

Emerging Triggers:

Creating a Safe Space for Dark Matter

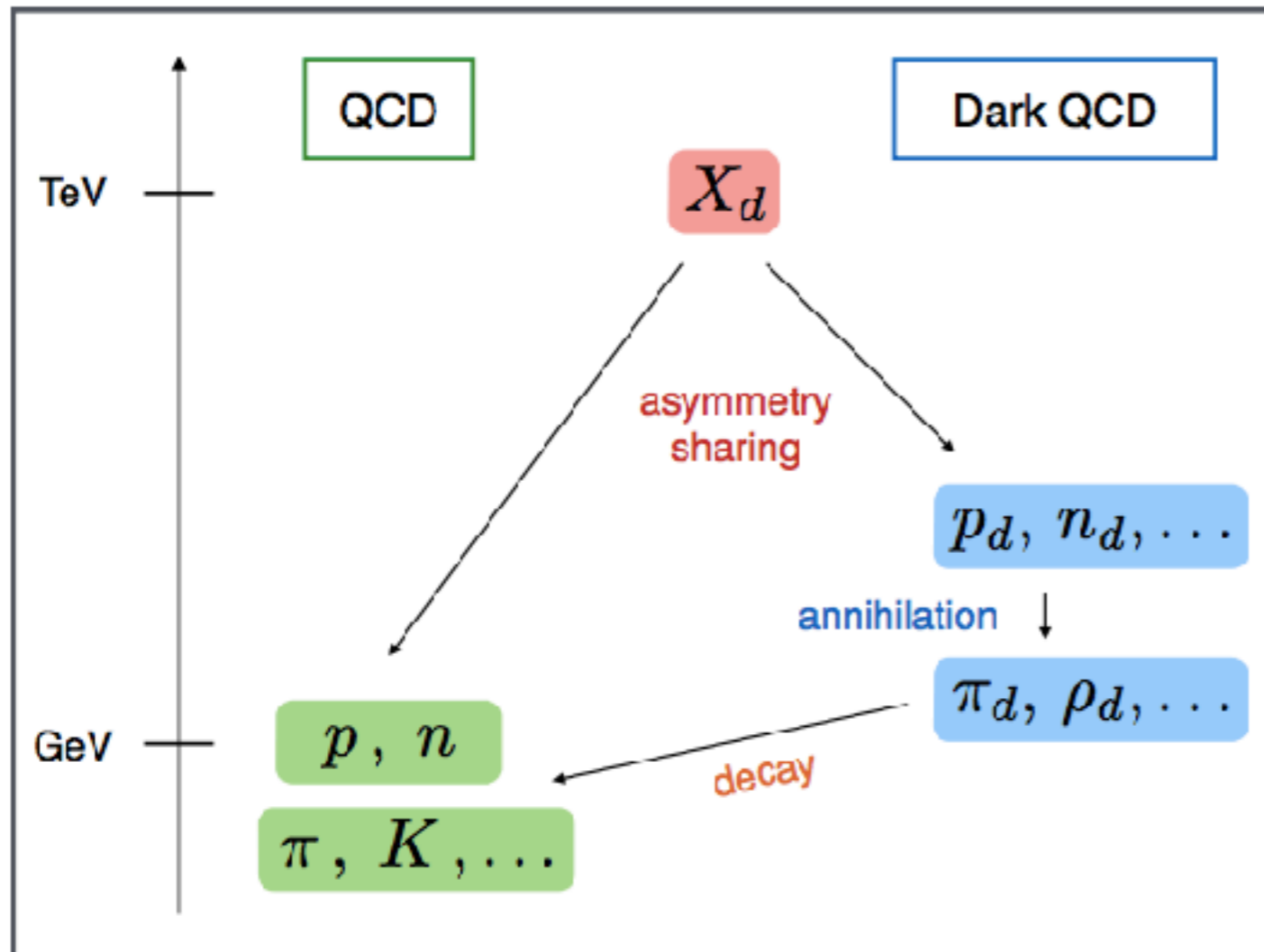
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Dark QCD and The Hidden Valley



Dark QCD confines at some scale,

$$\sim \Lambda_d$$

The sector is accompanied by a complicated spectrum

$$\pi_d \quad \rho_d \quad \textit{etc.}$$

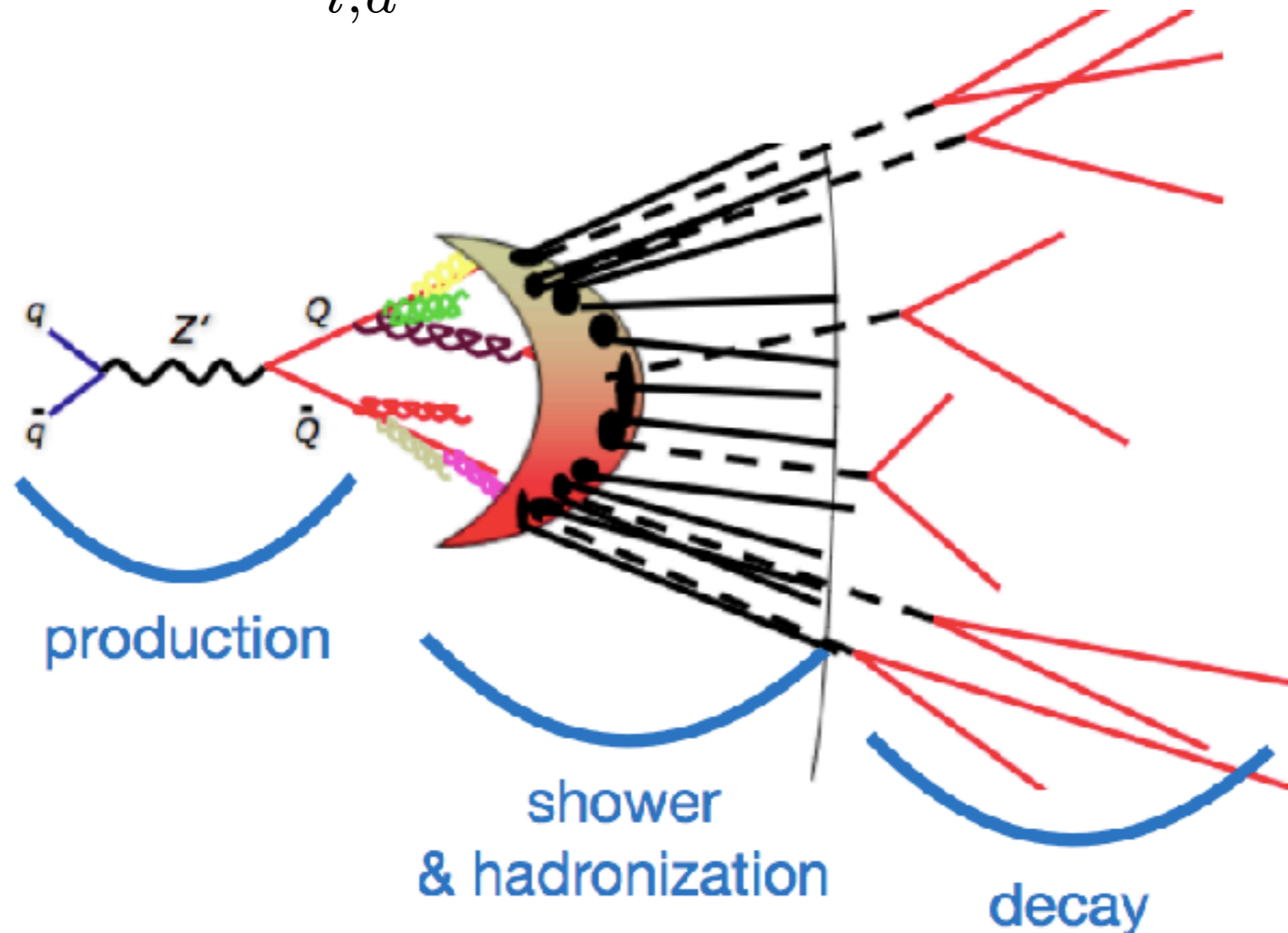
$$SU(3) \times SU(2) \times U(1) \times SU(3)_d$$

