



**EUROPEAN OPEN  
SCIENCE CLOUD**



# Dark Matter Science Project (DM SP)

JARED LITTLE, ON BEHALF OF THE DM SP TEAM

INPUT FROM: IAN BIRD, FRANCESCA CALORE, SIMONE CAMPANA, CATERINA DOGLIONI, XAVIER ESPINAL, KAY GRAF (+ KM3NET), LUKAS HEINRICH, TANYA HRYN'OVA, VALERIO IPPOLITO, STEPHANE JEZEQUEL, SAM MEEHAN, ARTURO SANCHEZ PINEDA, STEPHEN SERJEANT, PASQUALE SERPICO, + MANY OTHERS



# ESCAPE Virtual Research Environment

ESCAPE – Establish single collaborative cluster of next generation research infrastructure facilities for Astronomy- and Accelerator-based particle physics.

The ESCAPE Project is developing a virtual research environment as a prototype of the European Open Science Cluster (EOSC)



<https://projectescape.eu/>

Coordinated by L.A.P.P.

# ESCAPE Science Projects

Within ESCAPE, two “Science Projects” will be developed:

1. **Dark Matter**
2. Extreme Universe and Gravitational Waves

The goals of these science projects:

Demonstrate new cutting-edge science capabilities, especially involving collaboration across communities with different research infrastructure.

Validate that the software, tools, services, and infrastructure meet scientific needs.

Provide feedback to the ESCAPE Project, and ultimately the EOSC community.

**I was hired to work on the Dark Matter Science Project in the coming two years, to integrate collider searches using data from the ATLAS Experiment into the ESCAPE environment.**

# Science Question: Dark Matter

Many of the communities within ESCAPE have experiments searching for dark matter, with clear complementarity between experiments.

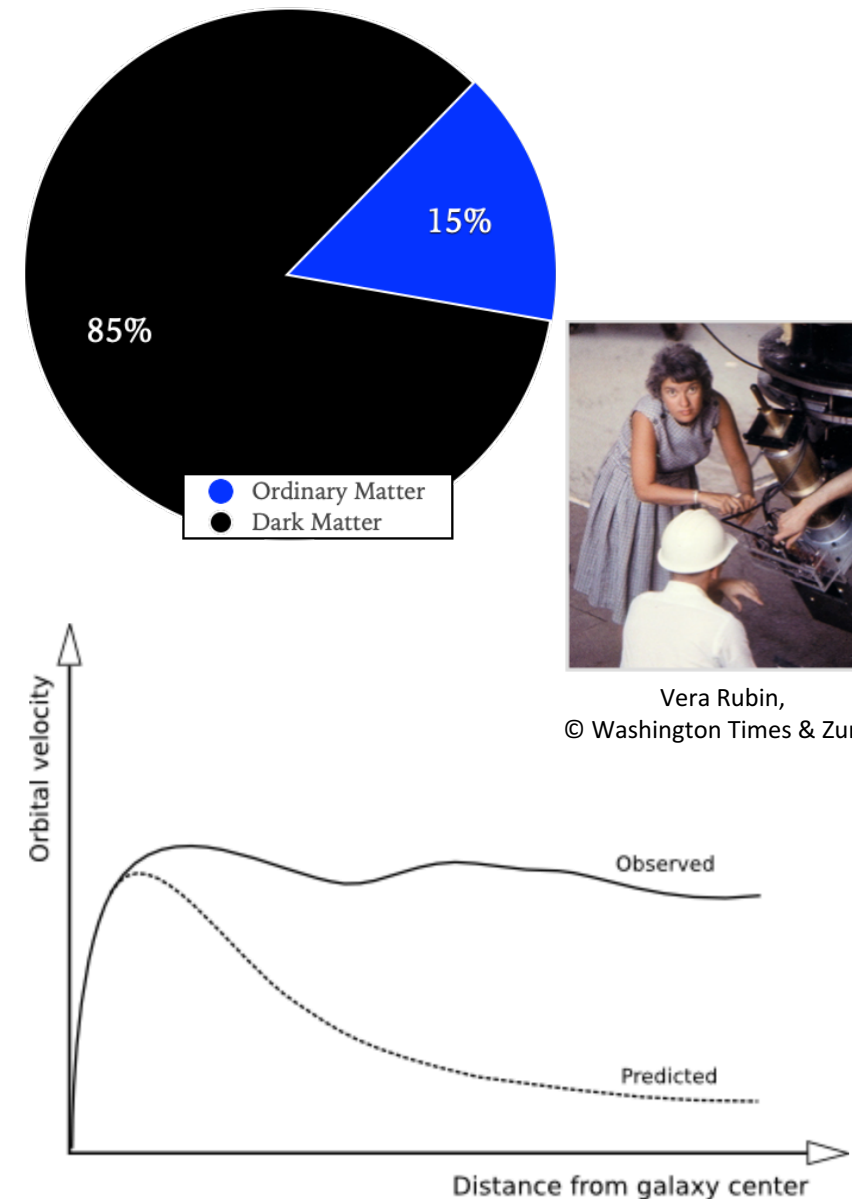
Aim to perform new analyses within the experiments involved.

- Collecting all digital objects related to those analyses on a broad platform, ultimately hosted on the EOSC Portal.
- Allow these analyses to be reproducible within various collaborations and by the entire community when possible.

Final science output of each workflow will be individual experimental curves.

- Can be interpreted in terms of Dark Matter particle properties.

