Linear Collider Workshop 2000 - LCWS 2000
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Studies for b-Tagging at the CLIC multi-TeV Collider

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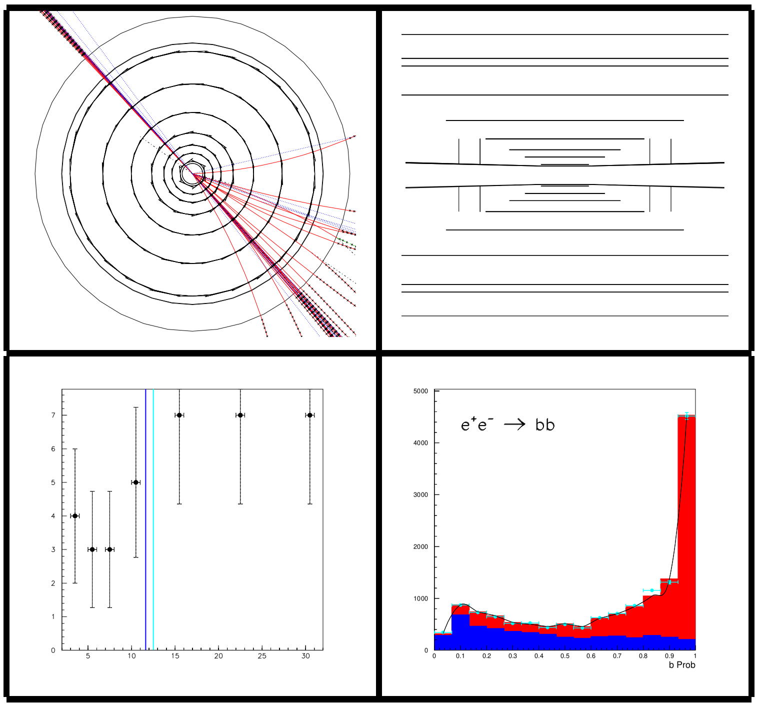
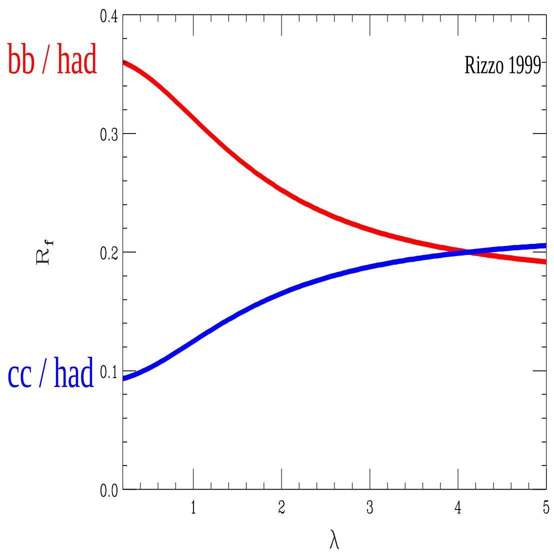


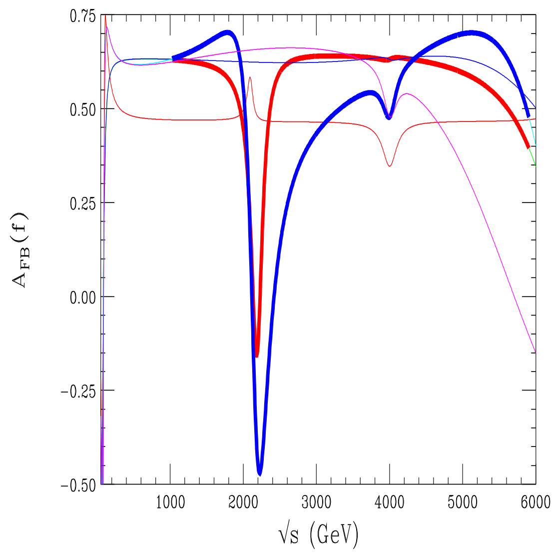
Physics with b-Tagged Final States

- By the start of CLIC, the LHC, and/or a lower energy e^+e^- LC, like TESLA/NLC/JLC, should have probed the multi-TeV domain by direct and indirect searches:
- If **new particles** have been **detected in the range 1 TeV - 5 TeV**, CLIC will produce them directly, provide accurate determination of their couplings and establish their nature:

A Physics Example: Telling a $Z^{(1)}/\gamma^1$ KK Excitation

, T. Rizzo, Phys.Rev. D61 (2000)



