

# Hardware and Software Upgrades for the Proton Irradiation Facility (IRRAD) after the LS2

Blerina Gkotse (EP-DT-DD)

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*Former IRRAD members contributors:* **Isidre Mateu Suau, Viktoria Meskova**  
*MINES ParisTech:* **Pierre Jouvelot**

EP-DT Seminar  
28 October 2020



*This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.*



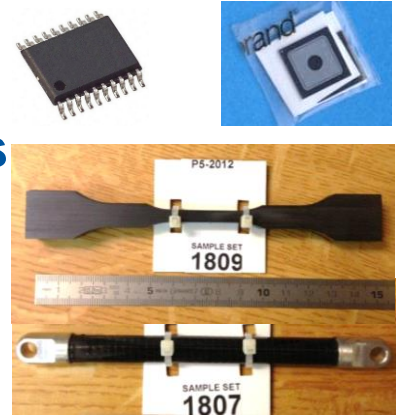
**AIDA** 2020

# Outline

- Proton Irradiation Facility (IRRAD)
- Software and Hardware Upgrades for IRRAD
- Software Developments for Users Community
- Towards Common Tools for Irradiation Facilities

# Irradiation Facilities: what for?

- **Radiation damage studies on:**
  - materials used around accelerators / experiments
  - semiconductors / electronic components
  - materials / accelerator components exposed to high-intensity pulsed beams

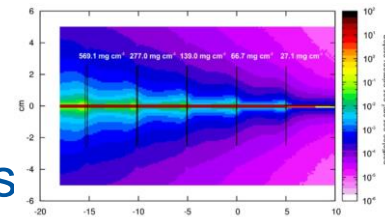


- **Test and development of prototypes / final assemblies / electronic equipment before installation**
  - performance degradation / ageing (TID, NIEL,...)
  - functional degradation of electronics (SEU,...)
  - performance evaluation with background (“noise”)



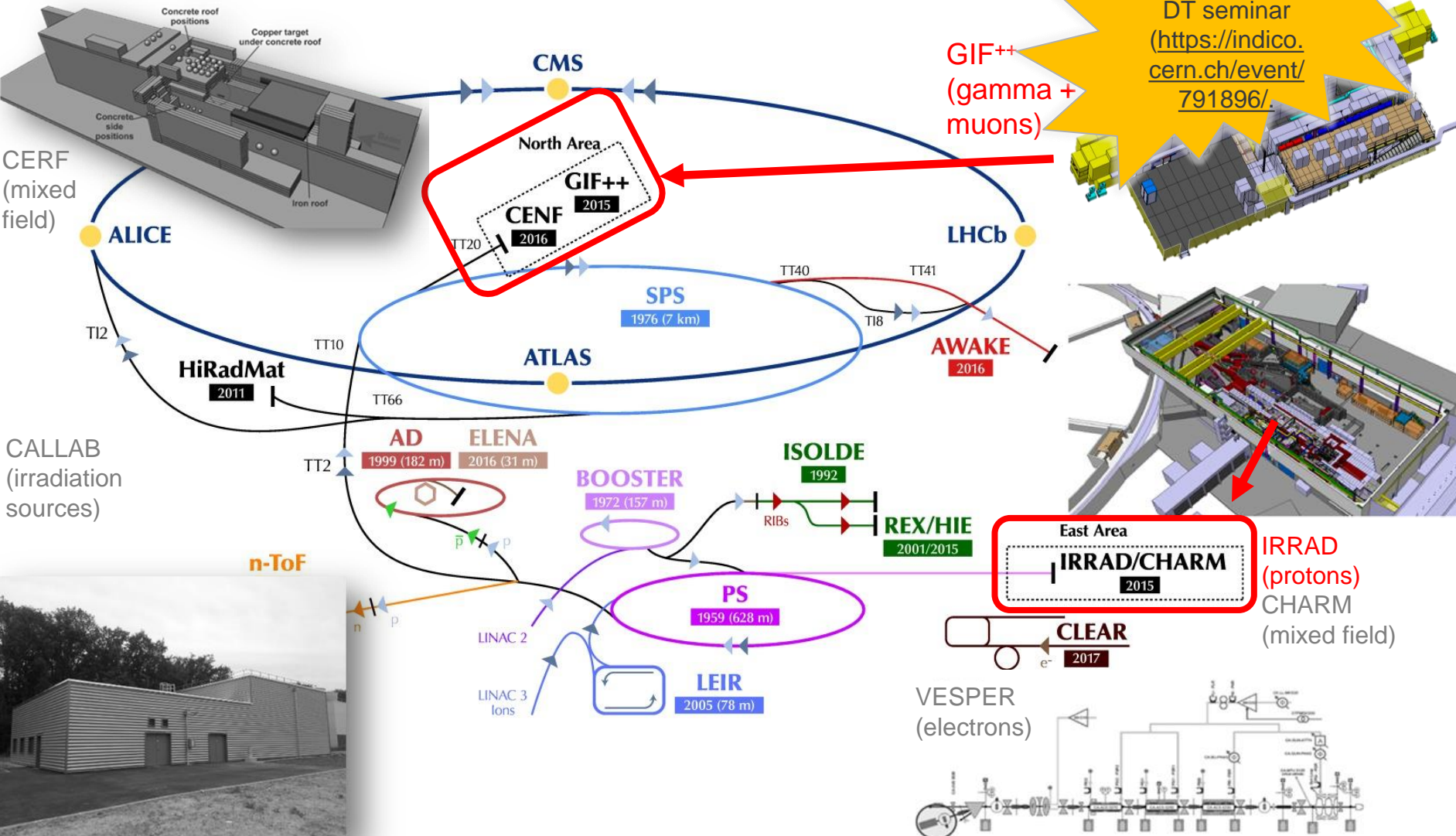
- **Test and calibration of components**

- dosimeters, radiation monitoring / measurement devices
- provide benchmark data for Monte Carlo particle transport codes



# CERN Irradiation Facilities

See previous M. Jaekel EP-DT seminar (<https://indico.cern.ch/event/791896/>).

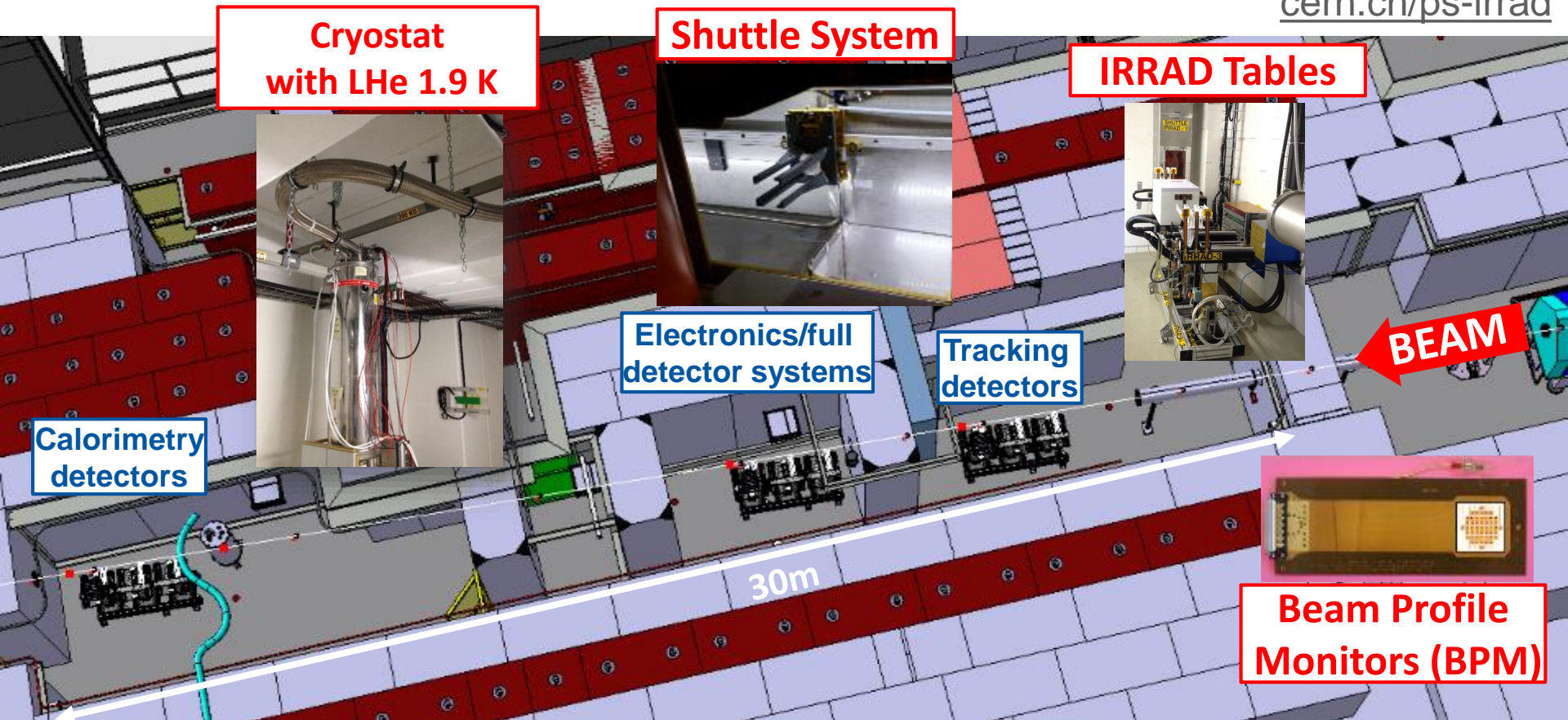




# CERN Proton Irradiation Facility (IRRAD)

- Testing components of HEP experiments
- 24 GeV/c, Gaussian 12×12 mm<sup>2</sup> FWHM
- Spills of 400 ms every ~10 s
- Fluence of  $1 \times 10^{16}$  p/cm<sup>2</sup> in 14 days
- Scanning also in dimensions of 10×10 cm<sup>2</sup>
- Low temperature irradiation (-25°C)

[cern.ch/ps-irrad](http://cern.ch/ps-irrad)



# IRRAD Experiments in 2018

81 experiments, 97 users, 792 samples, 405 dosimeters, 2056 dosimetry measurements

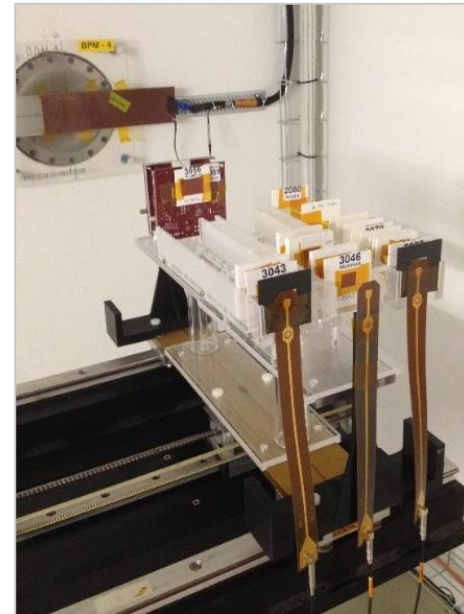
© ps-irrad.cern.ch



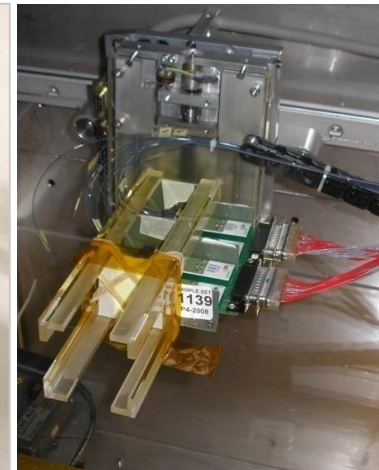
Piezo actuators



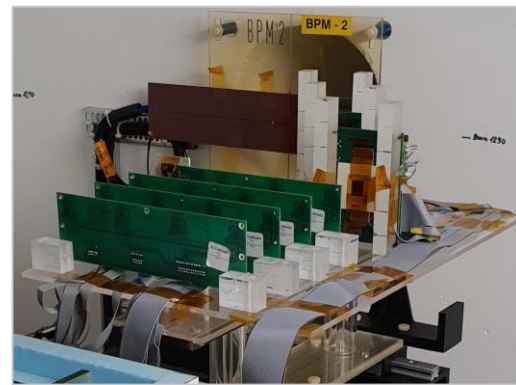
ECAL crystal



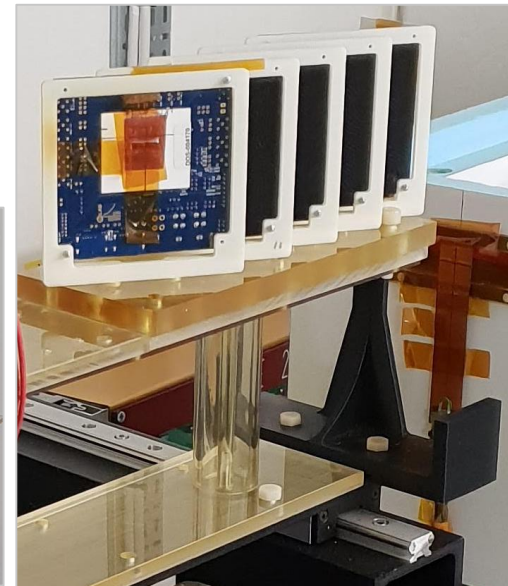
Si pad diode



Samples on shuttle



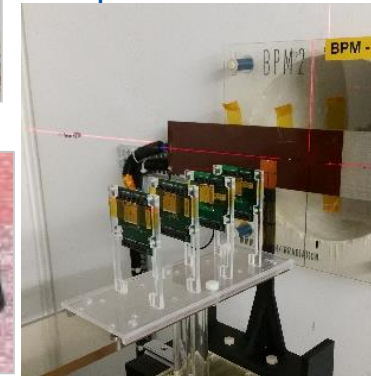
CLARO ASIC



RD53A modules



Full-tracking detector module



NA62 GTK TDCpix



# IRRAD Complex Experiment

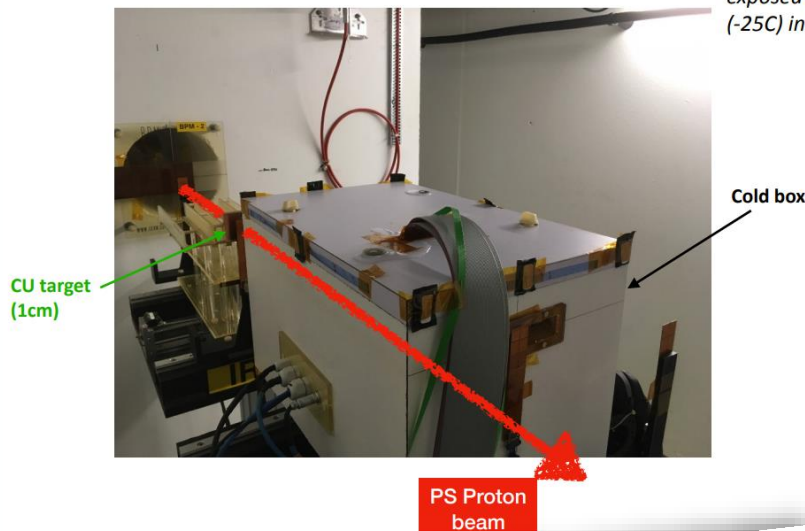
## Exposure of 32 FEAST2 at -25C at the CERN IRRAD facility

The facility run in a purposely modified configuration to expose the converters in a mixed field:

MANY THANKS to the IRRAD TEAM!

© F. Faccio EP-ESE seminar, 2019  
<https://indico.cern.ch/event/788031>

32 samples, both FEASTMP and CMS modules, are exposed and constantly monitored in a cold box (-25C) in the CERN IRRAD facility (May 2018).



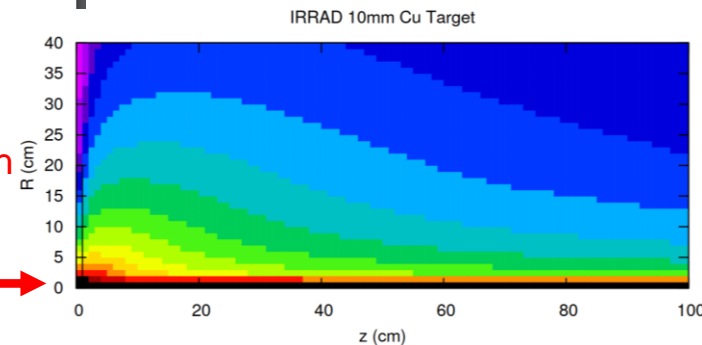
32 modules inside the cold box

2x FEAST2 DC/DC converters test in cold-box & RT with “thin” 10mm Cu target (EP-ESE)

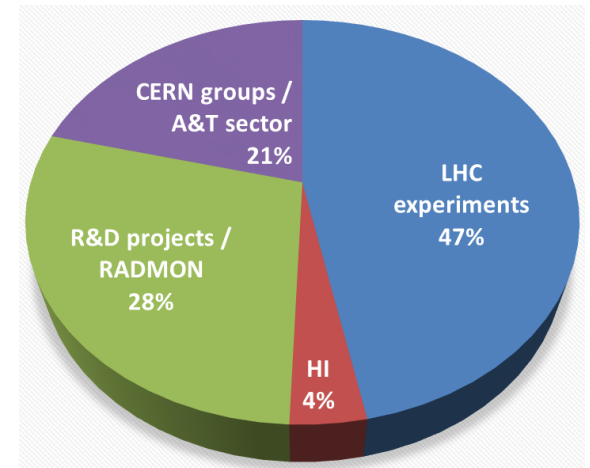
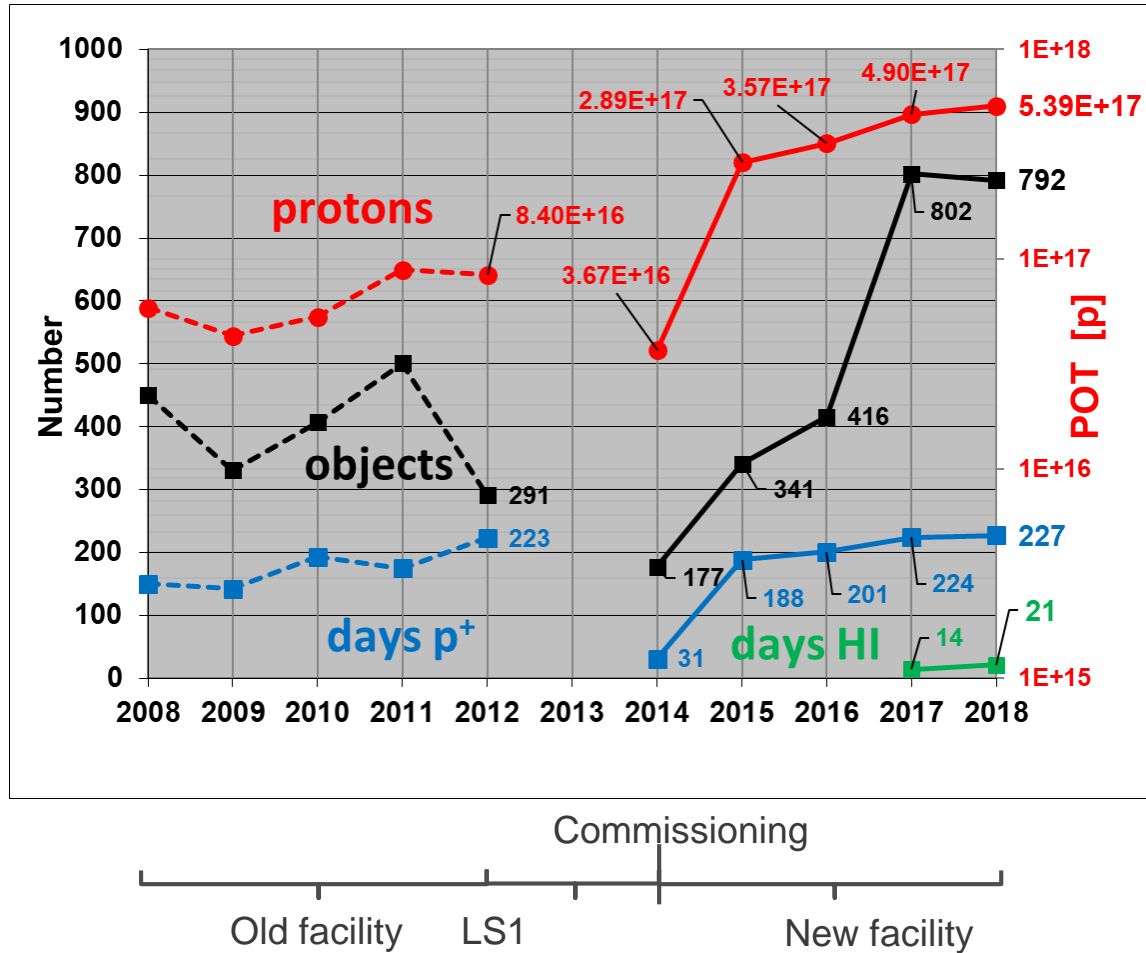
Radiation in ASIC? Environmental conditions? EM noise?

