Search for New Phenomena in Dijet Events with the ATLAS Detector at $\sqrt{s}$ = 13 TeV

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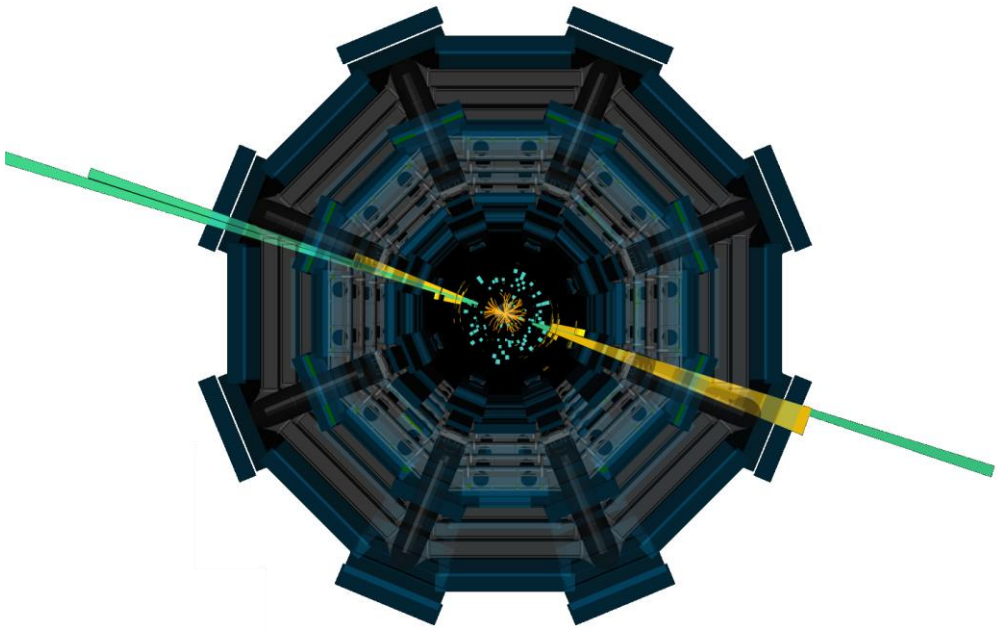
On behalf of the ATLAS Collaboration

KIRCHHOFF-INSTITUT FÜR PHYSIK

DIS2017, Birmingham, 3rd - 7th April 2017



FSP 103 ATLAS

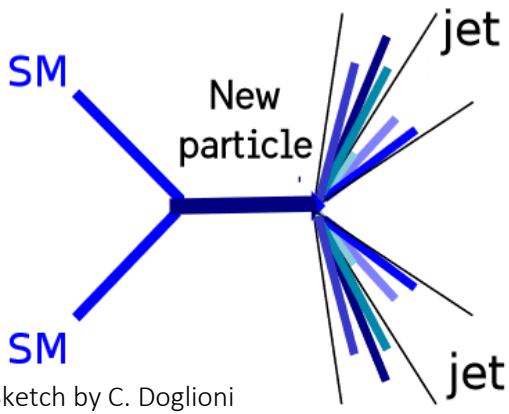
HGSFP

research training group DFG

Searches with dijets at hadron colliders

New particles produced at the LHC must interact with partons of proton

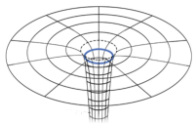
- They can also produce partons (jets) in final state!



Sketch by C. Doglioni

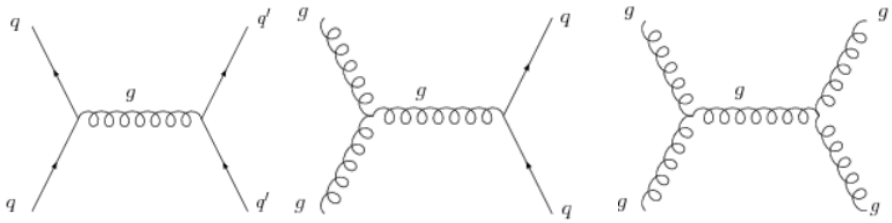
Large variety of models explored:

- Excited Quarks
- Quantum Black Holes
- Contact Interactions
- W‘, W*, Z‘
- Simplified models for DM (mediator) searches



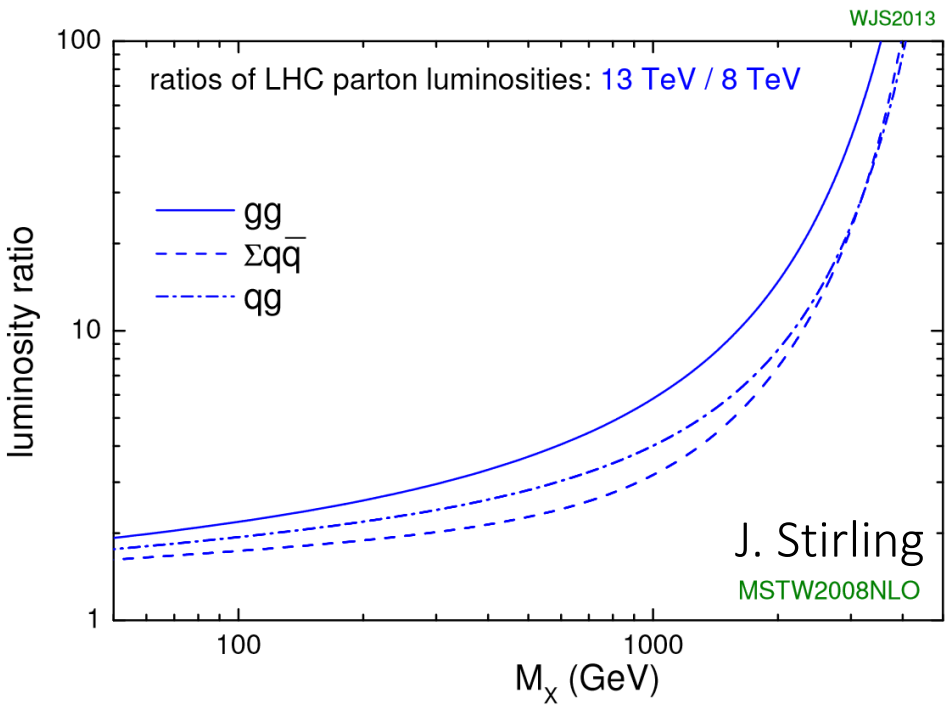
Largest Standard Model background (QCD)

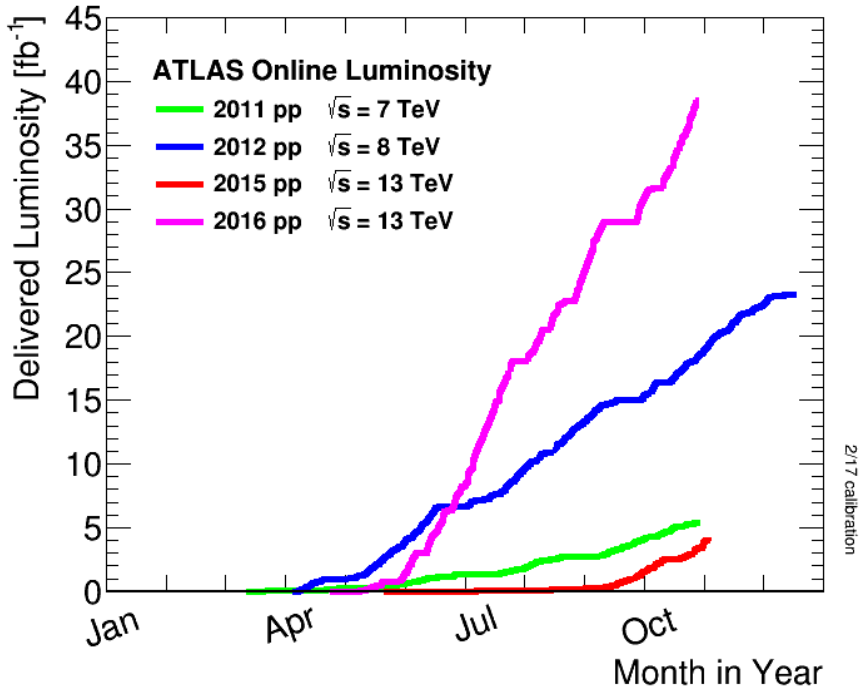
- Data-driven background estimation techniques are employed



Luminosities in LHC run 2

Proton-Proton collisions at 13TeV since summer 2015





- Large increase in parton luminosities (especially at high energy scales)
- Run II 13 TeV dataset larger than 8 TeV Run I dataset

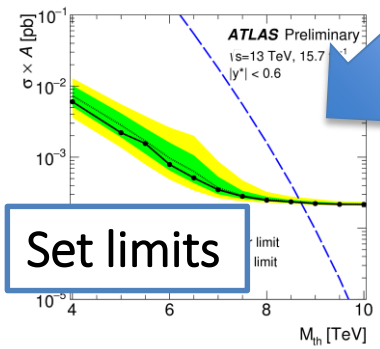
Dijet Search Strategy

Selection
(i.e. optimizing signal over background)

Interesting Observables
(dijet invariant mass, angular distributions, …)

Search phase: Compare data and background estimation
(i.e. „Bump Hunting“)
See deviations?

