CMS HH and HHH results
Towards measuring the Higgs potential at the LHC

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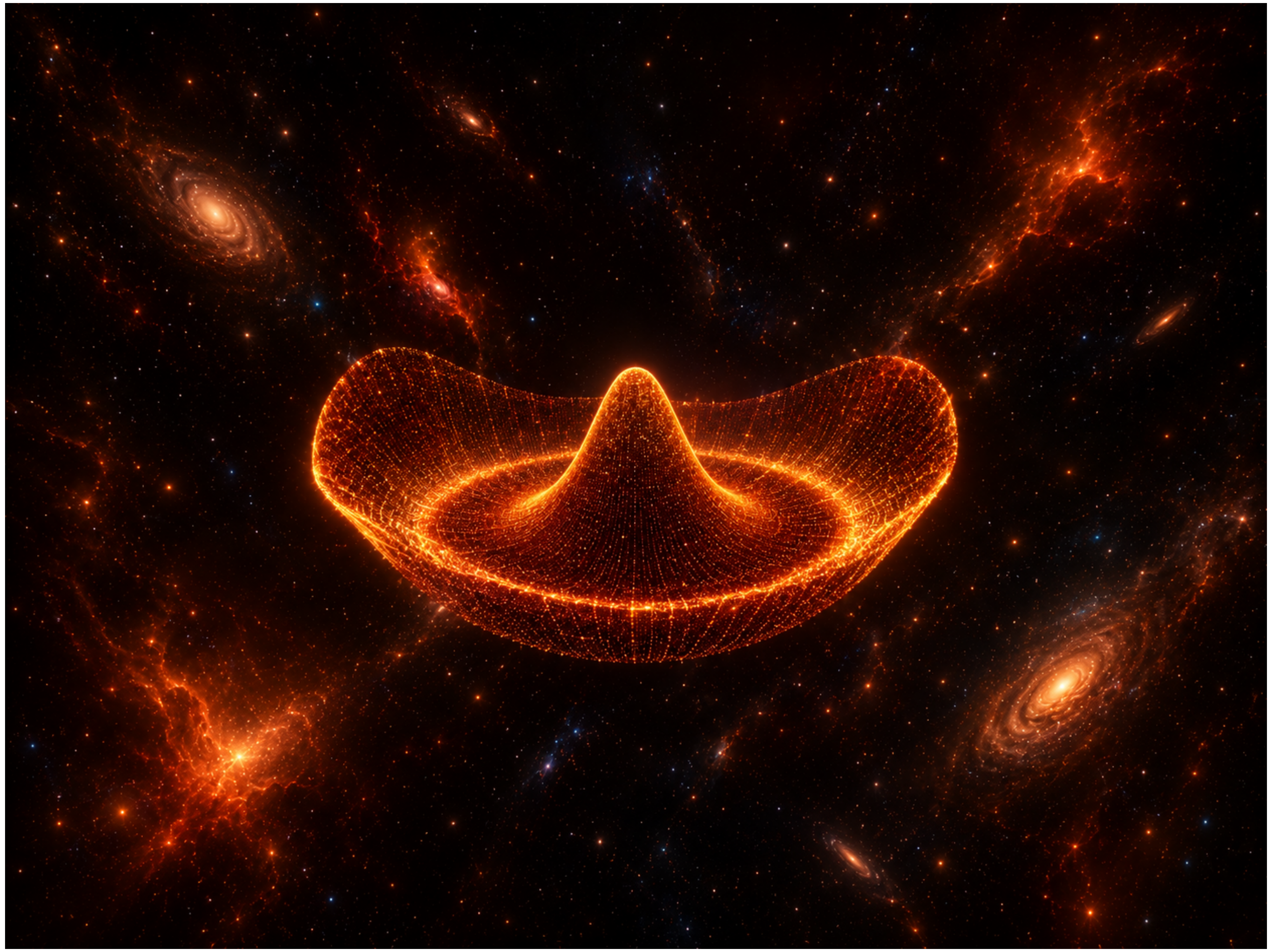
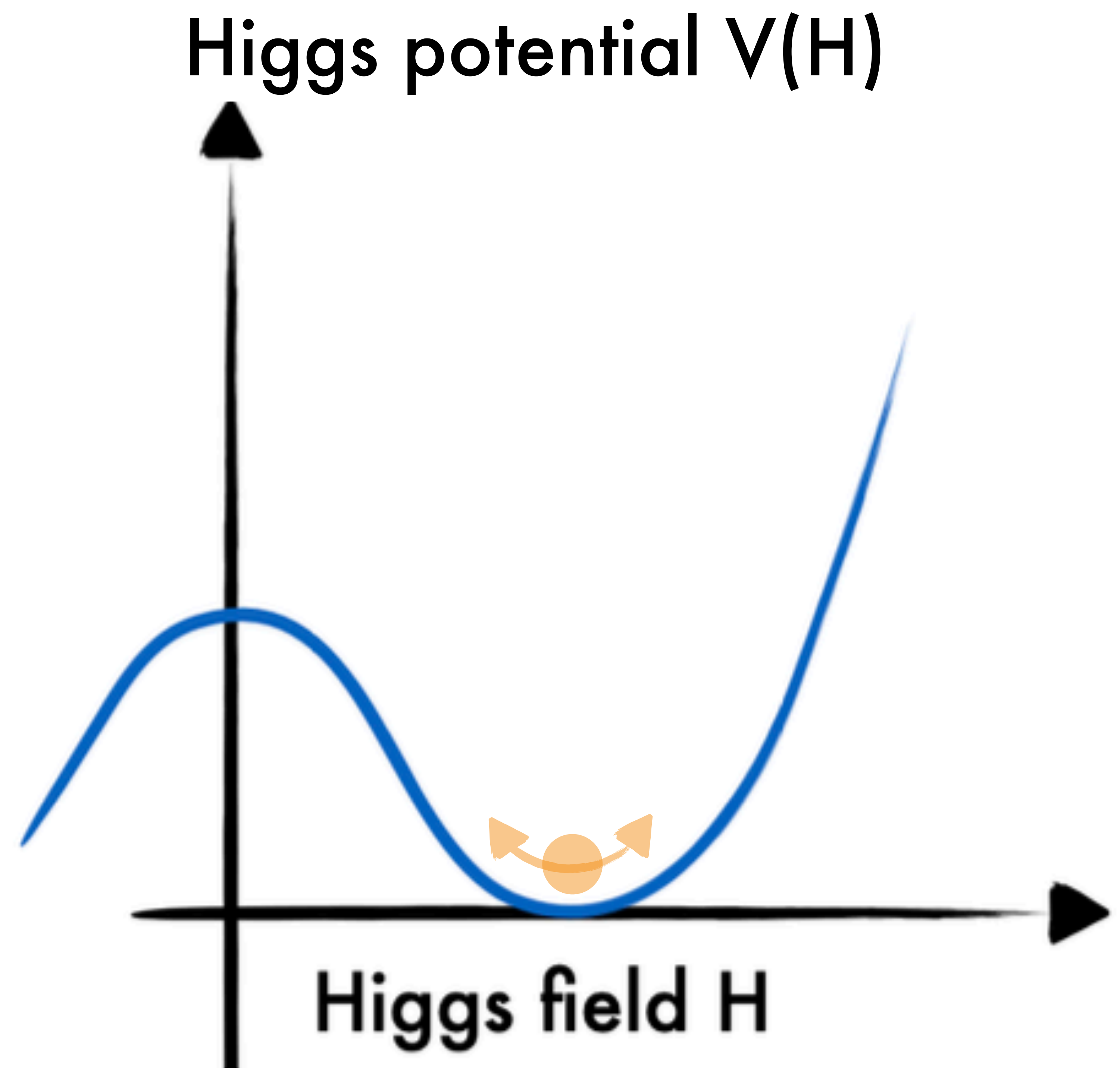
ATLAS HH France Grenoble
9th of July 2026



Scientific landscape: Higgs potential



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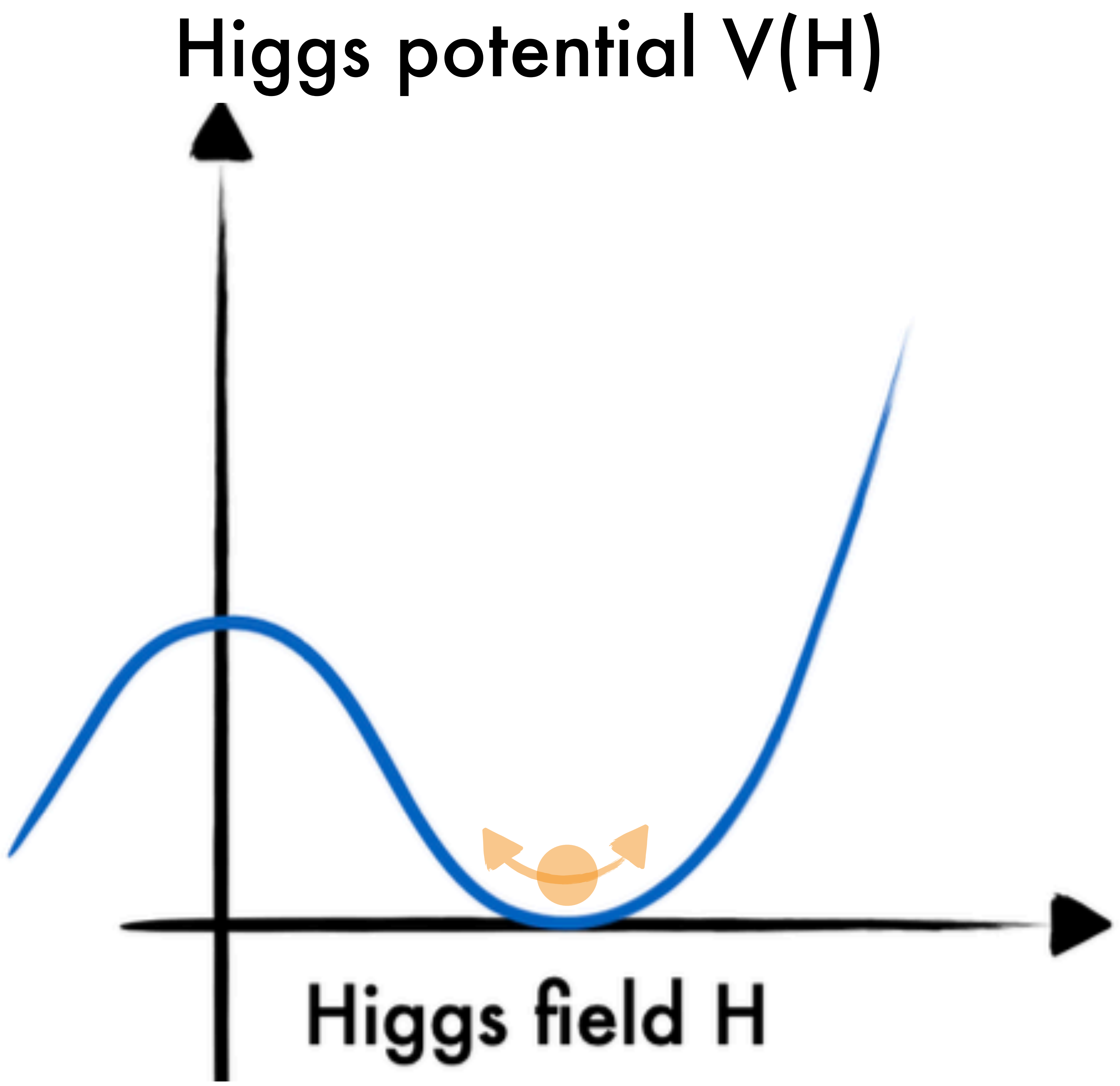
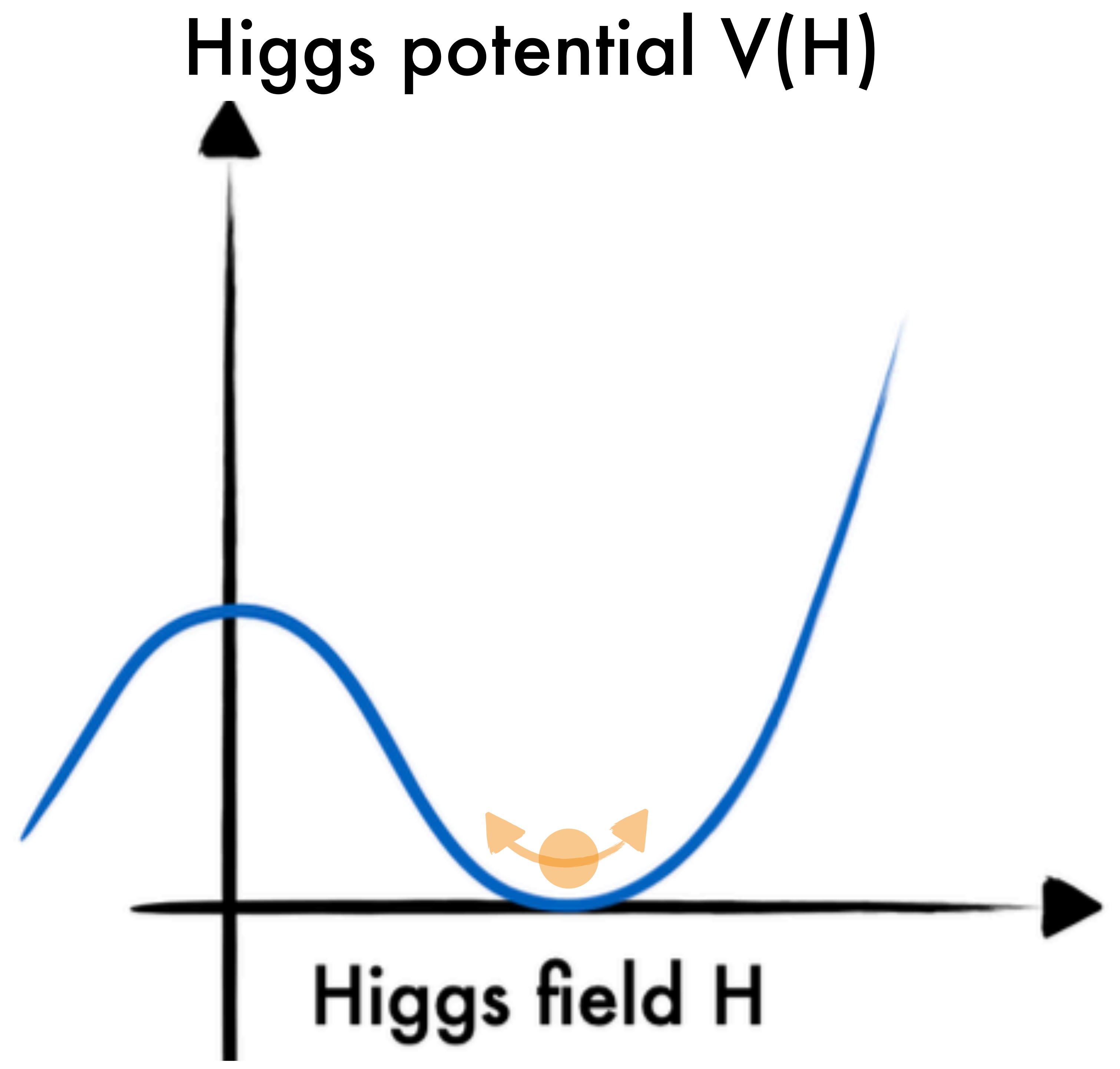


Higgs potential: decides what **"empty space" means**

- Selects vacuum value→ defines particle masses → flavor pattern → particle interactions

Scientific landscape: Higgs potential



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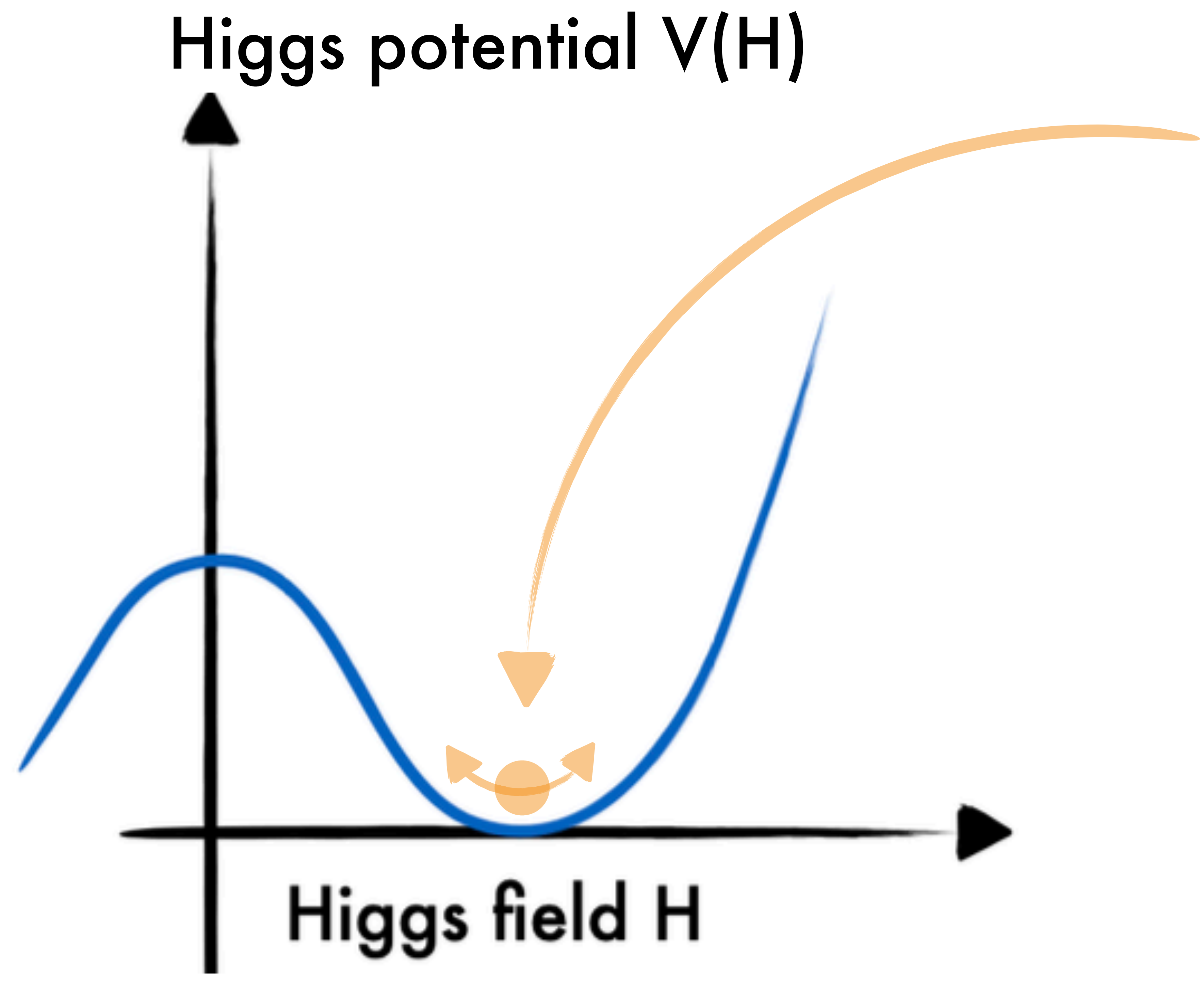
- Selects vacuum value→ defines particle masses → flavor pattern → particle interactions

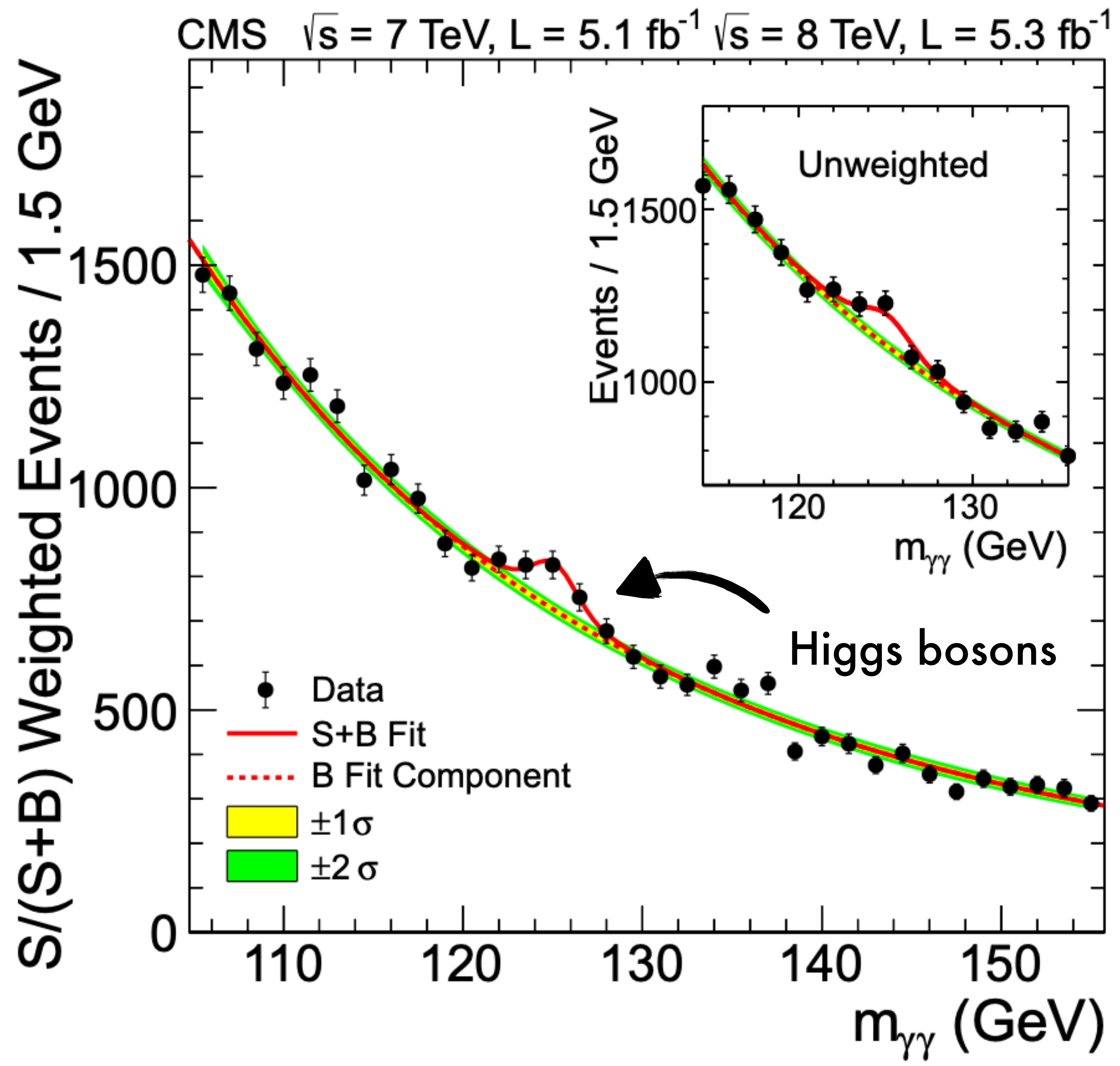
- At the core of the question *"Why is there something rather than nothing?"*

Scientific landscape: Higgs potential



$H \to b\bar{b}$
$H \to c\bar{c}$
ttH
$H \to \gamma\gamma$
$H \to ZZ$
$H \to WW$
$H \to \tau\tau$
$H \to \mu\mu$

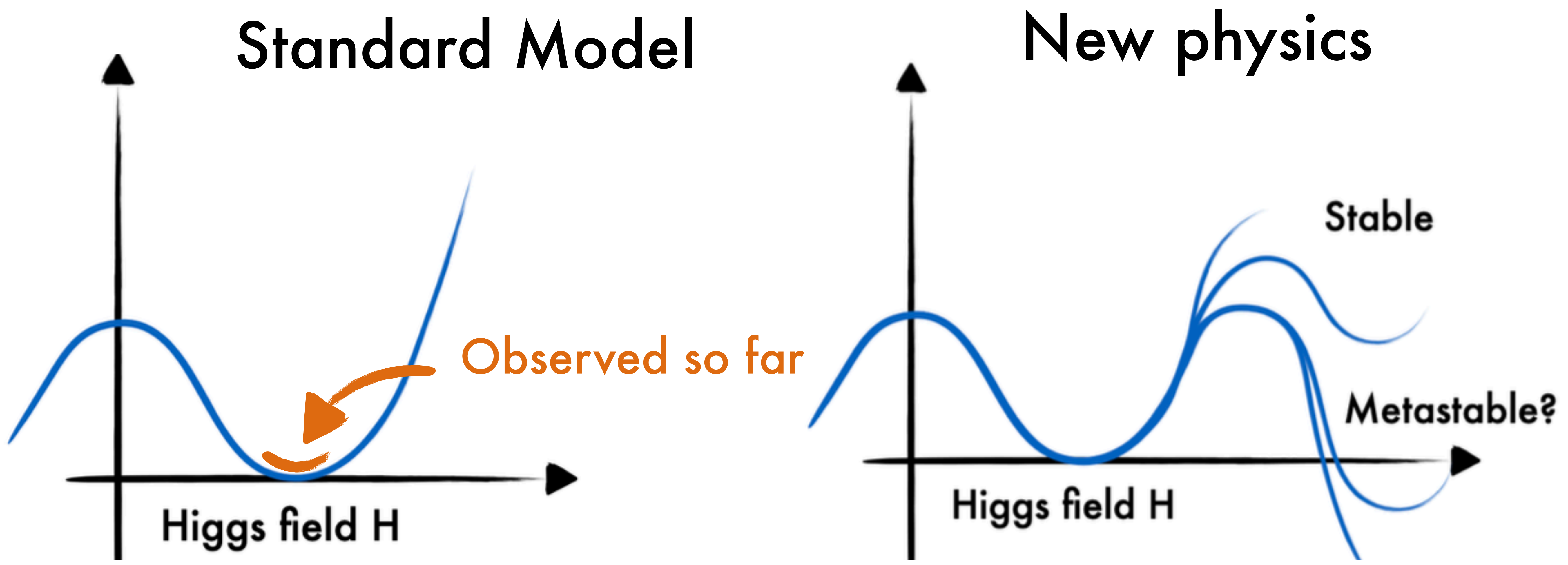
$H \to \gamma\gamma$



Higgs potential: decides what **"empty space" means**

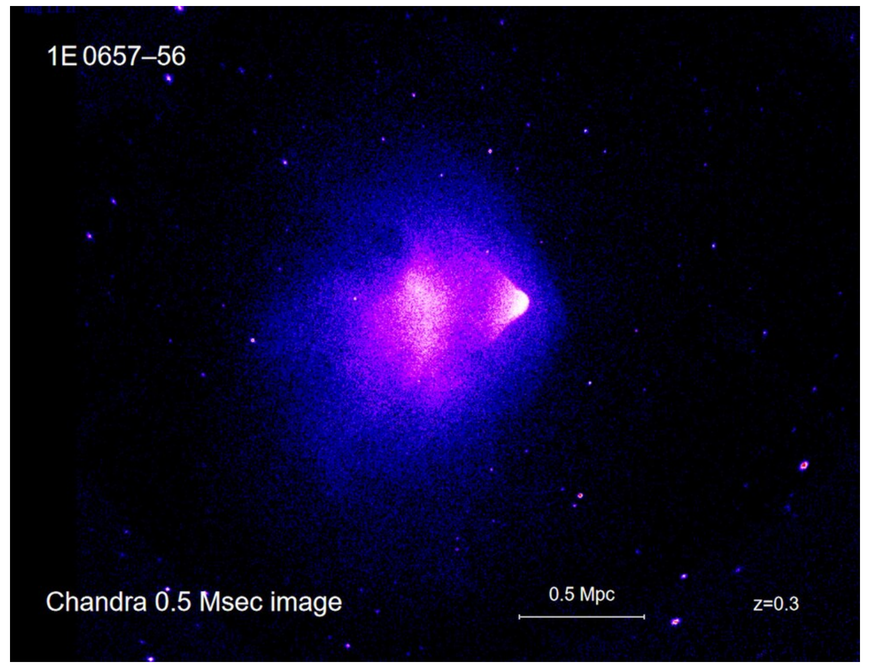
- Selects vacuum value→ defines particle masses → flavor pattern → particle interactions
- At the core of the question *"Why is there something rather than nothing?"*
- Higgs boson: discovered in 2012 → probes the minima of the Higgs potential

Standard Model Higgs potential: shortcomings

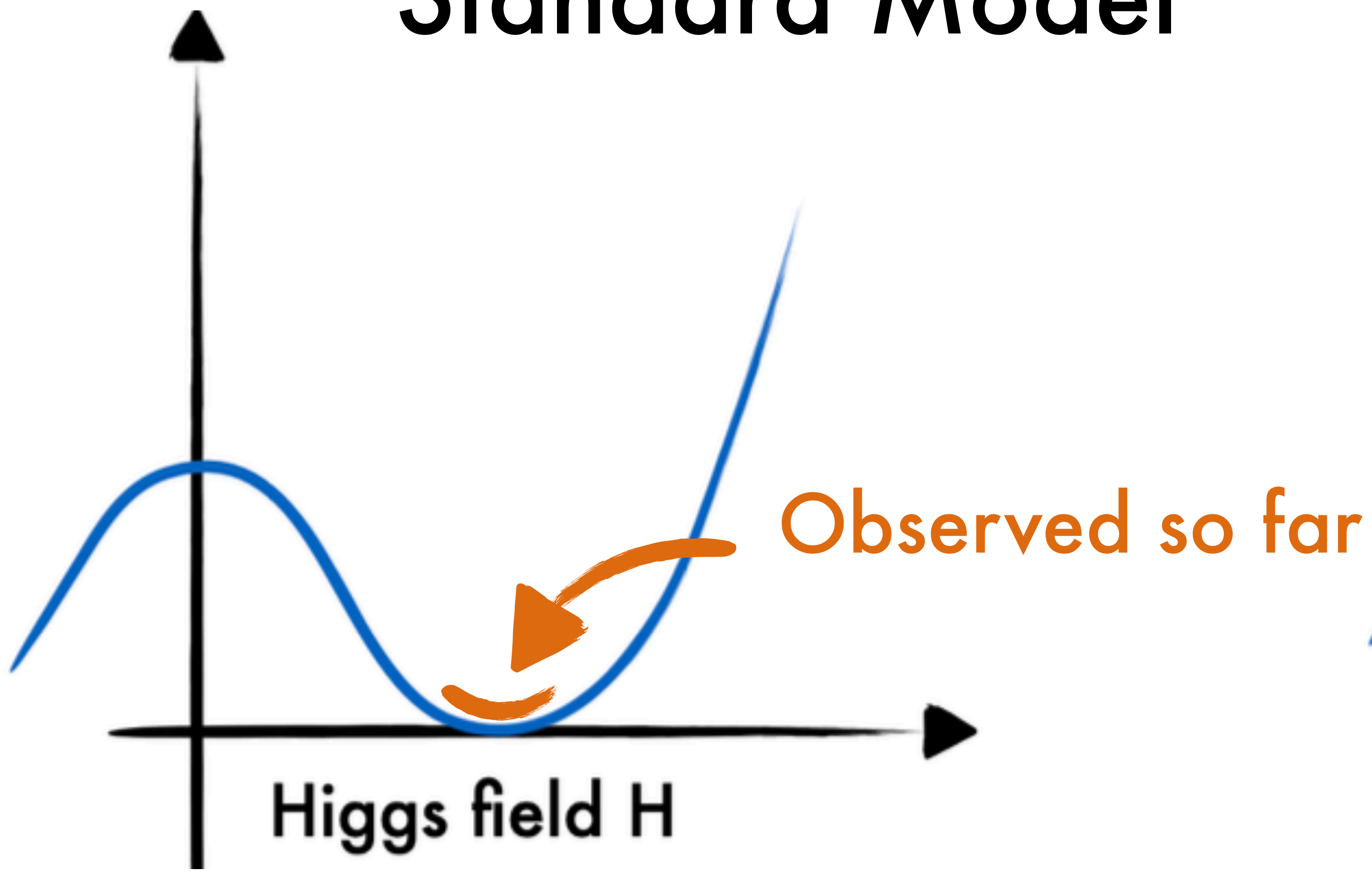


Standard Model Higgs potential: shortcomings

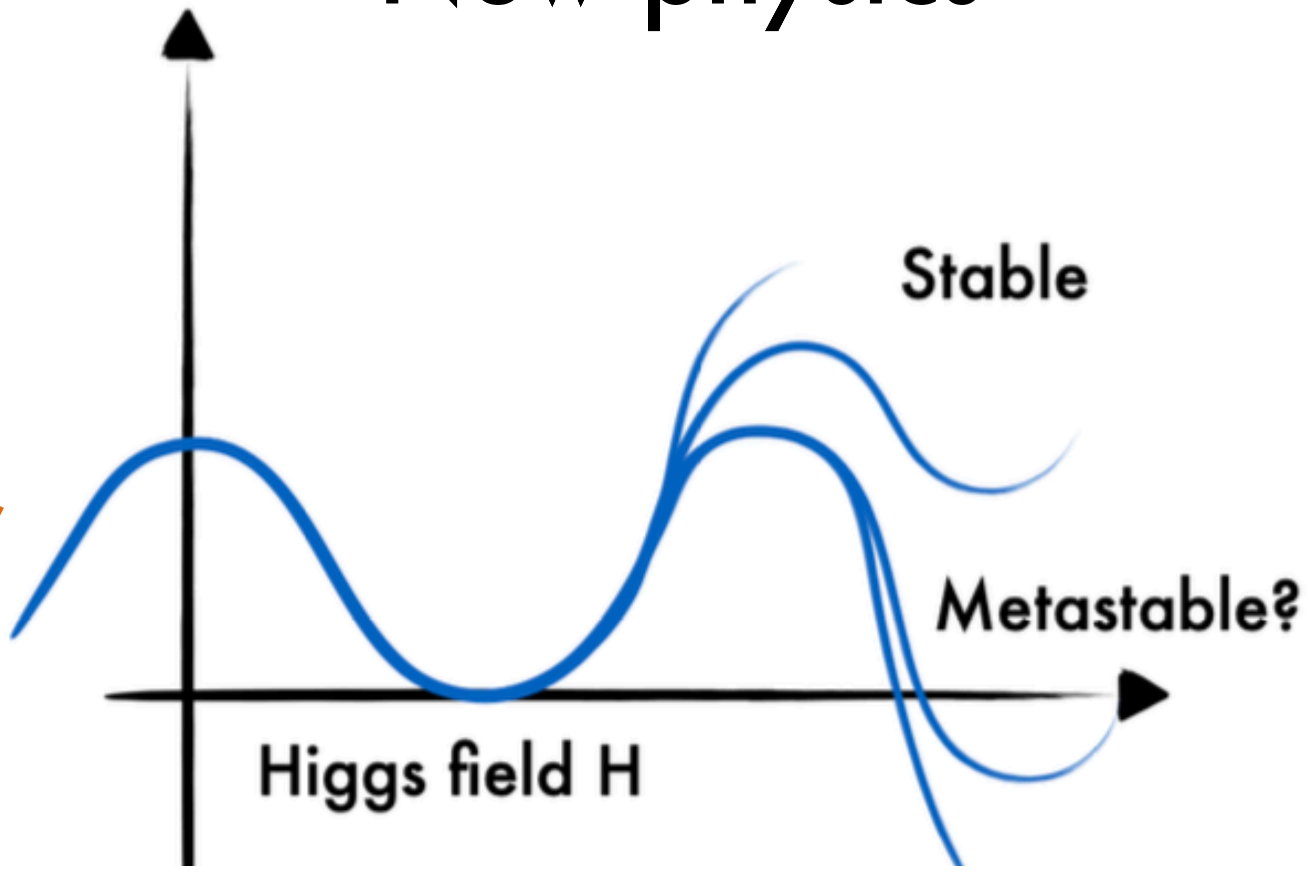
Dark Matter



Standard Model



New physics



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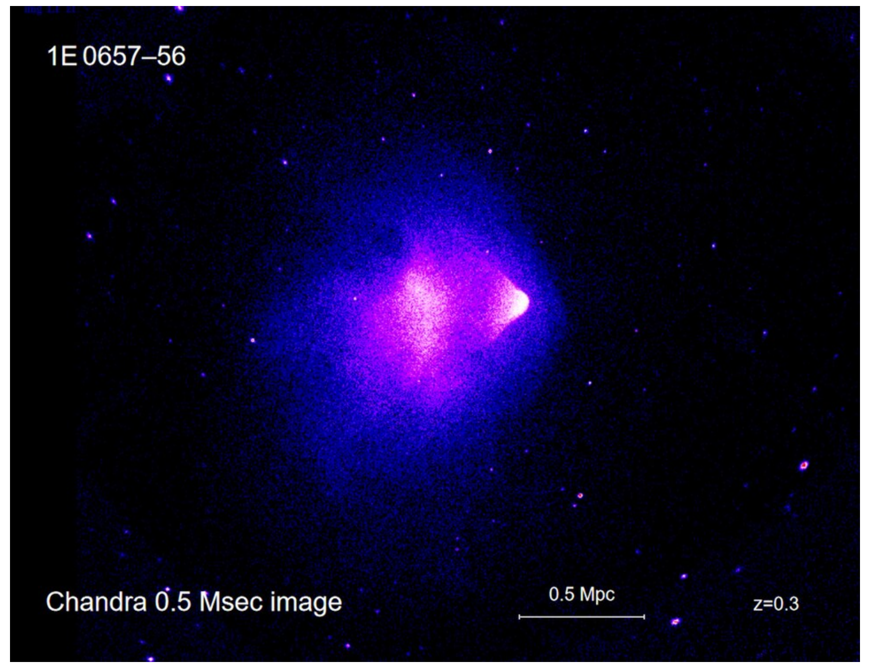
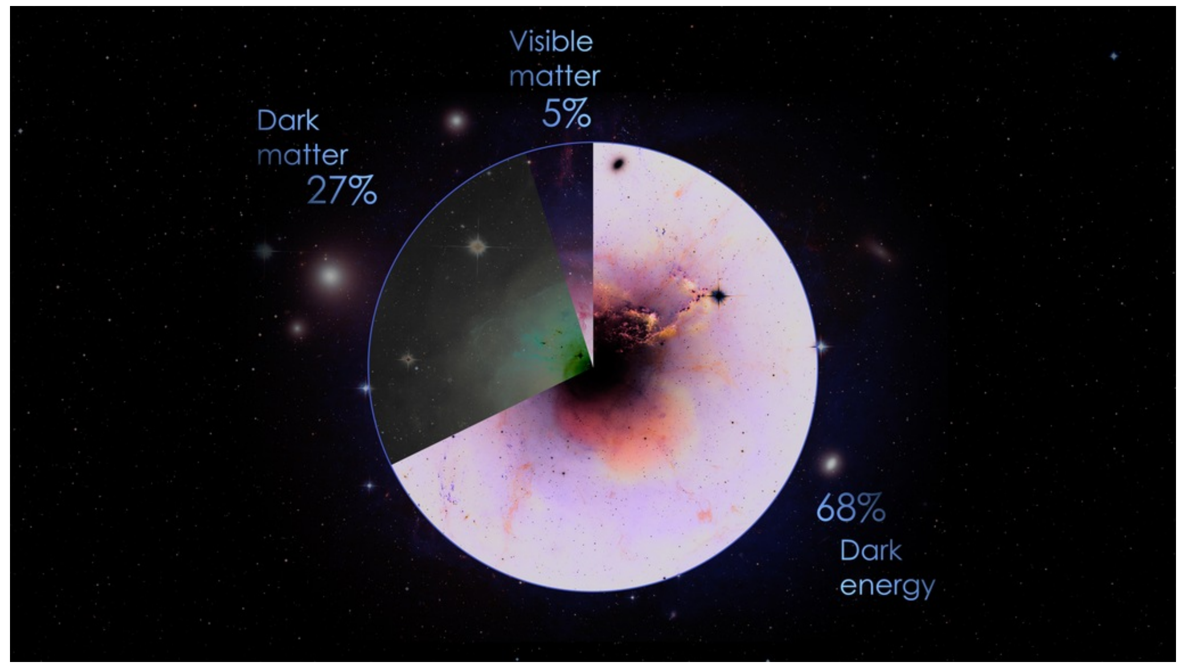


Vacuum energy / dark energy



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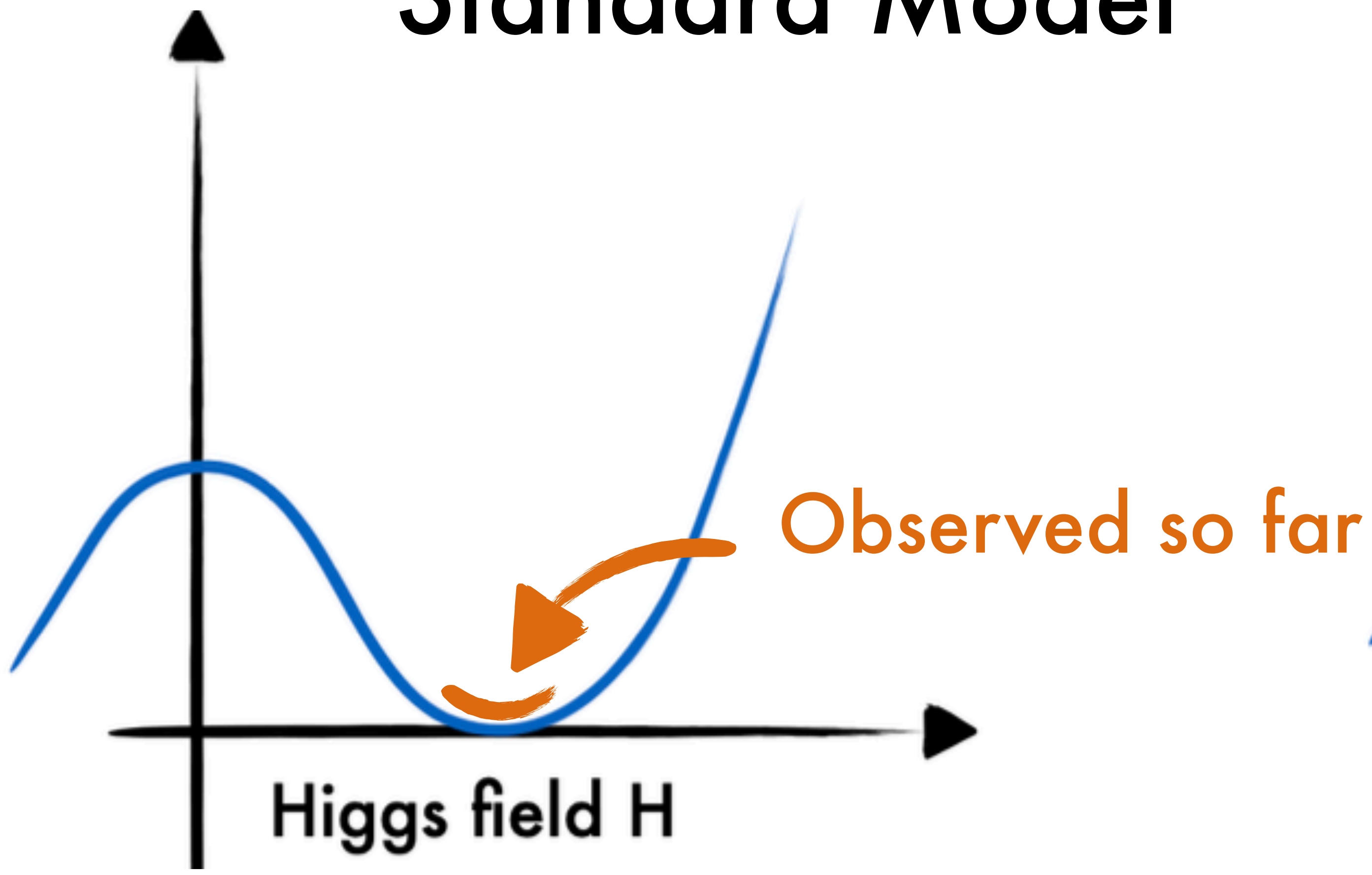

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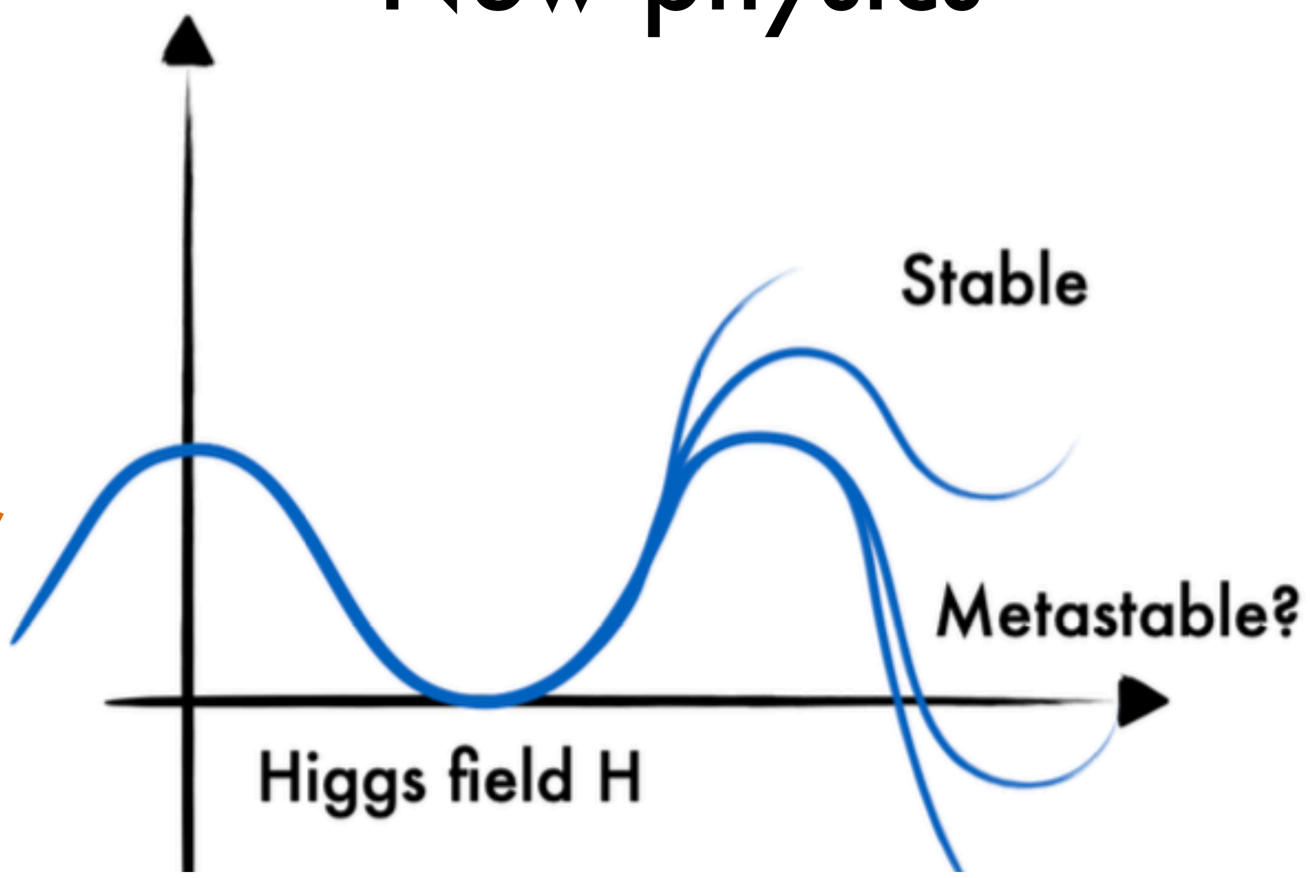

