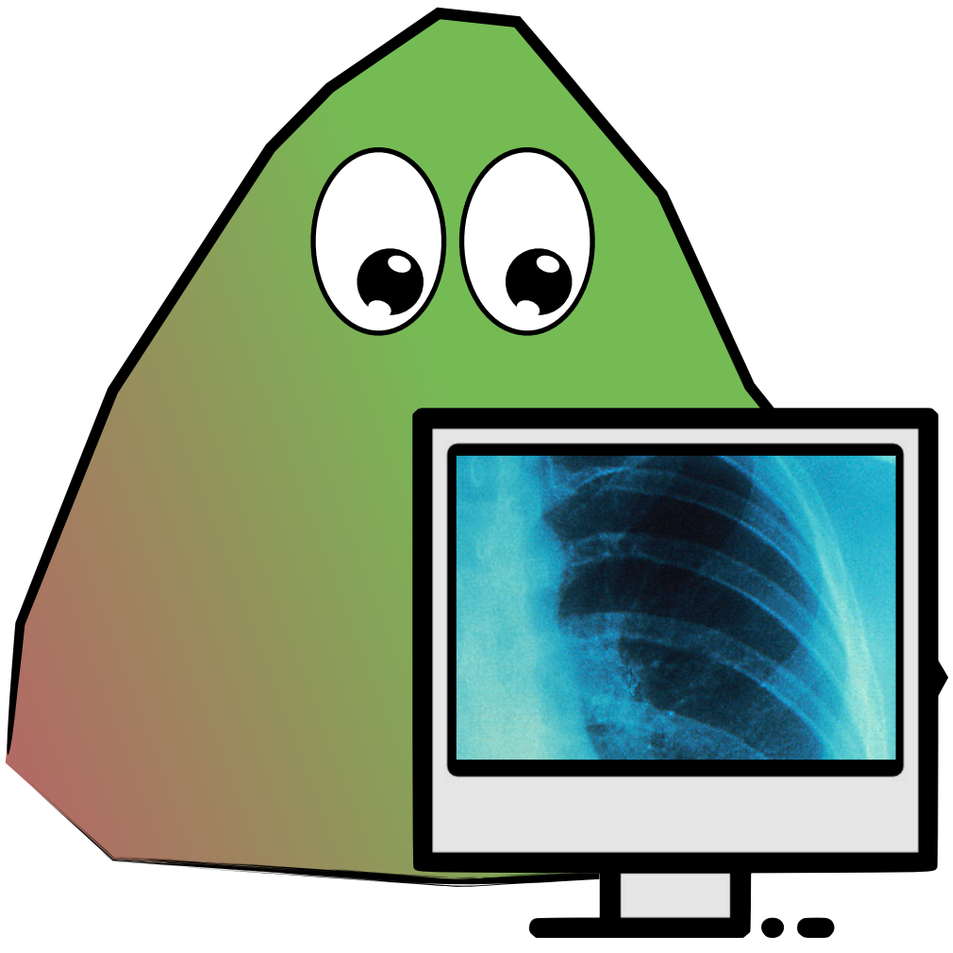
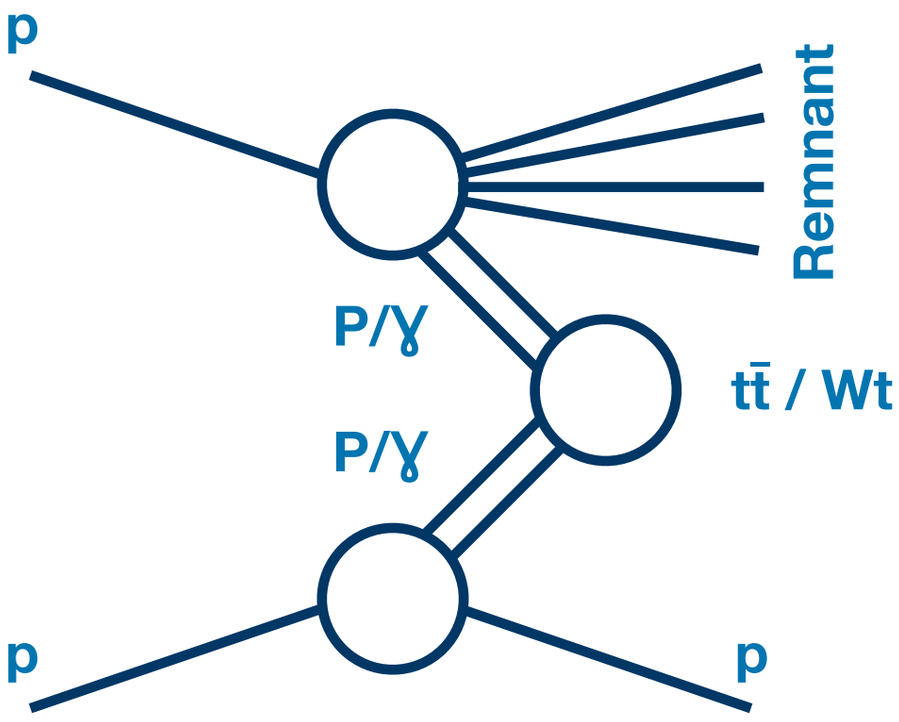
Top Processes

