New Phenomena Searches in Heavy Ion Collisions

SNOWMASS21-EF7_EF8-207 [Bruce et al. 2020; Apolinário et al. 2020]

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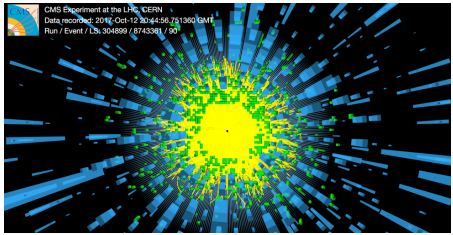
EF08: BSM — Model specific explorations

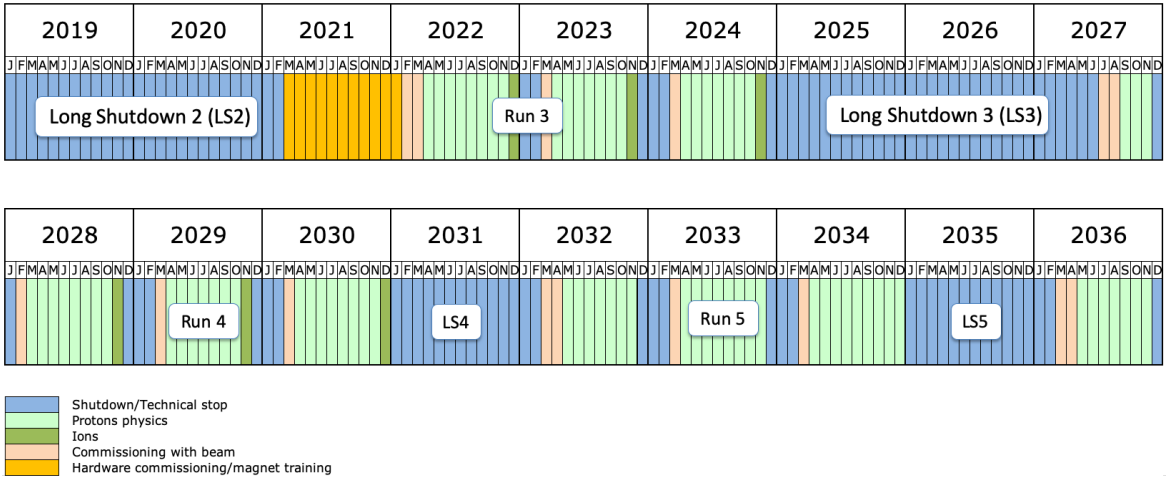
Heavy Ion Collisions

Properties

- Quark-gluon plasma (QGP)
- track multiplicity comparable to $\sim$ 200 pile-up in pp
- lower luminosity
- no pile-up
- large number of nucleons
- very strong electromagnetic field
- lower center-of-mass energy

Xenon event 2017





BSM search strategies

Photon-photon collisions

- EM field in ultra-peripheral collisions (UPC) have much larger fluxes than in *pp* collisions
- very clean environment
- Probe for modification of photon interactions such as axion like particles (ALPs)

New long-lived particles

- low luminosity allows for very loose kinematic triggers
- single primary vertex

New production mechanisms

- exotic QCD states such as strangelets or sexaquarks
- enhanced cross-section for magnetic monopoles

These models are mostly not supersymmetric and fit into

- Scans and limits of simplified models
- Other models benchmarks (lepto-quarks, etc)

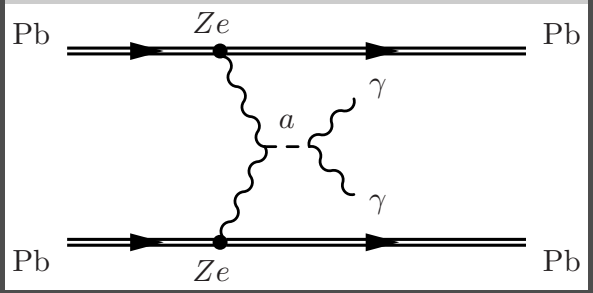
Ultra-peripheral collisions (UPC)

- heavy ions remain intact
- hard photons are emitted coherently
- no other signals in detector
- process scales with Z^4
- *e.g.* $Z = 84$ for Pb

Search for ALPs [Knapen et al. 2017]

