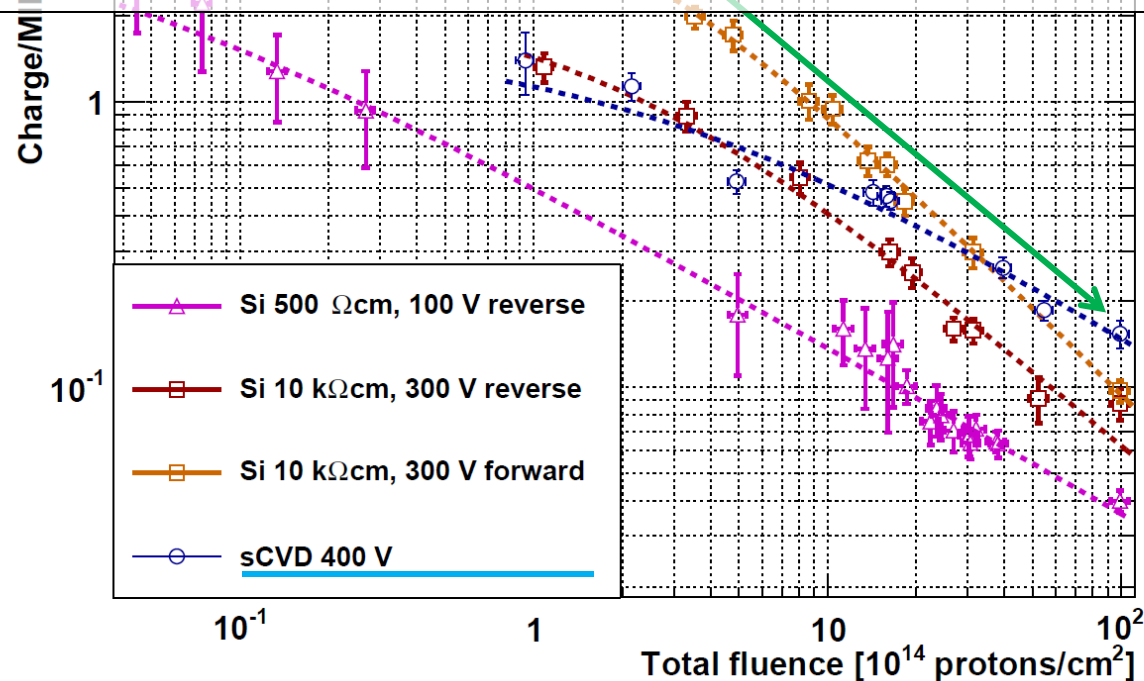
For very high radiations diamond sensors should provide the higher signal.



Comparison of sCVD diamond with 10 k $\Omega$ cm silicon in two modes and 500  $\Omega$ cm silicon as reference.

# Results of cryogenic irradiation tests

The expected reduction in detector sensitivity over **20 years (2 MGy)** of LHC operation is of a factor of  **$52 \pm 11$**  for the silicon detector under 300 V reverse bias and a factor of  **$14 \pm 3$**  for the diamond detector.

