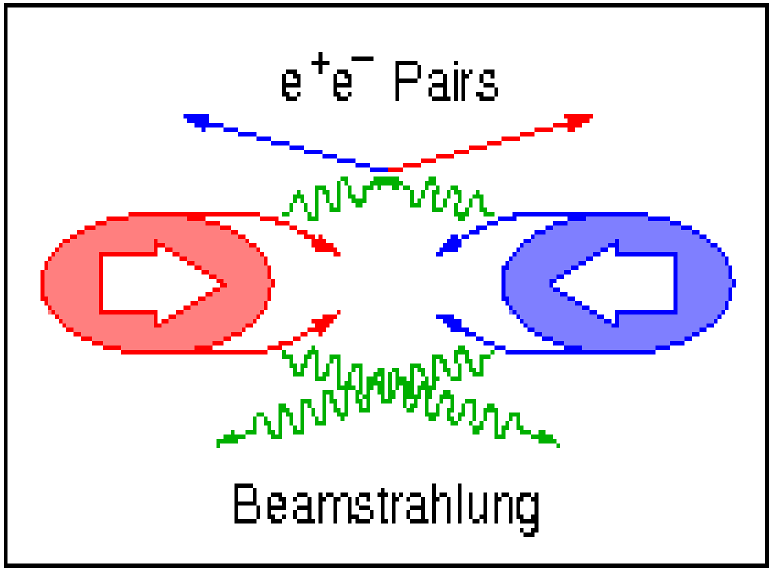
Beam backgrounds: Simulation & Effects on Reconstruction at ILD

- 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
- SB09 Beam Backgrounds

Beam Induced Backgrounds

<u>novel problem faced by linear colliders – beam induced backgrounds</u>

- 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



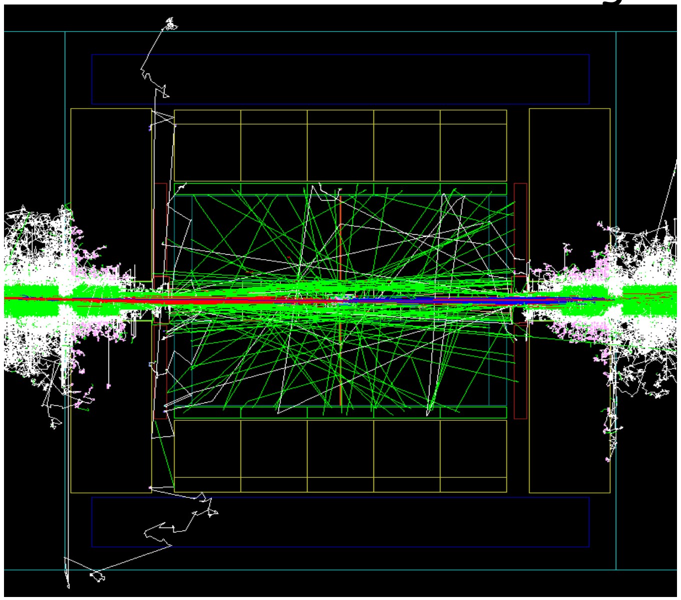
- electron-positron pairs are unavoidable backgrounds
- other beam beackgrounds (of small impact, not yet included in studies):
  - beam halo muons, beam gas interaction, synchrotron radiation from beam delivery, particle losses in extraction line, beam dumps

