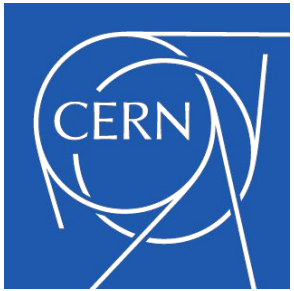
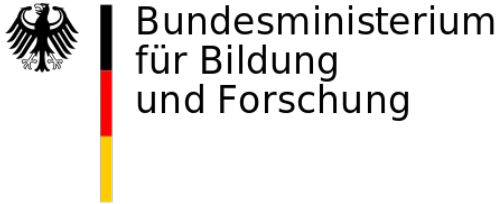




Enhancing the Phase Space for the Analysis of Inclusive H → bb Production Through Trigger-Level Analysis at the CMS Experiment

Adelina Lintuluoto

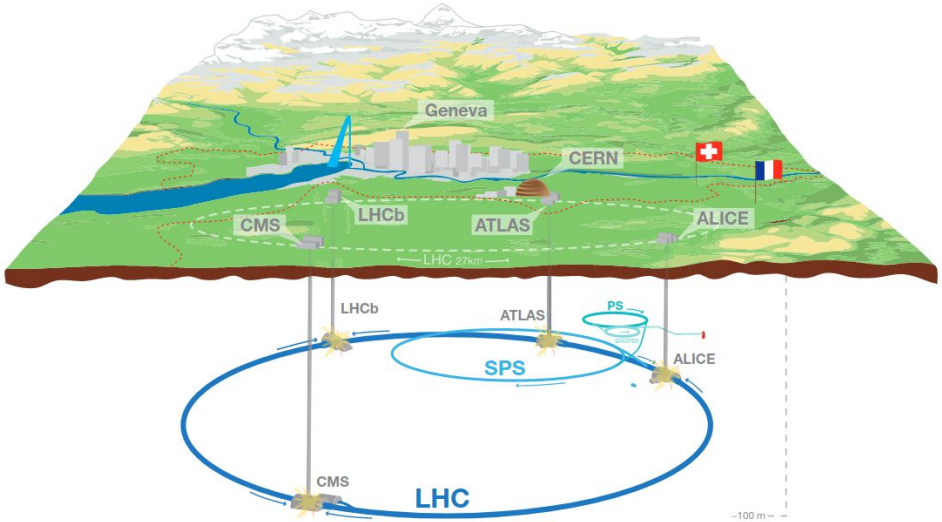
Mock-up defense

The Standard Model of particle physics

The Standard Model of particle physics is incomplete

The Standard Model of particle physics is incomplete

Advance the Standard Model and with that our understanding of the Universe

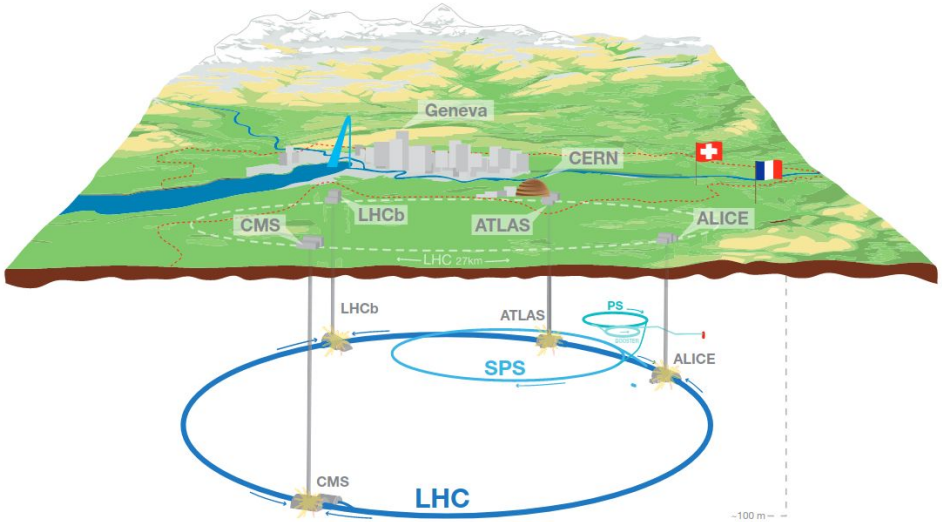


The Standard Model of particle physics is incomplete

Advance the Standard Model and with that our understanding of the Universe

...however...

...absence of clear signals for new physics 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 occur at low energies

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Strict energy thresholds to avoid overwhelming computing infrastructure

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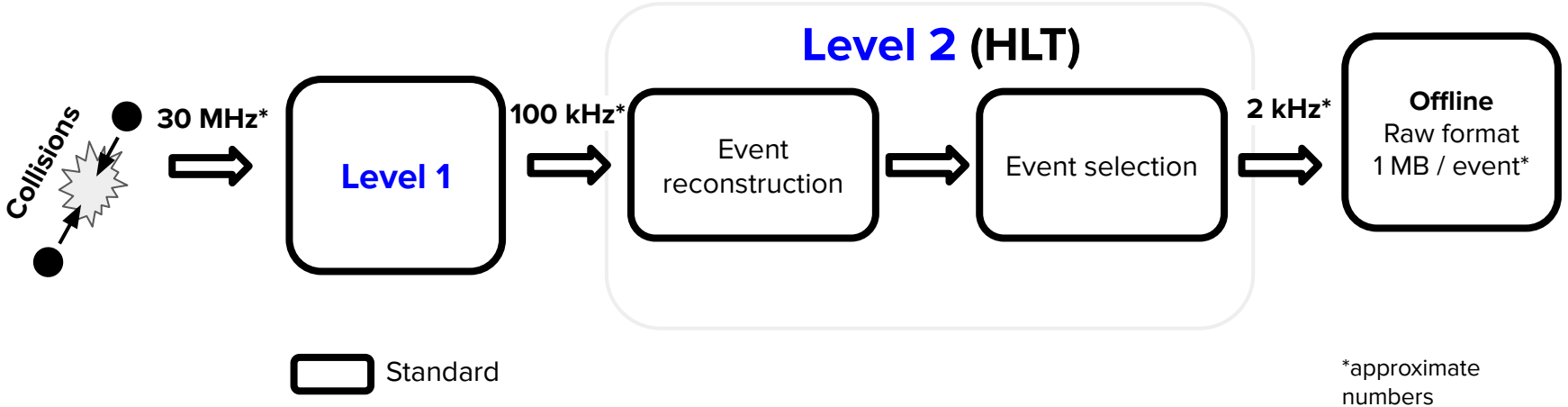
1. Large jet production
2. Subsequent (semi)leptonic decays of hadrons
3. Most p-p interactions occur at low energies

