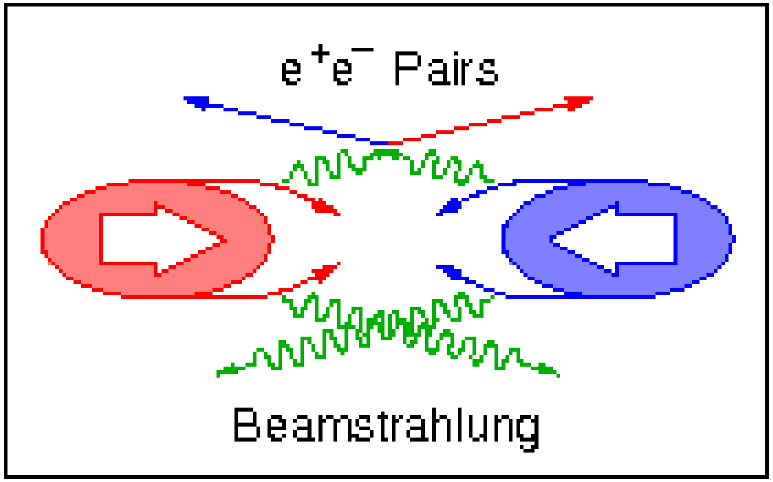
Beam backgrounds: Simulation & Effects on Reconstruction at ILD

- Introduction to beam induced backgrounds
- Simulation of beam background
  - Isotropic background
  - Overlaying real simulated background
- Background in TPC and VTX
- Physics analyses with beam background

Beam Induced Backgrounds

novel problem faced by linear colliders – beam induced backgrounds

- machine induced backgrounds -> most important source of unwanted interactions
  - beamstrahlung (photons) & e^+e^- pair production
  - photons strongly focused in forward direction, exit through beam tube
  - e^+e^- pair production: direct and scattered particles in the detector
  - 10^5 pairs per bunch crossing, total energy ~100TeV, average few GeV per particle



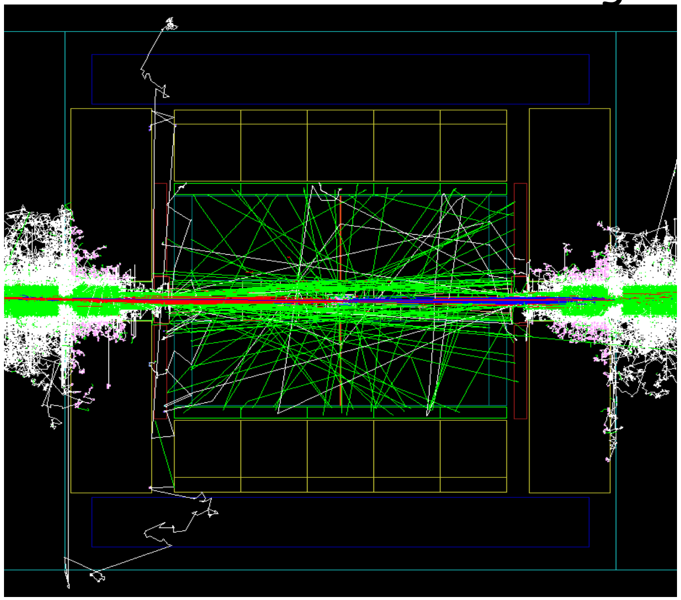
- electron-positron pairs are unavoidable backgrounds
- other beam beackgrounds (of small impact, not yet included in studies):
  - beam halo muons, beam gas interaction, synchrotron radiation from beam delivery, particle losses in extraction line, beam dumps

Beam Backgrounds in Detector

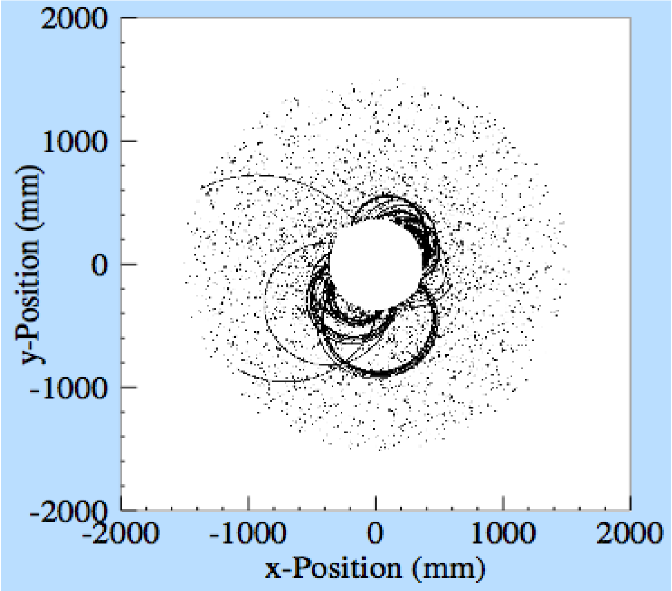
- Guinea Pig generation of e^+e^- pairs
- full GEANT-4 simulation of pairs background
  - includes realistic description of forward region and magnetic fields
  - main gaseous tracker conversion of backscattering photons
  - tracks from the IP, rare, but mostly curlers
  - recoil tracks from neutron-proton
- **mostly affected – VTX and forward detectors**
  - VTX will integrate a large number of bunch crossings for every physics event

- necessary to find a way to simulate background
  - salt & pepper BG in VTX
  - overlayed background

A. Vogel



1/10th of bunch crossing



Mokka hits in the TPC (100BX)

