

Conclusions

All participants¹

Wrong things by: Joerg Jaeckel

¹The Universe

Axions, WISPs and Stuff

We started really simple ;-).

- Solving a few problems in one go...

Z' from GUTs, weak CP, strong CP axions, and the μ problem,

$$\begin{aligned}
 \tilde{M}^{(u)} &= \begin{pmatrix} u\lambda^7, & 0, & 0 \\ -c\lambda^5, & c\lambda^4(1 + \frac{1}{6}\lambda^2), & c\kappa_t\lambda^6 \\ -\kappa_t e^{i\delta}\lambda^3(1 + \frac{1}{3}\lambda^2), & \kappa_t e^{i\delta}\lambda^2(1 - \frac{\lambda^2}{6} + [\kappa_b^2 - \frac{41}{360}]\lambda^4), & -e^{i\delta}(1 - \kappa_t \frac{\lambda^4}{2} - \kappa_t^2 \frac{\lambda^6}{3}) \end{pmatrix} \\
 \tilde{M}^{(d)} &= \begin{pmatrix} d\lambda^4(1 + \frac{2}{3}\lambda^2), & 0, & 0 \\ 0, & s\lambda^2(1 + \frac{\lambda^2}{3} + [\frac{8}{45} + \frac{\kappa_b^2}{2}]\lambda^4), & s\kappa_b e^{i\delta}\lambda^4(1 + \frac{2}{3}\lambda^2) \\ 0, & \kappa_b\lambda^2(1 + \frac{\lambda^2}{3} + [\frac{8}{45} + \kappa_b^2]\lambda^4), & -e^{i\delta}(1 - \kappa_b^2 \frac{\lambda^4}{2} - \kappa_b^2 \frac{\lambda^6}{3}) \end{pmatrix}.
 \end{aligned}$$

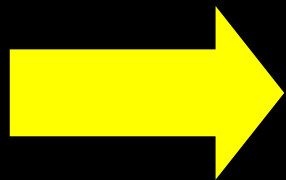
$R = L,$

$$\begin{aligned}
 \tilde{M}^{(u)} &= \begin{pmatrix} (c + \kappa_t^2\lambda)\lambda^6, & -(c + \kappa_t^2)\lambda^5, & \kappa_t\lambda^3(1 + \frac{1}{3}\lambda^2) \\ -(c + \kappa_t^2)\lambda^5, & c\lambda^4(1 - \frac{1}{3}\lambda^2), & -\kappa_t\lambda^2 + \frac{\kappa_t}{6}\lambda^4 + O(\lambda^6) \\ \kappa_t\lambda^3(1 + \frac{1}{3}\lambda^2), & -\kappa_t\lambda^2 + \frac{\kappa_t}{6}\lambda^4 + O(\lambda^6), & 1 - \kappa_t^2 \frac{\lambda^4}{2} - \kappa_t^2 \frac{\lambda^6}{3} \end{pmatrix} \\
 \tilde{M}^{(d)} &= \begin{pmatrix} d\lambda^4(1 + \frac{2}{3}\lambda^2), & 0, & 0 \\ 0, & s\lambda^2 + (\kappa_b + \frac{s}{3})\lambda^4 + (\frac{8}{45}s + \frac{2\kappa_b^2}{3})\lambda^6, & \kappa_b e^{i\delta}(-\lambda^2 + (s - \frac{1}{3})\lambda^4) + O(\lambda^6) \\ 0, & \kappa_b e^{-i\delta}(-\lambda^2 + [s - \frac{1}{3}]\lambda^4) + O(\lambda^6), & 1 - \kappa_b^2\lambda^4 + \kappa_b^2(s - \frac{2}{3})\lambda^6 \end{pmatrix}
 \end{aligned}$$

More motivation came from the the LHC...

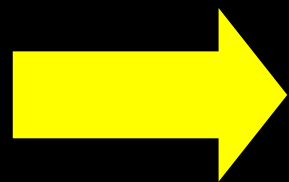
What if the LHC does NOT find new physics

The Nightmare Scenario



**Then Dark Matter
is made of Axions!**

More motivation came from the the LHC...

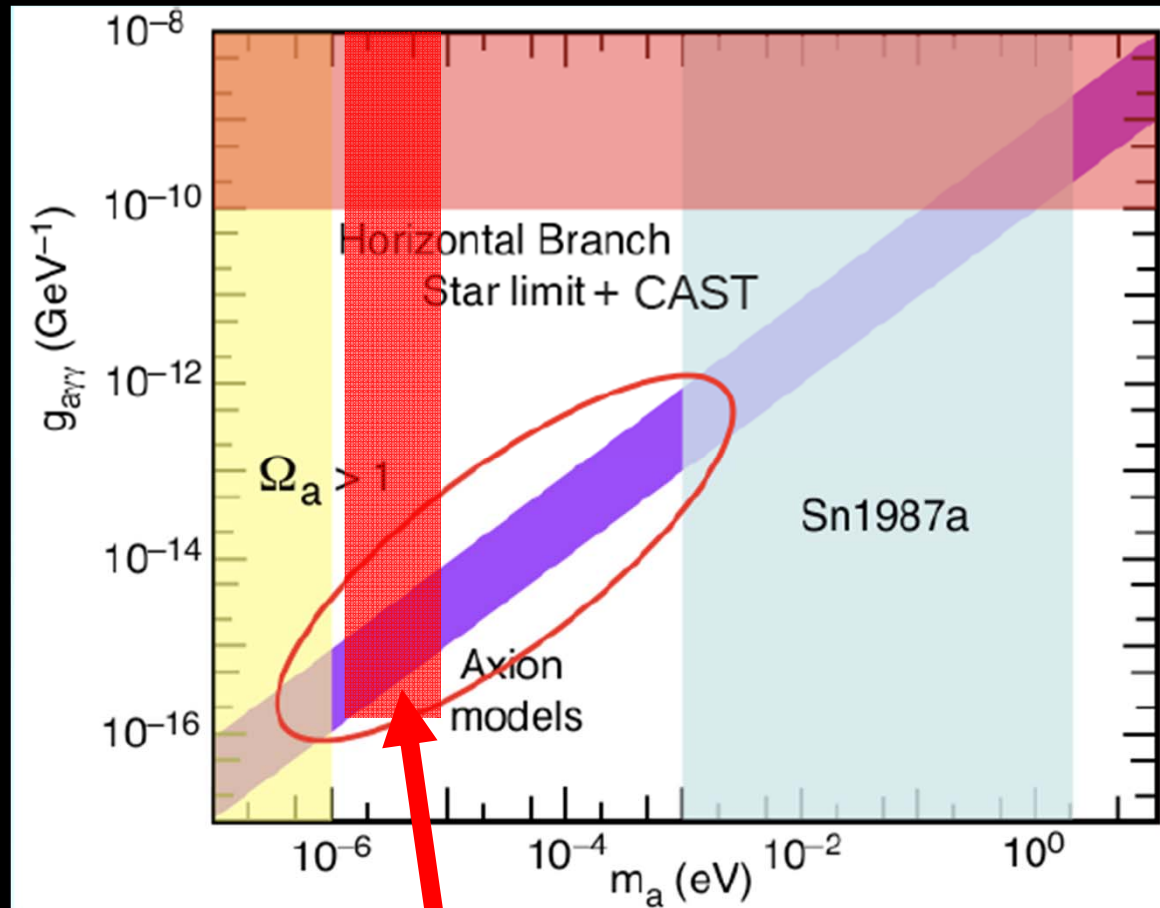


Then Dark Matter
is made of Axions!

Big Question:
Is it a Bose-Einstein Condensate?
Tests!!!

Axion Dark Matter searches

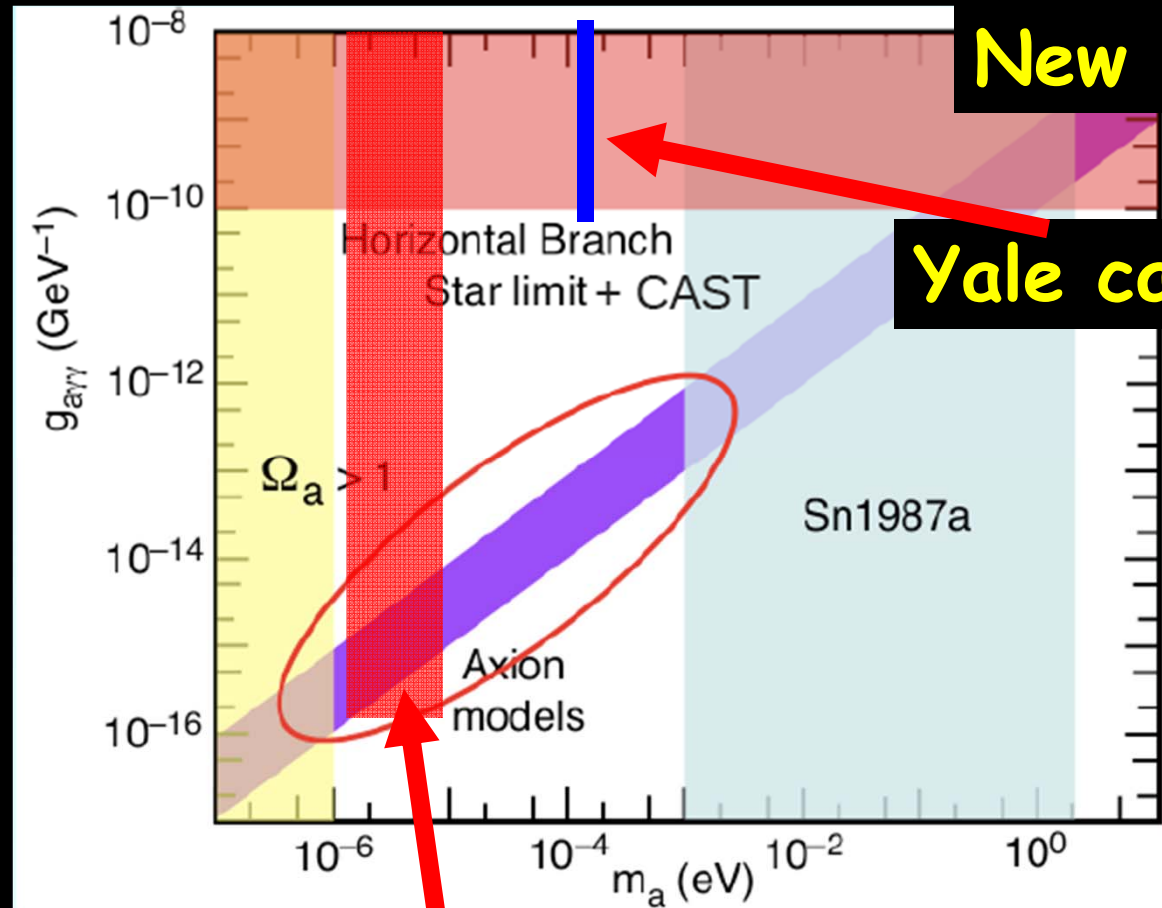
- The classic: ADMX



Till 2015 definitive search
over large range!!!

Axion Dark Matter searches

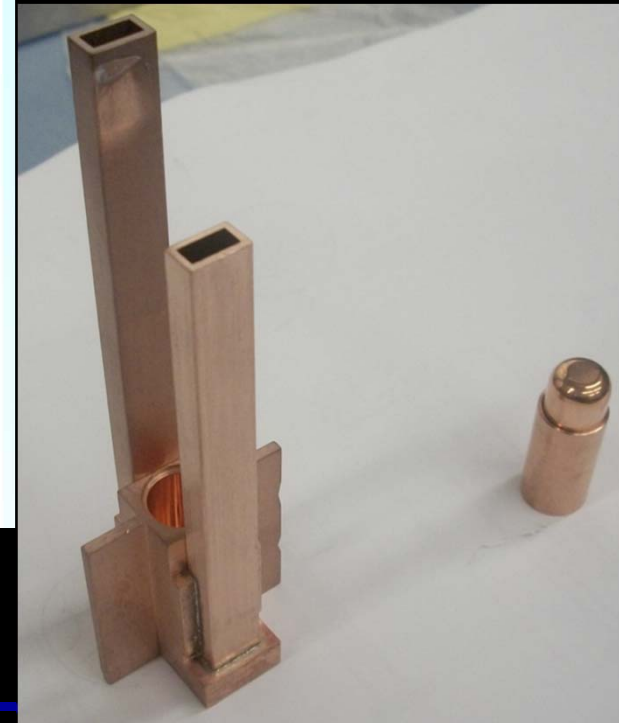
- The classic: ADMX



New kids on the block!

