Luminosity Measurement questions; beam-related

Stewart Takashi Boogert and David John Miller
Department of Physics and Astronomy
University College London
sboogert@hep.ucl.ac.uk, djm@hep.ucl.ac.uk

1. First order optimism
2. Measurement of absolute energy and spread.
3. Tolerable spread?
4. Correlated losses +some news
5. Horizontal disruption
6. How to unfold $\partial\mathcal{L}/\partial\sqrt{s}$?

Updated version of talk at LCWS Jeju

First order optimism

First order studies* suggested $\partial\mathcal{L}/\partial\sqrt{s}$ can be measured to the required energy precision:

~1 in 10^3 for top-antitop threshold
~1 in 10^4 for WW threshold

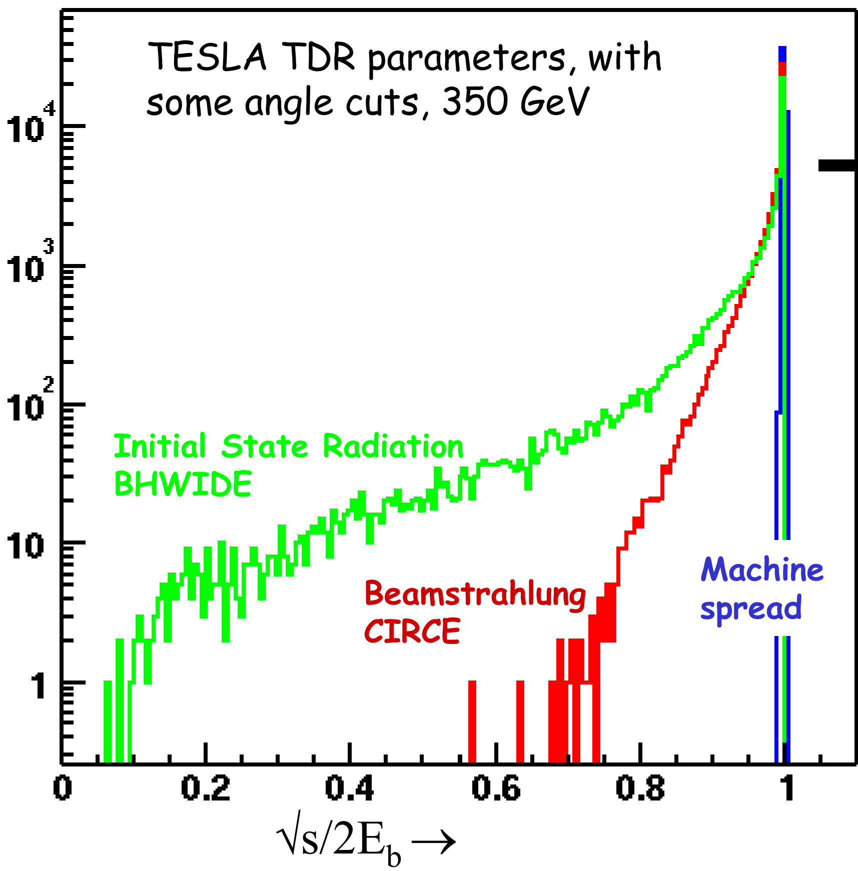
On that basis we have advertised

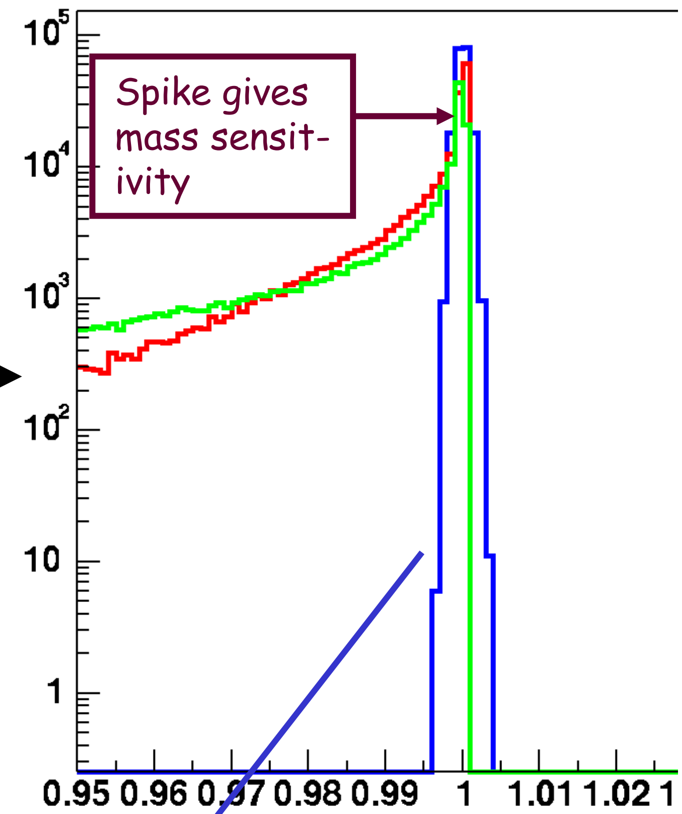
$\delta m_t \approx$ 10s of MeV (Martinez, St. Malo)

