

Vector mediator particle \supseteq **Dark photon** portal particle \rightarrow we can **recast** results from colliders in terms of accelerator benchmarks

Union's 824064



Funded by the European Union's Horizon 2020 - Grant N° 824064

The kind of plot we want to contribute to (from LDMX TDR)

Part of the KAW-funded Wallenberg Project Light Dark Matter

Parameter choices and experiments on this plot being updated for Snowmass (Rare & Precision Frontier) <u>Message of this plot:</u> colliders contribute to discoveries/bounds for dark photon mediated models at high dark photon/DM r



Work by Josh Greaves, supervised by Phil C. Harris and Caterina Doglioni, to be continued by M. Berkat

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- SM coupling

ε: Dark photon



What does it take to make this plot?

Code and resources are on GitHub: https://github.com/josh-greaves/darkphoton

Reinterpretation:

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A model file for signals \rightarrow GitHub repository Confidence limits or projections from collider search (currently: CMS jet+MET) \rightarrow GitHub repo Monte Carlo generator for signal events \rightarrow Madgraph Fast detector simulation \rightarrow Delphes Analysis software \rightarrow MadAnalysis

Relic density: Same model file for signal \rightarrow GitHub repo

Relic density calculator \rightarrow MadDM

Resources needed: HT Condor cluster, with ROOT installation



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How to include dark photon plot in ESCAPE DM Test Science Project?



 Plan (initially M. Berkat: Erasmus+ student from Paris-Saclay currently in Lund, then PhD students at University of Manchester):

- reproduce plot with agreed-upon coupling values and future colliders
- talk to software developers about onboarding in ESCAPE Software Catalogue, and how to best do so
 - MadGraph, MadDM, Delphes are widely used in HEP → participating to DM TSP may provide added visibility for the developers
- turn scripts into Jupyter Notebooks
 - could use CERN SWAN as initial testbed
- eventually move to Virtual Research Environment & reana workflow









European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

Backup slides See also E. Gazzarrini's talk for more up-to-date info: Link to a copy





ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme Horizon & Research and Science Agreement n° 824064.





TIMELINE



Slides by E. Gazzarrini with DM Science Project organizers (F. Calore, C. Doglioni, L. Heinrich)

Funded by the European Union's Horizon 2020 - Grant N° 824064





European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

Old slides one can also steal from



Input from: Tanya Hryn'ova, Stephane Jezequel, Simone Campana, Ian Bird, Xavier Espinal, Kay Graf (+ KM3Net), Valerio Ippolito, Francesca Calore, Pasquale Serpico, Sam Meehan, Lukas Heinrich, Stephen Serjeant, + many others

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Big science question: Dark Matter



NASA/CXC/M. Weiss

<u> https://cordis.europa.eu/project/id/679305</u>

Z= 4.9



Different kinds of DM, and synergies



Many hypotheses for dark matter

- \rightarrow many ways to detect it
 - \rightarrow many different experiments
 - \rightarrow many different data / workflow needs
 - \rightarrow many different data / result sharing policies







Astrophysics



Theory

Scientific added value of DM-TSP:

New plots of dark matter discoveries / constraints



arXiv:1912.12739 & refs therein

• There are many combinations/comparisons of results on the market... but none that sees them all work together with FAIR data & end-to-end workflows!

DM

DM

SM







Planned science outputs (to begin with)





Would propose a brief round-table - details are in this Google Document

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)

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







Connection to gravitational waves / extreme universe



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Knowledge exchange if we want to make this kind of plots is **essential**!



ESCAPE What to expect from ESCAPE / EOSC-Future

Global ESCAPE Science Project Document by Ian Bird

1. AAI (WP2): A fully developed AAI (identification/authentication) solution following the AARC blueprint is

fundamental. In EOSC-Future we must ensure that the ESCAPE solution is fully interoperable with EOSC.

Scientists in the TSP's should be using a single user identity for all aspects of work.

 (ESFRIs, WP4): Publication of data sets into the Data Lake - required from the TSP partners of the ESFRIs and
WP4.

