Fundamental Physics @ Low Energies

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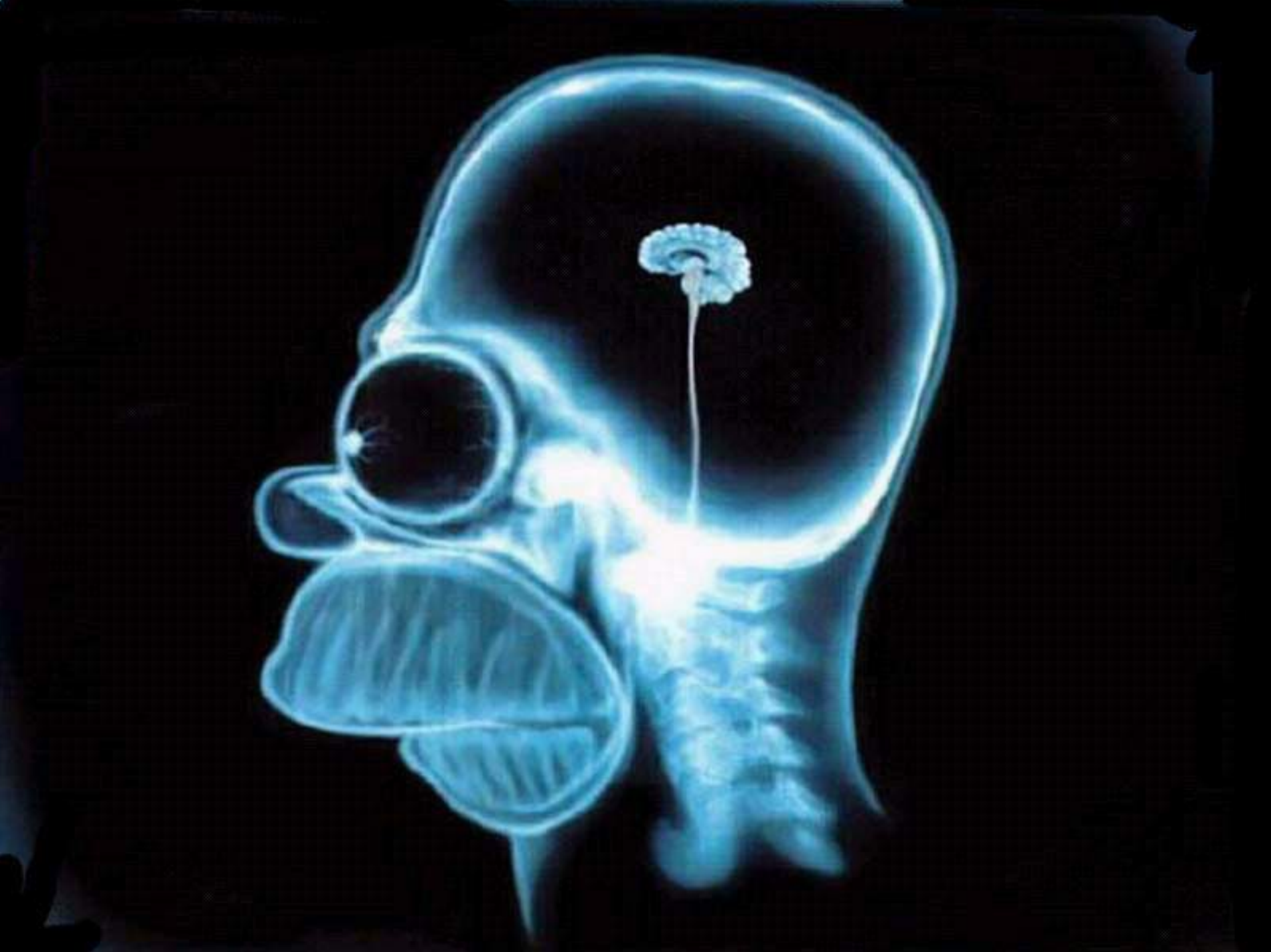

Hints for new Physics

Uglyness of old models

- The Standard Model has many free parameters: O(30)

- Naturalness problems. Finetuning.
  Examples:
  Higgs mass, θ-angle (strong CP-problem)

- Gravity separate, i.e. not unified.

- (Probably) Breaks down at a finite energy scale
  Landau poles etc.

Unexplained Stuff

- Dark Matter (25%)
  (astrophysical + cosmological observations)

- Dark Energy (70%)
  (astrophysical + cosmological observations)

- Mass Hierarchies
  (colliders, neutrino exp, etc)

- Small parameters (θ-angle, again)
  (neutron electric dipole measurements)

Contradictions (not proven)

- (g-2) deviations from SM prediction
- DAMA anomaly
- PAMELA observation

Hints for new Physics

Model Building

Bottom-up (pheno)

Fix problem
`here and now'

Top-down (theory)

Go back to drawing board
`Start from scratch'

No neutron electric dipole moment...

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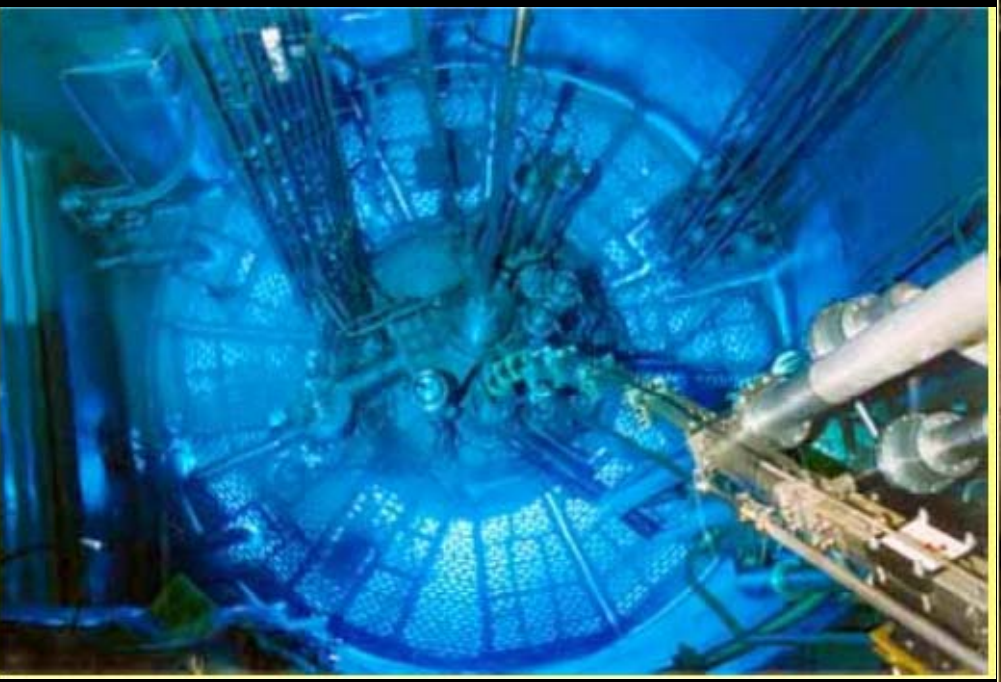

$$|\vec{d}| < 3\,10^{-26} e\,cm$$
$$= 3\,10^{-13} e\,fm$$

No neutron electric dipole moment...

