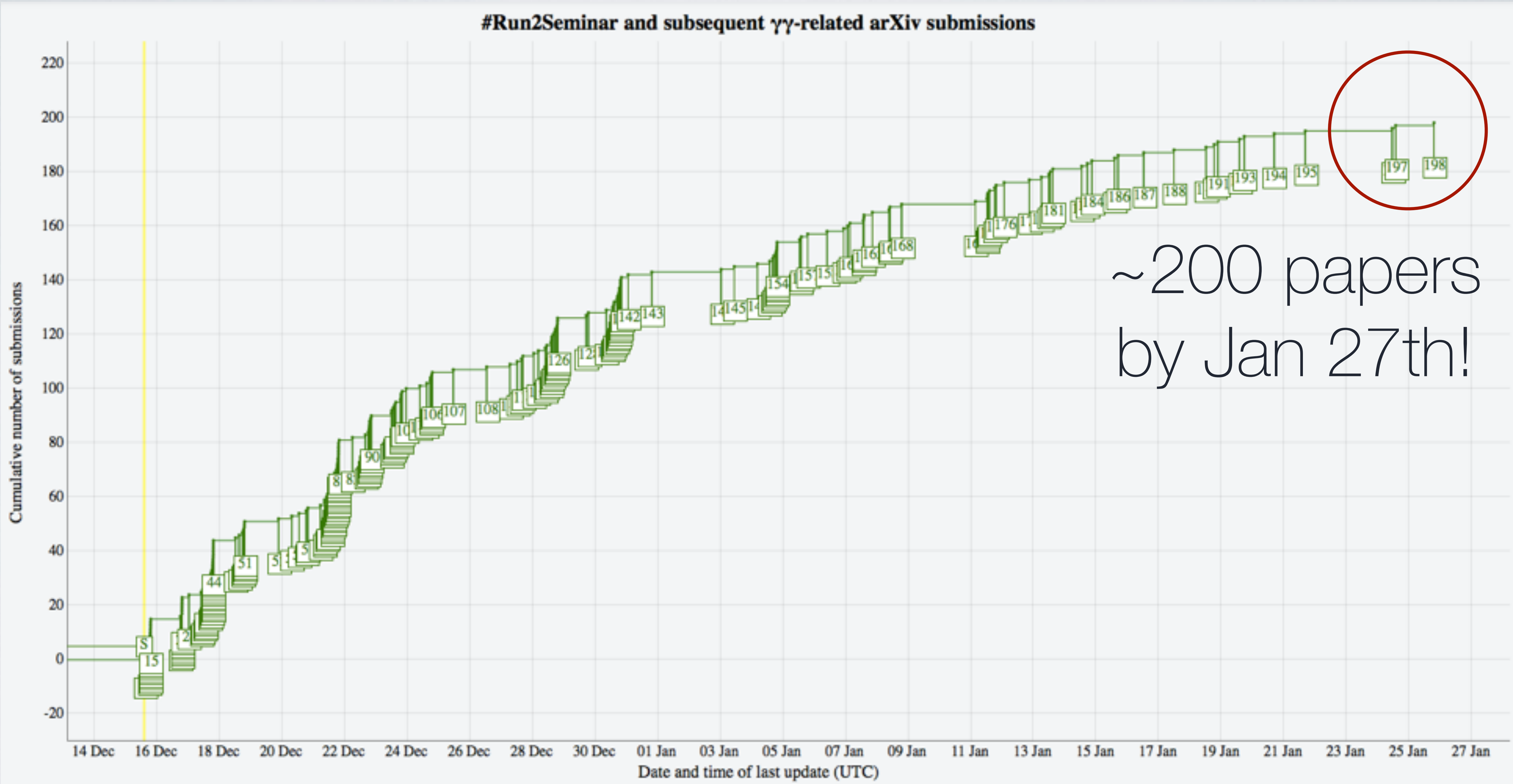
“**Vanilla scenario**” for the di-photon resonance

(Mihailo Backovic)
CP3-UCL

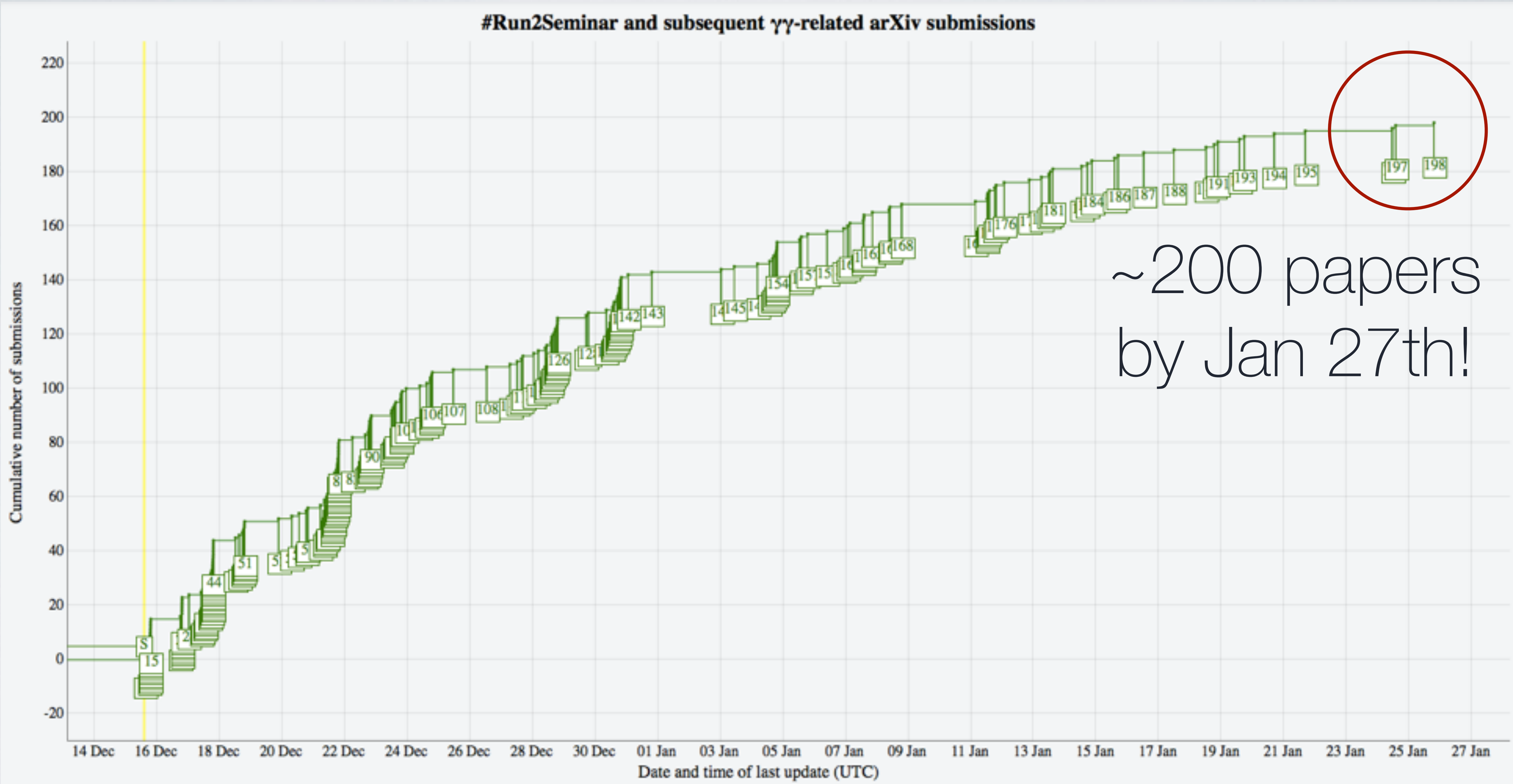
Enormous amount of theory papers!



~200 papers by Jan 27th!

0.1 seconds per paper in this talk.

Can we understand this?



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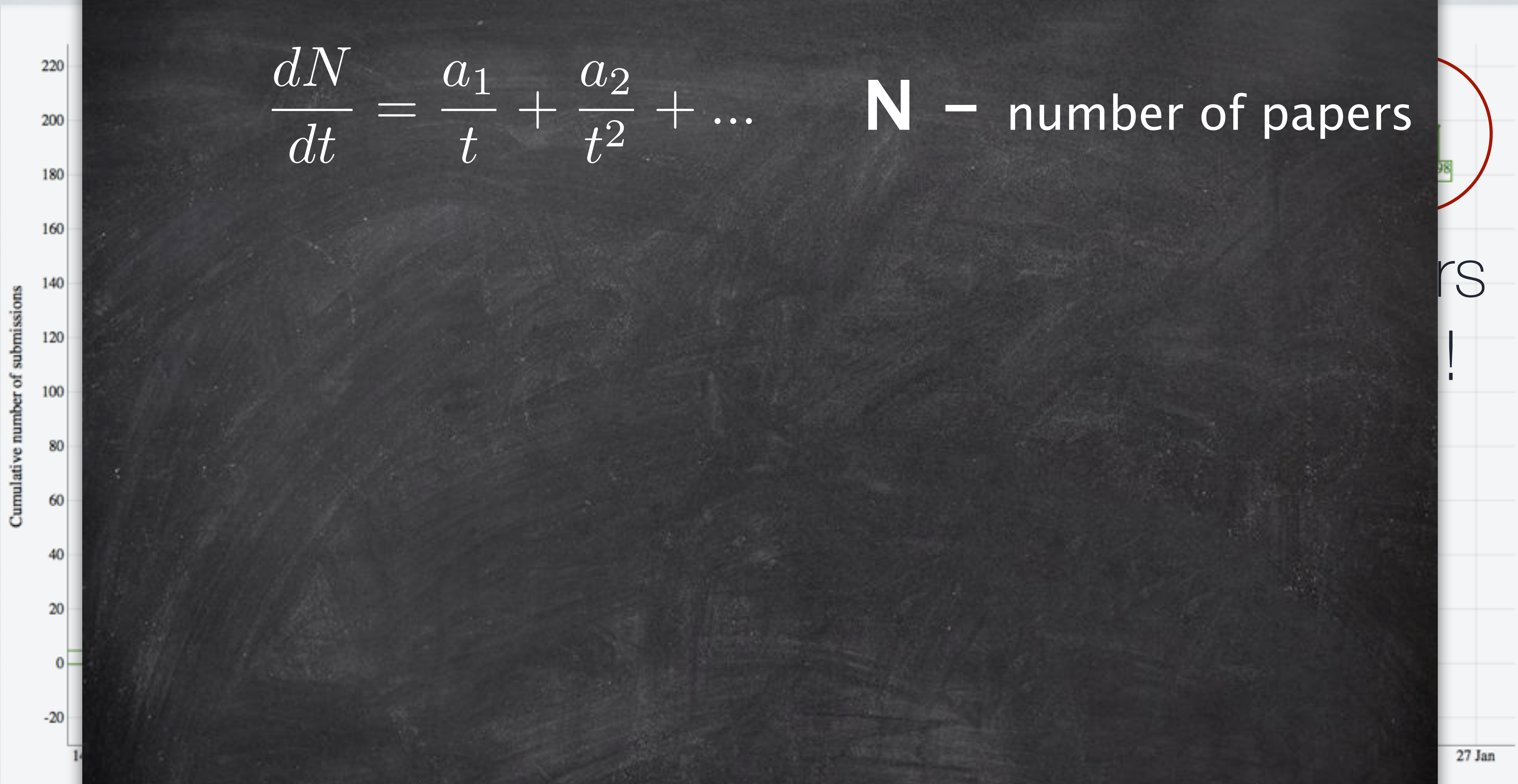

$$\frac{dN}{dt} = \frac{a_1}{t} + \frac{a_2}{t^2} + \ldots$$

N – number of papers

0.1 seconds per paper in this talk.

