Vertex detection for a charm tag in $e^+e^- \to W^+W^-$

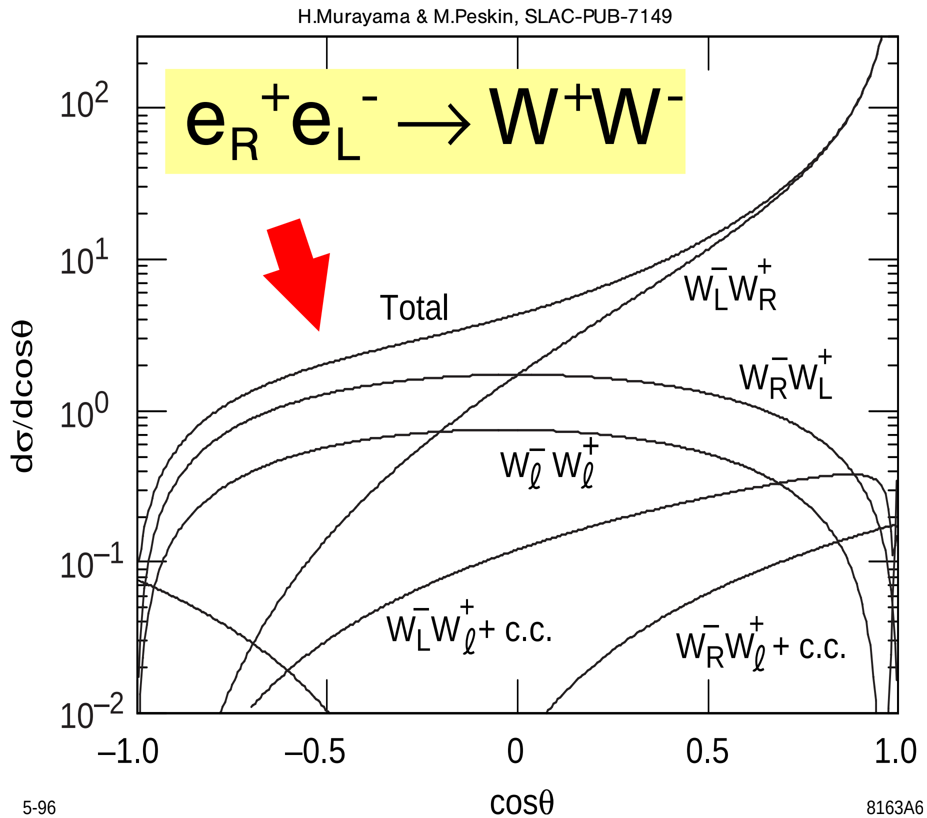
Wolfgang Walkowiak,
UC Santa Cruz

LCD Study Group Meeting,
SLAC,
30 October 2001

Introduction

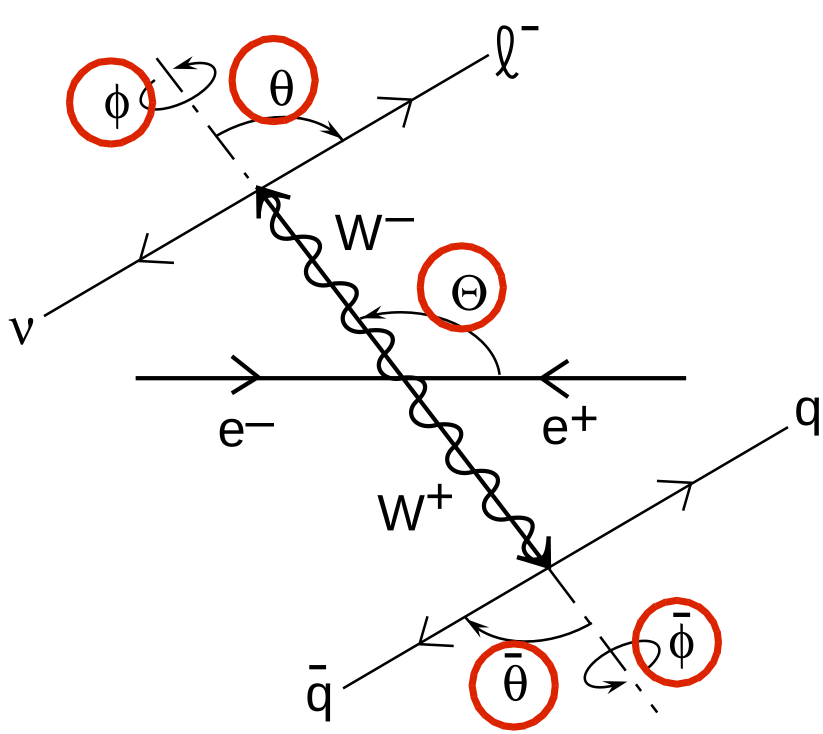
- Study $e^+e^- \to W^+W^-$:
  - Very high $M_H \Rightarrow \sigma_{W^+W^-}$ can show deviations from SM (anomalous gauge boson couplings, $W_L^+W_L^-$ rescattering).
- Presented in this talk:
  - Charm-tag using vertex multiplicities for W^+W^- helicity analysis.
  - Now uses DURHAM jetfinder and stricter $|\cos\theta_W|$ cut