- CMS [*CMS* 2019]
- ATLAS [*ATLAS* 2020]

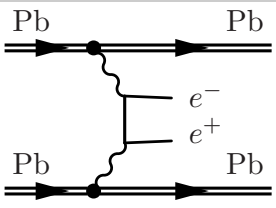
Axion-like particle production



Further processes

- lepton production e, μ, τ
- *e.g.* electromagnetic dipole moments of the τ-lepton [Beresford et al. 2019]

Lepton production



So fare unexplored

- more complicated hidden sectors *e.g.* $\gamma\gamma \to a \to a'a' \to$ SM
- Dark photons *e.g.* via pions $\gamma\gamma \to \pi^0 \to \gamma A'$ [Goncalves et al. 2020]

Further possibilities

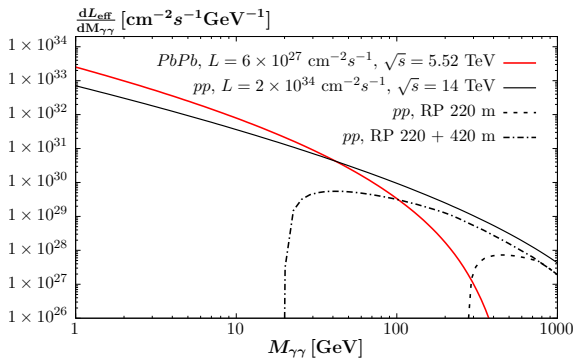
- Born-Infeld QED [Ellis et al. 2017]
- non-commutative geometries [Hewett et al. 2001; Horvat et al. 2020]

Non-perturbative production in the strong field

magnetic monopoles via magnetic analogoue of the Schwinger effect [Gould et al. 2019]

Axion-like particles

Effective $\gamma\gamma$ luminosity *vs.* γ-fusion mass



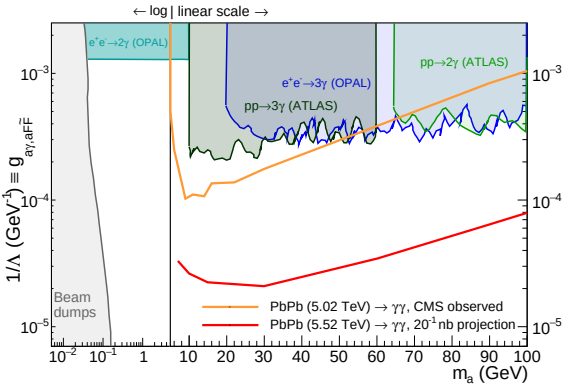
- PbPb *vs.* theoretical *pp*
- actual *pp* with current proton tagging
- actual *pp* with proposed proton tagging

Advantages

- no pile-up
- forward tagging of protons not necessary
- lower masses accessible

ALP-γ coupling ($g_{a\gamma}$) *vs.* ALP mass (m_a) plane

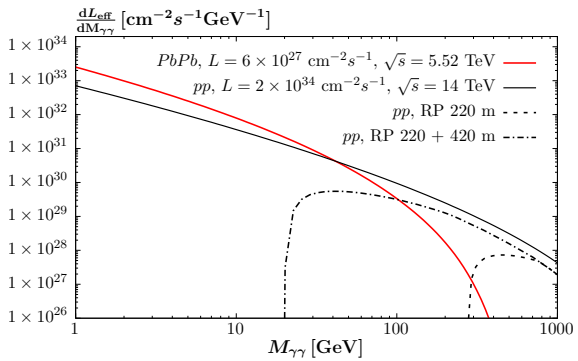
[*CMS* 2019]



- prior exclusion (shaded areas)
- PbPb UPC measurements
  - current CMS result (orange curve)
  - projections for 20 nb^{-1} (red curve)

Axion-like particles

Effective $\gamma\gamma$ luminosity *vs.* γ-fusion mass



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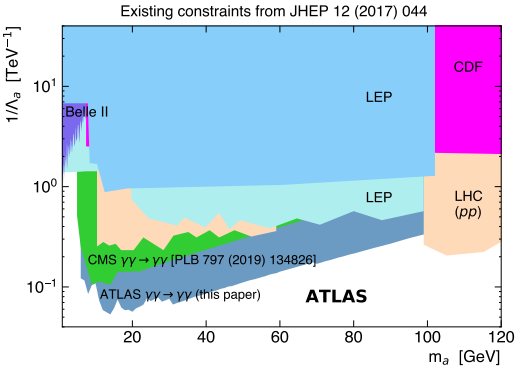
[*ATLAS* 2020]



