

HIGH-ENERGY PHYSICS
RESEARCH CENTRE

High-Energy Physics

May 22nd, 2018, Brussels; <http://we.vub.ac.be/en/HEPVUB>

Coordinator:

Jorgen D'Hondt

Group leaders:

Stijn Buitink

High-Energy Astrophysics

Ben Craps

Theoretical Physics

Jorgen D'Hondt

Particle Physics Experiments

Nick van Eijndhoven

Astro-Particle Physics



Curiosity driven research

Observable universe



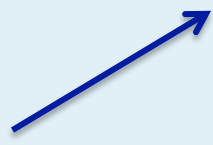
~ 1.000.000.000.000.000.000.000.000.000.000 meter

Visible with our eyes



~ 0.000000000000000000000001 meter

Smallest particles





Curiosity driven research

Standard Model of Cosmology
Gravity

Standard Model of Particle Physics
Quantum Field Theory

~ 1.000.000.000.000.000.000.000.000.000.000 meter

~ 0.000000000000000000000001 meter

IceCube/ARA @ South Pole
LOFAR @ Netherlands
Auger @ Argentina

CMS @ CERN
SoLid @ Belgium



Curiosity driven research

Standard Model of Cosmology
Gravity

Standard Model of Particle Physics
Quantum Field Theory

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For a profound understanding of Nature,
we need to understand the interplay
between high-energy phenomena on the
largest and the smallest scales

The VUB represents about 10% in the Flemish academic landscape, hence “covers” about 0.6M inhabitants

Strategic Research choices are to be made in order to excel on the international level

In this context HEP@VUB was established to have a major impact in reaching these scientific objectives



8 professors
10 part-time professors
3 active emeriti
15 postdocs
24 PhD students

Gender:
19% professors female
23% postdocs female
38% PhD students female

Since 2012:
±850 publications*
±55k citations (h-index 112)
16 PhD thesis
>14 awards for PD/students

** many with 1000+ authors*

1 Odysseus-I
2 Odysseus-II
(more selected but declined)
1 ERC Starting Grant

Leverage through FWO fellowships in Flanders:

37% of postdoc years
20% of PhD student years
i.e. 35-40% of those available in physics
(while VUB is 10% fair share in Flanders)

Over 5 years:
±16.5M Euro external funds
±2.7M Euro PhD/PD mandates
1.3M Euro from SRP

International:

less than 10% of our postdocs obtained PhD at VUB
20% of our PhD students obtained Master at VUB
20% obtained Master at another Belgian university
60% obtained their Master abroad

Many of our postdocs have
obtained a permanent
academic position



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Prof. B. Craps
Prof. A. Sevrin

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

Particle physics experiments

Prof. F. Blekman
(Odysseus 2)
Prof. J. D'Hondt
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High-energy astrophysics

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Prof. G. Gentile
Prof. T. Huege

Guest professor:
Prof. D. Vanbeveren

Phenomenology

Prof. A. Mariotti

Part-time:
Prof. K. Mawatari

HEP@VUB Coordinator: Prof. J. D'Hondt

Secretariat: M. Fabre and M. Goeman



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**International
Solvay Institutes**



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**Inter-university Institute for
High Energies (IIHE), VUB+ULB**



Research

Theoretical physics

- string theory
- holography
- cosmology

Particle physics experiments

- high-energy colliders
- neutrino physics

① CMS experiment

② SoLid experiment

Astro-particle physics

- cosmic neutrinos
- dark matter
- multi-messenger observations

③ IceCube observatory

④ ARA observatory

⑤ Auger observatory

High-energy astrophysics

- radio transients
- binary evolution

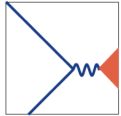
⑥ LOFAR observatory

⑦ SKA observatory

Phenomenology

- theoretical model building
- relation between small and large scales
- dark matter signatures and simplified models

- ① International mobility is very large and intrinsic to our field
- ② Unique range of topics in Belgium, from large to small scales



