Background Simulations for the ILC TPC with Geant 4

Adding Some Challenge to Tracking

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Beamstrahlung at the ILC

The ILC has the novel problem of beamstrahlung

- high luminosity is essential for measurements
- beams have to be focused to an extremely small spot at the IP (σ_x = 500 nm, σ_y = 5 nm, this is $\left(\frac{1}{1000}\right)^2$ LEP)
- bunches have a very high electric space charge
- particles in the oncoming bunch are deflected (beam-beam interaction) and emit photons
- photons can scatter and create e^+e^- pairs

This has never been relevant in experiments before, but theoretical models exist

Pairs from the Beamstrahlung

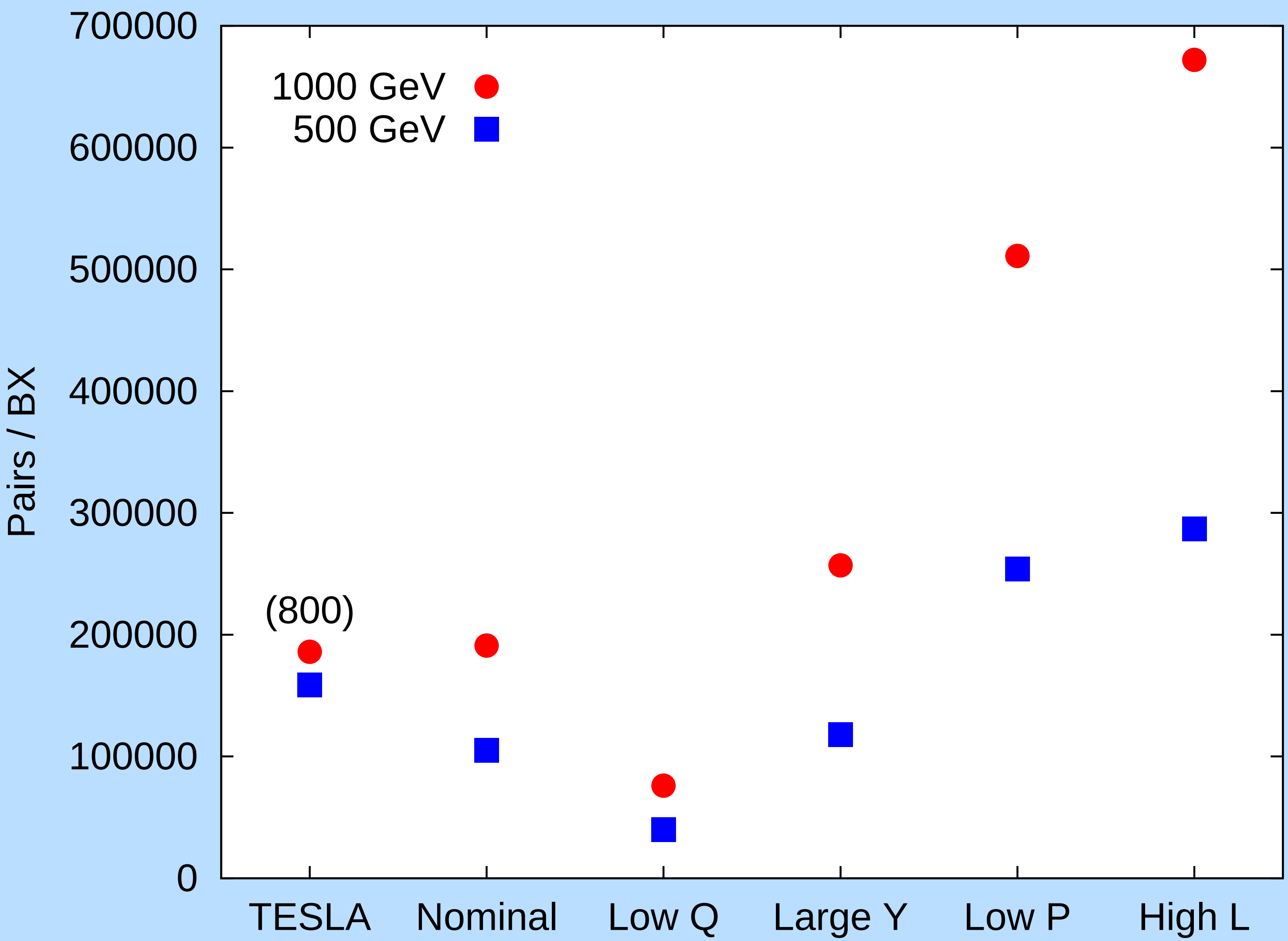
e^+e^- pairs are a main source of background

- energies up to several GeV
- strongly focused in the forward direction (small θ)
- curl around magnetic field lines more or less tightly

