Beam-Induced Background Studies for the ILC at 500 GeV

. . . With a First Glance at CLIC Beams

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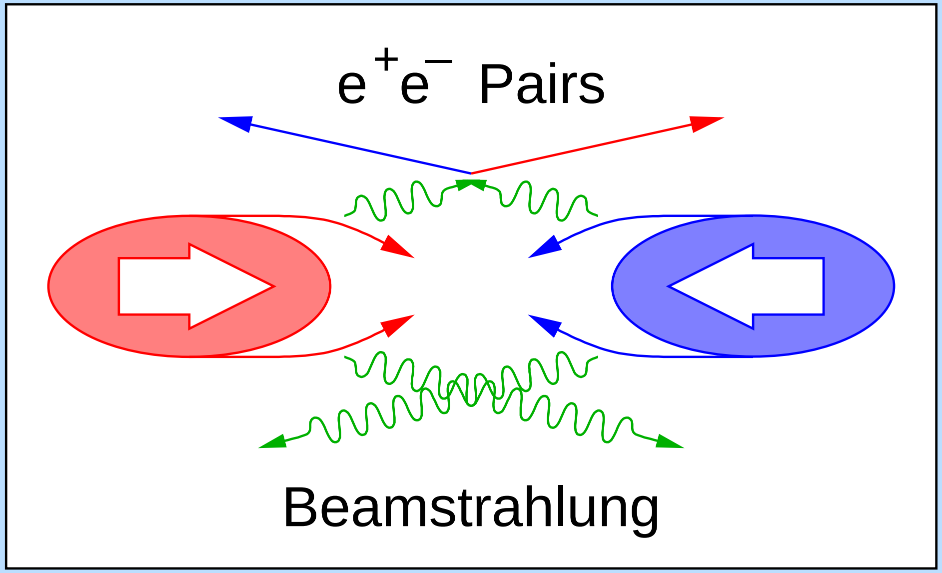
Beam-Beam Interaction

The ILC (and CLIC) have the problem of beamstrahlung

- high luminosity is essential for measurements
- tiny bunch size is required ($\sigma_x \approx 500\,\text{nm}$, $\sigma_y \approx 5\,\text{nm}$)
- bunches have a very high electric space charge
- particles are deflected and can emit photons ("beamstrahlung")
- 10^8 TeV / BX are lost



Electron-Positron Pairs

Beamstrahlung photons can scatter to e^+e^- pairs

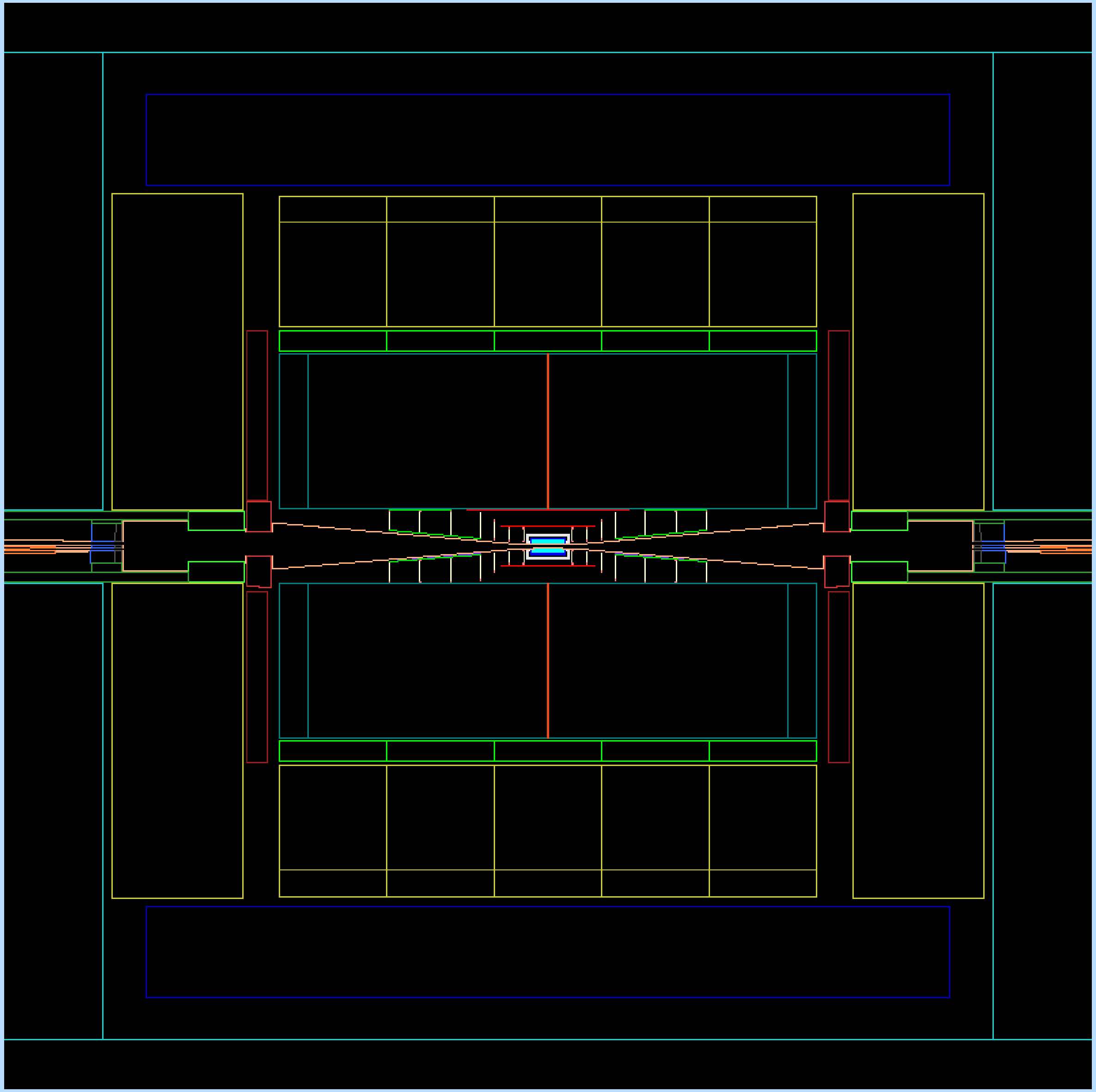
- 10^5 particles per BX for ILC beam parameters
- energies in the GeV range (100 TeV / BX in total)
- strongly focused in the forward direction (small θ)
- but sometimes also large polar angles (large θ)

