Forward Region Studies for 3 TeV CLIC

Konrad Elsener
Linear Collider Detector Project
CERN

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Outline:

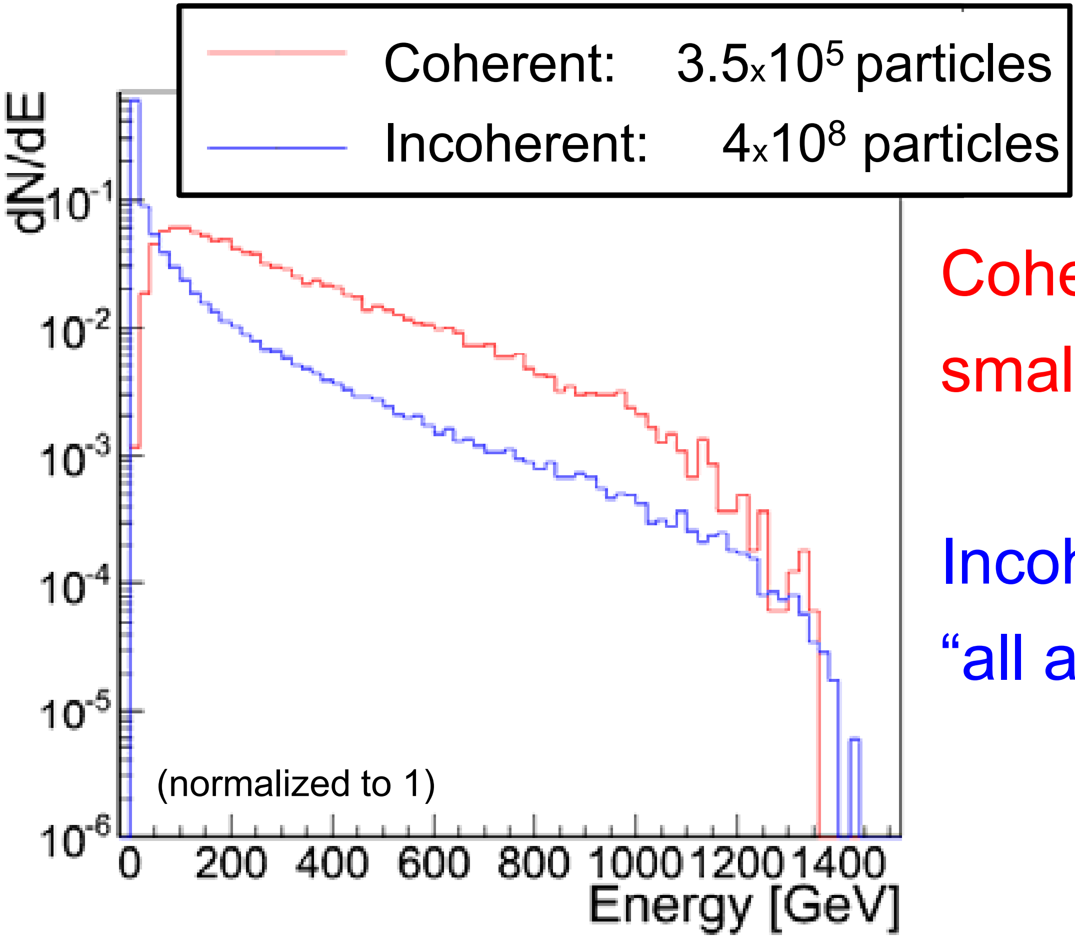
- CLIC at 3 TeV
- Forward Region at CLIC
- LumiCal – a first Proposal
- BeamCal Studies
- Background in the Vertex Detector
- Summary

(Other Issues under Study)

CLIC (at 3 TeV)

- NB. Push-Pull “just as at ILC”
- 20 mrad crossing angle
- Beam-beam effect strongly enhanced: (in-) coherent pairs,
  $\gamma\gamma$ -> hadron background
- Bunch spacing 0.5 ns, bunch train 156 ns,
  rep. rate 50 Hz -> time stamping, power pulsing etc.
- Small beam spots -> stability requirements for QD0 (and QF1)
- Crossing Angle + High Energy + Synchrotron radiation
  -> Luminosity Loss -> (most likely) no Anti-DiD

Incoherent and Coherent Pairs at 3 TeV CLIC



for 1 BX

Coherent Pairs: 6.5×10^{10} GeV

small angles

-> post-collision line

Incoherent Pairs: 1.3×10^{7} GeV

"all angles"

-> background !

CLIC synchrotron radiation,
solenoid, anti-DiD etc. …

Work by **Barbara Dalena**, CERN (CLIC study team):

- PAC'09 contributed paper

  "Solenoid and Synchrotron Radiation Effects at CLIC"

- presentation at ILC-CLIC LET Beam Dynamics Workshop, 24 June 2009

  http://indico.cern.ch/contributionDisplay.py?contribId=20&sessionId=3&confId=56133

Map	Bz [T]	L[m]	Lumi loss [%]
Old SiD	5	2.8	~4.0
New SiD	5	2.8	~3.0
ILD	4	3.7	~4.0
ILD + AntiDiD	4	3.7	~25.0

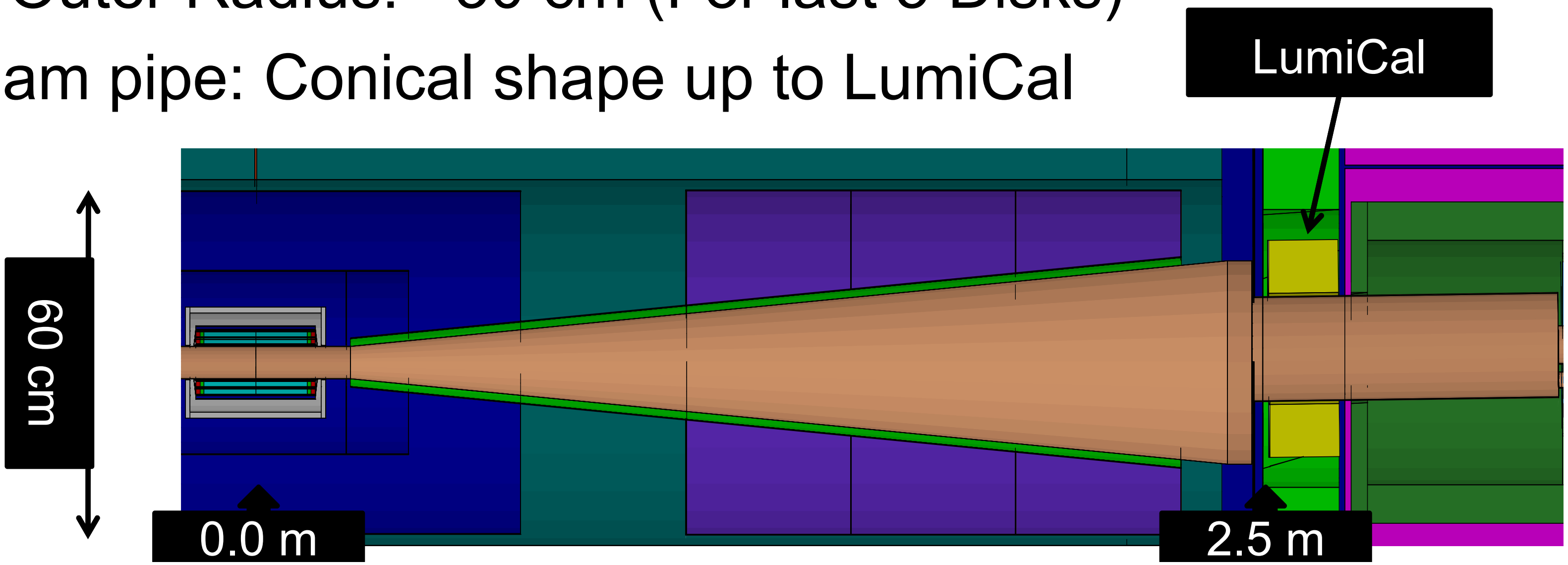
Forward Region at CLIC:
A snapshot at today's layout

- Detector concepts based on ILD and SiD are under study
- For the forward region, so far most of the work was done on the CLIC01_ILD concept
- For some studies, stand-alone "fast" simulations were used

(courtesy André Sailer, CERN)

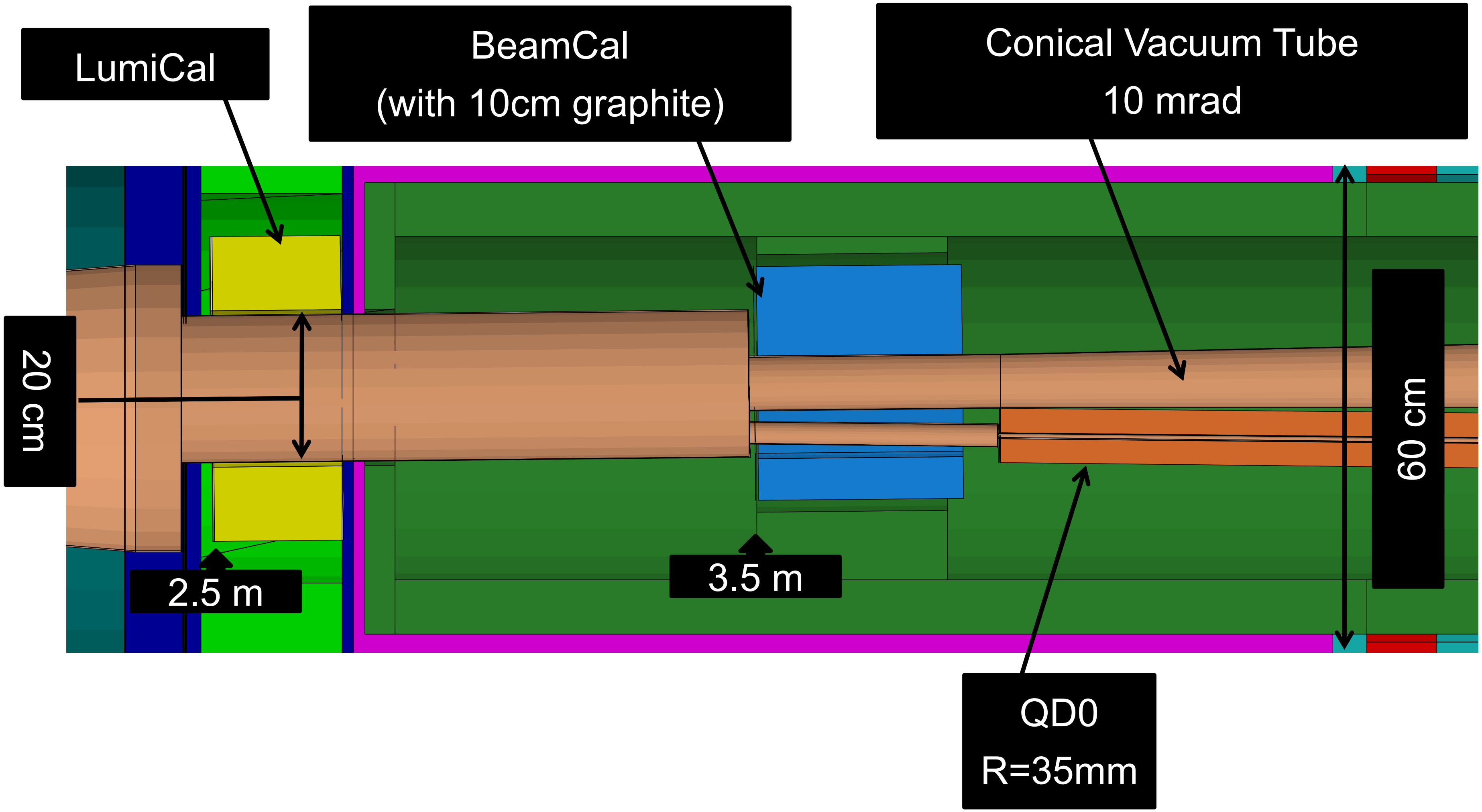
CLIC01_ILD: Vertex and Forward Tracker

- Vertex Detector: 3 double Layers of Silicon Sensors
  - At: 31, 46, 60 mm Radius, each 25 cm long (Z=±12.5cm)
- Forward Tracking: 7 Disks
  - Inner Radius: Beam pipe
  - Outer Radius: ~30 cm (For last 5 Disks)
- Beam pipe: Conical shape up to LumiCal



(courtesy André Sailer, CERN)