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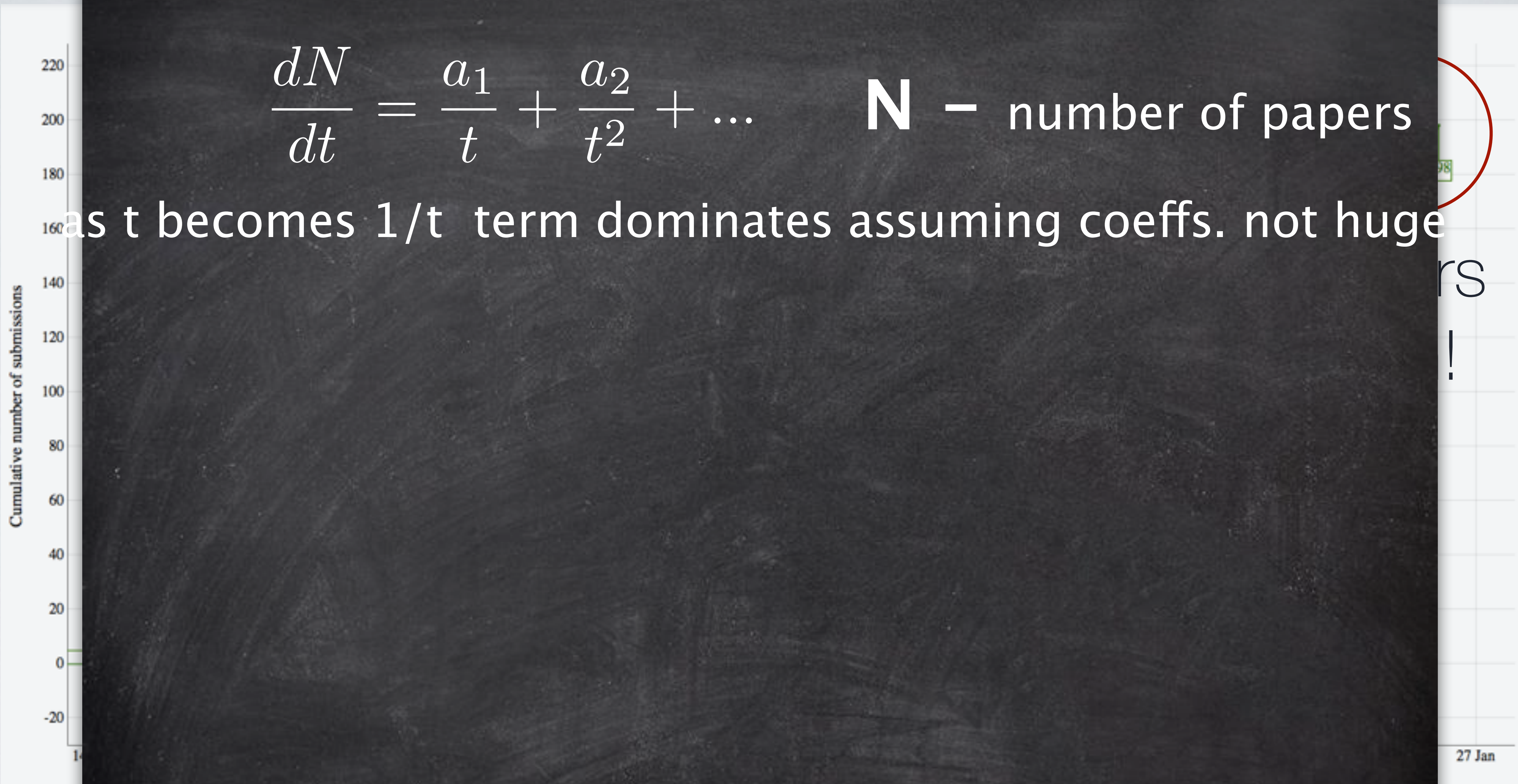

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as t becomes 1/t term dominates assuming coeffs. not huge

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$$N = a\,log(b\,t)$$

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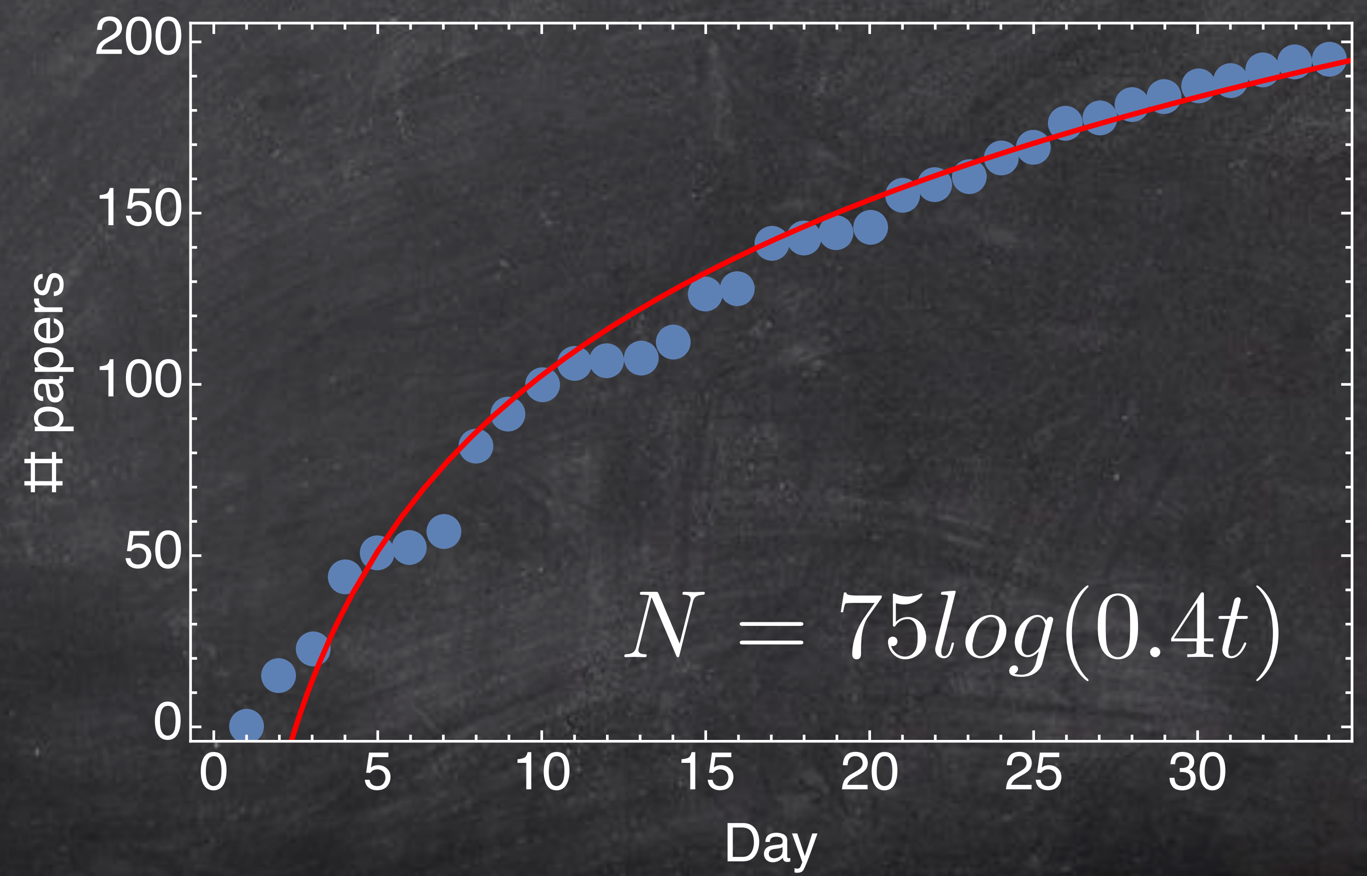

