Charm Jet Identification Using Flavor Tagging

C. Milsténe- Fermilab- ILC workshop Fermilab- October-22-27-2007

In collaboration with: A. Sopczak (Lancaster U.),

- The $\tilde{t}_1$ production and decay $e^+e^- \rightarrow \tilde{t}_1\bar{\tilde{t}}_1 \rightarrow c\tilde{\chi}_0^1\bar{c}\tilde{\chi}_0^1$ has been studied at the ILC in the framework of (SUSY/MSSM) with the neutralino as a Dark Matter candidate.

  M. Carena, A. Finch, A. Freitas, C. Milstene, H. Nowak, A. Sopczak,
  Phys. rev. D 72,115008(2005)

- The stop mass has to be measured with high precision. The systematic uncertainty is the main factor limiting the precision and the stop fragmentation is an important part of it -*publication in preparation*- A. Freitas
- Zurich U.),C. Milsténe, M. Schmitt (Northwestern U.), A. Sopczak (Lancaster U.)
- (*see missing Et session- Mass precision Measurement*)

- The stop fragmentation transforms the 2 jets events into multi-jets events (3-4 jets). In this analysis, the Vertex Flavor Tagging plays a special role as a tool to identify the 2 charm Jets

Simulation Characteristics

- Signal and Background generated with Pythia + Simdet + Circe

  - Beamstrahlung & Bremstrahlung

  Hadronisation of the c quark and the stop from the Lund string fragmentation- Pythia uses Peterson fragmentation, we assume the precision from LEP *(Peterson et al PR D27:105)*

  - The stop fragmentation is simulated using Torbjorn's code

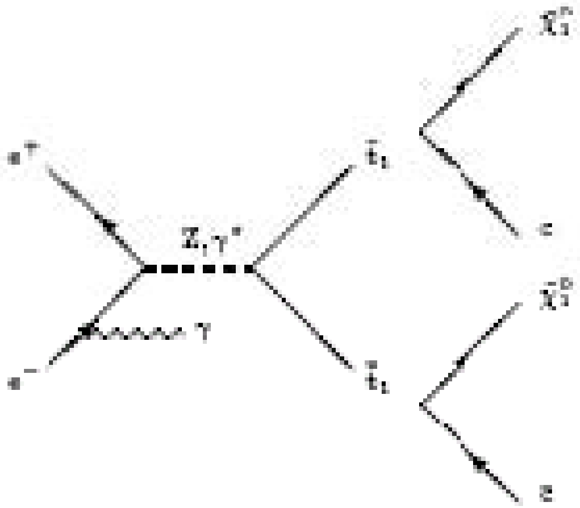
//http://www.thep.lu.se/torbjorn/pythia/main73.f

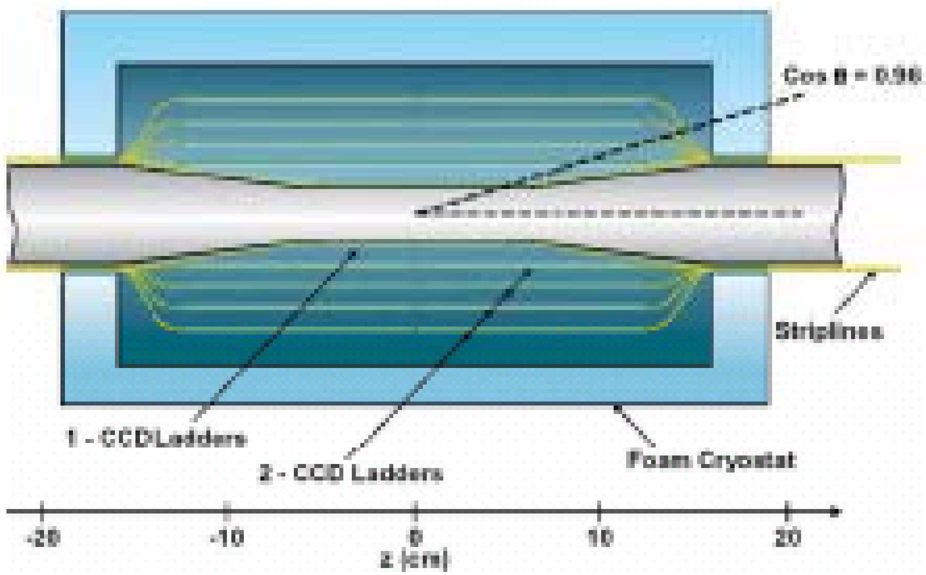
The stop fragmentation parameter is set relative to the bottom fragmentation parameter following (OPAL,EPJ C6:225)