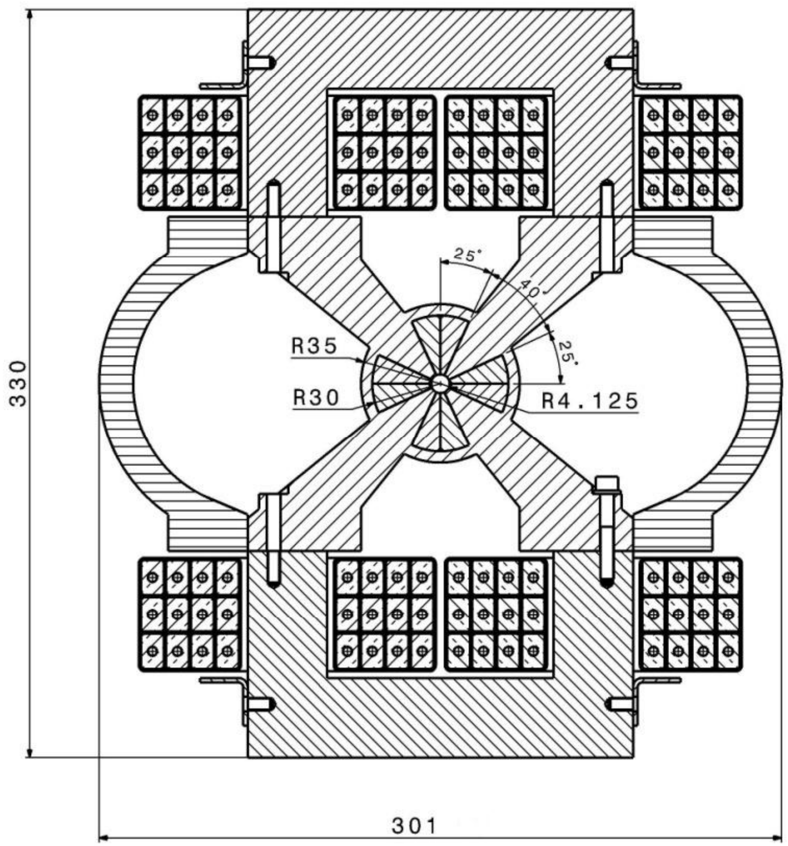
CLIC01_ILD: LumiCal, BeamCal and QD0

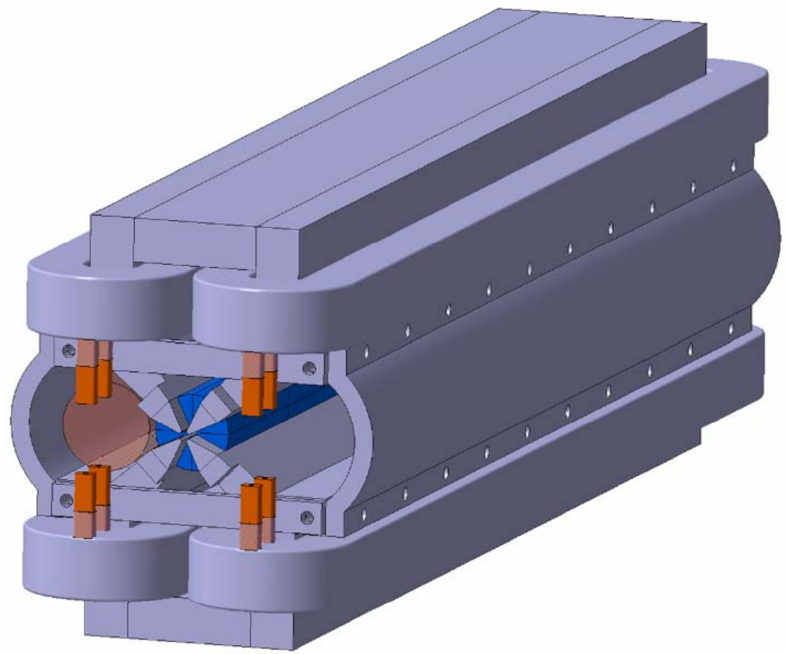


CLIC QD0 preliminary – hybrid permanent / warm e.m. magnet

Courtesy Michele Modena, Davide Tommasini, Evgeny Solodko, Alexey Vorozhtsov

http://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=66527





LumiCal – a first proposal

(courtesy Iftach Sadeh, Tel Aviv Univ.)

LumiCal – a first proposal

(courtesy Iftach Sadeh, Tel Aviv Univ.)

LumiCal Parameters (present status):

Design Goal: 1% accuracy for Luminosity Measurement

Distance (front-face) from IP: 2.27 m (-> 2.5 m for CLIC01_ILD)

Inner Radius geometric: 10 cm (44 mrad) fiducial: 50 mrad

Outer Radius geometric: 35 cm (153 mrad) fiducial: 130 mrad

Passive Layers: 3.5 mm W

Active Layers: Si (total space: 1 mm between W layers)

Radial Divisions: 50 Azimuthal Divisions: 48

dynamic range of signals (MIP->max.): 4 fC to 50 pC

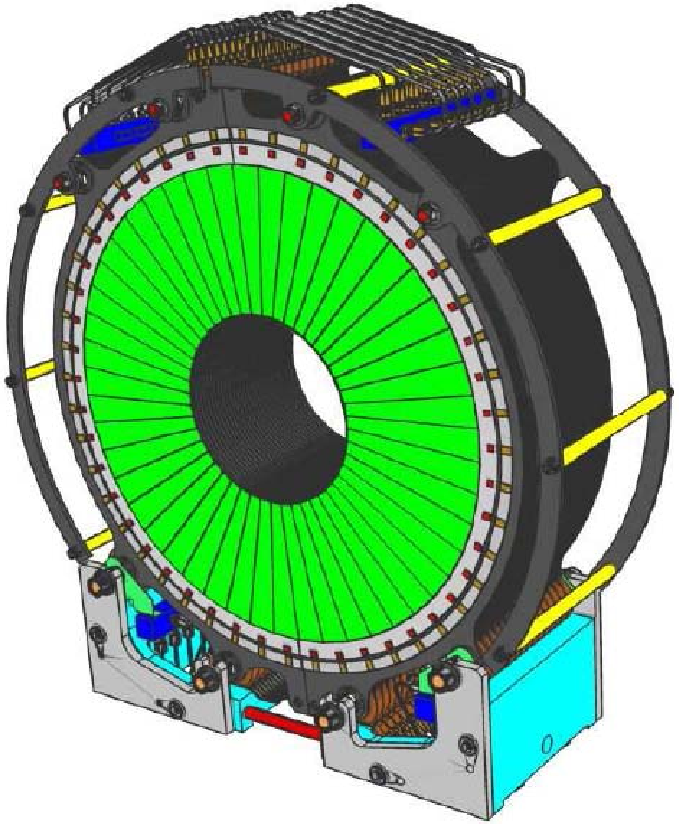
Number of Layers: 40

Bhabha event rate: 4×10^6 / year (50% selection efficiency, 10^7 s)

LumiCal – a first proposal

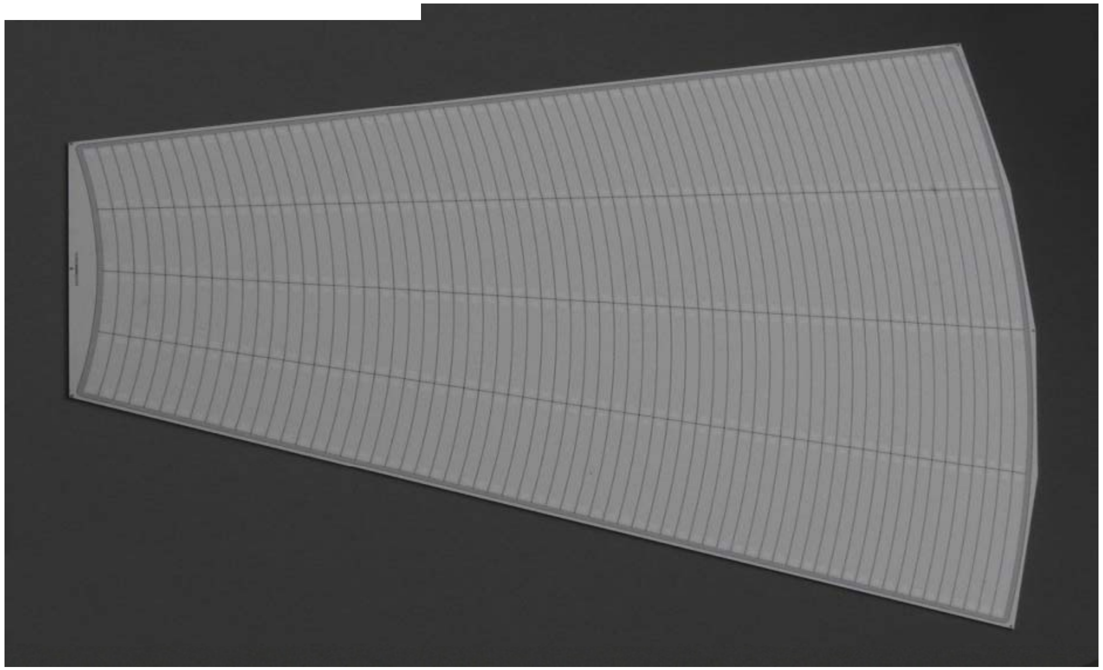
(courtesy Iftach Sadeh, Tel Aviv Univ.)

... Similarities with ILC LumiCal ...



Hamamatsu

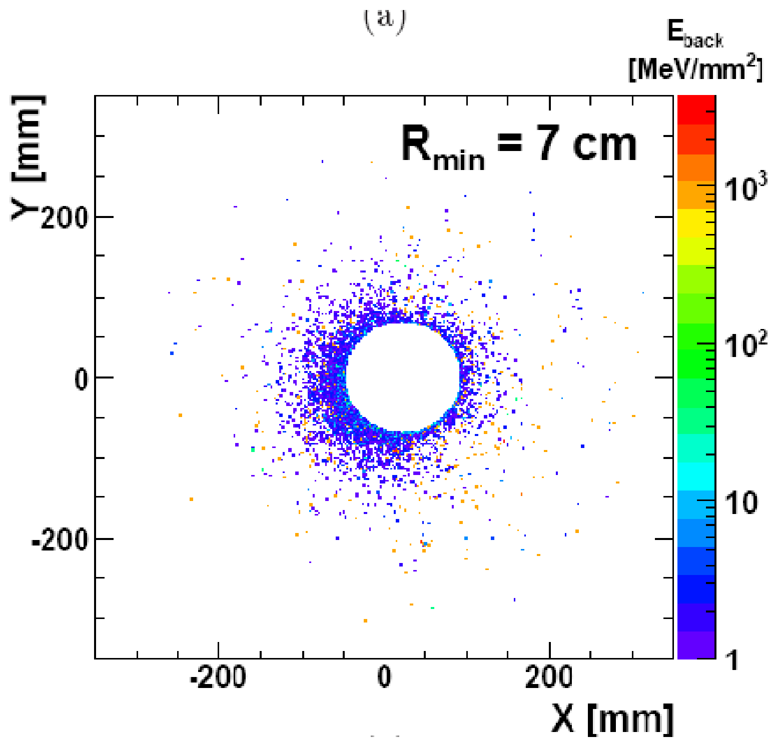
S10938-8380

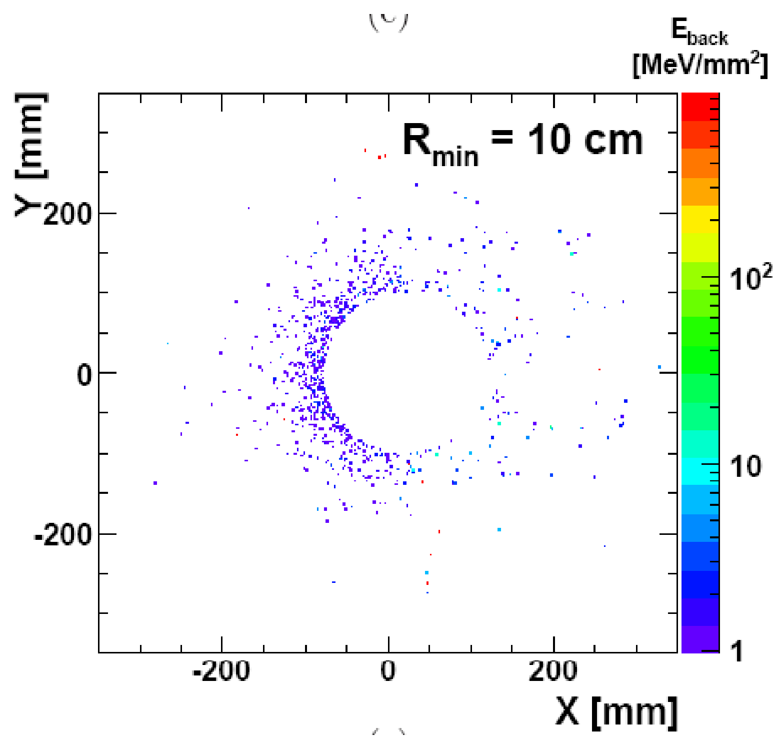


LumiCal – a first proposal

(courtesy Iftach Sadeh, Tel Aviv Univ.)

