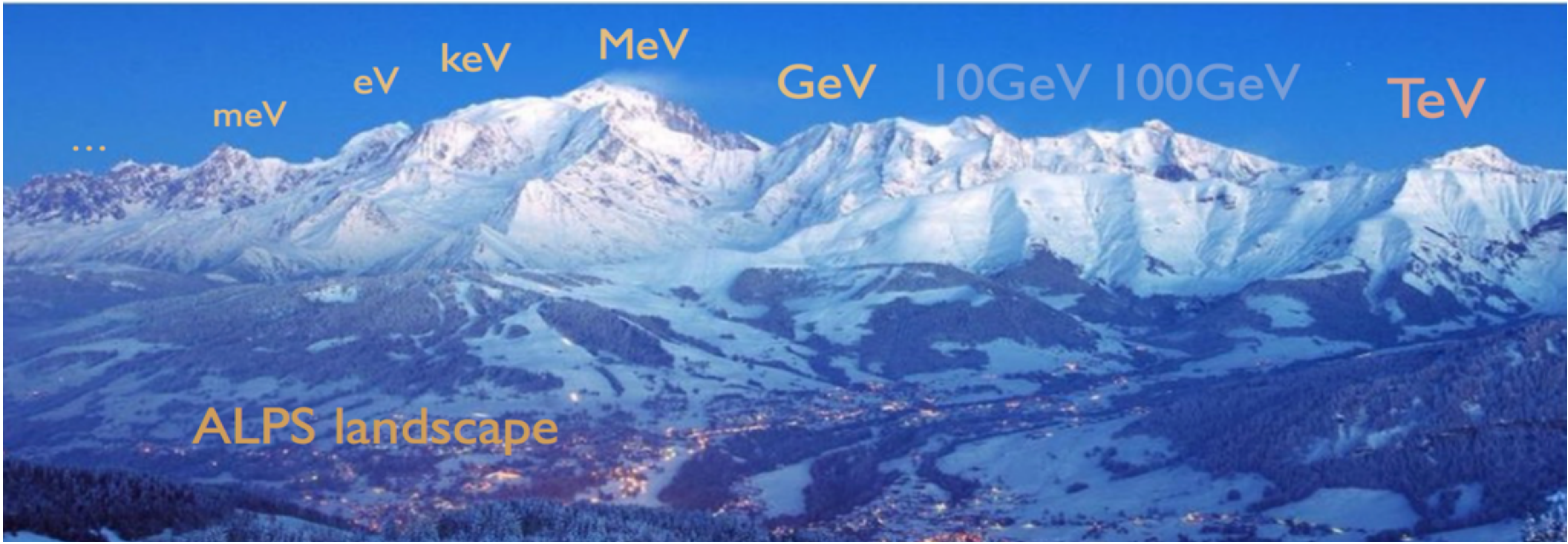
Axion-like particle @ LHCb



Istituto Nazionale di Fisica Nucleare
SEZIONE DI FIRENZE

Diego Redigolo

17/10/2019

Istituto Nazionale di Fisica Nucleare
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Axion-like particle (ALPs)

$$\mathcal{L}_{\rm ALP} = \underbrace{\frac{1}{2}(\partial_\mu a)^2 + \frac{1}{f_a}\partial_\mu a J_\mu^{\rm SM}}_{a \to a + c}$$

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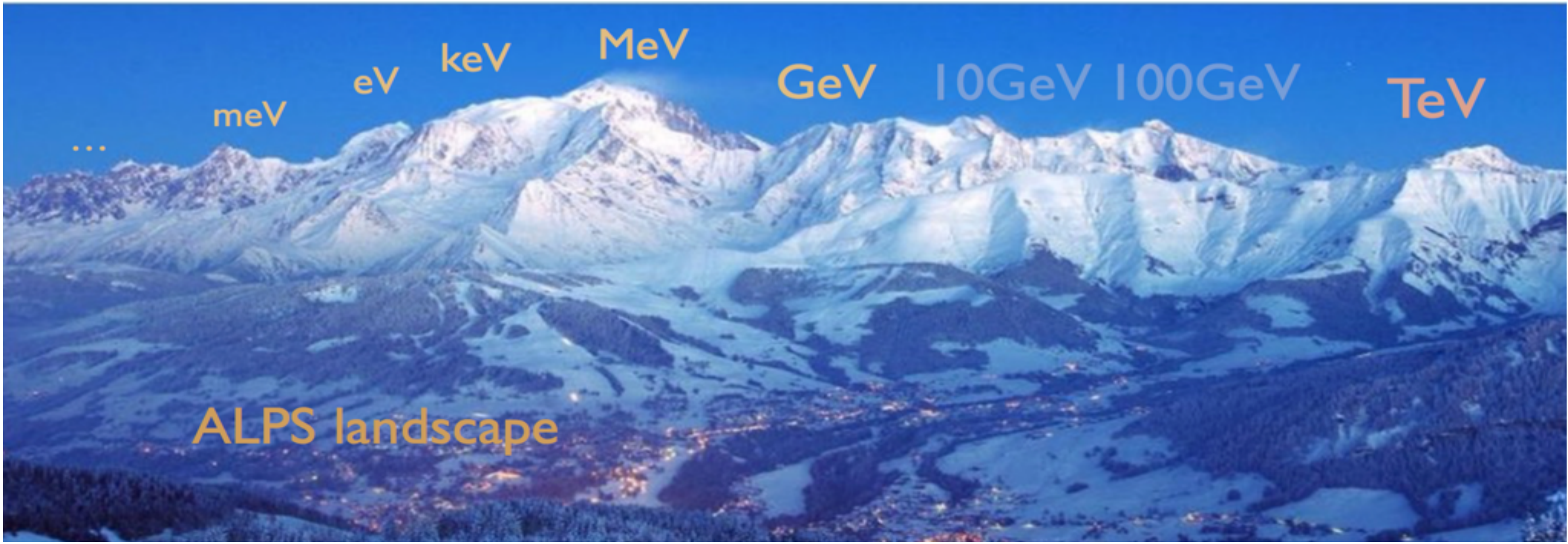
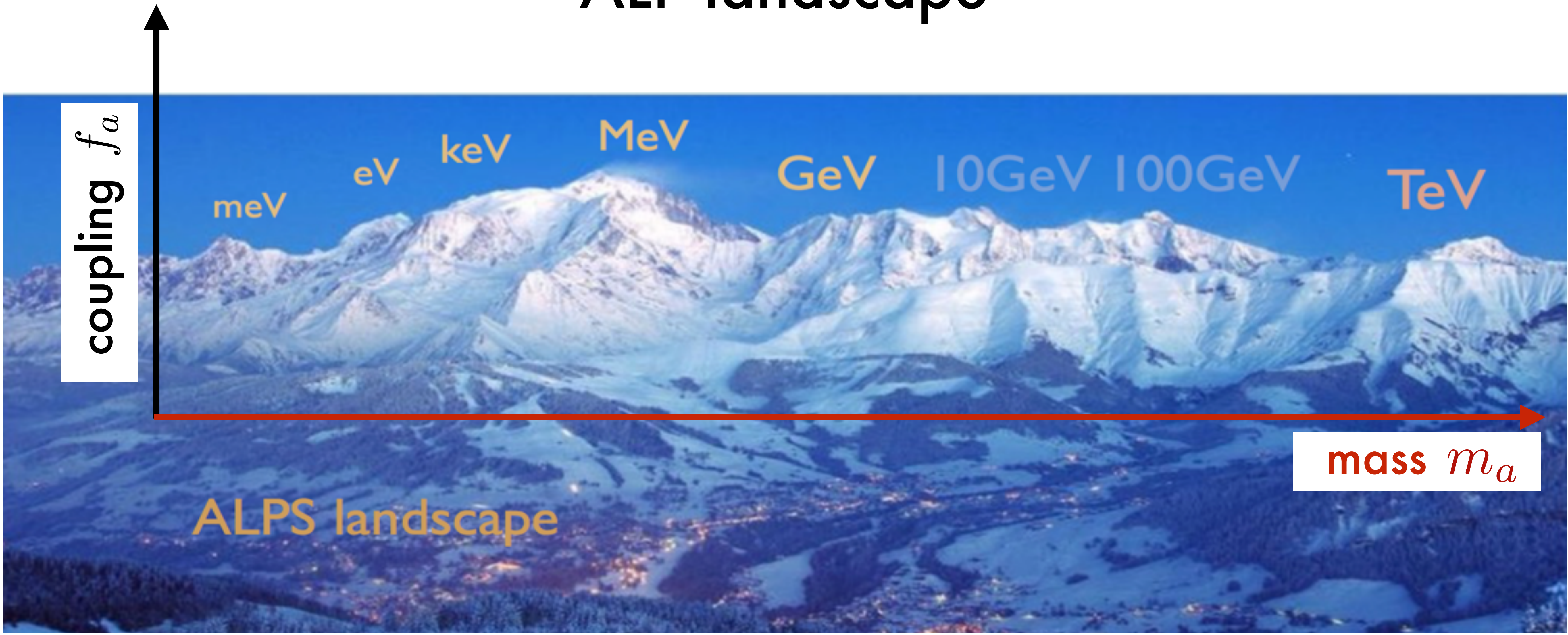


