The Same Procedure as Last Year?
The Trigger-Level Analysis and Bumps

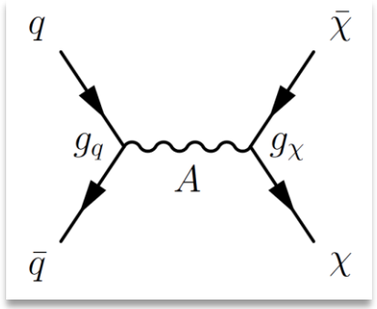
Falk Bartels

ATLAS @ Trifels

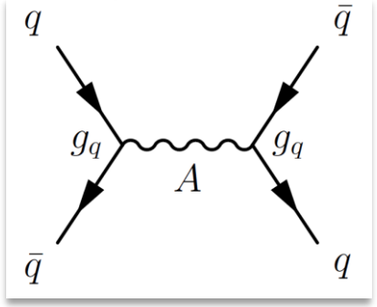
18.07.2024

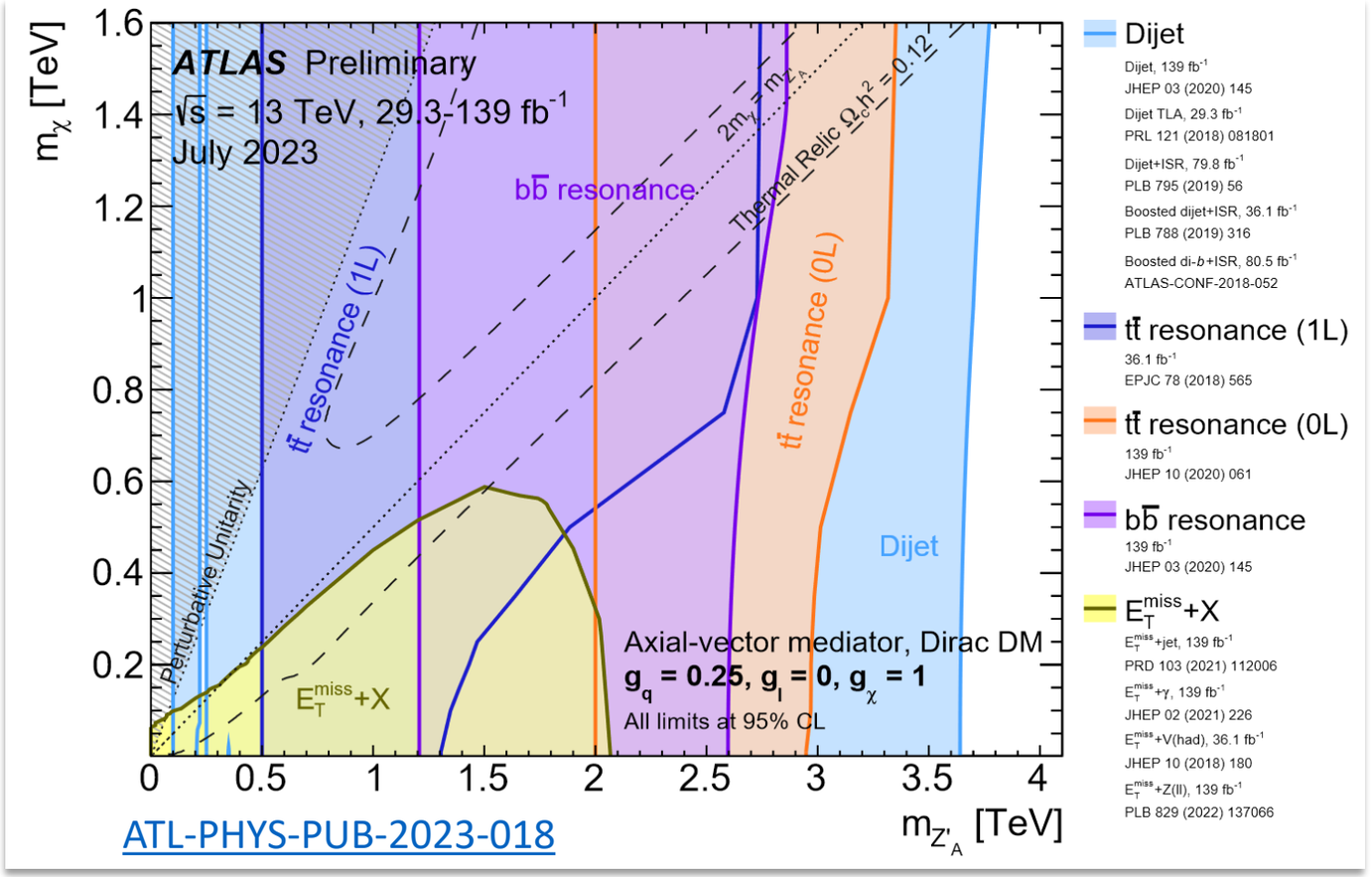
Dijet Resonances

Everyone interested in this:

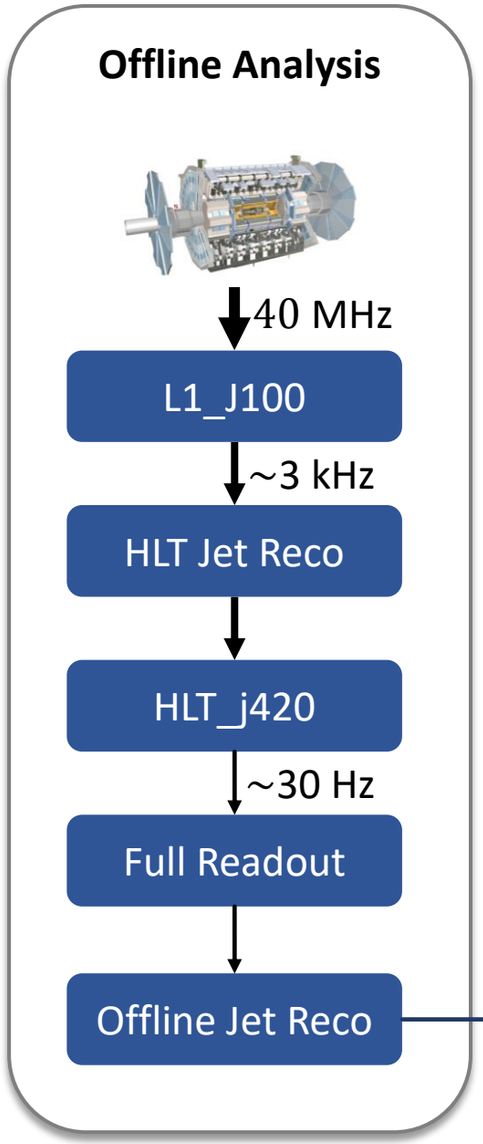


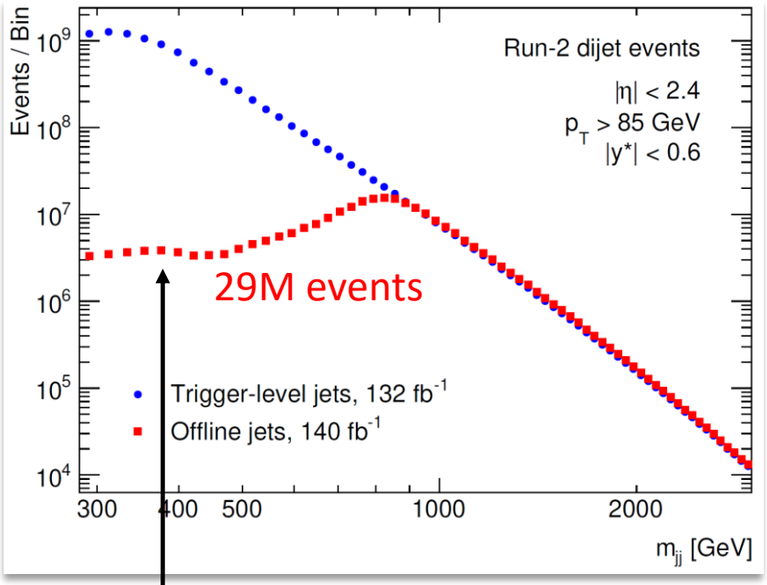
Should also show up like this:





Why TLA?


Offline Analysis
40 MHz
L1_J100
~3 kHz
HLT Jet Reco
HLT_j420
~30 Hz
Full Readout
Offline Jet Reco


Run-2 dijet events
|η| < 2.4
p_T > 85 GeV
|y*| < 0.6
29M events
Trigger-level jets, 132 fb^-1
Offline jets, 140 fb^-1
Events / Bin
m_jj [GeV]

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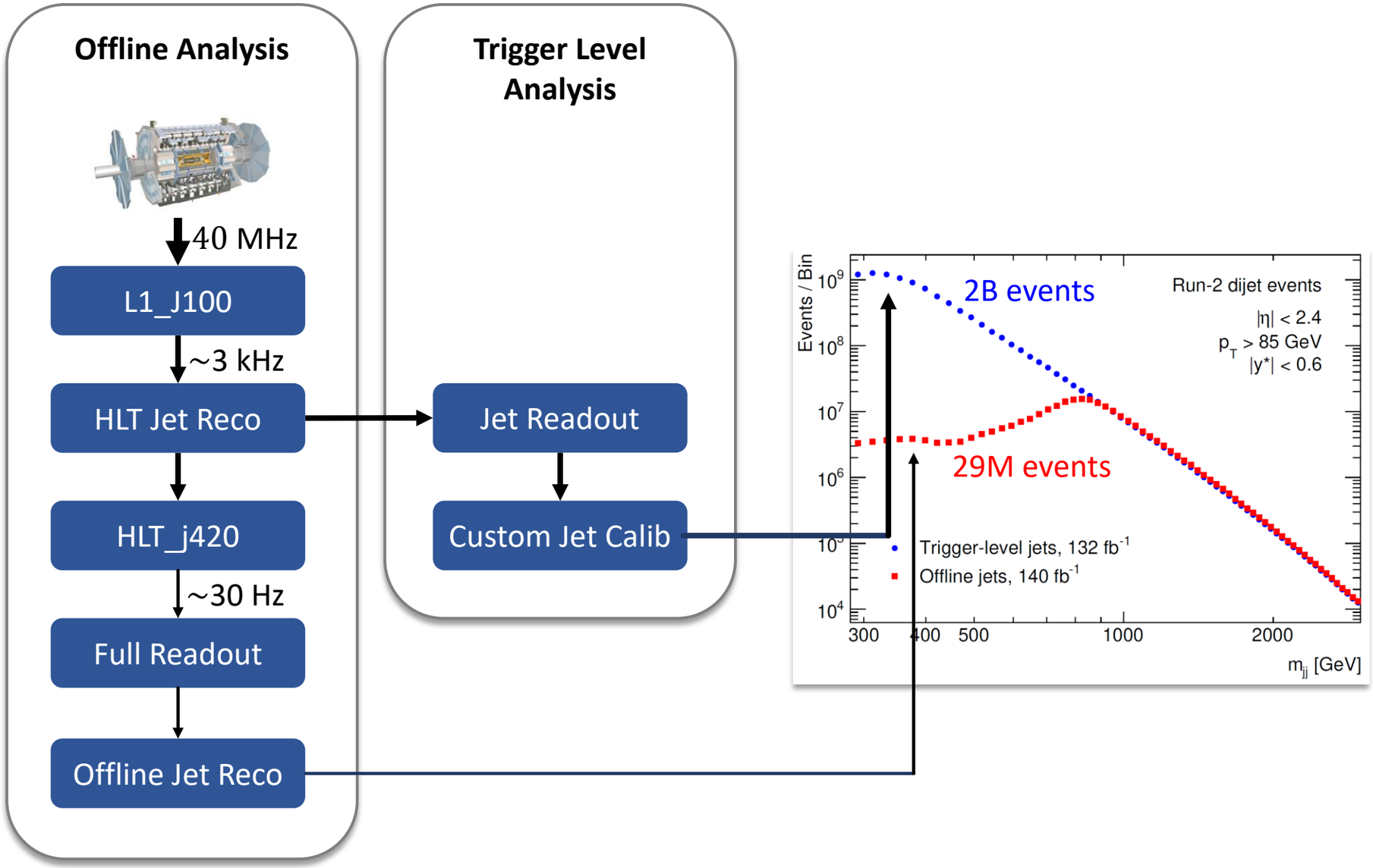
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40 MHz
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Custom Jet Calib
2B events
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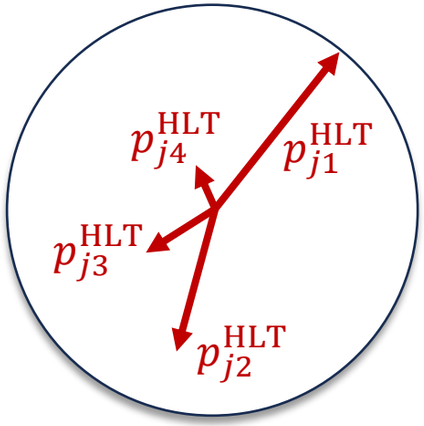
Trigger-level jets, 132 fb^-1
Offline jets, 140 fb^-1
Events / Bin
m_jj [GeV]

