AstroParticle Physics European Consortium (APPEC) Roadmap 2017 - 2026

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http://www.appec.org
Input #84 to the Update EU Strategy
The APPEC Consortium

• APPEC Consortium defined in the EU funded ERANET ASPERA (2006-2012): informal MoU of funding agencies/organisations.

• APPEC current scheme:
  
  • **The General Assembly**: strategic, decision making and supervisory body

  • Chair: TM (UniGeneva), Deputy Chair C. Stegmann (DESY), General Secretary: Job De Kleuver (NWO)

  • **The Scientific Advisory Committee**
    Chair: L. Baudis (UniZurich) vice-Chair: J. Monroe (UniLondon)

  • **The Joint Secretariat** running the functional centres.

  [https://www.appec.org](https://www.appec.org)
The APPEC Consortium science and tasks

**Science focus:** multi-messenger astrophysics and gravitational waves, neutrino nature and properties and the cosmological exploration (dark matter and dark energy)

**Coordination** of European Astroparticle Physics in Europe through:

- Development and update of roadmaps based on scientific strategies and financial considerations
- Mandates to experts panels on specific challenges (e.g. dark matter, neutrinoless double beta decay, CMB)
- Regular TownMeetings to collect the community ideas (last Apr. 2016/ next 2020 TBD)
- **APPEC Technical Fora** and Regular Seminars with other communities (e.g. APPEC-ECFA-NuPECC, GeO-8 & Academia Europaea)
- Express collective views on APP in international fora
- Accompany (scientific and organisational advice) communities in the process towards establishment of Research Infrastructures and facilities (ESFRI roadmap, EC funding, national and regional funds…)
- Common Outreach, Diversity, Education

These are ambitious objectives, not commensurate to current resources (~2 FTE, in kind contributions and 70k budget). A central office model is discussed in the General Assembly for a stronger and sustainable APPEC.
Astroparticle Roadmaps

2008 & 2011 Thanks S. Katsanevas & C. Spiering!

2017 Thanks F. Linde, A. Masiero!
APPEC 2017-2026 Roadmap

• 21 recommendations
• APPEC EPPSU input # 84:
  i) the dark matter searches;
  ii) the multi-messenger astronomy, in particular the 3G GW experiments (ET);
  iii) the neutrino physics;
  iv) the creation of a European Center for AstroParticle Theory (EuCAPT)
• Many EPPSU Inputs on ApP from national labs & organisations (INFN, Nikhef, KAT, SFP, JINR & RA,...)

- A resource aware roadmap (darker colors mark M&O of RI)
- Awareness on long-term operation of large RI
Input to the EPPSU on Dark Matter (DM) Searches

- **EPPSU Input**: *PP Cooperation with respect to DM searches, including R&D and enabling technologies* leading toward a global program on DM searches, similar in breadth to the neutrino physics program.

- The objective of DD experiments is to reach the neutrino floor beyond which new strategies/R&D need to be prepared as well to address other DM candidates than WIMPs.

- Many technology challenges shared with **CERN neutrino platform**: liquid noble gas in cryogenic environment, photosensors (SiPM/PMTs/CCDs,…). E.g. CERN-DarkSide close cooperation led to redefinition of veto from liquid scintillator into membrane cryostat technology developed for the ProtoDUNE / DUNE.

PPG: M Carena & S. Asai session. DD by : J. Monroe (APPEC SAC vice-CHair) and ID by C. Weniger
Input to the EPPSU on Dark Matter (DM) Searches

- Joint work of DD/ID/colliders is required to understand the nature of DM and its location in the cosmos.
- Increase presence of DD/ID scientists in Physics Beyond Colliders / LHC DM WG for cooperation on data analysis methods and comparison of data strategies.
- DM searches require a strong theoretical support which APPEC supports through EuCAPT.
- DM searches expanded further since last EPPSU to include non-WIMP DM, also observable with multi-messenger and gravitational waves. Support to smaller programs than LHC (like done for AMS, IAXO, CAST...) will secure physics results.
Input on Multi-Messenger

From the past EPPSU to this one, multi-messengers is **WORKING**!

