Charm Jet Identification Using Flavor Tagging

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In collaboration with:

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- The decay $e^{+}e^{-} \rightarrow \tilde{t}_{1}\overline{\tilde{t}_{1}} \rightarrow c\tilde{\chi}_{0}^{1}\overline{c}\tilde{\chi}_{0}^{1}$

  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 player.
- 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 Pythia/ Simdet code implemented by A. Finch

  - Hadronisation of the c quark and the stop from the Lund string fragmentation Pythia uses Peterson fragmentation

  (Peterson et al PR D27:105)

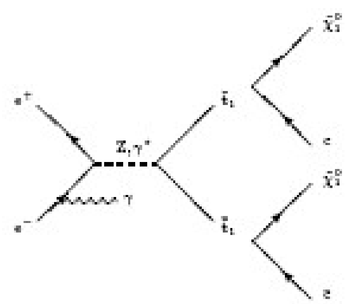
  - The stop fragmentation is simulated using Torbjorn code

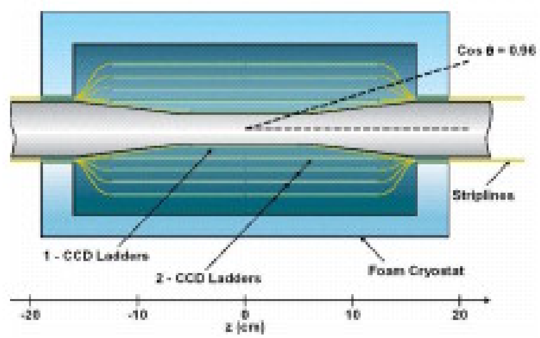
  //http://www.thep.lu.se/torbjorn/pythia/main73.f

  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:

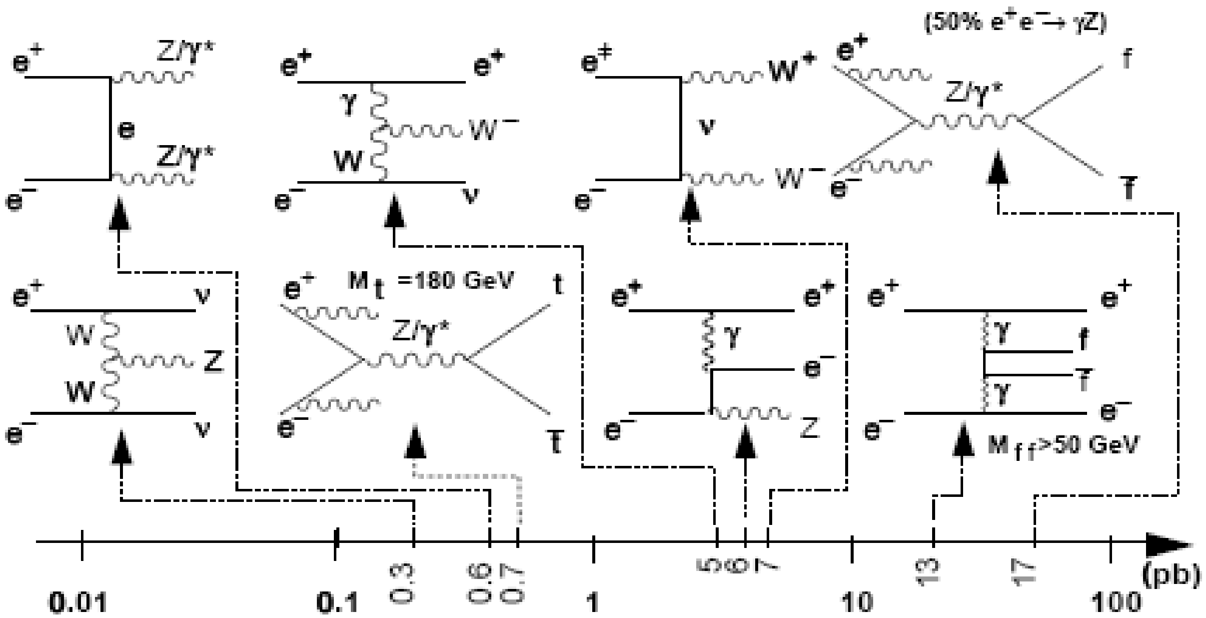
The Signal & Vertex Detector





Vertex Detector: Tesla type CCD layers @15,26,37,48 & 60mm each layer 0.064%X^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	Cross-sections (pb)		
	500 GeV	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