HIGH-ENERGY PHYSICS
RESEARCH CENTRE

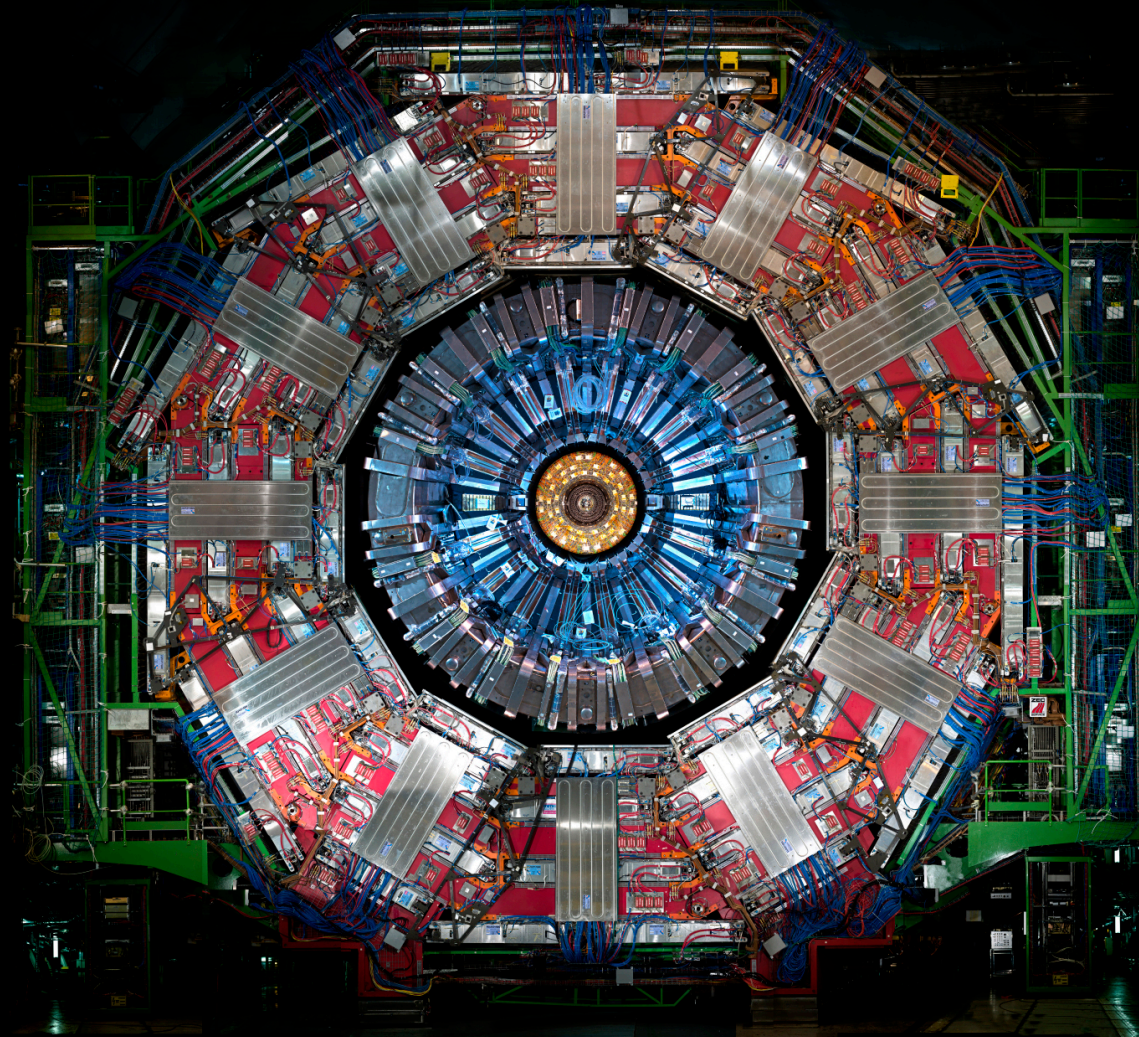
Experiments

Some experiments where we are involved in the construction, operation and exploitation.