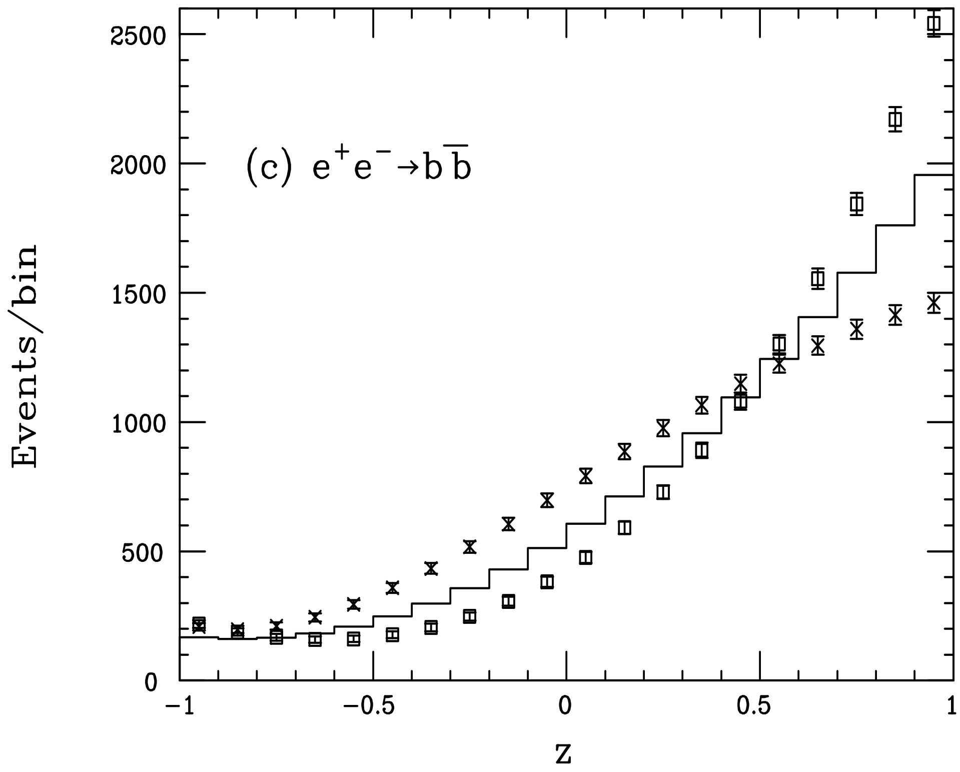


- Probe flavour dependent A_{FB} and partial widths to disentangle degenerate resonances from extended Gauge Boson Z' signature.

If **no evidence for new particles** by LHC/lc-500
CLIC will probe the energy domain beyond 10 TeV
by indirect searches.

Sensitivity to Xtra Dimensions from $A_{FB}^{b\bar{b}}$

J. Hewett, Phys.Rev.Lett. 82 (1999)



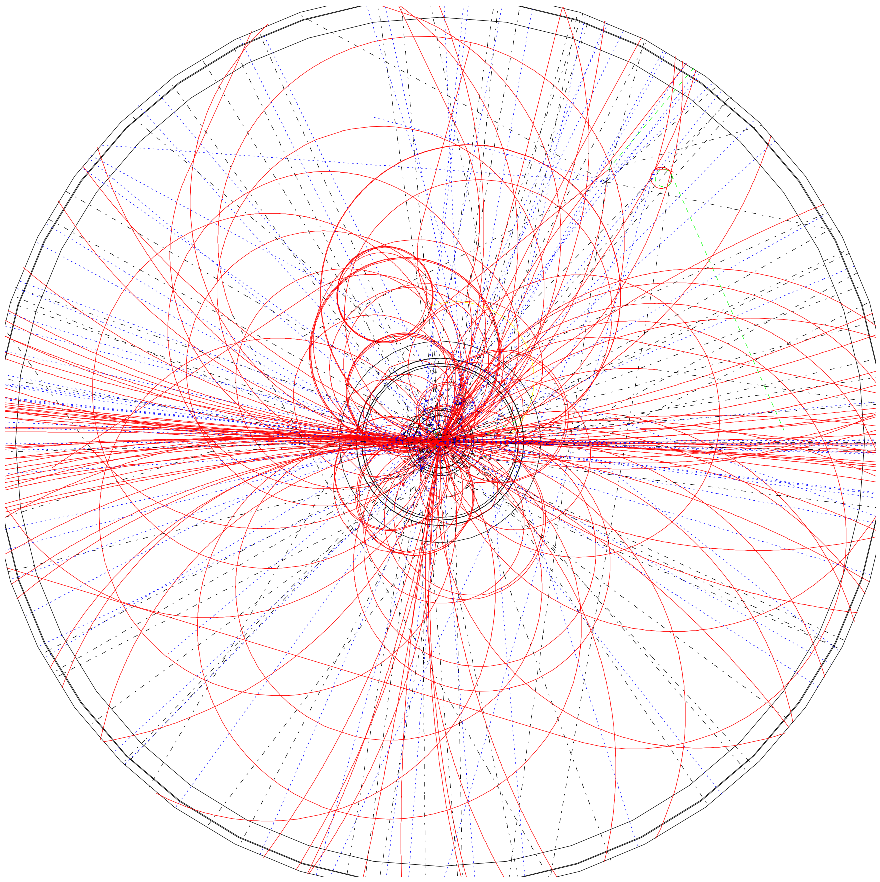
❖ Precision fits to EW observables ($\Gamma_{f\bar{f}}$, A_{FB}, A_{LR}) sensitive to virtual processes and vertex corrections from new particle contributions.

❖ Fits rely on beam polarization and **accurate flavour identification to probe dependence of couplings on fermion masses and species** ($t/b/c$ quark separation).

