Studies of Correlated Beamstrahlung

- Introduction and Motivation – what does this have to do with new physics?

- Cross section measurements

- Unfolding the luminosity spectrum

- GuineaPig Results

- Future plans

Beamstrahlung and New Physics

- An important mission of our group is to identify detector and machine parameters which may limit the reach of indirect new physics interpretations, eg:
  - Contact Interactions
  - Extra-dimensions
  - Doubly charged Higgs...
- Indirect limits on these processes require precise measurements of two-fermion processes:

  $$e^+e^- \rightarrow f\bar{f}$$

  Usually the cross section measurement is the most difficult

- At LEP 2 (see my Santa Cruz talk) these kind of limits, in the case of

$$e^+e^- \rightarrow e^+e^-$$

were limited by theory.

- At a linear collider we expect the theory to be solved, but luminosity spectrum may be the main challenge:
  $\Rightarrow$ understand the luminosity spectra at the 0.1%.

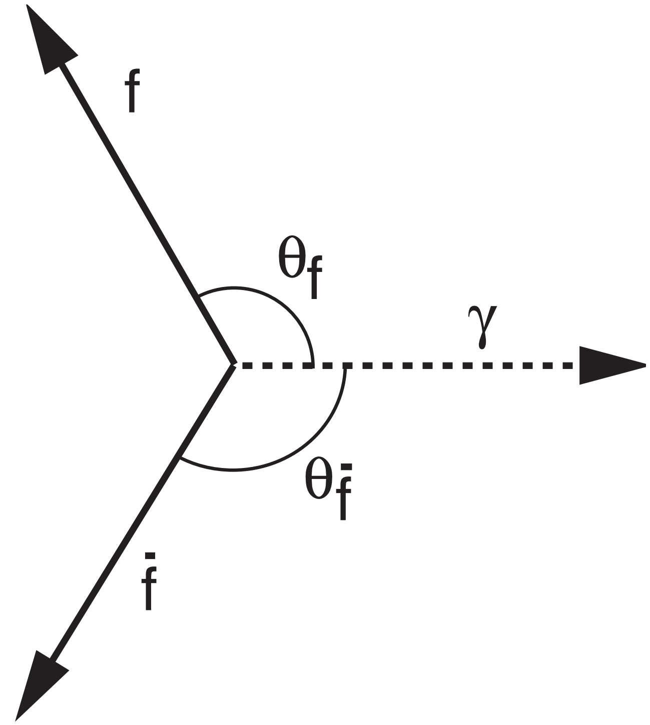
- Since most cross section go like $1/s = 1/E^2_{\text{cms}}$:
  $\Rightarrow$ understand the cms energy to better than 0.05%.
  (250 MeV at $\sqrt{s} = 500$ GeV)

Measuring cross sections

- Cross sections are usually measured for in some range of $\sqrt{s'}/\sqrt{s}$ where is $\sqrt{s'}$ is the invariant mass of the $f\bar{f}$ system.

  At LEP we used

$$\frac{\sqrt{s'}}{\sqrt{s}} > 0.85$$



Measurement of $\sqrt{s'}$ is effectively based on angles and depends on the polar angle of f and the $\bar{f}$:

$$\frac{\sqrt{s'}}{\sqrt{s}} = \sqrt{1 - \frac{2\sin(\theta_f + \theta_{\bar{f}})}{\sin(\theta_f + \theta_{\bar{f}}) - \sin\theta_f - \sin\theta_{\bar{f}}}}$$

- Note that for $\theta_f \sim \theta_{\bar{f}} \sim \pi/2$

$$\frac{\sqrt{s'}}{\sqrt{s}} \sim \sqrt{1-\Delta} \sim 1 - \frac{1}{2}\Delta$$

where Δ is the acollinearity $\delta = \theta_f + \theta_{\bar{f}} - \pi$

- At small angles (e.g. Bhabha scattering)

$$\frac{\sqrt{s'}}{\sqrt{s}} \sim \sqrt{1-\Delta/\theta} \sim 1 - \frac{1}{2}\frac{\Delta}{\theta}$$

