PBC
Technology Working Group

Andrzej Siemko and Babette Döbrich for the Working Group

CERN, June 2018

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Technology Working Group
Talk outline

- Mandate and goals of the Technology Working Group
- Initiatives integrated into the Technology WG
- Physics landscape
- Analysis of initiatives and their potential benefit from CERN expertise and technologies (selected examples)
- Analysis of synergies
- Status of the report and outlook

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

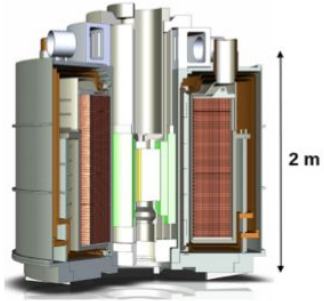
”Exploration and *evaluation* of **possible technological contributions of CERN** to non-accelerator projects possibly hosted elsewhere: **survey of suitable experimental initiatives** and their **connection** to and *potential benefit to and from CERN*; **description of identified initiatives** and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

Goals of the Techno Working Group

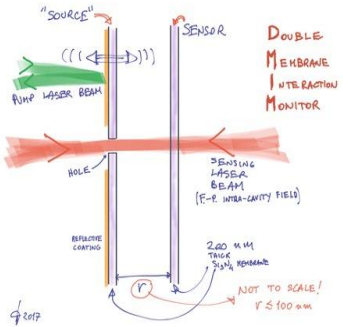
- Establish a list of non-accelerator proposals and all known new initiatives
- Address the physics case of the proposed initiatives in the worldwide landscape
- Address their feasibility and possible implementation at CERN (or elsewhere)
- Make a link between interested projects/experiments and CERN experts
- Identify requests to CERN for help and contribution
- Evaluate what sounds reasonable in order to put in balance wishes on one side and interest, availability and constraints on the other side, in particular CERN contributions to the preparation of the projects and, possibly, their future realisation at or outside CERN
- Help the preparation of the projects facilitating access to the unique expertise at CERN in various technologies
- Analyse synergies between different proposals and existing experiments in collaboration with other working groups
- Identify technologies that might be of interest for CERN in mid- and longer-term future

