Luminosity Monitoring and Beam Diagnostics

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FCAL Collaboration Workshop
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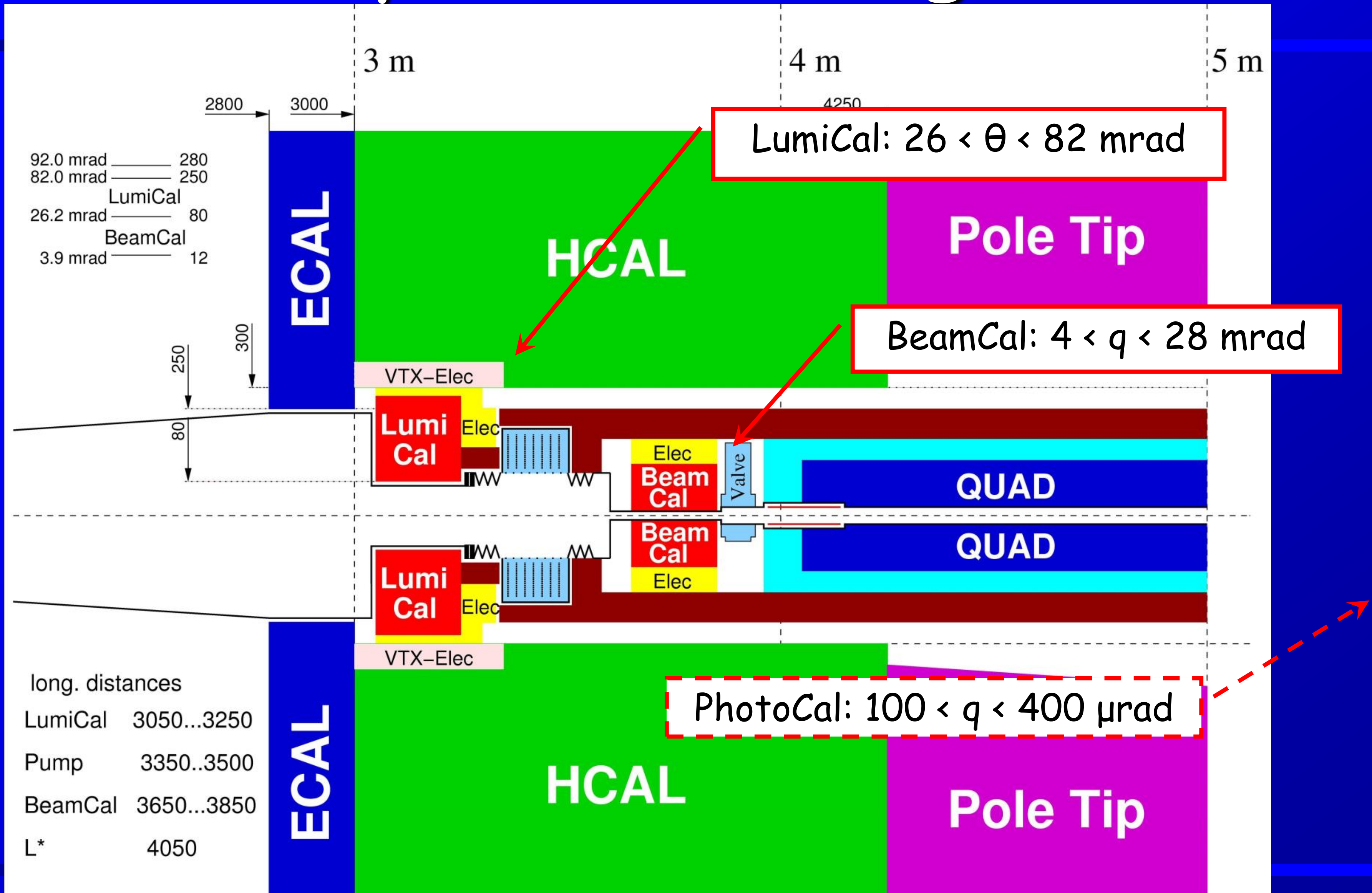
Outline

- Very Forward Calorimetry of LDC,
  - LumiCal
  - PhotoCal
  - BeamCal
- Fast luminosity monitoring
- Beam diagnostics from beamstrahlung
  - analyzing pairs and photons
- 20 mrad crossing angle
- Summary & outlook

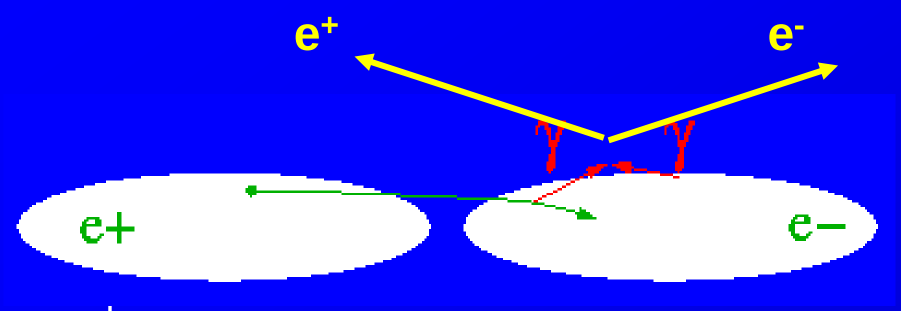
Very Forward Region



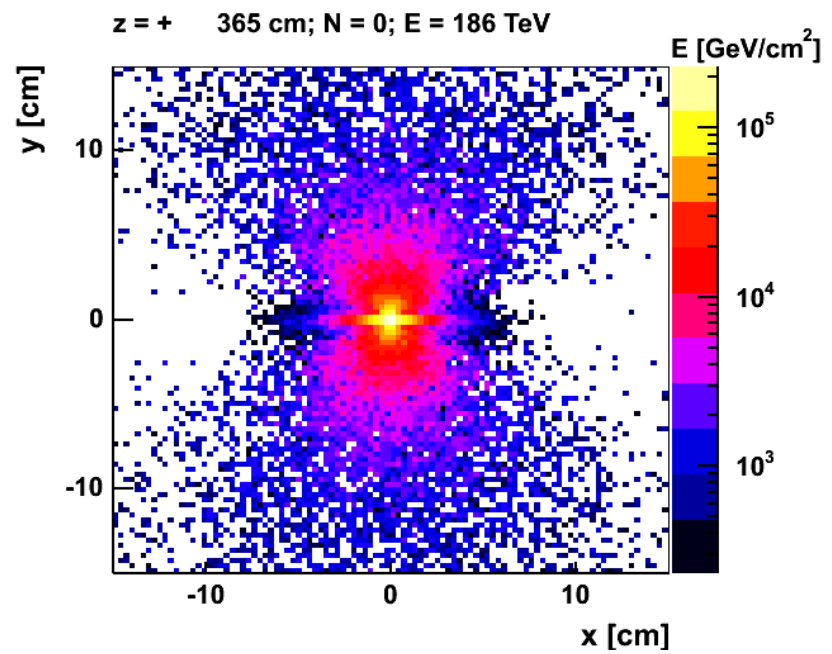
Very Forward Calorimeters

- LumiCal:
  - Precise measurement of the luminosity by using bhabha events (very high mechanical precision needed).
  - Extend coverage of the detector system.
- Photocal
  - beam diagnostics from beamstrahlung photons
- BeamCal:
  - detection of electrons/photons at low angle.
  - shielding of Inner Detector.
  - **beam diagnostics from beamstrahlung electrons/positron pairs.**

