Prospects for Searches for invisible Higgs Decays

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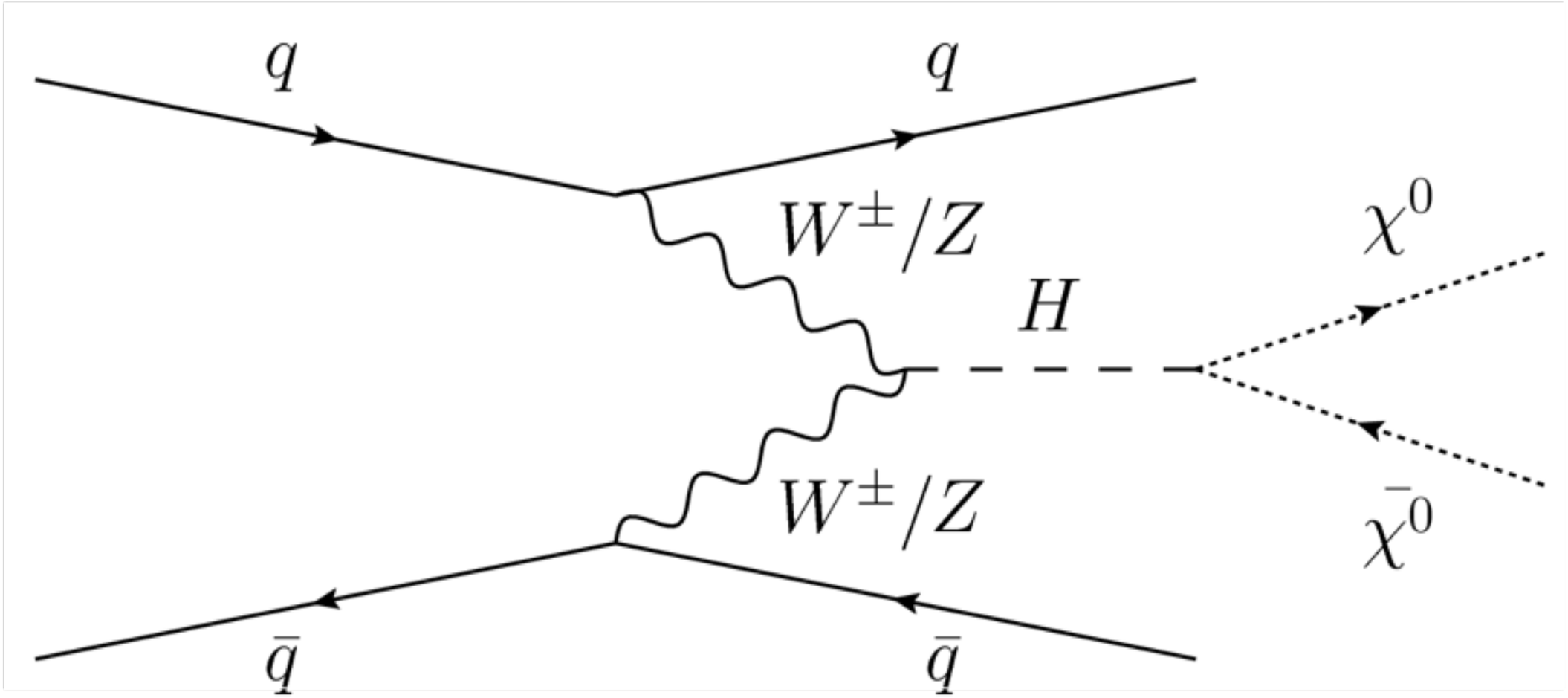
on behalf of the ATLAS and CMS collaborations

HE/HL-LHC workshop

Monday, June 18, 2018

Motivation



Higgs → MET

The Higgs could be the portal to Dark Matter.

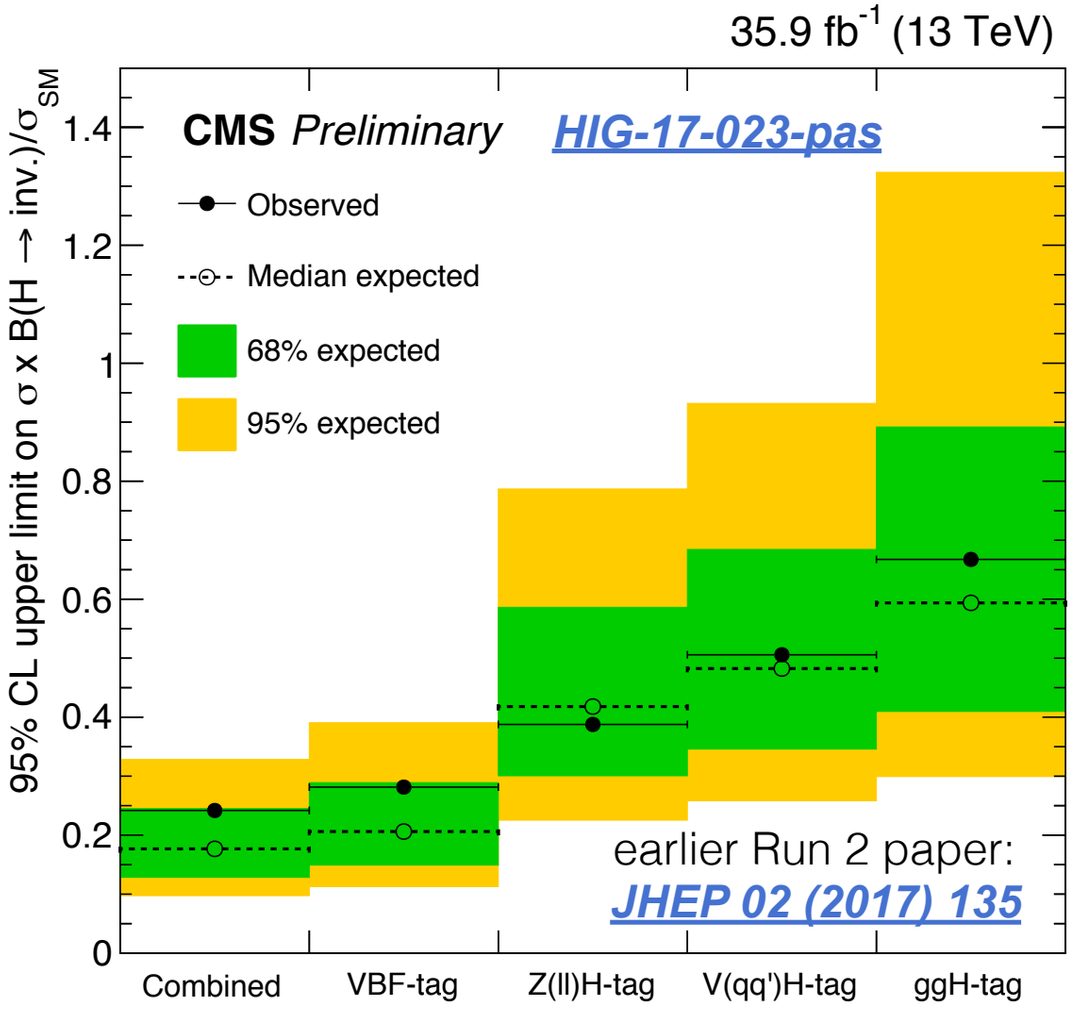
If a Hidden Valley (+ friends), Higgs could be bridge to BSM.

