PBC
Technology Working Group

Andrzej Siemko and Babette Döbrich for the Working Group

CERN, January 2019

PBC
Technology Working Group
Talk outline

- Reminder: Mandate and goals of the Technology Working Group
- Reminder: Initiatives integrated into the Technology WG
- Updates on our progress since June 2018 (https://indico.cern.ch/event/706741/contributions/2955697/ and https://indico.cern.ch/category/8816/
  Today: focus on Light-Shining-Through-Wall (LSW) + Vacuum magnetic birefringence (VMB), info on other initiatives to be found in our report
- Report and conclusions of the WG

The PBC Technology WG

Core members:

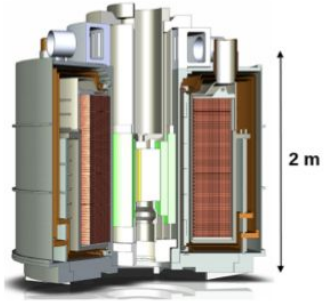
Giovanni Cantatore (aKWISP), Dimitri Delikaris (CERN), Babette Döbrich (CERN), Livio Mapelli (DARKSIDE), Antonio Polosa (Nanotubes), Pierre Pugnat (LSW/OSQAR), Joern Schaffran (DESY/ALPS), Andrzej Siemko (CERN), Paolo Spagnolo (STAX), Herman ten Kate (CERN/IAXO), Guido Zavattini (PVLAS)

Mandate of the Techno working group

”Exploration and *evaluation* of **possible technological contributions of CERN** to non-accelerator projects possibly hosted elsewhere: **survey of suitable experimental initiatives** and their **connection** to and *potential benefit to and from CERN*; **description of identified initiatives** and *how their relation to the unique CERN expertise is facilitated.***”**

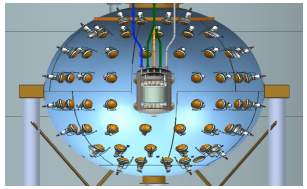
Reminder: Initiatives integrated into the Techno WG

1) Haloscope LNCMI-Grenoble



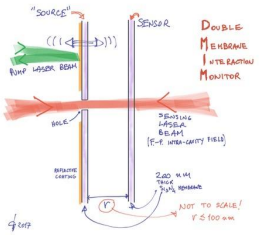
Covered Nov 2017

2) DarkSide



Covered June 2018

3) aKWISP



Covered Nov 2017

4) VMB@CERN

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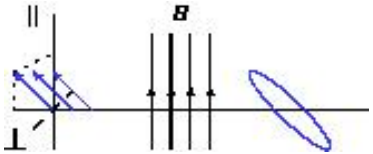
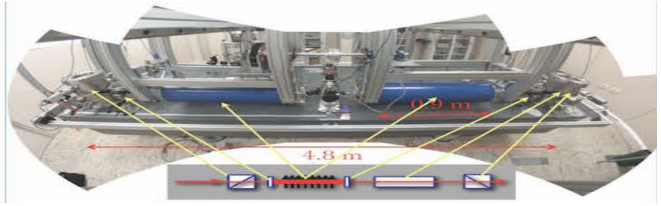
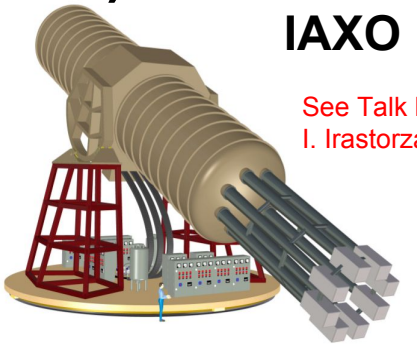




5) Helioscope IAXO



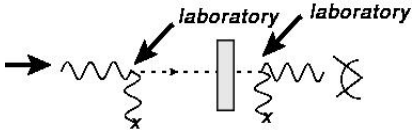
See Talk by I. Irastorza

6) JURA (LSW combining ALPS-III and OSQAR+)