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

Selection $e^+e^- \to \tilde{t}_1\bar{\tilde{t}}_1 \to c\tilde{\chi}^1_0\bar{c}\tilde{\chi}^1_0$

•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: Flavor Tagging -T. Kuhl

•Njets >=2 && En <25 GeV; n=3,4

•P_t >12 GeV

•T> 0.8 , $\cos\theta_{Thrust}$<0.7 :

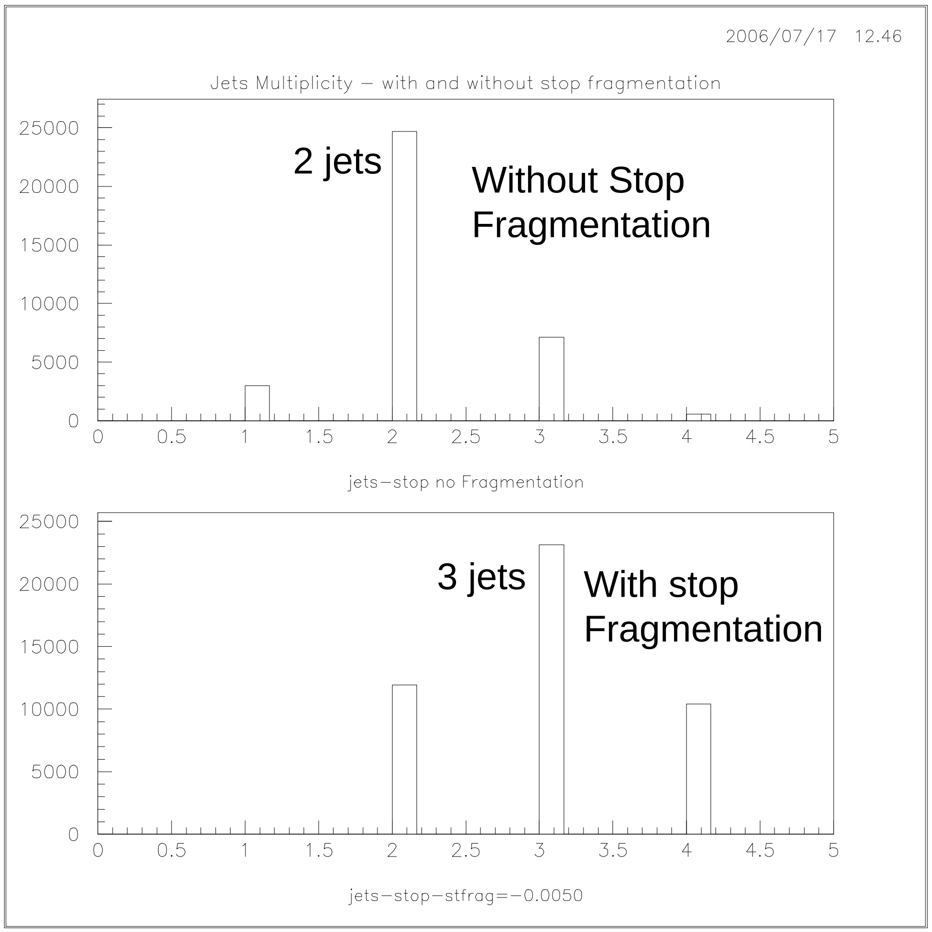
•E_{vis}< $0.4\sqrt{s}$