TLA in a Nutshell

High Level Trigger

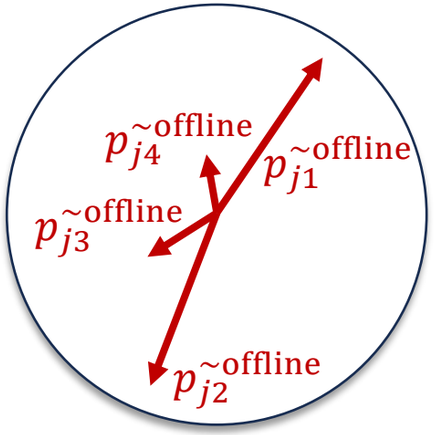
Jet Reco

HLT jet 4-momenta



Custom Calibration

jet 4-momenta @ offline scale



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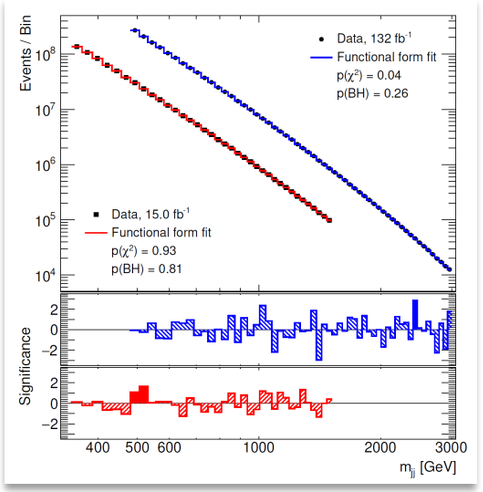
- $p_{\mathrm{T}} > 85$ GeV
- $|\eta| < 2.4$
- $|\Delta\eta| < 1.2$

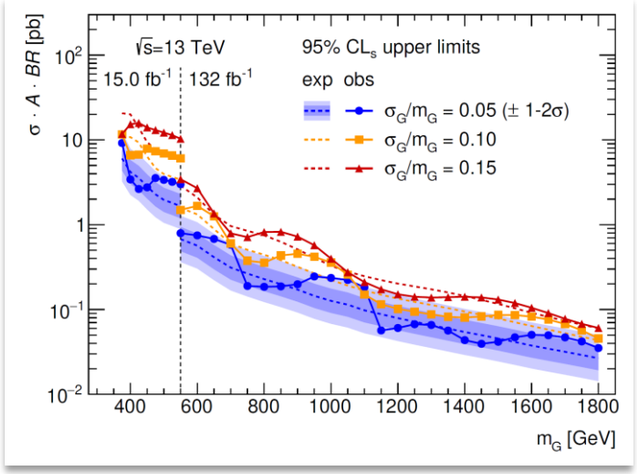
m_{jj} histogram



Fit with
Heuristic Function

$$f(x) = p_1(1-x)^{p_2}x^{p_3+p_4\log(x)+p_5\log^2(x)}$$

Limits or discovery



TLA in a Nutshell

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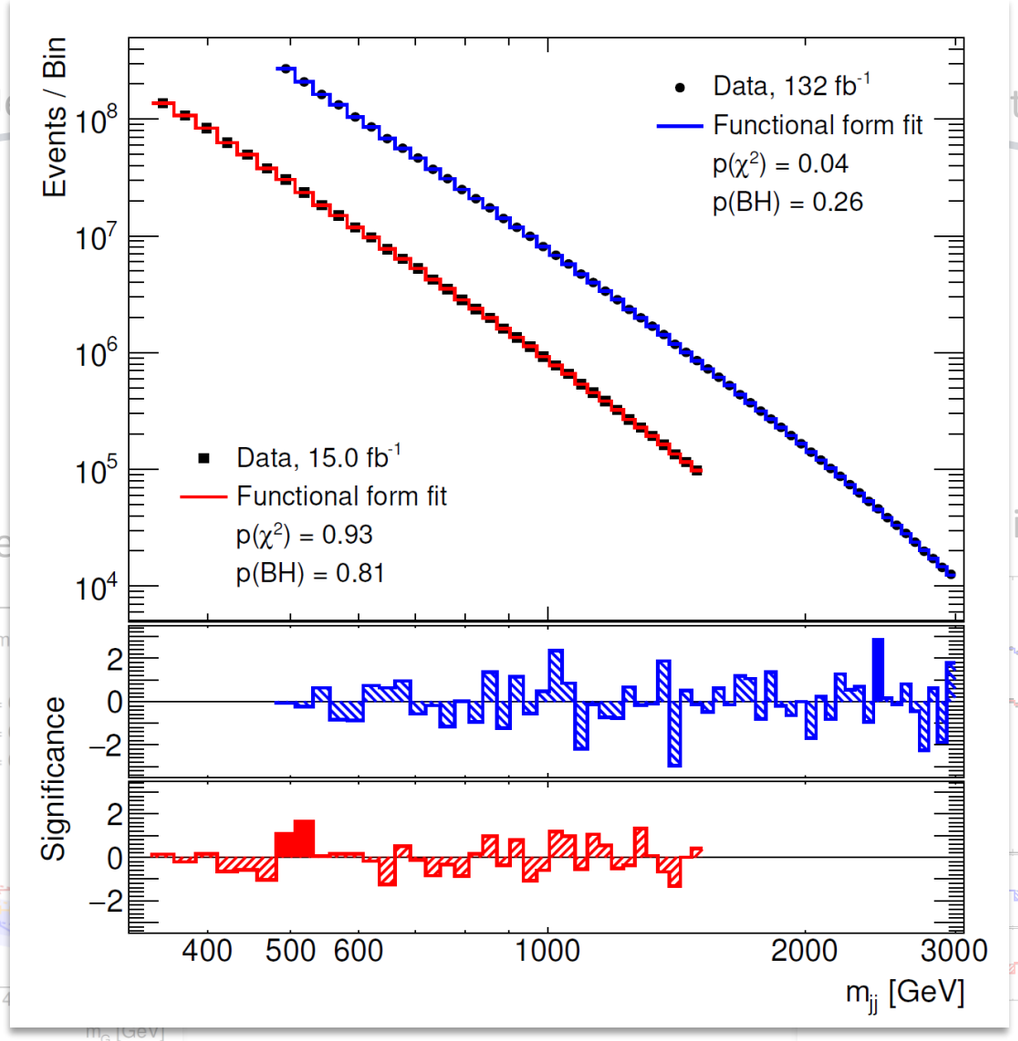

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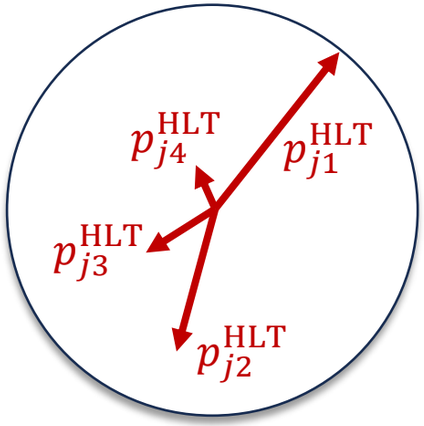

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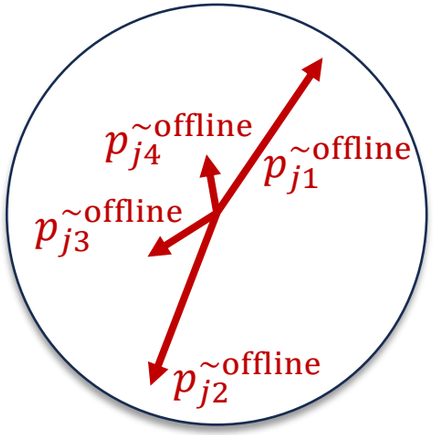

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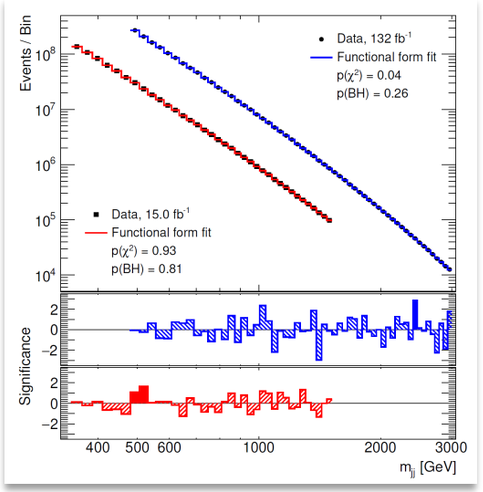

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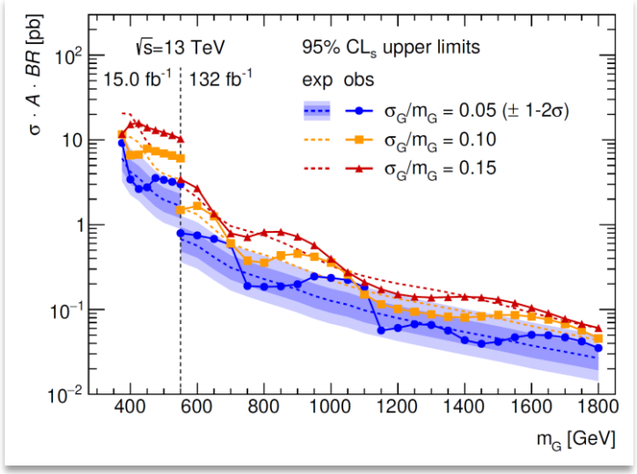

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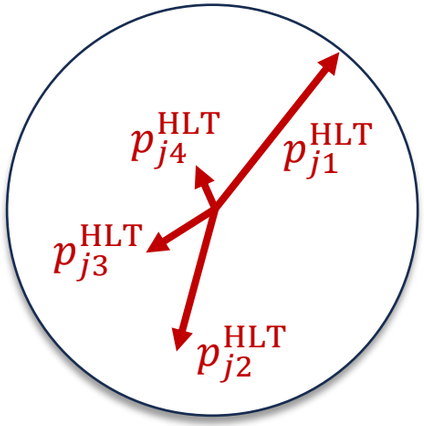

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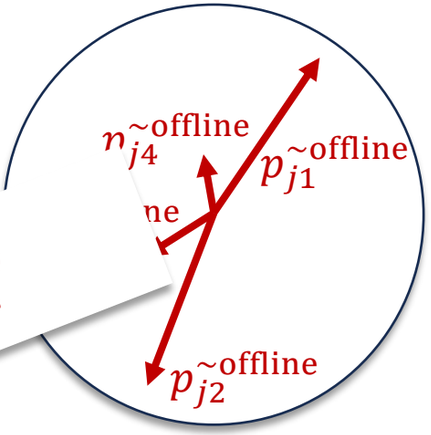
jet 4-momenta @ offline scale



How does this take 5+ years?

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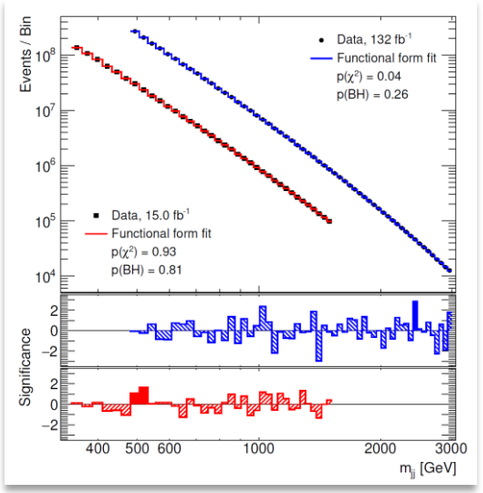

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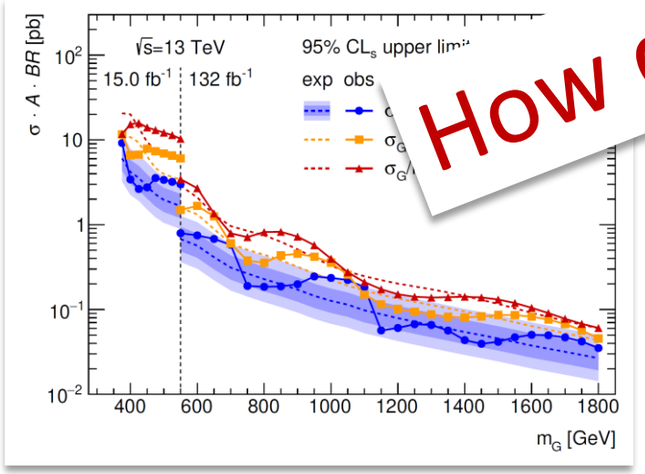

TLA in a Nutshell

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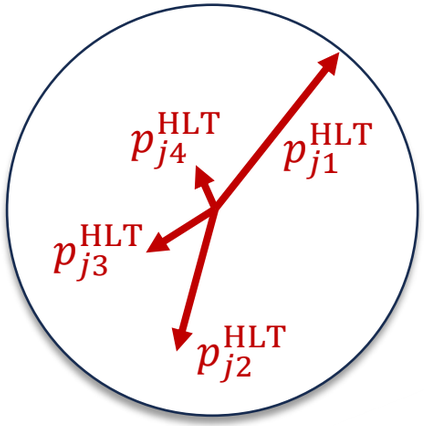

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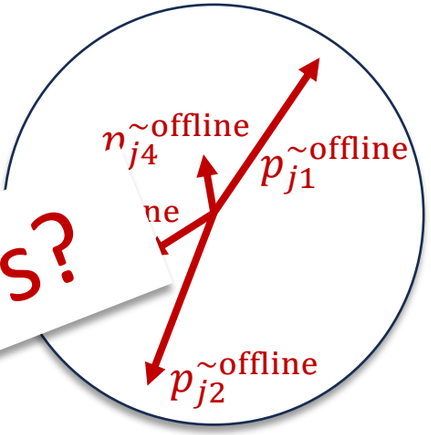
jet 4-momenta @ offline scale



