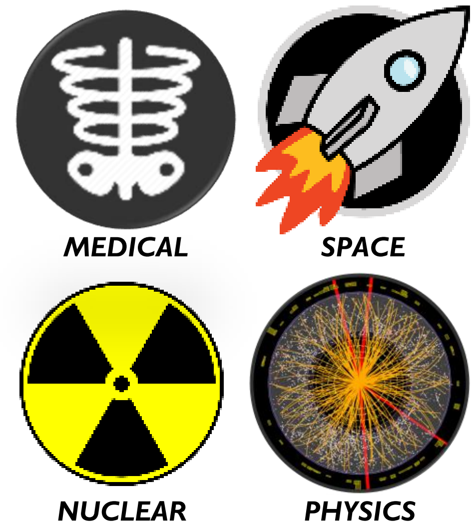
FCC Task 11 RHA - PROGRESS MEETING

Georgi Gorine – PhD Student at EP-DT / EDLAB

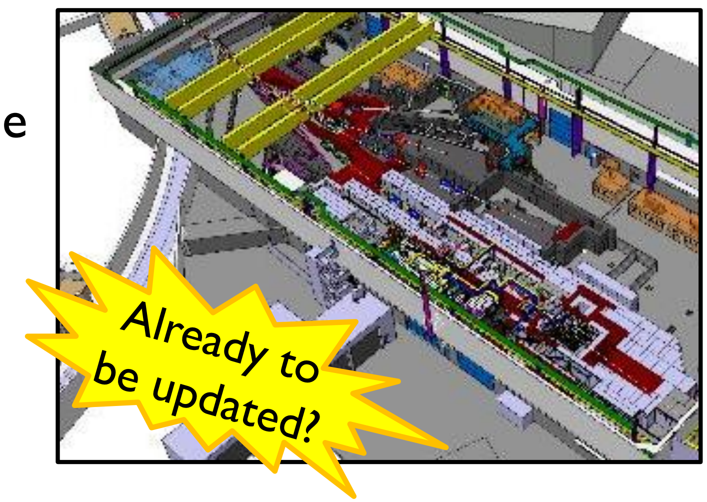
Supervisor at CERN: *Dr. Federico Ravotti*
Supervisor at EPFL: *Prof. Jean-Michel Sallèse*

OUTLINE = MAIN DELIVERABLES

- D5.3: Development of a Radiation Sensor for FCC / Testing Facilities
  - Analysis of state-of-the-art technologies for radiation measurement
  - Study of existent RADMON sensors at LHC;
  - Design, realization, and testing of an innovative dosimetry solution.



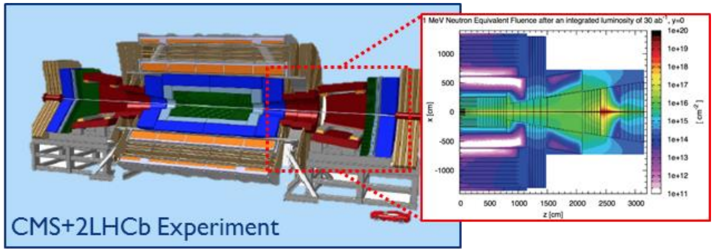
- D2.2: Evaluation of current irradiation facilities suitable for FCC at CERN and available worldwide
  - Evaluate limitations of current irradiation facilities joining irradiation tests (IRRAD, GIF++, CHARM)
  - Any other suitable external facilities? *(Database!)*
  - Produce a report with specifications and proposal of upgrade programmes for an *FCC-ready* facility;



OUTLINE

- Main Deliverables for FCC WP11
- D5.3: Development of a Radiation Sensor
  - **Requirements for FCC**
  - **RADFET Performance at High Dose**
  - Radiation Sensor Development
- D2.2: Evaluation of current irradiation facilities
  - Radiation Environment at GIF++ vs. FCC Requirements
  - Irradiation Facilities Database
- Conclusions

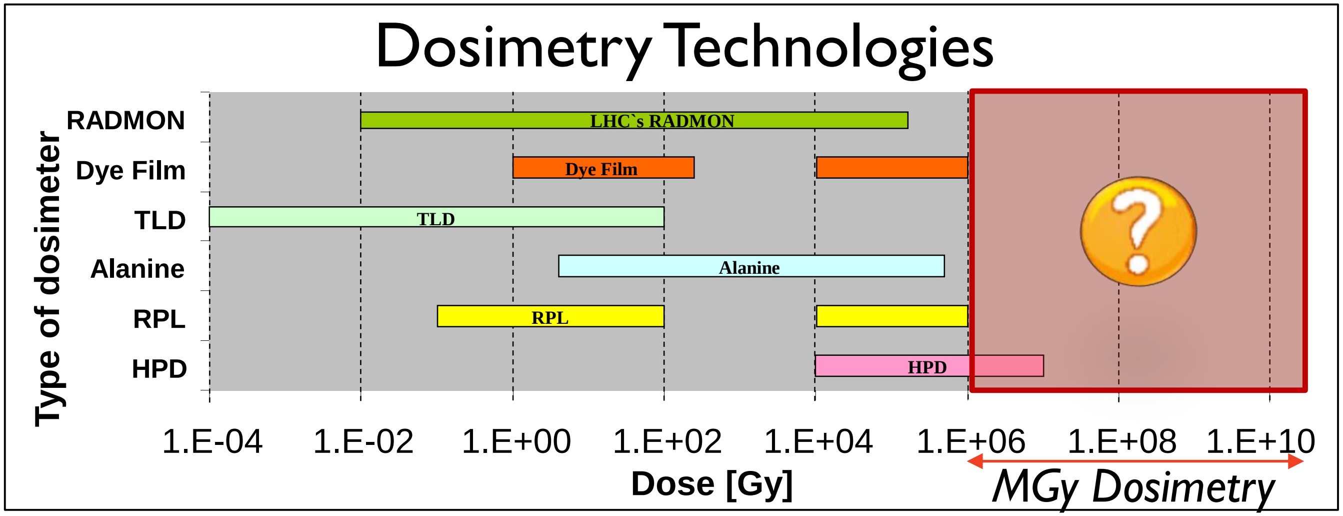
Deliverable D5-3 – FCC Radiation Sensor



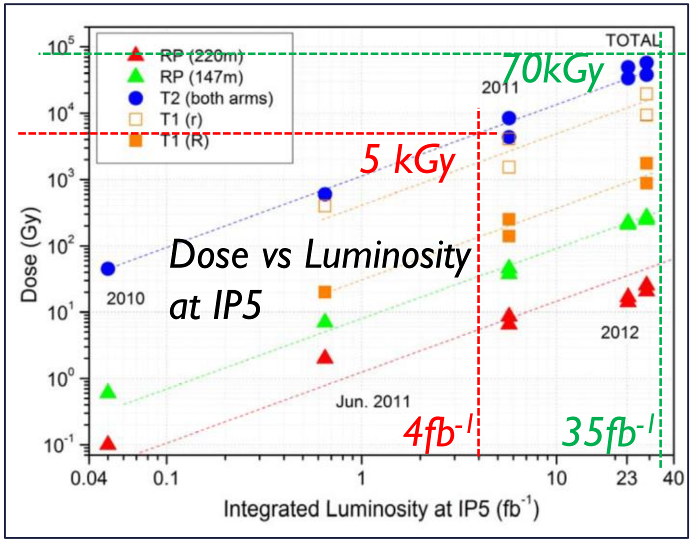
- **HL-LHC 3ab^{-1}** (Target for current IRRAD)
  - Fluence = 1.5×10^{16} cm^{-2} , Dose = 4.8MGy
- **FCC 3ab^{-1}**
  - Fluence = 2.8×10^{16} cm^{-2} , Dose = 9 MGy
- **FCC 30ab^{-1}**
  - Fluence = 2.8×10^{17} cm^{-2} , Dose = 90 MGy