Several processes can contribute

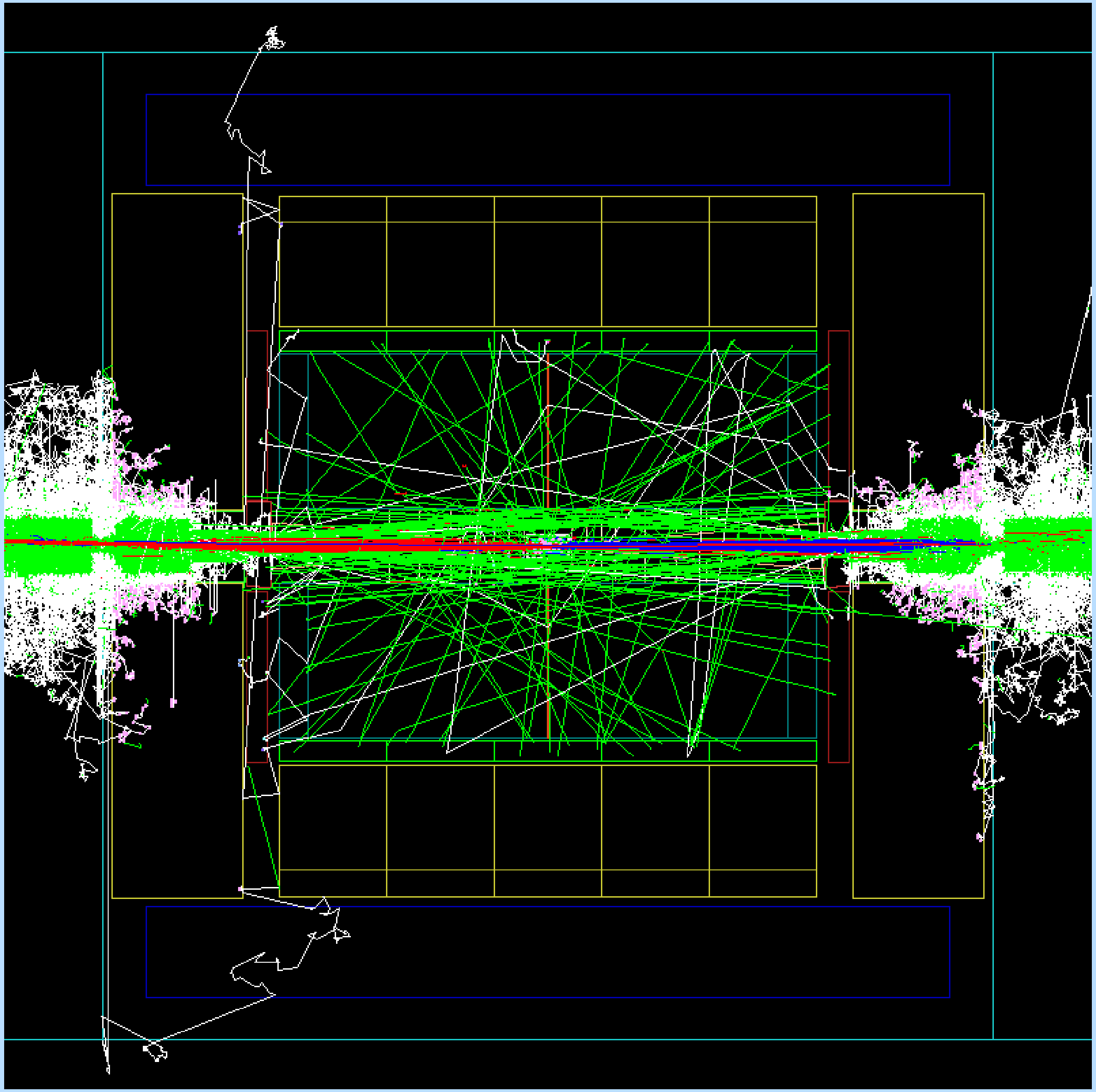
- incoherent and coherent pair creation
- real-real, real-virtual, virtual-virtual scattering

Pairs are a major source of detector backgrounds!

The Whole Detector – Before . . .



The Whole Detector – After 1/10 BX



Pairs in the Detector

Vertex detector

- direct hits from the IP (suppressed by the field)
- backscattering particles from the forward region

Main gaseous tracker

- conversion of backscattering photons
- tracks from the IP (rare, but mostly curlers)
- recoil tracks from neutron-proton collisions (CH_4)

Calorimeters

- randomly distributed low-energy hits
- possible neutron radiation damage of SiPMs

