Non-accelerator physics

The Physics Case
for
Axions, WIMPs, WISPs… and other weird stuff

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The Physics Case
for
A Low Energy Frontier of Fundamental Physics

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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
- PVLAS anomaly

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'

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

The Hierarchy Problem: WIMPs

- Introduce new Super-symmetry to solve hierarchy problem

- Predict zillions of new particles
  among them WIMPs
  (Weakly Interacting Massive Particles)

Dark matter candidate

may explain (g-2)

Good `physics case' for WIMP experiment

The PVLAS anomaly: Many WISPs

University of Durham

- Introduce new WISPs to explain PVLAS anomaly

Improve Experiment (anomaly vanishes)

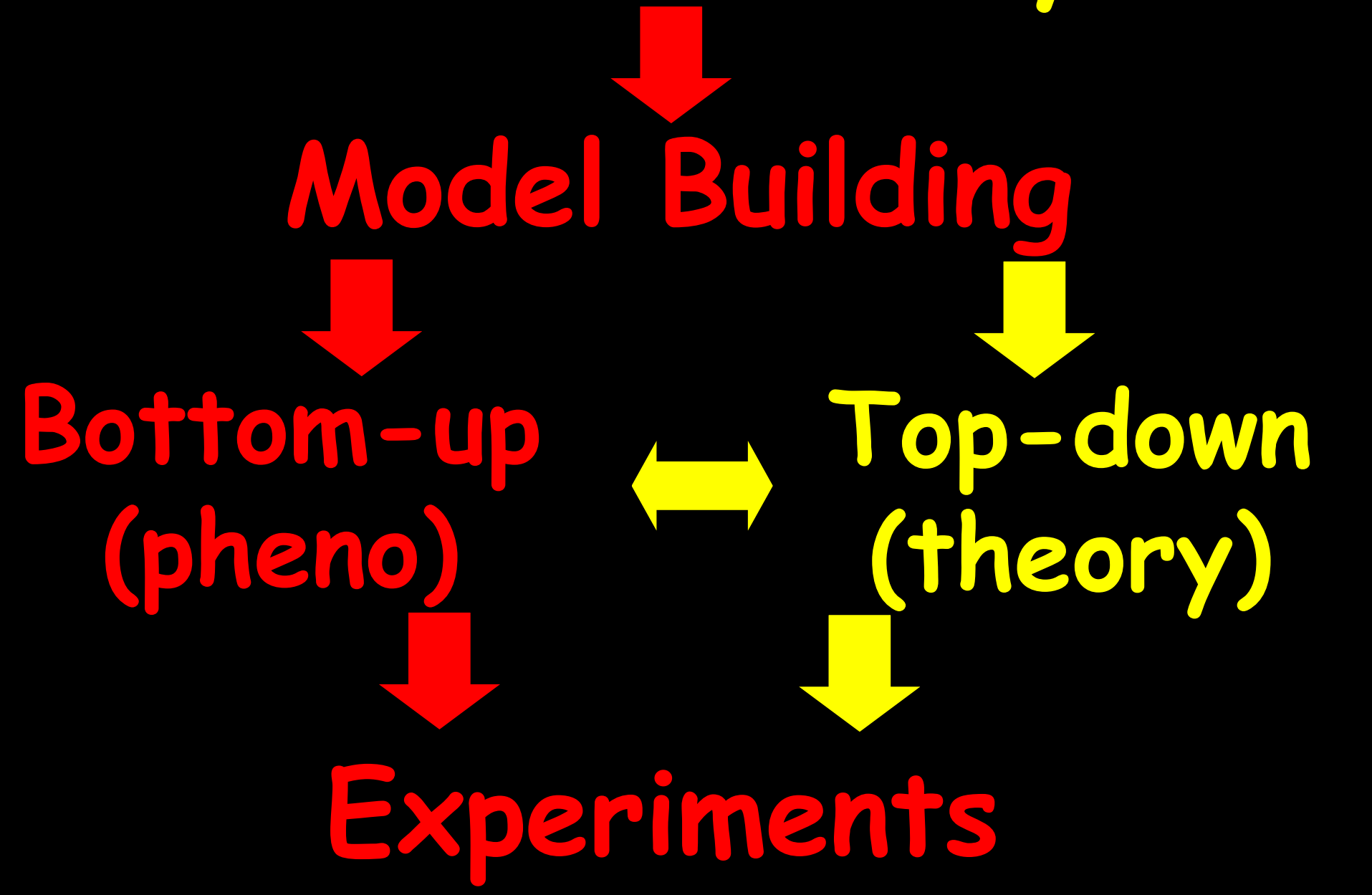
Find loads of unexplored parameter space

