Fast Luminosity Monitoring - FLUM

C.Grah

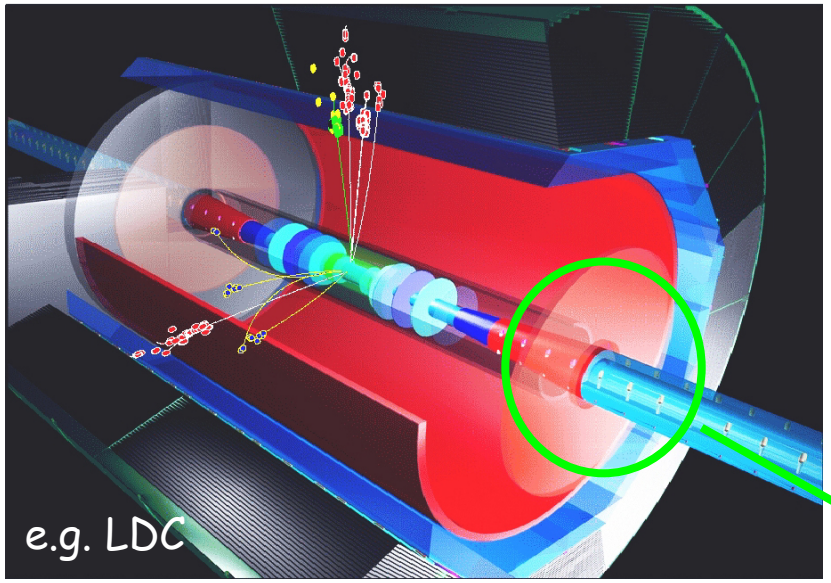
European LC Workshop

Daresbury, January 8th 2007

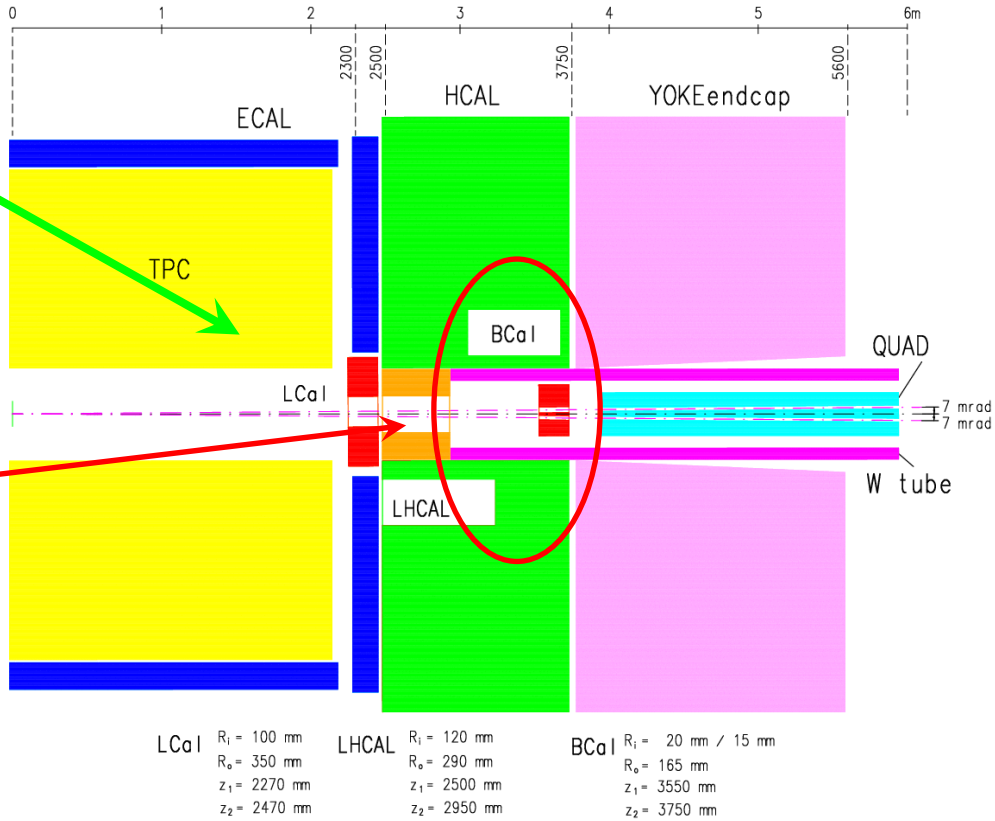
Overview

- Very Forward Region and BeamCal
  - **Changes since 2005**
- Fast beam parameter reconstruction
  - **Results for different setups**
- Geant4 Simulation
- Why we want to use a fast luminosity monitor…
- Beamstrahlung photons
- Summary

The Forward Region



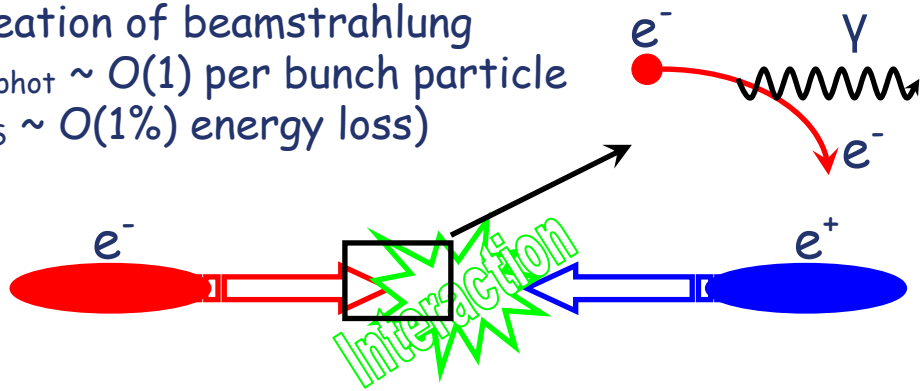
LDC V2
Shortened coil
LumiCal moved closer to the IP,
which improves the opening scheme
design for 14mrad beam crossing angle



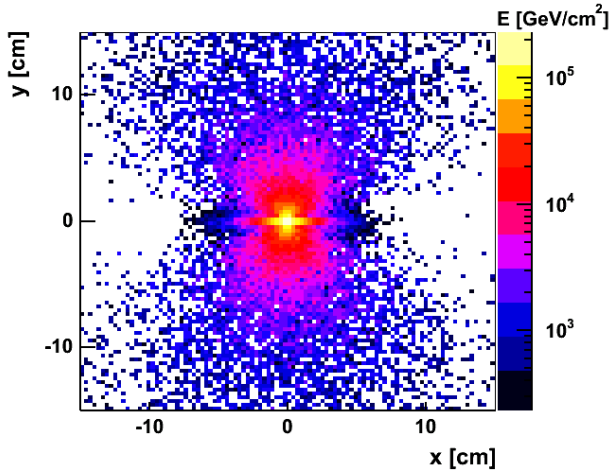
BeamCal will be hit by a large amount of electron-positron pairs stemming from beamstrahlung.