where θ is the smaller of θ_f and $\theta_{\bar{f}}$

$10\times$ **better resolution needed at 100mrad than at** $\pi/2$

- Require

$$\sqrt{\frac{s'}{s}} > 0.85$$

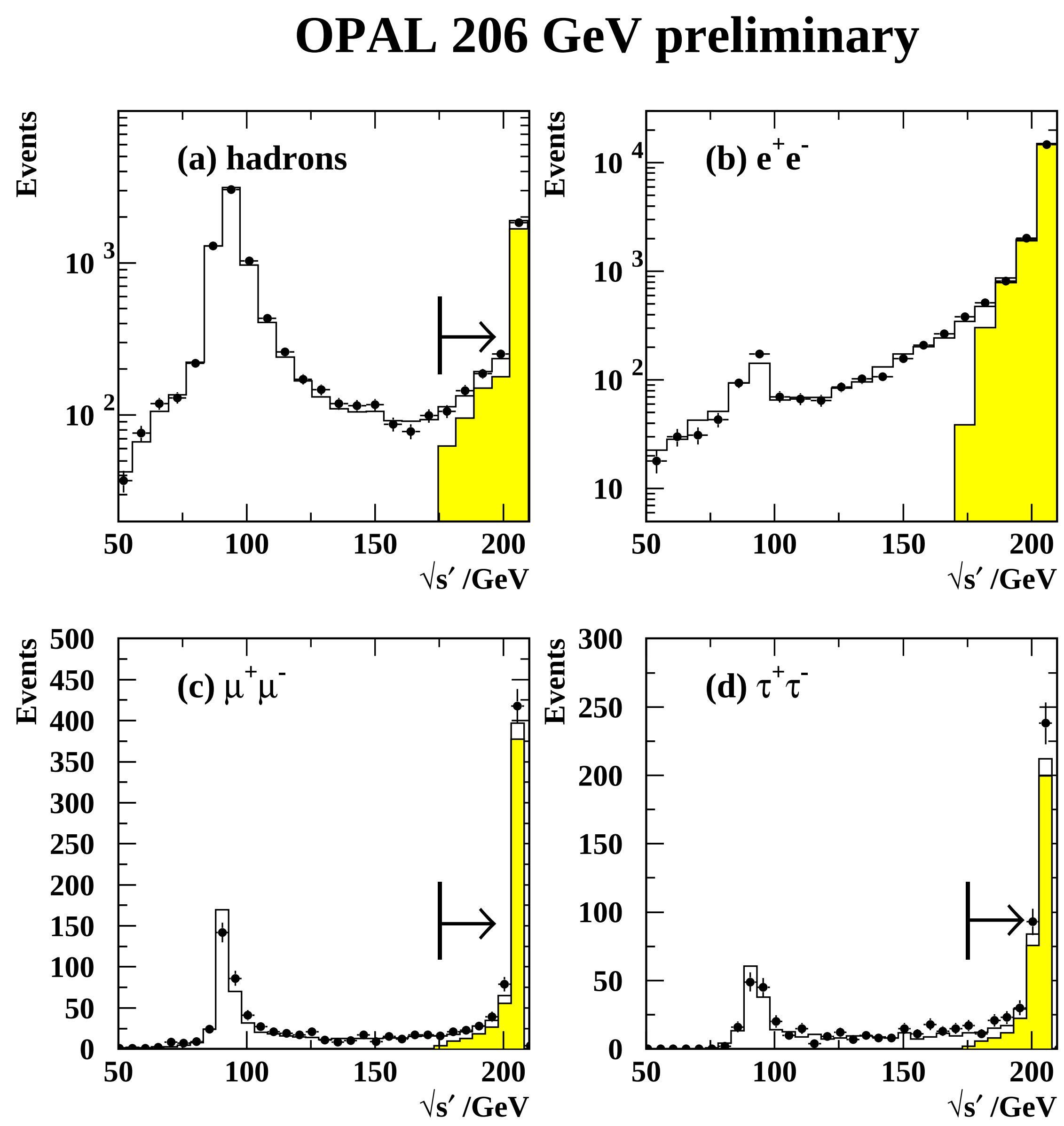
for $q\overline{q}$, $\mu^+\mu^-$ and $\tau^+\tau^-$