3. Data Lake (WP2): federated storage services should be made available to the TSPs, allowing all of the data

sets needed to be openly accessible to all participants, except for specific cases where datasets are





- Indirect detection (KM3NeT) [Subproject 2]
 - Embargoed simulated data:
 - Low-level data products: dedicated MC simulations to generate Instrument Response Functions:

typically 50 core years, 50 TB of storage

High-level data products: <1 TB of storage (processed data and MC)

- Indirect detection (Dwarf galaxies constraints) [Subproject 3]
 - \circ Data production done at the experiment level \rightarrow moderate space needed for data products at high level, < 1 TB.

Colliders (ATLAS for now) [Subproject 1 (initially, then extend to others), Subproject 4]







ESCAPE Resources: software for OSSR

- Indirect detection (KM3NeT) [Subproject 2]
 - MC analysis pipeline (part of ESCAPE, part KM3NeT-TSP post-doc)
 - Combination of Instrument Response Functions (possible combined effort)

- Indirect detection (Dwarf galaxies constraints) [Subproject 3]
 - The software we will produce needs to be stored in the software catalogue, in particular the code, input,
 - and output of the Glory Duck project which aims at combining results from five major gamma experiments.

• Colliders (ATLAS for now) [Subproject 1 (initially, then extend to others), Subproject 4]



REGAST/READA packaged analysis code to be included in the Software Catalogue Caterina Doglioni - EOSC-Future meeting - 22/01/2020







- Colliders (ATLAS for now) [Subproject 1 (initially, then extend to others), Subproject 4]
 - An instance of REANA+RECAST operating on the Analysis Platform (part of CERN postdoc)
 - This will need authentication and accounting of time usage, as well as helpdesk(s) for troubleshooting

- Indirect detection (KM3NeT) [Subproject 2]
 - Platform to run MC analysis pipeline/combination

- Direct detection (DARKSIDE) [Subproject 5]
 - Continuous Integration-like service running on the Analysis Platform





ESCAPE Recognition of software products

Lukas Heinrich's talk @ ESCAPE WOSSL 2020

Software Citation:

CITATION

Software is often the research product itself. Should be treated as part of the scholarly record.

- cite software directly instead of "software papers" to attirbute proper credit
- if you need a paper consider JOSS

CERN runs free service to mint DOI deposit code, datasets: **ZENODO**

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- Initial ideas: papers **with** code
 - Code: Zenodo
 - Future thought: will the Virtual Analysis Platform provide an interface to Zenodo a la Binder?
 - Journal of Open Source Software
 - Frontiers "Big Data and AI"
 - Need discussion with collaborations/ESCAPE: how to credit software curators in large collaborations?





ESCAPE Expanding the Dark Matter Science Project

Initial effort focused on first 5 sub-projects (+1 nuclear physics?)

- Goals:
 - make progress on science content of the sub-project
 - build know-how to interface experimental software with ESCAPE tools
 - documentation particularly important for onboarding of others
- During this period, always happy to help seek funding for more in-kind resources

Further directions

- Nuclear physics
 - Using ALICE measurements to determine indirect detection backgrounds
- Other DM Direct Detection experiments pipelines (early talks with Xenon1T)
- Ideas for CERN:
 - FCC and future colliders software pipelines & simulation
 - Other DM models (lighter DM to include e.g. FASER / forward physics facility)



ESCAPE Rough, preliminary timescale for DM Science Project

Months 1-6 (April-October 2021)

- Organise recruitment, define datasets, resources and algorithms
 - Most urgent (end of May): <u>recruitment, rough work plans</u>
 - need to put together one ad per postdoc job opening to add to overall (central) text about the project
 - Q for today: what about when we already have candidates?
- We will need a specific TSP meeting to discuss the rest of the plan below these are very preliminary thoughts coming from the <u>DM Science Project summary google doc</u> **Months 6-12 (October 2021-April 2022)** - need usable versions of Data Lake/OSSR/VRE
- CERN tests REANA elements with an existing RECAST implementation (collider search)
- Other subproject postdocs get trained on and make progress in data analysis
- First REANA implementation by CERN interfaced with Data Lake tested as ESCAPE challenge —> can serve as example for others who wish to use the same structure
- Discussion on presentation of results integrated (and first draft available) within the Snowmass project
 - Snowmass whitepaper as progress report to be delivered in early 2022