❖ Tagging and anti-tagging of t, b and τ final states will be instrumental to isolate signals of and to study the heavy Higgs sector in SM extensions (MSSM, 2HDM, ...) and to measure the Higgs potential in multiple Higgs production.

$$e^+e^- \to H^+H^- \to t\bar{b}\bar{b}t$$

for $M(H^{\pm}) = 900$ GeV at $\sqrt{s} = 3$ TeV



B Hadrons at CLIC

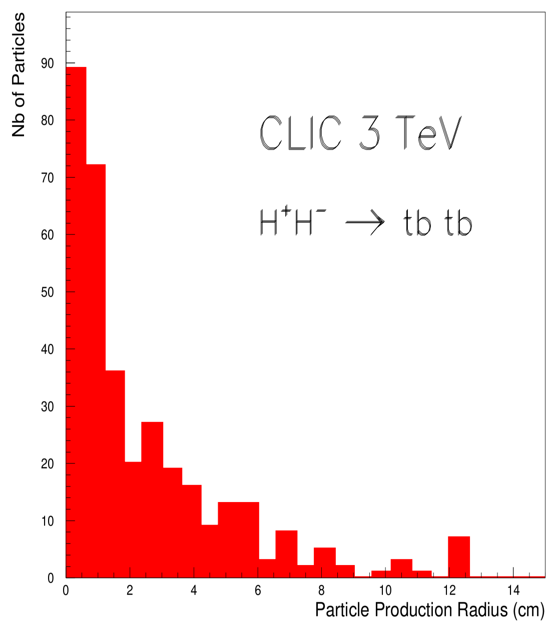
- Tag of heavy particle decays $\rightarrow t\bar{t}$
- EW observables in $e^+e^- \rightarrow b\bar{b}$

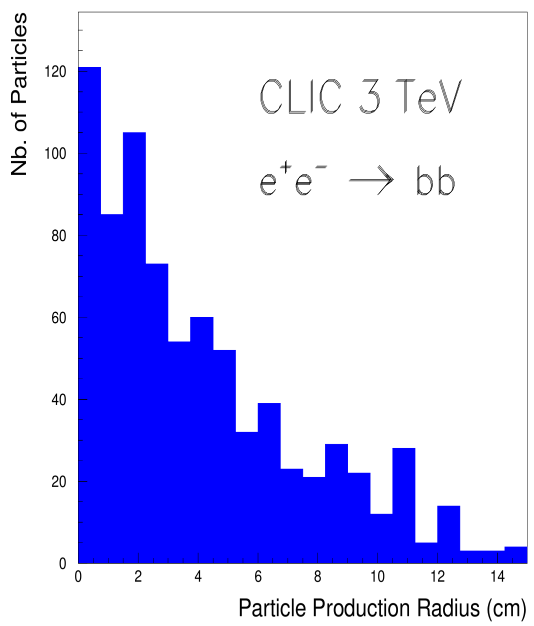
B production vs. $\sqrt{s}$

$\sqrt{s}$ (TeV)	0.09	0.5	0.8	**3.0**
$\sigma_{b\bar{b}}$ (pb)	9160	0.4	0.15	**0.014**
$\int L$		500 pb^{-1}	500 pb^{-1}	**5000 fb**$^{-1}$
$N_{b\bar{b}}$	900k	200k	75k	**70k**

$B \rightarrow X$ Decay Length

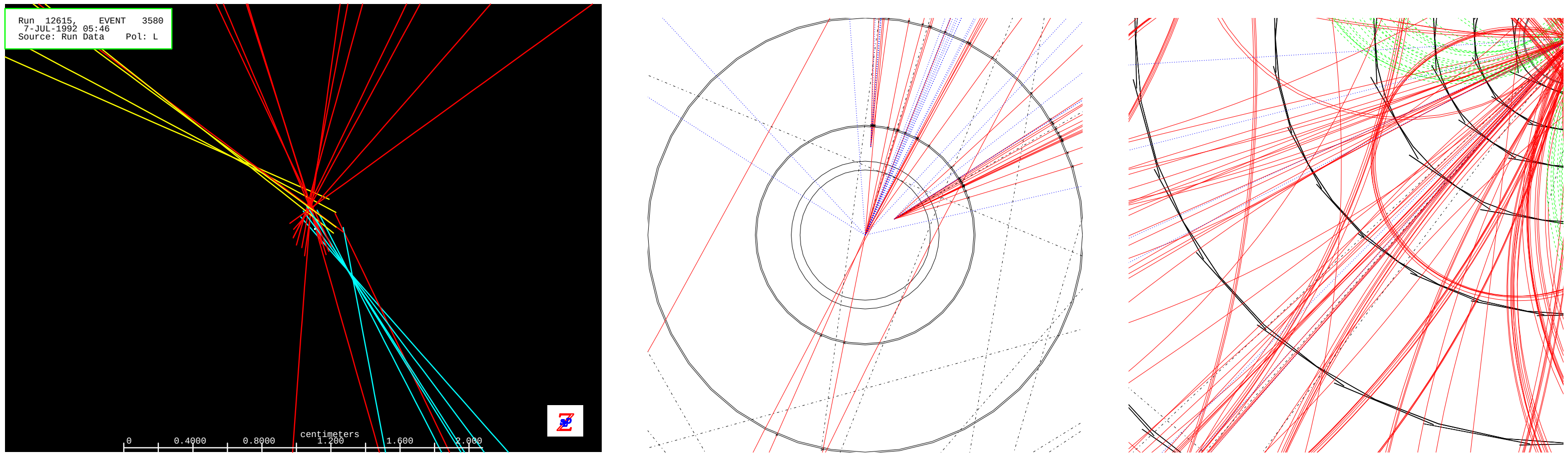
$\sqrt{s}$ (TeV)	0.09	0.2	0.35	0.5	**3.0**	
	Z^0	HZ	HZ	HZ	H^+H^-	$b\bar{b}$
d_{space} (cm)	0.3	0.3	0.7	0.85	**2.5**	**9.0**