•|Φacop| <0.9

•60 GeV < $Minv_{jets}$ < 90 GeV

Charm tagging likelihood >0.4

Jet Multiplicity – Without/With Fragmentation

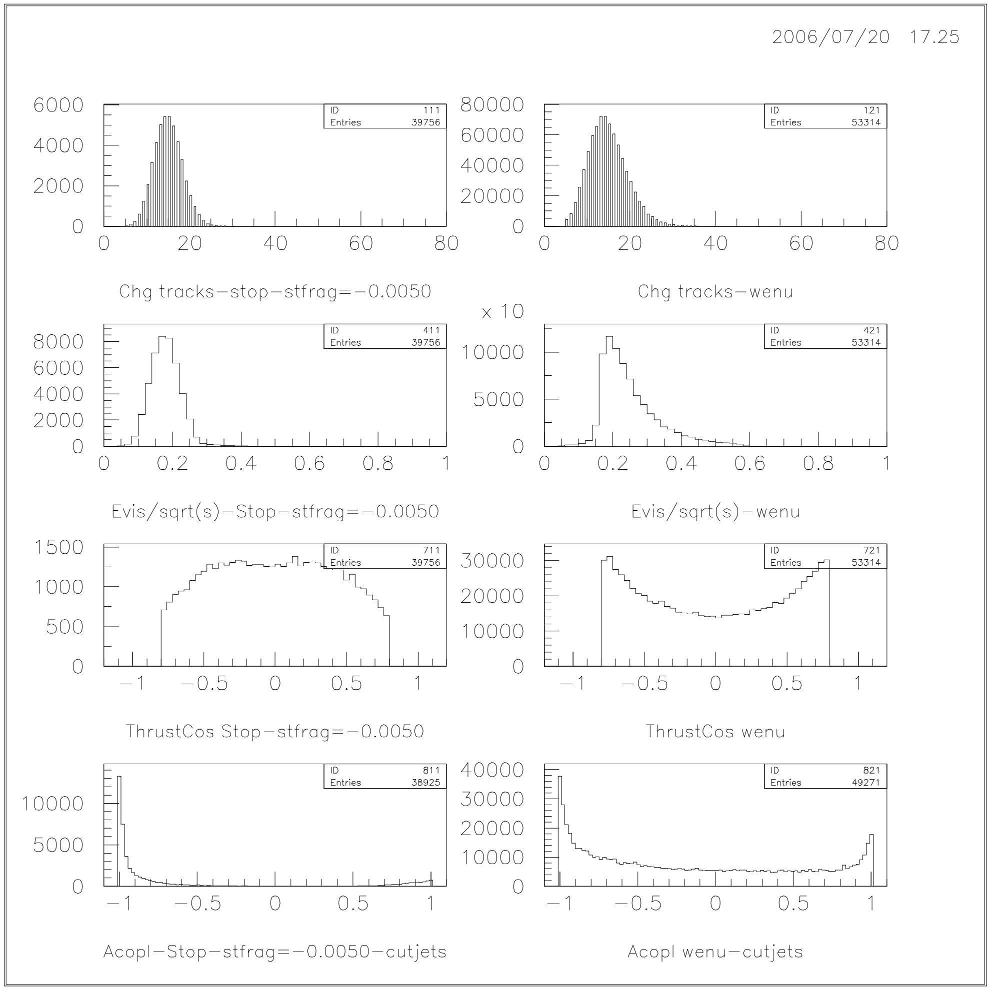


Stop fragmentation simulated using Torbjorn code
//http://www.thep.lu.se/torbjorn/pythia/main73.f

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 ε _b=-0.0050+ /- 0.0015
following (OPAL,EPJ C6:225)

