# b, c, τ Tagging for the ILC

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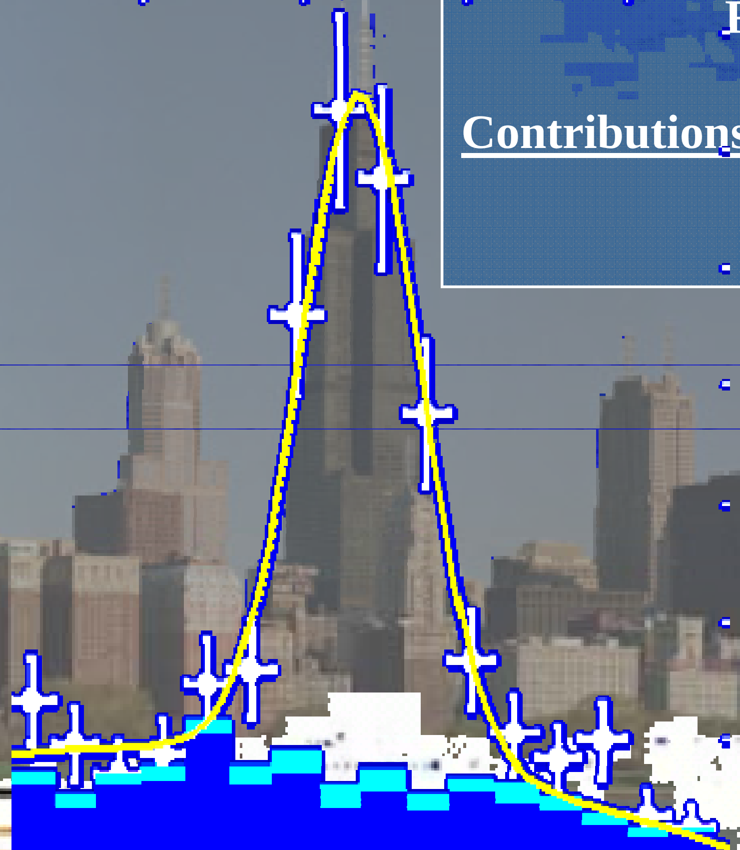
Contributions by: A Haas, M Peskin, C Milstene, S Hillert, M Battaglia, S Mrenna, B Hooberman, H Zhao, L Maczewski



M Battaglia

*UC Berkeley and LBNL*

ALCPG Plenary

October, 26 2007

# Charge to the WG and WG Structure

What does the physics require of the detector in terms of coverage and capability.
Are present detectors missing some important physics ?

How does the detector performance tradeoff with physics output ?
What performance do we really need ?

Is the technology there for the required detectors and performance ?
What needs more work ?

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Physics Objects:

b & c tag

Vertex Charge

$\tau$ tag

# A Theorist's View

**M Peskin**

Anti-tagging important for H→cc, gg with dominant bb decays, but also τ anti-tagging in searches for slepton flavour mixing such as $e^+e^- \to \tilde{\nu}\tilde{\overline{\nu}} \to \tau\mu\, C^+C^-$ which has to compete against

$$e^+e^- \to \tilde{\nu}\tilde{\overline{\nu}} \to \tau\tau\, C^+C^- \quad \tau \to \mu\nu\overline{\nu}$$

b-quark identification (and q/anti-q discrimination) may help in dealing with large combinatorial background in tt production but also:

$$e^+e^- \to \tilde{b}\tilde{\overline{b}} \to bN_2\overline{b}N_2 \to bq\overline{q}N_1\overline{b}q\overline{q}N_1$$

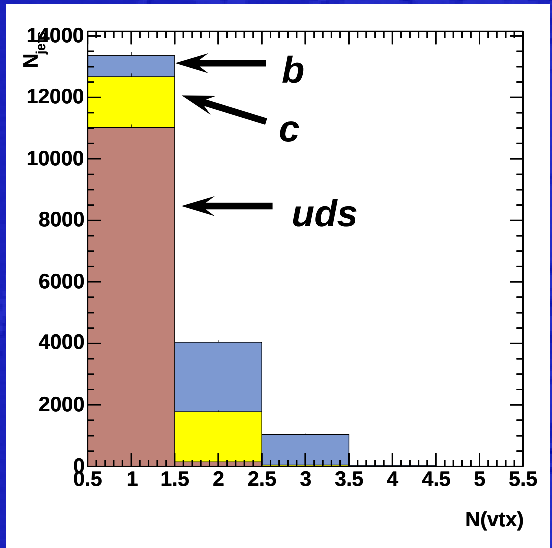
$$e^+e^- \to t\overline{t}h \to bq\overline{q}\,\overline{b}q\overline{q}\,b\overline{b}$$

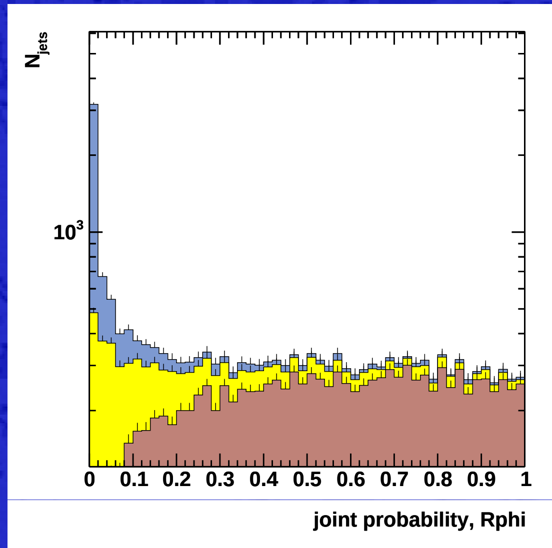
Ability to identify b and c and distinguish quarks from anti-quarks needed in study of s-channel resonances: cross sections and $A_{FB}$ for two initial state polarisations.

