ICNFP 2021

SGOLDSTINO SEARCHES AT FASER

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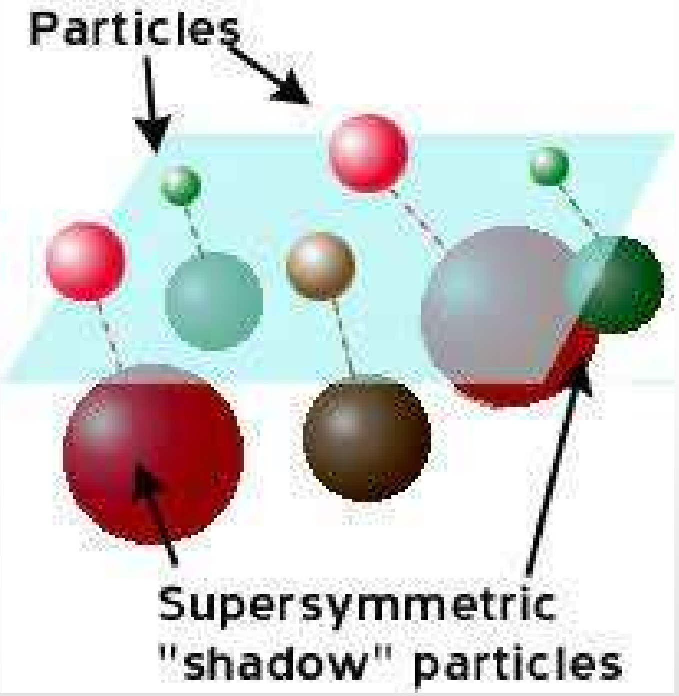
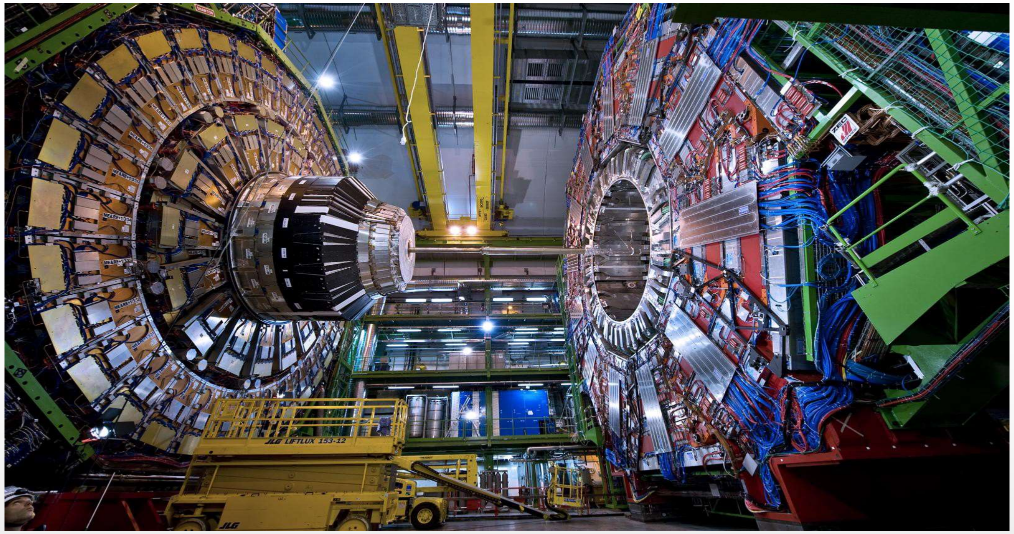


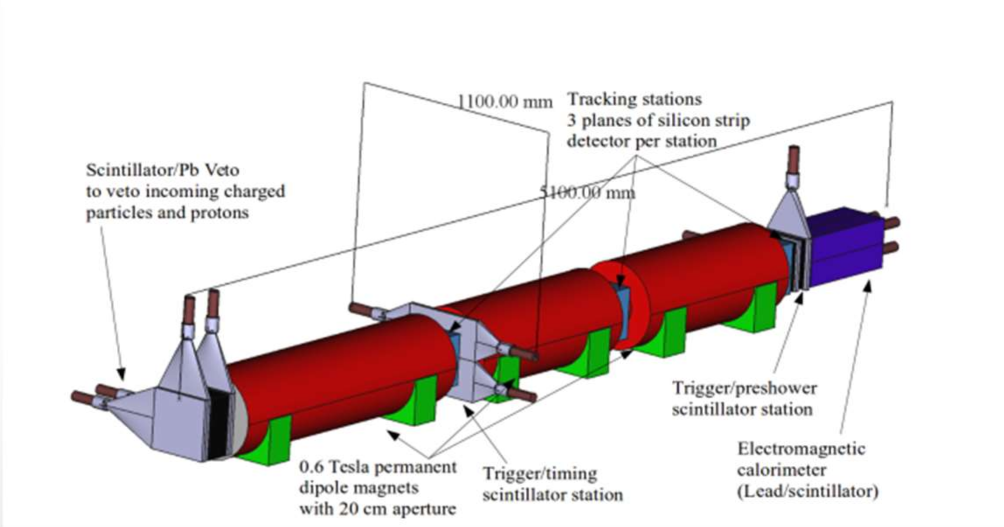
Supersymmetric extension of the Standard Model is a promising theory for new physics beyond SM