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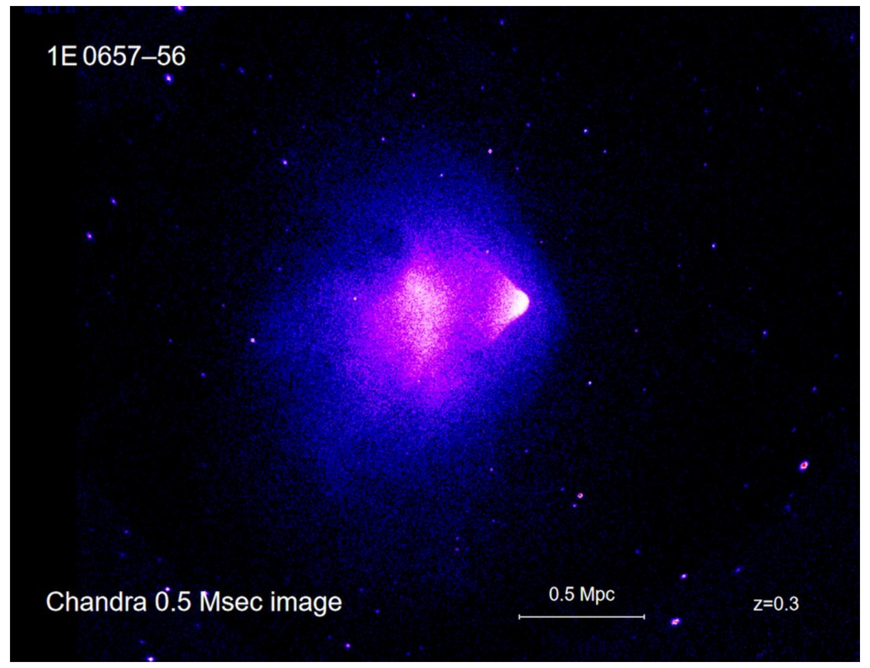

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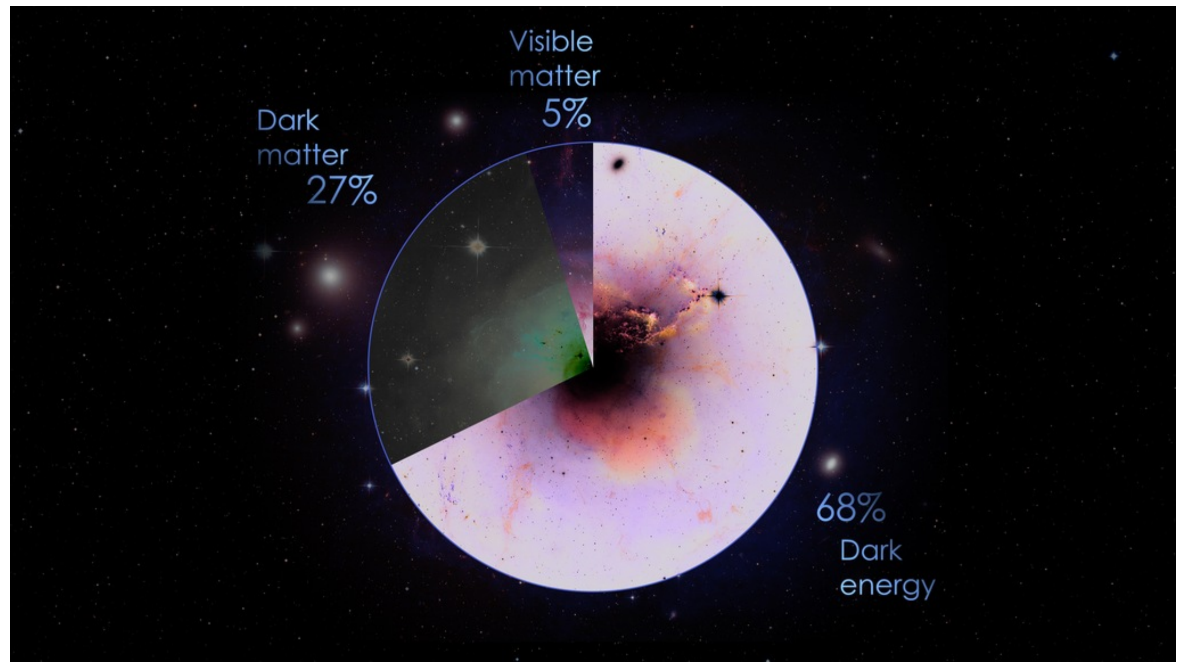
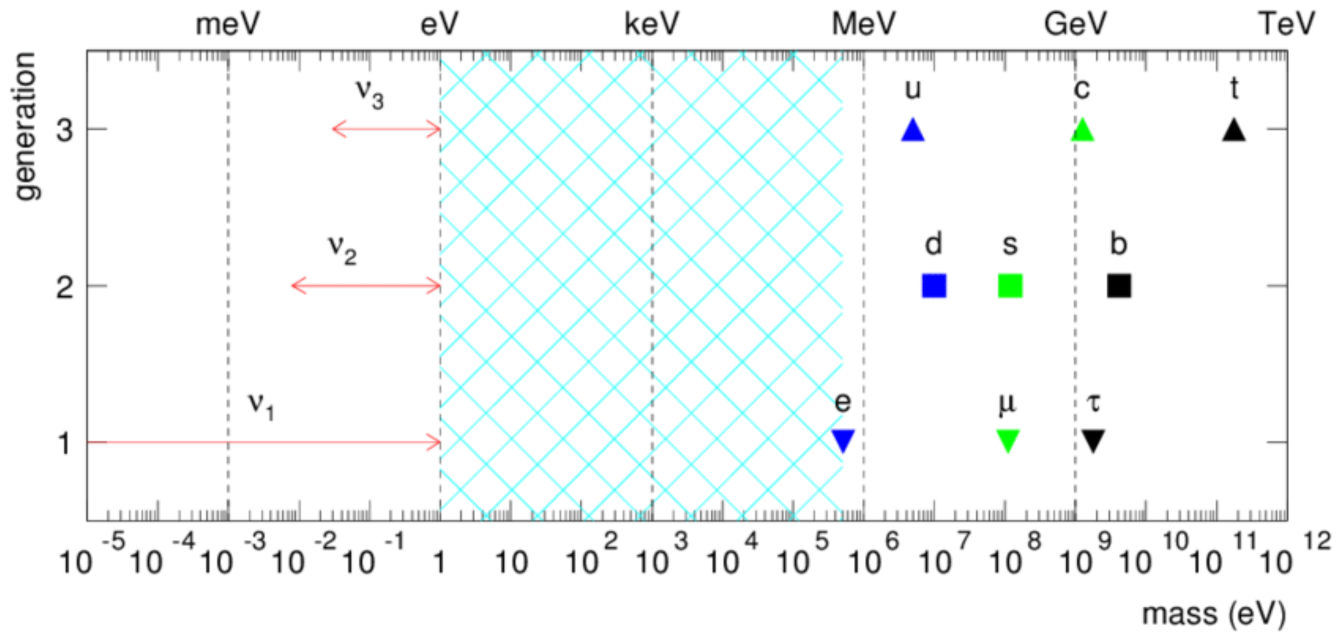


Flavor and mass pattern



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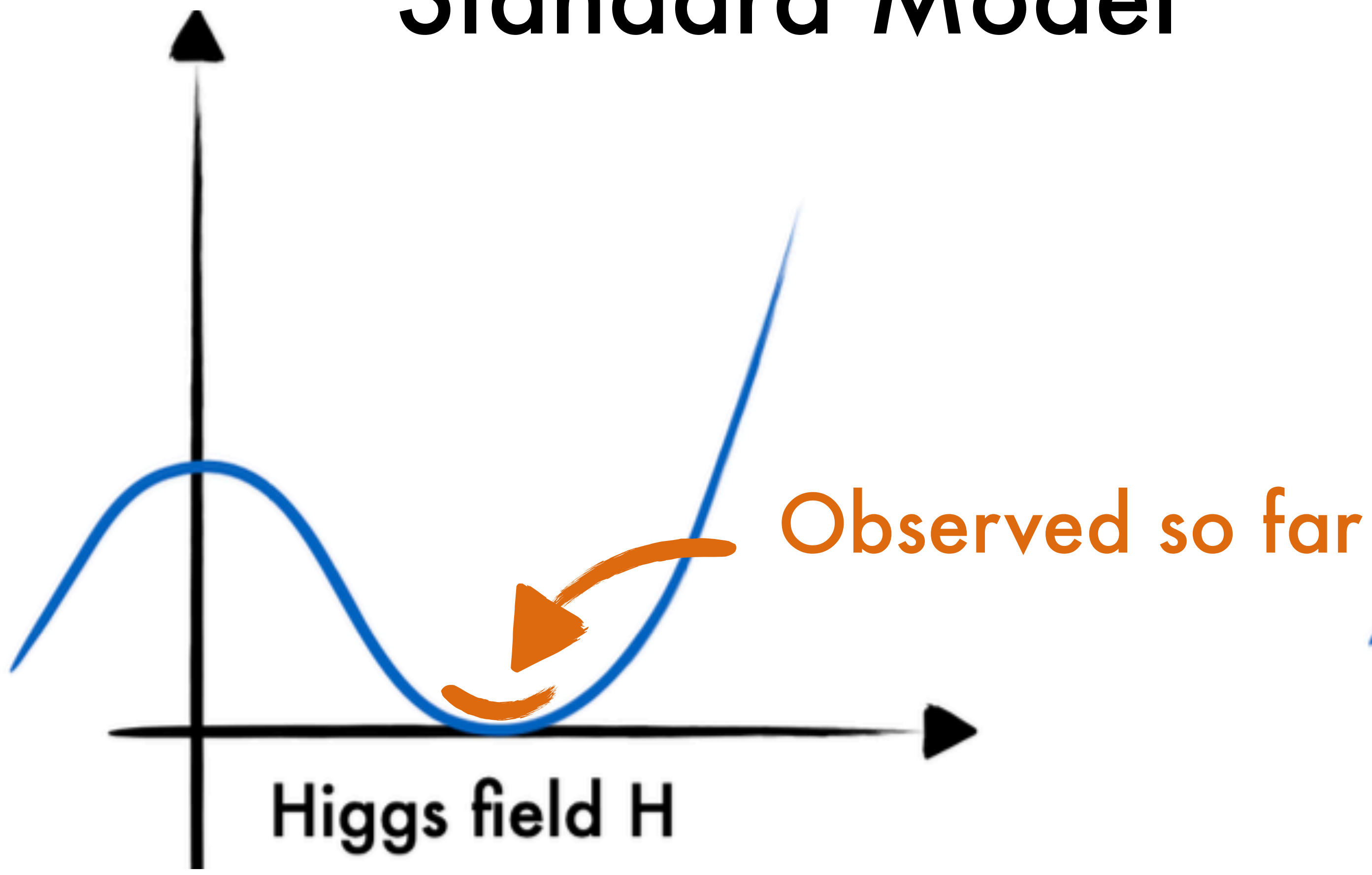

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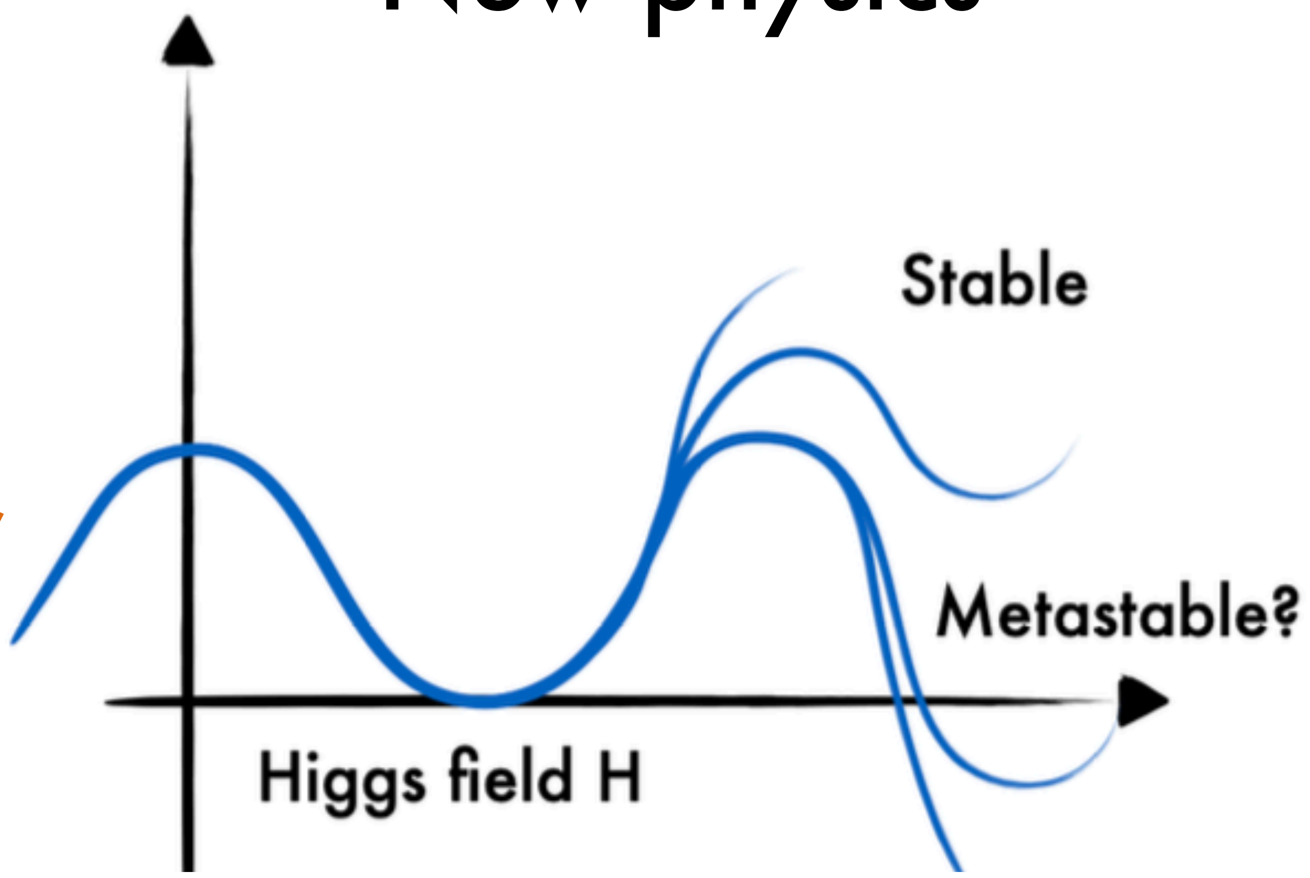

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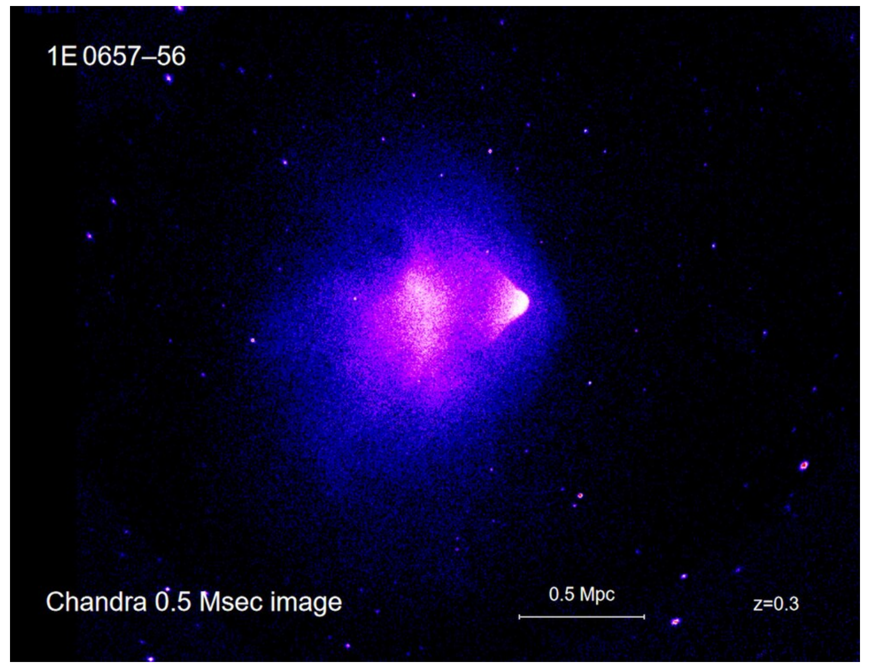

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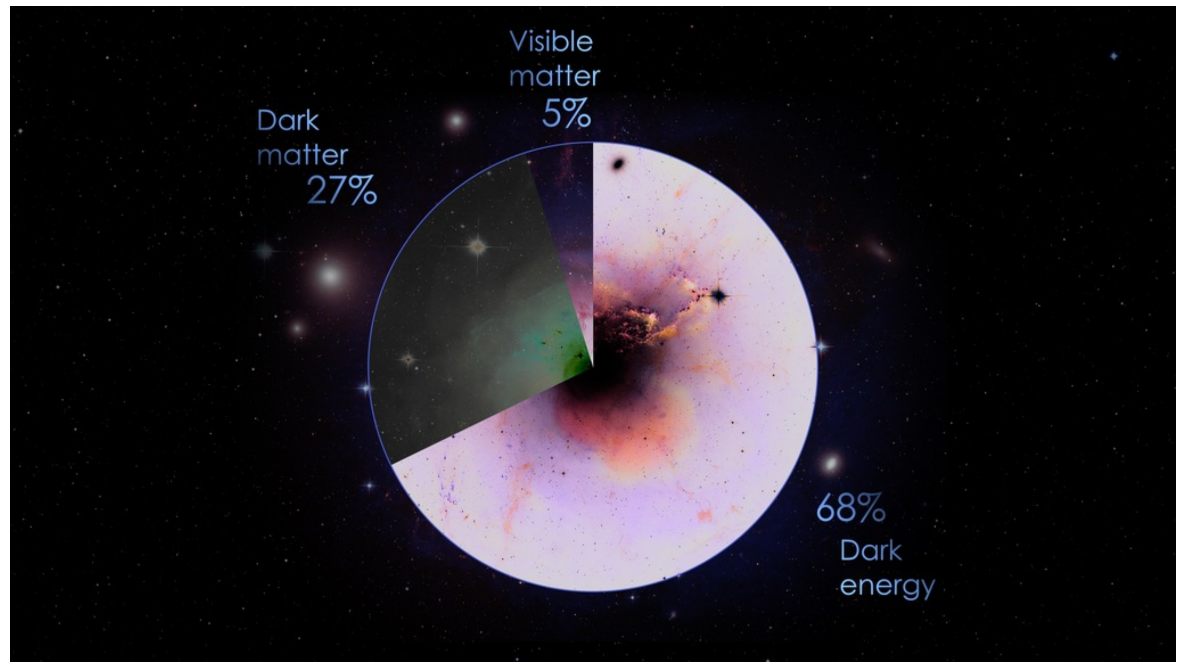

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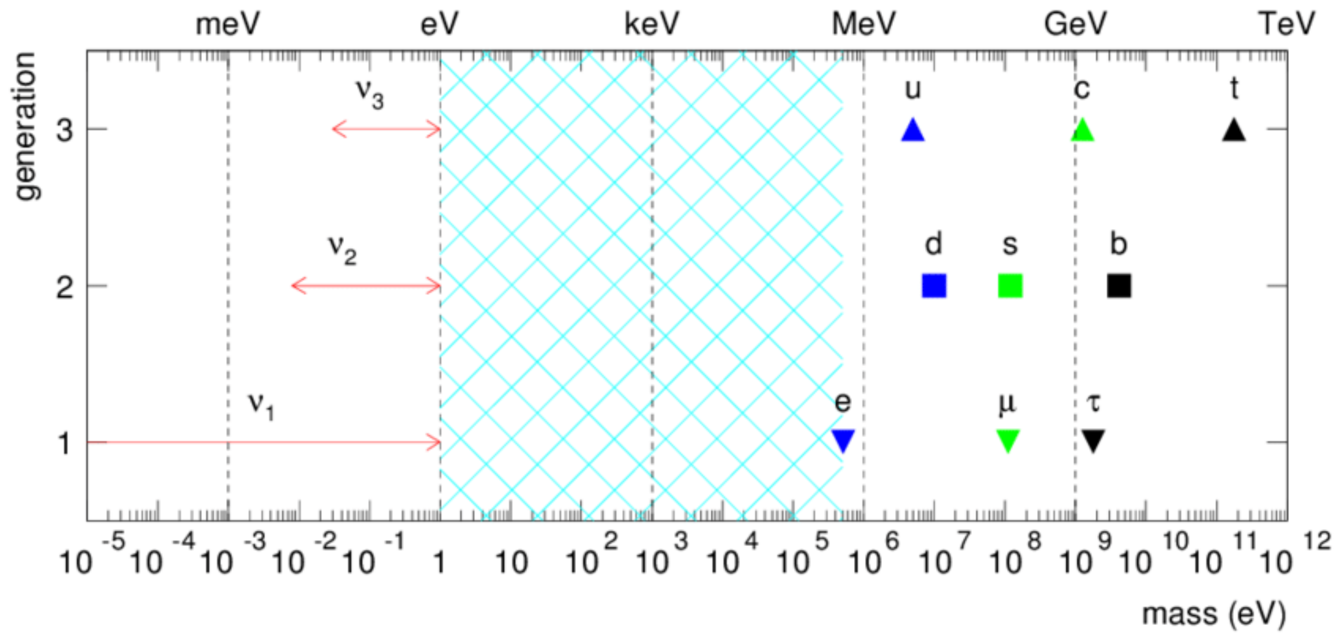

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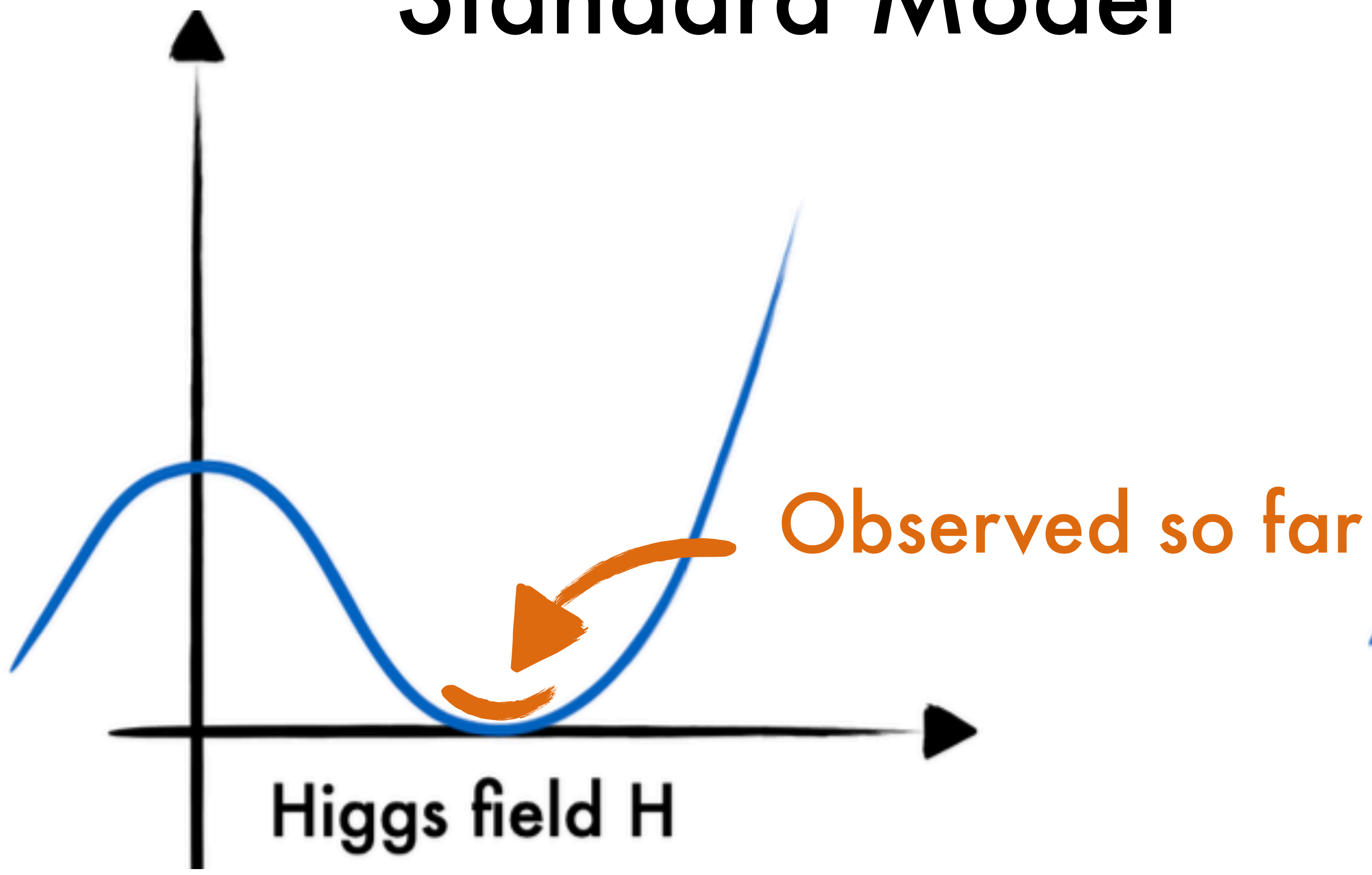

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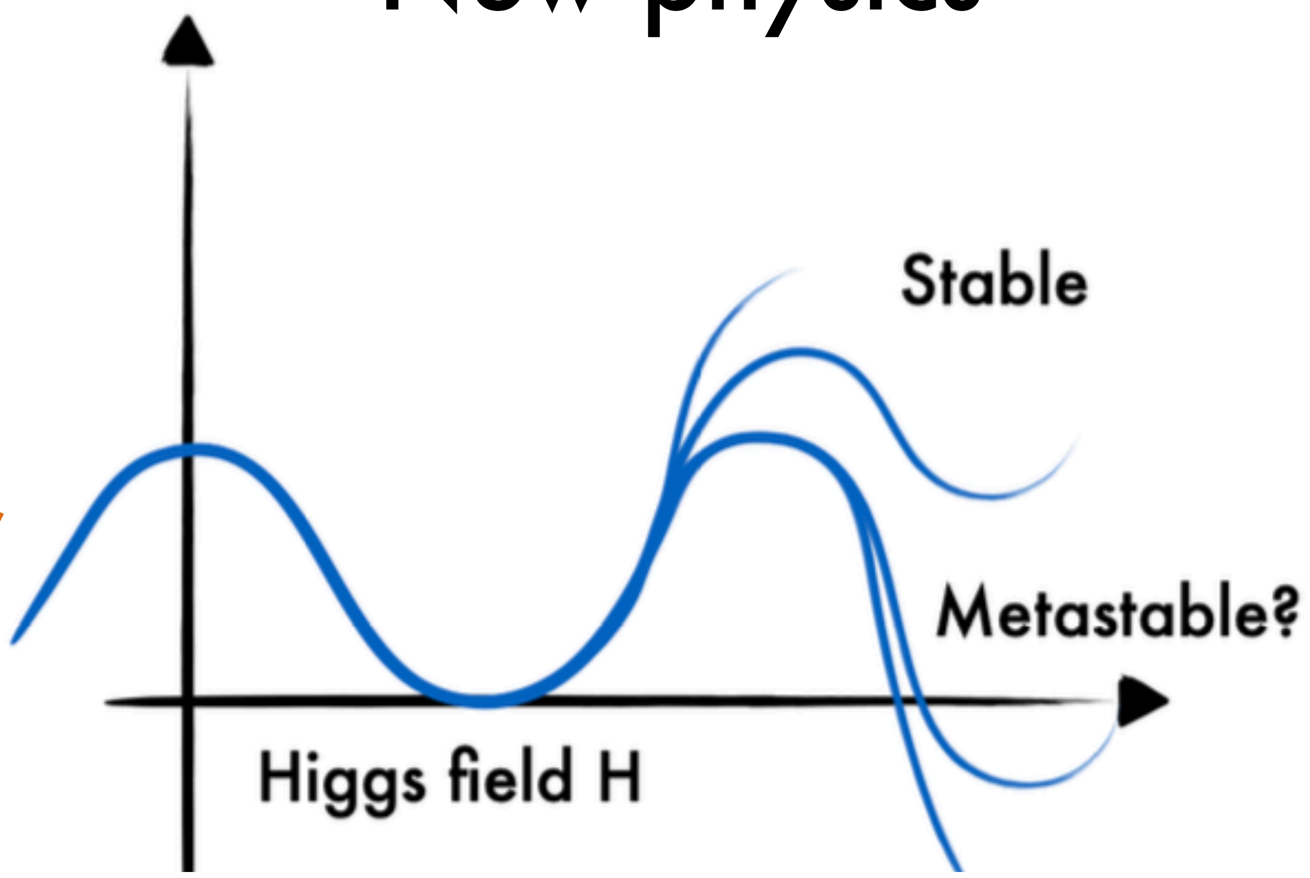
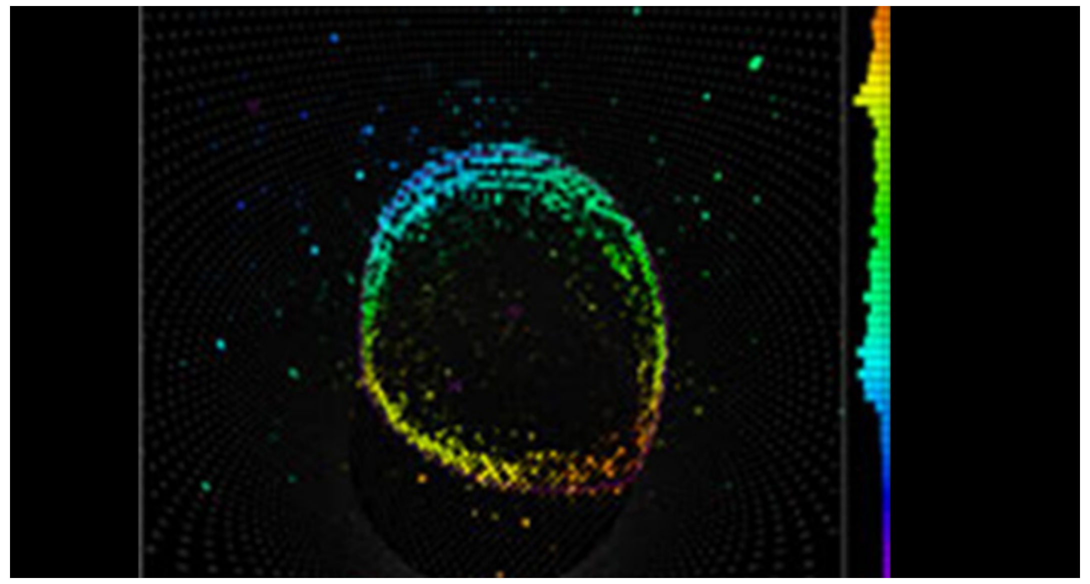
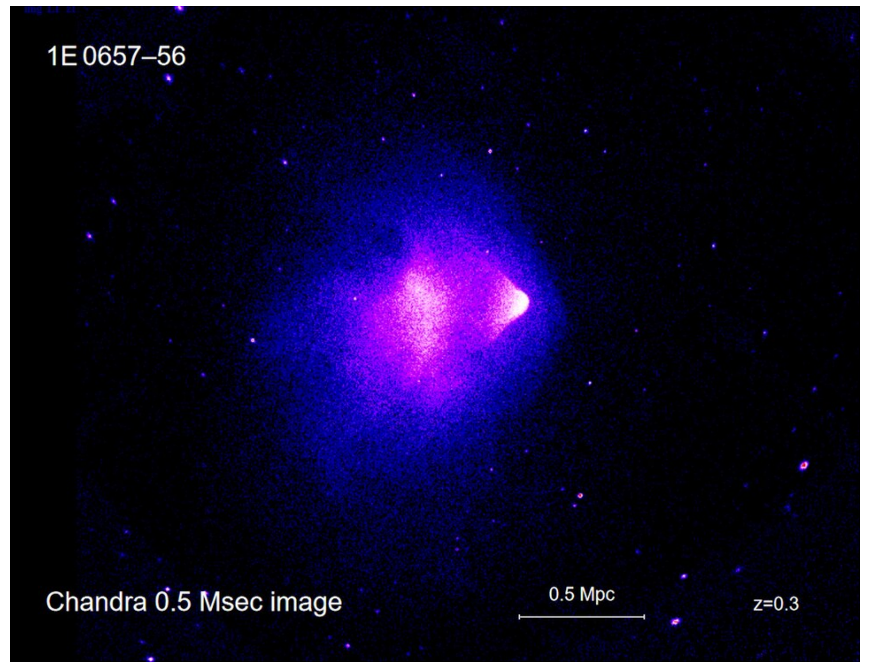




Neutrino masses

Standard Model Higgs potential: shortcomings

Dark Matter



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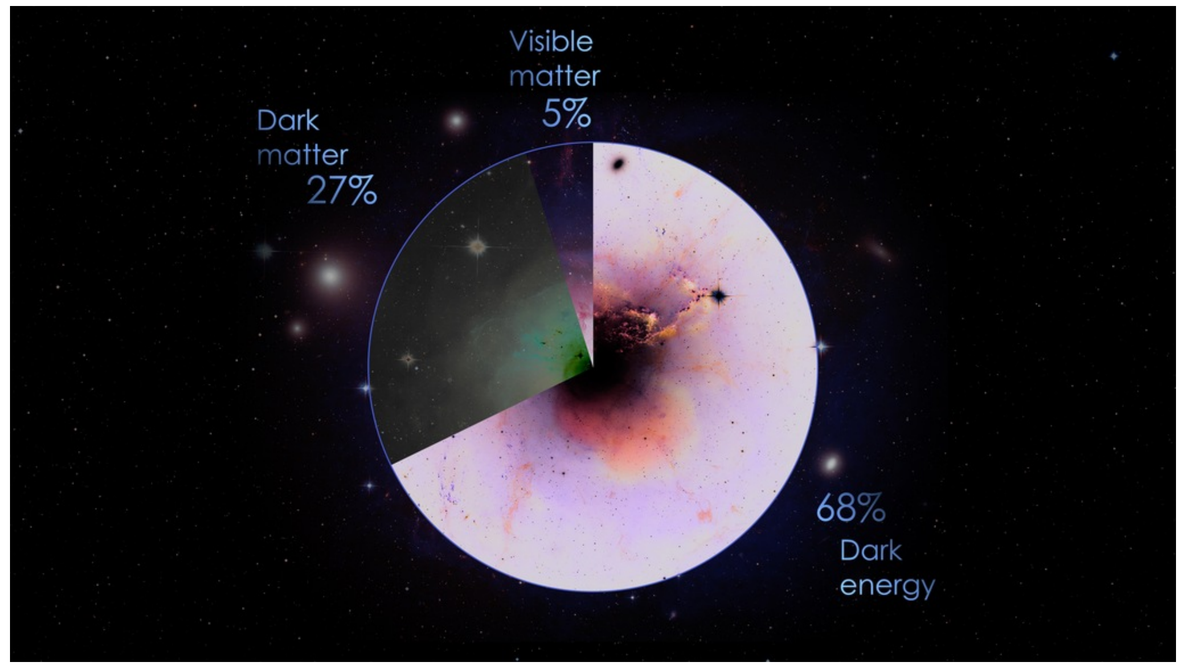

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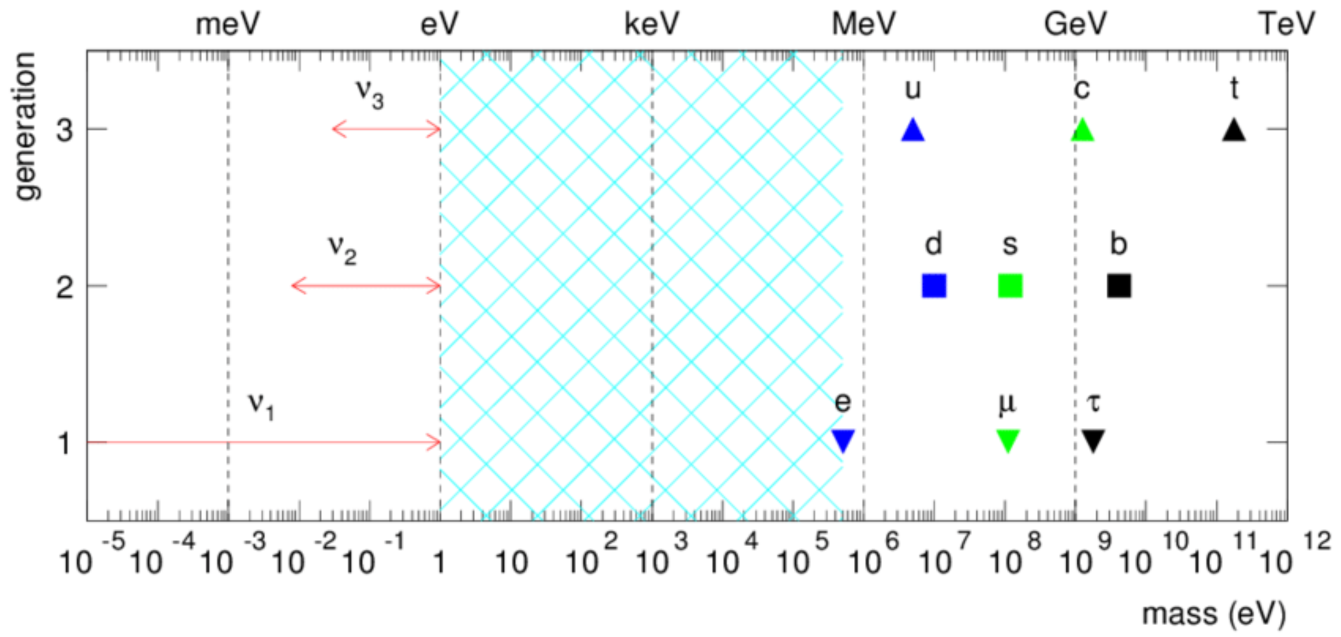

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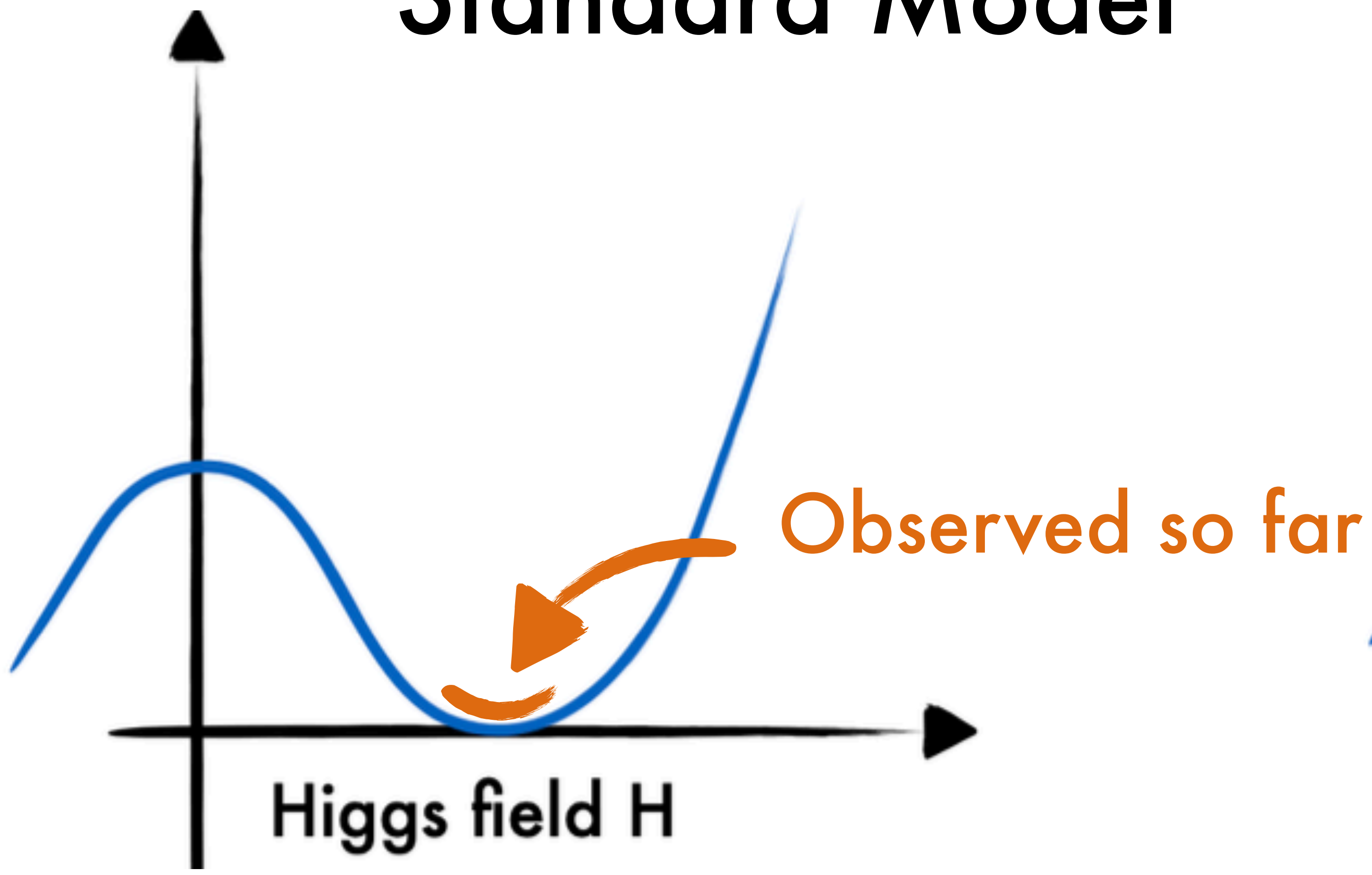

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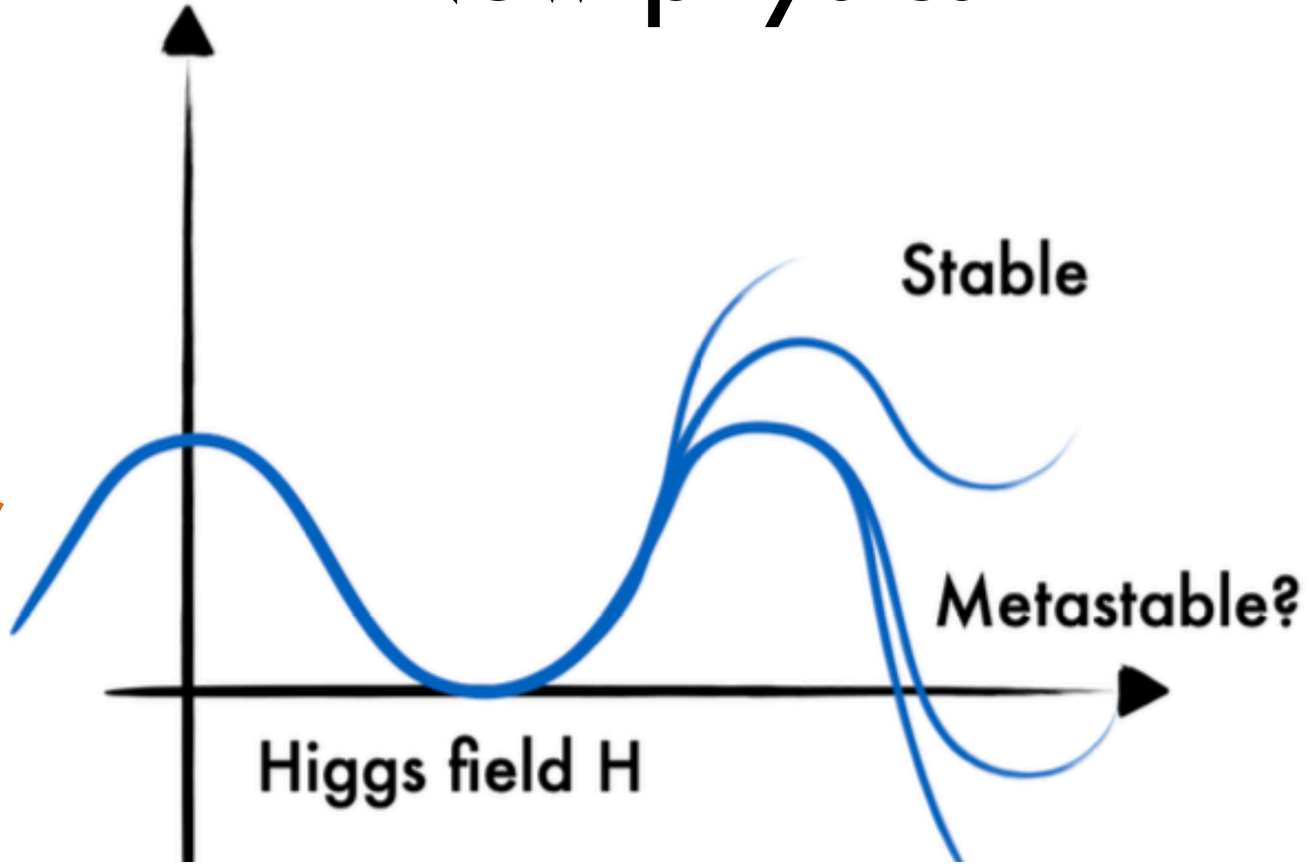

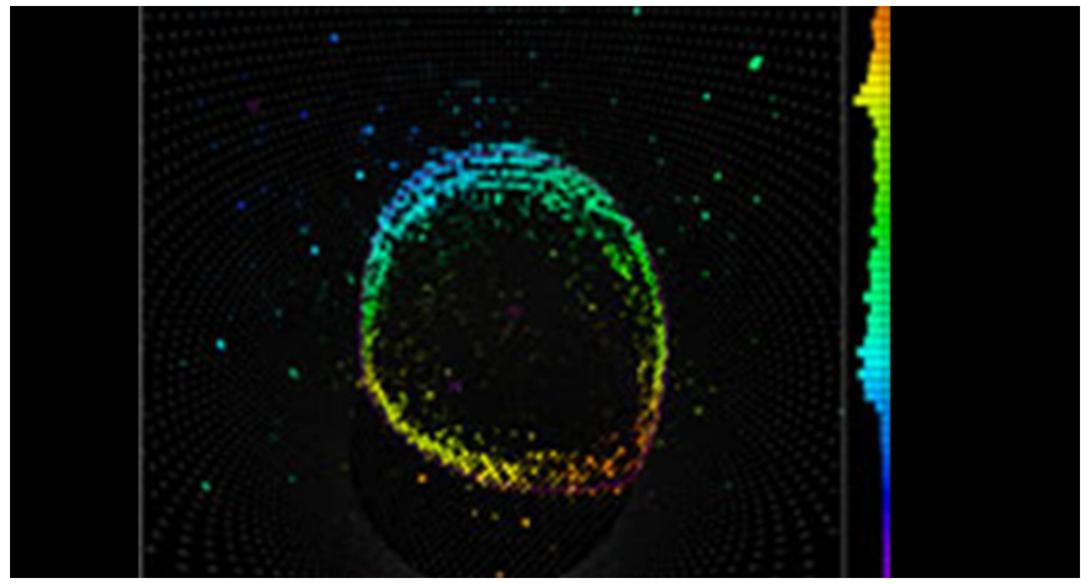

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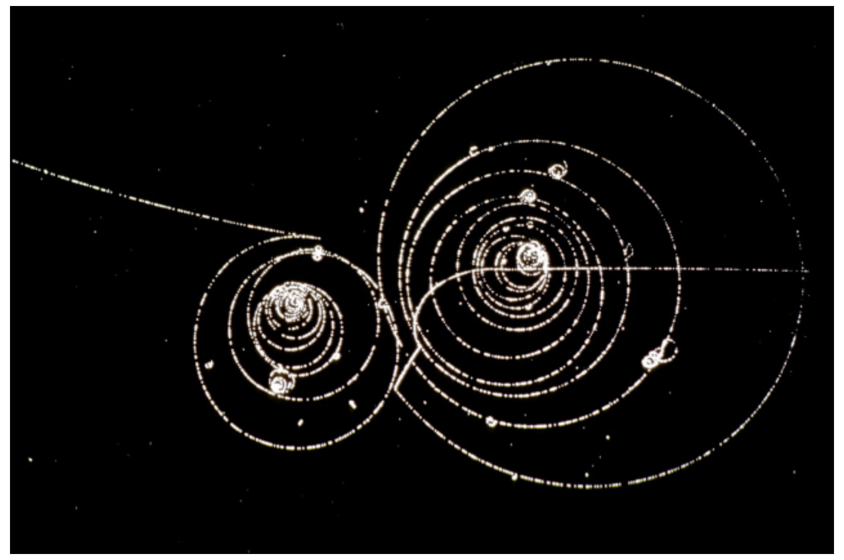
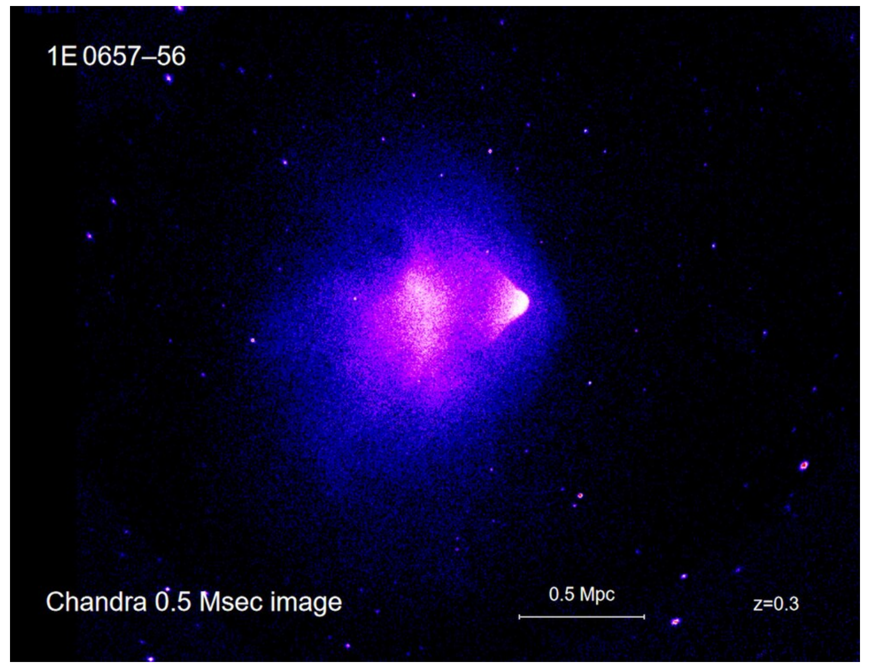