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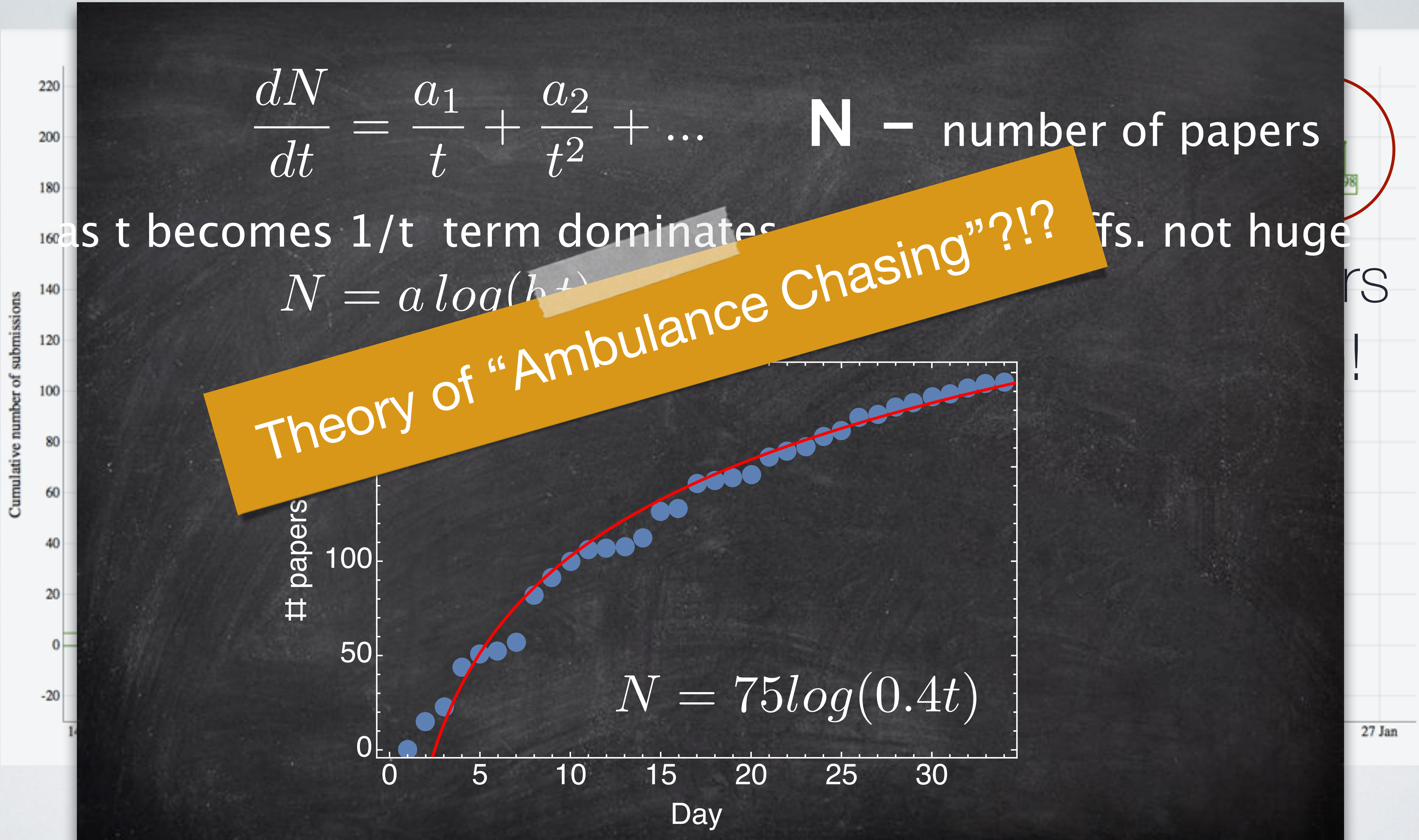

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Vanilla scenario

(Nothing here is set in stone… because there is no stone)

"The di-photon signal is a **new resonance!**"

Landau-Yang theorem suggests it's a **scalar**

(** spin-2 possible, but difficult if you keep universal couplings to matter)

Large production rate suggests it's **gluon initiated**

The minimal interaction Lagrangian you need is:

$$\mathcal{L} \sim \frac{g_{BB}}{\Lambda}\phi B^{\mu\nu}B_{\mu\nu} + \frac{g_{WW}}{\Lambda}\phi W^{\mu\nu}W_{\mu\nu} + \frac{g_{GG}}{\Lambda}\phi G^{\mu\nu}G_{\mu\nu}$$

The immediate implication is that the vanilla scenario predicts **new vector-like fermions!**

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Large production rate suggests it's …

Most of this works for pseudo-scalars as well

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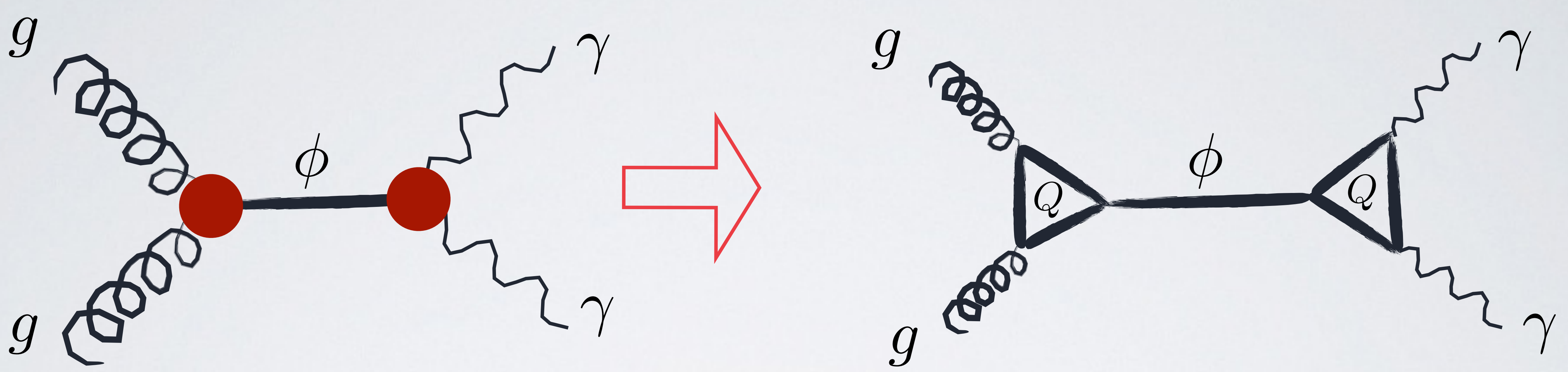
New Vectorlike fermions

The effective coupling to gluons and photons should be fairly large (O(1)) to accommodate $\sigma_{\gamma\gamma} \sim 1 - 10\,\mathrm{fb}$



- Loop-supressed
- How many vector-like generations do you need to fit the excess?
- What kind of couplings do you need?

Issue of the total width

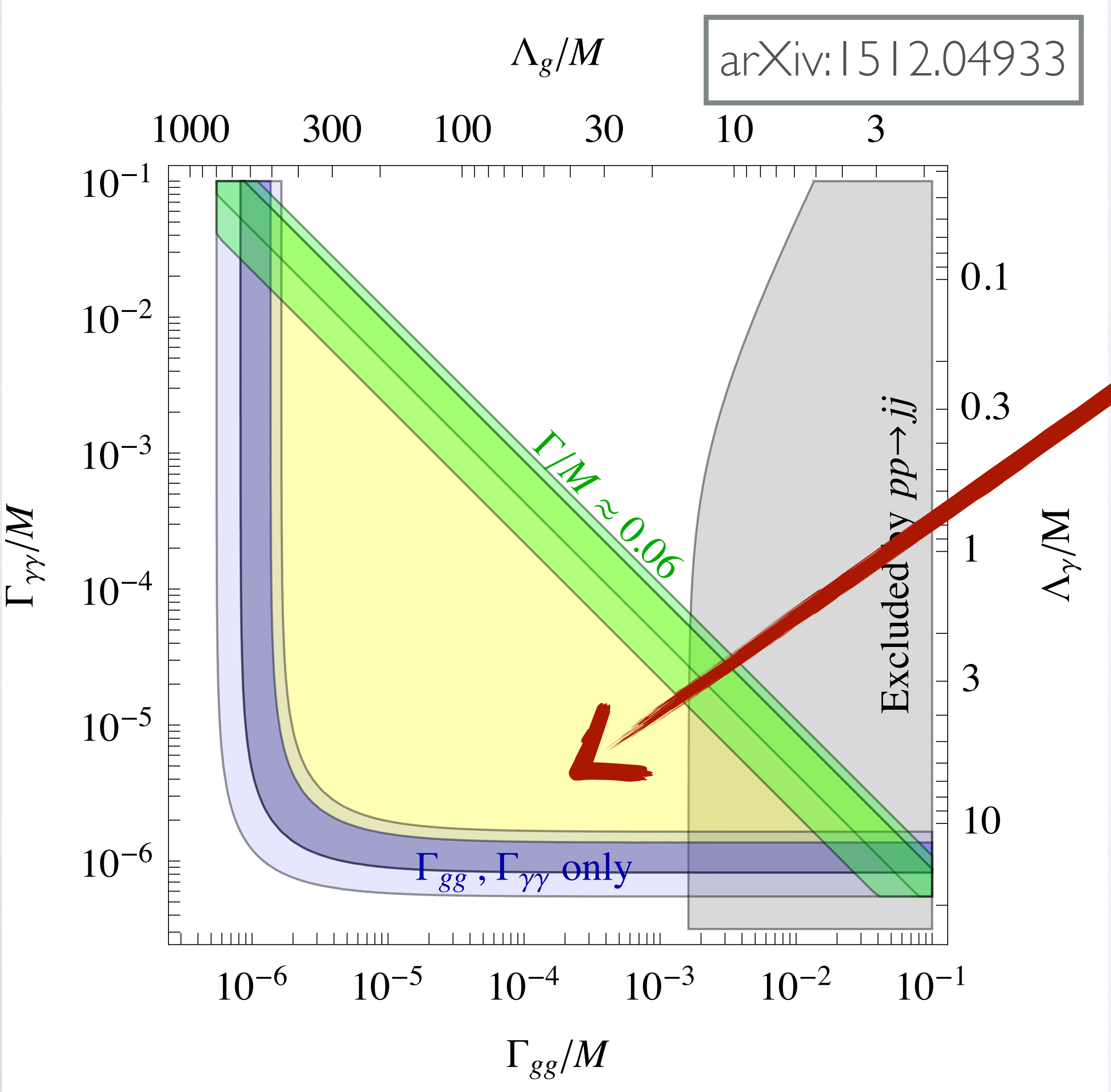
$$\Gamma[\phi \to gg] = \frac{2g_{GG}^2}{\Lambda^2}\frac{m_\phi^3}{\pi}$$

similar exp. for photons

$$g_{GG} \sim \alpha_s/4\pi \times O(1)$$

Generically difficult to boost up the couplings. **Big problem with all models.**

Narrow width (< O(1) GeV)?

