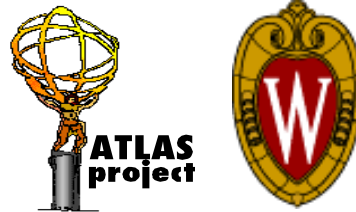


# Progress on Higgs- $\rightarrow$ ZZ- $\rightarrow$ 4e and 2e2 $\mu$ analyses with full ATLAS simulation

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University of Wisconsin



ATLAS SW & Perf. Meeting, CERN, Jan/28 2004

# Outline: focus on LAr electrons

- ➡ First Electron-Based calibration for LAr Barrel in ATLAS, using TestBeam03 input/ideas
  - ✓ Compare with present calibration
  - ✓ Impact on Higgs Analyses
- ➡  $H \rightarrow ZZ \rightarrow 4e, 2e2\mu$  common analysis with TDR-like cuts:
  - ✓  $4e, 2e2\mu$  Background Rejection (prelim)
- ➡ Application of EM-cluster classification:  
Trying to use EM shower information to maximize Higgs signal yield and improve ATLAS sensitivity.

# New Monte-Carlo Samples

(thanks to: A. Stradling and B. Mellado)

Events generated with:

Recon Offline Release 7.0.2, Pythia 6.203,

$pt(\text{leading lep}) > 17\text{GeV}$ ,  $pt(\text{lep}) > 4\text{GeV}$ ,  $|\eta| < 2.7$

- 0.2Mevents  $t\bar{t} \rightarrow 2e2\mu$  (**MC@NLO**)
- ~1Mevents  $pp \rightarrow ZZ \rightarrow 4l$  (**Pythia6.2**)
- ~0.6Mevents  $Zbb \rightarrow 4e, 2e2\mu$  (**ACERMC**)

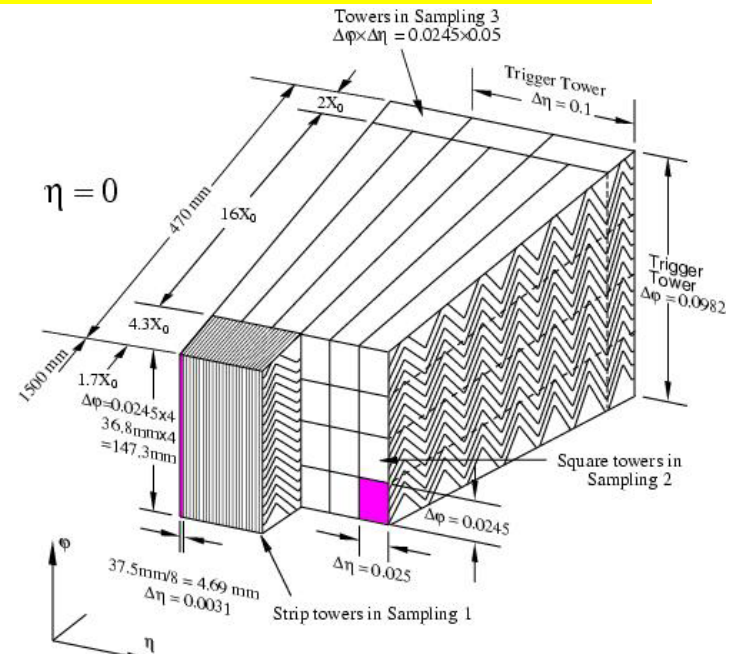
Events in CASTOR available to the ATLAS collaboration

# Electron-based LAr Barrel Calibration

- Uncorrect present calibration
- Use part of the present samples to extract the calibration constants  $\lambda$ ,  $b$  and  $W_0$ :

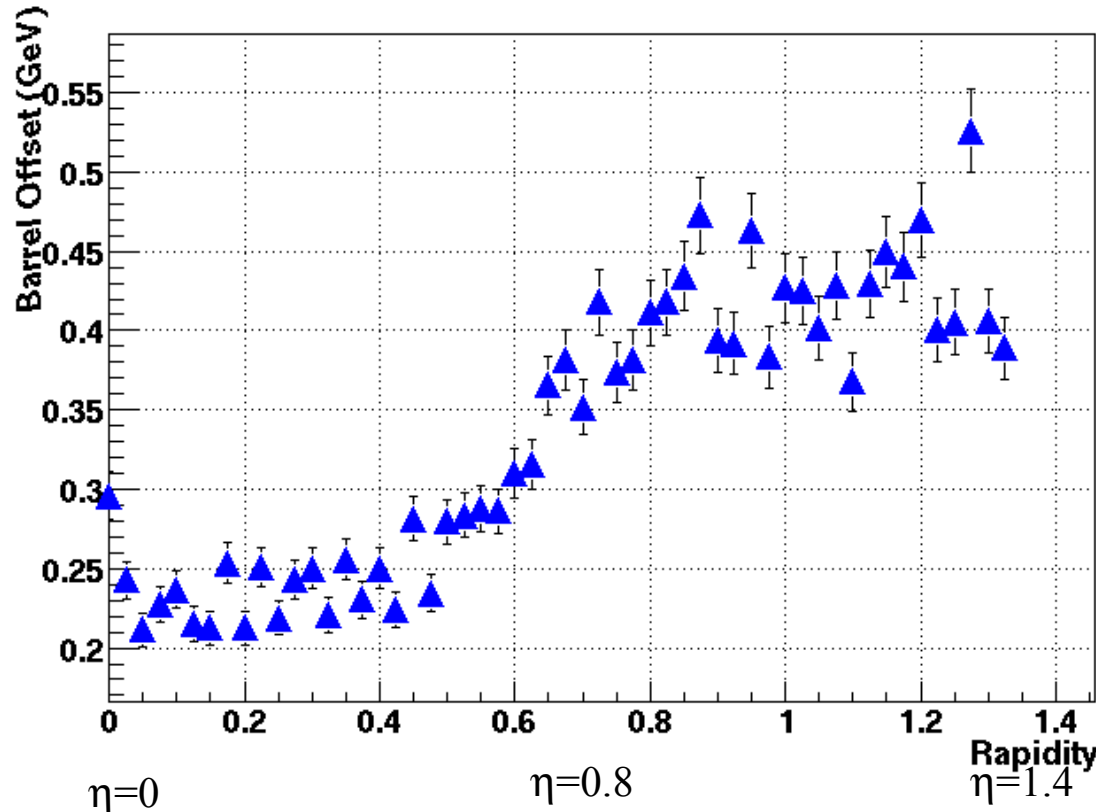
$$E_{rec} = \lambda \left( b + W_0 E_{pres} + E_1 + E_2 + E_3 \right)$$

Offset necessary to correct for residual Accordion non-linearity due to upstream material. Trying to understand the physical origin of the offset  $b$  (T.Carli et al, S.P.)

