Shashlik Physics Performance

U.S. CMS Joint Phase 1 Phase 2 Upgrades Meeting
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Adi Bornheim
Caltech

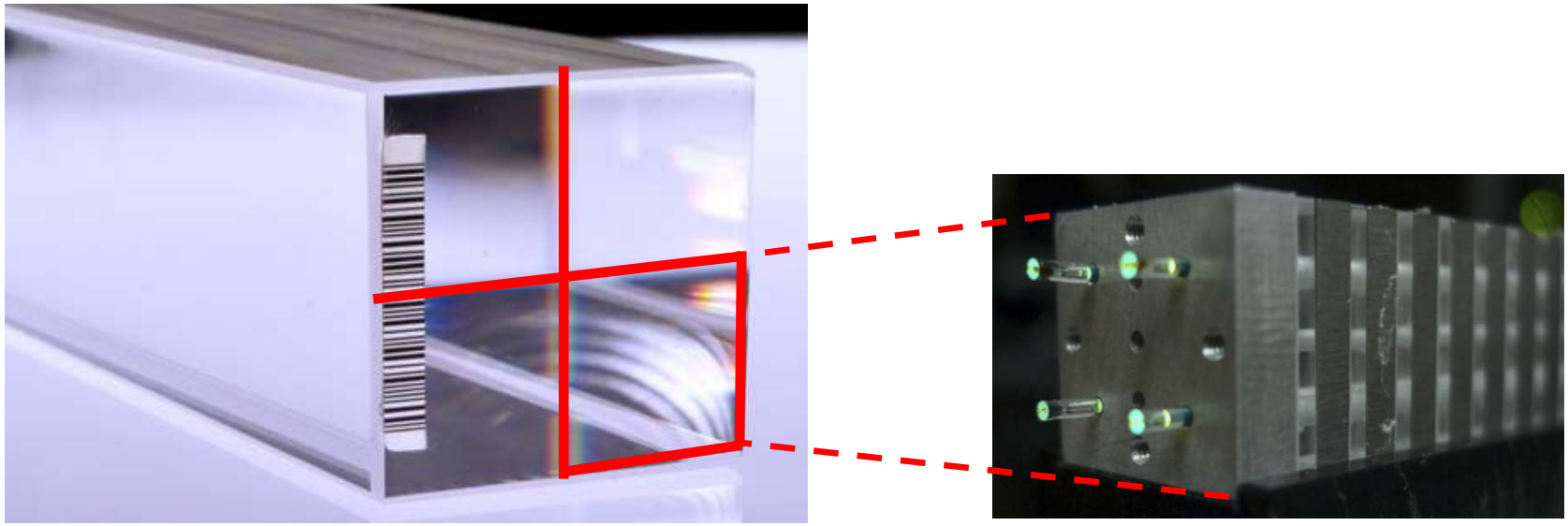
Introduction & Outline

Shashlik + enhanced HE rebuilt performance in the Phase II upgraded CMS detector at HL-LHC.

- **Signal creation and single cell performance**
- **Physics object performance**
- **Physics analysis prospects**

Exploit synergies with existing calorimeter detectors and build on Run I and Run II experience.

Signal creation



Photonics based technology : Primary signal is scintillation light.

Current ECAL :

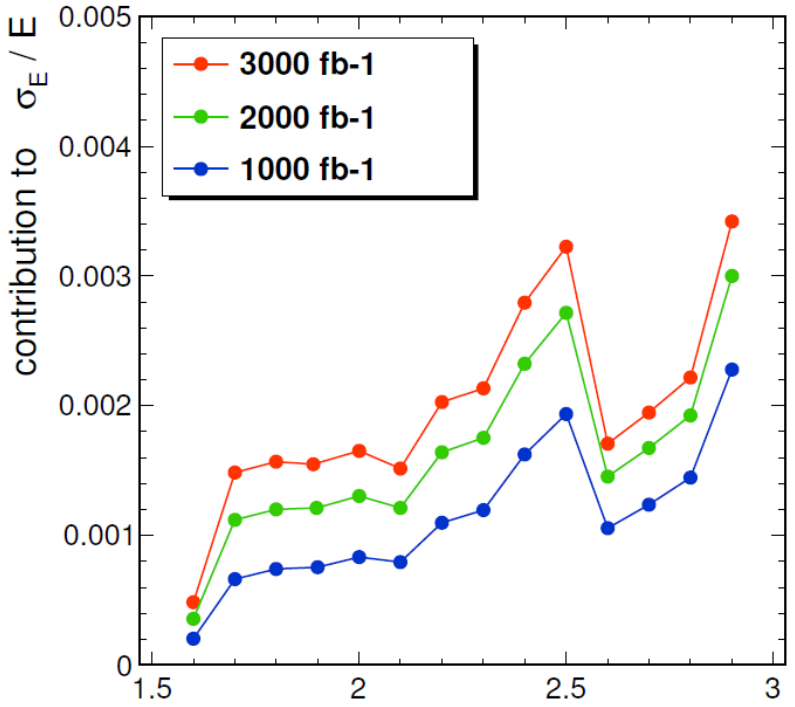
- **Optimized for extremely good energy resolution.**
- **PbWO has low light yield, short and long term response change in radiation field**
- **“front-end heavy” design.**
- **EE granularity sub-optimal.**

Shashlik :

- **Detector energy resolution very good.**
- **LYSO and CeF significantly more radiation hard.**
- **Exploiting large light yield of LYSO (CeF) to enable remote sensors and electronics.**
- **Shashlik design allows flexibility in geometry.**

Light creation and transport

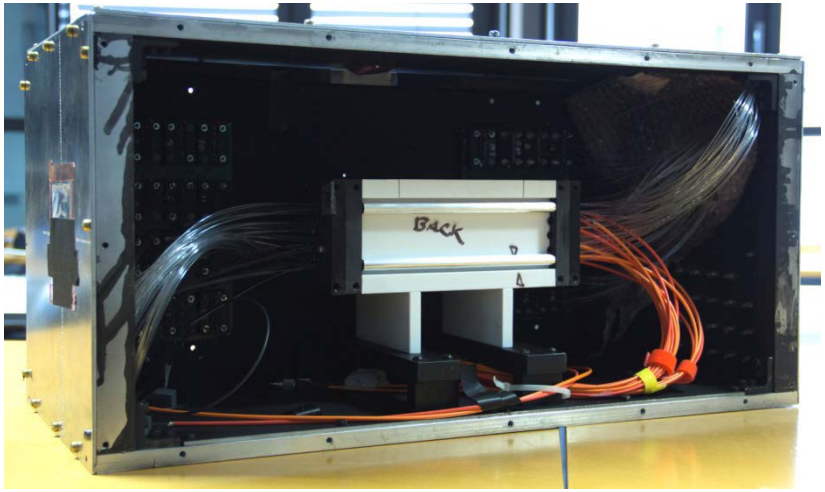
- **Uniformity of PbWO crystals was major R&D and production challenge.**
- **Contributions of hadronic and em type radiation damage, non-uniformity in crystal plates in production.**
- **Incorporating vast amount of data : simulation of Shashlik structure and CMS irradiation environment, irradiation data on PWO, CeF and LYSO crystals, etc.**
- **All indications are that there will not be a significant impact on the performance.**
- **Result of design choices.**