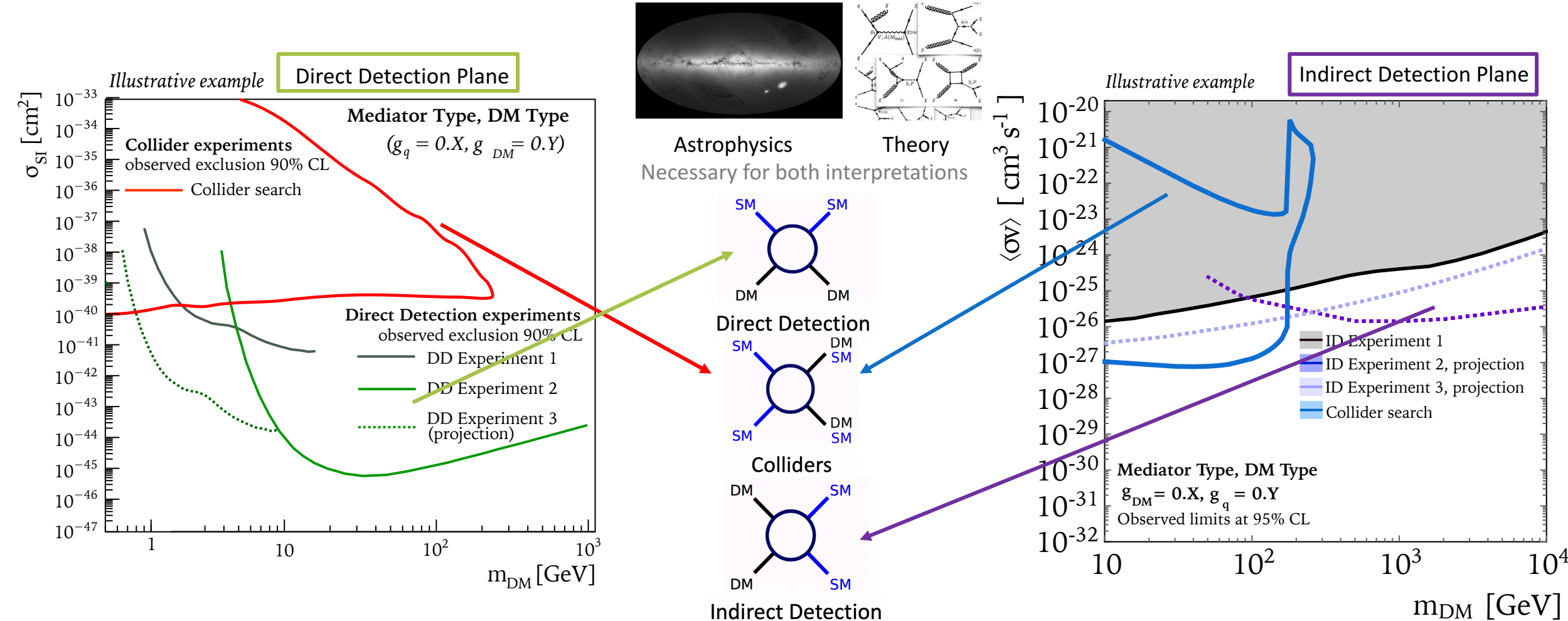
Provide a working example of open science from a bottom-up effort by different experiments.



# Scientific Output: Baseline

New analyses will be performed, with their results being compared (example curves below).

- Results and analyses will be made available on the Virtual Research Environment.



# Scientific Output: Baseline

## Infrastructure - CERN

## Postdoc: Elena Gazzarrini

Postdoc: Recruited soon

### Direct Detection

Partner  
INFN

Experiment  
Darkside

Postdoc: Jared Little

### Colliders

Partner  
LAPP, University of  
Manchester, Lund

Experiment  
ATLAS

Postdocs: Mikhail Smirnov  
Pooja Bhattacharjee

### Indirect Detection / Theory Tools

Partner  
CNRS-CPPM, FAU, INFN,  
NWO-Nikhef, LAPP(+LAPTh)

Experiments  
KM3NeT / CTA

# Workflow: Direct Detection

Discussions on improving interpretations/plots

Discussions on standardized data formats for other experiments

Theory input & code [LAPP/LAPTH]

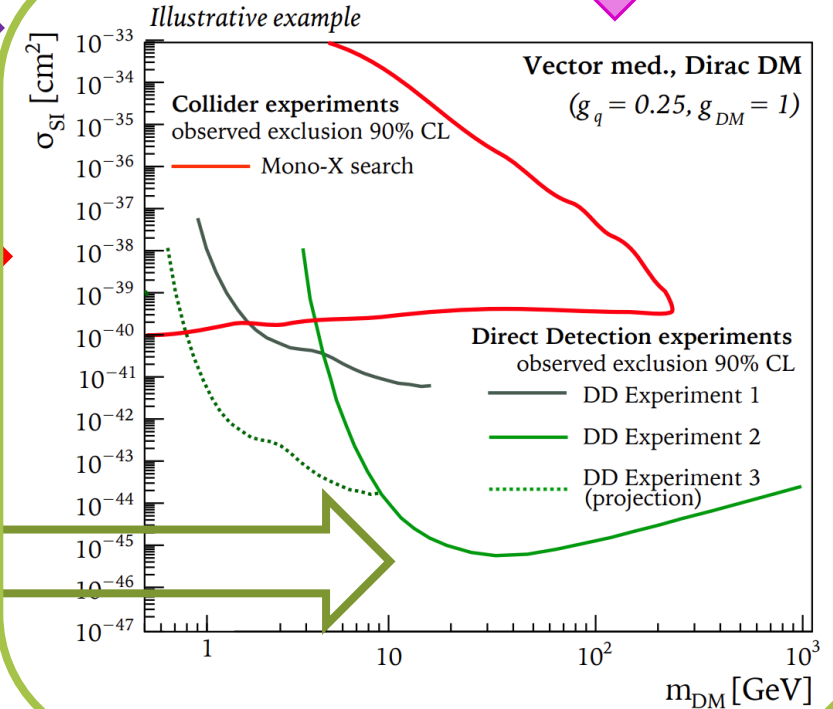
ATLAS/CMS [LAPP+Lund/INFN]