Higgs → MET/displaced

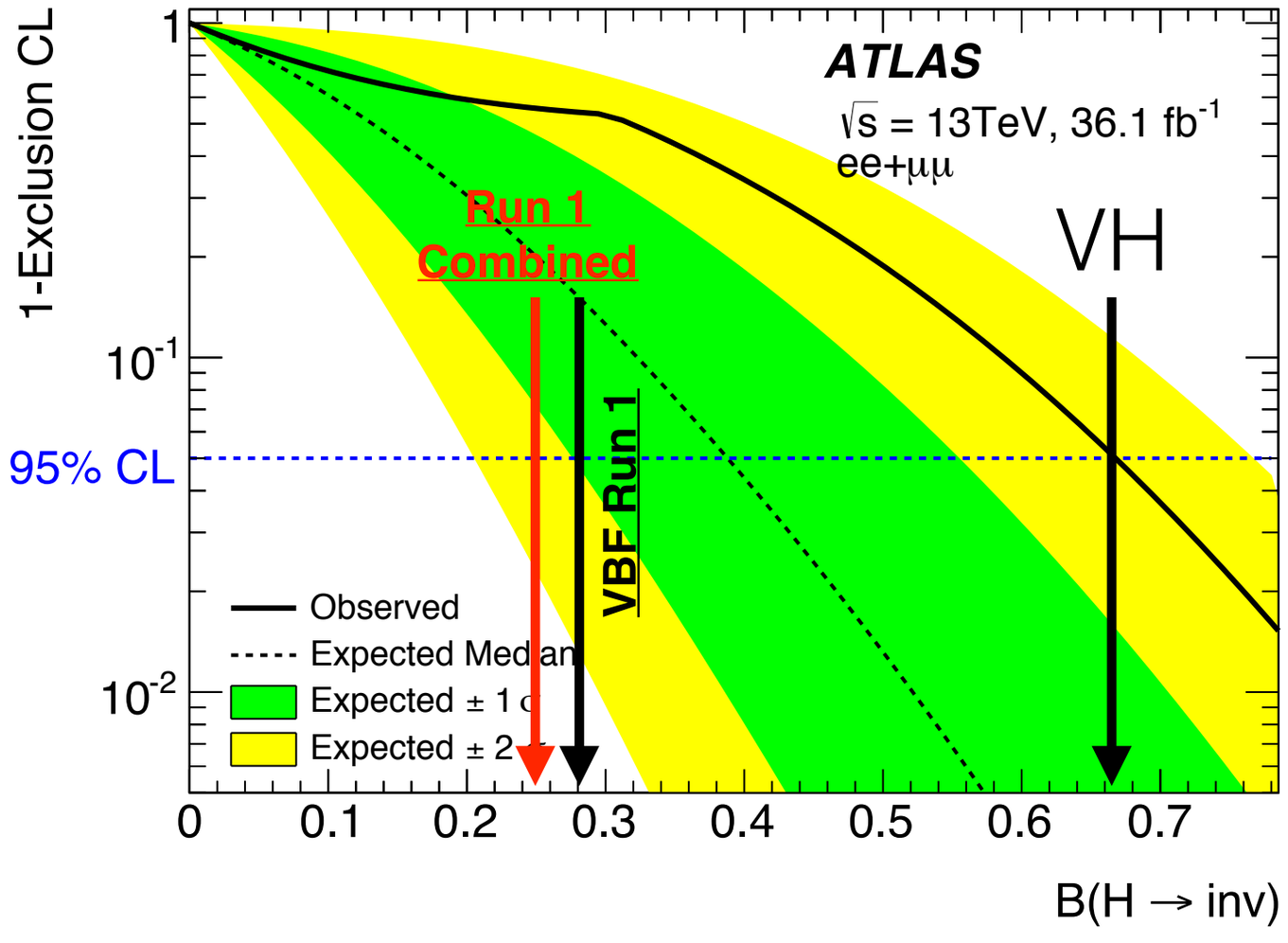
Current Status - Stable Invisible

Current limit is ~25%

dominated by VBF



PLB 776 (2017) 318



Challenge:
Systematic uncertainty ~ statistical uncertainty

Current Status - Stable Invisible

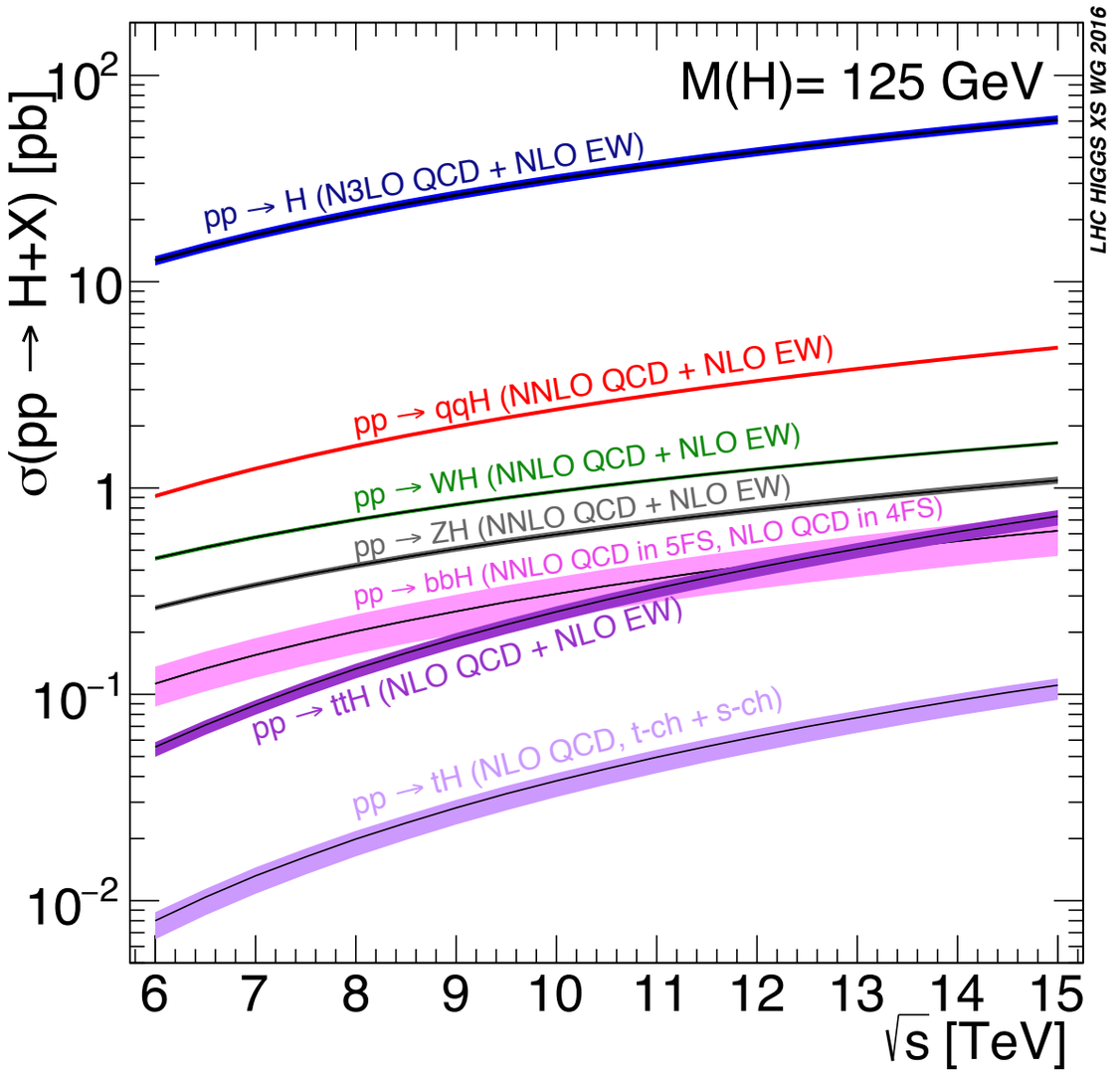
Current limit is ~25%

dominated by VBF

- large cross-section

- main background is qualitatively different than signal, i.e. pp → Z for ggH and pp → ZZ for VH, but for VBF,

$\sigma(EW\ qqZ) << \sigma(QCD\ Z+jets)$

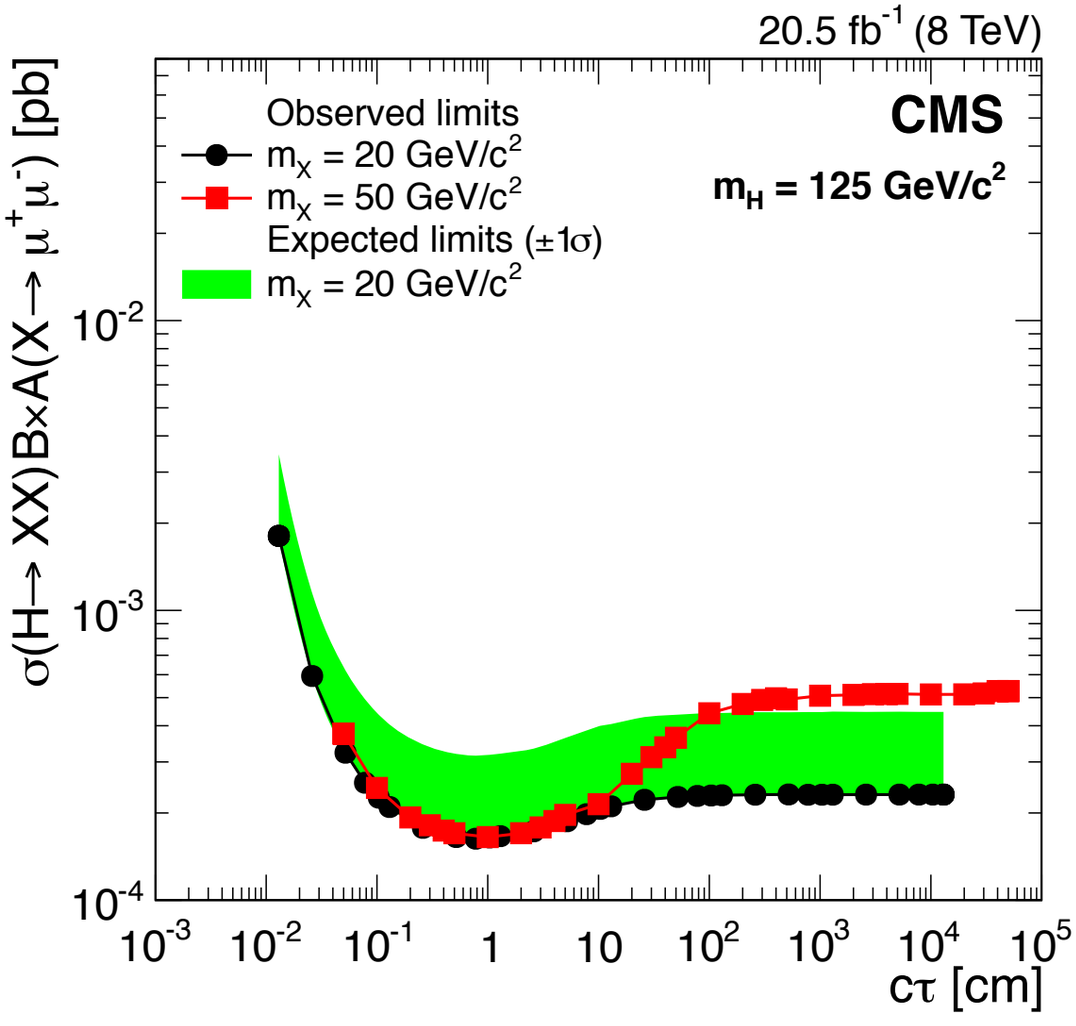


key uncertainty is from modeling $W \to l\nu$ / $Z \to \nu\nu$ ratio (more on this later)

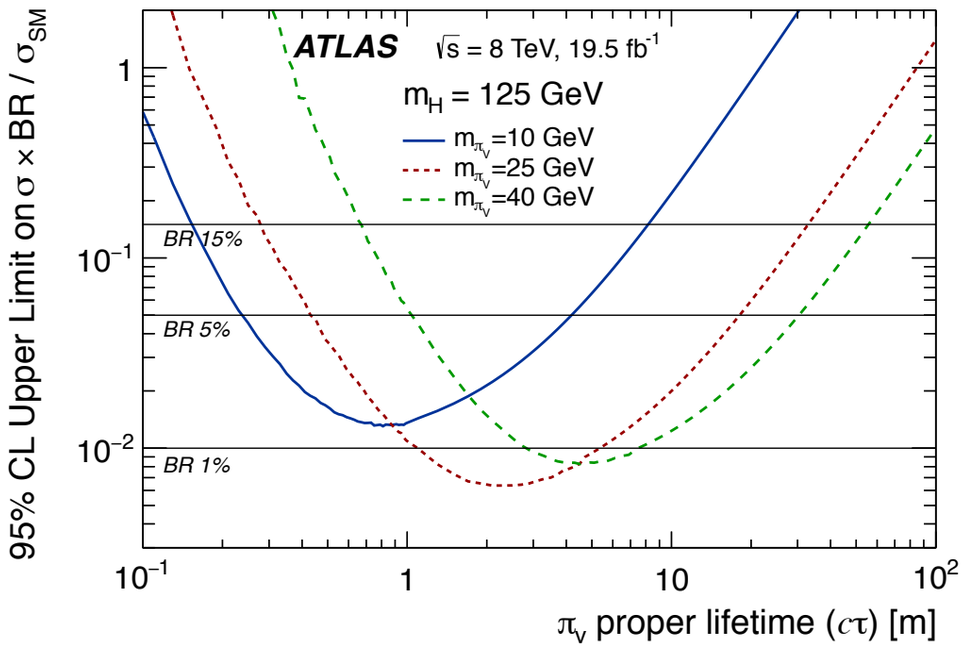
Challenge:
Systematic uncertainty ~ statistical uncertainty

Current Status - (semi)visible

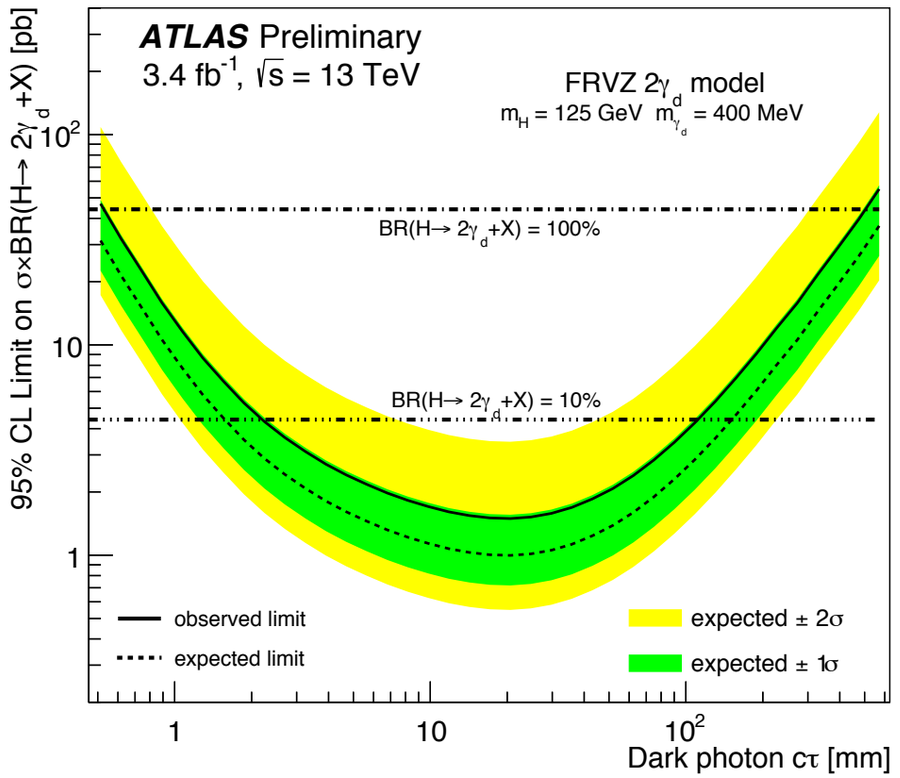
For a given topology, can do (much) better than bounds from h→invisible