See talk by A. Lindner (physics) + covered here (technology)

7) LSW-STAX

Covered here



8) CNT Based DM Detector

PTOLEMY (CNB)

See backup

Key technologies

"requested or offered" by initiatives:

- Magnet
- Optics
- RF technology
- Cryogenics
- Ultra-High Vacuum

Technology concerned	benefit from CERN	benefit to CERN	how facilitate?	Exps concerned
Magnet, concretely: high-field, large-bore	availability of strong fields, CERN expertise to build custom magnets	make optimal physics use of magnet resources (spares)	advertise magnet usage times, provide expertise in magnet design, PBC-fellow for IAXO	IAXO, JURA, STAX, VMB@CERN
Optics/Optics sensing, concretely: Fabry Perot, membranes	surface coating, possibility to combine magnet with optics	add local expertise on cavity optics technologies	"optics hub", as described in the document	aKWISP, VMB@CERN, JURA
Radiofrequency cavities, concretely: design for axion searches	experience in design and production	new cavity designs for various physics purposes, tuning and characterization in cryogenic environment	mandate for cavity experts to aid in design	Grenoble initiative, & other Haloscope initiatives operating already at CERN, STAX
Cryogenics, concretely: large-scale: helium, argon, krypton from 120K to mK	availability of cryogenic facilities	participate in research beyond collider	mandate through TE-CRG	DarkSide, aKWISP, VMB@CERN, IAXO
Vacuum, concretely: large-scale leak testing	experience & availability	participate in research beyond collider	mandate through TE-VSC	DarkSide, JURA, aKWISP, CNT

Table from WG report

Concrete examples:

- Vacuum/Cryo for DarkSide already effort by CERN (see June 2018 meeting)
- PBC fellow for baby IAXO magnet design (see talk by Igor Irastorza)
- RF studies for haloscope axion searches (cryolab+CAST) + progress in Grenoble haloscope (see backup)
- ...

Partial overlap of technologies/facilities in initiatives

Technology & resources commons/sharing: Synergy analysis within Light Shining through Walls (LSW) and Vacuum Magnetic Birefringence (VMB)

- Both LSW and VMB measurements are laser based experiments requiring **state of art optics and intense magnetic field**
- Measurements of both VMB and Vacuum Magnetic Dichroism (VMD) using CERN magnets can also be sensitive to **Axion-Like-Particles** albeit typically much less than LSW (see next slide)
- LSW measurements are also proposed in the micro-wave regime allowing a substantially increased number of input photons. Also, in this case the **necessary magnetic field is in common** with the other initiatives (slide 10)

	Light Shining through the Wall (LSW)					Dichroism
Status	Approved	Proposed initiatives				
Initiative	ALPS IIc	BabyJURA	JURA 1	JURA 2	STAX	VMB@CERN
Magnet assembly	10 + 10 HERA	1 + 1 LHC	4 + 4 LHC	LHC-FCC	1 + 1 FCC	1 LHC
Field length L_B [m]	94 + 94	14.3 + 14.3	57 + 57	100 + 100 480 + 480	1.5 + 1.5	14.3
B [T]	5.3	9	9	9 - 15	11	9
Photons/s R [s^{-1}]	$1.6 \cdot 10^{20}$	$1.6 \cdot 10^{20}$	$1.6 \cdot 10^{20}$	$1.6 \cdot 10^{20}$ - $2.7 \cdot 10^{21}$	$1 \cdot 10^{28}$	$2 \cdot 10^{18}$
Photon energy ω [eV]	1.17	1.17	1.17	1.17	1.2×10^{-4}	1.17
N_1	5000	5000	5000	5000	10000	1000
N_2	$4 \cdot 10^4$	$4 \cdot 10^4$	$4 \cdot 10^4$	$(4\text{-}10) \cdot 10^4$	10000	n.a.
Background B [s^{-1}]	10^{-4}	10^{-4}	10^{-4}	10^{-4} 10^{-6}	10^{-6}	n.a.
Shot-Noise floor NF	n.a.	n.a.	n.a.	n.a.	n.a.	10^{-12} rad
$g_{a\gamma\gamma}$ [GeV^{-1}]	$< 6 \cdot 10^{-11}$	$2 \cdot 10^{-10}$	$< 6 \cdot 10^{-11}$	$< 3 \cdot 10^{-11}$ $< 1 \cdot 10^{-12}$	$< 1 \cdot 10^{-11}$	$< 1 \cdot 10^{-9}$
m_a [eV]	$< 1 \cdot 10^{-4}$	$< 2.5 \cdot 10^{-4}$	$< 1.3 \cdot 10^{-4}$	$< 1 \cdot 10^{-4}$ $< 4 \cdot 10^{-5}$	$< 4 \cdot 10^{-6}$	$< 2.5 \cdot 10^{-4}$