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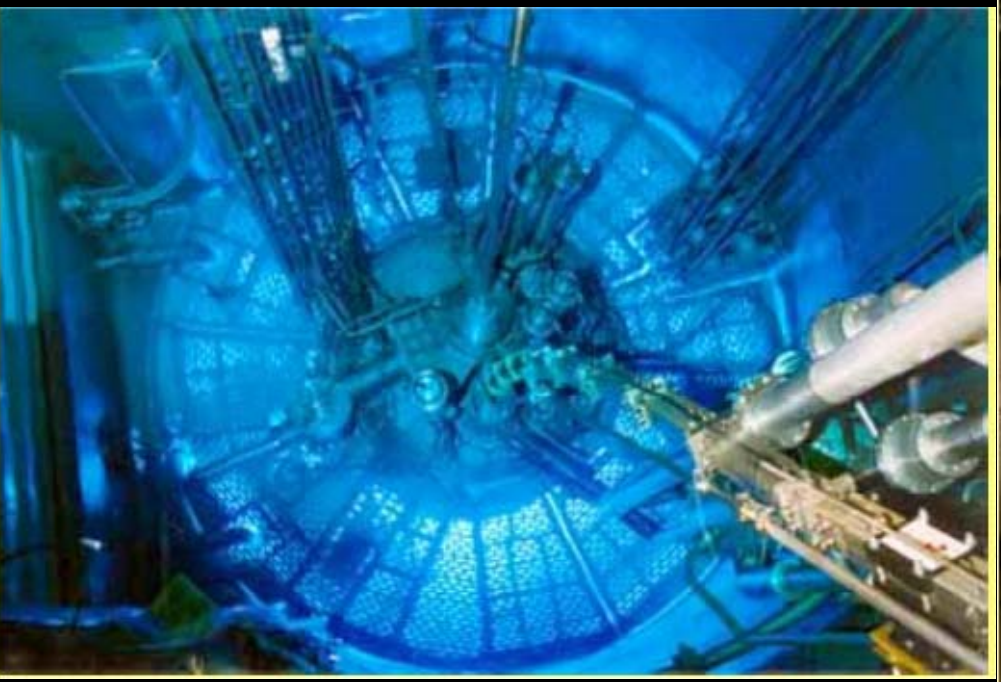


$$|\vec{d}| < 3\,10^{-26} e\,cm$$

$$= 3\,10^{-13} e\,fm \lll \frac{1}{16\pi^2} e\,fm$$

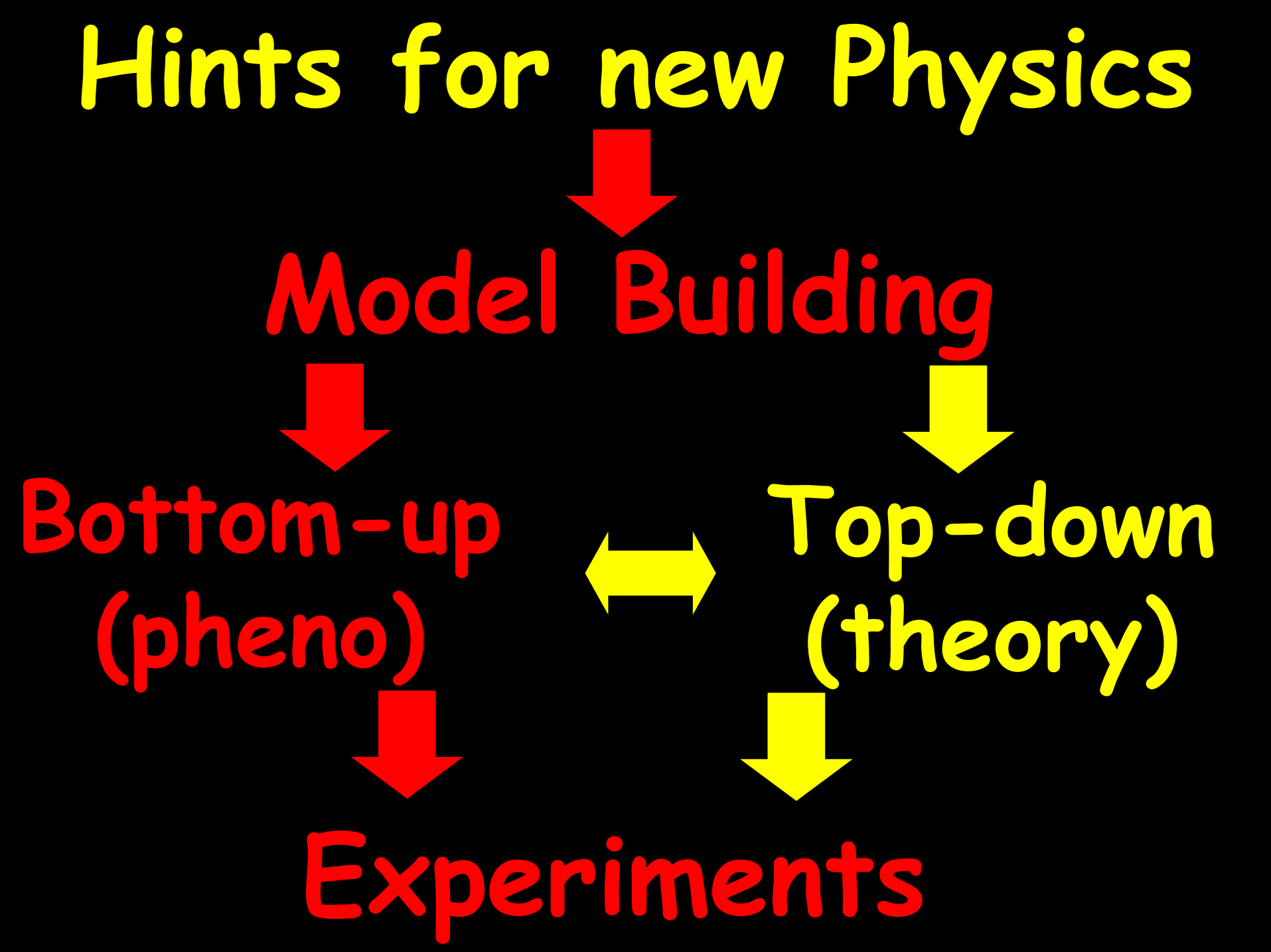
The strong CP problem: Axions

- Introduce new Peccei-Quinn symmetry to solve naturalness problem

- Predict as a consequence a new particle: The Axion
  (it's a Weakly Interacting Sub-eV Particle)

Dark matter candidate

Good `physics case' for WISP experiments


Hints for new Physics
Model Building
Bottom-up
(pheno)
Top-down
(theory)
Experiments

