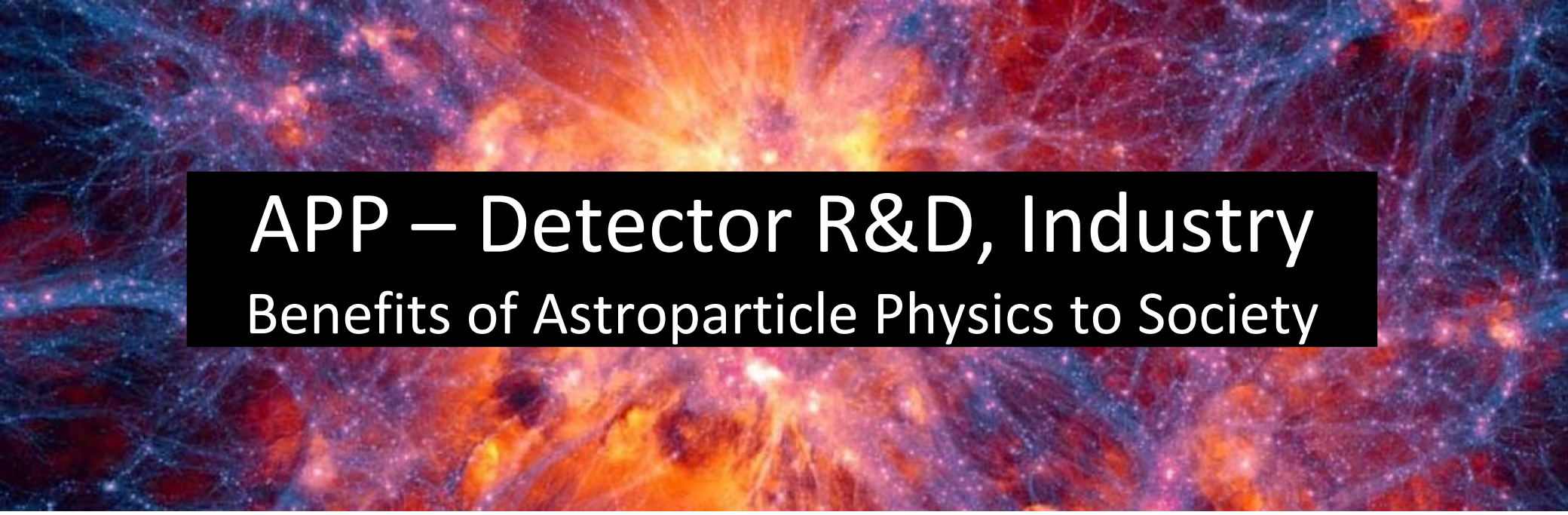


APP – Detector R&D, Industry

Benefits of Astroparticle Physics to Society

Prof.dr. Jo van den Brand

ApPEC Town Meeting, Sorbonne, Paris, 7 April 2016; jo@nikhef.nl

Benefits of Astroparticle Physics to Society

Case Studies

- Tomography with Cosmic Ray Muons
- SENSE coordinates R&D in academia and industry in low light level sensing

APIF: Benefits of ApP to Society

Case Study: gravitational waves

- Philosophy and Sociology
- Innovations, Industry, and Spin-off

ApPEC Considerations

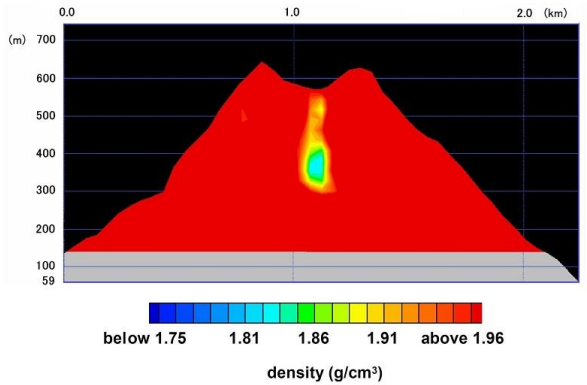
- What is provided now?
- Your input!

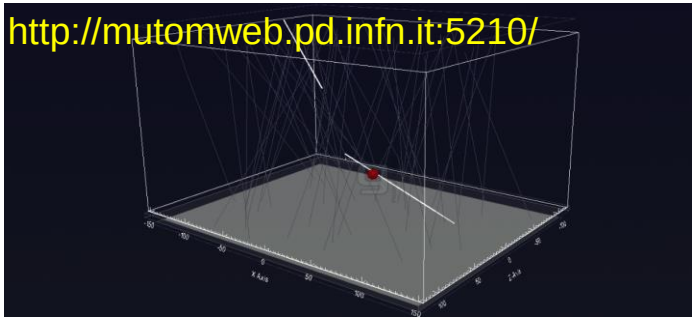
What can ApPEC do for you?

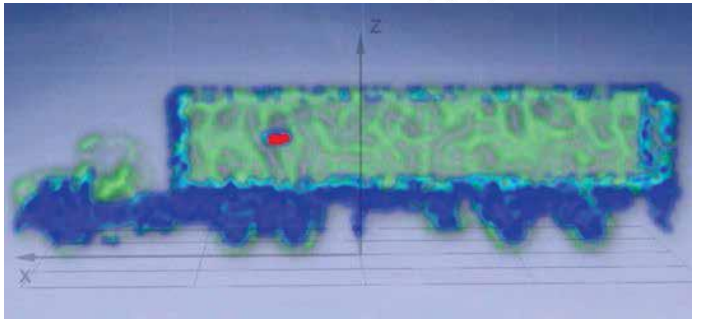
Case study 1: Tomography with Cosmic Ray Muons

Muography: cosmic rays are used to image the inside of an active volcano in Japan
Cosmic rays can also be used to screen trucks for high-Z materials

- What is going on inside an active volcano?
  - Mt. Asama in Japan is monitored by Center for High Energy gEophysics Research (CHEER) of UTokyo
  - Muographic images showing the interior of Mt. Asama
  - Solid red indicates magma that has cooled after extrusion
  - http://www.u-tokyo.ac.jp/en/whyutokyo/wj_001.html
  - Mu-Ray project to image Mount Vesuvius
- Mapping glaciers
  - http://www.naturalsciences.ch/service/news/57678-eiger-muon-glacier-tomography
- Industrial applications
  - Tata Steel: imaging of furnaces
- National Security
  - Identification of high-Z material
  - Screening trucks for nuclear material at Cosmic Muon Tomography CMT by INFN
- Neutrinos
  - Image Earth's core

