Introduction to BSM session

The experimental view

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Introduction

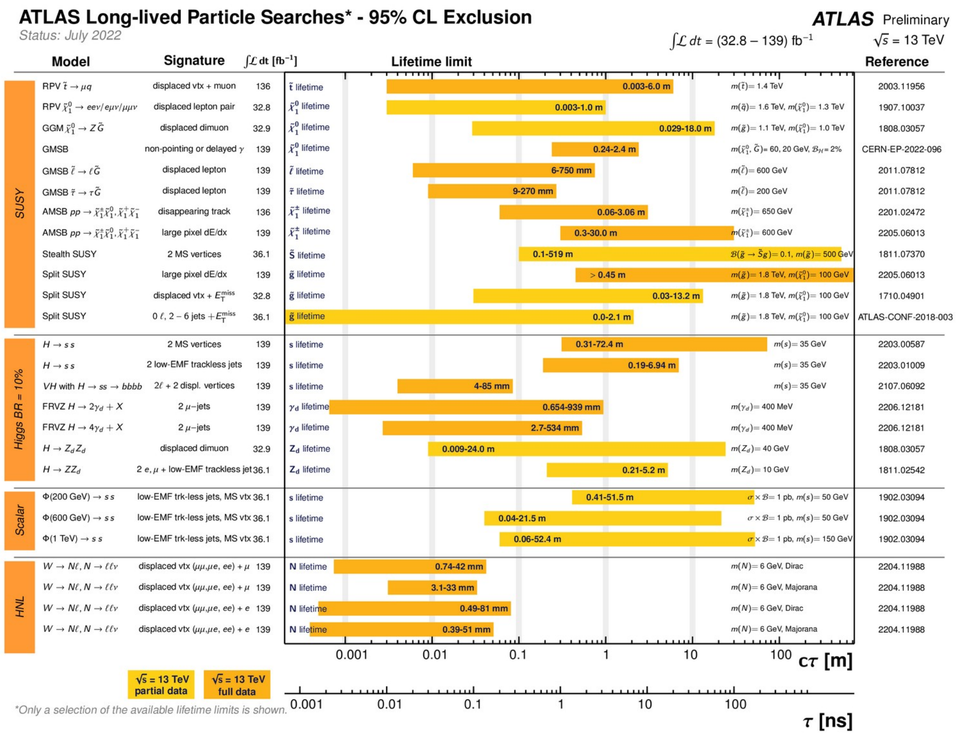
BSM at FCC:

- Approaches:
  - Direct detection of signals for new particles
  - Precision measurements: deviations from SM expectations
- Machines:
  - FCC-ee: precision machine: clean environment, limited CMS range, very high statistics
  - Fcc-hh: discovery machine: explore new energy regime

Main experimental thrust of PED BSM group:

- Define promising scenarios for direct BSM search at FCC-ee
- Establish requirements on detector design on the basis of detailed physics studies

The broader research goal



At the end of the HL-LHC, if no BSM found:

Top -down approach (theo):

Develop solutions to big issues:

naturalness, etc. compatible with LHC data

→ see talk by Tevong

Bottom-up approach (exp):

Among well-motivated models: FCC-ee signatures to which LHC not sensitive

- Low mass: obligated, but also opportunity, LHC typically reduced sensitivity at low masses
- Low couplings: profit from 10^{12} Z statistics, and better analysis efficiecy because of cleaner environment

→ Long lived: opportunity for detector optimisation

List of topics

Cross-check a recently circulated list of ECFA-WRG1-SRCH

(Rebeca G-S. is convener both for us and for that group)

– Heavy Neutral Leptons *

– Exotic Higgs boson decays *

– Light SUSY scenarios and scenarios with light scalars

– Axion-like particles (ALP) *

– Z’, dark photons and other light mediator scenarios

For items with * organised activity in our community, addressed

in talks by G. Ripellino and S. Kulkarni

For SUSY I’ll discuss some benchmark possibilities

Group organisation

Exp Conveners:

Rebeca Gonzalez-Suarez, GP

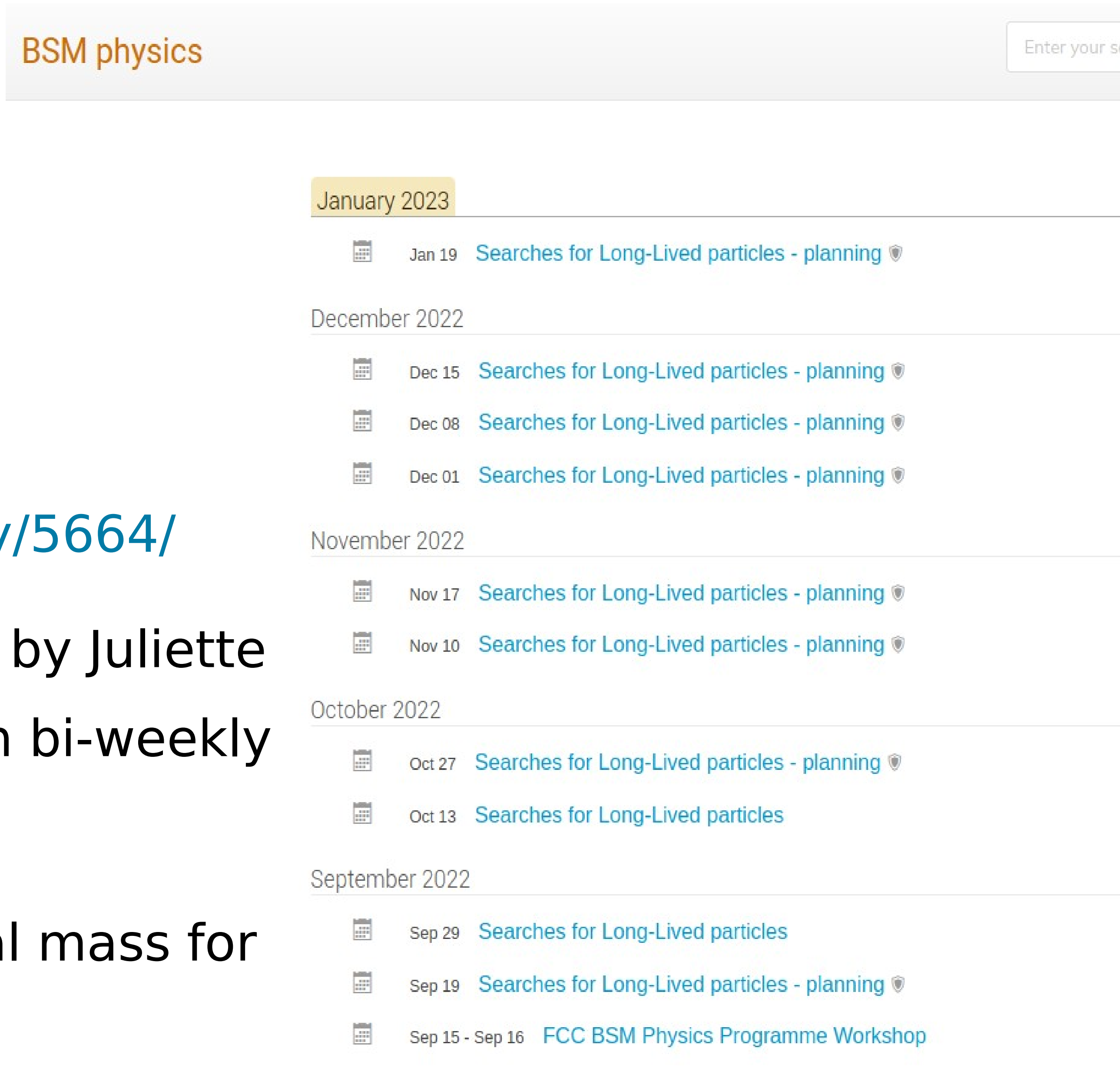
MC contact: Sarah Williams

Indico category:

https://indico.cern.ch/category/5664/

Very active LLP group chaired by Juliette Alimena (~10-15 people) with bi-weekly working meetings

Working on developing critical mass for prompt signatures



SUSY

Not very popular anymore, but holes in LHC offer opportunity for FCC-ee.

Two obvious examples:

- Compressed slepton
- Higgsino

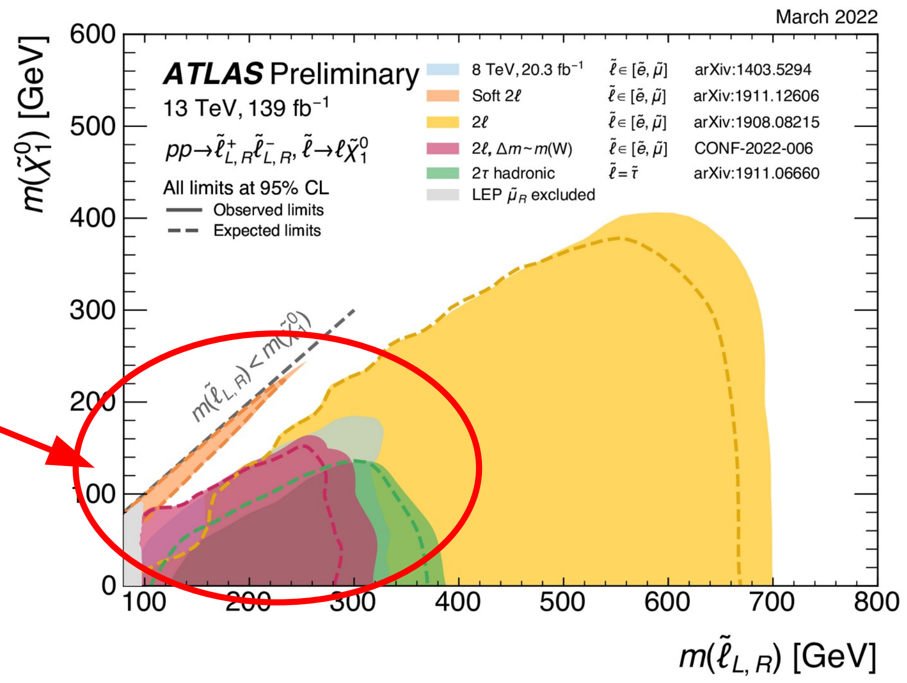
Need to verify what kind of challenges for detector design these signatures provide.

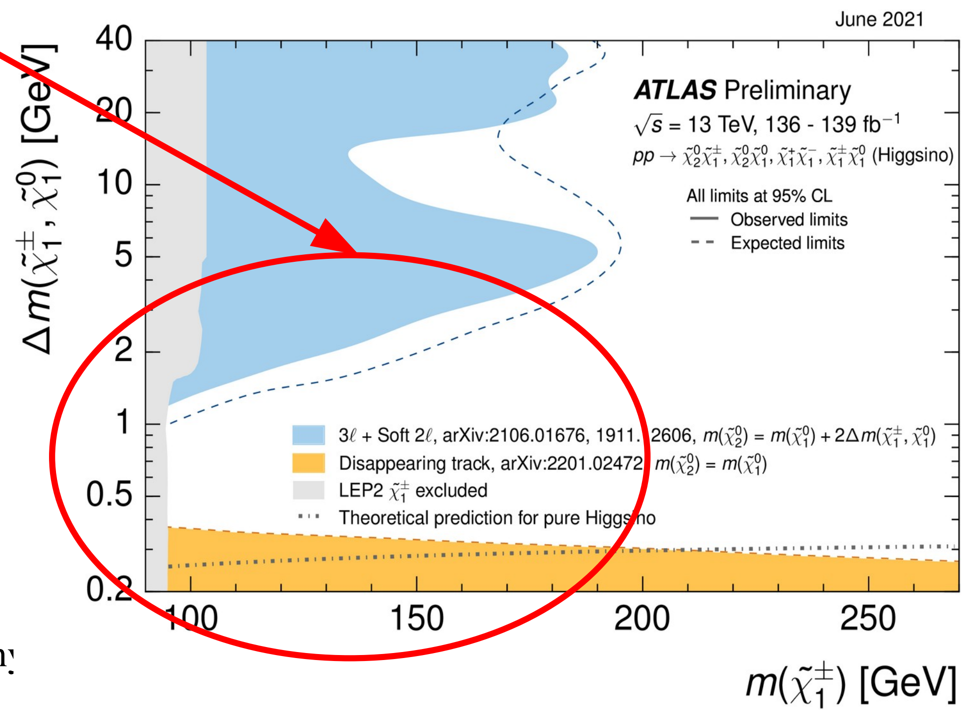
pMSSM scans can show uncovered points in gaugino parameter space

Need explicit benchmarks.

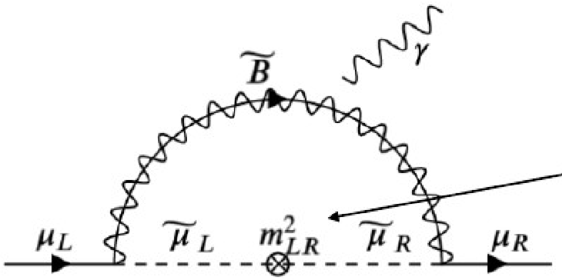
- Input from ATLAS/CMS pMSSM studies
- Input from theory, see e.g. the paper from one of our theory conveners:

  https://arxiv.org/abs/2207.05103





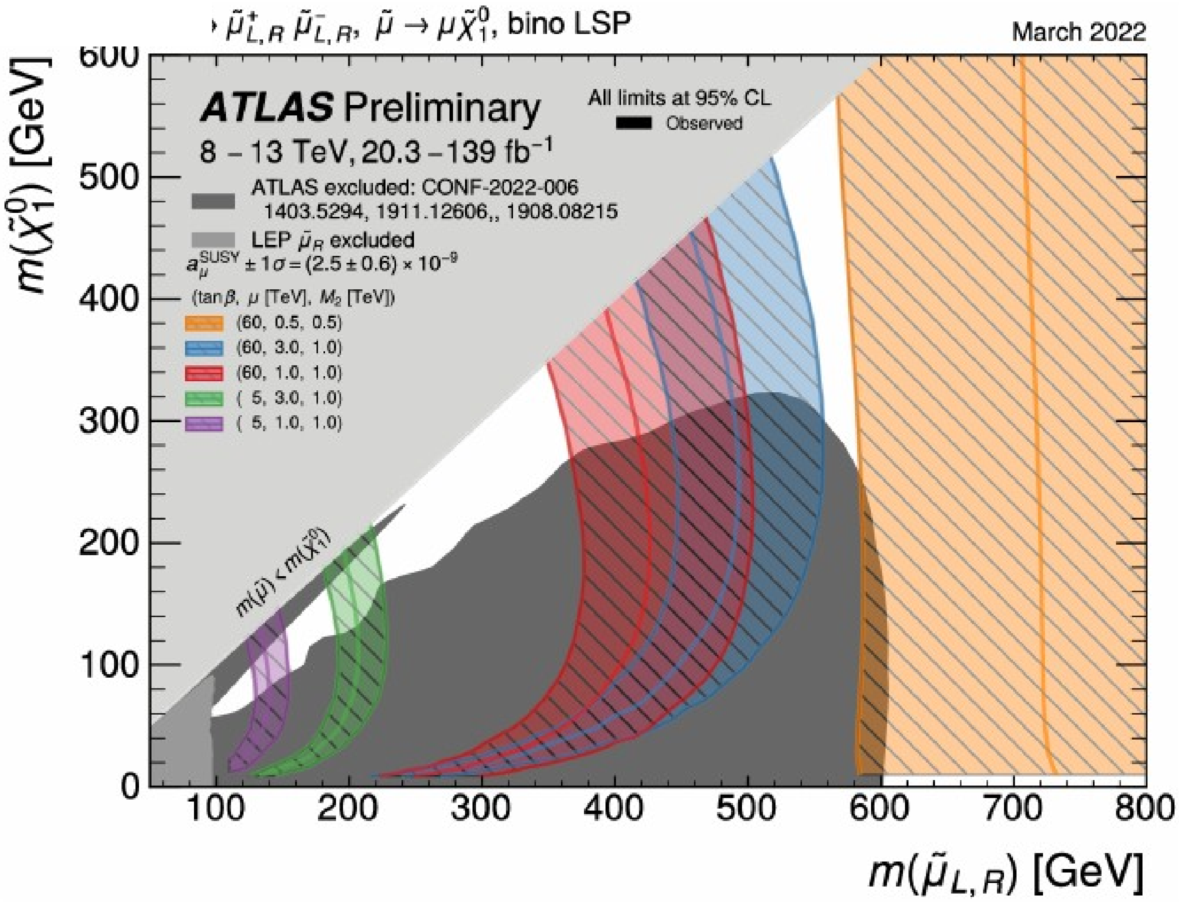
SUSY: g-2



$$m^2_{LR} = m_\mu \mu \tan\beta$$

From a talk by R.Barbieri

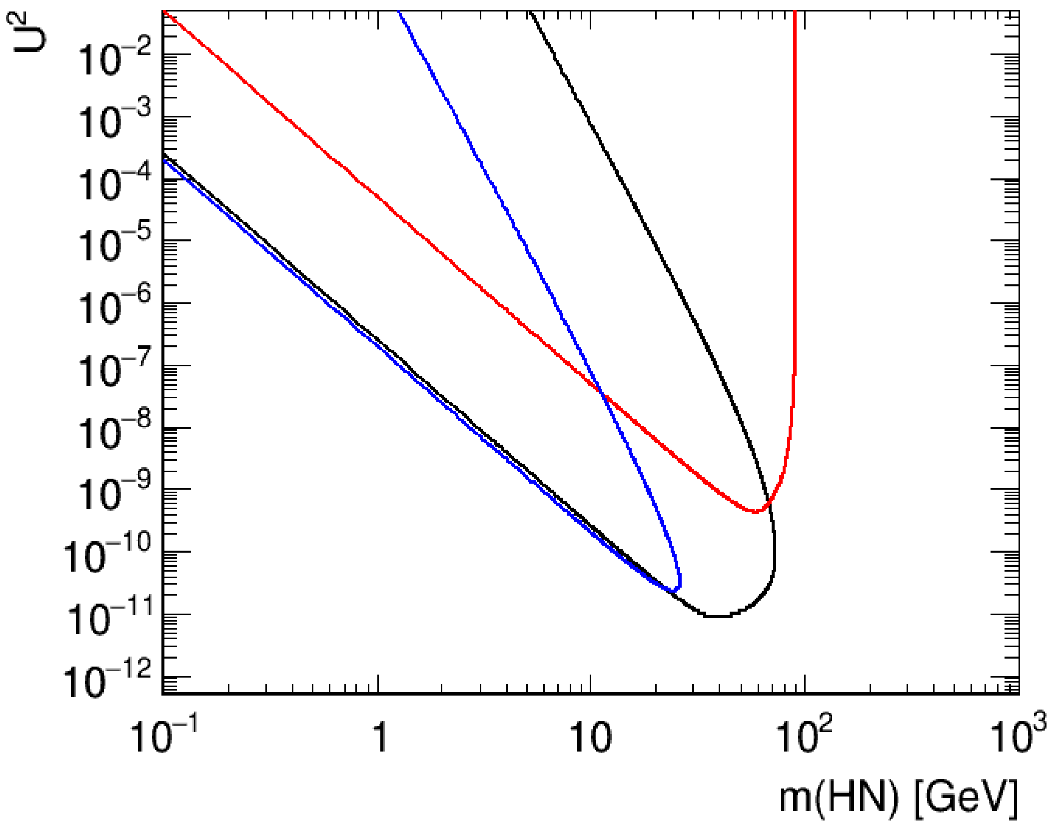
g-2 discrepancy can be explained with light sleptons
FCC should be able to cover uncovered area relevant for this explanation



Possible benchmark:
Simplified model: direct slepton production with
m(slep)=150 GeV
m(chi01)=100-140 GeV

Prompt vs LLP

Generically reach is defined in m(new physics)-coupling plane
True e.g for ALP, HNL



Complementary reach of three different signatures:

- Prompt
- Decay in inner detector
- Decay in calo/muon detector

Study of coverage for a given model should address all three signatures.