CLIC LumiCal Issue: Background (incoherent pairs)



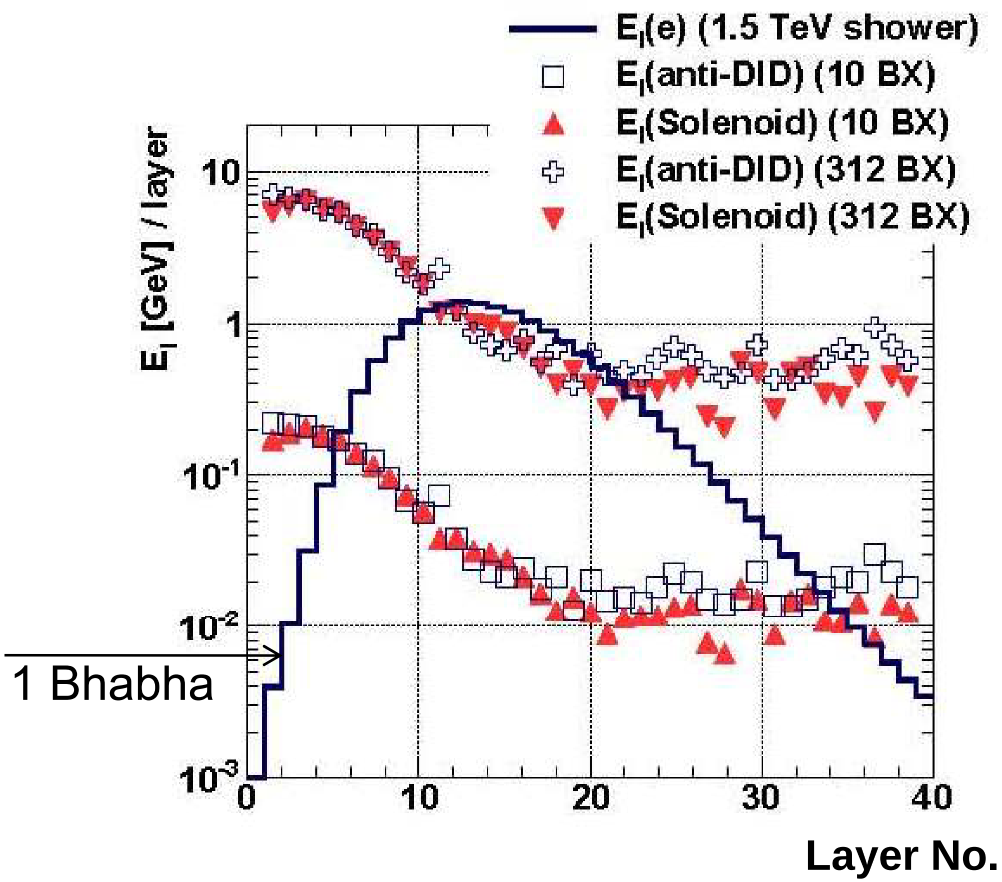


- Solenoid field (no anti-DiD)
- Integrated over 10 BX

LumiCal – a first proposal

(courtesy Iftach Sadeh, Tel Aviv Univ.)

CLIC LumiCal Issue: Background (incoherent pairs)



- this plot for R_{min} = 10 cm
- exaggerated / pessimistic

  Bhabha events are “local”,

  background is total LumiCal

CLIC LumiCal: work in progress

- topological cuts (“clustering”) to reduce background
- time-stamping layer needed ? (resolution ?)
- dynamic range of readout electronics > 10^4
  - – feasible? switching range for MIP calibration ?
- physics background and selection cuts

  models: WHIZARD vs. BDK

  beam-beam and Bhabha Suppression Effect,

  and influence on selection cuts
- ...

BeamCal Studies

(courtesy André Sailer, CERN)

BeamCal Parameters (present status):

Distance (front-face) from IP: 3.2 m

Inner Radius : 2.6 cm (8 mrad)

Outer Radius : 15 cm (46 mrad)

Passive Layers: 3.5 mm W

Active Layers: Si (for the purpose of simulations – will need radiation hard detectors)

Number of Layers: 40

Study high energy electron signal vs. background

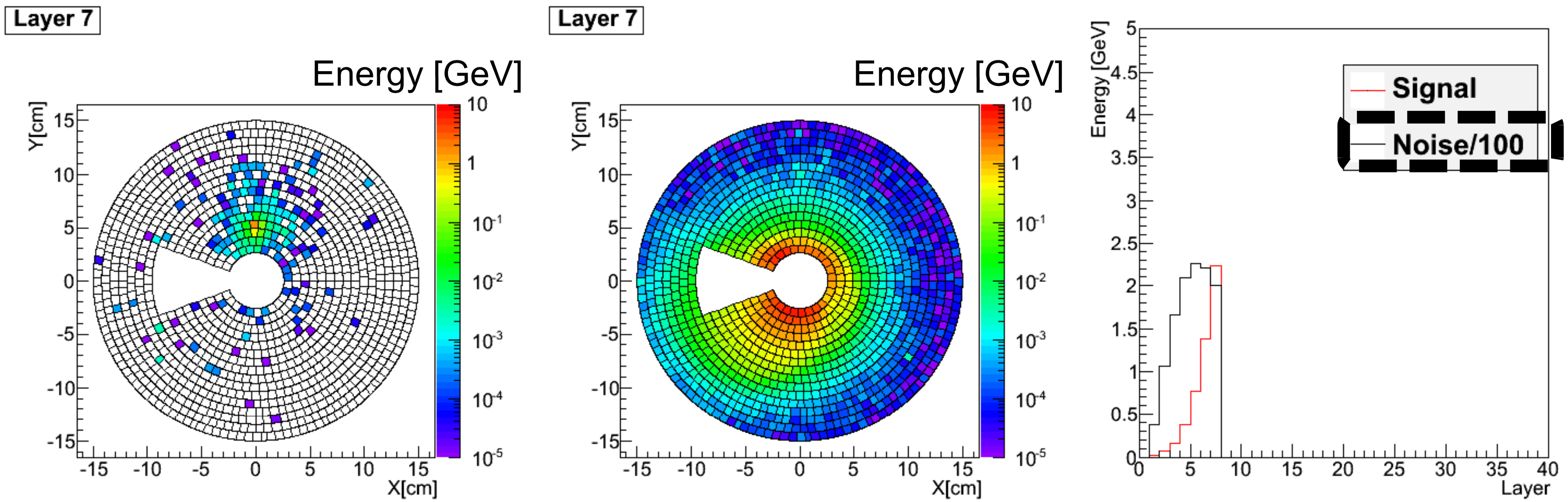
BeamCal Studies

(courtesy André Sailer, CERN)

Preliminary “quick test” of h.e. Electron identification in BeamCal

Example: 1500 GeV electron hitting at 19 mrad

background particles from 1 BX shown



FREEZE

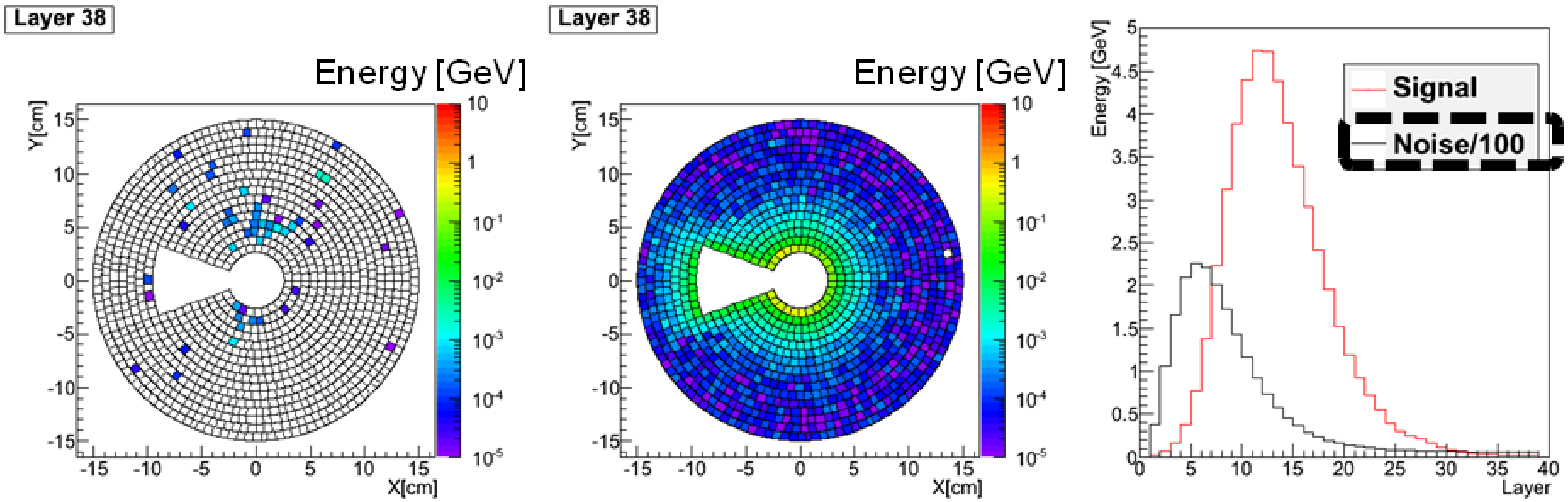
BeamCal Studies

(courtesy André Sailer, CERN)

Preliminary "quick test" of h.e. Electron identification in BeamCal

Example: 1500 GeV electron hitting at 19 mrad

background particles from 1 BX shown



BeamCal Studies

(courtesy André Sailer, CERN)

Preliminary "quick test" of h.e. Electron identification in BeamCal

- For each Pad of BeamCal
  - record deposited energy from 1.5 TeV electrons
  - record deposited energy fluctuation from background (for the given number of BX)
  - sum up the energies $E_{e,i} > \max \{<E_{bg}> - E_{bg,i}\}$

  from those pads in which the deposited energy from the h.e. electron is larger than the fluctuation (for the given number of BX)
- "Quality of Signal":

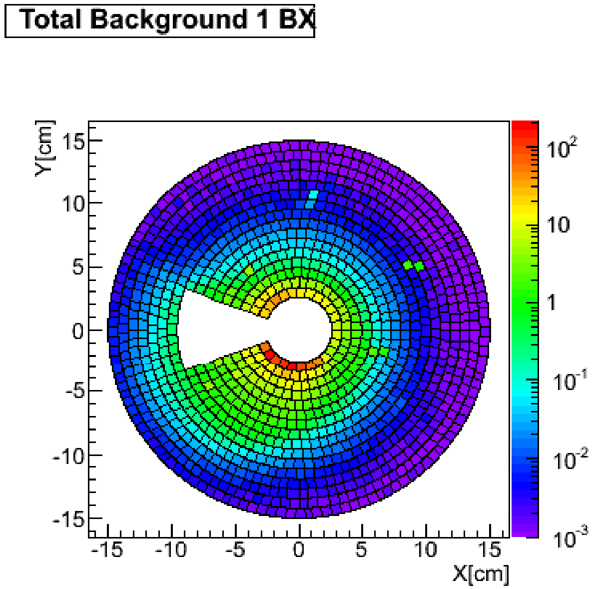
  sum of energy above fluctuation /

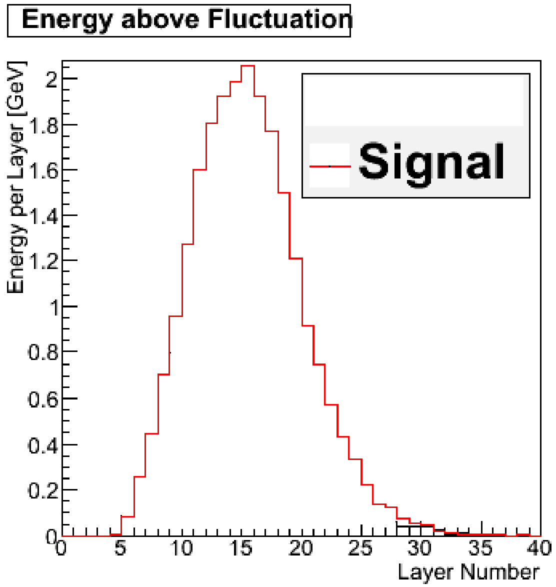
  total deposited energy from the high energy electron

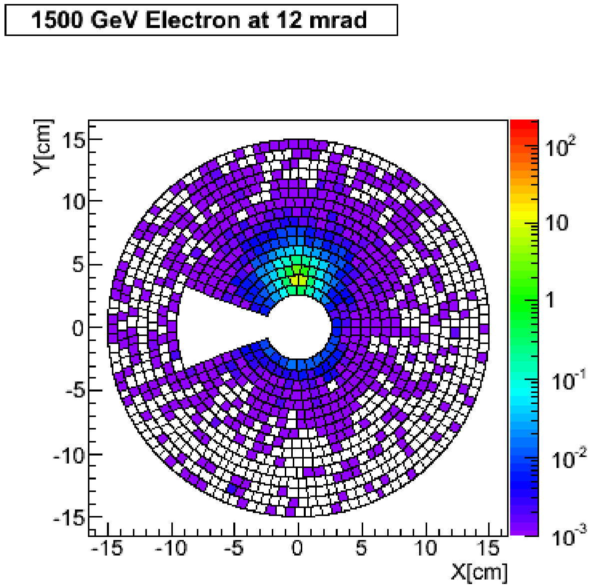
BeamCal Studies

(courtesy André Sailer, CERN)