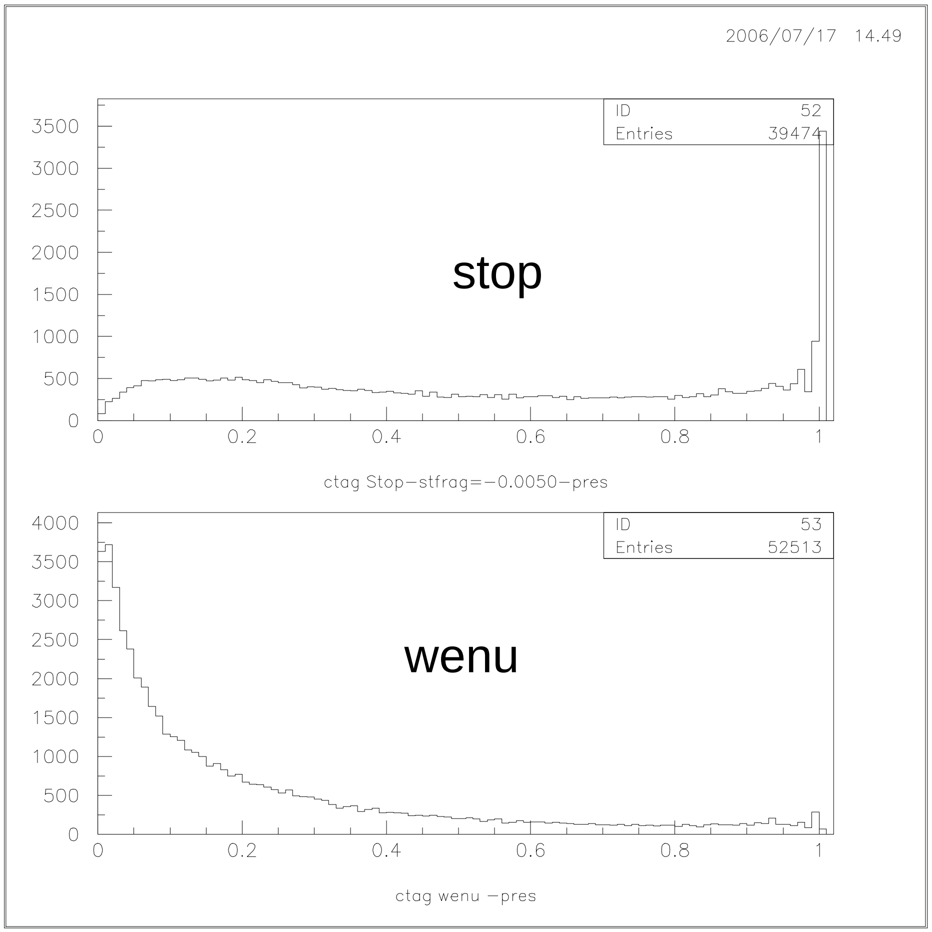
- *The jet Multiplicity without* $\tilde{t}$ *Fragmentation Upper figure*
  ~ 70% 2 jets
- *The jet Multiplicity with* $\tilde{t}$ *Fragmentation Lower Figure*
  ~ 50% 3 jets
  & bigger admixture of 4jets

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 & will
Be used here as a tool to find
The charm jets

C-tagging-The Principle

A Vertex Identification followed by a Neural Network application (ZVTOP) which operate 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)

