Searching for (Non-)Resonant Signals with ATLAS

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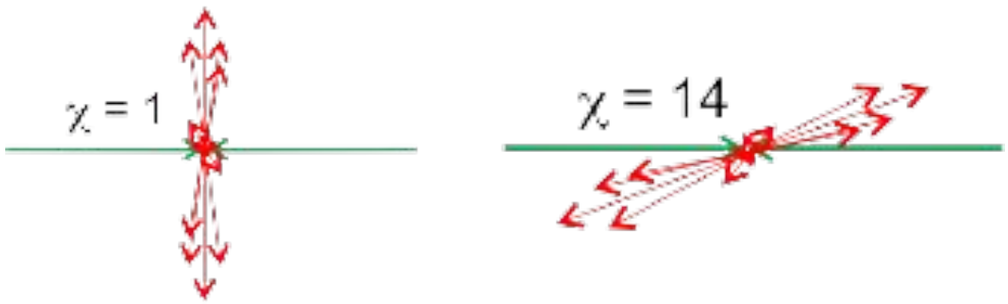
Outline

- Dijet angular analysis
  - Intro on whiteboard
  - Ratio analysis
- Ttbar resonance search
  - Intro on whiteboard
  - Fitting a m_{jj} spectrum
- Other projects
- Recommendations

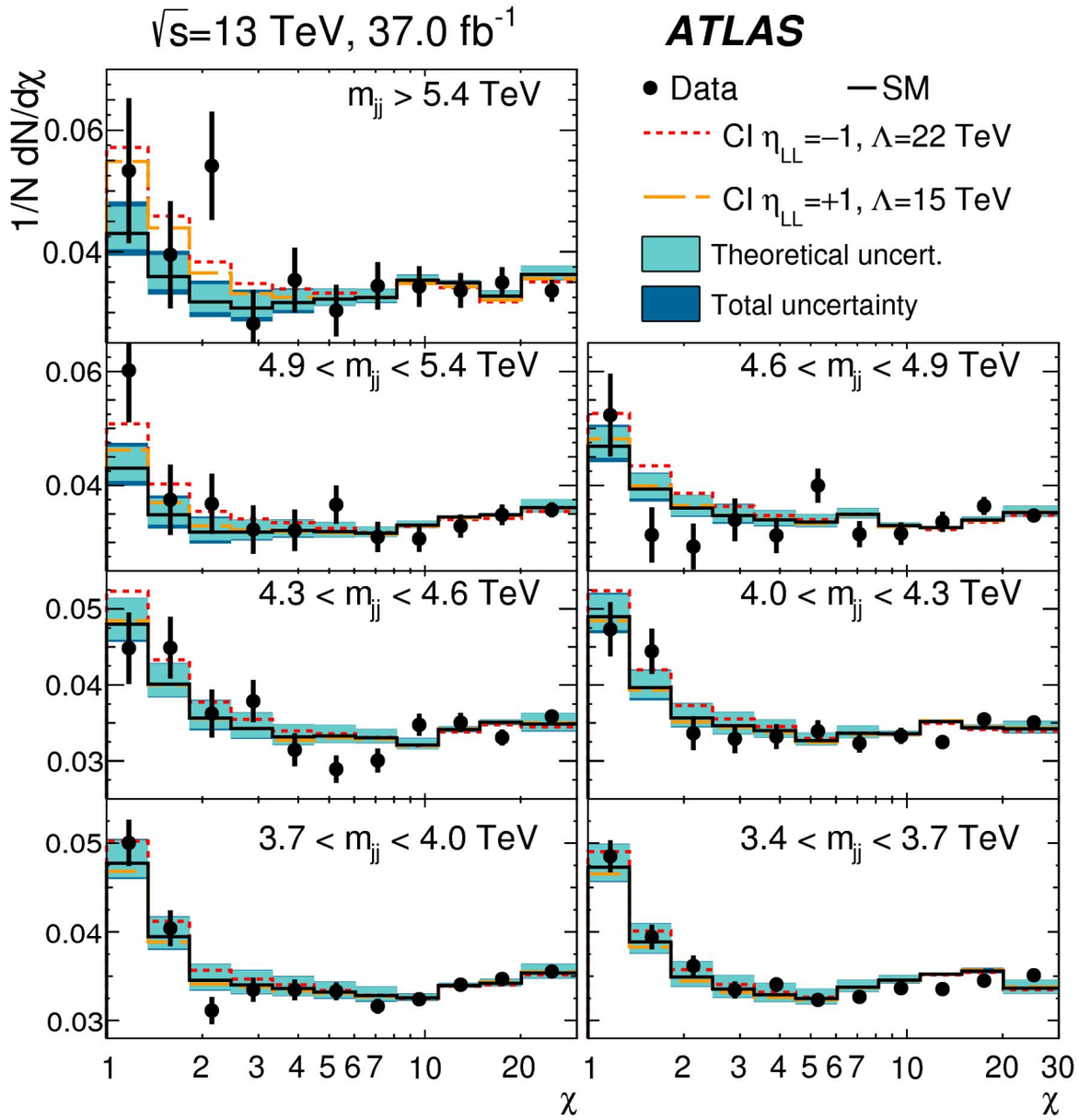
Dijet Angular Analysis - Whiteboard Intro

Traditional Dijet Angular Analysis

- The angular distribution of the dijets is given by $\chi = e^{|y1-y2|}$

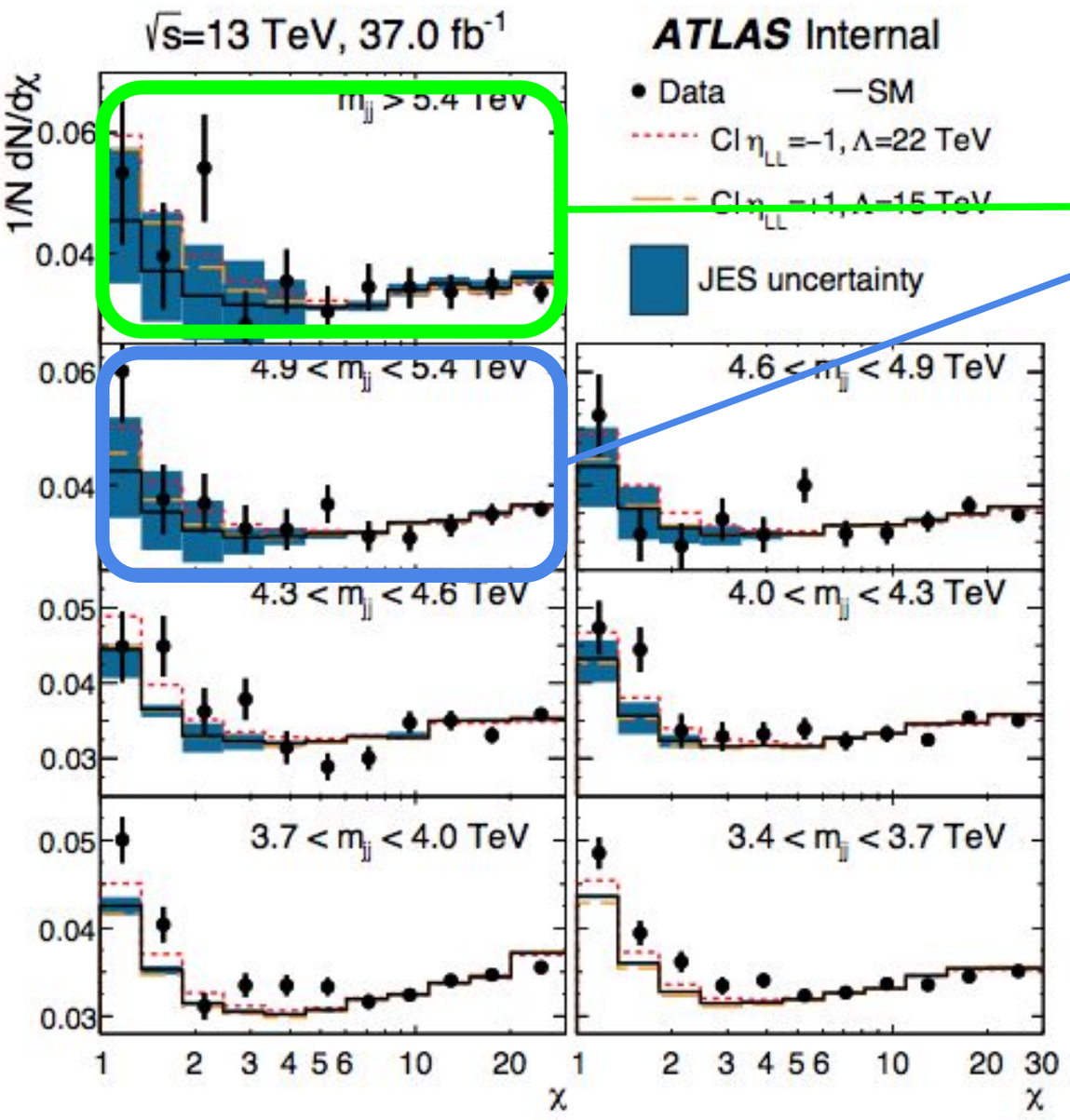


- Divided into **different mjj-bins**.
- The **data** is compared to PYTHIA with **next-to-leading order** QCD and EW corrections
- Combined fit over all mjj-bins