No



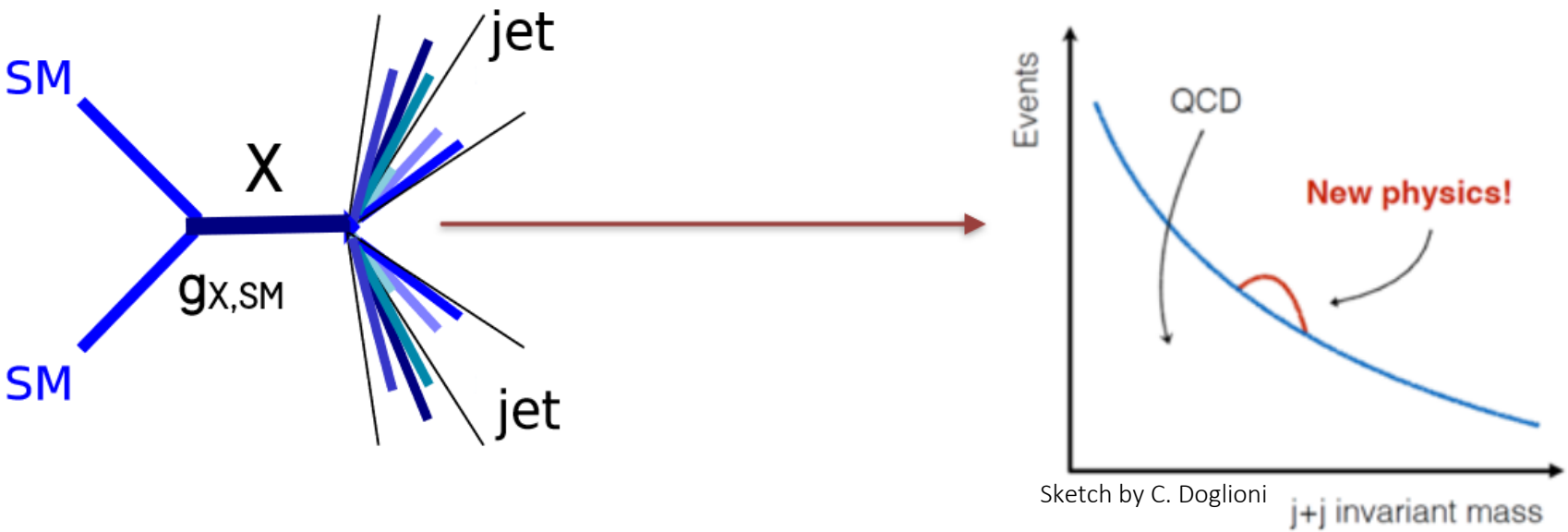
Set limits

Yes

High Mass Search for Resonant Phenomena

QCD predicts smoothly falling dijet invariant mass background

- Look for new particles decaying to quarks/gluons (jets) appearing as „bump“ over QCD background



Sketch by C. Doglioni

$pT_1 > 440$ GeV, $pT_2 > 60$ GeV
$M_{jj} > 1.1$ TeV
$y^* = 0.5\,|y_1 - y_2| < 0.6$
($y^* < 1.2$)

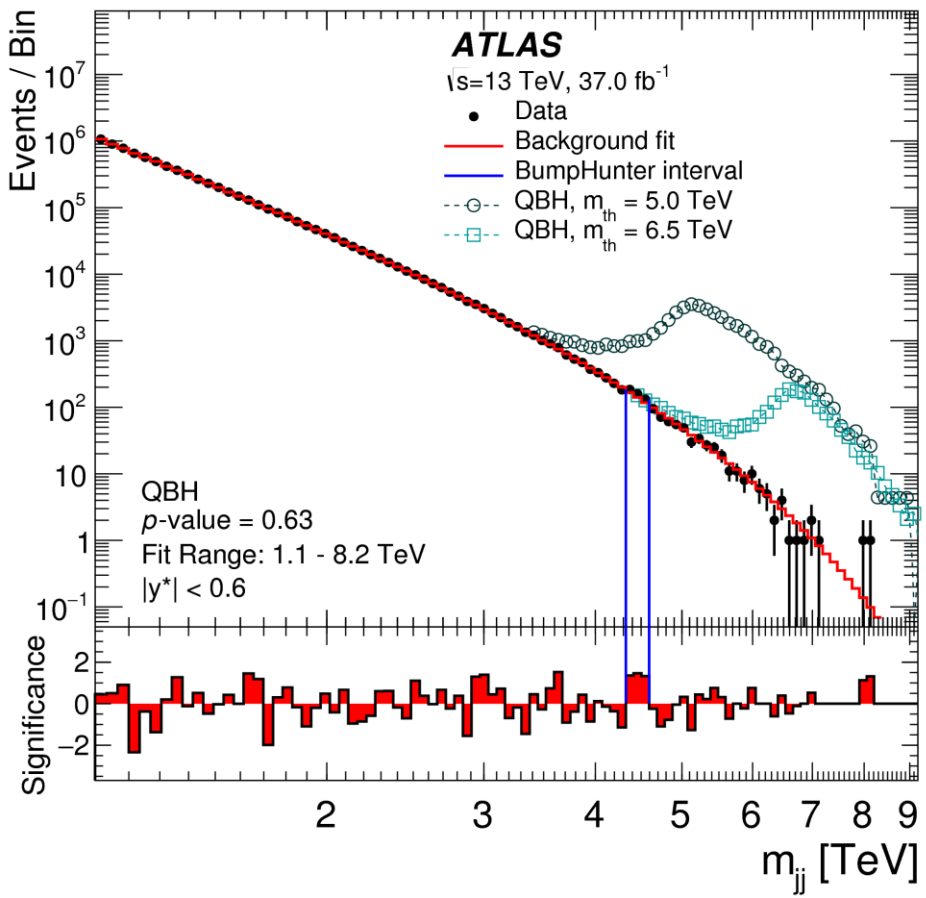
CERN-EP-2017-042

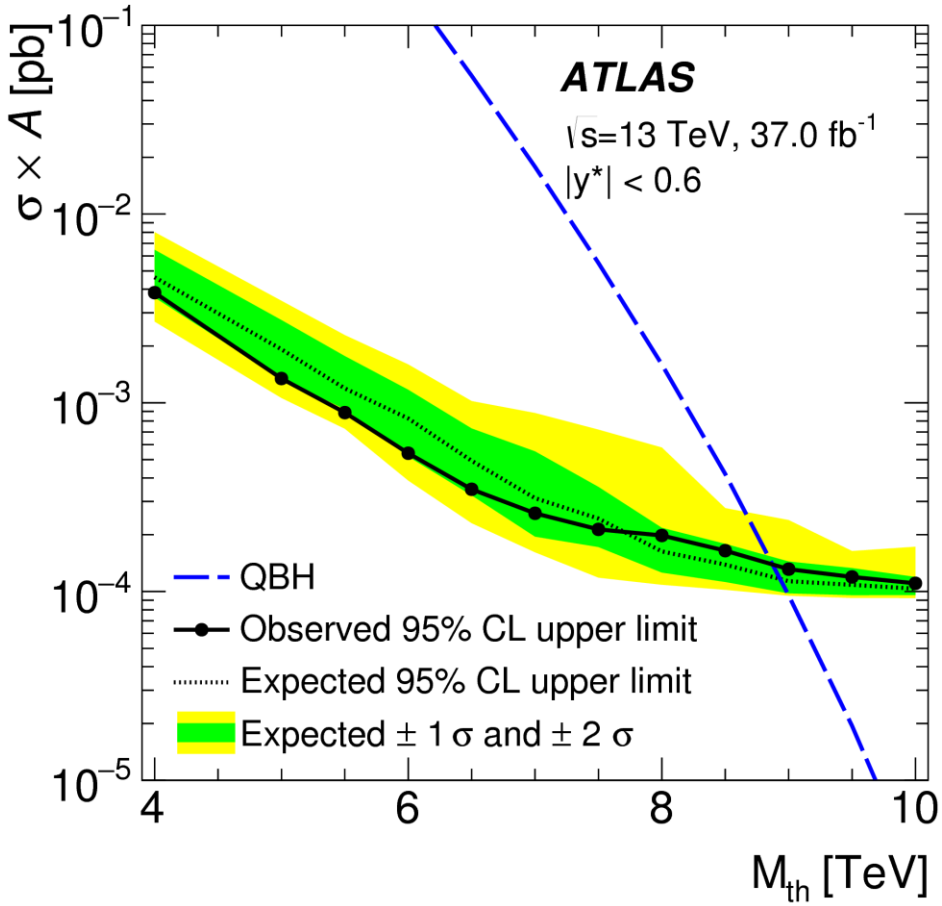
High Mass Search for Resonant Phenomena

Compare data to background estimation from sliding window fit: $f(z) = p_1(1-z)^{p_2} z^{p_3}$