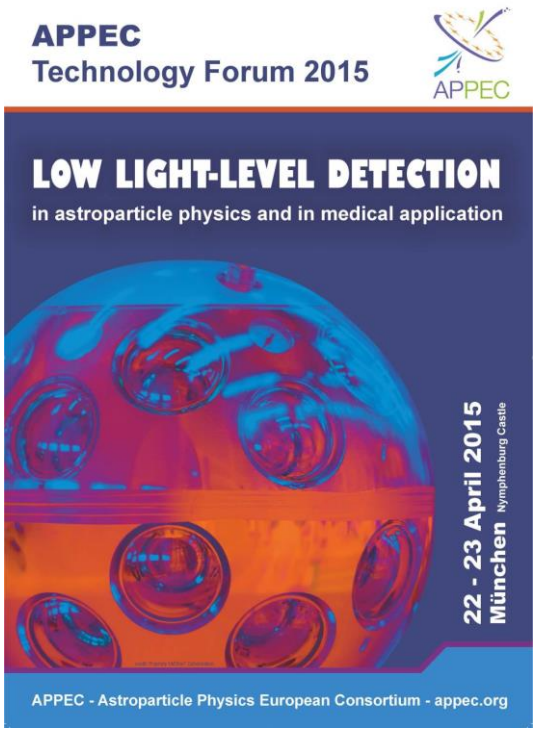






Case study 2: SENSE

SENSE will be funded under H2020-FETOPEN-2015-CSA. It builds on the ApPEC Technology FORUM April 2015 on "*Low light-level detection in APP and in medical application*"

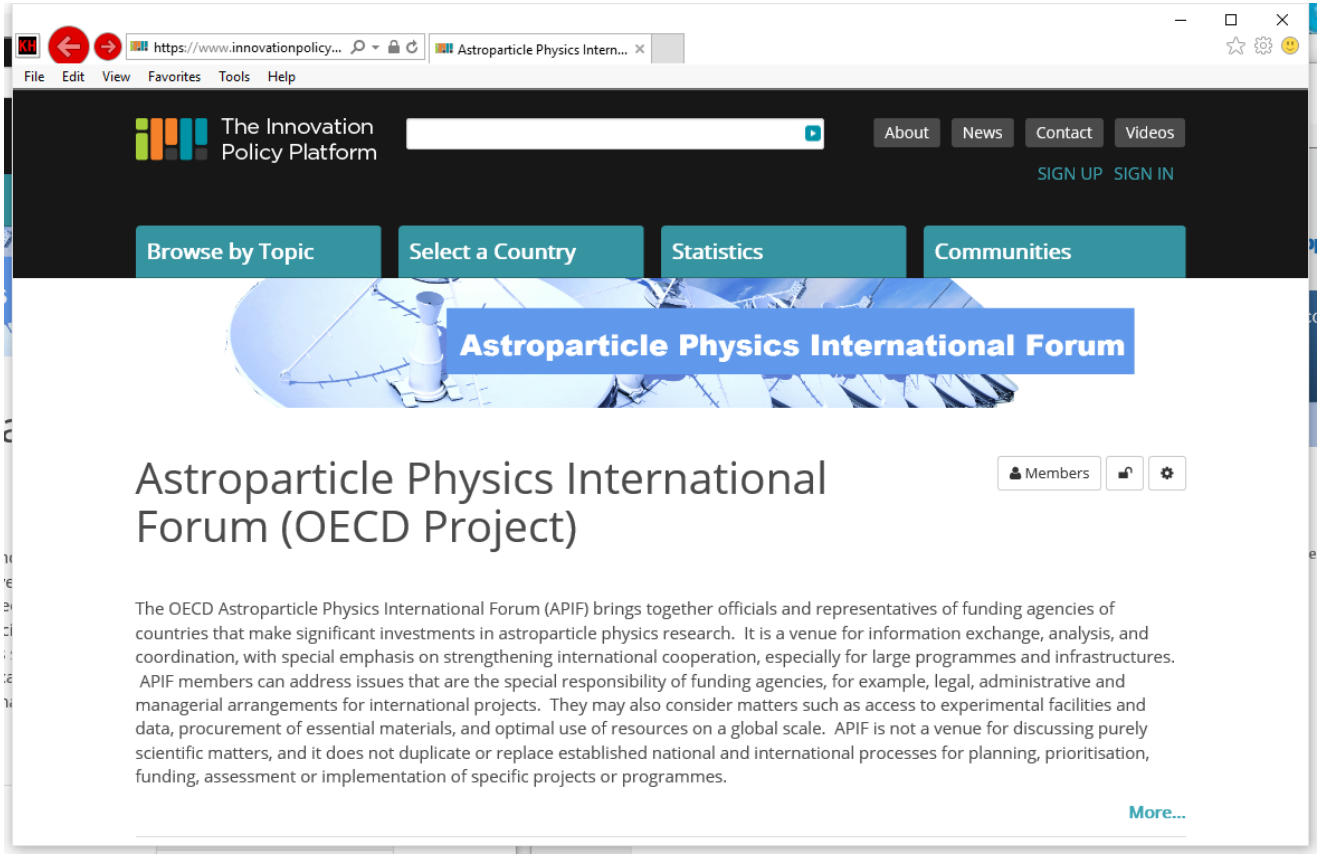


- The project's objectives are to coordinate the research and development efforts in academia and industry in low light-level detection
  - Kick-off September 2016
- This initiative has emerged from the series of Technology Forums organized within the frame of ASPERA and APPEC
  - About 80 participants from collaborations, industry, and funding agencies
  - ALPS, PAO, CTA, DARWIN, GERDA, IceCube, Jem-Euso, KM3NeT, MAGIC, Xenon
  - Bte Bedampfungstechnik, Entropy, ET EET, FBK, Hamamatsu LC, Ketek, MELZ, SensL
- Three APPEC related partners
  - University of Geneva ➔ Teresa Montaruli, Domenico della Volpe
  - MPI for Physics in Munich ➔ Razmik Mirzoyan
  - DESY (coordinator) ➔ Thomas Berghöfer, Katharina Henjes-Kunst
- SENSE
  - Invite R&D experts to prepare an R&D roadmap for ultimate low light level sensors
  - Coordinate, monitor, and evaluate R&D efforts of groups/industry advancing low light level sensors
  - Liaise with strategically important EU initiatives and research groups and companies worldwide
  - Foster cooperation and knowledge transfer, where SENSE will build up an internet-based Technology Exchange Platform
  - Training events and material shall be prepared to especially engage young researchers
- More information➔ sensepro@desy.de

