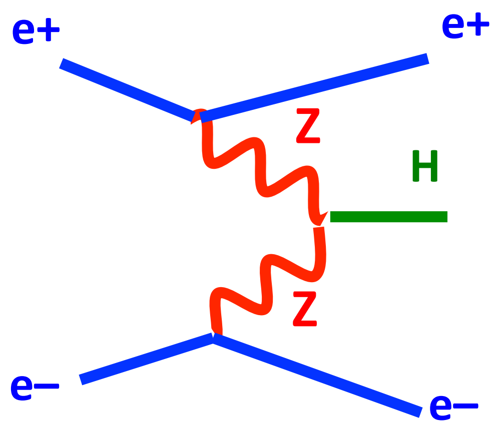
Higgs production in ZZ fusion at 1.4TeV



Aidan Robson

(on behalf of the CLIC Detector and Physics Study)

LCWS13
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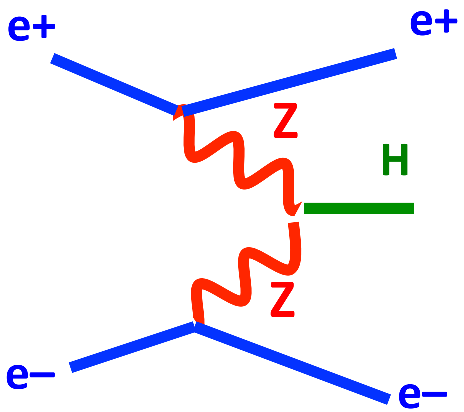
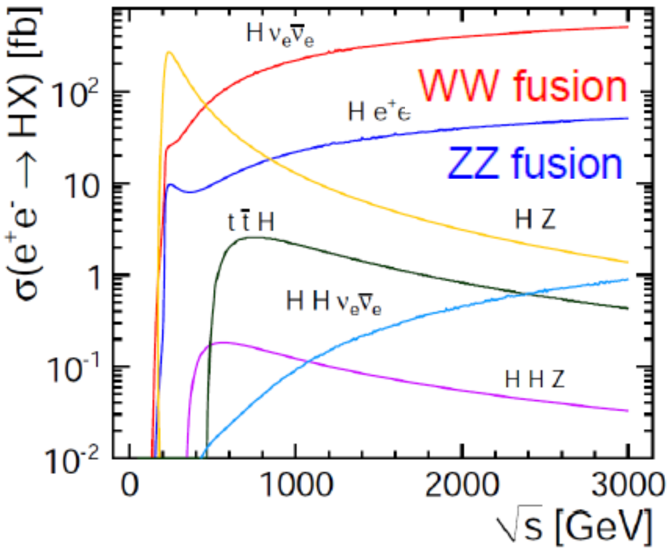
Tokyo

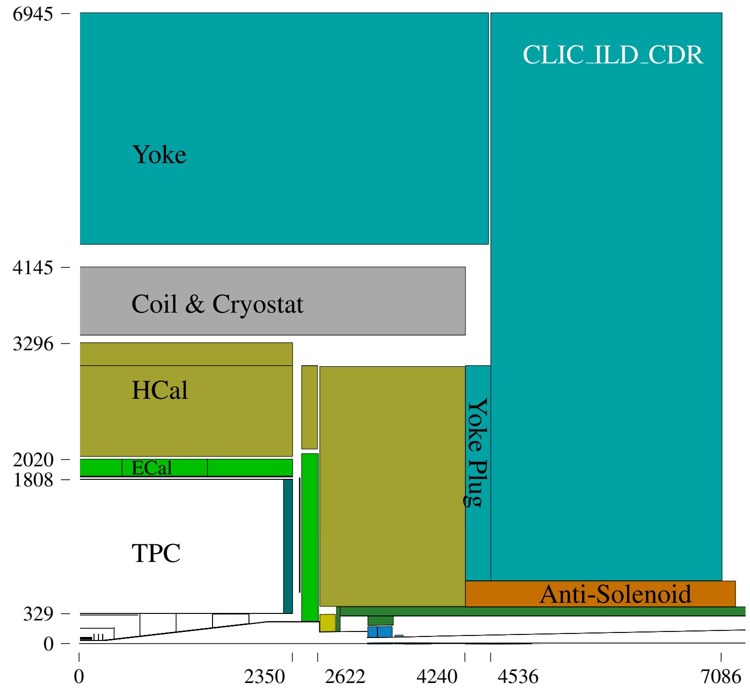
University of Glasgow | Experimental Particle Physics

Introduction



- Fusion process $e^+e^- \rightarrow e^+e^-H$
  Cross-section at 1.4TeV ~ 24.5fb
  10% of leading production process
  $e^+e^- \rightarrow \nu\nu H$
  but access to HZZ vertex