Example experiment 0: LHC

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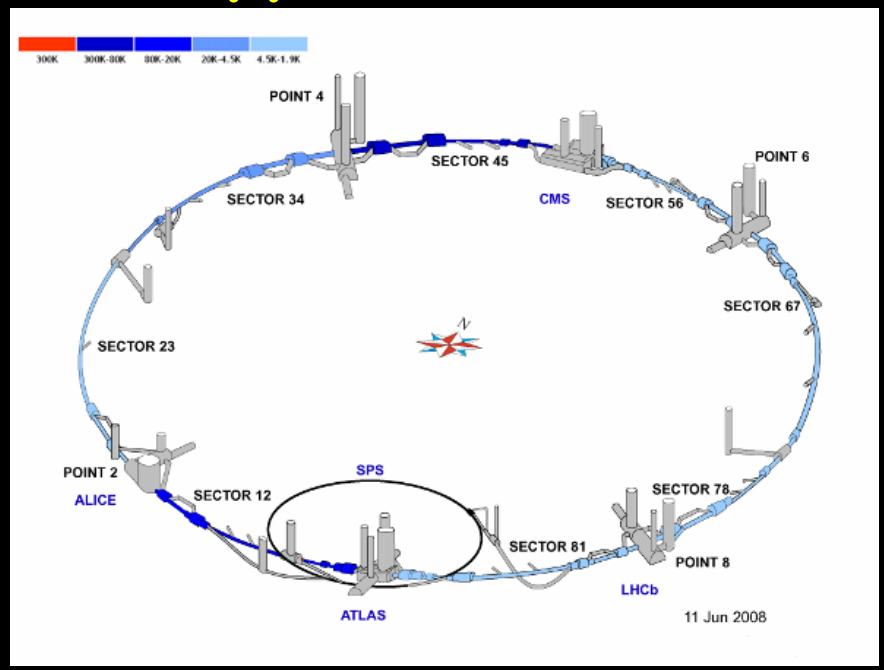
- The direct approach: MORE POWER



- Detects most things within energy range
- E.g. may find WIMPs

But…

- Current maximal energy few TeV
- May miss very weakly interacting matter (Axions, WIMPs, WISPs…)
- Only indirect evidence for dark matter

- Man its DANGEROUS…

Light Shining through a wall

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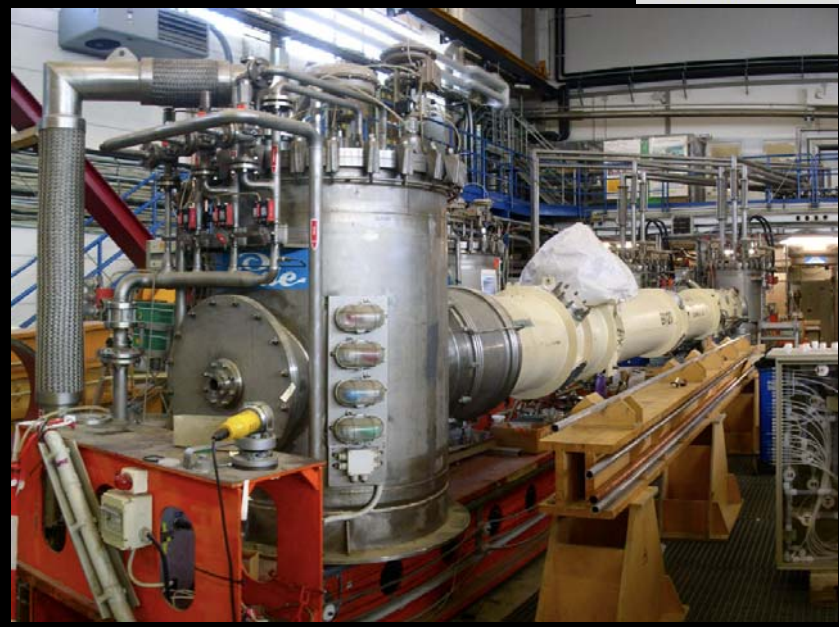
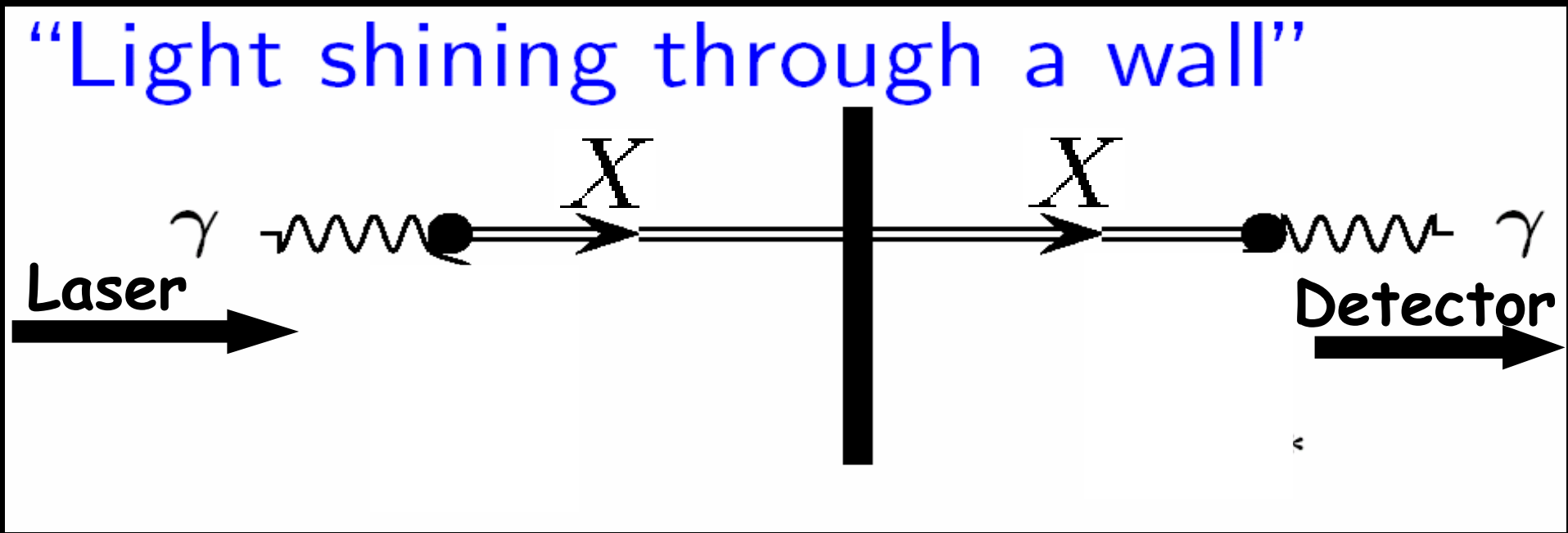
ALPS@DESY=
Axion-like particle search
Any-light particle search