In Photon-Induced Collisions

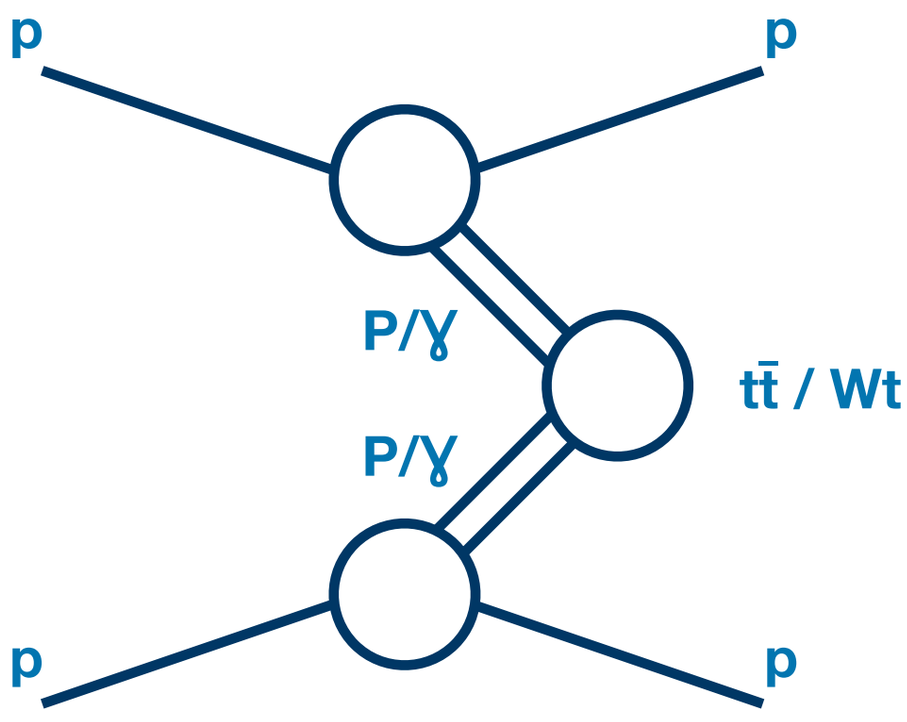


Elastic tops

Semi-elastic



Elastic



- **Many different processes with one or two intact protons and top quarks:**
  - Semi-elastic **tt̄** and **Wt** (via γ or pomeron)
  - Fully-elastic(diffractive) **tt̄** and **Wt** (via γ or pomeron)

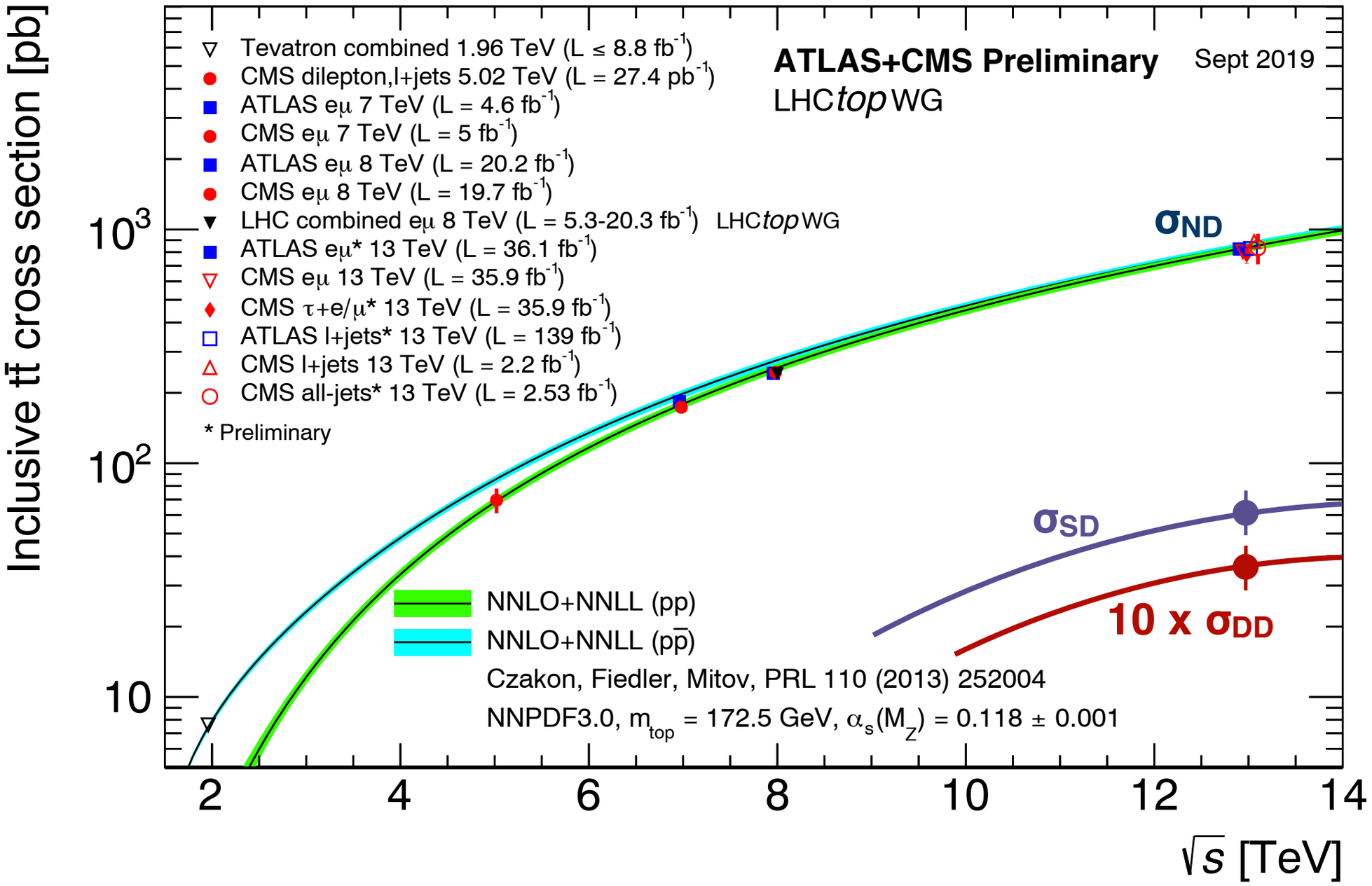
Elastic tops

P D B Collins and T P Spiller 1984 J. Phys. G: Nucl. Phys. 10 1667

	$\bar{p}p \to T\bar{T}X$				
	σB (nb)				
m_t(GeV)	σ(nb)	$k_T > 5$ GeV	8 GeV	15 GeV	20 GeV
25	150	9	3.5	0	0
35	72	5.6	4.0	0.1	0
45	30	3.0	2.0	0.7	6×10^{-2}

- **Well established idea, literature goes back more than 40 years…**

Photon-induced tops



- **Cross-sections are very small compared to non-diffractive.**

Elastic tops

Generator Setting	$\sigma_{(p\mathbb{P}\to t\bar{t})}$ [pb]	$\sigma_{(\gamma p\to t\bar{t})}$ [pb]	$\sigma_{(\gamma\mathbb{P}\to t\bar{t})}$ [pb]	$\sigma_{(\mathbb{P}\mathbb{P}\to t\bar{t})}$ [pb]	$\sigma_{(\gamma\gamma\to t\bar{t})}$ [pb]
SuperChic (isurv = 1)	–	–	–	$1.22(1)\cdot10^{-5}$	$2.05(2)\cdot10^{-4}$
(isurv = 2)	–	–	–	$3.21(2)\cdot10^{-5}$	$2.06(1)\cdot10^{-4}$
(isurv = 3)	–	–	–	$2.05(1)\cdot10^{-5}$	$2.05(1)\cdot10^{-4}$
(isurv = 4)	–	–	–	$1.59(1)\cdot10^{-5}$	$2.06(1)\cdot10^{-4}$
(sfaci = false)	–	–	–	$1.73(1)\cdot10^{-3}$	$2.77(2)\cdot10^{-4}$
MadGraph	–	1.23	–	–	$3.33 \cdot10^{-4}$
PYTHIA (MPI: unchecked)	90.5(1)	1.45	$1.26(6)\cdot10^{-1}$	–	$4.56(2)\cdot10^{-4}$
(MPI: checked)	5.14(5)	1.46	$1.27(6)\cdot10^{-1}$	–	$4.57(2)\cdot10^{-4}$
FPMC[7]	–	–	$5.2 \cdot10^{-2}$	$2.84 \cdot10^{-2}$	$3.4 \cdot10^{-4}$