Heavy Flavour Tagging

❖ Three Jet Flavour Tagging Scenarios :



b-tagging and reconstruction through I.P. and Sec. Vtx.

$$d_B << R_{vtx},\ F_b \leq F_{c,u,d,s}$$

b- & c-tagging and b/c separation with vertexing and kinematics

$$d_B \leq R_{vtx},\ F_c << F_b,\ F_b << F_c$$

b-tagging for long B decay length in highly collimated jets

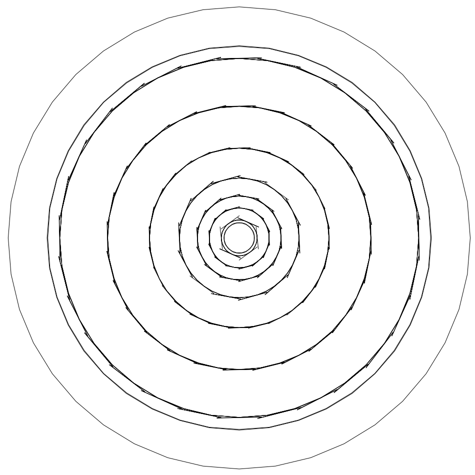
$$d_B > R_{vtx},\ F_b \leq F_{c,u,d,s}$$

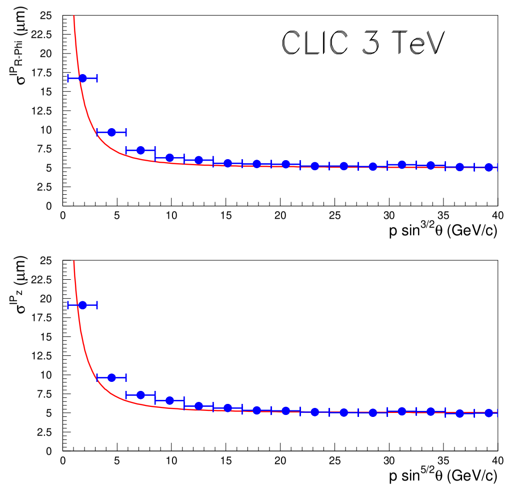
- Long B-decay length and jet collimation require new technique for tagging short lived particles traversing detector surfaces and tuned patrec
- Present study inspired by fixed target charm experiments:

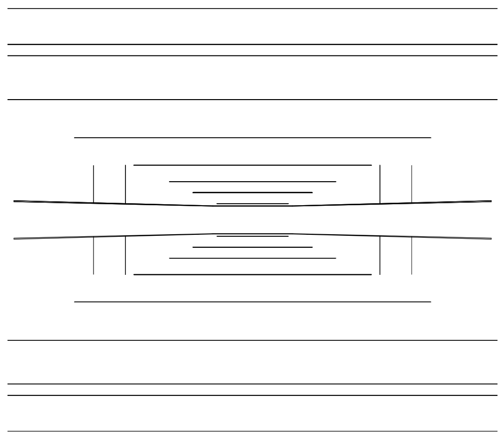
NA-1 FRAMM Collaboration

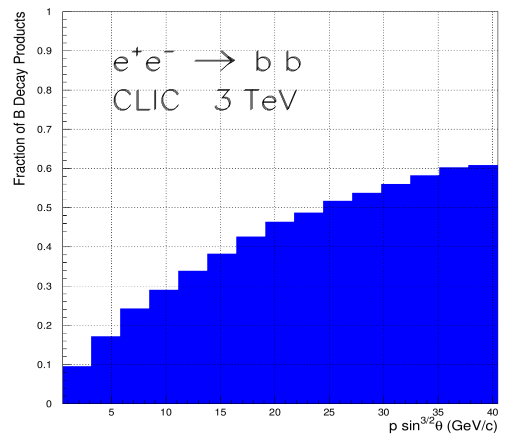
$\gamma N \rightarrow D\bar{D}X$ **at CERN SPS (1979)**

A Vertex Tracker Prototype for CLIC









- Seven layers with spacing optimised to decay length sampling; inner radius $R_{min} = 3.0$ cm and ensure polar coverage down $|\cos\theta| < 0.966$;
- Assume Si pixel detectors with fast time stamping capabilities.
- Vertex Tracker implemented in GEANT-3 with patrec + Trk. Fit.