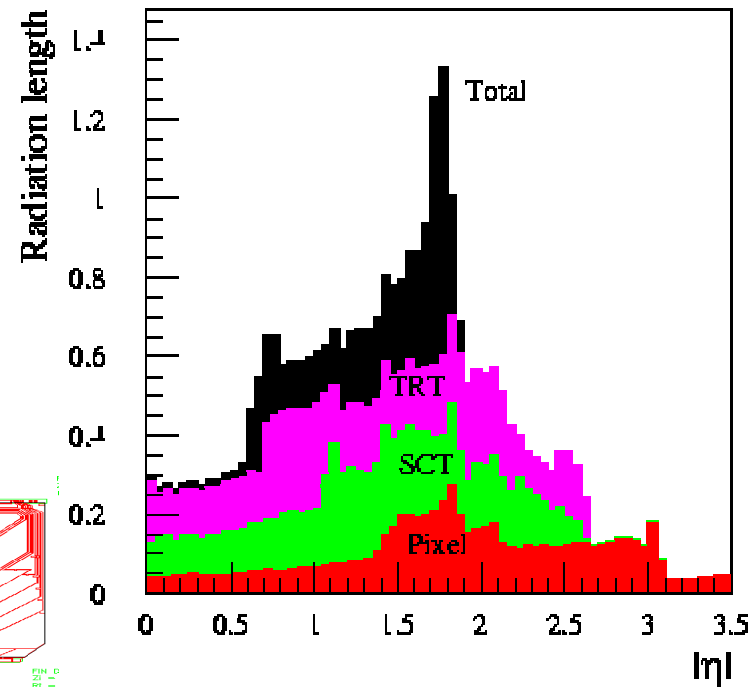


# Offset is large and correlated to the upstream material

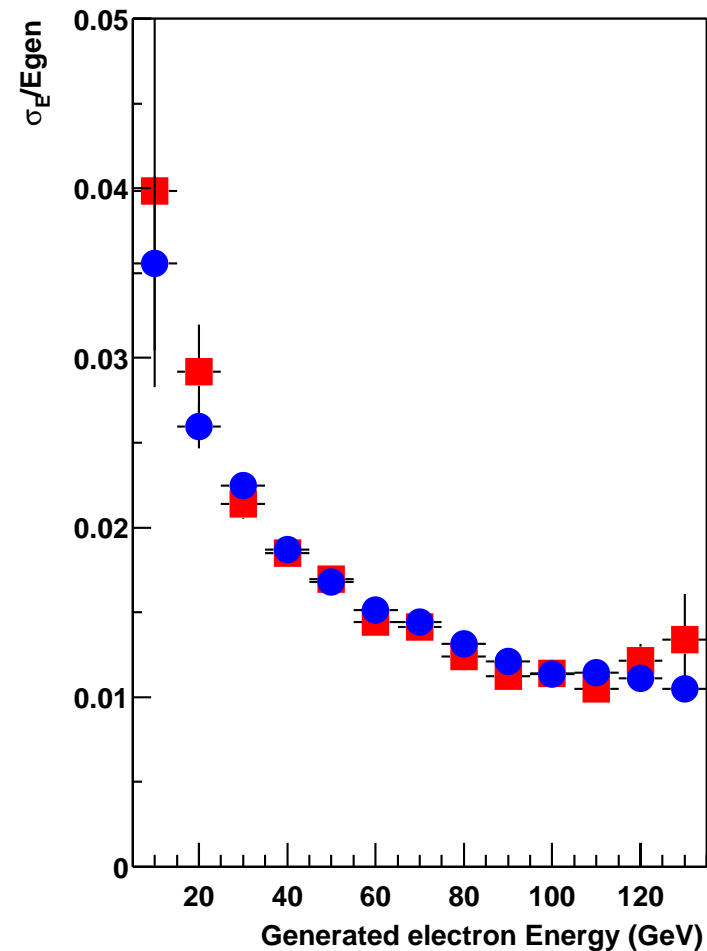
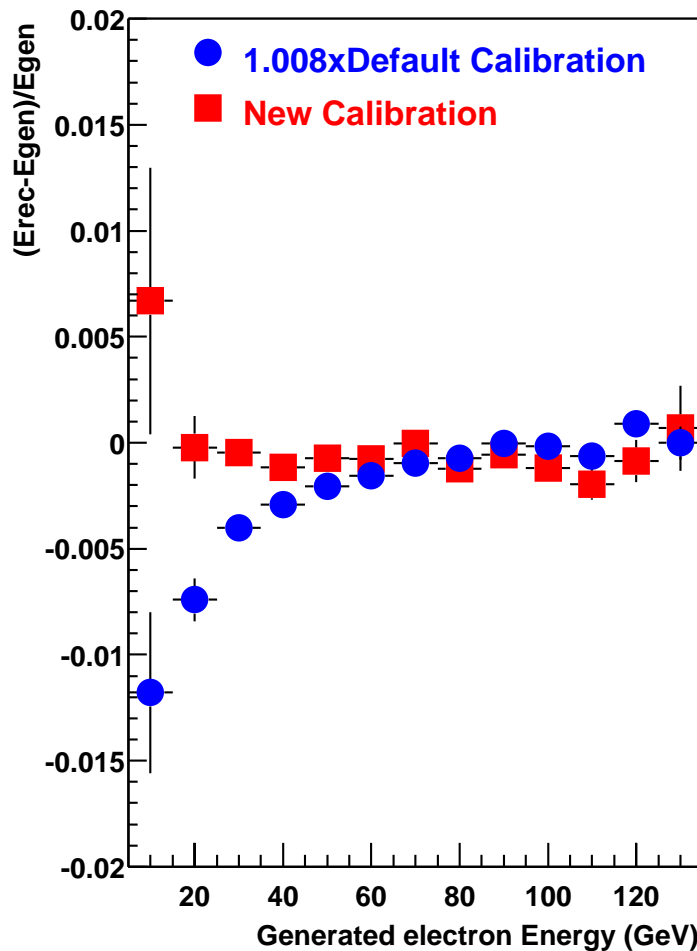
LAr Barrel Calibration Offset