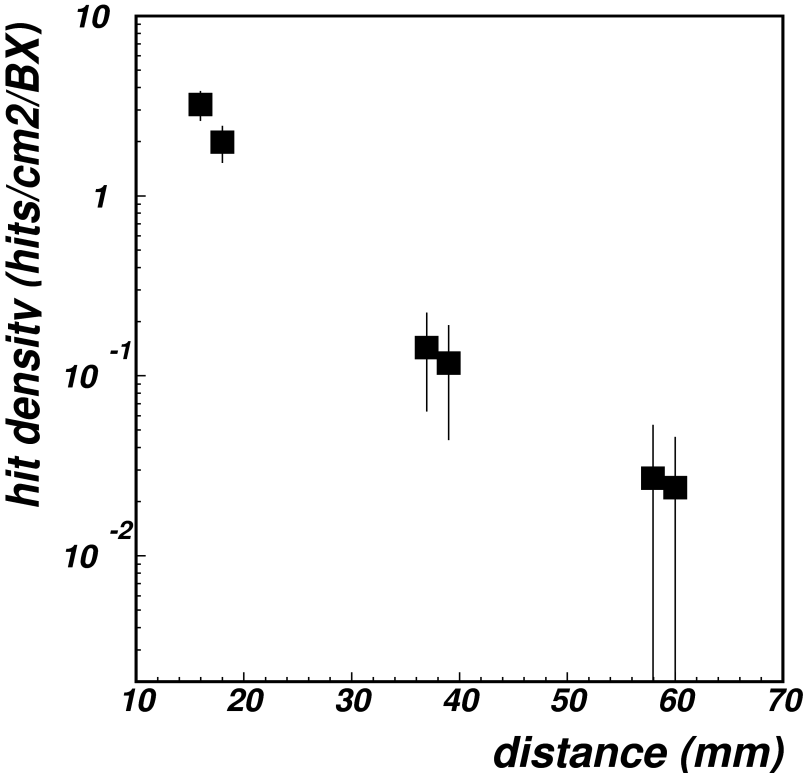
Salt & Pepper Background

- salt&pepper hits added to VTX (VTXNoiseHits Marlin Processor)
  - isotropically distributed hits added to SimTrackerHits collection after digitizing
  - hits added according to hit densities
  - layers 1-2: 83 BX/event, rest 333 BX/event (estimated from VXD readout times)
- fully reconstructed tracks after chain:
  - digitalization
  - silicon tracking
  - LEP tracking
  - full tracking

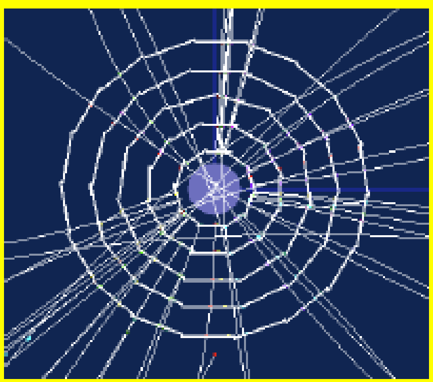
•hit densities calculated from number of hits in detector layers for 1 BX

- average number of VTX hits calculated from Guinea Pig files simulated with Mokka

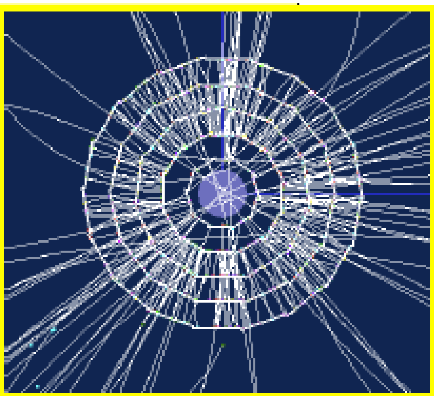
  (SimTrackerHit), ~100 BX used



Background: Hits & Tracks



w/o bg hits



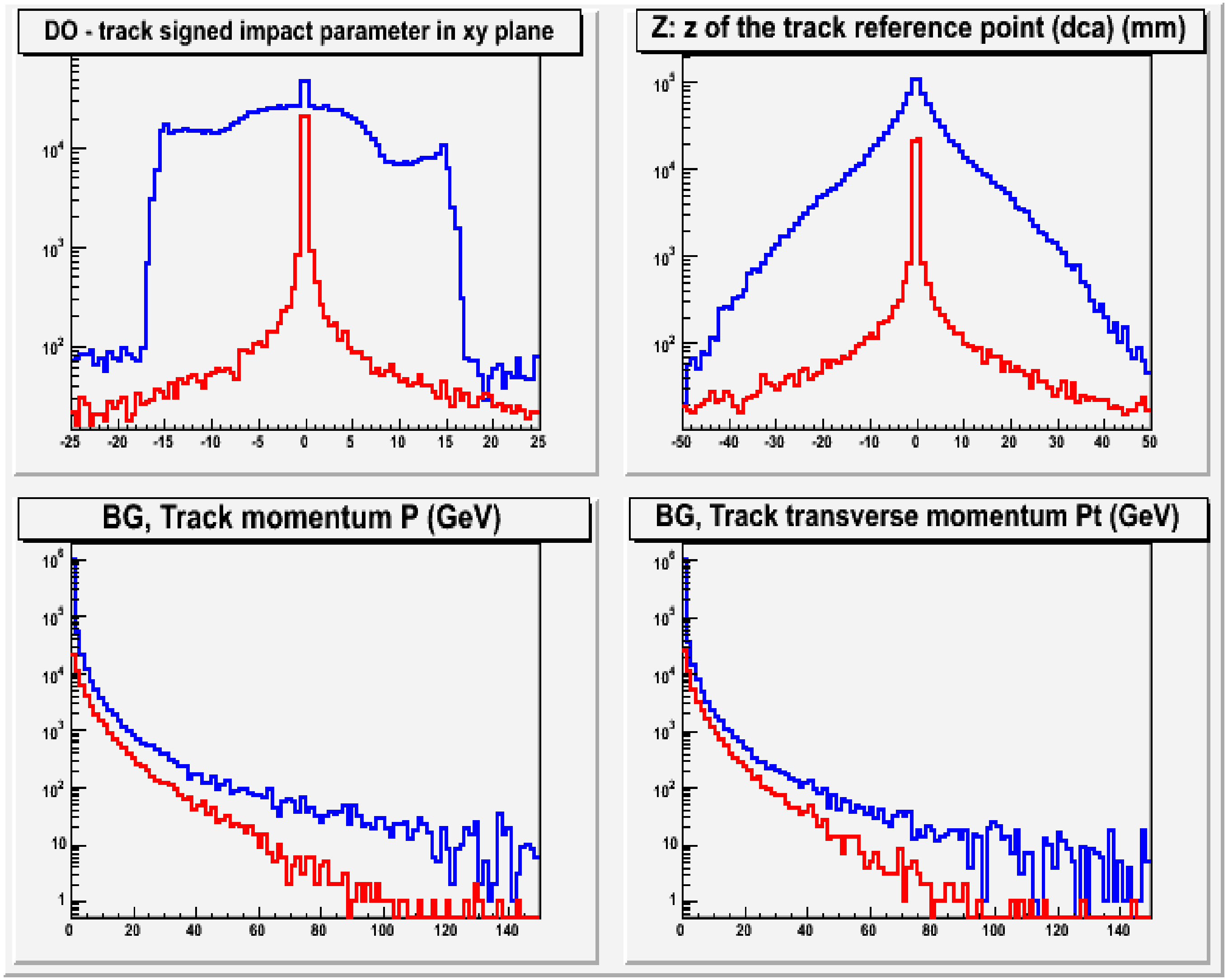
with bg hits

- **huge amount** of additional background hits in VTX
- **huge amount** of additional tracks in VTX and whole detector
- problems in reconstruction
- ghost tracks from 'noise' hits
- hits might degrade the measurement of physics hits that are nearby (cluster extension)
- is tracking reliable?