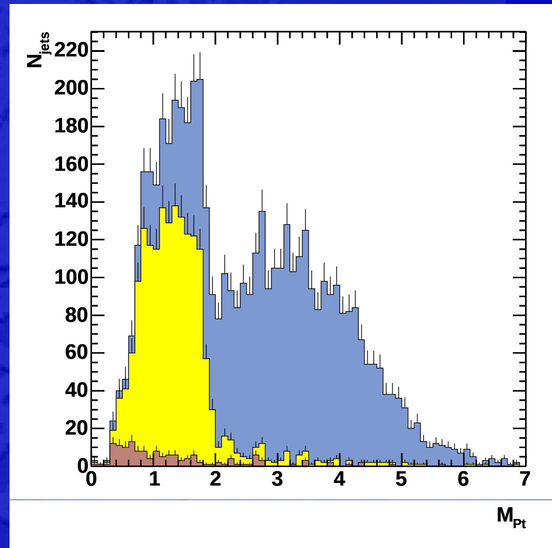
Efficient charm tagging makes t and W polarisation possible with had decays

# b and c tagging with LCFI Vertex Package

S Hillert

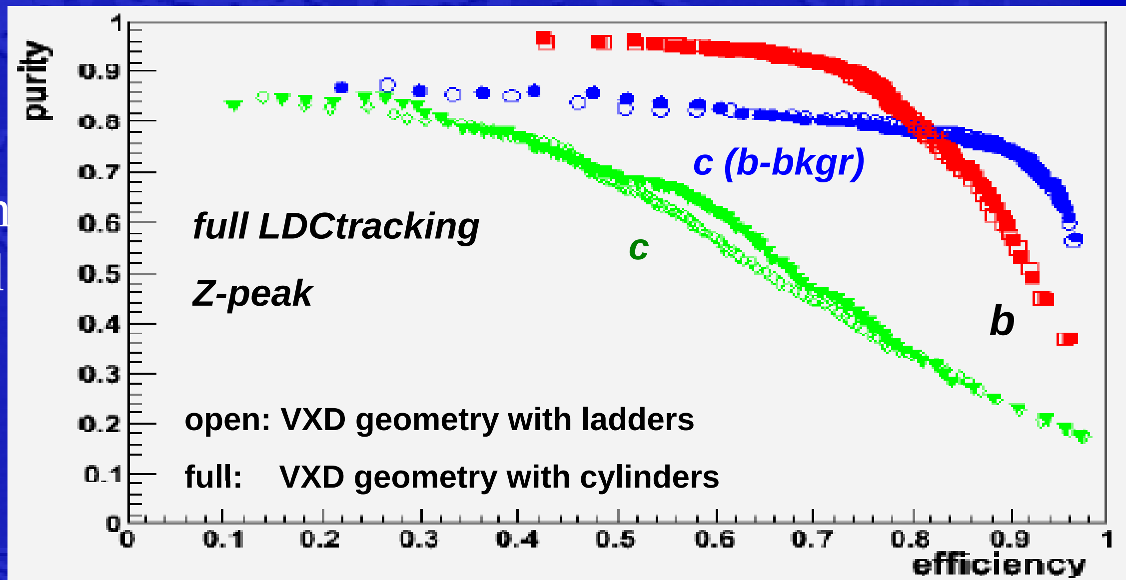



Port of ZVTOP algorithm, extensively tested on fast and full simulation and reconstruction and full tagging package released in April:

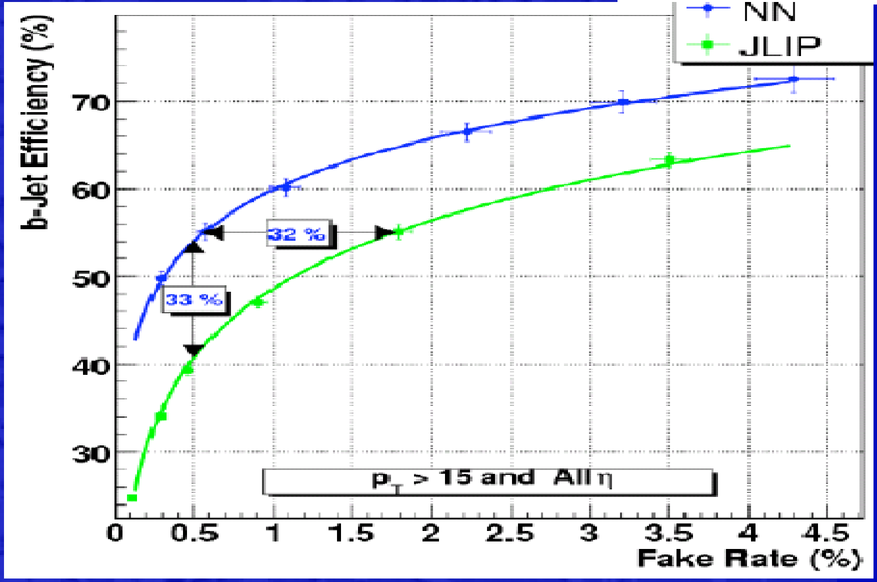
http://www-flc.desy.de/ilcsoft/ilcsoftware/LCFIVertex



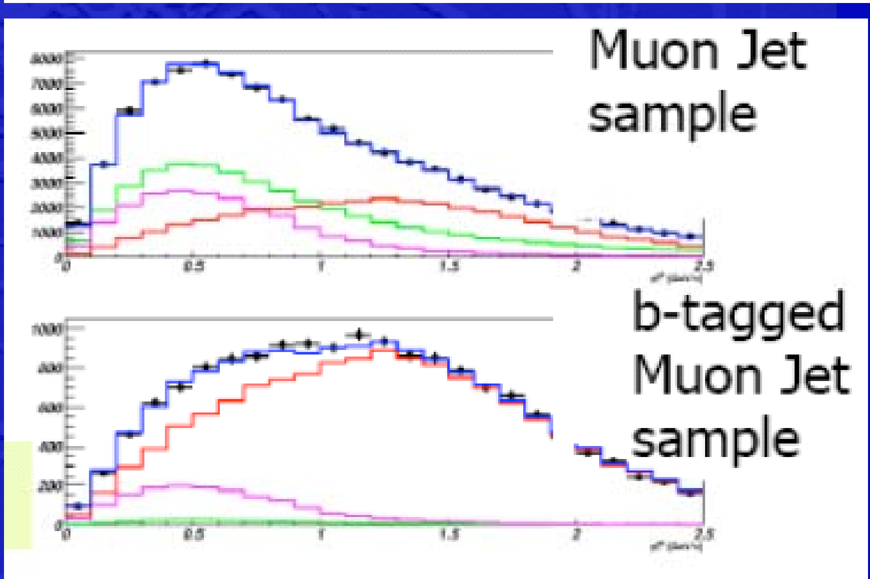
# b tagging at Tevatron

**A Haas**

Tagging algorithms (Track Counting, Jet Lifetime Impact Parameter, Secondary Vertex Tagger) combined by NN;