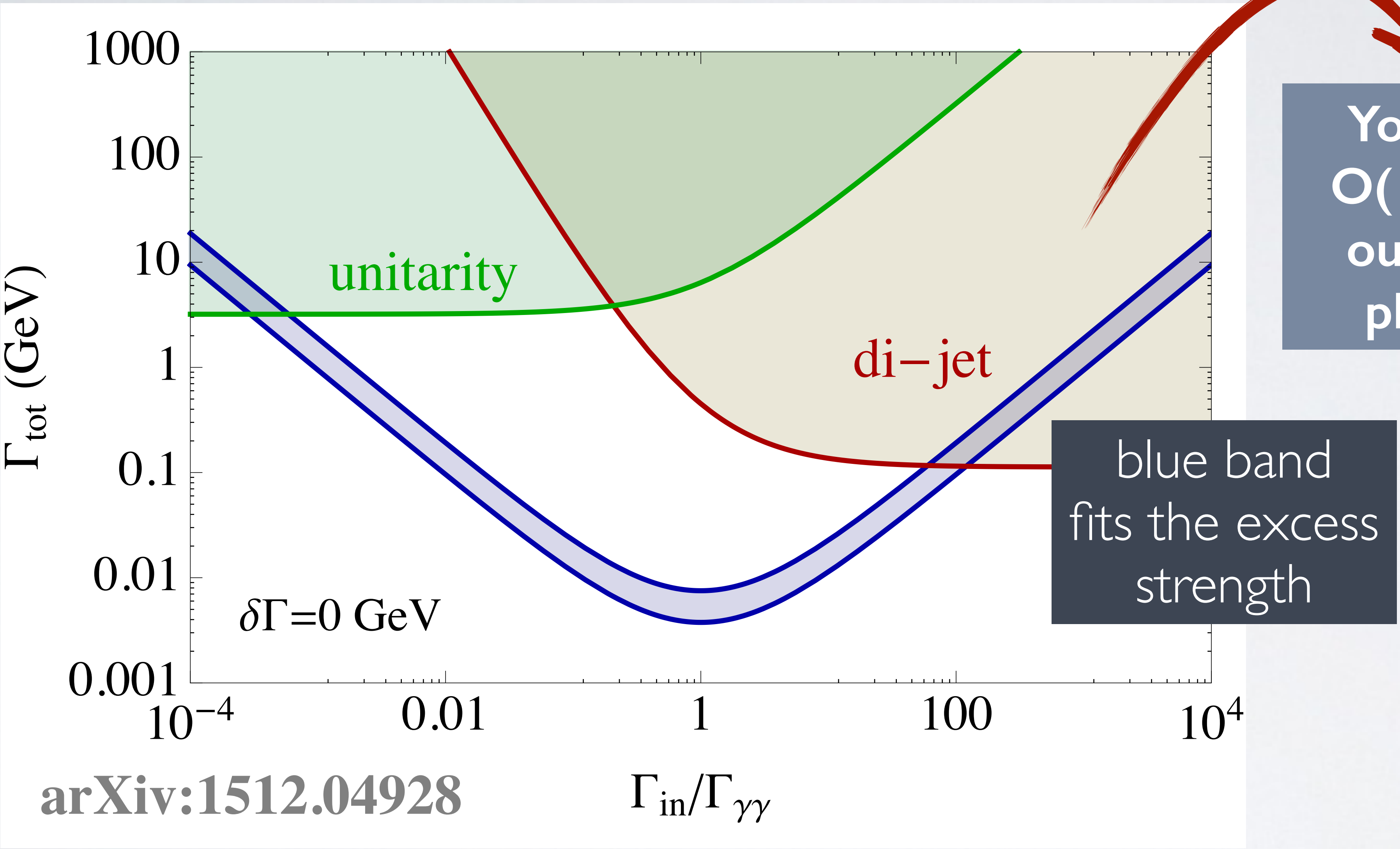


- Yellow region can fit the signal strength.
- Dark blue band can fit the signal strength assuming **only decays to photons and gluons.**

No real problems!
photons and gluons alone are sufficient
if the width is small!

Issue of the total width

Large width (> O (1) GeV)?



You can not get a width of O(10) GeV that is not ruled out and fits the signal with photons and gluons only.

The resonance must decay to states other than photons and gluons!

Issue of the total width

Large width (> O (1) GeV)?

What else could the new resonance decay to?

We haven't observed any charged states with mass of O(100) GeV…

Invisible particles?

Degenerate states?

Dark Matter?
Hidden Valleys?

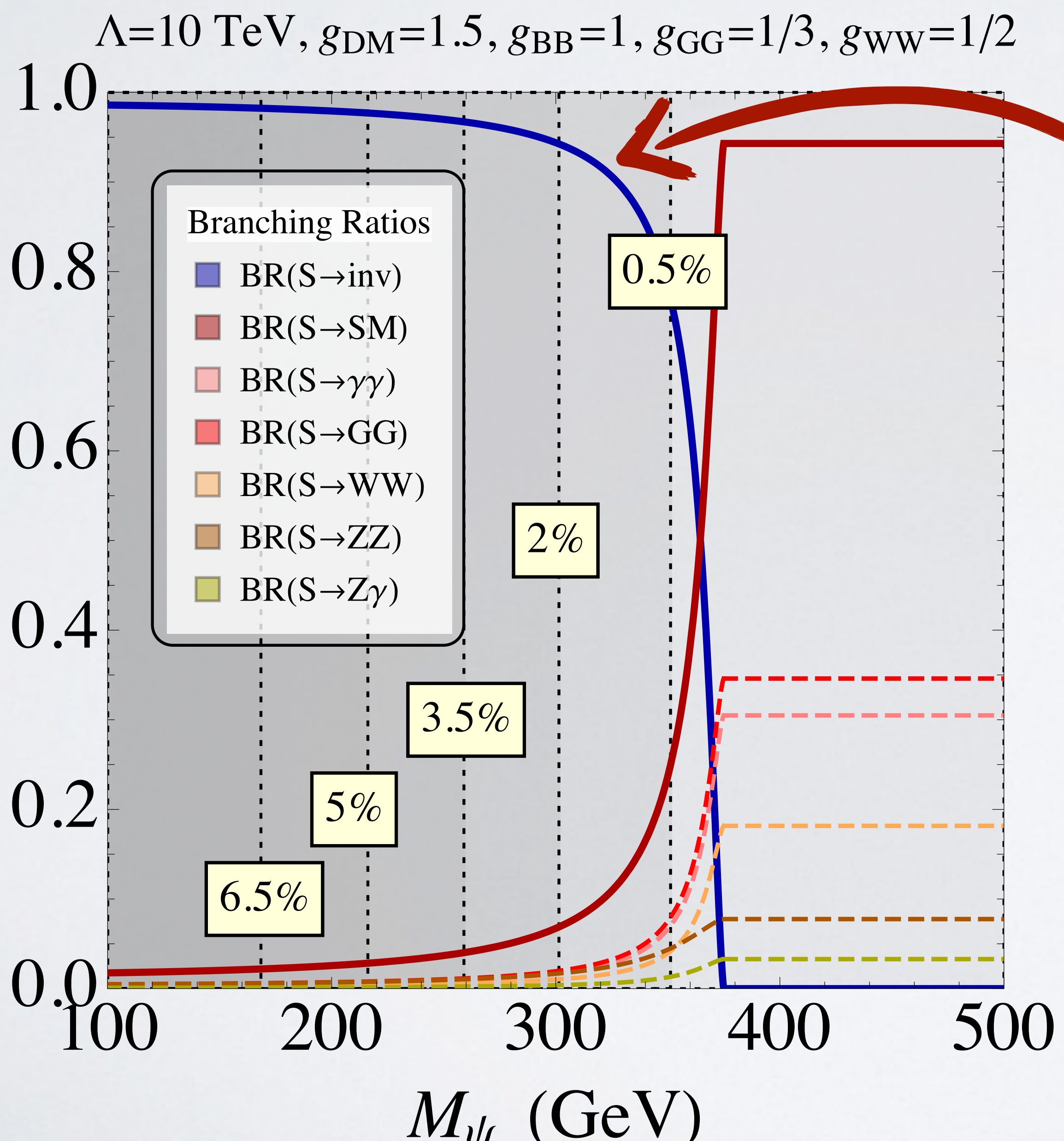
Large width and DM

Add a **Dirac Fermion Dark Matter** to the minimal Lagrangian

$$\mathcal{L}^{+}_{NP} = \frac{1}{2}(\partial S)^2 + \frac{m_S^2}{2}S^2 + \bar{\psi}\partial\!\!\!/\psi + (g_{DM}S + M_\psi)\bar{\psi}\psi + \frac{g_{GG}}{\Lambda}SG^{\mu\nu}G_{\mu\nu} + \frac{g_{WW}}{\Lambda}SW^{\mu\nu}W_{\mu\nu} + \frac{g_{BB}}{\Lambda}SB^{\mu\nu}B_{\mu\nu}$$

