Trigger Level Analyses in ATLAS (slides written in collaboration Lund/OSU)

Eric Corrigan
(Lund University)

Caterina Marcon
(Lund University)

William Kalderon
(Lund University)

Caterina Doglioni
(Lund University)

Oxana Smirnova
(Lund University)

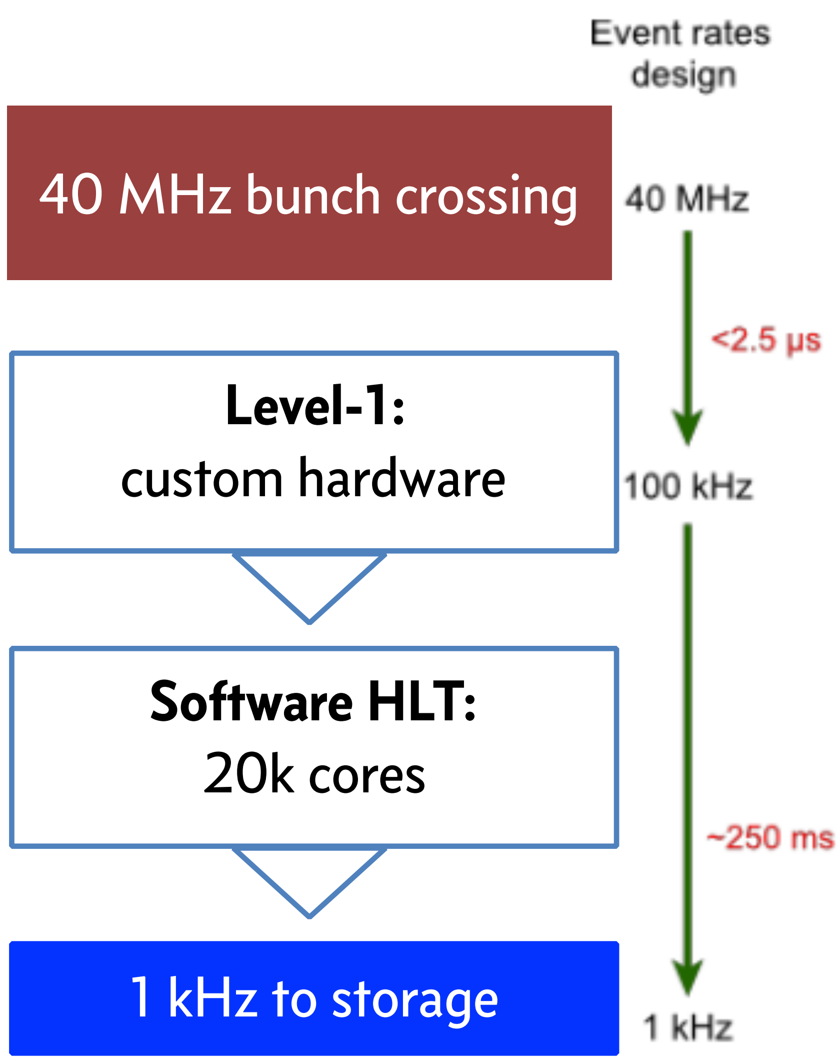
Antonio Boveia
(Ohio State University)

Emma Tolley
(Ohio State University)

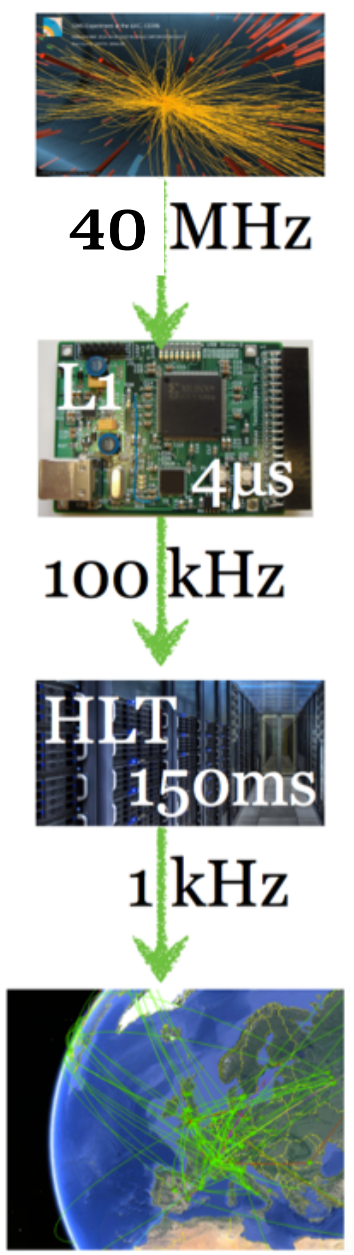
+ more Lund ATLAS students/seniors/engineers

Trigger systems in ATLAS/CMS

ATLAS



CMS



H. Brun, LP 2015

Limitations to recording all data

Limited by:

fast **read-out** of o(100M) detector channels

computing resources (reconstruction)

disk **storage** (saving for further processing)

everyone else's favourite **physics** channel

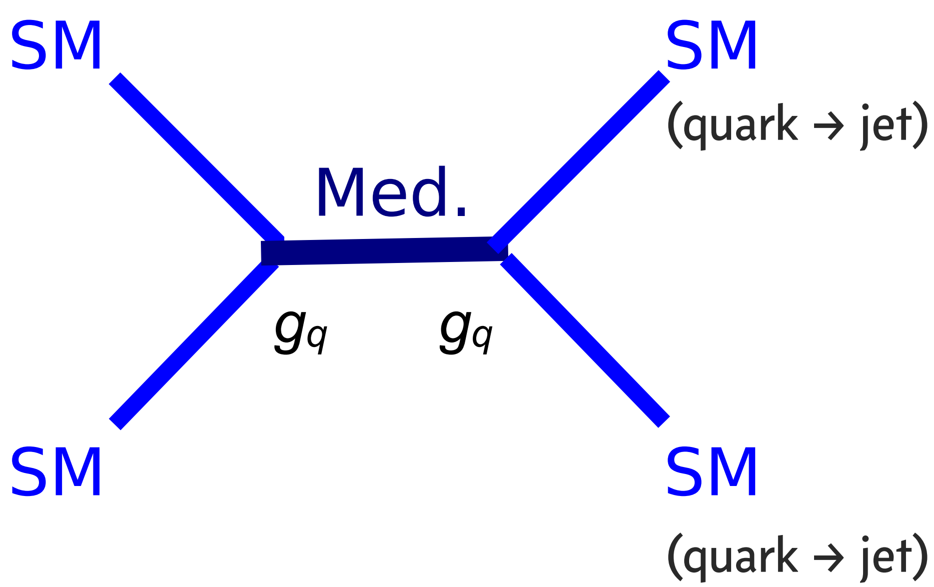
Bandwidth = Event rate **x** Event size

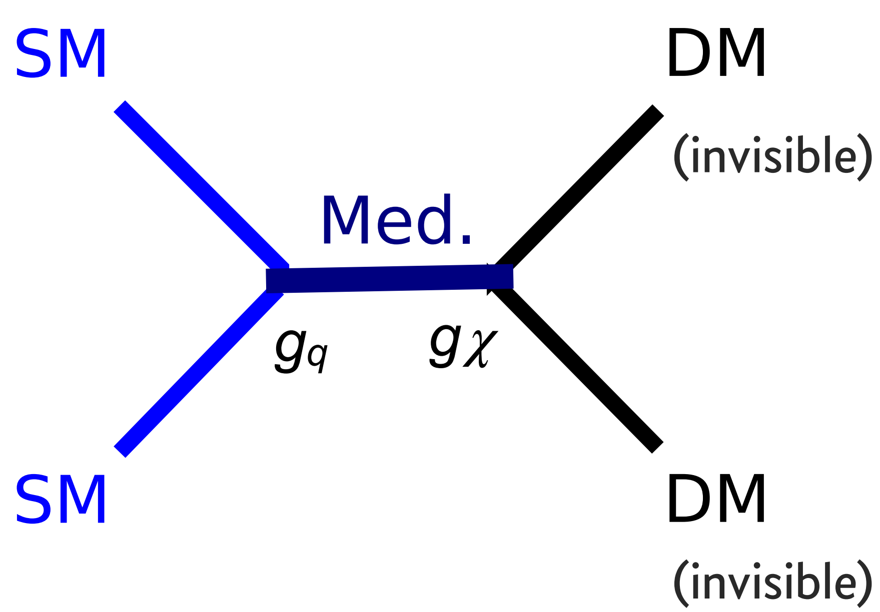
LHC: 40 MHz	(Reconstructed)
ATLAS: 1 kHz	ATLAS: o(MB)
LHCb: 12.5 kHz	LHCb: ~100 kB
CMS: 1 kHz	CMS: o(MB)

Probing for **low-rate** processes is important: LHC **luminosity** will increase but energy will not.

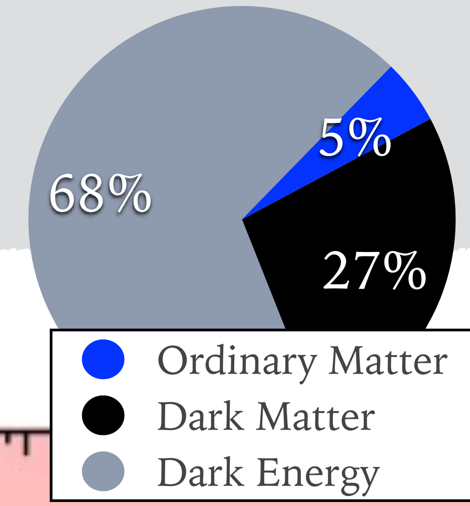
Readout bandwidth is an important limitation of searches when irreducible backgrounds are large.