Tagging performance reliably known only at pre-defined working points; Using continuous output of NN tagger brings problem of accounting for Data/MC scale factors

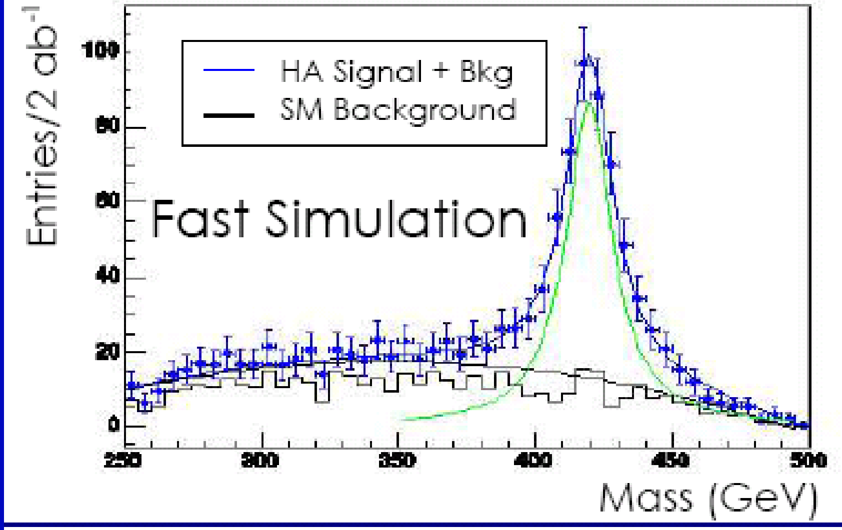


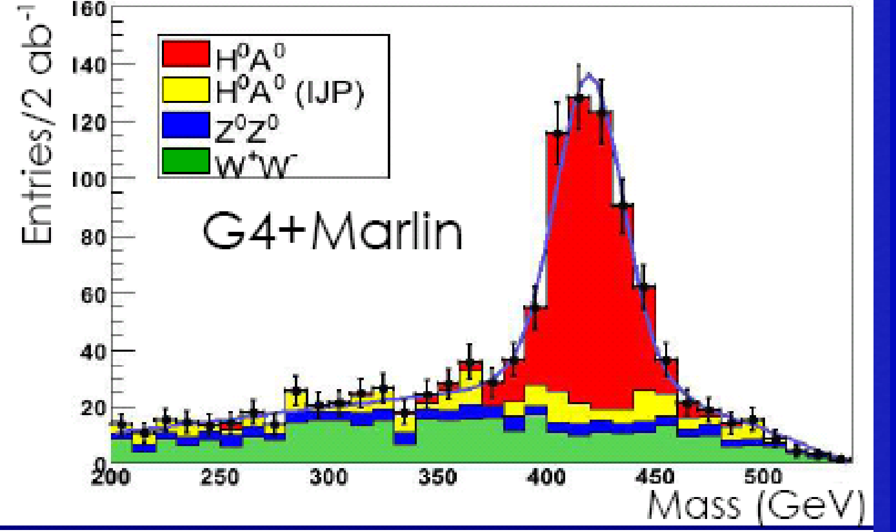

Extract b-tagging efficiency and misidentification rate from data: CDF eff. scaling factor: $0.91 \pm 0.06$

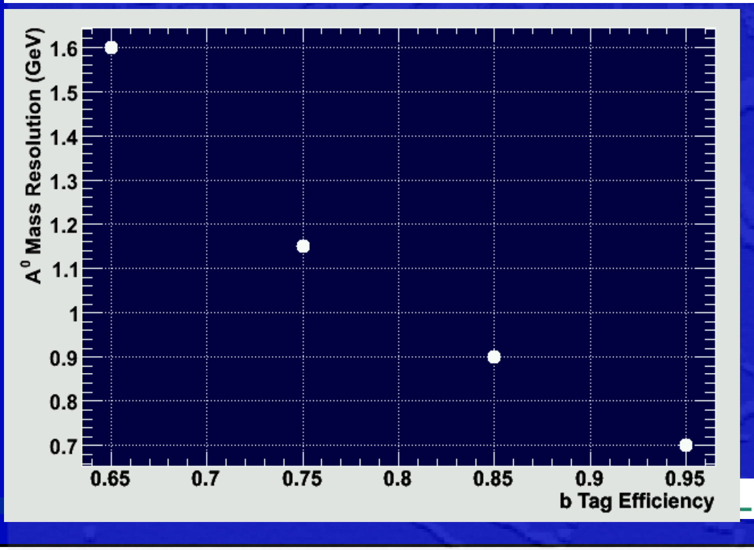
# $e^+e^- \to H^0A^0 \to bbbb, \tau^+\tau^- bb$ at 1.0 TeV

B Hooberman, MB, N Kelley

Full Simulation (G4-Mokka for LDC) and Reconstruction (MarlinReco) analysis of 4b final state with CKFit mass constrained fit;




| | $X_{RECO}$ [GeV] |
|---|---|
| $M(A^0)$ | 418.8±1.1 |
| $\Gamma(A^0)$ | 10.0±3.6 |

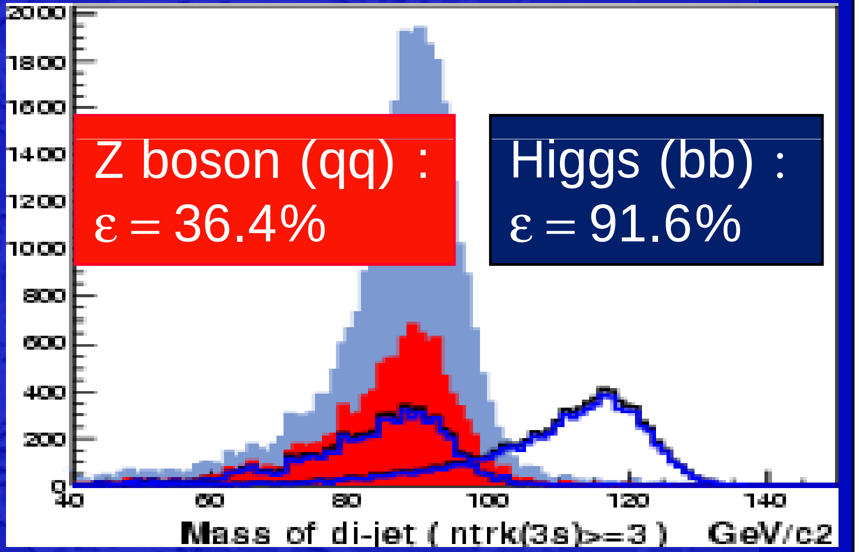
M($A^0$) Statistical Accuracy vs. b tag Efficiency

