Beamdiagnostics using BeamCal

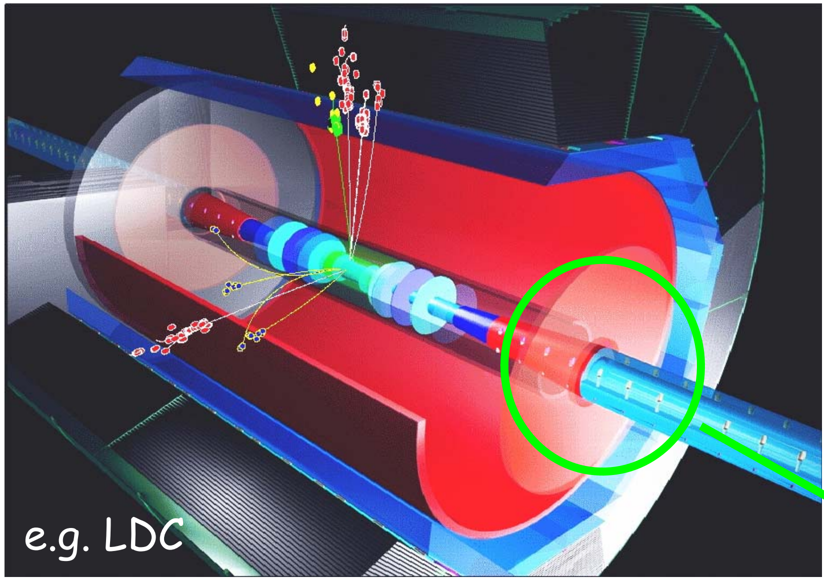
C.Grah

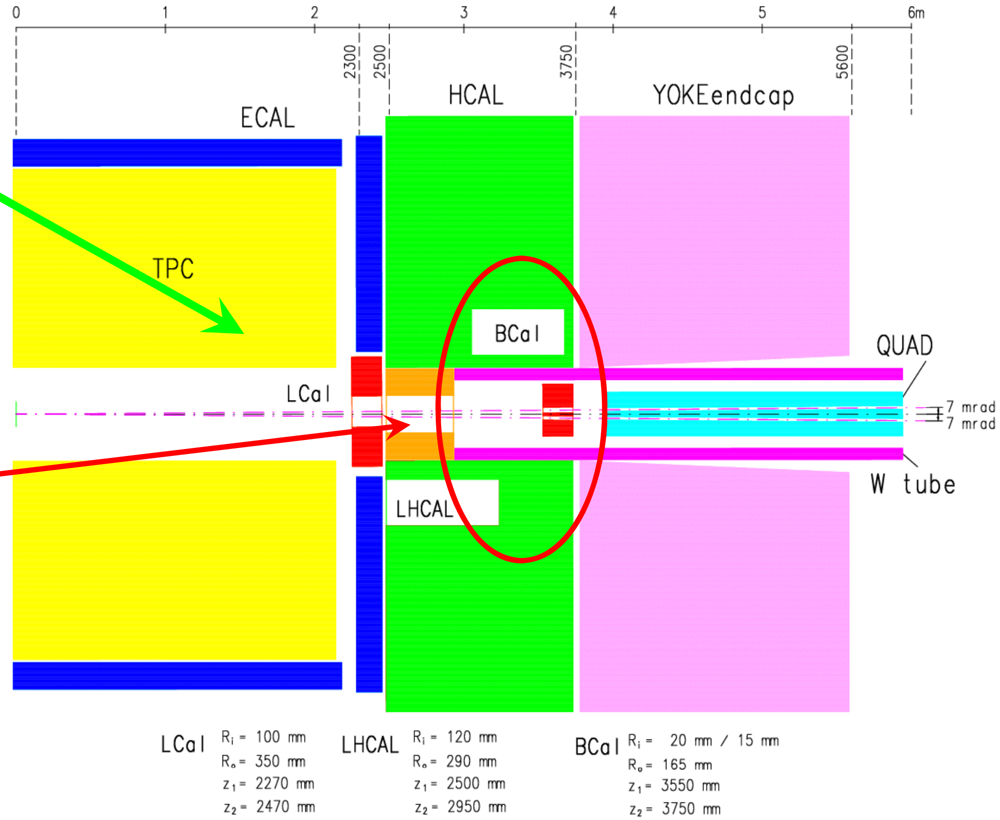
FCAL Workshop, Paris, 5.10.2007

Overview

- Very Forward Region and BeamCal
- Fast beam parameter reconstruction using the Geant4 based simulation BeCaS
- Possible reduction of information for beamdiagnostics (readout electronics)
- Including Beamstrahlung photons
- Summary and plans