- Require

$$\theta_{acol} < 170^\circ$$

and $|cos\theta| < 0.9$ for e^+e^-

- Note fuzziness of s' cut

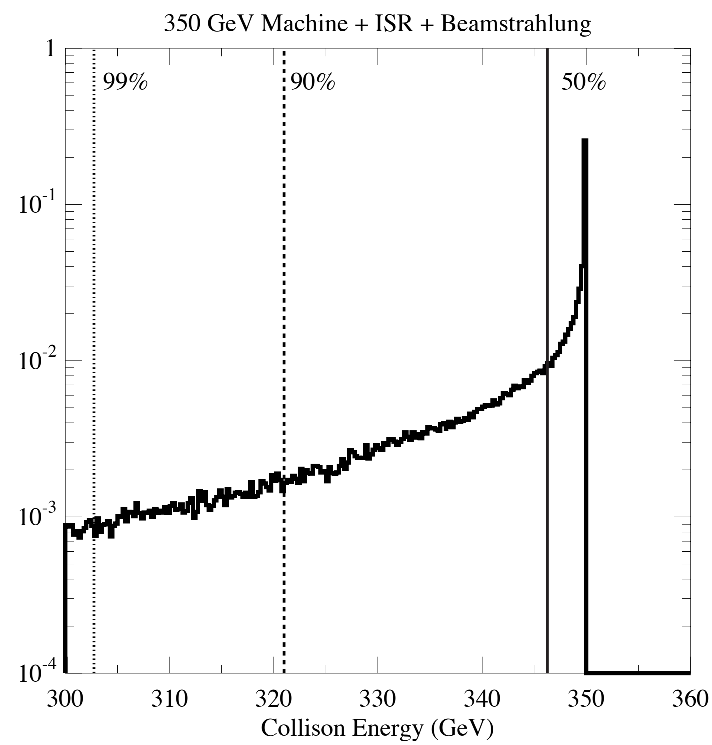


The Luminosity Sprectrum at an LC

- We can measure this using Bhabha scattering for single photon case
- At small angles higher precision is needed on the acollinearity to get the same precision on s', eg at 100mrad:

$$\sigma_\theta = 100\mu\text{rad} \rightarrow \frac{\sigma_{s'}}{s'} = 1.4\times10^{-3}$$

Caution: σ_θ could be dominated by machine effects, beam divergence is $\sim 30\mu$rad



- In a second approximation assume no correlation:

$$\frac{d\mathcal{L}}{dx_1 dx_2} = f(x_1)f(x_2)$$

where x_1 and x_2 are the energy fractions of the electron and positron.

(See studies by Klaus Mönig and Dave Miller)

- How good is the assumption that there are no correlations in the beamstrahlung?