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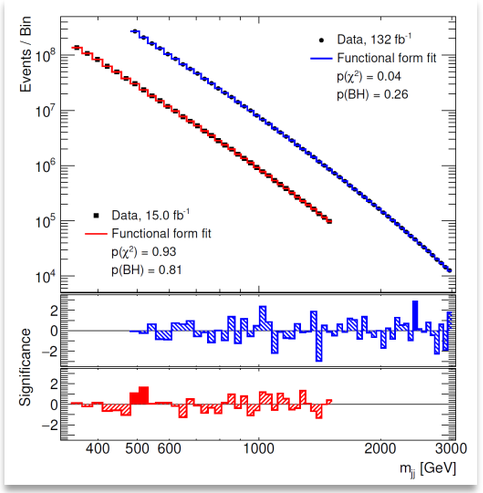

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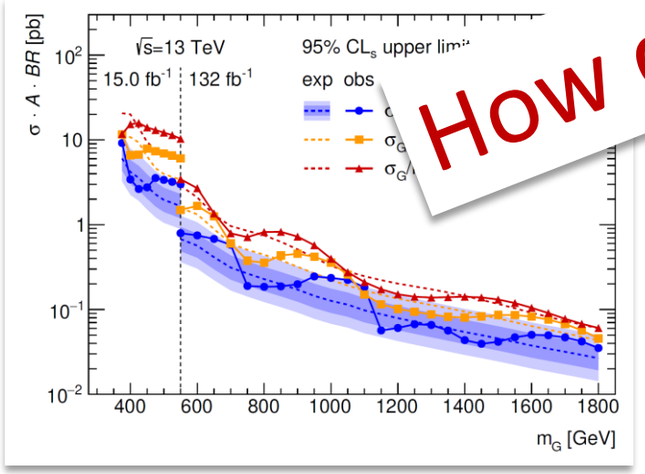
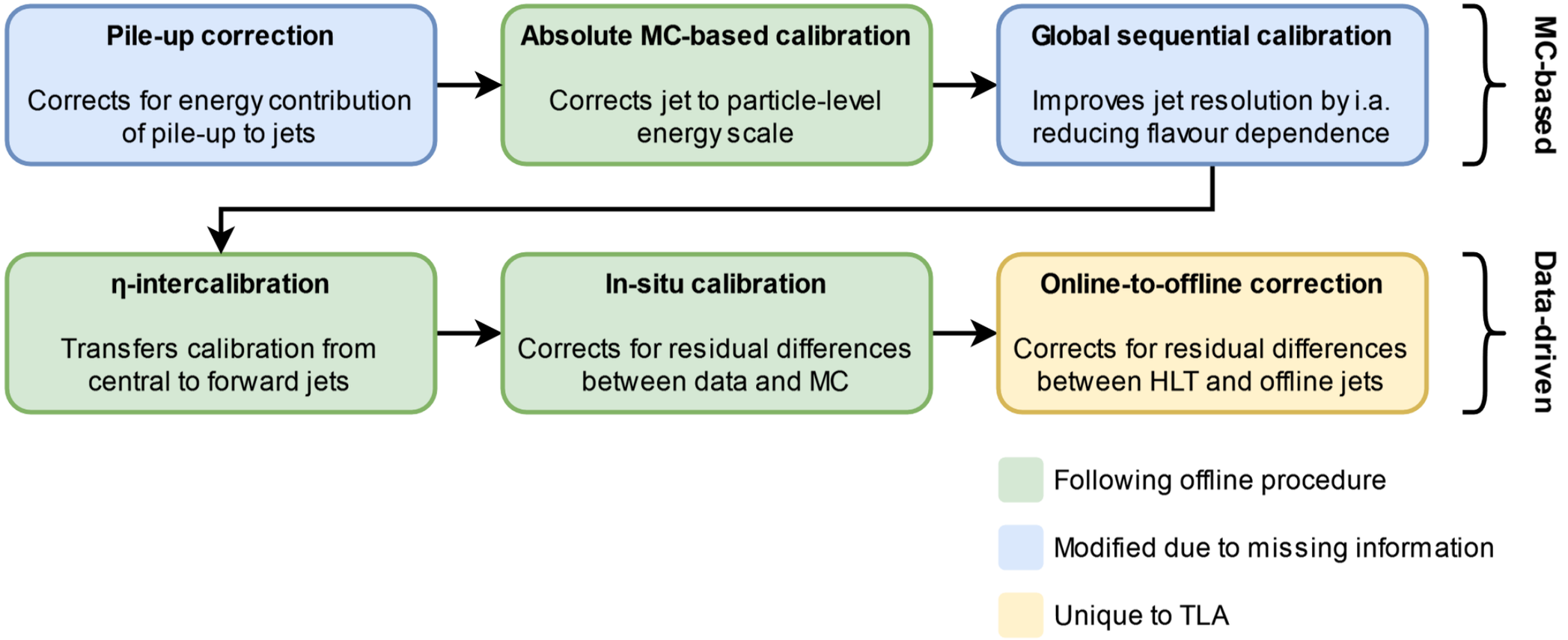


Calibration Steps



Calibration – Challenges

- Difficult due to huge statistics:
  - Sensitive to signals $\mathcal{O}(10^{-4})$
  - MC input for calibration much smaller
  - Offline jet calibration derived & tested on smaller datasets
- Blind analysis:
  - Define full analysis strategy (calibration, fit strategy, uncertainties, …) before looking at full dataset

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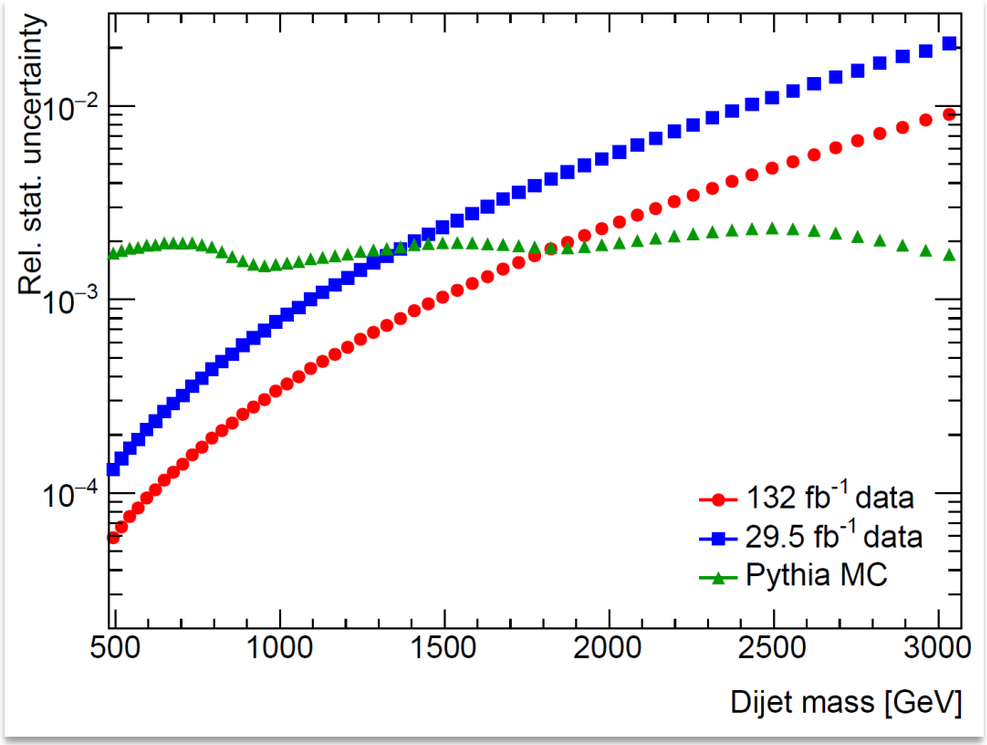
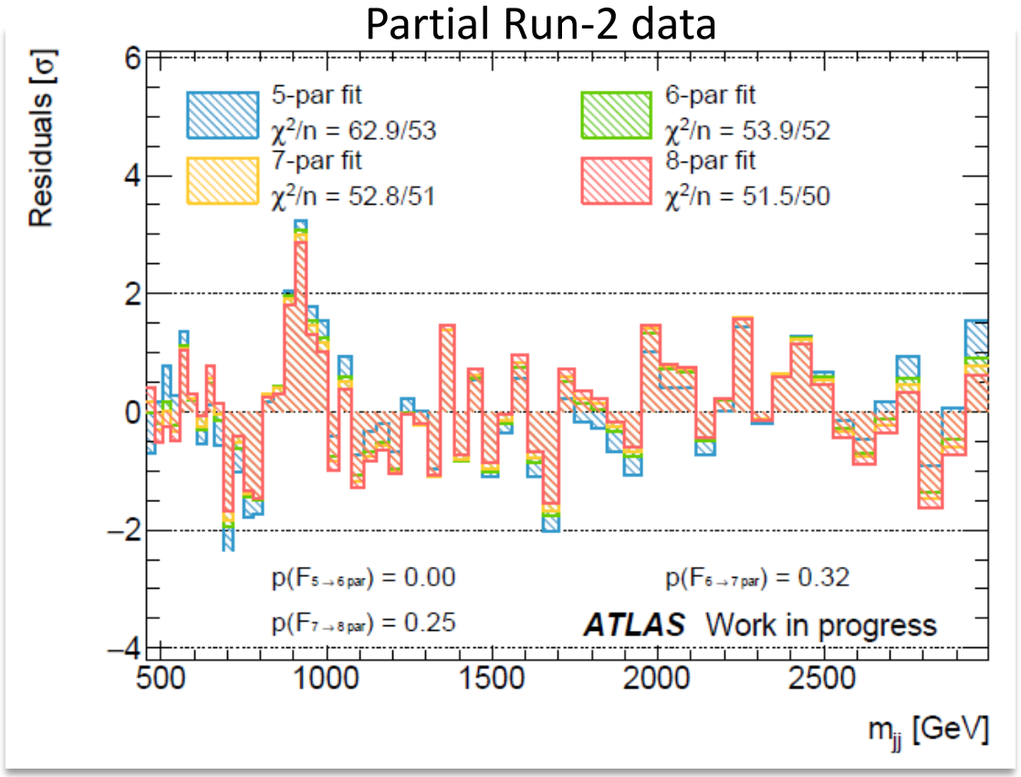
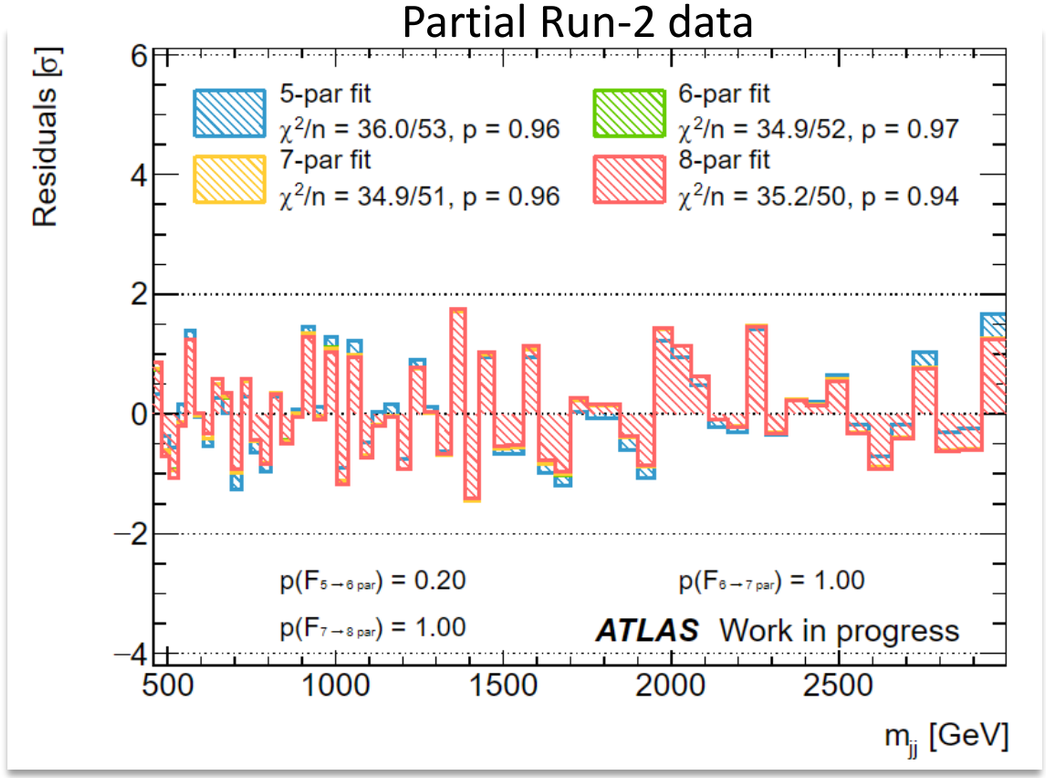


Calibration – May 2023

- Used 10% & 20% of TLA signal regions to test calibration and fitting
- Observed $> 3\sigma$ excess at 900 GeV
- Caused by Pythia MC slicing, fixed by rebinning GSC (2023 Trifels talk)