(Hidden Valley can have different # flavours and colours)

Dark Parton Shows

Heavy mediator, Z_d , will act as the portal to the standard model (SM)

$$\mathcal{L} \supset -Z_{d,\mu} \sum_{i,a} (g_q \bar{q}_i \gamma^\mu q_i + g_{q_d} \bar{Q}_{d,a} \gamma^\mu Q_{d,a})$$

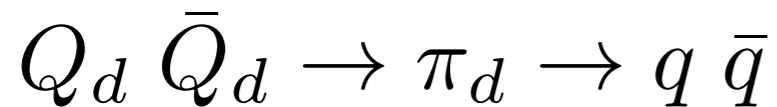


Emerging Jets at the Large Hadron Collider

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

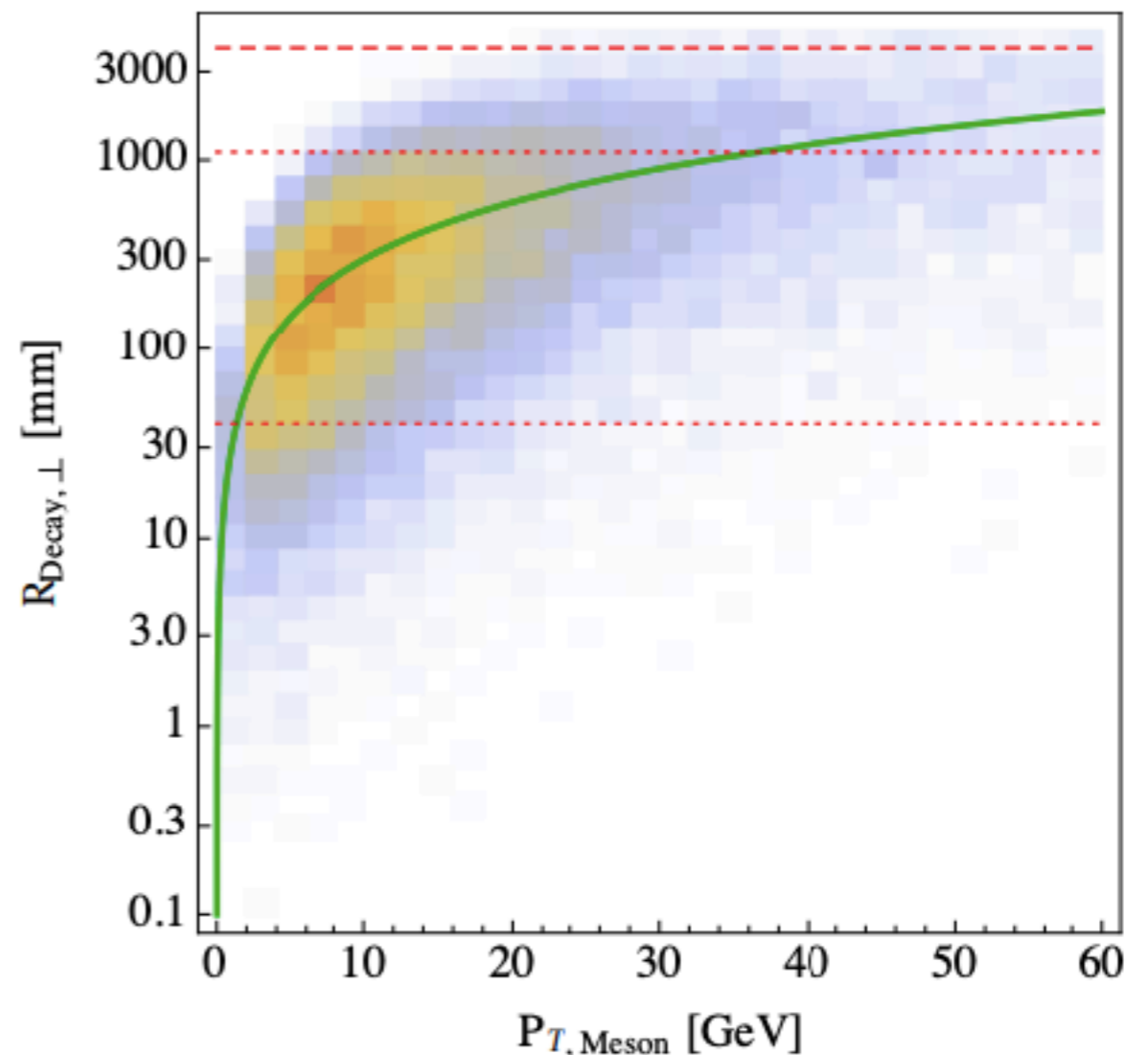
Emerging jets:

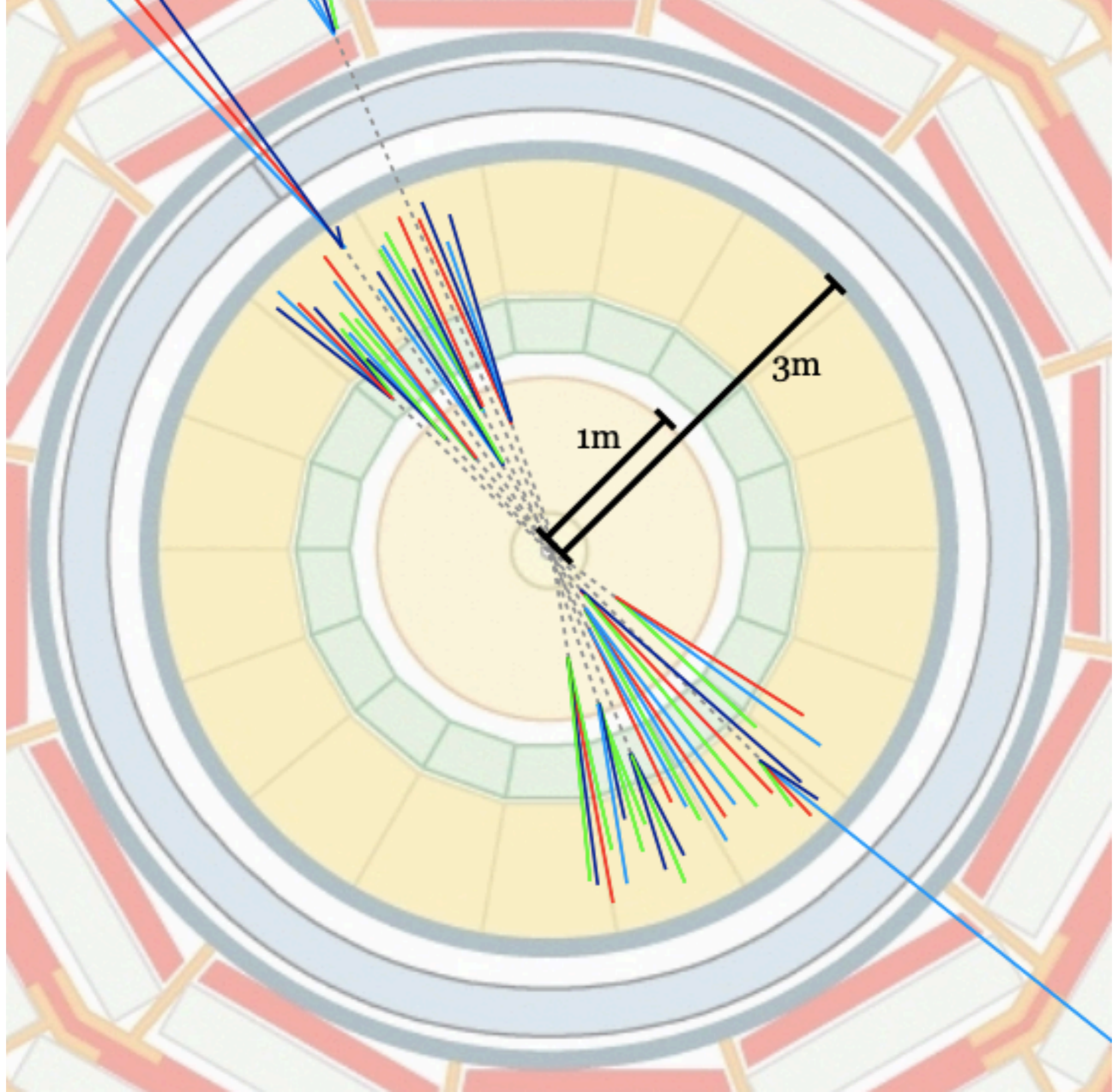
The dark pions being long lived will decay exponentially within the detector volume



The decay products will collimate within the jet cone with unique Parton evolution

Pion Lifetimes





Benchmark Models

Using Hidden Valley/Dark QCD modules now in PYTHIA8

	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

Dark Sector

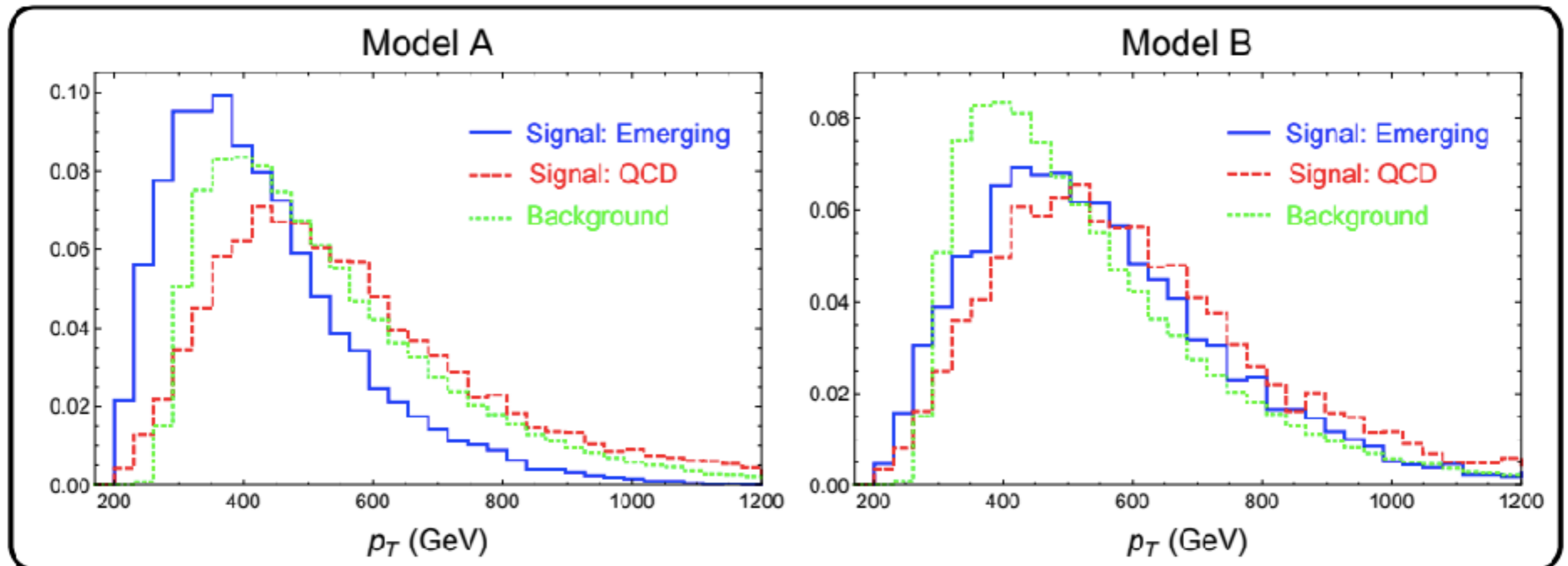
$\times SU(3)_d$

$N_c = 3$ and $n_f = 7$

Varying # colours and flavours has little effect to our work

Jet Momentum and Triggering

Hardest jet p_T



Triggering on EJ events is easy with heavy mediator masses (four hard jets)



We attempt to probe the low mediator mass scales with current triggers

ATLAS Triggers

The proton-proton collisions at the LHC produce **Far** too much data for the
The experiments (ATLAS, CMS, LHCb) to record offline