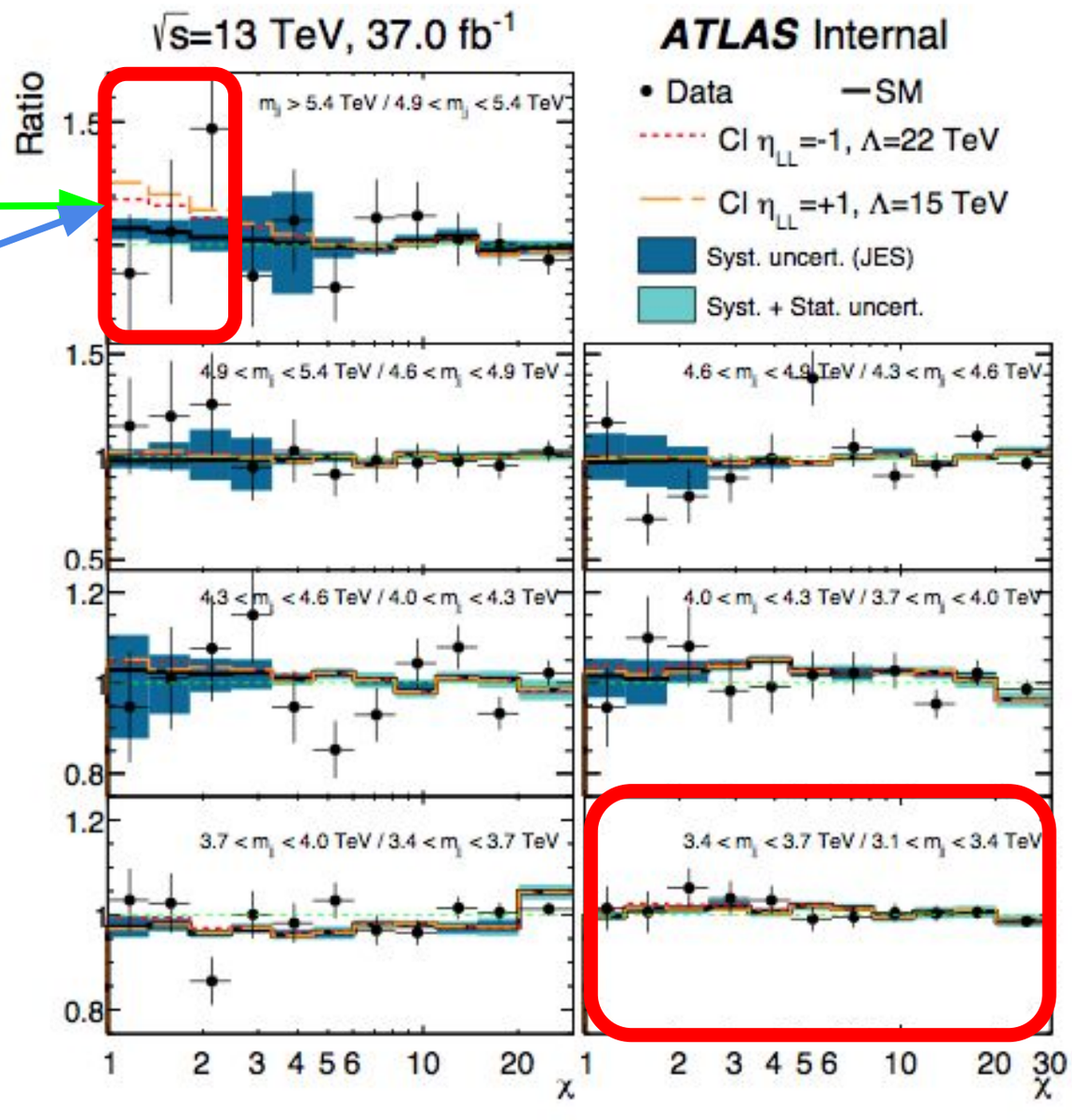


EXOT-2016-21

Dijet Angular Analysis Idea- Ratios



Original method (pre-fit)



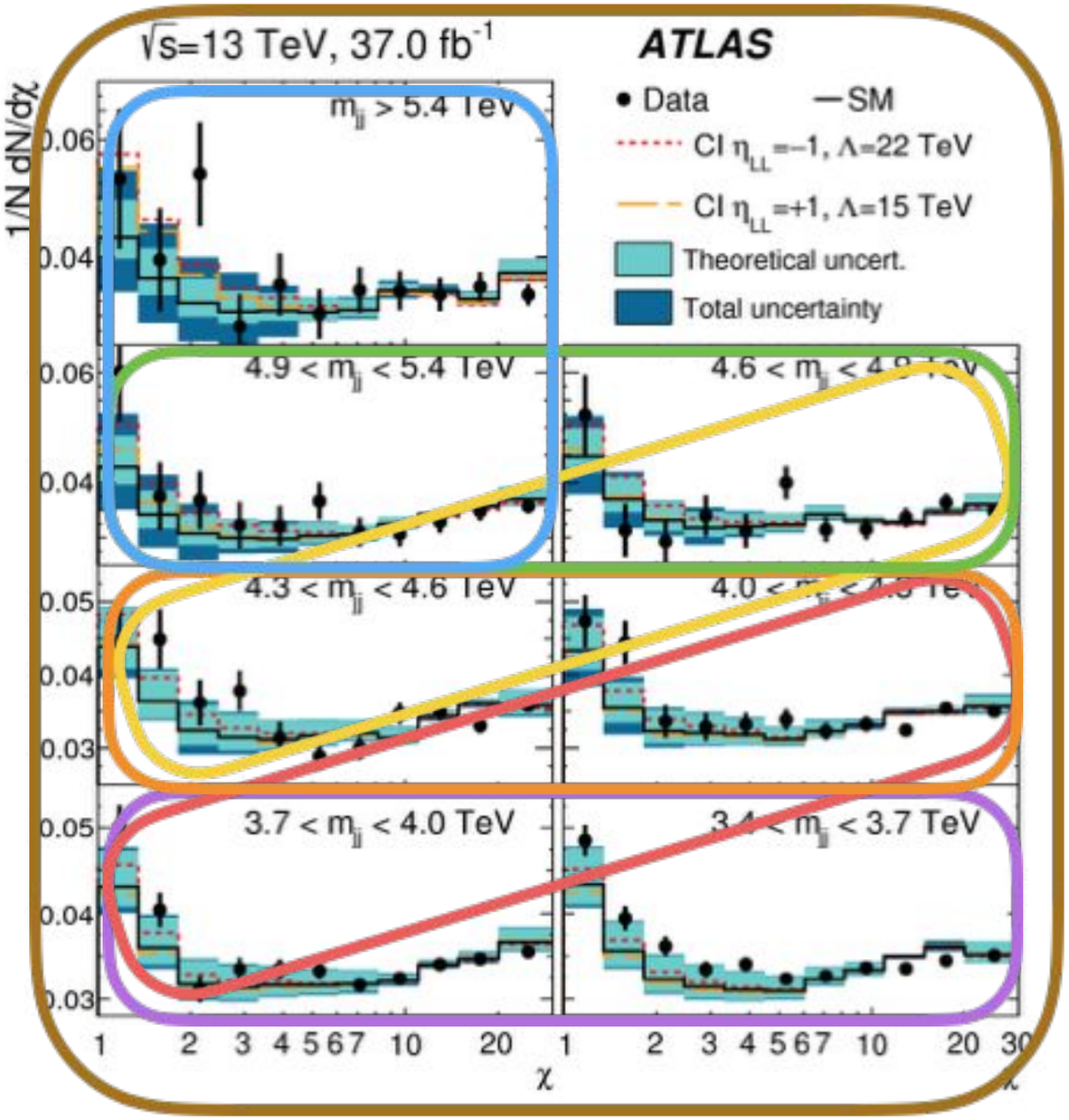
Ratio method

Dijet Angular Analysis Idea - Chained Correlations

- Instead of having **one** nuisance parameter for each uncertainty for all mjj bins

