JENAS-Seminar, Takeaway Message

Jared Little

Physics Highlights and Challenges

Nuclear Physics

CONCLUSIONS

- Ab-initio models as well as density functional theories are progressing fast and will have a strong impact on the predictability of nuclear properties (important for neutrinoless double-beta decay, astrophysics, …).
- Upcoming facilities (and upgrades) like e.g. FAIR, SPIRAL2, HIE-ISOLDE, SPES, ISOL@MYRRHA, … and developments/improvements of instrumentation is boosting the field (see M. Lewitowicz, I. Shipsey, J. D'Hondt)
- Nuclear-physics research is a multi-facetted research area reaching out to many different fields of science and applications
- Precision measurements become more and more important and make the link towards particle physics and fundamental symmetry studies (see talk K. Jakobs)

Thanks to P. Van Duppen, N. Kalantar, C. Scheidenberger, P. Greenlees, Y. Leifels, P. Roussel Chomaz, W. Korten, … for input

KU LEUVEN

Pseudosummary/Outlook

- **Extremely rich physics program ahead to understand the scalar sector**
  - The LHC and HL-LHC will get us to 3-5% couplings;
  - All options for a Higgs "factory" bring in ~O(10^{-2}–10^{-3}) understanding of couplings.
  - Important aspects: EWPO (needs next-gen Z factory) and top threshold.
    - Actually, the linear and circular options are quite complementary…
  - Fundamental scalar? Probe to 15-18 TeV. HE ee and pp colliders offer supplementary information.
  - FCC-ee/hh combination has the largest direct reach to new particles/phenomena. From new
- **Dark Matter:**
  - Complementarity with indirect searches at colliders (and astroparticle expts).
  - Next-gen colliders can cover the thermal WIMP scenario.
- **Flavor Physics: Neutrinos have all one could ask for (albeit it with small δ_{int}). But quark sector may hold the first genuine surprises(?)**
  - In the next 5-10 years: could get very pleasant news on CP front. Definitive statement of mass hierarchy and CP from the full program (DUNE and HyperK).
    - Again: complementarity also important here.
  - Quark sector: the current situation will be resolved in the next five years. If current small deviations confirmed: we will have the first experimental evidence for New Physics from the current collider HEP program.
    - Kaon program complementary; Very important ongoing experiments on charged lepton flavor studies.
- **It is the best of times; as long as there is (soon) an international move towards a new collider.**

Particle Physics

Summary and Outlook

APPEC

- Many observatories/experiments => many results
- Theory/Phenomenology key in linking the results
- Ready for many next-generation detectors:
  - many multi-purpose and/or multi-probe
  - many require more R&D
  - all requiring substantial funding
- A variety of observatories ⇒ multi-messenger ⇒ much enhanced science
- Most overlap with particle physics and astronomy, but also significant overlap with nuclear physics

Astroparticle Physics

During the opening sessions each member made clear statements regarding the complementarity.

Overall Strategies

The importance of open science was stressed during the strategic outlooks:

- ESCAPE/EOSC was referenced early and often.

NuPECC Strategy for Nuclear Physics

Strategy Pillars

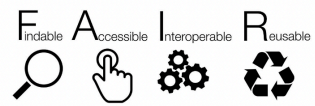
- **Science: Interplay between Theory & Experiment**
- **Applications - huge societal impact**
- **Facilities – in Europe (FAIR, SPIRAL2, ELI-NP, ISOLDE, SPES) and at other continents (RIBF, TRIUMF, iThemba, EIC, FRIB)**
- **Detectors - ex. ALICE3 and AGATA**
- **Data and Open Science – ex. ESCAPE**
- **Synergies with neighbouring fields - DM, GW, neutrinos, EDMs, detectors,…**

Strategy Development

- The 2017 NuPECC Long Range Plan defined an ambitious strategy for European Nuclear Physics
- NuPECC efforts to transform the LR Plan into reality -> Task Force meetings in European countries
- **Next NuPECC LRP 2024 begins now**
- Development of a global international approach to nuclear science in collaboration with CERN, IUPAP, NPD/EPS, ECFA, APPEC, NSAC (US), ANPhA (Asia), ALAFNA (S. America), CINP (Canada)