Generating & Simulating Backgrounds

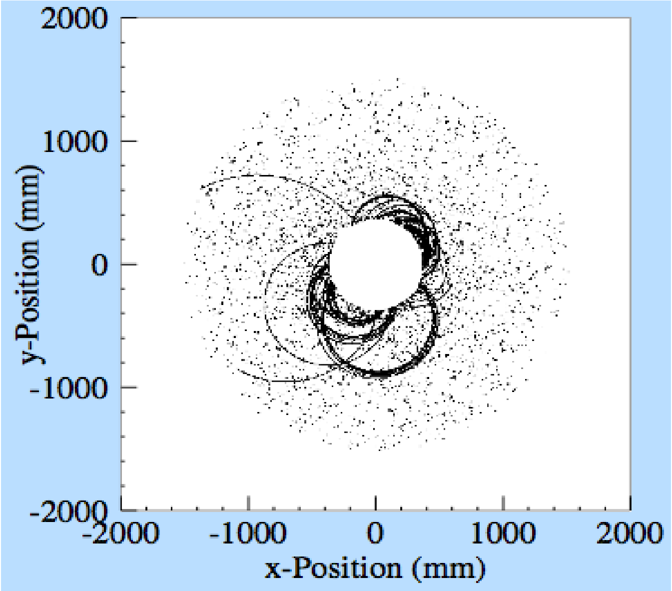
- **generation of e^+e^- pairs:**
  - GP++ - DESY
  - GuineaPig, CAIN - Japan
- **full GEANT4 simulation of pair background**
  - 2 software models used (differences in anti-DID magnetic field)
    - ILD00_fw (DESY)
    - ILD00_fwp01 (Japan)
  - realistic description of fwd region and magnetic fields
  - main gaseous tracker conversion of backscattering photons
  - tracks from the IP, rare, but mostly curlers
  - recoil tracks from neutron-proton

Simulating Beam Backgrounds

A. Vogel



1/10th of bunch crossing



Mokka hits in the TPC (100BX)

- from simulation - **mostly affected – VTX and forward detectors**
- due to readout time VTX will integrate a large number of bunch crossings for every physics event
- TPC also might suffer from accumulating many BXs of background
- necessary to find a way to simulate BG
- now we have 2 way of imposing background events on real physics events

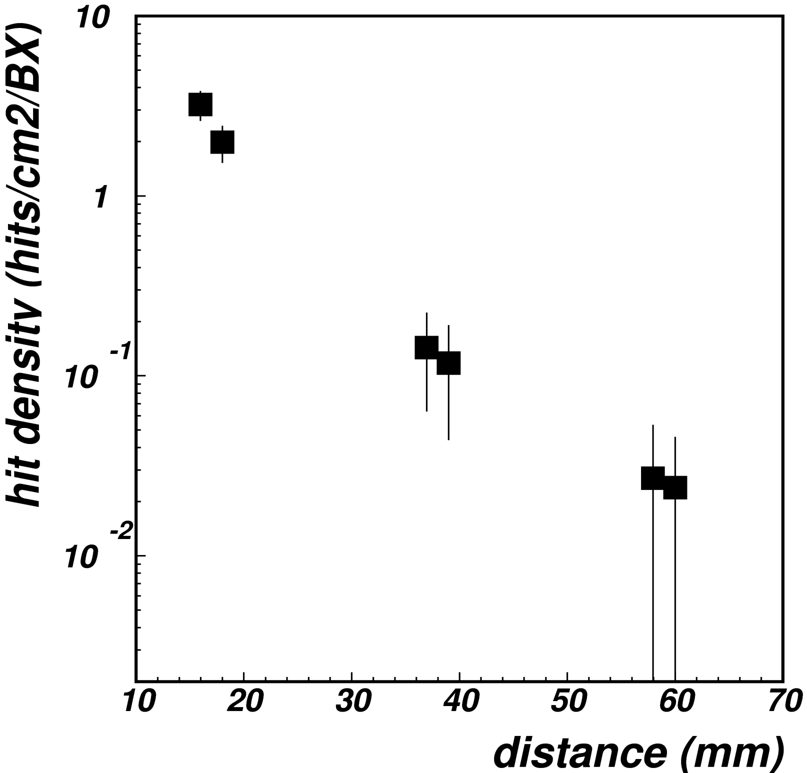
> - salt & pepper BG in VTX
> - overlayed background

Salt & Pepper Background

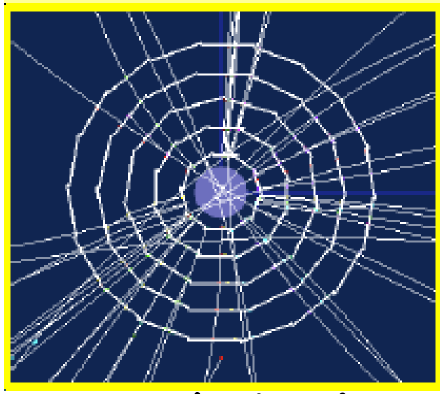
- salt&pepper hits added to VTX (VTXNoiseHits Marlin Processor)
  - isotropically distributed hits added to SimTrackerHits collection after digitizing
  - hits added according to hit densities
  - layers 1-2: 83 BX/event, rest 333 BX/event (estimated from VXD readout times)
- fully reconstructed tracks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