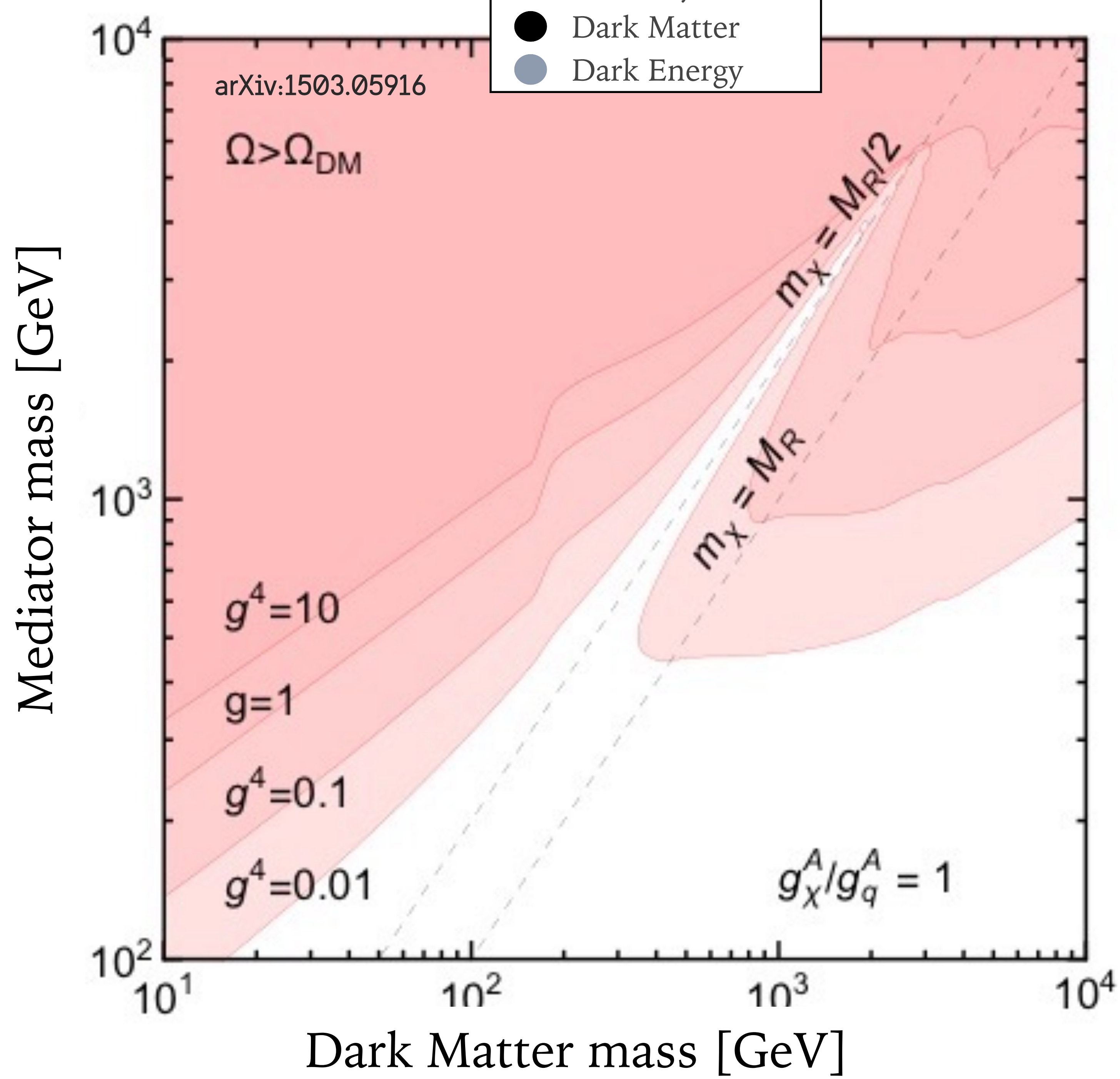
Dark Matter mediators constraints and DM relic density





$$g \equiv (g_q^A \, g_\chi^A)^{1/2}$$

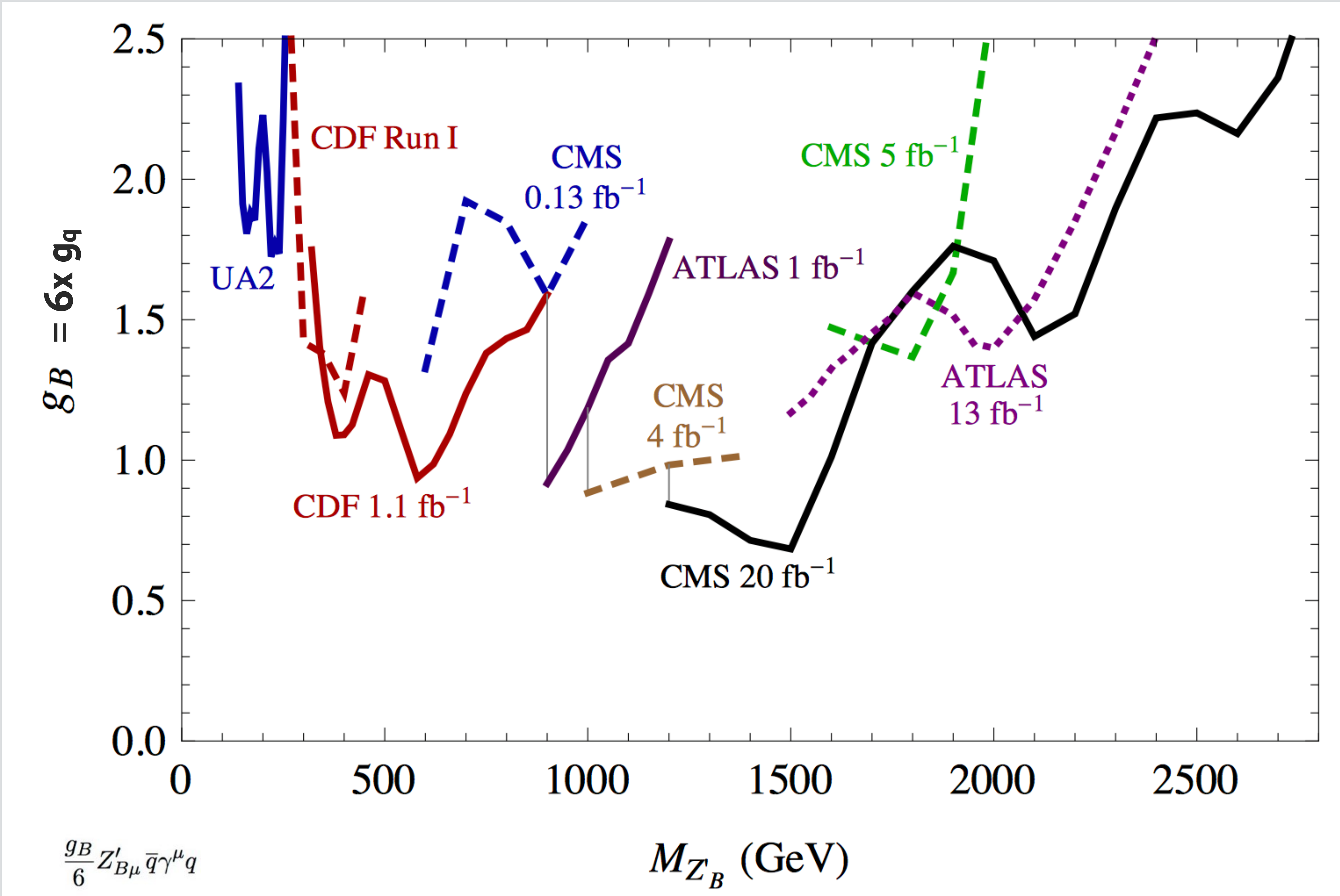




Dijet Resonances: Constraints on Coupling Values vs. Mass

Dobrescu, Yu Phys Rev D 88 035021 (**2013**)

Coupling of new particle to quarks



High Energy Physics – Experiment

Dark Matter Benchmark Models for Early LHC Run-2 Searches: Report of the ATLAS/CMS Dark Matter Forum

Daniel Abercrombie, Nural Akchurin, Ece Akilli, Juan Alcaraz Maestre, Brandon Allen, Barbara Alvarez Gonzalez, Jeremy Andrea, Alexandre Arbey, Georges Azuelos, Patrizia Azzi, Mihailo Backović, Yang Bai, Swagato Banerjee, James Beacham, Alexander Belyaev, Antonio Boveia, Amelia Jean Brennan, Oliver Buchmueller, Matthew R. Buckley, Giorgio Busoni, Michael Buttignol, Giacomo Cacciapaglia, Regina Caputo, Linda Carpenter, Nuno Filipe Castro, Guillelmo Gomez Ceballos, Yangyang Cheng, John Paul Chou, Arely Cortes Gonzalez, Chris Cowden, Francesco D'Eramo, Annapaola De Cosa, Michele De Gruttola, Albert De Roeck, Andrea De Simone, Aldo Deandrea, Zeynep Demiragli, Anthony DiFranzo, Caterina Doglioni, Tristan du Pree, Robin Erbacher, Johannes Erdmann, Cora Fischer, Henning Flaecher, Patrick J. Fox, et al. (94 additional authors not shown)

(Submitted on 3 Jul 2015)

This document is the final report of the ATLAS-CMS Dark Matter Forum, a forum organized by the ATLAS and CMS collaborations with the participation of experts on theories of Dark Matter, to select a minimal basis set of dark matter simplified models that should support the design of the early LHC Run-2 searches. A prioritized, compact set of benchmark models is proposed, accompanied by studies of the parameter space of these models and a repository of generator implementations. This report also addresses how to apply the Effective Field Theory formalism for collider searches and present the results of such interpretations.

Subjects: **High Energy Physics – Experiment (hep-ex)**; High [...] (hep-ph)

Cite as: **arXiv:1507.00966 [hep-ex]**
(or **arXiv:1507.00966v1 [hep-ex]** for this version)

Submission history

From: Antonio Boveia [view email]
[v1] Fri, 3 Jul 2015 16:54:32 GMT (3860kb,D)

