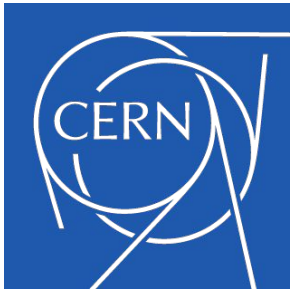
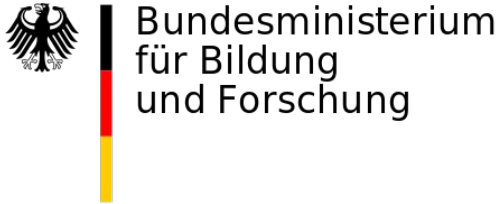




Enhancing the Phase Space for the Analysis of Inclusive H → bb Production Through Trigger-Level Analysis at the CMS Experiment

Adelina Lintuluoto

11th KSETA Plenary Workshop 2024

Karlsruher Institut für Technologie

Bundesministerium
für Bildung
und Forschung

Chaining Myself to the Trigger for Analysis of the Higgs Boson

Adelina Lintuluoto

11th KSETA Plenary Workshop 2024

LHC and CMS has been a remarkable success

- Scrutinised the SM with great precision
  - Higgs boson discovery
- Constrained the available parameter space for BSM scenarios
- Excluded BSM scenarios up to several TeV

LHC and CMS has been a remarkable success...

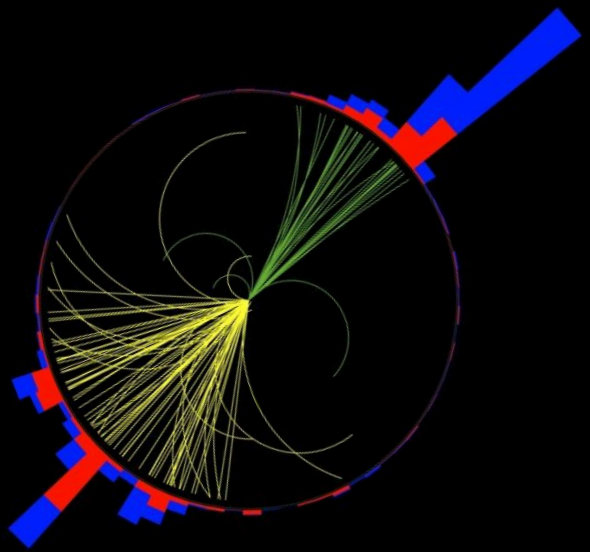
- Scrutinised the SM with great precision
  - Including discovering the Higgs boson
- Constrained the available parameter space for BSM scenarios
- Excluded BSM scenarios up to several TeV

...however...

...absence of clear signals for physics BSM necessitates new approaches

Detecting new physics is difficult as new particles often have low masses and feeble couplings

1. Large jet production
2. Subsequent (semi)leptonic decays of hadrons
3. Most p-p interactions happen at low energies



cms.cern/news/machining-jets

Experimental signatures of quarks and gluons produced in proton-proton interactions

Reduces the complexity of the final state and facilitates analysis

Detecting new physics is difficult as new particles often have low masses and feeble couplings

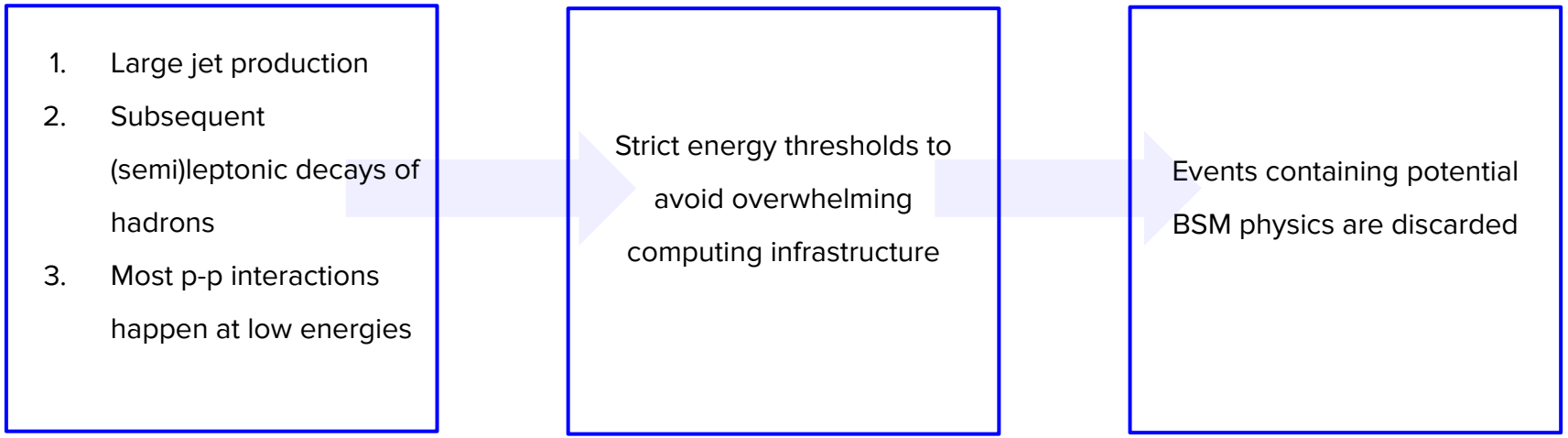
1. Large jet production
2. Subsequent (semi)leptonic decays of hadrons
3. Most p-p interactions happen at low energies

Detecting new physics is difficult as new particles often have low masses and feeble couplings

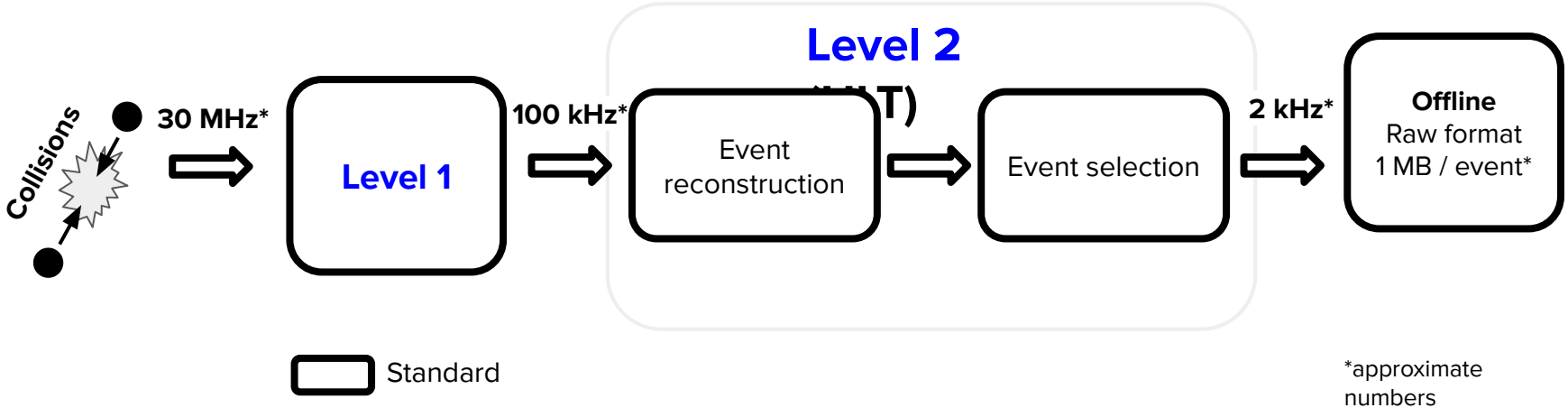
1. Large jet production
2. Subsequent (semi)leptonic decays of hadrons
3. Most p-p interactions happen at low energies

Strict energy thresholds to avoid overwhelming computing infrastructure

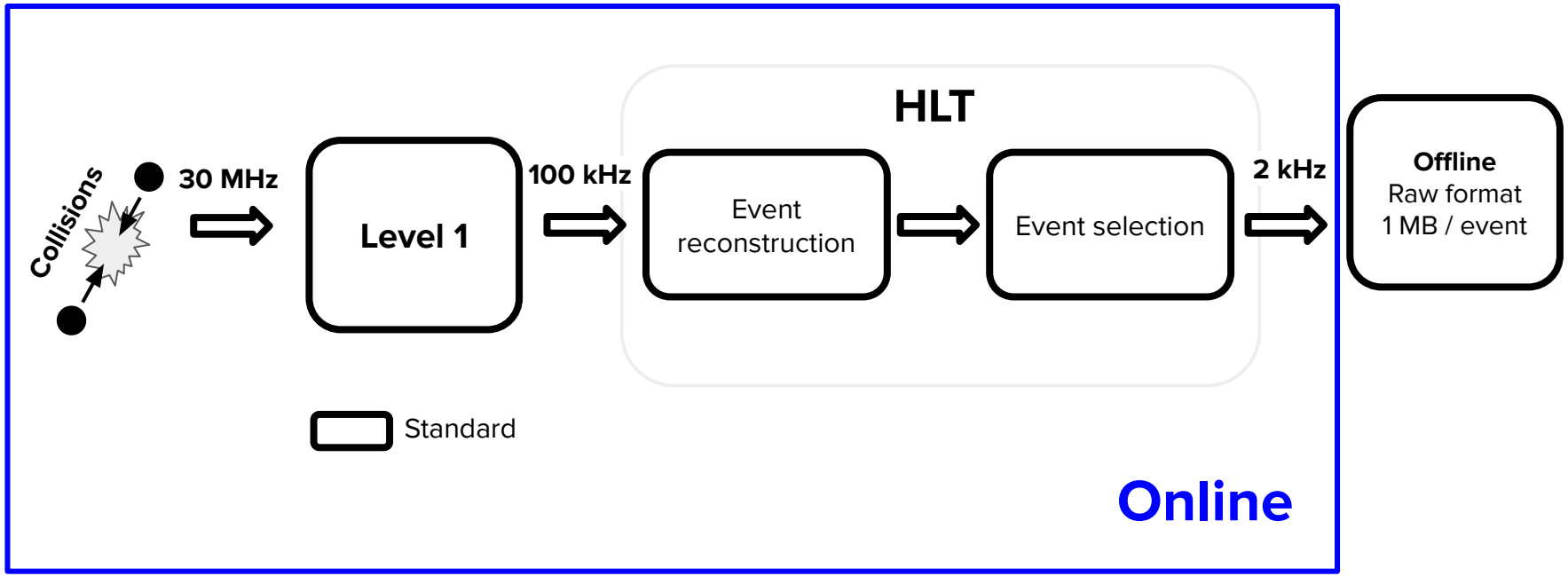
Detecting new physics is difficult as new particles often have low masses and feeble couplings