S = *new resonance*

arXiv:1512.04917



Most of the width generically comes from invisible decays

Large width and DM

<u>Signal strength</u>

$$\frac{g_{BB} \times g_{GG}}{g_{DM}^2}$$

<u>Relic density</u>

$$g_{BB}, g_{GG}, M_\psi, g_{DM}$$

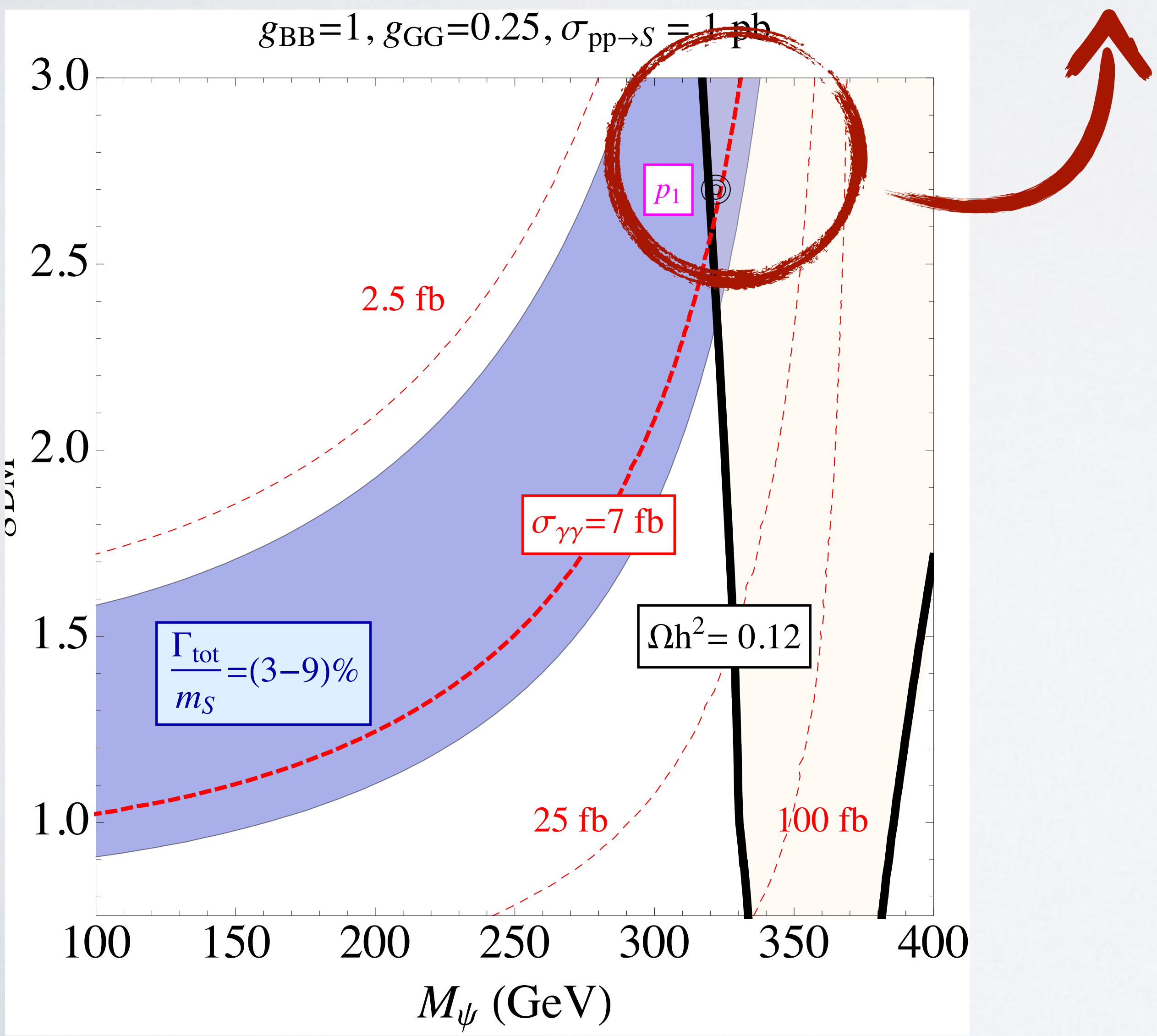
<u>Total width</u>

$$M_\psi, g_{DM}$$

Large width and DM

Signal strength	Relic density	Total width
$\dfrac{g_{BB} \times g_{GG}}{g_{DM}^2}$	$g_{BB}, g_{GG}, M_\psi, g_{DM}$	M_ψ, g_{DM}

In fact, requiring $\Omega h^2 \sim 0.1$ and **the width essentially fixes the DM parameters!**



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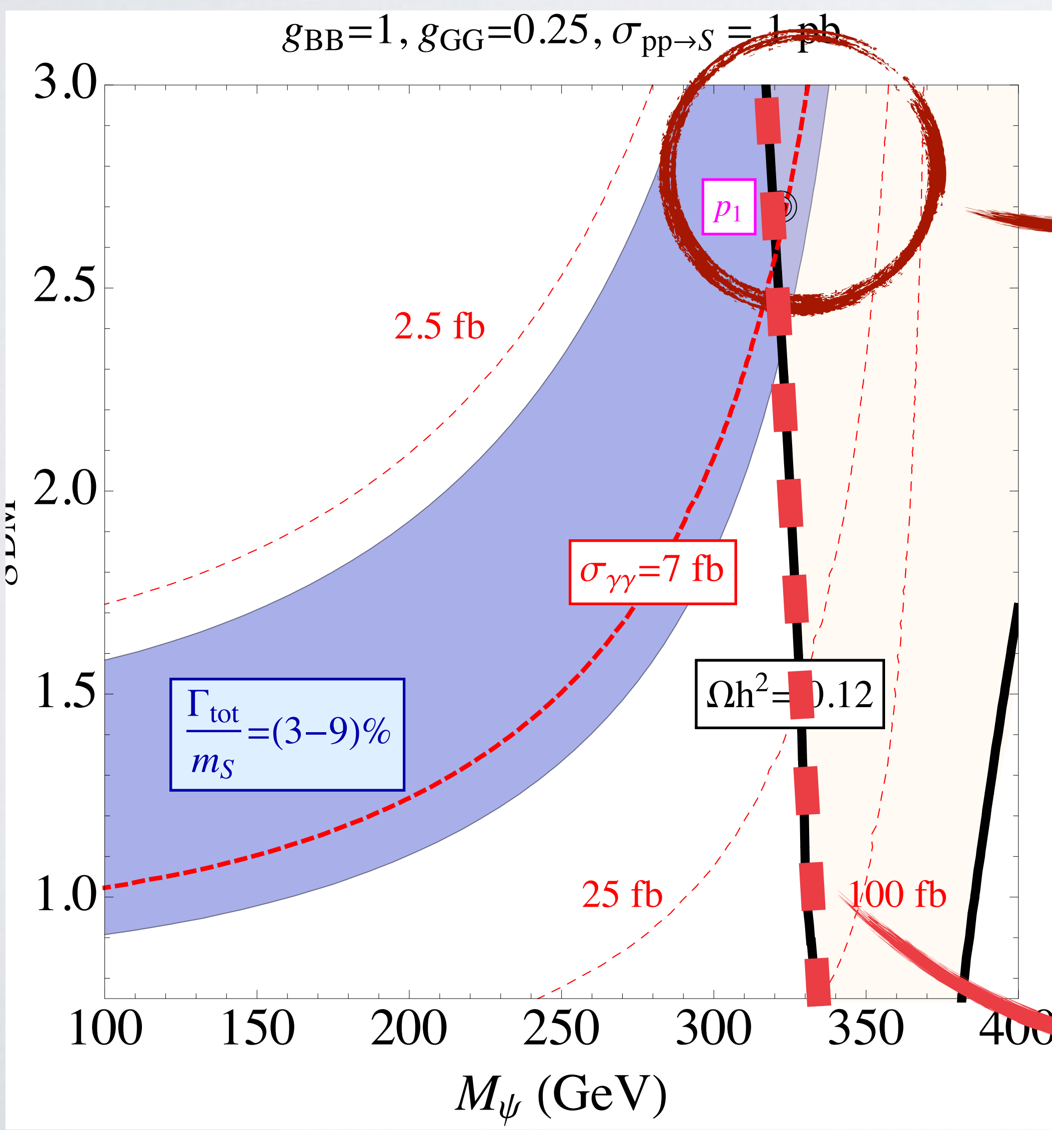

Correct relic density

Large width and DM

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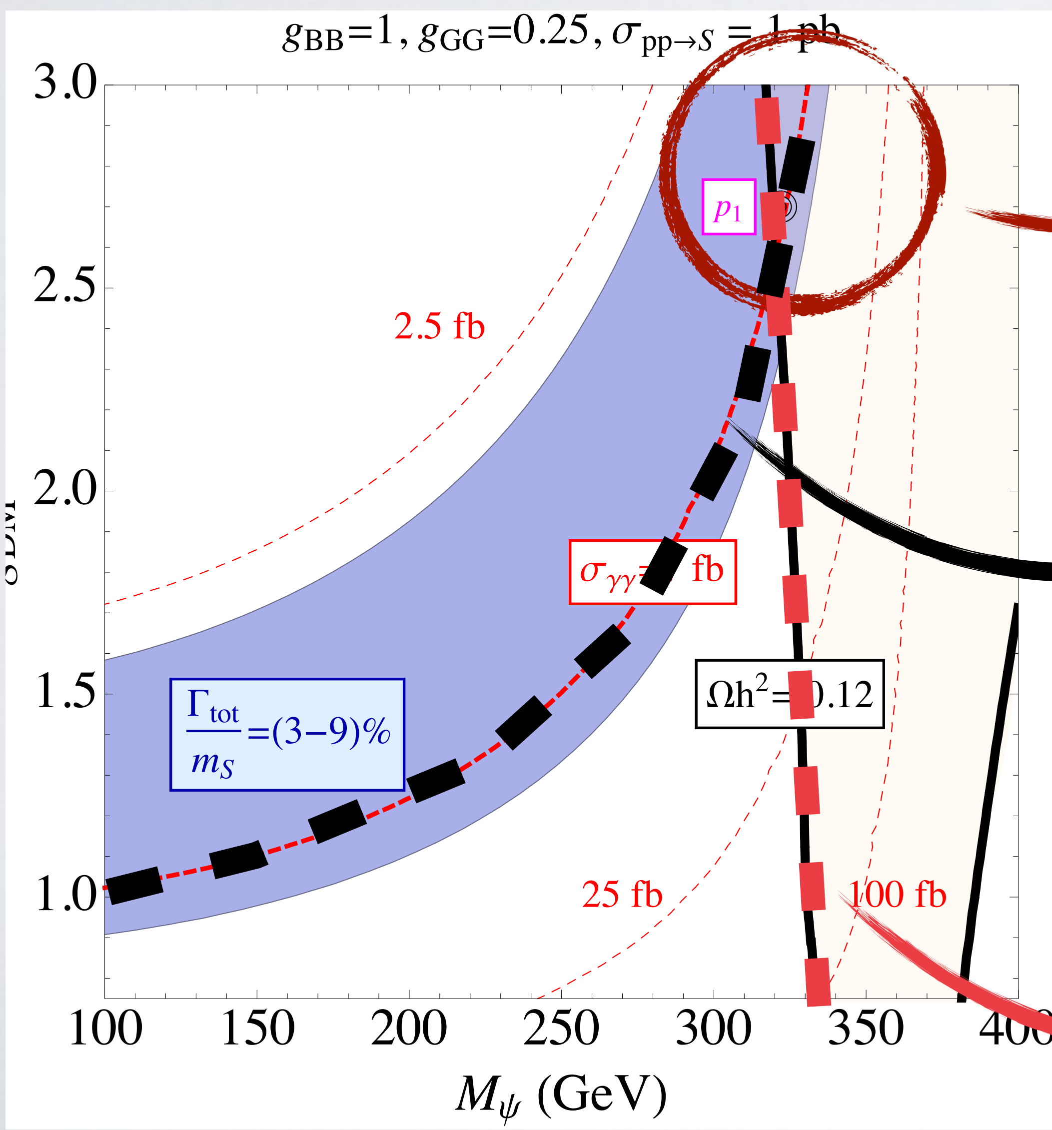

