

Beyond the Standard Model (at colliders)

Gian Giudice and Paris Sphicas

Apr 09, 2019

- **introduction**
- **BSM physics in the PPG**
- **Granada**
- **Ongoing work – next steps**

Topics in BSM – internal organization

1) Electroweak breaking dynamics and resonances

Composite Higgs, top partners, particles associated with EW breaking, heavy Z' and W'

2) Supersymmetry

Collider searches, motivations for supersymmetry after the LHC, unexplored corners, new models

3) Extended Higgs sectors and High-energy flavor dynamics

Two Higgs doublets, singlets, new particles accompanying the Higgs, leptoquarks, particles related to flavour dynamics at the EW scale, rare top decays

4) Dark matter

Collider searches, simplified models, comparison with direct/indirect searches

5) Feebly-interacting particles

long-lived particles, right-handed neutrinos at the EW scale, dark photons at colliders, dark scalar/relaxion, ALPs at colliders

BSM: the “think tank” (TT)

1) Electroweak breaking dynamics and resonances

Andrea Wulzer (CERN) – TH

Juan Alcaraz (CIEMAT) – EP

2) Supersymmetry

Andreas Weiler (TUM) – TH

Monica D'Onofrio (Liverpool) – EP

3) Extended Higgs sectors and High-energy flavor dynamics

Veronica Sanz (Sussex) – TH

Philipp Roloff (CERN) – EP

4) Dark matter

Matthew McCullough (CERN) – TH

Caterina Doglioni (Lund) – EP

5) Feebly-interacting particles

Gilad Perez (Weizmann) – TH

Gaia Lanfranchi (INFN, Frascati) – EP

BSM TT: mode of operation

- **Our plan: the content of the talks in Granada should come from a common thinking process (not simply result of individual work).**
 - ◆ Crucial part of the Members of the TT (MTT) job: (along with GG&PS) study BSM submissions and look beyond executive summaries into the detailed material in order to compile a comparison of proposed facilities and their impact on the various topics in BSM, to be presented in Granada.
 - ◆ Discuss together the outstanding questions, identifying possible answers.
 - ◆ Discussions involve other groups, submitters, etc.
- **Speakers in BSM session: the members of the TT.**
 - ◆ Scientific secretaries: ditto.
- **Post-Granada: MTT will contribute to content of the document**
 - ◆ Although much of the writing will be responsibility of GG&PS

Organization of BSM@Granada (I)

- **BSM days: Tue and Wed morning**
 - ◆ 09:00-11:00; 11:30-13:30
- **Triplet of issues for day 1 (Tue):**
 - ◆ ESWB/resonances
 - ◆ SUSY
 - ◆ Extended scalar sectors and HE flavor dynamics
- **A doublet of issues → overlap with DM group:**
 - ◆ Dark Matter (at colliders)
 - Joint session on Mon afternoon (during DM group time)
 - ◆ Feebly Interacting Particles (at colliders)
 - Joint session on Wed morning (during BSM group time)

Organization of BSM@Granada (II)

- **Typical layout per physics topic: allocate 80 mins/topic**
 - ◆ EX Summary – 30 min
 - ◆ Discussion – 10 min
 - ◆ TH Summary – 30 min
 - ◆ Discussion – 10 min
 - For now: accuracy of above $\sim\pm 5$ min
 - Note: DM session a bit different (extra talk: interplay with DD expts)
- **Two “global discussions” on Wed (40 min each)**
 - ◆ On the doublet (DM & FIPs)
 - ◆ On the triplet (ESWB/NewRes, SUSY, ExtraScalars&HEF)
- **Summary (80):**
 - ◆ Presentation of group conclusions + discussion
- **Overall: ~300 min for talks; 260 min for discussion**

Work since we started/currently ongoing

- **We have been having regular meetings since Feb 5**
 - ◆ Will continue until right before Granada
- **Identified four big questions for BSM (@colliders):**
 - ◆ To what extent can we tell whether the Higgs is fundamental or composite?
 - ◆ Are there new interactions or new particles around or above the electroweak scale?
 - ◆ What cases of thermal relic WIMPs are still unprobed and can be fully covered by future collider searches?
 - ◆ To what extent can current or future accelerators probe feebly interacting sectors?
- **We are NOT planning to provide an exhaustive list of reach for each and every model/parameter hypothesis.**
 - ◆ Rather, concentrate on wide comparisons that cover the essence of each thematic area

One example: FIPs (I)

- Very wide range of possibilities .AND. Models

- How to search for such broad class of models?
 - Following PBC: Simplified models (some tweaks).
- How to compare frontiers? Experiments?
 - Use benchmarks.
- Simplified models: four “portals”

PBC report, arXiv:1901.09966

Portal	Coupling
Dark Photon, A_μ	$-\frac{\epsilon}{2 \cos \theta_W} F'_{\mu\nu} B^{\mu\nu}$
Dark Higgs, S	$(\mu S + \lambda S^2) H^\dagger H$ (Relaxion toy model, mixes \w Higgs)
Axion, a	$\frac{a}{f_a} F_{\mu\nu} \tilde{F}^{\mu\nu}, \frac{a}{f_a} G_{i,\mu\nu} \tilde{G}_i^{\mu\nu}, \frac{\delta_\mu a}{f_a} \bar{\psi} \gamma^\mu \gamma^5 \psi$
Sterile Neutrino, N	$y_N L H N$