Matter / anti-matter asymmetry

Standard Model Higgs potential: shortcomings

Dark Matter



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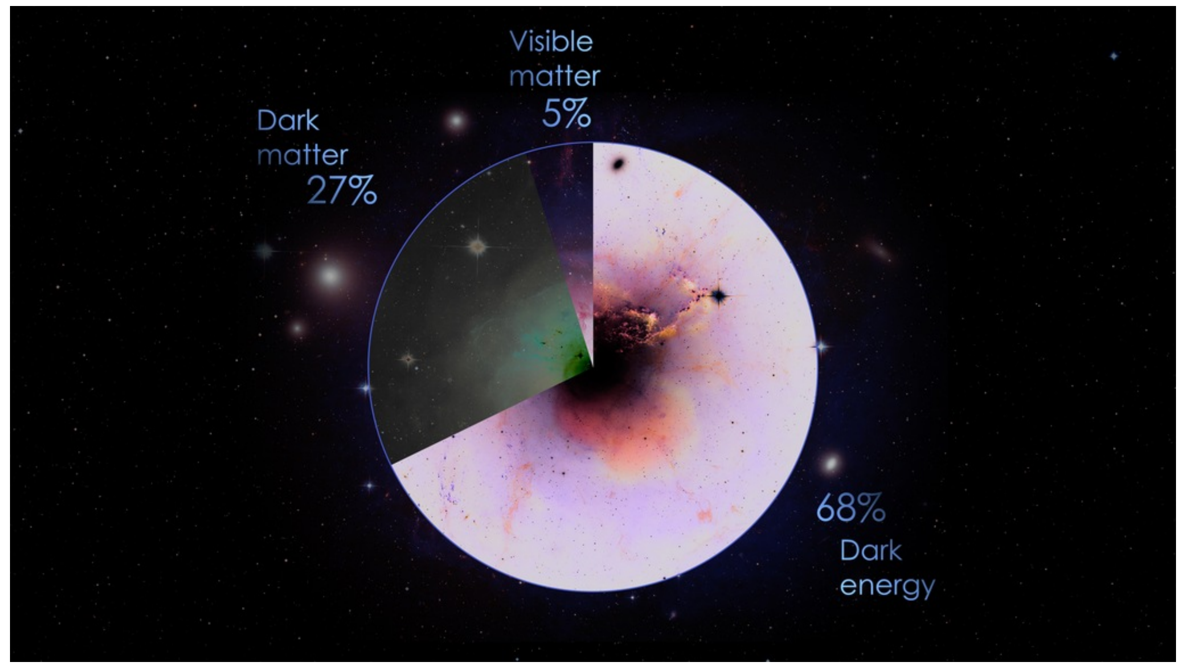

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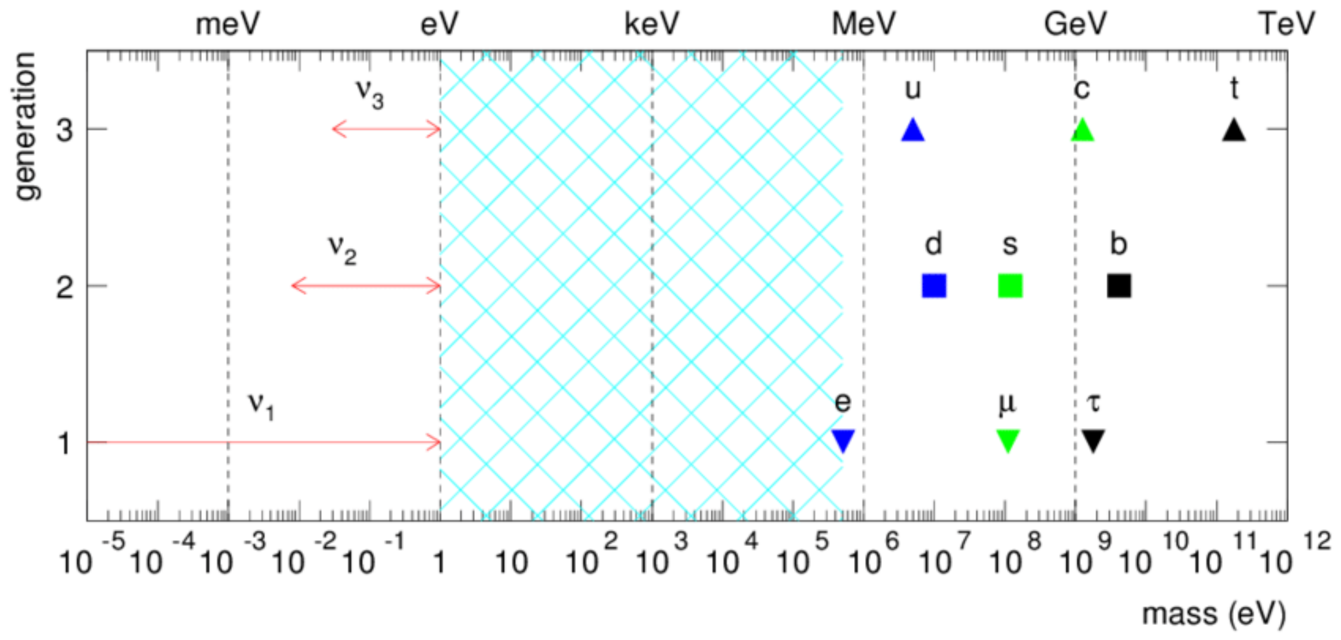

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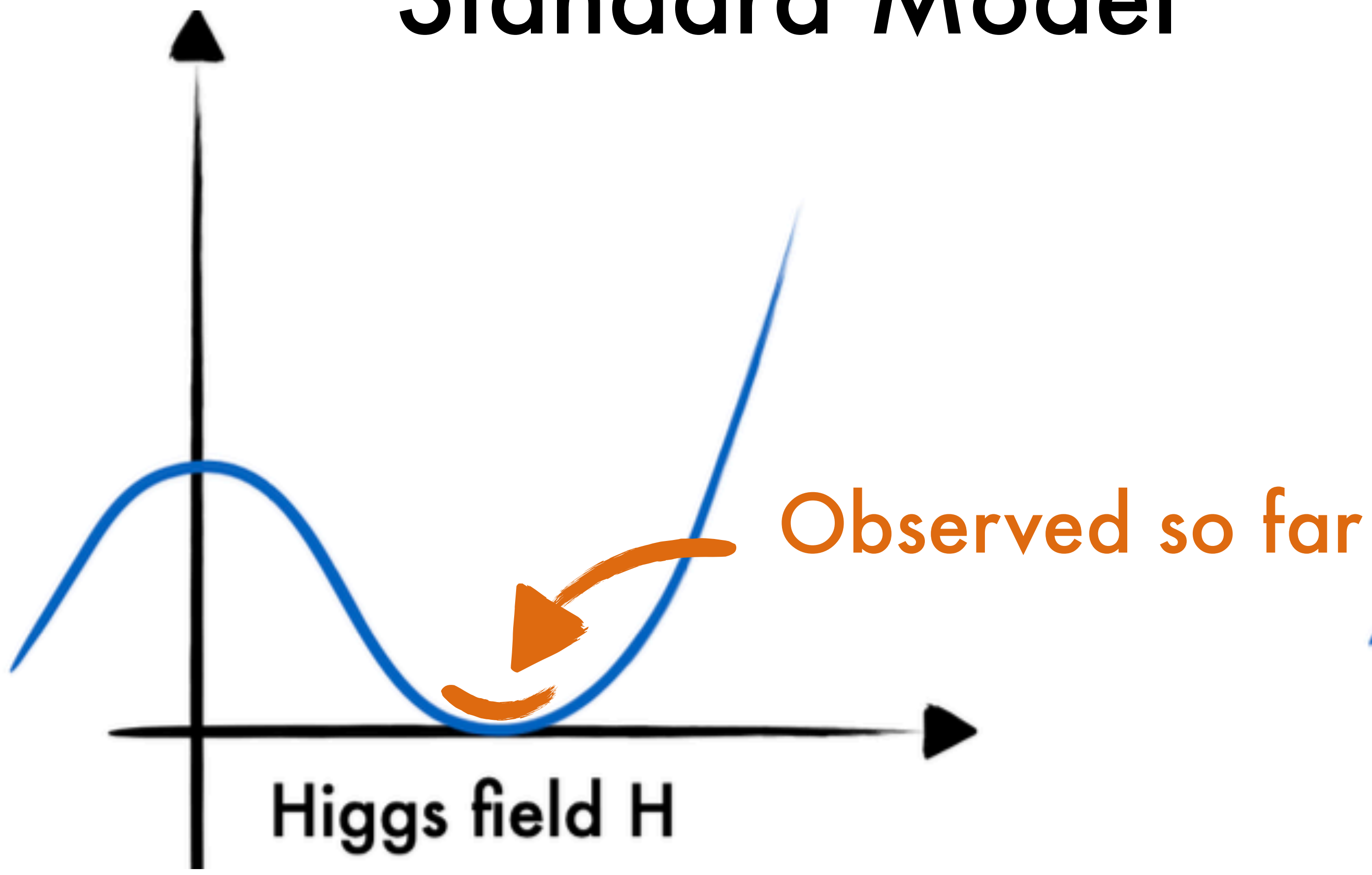

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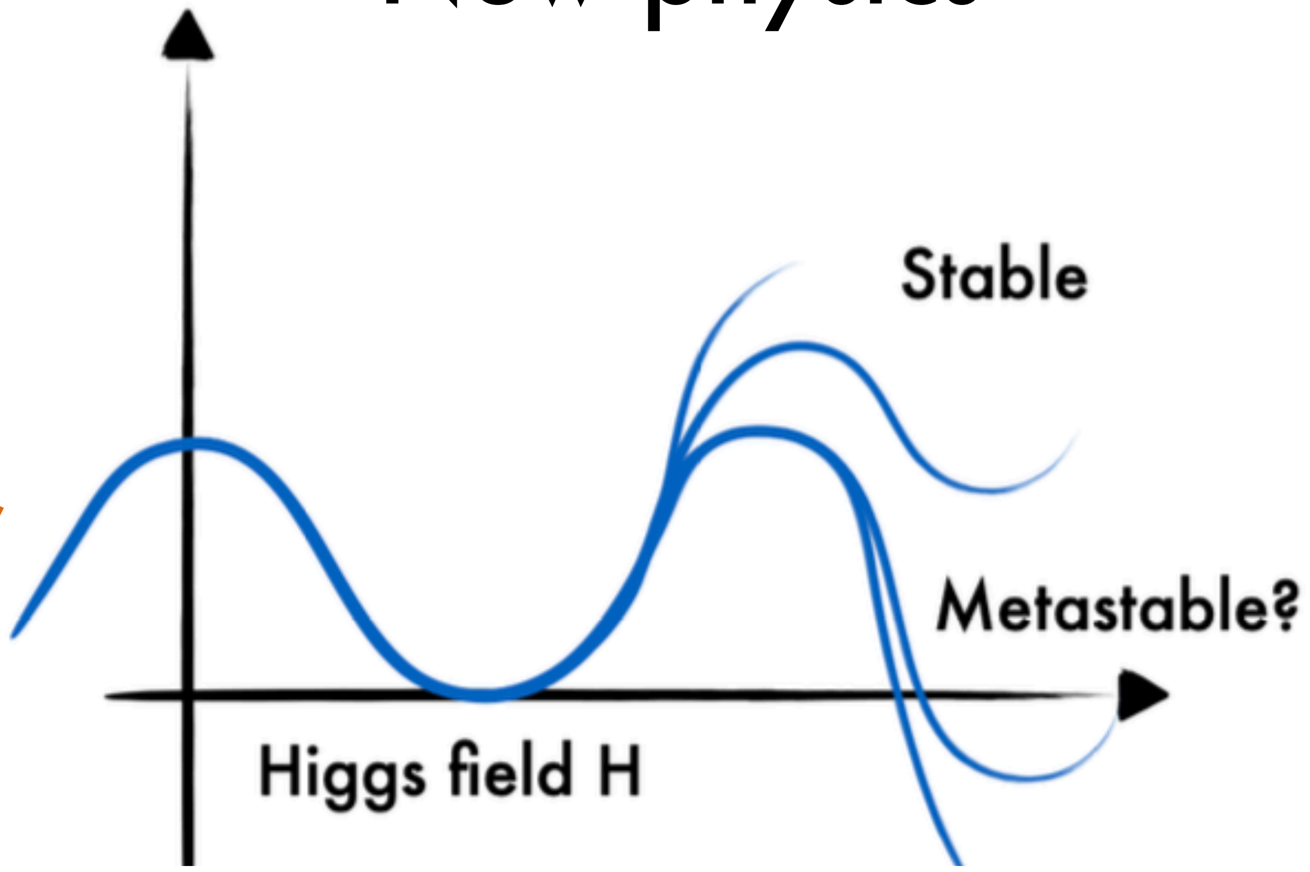

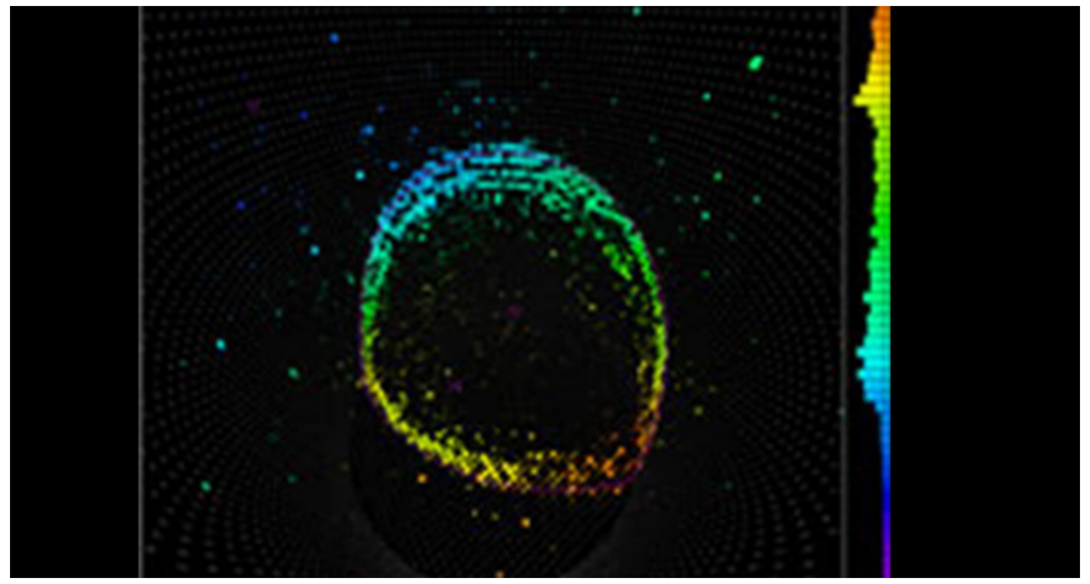

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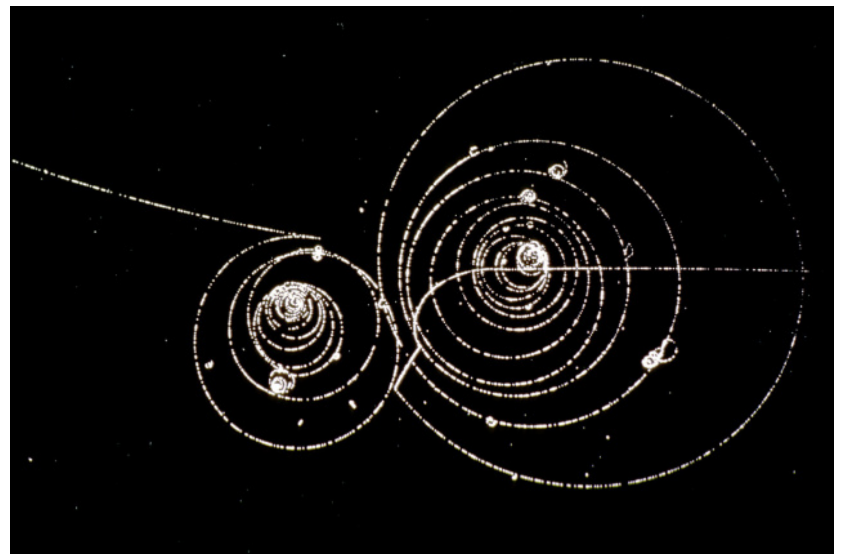

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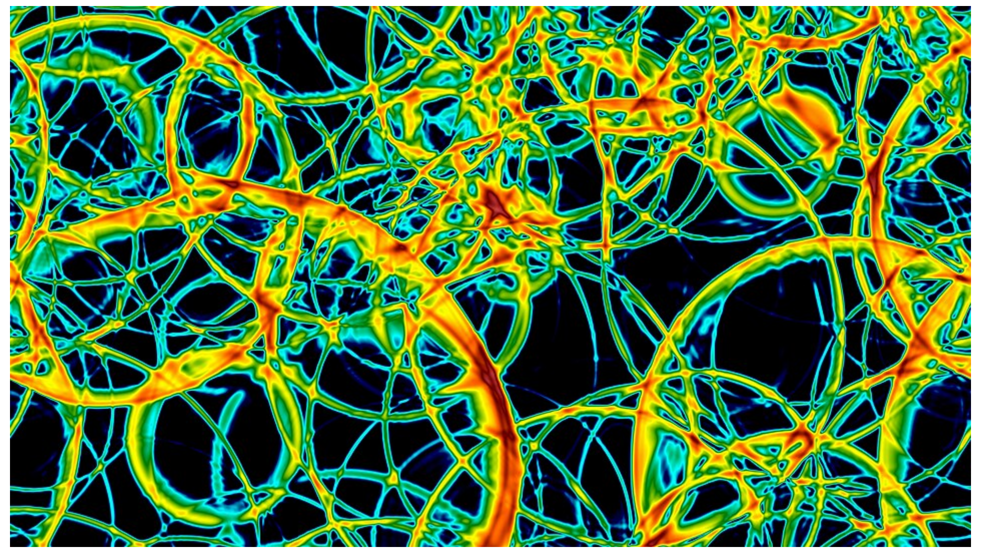
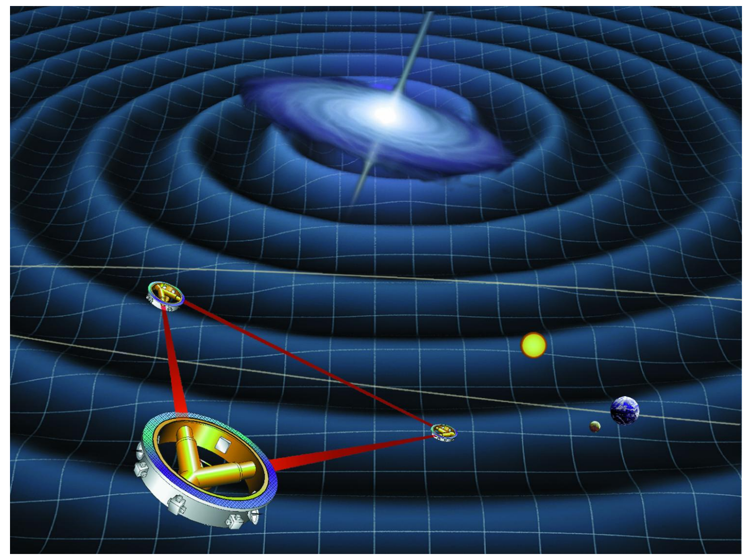




Electroweak phase transition

The LHC discovered the Higgs boson

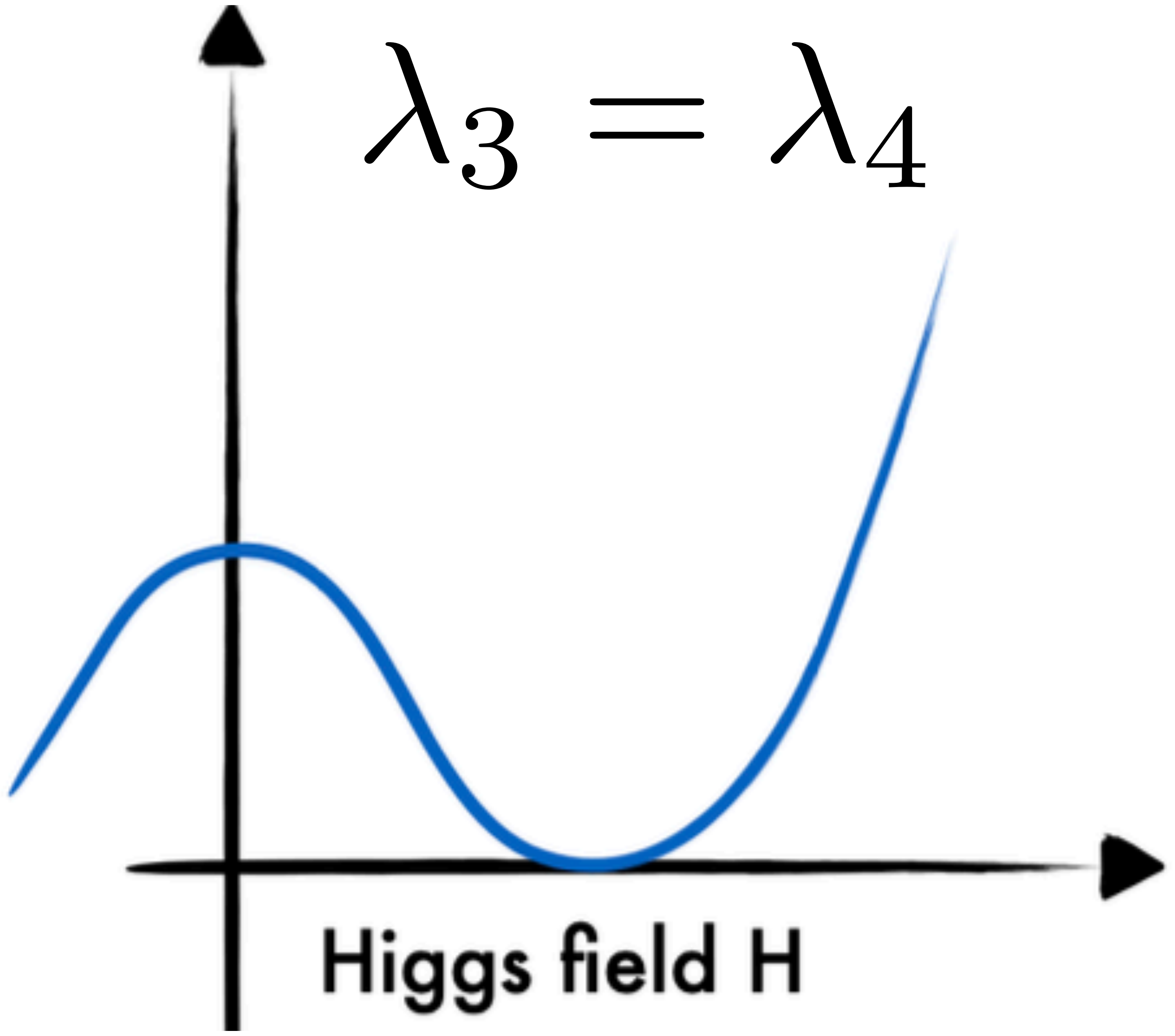
but it **did not discover the Higgs potential**

Measuring the Higgs potential

$$V(H) = \frac{1}{2}m_H^2 H^2 + \lambda_3 v H^3 + \frac{1}{4}\lambda_4 H^4$$

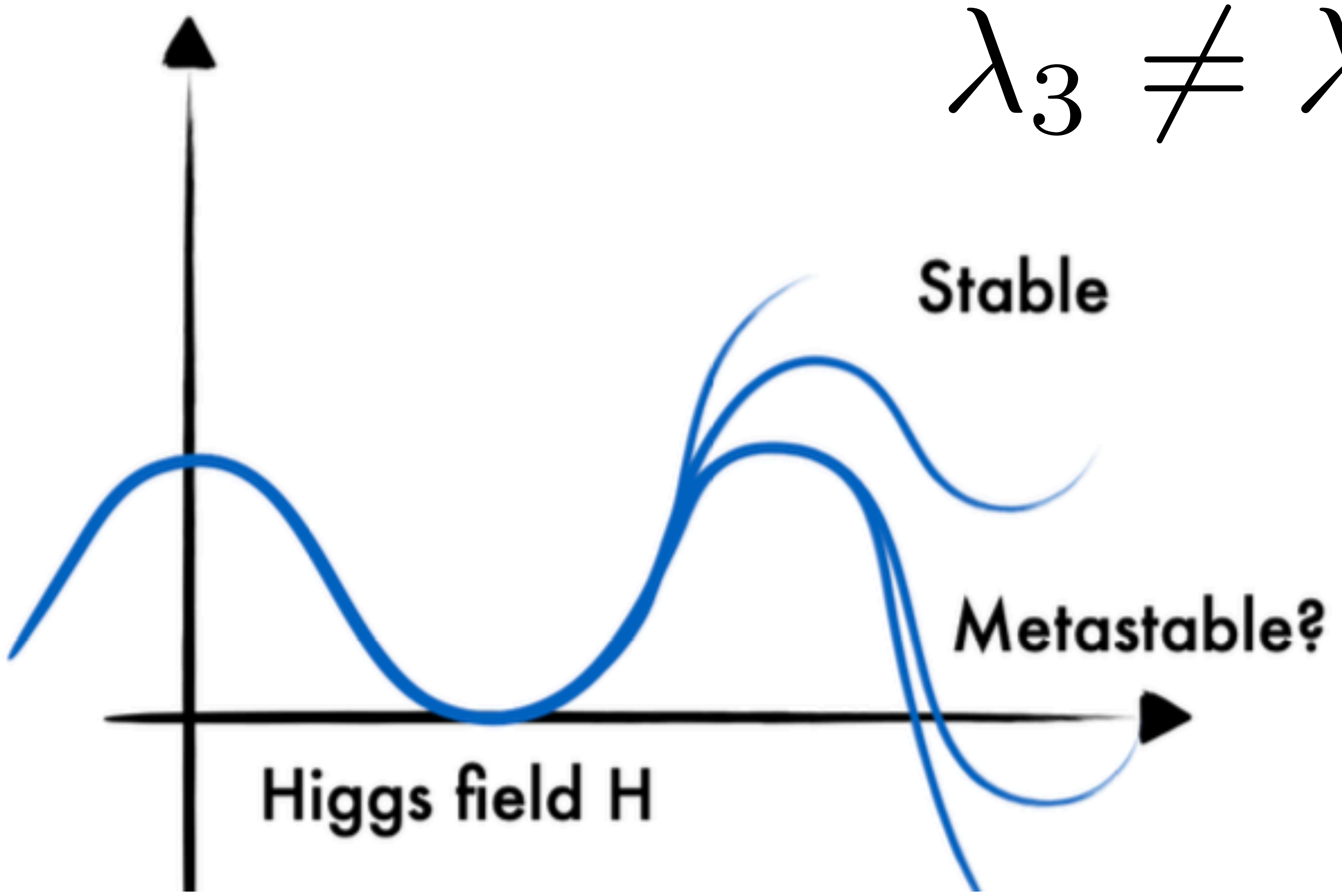
Standard Model

$$\lambda_3 = \lambda_4$$



New physics

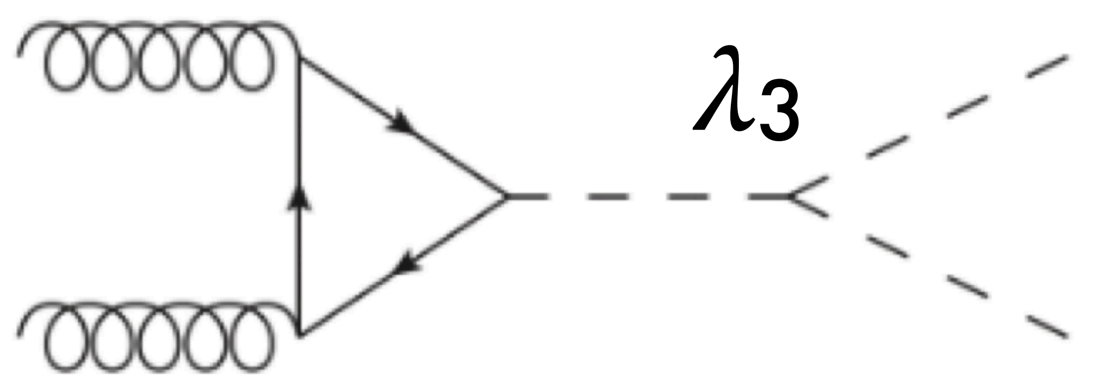
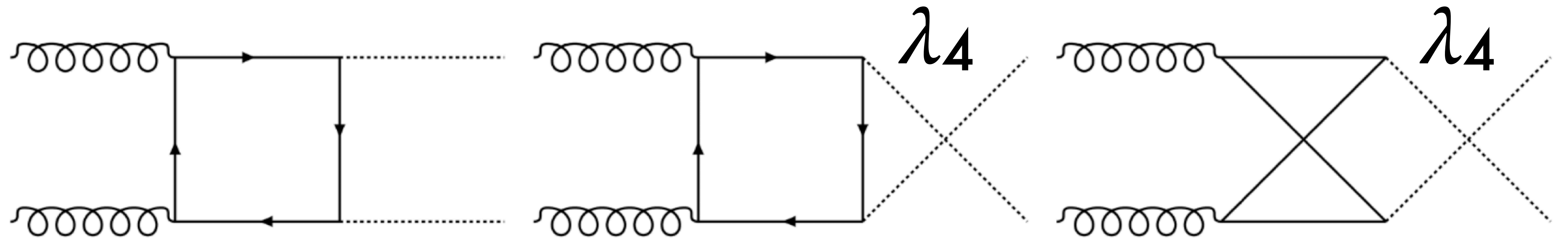
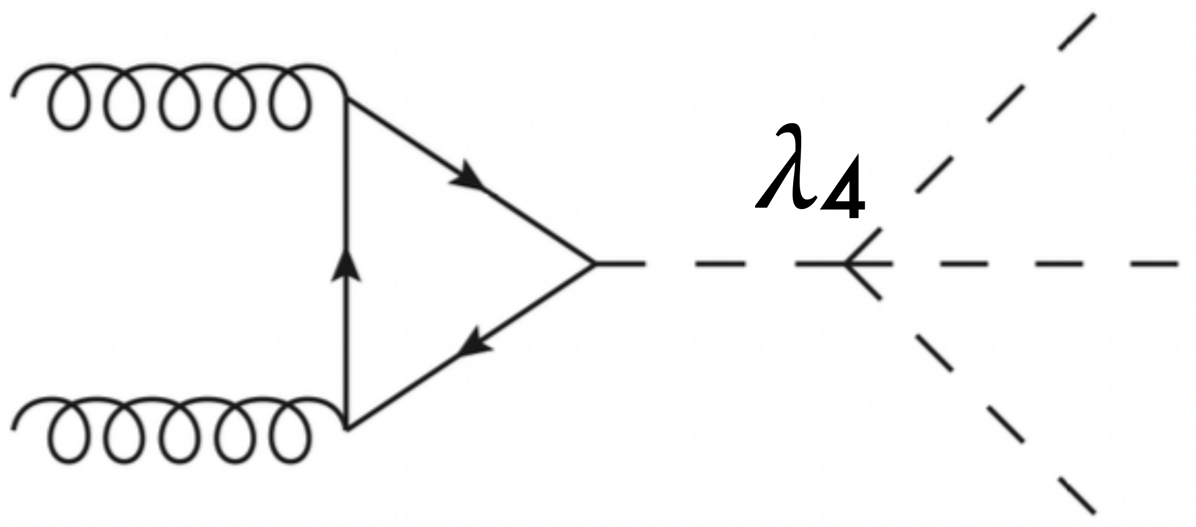
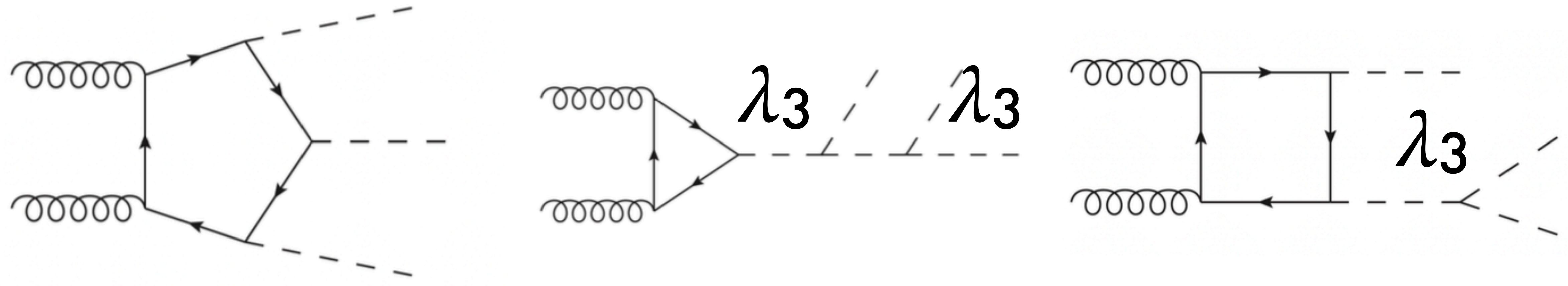
$$\lambda_3 \neq \lambda_4$$



In the Standard Model: $\lambda_3 = \lambda_4$

- Not given for a fact, needs to be measured
- New physics can affect the shape of the Higgs potential → large consequences for the Universe

Probing self-interaction di-Higgs and triple Higgs

	Signal	Irreducible background with Higgs bosons
Di-Higgs		
Triple Higgs		

Probing the Higgs self-coupling possible through di-Higgs and triple Higgs measurements:

- Di-Higgs: nearly exclusively sensitive to λ_3 coupling (very small contribution from λ_4)
- Triple Higgs: sensitive to both λ_3 and λ_4 coupling

→ Full determination of the Higgs potential only possible through combined measurement!

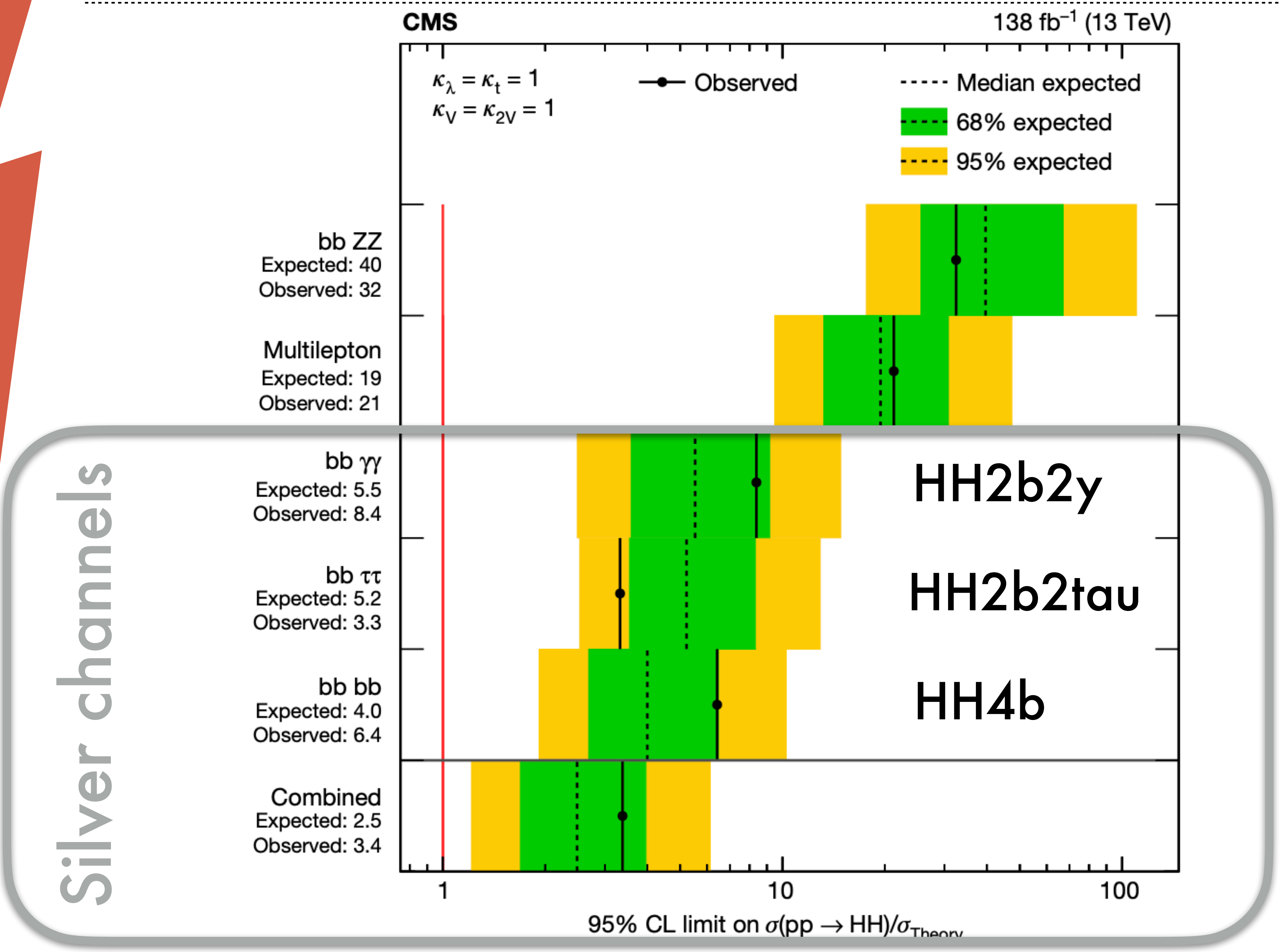
HH is at the centre of ATLAS and CMS physics program, HHH is novel and recently explored

Run 2 overview

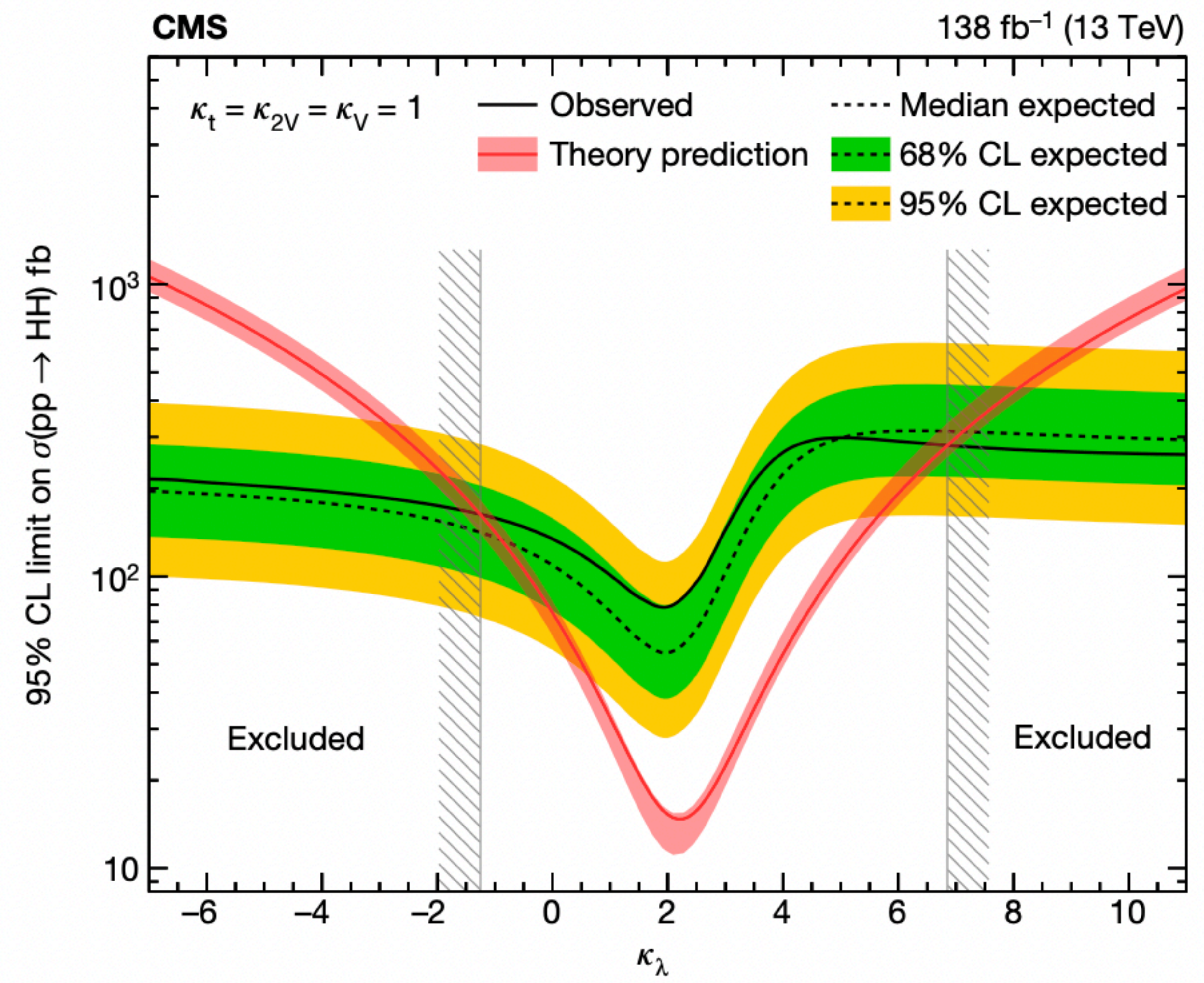
Results: sensitivity and interpretation

Nature 607 (2022) 60-68

Limit on signal strength



κ_λ interpretation



Expected: μHH < 2.5 x SM @ 95% CL
Observed: μHH < 3.4 x SM @ 95% CL

Expected at 95%: -0.9< κ_λ < 7.1
Observed at 95%: -1.2 < κ_λ < 6.5

HH combination: similar sensitivity between boosted **HH4b**, **HH2b2tau** and **HH2b2y**

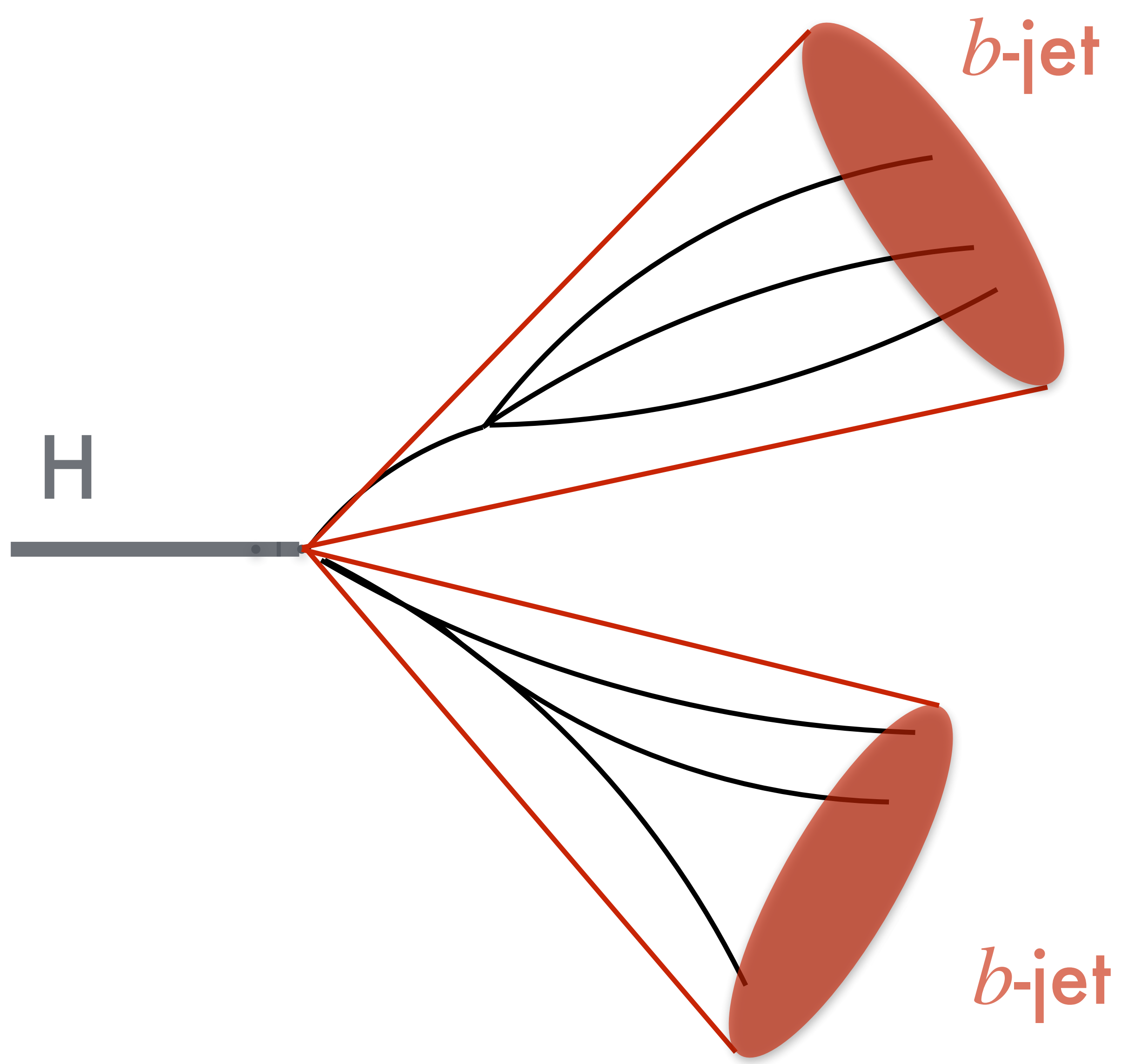
- Combination of HH4b boosted and resolved drives with 20% better sensitivity

Revolutions since Run 2: flavor tagging and trigger

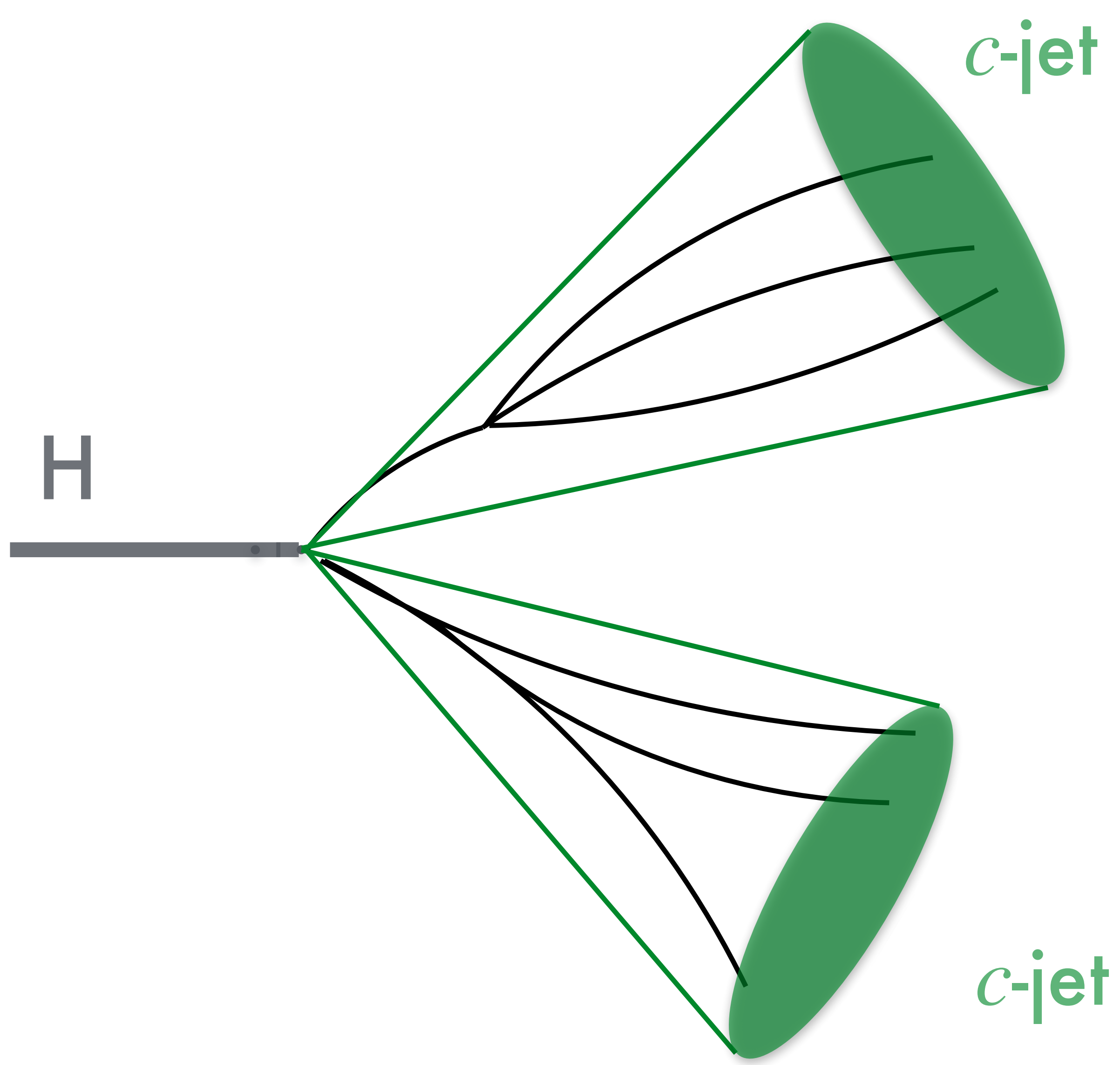
Flavor tagging

Higgs decays to heavy flavor quarks

$H \to b\bar{b}$



$H \to c\bar{c}$



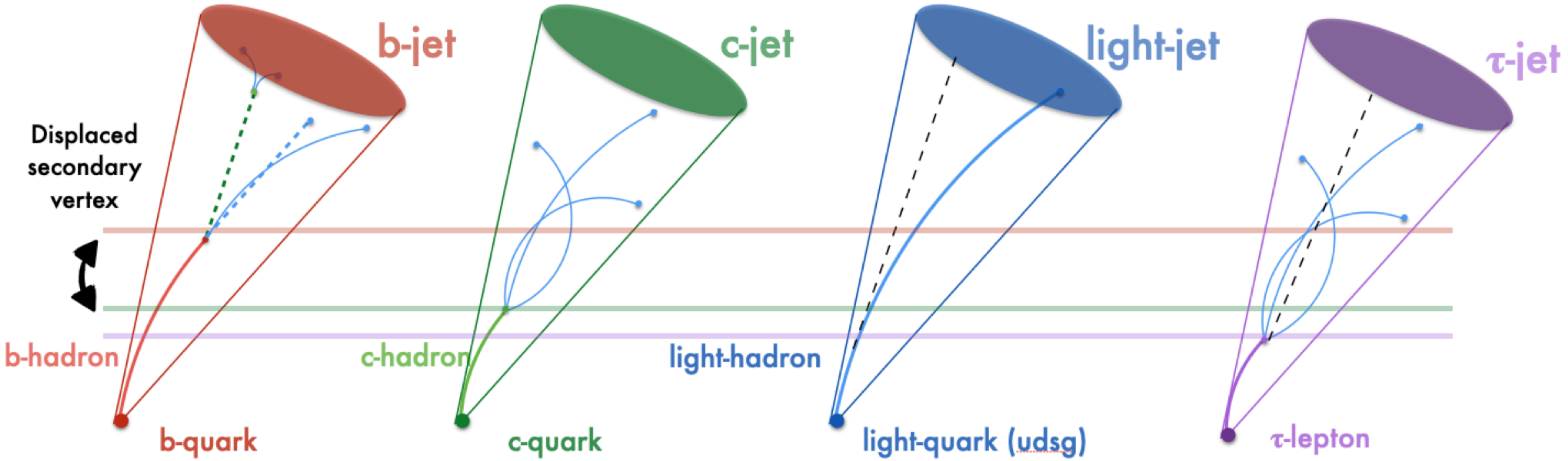
60% of Higgs bosons decay to b-quarks

3% of Higgs bosons decay to c-quarks

Major challenge: Higgs predominantly decays to heavy flavor b- and c-quarks

- Quark hadronize and decay in the detector to form jets
- Need to infer the flavor of the quark from the decay final states!
- Measuring most of the Higgs bosons requires precise identification of b- and c-jets!

