BeamCal/GamCal

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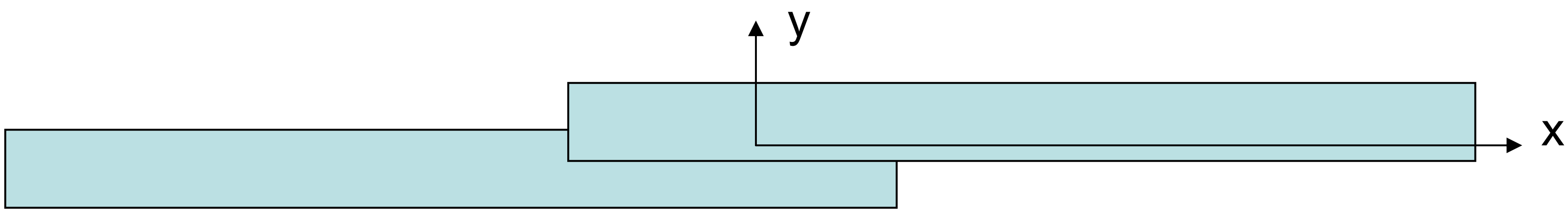
Achieving the ILC Luminosity Will Be a Challenge

- Bunch $P_-(t)$ $\{N,\ \sigma_x,\ \sigma_y,\ \sigma_z,\ \sigma_{xy},\ \psi_x,\ \psi_y\}$
- Bunch $P_+(t)$ $\{N,\ \sigma_x,\ \sigma_y,\ \sigma_z,\ \sigma_{xy},\ \psi_x,\ \psi_y\}$
- Instantaneous Luminosity:

$$L(t) \propto \frac{N_+^o N_-^o}{\sigma_x^o \sigma_y^o}$$



Luminosity Feedback Detectors BeamCal and GamCal

2.7.4.2.3 Luminosity feedback Because the luminosity may be extremely sensitive to bunch shape, the maximum luminosity may be achieved when the beams are slightly offset from one another vertically, or with a slight nonzero beam-beam deflection. After the IP position and angle feedbacks have converged, the luminosity feedback varies the position and angle of one beam with respect to the other in small steps to maximize the measured luminosity.

Beam-strahlung Gammas

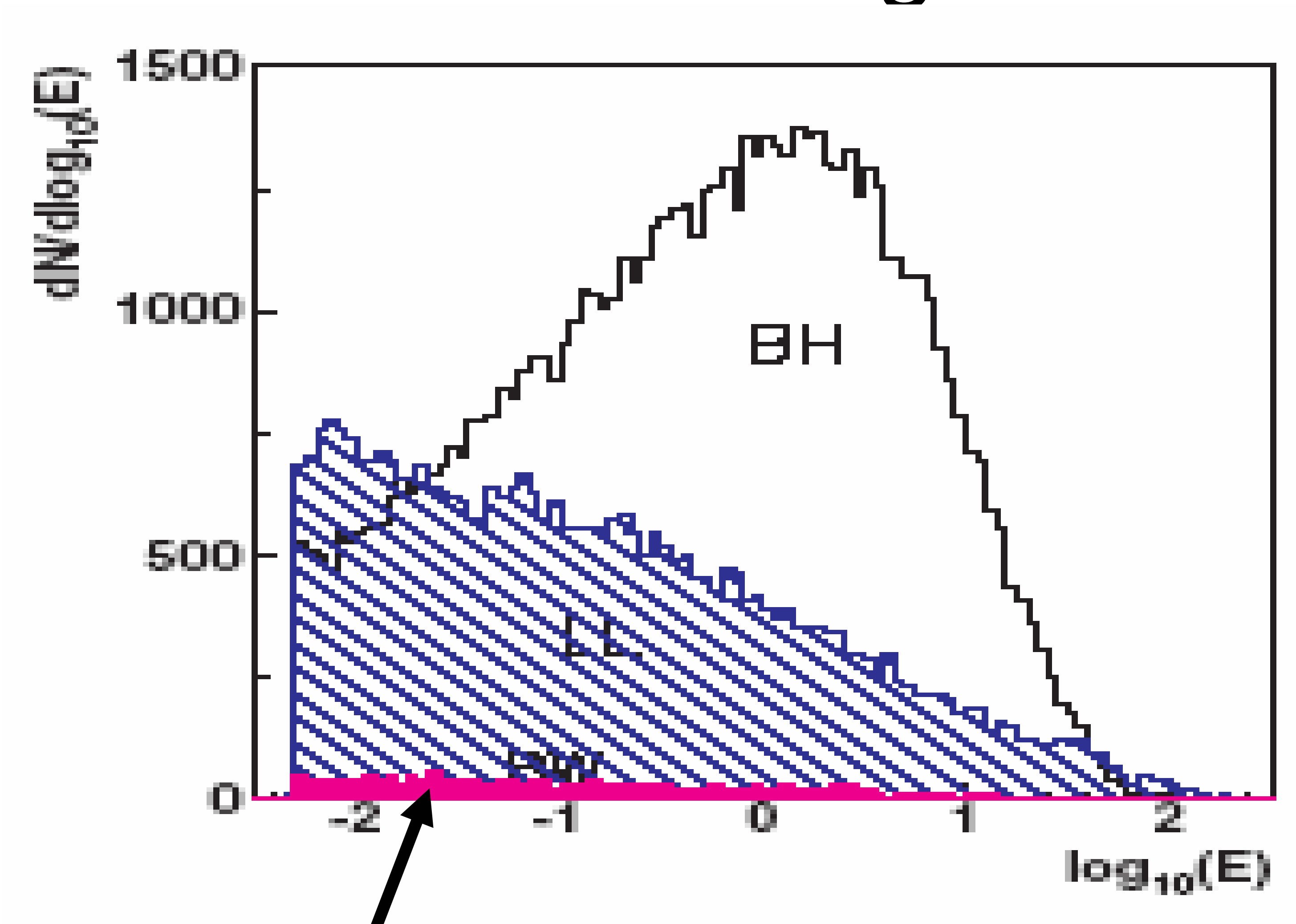
- $F = e(E + c\beta \times B)$
- $E = 0$, $B_{max} \approx 1KT$
- $P_\gamma \approx 3\% \, P_e \approx 0.4MW$
- $N_\gamma \approx 1.5N_e \approx 3\times10^{10}$ /BX

$$B_x = \frac{\mu_0 N e \beta c}{\sigma_x \sigma_z} \frac{y}{\sigma_y} \qquad P_\gamma = \frac{2 r_0 \gamma^2 F^2}{3mc}$$

Beam-strahlung Pairs

- Bethe-Heitler: $\gamma e \rightarrow e\ e^{+}e^{-}$
- $\sigma_{BH} \approx 38$ mb $\langle E \rangle \approx 1$GeV
- $N_{ee} \propto N_{e}^{3}$
- Landau-Lifshitz: $ee \rightarrow ee\ e^{+}e^{-}$
- $\sigma_{LL} \approx 19$ mb $\langle E \rangle \approx 0.15$GeV
- $N_{ee} \propto N_{e}^{2}$
- Breit-Wheeler: $\gamma\gamma \rightarrow e^{+}e^{-}$ $\sigma_{BW} \approx 1$ mb
- $\approx 10^{5}\ e^{+}e^{-}$ /BX   Maximum $P_{T} = 0.1$ GeV/c