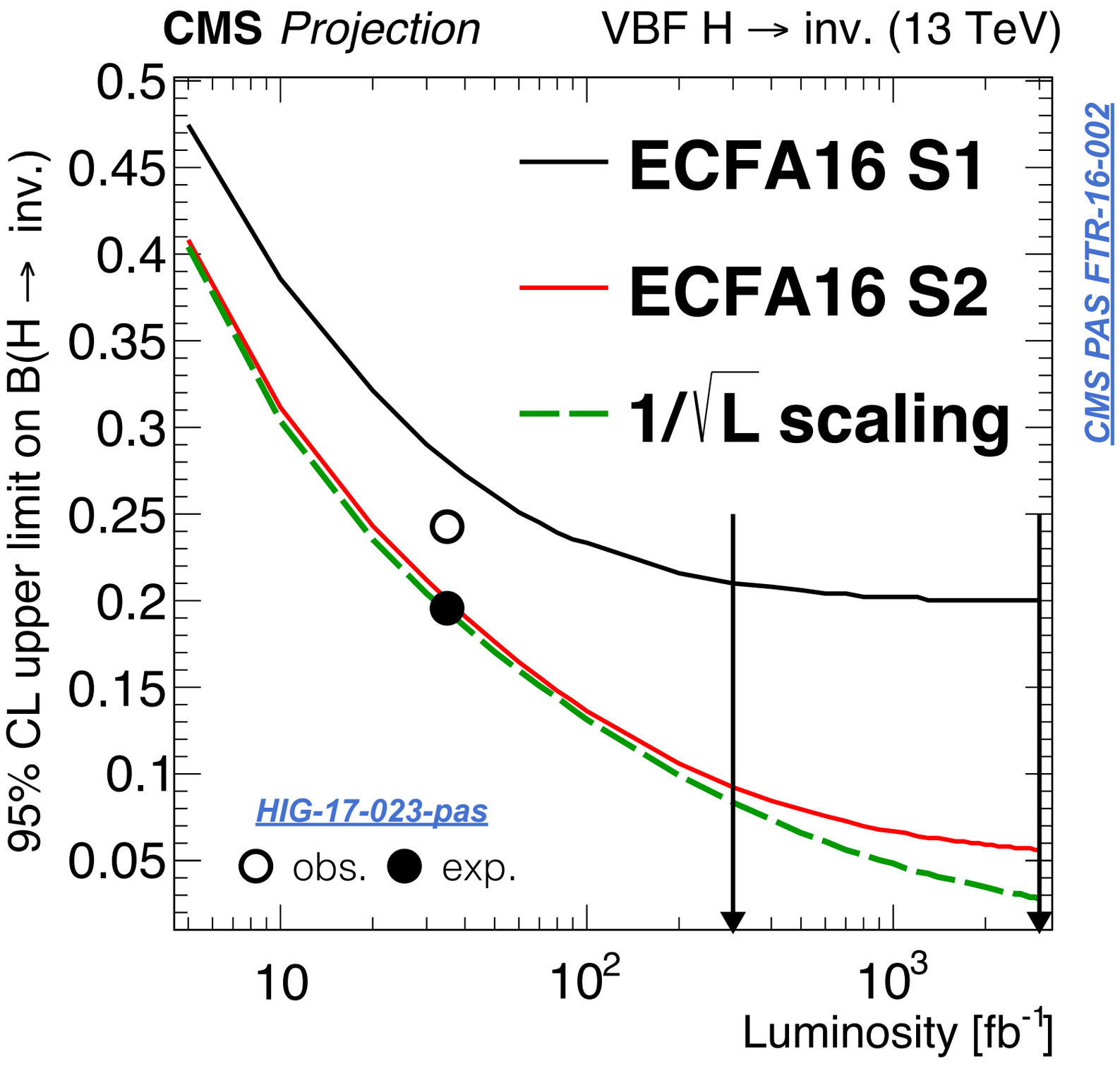
[Phys. Rev. D 92, 012010 (2015)]



[ATLAS-CONF-2016-042]



Projections for HL-LHC



Extrapolations from 2015 analysis; **2016 analysis** follows optimistic scaling.

theory uncerts. drop by 50%
exp. uncerts. scale with lumi
(until a bound)

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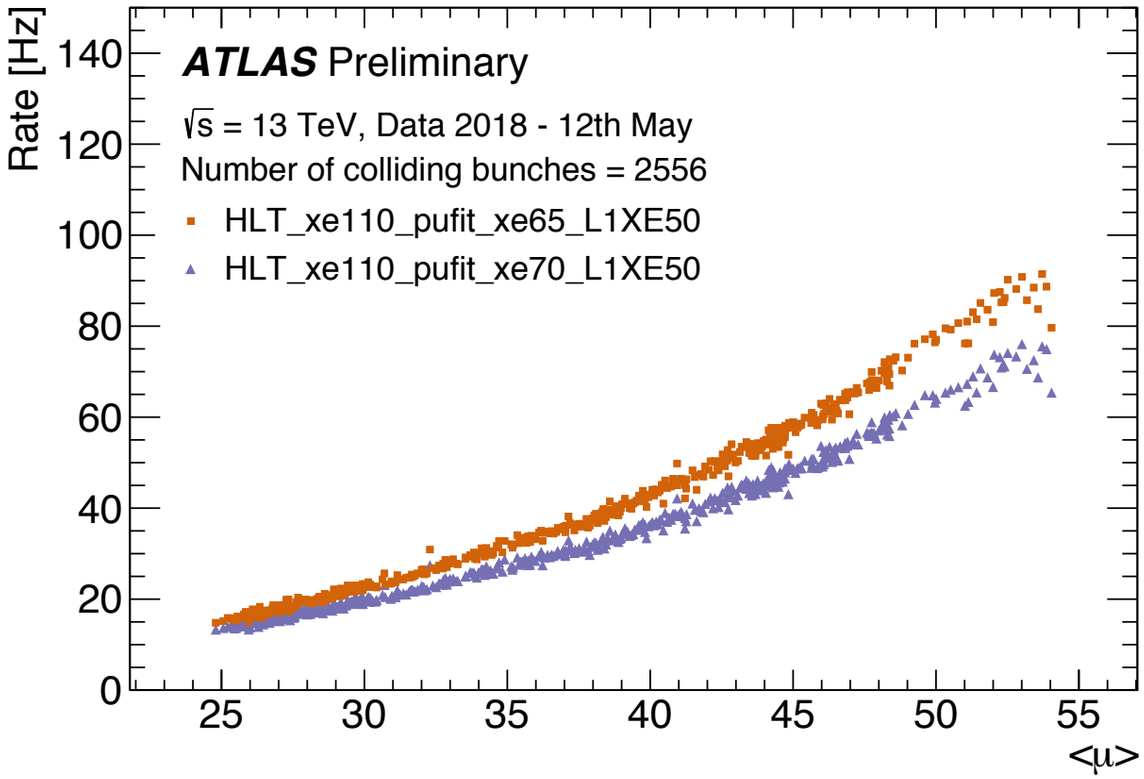
exp. uncerts. scale with lumi

+ analysis improvements possible over the next 10 years!

Challenges: Trigger

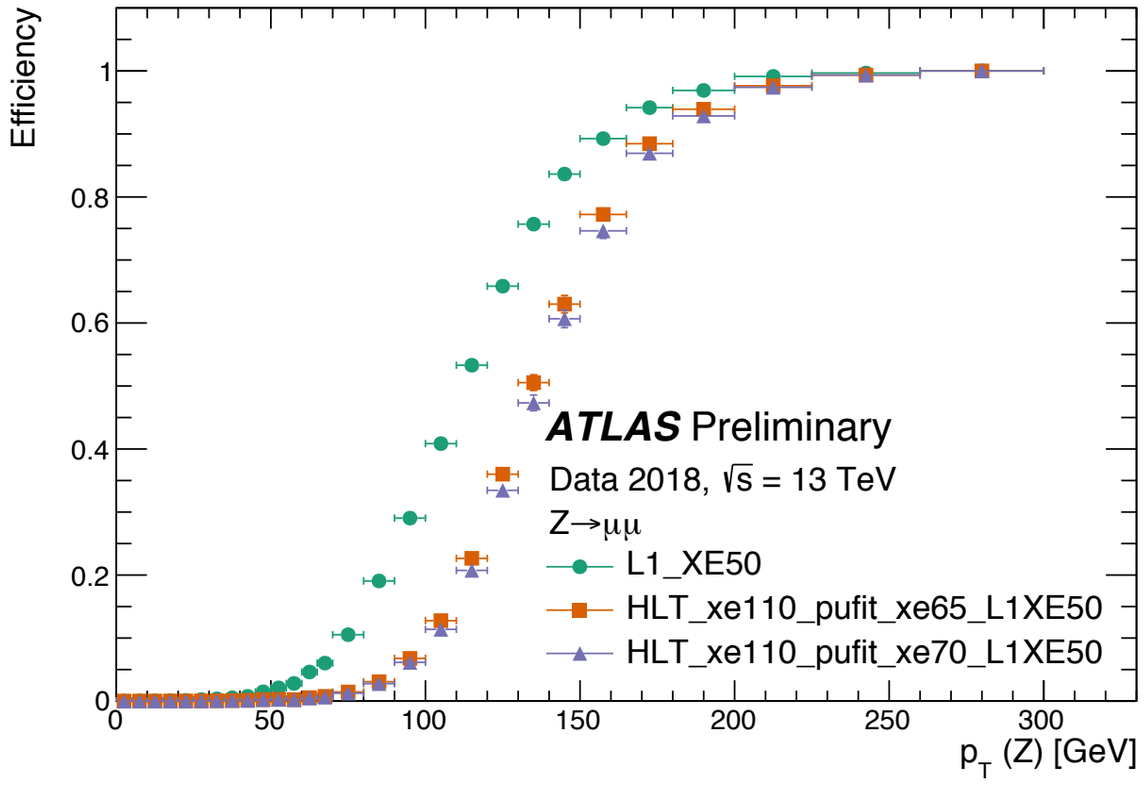


MET trigger heavily affected by pileup

Trigger thresholds will continue to increase

Possible solutions:

-Improve online calibrations
-Multi-object triggers (e.g. VBF + MET)
-Trigger-level PU suppression
-Tracking (+displaced?)



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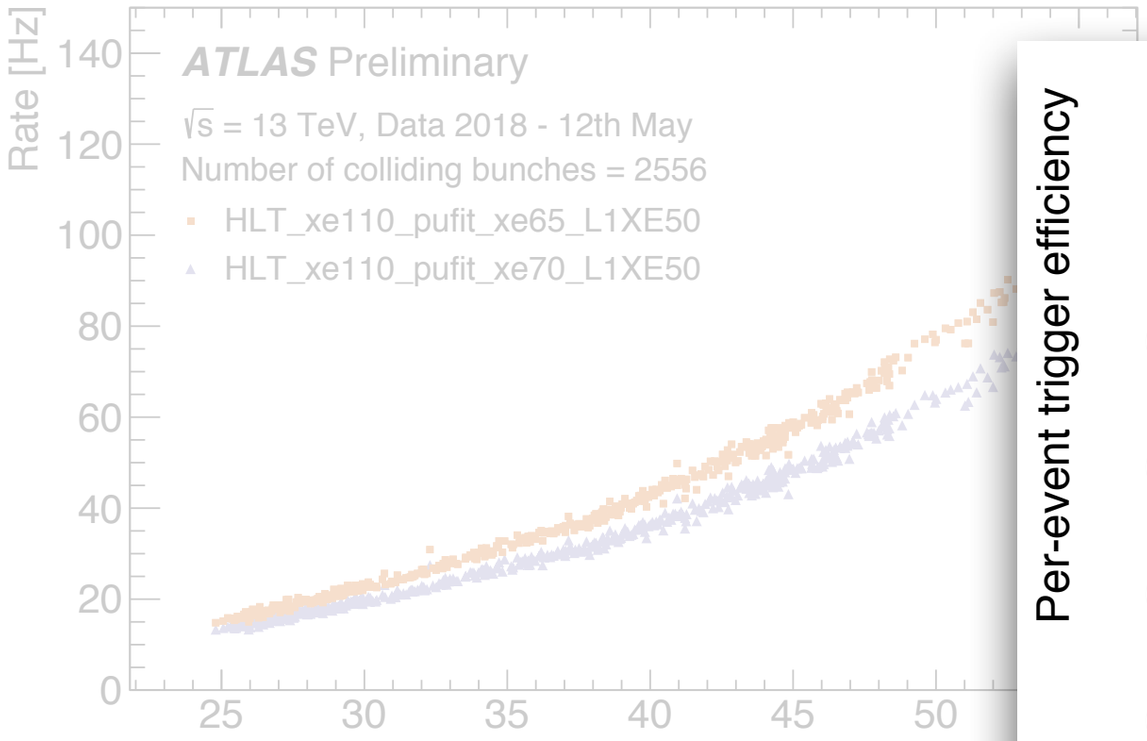