Two irradiation runs at the CERN IRRAD facility were instrumental in understanding the origin of the damage

1MeV eq.  $\Phi$  simulation with Cu-target

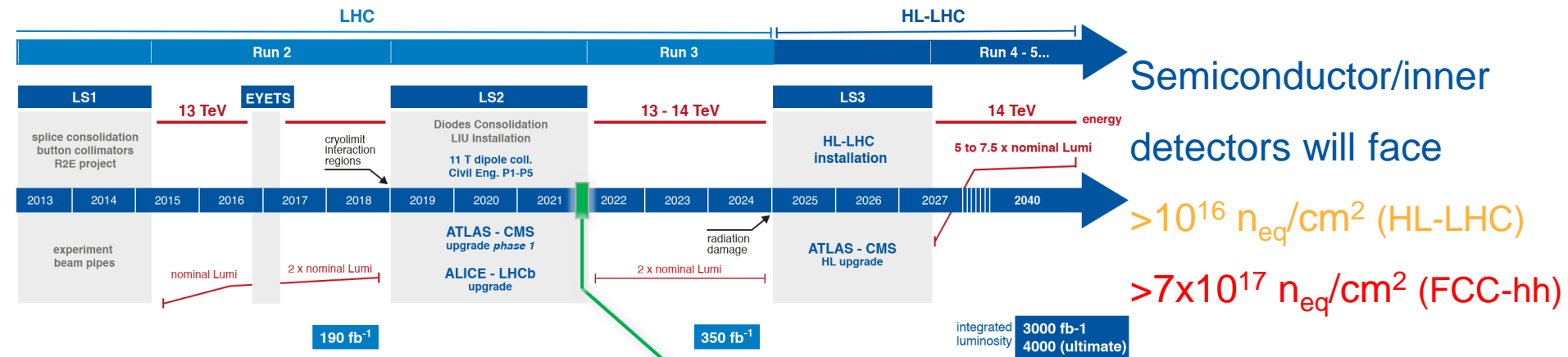


# IRRAD Statistics for the Last 10 Years



Repartition of the users in 2018

# IRRAD Towards Phase II Upgrade



Semiconductor/inner detectors will face

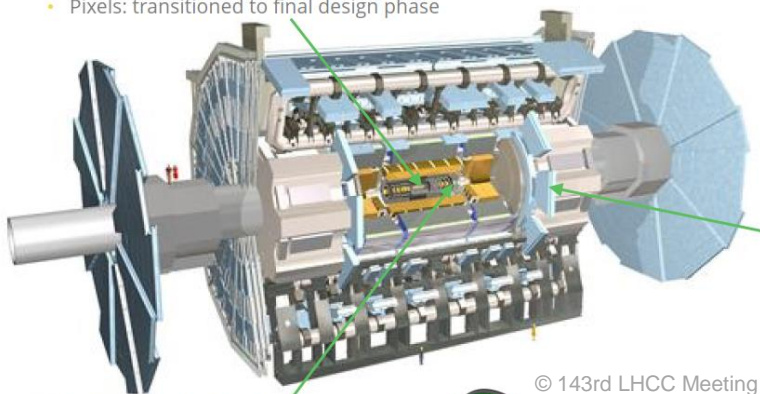
$>10^{16} n_{eq}/cm^2$  (HL-LHC)

$>7 \times 10^{17} n_{eq}/cm^2$  (FCC-hh)

## Phase-II upgrade

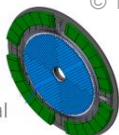


- New all-silicon Inner Tracker (ITk)
  - Strips: preproduction
  - Pixels: transitioned to final design phase



© 143rd LHCC Meeting

- High Granularity Timing Detector
  - TDR preliminarily approved
  - Upgrade cost group review this week → last step before research board approval



## IRRAD-RUN2 from 18/10/2021

### Experiments R&D on for Phase II upgrade:

- 3D pixels, SiPM, LGADs, HV-CMOS, ...
- CMS pixel, ATLAS ITk strips, CMS Timing Detector, ATLAS HGTD, ...

### Electronic developments: RD53, DC/DC, etc.

### Accelerator components:

- Vacuum/Magnet parts, collimator actuators, ...

### Increasing number of requests for IRRAD-RUN2!

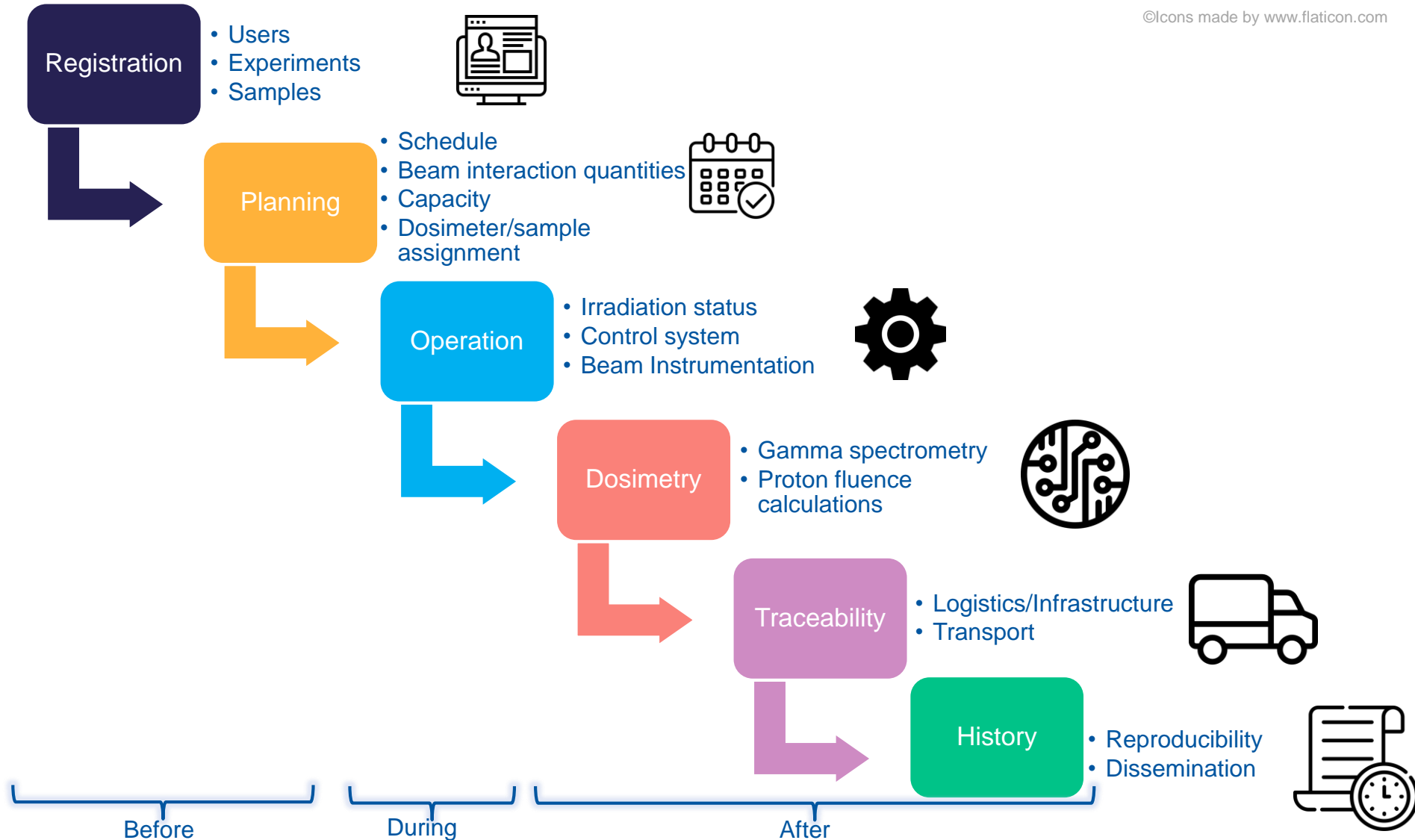


# Outline

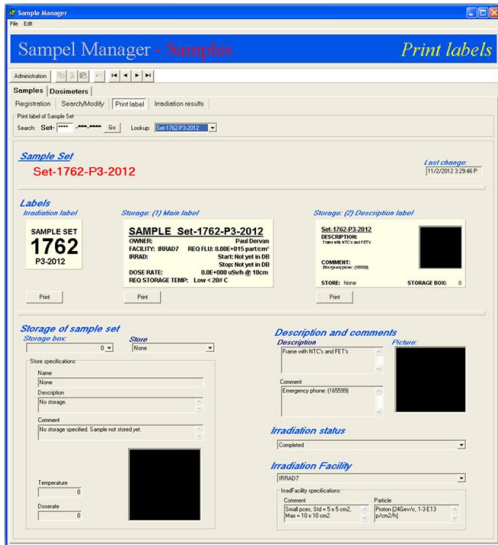
- Proton Irradiation Facility (IRRAD)
- **Software and Hardware Upgrades for IRRAD**
- Software Developments for Users Community
- Towards Common Tools for Irradiation Facilities

# Irradiation Experiment Workflow in IRRAD

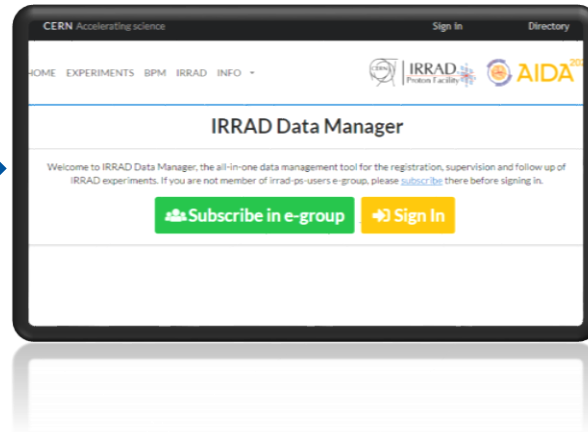
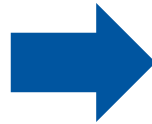
©Icons made by www.flaticon.com



# Data Management in IRRAD

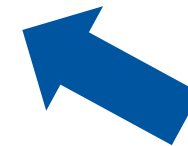


Traceability  
(Before)



The screenshot shows a large spreadsheet with many columns and rows of data, representing facility operation records during an experiment.

Facility Operation  
(During)



Dosimetry Results & Archive  
(After)

# IRRAD Data Manager (IDM)

A unified data management tool for Irradiation Experiments follow-up

IRRAD Data Manager - Irradiation Experiments

ID	Irradiation title	Availability	No. irradiations/defined samples	Estimated No. Cells Length Occupancy (%)	No. Users	Responsible person	Status	Actions
81	FCC-RADIATION (S1)	01/04/2018	4/6	4.39 1.8%	0	Georg Garber	Completed	View Edit Delete
841	Photo-study Irradiation (S1)	29/06/2018	3/7	9.11 4.3%	0	Luigi Albert Osteria	Completed	View Edit Delete
1403	Newly Ion irradiation for electron defect spectroscopy (S1)	16/11/2018	4/4	0.12 0.0%	0	Silvia Manes	Validated	View Edit Delete
1402	NEL Irradiation - Heavy ION 2018 - RADIATION (S1)	14/11/2018	5/5	0.05 0.0%	0	Giuseppe Petroliti	Validated	View Edit Delete
1401	NEL Irradiation - Heavy ION 2018 (S1)	14/11/2018	5/5	3.05 0.0%	0	Giuseppe Petroliti	Validated	View Edit Delete

IRRAD Data Manager - Dosimetry results for SET-003252 (ULTEM1000)

Dosimeter	Dimensions (mm <sup>2</sup> )	Date In	Date Out	SEC	Accumulated fluence	Error (%)	Comments
DOS-004023	10x10	18/04/2018 10:00	05/09/2018 03:00	1.41e+10	9.79e+16	7	
DOS-004151	10x10	12/09/2018 13:25		0.00e+00			

Dosimeter dimensions (mm<sup>2</sup>): 10x10 mm<sup>2</sup> | Total accumulated fluence: 9.790e+16 Protons/cm<sup>2</sup>

IRRAD Data Manager - TREC Data of Sample SET-003122

Characteristics:

- Length: 1 cm
- Width: 0.1 cm
- Height: 0.002 cm
- Weight: 0.1 kg
- Family: -
- Material: -

Registration

Planning

Operation

Dosimetry

Traceability

History

Sample Details

Sample dimensions:

Test with (mm):

Name	Length (mm)	Weight (g)	Date
S1	1.0	0.1	18/04/2018
S2	1.0	0.1	18/04/2018
S3	1.0	0.1	18/04/2018

IRRAD Data Manager - Irradiation Status

Updated at	Sample	Dosimeter	Date In - Date Out	IRRAD table	Table position	Accumulated fluence	SEC	Updated by	Status	In Beam	Actions
15/11/2018	SET-003899	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center	272851		irradiation.facilities@cern.ch	Registered	<input type="checkbox"/>	View Edit Delete
15/11/2018	SET-003900	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center	272851		irradiation.facilities@cern.ch	Registered	<input type="checkbox"/>	View Edit Delete
15/11/2018	SET-003901	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center	272851		irradiation.facilities@cern.ch	Registered	<input type="checkbox"/>	View Edit Delete
15/11/2018	SET-003902	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center	272851		irradiation.facilities@cern.ch	Registered	<input type="checkbox"/>	View Edit Delete
15/11/2018	SET-003903	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center	272851		irradiation.facilities@cern.ch	Registered	<input type="checkbox"/>	View Edit Delete

IRRAD Data Manager - 3D pixel for ATLAS ITK

Treatment Details:

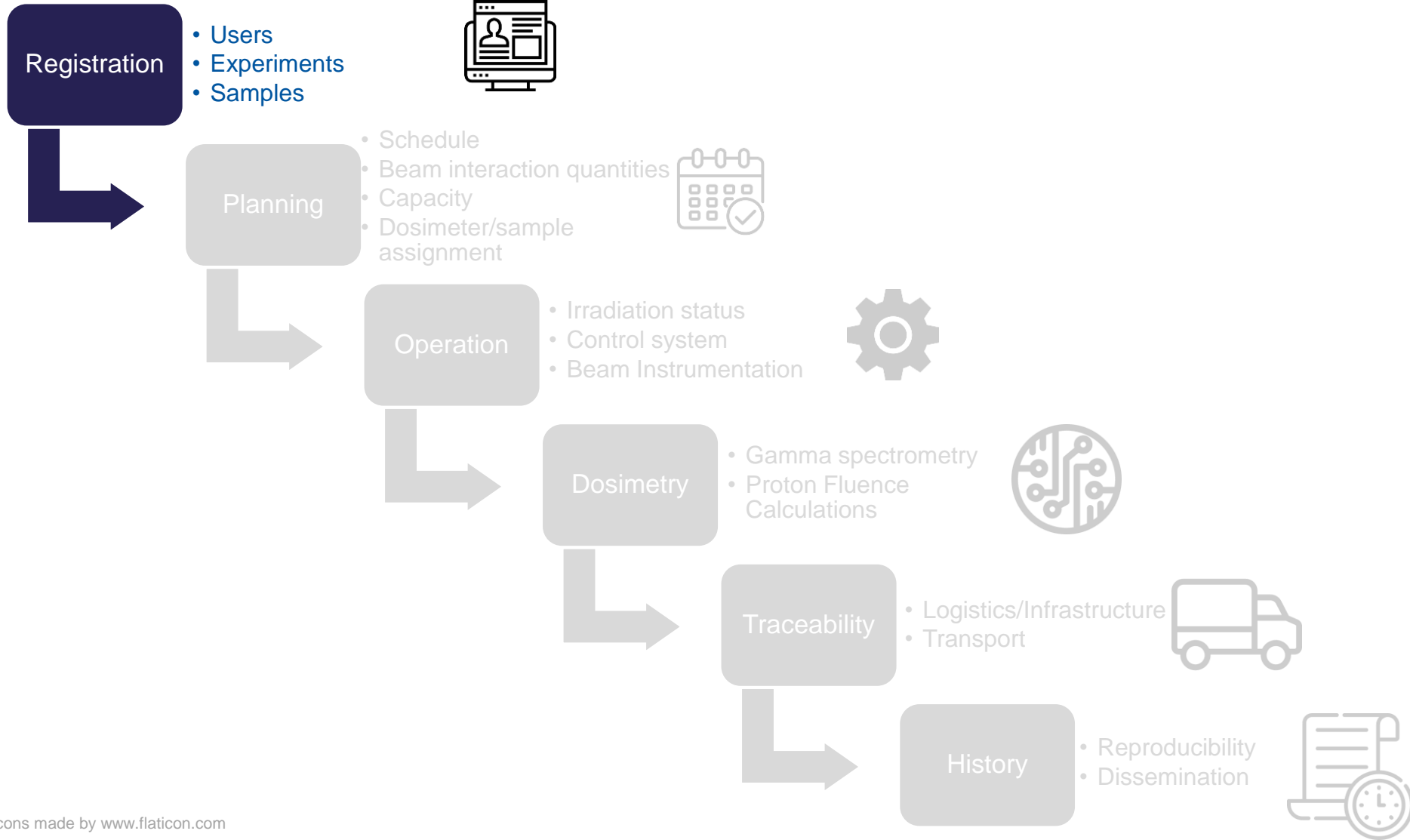
- Beam: 100 pps for ATLAS ITK
- Characteristics: Study of radiation hardness of 2D silicon photomultiplier for the innermost pixel layer of ATLAS ITK with fluence up to 1e16 protons/cm<sup>2</sup>. Both FET prototypes and modules with the new 8025A readout chips are going to be tested.
- Responsible person: joan.lange@cern.ch
- Irradiation type: Protons
- Additional comments: Important to characterize the new 8025A readout modules for ATLAS ITK prior before the PS SPS shutdown in 2019/20.

Sample Details:

- Category: Proton Custom
- Name: Room Temperature
- Dimension: 10x10x2
- Material category: Flat modules on the ATLAS 3Dx3Dx2 PCBs the last year, ideally wide beam (20x20cm<sup>2</sup> at end of beam line)
- Fluence: 1e16 Protons/cm<sup>2</sup> 2e16 Protons/cm<sup>2</sup> 5e16 Protons/cm<sup>2</sup>
- Type of sample: Silicon sensor + readout chip being bonded
- Dosimetry results: 1e16/1e16 with dosimeter 10x10 mm<sup>2</sup> 1.200e+16 Protons/cm<sup>2</sup> 1.000e+16 with dosimeter 10x10 mm<sup>2</sup> 1.210e+16 Protons/cm<sup>2</sup> 1.000e+16 with dosimeter 10x10 mm<sup>2</sup> 1.200e+16 Protons/cm<sup>2</sup>



# Irradiation Experiment Workflow in IRRAD





# Registration



### Sample dimensions

Total height (mm) \*

Total width (mm) \*

[+ Add new compound](#)

Name *	Length (mm) *	Element/Compound	Delete
L1	0.13	kapton	✕
L2	0.0006	Al(13)	✕
L3	0.0006	SiO2	✕
e.g. L1		-----	✕

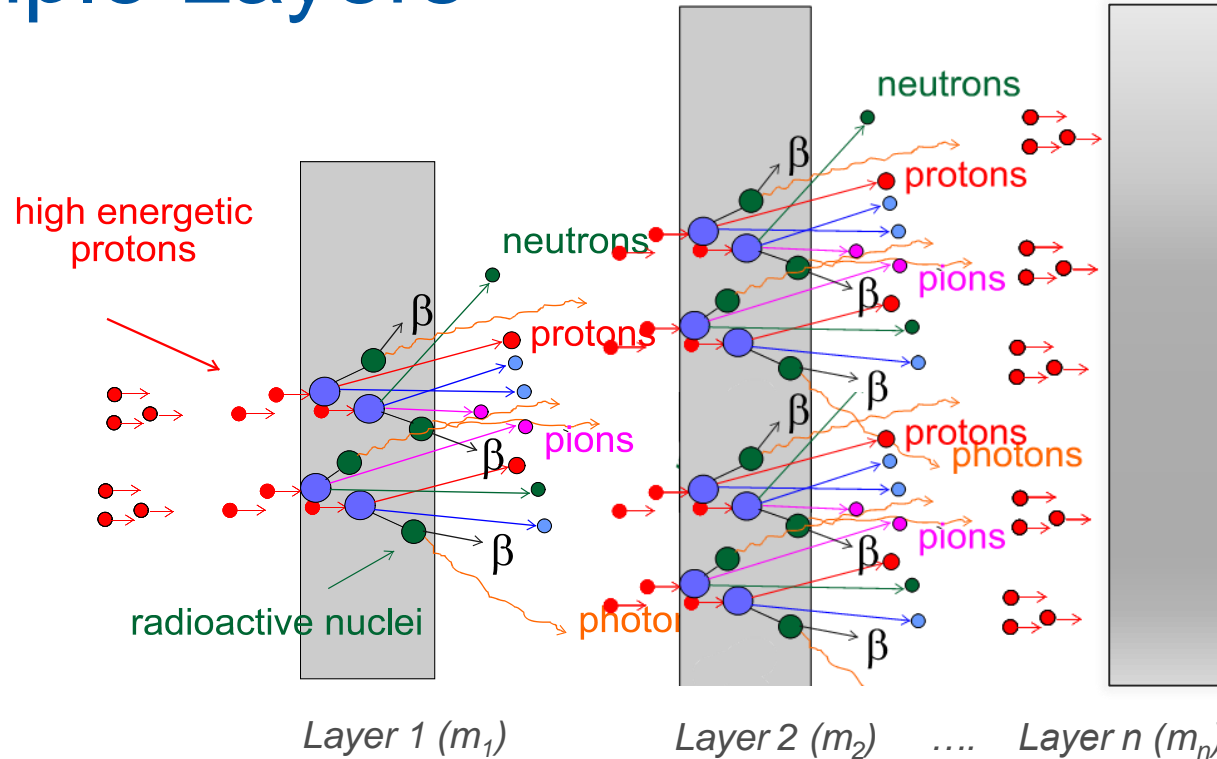
[Add Layer](#)

[Previous](#) [Next](#)

[+ New Sample](#)

Last updated by	Actions
pezzullo@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
pezzullo@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
gorine@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
gorine@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
facilities@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
facilities@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
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gklotse@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>
gklotse@cern.ch	<a href="#">View</a> <a href="#">Edit</a> <a href="#">Delete</a>