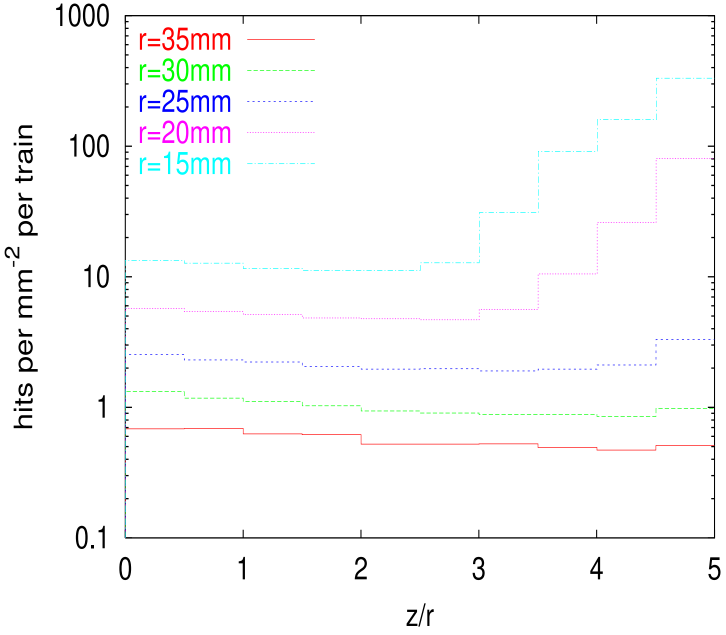
Background and Occupancy

Pair Background

✧ In large Υ regime important background from coherent pair creation

✧ assume Forward Mask to protect Vertex Tracker from backscattered radiation

Hit Density at Vtx

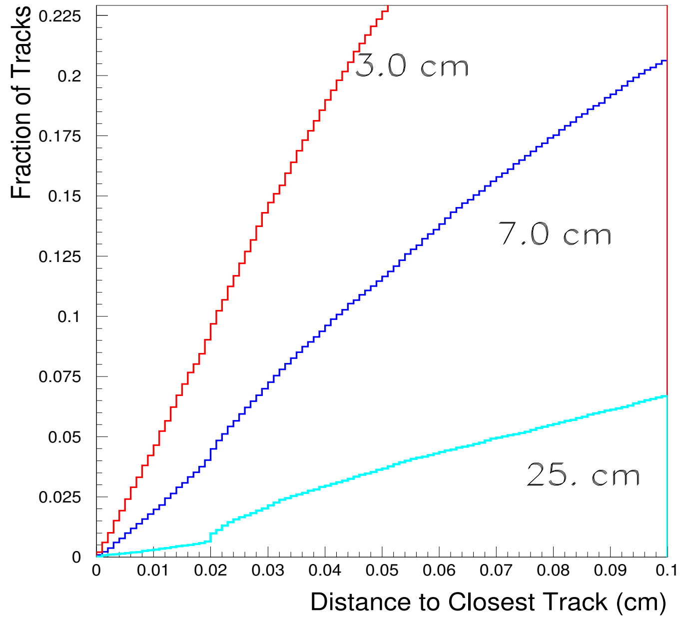


Track Density in Jets

✧ High track density in jets set challenges to patrec

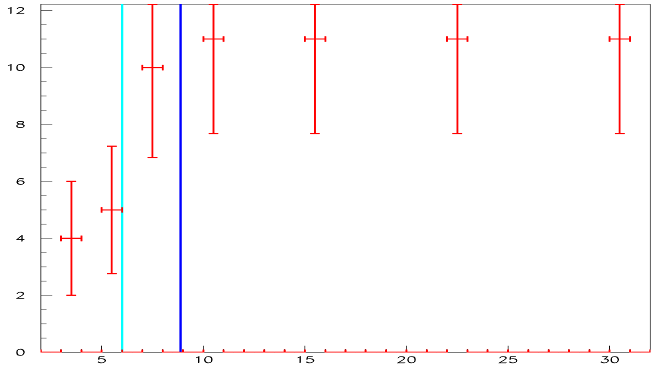
✧ Need to develop robust algorithms for vertex tagging

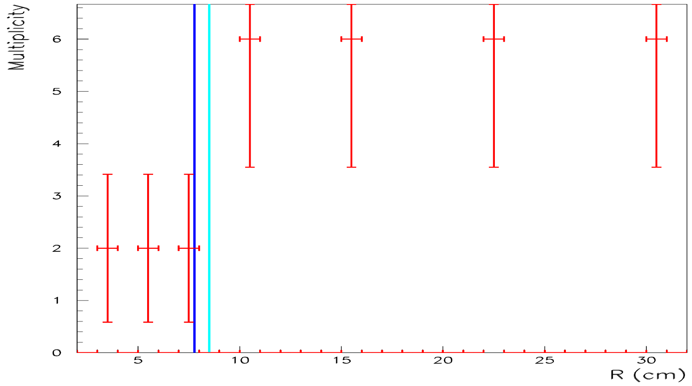
Distance to Closest Track



Multiplicity Tag in the Vertex Tracker

- Get Jet directions based on calorimetry;
- Define Area of Interest by $\pm$ 40 mrad cone around Jet axis;
- Count hit multiplicity (or pulse heigh) in Vertex Tracker layers;
- Tag heavy hadron decay by step in detected multiplicity;