Initiatives integrated into the Techno WG

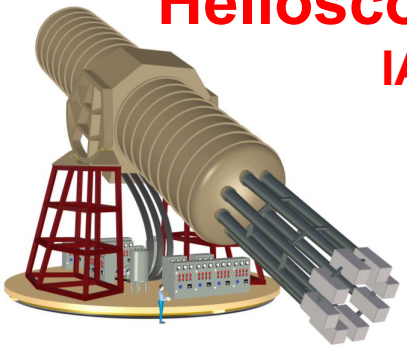
Haloscope LNCMI-Grenoble



aKWISP



Helioscope IAXO

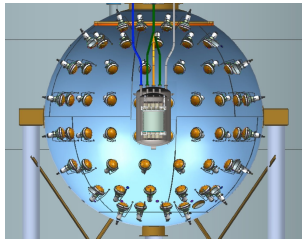


ALPS III

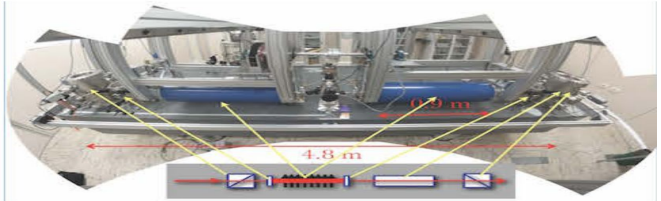
HALOSCOPE STAX

Nanotube Based DM Detector

DarkSide proto



New QED-VMB Experiment at CERN



New LSW Experiment at CERN OSQAR+

Physics Landscape in the Technology Working Group

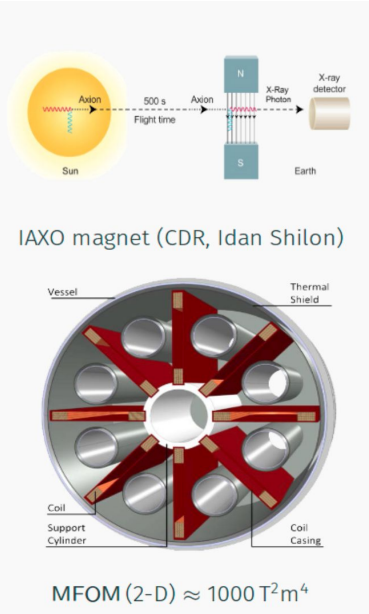
1. Direct detection of Dark Matter
   a. Ultralight (sub-eV) DM candidates like axions and ALPs (physics potential of respective experiments evaluated by BSM WG) . Initiatives concerned: IAXO, ALPS-III, STAX, OSQAR+, Grenoble Haloscope
   b. WIMPs: nuclear recoil. Initiatives concerned: DARKSIDE, Nanotubes
2. Test of density-dependent fields. Initiatives concerned: aKWISP
3. Fundamenal tests of QED: Vacuum magnetic birefringence. Initiatives concerned: OSQAR+, PVLAS

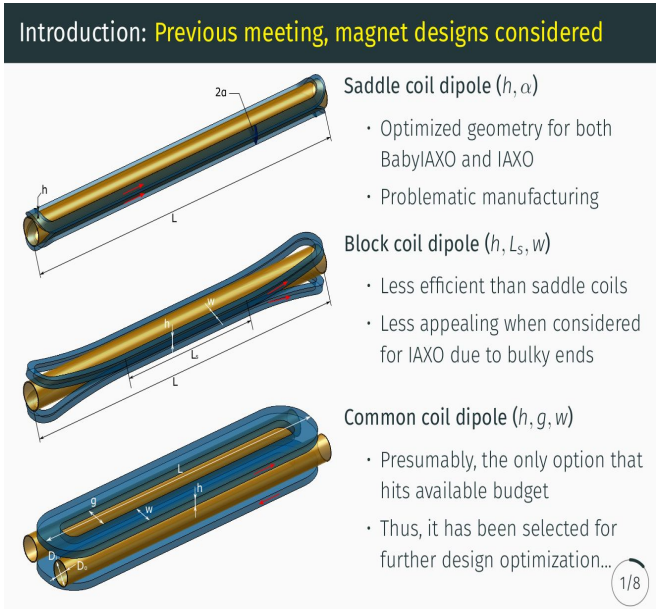
Details on initiatives presented in November: https://indico.cern.ch/event/644287/contributions/2724494/

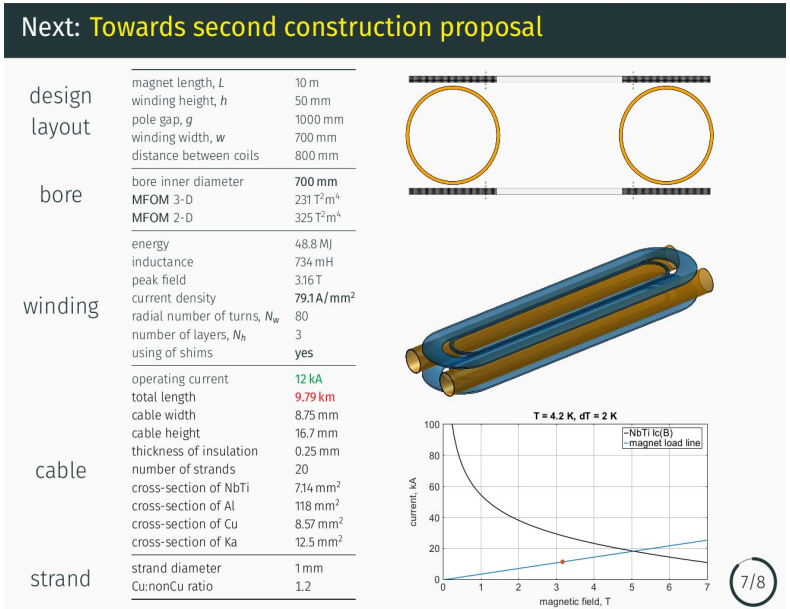
Initiatives and their potential benefit from/to CERN Summary table