HIGH-ENERGY PHYSICS
RESEARCH CENTRE

CMS experiment @ CERN



15m

BREAKTHROUGH
of the YEAR
The **HIGGS**
BOSON
2012

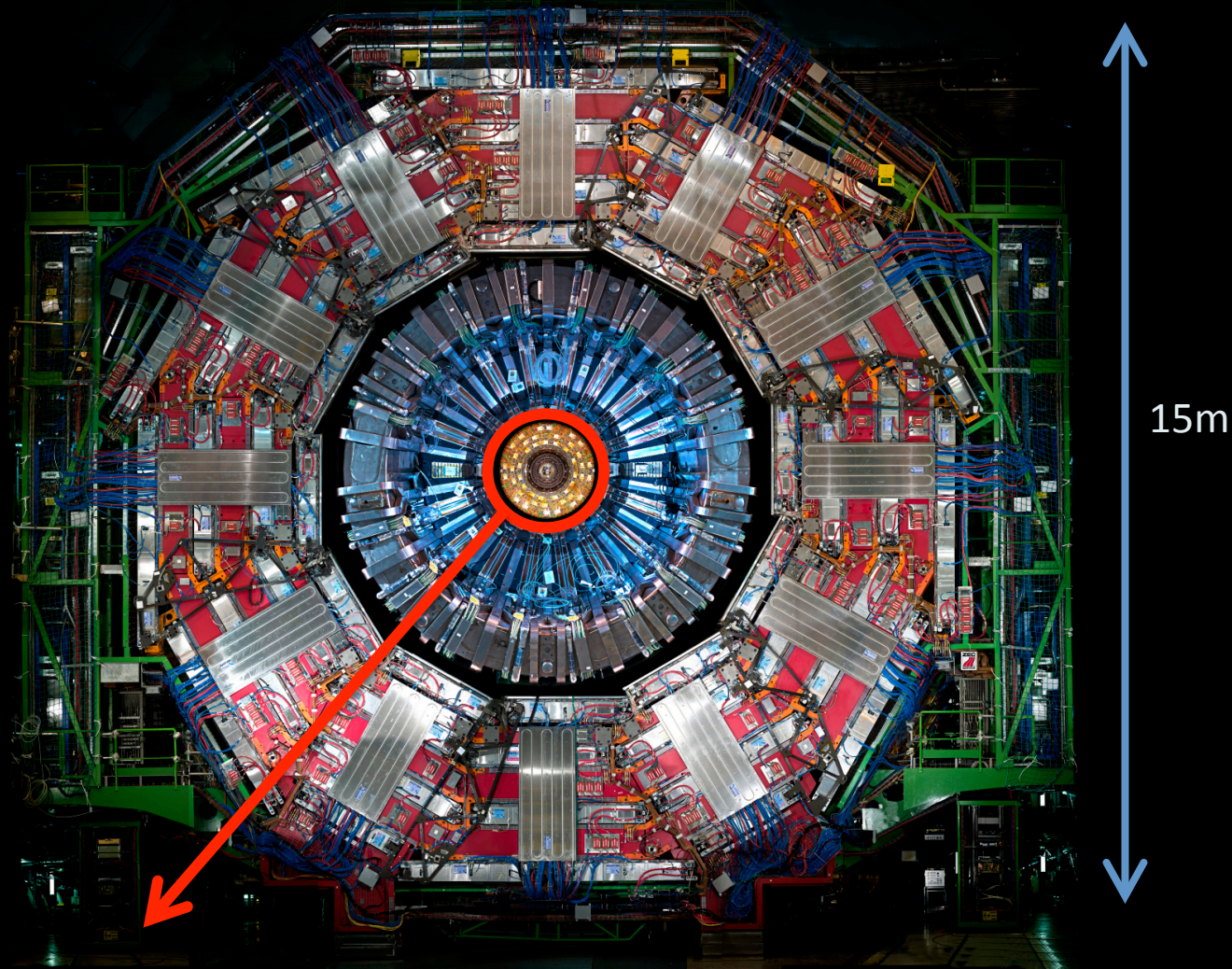


related to
Nobel Prize
in 2013



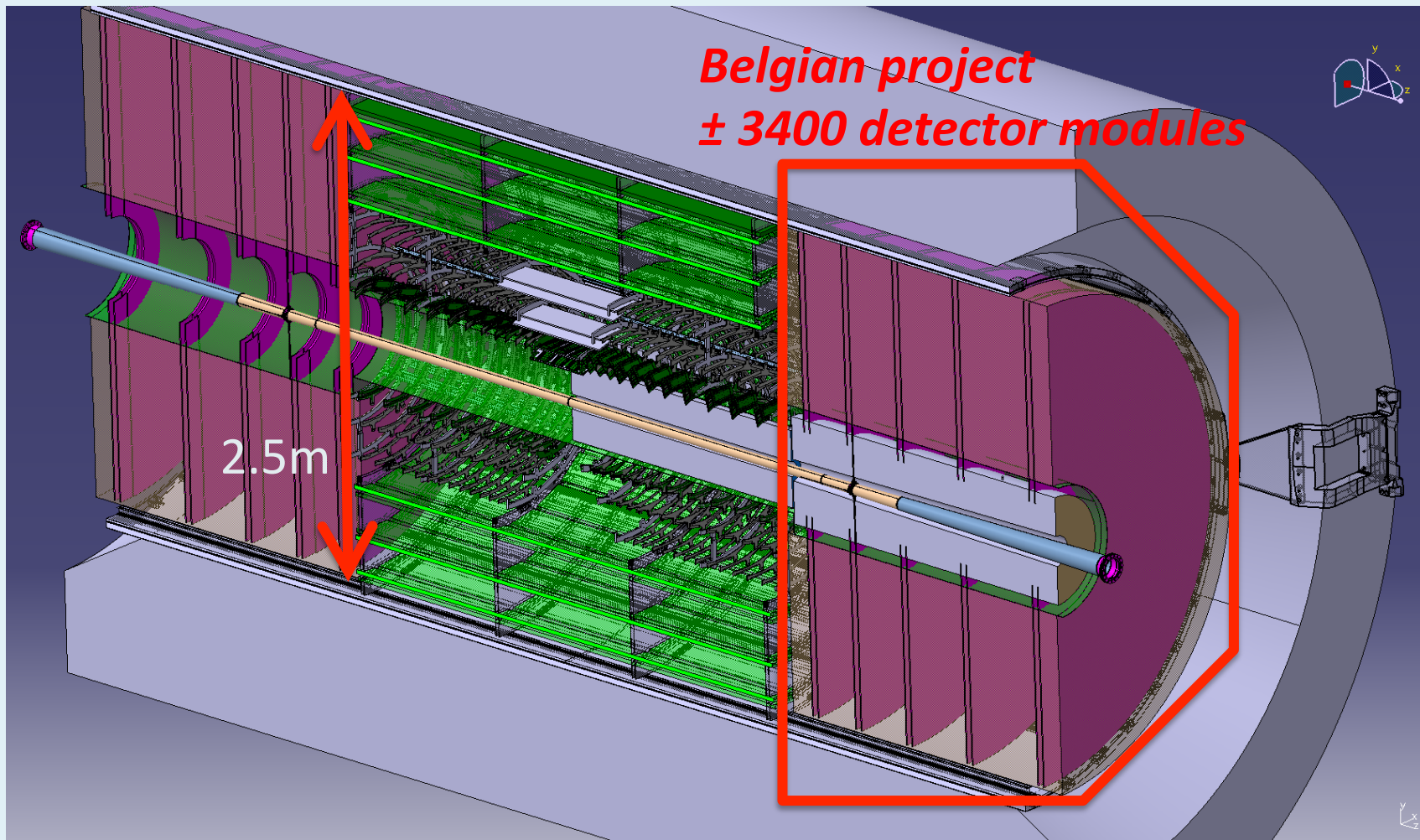
HIGH-ENERGY PHYSICS
RESEARCH CENTRE

CMS experiment @ CERN



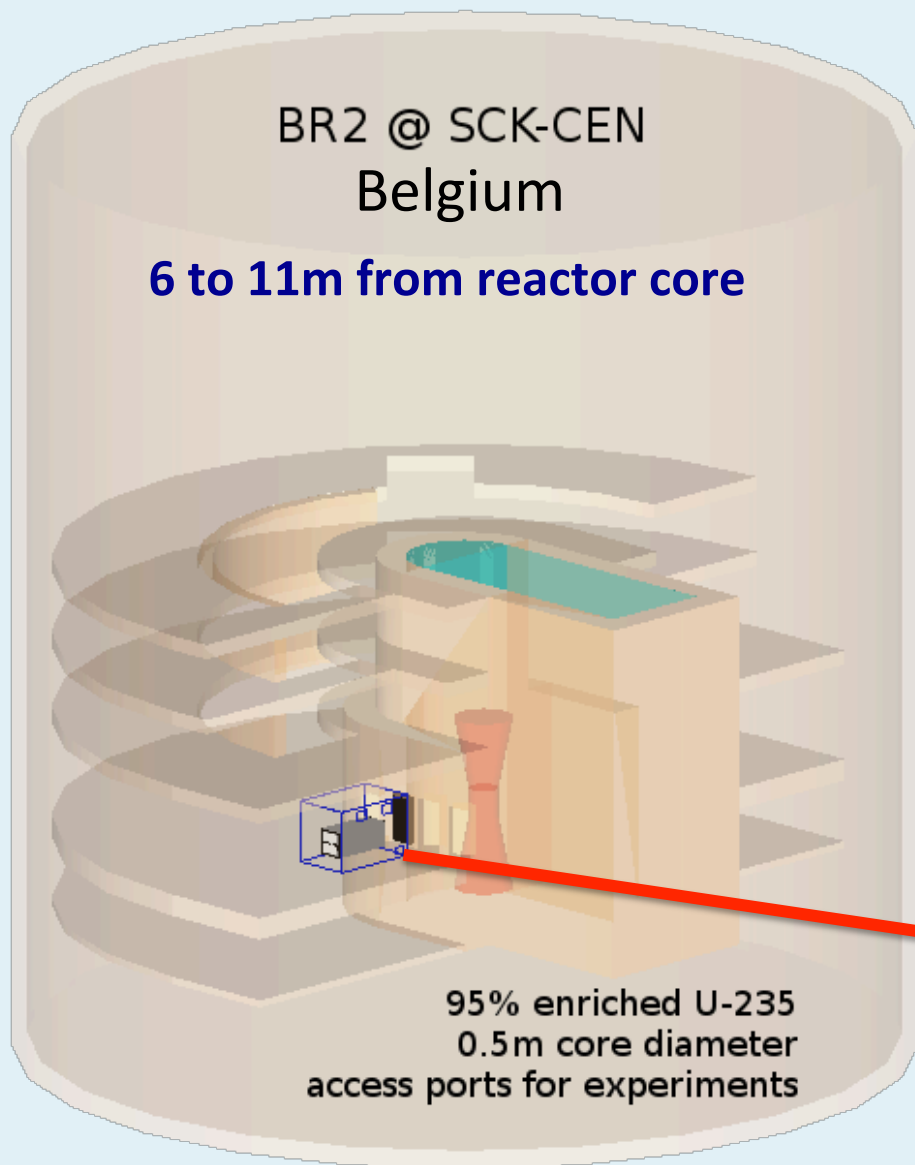