Four recommendations in the APPEC roadmap on the High-energy Universe and as input to the strategy process, with focus on the GW future.
Multi-Messenger challenges

- Build CTA (ESFRI landmark), KM3NeT (ESFRI project), Lake Baikal GVD
- Upgrade of IceCube and Pierre Auger Observatory
- Operation for up to 30 years during ramp up of new GW facility

Pierre Auger 3000 km²
extensive air shower array

Cosmic ray strategy (A. Haungs’ talk) and hadronic interaction synergy
with CERN (P. Tanguy’s, F. Sanchez’ talk)

#117 PAO
#14 NEVOD
Gravitational wave searches

Input to the EPPSU: The development of the synergies between the Particle Physics community and the next generation of observatories of Multi-messenger Physics and in particular the third-generation gravitational-wave observatory Einstein Telescope (ET), on science, infrastructure, detector R&D, computing and governance.
GW address exciting science: tests of gravity in regions of greatest space-time curvature, graviton mass constraints, Hubble constant, black holes existence, their horizon and their connection to dark matter, matter in extreme environment, origin of heavy elements, equation of state of ultra-dense matter elements, exotic objects.
ET Science and Roadmap

- 2022-23: site selection & TDR = ET approval
- 2025: infrastructure realization start
- 2030-31: end of civil infrastructure construction
- 2032+: commissioning and operation

An accelerator beam pipe without a beam (quote from C. Stegmann)
Towards 3G GW detectors

The definition of a fruitful and bidirectional cooperation with CERN is of primary importance for ET. **Governance:** APPEC is considering how to support the development of ET governance, e.g. a WG with CERN involvement with GWIC and GWAC representatives, in view of the ESFRI proposal submission aimed at on Apr. 2020. GWAC is an informal exchange forum of Agencies representatives to develop higher level coordination.

**Technical challenges shared** with CERN community:
- long term operation of **underground facilities**; **low noise** ventilation for radioactivity elimination, **safety** (descenderies, deep shafts, policies, monitoring), definition of criteria for **site** choice;
- **Vacuum** technologies applied to large volumes
- **Cryogenic** technology also shared by **DM and ββν**
- Lasers, mirrors, coatings (1 suitable facility only), electronics, data acquisition, monitoring
- computing/software/**DATA** policies,
Neutrino nature and mass in APPEC Roadmap

Input to EPPSU: The vigorous continuation and full development of the CERN neutrino platform as well as an active role of particle physicists and engineers for global collaboration on neutrino projects aiming at clarifying the crucial puzzle of the origin, nature and features of neutrino masses and mixings and the possible existence of sterile neutrino states.

See Parallel session organized by S. Bentvelsen & M. Zito
18 Inputs: 1, 19, 30, 45, 57, 70, 76, 84, 98, 106, 119, 124, 126, 131, 137 ; 154,158,167

APPEC 0νββ panel chaired by S. Pascoli will submit a document to SAC in Jun 2018.
Accelerator/Astro-Atmospheric/Reactor neutrinos

Updated to 2018

NO favored over IO at $\sim 2\sigma$ level

NO favored over IO at $\sim 3\sigma$ level. $\theta_{23}$ octant undetermined at $1.5\sigma$, CPV favored with $\sin\delta<0$

Considerable funds secured for Orca & ARCA

Approval of HK program expected

JUNO data taking

IceCube Upgrade and PINGU starts

Dune/Hyper-K Completion 2026

Input on Protvino beam and on ESS nu beam.
Nutau appearance and Exploring extreme energies

Diversity (channels, baselines, energies, sources,...) is important! (E. Lisi)

\[
\begin{align*}
\left( \frac{L}{E} \right)_{\text{atmo}} &\approx \left( \frac{2 R_\odot}{1 \text{ GeV}} \right) \approx 10^9 \text{ cm} / \text{GeV} \\
\left( \frac{L}{E} \right)_{\odot} &\approx \left( \frac{1 \text{ AU}}{1 \text{ MeV}} \right) \approx 10^{16} \text{ cm} / \text{GeV} \\
\left( \frac{L}{E} \right)_{\text{astro}} &\approx \left( \frac{\text{Gpc}}{10 \text{ TeV}} \right) \approx 3 \times 10^{23} \text{ cm} / \text{GeV} \\
\left( \frac{L}{E} \right)_{\text{SN}} &\approx \left( \frac{10 \text{ kpc}}{10 \text{ MeV}} \right) \approx 3 \times 10^{24} \text{ cm} / \text{GeV}
\end{align*}
\]