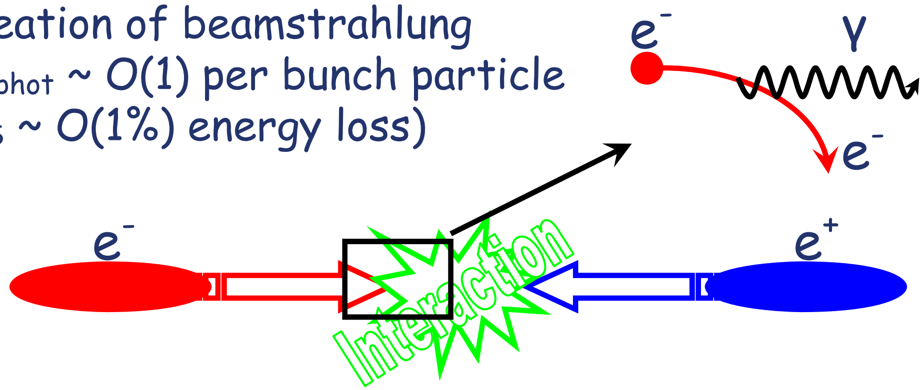
The Forward Region

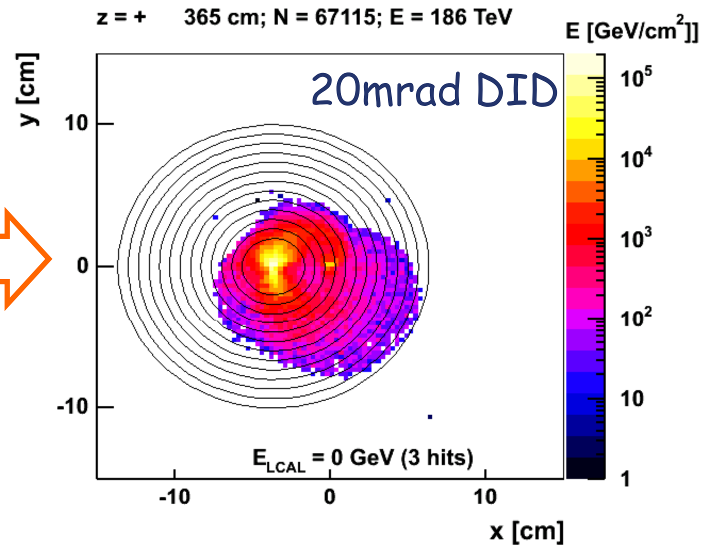




BeamCal will be hit by a large amount of electron-positron pairs stemming from beamstrahlung.

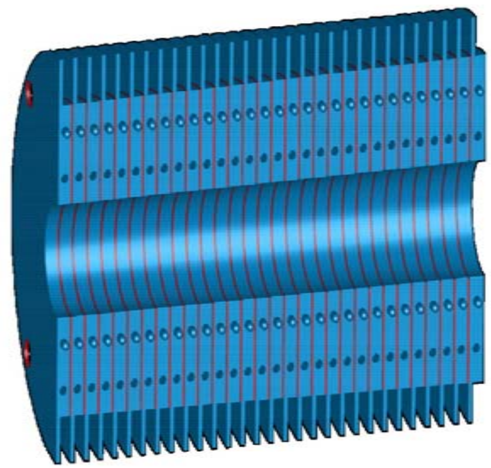
Creation of beamstrahlung
(N_{phot} ~ O(1) per bunch particle
δ_{BS} ~ O(1%) energy loss)





BeamCal: sandwich em. calorimeter
Length = 30 X_0
3.5mm W + .5mm radiation hard sensor
~ 10^4 - 10^5 channels of ~0.8 R_M
~ 1.5 cm < R < ~10(+2) cm
Each sensor layer divided into 8-9 sectors.

Space for electronics



BeamCal: 4 < θ < 28 mrad

Requirements on BeamCal

- Efficiently detect single high energetic particles at lowest polar angles.
- Shield the Inner Detector against backscattering from beamstrahlung pairs.
- Use the pair background signal to improve the accelerator parameters.
  - **The spatial distribution of the energy deposition from beamstrahlung pairs contains a lot of information about the collision.**
  - **Use a** fast **algorithm to extract beam parameters like:**

beam sizes (σ_x, σ_y and σ_z)
emittances (ε_x and ε_y)
offsets (Δ_x and Δ_y)
waist shifts (w_x and w_y)
angles and rotation (α_h, α_v and φ)
Particles per bunch (N_b)