Particles hit different parts of the detector

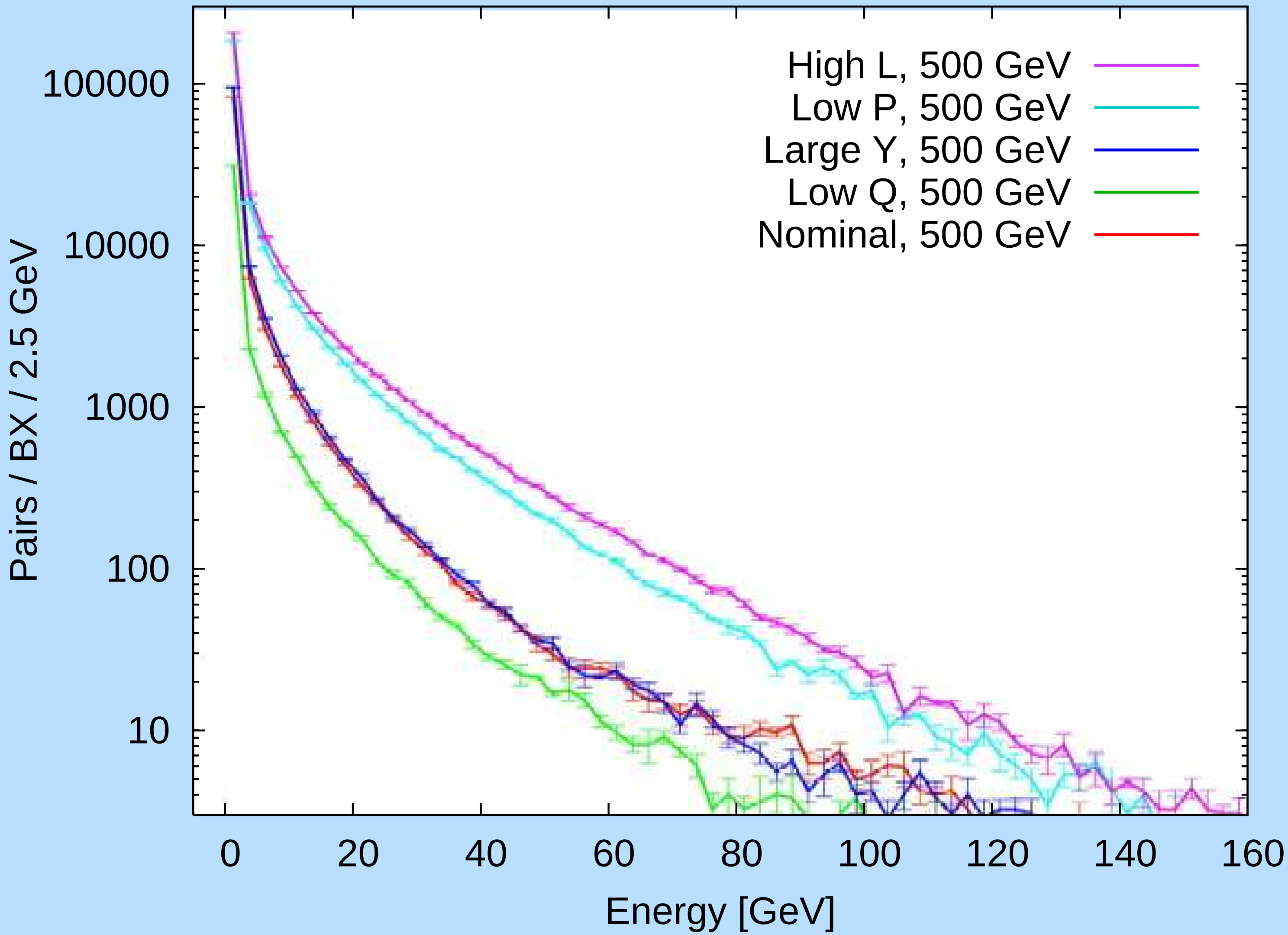
- direct hits on the vertex detector (only if θ is large)
- lots of hits on the BeamCal (pattern is used for fast feedback during one bunch train)
- magnets and other parts of the extraction line

Pairs – Beam Parameters



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

Pairs – Energy Spectrum



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Problems with the Pairs

Direct hits on the VTX can hardly be avoided

- stay clear of the cone of pairs! (the B-field helps)

Hits on the BeamCal induce particle showers

- create charged particles, photons, and neutrons
- secondary particles can backscatter into the detector
- charged particles give indirect hits on the VTX
- photons and neutrons can reach the TPC
- photo effect, nuclear interactions, recoil protons
- long-term radiation damage (esp. from neutrons)

Try to reduce the backscattering of secondaries!

Other Sources of Background

Beamstrahlung, synchrotron radiation from the FF

- better do not hit anything with these photons!

Disrupted outgoing beam

- losses in the extraction line are being studied

Beam halo (muons travelling alongside the main beam)

- few muons per BX strike through the TPC

Beam dumps (main dump and beamstrahlung dump)

- huge radiation, but far away

Hadrons from beam-beam interaction (“minijets”)

- much smaller numbers than e^+e^- pairs

Simulation Tools

Guinea-Pig (e^+e^- pairs generator)