$$\mathcal{L}_{\mathrm{ALP}} = \underbrace{\frac{1}{2}(\partial_\mu a)^2 + \frac{1}{f_a}\partial_\mu a J_\mu^{\mathrm{SM}}}_{a \to a + c} \underbrace{+ \frac{m_a^2}{2} a^2}_{\cancel{a \to a + c}}$$

ALP landscape



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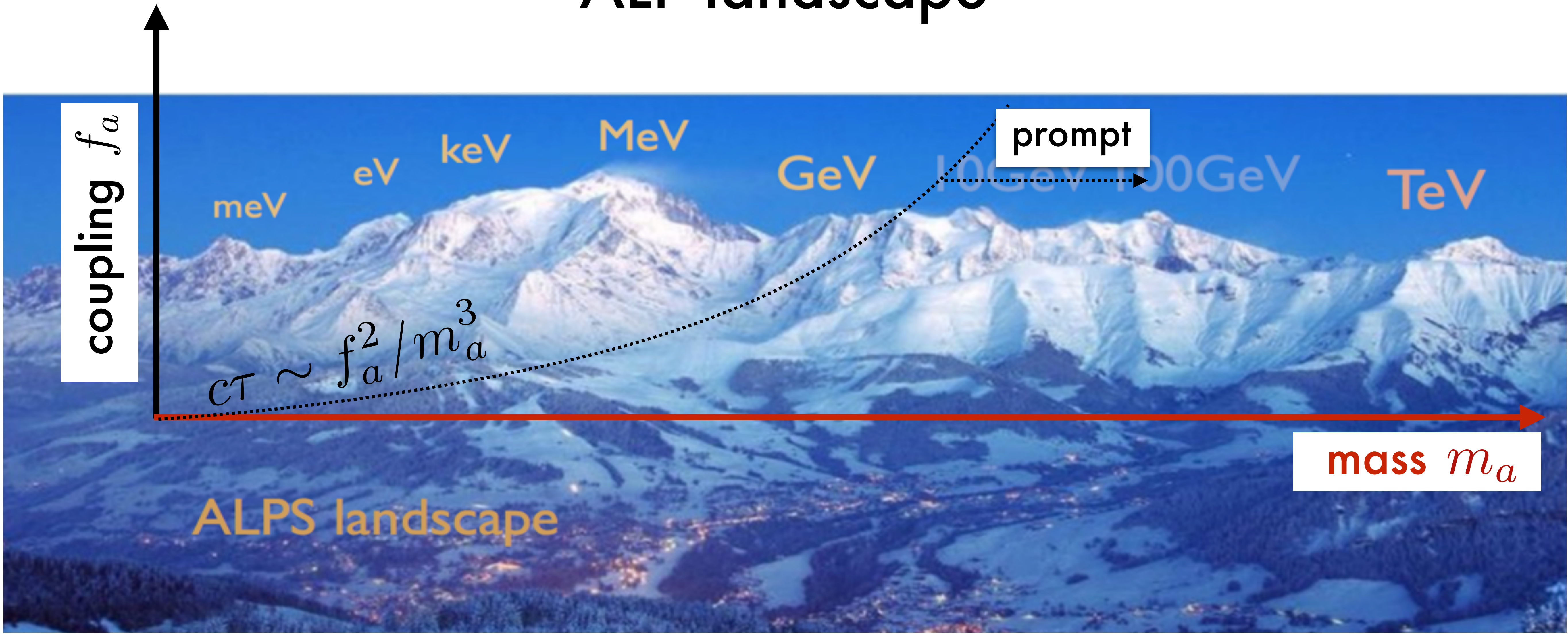
ALP landscape