BeamCal: Beam Diagnostics and Fast Luminosity Monitoring



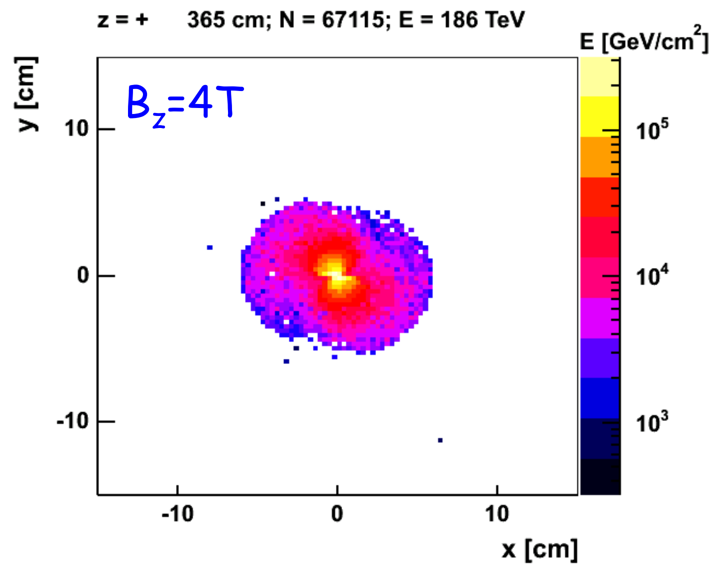
e^+e^- pairs from beamstrahlung are deflected into the BeamCal

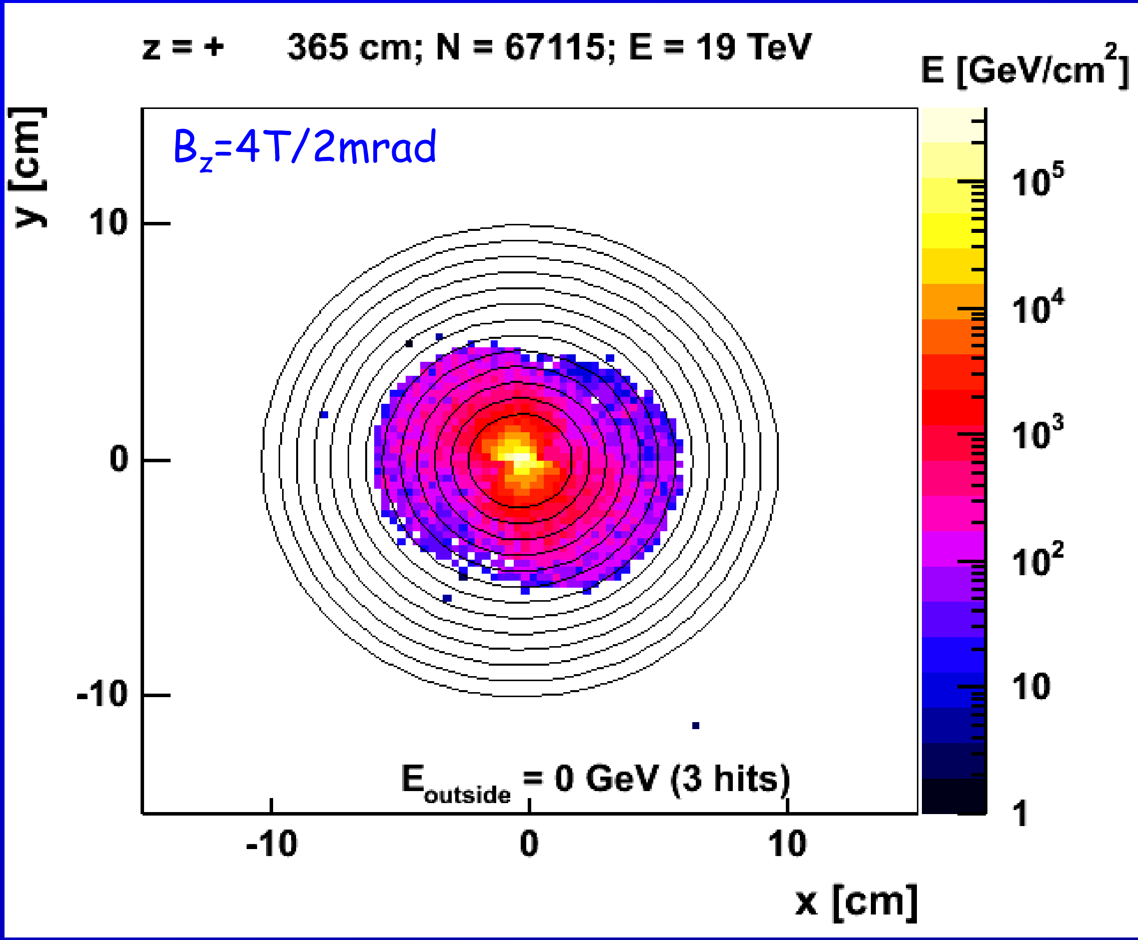


Deposited energy from pairs at z = +365 (no B-field, TESLA parameters)

- 15000 e^+e^- per BX => 10 – 20 TeV
- ~ 10 MGy per year
- "fast" => O(μs)
- Direct photons for θ < 400 μrad (PhotoCal)

Distribution of pairs





BeamCal: W-Diamond Sandwich

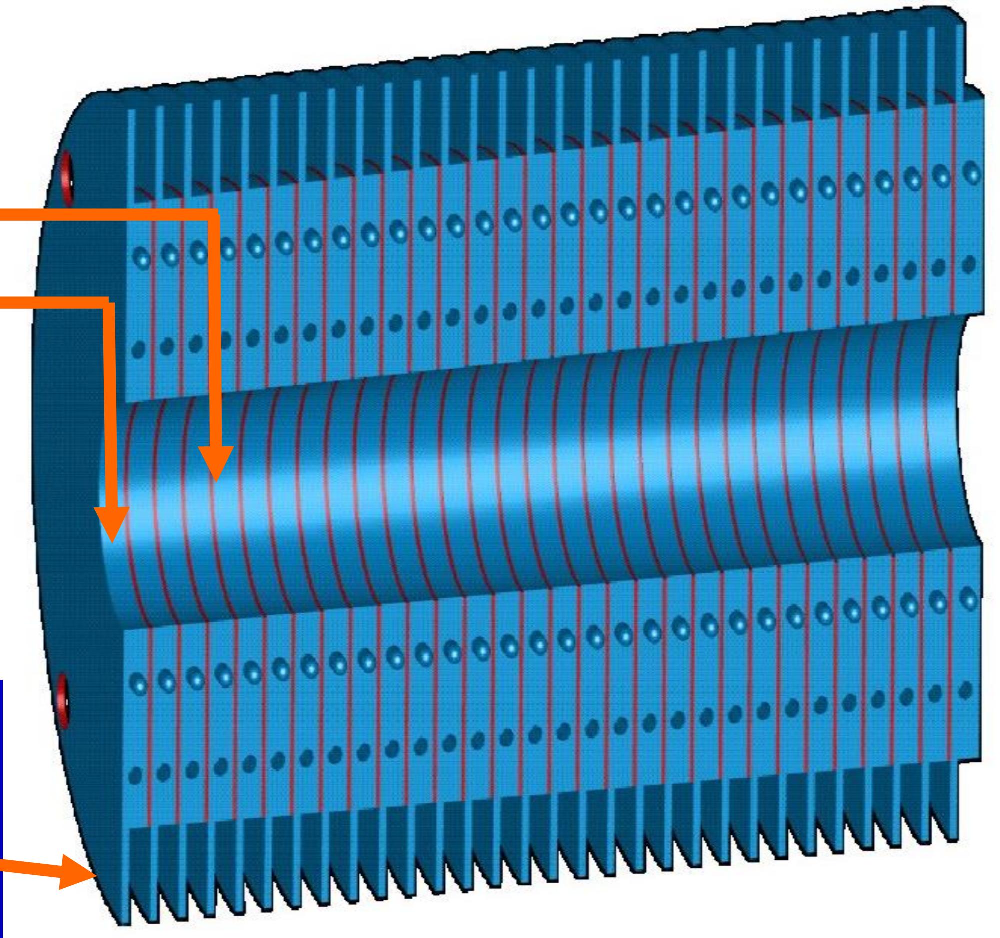
Length = 30 X_0

(3.5mm W + .5mm diamond sensor)