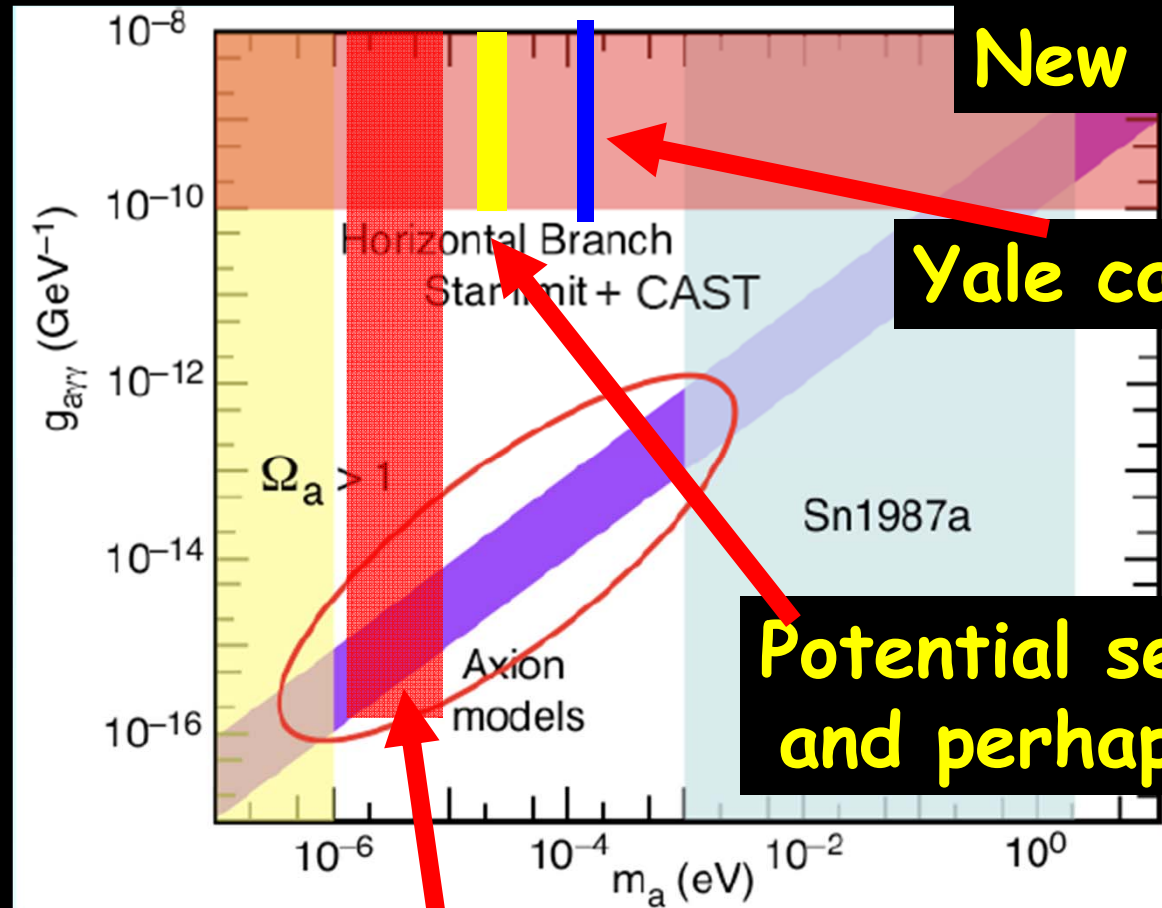
Yale cavity search ($\times 10^3$)!

Till 2015 definitive search
over large range!!!



Axion Dark Matter searches

- The classic: ADMX



New kids on the block!

Yale cavity search ($\times 10^3$)!

Potential search also at Cern
and perhaps UWA (roughly)!

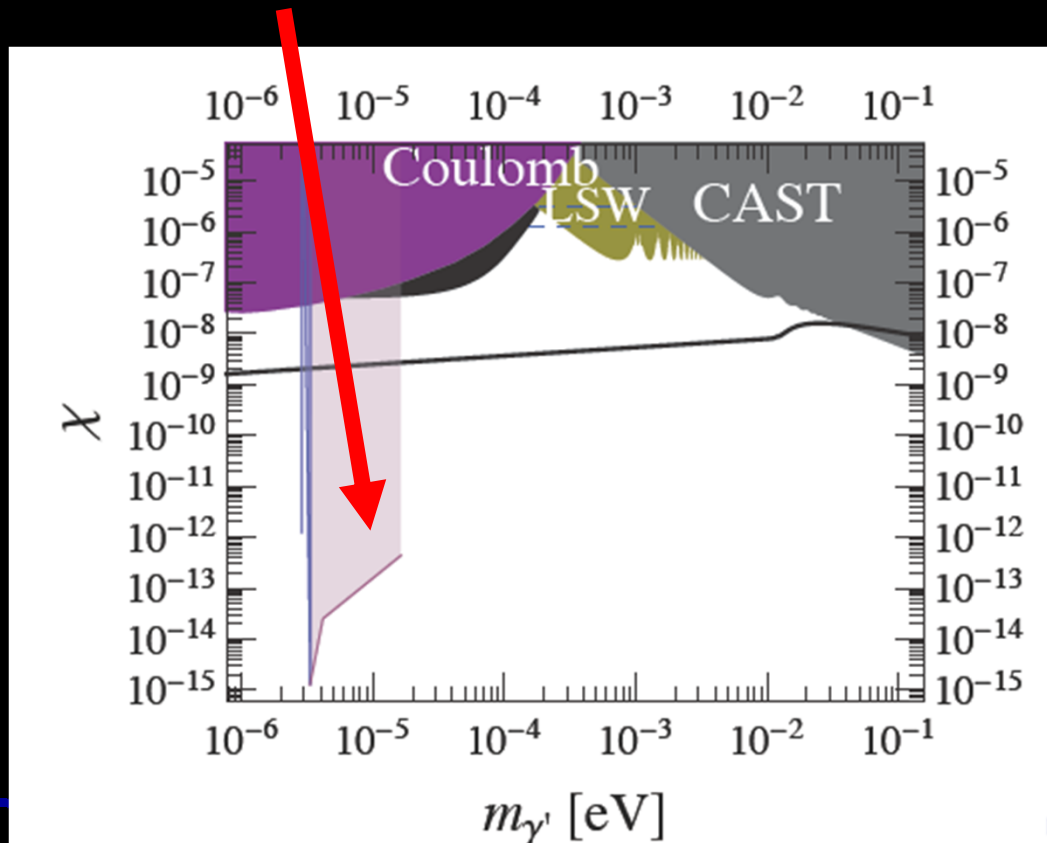
Till 2015 definitive search
over large range!!!

Personal note...

Dark Matter could also be...

Hidden Photons

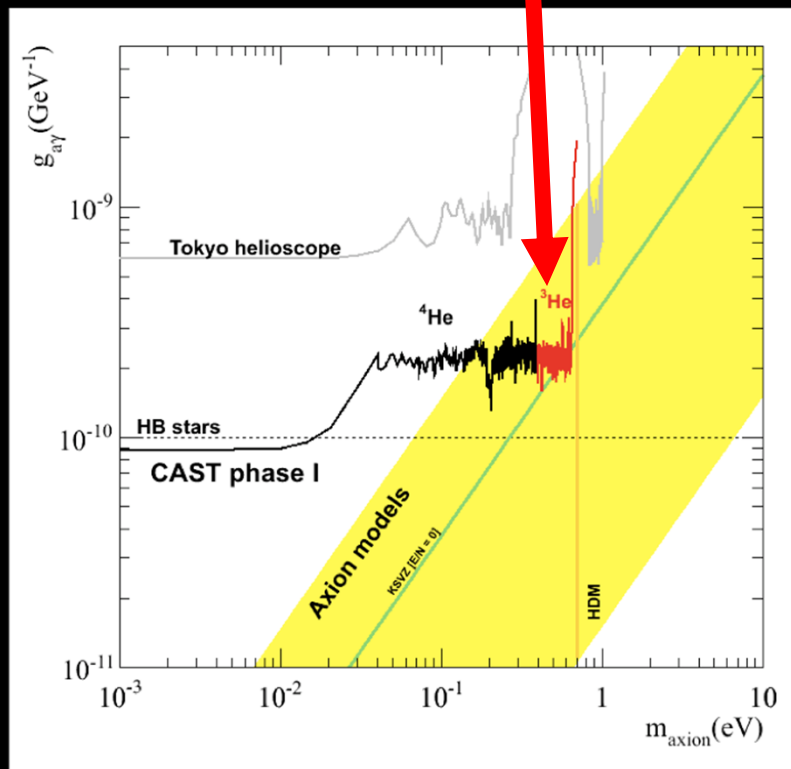
ADMX and Co can reach fantastic sensitivity!



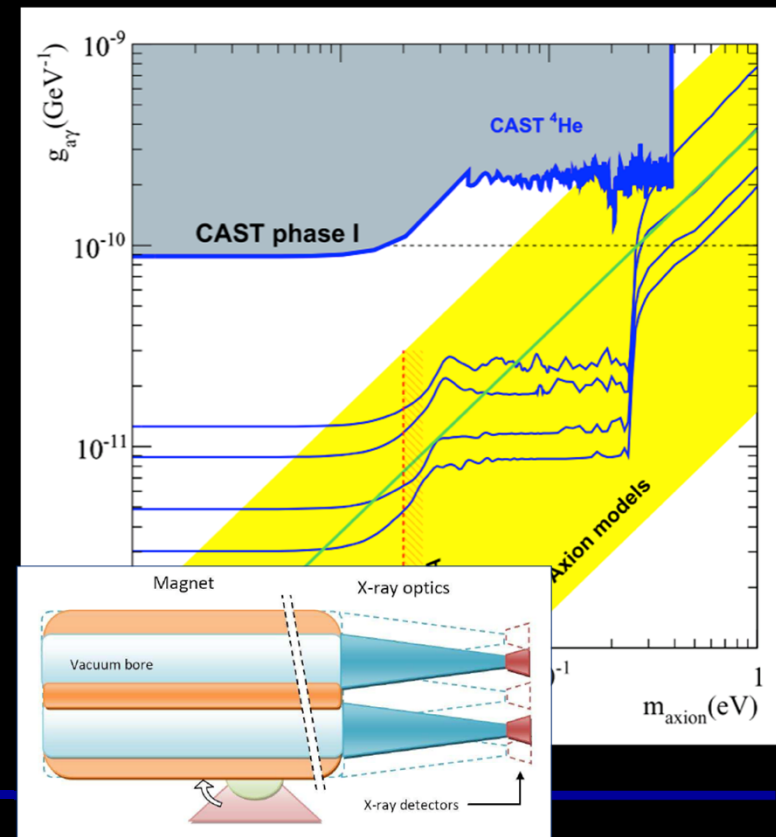
Axion Helioscopes...