- **Fully-elastic cross-sections are ~0.1 (1) fb for EW (QCD)** (not including survival factor)**.**

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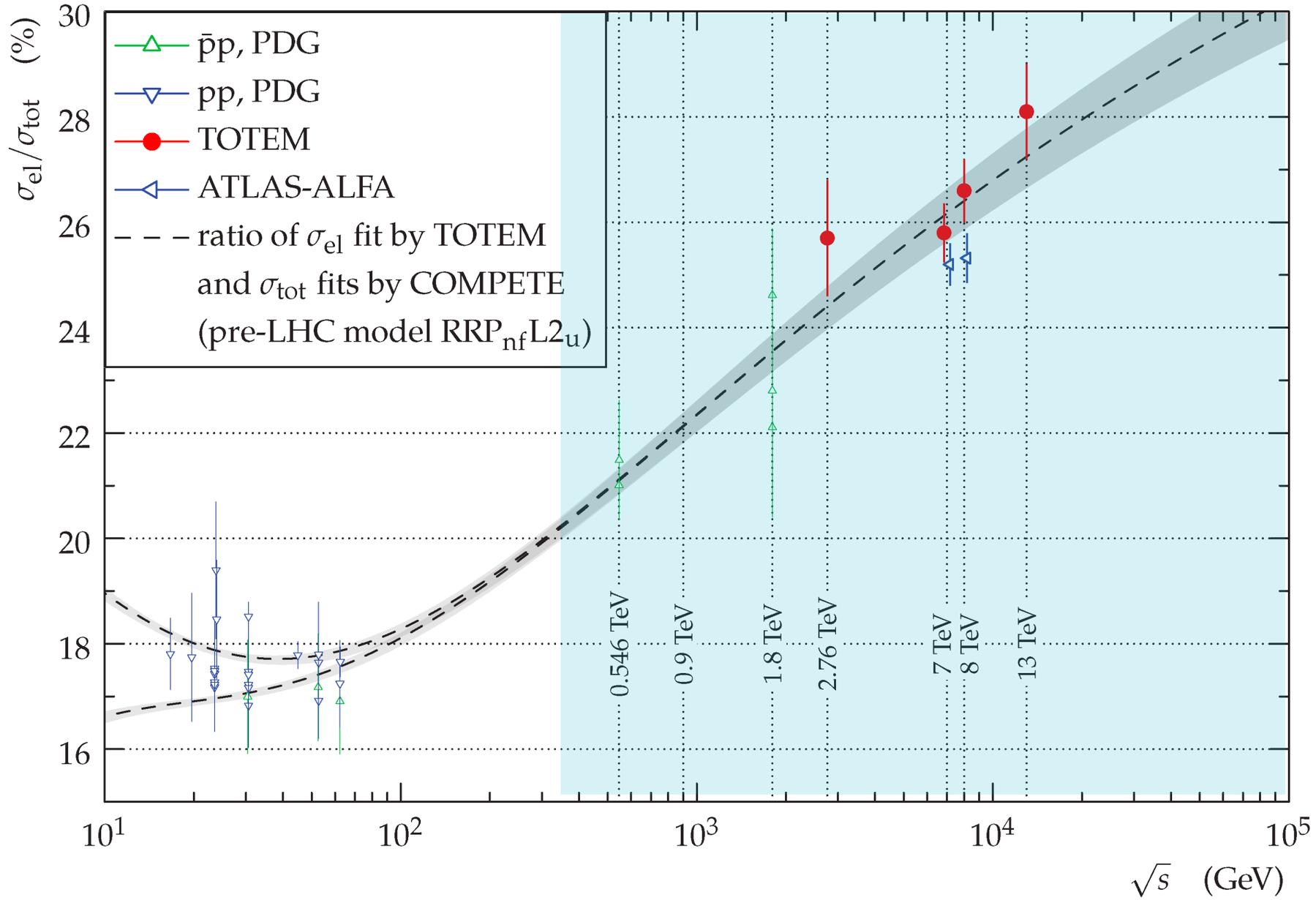
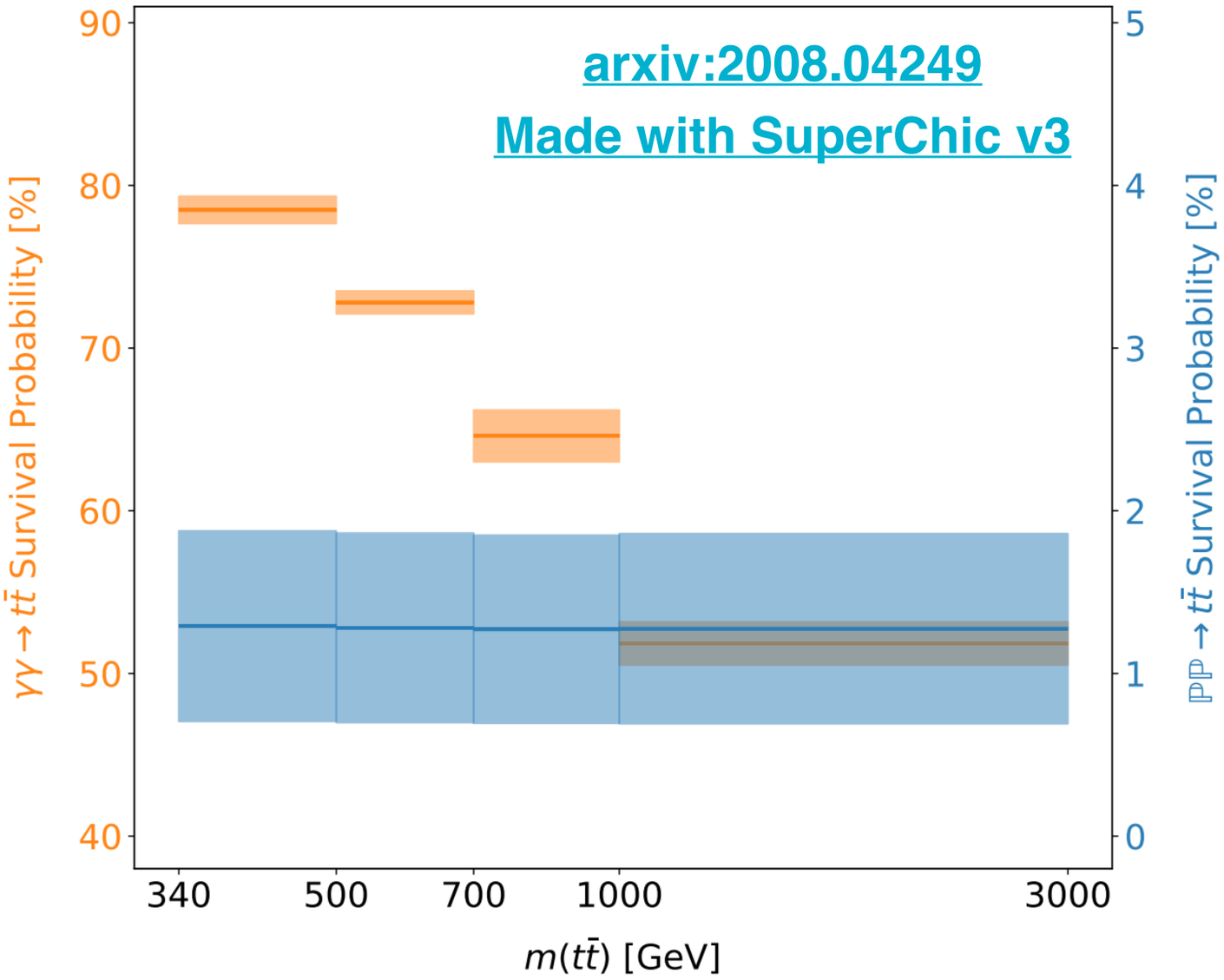
- **Fully-elastic cross-sections are ~0.1 (1) fb for EW (QCD)** (not including survival factor)**.**
- **Semi-elastic cross-sections are significantly larger, on the order of pb.**