	no background	background
VTX hits	~400	~10^5
Si tracks	~60	~4000
Full tracks	~70	~1500

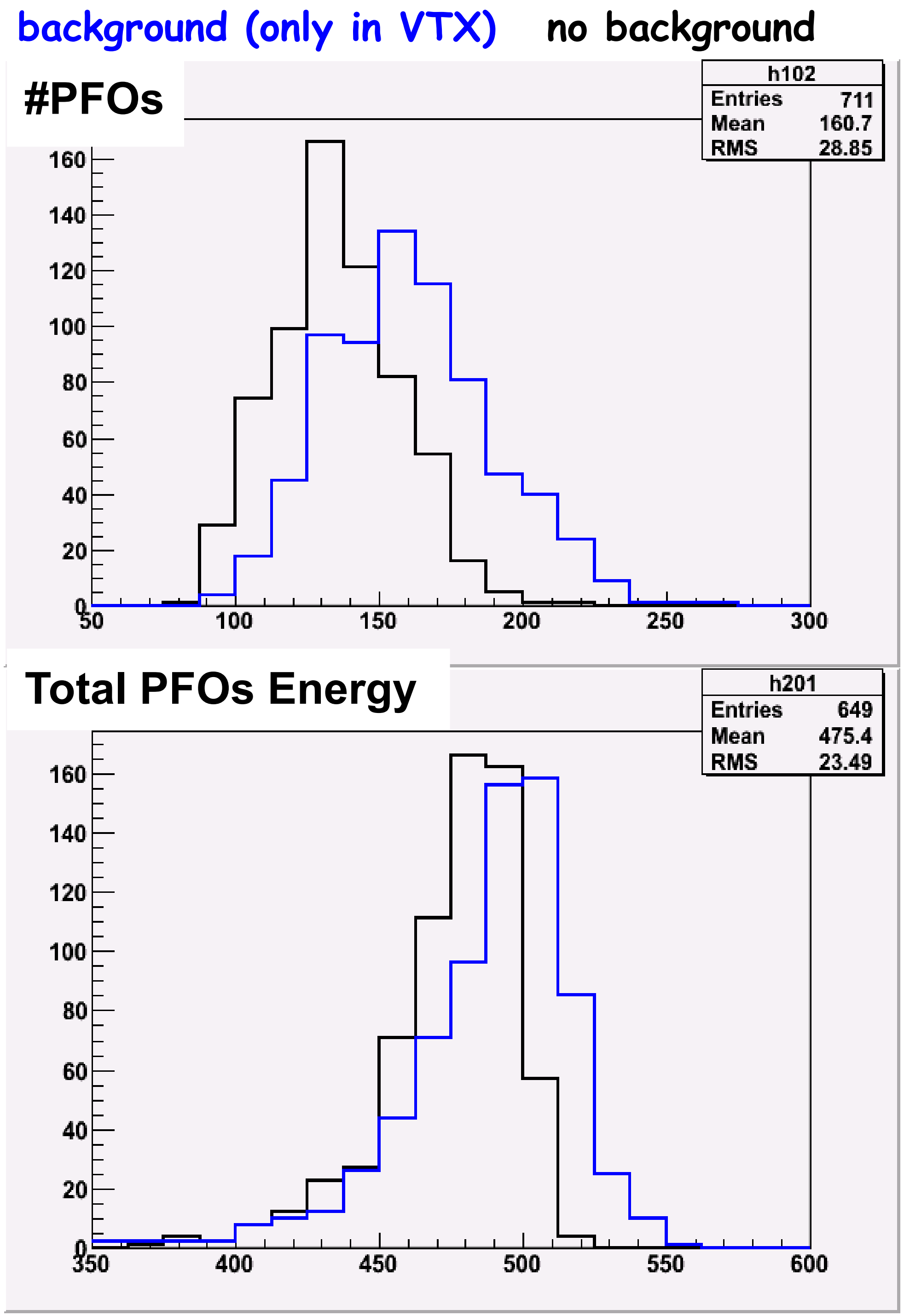
Background & Full Tracking

background (only in VTX) no background



- tracking not really reliable
- can Pandora deal with that?