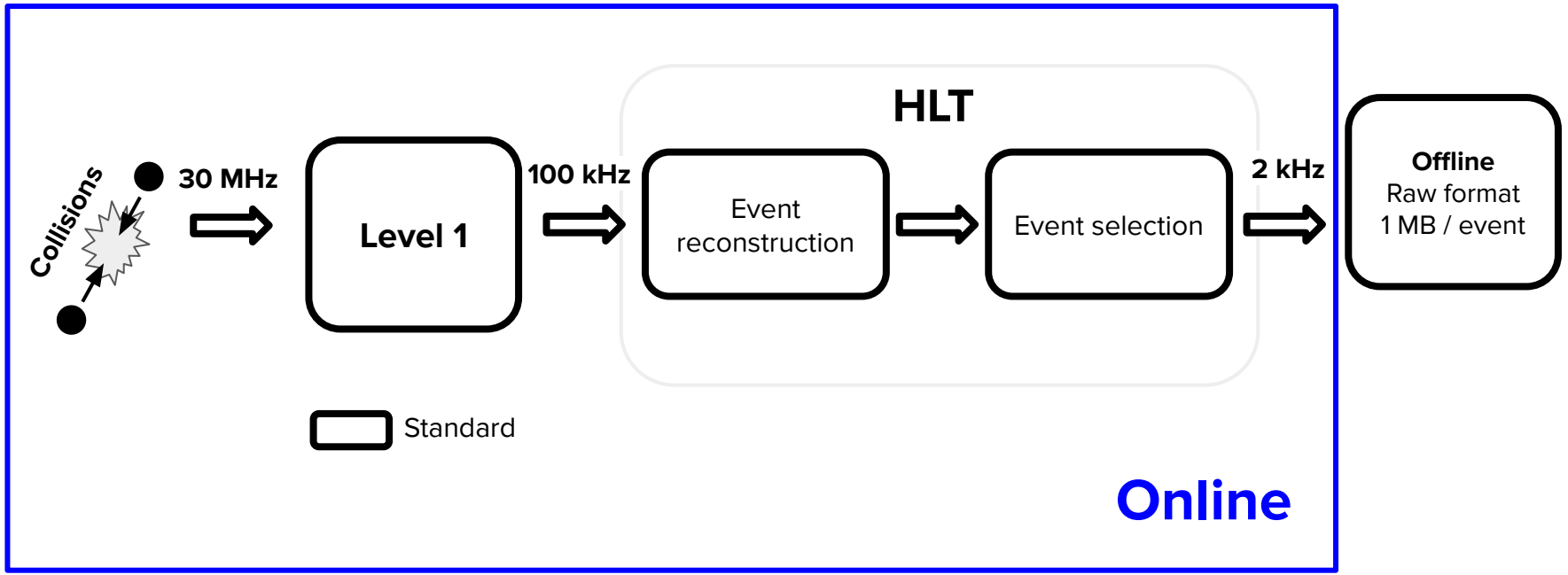
Strict energy thresholds to avoid overwhelming computing infrastructure

Events containing potential new physics are discarded

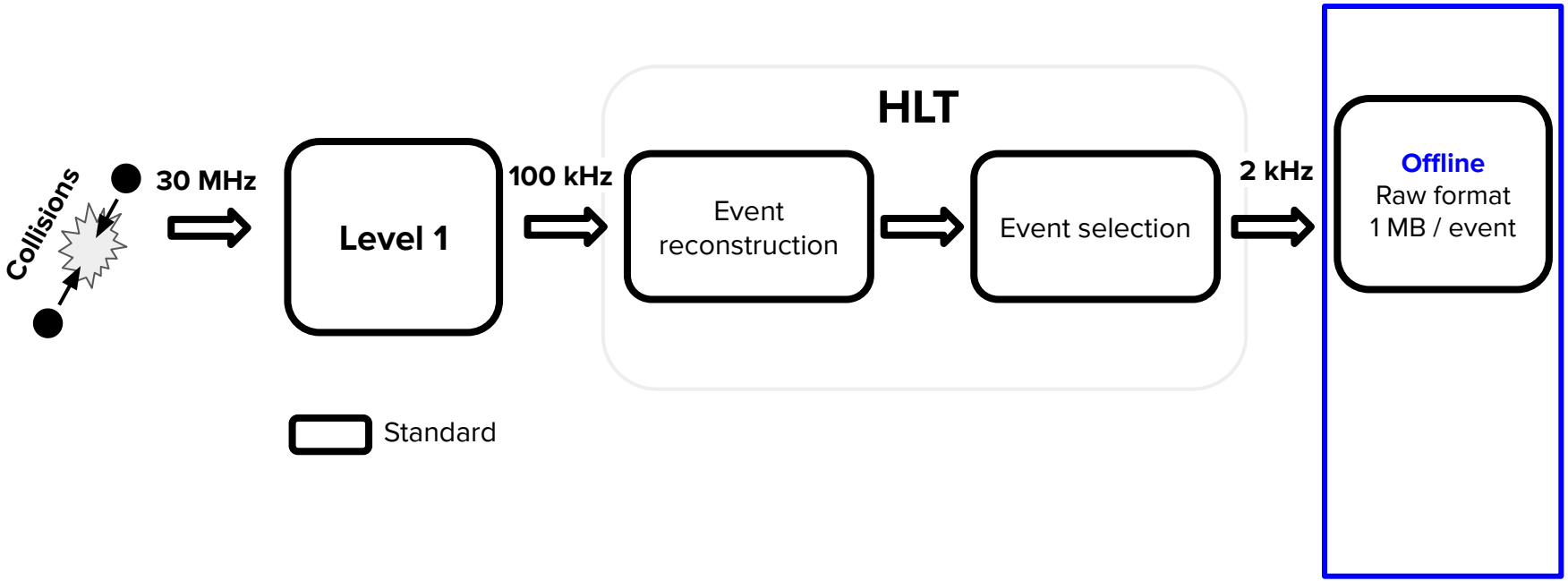
At CMS, events are selected by a two-tiered trigger system