The Physics Case



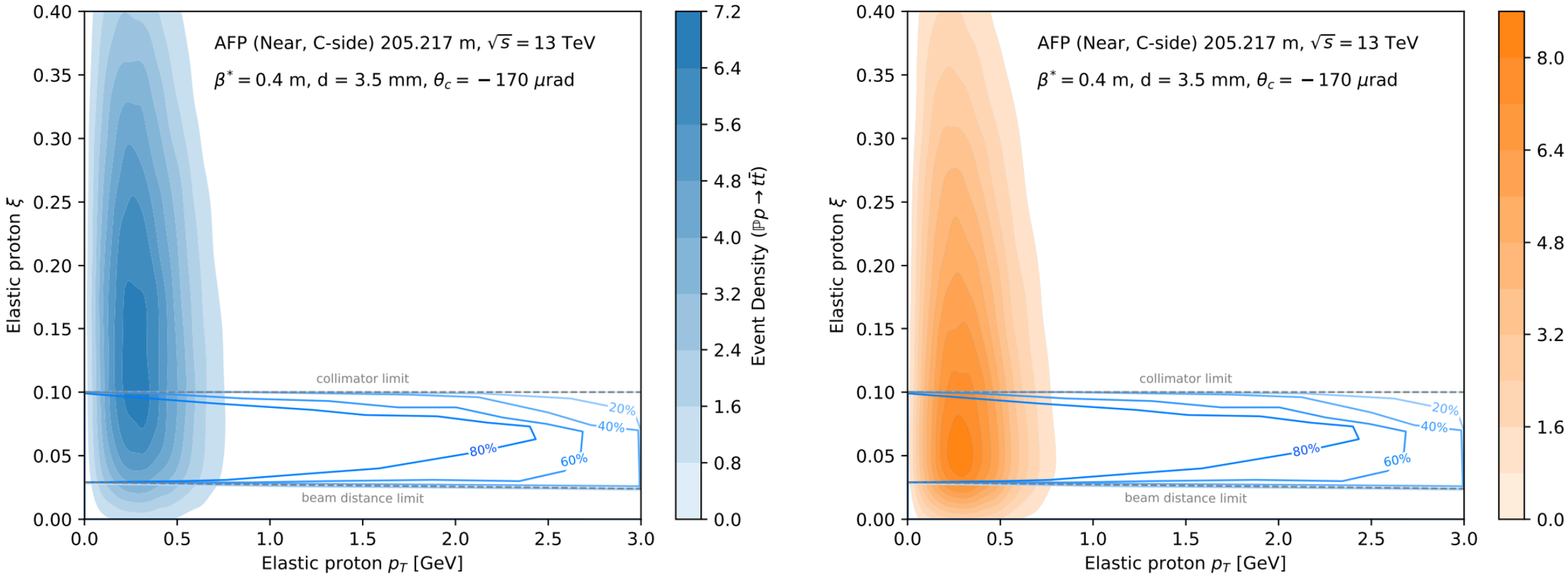
- **Can be used to measure the proton survival probability** (both the EW and QCD components)**.**

The Physics Case



- **The EW and QCD parts of the survival probability are quite different vs. m(tt̄)** (useful analysis handle)**.**