APIF

Benefits of Astroparticle Physics to Society
Credit: Jim Whitmore, NSF (Rome, November 15, 2015)

- Partnerships with industry
- Studies of terrestrial environments
- Studies of atmospheric and solar environments
- Studies of interstellar space environments
- Security
  - National, reactor, non-proliferation…
- Bio-medical applications
- Societal enhancements
- Work-force training



Benefits of ApP to Society

J. Whitmore, NSF, APIF Meeting Rome/LNGS

	I	II	III	IV	V	VI	VII	VIII
	Industry	Terrestrial	Atmospheric	Space	Security	Medical	Society	Work Force
Underground Labs								
LSM		☺				☺	☺	
LNGS		☺					☺	
Dark Matter								
SABRE	☺							
DarkSide	☺				☺	☺		
DRIFT					☺	☺		
XENON		☺					☺	
ADMX-HF							☺	
CDMS							☺	☺
ARDM					☺			
Cosmic Rays								
PAO	☺	☺	☺					
TA			☺					
AMS-02			☺	☺				
ARGO-YBJ			☺					
Gamma Rays								
VERITAS	☺					☺		
H.E.S.S.			☺					
Tibet AS-Gamma								
				☺				

Benefits of ApP to Society

J. Whitmore, NSF, APIF Meeting Rome/LNGS

	I	II	III	IV	V	VI	VII	VIII
	Industry	Terrestrial	Atmospheric	Space	Security	Medical	Society	Work Force
Neutrinoless Double Beta Decay								
CUORE	☺				☺		☺	☺
MAJORANA	☺				☺			
NEMO		☺					☺	
EXO-200					☺	☺		
Accelerator								
IsoDAR/ DAEDALUS	☺					☺		
Neutrinos								
IceCube		☺	☺	☺				☺
Daya Bay					☺			
Borexino		☺	☺		☺	☺	☺	
KAMLAND		☺						
Other								
CLOUD			☺					
SKY			☺					
RUAG				☺				
SAGe	☺							

Case study 3: How does GW research address this challenge?

Gravitational wave research was not included in the above study, and since I work on this, a few slides will be shown. Scientific merit will be discussed by Patrick Sutton

Gravitational waves: a discovery by physicists and what's next

Gravitational waves: a tool for astronomy, cosmology

Spacetime: aspects from philosophy

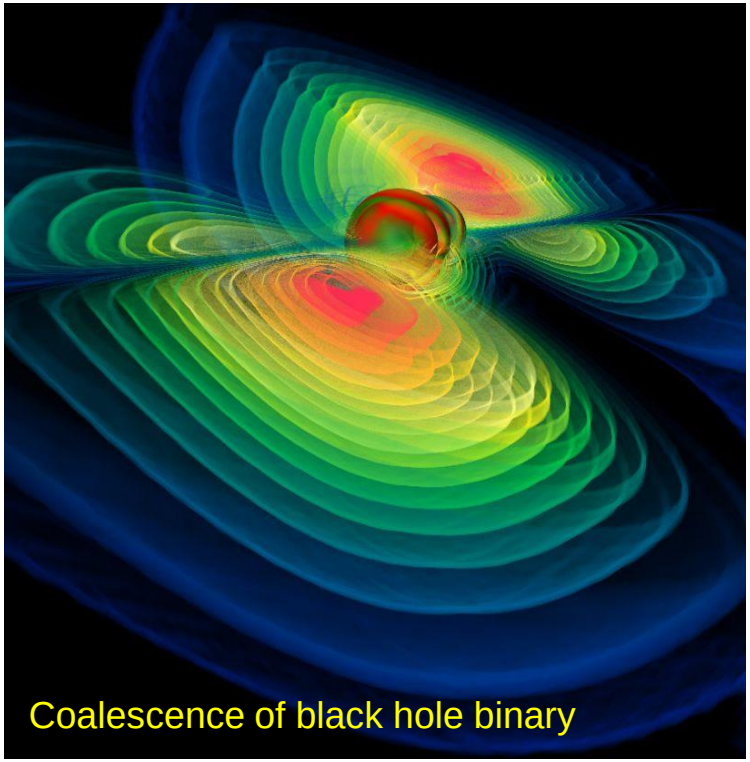
The quest for gravitational waves: a case study for sociology

Mathematics: symmetry and geometry

Central topics: new particles (DM), GWs, BHs, quantum-gravity theory

International experimental infrastructures

Proven impact on technological innovation and spin-offs

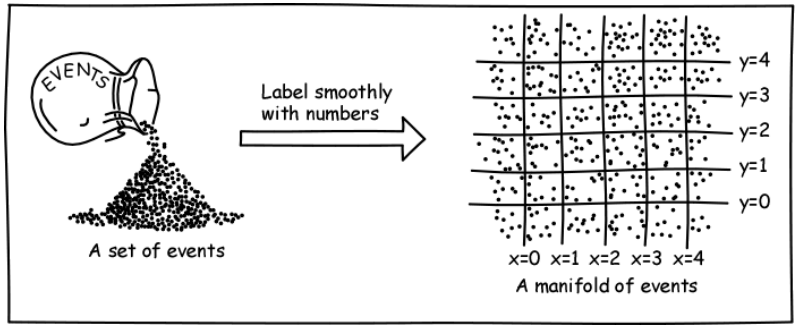


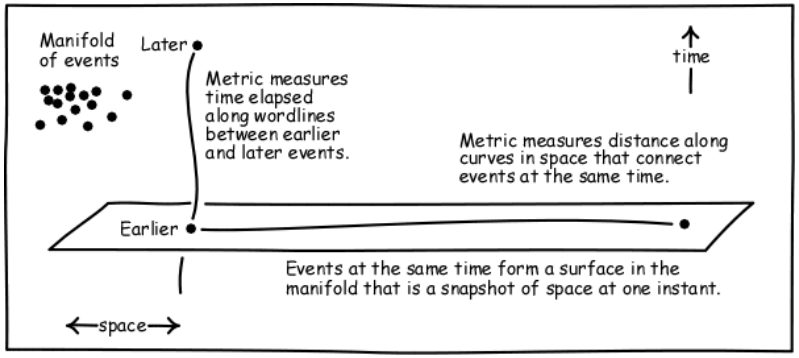
(Mathematical) Philosophy

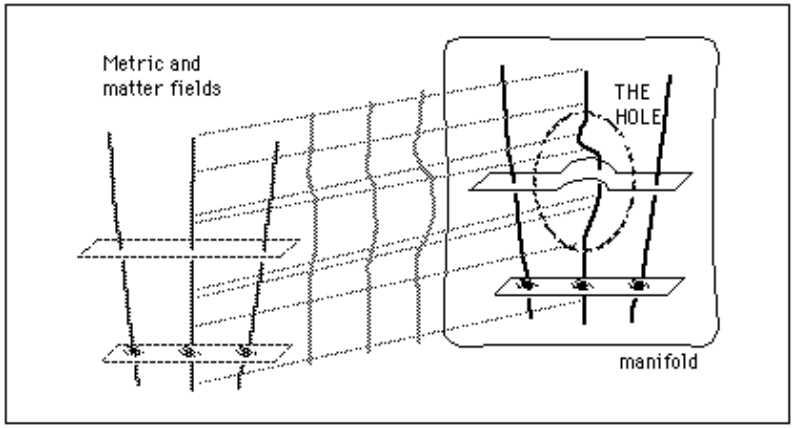
Pure philosophical questions related to the origin of space and time exist for centuries.