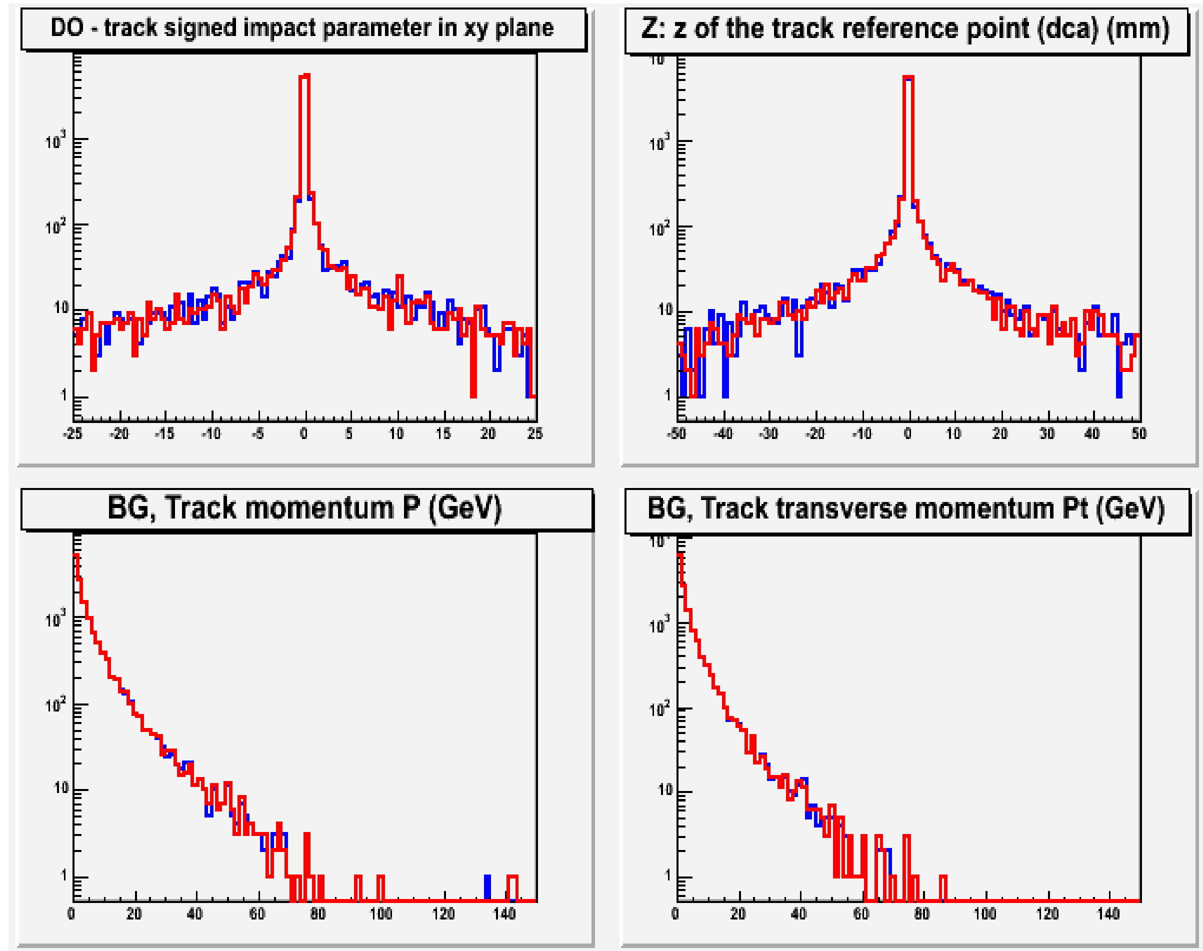
Background: PFOs



- Pandora does not crash!
- number of PFOs higher
- total energy slightly higher (more PFOs) but in reasonable range
- **Pandora** (sort of) **works** but reconstructs too many PFOs
  - uses other variables & detectors
  - selection on tracks

Reducing Background after Reconstruction

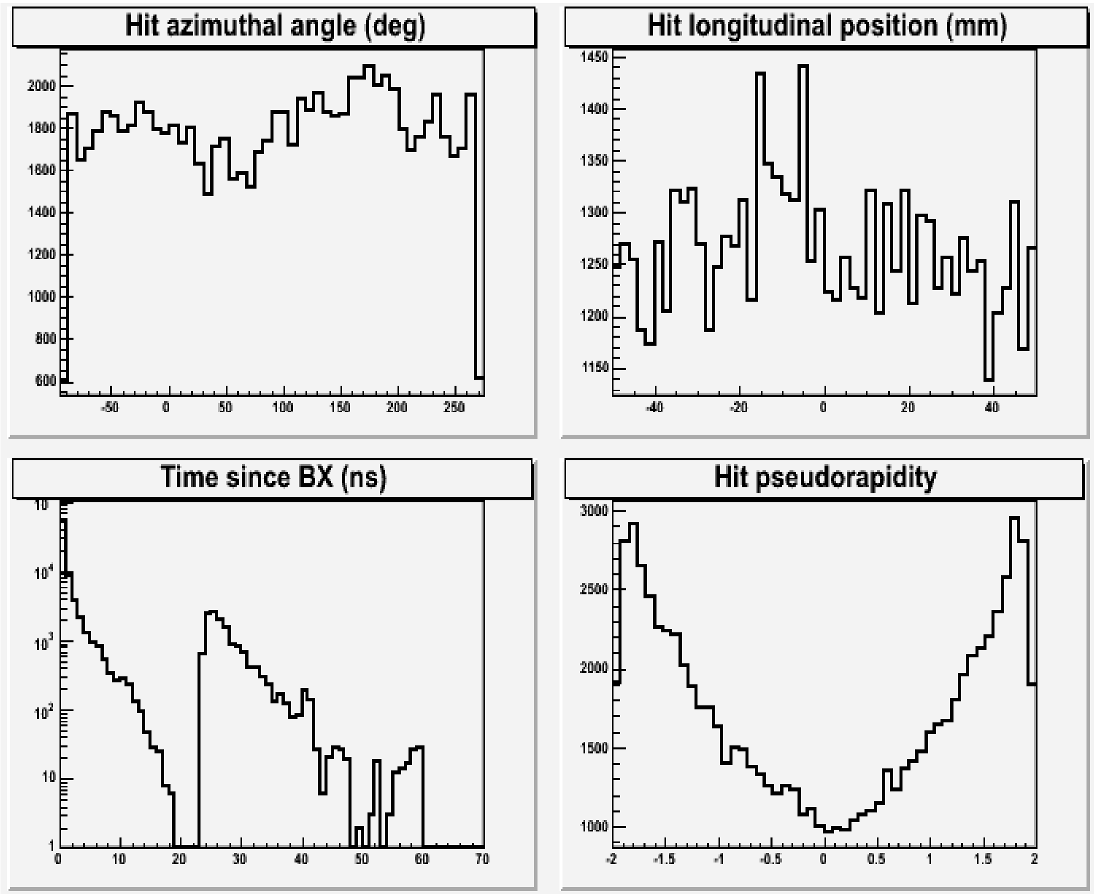
- cuts to reduce background and keep physics events?
- best results with 2D cuts based on track D0, track pseudorapidity and number of hits used for track fit coming from TPC (background tracks rarely reach TPC)



⇒ good agreement for track variables
background rejection ~97%, track efficiency ~1.5% for pT>0.5 GeV

