LumCal, BeamCal and GamCal

William Morse - BNL

FCAL Meeting Oct. 17 MPI Munich

- W. Lohmann (DESY Zeuthen) spokesman
- W. Morse (BNL) beam diagnostics (BeamCal/GamCal) coordinator
- B. Pawlik (Cracow) simulations
- W. Lange (DESY) sensors
- Cracow TBD electronics
- W. Wierba (Cracow) LumCal laser alignment

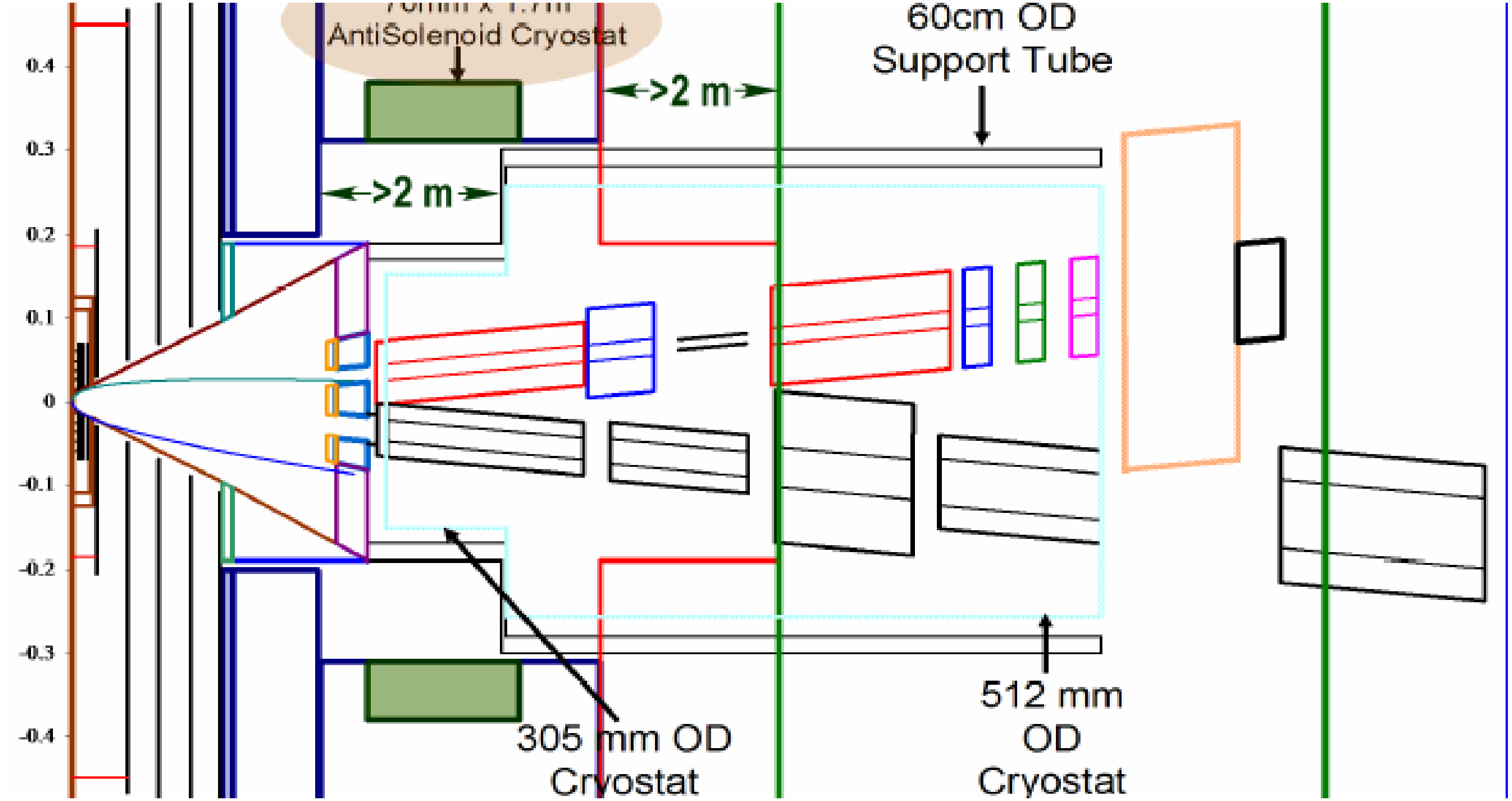
U.S. Forward

- BNL PI: W. Morse
- F. Lanni, D. Lissauer: BeamCal readout issues
- Z. Li: radiation damage issues
- B. Parker: machine interface issues
- Yale PI: M. Zeller
- G. Atoian, V. Issakov, A. Poblaguev: GamCal design issues
- Colorado PI: U. Nauenberg: SUSY studies

BeamCal Radiation Damage

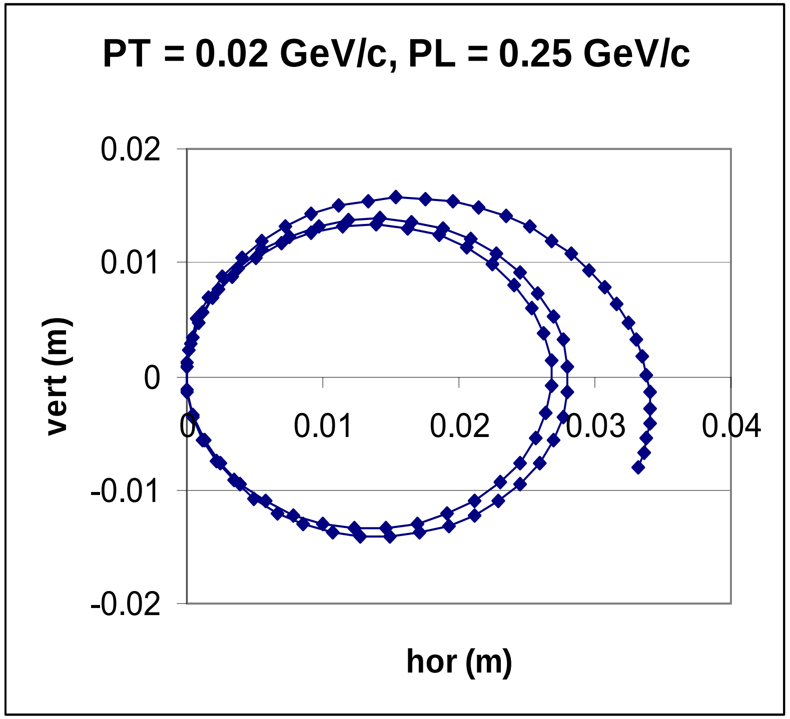
- 10MGy/yr from beam-strahlung electrons
- 2×10^{14} n/cm^2 per yr, mainly from giant dipole resonance (10-40 MeV $\gamma N\rightarrow nN^*$)
- Zheng Li (BNL Instrumentation) recommends high resistivity MCZ Si cooled to -10C
- They have tested diamond. It does not pass. They plan to test Ga-Ar