- We calibrate within  $|\eta| < 1.37$
- We use 54  $\eta$  bins i.e. the granularity of the second sampling ( $\Delta\eta = 0.025$ )



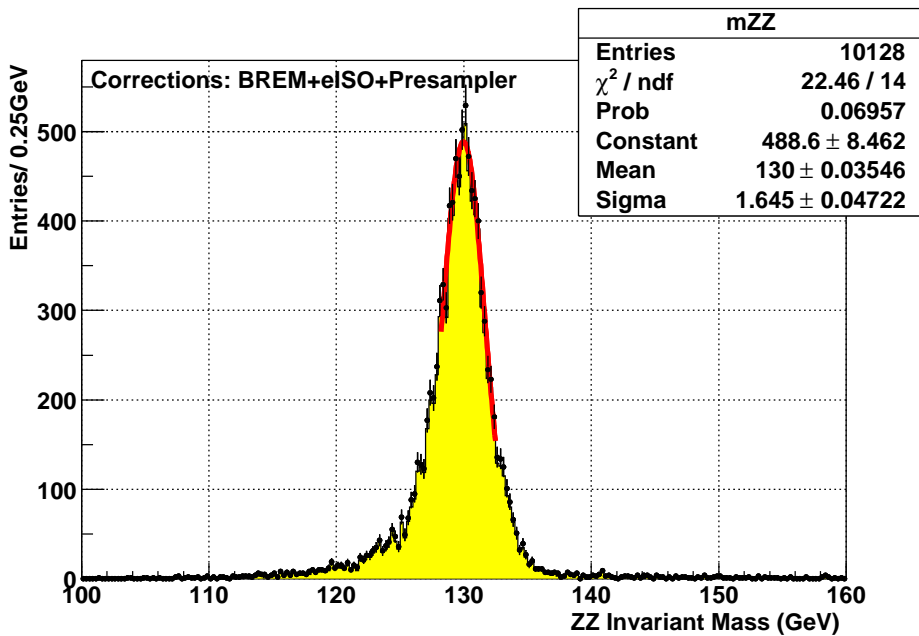
# Comparison with present calibration



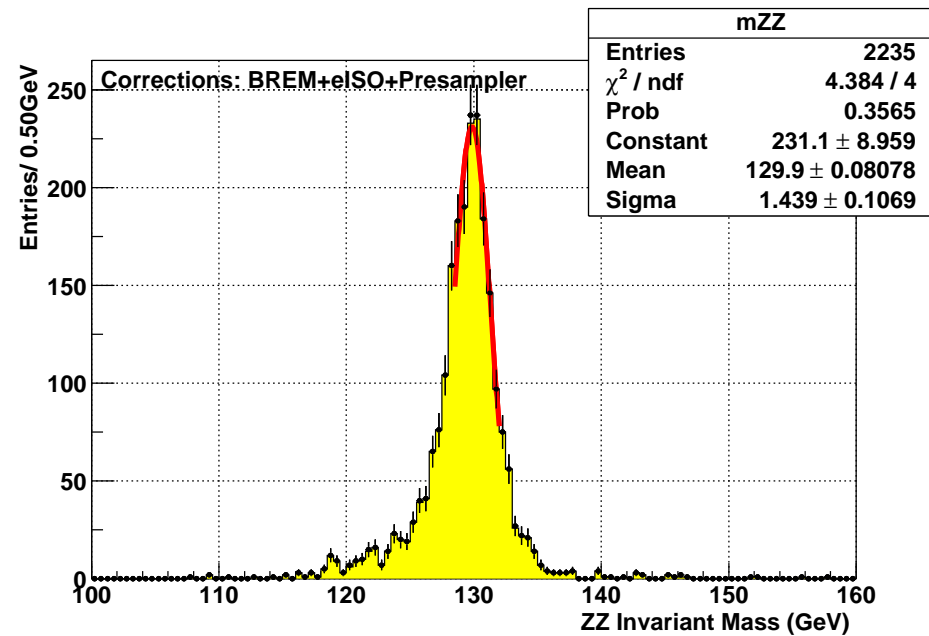
New e-based Calibration is better behaved: **test-beam experience is paying off**

# H(130)->ZZ->4e, 2e2μ resolutions

H->ZZ->4e



H->ZZ->2e2μ



(From  $\sigma=1.71\text{GeV}$  in Dec/03 to  $1.65\pm 0.04$  now)

Small Improvement in resolution and linearity (see Dec/03 HWG)

# H→4l Analysis Review

## H→ZZ→4e

- Apply EM corrections to the 4e
- Use Et from LAr,  $\eta$ ,  $\phi$  from tracks and combine ID with LAr for tracks with  $0.1 < E/p < 1.02$
- Apply TDR-like cuts
  - 4 electrons with  $pt(1,2) > 20$ ,  $pt(3,4) > 7\text{GeV}$  with  $|\eta| < 2.5$  units
  - EM isolation cuts (low mass only)
  - ID isolation cuts (low mass only)
  - Impact Parameter cut (low mass only)
- Study possibility of enhancing signal yield without increasing the reducible backgrounds, using EM cluster/shower information.