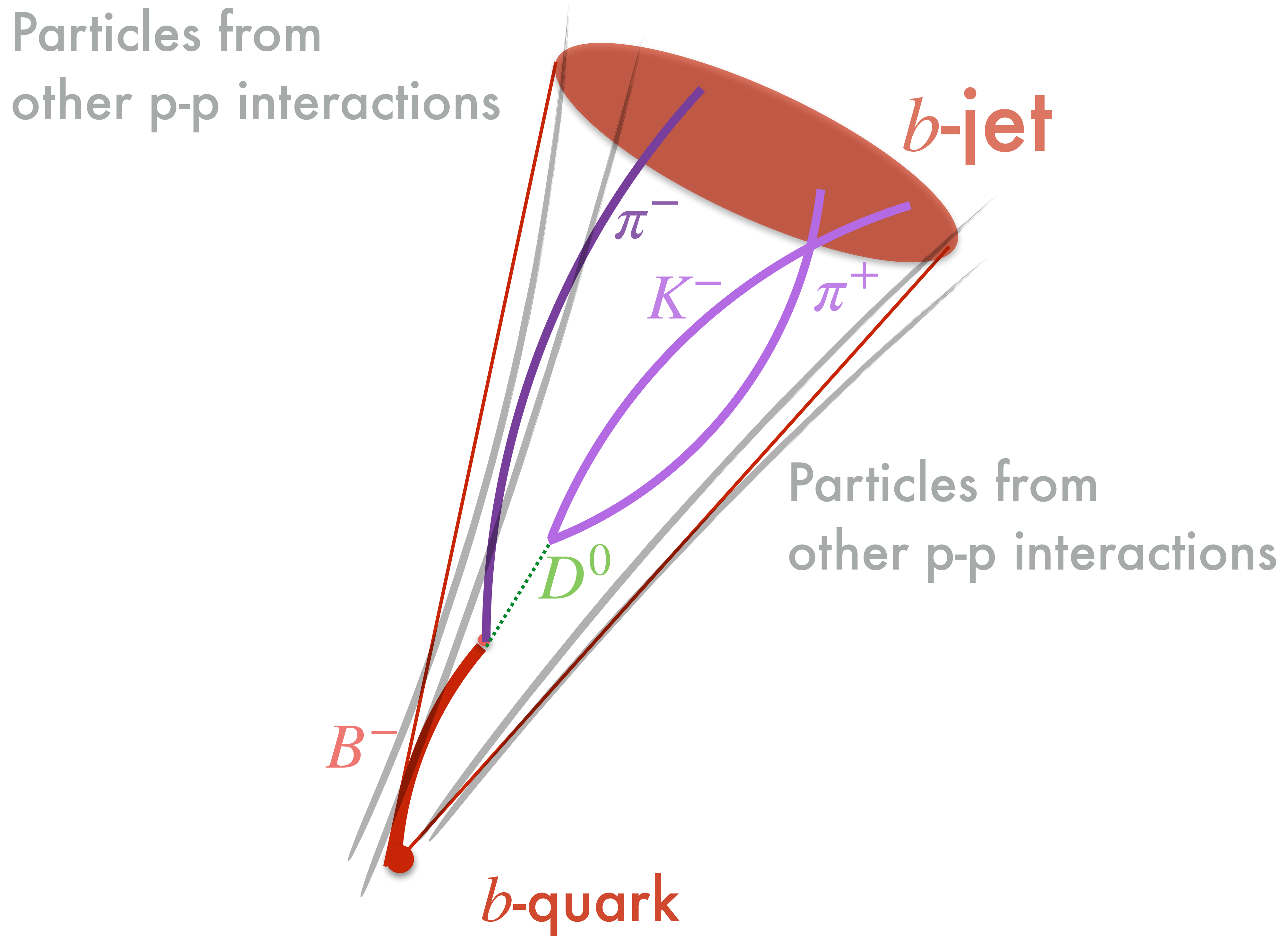
Flavor tagging concept



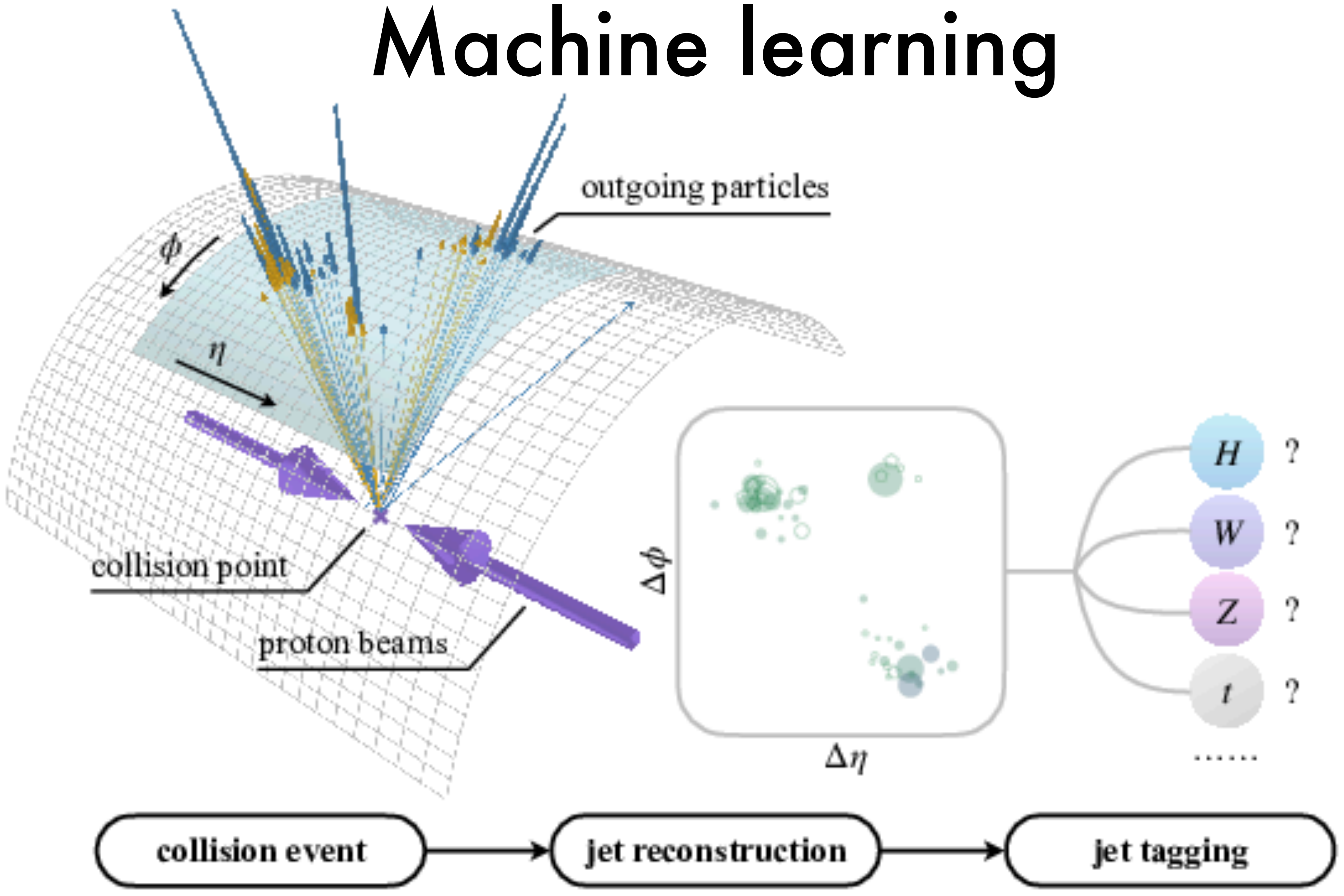
By 2022: concept to identify heavy hadrons - lifetime and displacement

- Hadrons decay via W transition, top transitions are suppressed due to vey large mass
  - $b \rightarrow c$ and $c \rightarrow s$ transitions, longer lifetime for b-hadron than c-hadrons
  - Identification algorithms **heavily relied on secondary vertices reconstruction**
    - Usage of machine learning algorithms with higher-level reconstructed variables
  - In general, **easier** to **identify b-jets** than **c-jets** due to physics properties of b-hadrons

Paradigm shift for Run 3 and Run 2 re-analysis



Machine learning

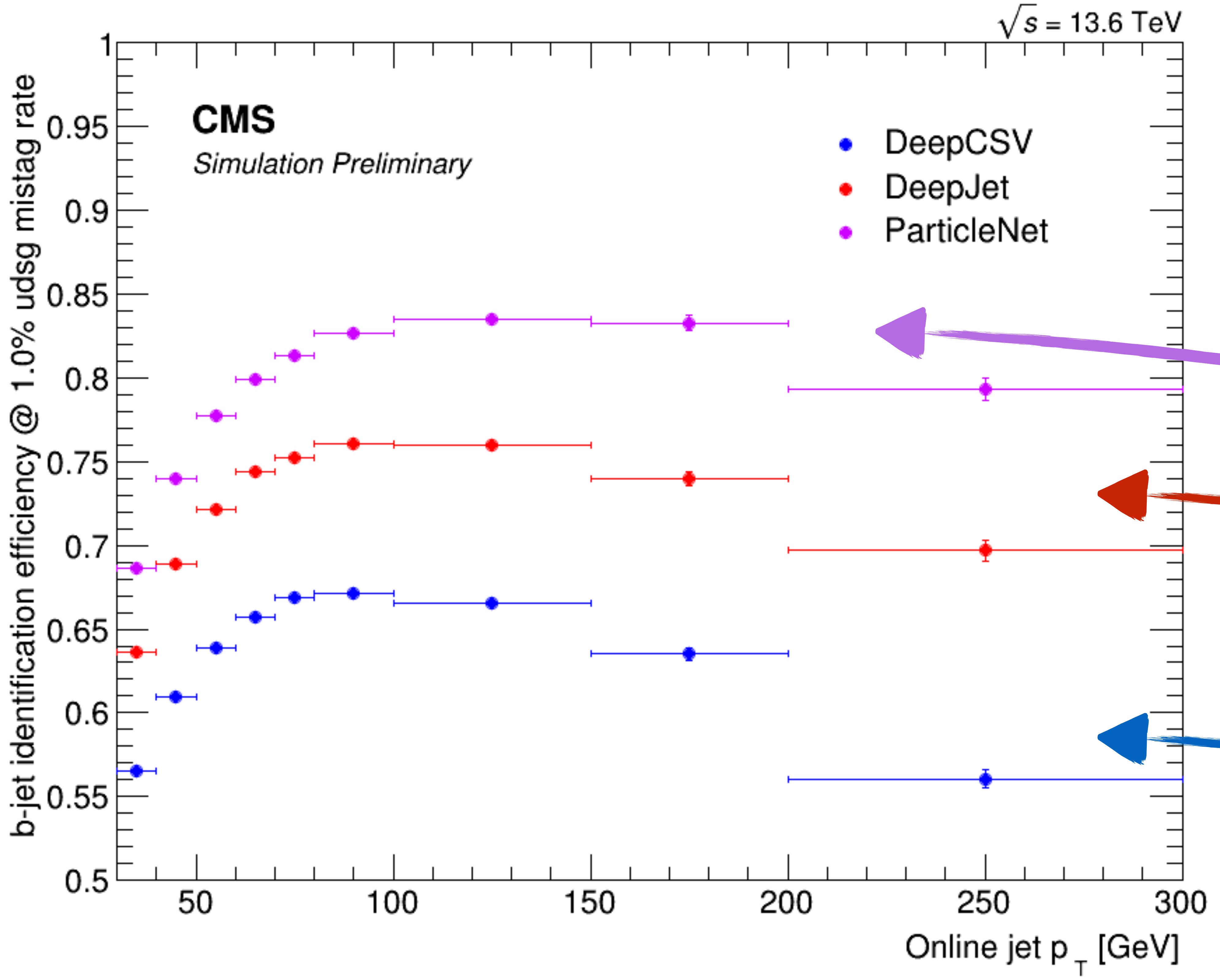


Advances in machine learning and computing (GPUs)

- Instead of relying on secondary vertices, use **all charged and neutral particles**
- Train algorithms to predict flavor of a jet using tens and hundreds of particles in jet
  - Momenta, position, angular separation, secondary vertices...

Paradigm shift for Run 3

CMS DP-2023/021



Tagger in 2022

Tagger in 2018

Tagger in 2016

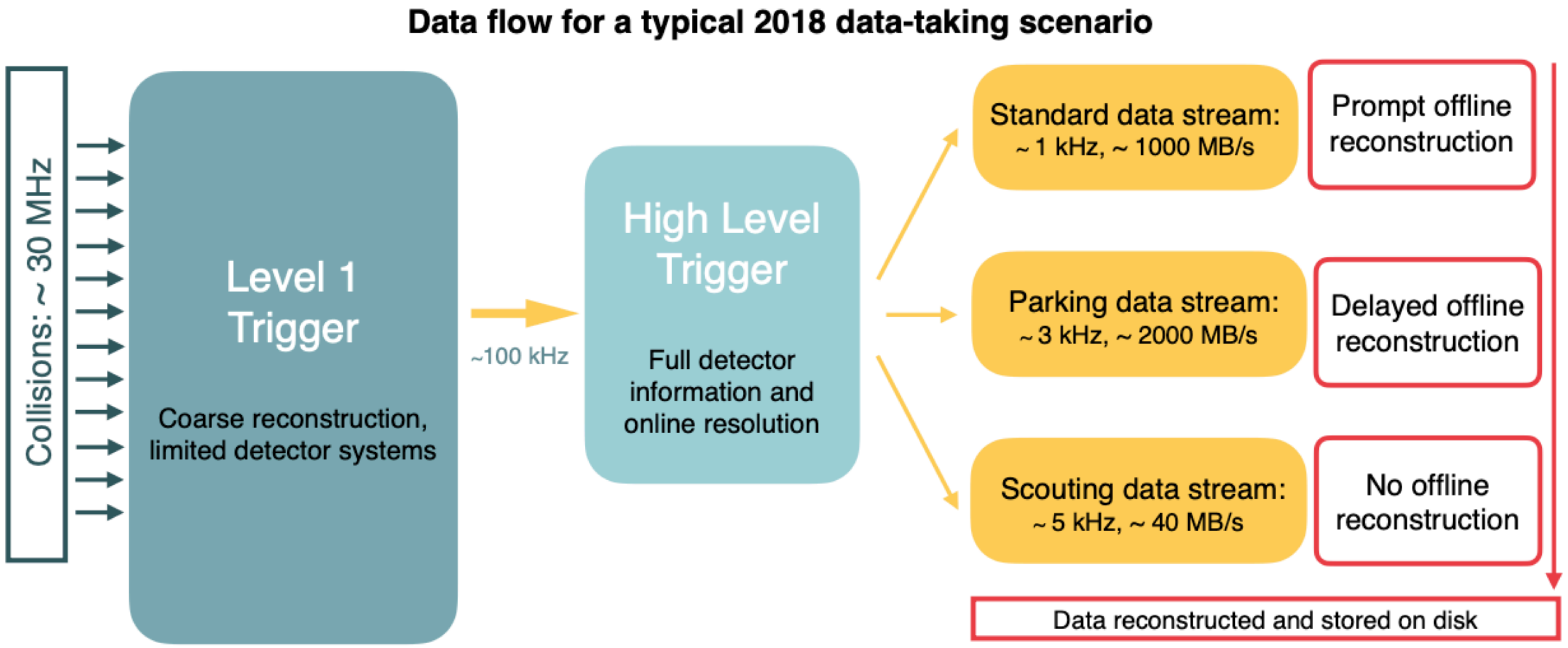
Performance of b-jet identification at fixed 1% mis-identification rate for other flavors

- 2016: ≈65%
- 2018: ≈75%
- 2022: ≈85% more than **30% improvement on same jets** in 6 years **just using better tools**!

Trigger

Data acquisition in CMS

arXiv:2403.16134

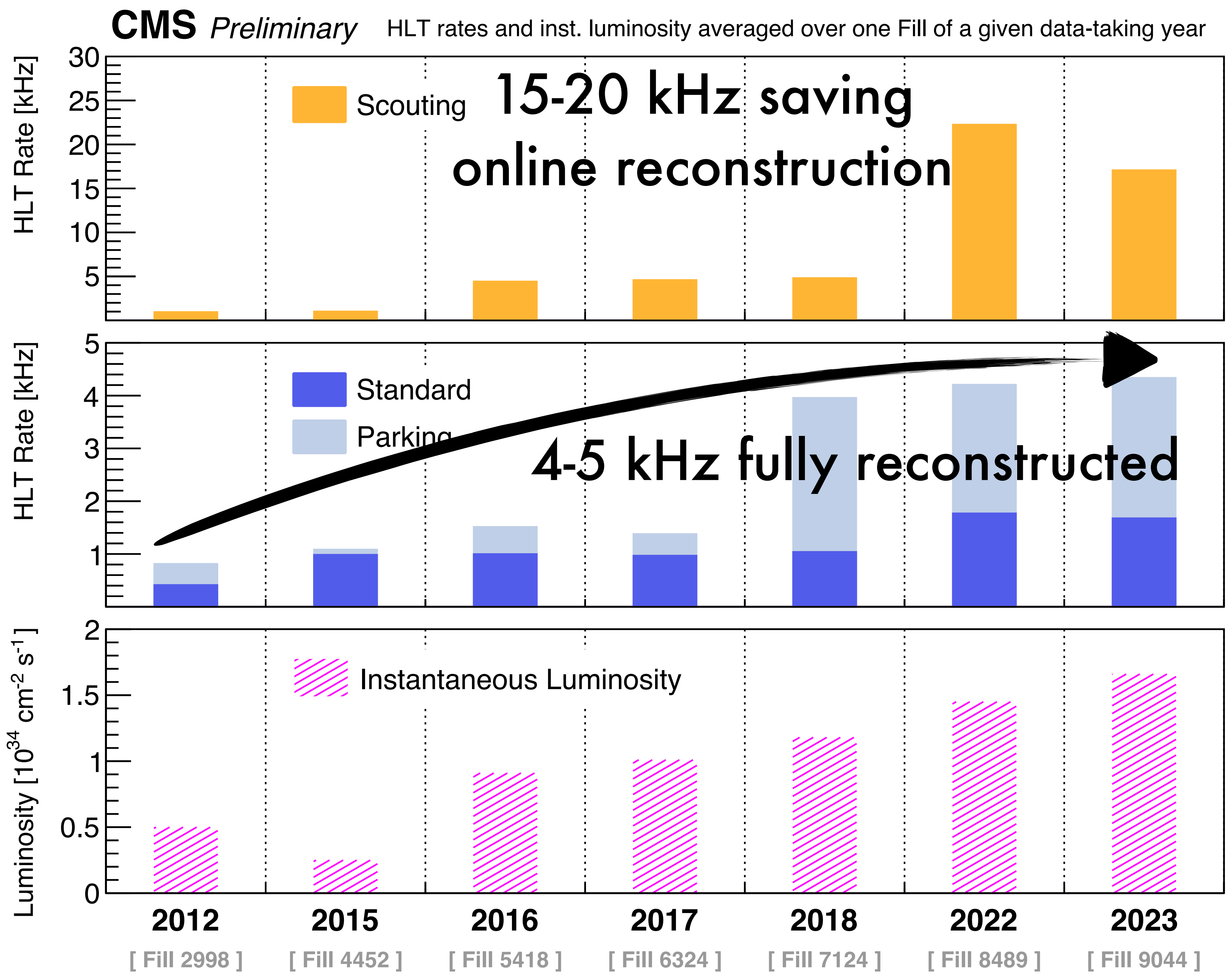


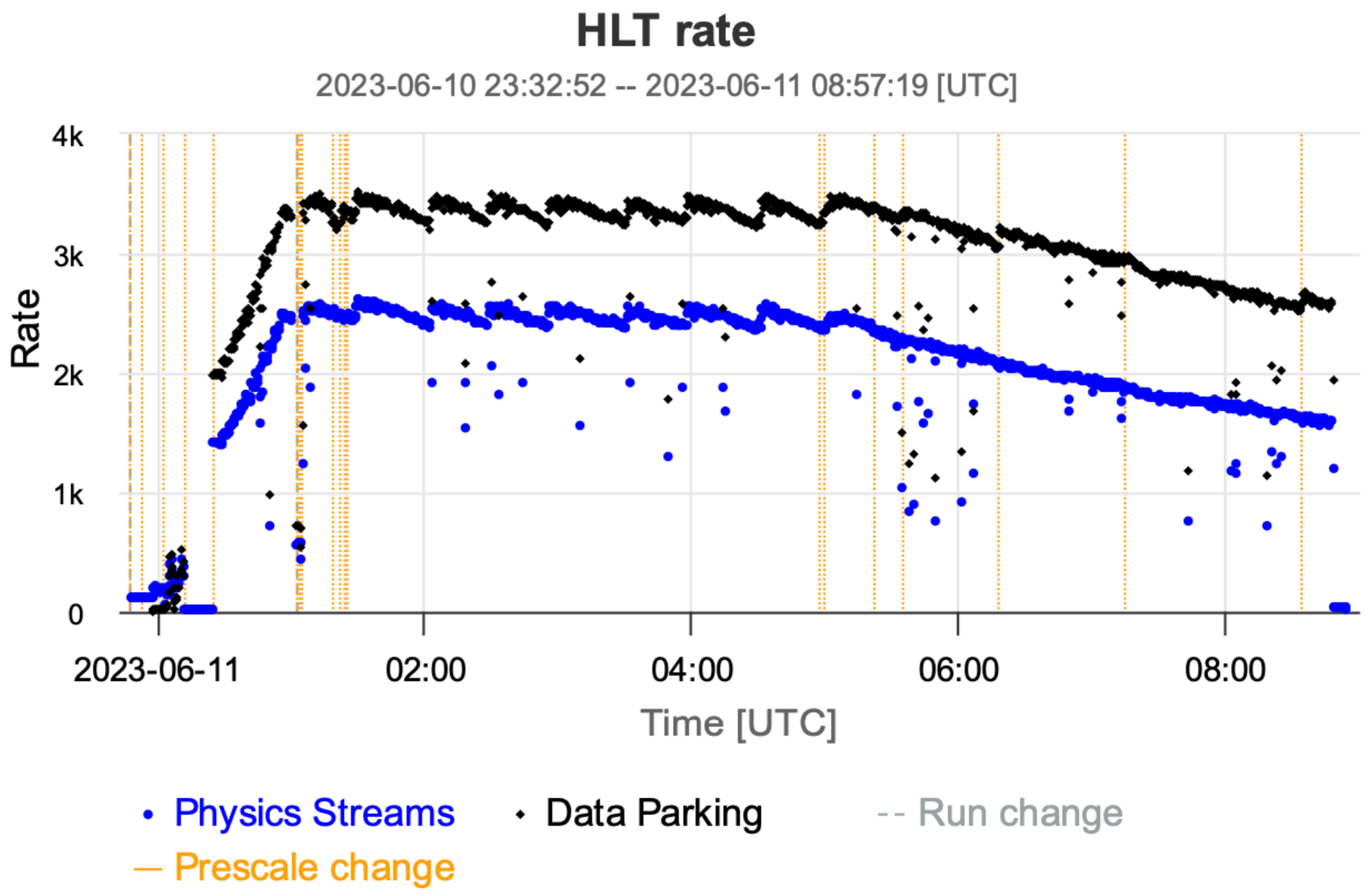
Data acquisition in 2018 and Run 3 (2022 - 2026):

- LHC produces **40 MHz bunch crossings** with **pp-collisions at 33 MHz**
  - Can't technically store that much information, 1 event is about 2 MB
- L1 trigger: reduces rate to **100 kHz (2018) to 110 kHz (Run 3)**
  → Relying on calorimeter and muon system
- HLT: 3 different strategies:
  - Prompt stream (**1 kHz**) / parking stream (**3 kHz**) / scouting stream (5 kHz)

Run 3 HLT rates

CMS-DP-2024/012
arXiv:2403.16134





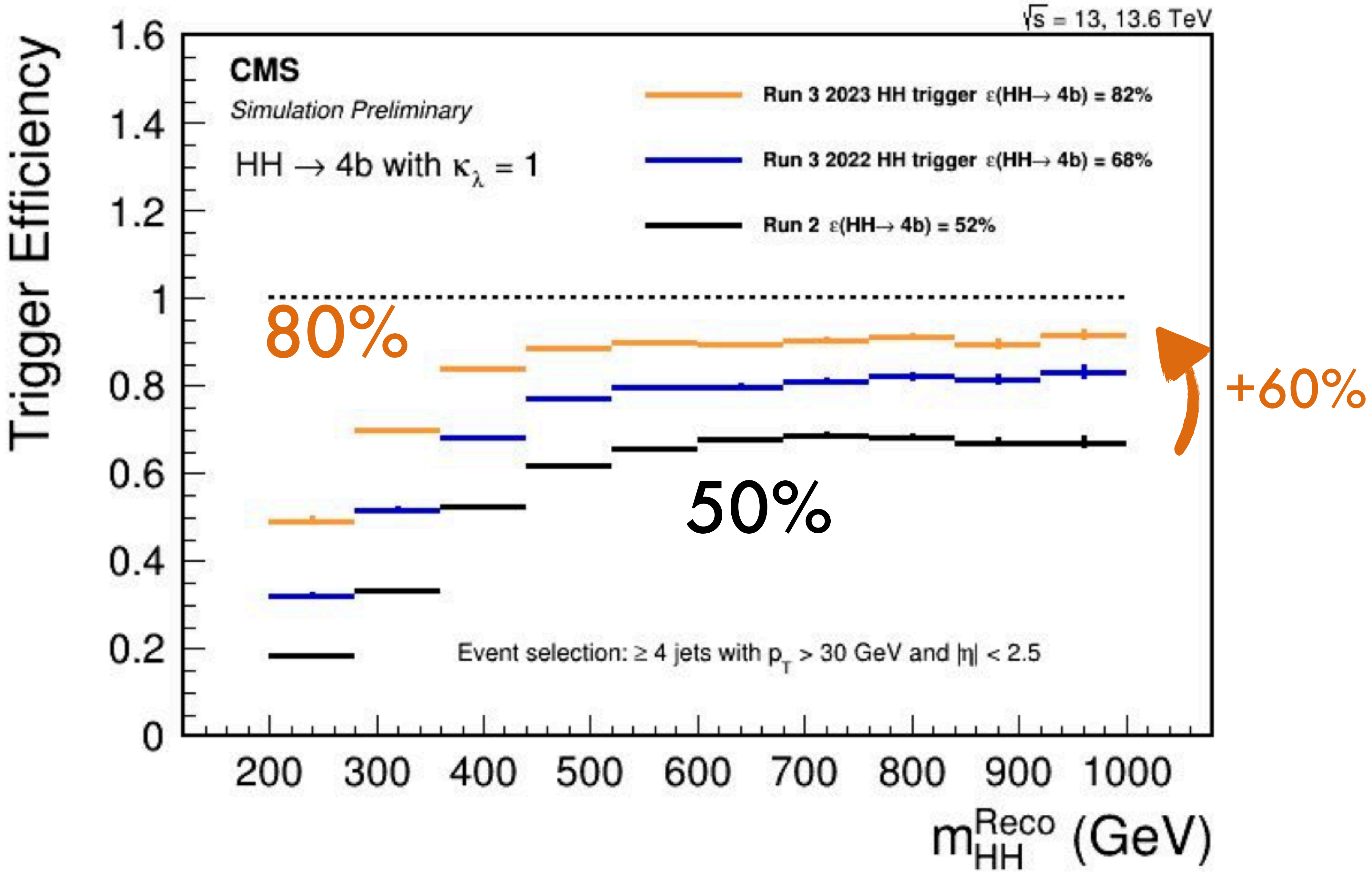
Extraordinary increase in computing capacities:

- In 2012: prompt rate and parking rate about 0.3 kHz each for total of 0.6 kHz
- In 2023: prompt rate about 2 kHz and parking rate about 3 kHz for total of 5-6 kHz
- Increase of a factor **5-10x in number of events saved to disk**
- Increase storage capacity to write events / extensive usage of CPUs and GPUs to trigger
- In 2023: CMS dedicated **7% of total HLT budget** to HH and HHH searches!

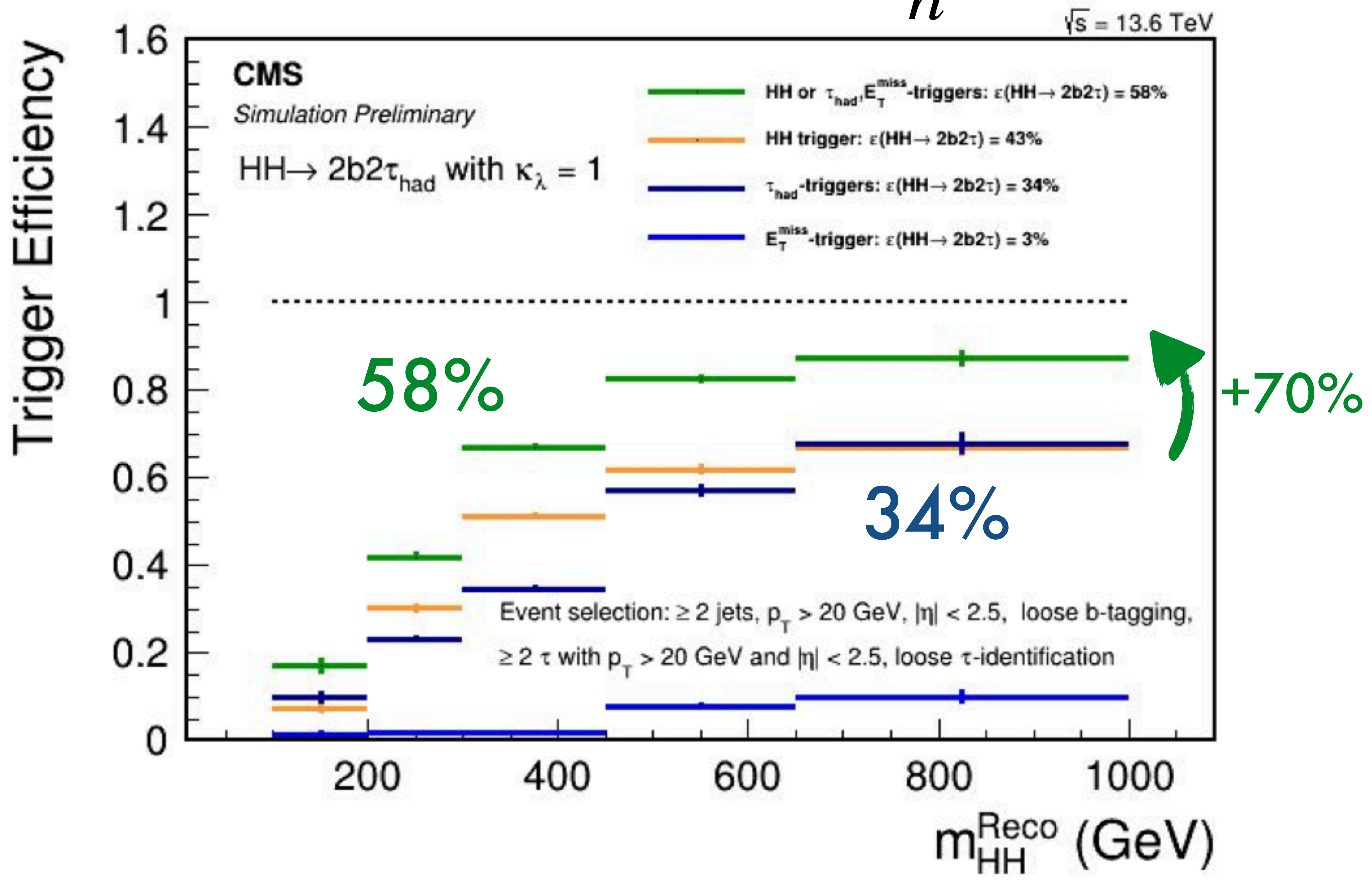
New triggers for multi-Higgs production

[CMS DP-2023/021](#)
[CMS DP-2023/050](#)

$HH \to 4b$



$HH \to 2b2\tau_h$



New flavor tagger + extensive usage of CPU and GPU farms at trigger

- Allows large increase in the number of multi-Higgs events recorded!
- In 2018: only recording 50% of $HH \to 4b$ and 34% of $HH \to 2b2\tau_h$ events
  - HH events are already hard to produce, we recorded only a small faction of them
- In Run 3: increased to **60% and 70% respectively**

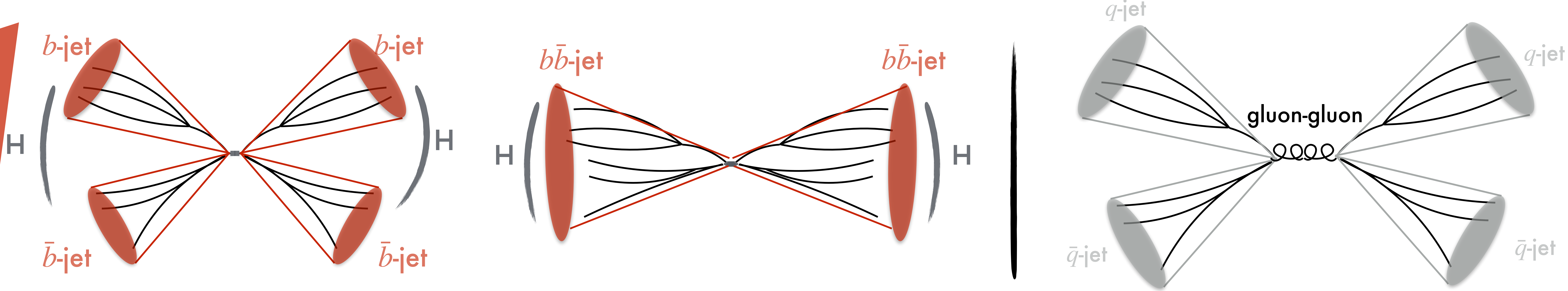
With new flavor taggers and new triggers:
Improve existing analyses and
new analyses become possible!

Run 2 and partial Run 3 HH4b (22+23)

Signal vs background: challenge

Higgs pairs production (HH)

Backgrounds



2000 events produced between 2016 and 2023

2 billion!

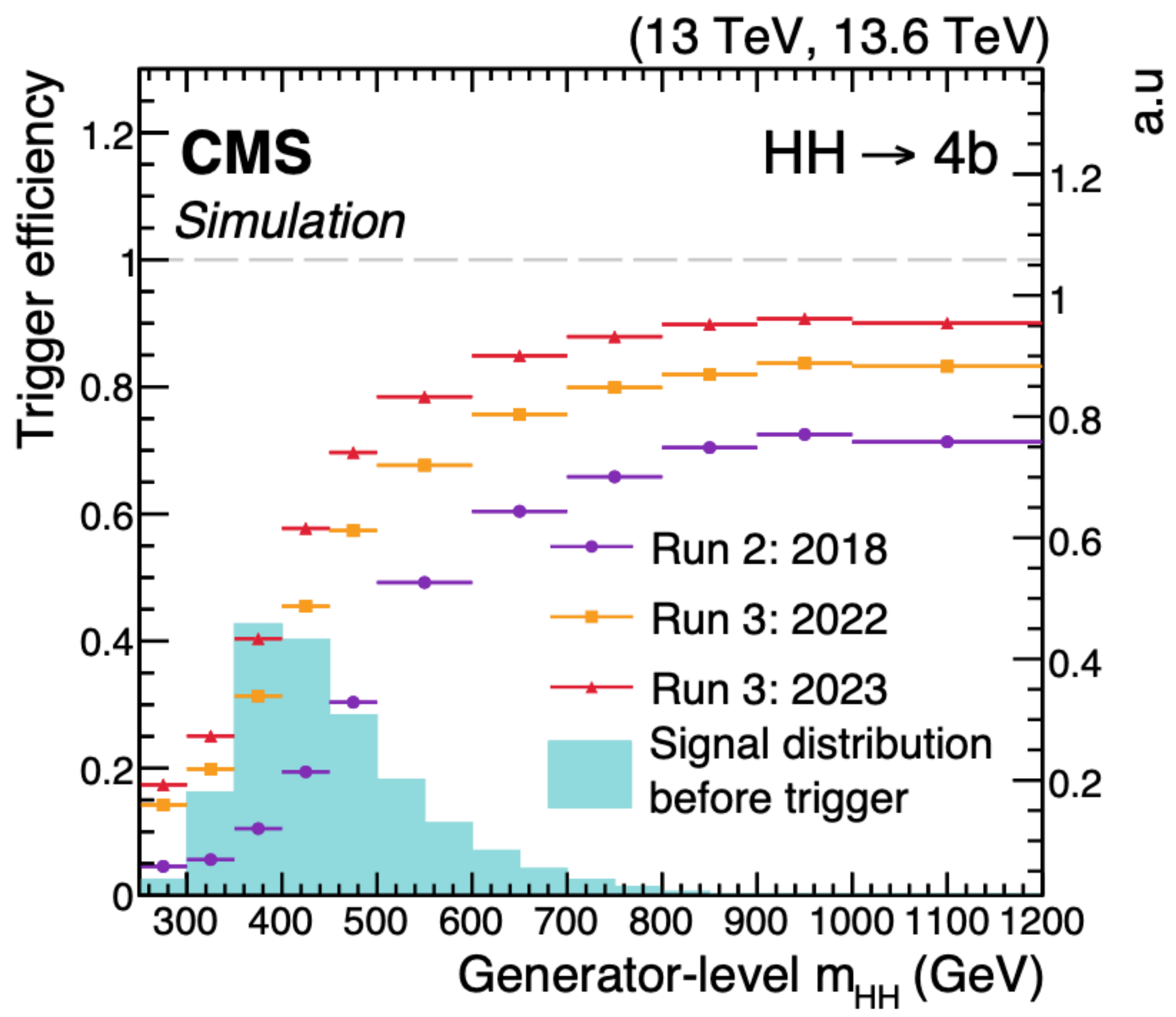
HH4b: extremely large background contamination with 4 b-jets in the final states

- Exploit HH topologies with 4 small-radius jets (resolved) and 2 large radius jets (boosted)
- Rely on pairing and correct assignment, exploiting the Higgs mass information!
- Use advanced machine learning to separate signal from background and model background
- 95% of background is from QCD multi-jets production, 5% from ttbar, other subdominant

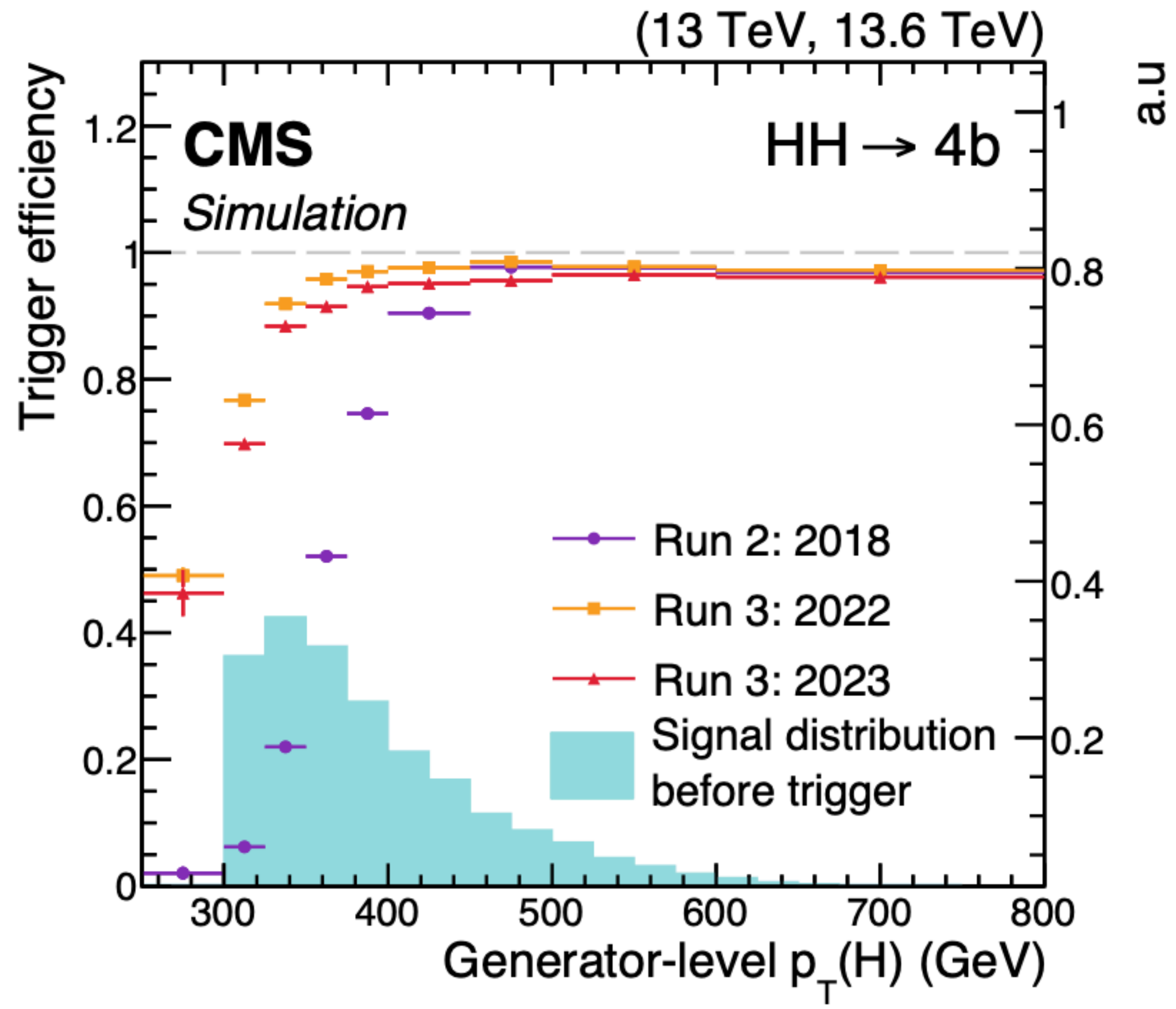
Trigger improvements

arXiv.2604.27044

Resolved topologies



Boosted topologies



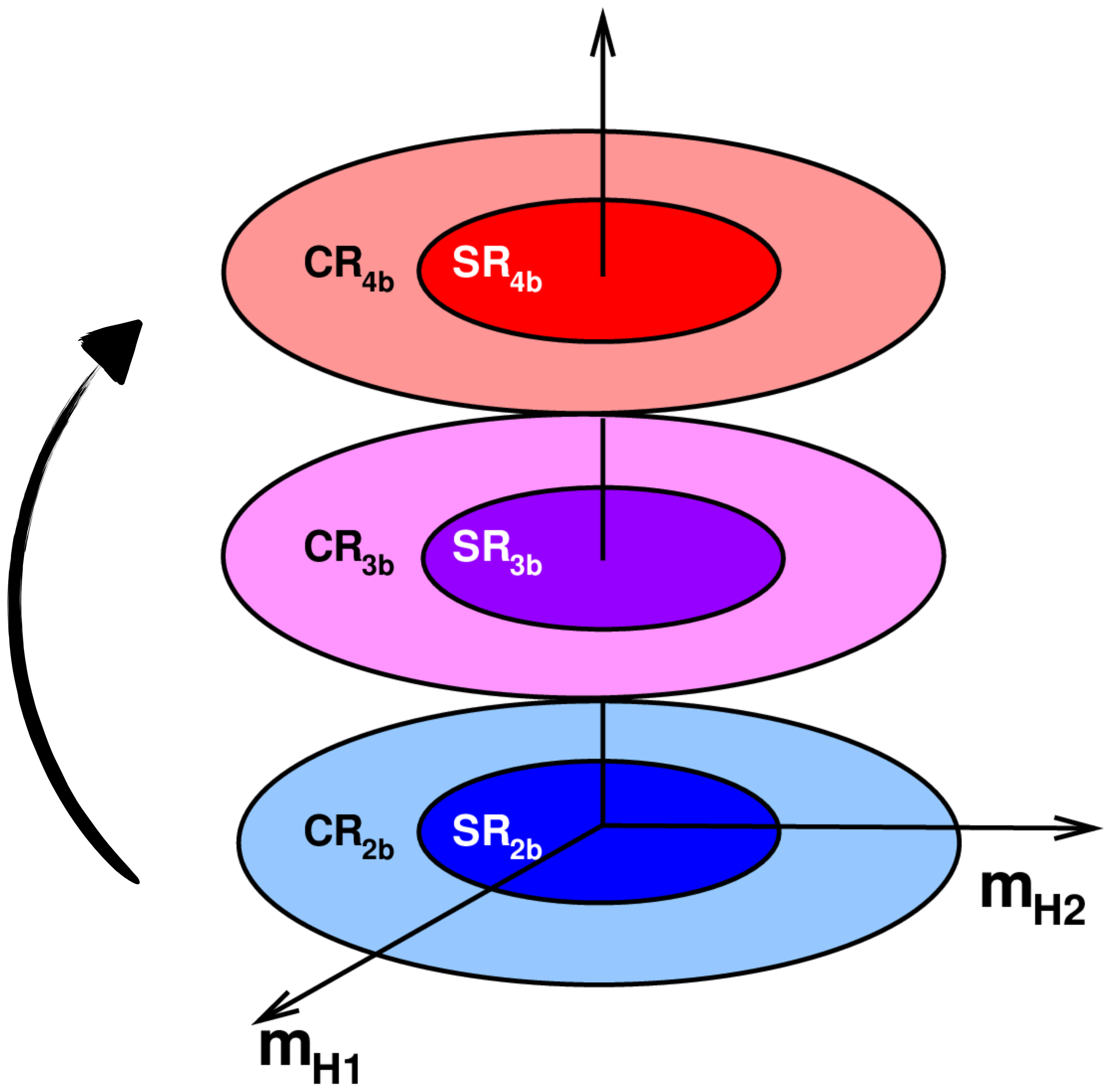
New flavor tagging incorporated in trigger for both small-radius and large radius jets