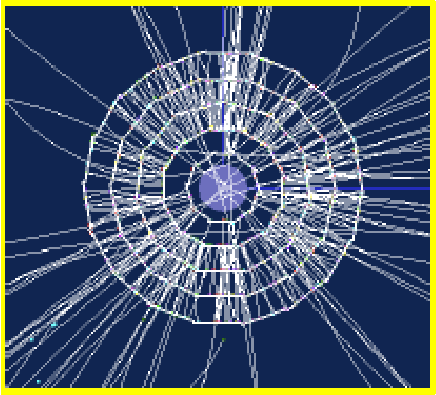
    (SimTrackerHit), ~100 BX used



Background: Hits & Tracks



w/o bg hits



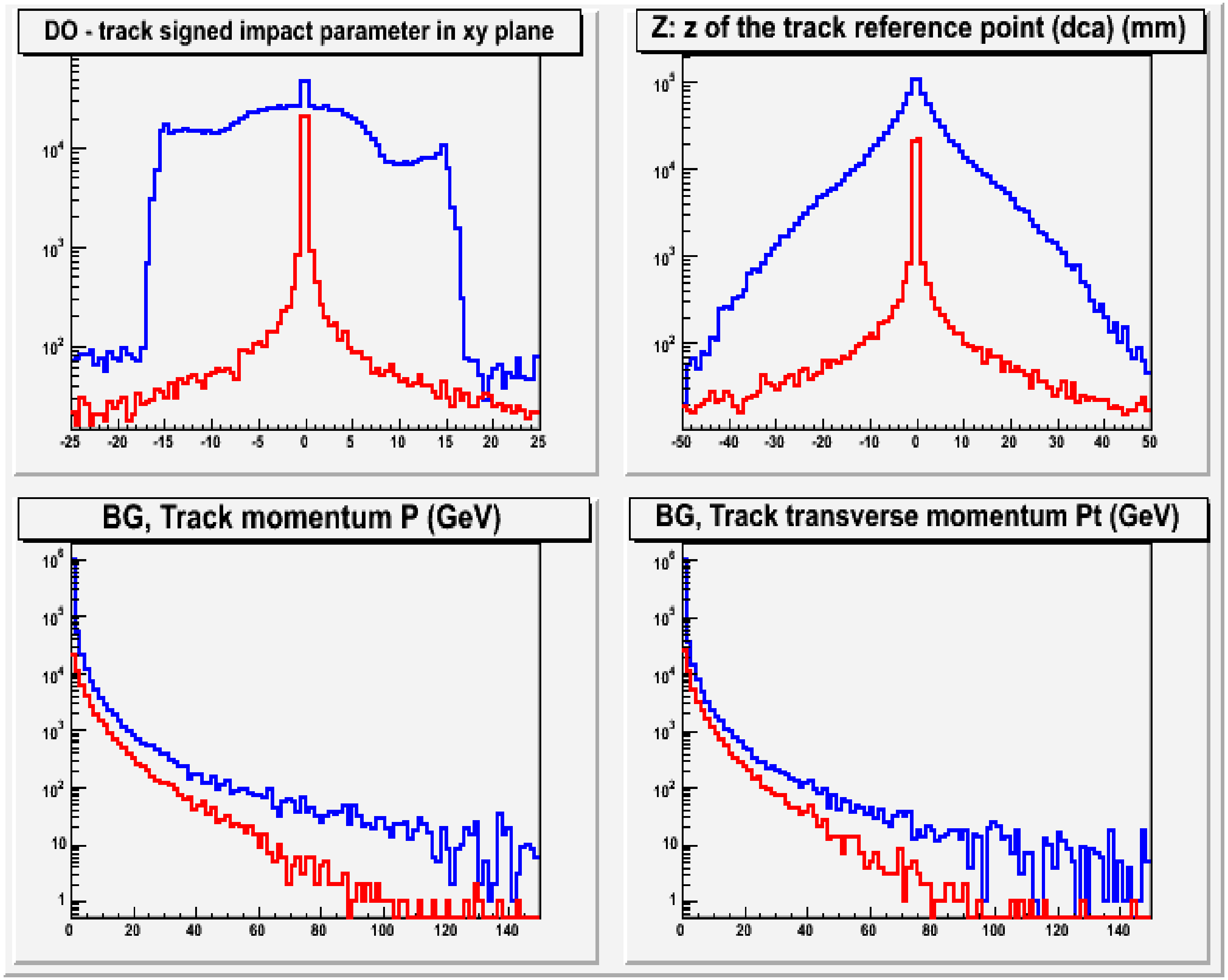