Run BumpHunter algorithm to find most significant excess

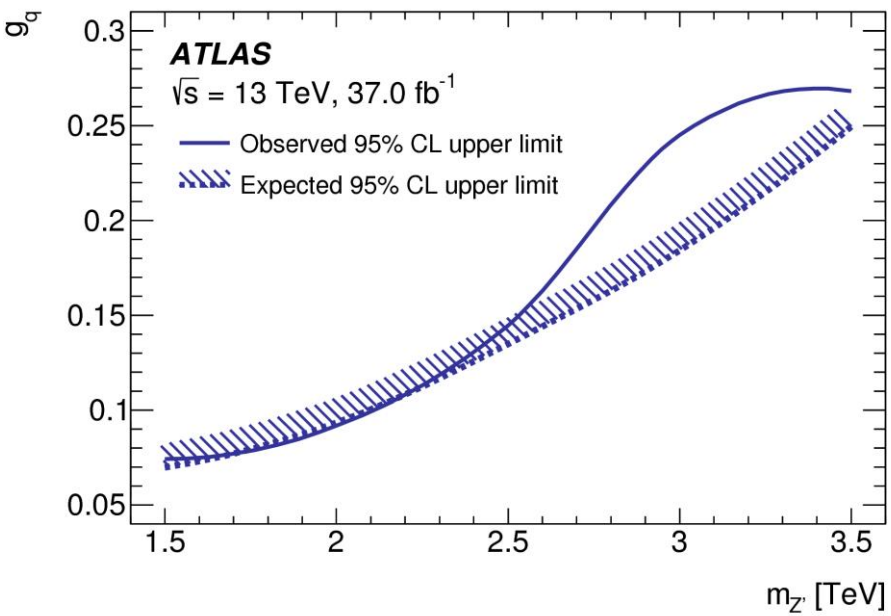
$|y*| < 0.6$ search and limits for Quantum Black Holes





High Mass Search for Resonant Phenomena

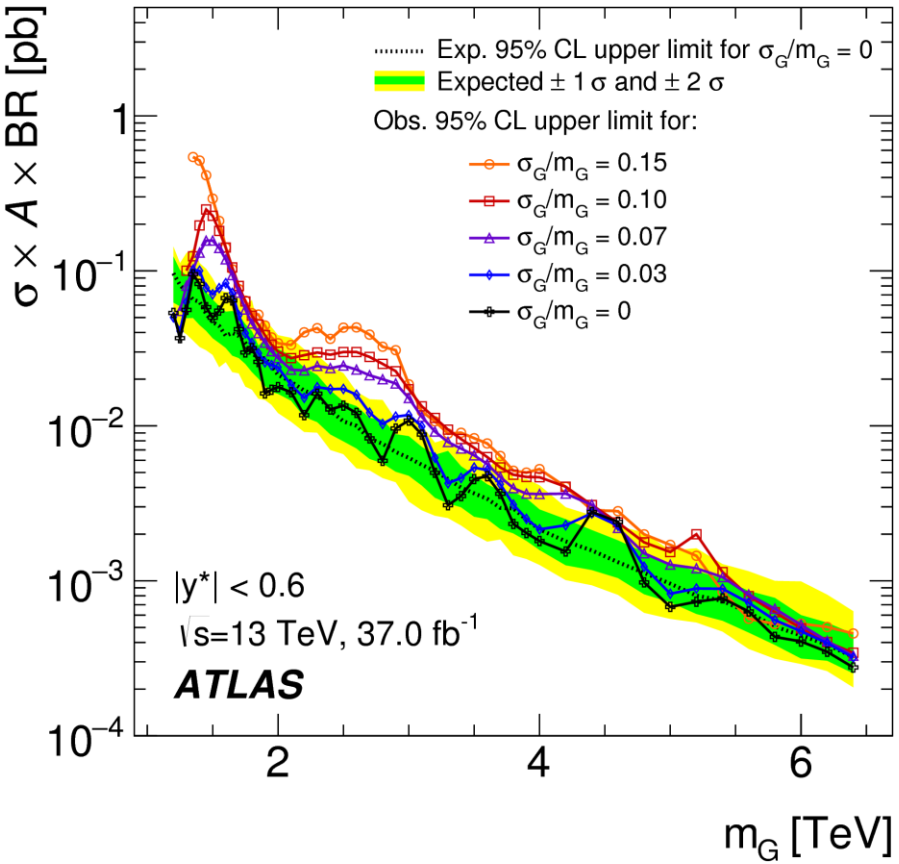
Limits on axial-vector Z' couplings (interesting for DM interpretations):



Model	95% CL exclusion limit	
	Observed	Expected
Quantum black hole, ADD	8.9 TeV	8.9 TeV
Excited quark	6.0 TeV	5.8 TeV
W'	3.7 TeV	3.7 TeV
W^*	3.4 TeV 3.8–3.9 TeV	3.6 TeV
Contact interaction (η_{LL} =-1)	21.8 TeV	28.3 TeV
Contact interaction (η_{LL} =+1)	13.1 TeV 17.4 TeV- 29.5 TeV	15.0 TeV

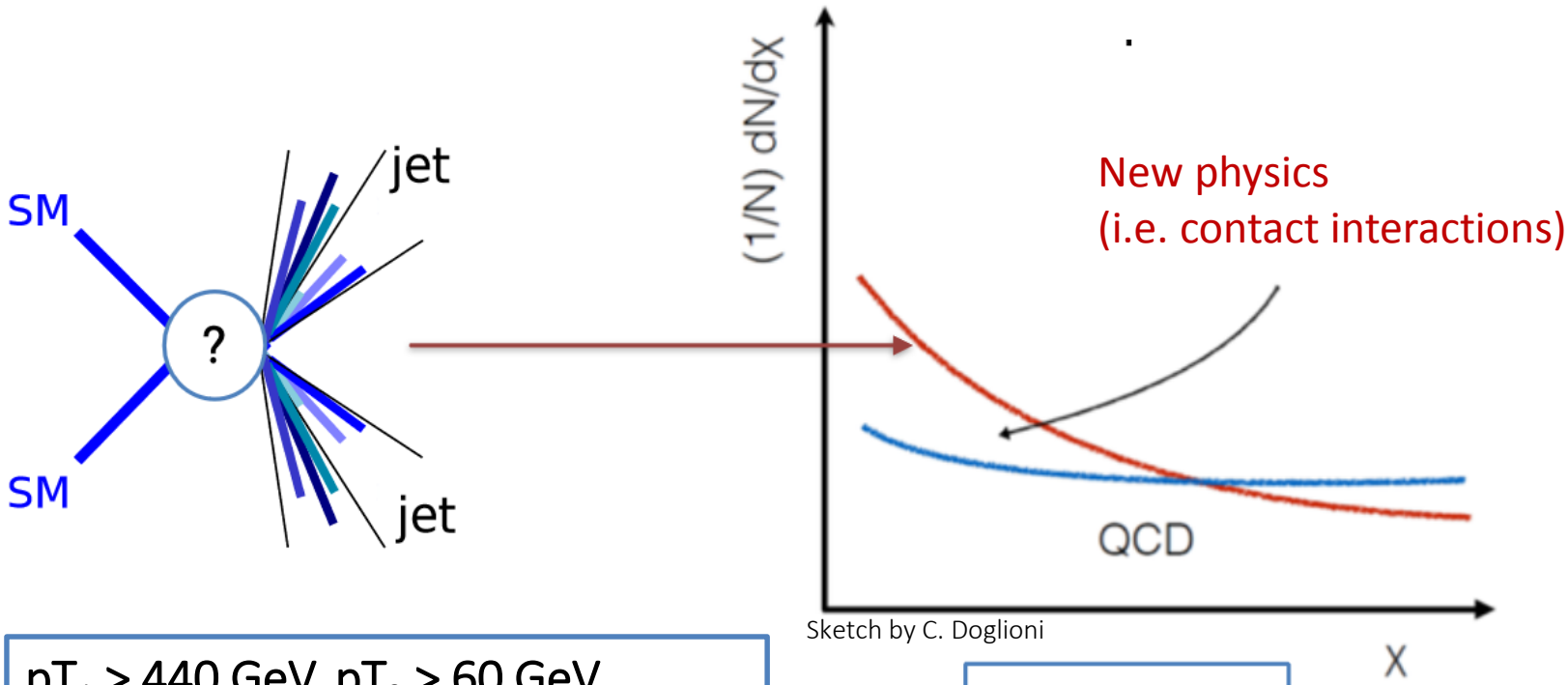
Limits on generic gaussian resonances:

- Use unfolding technique to set limits on truth-level widths



High Mass Search for Non-Resonant Phenomena

In QCD: Due to t-channel poles in dominant scattering cross-sections, most dijet production occurs at small angles wrt beam



Sketch by C. Doglioni

$\chi = \exp(y_1 - y_2)$

$pT_1 > 440$ GeV, $pT_2 > 60$ GeV
$M_{jj} > 2.5$ TeV
$y^* = 0.5\,|y_1 - y_2| < 1.7$
$y_B = 0.5\,|y_1 + y_2| < 1.1$