- CAST is going strong...

towards higher masses

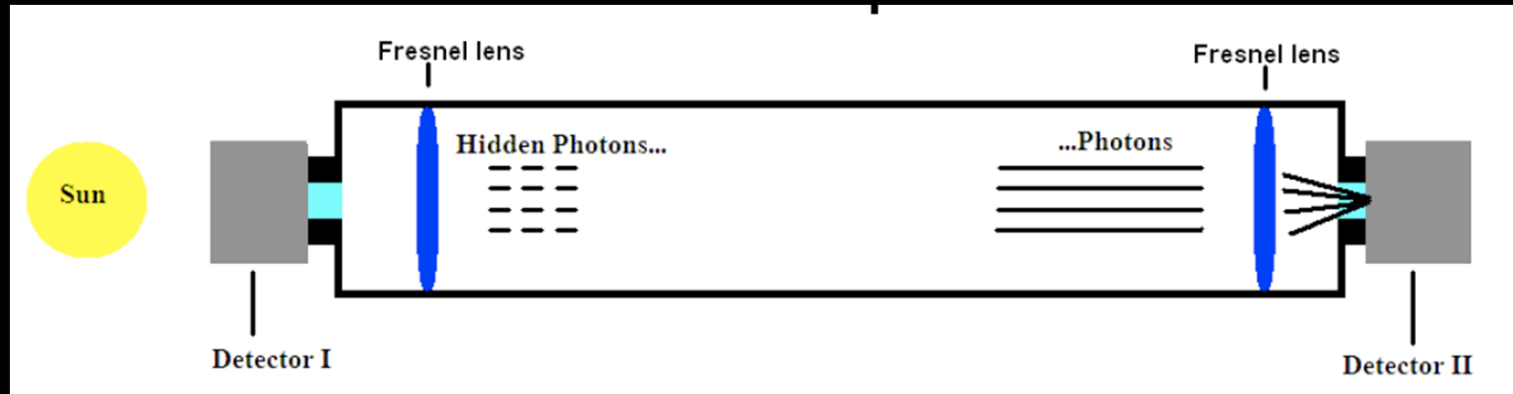


towards the future
SUPER-CAST

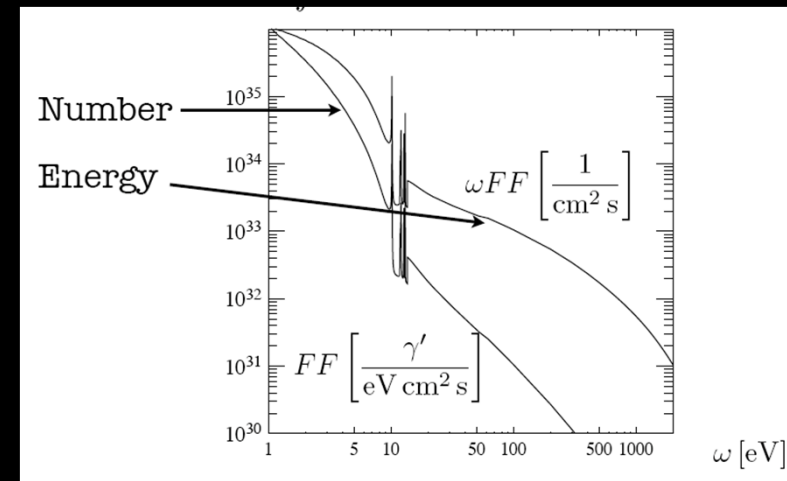
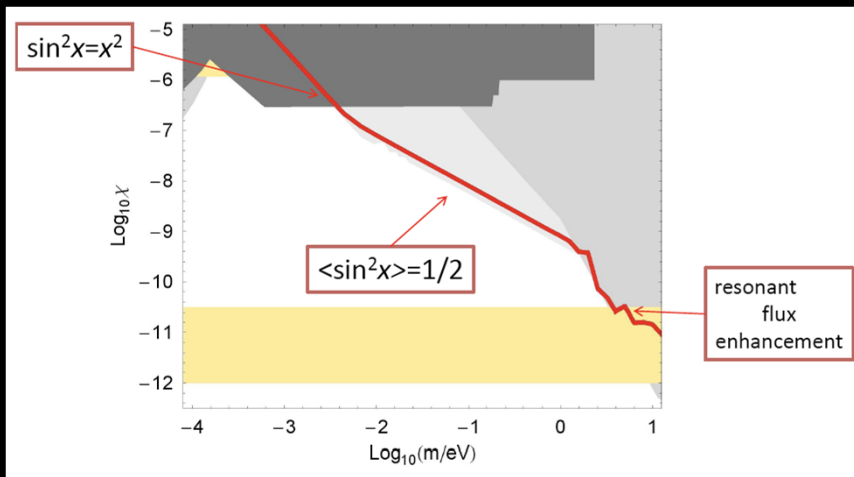


Axion helioscopes...

- New experiments: SHIPS

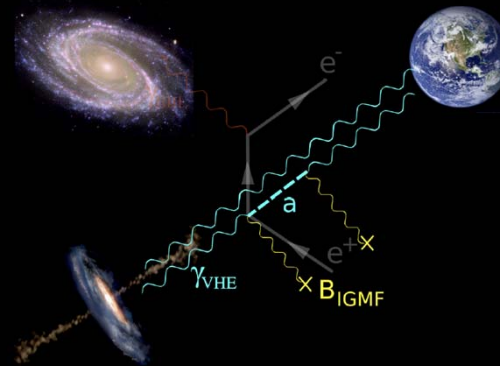


- Improved understanding: Hidden Photon flux

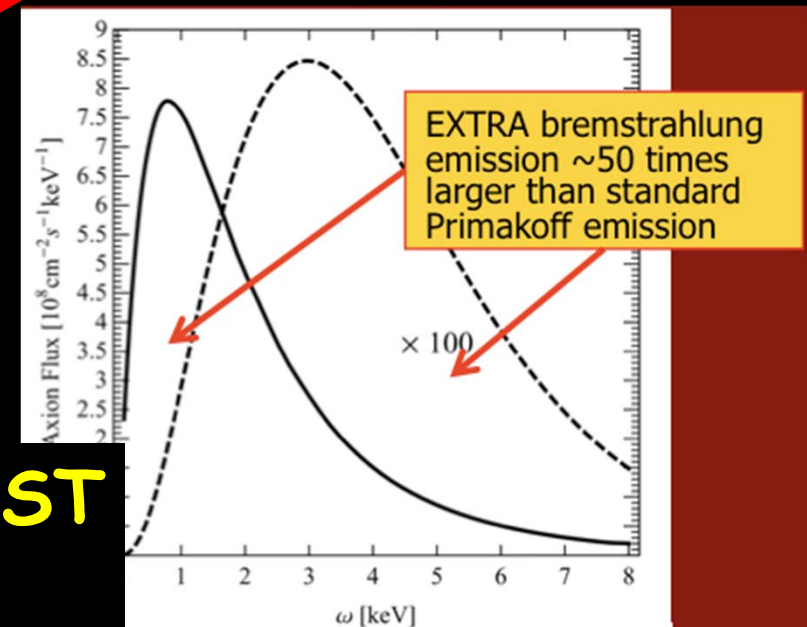
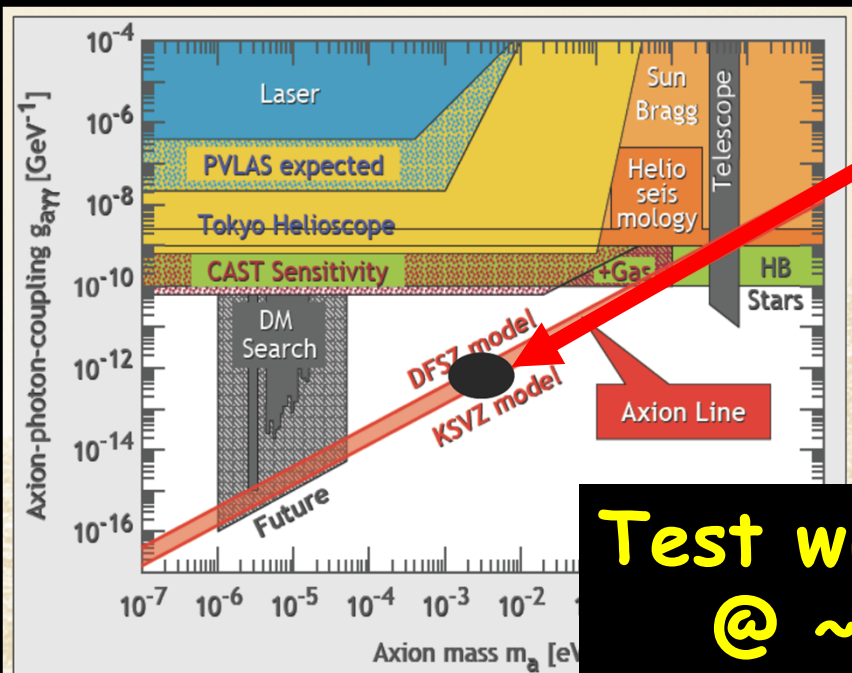


Hints to test (also for LSW)

- From astrophysics



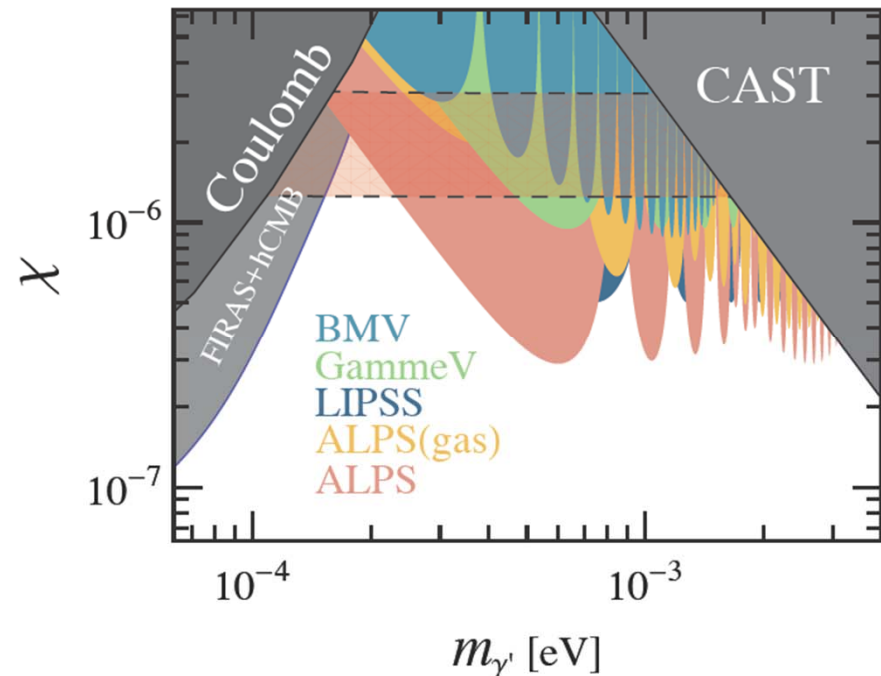
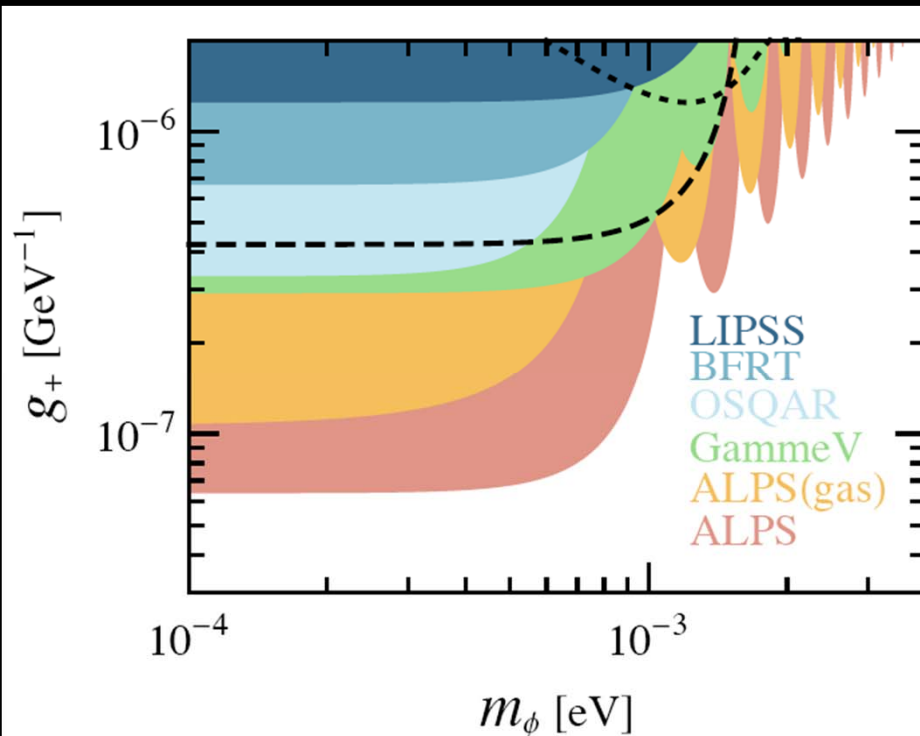
White dwarf cooling gives us: $g_{ae} \sim 2 \times 10^{-13}$



Test with CAST
@ ~1 keV

Light Shining Through Walls

- First round of experiments are done!
- Achieved impressive sensitivity



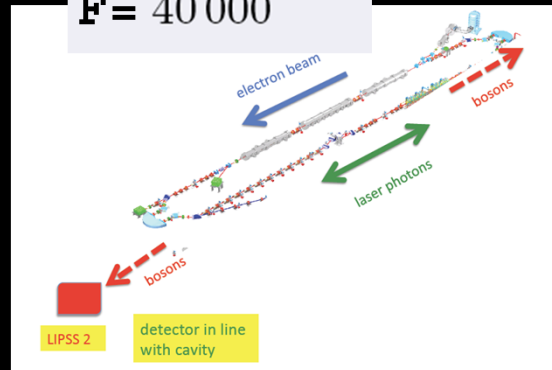
Light Shining Through Walls

- Is gearing up for the future.
- Trying to beat *CAST* ;-).