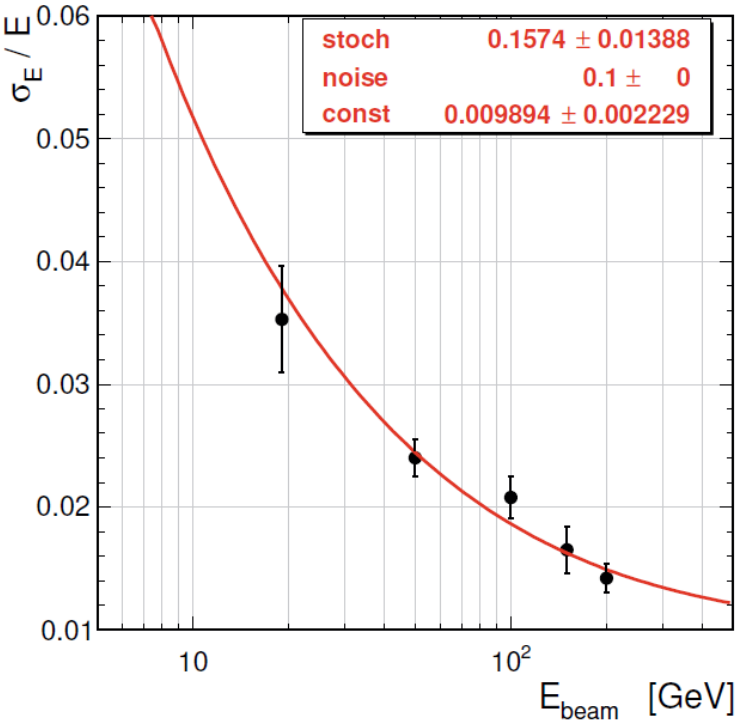


Beam test results

- **Test beam results match simulation of Shashlik cell.**
- **Four fibers in cell un-calibrated, as expected for real detector.**
- **Light in TB attenuated by factor 32 (!), stochastic term 16%, with factor 10 attenuation 11% as expected.**
- **Constant term 1% in test beam.**
- **Confirms simulations and gives confidence in previous slide.**

ND Filter	Expected	Measured
None	10.1%	
LO/8	11.3%	11.7%
LO/32	15.6%	15.8%





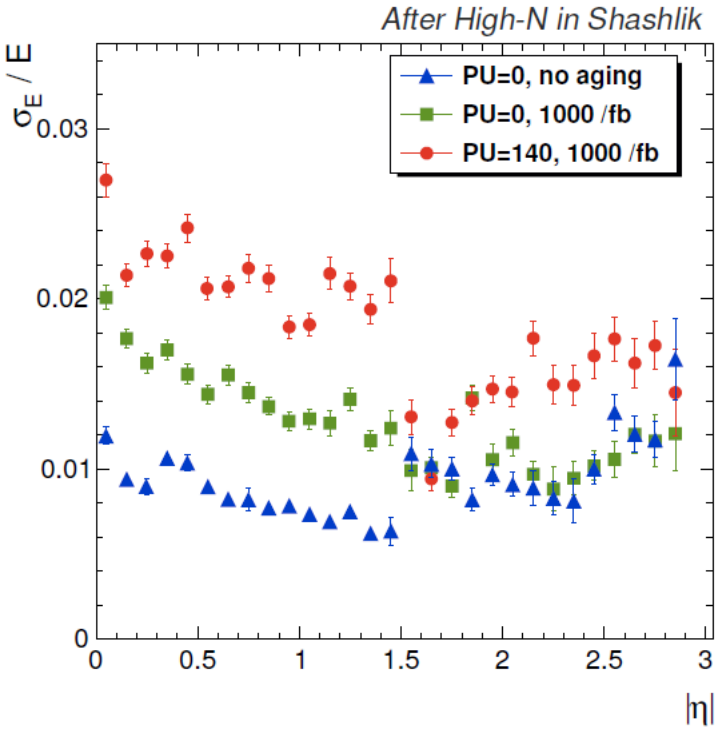
EM Energy Resolution

	PU=0/0 fb^{-1}	PU=140/0 fb^{-1}	PU0/1000 fb^{-1}	PU140/1000 fb^{-1}
Barrel	0.80%	1.66%	1.49%	2.09%
Shashlik	1.01%	1.52%	1.01%	1.45%

Resolution for unconverted photons
EB is noticeably worse than Shashlik

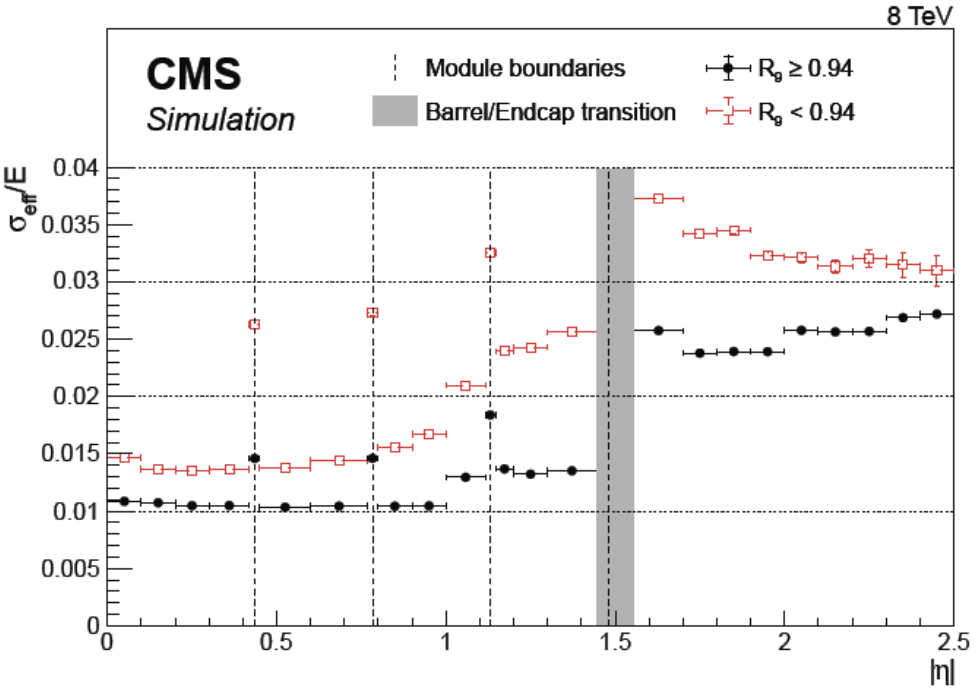
Mass resolution (true vertex)
unconverted γ at PU=140/1000 fb^{-1}