Find that exps. are sensitive to ultrahigh energy scales ~10^5-10^{15} GeV

New ideas for experiments

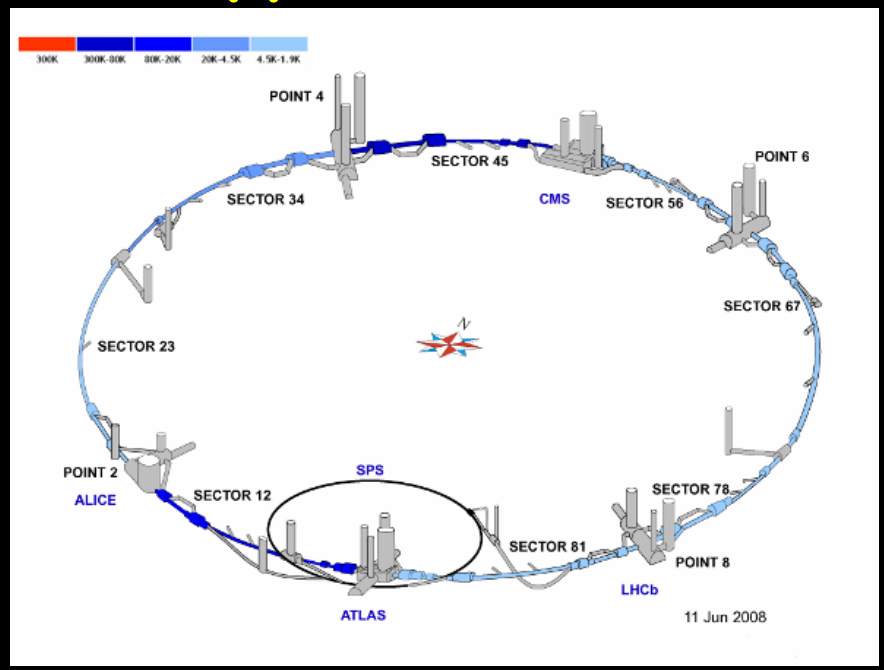
Good `physics case' for new and improved WISP experiment

Hints for new Physics



Example experiment 0: LHC

- The direct approach: MORE POWER



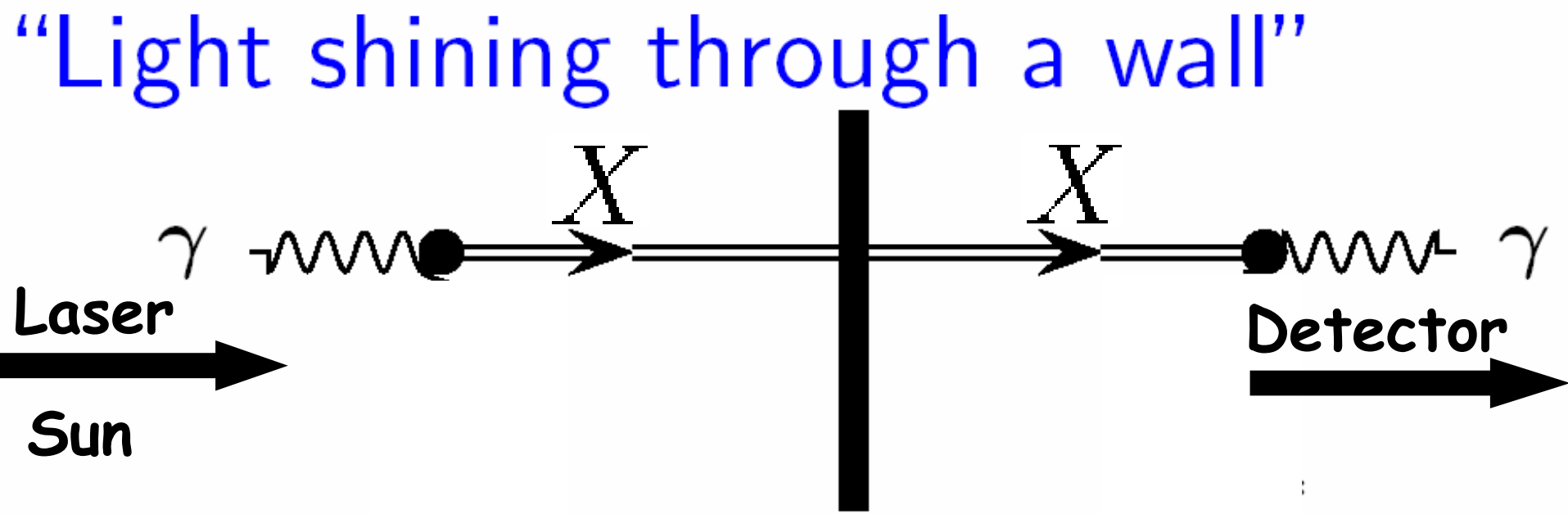
- Detects most things within energy range
- E.g. may find WIMPs

But…

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

Example experiment I: WISPs

- Laser is shone on an opaque wall
- One searches for photons `appearing' on the other side of the wall