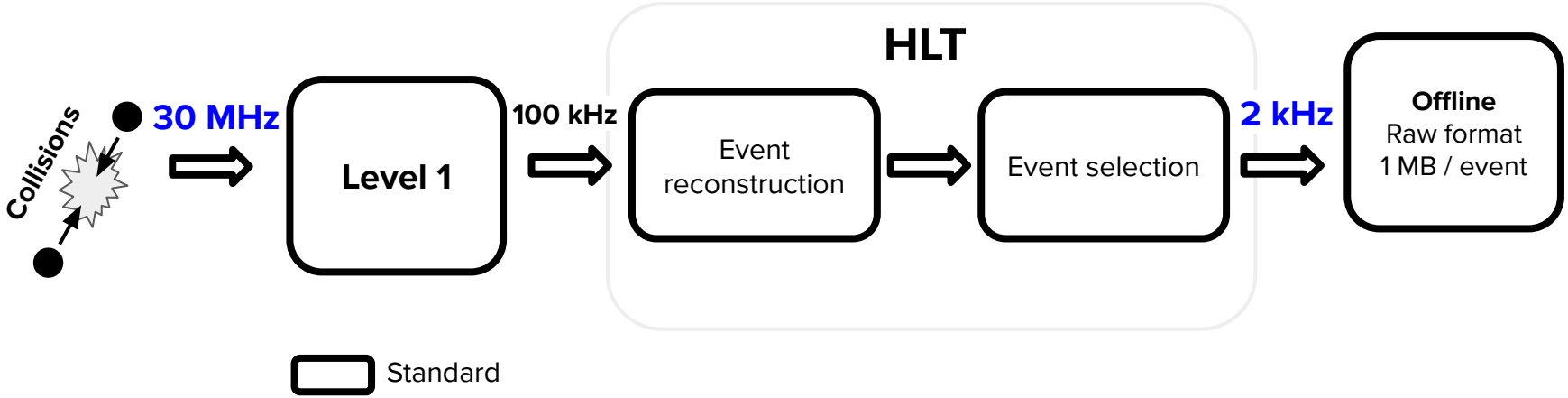
Online reconstruction aims to provide low latency



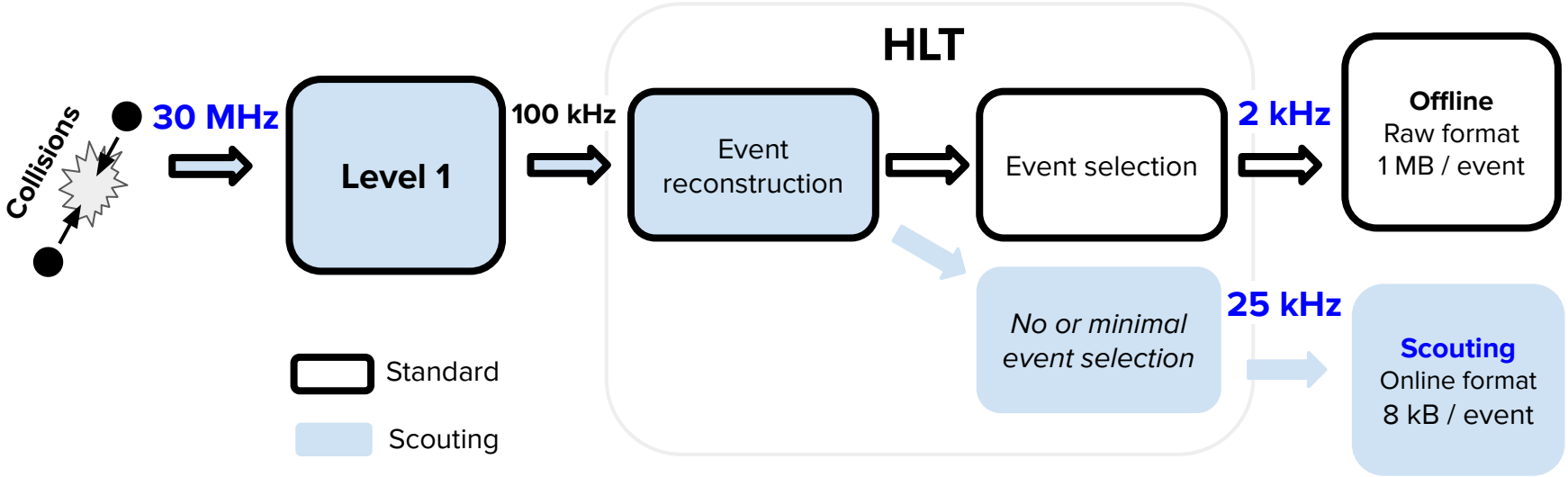
Offline reconstruction aims to provide the best physics objects for analysis