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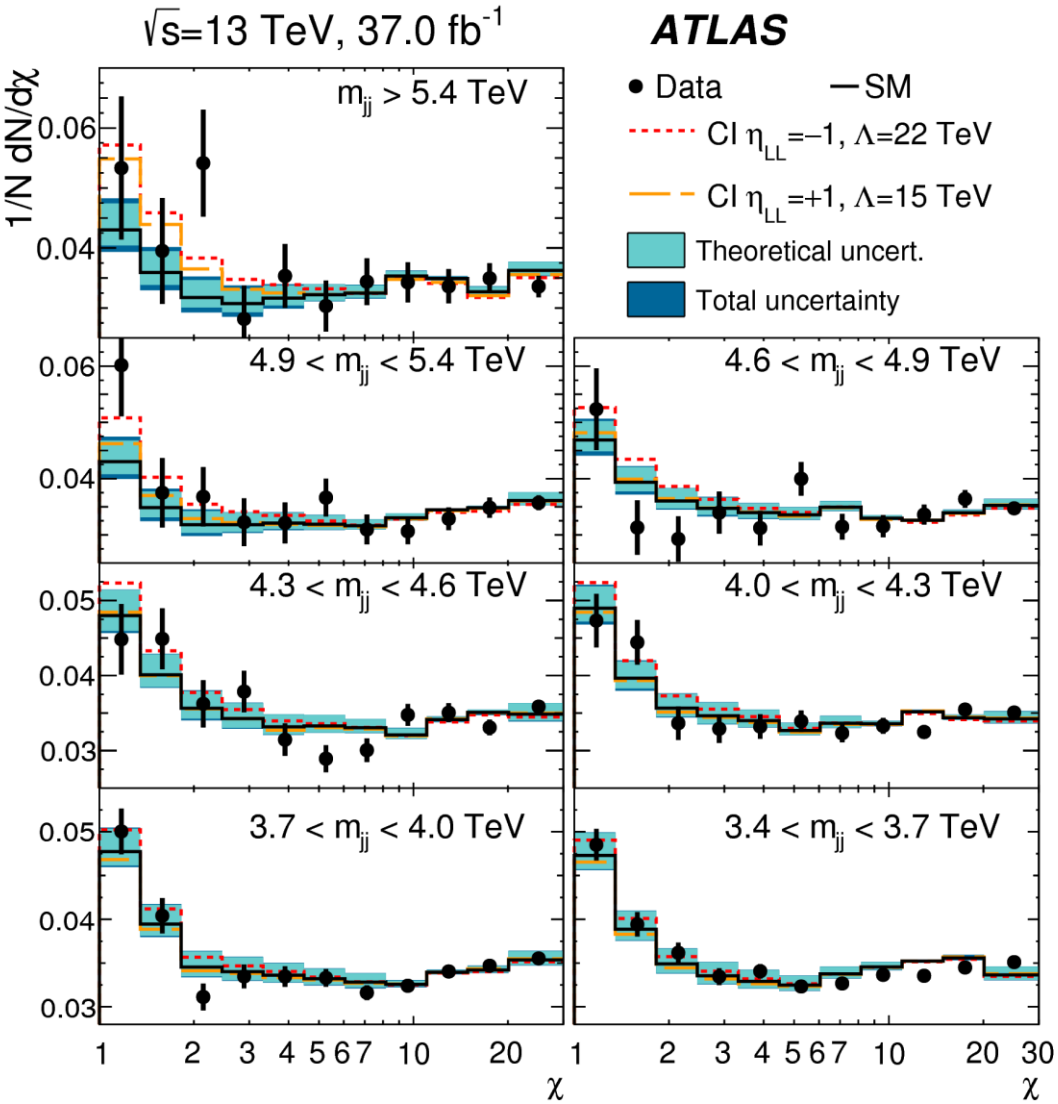
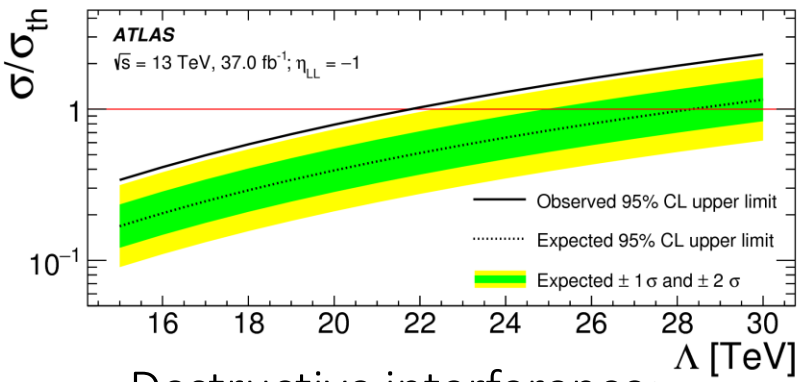
High Mass Search for Non-Resonant Phenomena

Compare data to MC Bkg estimate from *LO Pythia* + *NLO QCD* and *LO EW* corrections:

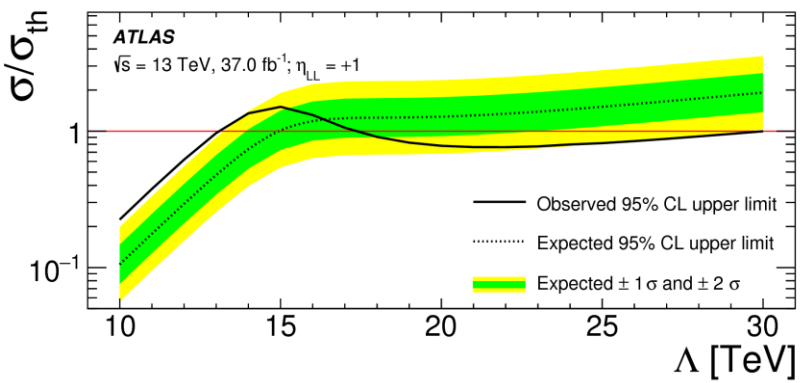


Use CL_S method with combined fit on 7 m_{jj} regions to set limits on contact interactions

Constructive interference:



Destructive interference:

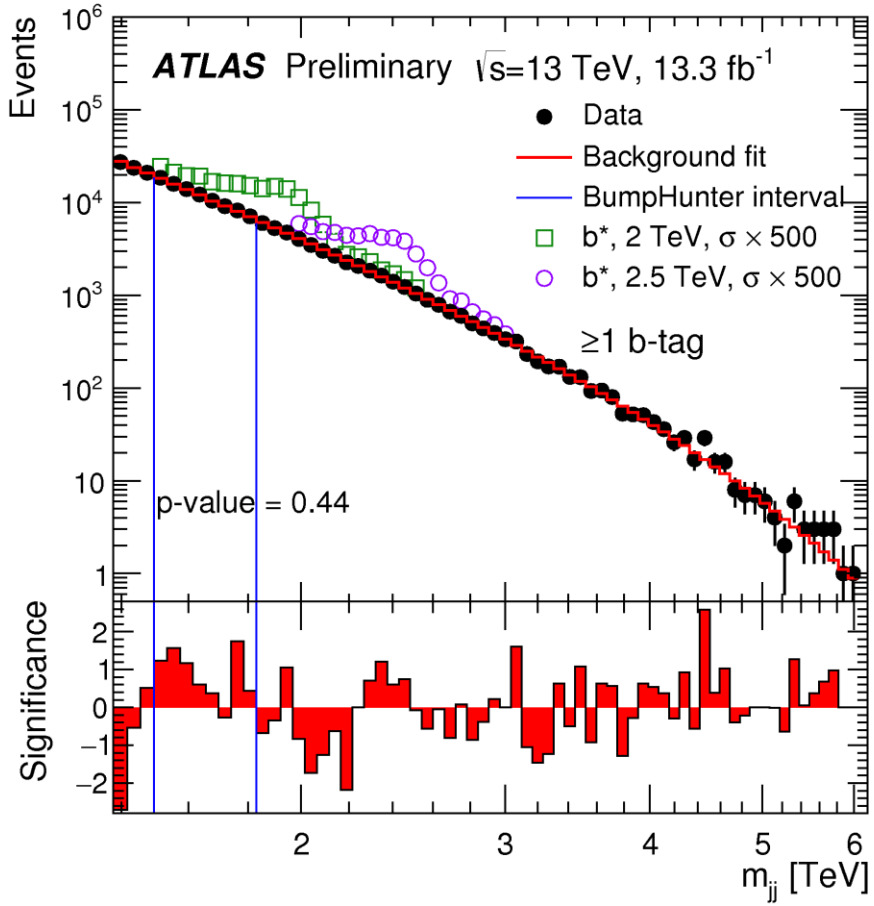


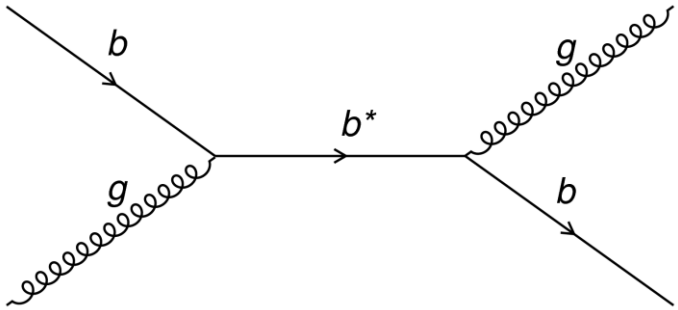
b-Tagged Search for Resonant Phenomena

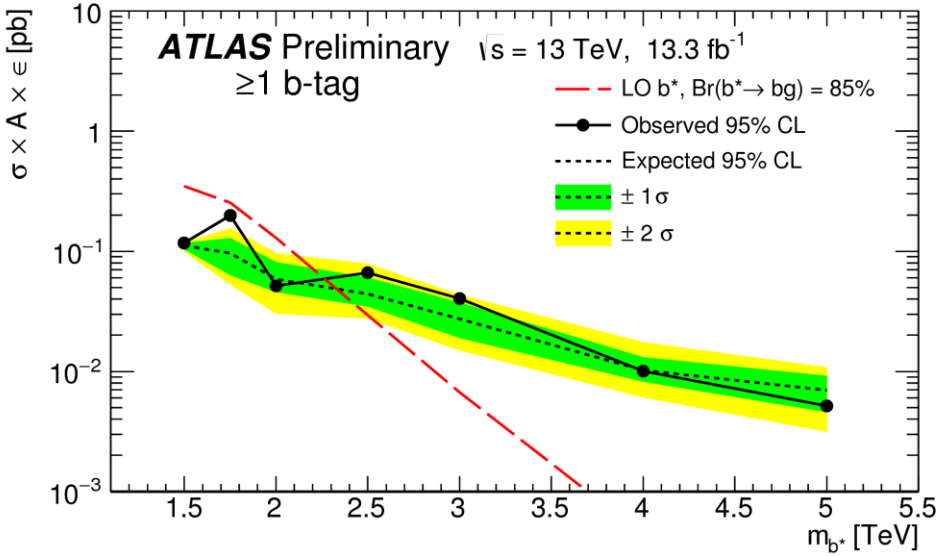
If new particle couples to *b*-quark, sensitivity can be improved by requiring one or both outgoing jets to be identified as *b*-jets

Benchmark model: Excited *b* quark *b**

Compare to fit: $f(z) = p_1(1-z)^{p_2} z^{p_3}$







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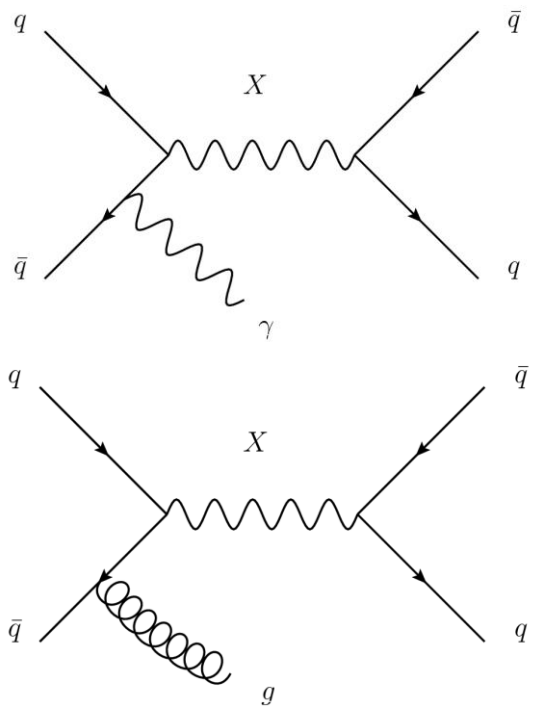
Low Mass Search for Resonant Phenomena + ISR

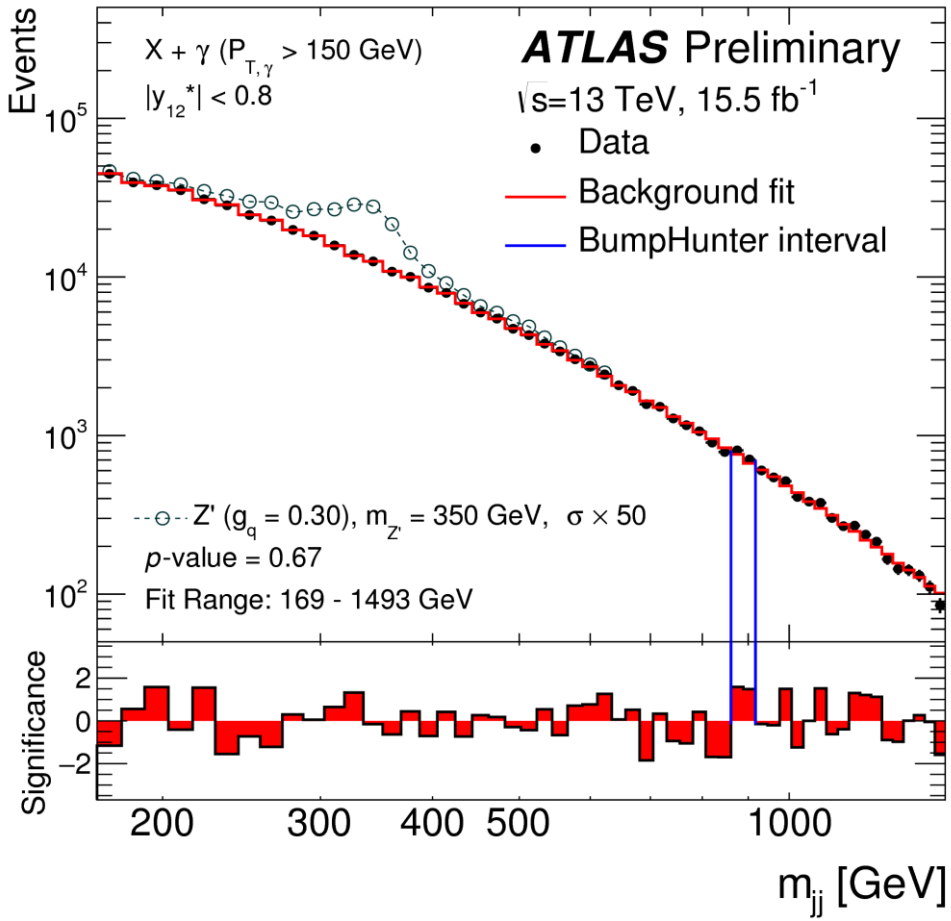
Data archiving rate limited in ATLAS:

- Sensitivity to light dijet resonances statistically limited due to jet trigger prescales

Trigger limitations can be avoided by requiring initial state radiation hard photon/jet



Compare to fit: $f(z) = c_1(1-z)^{c_2} z^{c_3 + c_4 \ln z}$



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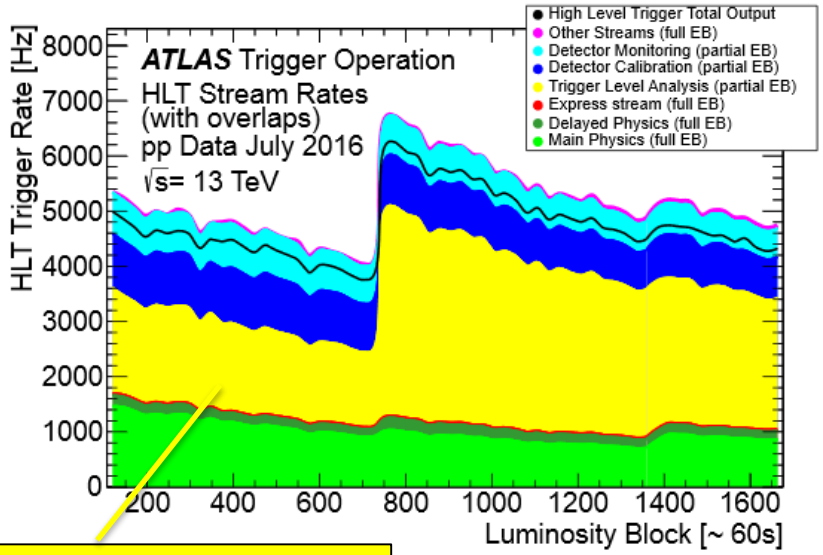
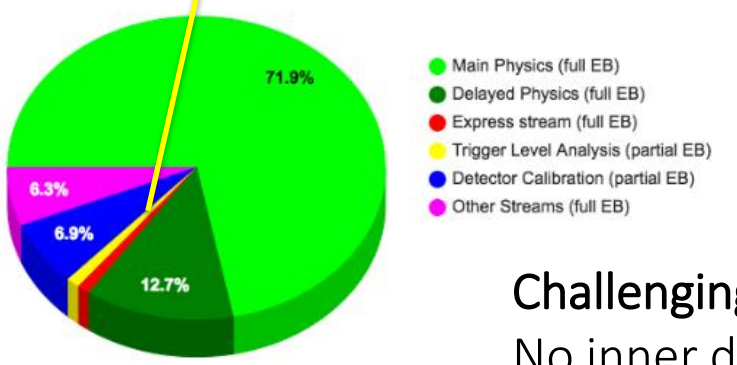
Low Mass Search for Resonant Phenomena at Trigger Level