More Realistic Background

- is isotropic background from Salt&Pepper processor realistic enough?
  - not all distributions flat
  - lack of real tracks
  - background hits only in VTX
- more realistic S&P:
  - parametrize isotropic background according to real distributions
  - add background in other detectors
- best approach - overlay simulated background on physics events →



physics processes overlayed with hits from simulated Guinea Pig e^+e^- pairs

Overlay Processor

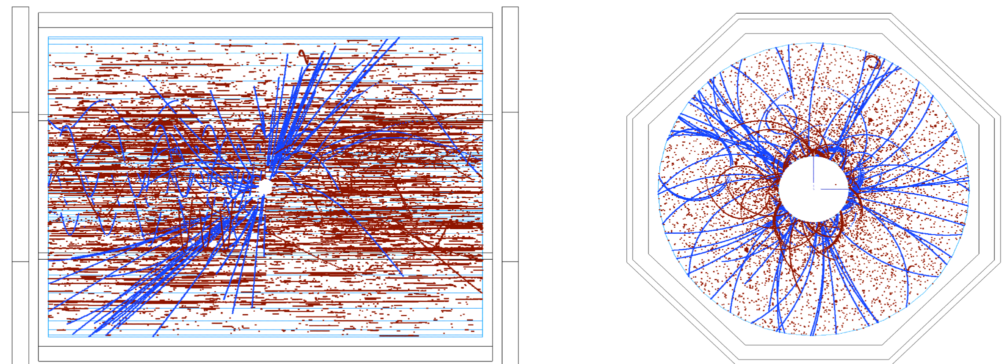
- **OverlayBX processor**, version v01-06-fw:
  - possibility to overlay n BX in TPC
  - 1 BX in other detectors with fast readout: SIT, FTD, SET, ECAL, HCAL, BCAL, LCAL, LHACAL
  - in VTX number of overlayed BX evaluated from readout times, 83 for 1-2 layers and 333 for the rest
  - uses ~2000 Ginea Pig BX
  - ILD_00fw model created to study background

- technically challenging
  - time consuming
  - different components – different readout times – different number of BX
  - need to account for time- and space-shifts for different BX
  - large pool of GP events necessary: 2000 BX (thanks to T. Hartin)

Beam Background in TPC

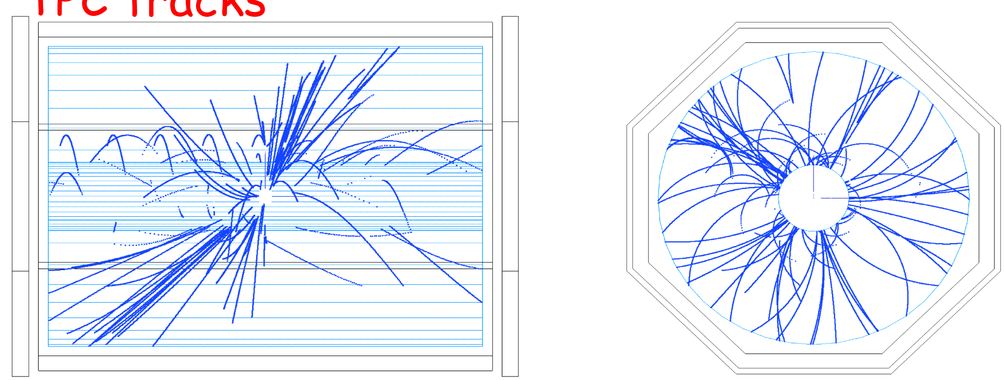
- background hits in TPC →
- ttbar events overlayed with hits from e^+e^- pairs
  - 150 BX overlayed
  - improved digitalization
- specific pattern recognition software
  - micro-curlers removed:
    - 99% background hits removed
    - 3% signal hits removed, only 1% hits from tracks $p_T > 1$ GeV
- remaining hits – no problem for track-finding pattern recognition software

TPC hits for ttbar events overlayed with 150 BX of pair-background hits



improved reconstruction "killing" micro-curlers

TPC tracks



courtesy of S. Aplin

<u>for details check S. Aplin talk</u>

Beam background in VTX

- GineaPig simulation of background analyzed (R. de Masi)
  - distribution of cluster sizes calculated
  - clusters: ellipses or rectangles on VTX ladder surfaces
    - two main cluster axes on the ladder
  - root-histograms provided
- cluster sizes are strongly peaked at 3x3 pixels with long tails

- 2 Marlin processors adding ClusterParameters to VTX hits
- VTXNoiseClusters
  - distribution of cluster sizes from root-histograms
- VTXBgClusters
  - projected path length of MCParticle when going through sensitive part of VTX ladder
  - oriented along projection of particle's 3-momentum
  - needs 'dedicated' configuration parameter in Mokka simulation (not mass production)

Beam Background in VTX

- effect of measurement degradation from clusters studied
  - hit position of a physics hit (space point) falls within a background cluster hit:
    - physics hit removed (optionally background hit moved to the intermediate position)
    - resolution kept

•effectively removes ~0.1-3.3% (occupancy) of the physics hits (different for different layers)

