iDMEU kick-off meeting live notes
Community Talks

Agenda: https://indico.cern.ch/event/1016060/

Anyone can use these notes for:
- Summarizing the most important points of each talk and Q&A
- Jotting down points that we didn't have time to follow up on in the time allocated to the discussion
    - Feel free to add yours also after the talks
- Giving organizers feedback on how you'd think iDMEu could be useful for your community [at the end of the document]

Our meeting will be live-captioned and the transcript will be made available once ready, so these won't serve as " live minutes".

2020-06-10 - Community Talks

Welcome and introductory words from iDMEu proponents
14:00 - 14:10

Andreas Haungs, Karl Jakobs, Marek Lewitowicz
Introductory words from JENAA
14:10 - 14:30

JENAA = APPEC (astroparticle physics) + ECFA (particle physics/accelerators) + NuPECC (nuclear physics)
Next appointment/milestone: Common seminar JENAS 3-6/05/2021
APPEC Roadmap Subtopic Report on Direct DM: https://arxiv.org/abs/2104.07634

Laura Baudis
Dark Matter Direct Detection Experiments based on nuclear recoils
14:30 - 14:55

Main points for discussion & future challenges:
- Within-field comparisons: which DM halo model to use to make results comparable?
- Particle physics inputs: What are plausible cross-section targets (within selected models) to guide future detectors?
    - Further discussion of reliable comparisons are needed to make underlying assumptions transparent
- WIMP-nucleon cross-sections require input from nuclear physics.
- Neutrino fog (vs neutrino floor): how well do we know the backgrounds of future DD experiments? Nuclear and astro inputs needed.

- Statistical framework recommendations whitepaper recently developed within phystat DM: https://arxiv.org/abs/2105.00599 → community can adopt these recommendations after discussions (also astro input needed)
- Data sharing: uniformity / metadata / documentation can be a challenge for data reuse
    - *Q to community: where/how can such a discussion take place? [not covered yet but people should feel free to add their inputs/ideas below!]*
- Software tools: various tools on GitHub
    - *Q to community: would a list be useful? Who could help maintain it? [How do we recognize enough those maintaining the tools?]*
        - *Is a list sufficient for this purpose, or do we need a wishlist for more tools that we would need?*
        - *Question about tools "fading away" (community using them moves on to something new) - we need expert input on what is used/usable and what can be improved. E.g. DMTools may need an improved interface.*

Paolo Privitera
Dark Matter Direct Detection Experiments based on electron recoils
14:55 - 15:20

Main points for discussion & future challenges:
- Lowering backgrounds as much as possible (cosmogenic/material-based)
- Sharing information about e.g. list of ultrapure material (so far we talk to each other, can we have more of an infrastructure for it?)
- Theory needs input from a variety of fields → a common framework for the field would be useful (including statistical methods)
- Program is new and there's a lot of different ideas → within-community discussion also useful and not yet structured
- Need to connect to astrophysics searches as well
    - *Model-building aspects going on in FIPs Physics Center within the Physics Beyond Colliders effort, aiming to provide theoretical framework for embedding DD/ID/accelerator for light DM searches & Feebly Interacting Particles*
    - *Proceedings of FIPs workshop using this framework: https://arxiv.org/pdf/2102.12143.pdf, need to be improved on*
        - *Discussion from Zoom: Section 2.6, Fig.18 and Section 2.6.2 about recommendations for comparison between DD and accelerators for sub-GeV DM, e will evolve from there improving the models. Fig.18 should be filled up with new bounds/projections from the DD community, this is in the todo list of the Physics Beyond Colliders effort within the FIPs physics center and needs help from the DD community.*

- *Question: what are the inputs and the challenges that the rest of the community can give, what are the main inputs you'd like to have?*
    - *A: about defining the science target = similar to nuclear recoil, astro/cosmology. For electron recoil: part related to specific DM models and interactions from the theory point of view, and how to go from energy deposited to electrons (measured). We need a common strategy if we want to compare limits.*

Bela Majorovits
Axions and Axion-like particles
15:20 - 15:45

Main points for discussion & future challenges:

- Hardware challenges: magnet development, photon detection, materials, infrastructures
    - Magnet development can be share between different communities (e.g. accelerator but also medical / fusion / solid state)
    - Detection of photons R&D
        - Quantum detection also needed for much lower masses
        - Single photon detectors: shared with light DM
    - Cryogenic & infrastructure also similar to accelerator R&D
    - *Q: In practice, what kind of support do you need?*
        - *A: [opinion, not necessarily community] Many challenging and interesting research topics to solve. Could see that there is the need for "enforced" communication between different community. Difficult to understand what is going on in medical physics. Can iDMEu help facilitate communication and understand what different ongoing things are?*
    - *Q: ECFA detector roadmap happening now. How to integrate different efforts? APPEC Technology Forum also mentioned.*
        - *Zoom-chat: regarding the mentioned APPEC Tech Forum: one needs an Technological Topic, not a scientific one. Which specific technology do you have in mind for such a forum? Here industry and science could come together.*
        - *A: everything related to magnets and detection in general. Quantum detector. Precision and cryoengineering. Dielectric materials...we have a list, it would be interesting to dig deeper.*
        - *ECFA has experts in magnets. Detector roadmap and how it overlaps to APPEC/NuPECC: roadmap is oriented & driven by the European Strategy & projects listed in there. But input from neighboring fields are welcome. Want to capitalize on synergies, but we can't make a roadmap that covers all the areas because that's outside our scope.*
- Theory: how to compare in the context of different models?
- Astrophysics: a number of tantalizing hints need integrated in the current limits (e.g. stellar cooling, also constraints from supernovae), but also astrophysical inputs and assumptions should be fixed for all
    - *Speed in halo affects your limits. Can you describe how / point me to references?*
        - *A: you assume a Maxwellian halo. If you change the assumptions, you change the shape of your signal.*

Justin Read
Galaxy formation, including numerical simulations
15:45 - 16:10

Main points for discussion & future challenges [need slides uploaded to complete this part]:

- Inclusion of baryons is hard, but we're converging (but not yet at lower masses)
- *New techniques = machine learning? There is a tight correlation between rate at which stars form and DM halo, and that is enough to capture properties of simulation. We can try ML next.*
- Cosmological simulations are useful for calculating halos and other inputs needed by other communities
- *Q: In your simulation, can you predict black holes? Does it matter what is included in the black holes (DM or not)? A: Yes*

Coffee break
16:10 - 16:30

Dr Bradley Kavanagh and Djuna Croon
Primordial Black Holes and gravitational wave probes of dark matter
16:30 - 16:55

Main points for discussion & future challenges [need talks]:

- *How to connect GW instruments to other fields (e.g. DD, or others), beyond PBH*
    - *Example: https://arxiv.org/pdf/1909.00654.pdf (also https://arxiv.org/abs/1903.00492, and Sec V. of https://arxiv.org/abs/1907.10610 more generally)*
    - *A: There are many ways to probe DM but it's very model-dependent. Challenging to put constraints on there because one needs to make some assumptions. But now that we're going to have larger datasets, we identified opportunities and now it's worth thinking about how to connect to the other DM communities to identify regions of complementary space*
- *There are a number of constraints on evaporating PBH, how do you improve on that?*
    - *A: can go lower, MeV- or less-energetic photons -> some experiments can do that. Those constraints would however not reach down the interesting populations of PBHs. (see e.g. https://arxiv.org/abs/2104.06168, https://arxiv.org/abs/2010.04797)*
- *There are methods to search for extrasolar planets (e.g. star wobbles, light), are you considering those as well?*
    - *A: in the mass range the most interesting constraint is microlensing. Problem: you have to first capture a PBH around the star and get into a bound system.*
- *[BJK:] If we're comparing constraints from GWs/PBHs with constraints from direct/indirect/collider searches, how do we put them on an equal footing (given the large systematic/theory uncertainties in the former case)? Are there many examples of this kind of direct complementarity?*
- *[BJK:] As we move towards more 'complete' DM models (e.g. 2HDM, https://arxiv.org/abs/1701.07427, https://arxiv.org/abs/1810.09420) for LHC/direct/indirect searches, these models could give rise to phase transitions in the early Universe. Are there generic/robust predictions for whether a phase transition should happen (e.g. https://arxiv.org/abs/1509.08394, https://arxiv.org/abs/1711.09849)? Should we be including/considering constraints on GWs from phase transitions in these models?*

Maria Archidiacono
Dark Matter in Large Scale Surveys
16:55 - 17:20

Challenges and inputs:

- Large scale surveys can probe structure formation very well
    - But many systematic/theory uncertainties
- For dark photons / self-interacting DM, ETHOS can connect particle physics to structure formation's effective parameters
    - *Q: from Justin's talk, the challenge is the baryons - how much can you say about the nature of DM and how much do you need to say even more?*
        - *A: the majority of the uncertainty is about the baryons, but even if we don't look at the baryons & not use simulations (but rather new prescriptions and emulations) we have uncertainties about the DM*
        - *About the baryons, they are a large source of uncertainty. Distinction of different DM models, the suppression on baryonic feedback changes in case of self-interactions.*
            - *Detecting these variations with surveys: this possibility relies on the observation at very small scales, not weak lensing/clustering but rather strong lensing. If you have strongly interacting DM, the substructure of the halo will be different and you can be sensitive to deviations from different DM models wrt CDM.*
    - *Comment: very low mass range should also be included (dark photons axions)*
- Input in terms of parameter space & model selection via global fits (e.g. GAMBIT)
- Cross-correlation between large scale structures (lensing, galaxy, clusters, 21 cm) and Fermi gamma rays (e.g. https://arxiv.org/abs/1907.13484)

Oleg Brandt
The activities of the Dark Matter Working Group
17:20 - 17:45

Challenges and inputs:

- Direct and indirect detection uncertainties could be added to the plots as well, but we need input (and agreement) from these communities\
- New models being developed and studied by LHC community beyond the "low-hanging fruit" (e.g. t-channel models, dark photons minimal and not, rarer SUSY models, Wino/Higgsino…) → need established ways to put curves into a plot
    - *Discussion can happen e.g. between DMWG/PBC*
- *Model-dependence is very evident when you have to assume a mediator - are we displaying our assumptions clearly enough, or are we giving the wrong impression of "everything is excluded so the WIMP is dead" / "there is parameter space that others have already excluded"?*
    - *We know much more than when we wrote the "early Run-2 benchmarks" paper*
    - *PBC studies: for scalar/vector mediators*
        - *Couplings > 10^(-3) are already excluded*

    - *Discussion between PBC and DMWG will continue*
- *[Bradley J Kavanagh:] Do we also need to be careful about comparing energy-scales? Colliders probe O(TeV) scales and Direct detection probes O(GeV), meaning that other interactions can be 'switched on' between the scales due to operator running/mixing (e.g. https://arxiv.org/abs/1402.1173, https://arxiv.org/abs/1605.04917). This is occasionally something to worry about for (vector/axial-vector) simplified models. Is it something which is being explored for newer benchmark models? This may also be relevant for complementarity with beam-dump experiments.*
    - *CD, later: this has been investigated by the DMWG in 2017 (?) and it wasn't fully pursued as you said the effects were only relevant for certain models but studies should be continuing indeed, especially now that the complementarity with lower-energy experiments becomes more relevant*

José Francisco Zurita
The activities of the LLP WG and Community, in terms of Dark Matter
17:45 - 18:10

Challenges and inputs:
- Reinterpretation of LHC searches for different models (since there are many models)
- Freeze-in DM is needed for a number of models
    - *Q: this requires tools and constraints to the tools (to avoid going for freeze-in when it's not possible) → Micromegas discussion can continue*
- Would like to collaborate with other communities on:
    - Models of self-interacting DM solving cusp/core problems (e.g. SIMPs)

2020-06-11 - Community Talks

Christoph Weniger
Dark Matter Indirect Detection (photons and neutrinos)
14:00 - 14:25

Challenges and inputs:
- Main question: What is the precondition for enabling our community to agree on DM signals in photon/neutrino data (excluding obvious "smoking guns")?
- Indirect searches for dark matter with photons are often systematics dominated
    - Fermi GeV excess: Modeling of foregrounds and PSC populations
    - X-ray line searches: Background modeling
    - dSph: modeling of J-values for ultra-faint dwarfs
- Our statistical inference techniques force us to keep astrophysical and DM models simple
    - We only look for some of the signals (bb, lines, etc), no search for all possible WIMP spectra
    - We neglect many of the actual uncertainties (gas distributions, interstellar radiation field, source stochasticity, etc)
    - We define summary statistics rather than analysing all informative data directly.

        - This is contributing to divergent results between different groups, and makes it difficult to converge on interpretations and results as a community.
        - Not a problem for upper limits, but a problem if we want to discover a signal.
    - Simulation-based inference can remove that bottleneck. What do we need to exploit that?
        - **Experimentalists:** Publish fast instrumental forward simulators, for instrument response functions.
        - **Phenomenologists:** Results on inputs for indirect searches can/should be **published as samplers** rather
        - than mean values and error bars (e.g. random realizations of gas maps that fit the 21 cm observations).
        - We need a way to **share simulations**, in order to enable more realistic, e.g., GALPROP runs.