## H→ZZ→2e2 $\mu$

- Apply EM corrections to the 2e
- Use Et from LAr,  $\eta$ ,  $\phi$  from tracks and combine ID with LAr for tracks with  $0.1 < E/p < 1.02$
- MuID-Comb block for muons
- Apply TDR-like cuts
  - 2e and 2 $\mu$  with  $pt(1,2) > 20$ ,  $pt(3,4) > 7\text{GeV}$  with  $|\eta| < 2.5$  units
  - EM isolation cuts (low mass only) only for e
  - ID isolation cuts (low mass only) separately for e,  $\mu$
  - Impact Parameter cut (low mass only): use `aOvert` separately for e,  $\mu$
- High Mass: one iso-e, (Prelim)

# Rejection of $H(150) \rightarrow 4e, 2e2\mu$ with new Atlas layout

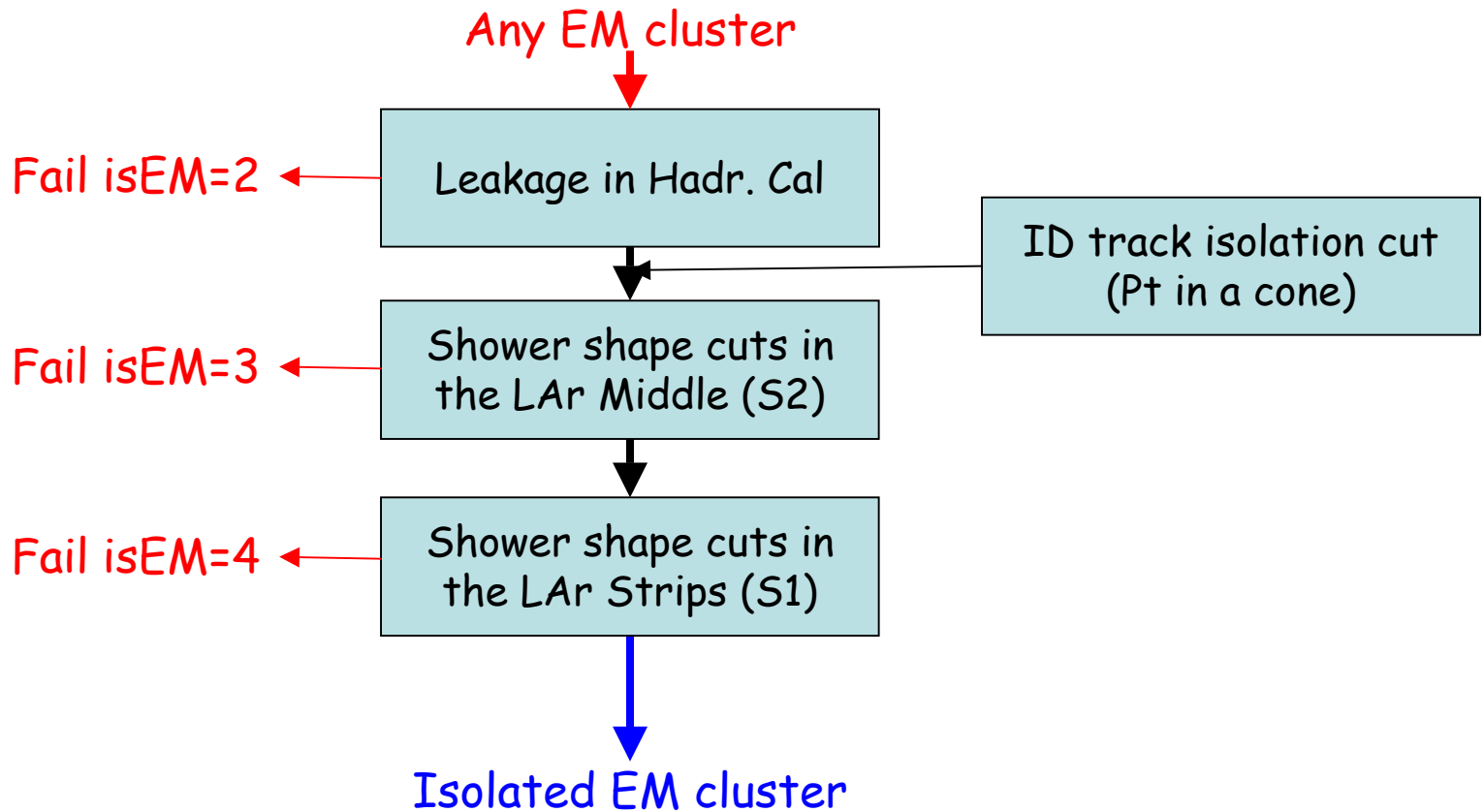
Cut	$t\bar{t} \rightarrow 4e$ (Rej)	$Zbb \rightarrow 4e$ (Rej)	$Zbb \rightarrow 2e2\mu$ (Rej)
<b>EM LAr</b>			
Hac+2S+1S	123+/-10	63	Only for 2e
<b>Inner Detector</b>			
ID SumPt<10GeV, (5GeV for muons)	45+/-2	-	30
<b>Combined</b>			
EM(H+2+1)+ID	418+/-61	140	109
EM+ID+ImpPar.	1155+/-280	330	350+/-25

Cuts are the same as in HWG-Dec/03 talks S.Armstrong, SP

The "Impact Parameter" Cut (a0vert) needs improvement.

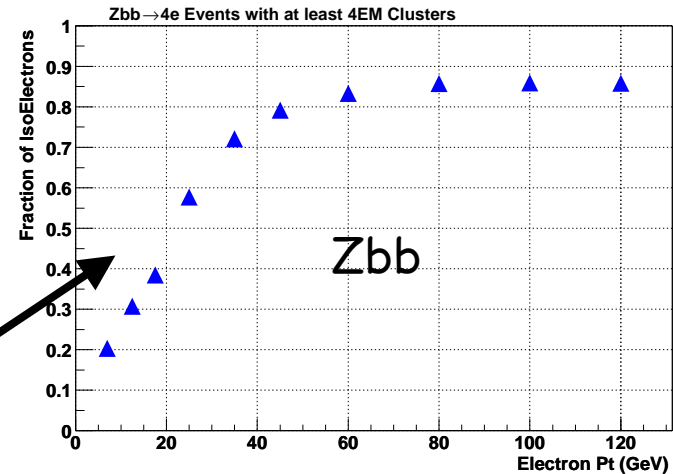
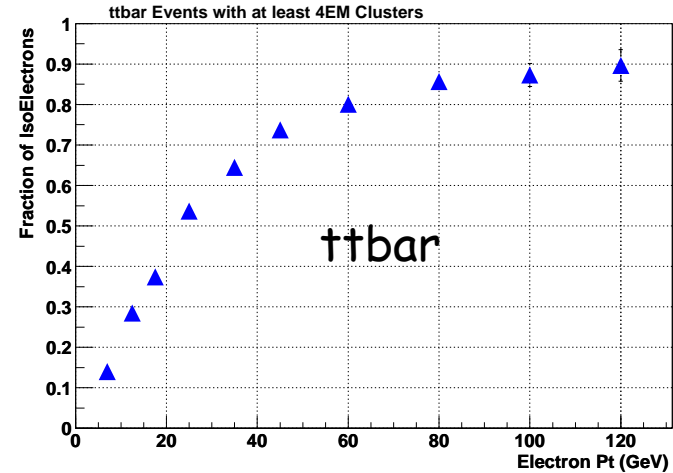
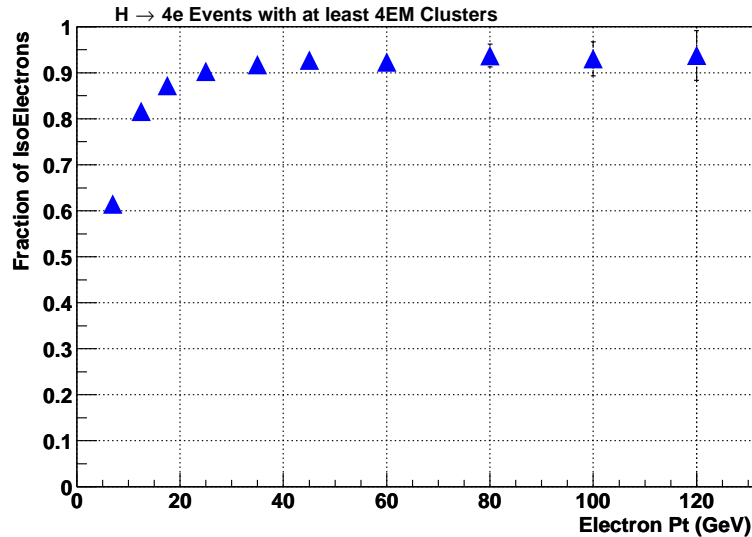
Preliminary