Beam-strahlung Pairs



10cm low Z

Bethe-Heitler Pairs

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

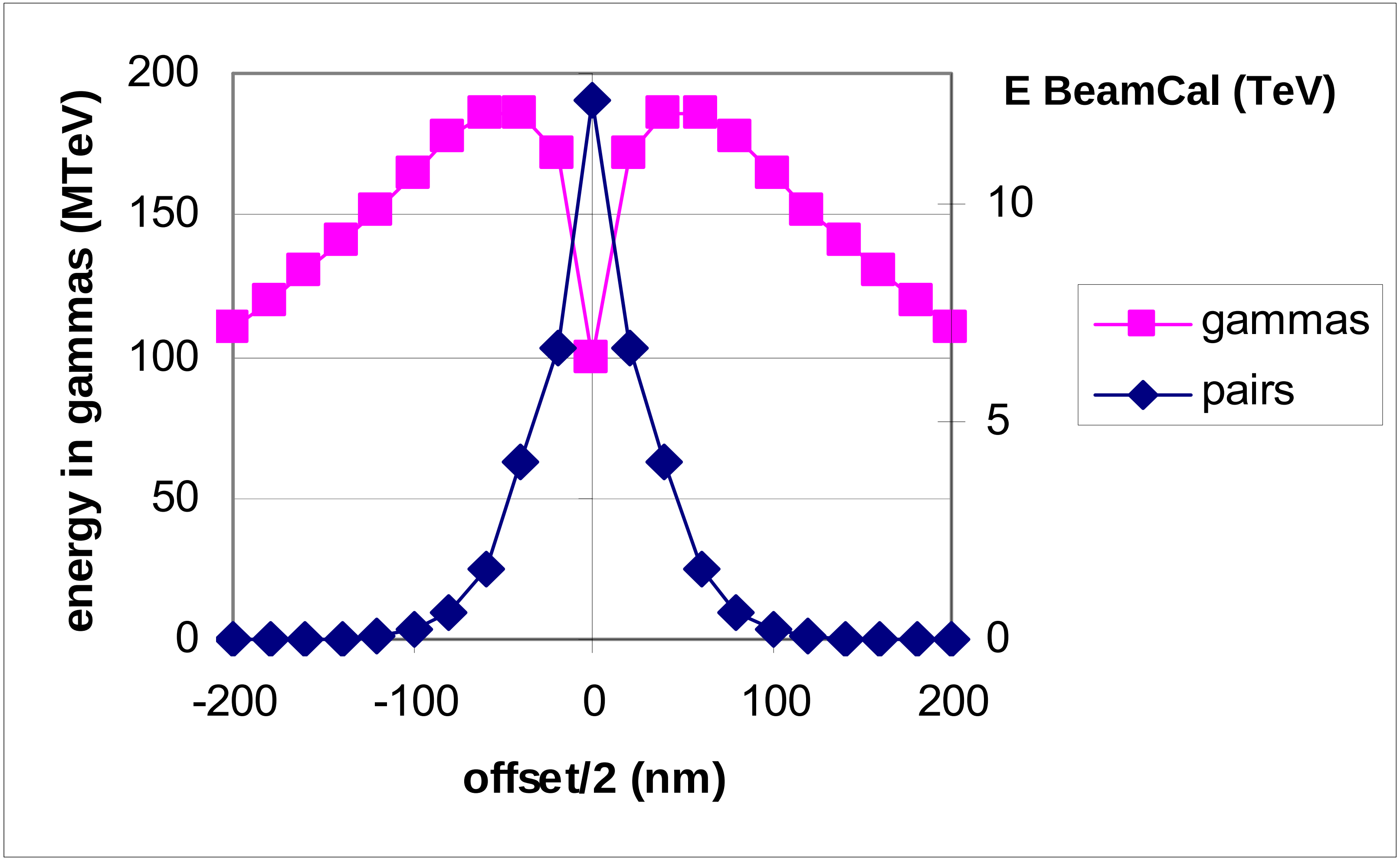
$$N_{ee} \propto \frac{\sigma_{BH} N_\gamma^o\, N_e^o}{\sigma_x^o\, \sigma_y^o}$$

$$\frac{N_{ee}}{N_\gamma} \propto \frac{\sigma_{BH} N_e^o}{\sigma_x^o\, \sigma_y^o}$$

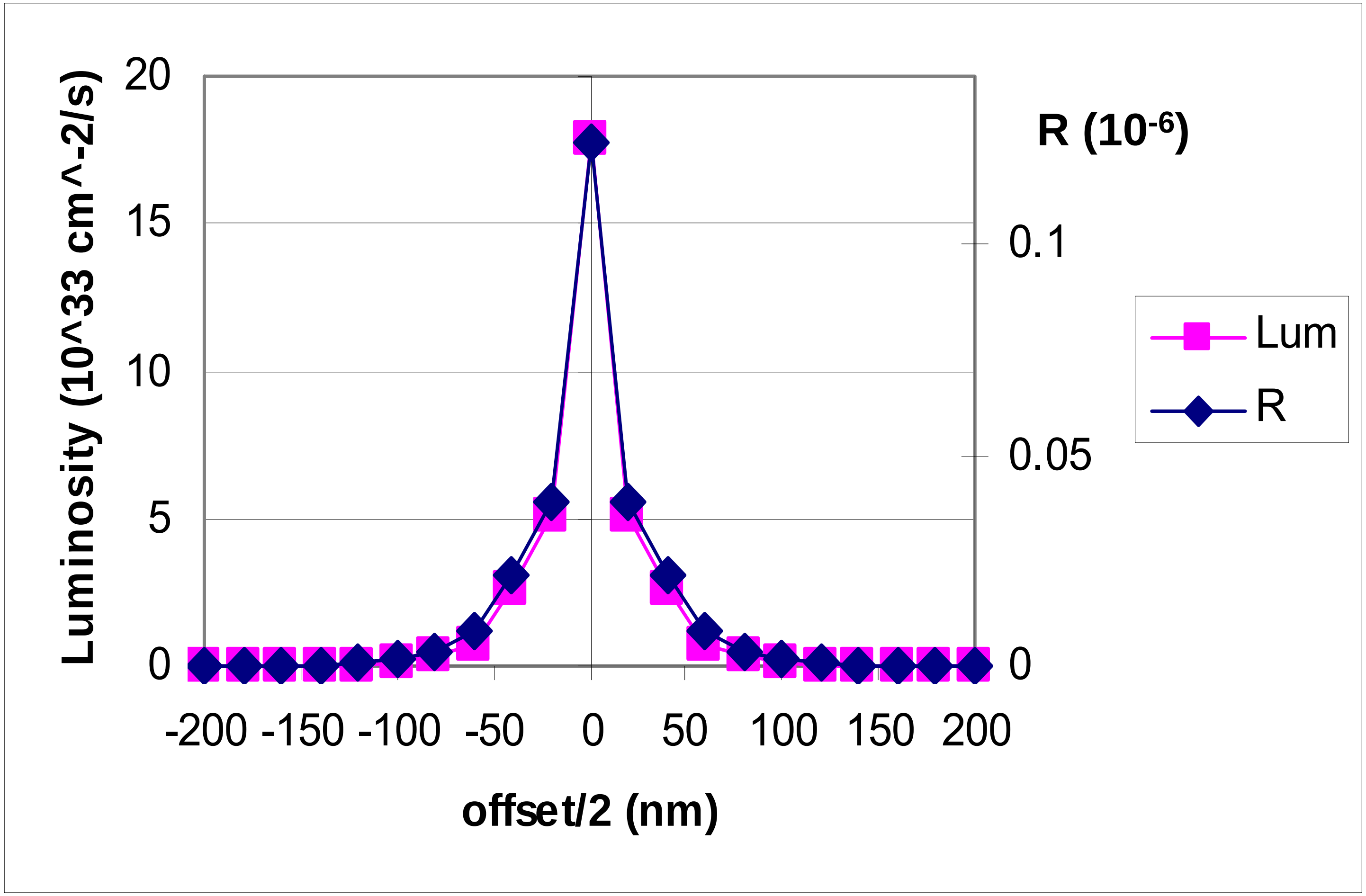
$$\frac{E_{ee}}{E_\gamma} \propto \frac{N_e^o}{\sigma_x^o\, \sigma_y^o}$$