Concepts of the Beamstrahlung Pair Analysis

Simulate Collision
with **Guineapig**
1.) nominal parameter set
2.) with variation of a specific beam parameter
(e.g. σ_x, σ_y, σ_z, $\Delta\sigma_x$, $\Delta\sigma_y$, $\Delta\sigma_z$)
G.White: 2nd order dependencies

Produce photon/pair output ASCII File

A.Stahl: beammon.f

Extrapolate pairs to BeamCal front face and determine energy deposition (geometry and magnetic field dependent)

Calculate Observables and write summary file

A.Sapronov: BeCaS1.0

Run full GEANT4 simulation BeCaS and calculate energy deposition per cell (geometry and magnetic field dependent)

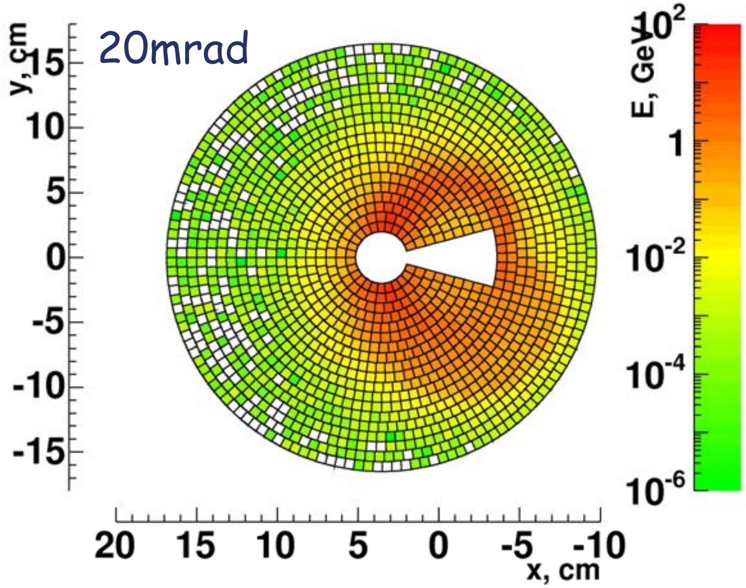
Calculate Observables and write summary file

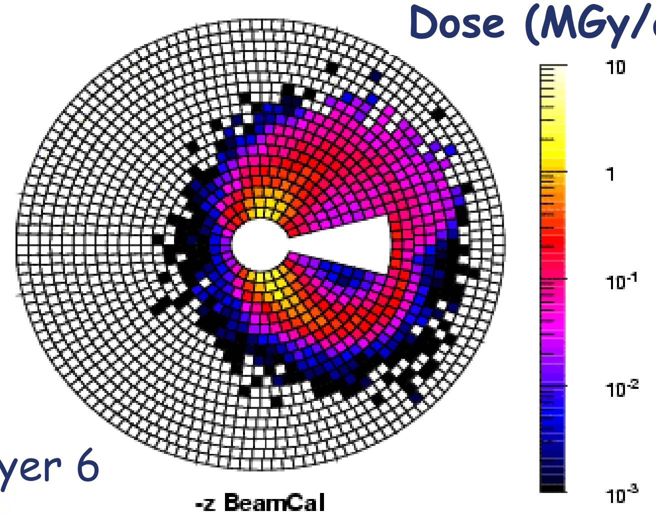
Do the parameter reconstruction using
1.) linear approximation (Moore Penrose Inversion Method)
2.) using fits to describe non linear dependencies

LC-DET-2005-003
Diagnostics of Colliding Bunches from Pair Production and Beam Strahlung at the IP
Achim Stahl

Geant 4 Simulation - BeCaS

- A Geant4 (4.8.0) BeamCal simulation has been set up (A.Sapronov).
- BeCaS can be configured using a configuration file to run with:
  - different crossing angles: 0, 2, 14, 20mrad corresponding geometry is chosen
  - various magnetic field types (solenoid, (Anti) DID, use field map)
  - detailed material composition of BeamCal including sensors with metallization, absorber, PCB, air gap
  - Root tree output containing energy deposition per cell
- **Also used to determine radiation levels.**
  TID ≤ 10 MGy/a
  NIEL (in work)