Width = 30 GeV

Correct relic density

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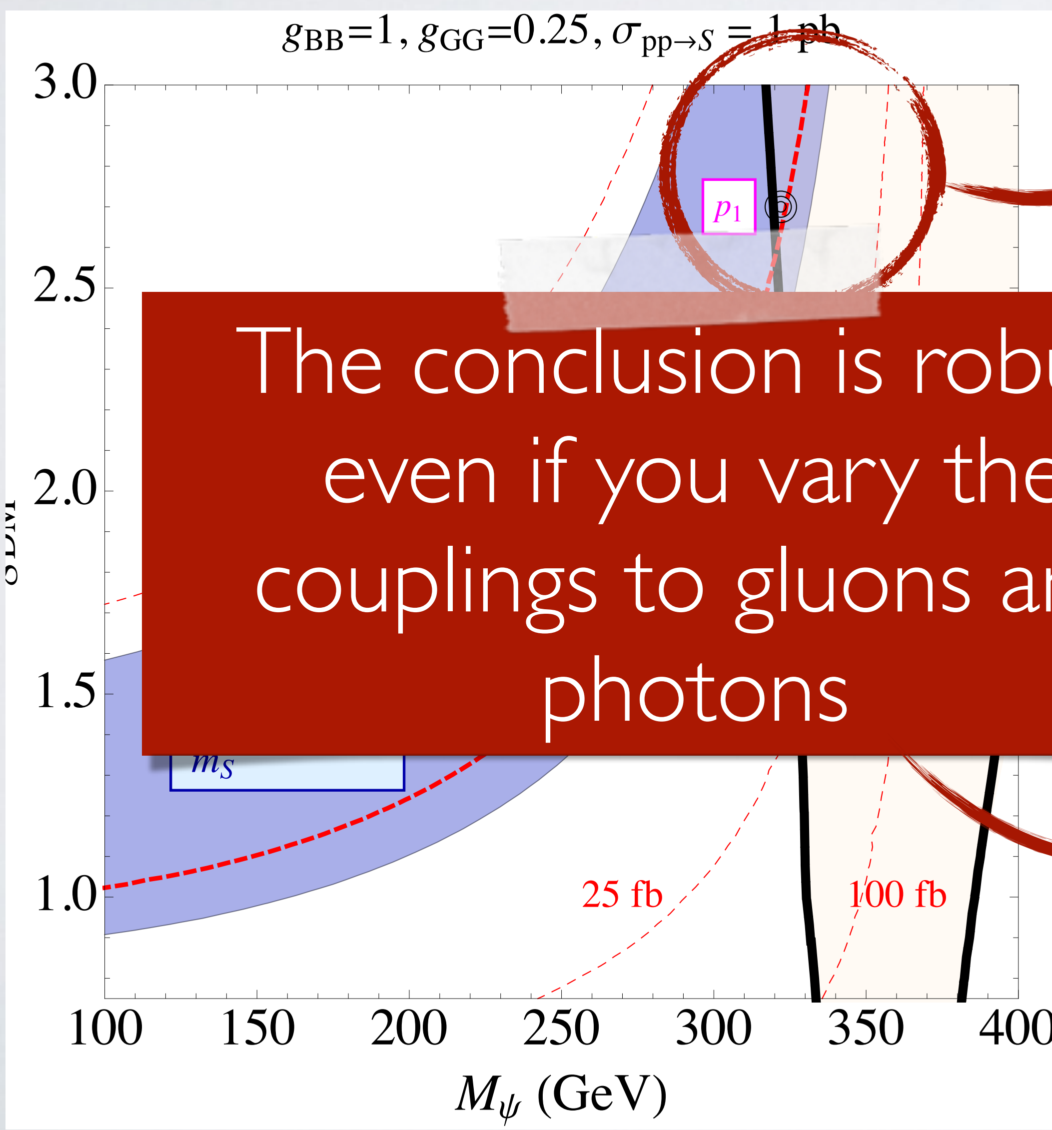
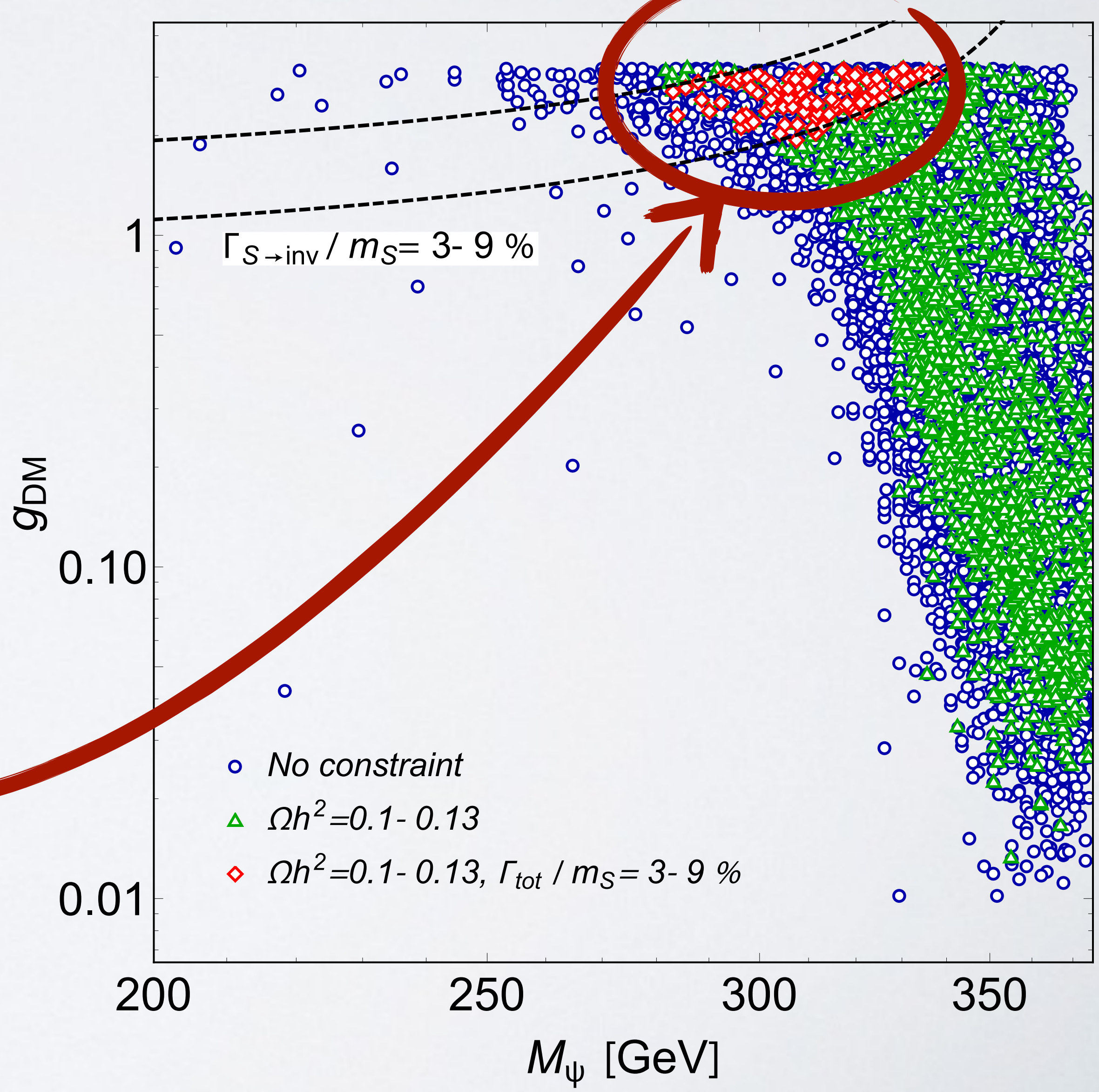
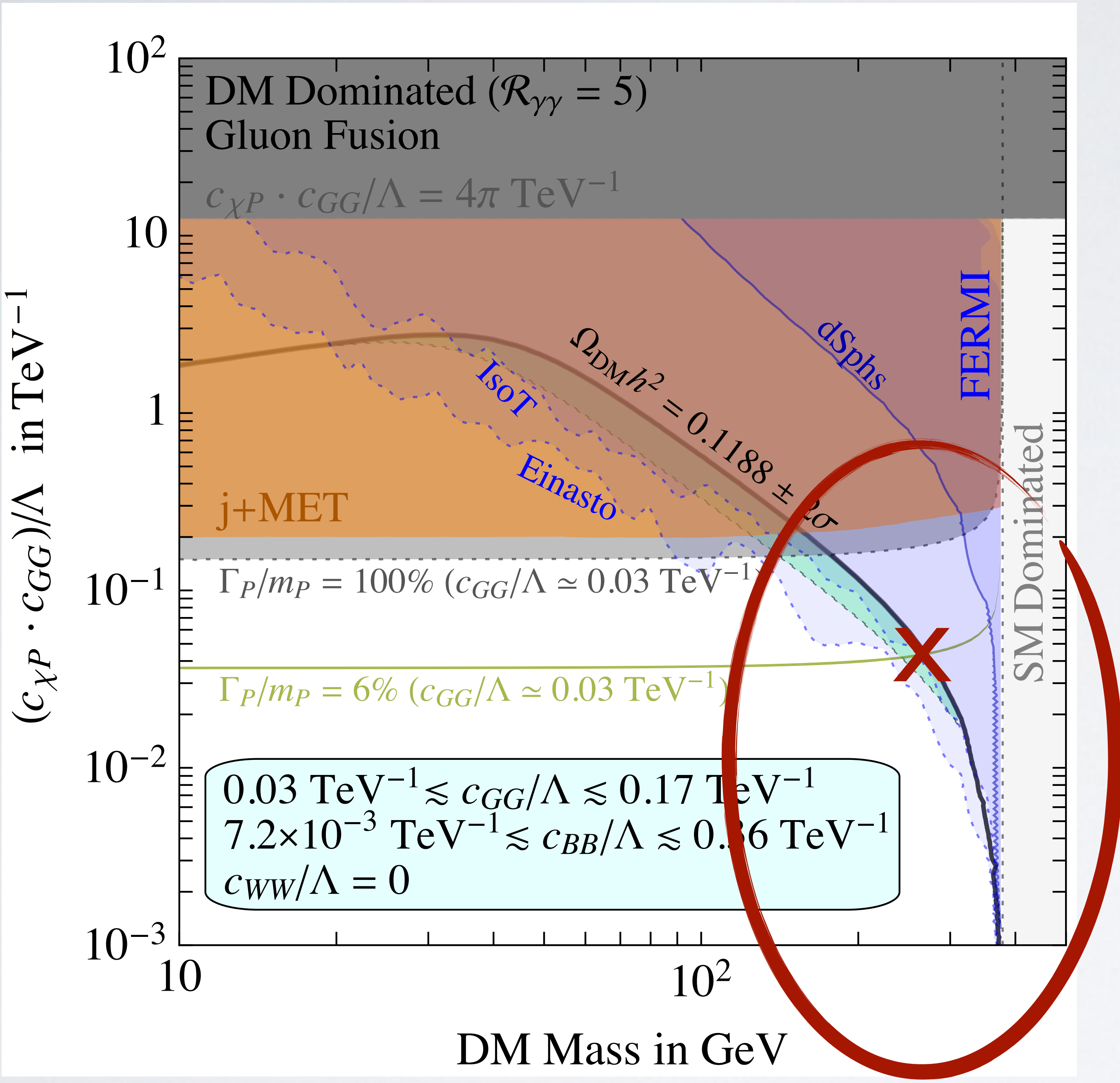


The conclusion is robust even if you vary the couplings to gluons and photons



Can the DM mediator be a pseudo-scalar ?

arXiv:1601.01571



Annihilation cross section of two **Dirac fermions** via a pseudo scalar **not velocity suppressed!**

More susceptible to the limits from Indirect Detection (ID)

Requiring correct relic density and the large width is ruled out.