Discussions on using common steering (declarative?) analysis code



Darkside [INFN]



LHC Data

Direct Detection Data

Data Lake

Software Catalogue

Science Output

Cross-Science Project: novel algorithms



# Scientific Added Value

- **Theoretical and observational constraints.**
  - New analyses being performed from the complementary experiments.
- **Cohesive workflows / pipelines.**
  - Displayed in a summary plot showcasing their synergy.
- **Adaptation of innovative techniques.**
  - Innovative algorithms or procedures to distinguish signal from background can be highlighted and shared across communities.
- **Facilitation of the combination of results from different experiments.**
  - May happen after the timescale of this project.

# Open Science Added Value

## **ESCAPE infrastructure Data and Software access.**

- ESCAPE infrastructure for Open Science in the European Open Science Cloud to store, distribute, and provide data and software access to the broad dark matter community.

## **Unique link across scientific communities.**

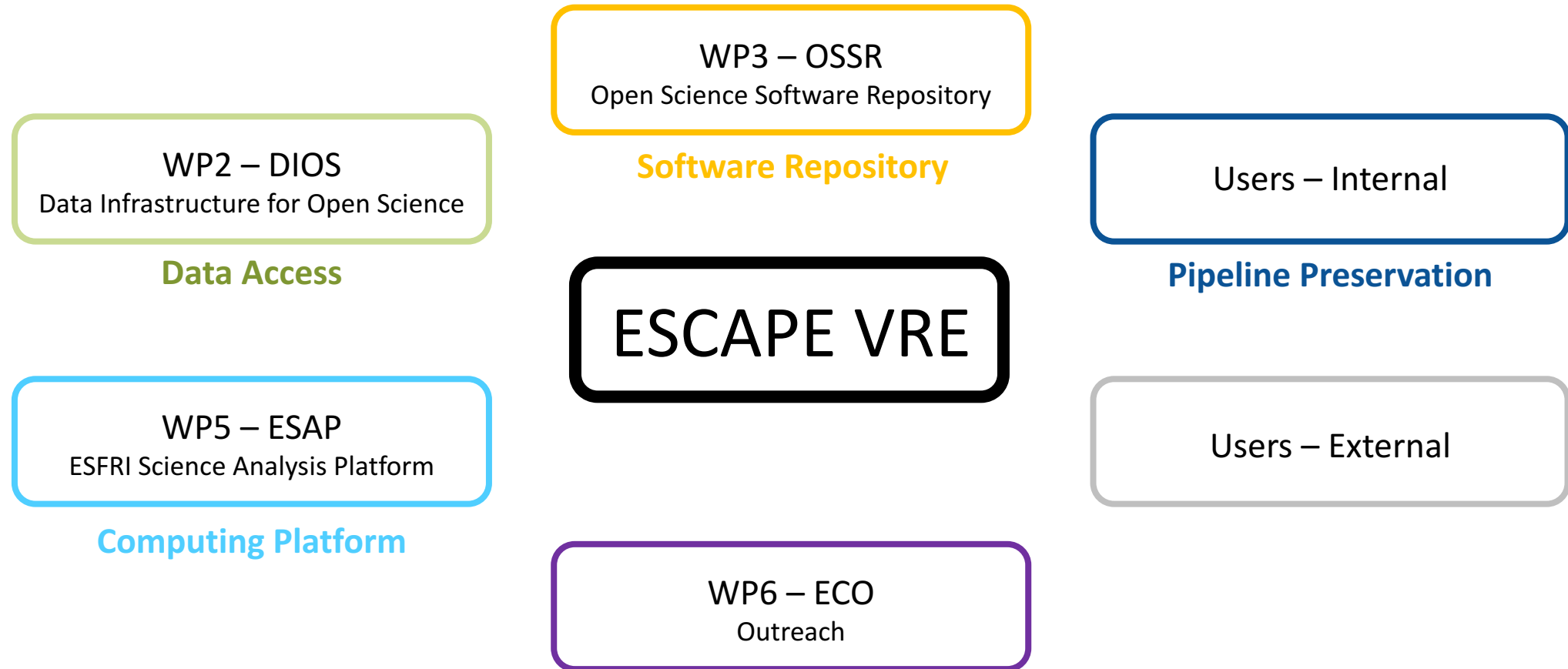
- Open science services to answer dark matter as a fundamental science question while benefiting the scientific community as a whole.

## **Showcase ESCAPE services.**

- The analyses will rely on ESCAPE services within EOSC-Future developed with sustainable analysis pipelines.