Helicity analysis



- Forward WW scattering dominated by T-channel process (ν exchange)
- $\sigma_{W_L W_L} \sim \sin^2(\Theta)$
  - Sensitive to $W_L^+ W_L^-$ in backward direction

Helicity analysis



- Quantities to be measured:
  - cos(Θ) production angle
  - Helicity angles of W decay products in W rest frames: cos(θ), φ, cos(θ̄), φ̄
- Use likelihood fit to extract L_{9R} and L_{9L} or $Re(F_T)$ and $Im(F_T)$.

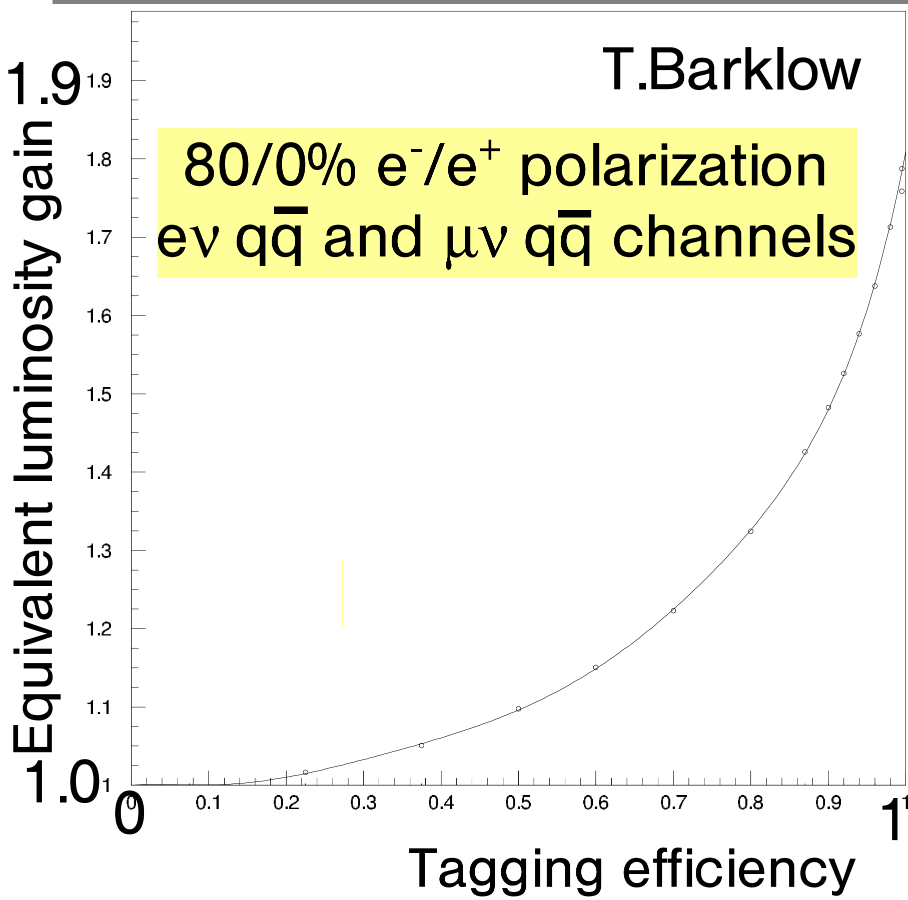
Flavor tagging

- Lepton is expected to be identified, but there is an ambiguity on hadronic side in W decay tensor:

$$\bar{H}^{\bar{\lambda}}_{\bar{\lambda}'} = \left[\bar{D}^{\bar{\lambda}}_{\bar{\lambda}'}(\cos(\bar{\vartheta}^*), \bar{\phi}^*) + \bar{D}^{\bar{\lambda}}_{\bar{\lambda}'}(-\cos(\bar{\vartheta}^*), \bar{\phi}^* + \pi) \right]$$

- Loosing information by ´averaging´ over these two states.
- Need flavor tagging to make this information accessible.