Trigger-Level-Analysis: Search for low-mass, low-cross-section, dijet resonances using trigger-level jets only in partially recorded events



TLA rate vs bandwidth



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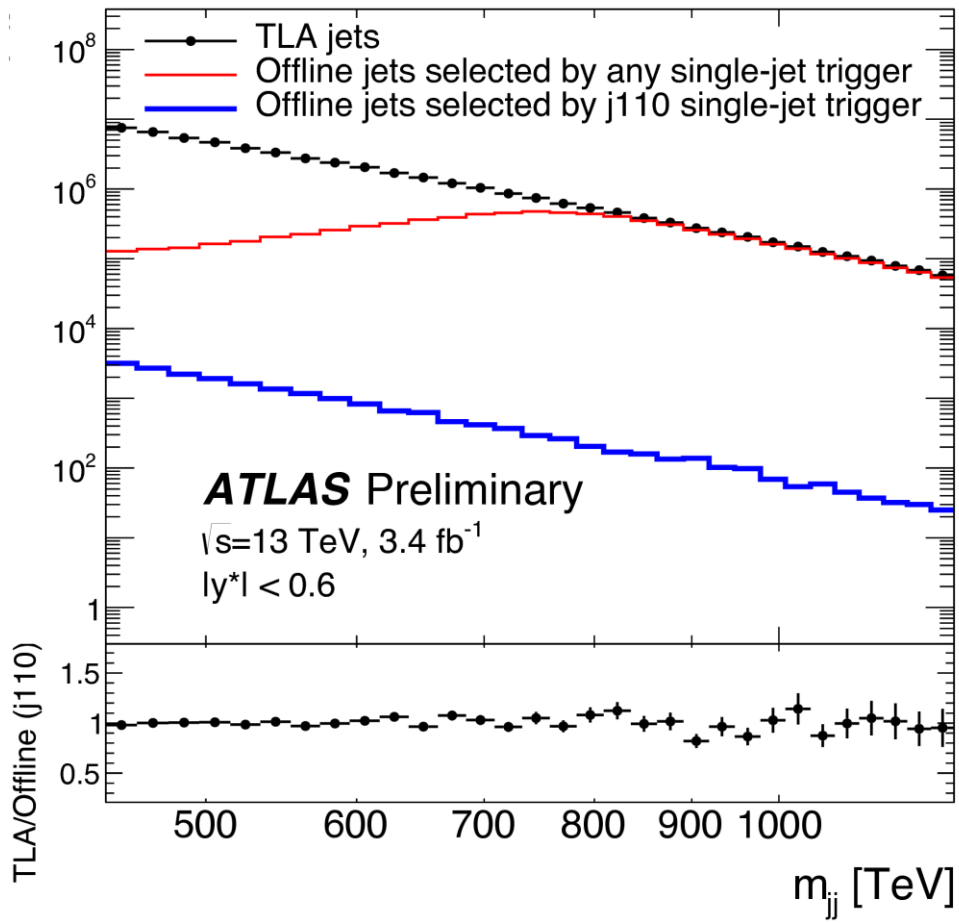
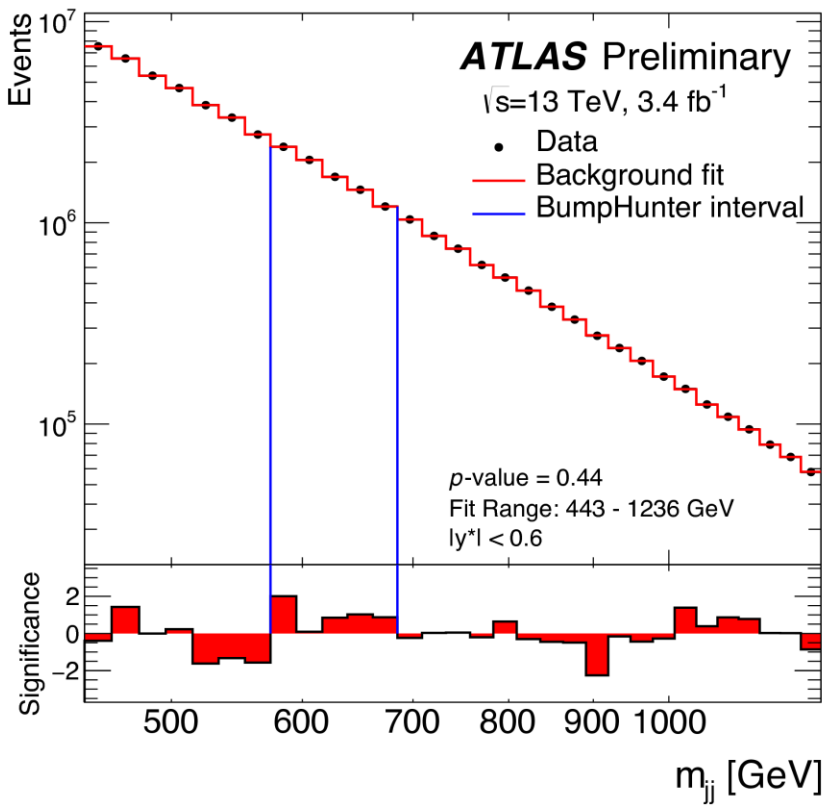


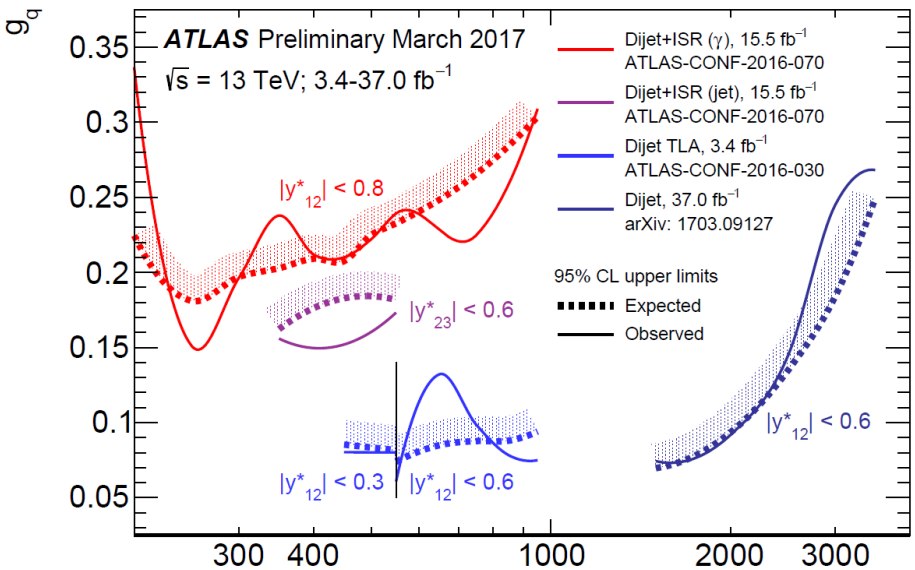
Challenging Jet Reconstruction and Calibration:
No inner detector information at Trigger-Level!

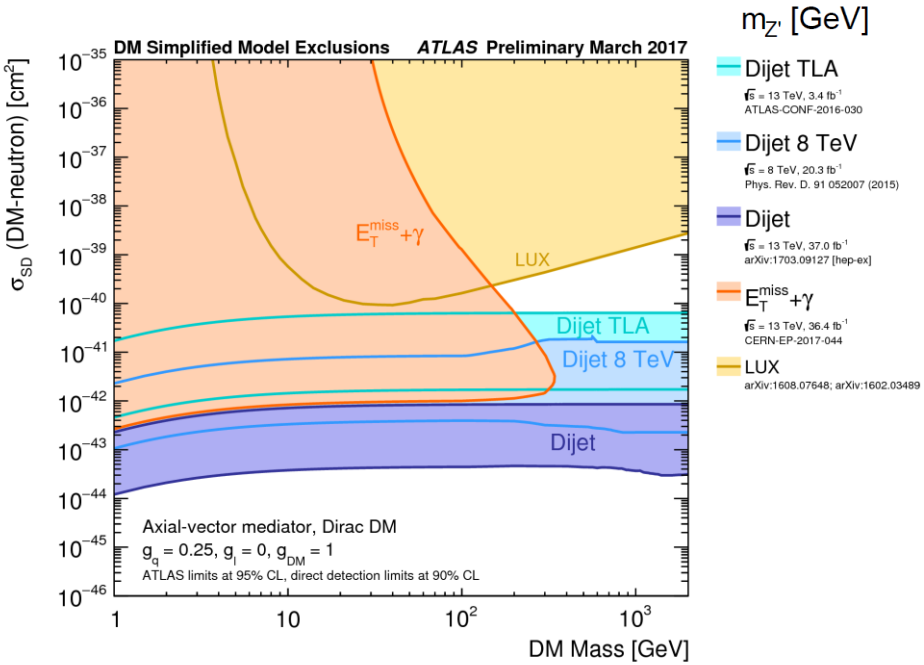
Low Mass Search for Resonant Phenomena at Trigger Level