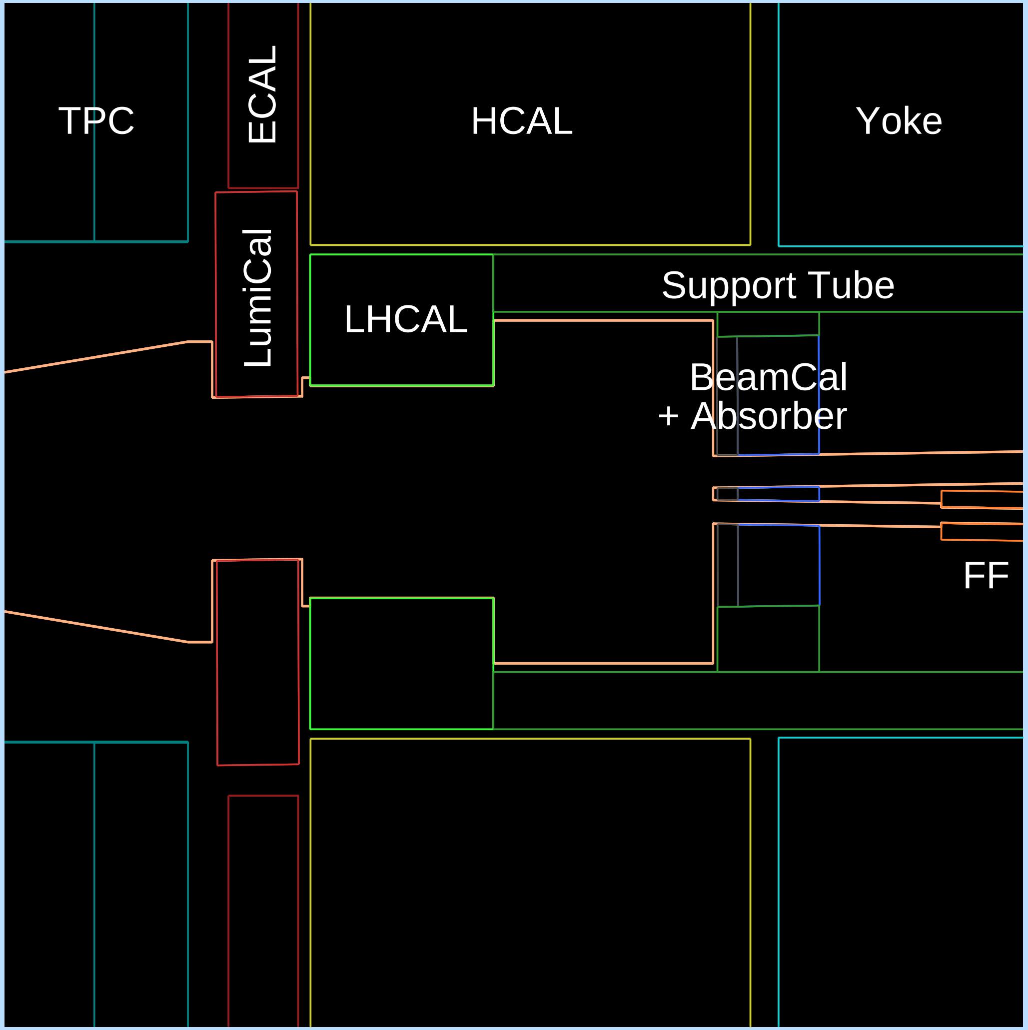
- used with different ILC beam parameter sets
- gives $\mathcal{O}(10^5)$ background particles per BX

Mokka (full detector simulation)

- based on the Geant 4 framework
- simulates interaction of particles with matter
- contains the latest detector models
- reads pairs from Guinea-Pig as input
- writes out hits in the different subdetectors as LCIO

Geometry – Forward Region

- LumiCal (red)
  $R_i = 120\,\text{mm}$
- Low-Z absorber
- BeamCal (blue)
  $R_{i\,1} = 15\,\text{mm}$
  $R_{i\,2} = 20\,\text{mm}$
- Centered on the downstream axis
- crossing angle of 14 mrad
- anti-DID field