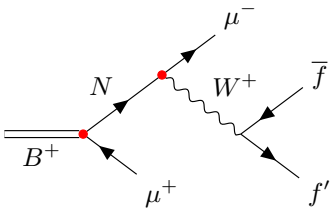
- prior exclusion (shaded areas)
- PbPb UPC measurements
  - CMS (green)
  - ATLAS (grey)

Long-lived particles

Intermediate Ions

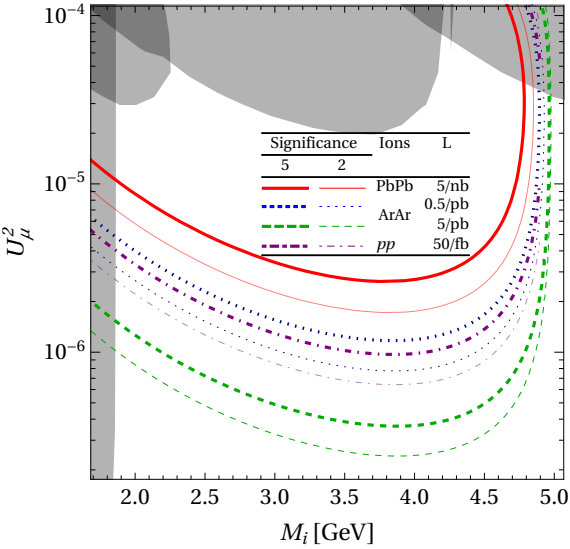
- luminosity shrinks with size of ion
- crosssection grows with size of ion
- heavy ions allow for much lower p_T cut
- therefore lighter ions allow can have an advantage

Heavy neutrino production [Drewes et al. 2020a]



- weakly interacting and long lived
- escapes QGP, detectable via displaced vertex

Heavy Neutrinos [Drewes et al. 2020b]

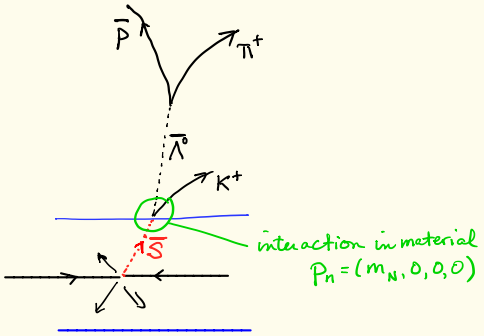


Intermediate (ArAr) ions can have an advantage over PbPb and pp

New production mechanisms

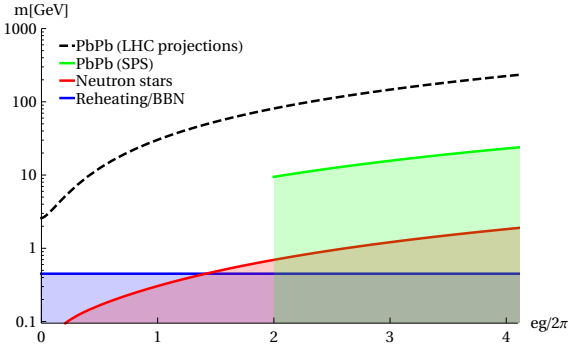
Sexaquarks [Farrar et al. 2020]

- six light quarks bound state $uuddss$
- neutral, color-flavor-spin-singlet
- (quasi-) stable with mass $m_S \simeq 2m_p$
- could explain DM
- hard to produce in particle collisions
- might be produced in QGP



Magnetic monopoles [Gould et al. 2017]

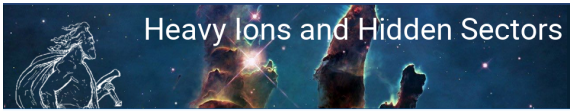
- magnetic monopole can not/hardly be produced in pp or e^+e^- collisions
- extremely high magnetic field of $\mathcal{O}(10^{16}\,\mathrm{T})$ in heavy ion collisions



magnetic monopole mass (m) *vs.* magnetic charge ($e \cdot g/2\pi$)