- Make **several** which are connected in a chain
  - Each nuisance parameter affect only two bins

- This way the low-mjj region will **not overconstrain** the high-mjj (signal) region

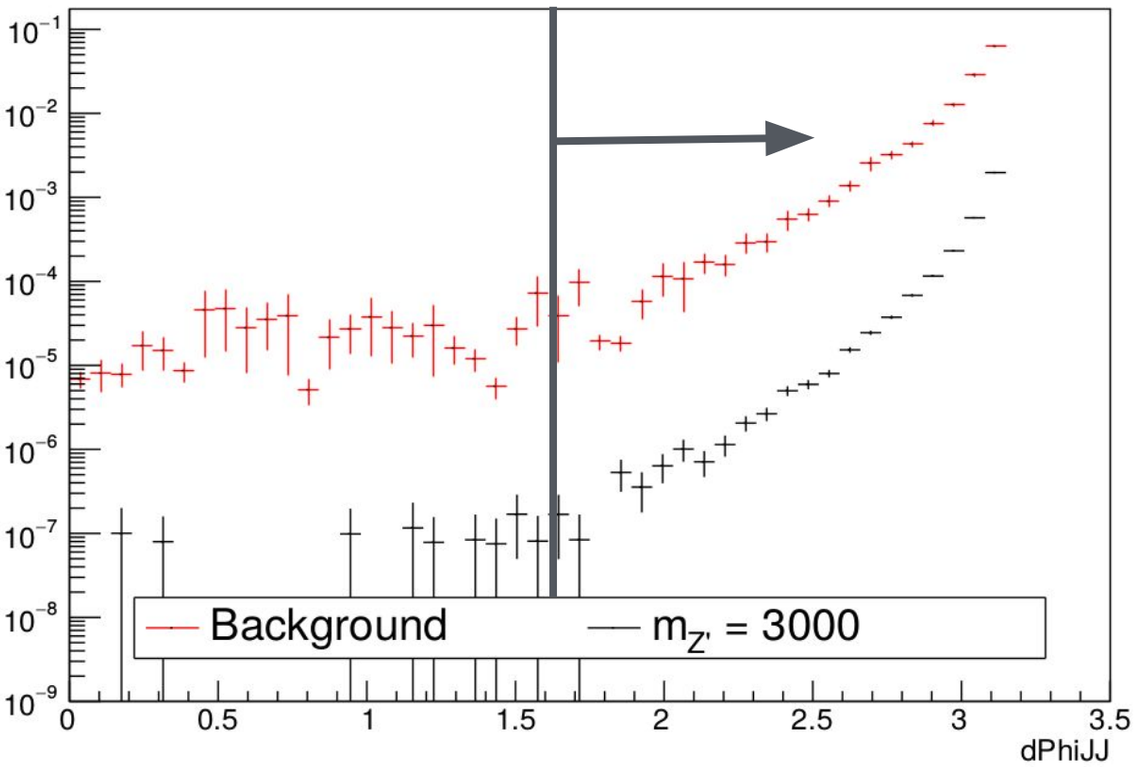


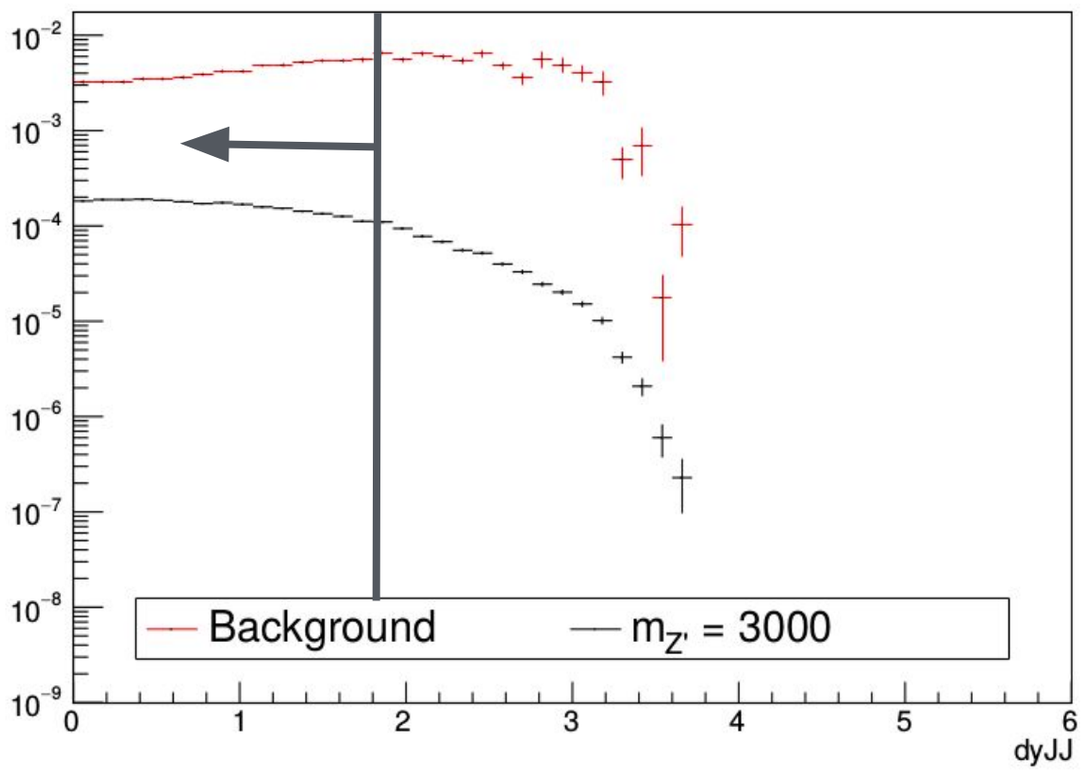
Idea from Alex Read

TTBAR RESONANCE SEARCH - WHITEBOARD INTRO

Ttbar Resonance Search

- All-hadronic ttbar resonance search: X → tt → bqq+bqq
  - **Looking for bumps** in the m(ttbar) spectrum at high mass
- Kinematic selection
  - Back-to-back jets: dphi(J1,J2) > 1.6
  - s-channel resonances: dy(J1,J2) < 1.8