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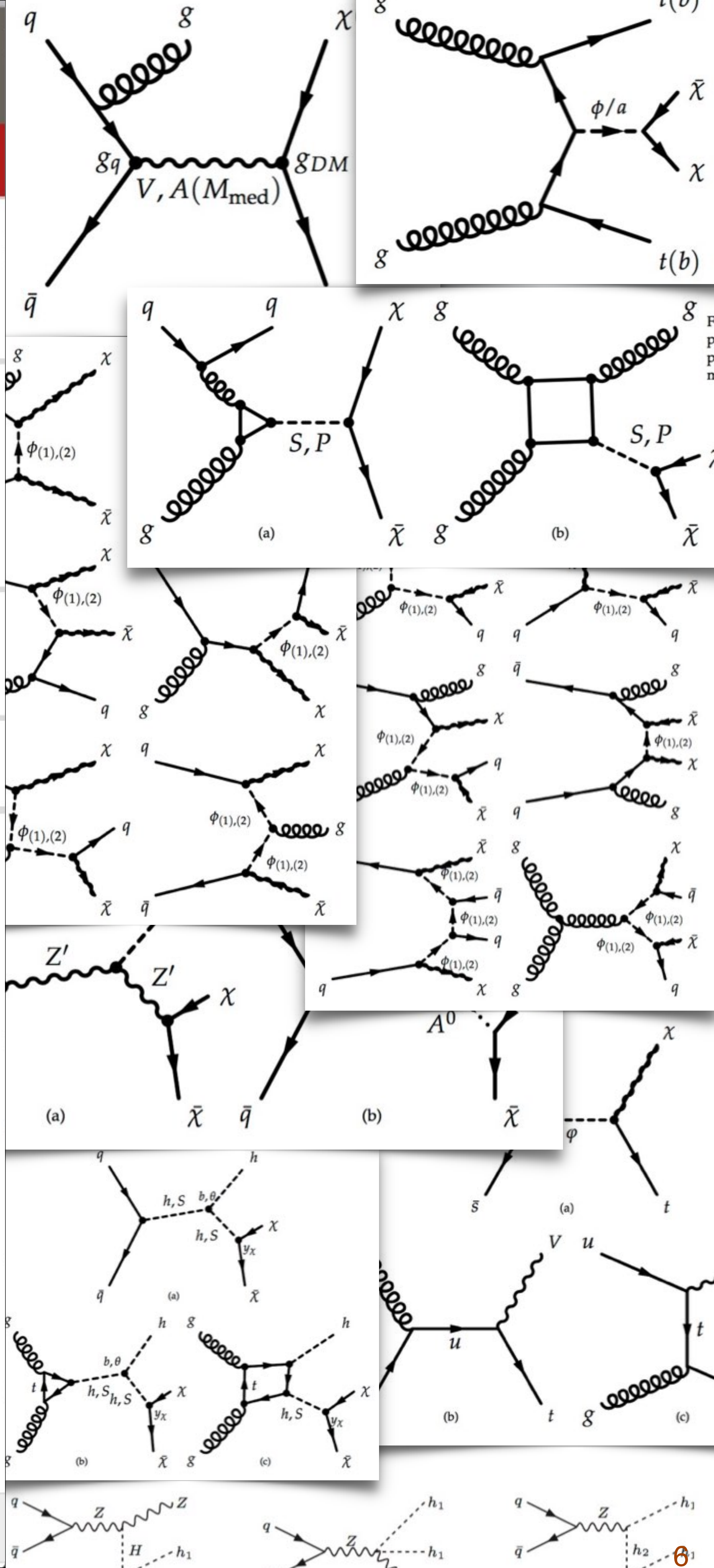
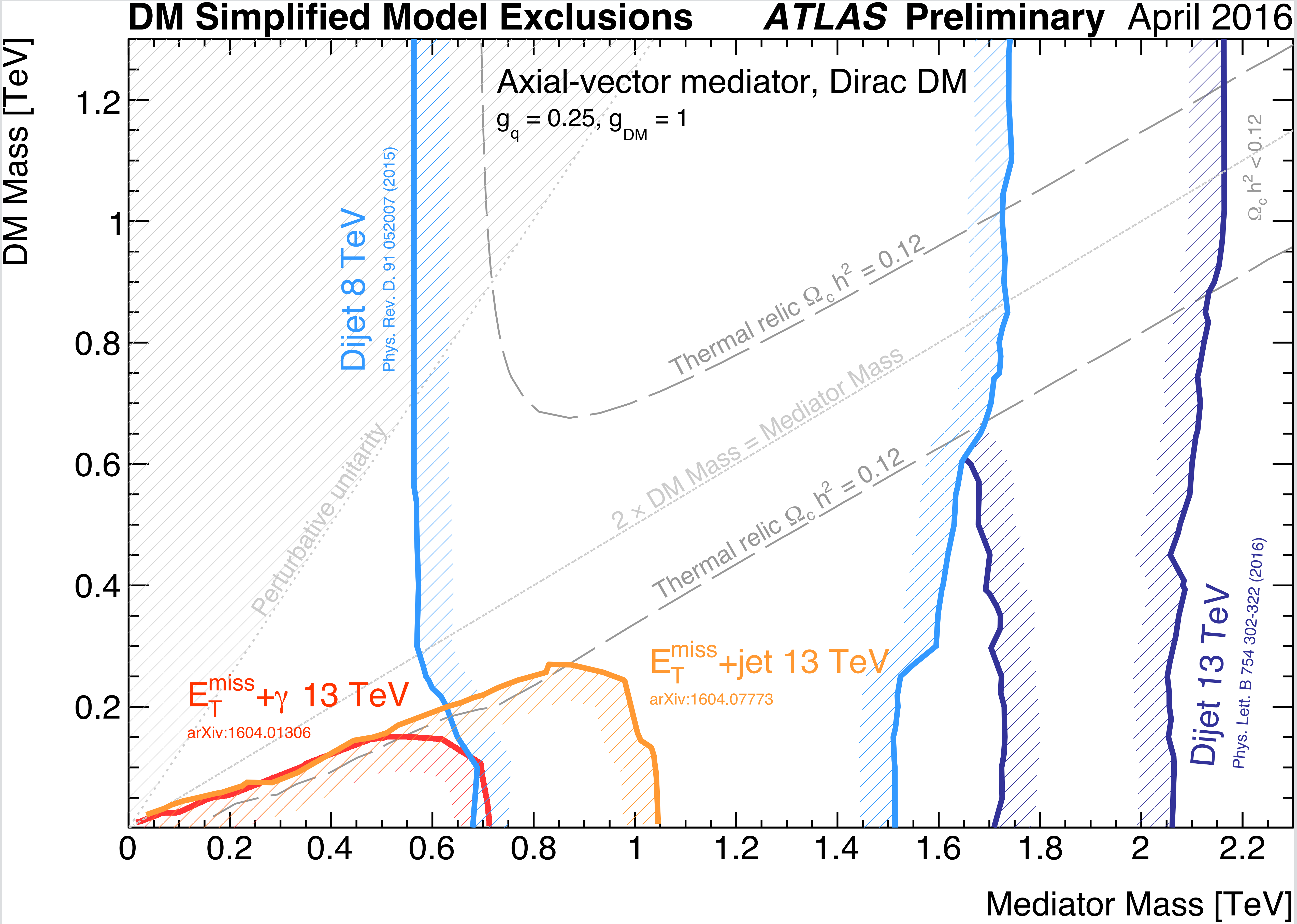
Dirac WIMP mediators:
s- and t-channel
vector/axial-vector/scalar/pseudo-scalar
MET+heavy flavor, W, Z, and Higgs





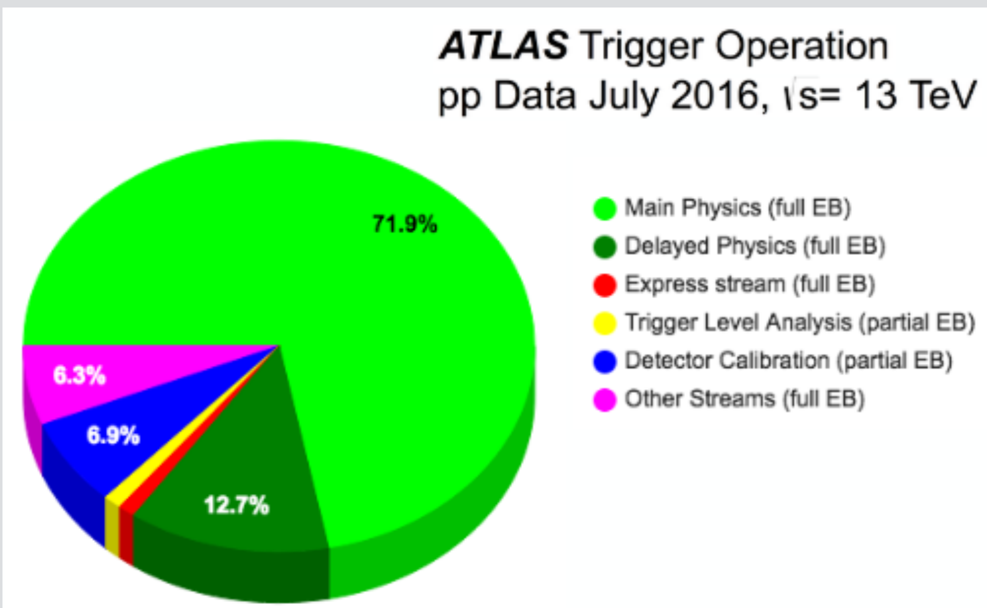
DM Simplified Model Exclusions
ATLAS Preliminary April 2016
Axial-vector mediator, Dirac DM
g_q = 0.25, g_DM = 1
DM Mass [TeV]
Mediator Mass [TeV]
Dijet 8 TeV
Phys. Rev. D. 91 052007 (2015)
Dijet 13 TeV
Phys. Lett. B 754 302-322 (2016)
E_T^miss+γ 13 TeV
arXiv:1604.01306
E_T^miss+jet 13 TeV
arXiv:1604.07773
Perturbative unitarity
Thermal relic Ω_c h^2 = 0.12
2 × DM Mass = Mediator Mass
Thermal relic Ω_c h^2 = 0.12
Ω_c h^2 < 0.12
0.2
0.4
0.6
0.8
1
1.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2

Trigger-Level Analysis technique

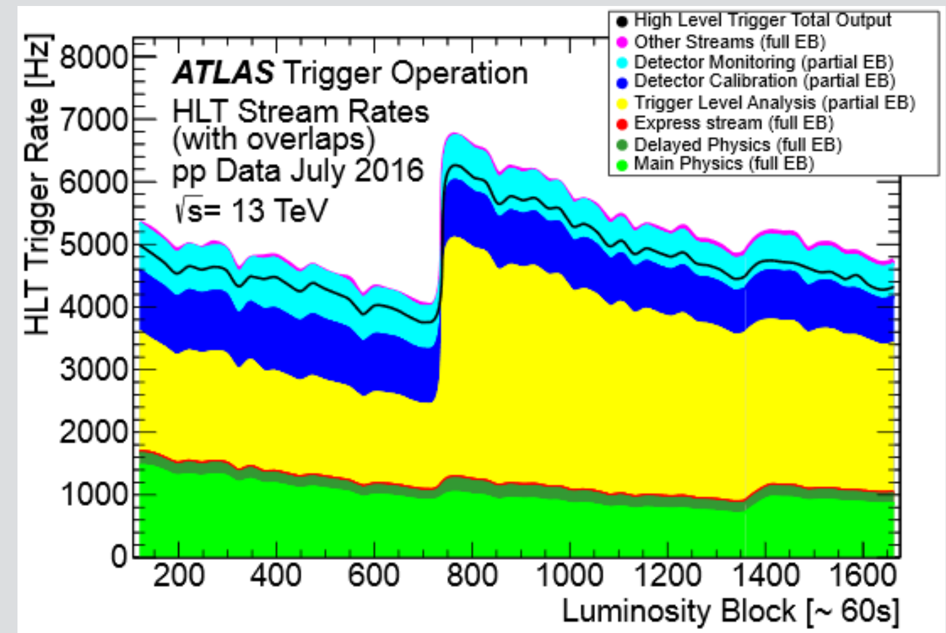
Record only necessary information for jet search: **jets**

