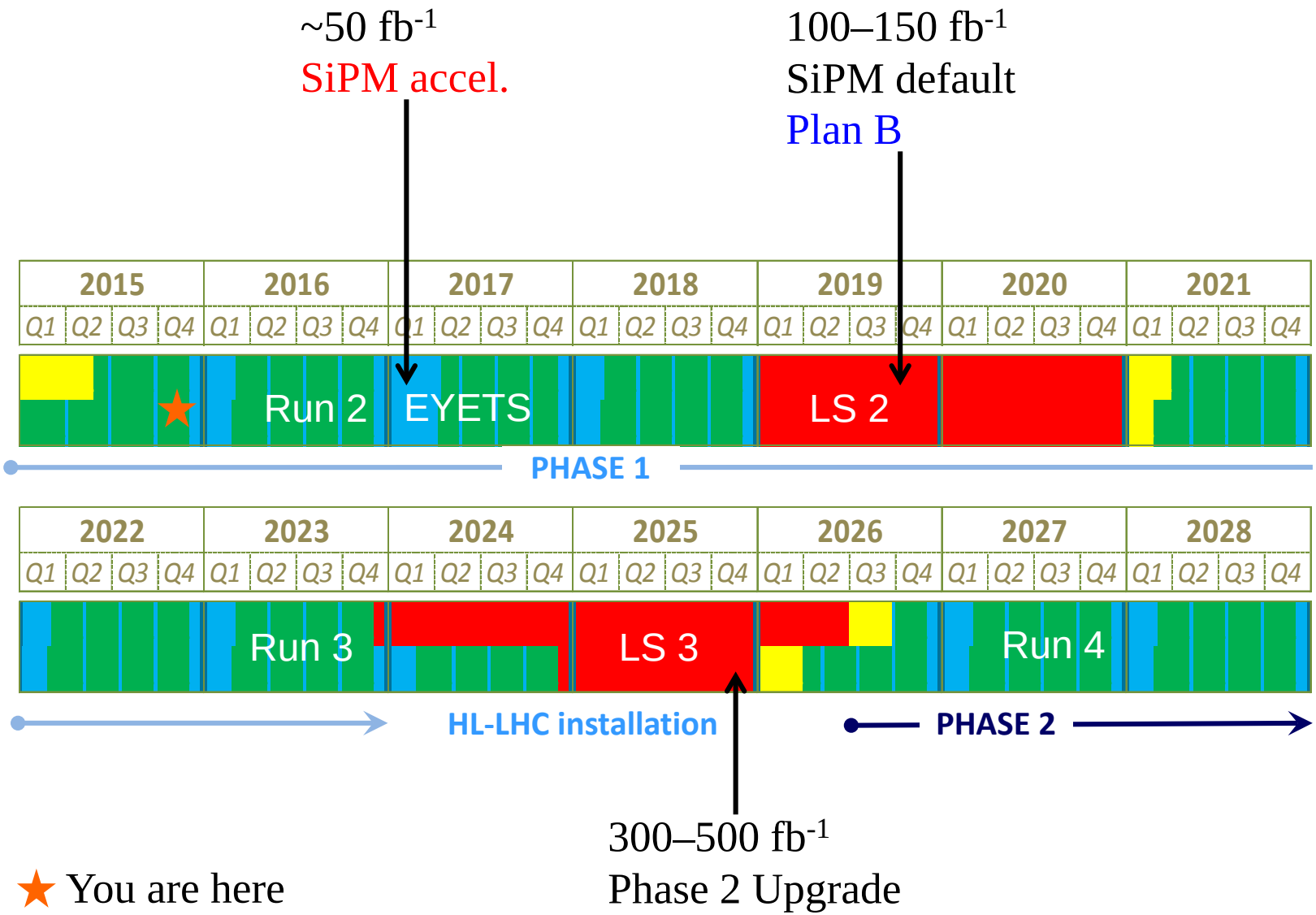
HE PlanB Simulation Report

Kevin Pedro (FNAL)
On behalf of the HE PlanB Simulation Working Group
December 3, 2015

Timeline



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Configurations

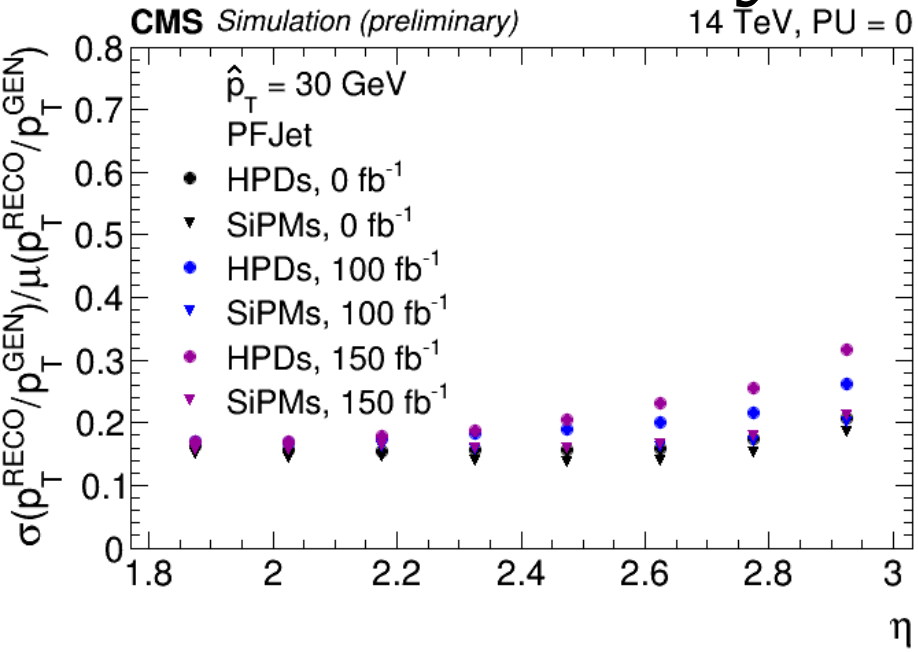
Aging conditions	HPDs 2017 ECAL aging HE aging	SiPMs 2019 ECAL aging HE aging	Plan B (w/ SiPMs) 2019 ECAL aging HE unaged
0 fb^{-1}			
100 fb^{-1}			
150 fb^{-1}			
300 fb^{-1}			
500 fb^{-1}			

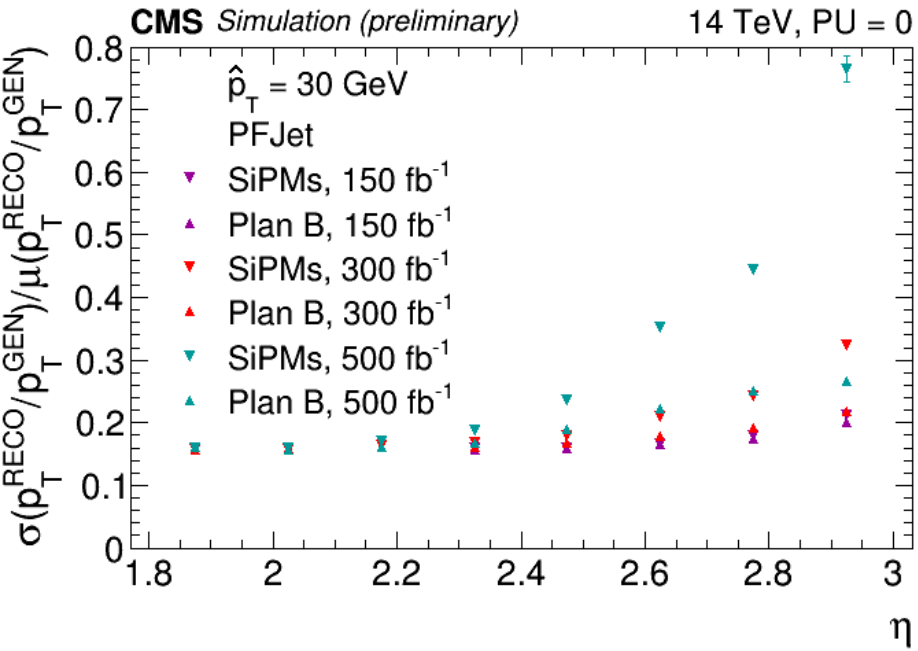
- Red: input to SiPM acceleration
- Blue: input to Plan B
- Purple: input to both
- 11 total configurations

List of Studies

- 2013 study with CaloJets:
  Sarah Eno, Kevin Pedro, et. al
  AN-13-268
- Pilot study with privately-produced samples (PFJets):
  Kevin Pedro
  https://indico.cern.ch/event/387707/contribution/6/attachments/774649/1062393/he_raddam_study_dpg.pdf
- Private study with QCD & VBF Higgs (50PU, PFCHSJets):
  Adel Terkulov
- JetMET studies with centrally-produced samples at 50PU (PUPPI):
  Andrea Delgado, Taylor Whitehead, Zhenbin Wu
  Jets:
  http://people.physics.tamu.edu/delgado_andrea/CMS_upgrade/index.php?path=HEAging_JetPerformance/
  MET:
  https://app.box.com/s/0w0eq8tu7gmiab447d96nw8g1lywkxmd
- VBF Higgs study with centrally-produced samples:
  Phil Dudero, Aram Apyan
  https://www.dropbox.com/sh/ctjnger2omeeiy4/AAAfBskeA1zFgNaxB-qT9lNaa?dl=0
- Recent status report for all 2015 studies:
  Kevin Pedro, et. al
  https://indico.cern.ch/event/459487/contribution/2/attachments/1185971/1719370/he_raddam_study_status_nov_12.pdf

Pilot Study: PFJet Resolution





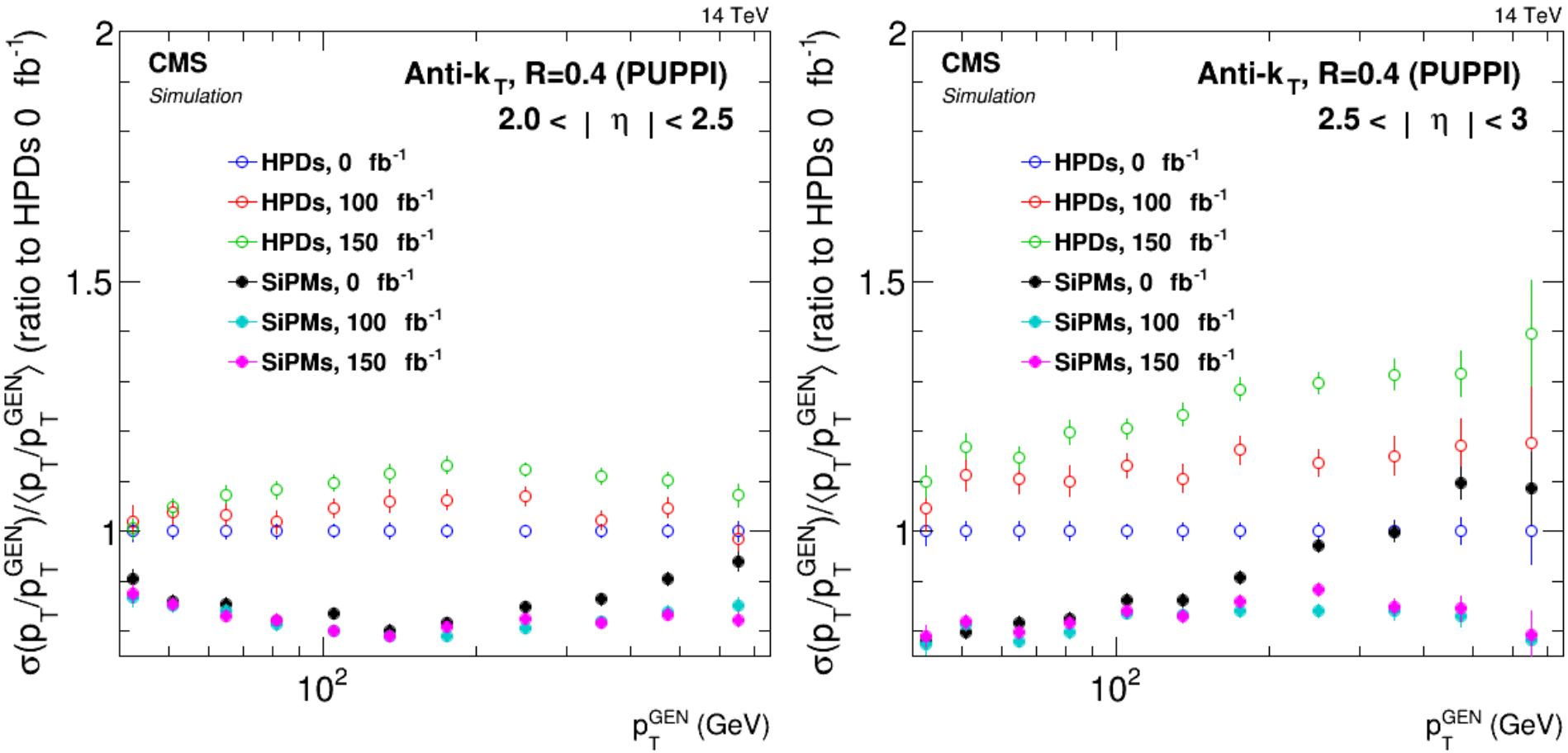
SiPM acceleration:

- HPD PFJet resolution stable for $\eta < 2.5$
- HPD PFJet resolution for $\eta > 2.5$ degrades:
  ~20-30% after 100 fb^{-1}
  ~30-60% after 150 fb^{-1}
- SiPM PFJet resolution shows almost zero degradation for all η after 150 fb^{-1}

Plan B:

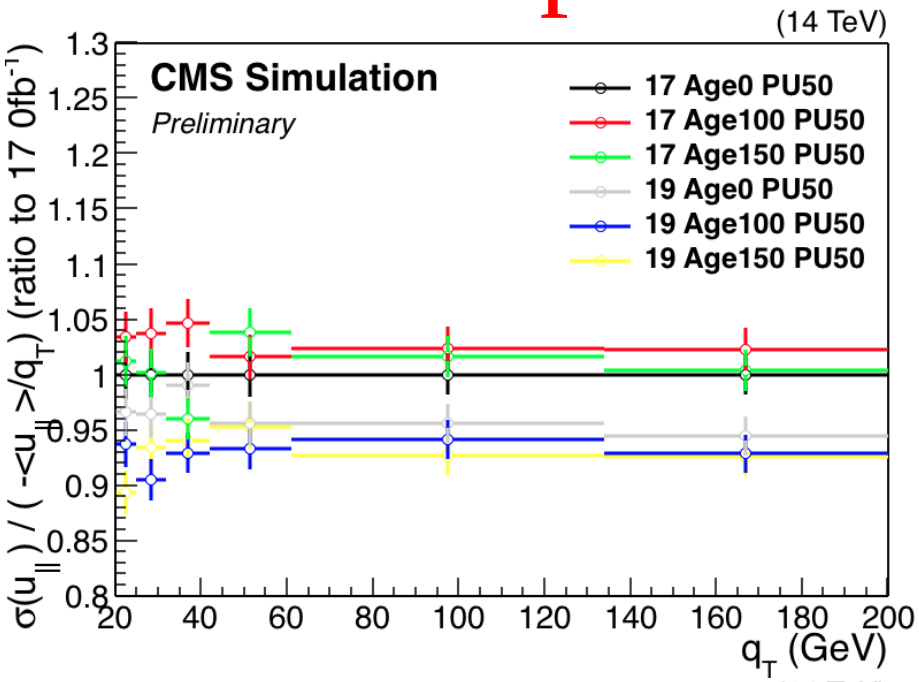
- SiPM PFJet resolution stable for $\eta < 2.5$
- SiPM PFJet resolution for $\eta > 2.5$ degrades:
  ~15-60% after 300 fb^{-1} (~ HPDs @ 150 fb^{-1})
  ~50-300% after 500 fb^{-1} (extreme loss)
- Plan B handles degradation through 500 fb^{-1} very well (by design)