The stop quark is **set stable** until **after fragmentation** where it is Allowed to **decay again** as described in (*Kraan, EPJ C37:91)*

- Signal and Background are generated in each channel in conjunction to the cross-sections:

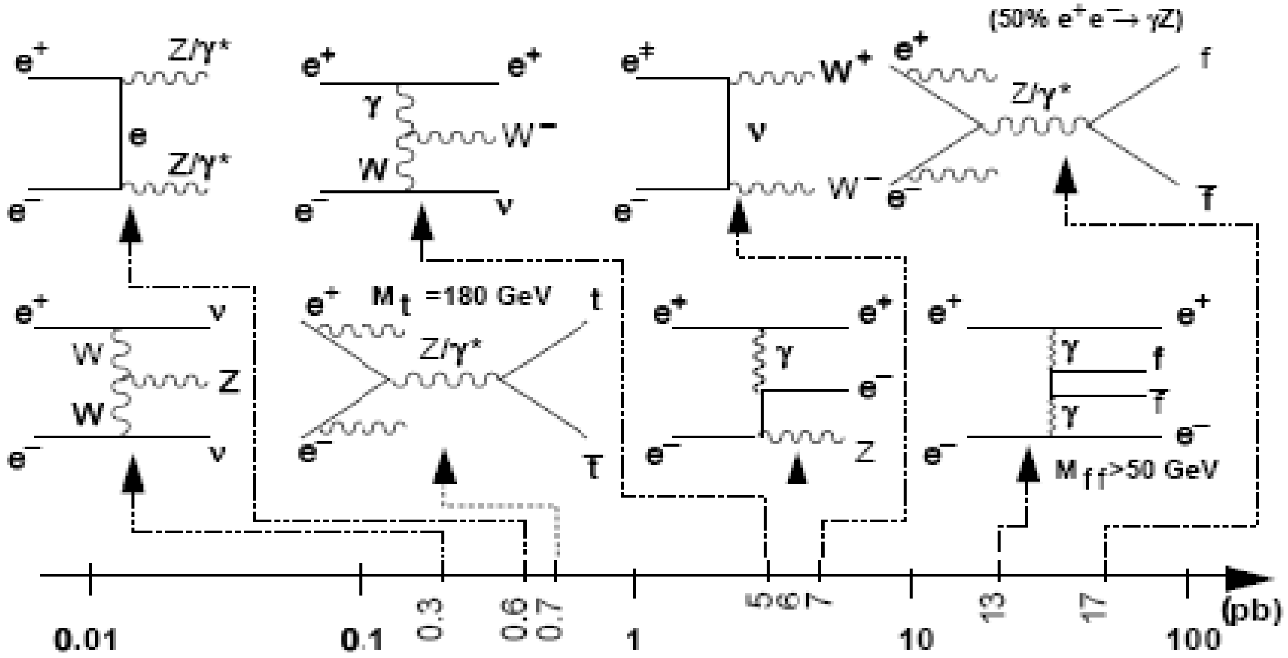
The Signal & Vertex Detector





Vertex Detector: Tesla type CCD layers @15,26,37,48 & 60mm each layer 0.064X^0

Background- Channels



hep-ph9701336-A.Bartl,H. Eberl,S. Kraml, W.Majerotto,W.Porod,A. Sopczak

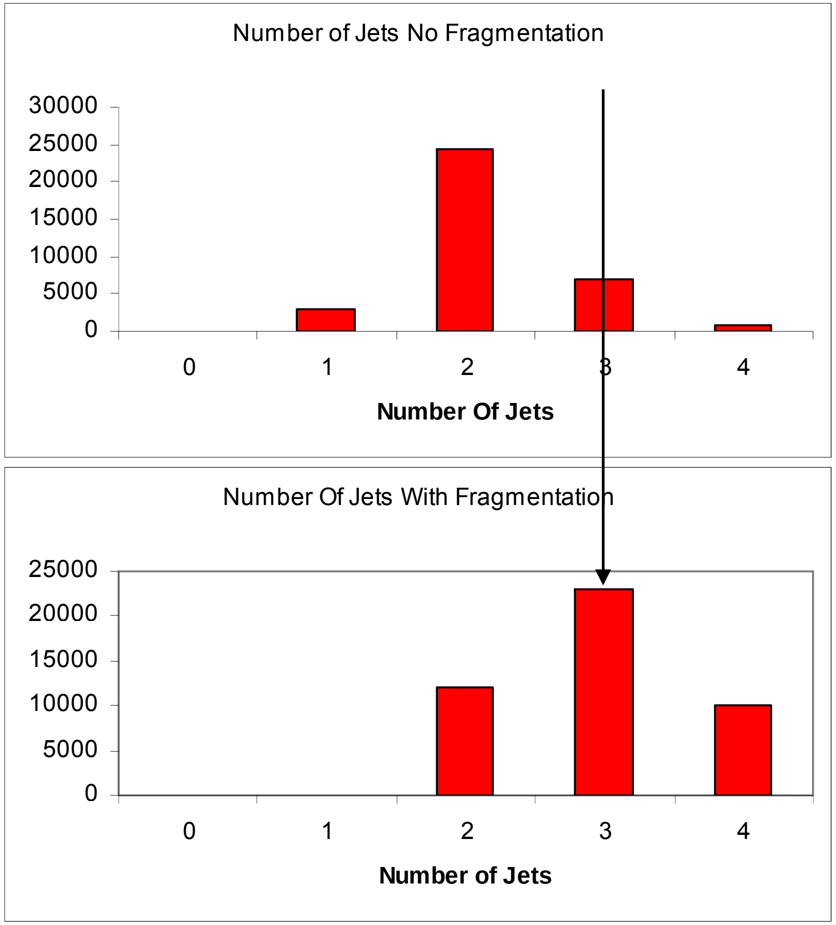
Signal And Background Cross-Sections (pb)

Process	ECM 500 GeV	Cross-sections (pb) 0/0	-80%/+60%	+80%/-60%
$\tilde{t}_1\tilde{t}_1^*$		0.118	0.072	0.276
	Pythia -ISub			
ww	25	8.60	24.5	0.77
Wenu	36	6.14	10.6	1.82
ZZ	22	0.49	1.02	0.44
eeZ	35	7.50	8.50	6.20
tt	1	0.55	1.13	0.50
qq*	1	13.10	25.40	14.90
2-photon		936		

The Events have been produced with Beamstrahlung Right-Chiral stop With mass
$M_{\tilde{t}_1}$=122.5 GeV

A. Freitas et al EPJ C21(2001)361, EPJ C34(2004)487
And GRACE and COMPHEP

Jet Multiplicity – Without/With Fragmentation



- Stop fragmentation simulated using Torbjorn code *//http://www.thep.lu.se/torbjorn/pythia/main73.f*
- *The stop fragmentation parameter is set relative to the bottom fragmentation parameter*
  $\varepsilon_{\tilde{t}} = \varepsilon\_b * m_b^2 / m_{\tilde{t}}^2$
  And $\varepsilon\_b = -0.0050 +/- 0.0015$
  following (OPAL,EPJ C6:225)
- *The jet Multiplicity* *<u>without Fragmentation</u>* *Upper figure*
  ~ 70% 2 jets
- *The jet Multiplicity* *<u>with $\tilde{t}$ Fragmentation</u>* *Lower Figure*
  ~ 50% 3 jets
  & bigger admixture of 4jets

C-tagging-The Principle

A Vertex Identification followed by a Neural Network application (ZVTOP) which operates on tracks within a jet

•*Vertex Identification:*

Is a maximum in track overlapping (product of probability density tubes defined using the track parameters and the Covariant matrix)