Questions

- What is space? What is time?
- Spacetime and (growing) block universe, eternalism
- Do they exist independently of the things and processes in them? Or is their existence parasitic on these things and processes?
  - Spacetime substantivalism: “The hole argument”
  - http://plato.stanford.edu/entries/spacetime-holearg/
  - No successful theory of quantum gravity can be set against an independent, container spacetime
  - (Weak) Leibniz equivalence: GR is a "diffeomorphism invariant" theory: if the universe is represented by a manifold M with metric $g_{\mu\nu}$ and matter fields ψ , and $\phi{:}M\rightarrow M$ is a diffeomorphism, then the sets $(M, g_{\mu\nu}, \psi)$ and $(M, \phi{*}g_{\mu\nu}, \phi{*}\psi)$ represent the same physical situation





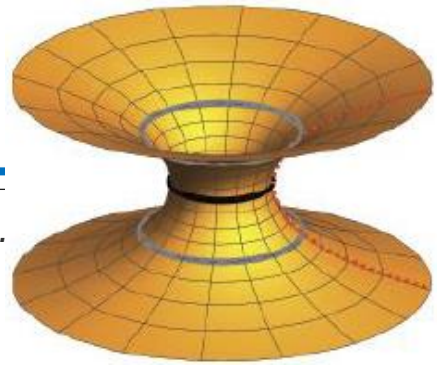


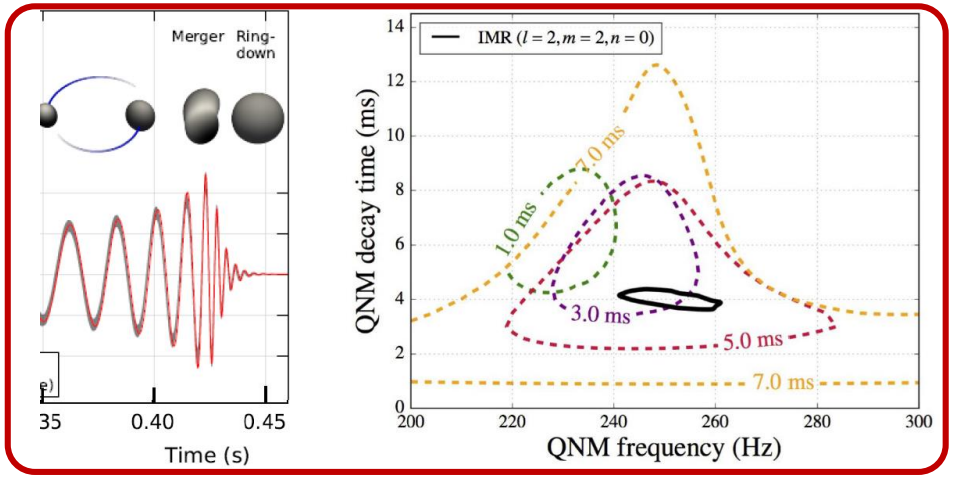
(Mathematical) Philosophy

Pure philosophical questions related to the origin of space and time exist for centuries. Now the anwers to such questions maybe within reach of the physical sciences

Questions

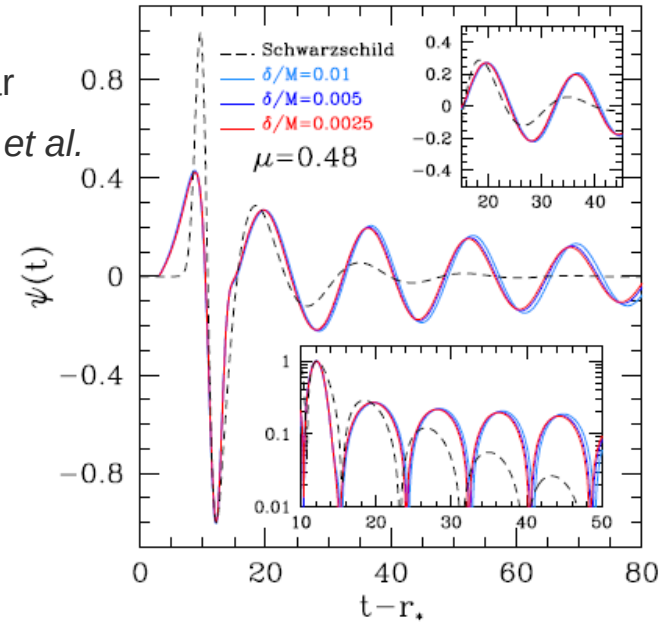
- Is spacetime emergent?
  - Black hole information paradox
  - AMPS firewall paradox and EP = EPR
- What can GWs say about this?
  - Black hole: QM meets GR
  - Unknown UNKNOWN





Gravastar

Rezzolla *et al.*



Sociology of gravitational wave physics

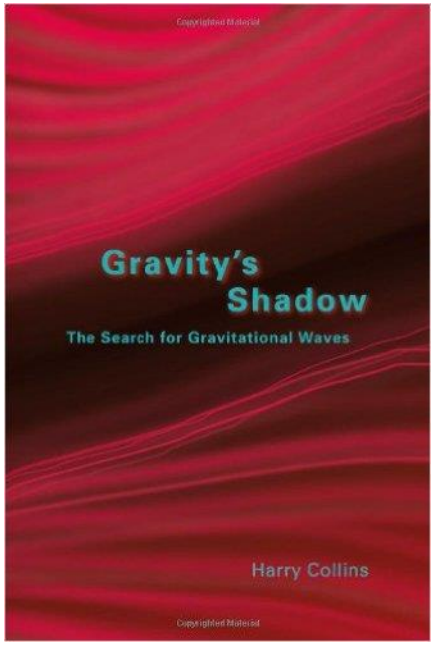
Harry Collins (University of Bath) has followed the GW field since 1972