- Using CLIC-ILD detector, good forward coverage – important here

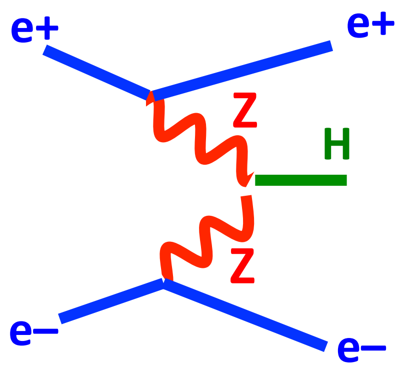
Summary

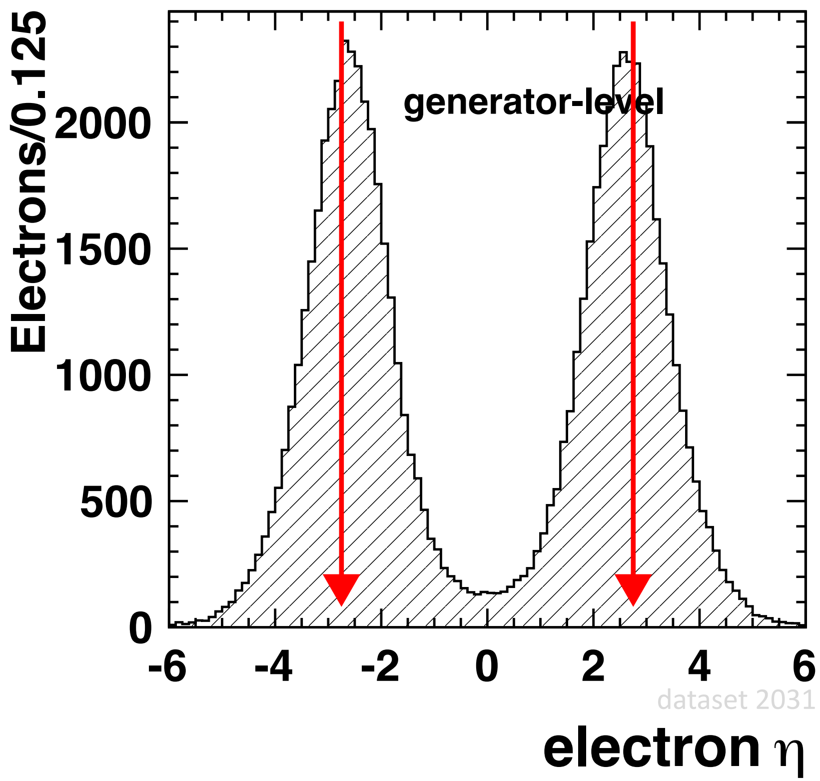
- Signal characteristics
- Analysis strategy
- Preselection
- Backgrounds
- Extracting the signal

Characterising the signal

- Signature: 2 forward electrons, plus Higgs decay

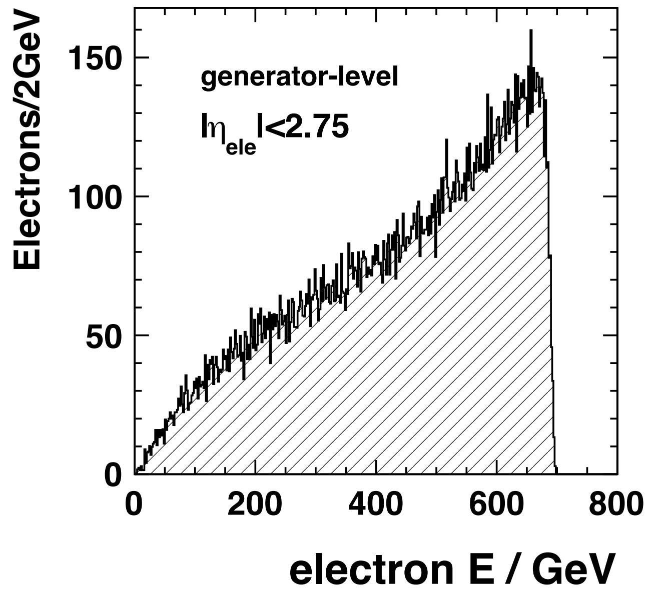
Scattered beam electrons at gen.-level:





Red arrows show detector acceptance

in acceptance:



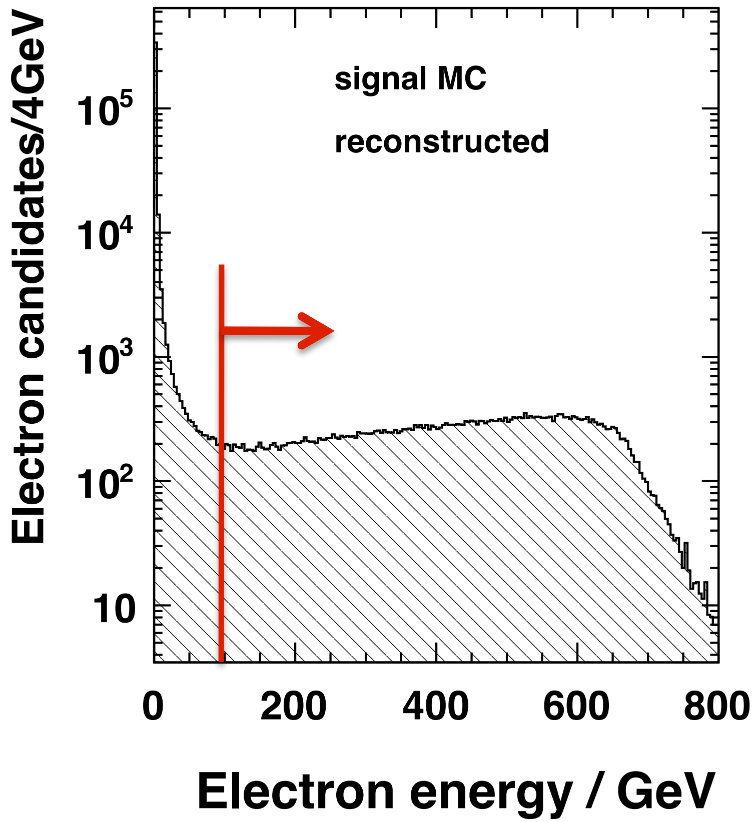
Plots all normalised to 1.5 ab^{-1}

Analysis strategy

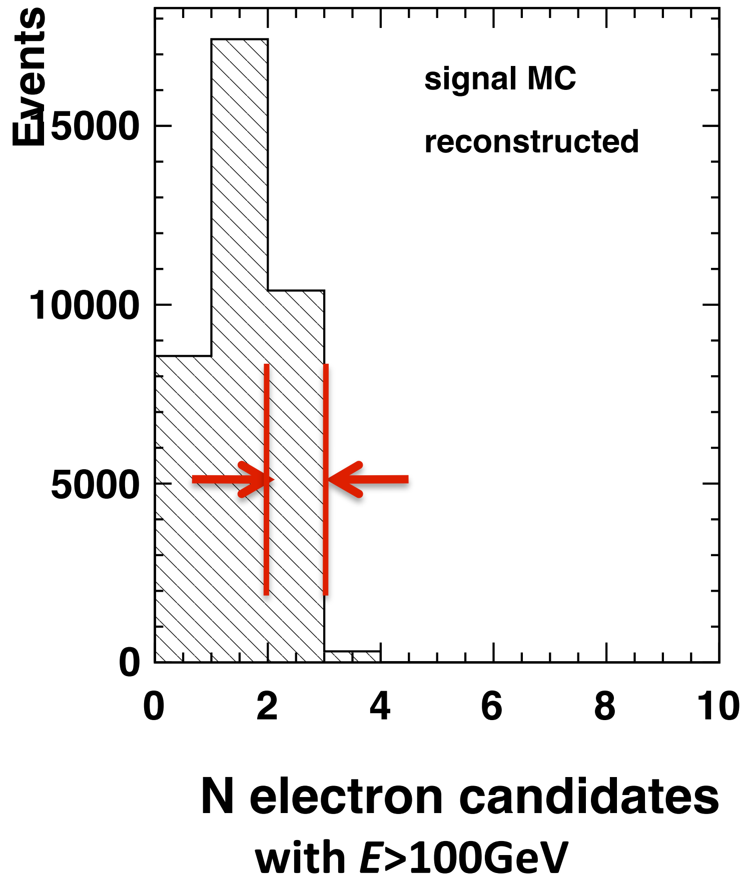
- **FASTJET** — Events forced into 4-jet k_T exclusive clustering of PFOs, R=1.0 (Irrespective of final state)
- **SIMPLE KINEMATIC SELECTION** — 2 opposite-charge electrons, E>100GeV and separated $\Delta\eta$>1
- **MV SELECTION** — Multivariate analysis, currently likelihood
  - → FIT (INDEPENDENT OF FINAL STATE)
  - → **LCFI VERTEX** — b-tag for H->bb final state
  - → **FINAL STATE SELECTION** — 2 b-tagged jets
  - → **FIT** — Extract cross-section x BR

Kinematic preselection

- Look at energies of all reconstructed electron candidates

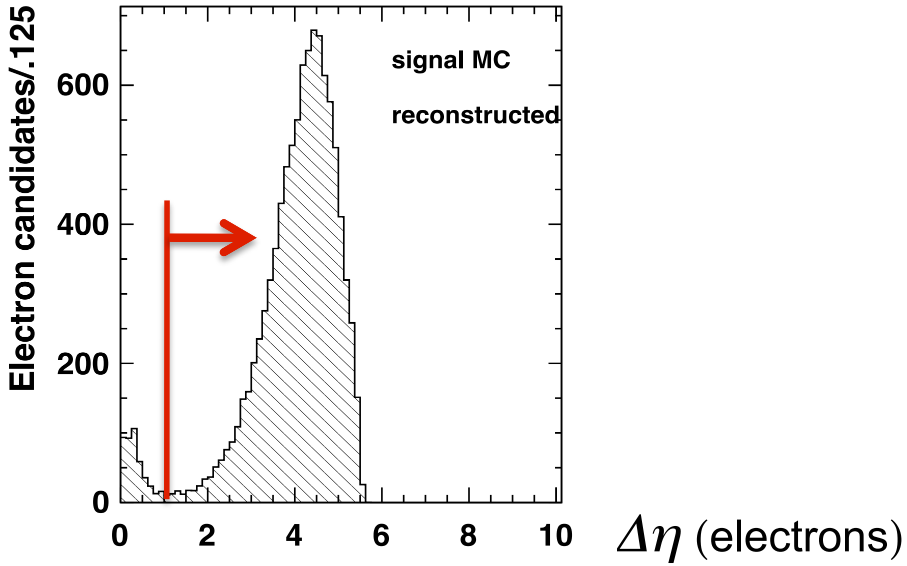


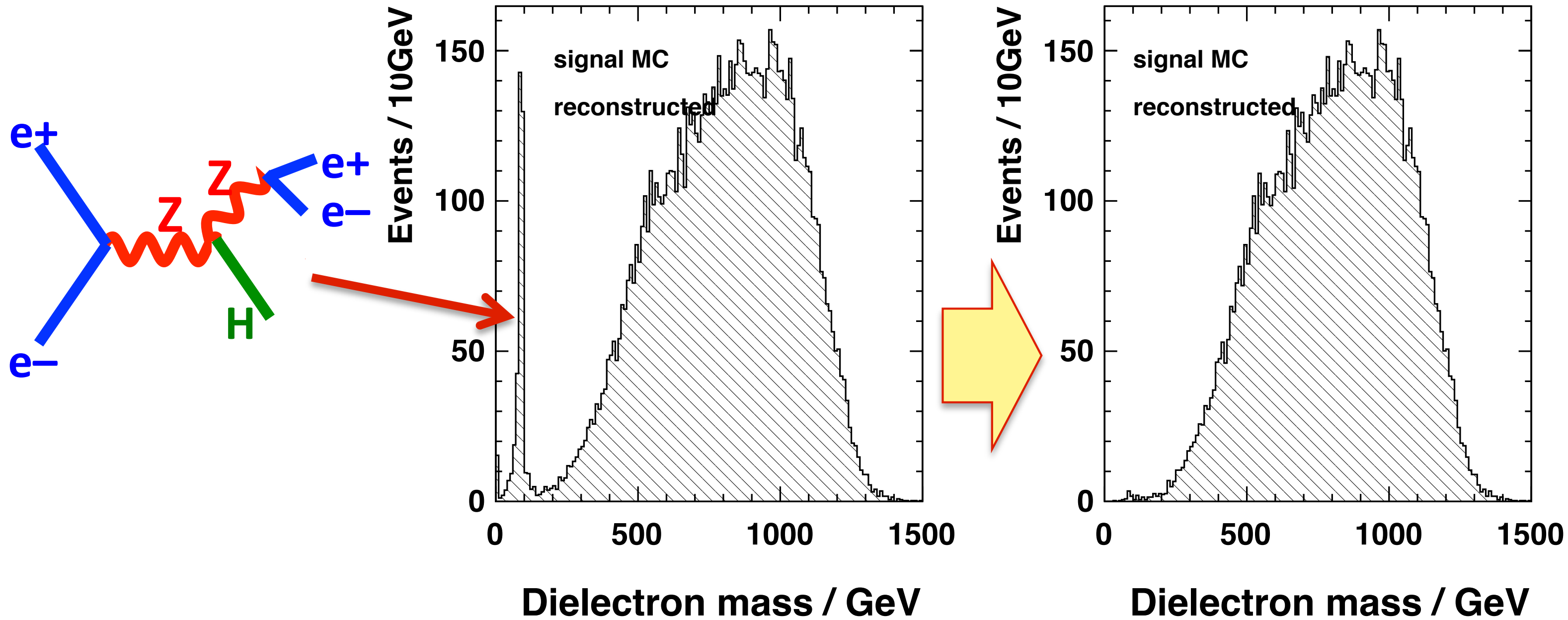
- Count reconstructed electron candidates having E>100GeV



