RF6 kickoff meeting, August 12-13. Minutes and discussion sessions

August 12

[Minutes by MW]
Overview of RF6 by Stefania Gori [slides attached on indico]
- Schedule of this 2-day workshop
- Motivation for studying dark sectors
- Goals and organization of RF6
- Some more info about RF6

[Discussion]
- [AW] What about neutrinos? [NT] Neutrinos are SM, very different physics than DM motivated studies.
  Discussion about where these fit into the organization.
- How should I contact you if I want to do a study?
  Re: fill out the form at
  https://docs.google.com/forms/d/e/1FAIpQLSeLEgcQxYTooyS17LoR06GpZD2tXBu8QG4hQqvPTxSwTIE78w/viewform
- Where does DM scattering belong (referred to slide 10)? Re: first box, invisible non-SM

[Minutes to be added by BB and PS]
Theory Session
[GK talk] CG: Mentioned the possibility to probe invisible particles in eta decays
[AR talk] YDT: Re-analyze the gaps...some past experiments should be re-anayized since there are production modes that were not considered. (see e.g. https://arxiv.org/abs/1908.07525)
[AB talk] CD: how to characterize dark showers. Tomorrow's EF meeting

[CH talk, e+e-]
[MW] GAZELLE is a proposal?
[CH] It is an LoI to go in and then will be fleshed out with a white-paper.
[JF] Can you give more details on GAZELLE?
[CH] Good lifetime (100 ps), decent segmentation (for separation of decay products), same collider hall, how much shielding, reasonable cost.
[JF] 10 meters away?
[CH] 10s of meters away.

EF Session
[SG talk, LHC]

[GK] What about Z' masses that are heavier than the Z, with a 4 muon final state?

[JS] I have not heard of this being done, but one could fit cross-sections.

[SG] We proposed a search similar to this idea, because of the rate the bound is very very weak (trident paper). One could do better in the future. A couple of refs:
https://arxiv.org/pdf/1403.1269.pdf, https://arxiv.org/pdf/1511.04107.pdf,
https://arxiv.org/pdf/1609.04026.pdf

[GK] What happens if you have a very specific model, e.g. scalar coupling only to muons? Bounds then could be interesting.

[DR talk, LLPs]

[YDT] Agrees with DRs assessment of benchmarks vs signatures.

[MW] Should be further discussed.

[MC talk, mQ]

[JF] What is the signal - requiring something in each layer?

[MC] Hit in each layer within 15 ns consistent with IP.

[JF] What is the background that requires 3 -> 4 layers.

[MC] Cosmic ray showers.

[JF] Is there room for the fourth layer, things seem type?

[MC] The layers are 60cm rather than 80cm and are staged.

[YDT] Proposal for placing in forward physics facility. To be on arXiv shortly.

[MC] Would be ideal, rather than current location.

[ML talk on Future Facilities]

[NT] How can AF5-RF6 collaborate? [EP] AF5 is addressing technologies that are cross cutting, and also how AF5 can influence facilities that may benefit dark sectors. [ML] AF5 collecting and exploring options ATM, conversations needed to sort out how to move forward.

[JF] We now have an idea of UL on costs. AF5 can help judge viability / reality check to facility proposals.

[NT] AF5 engagement: Useful to expand on the table / plot showing us what facilities could do. Broaden awareness of a new facility and find use cases. [EP] Yes, that is in AF5. [ML] Agree.

[RB] Agrees would like to see AF5 help judge new facility ideas, promote them, etc.

[General agreement that there should be some dedicated meeting soon, and a session at the CPM. AF5 will look into organizing the first workshop.]

Discussion session

Questions: something missing? Something particularly to emphasize?

[CG]: looks like a duplication of PBC. Suggestion: Going a bit further.

Rather than picking up observables, should we present sensitivity to BRs, without specifying the model? The experiments are ultimately counting experiments.

[YDT]: proposal: divide into decay searches, scattering searches, invisible (DM+neutrino) production searches

[DR] we should be hesitant to reinvent the wheel. Division of the table is fine, but highlight the complementarity...make it clear that the minimal models are a metaphor...representative of physics that come from more complete models.

Concerning sterile neutrinos: keep it simple without much additional flavor structures...rabbit hole. Some processes could be classified in terms of BRs and sigmas...for example b->s transitions

[JF]: PBC: good sample of benchmarks. A bit frustrating that there can be experiments that are pushing the sensitivity by orders of magnitude, but one can see a tiny region of additional parameter space that is probed (short lifetime -> exponential suppression). This makes a big difference in perception on how the parameter space is seen. Example: 90% of the area is probed in the first 10% of the running. Picking a few benchmarks and present them in a clever way to avoid this problem?

[BE]: a second classification: more signature oriented table. This could show to experimentalists what to search for...maybe change some trigger

[PH]: What indirect measurements are critical

[CD]: all possible facilities in one plot. For that, we need to give very clear instructions. Emphasis on a small set of benchmarks. How to proceed in the prioritization.