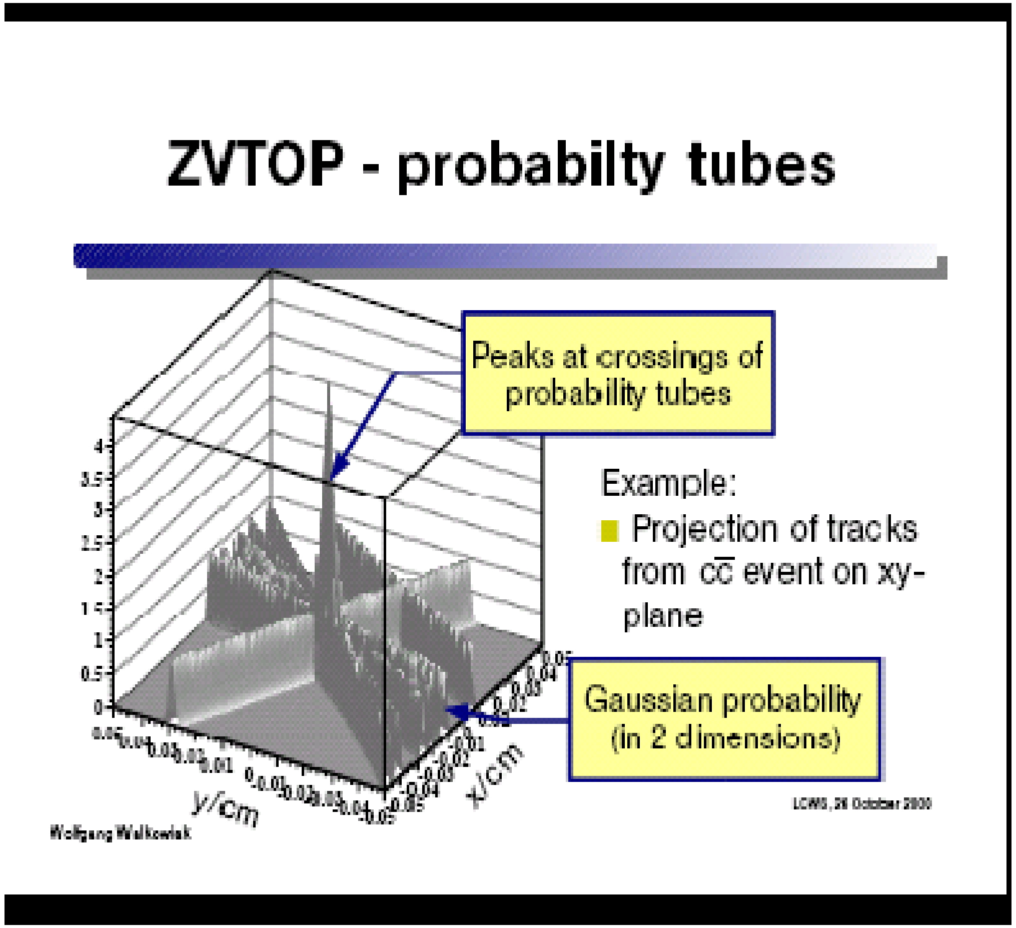
3 cases:

Case 1) Only a primary Vertex

Case 2) 1 secondary vertex

Case 3) >1 secondary vertex

Probability Tubes & Overlap Into a Vertex

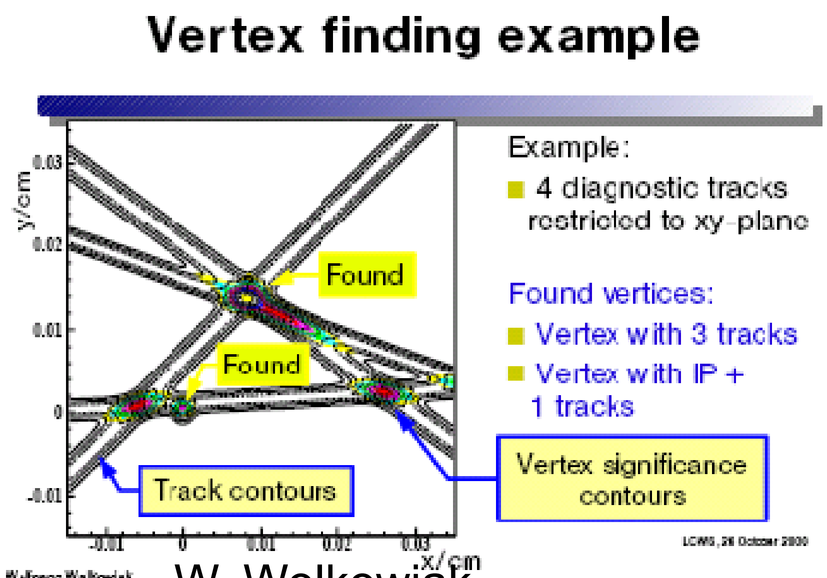


W. Wolkowiak

1/ The probability tubes are shown
2/ The vertex significance is determined by the overlap of the probability tubes
3/ At 1st a 2 tracks vertex is formed by the overlap of their probability tube