For left and right detectors separately: $N^+/\sigma_x\sigma_y$ and $N^-/\sigma_x\sigma_y$.

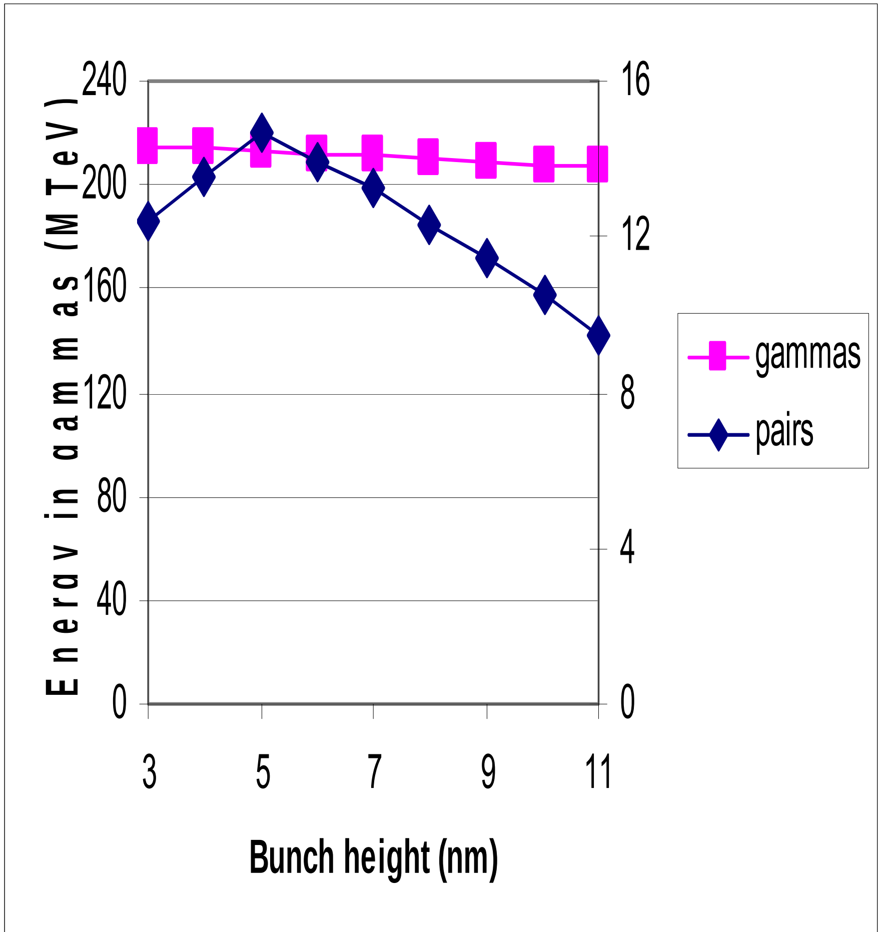
Vertical offset

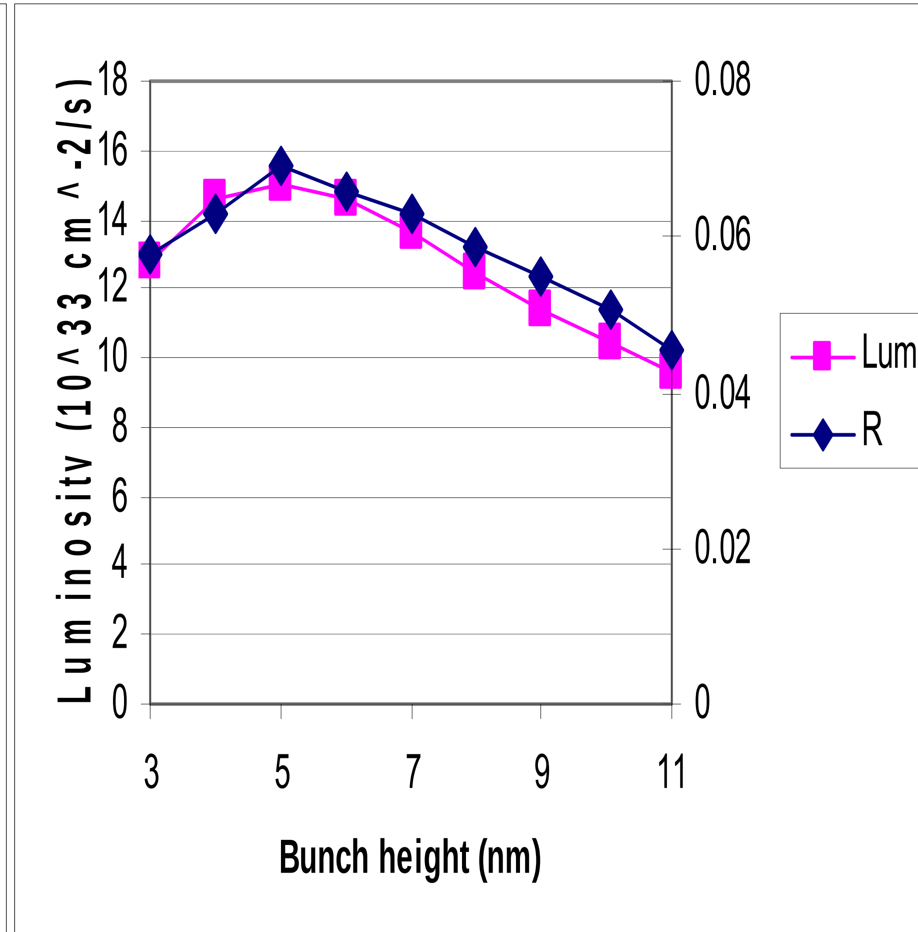


Vertical Offset

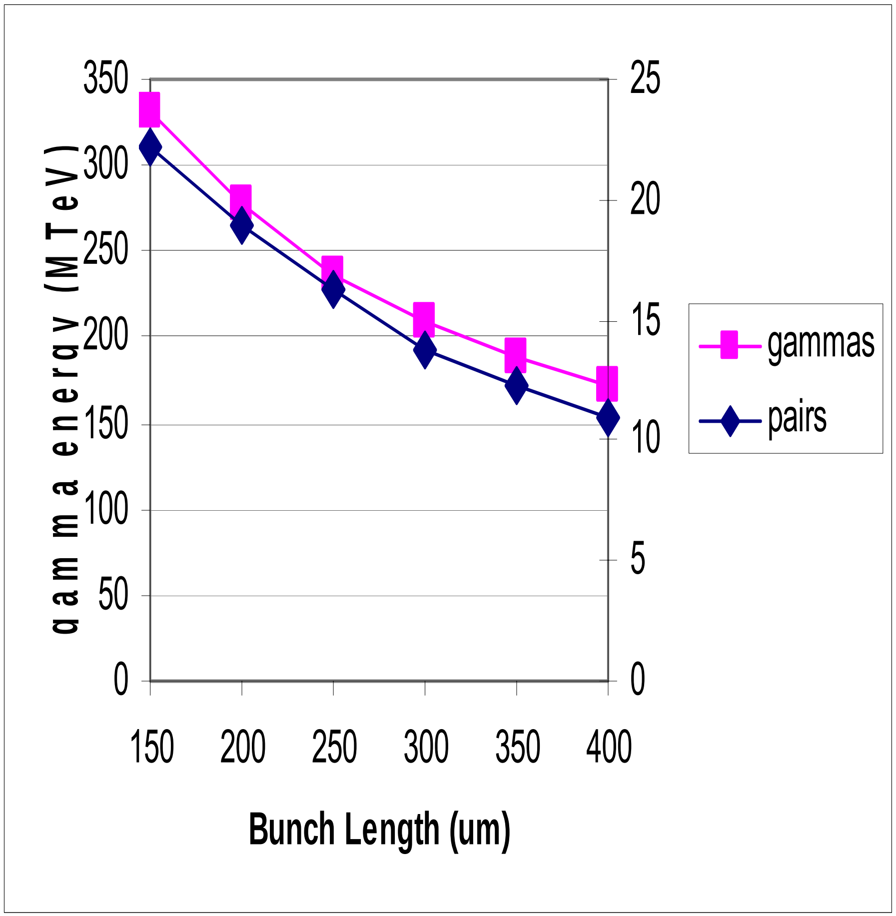


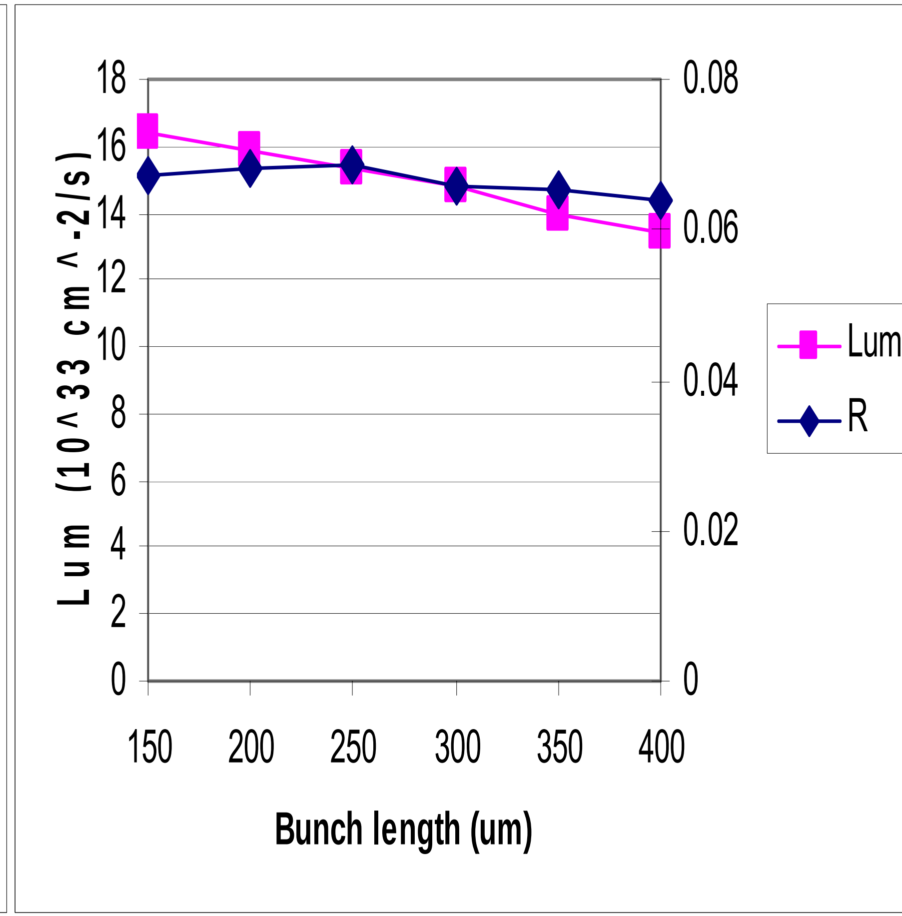
Bunch Height





Bunch Length





GamCal and BeamCal

- Measuring the beam-strahlung pairs and gammas provides robust complementary information
- Ratio of pairs to gammas is largely proportional to the instantaneous luminosity
- Need to *intellectually* understand what is happened at the IP – a tremendous challenge