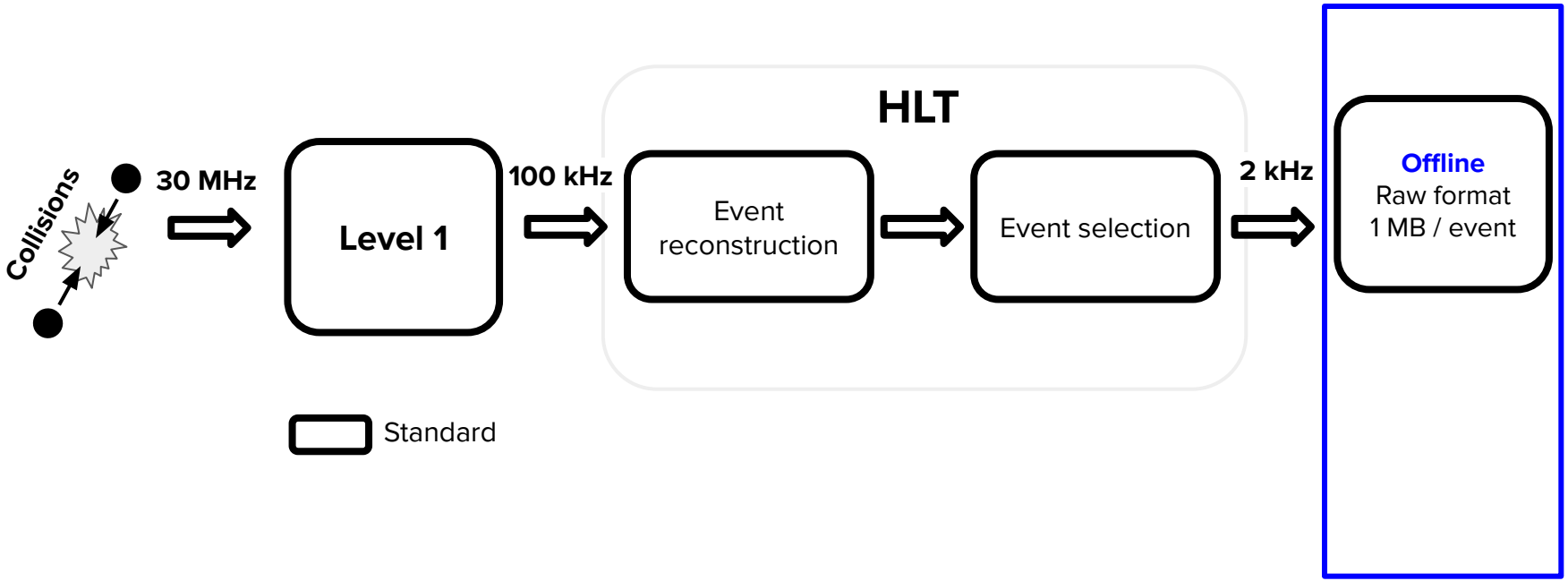
At CMS, events are selected by a two-tiered trigger system



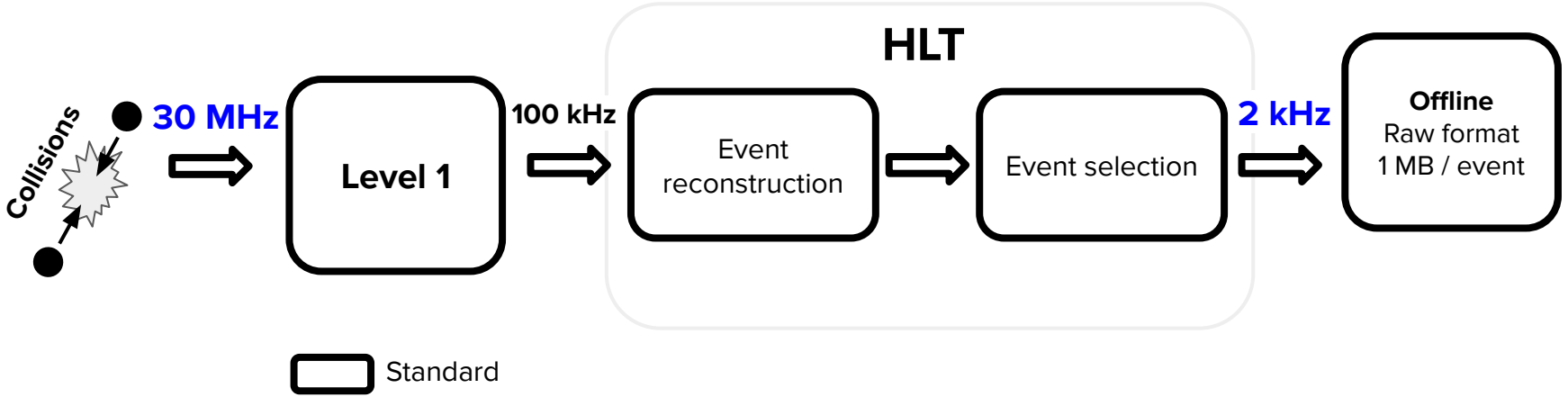
Online reconstruction aims to provide low latency



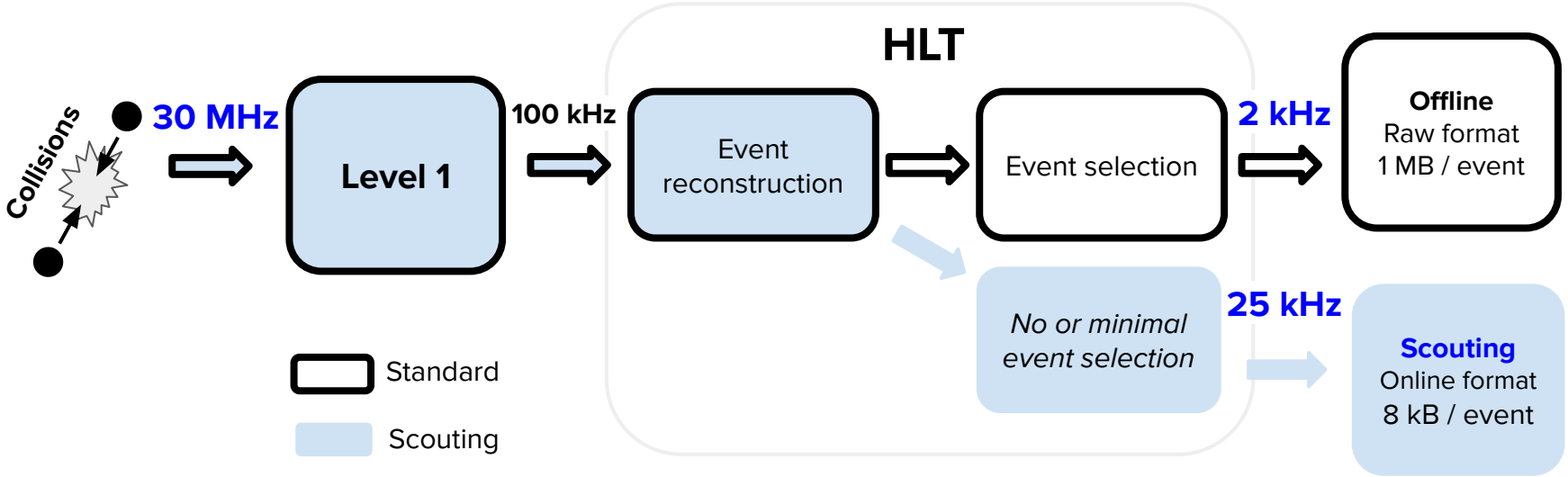
Offline reconstruction aims to provide the best physics objects for analysis



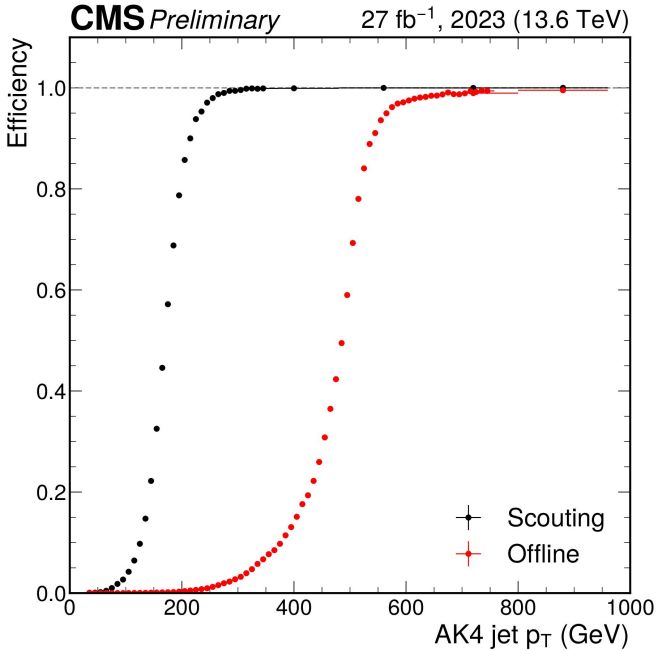
The vast majority of events are lost



Scouting attenuates this problem by increasing the event rate, allowing analysis of previously unexplored phase spaces

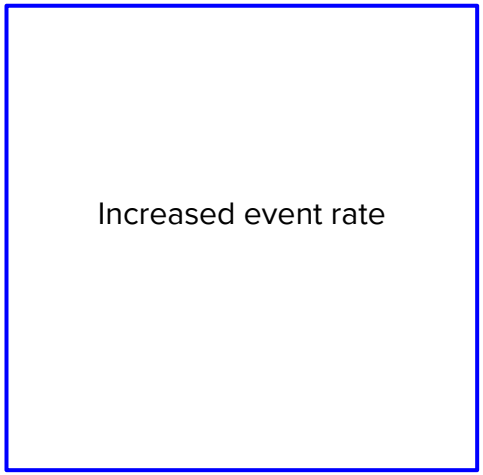


Access to unexplored phase spaces is achieved by lowering the trigger thresholds



- **Scouting** is fully efficient earlier than the **standard strategy**
- Potentially revealing new interactions or particles that were previously overlooked due to higher trigger thresholds