BeamCal Details

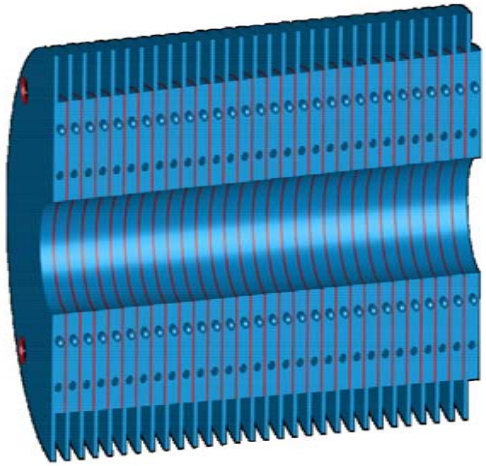
Creation of beamstrahlung
(N_{phot} ~ O(1) per bunch particle
δ_{BS} ~ O(1%) energy loss)



Incoherent e^+e^- - pairs at z=365



BeamCal: sandwich em. calorimeter
Length = 30 X_0
3.5mm W + .5mm radiation hard sensor
~ 10^4 - 10^5 channels
~ 1.5 cm < R < ~10(+2) cm



Space for electronics

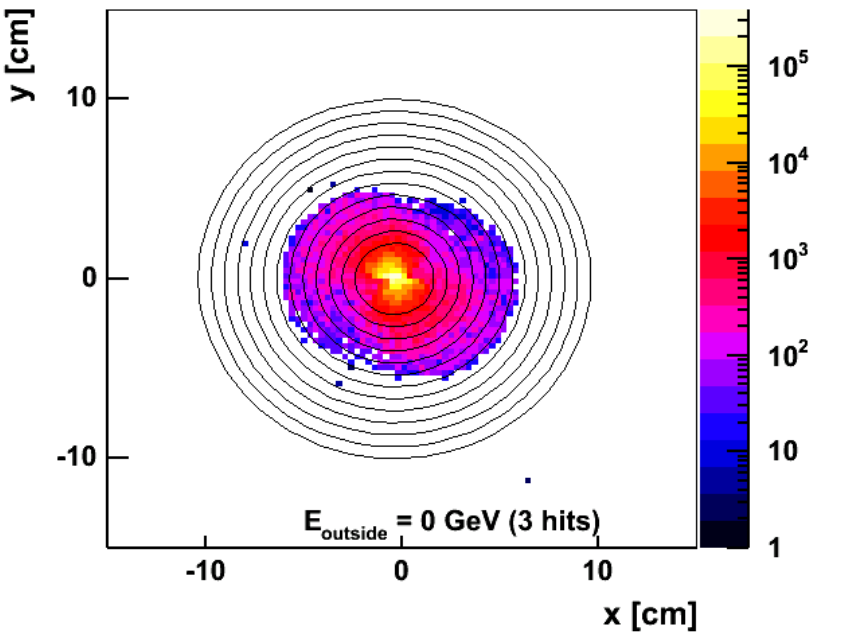
BeamCal: 4 < θ < 28 mrad

BeamCal Requirements

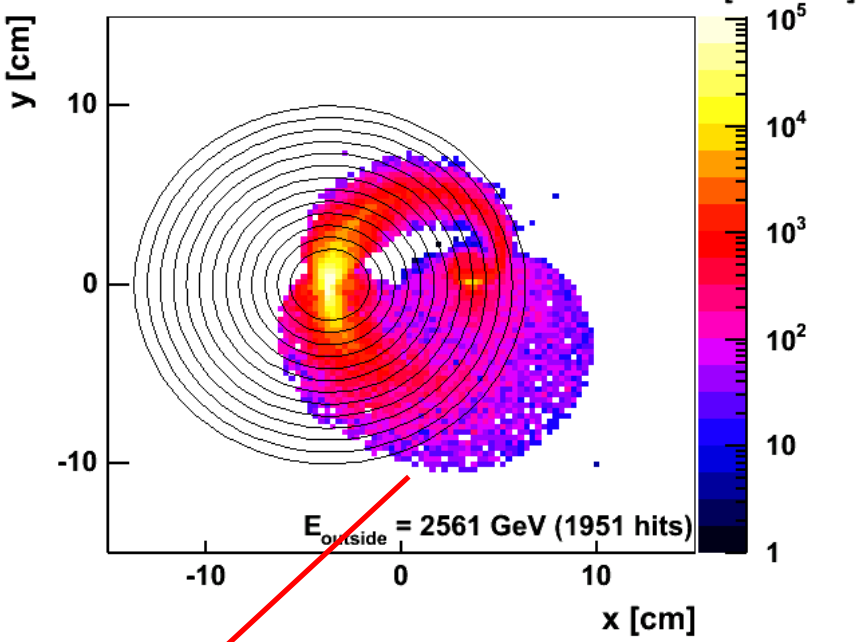
1. Minimize the amount of backscattered particles into the Inner Detector, while shielding QD0 against pairs from beamstrahlung.
2. Highly efficient detection (veto) single high energetic electrons (photons) at lowest angles.
3. Provide a signal for the use of luminosity optimization and beamdiagnostics (main part of this talk).

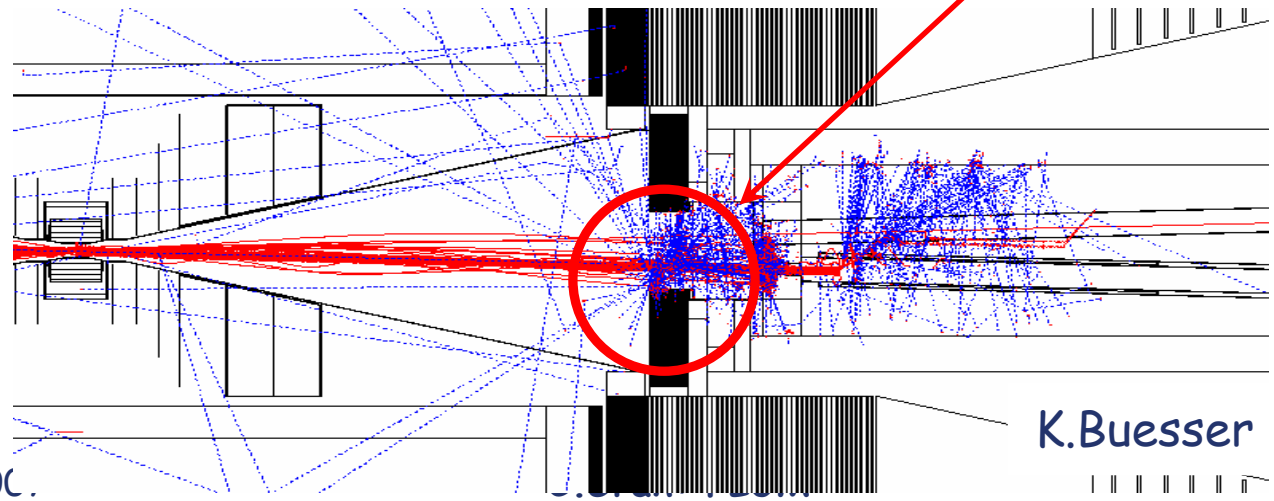
Impact of Large Beam Crossing Angles on the Forward Region