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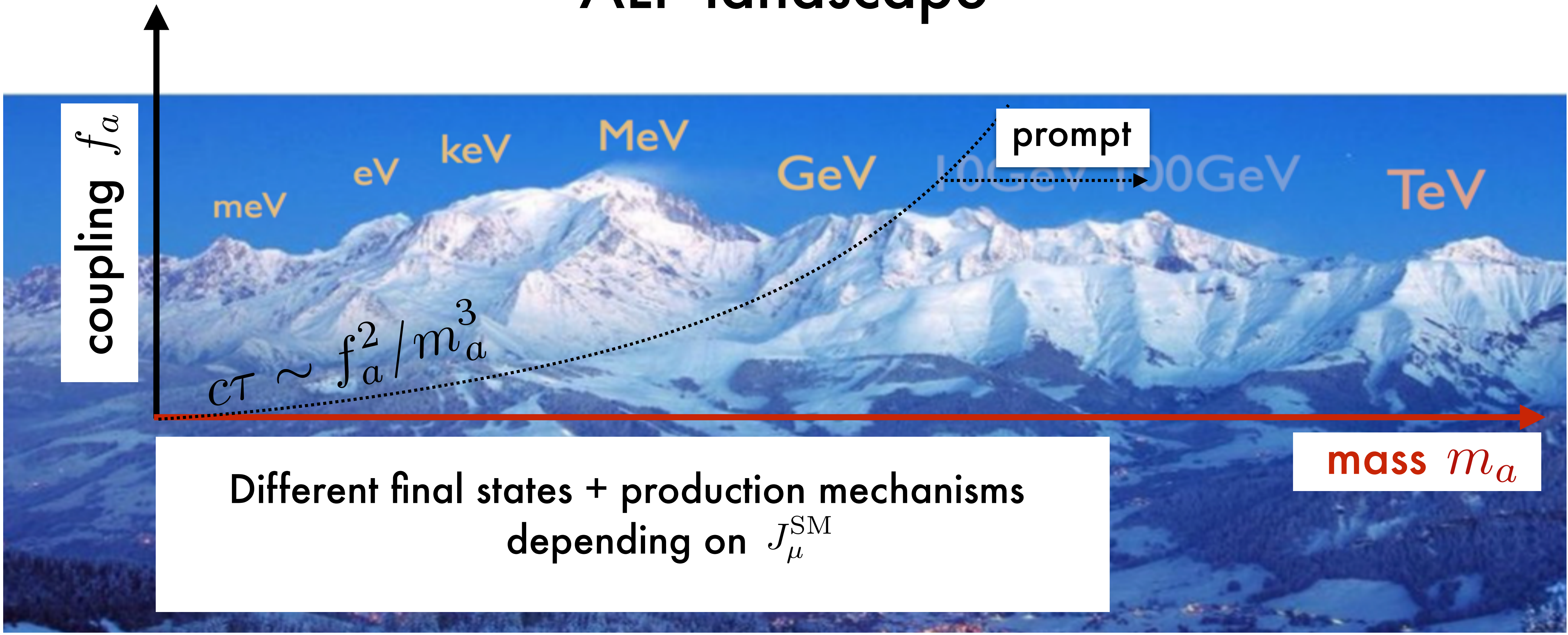
ALP landscape



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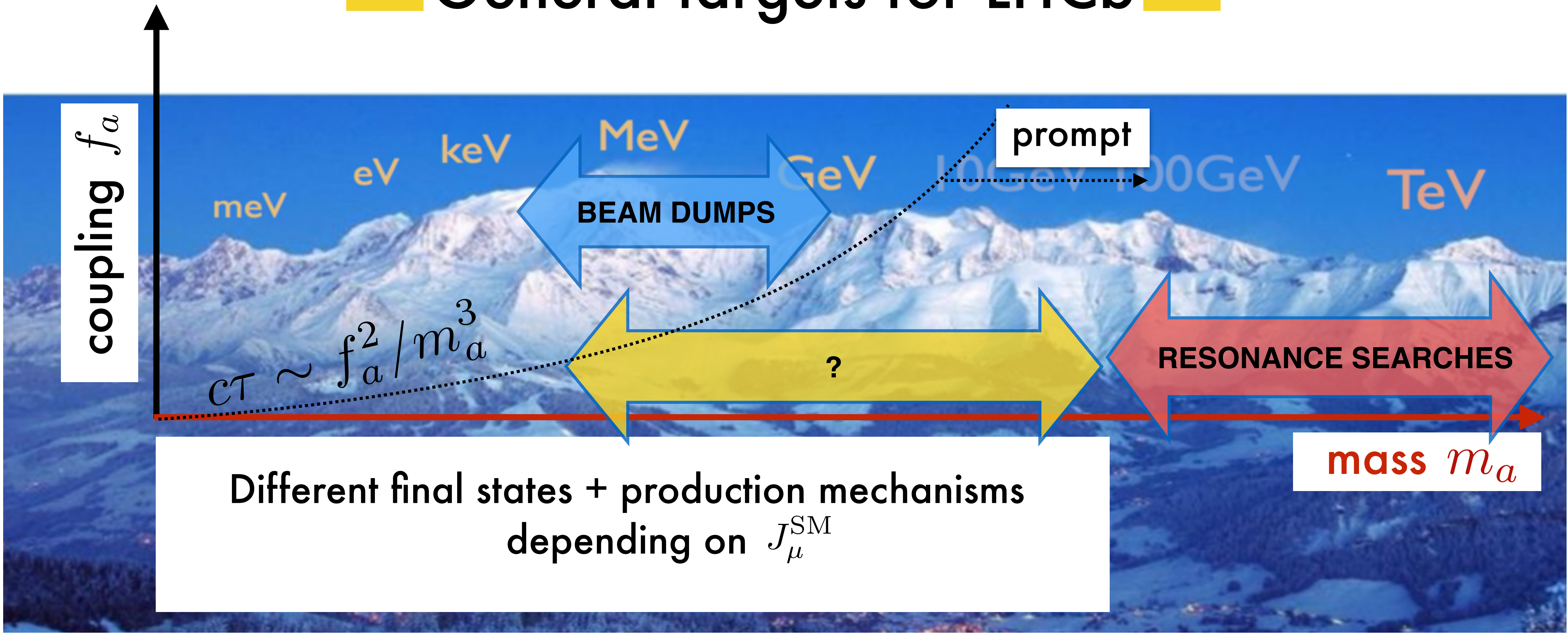
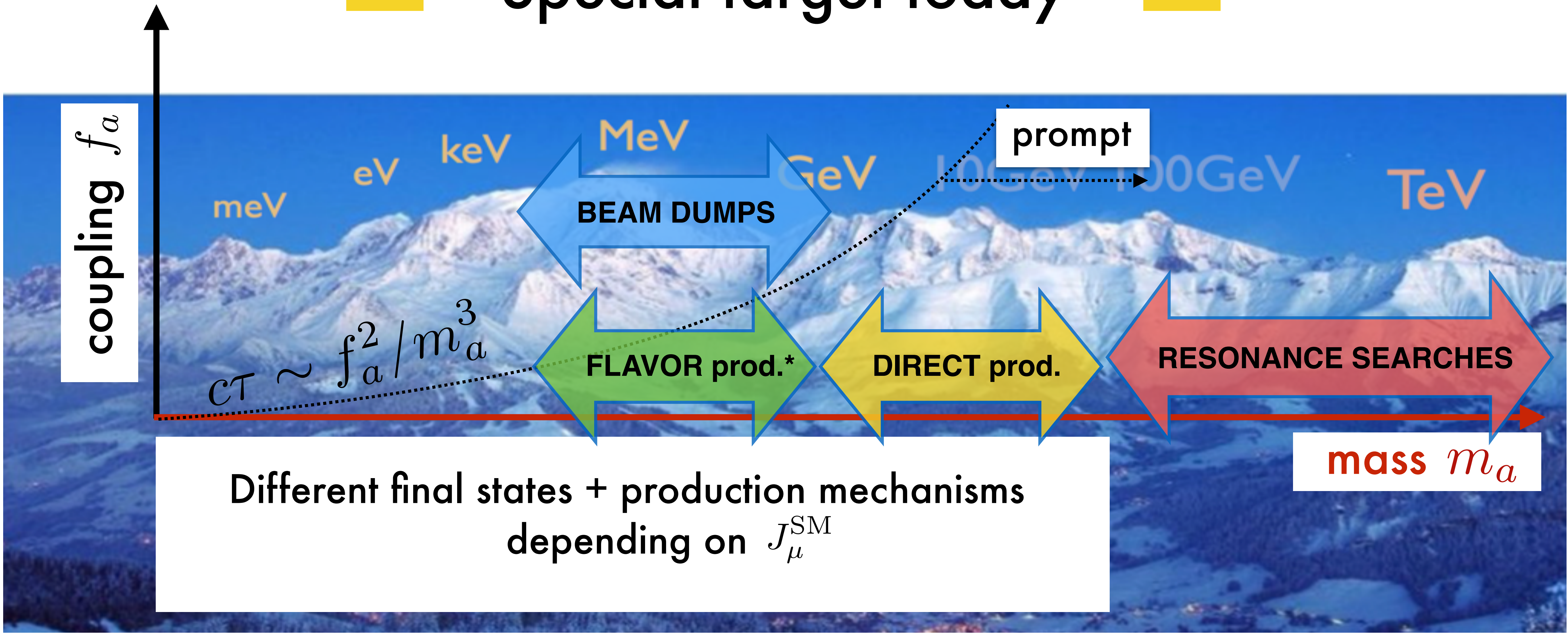
General targets for LHCb