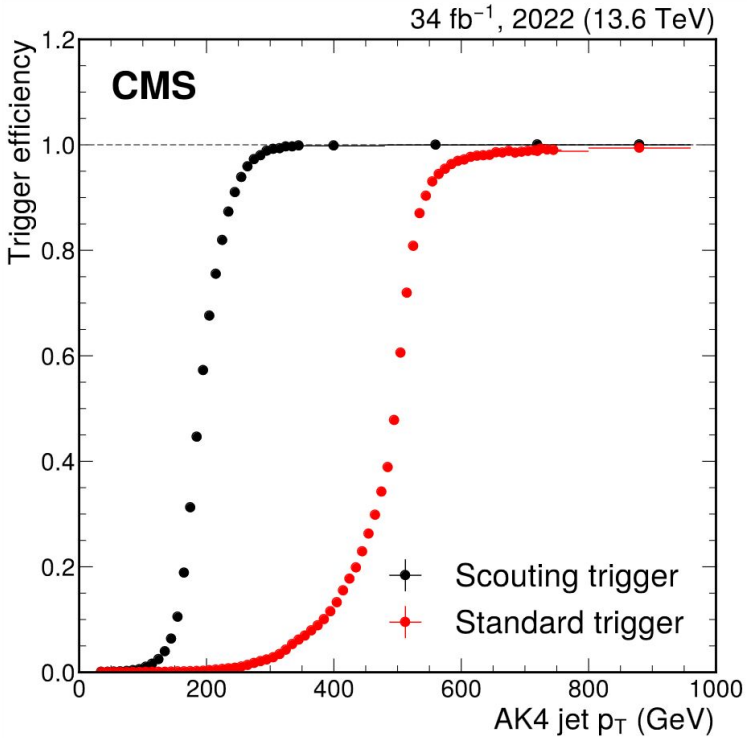
The vast majority of events are lost



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

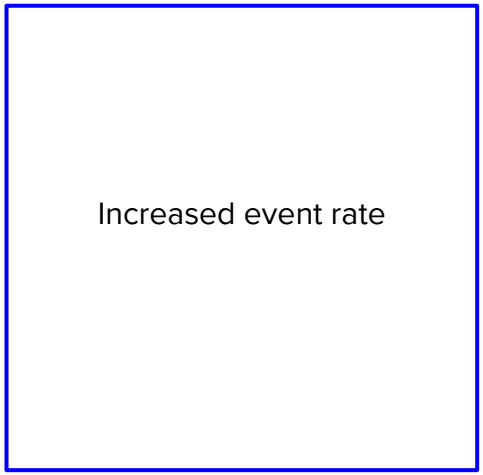


Access to unexplored phase spaces is achieved by lowering the trigger thresholds

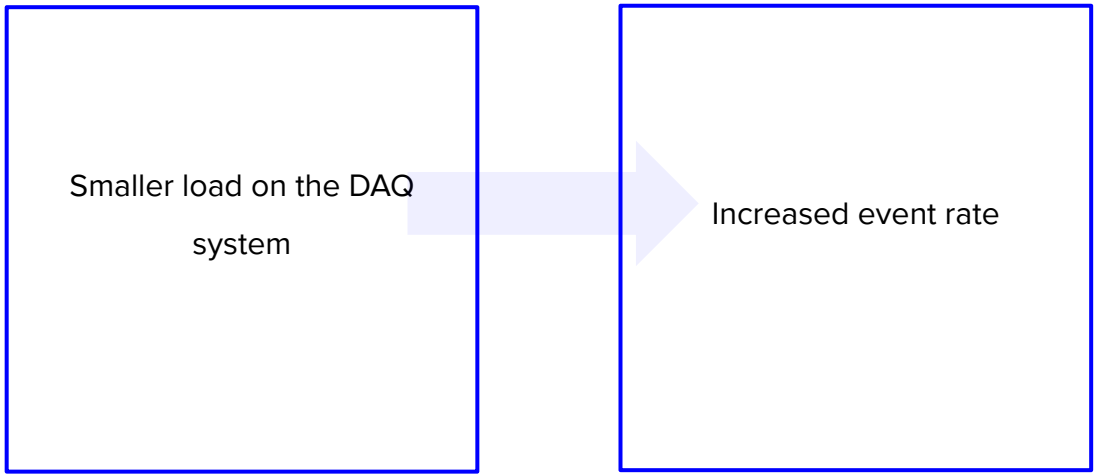


- **Scouting** is fully efficient earlier than the **standard strategy**
- Potentially revealing new interactions or particles that were previously overlooked due to higher trigger thresholds

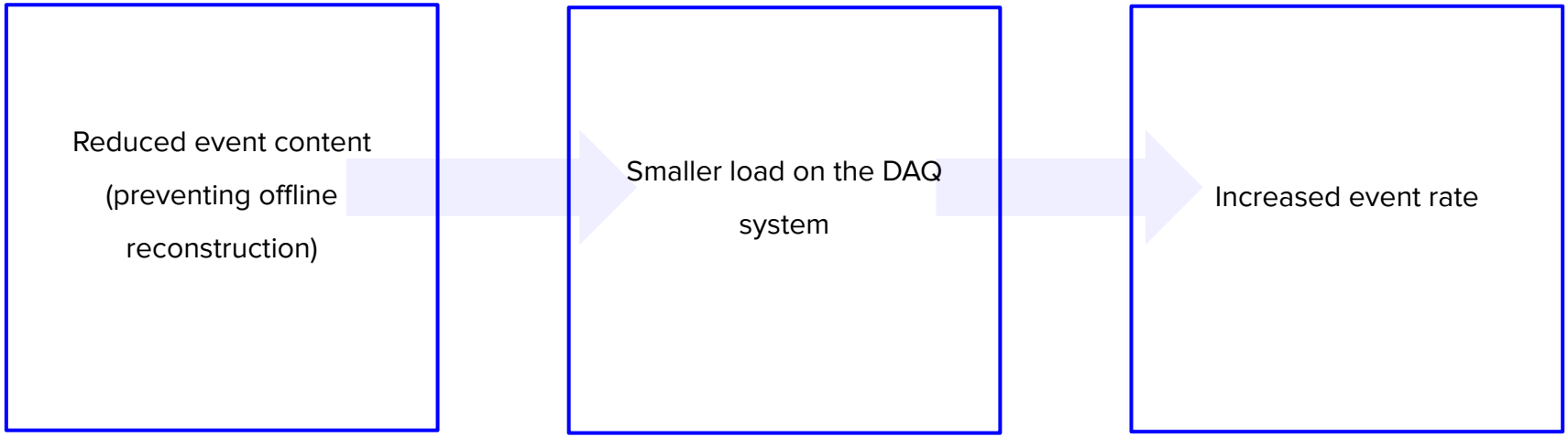
While scouting increases access to unexplored phase spaces, it comes at a cost



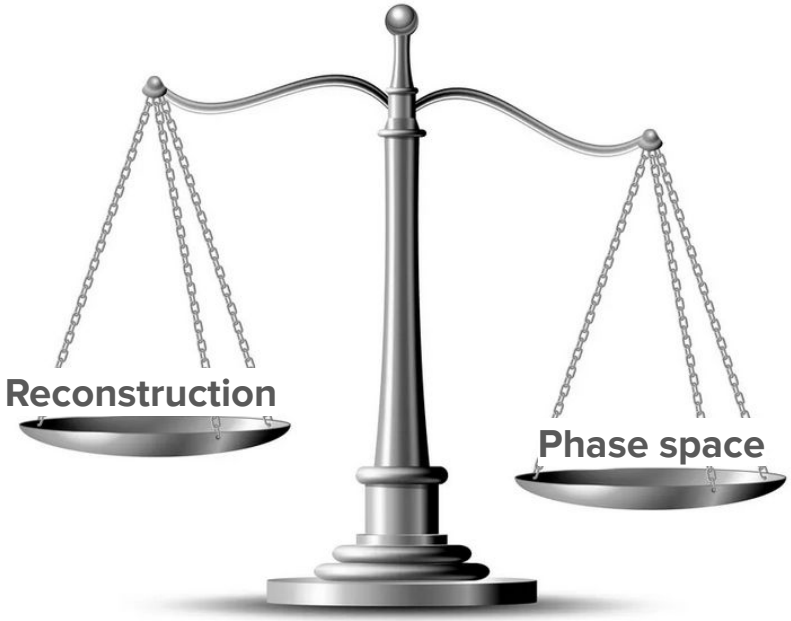
While scouting increases access to unexplored phase spaces, it comes at a cost



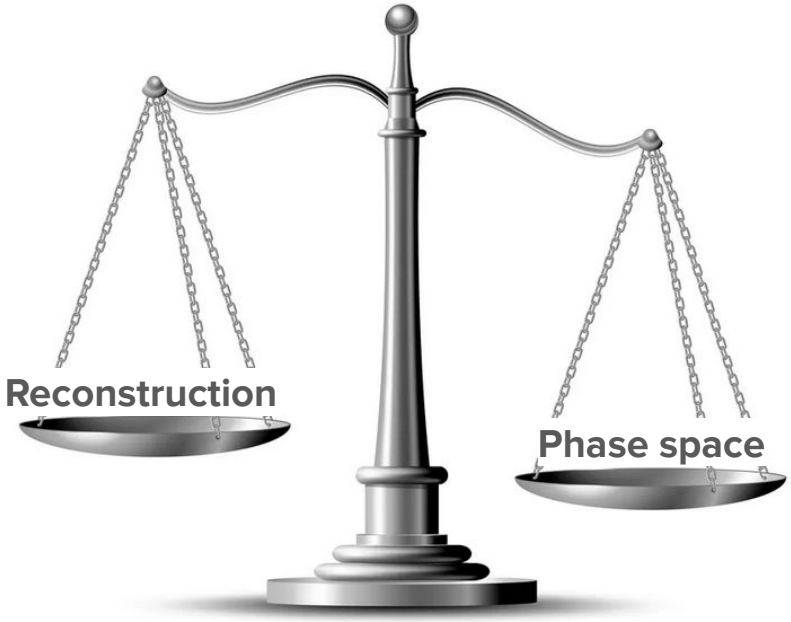
While scouting increases access to unexplored phase spaces, it comes at a cost