Overarching Topics in the Roadmap

- Ecological Impact
  - ..of satellites, observatories, infrastructures, travel…
  - ..provide spin-offs for other research areas
- Societal Impact
  - Survey and fostering of impact on society
- Open Science and Human Talent Management
  - Outreach and education
  - Open Data and Citizen Science ESCAPE https://projectescape.eu/
- Computing
- European Centre for Astroparticle Physics Theory EuCAPT
  - https://www.eucapt.org/
- Underground and Large-scale Infrastructures
  - Coordination of European Underground Labs



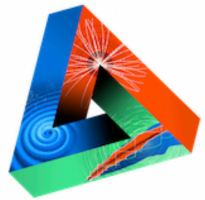
Update of the European Strategy for Particle Physics

5. Synergies with neighbouring fields

Europe should maintain its capability to perform innovative experiments at the boundary between particle and nuclear physics, and CERN should continue to coordinate with NuPECC on topics of mutual interest.

Synergies between particle and astroparticle physics should be strengthened through scientific exchanges and technological cooperation in areas of common interest and mutual benefit.

→ Joint ECFA-NuPECC-APPEC Activities (JENAA) and Joint ECFA-NuPECC-APPEC Seminars



Challenges in computing and software for our Big Data
Gonzalo Merino Arevalo

European Open Science Cloud - EOSC

An EC action to implement the Open Science vision and policies shared by member states

- A cloud for research data in Europe allowing seamless access to data and interoperable services
- Will federate existing e-infrastructures, national data centres and research infrastructures, allowing researchers and citizens to publish, access and re-use data

EUROPEAN OPEN SCIENCE CLOUD
https://eosc-portal.eu/

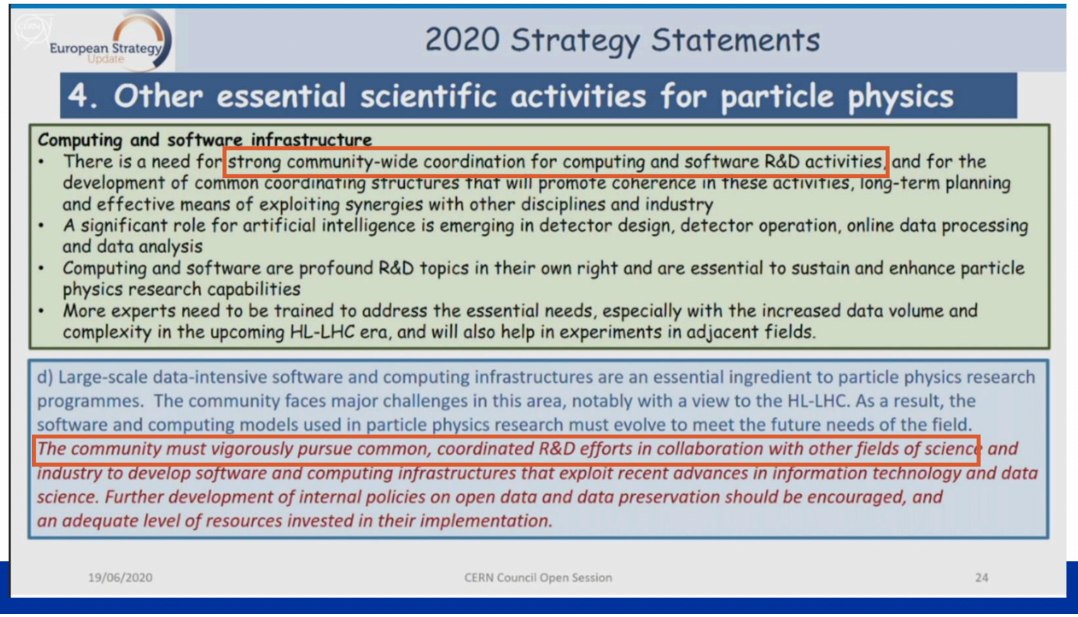
ESCAPE

EU project in response to H2020 call to build the EOSC by co

ESCAPE: Astronomy and Particle Physics ESFRIs (2019 - 2022

- Goal: Develop common "e-infrastructure" solutions for physics & astronomy research facilities.
- Acknowledge that both communities will generate mas state-of-the-art in data mgmt. and computing R&D.
- Common challenges for long-term data preservation, sustainability and open access to data.
- Exploit synergies between both communities expertise