$\delta M_W \approx 6MeV$ (TESLA TDR)

* *Frary and Miller;* DESY 92-123A, http://www.hep.ucl.ac.uk/lc/documents/frarymiller.pdf.
Y.Kurihara, talk at Munich workshop 1993.
D.Cinabro, LCWS Sitges, proceedings p249, http://www.desy.de/~lcnotes/sitges/D.Cinabro-10.ps.gz
K.Moenig, LC-PHSM-2000-60-TESLA; http://www.desy.de/~lcnotes/2000/060/beamspec.ps.gz

Sources of Energy Spread





To make polarised positrons in TESLA, get $\delta p/p \sim 0.15\%$ for e^-, $< 0.05\%$ for e+ (what is NLC spread?).

Maybe tolerable for top threshold, if spread can be well measured.

For W mass at $\sqrt{s} = 161$ GeV *have separate e+ source from other part of e- linac.*

Bhabha acollinearity

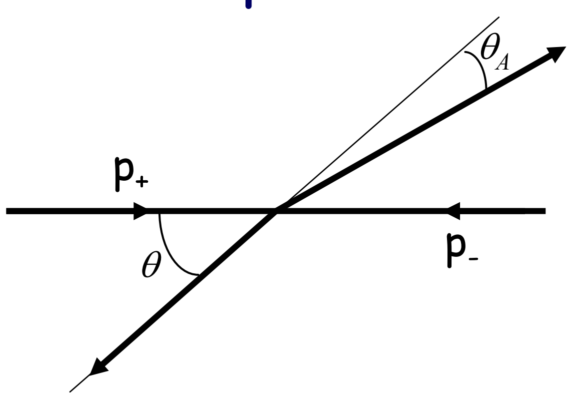
Reference process should:

1. be based on real events, to truly represent the physics samples.
2. have better statistics than the physics channels.
3. have energy resolution to match the mass resolution required.

Measurement of Bhabha acollinearity in the endcap region ($100 \le \theta \le 450$ milliradians) appears to meet all 3 criteria.

Nothing else does ($\mu\mu$ rate ~ physics rates; $Z\gamma$ not so precise; etc. etc.)

Basic Principle



$$\theta_A \simeq \frac{\Delta p \sin\theta}{p_b}$$, small θ_A

Where $\Delta p = p_+ - p_-$ but $\sqrt{s} \simeq p_+ + p_-$

$$\Delta p \simeq \frac{\theta_A p_b}{\sin\theta}$$

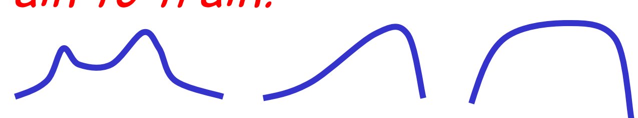
so resolution worse at small θ.
Use endcap, not small angle.
Rates still >> physics channels.

Measuring absolute energy and linac beamspread

Not the primary concern of this talk - but totally vital.
(Inputs from Eric Torrence and Stan Hertzbacher)

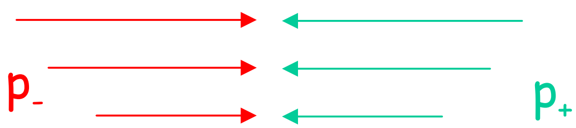
Lots of questions here too:

* *For uninteracted beams (upstream BPM spectrometer - Hildreth - or downstream spectrometer with other beam suppressed - Hertzbach).* Aiming for 200 ppm.
  - *can we get mean energy AND beamspread shape?*
  - *can we measure bunchlet by bunchlet or only train by train?*
  - *how is TESLA different - if zero crossing angle(?) followed by kicker would make downstream spectrometer hard.*
    - *will 100s of ns spacing allow BPMs to resolve individual bunchlets?*
* *For interacted beams in downstream spectrometer, what can we learn from disrupted outgoing spectra?*
* *How much will mean energy wander from train to train?*
* *Will the spread ever be Gaussian?*
* *How do we unfold it, if not Gaussian?*
* *How get luminosity-weighted mean energy and spread for a run?*

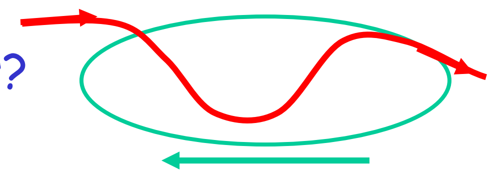


Correlated $\overline{\Delta p_+ \Delta p_-}$?