with bg hits

- **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

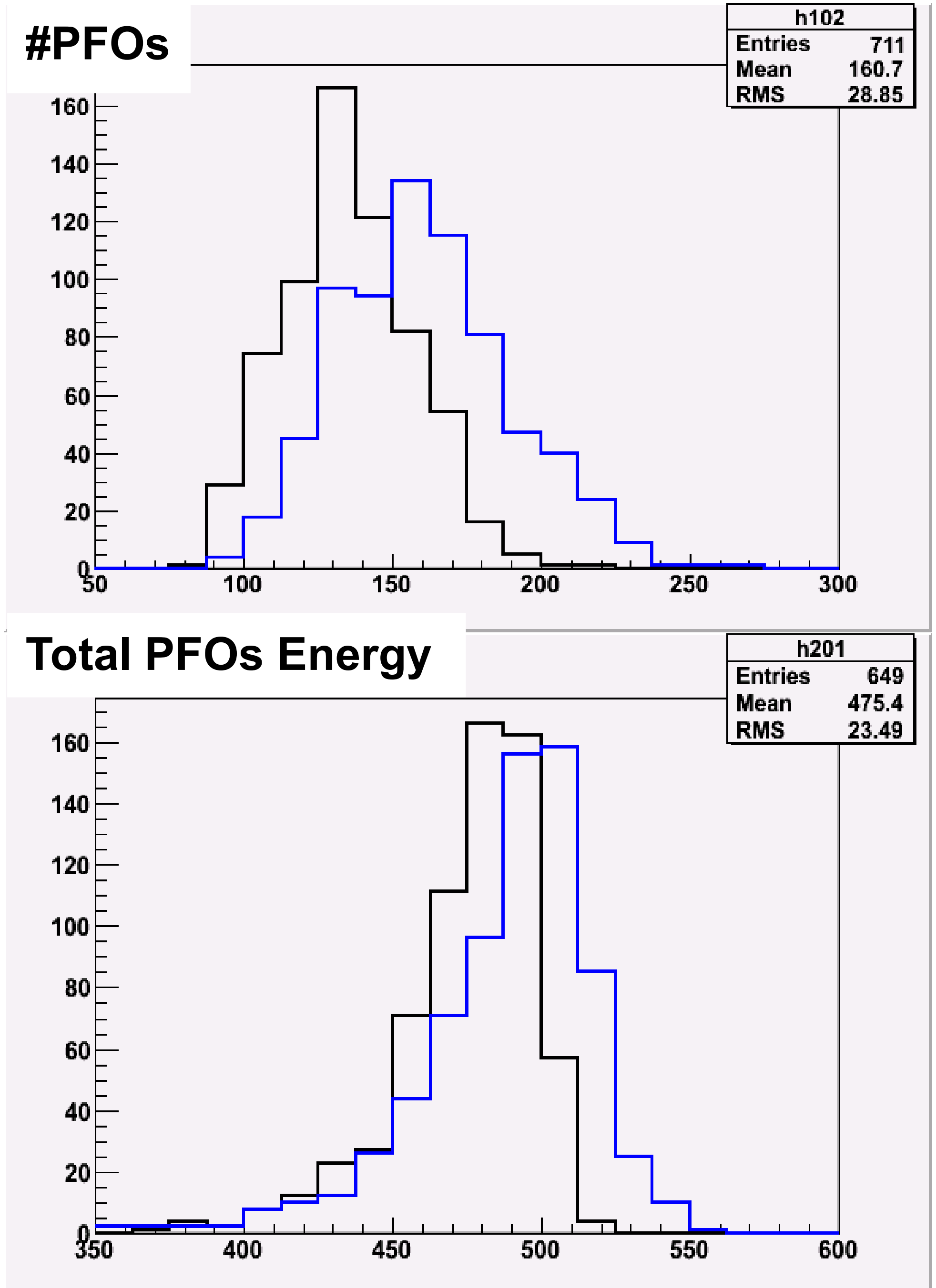
background (only in VTX) no background