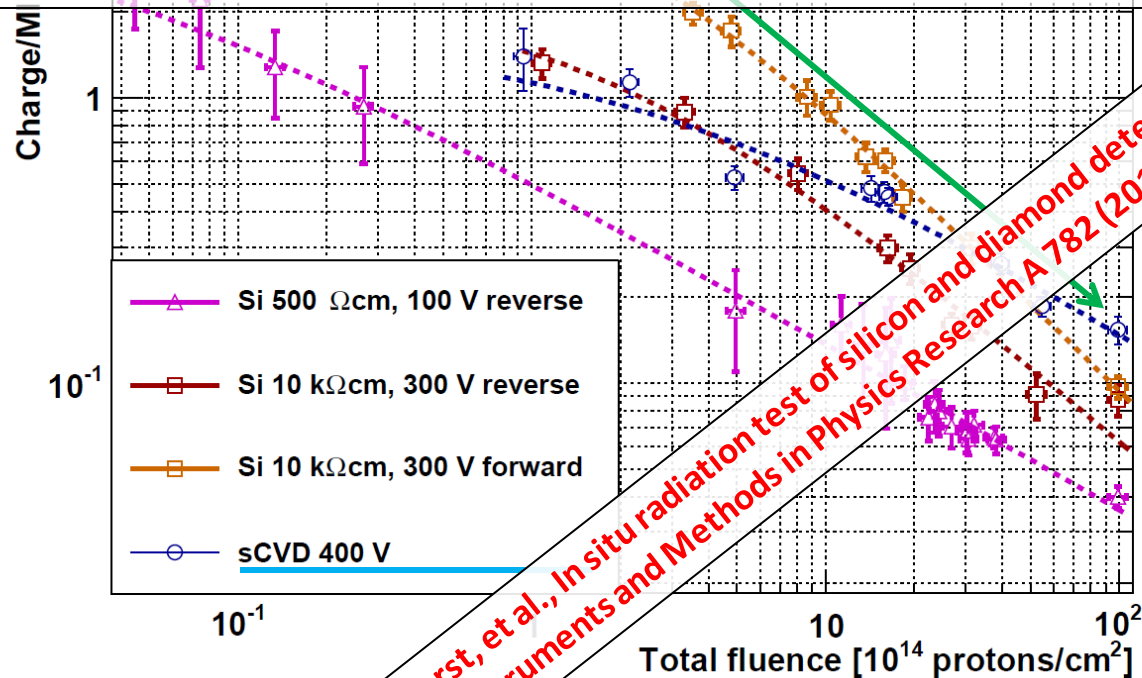


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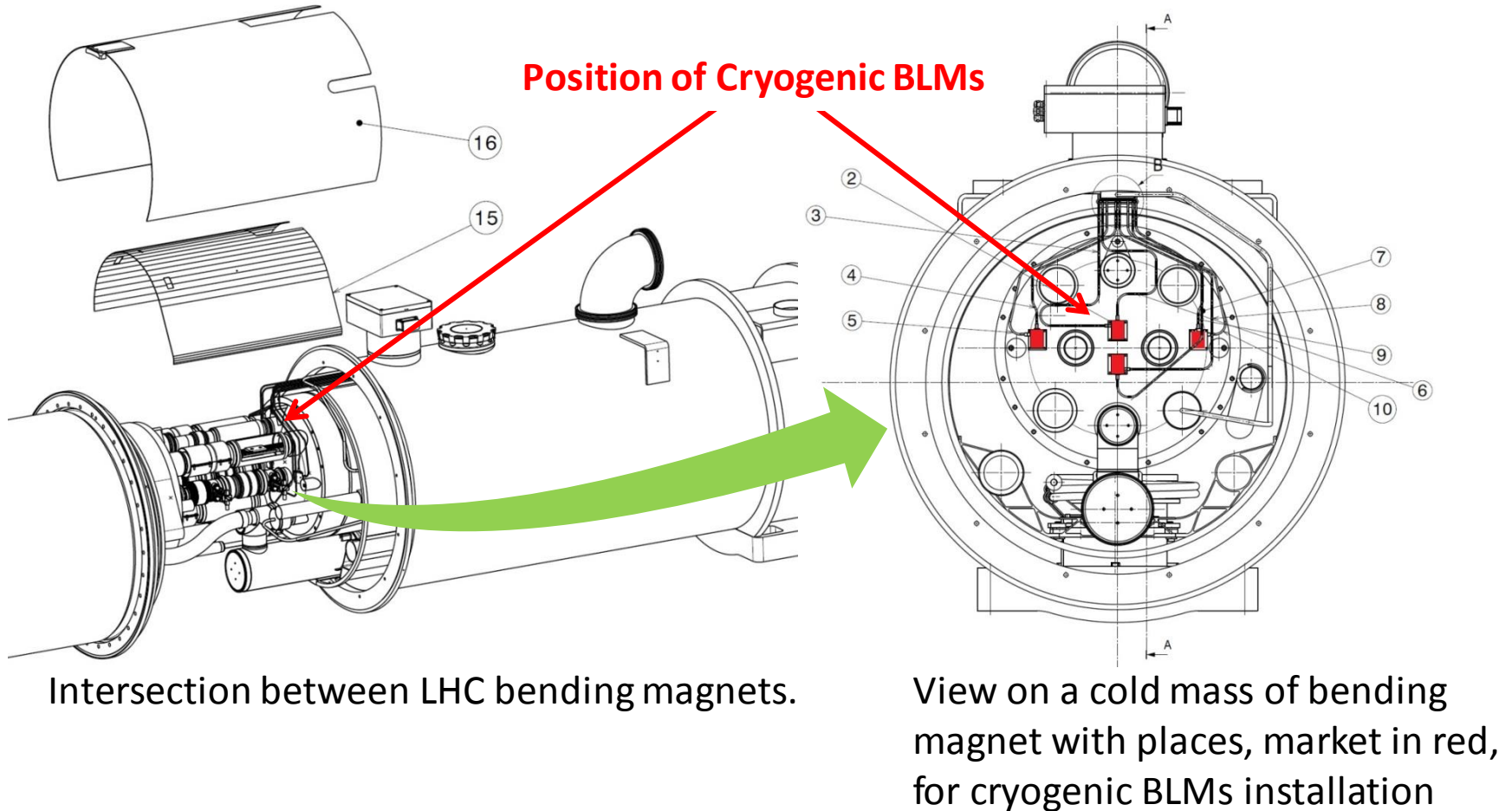


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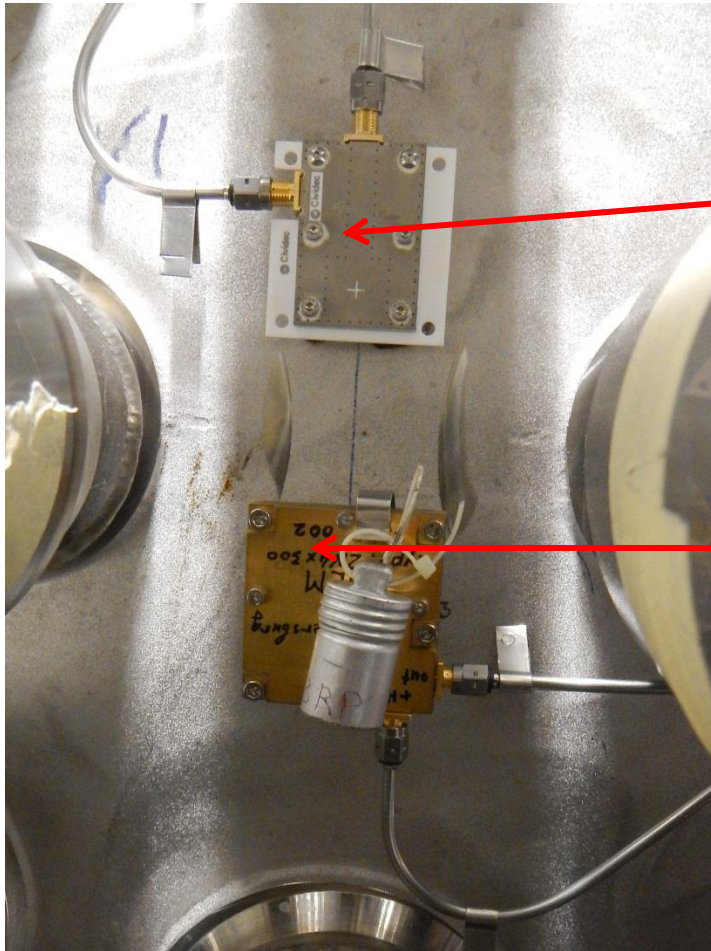
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We have installed in the LHC, for example:

**A 500µm scCVD diamond detector**

(In collaboration with Erich Griesmayer, CEO of CIVIDEC instrumentation GMBH, Vienna).