In Mönig's studies effects were small, but this may depend on beam parameters

GuineaPig Studies

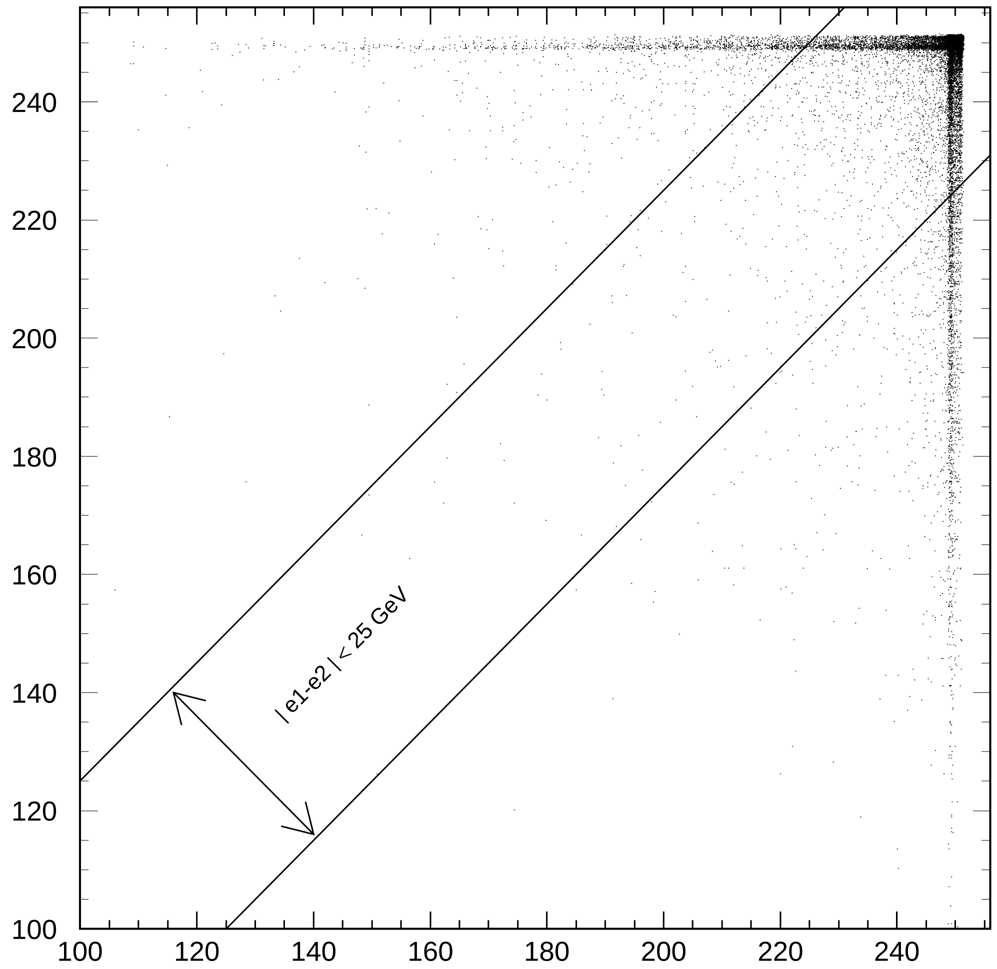
- D. Schulte's program GuineaPig simulates interaction of two beams at an LC
- Calculates energy loss and position of individual electrons and positrons
- Turn off initial state radiation (assume additional correlations can be computed exactly...)
- Simulate NLC machine with $\sqrt{s} = 500$ GeV
- Simulate s' cut with a cut on difference in energy between electron and positron

$$\begin{aligned} |E_1 - E_2| &< 50\text{GeV} \\ |E_1 - E_2| &< 25\text{GeV} \\ |E_1 - E_2| &< 5\text{GeV} \end{aligned}$$

Example cut in e_1 e_2 plane

This sample includes simulation of NLC optics

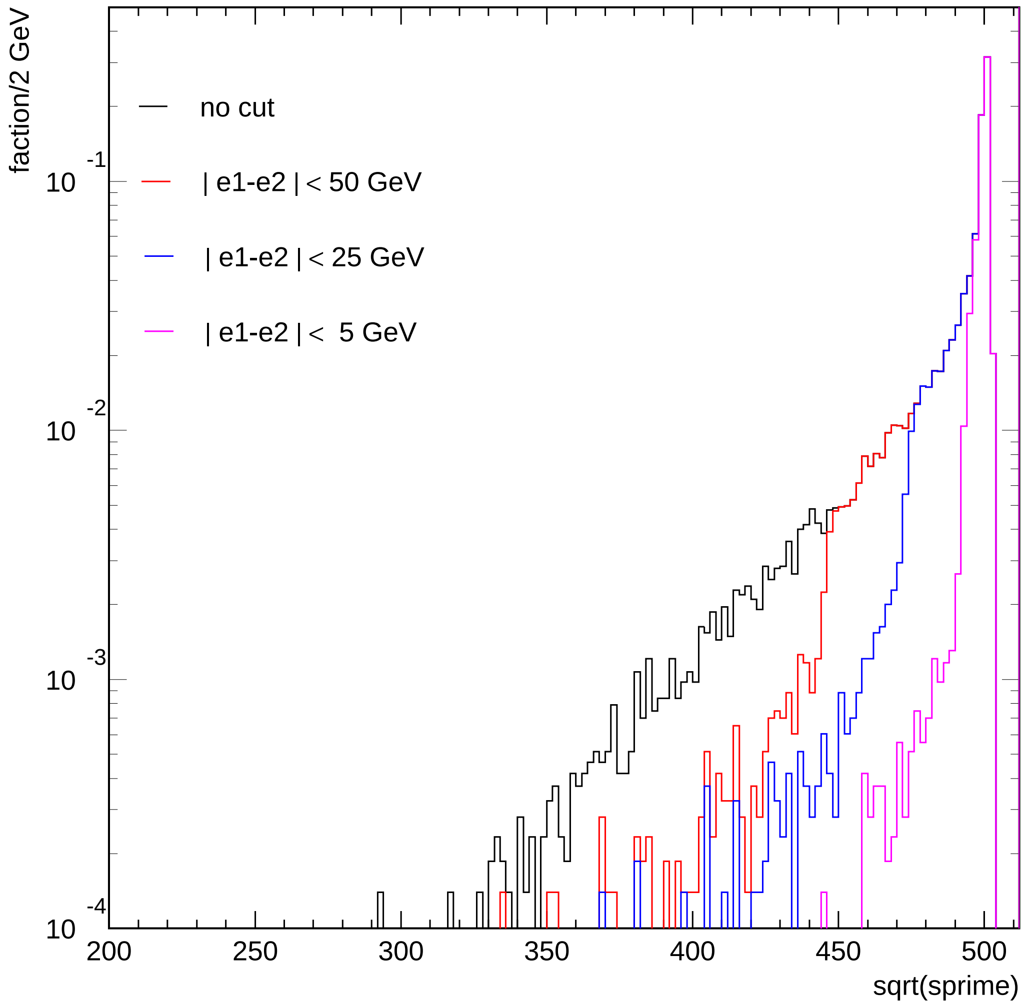
In this plot and following, ISR is turned off