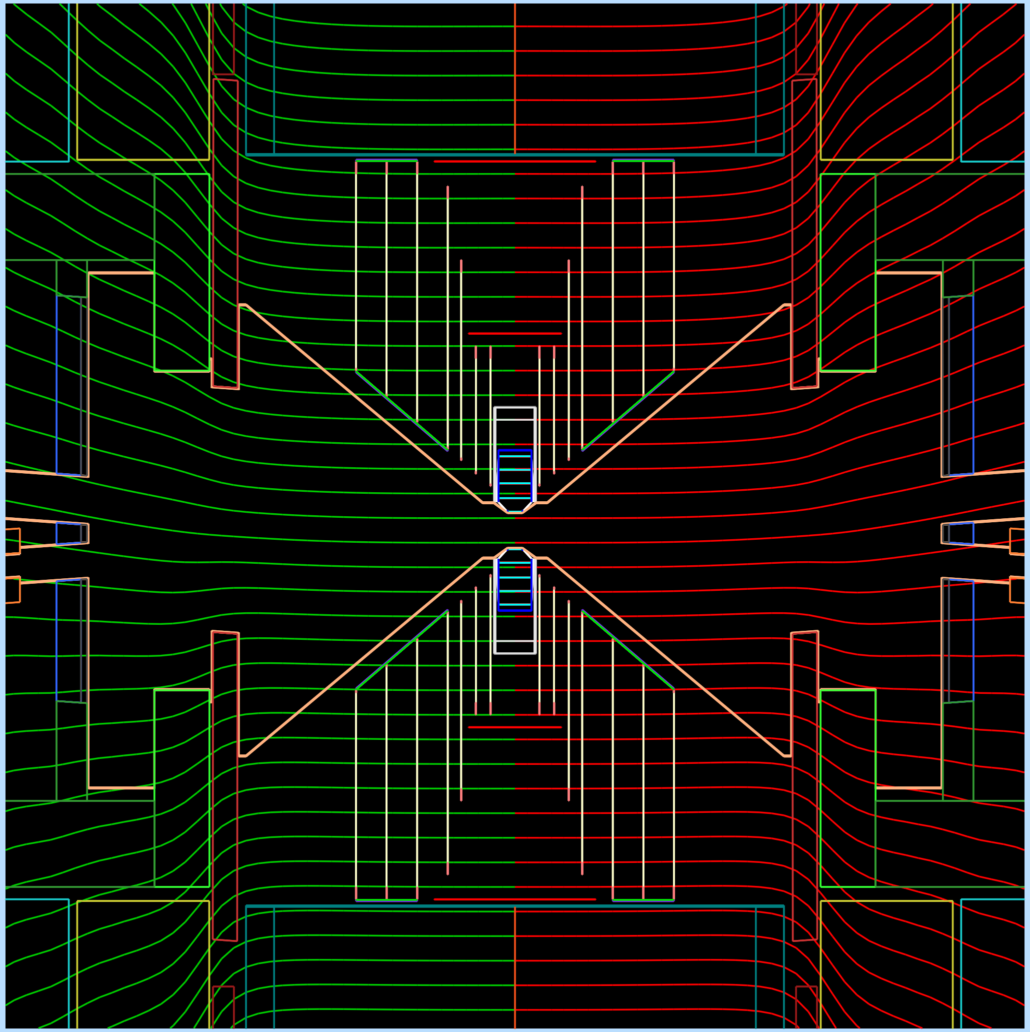


Compressed view 1:2

Geometry – Detector-Integrated Dipole

- Superimposed on the main solenoid field
- Introduced to prevent spin precession

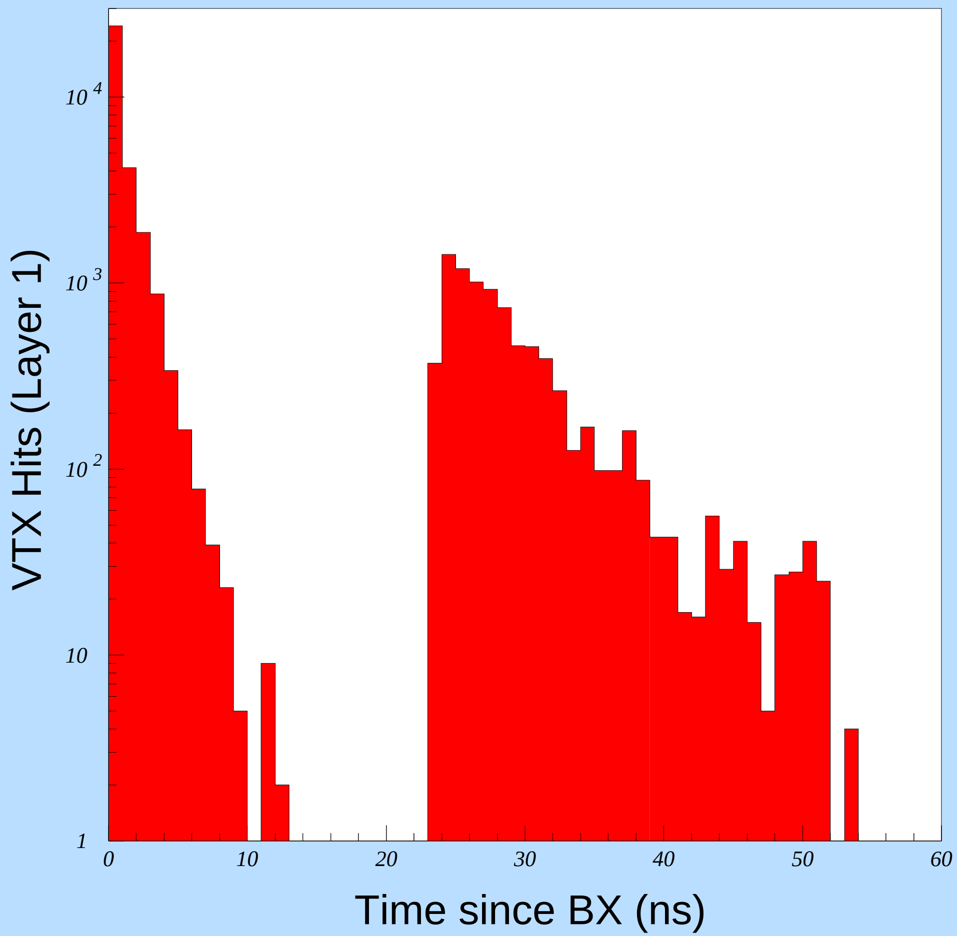
- But has also a major impact on background
- Low-energy particles follow the field lines
- Now with reversed polarity: anti-DID



