Top quark physics at lepton colliders

Problems to be sorted out quickly; towards a long term plan

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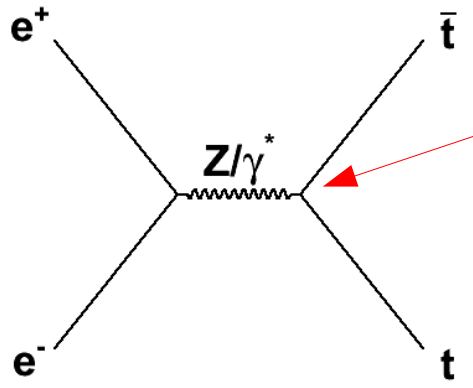
Work in progress

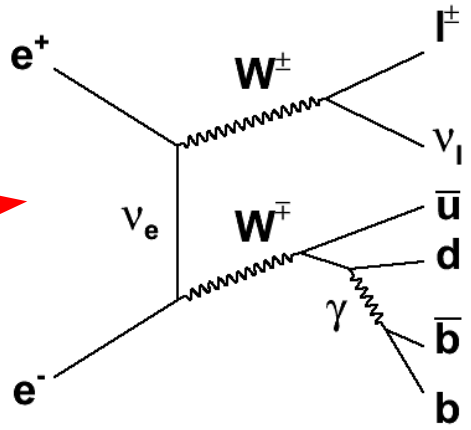
Don't expect final answers just yet
(despite Eduardo's strong claims)

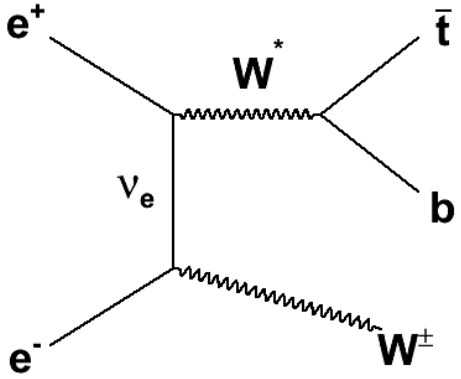
Problem I: The good, the bad and the ugly



This is the vertex we want to probe

This is a background we can reduce





This is a problem

Problem I

WHIZARD generates $e^+ e^- \to b \bar{b} l \nu j j$
Includes the good, the bad and the ugly
Interference taken into account

Unpolarized cross-sections according to MadGraph
tt production (2 diagrams) : 29 fb
6-fermion production (250 diagrams) : 30 fb

The Barklow criterion: consider events with two on-shell top quarks only ($| m_{bW} - m_t | < 5 \Gamma_t$)

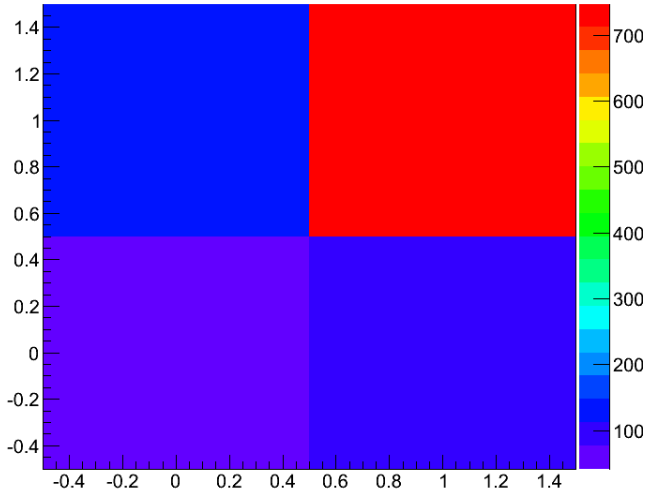
Ttbar : 75 %
Single top : 20 %
Others : 4.2 %

Not too dissimilar from the result of the Barklow

On-shell anti-top?

YES

NO



NO YES

On-shell top?