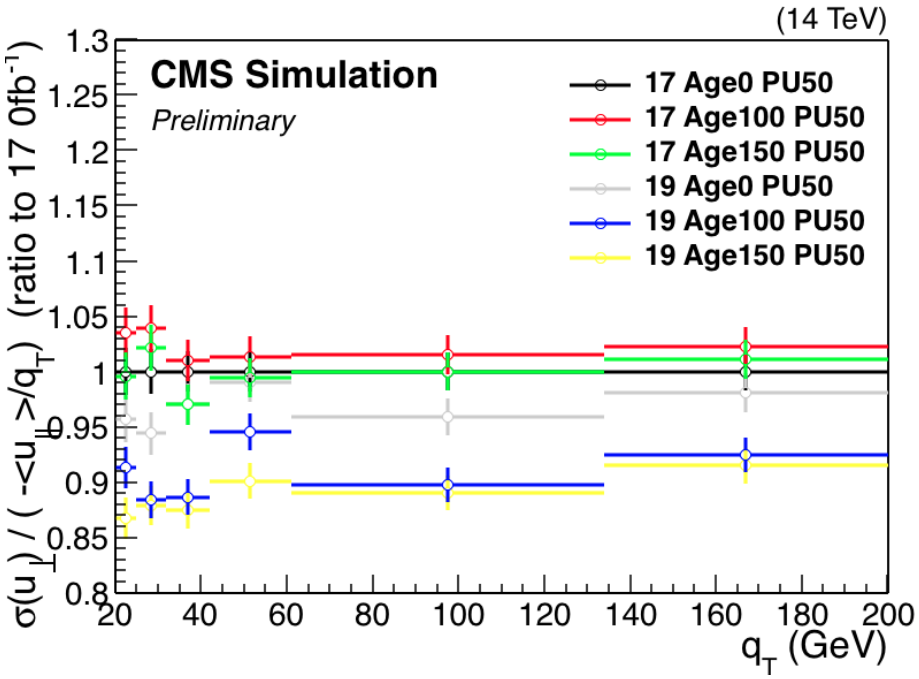
Jet Resolution Ratio vs. p_T

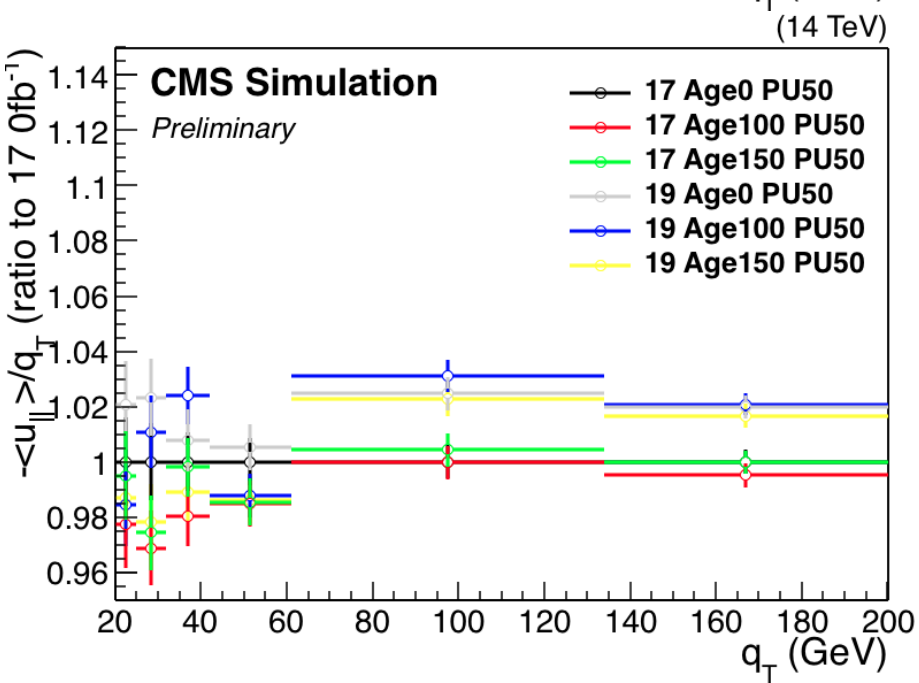


- Radiation damage effects more severe at higher η
- SiPMs provide significant improvement (up to ~30% better resolution)

MET Response & Resolution Ratios

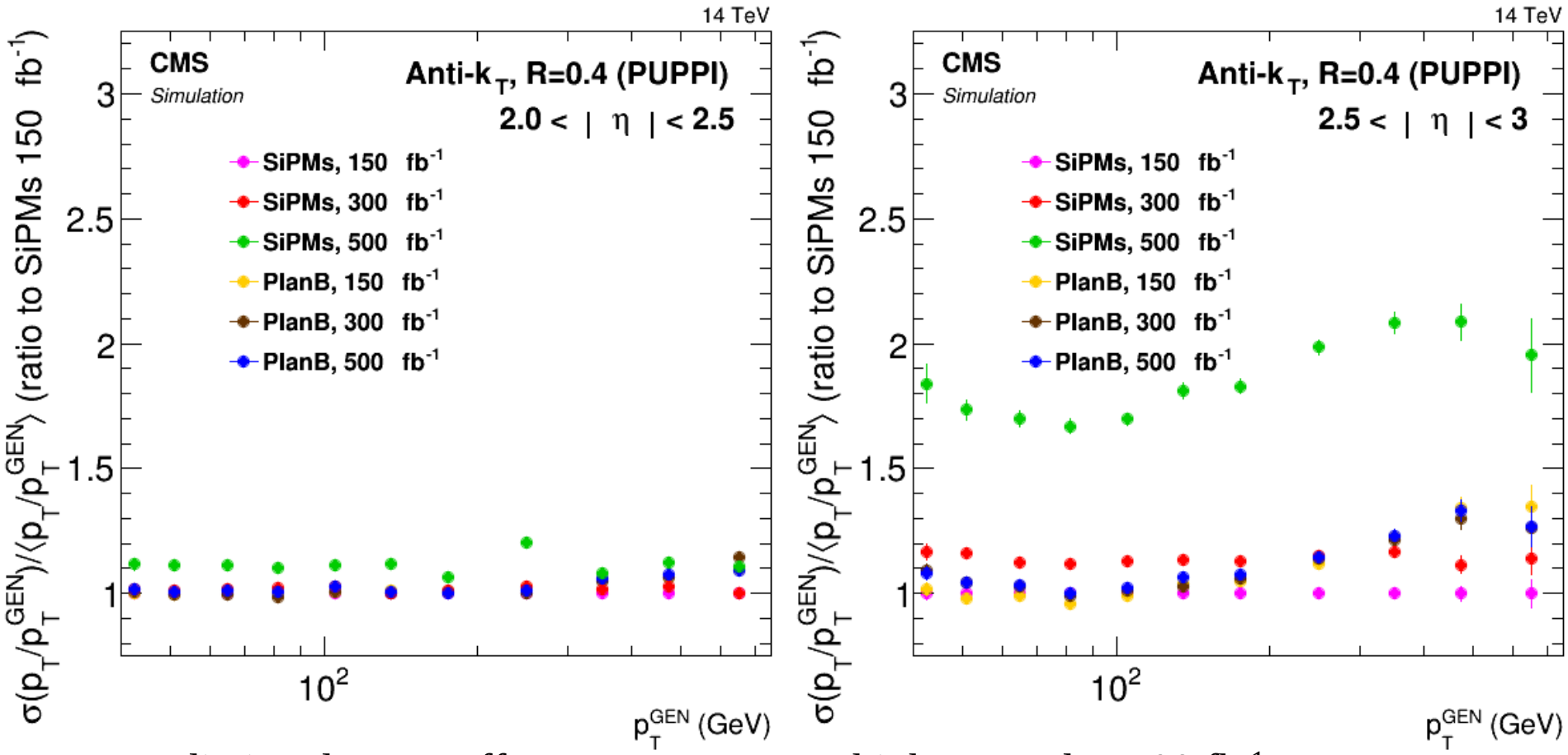






- Better response and resolution for SiPMs (vs. HPDs)

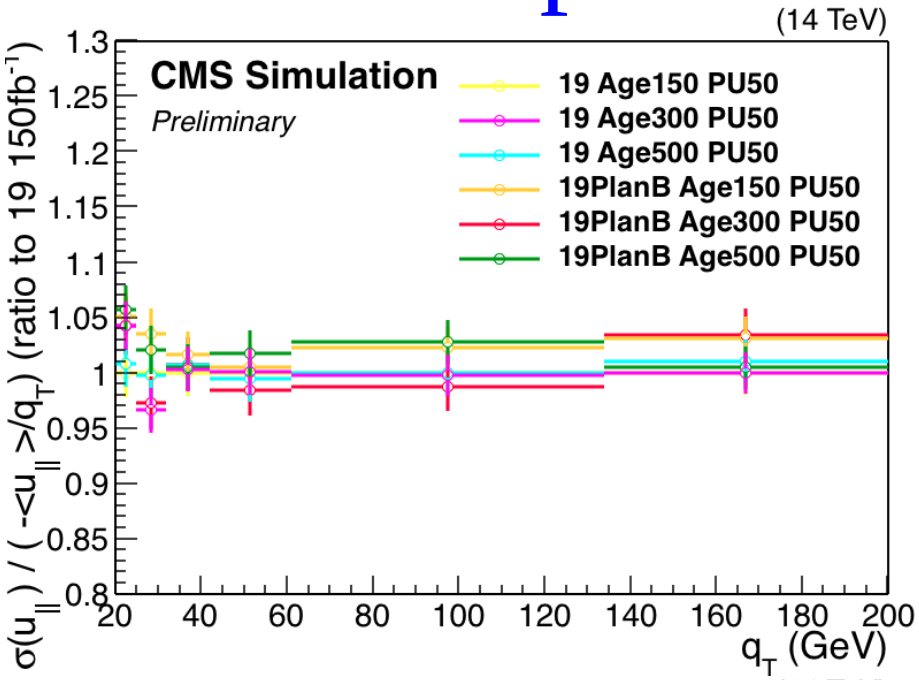
Jet Resolution Ratio vs. p_T

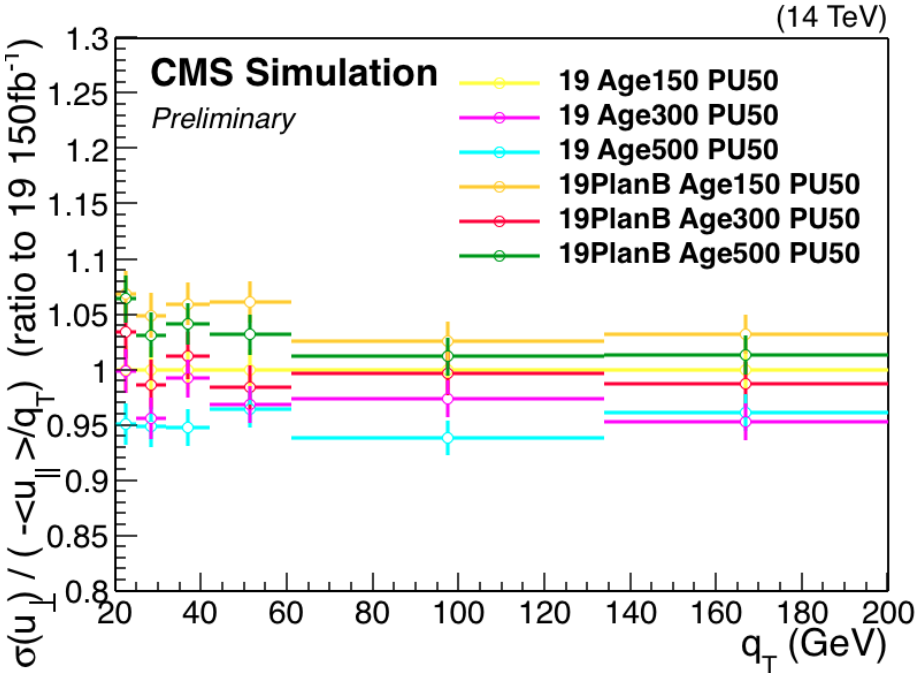


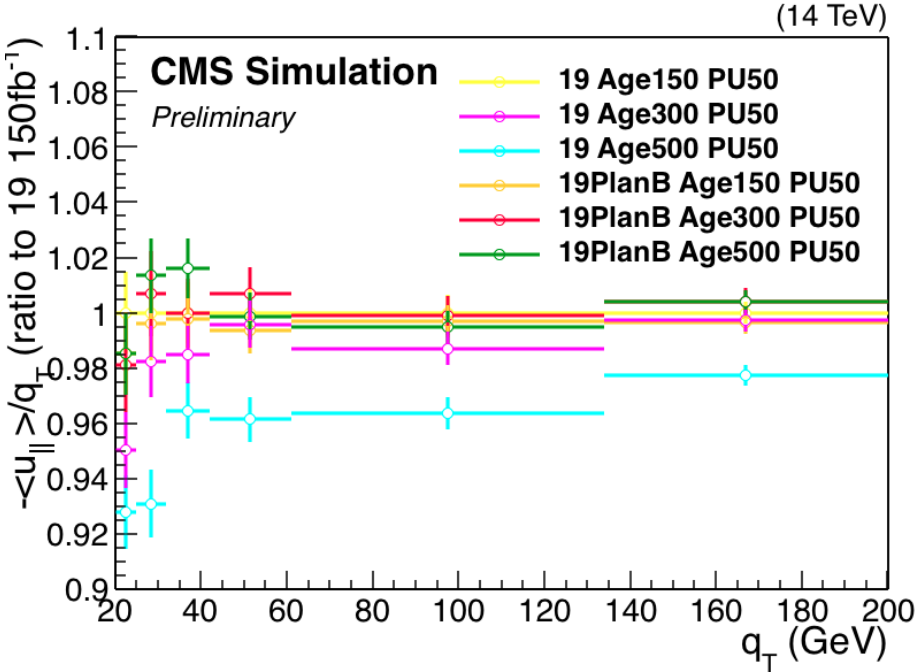
- Radiation damage effects more severe at higher η and at 500 fb^{-1}

- Degradation at 300 fb^{-1} understated – significant variation within the range $2.5 < |\eta| < 3.0$