To be replaced by 2026

Construct new detector

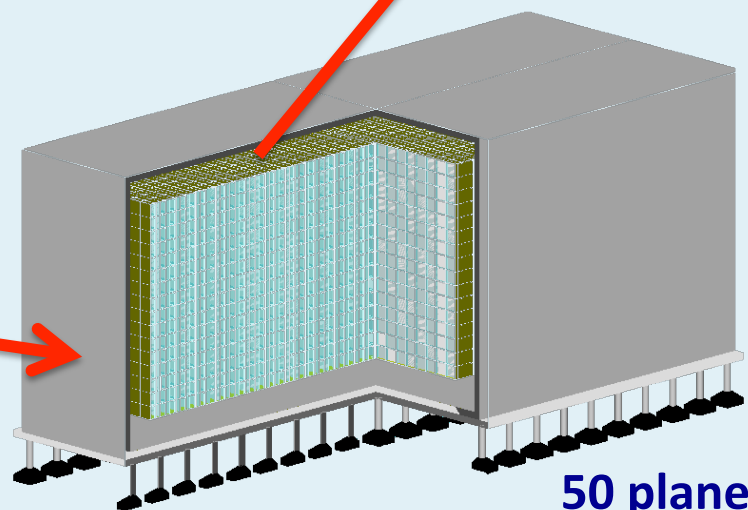
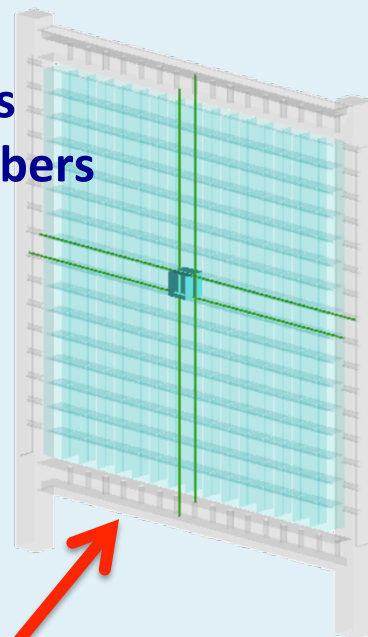


Jorgen D'Hondt is PI of this Belgian project with >10M Euro core budget secured, and >5M Euro human resources cost

SoLid @ BR2 reactor

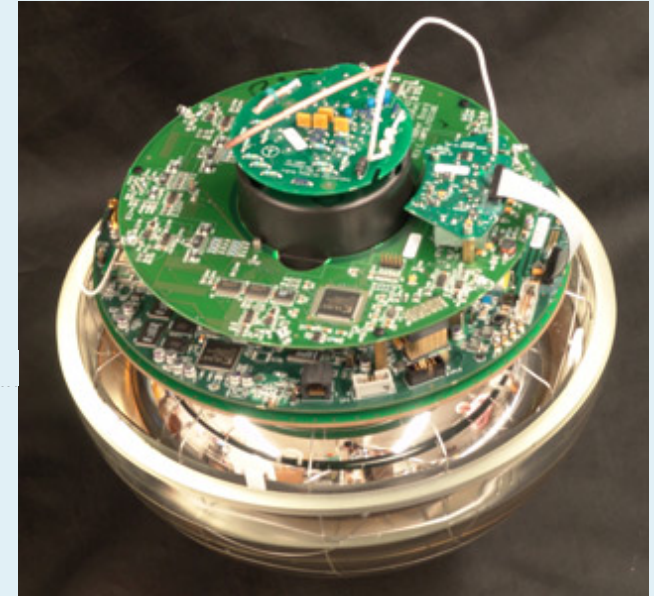
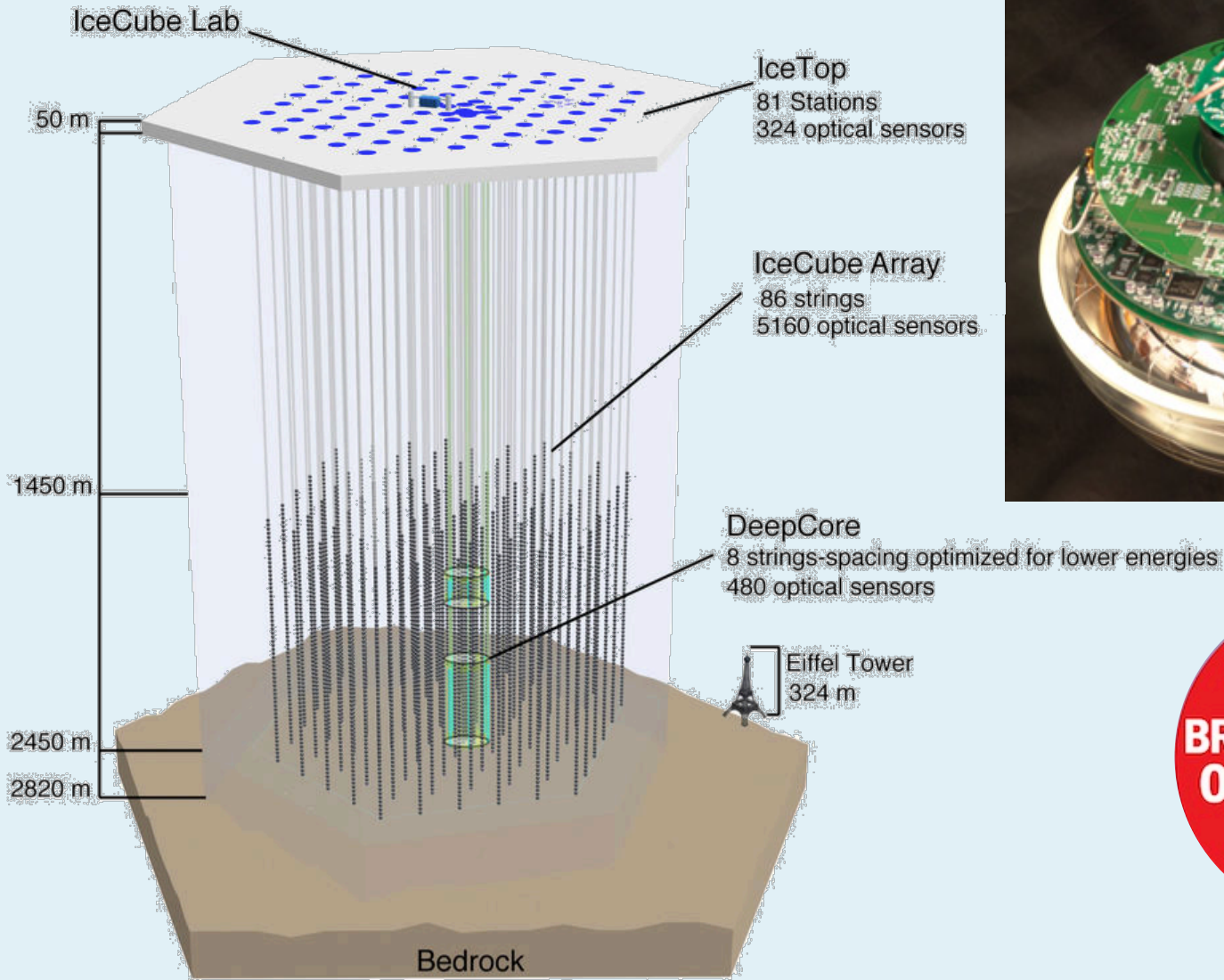