s' inside cuts

This sample includes full simulation of NLC optics

No ISR off

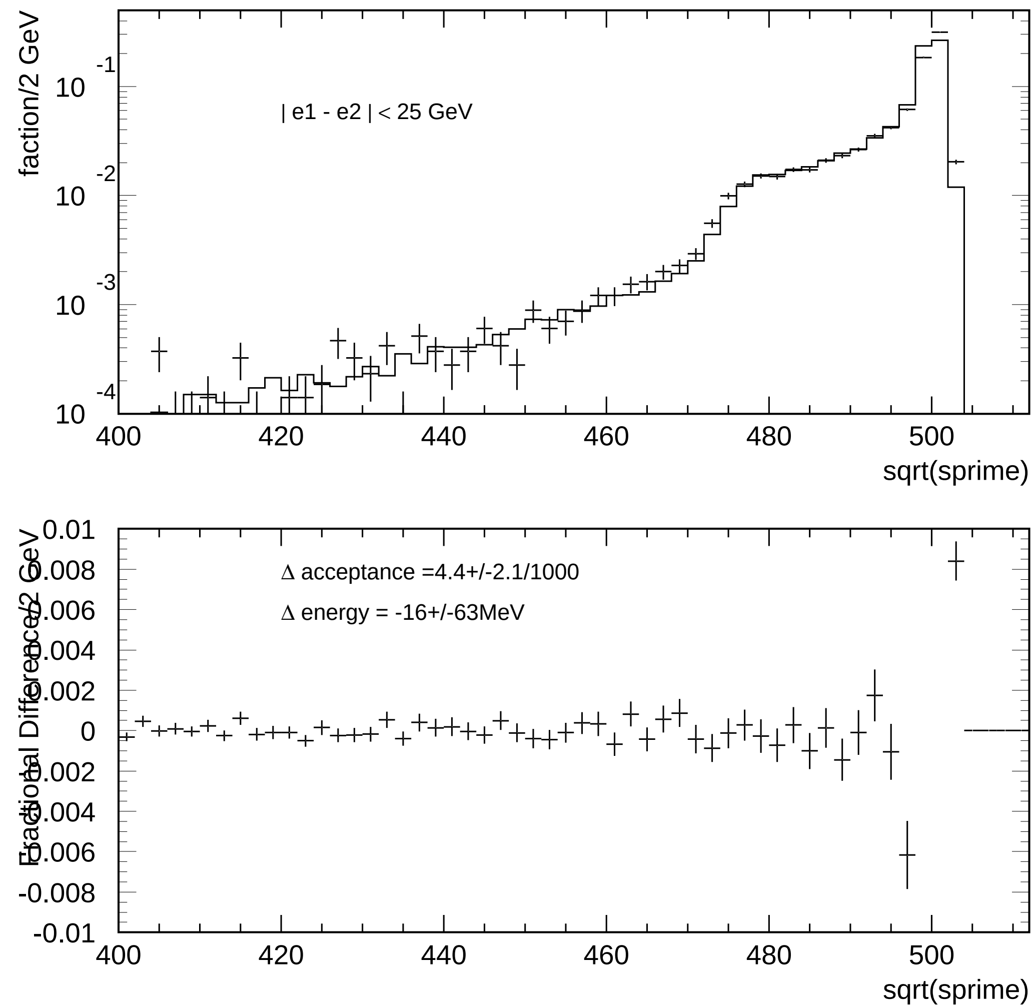


Includes NLC optics

Compare s' with randomly chosen electron and positrons

Largest effect is due to intentional correlation between energy spread and position