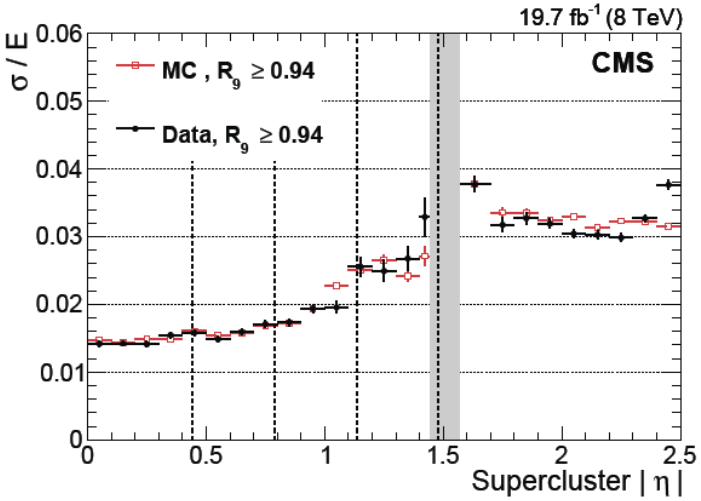
	$\sigma_{\gamma\gamma}$
EB-EB	1.34%
EB-EE	1.44%
EE-EE	0.98%

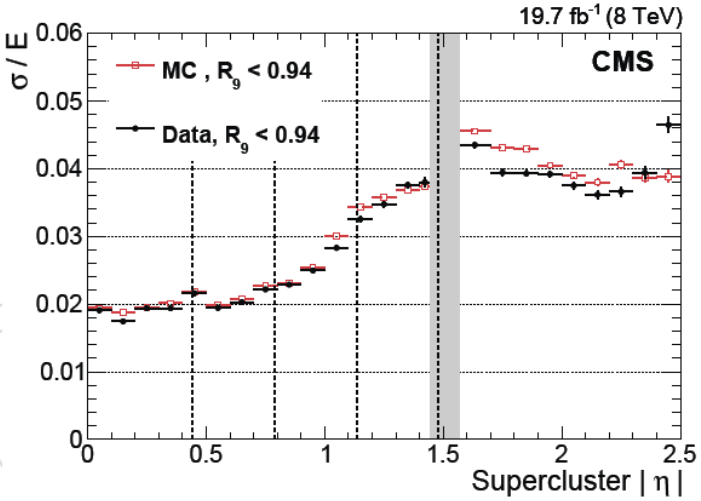


Current detector performance

- From recent EGM-14-001.
- Balance between EB and EE inverted.
- Reality factor to match DATA to MC.

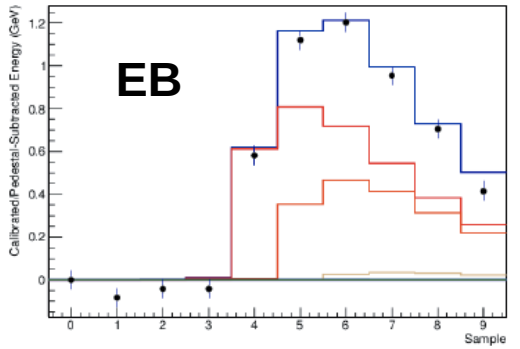


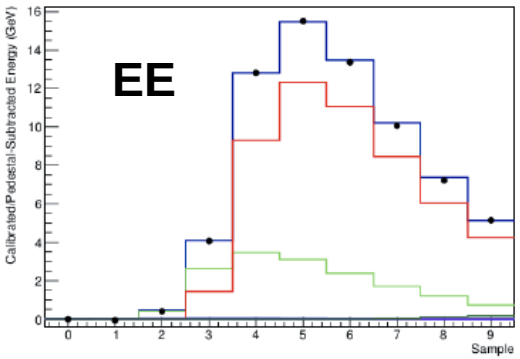


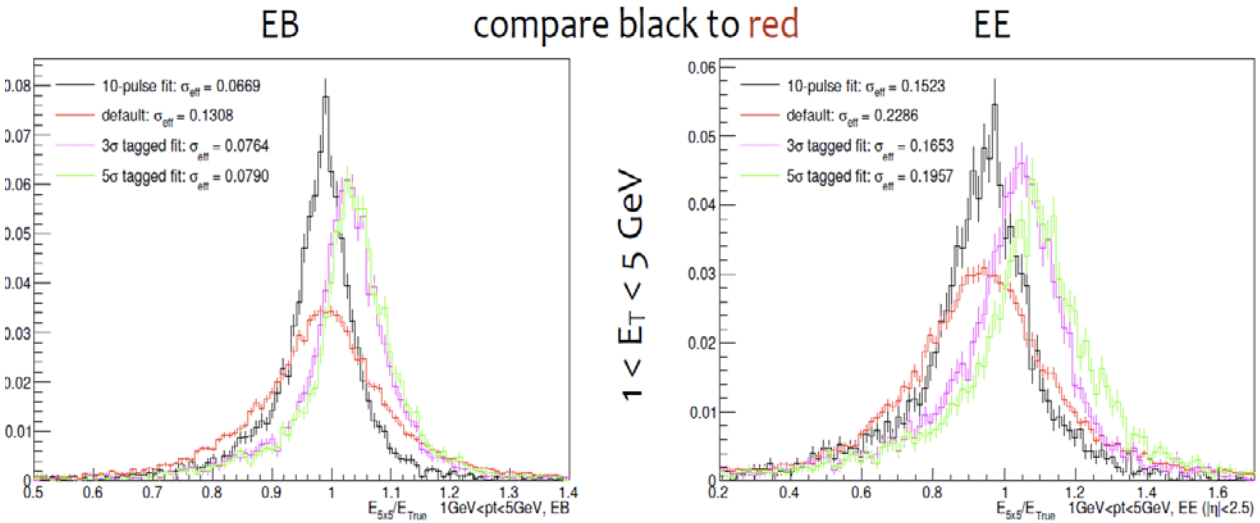


Multi-fit PU Mitigation

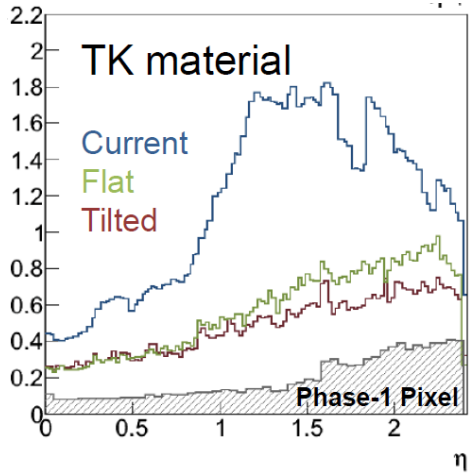
- **Exploit high precision to disentangle OOT PU overlapping pulses with multi-fit reconstruction.**
- **Non-overlapping pulses rejected with timing.**
- **Run 2 development, used for Shashlik as well.**
- **Suggests performance gain for low pT em objects, impact on eg. calibration to be explored in Run II.**
- **HCAL using similar strategy as well.**