Supersymmetry spontaneously breaks and gives goldstino and it’s superpartner sgoldstino

Sgoldstino couples to SM particles and can be found in future experiments

Searches for new particles



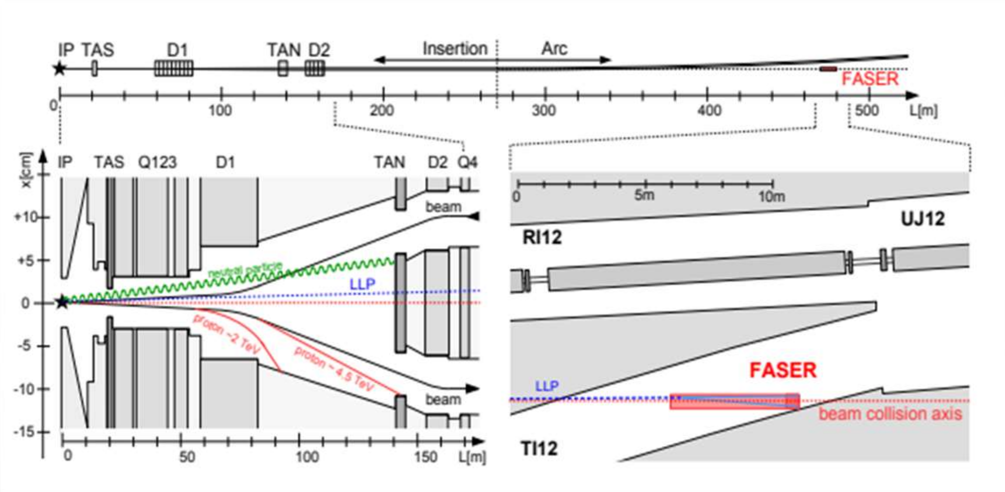


LHC ATLAS
LHC – the biggest science project in the world
LHC – confirmation of existing theories
LHC – searches for new theories

FASER detector layout
FASER – far-forward detector
FASER –searches for light, weakly-interacting particles
2 stages: FASER1 ($L = 150\ fb^{-1}$) and FASER2 ($L = 3000\ fb^{-1}$)

FASER

Sgoldstino model



Free parameters: $m_S, F, M_3, M_{\gamma\gamma}, A_Q, A_l, m^{LR}_{F\ ij}$

$$M_3, M_{\gamma\gamma}, A_Q, A_l < \sqrt{F}$$

$$m^{LR}_{F\ ij} < 100\ GeV$$

Sources: pp-scattering, Meson decay

Decay modes: $\gamma\gamma, l^+l^-$, dimeson decay

Sgoldstino model

$$\mathcal{S} = s + \sqrt{2}\theta\psi + \theta^2 F_s$$

$$\langle F_s \rangle \equiv F$$

$$s = \frac{1}{\sqrt{2}}(S + iP)$$ - R-even

$$\mathcal{L} = \frac{1}{F} J^{\mu}_{SUSY} \partial_\mu \psi$$

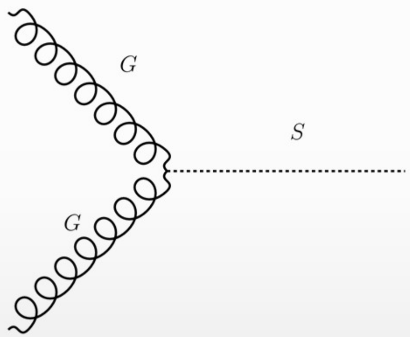
Current can be characterized by a mass parameter ΔM
ΔM is a typical mass split within the supermultiplets

Mass of superpartners is larger than mass of known particles, therefore $\Delta M \approx M_i$, where i-particle index.

$$\mathcal{L}_{S\gamma\gamma} = \frac{M_{\gamma\gamma}}{2\sqrt{2}F} S F_{\mu\nu} F^{\mu\nu}$$