- **ALPS II**

ALPS II
150 kW
12 + 12 HERA
$F = 40\,000$

- **LIPSS 2**



- **Grim Repr**



GammeV
Reconstituted &
Instrumented
Magnets

for

Resonantly
Enhanced
Photon
Regeneration

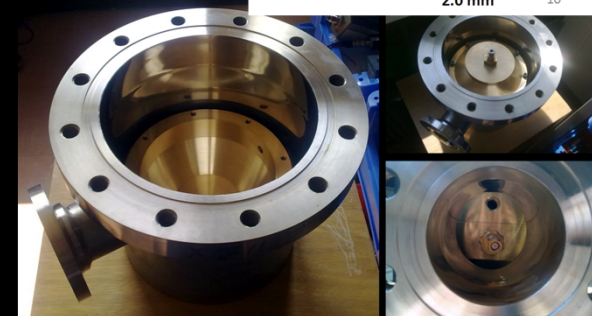
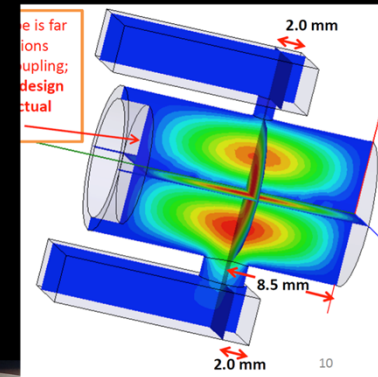
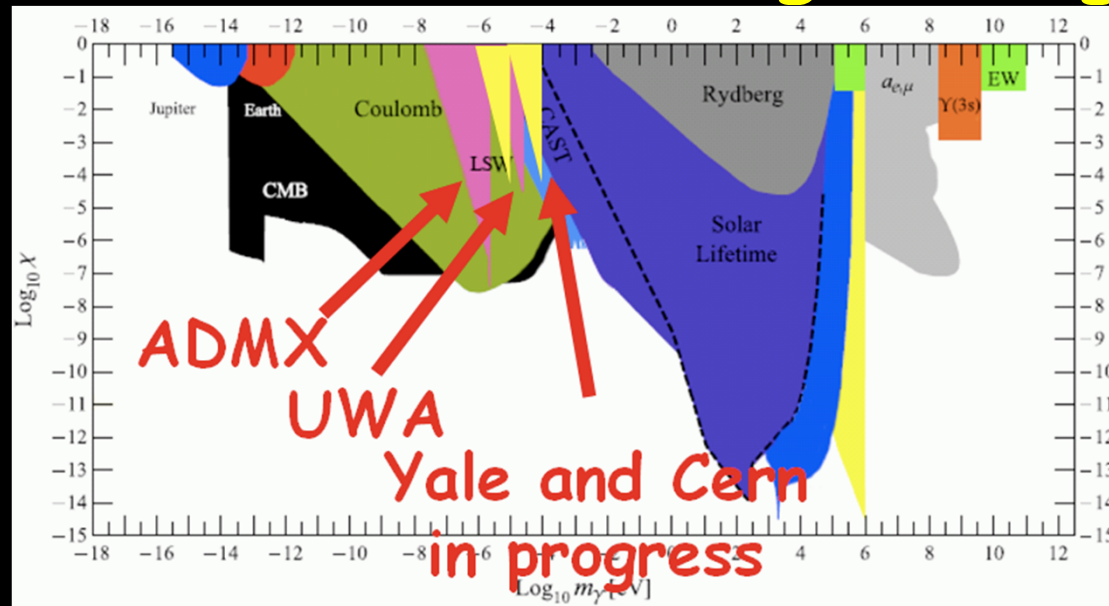


Think BIG!!

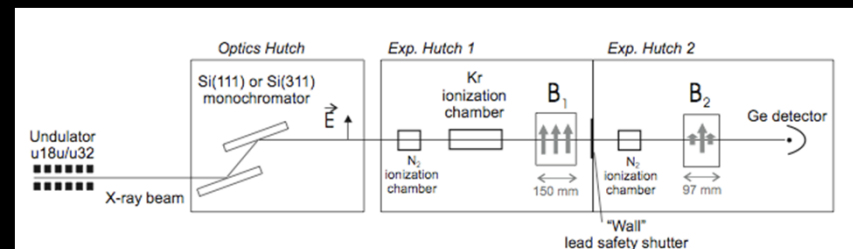
Light Shining Through Walls

Is exploring new frequencies:

- Microwaves shining through walls



- Synchrotron radiation: XAX experiment (next stage use full spectrum)



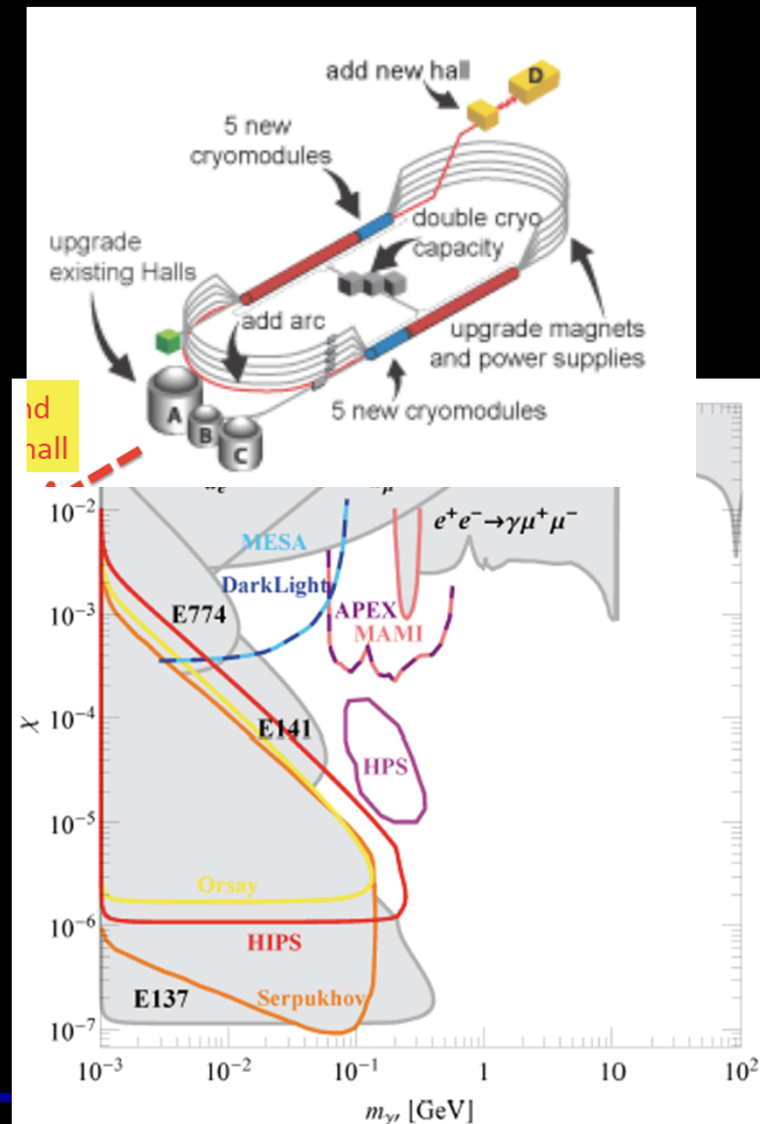
Heavier WISPs

- Very interesting developments in the MeV-GeV range!
May be connected to Dark Matter

Small accelerators useful!

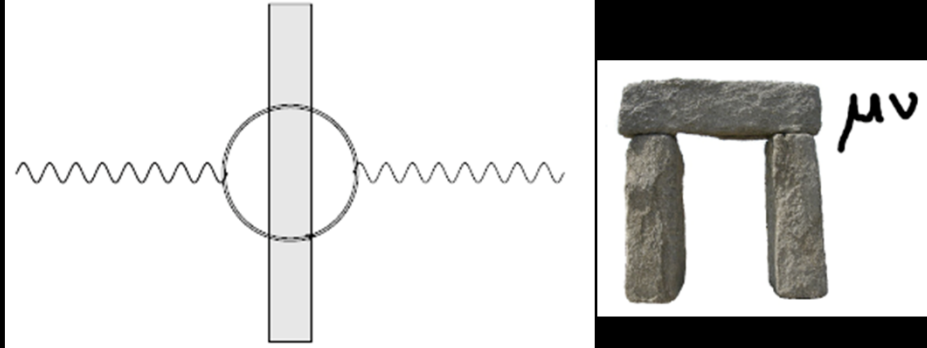
Many experiments in planning or underway!!!

Stay Tuned!!!

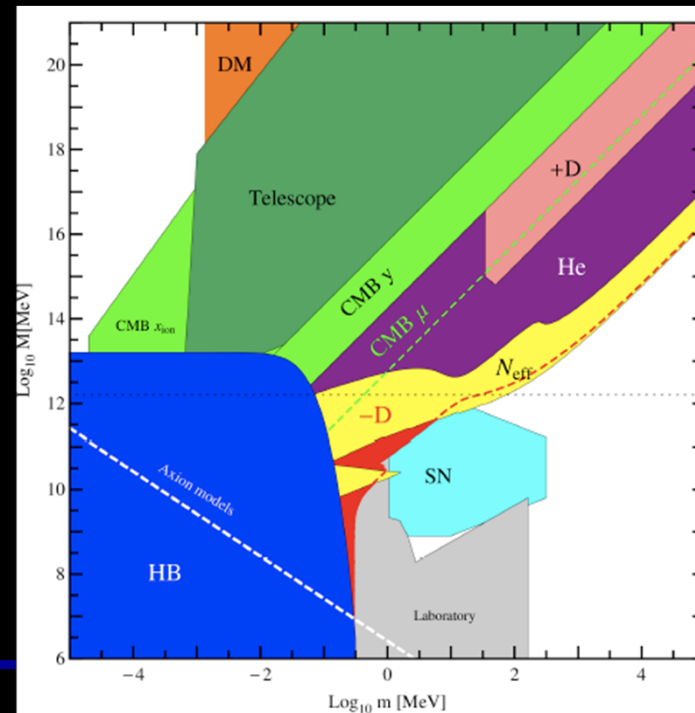


New Ideas and tests from Theory

- LSW via tunneling

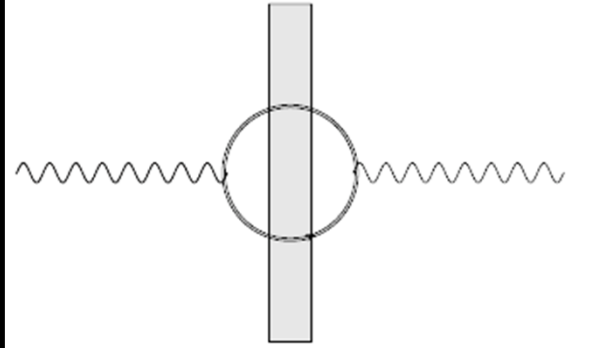


- Astrophysical tests of ALPS

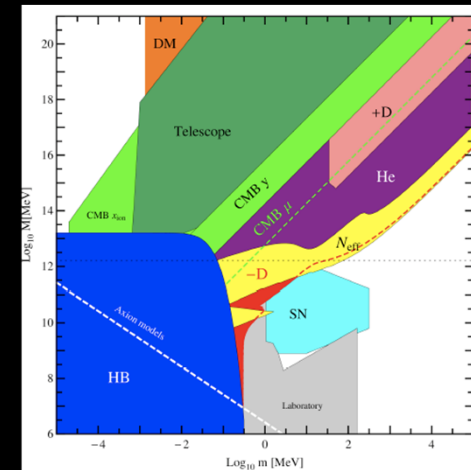


New Ideas and tests from Theory

- LSW via tunneling



- Astrophysical tests of ALPS



And always a surprise...