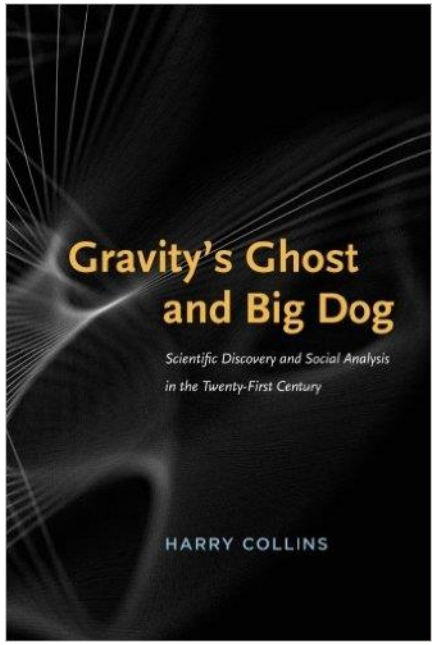
Books

- Harry Collins published 2 books
  - *"Gravity's Shadow the Search for Gravitational Waves" (2004)* Chicago: University of Chicago Press. ISBN 9780226113784
  - *"Gravity's Ghost: Scientific Discovery in the Twenty-First Century"* Chicago: The University of Chicago Press. ISBN 9780226113562
- Central topics
  - Definitive account of the controversy surrounding Weber's claims
  - Provide insight in the way big science projects evolve
- Essential (as opposed to derivate) values of science
  - Integrity in the search for evidence and honesty in declaring results
  - Willingness to listen to anyone's theories
  - Readiness to expose one's findings to criticism and debate
  - Specify the means by with theories can be shown to be wrong
- Social engineering
  - Hardware injections: Equinox event and Big Dog event

Outreach

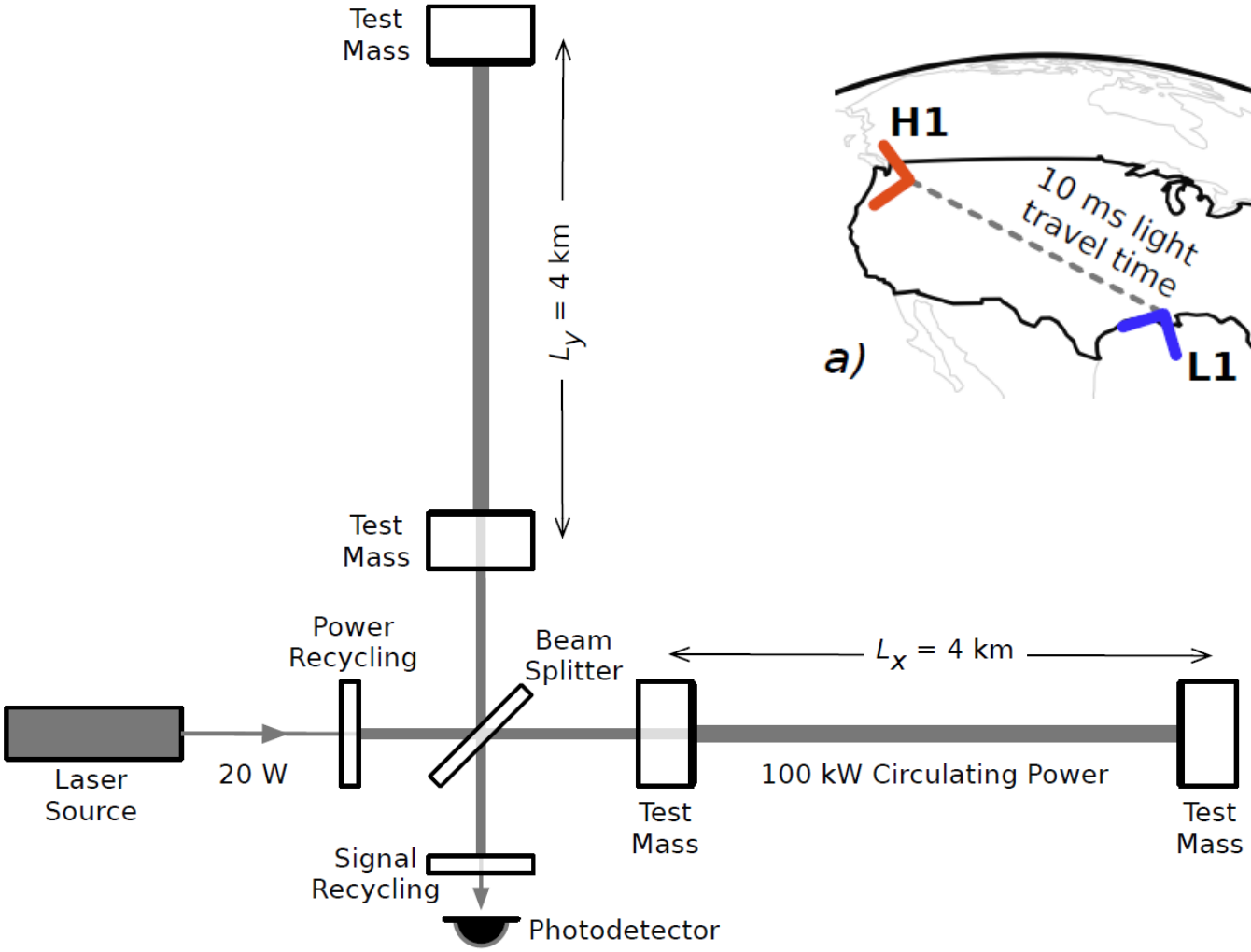
- Einstein@home
  - World Year of Physics 2005 and an International Year of Astronomy 2009 project. It is supported by APS, NSF, and MPG





The Advanced detectors

Only the LIGO detectors of the LIGO Virgo Consortium were operational last year. GEO is sensitive at higher frequencies, while Virgo will join the network this year. KAGRA is expected to join later. During the detection the mirrors moved by about 10^{-18} m

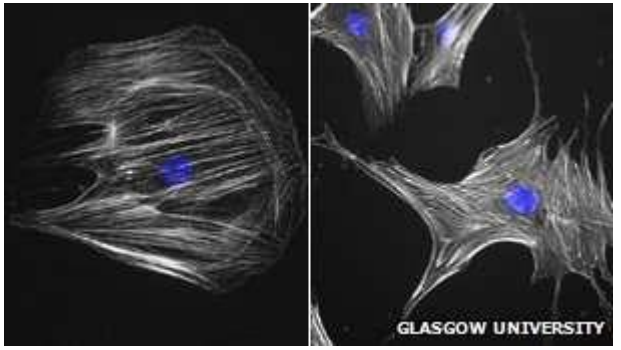


Examples of spin-off from gravitational wave research

Prof Stuart Reid (Univ of West of Scotland)

- Working with cell biologists on adapting sensing techniques from GW technology to control stem cell differentiation for bone healing - spin-off company in progress.