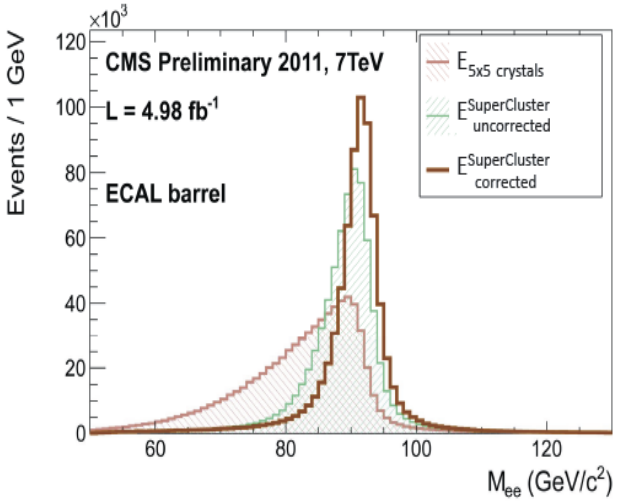


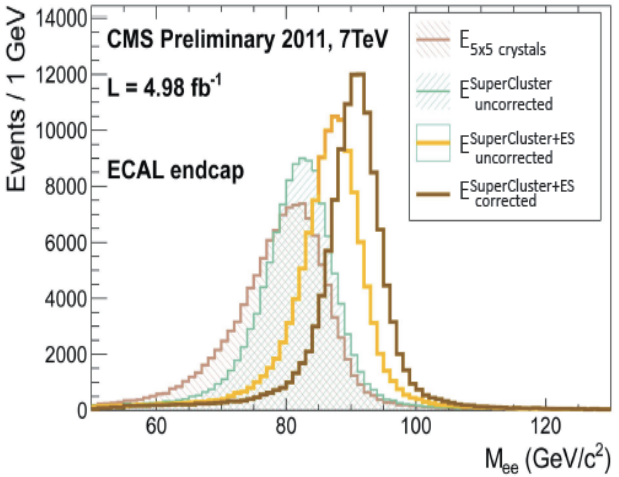




In-situ performance





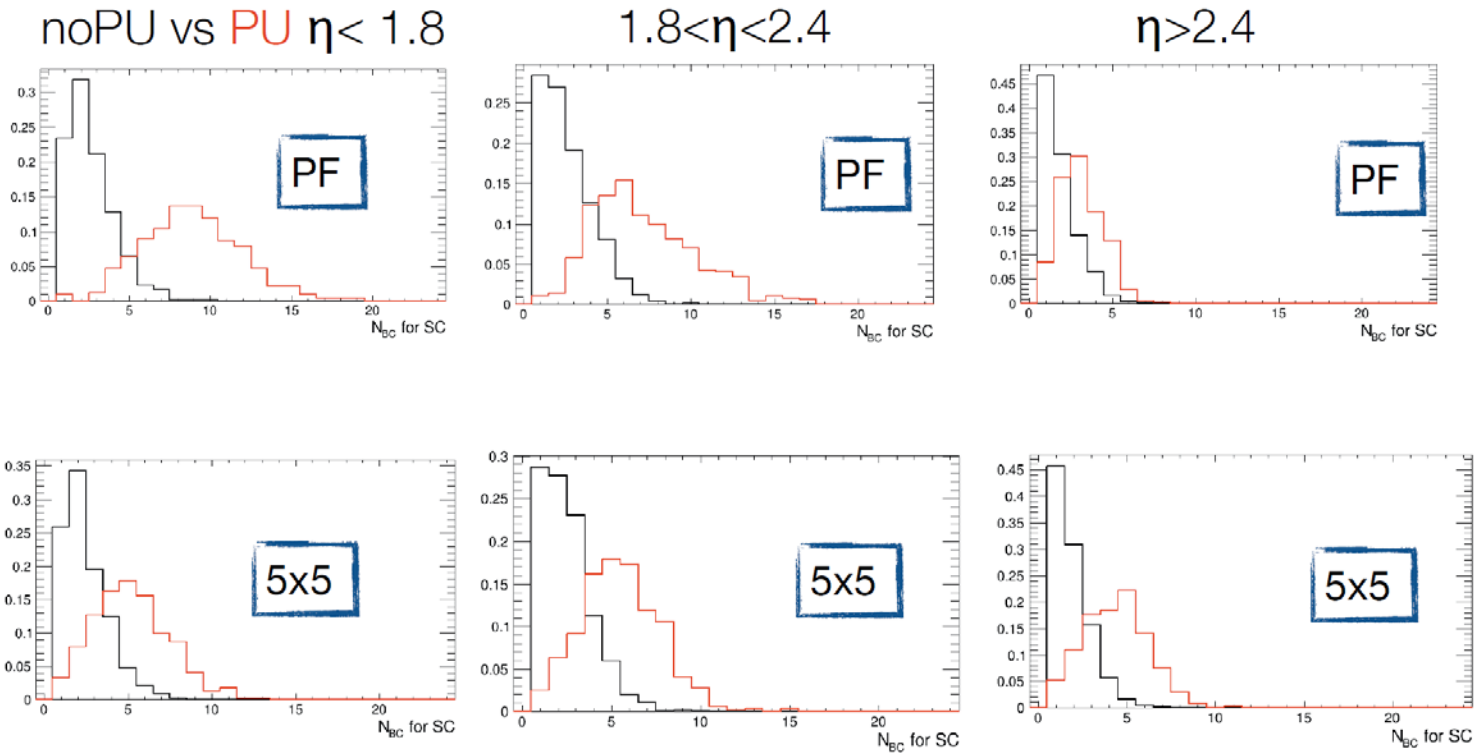


In-situ EM performance relies on clustering algorithms and corrections.

- **Reduced tracker material will have significant impact.**
- **Run I analysis based on traditional clustering technique, now using PF based algorithm.**
- **Regression based techniques for correction became standard in Run I. Exploiting full detector information maximally.**
- **Clustering under study for Shashlik. Already rather simple "highest-N" algorithm shows advantages in certain cases.**