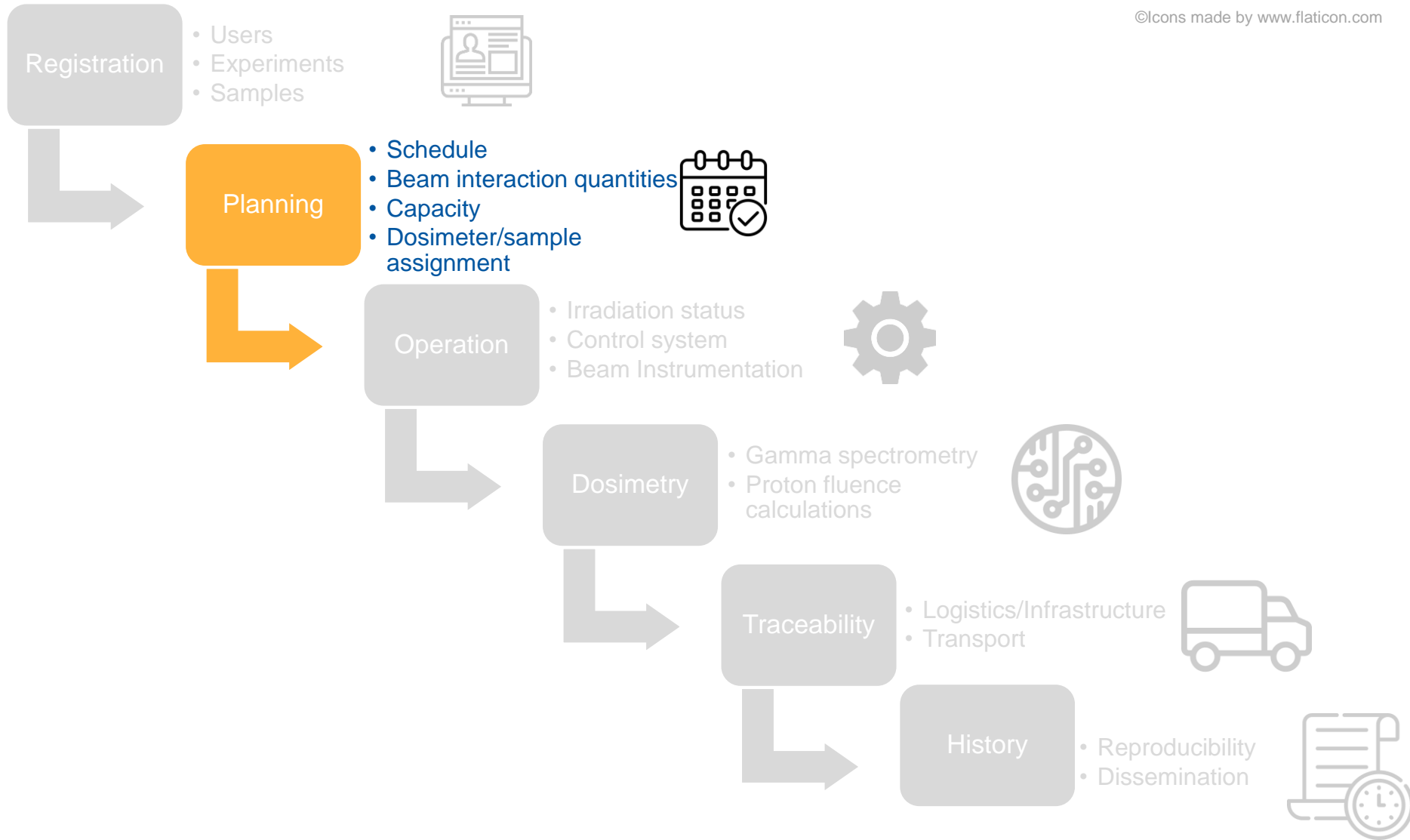
# Sample Layers



- High energy protons interact with all materials (not only samples!) in the beamline
- To perform a “good” irradiation:
  - Need to estimate the relevant “physics” parameters: interaction ( $\lambda$ ) / radiation ( $X_0$ ) lengths, etc.
  - Feedback to the operation / planning of the whole (IRRAD/CHARM) facility
- Same interactions responsible for making the material radioactive

# Irradiation Experiment Workflow in IRRAD

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# Planning

IRRAD Operating team:

- Experiments scheduling
- Beam interaction quantities calculations
- Generation of sample identification
- Dosimeters assignment

The screenshot displays the IRRAD Data Manager interface. At the top, it shows the CERN logo and navigation links. The main heading is "IRRAD Data Manager" and the sub-heading is "FCC-RADMON samples". Below this, there are several action buttons: "Assign SET ID", "Print labels", and "New irradiation". A dropdown menu is set to "Move samples to another experiment". A toggle switch is turned on, with the text "Your experiment is now visible to other users. To visit other user's experiments please [click here](#)." Below this is a table of samples.

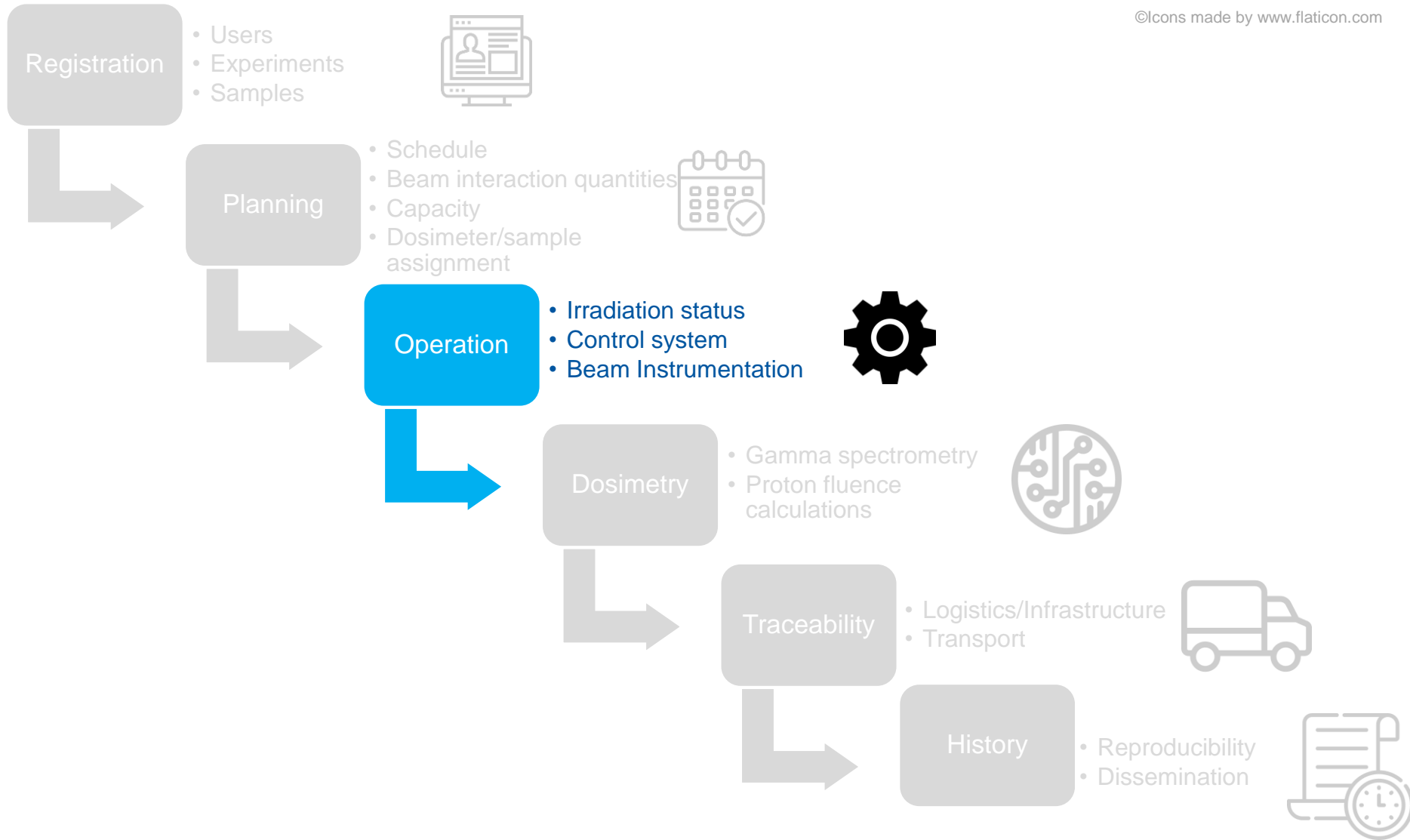
<input type="checkbox"/>	Last update	ID	Name	Category	Requested fluence	Radiation / Nu. Coll. / Nu. Int. Length Occupancy (%)	Last updated by	Actions
<input checked="" type="checkbox"/>	07/08/2018	SET-002405	PCB5-run2017	Room temperature, in irradiation area: 10x10 mm2	3e17	1.163 / 0.623 / 0.414	blerina.gkotse@cern.ch	<a href="#">Edit</a> <a href="#">Results</a> <a href="#">More</a>
<input type="checkbox"/>	26/11/2018	SET-003541	PCB19-run2018	Room temperature, in irradiation area: 10x10 mm2	3e17	0.96 / 0.348 / 0.227	georgi.gorine@cern.ch	<a href="#">Edit</a> <a href="#">Results</a> <a href="#">More</a>
<input type="checkbox"/>	05/11/2018	SET-003542	PCB18-run2018	Room temperature, in irradiation area: 10x10 mm2	3e17	0.96 / 0.348 / 0.227	georgi.gorine@cern.ch	<a href="#">Edit</a> <a href="#">Results</a> <a href="#">More</a>
<input type="checkbox"/>	19/09/2018	SET-003686	PCB22-ALD2018	Room temperature, in irradiation area: 10x10 mm2	3e17	1.106 / 0.576 / 0.389	georgi.gorine@cern.ch	<a href="#">Edit</a> <a href="#">Results</a> <a href="#">More</a>

1  
Archive

Planning which samples will be put in beam

# Irradiation Experiment Workflow in IRRAD

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# Operation – Irradiation Status

- Data extraction from IRRAD Beam Instrumentation
- Accumulated proton fluence estimation
- Notification of irradiation completion

The screenshot shows the IRRAD Data Manager web interface. At the top, it displays the CERN logo and navigation links. The main content area is titled "IRRAD Data Manager" and "Irradiation Status". Below the title, there are buttons for "Back", "New Irradiation", and a "Select a table" dropdown. The main part of the interface is a table with the following columns: Updated at, Sample, Dosimeter, Date IN - Date OUT, IRRAD table, Table position, Accumulated fluence, SEC, Updated by, Status, In Beam, and Actions. The table contains five rows of data, all with a status of "Registered" and "In Beam" toggle set to "On".

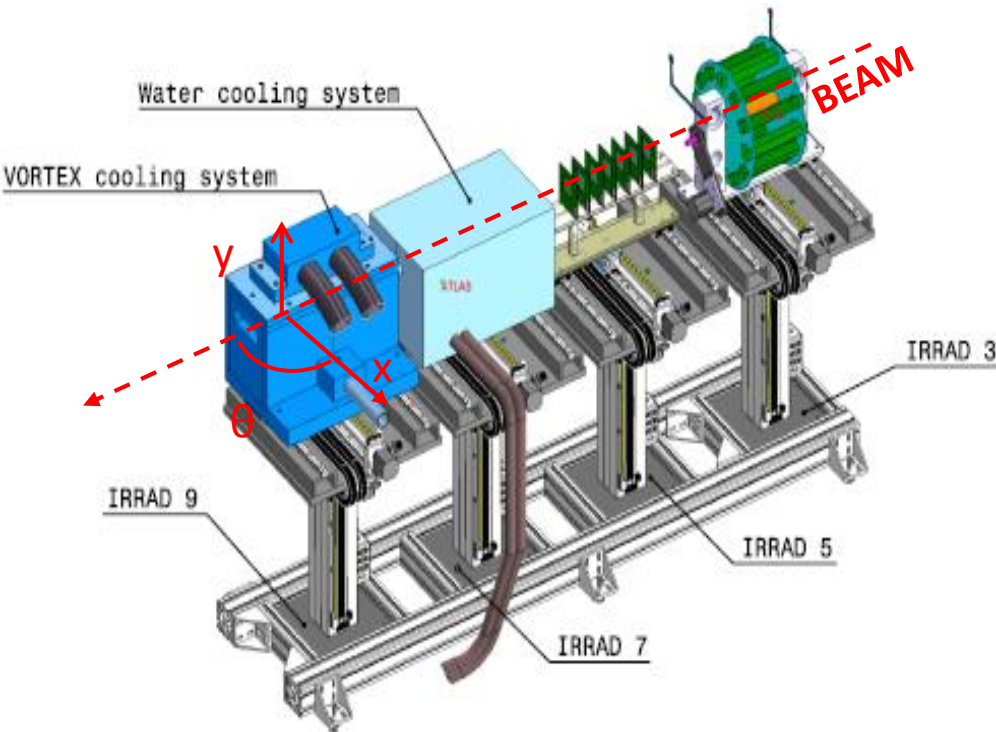
Updated at	Sample	Dosimeter	Date IN - Date OUT	IRRAD table	Table position	Accumulated fluence	SEC	Updated by	Status	In Beam	Actions
15/11/2018	SET-003899	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center		272851	irradiation.facilities@cern.ch	Registered	<input checked="" type="checkbox"/>	<a href="#">Print</a> <a href="#">Status</a> <a href="#">Delete</a>
15/11/2018	SET-003900	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center		272851	irradiation.facilities@cern.ch	Registered	<input checked="" type="checkbox"/>	<a href="#">Print</a> <a href="#">Status</a> <a href="#">Delete</a>
15/11/2018	SET-003901	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center		272851	irradiation.facilities@cern.ch	Registered	<input checked="" type="checkbox"/>	<a href="#">Print</a> <a href="#">Status</a> <a href="#">Delete</a>
15/11/2018	SET-003902	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center		272851	irradiation.facilities@cern.ch	Registered	<input checked="" type="checkbox"/>	<a href="#">Print</a> <a href="#">Status</a> <a href="#">Delete</a>
15/11/2018	SET-003903	DOS-004211	15/11/2018 16:11 -	IRRAD19	Center		272851	irradiation.facilities@cern.ch	Registered	<input checked="" type="checkbox"/>	<a href="#">Print</a> <a href="#">Status</a> <a href="#">Delete</a>

Irradiation status

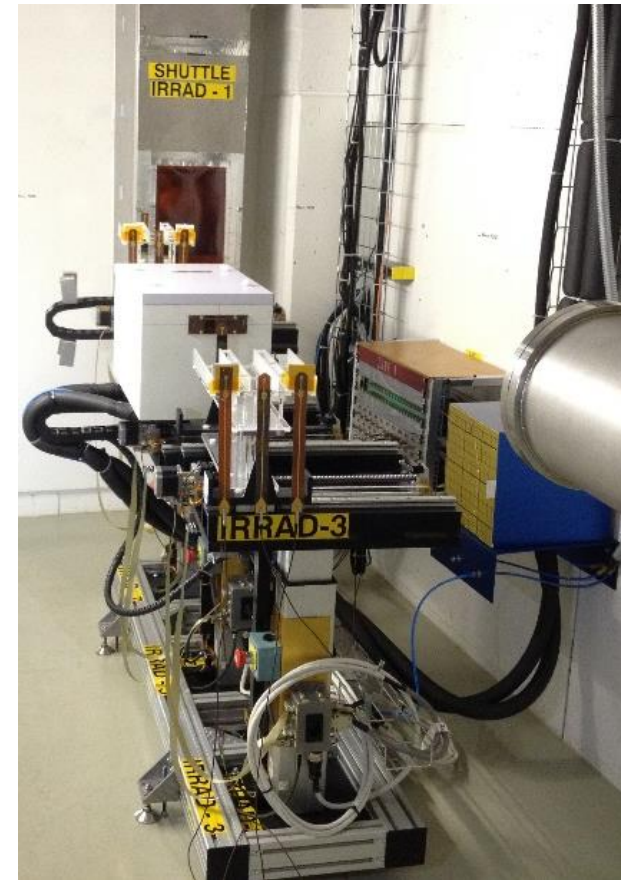


# Operation – IRRAD Tables

- 9 remotely controlled stands
- Moving samples on axes x, y and rotating by  $\theta$  angle
- 1 irradiation shuttle



IRRAD tables



IRRAD tables in Zone 1

# Operation – Control Systems for IRRAD Tables



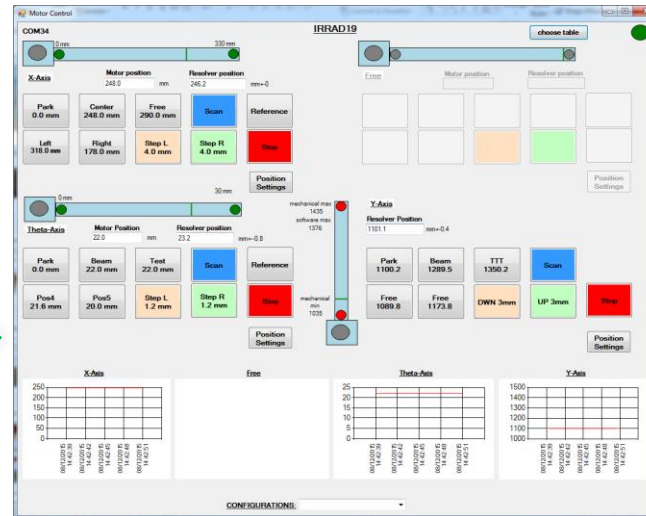
2008



Hardware Box

- manual control on-site
- no remote operation

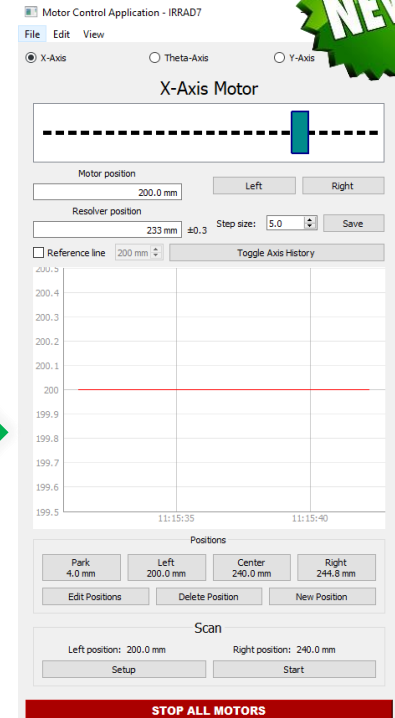
2014 (LS1)



Graphical User Interface (GUI)

- Microsoft-based (Visual Studio, C++)
- Only operational on Windows

2021 (LS2)



New GUI



# Operation – New Table Control System

- Based on pyQT (python) – no license required
- Compatible with Windows and Linux
- Database in the backend

A. Mølholm  
(EP-DT)

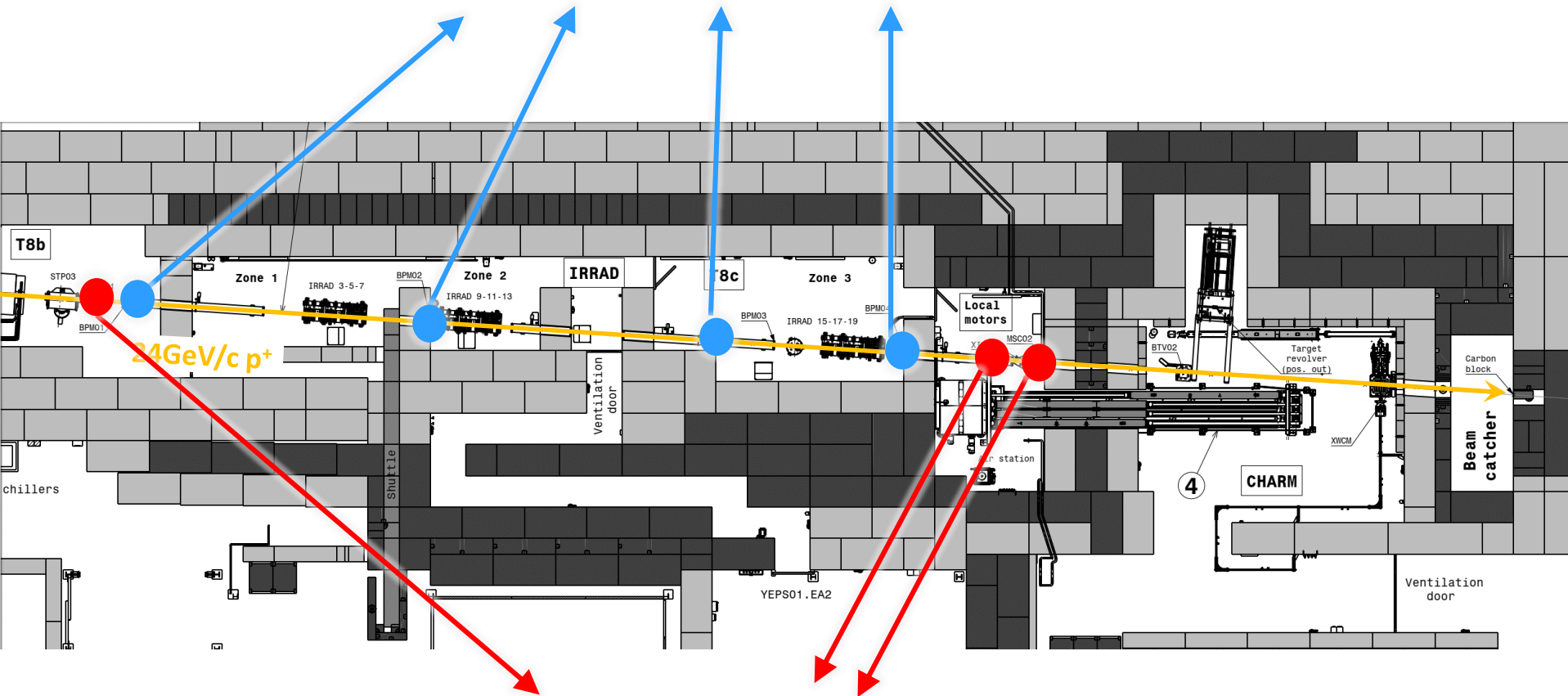
The screenshot displays the 'Motor Control Application - IRRAD7' interface, which is divided into three main sections for X-Axis Motor, Theta-Axis Motor, and Y-Axis Motor. Each section includes a graphical representation of the motor's movement (a slider for X and Y, and a circular dial for Theta), numerical readouts for motor and resolver positions, and control buttons for movement (Up/Down for X and Y, Left/Right for Theta). Below each motor control panel is a graph showing the motor's position over time, with a red line indicating the current trajectory. At the bottom of the interface, there are 'Positions' and 'Scan' sections for each axis, providing specific coordinates and step counts. A prominent red button labeled 'STOP ALL MOTORS' is located at the bottom center of the main window.