A 1500 GeV electron at **12 mrad** and background from 1 BX



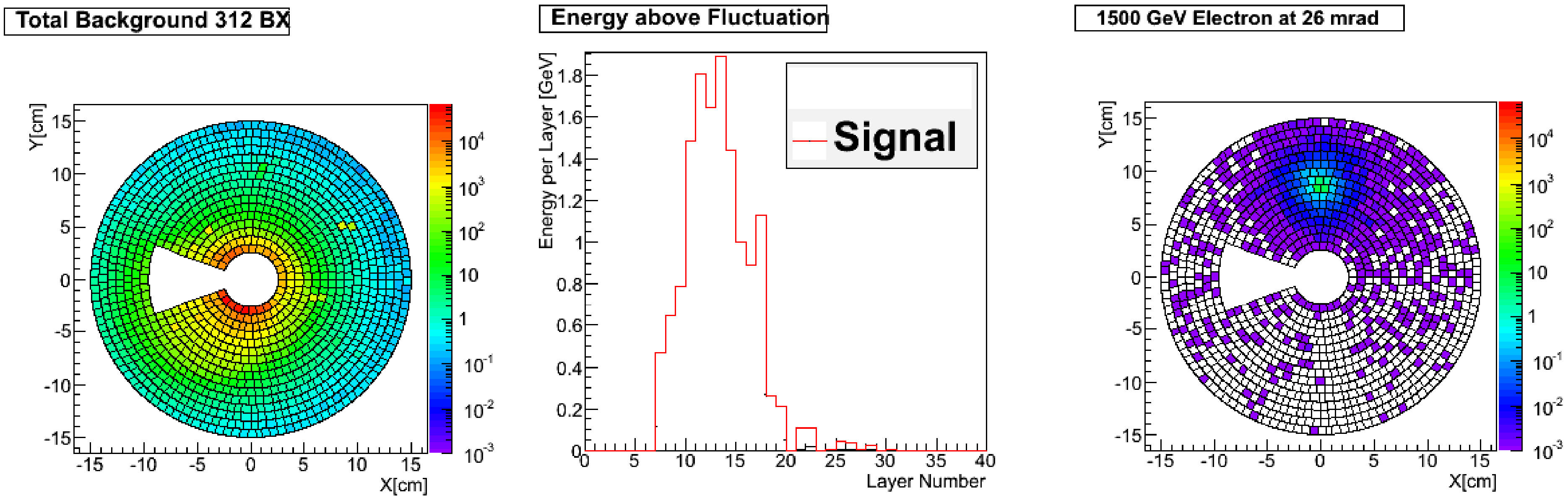




BeamCal Studies

(courtesy André Sailer, CERN)

A 1500 GeV electron at **26 mrad** and background from 312 BX

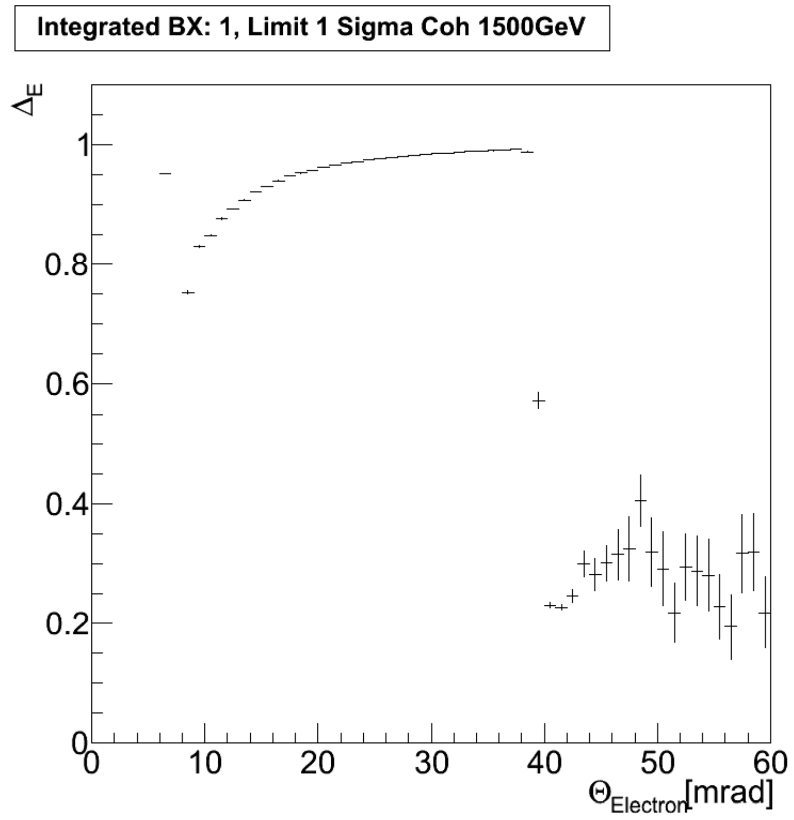


BeamCal Studies

(courtesy André Sailer, CERN)

"Quality of Signal" as function of electron impact angle

- 1500 GeV electrons
- 1 BX Background
- fiducial volume goes up to 40 mrad
- leakage for larger angles

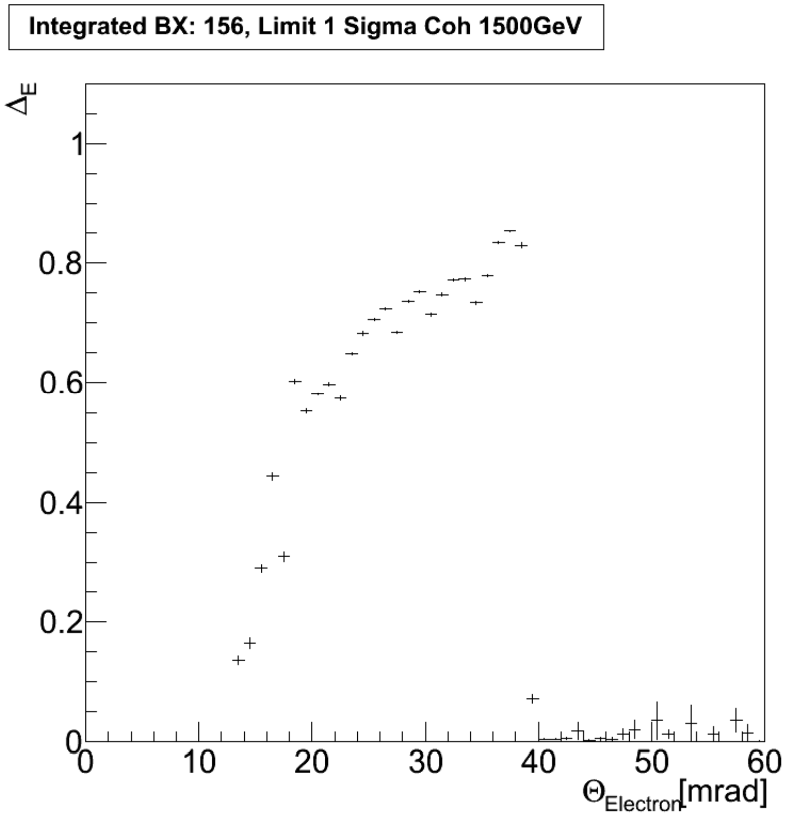


BeamCal Studies

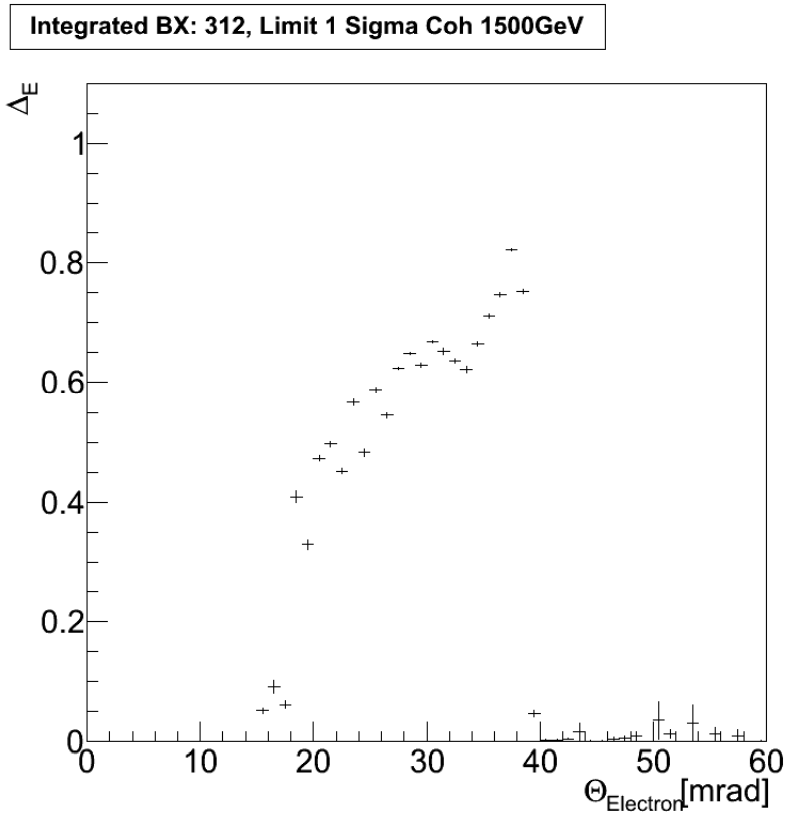
(courtesy André Sailer, CERN)

"Quality of Signal" as function of electron impact angle

156 BX



312 BX



Summary of BeamCal Issues – very preliminary

- work in progress – more detailed studies needed on
  - use of BeamCal for h.e. electron identification / veto at small angles: need improved method (cf. work by Gleb Oleinik, Colorado)
  - checking use of BeamCal for beam diagnostics
  - angular coverage and masking

- need for time-stamping to improve electron identification

Background in the Vertex Detector

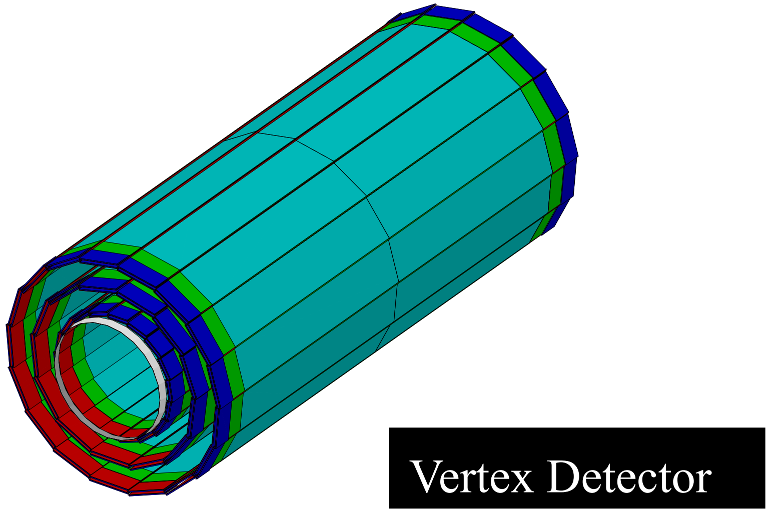
(courtesy André Sailer, CERN)

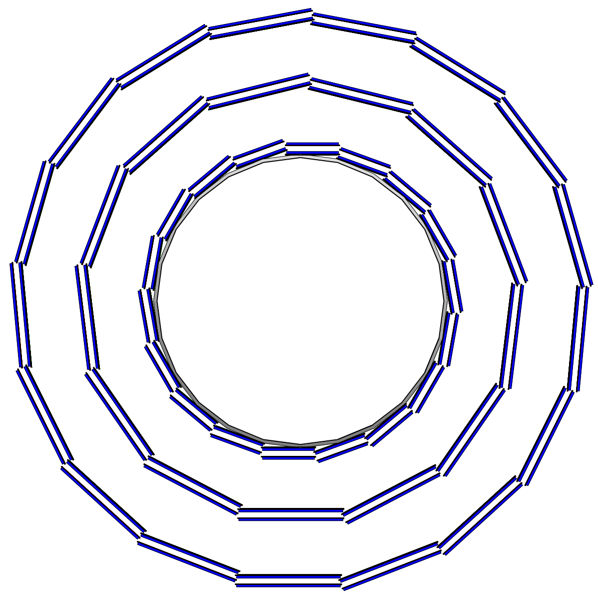
Background in the Vertex Detector

(courtesy André Sailer, CERN)

- CLIC01_ILD
- Vertex Detector
  - 3 double Layers at R=31/45/60mm
  - All layers 25 cm long
  - 50 μm active Silicon
  - Threshold: 3.4 keV
- 4 T Solenoid Field

(Hadronic Calorimeter
  - 8.5λ
  - Absorber: Tungsten, 1cm thick, 77 layers)





Background in the Vertex Detector

(courtesy André Sailer, CERN)