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

Background: PFOs

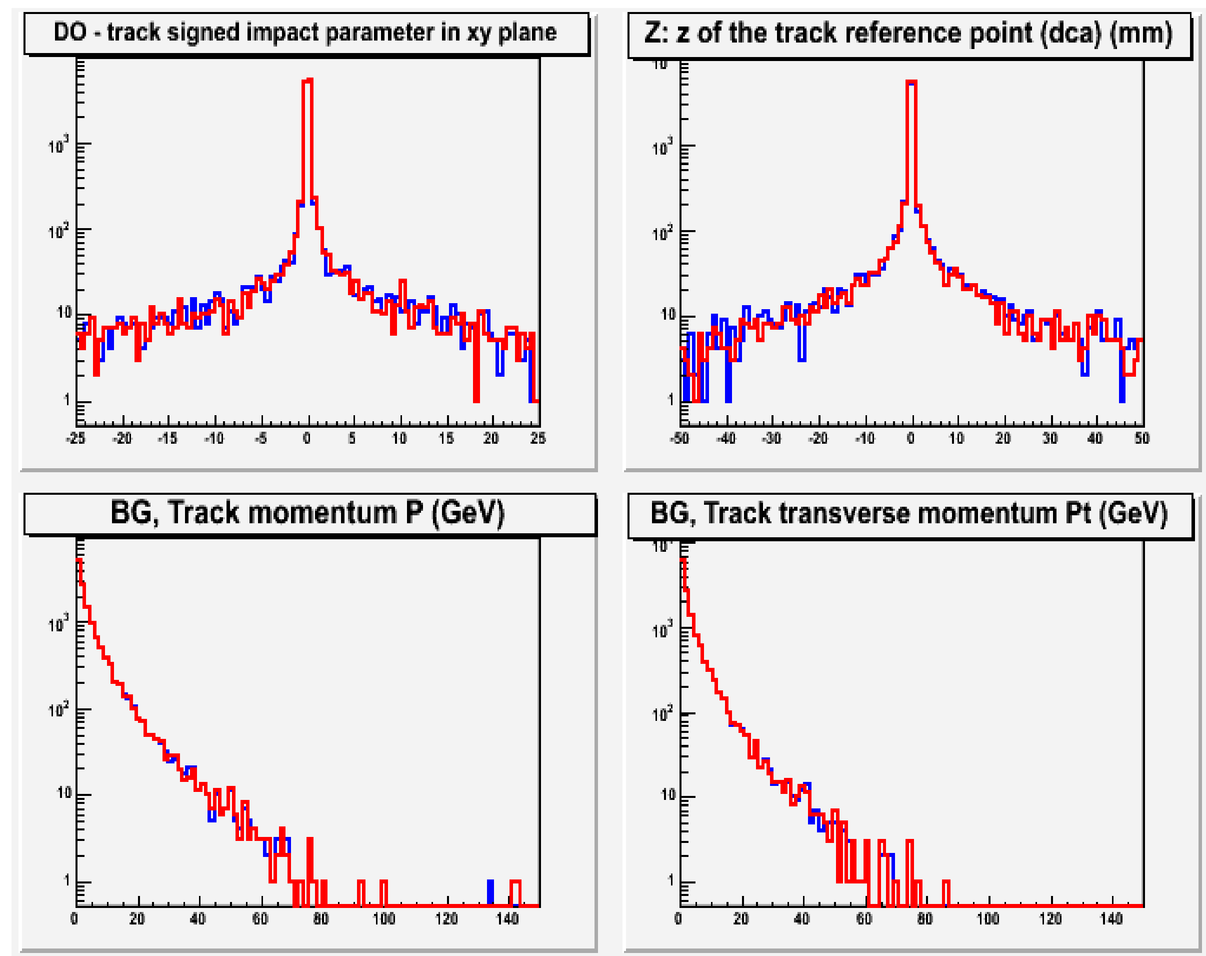
background (only in VTX)   no background