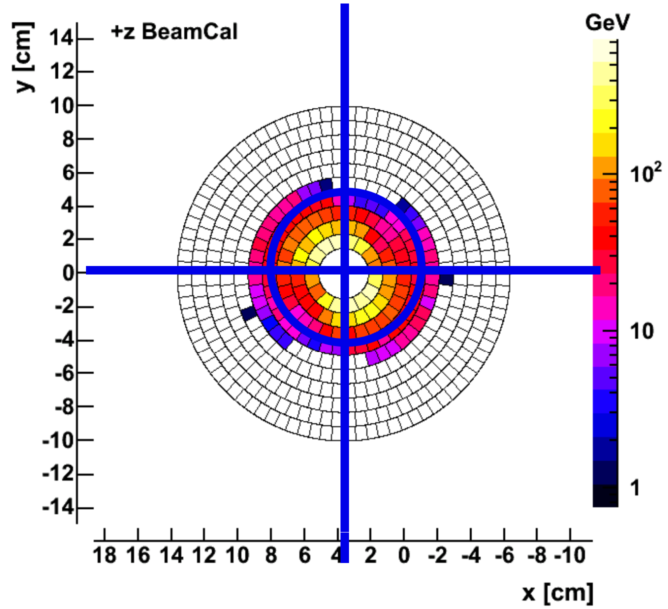




Layer 6

Moore Penrose Method

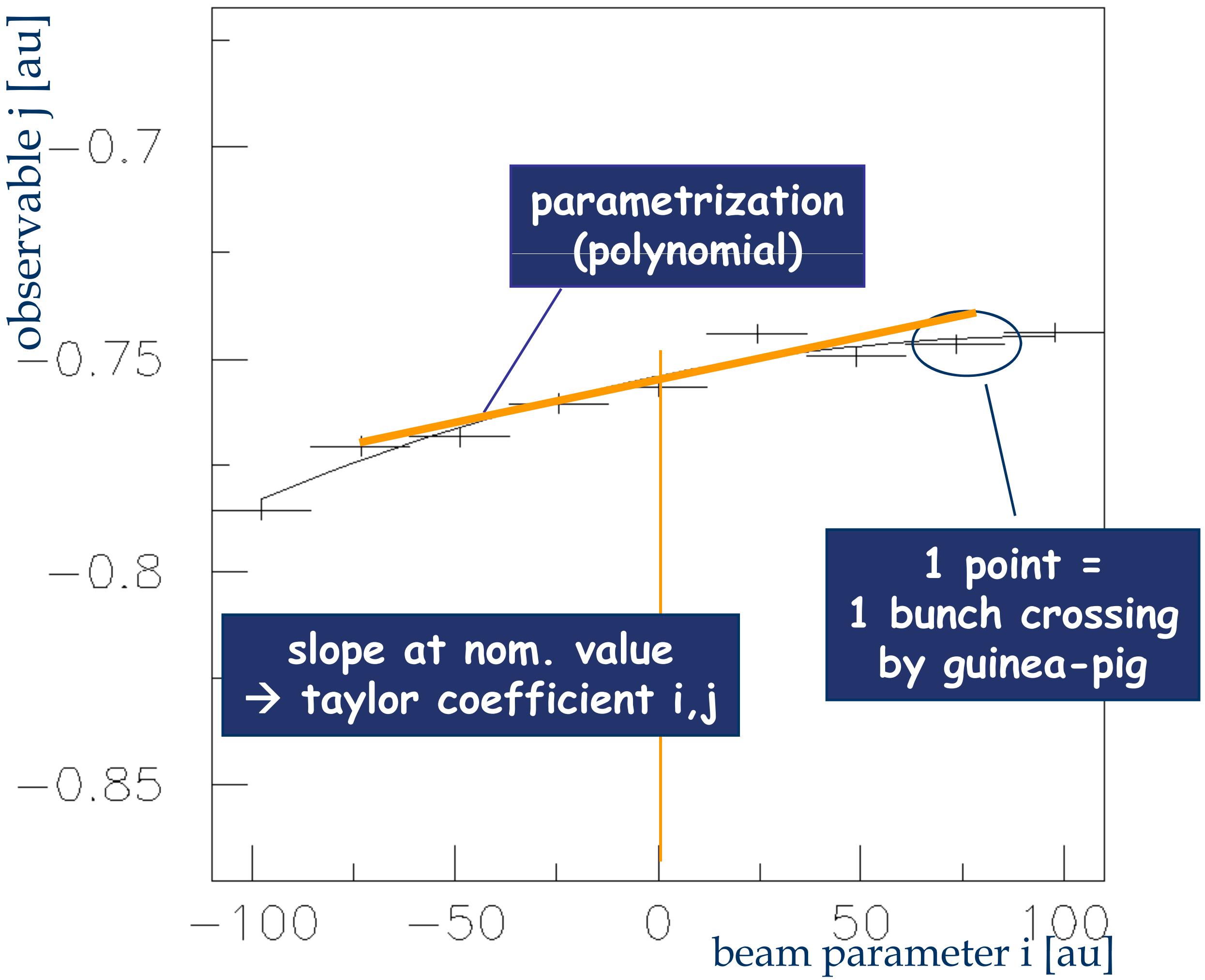
$$\left(\text{Observables}\right) = \left(\text{Observables}\right)_{nom} + \left(\text{Taylor Matrix}\right) * \left(\Delta\ \text{BeamPar}\right)$$