W. Wolkowiak: NIM A388-247-153, 1997

Vertex Finding



W. Wolkowiak

1/ Tracks are assigned to the vertex according to the vertex significance
2/ Vertices which are not resolved are merged

C-tagging-Neural Network Input

•Vertex Case 1:NN Input variables

- *Impact parameter* significance (impact parameter/error) of the 2 most significant tracks in the r-Φ plane (highest separation power) && their Impact parameters.
- The impact parameter significance & Impact parameters of the 2 tracks in z
- Their momenta
- The joint probability in r- Φ (tiny beamspot size in that plane)& z

•Vertex Case 2: NN Input variables (all of Case 1+below)

- *Decay Length* significance of the secondary vertex && Decay Length
- Momentum of all tracks associated to the secondary vertex && Multiplicity
- Pt corrected mass of secondary vertex (corrected for neutral hadrons&ν's), the pt of the decay products perpendicular to the flight direction (between primary && secondary Vertex) && joint probability in r-Φ and z

•Vertex Case 3: 2 secondary vertices, the tracks are assigned to the vertex closest to the primary vertex and the NN input variables are those of case 2

$e^+e^- \to \tilde{t}_1\overline{\tilde{t}_1} \to c\tilde{\chi}_0^1\bar{c}\tilde{\chi}_0^1$ Selection for Stop Mass Determination

•A short list of the sequential cuts applied as a preselection first, allowed larger samples to be produced and the cut refined at selection stage.

Pre-selection:

•4<Number of Charged tracks<50

•Pt> 5 GeV

•$\cos\theta_{Thrust} < 0.8$

•$|P_{l,tot} / P| < 0.9$

•$E_{vis} < 380$ GeV

•M(inv)<200 GeV

Selection:

•$5 \leq$ Ntracks≤ 20

•$|p_L / p_{tot}| < 0.85$

•$22 < P_t < 50$ GeV

•$0.55 < T < 0.9$, $\cos\theta_{Thrust} < 0.7$:

•$0.1 < E_{vis}/\sqrt{s} < 0.3$

Flavor Tagging -T. Kuhl

Charm jets identified by the charm tagging

•Njets >=2 && En <25 GeV; n=3,4

•$Minv_{jets}^2 < 5500$ GeV^2 or $Minv_{jets}^2 > 10000$ GeV^2

•Charm tagging likelihood >0.6

Selected Signal and Background Events

Process	Number generated	After sequ. cuts 0/0	For 500 fb^-1 +80%/-60%
$\tilde{t}_1\tilde{t}_1^*$	0.50 M1	12514	29270 (22%eff.)
2- photon	*8.5* M	31	31
zz	0.03 M	90	81
qq	0.35 M	37	43
ww	0.21 M	< 20	<2
tt	0.18 M	18	17
wenu	0.21 M	18540	5495
eez	0.21 M	<18	<15
Total Bg		*18716*	*5673*
S/B		*0.7*	*5.2*

Table 1

Luminosity 500 fb^-1, Ecm=500 GeV . The number of events after selection are given with and without polarization. Table 1 show an improvement from our previous study in (*Phys. rev. D 72,115008(2005)*). And we have now M$\tilde{t}$1=122.50+/- 0.44GeV using 2 energy points, one @ Threshold (*To be Published*).