MET Response & Resolution Ratios

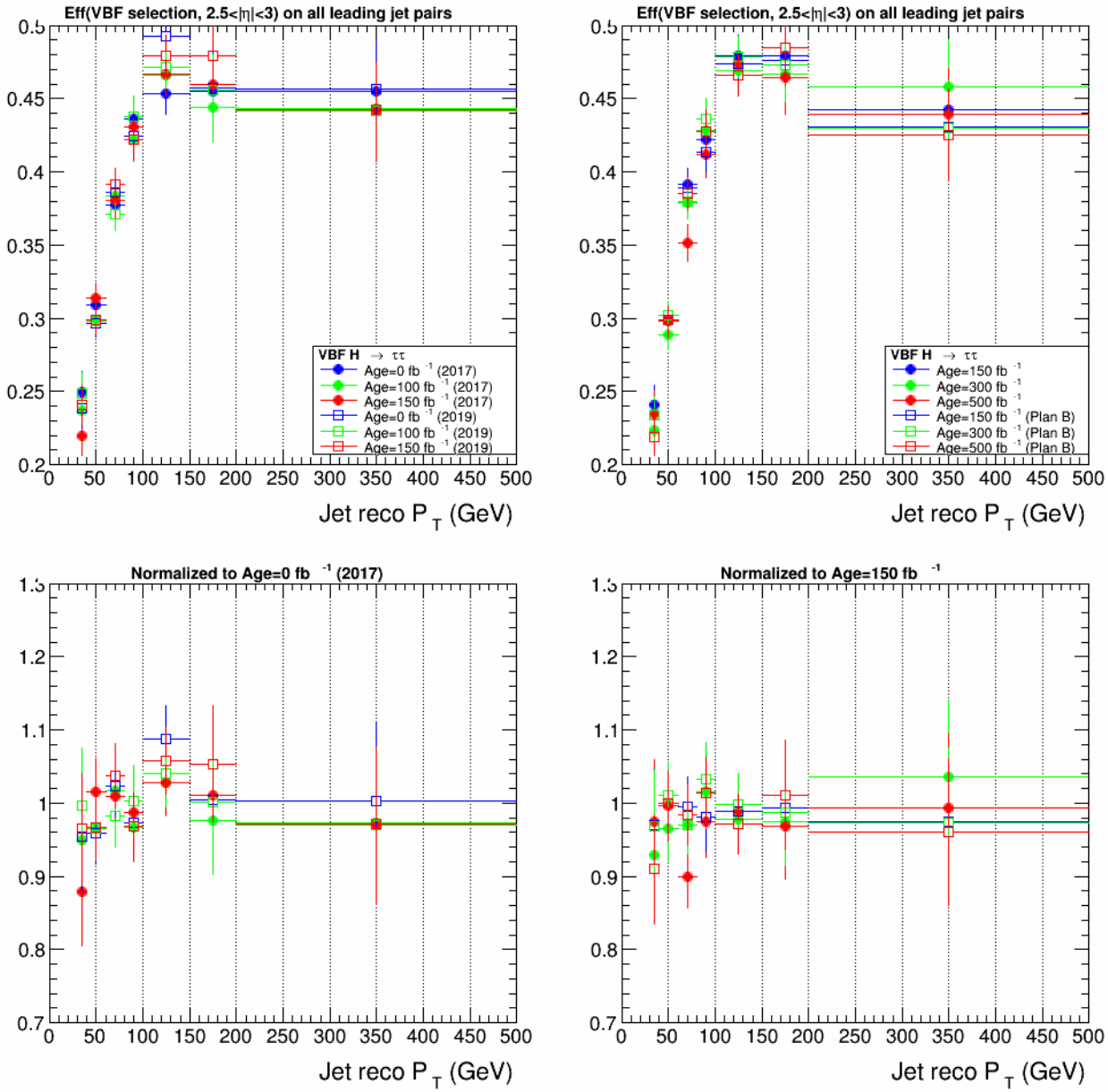






- Better response with PlanB
- PlanB does not improve resolution
- Investigation is ongoing

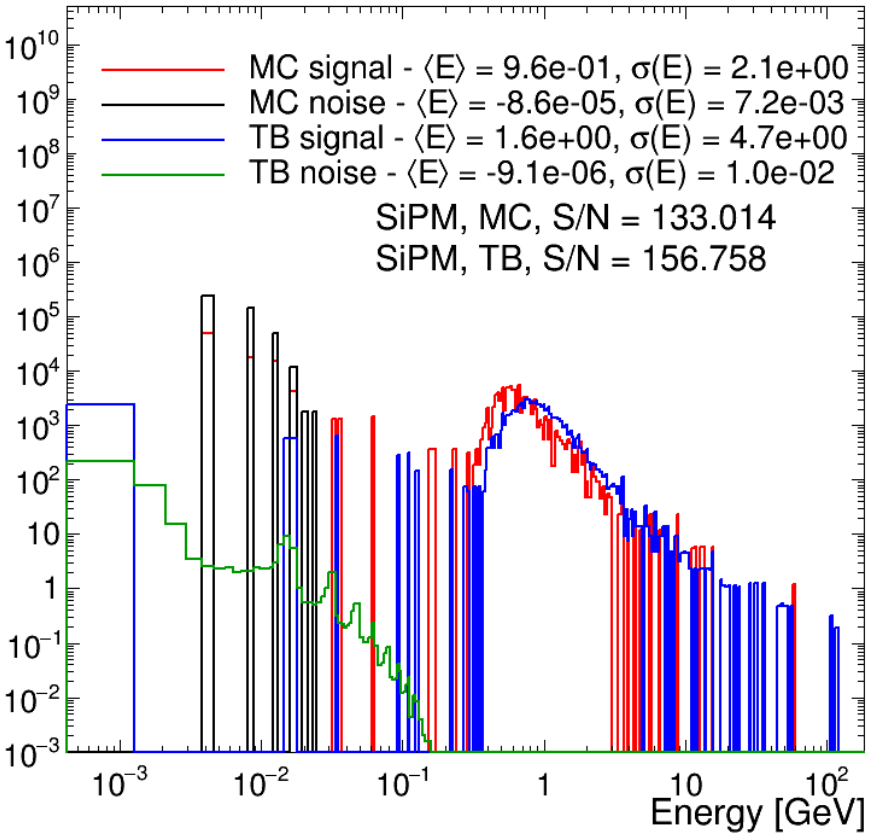
VBF Efficiency, high η (all jets)



Aging Studies: Continuing Work

- VBF study limited by statistical precision – hard to draw solid conclusions
- Larger samples (1M events) have been requested and injected
  needed to extend LHE as well as GEN-SIM (and then DIGI-RECO)
  now caught in the middle of the Run2 re-reco campaign
- Also interested in comparing $S/\sqrt{(B)}$ for the different scenarios, in various regions: $2.5 < \eta < 3.0$ (worst aging), $2.0 < \eta < 2.5$ (comparison), all η
- Consideration of HE PlanB aging:
  - Suggestion was made to redo studies with HE PlanB aging taken as current aging with an offset for installation at 150 fb^{-1} (worst case)
  - This comparison can be effectively made now: use the SiPM low-lumi samples (radiation damage to SiPMs is a smaller effect)
- Following up on comments from the Upgrade Studies group
- Eventually, will collect and document all findings in a concise AN
- Thanks to everyone for the impressive effort in these studies!

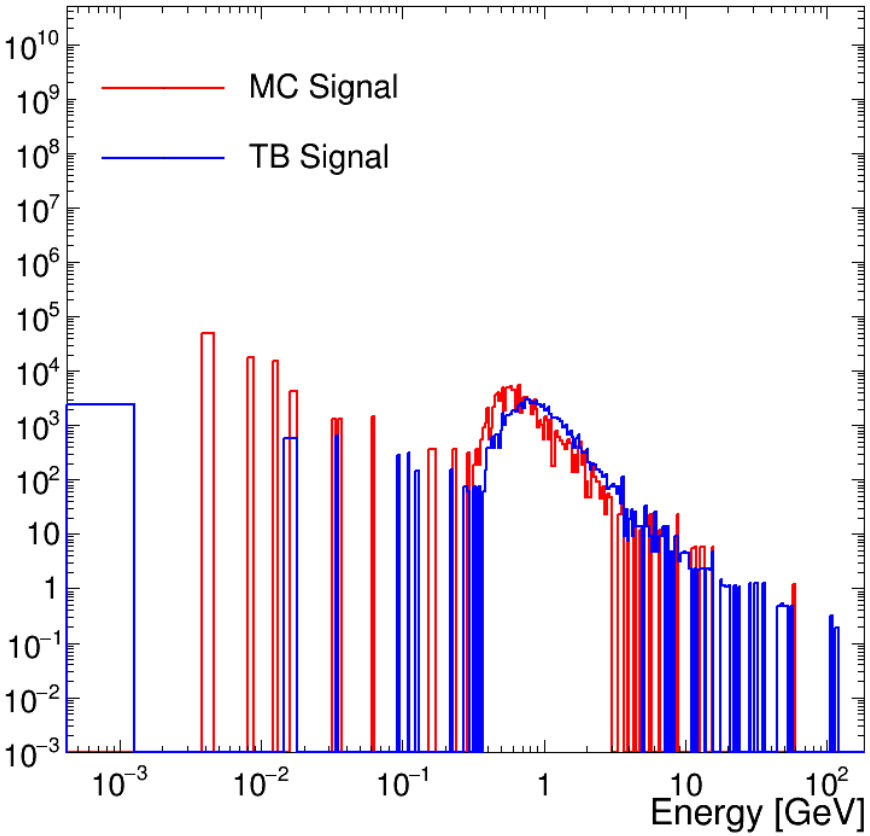
SiPM MC vs. TB

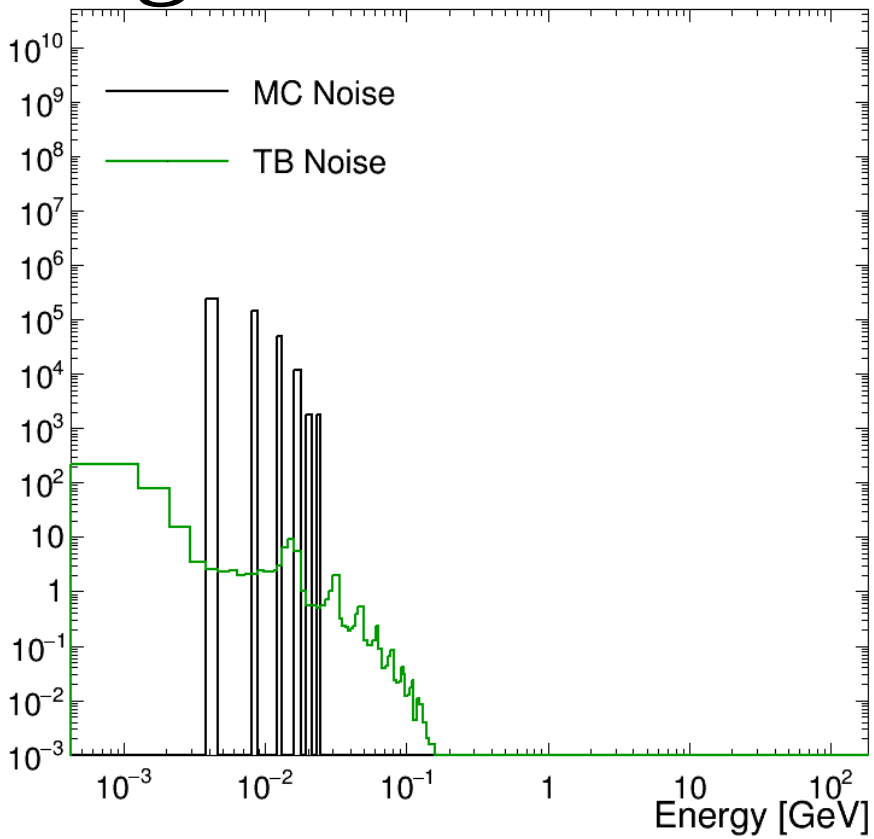


Quantity	MC	TB
fC/GeV	900	3742.19
fC/pe	10	60.30
pe/GeV	90	62.06

- fC-related values for MC and TB very different
- But similarity in underlying physical quantity pe/GeV and in S/N value
- Thanks to Joe Pastika for working with the TB data to make a good comparison to the MC
- NB: TB values are for the no-shunt case

SiPM MC vs. TB: Signal & Noise

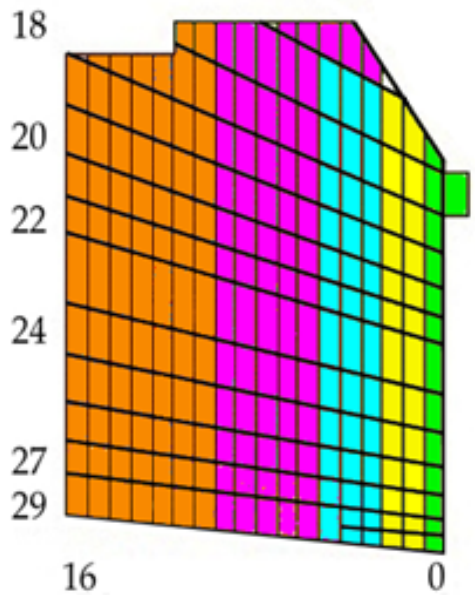




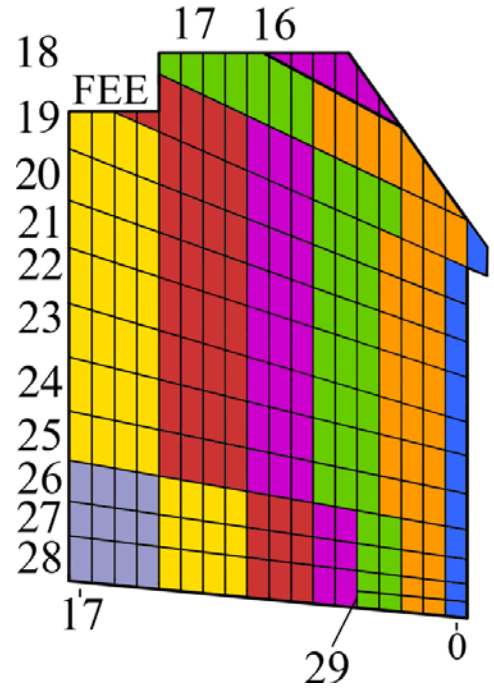
- Signal distributions are fairly similar
- Noise distributions differ:
  TB data contains both pedestal and single-pe noise
  MC does not contain single-pe noise
  Should it be parameterized and added to the simulation?
- Baylor students working on deriving TB pedestal and pedestal width values

Depth Segmentation

CMSSW_6_2_X_SLHC



New recommendation



New recommendation enables consistent replacement of layers 1–6 or 1–9

(neutral density filters can be used for layers 7–9 in tower 17, where damage is minimal)

Conclusions

- Aging studies for physics objects (jets, MET) are in good shape
- Aging studies for physics case (VBF Higgs) are ongoing, awaiting larger samples to be more conclusive
- SiPM MC/TB comparisons are making progress
- Need to consider uncertainties in aging model and recalibration methods/capabilities to understand the case for PlanB