Nicola Tomassetti
Dark Matter Indirect Detection (charged particles)
14:25 - 14:50

Challenges and inputs (mostly relevant for antiproton experiments):
- Simplifying assumptions in interstellar propagation
- Cosmic ray modulation is sign-dependent and it's not yet always accounted for
- Uncertainties are often not broken down and can be large / help disentangling different effects
- Can exploit data from a variety of experiments (e.g. LHCb / ALICE / NA49/61 / Brahms) to constrain some of the cross-sections and uncertainties

Kerstin Perez
Dark Matter Indirect Detection (antinuclei)
14:50 - 15:15

Challenges and inputs:
- How to compare antinuclei results with other methods?
    - Antiproton production cross-sections
    - Antinuclei formation
        - Connections with collider & accelerators to improve on uncertainties
        - Connections to nuclear physics (e.g. ALICE)
        - *Which coalescence models can help the uncertainties?*
            - *Lower-energy antiproton beam at fixed target*
    - Propagation in galactic disk and solar field
        - Other ID experiments can help with this topic
- *Data sharing for GAPS?*
    - *Data management plan: "clean", calibrate and eventually release the data*
        - *No policy for making it public yet*
- *Are the ID data sharing policies similar across experiments?*
    - *Data sharing policies vary by funding agencies and funding mechanisms*
        - *E.g. NASA-funding has very small proprietary time, DOE/NSF have different policies*

Timothy Knight Nelson
Dark Matter at extracted beam lines
15:15 - 15:40

Challenges and inputs:
- Statistical treatment in various experiments (90% CL limits, discovery coverage, treatment of systematics)
- Complementarity plots for dark photons (and other mediators/portals) need both leptonic/hadronic channels. This shows that certain regions are harder to cover.
- Interfaces with other fields:
    - Proton fixed targets
    - e+e- colliders
    - pp colliders
        - In some cases minimal vs non-minimal models can't be compared (non-minimal: you need to assume a production at colliders)
    - *Do you find that the current discussion venues & information propagation to the experiments are sufficient?*
- Where we need more "interfaces"
    - Astrophysics - needs a common language
        - E.g. self-interacting DM
- What we need to make progress
    - Signal generation → documented database of benchmark models + instructions
        - Also embedding processes in medium, Geant4 simulation issues
        - Nuclear physics input needed (form factors, interactions with matter)
    - Background modelling
        - Especially extremely rare backgrounds, would benefit from common solutions

Coffee Break
15:40 - 16:00

David Marsh
Dark Matter Theory and Paradigmatic Models
16:00 - 16:25

Challenges and inputs:
- Every sub-field has its own challenges
- Inclusion of Non-particle DM

DM whitepaper writing (5 pages): how is that going / be organized
- Discussion on Mattermost (active during the symposium, last week)
- Bottom-up approach: people are discussing what they want to add
- A few people are responsible for the topic, multiple people can contribute to these papers
- If you want to contribute, go to the webpage and join mattermost https://www.eucapt.org/white-paper

Marc Kamionkowski

Dark Matter and/in the Early Universe
16:25 - 16:50

[Note: this talk referred to work done in the papers referred to in the presentation, see talk for details of specific challenges]

2020-06-11 - Full sets of slides for breakout sessions

17:00 - 18:00

Breakout session #1: Feebly Interacting Massive ParticleS (FIMPS), accelerators and cosmology - Moderator: F. D'Eramo
Slides:
https://docs.google.com/presentation/d/1NCfkgrWdPGYnkEQyE6YRWFevP__V5Tx433KvKJbNJA8/edit#slide=id.gd82c410e22_0_0

Breakout session #2: Data sharing in direct detection experiment - Moderator: F. Reindl
Slides:
https://docs.google.com/presentation/d/1k5XVOkcqXM2y3lR1k16IlabSvnySMQHn76_71-z7zhg/edit?usp=sharing

Breakout session #3: Hardware knowledge exchange - Moderator: B. Majorowits
No slide template, had a discussion

Breakout session #4: Future and uncovered community topics for iDMEu - Moderator: C. Doglioni
Slides:
https://docs.google.com/presentation/d/10Vm1wU5aqk5ai9-p4qlUj2aNH2Jz2X_PWaiz4kqCwCc/edit?usp=sharing

Template for breakout sessions:
https://docs.google.com/presentation/d/1IesgN6cYUMg9U03dKrAeECwCaS5KHC-ndR1Kgbas4Ug/edit?usp=sharing