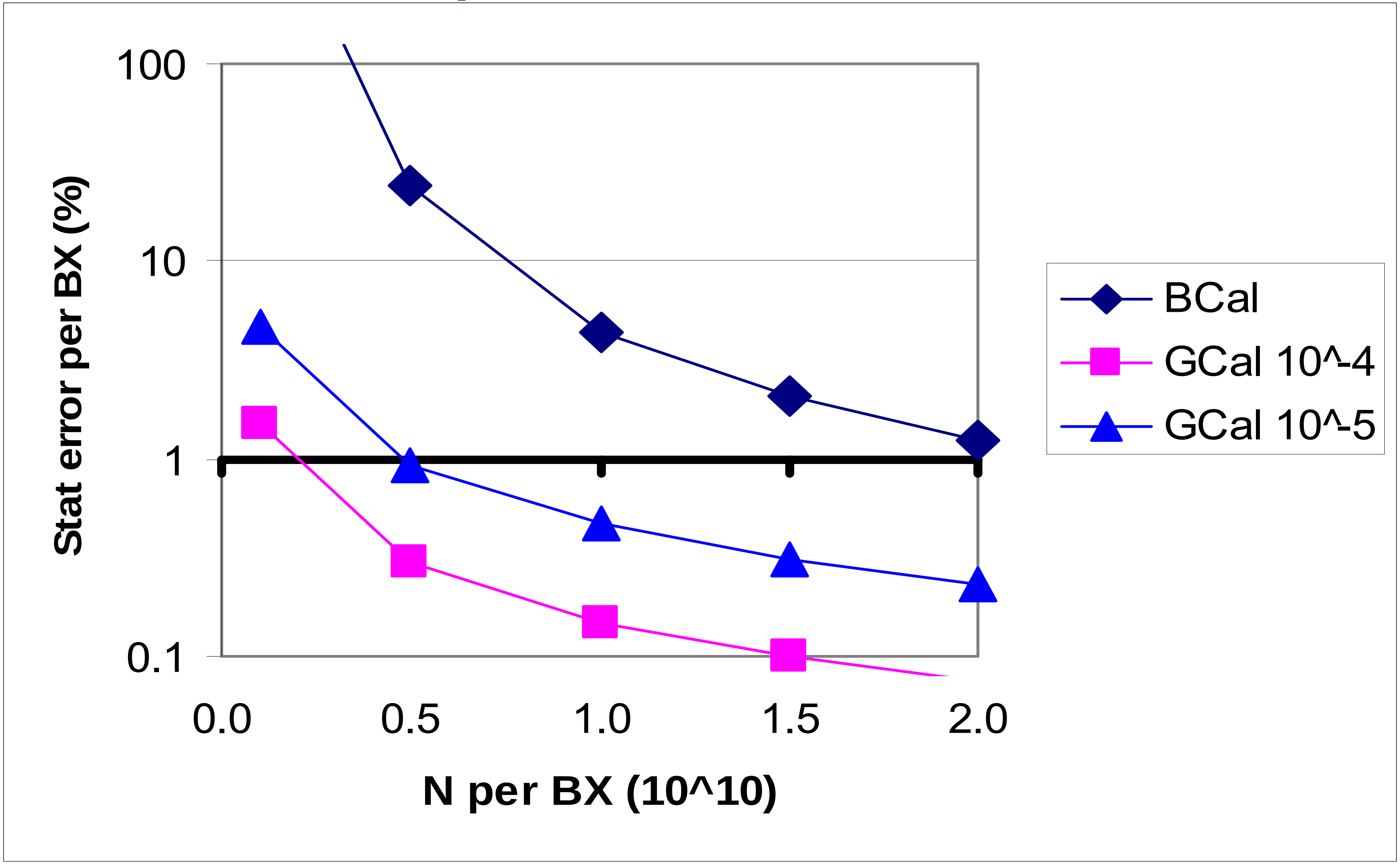
BeamCal

- $.003 < \theta < .02$ rad
- $\approx$3.5m from IR
- Pairs curl in the magnetic field
- Measure the $\approx 10^4$ beam-strahlung e^+e^- pairs/BX for beam diagnostics
- 2-10MGy/year
- R&D on cvc diamond, rad-hard Si, ….

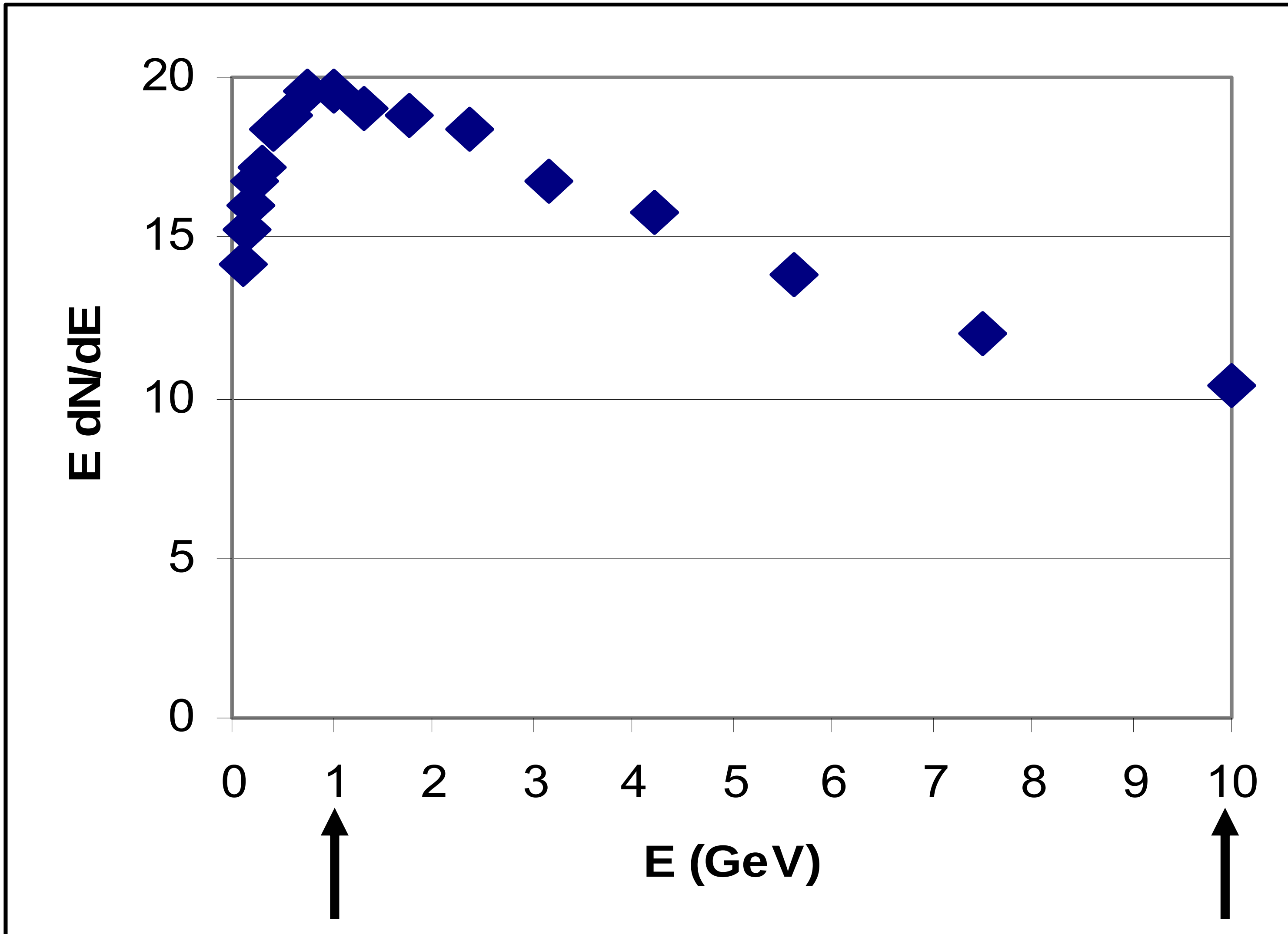
GamCal Detector

- $\approx$180m from IR
- $\approx 10^{-5} - 10^{-4}\ X_0$ to convert beam-strahlung gammas into e^+e^- pairs
- Converter could be gas jet or a thin solid converter
- Magnet with P_T kick 0.25 GeV/c separates the pairs from beam electrons
- Calorimeters outside vacuum after magnet measure the 1-10 GeV positrons