Light Shining through a wall

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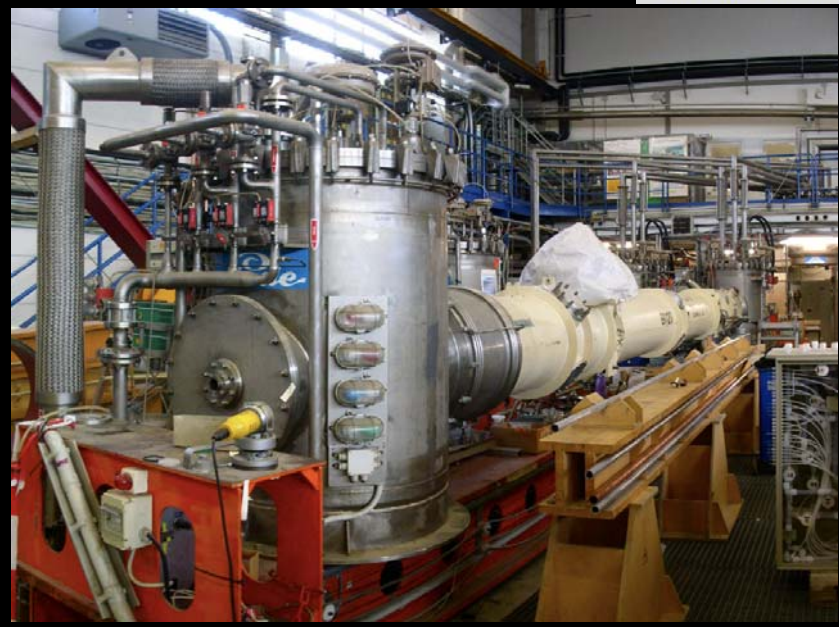
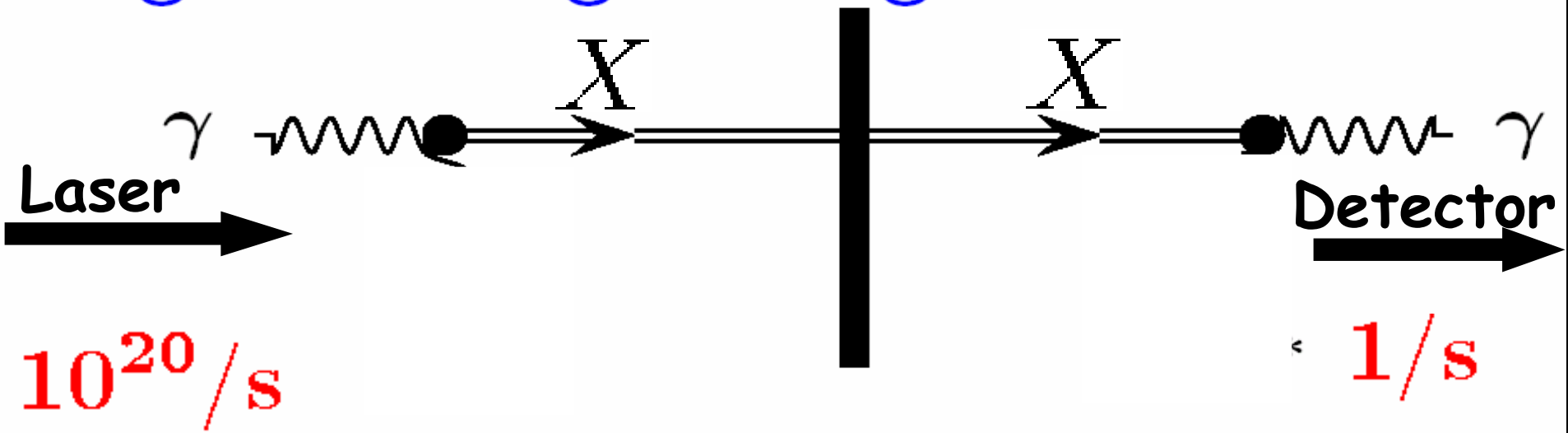


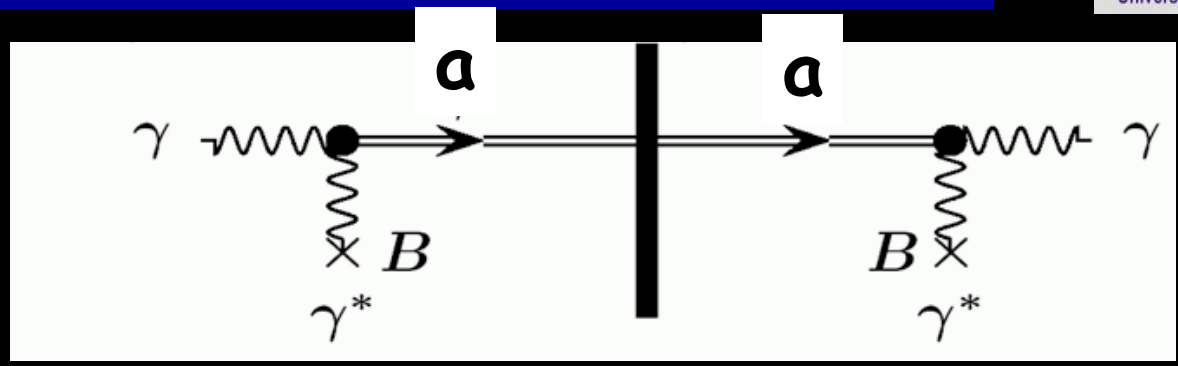
"Light shining through a wall"



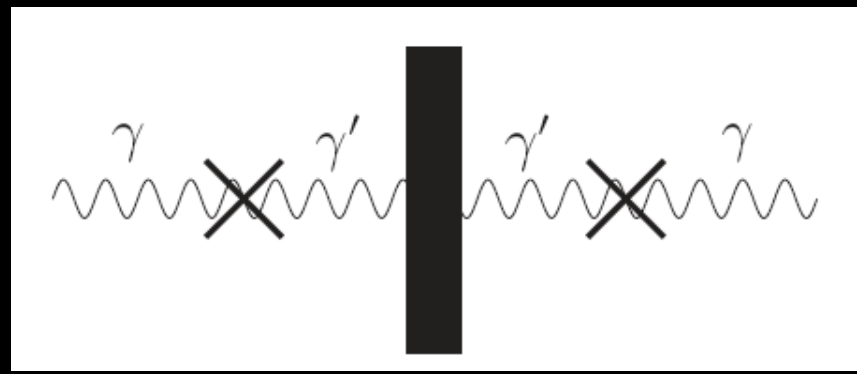
WISPs=Weakly interacting sub-eV particles