~ 15 000 channels

~1.5/2 cm < R < ~10(+2) cm

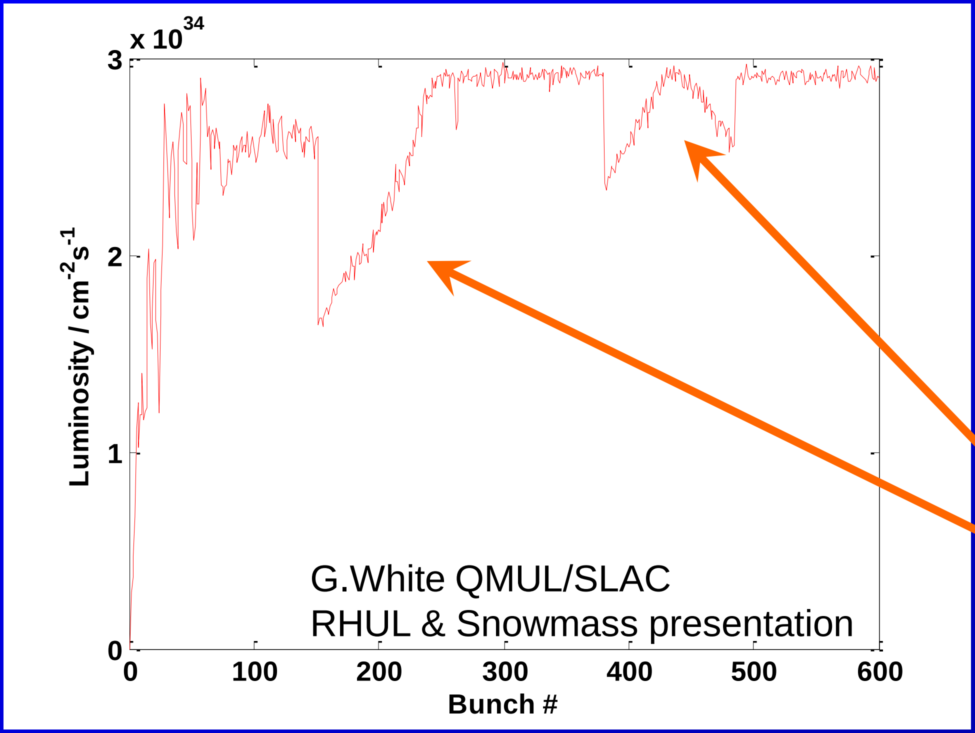
Space for electronics



Fast Luminosity Monitoring

A fast estimation of the luminosity is needed, e.g. number of pairs/total energy.

- This will be included into the fast feedback system.



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

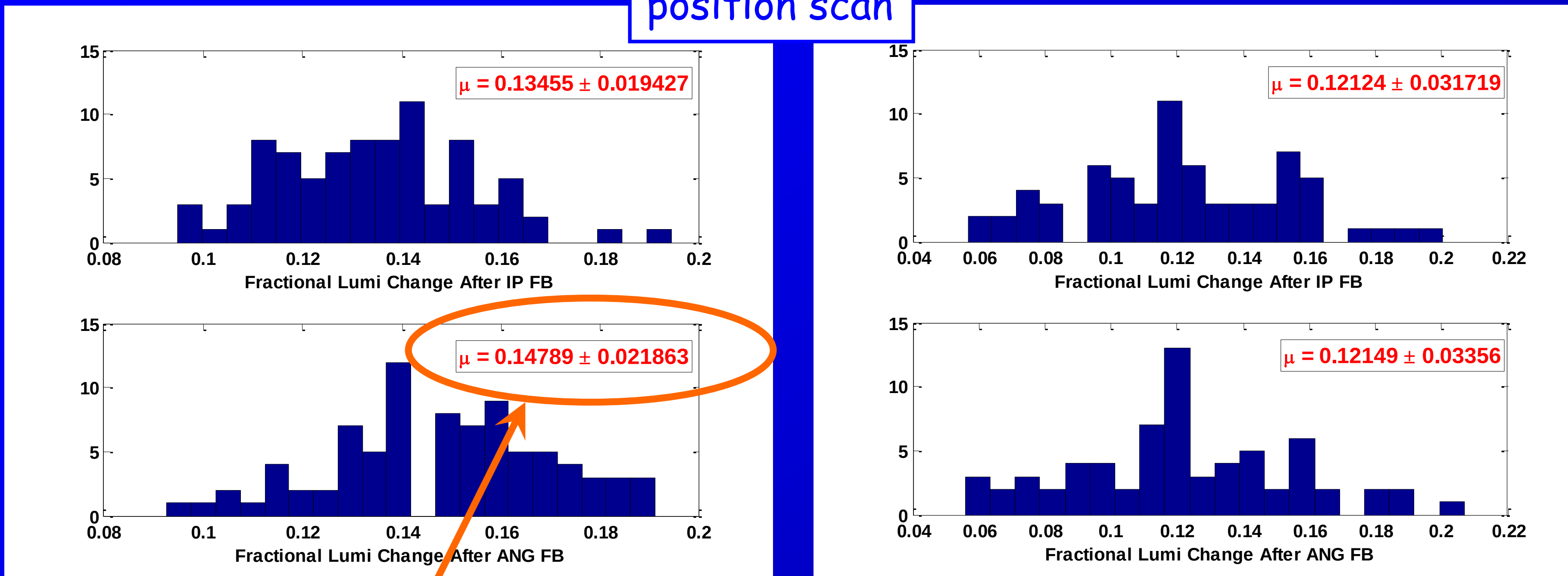
L_{total} =
L(1-600) + L(550600)*(2820-600)/50

position and angle scan

L Improvement by including Pair Signal

G.White

position scan



350 GeV

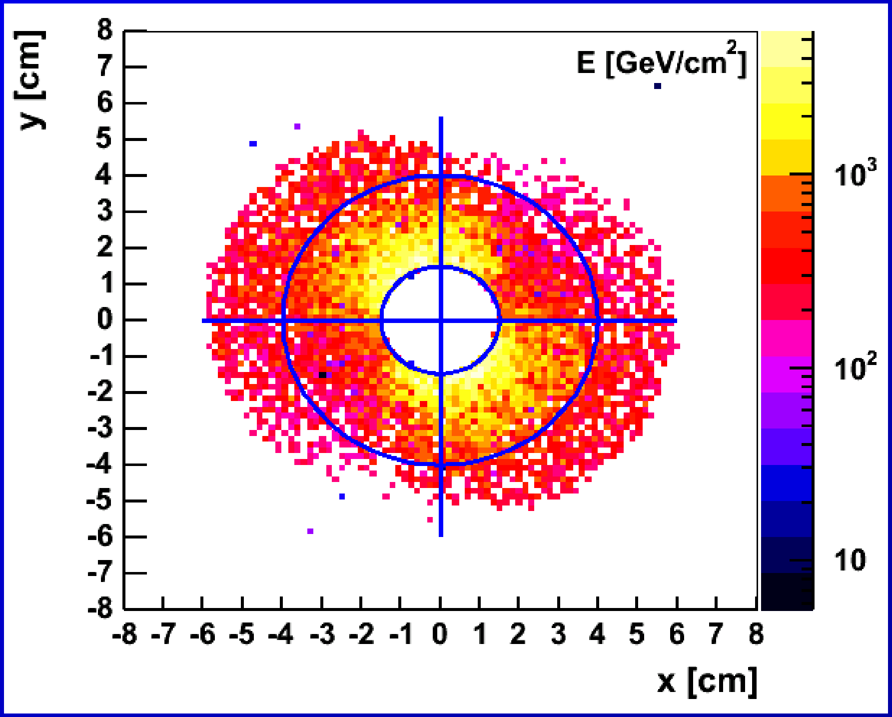
position scan & angle scan

500 GeV

Up to 14.8 % improvement on the overall luminosity.
A fast luminosity signal is a must have for the ILC.