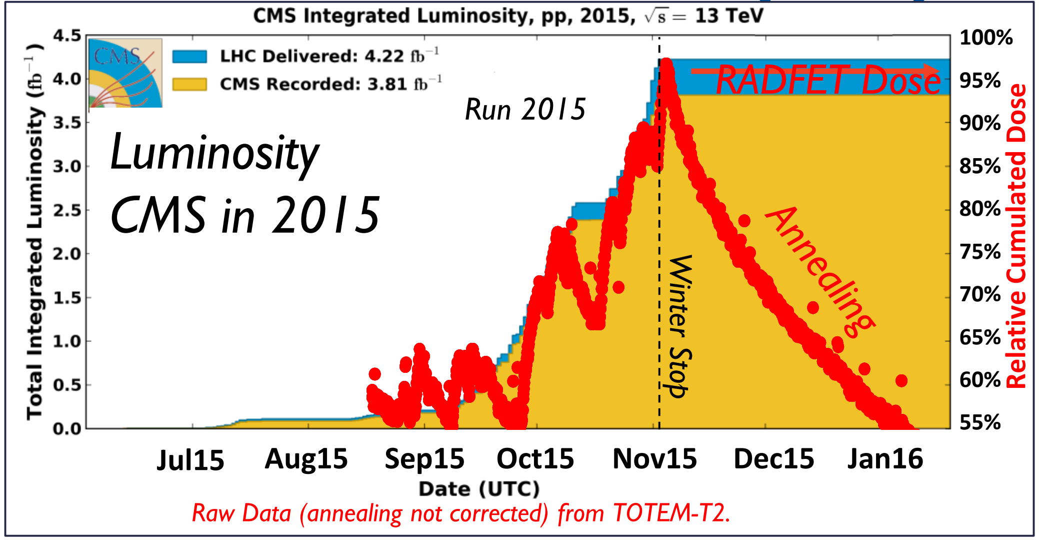
For FCC experiments very high dose levels are expected in the inner detectors

- Are there any available candidate technologies?
- Are our RADMONs still good?



RADFET PERFORMANCE IN CMS(IP5)

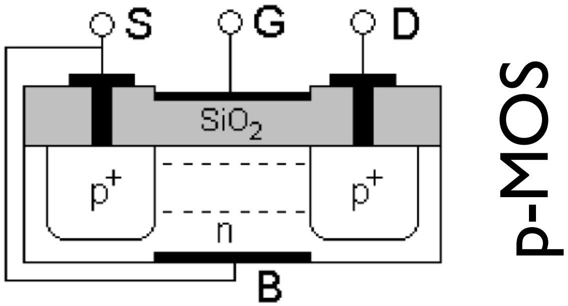


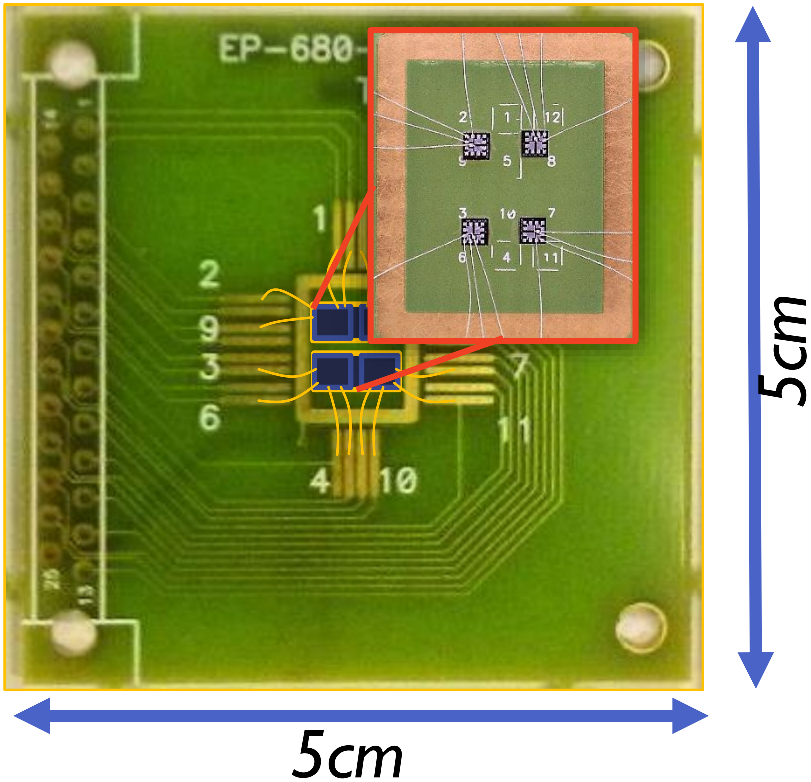


- RADFETs **heavily irradiated** in hadron field *(analysis ongoing)*:
  - Studying annealing and other damage related phenomena.
- Until **2012**, during phase 1, integrated luminosity of ~30 fb^{-1}
  - RADFETs integrated 60 kGy
- In **2015**, total luminosity reached 4 fb^{-1}
  - Same RADFET integrated additional ~5 kGy in 2 months of operation,
- In **2016** expected luminosity of 35 fb^{-1} *[estimation based on Chamonix`16]*
  - Corresponding to a additional dose of ~70kGy.