# $e^+e^- \to \nu\nu H^0 \to bb$ at 0.25 TeV

**H Zhao**

Fast simulation study with `org.lcsim` for SiD concept; simple count-and-cut b-tag based on i.p. significance;

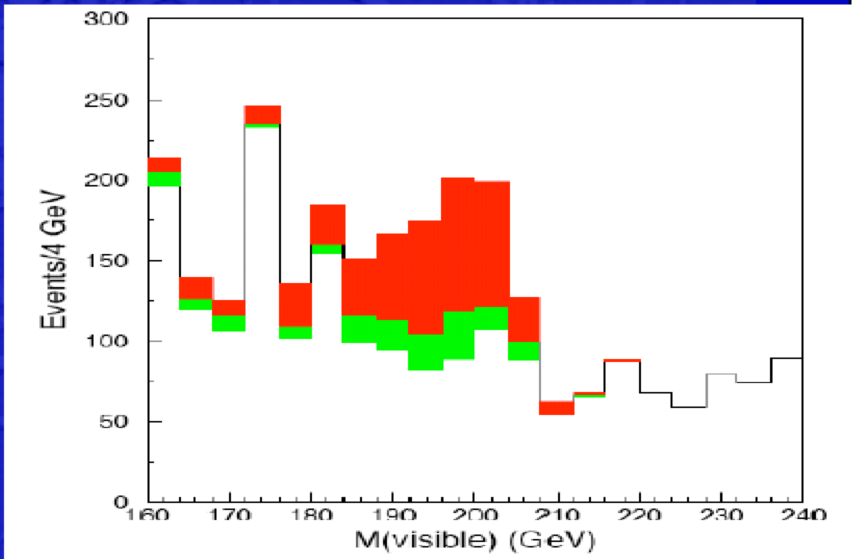
Analysis to be optimised, move to more advanced tag algorithm and use full simulation and reconstruction;




# $e^+e^- \to \nu\nu H^0 \to bb$ at 1 TeV

**T Barklow**

For MH = 200 GeV, H→bb becomes rare decay (2 x $10^{-3}$), still ILC at 1 TeV can get the branching fraction to 9% accuracy:

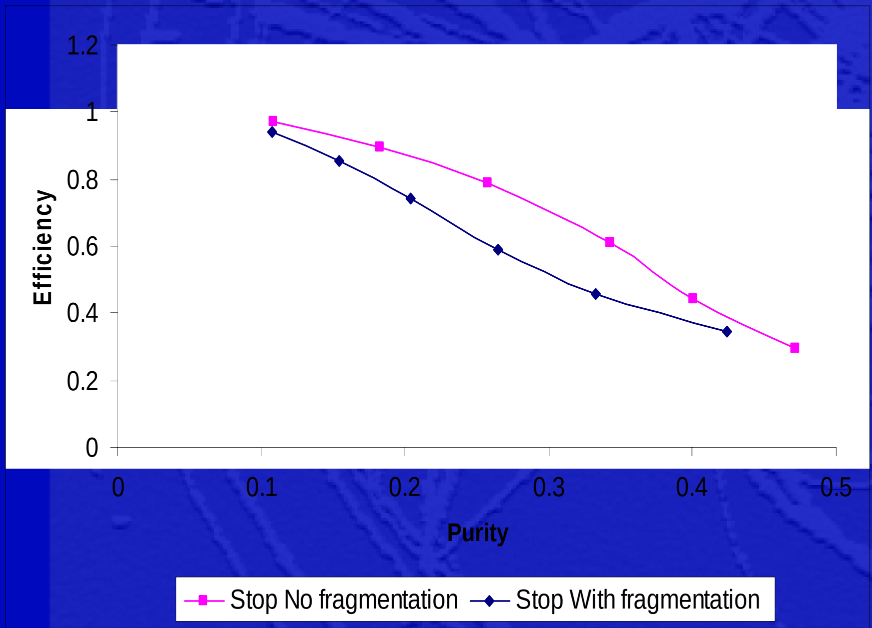


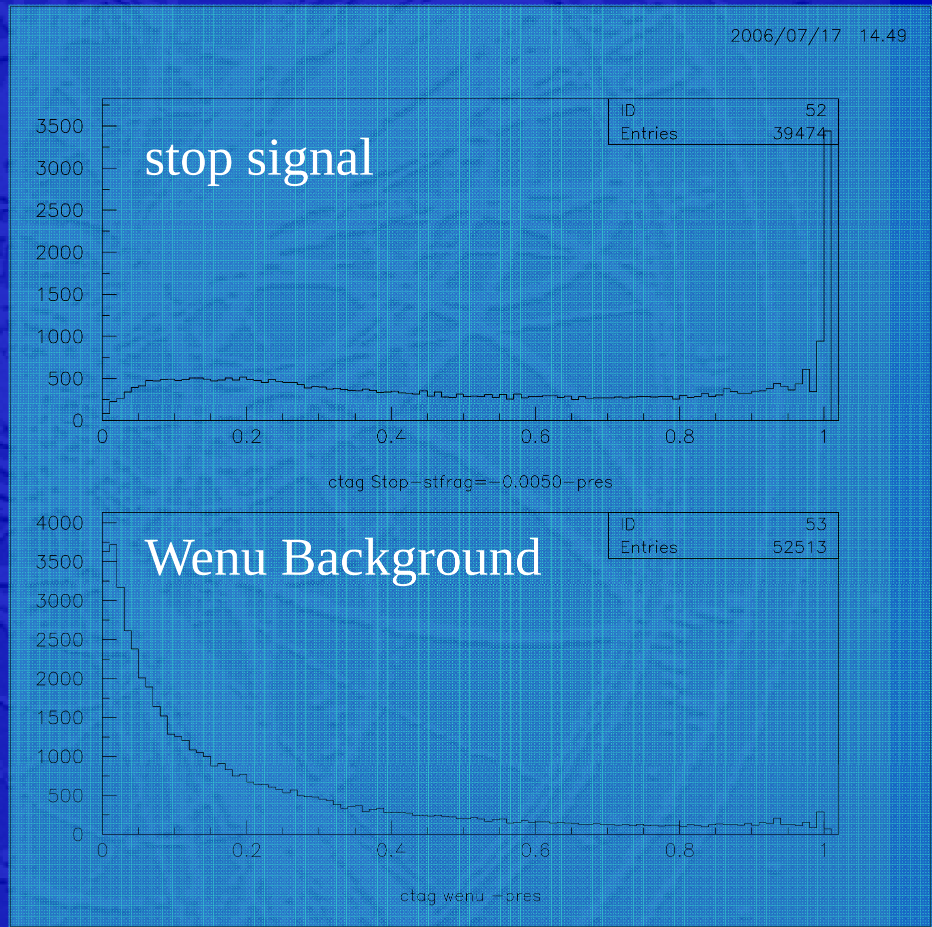
# $e^+e^- \to \tilde{t}_1\bar{\tilde{t}}_1 \to c\tilde{\chi}^1_0\bar{c}\tilde{\chi}^1_0$ at 0.5 TeV