[PS]: We need maybe to step back: what do we want to achieve with these benchmarks? If the goal is to convey the importance of the program, then we should present a set of benchmarks; this will be different if we want to show the breath of the possibilities.

[CG]: picking a signature, instead of a model. Not challenge a model vs. another. Already done in PBC

[MW]: a complication is that we have a 3D problem (mass-life time-BR). It can be complicated from the presentation point of view. One can present it in some model, and then one can recast in different models https://arxiv.org/abs/1801.04847

[CD]: we need to give a big picture as well. A simple message. To highlight the complementarity with other frontier (cosmic). We need a small set of simple benchmarks

[JF]: it s not that simple and immediate to have a recast. There are garbage curves shown in talks. It takes time. A lot of value to present things in a way that is impressive to people that are not experts

[NT] What are the plots to highlight the strength of this program.

PBC was in some way not complete (see the table by Natalia...things not in italic were not considered by PBC). We should not assume that PBC did everything. Some benchmarks proposed for BRN. The boundary conditions for snowmass were different than PBC and BRN

August 13
[SI talk, PIENU]
[JC]: slide 5: why not mono-energetic e^+ peak: energy smearing
[SG]: possibility to search for a non invisible X (either prompt or displaced). They are working on this
[CG] also eta factories produce a lot of pions

[DR] looking for mu^+ instead of e^+. They are working on this. Also in this case they could look for di-photon or di-e signals

[BB talk on nu experiments]
[YDT] DM scattering at MINOS? [BB] Maybe because of the longer baseline (1km) the flux is lower and not that much sensitivity. [KK] Nuclear scattering instead of electron scattering, because of the detector composition
[JB] has developed the tools for DM scattering in nucleons (generalization of Genie for DM scattering)
[BB] Boosted DM can be studied as well. Another interesting direction
[MT] complementarity between proton and lepton beams for neutrino experiments? [BB] e- and proton beams probe different couplings of the mediator. So it will depend on the model...e.g. scalar coupling preferably to quarks

[JB talk on neutrons]
[CG] is the proton beam at oakridge available or only to produce neutrons? Yes, one can collaborate to investigate DM possibilities. 1.4MW now will double in the coming years.
[MT] What fraction of the hall can be allocated to particle physics? [JB] 2nd target station primarily non particle physics focused, but to discuss with Leah. [MT] 1st target station was mainly dedicated to non particle, but to BES. Maybe Marcel is supportive for the 2nd target station. To follow up on this

[DR talk on Kaons]
[JZ] the pion gap is very small. ~5MeV. It is basically their mass resolution
[SG] on slide 17: one can go to lower masses with NA62. The bound was computed rescaling the NA62/48 measurement. Also one can avoid the 1/400 rescaling…[DR] this is coming from the pi^+ trigger, but, since we have 2 additional photons, maybe one can do something more clever
[BE] What about NA62 beam dump? [BD] the beamdump foreseen is 10^18 POT sometime during the next run, but we don't know when yet exactly. what is on tape is 10^16 POT, they are being analyzed . [NB] Also see
https://indico.cern.ch/event/755856/contributions/3263618/attachments/1779708/2894803/Spadaro_NA62_PBC_16_1_2019_v1.pdf
[DA] K -> pi X, X->ee what s the difficulty to look into this final state? [DR] For NA62 there is no difficulty. This decay mode should be added to the list

[ST talk on etas]
[MW] decays e.g. into e^+e^- would be picked by LHCb since LHCb is a eta factory
[JB] More details on JEF experiment (slide)? [ST] It s in hall D running simultaneously with GlueX. Designed around the forward calorimeter. Optimized for neutral decays of eta, eta' (any number of photons and pi^0)

[CG] Question re: slide # 12 Could the argument made on slide #11 be applied to the X(17) boson and look for that boson in the eta-> pi+ pi- e+ e- final state?

[TC talk on electron beam dumps]
[PH] What is the critical limiting factor in the missing energy resolution? Is it hermiticity? [TC] Resolution is quite good and we can cut on the missing momentum. However the critical background are escaped neutrons
[MT] How is the background treated on the projectons. [TC] ½ event of background 2-3 signal is the projection curves Typically no or small backgrounds are used but also limited cuts are sued.
[CG] Have you taken into account all new experiments? [TC] We do the best we can so that things are legible.

[TC talk on positron/electron beam dumps]
[SG] Its important to note the epsilon2 penalty is not a penalty since when DM is heavy all you have is the visible option. [MB] We need to present the complementarity well
[AF] Where does the heightened sensitivity come from the positron beam. [MB] The DM is proportional to the resonance, so by building a shower of many particles through a thick target and positron beam you can scan the possibilities of resonance production making a significant sensitivity for positron.

[NT talk on proton/muon beam dumps]
(No questions, great talk!)