The Physics Case



- **Expect to loose a fair amount of single due to the AFP acceptance.**

- **Even small improvements can improve QCD case.**

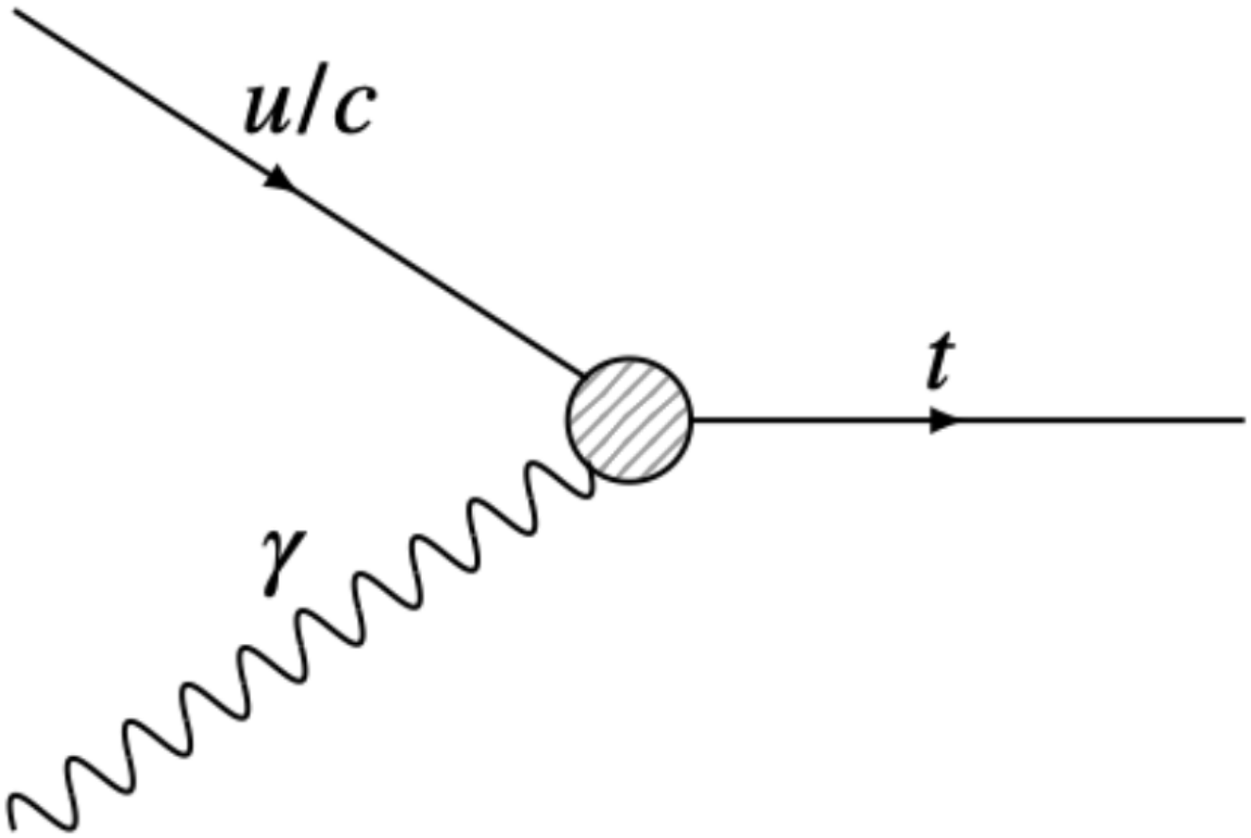
The Physics Case

Process	$100\ \text{pb}^{-1}$	$300\ \text{pb}^{-1}$	$1\ \text{fb}^{-1}$
$\gamma\gamma \to t\bar{t}$	$9 \cdot 10^{-4}$	$2.7 \cdot 10^{-3}$	$9 \cdot 10^{-3}$
$\mathbb{P}\mathbb{P} \to t\bar{t}$	$6 \cdot 10^{-5}$	$1.7 \cdot 10^{-4}$	$6 \cdot 10^{-4}$
$\gamma\mathbb{P} \to t\bar{t}$	$1.6 \cdot 10^{-1}$	$4.9 \cdot 10^{-1}$	1.6
$\gamma p \to t\bar{t}$	9.4 ± 0.3	30 ± 1	94 ± 3
$p\mathbb{P} \to t\bar{t}$	15 ± 2	40 ± 7	150 ± 20
Total	24 ± 2	70 ± 7	240 ± 20

- Expected number of events using an AFP-tagged dilepton + l+jets $t\bar{t}$ selection assuming low μ.

- ATLAS has ~150 pb of usable low-μ data for this type of analysis.

The Physics Case



- **Photon-initiated processes are sensitive to FCNCs.**
- **Cool think is that this doesn't require CEP to be sensitive.**