Polarized x-sections

Unpolarized:

total	->	564.2 fb
ttbar through gamma	->	422.5 fb
ttbar through Z	->	96.1 fb
WW* nu-exchange	->	24.7 fb
WW* through Z	->	11.5 fb
WW* through gamma	->	9.1 fb

P: +30%, -80%

total	->	957.9 fb
ttbar through gamma	->	669.3 fb
ttbar through Z	->	208.2 fb
WW* nu-exchange	->	58.3 fb
WW* through Z	->	13.3 fb
WW* through gamma	->	8.3 fb

P: -30%, +80%

total	->	441.5 fb
ttbar through gamma	->	376.2 fb
ttbar through Z	->	32.5 fb
WW* nu-exchange	->	3.4 fb
WW* through Z	->	15.0 fb
WW* through gamma	->	14.2 fb

Strategy...

Attempts to disentangle single top and $t\bar{t}$ production seem to show this is difficult (maybe not impossible)
In any case the processes are entangled at the theory level by the interference term (confirmation of this statement?)

Solution: measure and rate and differential distributions for the full six-fermion final state → compare this to prediction
Complicates matters:

- less experimental handles (top mass constraint)
- theory now depends on Wtb vertex in production as well
- definition of form factors

Problem II

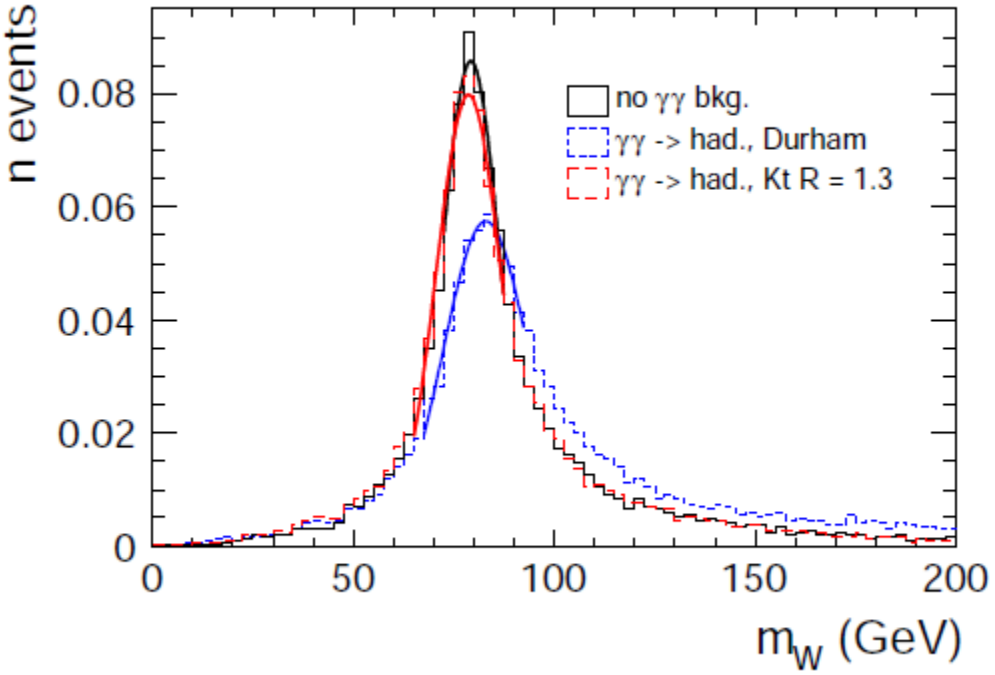
François Richard: The gamma-gamma background is not innocuous since Jeremy finds that the top angular distribution suffers from the presence of this component for P=-.

Quoting the DBD:
At lepton colliders exclusive jet algorithms, in which every particle is assigned to a jet have been favoured. However, at the ILC such algorithms work poorly [...] the large cross section for $\gamma\gamma \rightarrow$ hadrons implies that most interesting events will be accompanied by several unrelated “pile-up” events in the same bunch crossing.

Problem II: DBD solution

Still from the DBD:
This problem was studied at CLIC, where the pile-up conditions are much more challenging than at ILC. It was concluded that the use of inclusive algorithms, developed for hadron colliders, was well-suited to mitigate this problem.