C Milstene, A Sopczak

Fast Simulation analysis using c tag with ZVTOP;

Signal cross section 118 fb
Main background Weν **6.14 pb**



# $H^0 \rightarrow bb$, cc, gg at 0.35 - 0.5 TeV

| Channel | Change | Rel. Change in Stat. Uncertainty |
| --- | --- | --- |
| H→bb<br>H→cc<br>H→gg | Geometry:<br>5 → 4 layer VTX<br>Thickness:<br>50 µm → 100 µm | + 0%<br>+15%<br>+ 5% |
| H→cc | $\sigma_{point}$:<br>4 µm → 6 µm<br>4 µm → 2 µm | +10%<br>-10% |
| H→cc | Thickness:<br>50 µm → 100 µm | +10% |

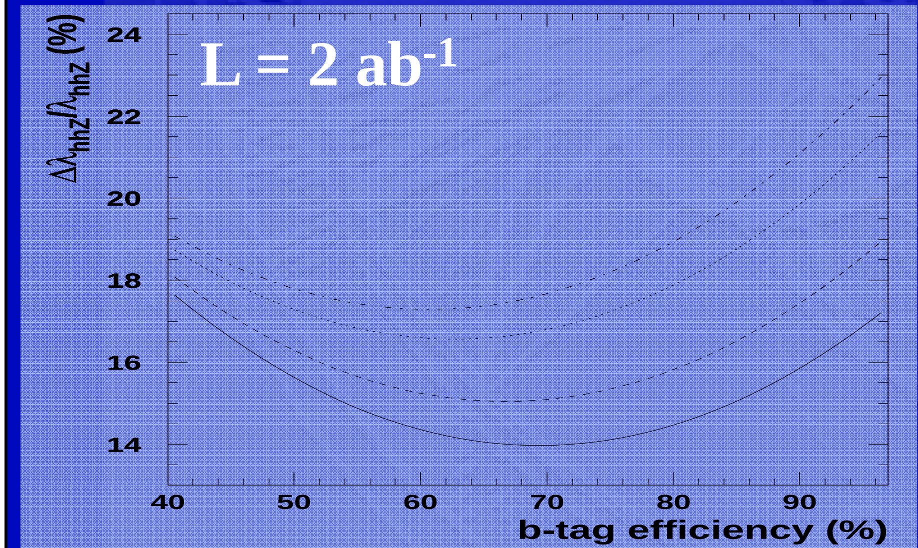
Degradation in performance correspond to 20-30% equivalent Luminosity loss.

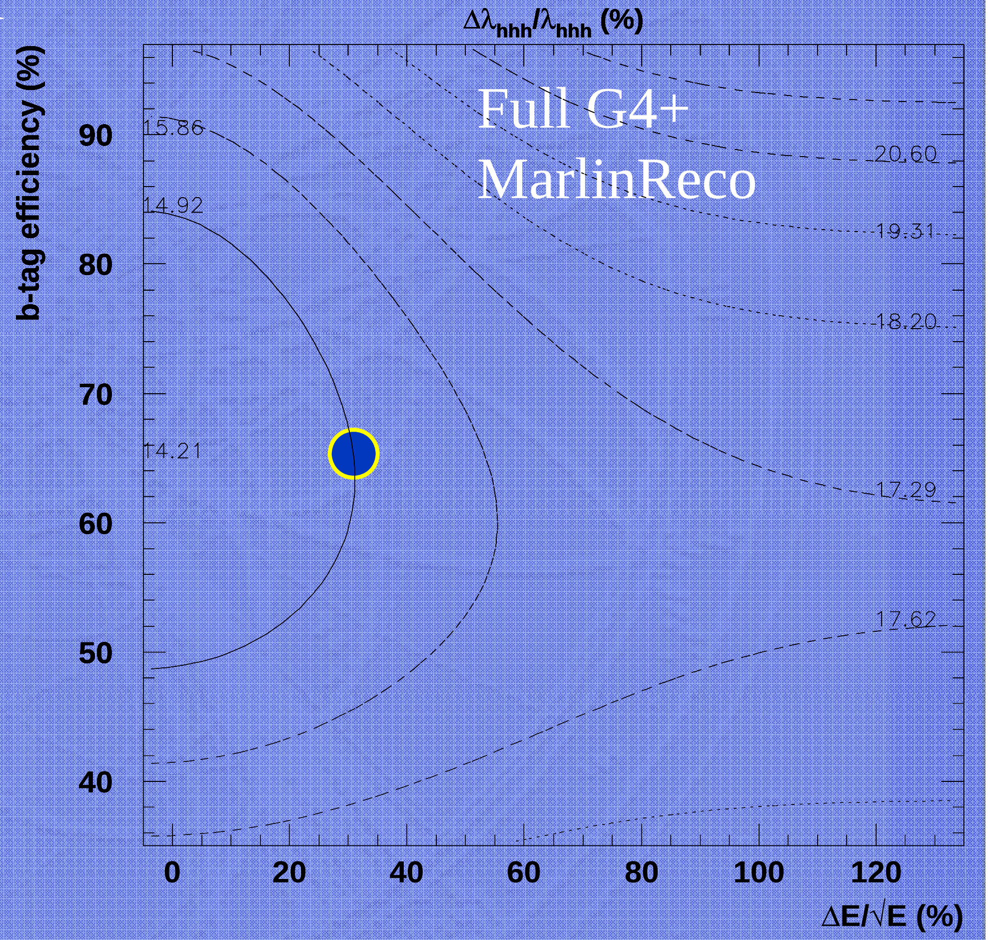
**Yu et al.**
**J. Korean Phys. Soc. 50 (2007);**
**Kuhl, Desch**
**LC-PHSM-2007-001;**
**Ciborowski,Luzniak**
**Snowmass 2005**