- Select n=2 bin

◆ Look at separation of electron candidates in $\Delta\eta$

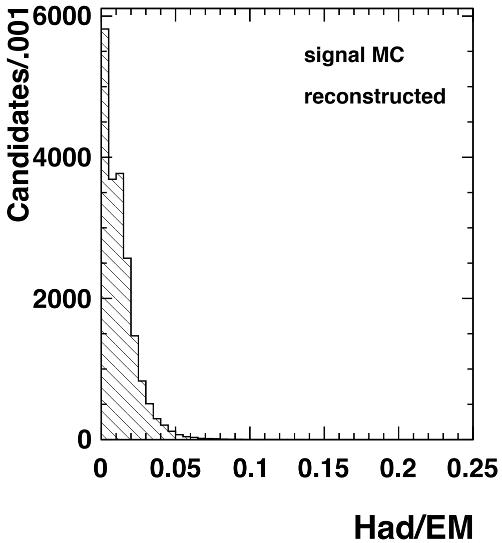


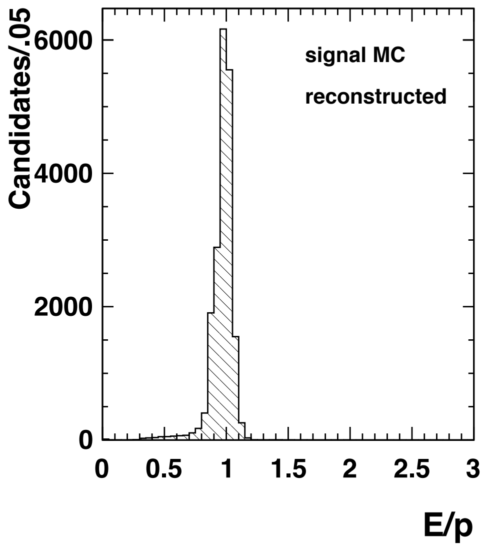


◆ $\Delta\eta > 1$ cut removes H-strahlung contribution

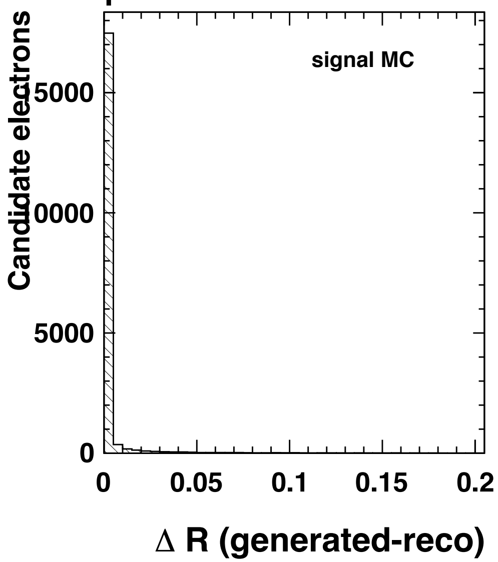
Electron reconstruction checks

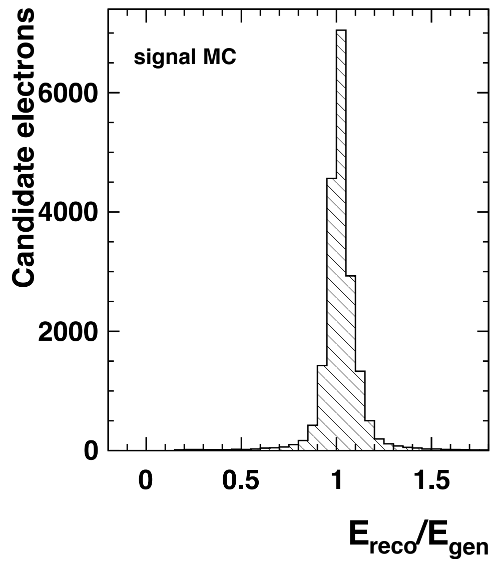
◆ Check electron candidate PFO characteristics:





◆ and match to generator-level electrons:





◆ including PFO photons within cosθ>0.9 of electron candidates

Cutflow for initial selection

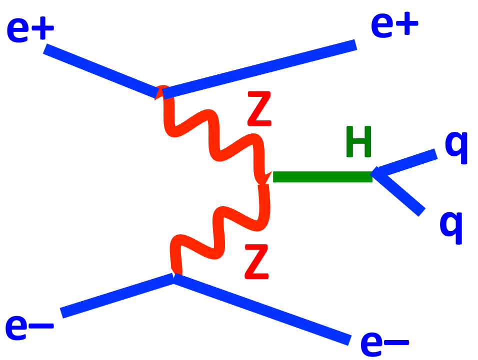
Monte Carlo generated using WHIZARD 1.95