“It's just like the Higgs mechanism
but without a Higgs”

Intermezzo:
Particles that exist ;-)

Measure dipole moments of

- Neutron



$$d_n < \text{few} \times 10^{-27} \text{ e cm}$$

Measure dipole moments of

- Neutron



$$d_n < \text{few} \times 10^{-27} \text{ e cm}$$



Mechanical shocks

Precision tools

Measure dipole moments of

- Neutron

$$d_{\text{near future}}^n < \text{few} \times 10^{-27} \text{ e cm}$$



- Proton

- BNL, USA: proton “magic” ring

- COSY/IKP, Jülich/Germany
deuteron ring: JEDI



$$d_{\text{target}}^p < 10^{-29} \text{ e cm}$$

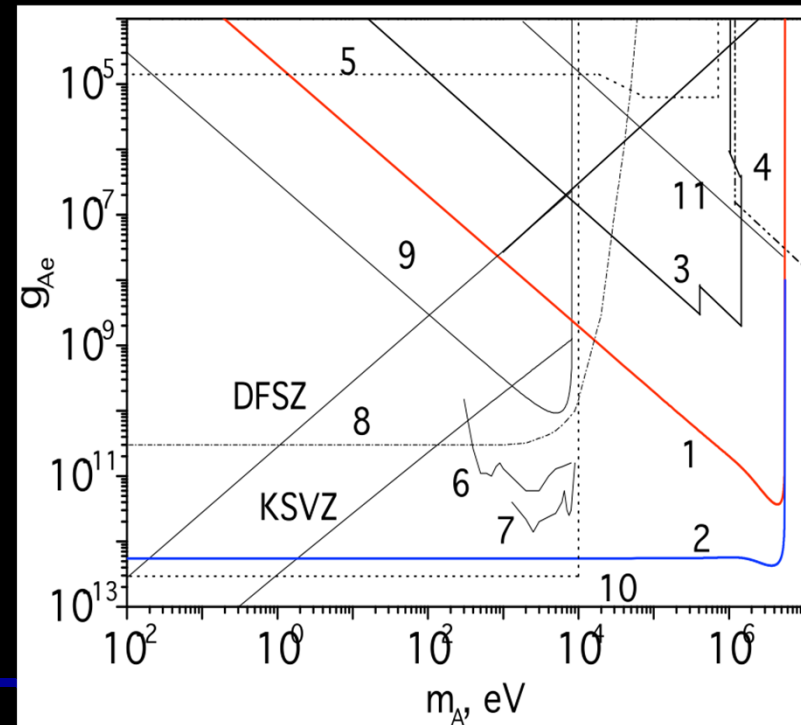
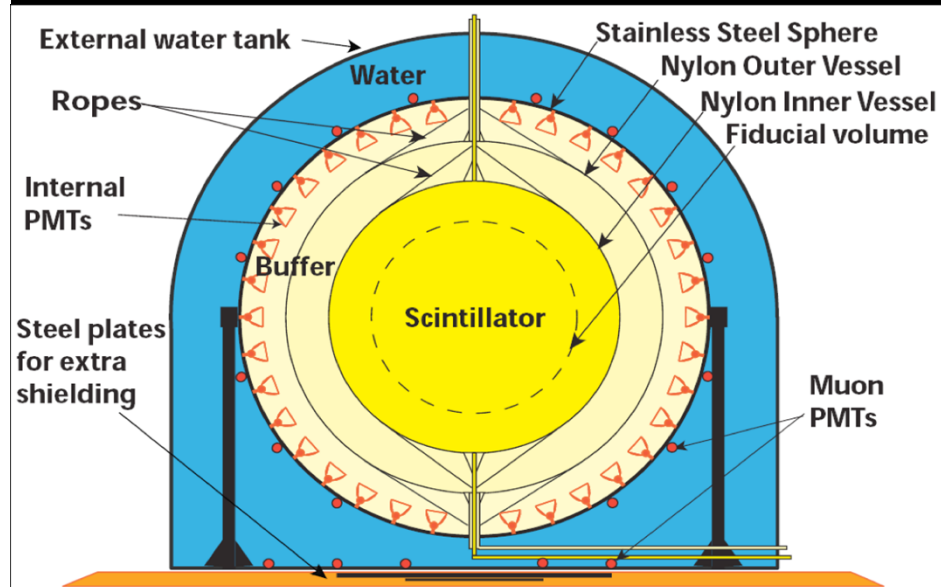
- Do not forget electron: Recent measurement:

$$d_e < 10^{-27} \text{ e cm}$$

T2K: $\theta_{13} \neq 0$

Neutrino detectors can do something useful...

... search axions

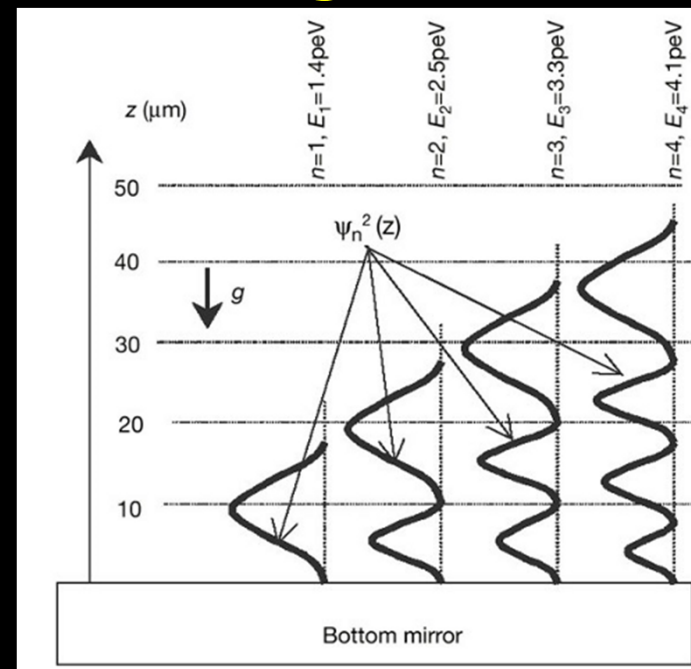


Bouncing neutrons...

Bouncing ball



bouncing neutron

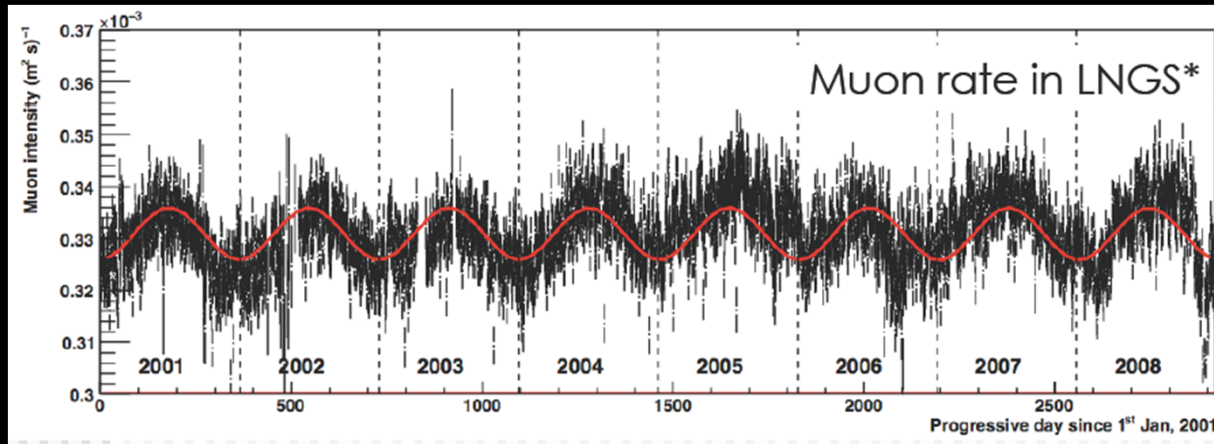


Test of 5th forces at μm level!

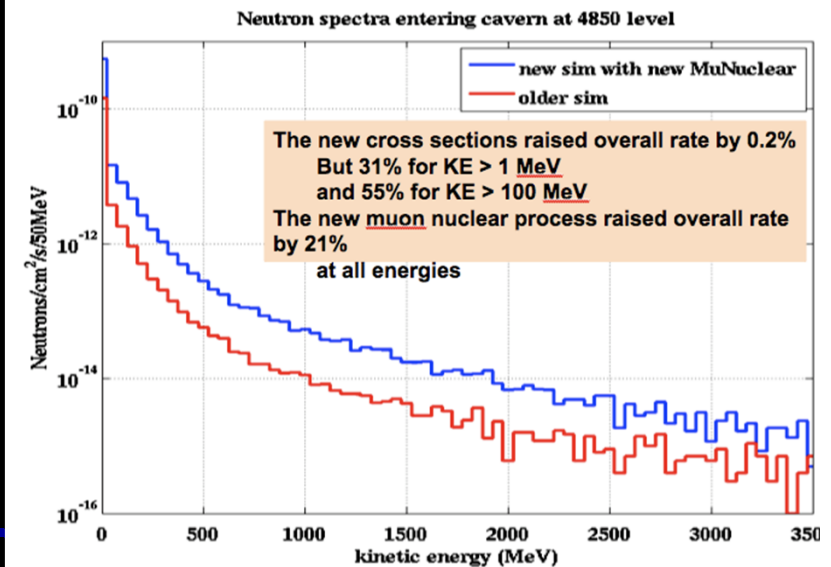
➔ Explore new possibilities!

Particles that exist...

...are a real pain for WIMP searches
From where do all those neutrons come...

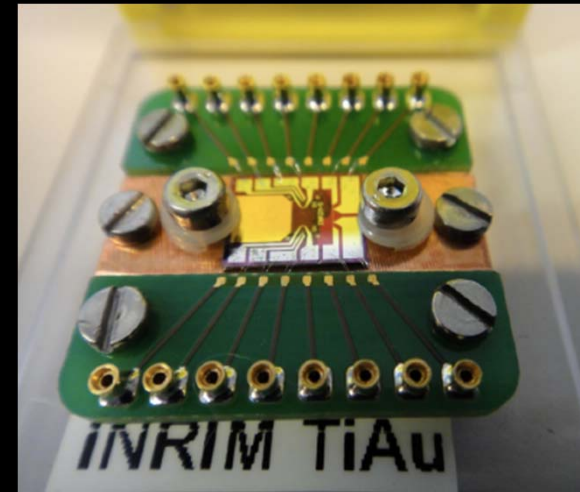
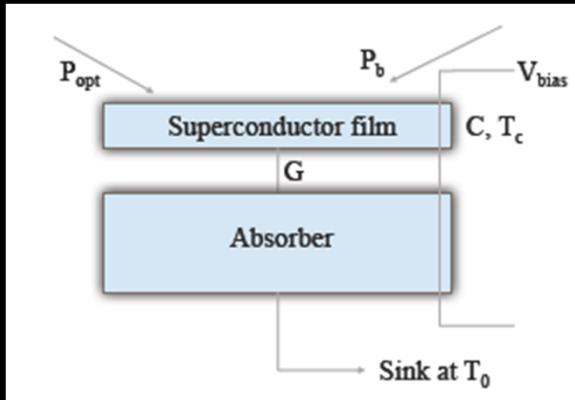


- Understand background...
Do dedicated background study!!!!