While scouting increases access to unexplored phase spaces, it comes at a cost



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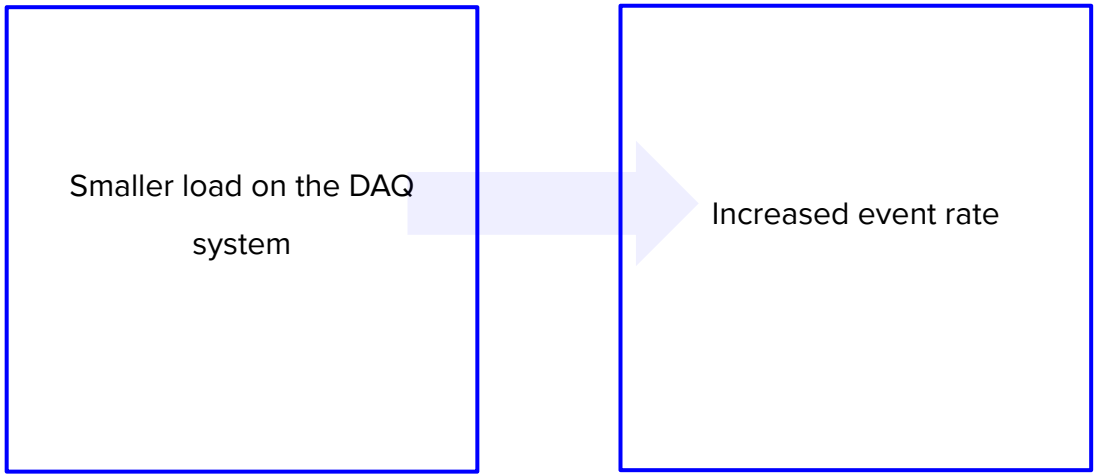

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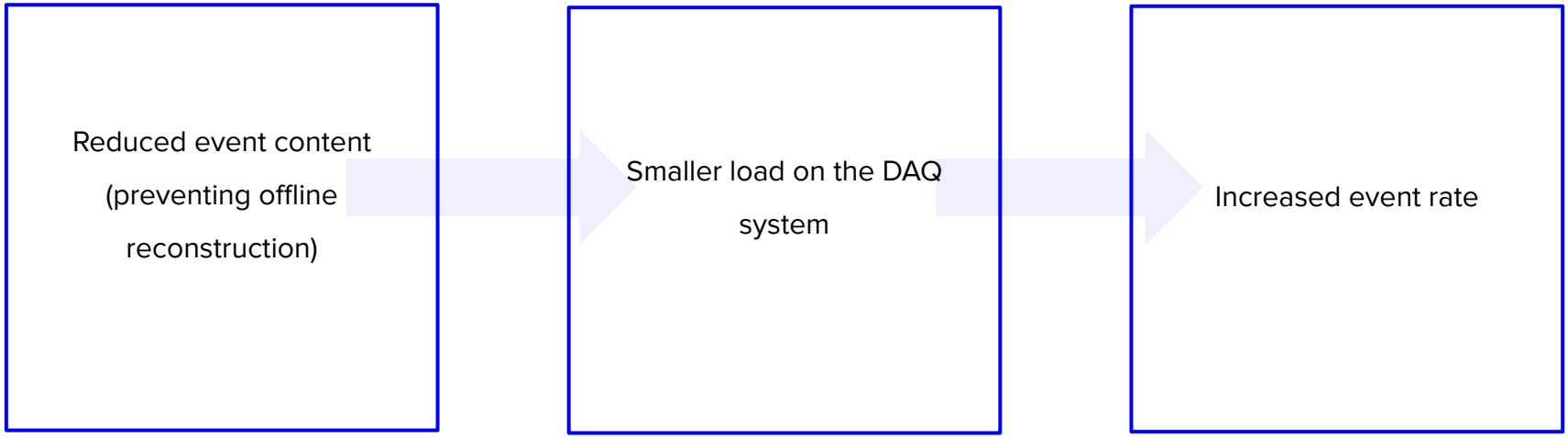
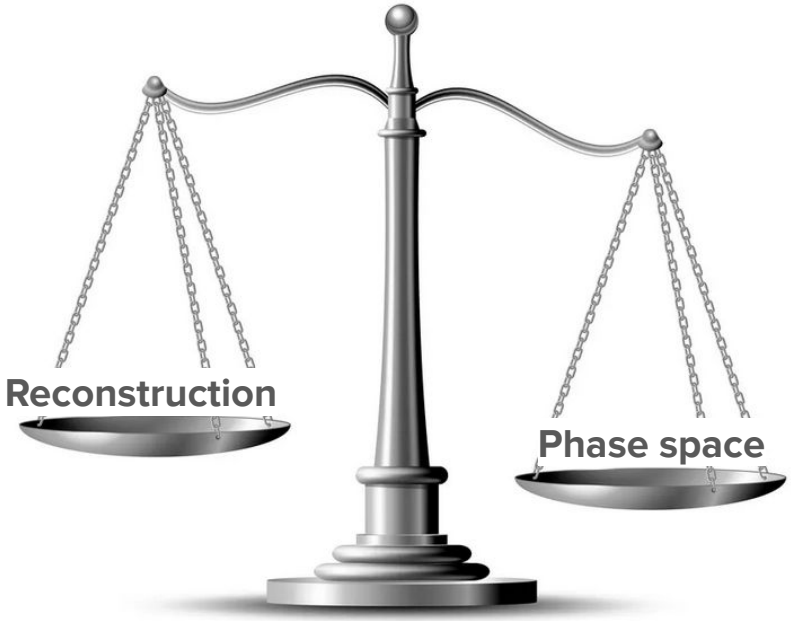


The quality of reconstruction is affected



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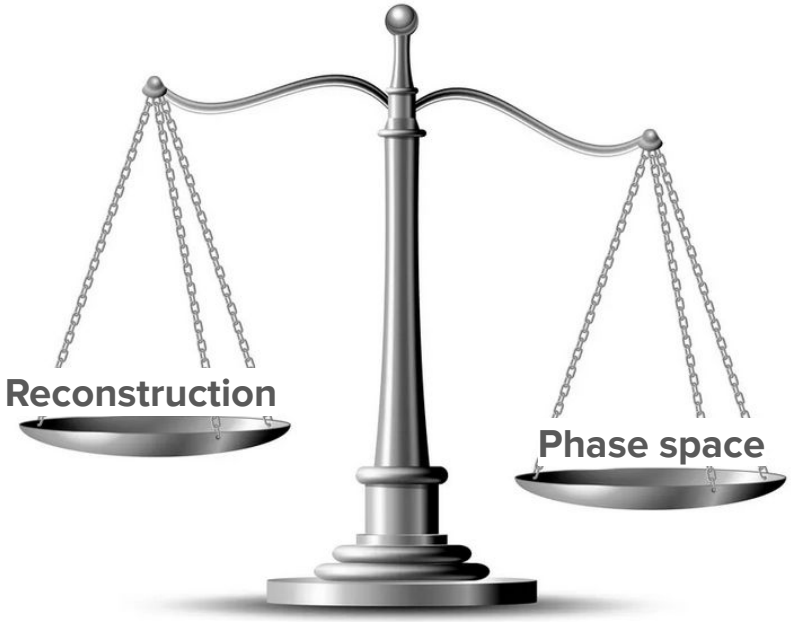

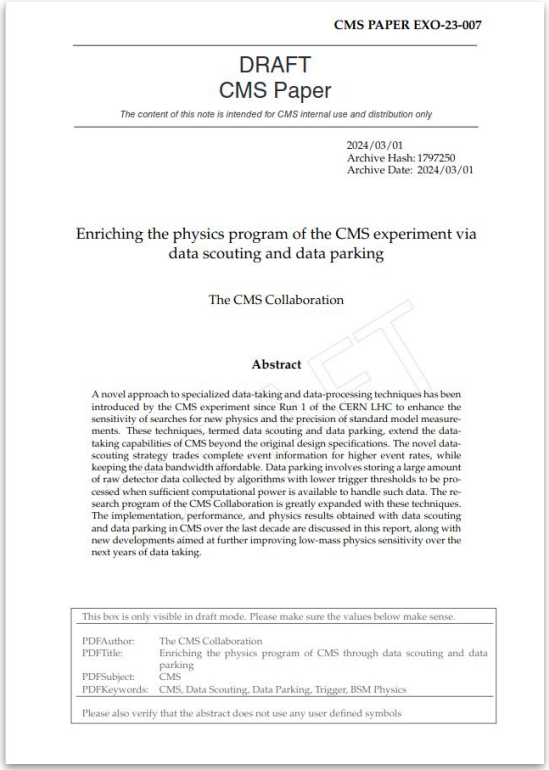

CMS PAPER EXO-23-007

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2024/03/01
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Enriching the physics program of the CMS experiment via data scouting and data parking

The CMS Collaboration

Abstract

A novel approach to specialized data-taking and data-processing techniques has been introduced by the CMS experiment since Run 1 of the CERN LHC to enhance the sensitivity of searches for new physics and the precision of standard model measurements. These techniques, termed data scouting and data parking, extend the data-taking capabilities of CMS beyond the original design specifications. The novel data-scouting strategy trades complete event information for higher event rates, while keeping the data bandwidth affordable. Data parking involves storing a large amount of raw detector data collected by algorithms with lower trigger thresholds to be processed when sufficient computational power is available to handle such data. The research program of the CMS Collaboration is greatly expanded with these techniques. The implementation, performance, and physics results obtained with data scouting and data parking in CMS over the last decade are discussed in this report, along with new developments aimed at further improving low-mass physics sensitivity over the next years of data taking.