B_z=4T, 2mrad



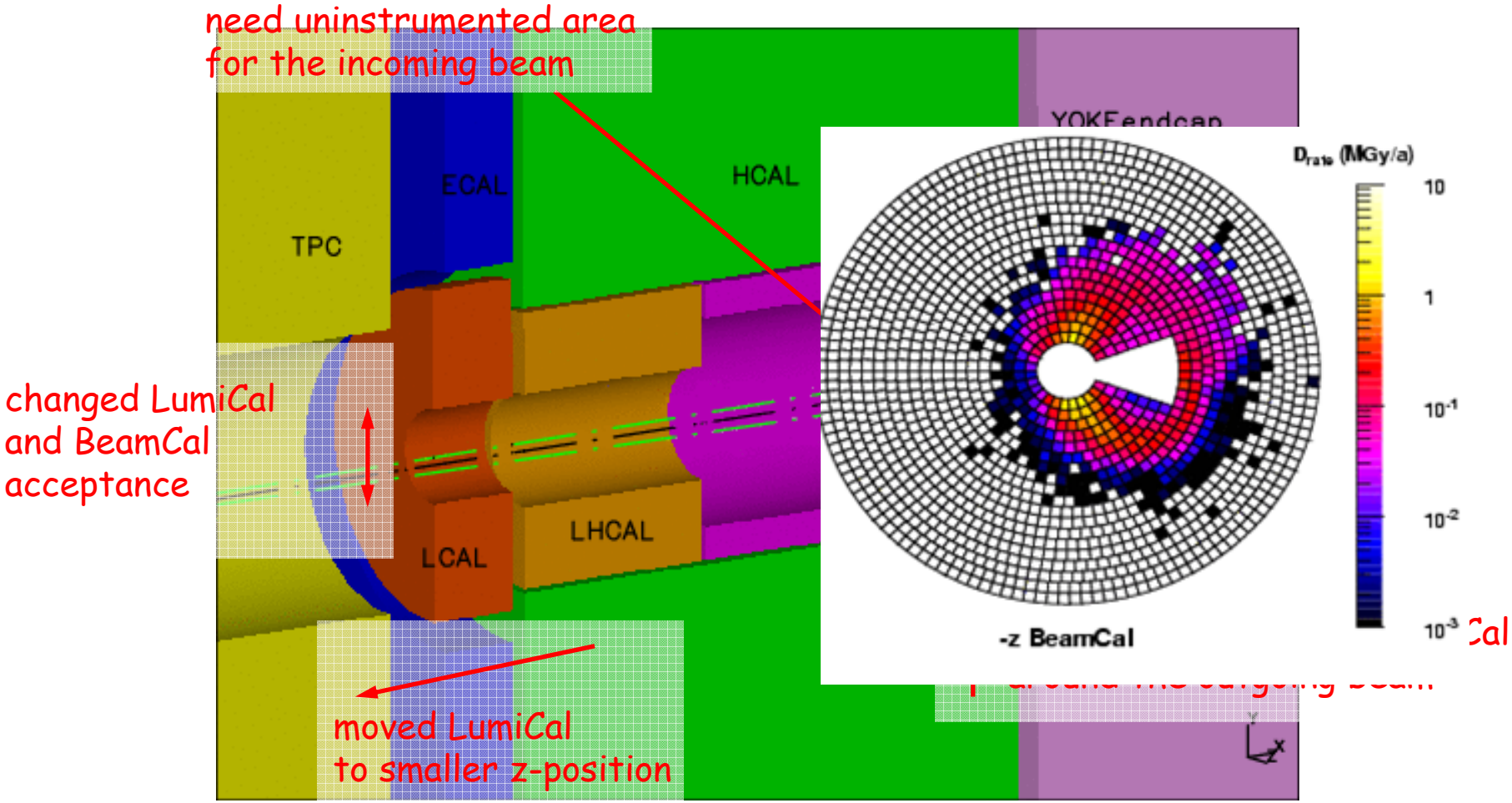
|B| = 4T, DID, 20mrad



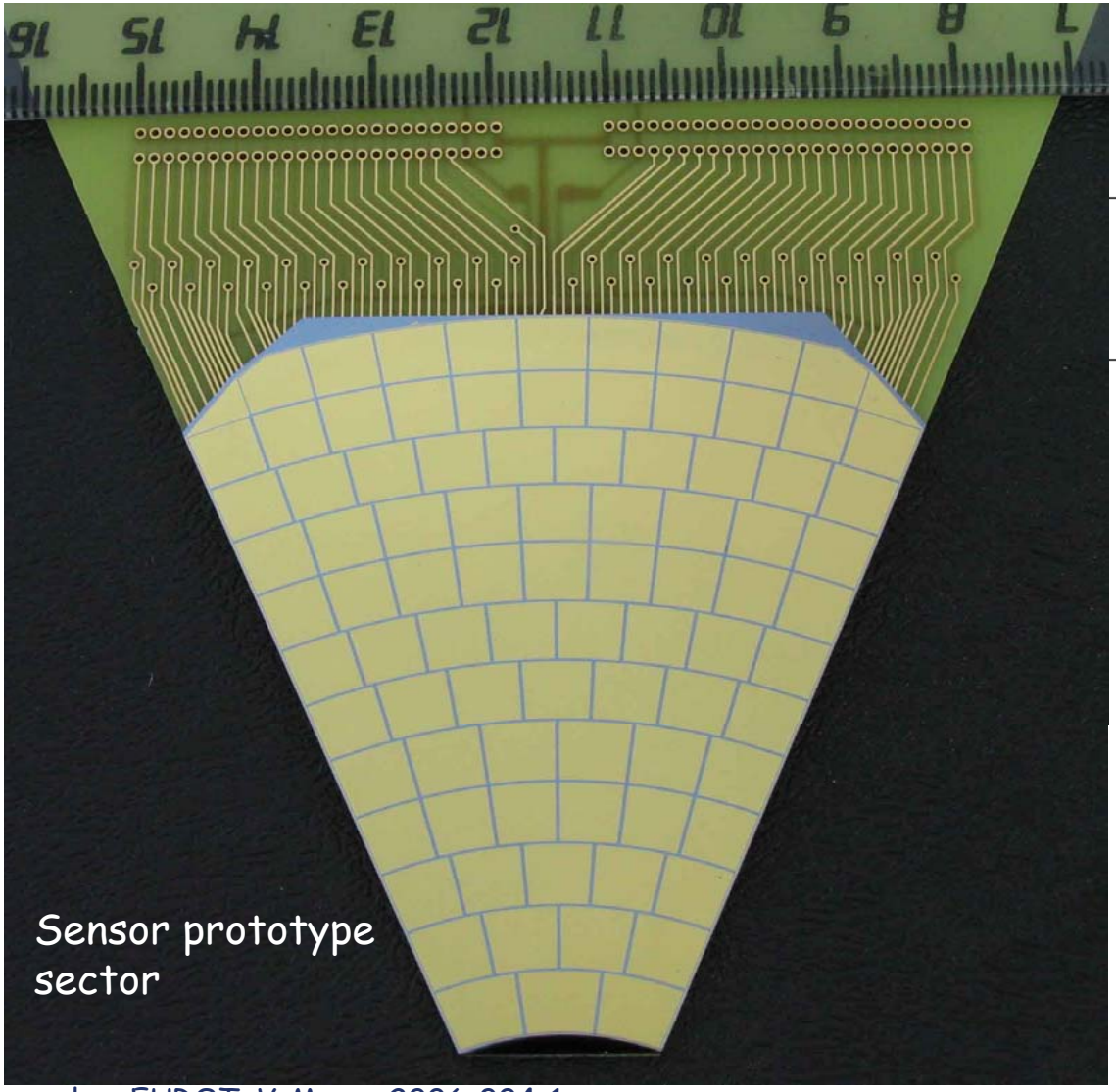


K.Buesser

Geometry for the new ILC baseline of 14mrad



Readout Scheme for BeamCal



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

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

Segmentation of the BeamCal Sensor Planes

- The efficient detection of single high energetic particles at lowest angles drives the segmentation needed of the very compact calorimeter. ($R_M \approx 1$cm)
- The technical feasibility (channel number) is the tradeoff.
- A smaller segmentation than $0.5 \times R_M$ does not improve the efficiency. $0.8 \times R_M$ decreases the veto performance only slightly at smallest radii.