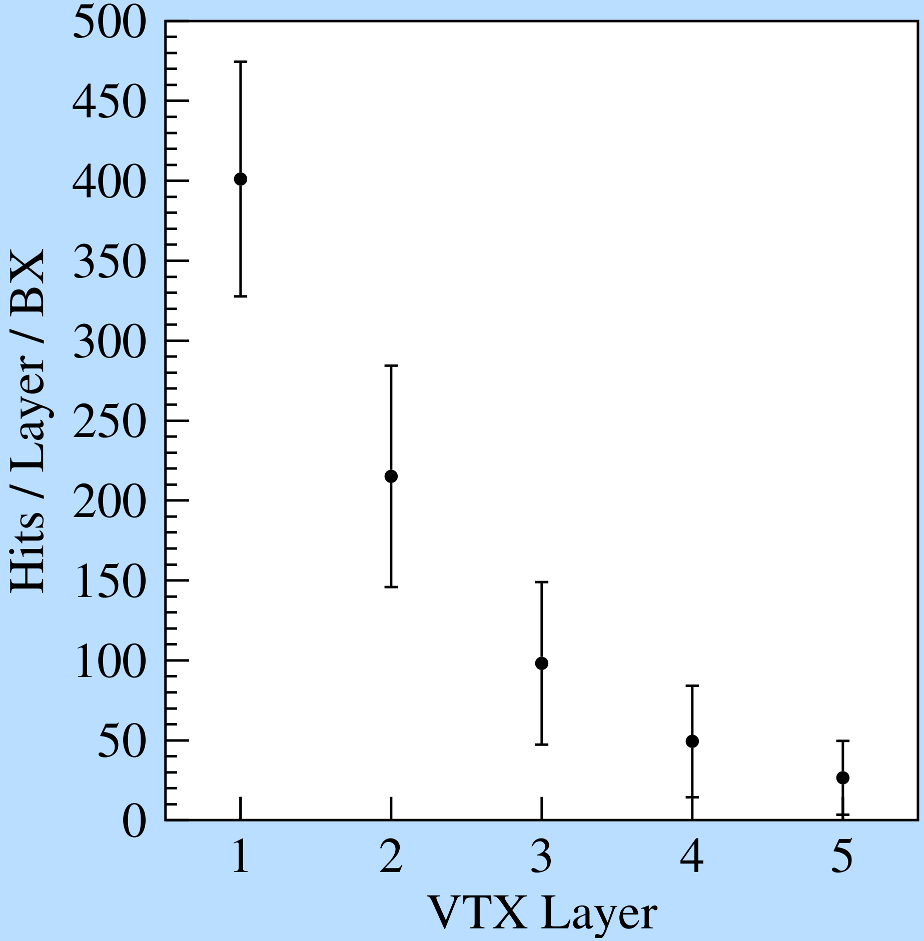
Other Kinds of Backgrounds

Other sources of backgrounds

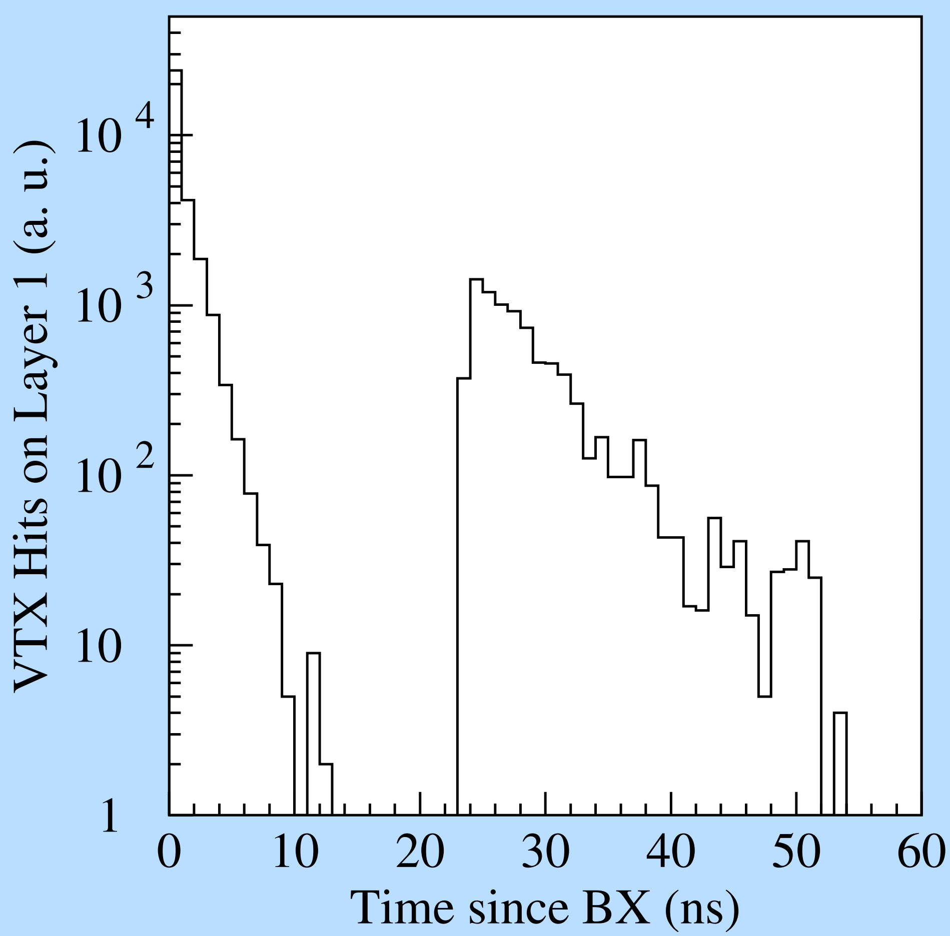
- beam halo muons $\longrightarrow$ magnetised spoilers
- beam-gas interaction $\longrightarrow$ vacuum requirements
- synchrotron radiation from beam delivery $\longrightarrow$ exit
- particle losses in the extraction line $\longrightarrow$ careful!
- beam dumps $\longrightarrow$ avoid direct line of sight

Those can be controlled by proper design,
but pairs are unavoidable: dominant source!

Vertex Detector – Hits



Innermost layer gets the most hits (0.04 / mm^2 / BX)



Clear separation of direct hits and backscatterers

Vertex Detector – Results

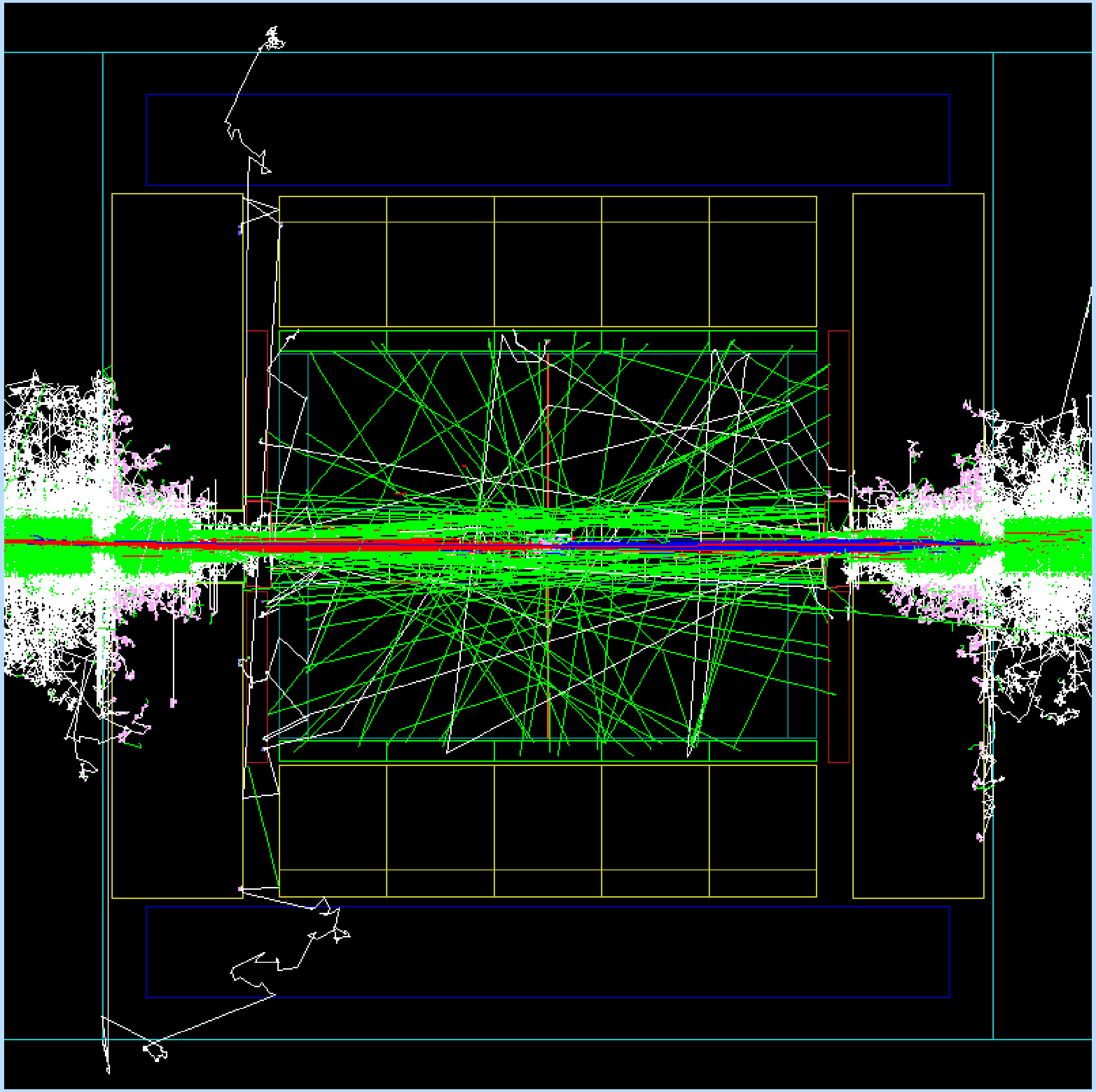
Hits on the vertex detector

- innermost layer has 400 hits / BX
- 80 % direct hits, 20 % from backscatterers
- background levels drive the VTX design
- resulting backgrounds are still manageable