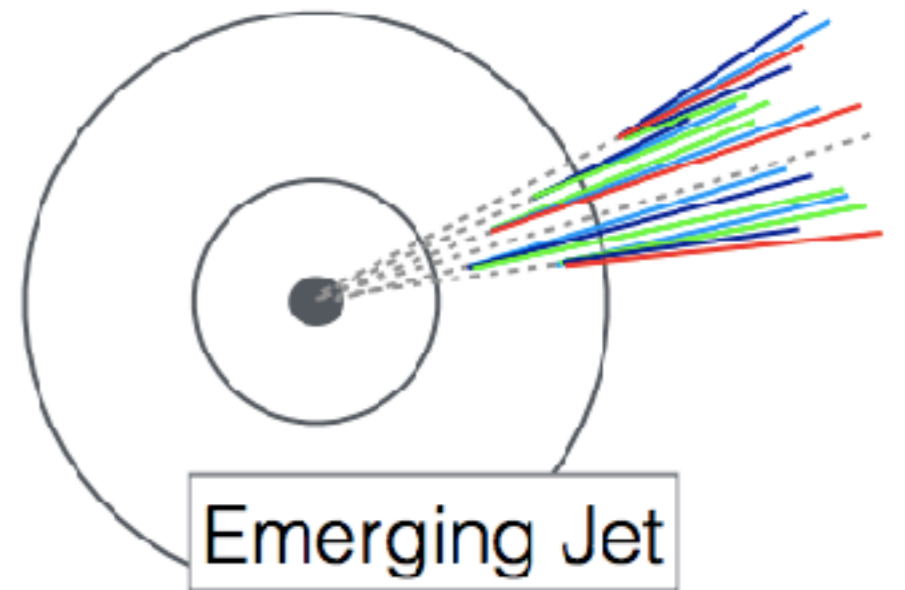
Dedicated triggers \longrightarrow **biasing novel/unique signatures**

Missing Transverse Energy:

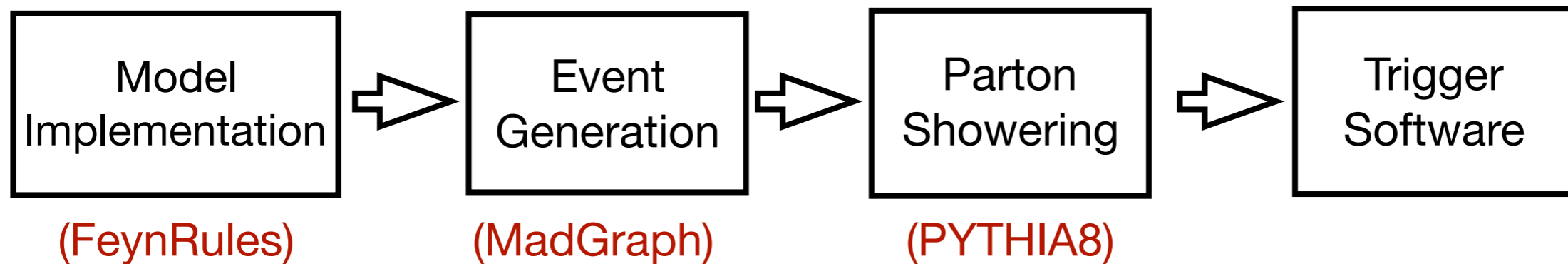
$$\text{MET} = -|P_T| \quad P_T^2 = \left(\sum_i P_{x,i} \right)^2 + \left(\sum_i P_{y,i} \right)^2$$

HT Trigger:

$$\text{HT} = \sum_i P_{T,i} \quad , P_{T,i} > P_{max}$$



Simulation Pipelines:

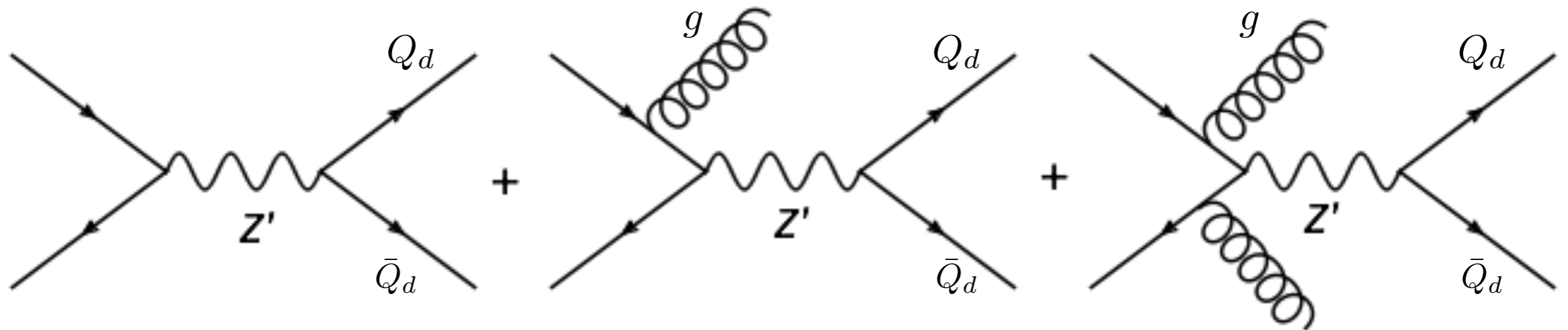


The efficiency of the event can be calculated be calculated, $\text{eff} = \frac{N_{acc}}{N_{tot}}$