Francesco Micheli

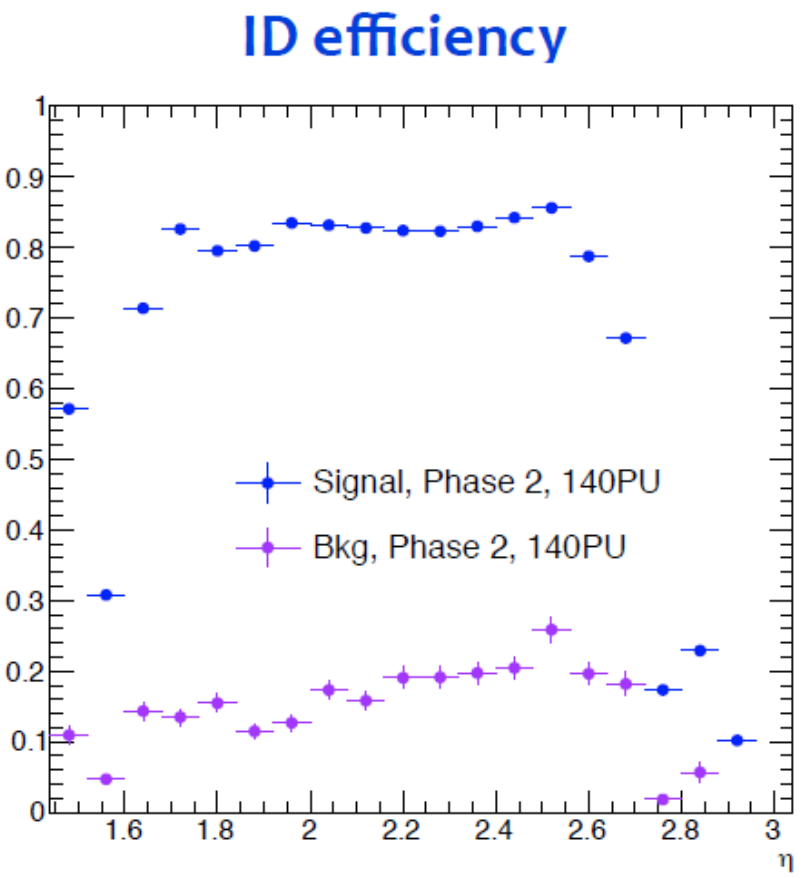
SH Clustering at 140 PU



- **Retuning of SC formation.**
- **Suggest PF SC at high low eta in EE somewhat more sensitive to PU**

EM Object Reconstruction

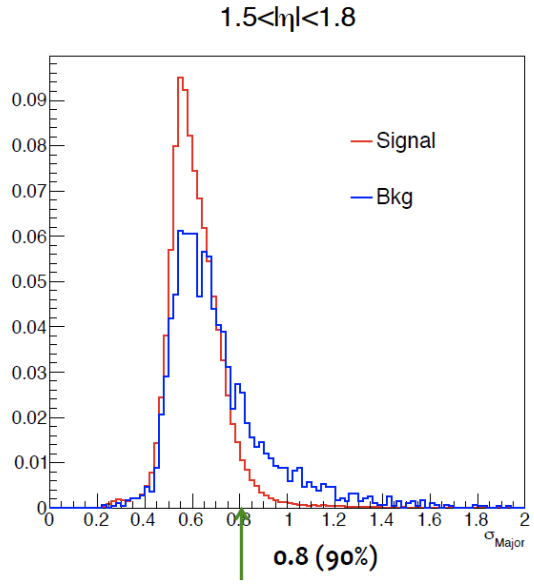
- η-dependent cut on $\sigma_{i\eta i\eta}$
  - $1.5 < |\eta| <= 1.8$, $\sigma_{i\eta i\eta} < 0.037$
  - $1.8 < |\eta| <= 2.4$, $\sigma_{i\eta i\eta} < 0.034$
  - $2.4 < |\eta| <= 2.7$, $\sigma_{i\eta i\eta} < 0.032$
  - $|\eta| > 2.7$, $\sigma_{i\eta i\eta} < 0.031$
- H/E < 0.06
- Relative isolation cuts:
  - emIso < 0.28*Pt(γ)
  - chIso < 0.10*Pt(γ)
  - nhIso < 0.30*Pt(γ)

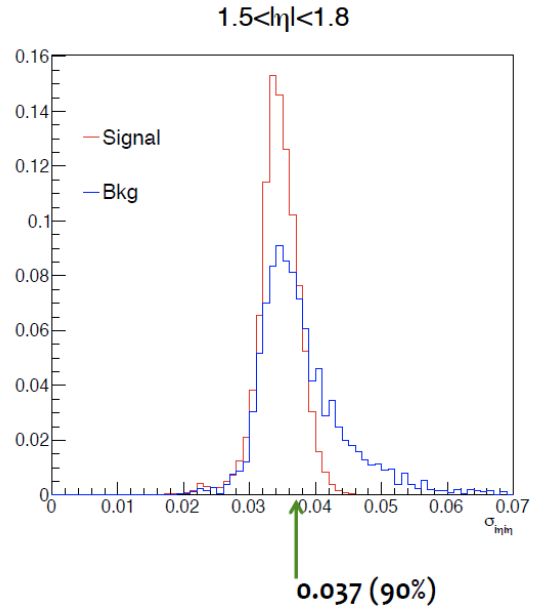


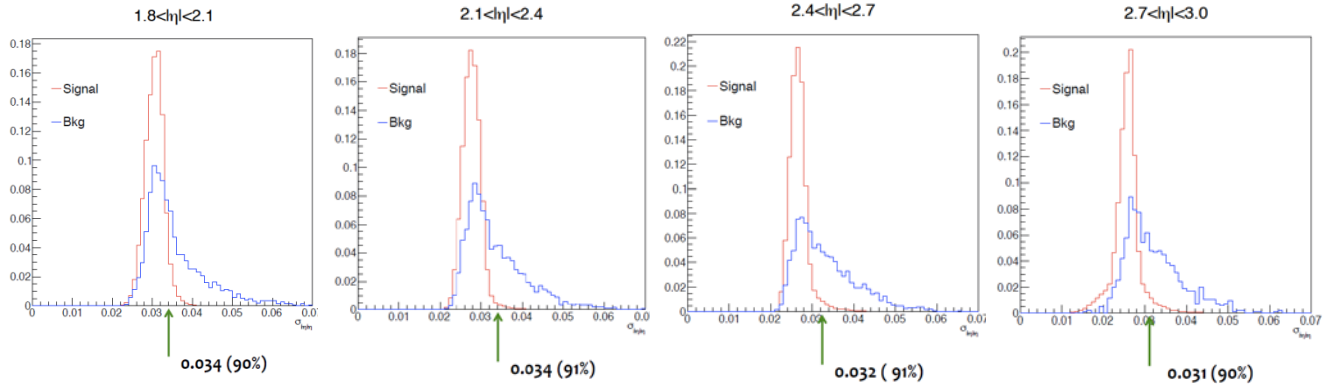
- **Similar performance as in EB for 140 PU.**
- **Work on MVA ID ongoing.**

Shashlik Shower Shapes

- $\sigma_{i\eta i\eta}$ important input to photon ID.
- Convolution between detector geometry and physical shower shape.
- Non-pointing geometry reflects in the shape difference between real and fake photons.
- For current "flat non-pointing" geometry, effect mostly in the eta range close to the EB/EE boundary.
- Current H→γγ analysis is dominated by unconverted photon and irreducible background.