Statistically limited

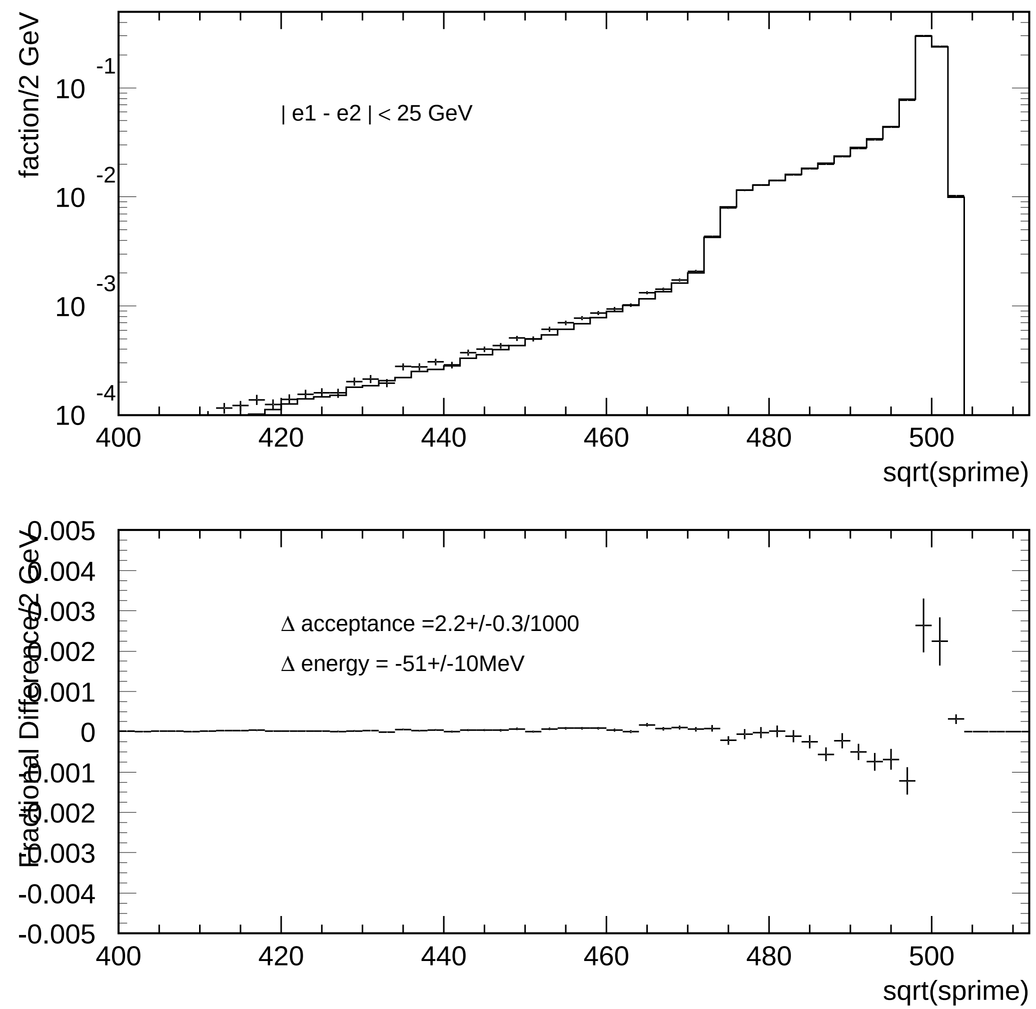


Standard, $|e_1 - e_2| < 25$ GeV

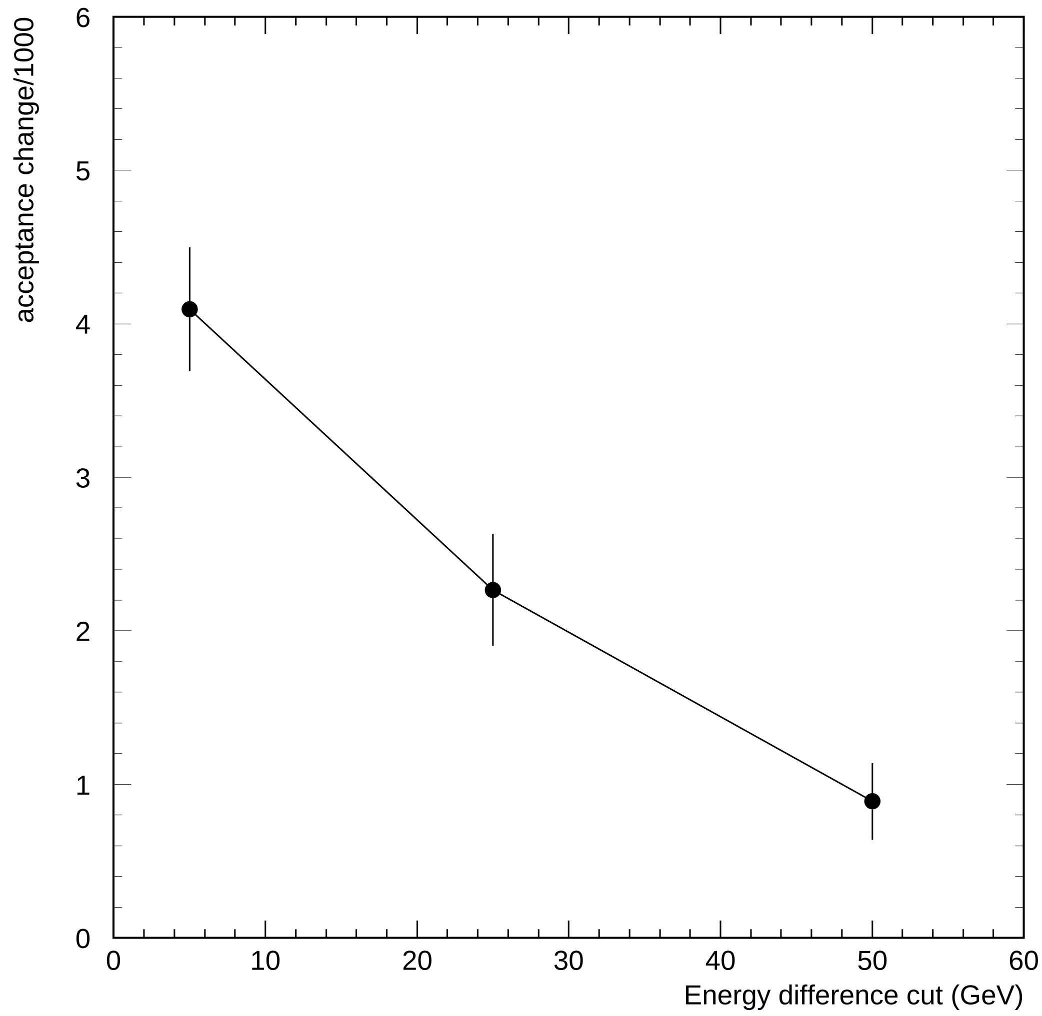
Compare s' with randomly chosen electron and positrons

Total change in acceptance is 2.2/1000.
$\Rightarrow$ Just above threshold

Change in mean energy not significant



Acceptance effect larger for tighter $|e_1 - e_2|$



- Shows largest effect near peak (soft photons)