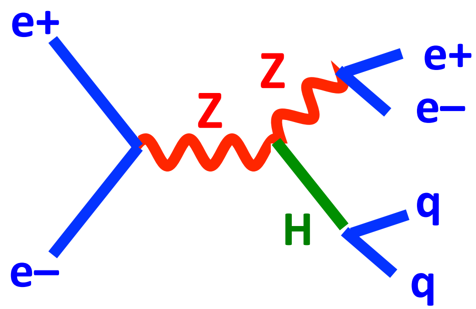
eeH signal dataset 2031	surviving	xs/fb
All events		24.47
>= 2electron cands, *E*>100GeV	29.2%	7.14
==2 electron cands, *E*>100GeV	28.3%	6.93
opposite charge	27.7%	6.79
DeltaEta>1	26.5%	**6.49**

geometrical acceptance

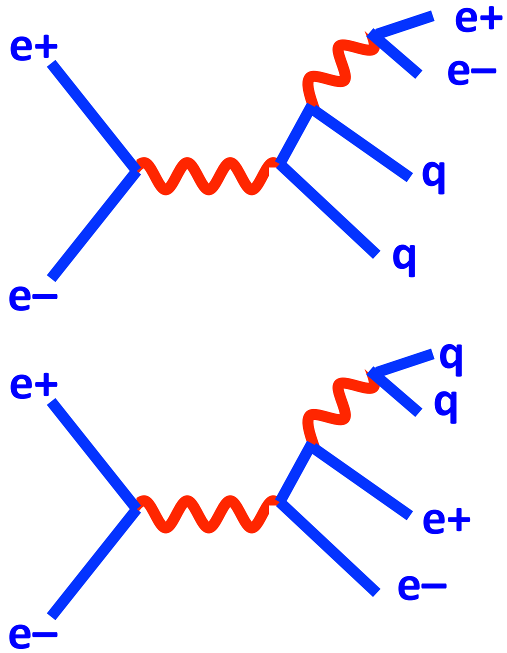
ie, 9375 events in 1.5 ab^{-1}

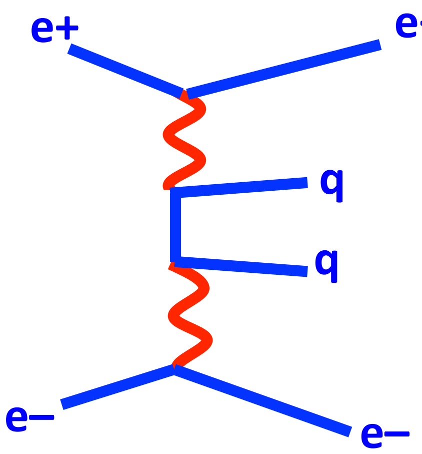
Backgrounds



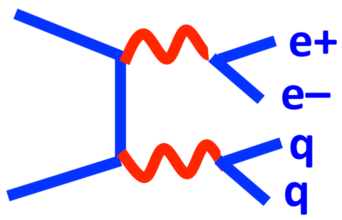


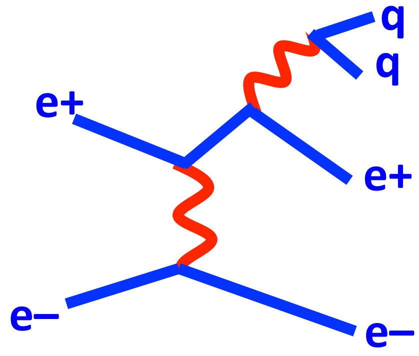
possible to remove with ΔR(electrons)>1





continuum





dataset 2645

Leading background

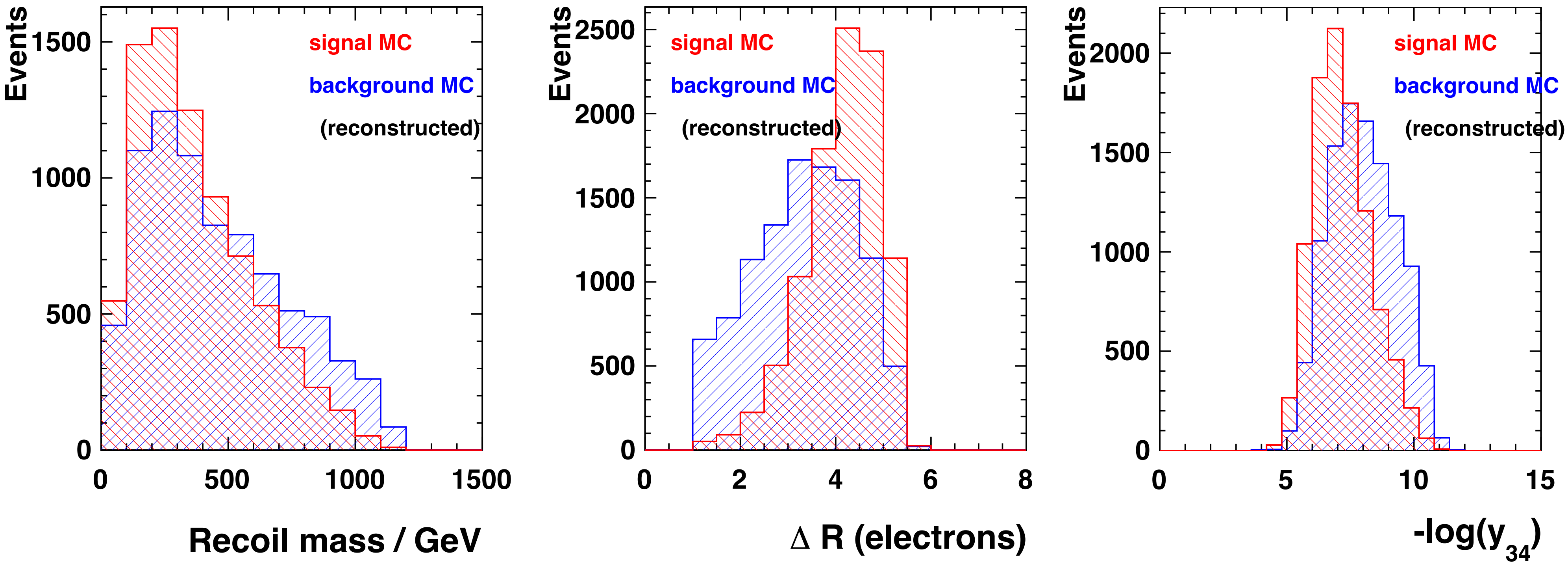
	eeH signal (dataset 2031)		qqll background (dataset 2645)	
	surviving	**xs/fb**	surviving	**xs/fb**
All events		24.47		2726.7
>= 2electron cands, *E*>100GeV	29.2%	7.14	2.1%	58.02
==2 electron cands, *E*>100GeV	28.3%	6.93	2.1%	56.86
opposite charge	27.7%	6.79	2.0%	54.41
DeltaEta>1	26.5%	**6.49**	1.8%	**48.12**