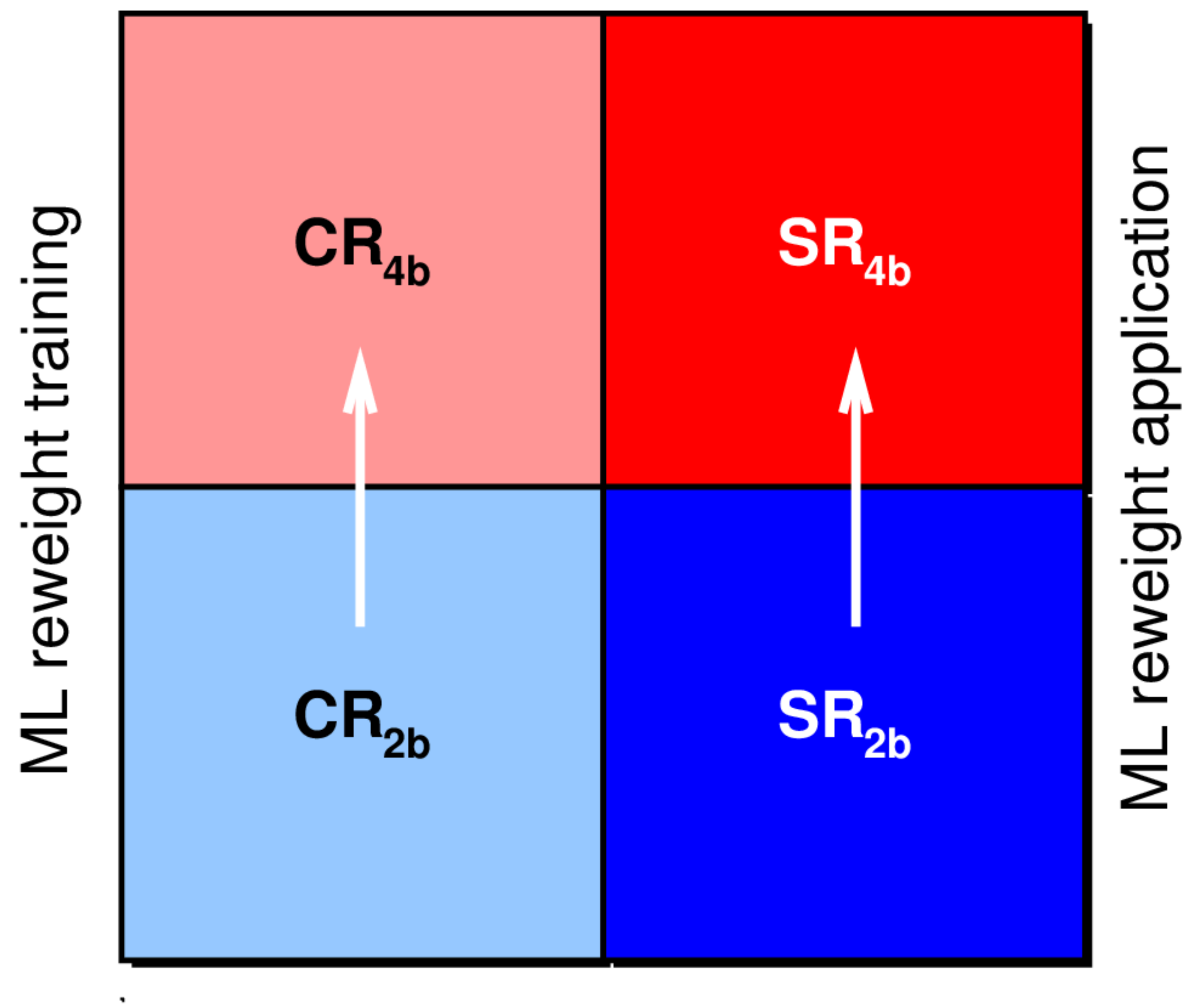
- Main limitations at trigger, large c-jets and light-jets background
- Better tagging enables higher efficiency for same rates
- More bandwidth allocated at the trigger level
  - When flavor anomalies from LHCb started disappearing, larger rate available for HH in CMS!
- Recording **50-70% more events at the trigger level,** allowing **large gains at analysis level**

Analysis strategy

arXiv.2604.27044

New: use 2 b-tags
thanks to Run 3 triggers



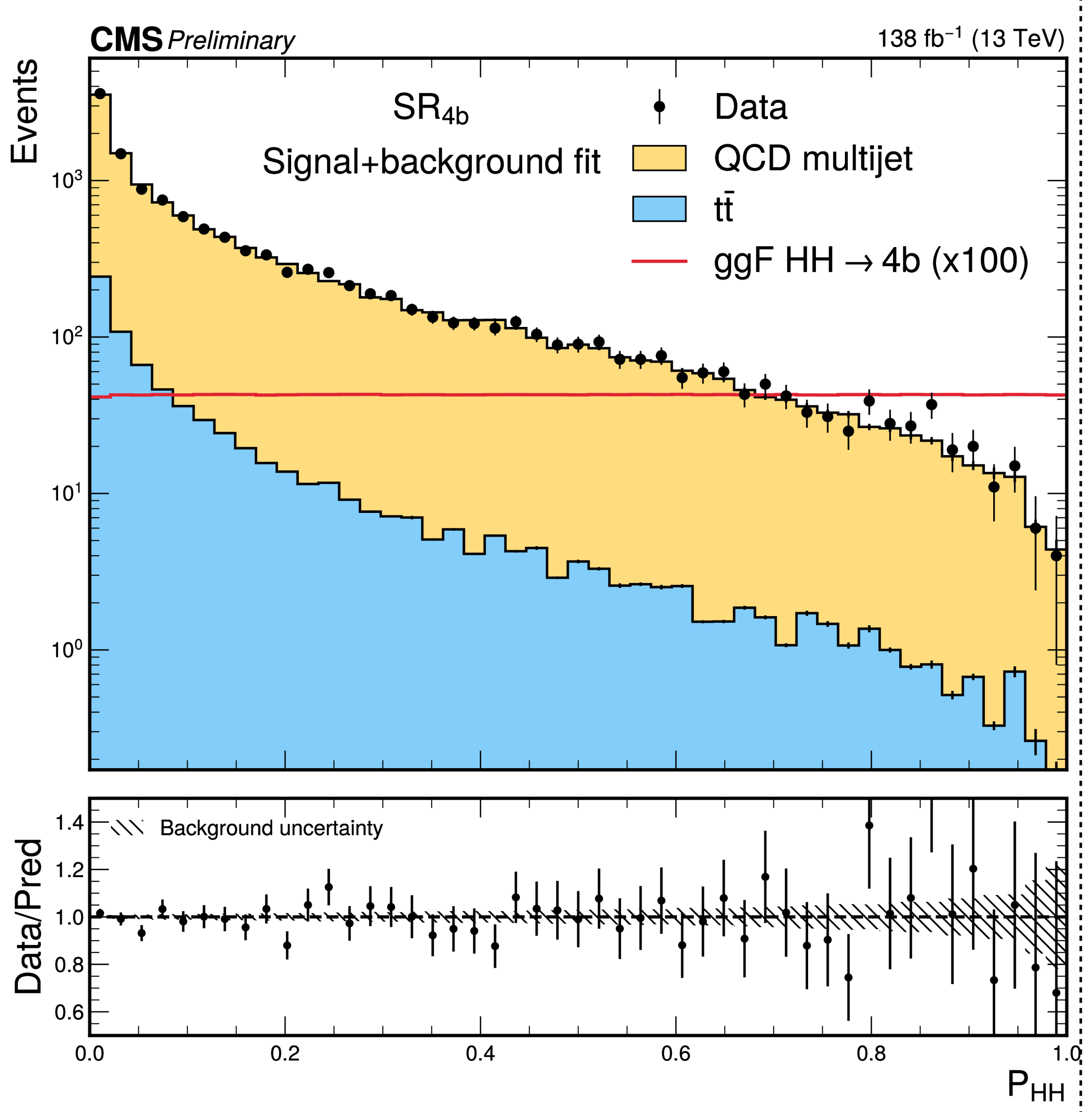
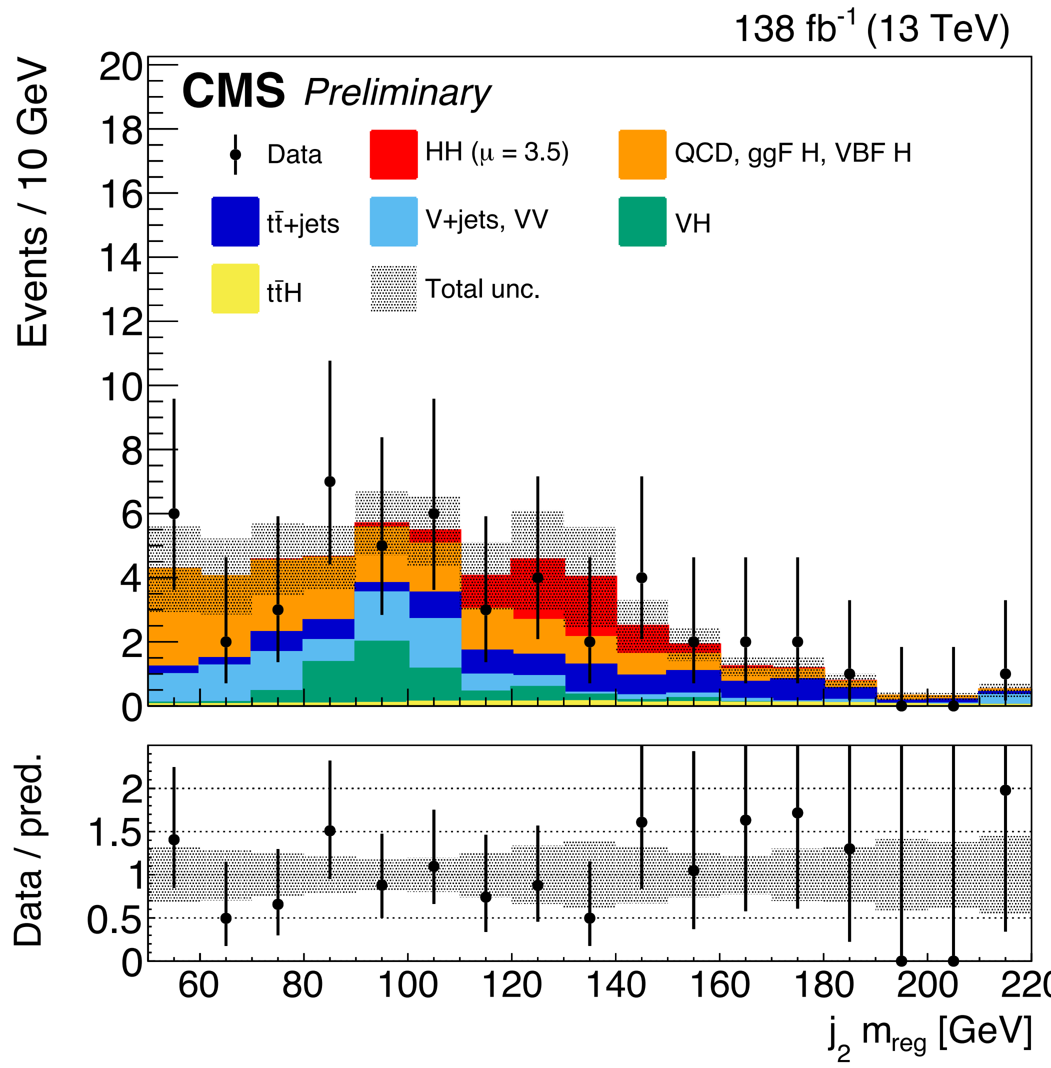
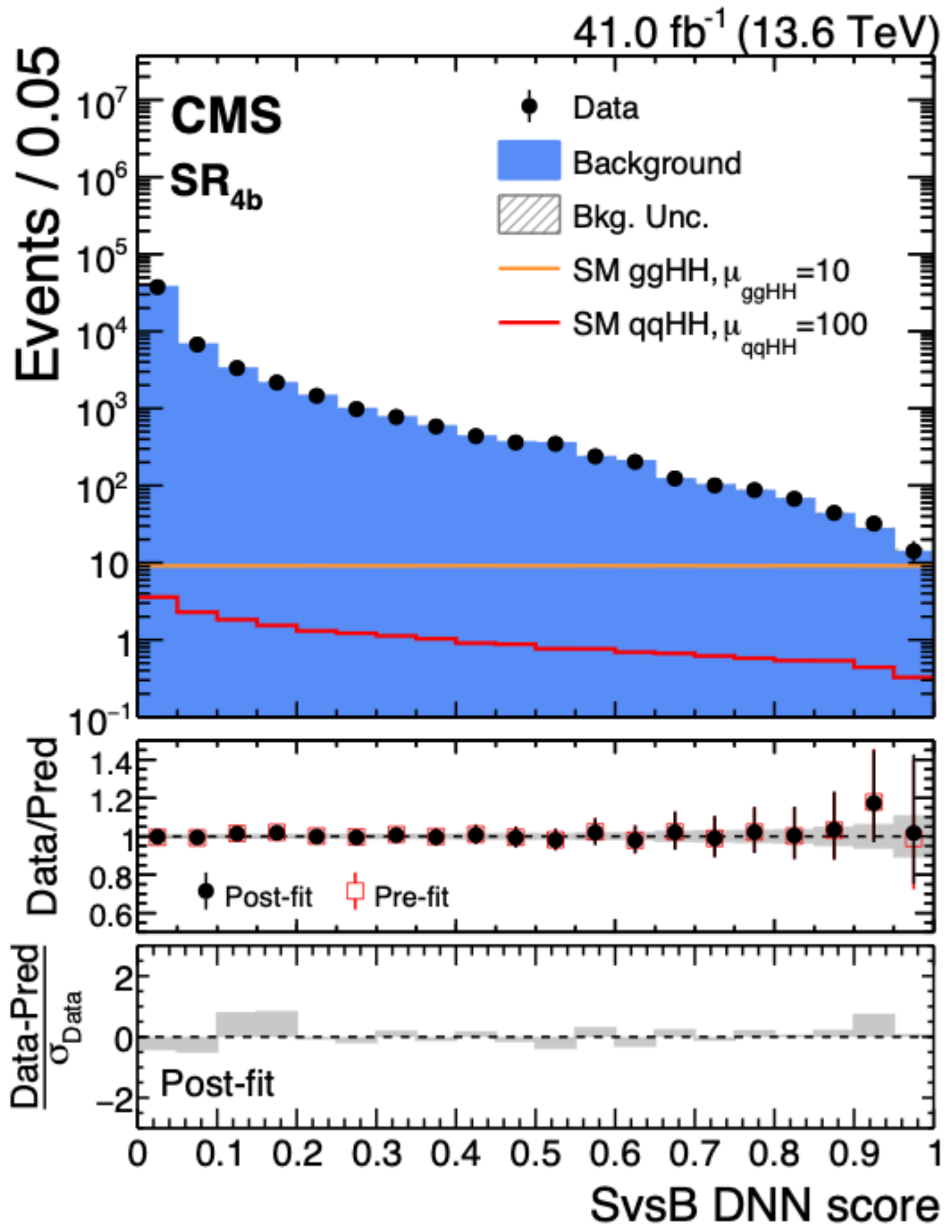
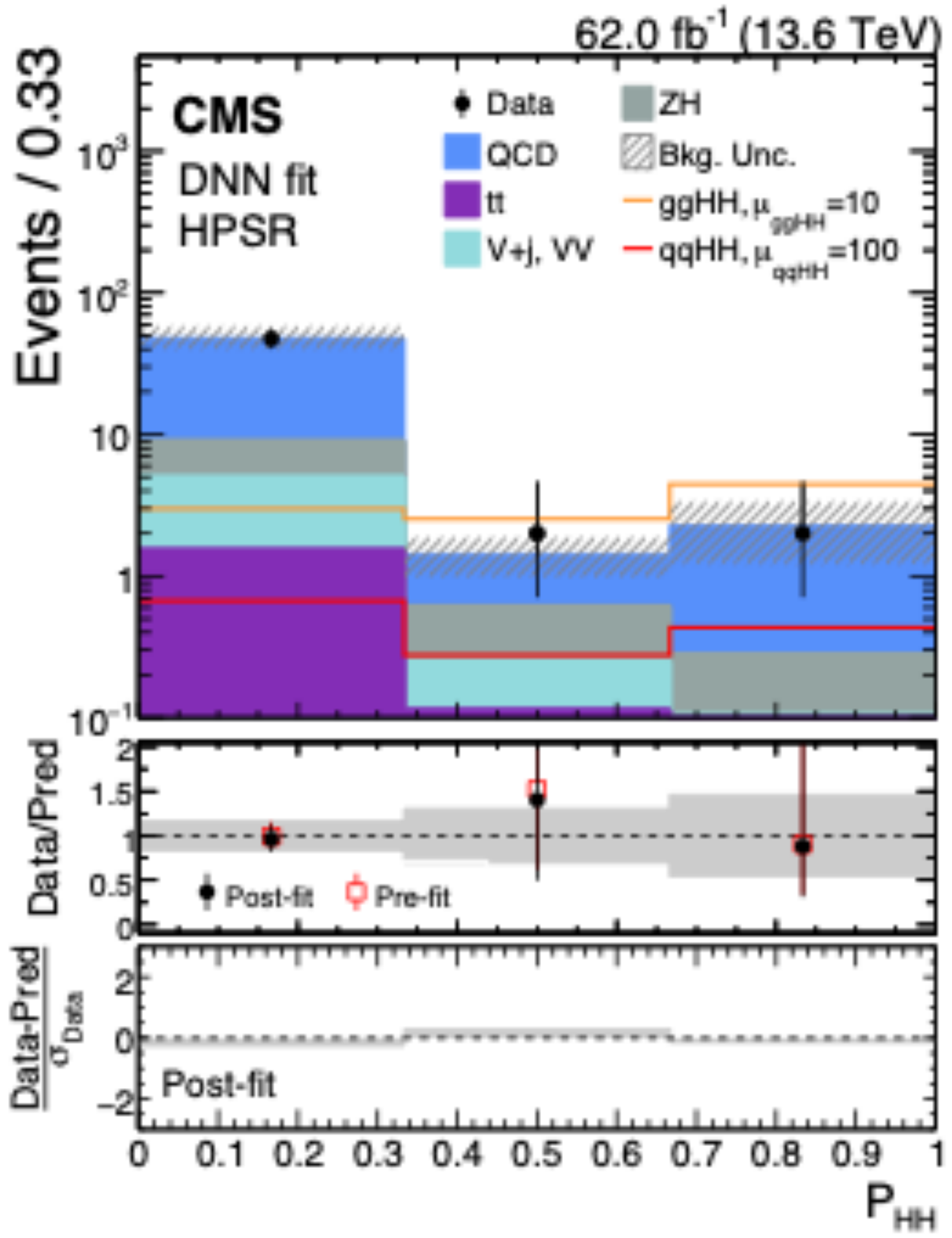


Exploit mass of two Higgs candidates to build signal and control regions:

- Large multi-jet background estimated in data-driven way
  - Control regions: machine learning to morph 2 b-tag data events to look like 4 b-tags
  - **Apply in 2 b-tag signal region to estimate shape in 4 b-tag**
  - 2 b-tag region available thanks to new triggers!
- Signal vs background: train second machine learning algorithm using **data bkg model**
- **Similar strategy used in both resolved and boosted topologies**

Data / background model comparison

arXiv.2604.27044

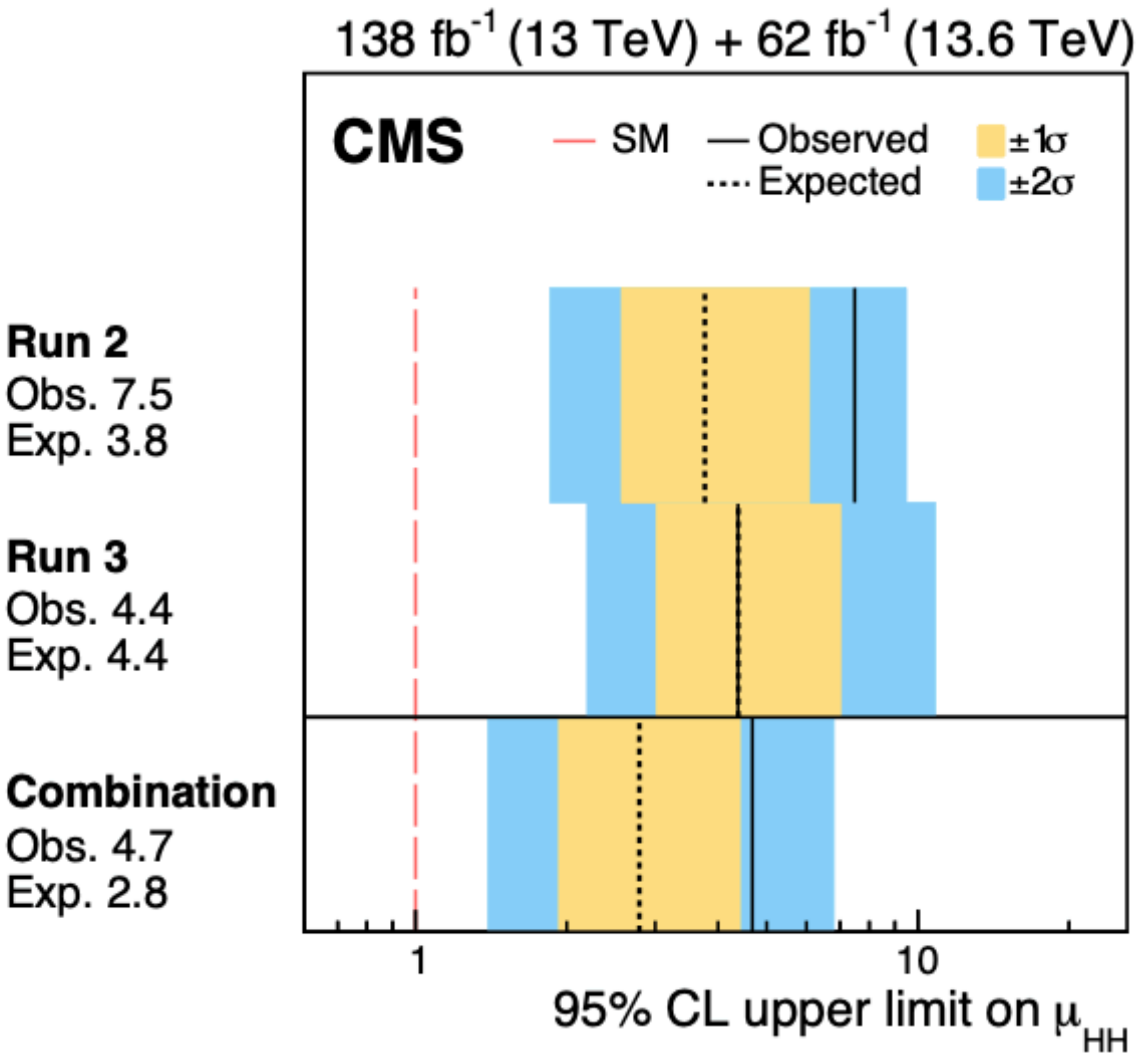
Run 2 resolved	Run 2 boosted	Run 3 resolved	Run 3 boosted
			
Upper limit < 5.9 x SM	Upper limit < 5.5 x SM	Upper limit < 5.5 x SM	Upper limit < 8.1 x SM

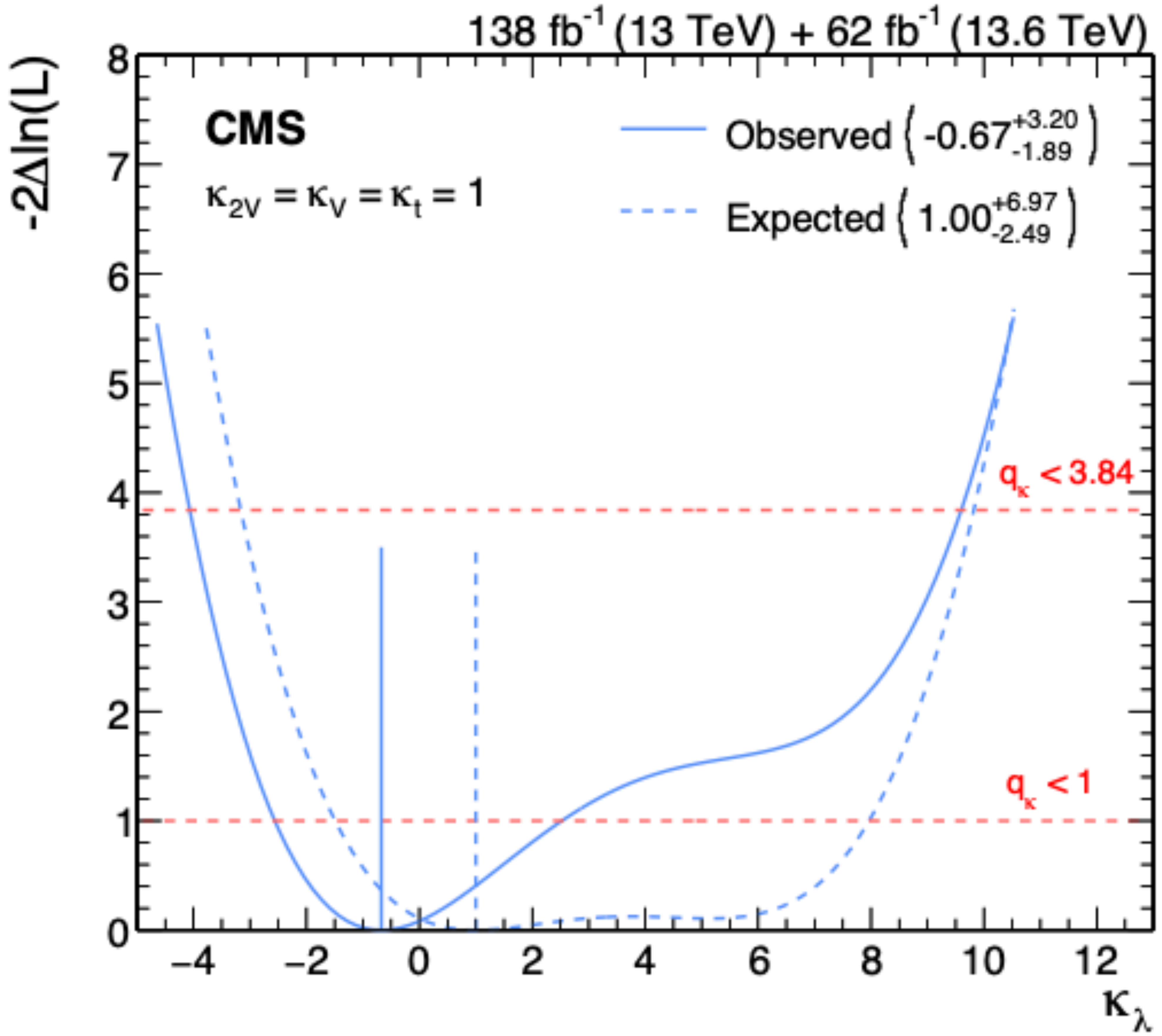
Run 3 (61 fb-1) strategy is **as sensitive as Run 2 (140 fb-1) with half the dataset!**

- Large improvement enabled by new flavor tagging and trigger strategy

Interpretation SM and κ_{λ_3}

arXiv.2604.27044





SM interpretation with $\mu_{HH} = 0$: $\mu_{HH} < 4.7\ (2.8)$ observed (expected)

- **One of the most sensitive channel at the LHC!**

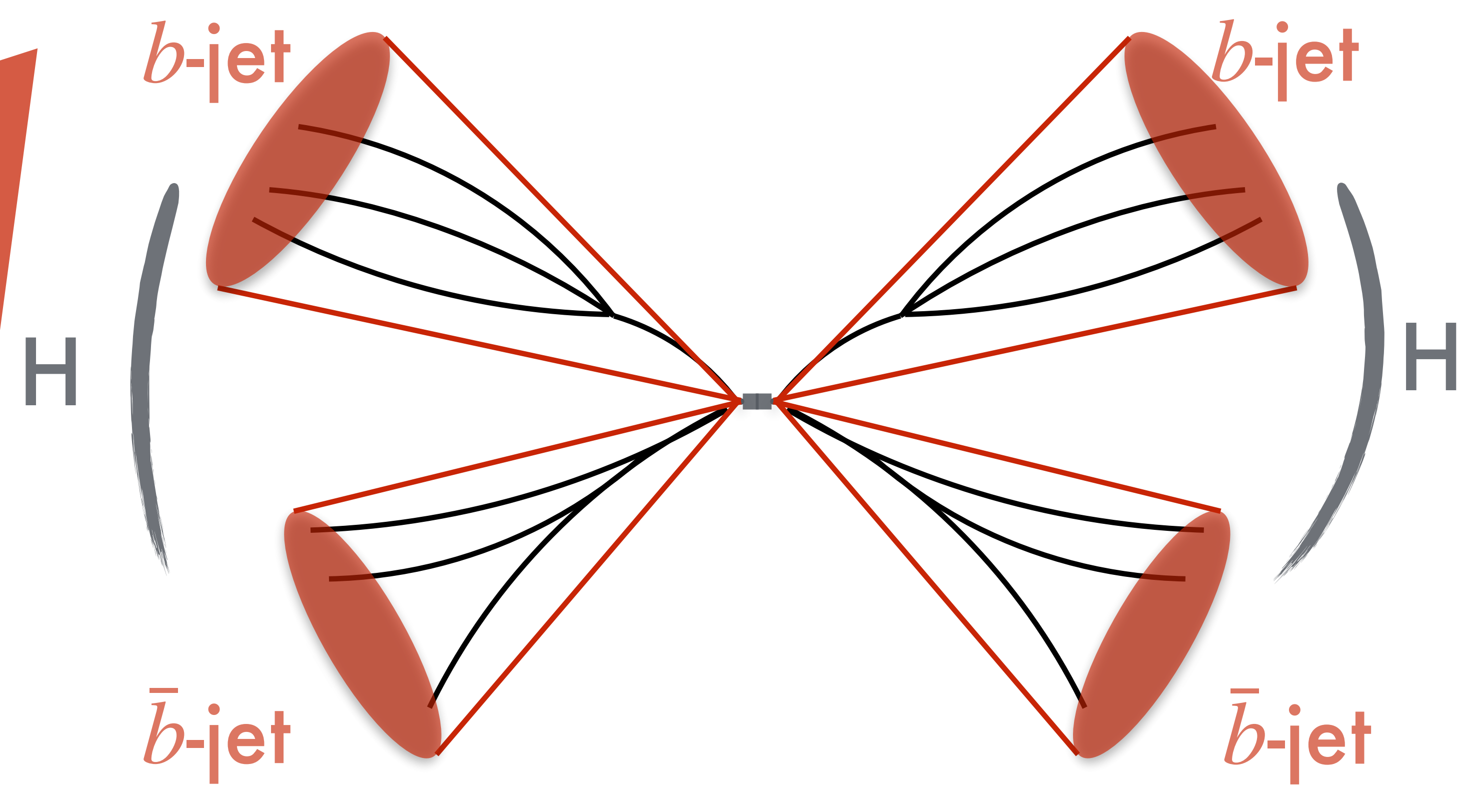
Observed contraints: $-4.1 < \kappa_{\lambda_3} < 9.6$

Expected constraints: $-3.2 < \kappa_{\lambda_3} < 9.8$

Partial Run 3 HH2b2y 22+23

Silver channel: HH2b2y

$HH \to b\bar{b}b\bar{b}$

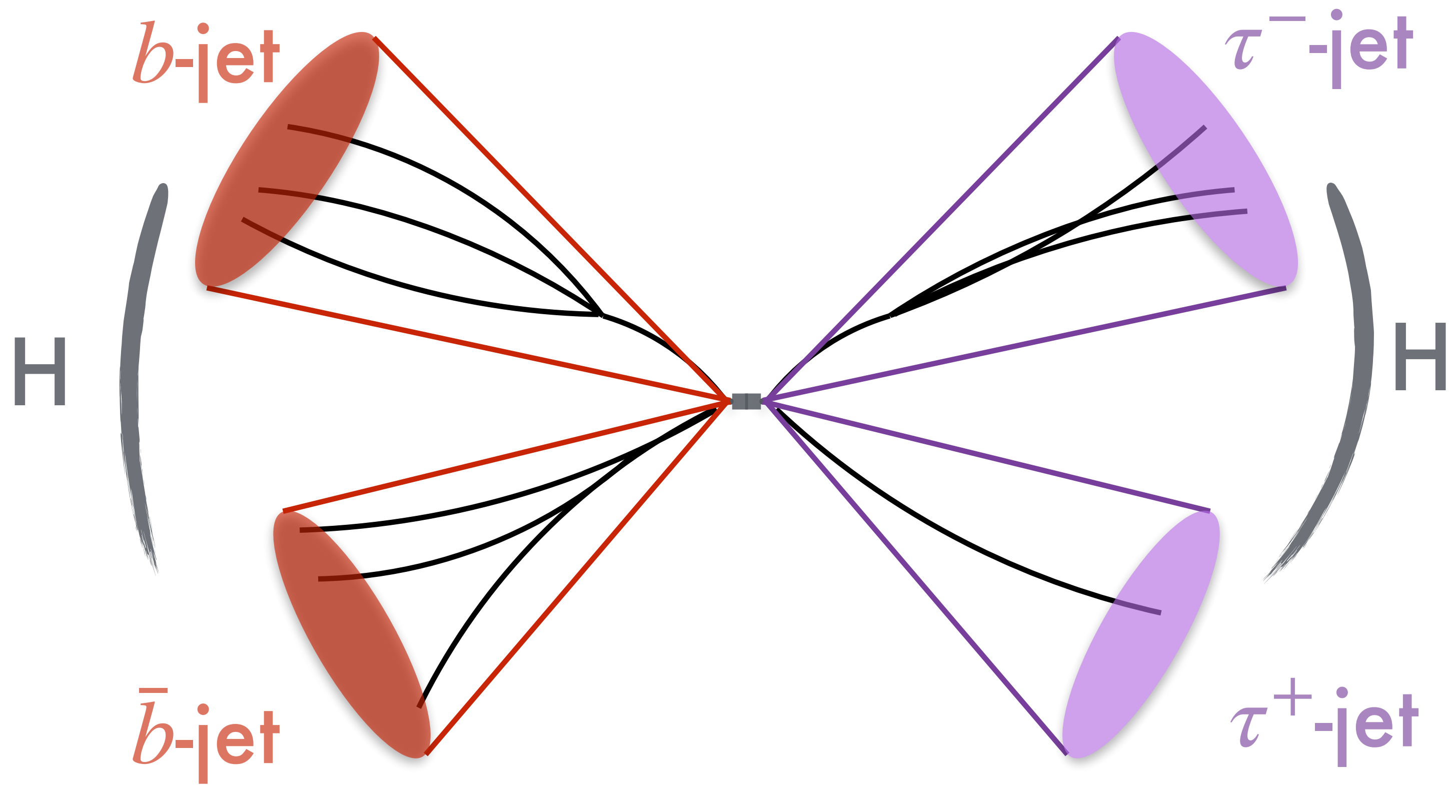


$Prob(HH \to b\bar{b}b\bar{b})$ = 34%

Large signal but large background

Heavily relies on b-jet identification

$HH \to b\bar{b}\tau^+\tau^-$



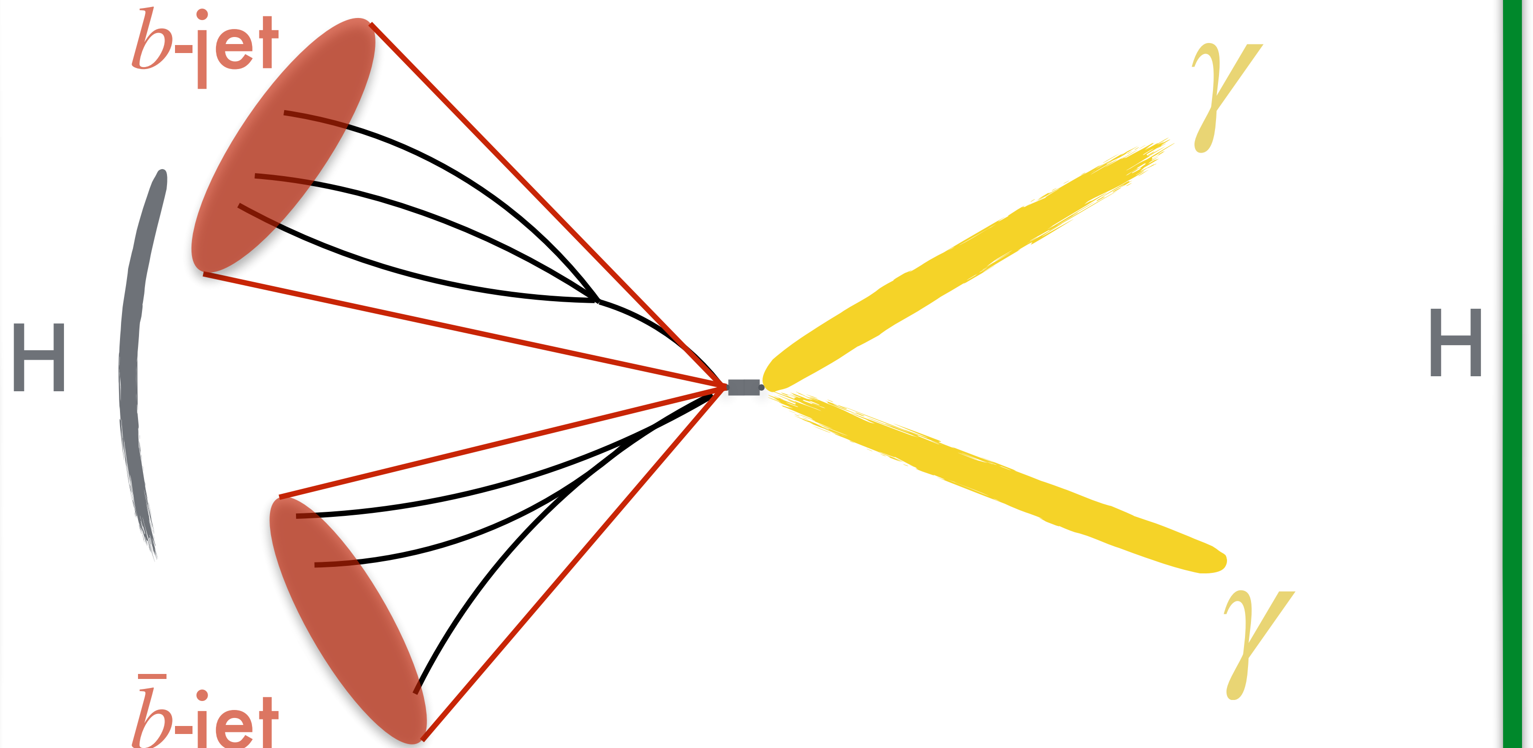
$Prob(HH \to b\bar{b}\tau^+\tau^-)$ = 7%

Sizable signal, lower background

Relies on both b-jet and τ tagging

Expect result soon

$HH \to b\bar{b}\gamma\gamma$



$Prob(HH \to b\bar{b}\gamma\gamma)$ = 0.3%

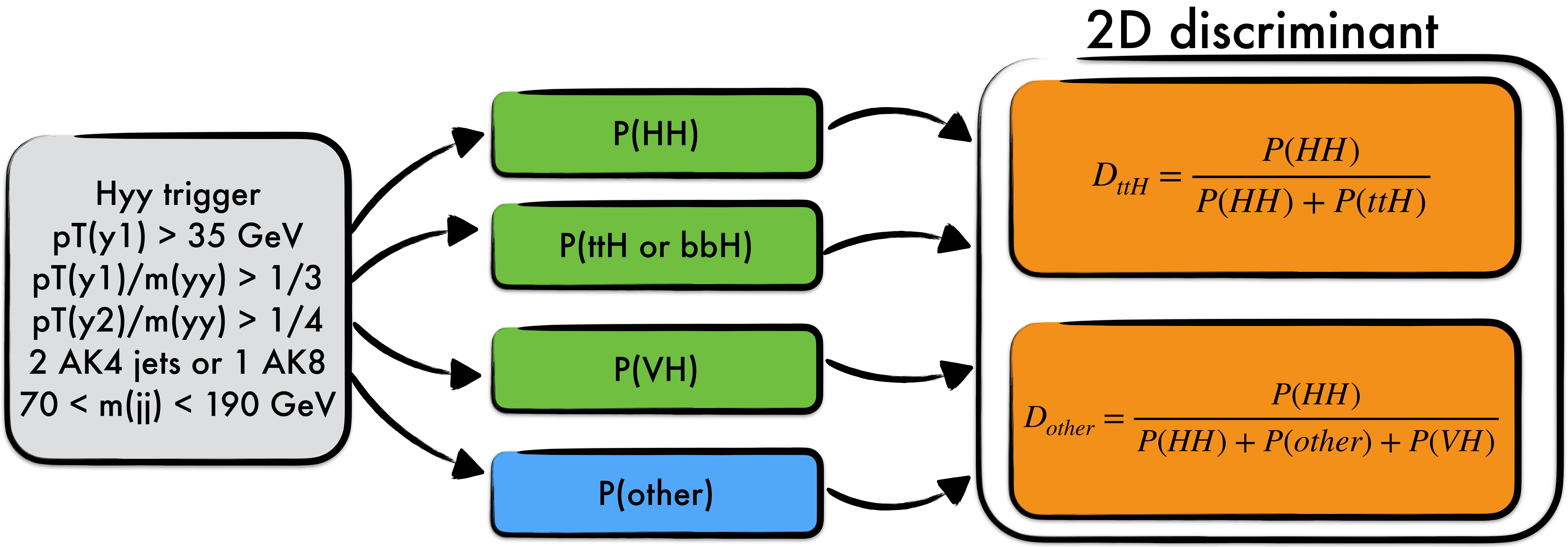
Very low signal, low background

Very clean di-photon signature

Preliminary result

Strategy: resolved and boosted analysis

CMS-PAS-HIG-25-007



Three major backgrounds:

- Double resonant background: V(bb)H(yy)
- Single resonant background: ttH(yy) and bbH(yy)
- Non-resonant background: yy+jets, y+jets, QCD, ...