•Marlin processor to "simulate" lower occupancy

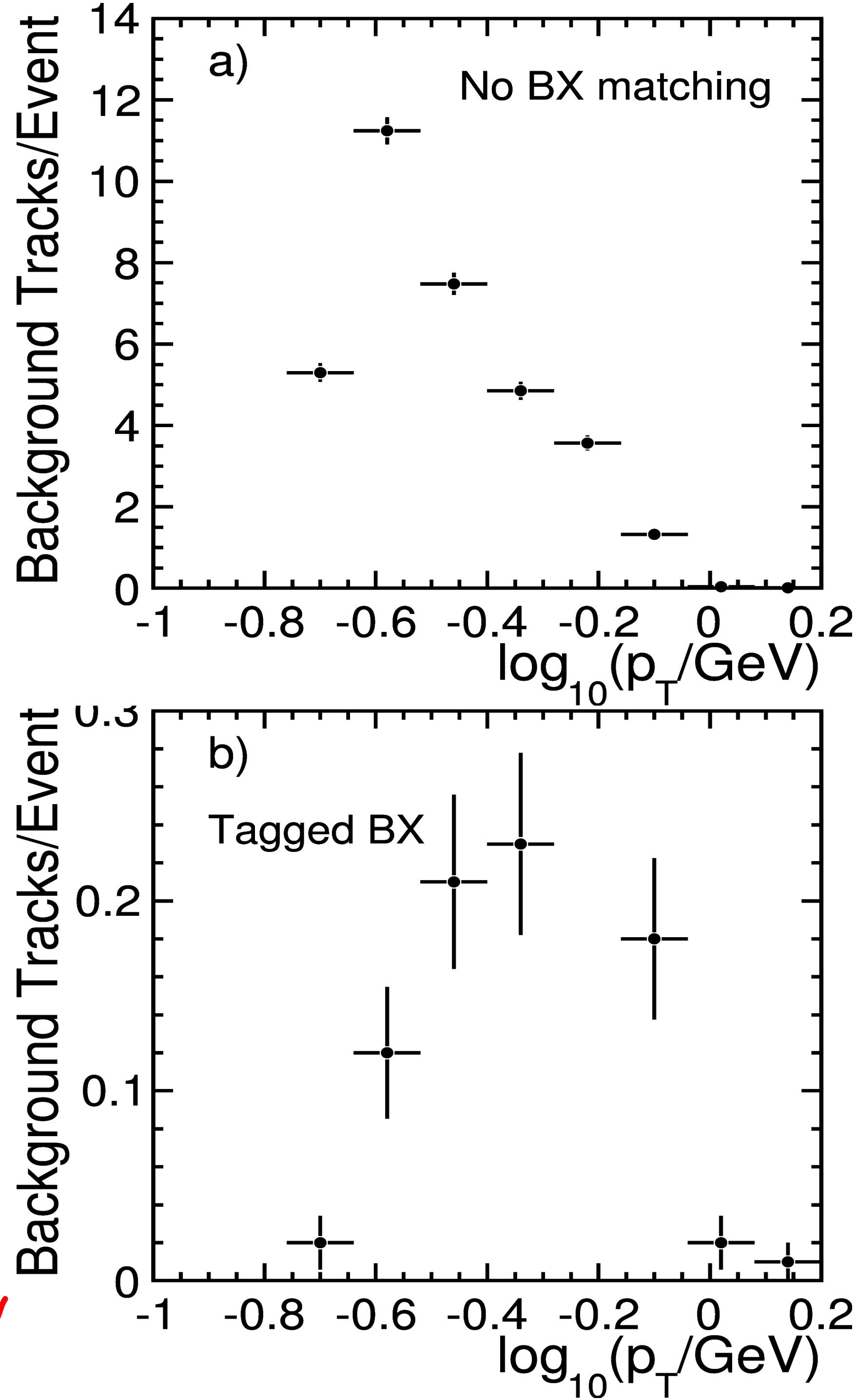
- removes on statistical basis random hits from physics hits in VTX layers, according to numbers from degradation studies
- quick – uses only physics sample
- tests ran so far

•another processor (not used yet)

- uses simulated GP background to remove hits
- time & resources consuming

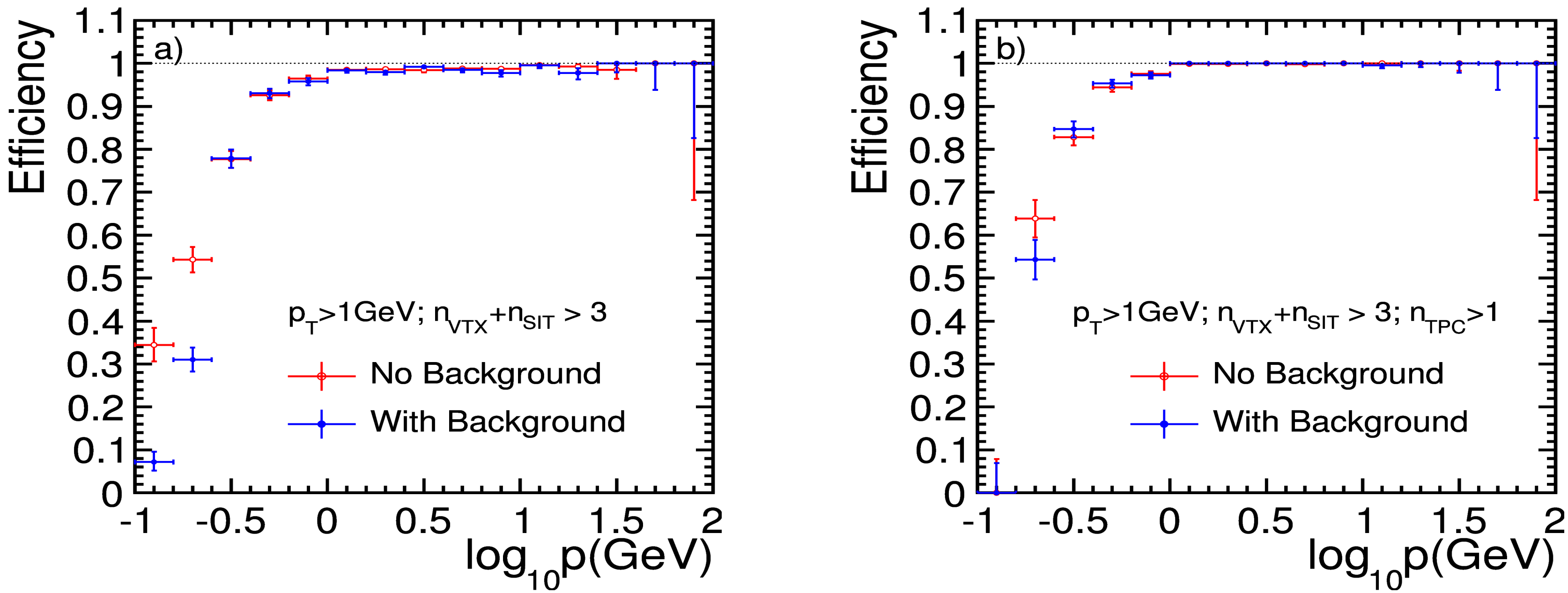
Tagging Bunch Crossings

- pattern recognition in presence of background challenging
  - seeding for Si tracks changed
- number of background ghost tracks dramatically decreased if BX tag used
  - at least 1 SiT hit OR
  - at least 10 TPC hits
- much less tracks and higher p_T
- leftover tracks
  - relatively high p_T e^+/e^-
  - combination of physics and BG hits
- loss of efficiency due to requirements
  - 1% for $p_T < 1$ GeV, none for $p_T > 1$ GeV