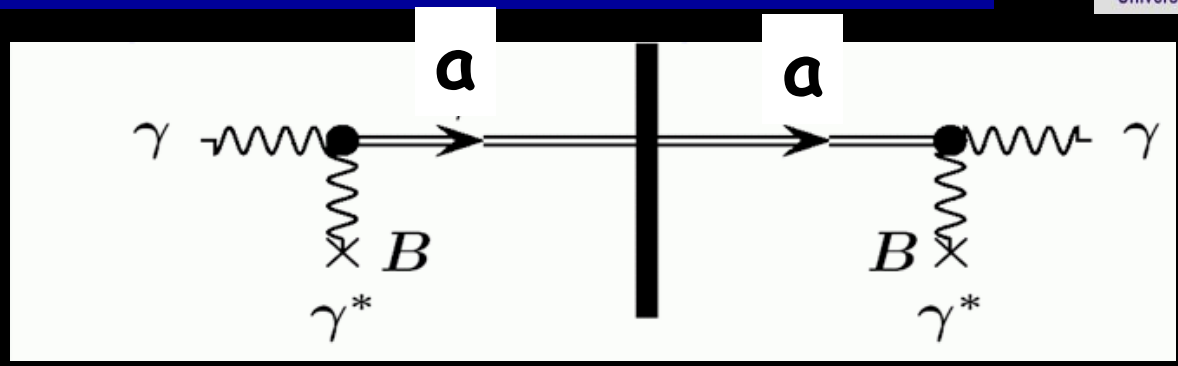


Light shining through walls experiments and helioscopes

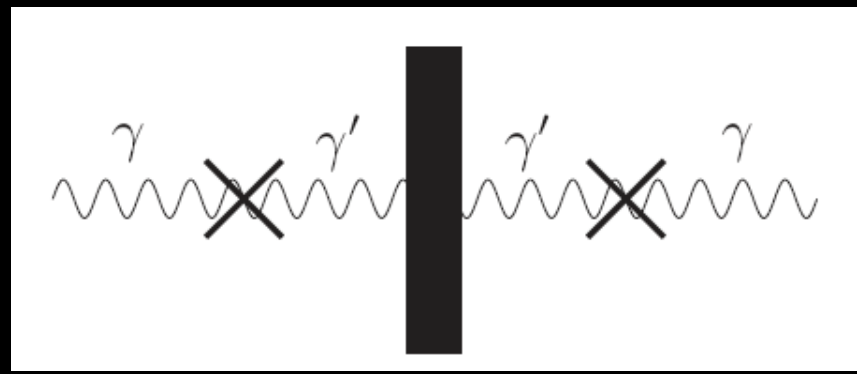
WISPs=Weakly interacting sub-eV particles

- Axions

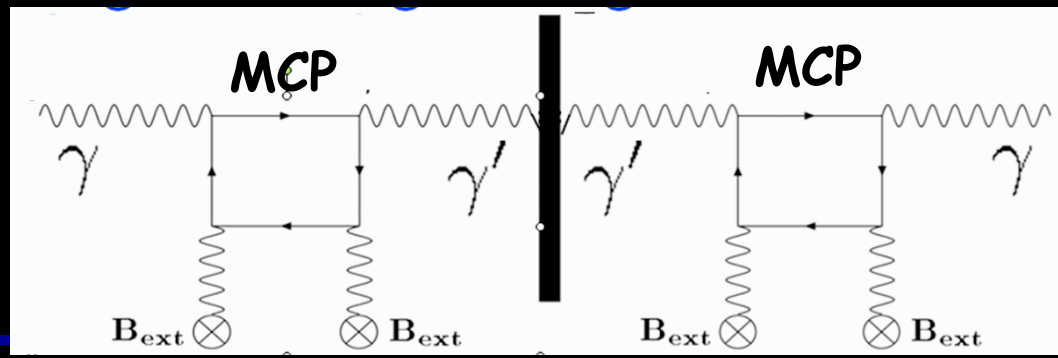
$$\frac{1}{M} a \tilde{F} F$$



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

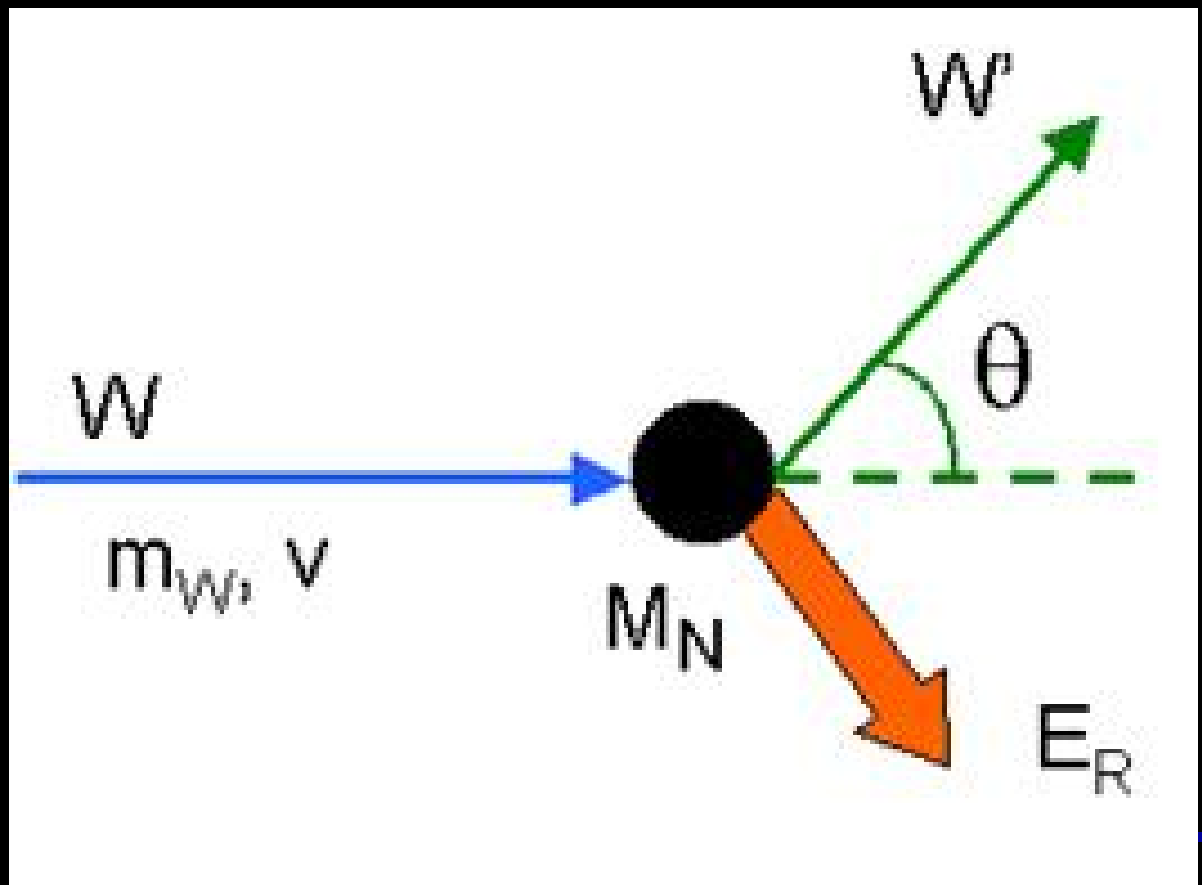


- Hidden photon + minicharged particle (MCP)