# ESCAPE Virtual Research Environment



<https://escape2020.pages.in2p3.fr/virtual-environment/home/tsp-higgs/>

# ESCAPE VRE – Data Infrastructure for Open Science

## WP2 – DIOS

Data Infrastructure for Open Science

## Data Lake

Collection of sites (RSE) that store replicas of the experiments datasets, simulated and real.

<https://opendata.cern.ch/>

## Data Catalogue

Over two petabytes of particle physics open data already available from CERN open data.

## Rucio Client(s)

RUCIO CLI and RUCIO Jupyter Extension.

## User Services

Monitoring with Grafana.

# ESCAPE VRE – Open Science Software Repository

## WP3 – OSSR

Open Science Software Repository

### Zenodo

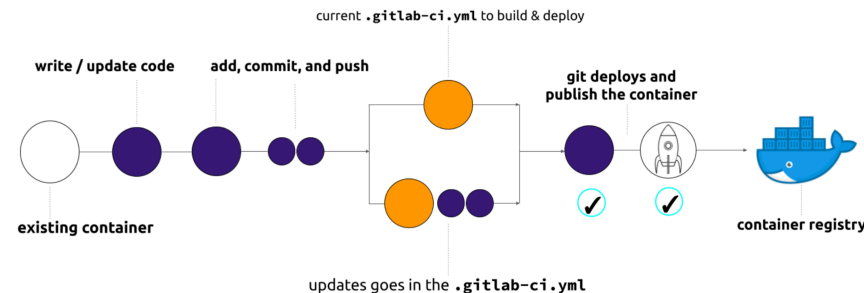
ESCAPE OSSR is a sustainable open-access repository for sharing scientific software.

<https://zenodo.org/communities/escape2020/?page=1&size=20>

### GitLab

Continuous Integration and Development for sustainability and containerization.

### Containerization



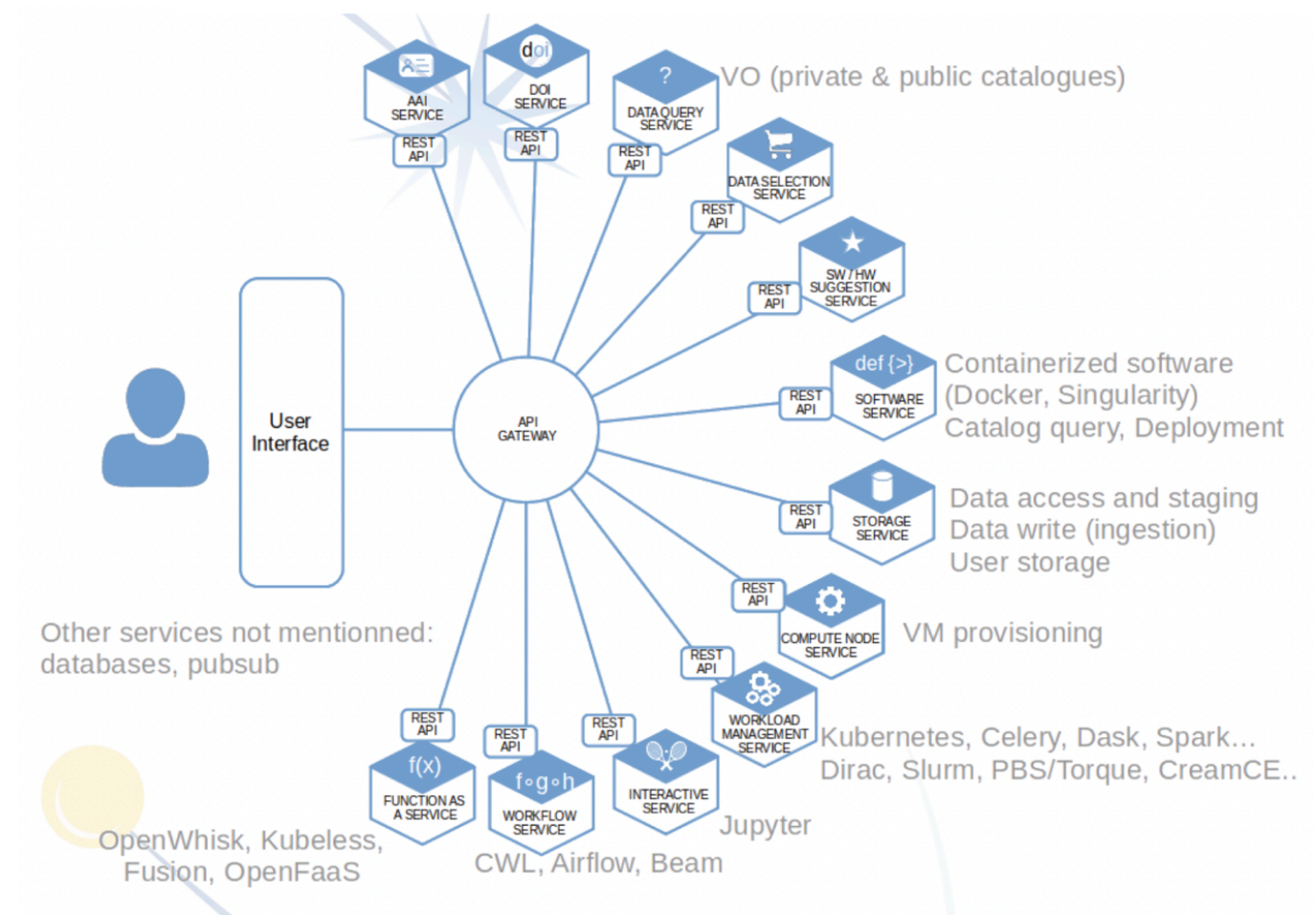
# ESCAPE VRE – ESFRI Science Analysis Platform