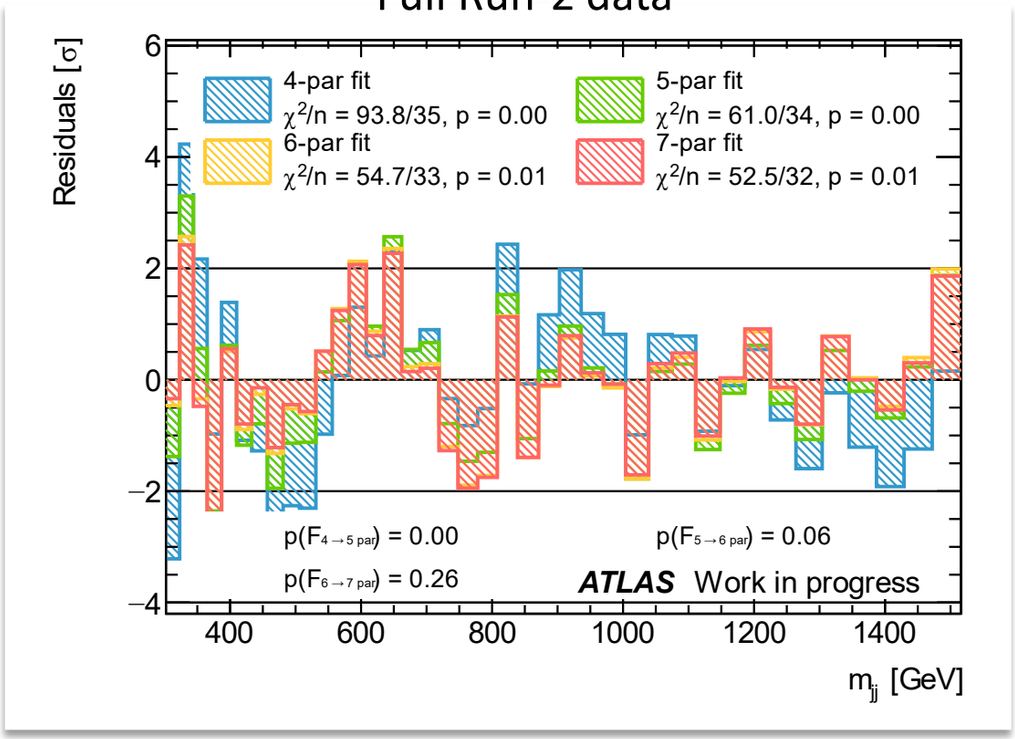




Calibration – August 2023

- Fully unblinded data
- Observed large fluctuations in low-mass signal region (L1_J50)
- Outdated efficiency turnons had us start fit at too low m_{jj}

Full Run-2 data



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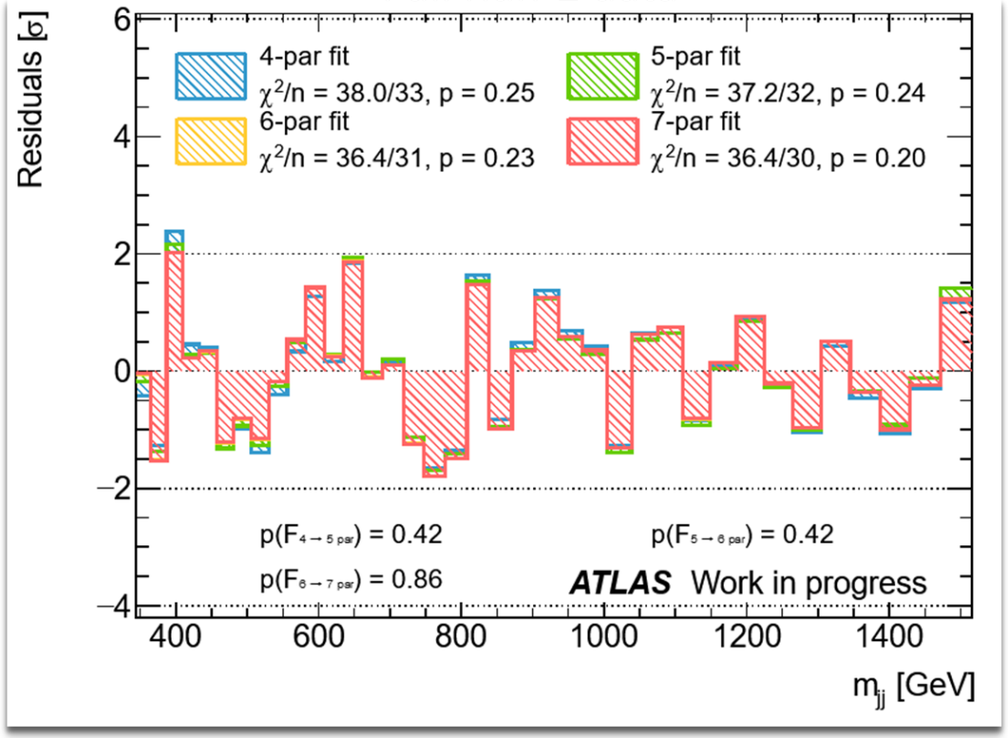
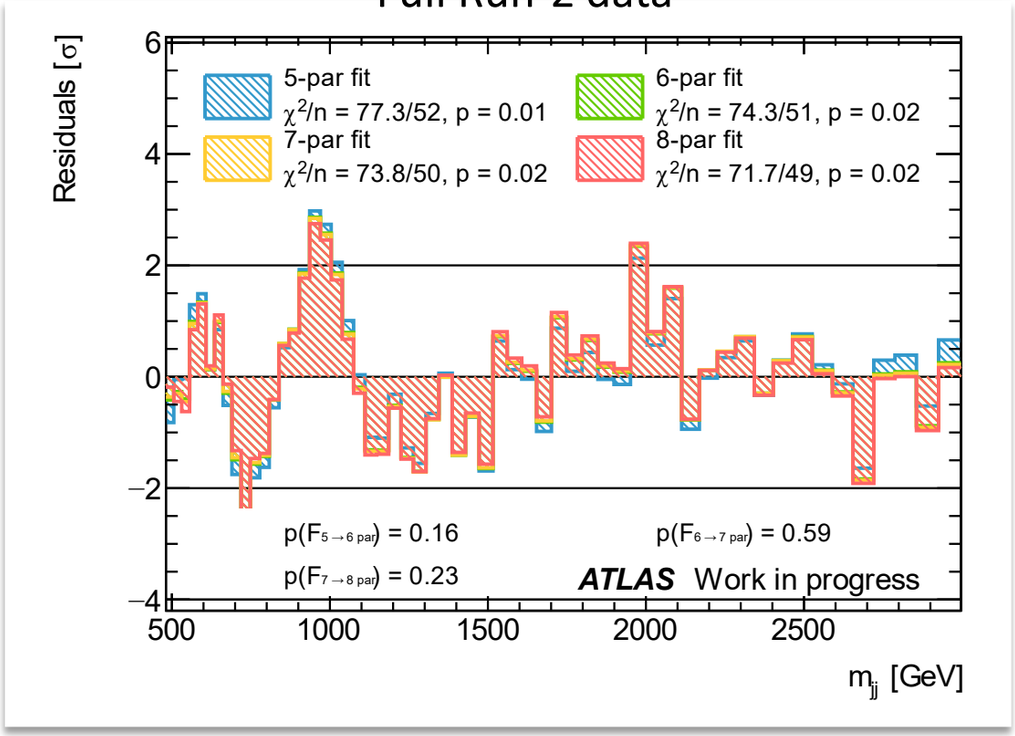


Calibration – August 2023

- Fully unblinded data
- Again very large bump in main signal region (L1_J100)
- Bump found to appear with GSC again

Full Run-2 data



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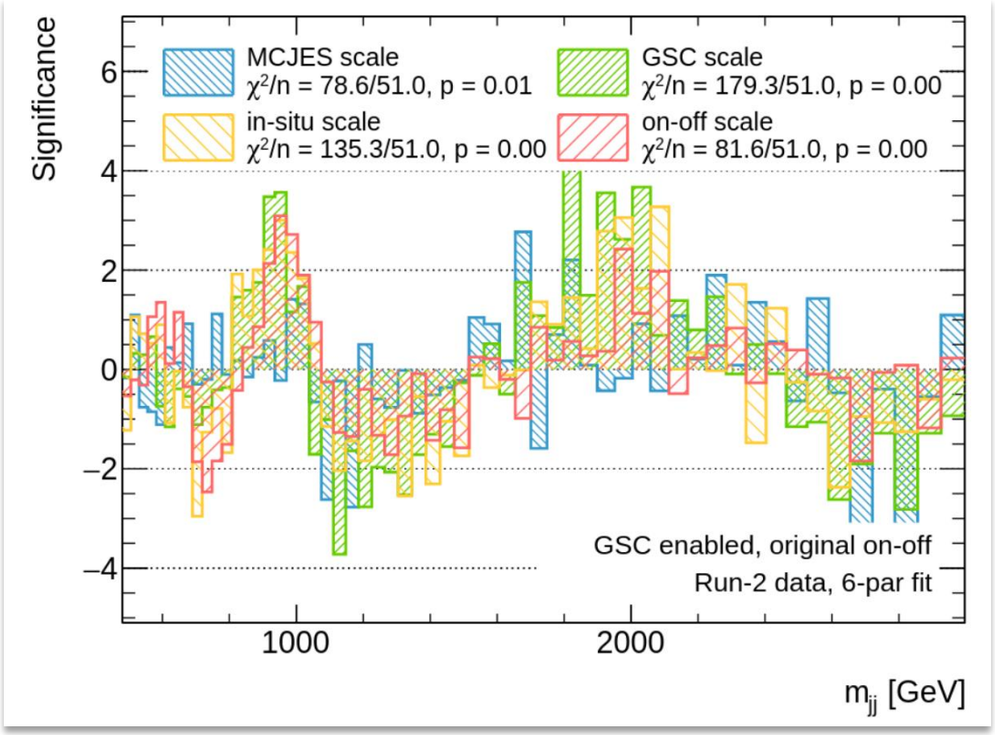
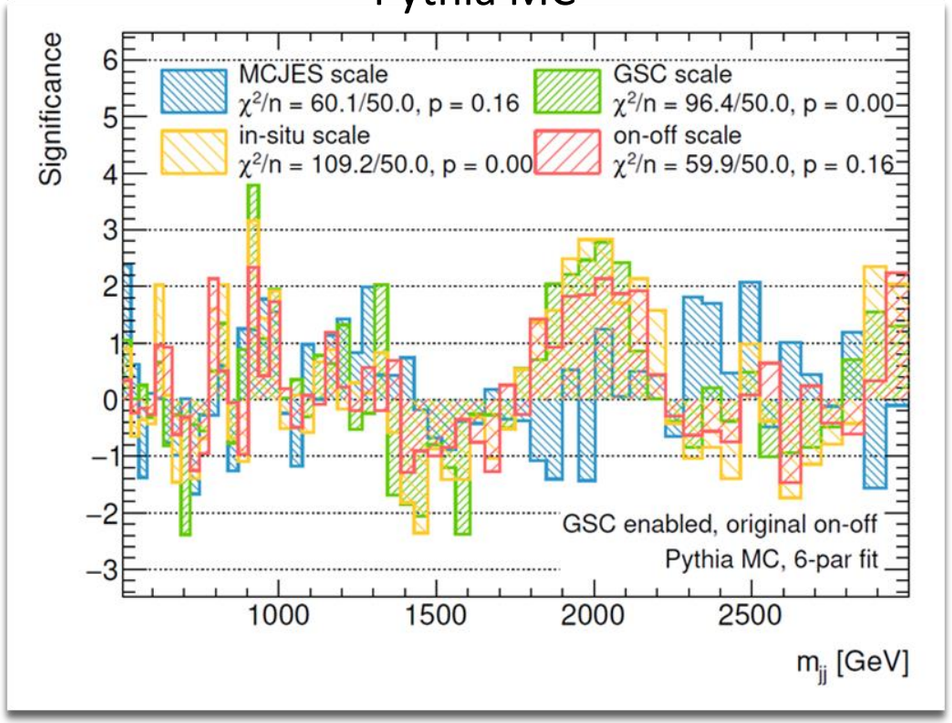


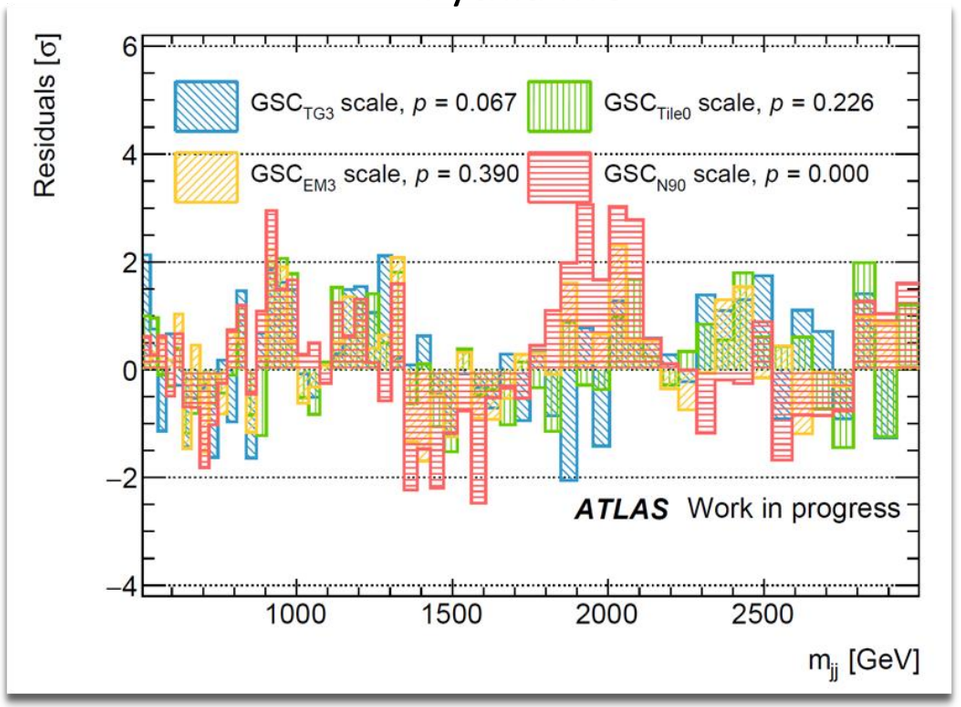
Calibration – August 2023

- Bump also visible in MC (in hindsight)
- GSC corrects for 4 jet structure variables: $f_{\mathrm{TileGap3}}, f_{\mathrm{EM3}}, f_{\mathrm{Tile0}}, N_{\mathrm{90Const}}$
  → remove N_{90Const} from GSC & rederive last calib step