Neutron fluence in the vertex detector

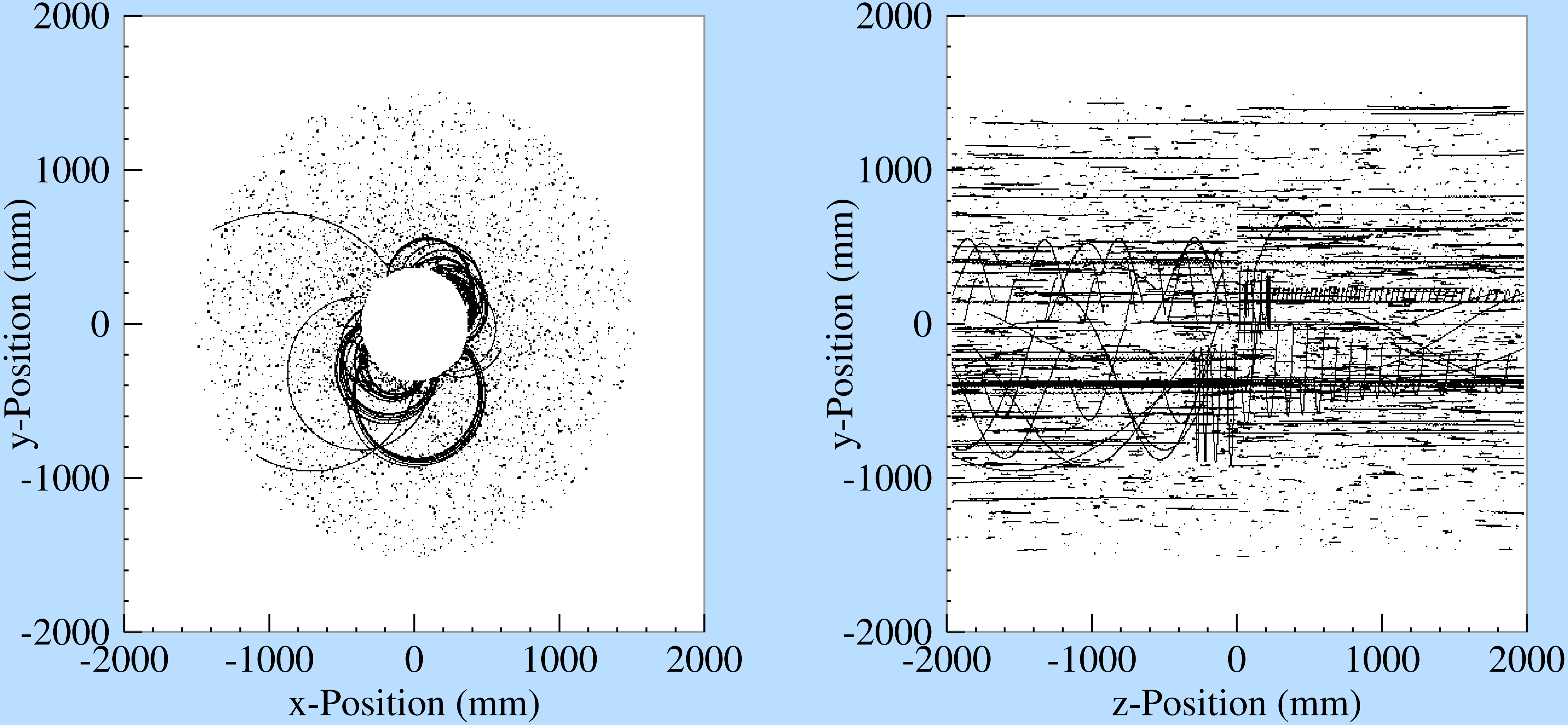
- extrapolation from 100 BX to 500 fb^{-1} total run time
- energy-dependent weighting of neutrons (NIEL model)
- fluence (10^8 n / cm^2) is uncritical for all layers

TPC – Backgrounds



TPC – Spatial Distribution of Hits

Mokka hits in the TPC (overlay of 100 BX)