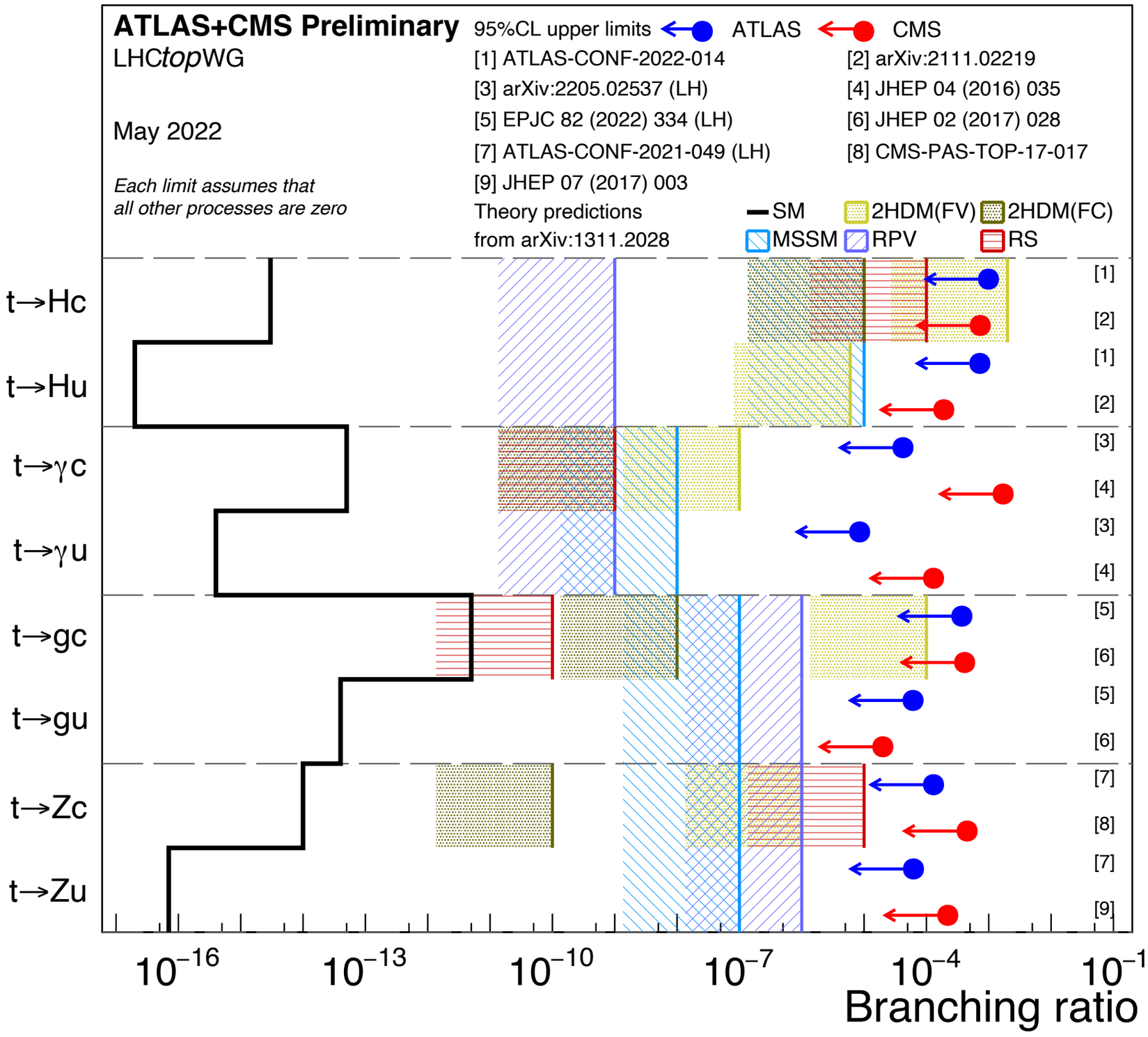
The Physics Case

arxiv:2008.04249

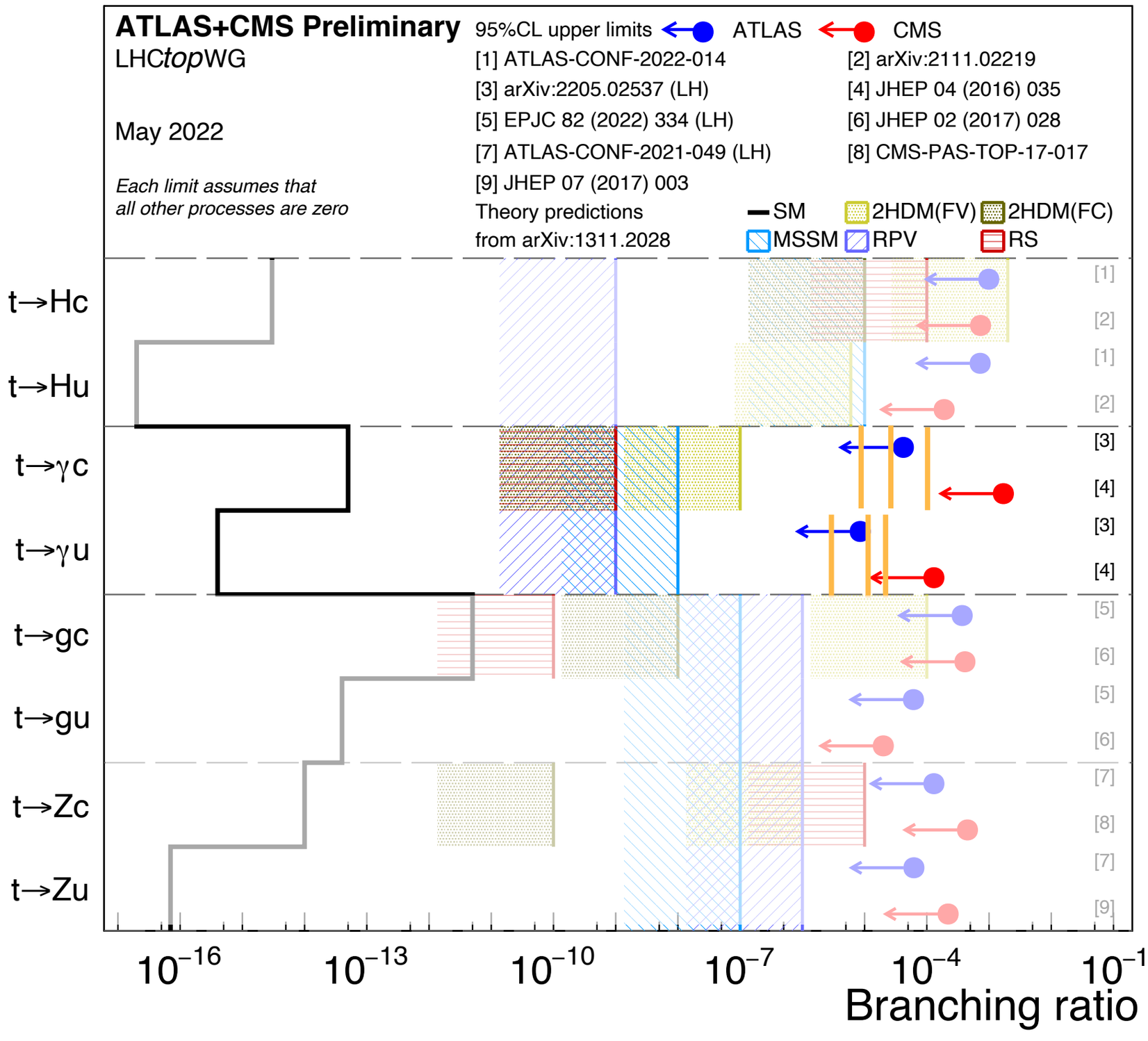
Operator	0.1 fb^{-1}	0.3 fb^{-1}	1.0 fb^{-1}	ATLAS [28]
$\lvert C_{uW}^{(13)*} + C_{uB}^{(13)*}\rvert$	< 0.23	< 0.13	< 0.07	< 0.19
$\lvert C_{uW}^{(23)*} + C_{uB}^{(23)*}\rvert$	< 0.35	< 0.20	< 0.11	< 0.52
$\mathrm{BR}(t \to u\gamma)[10^{-5}]$	< 4.05	< 1.35	< 0.39	< 2.8
$\mathrm{BR}(t \to c\gamma)[10^{-5}]$	< 9.80	< 3.20	< 0.97	< 22

- **Using expected Run2 data expected limits are very good** (considering how “simple” the analysis is)**.**