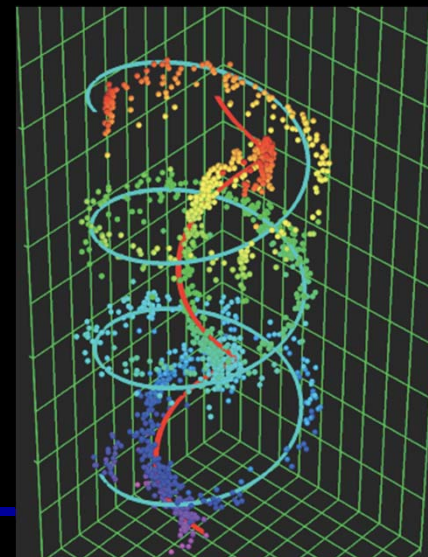
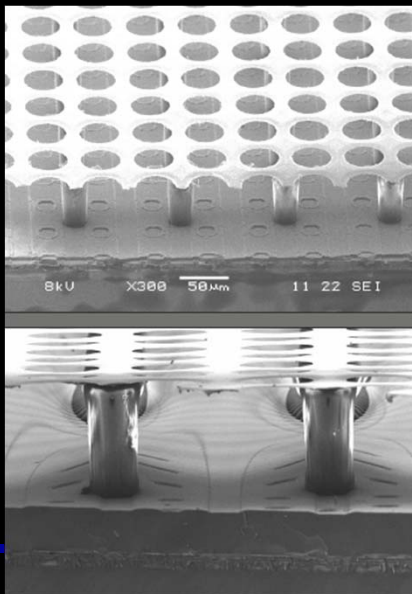


Great new detectors

- TES: Hope: Background free!!!!!!!!!!!!!!

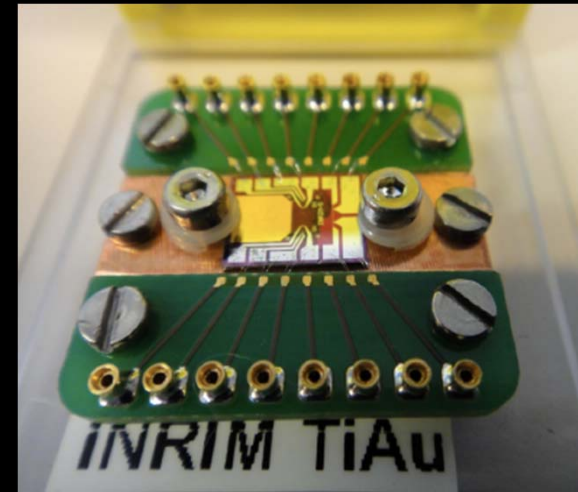
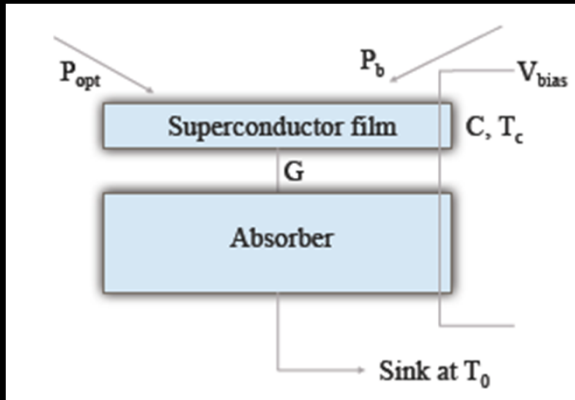


- GridPix (all kinds of Pix)

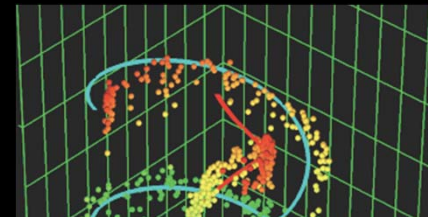
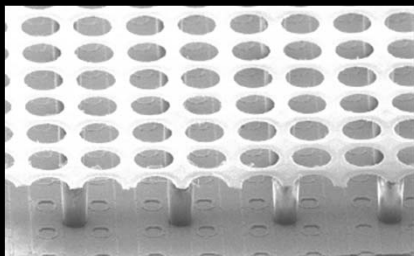


Great new detectors

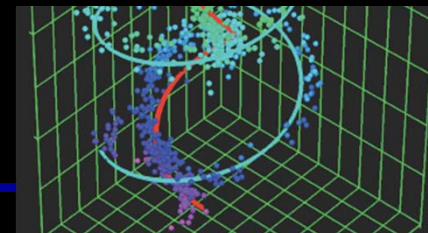
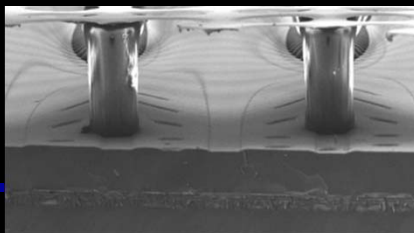
- TES: Hope: Background free!!!!!!!!!!!!!!



- GridPix (all kinds of Pix)



Impressive 78 slides in 20 minutes!!!



The Sun...

Konstantin is a steadfast disciple of the sun ;-)

“Sun’s intense X-ray emission: remarkable +
fascinating ...**mystery** “.

We were introduced into his religion on Delos ;-)
Not only: The sun (and the moon) were born on
Delos



SPHINX

WIMPs

The attack...

- The time for the discovery of WIMPs has come

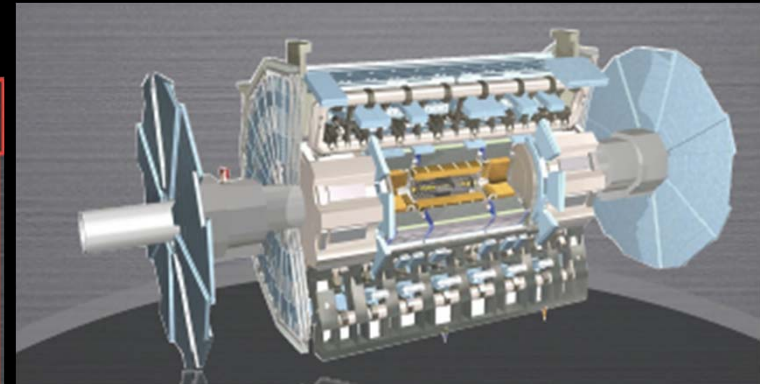
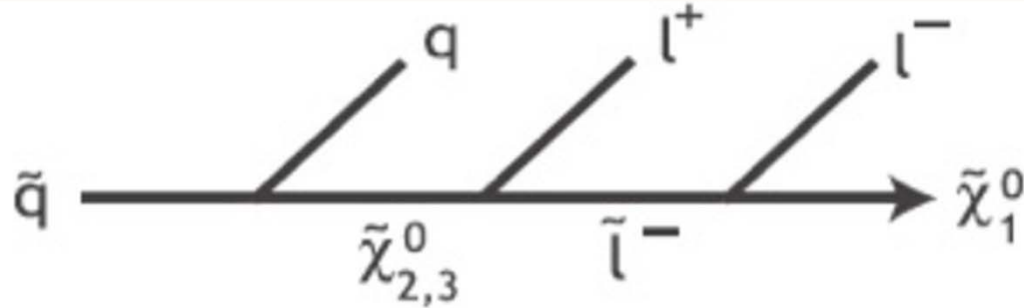
A large variety of experiments taking and publishing data!



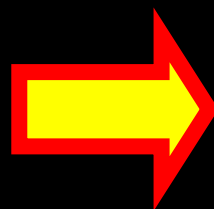
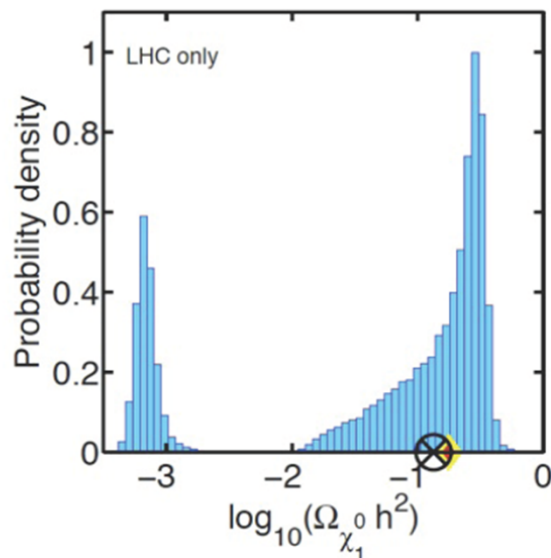
LHC can give us...

A candidate

SEARCH AT LHC FOR PROCESSES LIKE E.G.



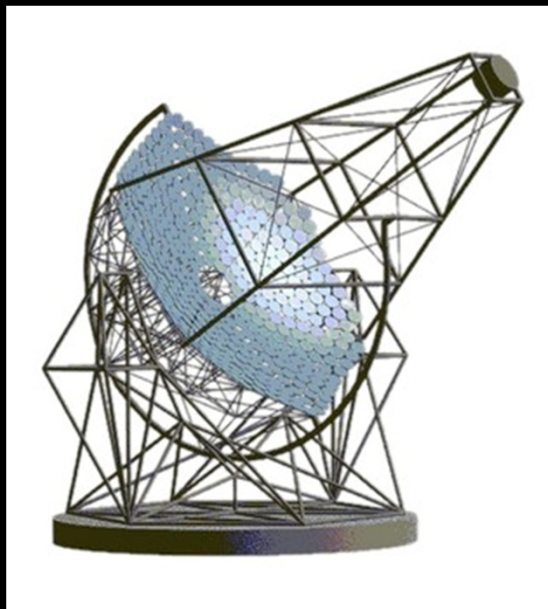
But can't tell us if enough was produced...



