Triggering on Emerging Jets

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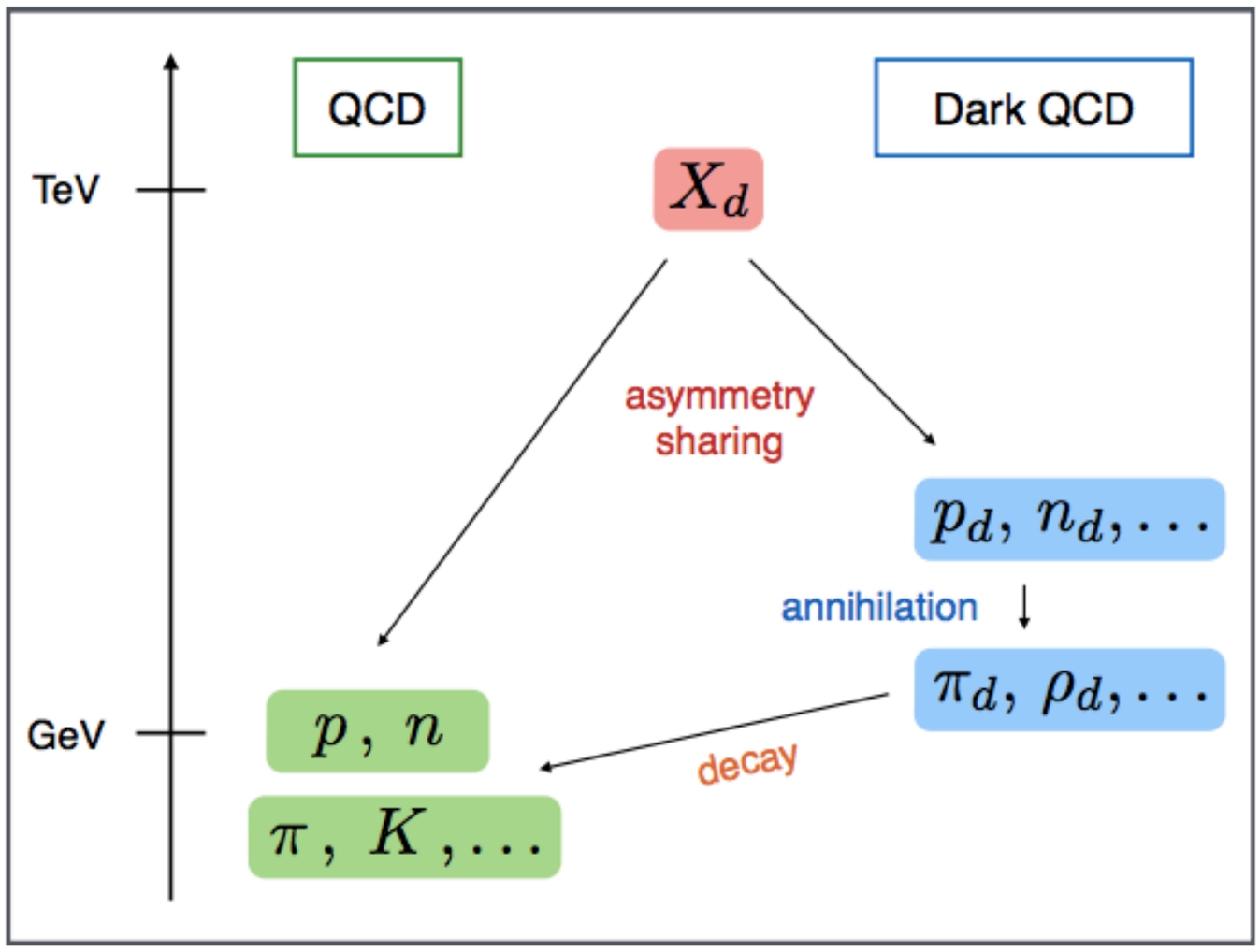
arXiv:2103.08620

May 27th, LLP 9 Workshop

(Ref: Schwaller et al arXiv:1502.05409)
(Ref: Strassler et al hep-ph/0604261)