# LAr Electron Isolation



# Fraction of iso-electrons vs Pt

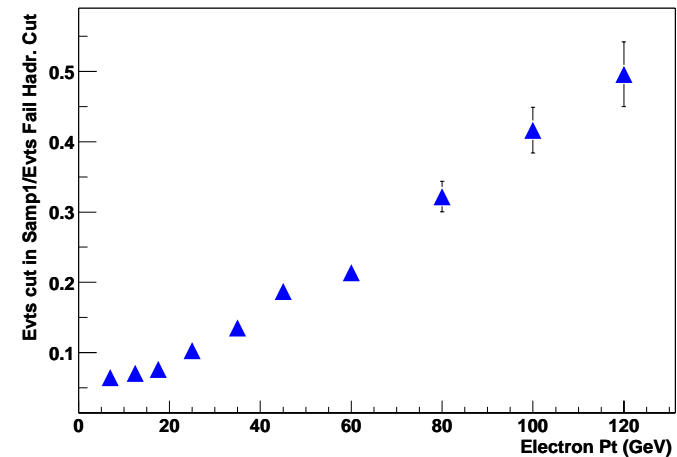
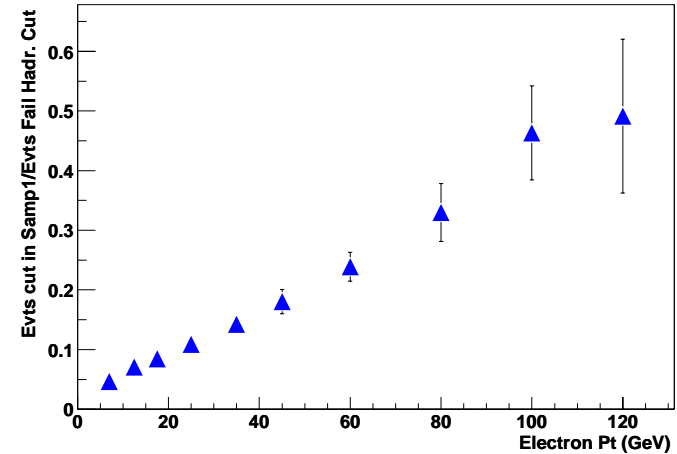
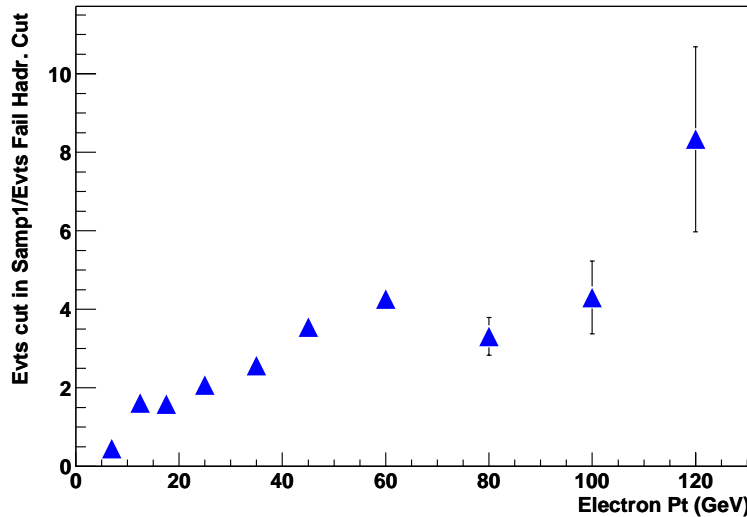
Signal: Loss of efficiency at low Pt < 20 GeV