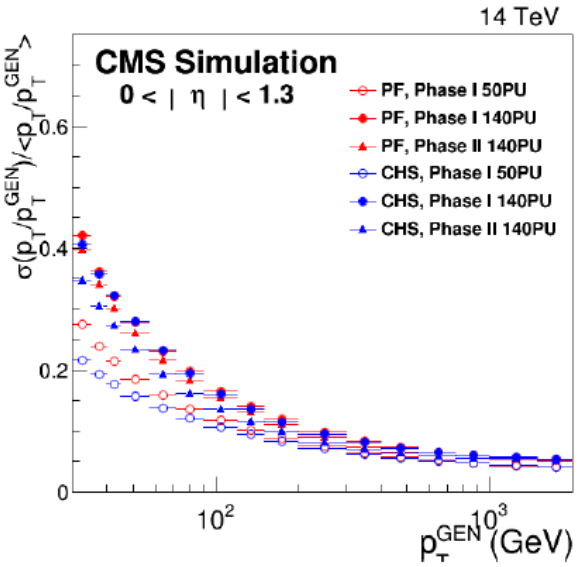


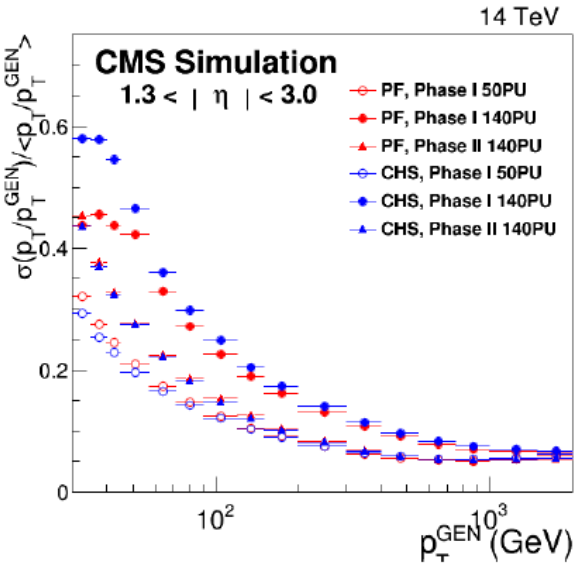


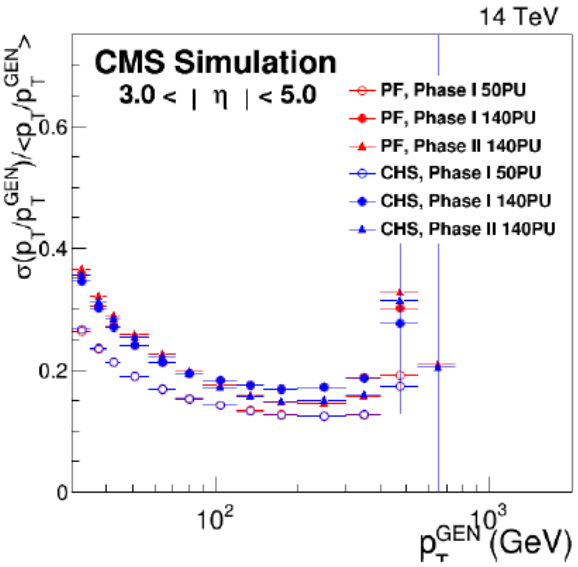


Ricardo Eusebi

JetMET

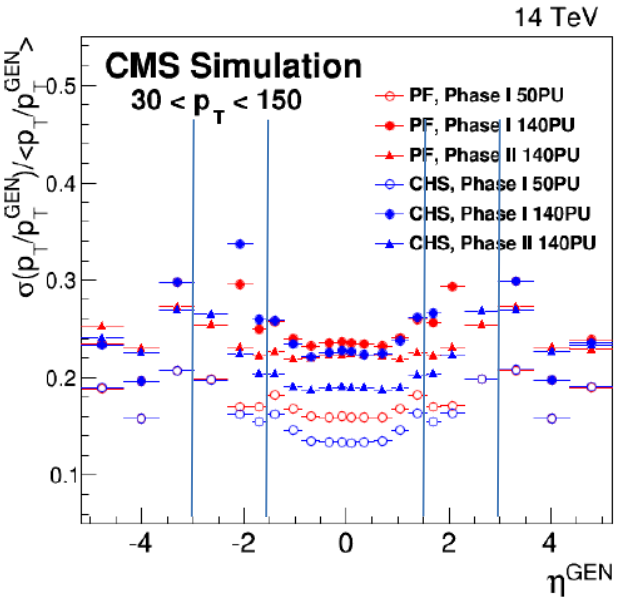


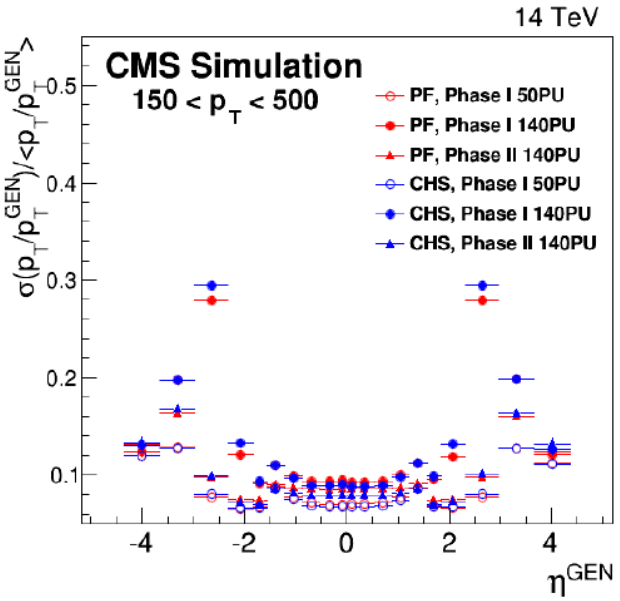


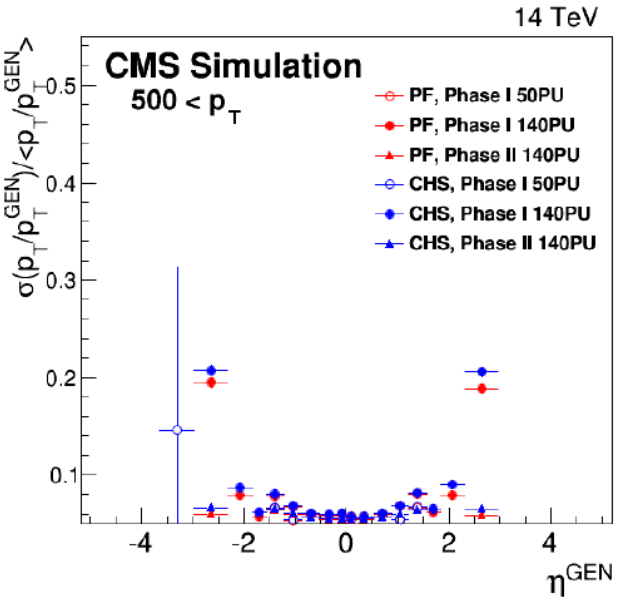


- **Jet energy resolution looks OK**
- **Shashlik better than current detector at same PU.**
- **Advanced Jet reco (PUPPY) still to come.**