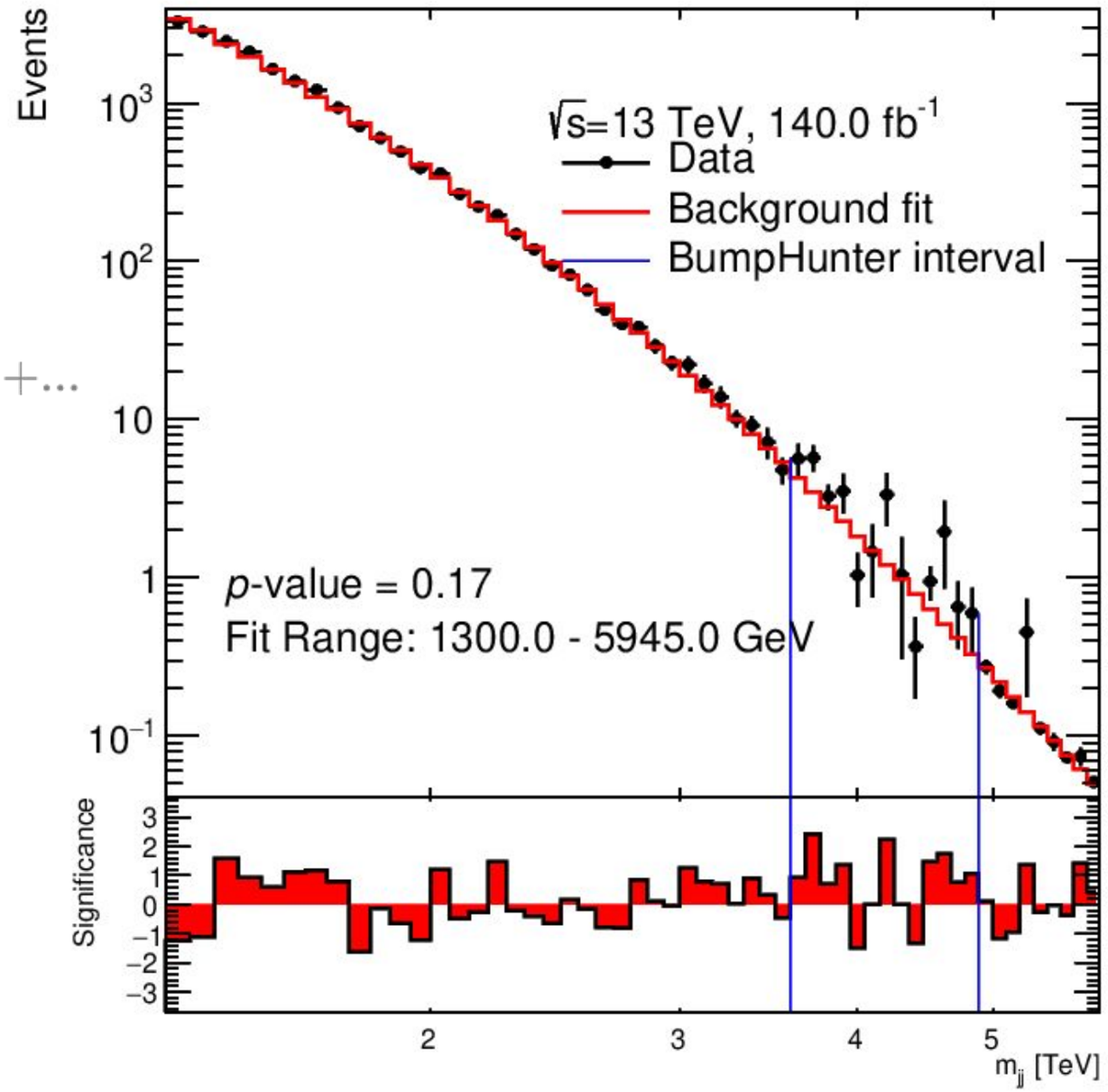


TTBAR RESONANCE SEARCH - BACKGROUND FIT

- Instead of comparing data to MC
  - Fit **smoothly falling** m_{jj} distribution with

$$f(x) = p_0(1-x)^{p_1} x^{p_2+p_3 \log x + p_4 (\log x)^2 + \ldots}$$

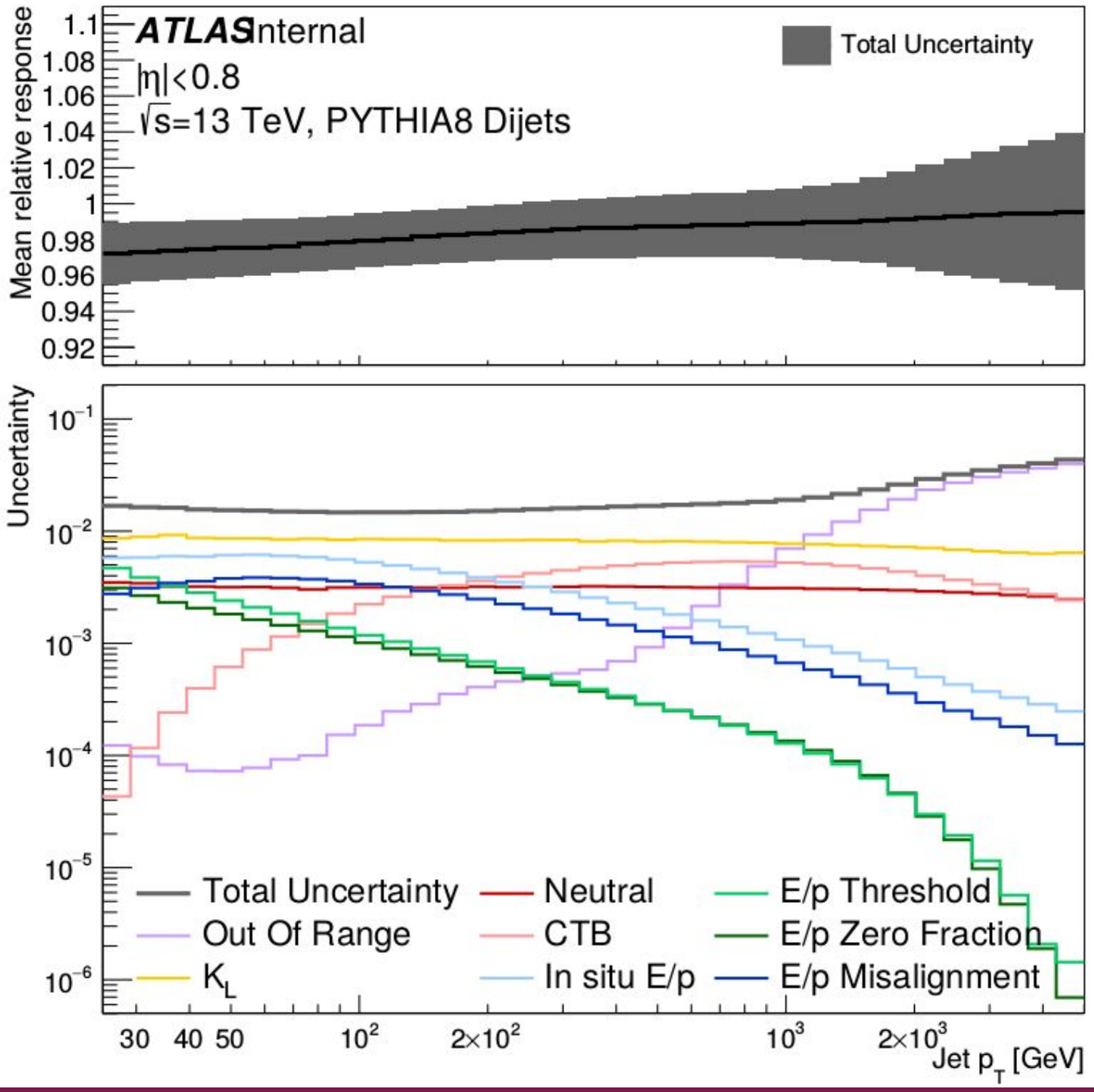
- First find baseline function by fitting **datalike** histograms made from MC
- Then **validate** on background control region
  - Inverse cut: dy(J1,J2) > 1.8



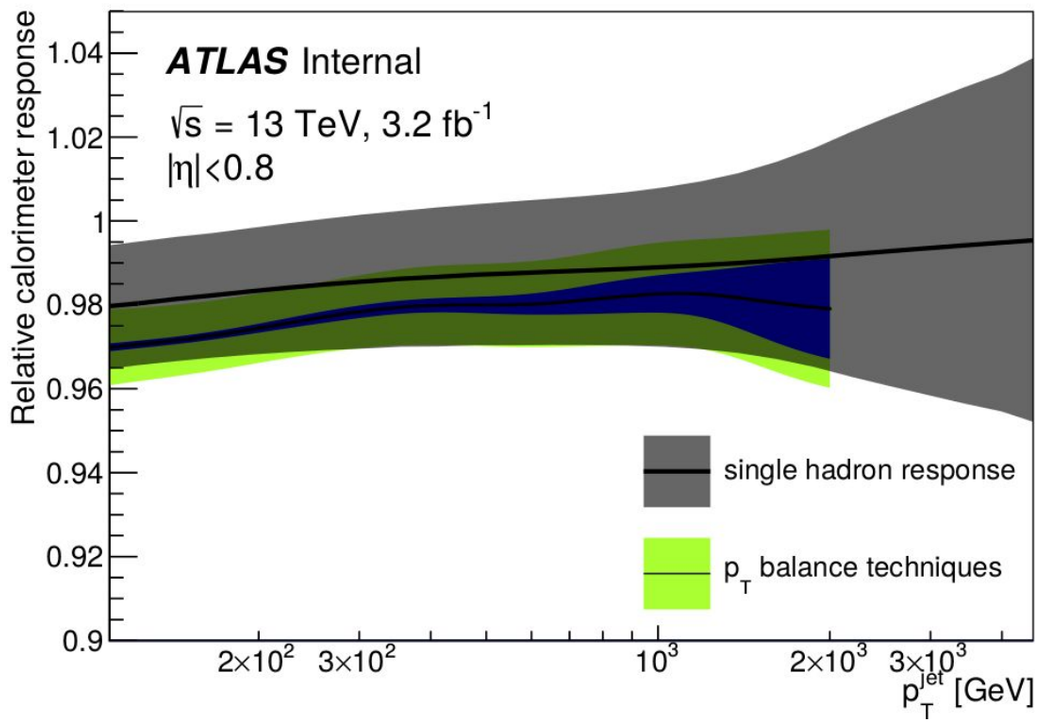
Other Projects

- Theory paper with Johan Rathsman
- **Combined Performance paper** with Millie McDonald
- Heavy Resonance Combination of ATLAS analyses
- Top tagger development with Robin Newhouse *(August)*
- Angular ttbar analysis *(Future)*