The quality of reconstruction is affected



The quality of reconstruction is affected



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-EP-2024-068
2024/03/26

CMS-EXO-23-007

Enriching the physics program of the CMS experiment via data scouting and data parking

The CMS Collaboration*

Abstract

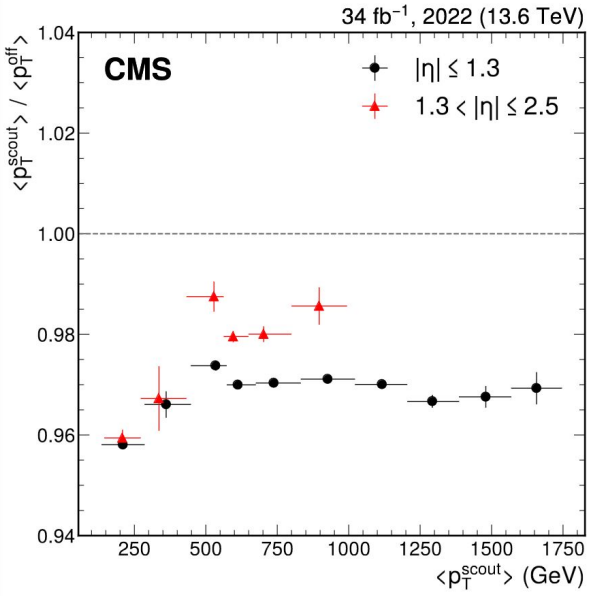
Specialized data-taking and data-processing techniques were introduced by the CMS experiment in Run 1 of the CERN LHC to enhance the sensitivity of searches for new physics and the precision of standard model measurements. These techniques, termed data scouting and data parking, extend the data-taking 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 within limits. Data parking involves storing a large amount of raw detector data collected by algorithms with low 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.

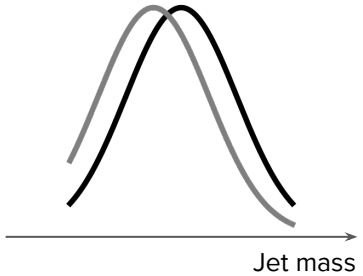
To be submitted to Physics Reports

*See Appendix B for the list of collaboration members

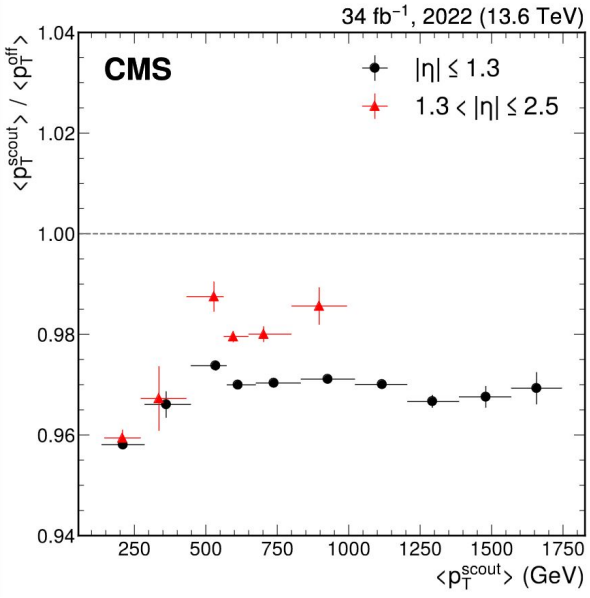
arxiv.org/abs/2403.16134

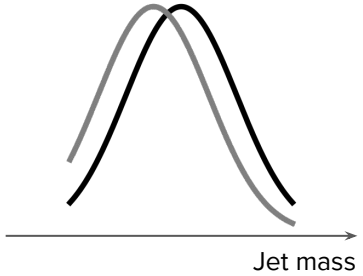
Assessing the reconstruction with calibration studies