Compressed view 1:10

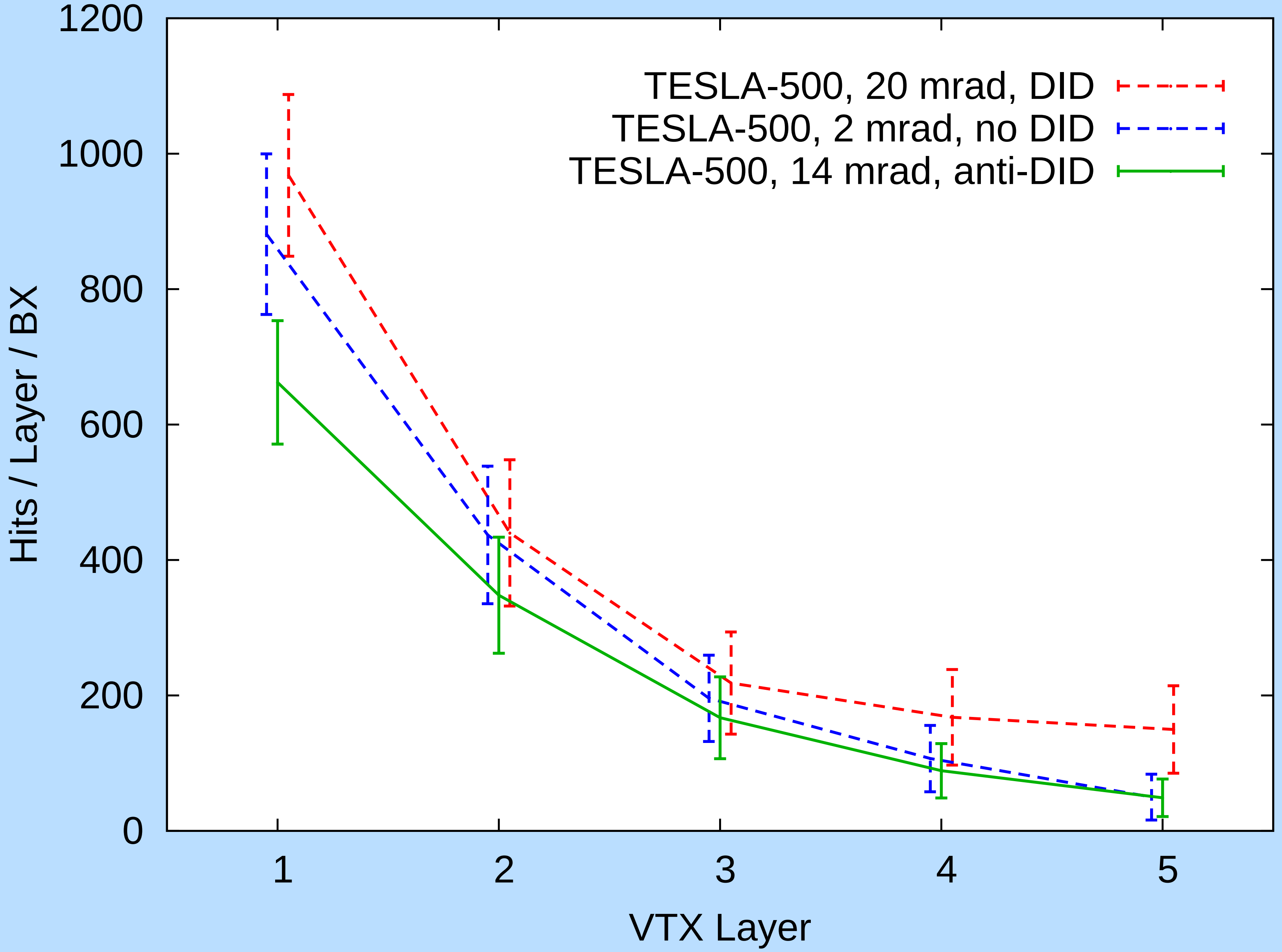
VTX Hits – Time Structure

- Clear separation between direct hits and backscattered particles
- $t \approx 23\,\text{ns}$ corresponds to a distance of 7.0 m (3.5 m in each direction)
- Most backscatterers come from the BeamCal