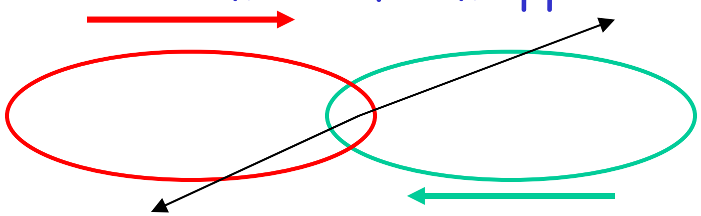
A. Telnov's warning; correlated dispersion gives reduced acollinearity

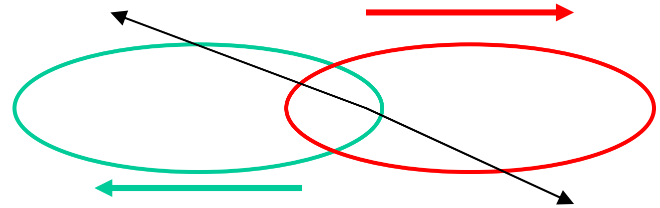


Does disruption eliminate this?

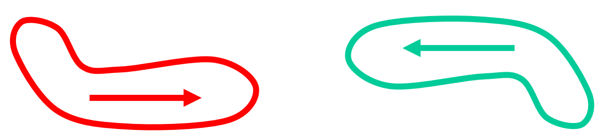


B. Moenig observed significant effects in simulation if e^+ and e^- collide early in the bunchcrossing *or* collide late - having lost energy - again reducing acollinearity.
Can this be estimated from apparent beamstrahlung rate, e.g. from mean Δp ?



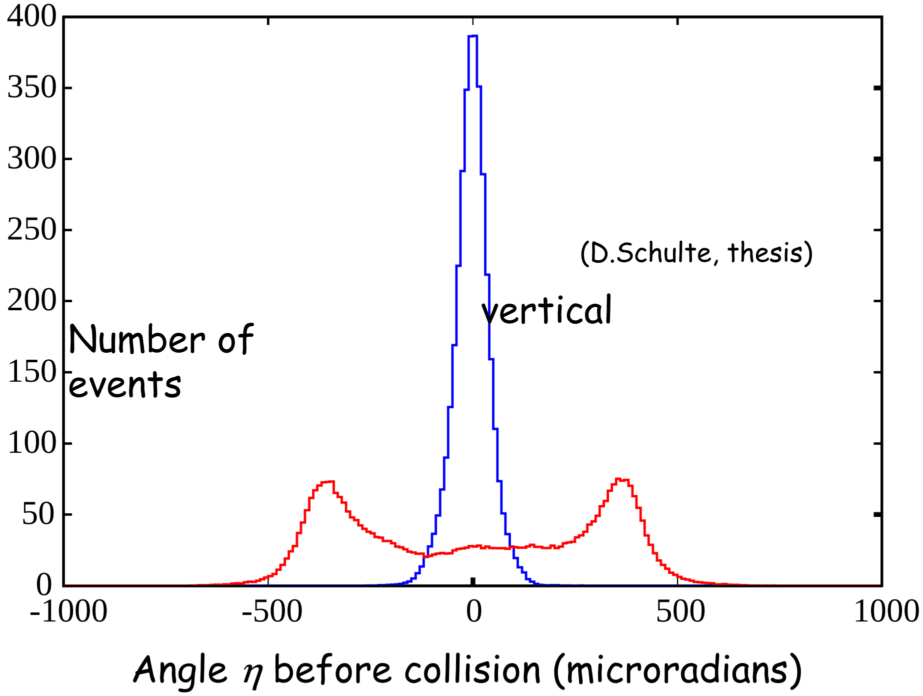


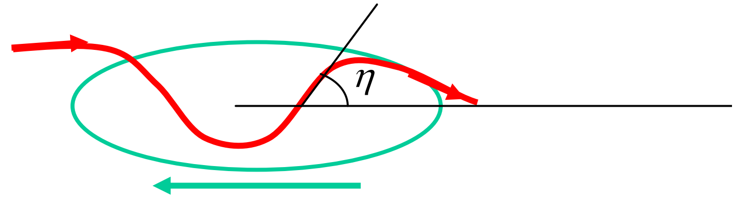
C. Do bananas bring correlations? Do offsets?



All needs Guinea Pig study. We're starting on B; see below.