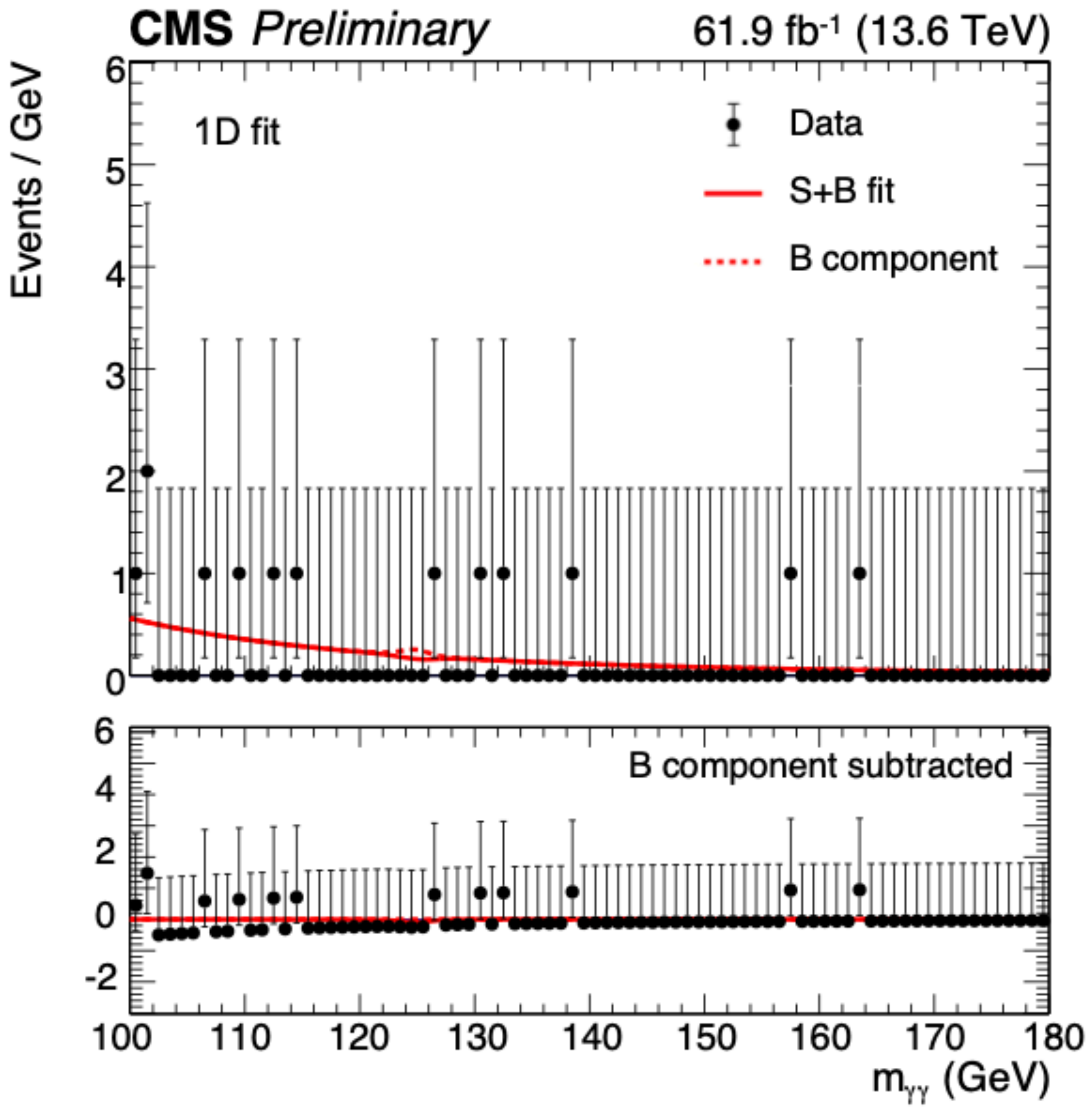
Train multi classifier using MC simulation for all processes

- Build 2D discriminant and **optimize 3 categories** for sensitivity and purity
- Minimum 8 events in the sideband

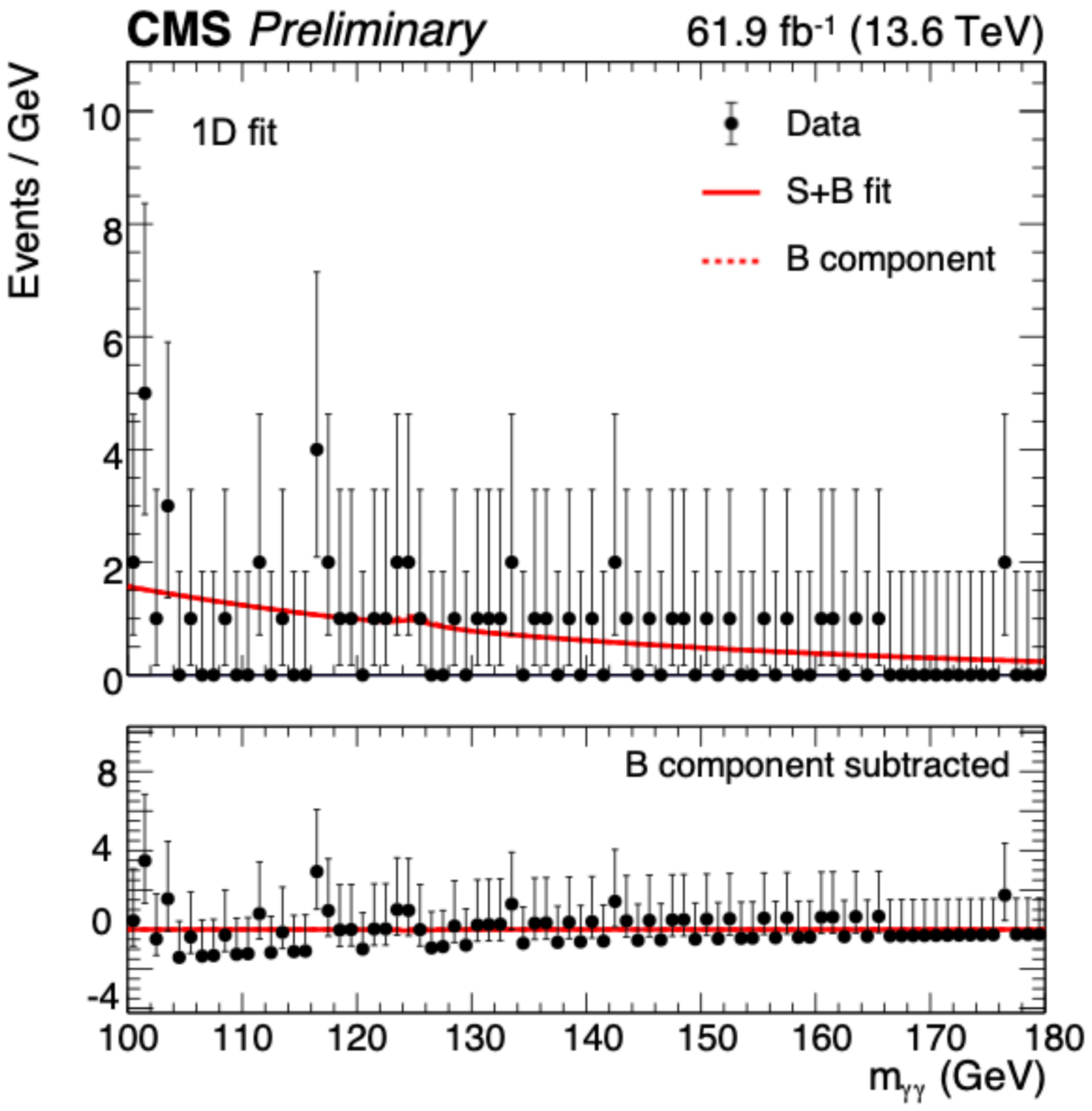
Signal region fit

CMS-PAS-HIG-25-007

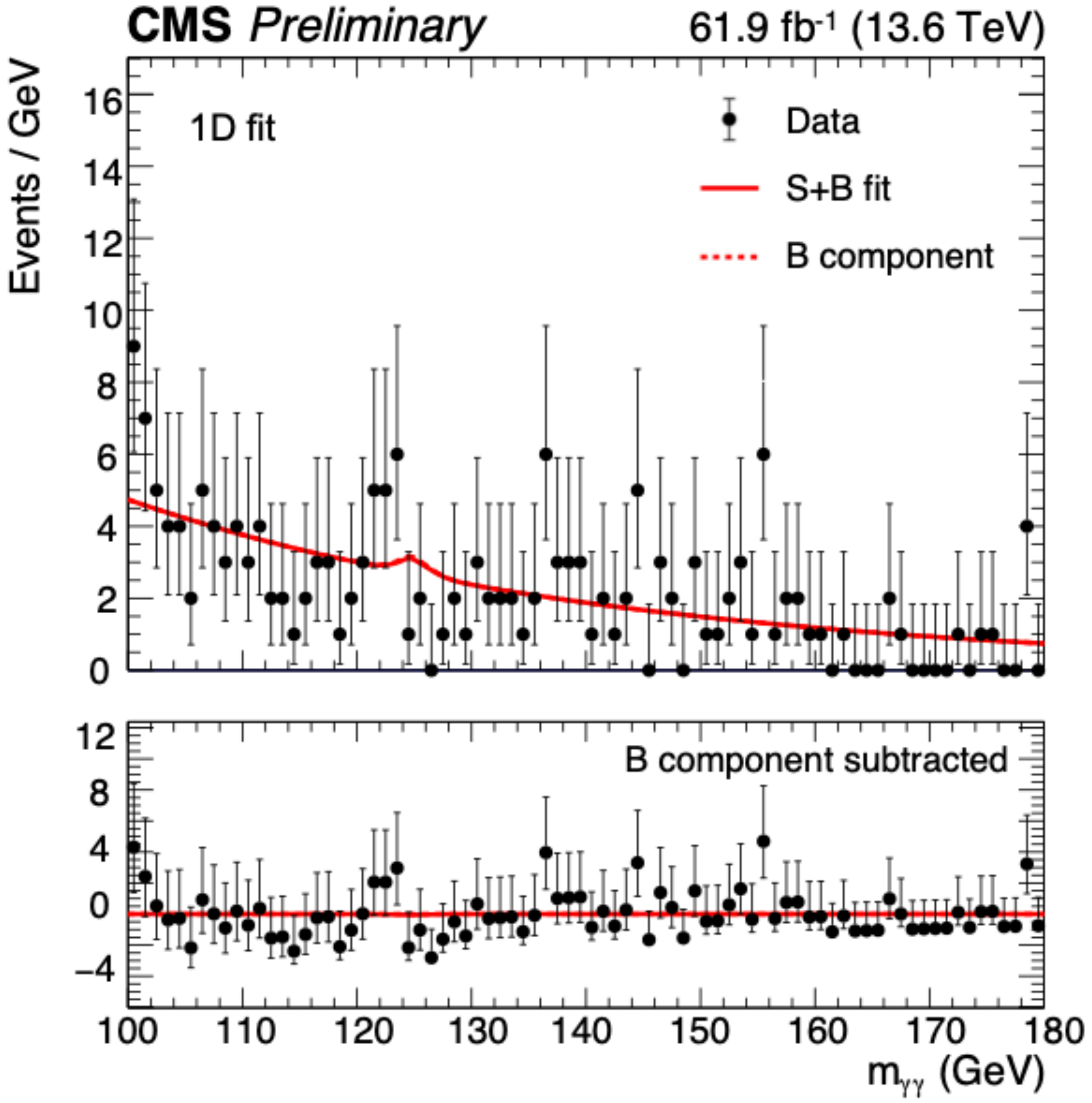
Category 1



Category 2



Category 3

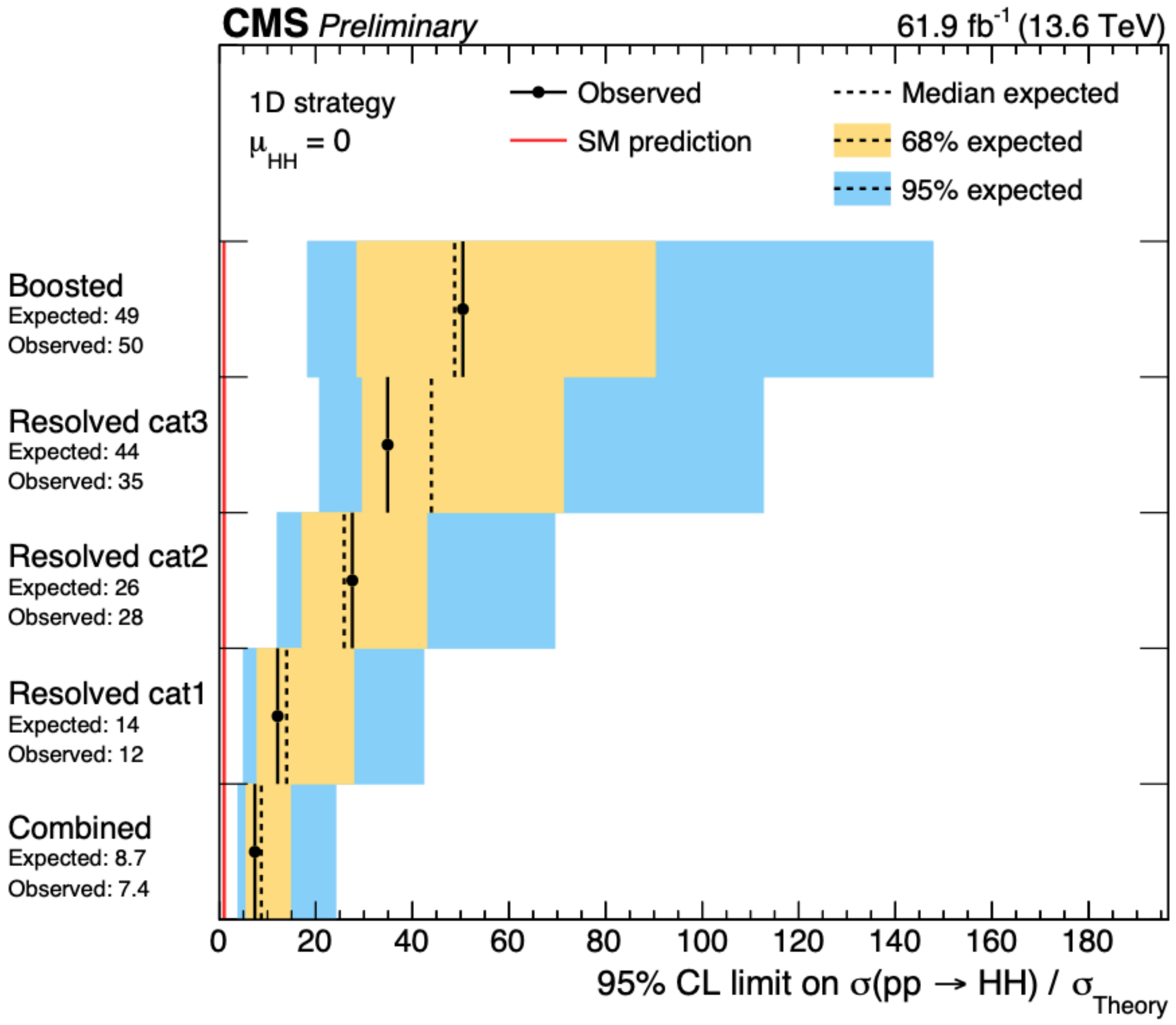


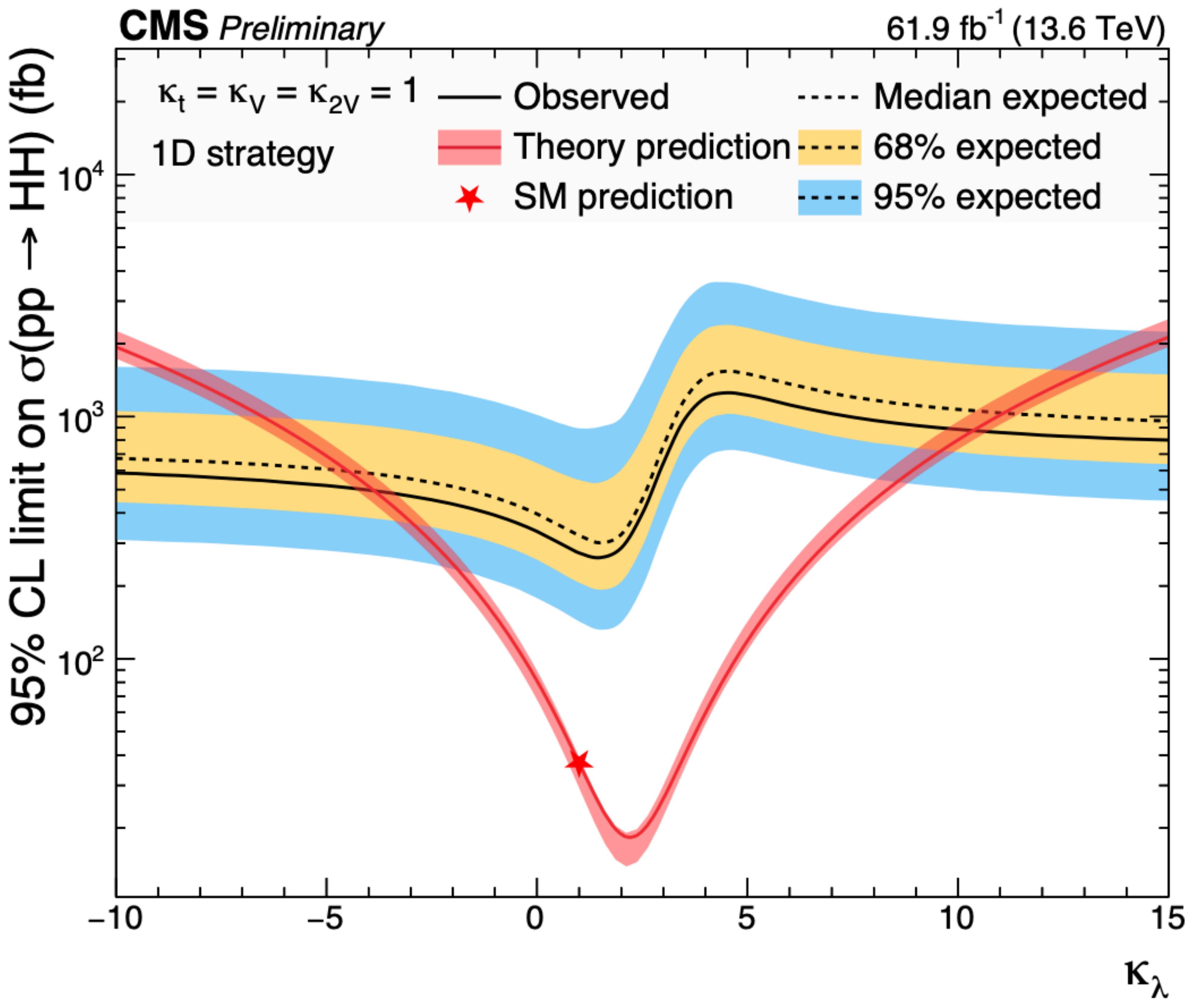
Strategy: after selection - fit invariant mass distribution in m(yy) (best resolution)

- Resonant backgrounds fixed to SM expectation
- Background model described by exponential function selected by Fisher test
- Signal model: by N gaussians

Results and interpretation

CMS-PAS-HIG-25-007





SM interpretation: $\mu_{HH} < 7.4\ (8.7)$ at 95% CL for observed (expected)

- Lower than simple scaling with respect to Run 2 due to lower luminosity and less stringent cuts

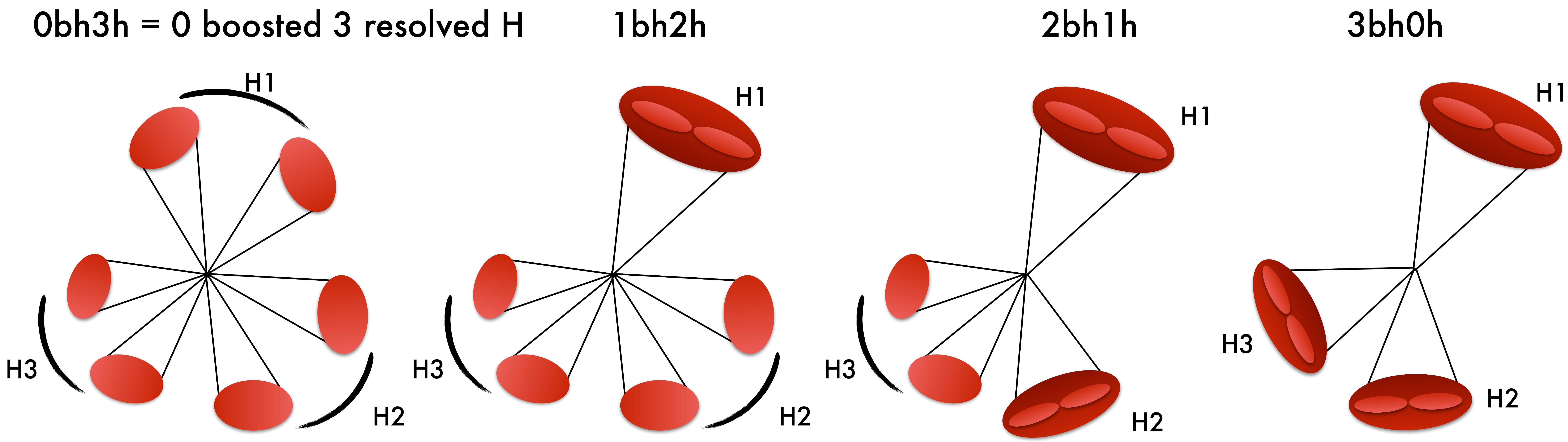
Trilinear coupling interpretation: $-4.5 < \kappa_{\lambda_3} < 11.1$

Run 2 HHH6b

Non-resonant $HHH \to 6b$

CMS-PAS-HIG-24-012

arXiv.2607.05145



3 events produced in Run 2, up to 60 events by the end of the HL-LHC

HHH6b: rich experimental topology

- Resolved Higgs: reconstructed from 2 small-radius jets
- Boosted Higgs: reconstructed from one large-radius jets
- Complex mixing, dependent on momentum of the Higgs candidates

Rare process, but backgrounds faking 3 Higgs boson masses is also rare!

- Probe the trilinear λ_3 and quartic λ_4 couplings: *can we measure it at the HL-LHC?*

Non-resonant $HHH \to 6b$

[CMS-PAS-HIG-24-012](CMS-PAS-HIG-24-012)
arXiv.2607.05145

Number of reconstructible Higgs in **2 AK4**

Reconstructible Higgs in **AK8**	0h	1h	2h	3h
3bh	1.7%			
2bh	12.5%	5.9%		
1bh	8.6%	**17.5%**	**7.9%**	
0bh	1.3%	11.1%	**22.0%**	**11.1%**

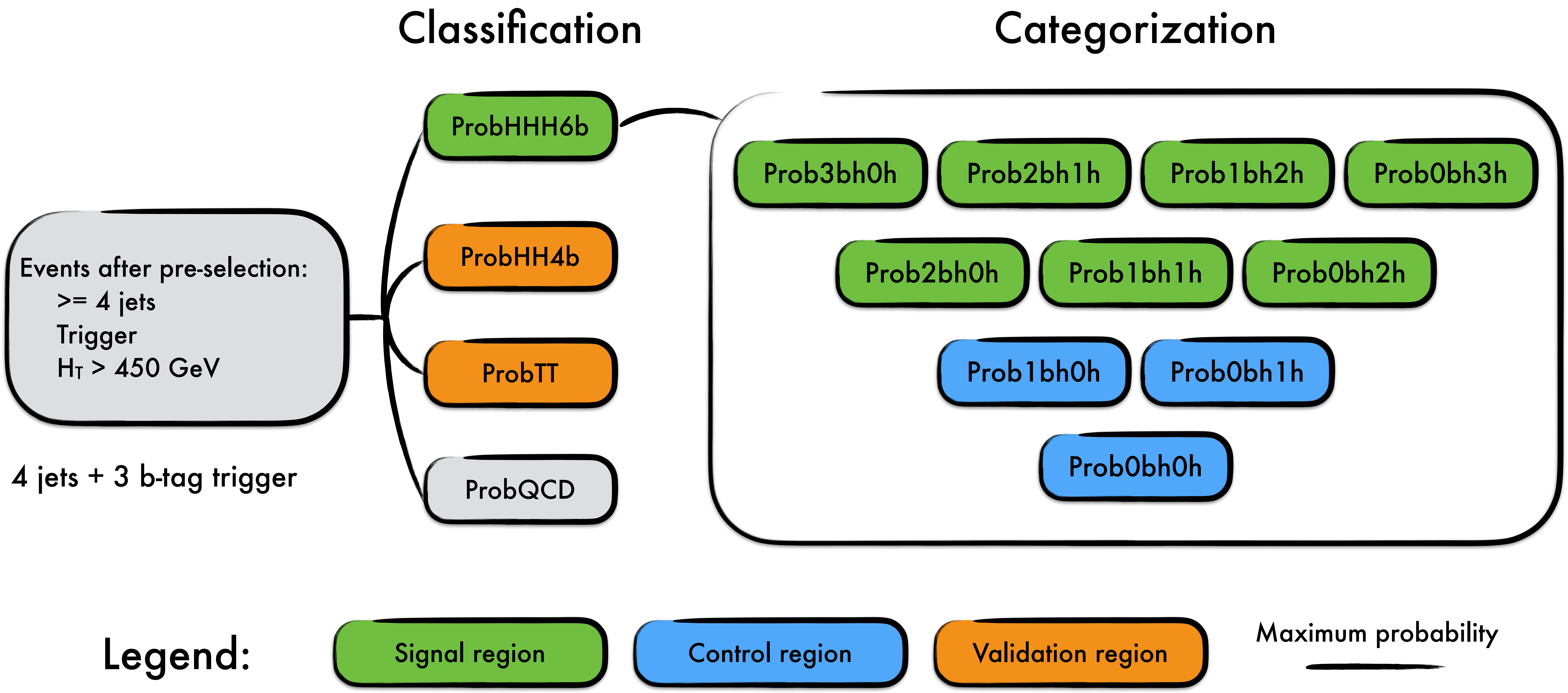
0Higgs	1Higgs	2Higgs	**3Higgs**
1.3%	19.7%	52%	**27%**

From MC study matching simulated b-quarks and Higgs bosons to small-and large-radius jets

- **Only 27% of signal events have 3 Higgs** that can be reconstructed in the detector acceptance!
  - Main issue: tracker acceptance needed for b-tagging
  - Most populated regions: resolved Higgs reconstruction

Non-resonant $HHH \rightarrow 6b$

CMS-PAS-HIG-24-012



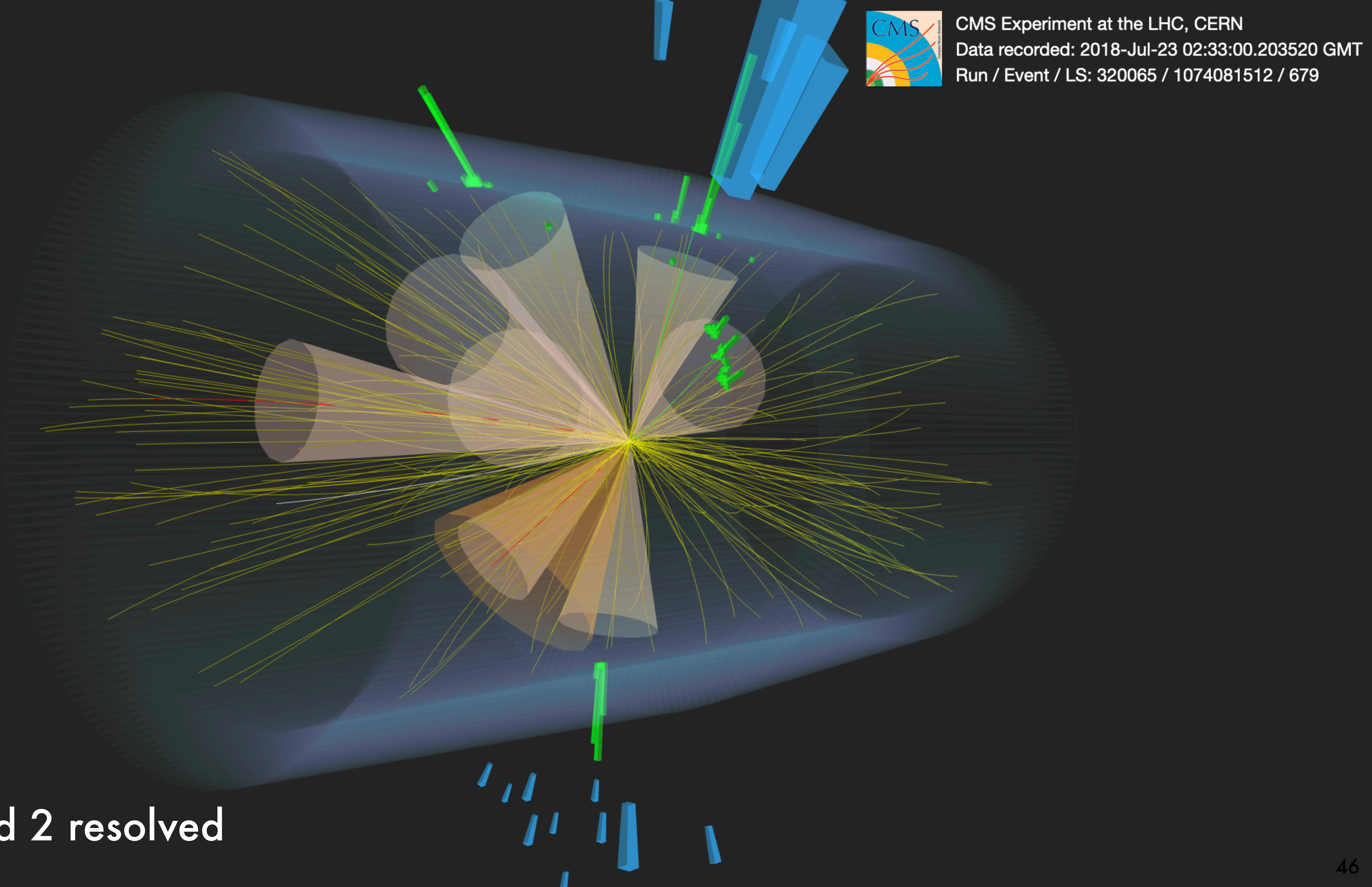
Dominant background: QCD (95%) and ttbar (5%)

Train two machine learning networks (attention network) used

- Multi-classifier: **HHH6b** vs **HH4b** vs **QCD** vs **ttbar** → Effectively vetoing HH4b events
  - Use HH4b-like events to validate background model, use ttbar node to validate Data / MC
- Multi-categorization: trained on HHH6b and HH4b **predict categories** based on truth matching

3 boosted 0 resolved

2 boosted 1 resolved



1 boosted 2 resolved

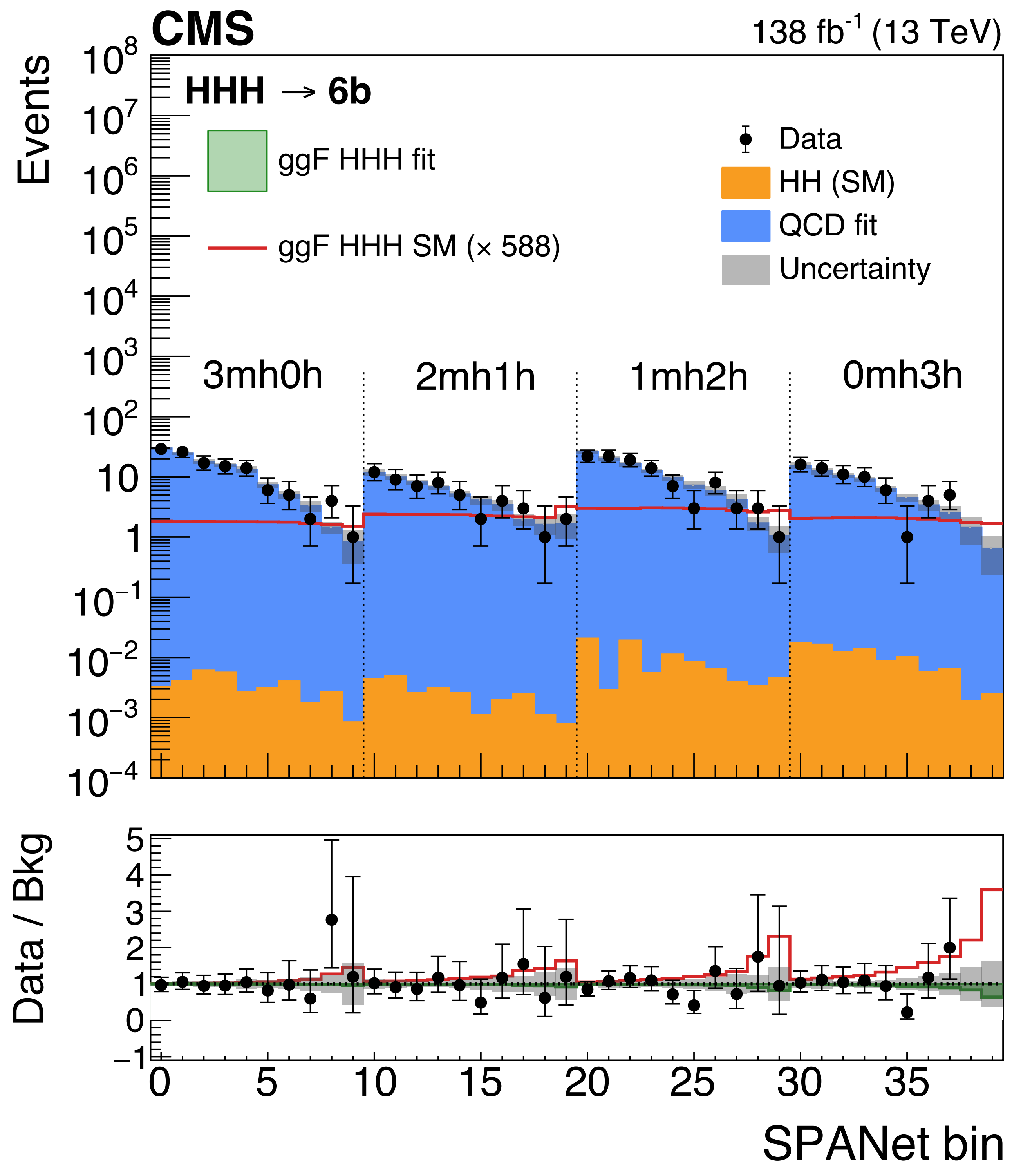
0 boosted 3 resolved

Non-resonant $HHH \to 6b$

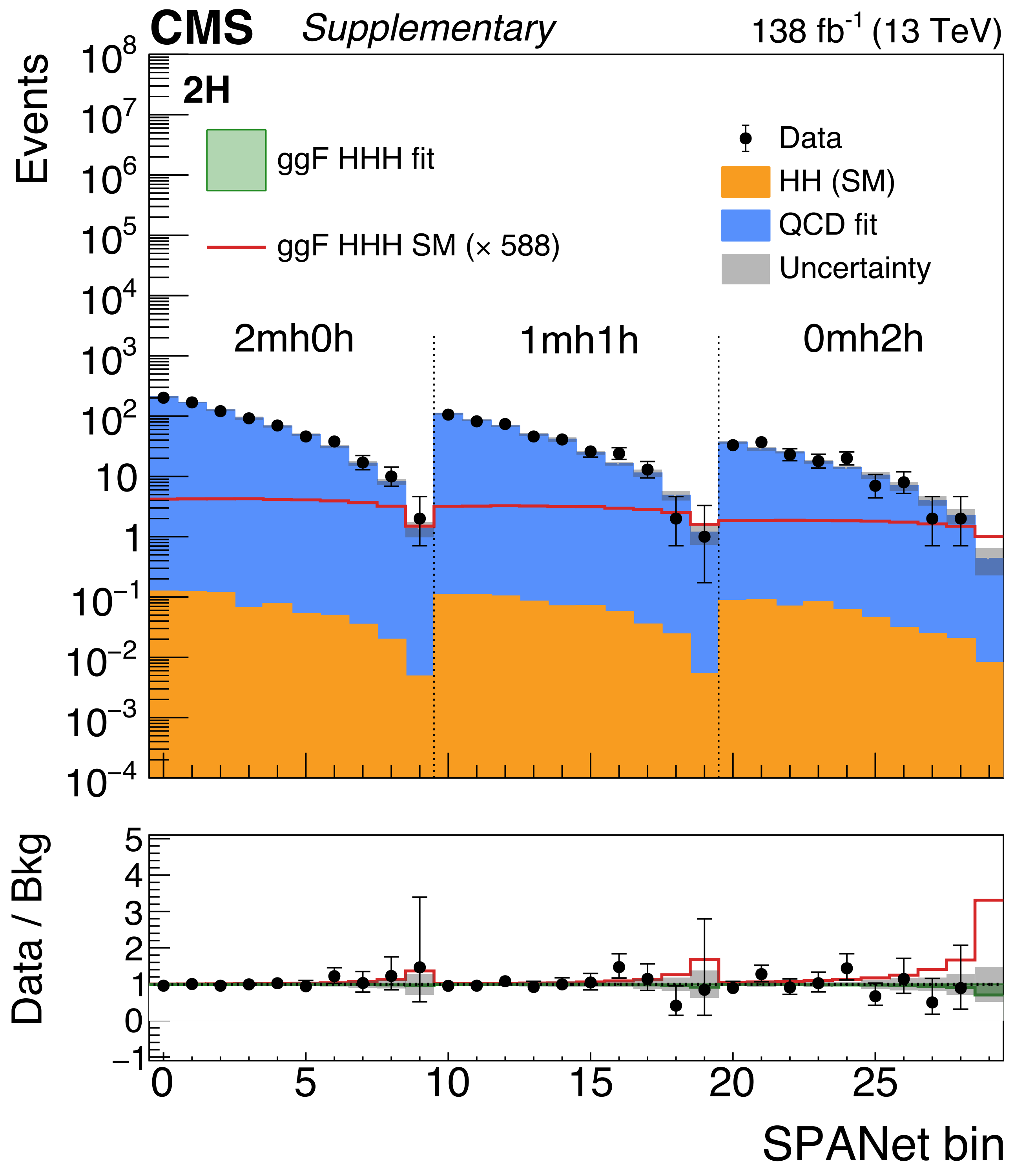
[CMS-PAS-HIG-24-012](CMS-PAS-HIG-24-012)

arXiv.2607.05145

3 reconstructed Higgs bosons



2 reconstructed Higgs bosons



Background modeling: data driven approach due to overwhelming QCD

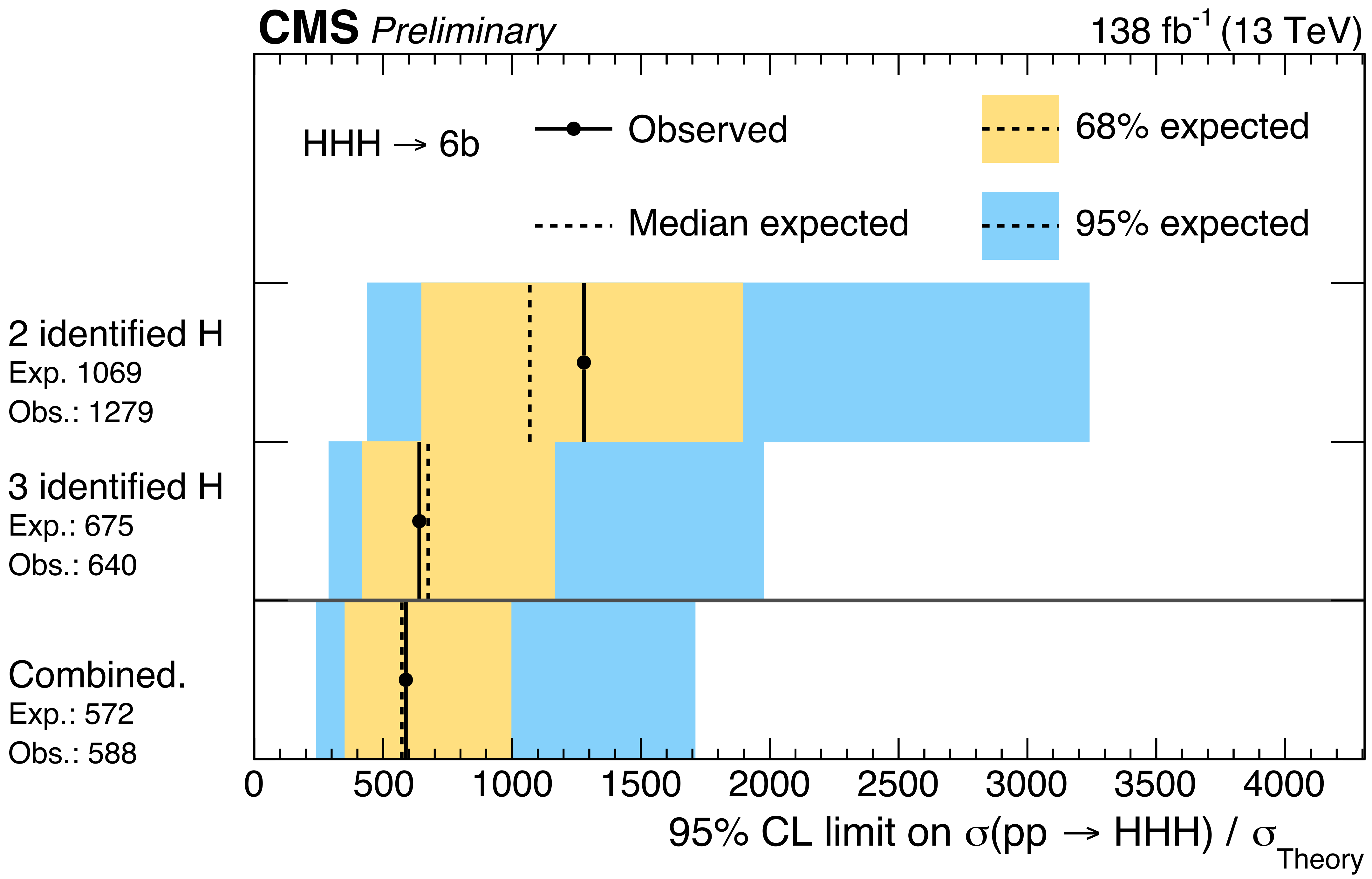
- Jet-flavor embedding: event failing HHH and HH selections are used
- Sampling flavor tagging information from data SR and replace it in failed region
- Perform prediction of machine learning algorithm on artificial data set to get background model
  - Extensively validated on HH4b-like events, QCD MC… Additional shape uncertainty derived from CR assigned

Non-resonant $HHH \to 6b$

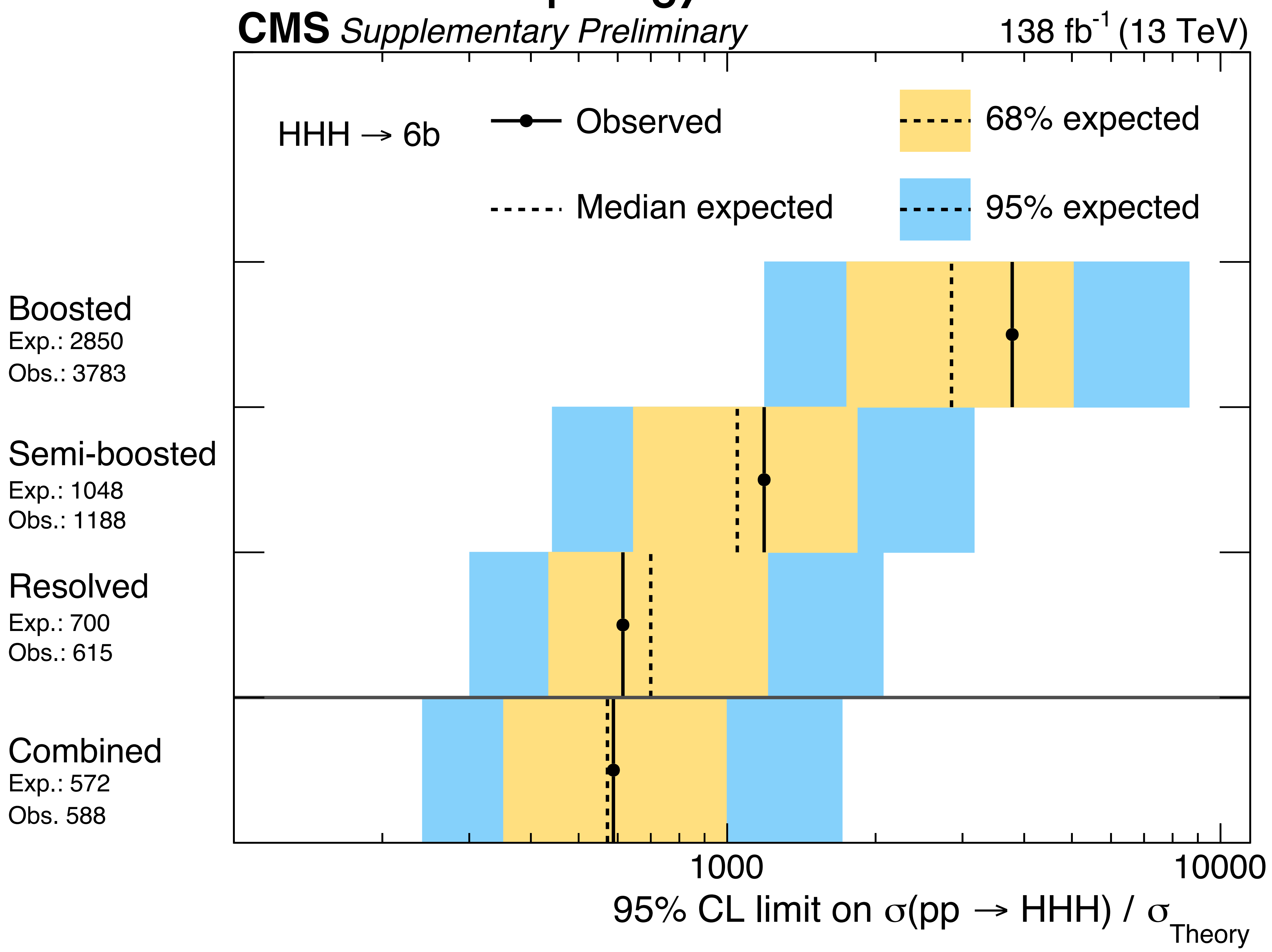
CMS-PAS-HIG-24-012

arXiv.2607.05145

Categories breakdown



Topology breakdown



Result: observed (expected) limit of $\mu < 588\ (572)$ x the SM at 95% CL

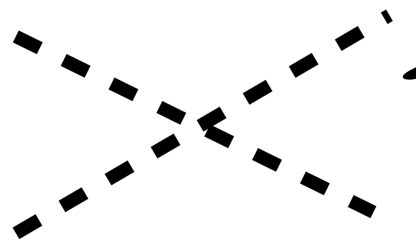
- 3 reconstructed Higgs category drives the sensitivity
  - **+18% sensitivity** achieved thanks to **2Higgs categories**!
- Resolved categories drive the sensitivity
  - **+20% sensitivity** achieved thanks to **semi-boosted and boosted categories**!
- About 25-30% better than ATLAS, benefitting from semi-boosted and boosted categories!