High-p_T Jet Energy Scale Uncertainty from E/p Measurements



- Intro on whiteboard



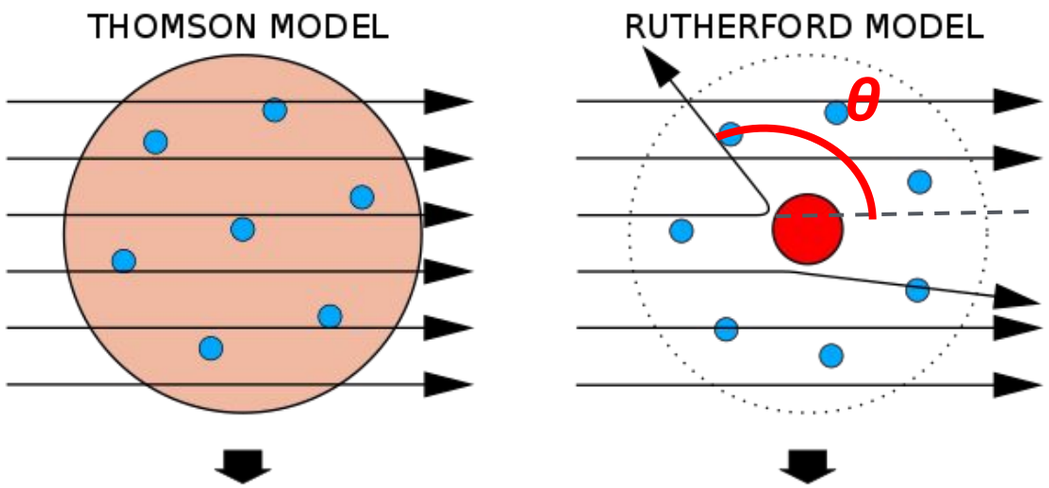
Recommendations

- Schools/Courses:
  - CTEQ/MCnet School
  - Nordic Winter School
  - Terascale Statistics School
  - Dark Matter school
  - **Introduction to High Performance Computing**
  - Learning and Teaching in Higher Education
  - **Particle Physics Phenomenology**
  - **CERN School of Computing**

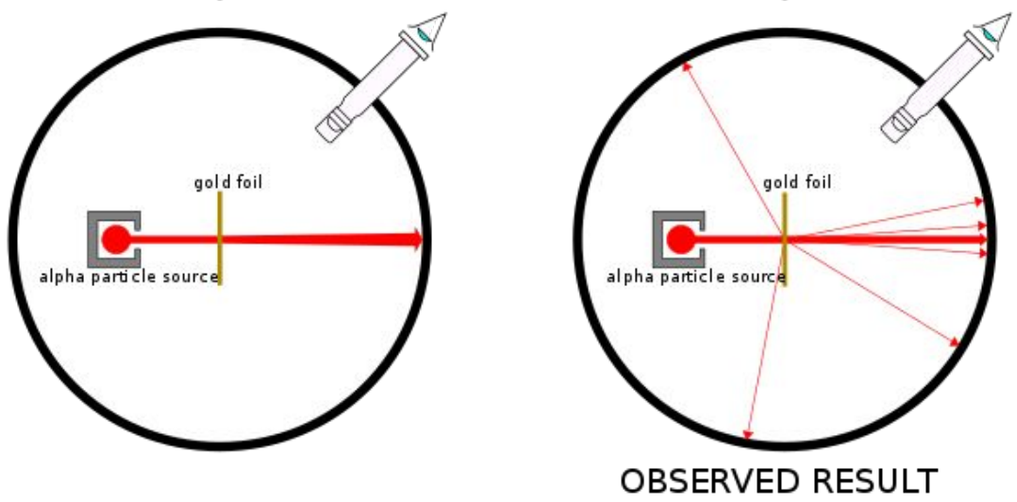
BACKUP

Introduction to Angular Analysis

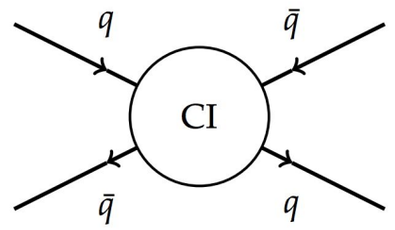
- What is an angular analysis?
  - Looking at the **angle** between **two outgoing objects** after a collision
  - In ATLAS we look at the **rapidity difference** between two leading objects



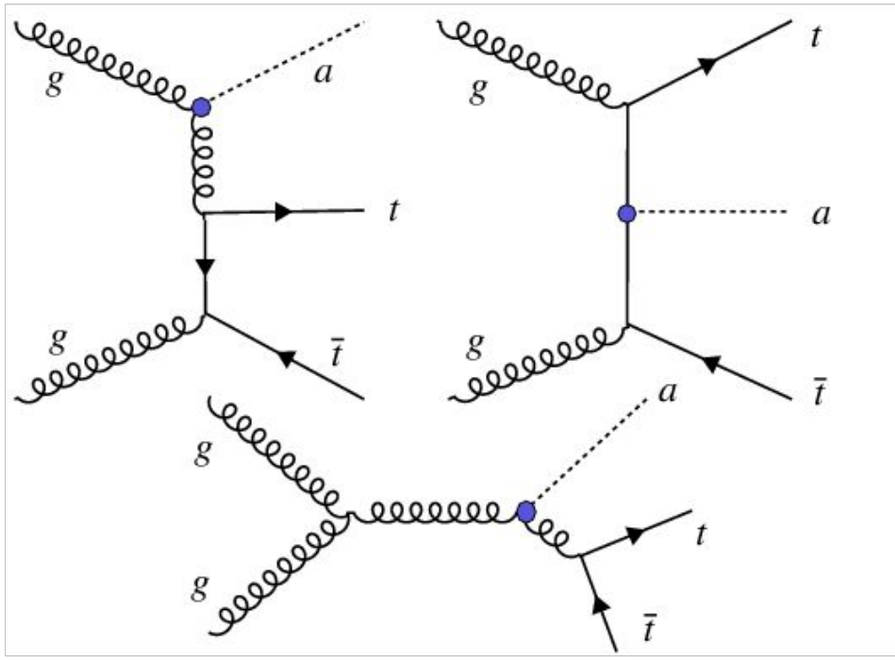
- Why do an angular analysis?
  - **Rutherford** gold foil experiment
  - Signal has a lower rapidity difference than SM interactions