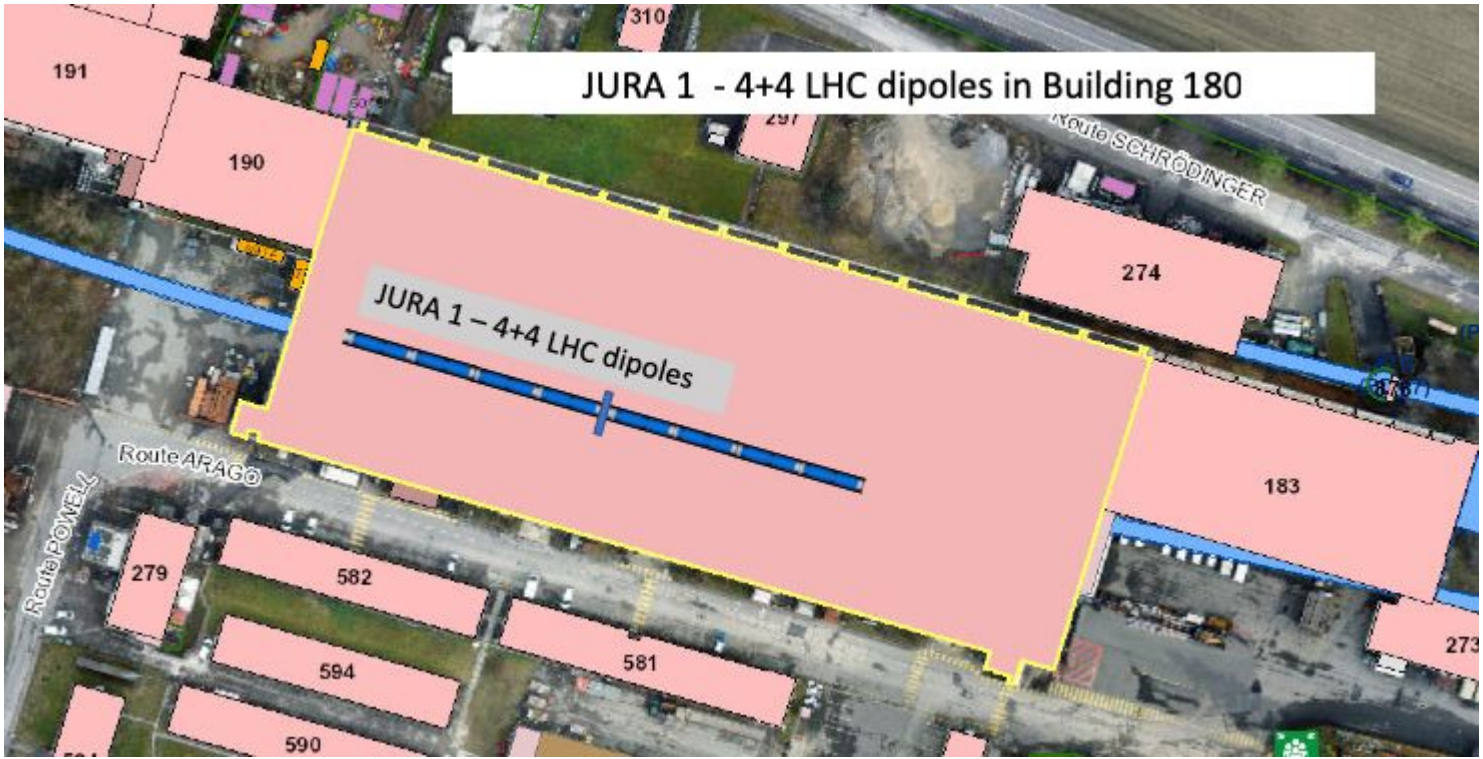
Comparison, connection/ synergies of LSW and VMB