Use information already available to make the decision: **HLT jets**

Event size reduced to 5% of fully recorded event

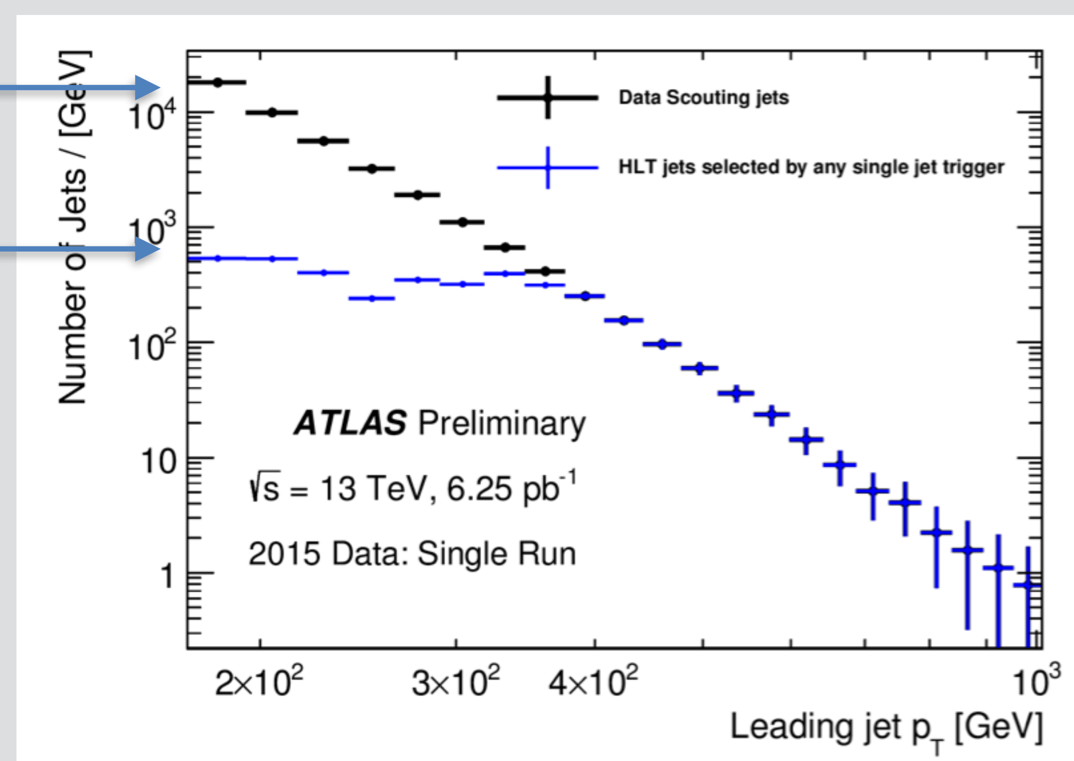


Reduced size → increase unprescaled trigger rate



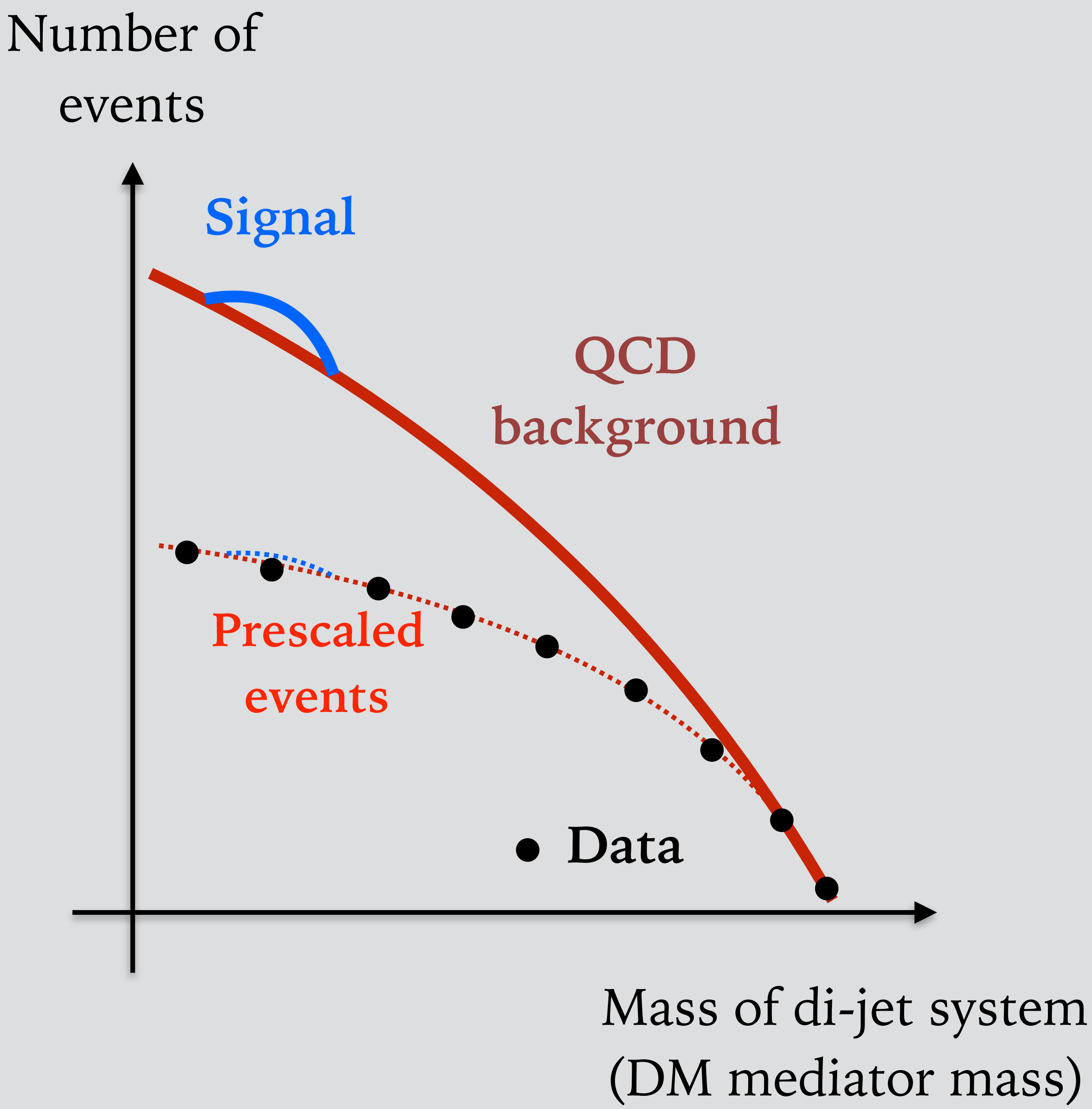
unprescaled

prescaled

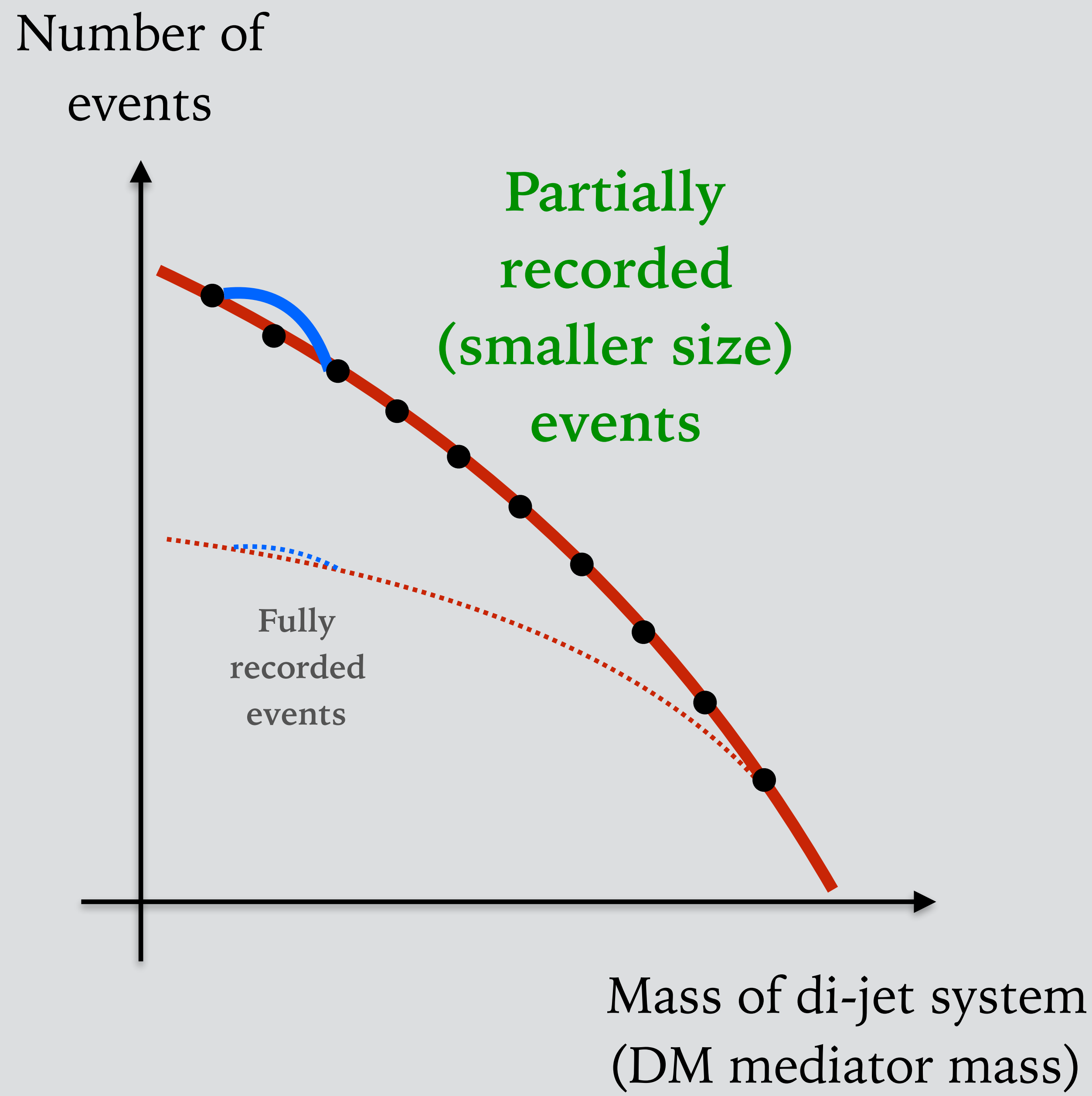


Statistics increase from Trigger-Level Analysis technique

Standard analysis



Trigger-Level Analysis

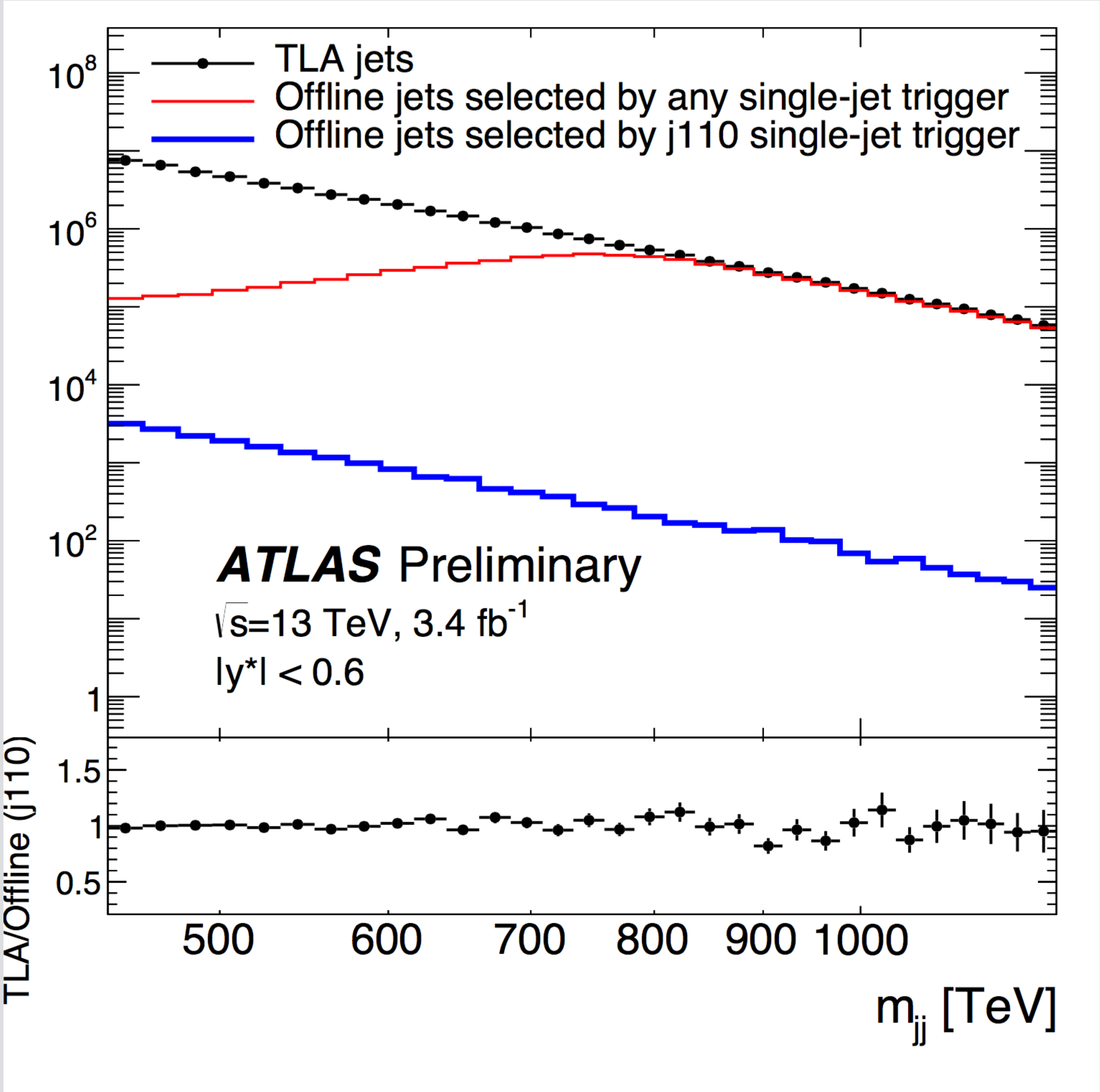


Statistics increase from Trigger-Level Analysis technique: dijet invariant mass

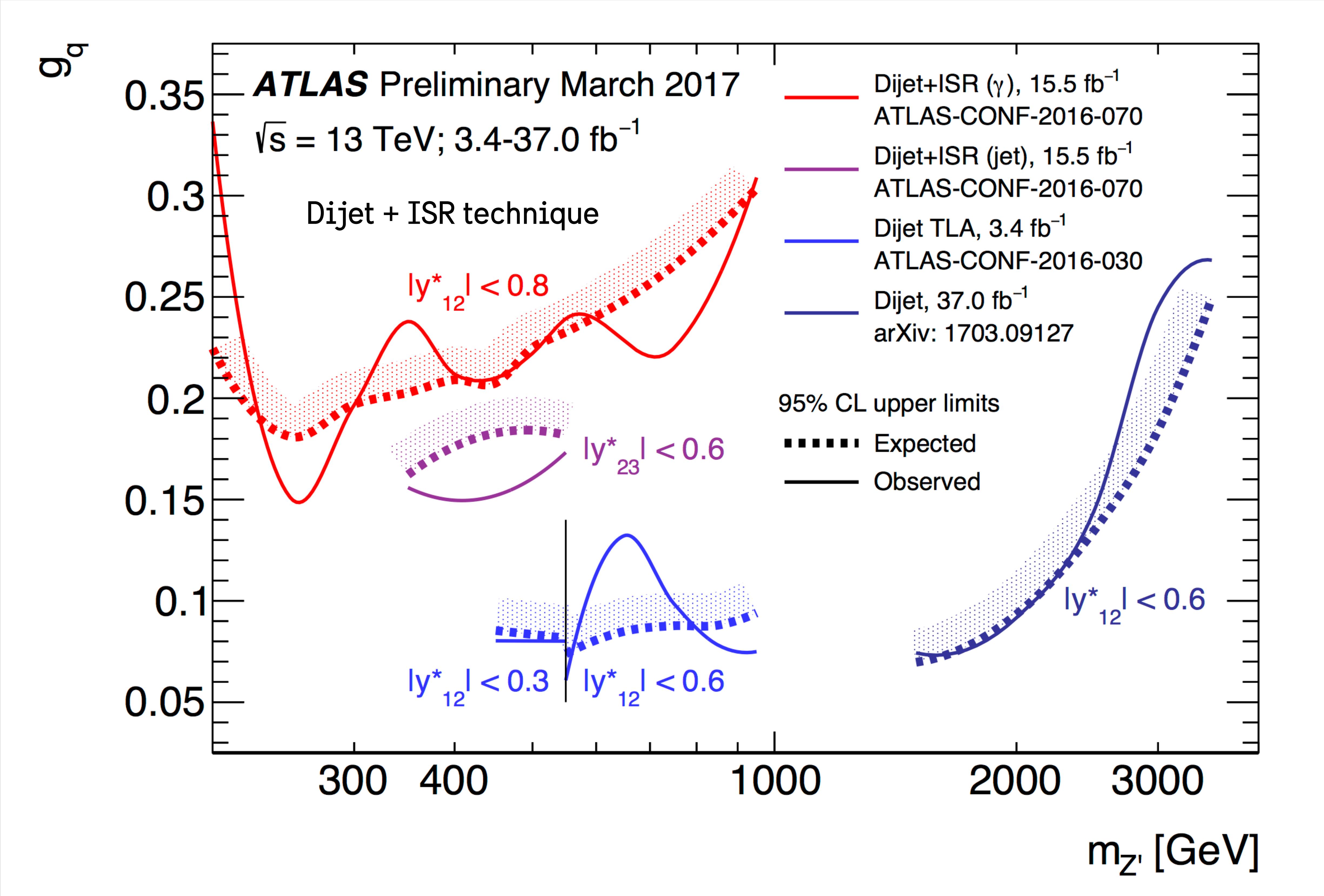
Statistics increase

Performance comparison:

trigger/offline response = unity
this requires custom offline calibrations for trigger jets



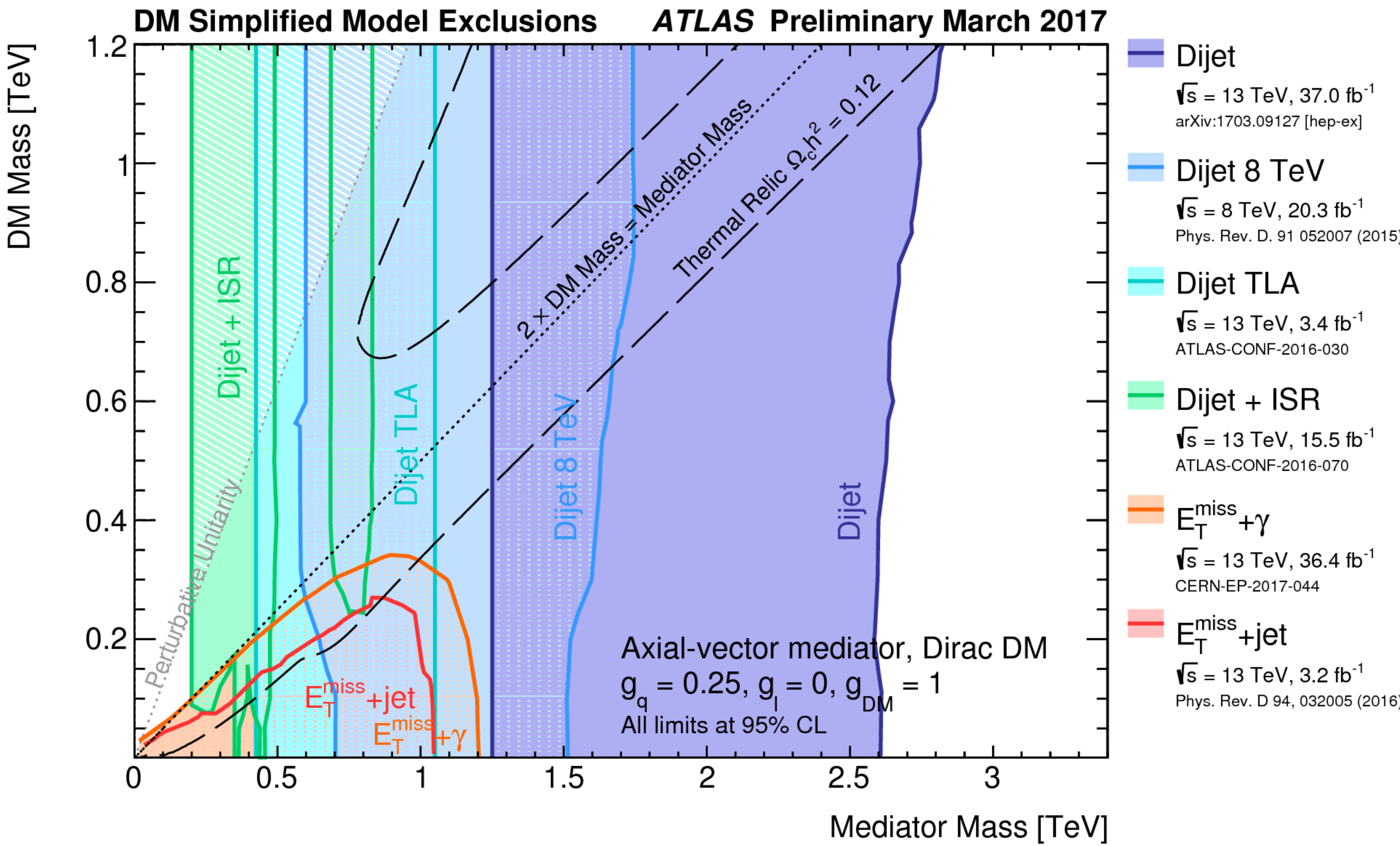
Results