- 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

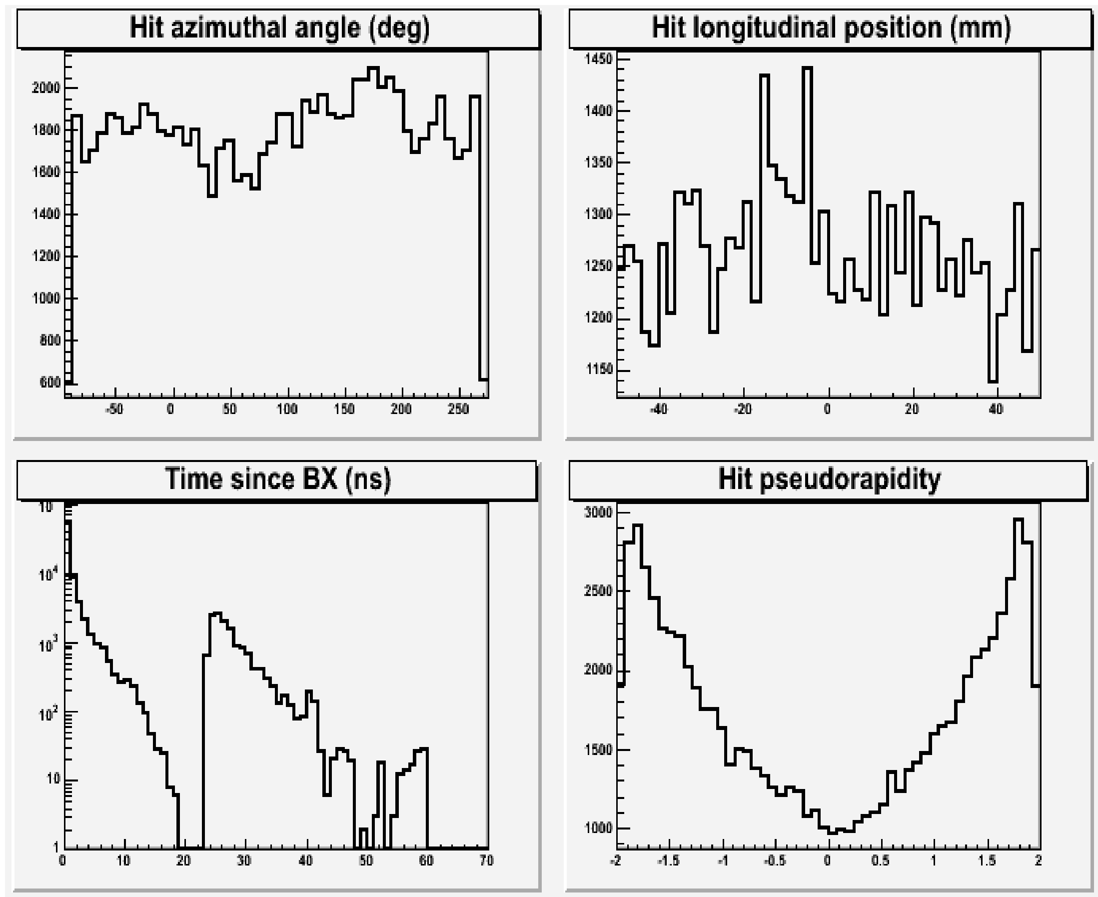
- cuts to reduce background and keep physics events?
- best results with 2D cuts based on track D0, track pseudorapidity and number of hits used for track fit coming from TPC (background tracks rarely reach TPC)