- Guidance assessing future activities (e.g. ALP physics sensitivity)
- Guidance on combined studies (resource sharing) for similar set-ups
- New: Efforts of teams joined (as in JURA and VMB@CERN) -> see next slide

The JURA initiative

- A proposal for a new multi-stage LSW experiment is the “Joint Undertaking on Research for Any-light particles” (JURA) which combines the detector and optics development by ALPS II **(using HERA magnets)** with dipole magnets existing or under development at CERN **(see talk by A. Lindner on physics: most model-independent search)**
- The JURA initiative is separated into 3 phases:
  - babyJURA:
    - BabyJURA consist of 1 + 1 LHC dipole magnet with a **powerful optical system equal to ALPS II.** The preparation phase of babyJURA will start soon and data taking could be in 2023
  - JURA 1:
    - Initiative with 4 + 4 LHC dipole magnets, which should be realized, **if there is a corresponding physics case** in view of ALPS II result. **JURA 1 would reach sensitivity similar to ALPS II**
  - JURA 2:
    - JURA 2 stands for 3rd generation LSW experiment by either using LHC or FCC like magnets. Such an experiment would for example allow to study an ALP detected by IAXO (if its mass is sufficiently low) or **even surpass the sensitivity of IAXO if there is a corresponding physics case**, no discussion before 2025

The JURA initiative – first ideas of possible placing at CERN



Synergy, part 2: The STAX initiative and possible collaboration with OSQAR

- The STAX initiative suggests an innovative version of the LSW class of experiments, achieved with the use of **extremely intense photon fluxes, obtained moving to the sub-THz** region where gyrotrons or klystrons can operated and the **first implementation ever** of a Transition-Edge-Sensor (TES) single photon detector below the THz region.
    - The implemented solution could, in principle, improve the present laboratory limits on the **ALP-photon coupling by four orders of magnitude at lower masses**

- The STAX facility would rely on two strong dipole magnetic fields such as suggested **prototypes of the HL-LHC**
- The OSQAR LSW experiment makes use of two LHC superconducting dipole magnets that contain a vacuum chamber measuring 55 meter in length by 40 millimeters across.
- STAX and OSQAR LSW could be **synergetic**, in a picture where the **OSQAR scheme and infrastructure in the SM18 location and the cryogenic system could be used** or partially used, **moving to the microwaves domain**
- In principle, a very good solution could be to use the OSQAR infrastructure at SM18, possibly replacing in the future the two LHC dipoles with the 11 T HL-LHC prototypes

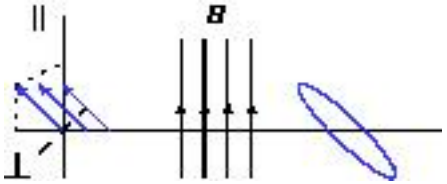
Example of sharing technology ideas: Optics Technology Hub (OTH) proposal

- The OTH could be structured as a **semi-informal working group** aiming at: following the most recent applications of optics technologies to particle physics experiments and sharing information + fostering collaboration among CERN-based groups employing optics + keeping contacts to outside