Reconstructed di-jet mass distribution in $e^+e^- \rightarrow W^+W^- \rightarrow l\nu q\bar{q}$.

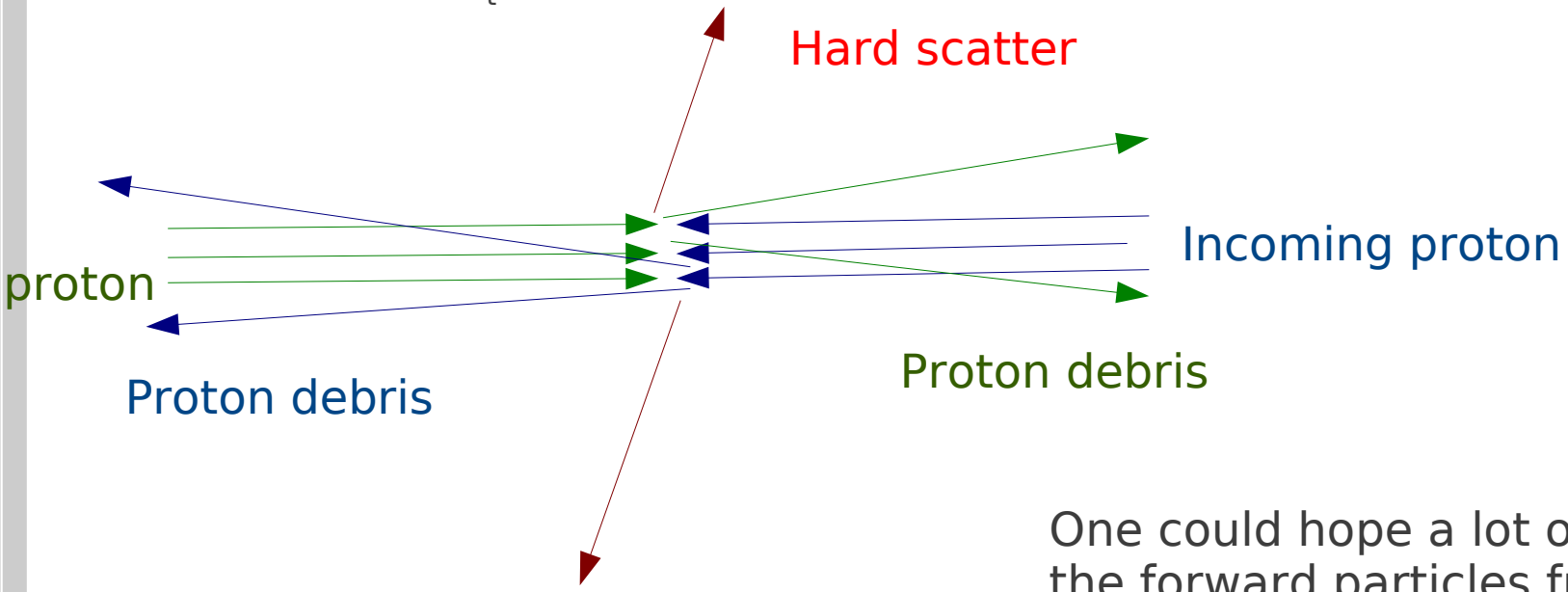


Problem II: discussion

The DBD actually uses two solutions in one go:

exclusive jets → inclusive jets

Durham → k_t



One could hope a lot of the forward particles from $\gamma\gamma \rightarrow$ hadrons end up in "beam jets"