- We chose $0.8 \times R_M$ as the baseline for the beamdiagnostics simulation.

What else can we learn about the collision?

- 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)

Concept 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)

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

Calculate Observables and write summary file

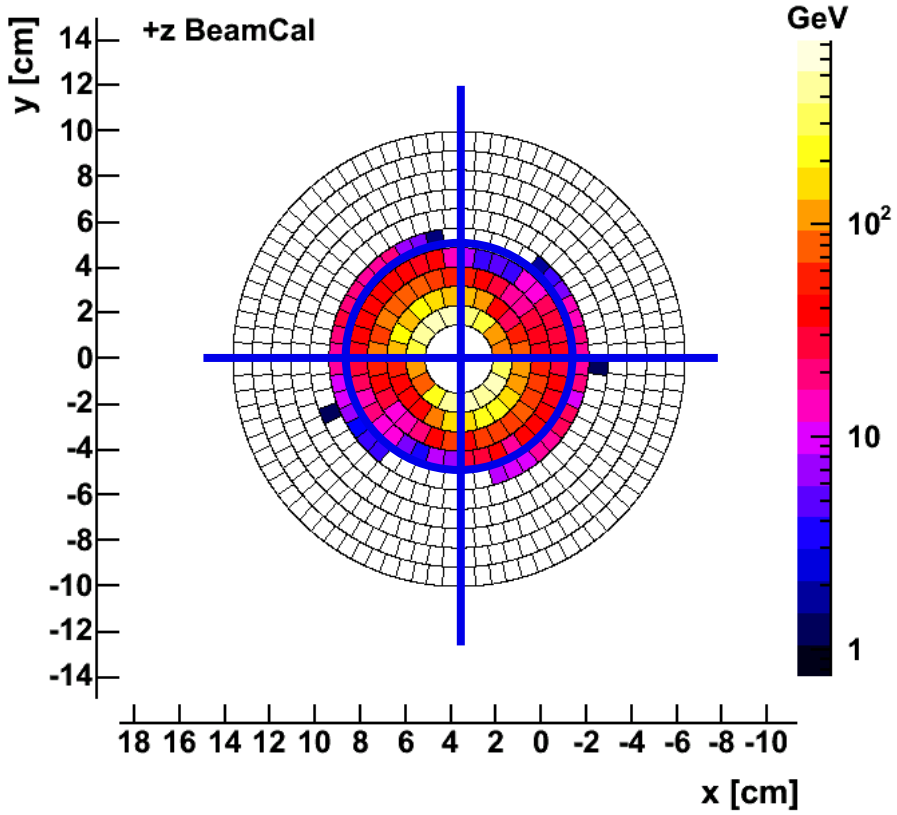
LC-DET-2005-003
Diagnostics of Colliding Bunches from Pair Production and Beam Strahlung at the IP
Achim Stahl

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

Moore Penrose Method

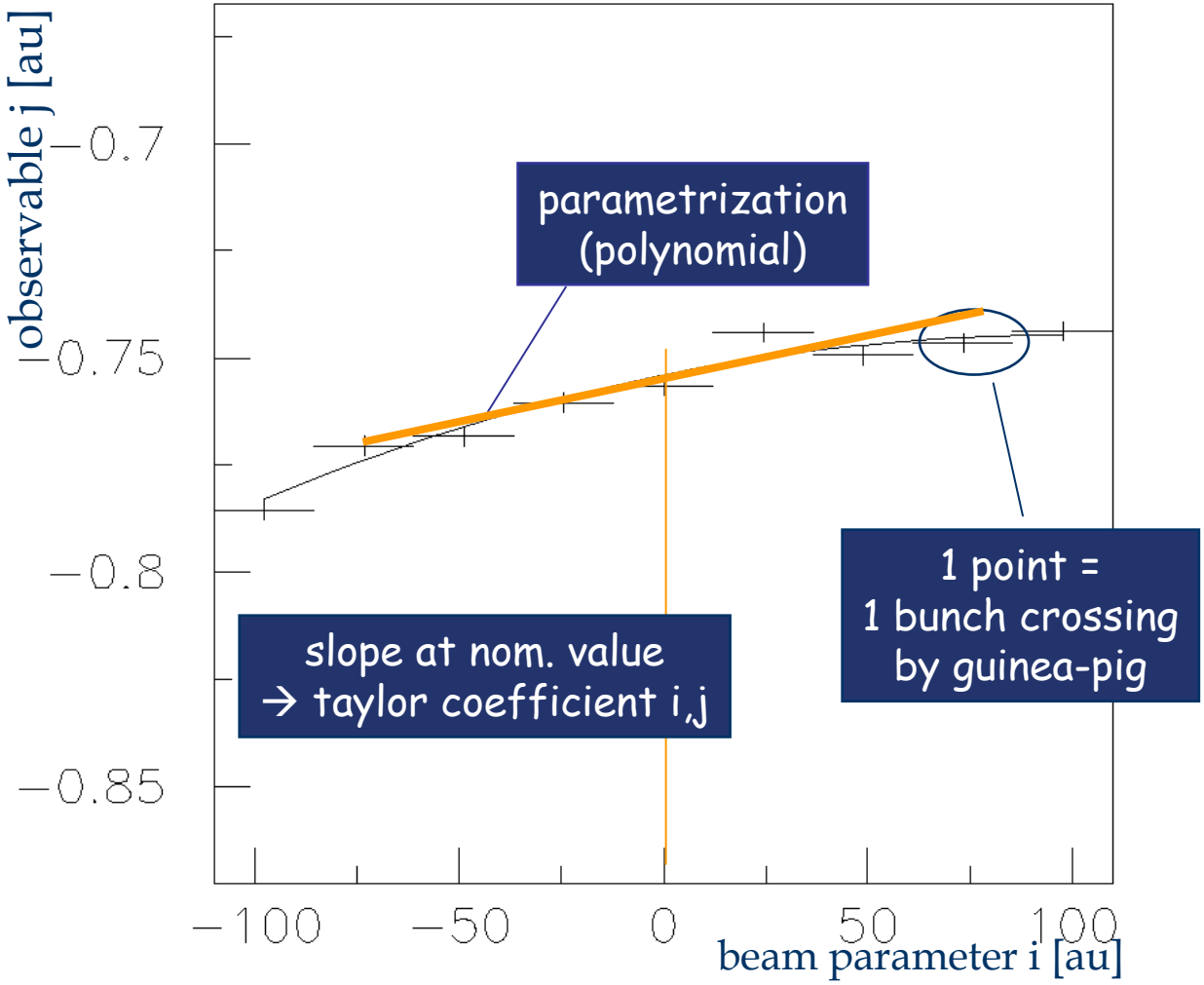
- Observables (examples):
  - total energy
  - first radial moment
  - thrust value
  - angular spread
  - E(ring ≥ 4) / Etot
  - r-φ observables T1, T2
  - E / N
  - l/r, u/d, f/b asymmetries