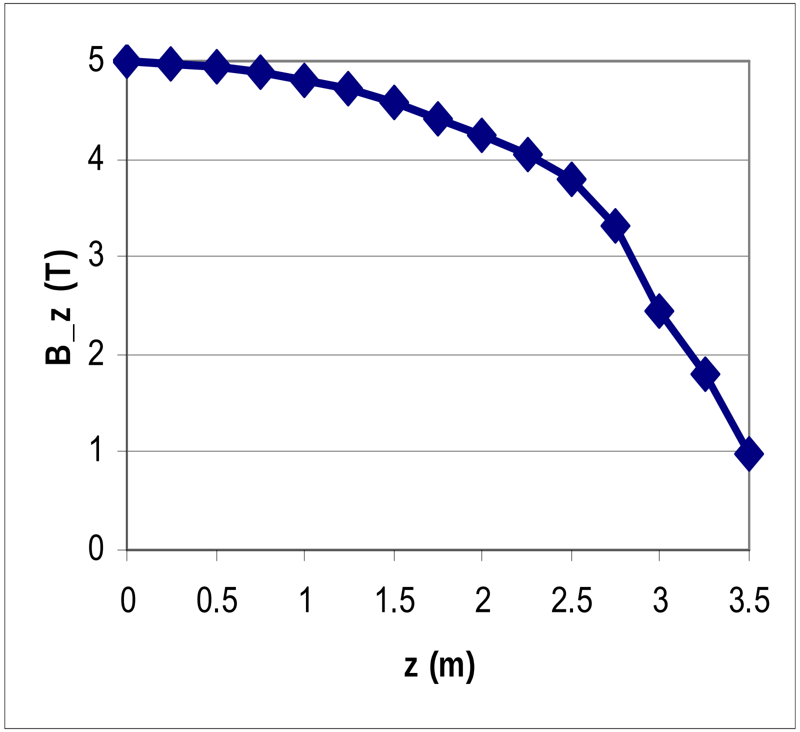
14mrad with Anti-solenoid



SiD Anti-Solenoid Magnet

- Brett Parker (BNL) design – see VLCW06 talk
- Lower B affects pairs and also backsplash to vertex detector

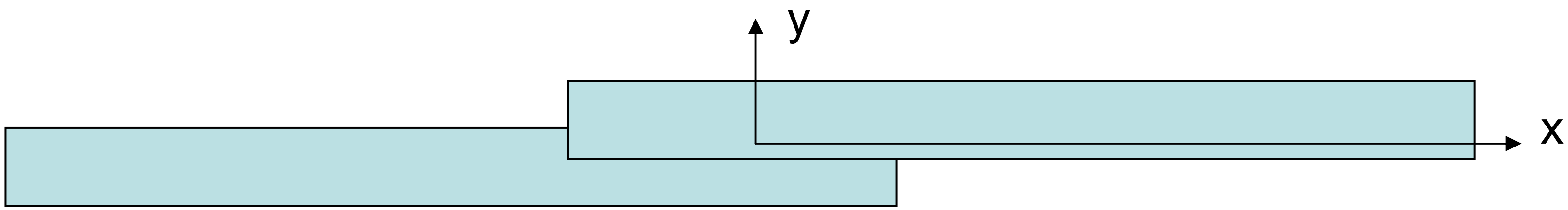




Achieving the Design Luminosity Will Be a Challenge

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

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



Run Time Measurements

- Beam-beam deflections (pickup electrodes)
- Beam-strahlung gammas (GamCal)
- Beam-strahlung pairs (BeamCal)
- We need robust and complementary information

Beam-strahlung

$$P = \frac{2 r_0 \gamma^2 F^2}{3mc}$$

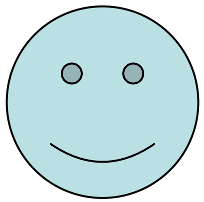
- $F = e(E + c\beta\times B)$. $B_{max} \approx 1KT$
- Instantaneous power radiated:
- $P_\gamma \approx 3\%\ P_e$ $N_\gamma \approx 1.5N_e$
- Bethe-Heitler: $\gamma e \to e\ e^+e^-$
- $\sigma_{BH} \approx 38$ mb
- <E> ≈ 1GeV
- Landau-Lifshitz: $ee \to ee\ e^+e^-$
- $\sigma_{LL} \approx 19$ mb
- <E> ≈ 0.15GeV
- Other processes much smaller
- C. Rimbault et al., Phys Rev ST AB 9,034402 (2006).

Bethe-Heitler Pairs

- $\gamma e \rightarrow e\, e^{+}e^{-}$

$$N_{ee} \propto \frac{\sigma_{BH} N_{\gamma}^{o} N_{e}^{o}}{\sigma_{x}^{o} \sigma_{y}^{o}} \qquad \frac{N_{ee}}{N_{\gamma}} \propto \frac{\sigma_{BH} N_{e}^{o}}{\sigma_{x}^{o} \sigma_{y}^{o}}$$

$$\frac{E_{ee}}{E_{\gamma}} \propto \frac{N_{e}^{o}}{\sigma_{x}^{o} \sigma_{y}^{o}}$$



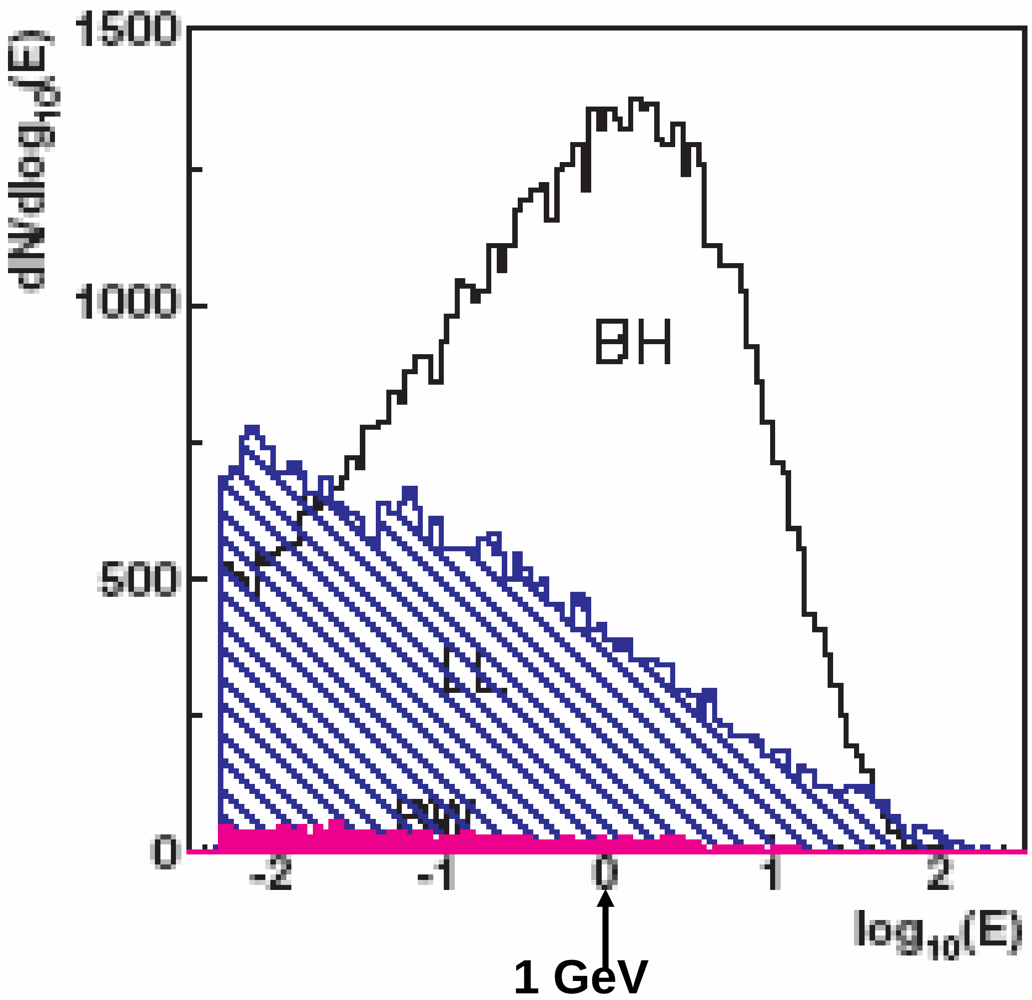
For left and right detectors separately: $N^{+}/\sigma_x\sigma_y$ and $N^{-}/\sigma_x\sigma_y$. Question: How well does this really work? Answer: Needs simulation.