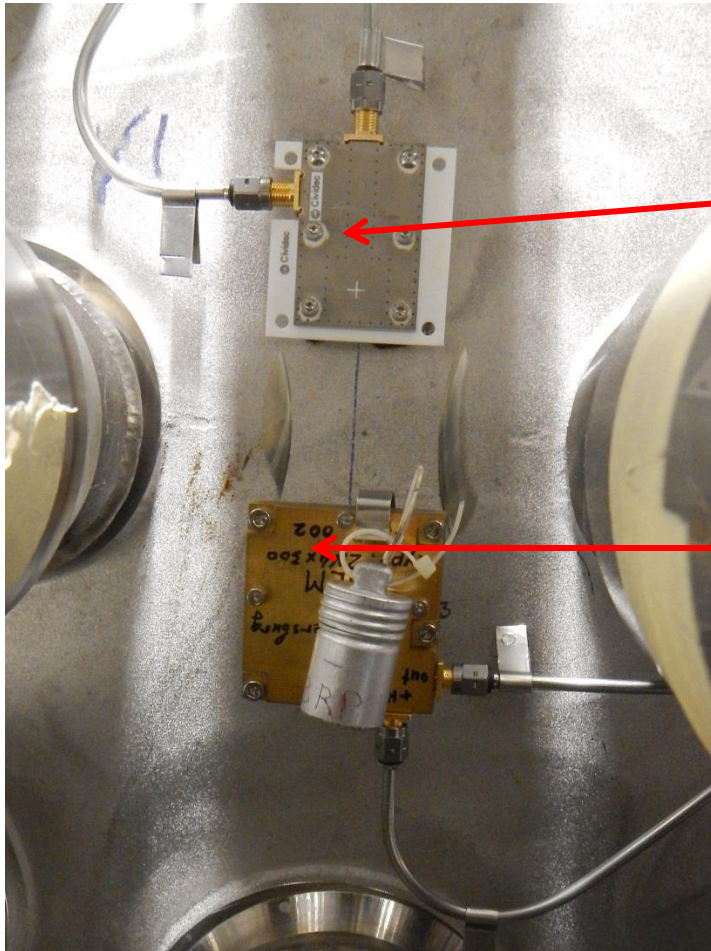


**A module with four 300µm Si detectors**

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**A module with four 300µm Si detectors**

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**M. R. Bartosik, et al., Cryogenic Beam Loss Monitors I...I, Proceedings of IBIC2014, Monterey, CA, USA, TUPD25**



# Cryogenic BLMs in LHC ring

Vistars - Internet Explorer  
 https://op-webttools.web.c...  
 LHC Page 1 Vistar

LHC Page1 Fill: 4455 E: 6500 GeV t(SB): 00:21:04 04-10-15 19:14:28

## PROTON PHYSICS: STABLE BEAMS

Energy: 6500 GeV I(B1): 1.63e+14 I(B2): 1.63e+14

FBCT Intensity and Beam Energy Updated: 19:14:28

Instantaneous Luminosity Updated: 19:14:29

BIS status and SMP flags		B1	B2
Link Status of Beam Permits		true	true
Global Beam Permit		true	true
Setup Beam		false	false
Beam Presence		true	true
Movable Devices Allowed In		true	true
Stable Beams		true	true

Comments (04-Oct-2015 19:01:59)  
 Fill with 1464 bunches (72g72 scheme)

AFS: 25ns\_1464b\_1452\_1218\_1248\_144bp12Inj\_sp PM Status B1 ENABLED PM Status B2 ENABLED

LHC BLM Fixed Display  
 File Tools Status  
 Unit: Gray/s Scale: Log Integration Time: 1.3 s Display: Acquisition

Octant Filter Sectors Filter Dump Filter List Filter Regex Filter

Filter (3986 / 3933)

Location	Type	Section	Left Right	Octant	Beam	Transverse P...	Position on EL...	Observed Ele...
<input checked="" type="checkbox"/> Q...	<input checked="" type="checkbox"/> IC	<input type="checkbox"/> LIC	<input checked="" type="checkbox"/> LSS	<input checked="" type="checkbox"/> 1	<input checked="" type="checkbox"/> Beam 1	<input checked="" type="checkbox"/> External	<input checked="" type="checkbox"/> Entrance	%
<input checked="" type="checkbox"/> B...	<input type="checkbox"/> 2...	<input type="checkbox"/> FC	<input checked="" type="checkbox"/> DS	<input checked="" type="checkbox"/> 2	<input checked="" type="checkbox"/> Beam 2	<input checked="" type="checkbox"/> Internal	<input checked="" type="checkbox"/> Center	
<input checked="" type="checkbox"/> T...	<input checked="" type="checkbox"/> M...	<input type="checkbox"/> S...	<input checked="" type="checkbox"/> ARC	<input checked="" type="checkbox"/> 3	<input checked="" type="checkbox"/> Centre	<input checked="" type="checkbox"/> Top	<input checked="" type="checkbox"/> Exit	
<input checked="" type="checkbox"/> O...	<input type="checkbox"/> DL...			<input checked="" type="checkbox"/> 4		<input checked="" type="checkbox"/> Bottom		
			<input checked="" type="checkbox"/> Left	<input checked="" type="checkbox"/> 5				
			<input checked="" type="checkbox"/> Right	<input checked="" type="checkbox"/> 6				
				<input checked="" type="checkbox"/> 7				
				<input checked="" type="checkbox"/> 8				

Total Losses: 0.1767 [Gray/s] 04.10.2015 19:14:36

Status	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
Ok	Warning	Ok	Ok	Ok	Warning	Ok	Ok	Ok

Monitors

Show Labels  Display Optics Elements  Use DCUM

Start Stop Save Continuous Saving

19:14:36 - Warning on: BLMQI.02L8.B2I30\_MQXB, integration time: 83.8 s, losses = 1.370141E-05, threshold = 4.511208E-05, ratio = 30%

EN 7:14 PM 10/4/2015

# Cryogenic BLMs in LHC ring

Vistars - Internet Explorer  
 https://op-webttools.web.c...  
 LHC Page 1 Vistar

LHC Page1 Fill: 4455 E: 6500 GeV t(SB): 00:19:26 04-10-15 19:12:51

**PROTON PHYSICS: STABLE BEAMS**

Energy: 6500 GeV I(B1): 1.63e+14 I(B2): 1.64e+14

FBCT Intensity and Beam Energy Updated: 19:12:50

Instantaneous Luminosity Updated: 19:12:50

BIS status and SMP flags		B1	B2
Link Status of Beam Permits		true	true
Global Beam Permit		true	true
Setup Beam		false	false
Beam Presence		true	true
Movable Devices Allowed In		true	true
Stable Beams		true	true