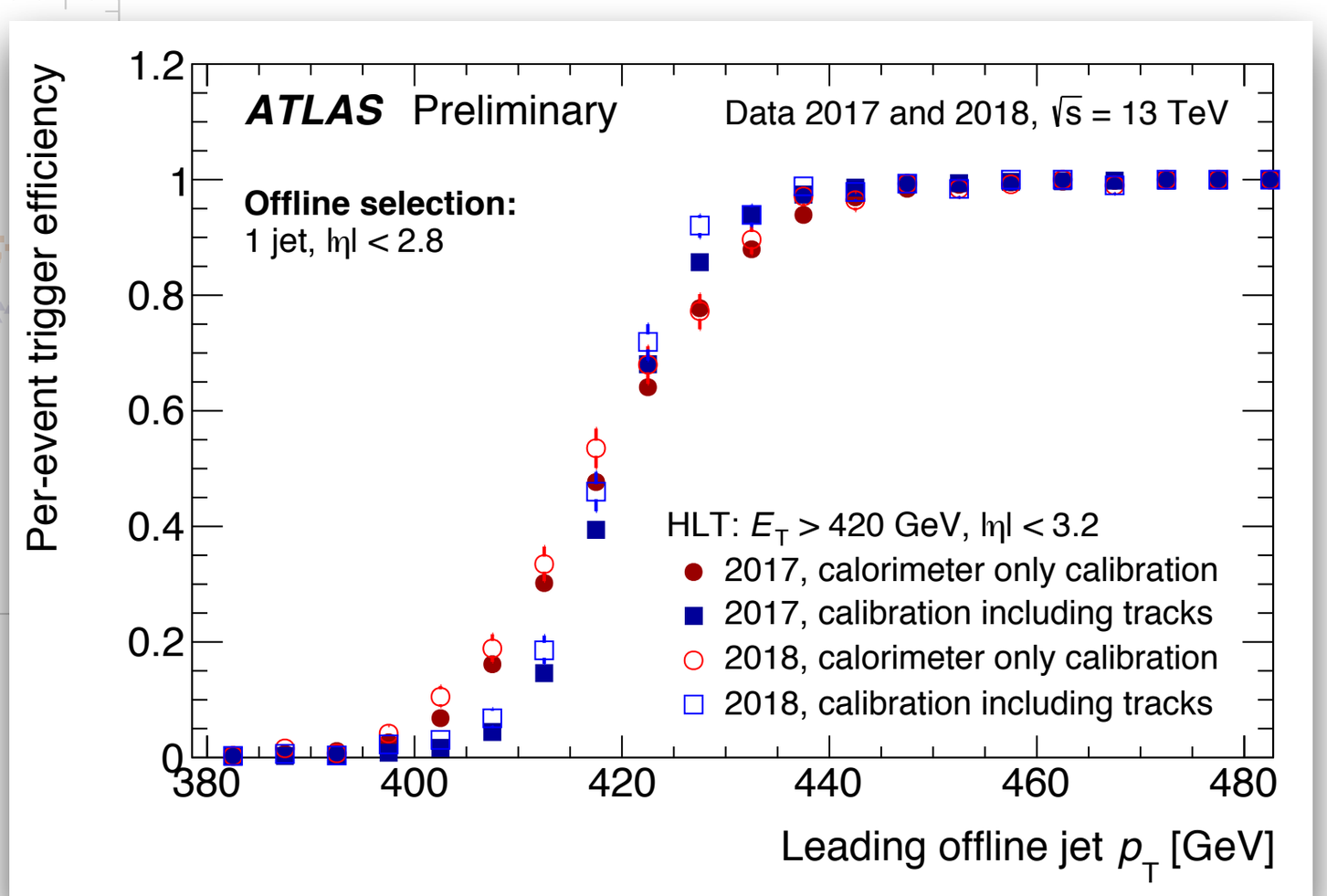

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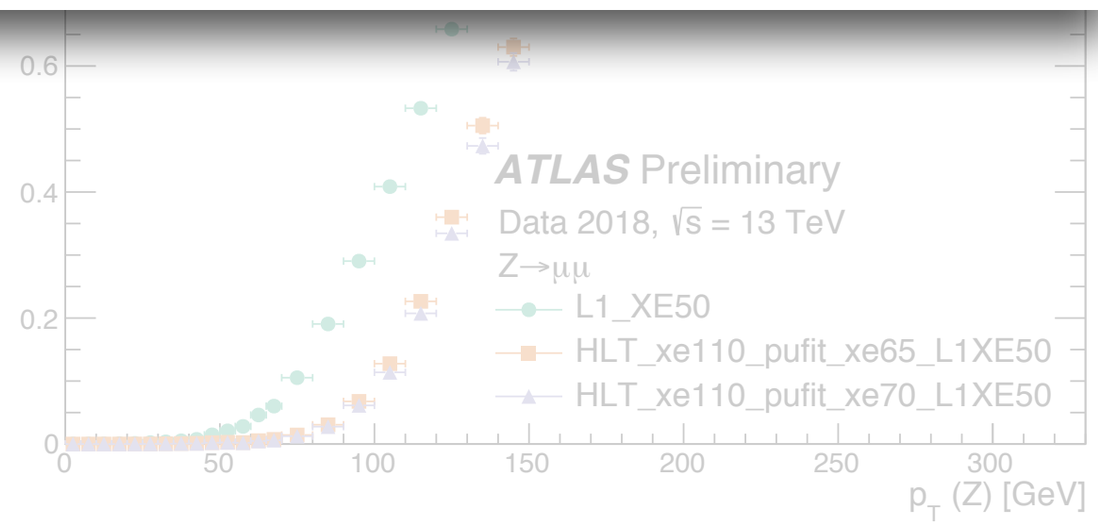

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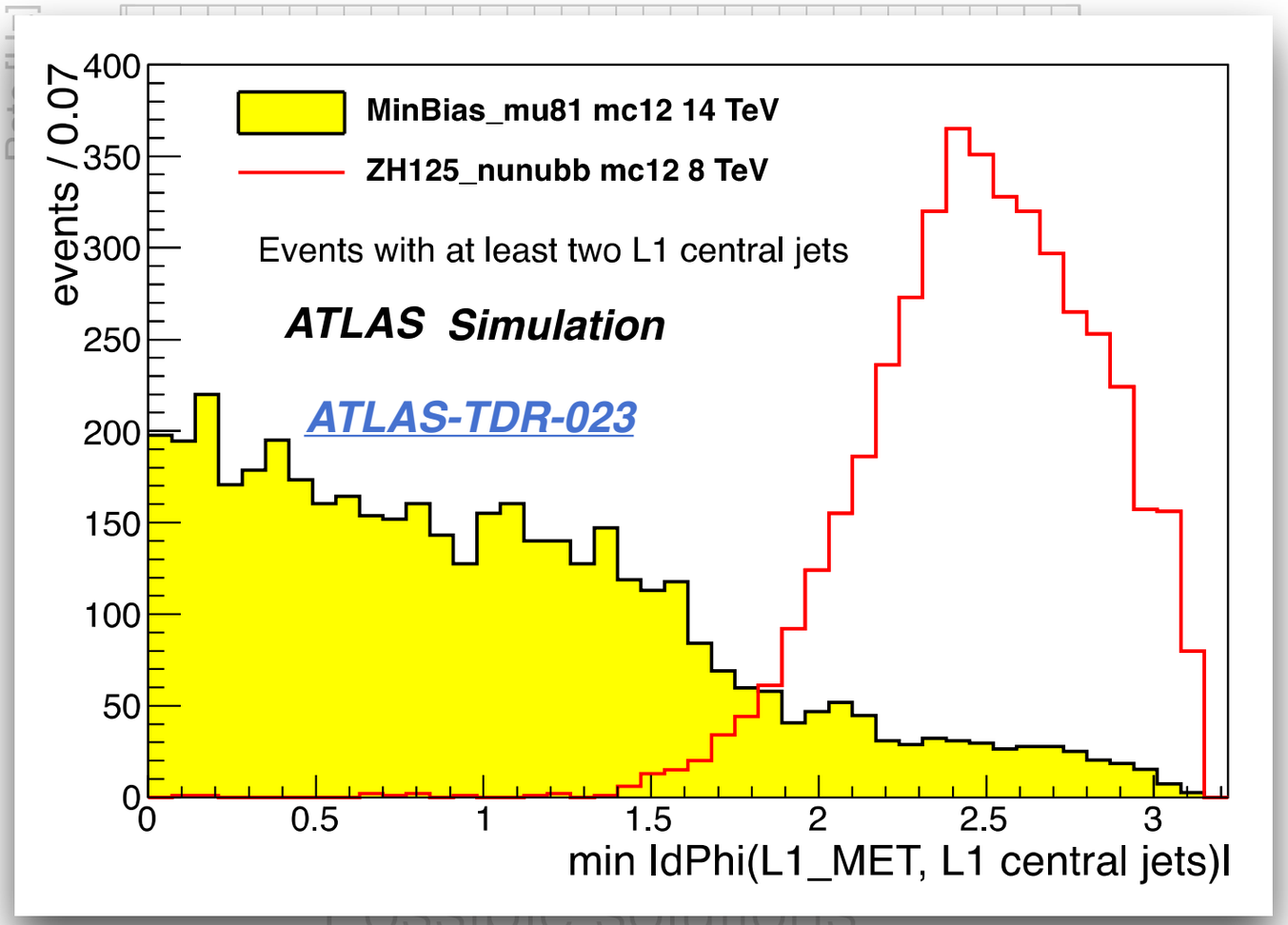

Possible solutions:

-Improve online calibrations

-Multi-object triggers (e.g. VBF + MET)