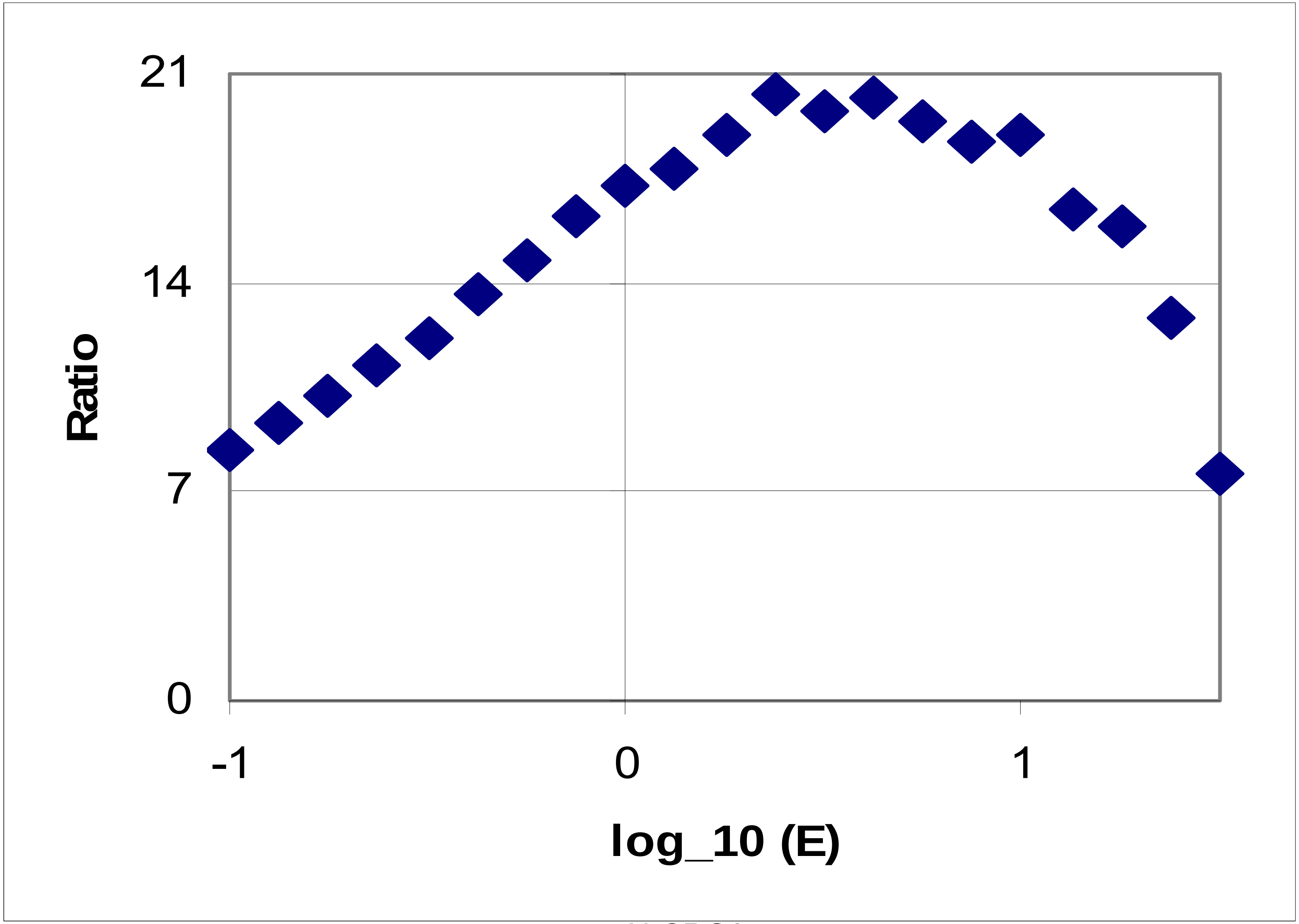
BeamCal problem when N is low



Beam-strahlung $\gamma Z \rightarrow eeZ$

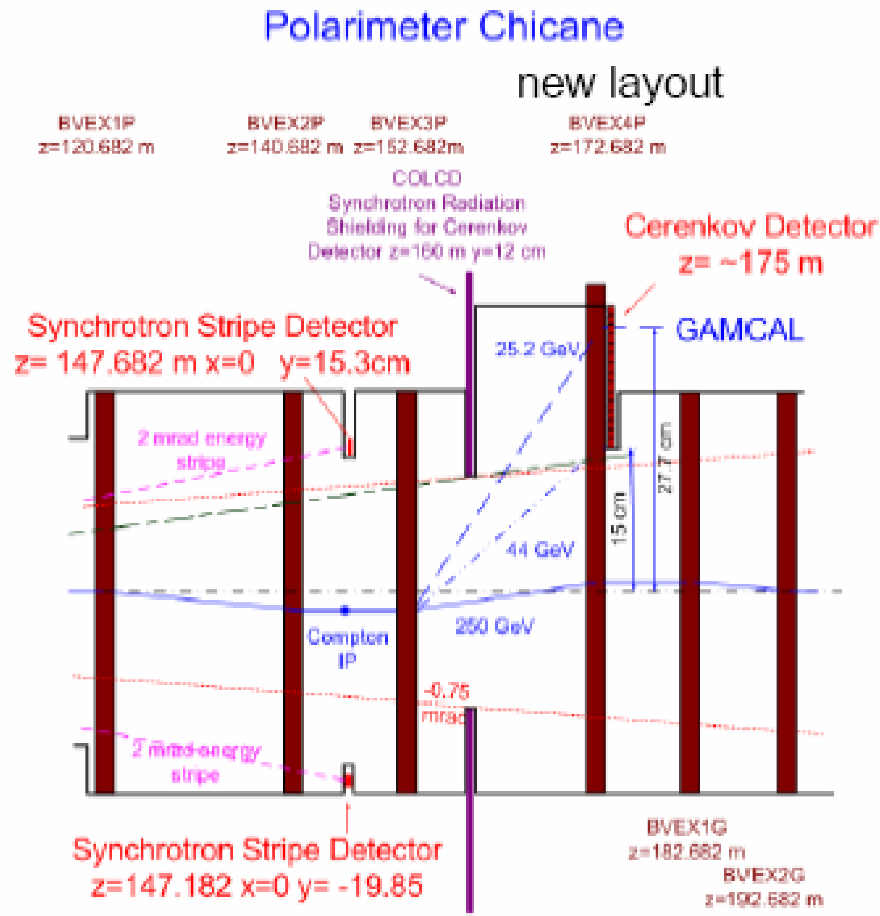


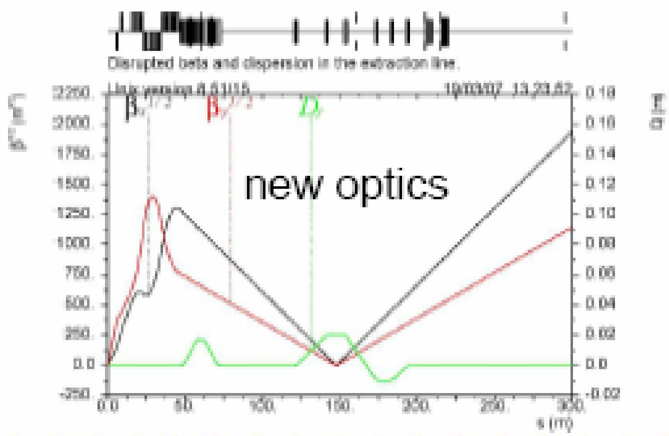
Ratio of $\gamma Z \rightarrow eeZ$ vs. $eZ \rightarrow eZee$