TEST AT ULTRA HIGH DOSE

- Currently testing RADFETs also with mono-energetic particles
  - **Target TID: 10s MGy.**
- Simultaneous test of RADFETs with different SiO_2 thickness of:
  - 130 nm and 250 nm.
- Experimental setup in IRRAD since May 2016
  - Allows truthful characterization of MOS structure (each pin wire bonded)
  - Test bench ready for future structure *(see next slides)*
- Data collection and analysis ongoing





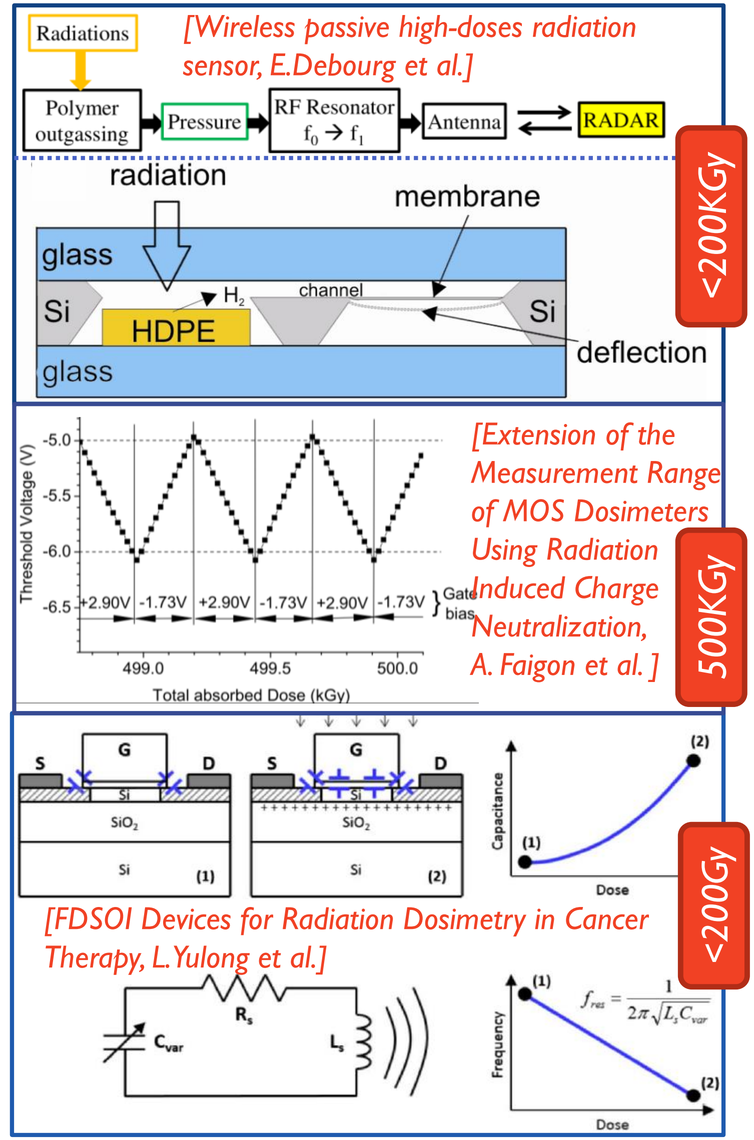
OUTLINE

- Main Deliverables for FCC WP11
- D5.3: Development of a Radiation Sensor
  - Requirements for FCC
  - RADFET Performance at High Dose
  - **Radiation Sensor Development**
- D2.2: Evaluation of current irradiation facilities
  - Radiation Environment at GIF++ vs. FCC Requirements
  - Irradiation Facilities Database
- Conclusions

MGy DOSIMETRY

Clear necessity of novel dosimetry technologies for MGy range:

- Known trade-offs and challenges:
  - Functioning over a <u>very large </u>dose/fluence range (in experiments);
  - Very few publications on MGy *(solid state)* dosimetry *(HL-LHC, ITER, XFEL)*.
- Ideal radiation sensor features:
  - Measurement and monitoring in a mixed-radiation environment of *Total Ionizing Dose*, *Displacement Damage* and *Single Event Effects;*
  - Reduced size and Wireless readout, etc.
- *Other FCC-driven requirements/specifications may arise.*



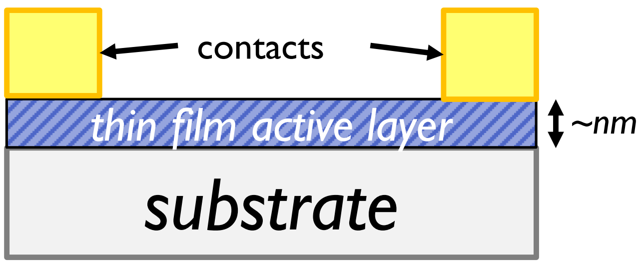
https://indico.cern.ch/event/467114/

DEVELOPMENT OF DOSIMETRY FOR FCC

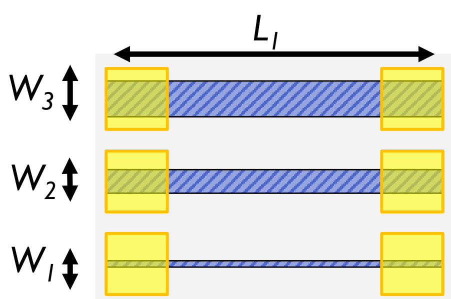
- Development of a novel dosimetry solution for **FCC radiation levels** based on metal nanostructures of *nanometer thickness*.
  - Innovative concept! *(to our knowledge)*
- Studying the **impact of radiation on the nanolayer** with a complete *electrical*, *optical* and *geometrical* characterization.
- Several test structures are being fabricated with different geometrical *(thickness, W, L, shape)* properties of the nanolayer.

CMi EPFL Center of MicroNanoTechnology
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
✓ *Design and Microfabrication*

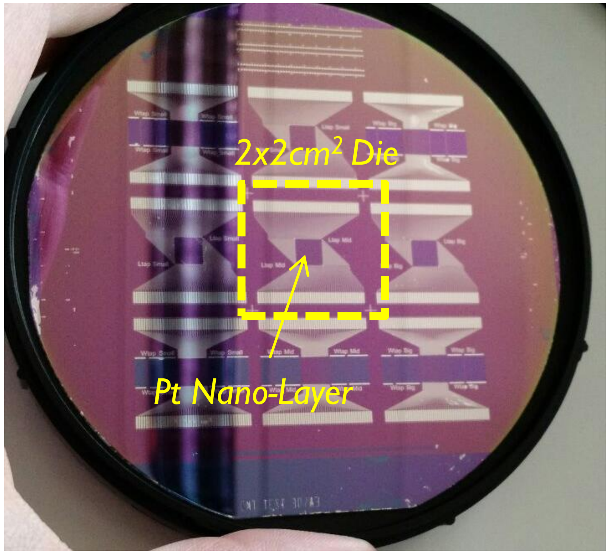
CERN
EP DT
Irradiation Facilities
✓ *Irradiation and Characterization*