European Strategy Update 2020



Concrete project example: direct detection DM data

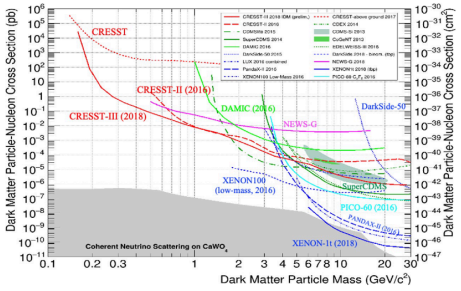
iDMEu

What we have: Compilation of experimental results in certain scenarios/models
Very broad range of DM masses and couplings probed!

What we need: Sharing of (reduced) data sets to:
- Interpret for different scenarios/model
- Interpret with common statistical tools
= Combine results inside direct detection but also beyond (with accelerators and indirect detection)

What iDMEu could help facilitating: Creation of data repository + tools for theory interpretation, using and connecting existing tools wherever possible

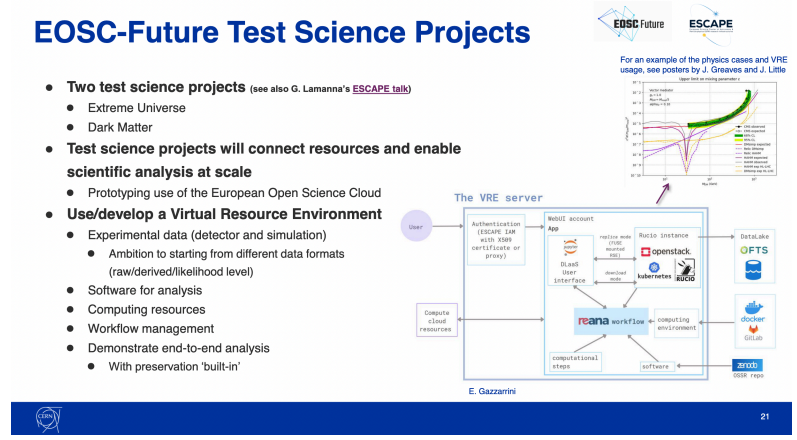
F. Reindl @ iDM 2020



Examples of concrete questions:
- "What is the best way to share not only results, but also data? What is the 'metadata' needed?"
- "How do different experiments treat their statistical analysis?"
- "How can we version existing repositories of results?"

EoI 1 - Dark Matter – iDMEu
Federica Petricca

Sustainability and Future of Software Frameworks
Graeme Stewart



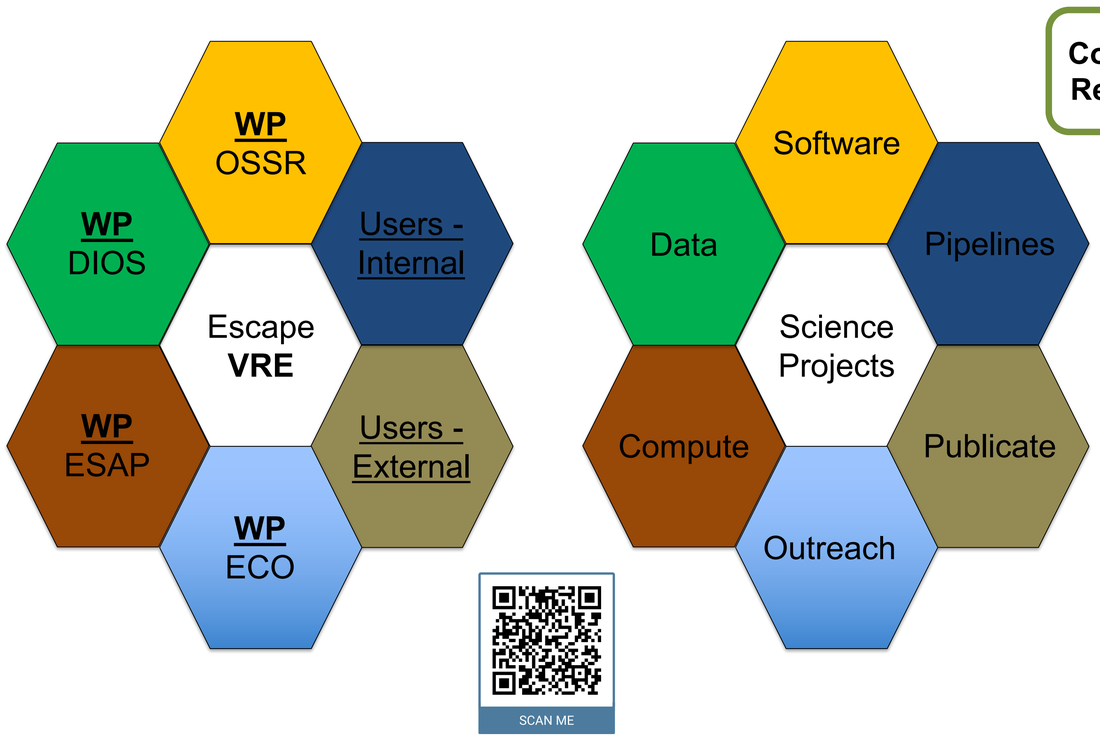
THE DARK MATTER SCIENCE PROJECT IN THE EUROPEAN OPEN SCIENCE CLOUD (EOSC) FUTURE