$$\mathcal{L}_{\rm ALP} = \underbrace{\frac{1}{2}(\partial_\mu a)^2 + \frac{1}{f_a}\partial_\mu a \overbrace{J_\mu^{\rm SM}}}_{a \to a + c} \underbrace{+\frac{m_a^2}{2}a^2}_{a \not\to a + c}$$

Special target today



* B, K, η, π – factories

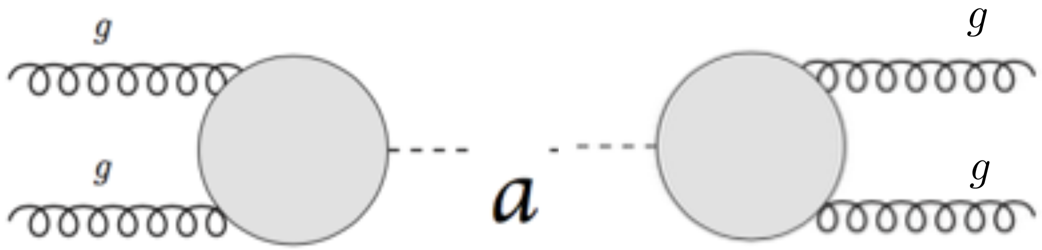
$$\mathcal{L}_{\rm ALP} = \underbrace{\frac{1}{2}(\partial_\mu a)^2 + \frac{1}{f_a}\partial_\mu a \overbrace{J_\mu^{\rm SM}}}_{a \to a + c} \underbrace{+\frac{m_a^2}{2}a^2}_{\cancel{a \to a + c}}$$

RESONANT SEARCHES below 50 GeV

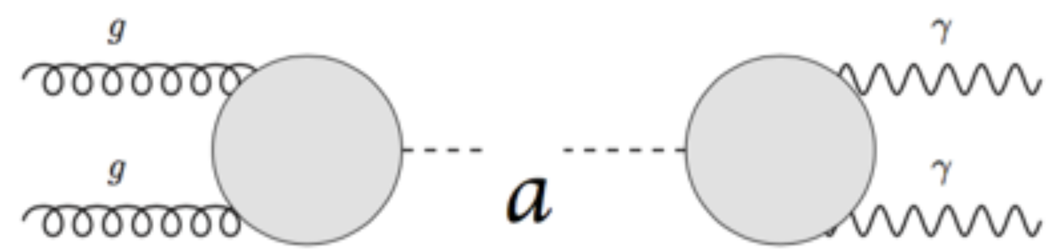
$$\frac{1}{f_a}\partial_\mu a J^\mu_{\rm SM} = a\left[\frac{N\alpha_{\rm s}}{4\pi f_a}G\tilde{G} + \frac{E\alpha_{\rm em}}{4\pi f_a}F\tilde{F}\right]$$

FOCUS HERE: dominant couplings with gauge bosons

RESONANT SEARCHES below 50 GeV



di-jets



di-photons

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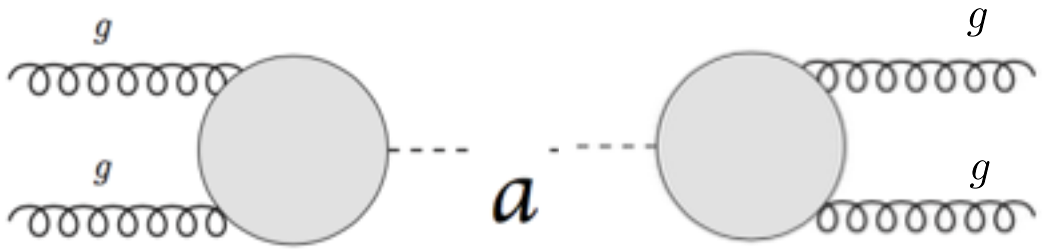

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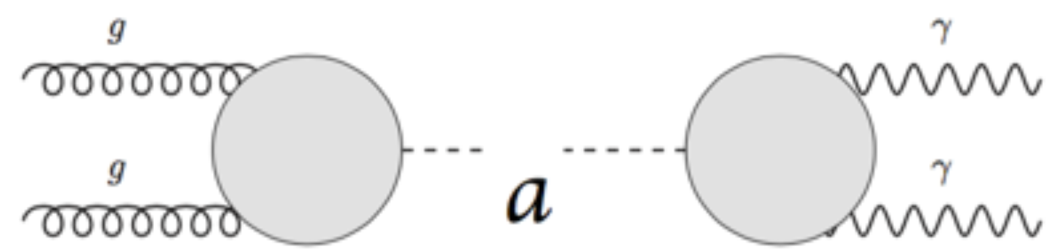