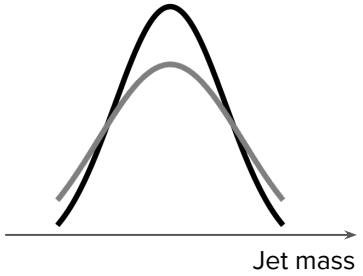




Assessing the reconstruction with calibration studies

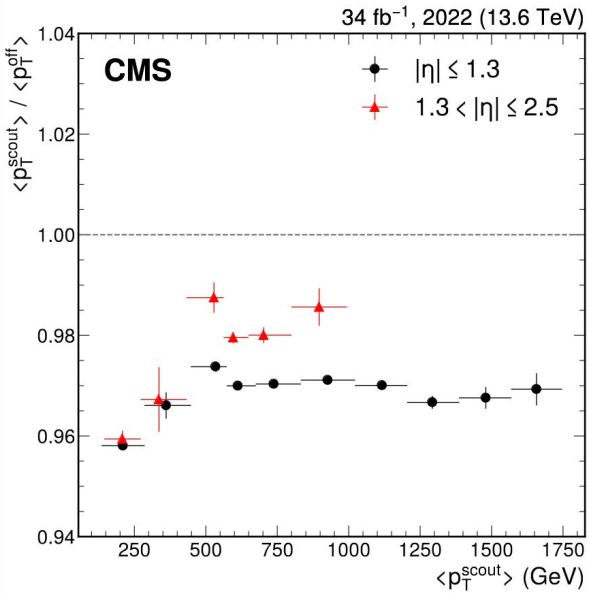


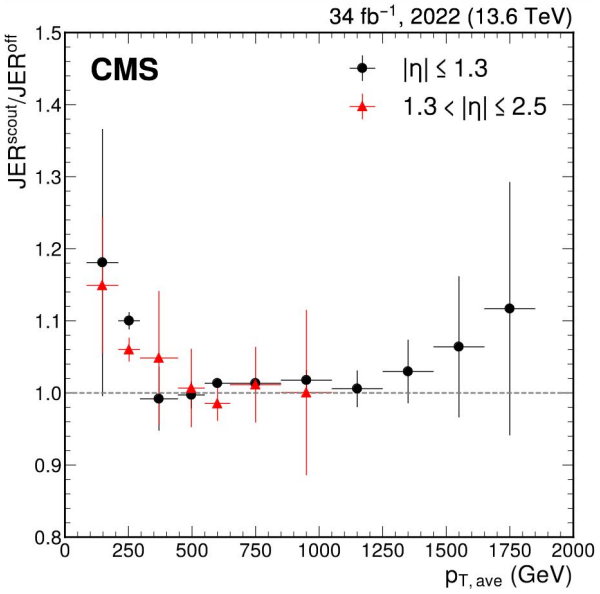


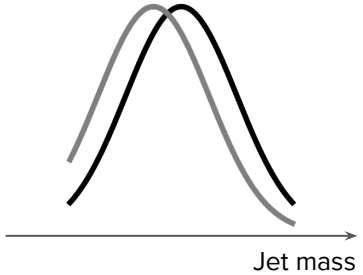


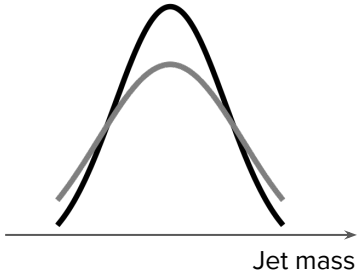
arxiv.org/abs/2403.16134

Assessing the reconstruction with calibration studies

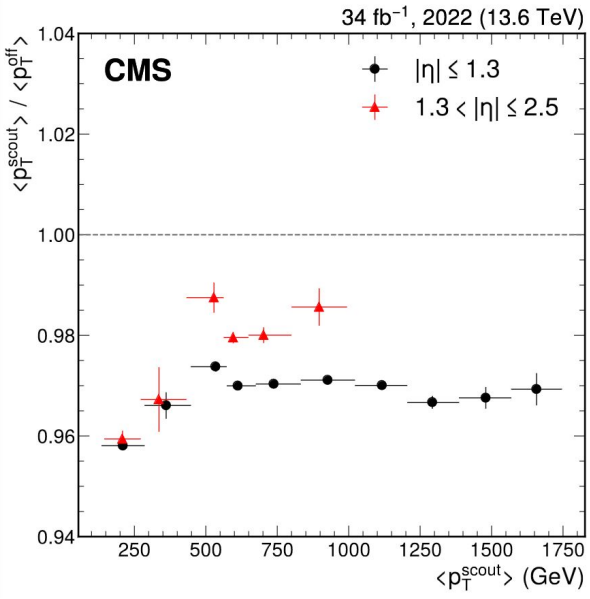


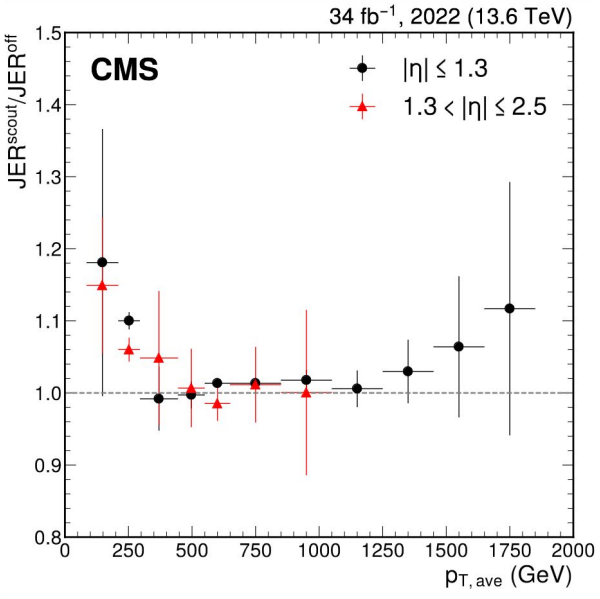


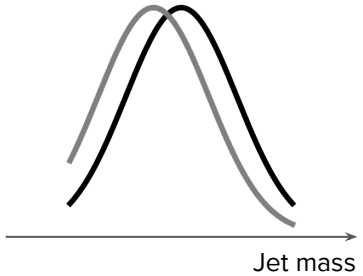


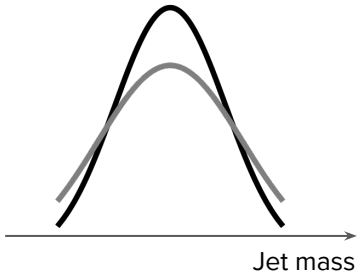


Assessing the reconstruction with calibration studies





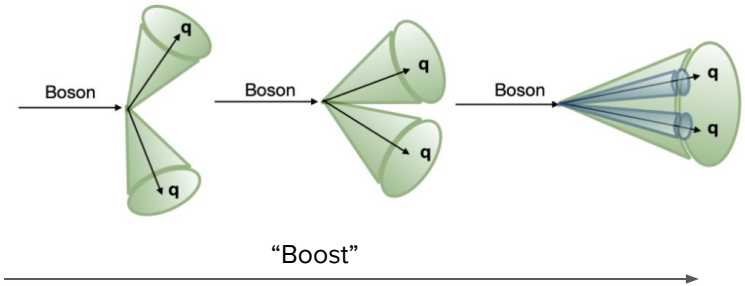




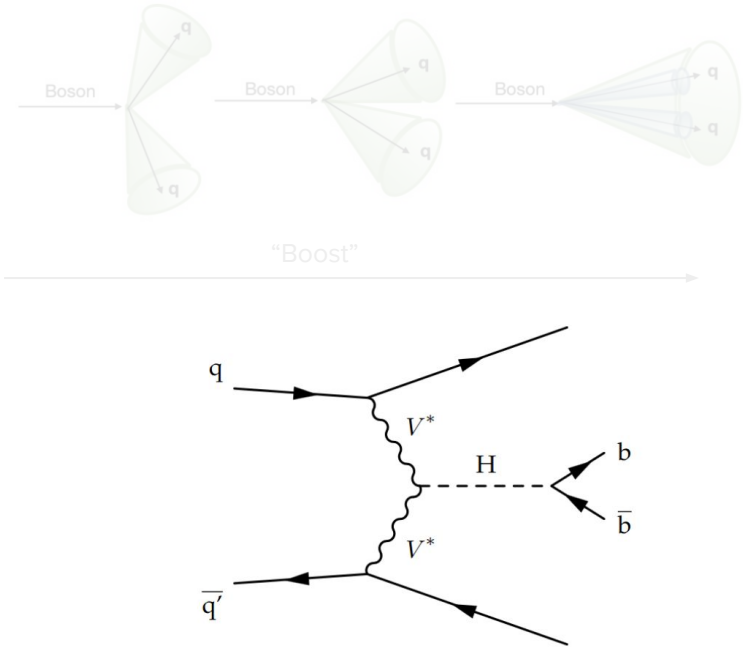
Negligible impact on searches that are statistically limited...