Bgnd: Cannot "relax" iso-cuts at low Pt!  
Because this is where Rejection works

# $(e \text{ cut at strips}) / (e \text{ cut due to leakage in HCAL}) \text{ vs } P_t$

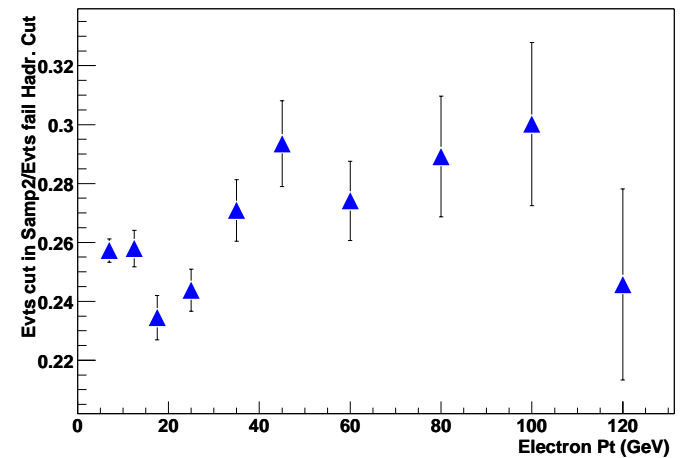
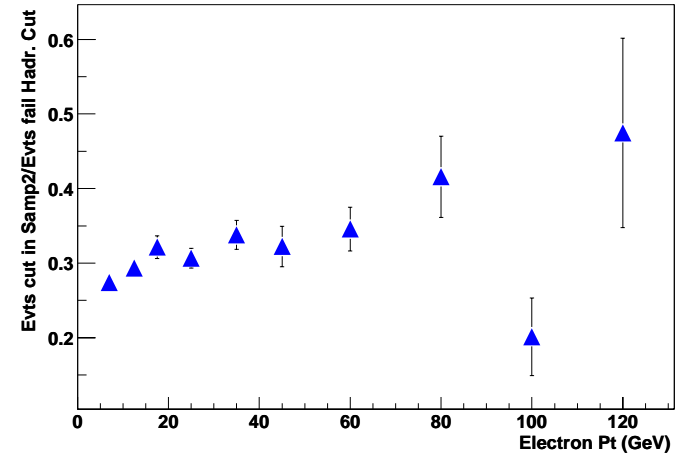
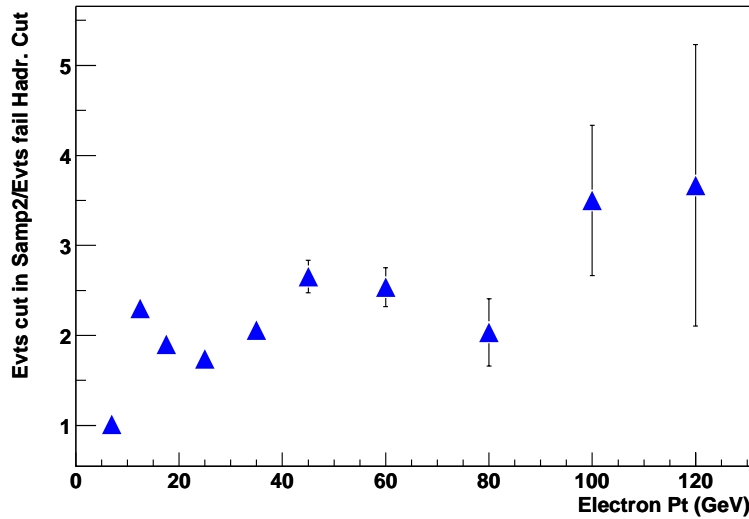
Signal: factors (2~8) more electrons are cut at strips than due to leakage



Bgnd: only a small fraction 10-60% of electrons is cut at strips

# (e cut at middle)/(e cut due to leakage in HCAL) vs Pt

Similar situation for the middle:



# Find a test-statistic (LAr strips, middle)

$g(p_T | e_{H \rightarrow 4e})$  PDF for a non-iso electron with certain Pt to come from signal

$g(p_T | e_{t\bar{t} \rightarrow 4e})$  PDF for a non-iso electron with certain Pt to come from bgnd

$a_{e(H)}, a_{e(t\bar{t})}$  electron Efficiencies for signal and bgnd

(Bayesian/Freq.) Probability of a "signal" non-iso electron, given a Pt.

$$p(e_{H \rightarrow 4e} | p_T) = \frac{a_{e(H)} g(p_T | e_{H \rightarrow 4e})}{a_{e(H)} g(p_T | e_{H \rightarrow 4e}) + a_{e(t\bar{t})} g(p_T | e_{t\bar{t} \rightarrow 4e})}$$

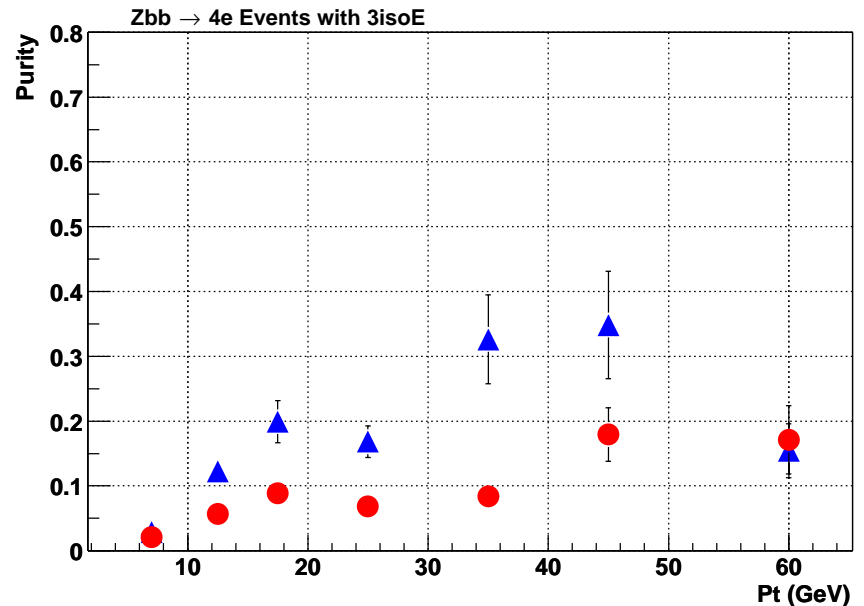
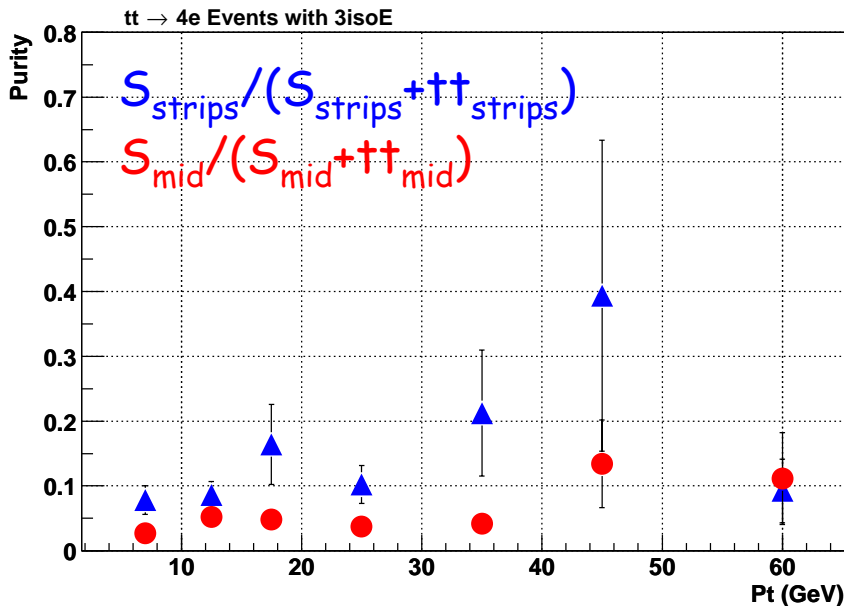
Strips (S1)