New Table Control GUIs



# Operation – Beam Instrumentation

## Fixed IRRAD Beam Profile Monitors (BPMs)



## BE-BI Intensity Measurement Instrumentation

IRRAD

CHARM





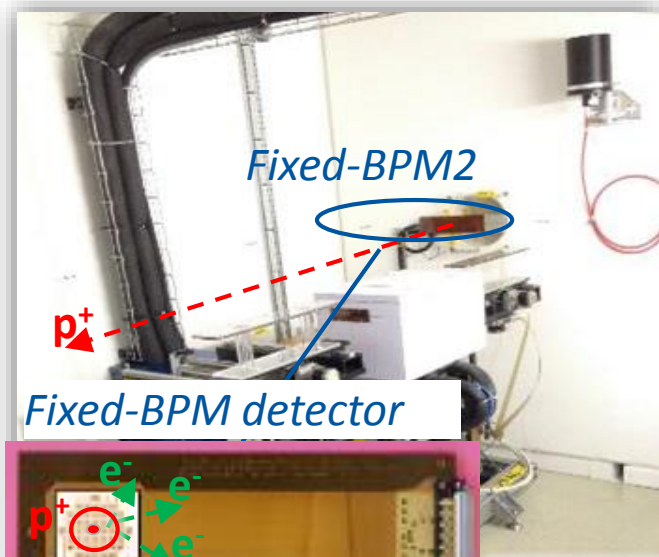
# Operation – BPMs

## Fixed BPM

For the beam alignment

## Mini and single-pad BPMs

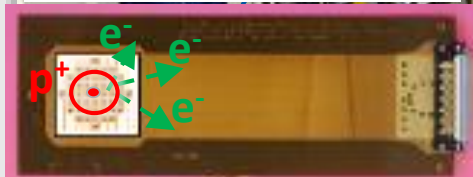
IRRAD tables alignment purpose and “in-beam” detection



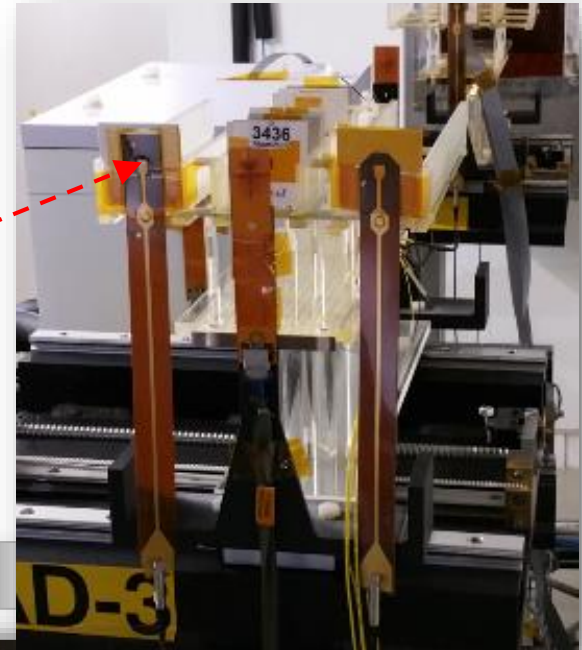
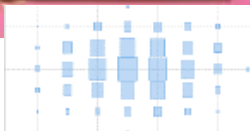
Fixed-BPM2

$p^+$

Fixed-BPM detector



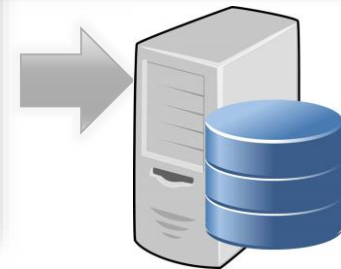
Transversal beam profile



$p^+$

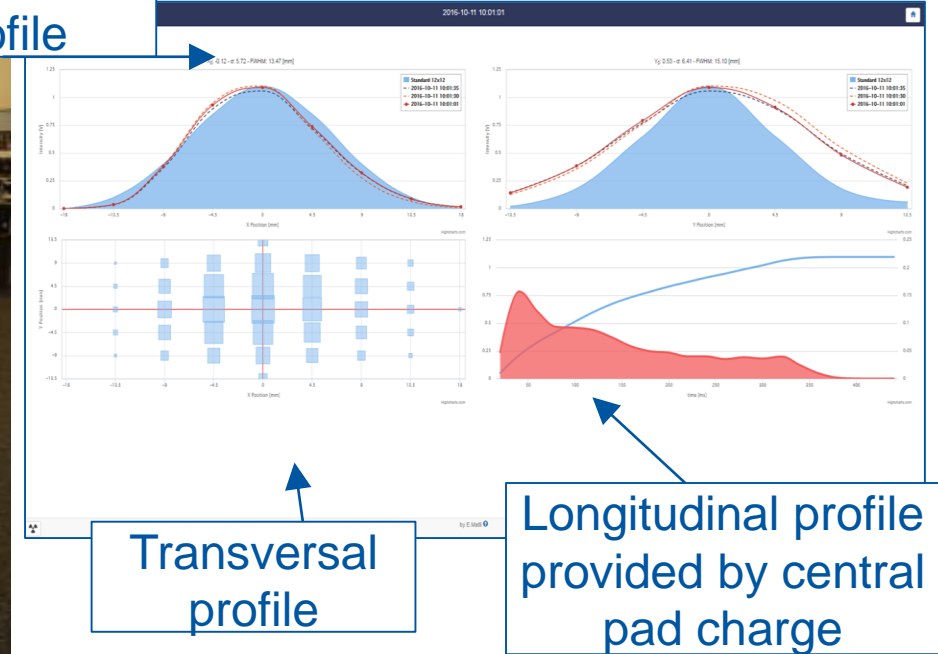
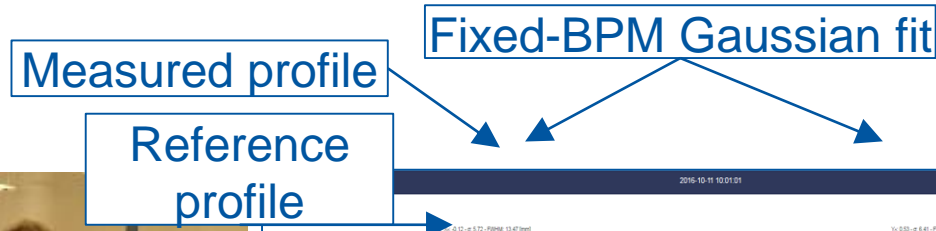


BPM DAQ unit 25-35m away from fixed-BPM device





# Operation – BPM Pages used in CCC



Beam monitoring at CERN Control Center (CCC)

<https://op-webtools.web.cern.ch/irrad/index.php>

E. Matli (BE-ICS)

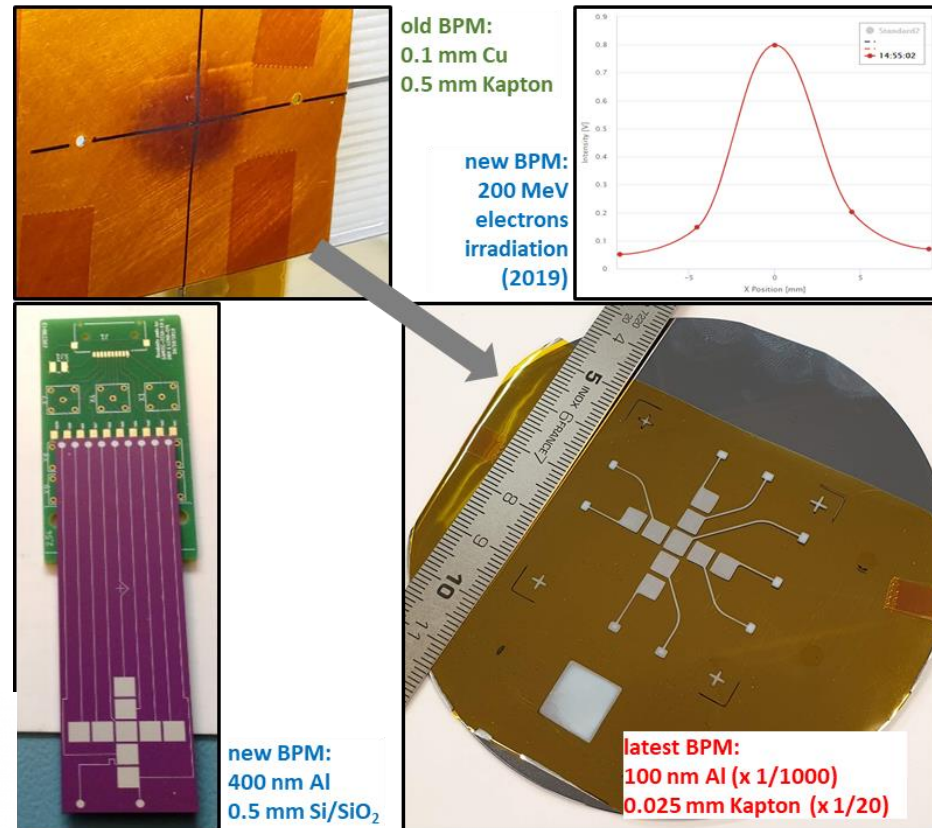


# Operation – New micro-BPM

- Understand the proprieties of ultra-thin [nm] metal layers exposed to ultra-high particle fluence levels ( $\geq 10^{18}$  p/cm<sup>2</sup>)
- Requirements:
  - simple
  - non-invasive
  - low-activation
  - high-sensitivity
  - radhard
- Use at IRRAD and possibly at lower-energy beam facilities (MeV, keV)



V. Meskova  
O. Sidiropoulou  
G. Pezzullo  
(EP-DT)

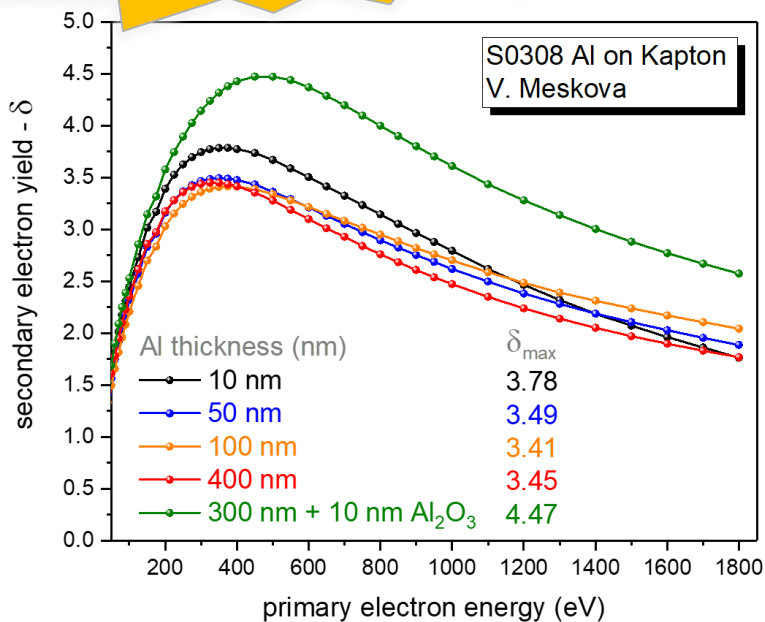


**CMi** EPFL Center of  
MicroNanoTechnology

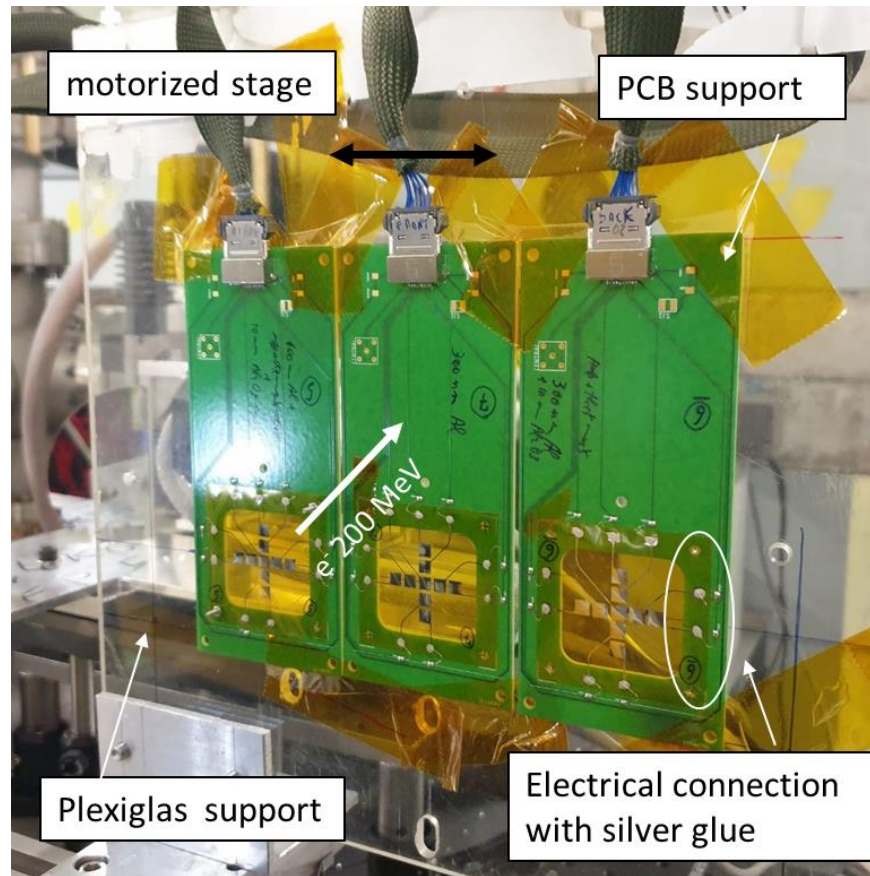


# Ultra High-level Radiation Monitoring with Thin Metal Nano-layers (NanoRadMet)

Future EP-DT seminar



Material Studies / Fabrication techniques

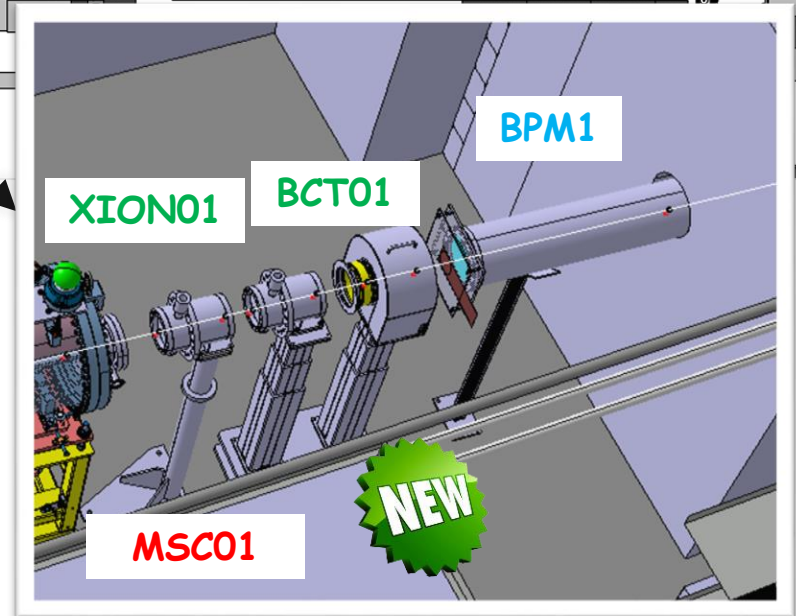
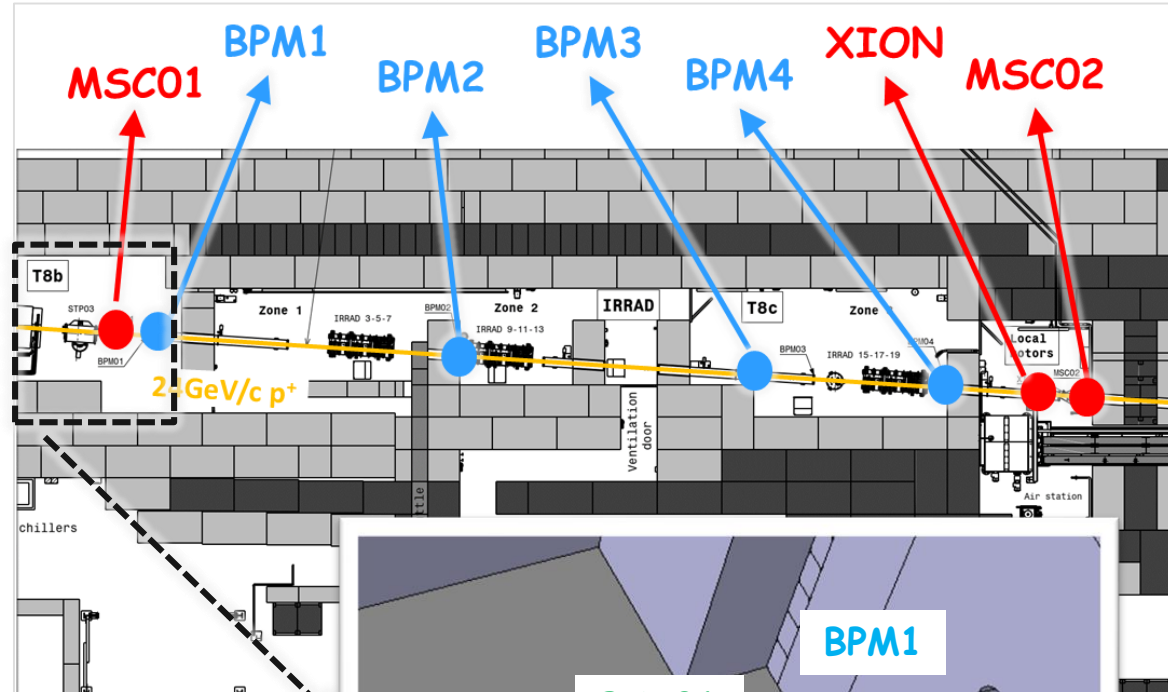


Prototypes of new micro-BPM being tested at VESPER facility (200 MeV electrons)



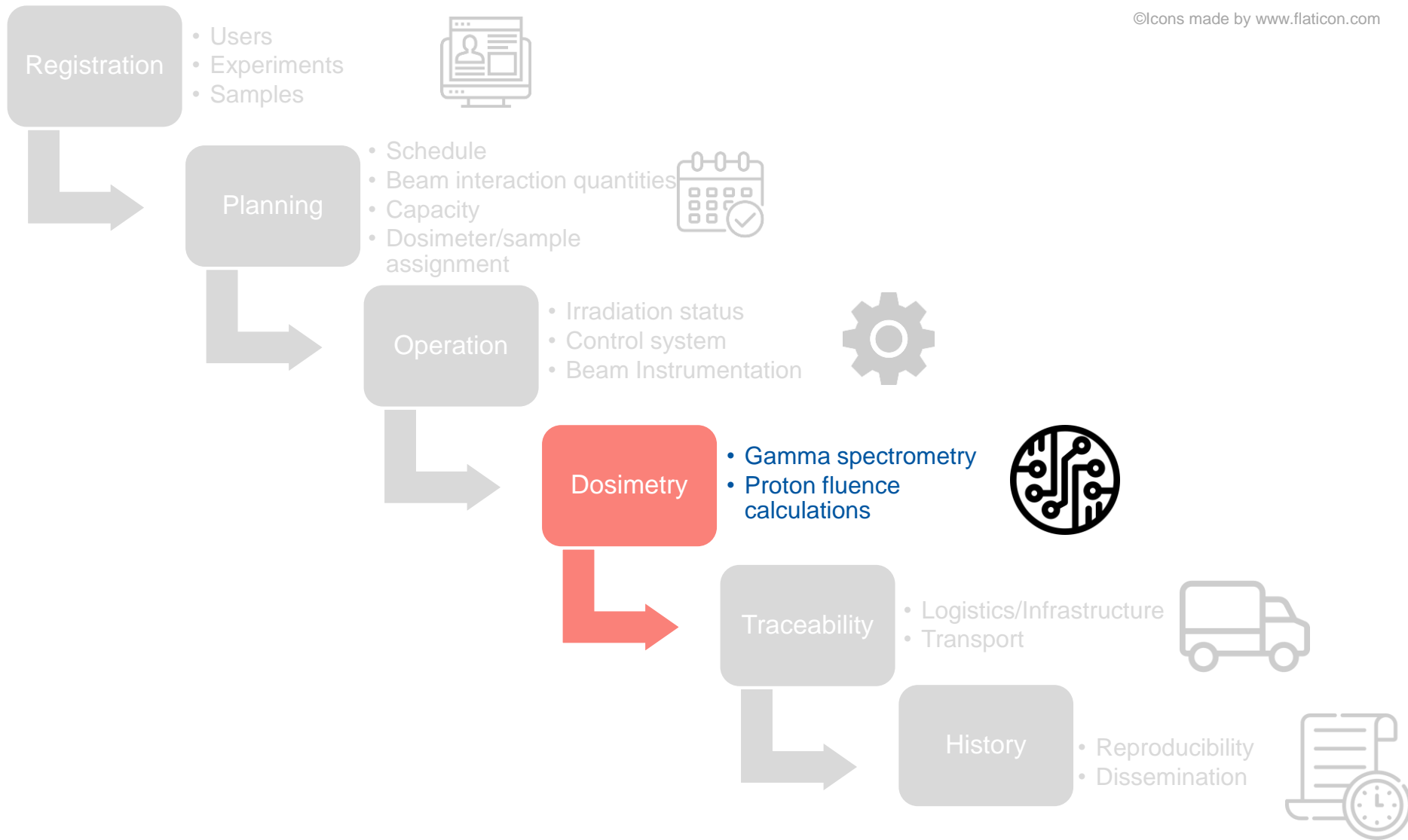
# Beam Instrumentation – New Hardware

- Better understanding of proton beam intensity:
  - T08 transport, calibrations, etc. ( $10^{11}$  p/spill)
  - Low intensity ( $10^9$ - $10^{10}$  p/spill)
  - **Heavy Ion runs**
- New measurement point upstream IRRAD:
  - **XION01**
  - **BCT01**
- New **XION02** downstream
- Devices on **telescopic feet** (IN/OUT)
- System being prepared in collaboration with EN-EA, EN-SMM, BE-BI