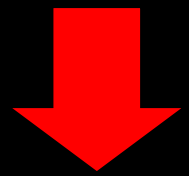


Example experiment II: WIMPs

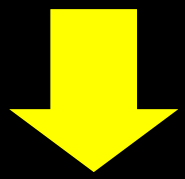
- Dark Matter searches.
- Search for recoil of a WIMP on a nucleus

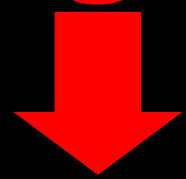


Hints for new Physics

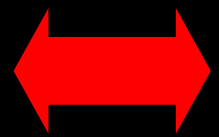


Model Building





Bottom-up (pheno)



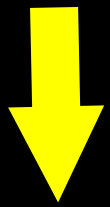
Top-down (theory)

String theory

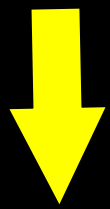
- Attempt to unify SM with gravity
- New concept: strings instead of point particles

String theory likes SUSY

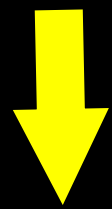
- Attempt to unify SM with gravity
- New concept: strings instead of point particles



Need SUSY for consistency



WIMPs etc.



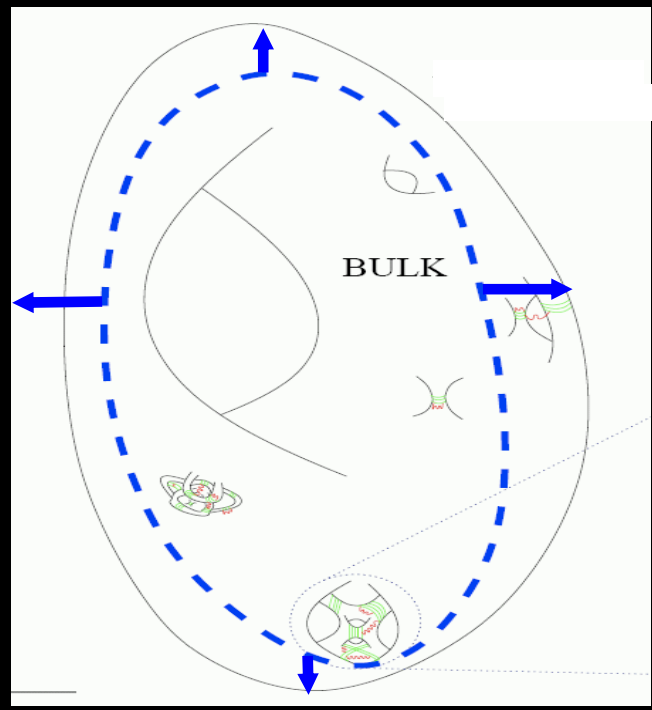
`Physics case' for WIMPs strengthened

String theory: Moduli, Axions, etc.