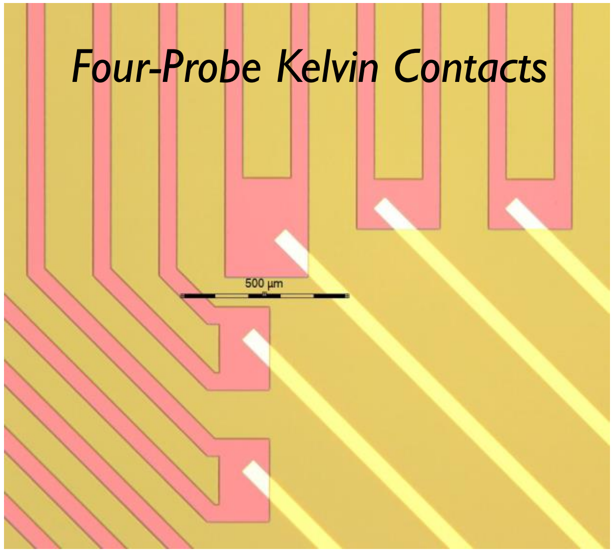
Side view



Top view



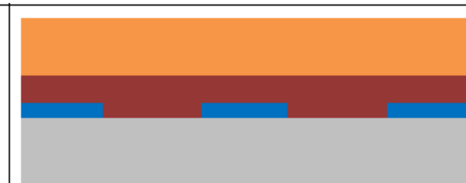
100mm test Wafer



Picture before Al deposition

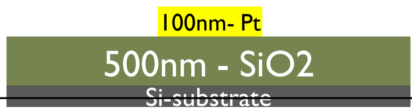
PROCESS FLOW

CMi EPFL Center of MicroNanoTechnology

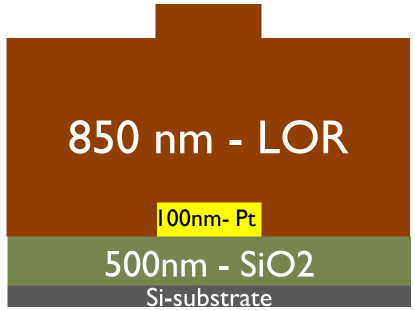
Step	Process description	Cross-section after process
01	*Pt Sputtering* Material : *Pt (47s – 200nm)* Machine: Spider 600 Thickness: *10 nm* *(5 Wafers:10,30,50,70,100 nm)*	
02	*Photoresist coating* Machine*: ACS200 Gen3* PR*: AZ ECI 3007* Thickness : 1.0 µm	
03	*Exposure* Machine*: MLA 150* Dose *:* 130 *mJ/cm²* , Def=*-5*	
04	*PR development with ACS200*	-
05	*Dry etching* Machine*: STS* Material: *Pt etch* Selectivity: *1:8* Etch Rate: *0.035 um/min*	
06	*Photoresist strip* Machine*: UTF remover 1165 + Oxygen Plasma with Tepla300*	
07	*Double PR coating for Lift Off* Machine*: ACS200 Gen3* PR*: LOR 5A + AZ 1512 HS*	
08	*Exposure* Machine*: MLA 150* Dose *:* 105 *mJ/cm²* , Def=*-7*	
09	*PR Development with ACS200*	-
10	*Metal Sputtering* Machine: *DP650* Metal *:Al (RTU_Al_unif)* Thickness : *200 nm (377 sec)* *300 nm (566 sec)*	
11	*Lift-Off* *Wet Bench: Remover 1165 + IPA + Ultrasounds*	