Exploiting Dedicated Triggers

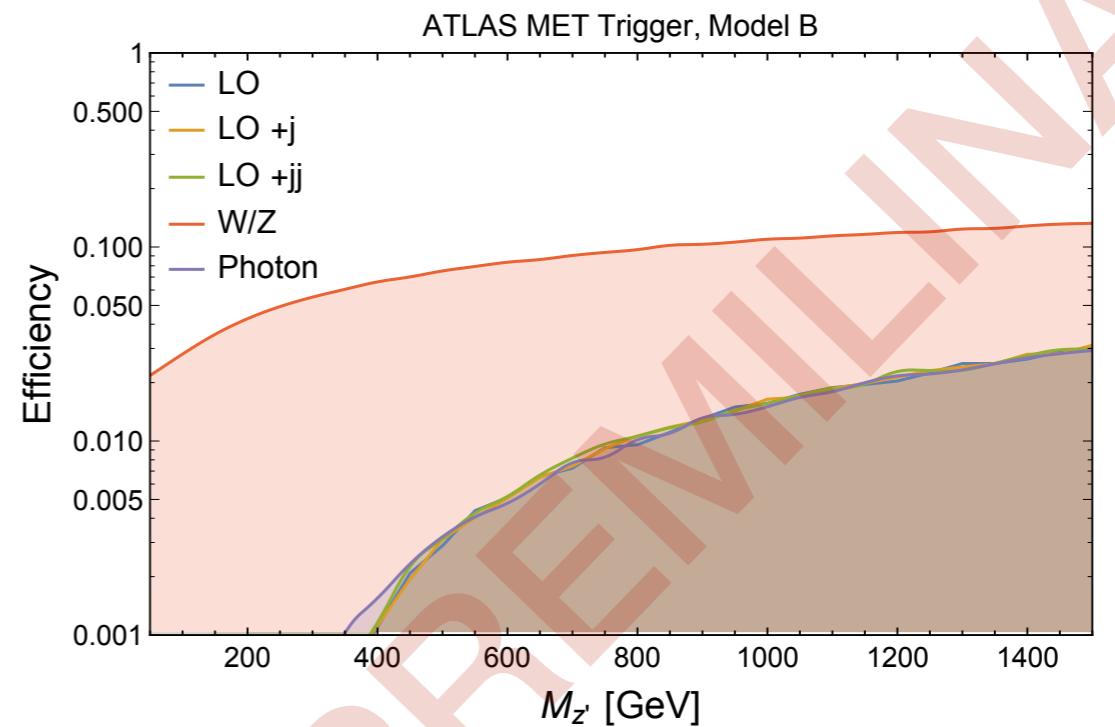
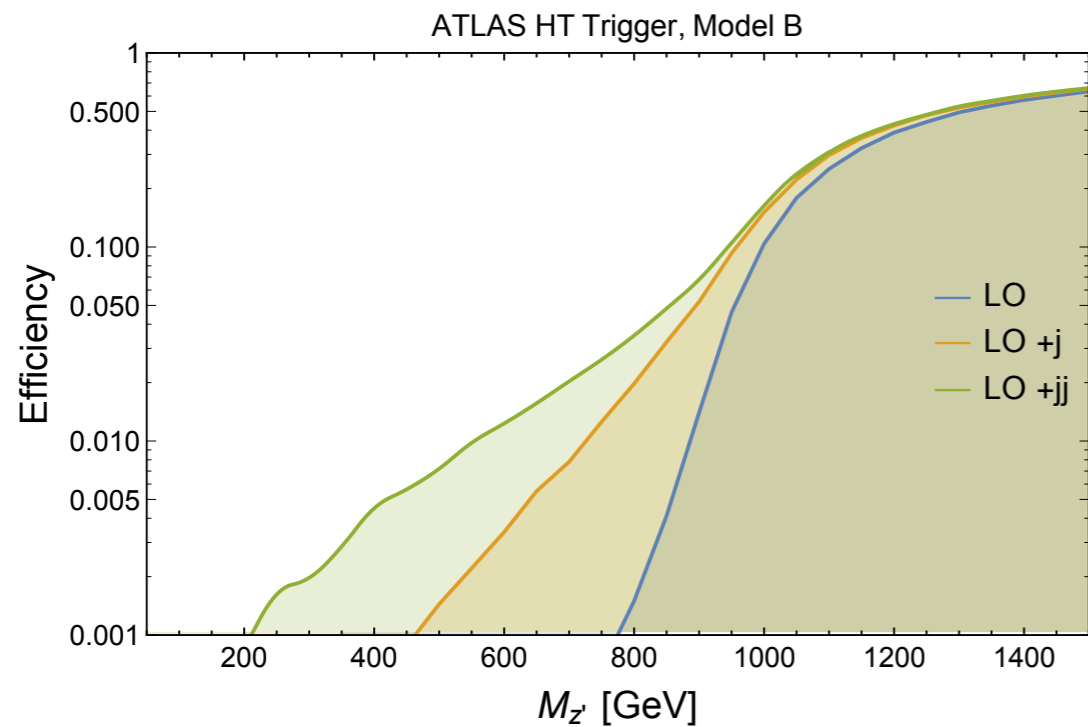
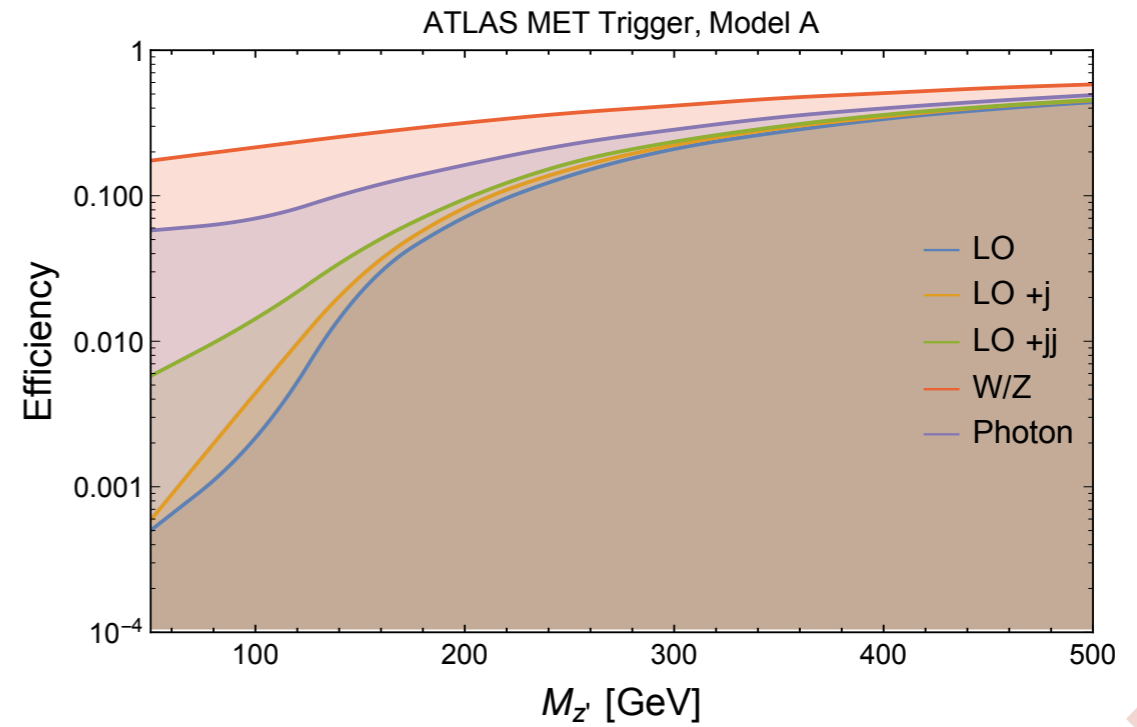
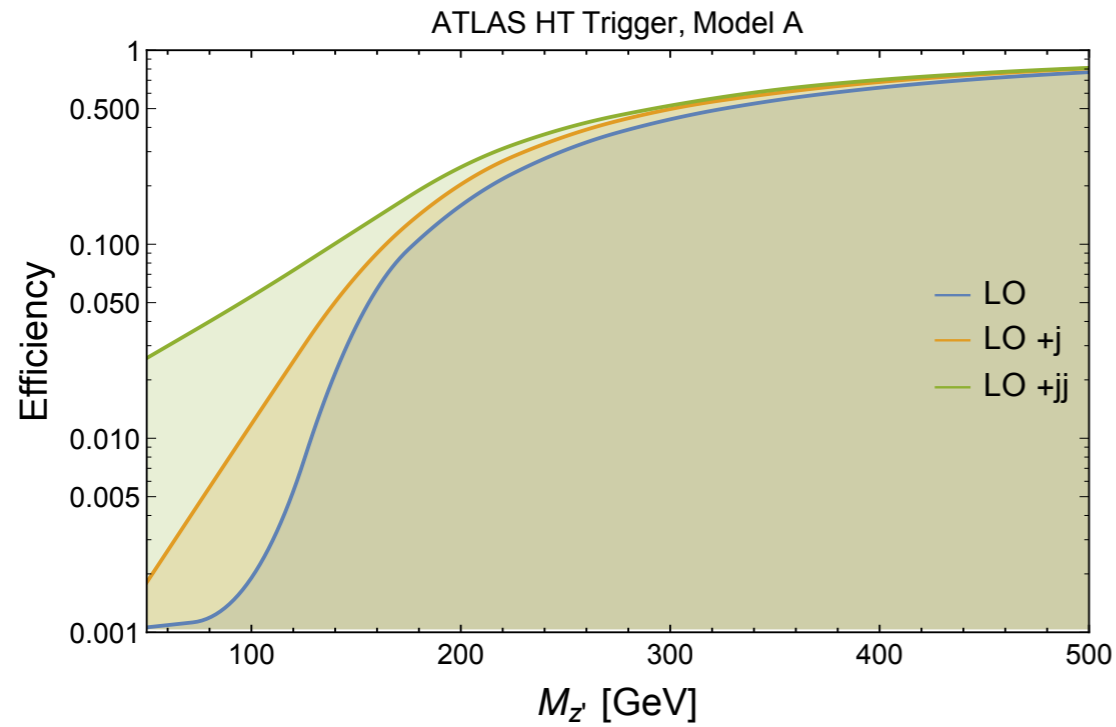
We exploit processes with additional radiation from the hard scattering