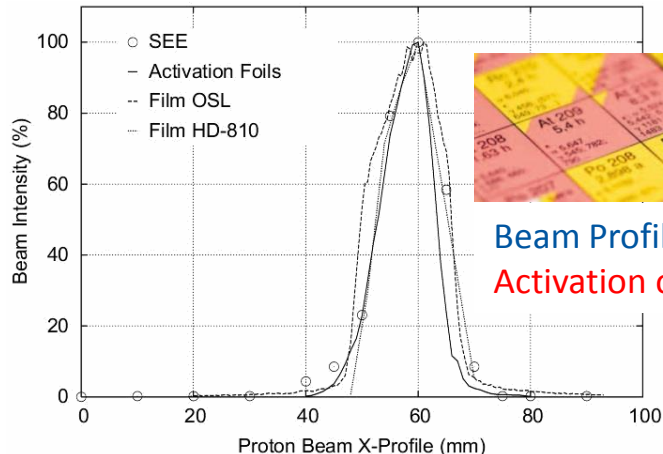
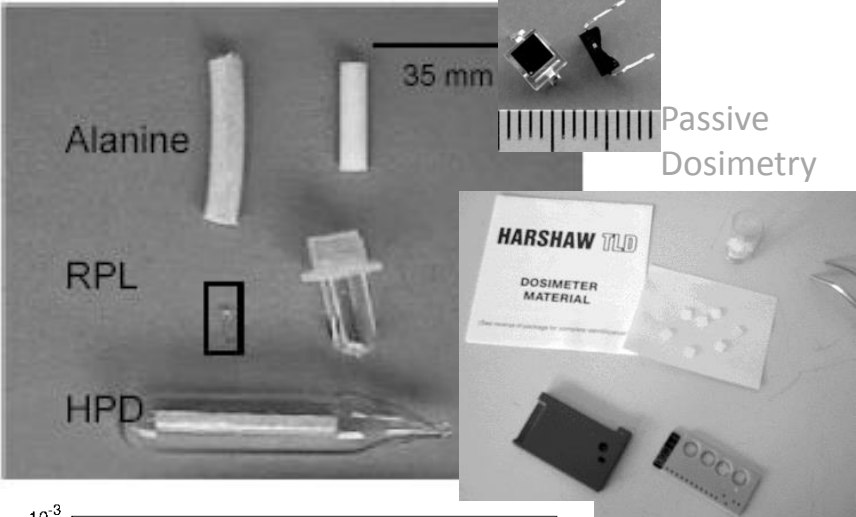


# Irradiation Experiment Workflow in IRRAD

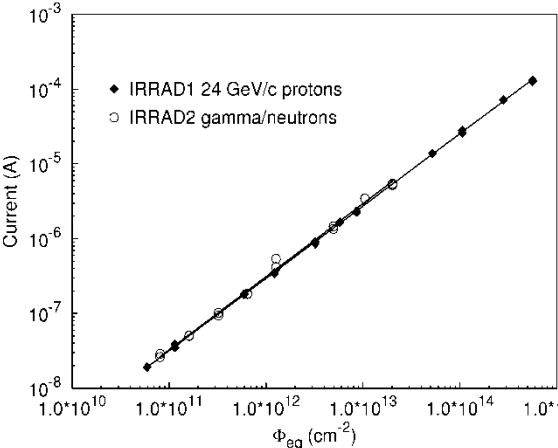
©Icons made by www.flaticon.com



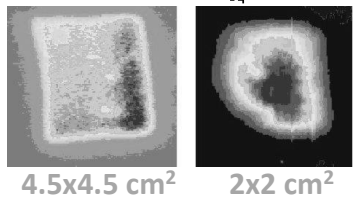
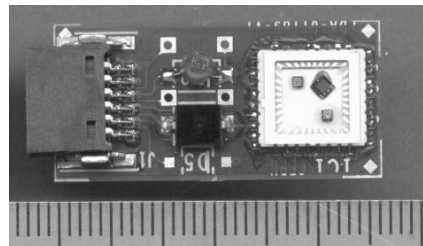
# Dosimetry & Radiation Monitor



Beam Profile / Intensity from Activation of Aluminium foils



Calibration curves Si-particle detectors



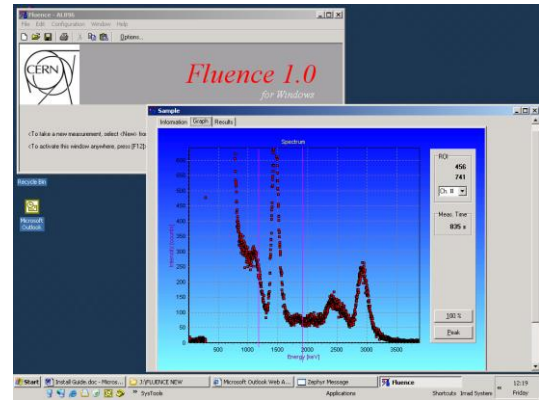
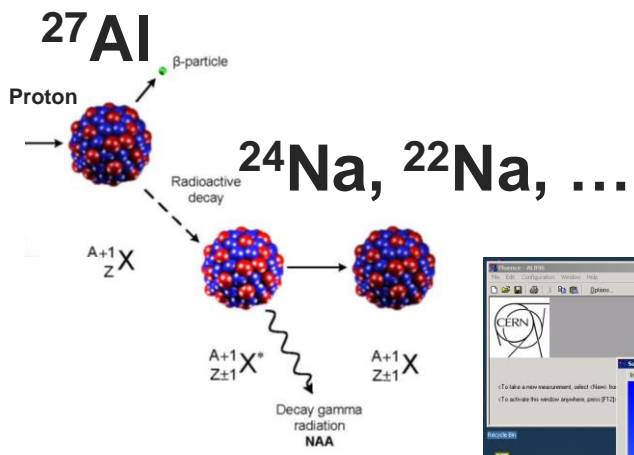
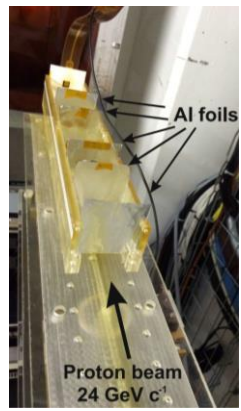
Proton beam spot characterized with GAF films

$(^{27}Al(p,3pn)^{24}Na, ^{27}Al(p,3p3n)^{22}Na)$   
 1x NaI spectrometer (+/- 6%)  
 $^{24}Na$ , half-life 15h,  $E\gamma = 1368.53$  keV  
 2x HpGe spectrometer (+/- 2%)  
 $^{24}Na, ^{22}Na$ , half-life 2.6y,  $E\gamma = 1274.54$  keV





# Activation-foil Dosimetry



1.

2.

3.

4.

Aluminum-foils preparation

Beam exposure / activation

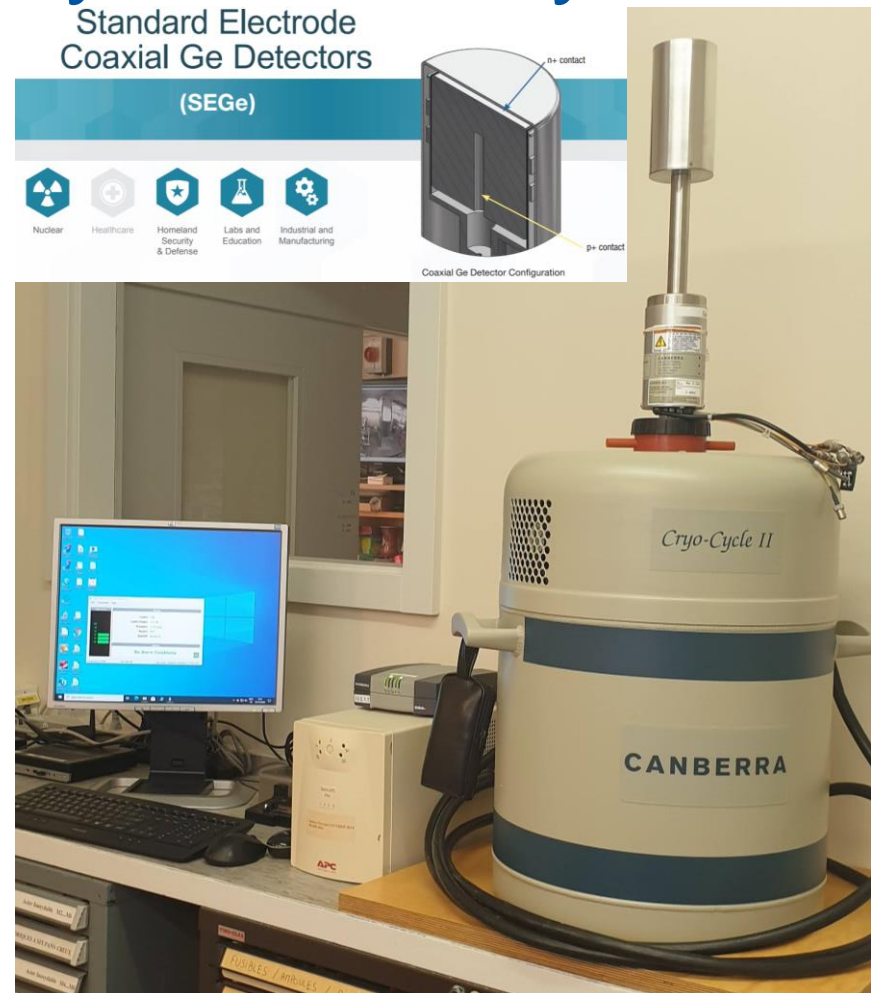
Gamma Spectrometry

Proton Fluence Calculation



# Upgrade of Spectrometry Laboratory

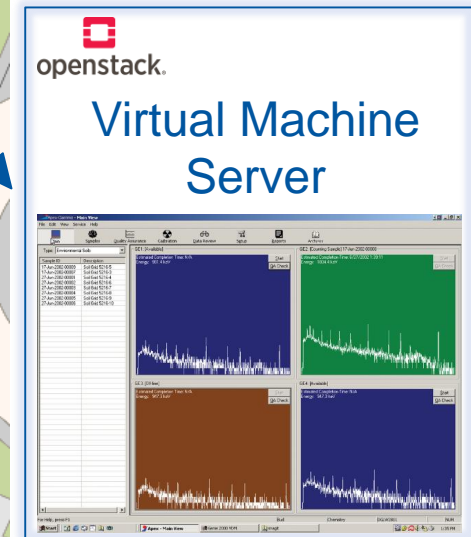
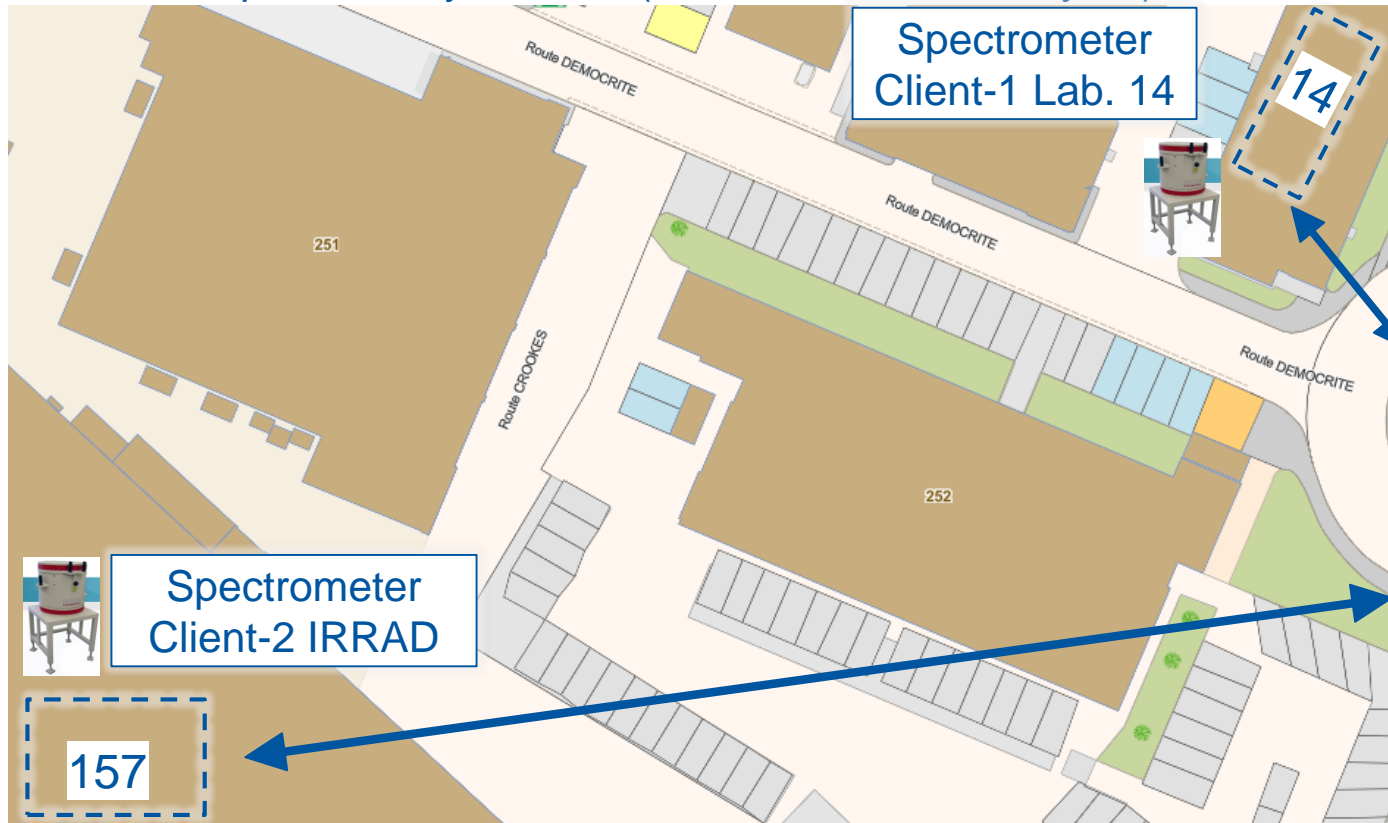
- New HPGe detector (1998) recovered from HSE-RP:
  - refurbished (~x5 cheaper)
  - coupled to *Cryo-Cycle II* (LN<sub>2</sub>) and new DAQ (**client-2**)
  - full lead background shield
- New measurement Lab in bld. 157 after the LS2:
  - Increase measurement capabilities (<sup>24</sup>Na Al-samples)
  - Decrease number of transports to Lab in bld. 14 (<sup>22</sup>Na Al-samples)





# Dosimetry Results

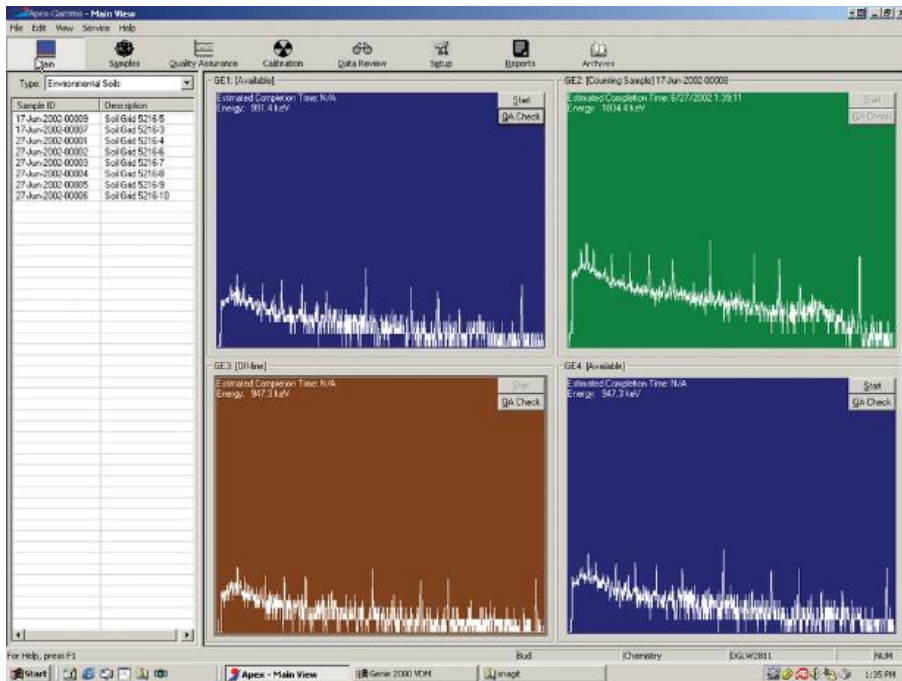
- Canberra (Mirion) Software (Apex-Gamma) installations
- Collaboration with HSE-RP
- New software architecture
  - Openstack Virtual Machine (VM) Server
  - 2 spectrometry stations (IRRAD and Laboratory 14)





# Dosimetry Results

- Dosimetry measurements through proprietary software **New**
- Dosimetry data calculation through post-processing software **Future Work**
- Dosimetry results through IDM **Future Work**



Canberra (Mirion) software

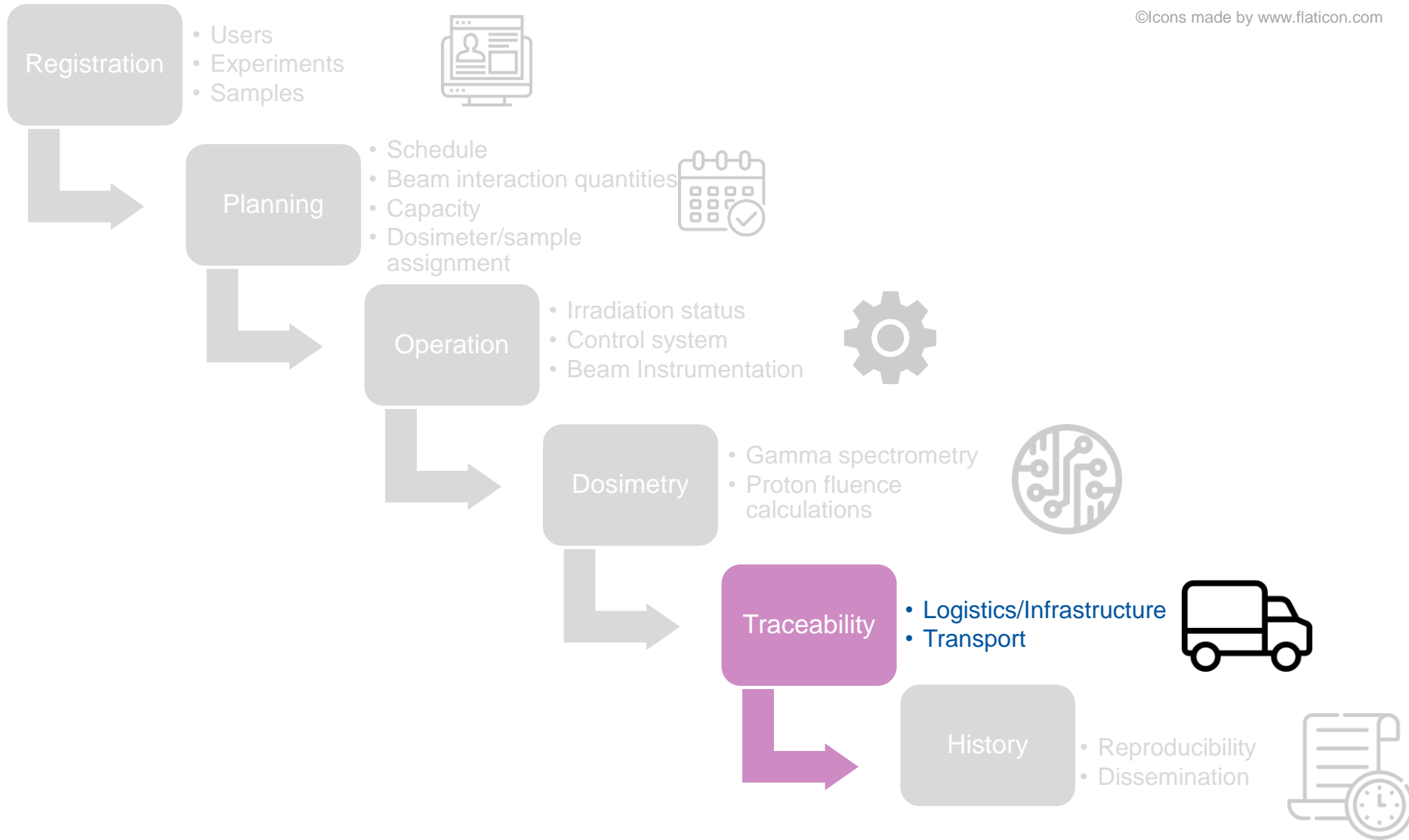
The screenshot shows the 'IRRAD Data Manager' web interface. The page title is 'IRRAD Data Manager' and the subtitle is 'Materials for Sample Holder samples'. There is a search bar and a '+ New Sample' button. A table lists the materials, with columns for 'Last update', 'ID', 'Name', 'Category', 'Requested fluence', 'Radiation / Nu. Coll. / Nu. Int. Length Occupancy (%)', 'Last updated by', and 'Actions'. The table contains five rows of data, each with a 'Results' button and a 'More' button. A green arrow points from the software screenshot to this table.