Background in VTX -

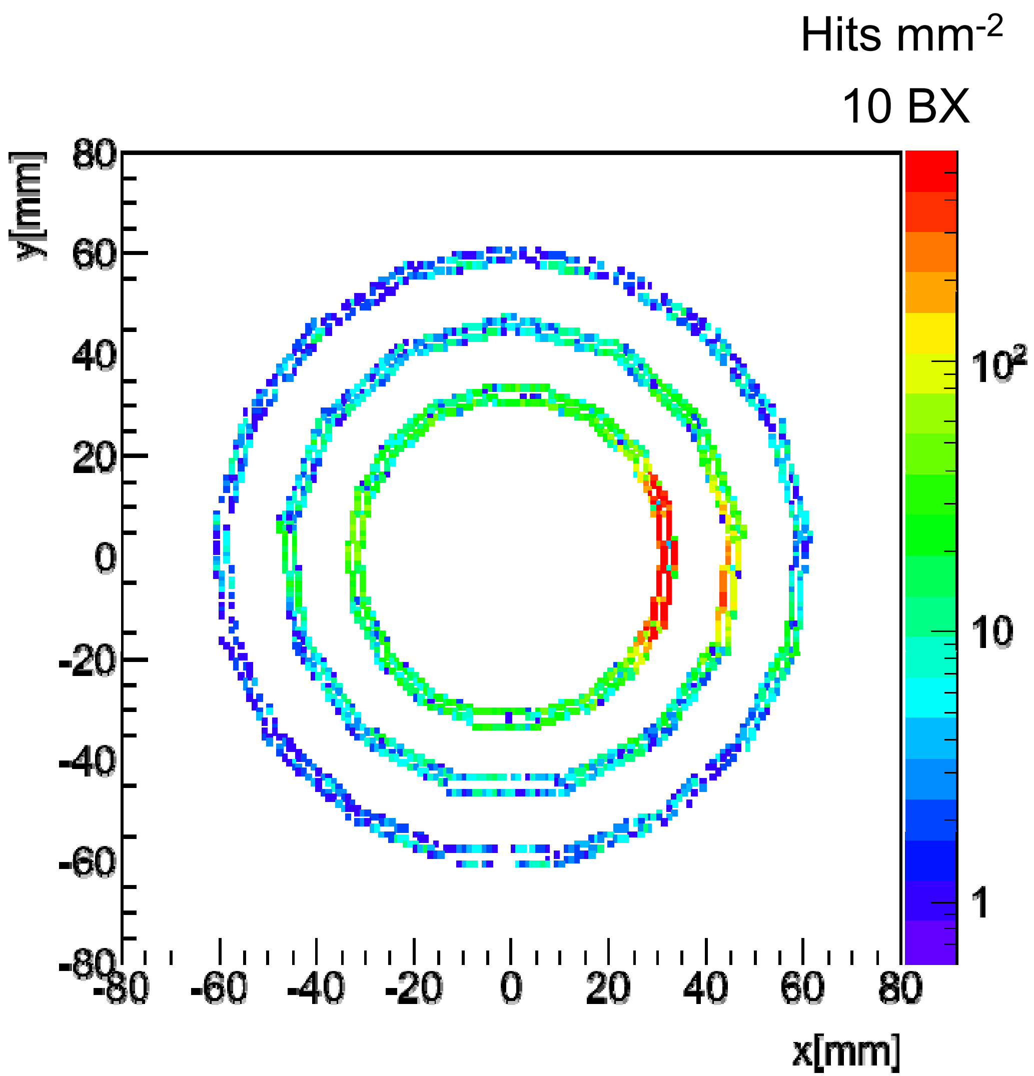
hit distribution

(before modification of

BeamCal inner radius and

the vacuum tube

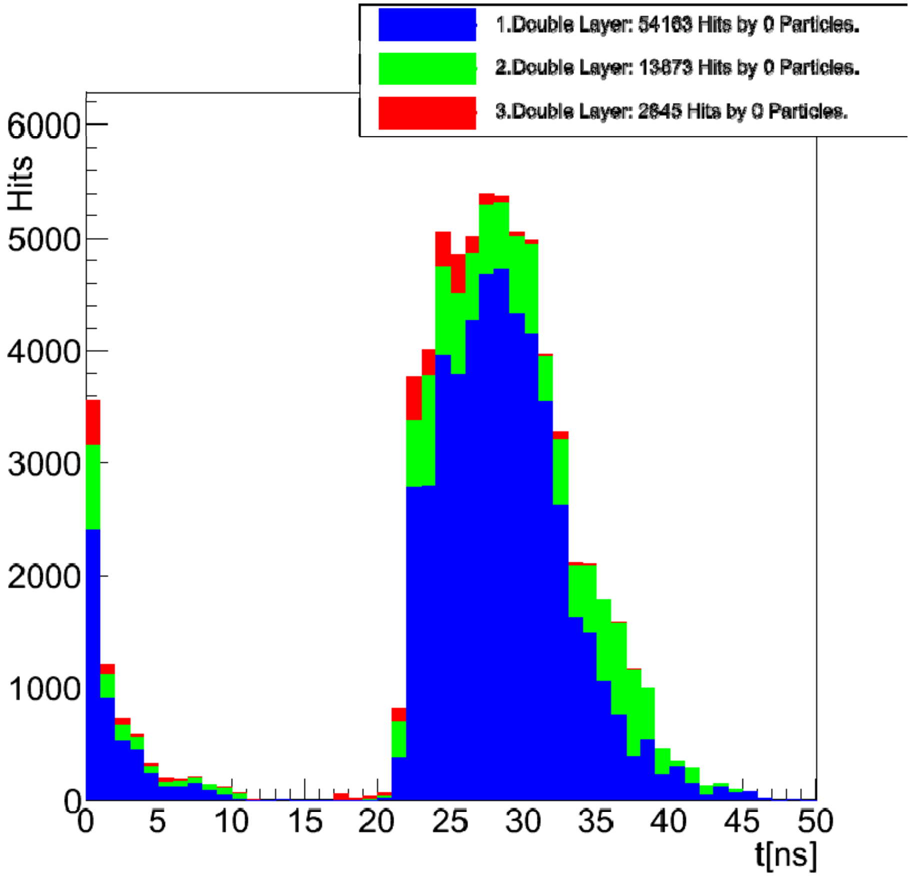
downstream of BeamCal

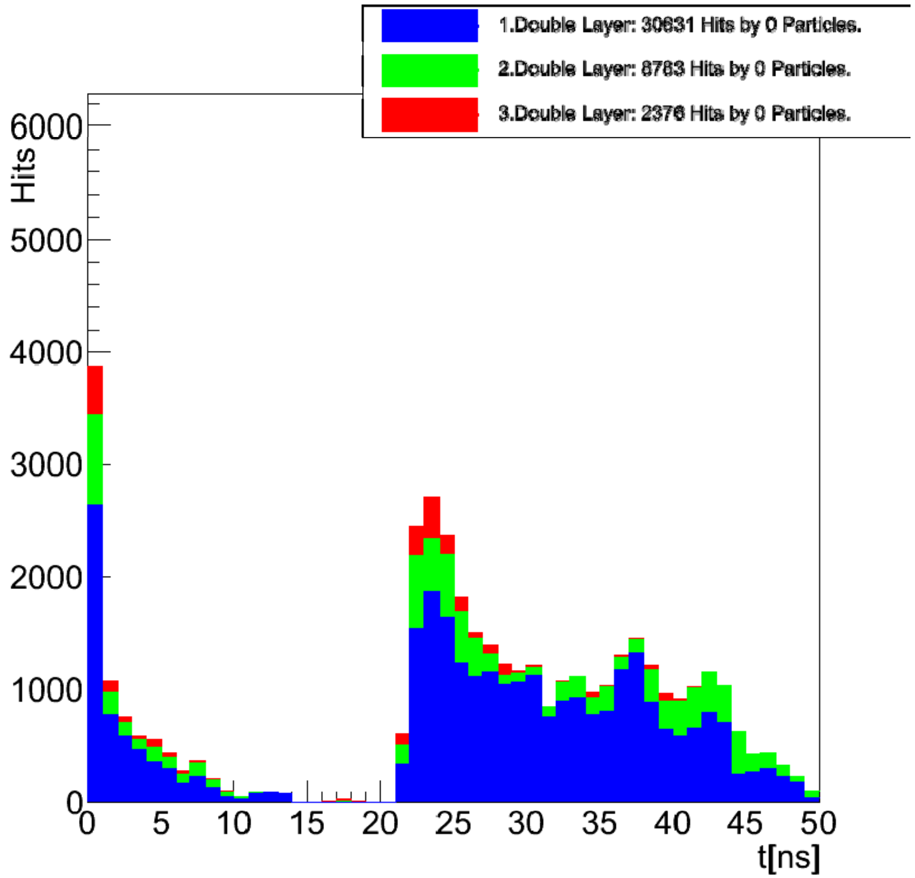


Background in the Vertex Detector

(courtesy André Sailer, CERN)

Background in Vertex and Trackers – time distribution for 2 geometries





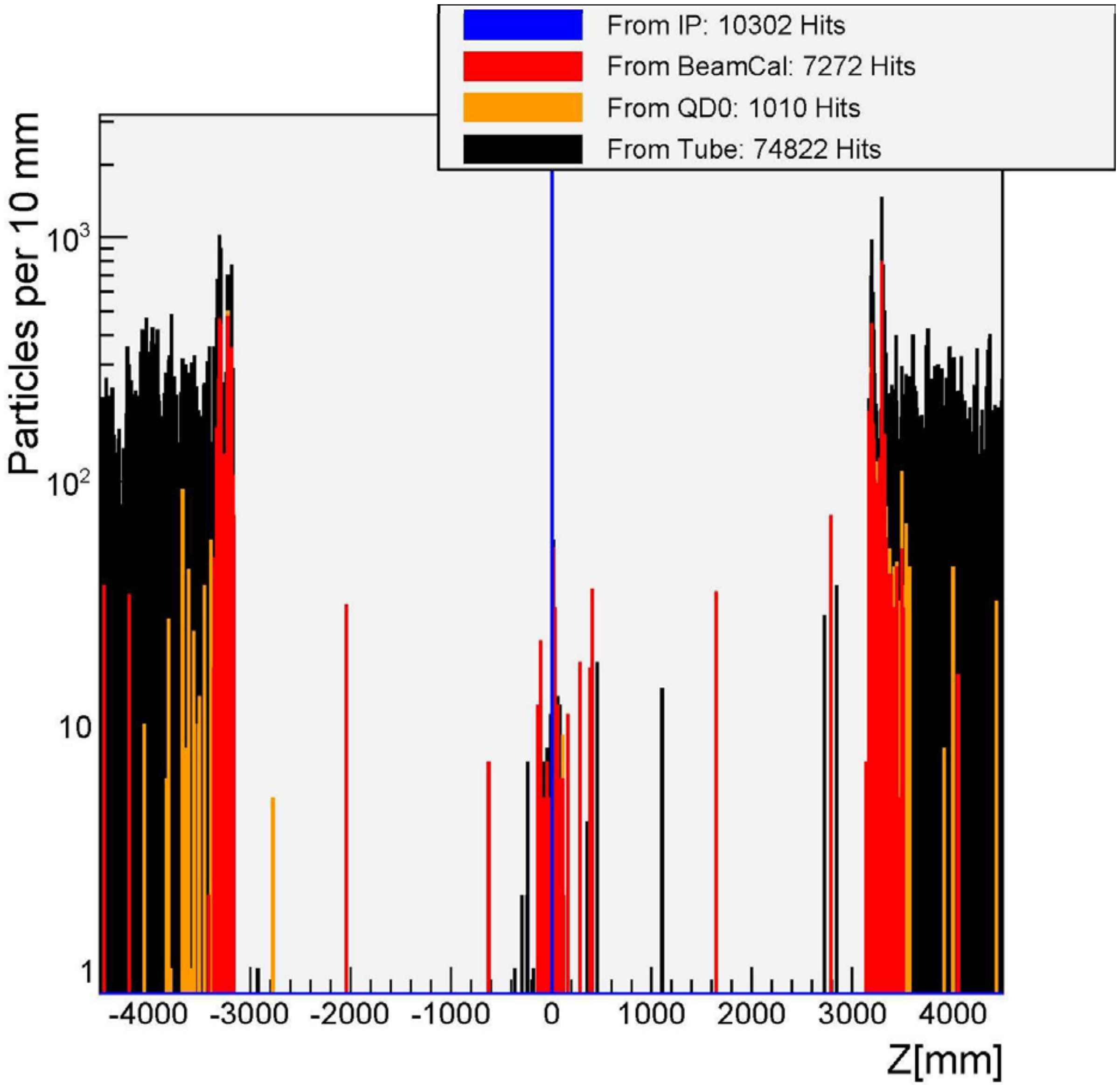
Background in the Vertex Detector

(courtesy André Sailer, CERN)

Origin of hits in VTX:

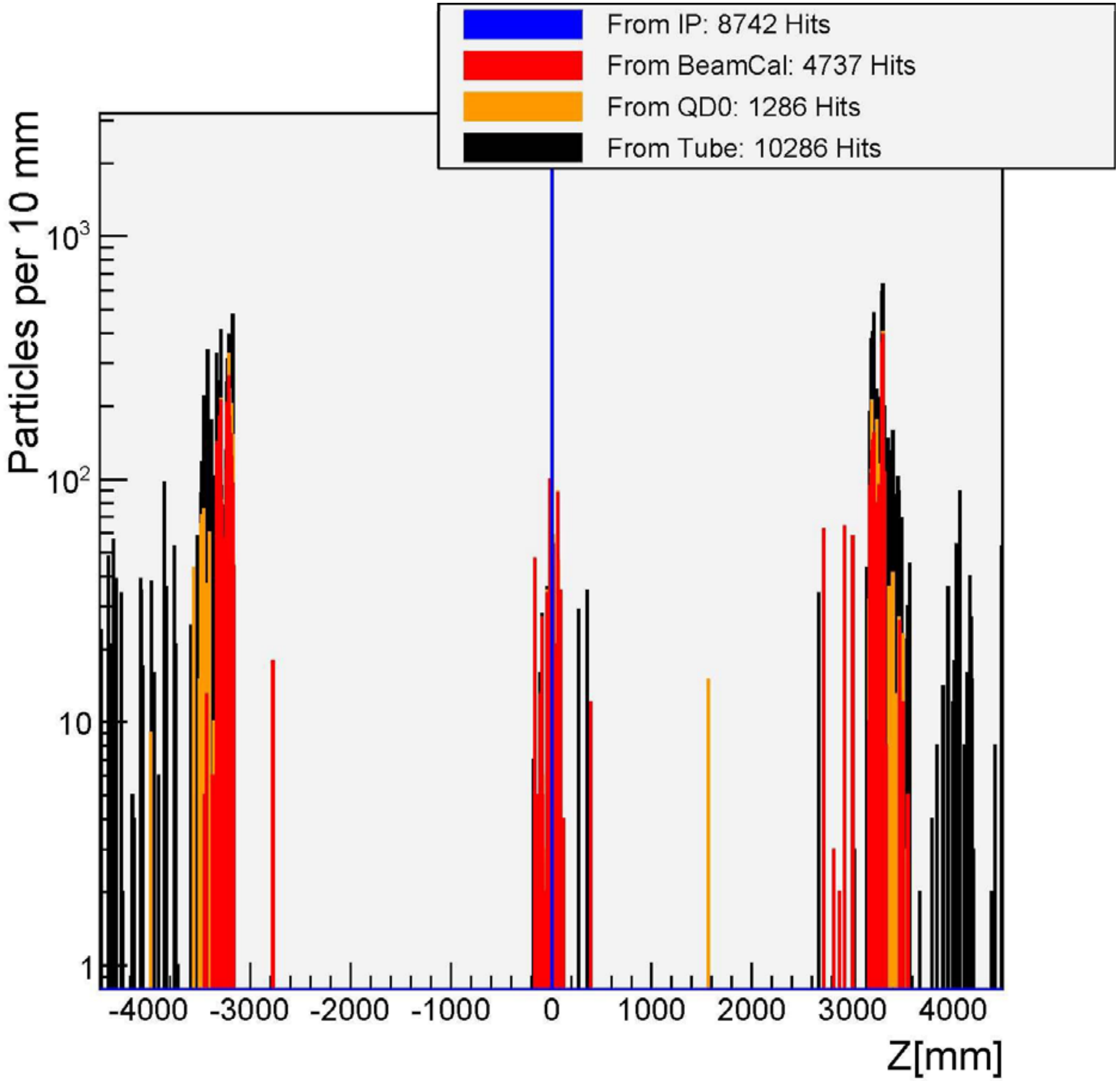
before modifications

(10 BX)



Background in the Vertex Detector
(courtesy André Sailer, CERN)

Origin of hits in VTX:
after modification of the BeamCal inner diameter and the vacuum tube diameter and shape (10 BX)



Background hits in whole Vertex detector, per BX (no anti-DID)

Origin of particle	first CLIC model	latest model
IP	1030	874
LumiCal	0	0
BeamCal	727	474
QD0	101	129
Vacuum Tube	7482	1029
Total	9341	2505

On innermost vertex double layer: **1.9 Hits / cm^2 / BX**

Summary of Background in Vertex Issues

- innermost vertex (double-)layer at 31 mm
  (avoid direct hits from incoherent pairs)

- much progress made to reduce backscattering into vertex
- additional difficulties since we have no Anti-DiD field

- number of hits **per BX** in the innermost vertex detector layer
  now comparable to ILC

- need time-stamping to avoid accumulation of BG hits

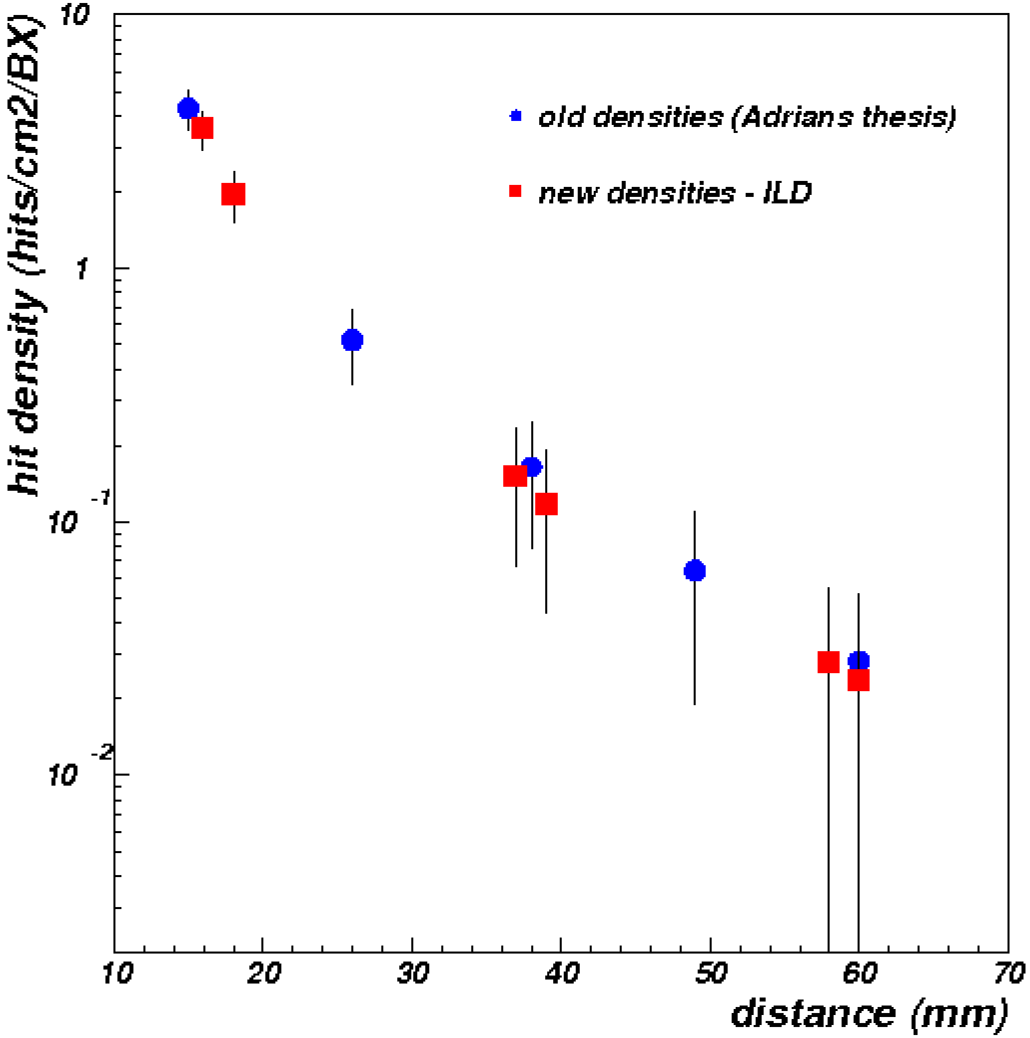
Summary

- Forward region at 3 TeV CLIC: significant progress in 6 months
  many thanks to FCAL collaboration for support,
  thanks to ILD and SiD for software and much input
- clear path towards a LumiCal (but more studies needed
  concerning topological cuts and - possibly - time stamping)
- BeamCal looks difficult, even with good time stamping –
  work needed to understand physics reach if electron veto is
  only o.k. at angles, e.g., larger than 15 mrad
- Background in vertex detector appears under control
  (as long as time stamping is used)
- Work in progress – thank you for your attention !

Other Studies w.r.t. "forward" + "MDI"

- New MDI chair at CERN: Lau Gatignon – MDI priority on QD0 design and stabilisation
- Phil Burrows et al. (Oxford): intrabeam feedback (based on FONT experience)
- Rob Appleby, Mike Salt et al. (Cockcroft): gamma (and neutron) background in detector due to backscattering from post-collision line
- LCD Project Team at CERN: Physics Case for a longer barrel (aspect ratio)
- Ivanka Bozovic-Jelisavcic et al. (Belgrade): BHSE and systematic errors in LumiCal, Physics background, differences between Whizard and BDK
- Barbara Dalena, Detlev Svoboda (CERN): anti-solenoid coils (improve optics, shield QD0 against main solenoid field)
- Alain Herve (ETH Zurich): support QD0 independently of the detector, push-pull, etc.
- Hubert Gerwig (CERN): reduce the amount of iron in the yoke … (hybrid yoke+coils)
- Claude Hauviller et al.: vibration measurement in LHC tunnel on either side of LHCb; vibration measurements on the floor and on top of CMS
- Hermann Schmickler (CERN): measure nm vibration of a quadrupole by observing the beam
- Annecy+CERN: stabilisation of CLIC modules and FF quadrupole
- …

SPARE SLIDES



Source :

K. Wichmann (DESY)

ILD Detector Optimisation

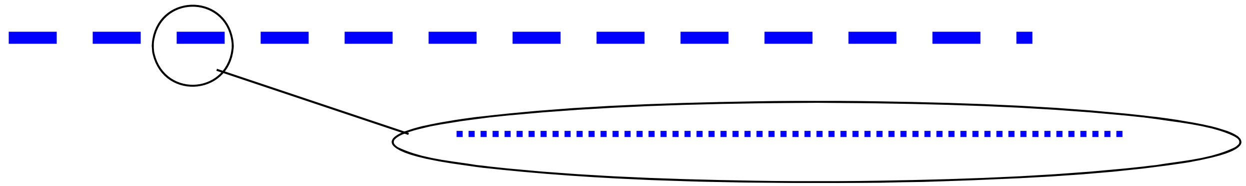
WG Phone Meeting

13 May 2009

CLIC time structure

Train repetition rate 50 Hz

CLIC



CLIC:	**1 train = 312 bunches**	**0.5 ns apart**	**50 Hz**
ILC:	1 train = 2820 bunches	308 ns apart	5 Hz

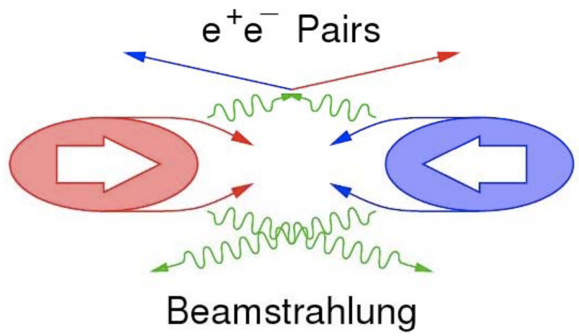
Consequences for CLIC detector:

- Need for detection layers with **time-stamping**
    - Inner-most tracker layer with ~ns resolution
    - or …. all-detector time stamping at the 10 ns (?) level
- Readout/DAQ electronics will be different from ILC
    - Power pulsing has to work at 50 Hz instead of 5 Hz

CLIC 3 TeV
Beam-induced background

Backgrounds:

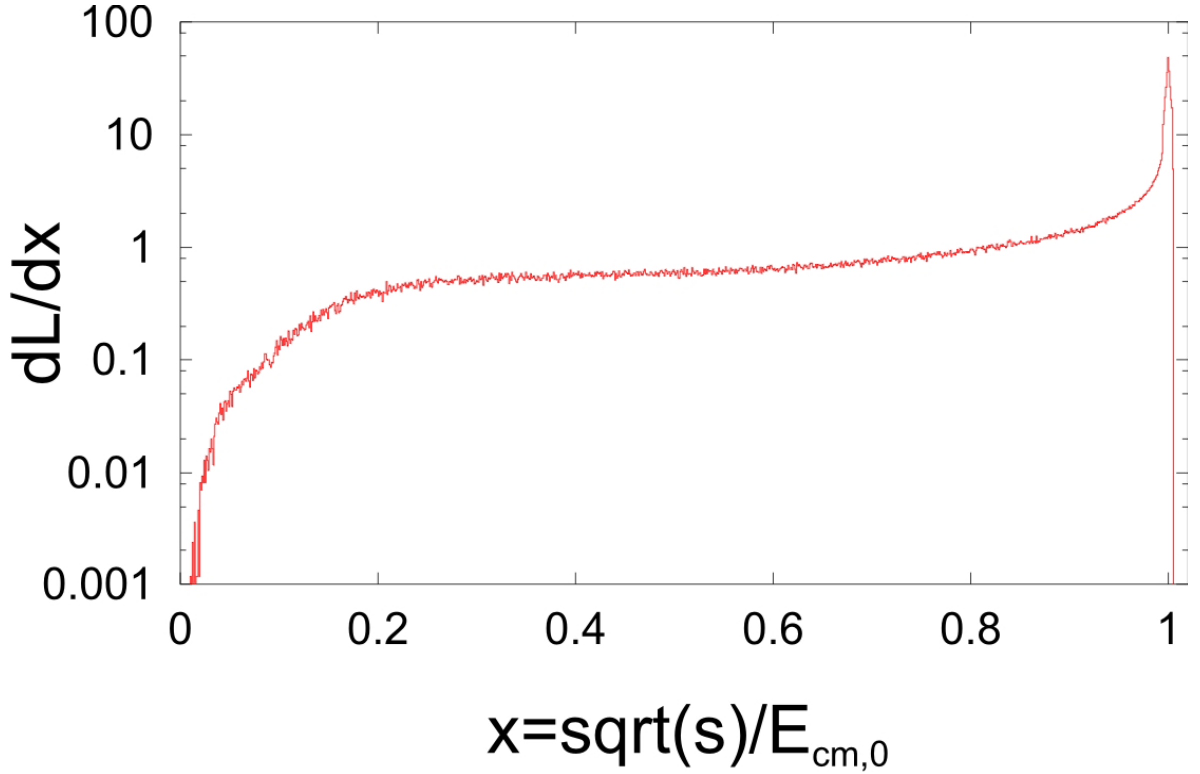
Due to the higher beam energy and small bunch sizes backgrounds are significantly more severe at CLIC.