Beamstrahlung Pairs

- Observables (examples):
  - total energy
  - first radial moment
  - thrust value
  - angular spread
  - E(ring ≥ 4) / Etot
  - E / N
  - left/right, up/down, forward/backward asymmetries



detector: realistic segmentation, ideal resolution bunch by bunch resolution

Aim: Reconstruction of Beam Parameters

Sigma x
Sigma y
Sigma z
Sigma x'
Sigma y'
x offset
y offset
x' offset
y' offset
x-waist shift
y-waist shift
Bunch rotation
N particles/bunch
Banana shape
… …
Luminosity

What do you want to know?

Analysis Concept

Beam Parameters

- determine collision
- creation of beamstr.
- creation of e^+e^- pairs

guinea-pig
(D.Schulte)

1^{st} order Taylor-Exp. →

Observables

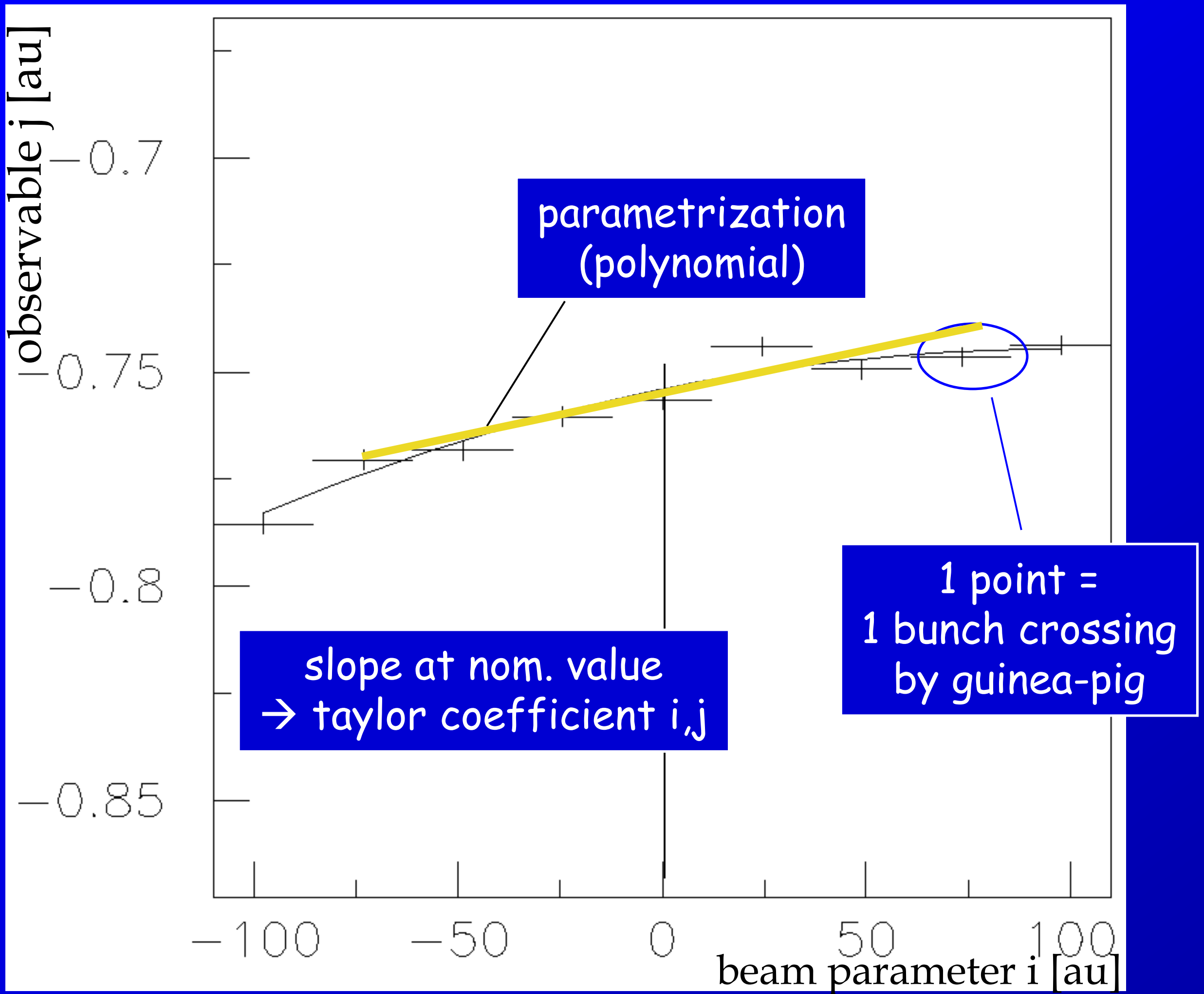
- characterize energy distributions in detectors

FORTRAN
analysis program
(A.Stahl)

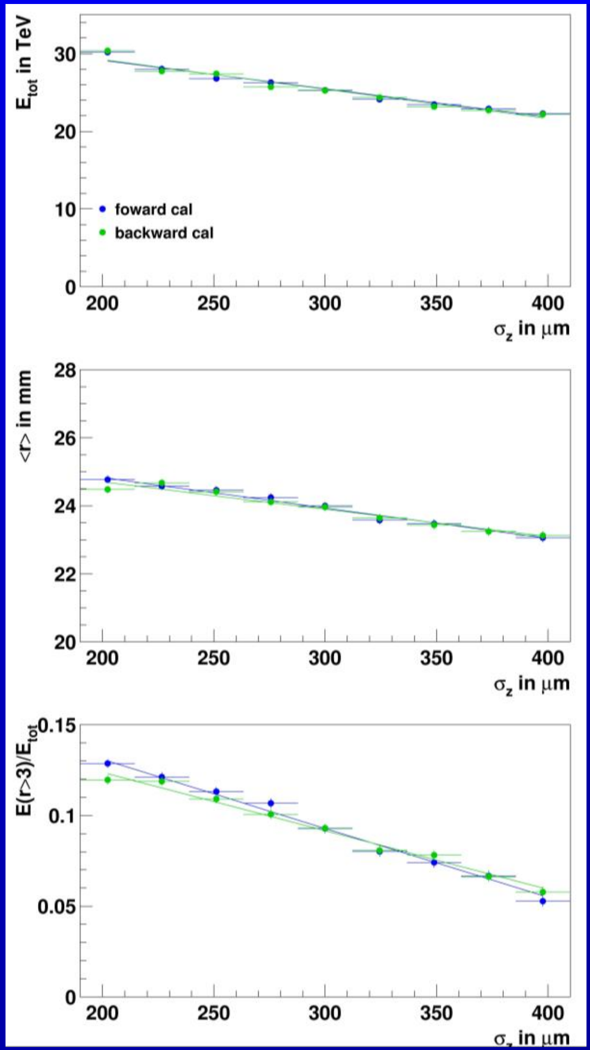
$$\begin{pmatrix}\text{Observables}\end{pmatrix} = \begin{pmatrix}\text{Observables}\end{pmatrix}_{nom} + \begin{pmatrix}\text{Taylor} \\ \text{Matrix}\end{pmatrix} * \begin{pmatrix}\Delta\,\text{BeamPar}\end{pmatrix}$$