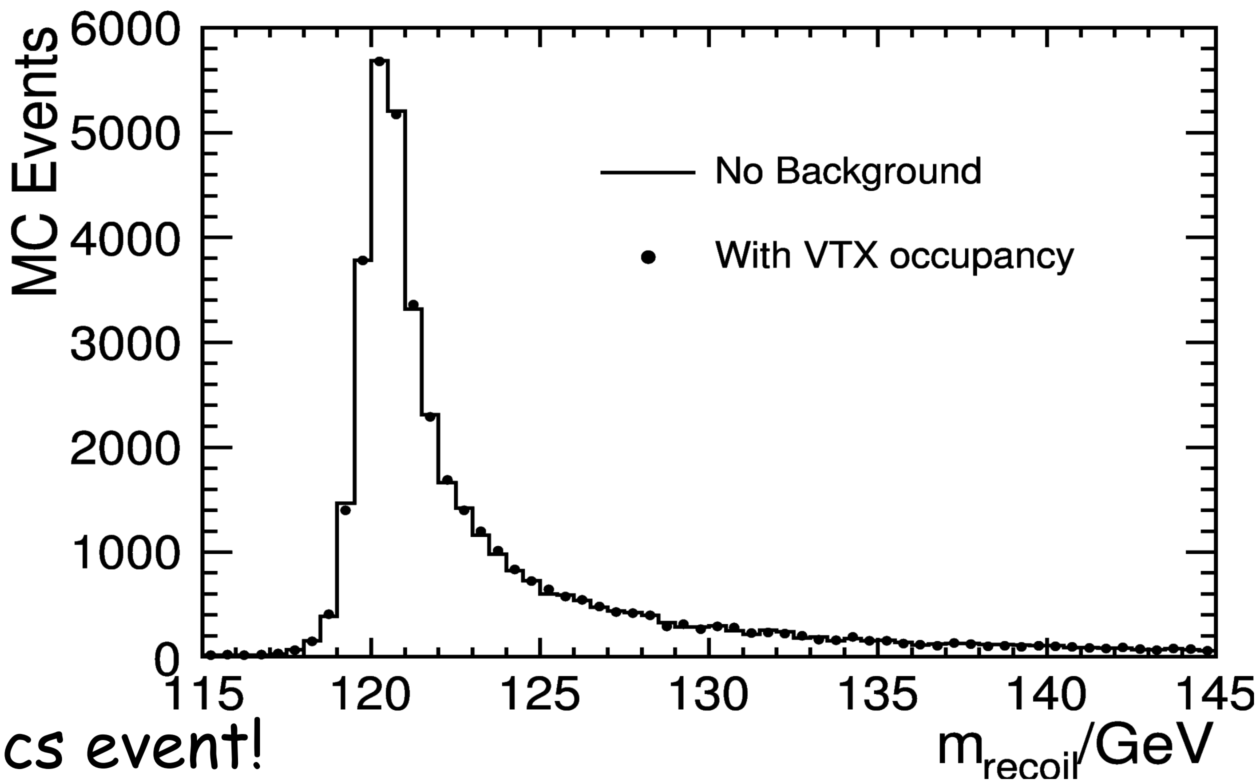
Tracking Efficiency

- effect of overlayed background and VTX hit inefficiencies studied for $t\bar{t} \rightarrow 6\ jets$ events (for CME 500 GeV)
  - track efficiencies for p_T < 300 MeV reduced
  - for p_T < 1 GV inefficiency less then 0.1%
    - track efficiency 98.8%
  - for tracks that deposit energy in TPC and with p_T < 1 GV efficiency is > 99.9%
- track efficiencies not significantly degraded in by nominal level of BG



Impact on Physics Analyses

- IDAG requested studies for Higgs recoil mass with beam BG
- track finding inefficiencies for high momentum muons from $ZH \rightarrow \mu^+ \mu^- X$ negligible
- low p_T tracks do not affect recoil mass distribution
- effect from loss of hits in VTX due to occupancy negligible
- full simulation of background time&CPU consuming
  - 150 BX in TPC
  - 1 BX in SiT
  - 83/333 BX in VTX

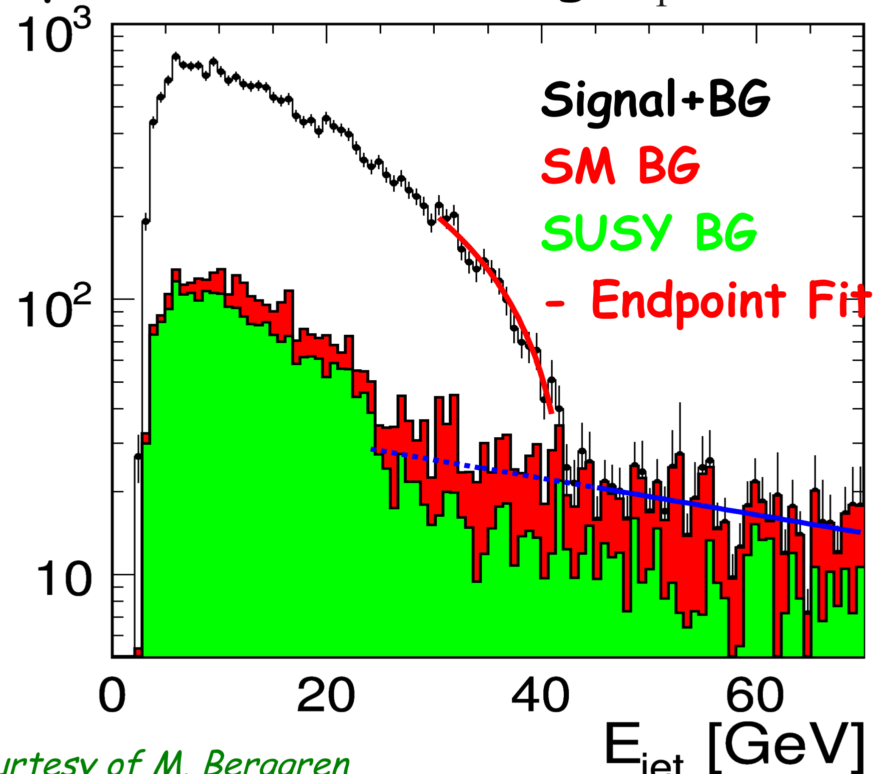


overlayed for each physics event!