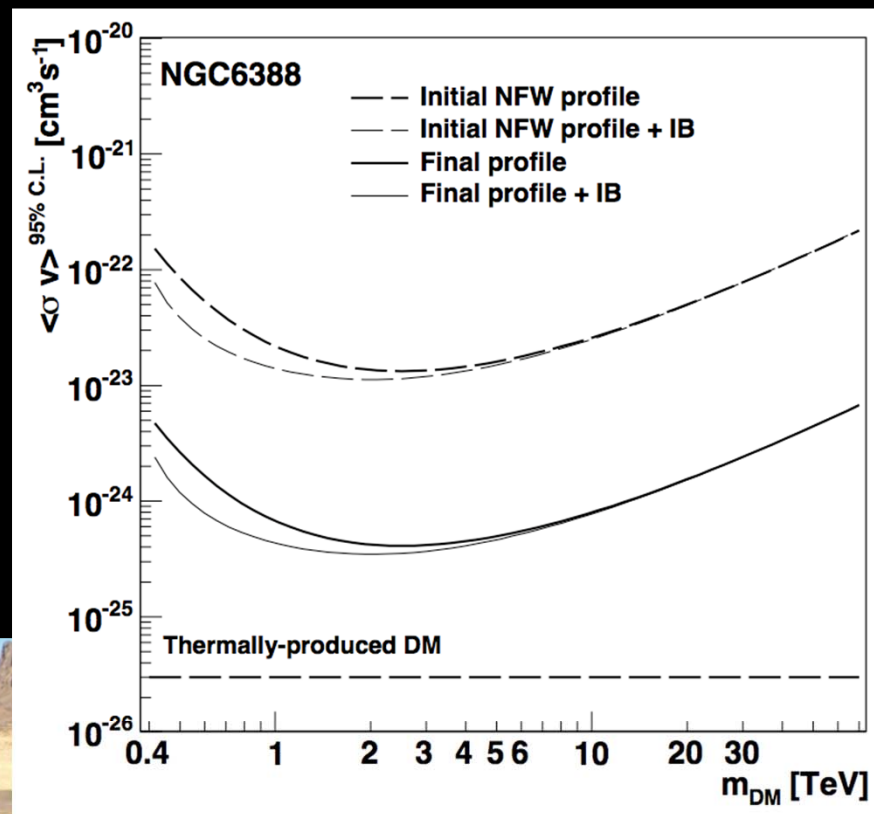
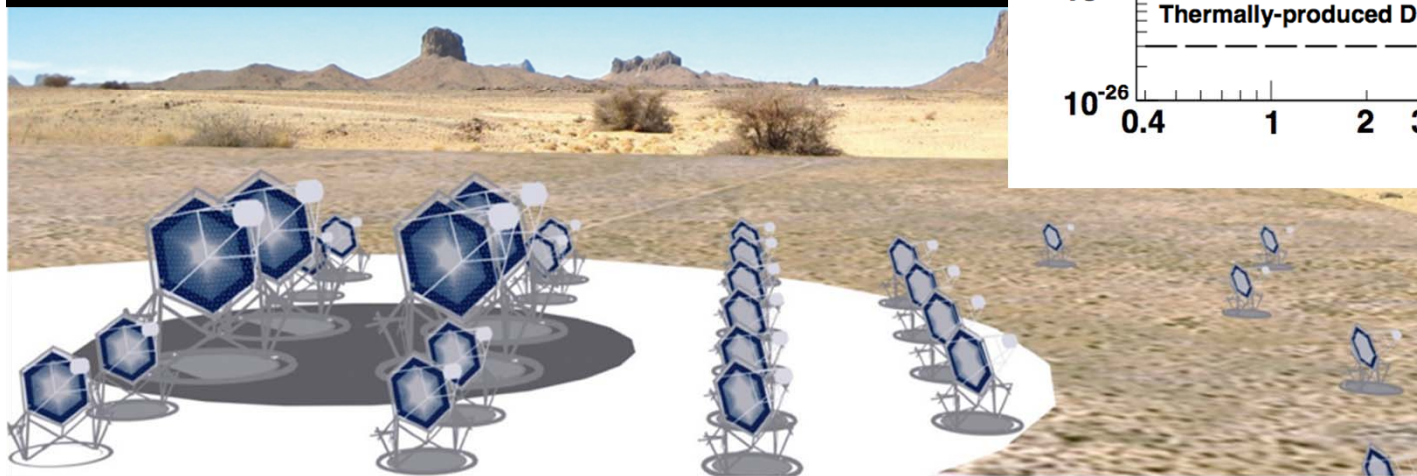
Need direct and indirect detection!!

Indirect detection

- HESS

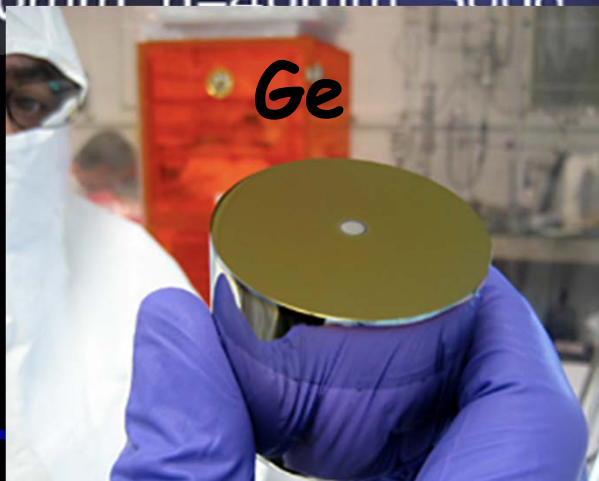
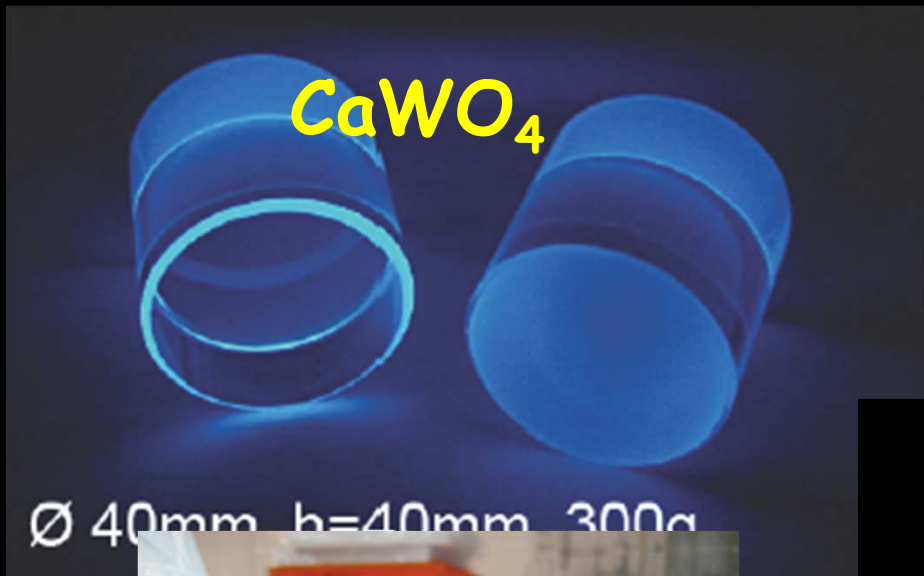


- CTA

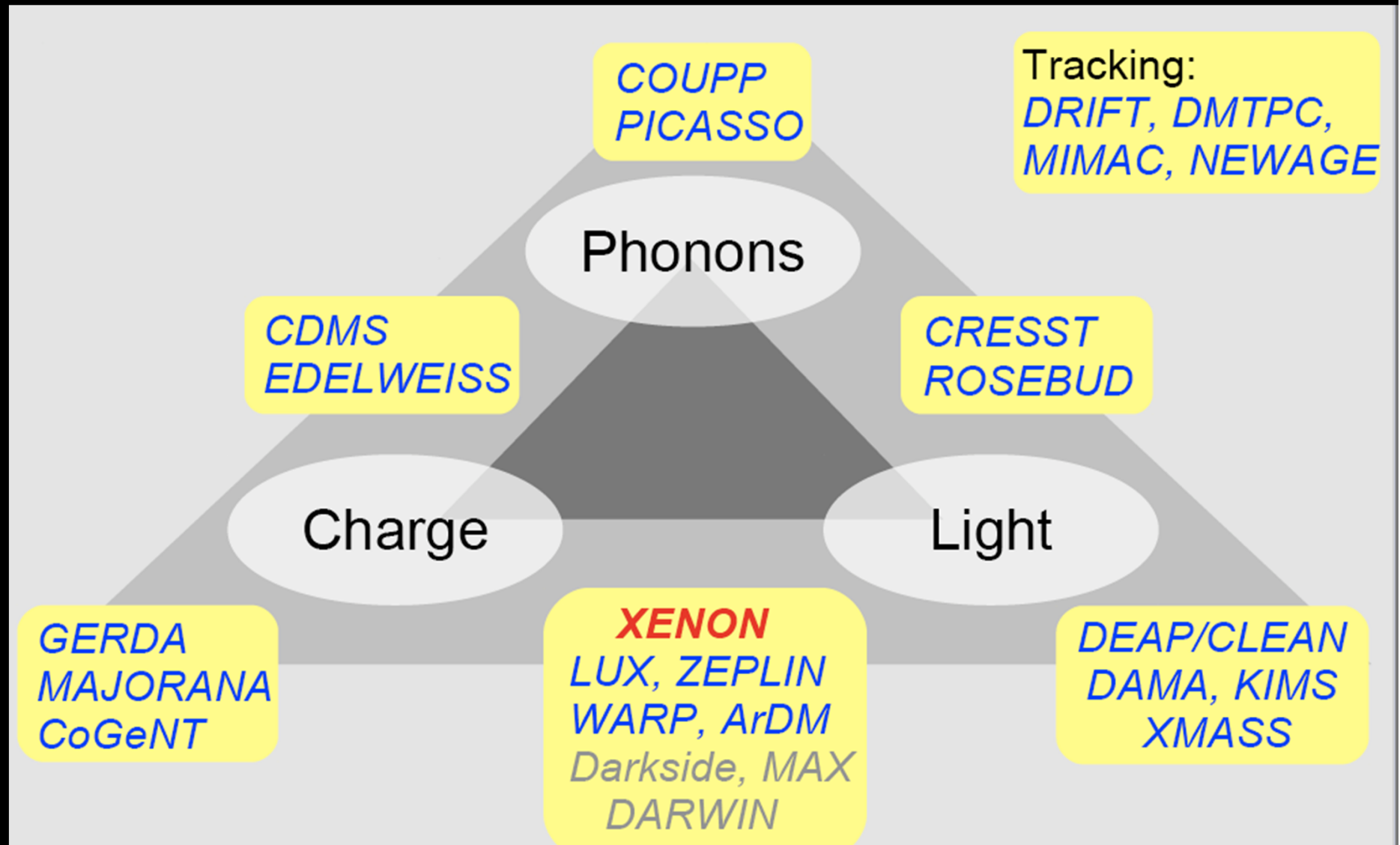


Direct detection

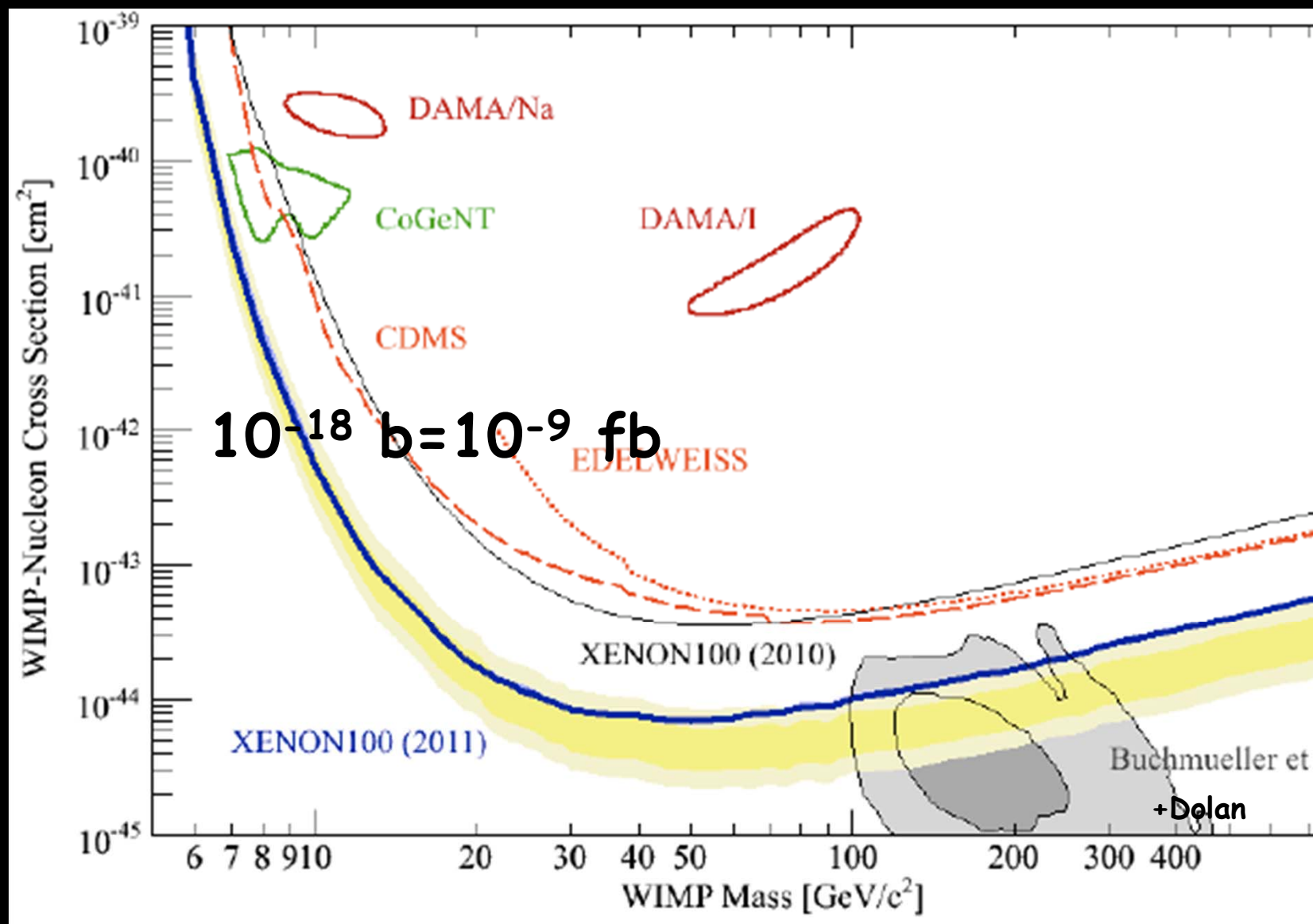
- A variety of targets: Complementary
Important cross check!