Very different experimental requirements

HNL

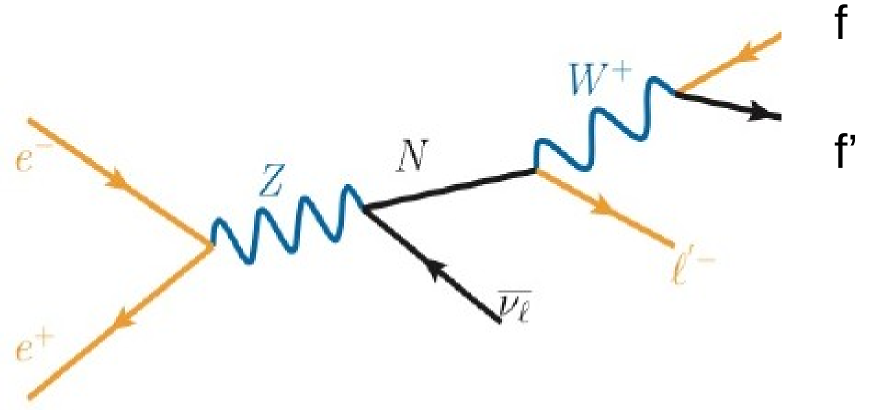
See talk by S. Kulkarni

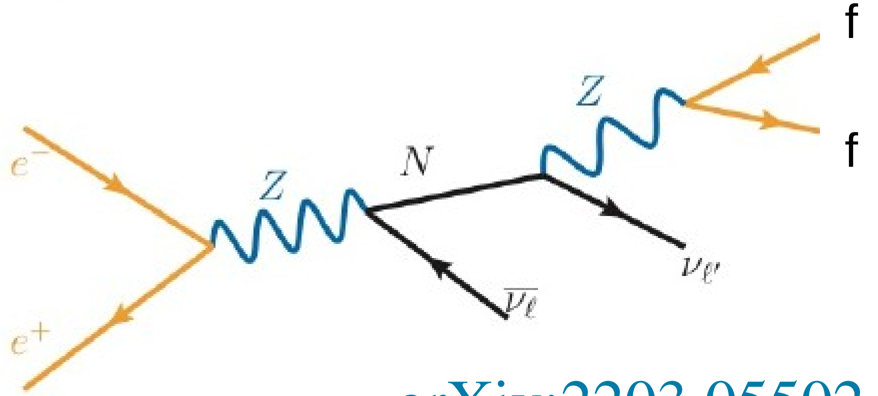
Rich set of final states and signatures, significant interest in the group for prompt and LLP signatures, in particular

- eenu: LLP in ID
- ejj and μjj prompt
- Dirac vs. Majorana

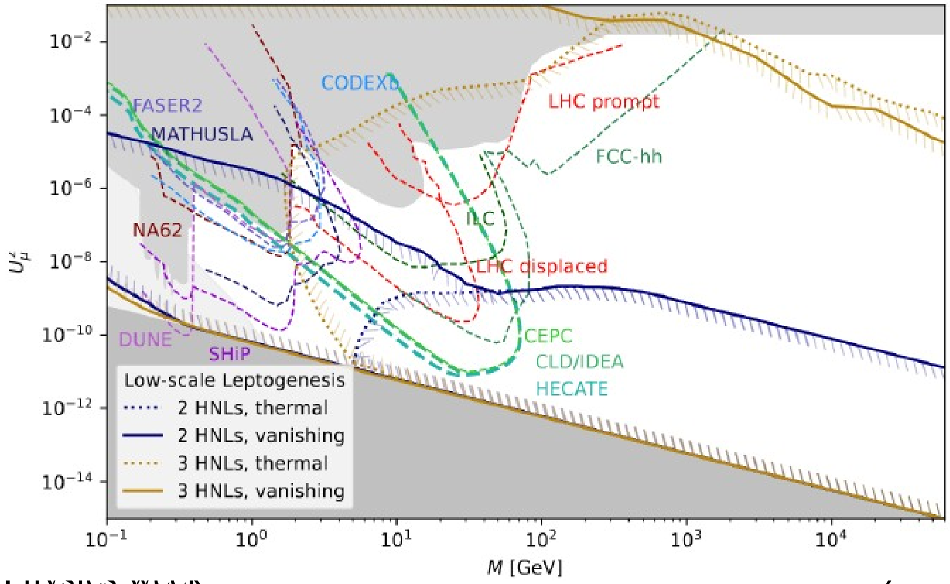
Analysis matrix

- Decay final state:
  - j j l
  - j j nu
  - l l nu
  - j nu nu
- Decay length
  - Prompt
  - LL decay In ID
  - LL decay in Calo

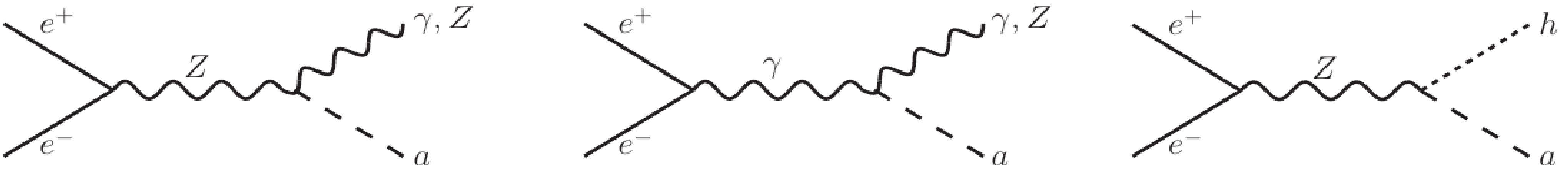




arXiv:2203.05502



ALP



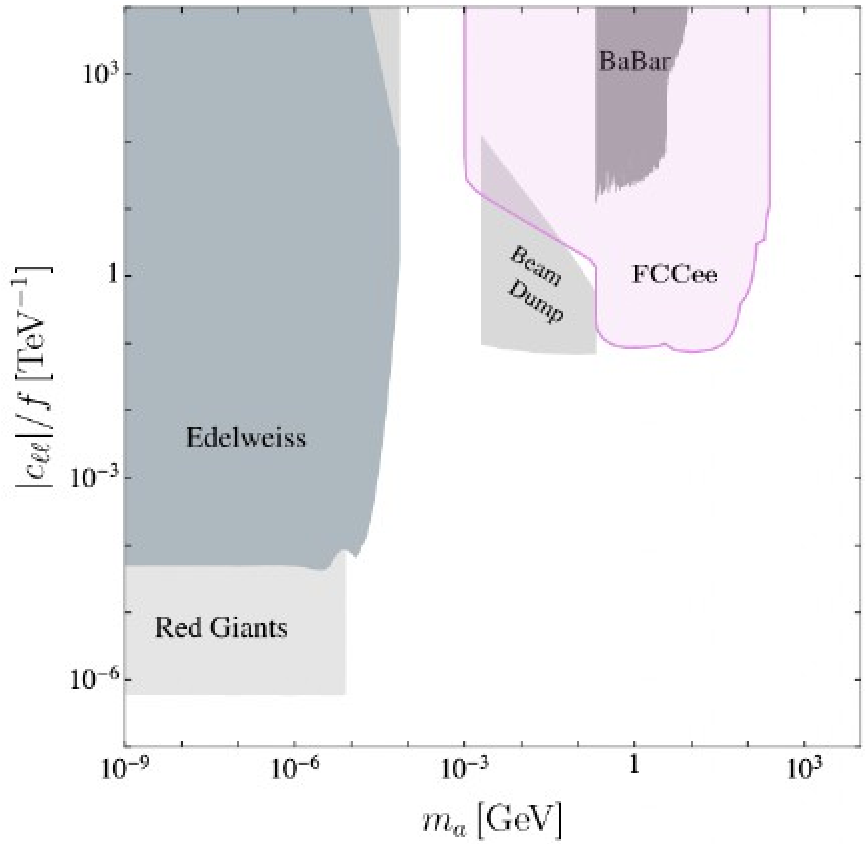
Simplified model with many possible signatures, e.g.