⇒ 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 GP e^+e^- pairs

Overlaying Background

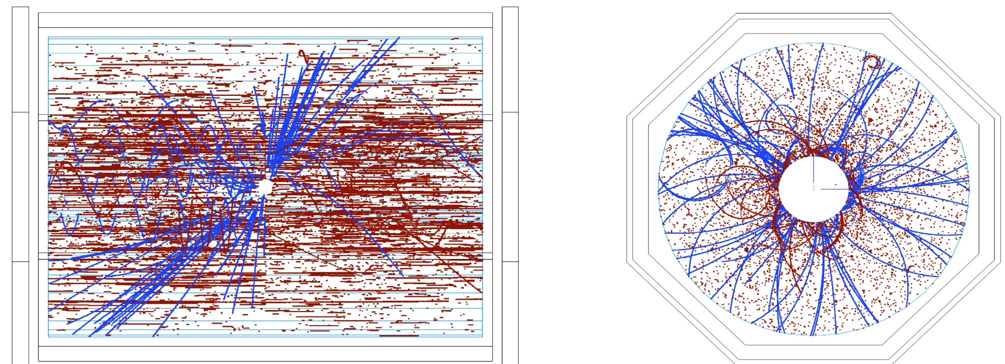
- **OverlayBX processor**, version v01-06-fw:
  - possibility to overlay n BX in TPC
  - 1 BX in other detectors with fast readout: SIT, FTD, SET, ECAL, HCAL, BCAL, LCAL, LHACAL
  - in VTX number of overlayed BX evaluated from readout times, 83 for 1-2 layers and 333 for the rest
  - uses ~2000 simulated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

- 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

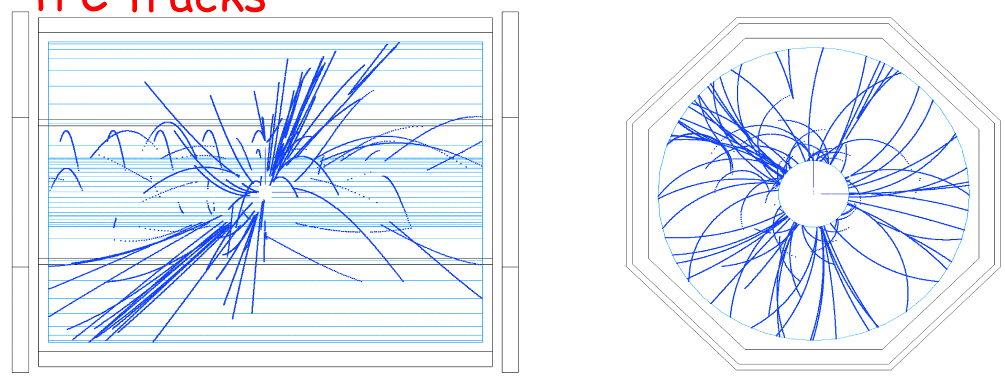
- background hits in TPC →
- ttbar events overlayed with hits from e^+e^- pairs
  - 150 BX overlayed
  - improved digitalization
- specific pattern recognition software
  - micro-curlers removed:
    - 99% background hits removed
    - 3% signal hits removed, only 1% hits from tracks $p_T > 1$ GeV
- 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