# $e^+e^- \rightarrow H^0H^0Z^0$ at 0.5 TeV

ILC offers unique opportunity to study the shape of the Higgs potential through measurement of Higgs self-coupling in HHZ and HH$\nu\nu$ at 0.5 and 1TeV

Isolating HHZ signal ($\sigma$=0.18pb) from tt (s=530pb), ZZZ ($\sigma$=1.1pb), tbtb (s=0.7pb) and ttZ (s=0.7pb) is an experimental ***tour-de-force***; b-tagging and jet energy resolution essential to suppress backgrounds;



# Charm Tagging vs. I.P. Resolution

Study change in efficiency of charm tagging in $Z^0$-like flavour composition

| Geometry | $\sigma_{IP}$ (μm) | | |
|---|---|---|---|
| R1 1.2 cm ↓ 1.7 cm | $4 \oplus 7/p_t$ <br> $4 \oplus 10/p_t$ | c purity=0.7 | $\varepsilon_c = 0.49$ <br> $\varepsilon_c = 0.46$ |
| R1 1.2 cm ↓ 2.1 cm | $4 \oplus 7/p_t$ <br> $5.5 \oplus 14/p_t$ | c purity=0.7 | $\varepsilon_c = 0.49$ <br> $\varepsilon_c = 0.40$ |
| HPS | $11 \oplus 15/p_t$ | c purity=0.7 | $\varepsilon_c = 0.29$ |

Total efficiency = $\varepsilon^N$ with N = number of jets to be tagged

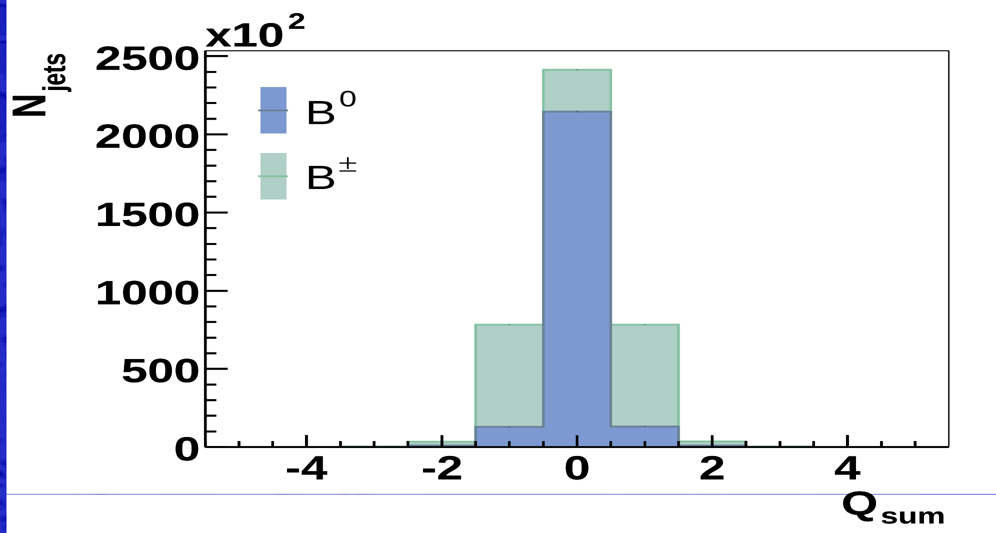
# Vertex Charge

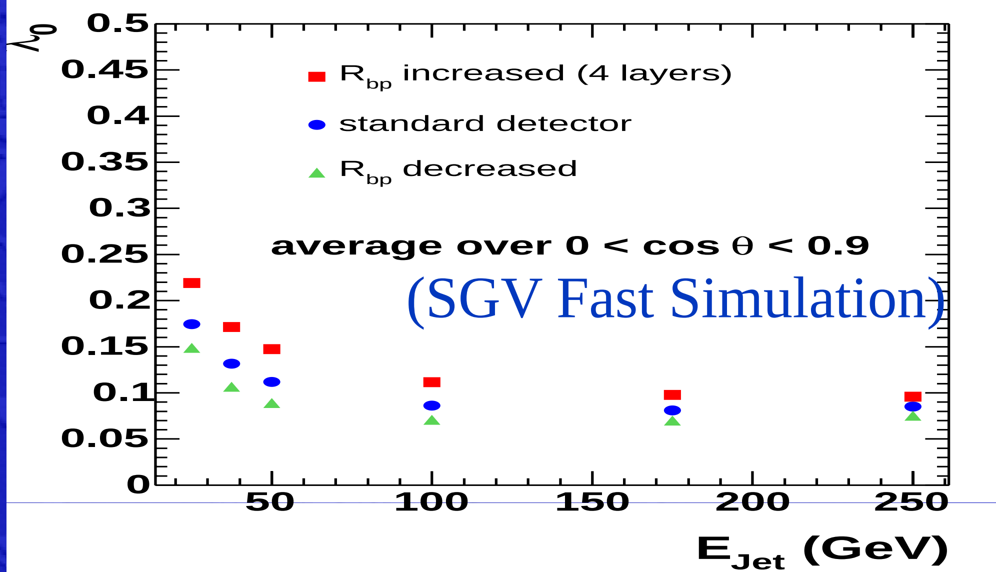
**S Hillert**

Vertex charge algorithms very promising for q-anti q discrimination in b and c jets

Vertex charge extremely sensitive to correct secondary particle tags: any mistake changes result by

Benchmark vertex charge performance using P($B^0$→B ) :



# Tau Tagging

MB

Tau tagging should exploit characteristic "jet" topology, mass and impact parameter; Use of calorimetric information has also been successful both for tagging and for identifying $\tau$ decay mode for polarization studies;