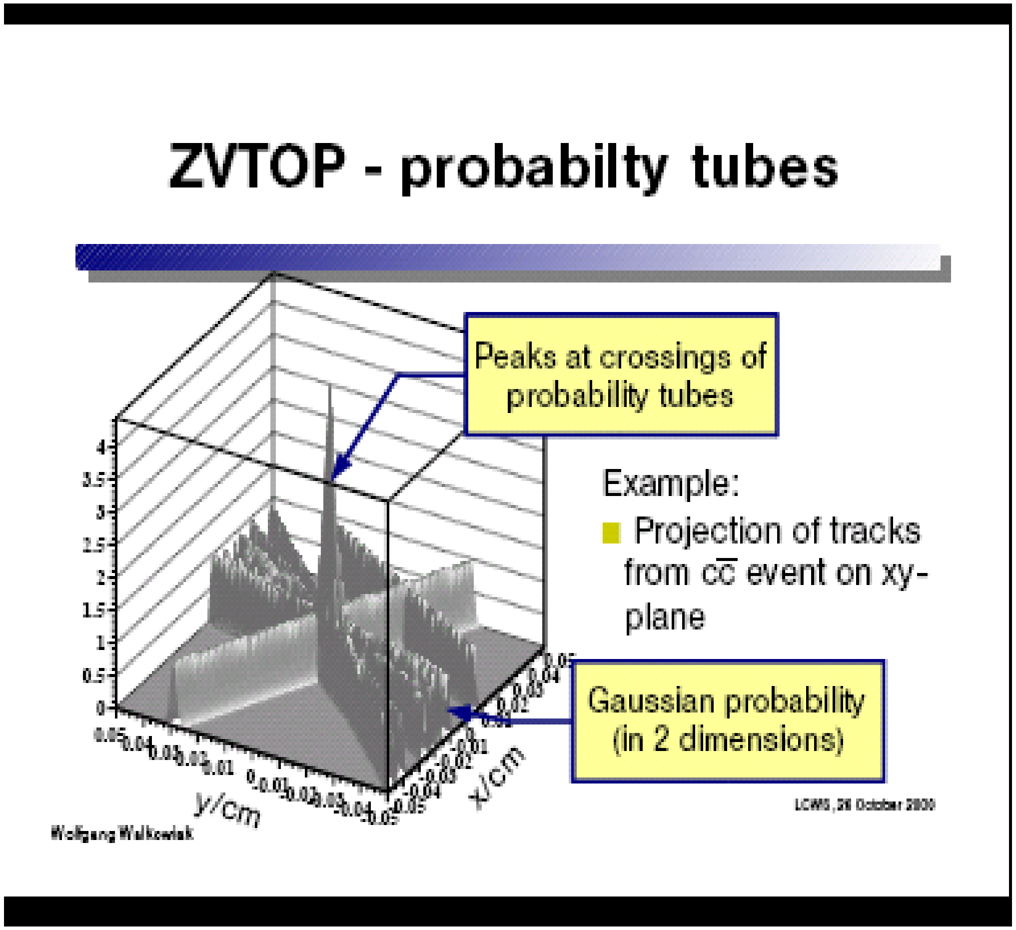
3 cases:

Case 1) Only a primary Vertex

Case 2) 1 secondary vertex

Case 3) >1 secondary vertex

Probability Tubes & Overlap Into a Vertex



W. Wolkowiak

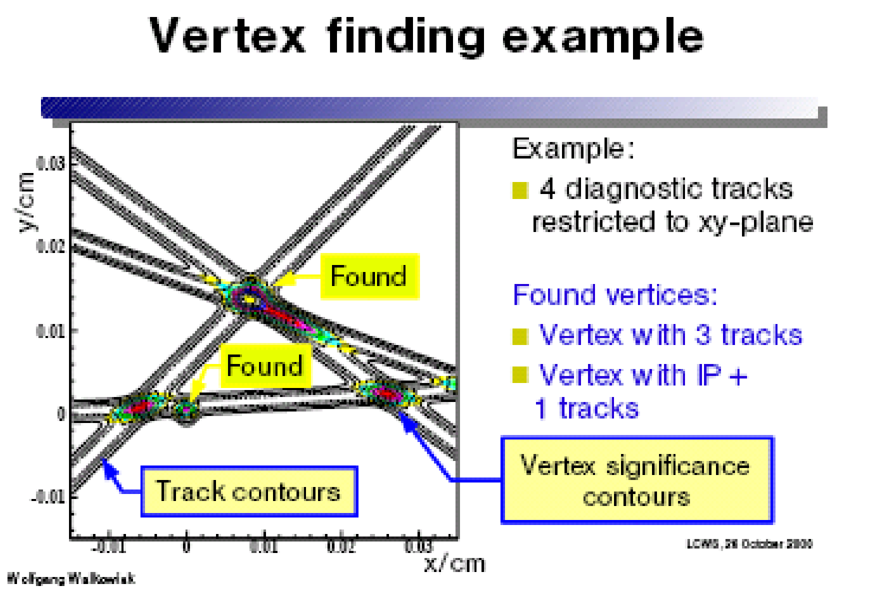
W. Wolkowiak: NIM A388-247-153, 1997

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

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 – The Data Samples

- *Neural Network (NN):*

data used: 255000 stops, Mstop=120-220; Dm=5,10, 20 GeV

240000 Weν, the most resilient background

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

Selection: The Background Rejection

Process	NumberGen.	Num Left. End Sel. – For 500 fb^-1 0/0 +80%/-60%
$\tilde{t}_1\tilde{t}_1^*$	0.50 M	11012 26430 (19%eff.)
2- photon	<u>8.5 Millions</u>	120(164) 120
zz	0.03 M	250(257) 224
qq	0.35 M	19(160) 22
ww	0.21 M	102(145) 9
tt	0.18 M	21(38) 19
wenu	0.21 M	10102 (5044) 2994
eez	0.21 M	0(2) 0