See: http://www.bbc.com/news/uk-scotland-glasgow-west-22035696



Stem cell control: After the stem cells are "nanokicked" they turn into bone cells

Dr Siong Heng (Univ of Glasgow)

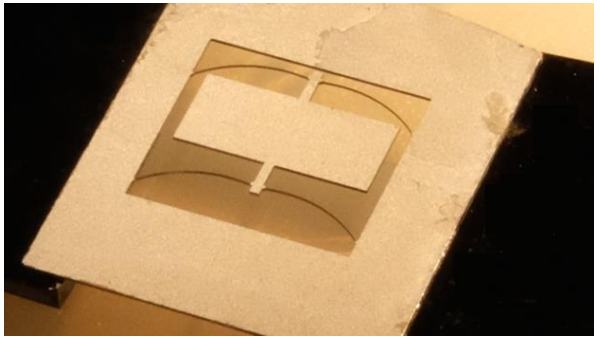
- Working with OPTOS Ltd developing algorithms for automated artefact detection for scanning laser ophthalmoscopes - potential to make significant savings by adopting new automated Quality Assurance processes during the manufacturing process.

See: http://censis.org.uk/censis_projects/optos2_gu/

Dr Giles Hammond, (Univ of Glasgow)

- Working with several industrial partners on utilising spin-offs from core GW technology research to build low frequency ultra-sensitive MEMS gravimeters with applications in the energy, security and geophysics fields. Patent filed (GB Parent Application No: 1415087.4).

See: http://www.bbc.com/news/science-environment-35926147



MEMS gravimetry: Carved from a sheet of silicon, the sensor contains a weight (the central slab) suspended by thin, curved shafts

Dr Stefan Hild (Univ of Glasgow)

- Working with Historic Scotland in the use of laser interferometry to enable accurate assessment of the climate-change driven decay of historic buildings and monuments

Prof Jim Hough, Prof Sheila Rowan and colleagues (Univ of Glasgow)

- Development of Oxide-bonding (patent granted for bonding silicon carbide) (US2007/0221326 A1), working with Gooch and Housego (UK) on extending this technique for jointing of compound optical systems for use at high laser powers

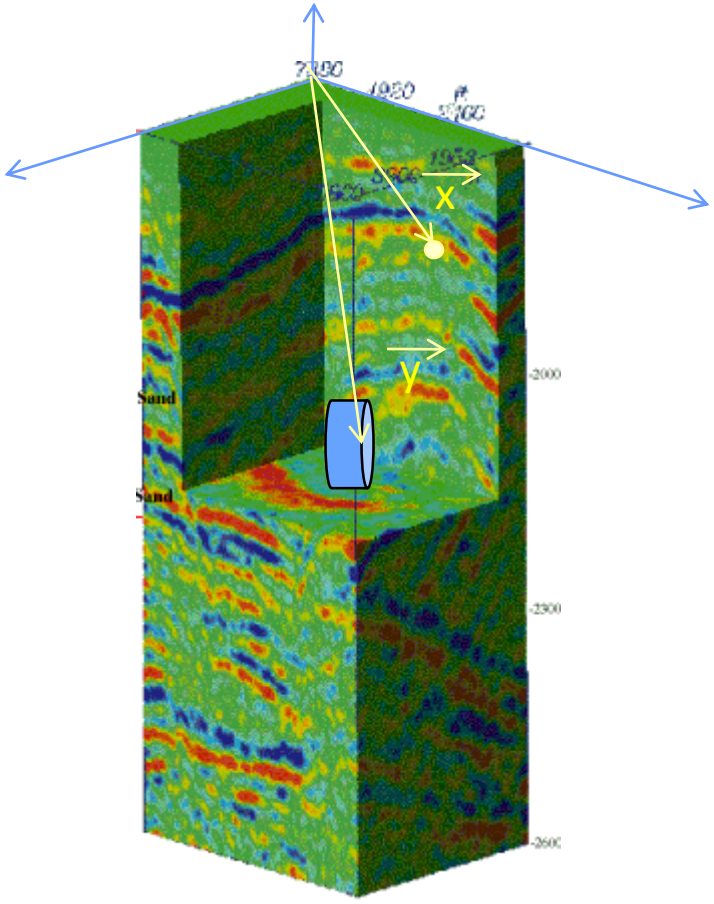
Technological innovation in opto/mechanics, and sensors

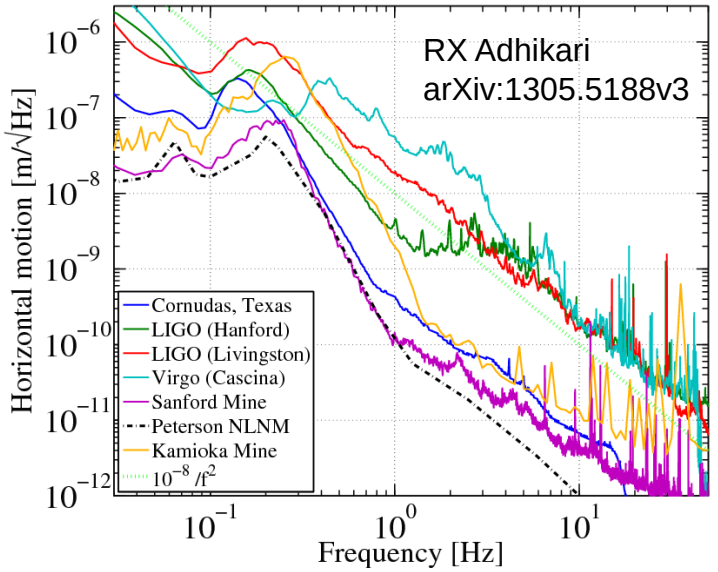
Developments in large optical components, coatings, interferometer controls, and vibration isolation. Here we discuss an example on sensor development and from spin-off activities at Nikhef