Backup

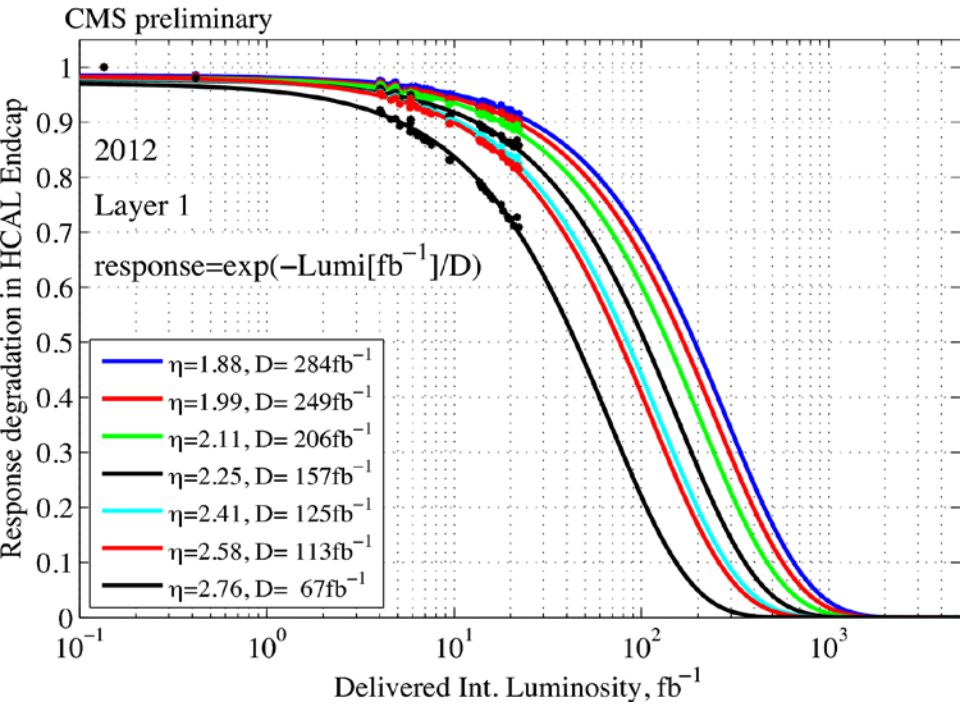
Program of Aging Studies

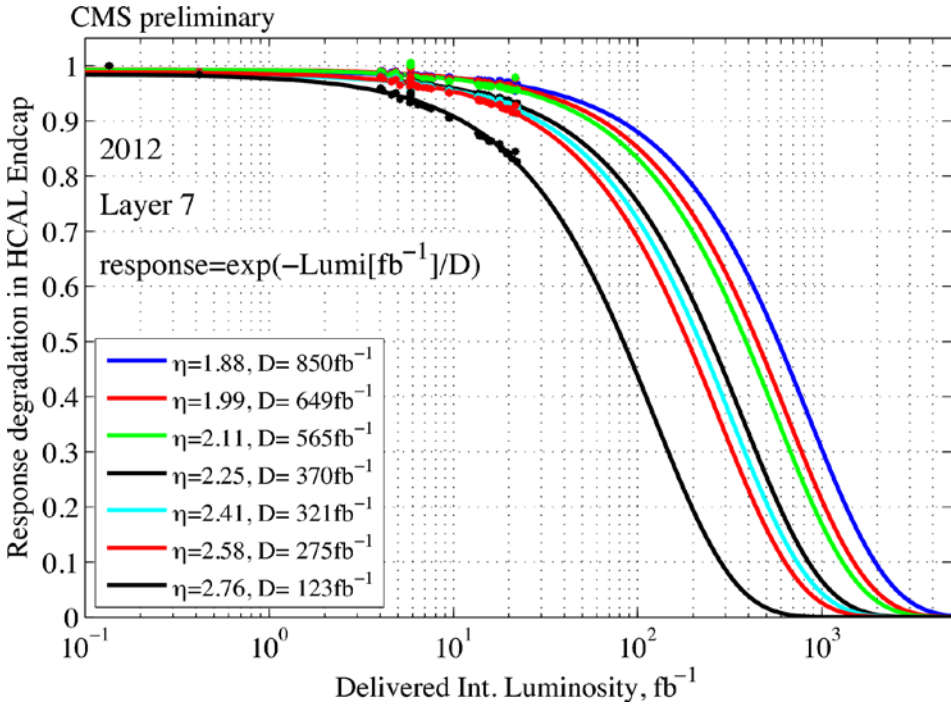
- Simulate physics performance for important processes, using various aging conditions
- Vary the chosen aging conditions around the benchmark integrated luminosity values defined as the expected end of each LHC run period, in case runs are extended
- List of samples centrally produced:
  - 3M QCD with PU=0 and PU=50
  - 100k VBF Higgs to Invisible PU=50
  - 1M DY to Taus PU=50
  - 1M DY to Muons PU=50
- https://dmytro.web.cern.ch/dmytro/cmsprodmon/requests.php?campaign=Upg2017Summer15DR
- https://dmytro.web.cern.ch/dmytro/cmsprodmon/requests.php?campaign=2019GEMUpg14DR

Subdetector Aging

- Plan B configuration:
  Simulated as unaged HE
- ECAL effective aging used for all samples:
  the ECAL will not be upgraded until LS3 in any scenario, so its aging should be considered
- HF, SiPM aging used for all samples
  (NB: SiPM aging is only applied for $L \geq 200\ fb^{-1}$ because of an offset to account for the installation, originally scheduled at $L = 200\ fb^{-1}$; in any case, it is a small effect compared to HE aging)
- Strip tracker and pixel aging not considered:
  found to be negligible in comparison to calorimeter aging
  (only defined for $L \geq 300\ fb^{-1}$ anyway)

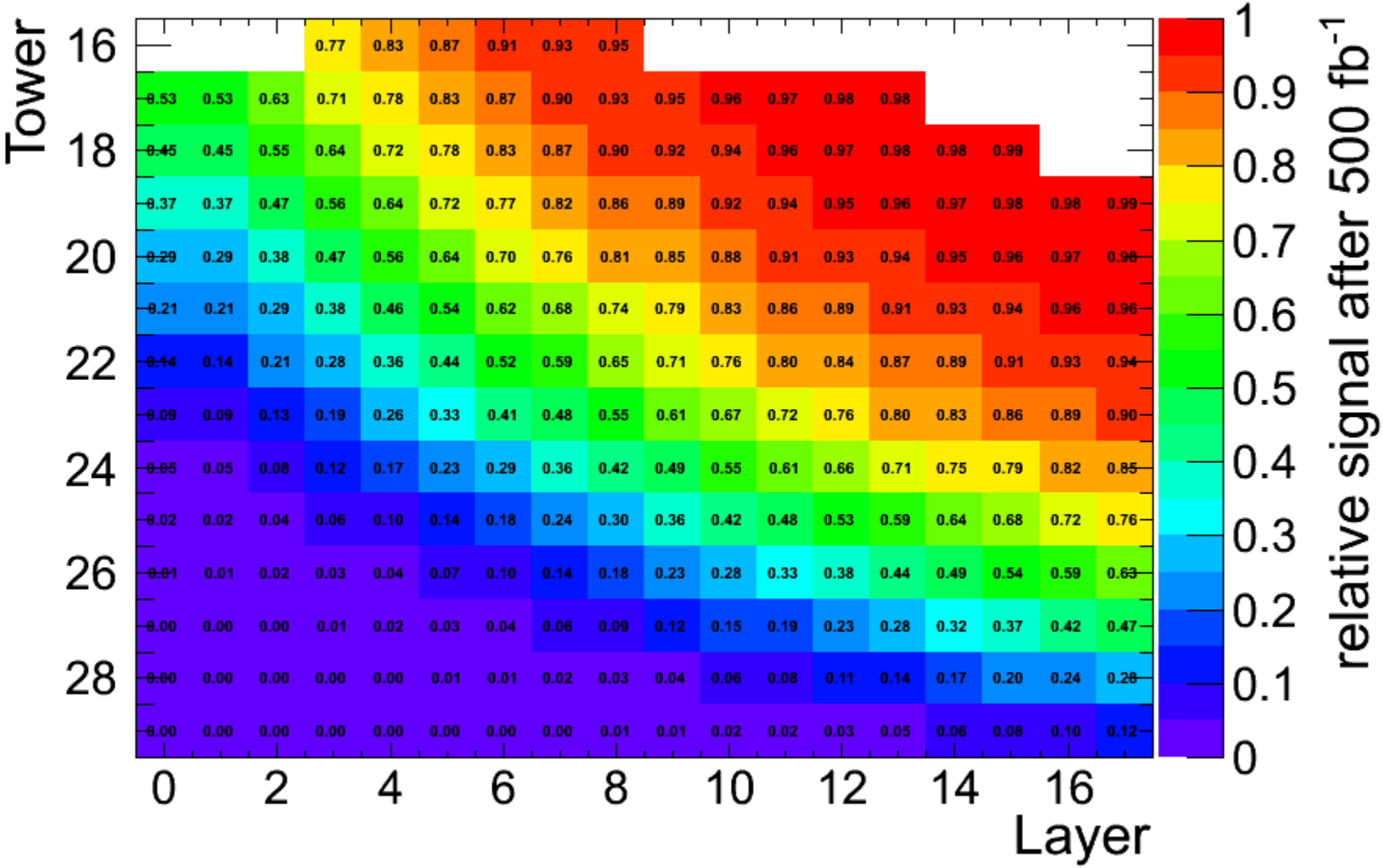
HE Radiation Damage Model





- Extrapolation from first ~30 fb^{-1} from Run 1, using laser calibration data in layers 1 and 7 (Vladimir Epshteyn)
- See AN-14-226 for more details

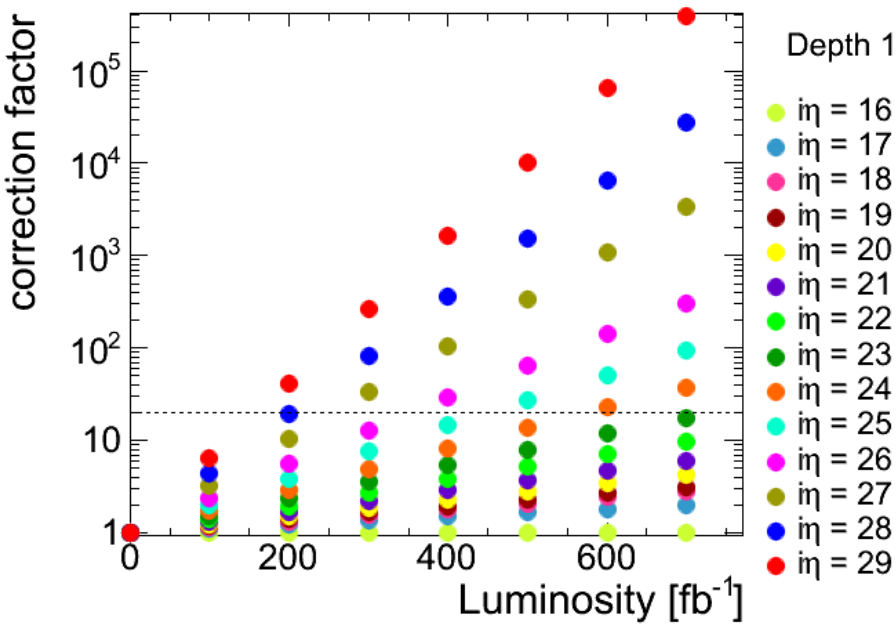
HE Relative Signal after 500 fb^{-1}



Recalibration Factors

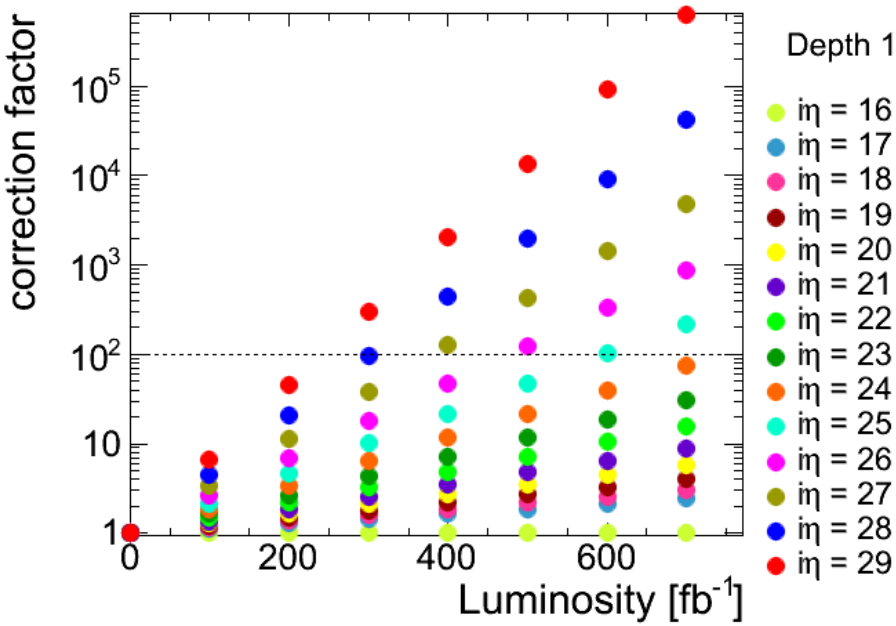
To correct for scintillator darkening, recalibration factors are applied to reconstructed energy. The recalibration is cut off at a certain point to limit the increase in the noise. Because the SiPMs have lower noise than the HPDs (see next slide), they have a higher cutoff and can recover smaller signals.

HPDs



Default cutoff = 20

SiPMs



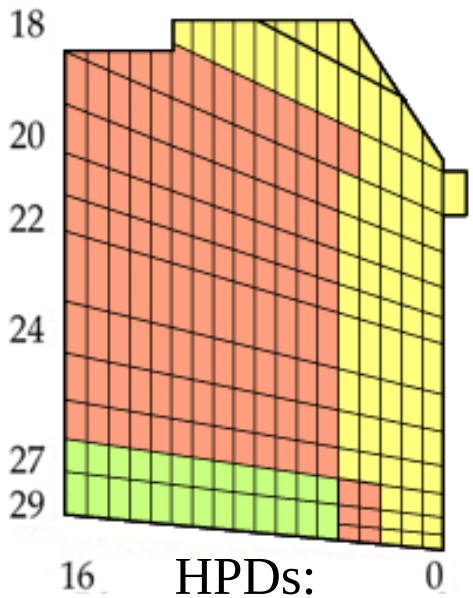
Default cutoff = 100

HE Phase 1 Upgrade

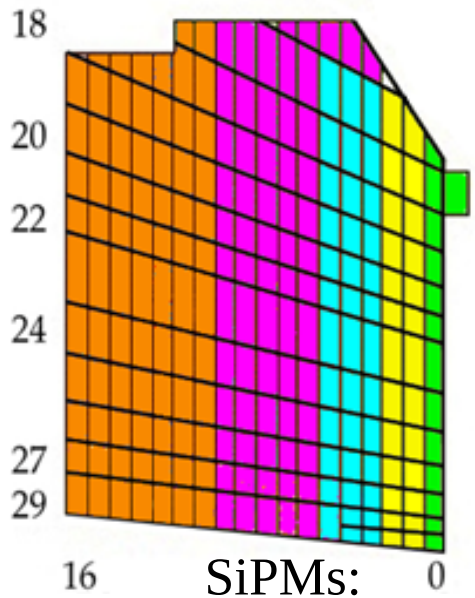
Replace HPDs with **SiPMs** (silicon photomultipliers)

Low noise → measure smaller signals to survive more radiation damage (higher recalibration cutoff)