ESCAPE Rough, preliminary timescale for DM Science Project

Months 12-24 (April 2022-October 2022)

- Focus of postdocs shared between science and implementation of workflows
 - Documentation needs to be written as we go
- First results from data analyses available
- Onboarding of other experiments can happen at this point

Months 24-30 (April 2021-October 2022)

- Full set of results from data analyses available —> creation of final plots
- Consolidation and dissemination

Planning for next DM TSP meeting: <u>https://lettucemeet.com/l/NrrXX</u> Add your availability before Friday 07/05







Initiative for Dark Matter in Europe and beyond



- Many DM discussions, from Granada to the ApPEC-ECFA-NuPECC JENAS meeting held in Orsay in October 2019
 - Talk on ESCAPE (G. Lamanna) in plenary programme
 - <u>HEP Software Foundation meeting</u> on possible software synergies



- JENAS prompted a new initiative centered around **dark matter:** <u>https://indico.cern.ch/e/iDMEu</u>, also featured in ESCAPE <u>newsletter</u>
 - *iDMEu* aiming to build a discussion platform to facilitate collaboration of existing groups/efforts
 - Dark Matter Test Science Project targeting data, software and tools sharing where necessary/useful
 - Points of contact between *iDMEu* and *TSP*:
 - participation of DM community to software catalogue
 - list and help populate common repositories of data and final results (e.g. versioning)
 - e.g. <u>DMTools</u>, <u>DM Limit Plotter</u>
- <u>Kick-off meeting on May 10-12</u> everyone is welcome to register and participate!
 - In this meeting we won't yet talk of how to connect to EOSC-Future as this is more of a meeting to "survey DM communities" and understand what the needs are, bottom-up
 - There are **breakout sessions** that will be of interest to the work we're doing and we can raise new topics









Lukas Heinrich's talk @ ESCAPE WOSSL 2020





Poster @ CHEP 2019







16/March/2019

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ESCAPE The TSP, in a nutshell

| Experimental method | Partners | EOSC Tools | DA Tools (Al/ML) | Project outcome |
|---|---|--|--|--|
| Producing DM in the lab (collider): ATLAS @ CERN | CERN LAPP | Data Lake Software Catalogue Analysis Platform | ML algorithms for: 1. Data compression 2. Data reconstruction (e.g. pattern recognition) 3. Background rejection | Constraints(/projectio ns) on dark matter cross-section / DM mass plane and on dark matter velocity-averaged xsection / DM mass plane |
| Detecting dark matter from the sky (direct detection): DARKSIDE @ INFN | INFN | Data Lake Software Catalogue Analysis Platform | твс | Constraints(/projectio ns) on dark matter interaction cross-section/mass plane |
| Detecting interactions of dark matter using neutrinos (indirect detection): KM3NeT | FAU | Data Lake Software Catalogue Analysis Platform | твс | Constraints(/projectio ns) on dark matter cross-section/mass plane |
| Detecting interactions of dark matter in space (indirect detection) | LAPP | Data Lake Software Catalogue Analysis Platform | твс | Constraints(/projectio ns) on dark matter velocity-averaged xsection / DM mass plane |
| Surveying dark matter in the universe (astrophysical probes) | Open University [not in WP6 in EOSC-Futur e) | Data Lake Software Catalogue Analysis Platform | твс | Combination of constraints on different models using simulation + statistical analysis software (Gambit) |
| [TSP2] Exploiting the gravitational interactions of DM (GW probes) | See GW TSP | Software Catalogue Analysis (multimessenger) Platform | See GW TSP | твс |



- Table, originally designed by ESCAPE-TSP-GW, is still as a work in progress
- Idea of Data Analysis Tools column: algorithms that can be shared beyond a single infrastructure / field
- IWAPP was very useful in terms of food for thought on how to implement these common algorithms (especially ML)
- How to follow up?





