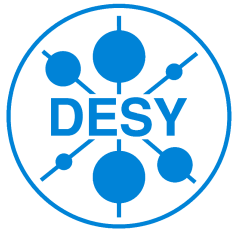
Higgs Activities in the DESY ATLAS Group

Kerstin Tackmann

DESY



Higgs@DESY Discussion – June 12, 2012 – Hamburg

People Involved

$H \rightarrow \gamma\gamma$

- Marcos Jimenez Belenguer
- Chris Hengler
- Until May: Martin Goebel
- Starting after ICHEP: Sergei Gleyzer
- Finishing his Bachelor thesis: Früd Braren
- Kerstin Tackmann

High-lumi studies (Higgs self couplings)

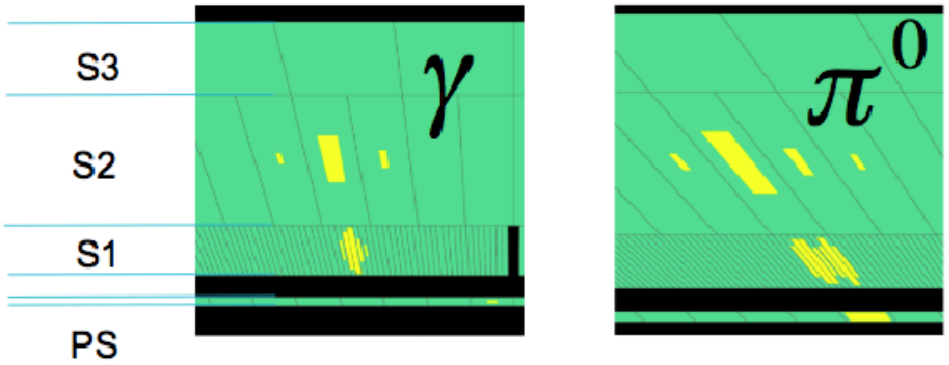
- Takanori Kono
- Peter Vankov
- Nick Styles

- Emphasize connection to Higgs property measurements

Photon Efficiency Measurement(s)

- Separation of photons and (overwhelming) jet-backgrounds through shower shapes in electromagnetic calorimeter
- Imperfect modeling of shower shapes in simulation

→ Important to measure photon identification efficiency from data

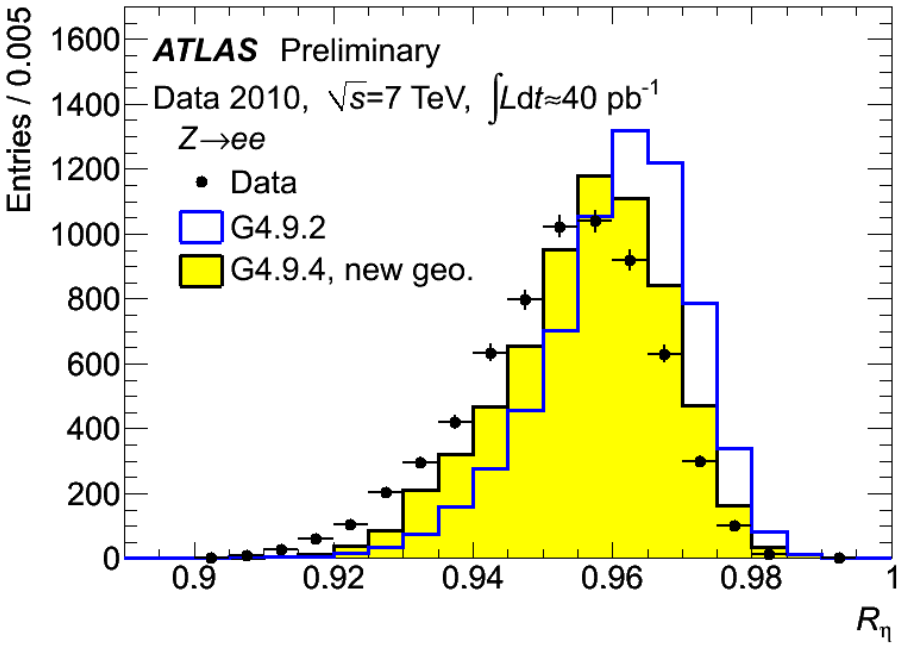


Baseline method

- Selection of clean electron sample using $Z \longrightarrow e^+e^-$ (tag-and-probe)
- Transformation of electron showers to resemble photon showers