Expected effect of c-tagging

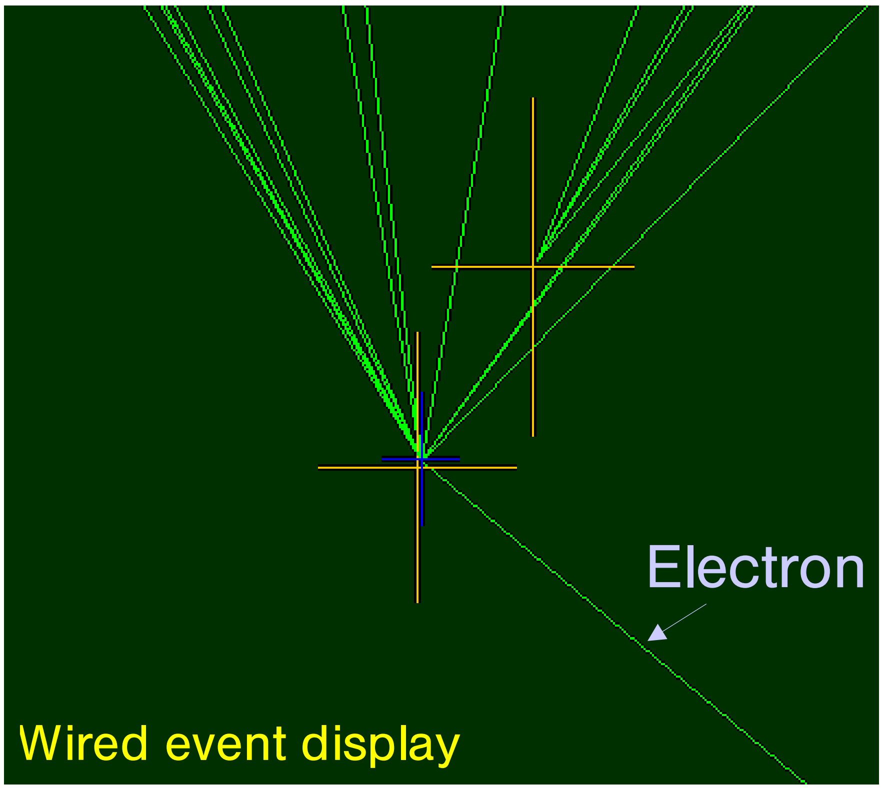


- Tagging ´efficiency´ includes mistag
- Equivalent luminosity gain up to a factor 1.8 in case of perfect c-tagging

MC Samples and Analysis

- 10000 Pandora-Pythia $e^+e^- \rightarrow W^+W^-$ events (SM) including a TechniRho at 1600 GeV at $E_{cms} = 500, 1000, 1500$ GeV with one W decaying leptonically, the other hadronically.
- Simplify: Use $W \rightarrow l\nu$ with $l = e, \mu$ only.
- Use events with $|\cos \Theta_W| < 0.90$ only.
- Use Fast Monte Carlo of lcd package (JAS) for track simulation.
- Vectors for neutral particles are created from MC truth information. (Only used for jet finding.)
- DURHAM jet finder used to create exactly two jets.
- Vertex finding: ZvTopVertexer (like SLD's ZVTOP).