- String theory needs Extra Dimensions

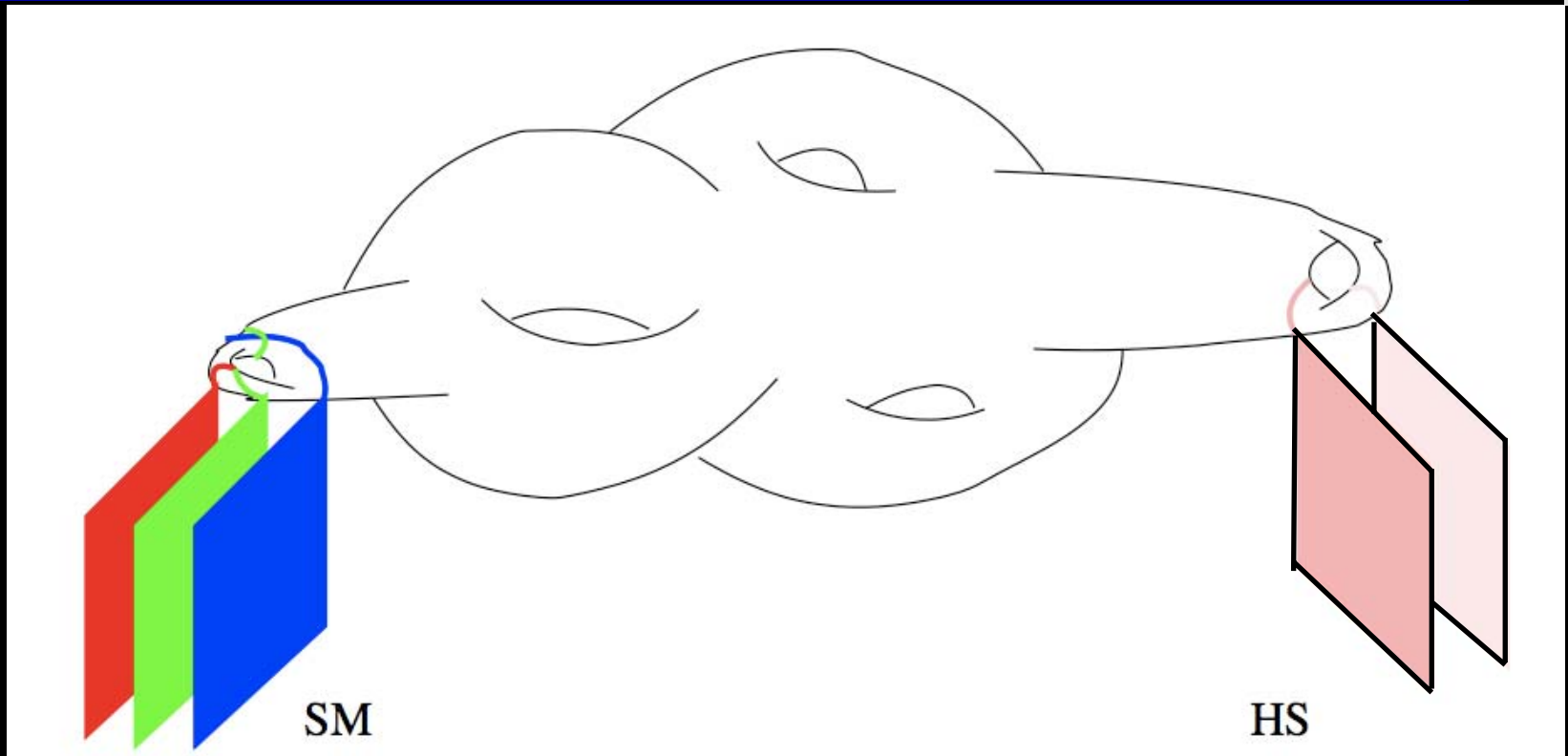
Must compactify

- 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



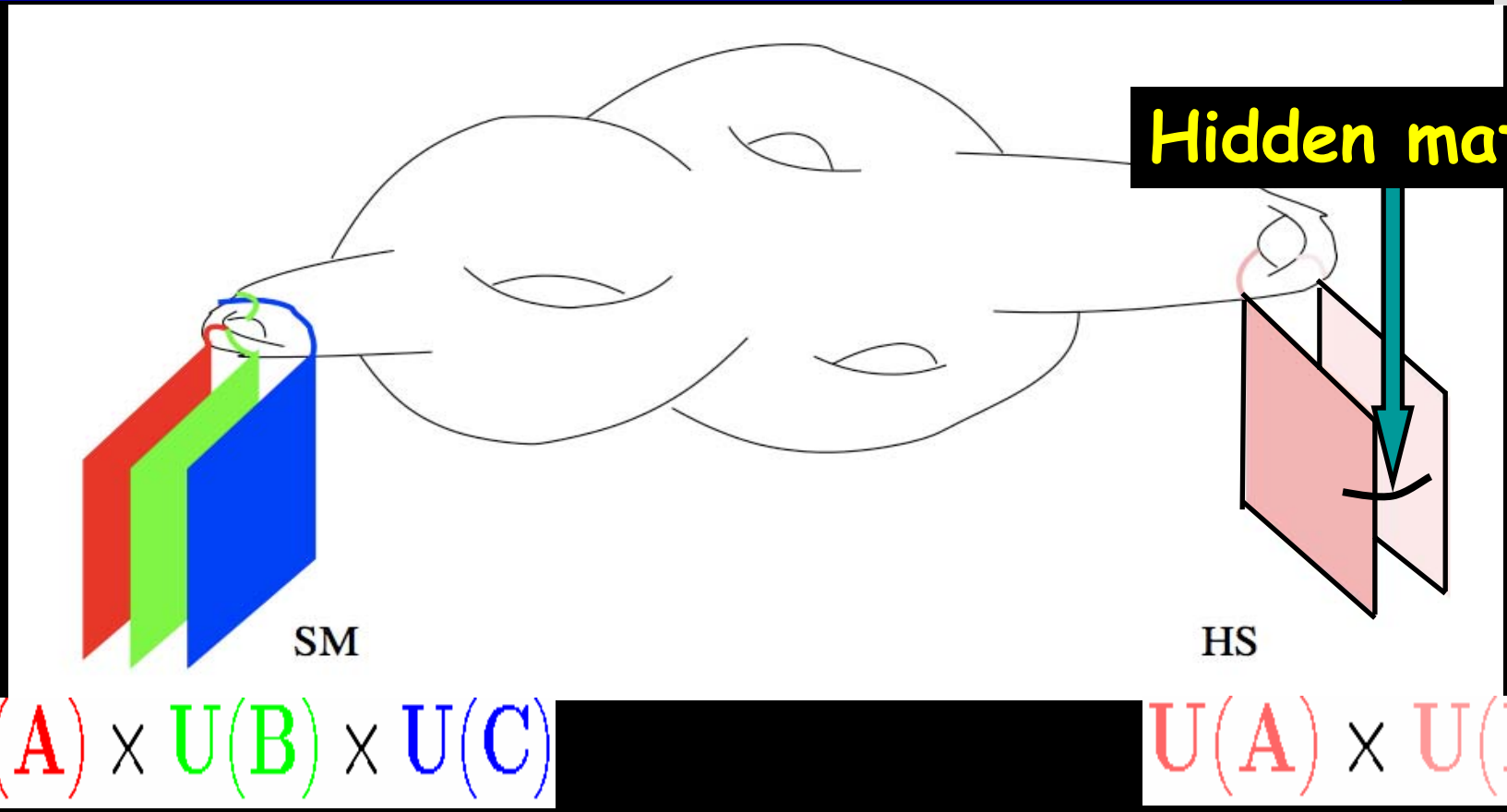
$U(A) \times U(B) \times U(C)$

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

Many extra U(1)s!