Sgoldstino sources

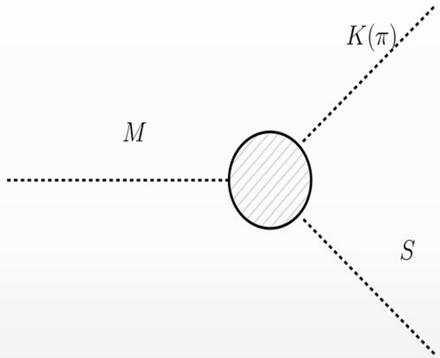
Gluon fission



$$\sigma \propto \frac{{M_3}^2}{F^2}$$

Meson decay

B, D, K_s, η



CRMC (EPOS-LHC) ⟶ K_s, η

LHCb ⟶ B, D

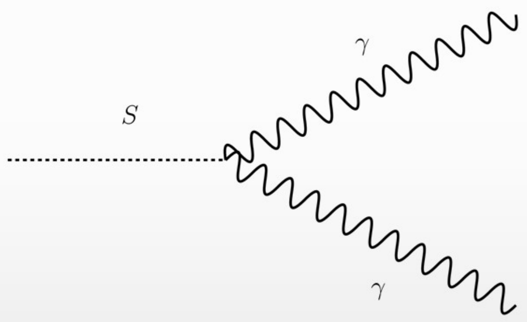
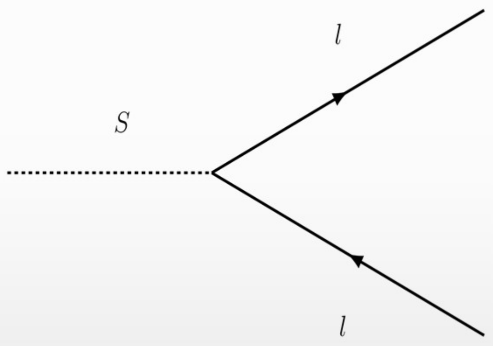
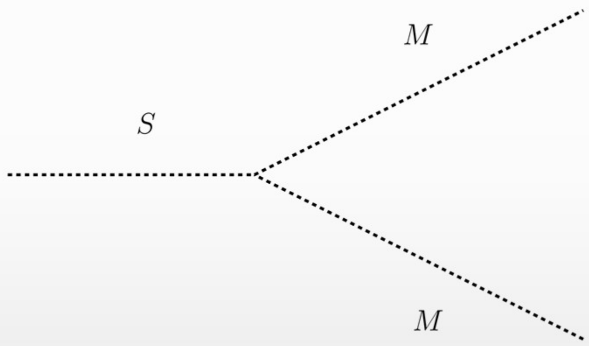
Flavor conserving

$$\Gamma \propto \left(\theta + \frac{A_Q}{F}\right)^2$$

Flavor violating

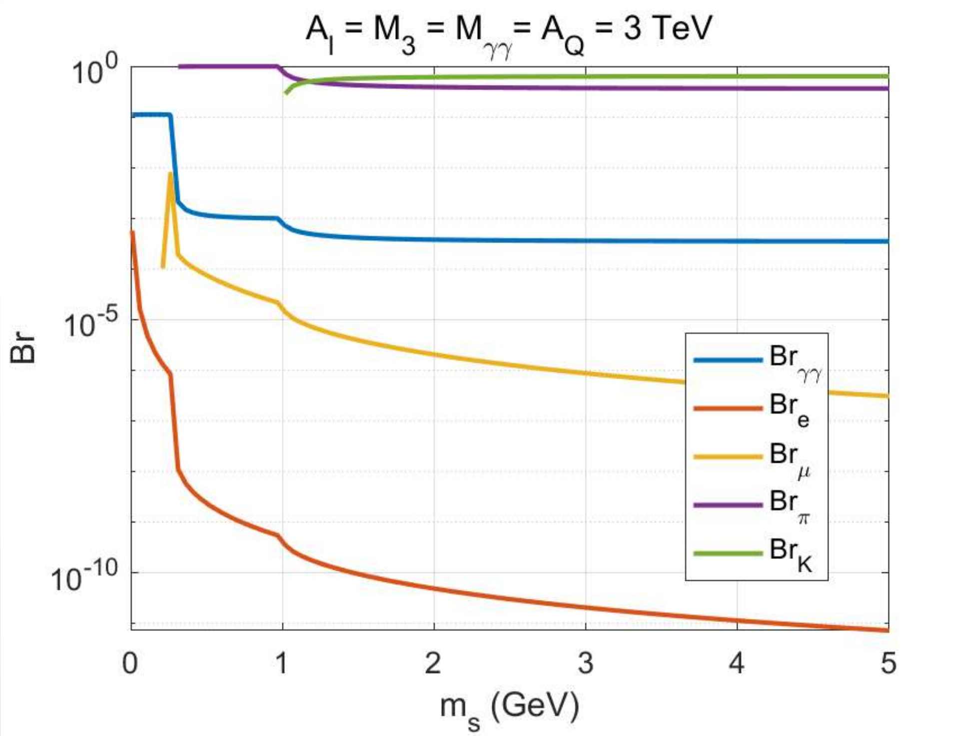
$$\Gamma \propto \frac{{m_{F\,ij}^{LR}}^4}{F^2}$$

Sgoldstino decays

Photon	Lepton	Meson (π, K)
		
$\Gamma \propto \frac{{M_{\gamma\gamma}}^2}{F^2}$	$\Gamma \propto \frac{{A_l}^2}{F^2}$	$\Gamma \propto \frac{{M_3}^2}{F^2}, \frac{{A_Q}^2}{F^2}$

Scope:

Determine soft-parameter space that will be probed at FASER



It is convenient to consider 2 cases with sgoldstino mass: $1) m_S < 2m_\pi$, 2) $m_S \geq 2m_\pi$