Dark QCD and The Hidden Valley



Dark QCD confines like the strong force (QCD) some scale,

$$\sim \Lambda_d$$

Hidden Valley equipped with a complicated spectrum of mesons and baryons,

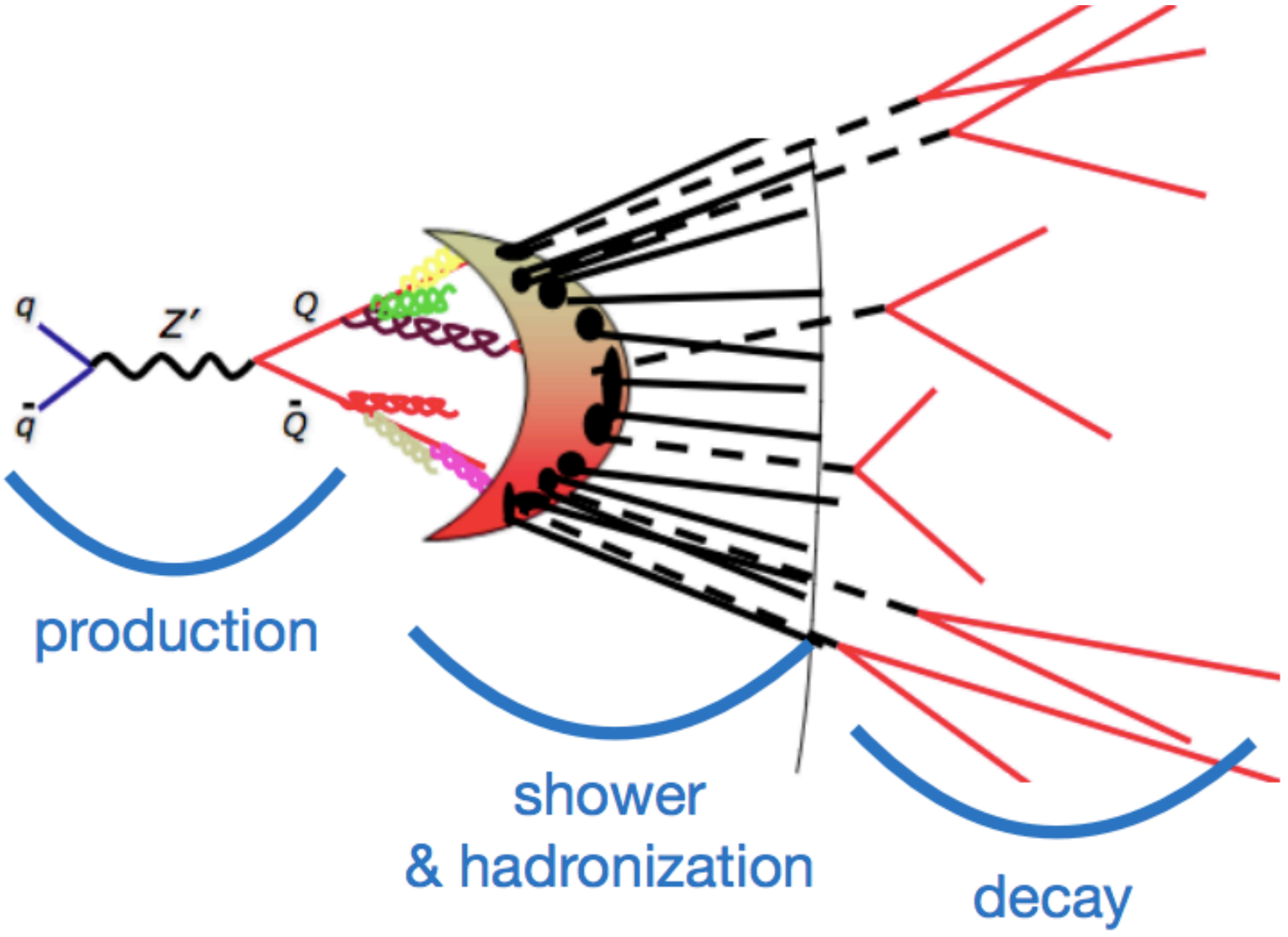
$$(\pi_d, \rho_d, \ldots)$$

$$SU(3) \times SU(2) \times U(1) \times SU(3)_d$$

(Ref: arXiv: 1903.04497)

Dark Parton Showers

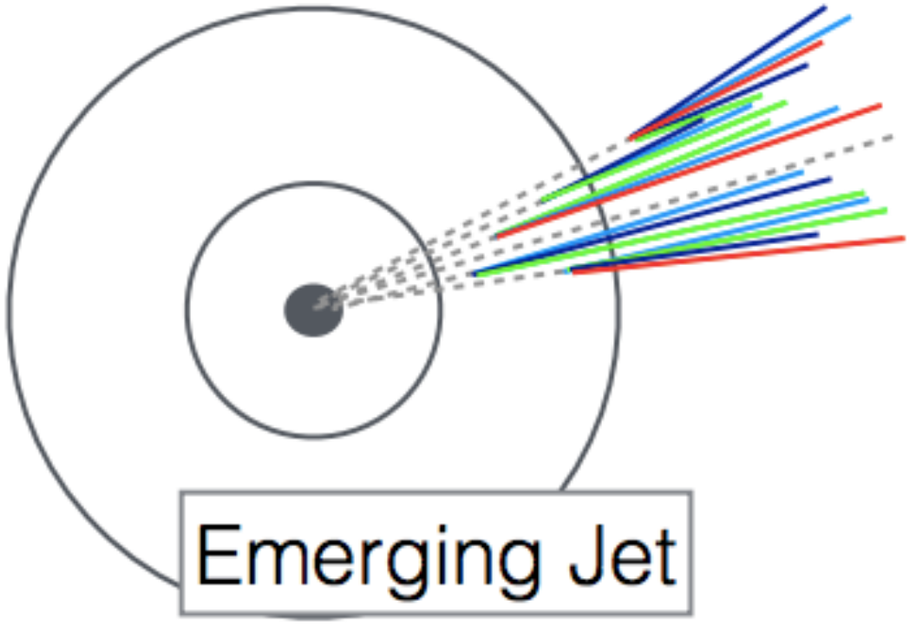
$$\mathcal{L} \supset \frac{1}{2} M^2 Z'^{\mu} Z'_{\mu} + Z'^{\mu} \left(g_q \, \overline{q} \gamma_\mu q + g_d \, \overline{Q} \gamma_\mu Q \right)$$

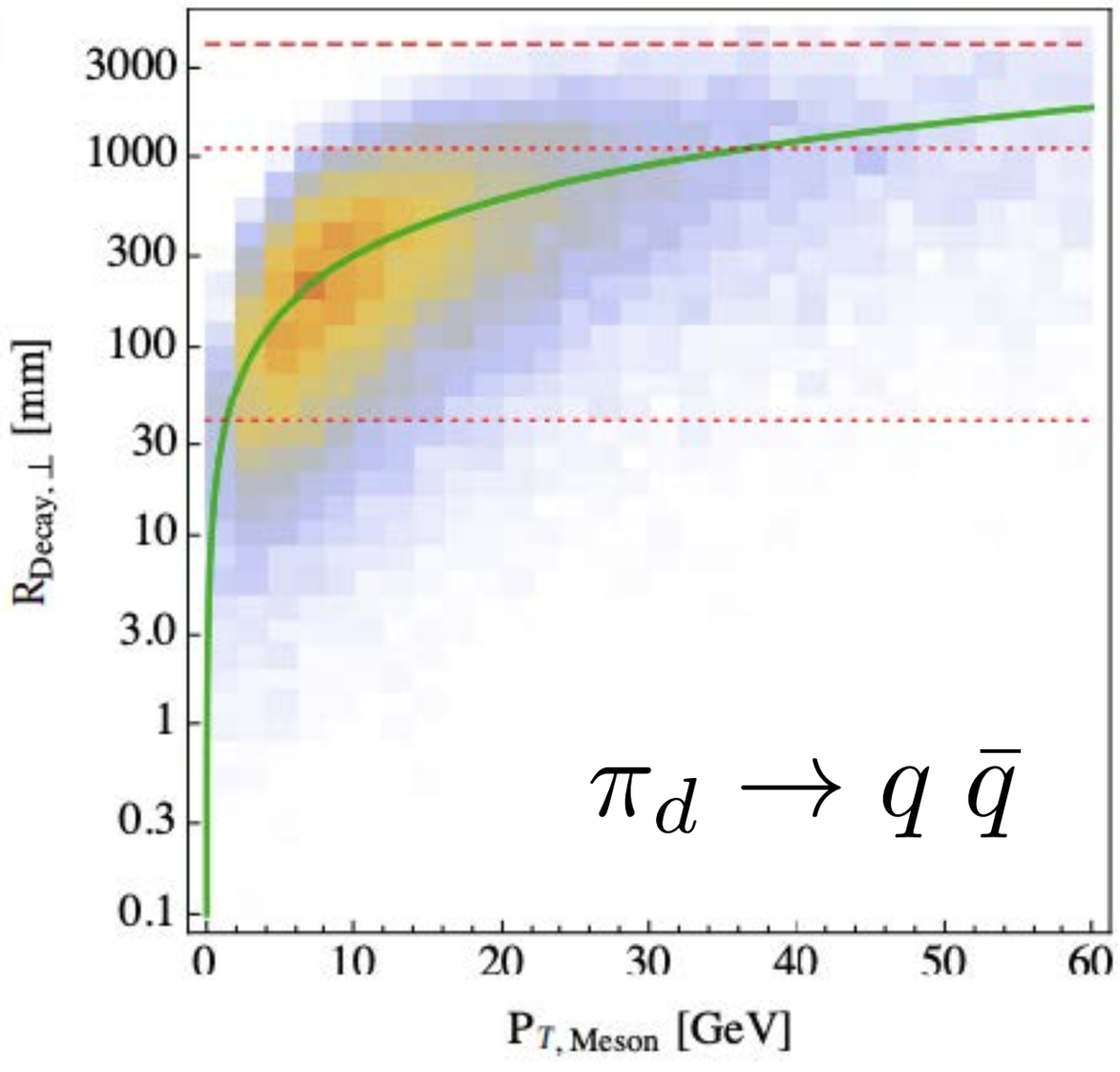


Emerging Jets at The LHC

$$c\tau_0 = \frac{c\hbar}{\Gamma} \approx 80\,\text{mm} \times \frac{1}{\kappa^4} \times \left(\frac{2\ \text{GeV}}{f_{\pi_d}}\right)^2 \left(\frac{100\ \text{MeV}}{m_{\text{down}}}\right)^2 \left(\frac{2\ \text{GeV}}{m_{\pi_d}}\right) \left(\frac{M_{X_d}}{1\ \text{TeV}}\right)^4$$

The dark pions being long lived will decay exponentially within the detector volume.