JetMET





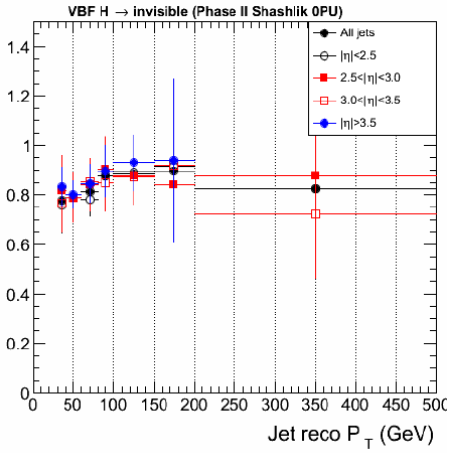


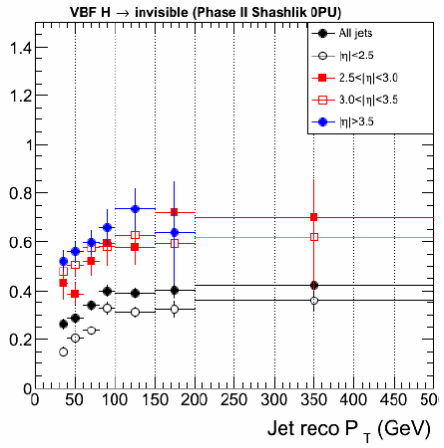
- **Jet energy resolution improved for Shashlik at same PU.**
- **Advanced Jet reco algorithms (PUPPY, etc.) still need to be tuned to 140 PU.**

VBF tagging

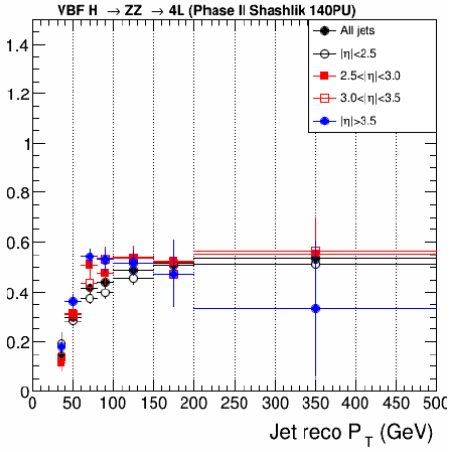
VBF H → ZZ → 4l

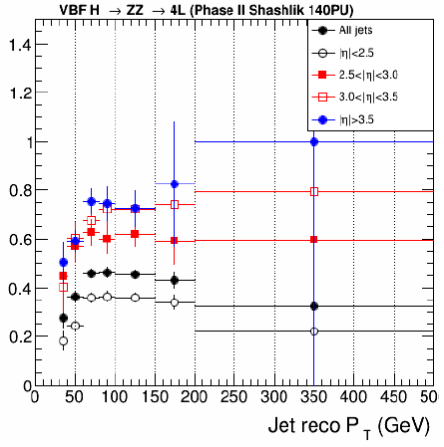
0 PU





140 PU

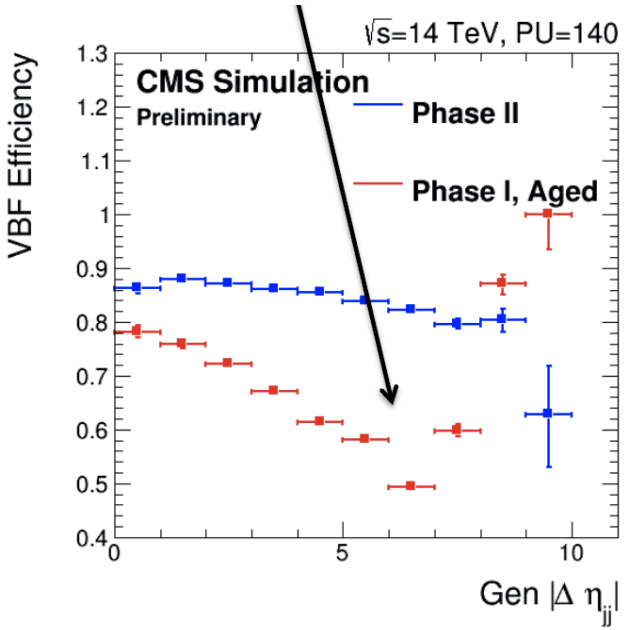


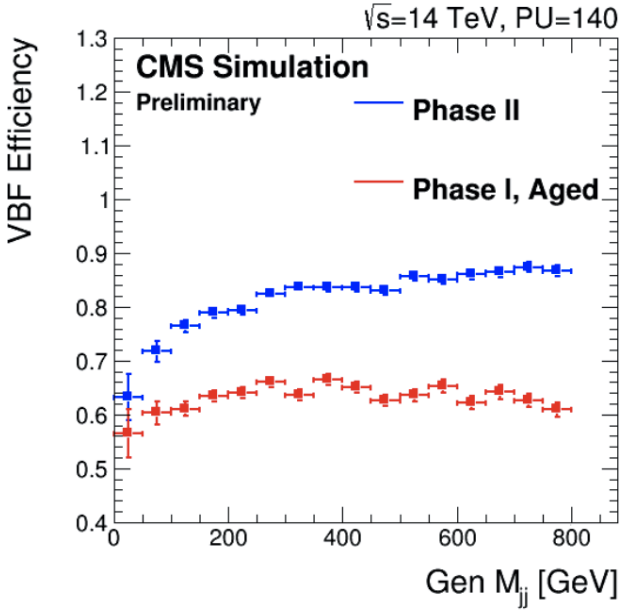


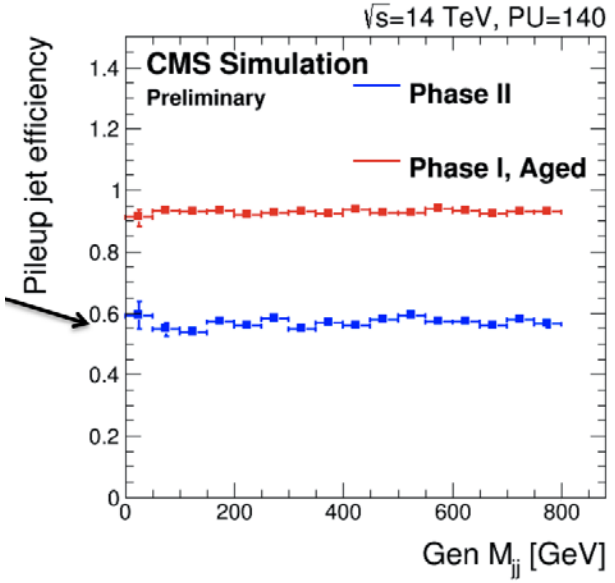
- **Efficiency good even at 140 PU.**
- **Increase in fake rate for VBF-like jets.**
- **PU Jet ID, PUPPY, etc. need to be tuned and tested.**
- **Target application for precision timing detector.**

VBF Efficiency

Loss of efficiency for aged detector if both jets are in endcaps.