-Trigger-level PU suppression

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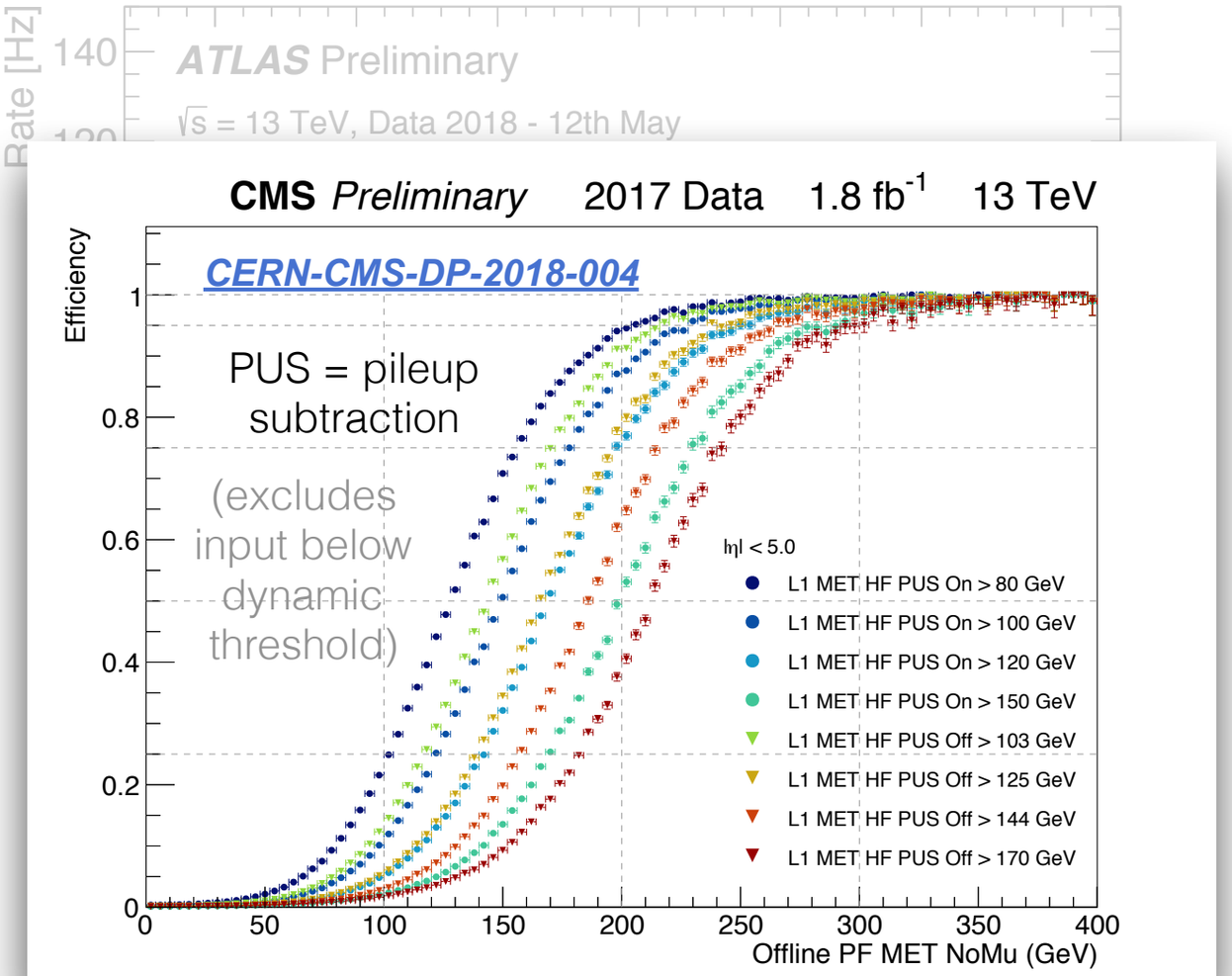
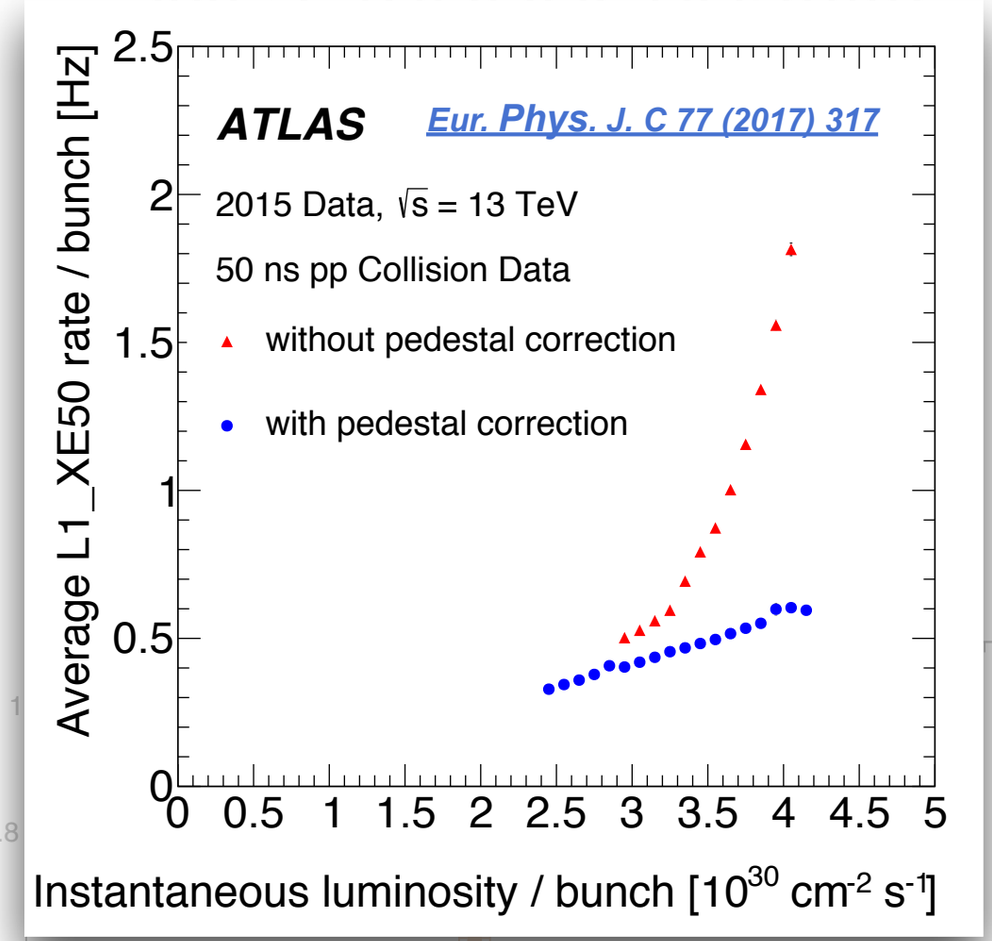
L1Topo trigger in ATLAS now allows for complex multi-object selections

CMS is already uses MET and jet counting at L1 - further improvements possible with topological selections and also including the forward region

Challenges: Trigger





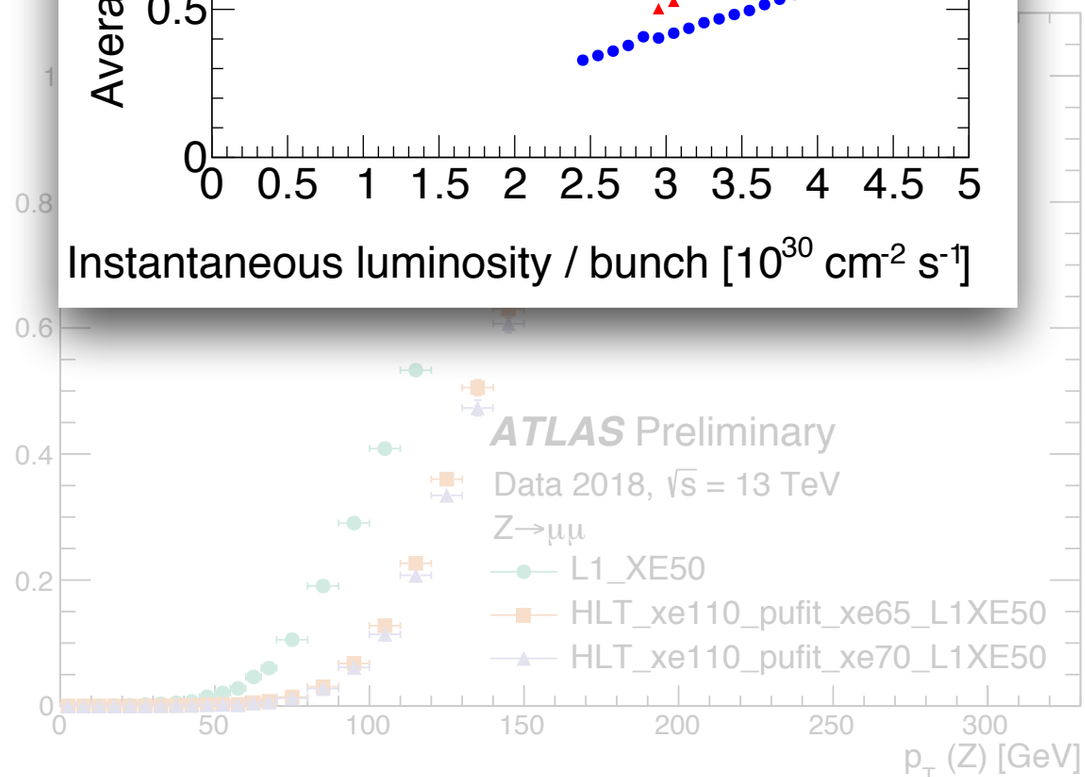
MET trigger heavily

-Improve online calibrations

-Multi-object triggers (e.g. VBF + MET)

-Trigger-level PU suppression

-Tracking (+displaced?)



Can we improve with deep learning? see e.g. JHEP 12 (2017) 051

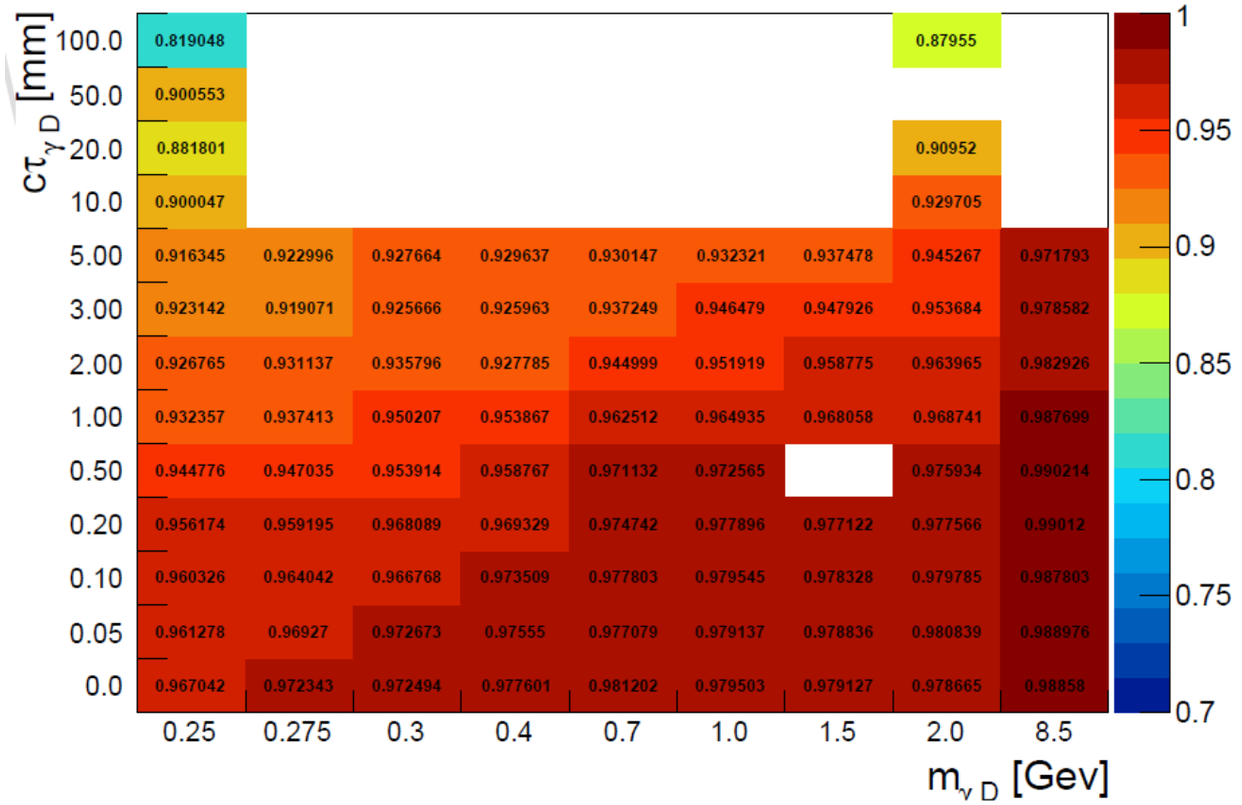
Challenges: Trigger

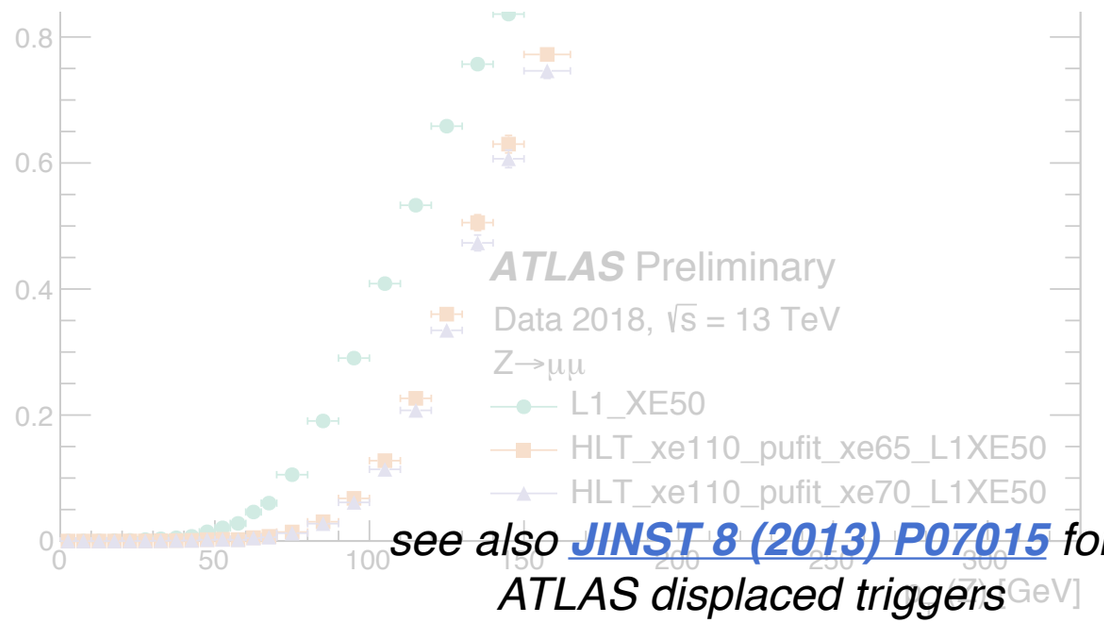
Tracking can generically help calibrations, tagging, etc.
For LLP, can significantly enhance acceptance

Muons at L1 can be used but more general displaced (track) triggers are challenging

-Improve online calibrations
-Multi-object triggers (e.g. VBF + MET)
-Trigger-level PU suppression
-Tracking (+displaced?)