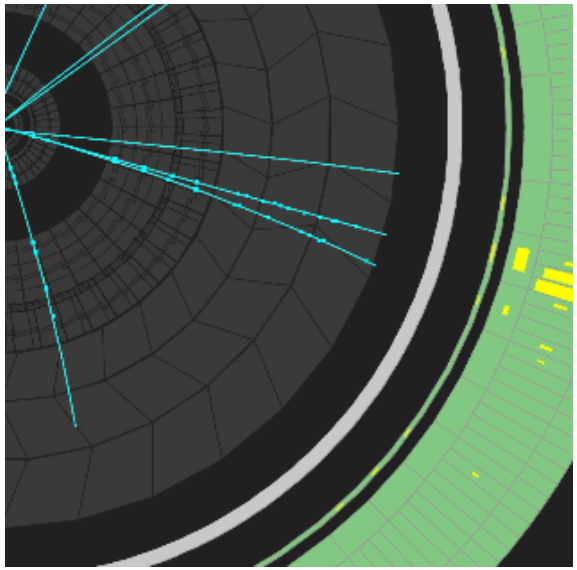
Good knowledge of efficiency necessary for branching fraction measurement

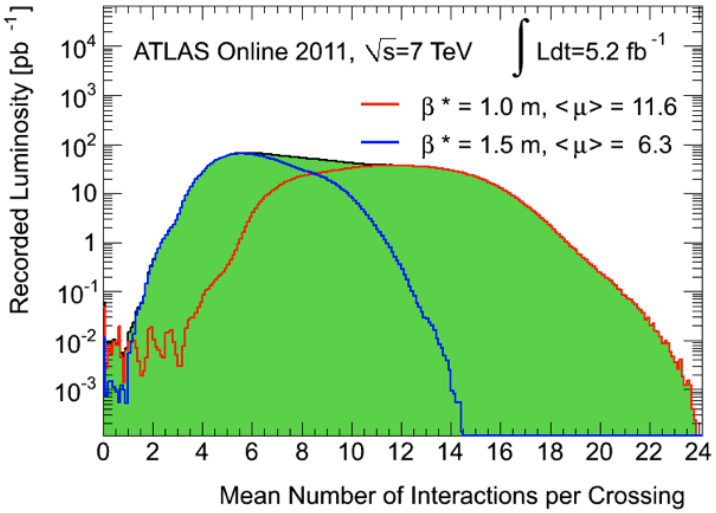
Cluster width in η



Photon Conversion Reconstruction

- Converted and unconverted photons reconstructed separately
  - ⋆ Different shower shapes ⟶ adapted photon identification
  - ⋆ Different amount of energy loss in tracker ⟶ adapted calibration
  - ⋆ Conversion vertex used in photon direction measurement ⟶ improved Higgs mass resolution
- Reconstruction needs to be adapted for given pileup conditions for good performance
- Also using dedicated electron track fits for conversion tracks