Horizontal disruption

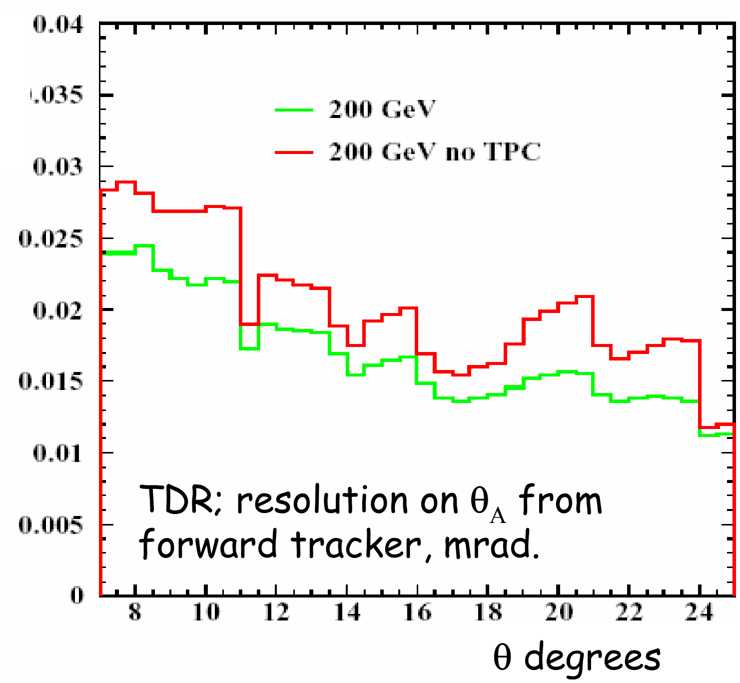




Should be resolvable in ϕ distribution of acollinearity.

η goes ~directly into acollinearity, for small θ. **Guinea Pig luminosity events don't sample transverse momentum (YET!)**

Maybe only use Bhabhas close to vertical plane for accurate Luminosity spectrum.



Unfolding $\partial \mathcal{L} / \partial \sqrt{s}$

Which observables will be useful? (Blair and Poirer investigating)

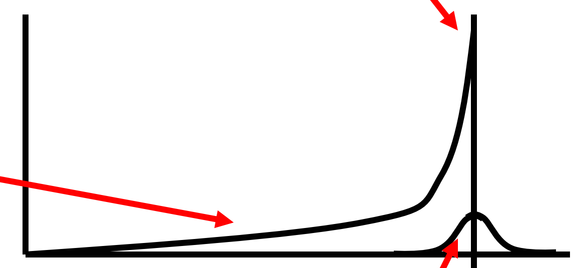
Frary and Miller suggested

$$\Delta p = p_+ - p_- \simeq \theta_A p / \sin\theta$$

Moenig uses $\sqrt{s'}$

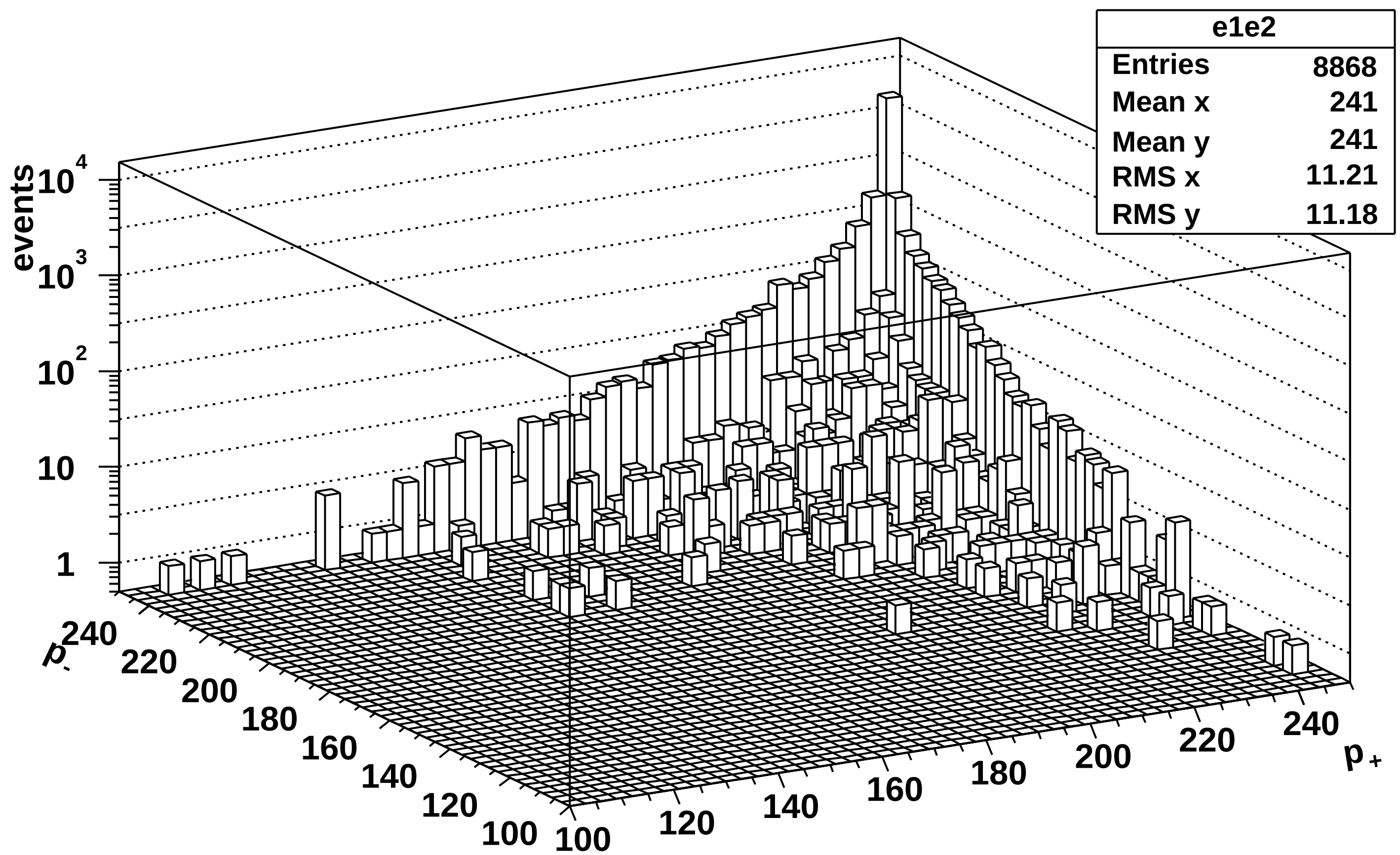
Both approximate since assume only one radiation. Good close to peak?