Last update	ID	Name	Category	Requested fluence	Radiation / Nu. Coll. / Nu. Int. Length Occupancy (%)	Last updated by	Actions
07/08/2018	SET-003282	ULTEM1000	Passive standard 10x10 mm <sup>2</sup>	1e17	0.527 / 0.38 / 0.282	blerina.gkotsse@cern.ch	Results More
13/08/2018	SET-003253	PEEK	Passive standard 10x10 mm <sup>2</sup>	1e17	0.314 / 0.305 / 0.223	blerina.gkotsse@cern.ch	Results More
07/08/2018	SET-003254	Carbon Fiber	Passive standard 10x10 mm <sup>2</sup>	1e17	0.211 / 0.152 / 0.105	blerina.gkotsse@cern.ch	Results More
07/08/2018	SET-003255	Aluminum Lid	Passive standard 10x10 mm <sup>2</sup>	1e14	0.112 / 0.039 / 0.025	blerina.gkotsse@cern.ch	Results More

Results availability in IDM

# Irradiation Experiment Workflow in IRRAD

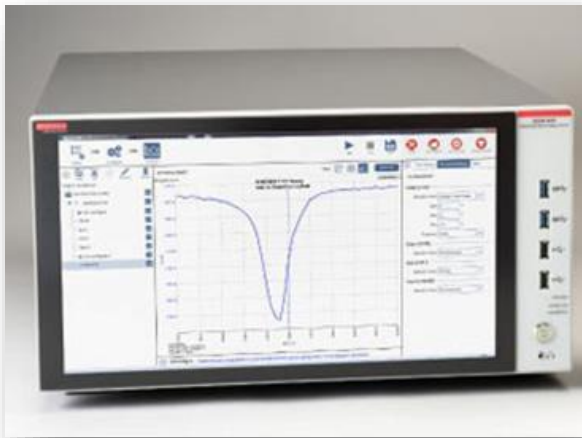
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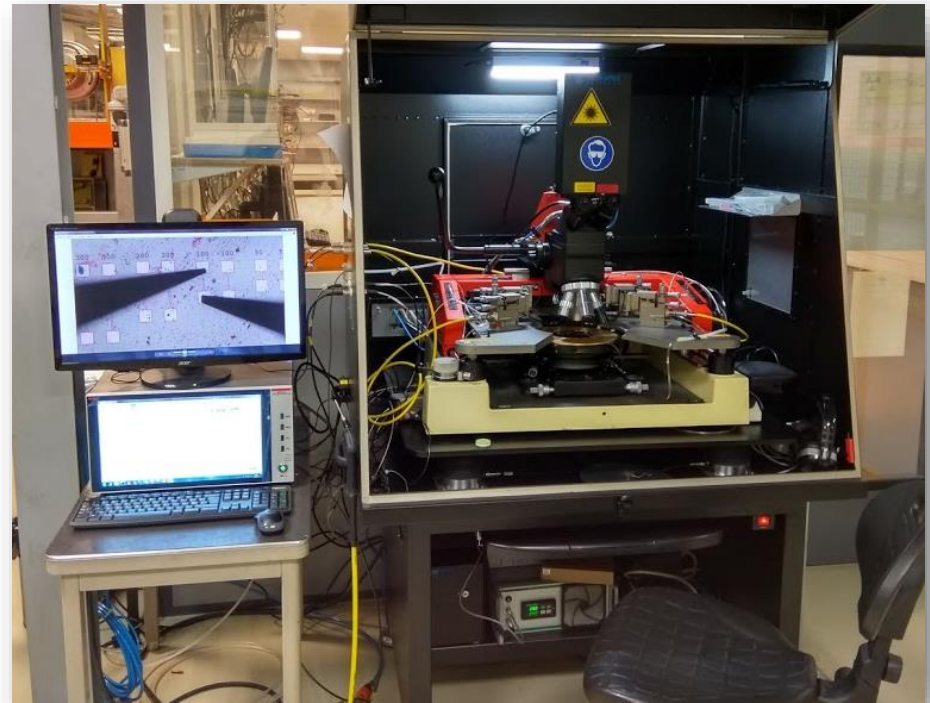


# Measurement Laboratory at IRRAD Facility

- New detector technologies need proper equipment to be characterized at both wafer level and for packaged-part testing
- A configurable bench top system for characterizing devices
- **Suss PM8 Probe Station** (4 manipulators, thermo-chuck 5-125 °C and a vibration isolated table in EM isolated dark box)
- **Keithley 4200A SPA**



+ **Keithley 2657A Extension**  
High Voltage SMU up to 3000V

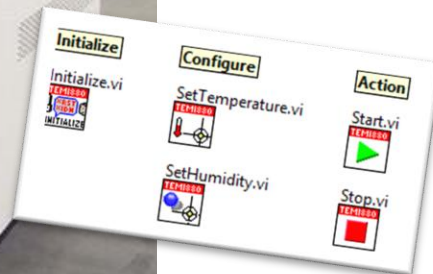
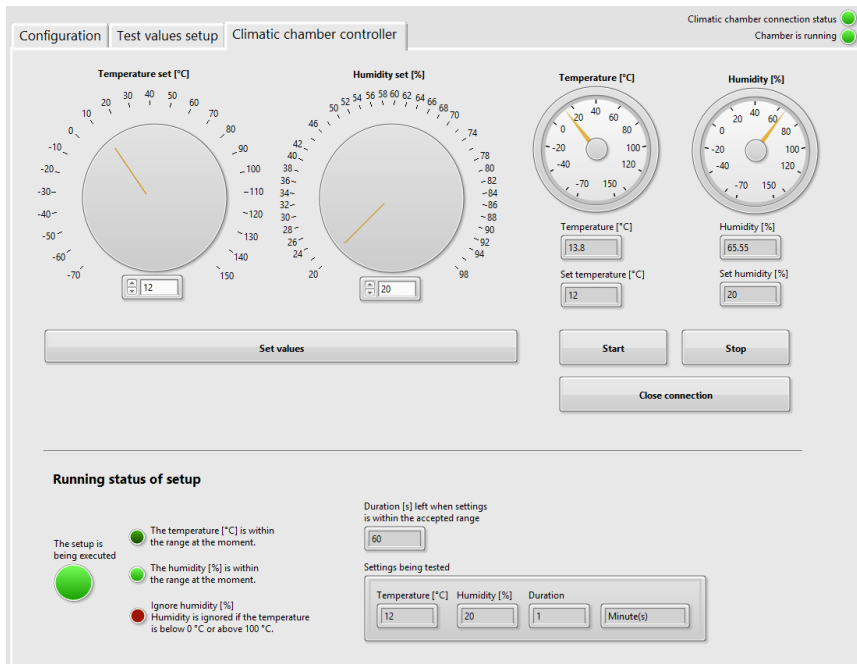


Probe station



# Measurement Laboratory

- TH100 **Temperature and Humidity Test Chamber** (LIB Industries)
  - Internal dimensions: 40x50x50 cm<sup>3</sup>
  - Volume: 100 litres
  - Temp. range: -70 to 150 °C
  - RH range: 20-98%
- LabVIEW Control system: VI function blocks & controller**



Calibration test-bench and LabVIEW-based DAQ for the RADMON portable readout system, Jes Rydall Larsen, AIDA-2020-NOTE-2020-002

J. Larsen  
I. Mateu  
(EP-DT 2019)



# Extension of Technical Area

- Reduce transport of irradiated material
- Increase storage / handling capabilities
- Provide users with advanced samples characterization tools

Current status  
(after COVID)



Conventional  
Storage

Spectrometer  
(client-2)

NEW

Operational  
Storage

New  
Access

High Activity  
Storage Bunker

Measurement  
Laboratory

Medium Activity  
Laboratory Bunker



# Traceability

Mandatory traceability of tested components according to French and Swiss regulations

**TREC** [Flags] [Logout]

Actions Search Equipment code Location Request Details Confirm

**Equipment Details**

Equipment: PXXISET001-CR003122  
 Other ID: SET-003122  
 Description: Sample Sets  
 Equipment Responsible: 124596 - CURRAS RIVERA ESTEBAN 75817

**Equipment comments**

ECR: 20-Jan-2018 16:03:35 by Esteban Curras Rivera  
 07-Mar-2019 10:30:12 by Esteban Curras Rivera  
 Lgafs modules

BG: Enter new comment here

MENU BACK NEXT



Use cases

CERN Accelerating science | Signed in as: | Sign out | Directory

HOME EXPERIMENTS BPM IRRAD INFO PREFERENCES

IRRAD Data Manager

TREC Data of Sample SET-003122 [Edit]

**Identification**

Code: PXXISET001-CR003122  
 Serial Number: SET-003122  
 Description: Sample Sets  
 Current location: 2S/2-019  
 Value: 1 CHF

**Characteristics**

Length: 1 cm  
 Width: 0.1 cm  
 Height: 0.002 cm  
 Weight: 0.1 kg  
 Family: -  
 Material: -

TREC data in IDM

TREC system

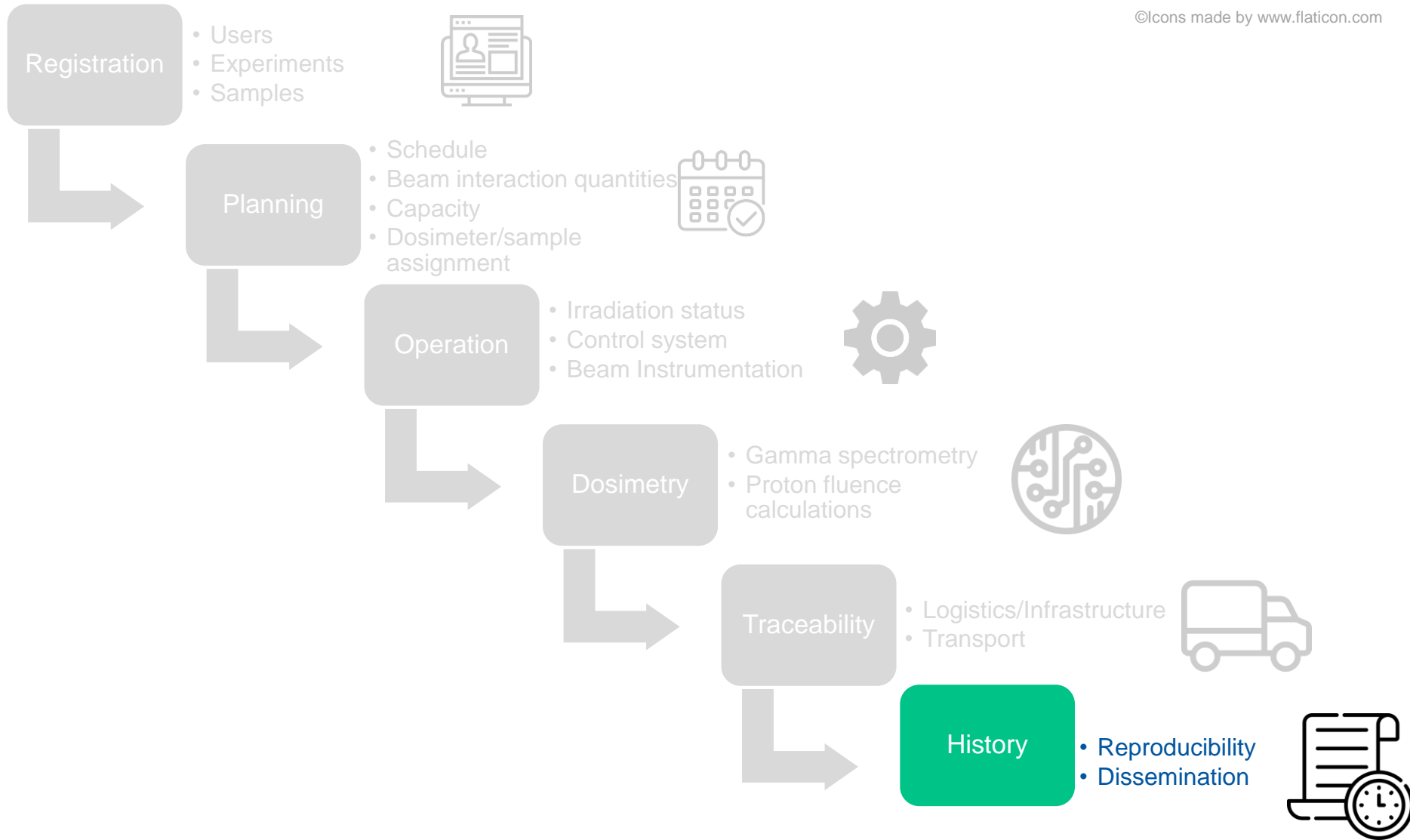


TREC Label

A. Nunez (EP-DT)

# Irradiation Experiment Workflow in IRRAD

©Icons made by www.flaticon.com



# History

Keeping experiments history for:

- documentation
- reproducibility
- optimisation
- dissemination

The screenshot shows the IRRAD Data Manager interface. At the top, it says 'CERN Accelerating science' and 'Signed in as: [user]'. The navigation bar includes 'HOME EXPERIMENTS BPM IRRAD INFO - PREFERENCES'. The main title is 'IRRAD Data Manager'. Below that, the specific experiment is titled '3D pixel for ATLAS ITk'. There are 'Back' and 'Add additional comments or publications' buttons. The 'Experiment Details' section includes: Title: 3D pixel for ATLAS ITk; Description: Study of radiation hardness of 3D silicon pixel sensors for the innermost pixel layer of ATLAS ITk with fluences up to 2e16 neq/cm2. Both FE14 prototypes and modules with the new RD53A readout chip are going to be tested.; CERN experiment/Projects: ATLAS ITk Pixel; Responsible person: joern.lange@cern.ch; Irradiation type: Protons; Additional comments: Important to characterise the new RD53A readout modules for ATLAS ITk pixel before the LHC/SPS shutdown in 2019/20. The 'Samples Details' section includes: Category: Passive Custom; Type: Room temperature; Irradiation area: 20x20mm2; Modus operandi: Pixel modules on the ATLAS 10x10cm2 PCBs like last year; ideally wide beam (20x20mm2) at end of beam line; Fluences: 1e16 Protons/cm2 2e16 Protons/cm2 3e16 Protons/cm2; Types of samples: Silicon sensor + readout chip bump-bonded; Dosimetry results: SET-002469 with dosimeter 5x5 mm2: 1.200e+16 Protons/cm2; SET-002469 with dosimeter 10x10 mm2: 1.234e+15 Protons/cm2; SET-002469 with dosimeter 80x80 mm2: 1.202e+18 Protons/cm2.

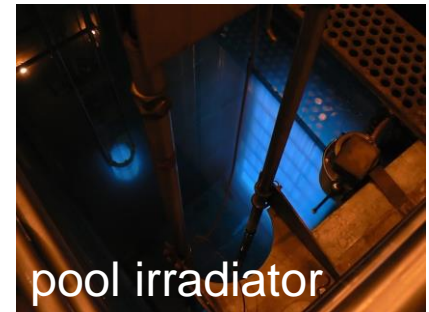
See previous EP-DT seminar (<https://indico.cern.ch/event/952416/>) – Material DB

# Outline

- Proton Irradiation Facility (IRRAD)
- Software and Hardware Upgrades for IRRAD
- **Software Developments for Users Community**
- Towards Common Tools for Irradiation Facilities

# External Facilities

- Some irradiation experiments cannot be performed at CERN
  - DD, SEE in accelerator environment (**p<sup>+</sup> low-E / Heavy Ions**)
  - TID, Polymers degradation (**strong  $\gamma$ -sources**)
  - Displacement in metals (**n<sup>0</sup> reactors / spallation sources**)
  - etc.
- CERN facilities not always available
  - Accelerators Technical Stops, maintenance, upgrades, etc. (months)
  - **Long Shutdown periods** (years!)
- Need for information about worldwide external facilities
  - **CERN experimental community** is very diverse (**not only for irradiation experiments**)
  - Need of **irradiation services** for some applications
  - Fostering new collaborations, etc.





# Irradiation Facilities Online Database

- Online database platform for searching irradiation facilities at **CERN** and **worldwide**
- Coordinators **inserting/updating** data
- **Annual reminders** for keeping data up-to-date
- **240** irradiation facilities
- **5500** visits from around the world
- Launched in 2017



**Facilities Database**

This database contains a list of several different irradiation Facilities available at CERN, in Europe and Worldwide. To show whole database, click on "Show Data". To search by Country, Source Type, or Radiation Field select your filter in the dropdown menu. If you would like to add a new facility, please first log in and then click on "Add Facility". You can only modify the facilities that you are responsible for. For further details please check our User Guide.

Details:	Institute Name	Country:	Facility Name:	Source Type:	Radiation Field Type:	Funding Details:
	UUV Fac	Czech Republic	Prague reactor			
	Uppsala University	Sweden	NESSA	Neutron generator	Neutron	
	University of Ljubljana	Slovenia	Reactor Centre	Nuclear reactor - TRIGA Mark II	Gamma	AIDA 2020 TA
	University of Jyväskylä DEPARTMENT OF PHYSICS	Finland	PROTON facility ZYFL K-130 cyclotron	Cyclotron	Proton	
	University of Jyväskylä DEPARTMENT OF PHYSICS	Finland	Heavy ions facility ZYFL K-130 cyclotron	Cyclotron	Heavy ions	
	University of Groningen	Netherlands	Irradiations of Materials (ACORF IM)	Cyclotron	Proton, Alpha, Heavy ions	
	University of California Davis	USA	MCCellan Nuclear Research Center	TRIGA Mark II	Neutron	
	University of Birmingham	United Kingdom	UoB MCR	Cyclotron	protons and light ions	AIDA 2020 TA
	URC (University Santiago Compostela)	Spain	Gamma facility	Co-60	Gamma	

**CERN FACILITIES**

- IRRAD** (Proton Facility): The Proton Irradiation Facility (IRRAD) is located on the TB beam-line in the Meyrin site East Area Proton Synchrotron (PS). For the irradiations, it uses a 240GeV/c proton beam.
- GIF+**: The new Gamma Irradiation Facility (GIF+) is located in the North Area. It contains a <sup>60</sup>Co source with a high-energy particle beam from the SPS H4 beam line.
- CHARM**: The Cern High energy Accelerator Mixed field facility (CHARM), located in the East Area, features a wide spectrum of radiation types and energies.
- HiRadMat** (High Radiation of Materials): The High-Radiation to Materials facility (HiRadMat), located in the Meyrin Site on the SPS accelerator is designed to provide High-Power LHC-type pulsed beams.
- CERF** (CERN-EU High-energy Reference Field): The CERN-EU high-energy Reference Field (CERF) is located in the North Area providing a neutron field for characterization of dosimetry at commercial flight altitudes and in space.
- CALLAB**: This new dedicated state-of-the-art facility replaces the ageing facility in building 172 (~30 years old). It houses several irradiation sources including the <sup>60</sup>Co source of CC60.
- CC60** (CERN Co-60): The CC60 facility, located in the same building as CALLAB, uses a <sup>60</sup>Co for the qualification of components against TID effects.
- VESPER** (Very Energetic Space Planetary Exploration Reference): The Very energetic Electron facility for Space Planetary Exploration missions in harsh Radiative environments, situated in CTF3, is a high energy electron beamline for radiation testing.
- X-Ray Facilities**: At CERN there are many X-ray irradiation facilities which are included in the database. Please click on the button to view a full list of the X-ray facilities at CERN.

<http://cern.ch/irradiation-facilities>

# Test Beam Facilities Database

- Request for test-beam database
- Similar functionalities**
- 16 test beam facilities**
- 27 beamlines**
- Launched in 2020

**Test Beamlines Database**

This database contains a list of several different Test-Beam Facilities available at CERN, in Europe and Worldwide.

Search by Country: Switzerland | Search by Particle Type: protons

[Show All](#)

[Log In to Edit Data](#)

Facility Name	Institute Name	Beamline Name	Country	Particle Type	Particle Energy	Coordinator
CERN SPS	CERN	H2	Switzerland	electrons, protons, hadrons, muons, ions	10-400GeV/c	sps.coordinator@cern.ch
CERN SPS	CERN	H8	Switzerland	primary protons, hadrons, muons, electrons, ions	10-400GeV/c	sps.coordinator@cern.ch
piE1, piM1	Paul Scherrer Institute (PSI)	Beamline	Switzerland	pions, muons, positrons, protons	50-450 MeV/c	davide.reggiani@psi.ch
PIF	Paul Scherrer Institute (PSI)	Beamline	Switzerland	protons	5 - 230 MeV/c	wojtek.hajdas@psi.ch

**CERN FACILITIES**

**CERN PS**

The Proton Synchrotron (PS) is a key component in CERN's accelerator complex, where it usually accelerates either protons delivered by the Proton Synchrotron Booster or heavy ions from the Low Energy Ion Ring (LEIR).

[ID ENTRY](#) [WEBPAGE](#)

**CERN SPS**

The Super Proton Synchrotron (SPS) is the second-largest machine in CERN's accelerator complex. It takes particles from the PS and accelerates them to provide beams for the LHC, the NA61-CHINE and NA62 experiments, the COMPASS experiment.

[ID ENTRY](#) [WEBPAGE](#)

**clear**

The primary focus for CLEAR is general accelerator R&D and component testing and possible future machines at CERN, based on a broad internal and external community.

[ID ENTRY](#) [WEBPAGE](#)

**Test Beam Facilities Database**

Map showing the locations of test beam facilities across Europe, including CERN in Switzerland, PSI in Switzerland, and various facilities in Germany, France, and the UK.