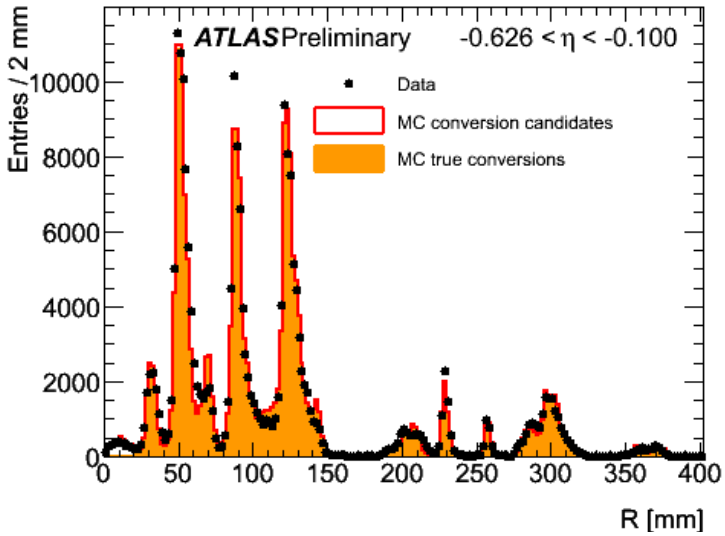


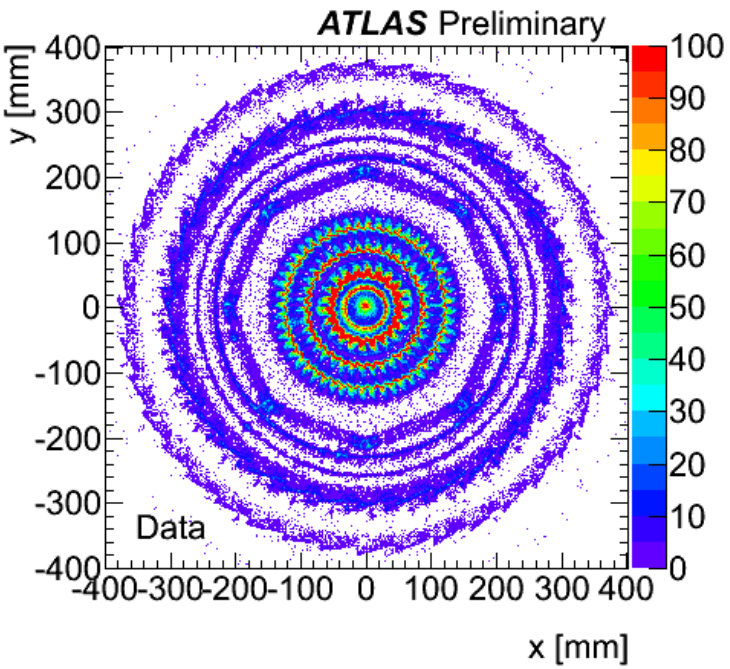
Need reliable reconstruction for any search and measurement

Inner Detector Material Mapping

- Dominant uncertainty in photon energy scale measurement: understanding of material budget upstream of calorimeter
  - ⋆ Radiation length knowledge from detector construction: $(5 - 20)\%$ depending on detector region
- Photon conversions provide way to measure Inner Detector radiation lengths distribution

Good understanding of energy scale necessary for Higgs mass measurement





Event Categorization for $H \longrightarrow \gamma\gamma$

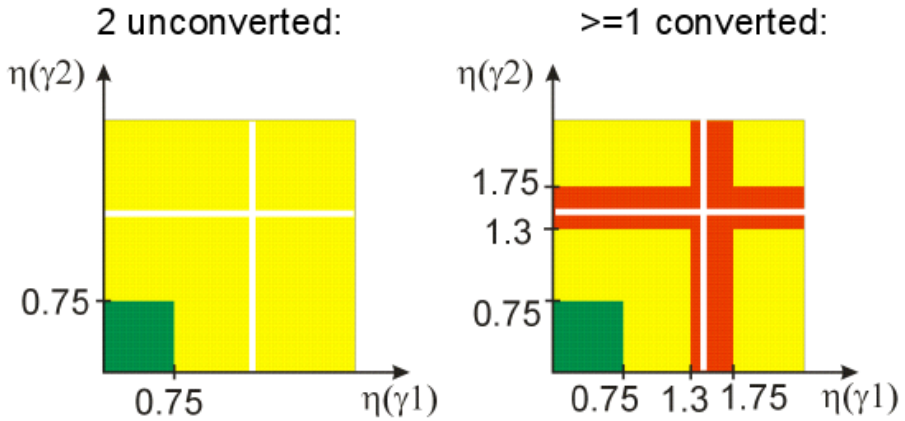
Events are categorized based on conversion properties and photon direction

Both unconverted:

- Central
- Rest

At least one converted:

- Central
- Transition
- Rest

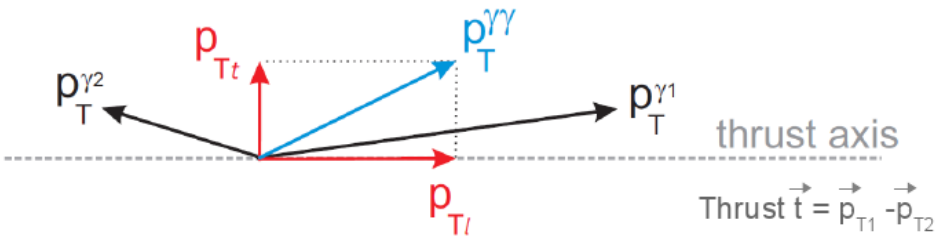


Resolution:

Good
Medium
Poor

Central and Rest divided into $p_{Tt} < 40\,\mathrm{GeV}$ and $p_{Tt} > 40\,\mathrm{GeV}$
$\longrightarrow$ Higher p_{Tt} for signal events (especially VBF and associated production)

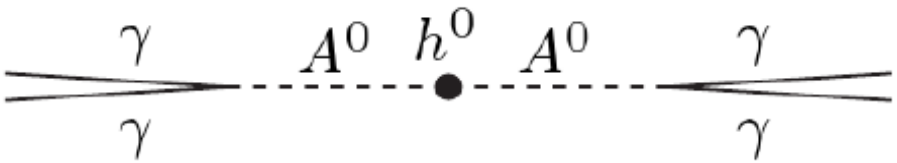
- $\sim 15\%$ improvement from conversion and η categories
- Additional $5 - 10\%$ improvement from p_{Tt} classification



Can also add category for VBF-like events $\longrightarrow$ sensitivity to Higgs production channels

$H \to A^0 A^0 \to 4\gamma$

- A variety of models predict a Higgs decay into two light CP-odd scalars $H \to A^0 A^0$, among which is NMSSM
- For $m_{A^0} < 3m_{\pi^0}$, A^0 decays into photons, $A^0 \to \gamma\gamma$
- Event signature very similar to $H \to \gamma\gamma$ since photon pairs are so collimated that they are reconstructed as a single photon candidate



- Model-independent search with dedicated "photon" identification
- If we see evidence for a Higgs boson, fraction of converted photon candidates can be used to distinguish between $H \to \gamma\gamma$ and $H \to 4\gamma$

Potential overlap with SUSY Higgs studies?
Would this be interesting to continue?