See: FastJet user manual
http://arxiv.org/pdf/1111.6097.pdf

Problem II: inclusive vs. exclusive jet reco

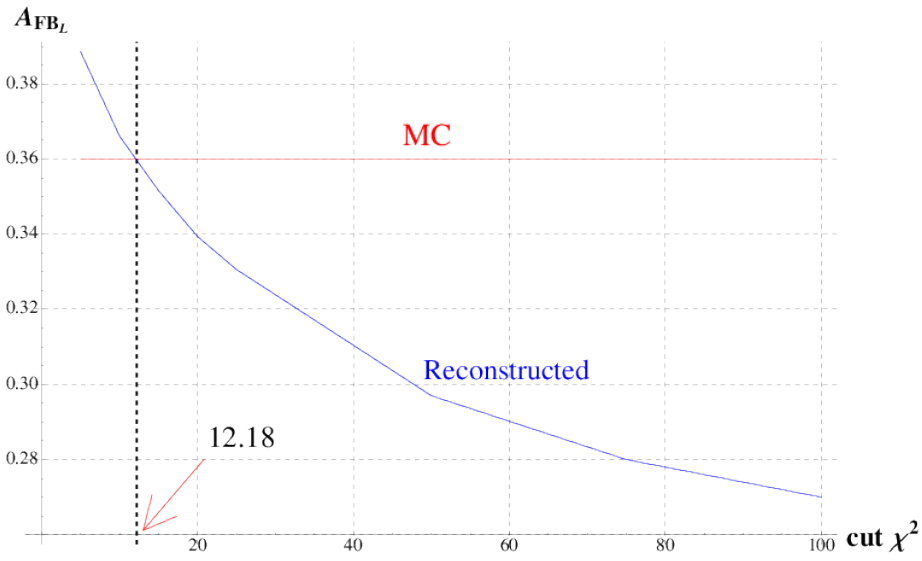
The DBD proposes to go to inclusive jet reconstruction

This implies that the jet algorithm keeps clustering, combining the proto-jets that are closest (according to the kt metric), until the smallest distance becomes greater than a certain number determined by the jet radius parameter R (AKA jet size)
Then the problem is to reconstruct the top candidates from the N jets

Exclusive jet reconstruction forces the algorithm to continue until a specified number of jets are found
FSR is automatically folded back into the parent.

Problem III

Nacho confirms the observation by François: there is a “lucky” value for The chi-squared cut

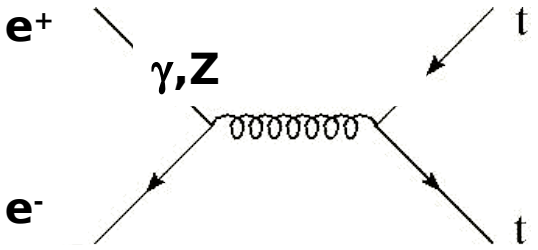


Some things that have kept us “honest” so far:
- we didn't know
- is the “lucky” chi-squared the same for both polarizations?

François proposes: What should be optimized is the differential agreement between the MC and the reconstructed angular distributions..

I'd like to know why this there is no plateau... Probably the chi2 we find depends on the polar angle of the top quark. Is it related to problem II?

Theory



tt production at ILC:

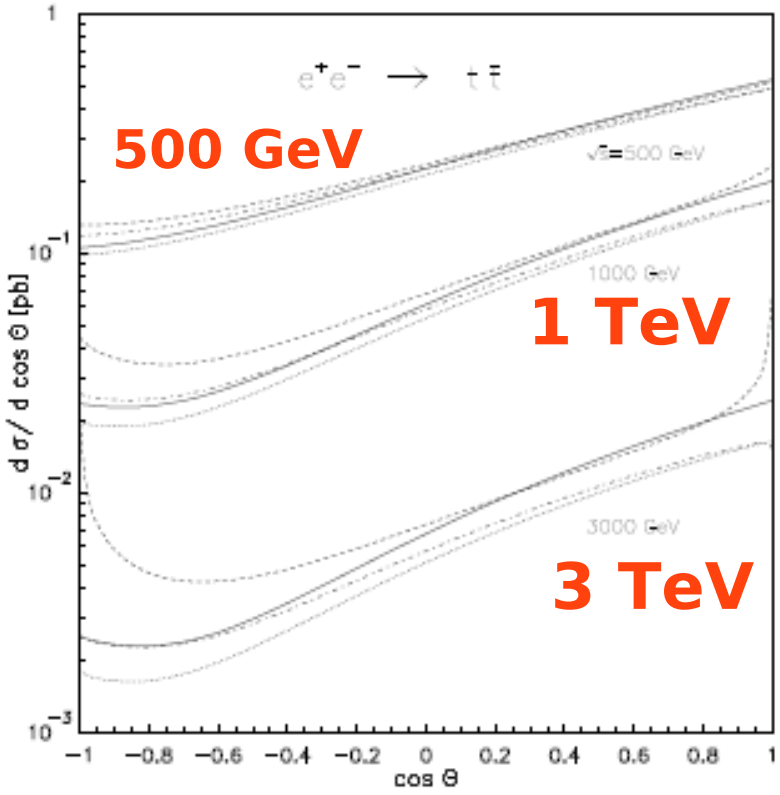
σ~0.6 pb

at √s = 500 GeV

~0.2 pb

at √s = 1000 GeV

120k tt events/year
Assuming L =10^{34} $cm^{-2}s$



Electroweak corrections

Glover et al. hep/ph04010110

Fleischer et al. hep/ph0302259

Is it safe to ignore the theory error?

This is an old slide, but the question still stands.

Backgrounds

$\sigma(tt) \approx 600$ fb at 500 GeV

$L=500\ fb^{-1} \rightarrow N_{total} \sim 570$ K

Semileptonic ~ 34%

Reducible backgrounds

WW → no b quark

bb → simple topology

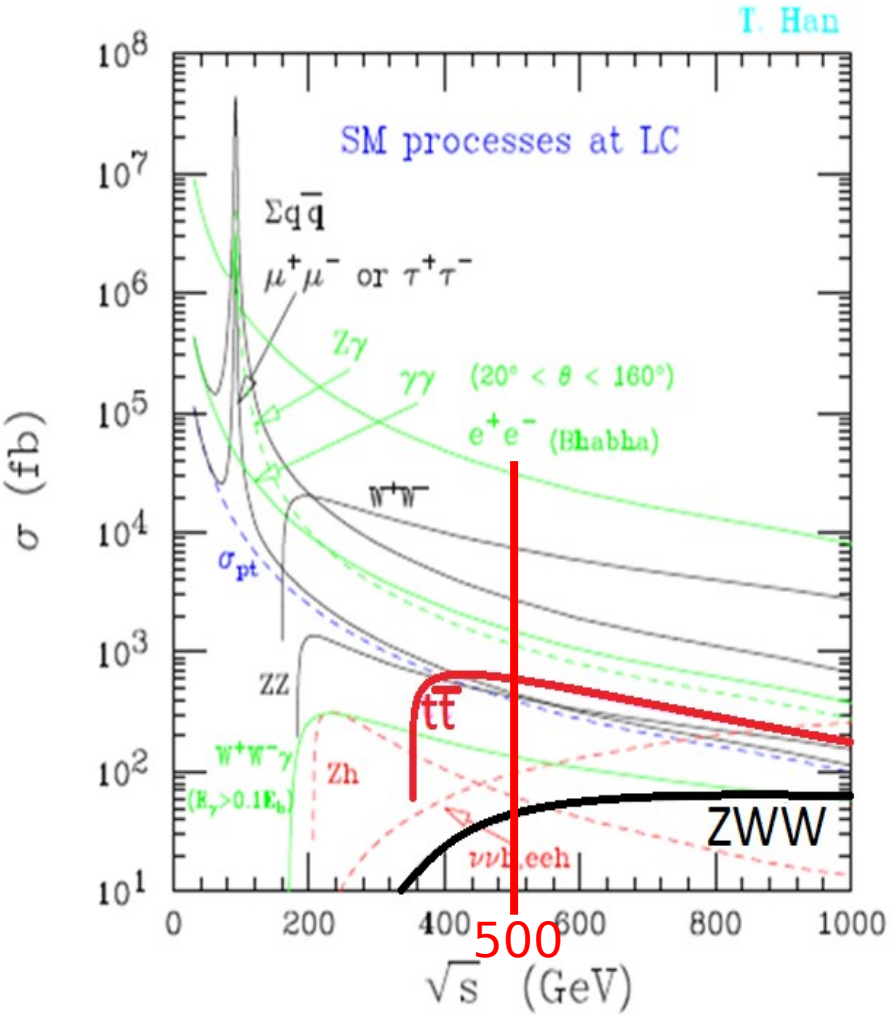
Other top decays (τ)