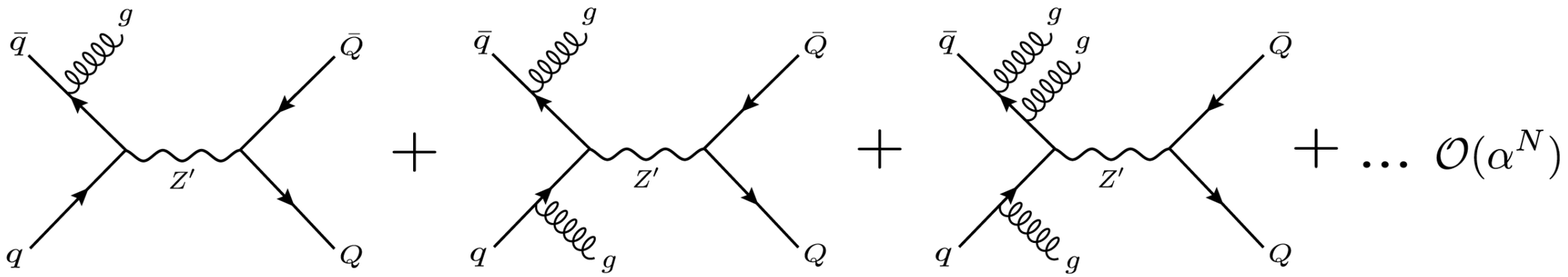




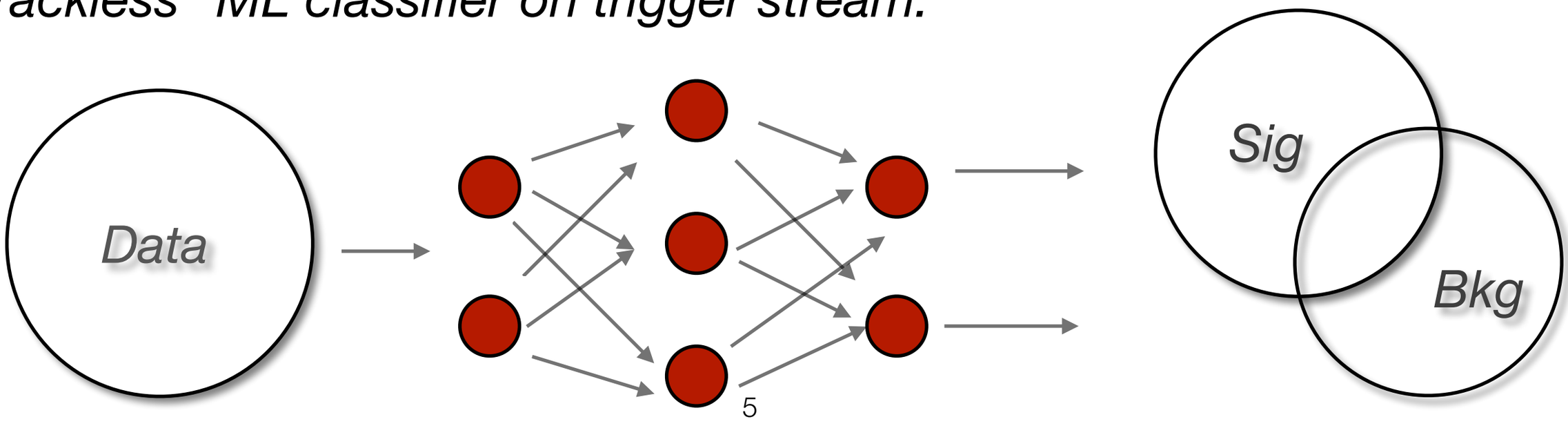
Strategies

Dedicated triggers (specific event criteria) were implemented to write a subset of data onto record completely biasing novel/unique signatures

i) Exploit existing triggers with hard ISR:



ii) "Trackless" ML classifier on trigger stream:



(Ref: Schwaller et al arXiv:1502.05409)

Benchmarks

	Model **A**	Model **B**
$c\tau_{\pi_d}$	150 mm	5 mm

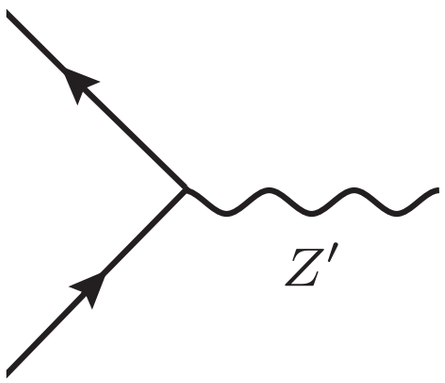
Scalar mediator

$(M_X > 1\text{TeV}, X)$ ✓

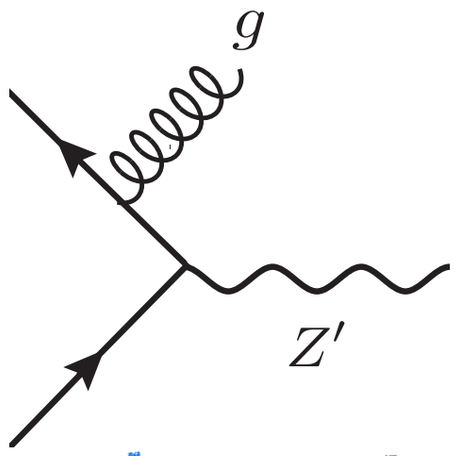
Vector mediator

$(M_{Z'} < 1\text{TeV}, Z')$ 🔍

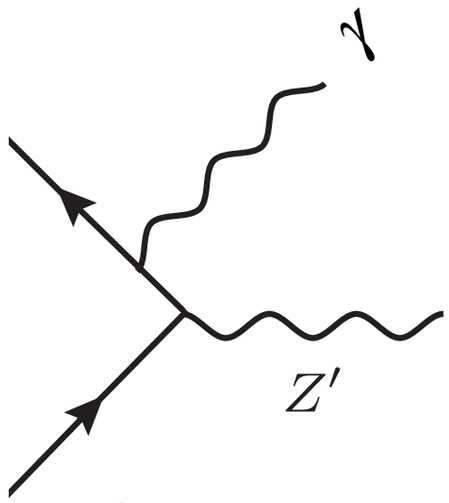
Types of radiation:



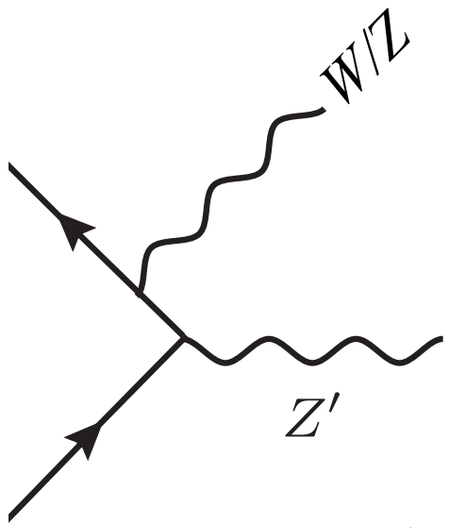
LO



LO + j

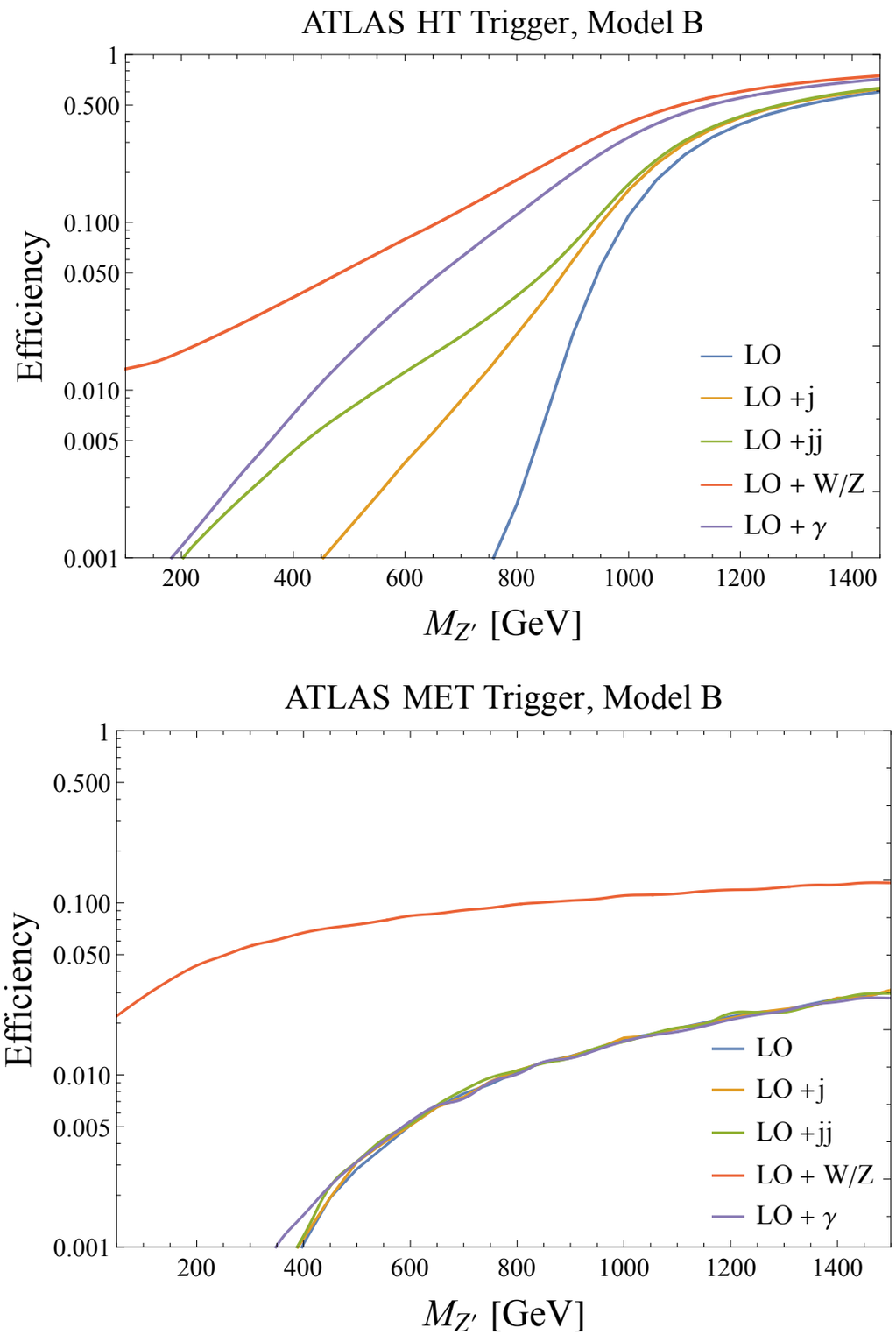


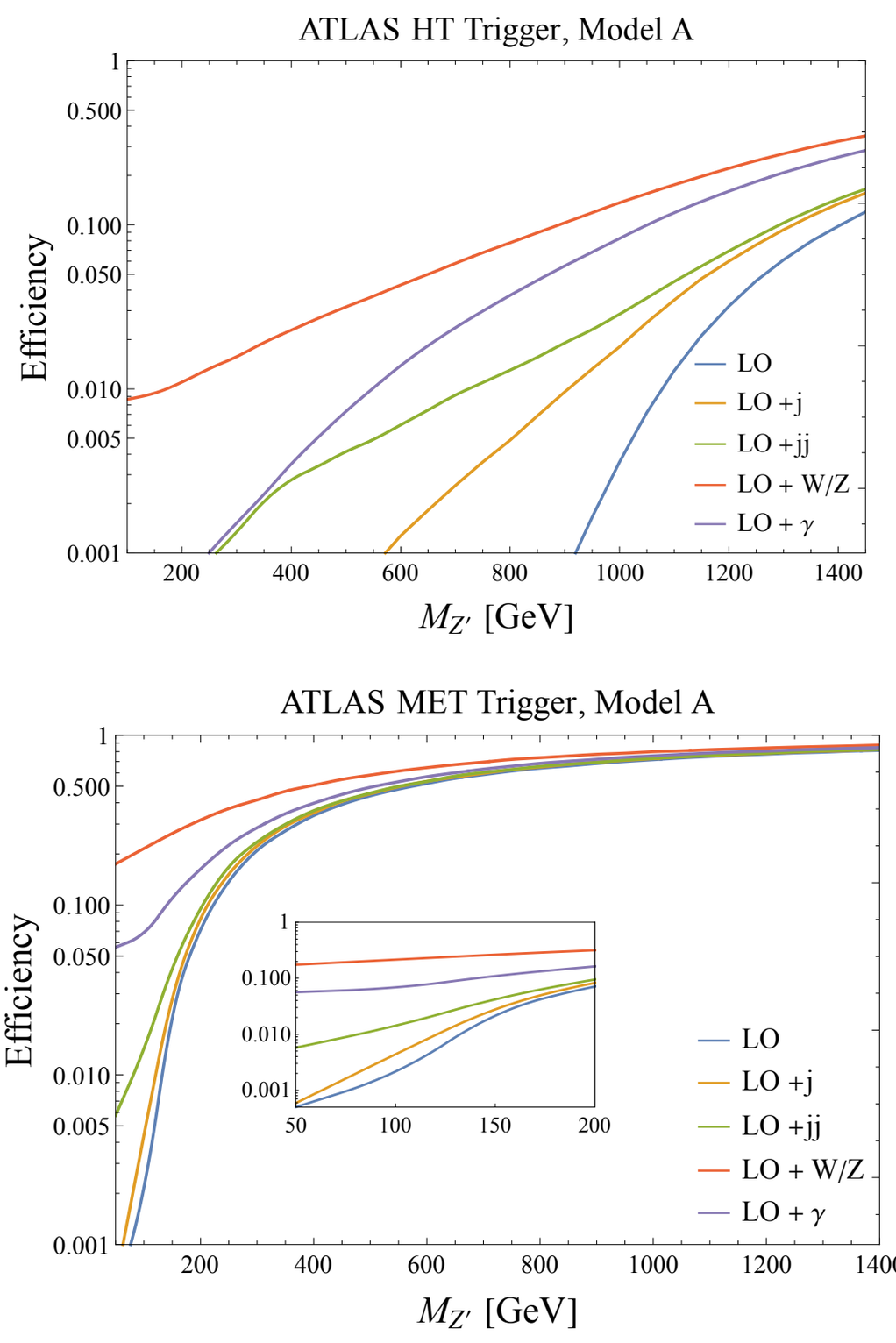
LO + γ

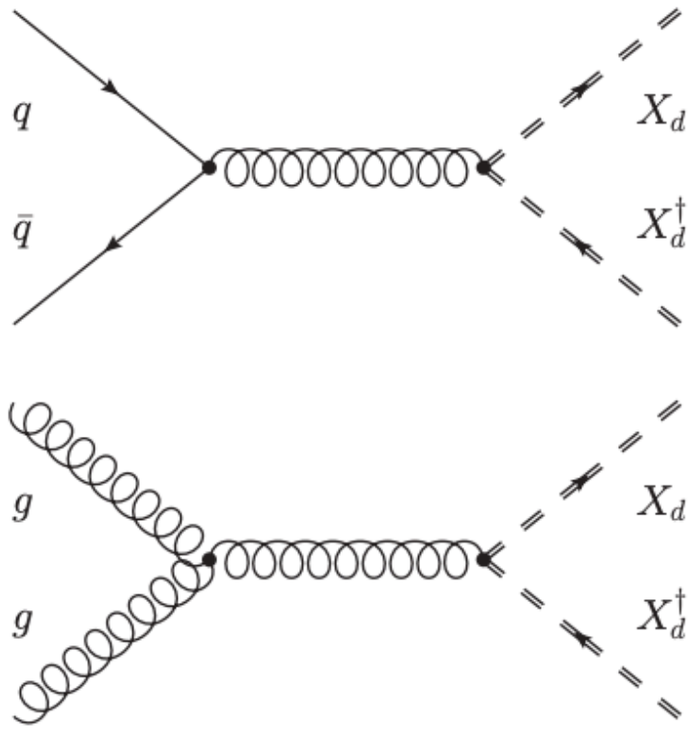