Landau-Lifshitz Pairs

- ee → eee$^+$e$^-$

$$N_{ee}^{LL} \propto \frac{\sigma_{LL} N_-^o N_+^o}{\sigma_x^o \sigma_y^o}$$

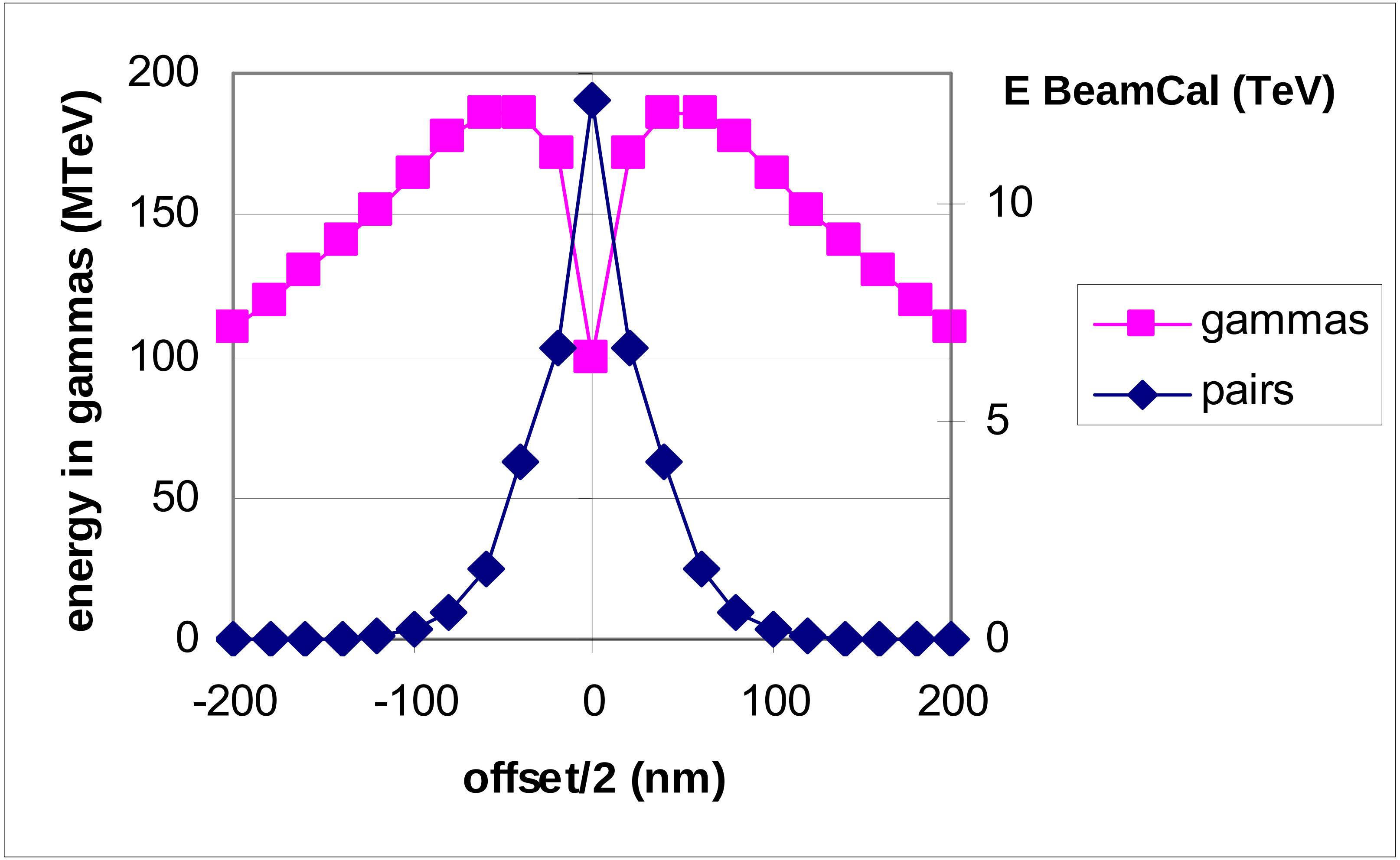
For left and right detector equally



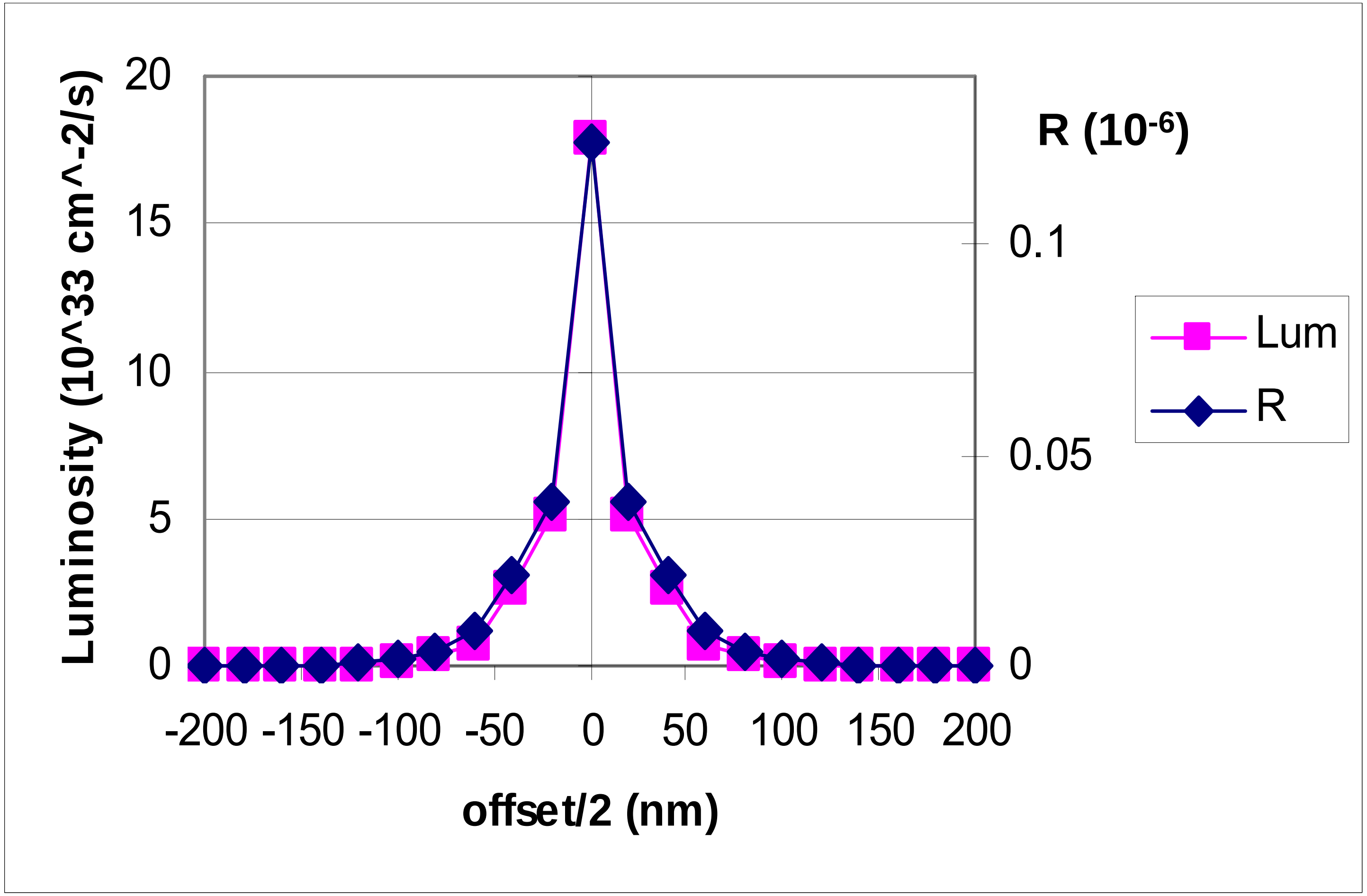
Simulations

- W. Morse (BNL)
- W. Lohman, E. von Oelson, and M. Ohlerich (DESY Zeuthen)
- To Be Submitted as an ILC Note
- Guinea Pig simulations varying some of the 500 GeV ILC bunch parameters around nominal values