Where problems occurred…

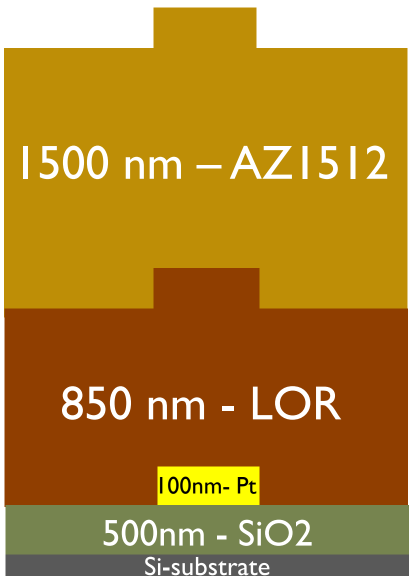
PROBLEM with Al Lift-Off



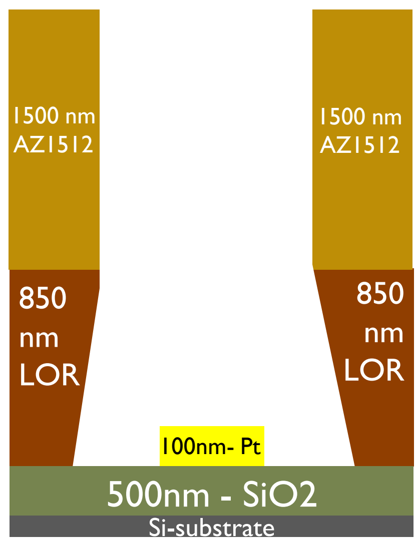
1. Platinum Litho



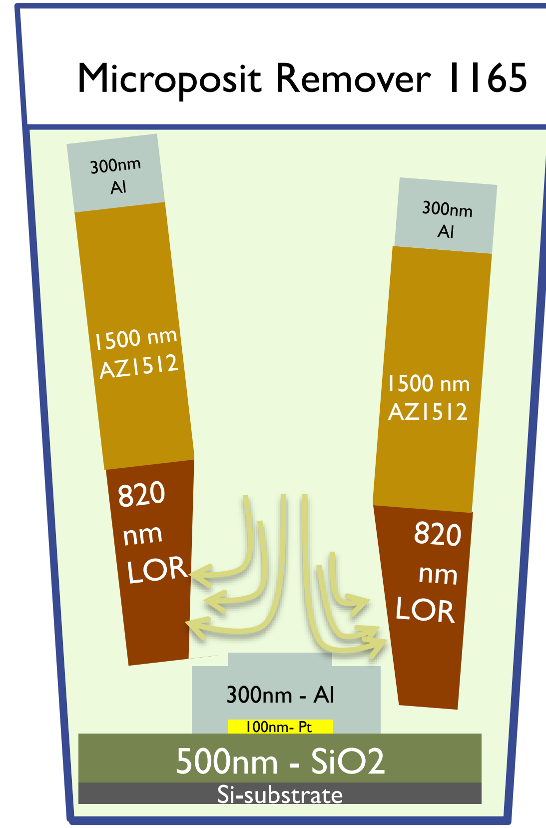
2. LOR coating



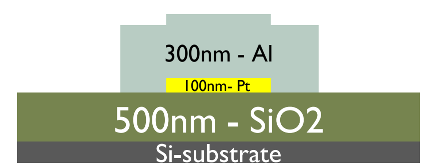
2. PR coating



3&4. PR exposure + development

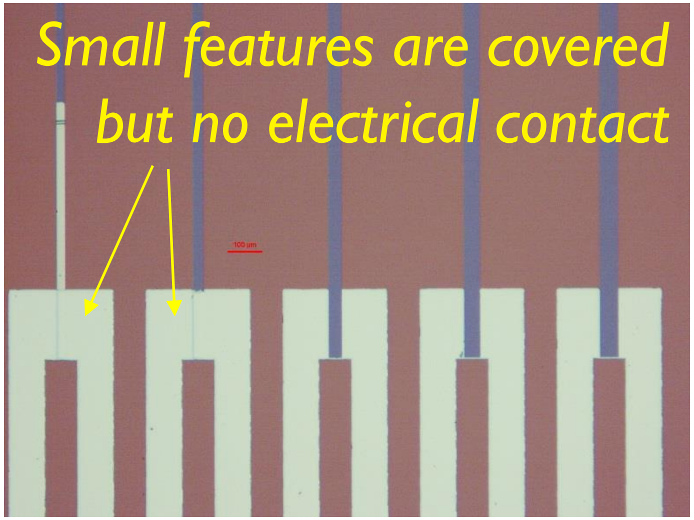


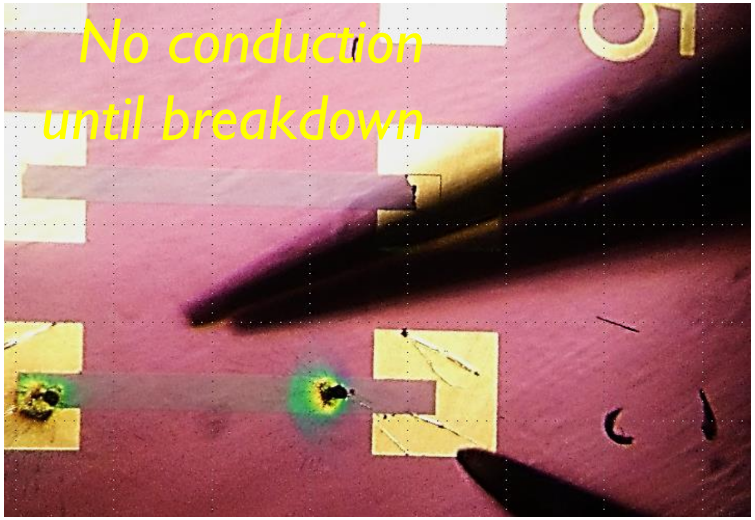
5. Lift Off in LOR Remover

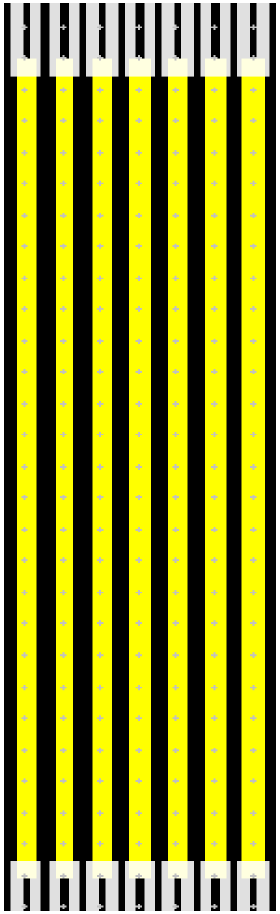


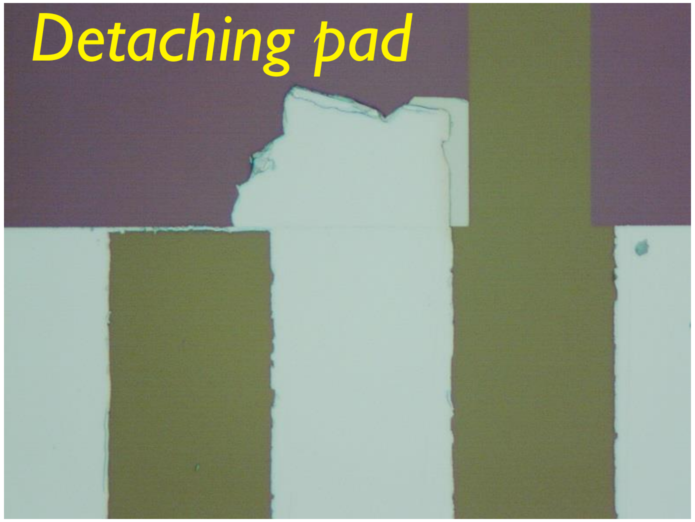
6. Final structure ready

RESULTING STRUCTURES







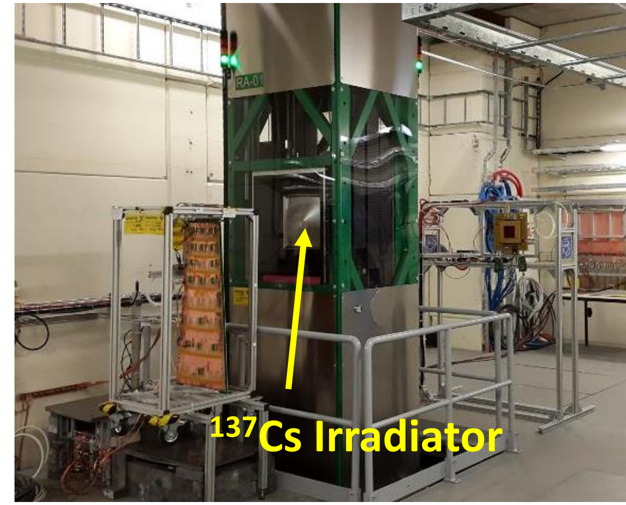


OUTLINE

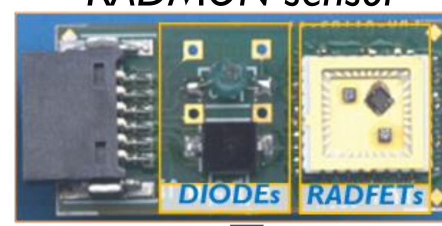
- Main Deliverables for FCC WP11
- D5.3: Development of a Radiation Sensor
  - Requirements for FCC
  - RADFET Performance at High Dose
  - Radiation Sensor Development
- D2.2: Evaluation of current irradiation facilities
  - **Radiation Environment at GIF++ vs. FCC Requirements**
  - Irradiation Facilities Database
- Conclusions

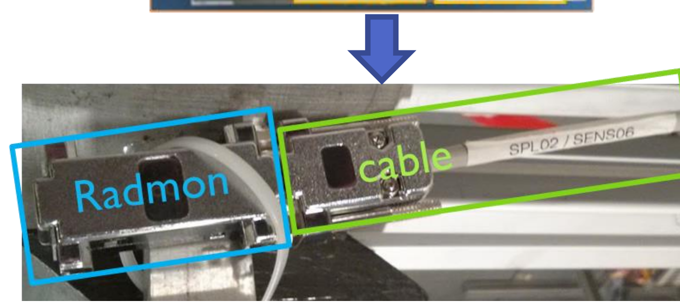
GAMMA FACILITY GIF++

- PH-RADMON based dosimetry system fully installed at GIF++ by INRNE/EP-DT (AIDA)
  - Up to 8 movable RADMONs monitoring dose levels in the bunker.
  - Used to make a full map of the Radiation Field
  - Users are now deploying them on their setups.
- Evaluation for FCC:
  - *What level of dose expected in FCC for muon detectors?*