Main backgrounds:

- CLIC 3TeV beamstrahlung average energy loss: **29%** ($10 \times ILC_{value}$)
  - **Coherent pairs** (3.8×10^8 per bunch crossing) <= disappear in beam pipe
  - **Incoherent pairs** (3.0×10^5 per bunch crossing) <= suppressed by strong solenoid-field
  - $\gamma\gamma$ interactions => hadrons ($\approx$ **3 hadron events per bunch crossing**)
- Muon background from upstream linac
  - More difficult to stop due to higher CLIC energy (active muon shield ?)

CLIC 3 TeV centre-of-mass energy spectrum

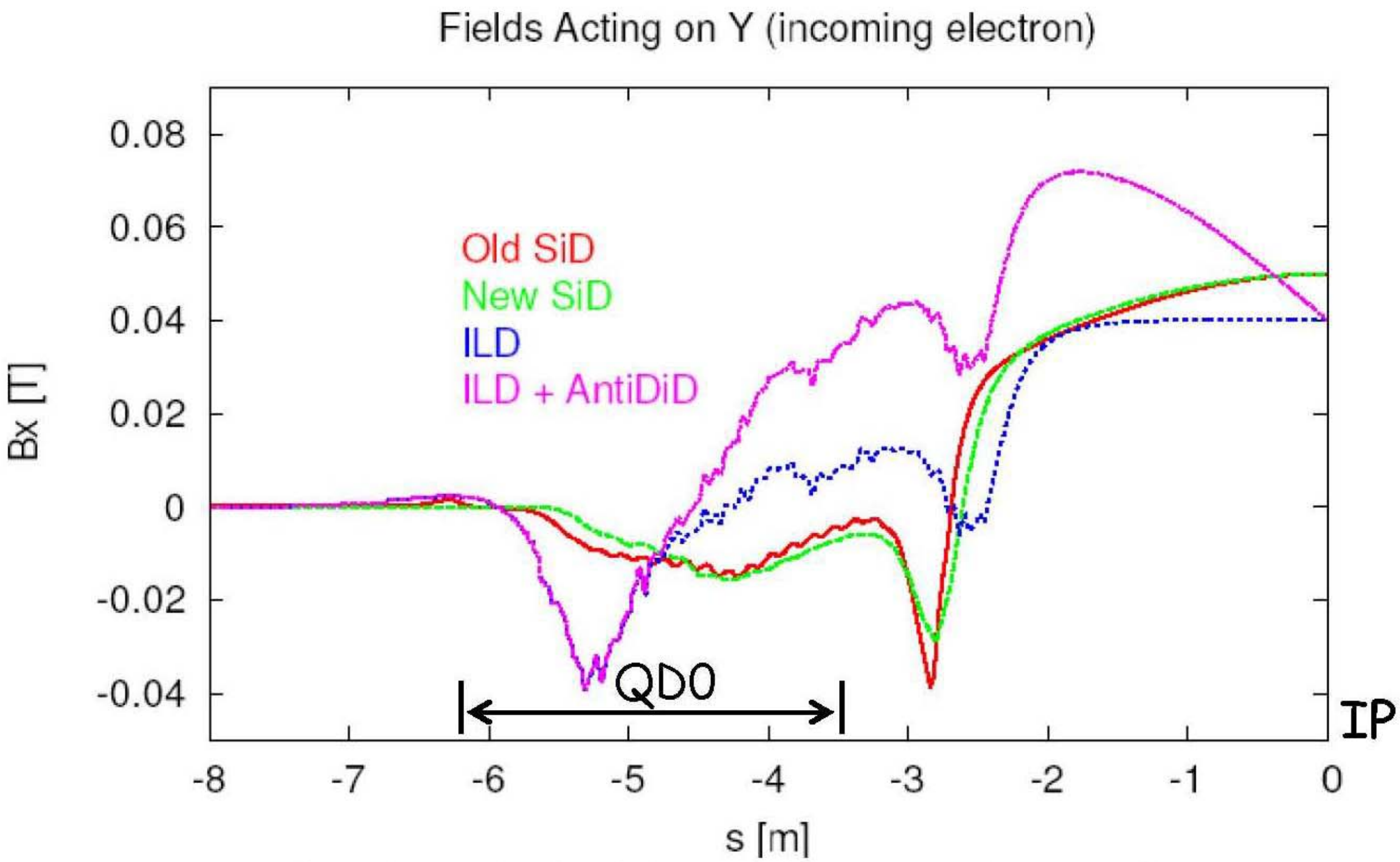


Due to beam-beam effects:

- At 3 TeV only 1/3 of the luminosity is in the top 1% centre-of-mass energy bin
- asymmetric situation -> many events with large forward / backward boost

CLIC synchrotron radiation, solenoid, anti-DiD etc. …

Work by **Barbara Dalena**, CERN (CLIC study team):



CLIC

20 mrad

B_x component of solenoid fields in the beamline reference system

Track Occupancy from γγ Background

VXD

	R=30 mm **-50<z<50mm**	R=50 mm **-125<z<125mm**	R=70 mm **-125<z<125mm**
Hits/mm^2/Train	~0.20	~0.17	~0.14

FTD

	z=200 mm **85<R<140mm**
Hits/mm^2/Train	~0.04

- $\gamma\gamma \rightarrow$ hadron background affects mostly channels with missing energy or precise di-jet mass reconstruction because of extra energy injected in the event;

- occupancy appears negligible in Barrel Cal and modest in Vertex tracking with time stamping $\sim$ 10-20 ns, preliminary results documented in CLIC Note in preparation;

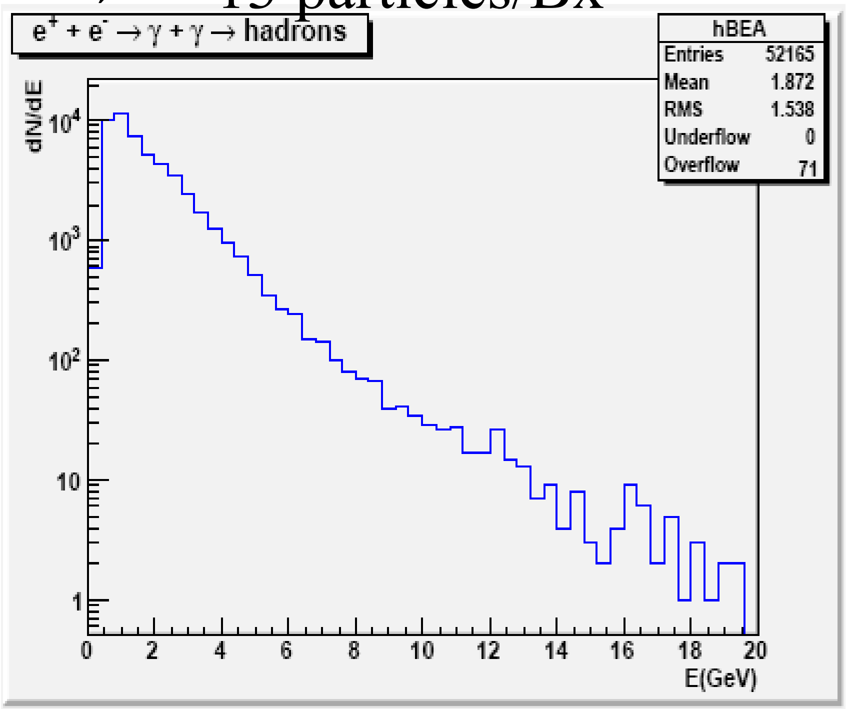
- optimisation of time stamping strategy (very precise timing at a single layer or distributed timing in innermost tracking layers) requires to consider constraints from layer material budget, power dissipation and pixel sizes.

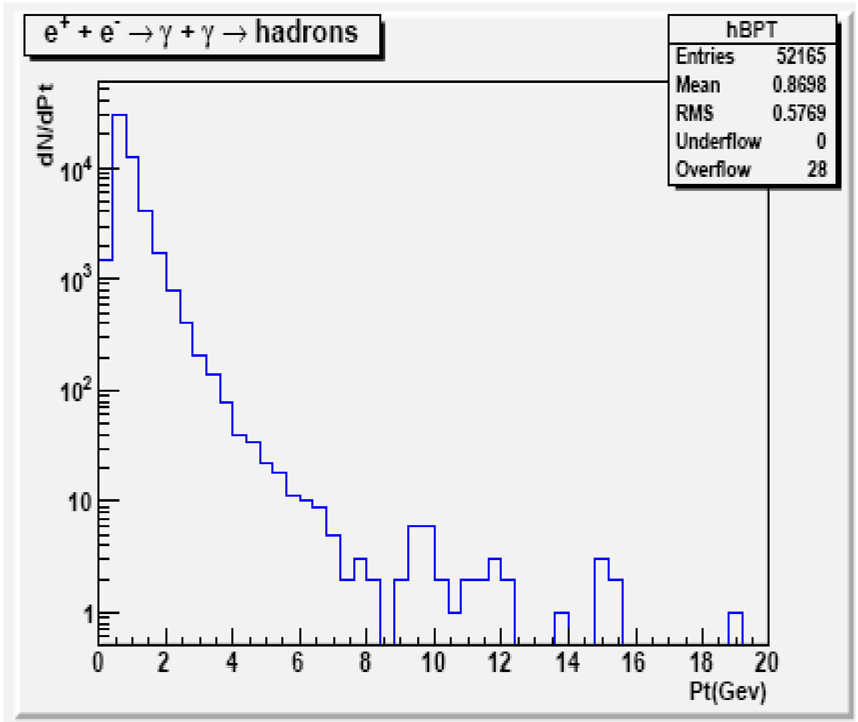
- study pattern recognition efficiency and performance for different VXD concepts (in collaboration with Alex Kluge et al.) on physics benchmarks + $\gamma\gamma \rightarrow$ hadrons and PAIR background.

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

At 3 TeV ~ 3.3 $e^+ + e^- \rightarrow \gamma\,\gamma \rightarrow$ hadrons events / Bx

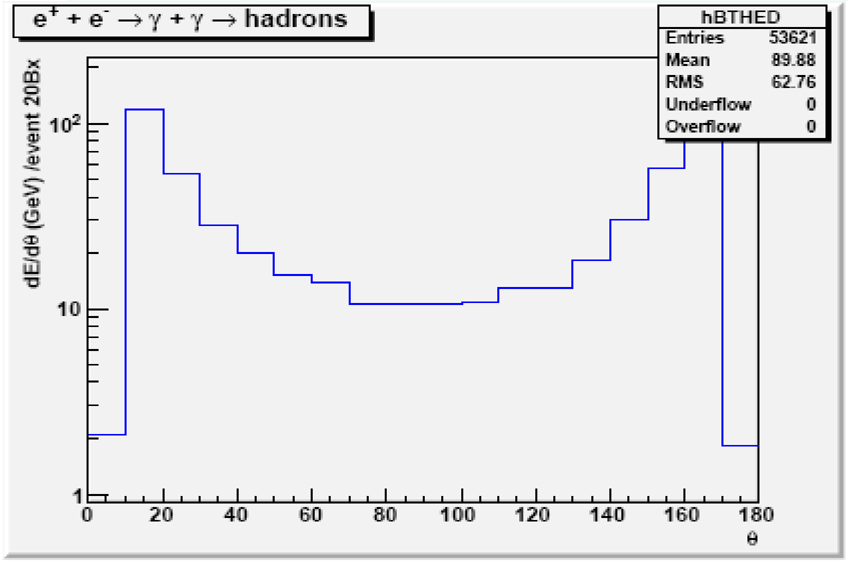
$\rightarrow$ ~ 13 particles/Bx

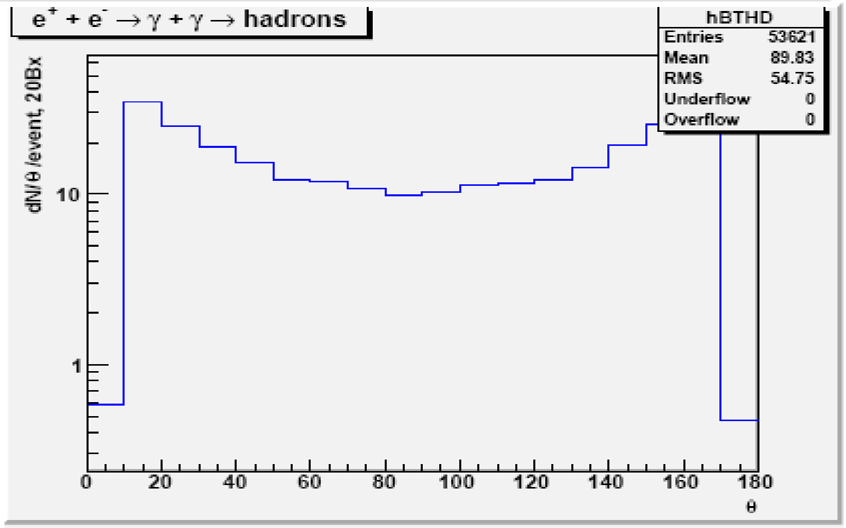




<Eh> ~ 1.9 GeV <Pt> ~ 0.9 GeV.

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





Background peaked in F/B region.

Fig1: dE/dθ **for 10 ns time window**

Energy deposit in a 10 ° cone:

- ~ 20 Gev in barrel region
- ~ 200 Gev in F/B regions

~ 7.5 Tev per train in the detector.