Higgs self-coupling measurement with HL-LHC

Takanori Kono, Nick Styles, Peter Vankov

High-Luminosity LHC (HL-LHC):

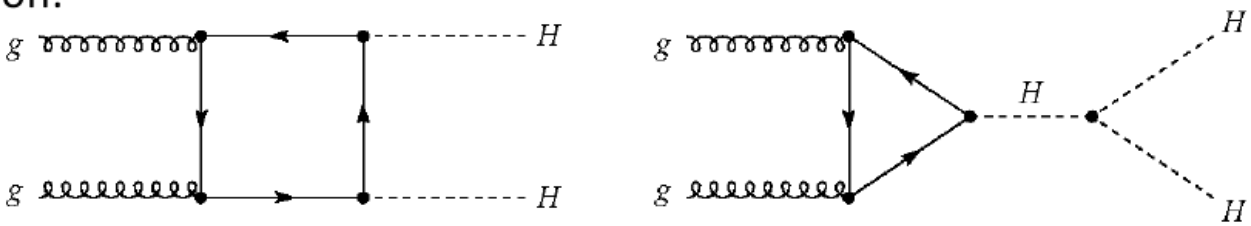
- 2022, $L=5\times10^{34}$ cm^{-2} s^{-1}
- Should collect 3000 fb^{-1} by ~2030

- Given that Higgs-like particle is discovered, then the next primary goal will be to define whether this is a SM Higgs or not (i.e, there's a new physics involved)
- For this, it is important to measure the physics properties of the Higgs particle:
  - Mass,
  - Width,
  - **Spin and CP,**
  - **Couplings to fermions and bosons, rare Higgs boson decays,**
  - **Rare Higgs boson decays,**
  - **Higgs self-couplings.**
- Since the expected cross sections for the above processes are small, integrated luminosities as large as ~3000 fb^{-1} may be needed

Higgs Self Coupling measurement

Takanori Kono, Nick Styles, Peter Vankov

- A direct measurement of λ_{HHH} could be performed via detection of Higgs pair-production
- At LHC or HL-LHC, the gluon-gluon fusion is the dominant mechanism for Higgs pair-production:



Decay channel	Branching ratio (%)	Events @ 14 TeV (L = 3,000 fb^{-1})
bb + W^+W^-	24.9696	24,472
bb + $\tau^+\tau^-$	7.3638	7,216
γγ + bb	0.2658	260

- We study **HH→bbγγ; prepare input for European strategy'2012 document**
- No time for detailed simulation and full event reconstruction
- Instead, perform studies using MC truth and applying simple smearing functions to physics objects, efficiency factors, etc, to account detector effects, trigger selection and offline reconstruction, and (possibly) for pile-up effects

Higgs Self Coupling measurement with HH→bbγγ

Takanori Kono, Nick Styles, Peter Vankov

Main background sources

irreducible:	reducible:
1) bb+γγ,	1) Multi-jets
2) (H->γγ)+bb	2) jet+γ
3) (H->bb)+γγ	3) H+jet+jet (where the jet is misidentified with b or γ)

Status:

Signal reconstruction
- Defined preliminary event selection/cut flow:
  - pt, eta cuts
  - "pseudo" b-tagging (matching jets with a B hadron within $\Delta R < 0.3$)
  - overlap removal
- Started implementing smearing functions.

Background
- Generated samples to study some irreducible backgrounds:
  - γγ+bb (Pythia)
  - H(→ bb) + γγ (MadGraph + Pythia)
  - bb + H(→ γγ) (MadGraph + Pythia)

Thoughts on the Future

- If we do see a Higgs candidate during this year, focus will move to property measurements
- Will continue reconstruction and performance activities
  - ⋆ Will be needed for property studies as much as it is needed for searches at the moment (if not more)
- We are seriously considering to contribute to studies of Higgs production: separating VBF from gluon-gluon fusion
  - ⋆ Overlap with Frank's group – jet binning uncertainties etc.
- Would it be interesting to continue $H \rightarrow 4\gamma$? Or anything else along these lines?
  - ⋆ Overlap with SUSY Higgs studies that could be taken advantage of?

- Studies for Higgs self coupling measurements to be finalized by September