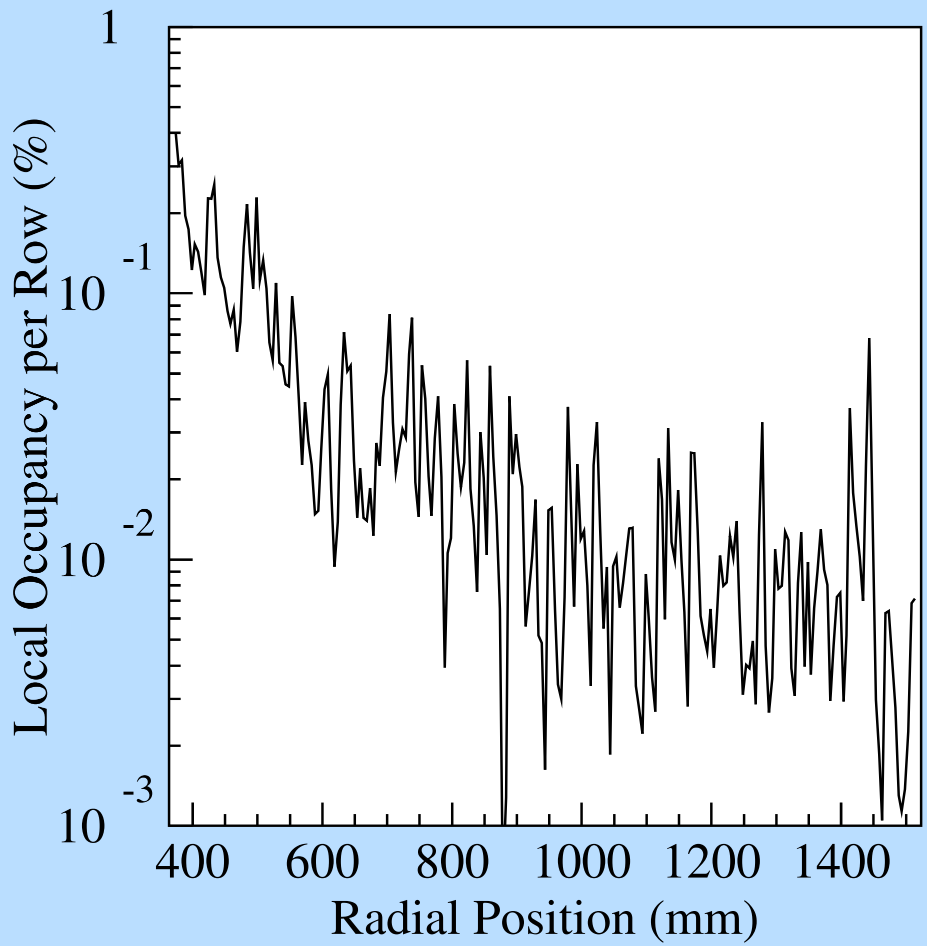


Front view

Side view

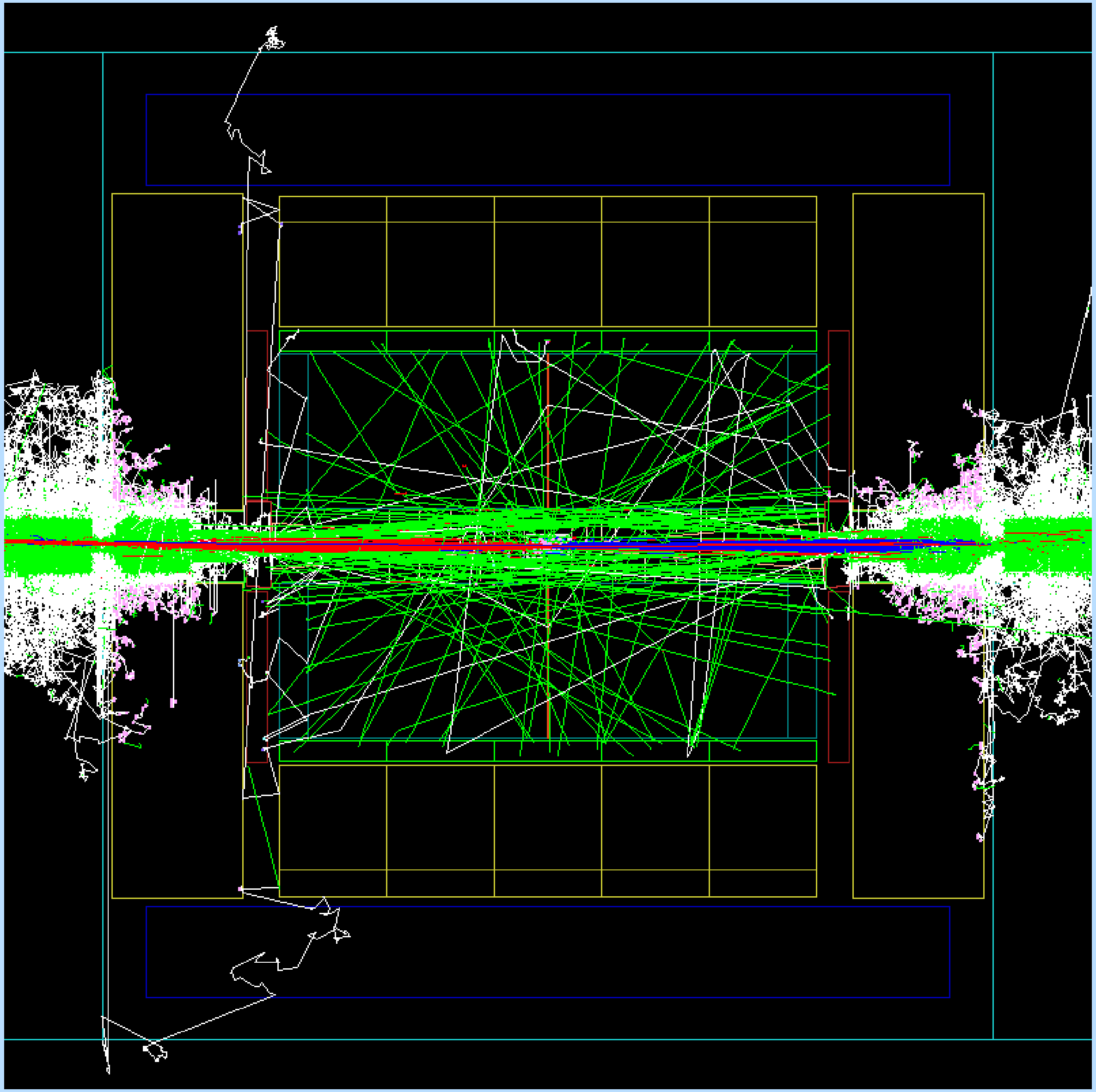
TPC – Occupancy

- highest occupancies at small radii
- overall value stays very well below 1 %
- outside-in tracking always possible
- n-p scattering gives negligible contribution
- backgrounds will be no problem for the TPC



Overlay of 100 BX

HCAL Endcap – Backgrounds



HCAL Endcap – Radiation Damage

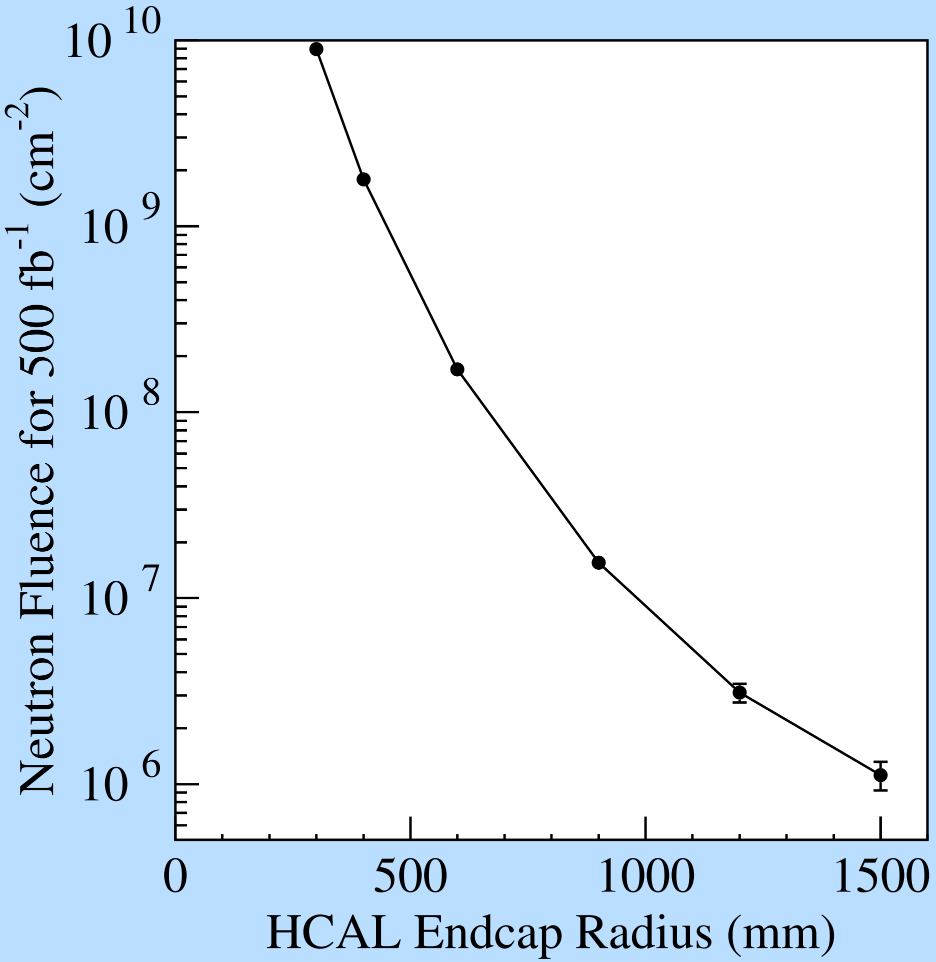
Simulation results (500 fb^{-1})

- neutrons are critical only at small radii
- photons are harmless

Possible solutions

- include neutron absorber
- replace innermost SiPMs after some years
- accept increased noise