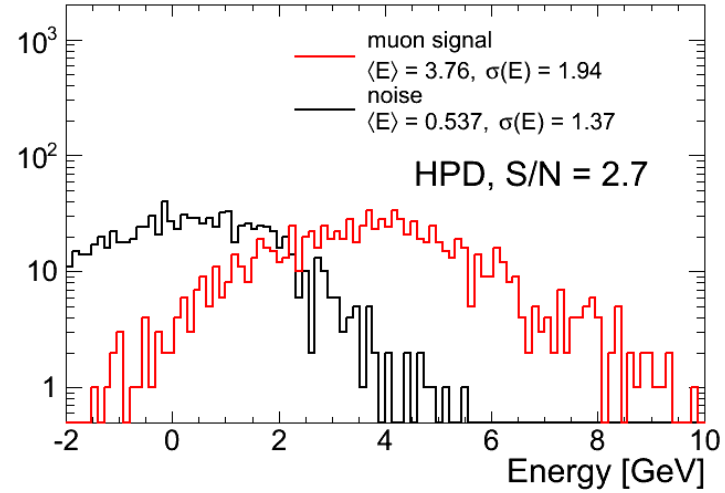
Small size → increase depth segmentation for more precise recalibration (averaging over fewer layers)

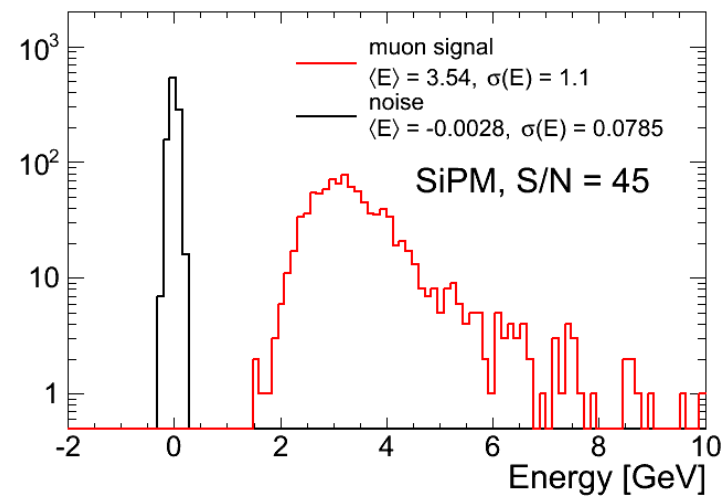


HPDs:
2-3 depths



SiPMs:
5 depths





Sources of Uncertainty for PlanB

1. Recalibration method and cutoff value
   - Current method is in-place: each cell's energy multiplied by a factor based on undarkened expectation for *that cell*
   - Could try a more advanced method, e.g. interpolating from surrounding cells (accounting for worse aging at higher eta and earlier depths)
   - The cutoff value of 1% of SiPMs is an educated guess based on S/N expectations – really needs to be tested in hardware/with up-to-date parameters in the simulation
   - Success of recalibration up to some luminosity depends on extent of aging
2. Amount of integrated luminosity expected before LS3
   - If it's only 300 fb^{-1}, with the current aging model (from 2012), might be able to survive without PlanB

Assumptions are probably optimistic:
more luminosity, worse aging, less recalibration ability
all seem more likely than the alternatives

Pilot Study: Jet Object Performance

- Jet object study underway with privately-produced QCD dijet samples:
  $\hat{p}_T$ = 30 GeV (similar to VBF jets)
  1 jet with $p_T > 10$ GeV and $0.0 < |\eta| < 1.8$ (barrel)
  1 jet with $p_T > 10$ GeV and $1.8 < |\eta| < 3.0$ (endcap)
  ~30% efficiency; ~30,000 events per configuration
  RecoJets (Calo or PF) matched to GenJets in cone dR < 0.3

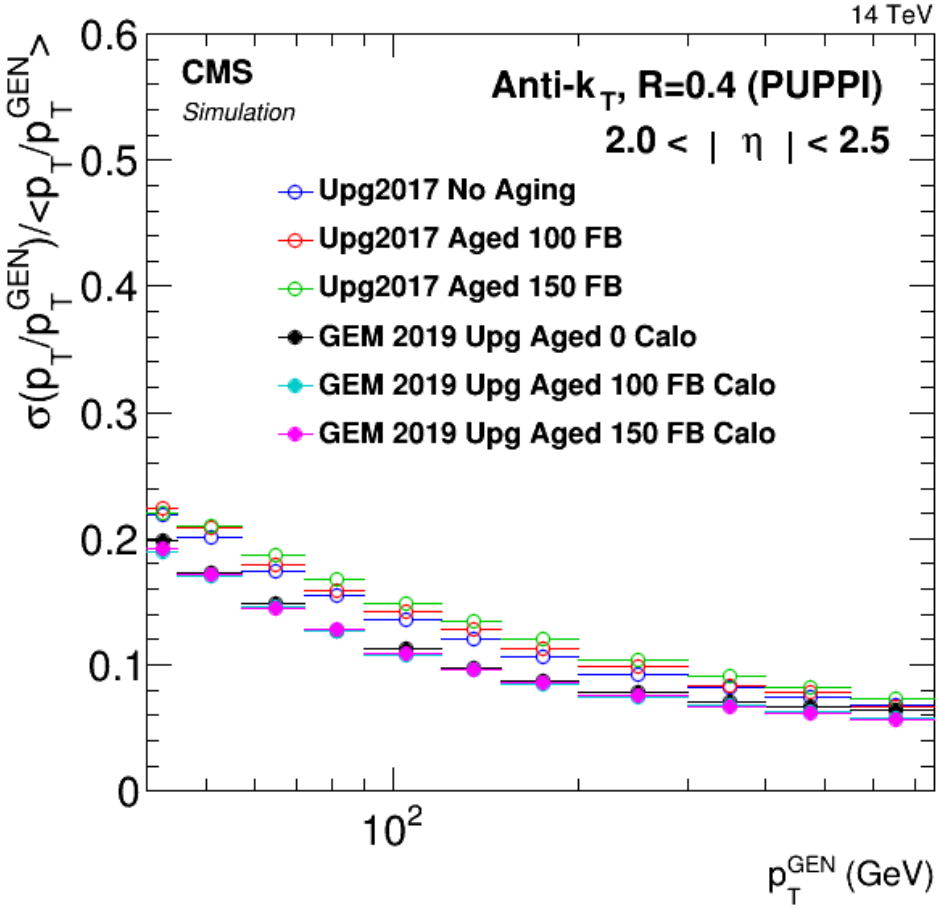
- L2L3 JECs applied
  (thanks to Alexx Perloff for answering my many questions about the JECs)

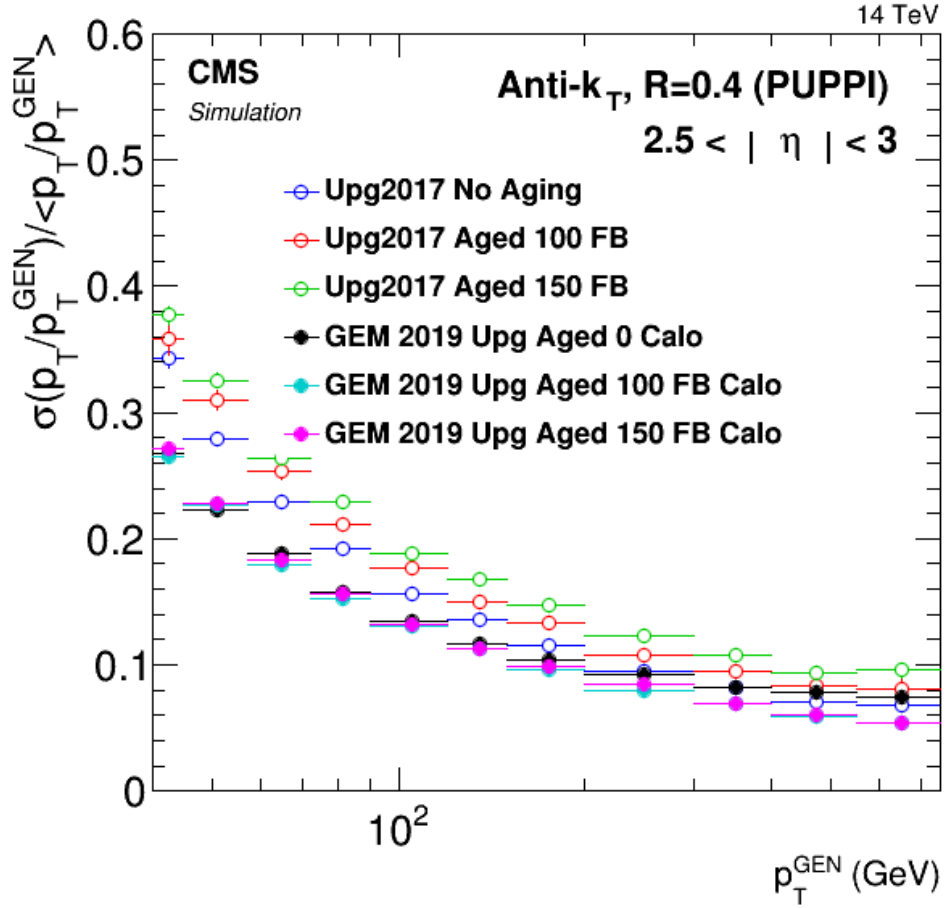
- Corrected samples have been analyzed, results on next slides

- My repository is here: https://github.com/kpedro88/HERadDamJets

- This study builds on previous results by the HE Radiation Damage Jet Team using CaloJets, which are documented in AN-13-268

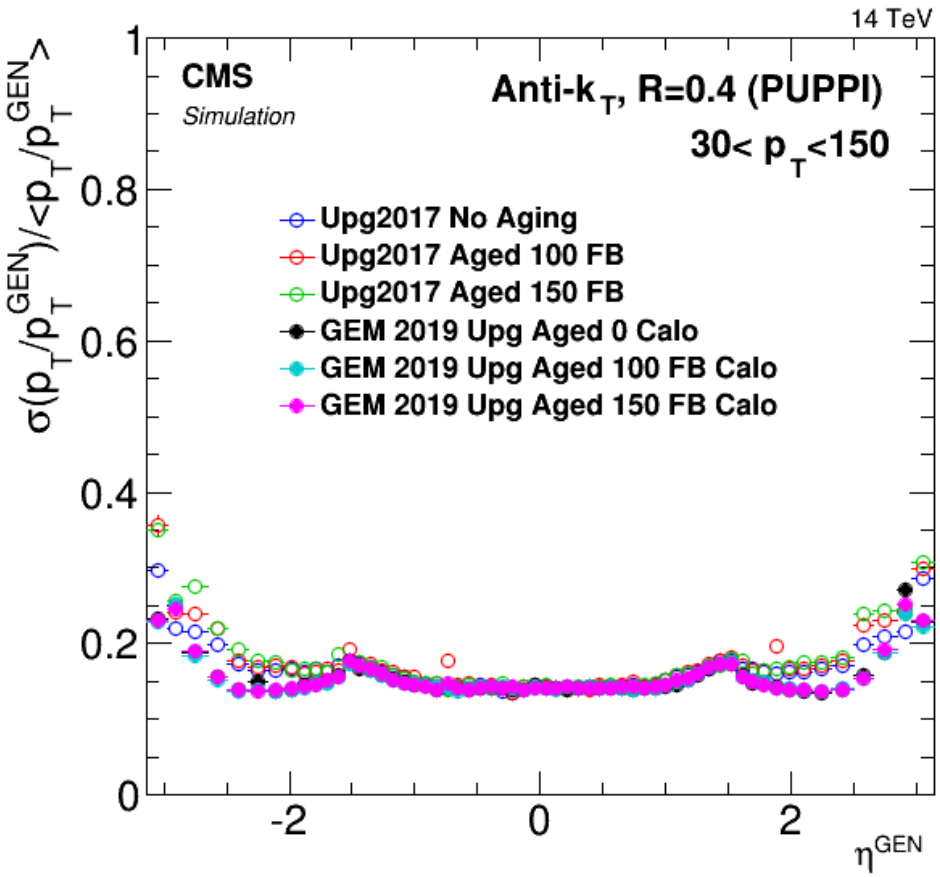
Jet Resolution vs. p_T

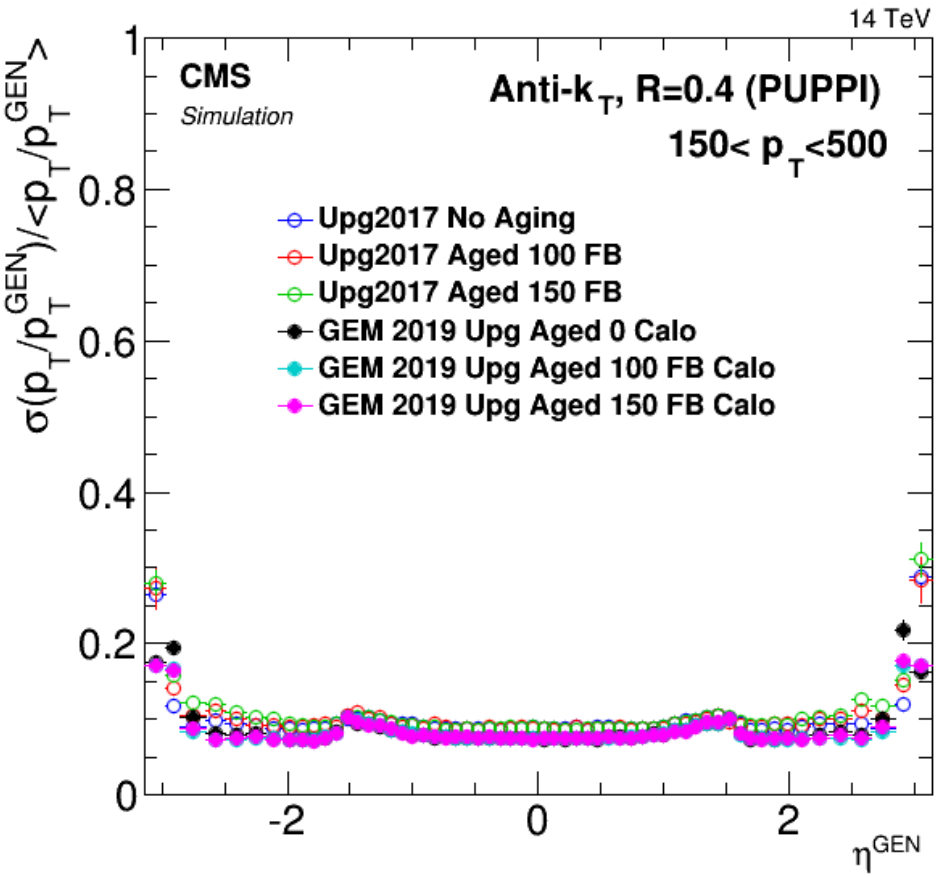




- Radiation damage effects more severe at higher η
- SiPMs provide significant improvement (up to ~30% better resolution)