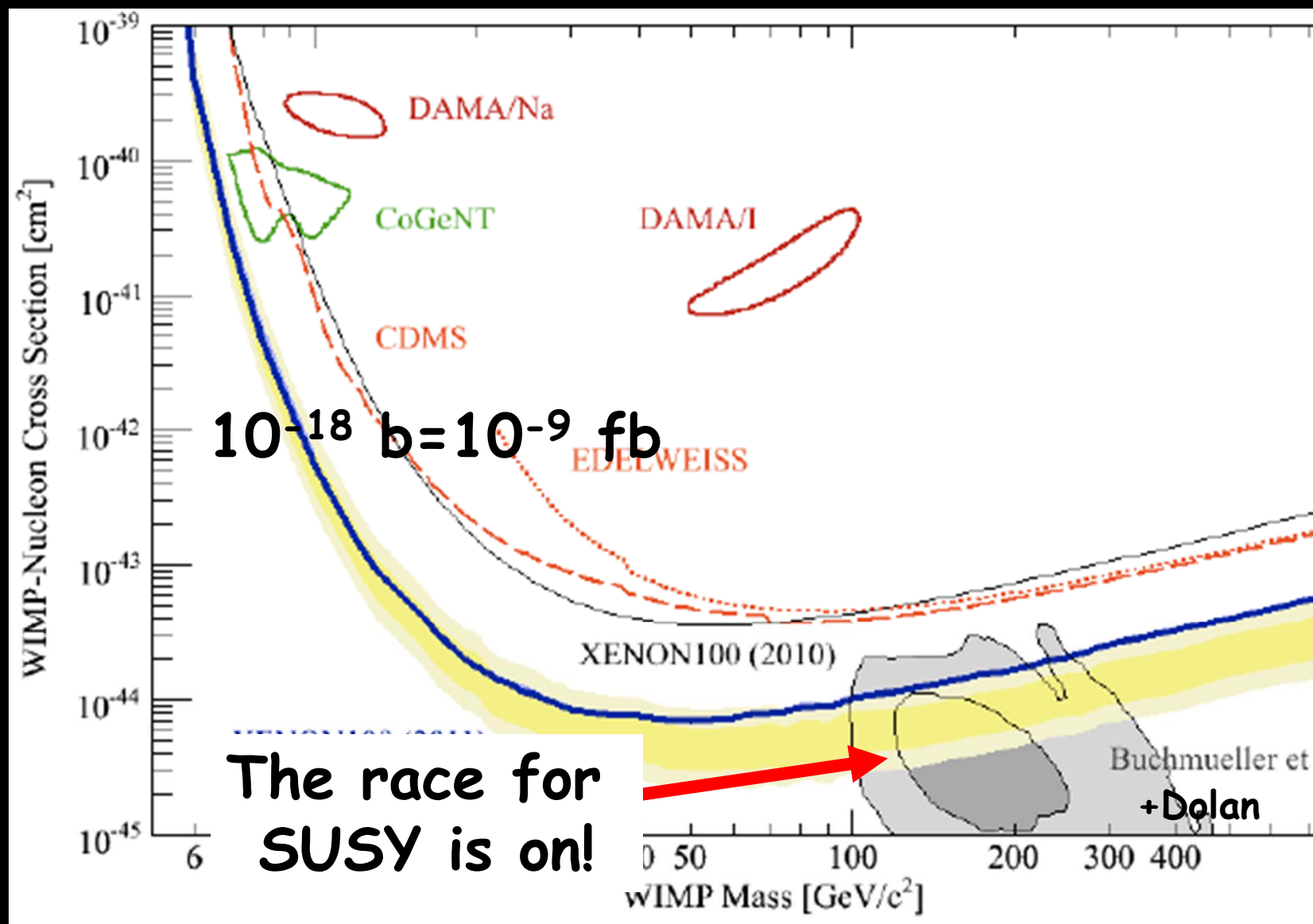
Variety of detection schemes



Impressive sensitivity



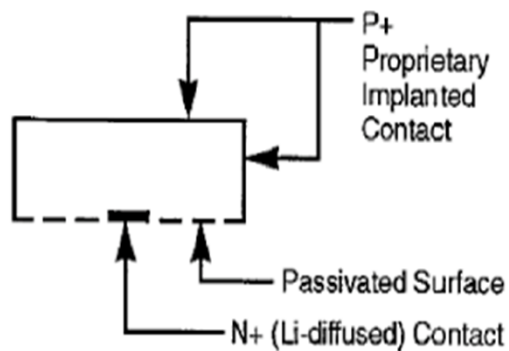
Impressive sensitivity



The challenge: go to lower masses

- Interesting region below 10 GeV

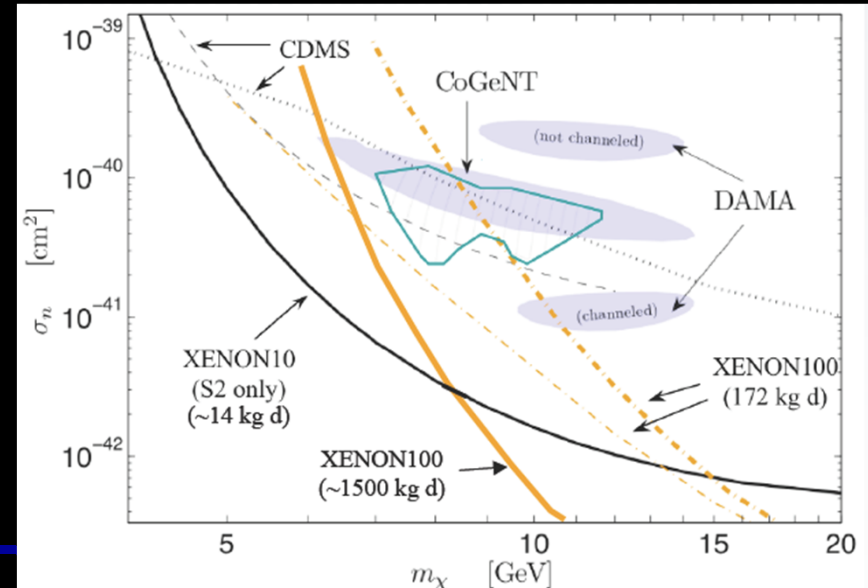
Low threshold technologies... e.g. TEXONO



4x5 g : threshold $\sim 220\text{eV}$



Carefully reanalyze existing data.



Signals?

A lively discussion is underway...

Ohhhhhh annual
modulation

CDMSnix
XENONnix

CoGeNTix

modulated Muonnix

DAMAix

This will be resolved...

In a small town
far far north

I have always
known that
DM is 49.5% WIMP and
49.5% axion

1%

The end



Last Words

Sorry if I forgot YOU...



4 years ago...

- We are (hopefully) witnessing the birth of a new field...
 - Fundamental Physics @ Low energy
 - Small scale experiments <<
 - Complementary to Accelerators
 - Clever Ideas
 - More fun!
-

Today...

Fundamental Physics @ Low energy

- Is not just walking... it's running ☺

- Is growing...

laser power	1 kW	150 kW
magnets	0.5 + 0.5 HERA	12 + 12 HERA
reg. cavity power	1	40 000
built-up		

1kg -> 1ton WIMP searches

- Racing LHC for DM

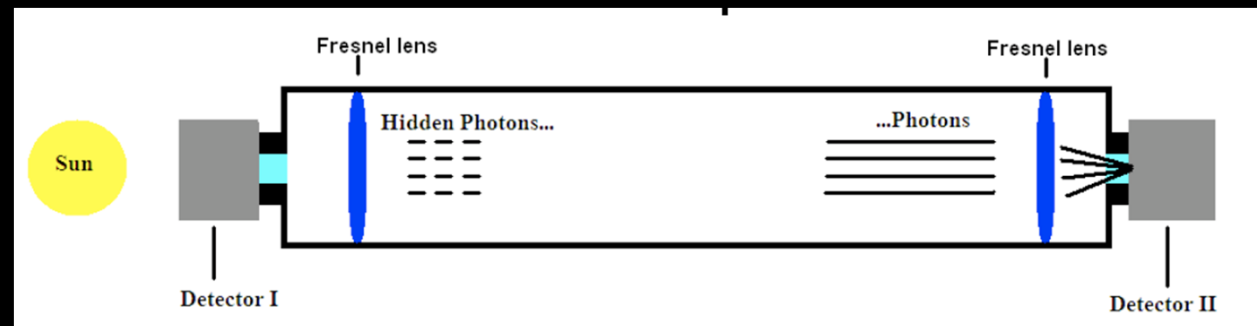
- Clever Ideas
- More fun!

Today...

Fundamental Physics @ Low energy

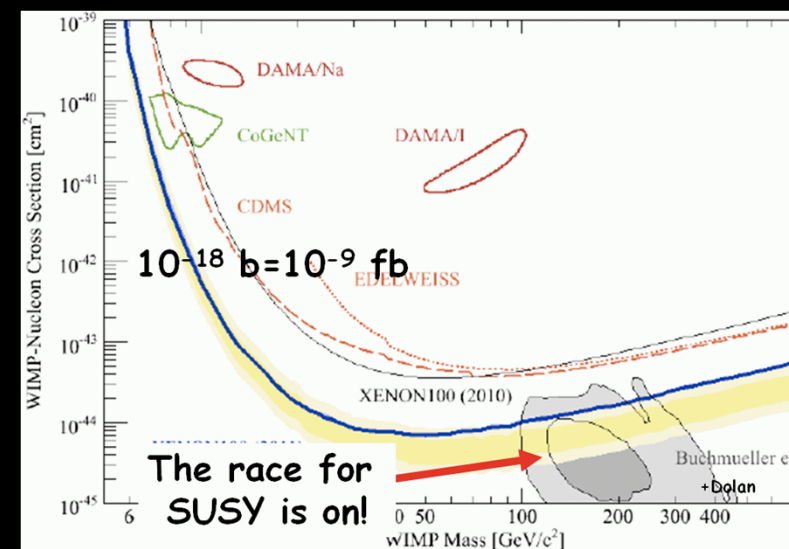
- Is not just walking... it's running ☺

- Is growing...



- Racing LHC for DM

- Clever Ideas
- More fun!



Thanks to all for a great...

7th Patras Workshop on Axions, WIMPs and WISPs

26 June - 1 July 2011
Mykonos (GR)

Programme

- The physics case for WIMPs, Axions, WISPs
- Review of collider experiments
- Signals from astrophysical sources
- Direct searches for Dark Matter
- Indirect laboratory searches for Axions, WISPs
- Direct laboratory searches for Axions, WISPs
- New theoretical developments

Organizing committee:

Vassilis Anastassiopoulos (University of Patras)
Laura Baudis (University of Zurich)
Joerg Jaeckel (BPP/Durham University)
Axel Lindner (DESY)
Andreas Ringwald (DESY)
Marc Schumann (University of Zurich)
Konstantin Zoubas (University of Patras) (chairman)

<http://axion-wimp.desy.de>

Patras goes West!

The 8th Patras Workshop on Axions, WIMPs, and WISPs
Chicago USA 2012



Don't forget:
Axion-Strategy Meeting
(after coffee)