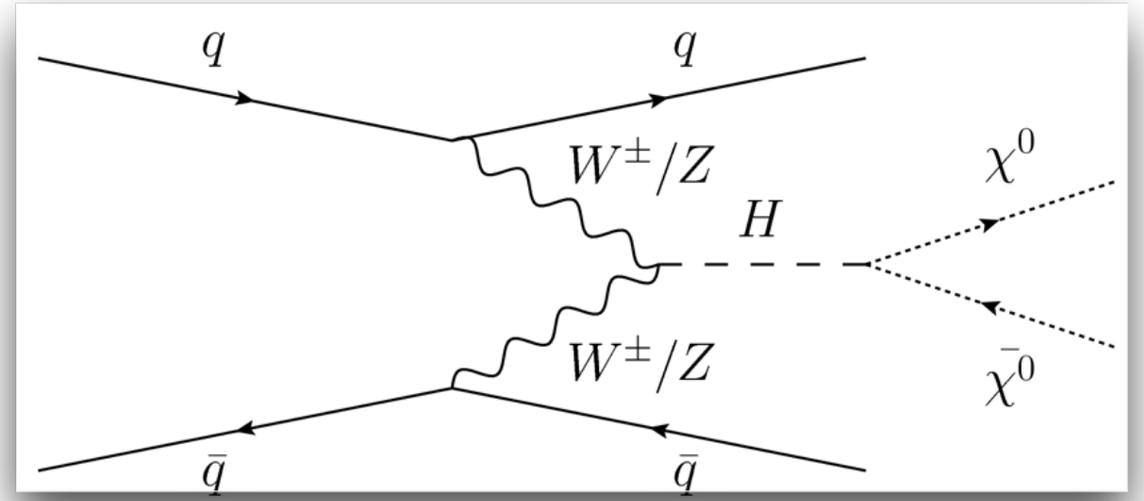
from HIG-16-035-pas and this talk.





see also JINST 8 (2013) P07015 for ATLAS displaced triggers

Challenges: Pileup (Jets)

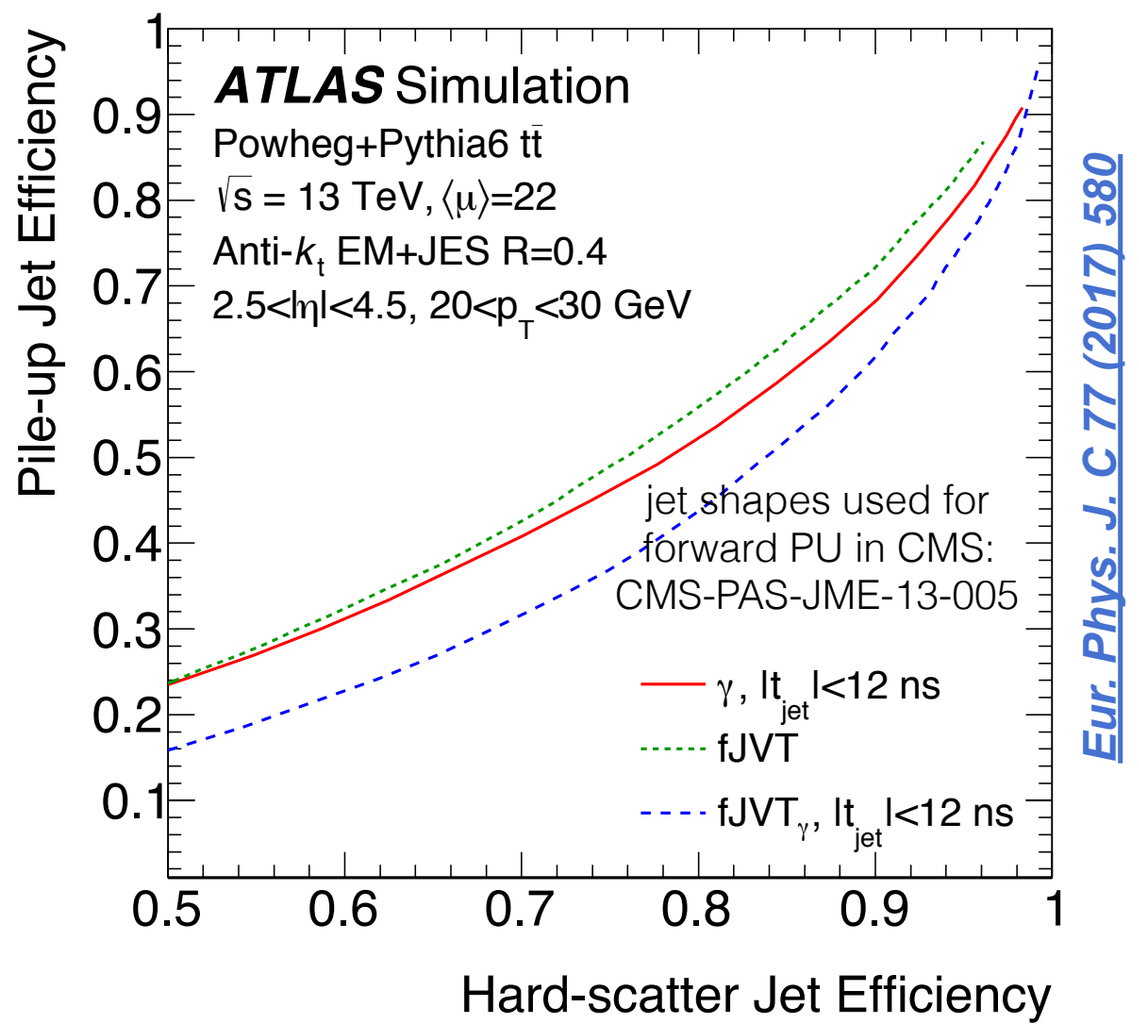


To be seen what role pileup jets play at $\mu \sim 200$ - could make VBF @ HL/HE-LHC much harder than now!

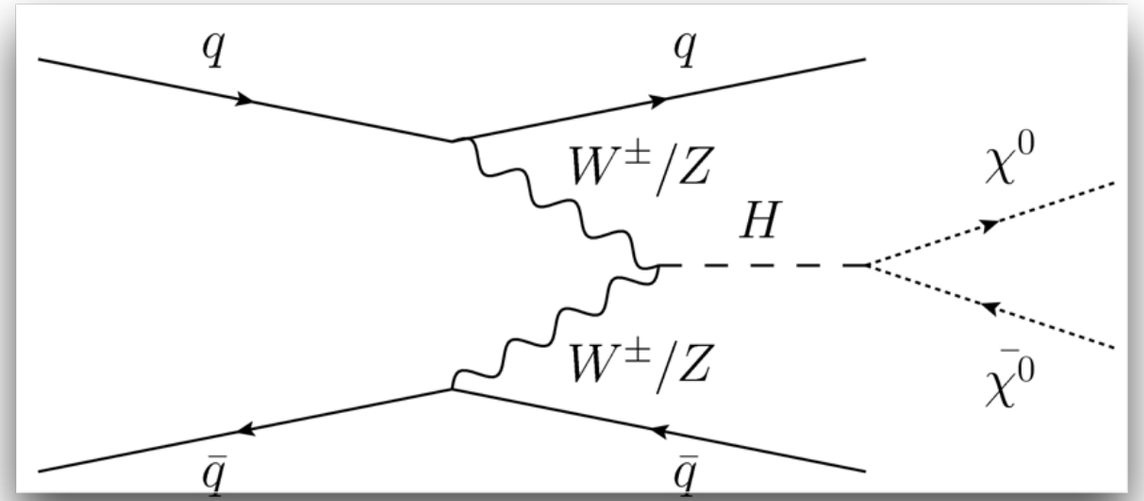
Some ideas already in place to reject forward pileup jets, though composition (QCD/ stochastic) between now and HL/HE-LHC will change.

VBF jets tend to be forward.

Due do limited tracker acceptances, forward jets harder to ID as not pileup.