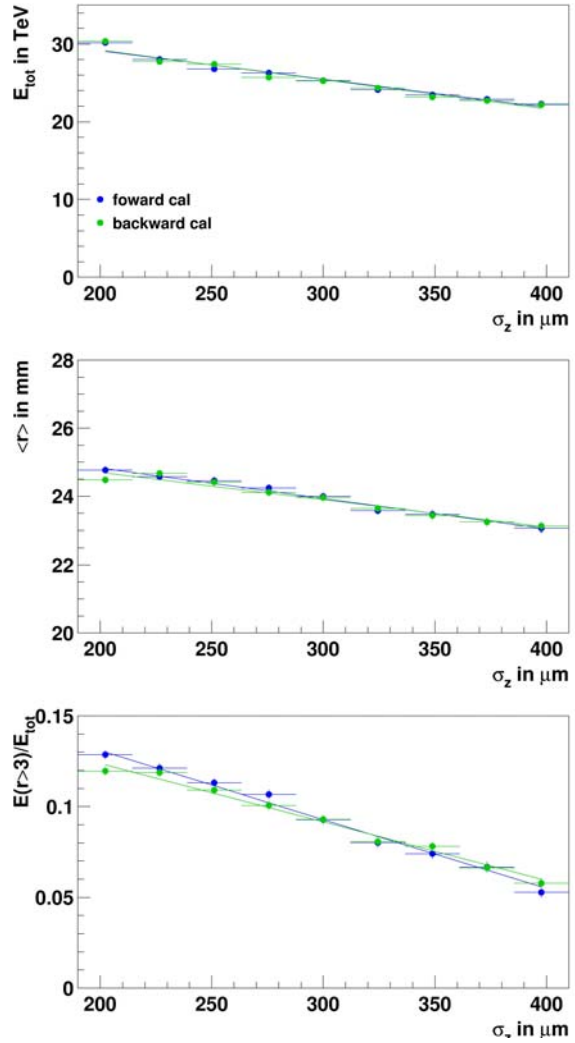
$$\begin{pmatrix}\text{Observables}\end{pmatrix} = \begin{pmatrix}\text{Observables}\end{pmatrix}_{nom} + \begin{pmatrix}\text{Taylor Matrix}\end{pmatrix} \begin{pmatrix}\Delta\ \text{BeamPar}^{*}\end{pmatrix}$$