Candidates for WISPs

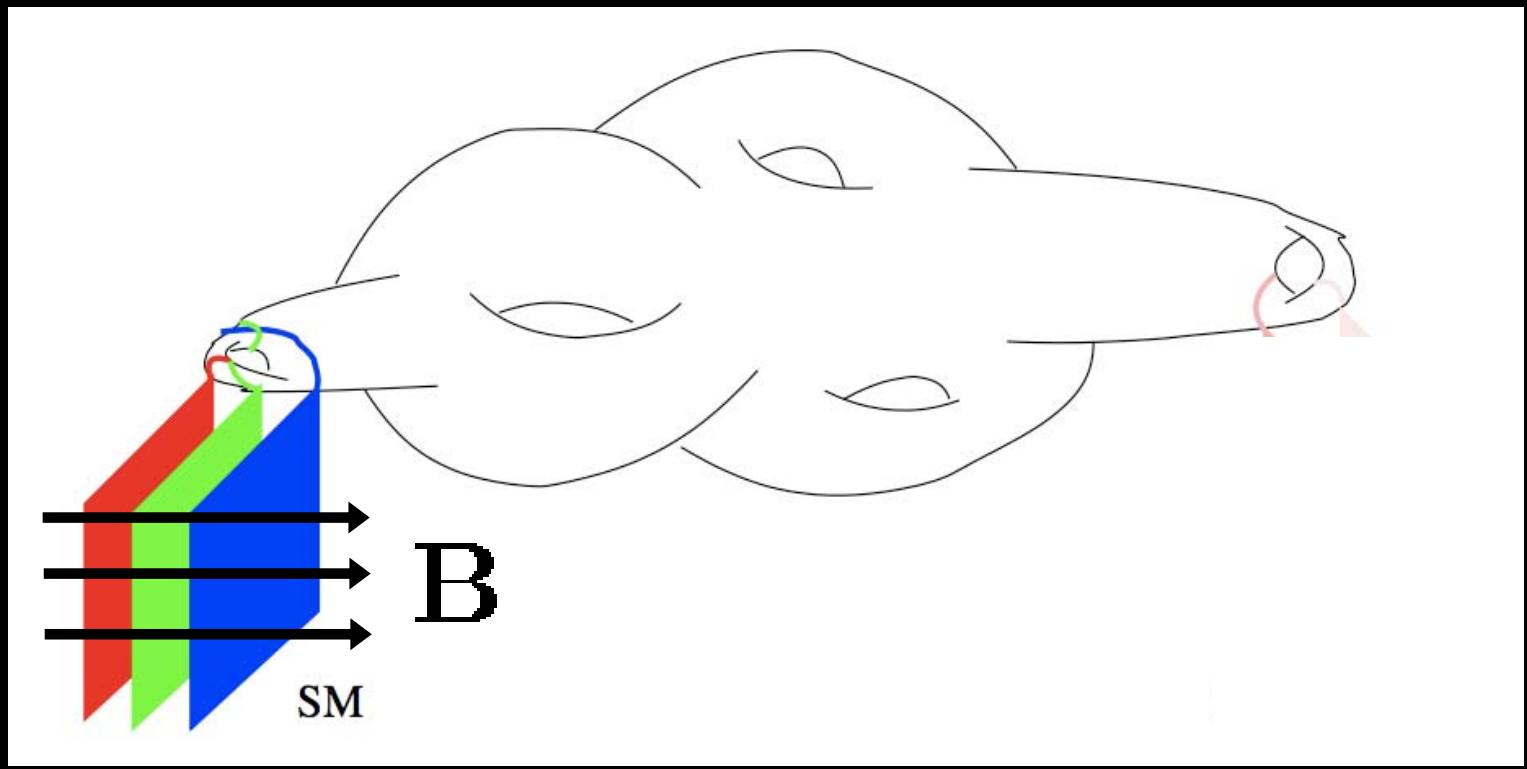
String theory likes extra matter

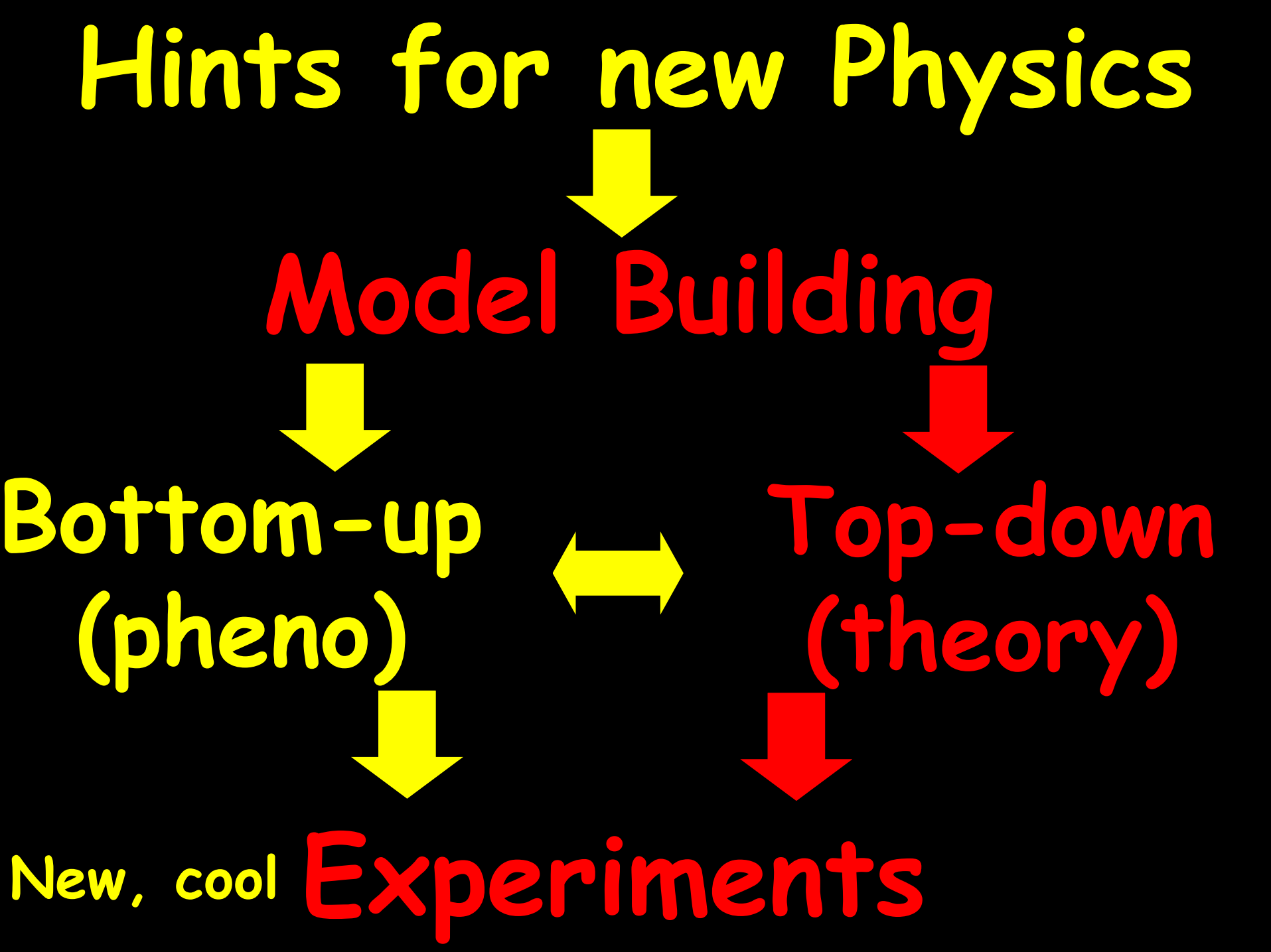


- Hidden sector matter
- May be light and WISPy
  Or WIMPy and dark matter

String theory inspires weird stuff

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




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