- **Fruitful contacts started** with:
  - DESY and locally based activities, chiefly the ALPS collaboration, who intensively use optics technologies. In particular, DESY hosts an optics laboratory and is connected with the LIGO/GEO gravitational wave community
  - LNCMI (Laboratoire National des Champs Magnétiques Intenses) laboratory, in particular the BMV group who aims at the VMB measurement using pulsed magnetic fields and precision cavity-enhanced polarimetry
  - Virgo collaboration would like to name an observer to follow the activities of the PBC Technology Working Group and to participate in the OTH

- **An essential action towards the OTH could be organizing an informal kick-off workshop at CERN**
  - The main aim would be to establish initial ties within the interested community, and to start discussing recently emerging themes, such as the **combination of cryogenic and optical techniques (e.g. VMB+ aKWISP)**

Concrete WG outcome: VMB@CERN



- Initiative joined beginning of 2018
- Potential first measurement of Vacuum Magnetic Birefringence predicted in 1936
- Submission of Letter of Intent in December 2018 to SPSC: http://cds.cern.ch/record/2649744
- First collaboration meeting 18th January 2019
- Excellent example of synergy efforts (PVLAS, OSQAR, gravitational wave community…)

2018-xxx
December 3, 2018

Letter of Intent to measure Vacuum Magnetic Birefringence: the VMB@CERN experiment

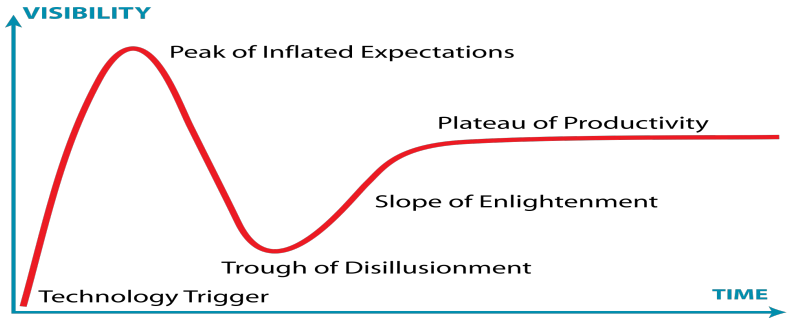
R. Ballou[1], F. Della Valle[2], A. Ejlli[3], U. Gastaldi[4], H. Grote[3], Š. Kunc[5], K. Meissner[6], E. Milotti[7], W.-T. Ni[8], S.-s. Pan[9], R. Pengo[10], P. Pugnat[11], G. Ruoso[10], A. Siemko[12], M. Šulc[5] and G. Zavattini[13]*

Final Report

- The technological contributions/needs and future expectations from 8 initiatives: **Grenoble-haloscope, STAX, aKWISP, DarkSide, IAXO, VMB@CERN, nanotube DM detector, JURA** were categorized and documented
- The working group's job is now completed and documented (on 31 pages) at https://cds.cern.ch/record/2652165/. An analysis of **synergies** was developed and estimates on **costing and timeline** documented
- A shortened version (10 pages) has been submitted to ESPP
- We are grateful to all WG members for their contributions

Technology subgroup outlook and plans

- **We tried to follow the main missions of the WG goals, direction in which we went was set by initiatives which contributed (-> not exhaustive!)**
- **PBC mandate extended!** Future work will concentrate on the follow up of new initiatives
  - Helping to prepare the projects facilitating access to the unique expertise at CERN in various technologies
  - Making a link between interested projects/experiments and CERN experts
- **New initiatives and projects that have sought to profit via PBC from the CERN technologies and expertise are still welcome to contact us**

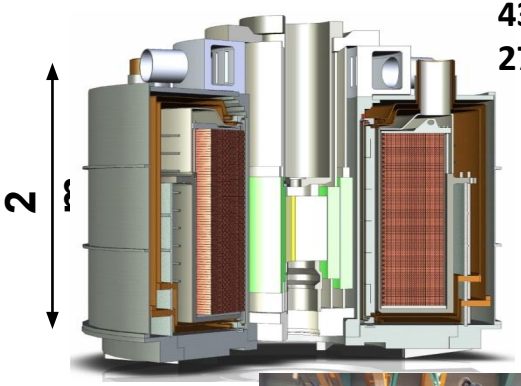


Thank you for your attention! And thanks again to all WG members + external experts