- Backgrounds well-suppressed – but still 8x signal

Separating signal from backgrounds

- Look for event variables to characterise signal
  - separation between electrons ΔR
  - recoil mass
  - y_{34} to characterise final state shape

fairly independent of decay mode, for visible decays



Background normalised to **signal** here

Likelihood

Using event variables

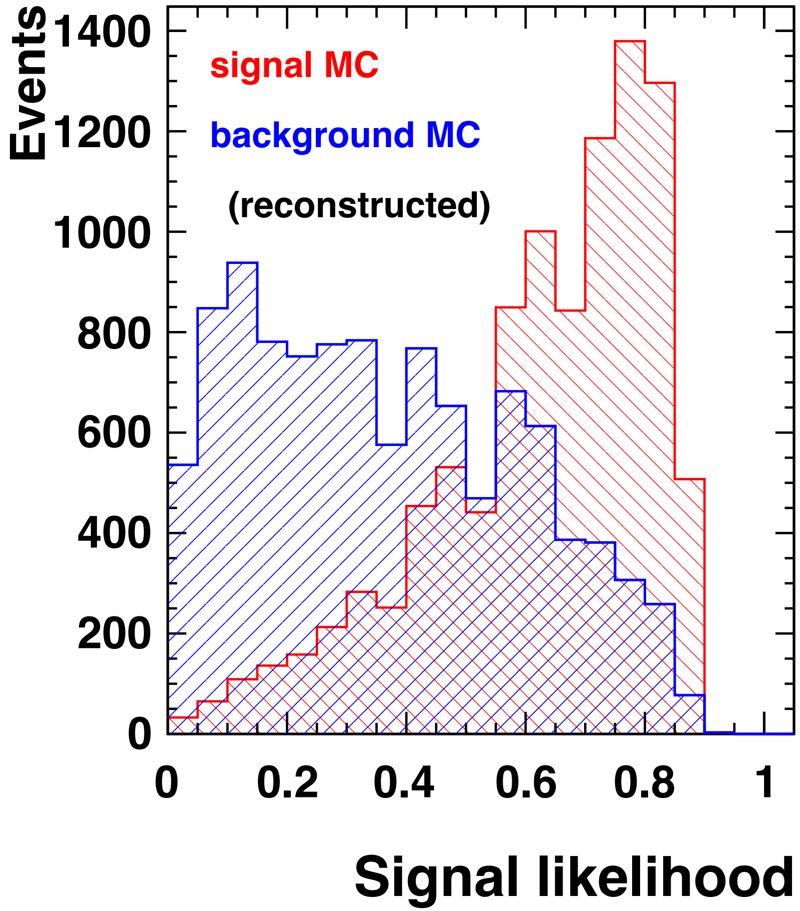
- electron ΔR
- recoil mass
- y_{34}

Construct probabilities

$$L_{sig} = P_{sig}(\Delta R) \times P_{sig}(m_{recoil}) \times P_{sig}(y_{34})$$

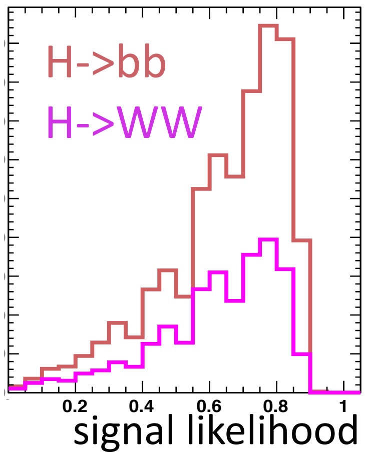
Signal likelihood:

$$\mathscr{L}_{sig} = \frac{L_{sig}}{L_{sig} + L_{bck}}$$



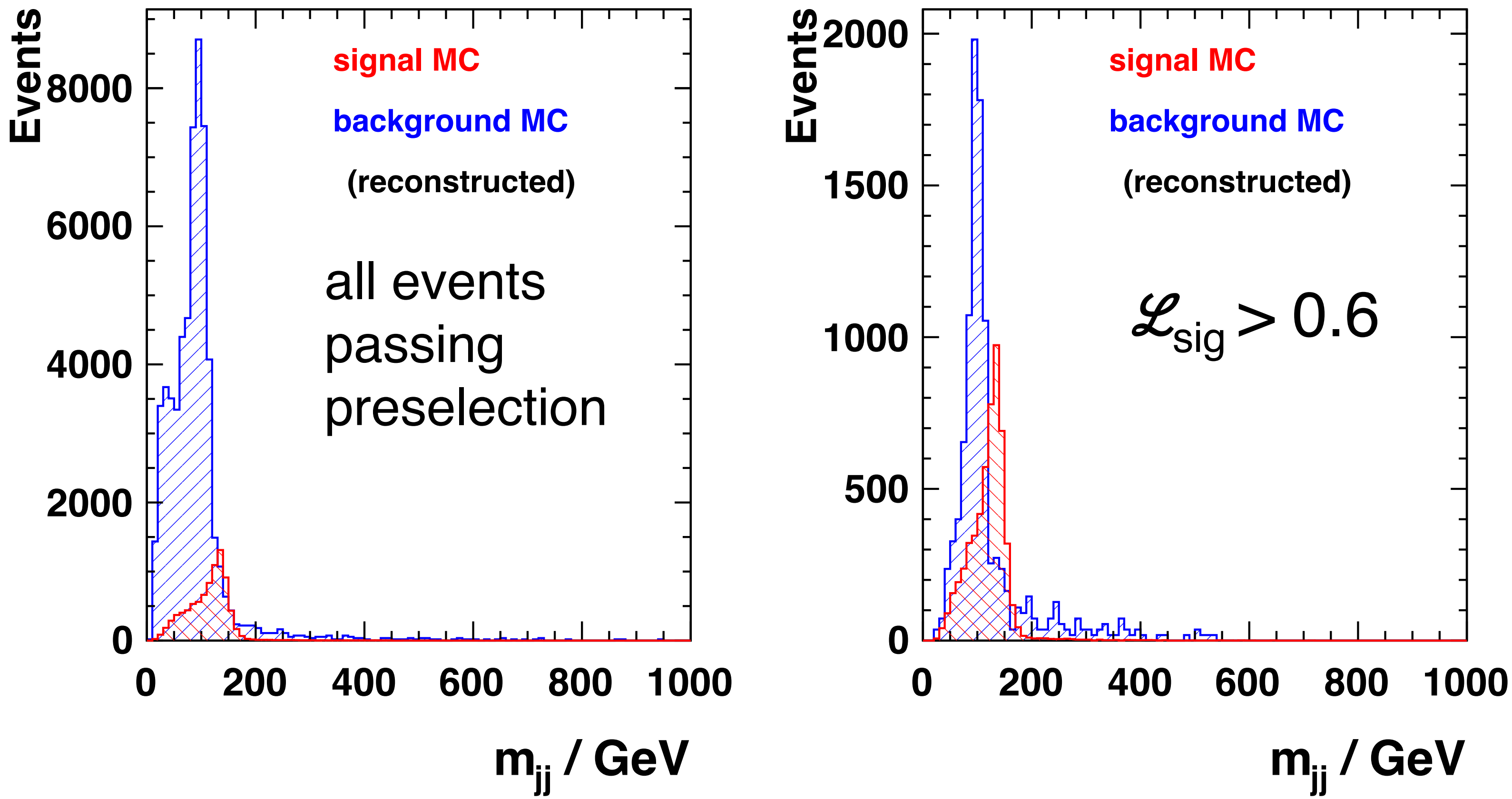
Background normalised to signal here
Background is actually ~8 x signal here