Middle (S2)

Integrate in a Pt bin to get signal PURITY

# Purity= $s/(s+b)$ vs Pt for events with 3 isoE

Signal: 4th electron comes from  $H(130) \rightarrow 4e$   
Bgd: 4th electron comes from  $t\bar{t}$  or  $Zbb$

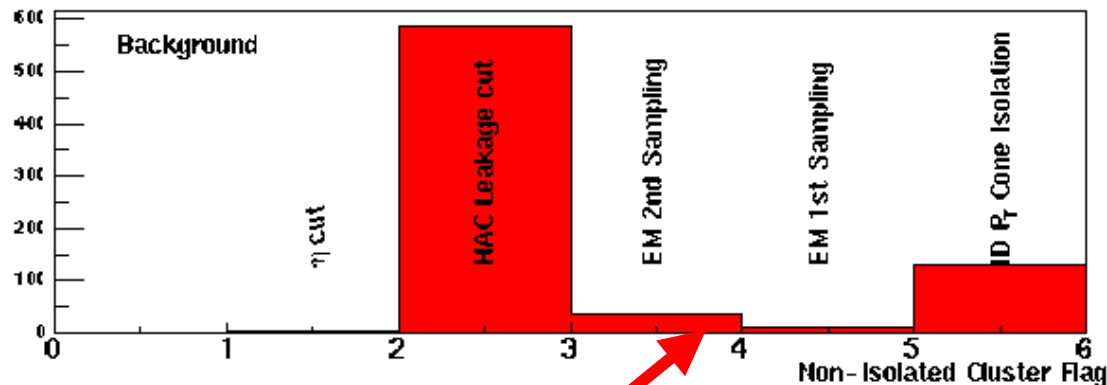
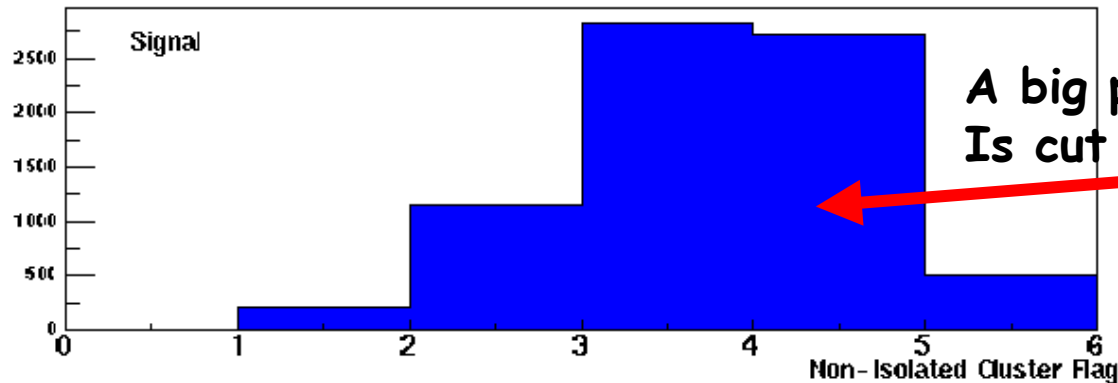


No Higgs mass window cut. No Impact Param cut:  
Purity after these cuts gets very high!

Without requiring the other electrons to be isolated Purity  $\sim 10^{-4}$  !!!

# EM cluster (shower) classification (HWG Dec/03)

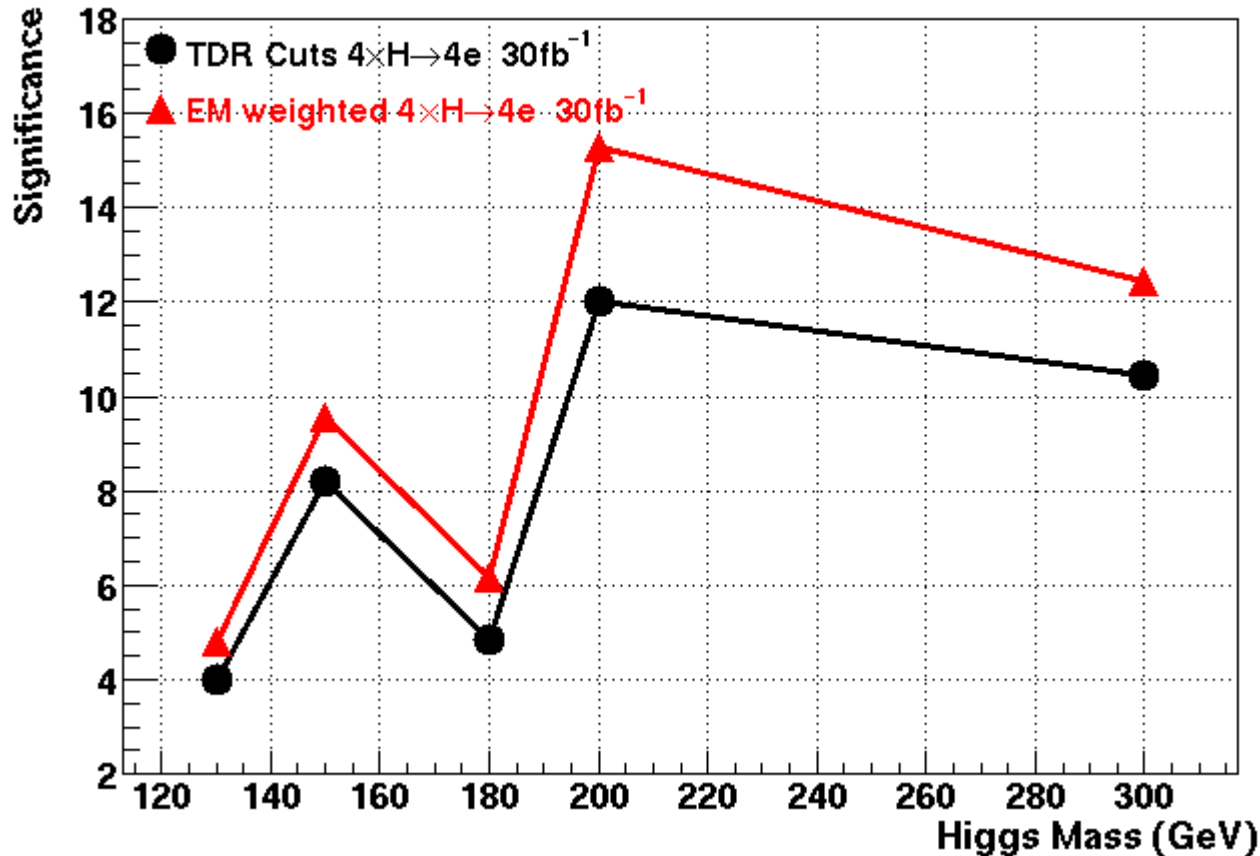
**Non-Isolated Electron** for events with 3isoElectrons + 1 non-isoElectron