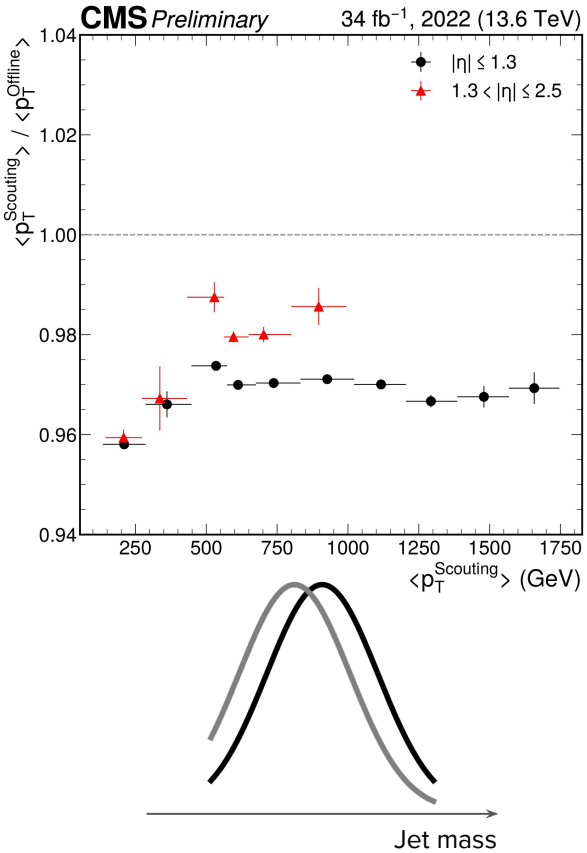
This box is only visible in draft mode. Please make sure the values below make sense.

PDFAuthor: The CMS Collaboration
PDFTitle: Enriching the physics program of CMS through data scouting and data parking
PDFSubject: CMS
PDFKeywords: CMS, Data Scouting, Data Parking, Trigger, BSM Physics

Please also verify that the abstract does not use any user defined symbols

cds.cern.ch/record/2887556

Improving the reconstruction with calibration studies



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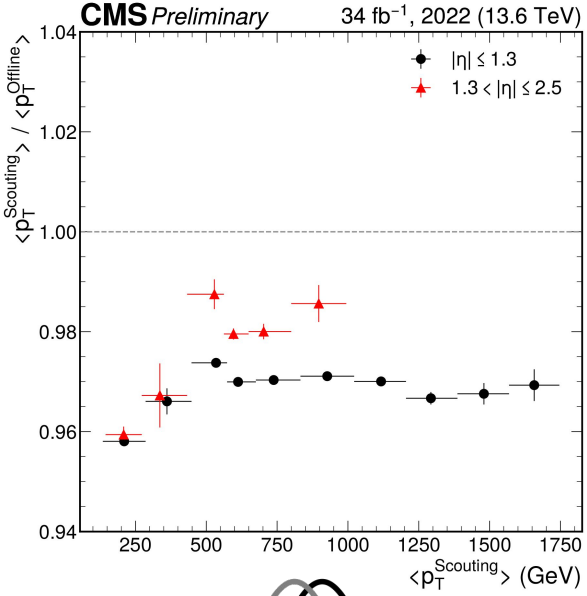

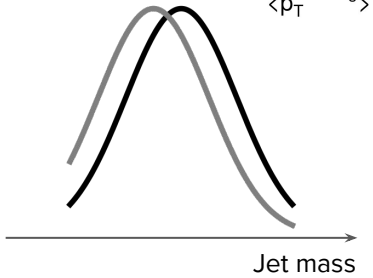

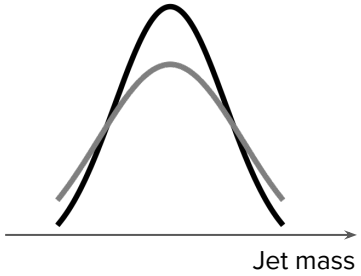

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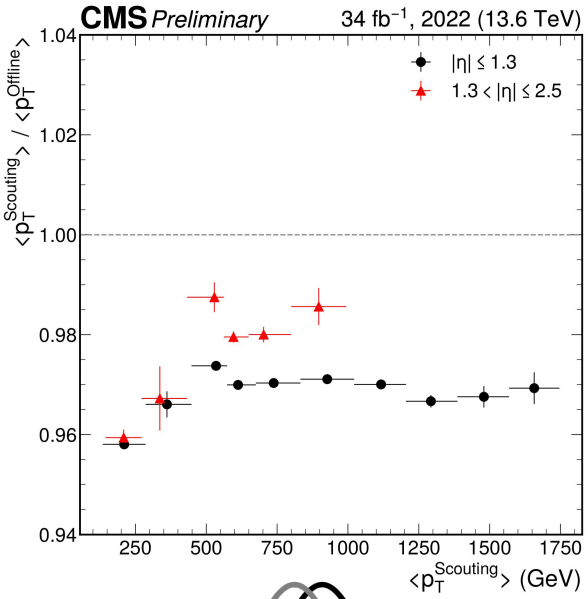

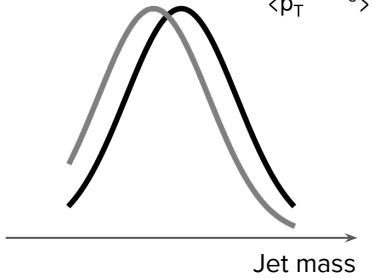

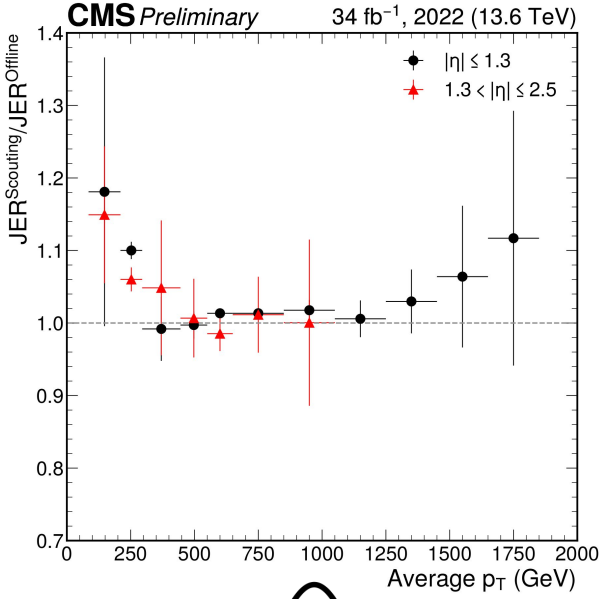

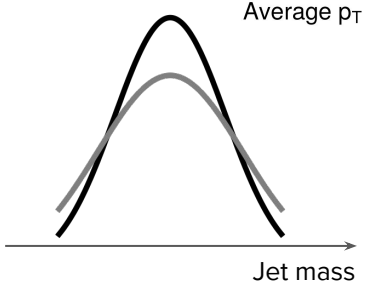

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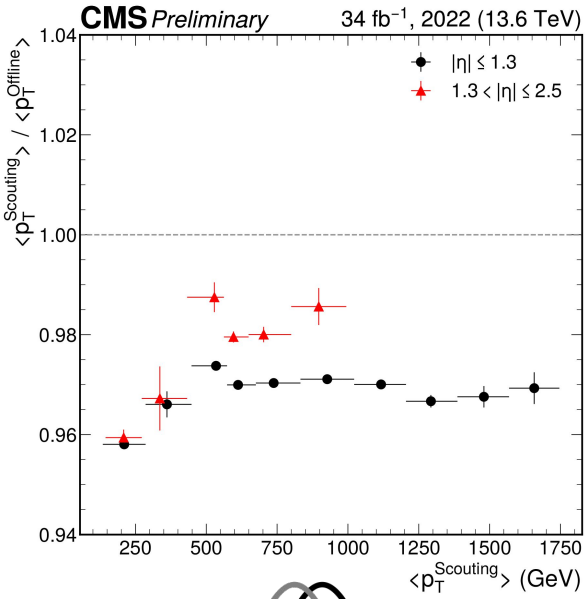
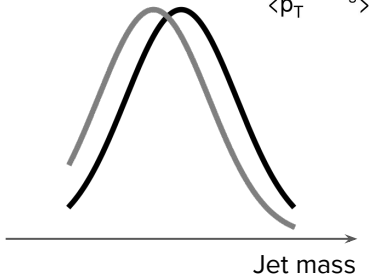
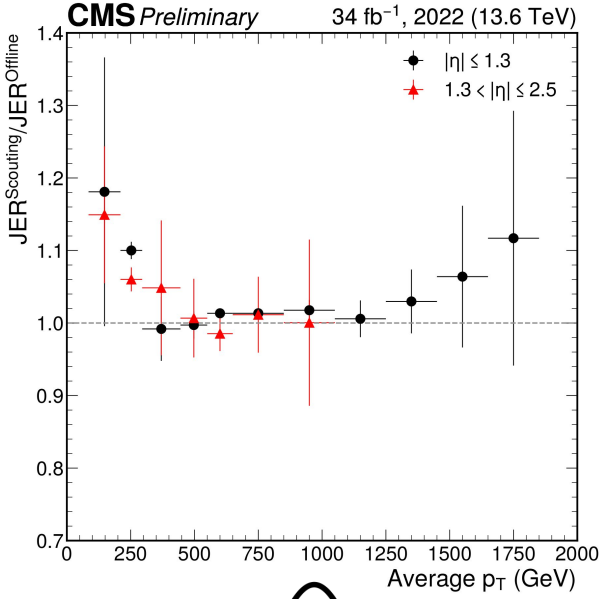
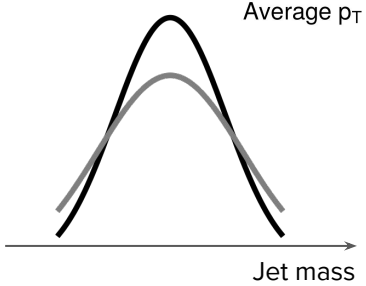








Negligible impact on searches that are statistically limited...