Solve by matrix inversion (Moore-Penrose Inverse)

Slopes



observable j [au]
-0.7
-0.75
-0.8
-0.85
-100
-50
0
50
100
beam parameter i [au]
parametrization (polynomial)
1 point = 1 bunch crossing by guinea-pig
slope at nom. value → taylor coefficient i,j

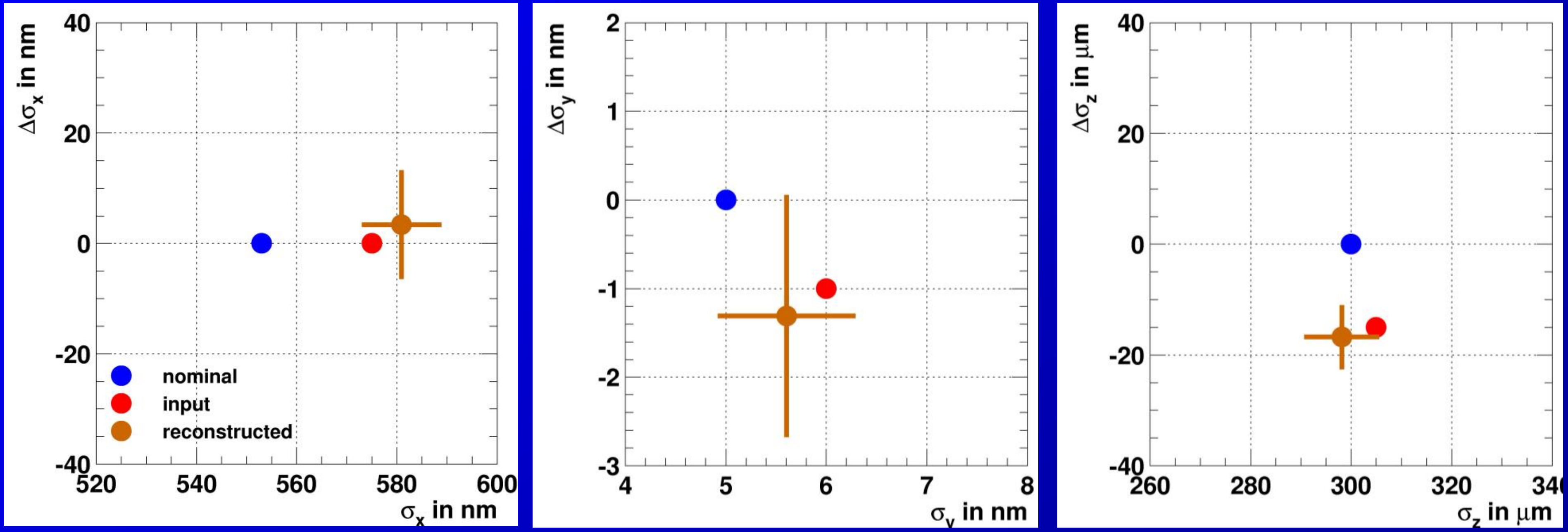


E_tot in TeV
<r> in mm
E(r>3)/E_tot
foward cal
backward cal
σ_z in µm

Analysis

Test with non-nominal bunches:

	e^-	e^+	nom.
bunch size x:	575nm	575nm	553nm
bunch size y:	5nm	7nm	5nm
bunch size z:	290µm	320µm	300µm



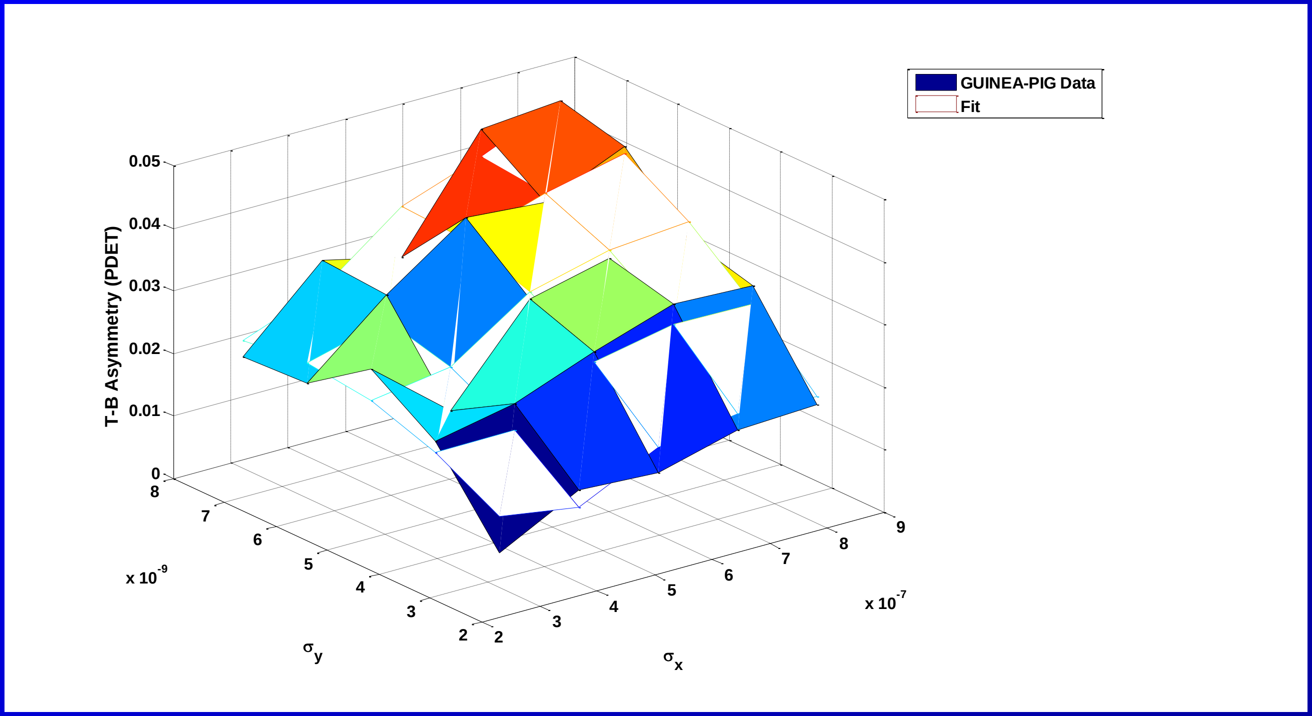
Multi Parameter Analysis

σ_x	$\Delta\sigma_x$	σ_y	$\Delta\sigma_y$	σ_z	$\Delta\sigma_z$
0.3 %	0.4 %	3.4 %	9.5 %	1.4 %	0.8 %
0.3 %	0.4 %	3.5 %	11 %	1.5 %	0.9 %
0.9 %	1.0 %	11 %	24 %		
		5.7 %	24 %	1.6 %	1.9 %
1.8 %	1.1 %	16 %	27 %	3.2 %	2.1 %

2nd Order Calculations

Fast feedback system group (QMUL) is studying higher order dependencies.
Computation of Taylor Matrix only to second order, due to cpu limitations:
2nd order requires 7 days on 100 CPU cluster.
This effort aims for an offline analysis/fitting routine.