Results of High-Mass Dijet, Dijet+ISR and Trigger-Level-Analysis on axial-vector Z' couplings:

Compare to fit: $f(z) = \frac{p_1}{z^{p_2}} e^{-p_3 z - p_4 z^2}$







Summary

Presented most of ATLAS‘ dijet searches:

- High-Mass Dijet Analysis
  - Resonance Search
  - Angular Search
- B-Tagged Dijet Analysis
- Low Mass Dijet+ISR Analysis
- Low Mass Dijet Trigger-Level-Analysis

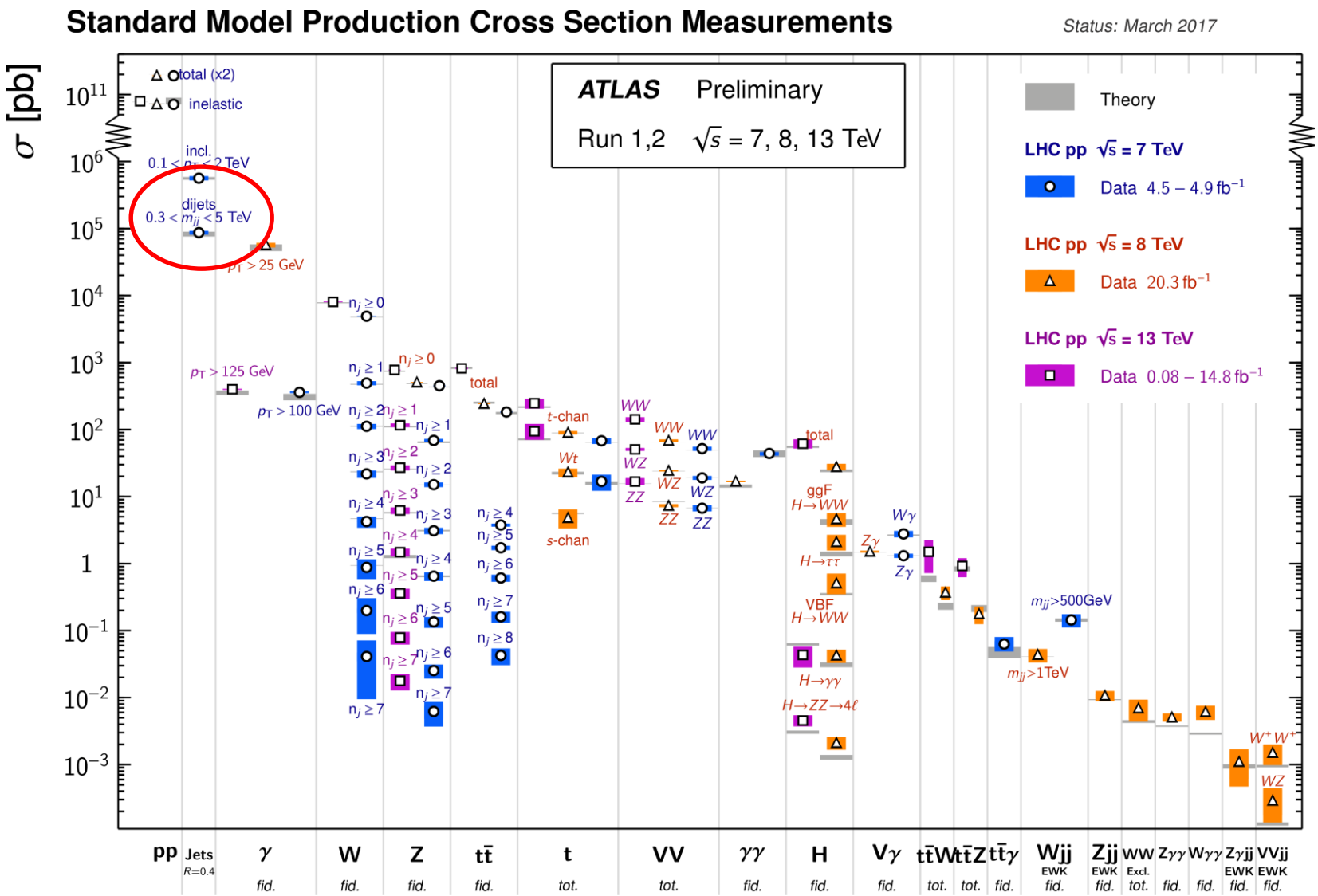
No significant excesses have been found. Limits have been set on:

- Quantum Black Holes
- Excited Quarks Q* (B*)
- Contact Interactions
- Z‘, W‘, W*
- Generic Gaussian Resonances

Thanks for your attention!

Backup

Large Statistics of Di-Jet Events

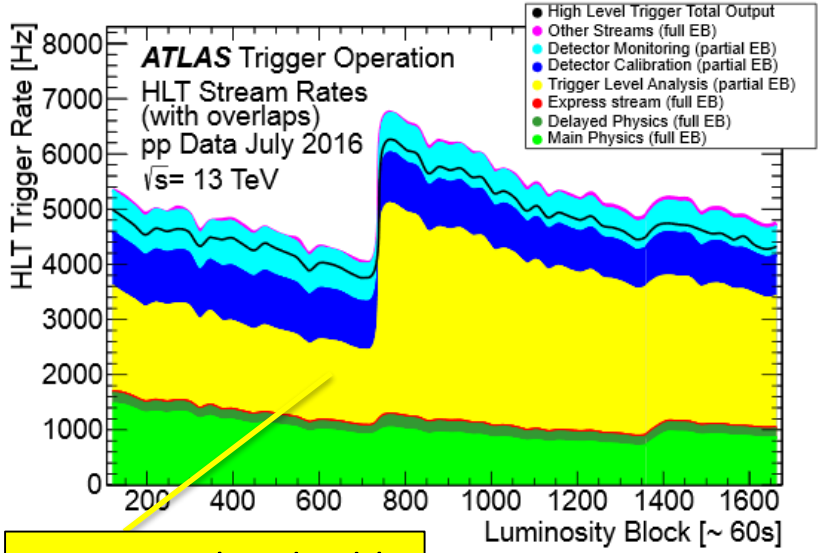


QCD Di-Jet production represents dominant SM background

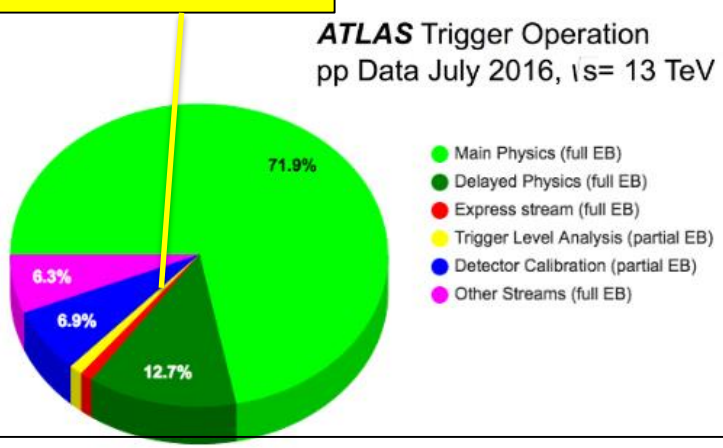
- Data-driven background estimation from early on

TLA in a nutshell

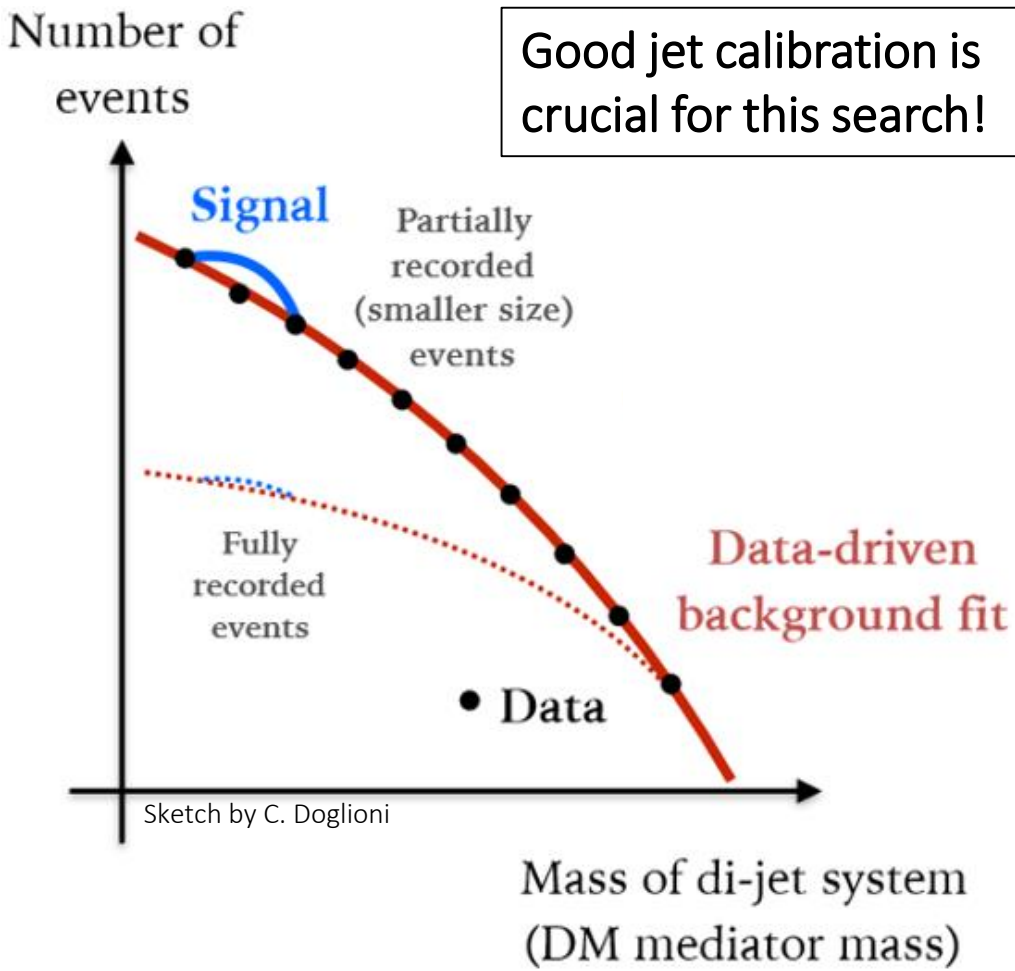
Search for low-mass, low-cross-section, dijet resonances using trigger jets within partially recorded events