detector: realistic segmentation, ideal resolution, bunch by bunch resolution

1st order Taylor Matrix





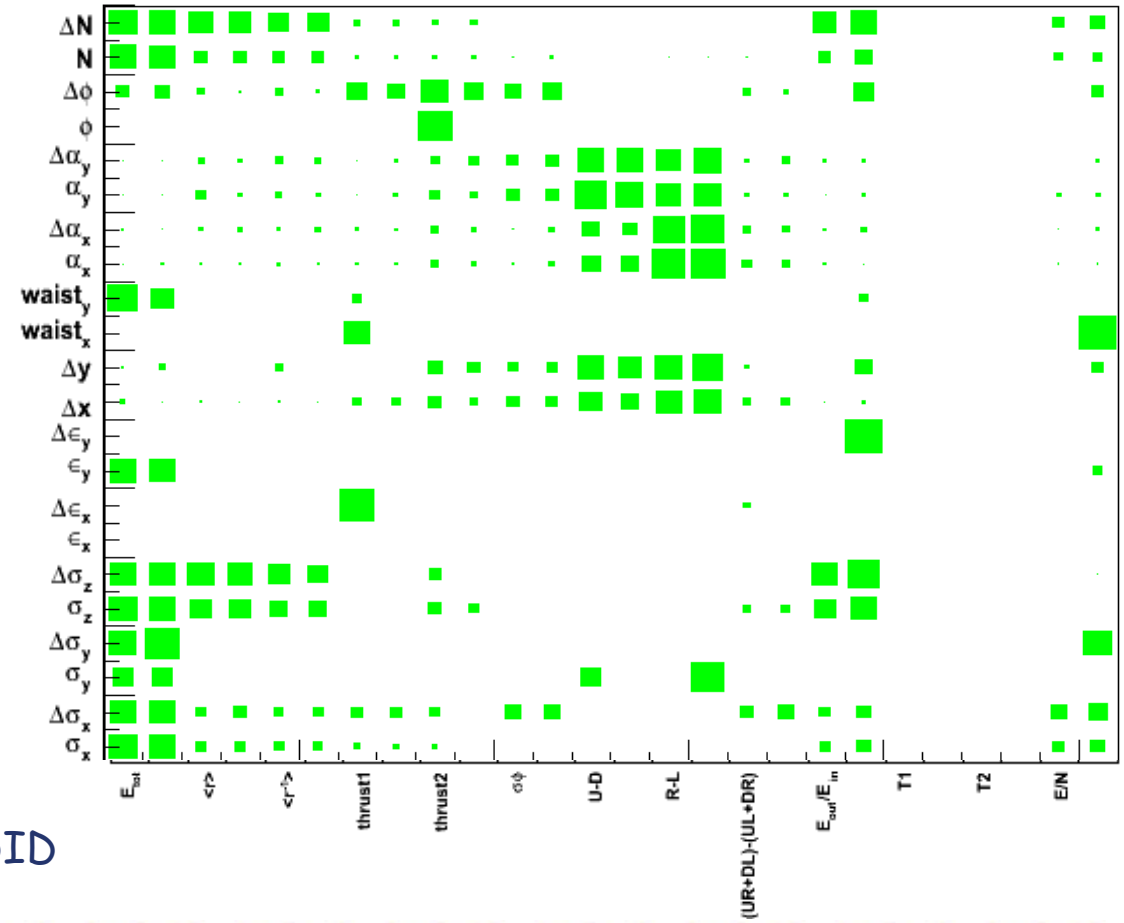
Beam Parameter Reconstruction

Single parameter reconstruction

Parameter	Unit	Nom.	2mrad μ	2mrad σ	14mrad DID μ	14mrad DID σ	14mrad antiDID μ	14mrad antiDID σ
σ_x	nm	655	653.42	1.95	653.66	3.42	653.89	2.27
σ_y	nm	5.7	5.208	0.371	5.464	0.520	5.395	0.229
σ_z	μm	300	300.75	4.56	306.60	5.13	299.83	4.11
ε_x	10^{-6}m rad	10	11.99	7.61	-	-	-	-
ε_y	10^{-9}m rad	40	40.41	1.29	40.22	1.19	40.72	1.19
Δx	nm	0	4.77	14.24	3.86	9.16	-3.24	10.70
Δy	nm	0	0.44	0.66	-2.07	0.81	0.05	0.65
waistx	μm	0	-69	141	-230.	828.	218.	349.
waisty	μm	0	12	24	-6.	19.	19.	25.
N_{bunch}	10^{10} part	2	2.009	0.005	2.001	0.007	2.009	0.005

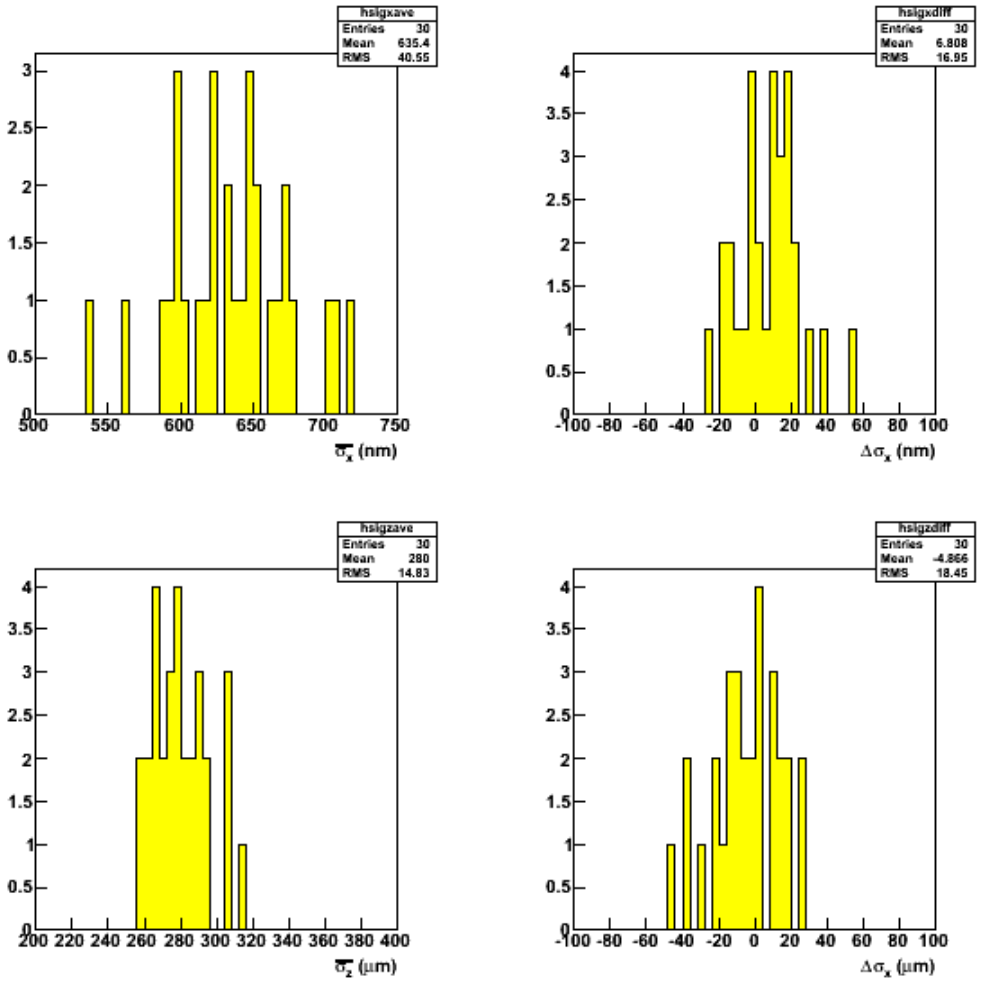
Beam Parameter Reconstruction

Beamparameters vs Observables
slopes (significance) normalized to sigmas



14mrad antiDID

Beam Parameter Reconstruction (Multiple)



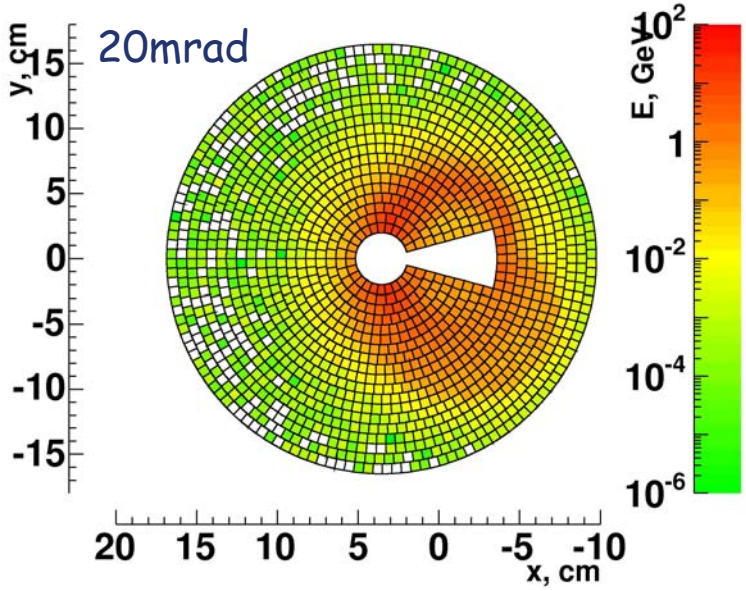
- Reconstruction of multiple beam parameters is feasible.
- E.g. simultaneous reconstruction of beam sizes and bunch charges:

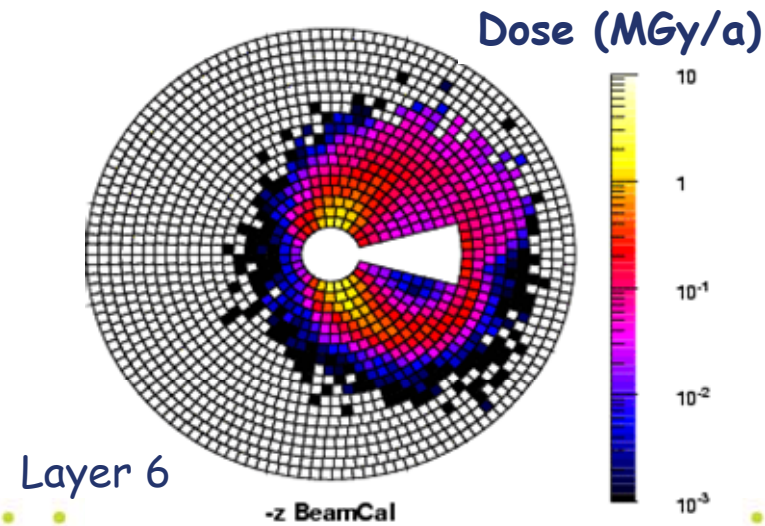
			14mrad antiDID	
Par	Unit	Nom.	µ	σ
σ_x	nm	655	635.4	41.3
$\Delta\sigma_x$	nm	0	6.8	17.3
σ_y	nm	5.7	5.5	0.3
$\Delta\sigma_y$	nm	0	0.6	1.2
σ_z	µm	300	280.0	15.1
$\Delta\sigma_z$	µm	0	-4.9	18.8
N_{bunch}	10^{10} part	2	1.93	0.10
ΔN_{bunch}	10^{10} part	0	0.03	0.07

Geant 4 Simulation - BeCaS

- A Geant4 BeamCal simulation has been set up (A.Sapronov).
- Energy distribution for 2mrad and 20mrad DID (14mrad not yet completely simulated).
- BeCaS can be configured to run with:
  - different crossing angles (corresponding geometry is chosen)
  - magnetic field (solenoid, (Anti) DID, use field map)
  - detailed material composition of BeamCal including sensors with metallization, absorber, PCB, air gap

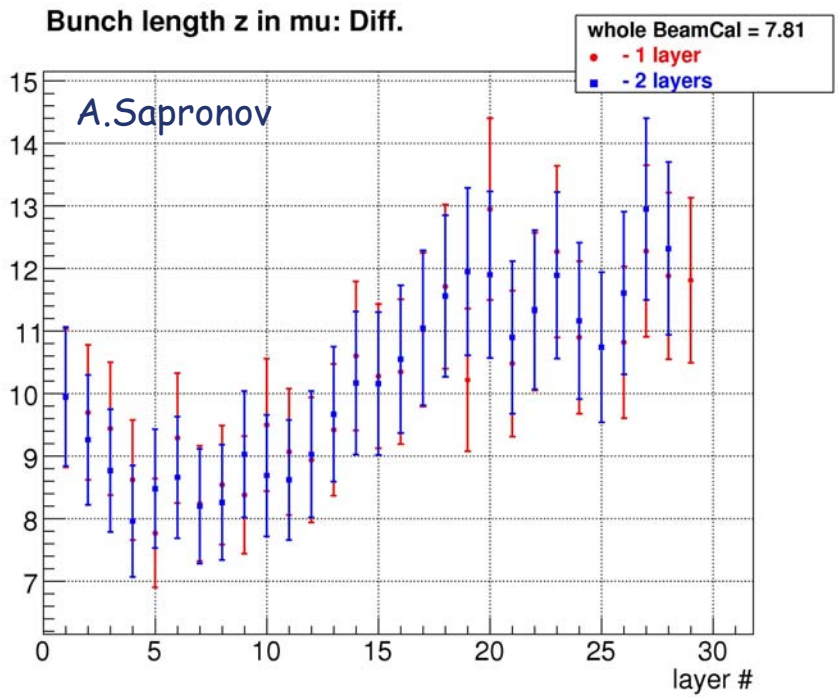
- It runs fast enough for a full shower simulation. √





Beamparameter Reconstruction

- Using the observables:
  - Etot // (1) Total energy
  - Rmom // (2) Average radius
  - Irmom // (3) radial moment
  - UDimb // (4) U-D imbalance
  - RLimb // (5) R-L imbalance
  - Eout // (6) Energy with r>=6
  - PhiMom // (7) Phi moment
  - NoverE // (15) N/E

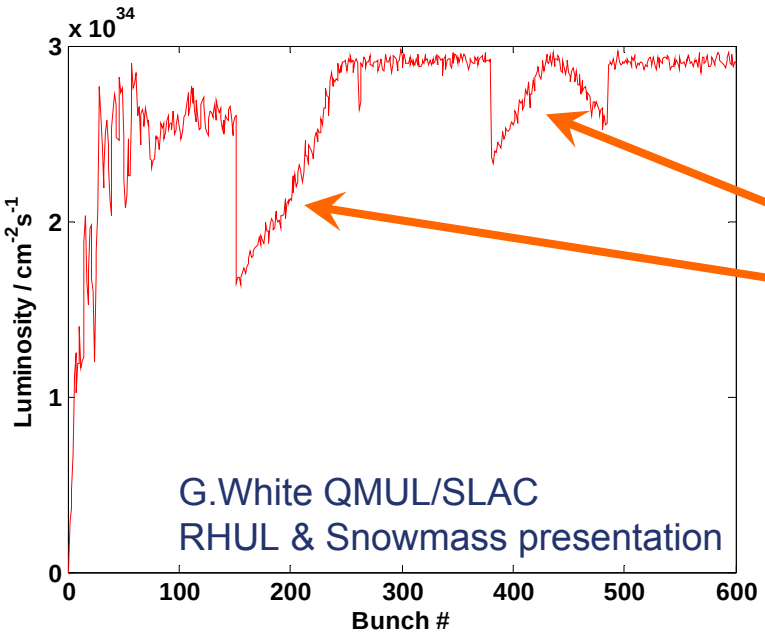


for 20mrad / DID fieldmap

Only minor reduction in resolution when using 1-2 layers of BeamCal.

Fast Luminosity Monitoring

- Why we need a fast signal from the BeamCal?
- We can significantly improve L!
- e.g. include number of pairs hitting BeamCal in the feedback system



Improves L by more than 12% (500GeV)!

position and angle scan

Luminosity development during first 600 bunches of a bunch-train.