Irreducible:

Small but need to be subtracted

Other top decays (τ)

ZWW (Z → bb) → 8 fb



Process	tt	bb	WW	ZZ	ZWW
A_{LR} (%)	36.7	62.9	98.8	31.0	89

CP violating Form Factors

Nachtmann et al. gives the receipt used for the TESLA TDR

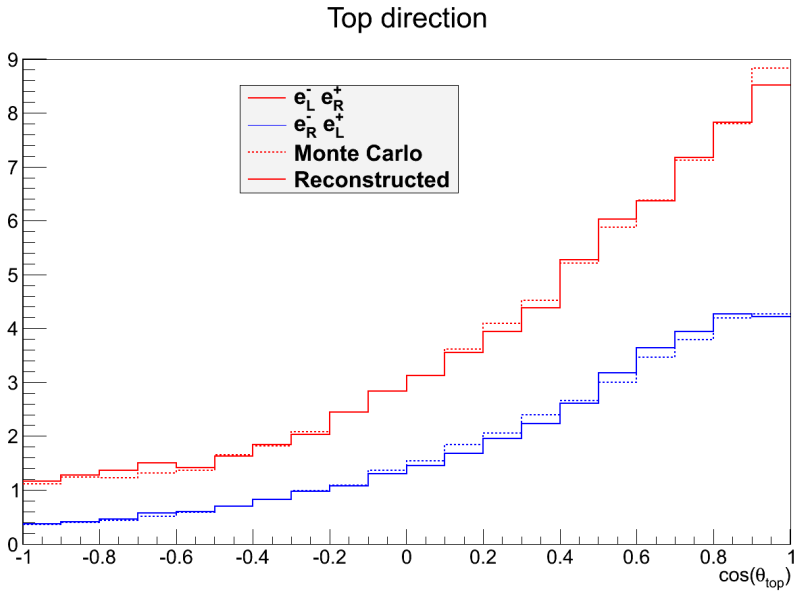
Toni Pich claims the Nachtmann paper is understandable

German Rodrigo has some orthogonal ideas

German Valencia (Iowa) has prepared a MadGraph UFO model that allows to generate events with an anomalous CP violating FF (electric dipole moment for the top quark) → unpacking later today

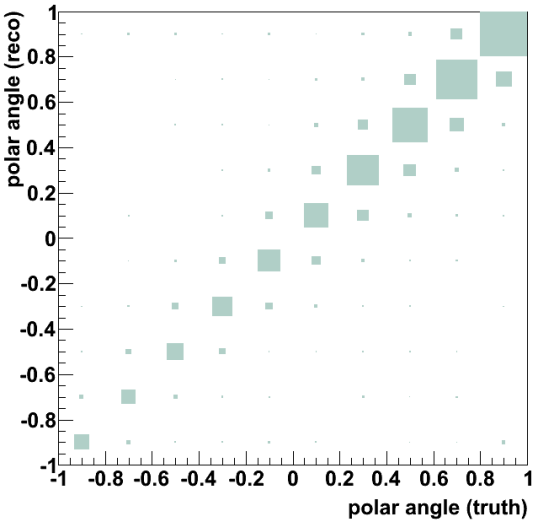
Try to reproduce TESLA numbers...

The FB asymmetry @ 1 TeV



reco = truth within 2 %

ILC1000



Mapping ÖK
> 90 % of events is correctly reconstructed

Off-diagonal elements disappear

I'm also interested to explore how the sensitivity evolves with center-of-mass energy (250-3000 GeV)

Summary

Three immediate problems + two optional ones

Proposal:

- Single top → MV
- Kt vs Durham → Nacho
- Chi-squared → Jeremy
- Paper draft → Roman

Future directions:

- different center-of-mass energy
- CP violating observables