Evolution at HE of Neutrino cross
Flavor
New neutrino interactions

New Physics effects

\[ \propto k \ E^n \ L \]

\[ n = 0 \quad \text{Lorentz invariance violations} \]

Decadal Survey 2020
Fundamental Physics with HE Cosmic Neutrinos

Cooper-Sarkar et al., JHEP 08:042, 2011
Connolly et al., PRD 83: 113009, 2011
(NB: errors overestimated because of including unphysical PDFs)
Input to EPPSU on EuCAPT European Centre for Astroparticle Theory

**Organisation:** a central **Hub** (first 5 yr: CERN) and distributed centres governed by a Director and **Steering Committee** including supporting Institutes:

**Activities:**
1. **Annual general meeting; Thematic workshops;**
2. **Dedicated meetings** to consolidate/finalize collaborative projects and common proposals;
3. **Coordination** of existing/planned activities of the **participating institutions**
4. **Contacts/coordination** with ApP theorists from **all over the world**
5. Advice, referee support, training concerning funding proposals;

- **APC Paris**, Fr [David Langlois]
- **CERN Theory Department** [Gian Giudice]
- **DESY (Hamburg+Zeuthen)**, G [Geraldine Servant]
- **GRAPPA/Nikhef Amsterdam**, NL [Gianfranco Bertone]
- **ICC Barcelona**, ES [Licia Verde]
- **IFPU (SISSA+ICTP+INFN+INAF)** Trieste, I [Piero Ullio]
- **IPPP, Durham**, UK [Silvia Pascoli]
- **IST Lisbon**, Portugal [Vitor Cardoso]
- **OKC Stockholm**, Sweden [Hiranya Peiris]
- **Paris-Saclay**, FR [Philippe Brax]
- **Université de Genève**, CH [Antonio Riotto]
- **University of Oxford**, UK [Subir Sarkar]
Computing / Data Sharing

Intensification of Computing/Software Development/FAIR DATA policies common activities through meetings/training and Agreements
- Agreement with SKA already active
- ESCAPE H2020 astronomy and particle physics cluster
- JENAS common symposia
- Rucio, EU Data Science Institute (#5)
- training/schools on deep learning and HPC software development (ISAPP schools, CERN summer school,...).

Rucio Workshops, schools/programs
APPEC transversal contacts with other communities are very important. First Seminar of triennial APPEC-ECFA-NuPECC meetings has a finalized program and > 100 invited people registered. From 1 June 2019 the community at large will be invited to register, and the remaining seats will be allocated on a first come basis.

Scientific Program on:
- Physics challenges, DM, vs, Beyond Standard Symmetries, Cosmology in the GW era.
- Big and Open data, Computing challenges
- Photosensors, Solid State devices, Calorimetry, Magnets, Accelerator technology, cryogenic
- Education, Outreach, Panel on Diversity (charter and survey)
- 1 early scientist/country/field for their feedback.

Next APPEC Technology Forum will be open to ECFA and NUPPEC
Conclusions

Briefing Book 2013: The question can be asked whether this support should be enlarged and also whether CERN should directly engage in Astroparticle Physics experiments.

For this Briefing Book: Given the extraordinary potential in clarifying the nature of gravity, matter in extreme conditions and dark matter, **involvement of CERN in Governance of ET is possible.**

Recomendations from the Strategy 2013 concerning APPEC program...

f) ...strong scientific case for a **long-baseline neutrino programme** exploring **CP violation** and the **mass hierarchy**.... CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments => **CERN Platform**

j)… In the coming years, CERN should seek a **closer collaboration with APPEC on detector R&D** with a view to maintaining the community’s capability for **unique projects** in this field.

For this Briefing Book: Full exploitation of Neutrino Platform and expansion into a **Technology platform for R&D and enabling technologies including GW & DM & 0vββ**. An active role of the ECFA Detector Panel where APPEC is represented can be foreseen, but also ATTRACT evaluators, RE Commission.

**Support to the EuCAPT Astroparticle Theory Centre.**

Support a WG and an experimental program for hadronic interactions and cross sections useful for neutrino program.