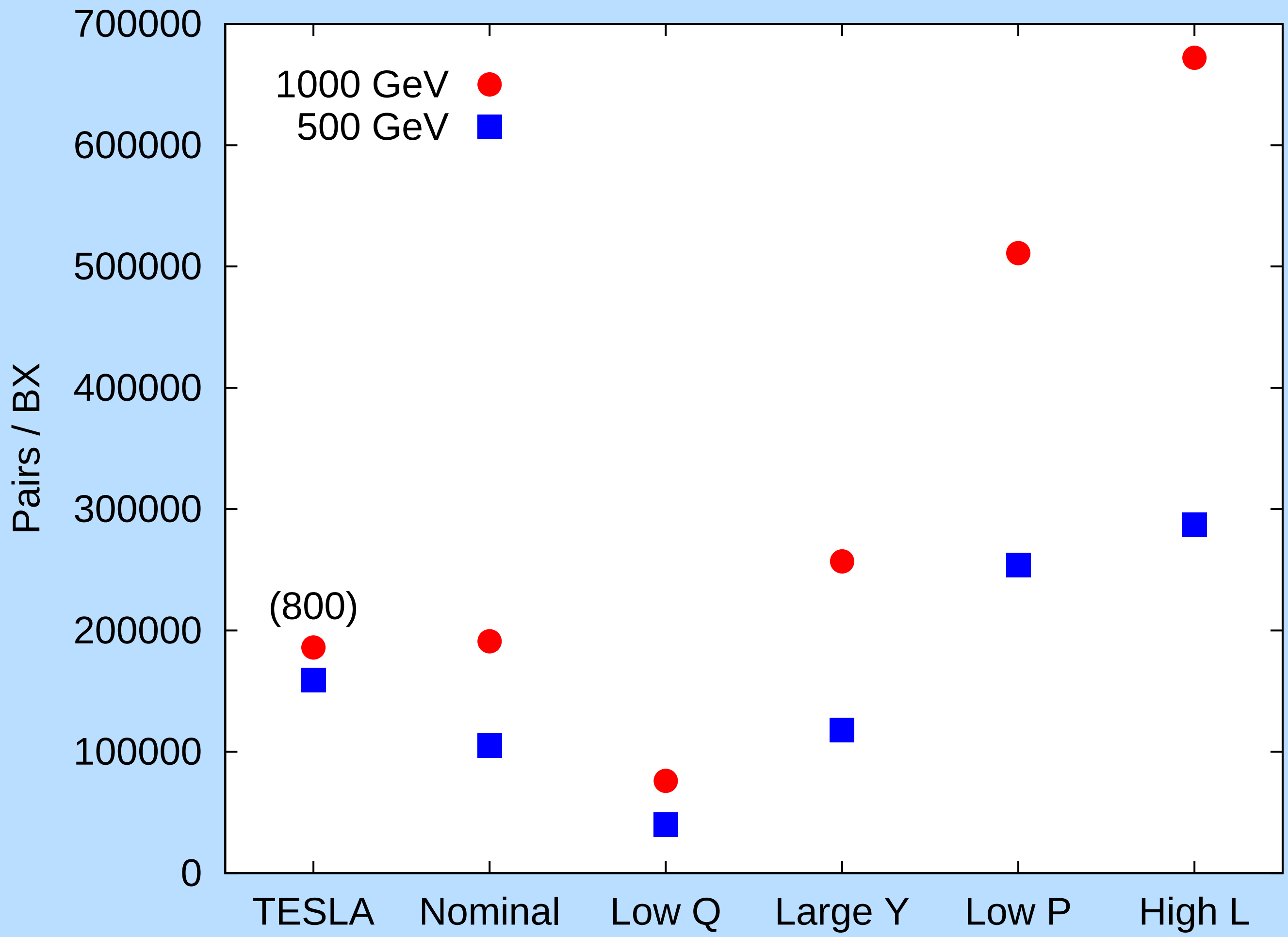
Tungsten tube is important!



ILC Beam Parameters – Numbers

$$\mathcal{L} = \frac{n_b N^2 f_{\text{rep}}}{4\pi\sigma_x\sigma_y} H_D$$

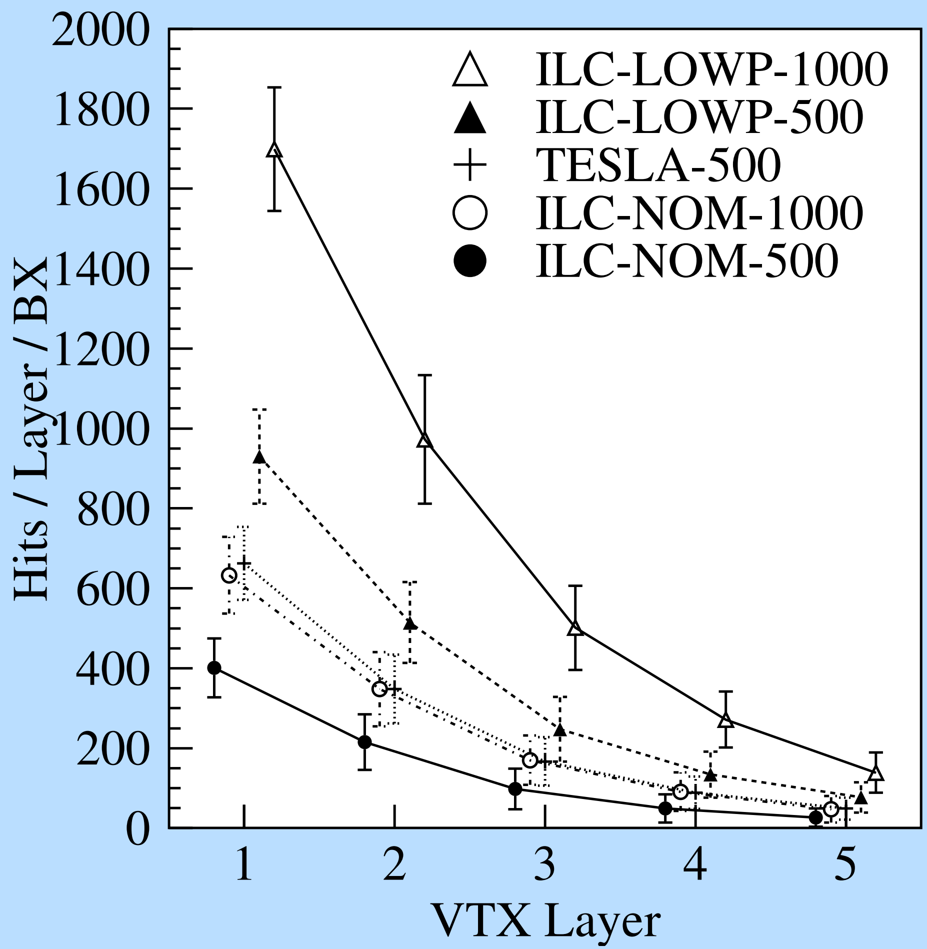
$$\delta \propto \left(\frac{N}{\sigma_x + \sigma_y}\right)^2$$



S. Gronenborn (EUROTeV-Memo-2005-003-1)

ILC Beam Parameters – Backgrounds

- “Low Power” option: 2.5 times more hits
- But: half the number of bunches per train
- Integrated backgrounds (over a fixed time) do not change much
- Upgrade to 1000 GeV: 2 times more hits



BeamCal Absorber

Graphite absorber (low *Z*) in front of the BeamCal

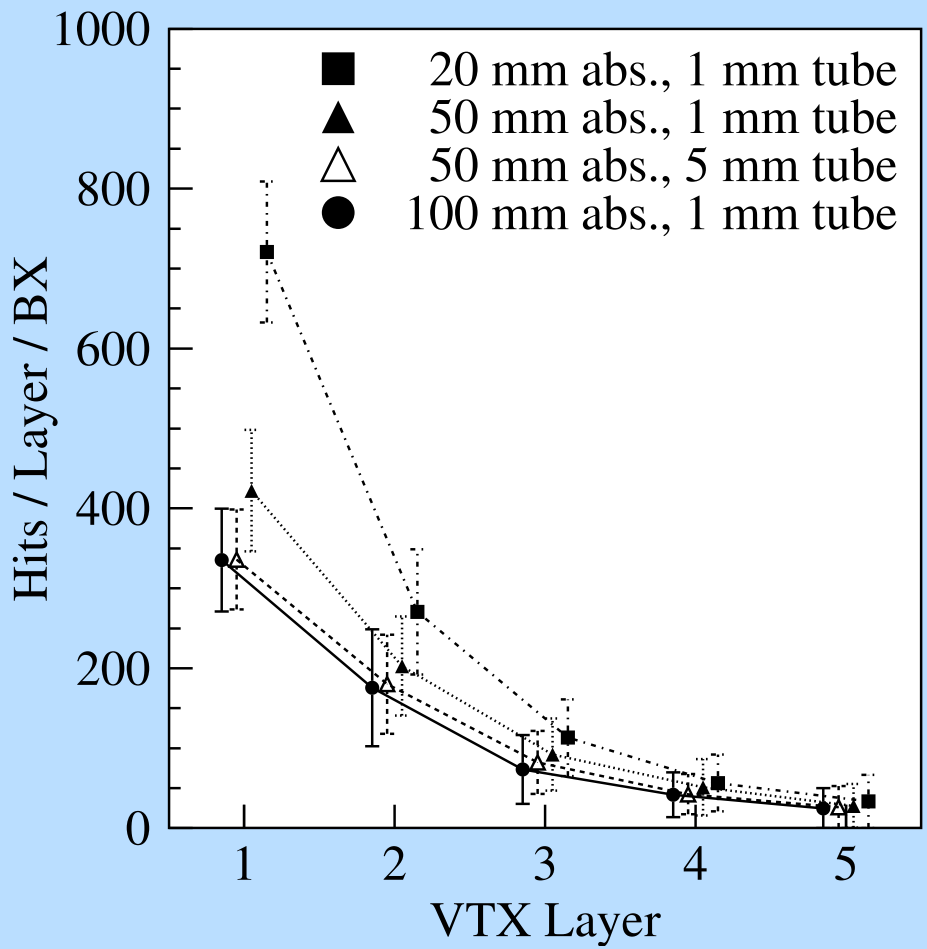
- reduces backscattering
- decreases performance