Table 1

Δm (GeV)	$M\tilde{t}_1$ 120GeV	$M\tilde{t}_1$ 140GeV	$M\tilde{t}_1$ 180GeV	$M\tilde{t}_1$ 220GeV
80		10%	15%	19%
40		10%	20%	24%
20	17%	21%	28%	35%
10	19%	20%	19%	35%
5	2.5%	1.1%	0.3%	0.1%

Table 2

Luminosity 500 fb^-1, Ecm=500 GeV .Table 1 the number of events after selection are given with and without polarization, Table 2 and in red Table 1 comes from our previous study in *Phys. rev. D 72,115008(2005), same efficiency for similar (*M$\tilde{t}$1, Δm). And we have now M$\tilde{t}$1=122.5+/- 1.2 GeV Instead of M$\tilde{t}$1=122.5+/- 1GeV.

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
- 2/ The 2 charm jets are now split into 3 or 4 jets events. (might be of interest for other physics channel changing the signature expected)
- 3/ The C-tagging has successfully been used as an active tool to Identify the charm jets in the 3-4 jets events
- 4/ The same overall signal efficiency is achieved with and without assuming stop fragmentation.
- 5/ Effect of Removing of 1st layer (radiation damage) increase in layer density (element support) and their effect on the c_tagging : efficiency and purity *SNOWMASS-2005-ALCPG1431,Dec2005,5pp* and is now under study with fragmenting stops (in progress)
- 6/ Next bigger projects for Vertex Studies:
  - full simulation
  - Going to a detector independent frame
  - Varying (vertex) Detectors

Backup

Background ()

- Remark:

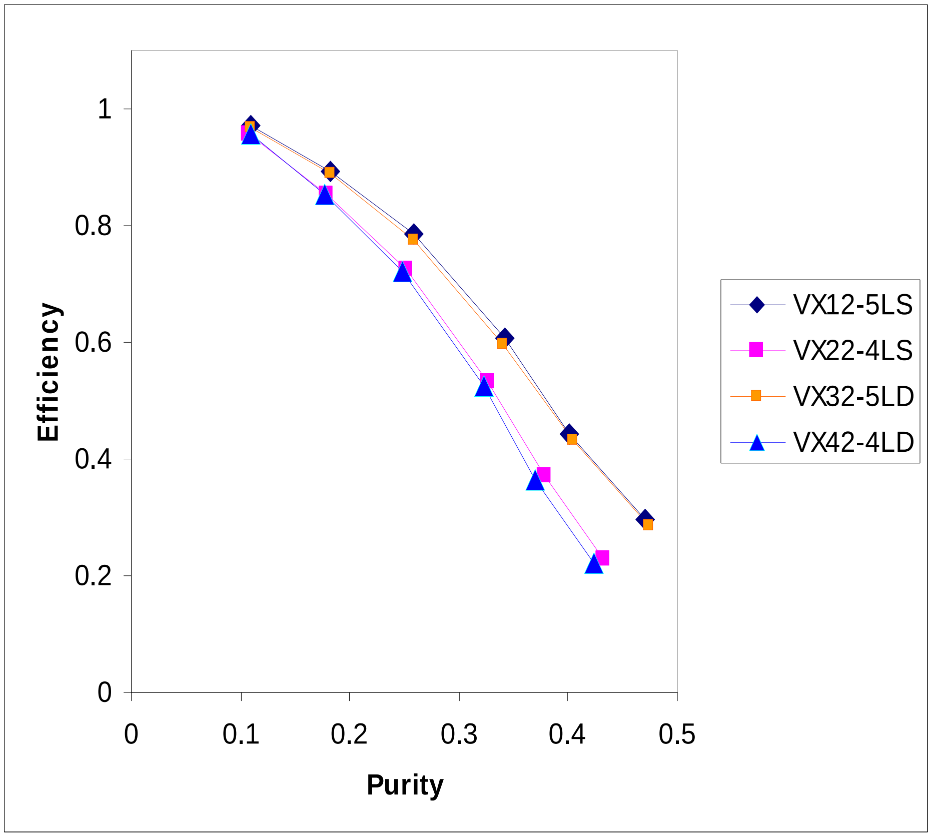
  In the Beamstrahlung are included processes