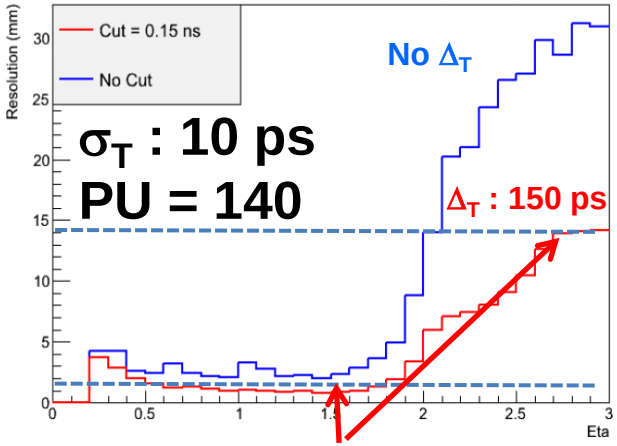
- **Consistent results from VBF H $\rightarrow\tau\tau$ sample.**
- **Efficiency loss of aged detector driven by loss of endcap performance**
- **Efficiency good even at 140 PU.**
- **PF jets, PUPPY under study.**

Precision Timing PU Mitigation

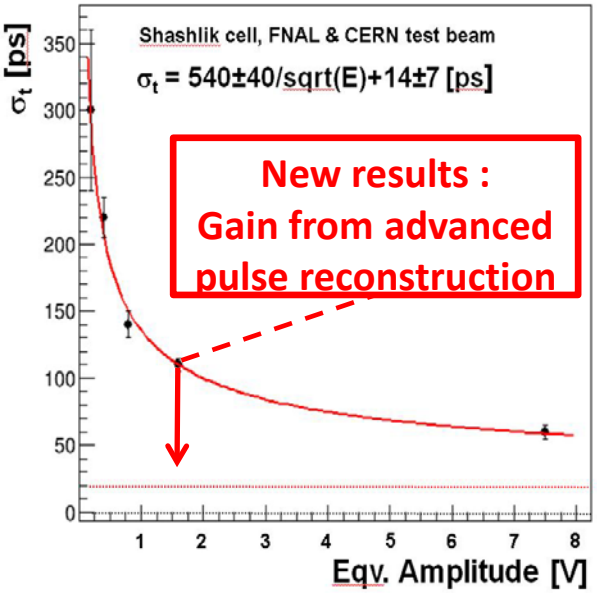
Precision timing may be exploited for PU mitigation.

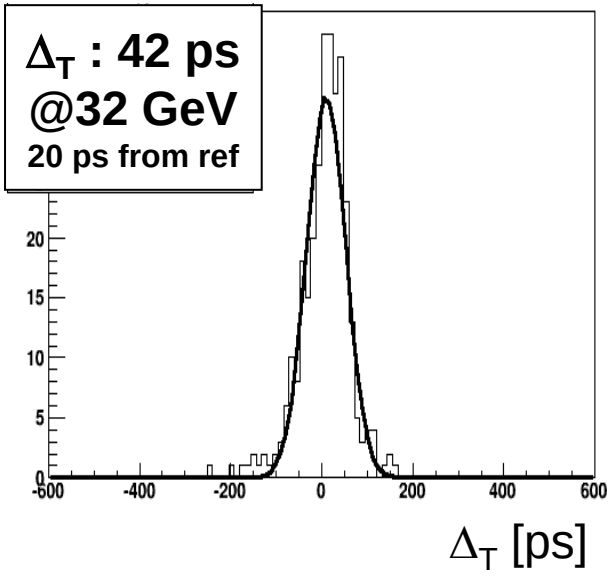
- **Vertex association of neutral particles, eg. photon vertexing and jet vertexing in high PU environment.**
- **Few 10 ps resolution from CMS Shashlik cell.**
- **Studied in the context of "Fast Timing Working Group"**
- **Here : Exploiting intrinsically good timing performance of Shashlik by optimizing detector for excellent timing performance.**
- **Dedicated MC samples which extracts precise time of arrival from EB and SH being requested.**

Toy MC Study, Phase I
Jet timing vertex



2 – 14 mm vertex resolution



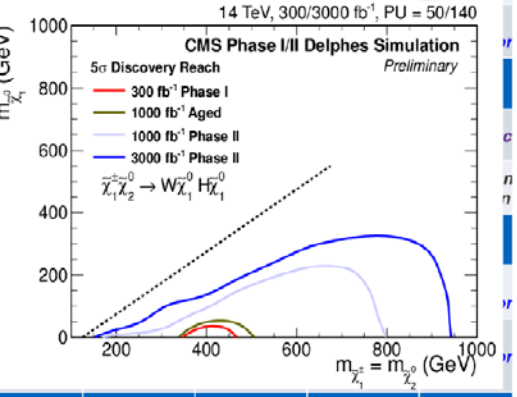


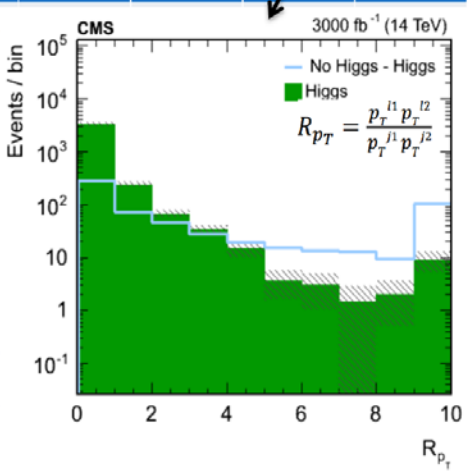
From Objects to Physics

H → γγ to benchmark EC performance

H → ZZ → 4l and H → μμ needs attention

Performance/ Physics	Higgs VBF H→ττ	Higgs H→γγ	Higgs H→ZZ→4l	Higgs H→μμ	Higgs HH→bbbb	Higgs HH→bbγγ	Higgs HH→bbττ	SUSY EWKino VH(bb) +MET	EXO A_{fb} (Z')	SMP Vector Boson Scattering	BPH $B_{s,d}\to\mu\mu$
Tracker											
Performance			mass resolution	mass resolution	b-tagging	b-tagging	b-tagging				
Extentions	forward jets / MET										
Trigger											
Bandwidth	acceptance										
Track Trigger	background rejection										
Calorimeter											
ECAL	forward jets / MET	mass res. / acceptance									
HCAL	forward jets / MET										
Muons											
Extension			acceptance						acceptance		





- **HL-LHC program covers precision physics, very rare processes and searches.**
- **So maximizing acceptance as much as possible as well as controlling systematics to the maximum.**

Summary

- **Performance evaluation of CMS Phase II upgraded detector with the Shashlik option is progressing well.**
- **Performance typically better than aged Phase I detector.**
- **Advanced reconstruction methods (EM energy regression, MVA EM Object ID, PU Jet ID, PUPPY, advanced usage of timing) under study. Further improvement of performance is expected.**