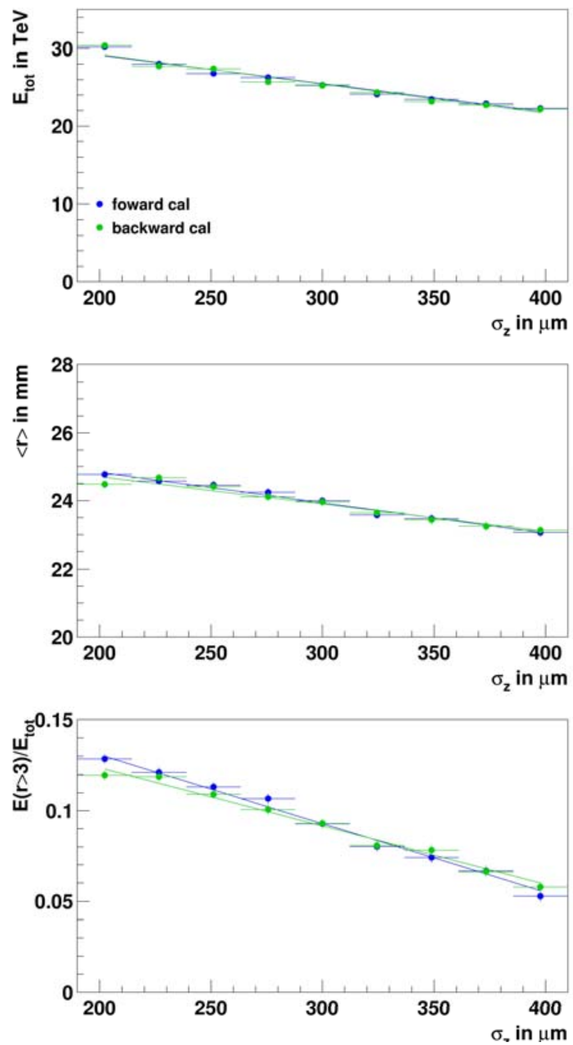


- observables:
  - total energy
  - first radial moment
  - inv. radial moment
  - l/r, u/d, diag asymmetries
  - E(ring ≥ 4) / Etot
  - E / N
  - phi moment
  - inv. phi moment
  - f/b asymmetries
  - total photon enegery (extern)

- beam parameters (diff and av)
  - bunch sizes
  - emittances
  - beam offsets
  - waist shifts
  - bunch rotations
  - profile rotations
  - number of particles