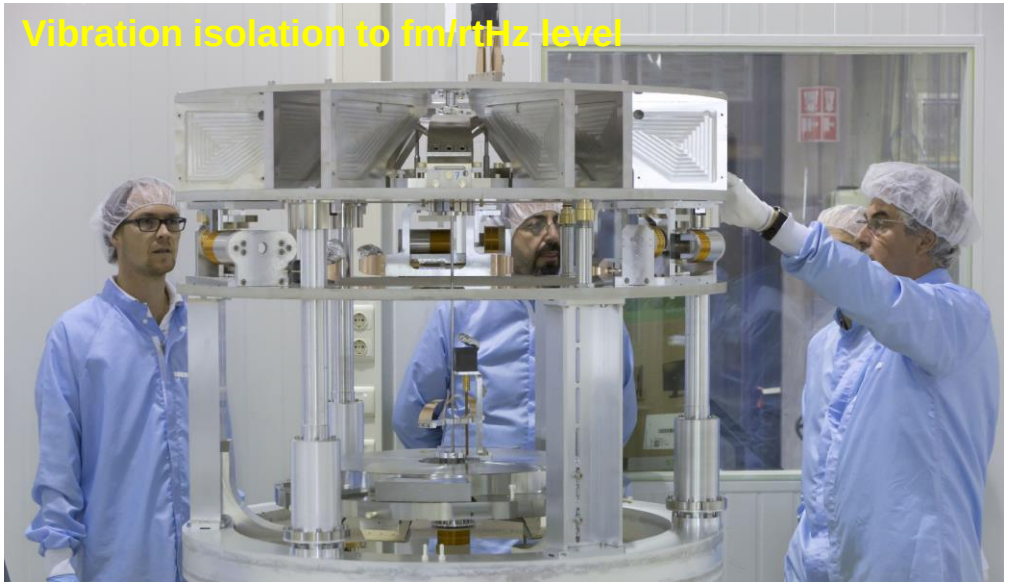
Issues

Seismic ground motion is about 10^{12} times higher than the GW effects. Thus vibration isolation systems are needed

Moreover gravity gradient noise can only be subtracted by sensor networks. This triggered sensor development



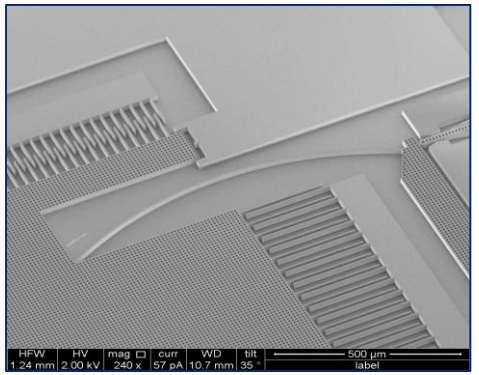




(Wireless) sensor development

In collaboration with industry sensors are developed for both gravity gradient noise suppression, and for oil & gas exploration. This involves MEMS and ASIC development within NL Topsector HTSM

PPS activity Shell, Nikhef, Innoseis



- Results of first field trial under evaluation
  - Earthquake monitoring, exploration
- Collaboration with geologists
  - KNMI in the Netherlands
  - Matra mountains, Wigner, Hungary
  - Istituto Nazionale di Geofisica e Vulcanologia (INGV)
  - Field trials in stringent environmental conditions (arctic / desert)
  - Larger-scale field trials
  - Design of seismic study of Virgo site

Added value for both industry and GW research

Sensors with high sensitivity allow subtraction of gravity gradient noise. This allows black holes to be observed over longer time, while Shell can target hydrocarbons in more challenging geology

Shell Nikhef INNOSEIS

Networks must be scalable up to 1 million nodes

Considerations

Considerations have been formulated and are up for discussions. The ApPEC Roadmap will have a set of recommendations

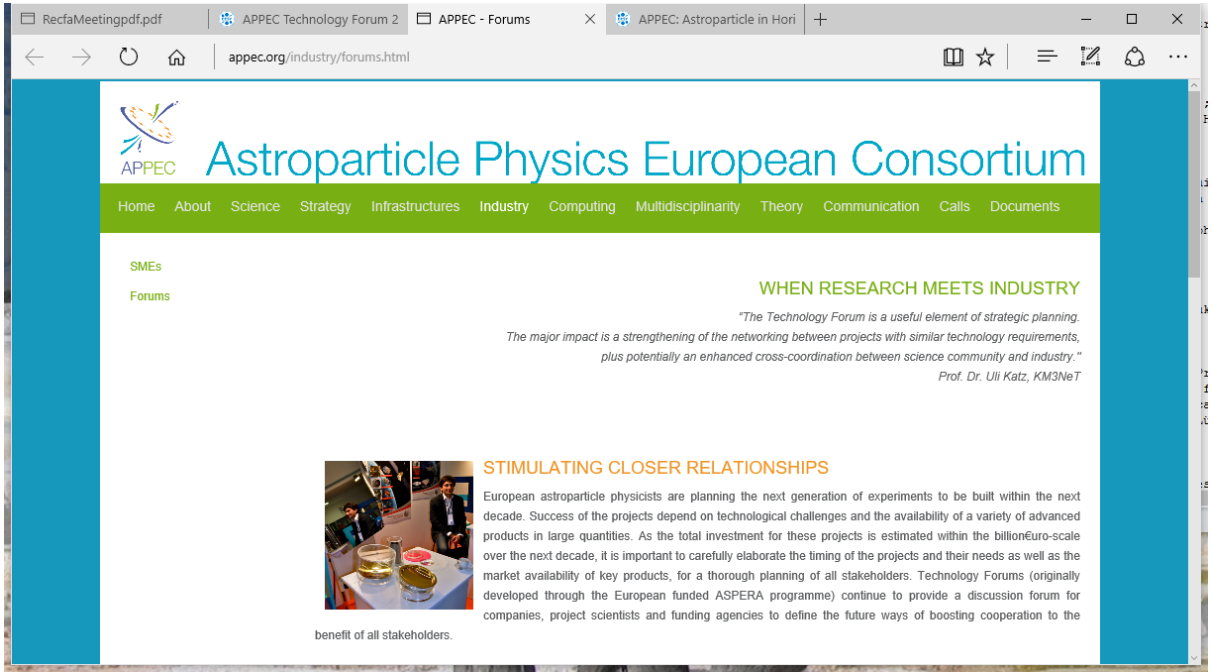
- ***R&D and Industry Consideration 1.*** *APPEC should encourage the use of astroparticle physics technology and concepts for direct societal benefit*