(Both QCD and EW ISR are considered)

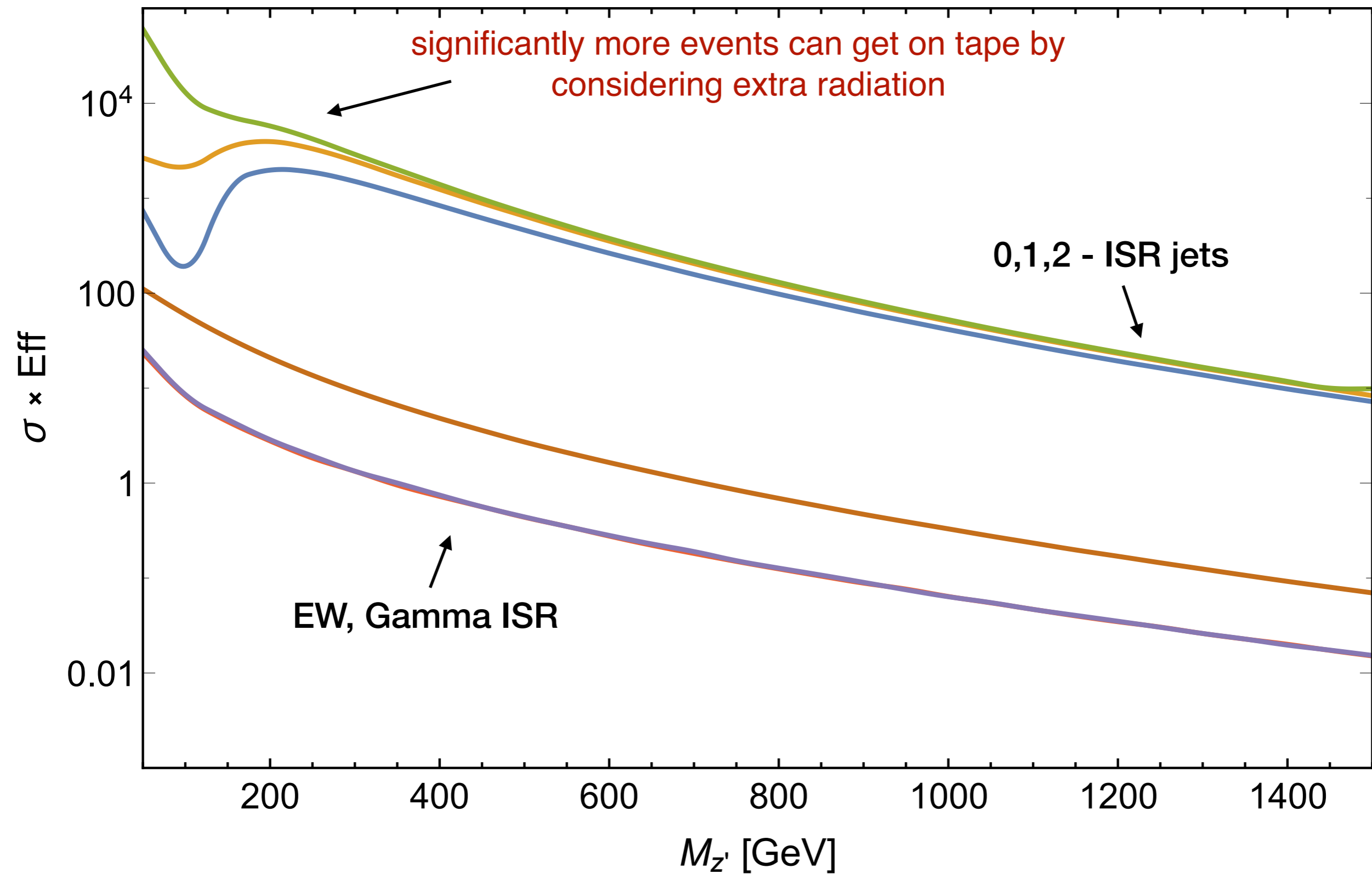


Initial State
Radiation

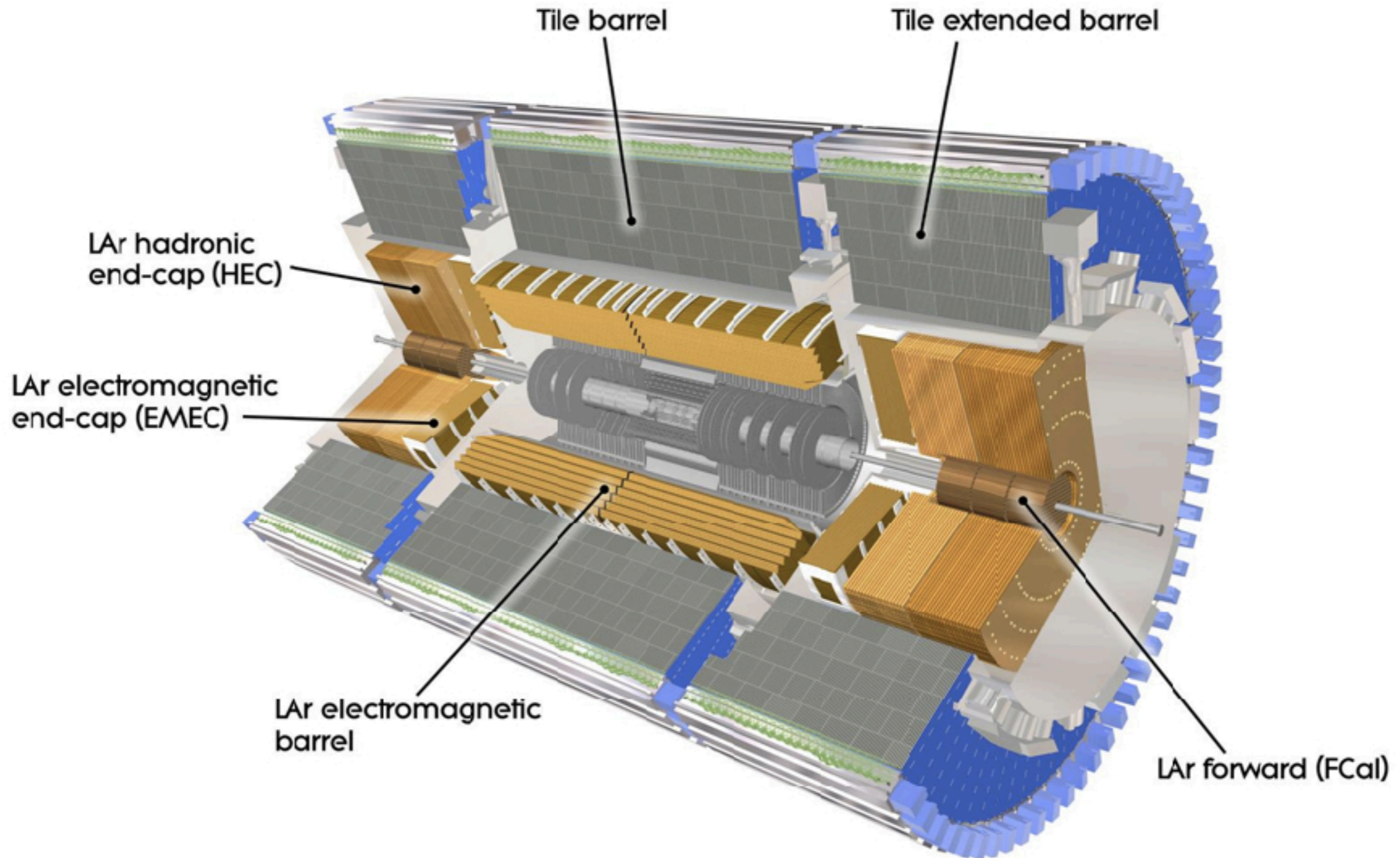