1^{st} order Taylor Matrix

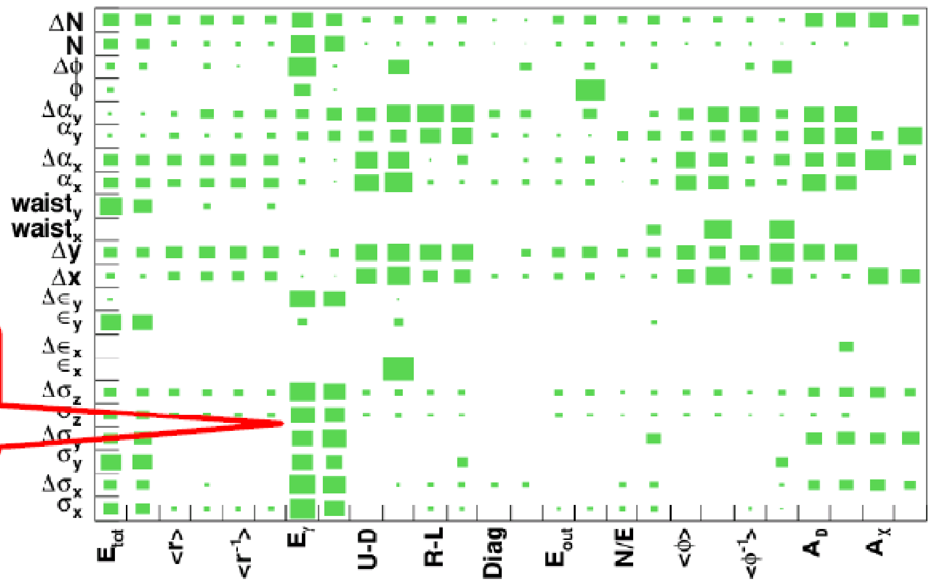




Beam Parameter Reconstruction

Single parameter reconstruction using whole calorimeter data

BP	Unit	Nom.	2mrad (old) μ	2mrad (old) σ	20mrad DID μ	20mrad DID σ	20mrad DID + Ephot μ	20mrad DID + Ephot σ	14mrad antiDID + Ephot μ	14mrad antiDID + Ephot σ
σ_z	μm	300	300.75	**4.56**	307.98	**4.72**	299.80	**1.69**	301.09	**1.65**
ε_x	10^{-6}m rad	10	11.99	**7.61**	-	-	-	-	9.94	**2.16**
Δx	nm	0	4.77	**14.24**	4.55	**8.14**	4.57	**8.13**	-3.84	**11.80**
α_x	rad	0	0.002	**0.016**	0.010	**0.025**	-0.001	**0.025**	-0.071	**0.017.**



High significance of information from gammas for bunch sizes reconstruction.

A.Sapronov

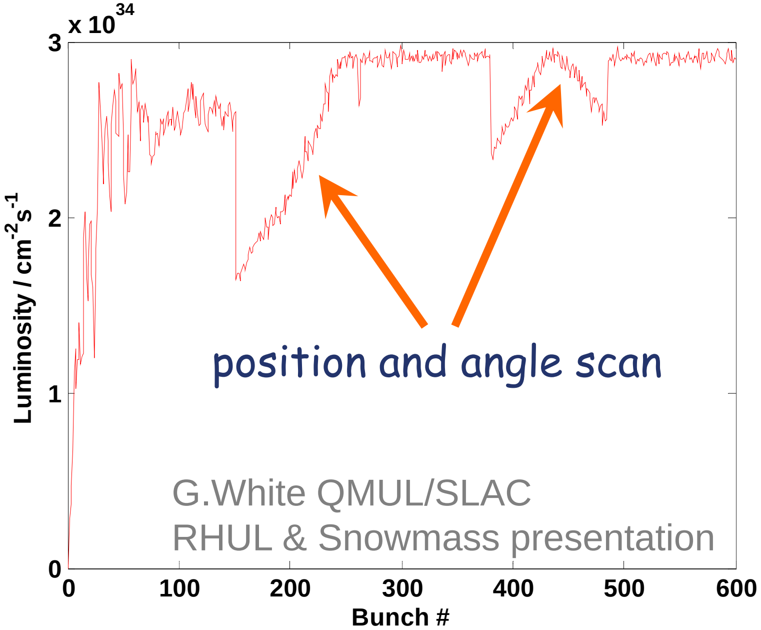
Photon energy can be provided by GamCal.

GamCal – Using Photon Information

- Use as much information about the collision as possible.
- BeamCal measures the energy of pairs originating from beamstrahlung.
- GamCal will measure the energy of the beamstrahlung photons.

1. Investigate correlation to learn how we can improve the beamdiagnostics and
2. define a signal proportional to the luminosity which can be fed to the feedback system.

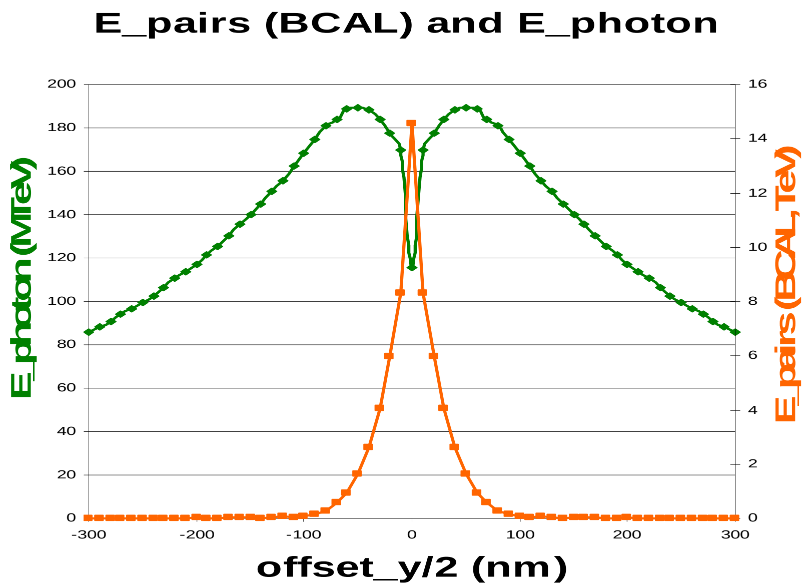
Simulation of the Fast Feedback System of the ILC.