<http://cern.ch/tbdb>

# CERN Directory

← → ↻ ⓘ directory.web.cern.ch ☆ Incognito

- IPT - Industry, Procurement & Knowledge Transfer
- SMB - Site Management and Buildings

Outreach

HSE - Occupational Health & Safety and Environmental Protection unit

## Experiments and projects

*Experiment, project and collaboration websites*

- CERN experiments (Grey Book)
- AEGIS
- ALICE
- ALPHA
- AMS
- ASACUSA
- ATLAS
- ATRAP
- AWAKE
- BASE
- CAST
- CERN Neutrino Platform
- CLIC
- CLOUD
- CNGS
- CMS
- COMPASS
- DIRAC
- ELENA
- FASER
- FCC
- GBAR
- HL-LHC
- Irradiation Facilities
- ISOLDE
- LHCb
- LHCf
- LIU project
- MoEDAL
- NA61/SHINE
- NA62
- NA64
- nTOF
- OSQAR
- PBC
- SHIP
- Test Beam Facilities
- TOTEM
- UA9
- WLCG

## Applications

*Commonly-used applications*

- ADaMS
- AIS Roles
- Book a room
- EDH
- EDMS
- E-groups
- CDS
- CET
- HRT
- IMPACT
- Indico
- OracleHR
- Phonebook
- Qualiac
- Learning Hub
- SNOW

## Admin and procedures

*Administrative procedures at CERN*

- Admin e-guide
- CERN design guidelines
- Computing accounts
- Users' Office

## Maps and access

*Finding a building, getting around*

<https://directory.web.cern.ch/#experiments>

## JUMP TO SECTION

- News and events
- Sectors, departments and units
- ← Experiments and projects
- Applications
- Admin and procedures
- Maps and access
- Accelerators and physics
- Documents, reports and publications
- Committees and council
- Working at CERN
- Life at CERN
- Training and development

# Outline

- Proton Irradiation Facility (IRRAD)
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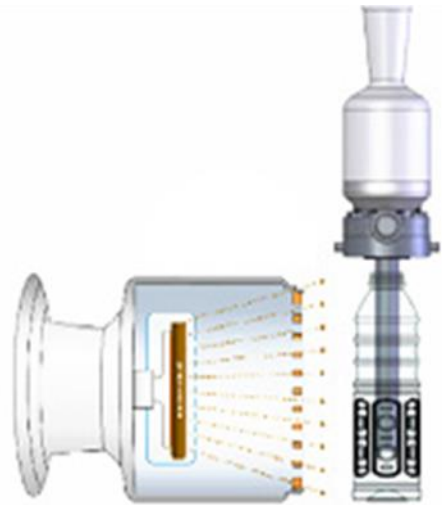
# Irradiation Experiments



CERN Large Hadron Collider (LHC)  
©cds.cern.ch



NASA's Orion spacecraft  
©arstechnica.com



Bottle sterilization by electron beam irradiation  
©Courtesy Frank-Holm Roegner

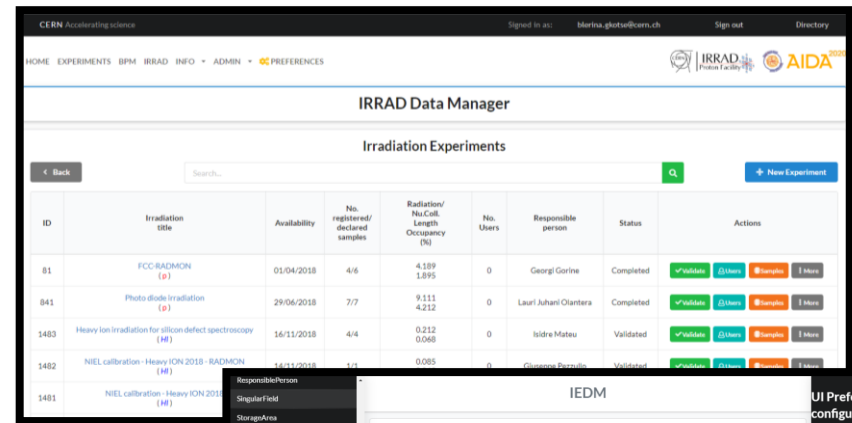
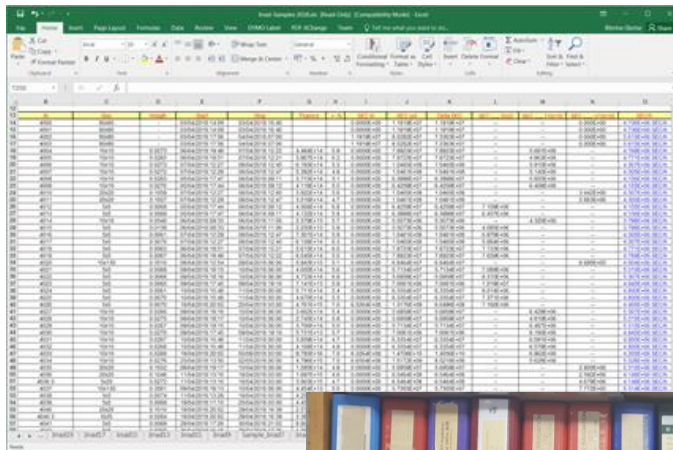


Clinac® iX System linear accelerator  
©medicalexp.com

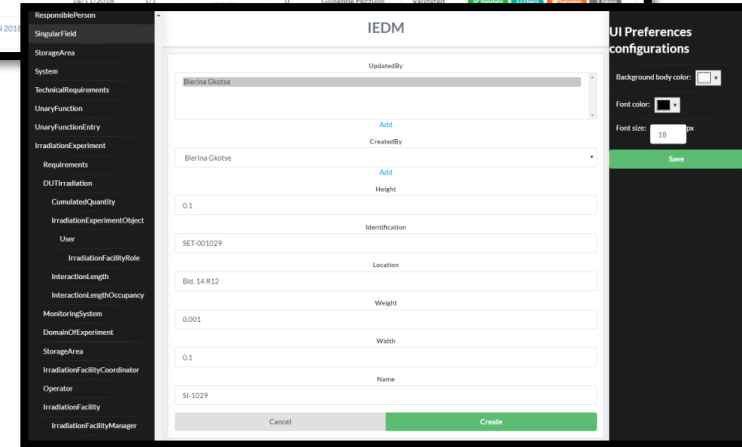


# Bridging the Gap in Data Management

- Knowledge sharing among communities
- Small experiments, no strong IT support
- User Experience
- ✓ Standardization
- ✓ Automatic generation of web applications
- ✓ UI personalization



ID	Irradiation title	Availability	No. registered/ declared samples	Radiation/ No.Coll. Length Occupancy (%)	No. Users	Responsible person	Status	Actions
81	FCC-BADMON (p)	01/04/2018	4/6	4.189 1.895	0	Georgi Gorine	Completed	✓ Addable ⬇️ Update ⬆️ Remove ⬇️ Help
841	Photo diode Irradiation (p)	29/06/2018	7/7	9.111 4.212	0	Lauri Ahanji Olantera	Completed	✓ Addable ⬇️ Update ⬆️ Remove ⬇️ Help
1483	Heavy Ion Irradiation for silicon defect spectroscopy (H)	16/11/2018	4/4	0.212 0.068	0	Ildre Mateu	Validated	✓ Addable ⬇️ Update ⬆️ Remove ⬇️ Help
1482	NIEL calibration - Heavy ION 2018 - BADMON (H)	14/11/2018	1/1	0.085	0	Christina Dorelli	Validated	✓ Addable ⬇️ Update ⬆️ Remove ⬇️ Help
1481	NIEL calibration - Heavy ION 2018 - BADMON (H)							



**IEDM**

Updated by: Birlinga Glotze

Add

Created by: Birlinga Glotze

Add

Height: 0.1

Identification: SET-001029

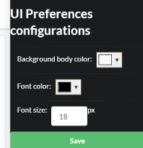
Location: Bld. 14 R12

Weight: 0.001

Width: 0.1

Name: SI-1029

Cancel Create



**UI Preferences configurations**

Background body color: [dropdown]

Font color: [dropdown]

Font size: [input]

Save



# Ontology Origin

Deriving from ancient Greek:

**Ontology = On (ὄν) + logos (λόγος)**

In philosophy:

**subject of existence**, science of being,  
"what exists" in the world

In computer science:

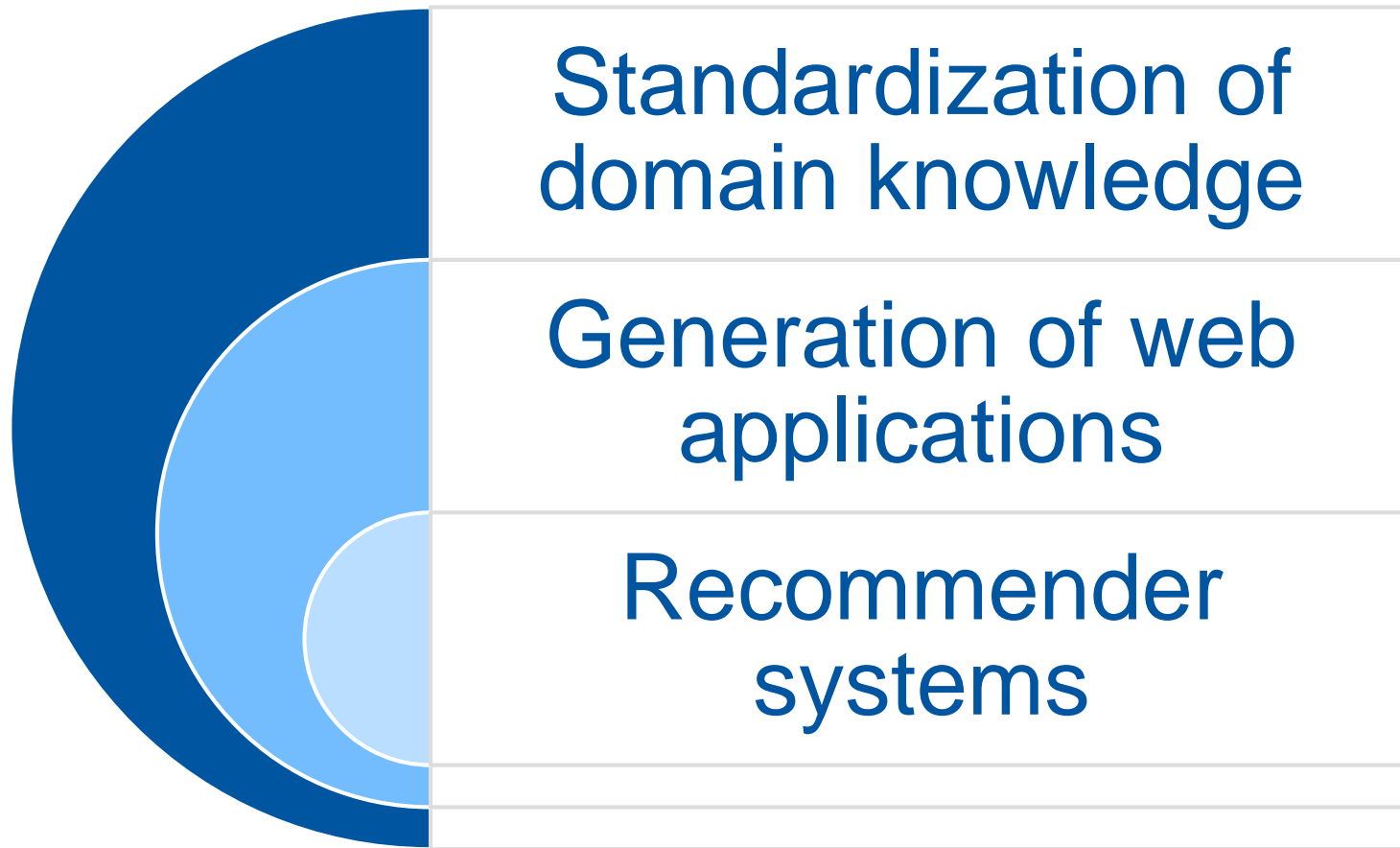
formal description and classification of "what exists",  
**what can be represented as a knowledge fact**



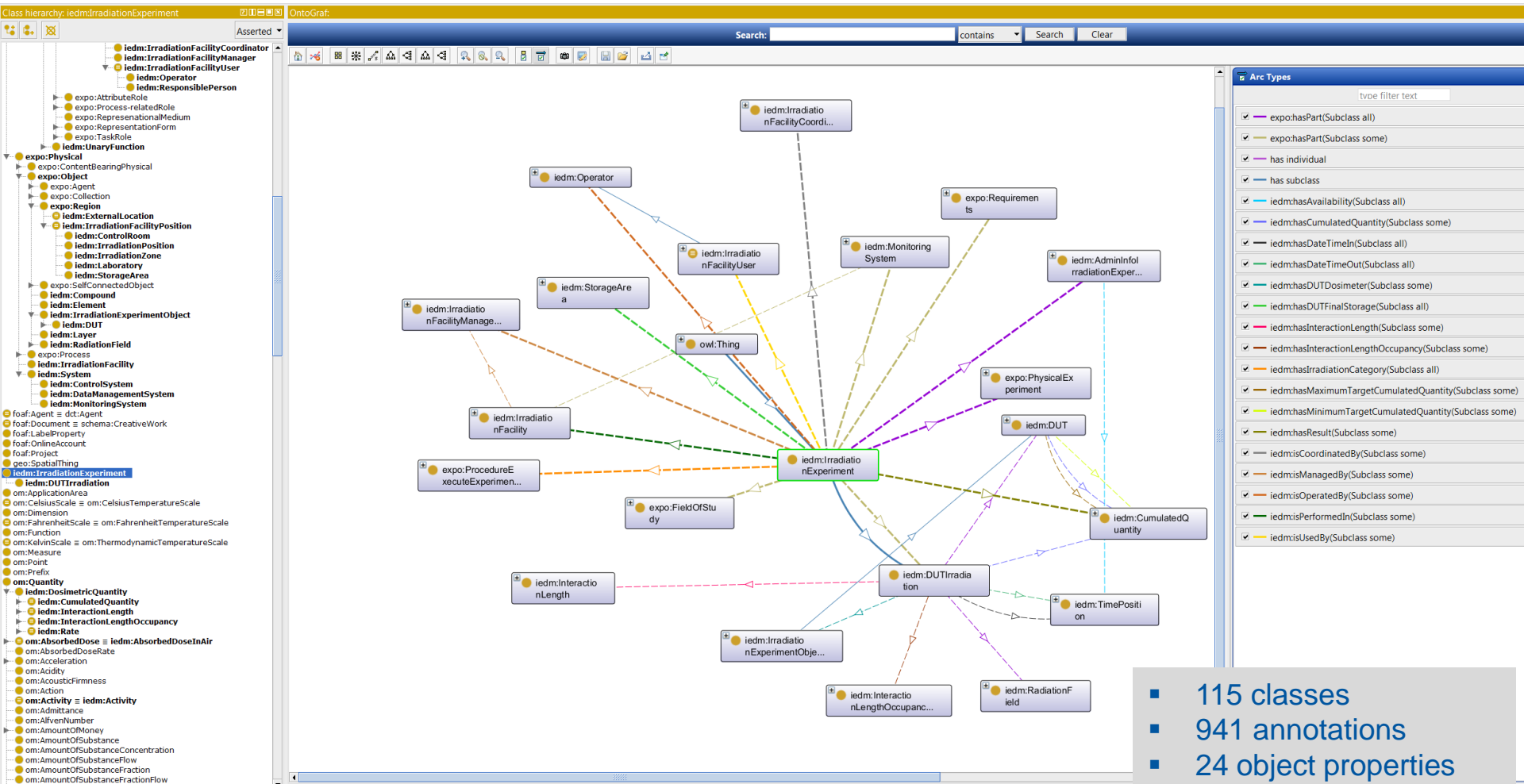
©shutterstock.com

*Aristotle*

# Ontology Use



# Irradiation Experiments Data Management (IEDM) Ontology



[www.cern.ch/iedm](http://www.cern.ch/iedm)

- 115 classes
- 941 annotations
- 24 object properties
- 16 data properties

# Web Application Generator (GenAppi)

Loading ontologies

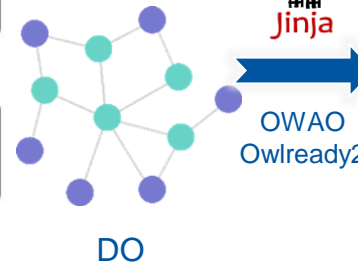
Transforming domain classes and object/data properties to Model classes and attributes

Generating Django view files for data operations (CRUD)

Creating Django Template and URLs files for the UI

Grouping files in specific directories

Migrating Model and server ready for start



```
django
class User(models.Model):
    hasRole=models.ManyToManyField("IrradiationFacilityRole")
    name=models.CharField(max_length = 50)
    surname=models.CharField(max_length = 50)
    email=models.CharField(max_length = 50)
    name=models.CharField(max_length = 50)
    def __str__(self):
        return self.name
```

Django Model

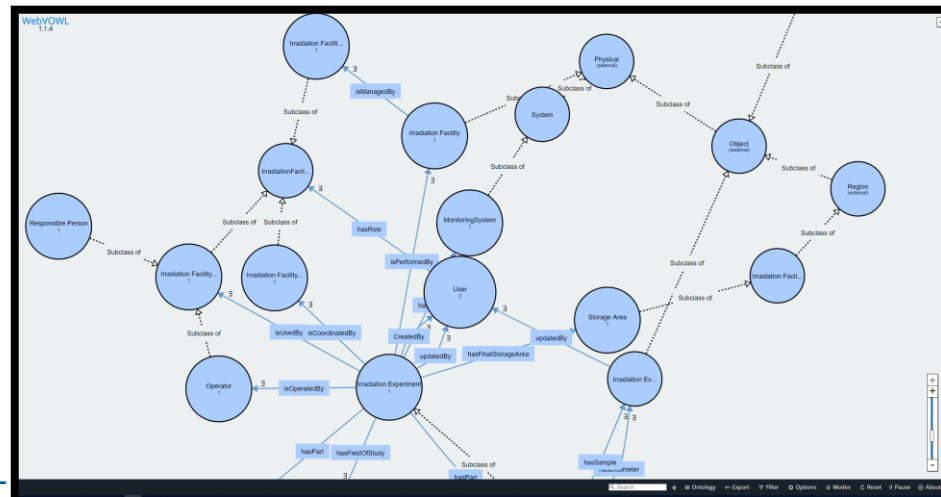


# IEDM Use Case

- Input form for each domain-ontology class instance:
  - Data properties = input fields
  - Object properties =
    - selection fields, links to the
    - corresponding class forms
- Django authentication and authorisation**
- UI adaptable to user's preferences**
- Visualisation of domain ontology**

The screenshot shows the IEDM web application interface. On the left is a dark sidebar with a list of domain ontology classes such as 'ResponsiblePerson', 'StorageArea', 'System', etc. The main area displays a form titled 'IEDM' with several input fields: 'UpdatedBy' (with a dropdown), 'CreatedBy' (with a dropdown), 'Height' (text input), 'Identification' (text input), 'Location' (text input), 'Weight' (text input), 'Width' (text input), and 'Name' (text input). Below the form are 'Cancel' and 'Create' buttons. On the right, a 'UI Preferences configurations' panel allows users to adjust 'Background body color', 'Font color', and 'Font size'.

*Registering an IrradiationExperimentObject instance*



*Visualisation using WebVOWL*

# User Interfaces Comparison: List Table

CERN Accelerating science Signed in as: blerina.gkotse@cern.ch Sign out Directory

HOME EXPERIMENTS BPM IRRAD INFO PREFERENCES

IRRAD Proton Facility AIDA 2020

## IRRAD Data Manager

### FCC-RADMON users

< Back Search... + New User

Name	Surname	E-mail	Telephone	Role	Actions
Blerina	Gkotse	blerina.gkotse@cern.ch	1111111	User	<a href="#">Edit</a> <a href="#">Remove</a>

IDM list table

- UnaryFunction
- UnaryFunctionEntry
- IrradiationExperiment
- Requirements
- DUTIrradiation
- CumulatedQuantity
- IrradiationExperimentObject
- User
- IrradiationFacilityRole
- InteractionLength

## IEDM

### User

[Create](#)

surname	email	name	hasRole	Actions
Gkotse	blerina.gkotse@cern.ch	Blerina	Responsible	<a href="#">View</a> <a href="#">Update</a> <a href="#">Delete</a>

### UI Preferences configurations

Background body color:

Font color:

Font size:  px

[Save](#)

IEDM\_APP list table



# Comparison of IDM and generated application

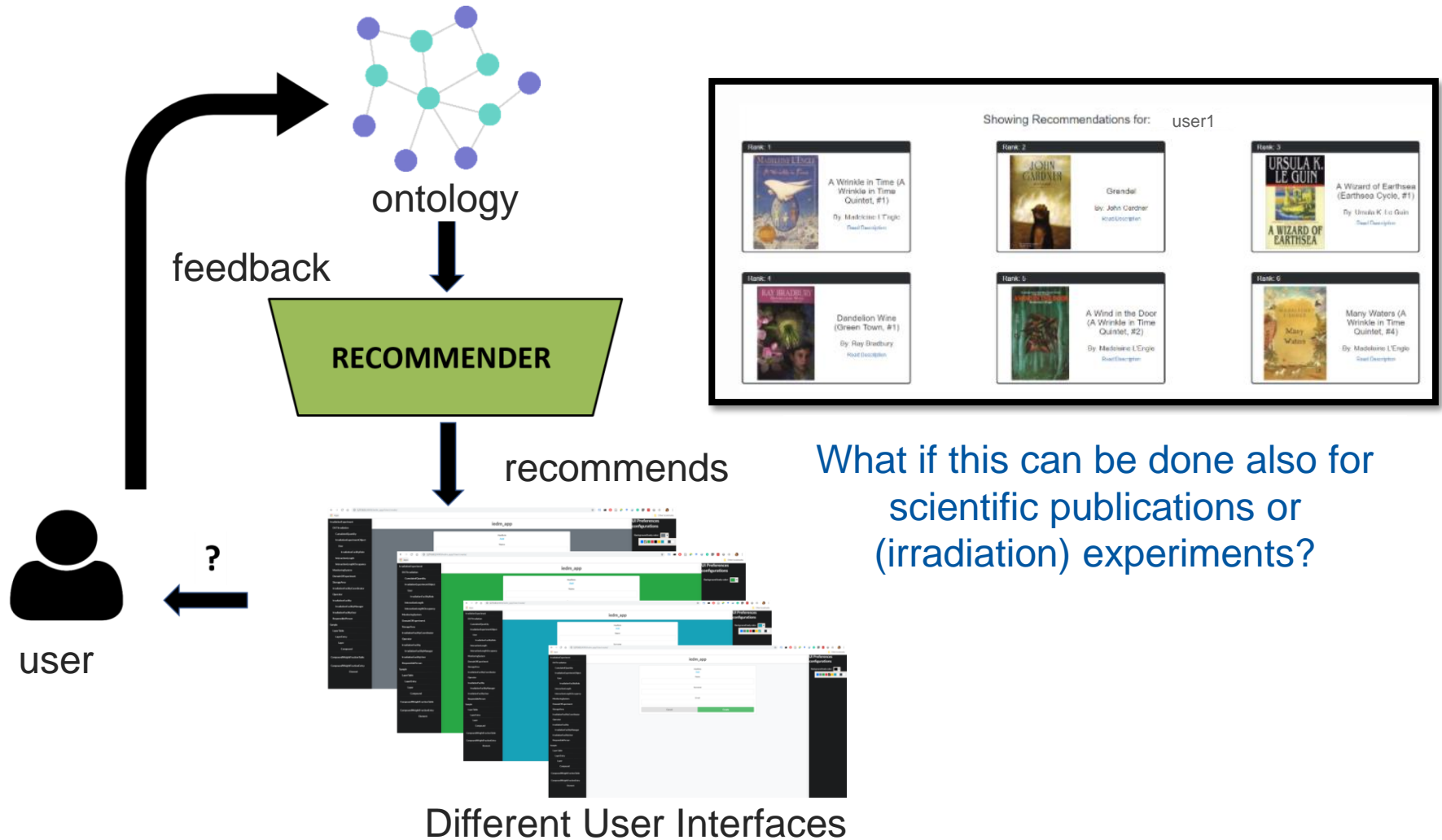
	IDM	Generated Application
Purpose	IRRAD facility data management	any domain
Software infrastructure	CERN	free and open-source
Storage	Oracle database	any relational database or ontology
Web Semantic technologies <sup>1</sup>	no	yes
Functionalities	more advanced	CRUD <sup>2</sup> operations

<sup>1</sup>Web Semantics, the field dealing with ontologies

<sup>2</sup>CRUD = Create, Read, Update, Delete


# UI Recommendations

Using recommender systems to suggest to users more user-friendly interfaces



What if this can be done also for scientific publications or (irradiation) experiments?