- γa, a→γγ
- γa, a→ ll
- ha, h→bb, a→ γγ

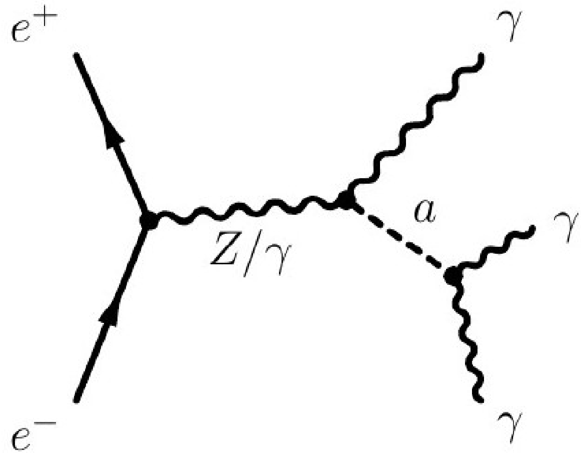
Different decays of a, depending which couplings non-zero

Both long-lived and prompt signatures, would be useful to define benchmarks beyond 3γ

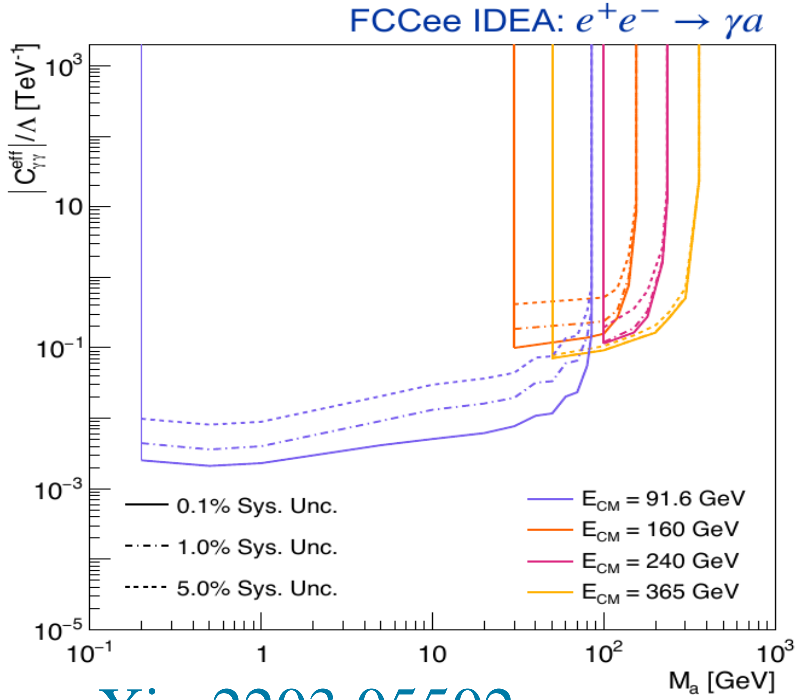
arXiv:2203.05502



ALP: 3γ final state



Thesis L. Pezzotti



3 photon state considered in preliminary detailed studies,

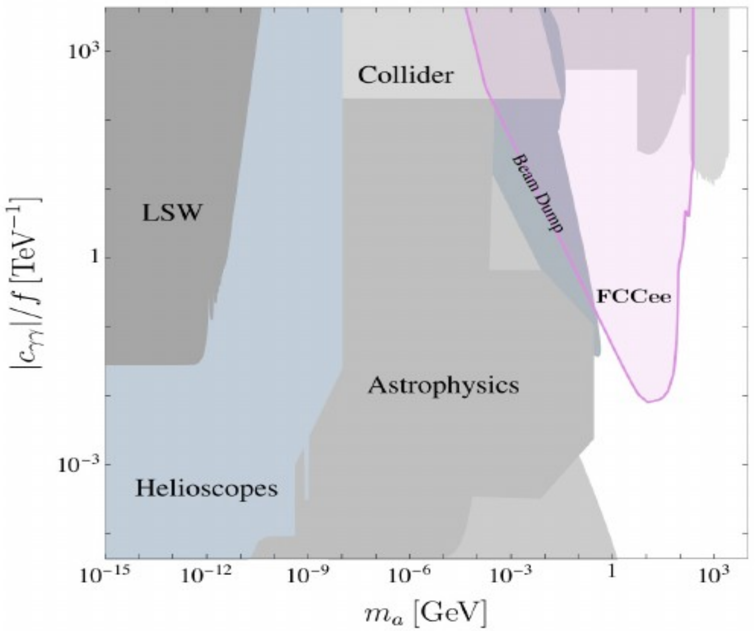
- Prompt
- Long-lived: see talk by G.Ripellino

Experimental implications:

- Mass reconstruction for very collimated photons
- Timing of photons for LLP

Key role of preshower?