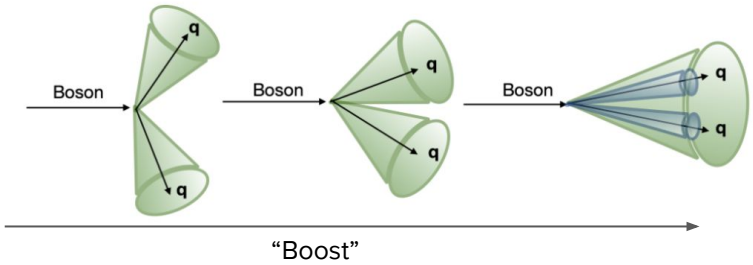
...such as most searches for new physics

Scouting jets have many potential applications

- Past contributions
  - Improved limits on production cross section of new dijet resonances, extending lower limit from 1.5 TeV to 600 GeV cds.cern.ch/record/1461223
  - Improved sensitivity to gluinos searches by extending multijet searches to lower energies

Scouting jets have many potential applications

- Past contributions
  - Improved limits on production cross section of new dijet resonances to 0.6 TeV cds.cern.ch/record/1461223
  - Improved sensitivity to gluinos searches
- Future contribution
  - Momentum-dependent anomalous couplings, probed via “boosted” Higgs production



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- Future contribution
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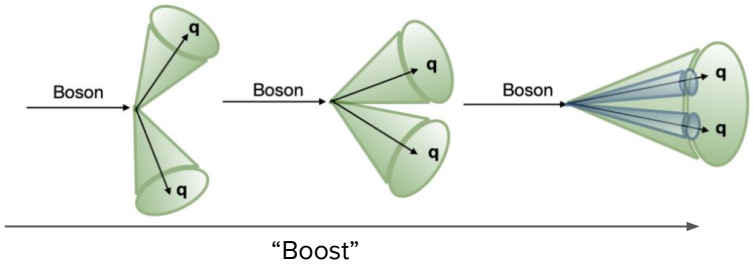
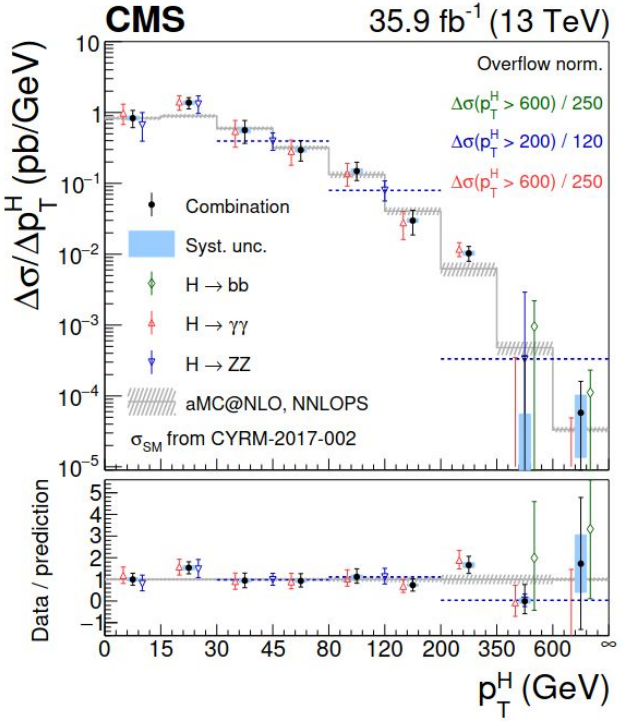
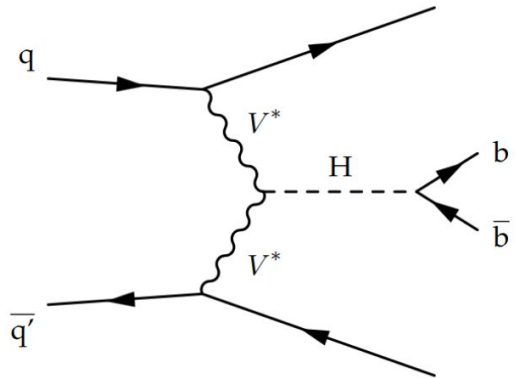


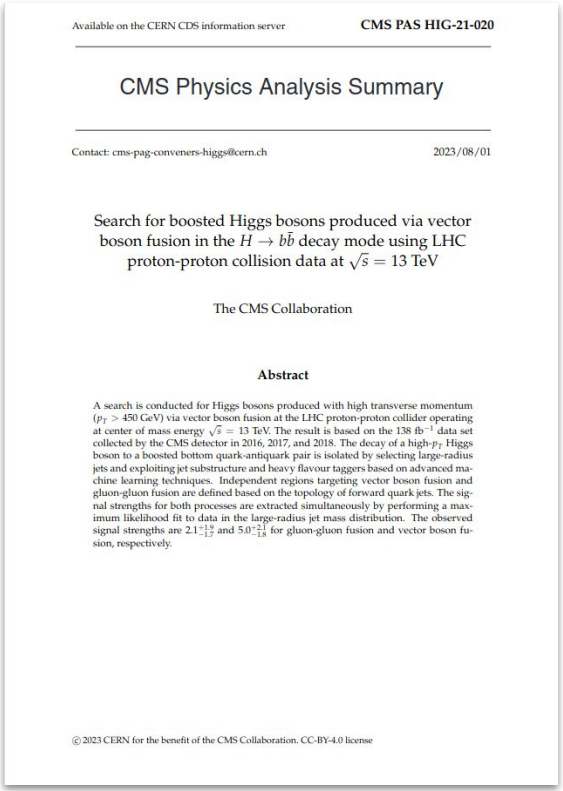
“Boost”



cds.cern.ch/record/2651932

Using the standard trigger strategy to search for boosted Higgs production





Available on the CERN CDS information server **CMS PAS HIG-21-020**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-higgs@cern.ch 2023/08/01

Search for boosted Higgs bosons produced via vector boson fusion in the $H \to b\bar{b}$ decay mode using LHC proton-proton collision data at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

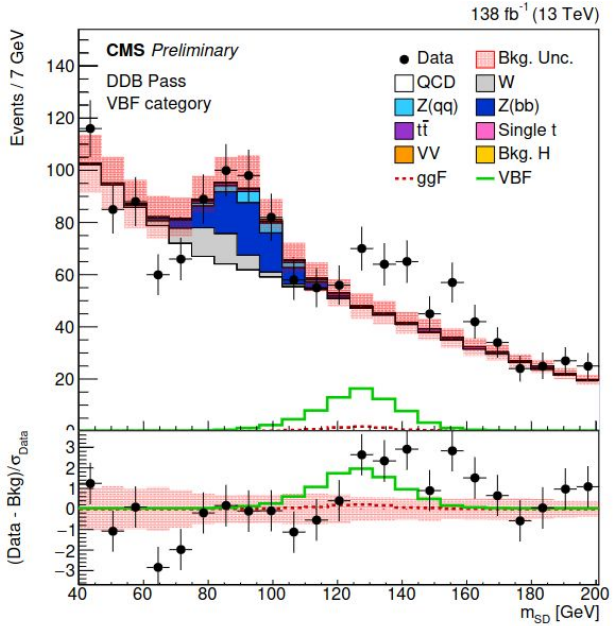
A search is conducted for Higgs bosons produced with high transverse momentum ($p_T > 450$ GeV) via vector boson fusion at the LHC proton-proton collider operating at center of mass energy $\sqrt{s} = 13$ TeV. The result is based on the 138 fb^{-1} data set collected by the CMS detector in 2016, 2017, and 2018. The decay of a high-p_T Higgs boson to a boosted bottom quark-antiquark pair is isolated by selecting large-radius jets and exploiting jet substructure and heavy flavour taggers based on advanced machine learning techniques. Independent regions targeting vector boson fusion and gluon-gluon fusion are defined based on the topology of forward quark jets. The signal strengths for both processes are extracted simultaneously by performing a maximum likelihood fit to data in the large-radius jet mass distribution. The observed signal strengths are $2.1^{+1.9}_{-1.7}$ and $5.0^{+2.1}_{-1.8}$ for gluon-gluon fusion and vector boson fusion, respectively.

cds.cern.ch/record/2866501

Using the standard trigger strategy to search for boosted Higgs production

Signal strength of:
$5.0^{+2.1}_{-1.8}$

Significance of:
3.0 σ

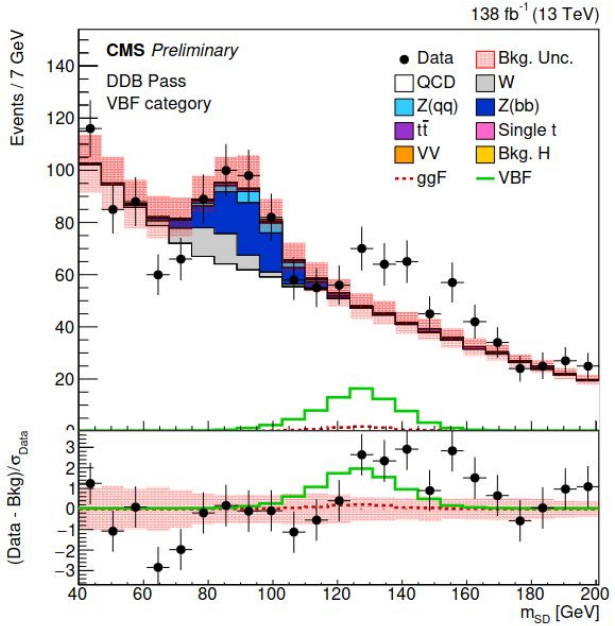


Using the standard trigger strategy to search for boosted Higgs production

Signal strength of:
$5.0^{+2.1}_{-1.8}$

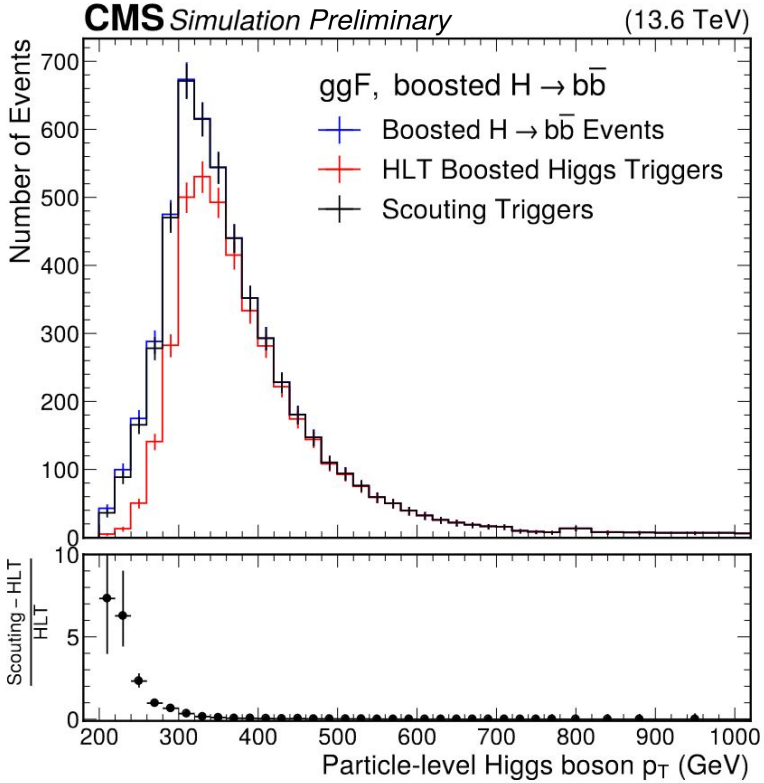
Significance of:
3.0 σ

Could this be evidence for anomalous Higgs couplings?