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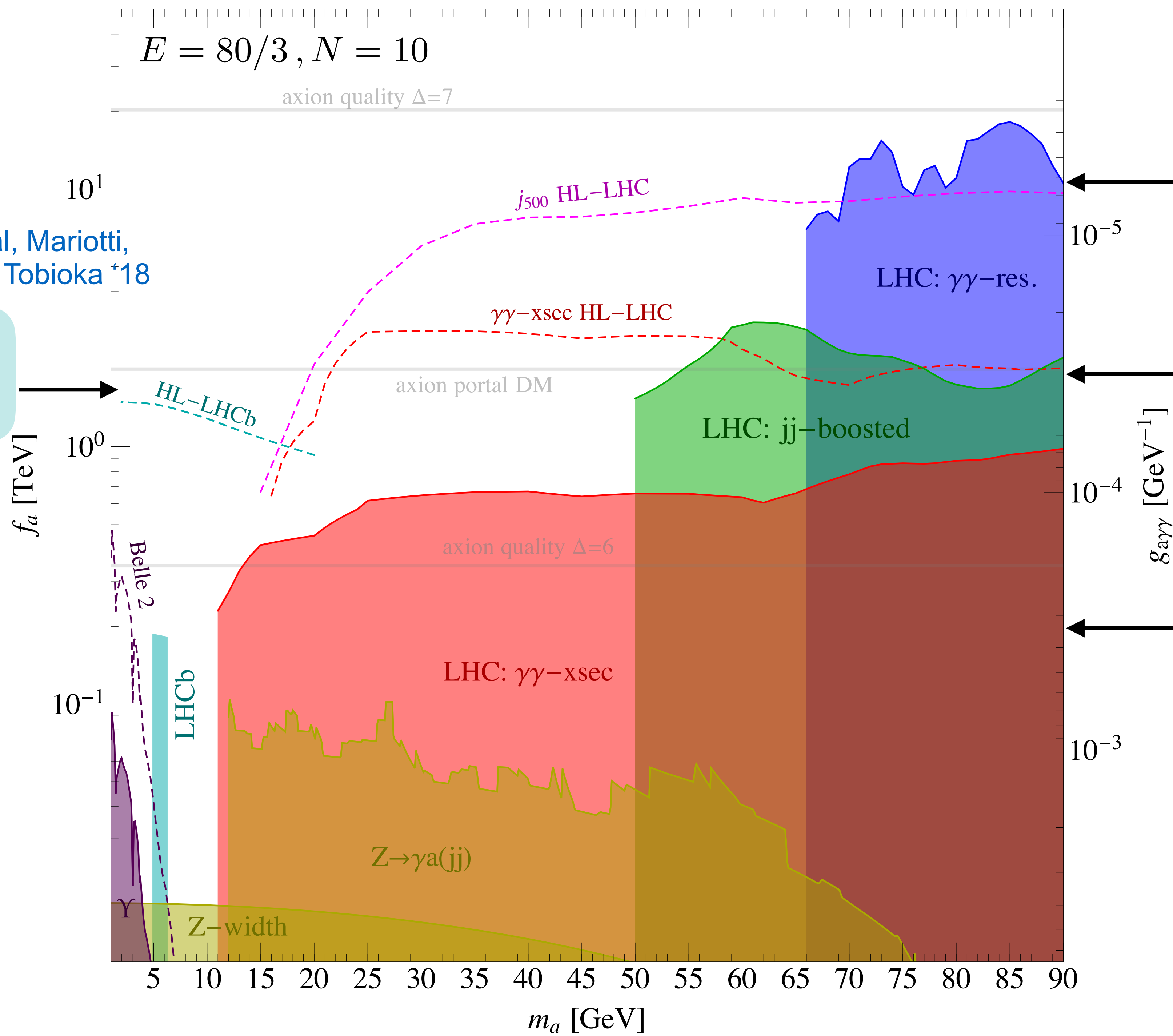
Comments:

- rate into di-photons suppressed: $\frac{\Gamma_{\gamma\gamma}}{\Gamma_{gg}} = \frac{\alpha_{\rm em}^2}{8\alpha_s^2}\cdot\frac{E^2}{N^2} \sim 10^{-4}\frac{E^2}{N^2}$
- production through gluon fusion & decay to photon or jet pairs