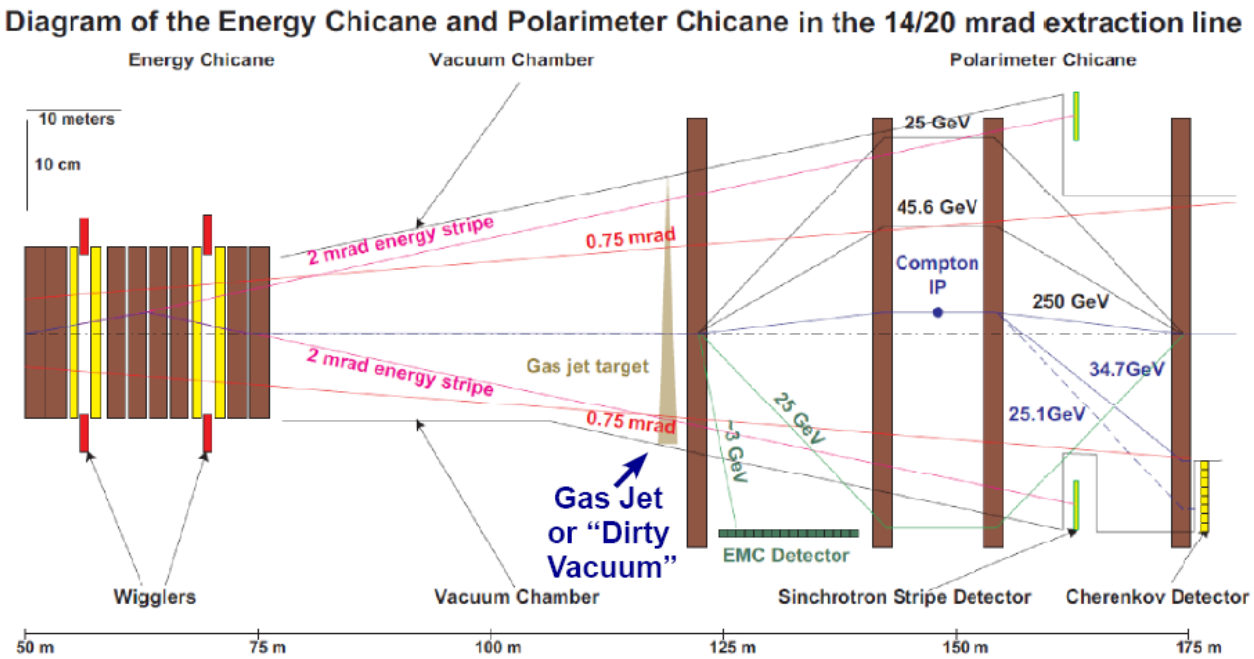
L_{total} = L(1-600) + L(550-600)*(2820-600)/50

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.

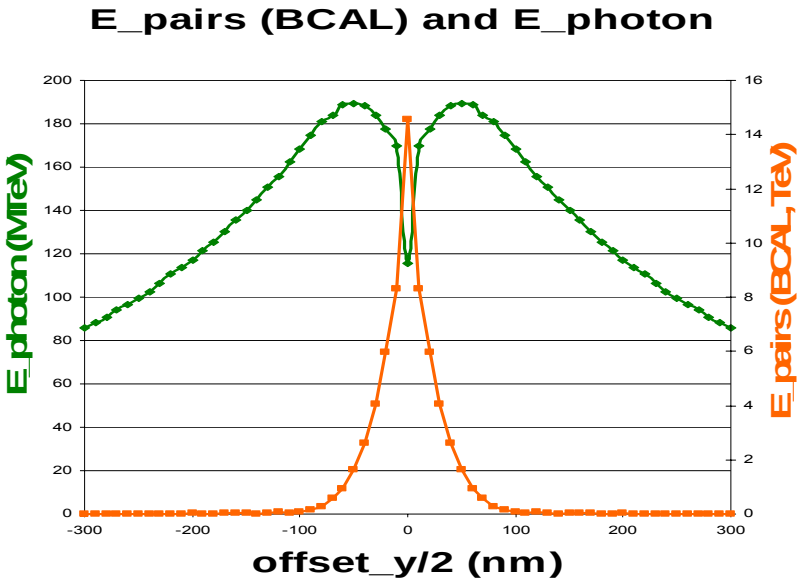
B.Parker, ILC ECFA Meeting

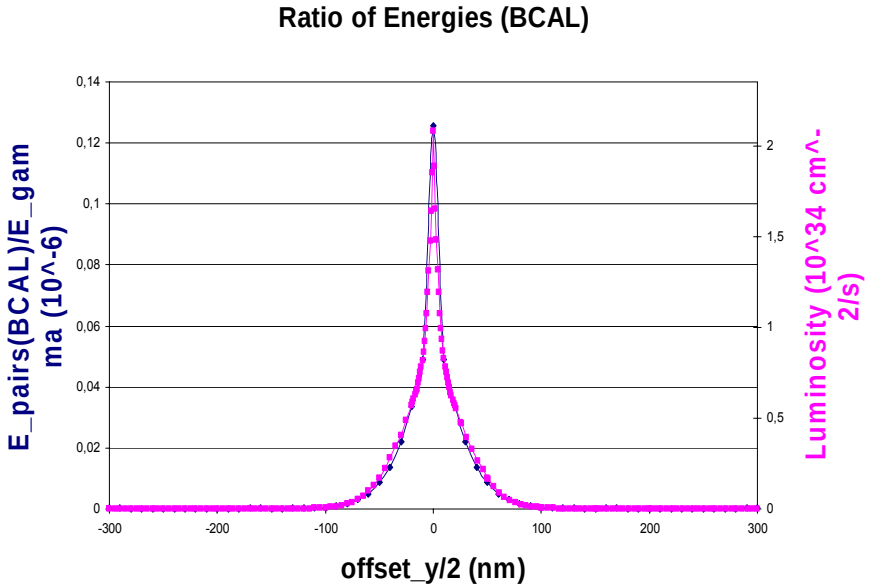
- Define a robust signal proportional to the luminosity which can be fed to the feedback system!
- Investigate correlation to learn how we can improve the beamdiagnostics.



Vertical Offset (y-direction)

M.Ohlerich





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 …

see also: EUROTeV-Memo-2006-011

Summary and Outlook

- The geometry of the forward region was adjusted to the case of a large crossing angle.
- We investigated the impact of a change in the segmentation on the electron veto efficiency. 0.8 R_M is still good and reduces the total channel number.
- Tested the fast beam parameter reconstruction for 2, 14 and 20 mrad configurations with DID/AntiDID field.
- A Geant4 simulation of BeamCal (BeCaS) is ready for usage. It is fast enough, so that we do not need a shower parametrization.
- First tests show that a subset (some layers) of the detector information seems sufficient for beam parameter reconstruction.
- Complete/optimize observable definition and include digitization.
- Complete 14mrad study
- Use the Real Beam simulation data.
- GamCal could provide valuable information about the collision
  - partly complementary to BeamCal information
  - E_{pair}/E_γ is a signal proportional to the luminosity for several beam parameters