ATLAS Preliminary March 2017
√s = 13 TeV; 3.4-37.0 fb^{-1}
Dijet + ISR technique
Dijet+ISR (γ), 15.5 fb^{-1}
ATLAS-CONF-2016-070
Dijet+ISR (jet), 15.5 fb^{-1}
ATLAS-CONF-2016-070
Dijet TLA, 3.4 fb^{-1}
ATLAS-CONF-2016-030
Dijet, 37.0 fb^{-1}
arXiv: 1703.09127
95% CL upper limits
Expected
Observed
$|y^*_{12}| < 0.8$
$|y^*_{23}| < 0.6$
$|y^*_{12}| < 0.3$
$|y^*_{12}| < 0.6$
$|y^*_{12}| < 0.6$
g_q
0.35
0.3
0.25
0.2
0.15
0.1
0.05
300
400
1000
2000
3000
$m_{Z'}$ [GeV]

ATLAS MET+X and Dijet Searches

Benchmark model points: LHC DM WG, arXiv:1703.05703



Outlook

TLA technique powerful when:

- use a subset of the detector information for the search
- object already reconstructed in the trigger and close enough to offline

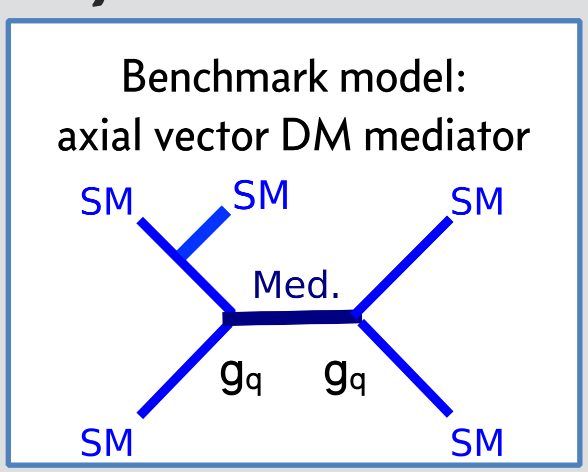
Other detectors that could help TLAs:

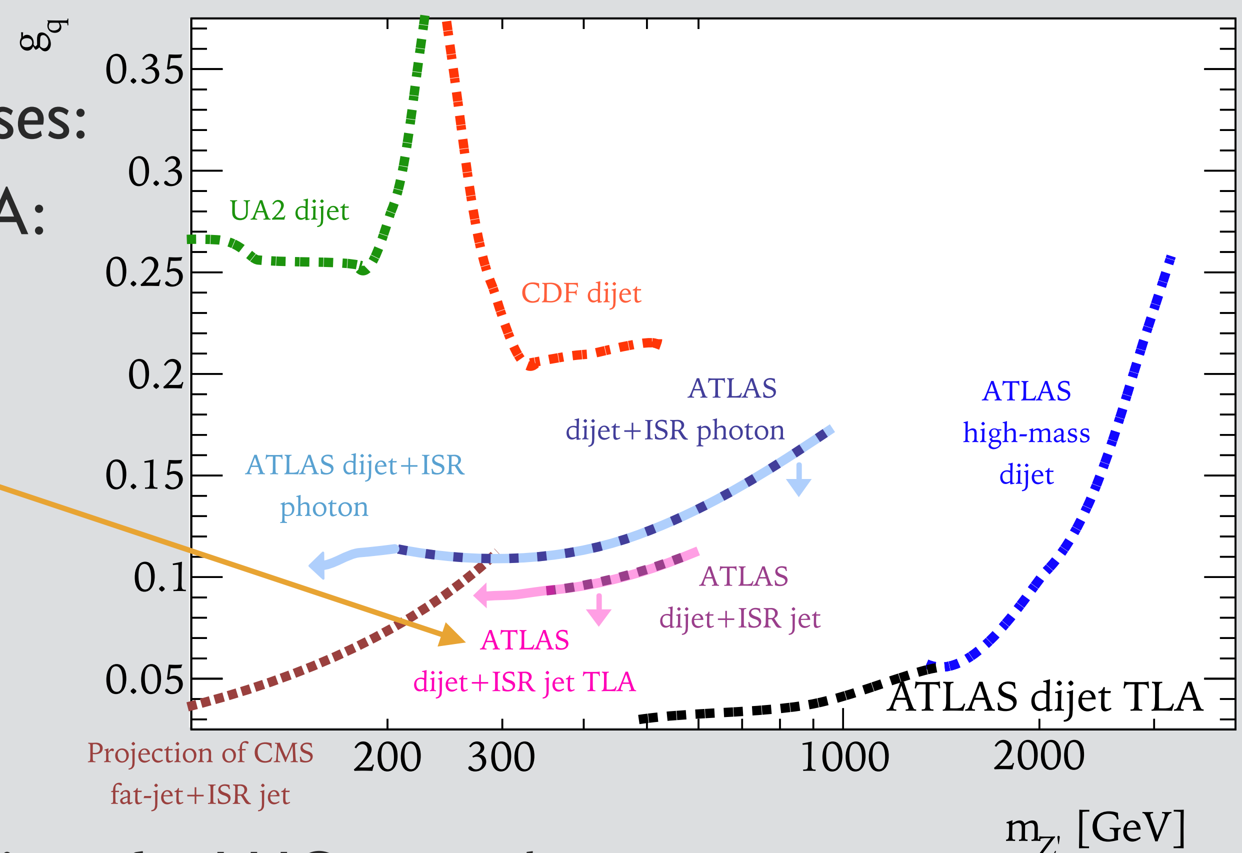
- pile-up subtraction
- rely on information computed in trigger and only write out summary information (real-time analysis)

TLA for SMARTHEP PhD project purposes:

- combine background reduction and TLA:

dijet+ISR TLA





- move towards real-time trigger calibrations for LHC upgrade

Additional Slides

Trigger Level Analysis: search

ATLAS-CONF-2016-030

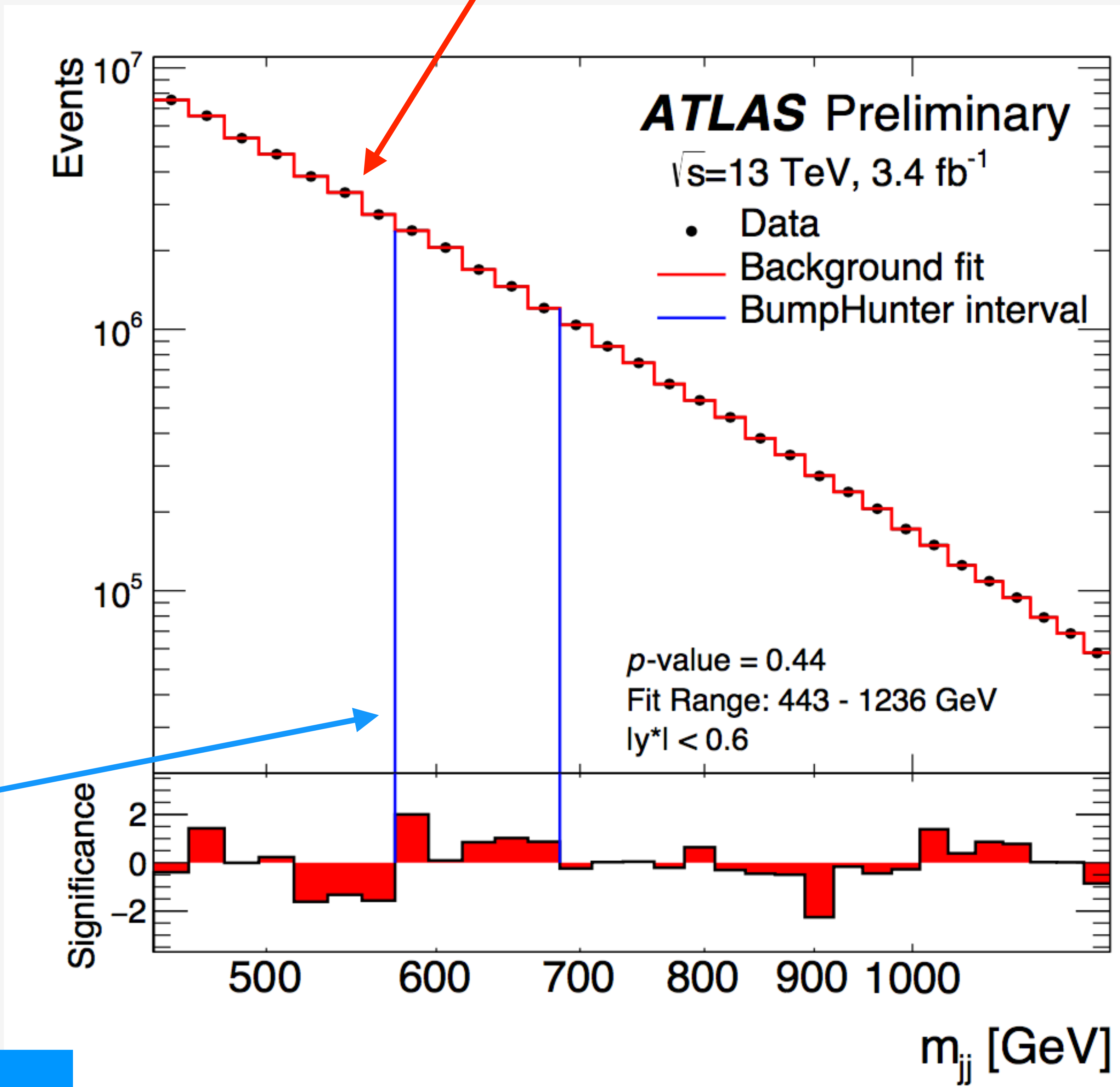
Data-driven background fit (UA2 fcn)

$$f(z) = p_1(1 - z)^{p_2} z^{p_3 + p_4 \log z}$$

Jet p_T > 185, 85 GeV

$|y^*| = |y_1 - y_2|/2 < 0.6$
(rejects forward-peaking t-channel QCD processes)
m_{jj} > 460 GeV

$|y^*| = |y_1 - y_2|/2 < 0.3$
(reaches lower in mass due to forcing more central, higher pT jets)
m_{jj} > 396 GeV



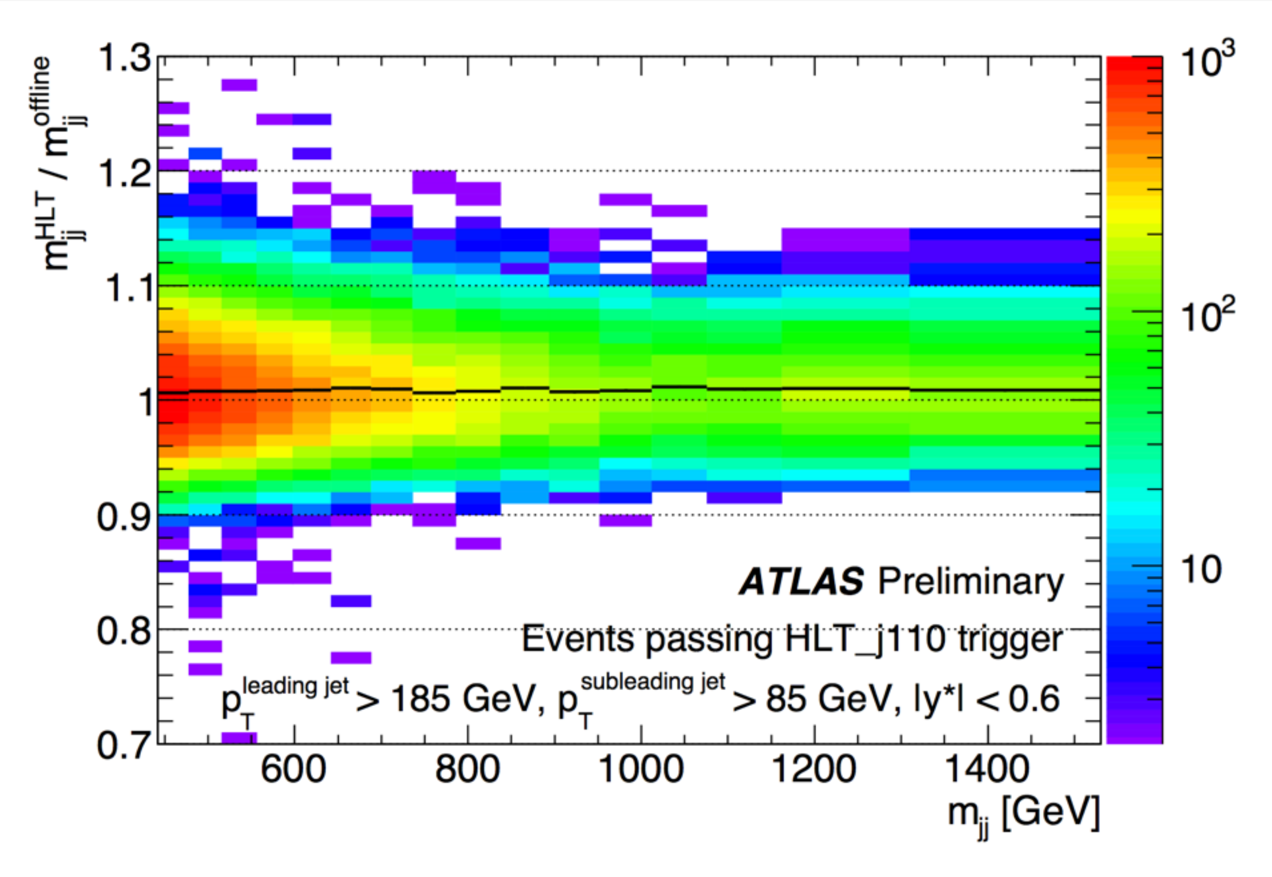
Most discrepant region (p-value 0.44)