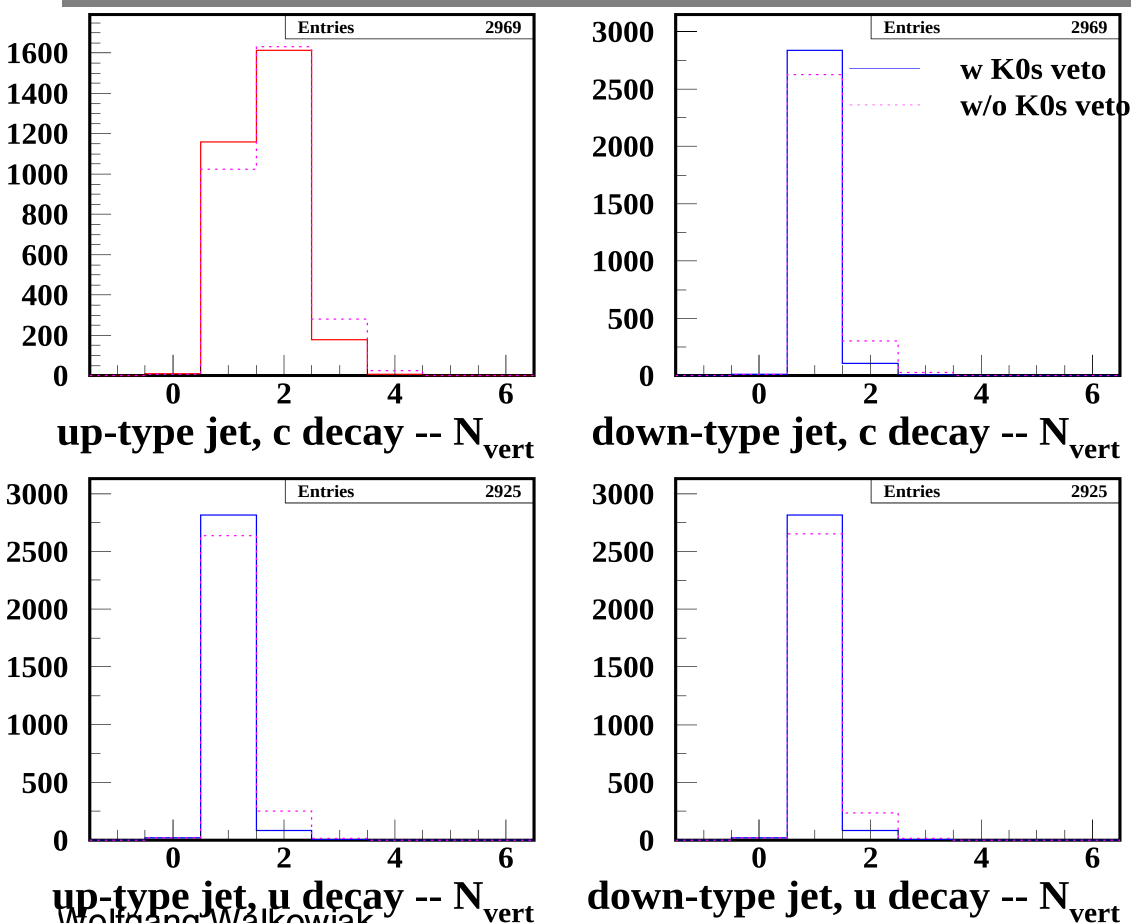
Topological vertex finding



(Vertex axes 1000x enlarged)

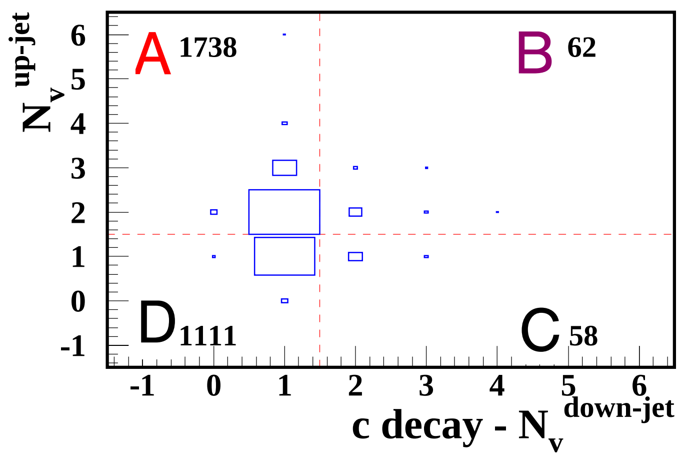
- ZVTOP: topological vertexing developed by SLD (D.J.Jackson, NIM A388 247-253,1997)
- Java implementation: ZvTopVertexer

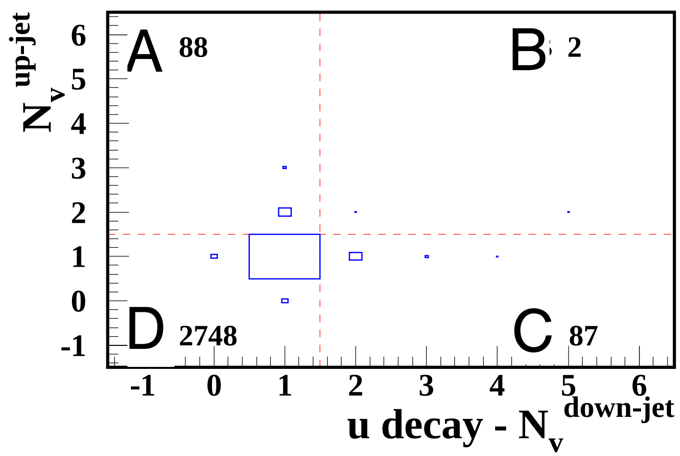
Vertex multiplicites in jets



- ZvTopVertexer finds vertices in each jet.
- The beamspot is included in the first vertex, if any vertices are found.
- Exclude furthest vertex, if $m_V = m_{K0s}$ +/-25 MeV
- Example for LD 500

Vertex multiplicites in jets
-- Correlations --





(LD 500 GeV)

With K^o_s vertex veto

- Very simple c-tag: $\geq$ 2 vertices in jet found.
- Field A in left plot gives the desired events, field C and fields A, B and C in right plot give mistags.
- Assume 50% chance to tag the correct jet in field B of left plot.

C-tag efficiency and analyzing power

- Table is for LD detector design.

DURHAM jetfinder && $|\cos \Theta_W| < 0.90$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	59.6%	61.2%	62.6%
c−tag purity	86.9%	89.6%	92.1%
Analyzing power	73.9%	79.3%	84.3%
Q=eff*A*A	32.5%	38.5%	44.4%

- Exclusion of K^0_s verticies important! (∼10% purity gain)
- No b-jets in $e^+e^- \rightarrow W^+W^-$ events.