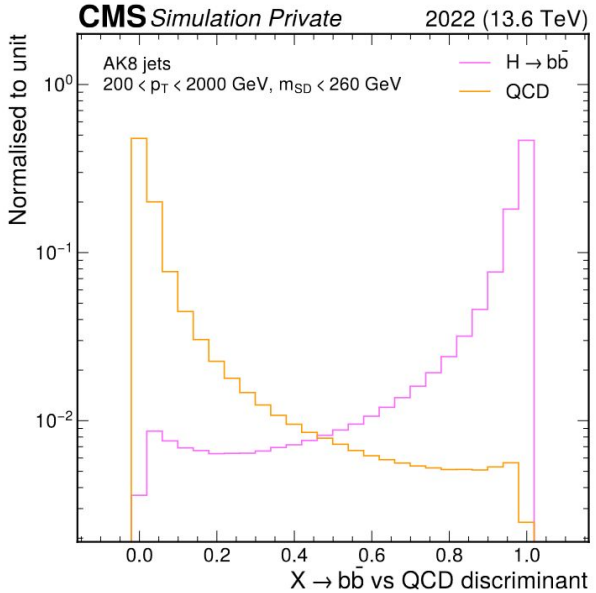


Using the scouting strategy to search for boosted Higgs production

- A ~20% improvement in number of signal jets when using scouting



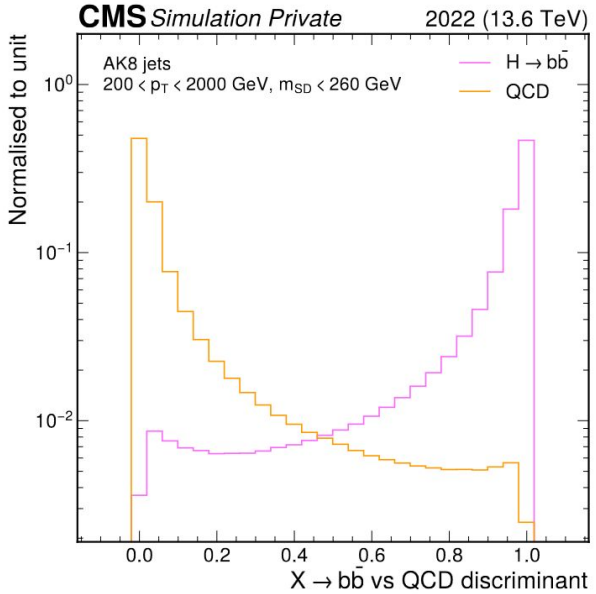
Using the scouting strategy to search for boosted Higgs production



40% likelihood of correctly identifying signal jets

⟶0.6% likelihood of misidentifying QCD jets

Using the scouting strategy to search for boosted Higgs production



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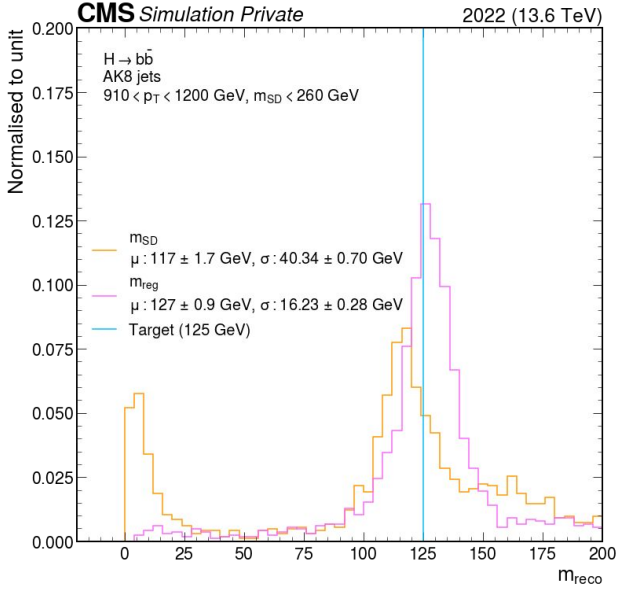
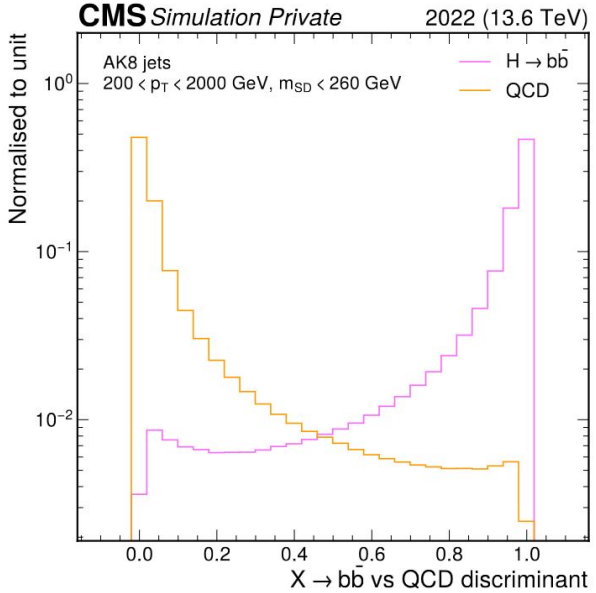


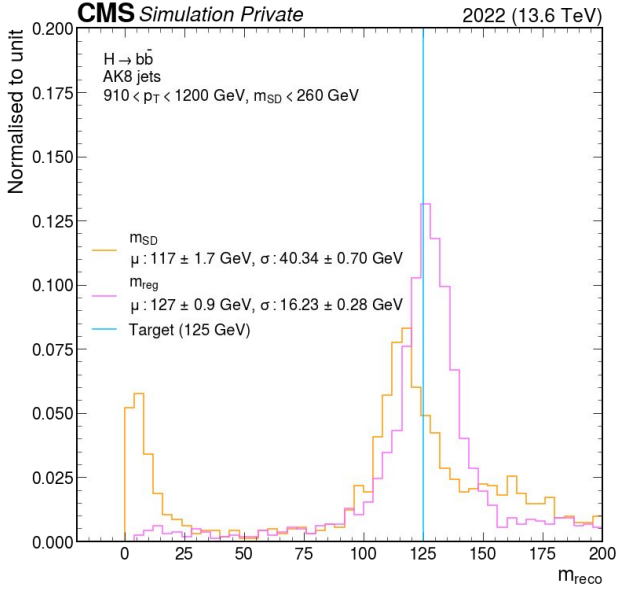
Jet mass resolution of roughly 10%

How does scouting compare with the standard trigger strategy?



40% likelihood of correctly identifying signal jets
⟶**0.5%** likelihood of misidentifying QCD jets

cds.cern.ch/record/2839736



Jet mass resolution of roughly **10%**

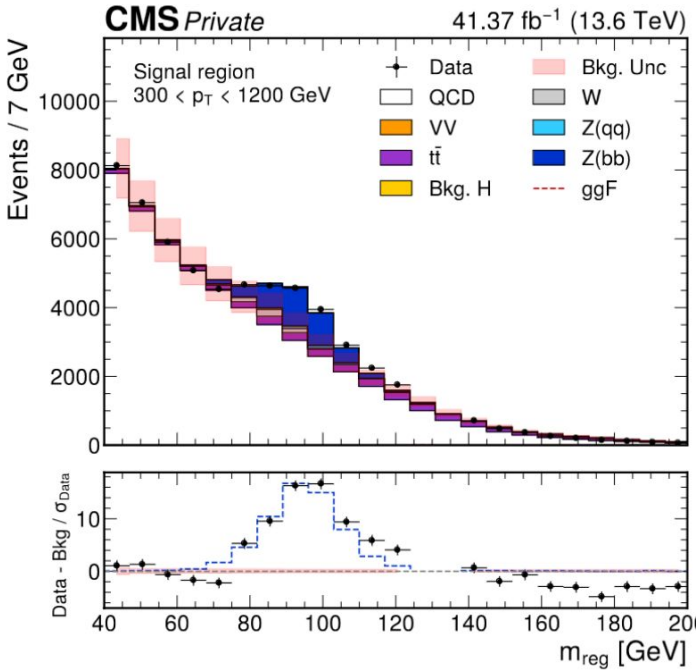
cds.cern.ch/record/2256875

Validating the scouting strategy by searching for boosted Z → production

Signal strength of:
$1.1^{+0.1}_{-0.1}$

Significance of:
20 σ

In agreement with SM



Using the validated strategy for the exploratory analysis of searching for boosted Higgs production

- Work is still ongoing
- Expected significance exceeds that of Run 2 analysis, even with ⅓ the integrated luminosity cds.cern.ch/record/2721858
- Completion of further work may affect the significance

Summary

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Thanks to Günter Quast, Clemens Lange, Paris Sphicas, the CMS Trigger Studies Group — Elisa Fontanesi, the DAZSLE group — Jennet Dickinson, and many more!