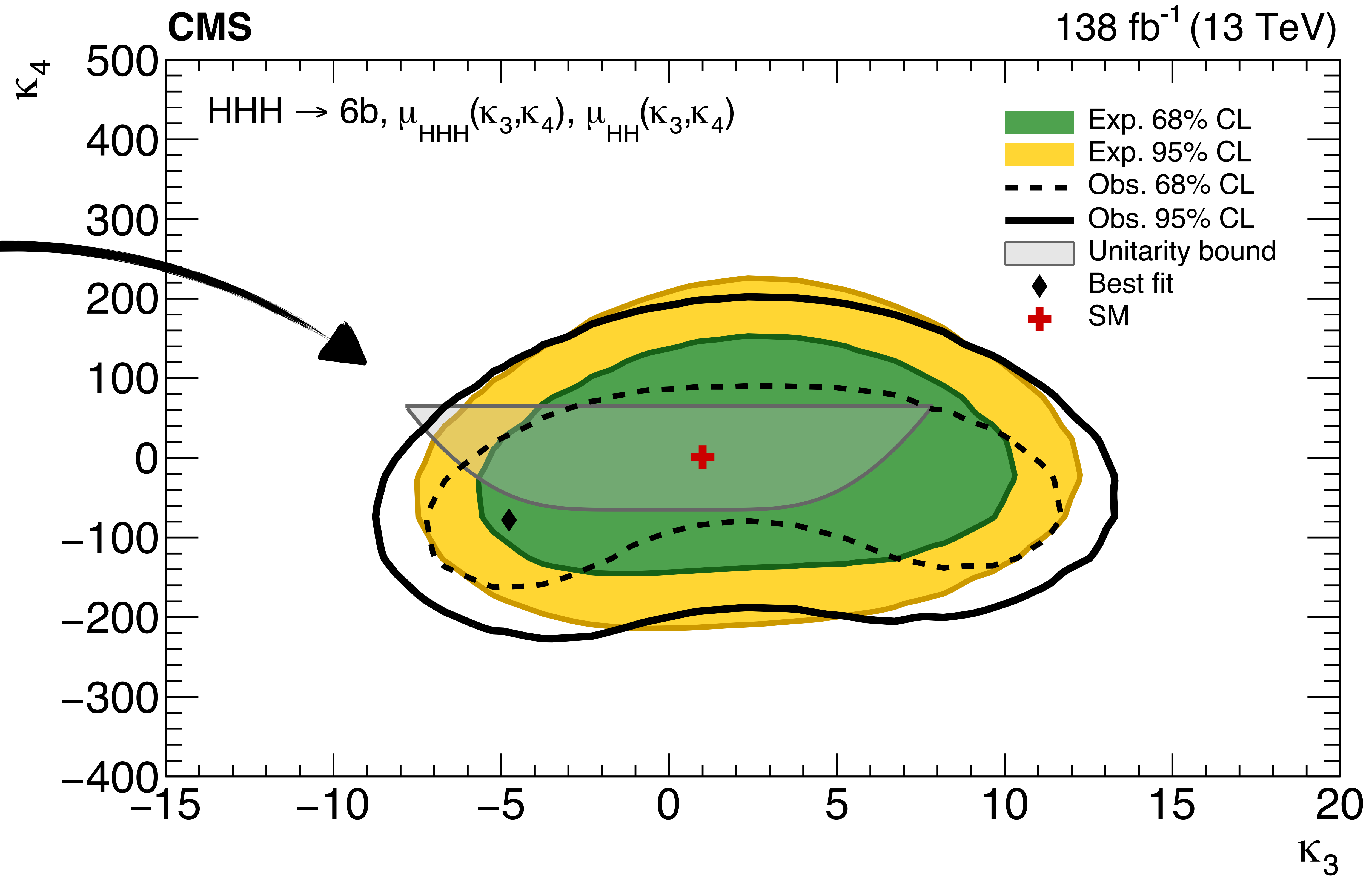
Non-resonant $HHH \to 6b$

CMS-PAS-HIG-24-012

arXiv.2607.05145

Theory: $HH \to HH$





Interpretation: normalization effects of κ_3 and κ_4 on HHH and HH

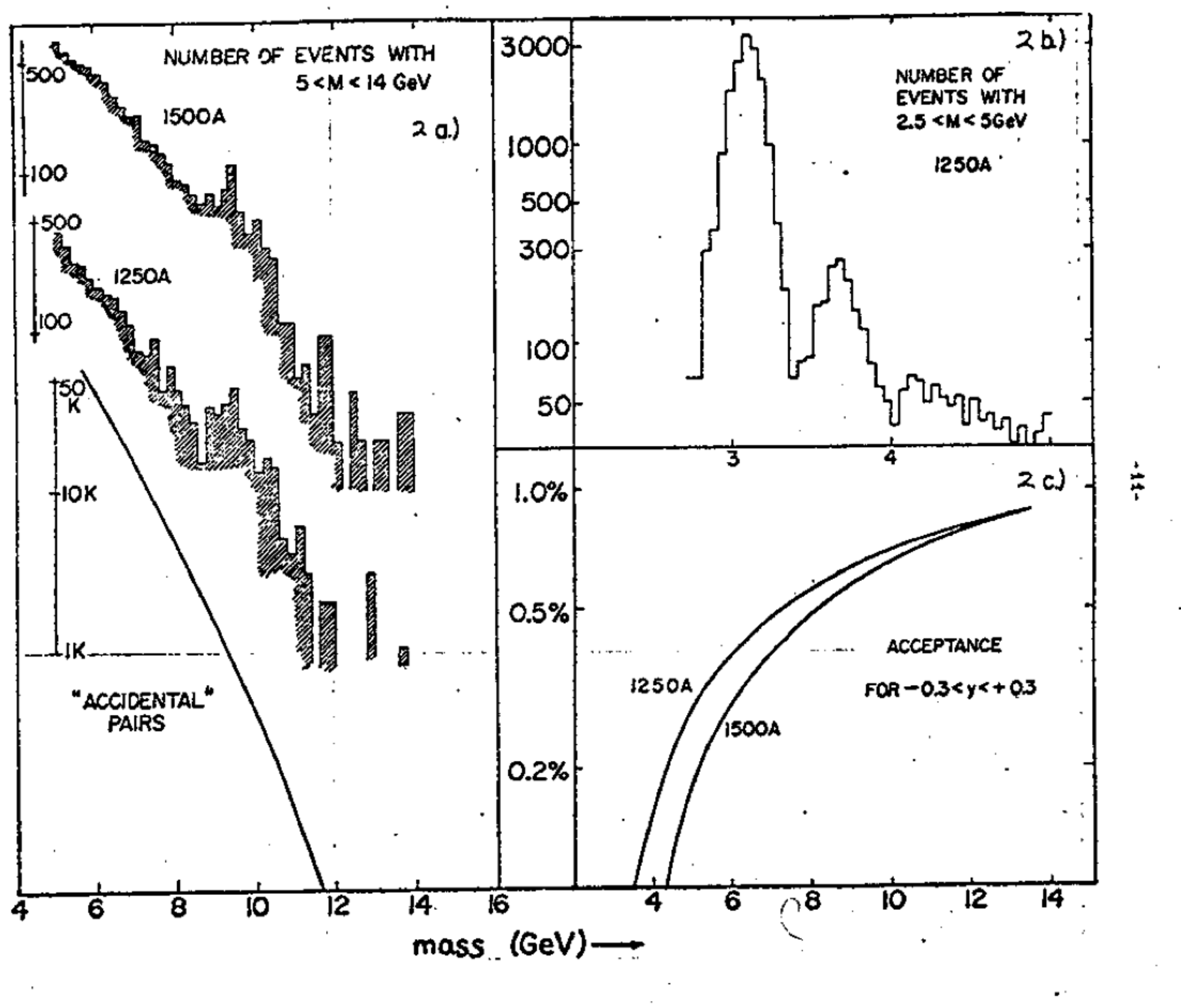
- Deviations constrained to $-7 < \kappa_3 < 12$ and $-190 < \kappa_4 < 190$

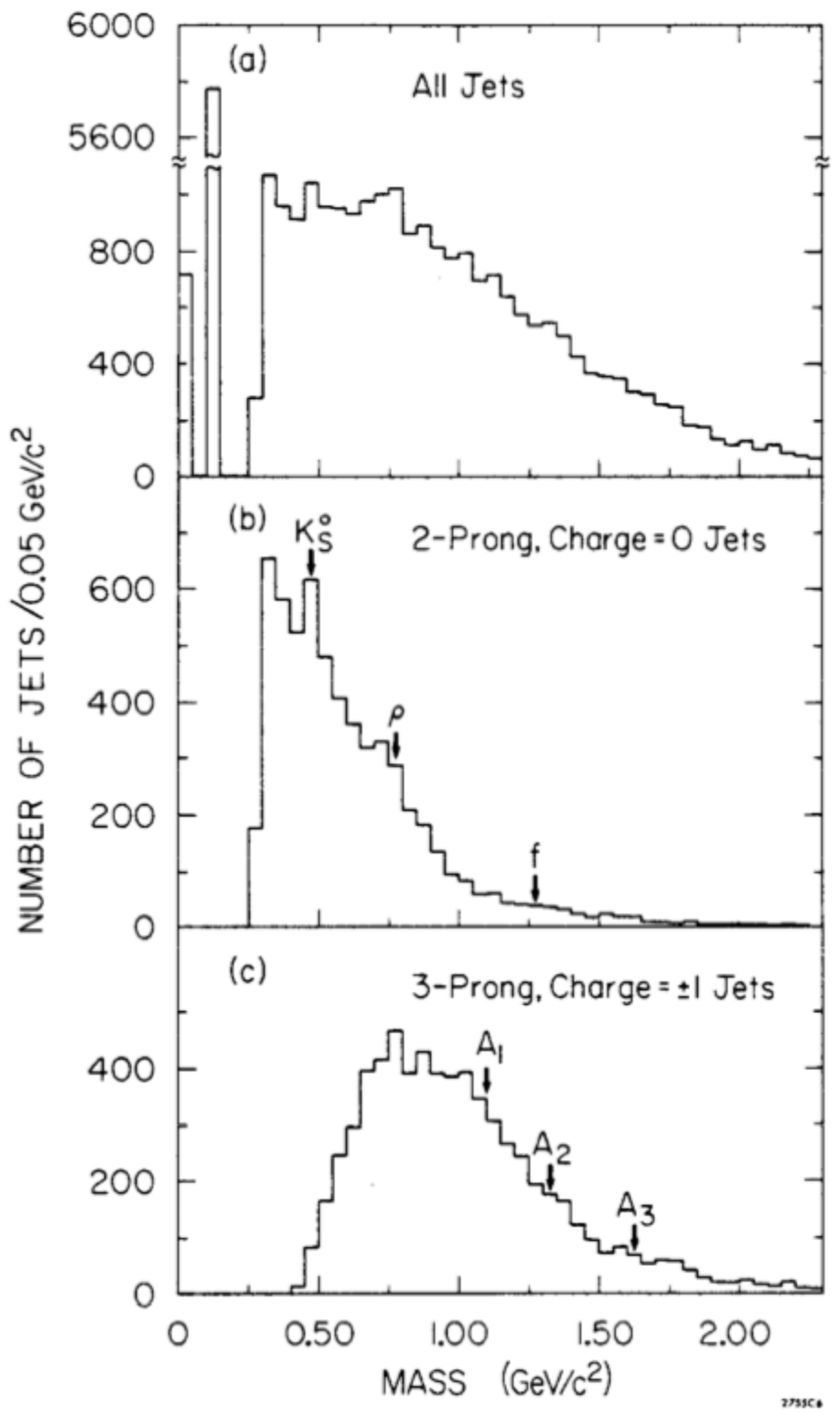
First exclusion of (κ_3, κ_4) at 95% CL in region **probing perturbative unitarity bounds**!

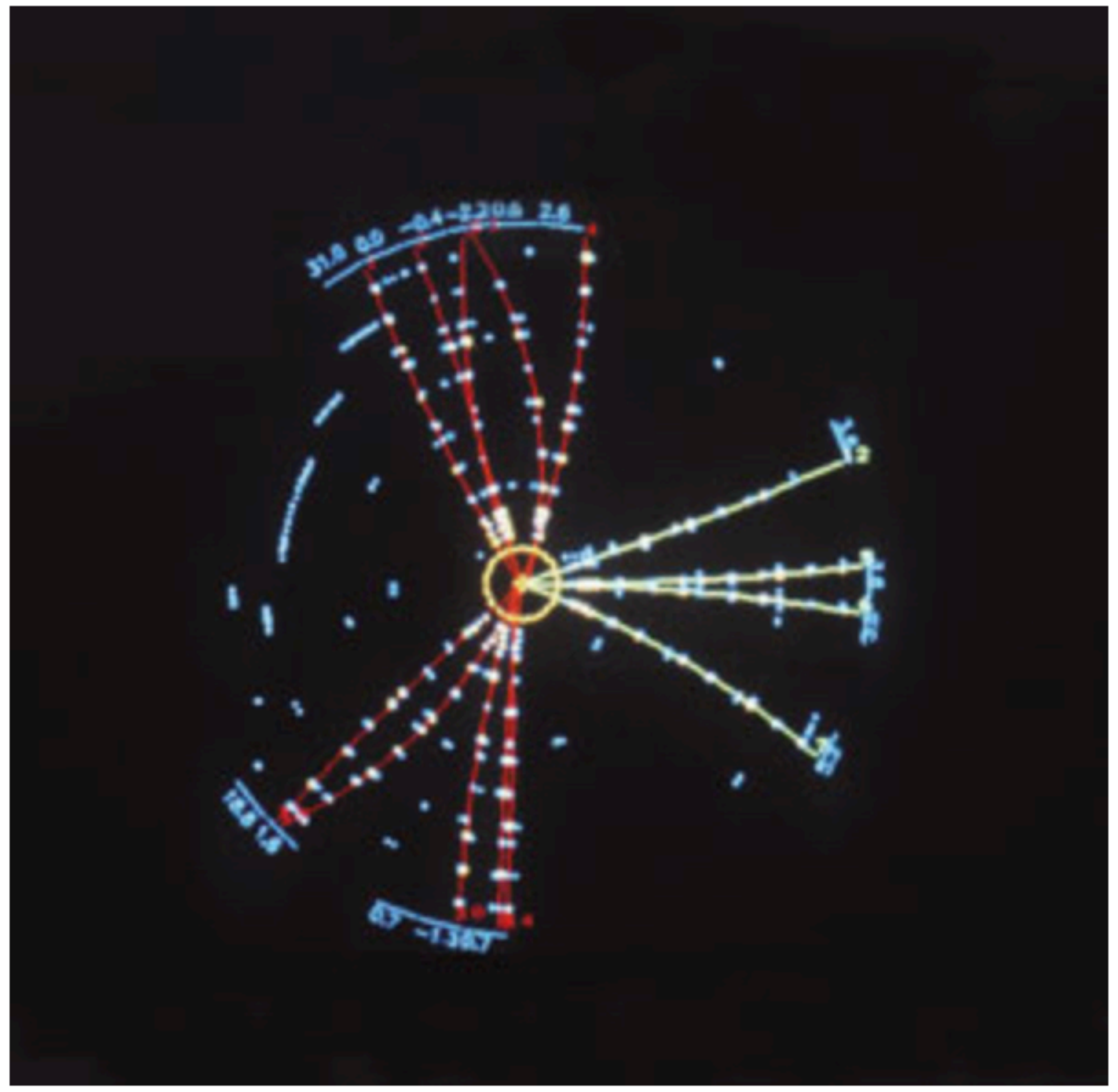
Where do we go from here: jet-charge tagger

Jet charge tagging

[1977 b-quark discovery at Fermilab](#) [1975 jet discovery at SLAC](#) [1979 gluon discovery at DESY](#)



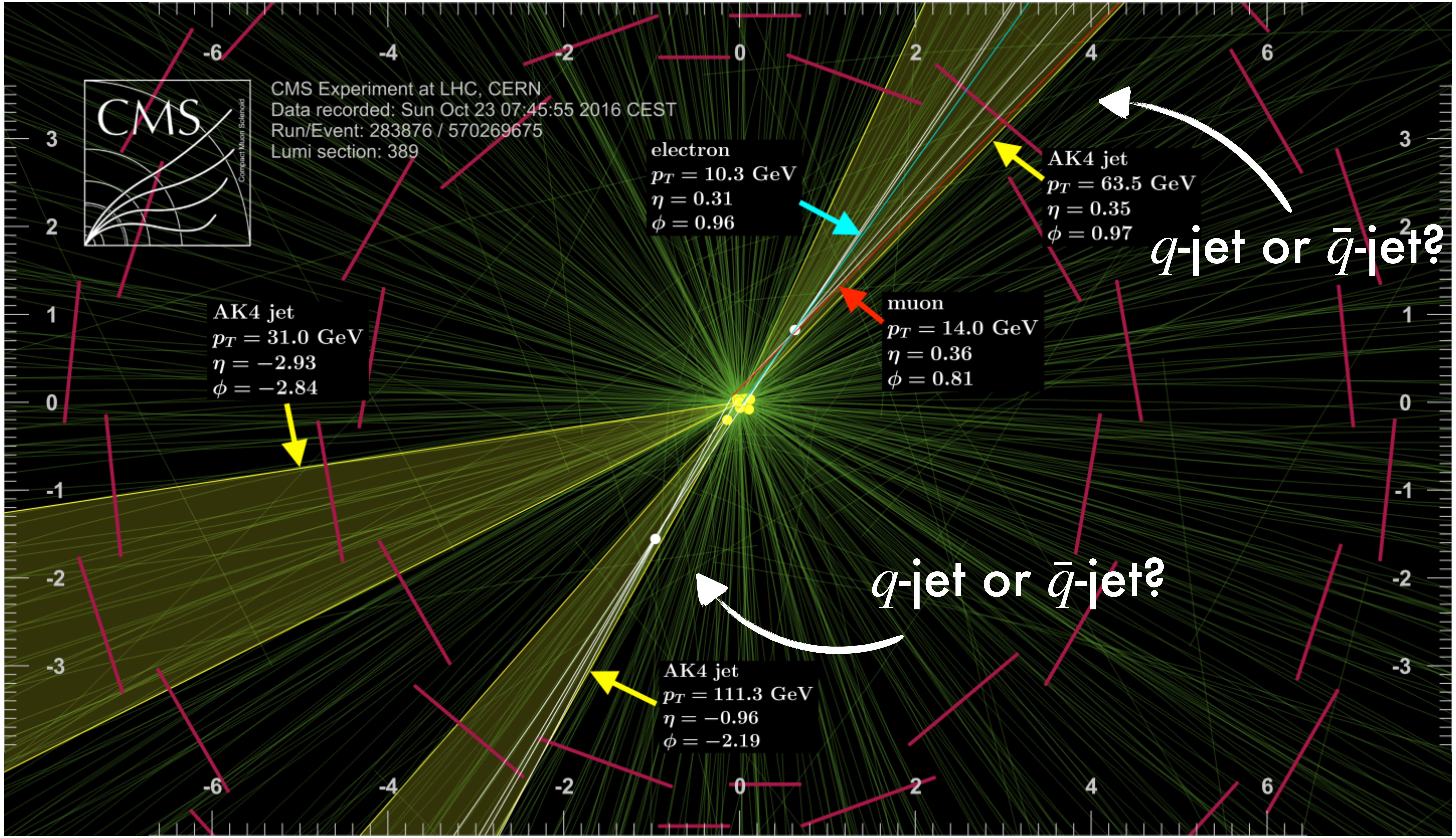




About 50 years after the **b-quark** and **jet discoveries**:

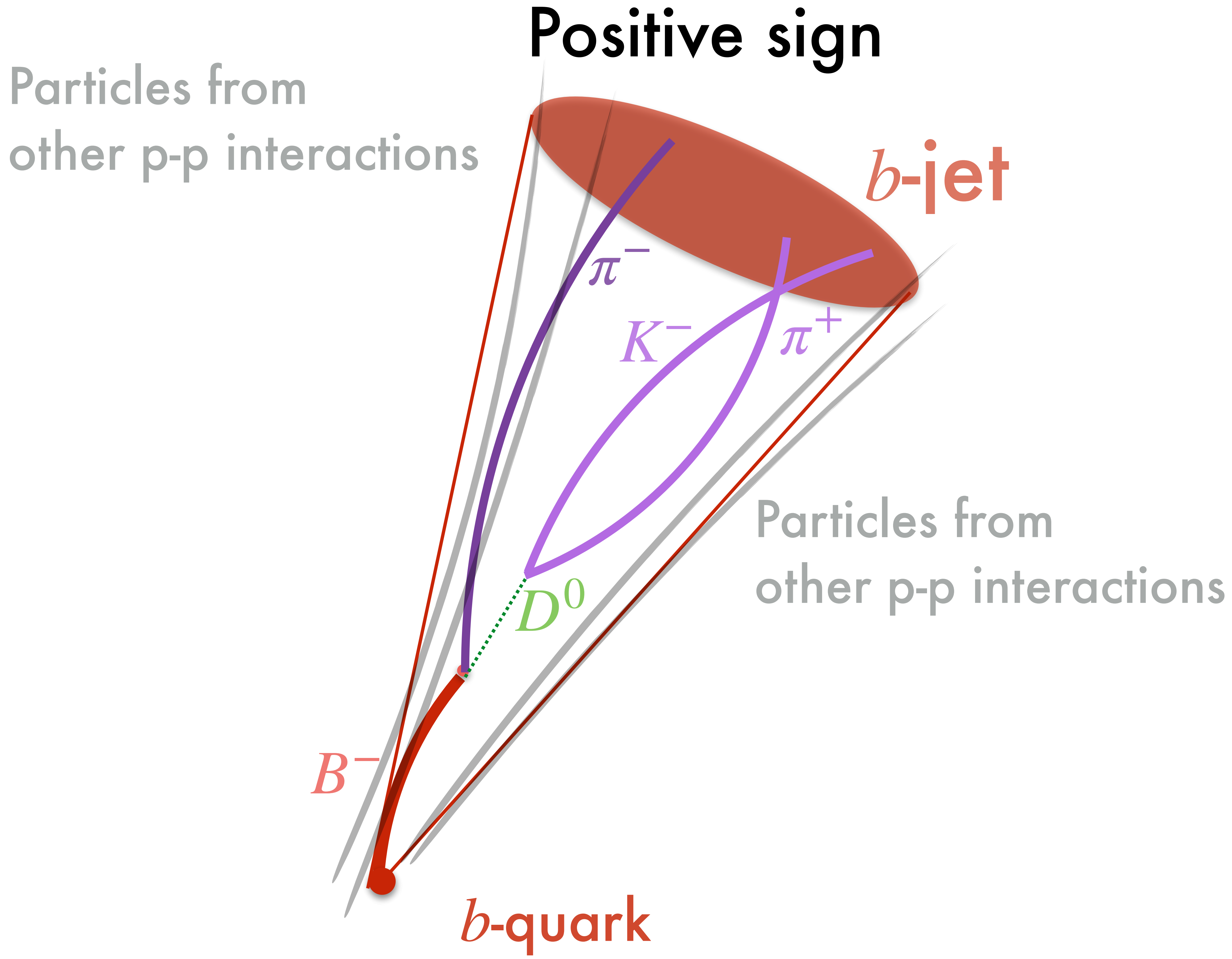
- Still no calibrated access to **sign of electric charge** of quark within jets in ATLAS and CMS!
  - We don't know how to **separate** jets originating from **quarks** and **anti-quarks**
  - Intrinsic signal property currently not used, decays conserve the electric charge!

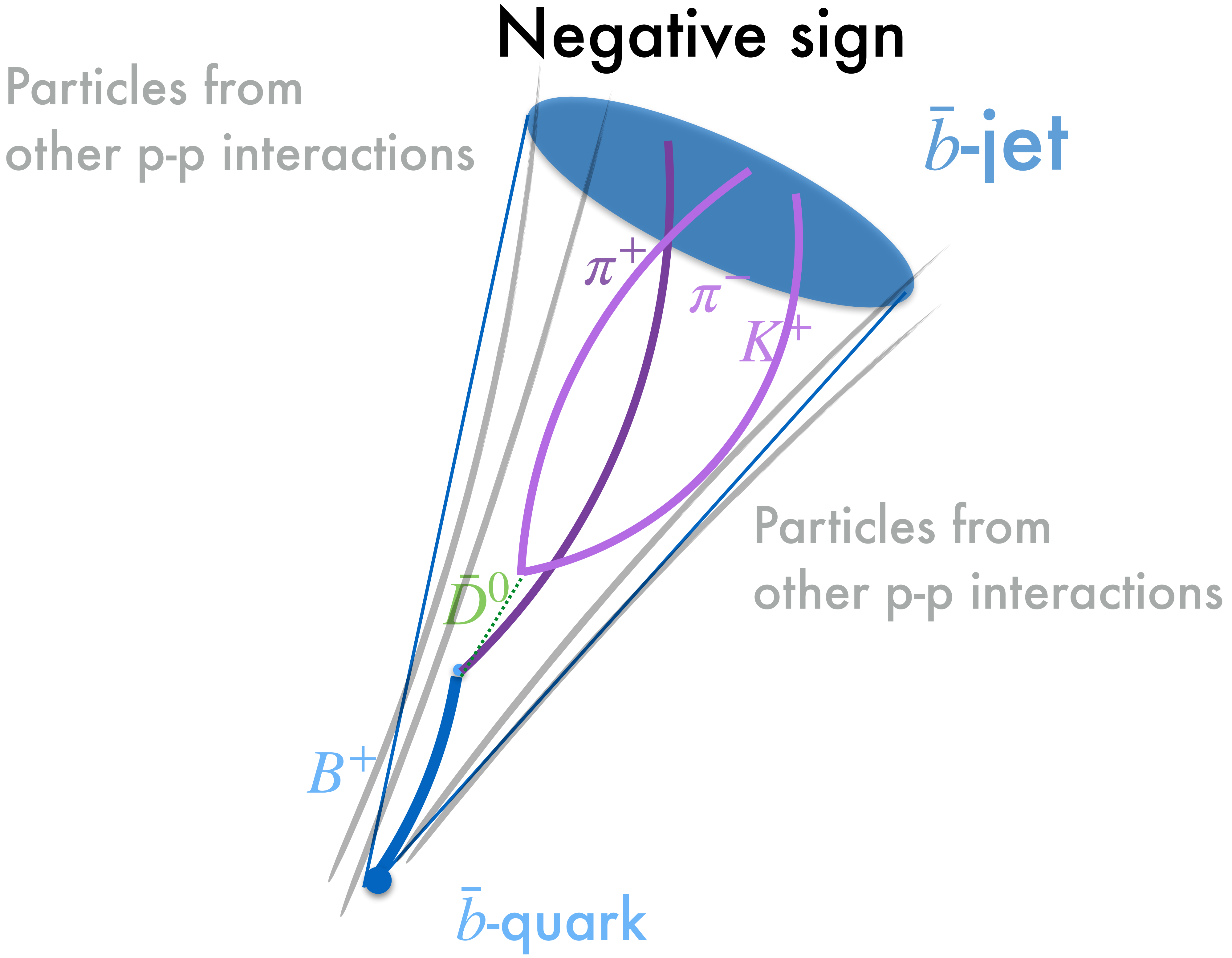
Why is this fundamental property not used?



Distinguishing quarks from anti-quarks in jets: extremely challenging task in data

Why is this not used in ATLAS and CMS?





Believed **impossible** to do efficiently at high luminosity proton-proton colliders:

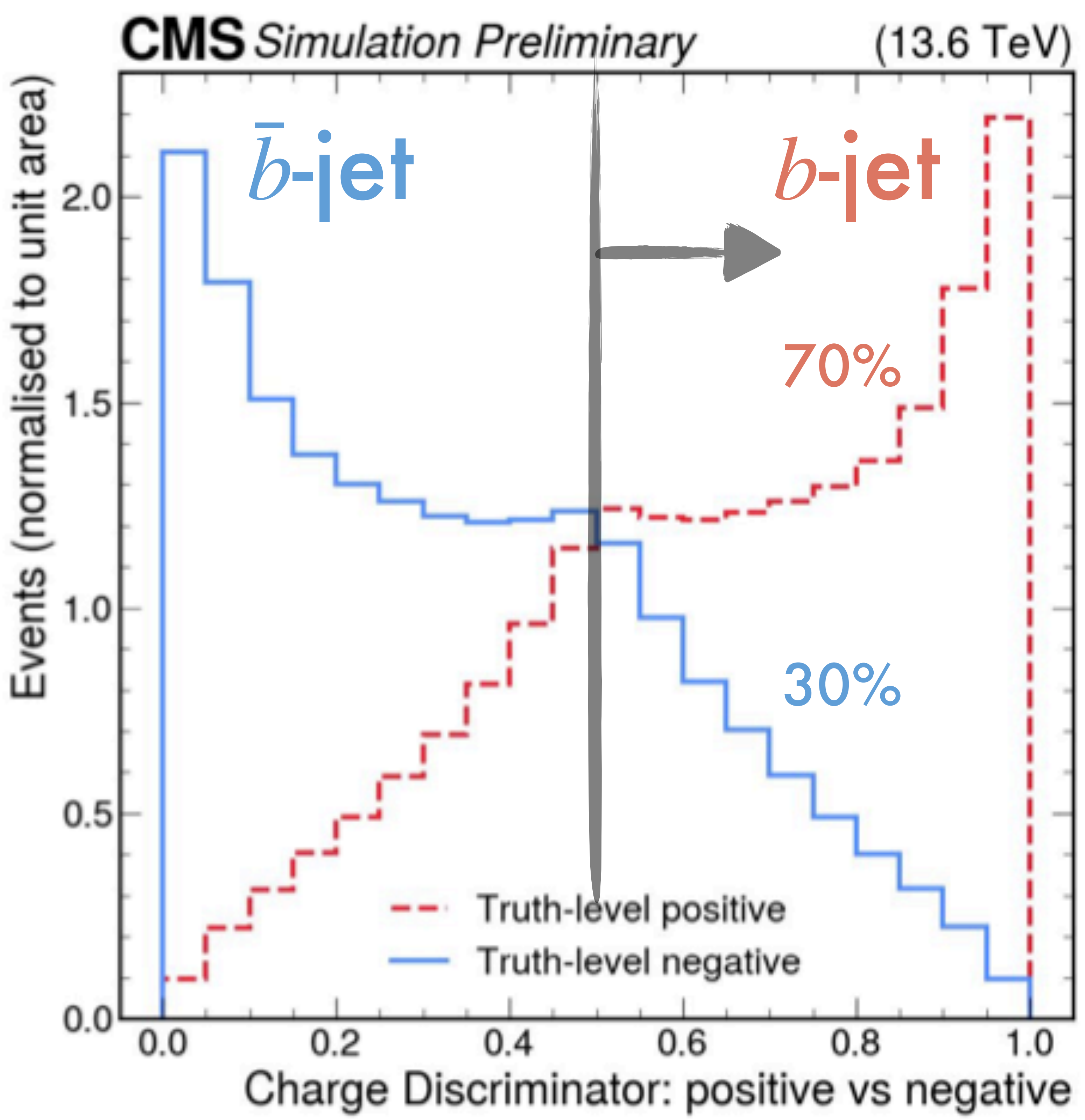
- Large variety of hadron decays: $B^- \to D^0\pi^-$ is one of the largest decay mode and only 0.5% of all B^-
- Contamination from additional particles produced in secondary proton-proton interactions
- Algorithmic limitations resulting in performance of 50-60% on CMS data, restricted to high rate process!

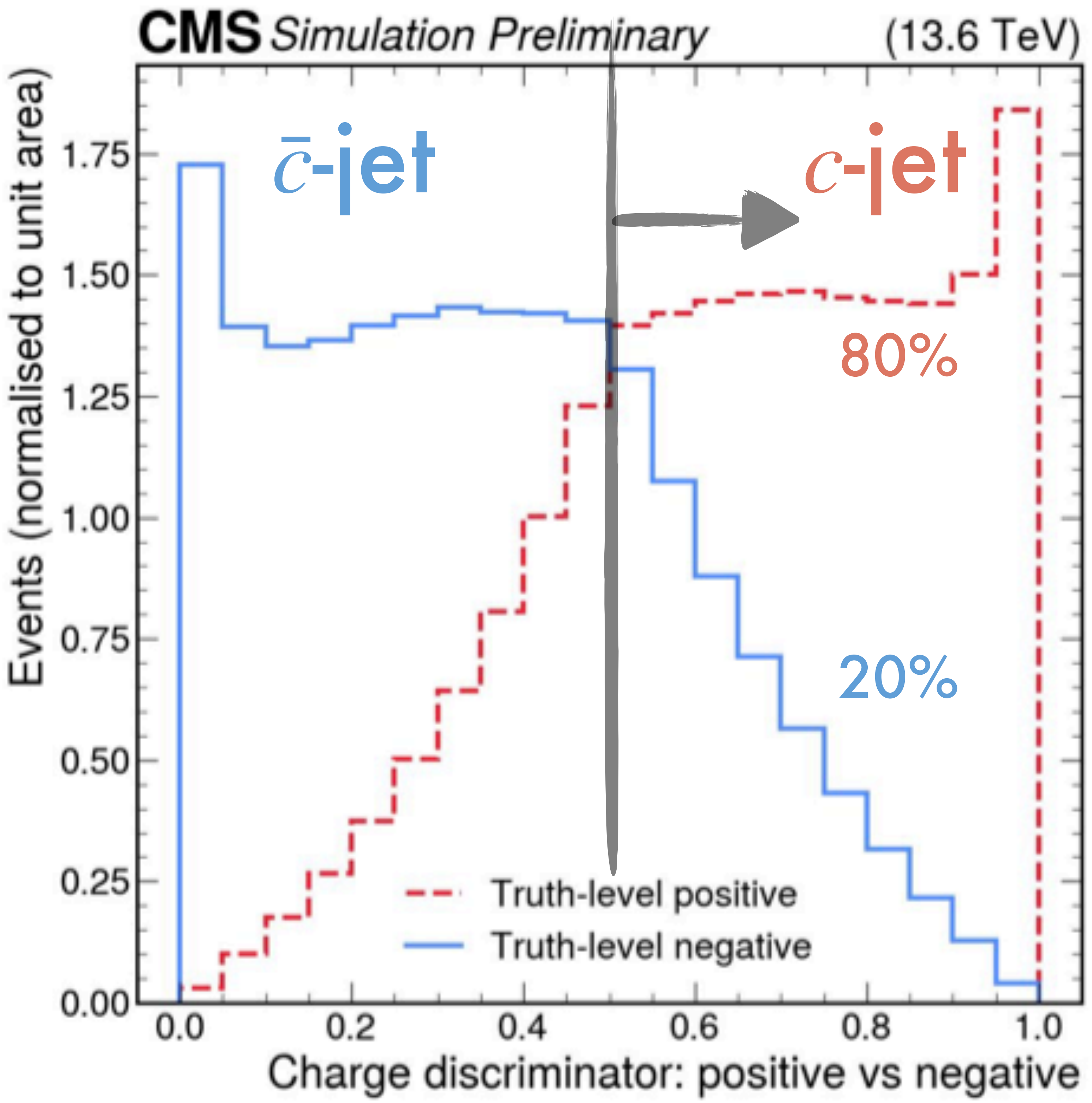
Timely: algorithms applied to b- and c-jet tagging improved performance by x10 to 100!

- Same tools can be extended to jet-charge identification!

Prototype jet-charge tagger

DP-2025-071





Extending flavor tagging to identify the charge $(+, -, 0)$

- Performance: **70%** accuracy on b-jets and **80%** on c-jets
  - Already achieved similar performance to electron-positron state-of-the-art jet-charge tagger

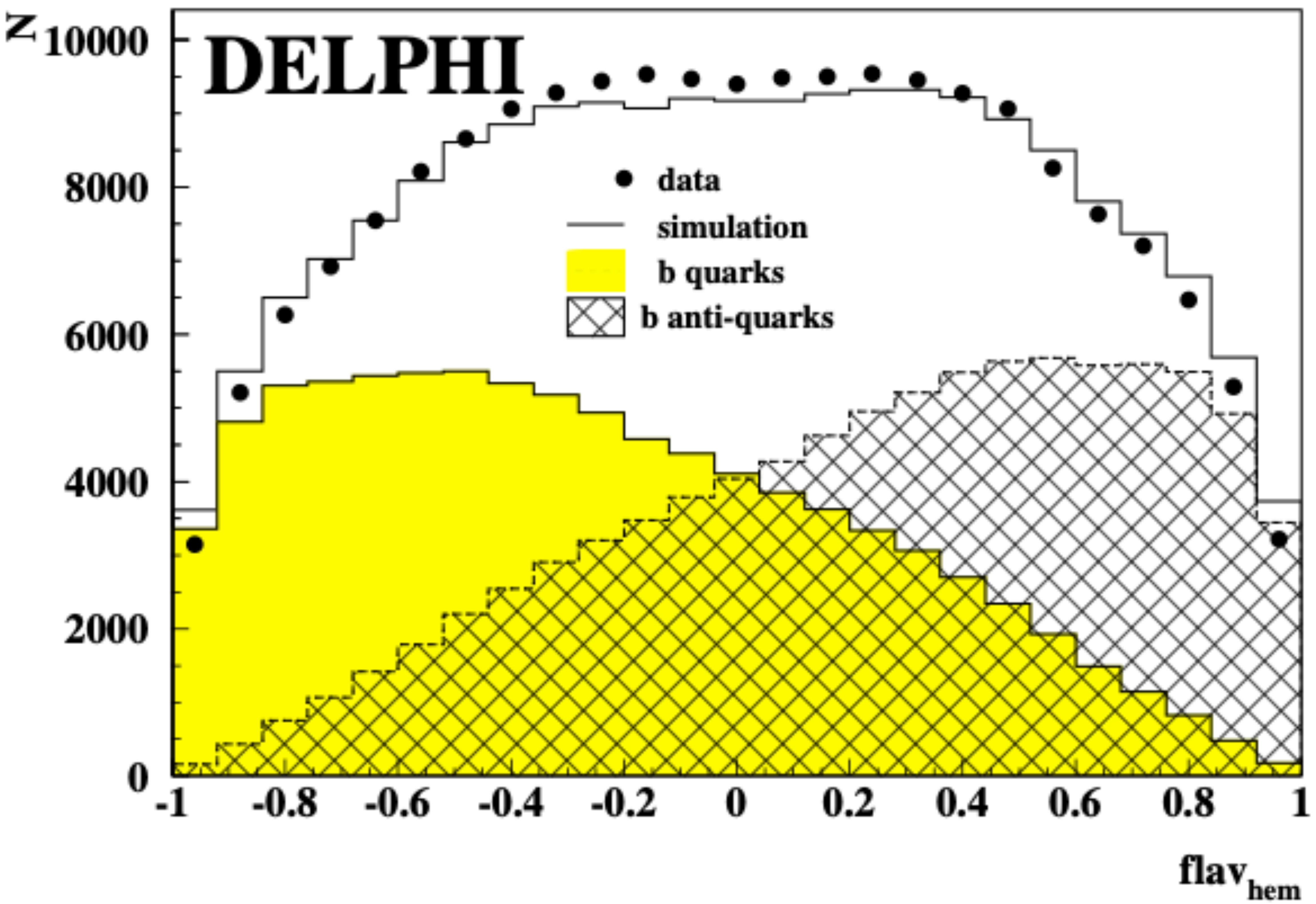
Demonstrates feasibility:

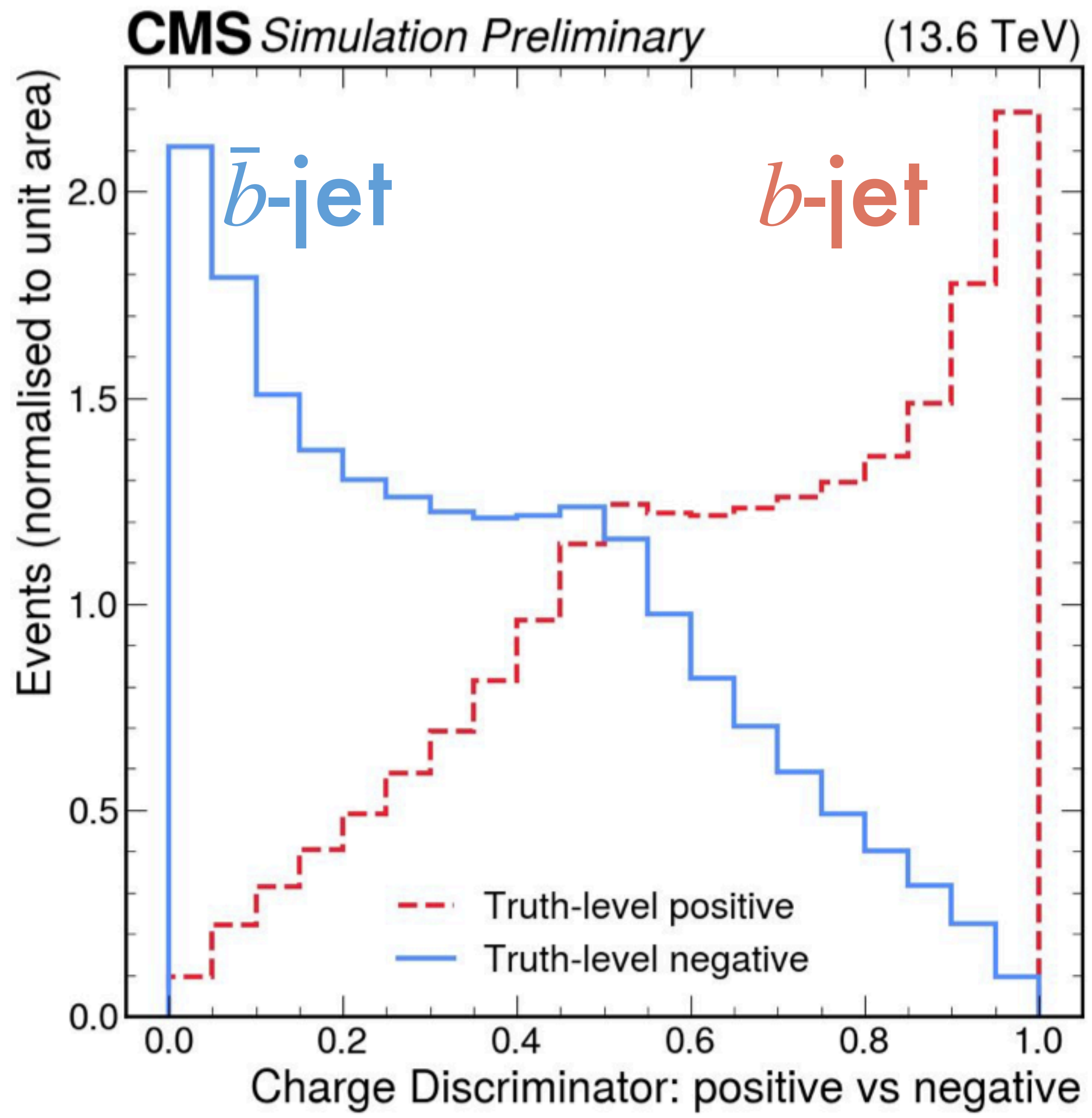
- Improvements in machine learning and physics driven inputs will maximize performance of algorithms!
- If flavor tagging can predict history, this is the **first** and **worst** jet-charge tagger performance in CMS!

DELPHI charge tagger

DP-2025-071

DELPHI

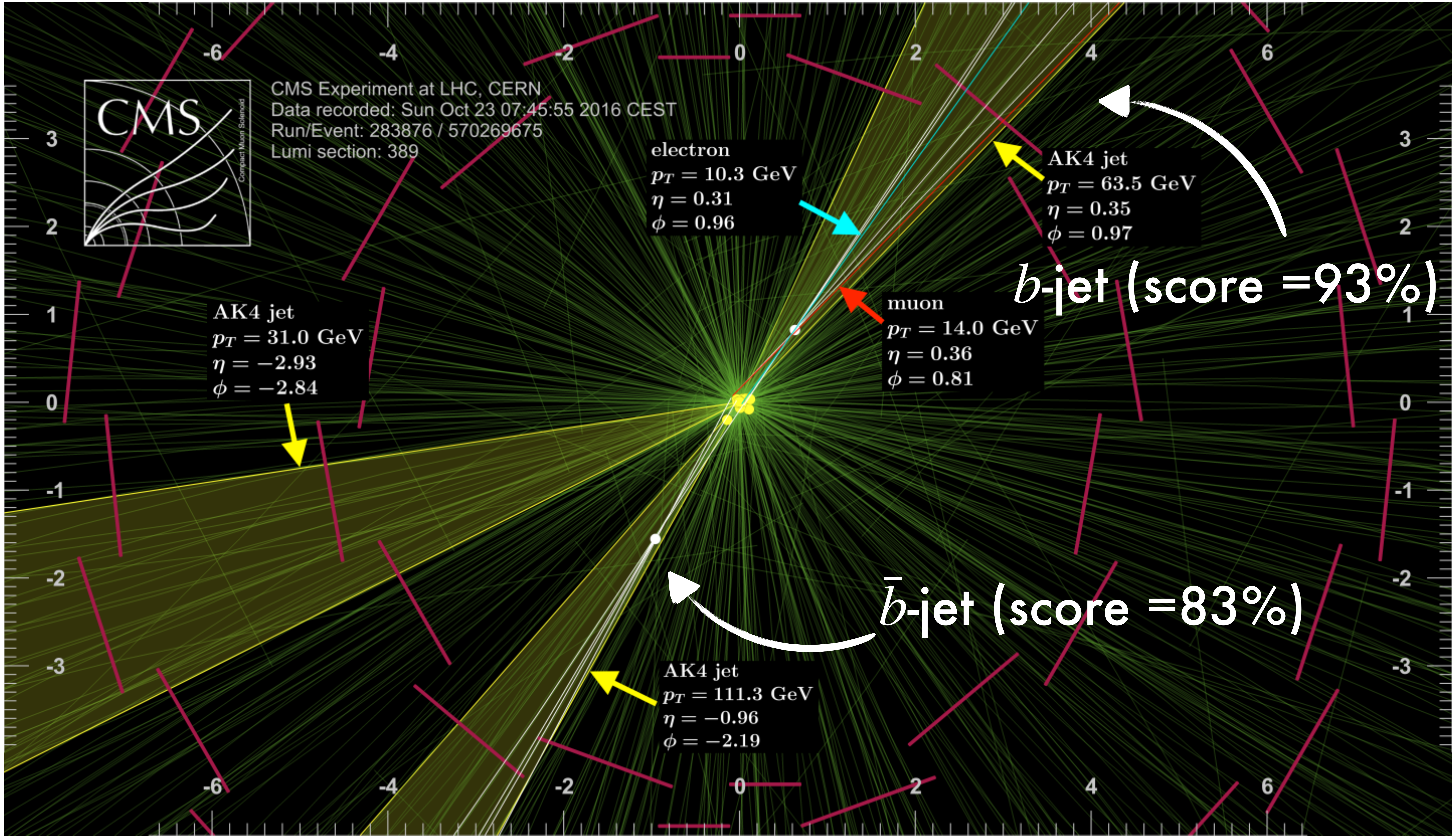




DELPHI: best jet-charge tagger of LEP using DNN on 1994 data

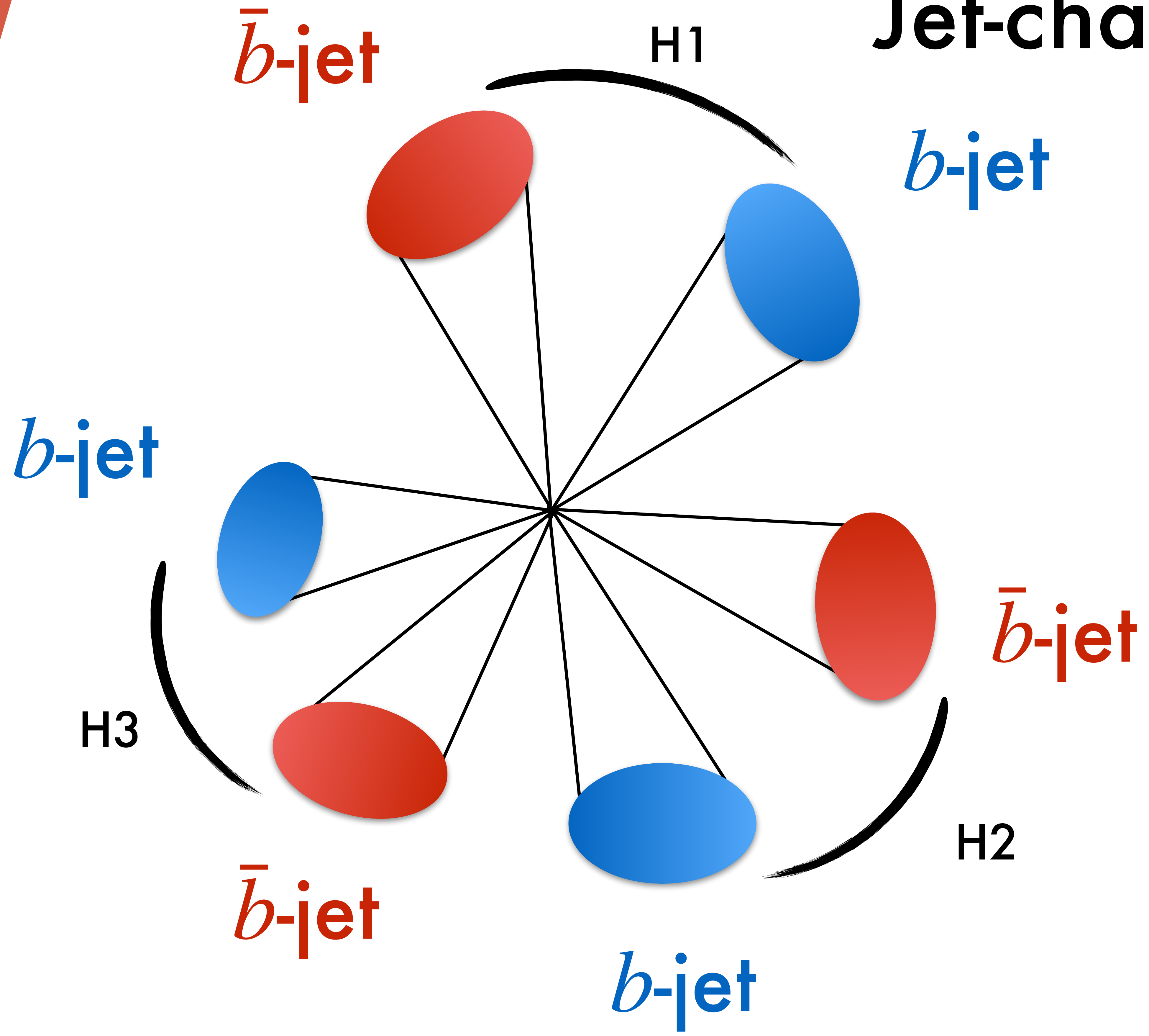
- AUC: 0.75 approximated
- **Similar performance achieved in CMS!**
- Already 25% better than LEP on c-jets vs $\bar{c}$-jets
  - Despite the Cherenkov detector, higher center of mass and better tracker results in better reconstruction

Feasibility: prototype jet-charge tagger

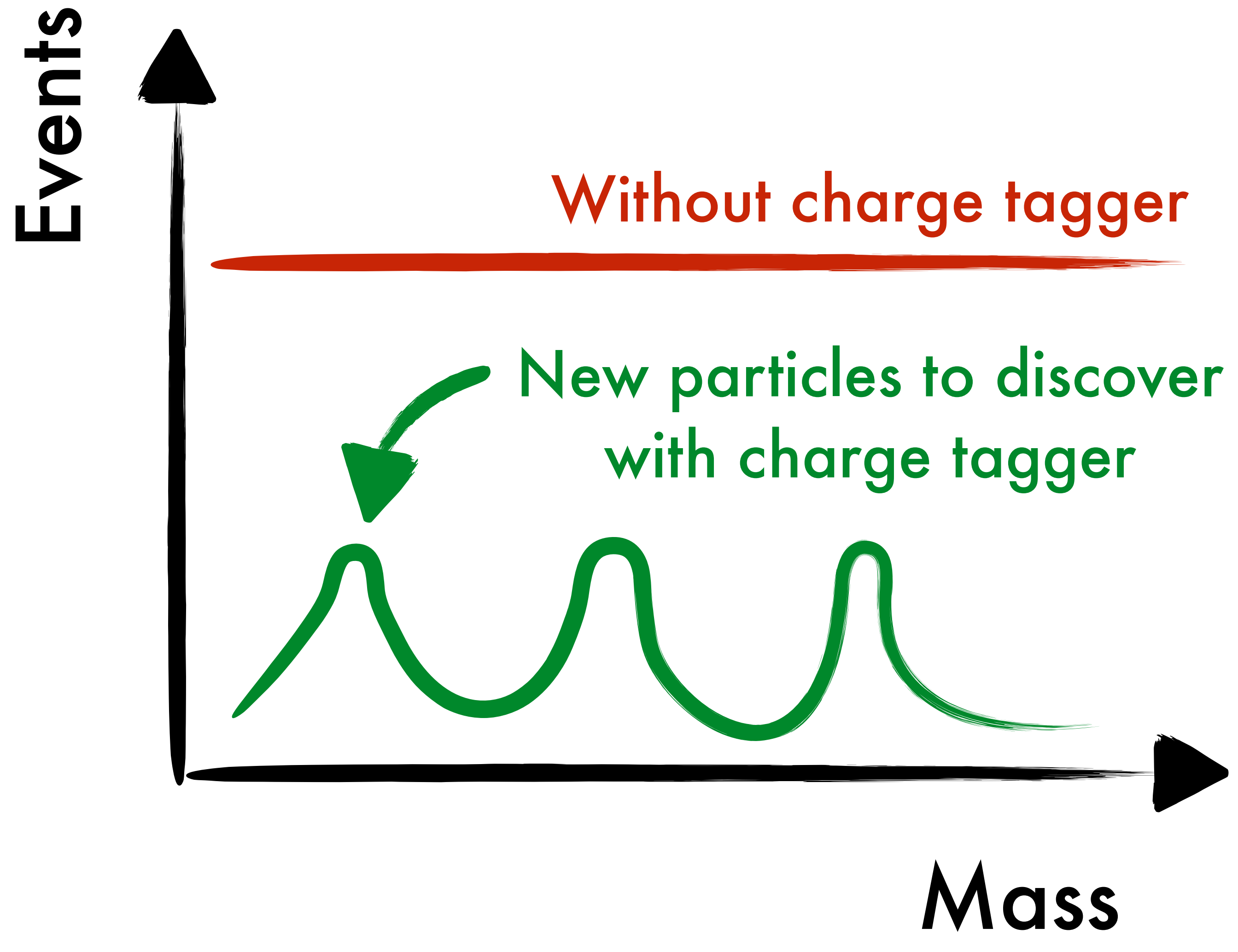


Now possible: distinguish quark and anti-quarks in the data

Jet-charge tagging



New physics?