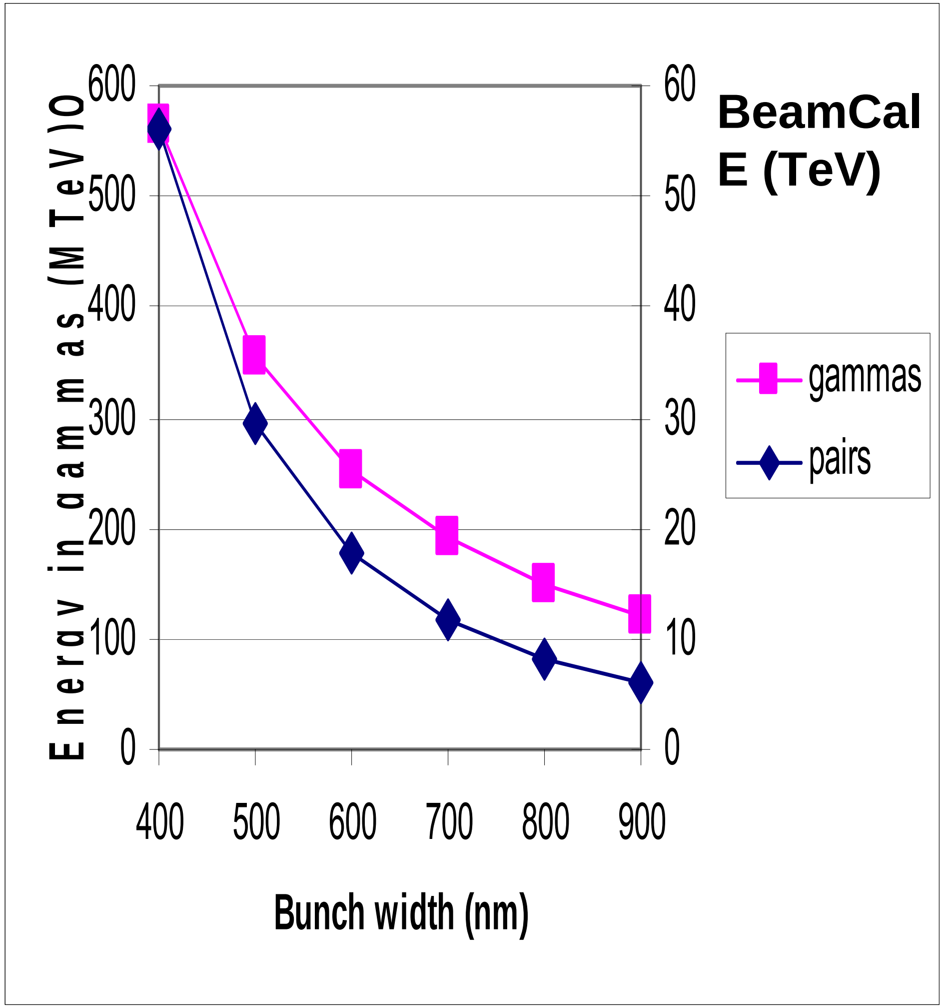
Vertical offset



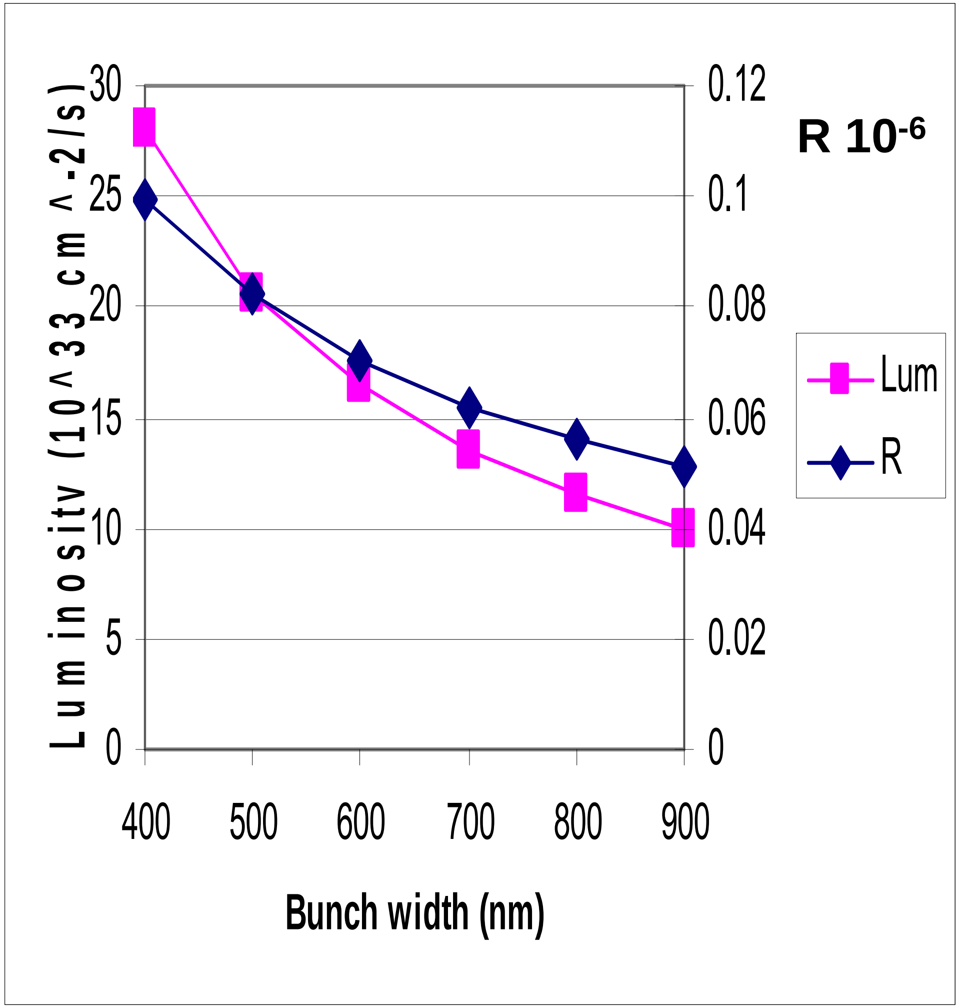
Vertical Offset



Bunch Width



Energy in gammas (MTeV)
600
500
400
300
200
100
0
60
50
40
30
20
10
0
BeamCal E (TeV)
gammas
pairs
400
500
600
700
800
900
Bunch width (nm)



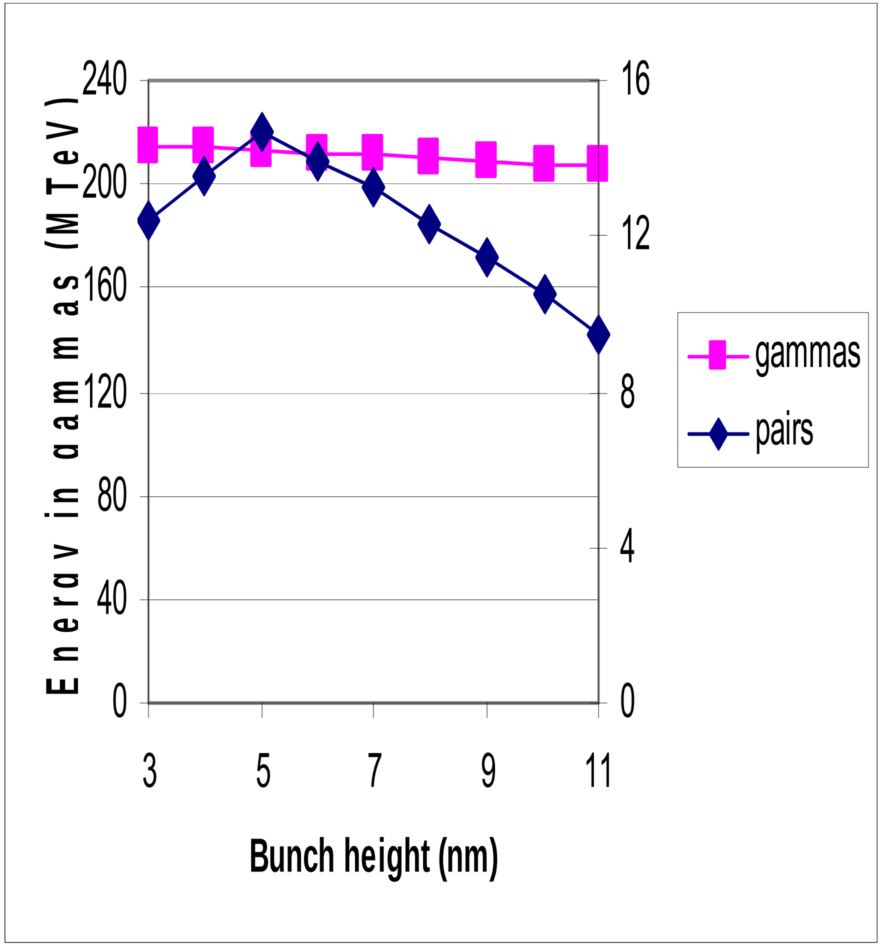
Luminosity (10^33 cm^-2/s)
30
25
20
15
10
5
0
0.12
0.1
0.08
0.06
0.04
0.02
0
R 10-6
Lum
R
400
500
600
700
800
900
Bunch width (nm)