Comments (04-Oct-2015 19:01:59)  
 Fill with 1464 bunches (72g72 scheme)

AFS: 25ns\_1464b\_1452\_1218\_1248\_144bp12Inj\_sp PM Status B1: **ENABLED** PM Status B2: **ENABLED**

LHC BLM Fixed Display  
 File Tools Status  
 Unit: Gray/s Scale: Log Integration Time: 1.3 s Display: Acquisition

Filter (4 / 3933)  
 Regular Expression: BLM%  
 Total Losses: -3.052E03 [Gray/s] 04.10.2015 19:12:56

Status	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
	Ok	Warning	Ok	Ok	Ok	Warning	Ok	Ok

Sector 5-6

Monitors

Show Labels Display Optics Elements Use DCUM

Start Stop Save Continuous Saving

Warning on: BLMQI.02L8.B2I30\_MQXB, integration time: 83.8 s, losses = 1.360276E-05, threshold = 4.511208E-05, ratio = 30%

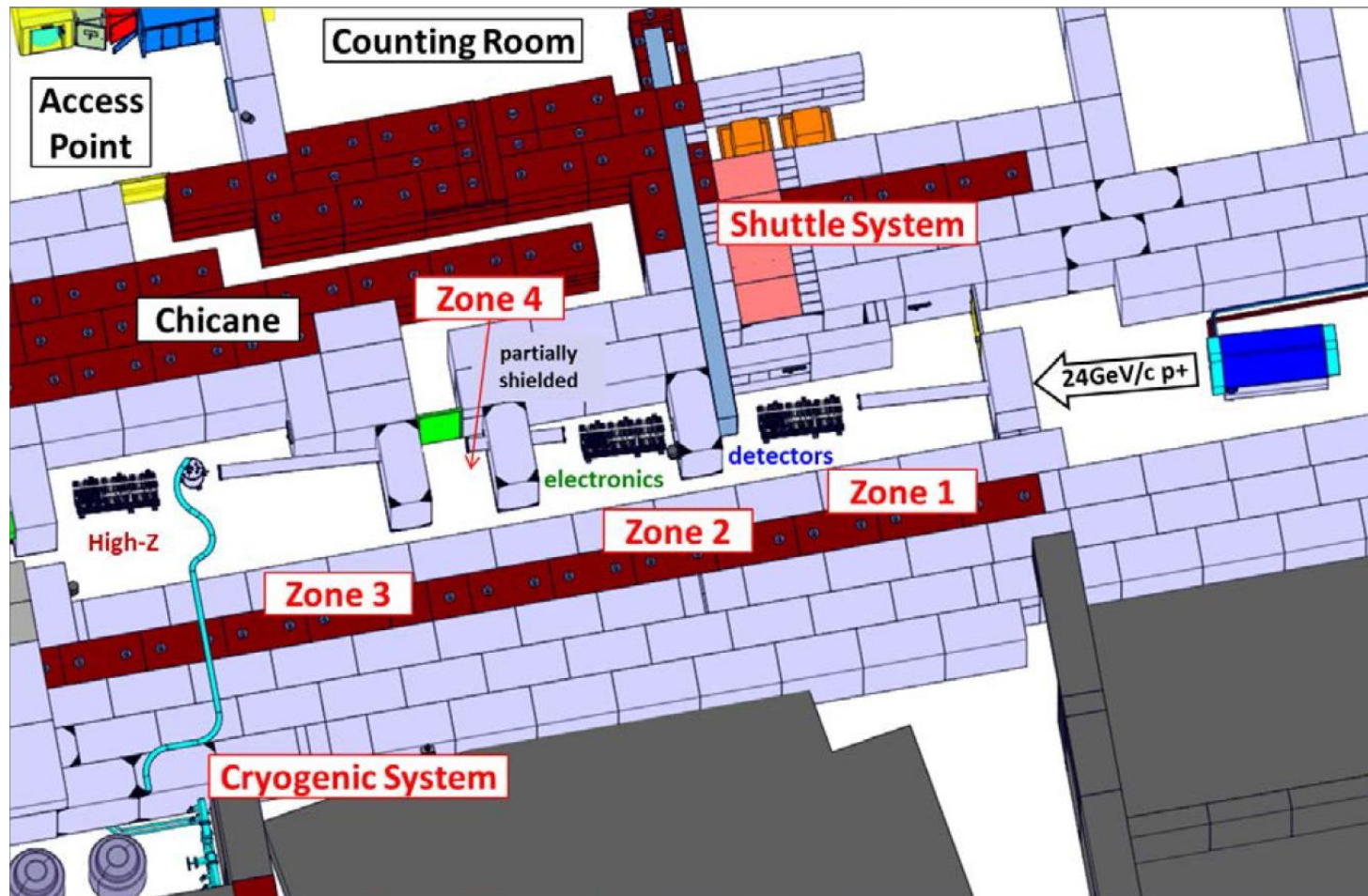
EN 7:12 PM 10/4/2015

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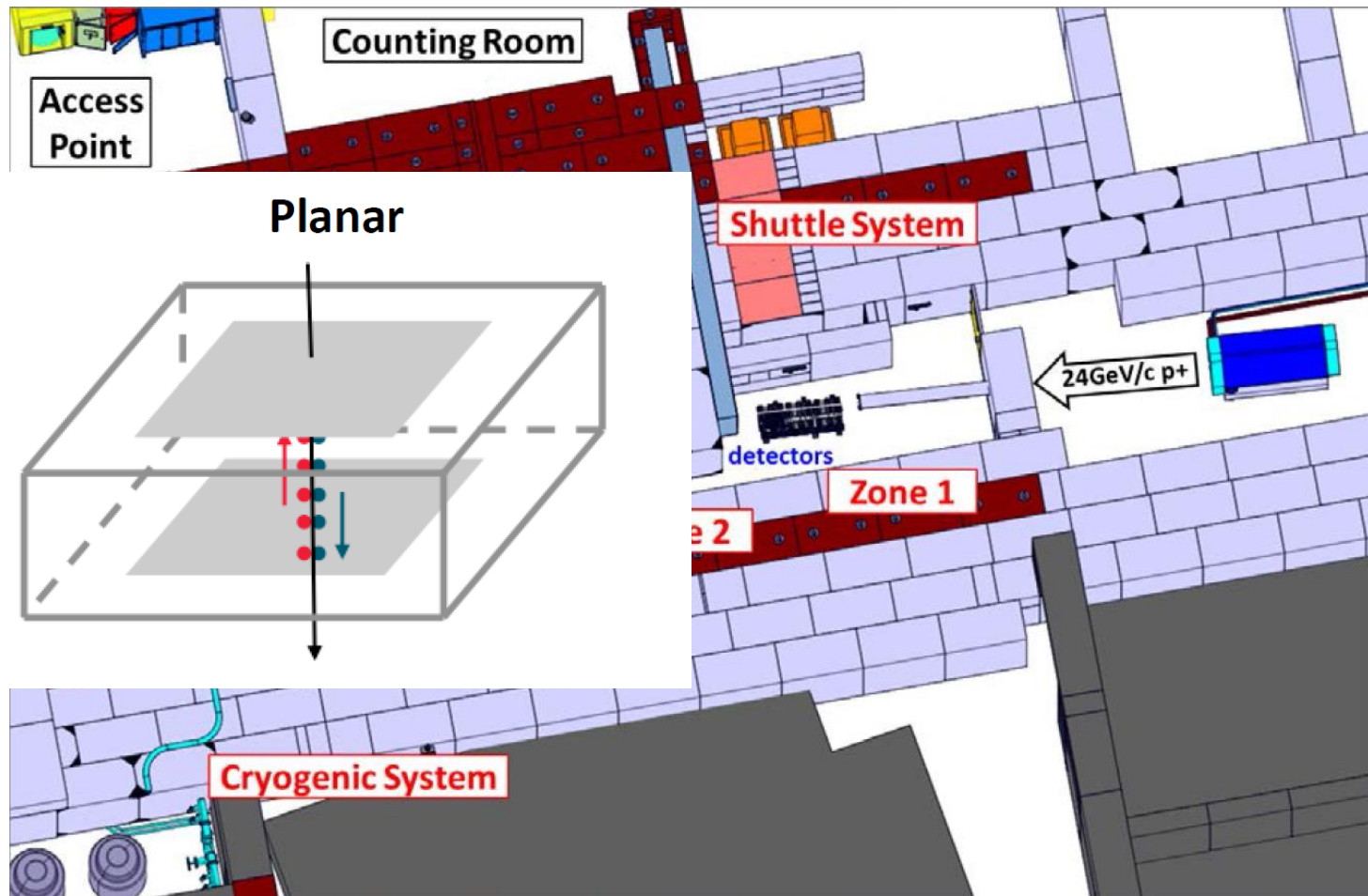
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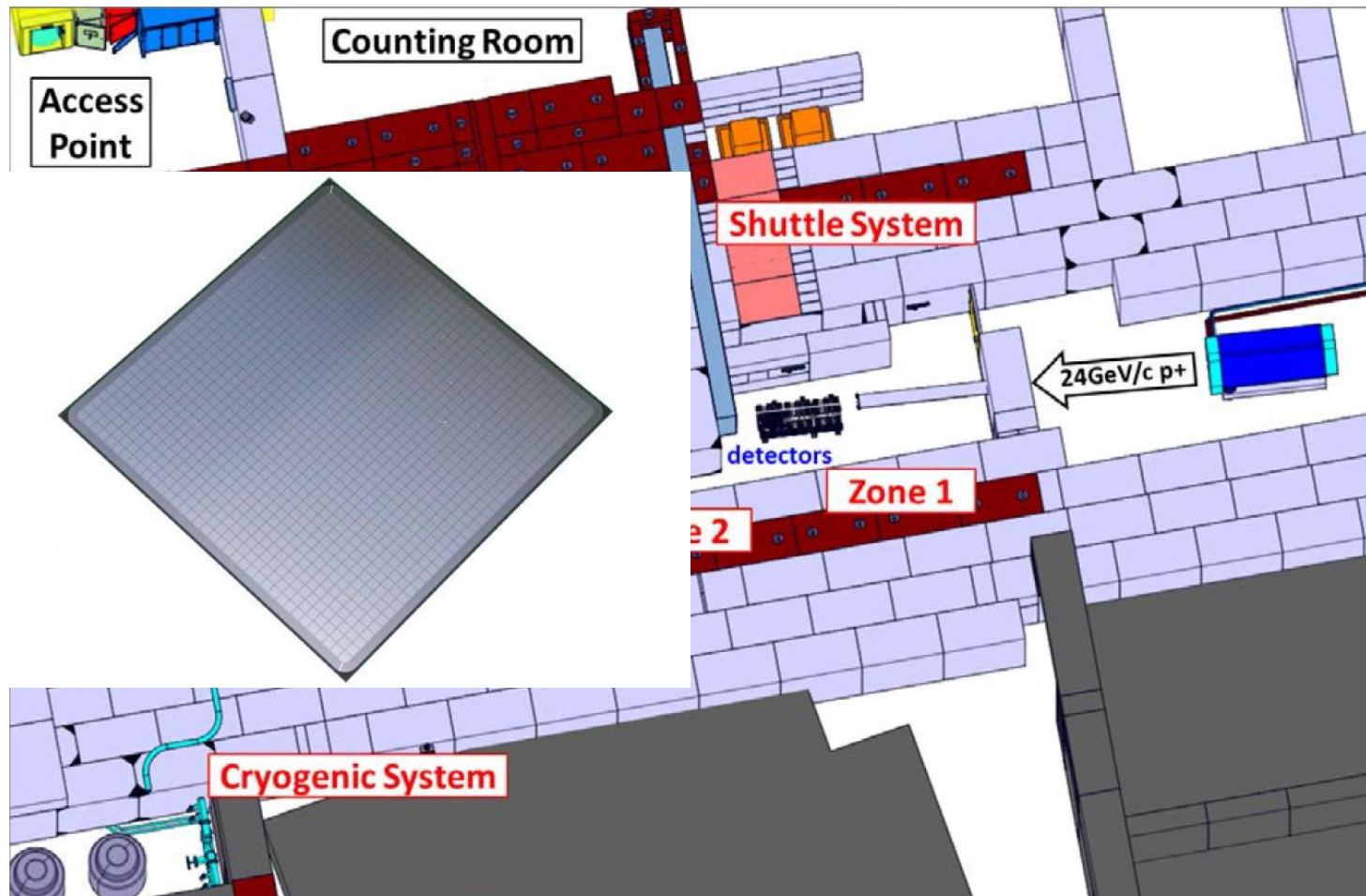
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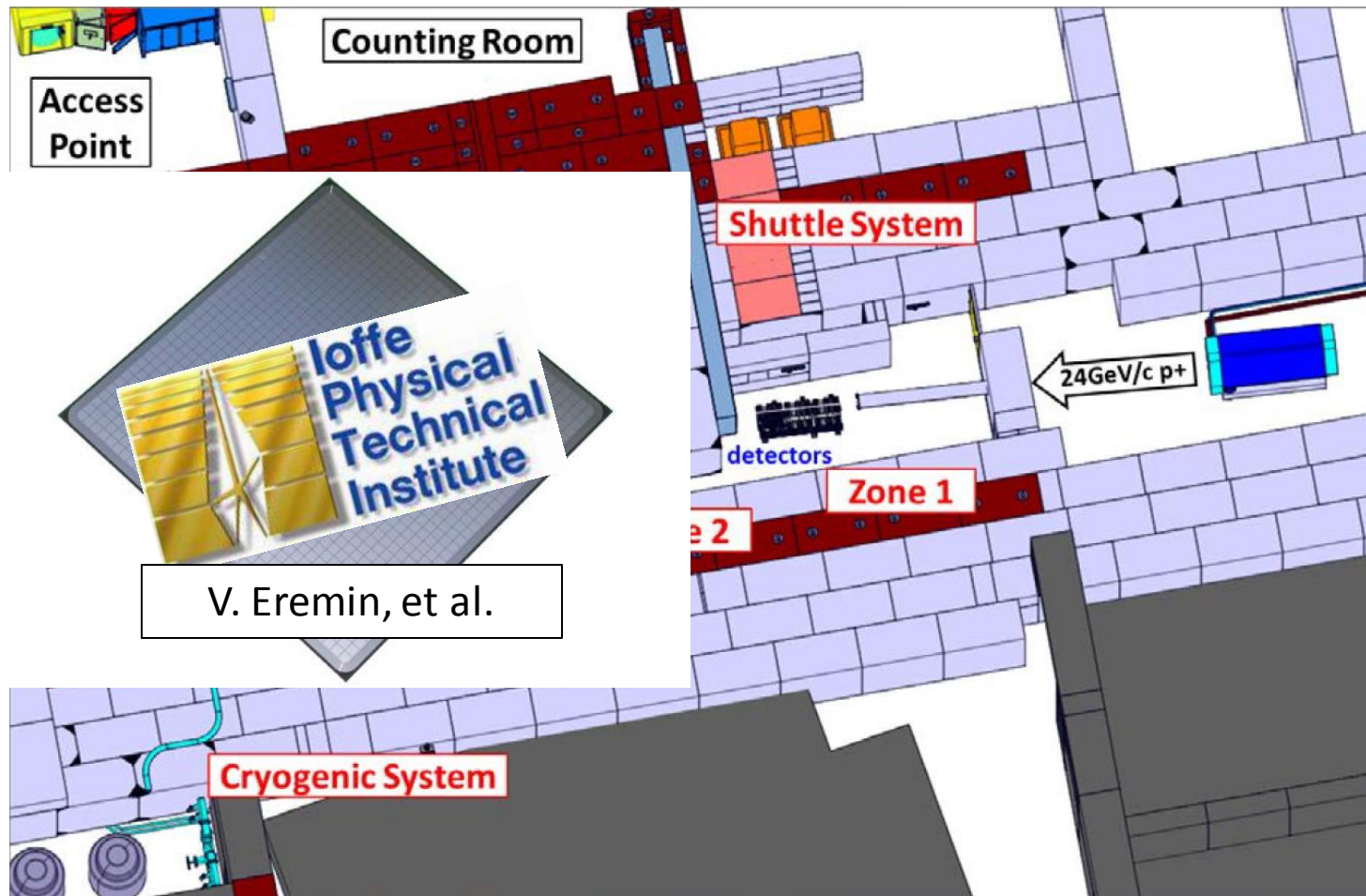