Test Lorentz symmetry

- Lorentz symmetry breaking can leads to vacuum birefringence

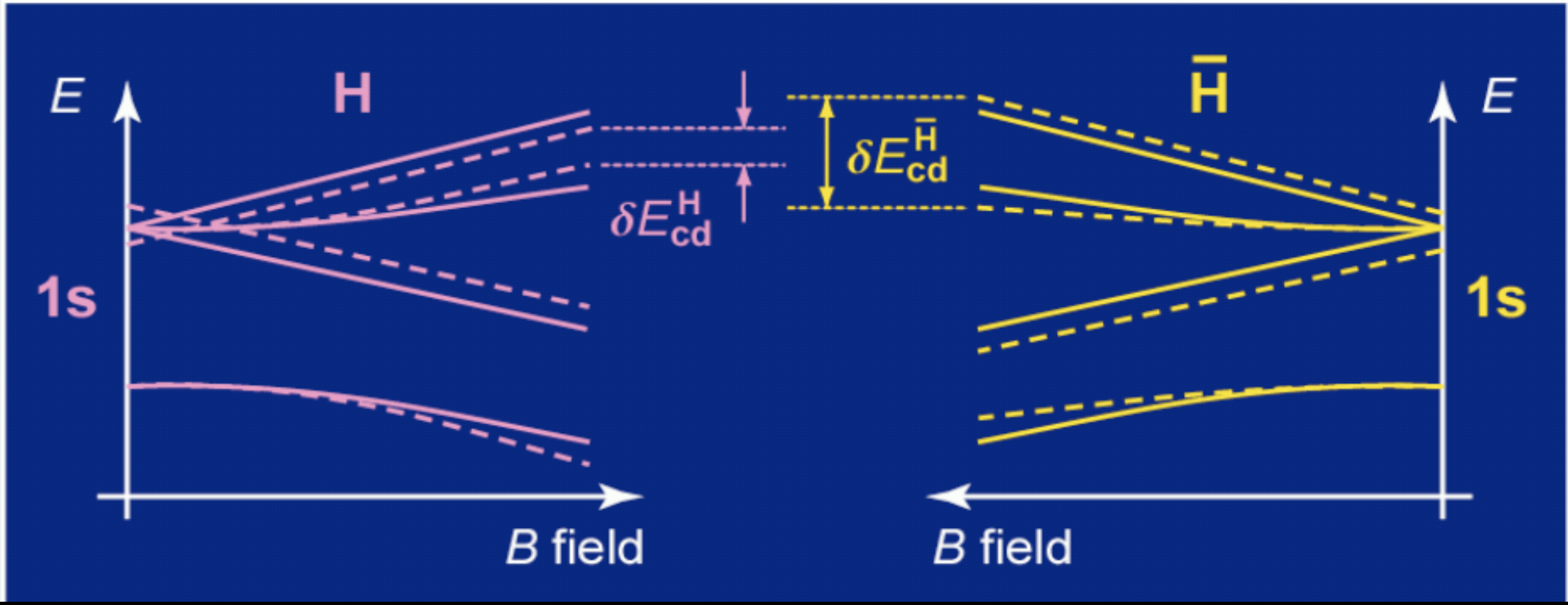
➡ Ultra high Precision

➡ Test (nearly) Planck scale physics

Test CPT, Matter – Antimatter (a)symmetry

University of Durham

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



Ultra high Precision

Test very high energy scales.