Pythia MC

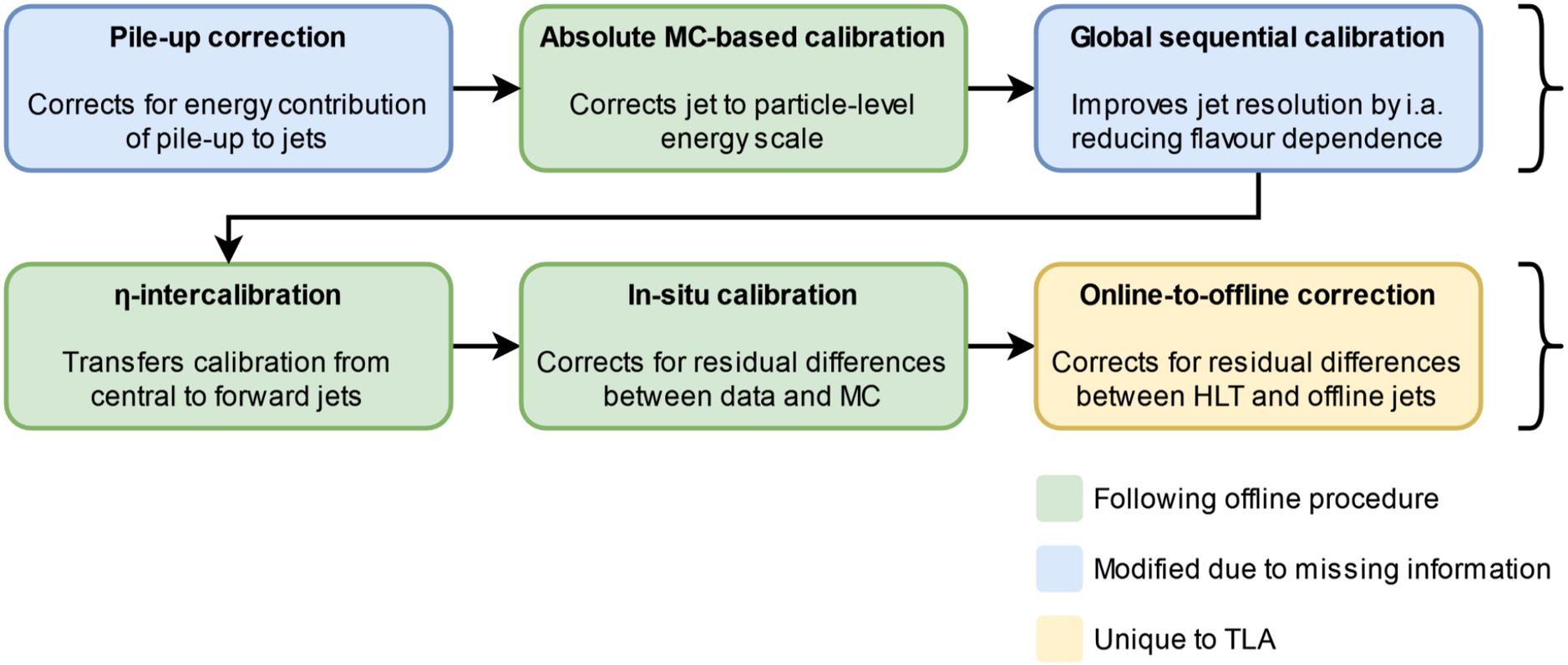


Pythia MC



Interlude – Bumpless TLA

- Time to graduate → sacrificed not well-understood GSC and online/offline correction



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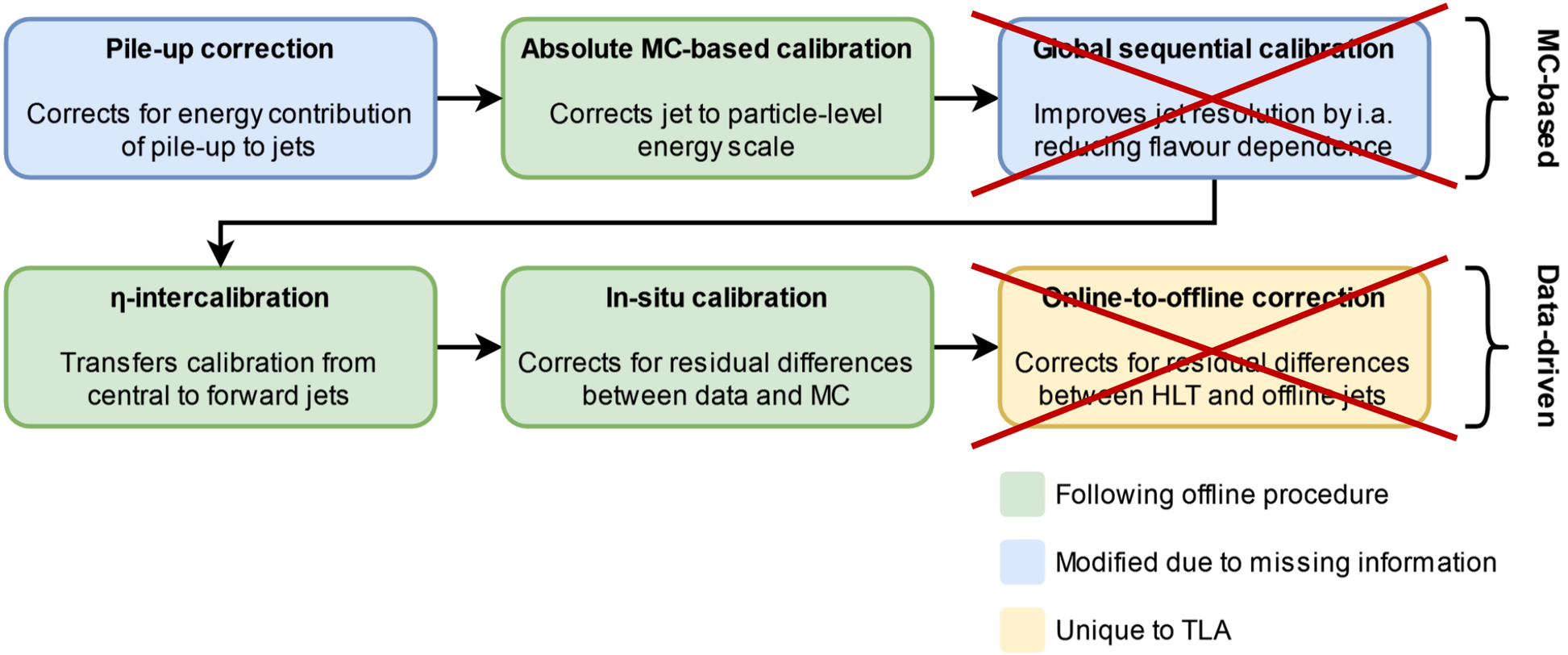
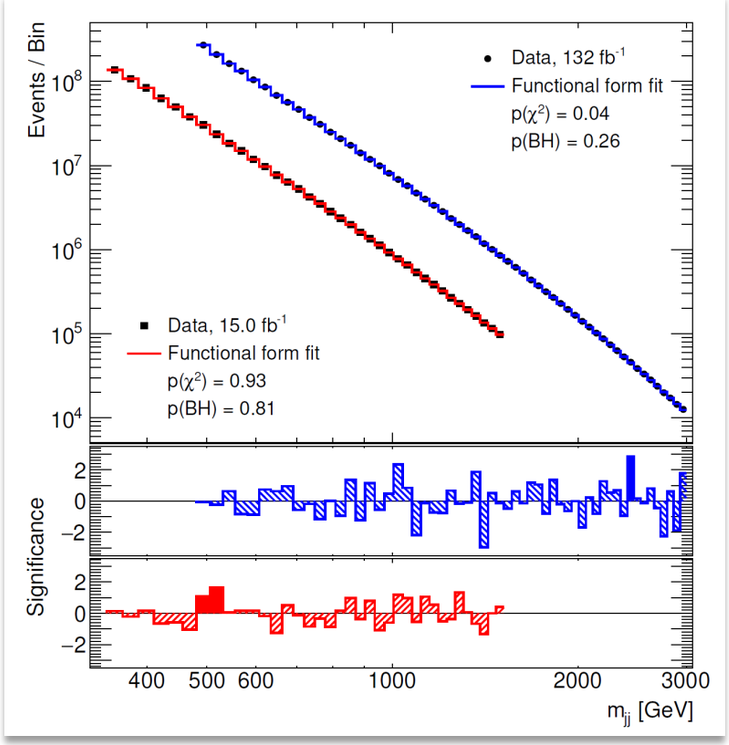
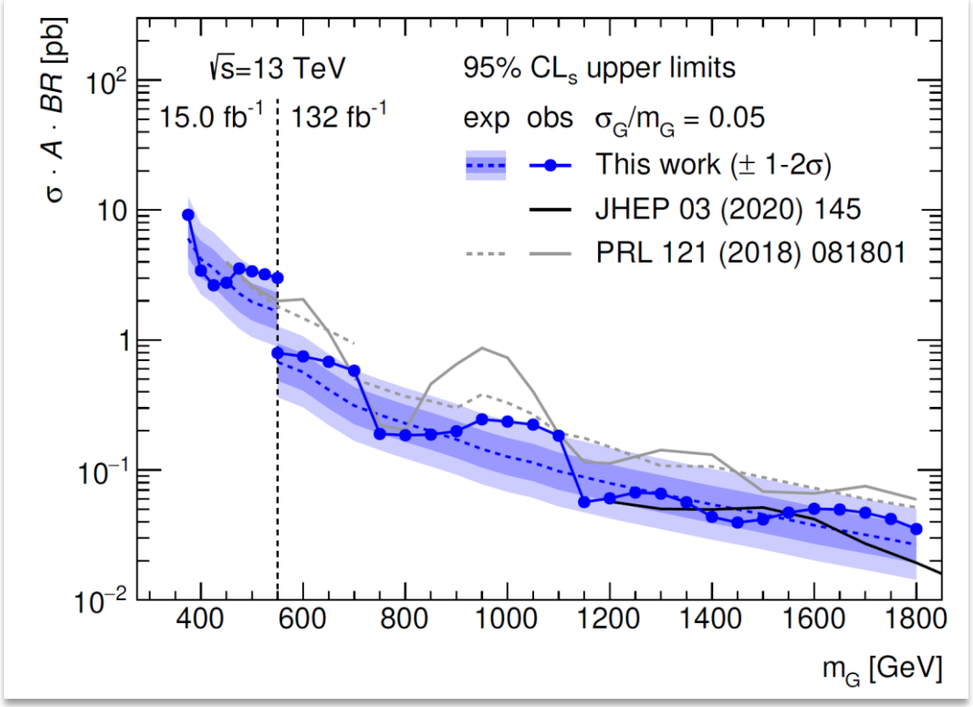


Interlude – Bumpless TLA

- Achieved good description of observed m_{jj} spectra
- Placed strictest limits on dijet resonances in 375 – 1200 GeV mass range
- But: Improved resolution from full calibration could enhance sensitivity to narrow signals