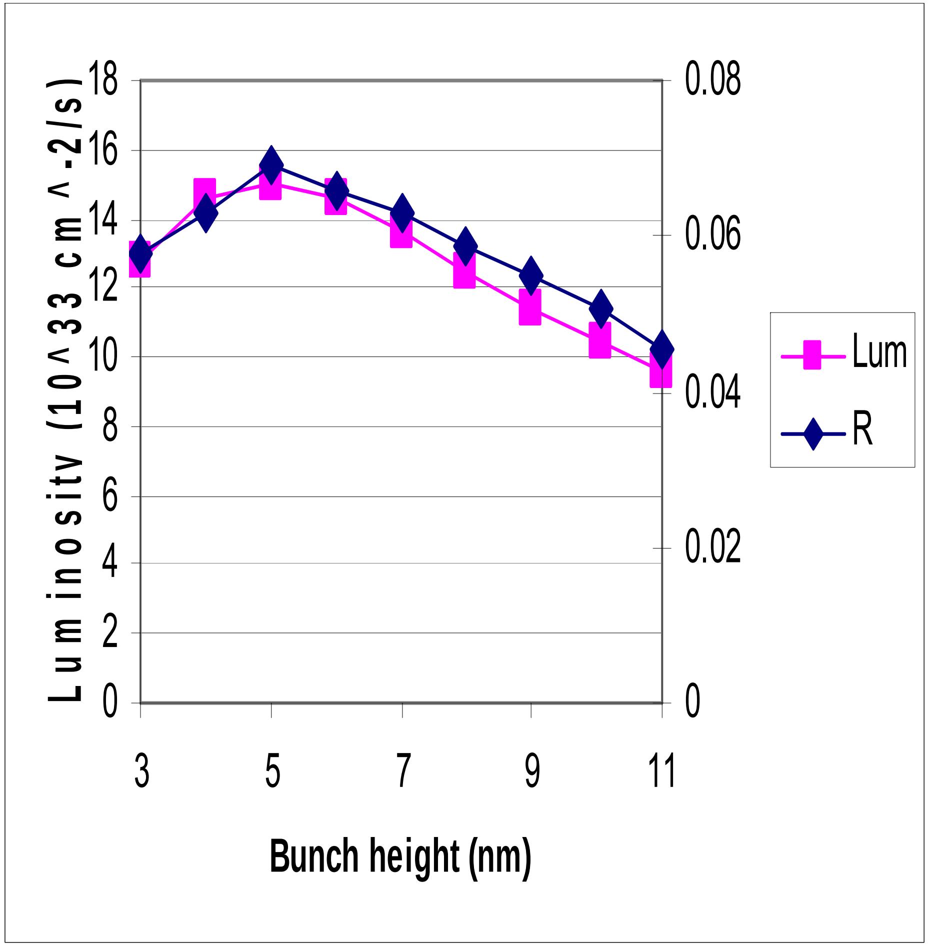
Comparison

- Sign of dE/d(bunch characteristic) at design values. Note that all five lines are different, which means complementary information.

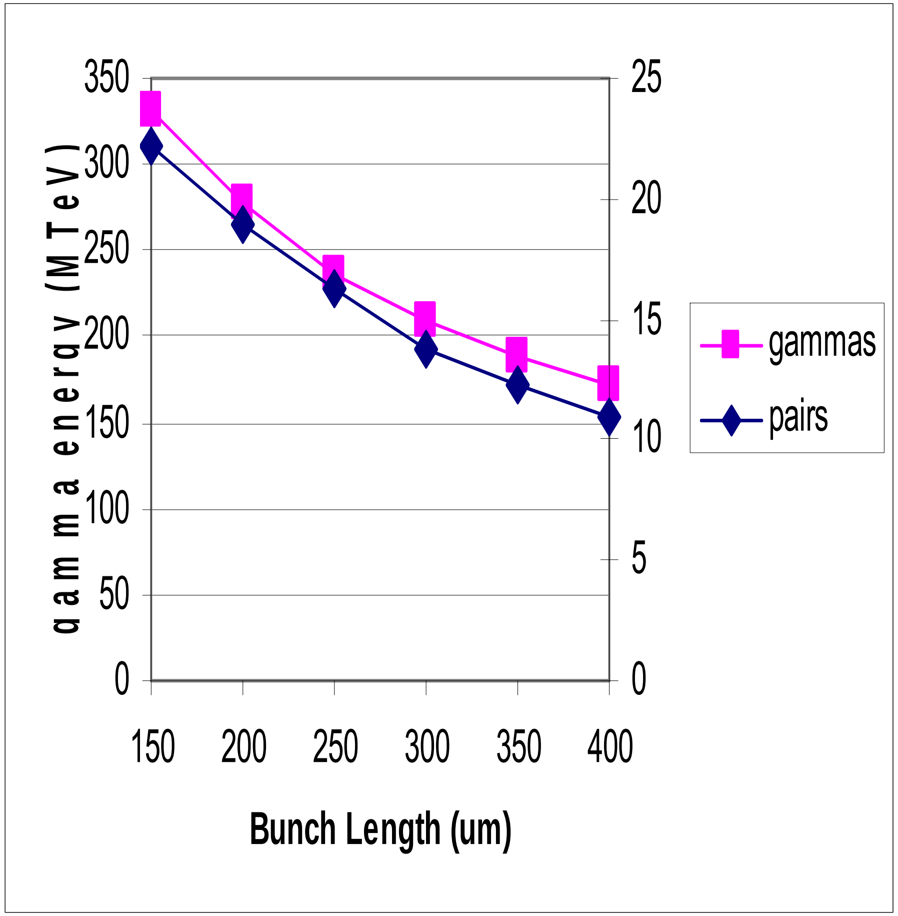
Parameter	Pairs	Gammas	Ratio
X offset	0 (max)	0 (max)	0 (max)
σ_z	-	-	≈0
σ_y	0 (max)	≈0	0 (max)
σ_x	-	-	-
Y offset	0 (max)	0 (min)	0 (max)