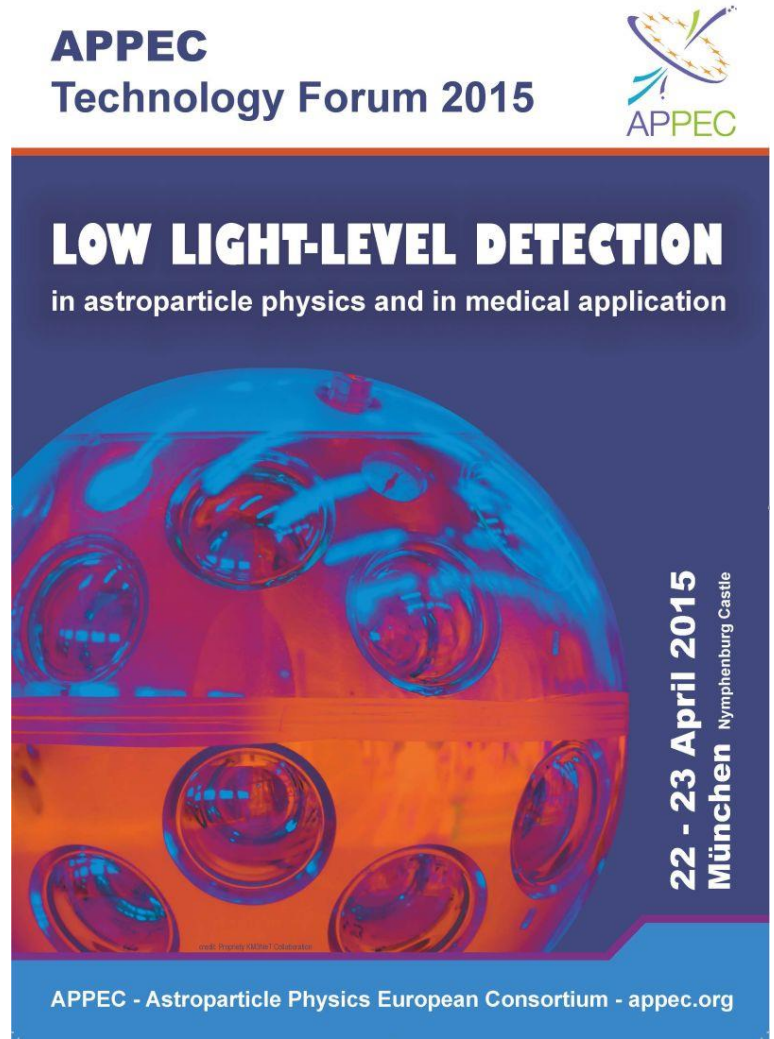
- How is ApPEC implementing this?

ApPEC Technology Forum 2015

The Astroparticle Physics European Consortium APPEC invites technology experts from industry, project scientists and funding agencies representatives for the APPEC Technology Forum

- 4rd ASPERA Technology Forum 2015, "Low light-level detection in astroparticle physics and in medical application“
- 3rd ASPERA Technology Forum 2012, "Vacuum and Cryogenics in Astroparticle Physics Infrastructures; Academia meets industry“
- 2nd ASPERA Technology Forum 2011, "Mirrors and Lasers in Astrpoparticle physics infrastructures“
- 1st ASPERA Technology Forum 2010, "Photosensors and auxiliary electronics"





ApPEC and Horizon 2020

APPEC organizes a community event to inform about the upcoming possibilities in Horizon 2020 for Research and Innovation

- Presentations by experts on the various funding instruments, advice on competitive proposal writing
- In dedicated sessions astroparticle physicists will have the chance to discuss ideas for collaborative projects and coordinate proposals for future calls
- Coordination of R&D projects of academic partners in collaboration with SME as well as the support of research institutions interested in teaming and twinning actions within the Spreading Excellence and Widening Participation programme

ApPEC Knowledge Translation and Transfer

What should APPEC do to encourage the use of astroparticle physics technology and concepts for direct societal benefit?

- Continue to focus on fundamental research, but always keeping an eye open for possible applications
  - ASPERA's R&D initiatives
- Improve the education of our scientists on the possibility of extracting value from fundamental research
  - Organization of KTT courses and workshops
- Stimulate networking with industry
  - Increase the opportunities for networking of our researchers with industry (continue Technology Forums)
- Help researchers, technology transfer staff, and research users
  - Act as knowledge broker who understands both "worlds"; communicate with stakeholders
- Lay down a clear Intellectual Property policy that is generous with the scientists and encourages KTT

The ATTRACT Initiative

From open science to open innovation. See www.attract-eu.org
Getting Europe back to work – with science. TWD Barcelona: https://indico.cern.ch/event/470460/

- Europe's scientific leaders, e.g. ESO, ESRF, EMBL, and CERN, join forces to create new products, companies and jobs, by taking detector and imaging technologies, and with PPS partners convert them to commercial use

Considerations

Considerations have been formulated and are up for discussions. The ApPEC Roadmap will have a set of recommendations

- ***R&D and Industry Consideration 1.*** *APPEC should encourage the use of astroparticle physics technology and concepts for direct societal benefit*

More than 1 consideration!

- DM Consideration 4. Europe should support R&D and technology to build a directional detector.Neutrino Consideration 4.
- Europe should support a strong R&D and prototyping program in the CERN North Area, related to the above program (considerations 1 to 3).
- HUE consideration 6. R&D for the next generation of ultra-high energy cosmic rays should be supported
- CMB Consideration 4. Technology wise, Europe should support R&D and TRL (TechnologyReadiness Level) upgrade of new detection technologies using cryogenic Transition Edge Sensors (TES) and Kinetic Inductance Detectors (KIDs).
- R&D and Industry Consideration 1. APPEC should encourage the use of astroparticle physics technology and concepts for direct societal benefit.

Eg. APPEC Common Calls?

APPEC Roadmap and R&D

- What to do to foster innovation in APP?
  - What is peculiar of APP of this? development of detectors in ‘house’ in the style of PP (compared to astronomers) requires engineers/technicians. **Funding agencies/Universities/Labs** should create more **long-term technical permanent positions**.
  - **Incentivate calls to finance people ideas** and introduce programs dedicated to **PhD/postdocs in connection with industry & education exchange programs**
  - Avoid approval of projects which do not imply any technological advance but are only based on ‘solid technology’…
- What to do to help in the innovation -> product process?
  - Add/reinforce in the organigram of research and funding Institutes **technology transfer offices and facilitate relation to industry**
  - Remove ‘country boundaries’ for at least a part of national programs with SME
  - Forums where politicians meet industry & academia to create proper organizations to foster innovation
  - Create roadmaps to facilitate formation of Consortium agreements and IPR (difficulty academia leaning towards open access, industry leaning towards profit?