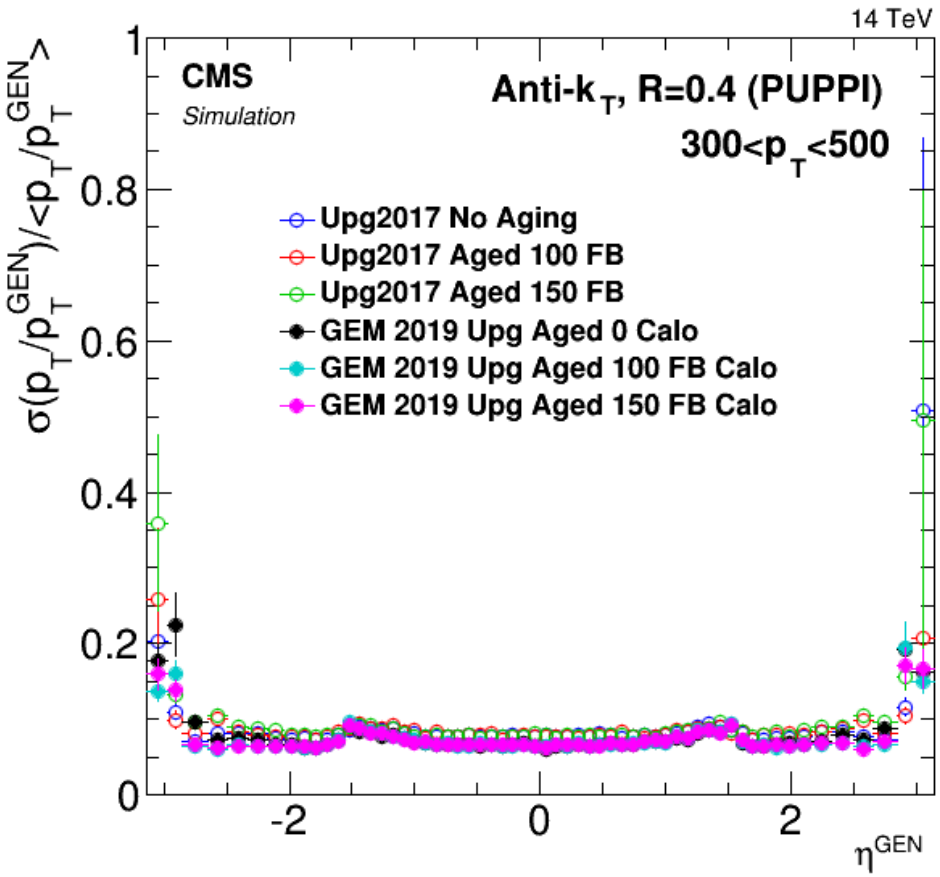
Jet Resolution vs. η (low p_T)

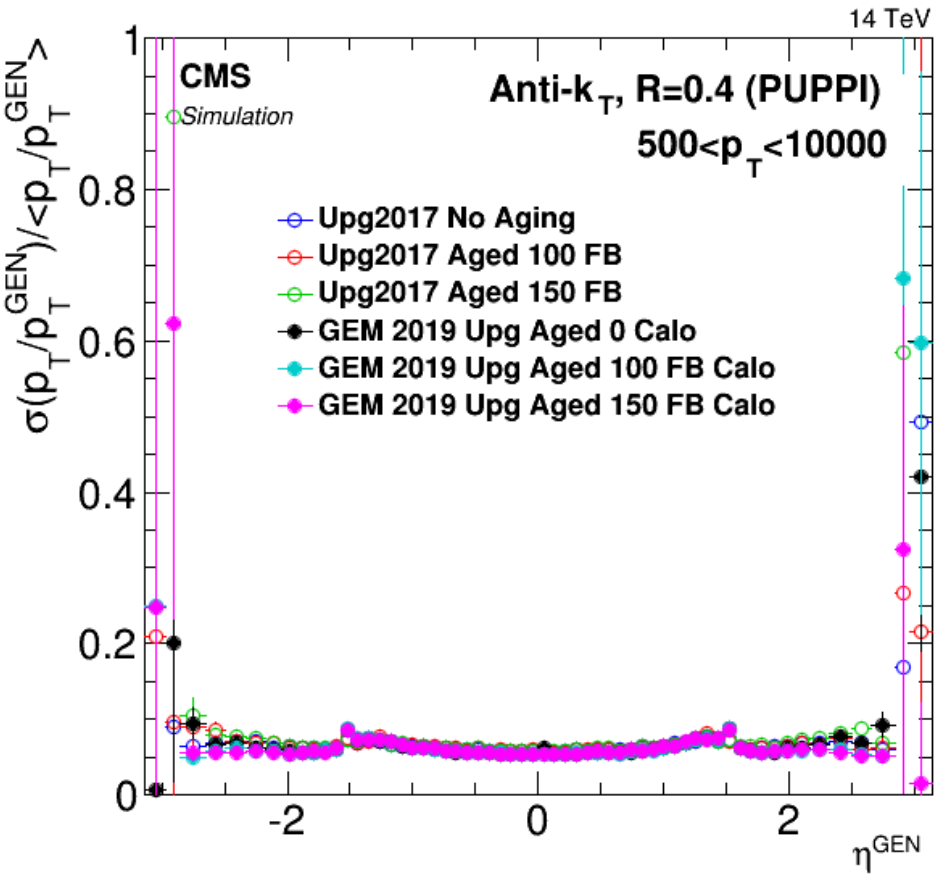




- Improved resolution for SiPMs in endcap can be observed
- HPD resolution gets worse with aging, SiPM resolution does not

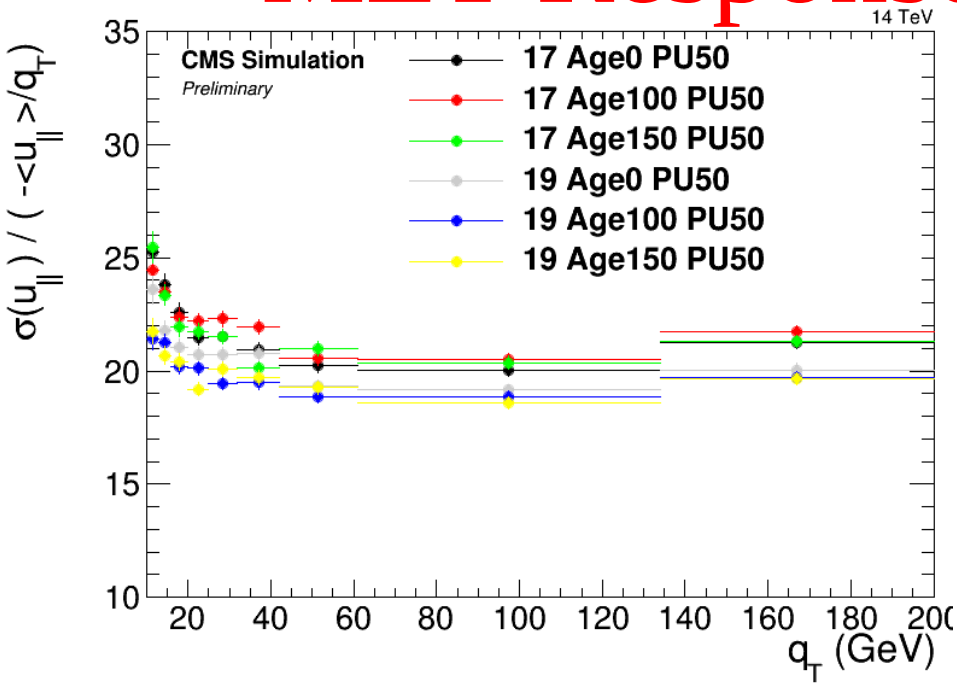
Jet Resolution vs. η (high p_T)

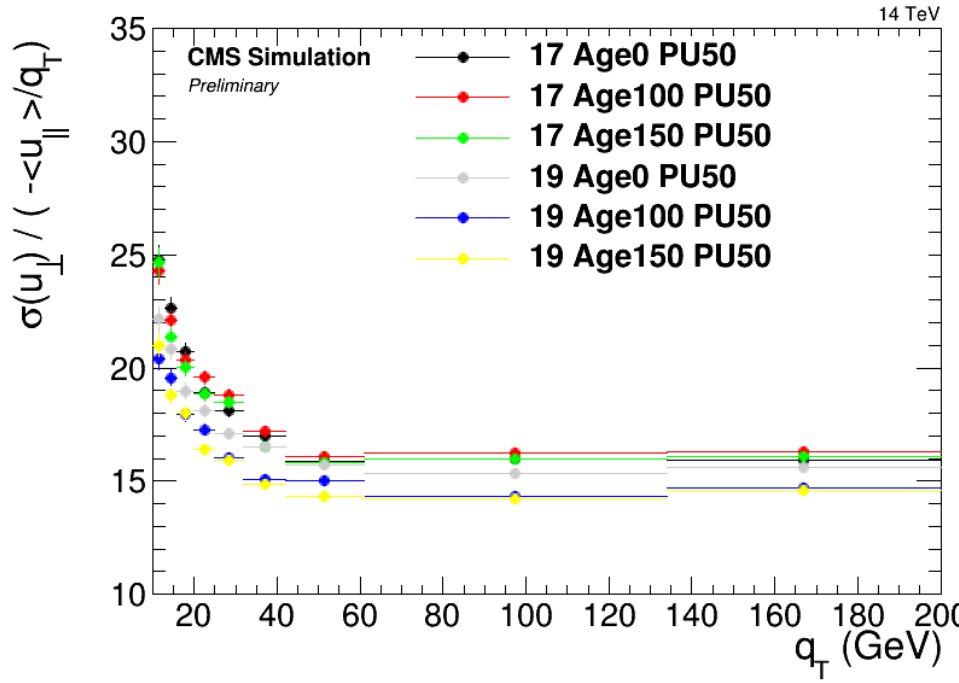


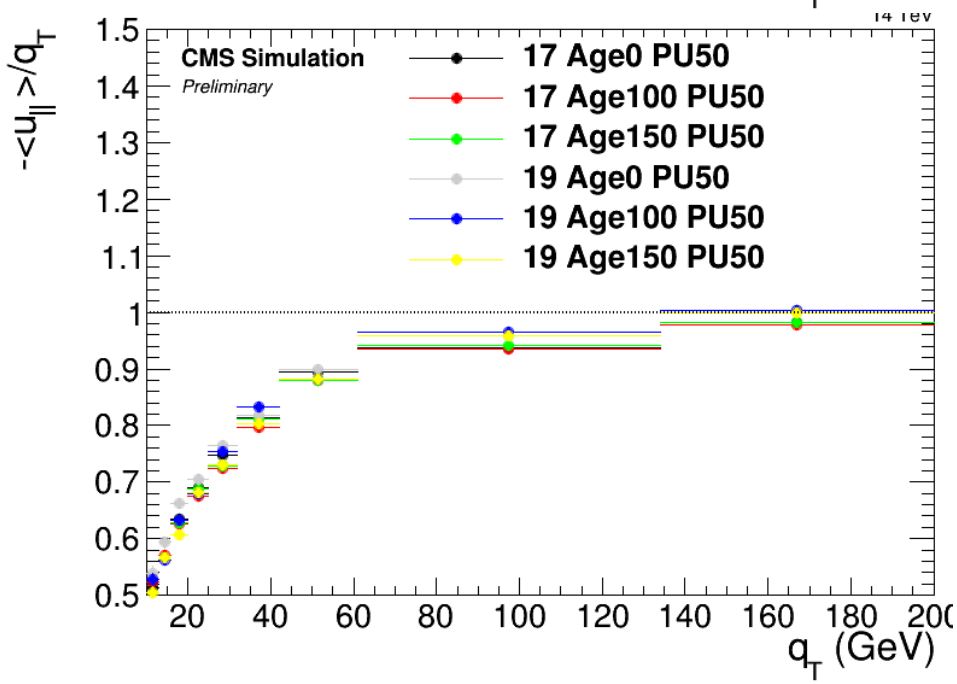


- Differences are less pronounced for high-p_T jets

MET Response & Resolution

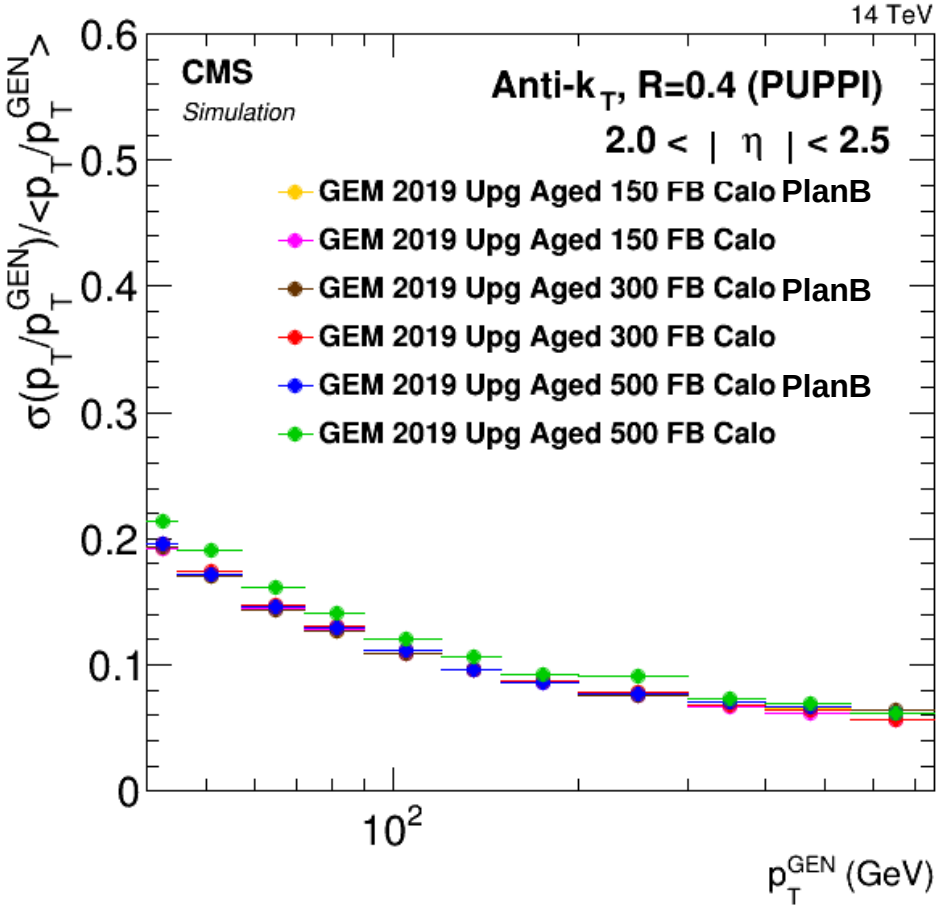


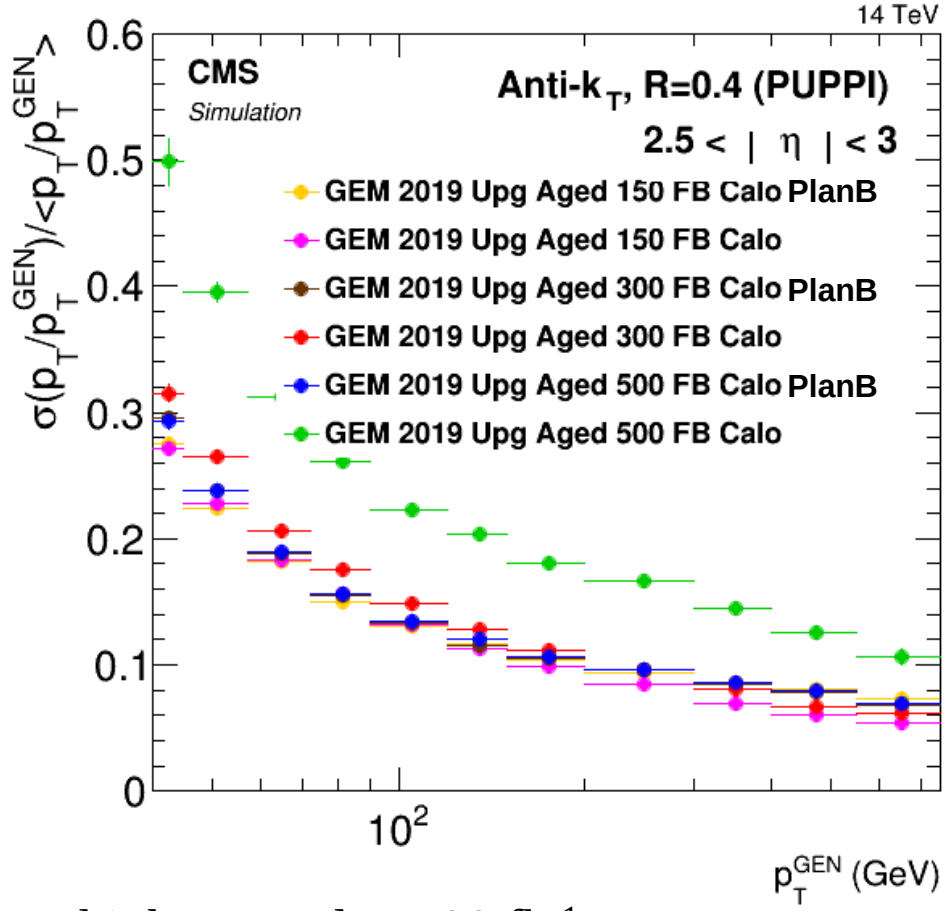




- Better response and resolution for SiPMs (vs. HPDs)