Trigger Efficiencies (Multi-jet Processes)



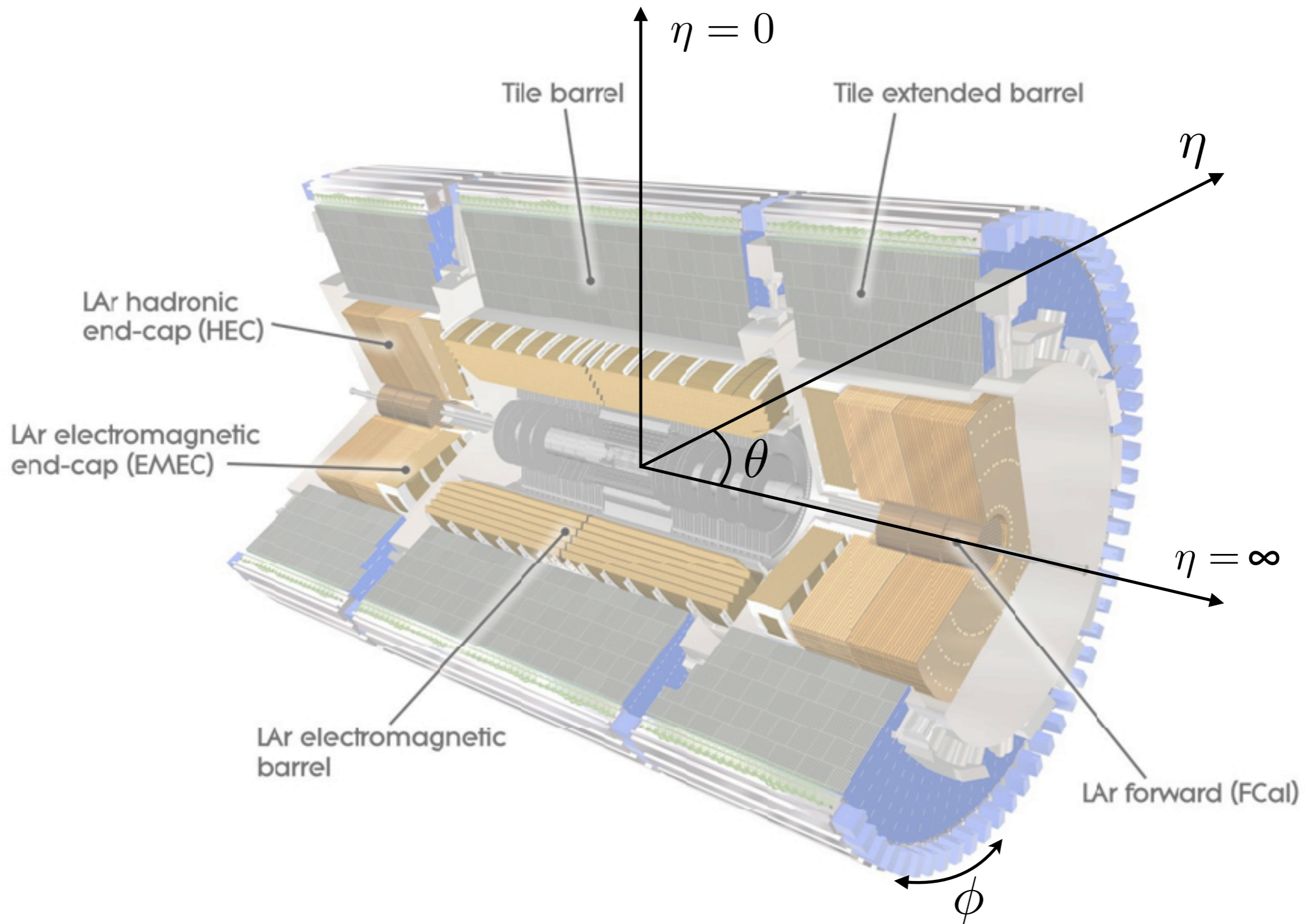
ATLAS HT Trigger Scaled Cross Sections, $\sqrt{s} = 13$ TeV