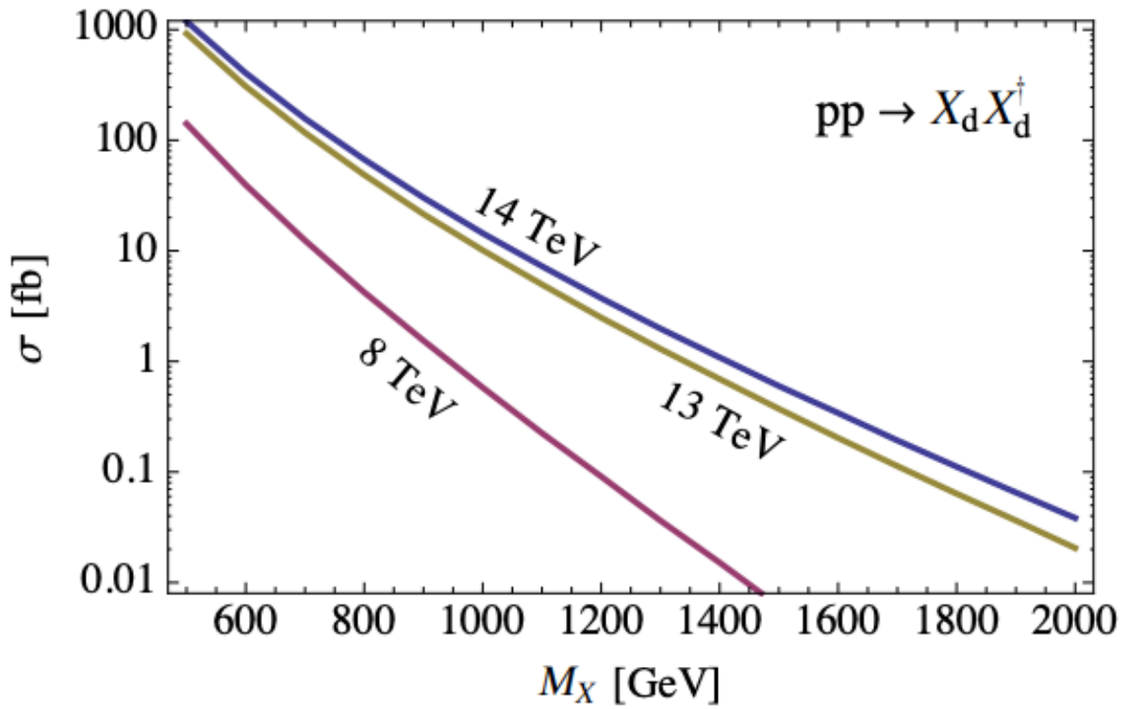
LO +W/Z

Trigger Efficiencies







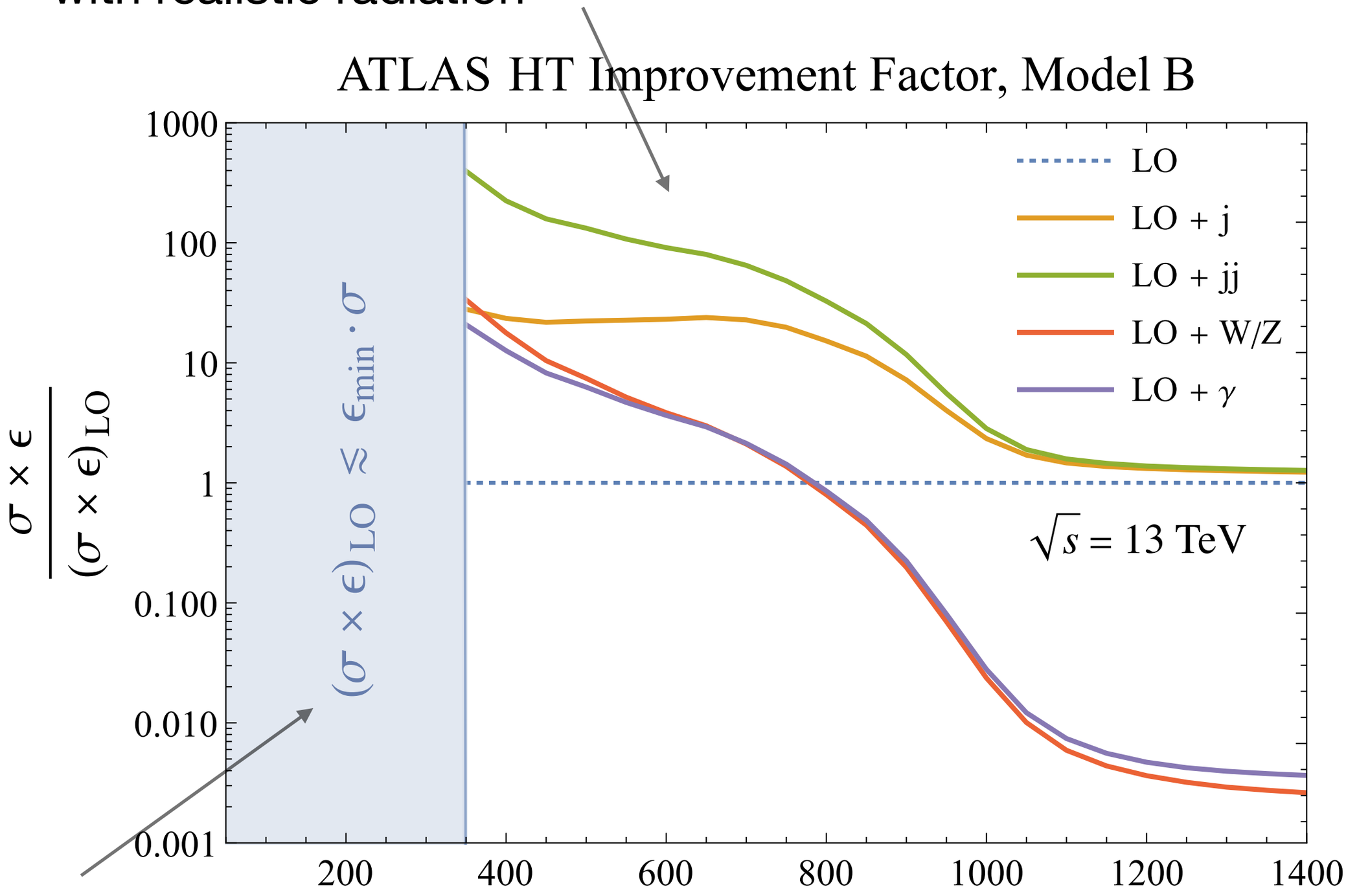


Scalar cross section: similar to known squark production.

Z' cross section: proportional to free parameters $g_{q/d}$