## WP5 – ESAP

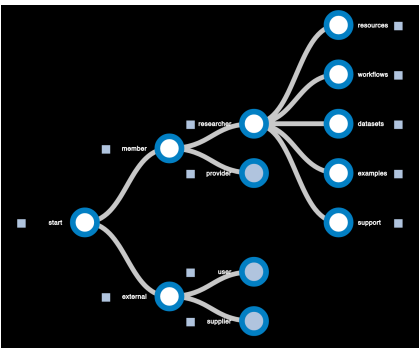
### ESFRI Science Analysis Platform

- A “science platform toolkit”: bring your own infrastructure and service capabilities.
- Focal point of a range of pluggable, independent microservices.
- Designed to be robust and extensible.

Currently, ESAP acts as a “hub,” effectively linking out to JupyterHub and HTC/HPC facilities.



<https://indico.in2p3.fr/event/23869/contributions/94010/attachments/63501/87434/2021-04-06%20E2%80%9420ESCAPE%20WP2-WP5%20Workshop%20E2%80%9420WP5%20Status.pdf>



## Onboarding / Training

Guide users to a specific tool.  
Decision Trees are a good option to avoid having  
and excess of information/boxes/tabs

## Users – Internal

<https://projectescape.eu/internal>

## Pipelines Preservation

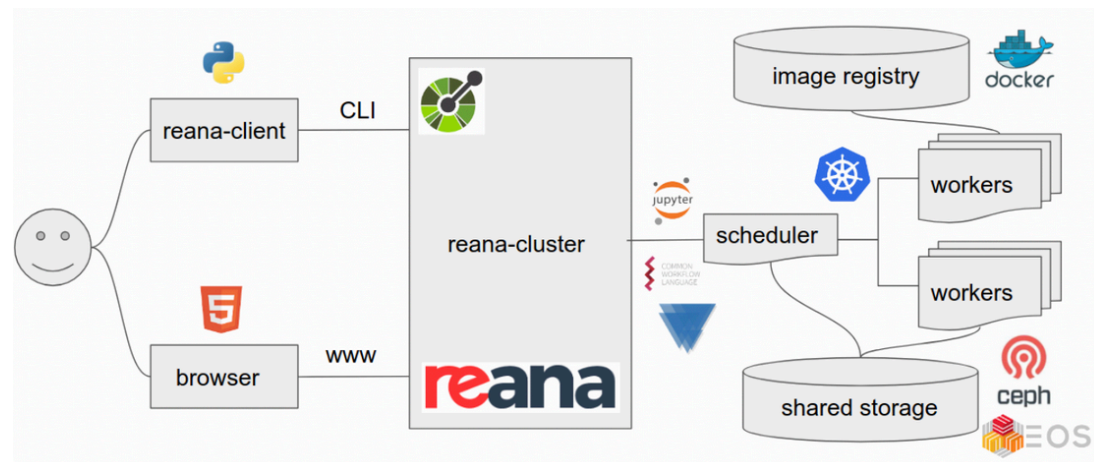
RECAST – a framework for reusing estimates of  
backgrounds, uncertainties, and observations in  
the data to test alternative signal hypothesis.

REANA - **r**eproducible **a**nalysis platform for  
running containerized data analysis pipelines on  
remote clouds.

## RECAST in simplified terms:

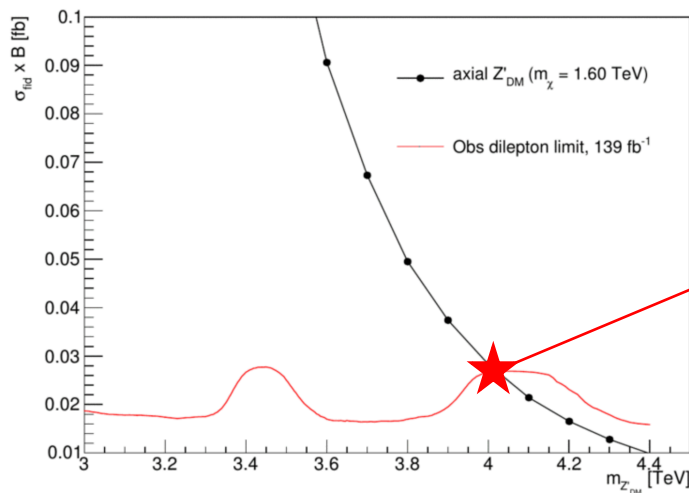
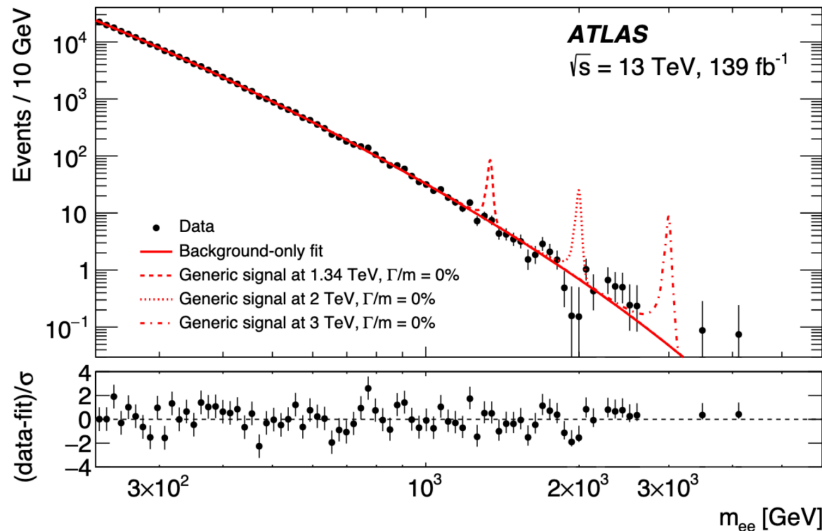
1. Analysis code preservation.  
Analysts preserve the code framework (git).
2. Environment preservation.  
ATLAS has developed version-controlled docker images,  
encapsulating the OS, compilers, and standard libraries.
3. Automated re-interpretation.  
Automate the steps for passing a new signal model through the  
analysis chain (yadage).