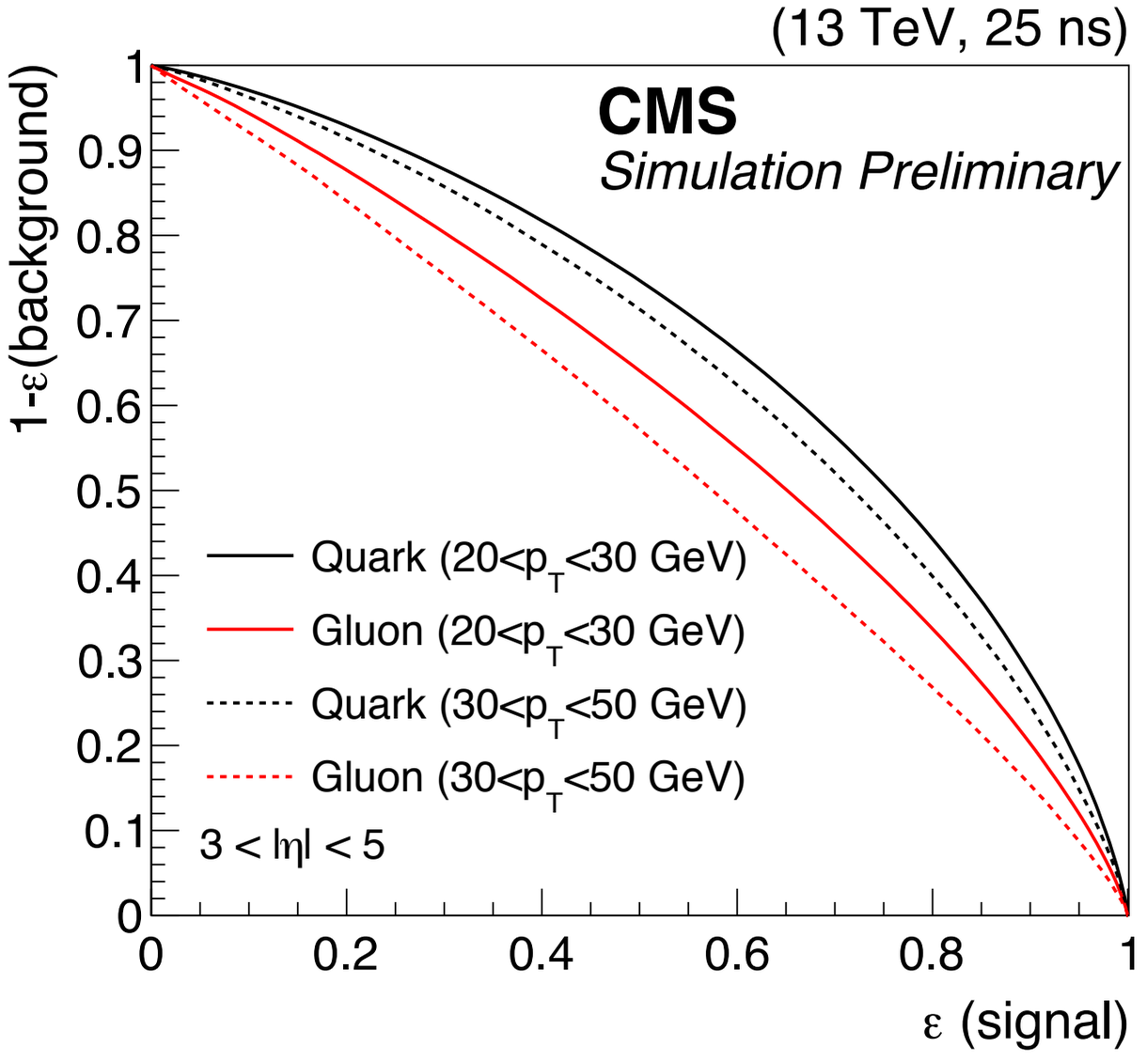
Challenges: Quark/gluon tagging



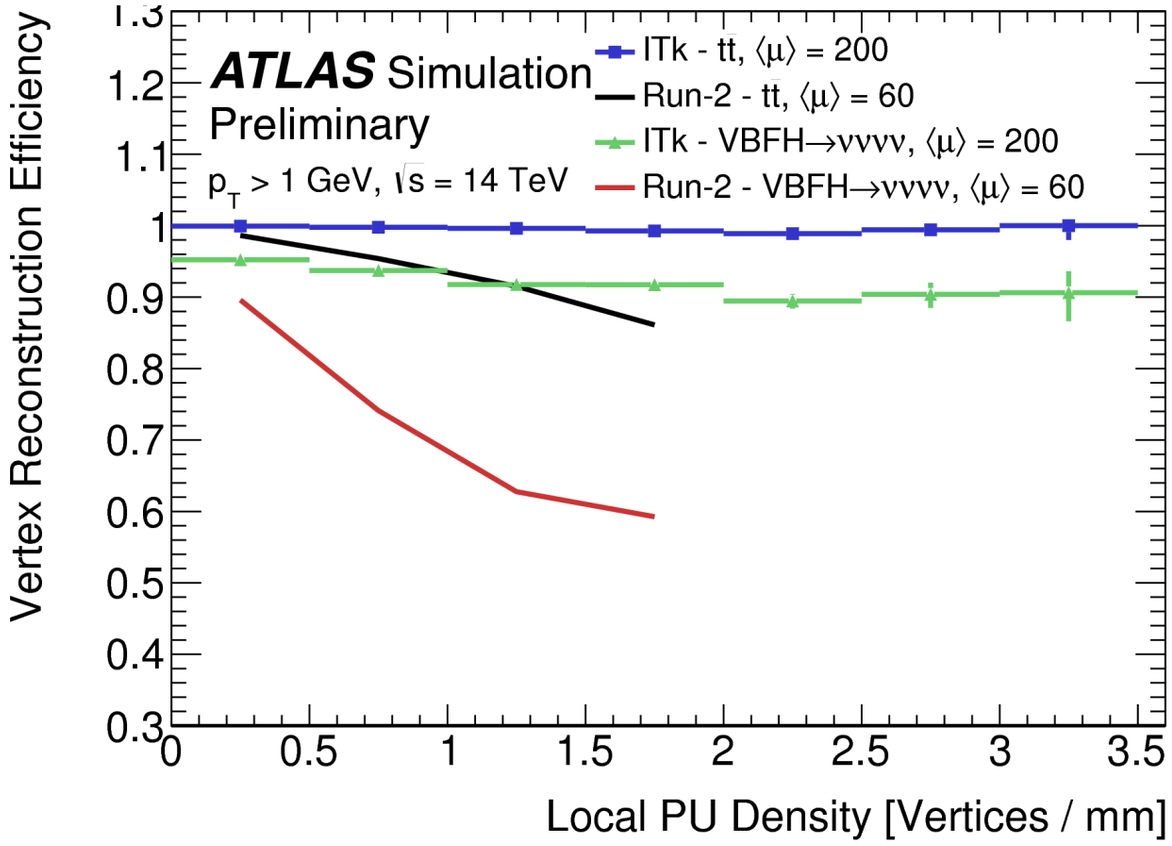
Interplay with PU jet tagging - gluon jets are easier to distinguish than quark jets as PU/HS

VBF jets are quark-initiated.

Forward QCD Z+jets are a mix of quarks and gluons.



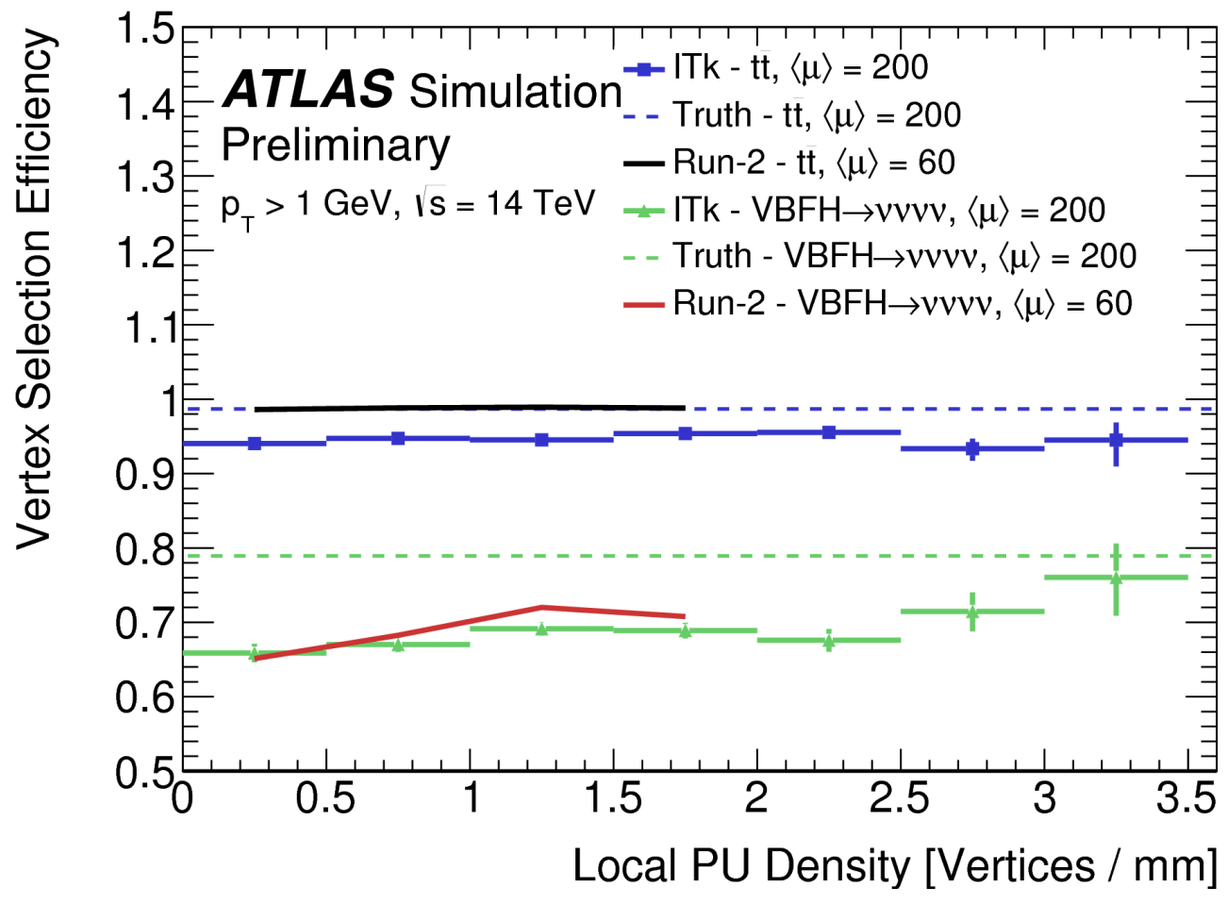
Challenges: Vertexing



Finding the correct vertex is a challenge in H → MET events.

With the wrong vertex, may label HS jets as PU.

Algorithmic improvements possible - also benefit from extended tracker coverage.



Challenges: Systematic Uncertainties

CMS, JHEP 02 (2017) 135

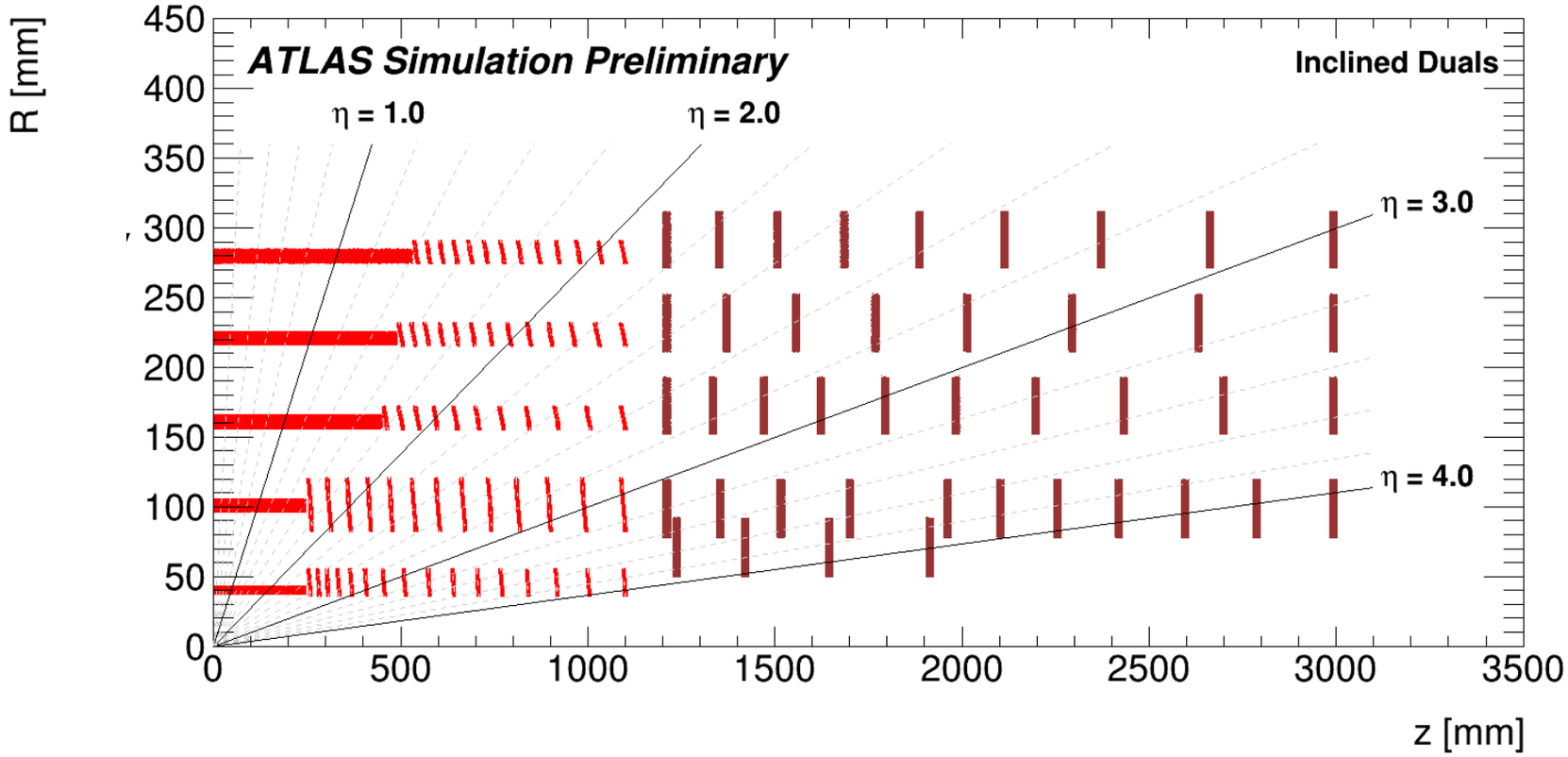
Systematic uncertainty	Impact
Common	
W to Z ratio in QCD produced V+jets	13%
W to Z ratio in EW produced V+jets	6.3%
Jet energy scale and resolution	6.0%
QCD multijet normalisation	4.3%
Pileup mismodelling	4.2%
Lepton efficiencies	2.5%
Integrated luminosity	2.2%
Signal specific	
ggH acceptance	3.8%
Renorm. and fact. scales and PDF (qqH)	1.8%
Renorm. and fact. scales and PDF (ggH)	$<0.2\%$
Total systematic	$^{+15}_{-19}\%$
Total statistical only	$^{+28}_{-27}\%$
Total uncertainty	$^{+32}_{-33}\%$

W/Z cross-section ratio is a significant source of uncertainty.