Variation of thickness

- 5 cm seems reasonable

Additional absorber inside

- will not hurt the BeamCal
- better suppression of detector backgrounds



Uncertainties

- Statistics from 100 BX generally sufficient
- Guinea-Pig is reliable on the level of 10–20 %
- Modelling of neutrons is always difficult
  $\longrightarrow$ assume uncertainty factor of two
- Small geometry changes can have large effects
  $\longrightarrow$ easily 2–3 times more backgrounds

- Always aim for a safety factor of five, at least!
- Don't forget other possible background sources

Summary for ILC + LDC

- e^+e^- pairs are a major source of backgrounds
- But: other possible sources must not be forgotten
- Current levels seem uncritical for all subdetectors
- Further studies are ongoing (e. g. VTX occupancy)

- Upcoming MC mass production for the ILD LoI will also take backgrounds into account
- Additional pattern recognition / suppression needed?
- Final impact on reconstruction and analysis?

A First Glance at CLIC

Simulation of e^+e^- pairs

- using Guinea-Pig with CLIC beam parameters
- 100 BX for 500 GeV, 1000 GeV, and 3000 GeV each

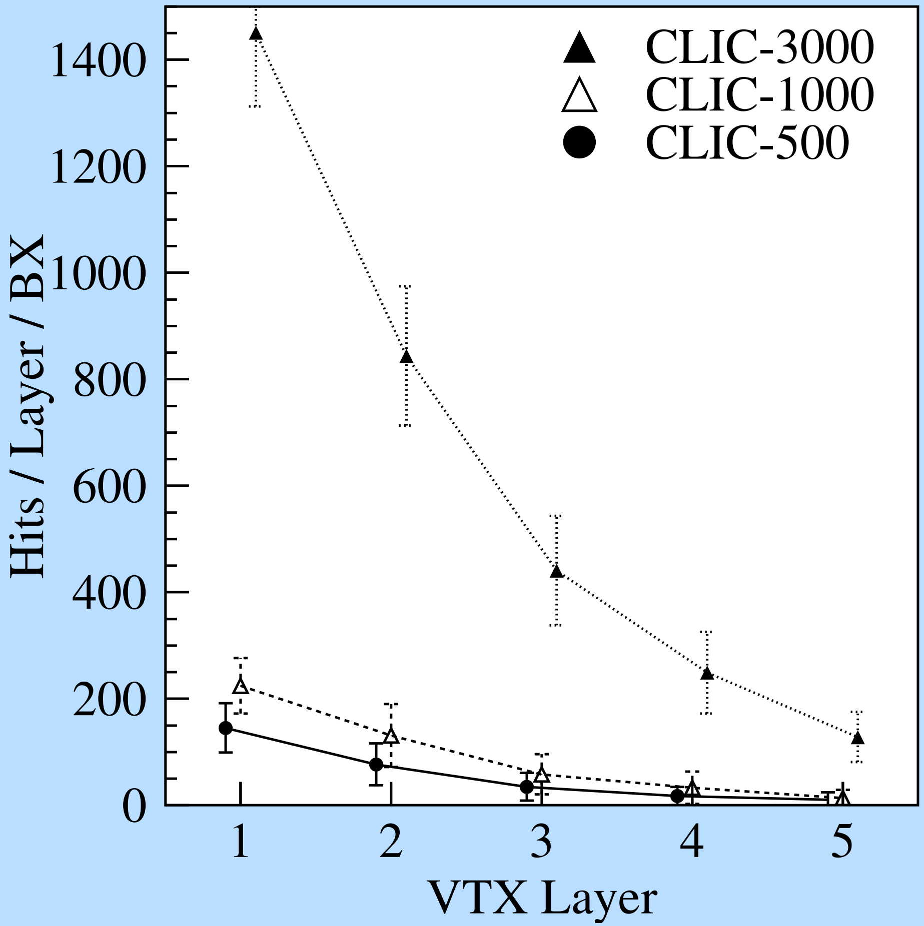
Full detector simulation of pair backgrounds

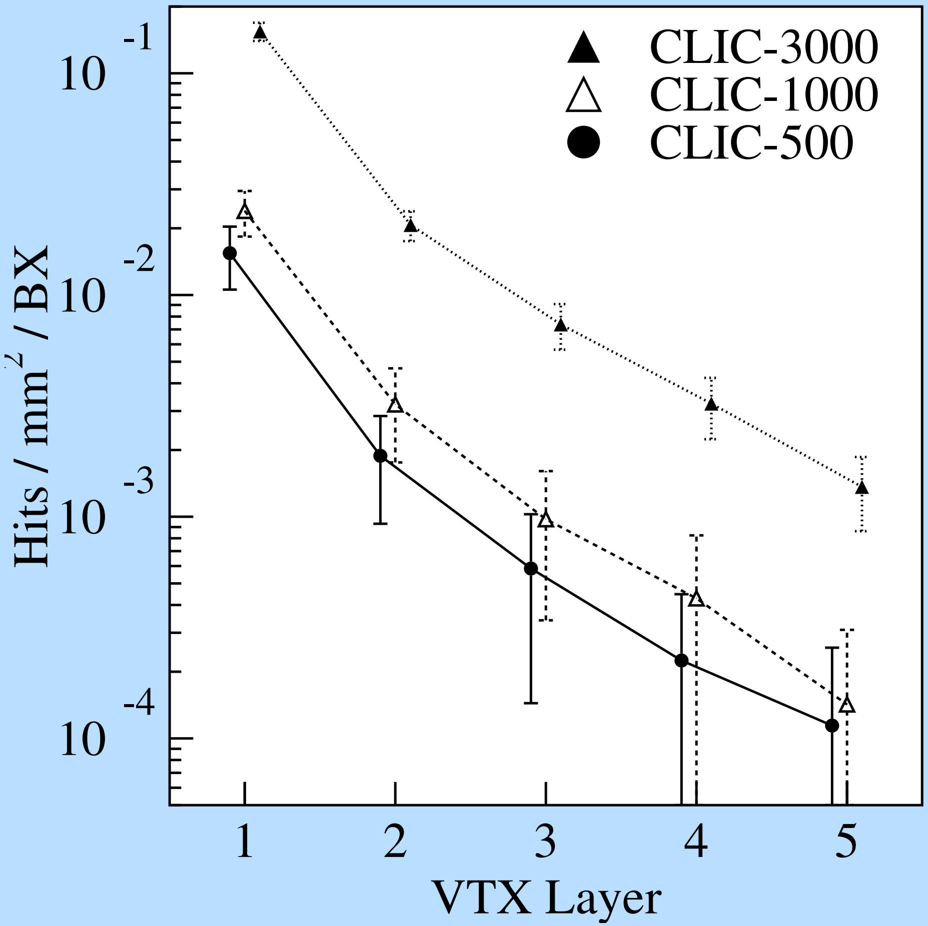
- using Mokka with the LDC detector geometry (for now)
- variation: remove the complete LDC forward mask
- run on the Grid: 50 GB of data, 3.5 CPU-years