12800 cubes
3200 readout fibers



50 planes
1.5 ton

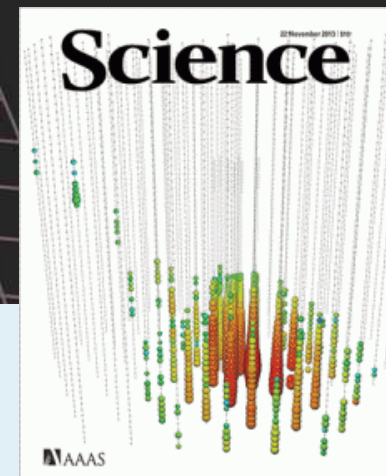
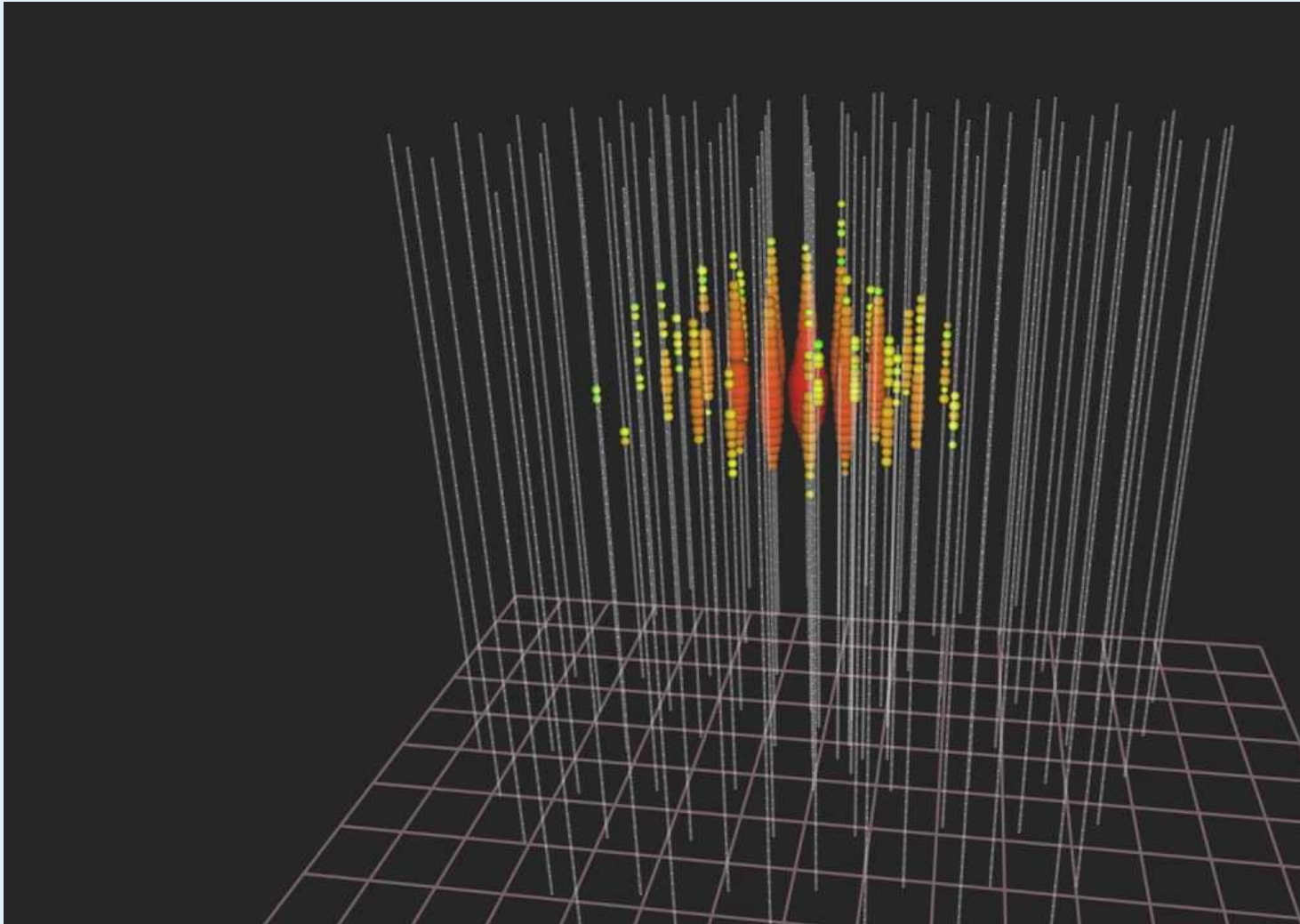
IceCube @ South Pole





HIGH-ENERGY PHYSICS
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IceCube @ South Pole

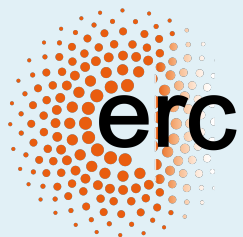
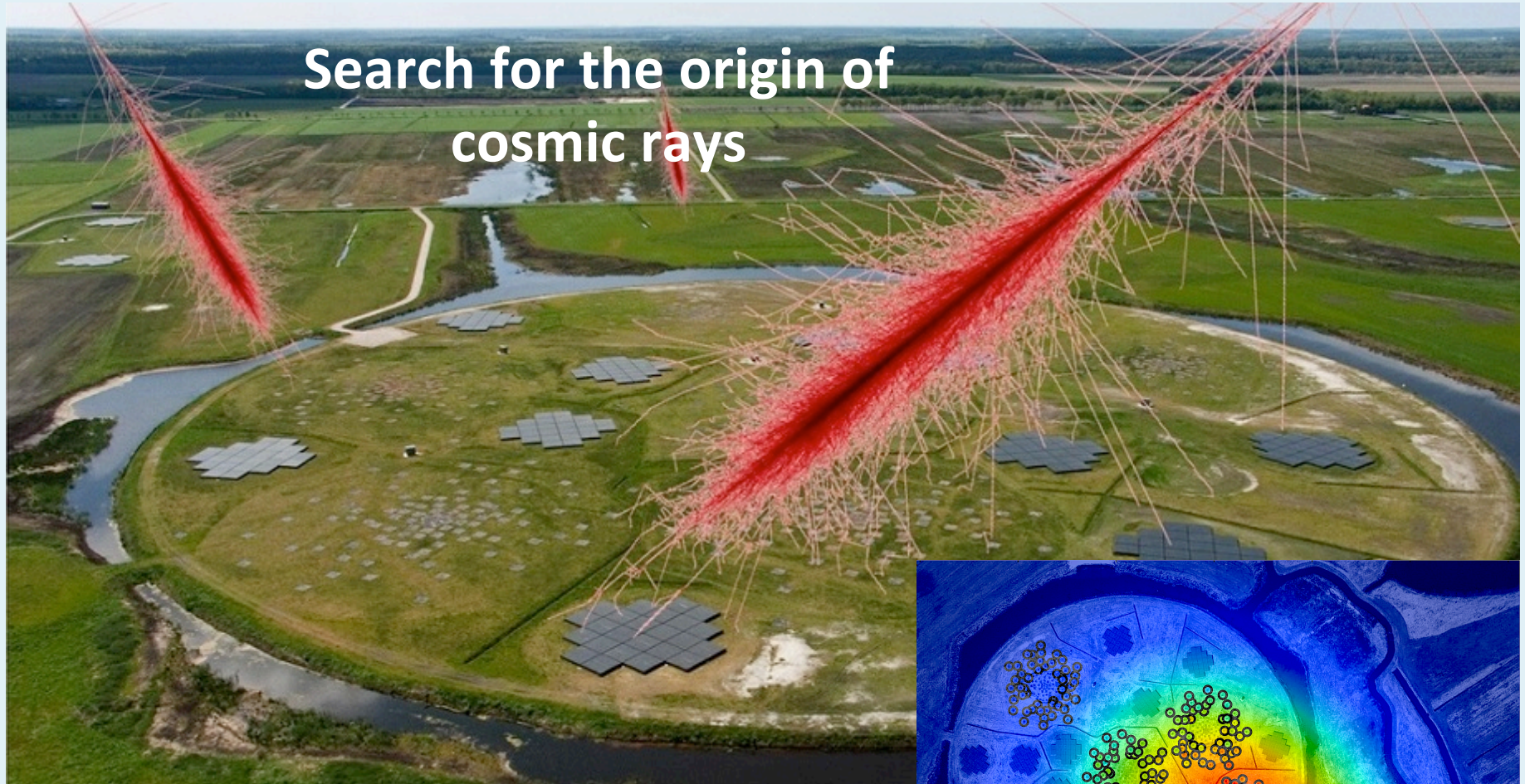