**Algorithm:** Require 3isoE+1E which passes the HAC and ID cuts, 4 matched EM/tracks, at least 3 not pointing to the crack.

# Classification of EM-clusters

H $\rightarrow$ 4e using EM/cluster classification



Note: typically Significance is increased at the cost of losing some signal.  
Here we increase the signal yield by 50% at the low mass region!

# Summary

- ➡ First calibration of the ATLAS Barrel using electrons:
  - ✓ Electron Linearity is improved (due to fixed offset)
  - ✓ Resolution not significantly improved (as it should->TBeam03)
  - ✓ Impact on  $4e$  and  $2e2\mu$  mass resolutions
- ➡  $H \rightarrow ZZ \rightarrow 4e$  and  $2e2\mu$  common re-analysis confirms results reported in Dec/03 HWG, now including the  $Zbb$  background.
  - ✓ Algorithms including EM/shower information yield large improvements in the  $H \rightarrow 4e$  analysis. Can we do the same for  $2e2\mu$ ?
- ➡ Next Steps:
  - ✓ TestBeam04 input crucial: calibrations, noise levels (example: cross talk),... how much our optimizations depend on all this?

# H $\rightarrow$ 4e with Pythia6.2 cross sections

Higgs Mass (GeV)	130	150	180	200	300
Xsection*BR (fb)	1.05	1.785	0.91	3.47	2.19
Signal (fb)	0.098	0.23	0.146	0.835	0.491
pp $\rightarrow$ ZZ (fb)	0.031	0.035	0.063	0.193	0.093
ttbar $\rightarrow$ 4e (fb)	<0.005	<0.005	<0.005	0.052	<0.005
Zbb (fb)	0.008	0.004	0.001	0.107	0.007
4*30 fb-1 Signal	11.76	27.6	17.52	100.2	51.72
4*30 fb-1 Bgnd	4.68	4.68	7.68	42.24	40.56
<b>Significance</b>	<b>4.0</b>	<b>8.2</b>	<b>4.87</b>	<b>12.0</b>	<b>10.46</b>

Impact Parameter cut applied at all masses due to large Zbb background

# H $\rightarrow$ 2e2 $\mu$ with Pythia6.2 cross sections

Higgs Mass (GeV)	130	150	180	200	300
Xsection*BR (fb)	1.05	1.785	0.91	3.47	2.19
Signal (fb)	0.172	0.405	0.327	1.624	1.05
pp $\rightarrow$ ZZ (fb)	0.025	0.025	0.062	0.222	0.1
ttbar $\rightarrow$ 2e2 $\mu$ (fb)	<0.003	<0.003	<0.003	0.055	0.015
Zbb (fb)	0.01	0.004	0.002	0.075	0.031
2*30 fb $^{-1}$ Signal	10.32	24.3	19.62	97.44	63
2*30 fb $^{-1}$ Bgnd	2.1	1.74	3.84	21.12	8.76
<b>Significance</b>	<b>4.58</b>	<b>9.52</b>	<b>6.56</b>	<b>14.5</b>	<b>13.3</b>

Good Agreement with S. Armstrong Analysis (HWG Dec/03)

# H $\rightarrow$ 4e with EM cluster classification (without Impact Parameter cut)

Higgs Mass (GeV)	130	150	180	200	300
Xsection*BR (fb)	1.05	1.785	0.91	3.47	2.19
Signal (fb)	0.161	0.354	0.217	1.00	0.573
pp $\rightarrow$ ZZ (fb)	0.038	0.041	0.085	0.216	0.097
ttbar $\rightarrow$ 4e (fb)	<0.005	0.014	<0.005	0.009	<0.005
Zbb (fb)	0.05	0.024	0.001	0.041	0.021
4*30 fb-1 Signal	19.32	42.48	26.04	120	68.46
4*30 fb-1 Bgnd	10.56	9.48	10.32	31.9	14.16
<b>Significance</b>	<b>4.81</b>	<b>9.54</b>	<b>6.15</b>	<b>15.28</b>	<b>12.44</b>

Comparison with std (TDR) analysis:

Large gains in **both** signal (50-60% at low mass) and significance (~20%)

# H→4e with EM cluster classification (with Impact Parameter cut)

Higgs Mass (GeV)	130	150	180	200	300
Xsection*BR (fb)	1.05	1.785	0.91	3.47	2.19
Signal (fb)	0.14	0.298	0.182	0.81	0.478
pp→ZZ (fb)	0.037	0.035	0.078	0.188	0.092
ttbar→4e (fb)	<0.005	0.014	<0.005	<0.005	<0.005
Zbb (fb)	0.02	0.01	0.006	0.012	0.01
4*30 fb-1 Signal	16.8	35.76	21.84	97.2	57.36
4*30 fb-1 Bgnd	6.84	7.08	10.08	24	12.24
<b>Significance</b>	<b>4.7</b>	<b>9.07</b>	<b>5.42</b>	<b>14.02</b>	<b>11.14</b>

Improving the Impact Parameter reconstruction will  
Increase even further the significance.