arXiv:2203.05502



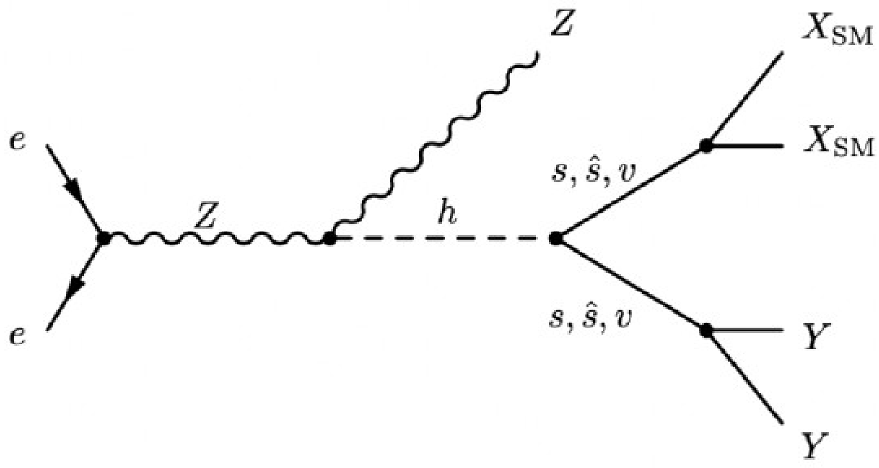
Exotic Higgs decays

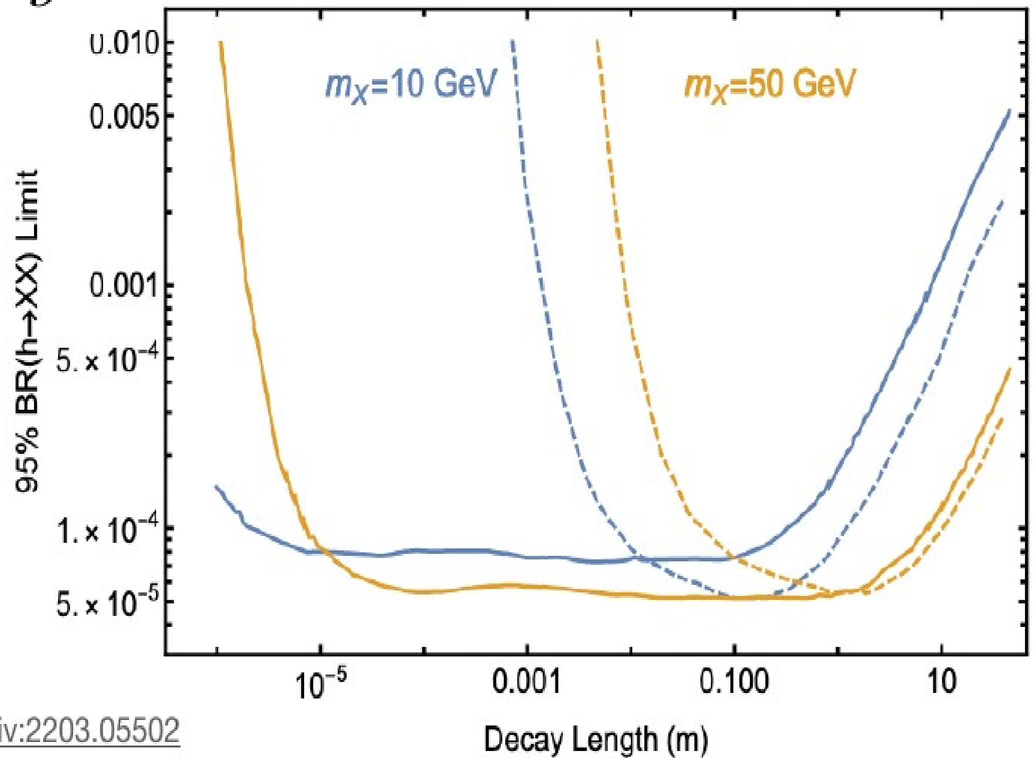
Higgs portal is one of favourite doors to new physics

Very recent work for the final state

$$e^+e^- \to Z \to Zh,\, Z \to l^+l^-,\, h \to ss,\, s \to b^+b^-$$

See talk by G. Ripellino





arXiv:2203.05502

Conclusions

Rich menu of BSM final states available for discovery at FCC-ee

Focus on models involving low-mass particles with feeble couplings to SM

Benchmark in these models are being identified

Present work mostly focused on detailed analyses of reach for long lived exotic particles

→ important detector challenges to exploit the signatures

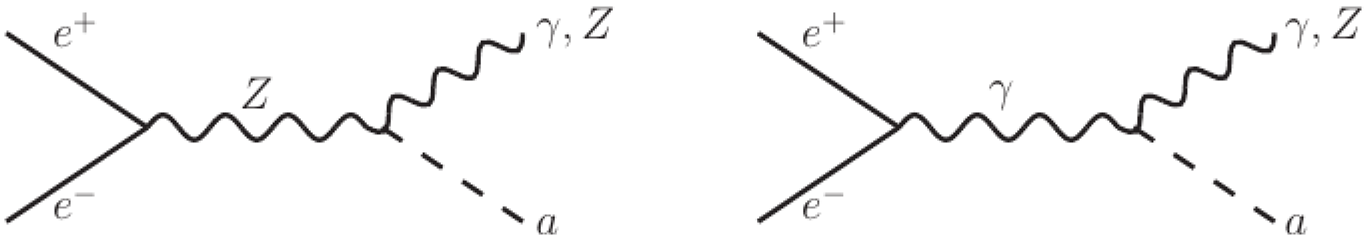
Follow the talks of Giulia Ripellino and Suchita Kulkarni for more details on ongoing work

Backup

The model

$$\mathcal{L}_{\rm eff} \ni e^2 C_{\gamma\gamma} \frac{a}{\Lambda} F_{\mu\nu} \tilde{F}^{\mu\nu} + \frac{2e^2}{s_w c_w} C_{\gamma Z} \frac{a}{\Lambda} F_{\mu\nu} \tilde{Z}^{\mu\nu} + \frac{e^2}{s_w^2 c_w^2} C_{ZZ} \frac{a}{\Lambda} Z_{\mu\nu} \tilde{Z}^{\mu\nu} .$$

We are interested in the associate production of a and γ



- Assume a only couples to hypercharge and not to SU2 $C_{\gamma Z} = -s_w^2 C_{\gamma\gamma}$
- Assume BR(a→ γγ)=100%