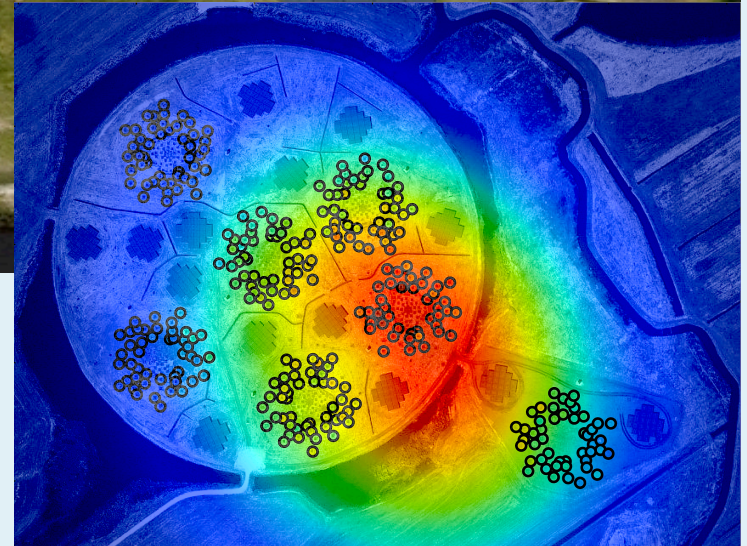
HIGH-ENERGY PHYSICS
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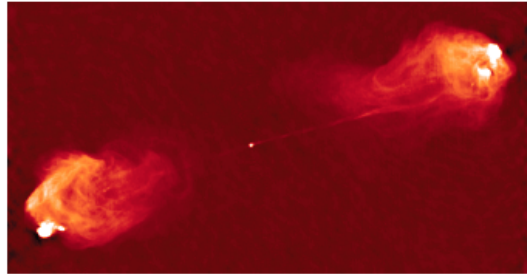
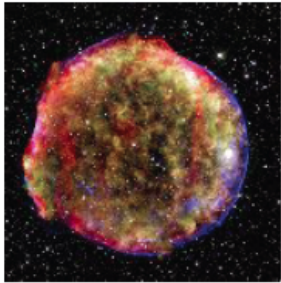
LOFAR @ Netherlands

Search for the origin of
cosmic rays



Low Frequency Array for
novel radio astronomy in the
10-240 MHz range





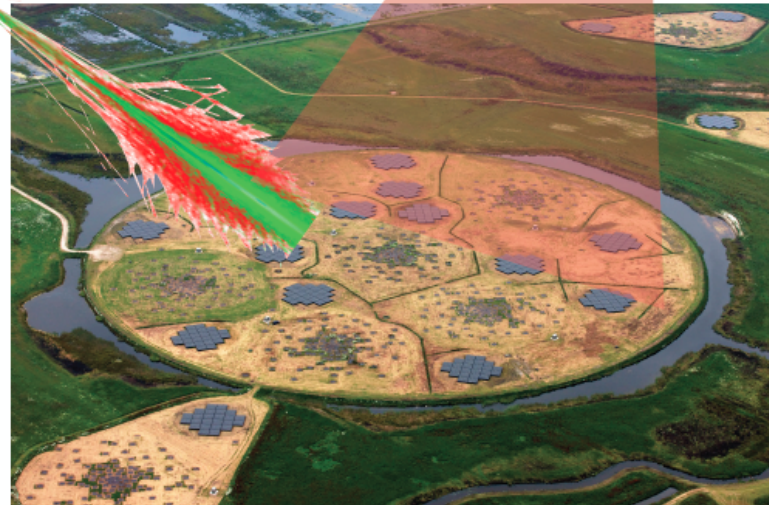
oorsprong ??

massabepaling deeltjes in atmosfeer

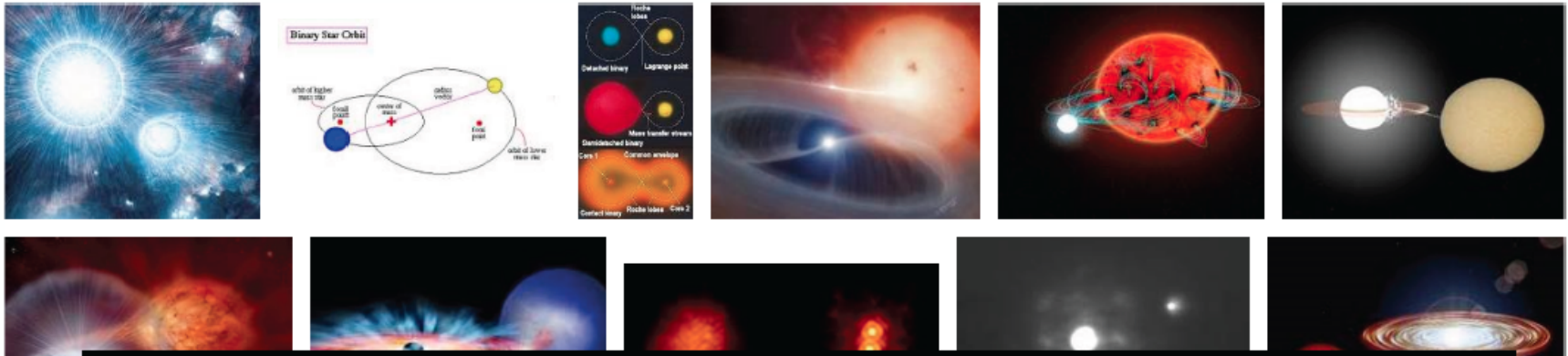
wat zijn de bronnen van de meest
energetische deeltjes in het
universum?