C-tag efficiency and analyzing power

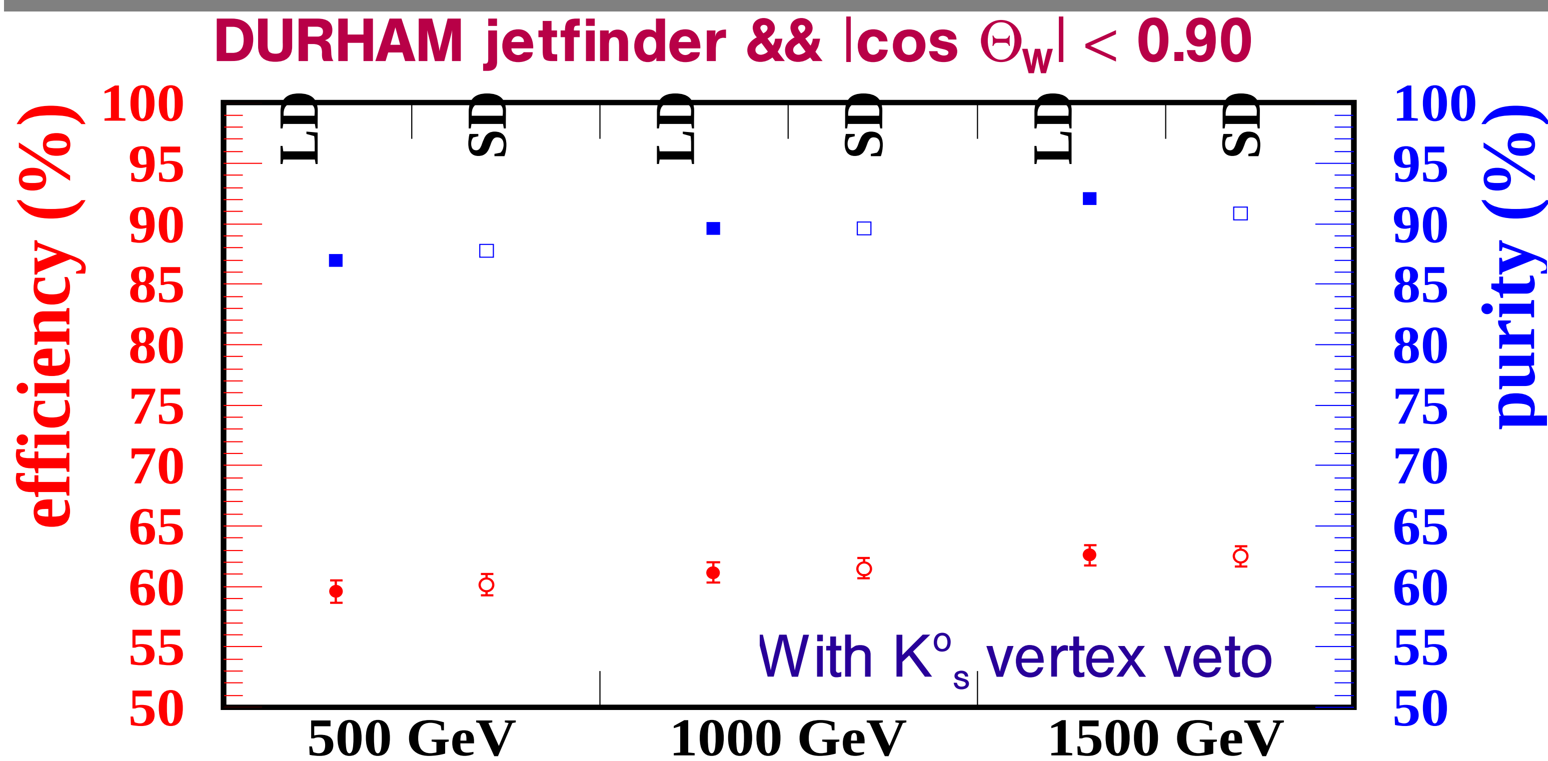
- Table is for SD detector design.

DURHAM jetfinder && $|\cos\Theta_W| < 0.90$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	60.1%	61.5%	62.5%
c−tag purity	87.8%	89.6%	90.9%
Analyzing power	75.5%	79.2%	81.8%
Q=eff*A*A	34.3%	38.6%	41.8%