It might possible to be consistent with ID bounds, either by requiring under-abundant DM or by changing the coupling to the W…

If the di-photon signal is indeed real…

… and the large width is explained by Dirac fermion DM …

… a signal consistent with a 750 GeV DM mediator and 300 GeV DM with O(1) couplings should appear in the MET+j channel

… and a signal consistent with ~300 GeV DM particle should appear in direct detection

Is the prediction reasonable?

example points which give
the right resonance features and
correct relic density

Predictions

benchmark	(g_{GG}, g_{BB})	g_{DM}	M_ψ (GeV)	Γ_{tot}(GeV)	$\sigma_{\gamma\gamma}$(fb) at 13TeV	Ωh^2
p_1	(0.25,1)	2.7	322	30	6.2	0.10
p_2	(0.25,2)	2.2	307	29	25	0.12
p_3	(0.14,1)	2.7	323	29	2.1	0.12
p_4	(0.14,2)	2.3	308	31	7.8	0.12

Constraints

Benchmark	$\sigma_{\gamma Z}$	$\sigma_{\mathrm{MET}+j}$	$\sigma_{\gamma\gamma}$	σ_{jj}	$\langle\sigma v\rangle_{\gamma\gamma}$	σ_{SI}
	< 3.5 fb	< 6 fb	< 2 fb	$< 10^3$ fb	$< 10^{-28}\,\frac{\mathrm{cm}^3}{\mathrm{s}}$	$< 4\times10^{-45}\mathrm{cm}^2$
p_1	0.86	3.7	1.4	1.3	$3.9\cdot10^{-32}$	$6.9\cdot10^{-46}$
p_2	3.6	3.5	6.0	1.4	$5.5\cdot10^{-32}$	$4.6\cdot10^{-46}$
p_3	0.3	1.2	0.48	0.14	$4.1\cdot10^{-32}$	$2.3\cdot10^{-46}$
p_4	1.1	1.2	1.8	0.13	$6.2\cdot10^{-32}$	$1.6\cdot10^{-46}$

except for $\boldsymbol{p_2}$, example points **consistent**
with existing exp. constraints

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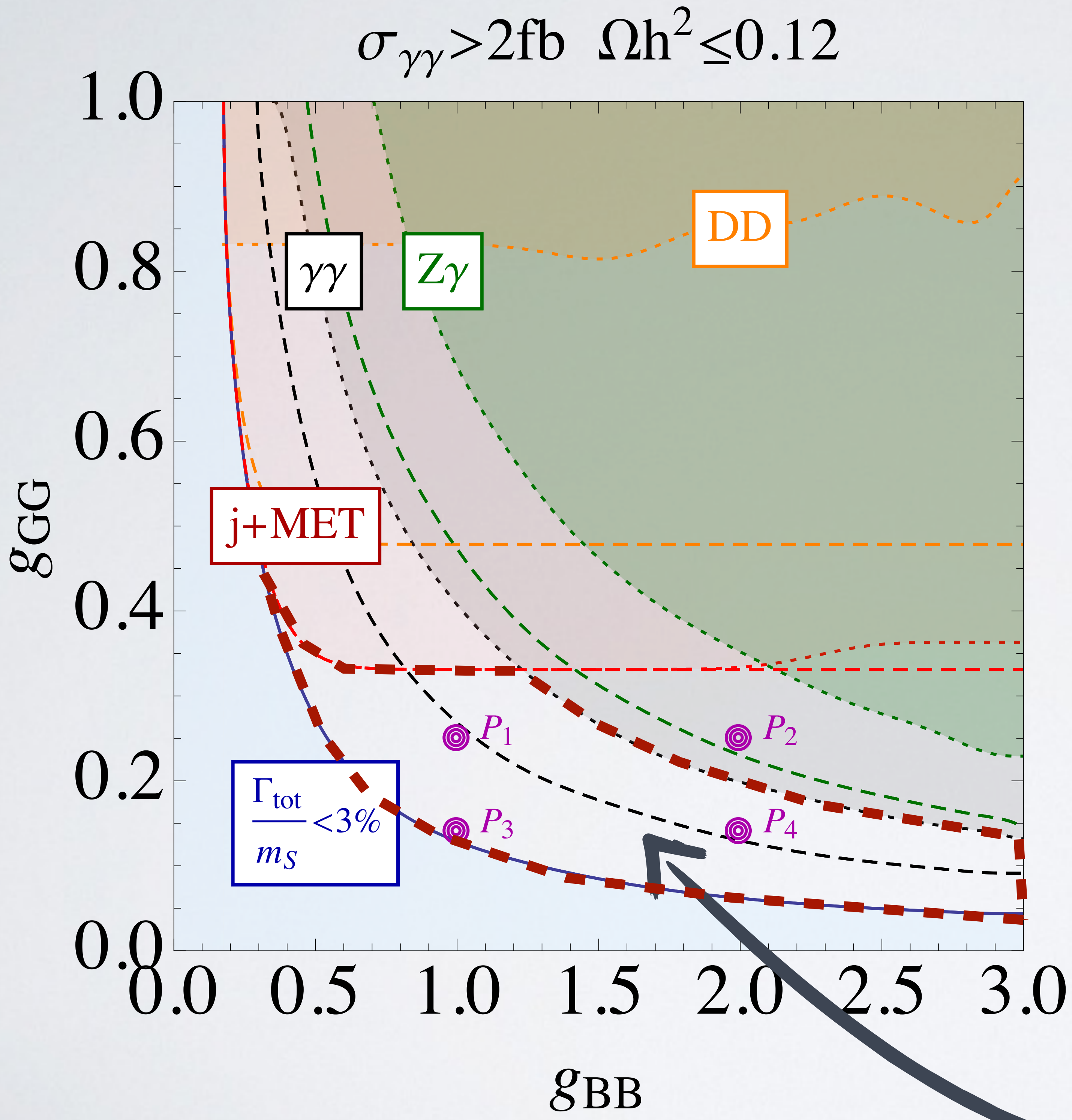
Indirect detection "favors" pure scalars because of *p*-wave suppression

except for ***p*₂**, example points **consistent** with existing exp. constraints

Is the prediction reasonable?



4-dimensional par. space projected onto **g_{GG}** and **g_{BB}**

Dashed/dotted curves represent the **strongest/weakest** bounds (depending on the values of DM mass and coupling)

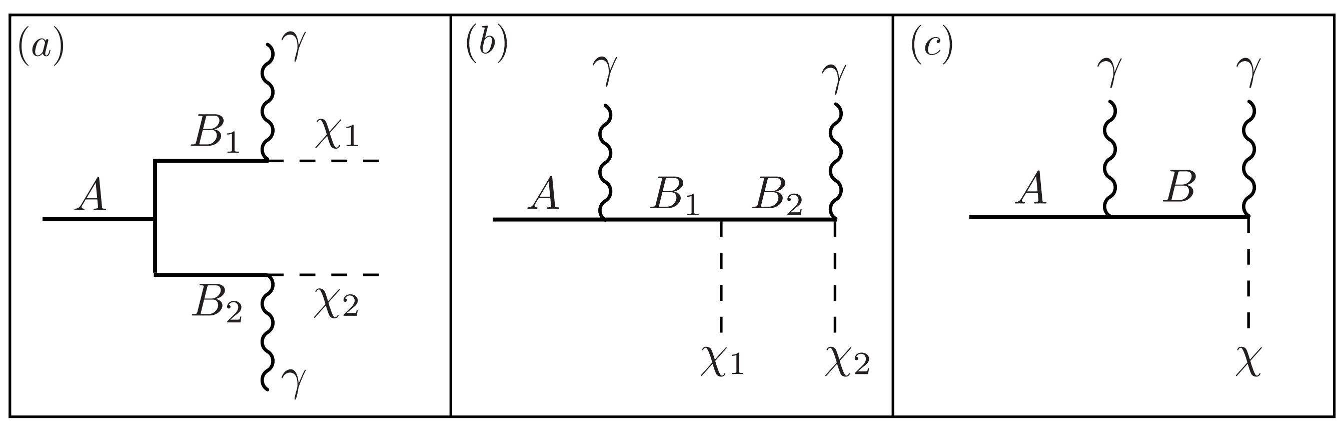
Allowed parameter space

“The di-photon signal is **not a new resonance!**”