RESULTS I

Cid-Vidal, Mariotti, DR, Sala, Tobioka '18

LHCb



HL-LHC monojet

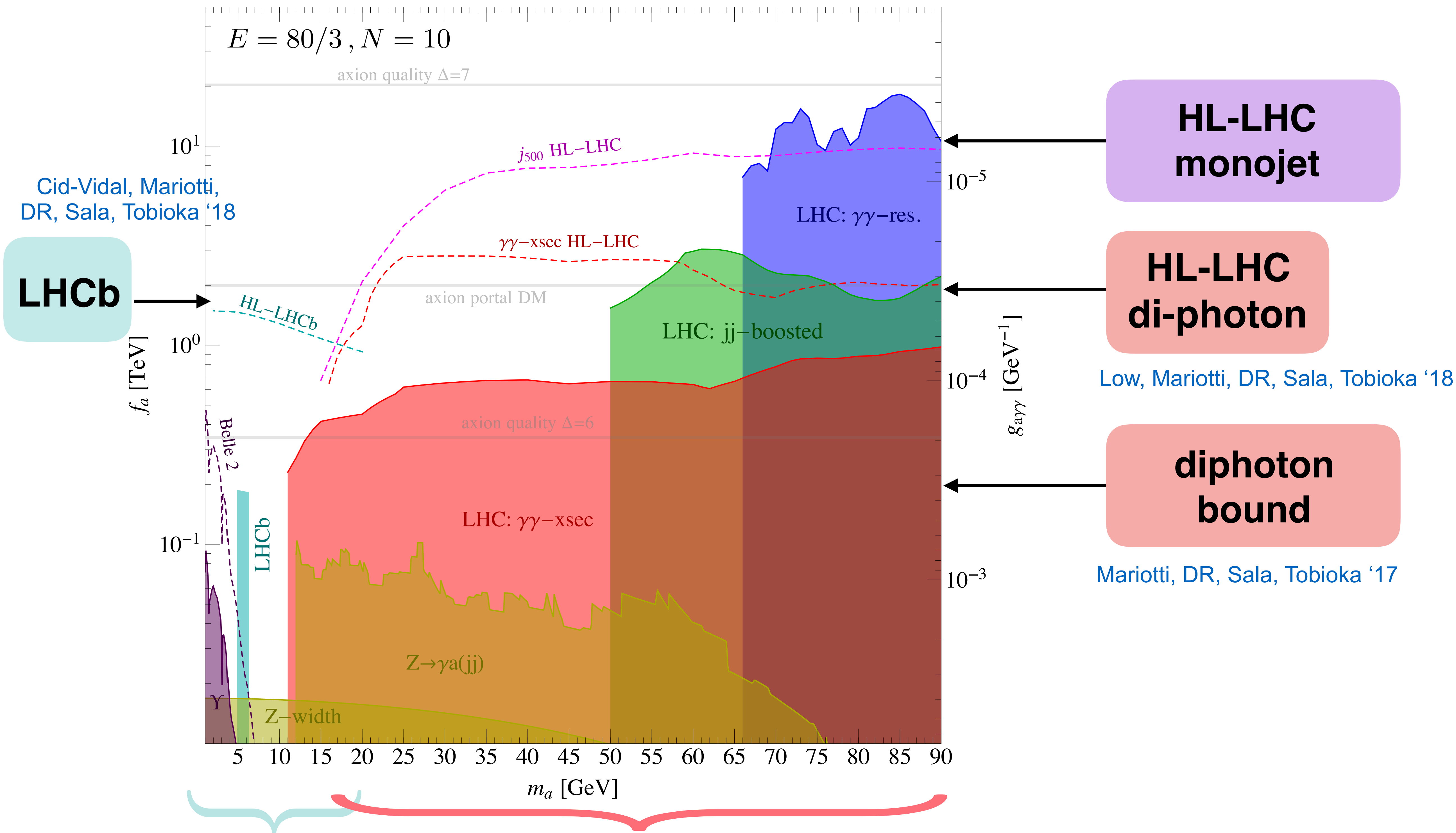
HL-LHC di-photon

Low, Mariotti, DR, Sala, Tobioka '18

diphoton bound

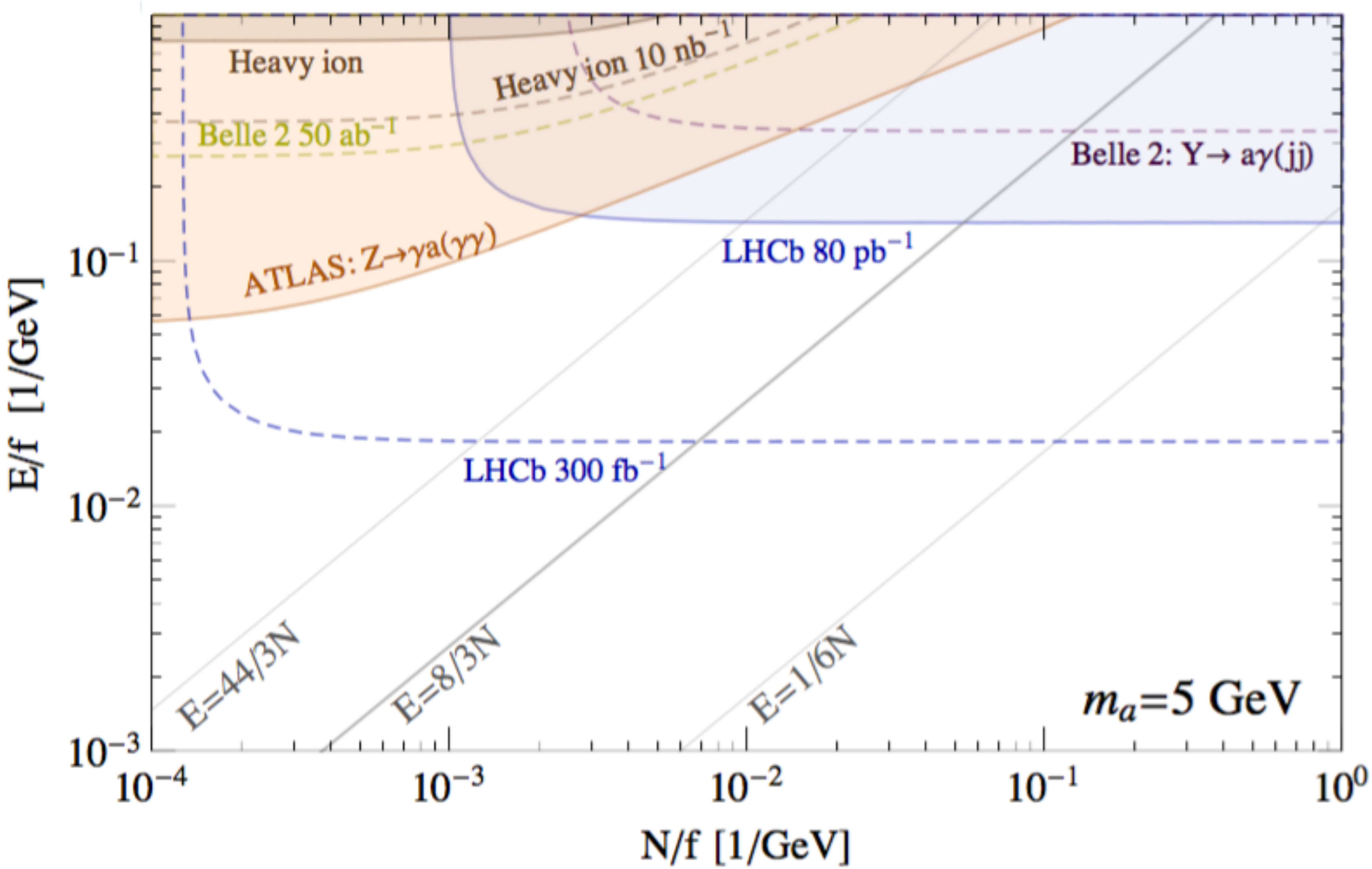
Mariotti, DR, Sala, Tobioka '17

RESULTS I



Complementarity between ATLAS/CMS & LHCb in mass coverage!