H->bb and H->WW very similar in this variable



Final state

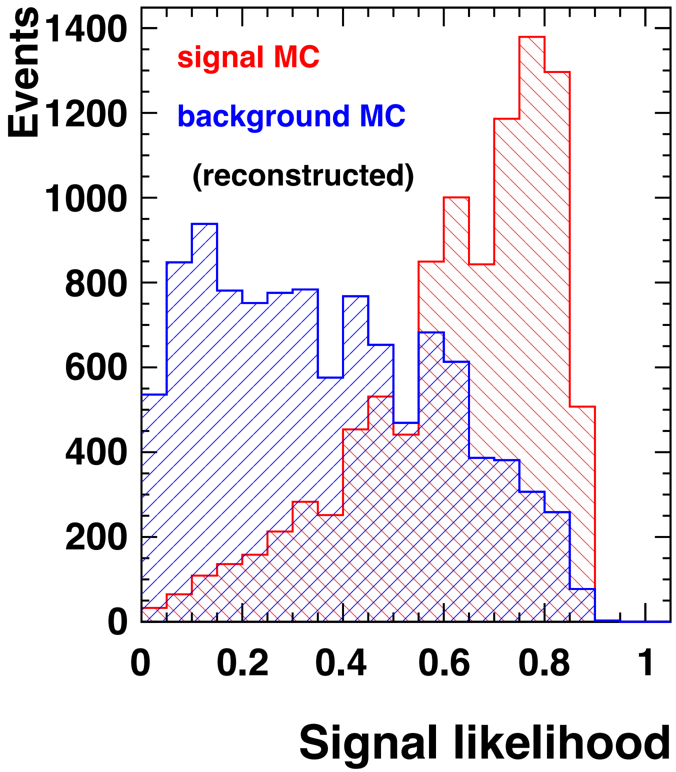
◆ look at m_{jj} for the two jets not matching the electron candidates:



normalised to 1.5 ab^{-1}

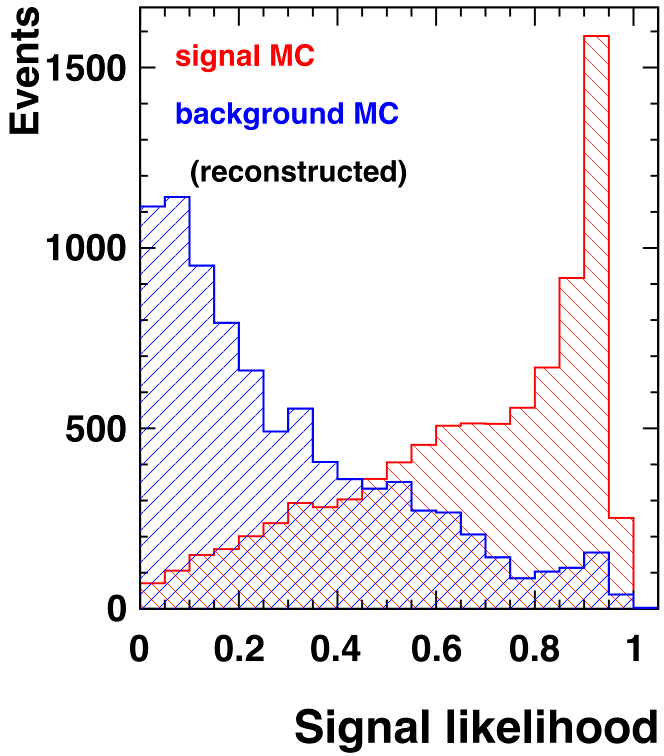
Likelihood incorporating final state jets