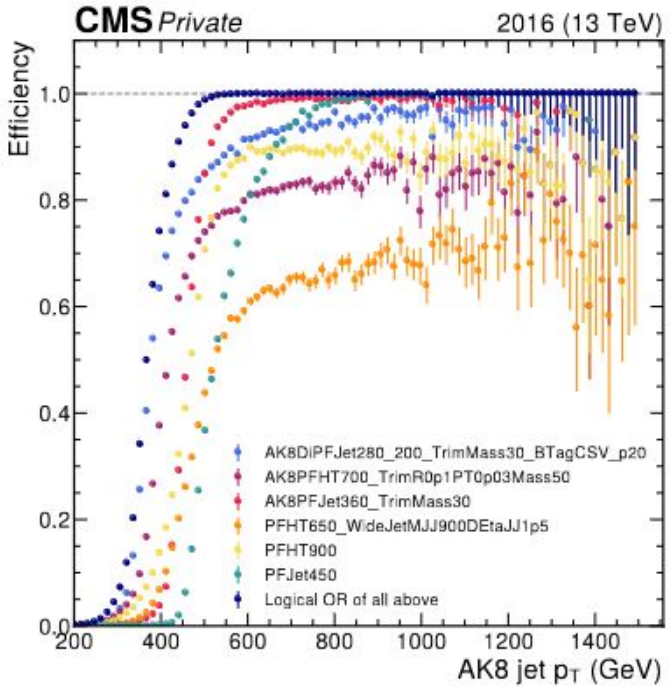
Karlsruher Institut für Technologie

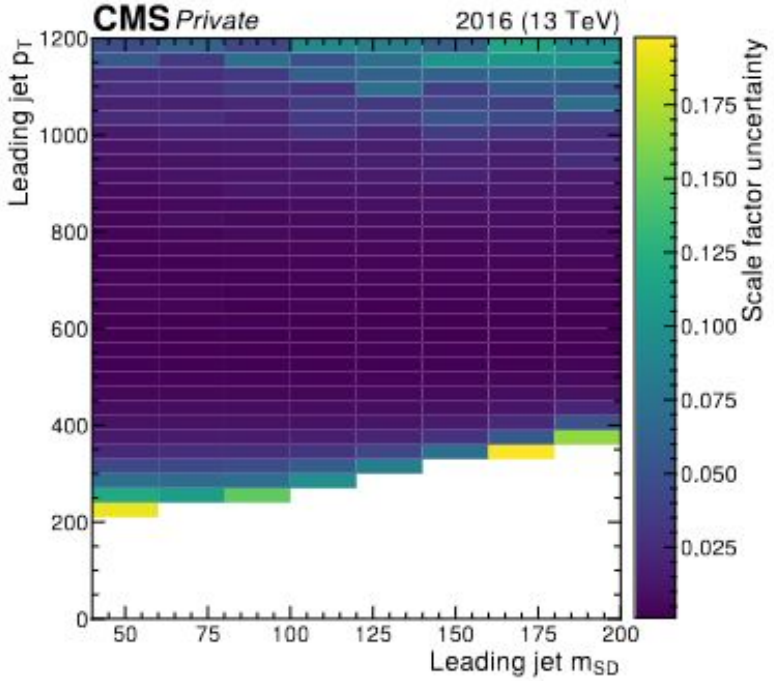
Bundesministerium
für Bildung
und Forschung

CERN

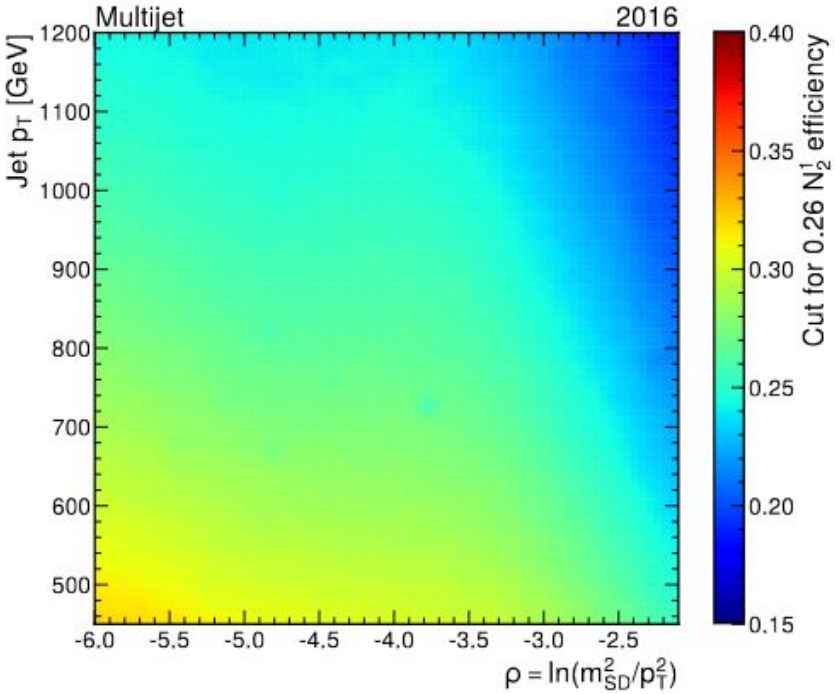
BACKUP

VBF trigger efficiency

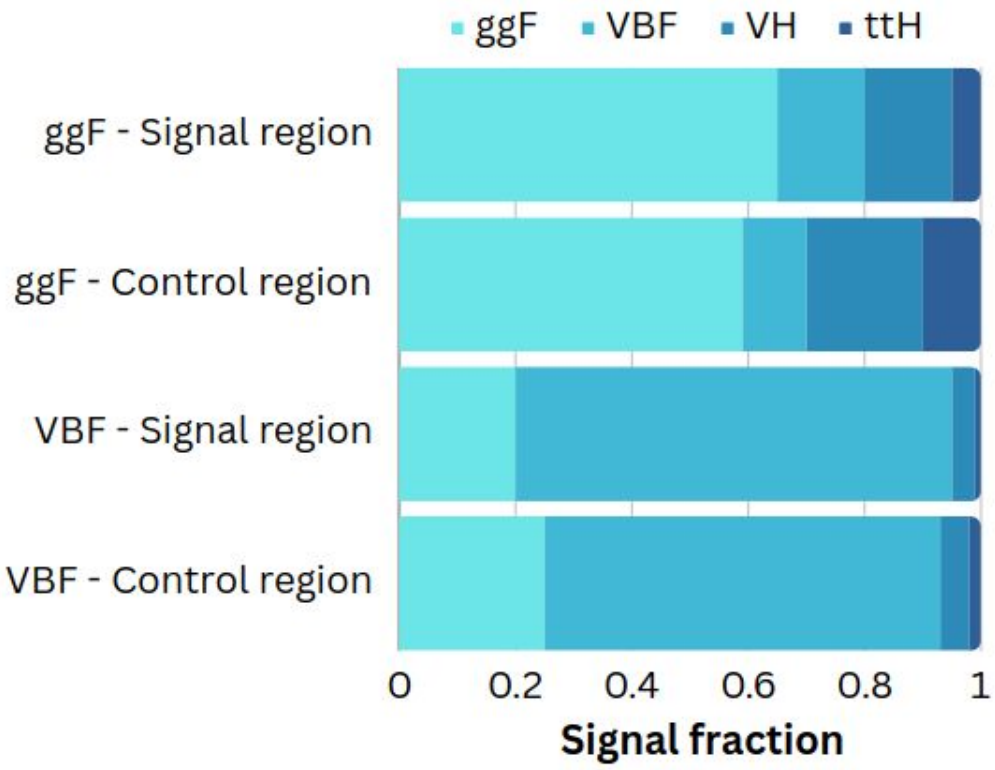




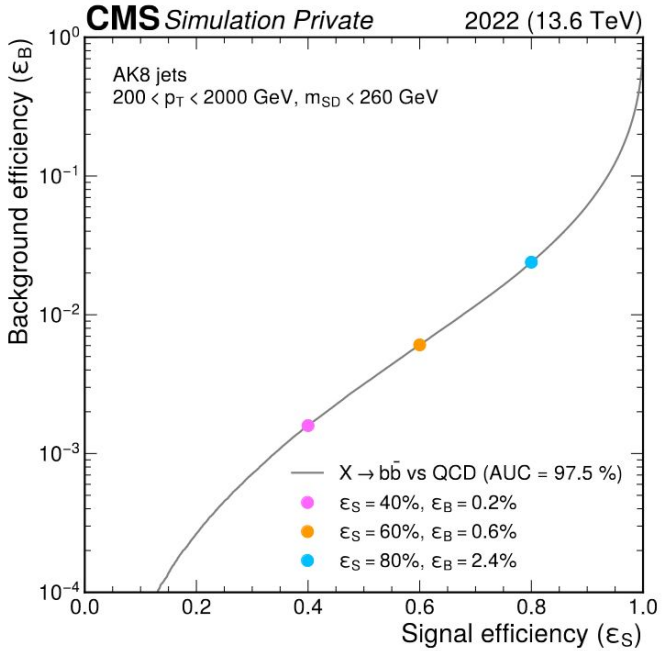
VBF N2DDT


Multijet
2016
Jet p_T [GeV]
1200
1100
1000
900
800
700
600
500
-6.0
-5.5
-5.0
-4.5
-4.0
-3.5
-3.0
-2.5
$\rho = \ln(m^2_{SD}/p^2_T)$
0.40
0.35
0.30
0.25
0.20
0.15
Cut for 0.26 N_2^1 efficiency