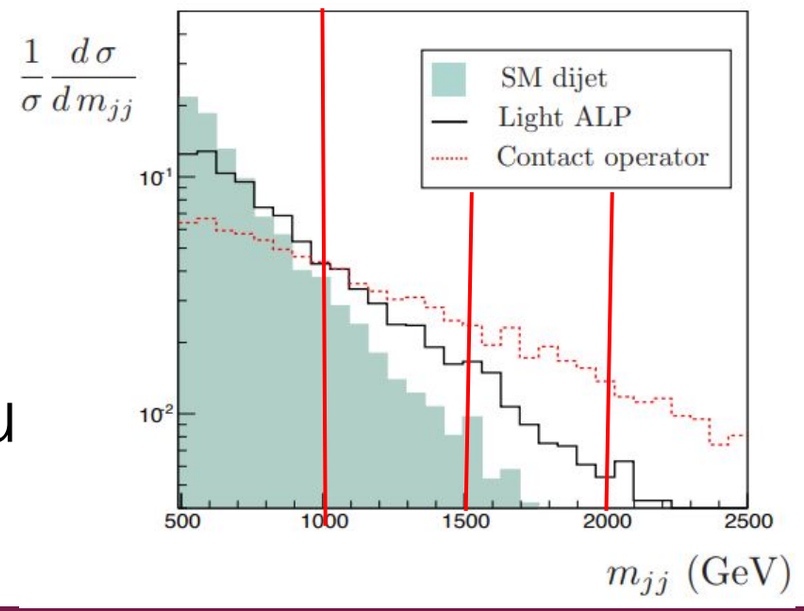


Possible signal

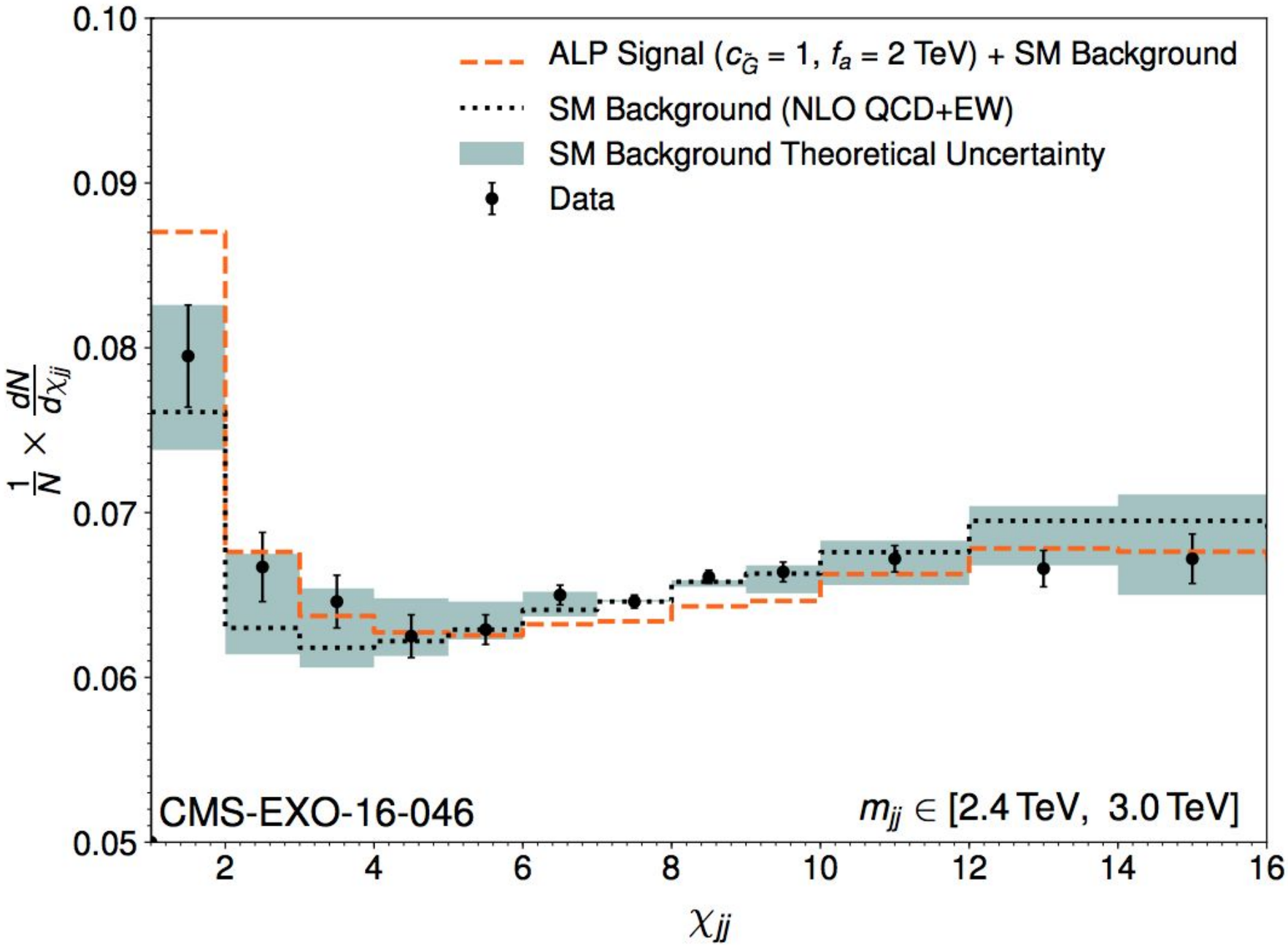


- Non-resonant signal
  - **Contact Interaction** (CI)
    - Fermion compositeness
    - Introducing scale Λ
  - **Axion-like Particles** (ALP)
    - Pseudo Nambu Goldstone bosons
    - New Probes for Axion-like Particles at Hadron Colliders
    - Non-Resonant Searches for Axion-Like Particles at the LHC
- Resonances
  - Narrow: Complementary to bump hunting
  - Broad: Difficult to do model-independent bu



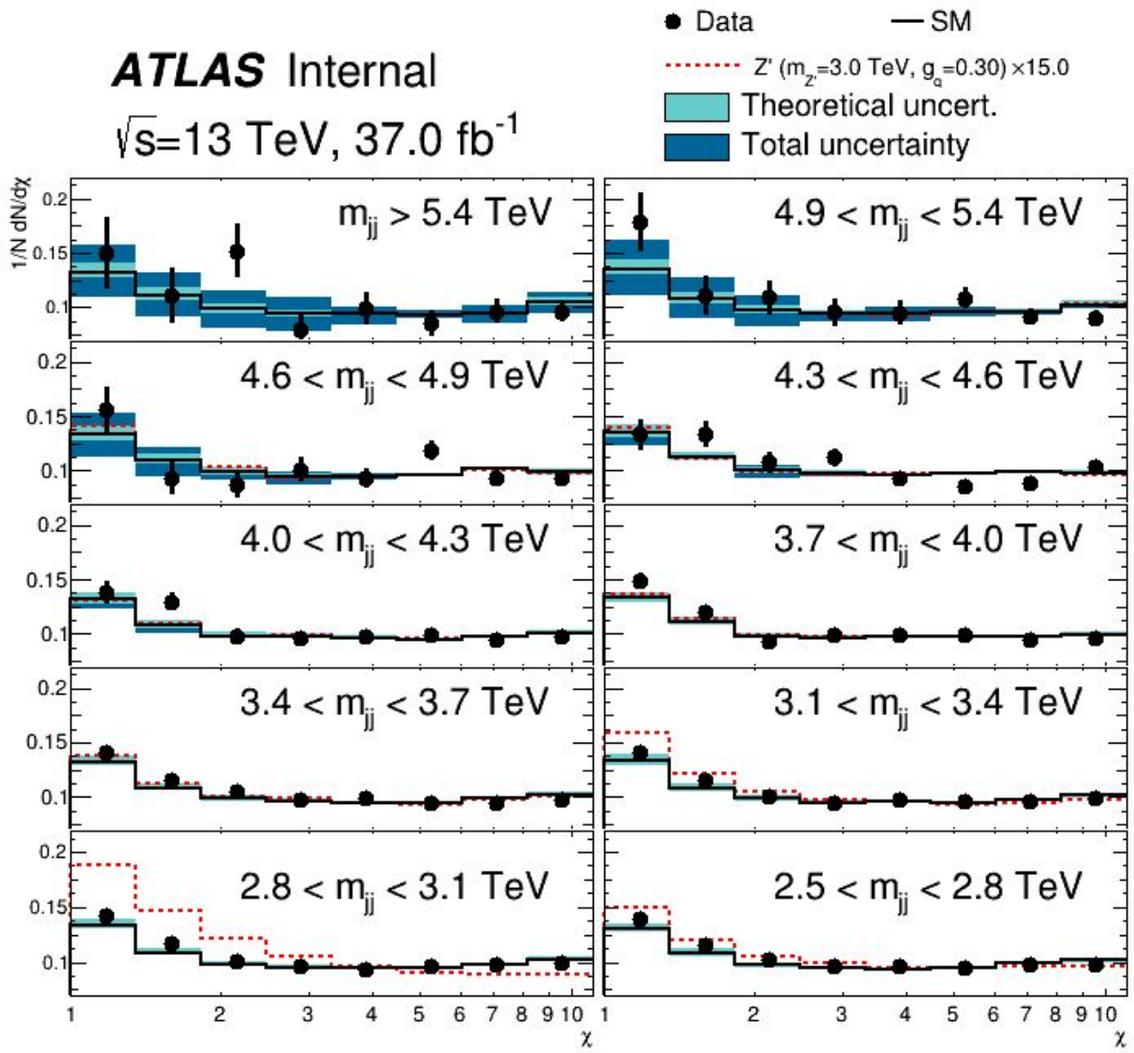


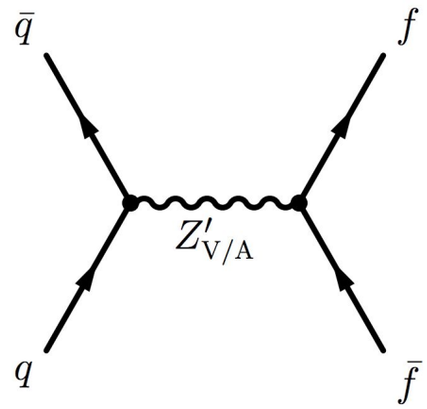
ALP SIGNAL COMPARED TO CMS ANGULAR DIJET



Dijet Angular Analysis - Recast for DM

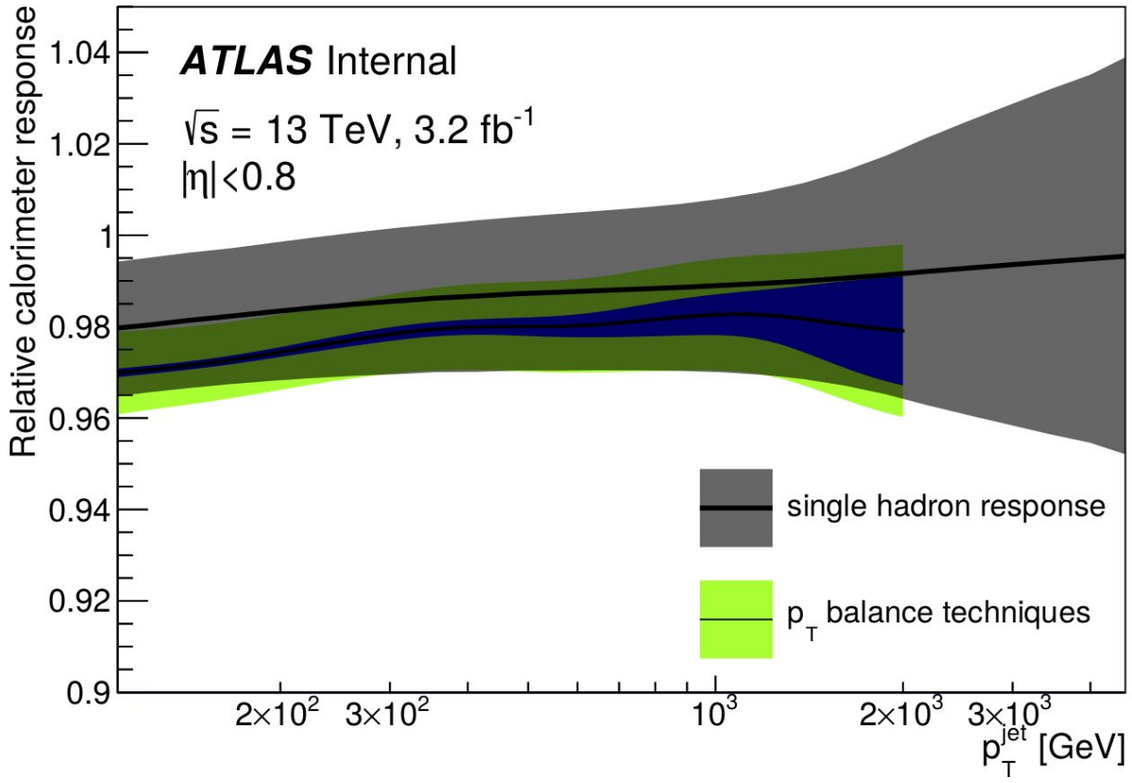
- The mjj threshold was lowered to study **Dark Matter Z' model**
- The χ **range** was **reduced** to avoid tensions due to
  - discrepancy in high stat. bins (low mjj)
  - assuming correlation over whole mjj range





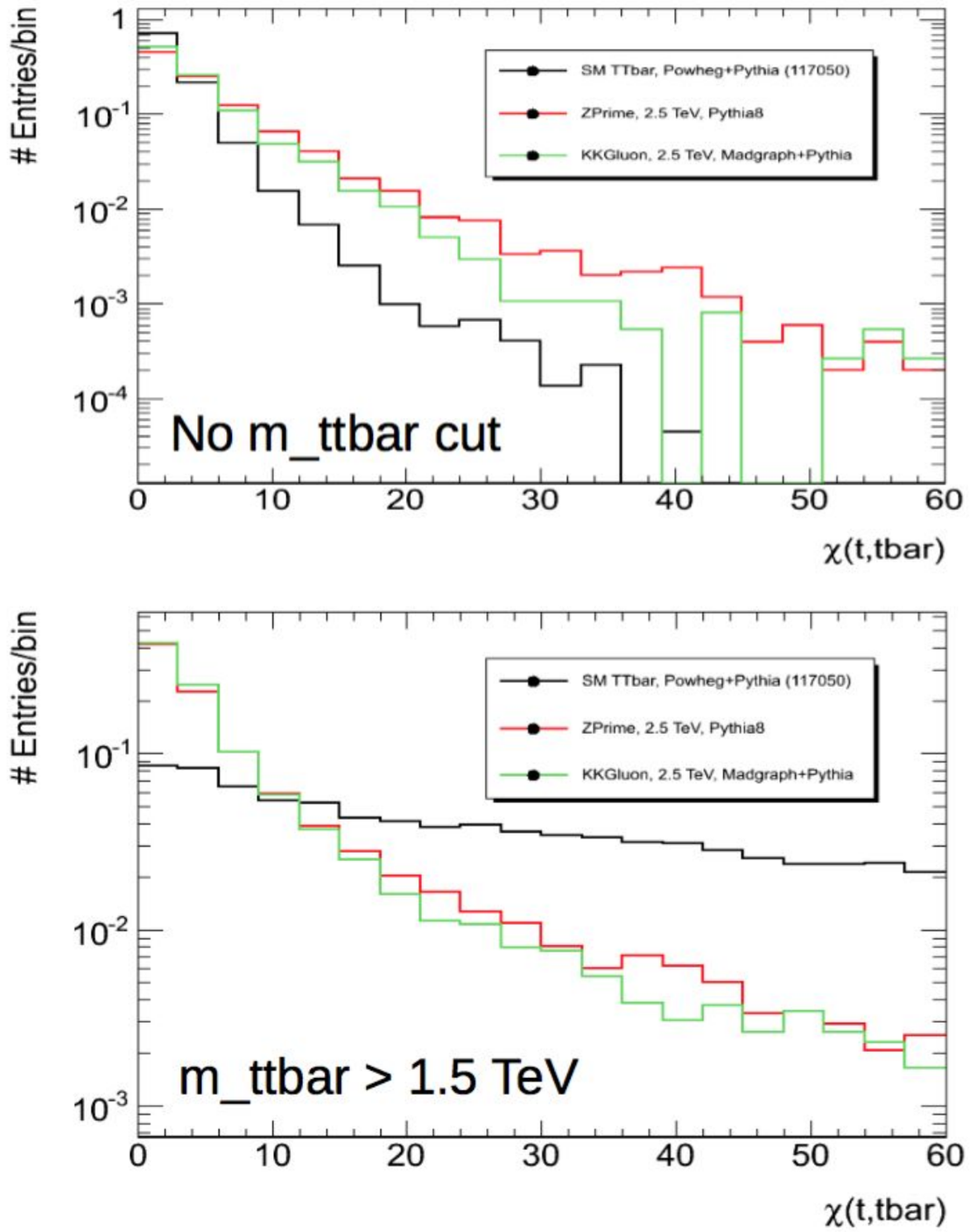
Other Ideas For Dijet Angular Analysis

- Use NLO **PowhegPythia** samples
  - Include PowhegPythia weights for pdf/scales/tune systematic variations
- Performance work
  - Include **high-pt single particle term** in combination
- Use **ratio information** as a ShapeFactor in HistFactory
- **Unfold** angular distributions
- **Data driven** approach



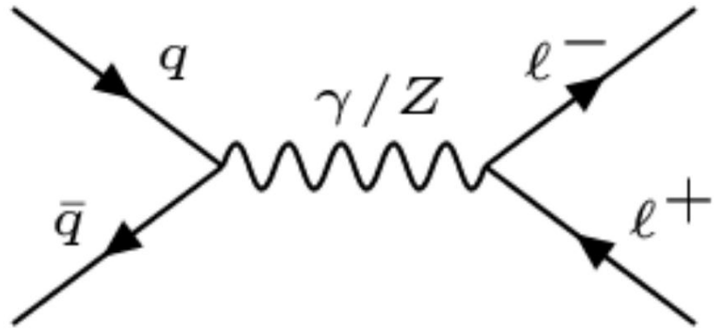
TTBAR ANGULAR ANALYSIS

- Apply methods from dijet angular analysis to ttbar events
- **8 TeV study** by Katharina Behr
  - Only **feasible** when looking at **high mass** resonances (>3TeV)
    - SM ttbar **t-channel** dominated
- Need to **redo study** with full Run 2 dataset



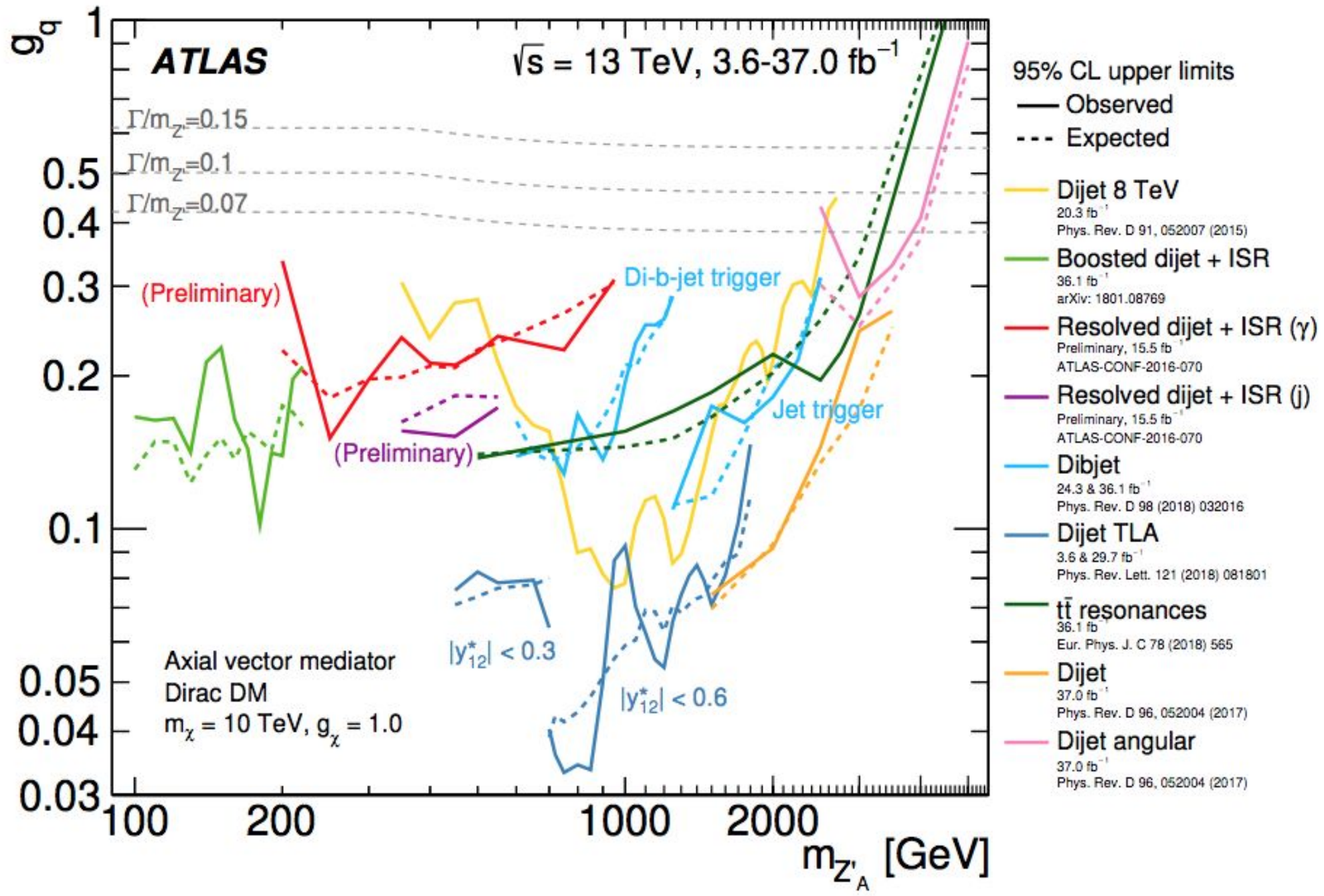
Other Angular Analyses

- Di-lepton
  - LPX wants to see if **angular di-lepton** analysis can help the **Contact Interaction search**
  - No dedicated study in Run 2 so far
  - Different from dijet search since all backgrounds come from **s-channel** (large t-channel contribution in dijets)



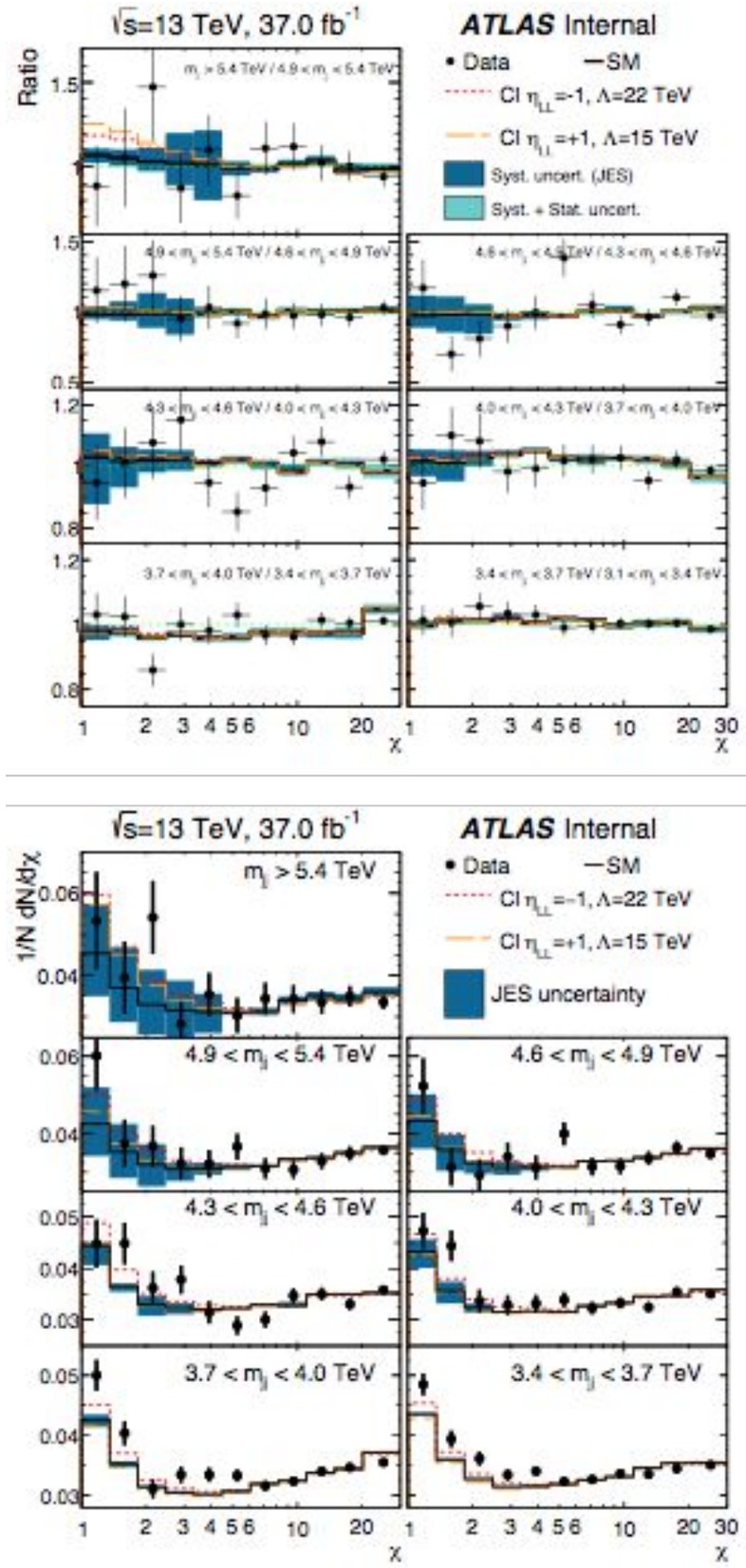
- Dibjet
  - **B-tagging** improve sensitivity for resonances
  - Never investigated
- Di-tau

DM SUMMARY PAPER



"By-hand" calculations

- Calculate expected significance in each bin
  - Signal / Total uncertainty
    - Total uncertainty is the quadrature sum of the statistical uncertainty on the data and the JES uncertainty (symmetrized)
    - Correlation between different bins is not accounted for
  - Result for two highest mjj bins:
    - Original: **1.25σ** (compared to 1.22σ (HistFactory))
    - Ratio: **1.08σ**
  - Result for all mjj bins:
    - Original: **2.52σ**
    - Ratio: **1.18σ**
- Further tests: Include all uncertainties



Pre-fit vs Post-fit