Experimental reach can be represented in 2-d M_a-$C_{\gamma\gamma}$ plane

Implemented in two UFOs: Brivio et al.:arXiv: 1701.05379

Bauer et al:arXv:1808.10323

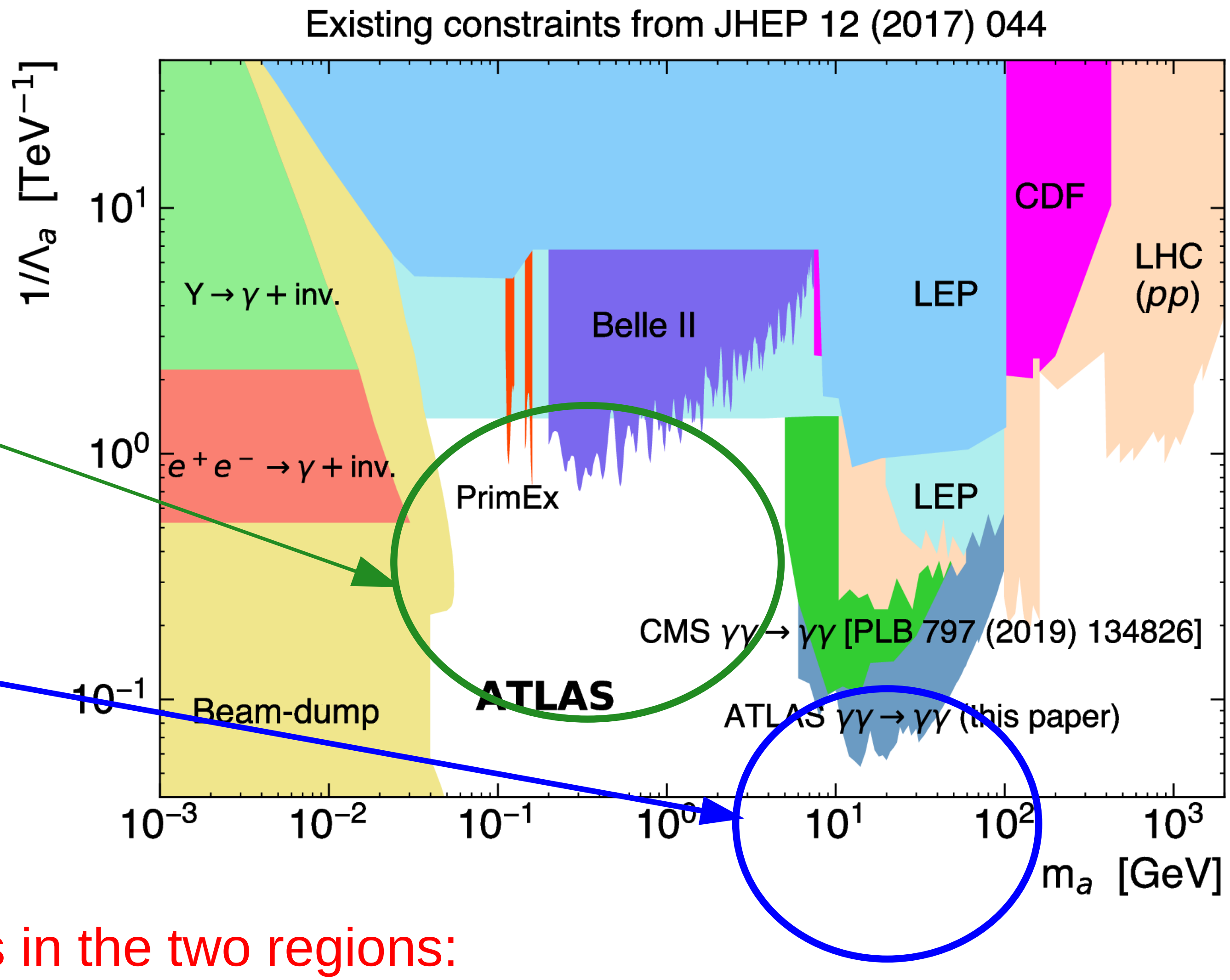
Checked that the two UFOs give the same results, use Bauer et al. for generation

Existing limits

Two mass ranges:

<~100 MeV – ~5 GeV:
Can we cover this difficult region?

>~5 GeV
Are we sensitive to lower couplings than the ones explored at the LHC in photon-photon collisions?



Different experimental issues in the two regions:

- >5 GeV: energy resolution
- <5 GeV: separation of two very collimated photons, resolution on position measurement

Figure from:

ATLAS:arXiv 200805355

Comparison with existing limits and projected reach

In the 10-100 GeV region FCC-ee reach in the same ballpark as projected PbPb LHC result

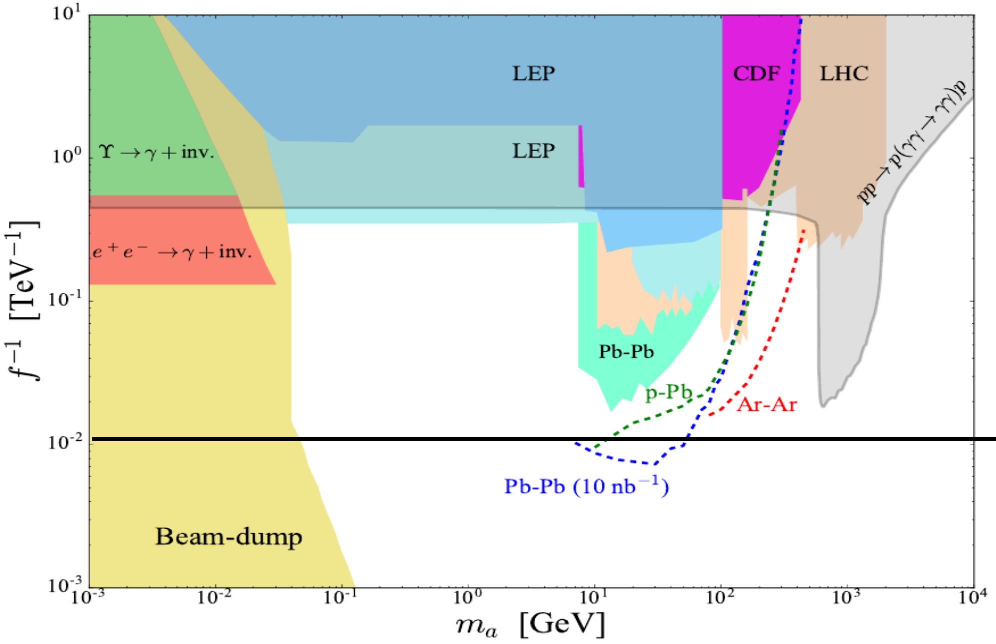
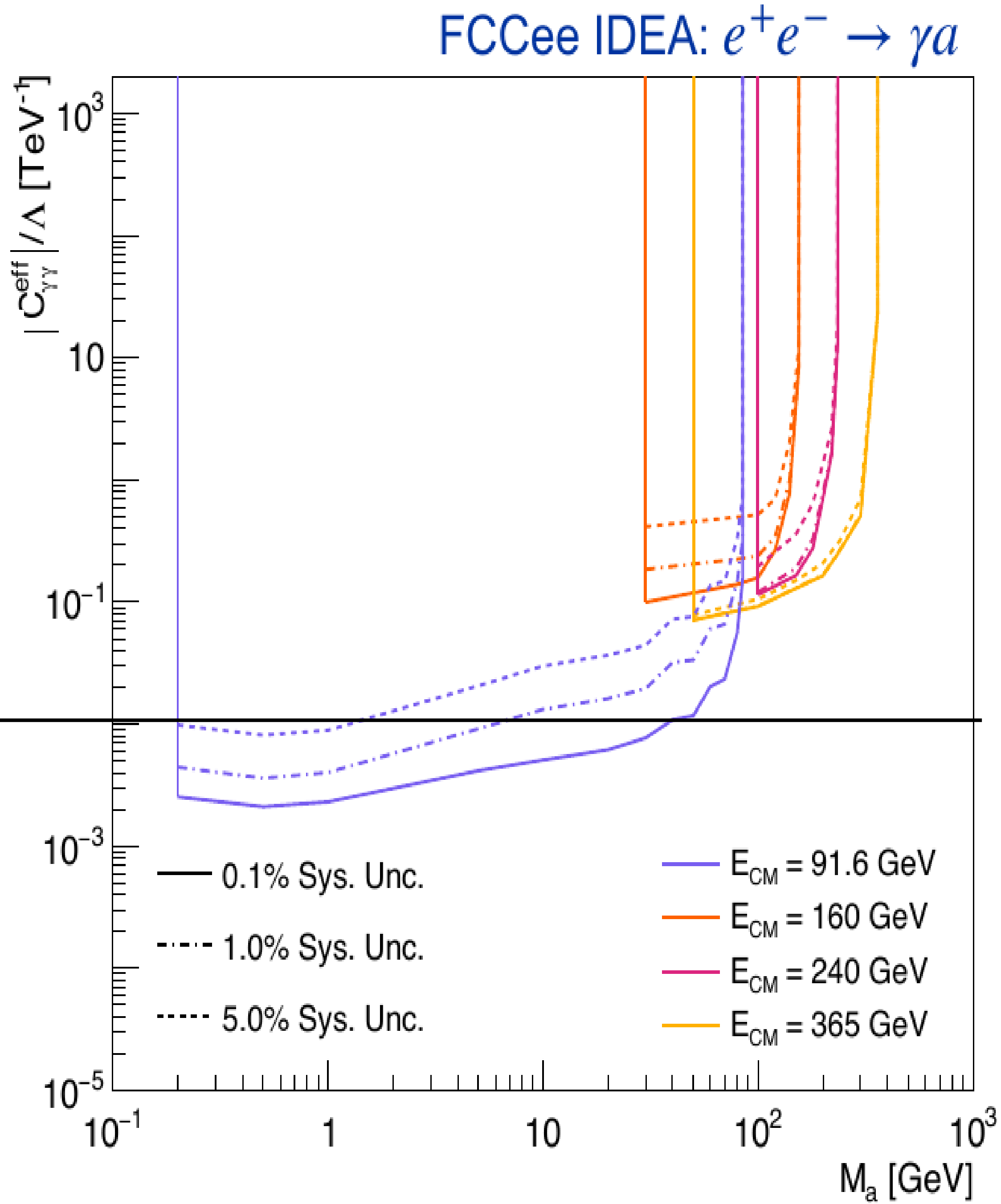