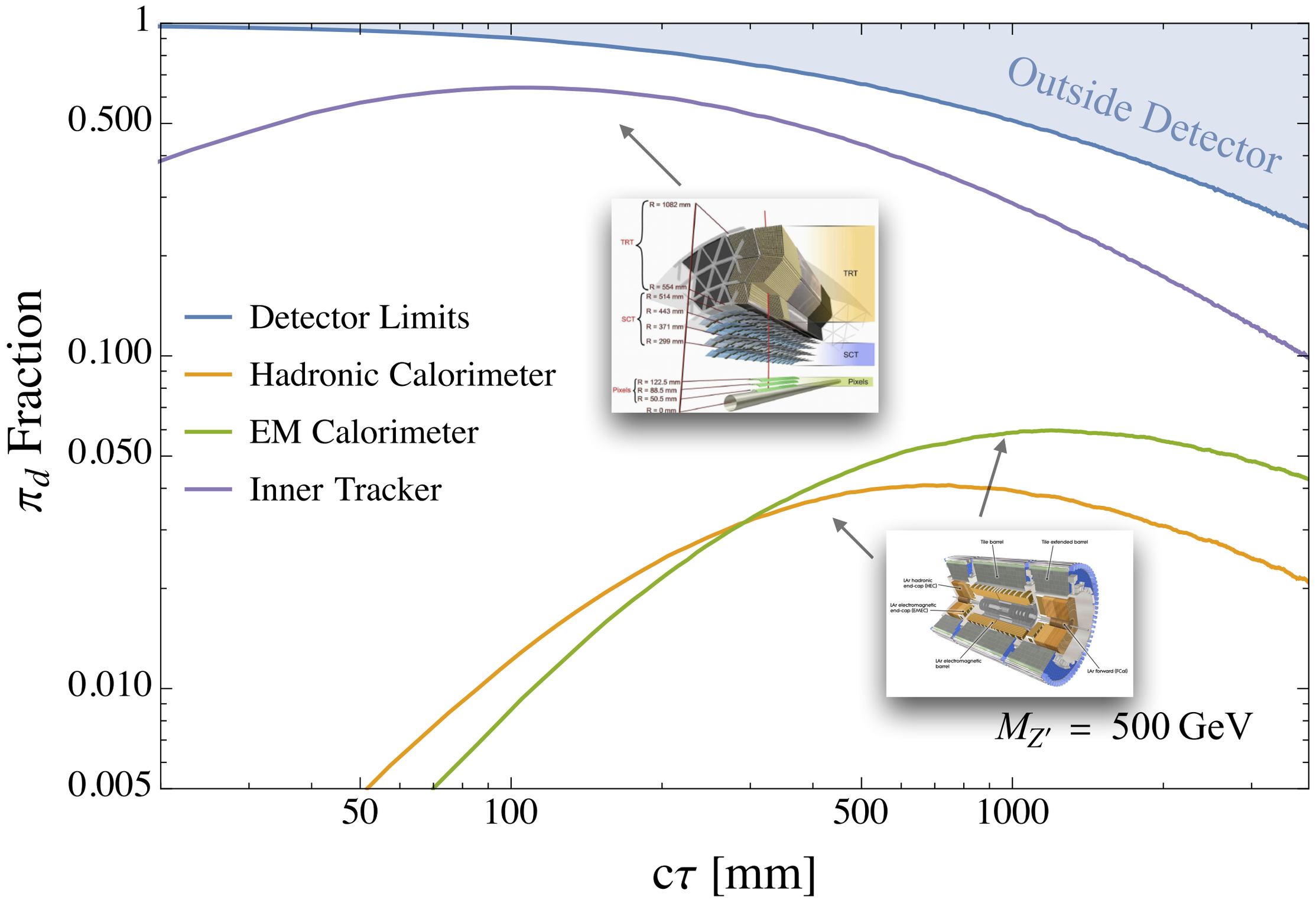
$$\frac{\sigma \times \epsilon}{(\sigma \times \epsilon)_{\mathrm{LO}}} = \text{Gives a sense of the rate independent of unknown Z' freedom.}$$