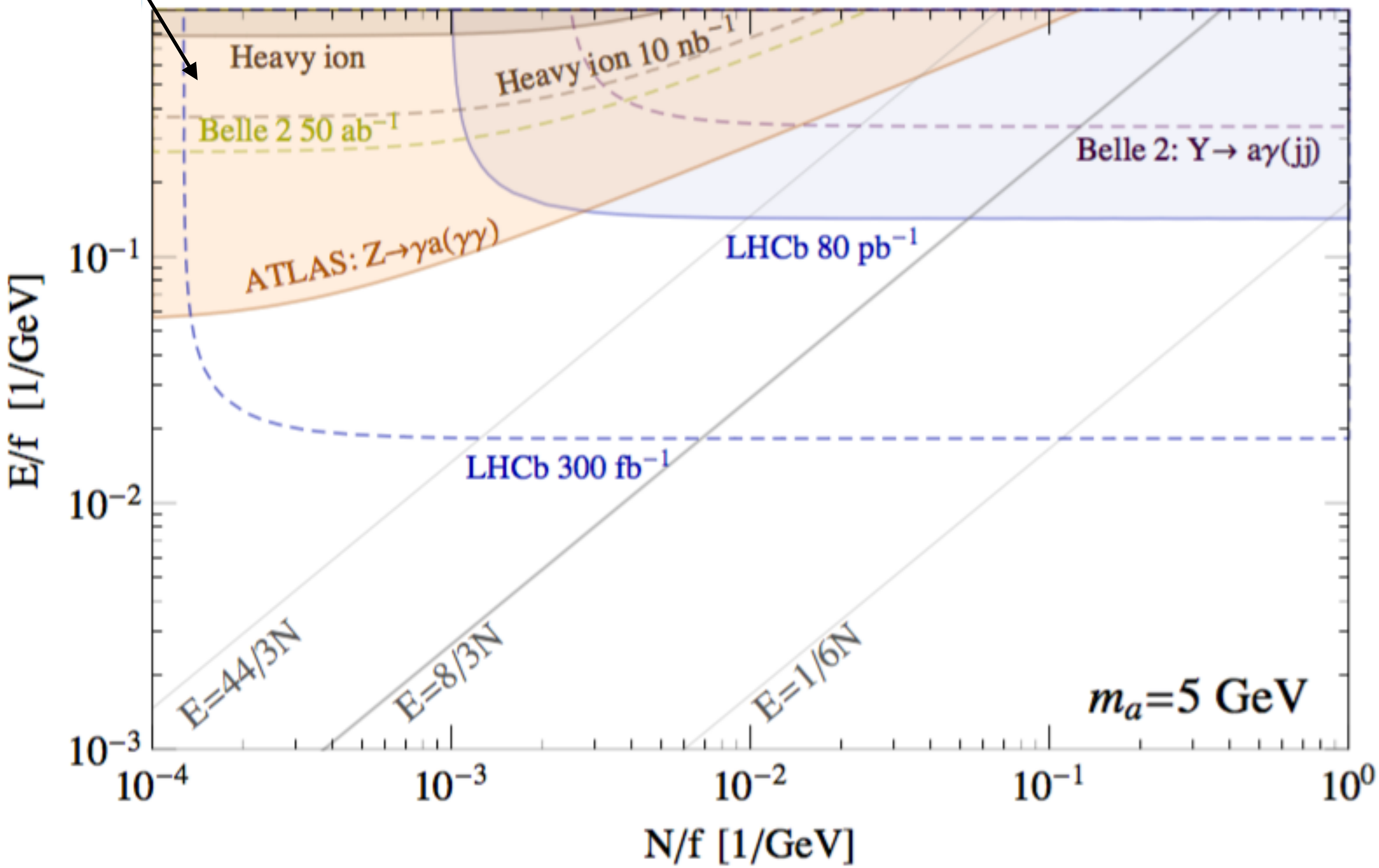
RESULTS II



LHCb di-photon search allows to explore: $\frac{E}{f} \simeq \frac{1}{100\ \mathrm{GeV}}$, $\frac{N}{f} \simeq \frac{1}{10\ \mathrm{TeV}}$

RESULTS II

E>>N
probed by photon coupling only



LHCb di-photon search allows to explore: $\frac{E}{f} \simeq \frac{1}{100 \text{ GeV}}$, $\frac{N}{f} \simeq \frac{1}{10 \text{ TeV}}$

LHCb can *easily* access the mass 1-10 GeV mass range

$$m_{\gamma\gamma} > \Delta R \sqrt{p_{T_1}^{\min} p_{T_2}^{\min}}$$

Photon/jet Isolation

$$\Delta R \equiv \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

Minimal pT cuts

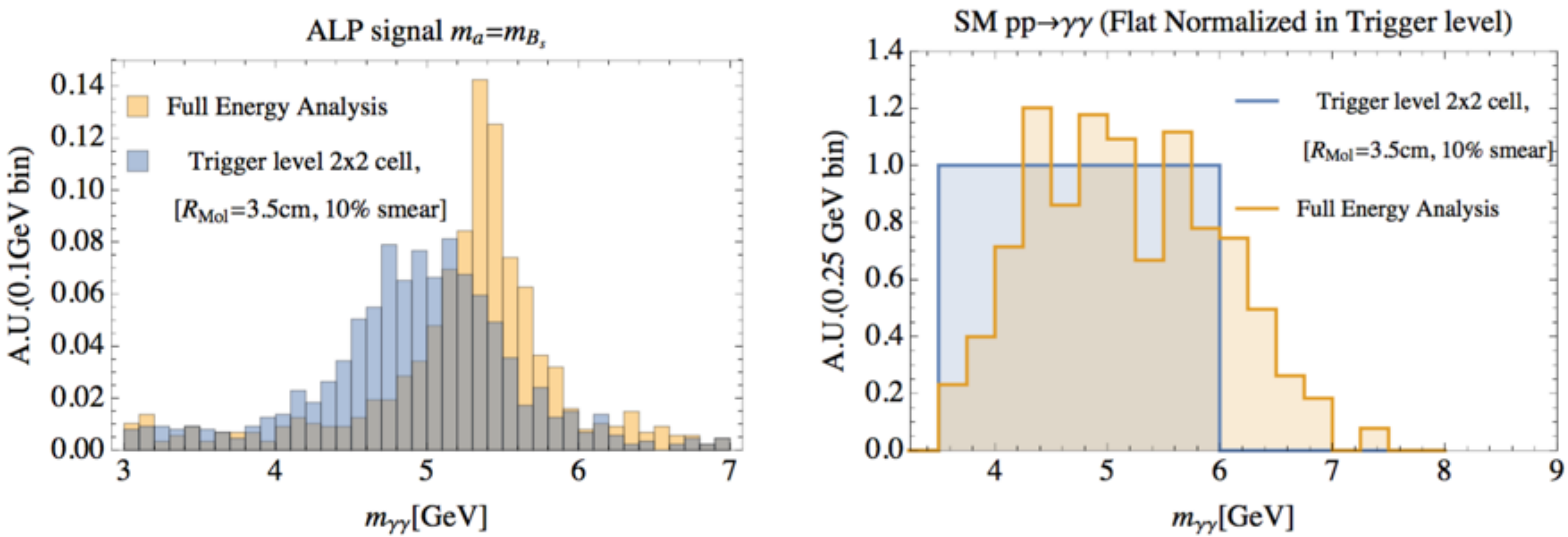
@ LHCb: lower mass threshold achieved by loosing photon pT cuts:

$$E_{\mathrm{T}}(\gamma_{1,2}) > 3.5 \text{ GeV}$$

- LHCb trigger strategy for $B_s \to \gamma\gamma$ S. Benson and A. Puig Navarro, Tech. Rep. LHCb-PUB-2018-006
- No displacement cut imposed if the two photons do not convert (0CV)!