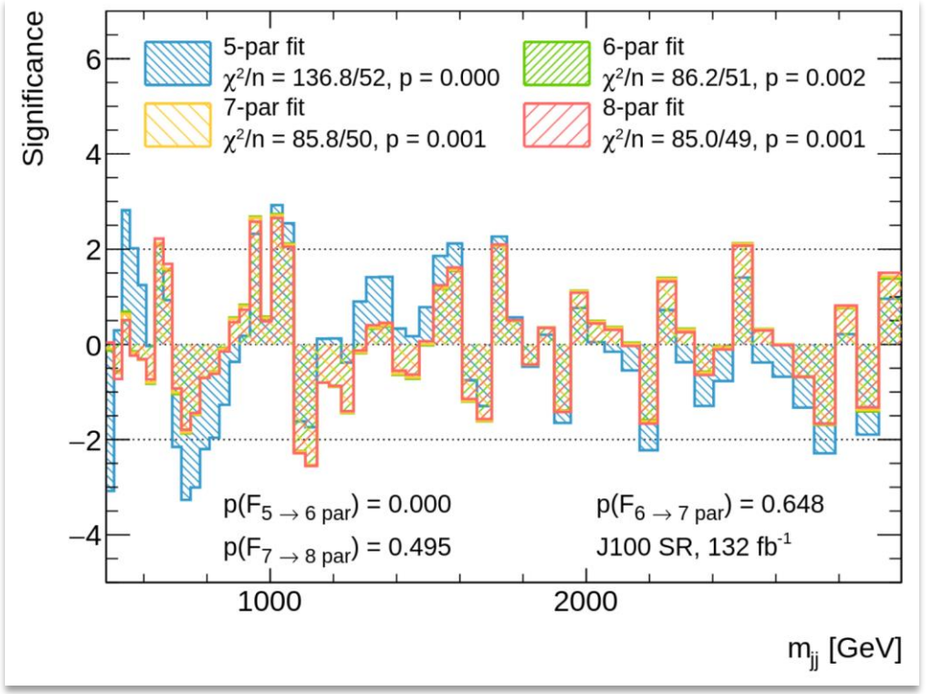




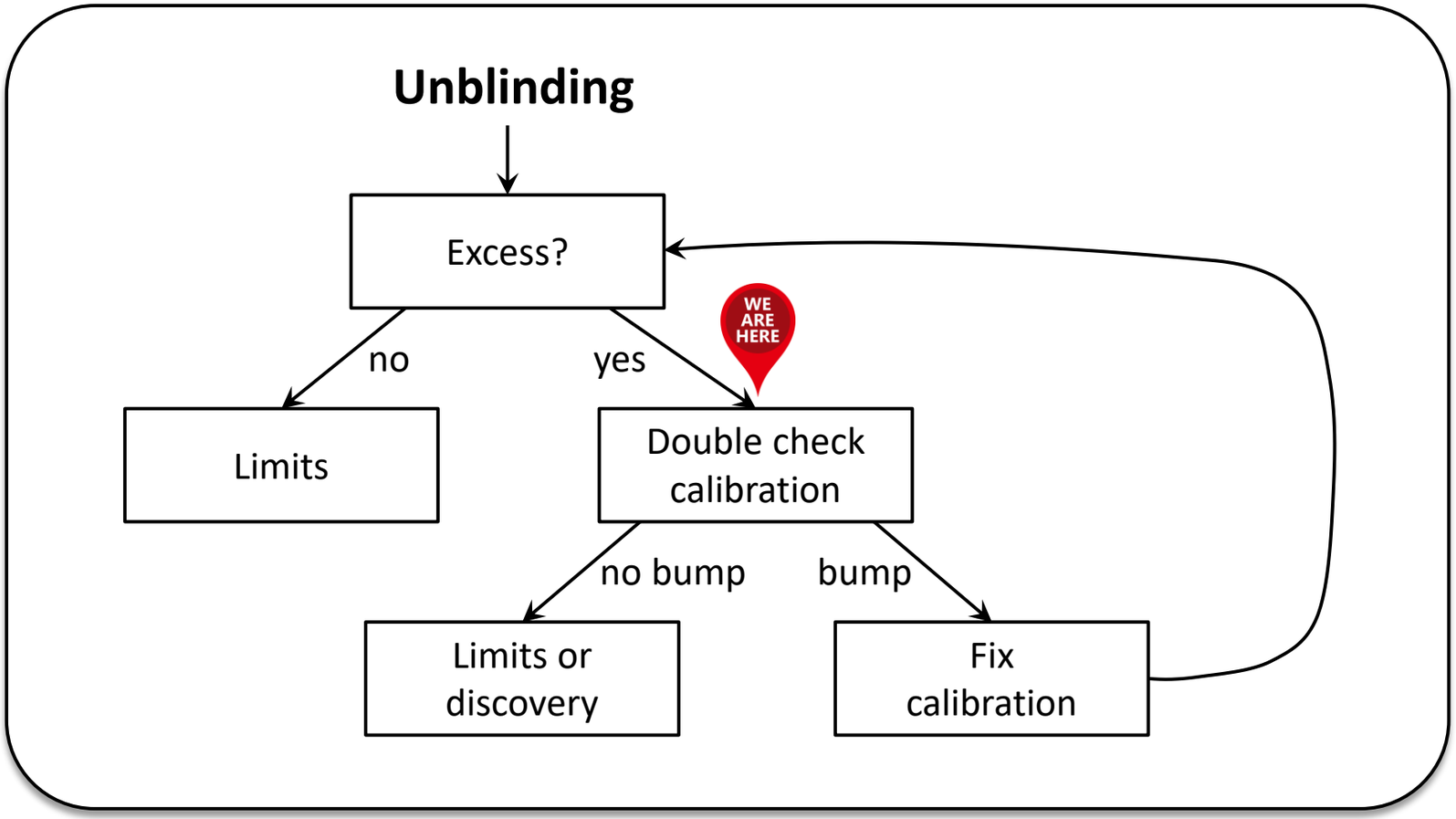
Calibration – June 2024

- Fully unblinded data (second time)
- Reduced, but still significant bump in main signal region (L1_J100)
  ($> 3\sigma$ local significance)
- Bump not arising from single calibration step
- Bump not occuring in MC due to lacking statistics
- Appears to be related to jets in TileGap region
  (much dead material, bad resolution)

Full Run-2 data

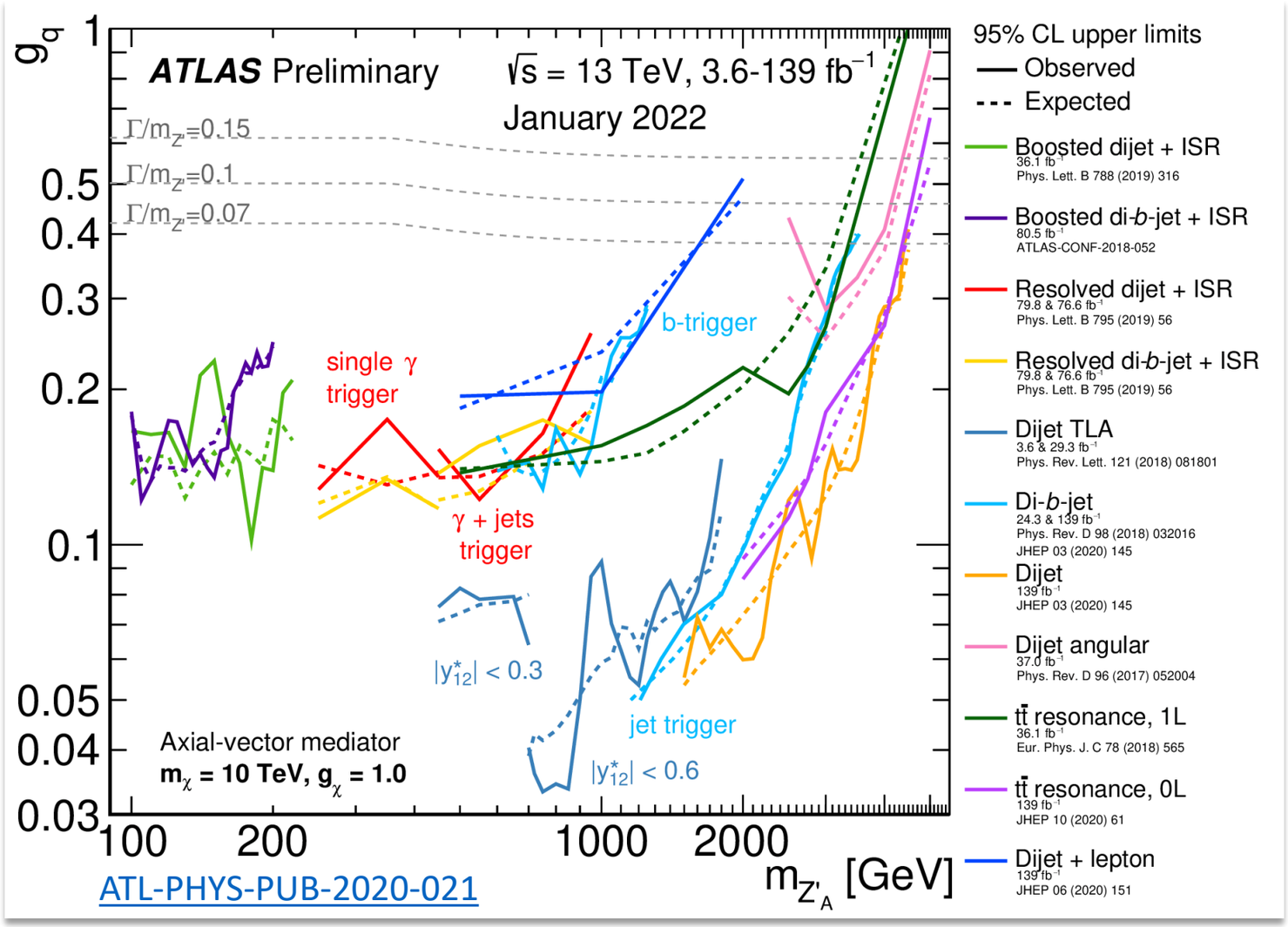


Outlook


Unblinding
Excess?
no
yes
WE ARE HERE
Limits
Double check calibration
no bump
bump
Limits or discovery
Fix calibration

Backup

Why TLA?


ATLAS Preliminary
√s = 13 TeV, 3.6-139 fb⁻¹
January 2022
Γ/m_Z'=0.15
Γ/m_Z'=0.1
Γ/m_Z'=0.07
b-trigger
single γ trigger
γ + jets trigger
|y*12| < 0.3
jet trigger
|y*12| < 0.6
Axial-vector mediator
m_χ = 10 TeV, g_χ = 1.0
g_q
m_Z'A [GeV]
95% CL upper limits
Observed
Expected
Boosted dijet + ISR
36.1 fb⁻¹
Phys. Lett. B 788 (2019) 316
Boosted di-b-jet + ISR
80.5 fb⁻¹
ATLAS-CONF-2018-052
Resolved dijet + ISR
79.8 & 76.6 fb⁻¹
Phys. Lett. B 795 (2019) 56
Resolved di-b-jet + ISR
79.8 & 76.6 fb⁻¹
Phys. Lett. B 795 (2019) 56
Dijet TLA
3.6 & 29.3 fb⁻¹
Phys. Rev. Lett. 121 (2018) 081801
Di-b-jet
24.3 & 139 fb⁻¹
Phys. Rev. D 98 (2018) 032016
JHEP 03 (2020) 145
Dijet
139 fb⁻¹
JHEP 03 (2020) 145
Dijet angular
37.0 fb⁻¹
Phys. Rev. D 96 (2017) 052004
tt̄ resonance, 1L
36.1 fb⁻¹
Eur. Phys. J. C 78 (2018) 565
tt̄ resonance, 0L
139 fb⁻¹
JHEP 10 (2020) 61
Dijet + lepton
139 fb⁻¹
JHEP 06 (2020) 151
ATL-PHYS-PUB-2020-021