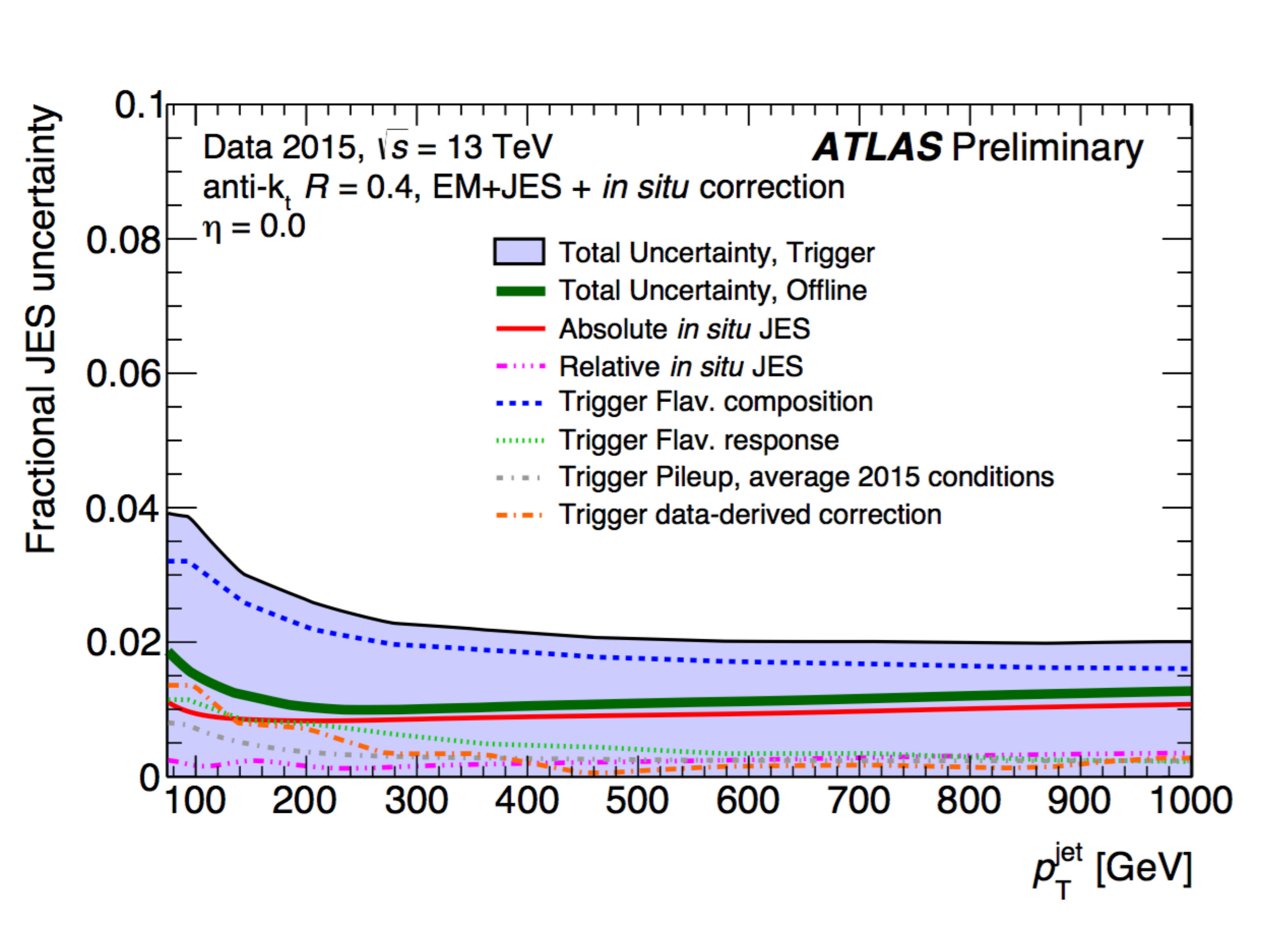
Only probing below M ~ 1.2 TeV (high-mass analysis takes over)

Jet performance for TLA

Performance of trigger jets comparable to that of offline jets

Improvements benefit jet trigger as a whole

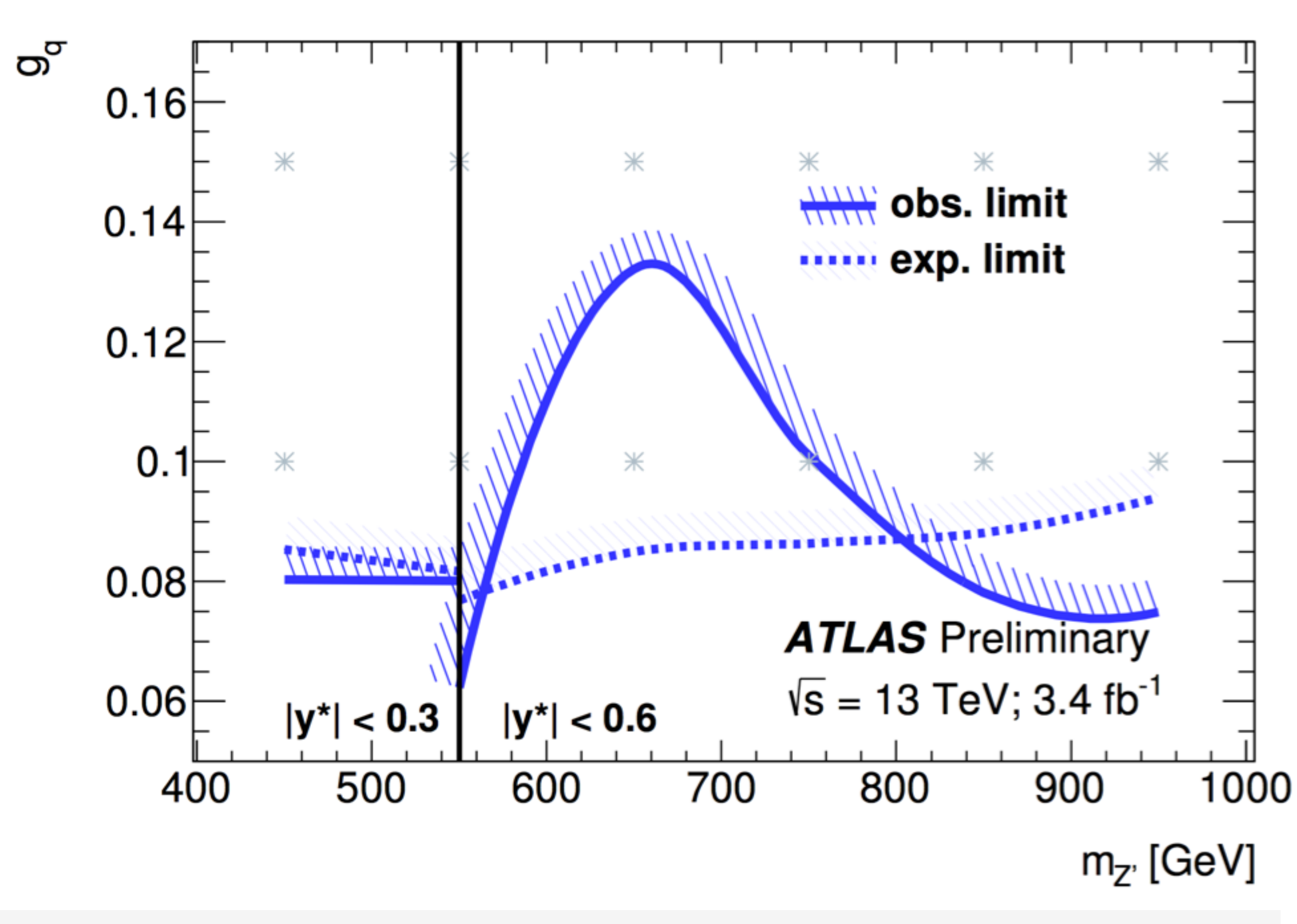




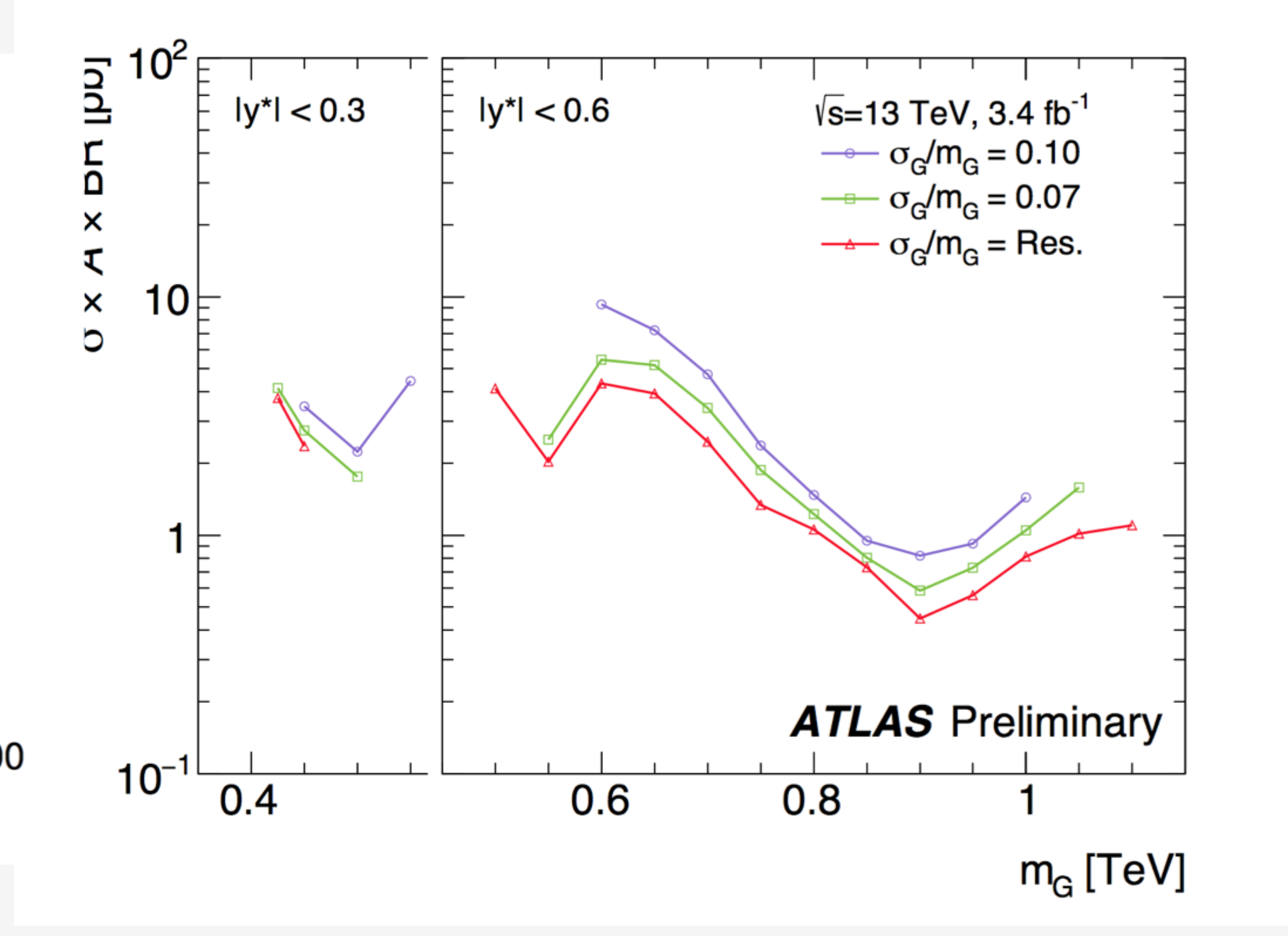
Trigger Level Analysis: results

ATLAS-CONF-2016-030

Constraints on DM mediator couplings



Limits on Gaussian-shape resonances (for reinterpretation)