G.White

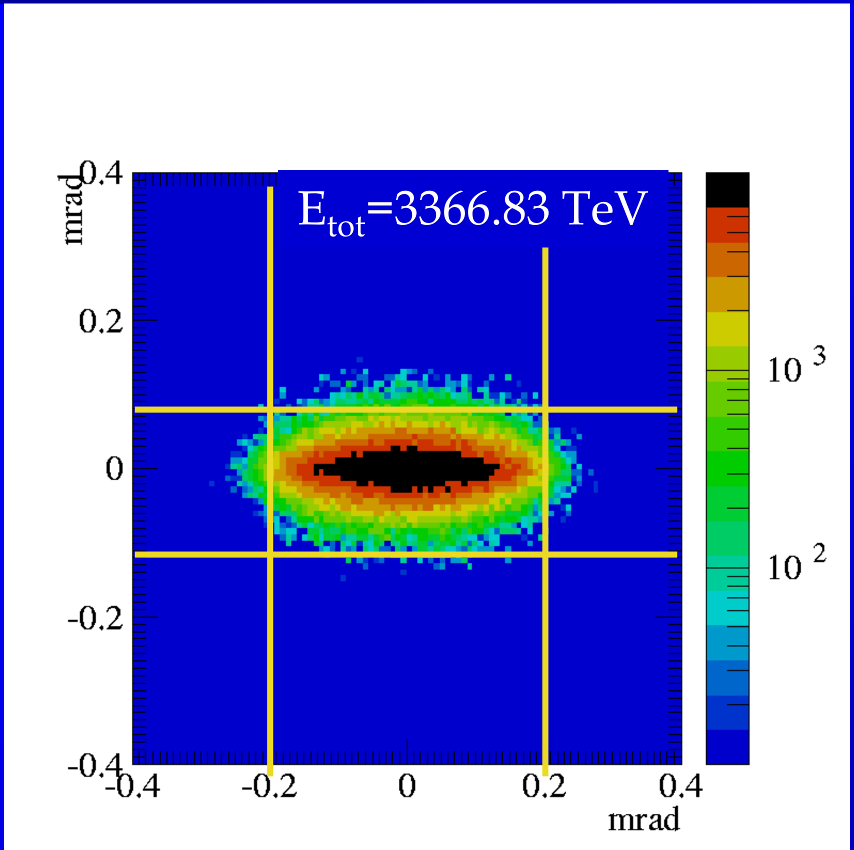


Photons from Beamstrahlung

- Report on analysis done by Andrei Rybin (Protvino)
- Beam parameters under investigation:
  - beam size σ_x, σ_y, σ_z
  - beam offset x,y
  - waist shift x,y
- Observables
  - E_γ (left – right) along x
  - E_γ (up – down) along y
  - E_γ (forward – backward) along z

Every beam parameter analyzed separately, all others were fixed to nominal value.

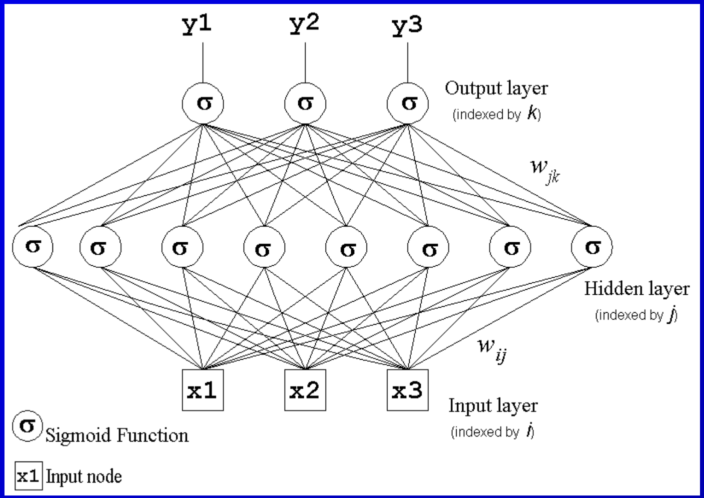
Interlude: Photon Distribution and Selection



Photon selection:

|angle x| > 0.2 mrad

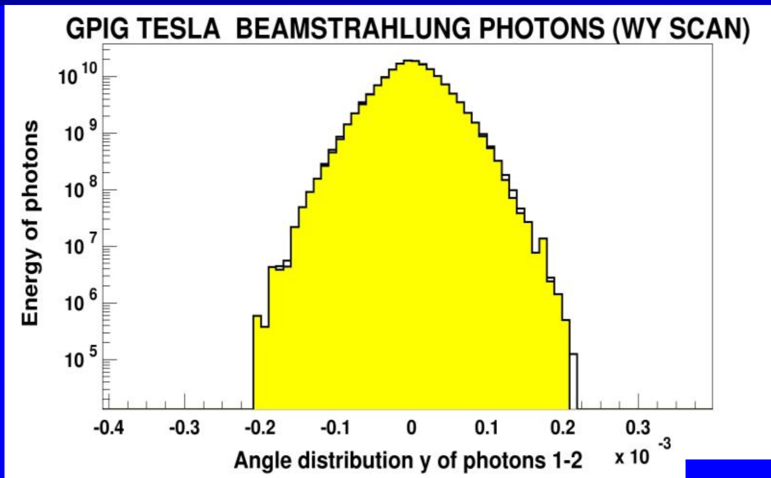
|angle y| > 0.1 mrad

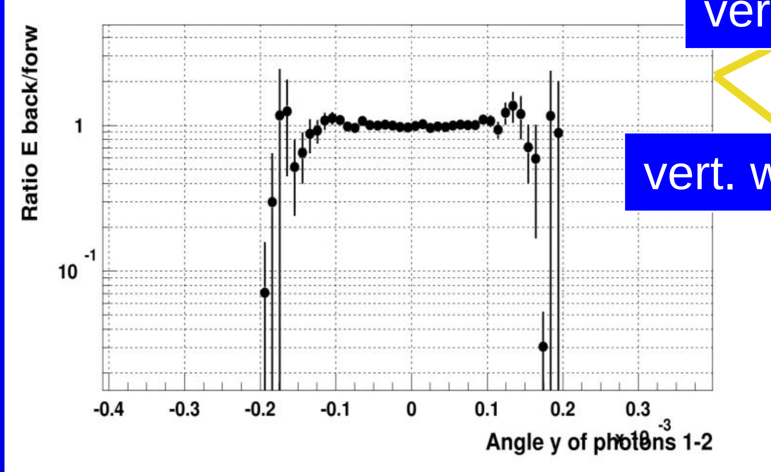


In use:
Multi layer perceptron feed-forward network.