Blair would also like to use $\Delta E = E_{+Calo} - E_{-Calo}$; limited by calorimeter resolution to $\Delta E / E$ ~1%, but may use small angles with high statistics. Good for long ISR tail?



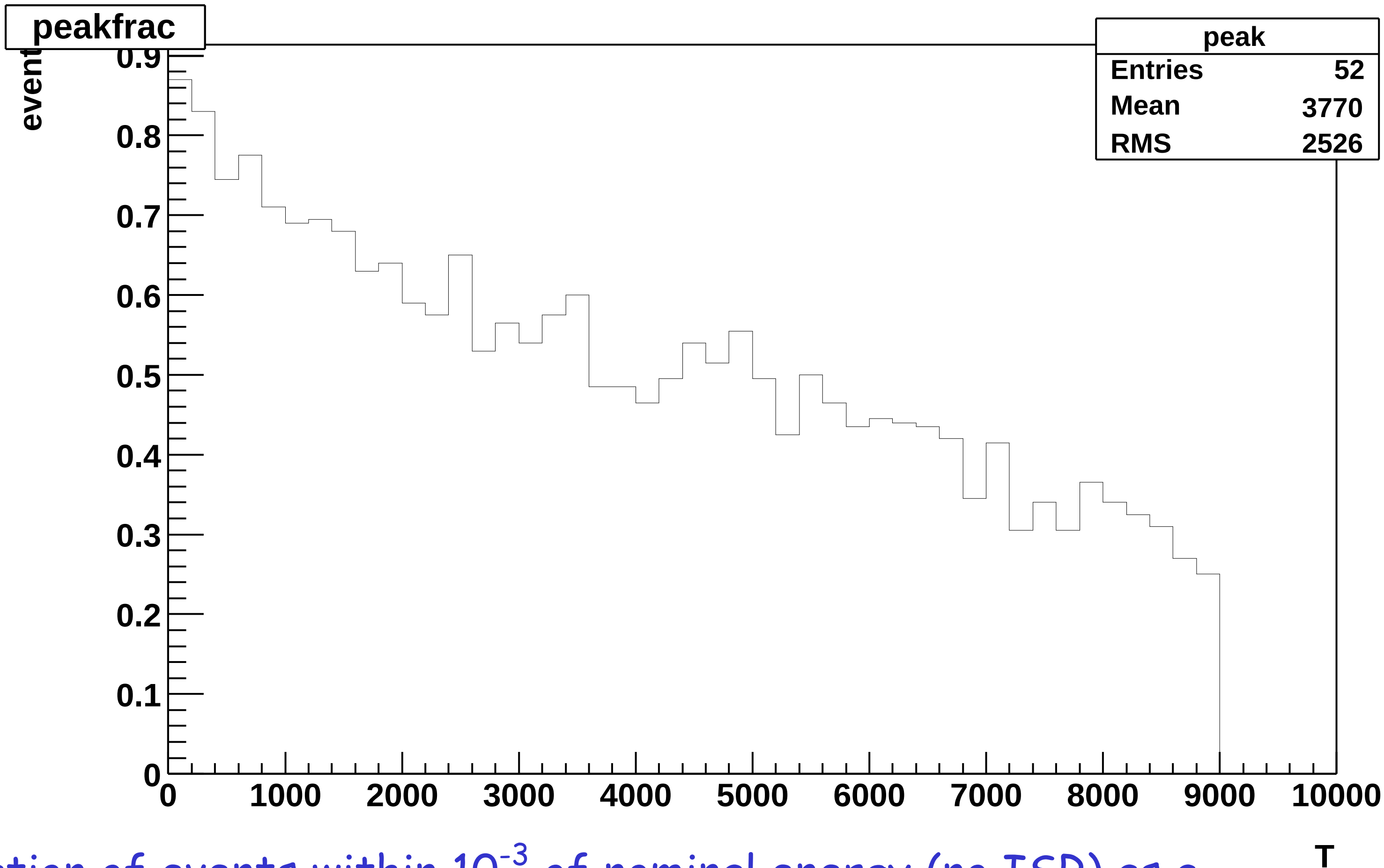
Still not sure how to incorporate machine energy spread, or to simulate its measurement.