Technology concerned	Benefit from CERN	Benefit to CERN	How to facilitate?	Experiments concerned
Magnet, concretely: high-field, large-bore	availability of strong fields, CERN expertise to build custom magnets	make optimal use of magnet resources (spares)	advertise existing magnet usage, provide expertise in magnet design, PBC-fellow	IAXO, OSQAR, ALPS, STAX, PVLAS
Optics/Optics sensing, concretely: Fabry Perot, membranes	surface coating, possibility to combine magnet with optics	integrate local expertise on optics technologies	``optics hub'', as described in the document	aKWISP, PVLAS, ALPS
Radiofrequency cavities, concretely: design for axion searches	experience in design and production	new cavity designs for non-accelerator purposes, tuning in cold	mandate for cavity experts to aid in design	Grenoble initiative and other Haloscope operating already at CERN (CAST-CAPP), STAX
Cryogenics, concretely: large-scale: helium, argon, krypton from 120K to mK	availability of cryogenic facilities	participate in research beyond collider	through TE-CRG	DarkSide, aKWISP, OSQAR-VMB, IAXO
Vacuum, concretely: large-scale leak testing, surface coating	experience and availability	participate in research beyond collider	through TE-VSC	DarkSide, OSQAR, aKWISP, Nanotubes

Magnets example: Design of baby-IAXO magnet

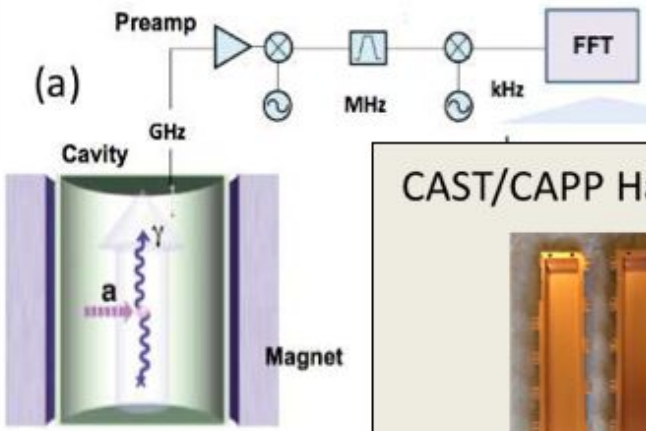






Thanks to: Nikolay Bykovskiy, Alexey Dudarev, Helder Silva and Herman ten Kate

RF example: Key RF components for Axion Haloscopes



RF cavities of various dimensions & geometries (cylindrical, rectangular) for the range (0.3-30 GHz) @ T < 40 mK

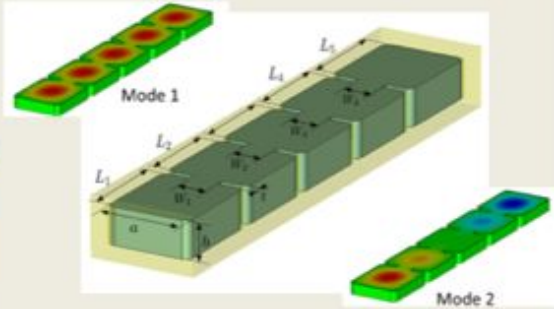
Technologies:

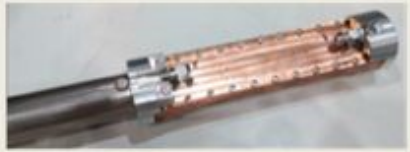
- Al, Cu, (Sc?)
- Quality Factor 10^5-10^6
- Cavity arrays with same frequency & phase matching
- Tuning systems