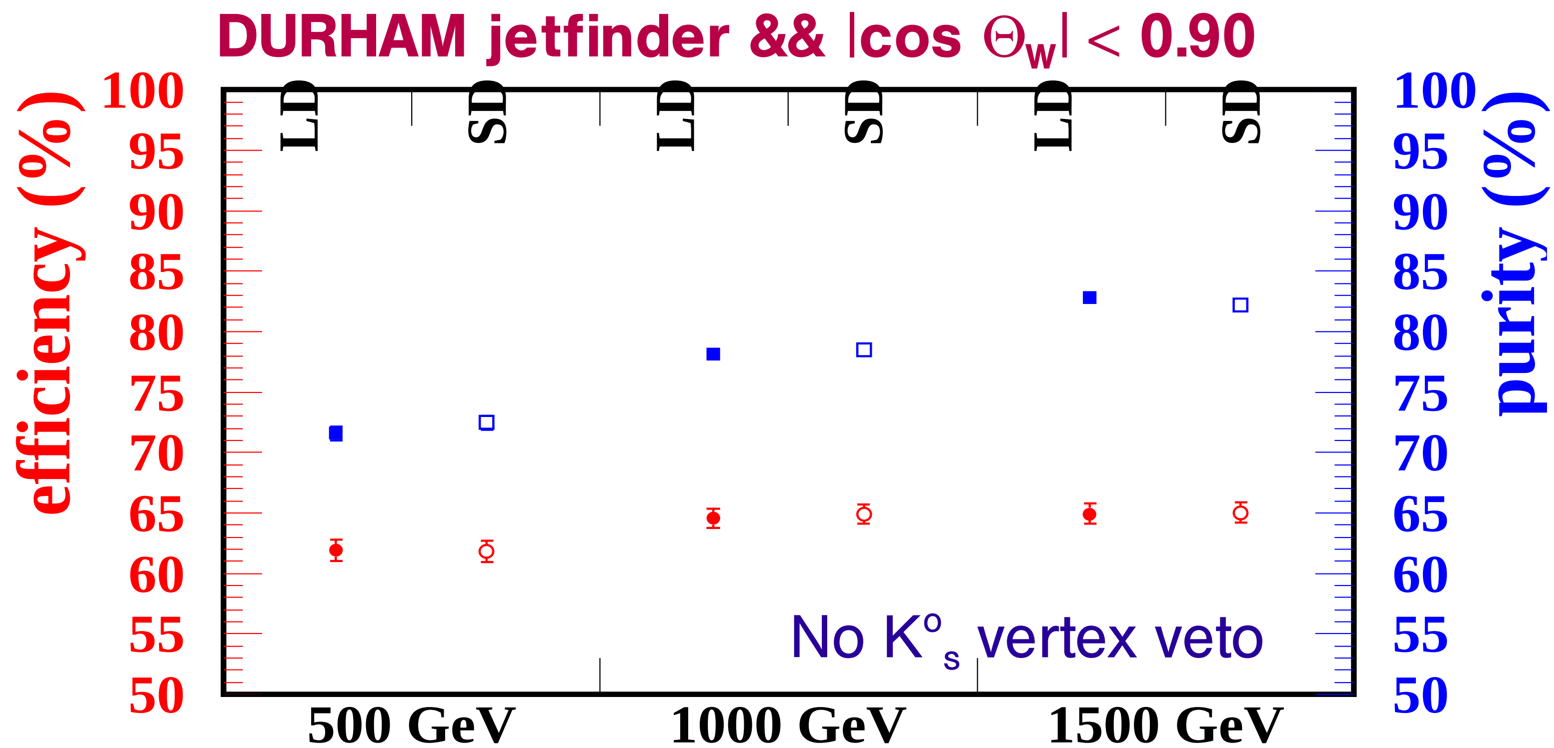
- Only minor differences to LD design.
- No b-jets in $e^+e^- \to W^+W^-$ events.

C-tag efficiency and purity



- Slight increases with higher beam energy.

C-tag efficiency and purity



- Purity is lower than with K^o_s vertex veto.

Plans

- Study additional variables to separate c- and non c-jets:
  - Secondary vertex related: M_{ptcor}, p_{secVtx}, d_{secVtx}, $N_{tracks,secVtx}$
  - Imp_{max} - Largest impact parameter of tracks
  - N_{imp} - number of tracks with considerable impact parameter
  - P_{max} - momentum of leading track
- Use NN technique for c-tag
  Question: Size of training sample needed?
- Working on ghosttrack algorithm for ZvTopVertexer

Conclusions

- Samples of $e^+e^- \to W^+W^-$ events including a TechniRho with $m_{TechniRho}$ = 1.6 TeV at three different LC energies have been simulated and passed through the LCD fast detector simulation to study the power of a charm tag using topological vertexing.
- Charm tagging efficiencies of ca. 61% with purities of 90 % are reached (in absence of backgrounds other than the $W \to$ u x decay) with a simple multiplicity tag.
- An slight increase in purity and efficiency with rising LC energy is seen.
- No significant differences between the LD and SD detector designs have been observed.

C-tag efficiency and analyzing power

- Table is for LD detector design.

DURHAM jetfinder && $|\cos \Theta_W| < 0.99$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	58.9%	61.2%	62.6%
c−tag purity	80.4%	89.6%	91.2%
Analyzing power	60.7%	79.3%	82.4%
Q=eff*A*A	21.7%	38.5%	42.5%

- Exclusion of K^0_s verticies important! (~10% purity gain)
- No b-jets in $e^+e^- \to W^+W^-$ events.

C-tag efficiency and analyzing power

- Table is for SD detector design.

DURHAM jetfinder && $|\cos \Theta_W| < 0.99$

Sample	500 GeV	1000 GeV	1500 GeV
c–tag efficiency	59.7%	61.2%	62.6%
c–tag purity	80.6%	87.7%	90.1%
Analyzing power	61.3%	75.4%	80.3%
Q=eff*A*A	22.4%	34.8%	40.3%

- Only minor differences to LD design.
- No b-jets in $e^+e^- \rightarrow W^+W^-$ events.