Significantly more events written onto tape
with realistic radiation



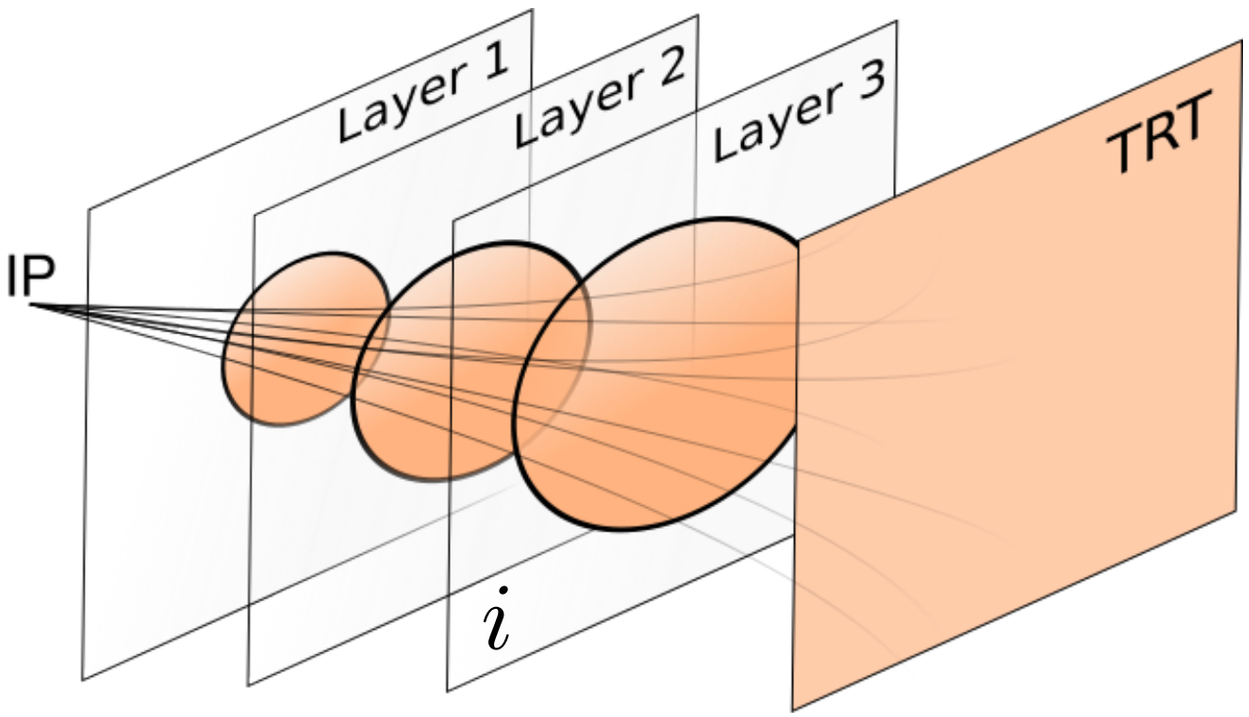
Not enough events pass at LO

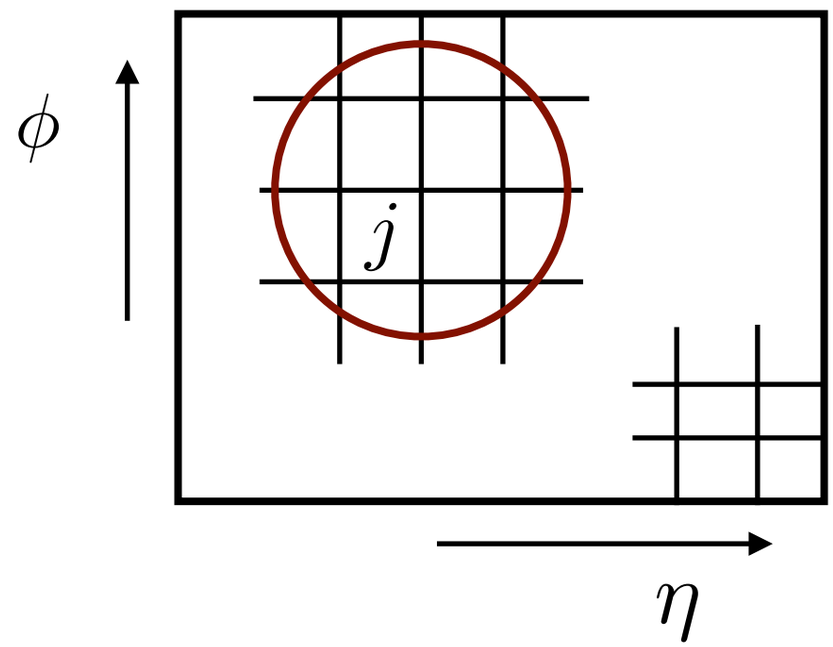
Dark Pion Decays at Truth Level, ATLAS



(Ref: Huffmann et al arXiv:1604.05036)

Learning from The Tracker (without Tracks)





Using tracker hit profiles to train a ML algorithm on the trigger stream.

$$N^i_{cor} \equiv \sum_j N^i_{h,j} \left(\sqrt{(\Delta\eta)^2_j + (\Delta\phi)^2_j} \leq \mathcal{R} \right)$$

Hits within hard jet direction

ML Trigger Results

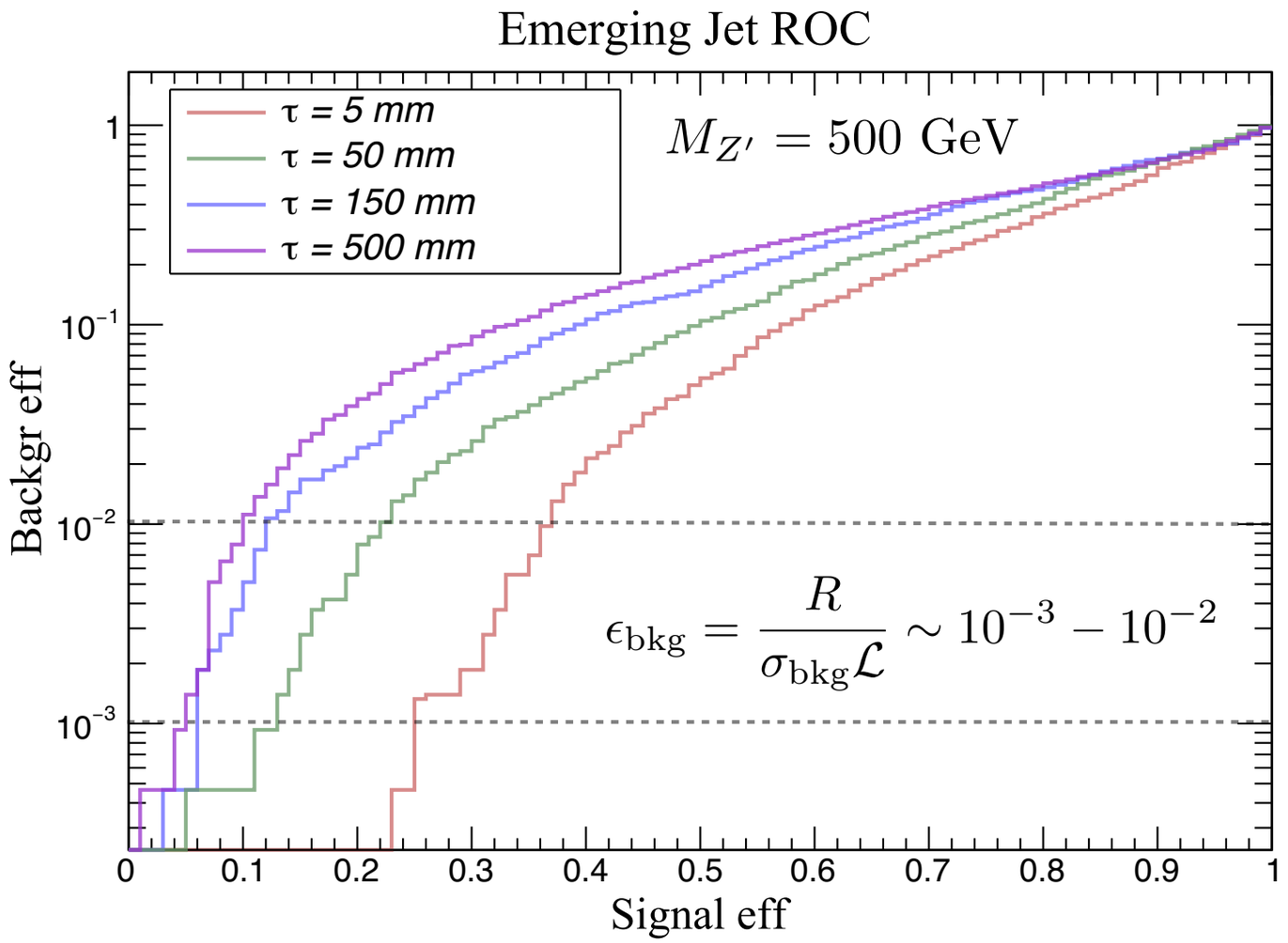
Background:

Heavy flavours mimic E-jets with displaced vertices

$$g \to b\bar{b}$$

Available new physics bandwidth of ~1 Hz.

Due to boosts, lower lifetimes span hits considerably along all layers.



$c\tau_d$	ϵ (Bkg rej 10^{-2})	ϵ (Bkg rej 10^{-3})
5 mm	0.370	0.250
50 mm	0.230	0.125
150 mm	0.122	0.060
500 mm	0.100	0.050

Conclusion

- Emerging jets, although novel, may pose difficulties at the triggering stage. Previous studies showed that a large massed scalar mediator is efficient enough.

- We show that triggering on lower mass vector mediators greatly benefits from the inclusion of realistic radiation.

- Online trigger strategies that employ ML techniques can use low level variables (I.e. tracker hits) to probe lower mediator masses.

Questions

Benchmarks

	Model **A**	Model **B**
Λ_d	10 GeV	4 GeV
m_V	20 GeV	8 GeV
m_{π_d}	5 GeV	2 GeV
$c\tau_{\pi_d}$	150 mm	5 mm

$\times SU(3)_d$

$N_c = 3$ and $n_f = 7$

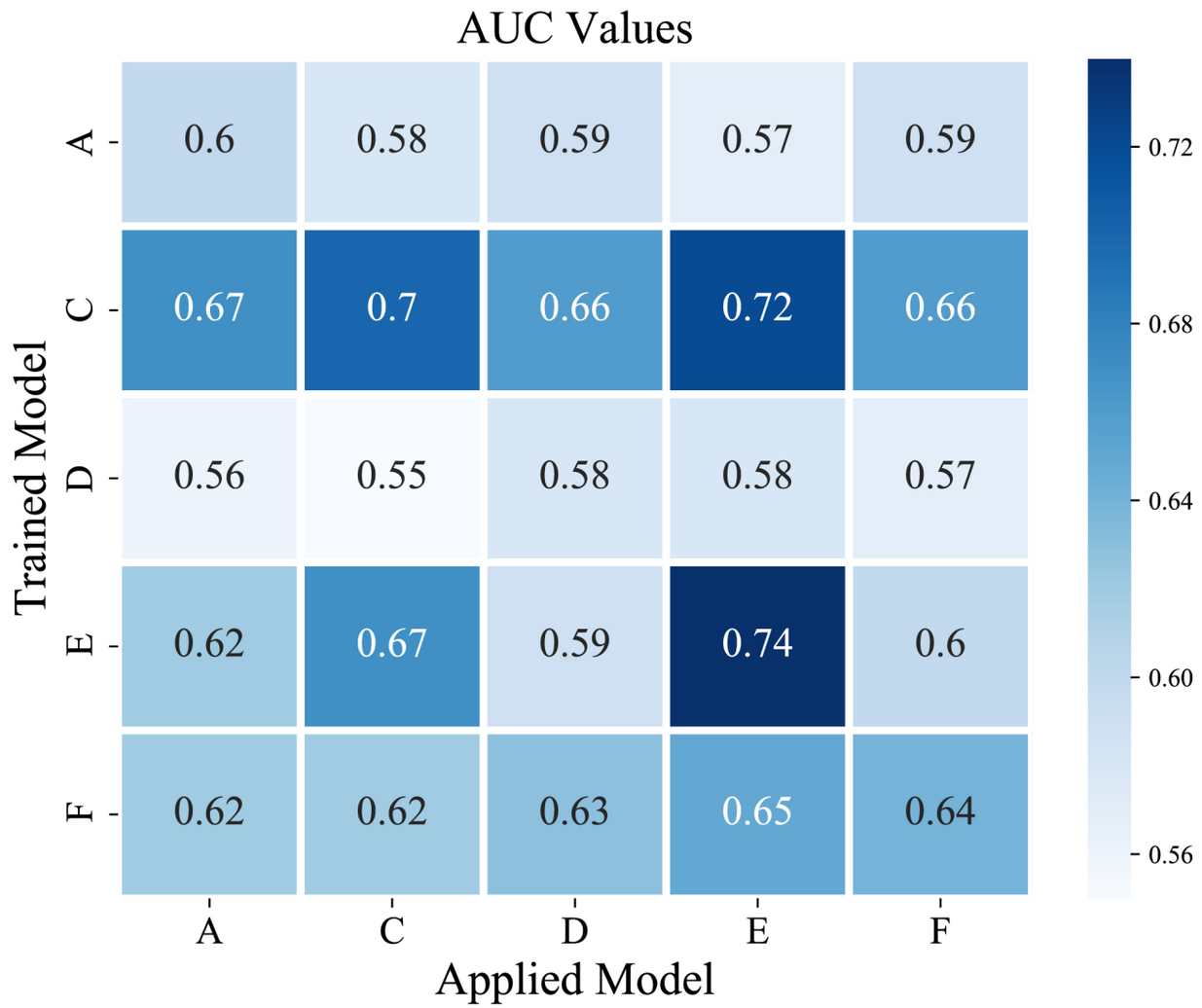
Original paper benchmarks, where a Heavy scalar mediator was explored.

Field	$SU(3) \times SU(2) \times U(1)$	$SU(3)_{\text{dark}}$	Mass	Spin
Q_d	$(1, 1, 0)$	(3)	m_d $\mathcal{O}(\text{GeV})$	Dirac Fermion
X_d	$(3, 1, \frac{1}{3})$	(3)	M_{X_d} $\mathcal{O}(\text{TeV})$	Complex Scalar
Z_d	$(1, 1, 0)$	(1)	M_{Z_d} $\mathcal{O}(\text{TeV})$	Vector Boson

Scalar model has a dedicated CMS search: 1810.10069

Universality

Triggers show similar trends independent of which model it is trained on.



Model	**A**
Λ_d	10 GeV
m_V	20 GeV
m_{π_d}	5 GeV
$c\tau_{\pi_d}$	150 mm

C	**D**	**E**	**F**
10 GeV	10 GeV	10 GeV	20 GeV
20 GeV	20 GeV	20 GeV	40 GeV
5 GeV	5 GeV	5 GeV	10 GeV
50 mm	500 mm	5 mm	500 mm