SUSY Sps1a': Stau Mass

$$e^+ e^- \to \tilde{\tau}\,\tilde{\tau} \to \tilde{\chi}_1^0 \tau\, \tilde{\chi}_1^0 \tau$$

- missing energy and 2 low multiplicity tau-jets
- τ mass extracted from end-point of tau-jet energy spectrum (assuming $\tilde{\chi}_1^0$ mass)



courtesy of M. Berggren

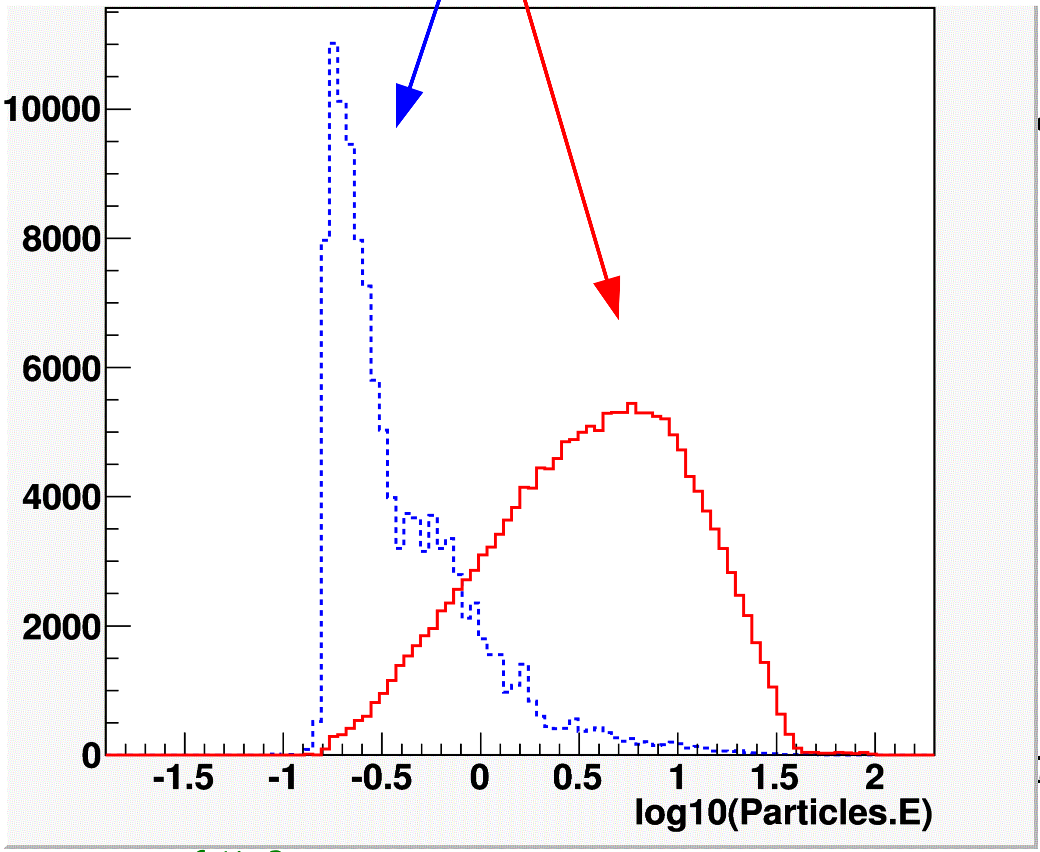
- requirements:
  - precision tracking
  - good particle identification
  - hermetic detector
  - **low machine background**
- stat. error on end-point: 0.1 GeV
- accounting for $\tilde{\chi}_1^0$ mass uncertainty: $0.1\ \text{GeV} \oplus 1.3\sigma_{LPS}$

SUSY Sps1a': Staus Revisited

$$e^+ e^- \rightarrow \tilde{\tau}\,\tilde{\tau} \rightarrow \tilde{\chi}_1^0 \tau\, \tilde{\chi}_1^0 \tau$$

- studied with beam background present
  - each physics event overlayed with 1 BX of Guinea Pig pairs

charged particle log10(E)



courtesy of M. Berggren

- set of cuts to remove background
  - particle energy E > 0.5 GeV
  - at least 1 hit in TPC (charged and neutral)
  - DELPHI jet algorithm used to find taus (more efficient than Durham)

no difference in τ mass extracted with beam background and without

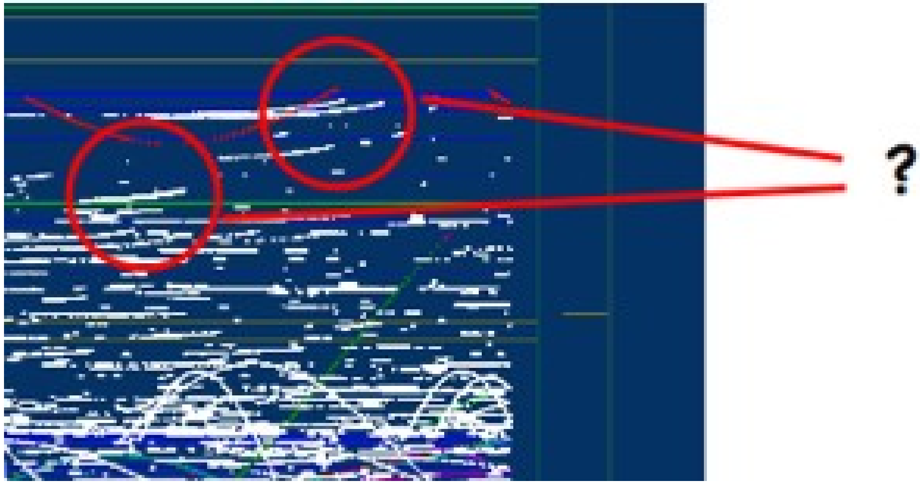
for details check M. Berggren talk

Summary

- ILC faces novel problem of beam-related backgrounds
- we have to know its impact on reconstruction and physics analyses
  - we can simulate it
  - we are learning how to deal with it
  - we start to do analyses with real background simulation

Magnetic Field in Mokka

- B-Field problems found in the ILD_00fw model created to study background
  - strange radial components in the B-Field in the TPC



- new model created ILD_00fwp01
  - new non-uniform solenoid with anti-DID
  - GP files for background studies created with proper B-field