The Physics Case

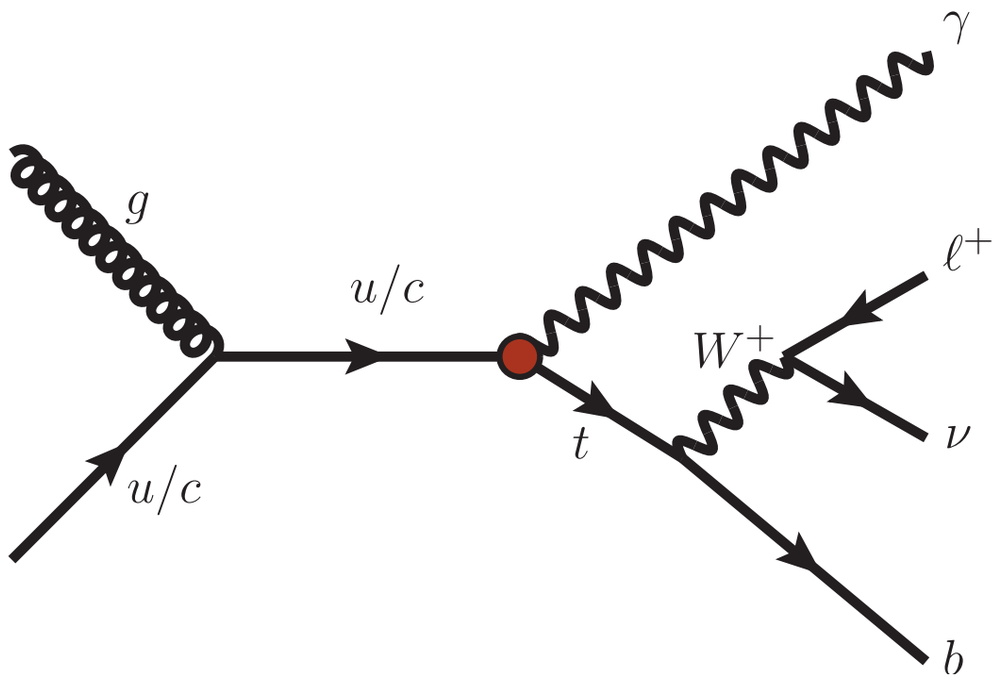


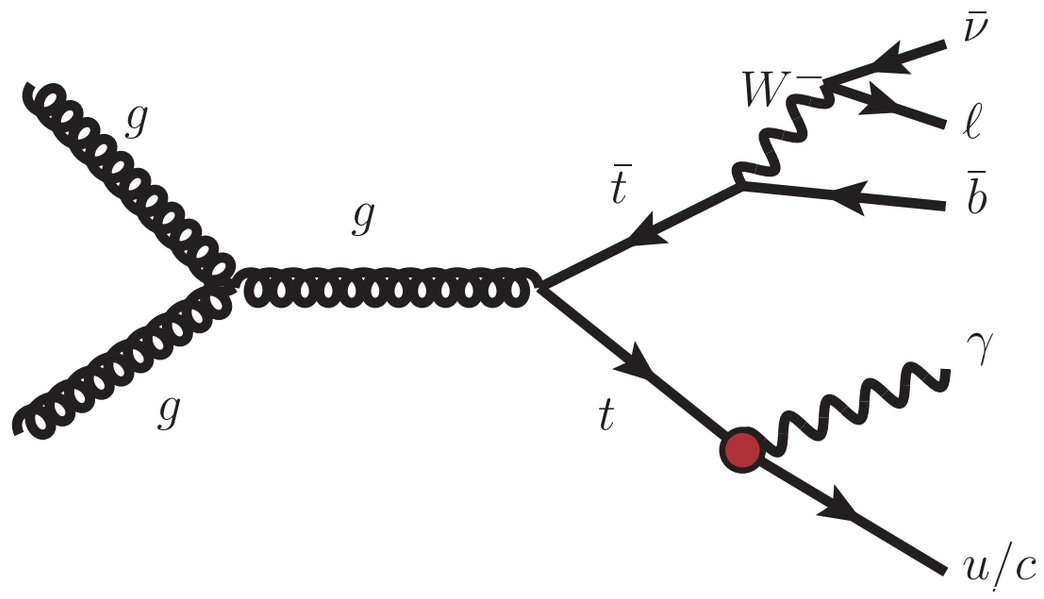
The Physics Case



The Physics Case

arxiv:2205.02537 (accepted by PLB)