<https://danikam.github.io/2019-08-19-usatlas-recast-tutorial/>



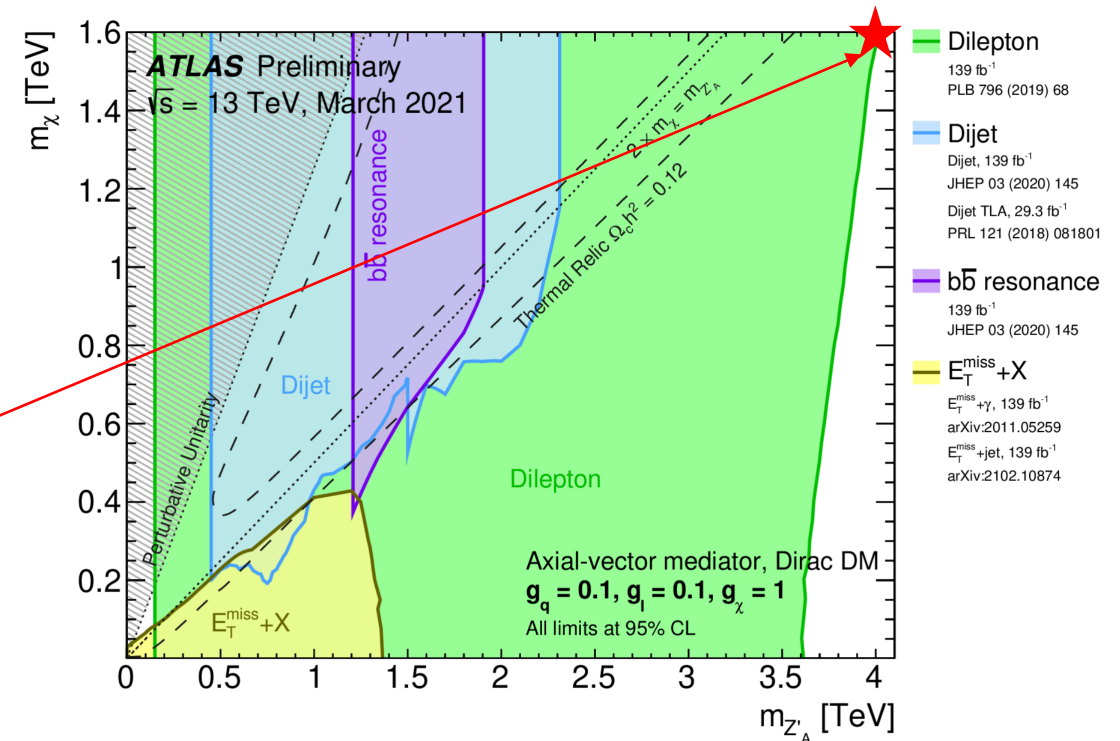
<https://docs.reana.io/>

# Integration of Collider Search – Short Term



**Using dilepton resonant search for constraining dark matter mediators.**

- Setting limits on  $Z'_{\text{DM}}$
- Use as test-case scenario within ESCAPE platform for quick results!



# Summary

Development of two science projects is ongoing and very active.

- Dark Matter Science Project meeting monthly.
- Lots of interest and infrastructure largely in place.
- Project timeline is 30 months (Around the end of 2023)

Develop a novel approach to perform cross-science dark matter searches.

- Aim for new results to be hosted on the EOSC Portal.
- Allow analyses to be reproducible within various collaborations.
- Provide a working example of open science from a bottom-up effort by different experiments.
- Collaborate with existing communities, JENAS EoI (iDMEu) spanning high-energy physics, nuclear physics, and astroparticle physics.