The ATLAS Detector



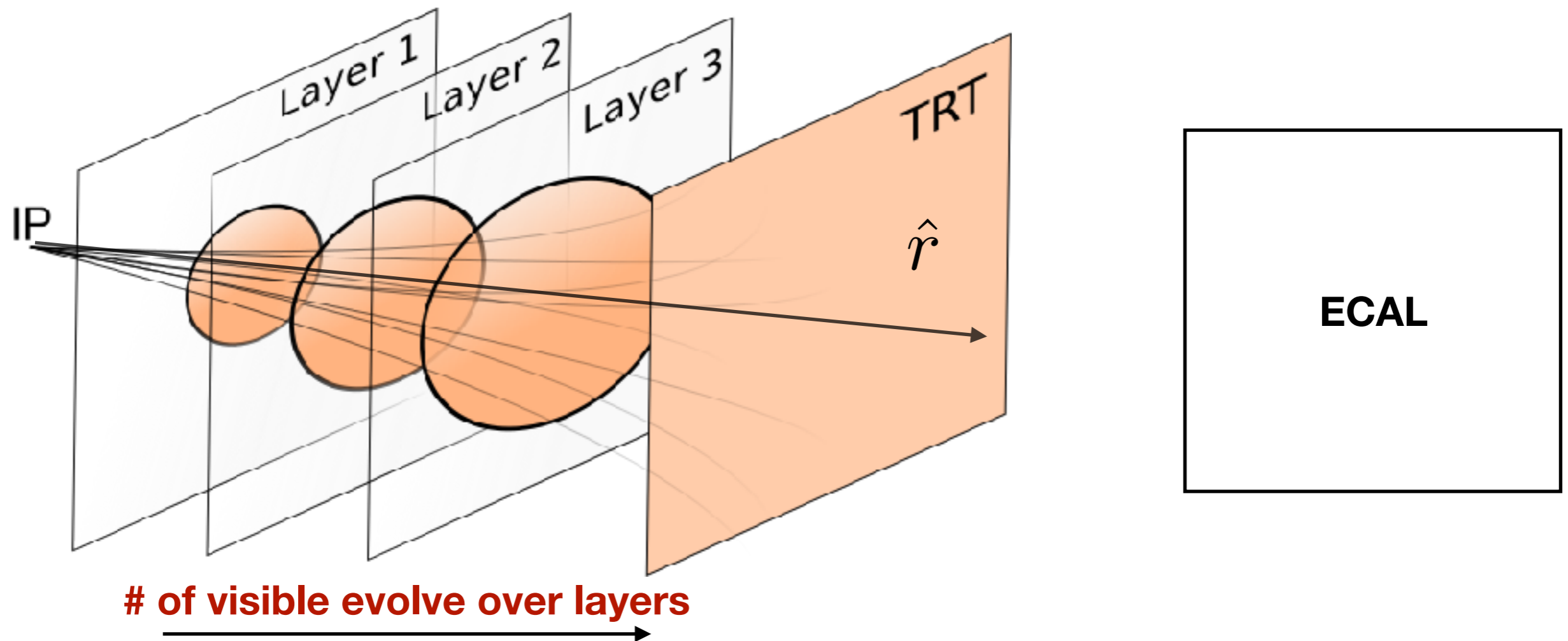
The ATLAS Detector



Just Another Cog in the Machine

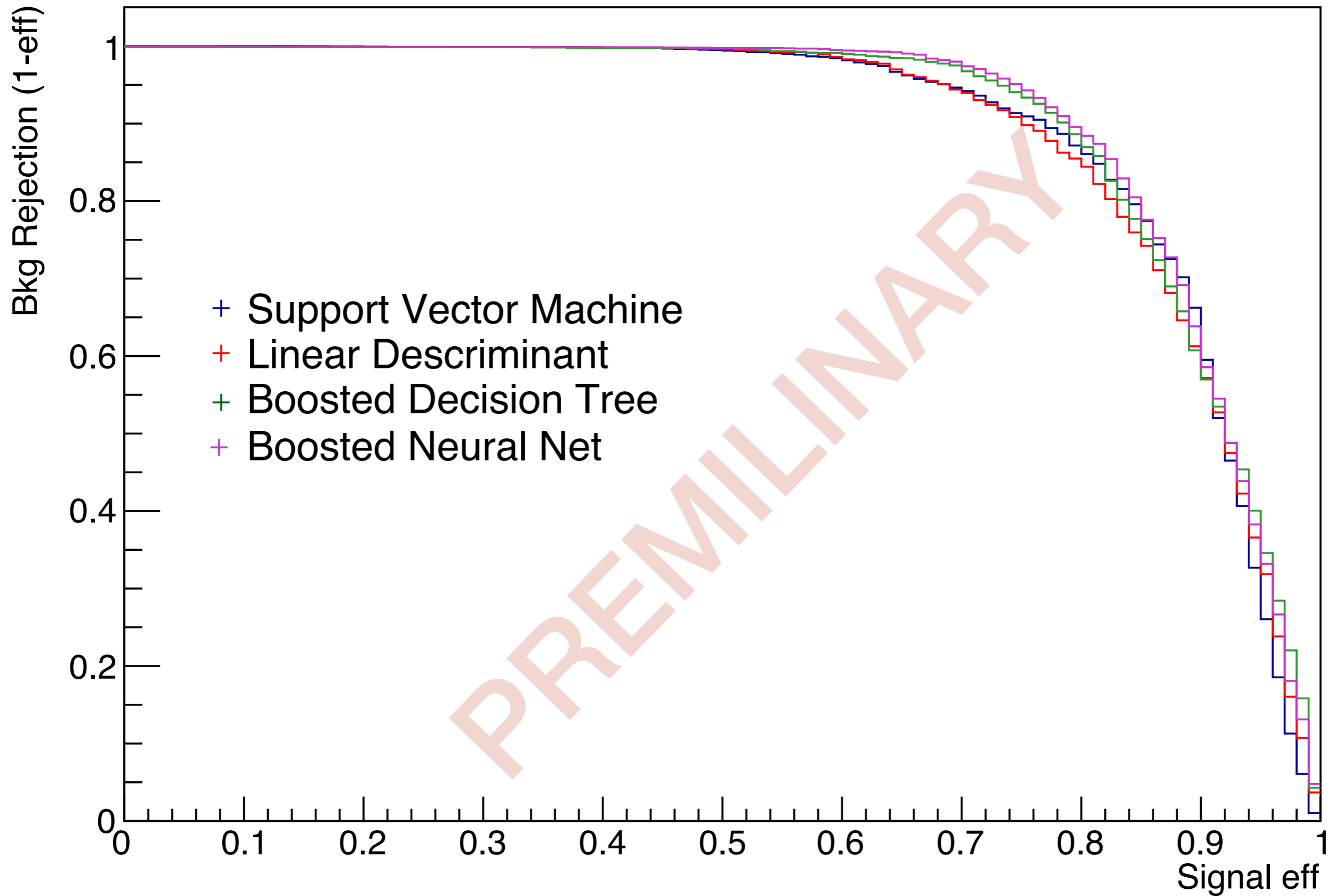
Using hit pattern information of only the tracking layers

Modelled after the ATLAS inner detector



Using only hit patterns and forgoing track reconstruction is less computational heavy

Receiver Operating Characteristic (R.O.C)



Summary

- Emerging jets, although novel, may not pass the dedicated triggers at colliders.
- Light mediator masses have higher trigger efficiencies when additional radiation is considered (ISR).
- New triggers may be motivated using ML techniques with low level variables such as hit patterns on detector layers.

How Long Is Too Long?

Dark Pion Decay Pattern At Truth Level, ATLAS