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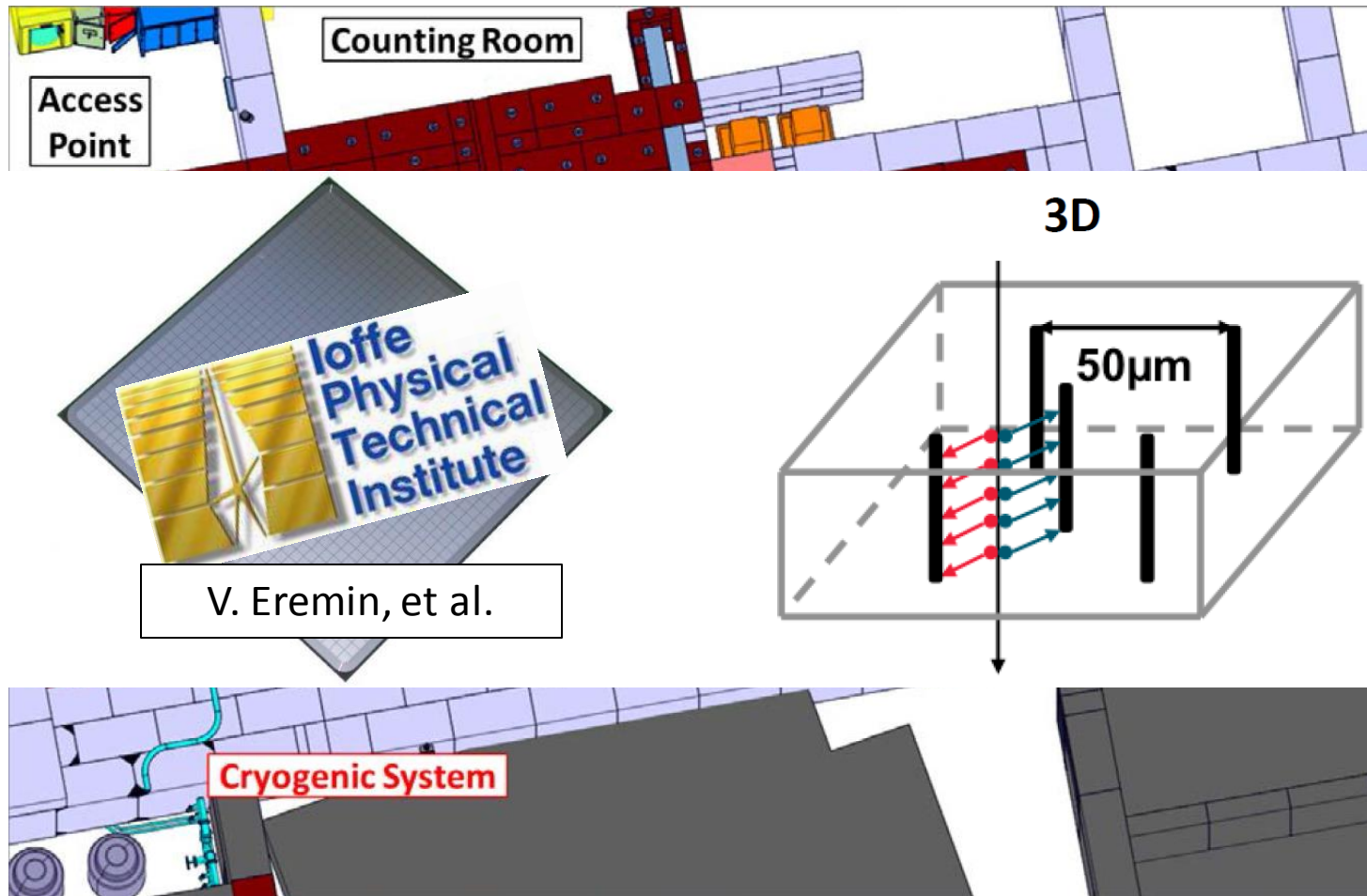
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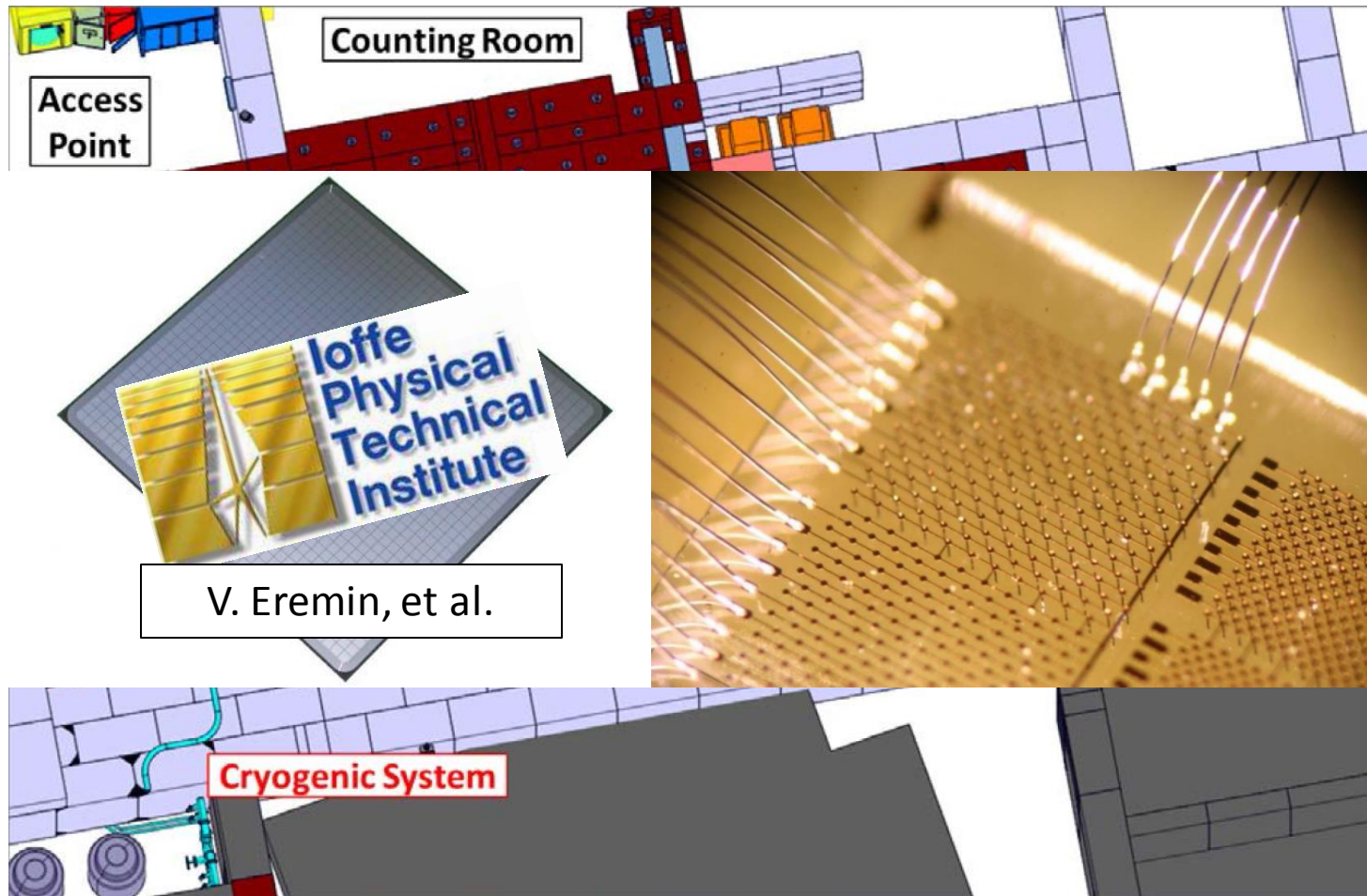
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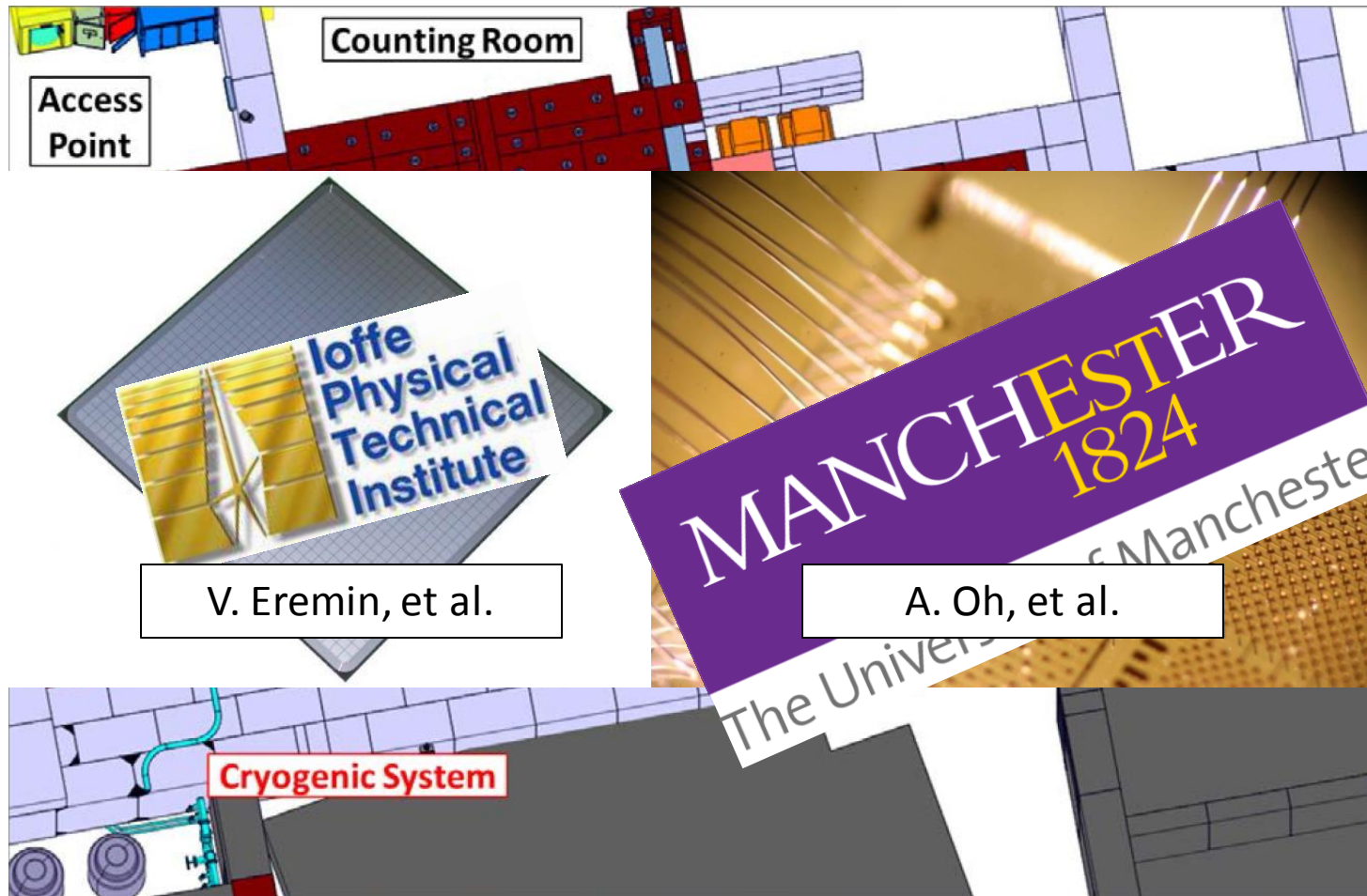
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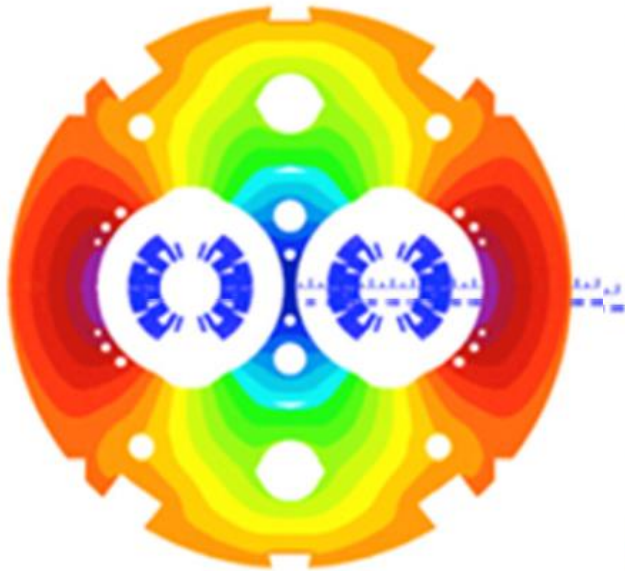


