

# Hunting light-weight and very weakly coupled particles

Babette Döbrich (CERN)

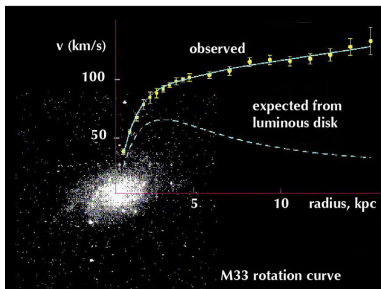
Kitzbühel 06/16

The screenshot shows a 'Run Infos' panel with the following details:

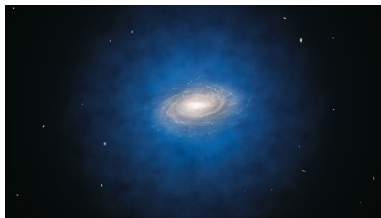
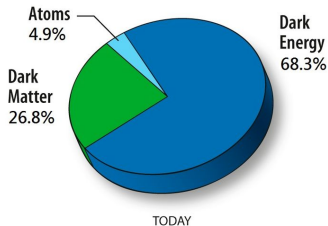
- Run Type: Fw\_303\_T10\_33e11
- Start Time: 2015.11.15 18:40:56.812
- End Time: 2015.11.15 19:35:52.498
- Beam Type: (empty field)
- Shift crew: Martellotti Piccini
- StartRun Comment: Axion run: K12 tax closed. LKr > 1.3 GeV/1. T10 31.7. No GTK.
- EndRun Comment: End of axion run. CHANTI threshold scan during run. Last 10 bursts have special triggers (SOB/EOB) only.
- RunNumber: 4139
- Burst #: 127
- Burst State: (represented by a grey circle)

Navigation icons are visible at the bottom right of the panel.

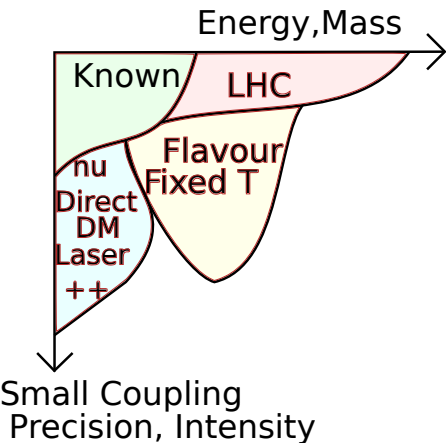
# New physics at low masses, extremely weak coupling?



- particle physics not complete

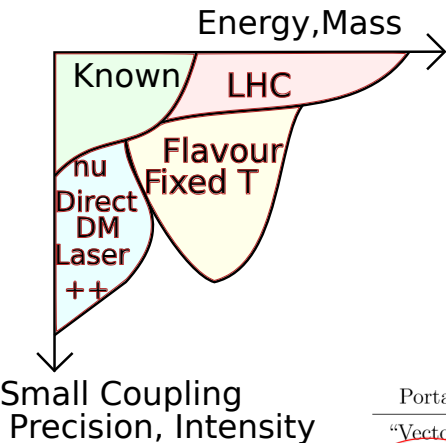


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- could be at low mass and very small couplings (pragmatic paradigm)

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- presentation will just pick representative examples (biased by my experience)

Portal	Particles	Operator(s)
“Vector”	Dark photons	$-\frac{\epsilon}{2\cos\theta_W} B_{\mu\nu} F^{\prime\mu\nu}$
“Axion”	Pseudoscalars	$\frac{a}{f_a} F_{\mu\nu} \tilde{F}^{\mu\nu}, \frac{a}{f_a} G_{i\mu\nu} \tilde{G}_i^{\mu\nu}, \frac{\partial_\mu a}{f_a} \bar{\psi} \gamma^\mu \gamma^5 \psi$
“Higgs”	Dark scalars	$(\mu S + \lambda S^2) H^\dagger H$
“Neutrino”	Sterile neutrinos	$y_N L H N$

[from arxiv/1311.0029]

# New physics at low masses, extremely weak coupling?

cleans (detergent!)