Time stamping is essential.

Fig2: dN/dθ **for 10 ns time window**

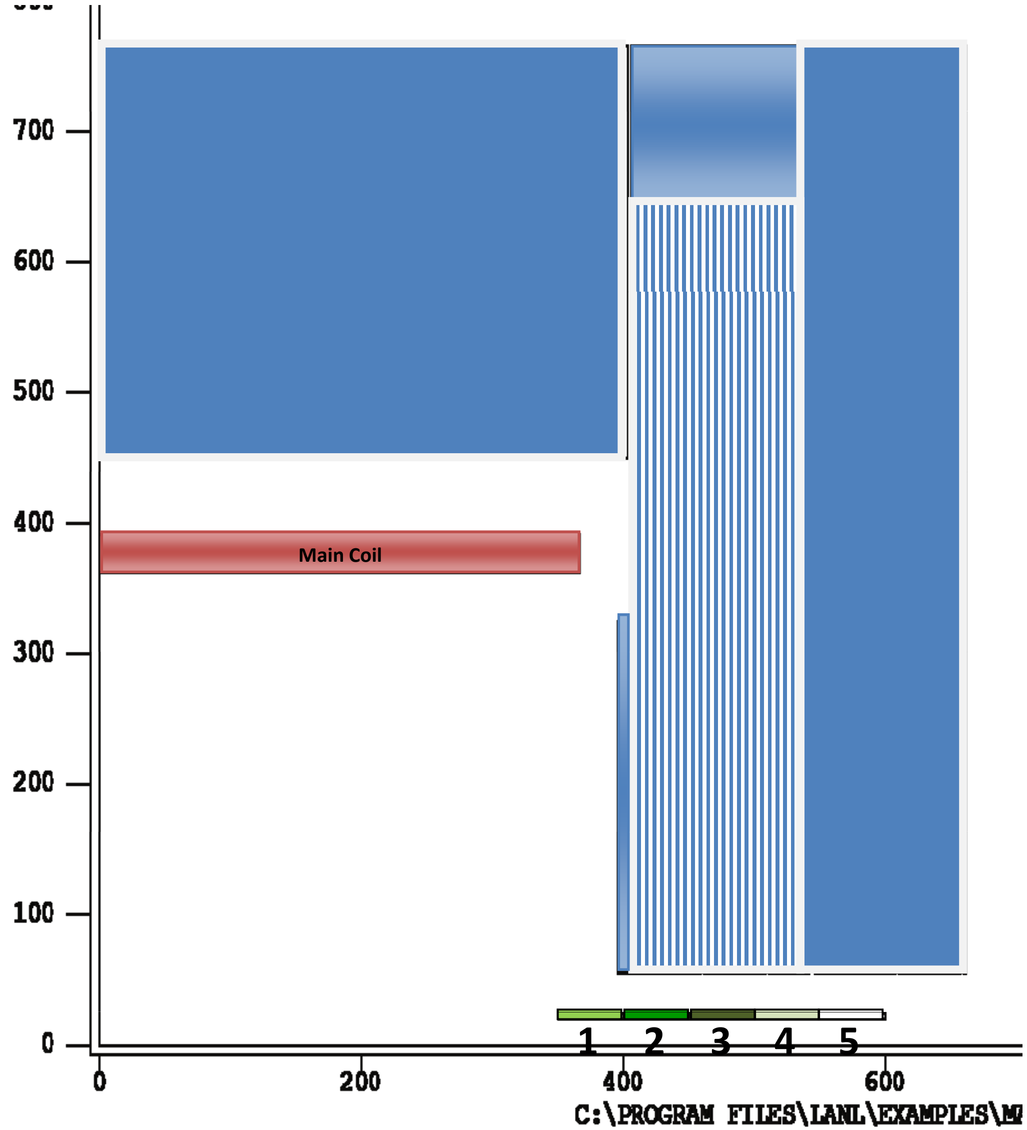
Occupancy/train/cm2 at 2m

- ~ 0.08 in barrel region
- ~ 0.3 in F/B regions

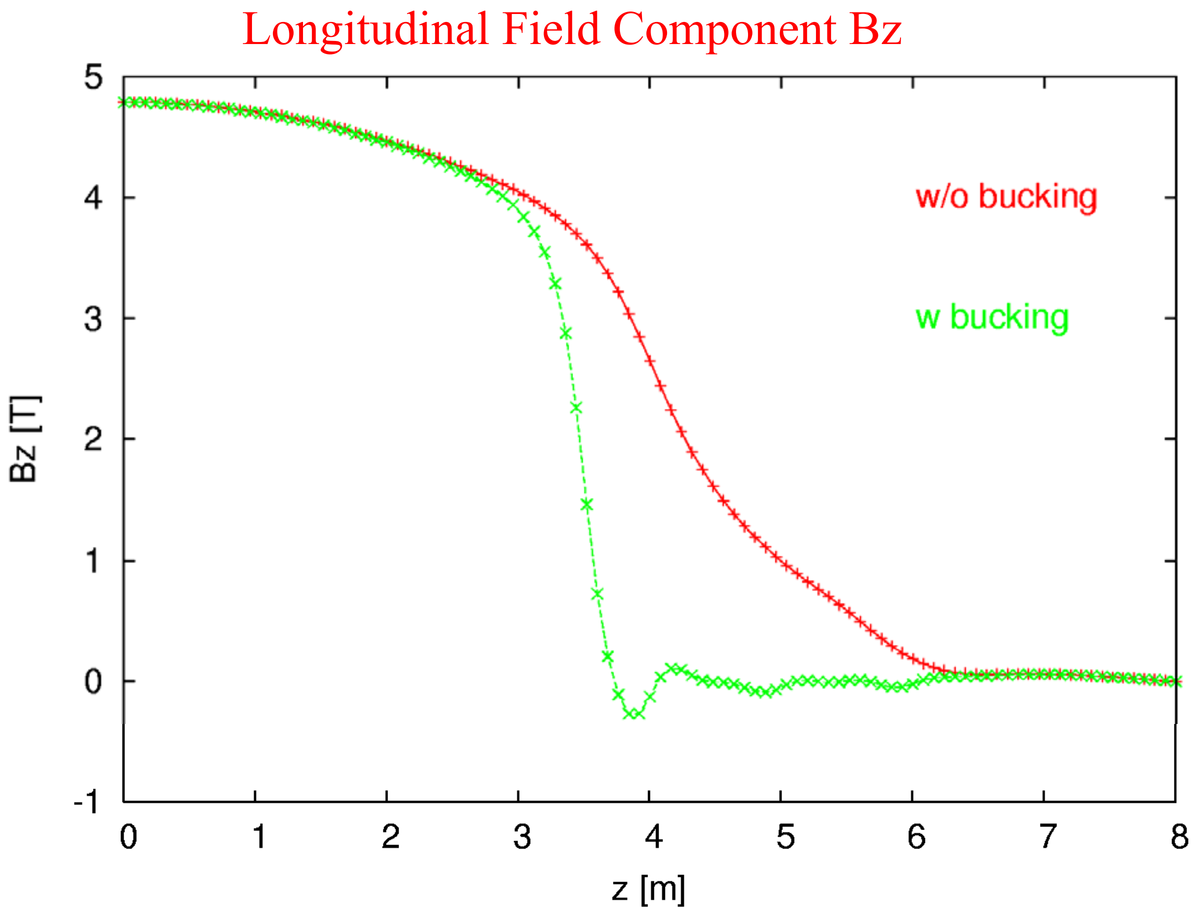
May be an issue for HCAl if cells >> 1 cm2.

Detlev Svoboda (CERN) – antisolenoid coils

FE model

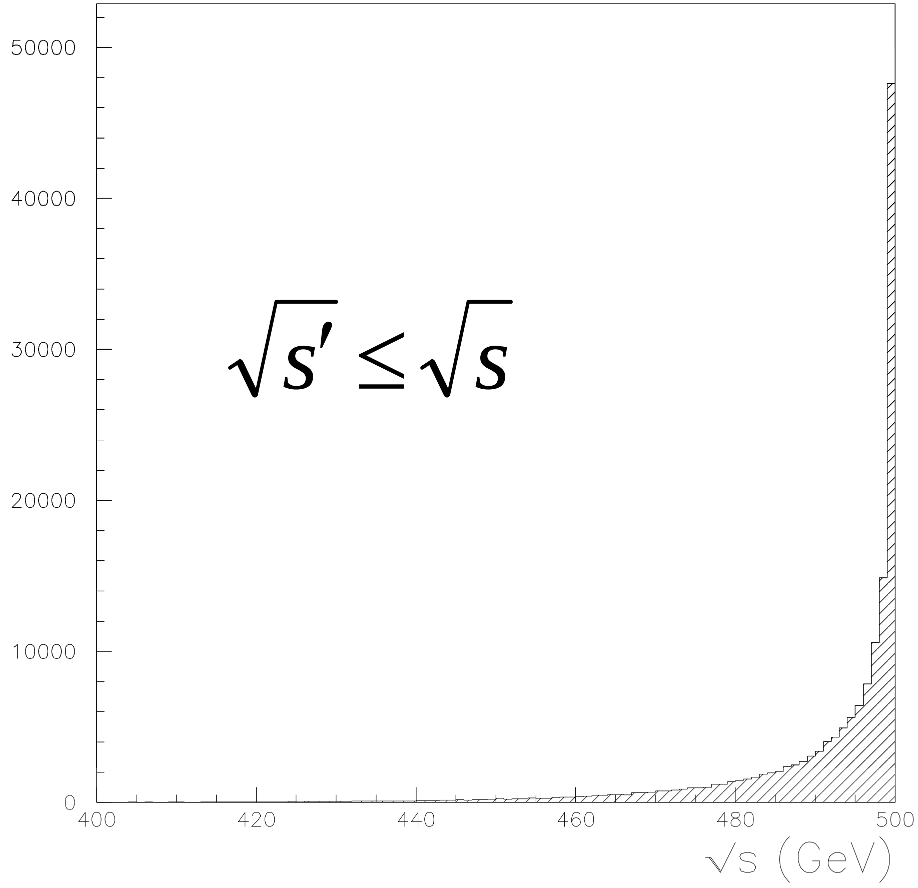


Detlev Svoboda (CERN) - Bucking Coil Effect



C. Rimbault et al. – BHSE effect

http://accelconf.web.cern.ch/accelconf/p07/PAPERS/FRPMN012.PDF



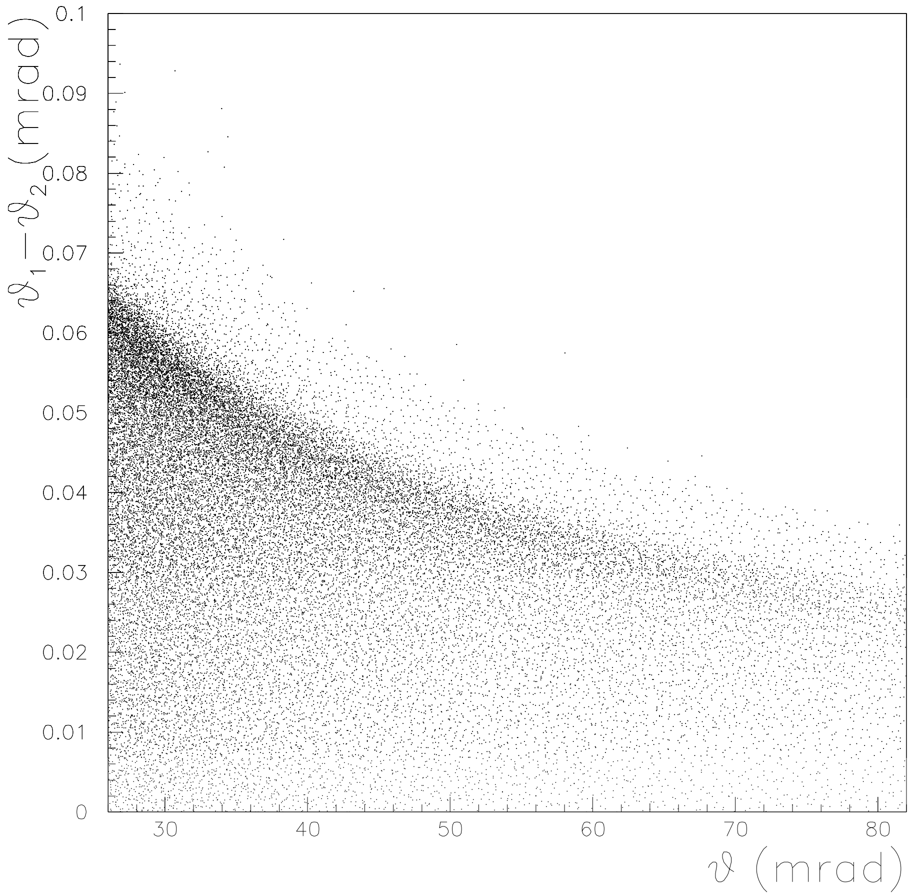
BHSE (1)

Bhabha suppression effect

Energy loss due to strahlung

C. Rimbault et al. – BHSE effect

http://accelconf.web.cern.ch/accelconf/p07/PAPERS/FRPMN012.PDF



BHSE (2)

Bhabha suppression effect

Angular smearing due to

Beam-beam effect