C-Tagging – The Data Samples

- *<u>Neural Network (NN):</u>*

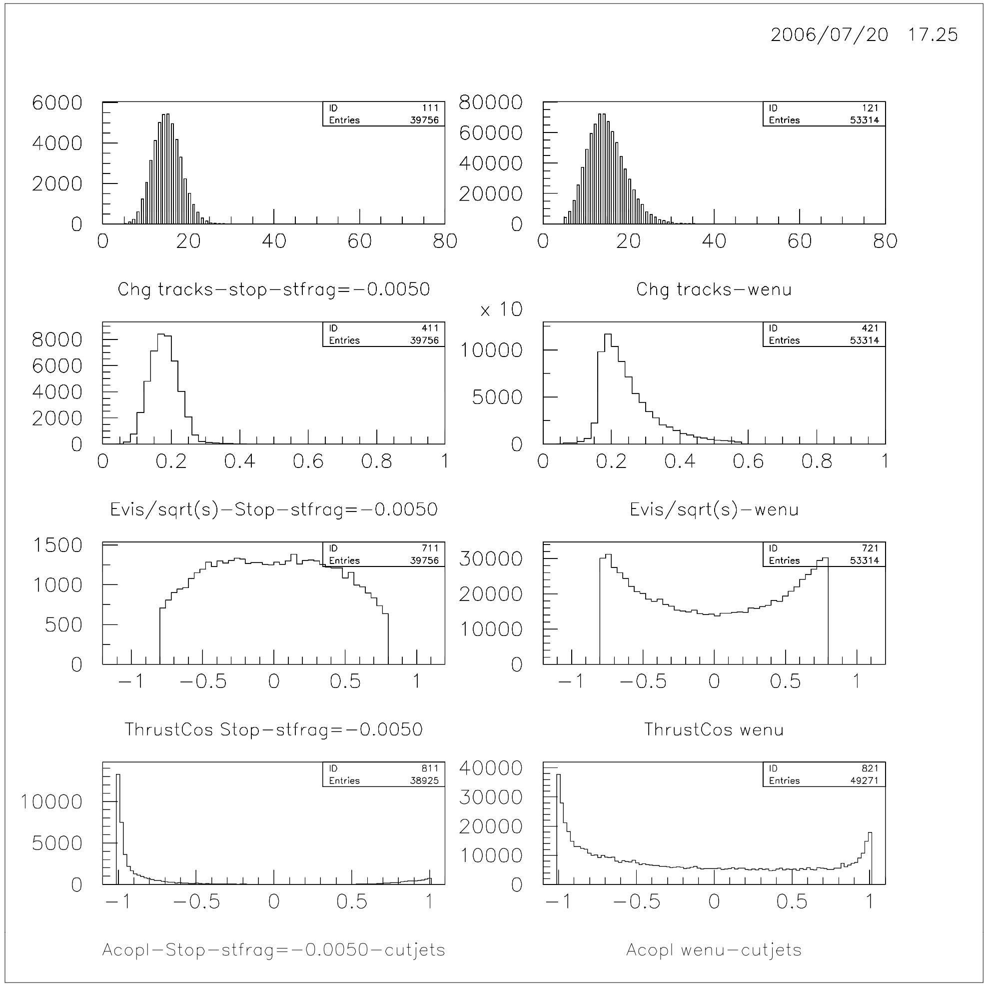
data used: 255000 stops,

Mstop=120-220 GeV,

Δm=5,10, 20 GeV

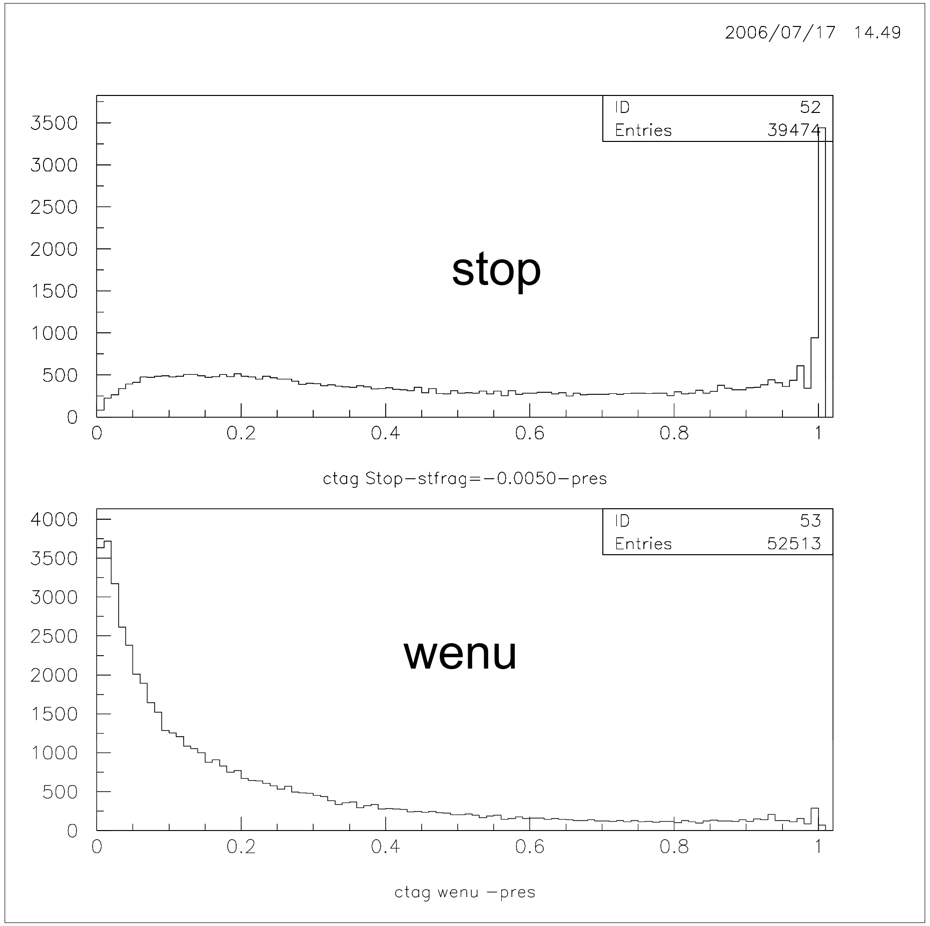
240000 Weν, the most resilient background