Higgs decays to **b**-quark and **anti-b** quark: currently unused in CMS

- HHH is extremely challenging, need extraordinary tools to measure it at the LHC

Potential **to very significantly improve HH and HHH!**

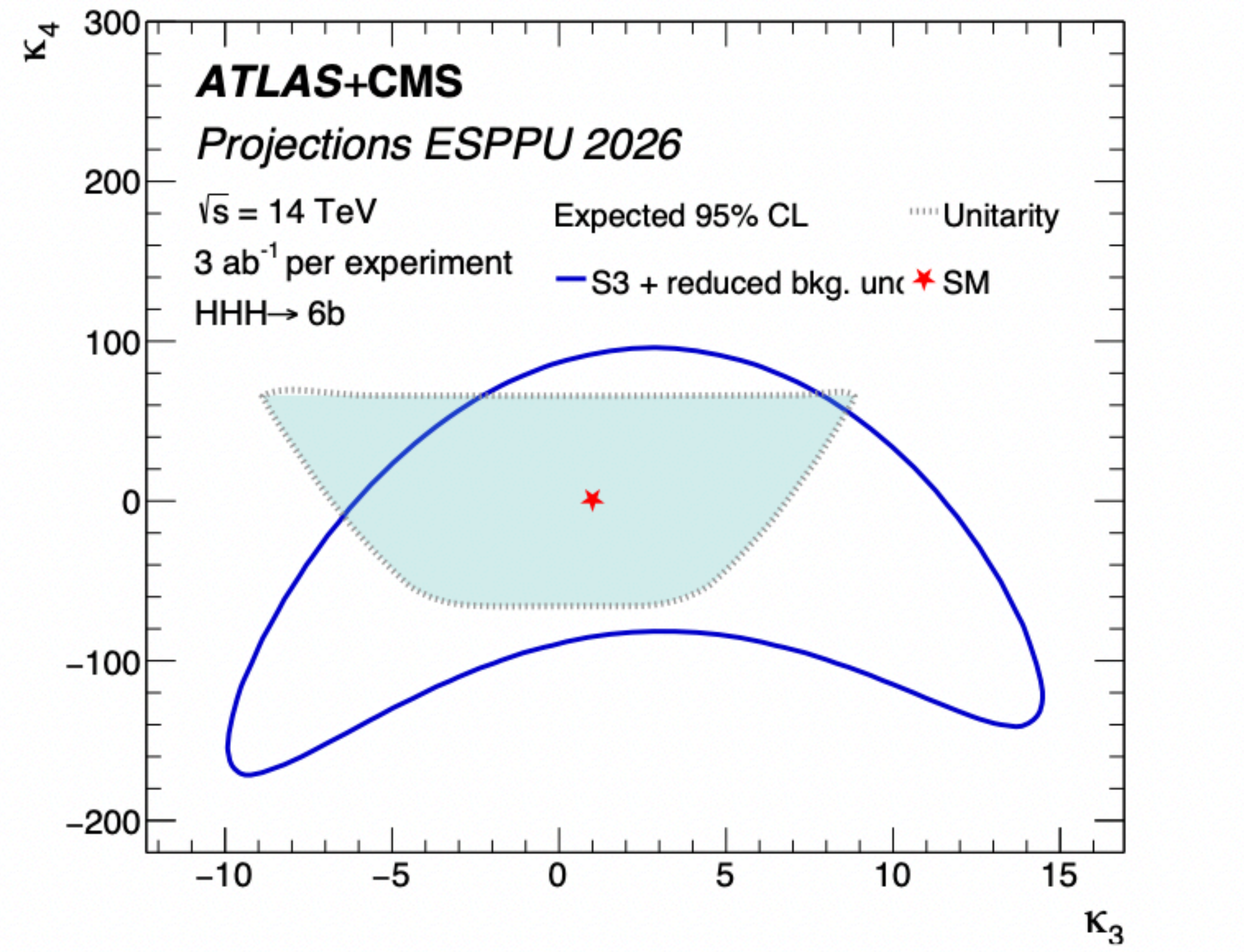
Accelerate the physics program of CMS and **enable potential discoveries**

Summary

HL-LHC projections: HH

	2 ab^{-1} ($S2$) ATLAS	2 ab^{-1} ($S2$) CMS	3 ab^{-1} ($S2$) ATLAS	3 ab^{-1} ($S2$) CMS	3 ab^{-1} ($S3$) ATLAS	3 ab^{-1} ($S3$) CMS
			HH statistical significance			
$b\bar{b}\tau^+\tau^-$	3.0†	1.9	3.5†	2.4	**3.8†**	**2.7**
$b\bar{b}\gamma\gamma$	2.1†	2.0†	2.4†	2.4†	**2.6†**	**2.6†**
$b\bar{b}b\bar{b}$ resolved	0.9	1.0†	1.0	1.2†	**1.0**	**1.3†**
$b\bar{b}b\bar{b}$ boosted	–	1.8†	–	2.2†	–	**2.2†**
Multilepton	0.8†	–	1.0†	–	**1.0†**	–
$b\bar{b}\ell^+\ell^-$	0.4†	–	0.5†	–	**0.5†**	–
Combination	3.7	3.5	4.3	4.2	**4.5**	**4.5**
ATLAS+CMS	6.0		7.2		**7.6**	

HL-LHC projections: HHH



Exciting new developments in flavor tagging / trigger / charge tagging:

- **HH** and **HHH**: **high priorities** for the **2026 European Strategy Updates**
  - Expected first 3σ **evidence of HH** and about **100x SM HHH by 2040**
  - **New tools allow to reach these milestones earlier, potentially with Run 3**

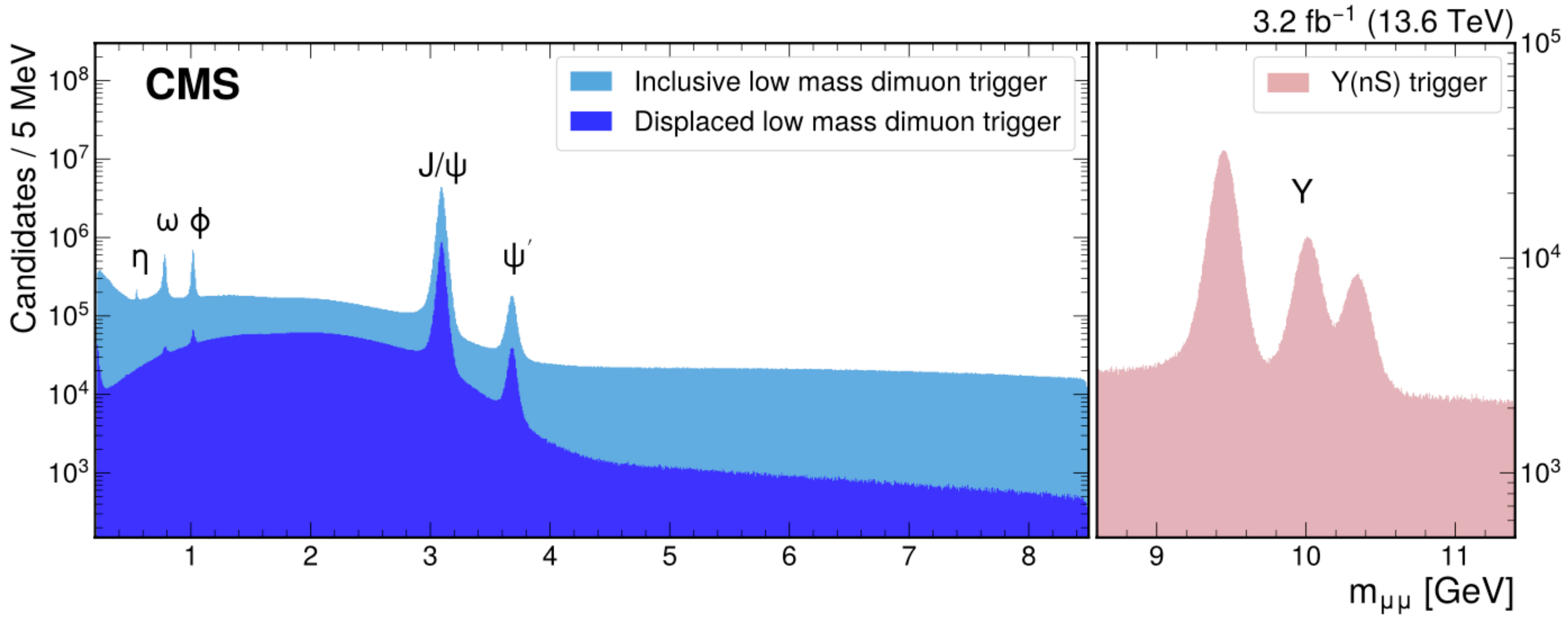
- **HH and HHH** processes: **only produced at the LHC, next 10 years will be crucial**

Back-up

Parking rates allocation

CMS DP-2023/043
arXiv:2403.16134

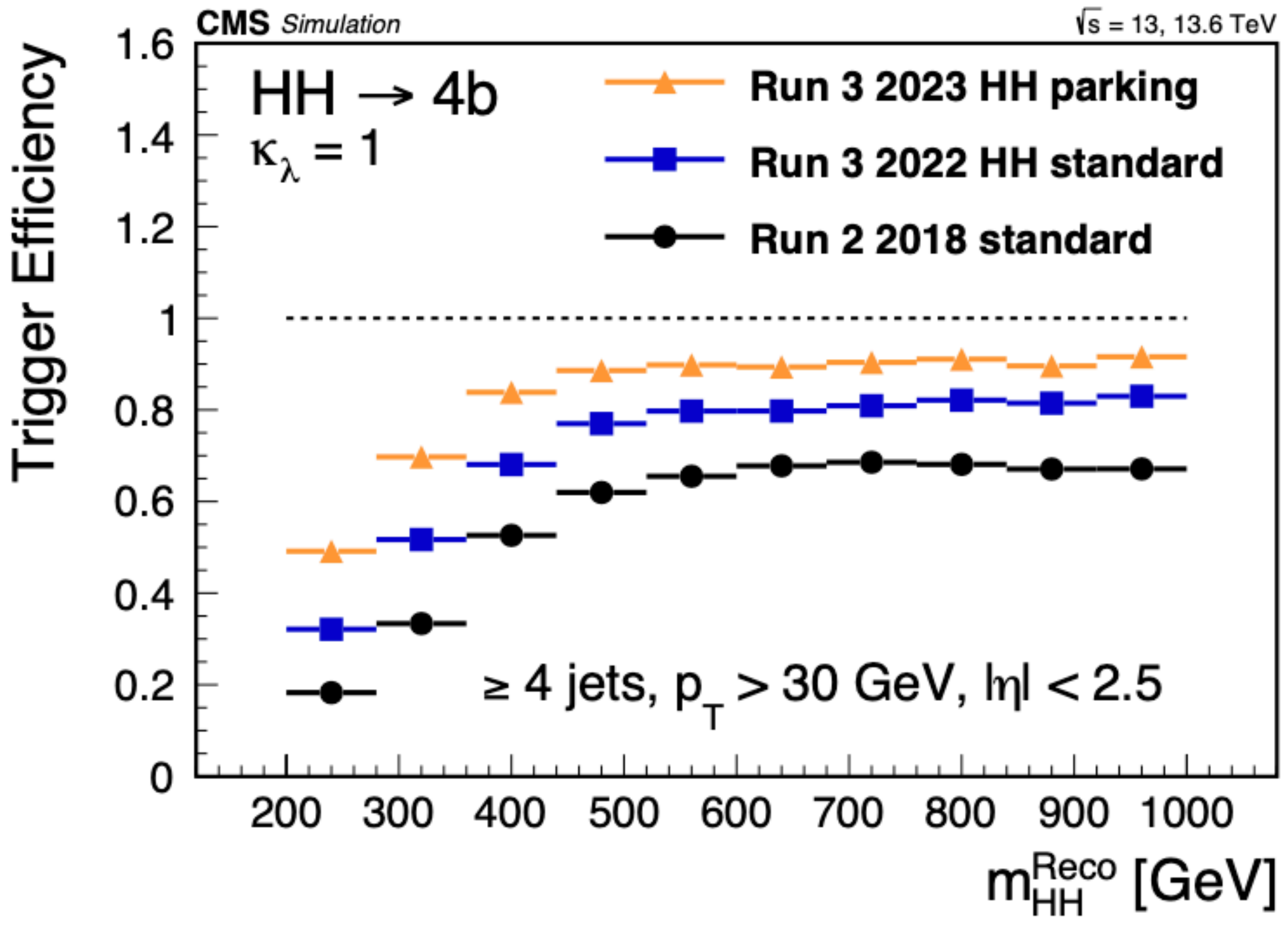
B-physics: low mass dimuon triggers **1.6 kHz**



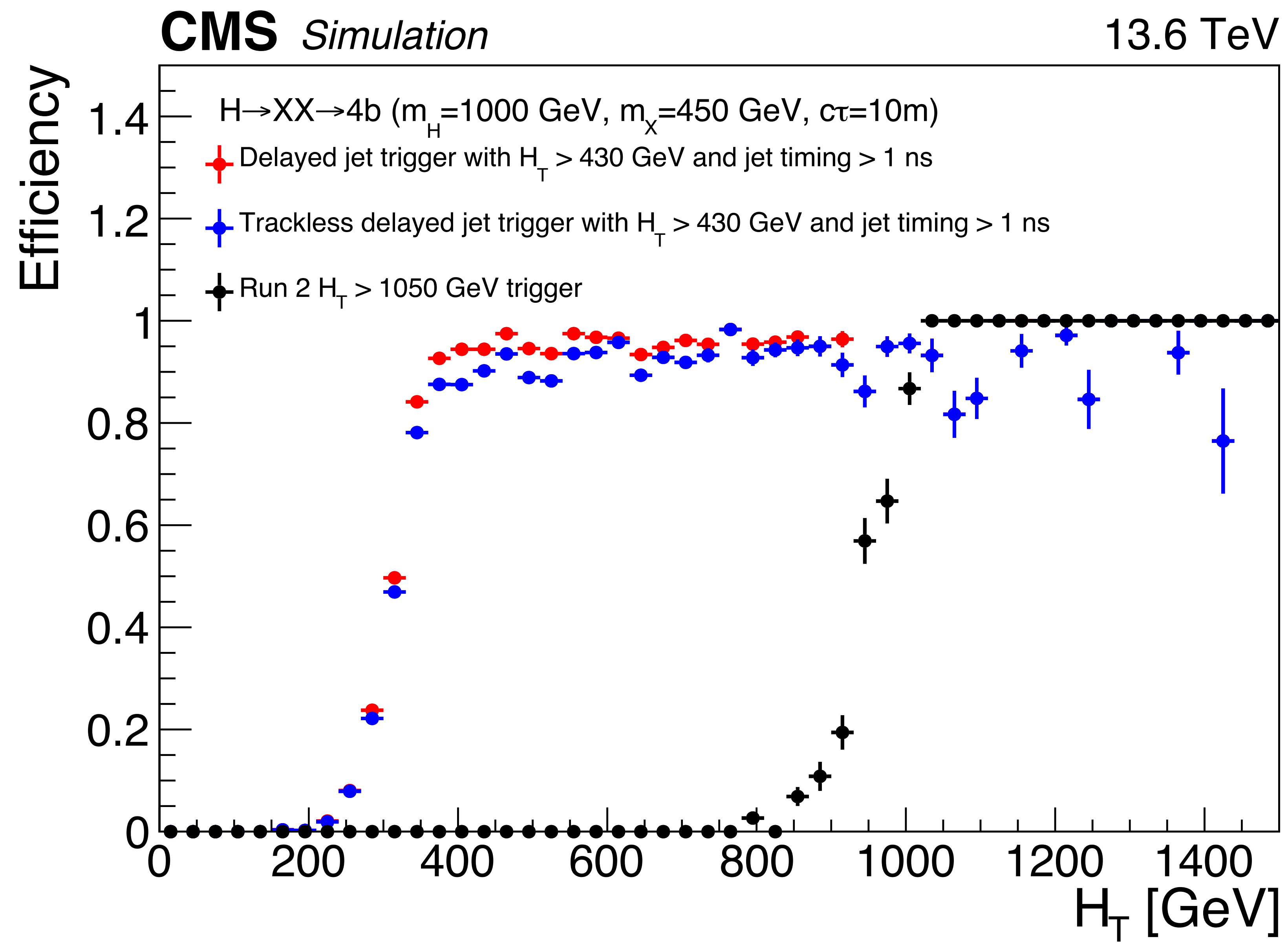
VBF triggers: inclusive and object specific **1.2 kHz**

Benchmark signal	Standard triggers	Parking triggers	Acceptance gain
VBF H $\to$ SUEPs	H_{T}	VBF inclusive	+2500%
Fully hadronic VBS	Multijet, H_{T}	VBF + 2 central jets	+30%
VBF H $\to$ invisible	$p_{\mathrm{T}}^{\mathrm{miss}}$, tight VBF+$p_{\mathrm{T}}^{\mathrm{miss}}$	VBF + $p_{\mathrm{T}}^{\mathrm{miss}}$	+60%
VBF H $\to \tau\tau(\to \tau_{\mathrm{h}}\tau_{\mathrm{h}})$	Di-τ_{h}, VBF+di-τ_{h}	VBF + τ_{h}	+50%
VBF H $\to \tau\tau(\to \mu\tau_{\mathrm{h}})$	Single-μ, $\mu + \tau_{\mathrm{h}}$	VBF + μ	+30%
VBF H $\to \tau\tau(\to \mathrm{e}\tau_{\mathrm{h}})$	Single-e, e + τ_{h}	VBF + e	+40%
VBF H $\to \rho\gamma$	γ + 2 collimated tracks	VBF + γ	+25%

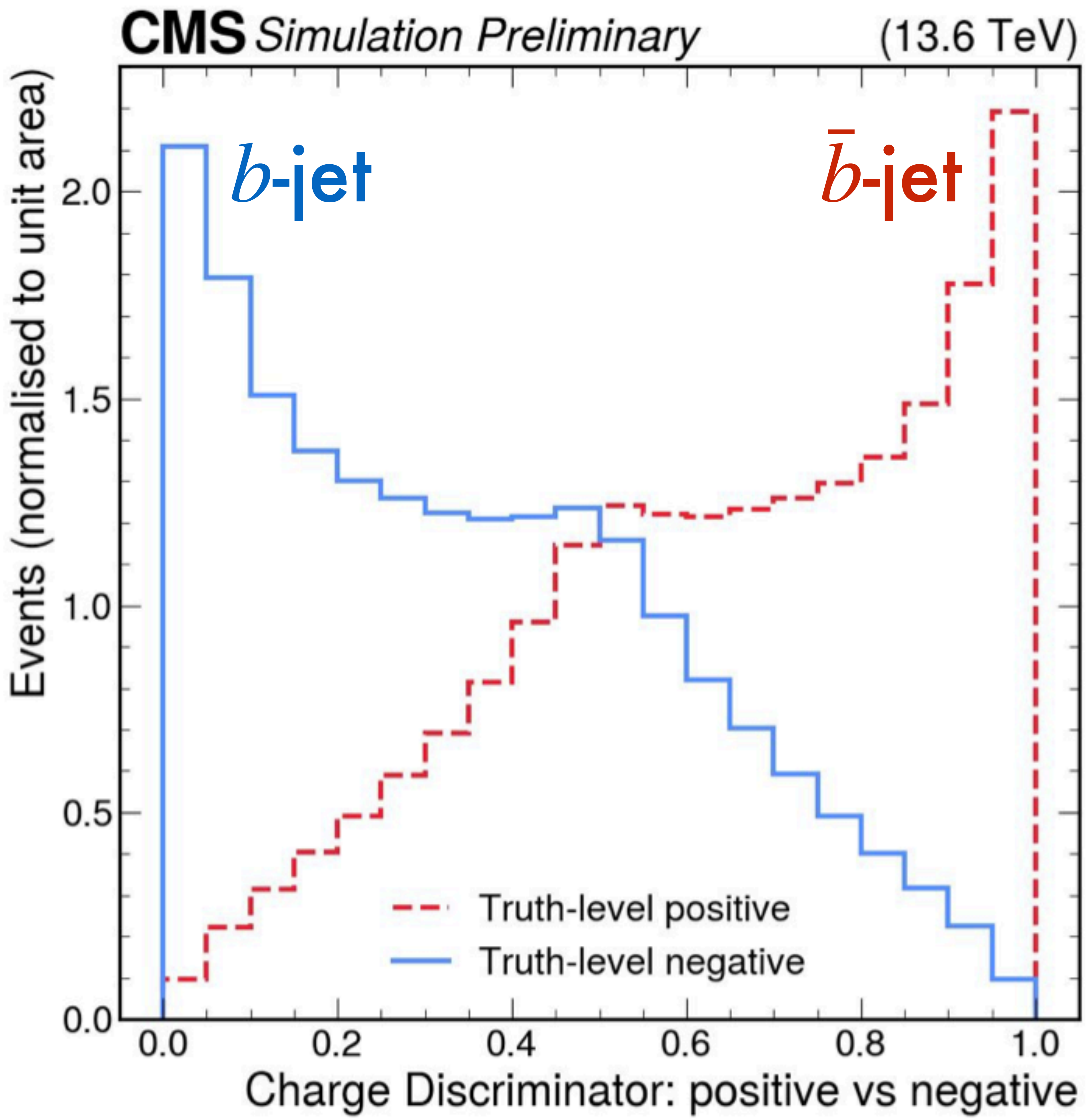
HH and HHH parking **0.3 kHz**

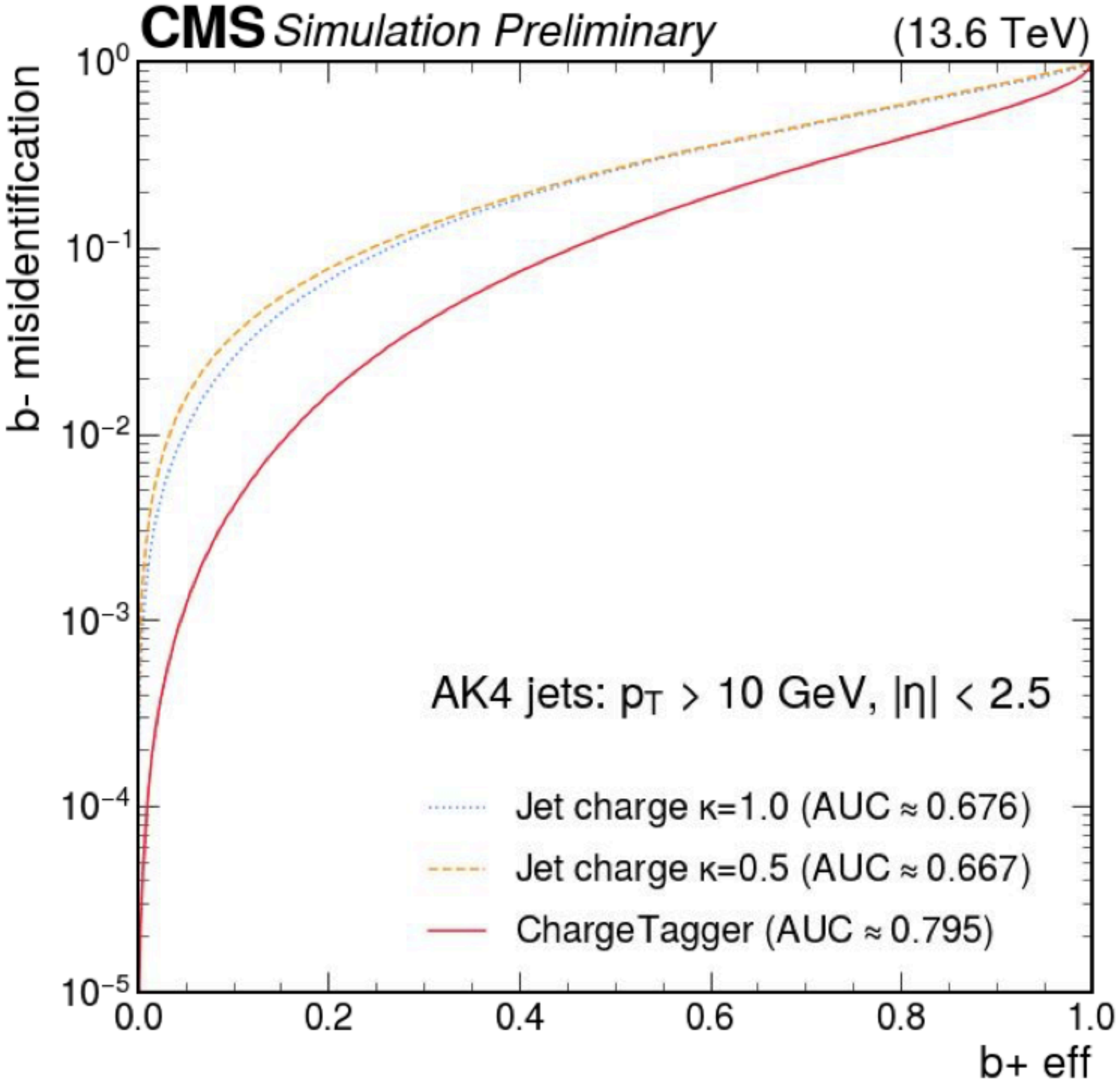


Long lived particles: **0.2 kHz**

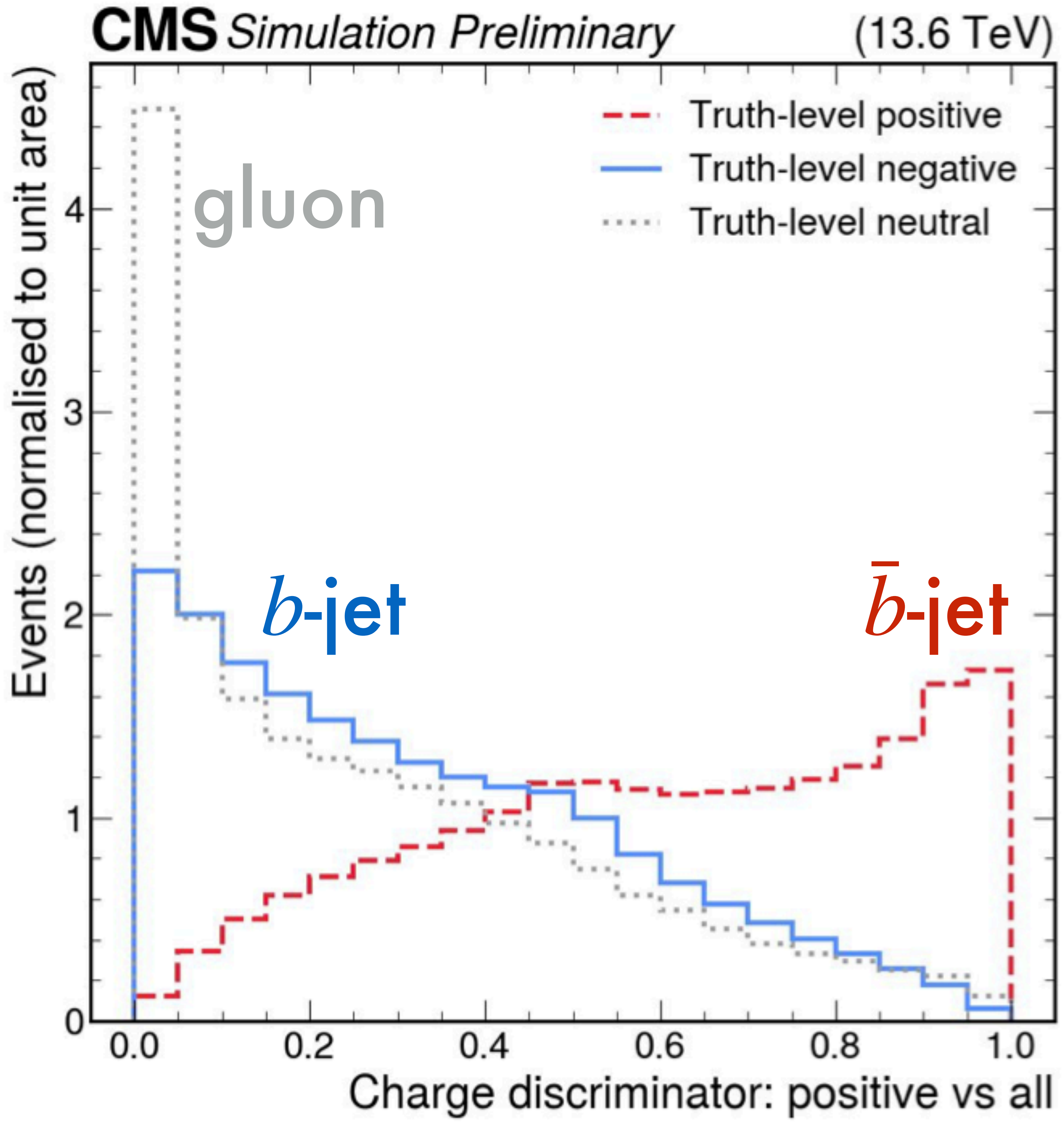


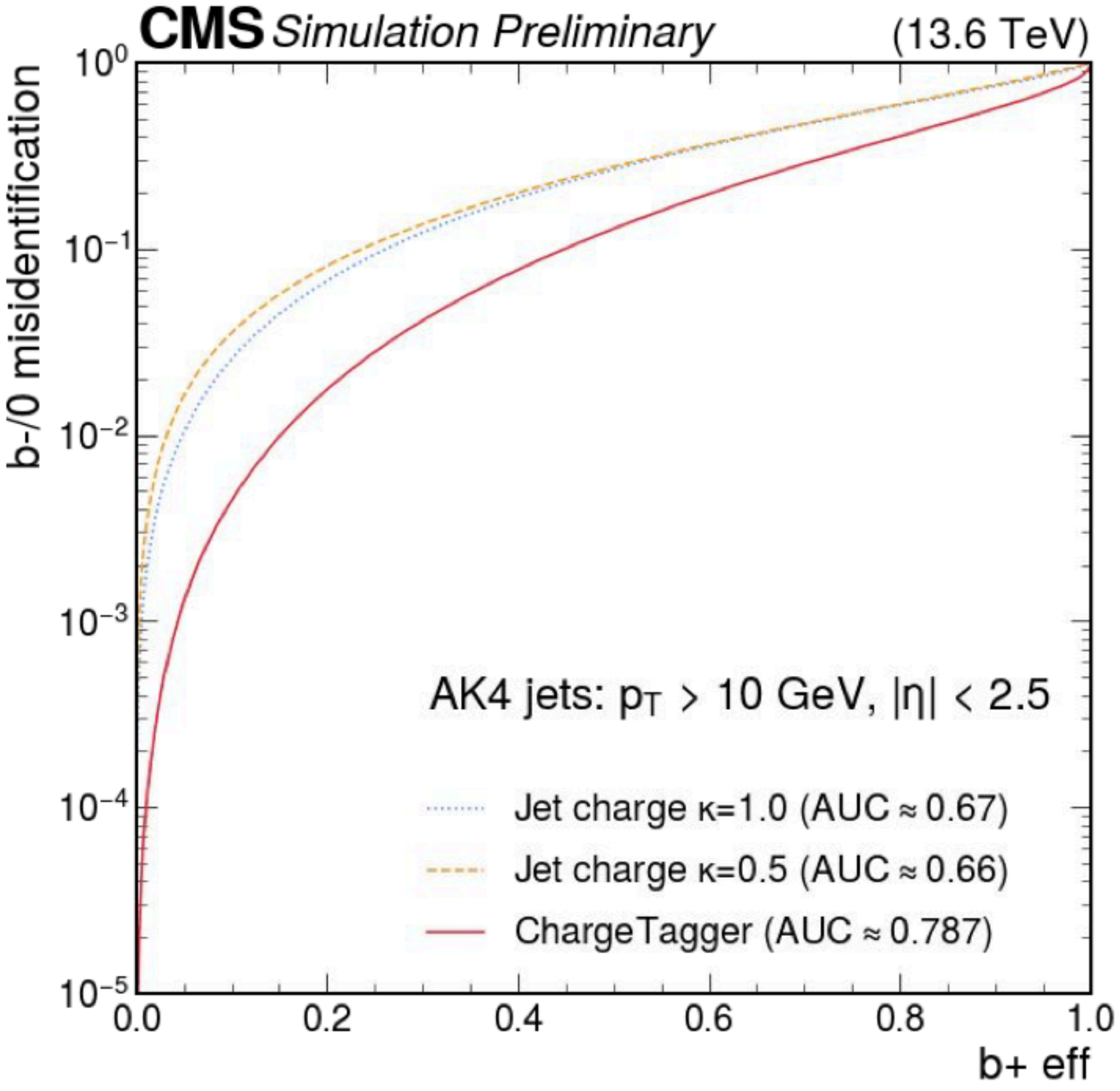
Charge-tagger



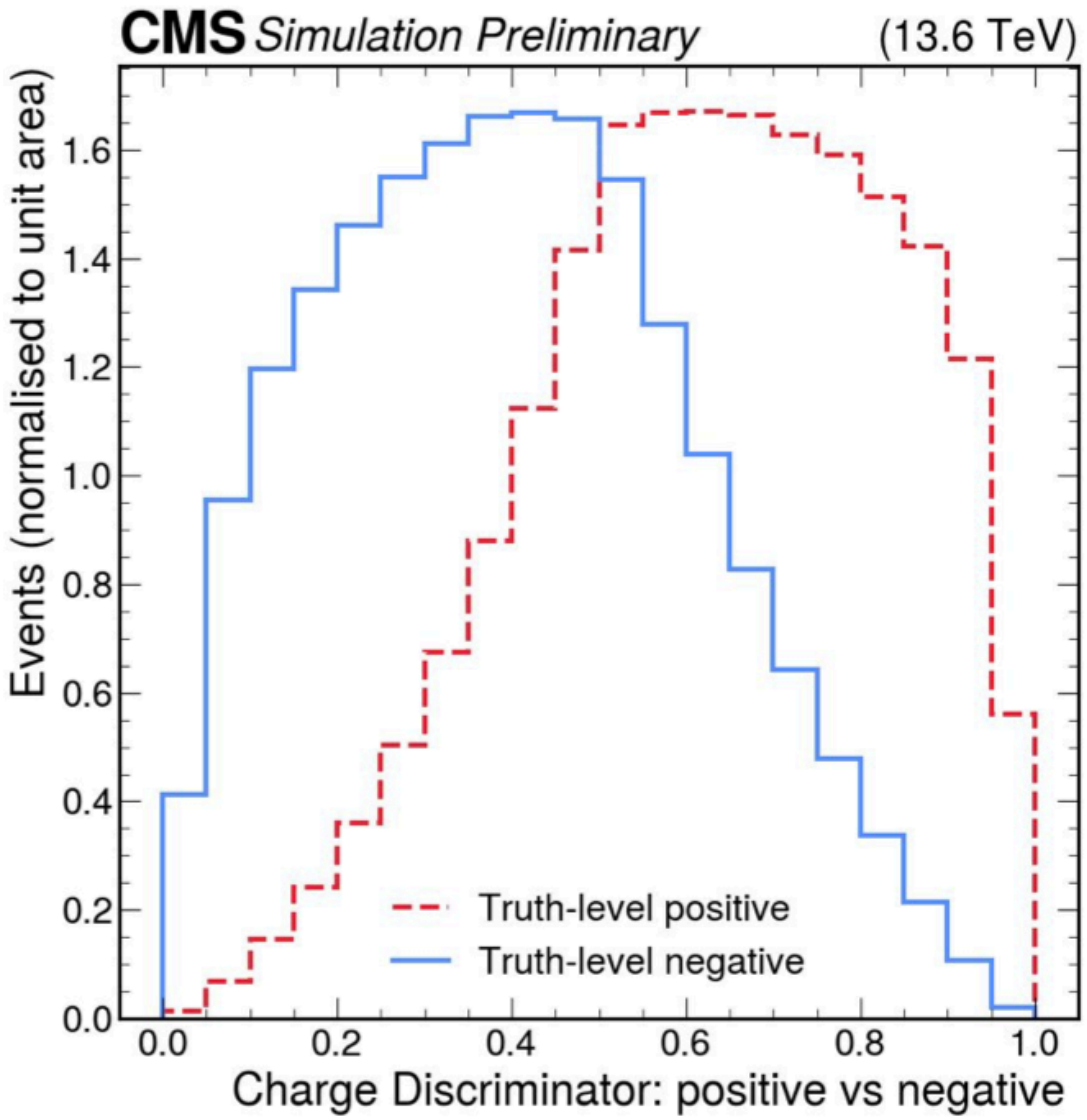


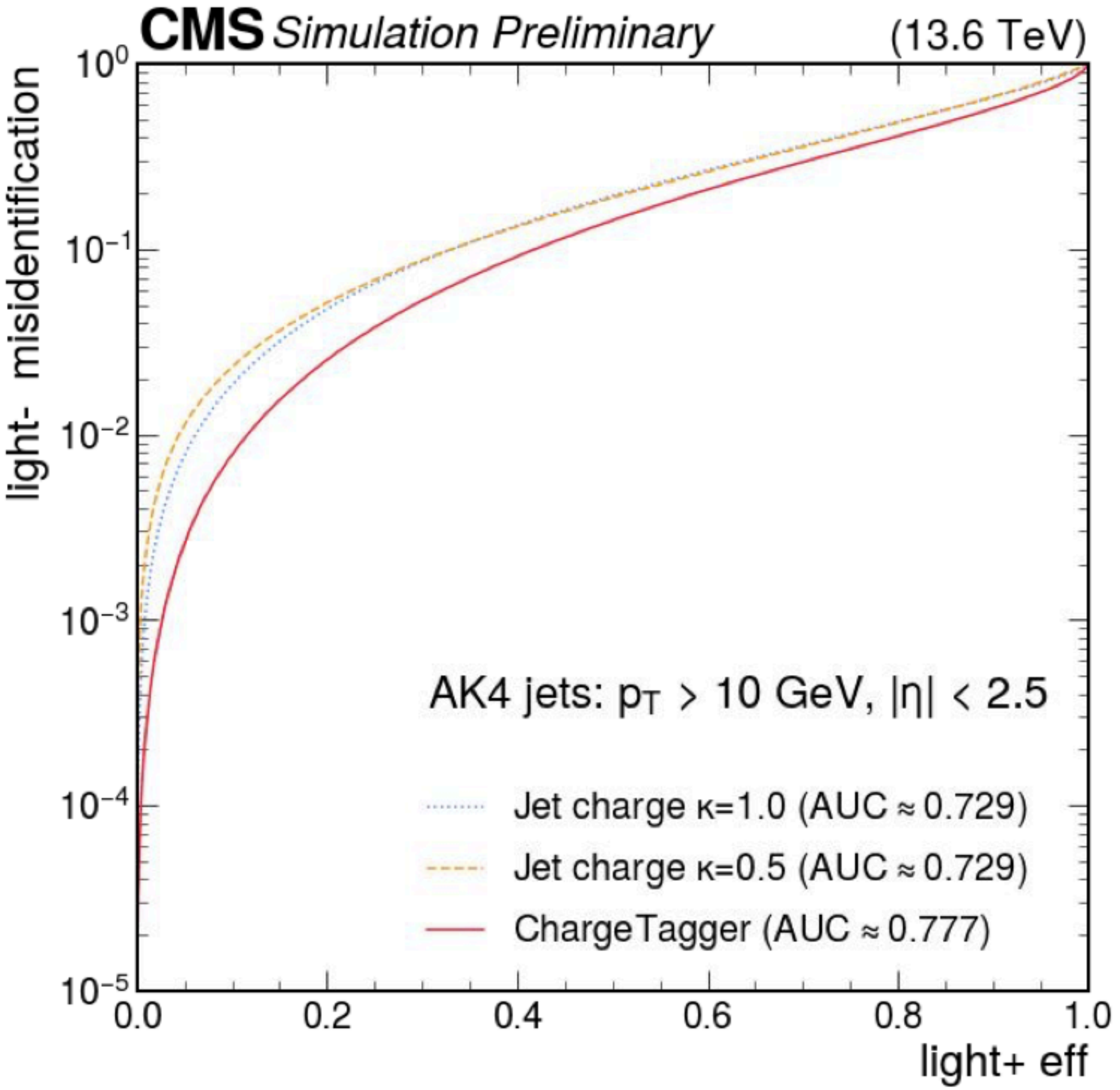
Charge-tagger





Charge-tagger

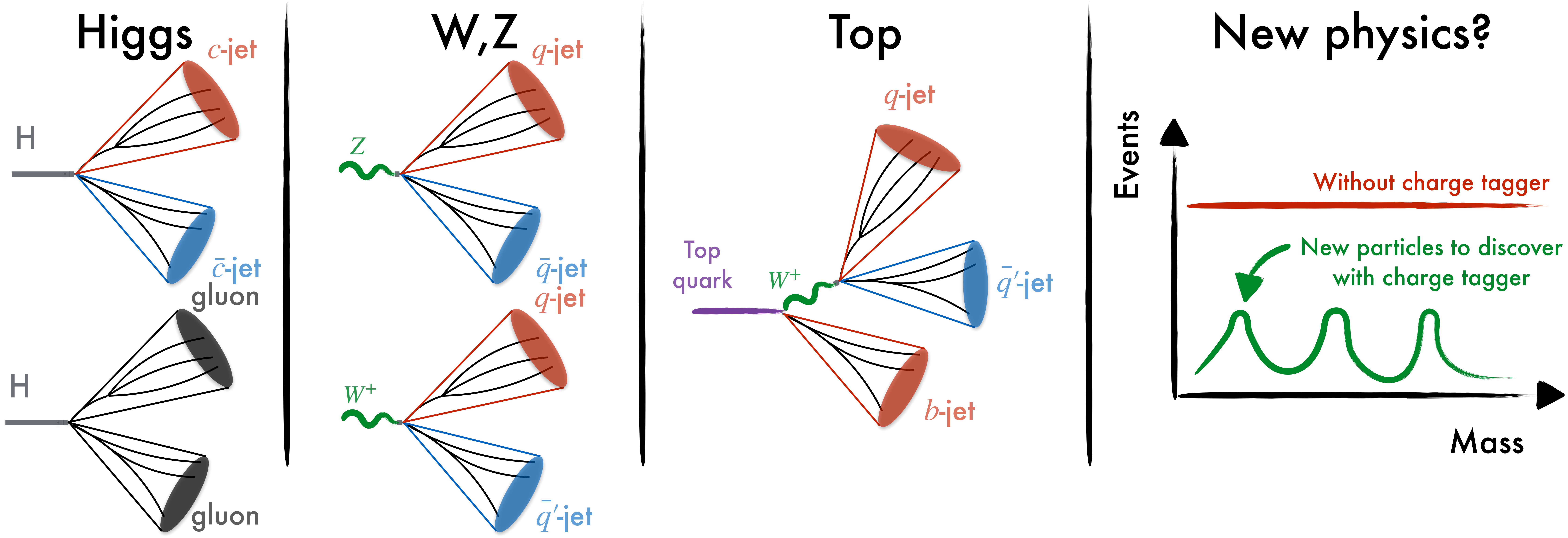




Charge-tagger

	Efficiency (%)		
b+	90	70	50
b-	55	28	12
c+	93	73	50
c-	58	27	10

Potential impact on CMS physics program



Conservation of electric charge is a fundamental property of matter!

- Jet-charge tagger: add completely new and orthogonal dimension to probe LHC data
- Large and profound impact on ATLAS and CMS, from precision measurements to new physics!

Identification of b- and c-hadrons used in **50% of CMS publications** → similar **impact** expected for **jet-charge tagger**!

Uncertainties HH2b2y

Uncertainty source	uncertainty Size	1D fit	2D fit	boosted
b tagging	6–9%	norm	norm	norm
Trigger efficiency	1–2%	norm	norm	norm
Preselection efficiency	1–2%	norm	norm	norm
Electron veto efficiency	1–2%	norm	norm	norm
Pileup	1–4%	norm	norm	norm
Luminosity	1.4%	norm	norm	norm
Photon energy scale	$< 10\%$	shape	shape	shape
Photon energy resolution	$< 10\%$	shape	shape	shape
Jet energy scale	4–9%	norm	shape	norm
Jet energy resolution	1–4%	norm	shape	norm
Higgs boson branching ratio	2 %	norm	norm	norm
ggH, VH, VBF H cross section	1–4%	norm	norm	norm
$t\bar{t}$H cross section	9%	norm	norm	norm
PDF	1–3%	norm	norm	norm
α_S	1–3%	norm	norm	norm
HH theory cross section	23%	norm	norm	norm
bbH modeling	50%	norm	norm	norm
Bias uncertainty	3–30%	–	norm	–
MC statistics	1–20%	norm	norm	norm