- Axions

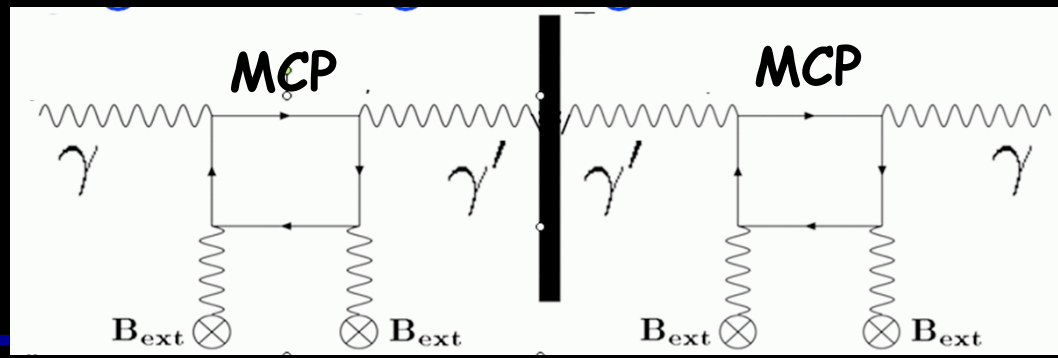
$$\frac{1}{M} a \tilde{F} F$$



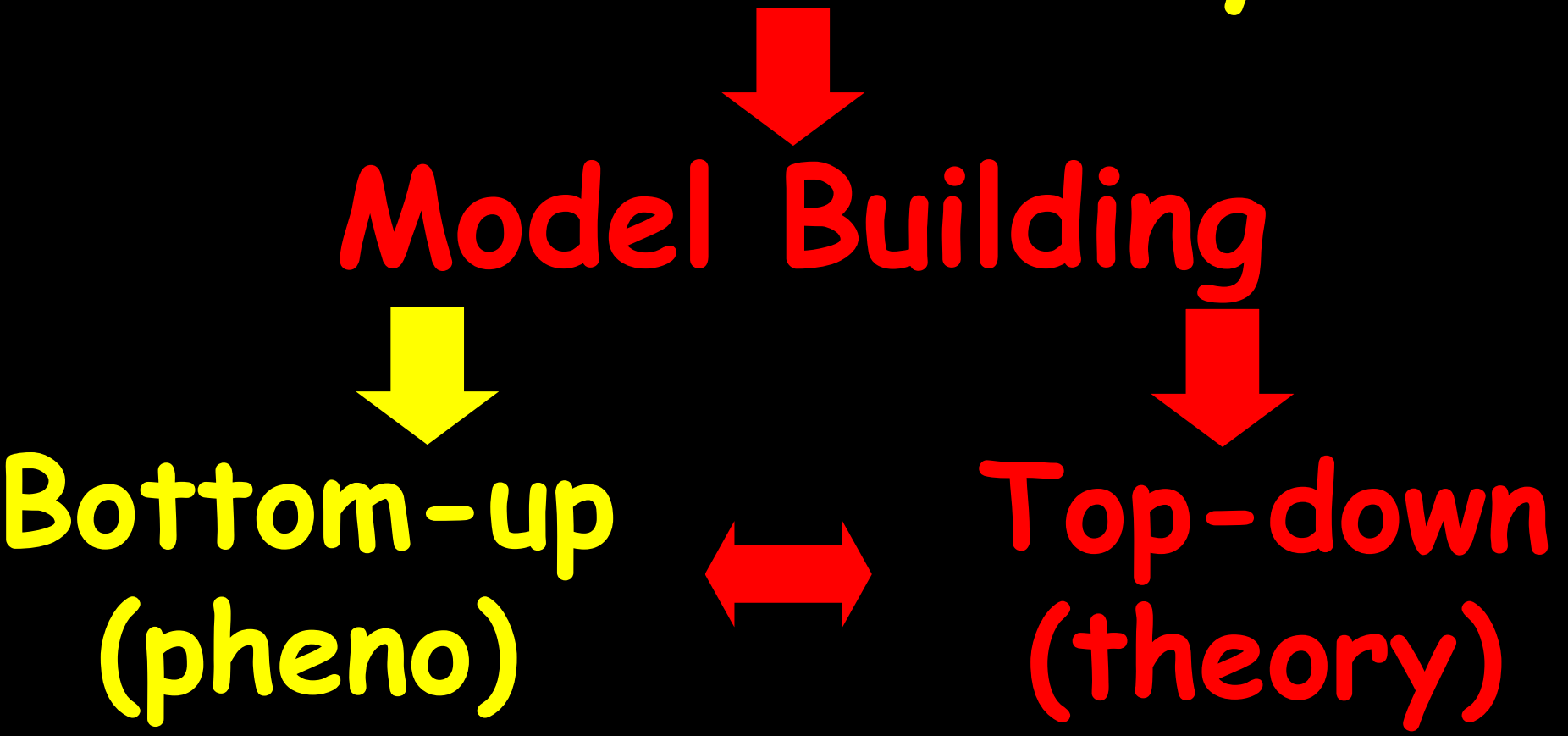
- Massive hidden photons (without B-field) =analog ν-oscillations



- Hidden photon + minicharged particle (MCP)



Hints for new Physics



String theory

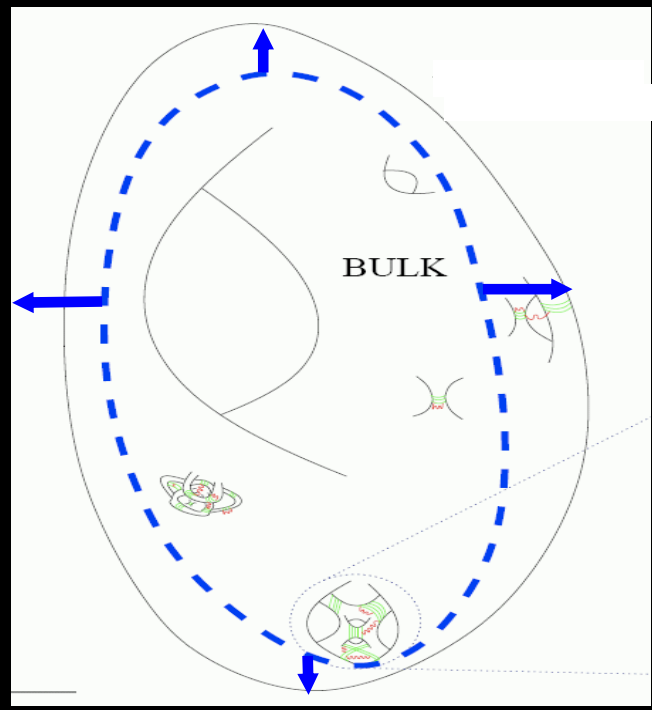
- Attempt to unify SM with gravity
- New concept: strings instead of point particles

String theory: Moduli, Axions, etc.