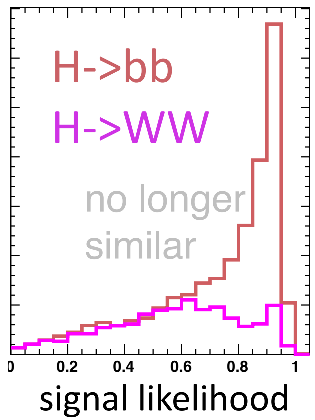
- Can include m_{jj} in likelihood and improve separation … but then H->bb and H->WW look quite different



all events passing preselection

include m_{jj}

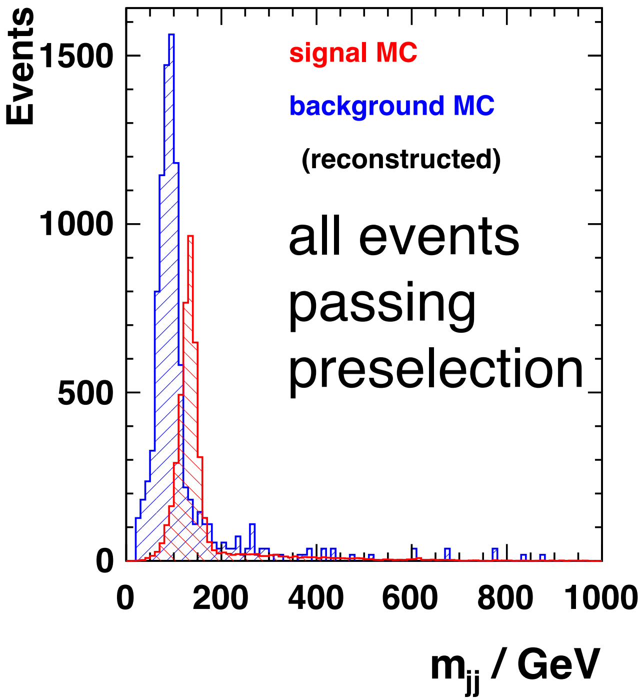


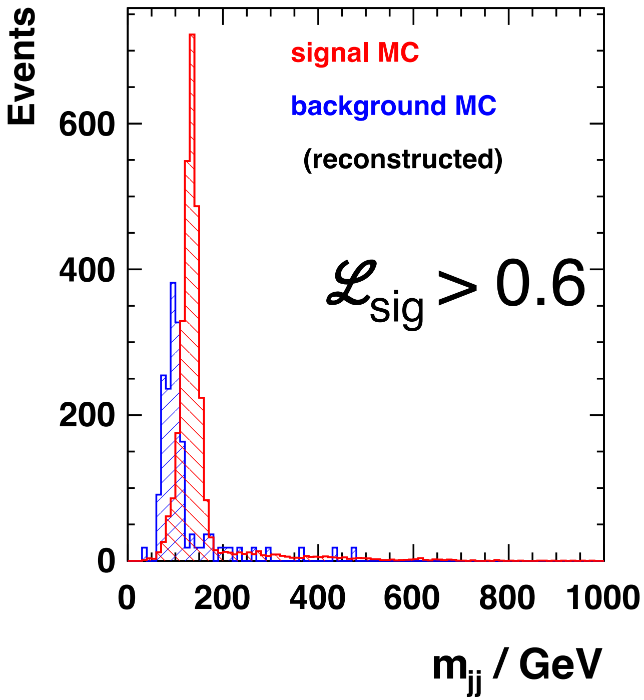


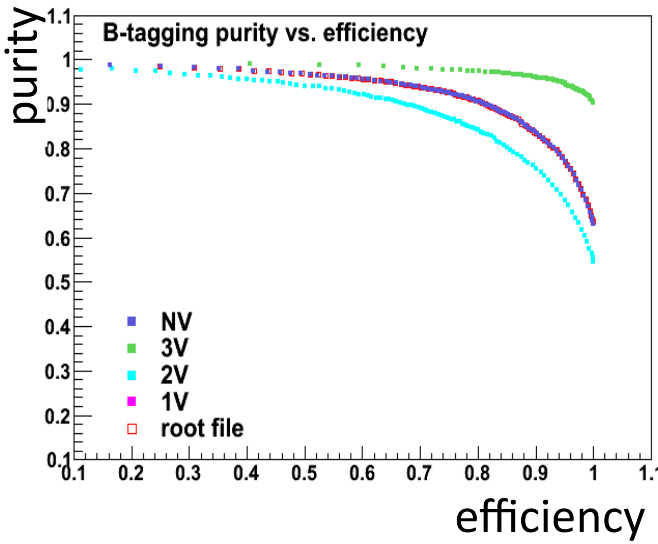
Background normalised to signal here
Background is actually ~8 x signal here

Final state with b-tag

- alternative way of improving signal separation:
- explicitly select H->bb by requiring both jets to have a b-tag







LCFI b-tag tools

normalised to 1.5 ab^{-1}

Final state with b-tag

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	surviving	**xs/fb**	surviving	**xs/fb**
All events		24.47		2726.7
>= 2electron cands, E>100GeV	29.2%	7.14	2.1%	58.02
==2 electron cands, E>100GeV	28.3%	6.93	2.1%	56.86
opposite charge	27.7%	6.79	2.0%	54.41
DeltaEta>1	26.5%	6.49	1.8%	48.12
4-jet topology has 2 jets matching electron cands	23.3%	5.70	1.4%	39.18
2 (truth) b-tags	12.5%	**3.06**	0.2%	**6.26**

ie, 4590 events in 1.5 ab^{-1}

Other backgrounds with two electrons, two jets, eg top:
– low dielectron mass and separation compared to signal

Extracting physics

- Avoiding selecting a final state gives access to g_{HZZ} (and Γ_H) only; however sensitivity is limited.
- Including the reconstructed final state selects mostly H->bb, plus some H->WW, with statistical uncertainty on cross-section of ~1% in 1.5 ab^{-1}.
- Explicitly requiring H->bb using b-tag gives clean signal separation but increases statistical uncertainty to ~1.5%.
- Ratio of $\sigma(ee \to eeH).Br(H \to bb)$ to $\sigma(ee \to \nu\nu H).Br(H \to bb)$ is promising for the ratio g_{HZZ}/g_{HWW} without g_{Hbb} or Γ_H
- Systematic uncertainty on cross-section measurement is fairly large because detector acceptance truncates electron η distribution.

Summary

- We have reconstructed ZZ fusion events at 1.4TeV, using fully-measured forward electrons, with an acceptance of around 30%.
- Signal has been separated from background using a simple likelihood technique.
- Signal sensitivity is limited when assuming nothing about the final state, except that it is visible;
- but with some assumption about the ratio of H->bb and H->WW, the signal : background is good (statistical uncertainty on cross-section ~1.5%).
- Alternatively, the H->bb final state can be successfully isolated using b-tagging (statistical uncertainty ~1%).