Conclusions

Conclusions

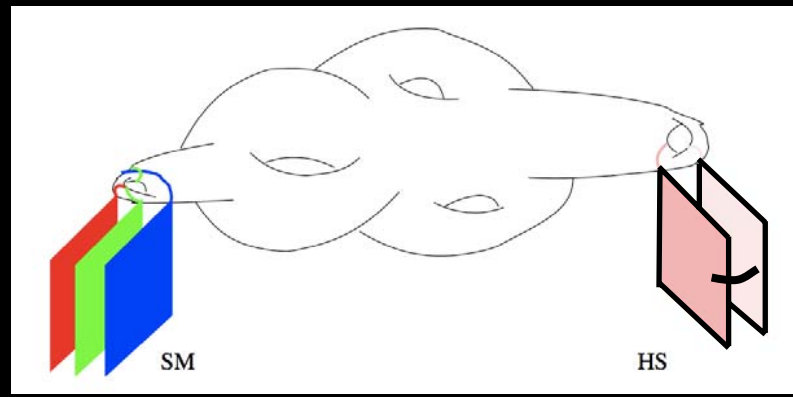
- Good Physics Case for Axions, WIMPs and WISPs

  ➡ explore `The Low Energy Frontier'

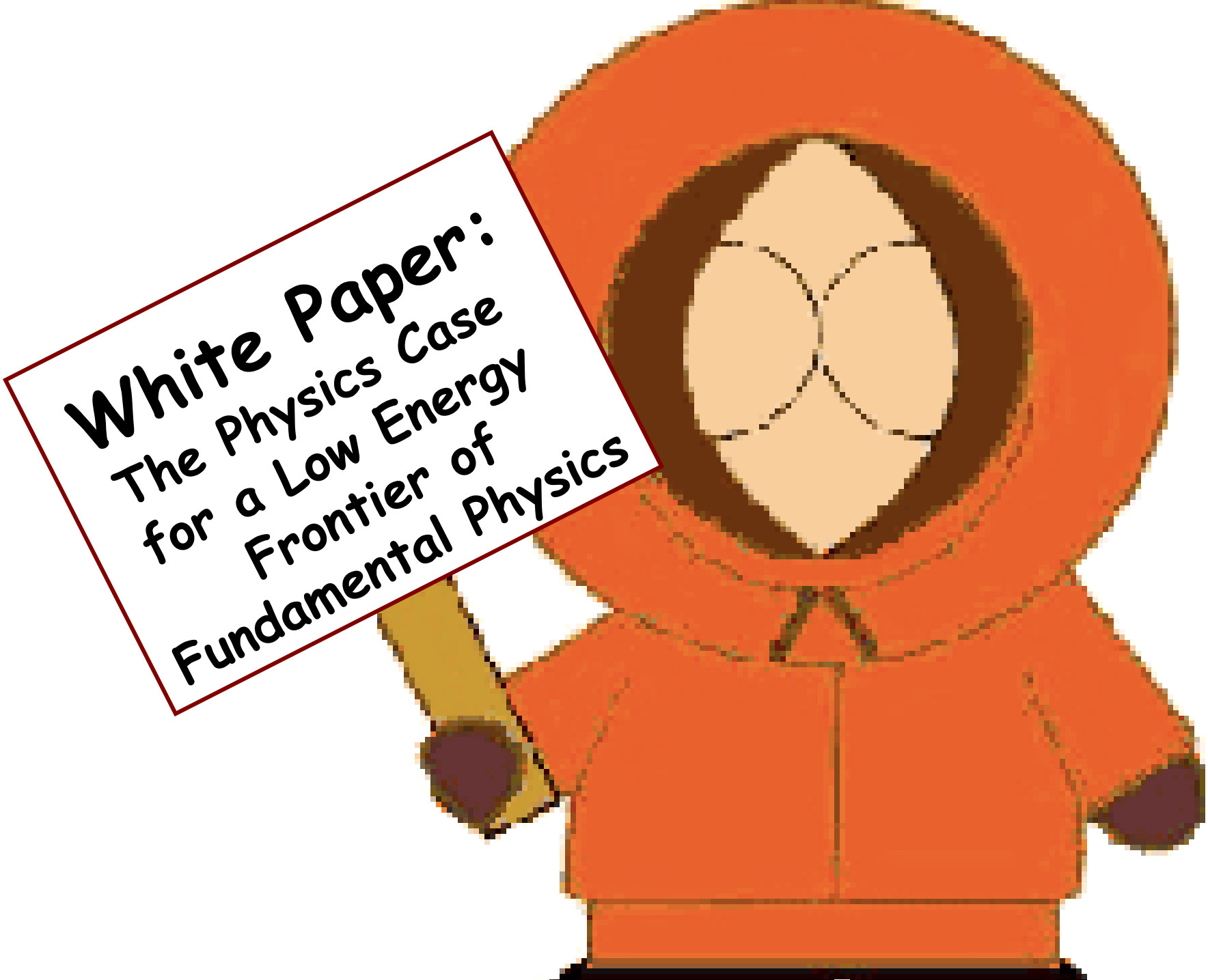
- Low energy experiments test energy scales much higher than accelerators

  ➡ Complementary!

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



- Surprises like Lorentz symmetry violation possible!


White Paper:
The Physics Case
for a Low Energy
Frontier of
Fundamental Physics

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