- String theory needs Extra Dimensions

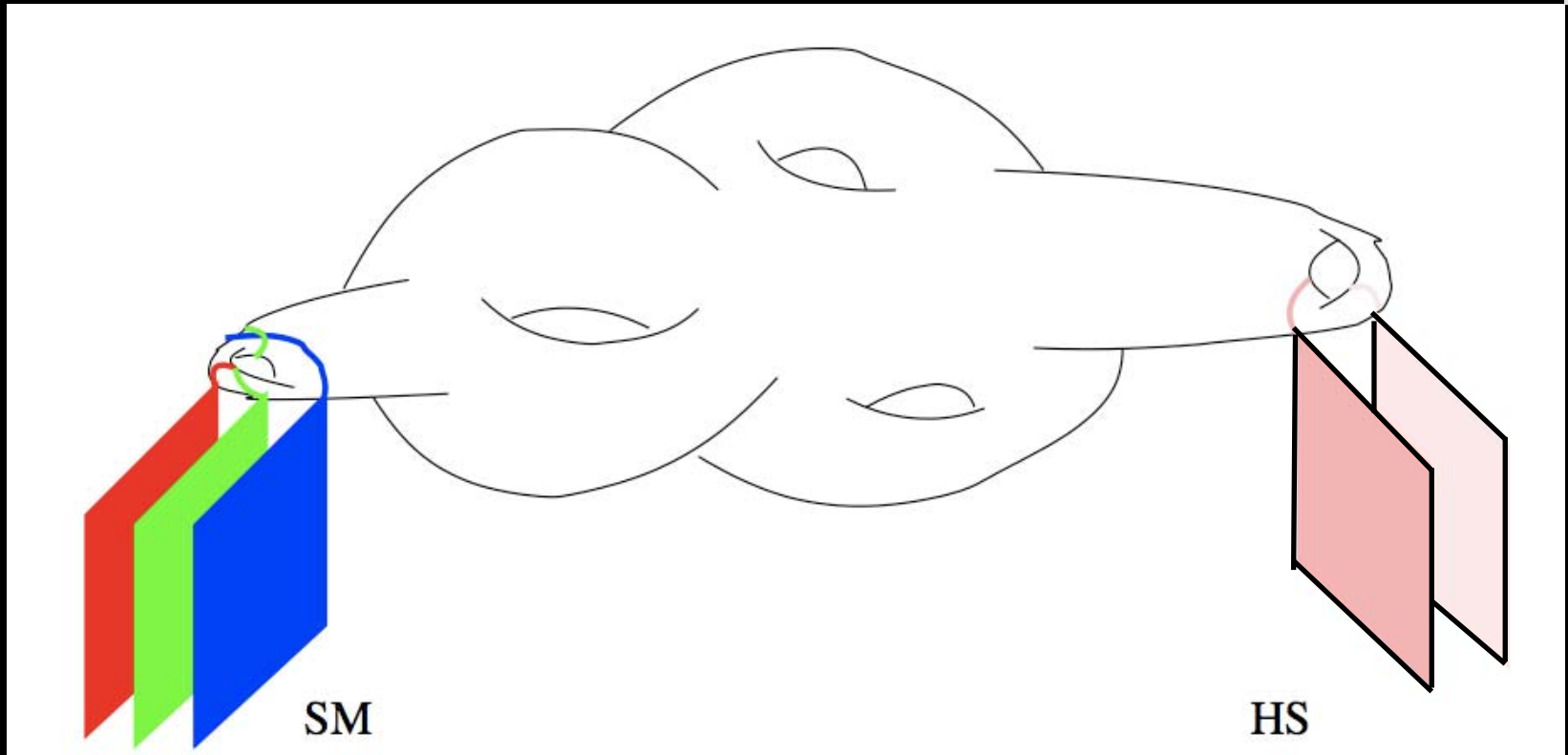
Must compactify

- Shape and size deformations correspond to fields:
  Moduli (WISPs) and Axions
  Connected to the fundamental scale, here string scale



`Physics case' for WISPs strengthened

String theory likes extra gauge groups



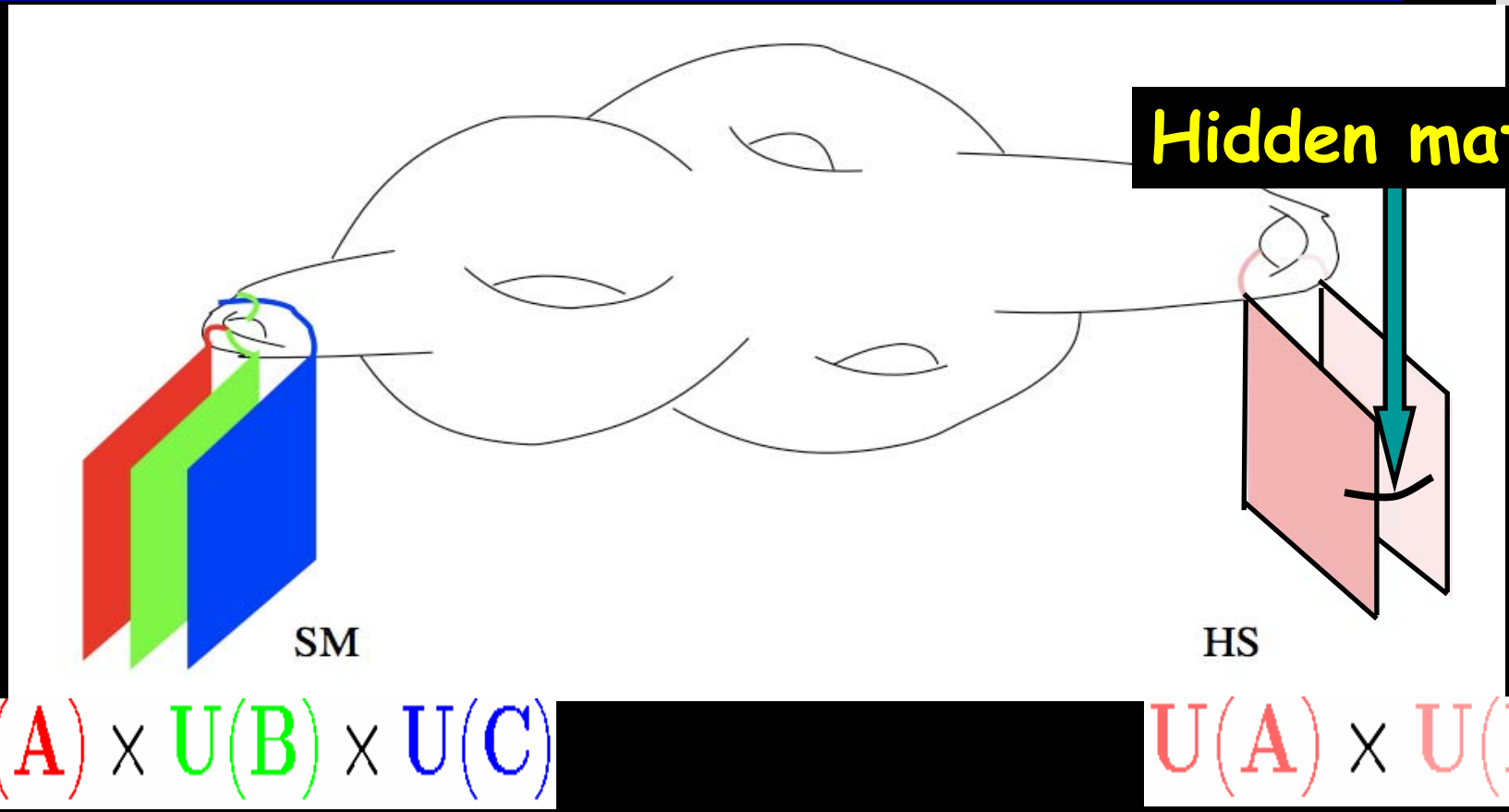
$U(A) \times U(B) \times U(C)$

$U(A) \times U(B)$

➡ Many extra U(1)s!