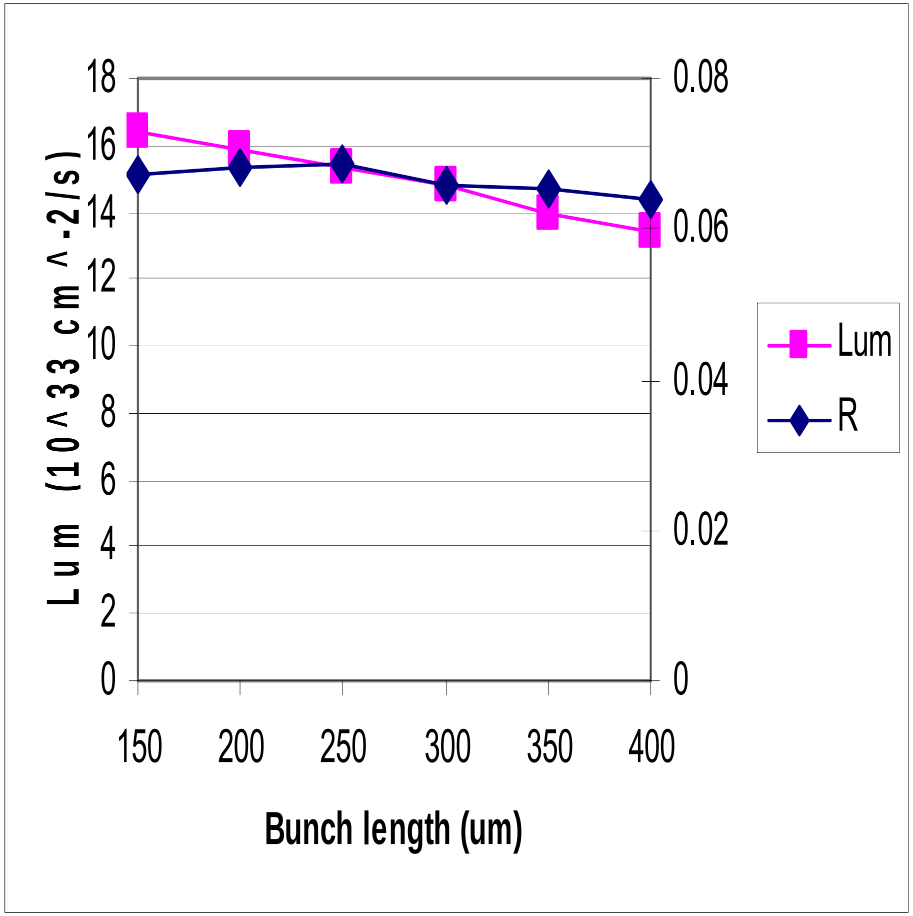
Bunch Height





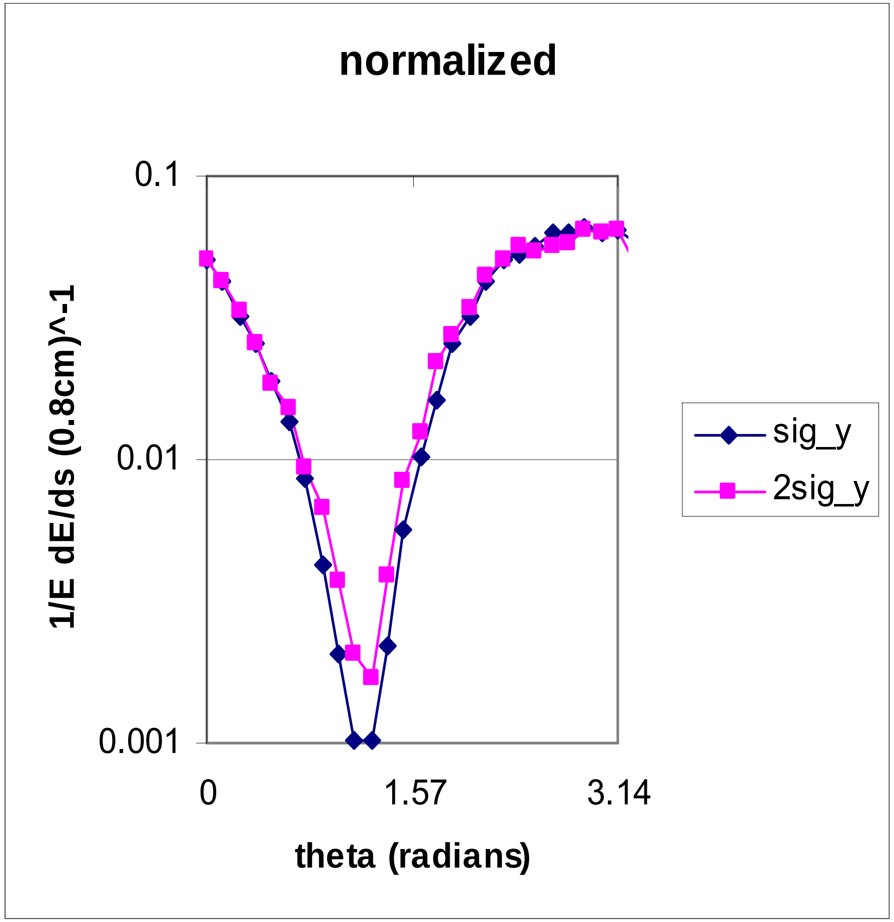
Bunch Length





Is There More Info in BeamCal?

- T.Tauchi,K.Yokoya
- Phys Rev E51,6119(95)
- 6<*r*<7cm azimuthal dist
- But, Moliere dia. ≈2cm!
- Also, ≈1 Bhabha/BX!
- Thus we need more simulation to show that it is robust enough.
- Christian Graf (DESY Zeuthen) has started.



Robust and Complementary

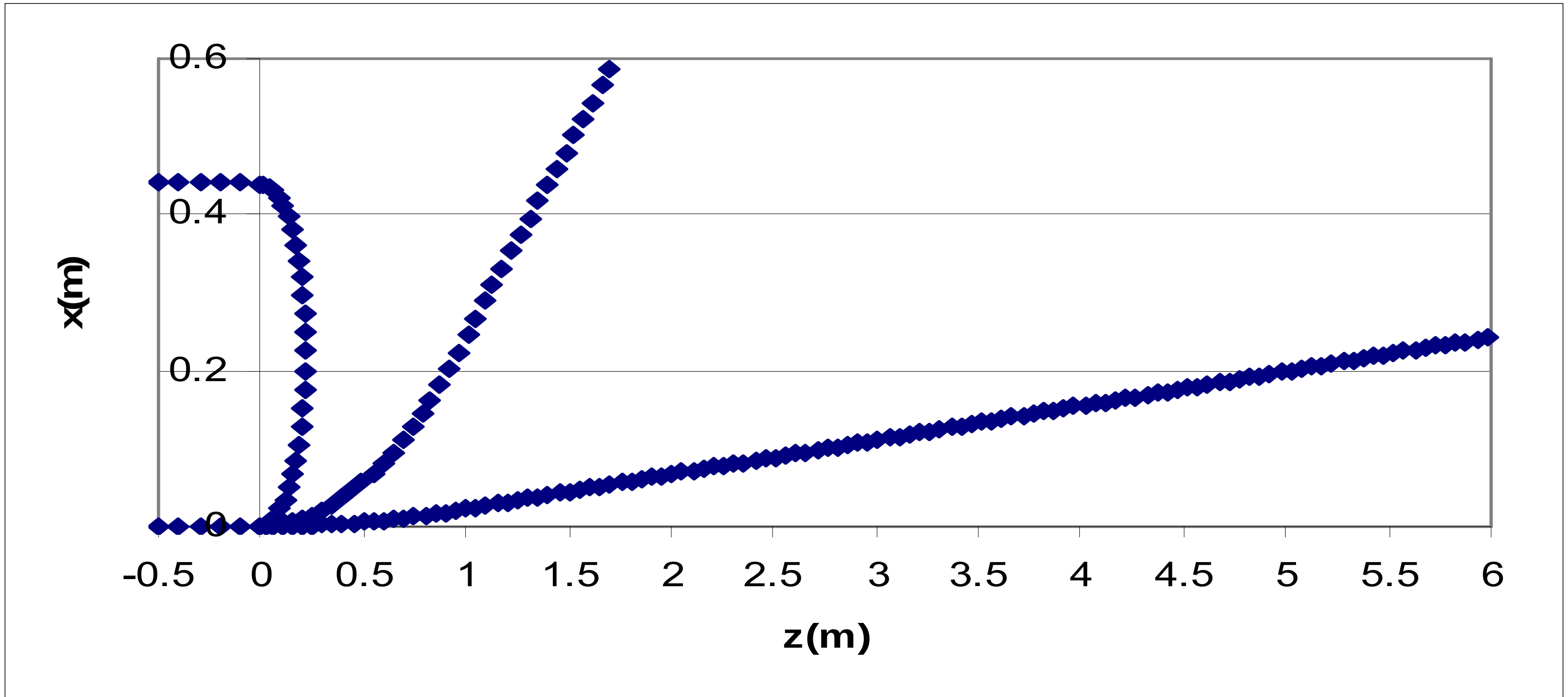
Luminosity, ie. R, is low. Note that all columns are different, ie. complementary information.