200 Epochs for learning
hybrid linear BFGS learning method

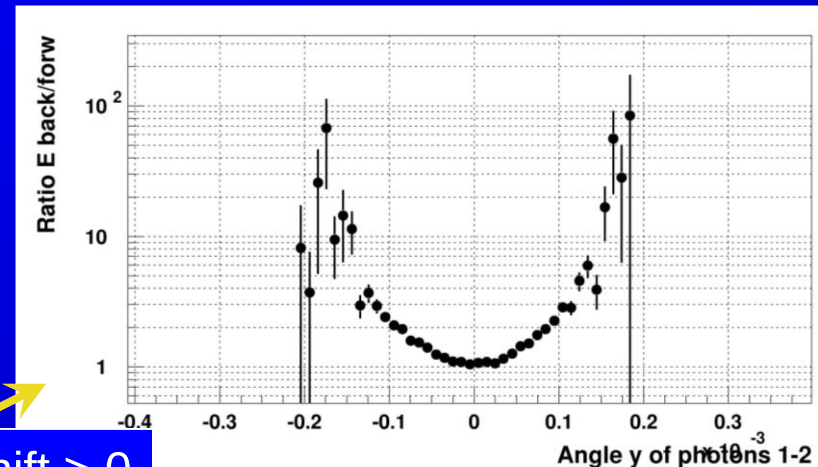
Vertical Beam Waist Variation



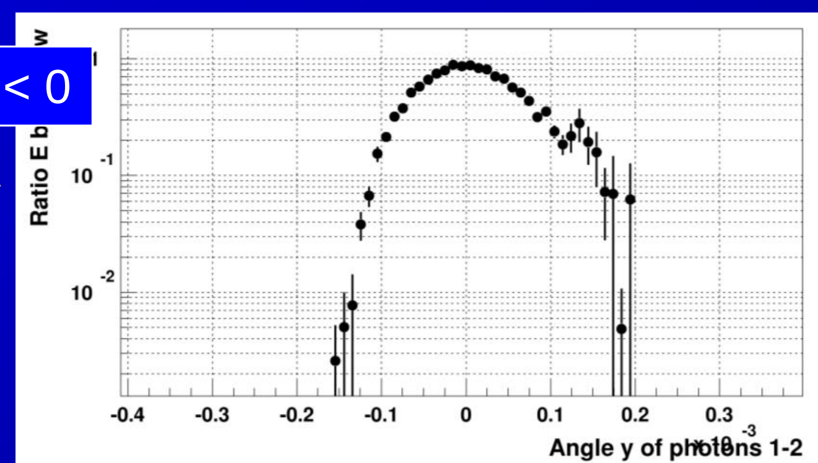


nominell beam parameters

vert. waist shift > 0



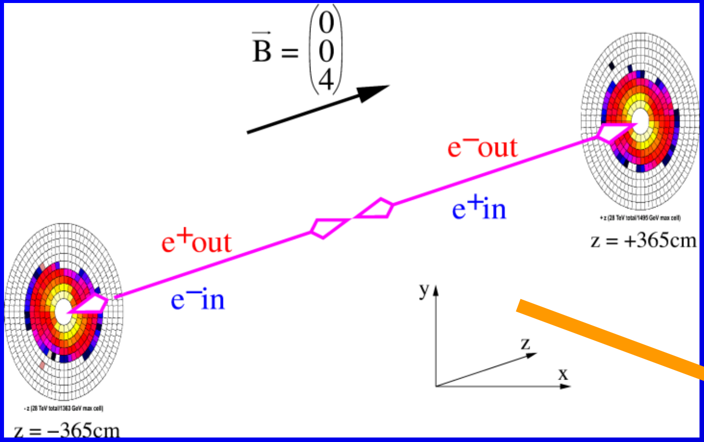
vert. waist shift < 0

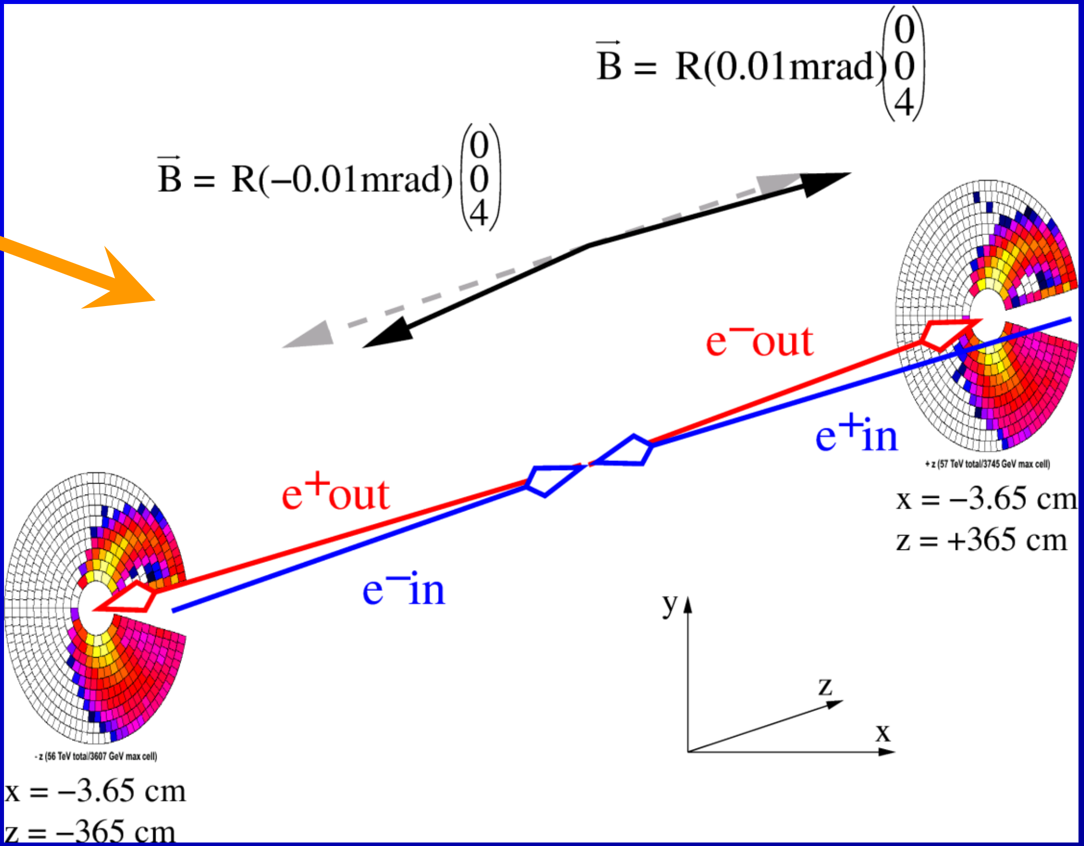


Results of Analysis

Parameter	nom.	in	phot.	pairs
➢ σ_x	553	nm	4.2	1.5
➢ σ_y	5.0	nm	0.1	0.2
➢ σ_z	300	µm	7.5	4.3
➢ beam offset x	0	nm	4.0	6.0
➢ beam offset y	0	nm	0.16	0.4
➢ vertical waist shift	360	µm	14	24