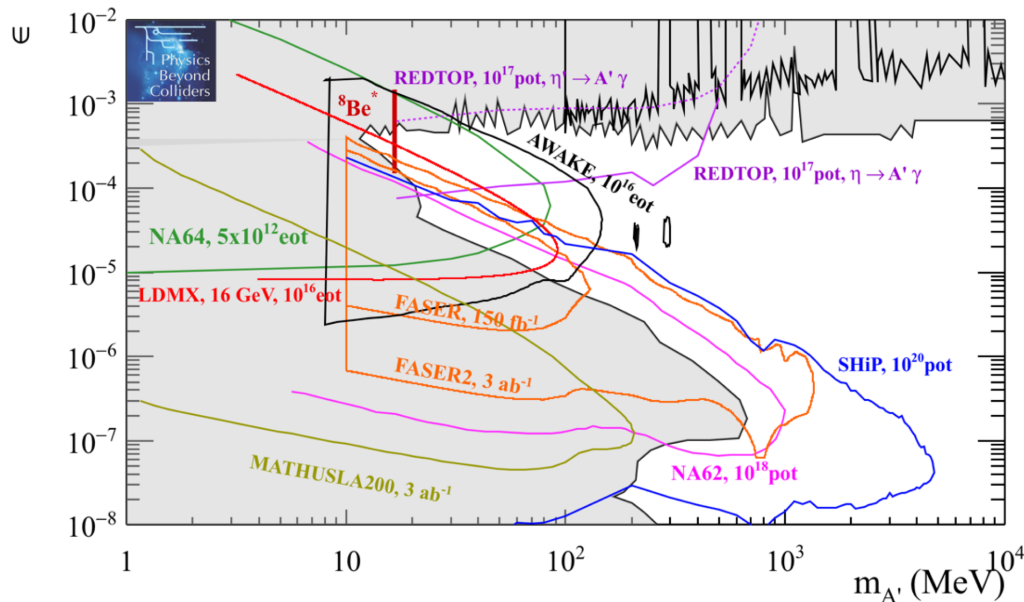
- From portals: identify benchmark cases to evaluate experimental sensitivities. Common ground to compare machines/experiments and put them in worldwide context

One example: FIPs (II)

■ Goal for Granada:

- ◆ Produce set of common plots (at least one per portal) for all relevant projects

Example of common plot in the PBC report: Dark Photon portal



PBC BSM report
1901.09966

■ We have been reviewing submissions + related material

- ◆ Sending questions and requests for additional info to submitters (or contacts designated by them)

Summary/Outlook

- **We are trying to provide an AMAP comparison between the different machines and experiments**
 - ◆ **And to see what we really learn in terms of big questions**
- **For more: please come to Granada for some physics discussions!**

- **We are very thankful to all the collaborations for the gigantic effort put into the submissions – and all the accompanying materials**
 - ◆ **We are grateful for answering our questions and for running some extra scenarios [or existing scenarios with different parameters, etc].**
- **GG and PS most thankful to members of BSM TT/TF**

Backups

One example: FIPs (III)

	ID	ALPs - $\gamma\gamma$	Refs.
LHC Run 2/3:ATLAS/CMS		OK?	Bauer et al, 1808.10323
LHC Run 2/3: LHCb		NO	
Belle-II	# 11	OK	I have to check
HL-LHC: ATLAS/CMS	# 152	OK?	Beyond the Standard Model Physics at the HL-LHC and HE-LHC – 1812.07831
HL-LHC: Heavy Ions	# 151	OK	ESPP input #151 and references therein
FASER	# 94	OK	FASER physics case, 1811.12522
MATHUSLA	# 75	OK	Mathusla Physics case: 1806.07396
HE-LHC	# 160	OK?	Bauer et al, 1808.10323 and BSM physics at HL-LHC 1812.07831
FCC-ee	# 101	OK	CERN-ACC-2018-0056 (FCC Vol1) and 1808.10323
FCC-eh	# 135	NO	
FCC-hh	# 135	NO	
CEPC	# 29	OK	CEPC Physics case, 1901.03170
ILC	# 77	OK?	Gilad et al, 1807.10842
CLIC	# 145	OK	The CLIC potential for New Physics, 1812.02093
Muon Collider	# 120	NO	

Added LHeC

Since list was compiled: we have been contacting collaborations for missing input/additional input/confirmations. Response very positive.

Overlaps with other PPG groups

- **Discussed with them (and beign discussed):**

- 1) Electroweak (Ellis/Heinemann)**

SM-EFT? High-energy effects and comparison with precision measurements? Operators with quarks and gluons?

- 2) Neutrino (Bentvelsen/Zito):**

Right-handed neutrino at colliders? New states associated with see-saw at EW scale?

- 3) Dark (Asai/Carena):**

DM at colliders? Dark photon and ALPs at colliders? Comparison between collider and non-collider results?

- 4) Flavor (Gavela/Zoccoli):**

Particles associated with flavor dynamics at the EW scale? Leptoquarks? High- energy consequences of flavor anomalies?