  131,135,11,12,13,28,53,68

  In the Bremstrhalung

  11,12,13,28,53,68,131,132,135,136,137,138,139,140….

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

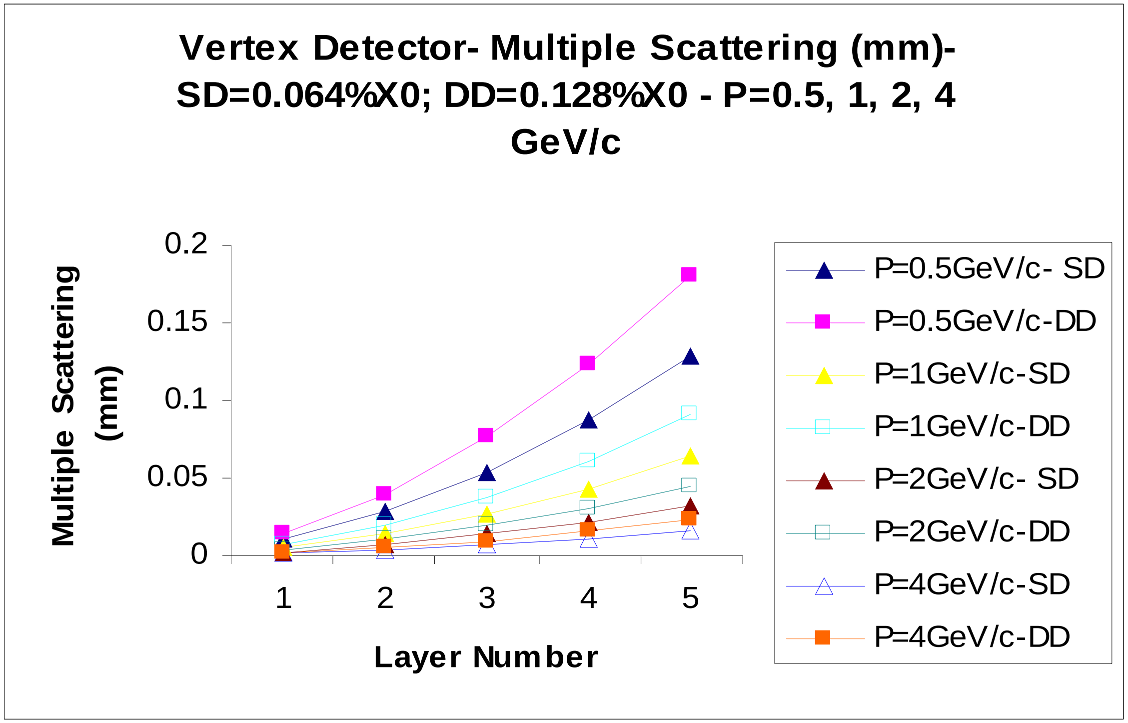


- VX_{12} ; 5 Layers, Single Density
- VX_{22} ; 4 Layers, Single Density
- VX_{32} ; 5 Layers; Double Density
- VX_{42} ; 4 Layers; Double Density

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

Multiple Scattering



e.g.
For a 0.5 GeV particle
In Layer 1,R=15mm
d=Rθ=15μm
Θ=(13.6/p) √(x/X0)
X0=radiation Length
Theta =Multiple Scattering angle