Can contain with leptonic Z decays, but stats are poor.

Theory input here could make a significant impact on results!

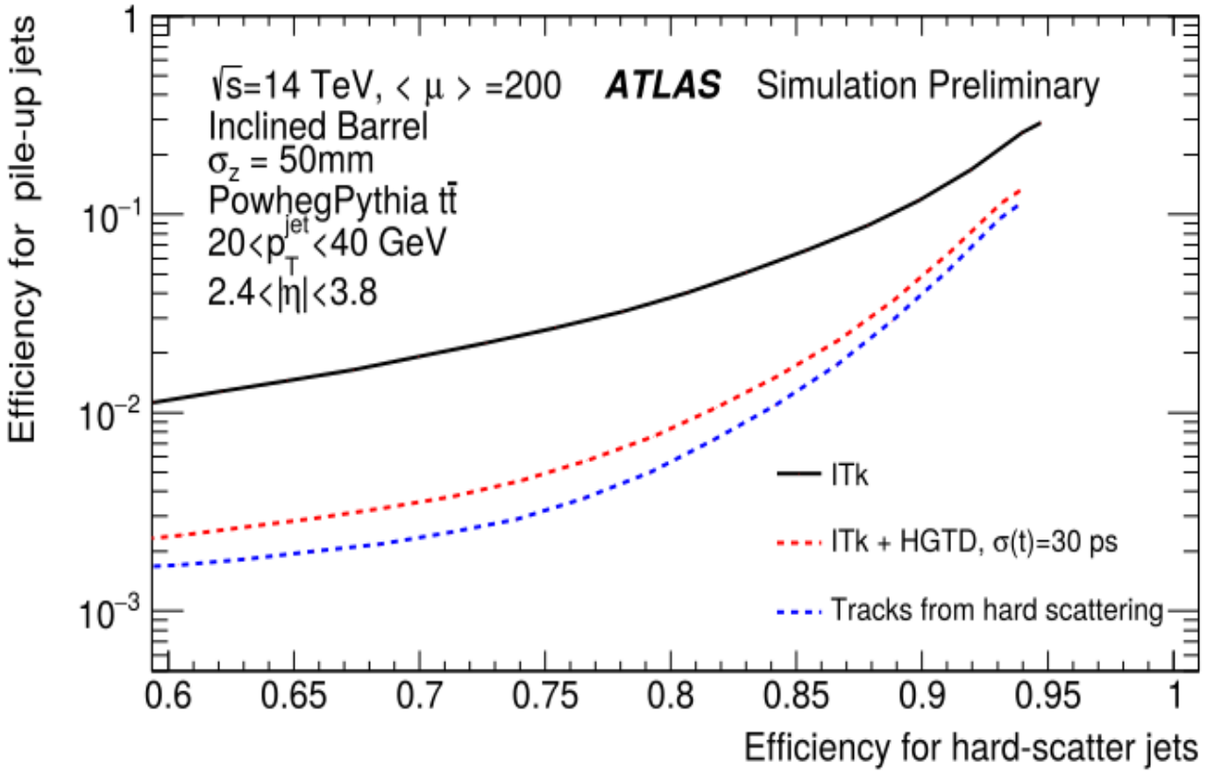
Opportunities - Extended Trackers



- Helps with lepton rejection ($W \rightarrow l\nu$)
- Improves forward jet calibration
- Improves forward jet PU/qg tagging

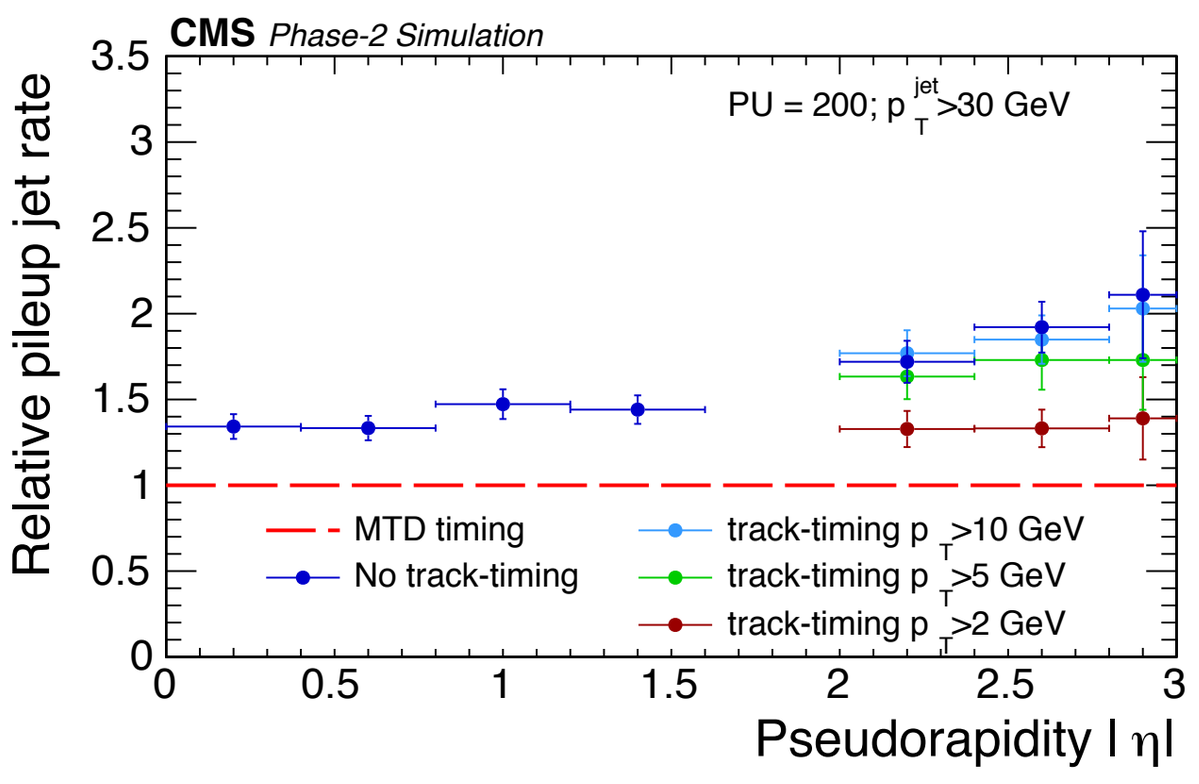
Likely that algorithms will need re-optimization to account for worse resolution at high $|z|$.

Opportunities - Timing



Both ATLAS and CMS are planning on including MIP timing detectors.

These detectors have a lot of promise for rejecting pileup, improving vertexing, etc.

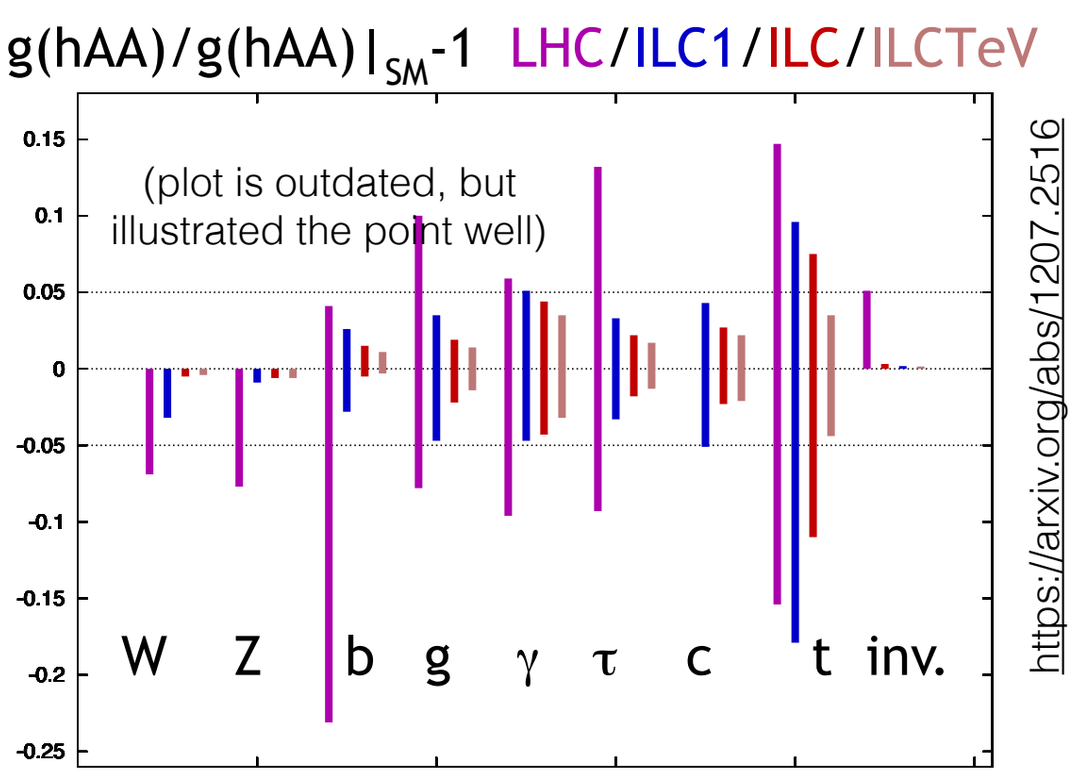


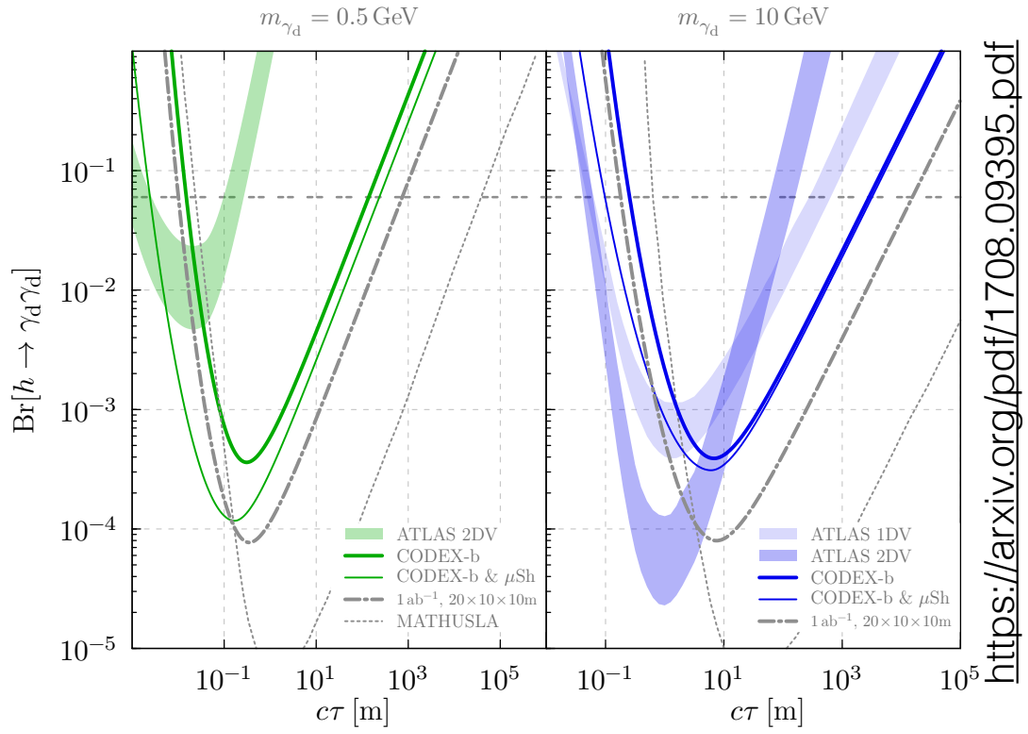
see also https://arxiv.org/pdf/1805.05957.pdf

Conclusions and Outlook

BR(H → MET) will be a key measurement from the full HL/HE-LHC program that will benefit from the full dataset and upgraded detectors.

…at the same time, we should strongly support other proposals to enhance / complement LHC sensitivity.





see also MATHUSLA:
https://arxiv.org/abs/1606.06298

Questions?