ESCAPE How/why Test Science Projects? Slide from G. Lamanna



- Propose Test Science Projects to demonstrate multi-domain science integration across ESCAPE / EOSC
- Involve researchers to demonstrate new cutting edge open science capabilities, making use of the services implemented within EOSC
 - researchers can give feedback on the capabilities delivered by ESCAPE/EOSC
 - researchers can exploit synergies between the ESFRIs and among the scientific communities of Astrophysics/Astroparticle, accelerator-based Particle and Nuclear Physics
- Supported by consortia of EU member states research agencies and institutes within the **J**oint **E**CFA **N**uPECC **A**PPEC **A**ctivities (JENAA)





Services towards the European Open Science Cloud ESCAPE Particle physics ESFRI research Infrastructures (EOSC)





Caterina Doglioni - EOSC-Future meeting - 22/01/2020



European Research Council

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Established by the European Commission



ESCAPE services Slide from G. Lamanna



🖵 Data Lake:

 Build a scalable, federated, data infrastructure as the basis of open science for the ESFRI projects within ESCAPE. Enable connection to compute and storage resources.

Software Repository:

Repository of "scientific software" as a major component of the "data" to be curated in EOSC. Implementation of a community-based approach for the continuous development of shared software and for training of researchers and data scientists.

Virtual Observatory:

 Extend FAIR standards, methods, tools of the Virtual Observatory to a broader scientific context; demonstrate EOSC ability to include existing platforms

Science Platforms:

Flexible science platforms to enable the analysis of open access data

Citizen Science:

Open gateway for citizen science on ESCAPE data archives and ESFRI community CS projects









ESCAPE software catalogue Slide from K. Graf



OSSR Overview



| ESFRI/RI | Institute/SME | |
|--------------|---------------|--|
| СТА | CNRS-LAPP | |
| СТА | CTAO | |
| CTA | IFAE | |
| СТА | MPG-MPIK | |
| СТА | UCM | |
| EGO-Virgo | EGO | |
| ELT | HITS | |
| EST | AIP | |
| EST | NWO-I-CWI | |
| EST | UNITOV | |
| FAIR | GSI | |
| HL-LHC, CERN | CERN | |
| JIVE | JIVE | |
| KM3NeT | CNRS-CPPM | |
| KM3NeT | FAU | |
| KM3NeT | INFN | |
| KM3NeT | NWO-I-Nikhef | |
| SKA | SKAO | |
| SME | OROBIX | |
| 9 ESFRI / RI | 19 Partners | |

10/2020



ESCAPE Dark matter complementarity

- DM discoveries need complementary experiments that involve DM with cosmological origin / can produce DM
 - Direct detection can **discover DM that interacts** inside the detector
 - Indirect detection can see **annihilating/decaying DM** through its decays







Synergistic initiatives following European Strategy Update



searches & interpretation



JENAS Eol: Initiative for Dark Matter in Europe and beyond: Towards facilitating communication and result sharing in the Dark Matter community (iDMEu)

https://indico.cern.ch/event/869195/ ESCAPE newsletter APPEC newsletter

build a discussion platform to facilitate collaboration of existing groups/efforts on **dark matter searches** and **interpretation**

> Towards a Dark Matter Test Science Project

> > ESCAPE Progress Meeting, 2020

provides a discussion platform for the **comparison of common DM** interpretations



allows to **create experimental curves** by **example ESCAPE experiments,** comparing and contrasting analysis pipelines that use ESCAPE / EOSC tools

software & data

More initiatives and links in backup slides



compare **end-to-end analysis workflows** for WIMP searches, towards their implementation in a common **Software Catalogue** and as input to the design of the **European Open Science Cloud**

Caterina Doglioni - TOOLS workshop - 04/11/2020