**$e^+e^- \to H^0Z^0$, $H^0\nu\nu$; $H^0 \to \tau^+\tau^-$, $\mu^+\mu^-$**

**Higgs Boson Parity in $H(A) \to \tau^+\tau^-$**

**Identify Light $H^-$ in large tan $\beta$ SUSY**

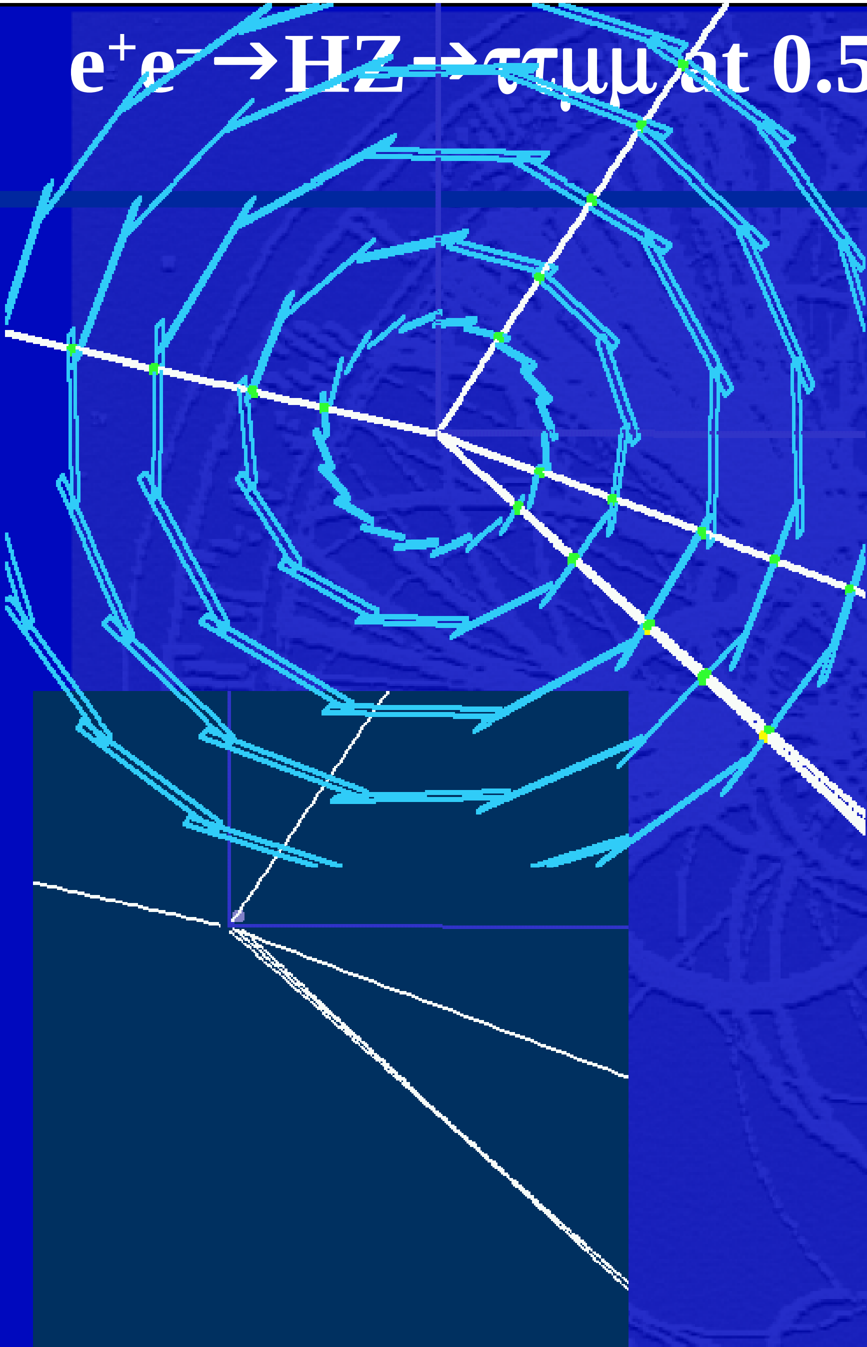
**$e^+e^- \to \tau_1\tau_1 \to \tau^+\tau^-\chi^0\chi^0$ in DM-motivated SUSY**

**Tau Polarization, tan $\beta$ and $A_{tau}$**

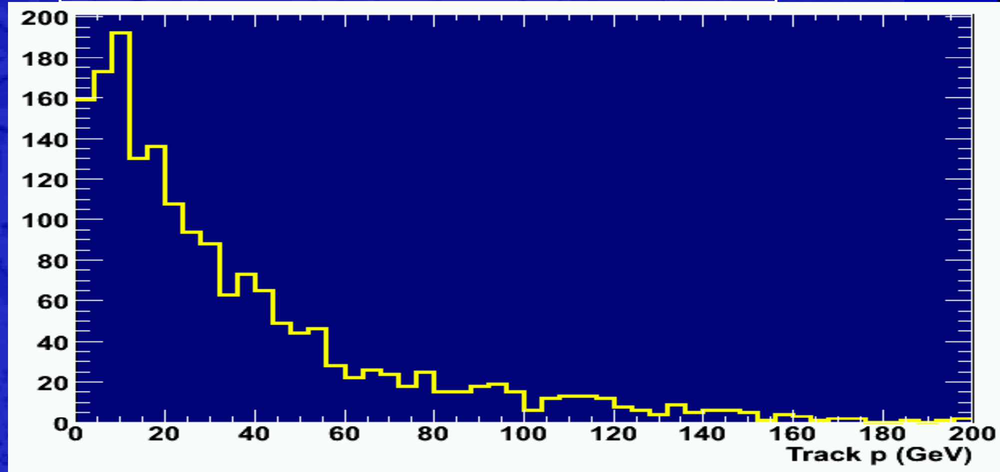
**Tau tagging, Charged Higgs decays and tan $\beta$**