LHCb Bump hunt

using public data from S. Benson and A. Puig Navarro, Tech. Rep. LHCb-PUB-2018-006

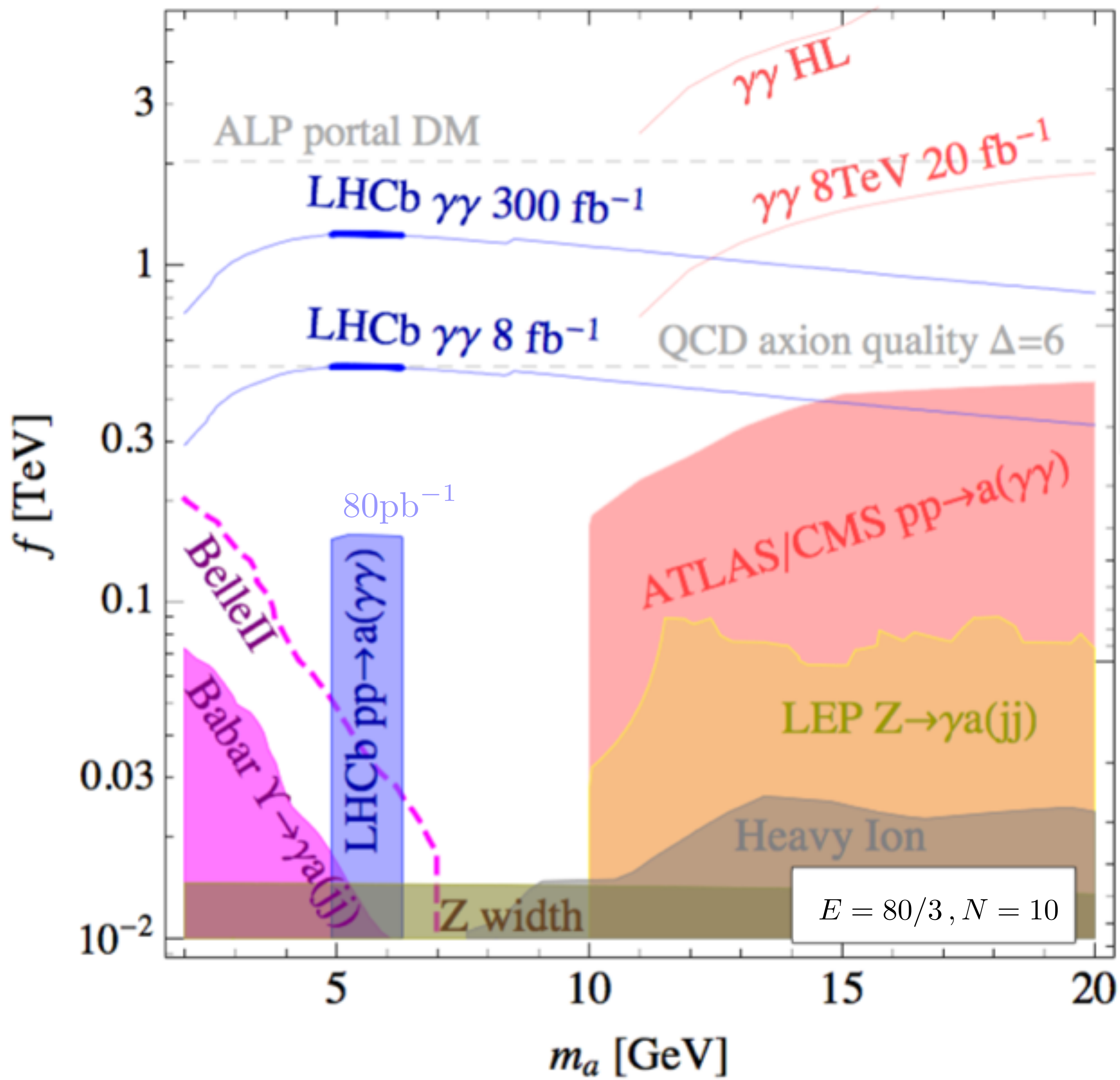


$$3.5 \text{ GeV} < m_{\gamma\gamma} < 6 \text{ GeV}$$

Comments:

- signal smearing due to 2x2 cell energy info @ trigger level
- background feature due to bin-migration (less events at high inv. mass)

Zooming-in & Concluding



LHCb can teach us something:

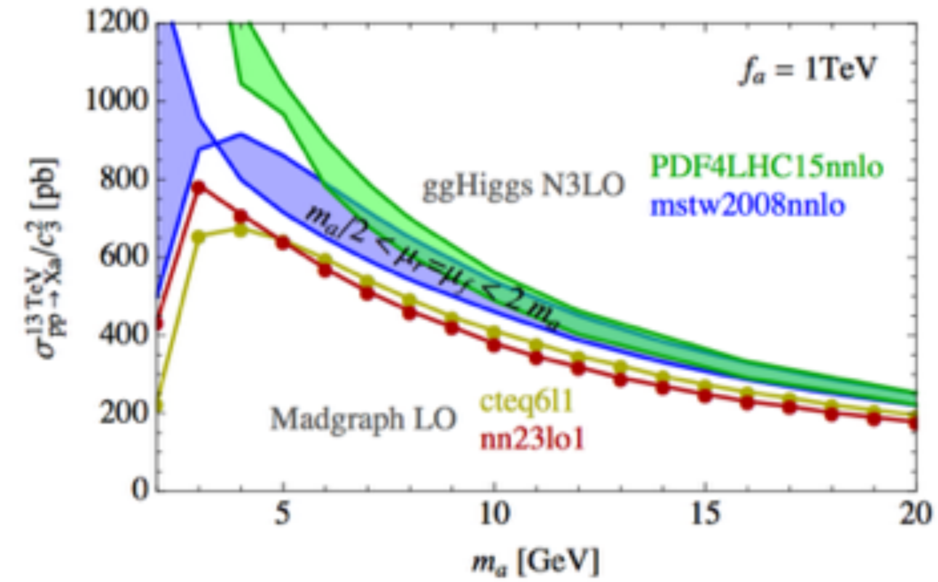
light PGBs from TeV scale NP

$$\Lambda_{\rm NP} = g_* f_a$$

EXAMPLES

- Heavy QCD axions
- Dark matter freeze-out
- SUSY & Composite

Gearing up for an actual search...



- Computing the signal strength at low masses
- Dynamical range of the ECAL to probe $m_{\gamma\gamma} > 10\ \mathrm{GeV}$
- Composition of the di-photon background
- Categorisation in eta

ASK Cid-Vidal, S. Benson and A. Puig Navarro…

& see you at

Stealth physics at LHCb:
Unleashing the full power of LHCb to probe new physics",
Santiago de Compostela February 17th 2020.