CAST/CAPP Haloscope

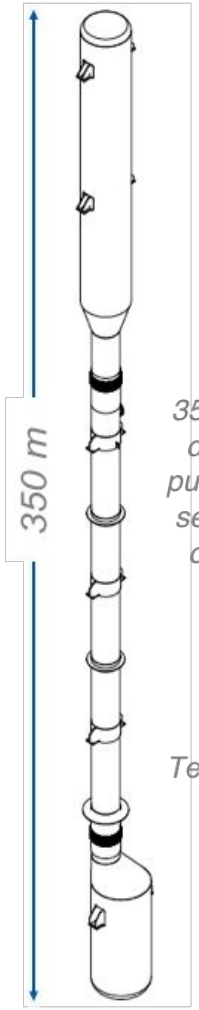
RADES project

arXiv:1803.01243v1, 3 March 2018





Vacuum example: ARIA facility for DarkSide 20k



ARIA

350-m LAr cryogenic distillation tower to purify and isotopically separate argon from other elements for DS20k

Full tower - 30 modules

Tested at CERN – 11 modules

Thanks to: Livio Mapelli

Analysis of synergies among LSW and VMD initiatives

The main characteristics of diferent Light Shining through the Wall and Vacuum Magnetic Dichrosim initiatives

	Light Shining through the Wall (LSW)				Dichroism
Parameter	ALPS IIc	OSQAR+	OSQAR++	STAX	OSQAR-PVLAS
Magnet assembly	$10+10$ HERA	$4+4$ LHC	$7+7$ LHC	$1+1$ FCC	1 LHC
Field length L_B [m]	88 + 88	57+57	100 + 100	1.5 + 1.5	14.3
B [T]	5.3	9	9	11	9
Photons/s, R $[s^{-1}]$	1.6×10^{20}	1.6×10^{20}	1.6×10^{20}	1×10^{28}	2×10^{18}
Photon energy, ω [eV]	1.17	1.17	1.17	1.2×10^{-4}	1.17
N_1	5000	5000	5000	10000	450000
N_2	40000	40000	40000	10000	n.a.
Background, B $[s^{-1}]$	10^{-6}	10^{-6}	10^{-6}	10^{-6}	n.a.
Shot-Noise floor, NF	n.a.	n.a.	n.a.	n.a.	10^{-12} rad
$g_{a\gamma\gamma}$ [GeV^{-1}]	$< 2 \times 10^{-11}$	$< 2 \times 10^{-11}$	$< 1 \times 10^{-11}$	$< 1 \times 10^{-11}$	$< 5 \times 10^{-11}$
m_a [eV]	$< 1 \times 10^{-4}$	$< 1.3 \times 10^{-4}$	$< 1 \times 10^{-4}$	$< 4 \times 10^{-6}$	$< 2.5 \times 10^{-4}$

N1 and N2 are the amplification factors of the generation and regeneration cavities.

Regeneration rate signal: $S = RN_1N_2 \left(\frac{g_{a\gamma\gamma}BL}{4}\right)^4$

Rotation due to dichroism $\phi = N_1 \left(\frac{g_{a\gamma\gamma}BL}{4}\right)^2$

Mass limits have been set from $m_a < \sqrt{\frac{4\omega}{L}}$

Limits on $g_{a\gamma\gamma}$ have been obtained by setting $S = B$ for the LSW cases and $\phi = NF$ for VMD

Everywhere $1\ \mathrm{T} = \sqrt{\frac{\hbar^3 c^3}{e^4 \mu_0}} = 195\ \mathrm{eV}^2$

$1\ \mathrm{m} = \frac{e}{\hbar c} = 5.06 \times 10^6\ \mathrm{eV}^{-1}$

Thanks to: Guido Zavattini

Status of WG report as input for summary document

Contents

Appendices: Description of all initiatives, plans, collaboration, time-lines...

Status of the Report and Outlook

- The technological contributions and future expectations from 9 new initiatives: **Grenoble-haloscope, STAX, aKWISP, DarkSide, IAXO, new QED-VMB experiment at CERN (OSQAR-PVLAS), nanotube DM detector, ALPS III and OSQAR+** were categorized and are being documented
- The working group's job is now to complete analysis of synergies and develop a form of executive summary with a proposal of recommendations for the future
- The Technology WG report is well advanced and will be submitted with a number of appendices describing all initiatives/experiments assigned to this WG