Work in Progress, with undergrad project student.



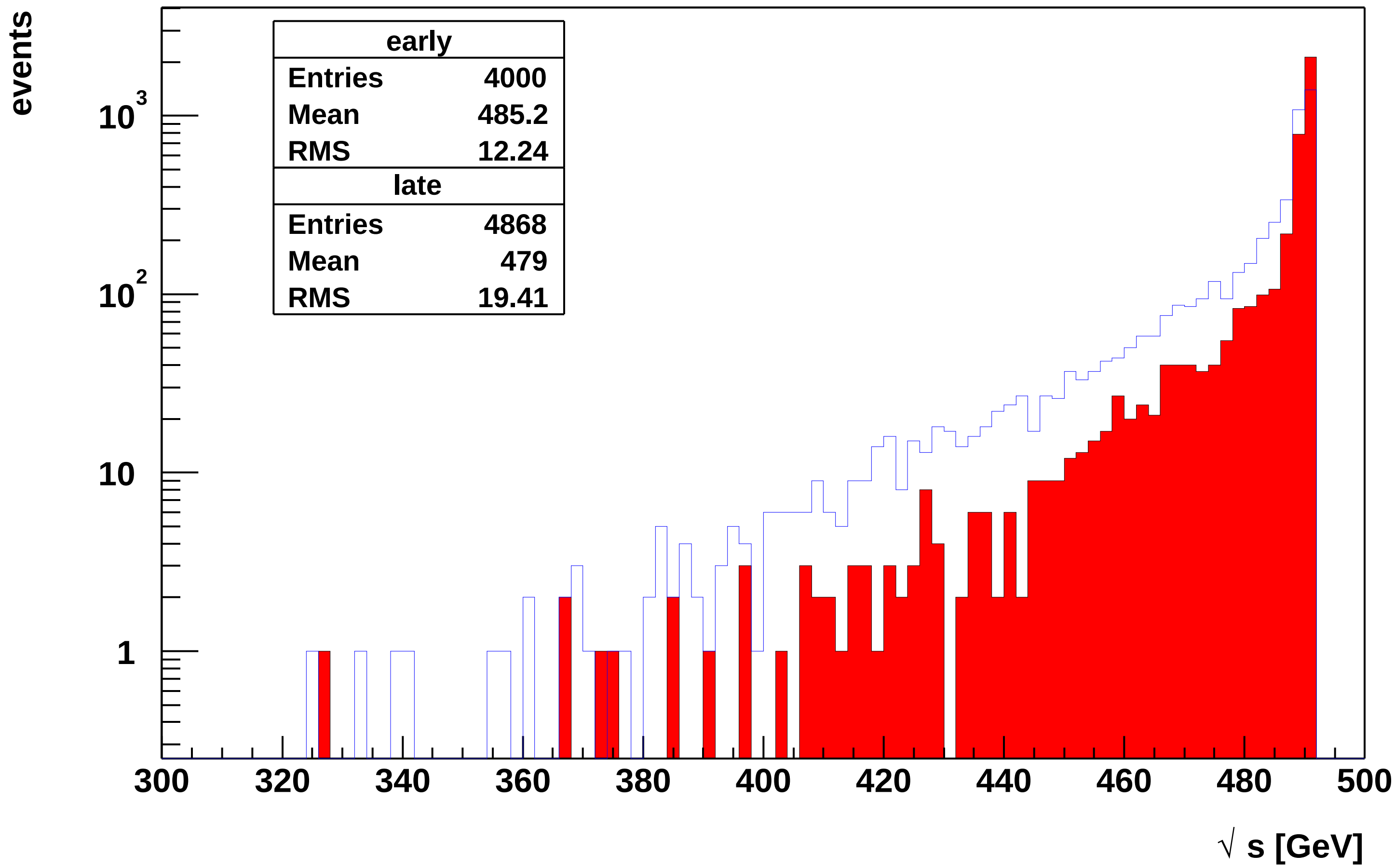
Guinea Pig "luminosity events"; p^+ versus p^-, after beamstrahlung
Note a few with radiations from both Leptons.