[SG : Discussion on wrapping up]
[SG] Everybody is available to add comments here . If you have more comments feel free to add comments (see above for examples)
[SG] Any feedback on missing experiments? Or topics? =>
[SG] 1.Working on a follow up meeting with the Accelerator frontier.
[SG] 2. Working on a discussion on finalizing benchmarks
[MT] Re: TC talks. Since many limits are based on 2 accounts S and 0.5 Bkg would be good to standardize the limit procedure.
[MW] Will send out a poll on what's the appropriate length and talk frequency
[YDT] It would be good to consider a way to tie High energy with low energy since they shake hands at roughly 1 GeV.
[MW] We should make sure that we have all of our signatures soon; it takes time to run these benchmarks.
[MT] Thermal target is a great uniter of experiments and good benchmark. However there are simplifications since alpha dark is merged into this model and this gives a message that searches should be targeted first towards specific experiments at the cost of having the other final states come later. [NT] There is a lot of work in the cosmic visions exploring various scenarios and there are new papers from Patrick/Asher/NT/PS…. We should think about these scenarios because its important to focus on these parameters. One note is that experiments tend to get better as alphaD gets smaller. There are motivators already for beam dump

experiments vs. prompt approaches since coupling space is probed differently giving complementary sensitivity and this should be a focus. [MT] Thanks, agreed. However, we should be aware of unexpected final states. [SG] For snowmass it would be good to go beyond the DM motivation for Dark sectors; we should also consider other anomaly resolutions (like Axions) and perhaps other motivations that dark sectors can help resolve.

[PS] Its important to be sure to convey the simple message across about "why we should care about this". Considering the benchmark coming from P5. [SG] Still we should be good to discuss anomalies.

[CG] we should be sure to cover ALPs.

[NT] US started with visible searches and has progressed to invisibles b/c of a clear goal through the thermal target. It would be good to highlight a few specific benchmarks with "diverse" signatures to explain the importance of specific features.

[SG] Agree that we need to make some essential rules as to how to drive the targets.

[PH] Can we have a short list of benchmarks?

[PS] Can we come up with a few set of additional arguments that explain the motivations for additional dark sector searches?

[MT-chat] Suggestion: Can split this up into 1) Cosmological targets (thermal DM), 2) Data-driven targets (anomalies), 3) Theory-driven targets?

[TC/PS/NT combined] Invisibles

[JB] How can reconcile recet DD results with the dark searches

[CG] It would be good to keep the benchmark space open so that all experiments get the opportunity to pursue the benchmarks that are most interesting.

Discussion:

[MW] Here are some thoughts and comments on benchmarks in response to yesterday's discussion:

There are various goals at different levels for the RF6 final paper, and this benchmark discussion affects these in different ways.

We will want an executive summary that can do precisely what Jonathan said yesterday. We have discussed this a lot in our convener meetings. Producing a few money plots that properly push dark sectors without oversimplifying what the full space of signatures and physics is will take some effort / thought. This is a high-level goal of Snowmass and of RF6.

That said, we also will want to present a more detailed overview of all of the efforts, and be able to compare and contrast these. This will require presenting the full space of signatures and physics motivations. I think Natalia's table combined with Yu-Dai's comments from yesterday are a great way to approach this part. While most of this won't make it into P5, it's still really important and novel if we can manage to properly compare EF to RF experiments, show how

and where NF contributes, and also where advances in AF5 could increase our discovery potential. This goes beyond PBC which was very CERN and LLP centric.

In addition, we should be mindful of the timescales of producing input here, e.g. producing totally new curves for models that cannot be recast from others already being used requires a lot of time, whereas recasting or simply reformatting / refining the presentation of existing curves can be done quickly.

This timescale issue is why, to me, we need to decide ASAP if there are additional signatures that have not been considered that we want to study in Snowmass. If so, we need to give everybody time to provide proper inputs for these signatures. Even if not, we need to make sure everybody understands the full space of signatures we plan to consider, and make it clear how to provide inputs to us so that we can easily do the recasting and updated presentations for any models or presentation methods we may end up deciding down the road are useful for comparing different types of experiments or producing the executive summary money plots.

Everything else, I think, can be still discussed and hashed out as we go through the process. It's useful though to hear comments like from Yu-Dai already now, as this is helpful in thinking about how to put this all together.

In summary, the basic inputs from all of the experimental efforts are their sensitivity to various signatures and processes. Producing these takes effort and time; therefore, we need to decide on the list of these inputs very soon. We need these to compare and contrast various dark sector efforts, to highlight novel advances and to demonstrate complementarity that is often lost when plotting only the most minimal portal models. Ultimately we will need to produce some P5-level money plots, and starting to discuss this now is great, but we do have time to hash this out as we go.

Additional inputs:
DR talk: Minimal model benchmarks are merely metaphors for underlying (dark sector) phenomenology/physics; complete model benchmarks often 'bake in' many assumptions or theory priors.
We should be cautious about over-emphasis on coverage of benchmark spaces versus coverage of the space of dark sector phenomenology/ signatures. (Eg for LLPs: displaced decays in flight)

Discussion topics
-   Future meetings. We are planning to have additional half a day meetings on more focused topics. Any suggestion/request?
Interplay with facilities

-
- Other opportunities for RF6: Are we missing something?
- Benchmark scenarios and organization of the final RF6 white paper