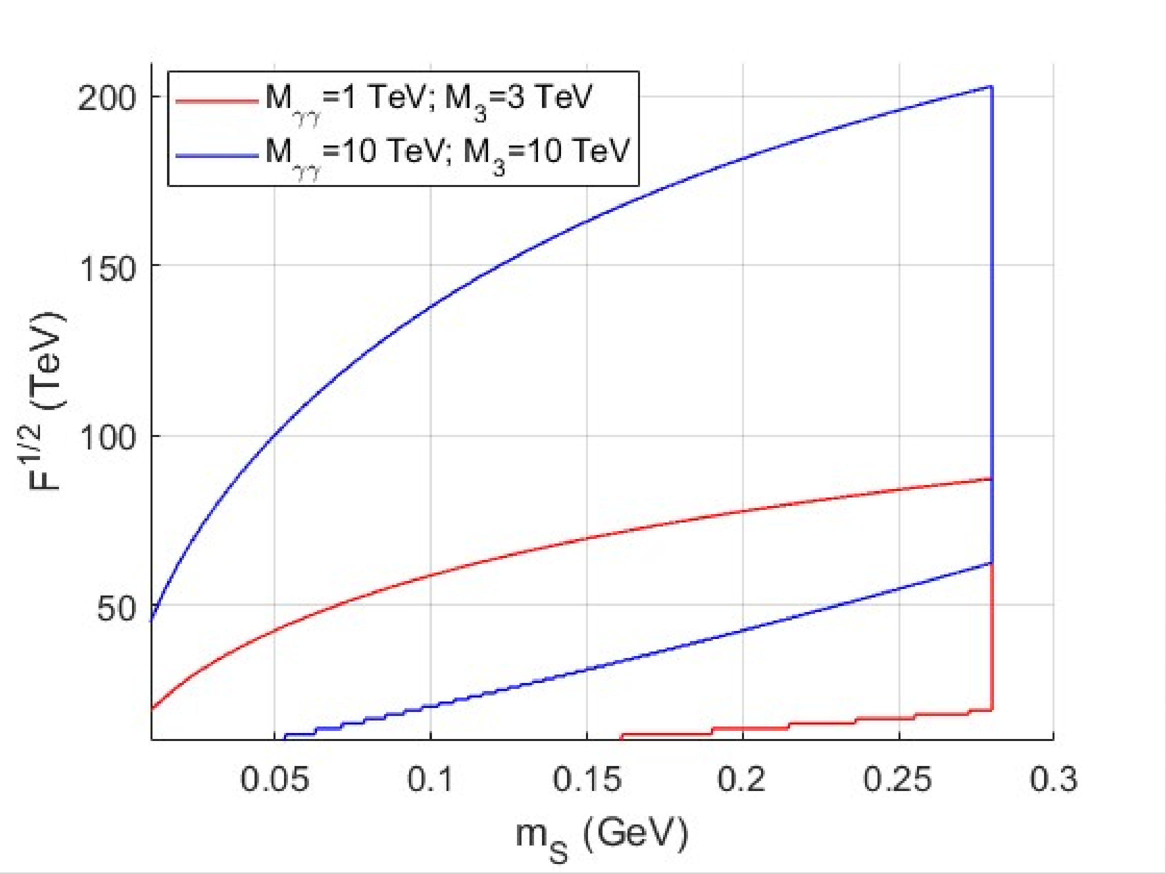
Soft parameters space
Photon

$$m_S < 2m_\pi$$
$$3\ TeV < \sqrt{F} < 7 \cdot 10^3\ TeV$$
$$100\ GeV < M_{\gamma\gamma} < \sqrt{F}$$
$$100\ GeV < A_Q < \sqrt{F}$$
$$3\ TeV < M_3 < \sqrt{F}$$
$$m_{F\ ij}^{LR} < 100\ GeV$$

$$2m_\pi < m_S < 4\ GeV$$
$$150\ TeV < \sqrt{F} < 7 \cdot 10^3\ TeV$$
$$150\ TeV < M_{\gamma\gamma} < \sqrt{F}$$
$$100\ GeV < A_Q < 10\ M_{\gamma\gamma}$$
$$3\ TeV < M_3 < 0.02\ M_{\gamma\gamma}$$
$$m_{F\ ij}^{LR} < 100\ GeV$$