JARED LITTLE
Centre National de la Recherche Scientifique (CNRS/IN2P3)

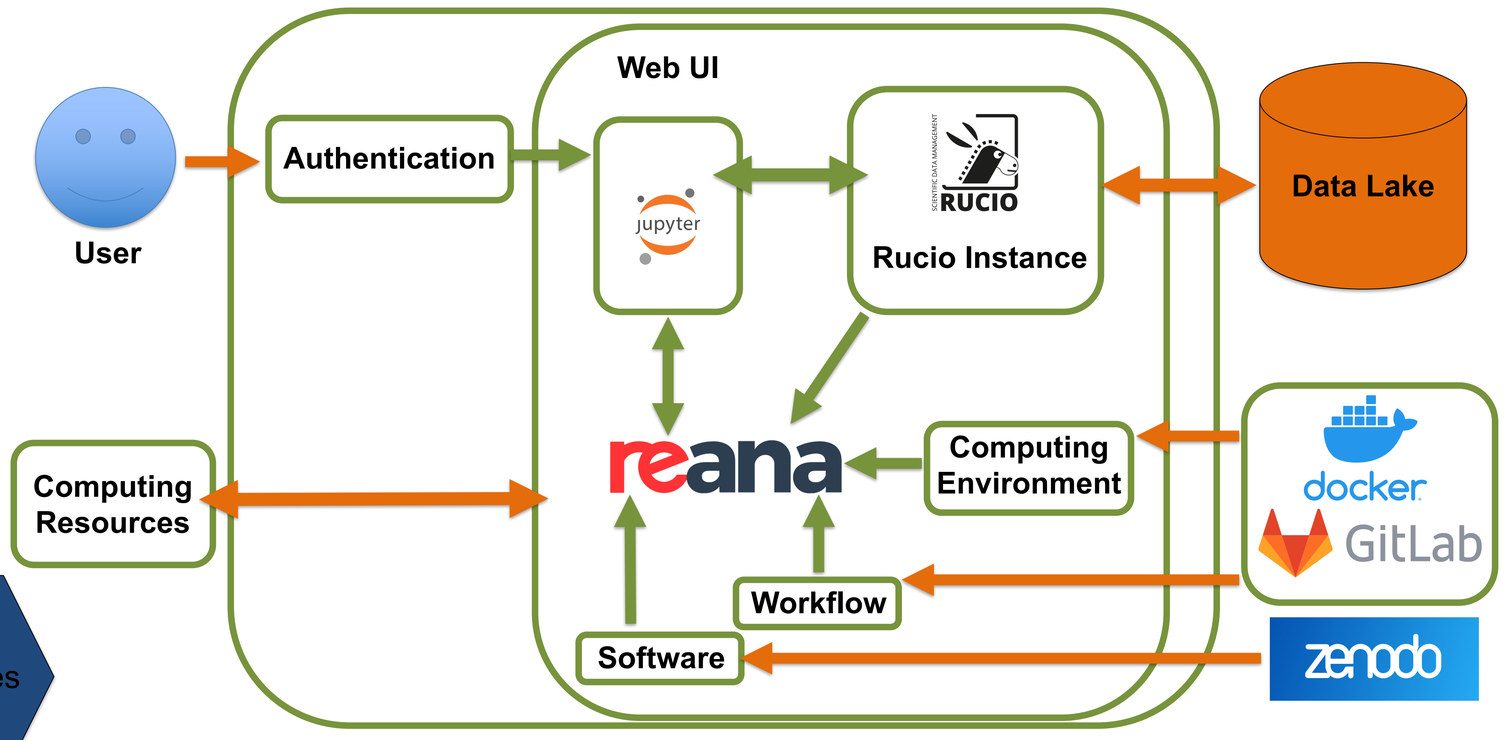
ESCAPE / EOSC Future

With the **ESCAPE Virtual Research Environment (VRE)** we are bringing together all ESCAPE services to facilitate **EOSC Future** project development.

- **ESCAPE VRE:** A collaborative open source environment to access all digital content related with a scientific result.
- Work packages were established to ensure milestones and deliverables are maintained.



Visit the VRE Website!



ESCAPE VRE

Work is very active on the ESCAPE VRE, with multiple researchers implementing two **Science Projects (SP)** to demonstrate the VRE capabilities, the **Dark Matter Science Project** and the **Extreme Universe Science Project**.

Dark Matter Science Project (DM SP) – Different experiments probing the nature of dark matter using different methods with clear complimentarity.

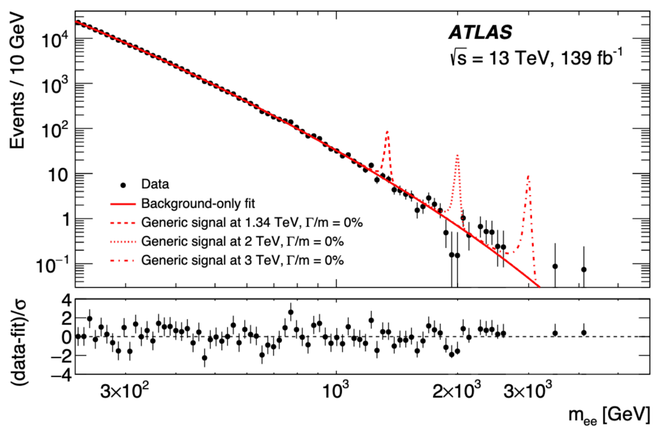