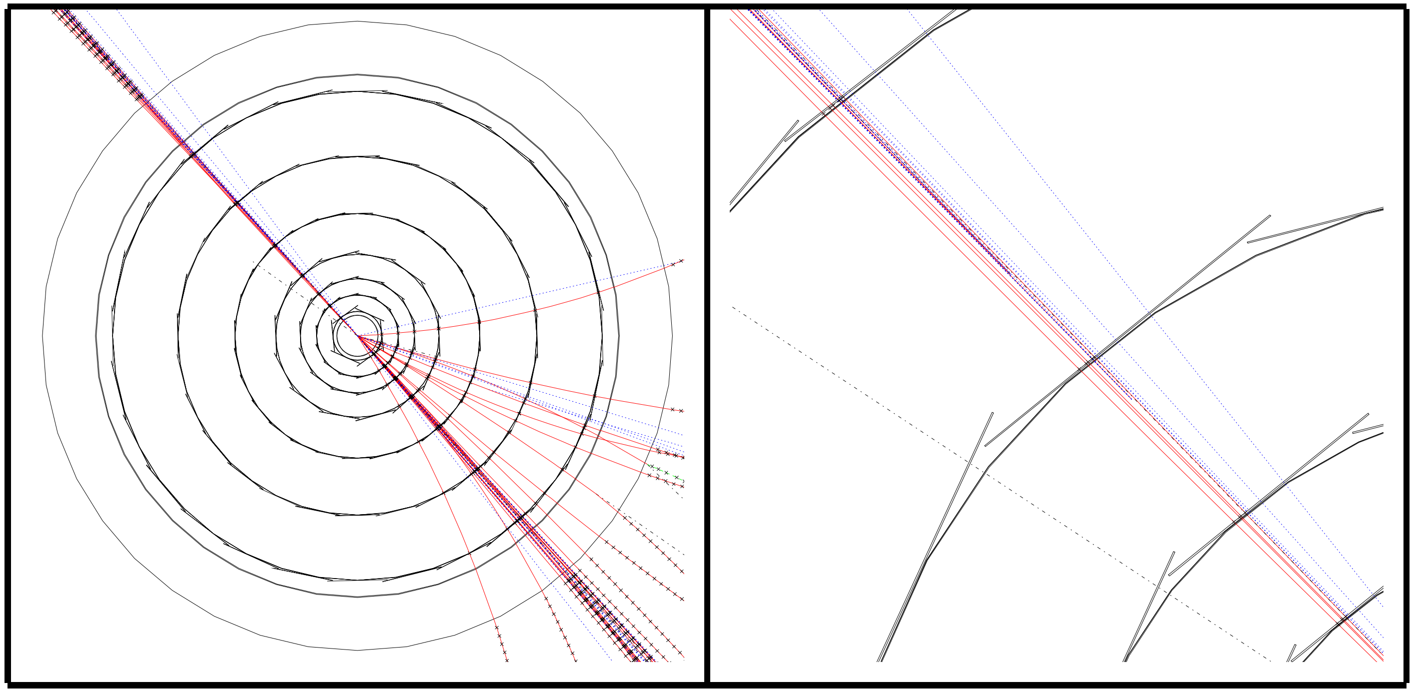




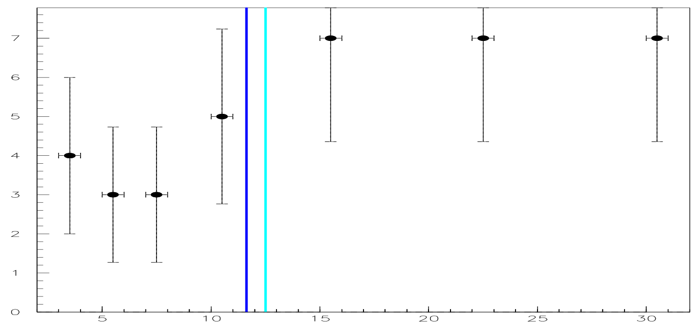
- Pair bkg constant and small over acceptance can be monitored outside AoI and subtracted, single layer fluctuations are rejected:

R (cm)	AoI (mm^2)	Hits BX^{-1}	Hits in AoI
3.2	4.0	0.0050	0.7
10.0	50.0	0.0004	0.7