Stop/wenu- Variables Distributions



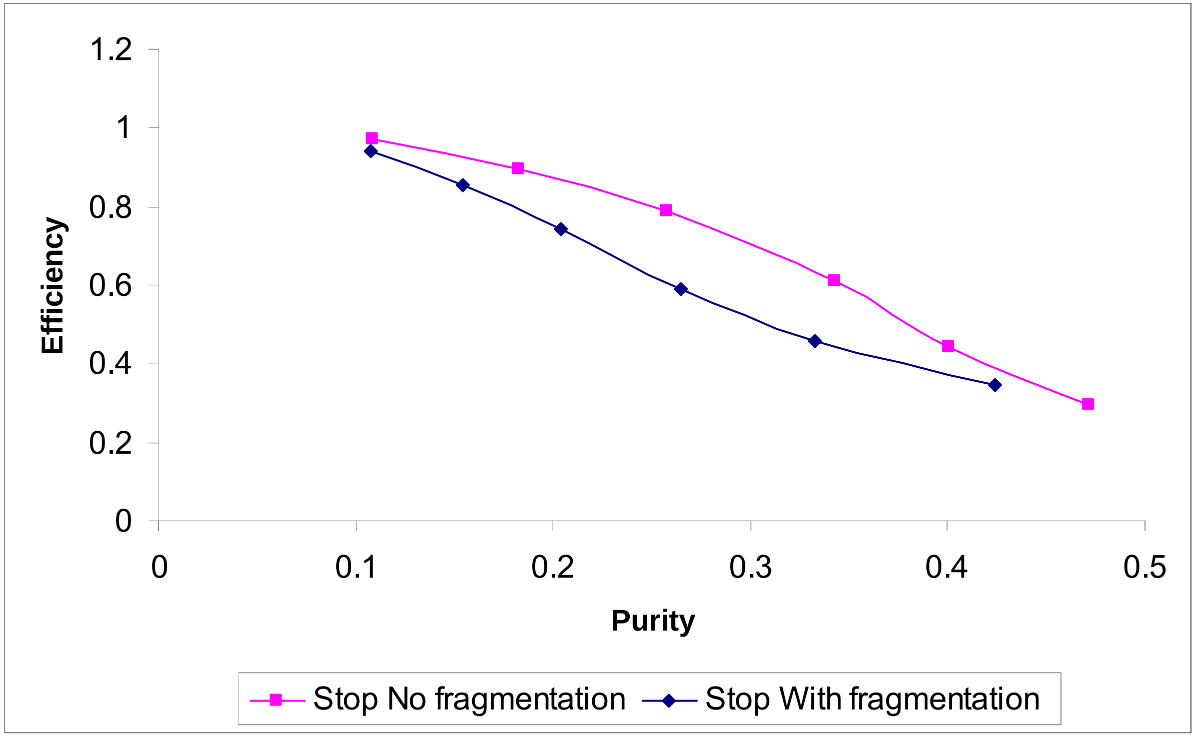
Left column: Stop
Right column: wenu (main Bg)

Charm-tagging



-The charm tagging provides the best cut between signal And wenu background
-It has been used here as a tool to find the charm jets in The multi-jet event

Efficiency versus Purity
With and Without Fragmentation*



- Corresponds ctag probability=0.2,0.4,0.6,0.8,0.9 ,0.95
- The lower the ctag cut, the lower the Purity and The higher the Efficiency
- The efficiency and purity are barely sensitive to the changes of stop fragmentation (at the 3 digit level) assuming the OPAL values