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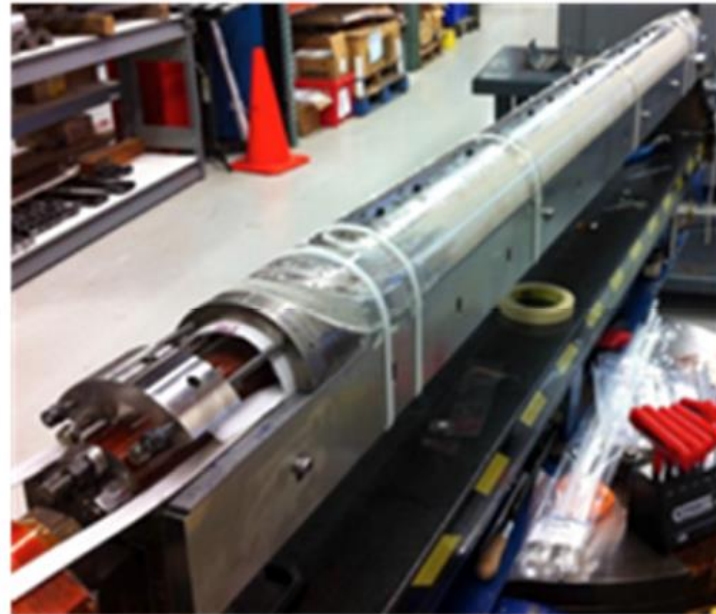
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# Future installations in LHC



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)]

Thank you!