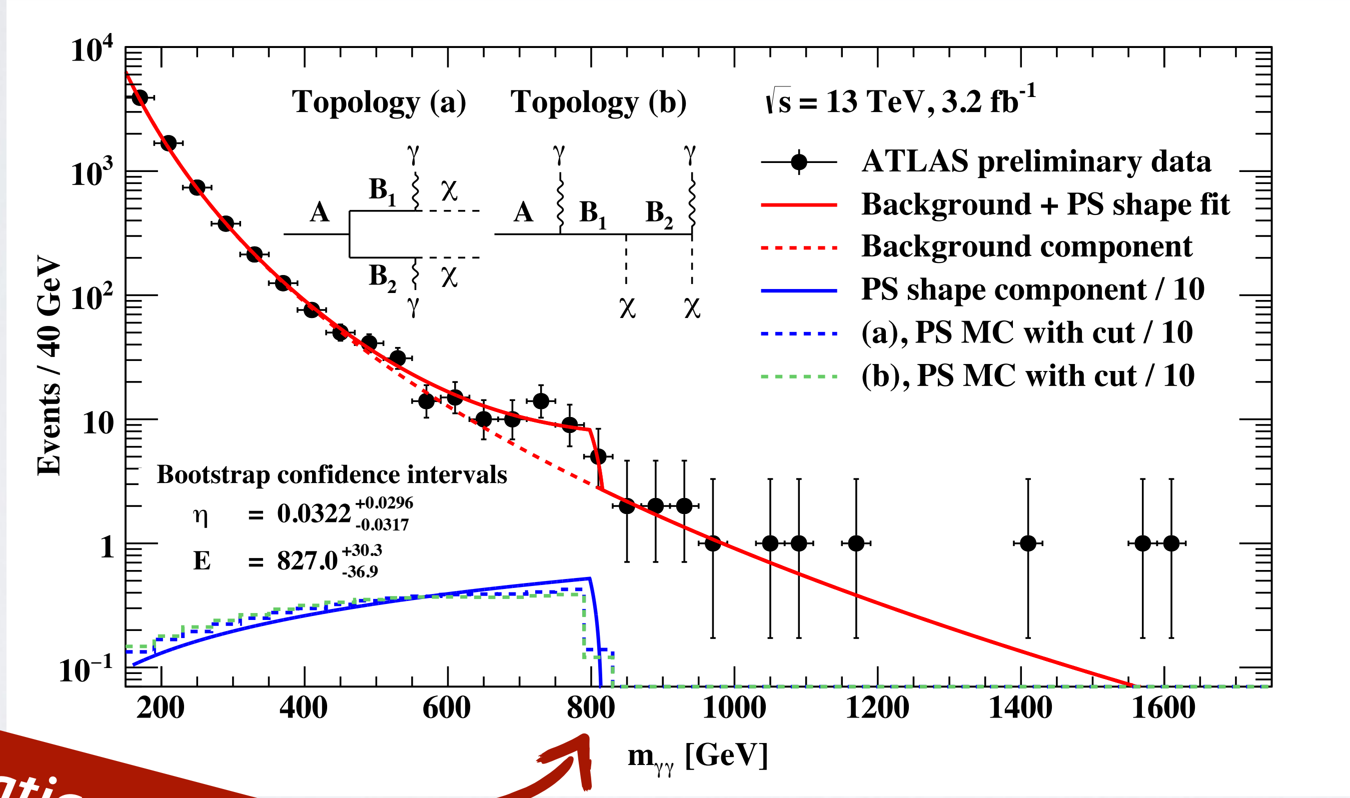
Kinematic edge

arXiv:1512.06824

Assume more complicated decay chain ending into invisible particles



Particle A generically heavier than 750 improving enhancement from 8 to 13



Kinematic edge depends on mass combination

Consistency with **observed signal ?**

Kinematic edge

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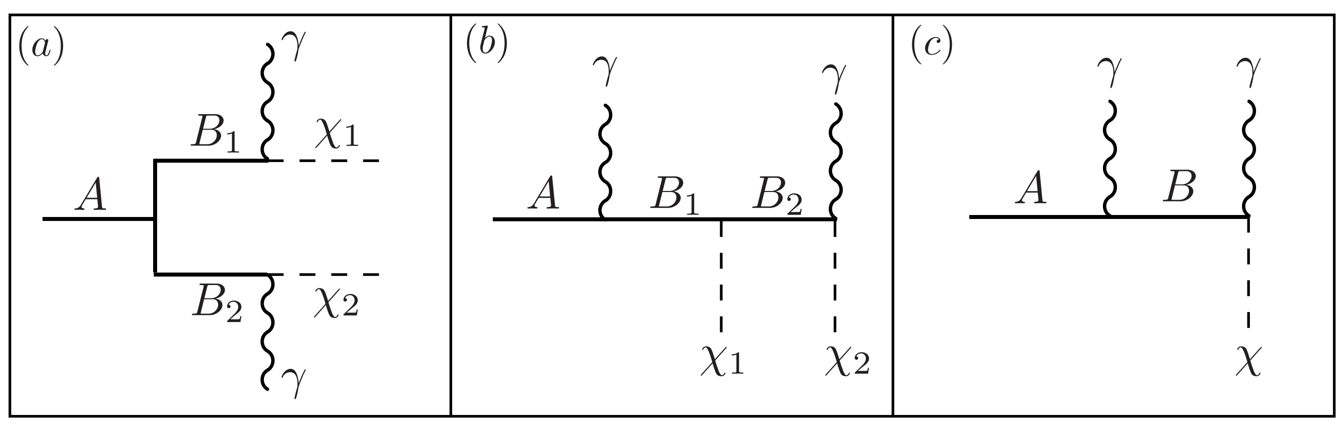

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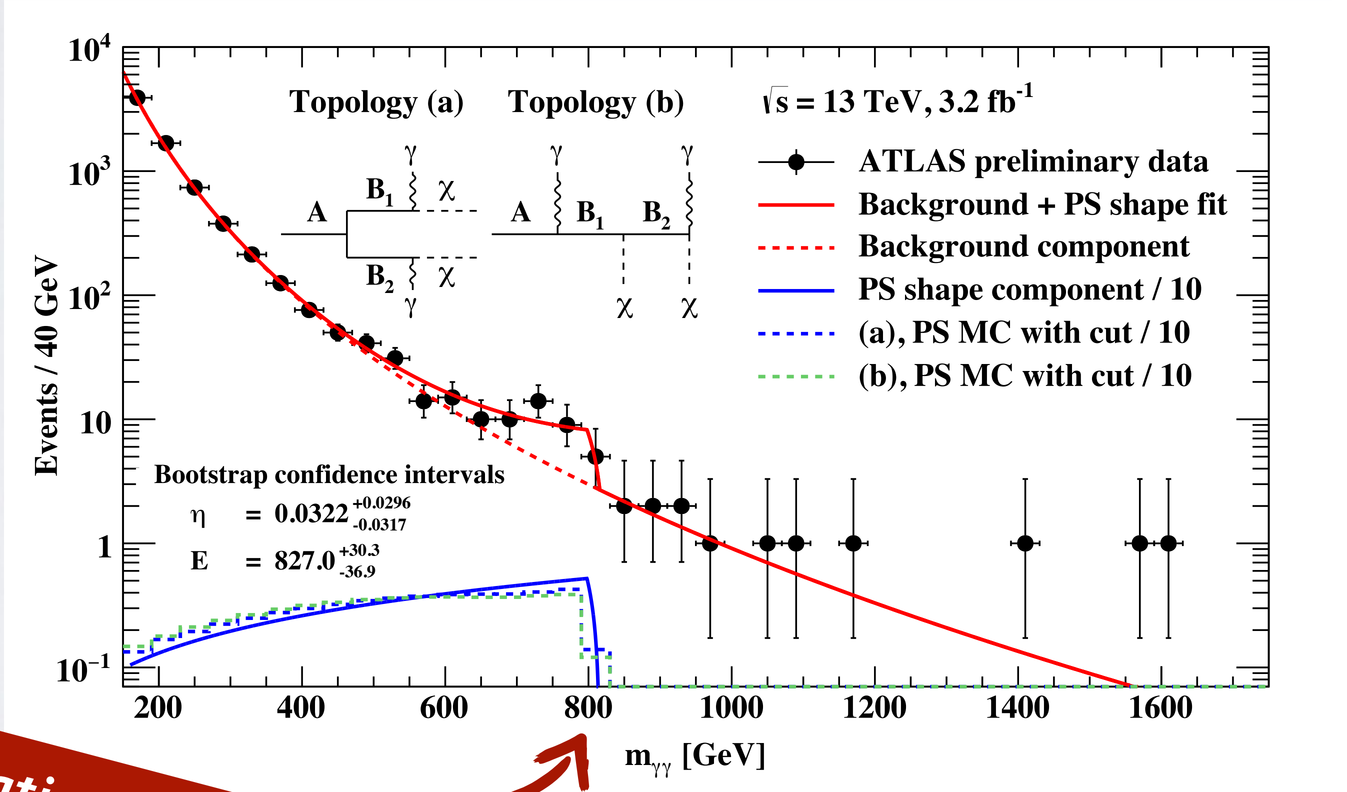

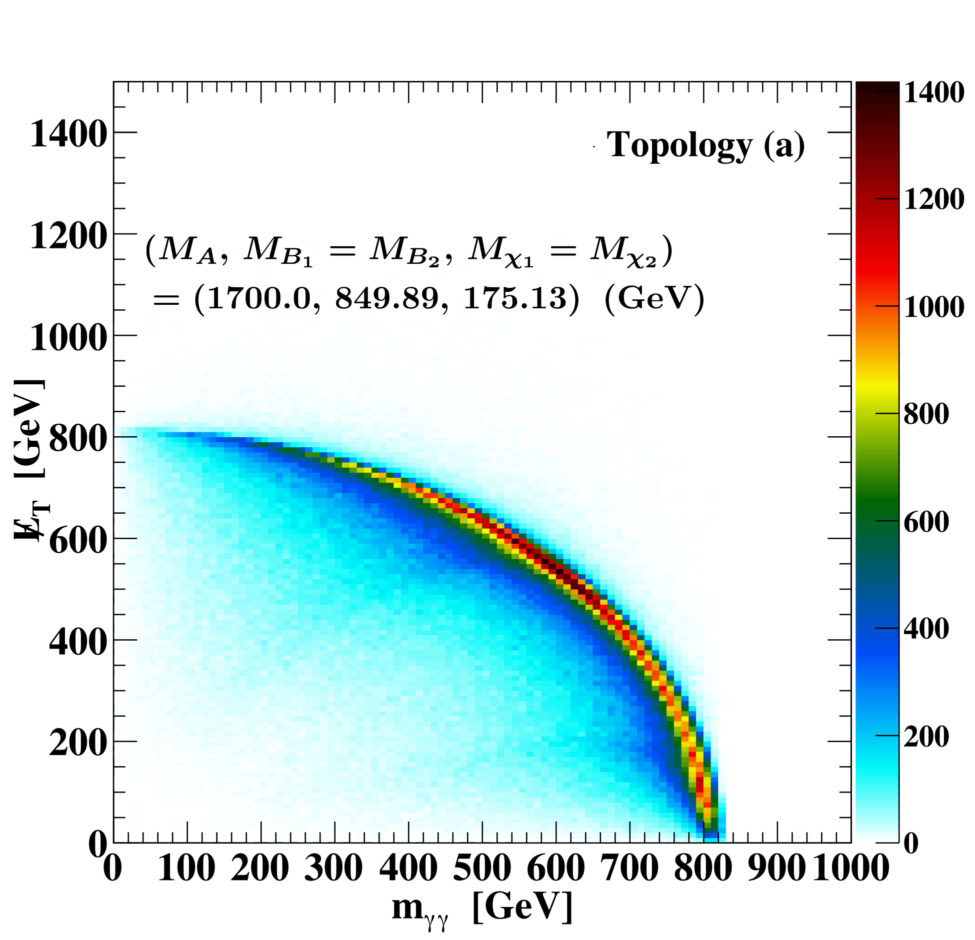

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Consistency with **observed signal**

Small Missing energy in events with large $m_{\gamma\gamma}$