Analysis of simulated data

- only preliminary results, of course!
- not straightforward to compare with ILC beams

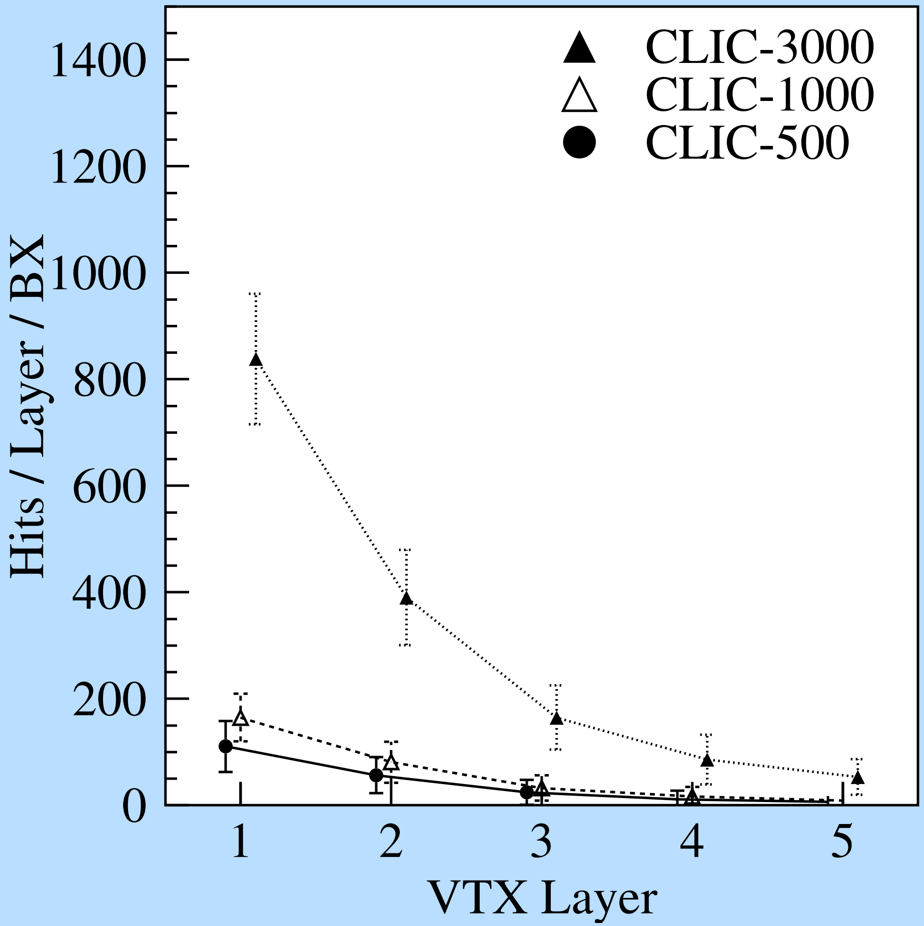
VTX Hits – LDC Geometry

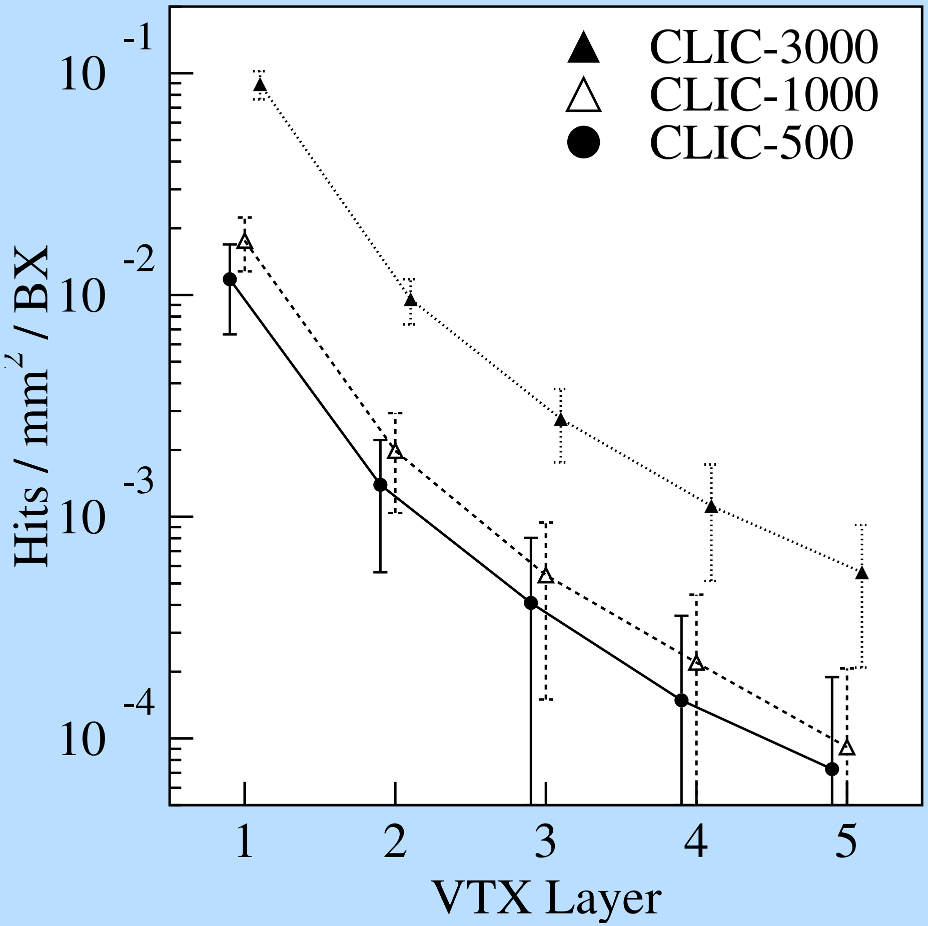




Low energy: 20 % hits from backscatterers
High energy: 45 % hits from backscatterers

VTX Hits – LDC Without Forward Mask





Over-optimistic: no BeamCal, no magnets at all

But: still with 4 T and 15 mm innermost VTX

A First Glance at CLIC – Results

Pile-up time (similar for VTX and TPC)

- ILC: approx. 100 BX (1 / 20 bunch train)
- CLIC: one whole bunch train (300 BX)

CLIC-500 vs. ILC-NOM-500 (with LDC geometry)

- similar background levels (for TPC and VTX)

CLIC-3000 vs. ILC-NOM-500 (with LDC geometry)

- VTX: $\mathcal{O}(10)$ times more backgrounds per readout
- TPC: $\mathcal{O}(30)$ times more backgrounds per readout
- modification of the mask may help (approx. 50 %)

Challenging, but not hopeless!