eos plans & vision

VUB group

Intro

- VUB group:
  - Focus on Theoretical HEP, Pheno, Experimental HEP (collider & neutrino), Astroparticle, High-Energy Astrophysics
  - Grown substantially over last 10 years
  - 1 ERC, 3 Odysseus mandates
  - One of the VUB Strategic Research Programs (formerly known as GOA)
    - We already recently went through the process of writing a successfull proposal spanning the fields above and hope this helps this discussion
  - In the coming slides I summarise what we do at VUB
  - And afterwards I will propose some work packages that are hopefully useful

Freya Blekman, freya.blekman@vub.ac.be

VUB SRP organisation

HEP@VUB BRUSSELS

High-Energy Physics

Theoretical physics

- string theory
- holography
- cosmology

Prof. B. Craps
Prof. A. Sevrin

Part-time:
Prof. V. Balasubramanian
Prof. O. Evnin
Prof. L. Lopez Honorez
Prof. D. Thompson

TENA

Particle physics experiments

- high-energy colliders
- neutrino physics

Prof. F. Blekman (Odysseus 2)
Prof. J. D'Hondt
Prof. S. Lowette (Odysseus 2)

Part-time:
Prof. P. Van Mulders

Active emeriti:
Prof. S. Tavernier
Prof. W. Van Doninck

ELEM

Astro-particle physics

- cosmic neutrinos
- dark matter
- multi-messenger observations

Prof. N. van Eijndhoven (Odysseus 1)

Part-time:
Prof. O. Scholten

Active emeriti:
Prof. C. De Clercq

ELEM

High-energy astrophysics

- radio transients
- binary evolution

Prof. S. Buitink (ERC Starting Grant)

Part-time:
Prof. J. Blommaert
Prof. G. Gentile

Guest professor:
Prof. D. Vanbeveren

AARG

Phenomenology

Prof. A. Mariotti

Part-time:
Prof. K. Mawatari

AARG – ELEM – TENA

HEP@VUB Coordinator: Prof. J. D'Hondt
Secretariat: M. Fabre and M. Goeman

Freya Blekman, freya.blekman@vub.ac.be

List of open questions (1)

- We collaborate with ULB experimental group in IIHE
  - List below was drafted together with IIHE colleagues

Some state-of-the-art questions as clear objectives for the project:

- How precise can we verify the relation of the BEH mechanism with the particles' masses?
- Does nature go along with a simple H-sector, or a more complicated scalar sector?
- What are the neutrino masses and what is the mechanism to explain these?
- What is the dark matter in our universe and what is the mechanism to explain this?
- Can we describe/verify the mass distribution and the evolution thereof in our universe?
- How can we include gravity in a quantum theory of nature?
- Will our understanding of the physics of mass/gravity hold in extreme situations?

List of open questions (2)

Based on recent successes that opened unique windows of opportunity:

Motivation for a consortium on these questions in an EOS-project:

- Need a combination of experimental and theoretical efforts in particle physics at colliders and elsewhere, astro-particle physics, cosmology and astrophysics
- Fits the interuniversity and interdisciplinary nature of the EOS program, with potential interdisciplinary joint-PhD and even joint postdoctoral projects
- Embraces coherently and strongly several of the most important experiments and theoretical model building directions in the field
- Has the potential for contributing major results on most (if not all) aspects

Proposal of some (not all) potential Work Packages
(obviously incomplete at this stage):

Objective 1: develop novel and adequate methods for further exploration
WP1-1: experimental techniques (incl. reconstruction methods, trigger, DAQ, …)
WP1-2: phenomenological methods (incl. physics generators of fundamental interactions, numerical methods to related observations with theoretical models, …)
WP1-3: theoretical methods

Objective 2: confirm the BEH mechanism and understand the scalar interaction
WP2-1: SM measurements of the masses of particles and QCD effects
WP2-2: precise measurements of H boson couplings at the LHC (incl. the top-H interplay)
WP2-3: test of the vector boson scattering and other predictions