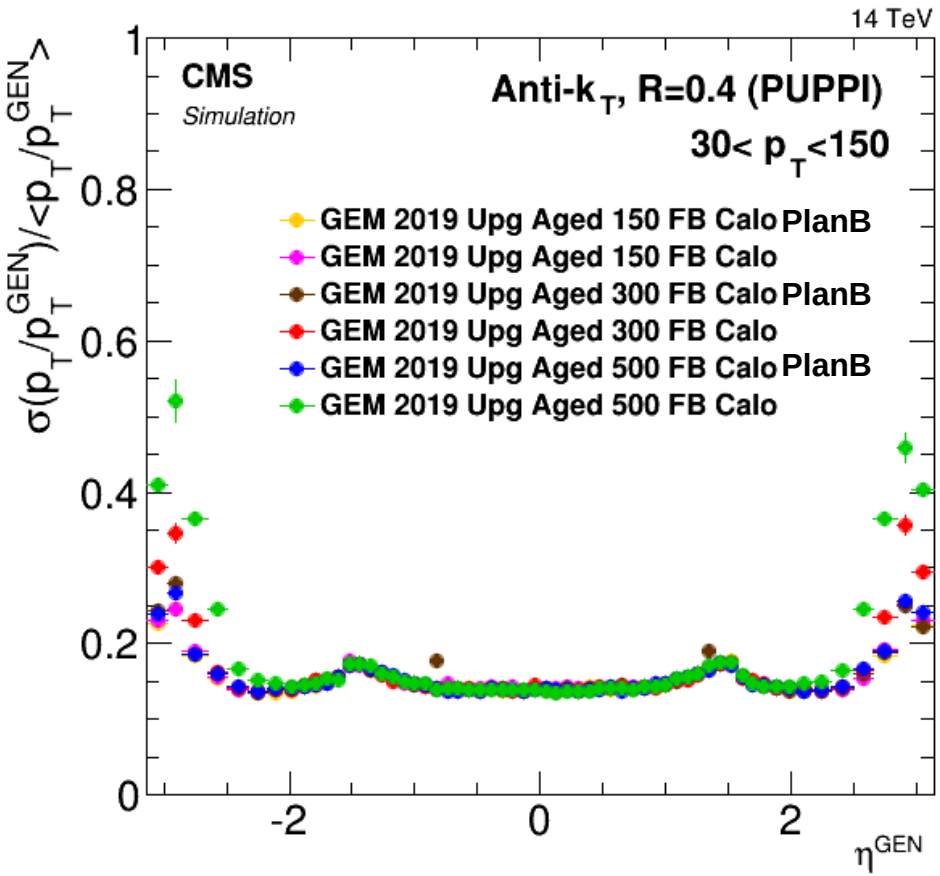
Jet Resolution vs. p_T

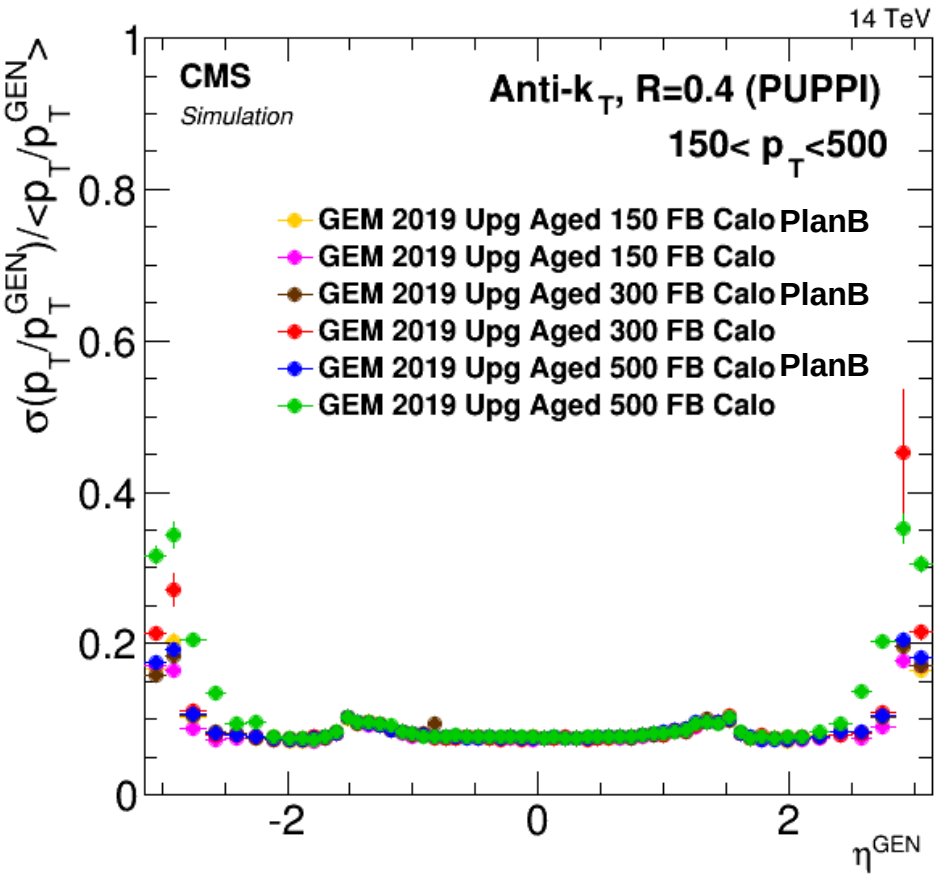




- Radiation damage effects more severe at higher η and at 500 fb^{-1}
- Degradation at 300 fb^{-1} understated – significant variation within the range $2.5 < |\eta| < 3.0$

Jet Resolution vs. η (low p_T)

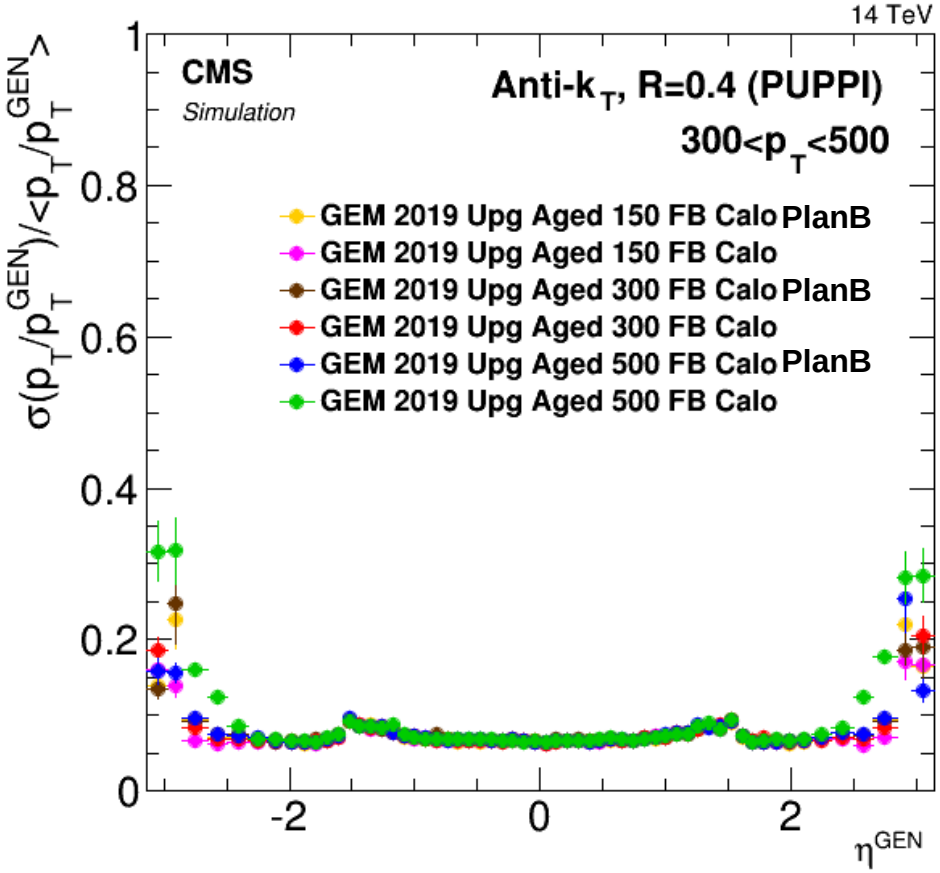


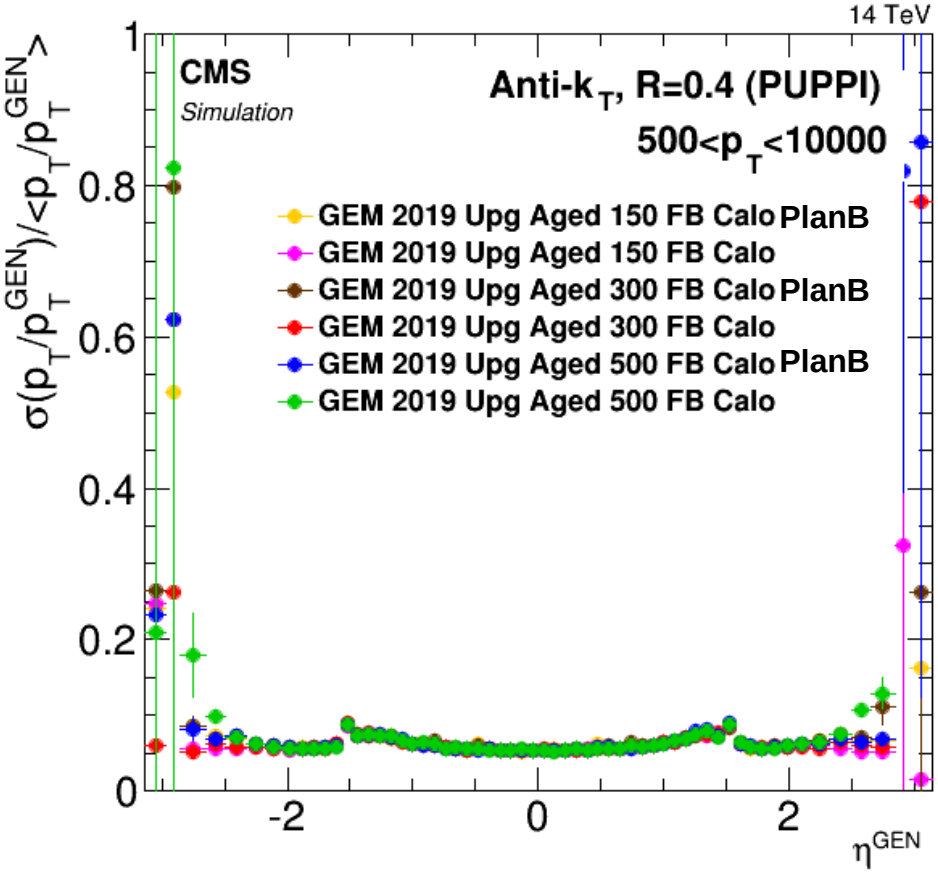


- Worse resolution for 300 fb^{-1} and 500 fb^{-1} aging with SiPMs
  – very η-dependent, especially at low p_T

- Plan B resolution is insensitive to aging even at 500 fb^{-1}

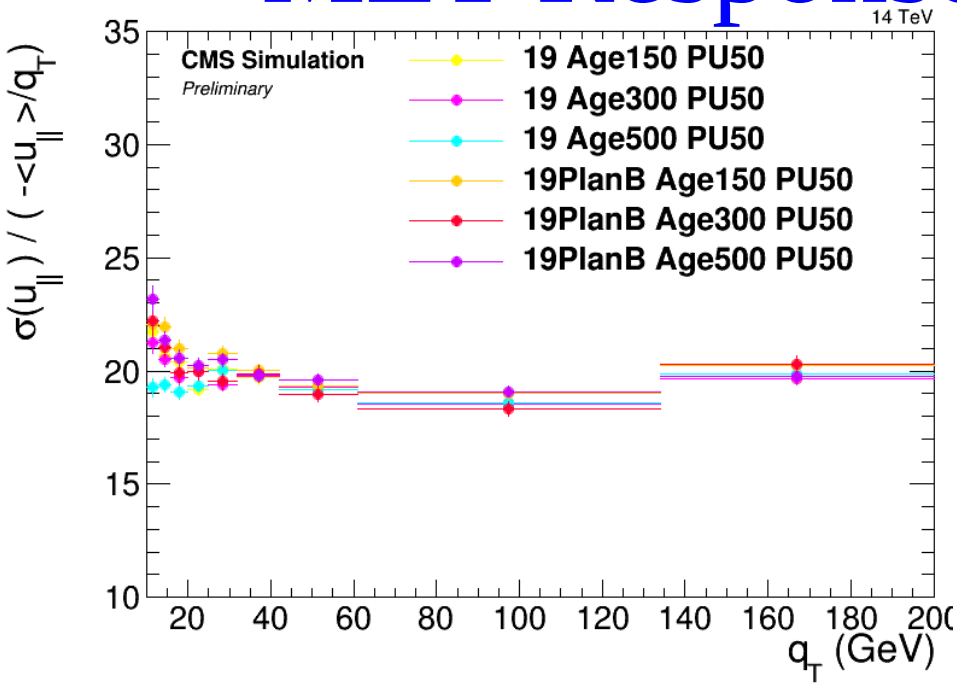
Jet Resolution vs. η (high p_T)