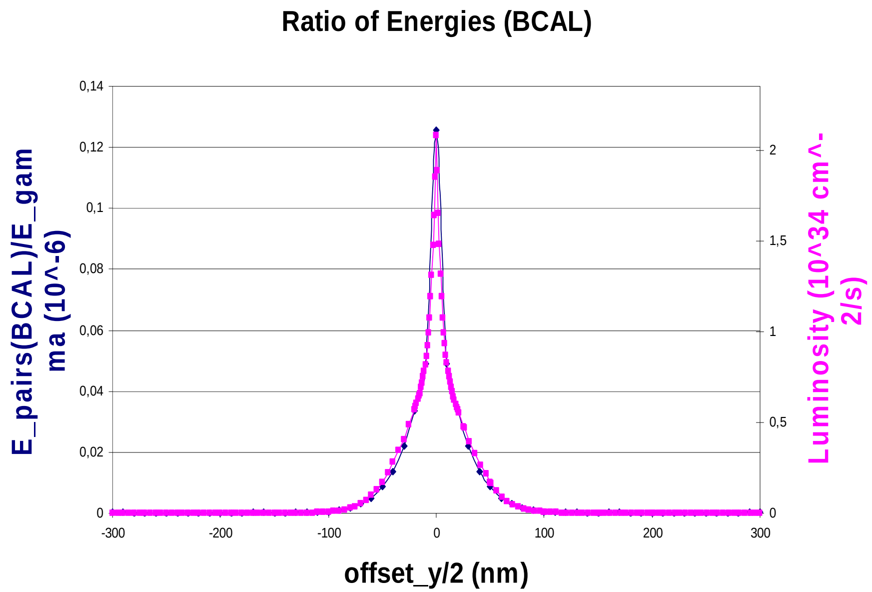


1. Standard procedur (using BPMs)
2. Include pair signal (N) as additional input to the sytsem

Increase of luminosity of 10 - 15%

Vertical Offset (y-direction)





complementary information from
1. total photon energy vs offset_y
2. BeamCal pair energy vs offset_y

ratio of E_pairs/E_gam vs offset_y is proportional to the luminosity

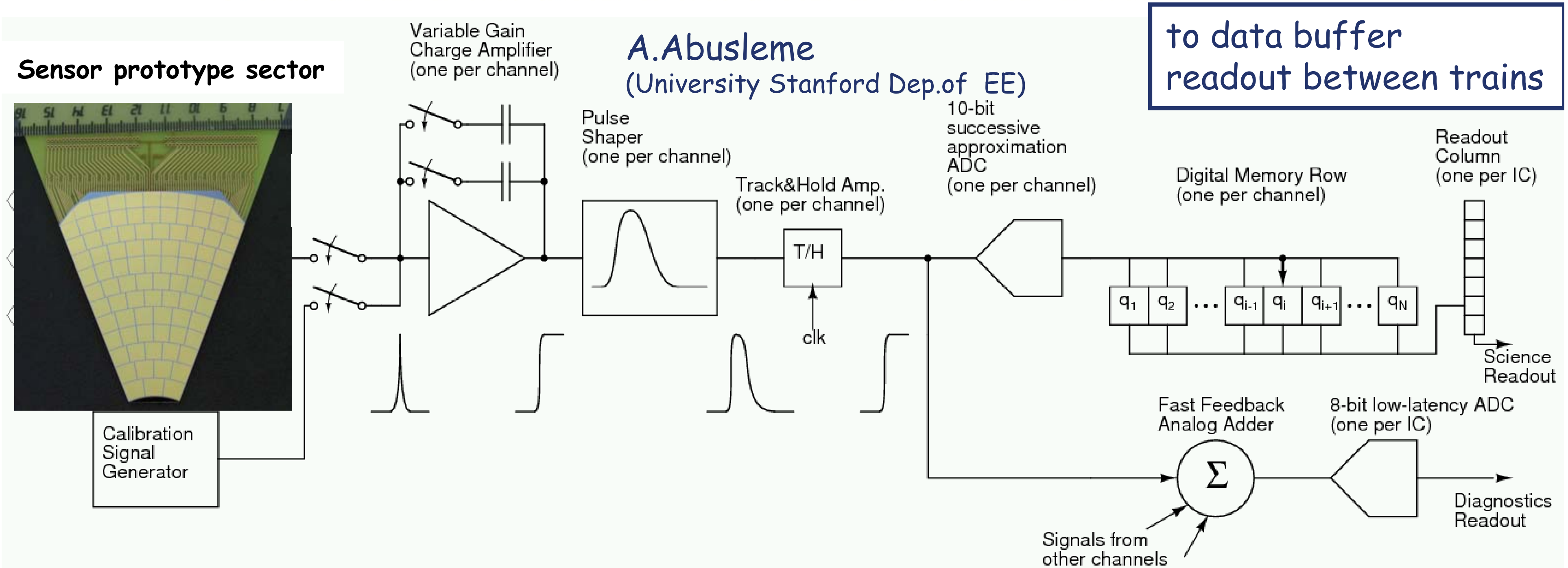
similar behaviour for angle_y, waist_y …