➡ Candidates for WISPs

String theory likes extra matter

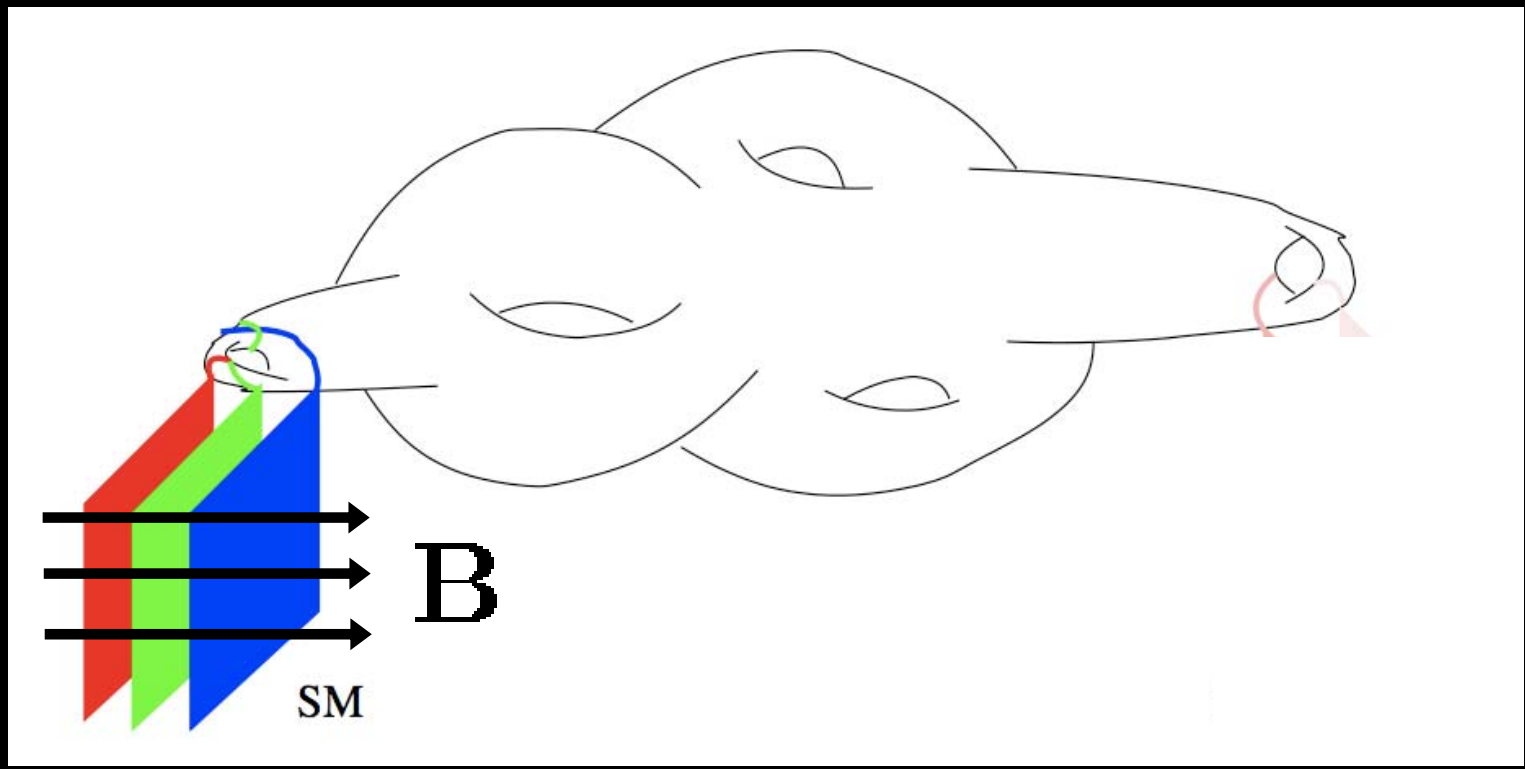


➡ Hidden sector matter

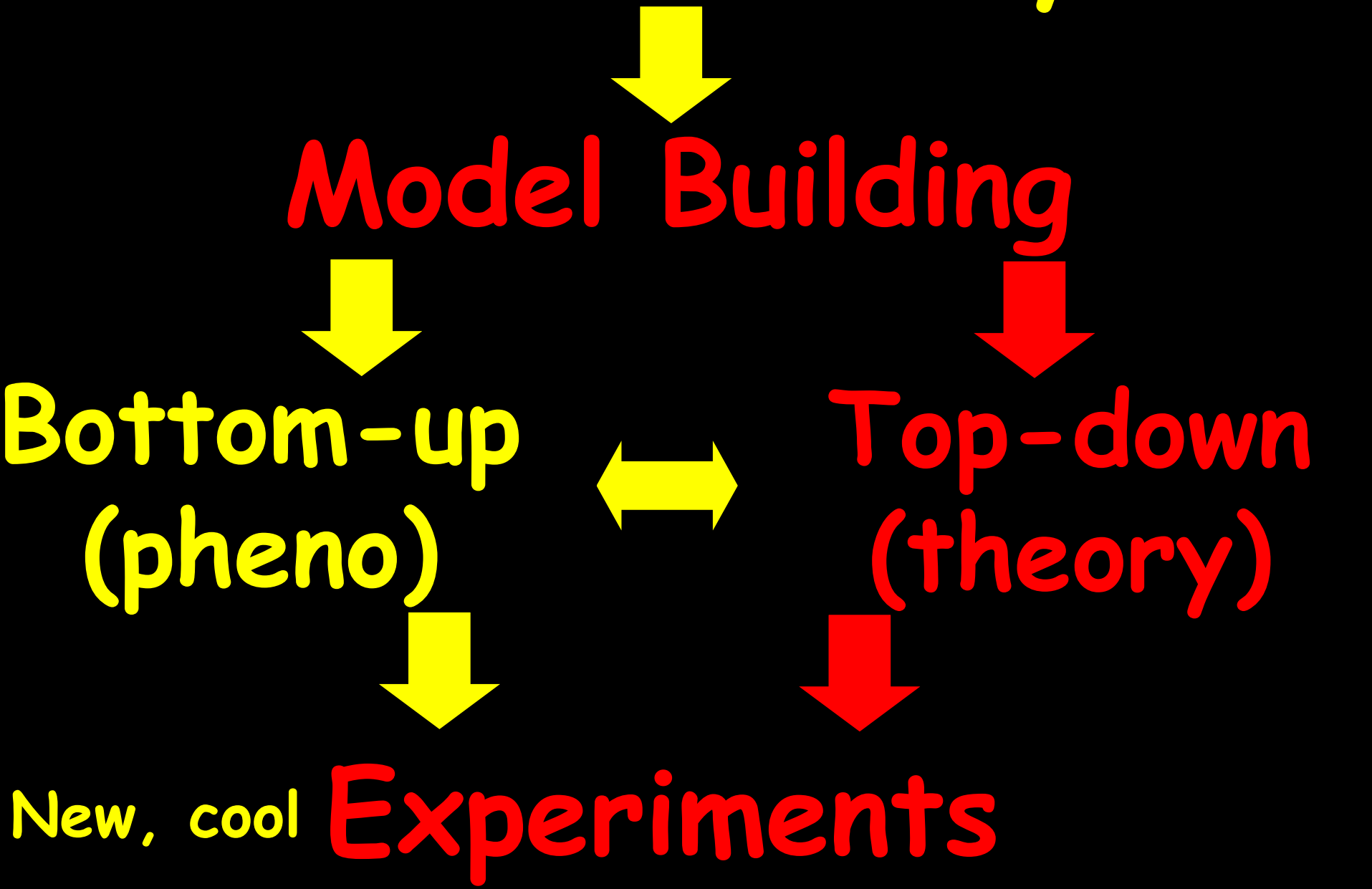
➡ May be light and WISPy
Or WIMPy and dark matter