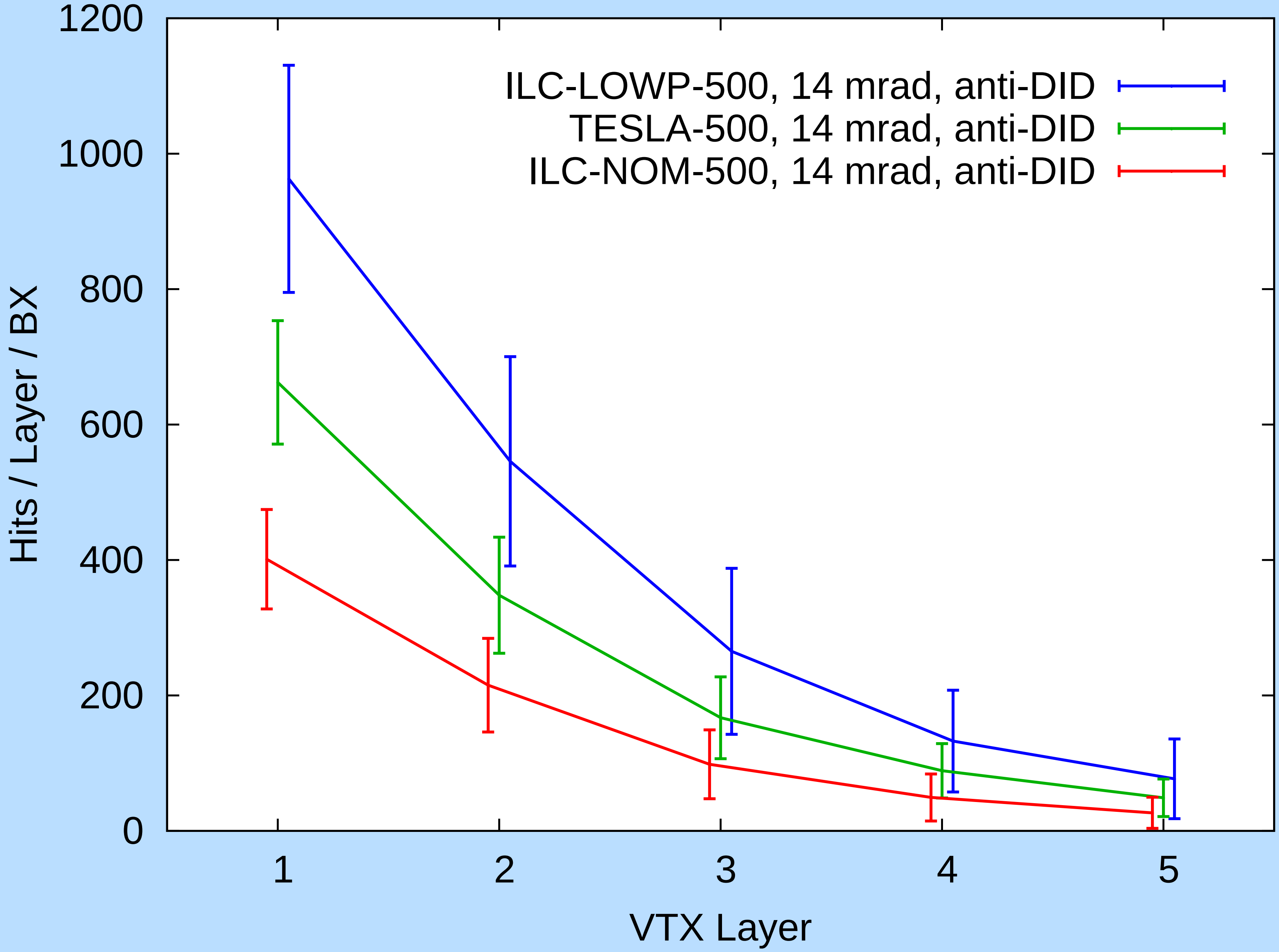


Note the log scale:
Most hits are direct

VTX Hits – Geometries

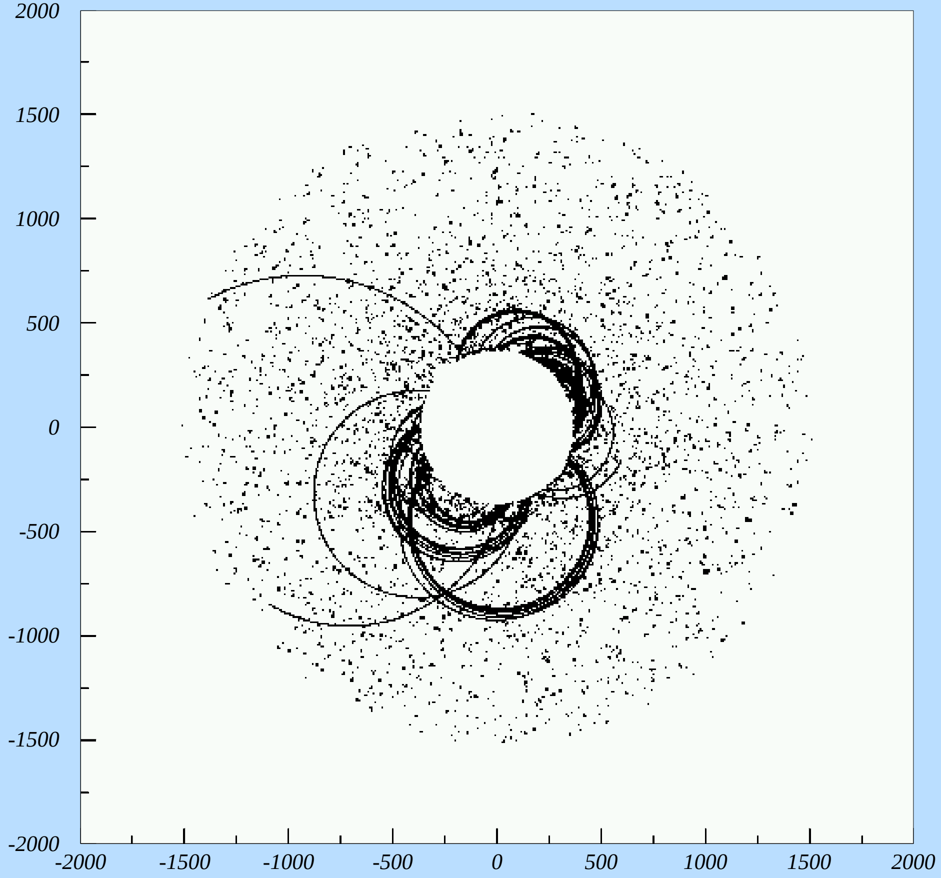