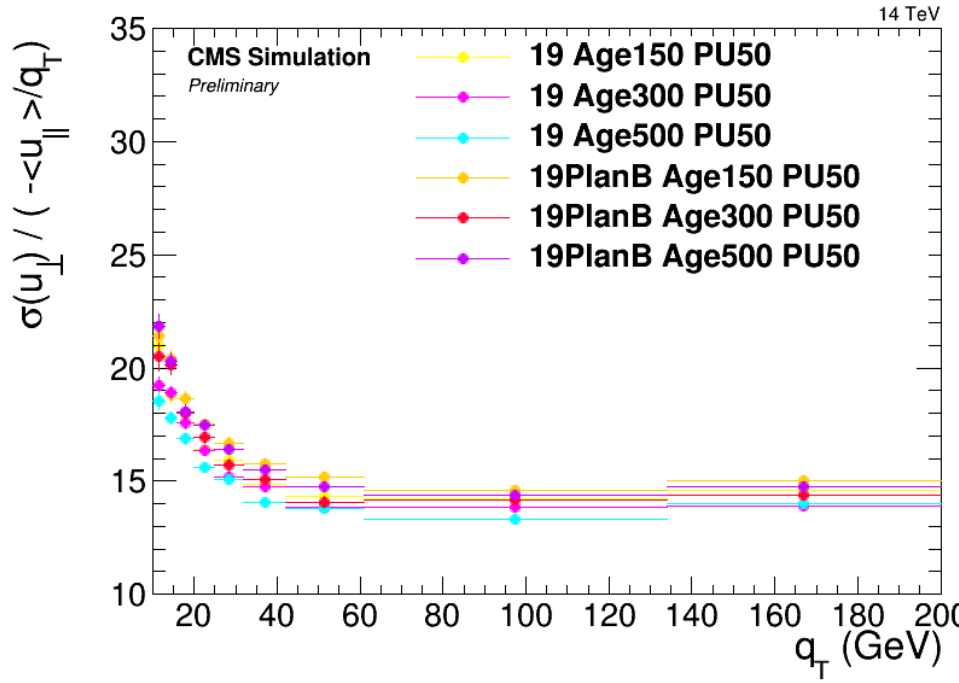


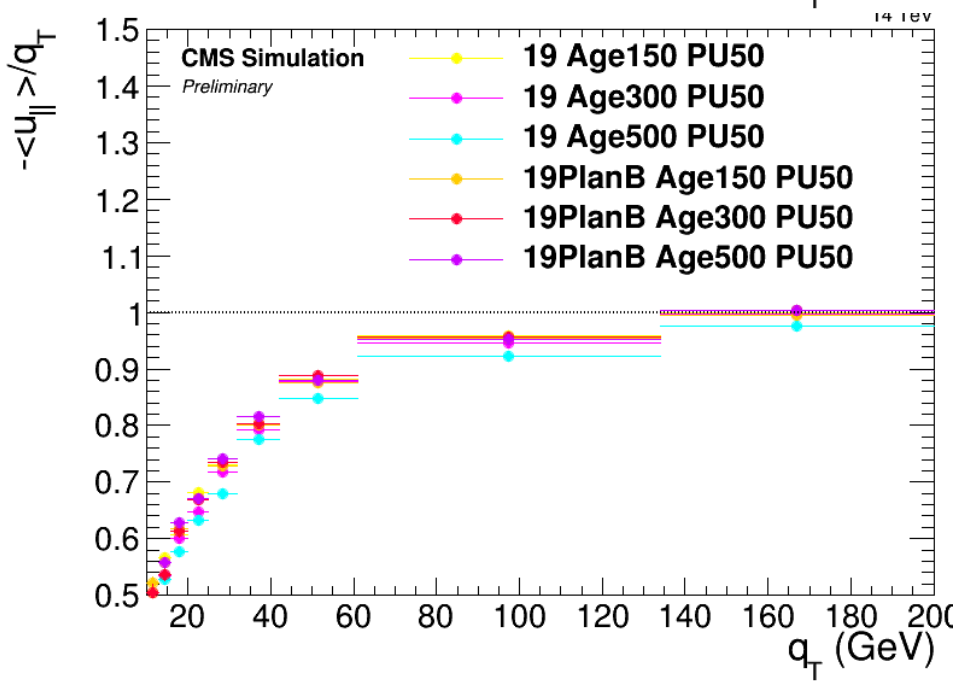


- Resolution changes are less pronounced for high-p_T jets
- Degradation at 500 fb^{-1} with SiPMs can still be observed at high η

MET Response & Resolution

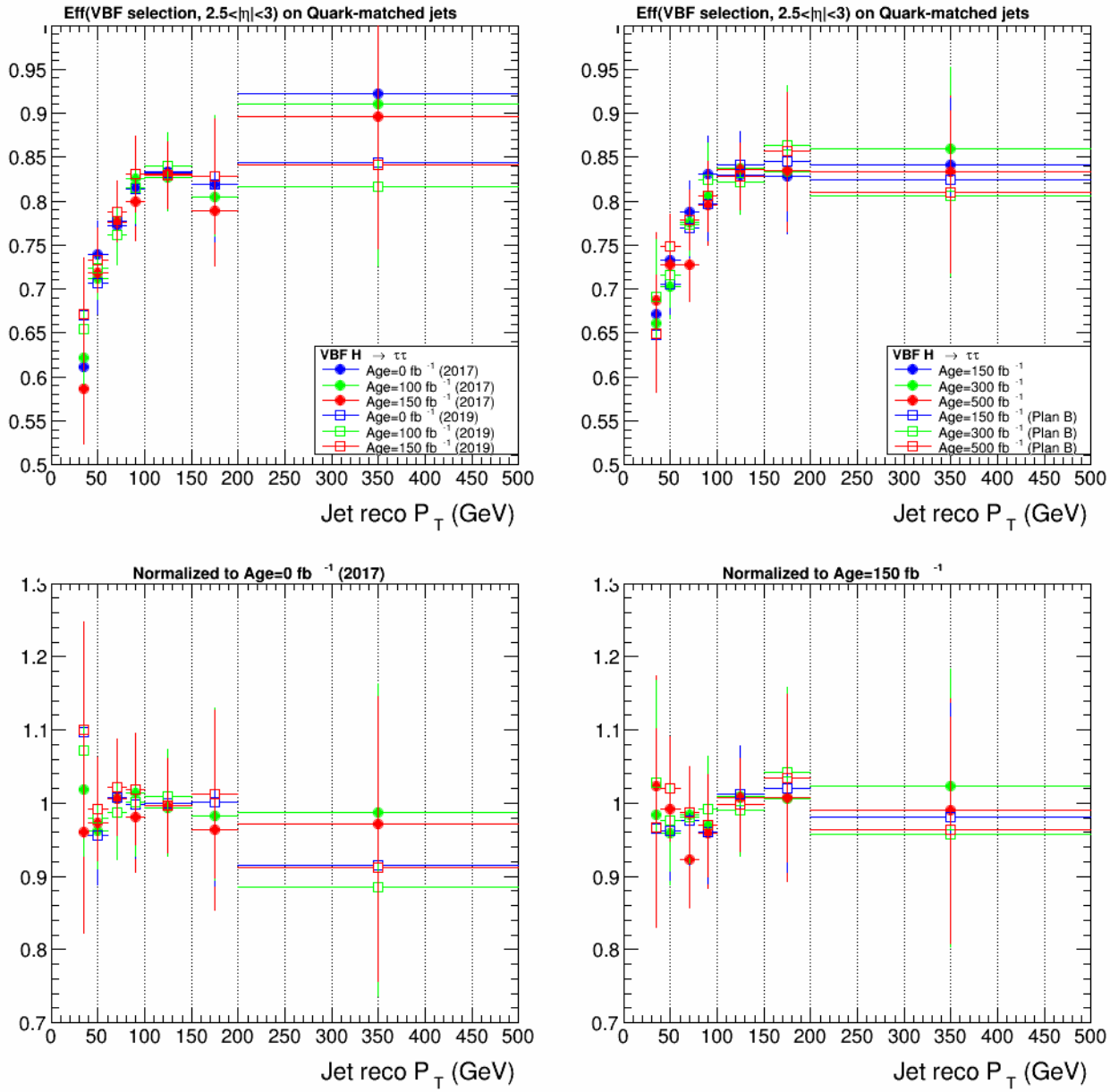




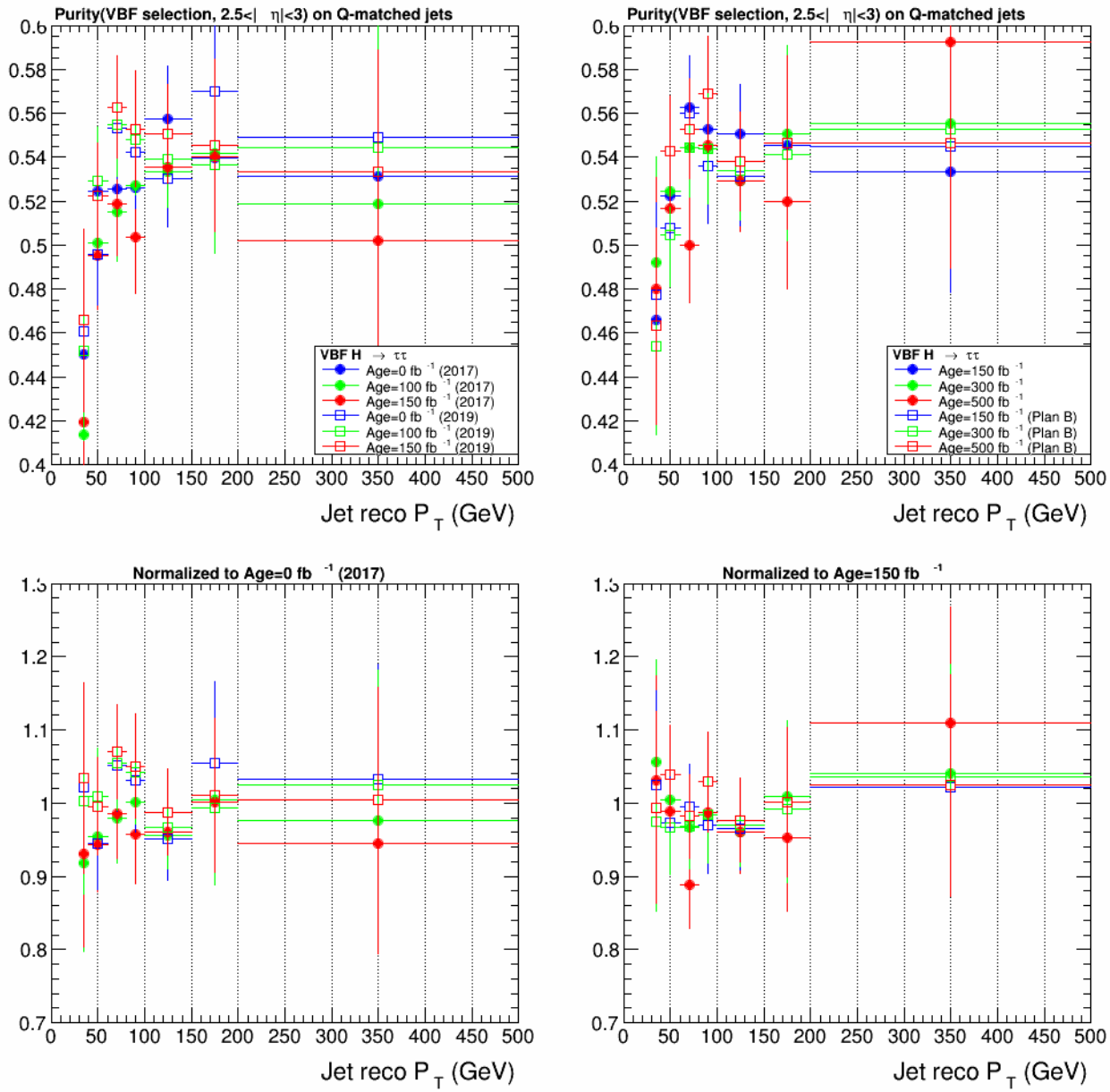


- Better response with PlanB
- PlanB does not improve resolution

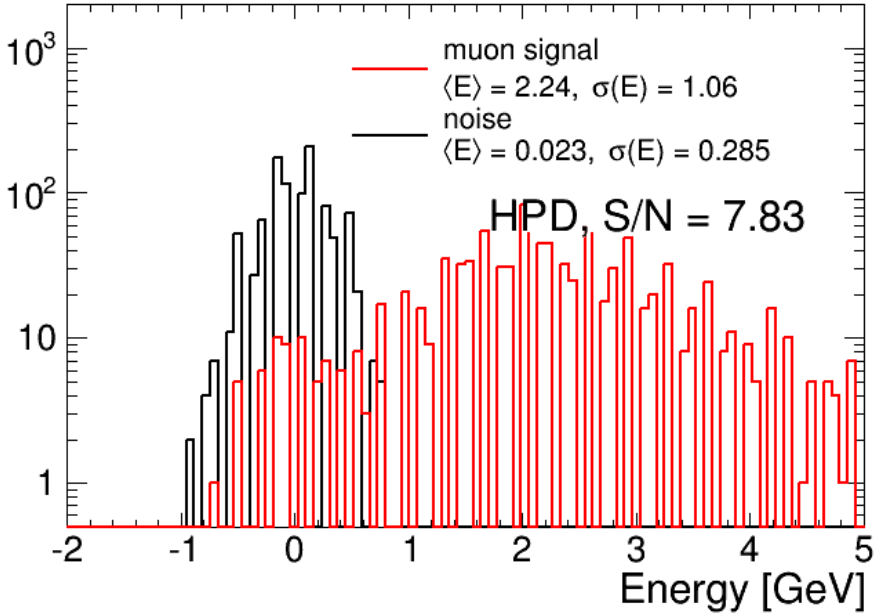
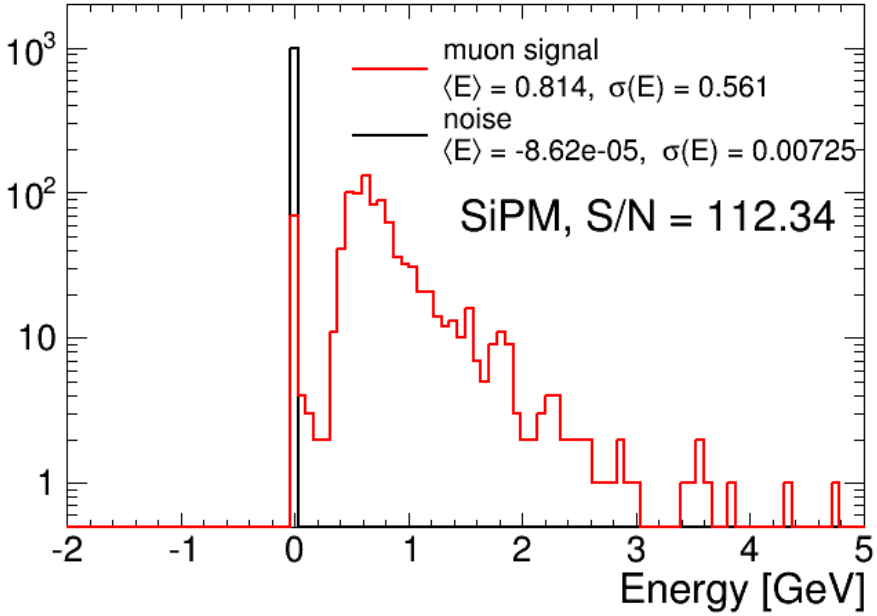
VBF Efficiency, high η (quark jets)



VBF Purity, high η (quark jets)



Muon MC Configuration

- CMSSW_6_2_0_SLHC25_patch3
- HCAL cell: iη 23, iφ 1, depth 2
- Modified geometry:
  12 layers (HPDs)
  4 layers (SiPMs)
- Muon beam:
  150 GeV
  $1.930 < \eta < 2.043$
  $0° < \varphi < 10°$
  (boundaries of the cell)
- Misc. settings:
  Magnetic field off
  HCAL reconstruction method 0
- 1000 events
- Noise collected from HCAL cell with iη –23

Muon MC Results