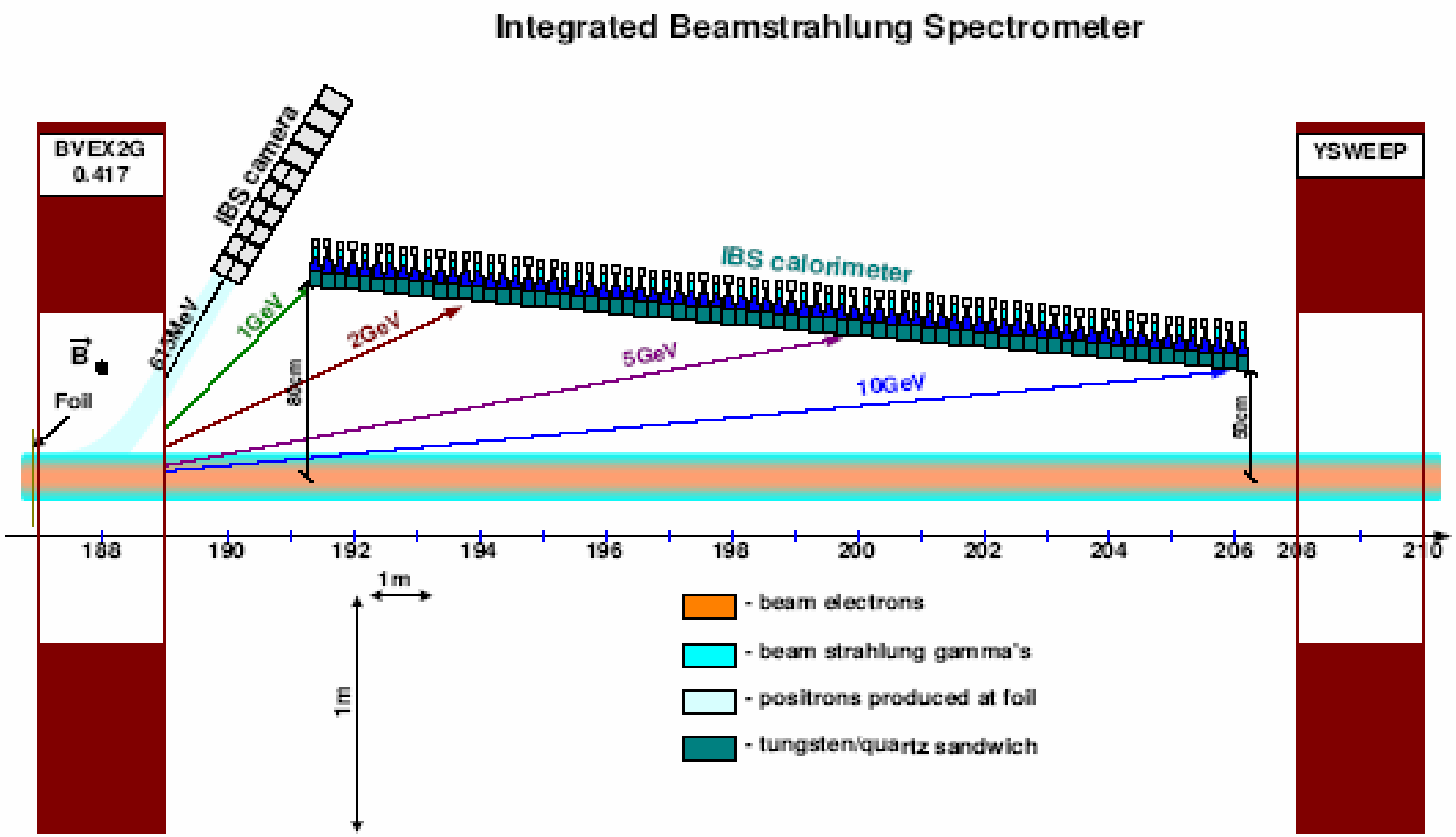
Modification of polarimeter chicane (CCR oncoming)

- Some increase of cost, improved performance
- More suitable for GamCal
- Ratio of energy in Gammas/Pairs ~ Lumi signal





Yale IBS Design



Conclusions

- We have concepts for beam-strahlung pair and gamma detectors.
- Challenging problems: rad damage, etc.
- Ratio of the beamstrahlung pairs (BeamCal) to gammas (GamCal) is largely proportional to the instantaneous luminosity.
- We will need *all the information we can get* to understand what is happening at the IP.

Extra Slides

π Production Compared to ee

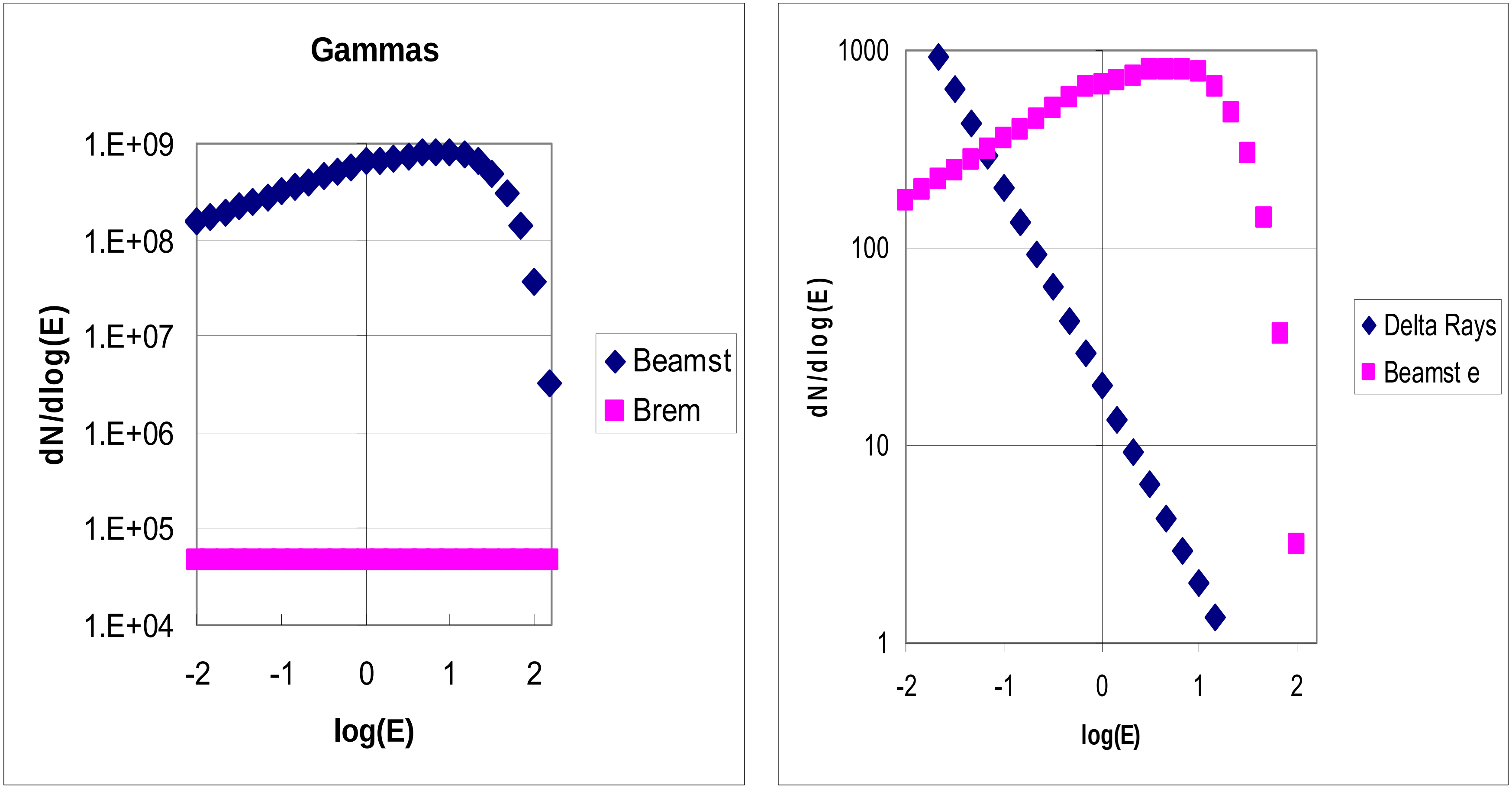
- $\gamma p \rightarrow eep \quad \sigma \approx 10$ mb
- $\gamma p \rightarrow \pi N \quad \sigma \approx 0.5$ mb on peak of Δ resonance
- $\gamma p \rightarrow \pi N \quad \sigma \approx 0.1$ mb $\quad E > 4$GeV
- $ep \rightarrow e \pi N \quad \sigma \approx 10^{-3}$ mb
- Thus $ep \rightarrow e \pi N$ is negligible