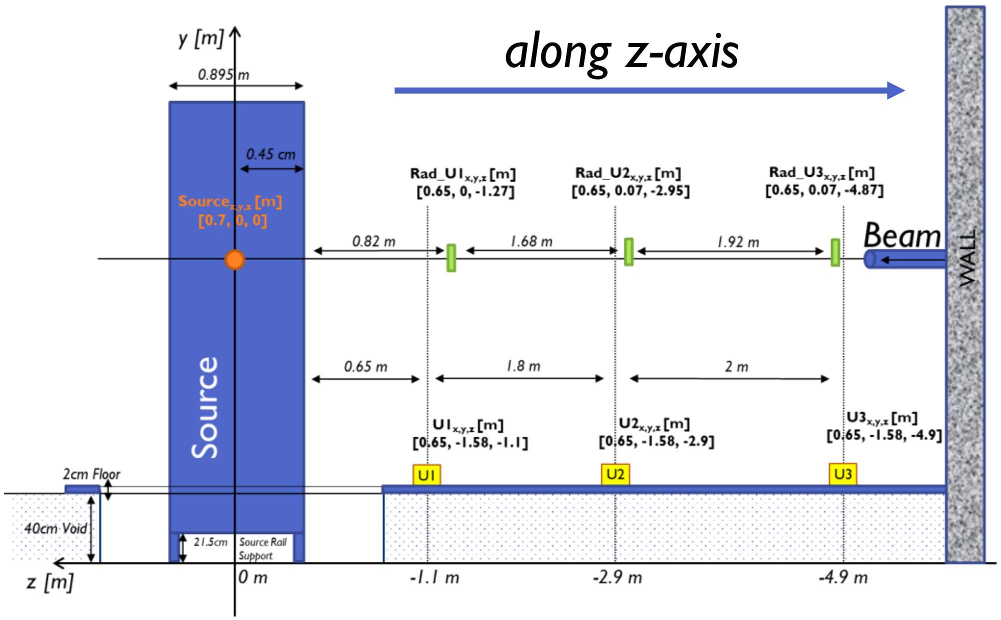
RADMON sensor

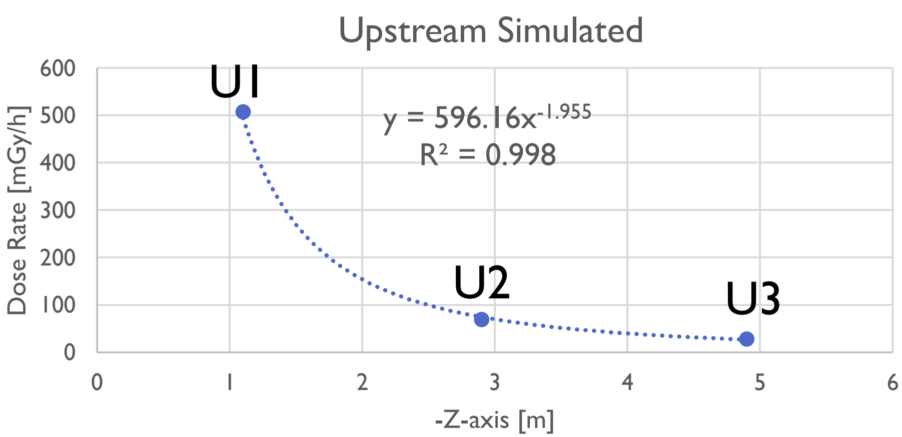


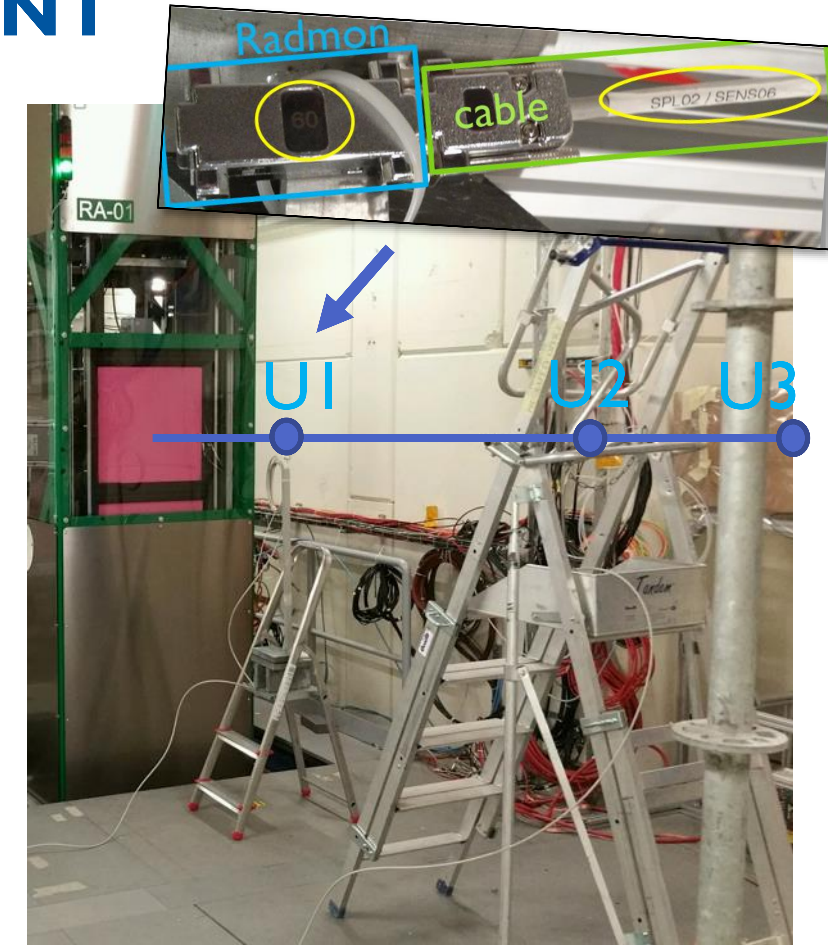


Protection case and flexible cabling

DOSE RATE MEASUREMENT

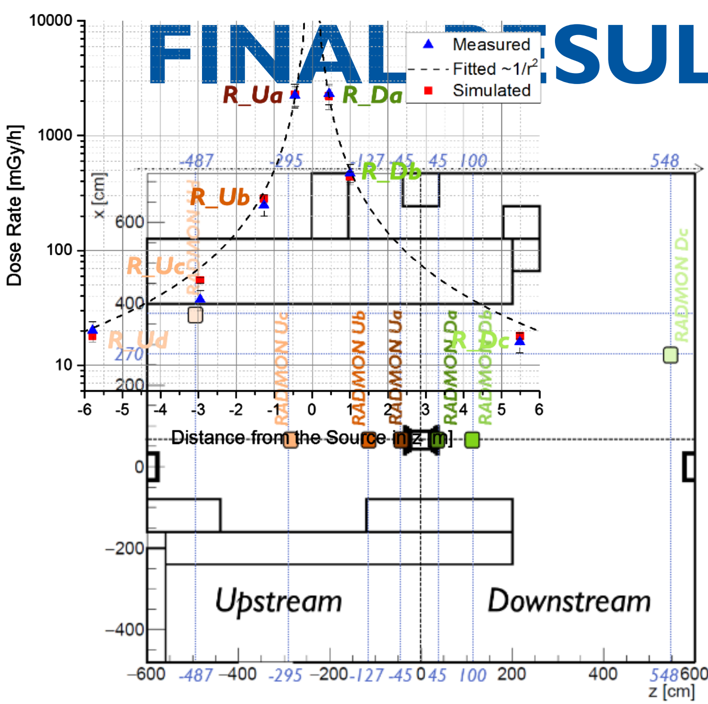




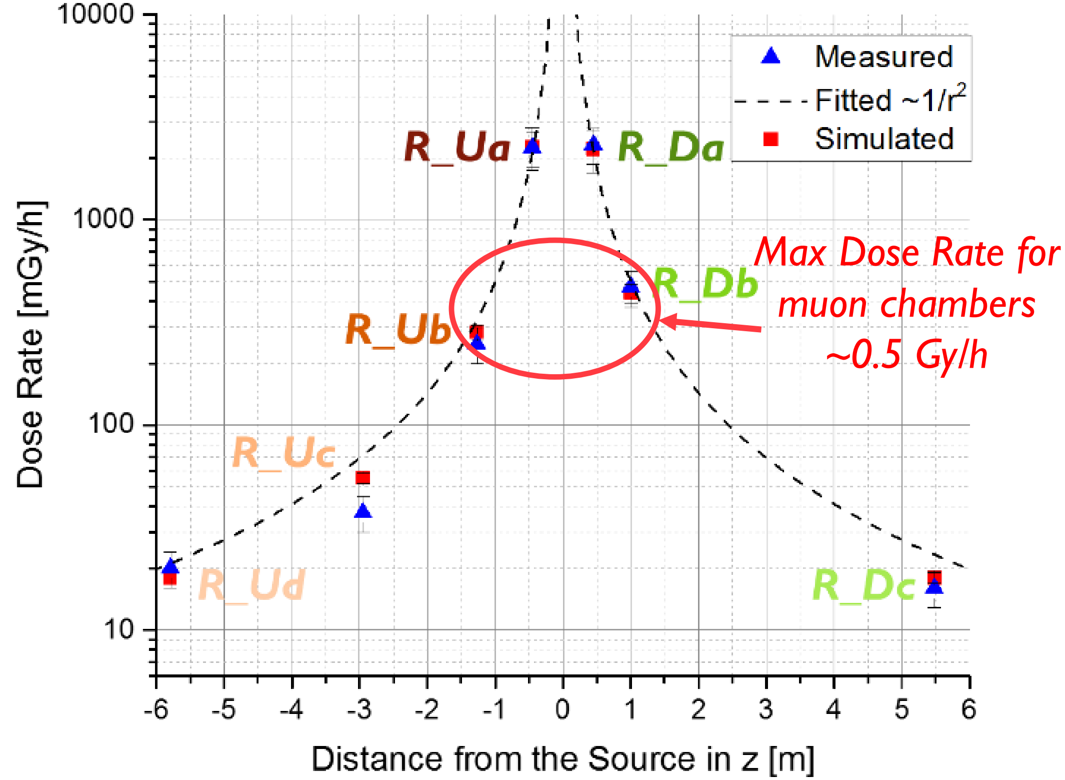


- Position error of ± 10 cm

FINAL RESULTS (Att.Factor 1)



Label	Z [m]	Sim[mGy/h]	Meas[mGy/h]	Ratio
R_Da	0.45	2213(521)	2330(531)	5%
R_Db	1	440 (47)	470 (48.3)	7%
R_Dc	5.48	18 (1)	16.1 (1)	-11%
R_Ua	-0.45	2274 (536)	2251 (531)	-1%
R_Ub	-1.27	283 (25)	249 (24)	-12%
R_Uc	-2.95	55 (3)	40 (3)	-25%