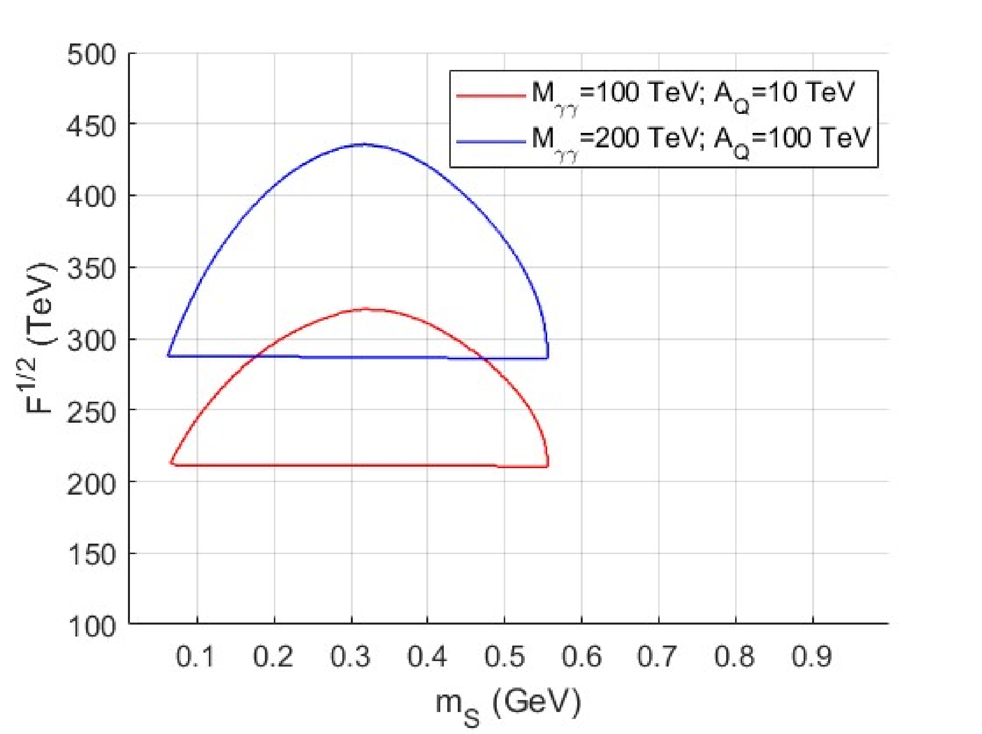
Soft parameters space

Source: Direct Production Decay: Photon

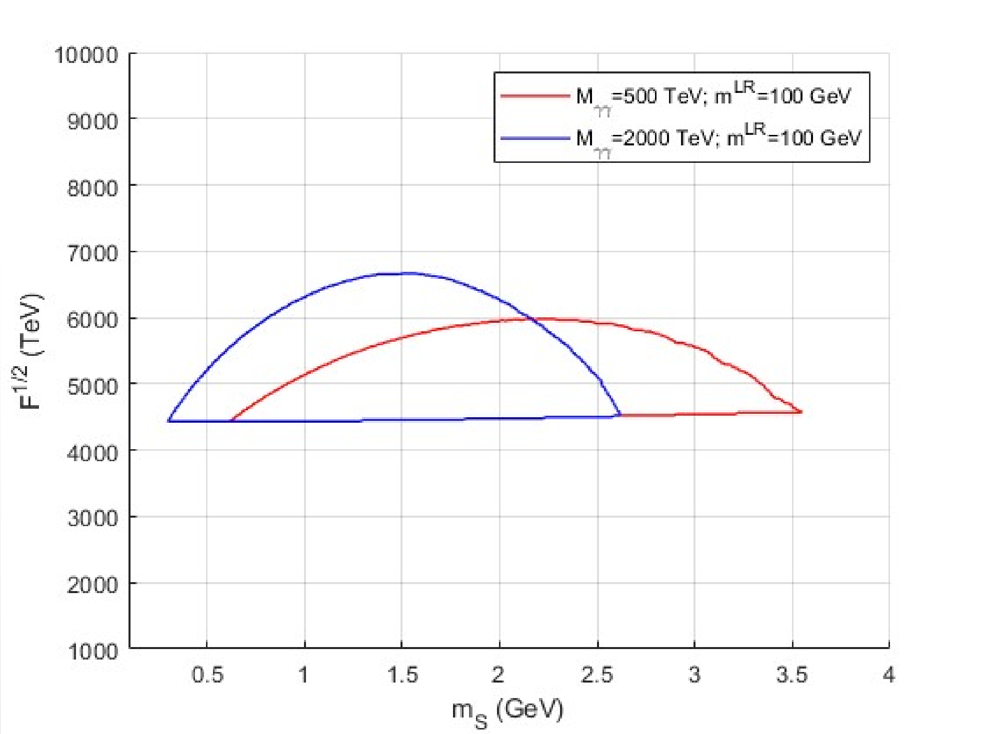


Soft parameters space

Source: Meson decay (B)   Decay: Photon



Flavor conserving meson decay



Flavor violating meson decay

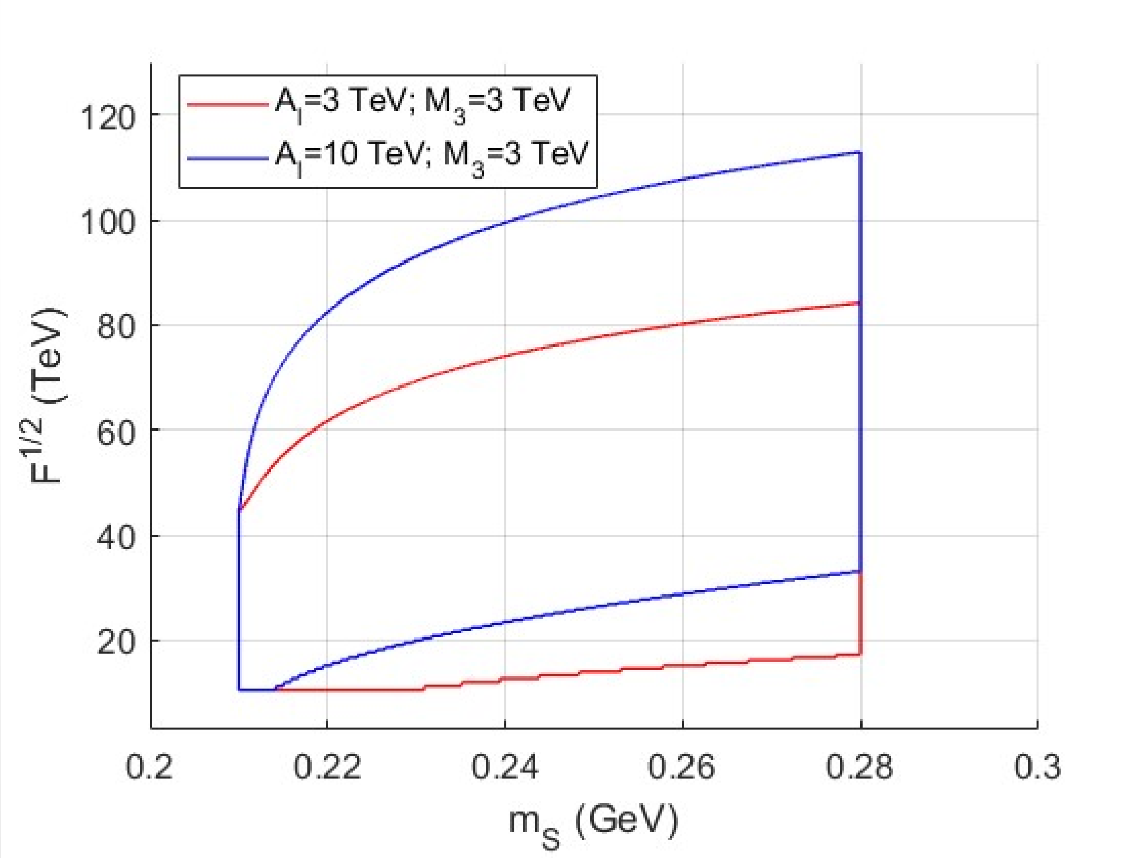
Soft parameters space
Lepton

$$m_S < 2m_\pi$$
$$3\ TeV < \sqrt{F} < 10^3\ TeV$$
$$10\ TeV < A_l < \sqrt{F}$$
$$100\ GeV < A_Q < \sqrt{F}$$
$$3\ TeV < M_3 < \sqrt{F}$$
$$m_{F\ ij}^{LR} < 10\ GeV$$

$$2m_\pi < m_S < 4\ GeV$$
$$10^3 TeV < \sqrt{F} < 6 \cdot 10^3\ TeV$$
$$1500\ TeV < A_l < \sqrt{F}$$
$$100\ GeV < A_Q < 0.2\ A_l$$
$$3\ TeV < M_3 < 0.002\ A_l$$
$$m_{F\ ij}^{LR} < 100\ GeV$$