# $e^+e^- \to HZ \to \tau\tau\mu\mu$ at 0.5 TeV

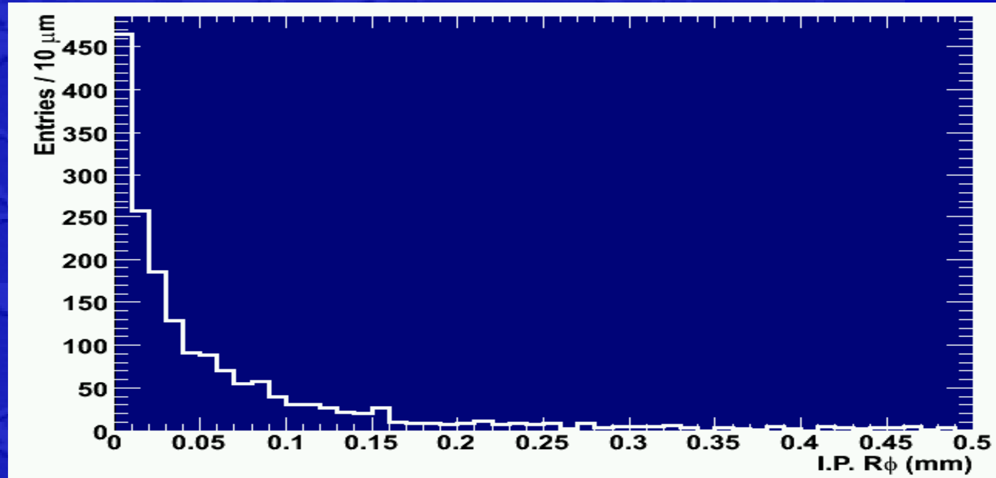
MB



## $\tau$ Decay Product Momentum

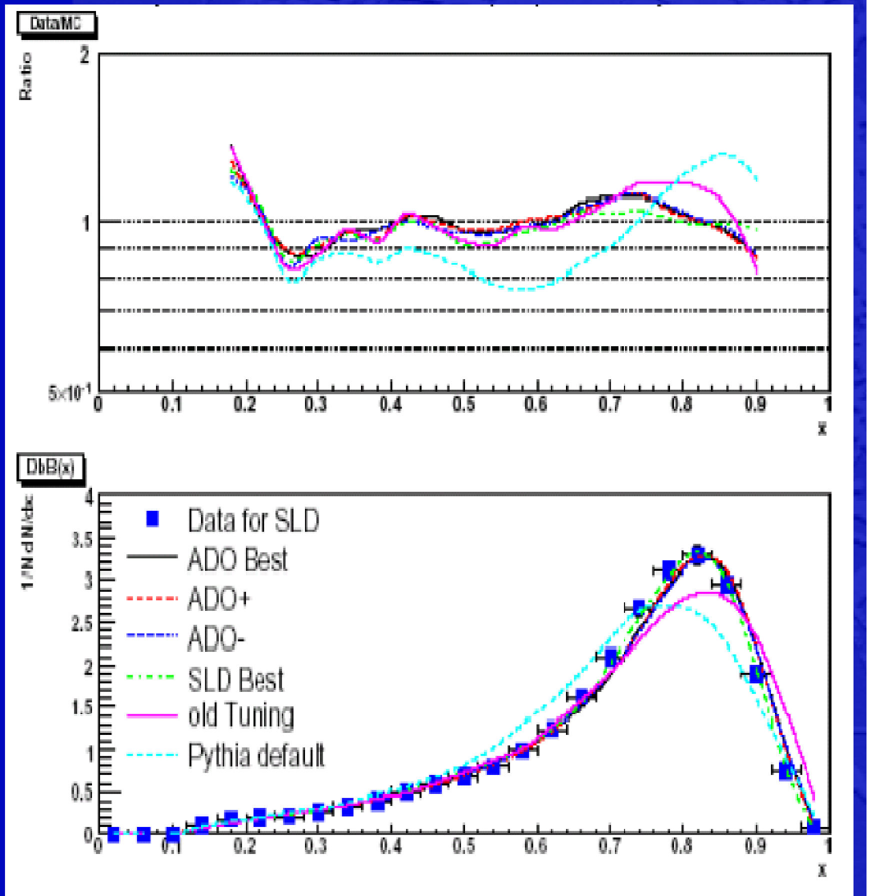



## $\tau$ Decay Product Impact Parameter R$\phi$



# b Fragmentation

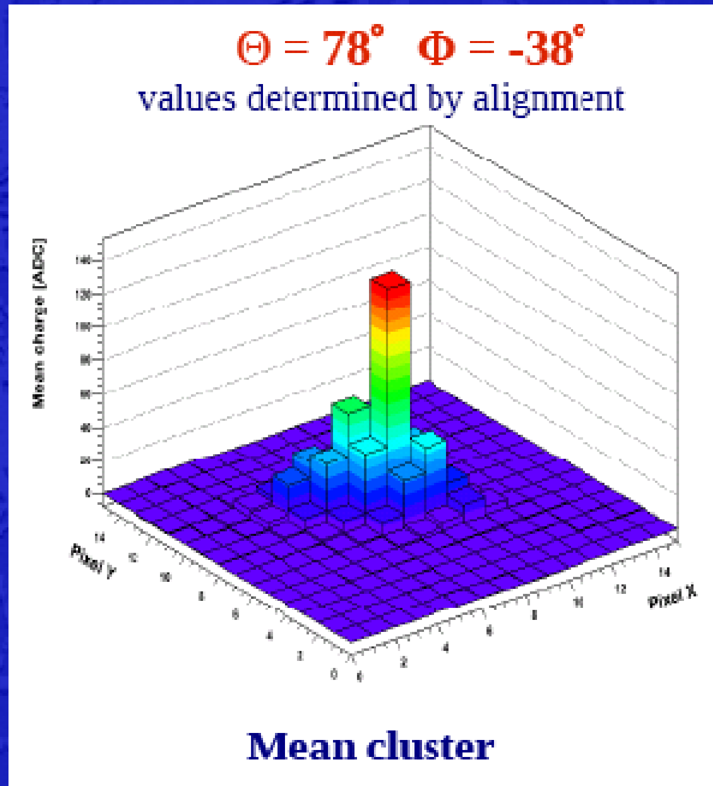
S Mrenna

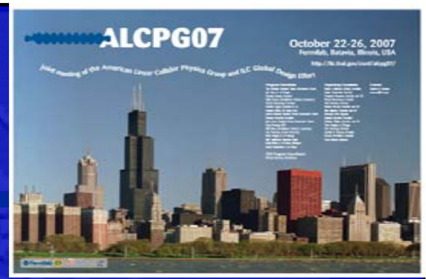



# Pair Background Rejection

L Marczewski

Study cluster shape of inclined electrons in pixel detector to characterise and reject pair background hits:






This meeting contributed to focus on the physics highlighting the variety of opportunities offered by flavour tagging and the requirements implied;

Beyond most obvious processes, there is a large set of processes involving tagging, anti-tagging, quark charge and polarization, probing tracking and vertexing over full momentum and angular range but also connection with calorimeters;

Significant progress in reconstruction packages and tagging tools make detailed studies with full simulation and reconstruction possible;

Essential to continue this program of studies for detector concept and sensor optimisation taking into account physics and machine backgrounds.