VTX Hits – Beam Parameters

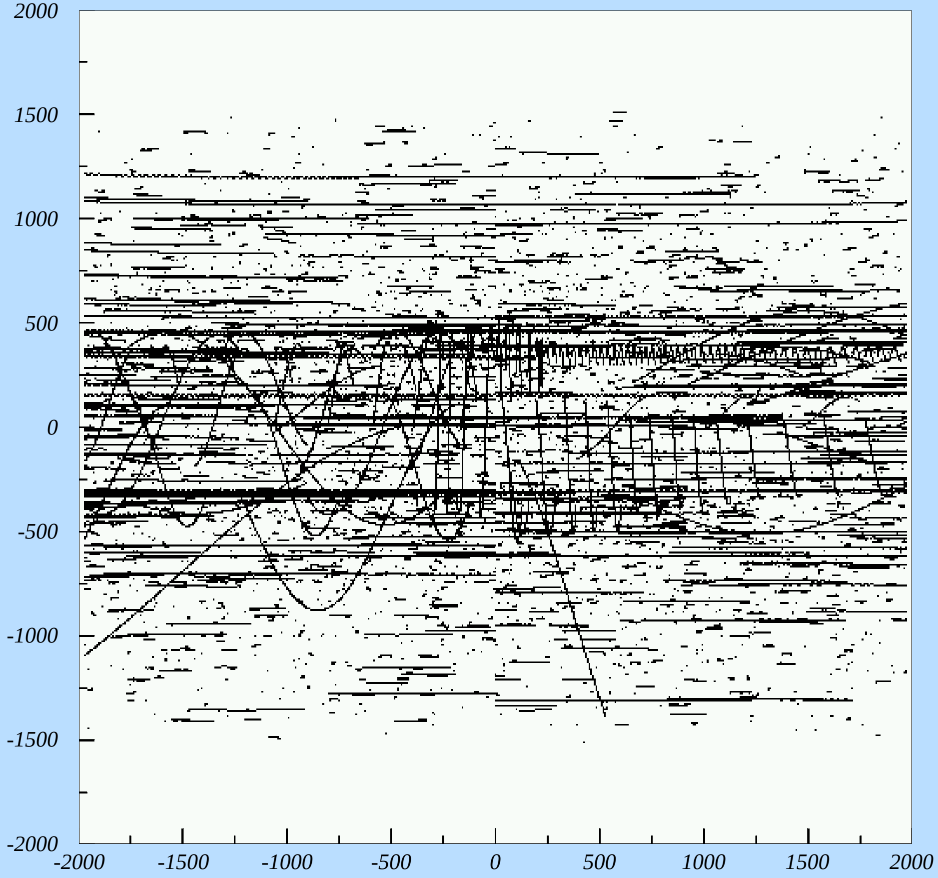


TPC Hits – “Salt and Pepper”

Mokka hits in the TPC (overlay of 100 BX)