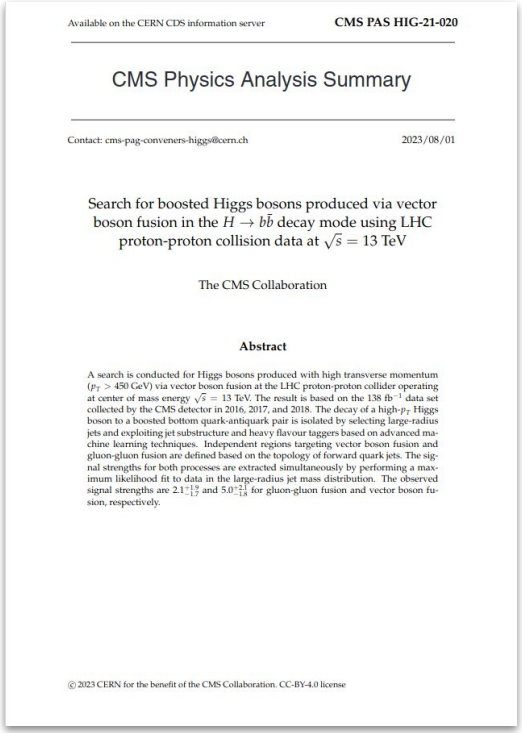
...such as most searches for new physics

The study of Higgs boson momentum-dependent anomalous couplings



The study of Higgs boson momentum-dependent anomalous couplings





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 $2.1^{+1.2}_{-1.7}$ and $5.0^{+2.1}_{-1.8}$ for gluon-gluon fusion and vector boson fusion, respectively.

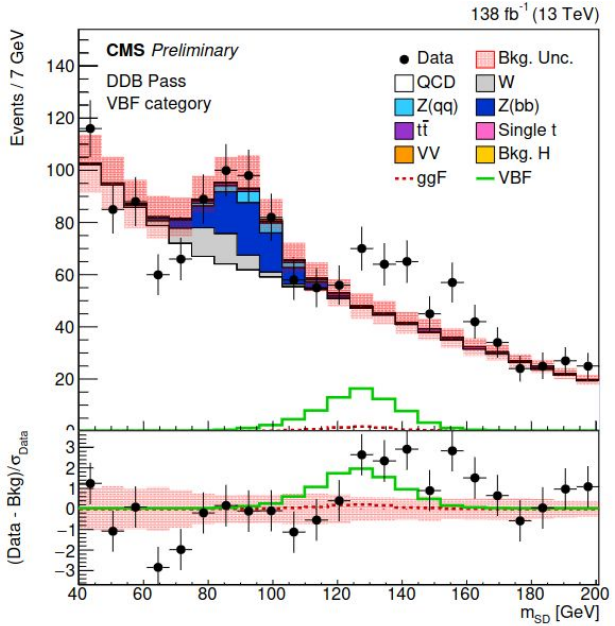
cds.cern.ch/record/2866501

Using the standard trigger strategy to search for boosted Higgs boson production

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

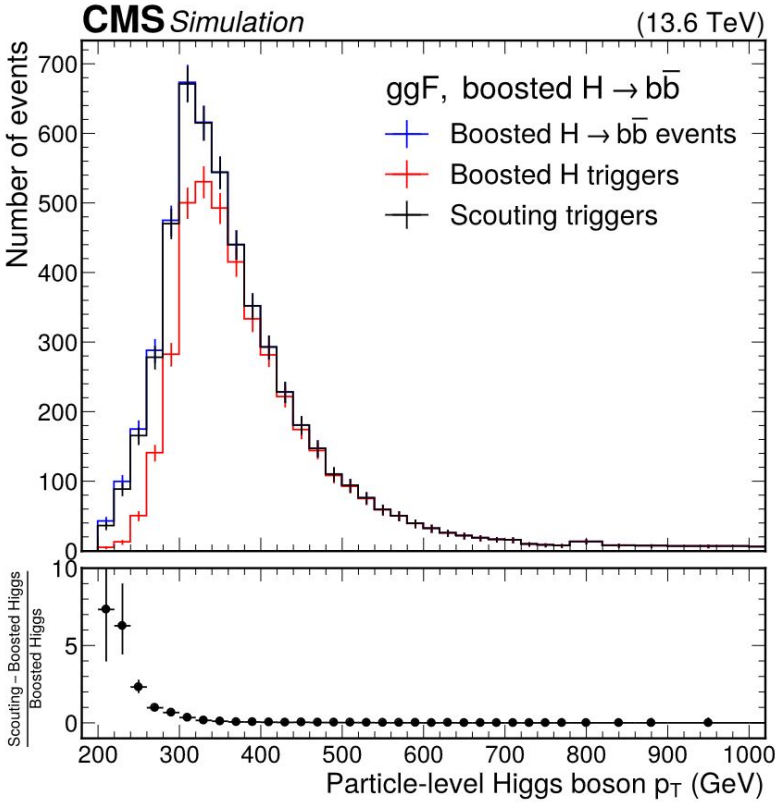
Significance of:
3.0 σ

Could this be evidence for anomalous Higgs couplings?

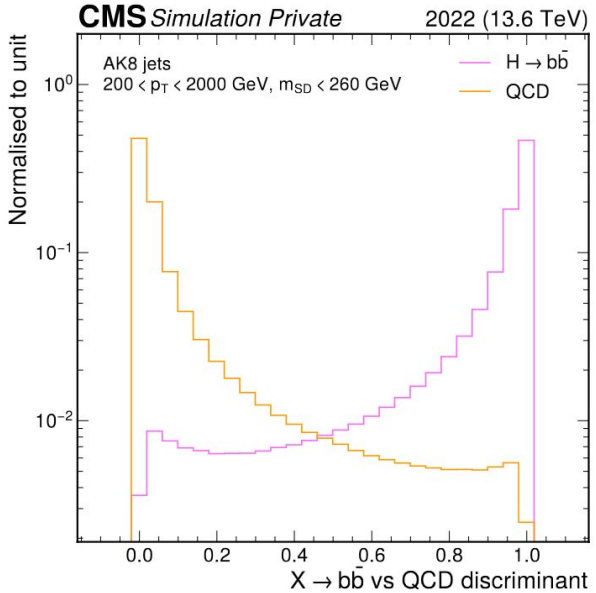


Using the scouting strategy to search for boosted Higgs boson production

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



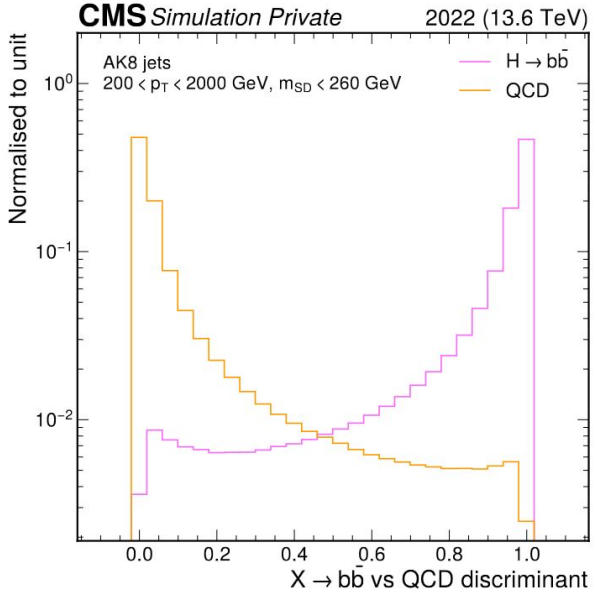
Using the scouting strategy to search for boosted Higgs boson production