$\gamma Z \rightarrow eeZ$ vs. $eZ \rightarrow eZee$

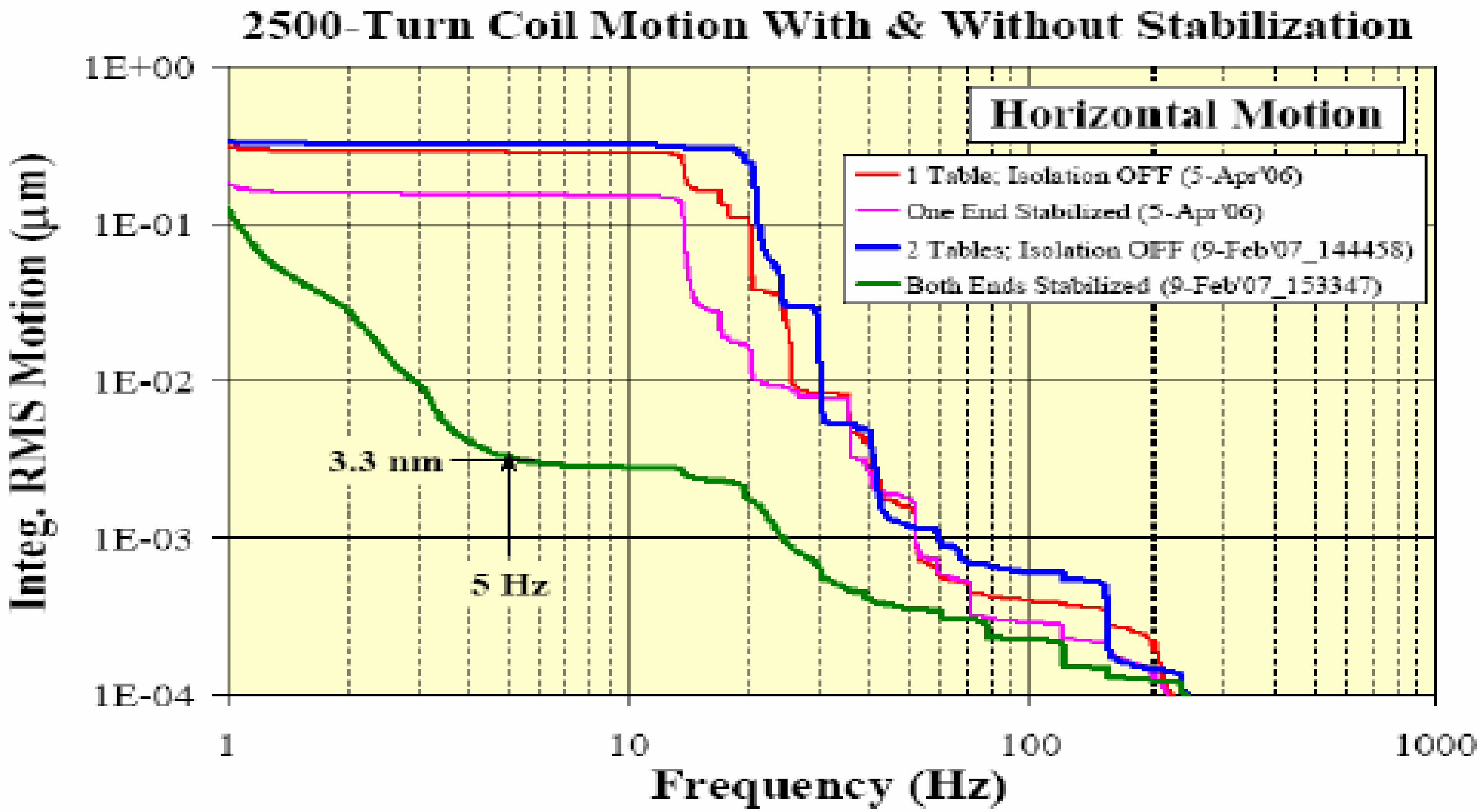
- Electron carries virtual gammas
- Landau Lifshitz conversion of virtual gammas

$$\frac{dN}{d\omega} = \frac{2\alpha}{\pi}\frac{1}{\omega}\left[\ln\frac{1.1\gamma\, c}{\omega\, b_{\min}} - \frac{1}{2}\right]$$

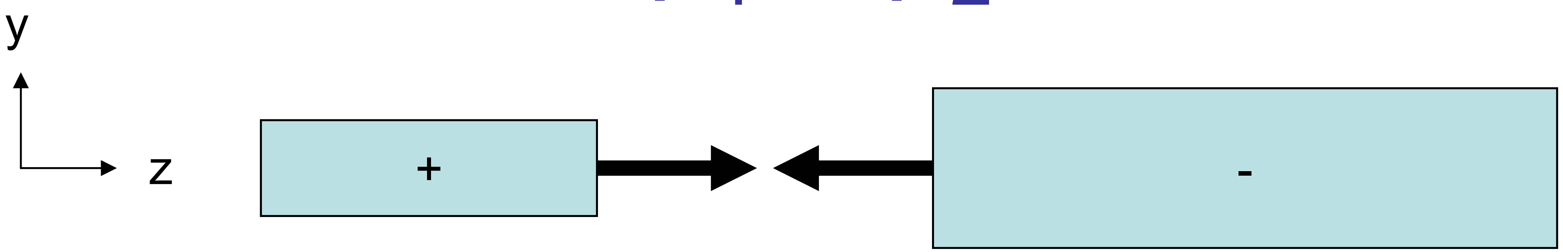
GamCal Backgrounds



BNL Magnet Division Position Stability



$\rho_1 \neq \rho_2$



$$F_1 = \frac{ey}{\varepsilon_0}\left(\rho_2 - \rho_1 + \beta^2\left(\rho_1 + \rho_2\right)\right) \approx \frac{2\rho_2 ey}{\varepsilon_0}$$

$$E = \frac{\left(\rho_1 - \rho_2\right)y}{\varepsilon_0} \qquad B = \frac{\beta\left(\rho_1 + \rho_2\right)y}{\varepsilon_0}$$

Perfect Collisions

$$E_\gamma \propto \frac{N^2}{\sigma_x^2 \sigma_z} \qquad E_{ee} \propto \frac{N^3}{\sigma_x^3 \sigma_y \sigma_z}$$