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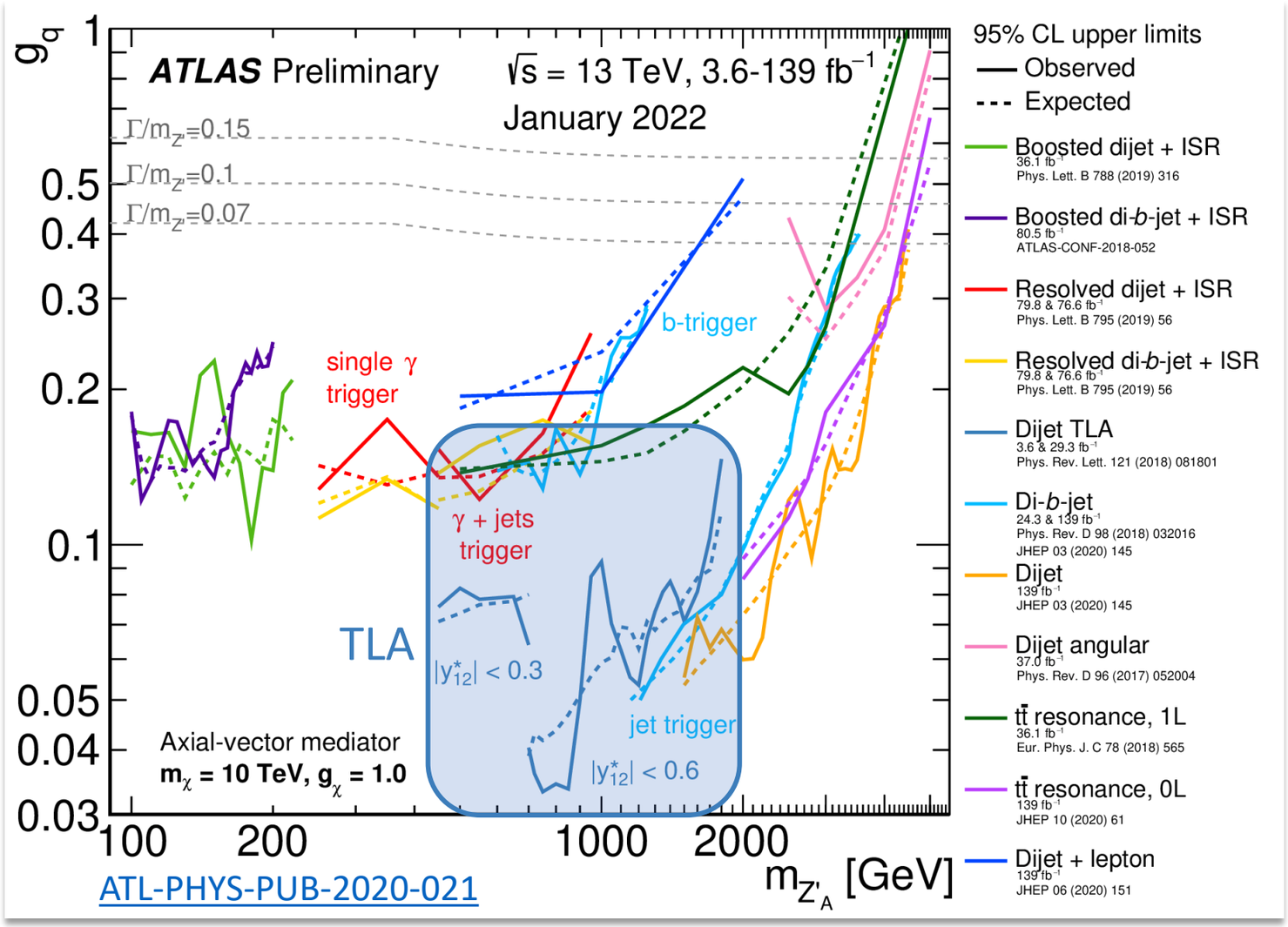
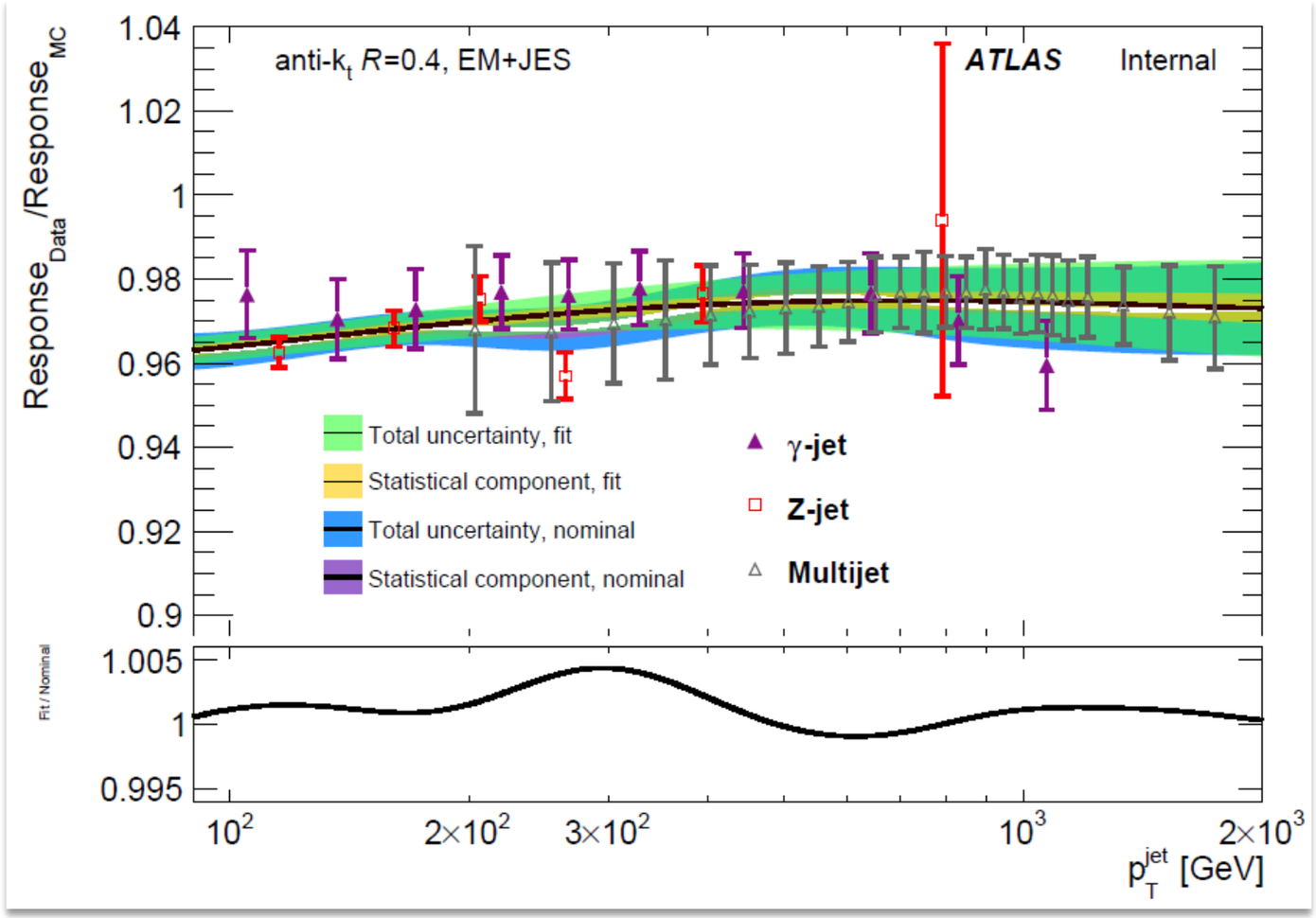


ATL-PHYS-PUB-2020-021

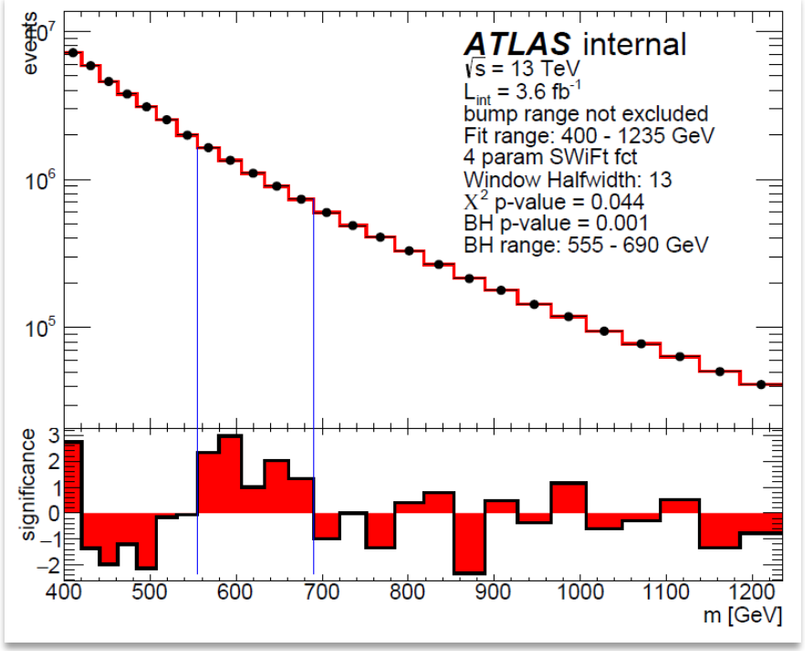
2016 In-Situ


anti-k$_t$ R=0.4, EM+JES
ATLAS Internal
Response$_{Data}$/Response$_{MC}$
Total uncertainty, fit
Statistical component, fit
Total uncertainty, nominal
Statistical component, nominal
γ-jet
Z-jet
Multijet
Fit / Nominal
p_T^{jet} [GeV]

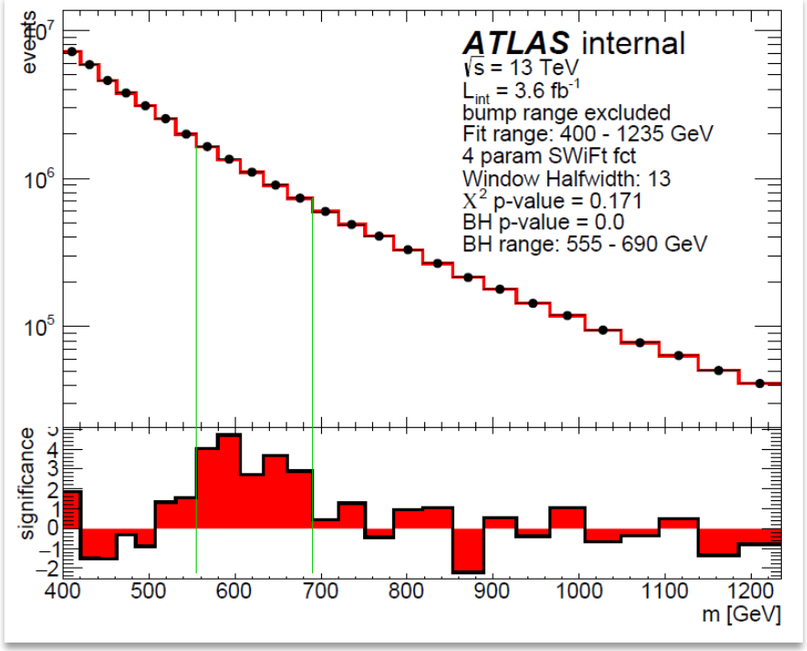
2016 Excess

- Already significant excess showing up in full spectrum bkg-only fit
- Following pre-approved unblinding strategy: Masking excess range and refit → increased significance

Full spectrum fit



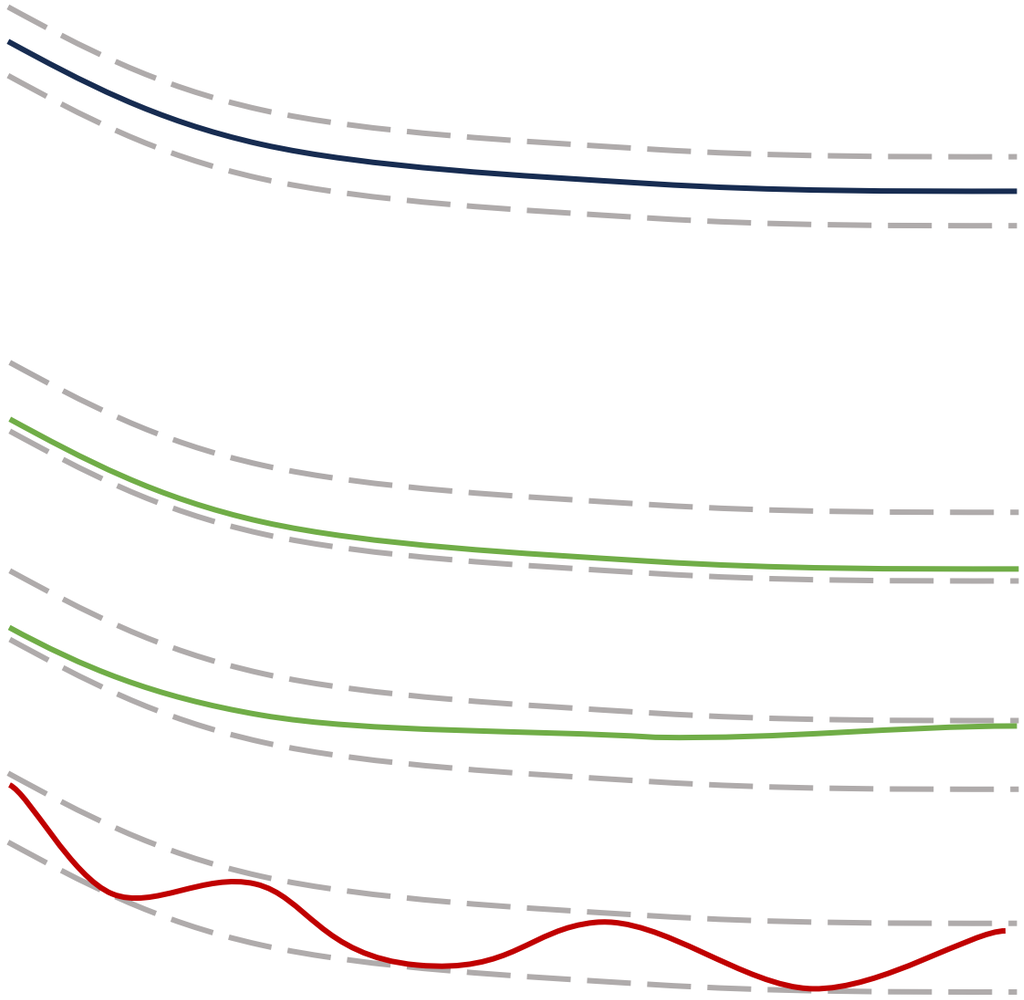
Excluding excess window



Uncertainties

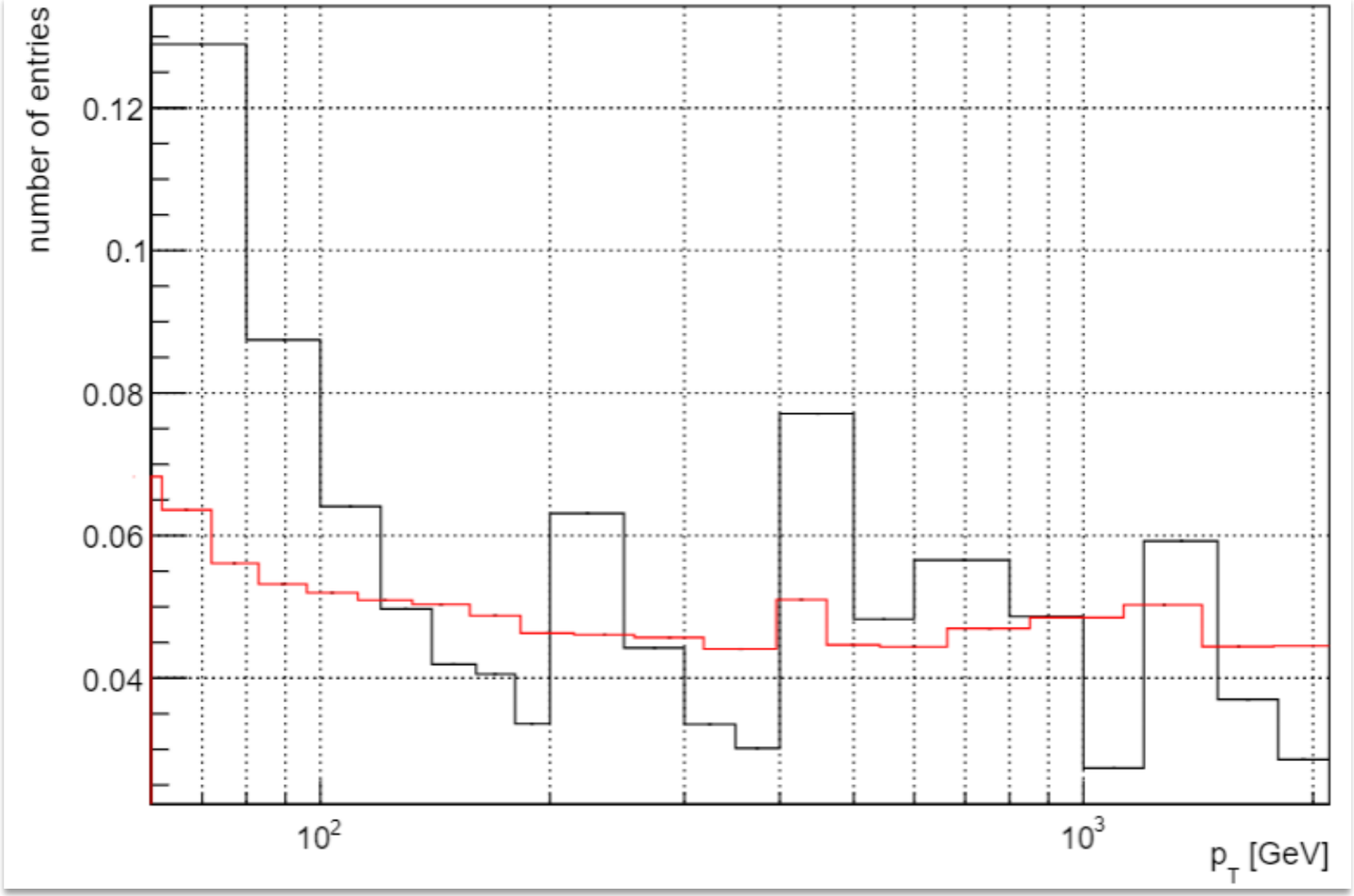
Why do we find a bump if the non-smoothness is smaller than the uncertainty on calibration?

- We do not apply calibration uncertainty on bkg
- Exact calibration shape does not matter because fit absorbs it
- Only apply uncertainty on signal MC

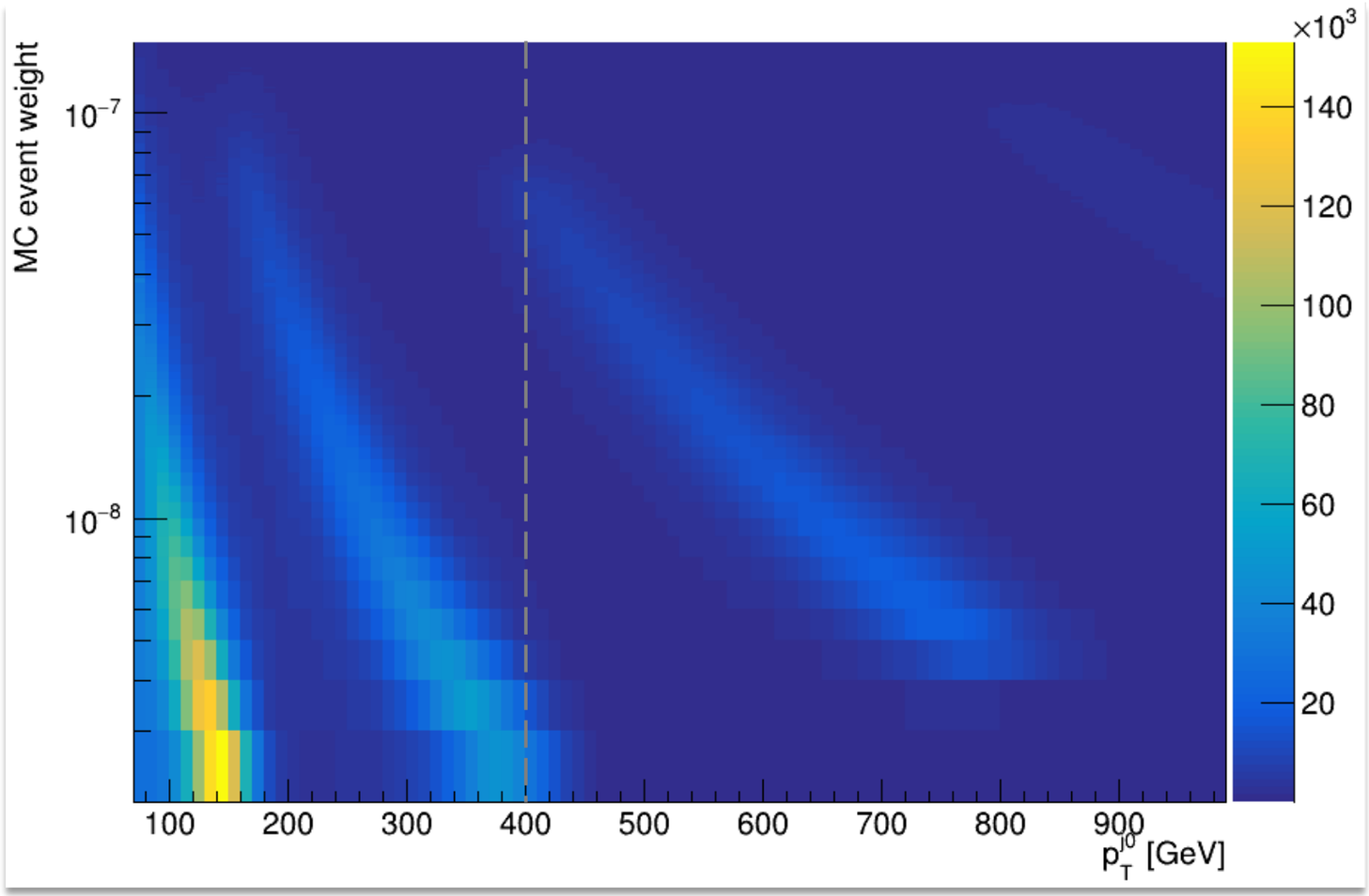


GSC Rebinning

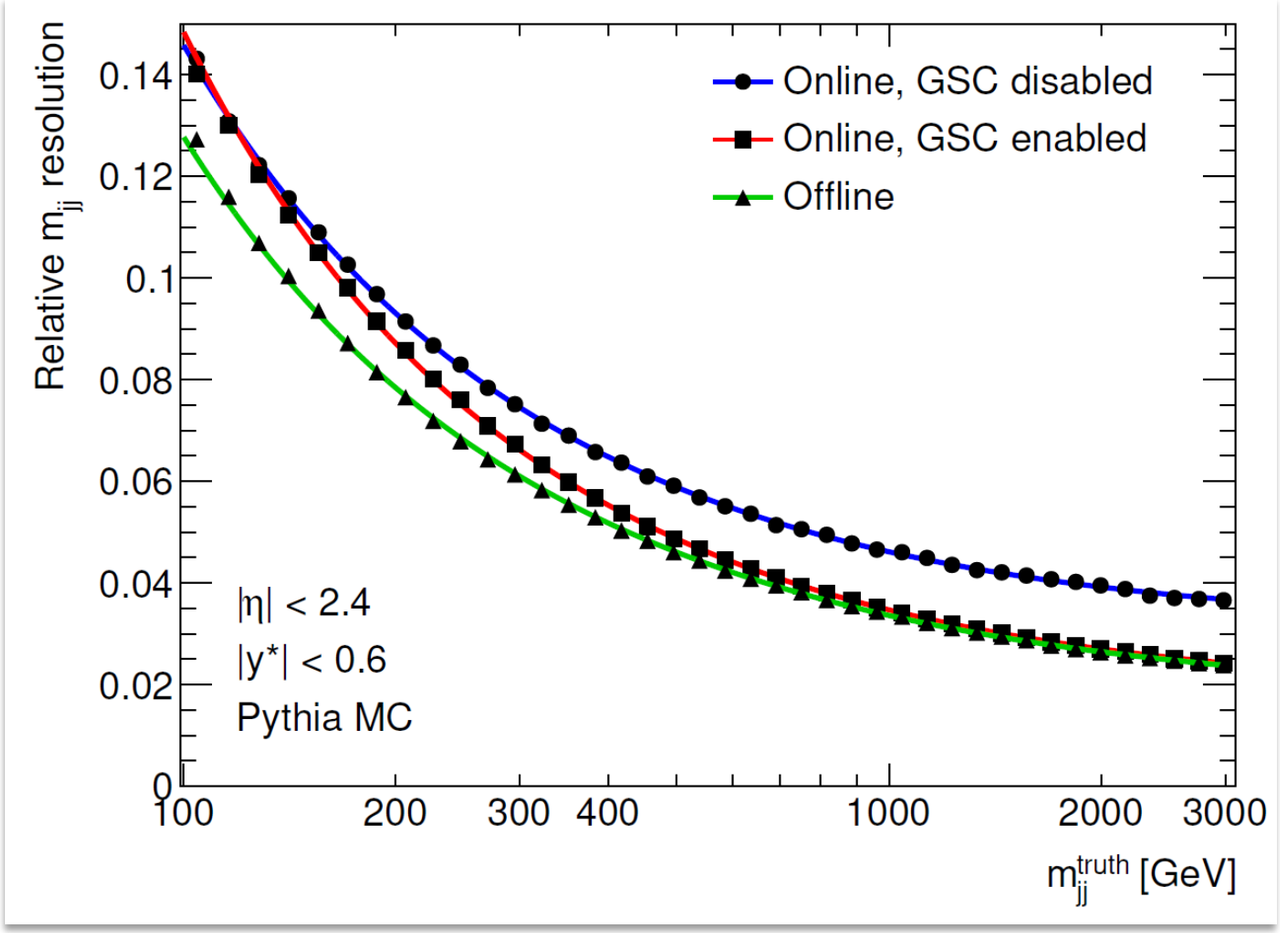
MC statistics per bin: old & new



GSC Rebinning

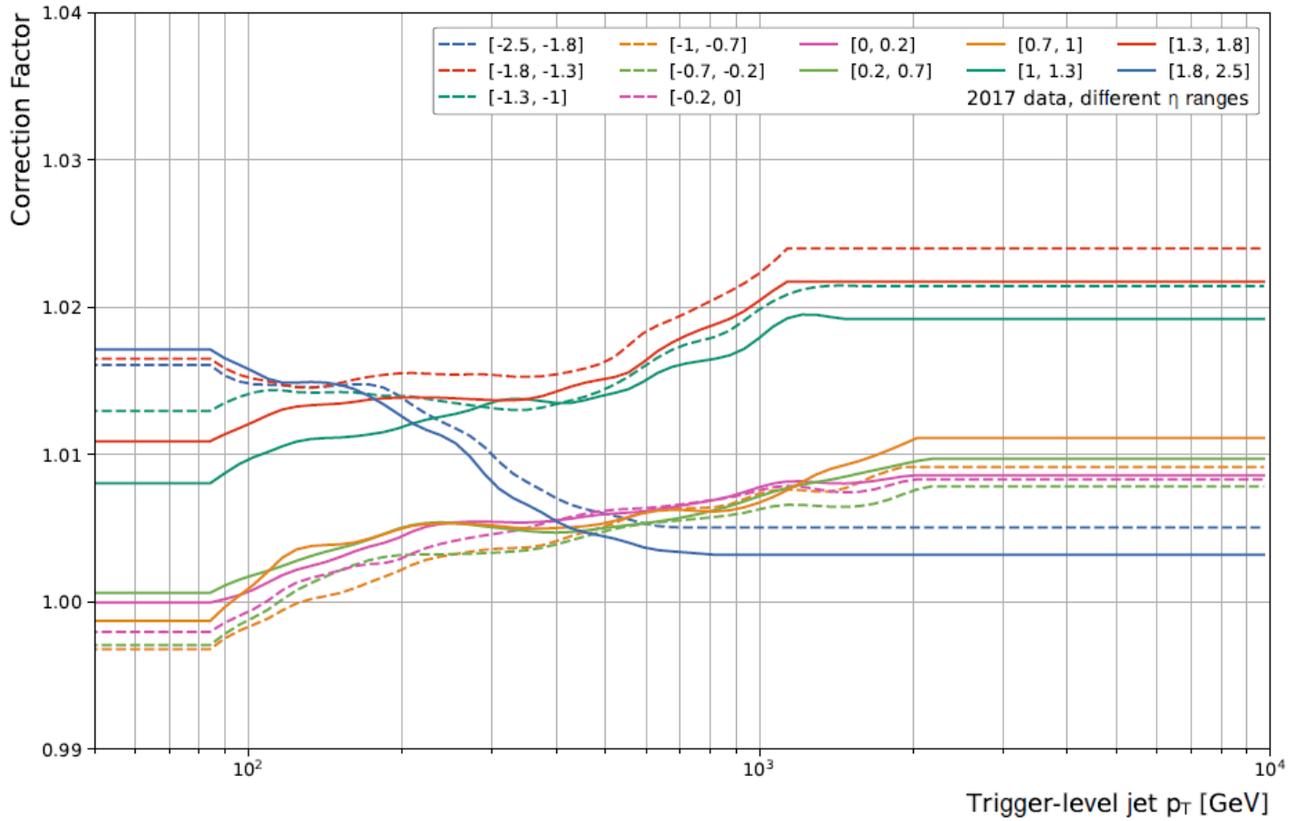


Disabling the GSC



Online/Offline Correction

- Ratio of online to offline jet response
- Do we trust offline as ground truth? What if this ratio is bumpy?



Calibration Smoothness

- Check average correction factor applied to jets in data for each calibration step