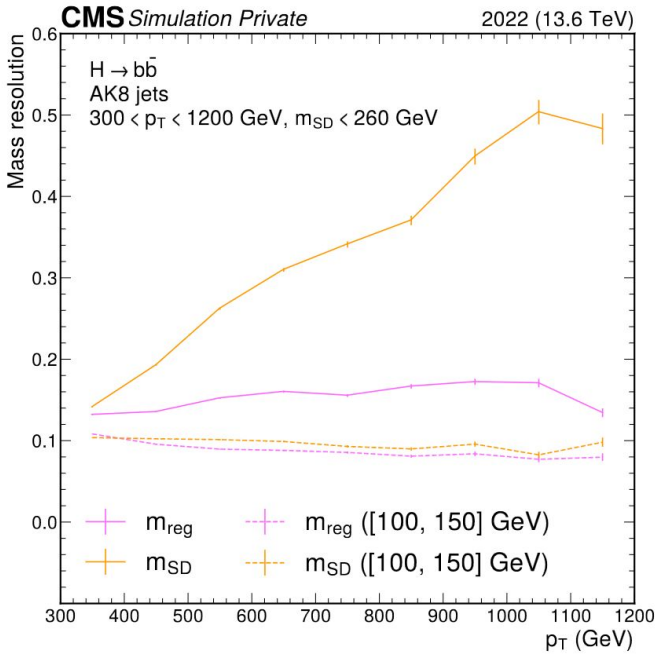
VBF signal fraction



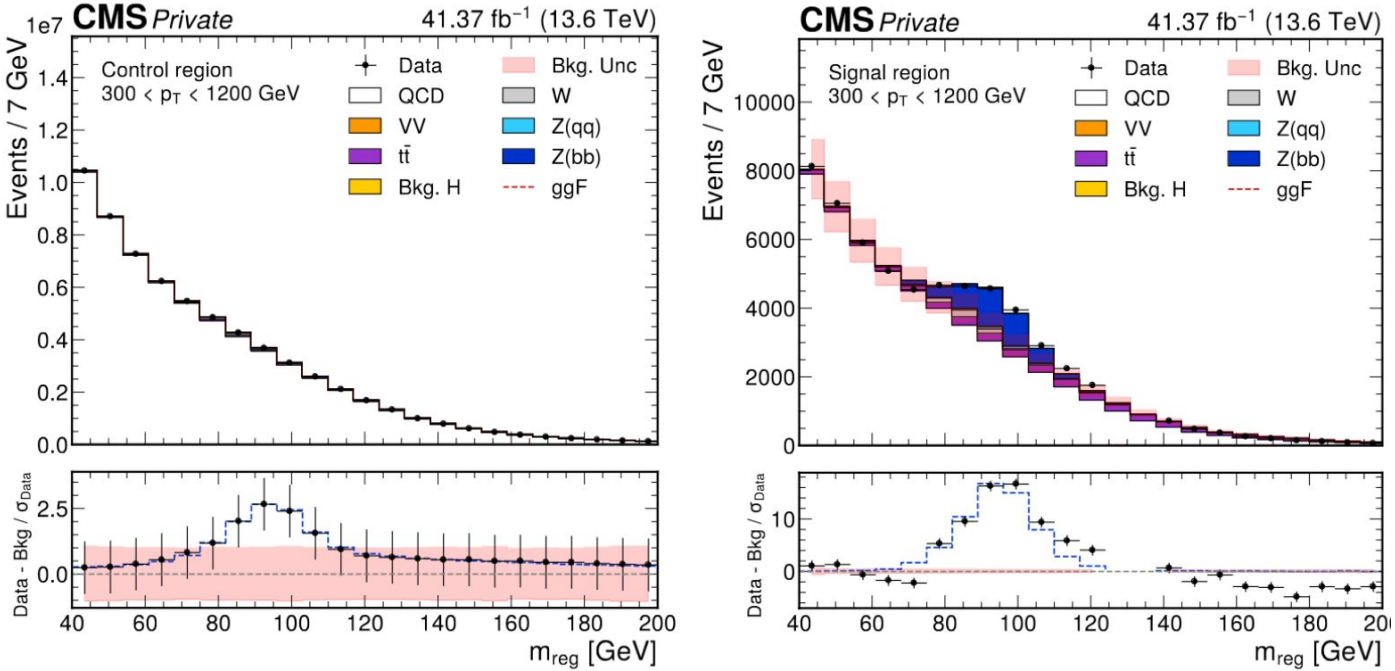
ROC curve


CMS Simulation Private
2022 (13.6 TeV)
AK8 jets
200 < p_T < 2000 GeV, m_{SD} < 260 GeV
Background efficiency (ε_B)
Signal efficiency (ε_S)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.0
0.2
0.4
0.6
0.8
1.0
$X \to b\bar{b}$ vs QCD (AUC = 97.5 %)
ε_S = 40%, ε_B = 0.2%
ε_S = 60%, ε_B = 0.6%
ε_S = 80%, ε_B = 2.4%

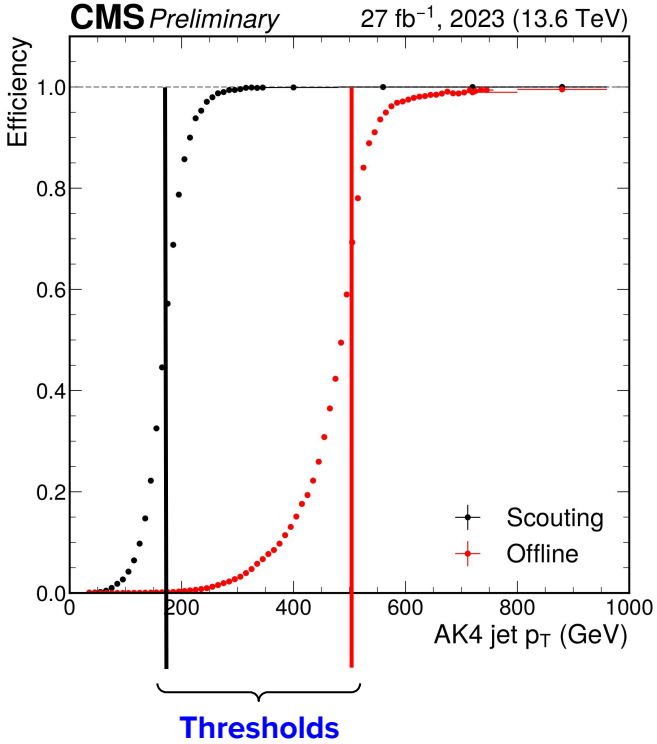
Jet mass resolution

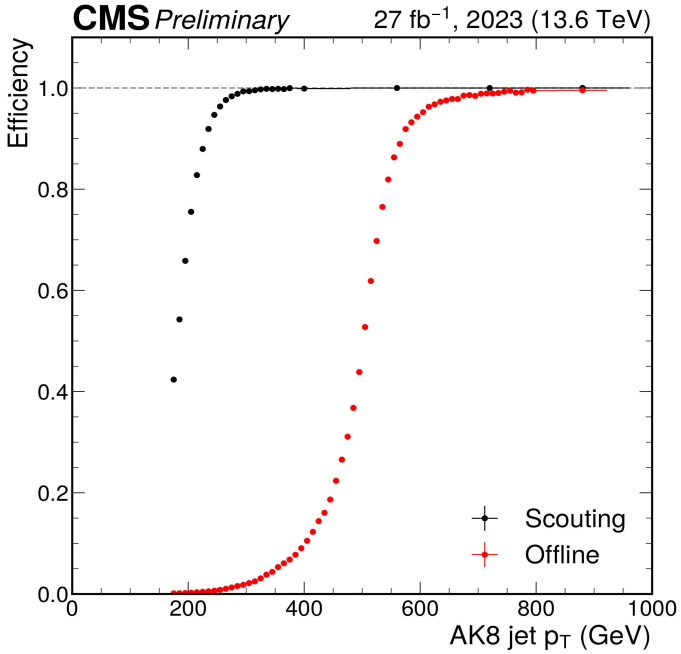


Control and signal region



Enhances sensitivity to low-energy processes by lowering the trigger thresholds



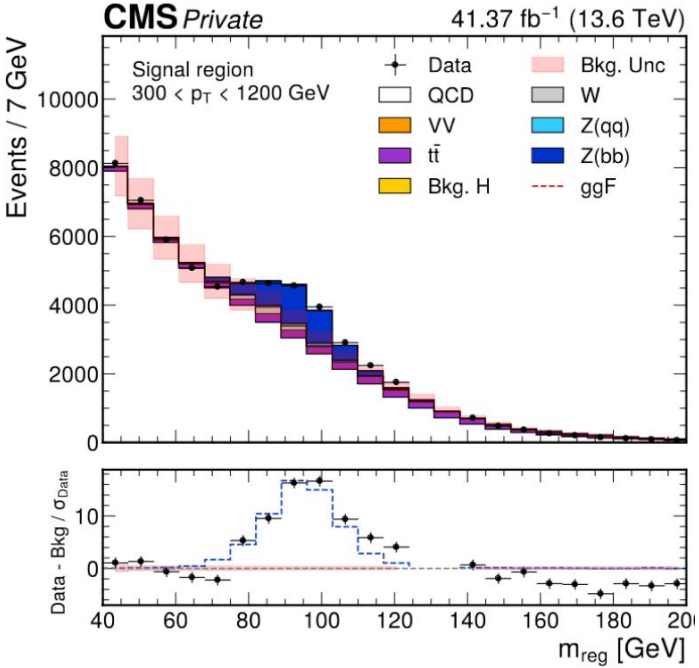


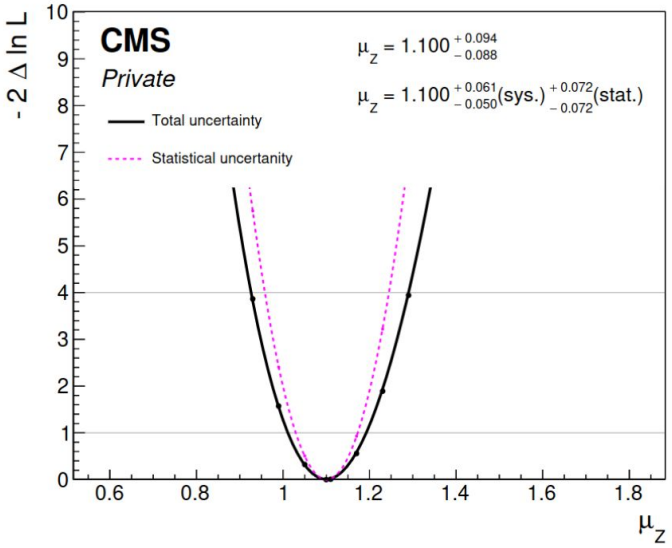
Using the scouting strategy to search for boosted Higgs production

Signal strength of:
$1.1^{+0.1}_{-0.1}$

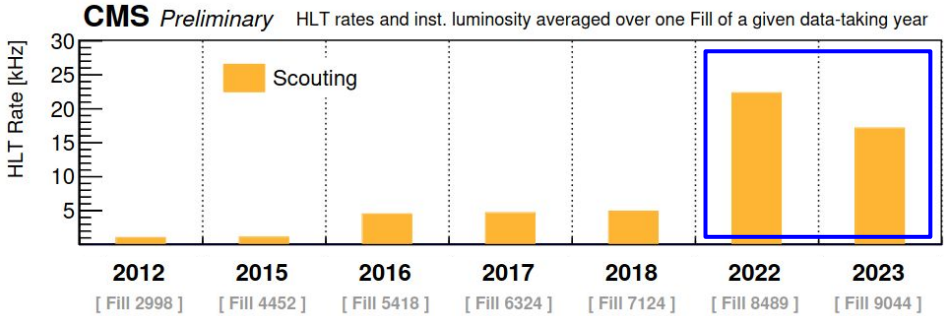
Significance of:
20 σ

In agreement with SM





Significant development of the scouting technique in preparation for Run 3



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