Beamstrahlung Correlations



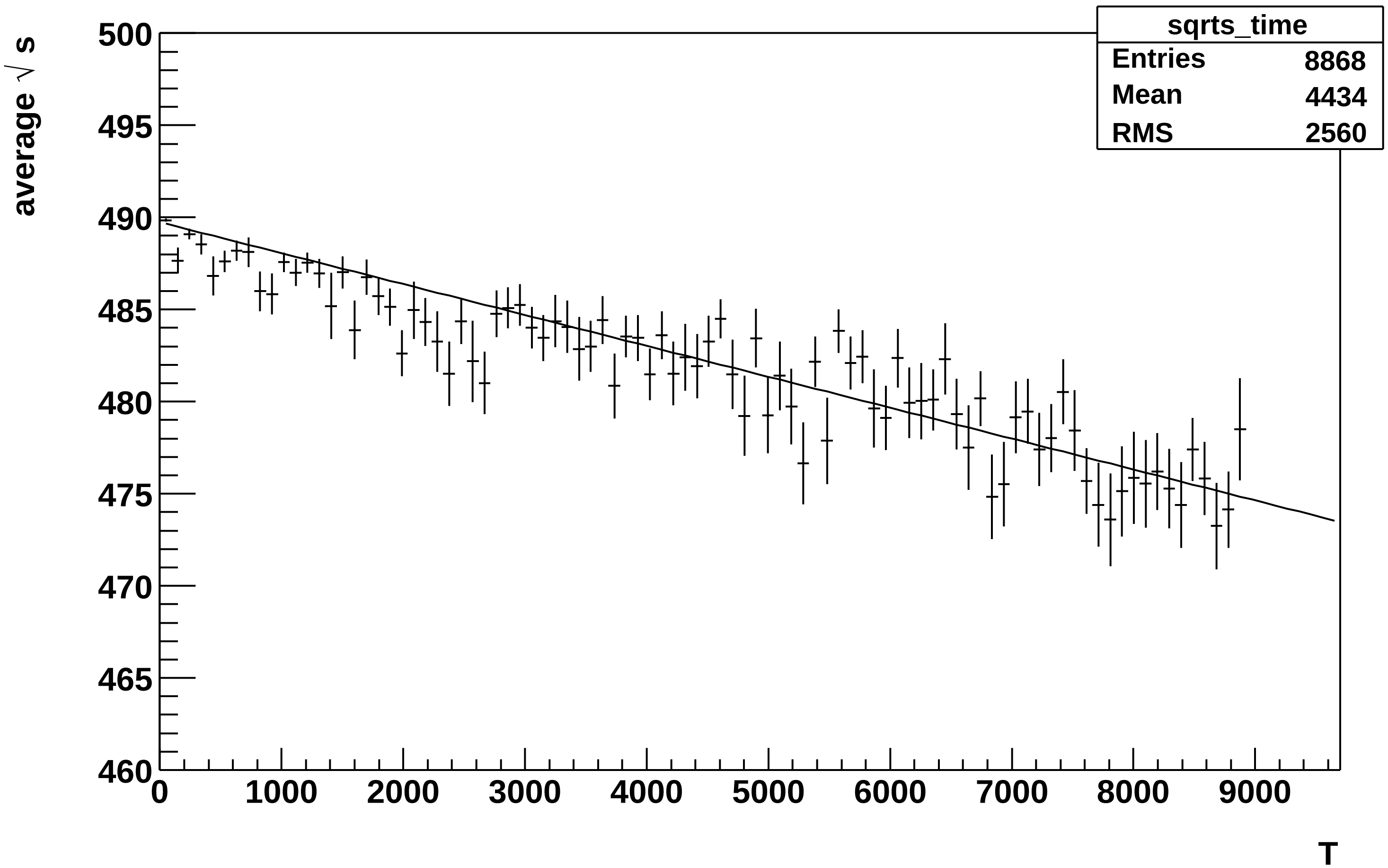
Fraction of events within 10^{-3} of nominal energy (no ISR) as a function of time within collision (≡ event number in G P sequence).

Beamstrahlung Correlations



Red: luminosity spectrum in 1st $\frac{1}{2}$ of bunch crossing
Blue: luminosity spectrum in 2nd $\frac{1}{2}$.