Tagged $e^+e^- \to b\bar{b}$ Event

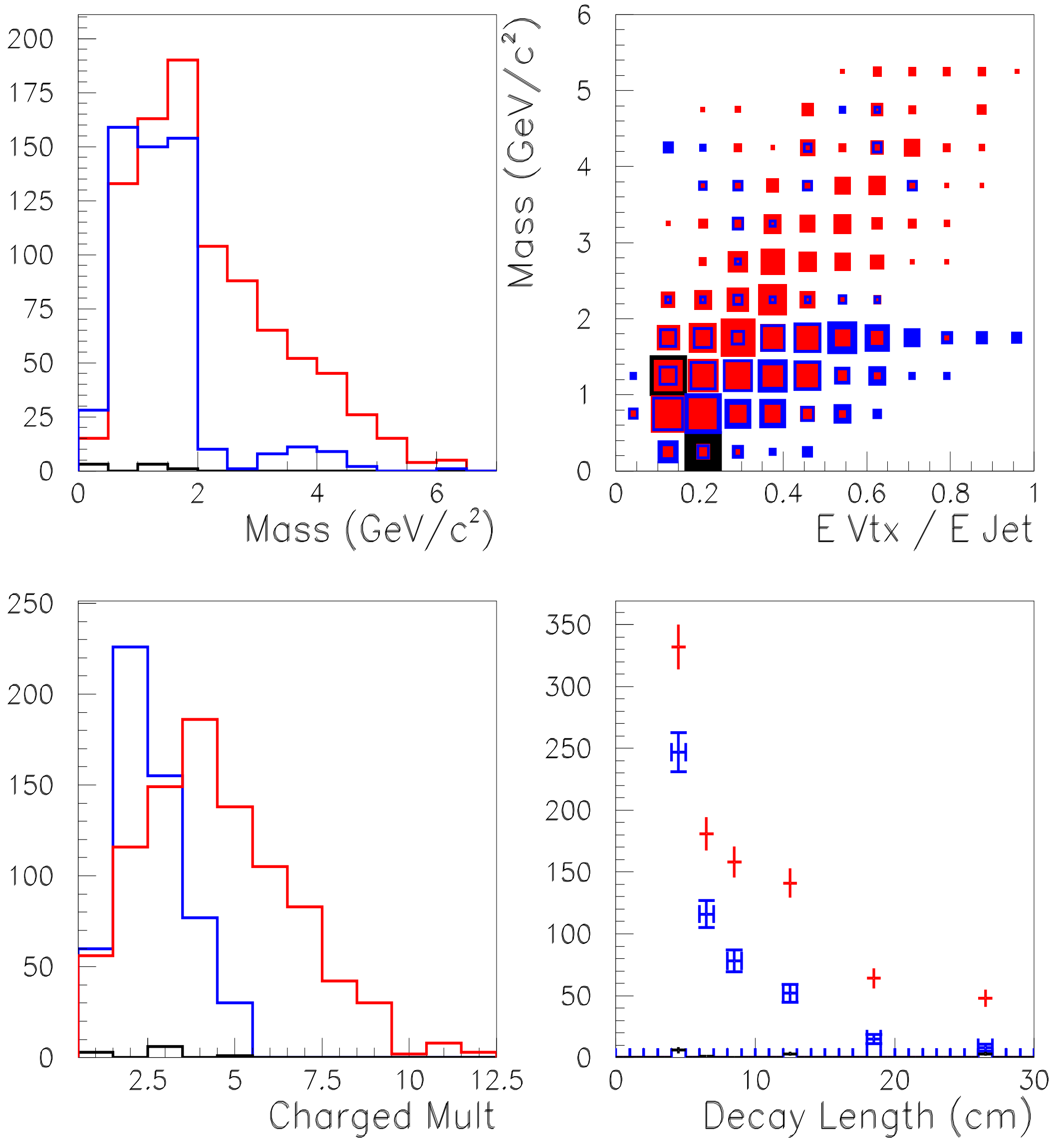


$$E_{jet} = 1485 \text{ GeV}$$
$$d_{sec} = 11.6 \text{ cm}$$
$$N_{sec} = 4$$
$$M_{vtx1} = 0.6 \text{ GeV}/c^2$$
$$M_{vtx2} = 1.4 \text{ GeV}/c^2$$



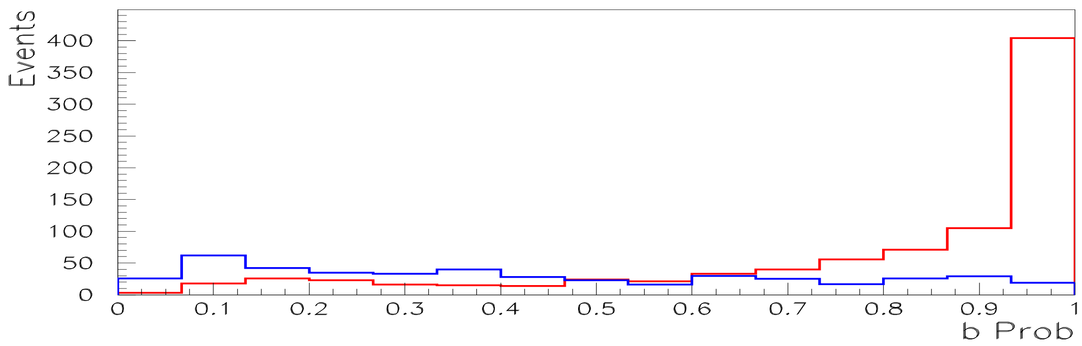
❖ Enhance b / c jet separation using kinematical and topological variables to be combined in global likelihood:

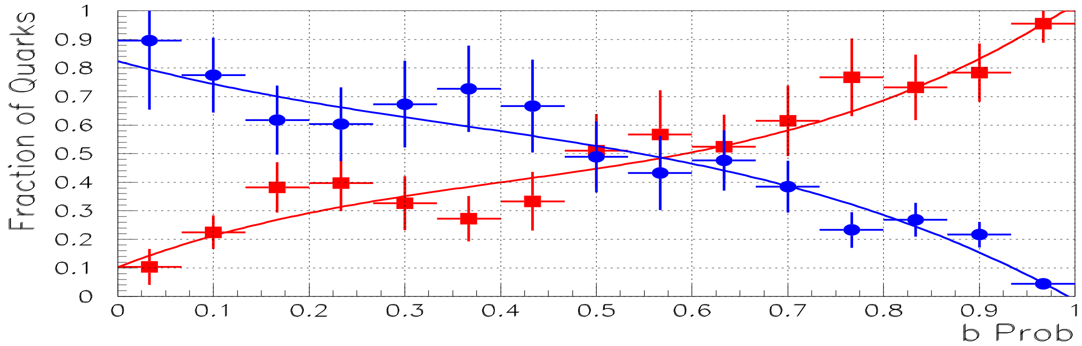
b-Tag Variables for b / c Separation



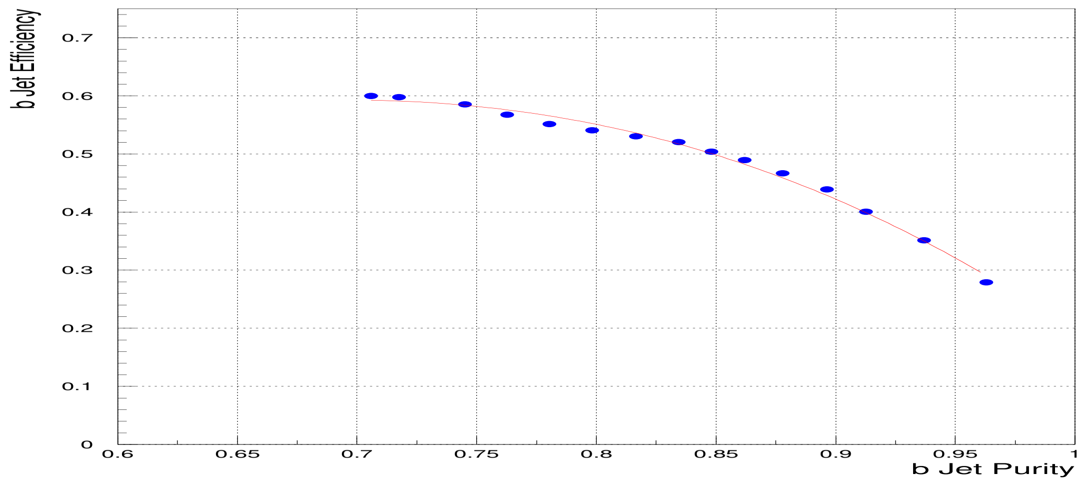
- Build b-likelihood from multiplicity tag and additional discriminating variables:

b-Tag Likelihood





b-Tag Efficiency and Purity

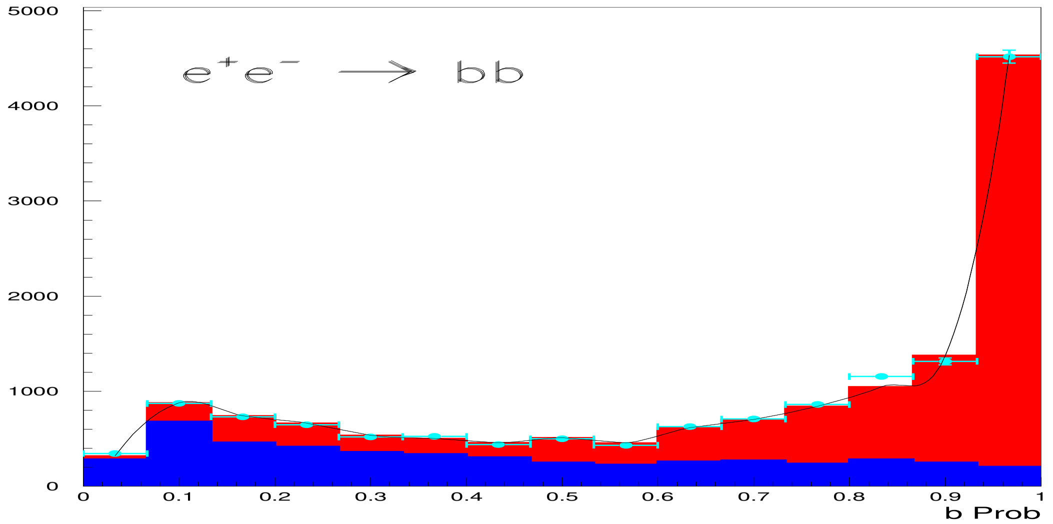


Example of physics analysis

$\sigma(e^+e^- \to b\bar{b})$ determination at $\sqrt{s} = 3$ TeV.

❖ Extract σ_{bb}/σ_{qq} from likelihood fit to response of multiplicity b-Tagging.

Likelihood Fit to b-Tag



Measured Cross-Section at $\sqrt{s} = 3$ TeV