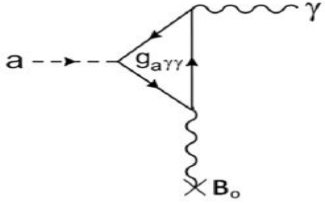
BACKUP

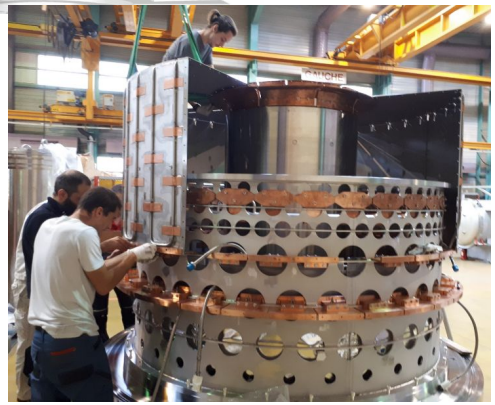
The Grenoble Axion Haloscope based on the Hybrid Magnet Platform in construction at CNRS/LNCMI

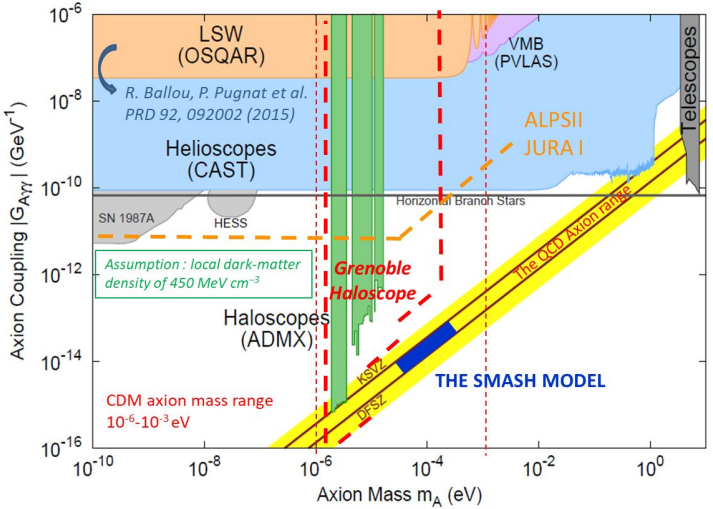
Based on the Grenoble Hybrid Magnet Platform equiped with RF cavities (0.3-30 GHz) at 20 mK & dedicated quantum amplifiers



43 T/34 mm, 40 T/50 mm
27 T/170 mm, 9 T/800 mm







P. Pugnat, CERN PBC Techn. WG 25.10.2017

- The LoI is close to be issued
- The final assembly of the hybrid magnet is ongoing & the commissioning will start in 2020

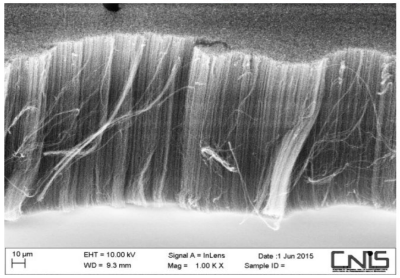
Carbon nanotubes DM target

G.Cavoto, F.Luchetta, A.D.Polosa, Phys.Lett. B776 (2018) 338-344

- Idea: DM scatters on a ***anisotropic*** target as ***aligned*** carbon nanotubes. **Directional** detectors for DM
- Interact with **electrons** : **DM mass is in the sub-GeV range (SIMP)**