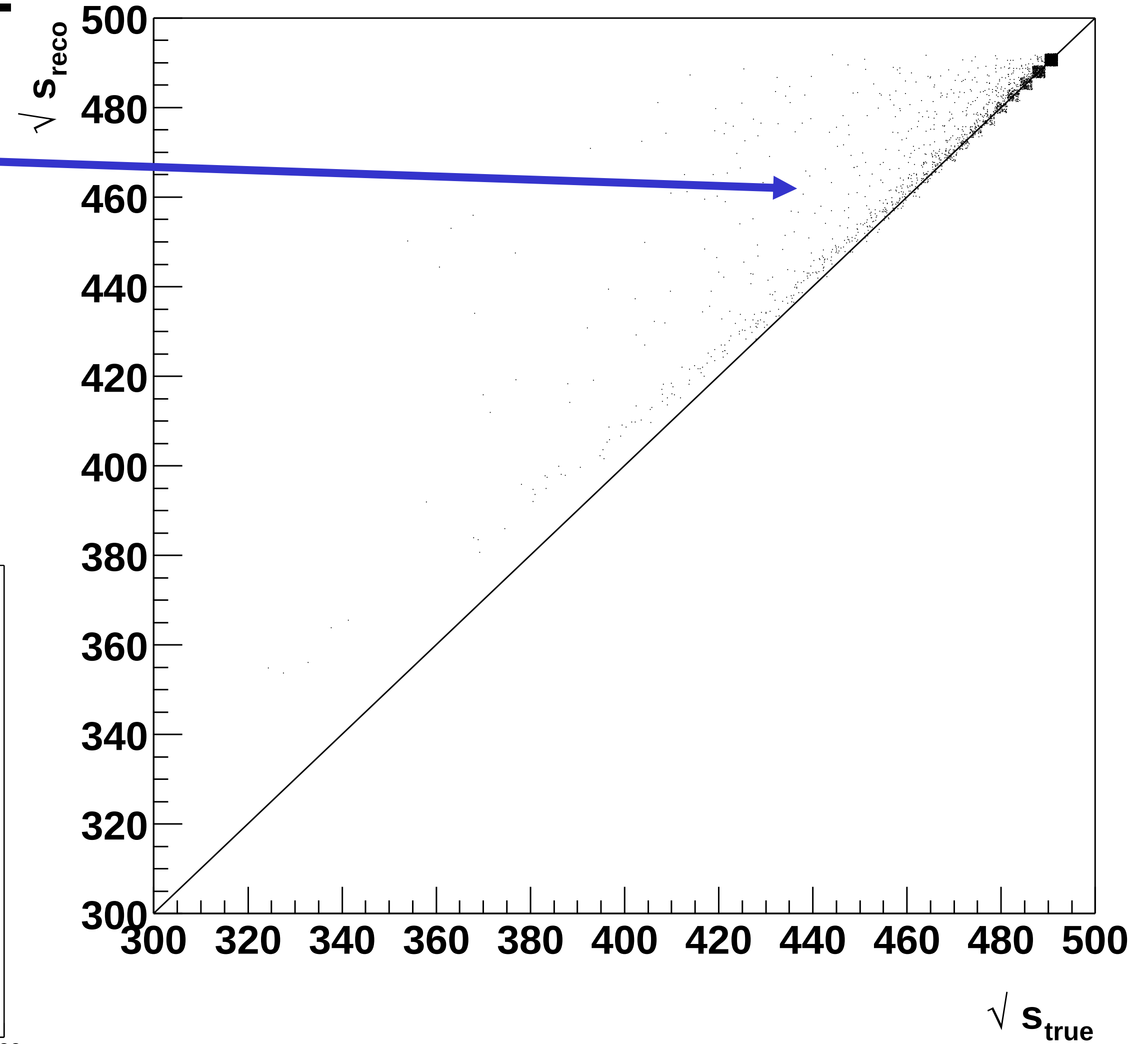
Beamstrahlung Correlations

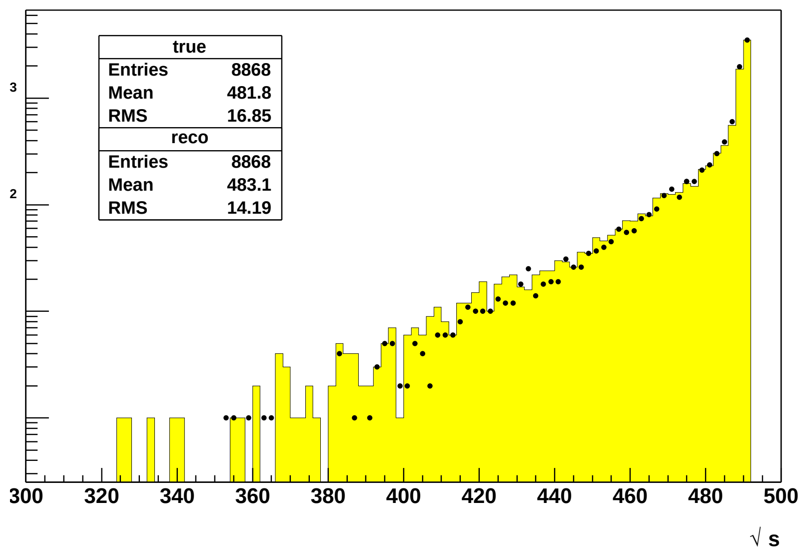


Average √s as a function of time (= GP event number)

Reconstruction $\sqrt{s_{reco}} \simeq p_+ + p_- - \Delta p$

As expected, assuming only 1 radiation under-estimates the true loss.





How to correct for this correlation?

Error in reconstructed spectrum due to these correlations increases with the luminosity per bunch.

Luminosity per bunch will fluctuate a lot over a bunch train, even more over a data-run.

What we want to try next:
Can we use bunch by bunch luminosity estimates (from LCAL, say, at small angles) and GP simulations to make a correction?

Your suggestions very welcome!