String theory inspires weird stuff

- Some string theory models predict noncommutativity and other forms of Lorentz symmetry violation



Hints for new Physics



Test Lorentz symmetry

- Lorentz symmetry breaking can leads to vacuum birefringence

➡ Ultra high Precision

➡ Test (nearly) Planck scale physics

Test CPT, Matter – Antimatter (a)symmetry

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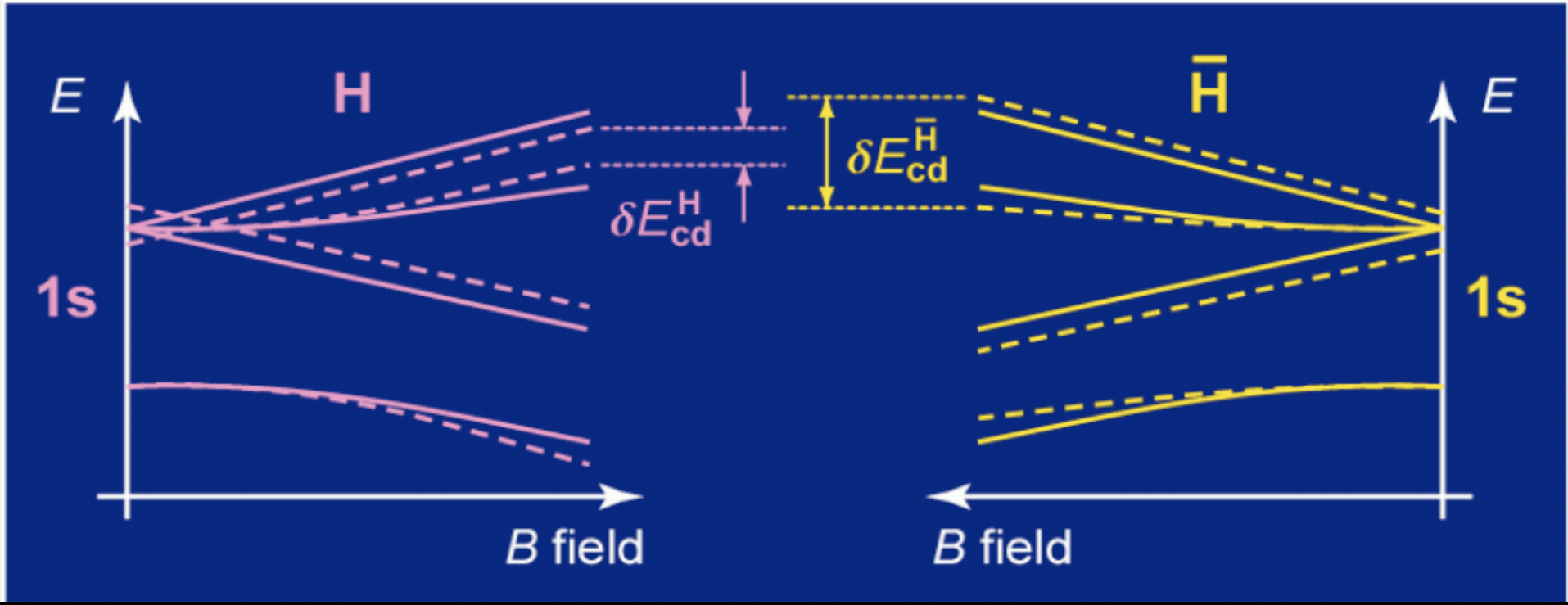
H / $\bar{H}$ spectroscopy: hyperfine Zeeman transitions



➡ Ultra high Precision

➡ Test very high energy scales.

Conclusions

Conclusions

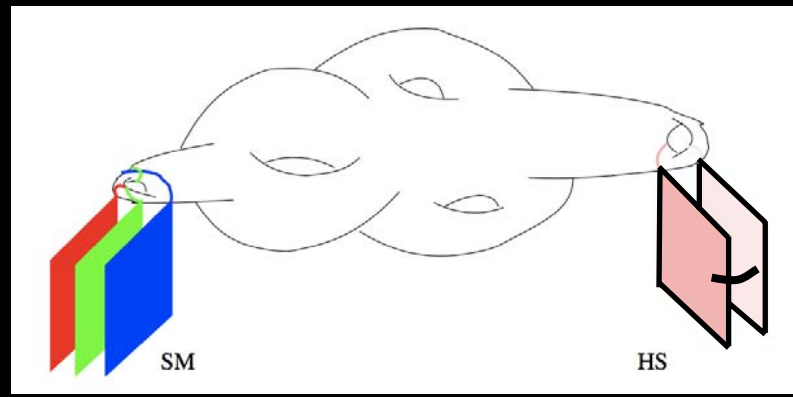
- Good Physics Case for Axions, WIMPs and WISPs

  ➡ explore `The Low Energy Frontier'

- Low energy experiments test energy scales much higher than accelerators

  ➡ Complementary!

- May provide information on hidden sectors and thereby into the underlying fundamental theory



- Surprises like Lorentz symmetry violation possible!

Further Probes?!?...

- Searches for fifth forces
- Casimir effect
- Atom interferometry
- B-field inside superconductors

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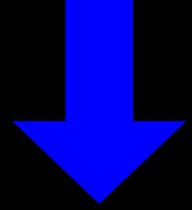
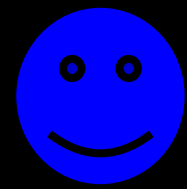


Low energy experiments can probe
Fundamental physics

Complementary to
accelerator experiments



Low energy experiments can probe Fundamental physics

Complementary to accelerator experiments

5th Patras Workshop on Axions, WIMPs and WISPs

13-17 July 2009

University of Durham (UK)

http://axion-wimp.desy.de

Organizing committee:
Laura Baudis (University of Zurich)
Joerg Jaeckel (IPPP/Durham University)
Axel Lindner (DESY)
Andreas Ringwald (DESY)
Konstantin Zioutas (University of Patras)

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