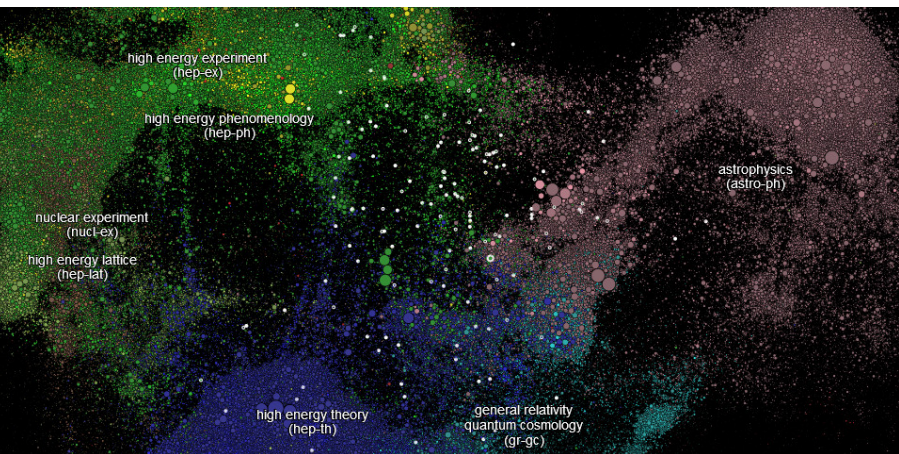
finetuning of  $\sim 10^{-10}$



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- could be at high energy/mass (traditional paradigm)
- could be at low mass and very small couplings (pragmatic paradigm)
- presentation will just pick representative examples (biased by my experience)
- e.g. Axion predicted to explain  $\theta$  parameter  $\simeq 0$  and (is DM candidate at same time!)

[Peccei, Quinn, 77; Weinberg, Wilczek, 78]

# New physics at low masses, extremely weak coupling?

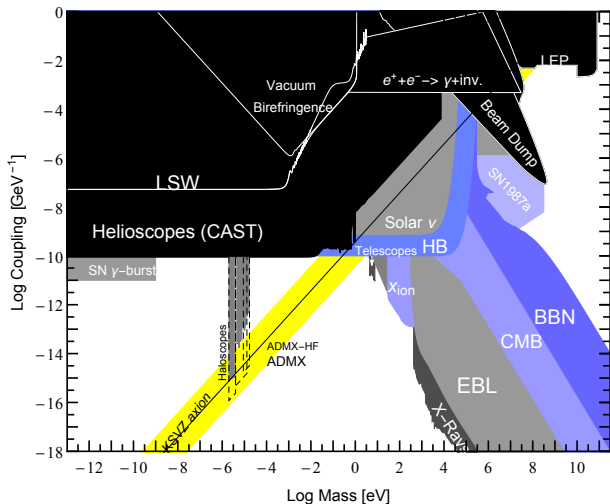


[created through paperscape.org]

- interplay of different physics fields and different scenarios

# Typical treasure map for weakly-coupled particle hunters

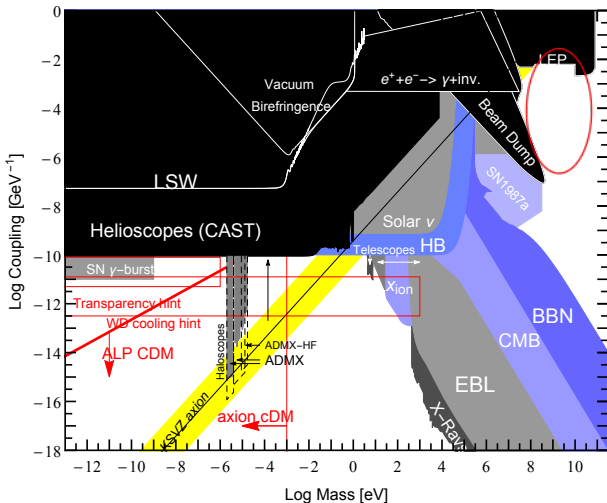
[adapted from 1311.0029]