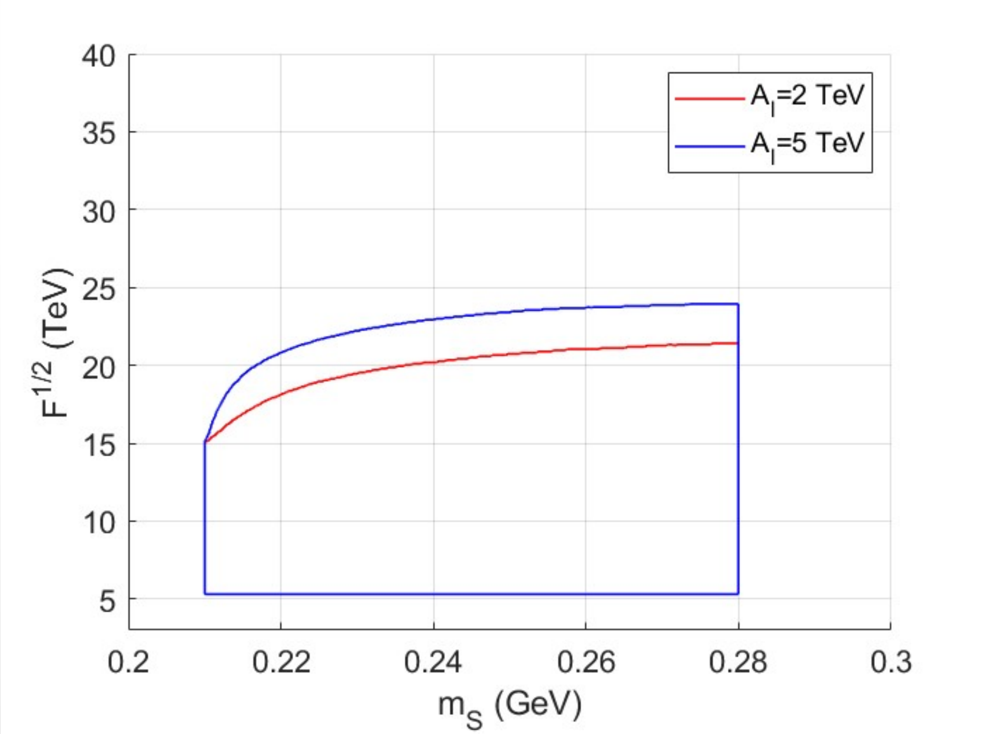
Soft parameters space

Source: Direct Production Decay: Lepton

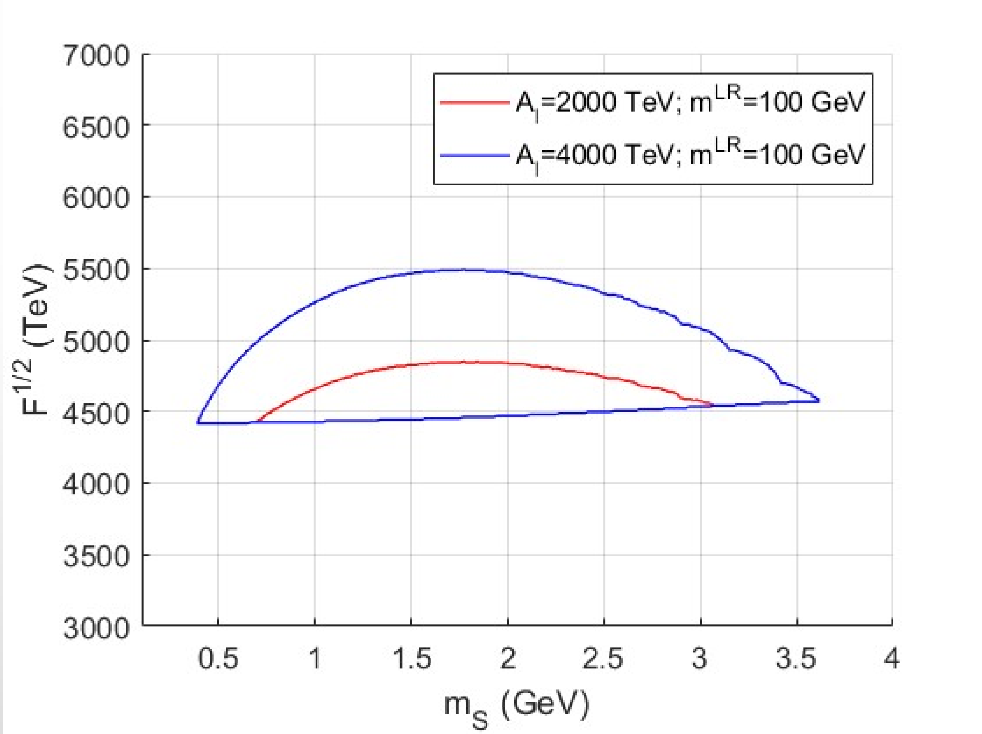


Soft parameters space

Source: Meson decay (B)   Decay: Lepton



Flavor conserving meson decay



Flavor violating meson decay

Soft parameters space
Meson

$$2m_\pi < m_S < 4\ GeV$$

$$3\ TeV < \sqrt{F} < 7 \cdot 10^3\ TeV$$

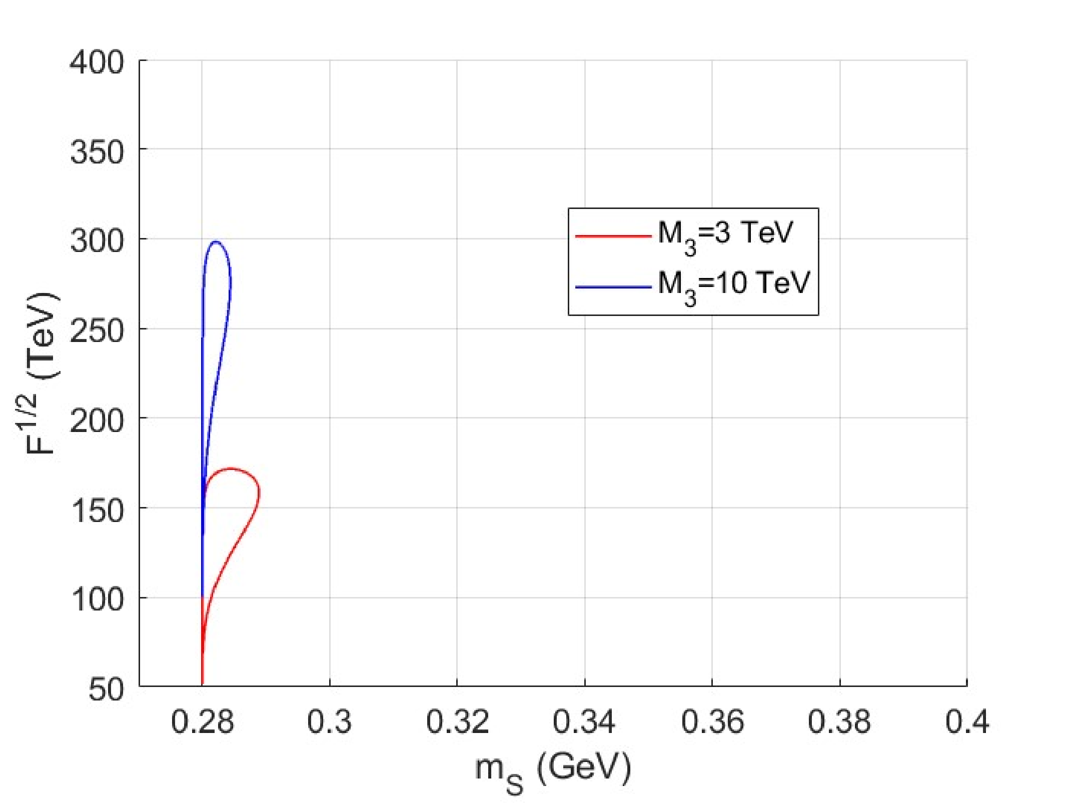
$$100\ GeV < A_Q < \sqrt{F}$$

$$3\ TeV < M_3 < \sqrt{F}$$

$$m_{F\ ij}^{LR} < 100\ GeV$$

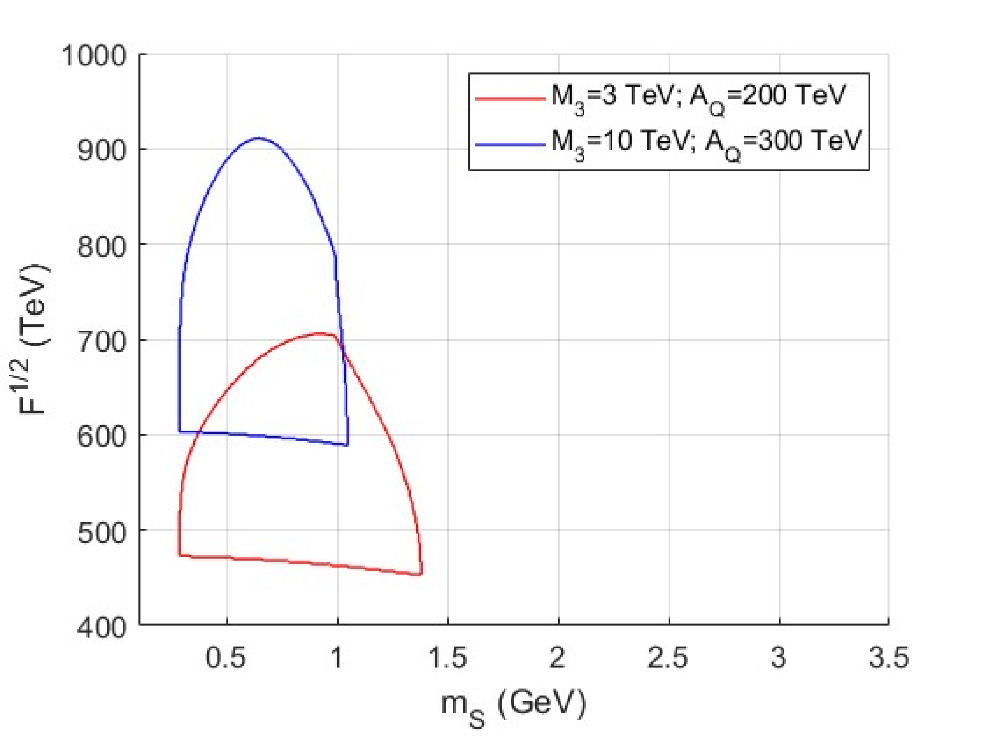
Soft parameters space

Source: Direct Production Decay: Meson

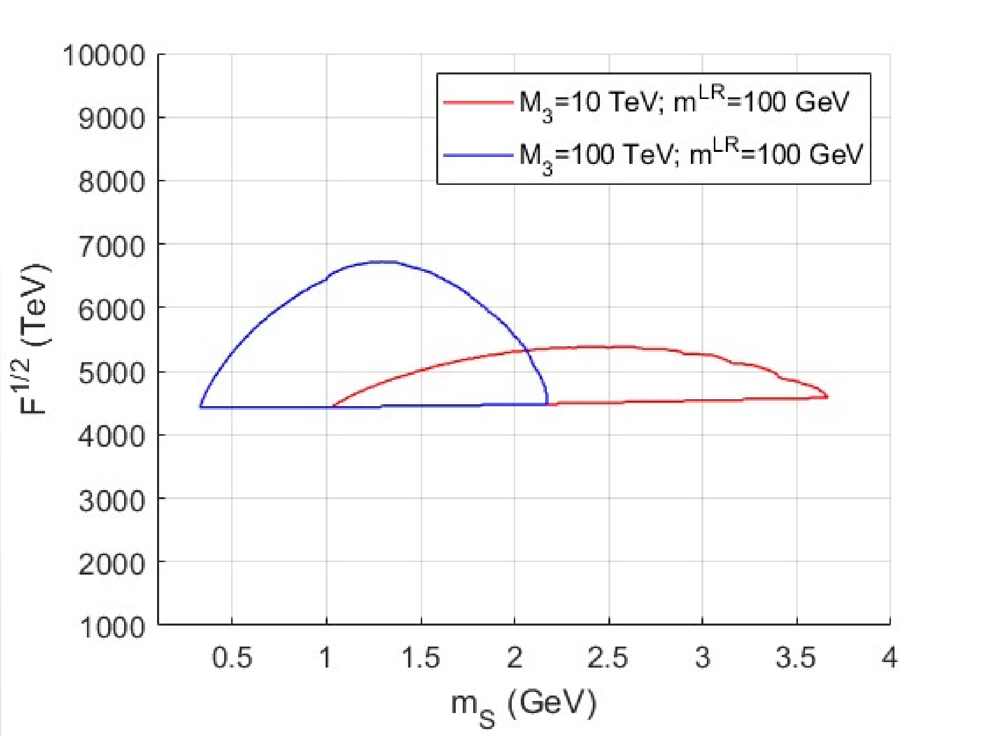


Soft parameters space

Source: Meson decay (B)   Decay: Meson



Flavor conserving meson decay



Flavor violating meson decay

FASER 1

Much smaller luminosity
Much smaller fiducial volume

⇓

Less sgoldstino in the detector. Only light η-mesons and direct production contribute

⇓

$$m_S < 0.35\ GeV$$
$$\sqrt{F} < 500\ TeV$$

Summary

- Most promising sgoldstino mass: $m_S < 2m_\pi$, but has uncertainties with gluon fission cross section
- Decaying into photons gives good possibility for detecting sgoldstino with small masses
- Lepton decays give strong restrictions on sgoldstino mass
- e^+e^- channel is always open, but it is suppressed by lepton mass
- Meson decay is main signal for sgolsino with masses above pion threshold

Thank you for your attention