# Data Management Perspectives

- **Standardisation** of data management for irradiation experiments
  - Online documentation: [www.cern.ch/iedm](http://www.cern.ch/iedm)
  - Next planned work: **GIF++ data management**
- **Common tools** in the HEP community
  - IDM installed in the upcoming **FERMILAB** proton irradiation facility
  - Future extension to **ENEA-FNG**, collaboration with industry (**CAEN**)
  - Proposal in  **AIDA**  
innova
- More **user-friendly interfaces** with recommender systems
- Irradiation experiments **publications recommendations**
  - Interest from **NEC-labs Europe** for building recommender systems for scientific publications

# Conclusions

- **New software tools** for the support of the IRRAD irradiation experiments after LS2
- **New hardware (beam instrumentation,...), larger technical area and additional equipment**
- **Irradiation facilities and test-beam DBs** functional and used by the HEP community at large
- Working towards building **common tools** for irradiation experiments data management (at CERN and outside)

# Hardware and Software Upgrades for the Proton Irradiation Facility (IRRAD) after the LS2

Blerina Gkotse (EP-DT-DD)

*on behalf of EP-DT Irradiation Facilities Team:* **Martin Jaekel, Alexander Smith Mølholm, Alfredo Maria Nunez Herrero, Giuseppe Pezzullo, Federico Ravotti, Ourania Sidiropoulou**

*Former IRRAD members contributors:* **Isidre Mateu Suau, Viktoria Meskova**  
*MINES ParisTech:* **Pierre Jouvelot**

EP-DT Seminar  
28 October 2020



*This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.*

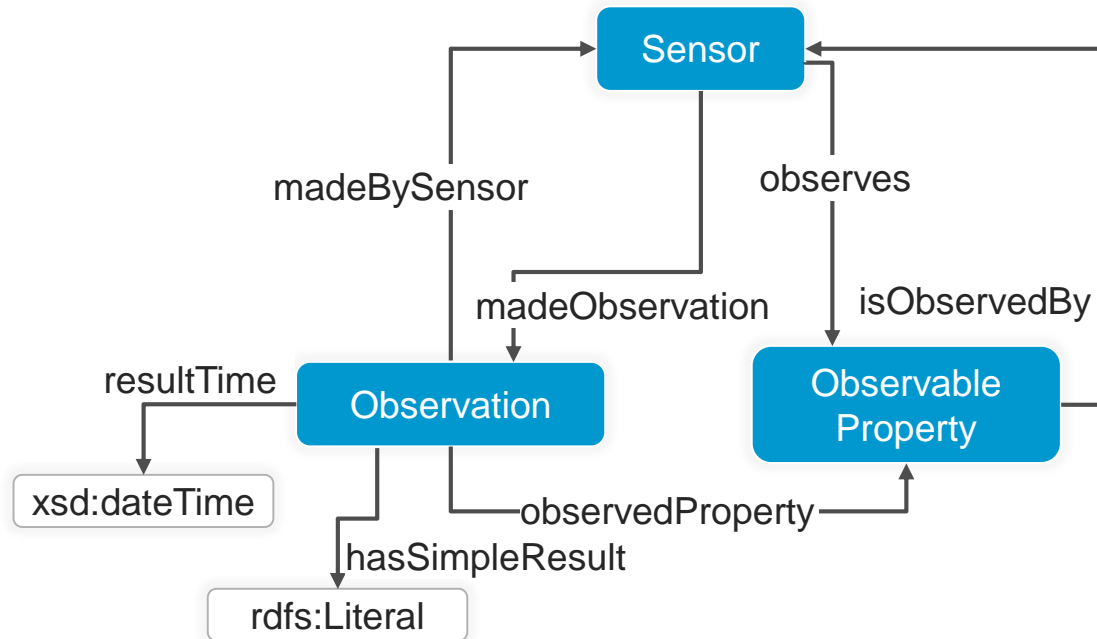


**AIDA** 2020



# Ontology: Structure

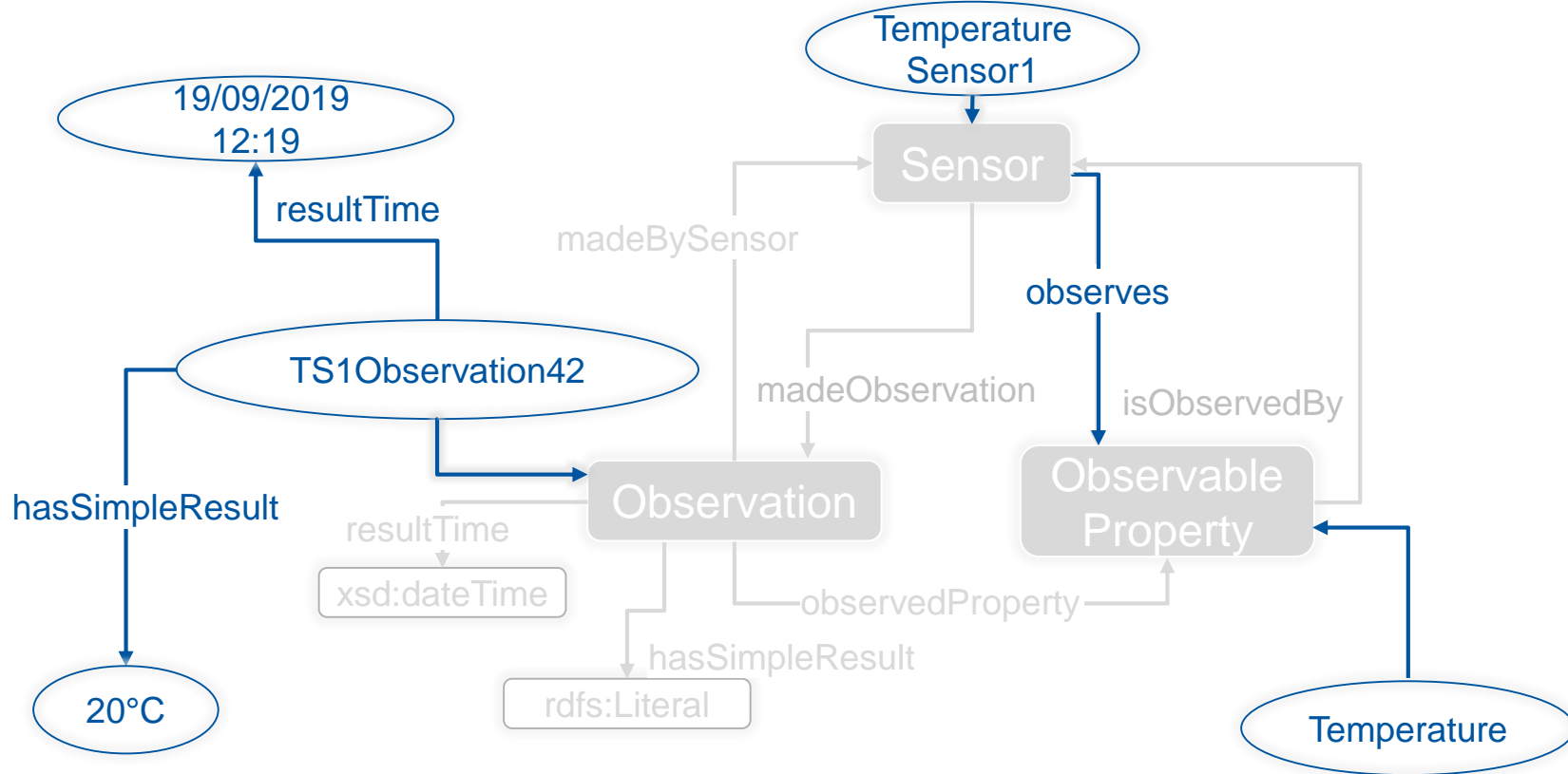
- **Class:** a set of entities of a specific domain of knowledge
- **Relation:** a semantic link among classes, also called **object property**
- **Property:** attribute of specific type, also called **data property**



*Excerpt from SOSA (Sensors, Observations, Samples and Actuators) ontology*

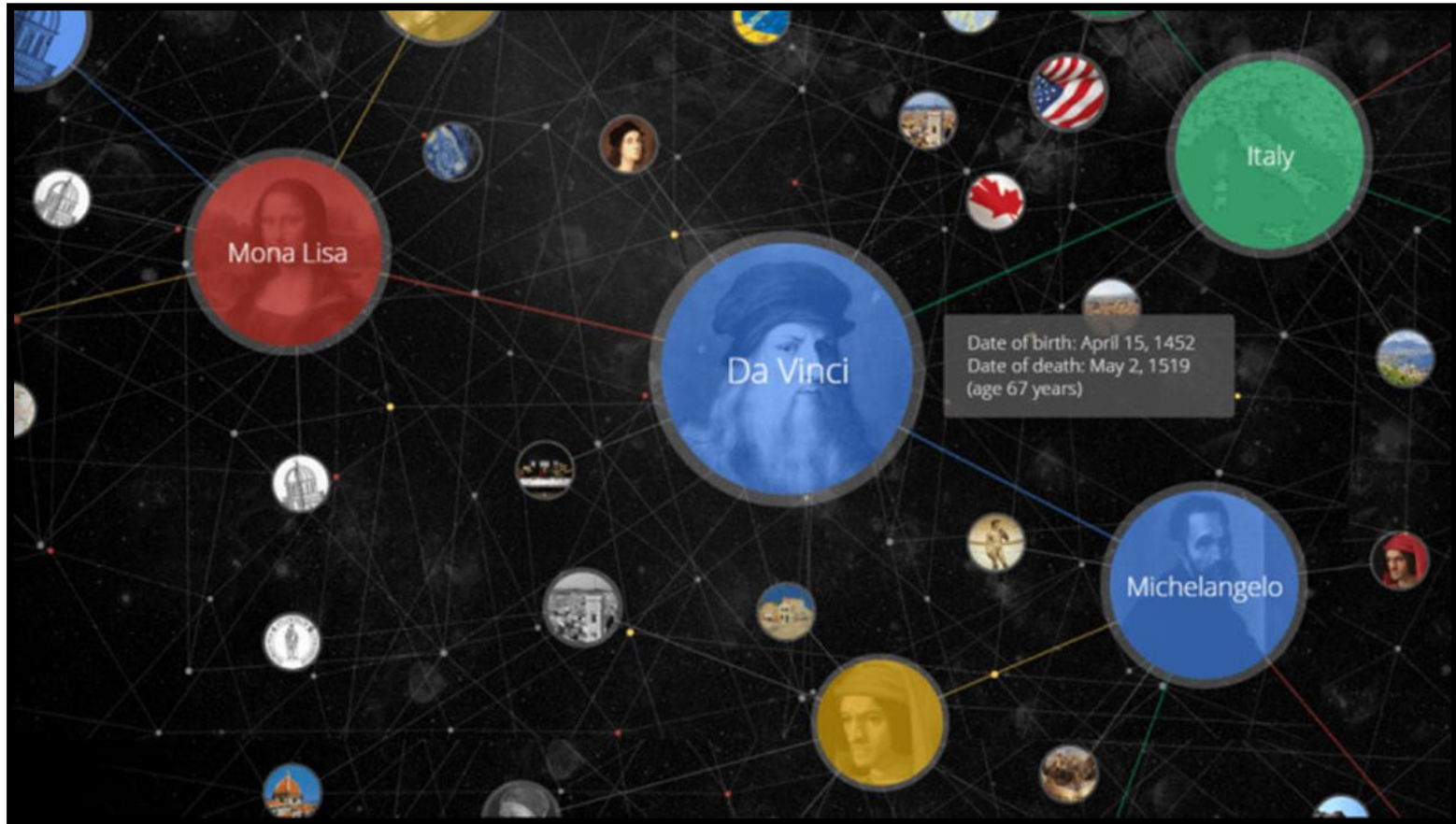
# Knowledge Base (KB)

- Individual instances of domain's classes
- RDF triples (Resource Description Framework)
- Stored in triple stores



# Knowledge Graph (KG)

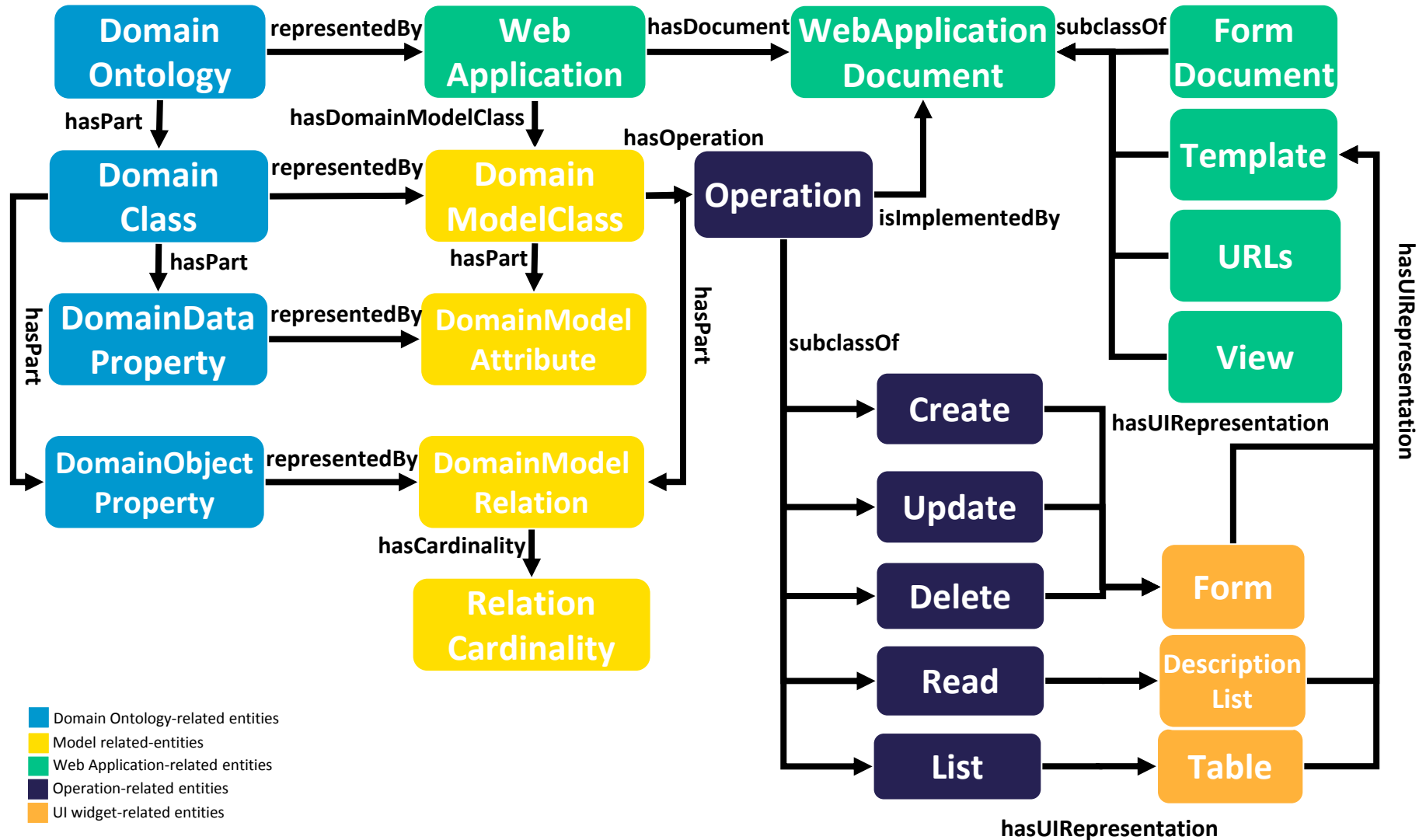
- Term coined by Google (2012)
- Knowledge bases from a variety of sources
- Used in academia and industry



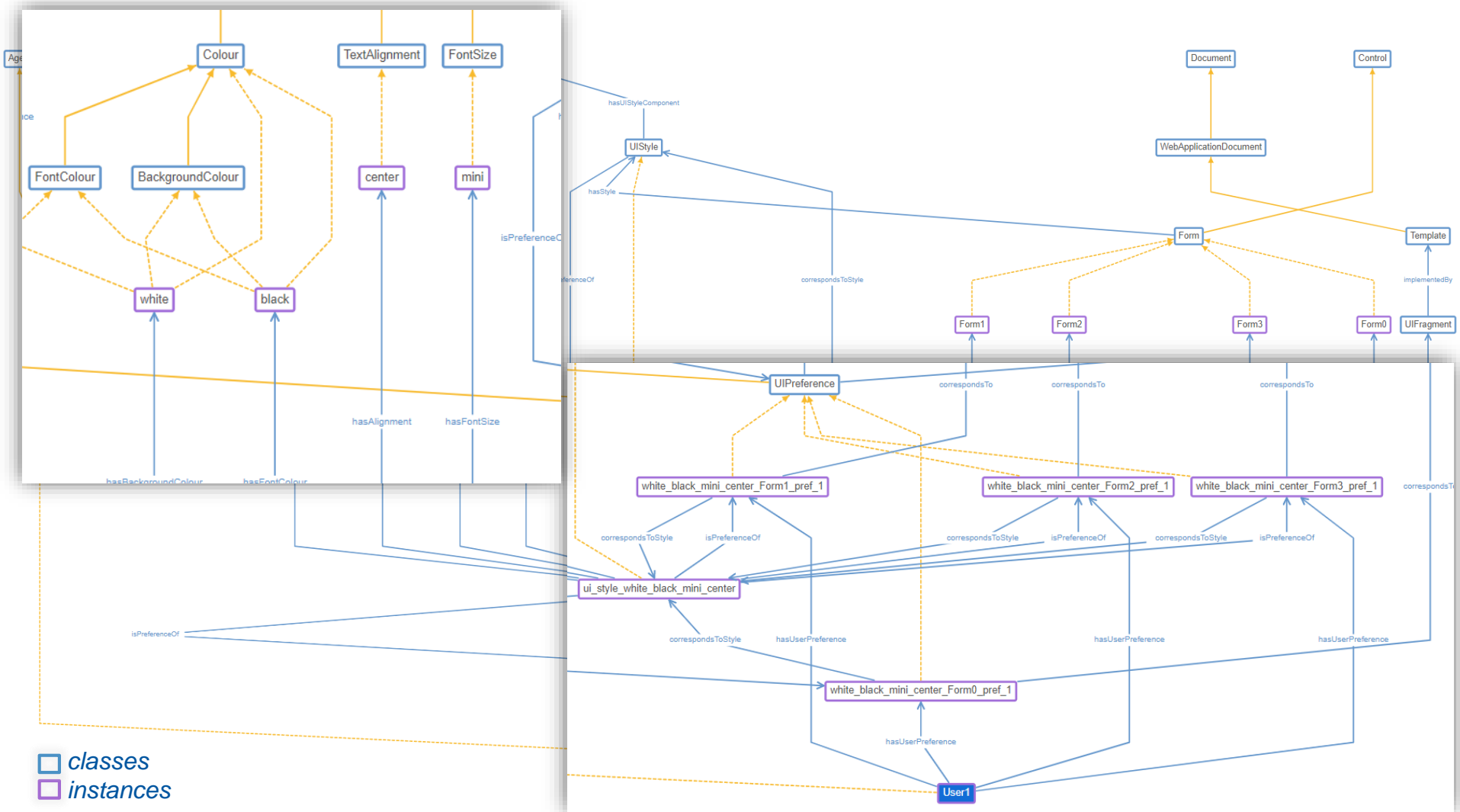
Google Knowledge Graph

©searchengineland.com

# Ontology-based Web Application Ontology (OWAO)



# OWAO UI Preferences Example



Excerpt from OWAO ontology showing "User1" instance and UI Preferences (displayed from web Protégé)



# Ontology Embedding

Ontology instances  $\rightarrow$  words, text

(e.g. *TemperatureSensor1* observes *Temperature*)

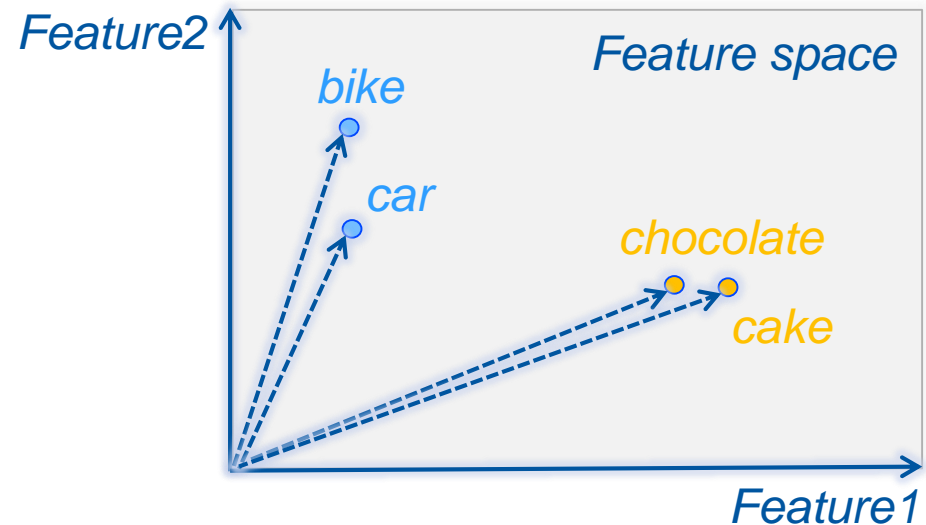
Word representation as feature vectors for tracking

- **similar words** and
- **words appearing in the same context**

Used in **recommender systems** for suggesting similar items

	<i>car</i>	<i>bike</i>	<i>cake</i>	<i>chocolate</i>
<i>Feature1</i>	1	1	6	7
<i>Feature2</i>	3	5	2	2
<i>Feature3</i>	4	4	1	1
<i>Feature4</i>	7	7	2	2

Feature Vectors



# New embedding: *ontowalk2vec*

New hybrid NLP model:

- *node2vec* → explicit structure of the ontology
- *RDF2Vec* → RDF triples

Algorithm:

