Search for X-> H/W/Z+γ in p p collisions at sqrt(s) = 13 TeV with the ATLAS detector

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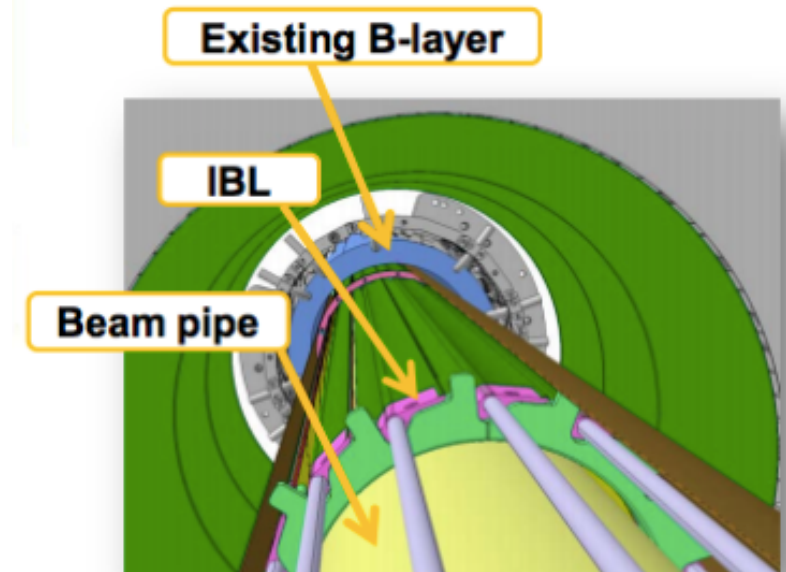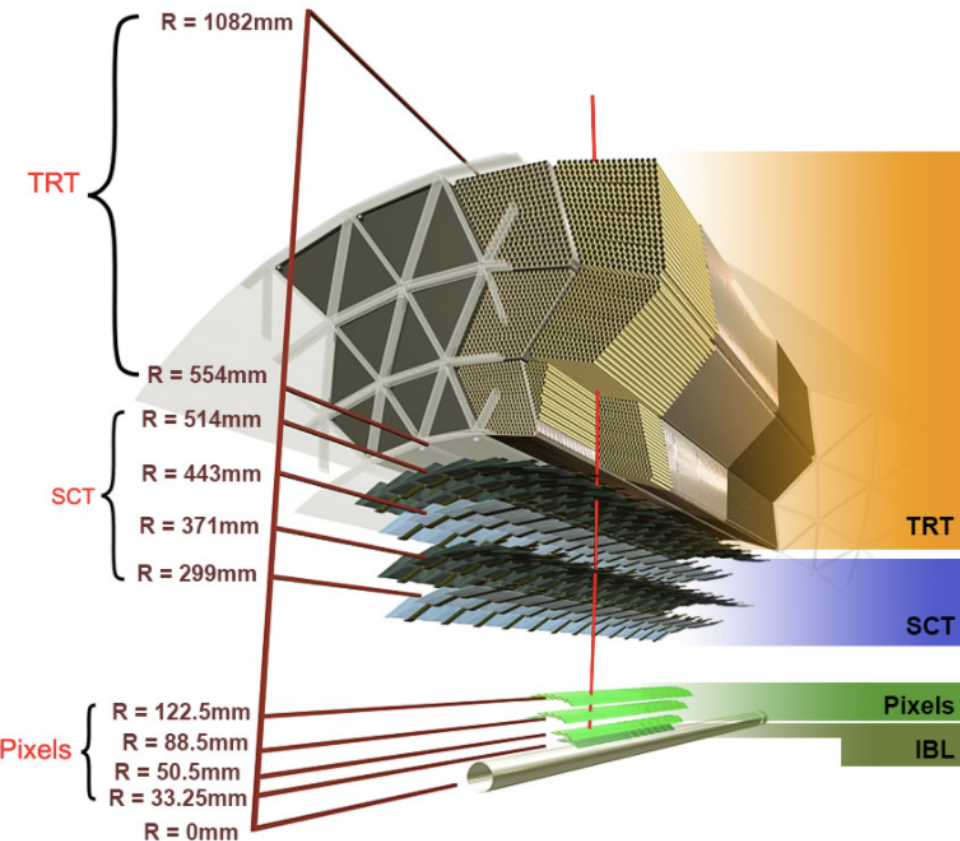
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Outline

- **ATLAS detector and B tagging performance in run 2**

- **Search for SM VBF H(bb)+γ production**

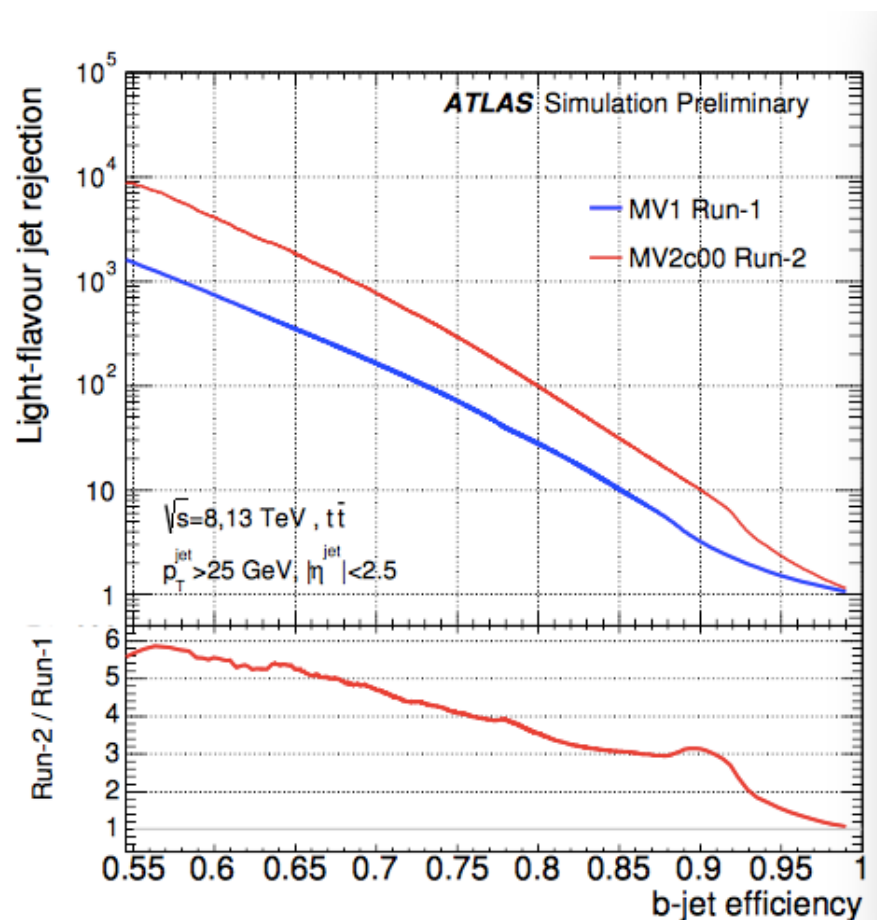- **Search for Exotics X-> H(bb)+γ production and X-> W/Z+ γ production**

# ATLAS Detector phase 0 upgrade from run 1 to run 2

- IBL = New Insertable pixel B-Layer at R=33 mm

R = 1082mm
TRT
R = 554mm
R = 514mm
R = 443mm
SCT
R = 371mm
R = 299mm
TRT
SCT
Pixels
IBL
Pixels
R = 122.5mm
R = 88.5mm
R = 50.5mm
R = 33.25mm
R = 0mm

Existing B-layer

IBL

Beam pipe

b quark jets in ATLAS (2)

- Light jet rejection power increases by a factor of 10 in run 2
- Two ways to Identify b jets
  - impact parameters
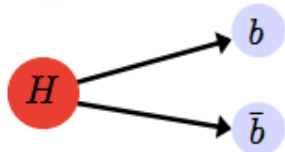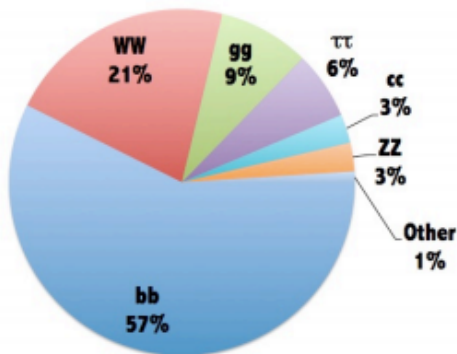 - secondary vertex from B decay
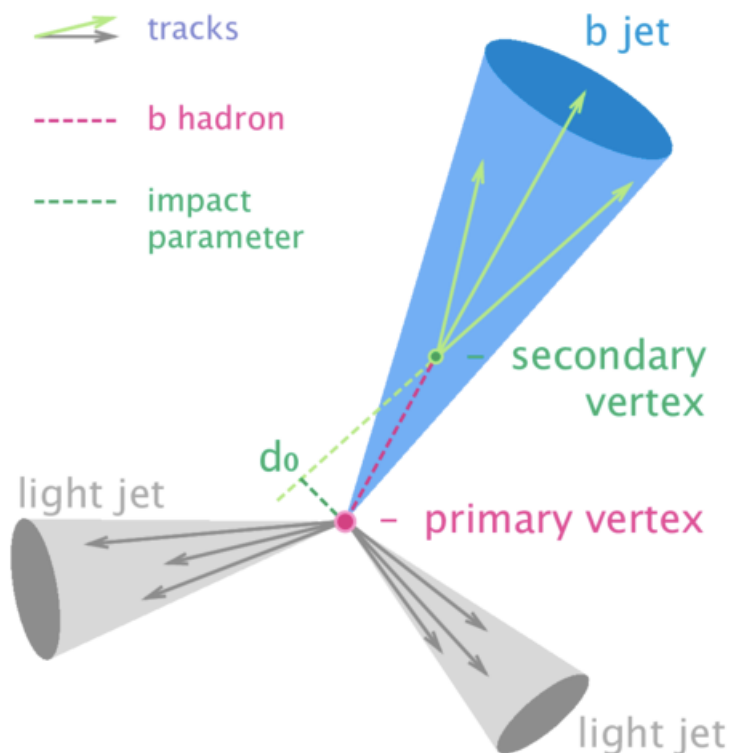
- **ATLAS detector and B tagging performance in run 2**
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- **Search for Exotics X-> H(bb)+γ production and X-> W/Z+ γ production**
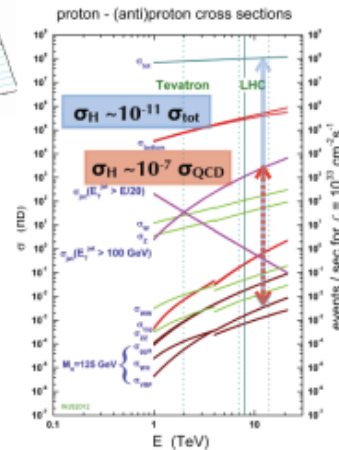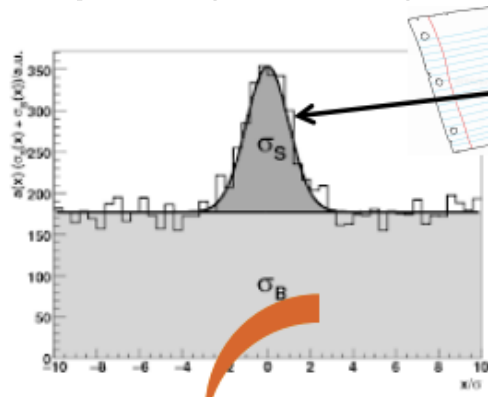
Search for SM VBF H(bb)+γ

- **Motivation: Search H→bb decay mode**
  - largest branching ratio (~58%), not confirmed yet
    - VHbb ATLAS (3.5σ), CMS (3.8σ).

**Higgs decays at m$_H$=125GeV**

$$m_H = \sqrt{(p_b + p_{\bar{b}})^2}$$

Need to reconstruct an individual quark
Need to identify the flavor of the quark
SM background is 10 orders of
magnitude higher

Search for SM VBF H(bb)+γ(2)

- Motivation2: background for X->H(bb)+γ search
- Benefit from high energy photon final state
  - Photon is easy to trigger
  - suppresses QCD background
  - IHEP group play proposed photon channel and design dedicated trigger. (γ+4jets triggers)
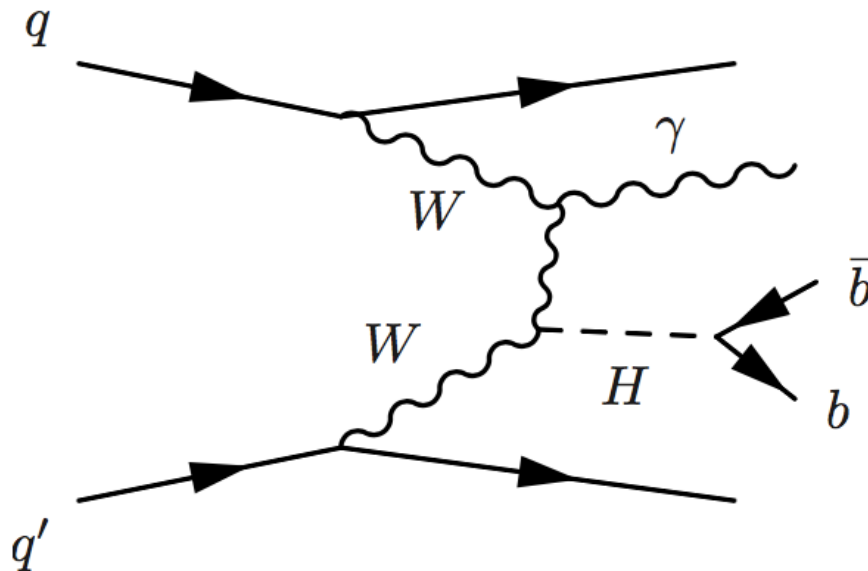
Results of VBF H(bb)+γ (30 fb^{-1} ,13TeV)

- Observed significance: **1.9σ (μ= 3+-1.7)**

  – **Analysis sensitivity dominated by the photon channel.**

  – **More details in Liaoshan Shi's poster.**

- **Dominant uncertainty from data statistics**

  – **Expect significant improvement with full run-2 data.**
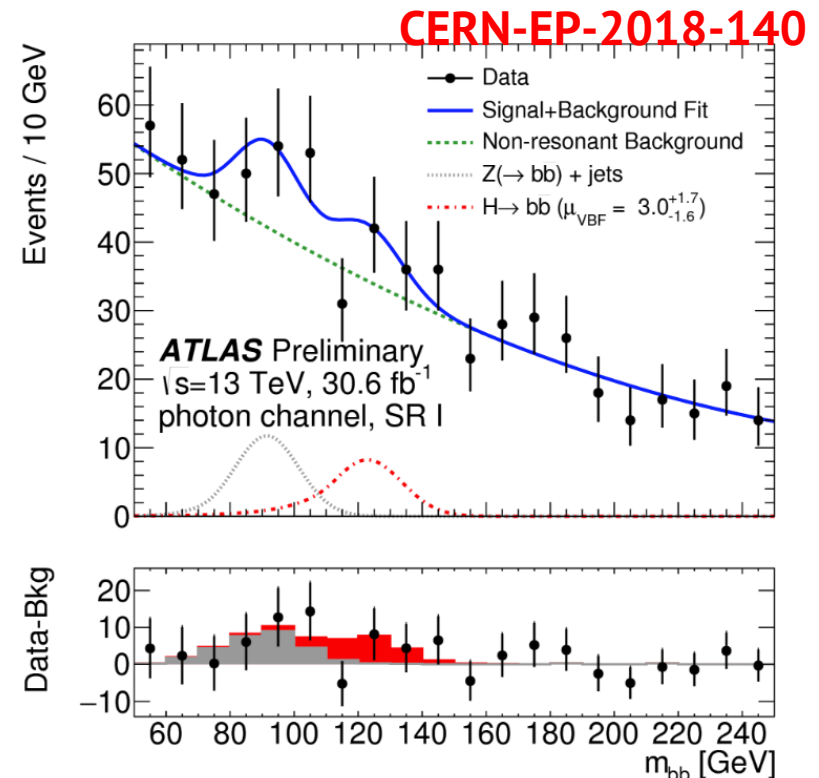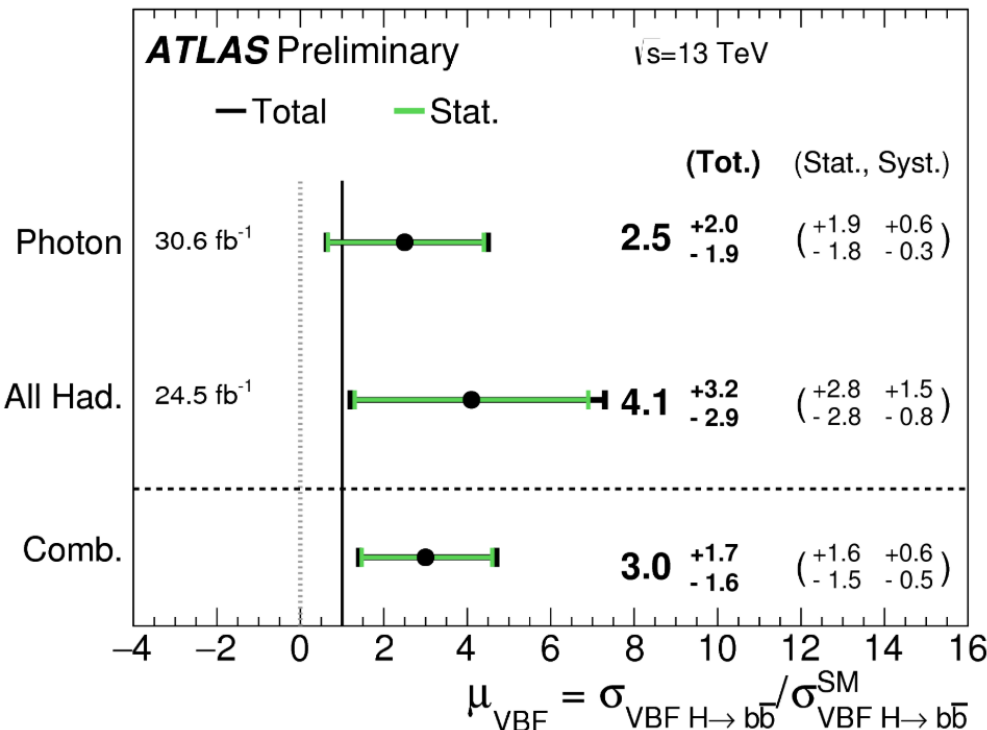
CERN-EP-2018-140

- **ATLAS detector and B tagging performance in run 2**
- **Search for SM H(bb)+γ production**
- **Search for Exotics X-> H(bb)+γ production and X-> W/Z+ γ production**

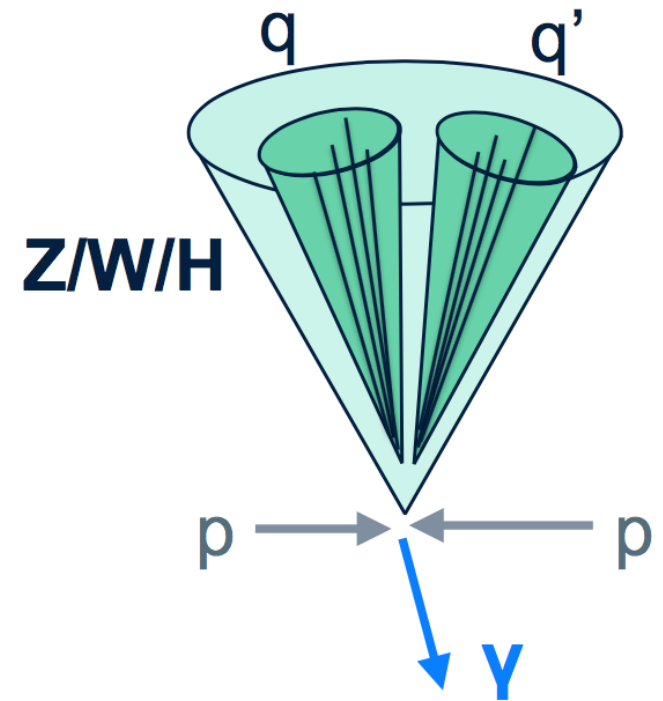# Introduction search for X-> Hγ
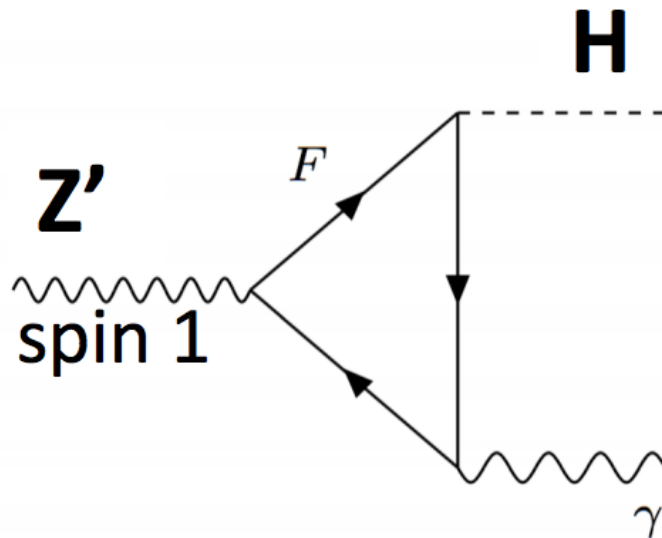
- **Motivation**
  - Search for anomalous magnetic moments of H (or W/Z)
    - ❑ More W/Z anomalous coupling will be covered Dr. Shu Li tomorrow
  - Several models predict a new massive scalar decaying into Hγ
- **Event selection :**
  - boosted jet (b tagging)   -- from H, W or Z decay
  - high pT γ (pT>250GeV)
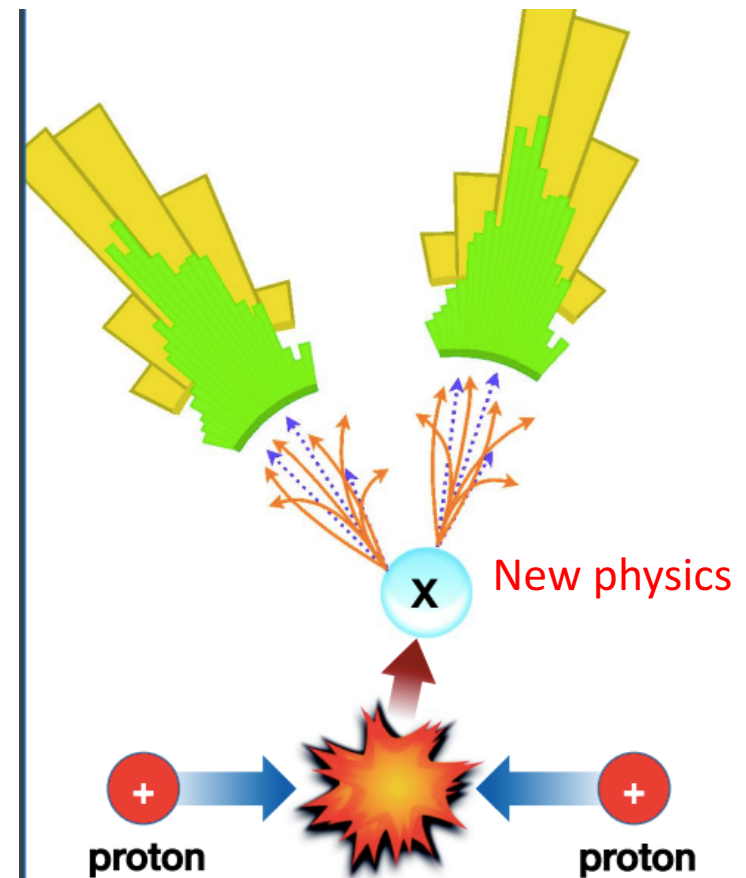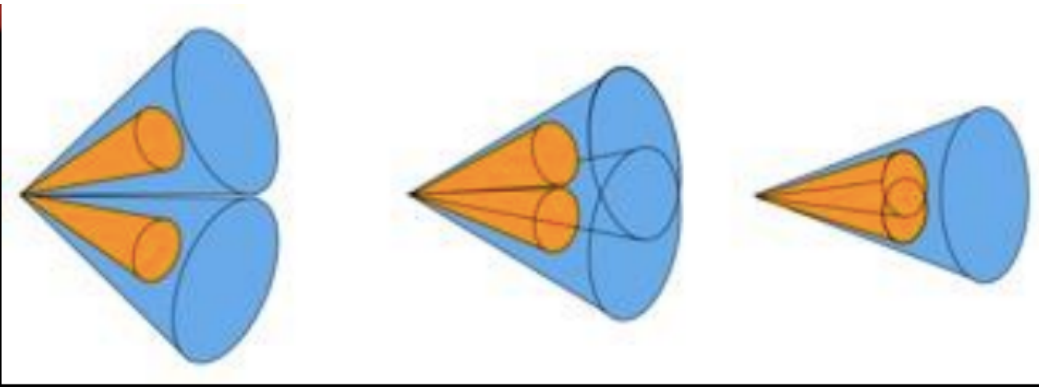- **The main background**
  - γ +jets
  - Hγ
 - Hγ

Key issue in search for TeV new physics

- Two b jets from boosted Higgs decay merge into one
- Difficult to reconstruct Higgs boson in jet final state
- Two new analysis technique used in this analysis
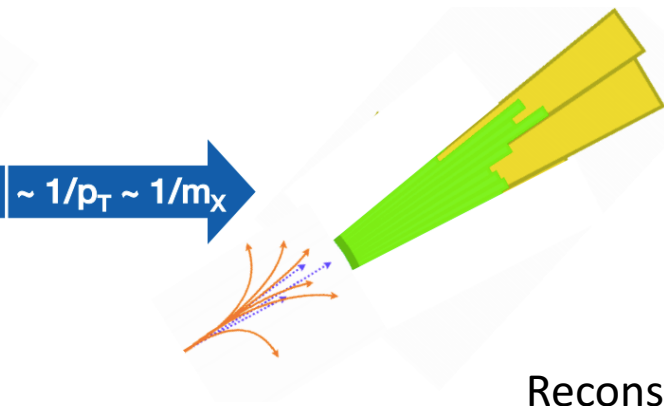 - **B tagging on track jets**
  - **Jet substructure**

New physics

X

proton   proton

Jet Substruture

Jet substructure crucial tool for:

- Inclusive search for and measurement of H→bb in boosted regime.
- Searches for heavy (>1 TeV) resonances decaying to SM-bosons, or top-quarks.
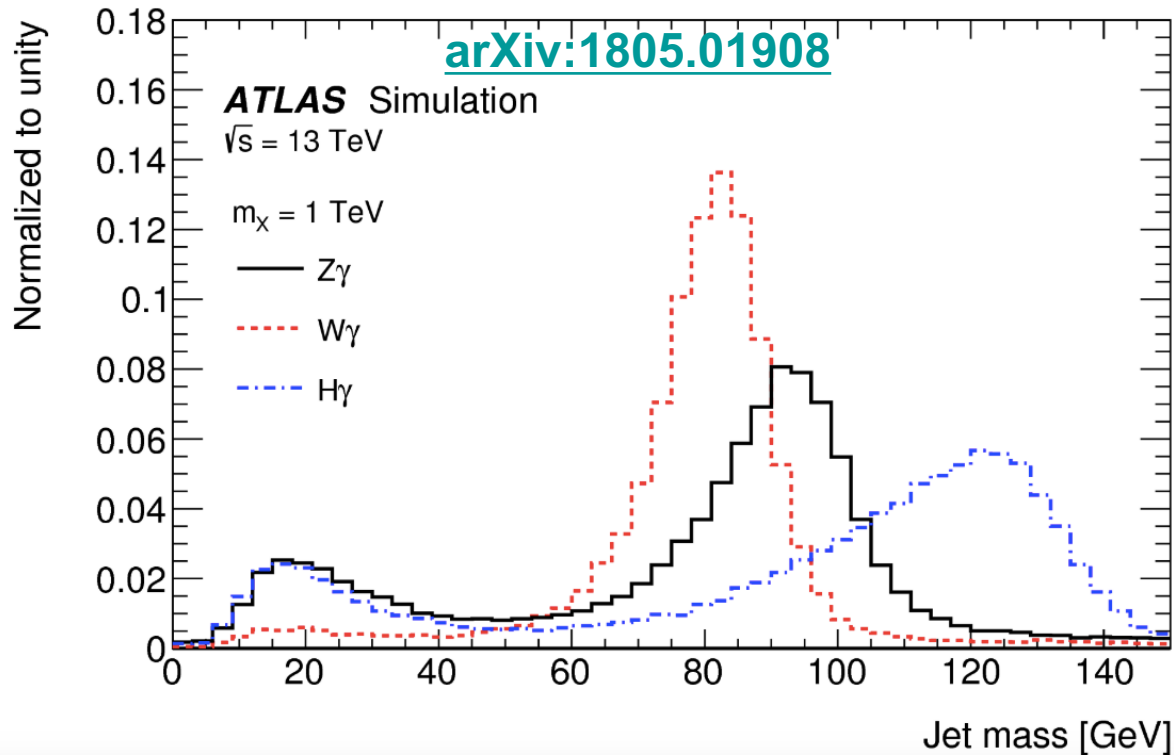- Precision measurements of SM in extreme phase-spaces.

γ

γ

X

H

two-prong structure (D_2)
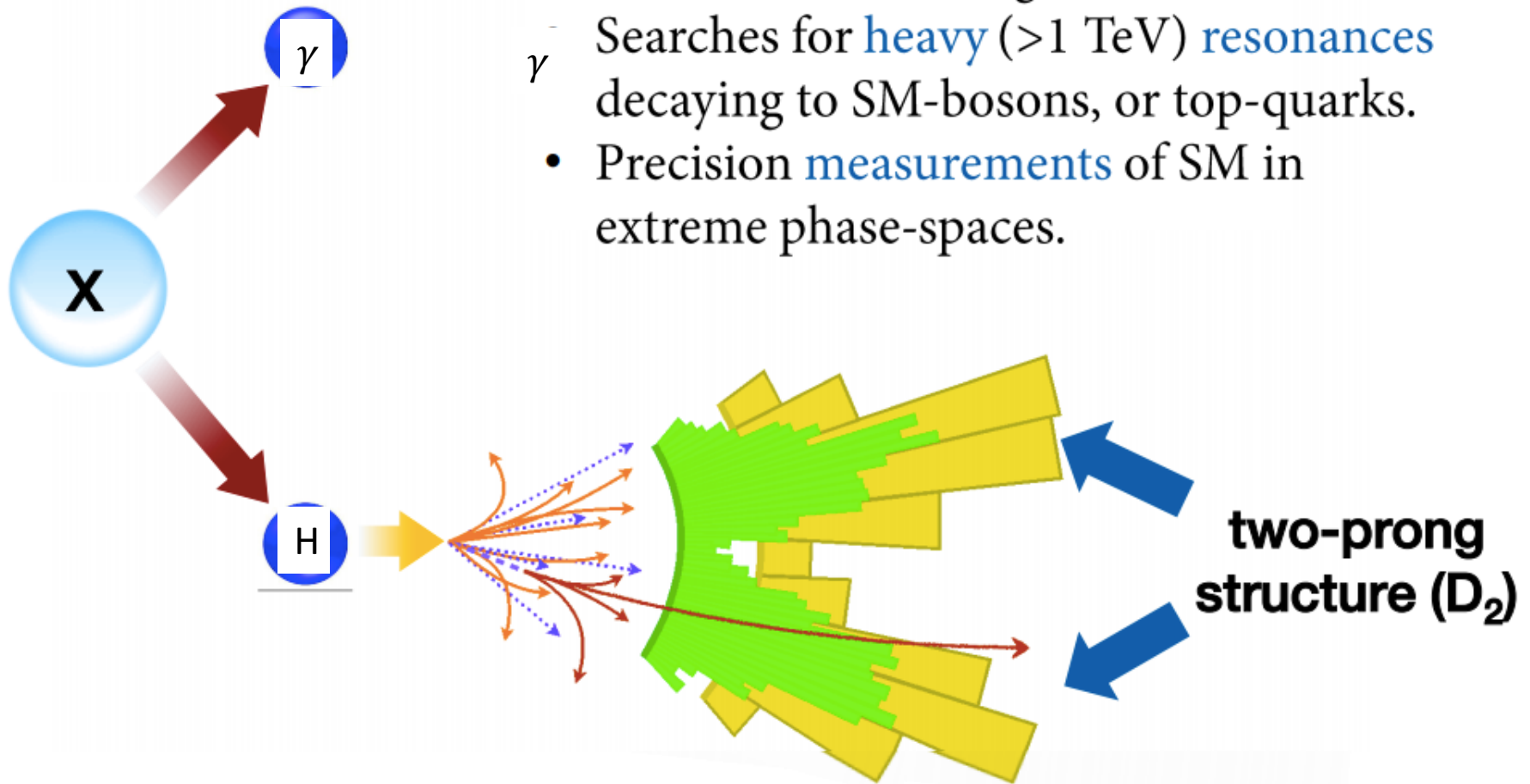
Jet mass

jet mass:

$$m^{calo} = \sqrt{\left(\sum_{i \in J} E_i\right)^2 - \left(\sum_{i \in J} \vec{p}_i\right)^2}$$

~ 1/p$_T$ ~ 1/m$_X$

Reconstructed boosted H, Z and W boson

arXiv:1805.01908

ATLAS Simulation
$\sqrt{s}$ = 13 TeV

m_X = 1 TeV

—— Zγ

- - - Wγ

-·-·- Hγ

Normalized to unity

Jet mass [GeV]

13

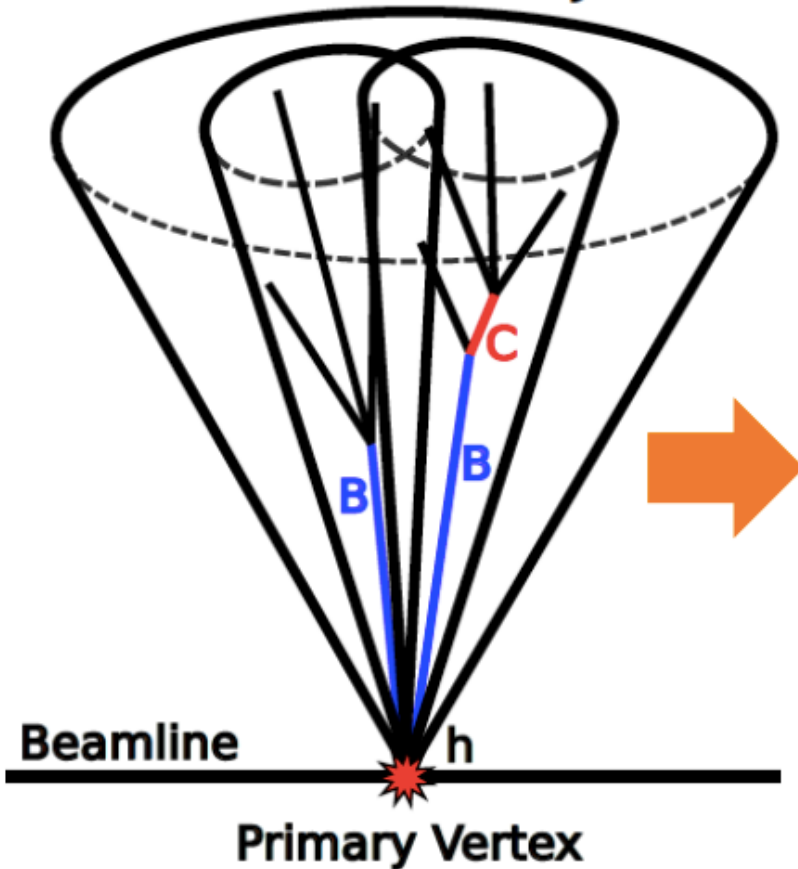# B tagging on track jet

- B tagging based on track jet

Track jets overlapping for Higgs with very high momentum

R=0.2 Track Jets

Beamline   h

Primary Vertex

Significant efficiency loss for resonance with higher mass

arXiv:1805.01908
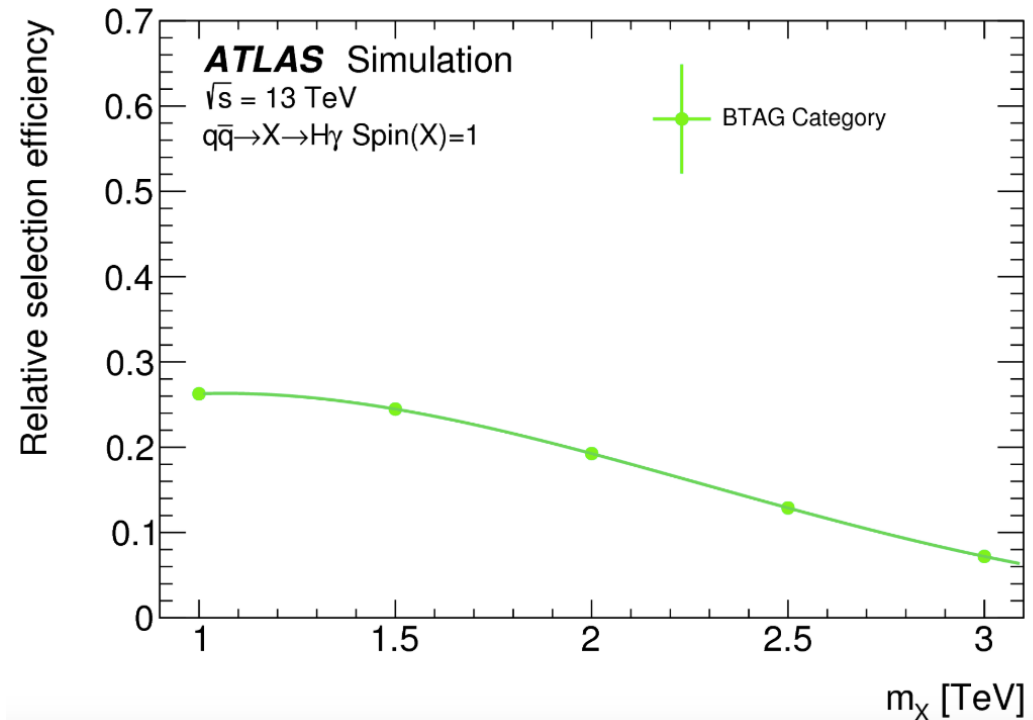
Limit setting of X-> Hγ search

- Use analytic function to fit fast falling background from
  - γjets, Zγ, SM VBF Hγ
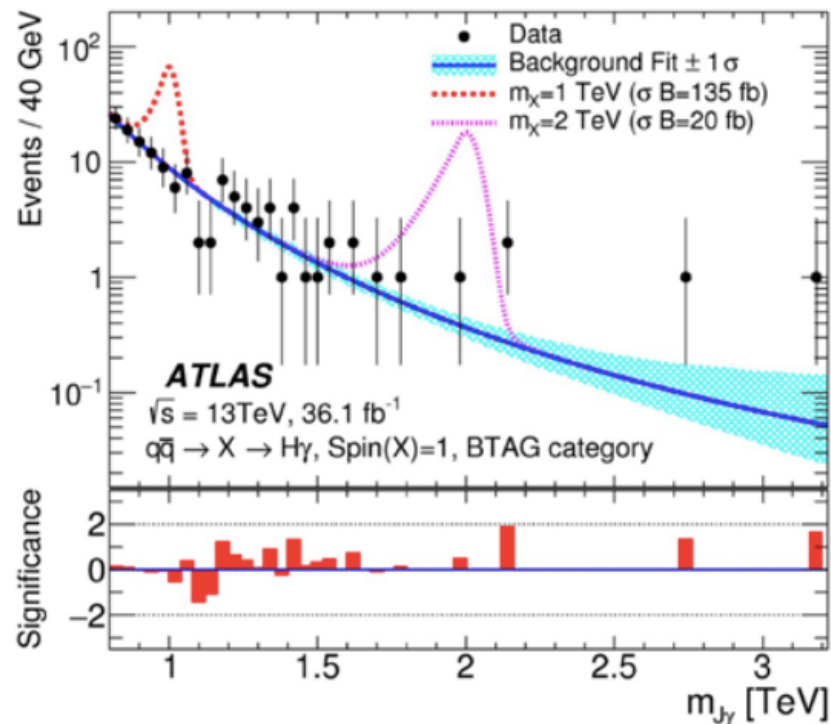- The first X-> Hγ limits (from 1TeV to 3TeV)

arXiv:1805.01908
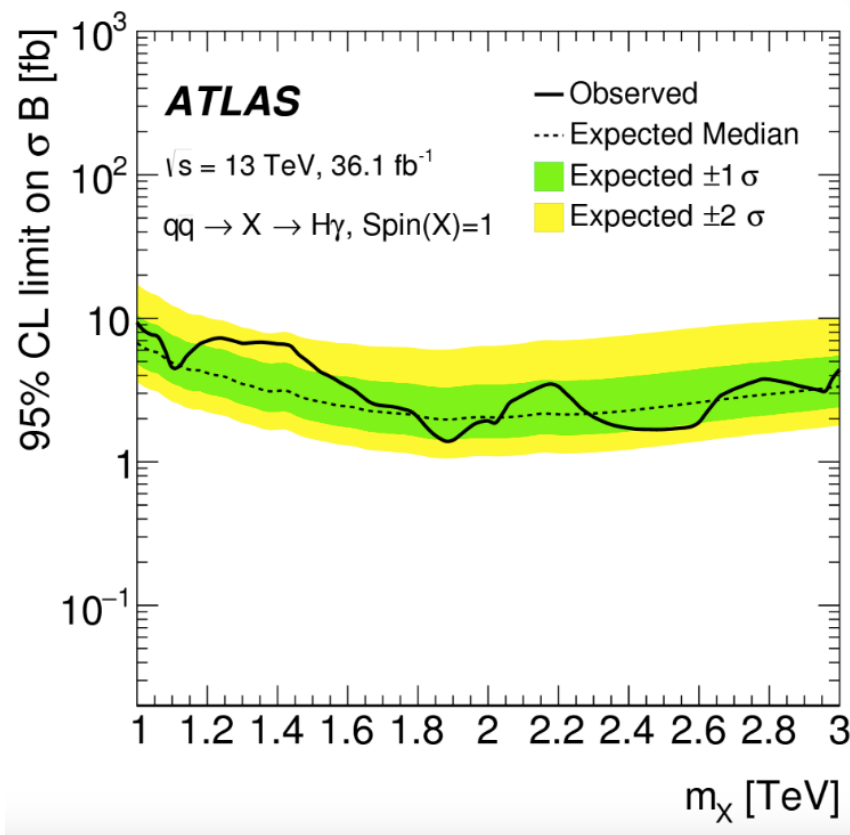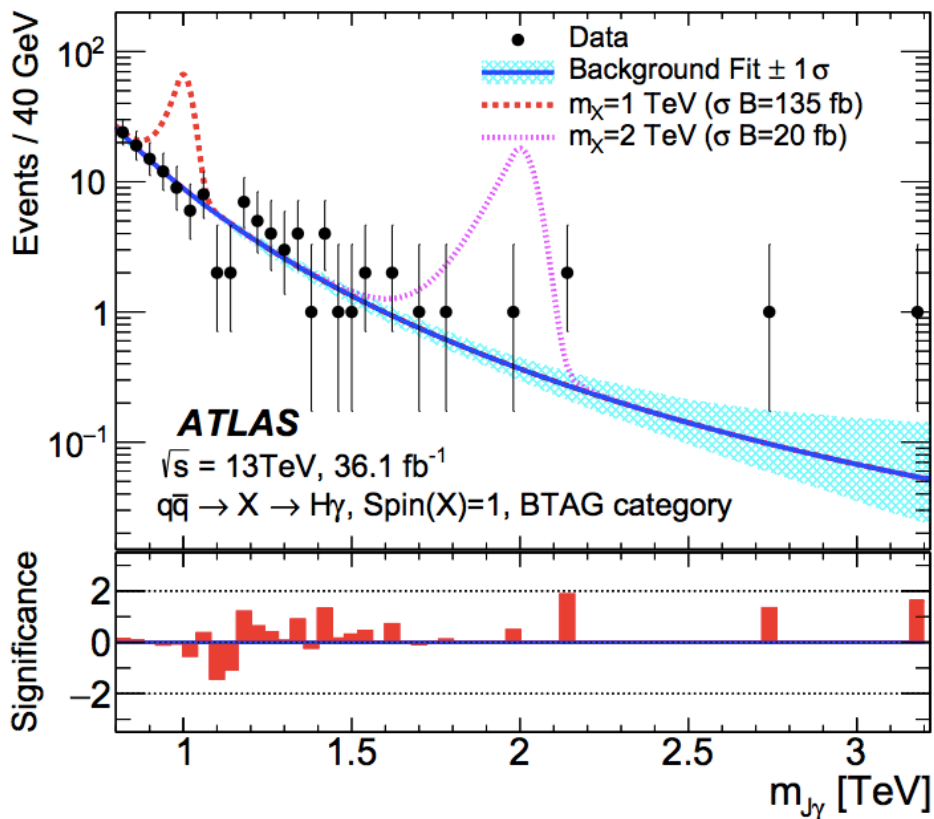
Result of X->H+γ search

- IHEP/TDLI played a leading role in this analysis
- First H+γ search Highlight by ATLAS experiment in LHCC open section (May 30,2018)
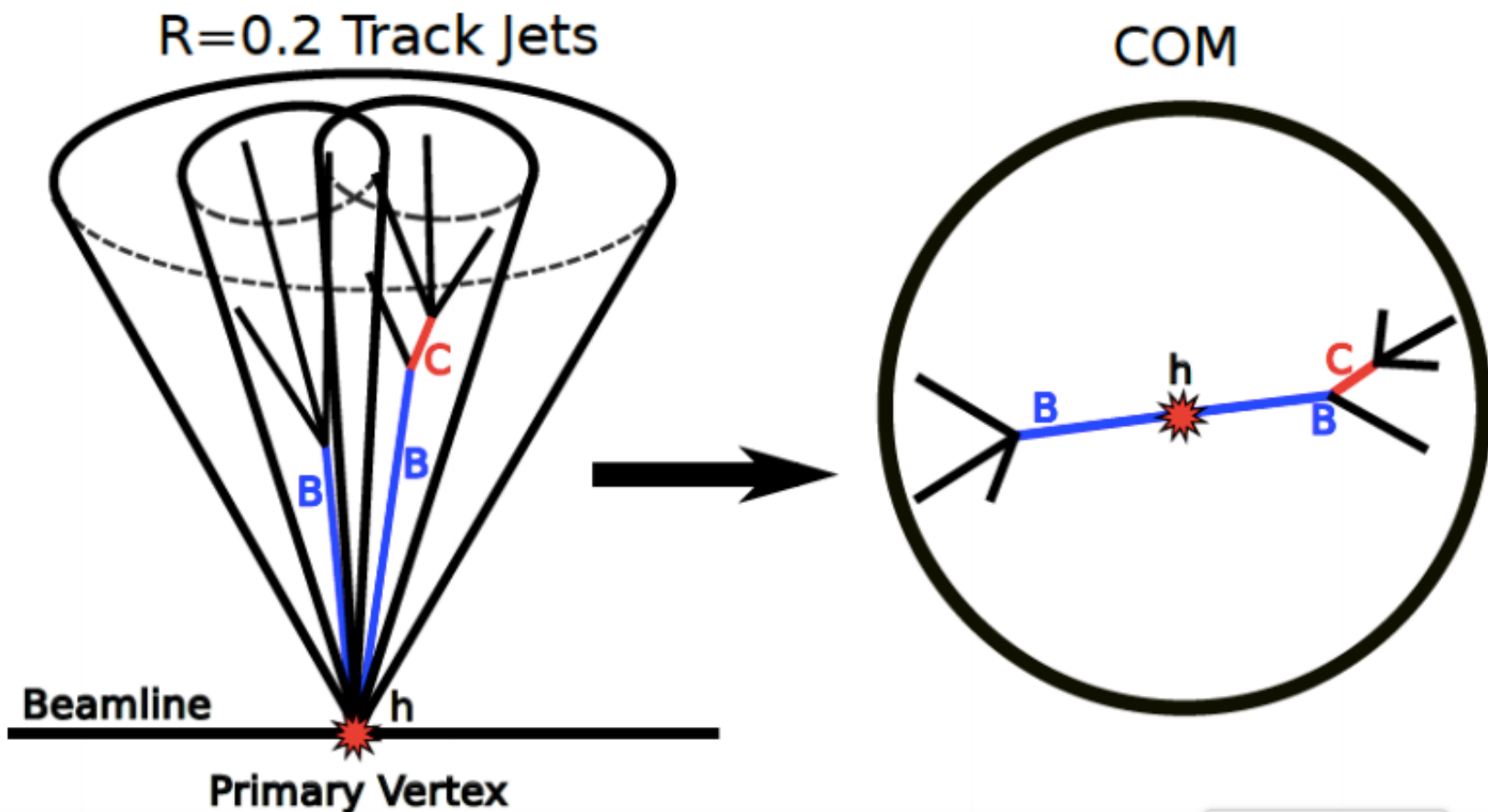- Physics briefing report in ATLAS webpage

Prospect of future X->H+γ search

- Development in advanced double b jet tagger

> ➤ Boost to the Higgs jet center of mass frame (COM)
> ➤ Use Higgs jet constitutes to cluster 2 EECambridge subjets
> ➤ Use angular seperation in COM for track-to-subjet association
> ➤ Boost back to the lab frame to apply for b-tagging

Prospect of future X->H+γ search

Expect significant improvement in full run-2 dataset
**In double b tagging efficiency**
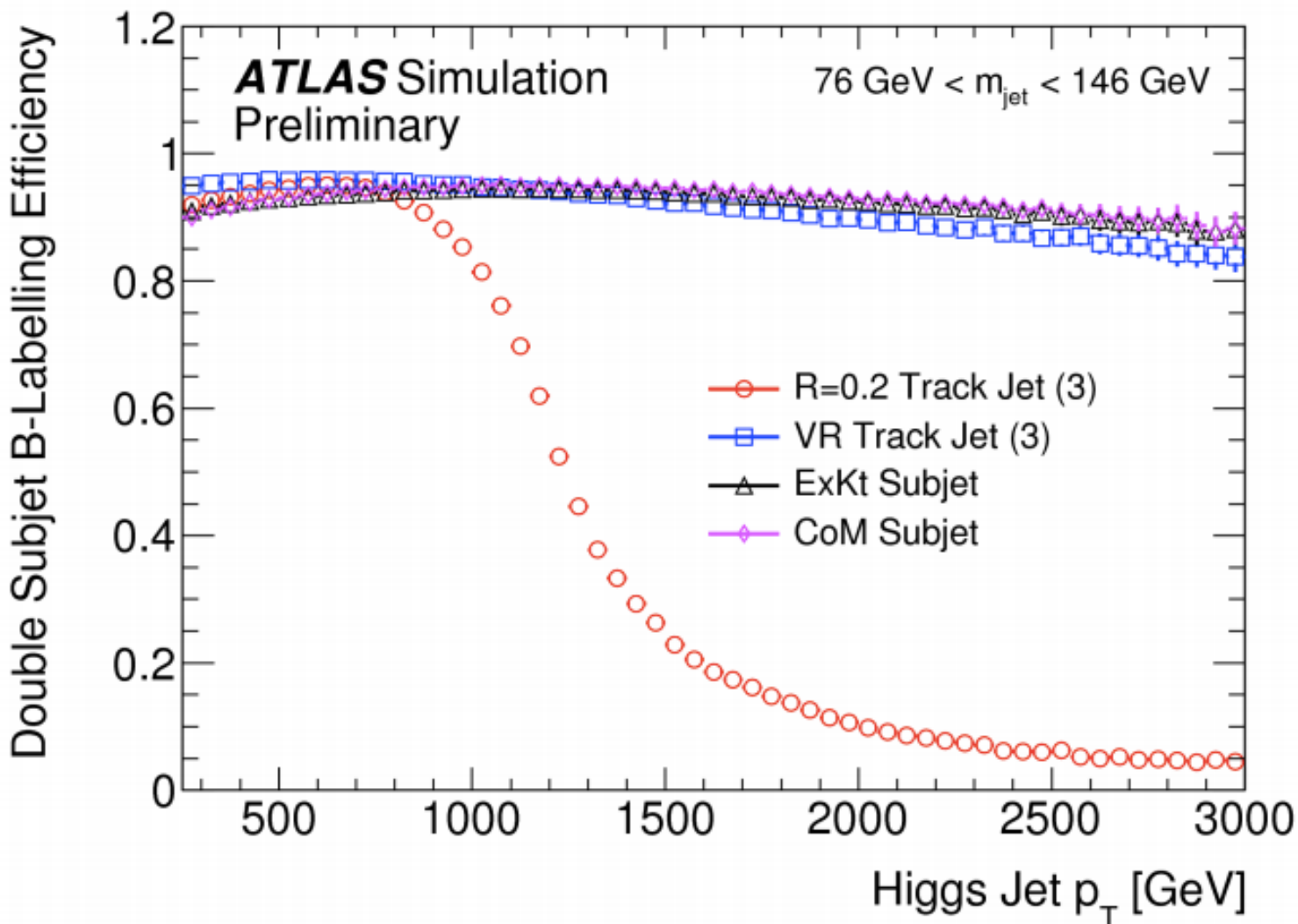
Summary

- **SM VBF H(bb)+γ production（30fb^{-1} ）**
  - **Alternative to VH(bb) analysis**
  - **Observed significance 1.9σ**
  - **Expect significant improvement in full run-2 dataset**
- **First H+γ search in LHC（ 36fb^{-1} ）**
  - **new tool for multi-TeV new physics**
  - **Expect significant improvement in full run-2 dataset**

B jet energy corrections

- ## Using ATLAS default jet energy calibrations
  - Higgs mass resolution is not great
  - Asymmetry in mass, long tail in low mass region
- ## Dedicated B jet calibration
  - Muon-in-jets corrections
  - Kinematic likelihood
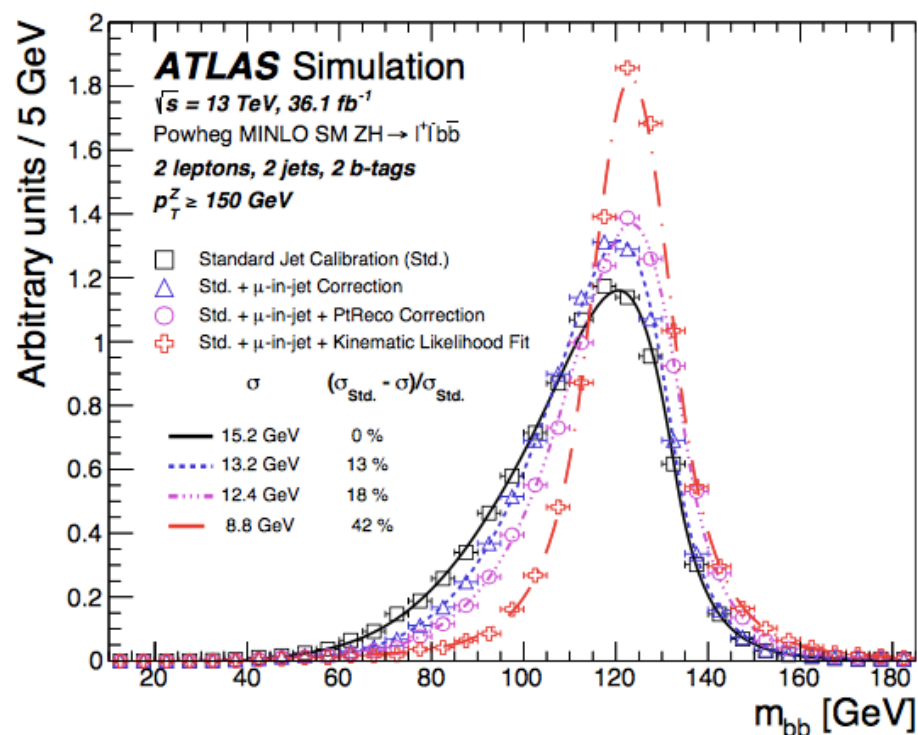
VBF H(bb)γ event selection

ATLAS-CONF-2016-063

- Trigger:
  - L1 trigger: single photon (pT > 25 GeV)
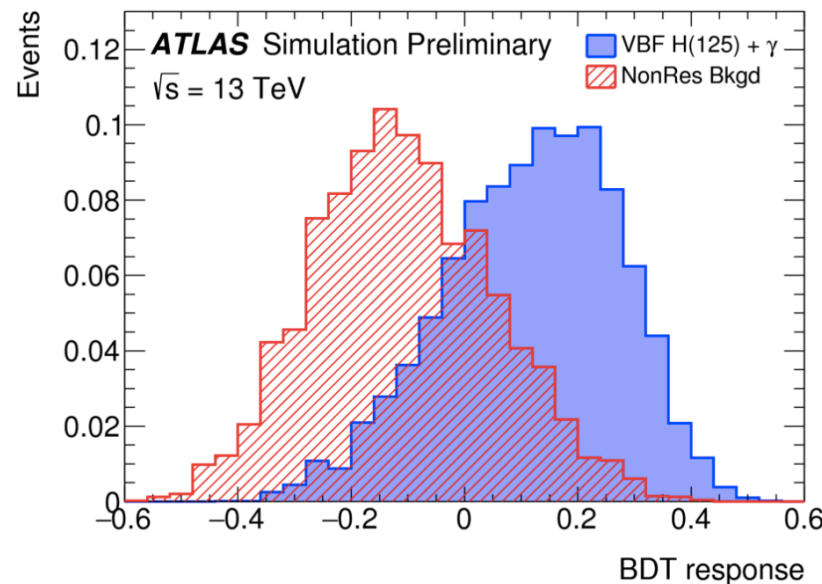 - High level trigger: 4 jets pT > 35 GeV, mjj> 700 GeV

- Offline Selection:
  - Tight ID photon, pT > 30 GeV
  - 4 jets with pT> 40 GeV
  - 2 central($|\eta|$<2.5) b-tagged jets
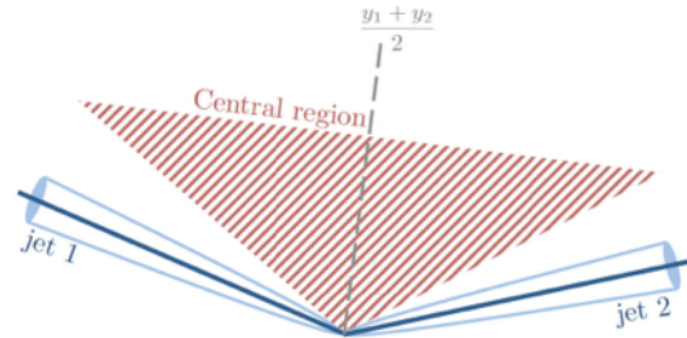 - pT(bb)>80GeV
  - mjj> 800 GeV

- BDT discriminant

$$\Delta R(jet,\gamma),\, m_{jj},\, \Delta\eta_{jj},\, H_T^{soft},\, jet\ width,\, \gamma\ centrality,\, p_T^{balance}$$

- Define 3 regions with different S/B

- Fit m$_{bb}$ in 3 regions

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VBF H(bb)γ MVA Input varialbe:

photon centrality

$$centrality(\gamma) = \left| \frac{y_\gamma - \frac{y_{j_1}+y_{j_2}}{2}}{y_{j_1} - y_{j_2}} \right|$$