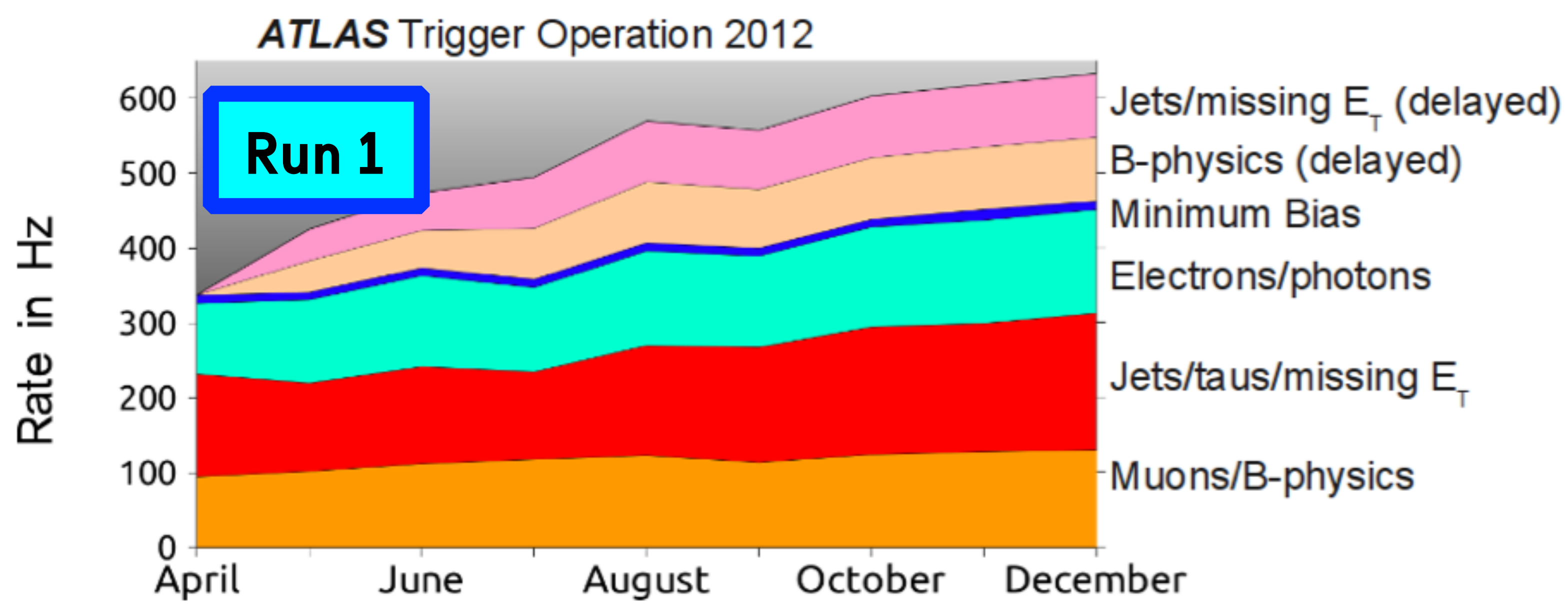


Data parking / delayed stream

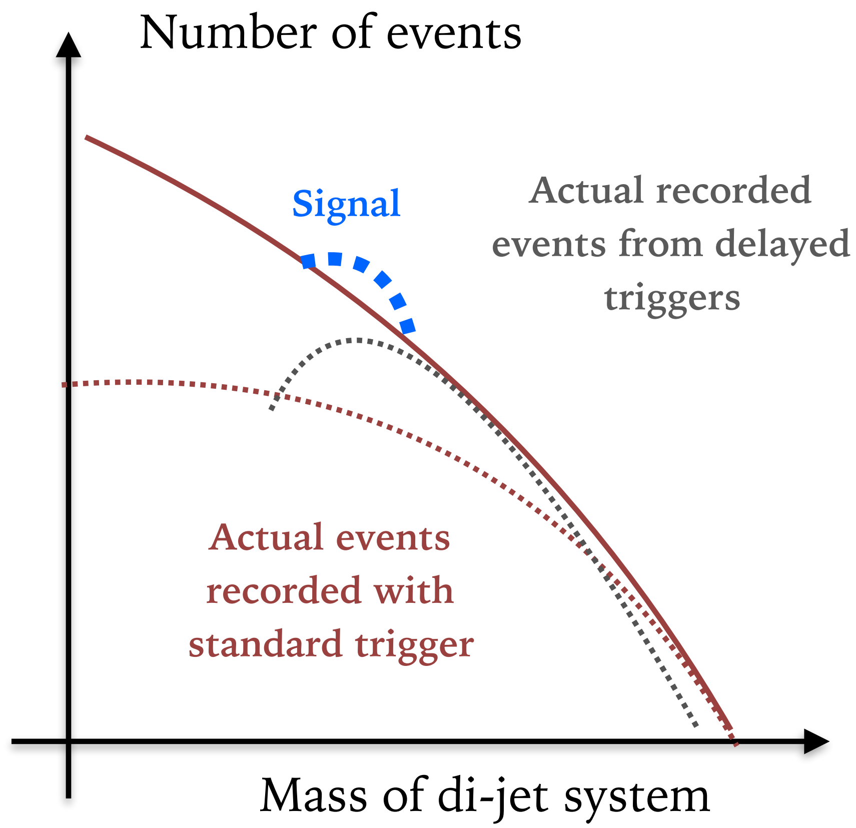
Bandwidth = Event rate **x** Event size

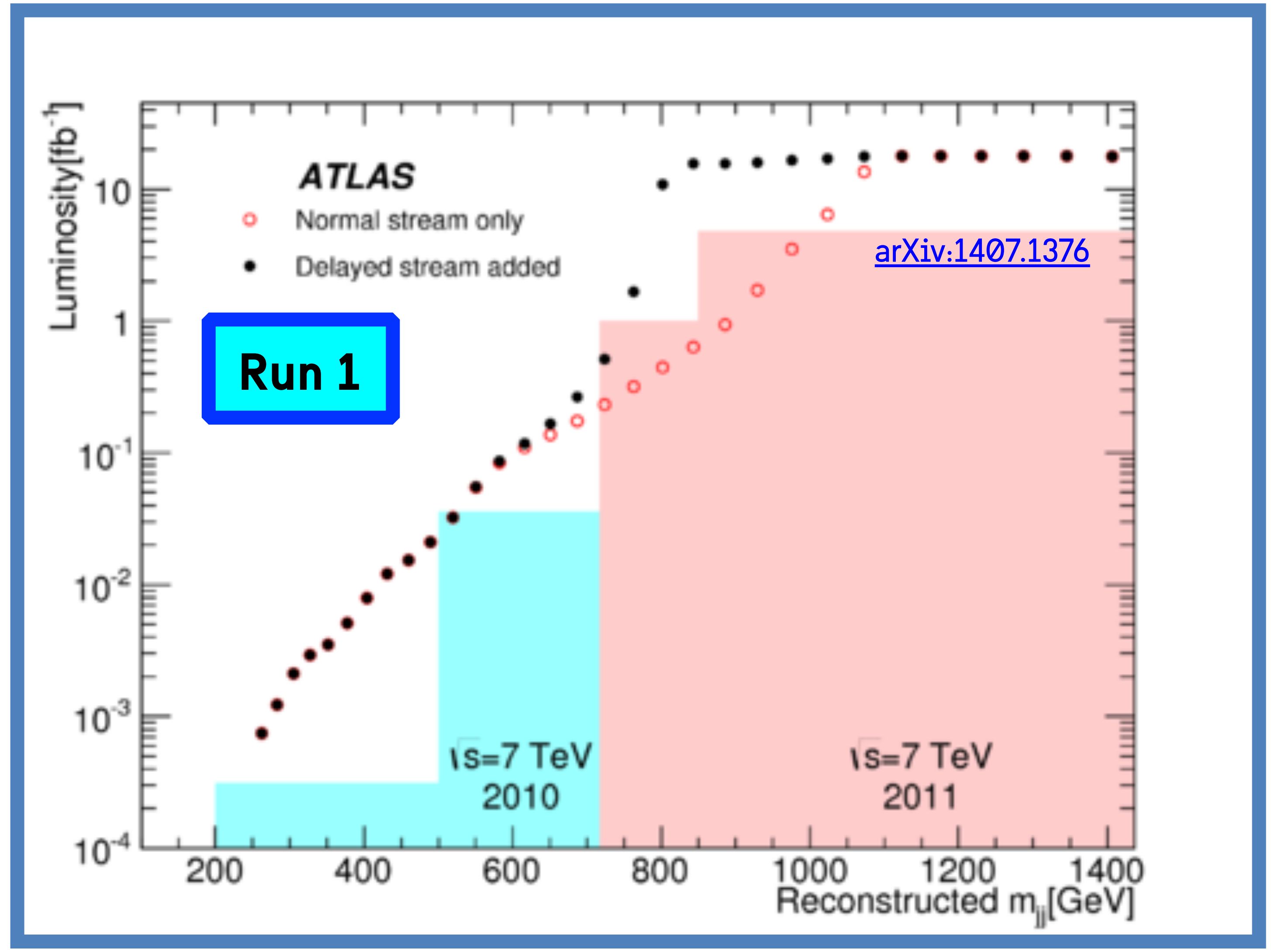
Extra bandwidth = Event rate **x** Event size
processed later

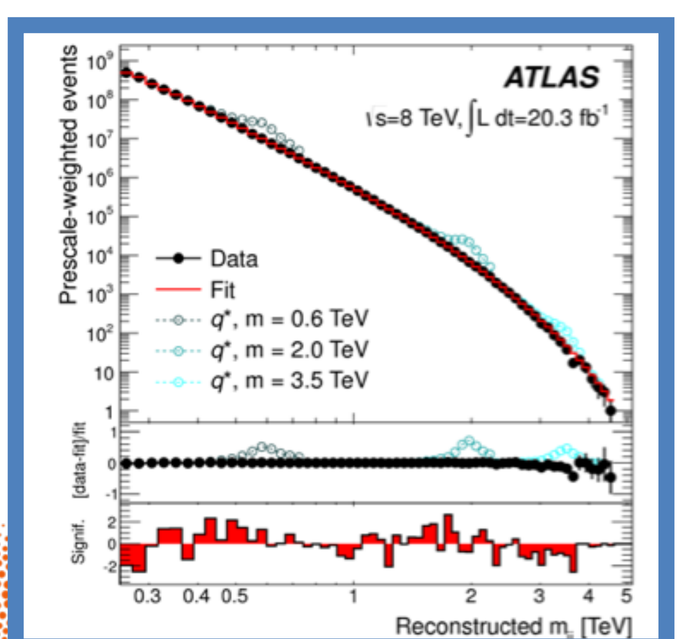
If computing resources for reconstruction limited:
park the raw data and wait (delay) until everything else is processed



ATLAS delayed stream results







Other analyses using delayed stream in ATLAS/CMS:

SUSY search for RPV stops

Dijet angular analysis…

Higgs → bbar

Fully hadronic top

DM searches…