- mass vs coupling-to-known: axion-like to two- $\gamma$
- colored is excluded (except yellow)

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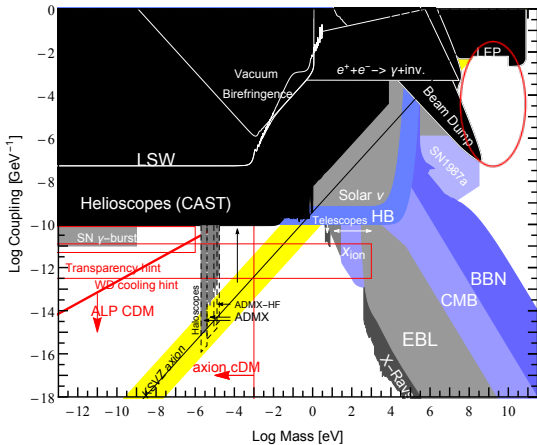


- mass vs coupling-to-known: axion-like to two- $\gamma$
- colored is excluded (except yellow)
- interesting regions (overlap with nearest searchable regions..):
  - cold Dark Matter (axion and ALP)
  - Dark Matter mediators
  - Astrophysical 'hints'



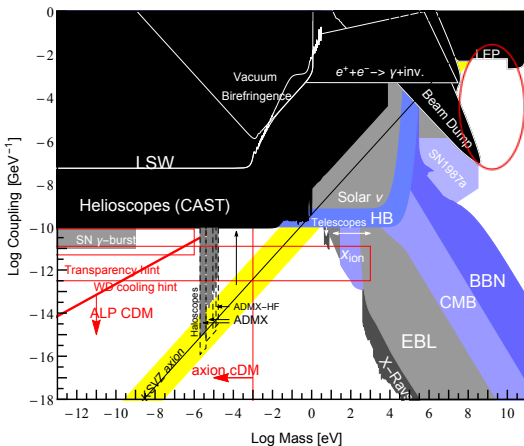
# Typical treasure map and hunter's tools

search strategy? (specify to particle &  $m, g$ )

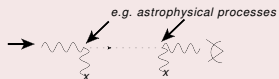


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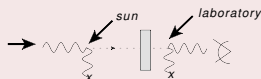
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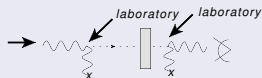
## Astrophysics, e.g. SN $\gamma$



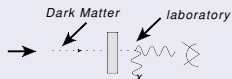
## Helioscope, e.g. CAST



## Laboratory, e.g. 'LSW'

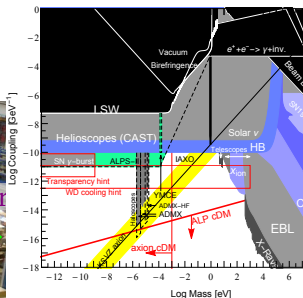
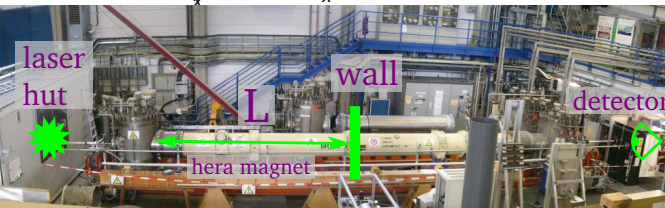
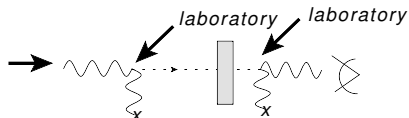