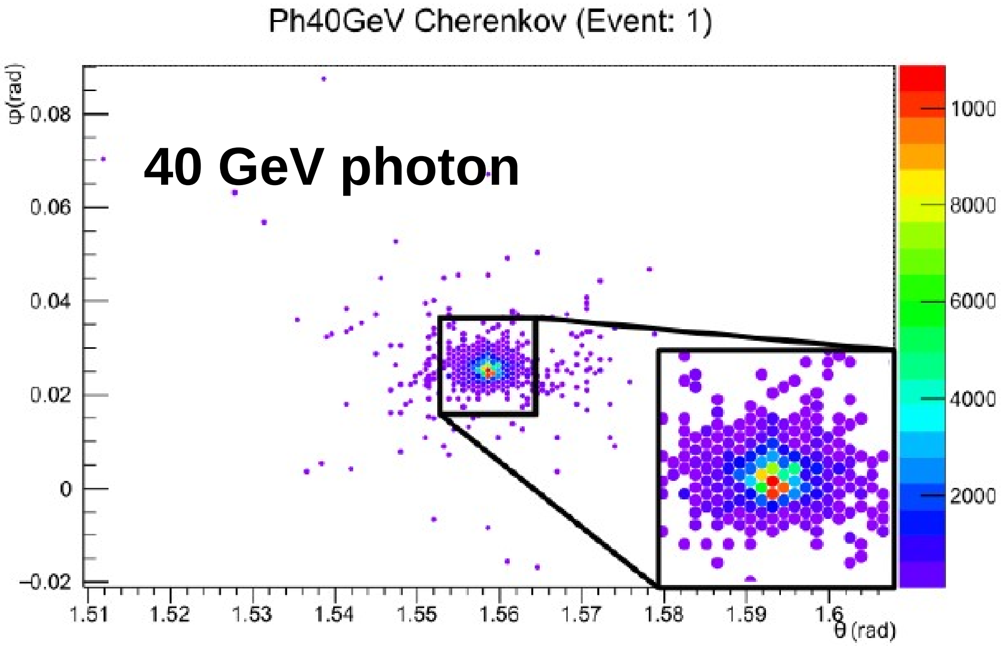
Figure from

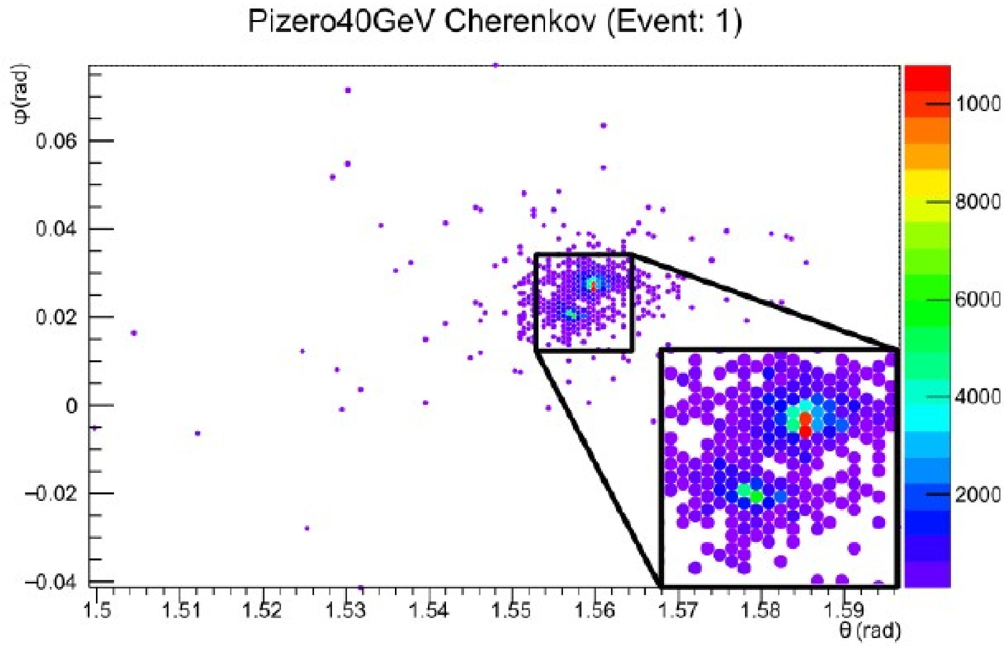
Schoeffel at al. arxiv:2010.07855



Example: exploiting the full granularity of IDEA DR Calo

With Silicon PMs it is possible to read one by one all of the fibers in the calorimeter → possibility to separate very close photons and to precisely measure invariant mass





Ideal field of application for ML image recognition, work ongoing in Pavia (master thesis A. Villa)