Moving to 20mrad crossing angle

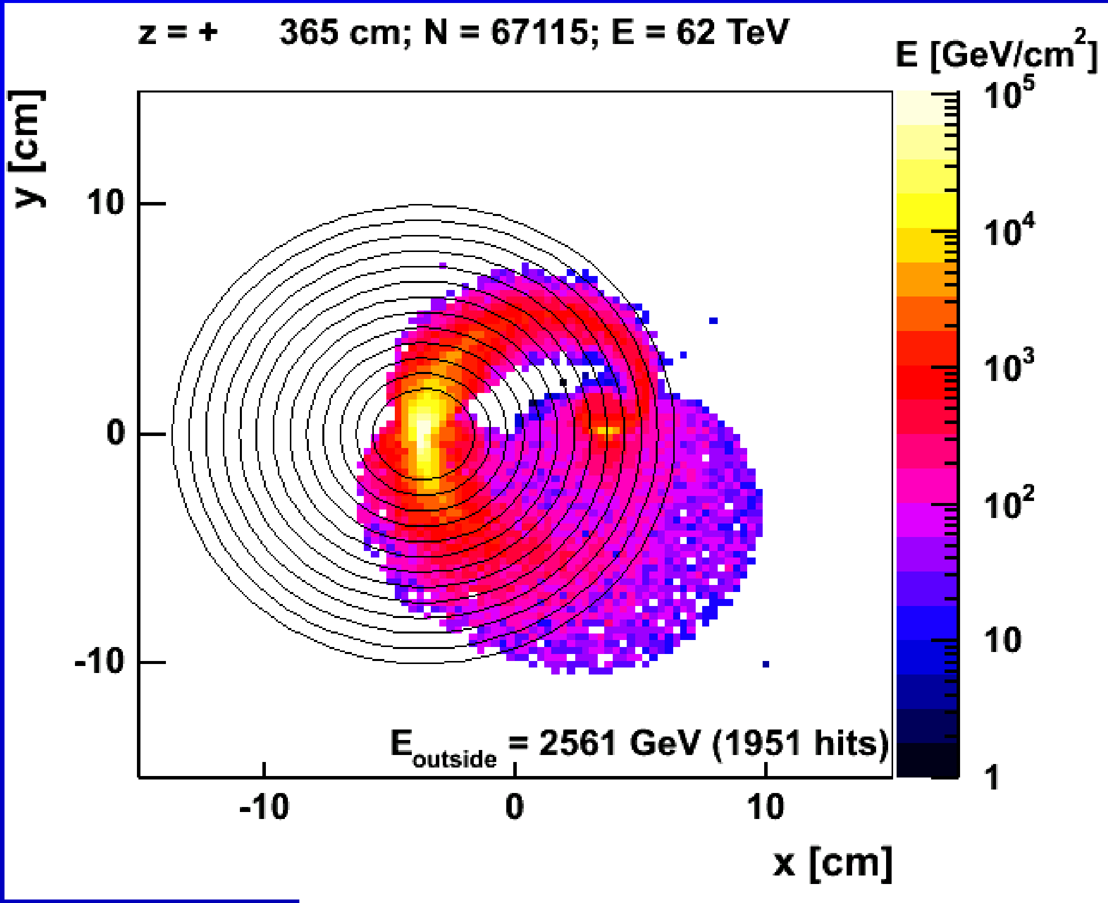




Simplification of DID field map
(B.Parker & A.Seryi)

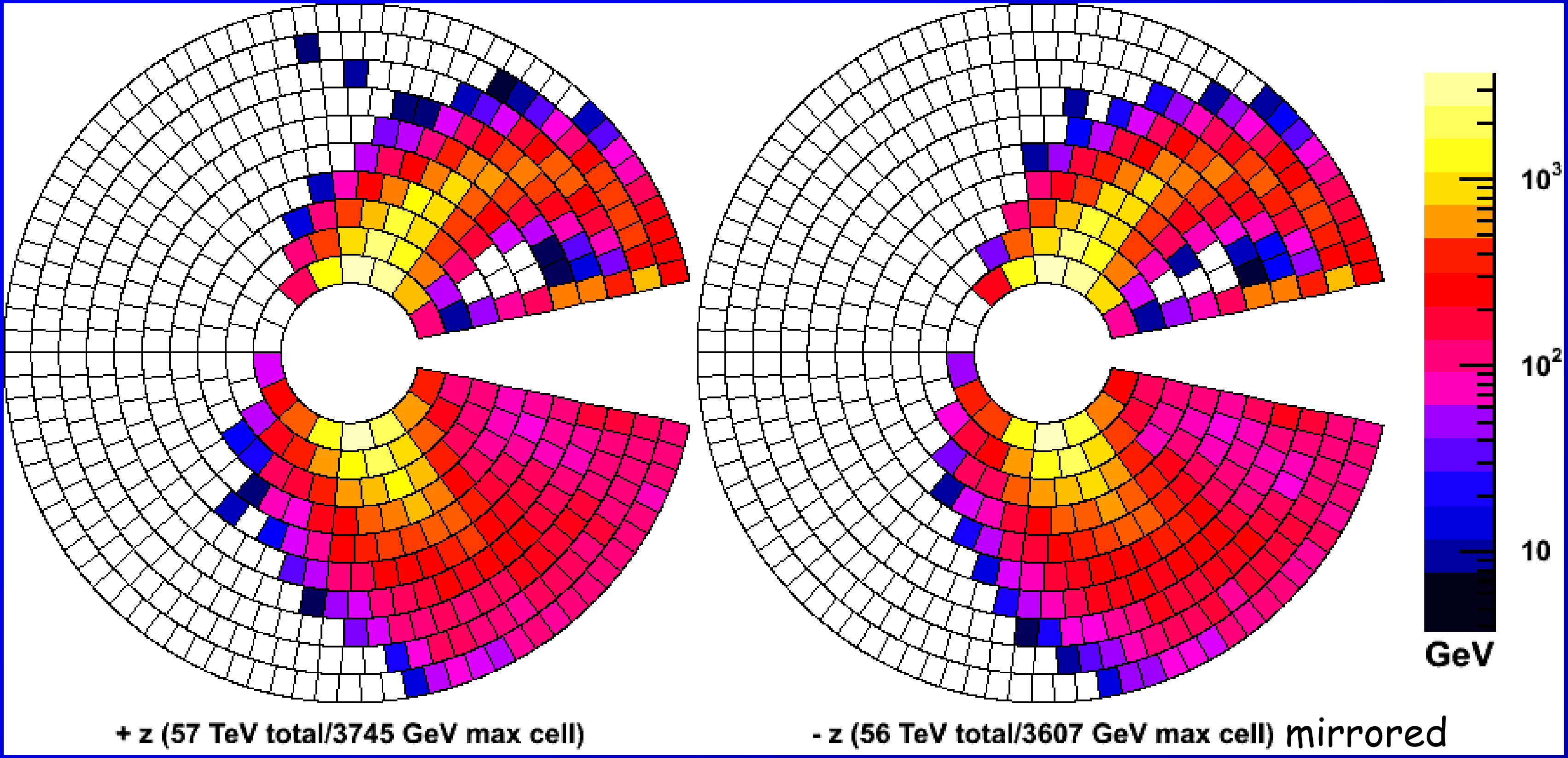
20mrad crossing angle

- 20mrad crossing angle and serpentine B-field implemented.



|B| = 4T, serpentine field, 20mrad

Geometry for 20mrad



Beamdiagnostics for 20mrad

- Simulate collision/beamstrahlung with Guineapig using head-on case.
- Use FORTRAN code by A.Stahl - extended by
  - Boosting the generated pairs according to crossing angle.
  - Calculate impact position at BeamCal front face by parameterized movement in constant b-field.
  - Use new geometries (headon, 2mrad, 20mrad).
- Used old set of observables (space for improvements).

Single Parameter Analysis for 20mrad

			Headon (old geom)		20mrad	
BeamPar	Unit	nom	MPI	FIT	MPI	FIT
σx (ave)	nm	553	3.69	2.55	4.67	4.92
σx (diff)	nm		3.69	5.48	3.88	4.67
σy (ave)	nm	5	0.209	0.336	0.125	0.111
σy (diff)	nm		0.585	0.240	0.137	0.161
σz (ave)	µm	300	11.46	6.56	8.46	8.13
σz (diff)	µm		4.11	2.88	6.72	5.02
N per Bunch (ave)	10^{10}	2	0.011	0.006	0.014	0.014
N per Bunch (diff)	10^{10}		0.011	0.007	0.021	0.022

Summary

- A fast luminosity signal could significantly increase luminosity.
- Analyzing beamstrahlung grants access to many beam parameters.
- Investigating the possibility of measuring the distribution of pairs from beamstrahlung with BeamCal. Promising results also for 20mrad case, but further work needed for final result.
- Single and Multiparameter analysis is feasible.
- Photon distribution at lowest angles (~100 µrad) with PhotoCal has potential. The more uncorrelated observables the better our parameter reconstruction will work.

Outlook

- Optimization of observables.
- Comparison of the simple b-field approximation to using the b-field map.
- Include a realistic detector response.
- Look at realistic beam simulation and non linear bunch effects.