R_Ud	-5.79	18 (1)	20 (2)	12%
FIT	Dose Rate = $485.32 * Z^{-1.979}$			



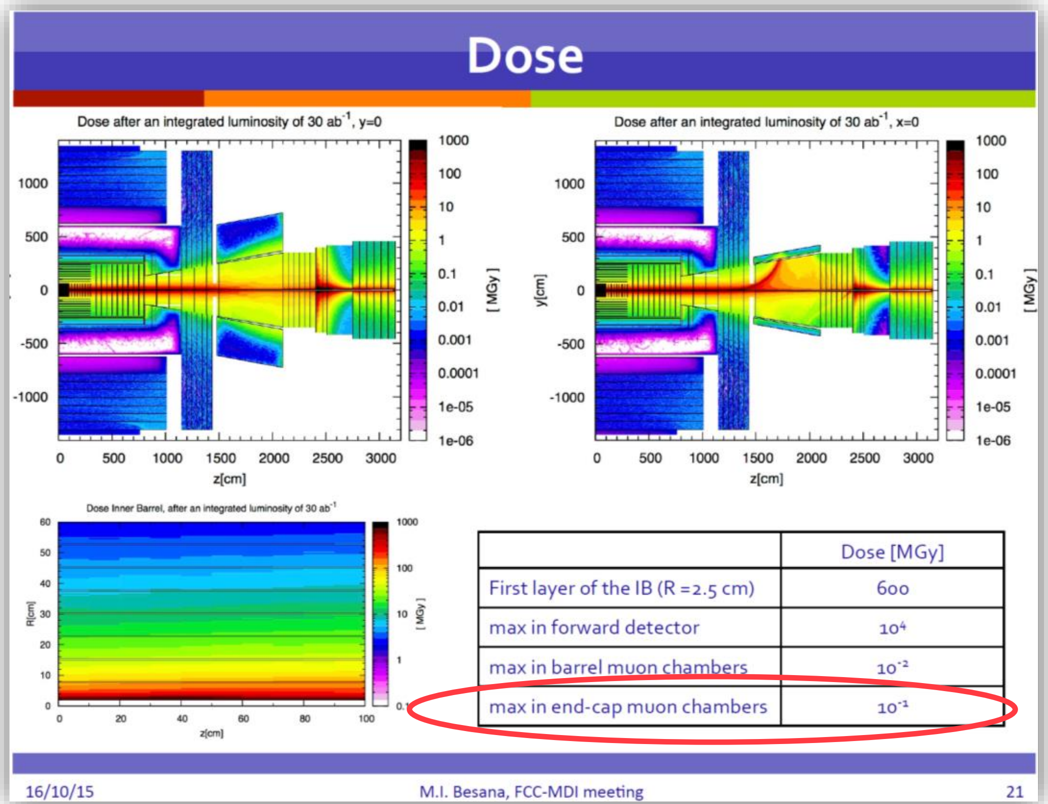
Simulations and first measurements of the Radiation Field in the New Gamma Irradiation Facility (GIF++) at CERN

Dorothea Pfeiffer*[,1,2], Georgi Gorine[2], Ali Day[2], Adrian Fabich[2], Joffrey Germa[2], Roberto Guida[2], Martin Jaekel, Federico Ravotti[2] Hans Reithler[3]

Abstract submitted for 2016 IEEE NSS/MIC

MUON CHAMBERS FOR FCC

In 2014 GIF was updated to GIF++ (*with ~x30 times stronger source*) for testing of Muon Chambers for HL-LHC era.