## DM-Haloscope, e.g. ADMX

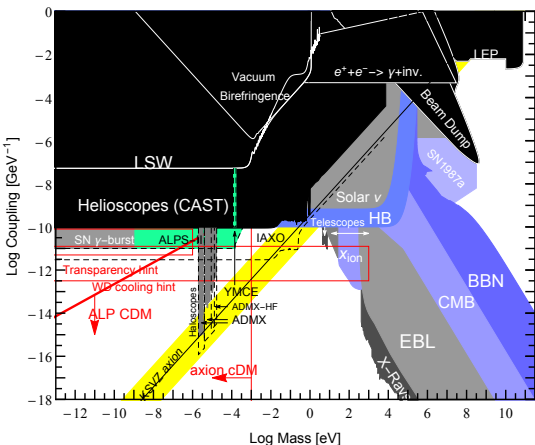


# Laboratory 'Light-Through-Walls'

- very weakly interacting: 'easy' to get rid of Standard Model background by a 'wall' (albeit a potential signal could arise from different Beyond-Standard-Model scenarios)
- depending on mass range, intense photon source of appropriate energy
- very low mass: laser in Dipole magnet field (virtual photon source): ALPS experiment at DESY [Ehret et al Phys. Lett. B **689**, 149 (2010)], currently undergoing upgrade: ALPS-II [Bähre, BD et al. JINST **8**, T09001]

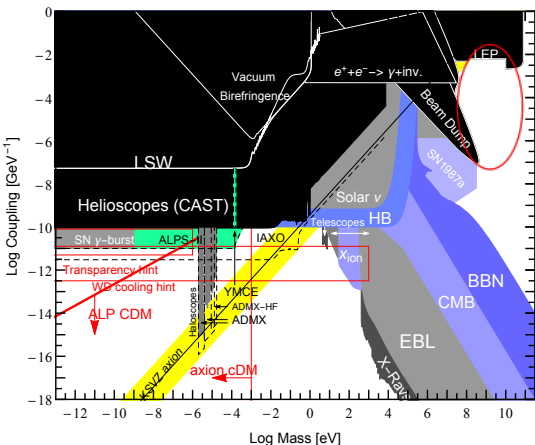


# Laboratory 'Light-Through-Walls' II, high masses

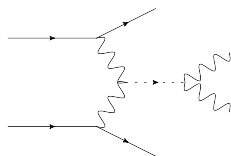


↑ **ALPS-II** expected reach 2018 [gain 3 orders of magnitude in sensitivity!]

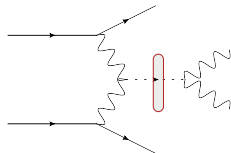
# Laboratory 'Light-Through-Walls' II, high masses



← high mass region?  
intense photon source?  
accelerate charged particles!



and shield from 'backgrounds'

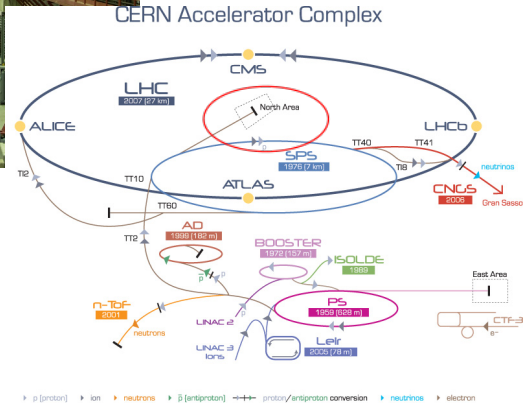


and highly charged particles → fixed target/dump

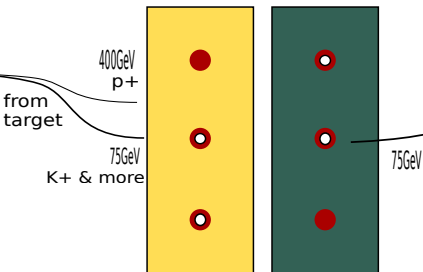
# Example: 'Light-Through-Walls' at NA62 at CERN

na62.web.cern.ch/NA62/

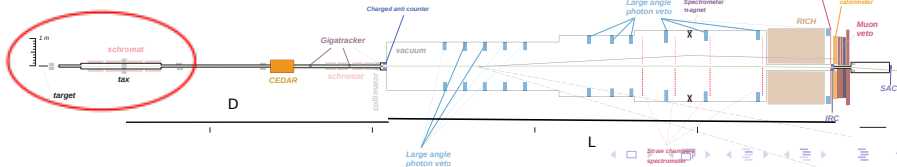
- NA62 currently taking data for measurement of  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  at CERN SPS (400GeV protons)