Detector	X offset	Y offset	σ_x	σ_y
PUE	$\pm x$	$\pm y$	Normal	Normal
E GamCal	Low	High	Low	Normal
E BeamCal	Low	Low	Low	Low

GamCal Detector Concepts

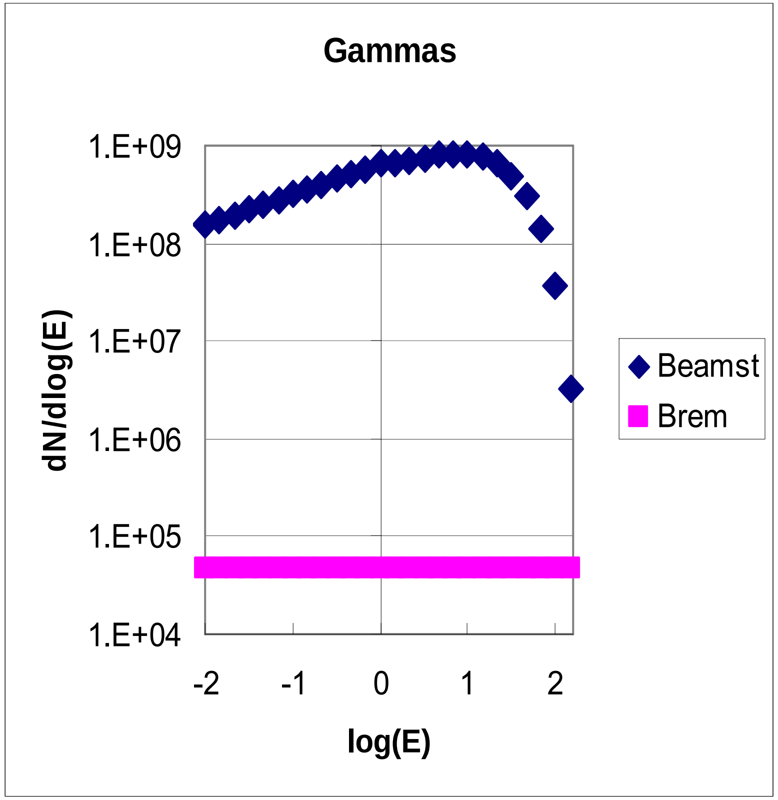
- 14mrad crossing angle
- $\approx 10^{-6}$ X_0 gas jet to convert beam-strahlung gammas into e^+e^- pairs
- Magnet to separate electrons from positrons
- Detect “wrong sign” particles
- Probably need to be after E/P detectors at z=175m
- GamCal z = 185m?

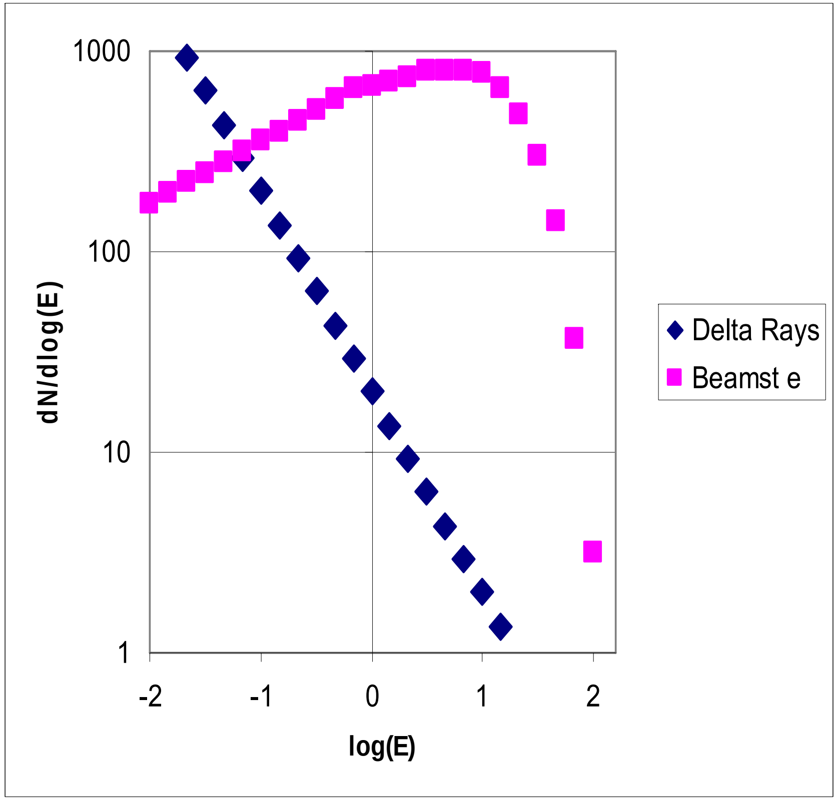
Large Crossing Angle GamCal



Gas jet followed by a 1m long 1.5T dipole magnetic field. Trajectories of positrons of momentum 0.1, 1, and 10 GeV/c are shown.