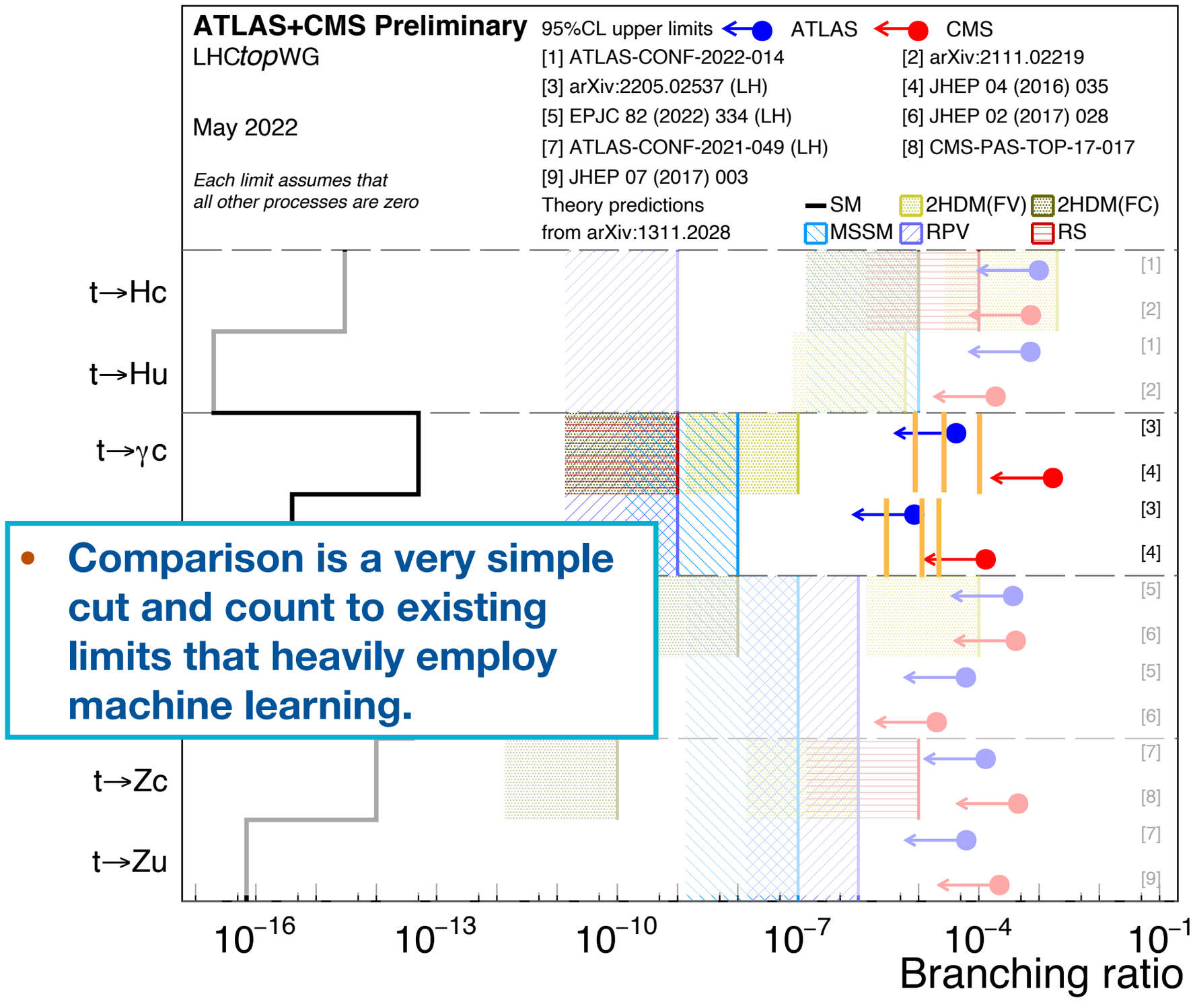




- **Current limits come from decay rather than production:**
  ➡ complementary limits even using the same dataset.

- **Analysis uses an “optimised” set of 37 inputs to a NN.**

The Physics Case



- **Comparison is a very simple cut and count to existing limits that heavily employ machine learning.**

CMS Result

- **CMS have searched for Central Exclusive Production of $t\bar{t}$ pairs: PAS-TOP-21-007 using 29 fb^{-1} of Run2 data.**

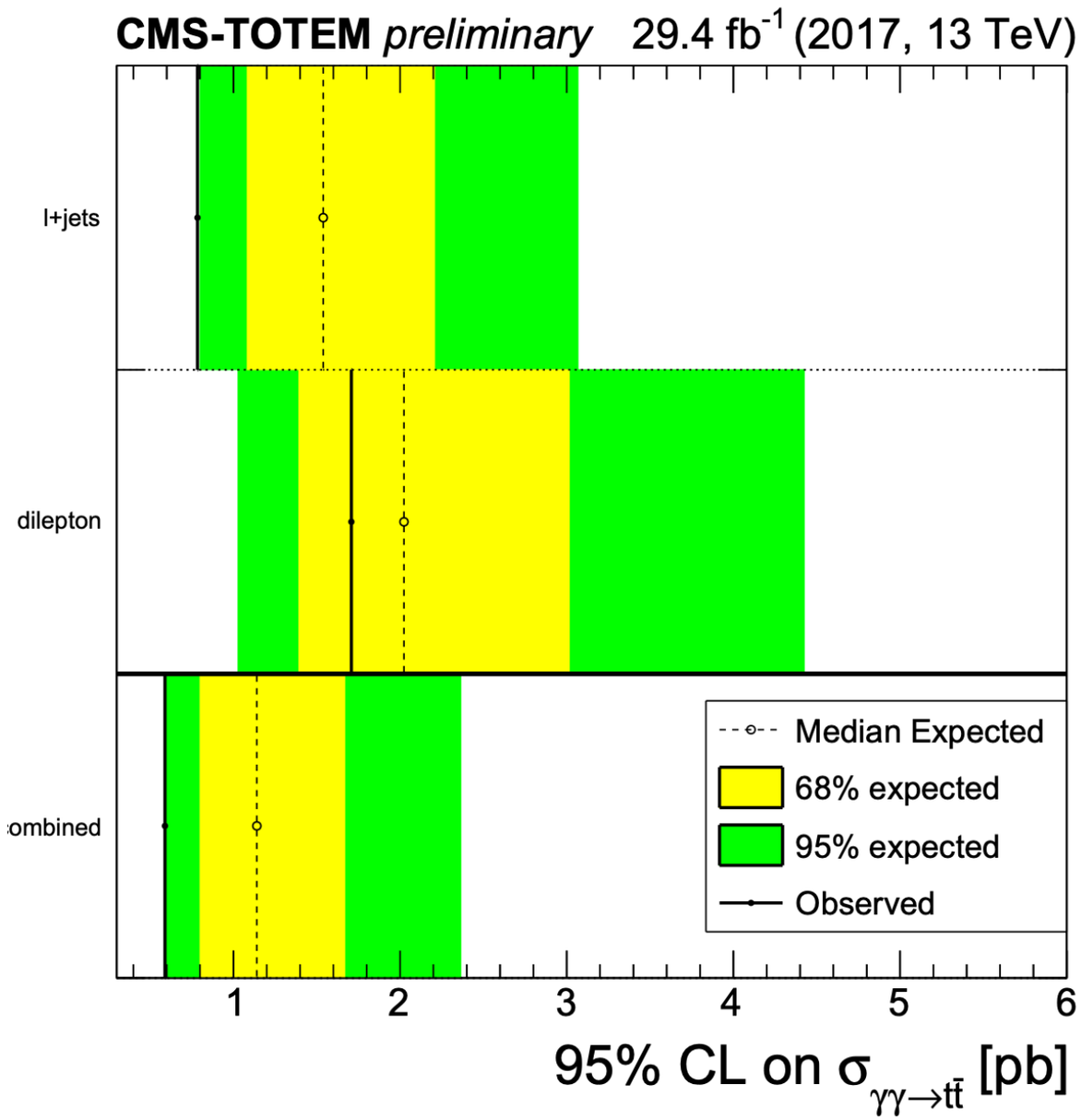
- **For pileup simulation they mix single-arm proton tags from data with their signal** (data-driven pileup)**.**

- **Signal generated with FCMC.**

are available, including both QED and QCD contributions [15–20]. A critical element, in particular in the case of strong interaction processes, is the evaluation of the so-called rapidity gap survival probability, quantifying the probability of no additional soft interactions between the

- **Everything put into a BDT to isolate signal.**

CMS Result



- **Set an limit of 0.59 pb on the production cross-section.**

Planned work

- **ATLAS plans to try to measure the semi-elastic process to set limits on FCNCs using single-arm AFP tagged events.**

- **Also plans to set limits on fully elastic (see papers by Marek: 2007.04565, 2202.01257).**

- **Current status is severe lack of person power, result likely won't be out until tail-end of 2023 at the earliest.**

Conclusions

- **There are a few nice areas where elastic top physics can play a role.**

- **These analyses use AFP tagged events** (likely not possible to do without it)**.**

- **Likely possible to observe semi-elastic case with existing and expected data in Run2 and Run3.**

- **Fully elastic cases will need HL-LHC.**

Backup