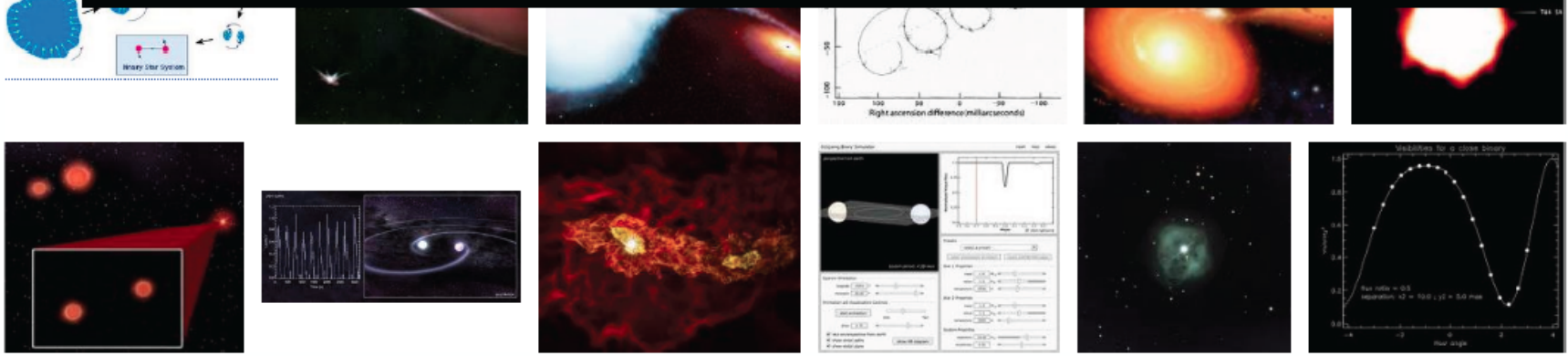
European Research Council



de maan als deeltjesdetector
extreem energetische neutrinos
superzware donkere materie?



⇒ Zwarte gaten en neutronensterren
 ⇒ Hoe evolueren dubbelstersystemen?
 ⇒ Zwaartekrachtgolven
 ⇒ Chemische evolutie heelal





Theoretical physics

- string theory

Prof. B. Craps
Prof. A. Sevrin

Particle physics

- high-energy colliders

Prof. J. D'Hondt

Ending FWO positions:
Prof. R. Roosen
Prof. W. Van Doninck

Active emeriti:
Prof. S. Tavernier

Astro-particle physics

- neutrino telescope

Prof. C. De Clercq

Theoretical physics

- string theory
- **holography**
- **cosmology**

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Part-time:
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Prof. L. Lopez Honorez
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Particle physics experiments

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- **neutrino physics**

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Astro-particle physics

- **cosmic neutrinos**
- dark matter
- multi-messenger observations

Prof. N. van Eijndhoven
(Odysseus 1)

Part-time:
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Active emeriti:
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High-energy astrophysics

- radio transients
- binary evolution

Prof. S. Buitink
(ERC Starting Grant)

Part-time:
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Prof. G. Gentile
Prof. T. Huege

Guest professor:
Prof. D. Vanbeveren

Phenomenology

Prof. A. Mariotti

Part-time:
Prof. K. Mawatari

- ① Strong evolution since 2010 (i.e. strategic choices)
- ② Enhanced connections and enlarged research portfolio

Theoretical physics

- string theory
- **holography**
- **cosmology**

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- **radio transients**
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- ① Temporary faculty members might not be possible
- ② Need to create (unpaid) structural connections now

Important recognitions

- Typically leading research on the national level, involved in one EoS project
- Leading functions in international collaborations with up to thousands of members, both in the coordination of physics research and in the management up to the highest level; example for CMS@CERN with >4400 members (numbers only available for Belgium)

±3% funding from Belgium

5.3% of PhD students
6.6% of physics conveners
8.3% of major conference talks
33% of Best Thesis Awards
1 out of 6 elected Collaboration Board chairs

- Several invited Opening and/or Plenary talks at major conferences
- Members in IUPAP C18 Mathematical Physics, Restricted European Committee for Future Accelerators (RECFA), Intern. Particle Physics Outreach Group (IPPOG), Eur. Physics Society board (EPS), Intern. Cosmic Ray Conferences board (ICRC), CERN Council (vice-president)
- Several national and international awards and prizes (e.g. World Economic Forum, guest professors, Distinguished Researcher Fermilab LPC, etc.)

Theoretical physics

- Interpretation of new Planck satellite data for dark matter models
- Thermalization properties of strongly coupled systems
- Investigating whether anti-de Sitter spacetime is unstable

Particle physics experiments

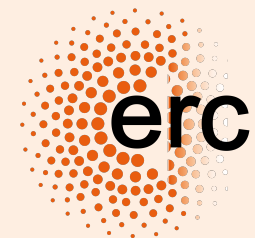
- Discovery of the Higgs particle (CMS)
- Leading contributions in top quark physics measurements and searches (CMS)
- Searches for dark matter and displaced supersymmetry (CMS)
- Commissioning of a real-scale proto-type of the SoLid detector

Astro-particle physics

- Discovery of cosmic high-energy neutrinos (IceCube)
- Most stringent limits on Earth and Solar dark matter (IceCube)
- Most stringent limit on cosmic ray flux from Gamma-Ray Bursts (IceCube)
- Leading investigation for novel radio detection and radar reflection in ice (ARA)

High-energy astrophysics

- Opened a unique radio observation window for the study of cosmic rays (LOFAR)
- Mass composition of cosmic rays (LOFAR)



Phenomenology

41 publications & 16 preprints
2200 citations, h-index 21

- Exploration of the Higgs sector & Higgs characterization
- Supersymmetry phenomenology
- Dark Matter simplified models

- ① Large potential for breakthroughs in the interplay of our research
- ② Enhanced by connecting our research through phenomenology

Future opportunities

Theoretical physics

- Holography (gauge/gravity duality): far-from-equilibrium aspects & role of quantum entanglement in the emerge of spacetime
- String theory: geometric nature of spacetime & its dualities

Particle physics experiments

- Leading actors in displaces signatures from dark sectors
- Interplay top quark and Dark Matter, and top quark and Higgs
- SoLid oscillation analysis & background estimation
- Construction of CMS Tracker Endcap: new 120 m² clean room