- Further understand the nature of DM by performing new analyses within experiments involved.
- Exploit synergies and complimentarities across different communities.
- Enhance the research participation in the EOSC, providing a working example of open science from a bottom-up effort from different experiments.

The Dark Matter Science Project

DM@LHC with the ATLAS Experiment

Dilepton Inclusive Search. Results of this analysis demonstrate good agreement with SM predictions.

https://doi.org/10.1016/j.physletb.2019.07.016



The dilepton inclusive search (above) concluded in 2019. We are developing new exclusive searches targeting, in particular, lower Z' masses.

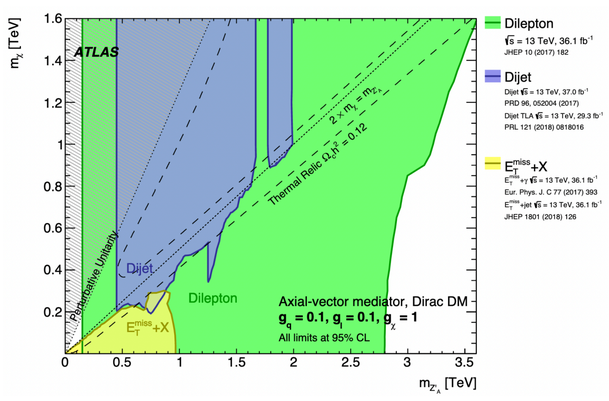
Three new dark matter mediated models being explored.

- Dark Higgs – new massive scalar (h_D) with couplings to Z' and dark matter (χ).
- Light Vector – Relatively light Z' with off-diagonal coupling to dark sector fermions (χ_1, χ_2).
- Inelastic EFT – Similar to Light Vector model, but produced through a contact interaction.