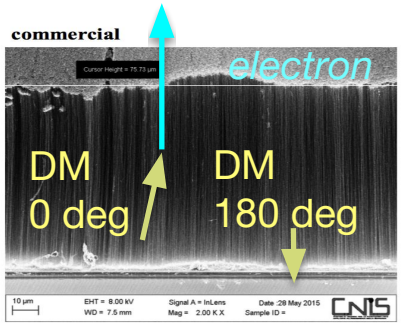
detector side

collaboration University of Mons, Belgium



length: ***100 μm (can be increased)***
ext. diameter: ***(20 ± 4) nm***
aspect ratio: ***5x10⁴***

commercial



length: ***75 μm***
ext. diameter: ***(13 ± 4) nm***
aspect ratio: ***0.6 x10⁴***

absorbing substrate

A first stage of the PTOLEMY experiment for Cosmic neutrino background measurement

https://arxiv.org/abs/1808.01892

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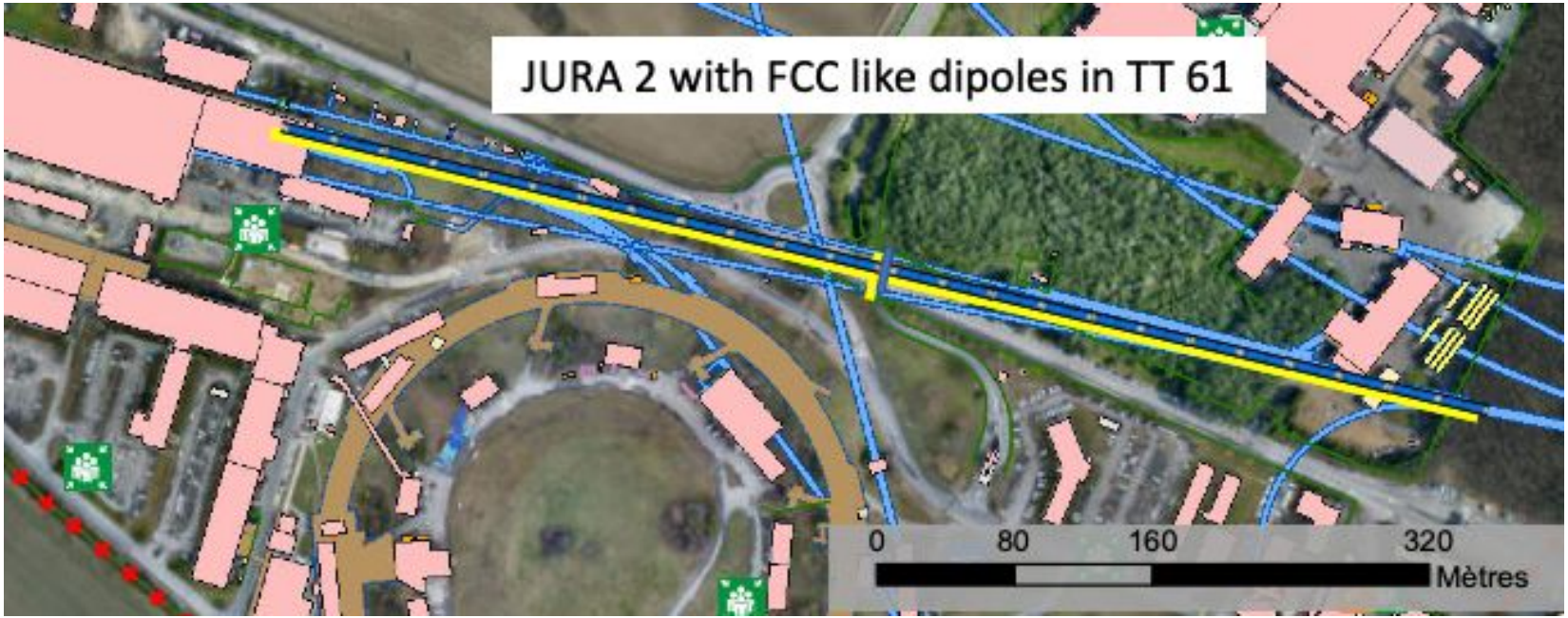
The JURA initiative – first ideas of possible implementation at CERN



From https://arxiv.org/abs/1801.08127