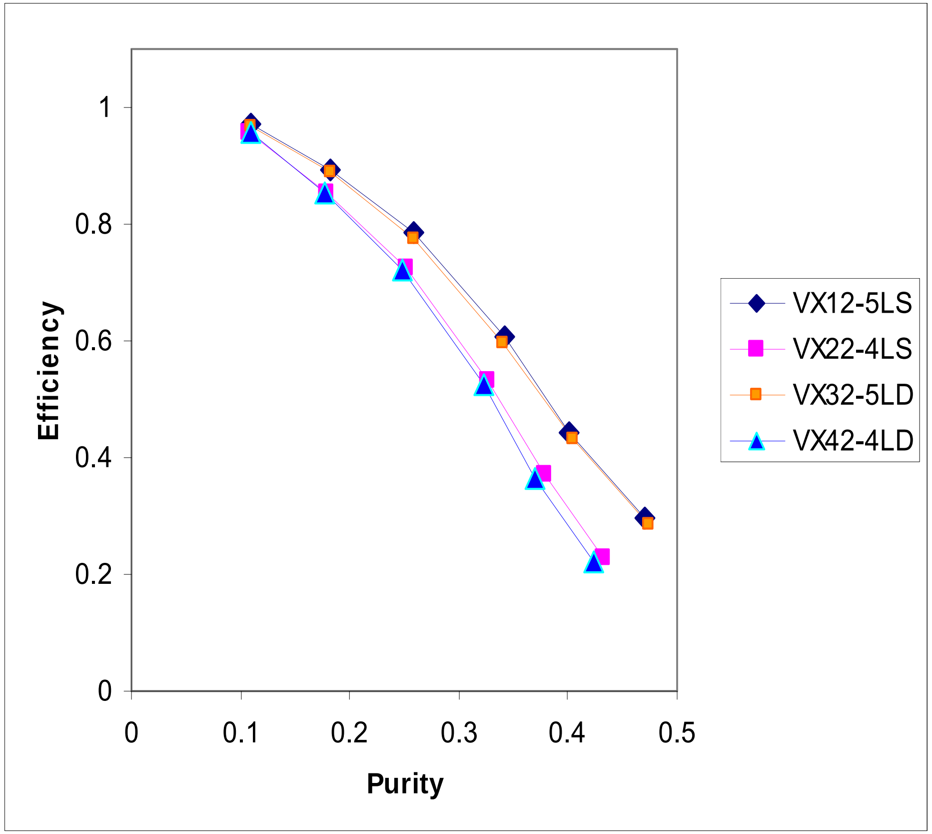
•*Plot without fragmentation taken from C.Milstene, A.Sopczak (Snowmass'05)*

Conclusions / Outlook

- 1/ When assuming a longer live stop hadron which fragments the 2-jets process becomes mostly a 3-4 jets final state with a residual 10% 2 jets events
- 3/ The C-tagging has successfully been used as an active tool to Identify the charm jets in the 3-4 jets events
- 4/ A better signal efficiency is achieved with more realistic data, namely, assuming stop fragmentation . The charm tagging plays an active role.
- 6/ For a given Efficiency the purity and efficiency are of the same order of magnitude han without fragmentation if we use the charm tagging to identify the charm jets in the multi-jet structure in that case in the more realistic data.
- One cannot use the jet-energy ordering to identify the charm jets in the more realistic data, the charm-tagging is a must !!!!
- New LCFI code based on same principles is now available with various detector setups see next talk (S. Hillert)

Backup

c-Tagging- Purity Versus Efficiency
4 Vertices configurations without Fragmentation



C.Milstene, A.Sopczak (Snowmass'05)

- VX_{12} ; 5 Layers, Single Density
- VX_{22} ; 4 Layers, Single Density
- VX_{32} ; 5 Layers; Double Density
- VX_{42} ; 4 Layers; Double Density

R_{Layer} = 15,26,37,48,60mm

E_{cm} = 500 GeV
Luminosity= $500fb^{-1}$
<u>Signal</u>:
$e^+ e^- \rightarrow \tilde{t}\,\tilde{t} \rightarrow c\, X_0^1\ c\, X_0^1$
mt = 120 GeV
mX01 = 110 GeV; dm=10 GeV
<u>Main Background:</u>
Wev
We will like to carry the same study
With fragmentation