TLA rate vs bandwidth



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TriggerOperationPublicResults



Sketch by C. Doglioni

Good jet calibration is crucial for this search!

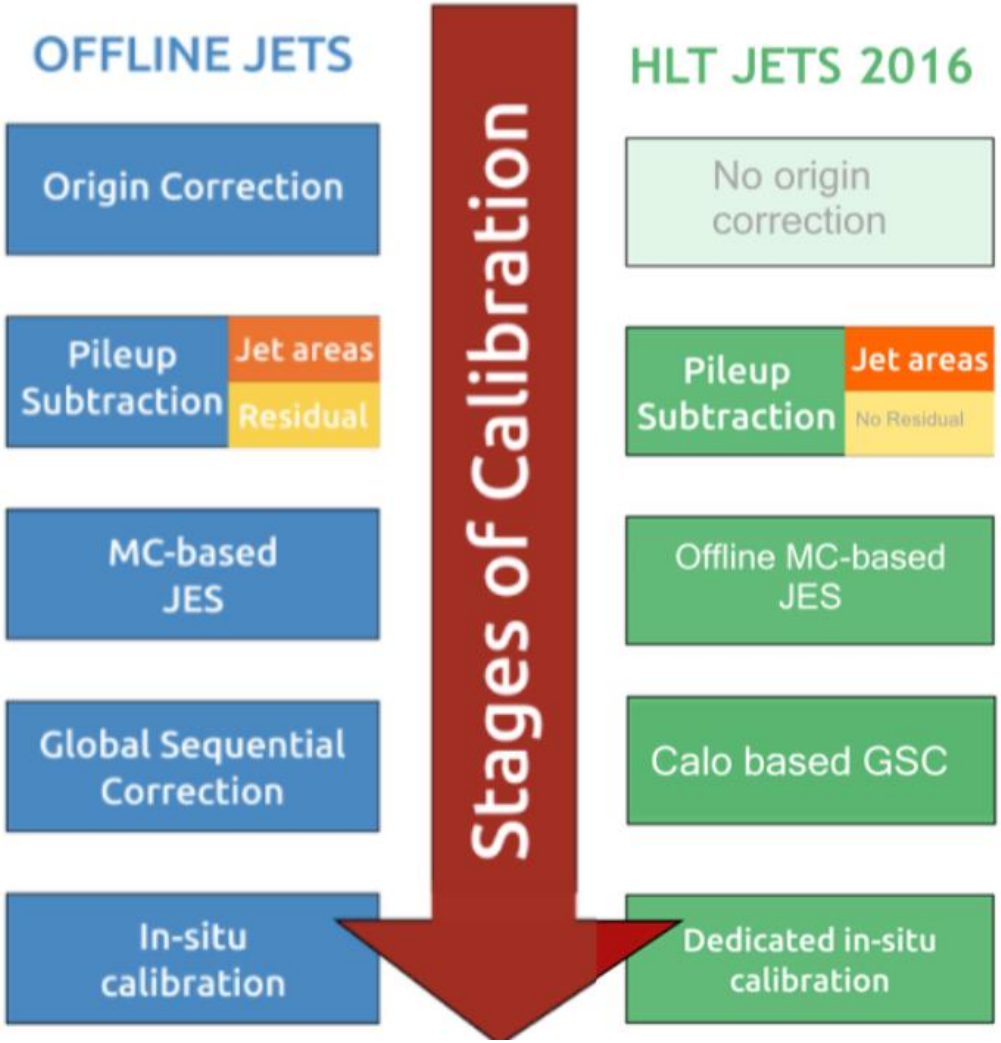
TLA Jet Calibration

TLA uses trigger jets only:

- No inner detector information available
- No muon information available

➢ Parts of offline jet calibration scheme must be modified to be applicable to trigger jets!

Example:
Dedicated **global sequential calibration (GSC)** using calorimeter information only

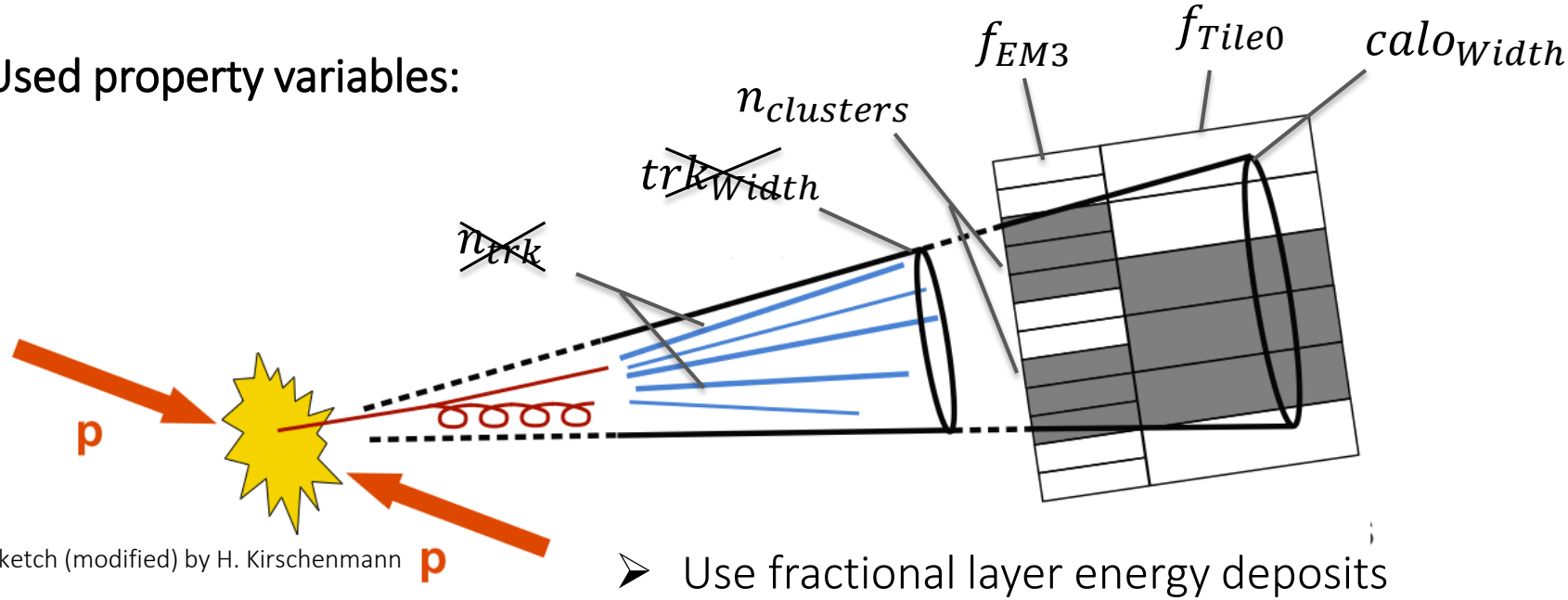


TLA Global Sequential Calibration

Global Sequential Calibration:

- Apply jet response (p_T^{HLT} /p_T^{Truth}) correction derived on truth MC
- **Global**: Correction parametrized as function of p_T, η and one jet property x
- **Sequential:** After one correction is applied. Repeat with a different jet property

Used property variables:



Sketch (modified) by H. Kirschenmann

- Use fractional layer energy deposits f_{EM3}, f_{Tile0} as in offline
- No inner detector readout:
  - Use $n_{clusters}$ instead of n_{trk}
  - Use $calo_{Width}$ instead of trk_{Width} (2017)