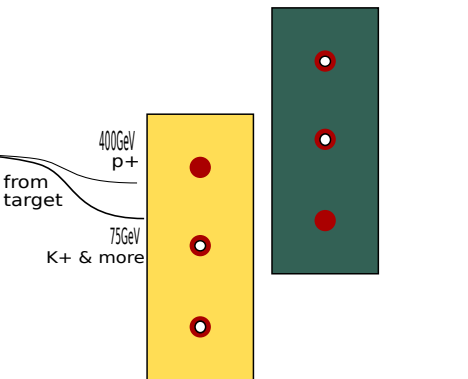
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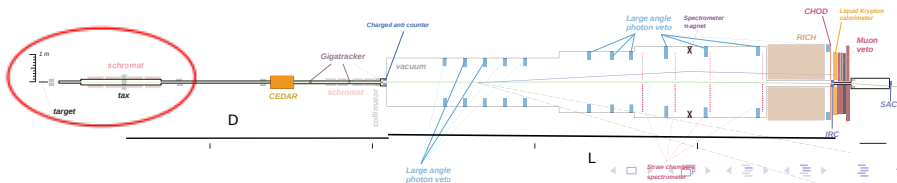
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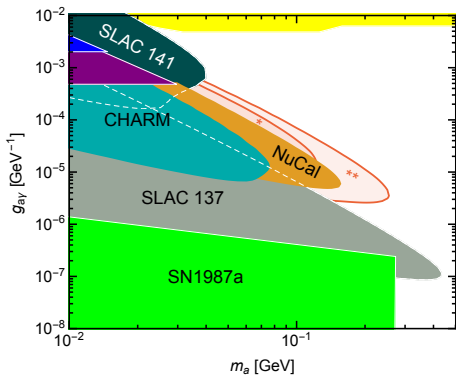


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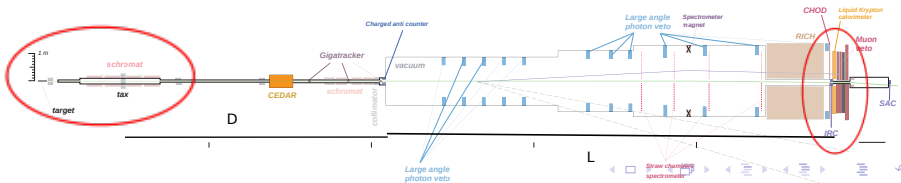


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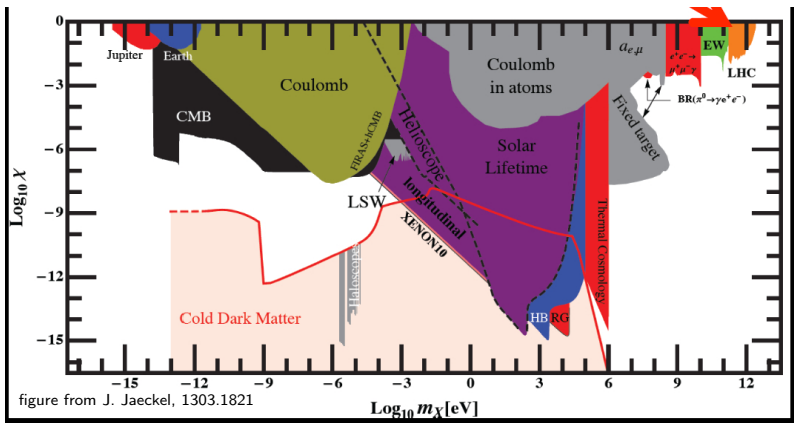


[BD, Jaeckel, Kahlhoefer, Ringwald, Schmidt-Hoberg JHEP 1602, 018]