C-tag efficiency and analyzing power

- Table is for LD detector design.

Preliminary!

JADE jetfinder && $|\cos \Theta_W| < 0.90$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	60.1%	61.7%	62.3%
c−tag purity	86.7%	90.0%	92.0%
Analyzing power	73.5%	80.0%	84.0%
Q=eff*A*A	32.5%	39.5%	43.9%

- Exclusion of K^0_s verticies important! (∼10% purity gain)
- No b-jets in $e^+e^- \rightarrow W^+W^-$ events.

C-tag efficiency and analyzing power

- Table is for SD detector design.

Preliminary!

JADE jetfinder && $|\cos \Theta_W| < 0.90$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	60.5%	61.4%	62.0%
c−tag purity	87.5%	89.8%	91.3%
Analyzing power	75.0%	79.6%	82.6%
Q=eff*A*A	34.0%	38.9%	42.2%

- Only marginal differences to LD design.
- No b-jets in $e^+e^- \rightarrow W^+W^-$ events.

C-tag efficiency and analyzing power

Preliminary!

- Table is for LD detector design.

JADE jetfinder && $|\cos \Theta_W| < 0.99$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	59.5%	61.6%	62.1%
c−tag purity	80.0%	87.7%	90.9%
Analyzing power	59.9%	75.4%	81.9%
Q=eff*A*A	21.4%	35.0%	41.6%

- Exclusion of K^0_s verticies important! (~10% purity gain)
- No b-jets in $e^+e^- \rightarrow W^+W^-$ events.

C-tag efficiency and analyzing power

- Table is for SD detector design.

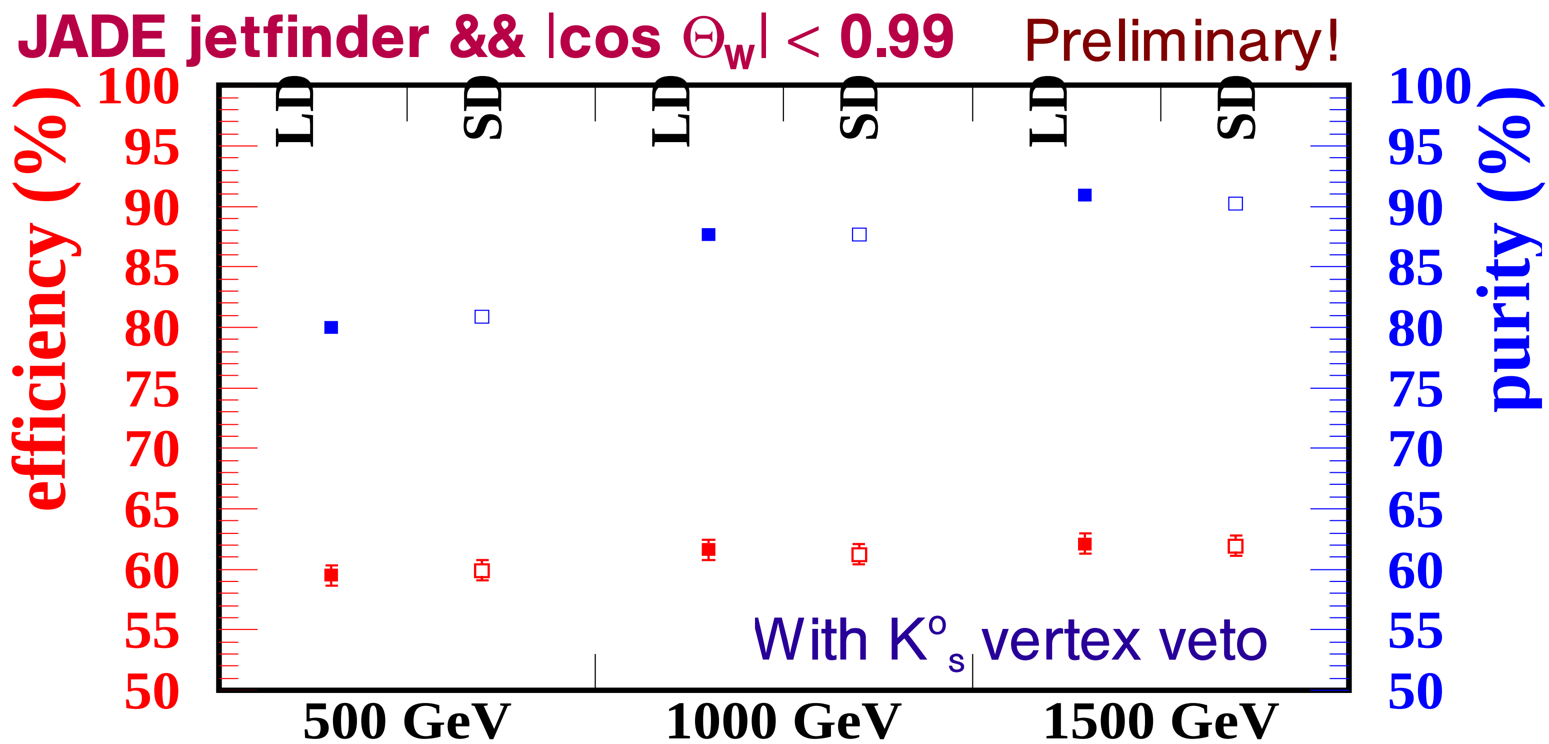
Preliminary!