Astro-particle physics

- Neutrinos from Gamma Ray Bursts & Active Galactic Nuclei
- Neutrinos related to gravitational waves
- Detection of GZK neutrinos (cosmic ray interactions with the CMB)
- Feasibility IceCube-Gen2 upgrade

High-energy astrophysics

- Signals from particle cascade on lunar surface & atmosphere
- Mass composition of cosmic rays (galactic & extragalactic origin)
- Search for extremely energetic particles from lunar surface (sensitive to physics beyond the SM)

Phenomenology

- **Research on the interplay between the large and the small scales**

- ① Large potential for breakthroughs in the interplay of our research
- ② Enhanced by connecting our research through phenomenology

Phenomenology

Hierarchy
problem

Multi-messenger
observations

Theoretical
physics

Particle physics
experiments

Astro-particle
physics

High-energy
astrophysics

Dark Matter

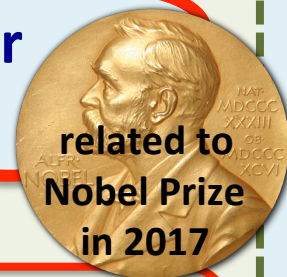
Sterile
neutrinos

*Recently installed
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HEP@VUB BRUSSELS: 1ST CROSSTALK WORKSHOP

THE FATE OF STERILE NEUTRINOS

January 18th, 2017

Vrije Universiteit Brussel, Belgium

Invited speakers:

Joachim Kopp (Mainz University): *Global Fits with Sterile Neutrinos*

Jordi Salvado (Valencia University): *IceCube and sterile neutrino results (pheno)*

Maria Archidiacono (Aachen University): *Cosmological aspects of sterile neutrinos*

Antonin Vacheret (Imperial College London): *Solid and reactor experiments*

Sebastian Boser (Mainz University): *IceCube and sterile neutrino results (exp)*

Denise Hellwig (Aachen University): *Double Chooz and the θ_{13}*

Please register on the Website:

hep.vub.ac.be

Local Organisers:

Alberto Mariotti, Laura Lopez Honorez

HEP@VUB
BRUSSELS

VUB
VRIJE
UNIVERSITEIT
BRUSSEL



The HEP@VUB centre is a Strategic Research Program on High-Energy Physics at the Vrije Universiteit Brussel



- ① **The fate of sterile neutrinos, January 2017**
- ② **The fate of naturalness, June 2017**
- ③ **Flavour anomalies, March 2018**



Valorisation successes

Royal Academy Award 2013
for Science Communication
Jorgen D'Hondt

Long list of
appearances on
television, radio
and newspapers

“90 degrees South”
contest & event



Regular Belgian VIP
visits to CERN

Participation to
Bright Club Bxl

Kwantumrevolutie documentary
(selected for several festivals)



Strong connections
and appearances in
New Scientist



Solvay Public Lectures

VUB annual Prize 2014
for Science Valorisation
(150k Euro)
Jorgen D'Hondt

Long list of
public
lectures



Workshops for kids



Royal Academy Award 2016
for Science Communication
Freya Blekman

Royal Academy Award 2017
for Science Communication
Gwen De Wasseige

Investment to connect

One-day **workshops** with invited international experts focusing on contemporary topics on the interplay between our groups.

Bi-weekly invited **seminars** both topical as well as on the interplay between our groups.

Short term **visitors** that help us making the bridge between groups.

Guido Tonelli (Pisa)
Dieter Lust (Munich)
Francis Halzen (Madison)

Seminars (20)
Crosstalk Workshops (3)
Visitor program (10)
Logistics, Outreach & Coordination
Advisory Board
Allocation per staff member (8)

Professors need to work on **joint projects** to hire a PhD student or postdoc. Salary and bench-fee of PD or student is around 50-55k euro.

Annual Budget (kEuro)
11.25
10
10.5
20
2,5
25.7 (x 8)
260

- ① Unique funding program to explore connections in our research
- ② Flexibility to act and react fast on novel scientific insights

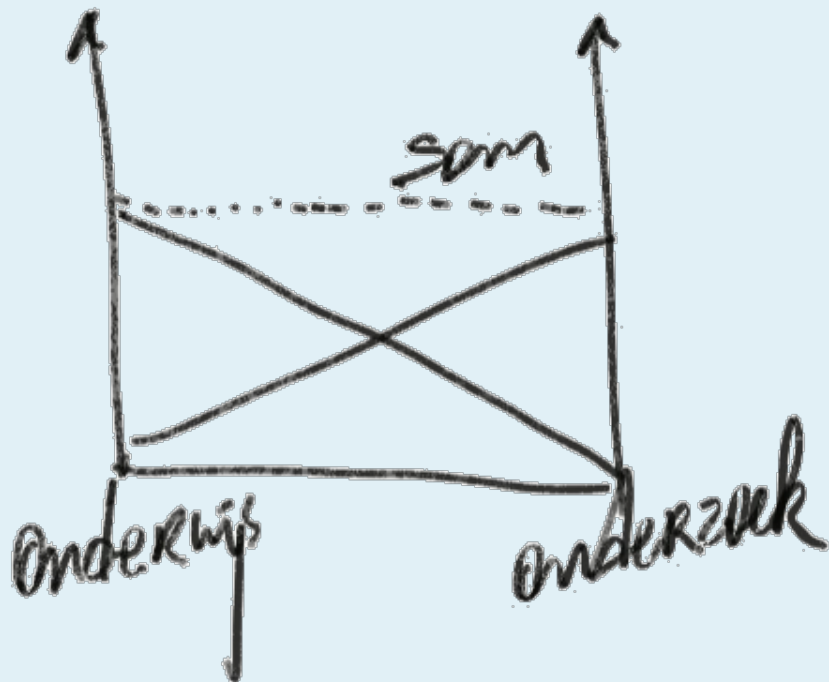
HEP@VUB: *investment to connect*

- ① Very strong international recognition of our groups
- ② Research groups are very successful in funding requests
- ③ Need to explore the interplay of our research towards potential breakthroughs connecting the large and the small scales in our universe
- ④ Successful strategic hiring choices make us unique in Belgium and internationally very competitive to reach these objectives

HEP@VUB: *investment to connect*

- ① **Erkenning binnen VUB:** “... werd geopteerd om prioriteit te geven aan [een ander onderzoeksdomein] dat zo actueel is dat een investering in het thema sterk aanbevolen is voor de VUB.”
- ② **Universiteit met bijzonder weinig technische ondersteuning voor onderzoek...**
- ③ **Universiteit met uitzonderlijk slechte staat van de gebouwen en onderzoeksfaciliteiten...**
- ④ **Streven naar internationalisering, en excellentie behouden, blijft moeilijk binnen de organisatie...**
- ⑤ **Klein departement gevoelig aan allocatiemodel...**

Van een lineair model naar een excellentiemodel



Van een lineair model naar een excellentiemodel