<https://indico.cern.ch/event/869195/>

**Postdocs are hired and beginning to actively work on this project.**



# BACKUP

# Dark Matter Sub-projects

## Subproject 1 [Infrastructure and support + colliders]

**Partner:** CERN

**Title:** Enabling dark matter science on the data lake

**PIs:** Xavier Espinal (CERN), Simone Campana (CERN), Ian Bird (LAPP), **Postdoc:** Elena Gazzarrini

## Subproject 2 [Indirect Detection]

**Partner:** KM3NeT - CNRS-CPPM, FAU, INFN, NWO-Nikhef

**Title:** Determination of KM3NeT Sensitivity to Dark Matter via Open-Science Tools

**PIs:** Kay Graf (FAU) **Partner PIs:** Cristiano Bozza (INFN), Pascal Coyle (CNRS-CPPM), Aart Heijboer (NWO-Nikhef)

## Subproject 3 [Theory tools, Indirect Detection]

**Partner:** LAPP

**Title:** Indirect dark matter search with gamma rays via open-science tools

**PIs:** Francesca Calore (CNRS, LAPTh), Christopher Eckner (CNRS, LAPTh), Pasquale Serpico (CNRS, LAPTh)

## Subproject 4 [Colliders]

**Partner:** LAPP + University of Manchester + Lund

**Title:** Reproducible ATLAS dark matter searches for visible and invisible particles

**PIs:** Tanya Hryn'ova, Stephane Jezequel, Giovanni Lamanna **Partner PIs:** Caterina Doglioni

## Subproject 5 [Direct Detection]

**Partner:** INFN

**Title:** Opening DARKSIDE and collider experiment data and software towards dark matter discoveries

**PIs:** Valerio Ippolito, Tommaso Boccali

# Workflow: Indirect Detection

Discussions on improving interpretations/plots

## Data Lake

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Indirect  
Detection Data

ATLAS/CMS [LAPP+Lund/INFN]



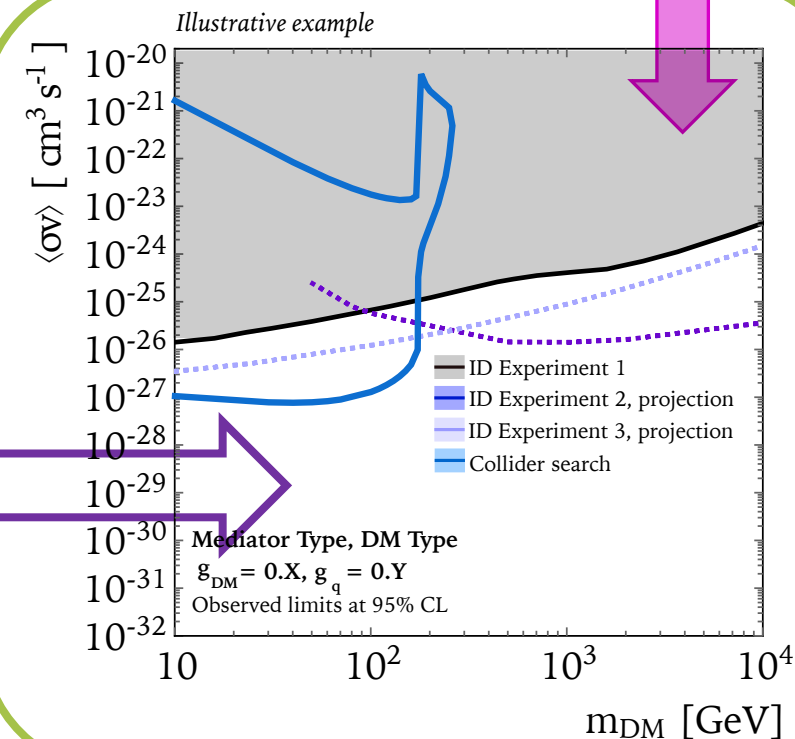
reana

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CTA [LAPP/LAPTH] KM3NeT [FAU]

Theory input & code [LAPP/LAPTH]