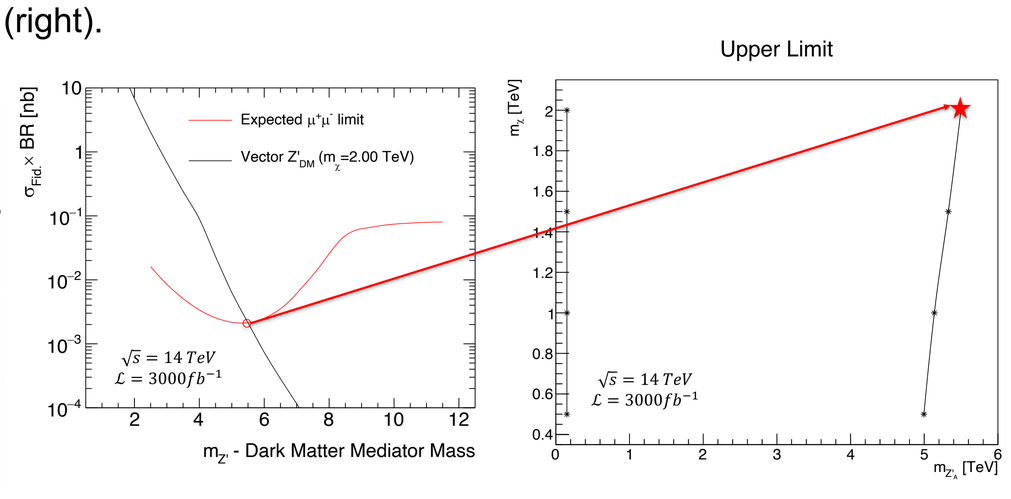
We would like this analysis to be a full test-case for the VRE.

Dark Matter Reinterpretation – Inclusive search was also reinterpreted to set limits on the $Z' \rightarrow \chi\chi$ process.

- We extended this reinterpretation, projecting our limits to 14 TeV and computing the cross-sections.
- As expected, we see significant improvement (right).



https://link.springer.com/article/10.1007/JHEP05(2019)142



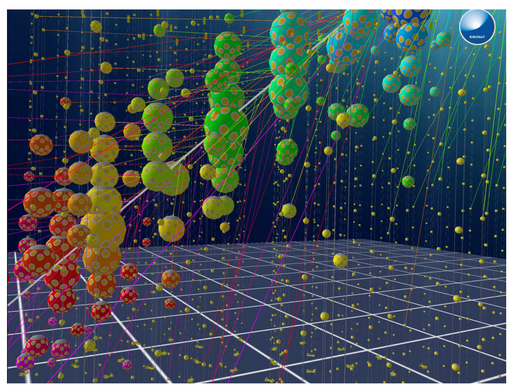
Expected HL-LHC limits from: http://cdsweb.cern.ch/record/2650549/files/ATL-PHYS-PUB-2018-044.pdf

Expected DM limits at 14 TeV. Summary plots were made within the ESCAPE VRE, where we are able to perform small computing tasks (maximum of 14 GB RAM).

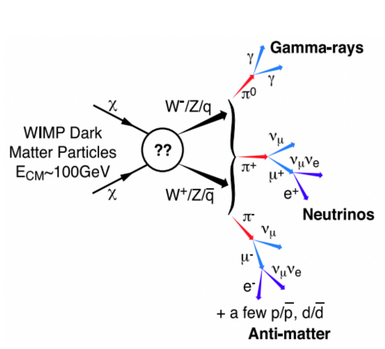
- Events generated independently, for now, but objects collected into the data lake.
- Cross section/limit crossing computed and summarized in the VRE.

Next: Send more demanding steps of our workflow to computing resources, connected through REANA with Kubernetes, HTCondor, or Slurm backends.

Science Projects Combining Indirect Searches



KM3NeT/ARCA – A cubic kilometer neutrino telescope located at the bottom of the Mediterranean Sea sensitive for large DM masses: observe the Galactic Center; low background for searches in the Sun; sensitive to candidates directly coupled to neutrinos.



CTA – next generation ground-based gamma-ray observatory.

Analysis will be performed from DM rich sources, searching for DM emission. Data from precursors HESS, MAGIC and Veritas as well as the space-borne Fermi-LAT will be combined and interpreted.

In the case no DM is detected, constraints will be set on the upper limits of the DM parameters.

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