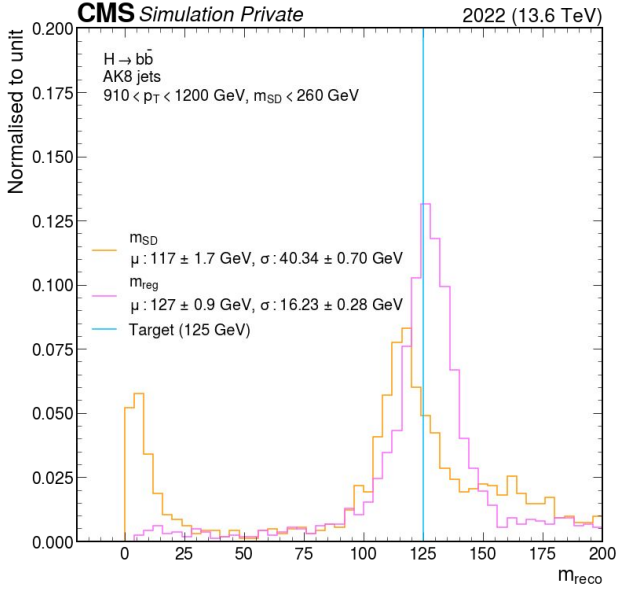
40% likelihood of correctly identifying signal jets

⟶0.6% likelihood of misidentifying QCD jets

Using the scouting strategy to search for boosted Higgs boson production

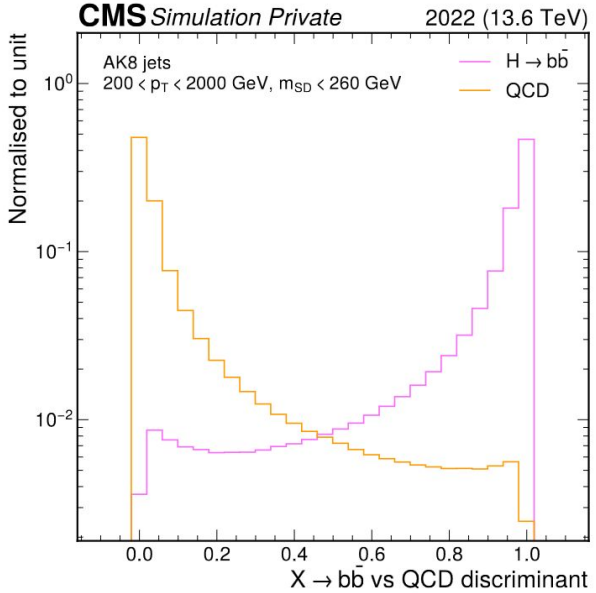


40% likelihood of correctly identifying signal jets
⟶0.6% likelihood of misidentifying QCD jets



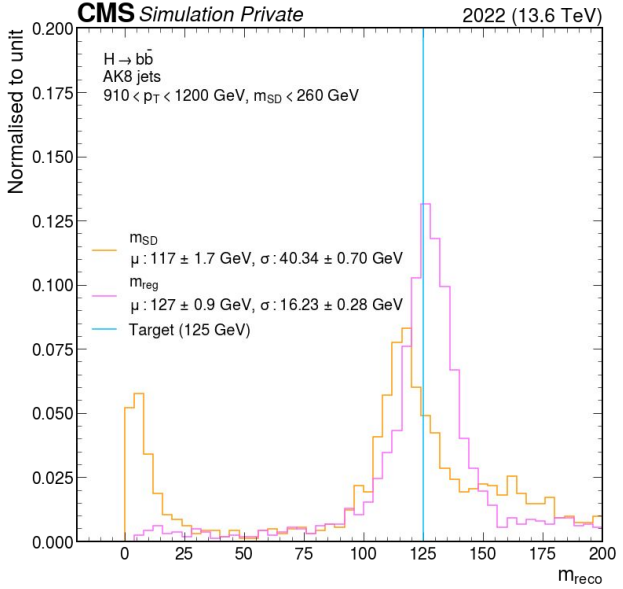
Jet mass resolution of roughly 10%

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%**

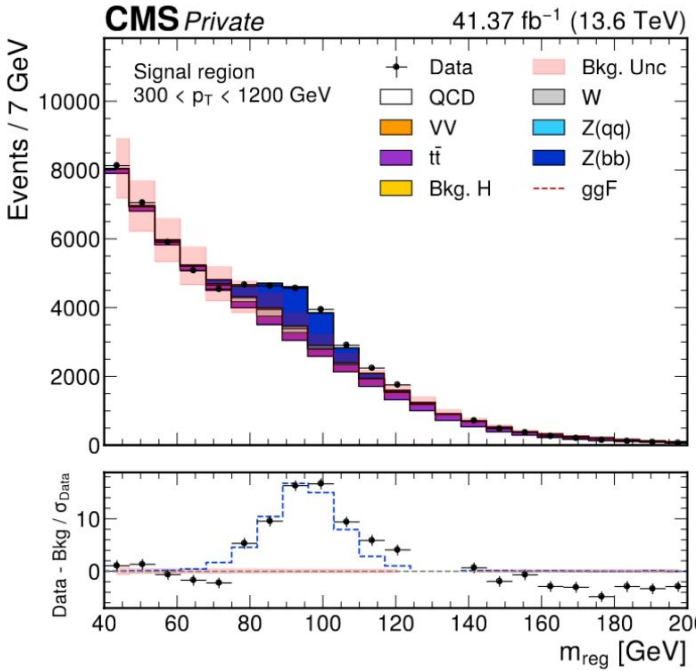
cds.cern.ch/record/2256875

Validating the scouting strategy by searching for boosted Z → bb 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

- Scouting broadens the range of events that are captured by CMS, potentially revealing new interactions or particles
- Resolutions of these objects approach those achieved by the full offline reconstruction
- Scouting jets are valuable in searches for boosted boson decay into hadronic final states

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