Expected requirement:

- From simulations, cumulated dose in muon chambers at FCC :
  - In 10 years max *100 kGy*.
- Testing aging at current GIF++:
  - *Cumulating at 0.5 Gy/h would require >22 years of non stop irradiation*

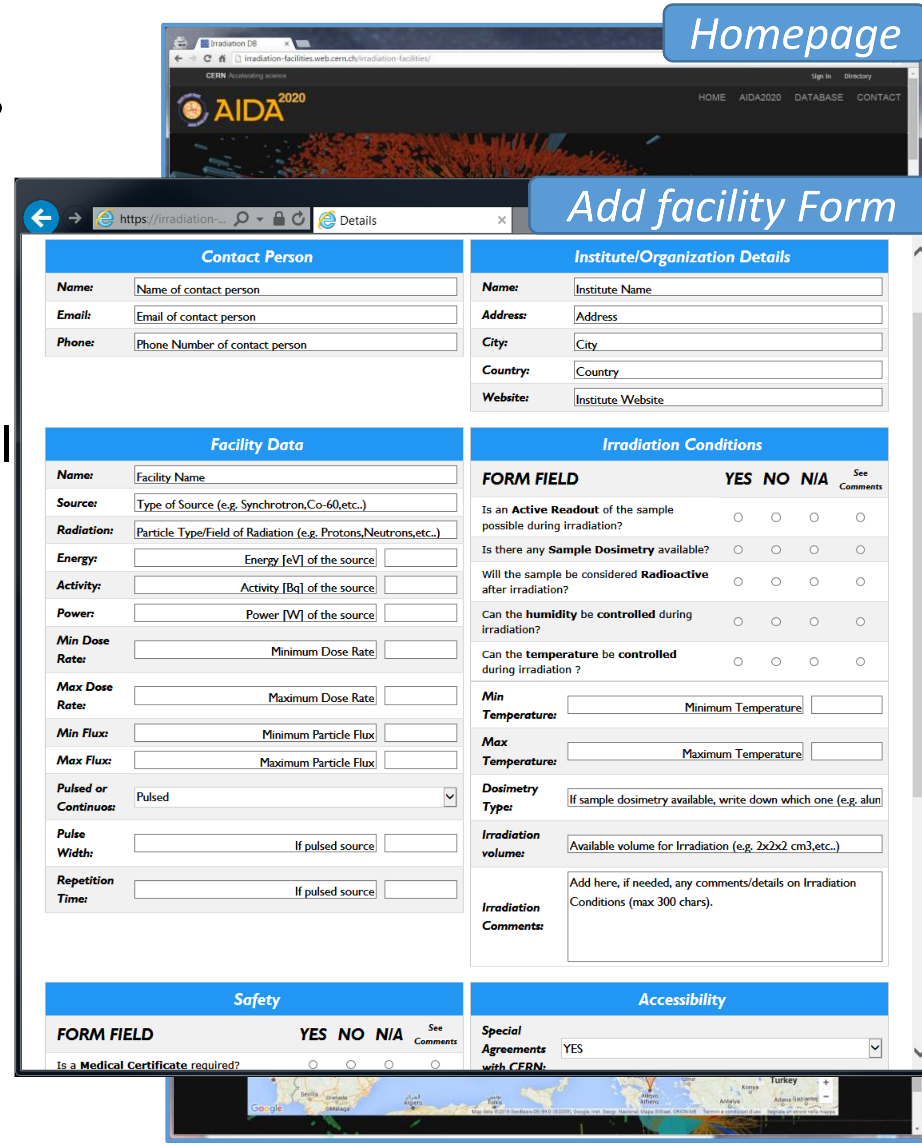
OUTLINE

- Main Deliverables for FCC WP11
- D5.3: Development of a Radiation Sensor
  - Requirements for FCC
  - RADFET Performance at High Dose
  - Radiation Sensor Development
- D2.2: Evaluation of current irradiation facilities
  - Radiation Environment at GIF++ vs. FCC Requirements
  - **Irradiation Facilities Database**
- Conclusions

D2.2 – CERN IRRADIATION FACILITIES DB

In the framework of AIDA2020 and D2.2, creation of the reference database of irradiation facilities at CERN, in EU, and Worldwide.

- http://cern.ch/irradiation-facilities
- Portal for CERN facilities operational
- DB structure implemented
  - Data being filled from EP/EN existing lists
- Auto-maintenance feature
  - Automatic (annual) reminders to facility responsible persons being implemented
- Allows a *"look into the future"*, which internal/external facilities could be used by future FCC community?



D2.2 – TESTING CAPABILITIES AT CERN

Facility	Particle	Energy	Intensity/Beam Spot	Irradiation Time	In one Year
IRRAD	p+	24 GeV/c	~1-3x10^{10} p/cm^2/s (5x5 mm^2)	~200days/y *(based on run 2015)*	~37 MGy
CHARM	mixed-field (24 GeV/c p+)	HEH>100MeV	10^8-10^{11} HEH/cm^2/h (~cm^2)	~200days/y *(based on simulations)*	~10-100 kGy
GIF++	γ	0.662 MeV	14TBq ^{137}Cs (~2.5Gy/h at 50cm)	Source on for 70% of the time *(with no attenuators)*	~15 kGy
CC60	γ	1.17 MeV, 1.33 MeV	10TBq ^{60}Co (~350 Gy/h, small samples)	Source on 70% of the time *(assumption)*	~few MGy
HiRadMat	p+ or HI	440 GeV or 173GeV/u	10^9 - 10^{11} p/pulse (< 1mm^2)	few weeks/year	-
CERF	mixed-field (120 GeV/c HEH)	<100 MeV n^0 + HEH	<10^8p/spill (on the target)	few weeks/year	-

Adapted from: F. Ravotti (EP/DT) – 02/2016

OUTLINE

- Main Deliverables for FCC WP11
- D5.3: Development of a Radiation Sensor
  - Requirements for FCC
  - RADFET Performance at High Dose
  - Radiation Sensor Development
- D2.2: Evaluation of current irradiation facilities
  - Radiation Environment at GIF++ vs. FCC Requirements
  - Irradiation Facilities Database
- Conclusions

CONCLUSIONS

- D5.3: Development of a Radiation Sensor for FCC / Testing Facilities
  - Analysis of state-of-the-art technologies for radiation measurement:
    - ✓ **DONE**: Existing technologies investigated.
  - Study of existent RADMON sensors at LHC;
    - ✓ **ONGOING**: Analysing data from LHC RADMONs and performing ad hoc tests in IRRAD.
  - Design, realization, and testing of an innovative dosimetry solution.
    - ✓ **2nd ROUND**: First production did not go well but problems are now understood and be fixed in a second production. Test bench in IRRAD ready for testing.
    - ✓ **NEW CONCEPT:** Thinking of other dosimetry device based on Junctionless FET *(collaboration with A.Mapelli, and EP-DT PhD student J.Bronuzzi)*
- D2.2: Evaluation of current irradiation facilities suitable for FCC at CERN and available worldwide
  - Evaluate limitations of current irradiation facilities joining irradiation tests
    - ✓ **ONGOING**: Actively participating in daily IRRAD and GIF++ operation
  - Any other suitable external facilities? *(Database!)*
    - ✓ **FILLING UP:** Irradiation Facilities website is online and being filled with EN/EP data.

CERN

www.cern.ch

Thank you!