GamCal Backgrounds

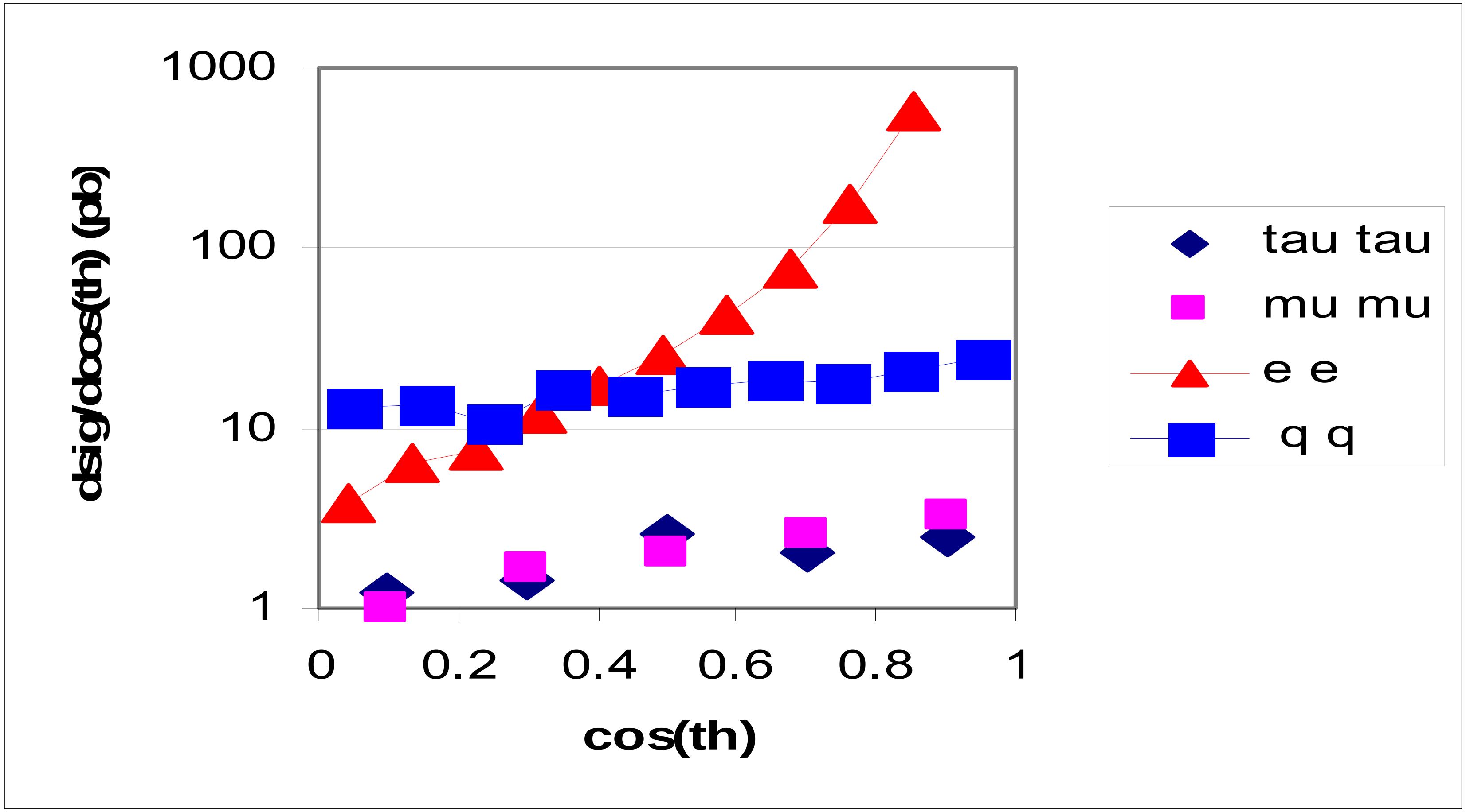




LumCal

- LumCal (20-140mrad) provides real time absolute luminosity measurement
- $\pm$10% every 5 minutes
- Hermeticity
- Need to study optimal cosθ range to get minimum Bhabha systematics with both beams polarized
- Goal is several 10^{-4} accuracy systematics

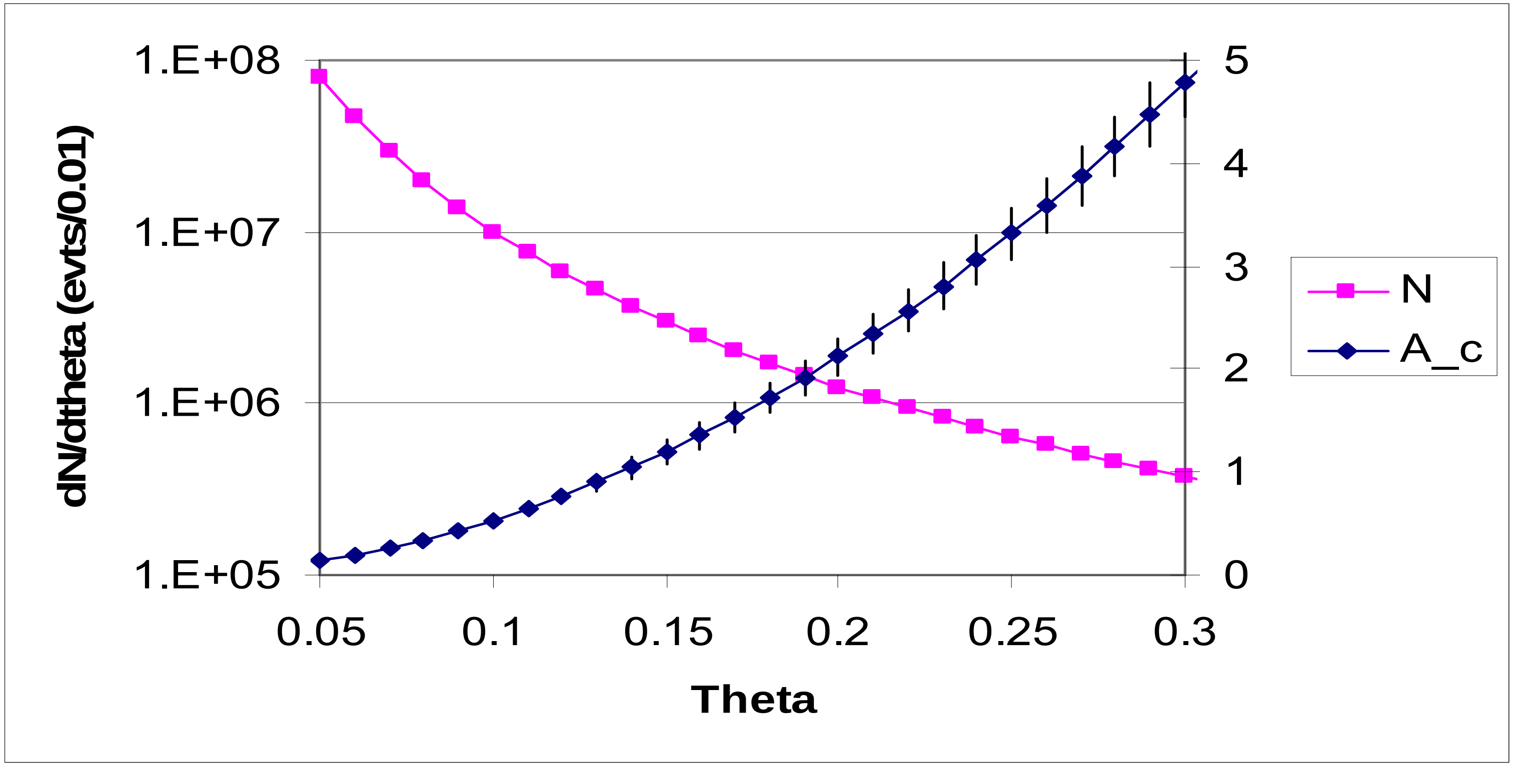
OPAL Data



1000
100
10
1
0
0.2
0.4
0.6
0.8
1
dsig/dcos(th) (pb)
cos(th)
tau tau
mu mu
e e
q q

But, if both beams are polarized

Asymmetry in percent (RHS) and dN/dθ per year (LHS) vs. the polar angle θ. The error bars on the Coulomb asymmetry correspond to 10^7 s running at nominal luminosity with 60% positron polarization, and 80% electron polarization.



Conclusions

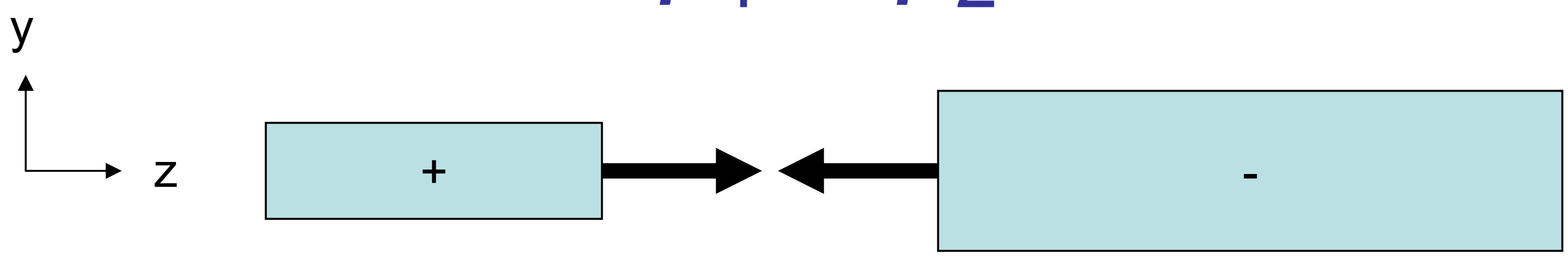
- We need robust, redundant information:
- Beam-beam deflections
- Beam-strahlung gammas
- Beam-strahlung pairs
- E(pairs)/E(gammas) particularly valuable
- Largely proportional to instantaneous luminosity

Conclusions

- BeamCal radiation damage issues.
- Readout electronics.
- What is optimal region for luminosity?
- Use real magnetic field with anti-solenoid for simulations.

Extra Slides

$\rho_1 \neq \rho_2$



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

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

Perfect Collisions

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