Objective 3: explore the place of the H boson in our theories
WP3-1: the H boson in the SM (spin/parity, mass, width, self-coupling, anomalous couplings and width, invisible decays, …)
WP3-2: the H boson sector beyond the SM (extended H sectors, 2HDM, LFV channels, …)
WP3-3: towards solutions for the hierarchy/naturalness problem

Objective 4: discover the neutrino mass mechanism
WP4-1: neutrino masses (incl. oscillations, mass hierarchy, see-saw mechanism, …)
WP4-2: neutrino properties (incl. Majorana vs Dirac, sterile neutrinos, …)

Objective 5: discover dark matter and its mass mechanism
WP5-1: search for dark matter particles (incl. searches at collider, non-collider, and astro-particle experiments, …)
WP5-2: dark matter mass mechanism (incl. model building, impact on observations, …)

Objective 6: develop quantum theories including and explaining gravity
WP6-1: string theory and supergravity (the fabric of space-time)
WP6-2: early universe models (incl. inflation)

Objective 7: exploring very massive, compact objects in the universe
WP7-1: using cosmic rays with neutrinos and radio signals
WP7-2: using the CMB to understand the evolution of mass in the universe
WP7-3: using gravitational waves

To reach success the scale of the EOS funding (1MEuro) fits well, for example with 2-4 doctoral students or postdocs hired per Work Package / Objective.

Summary

- VUB involved in many fundamental physics topics
  - Theoretical HEP, Pheno, Experimental HEP (collider & neutrino), Astroparticle, High- Energy astrophysics
- Hot topics in fundamental physics: QG incl GW, cosmic rays, neutrinos and the DM puzzle
  - This provides ties to all work we do at VUB and we think provides a useful starting point to find synergy with other groups as well!
- Understanding these in theory, at experiments and in the universe go hand in hand
- We believe this could be a competitive theme for the EOS proposal that also provides clear connections between many groups

Freya Blekman, freya.blekman@vub.ac.be

Theory@VUB

- Several research themes:
- Holography, gauge/gravity duality
  - Far-from-equilibrium physics (AdS instability, etc)
  - Quantum entanglement in the emergence of space time
- Supergravity & strings
- Geometric nature of spacetime in string theories and its dualities

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Pheno @VUB

- Phenomenology is *glue* between VUB HEP groups
- Topics:
  - Address BSM questions in unified descriptions (Susy, extra dimensions)
  - Propose new frameworks for BSM physics and signatures (unconventional susy, flavour violation etc.)
  - Phenomenology of BSM and dark matter simplified models (link with UCL and ULB)

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Astroparticle physics @ VUB

- **IceCube** has seen ultra-high-energy neutrinos that cannot be explained
- Joint effort with ULB experimental groups via IIHE
- Group focuses on point sources (GRBs etc) that could be the origin of these neutrinos and cosmic rays
  - Also involved with neutrino oscillations (sterile neutrinos) and DM searches
- Important role in the use of multimessenger study of astrophysical phenomena (incl. collaborations with Graviational Wave detectors (LIGO/VIRGO) and other detectors like Auger)
- Algorithms such as HitSpool are useful to pinpoint astrophysical events and also provide input to GW and AP collaborations
- Links with Gent (CR) and SoLid (Sterile Neutrinos, UA, Gent) and High Energy Astrophysics
- We would like to explore future efforts with KUL in context of GW

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High-Energy Astrophysics@VUB

- Studying mass composition of cosmic rays with the LOFAR multipurpose radio telescope
- Theoretical study of cosmic-ray acceleration and propagation
- Source GW can be matched to radio signals in LOFAR
- Collaboration with IceCube multimessenger efforts
- Synergy with Cerenkov Telescope Array (CTA)

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Experimental Particle Physics @VUB

- Commitments to **CMS** and **SoLid** exps
- CMS: broad research programme reaching from Top quark, SM Scalars to varied collection BSM searches incl. Dark Matter
  - Existing collaboration UA, UG, UCL, ULB & VUB
- SoLid: Oscillation analysis (main objective of experiment) looking for sterile neutrinos (clear BSM goal)
  - existing collaboration UA and UG
- Many EOS scopes can be well contained within this programme

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