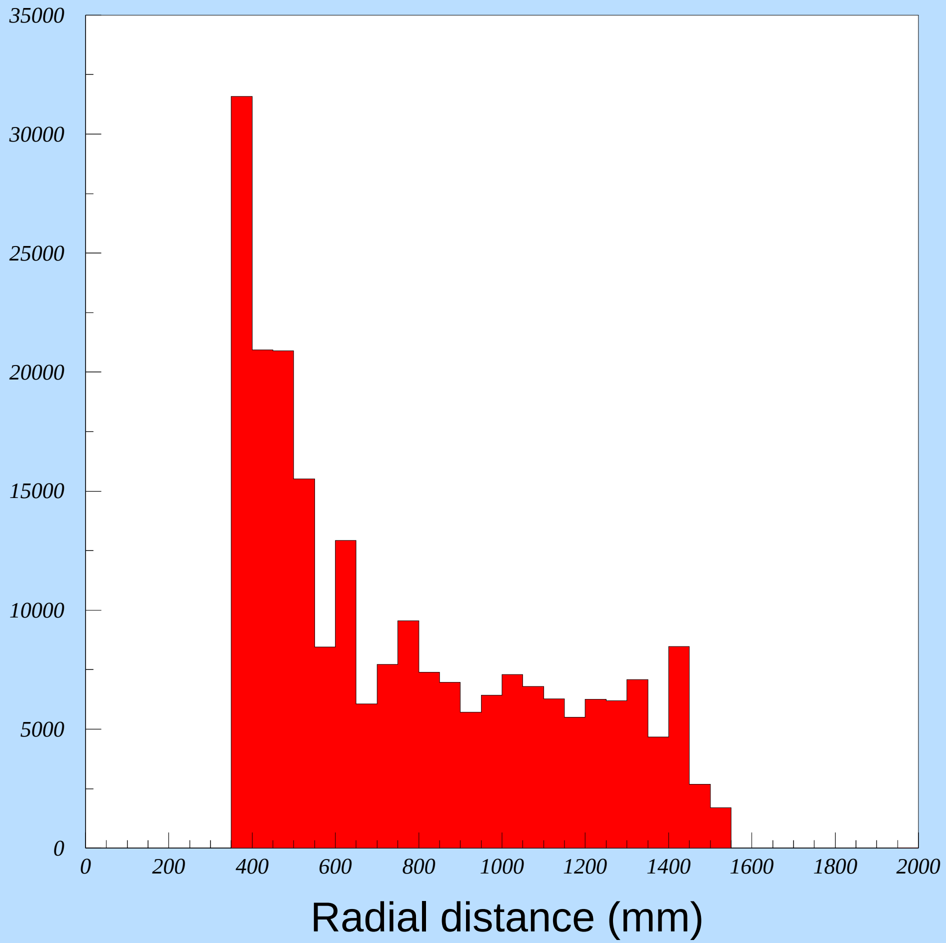
Front view



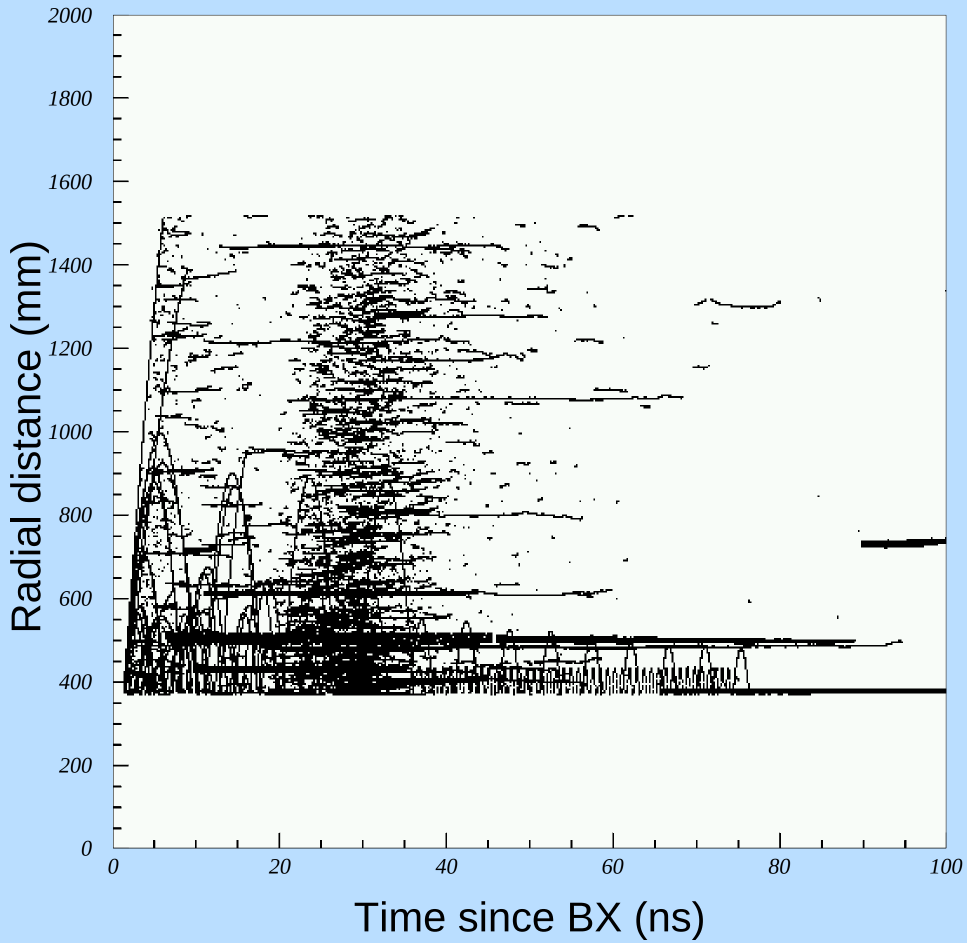
Side view

TPC Hits – Distributions

Mokka hits in the TPC (overlay of 100 BX)



Radial distribution



Time structure

Particles in the TPC

- Particles entering the TPC (per BX)

	Nominal	Low P
Neutrons	142 ± 20	590 ± 68
Photons	947 ± 57	3108 ± 148
Electrons	6 ± 13	30 ± 32

- Particles created in the TPC (per BX)

	Nominal	Low P
Electrons	292 ± 130	1596 ± 344
Protons	2 ± 2	9 ± 4

Outlook – Software Development

- Set up a consistent software toolkit for the TPC: digitisation – tracking – reconstruction – analysis
- Bring together existing bits and pieces of code (DESY, Aachen, Freiburg, Victoria, . . .)
- Effort has been started at the TPC Software Workshop (June 2006 at DESY, chaired by P. Wienemann)
- CVS repository for `MarlinTPC` exists at Zeuthen, but it's basically still empty

- Provide a "background library" with ready-to-use events to be superimposed on "real" physics for analyses

Outlook – Questions

- Which design decisions affect the TPC, and how?
- Can we use a quencher which contains hydrogen?
- How much will the additional primary ionisation from backgrounds distort the electric field?
- How large will the occupancy be at a given time? (with superposition of 160 bunch crossings)
- Will the background signals have an impact on pattern recognition, efficiencies, resolutions?

- Will a TPC be able to meet the very high performance goals for a tracker at the ILC?