Studies by M.Ohlerich

BeamCal Electronics

A.Abusleme
(University Stanford Dep.of EE)

to data buffer
readout between trains



to feedback system
(FONT)
real time + low latency!

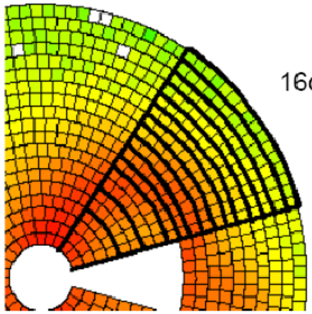
- Dual gain front-end
- Successive approximation ADC 1/ch
- Digital memory to store information of 1 train/ch
- Analog addition <u>of 32 ch</u> for fast feedback

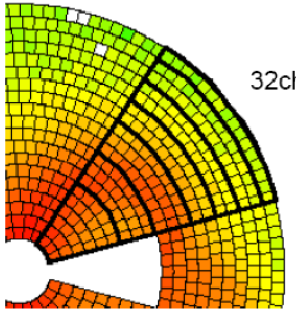
see also: EUROTeV-Memo-2006-004-1

Data Reduction

Scenarios of data reduction for the reconstruction of beam parameters:

- use not all layers (6th layer)
- use 32/16 channel clusters
- digitized information





			full details		digitized		16 channels		32 channels	
BP	Unit	Nom.	μ	σ	μ	σ	μ	σ	μ	σ
σ_x	μm	655	653.72	**1.29**	653.84	**1.35**	653.97	**1.30**	654.04	**1.27**
$\Delta\sigma_x$	μm	0.	-1.72	**2.01**	-1.87	**2.08**	-1.65	**2.01**	-1.65	**2.02**
σ_z	μm	300	300.90	**1.69**	300.35	**1.63**	300.48	**1.56**	300.39	**1.47**
$\Delta\sigma_z$	μm	0.	-0.59	**1.82**	-1.26	**1.97**	-0.41	**1.77**	-0.33	**1.82**
ε_x	10^{-6}m rad	10	10.18	**2.62**	9.71	**2.62**	10.18	**2.62**	10.18	**2.62**
Δx	nm	0	-5.35	**11.51**	-9.82	**12.63**	-7.26	**9.80**	-7.78	**9.76**
α_x	rad	0	-0.056	**0.019**	-0.119	**0.017**	-0.076	**0.025**	-0.077	**0.025**

Bhabha Events

- Overlayed a Bhabha event in each reconstructed event (expected: 0.13/BX) (COMPHEP)

			full BeamCal no bhabbhas		bhabhas	
BP	Unit	Nom.	μ	σ	μ	σ
σ_x	μm	655	653.799	**1.33**	653.17	**1.56**
$\Delta\sigma_x$	μm	0.	-0.96	**2.12**	-1.15	**2.47**
σ_z	μm	300	301.09	**1.65**	300.10	**2.47**
$\Delta\sigma_z$	μm	0.	-0.67	**1.90**	-0.79	**2.17**
ε_x	10^{-6}m rad	10	9.94	**2.16**	10.45	**2.93**
Δx	nm	0	-3.84	**11.08**	-5.03	**16.83**

Summary & Further Plans

- BeamCal is an important part of the ILC detector:
  - **Provides an efficient electron veto down to smallest polar angles (~5mrad)**
  - **Is carefully geometrically adjusted to keep backgrounds low**
  - **Provides fast feedback information to tune the ILC beams.**

- A Geant4 simulation of BeamCal (BeCaS) is ready for usage. The geometry of the forward region is for a large part parameterized.
- The photon energy is a valuable information to be included in the reconstruction.
- A subset of the detector information seems sufficient for beam parameter reconstruction.
- Overlayed bhabhas decrease the resolution slightly.

- Look on effects for a multiparameter reconstruction.
- Use full detector information for MP calculation and reduced set for reconstruction. Redefine clusters.
- **Implement BeamCal into Mokka.**
- Get/use the Real Beam simulation data.