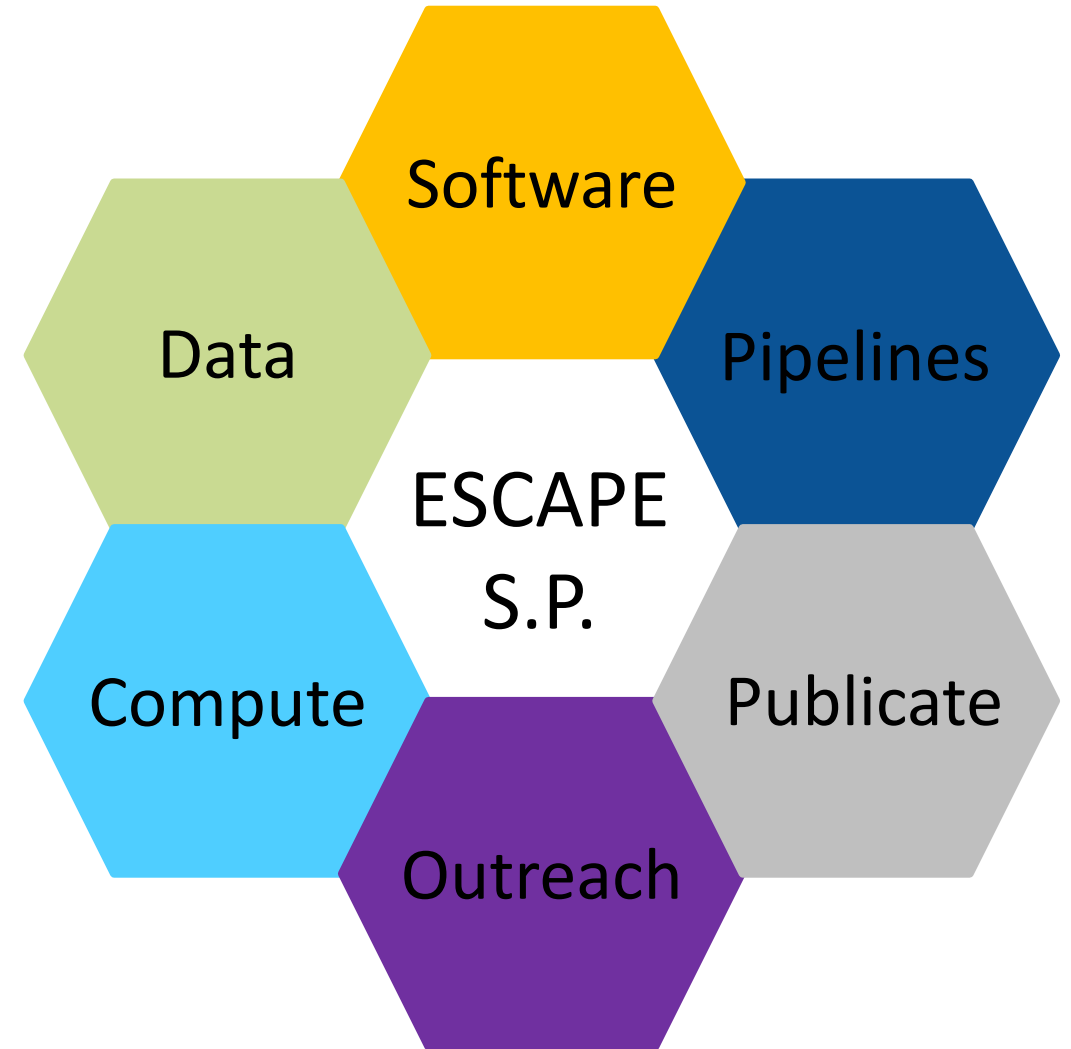
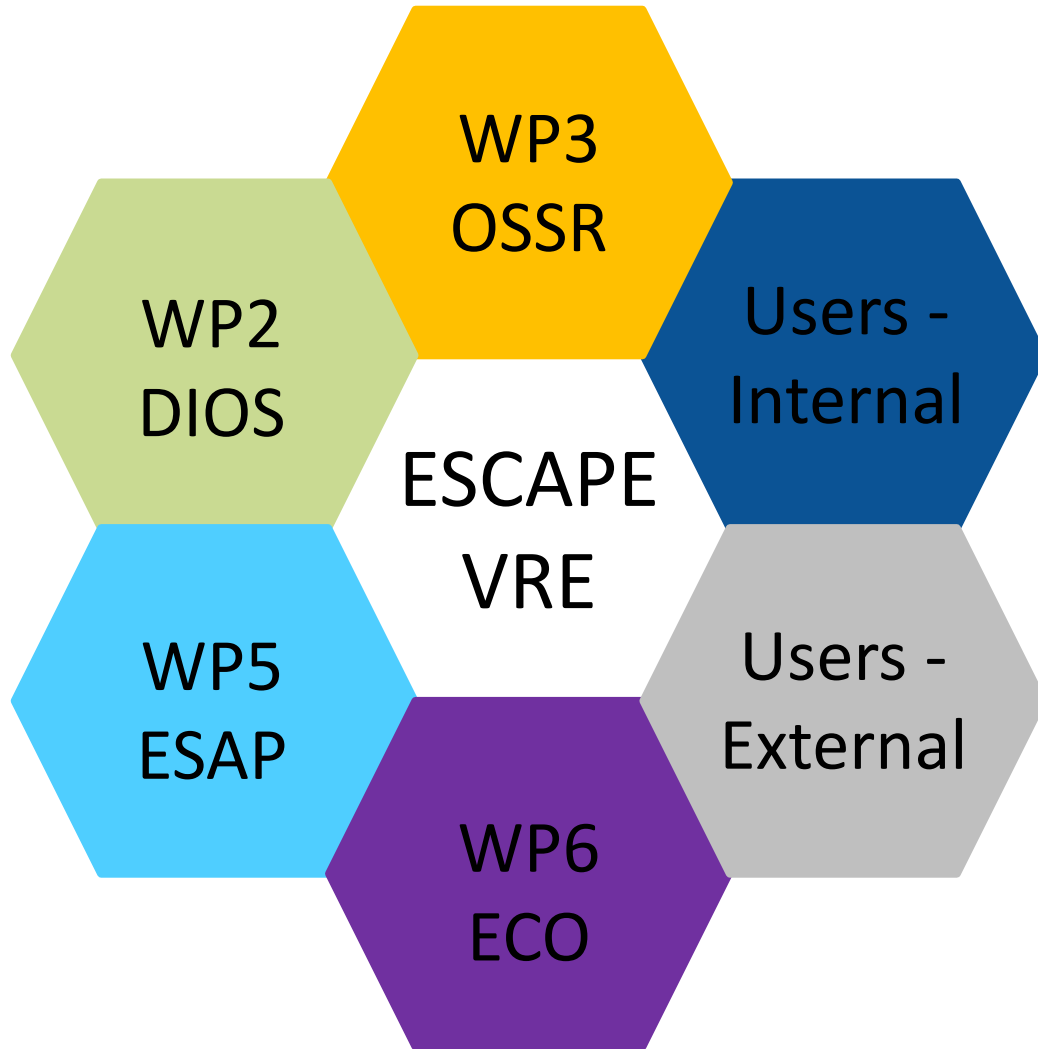
## Software Catalogue

## Science Output

Cross-Science Project: innovative algorithms

Discussions on standardized  
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