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- can run as dump, 'few' background  $\gamma$ s expected
- toy Model: novel sensitivity in 1 day (\*) (month (\*\*)) runtime
- ideally parasitic (under study)

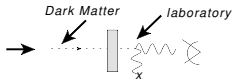


# Treasure map II: Dark Photon Dark Matter



if weakly coupled stuff = DM itself, convert it to visible  
(recoil measurement as for WIMPs less feasible)

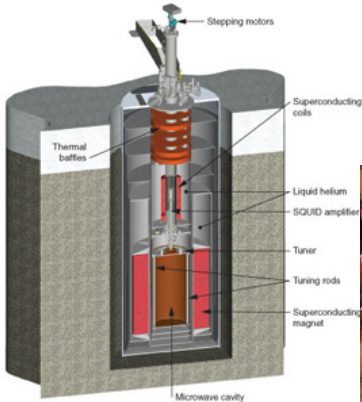
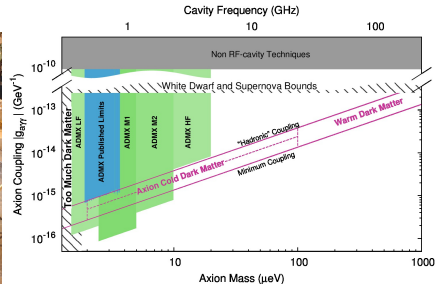
# Direct Dark Matter search at low-mass



- shielded microwave **resonator**  
 → Haloscope [Sikivie '83],  
 $f_{\text{cavity}} \sim m_{\text{axion}}$  (with (axions)  
 or w/o (dark photon)  $\vec{B}$ -field)

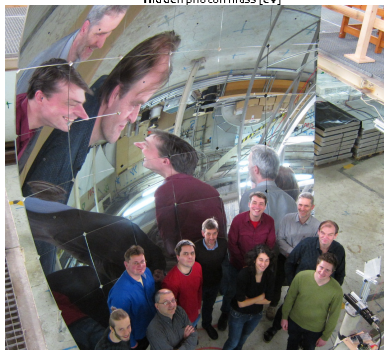
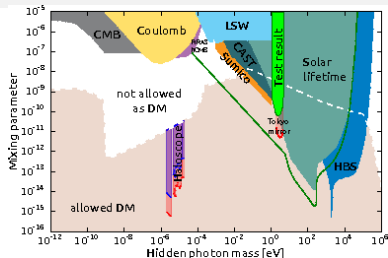
- results by ADMX [Phys.Dark Univ. 4, 14-16] but many new efforts (Korea CAPP, ADMX-HF CERN CAST, Munich MPP...)

ADMX Achieved and Projected Sensitivity



taken from learner.org

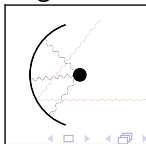
# Direct Dark Matter search at low-mass



FUNK Experiment Collaboration: PoS ICRC2015, 1191

Babette Döbrich (CERN)

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or w/o (dark photon)  $\vec{B}$ -field)
- results by ADMX [Phys.Dark Univ. 4, 14-16] but many new efforts (Korea CAPP, ADMX-HF CERN CAST, Munich MPP...)
- broadband-technique (half-resonator) [Horns et al. JCAP 1304, 016]: giant mirror in 'dark room', Dark Photon Dark Matter data taking at KIT



even better:

Dark Photon 'radio':

Chaudhuri et al PRD92,0750

Arias et al Eur.Phys.J. C75

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Kitzbühel 06/16

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# Thank you for your attention!



Life in the 'hidden sector'...

- new particles could have 'small mass' (below GeV) (if very weakly coupled)
- presented various non-collider tools: light through walls with lasers or particle beams, direct Dark Matter searches...
- searches for these particles often make use of existing infrastructure (of very different kinds)
- selection of results upcoming, stay tuned!

I cordially acknowledge my past and present collaborators

from ALPS-II at DESY, from NA62 at CERN, from FUNK at KIT, and phenomenologists all over the place