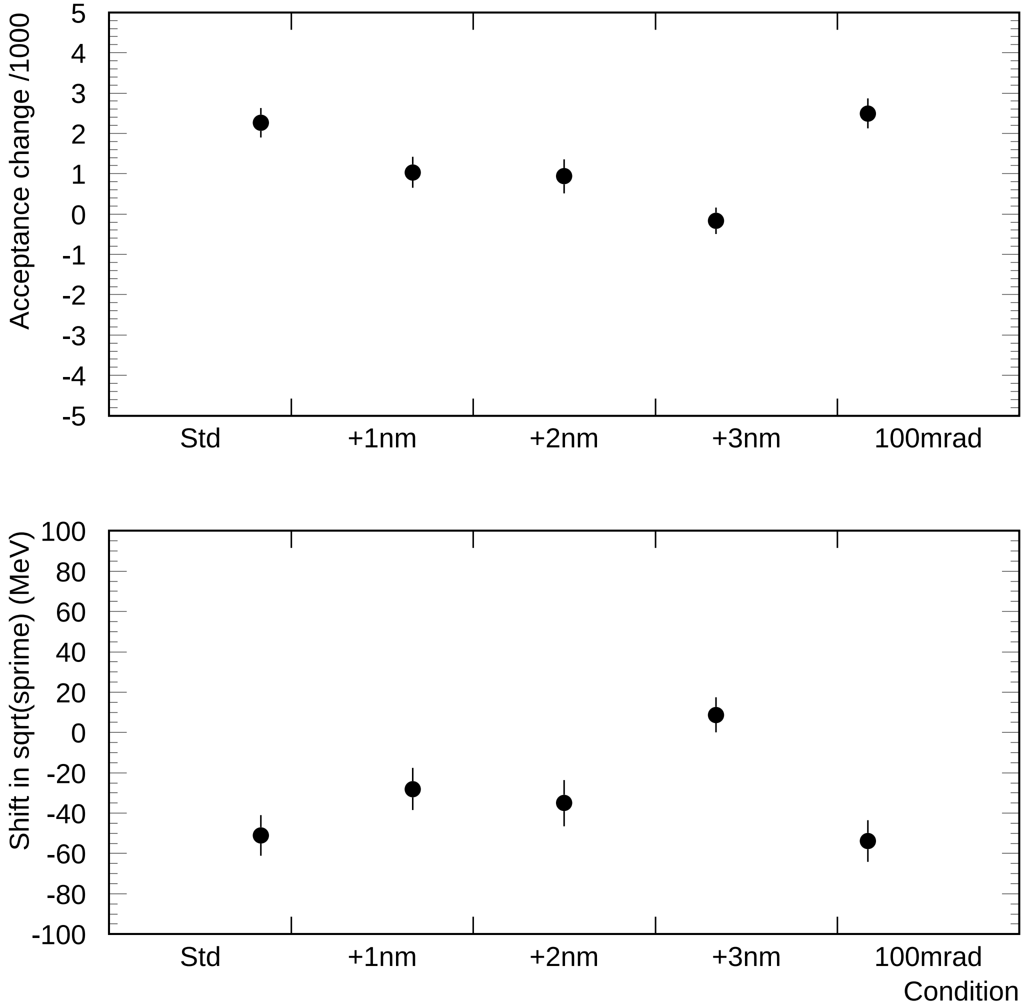
Standard conditions

Acceptance and Energy Shift

$|e_1 - e_2| < 25$ GeV

Conditions:

1. Standard
2. $y_{\rm off} + 1$nm
3. $y_{\rm off} + 2$nm
4. $y_{\rm off} + 3$nm
5. $\phi_{\rm rot} = 100$mrad



Conclusion

- Correlated Beamstrahlung introduces effects of order 2-3/1000 into the acceptance of fermion pair cross sections
  These acceptance shifts can not be decuded from the acolinearity of fermion-pairs

- These shifts do not appear to be highly dependent on beam alignment, but only a small portion of parameter space has been explored

- Need to understand the cocktail effect

- So far only initial-state effects have been studied. Final-state Beamstrahlung and scattering could be important.