JADE jetfinder && $|\cos \Theta_W| < 0.99$

Sample	500 GeV	1000 GeV	1500 GeV
c−tag efficiency	59.9%	61.2%	61.9%
c−tag purity	80.9%	87.7%	90.2%
Analyzing power	61.8%	75.4%	80.4%
Q=eff*A*A	22.9%	34.8%	40.0%

- Only marginal differences to LD design.
- No b-jets in $e^+e^- \to W^+W^-$ events.

C-tag efficiency and purity

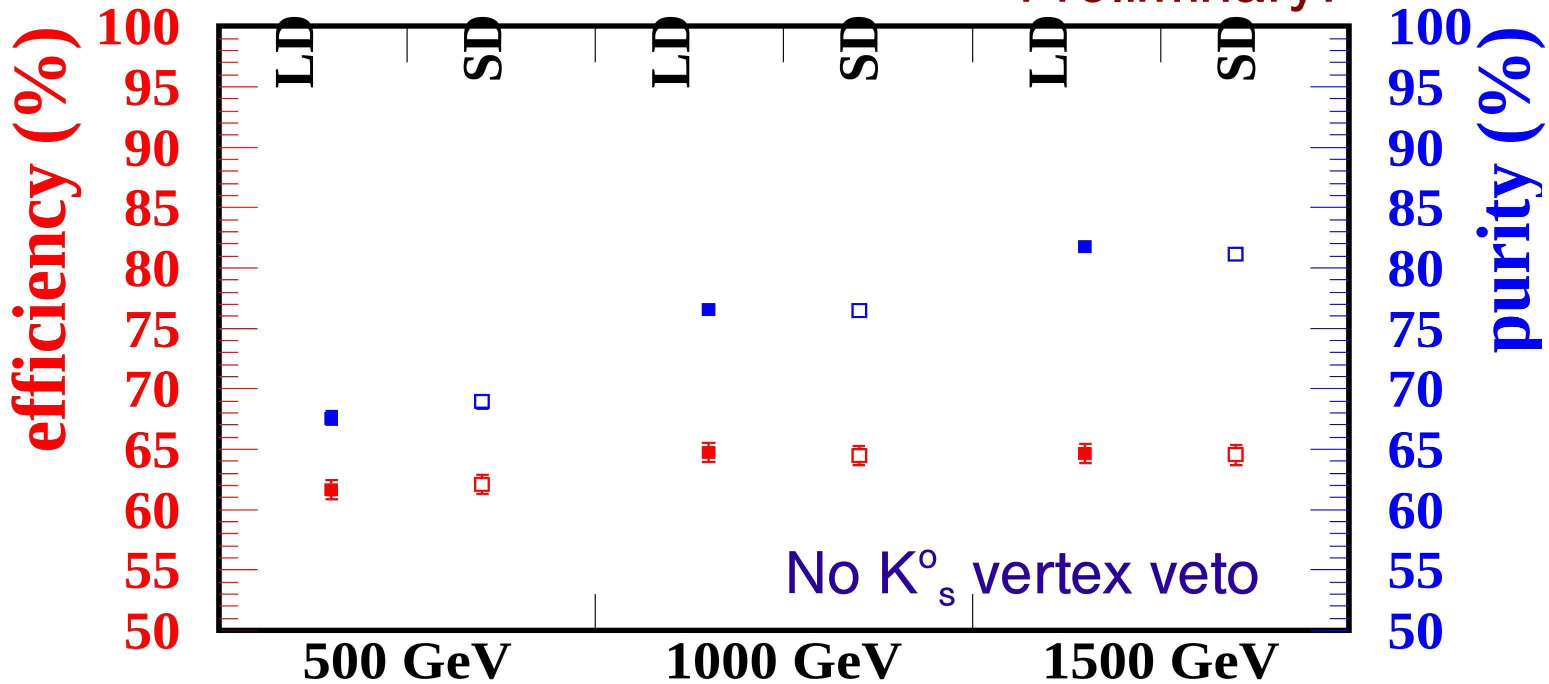


- Purity rises with higher beam energy.

C-tag efficiency and purity

JADE jetfinder && |cos Θ_W| < 0.99

Preliminary!



- Purity is lower than with K^o_s vertex veto.