Community coordination

Workshop 2018 ['Heavy Ions and Hidden Sectors' 2018]



4-5 December 2018
Europe/Brussels timezone

Overview
Timetable
Contribution List
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Participant List
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Getting there and away

In the recent past, several proposals have been made to exploit heavy ion collisions at the Large Hadron Collider (LHC) to search for new phenomena, including axion-like particles, long lived particles or magnetic monopoles. The objective of this workshop is to bring together members of the involved communities to exploit the potential of these ideas, either in a parasitic mode or in dedicated runs at the LHC or future colliders. We want to provide a unique opportunity for theorists, experimentalists and accelerator physicists who previously had no or little exchange with each other to discuss new approaches as well as practical and fundamental limitations and form collaborations for future research.

There is no fee. Formal registration (required to join the conference dinner) closes on Friday November 30th at 12:00. Everyone is, however, very welcome to join the talks and discussions without registration!

Contribution to ESPP [Bruce et al. 2020]

OPEN ACCESS
IOP Publishing
Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. 47 (2020) 060501 (20pp)
https://doi.org/10.1088/1361-6471/ab7ff7

New physics searches with heavy-ion collisions at the CERN Large Hadron Collider

Roderik Bruce[1], David d'Enterria[2,18], Albert de Roeck[2], Marco Drewes[3], Glennys R Farrar[4], Andrea Giammanco[3], Oliver Gould[5], Jan Hajer[3], Lucian Harland-Lang[6], Jan Heisig[3], John M Jowett[1], Sonia Kabana[7,16], Georgios K Krintiras[3,17], Michael Korsmeier[8,9,10], Michele Lucente[3], Guilherme Milhano[11,12], Swagata Mukherjee[13], Jeremi Niedziela[2], Vitalii A Okorokov[14], Arttu Rajantie[15] and Michaela Schaumann[1]

Workshop 2021 ['Heavy Ions and New Physics' 2021]

17-21 May 2021
ECT* - European Center for Theoretical Studies in Nuclear Physics and Related Areas
Europe/Zurich timezone
Search...

Overview
Scientific Programme
Timetable
Registration
Participant List
Venue (ECT* Trento)
Accomodation & Parking

In view of the Covid-19 pandemic the dates of the Workshop had to be shifted to May 17-21, 2021.

Overview

In the recent past, several proposals have been made to exploit heavy ion collisions at the Large Hadron Collider (LHC) to search for new phenomena in particle physics, including axion-like particles, long-lived particles beyond the Standard Model and magnetic monopoles. The objective of this

Unfortunately shifted to next year due to Covid

Contribution to Snowmass [Apolinário et al. 2020]

New Phenomena Searches in Heavy Ion Collisions

Snowmass 2021 Energy-Frontier – Letter of Interest

Liliana Apolinário[1], Lydia Beresford[2], Nora Brambilla[3], Émilien Chapon[4], Yang-Ting Chien[5], David d'Enterria[6], Albert De Roeck[6], Marco Drewes[7], Mateusz Dyndal[6], Hesham El Faham[7], Glennys R. Farrar[8], Sylvain Fichet[9], Andrea Giammanco[7], Victor P. Goncalves[10], Oliver Gould[11], Jan Hajer[7], Lucian Harland-Lang[12], Sonia Kabana[13], Simon Knapen[6], Vladimir Kovalenko[14], Georgios K. Krintiras[15], Jesse Liu[16], Steven Lowette[17], Michele Lucente[7], Daniel E. Martins[18], Guilherme Milhano[1,19], Matthew Nguyen[20], Vitalii A. Okorokov[21], James Pinfold[22], Arttu Rajantie[23], Patricia Rebello Teles[24], Federico Leo Redi[25], Ingo Schienbein[26], Matthias Schott[27], Gustavo Gil da Silveira[28], Rajeev Singh[29], Michael Spannowsky[30], Jiayin Sun[31], Ralf Ulrich[32], Merijn van de Klundert[33], and Michael Winn[34]

We aim to update the proposals for New Physics searches in heavy ion collisions

Conclusion

- Heavy ion collisions provide a complementary environment for new physics searches
- Searches in the ultra-peripheral collisions have been proposed and performed
- Searches in the hard collisions are considered
- We plan to contribute a white paper with updates for these searches for the Snowmass process

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