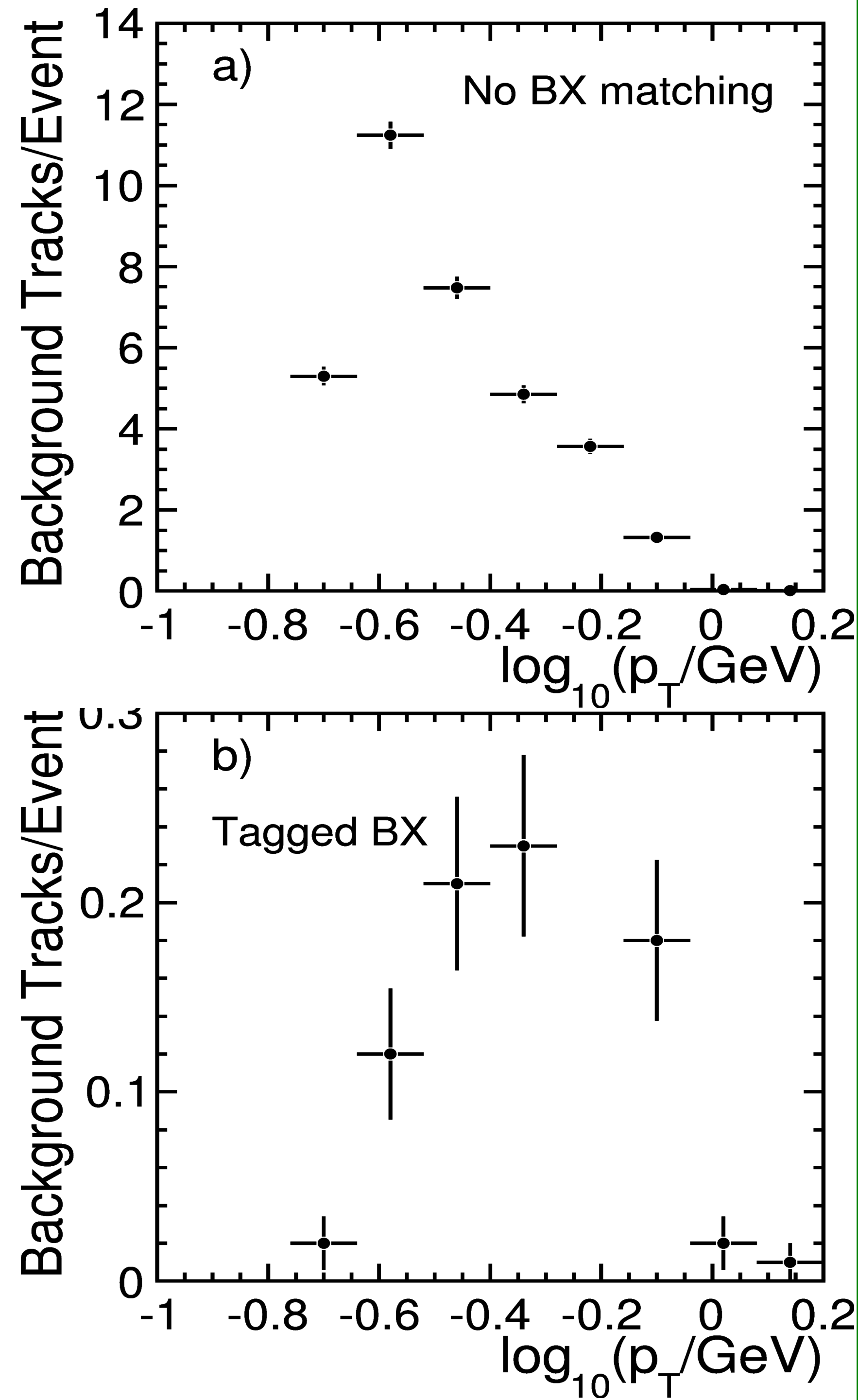


courtesy of S. Aplin

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

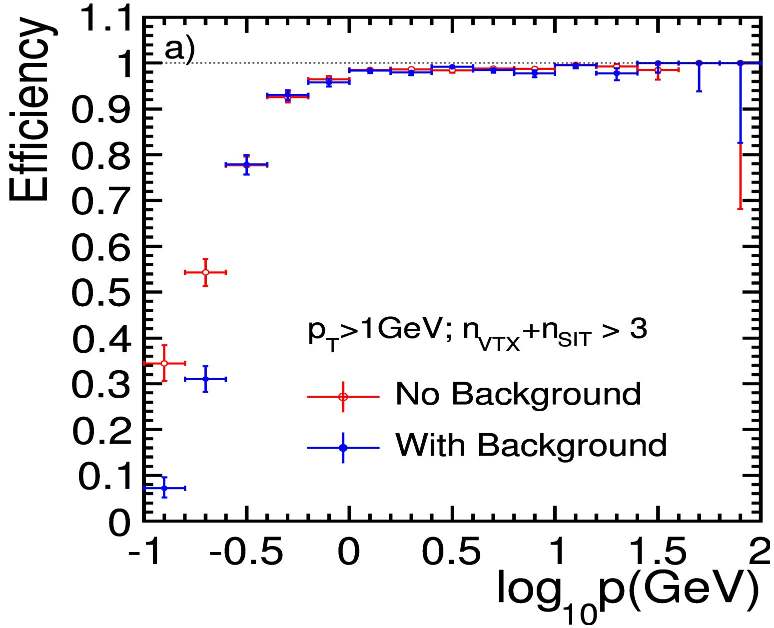
Tagging Bunch Crossings

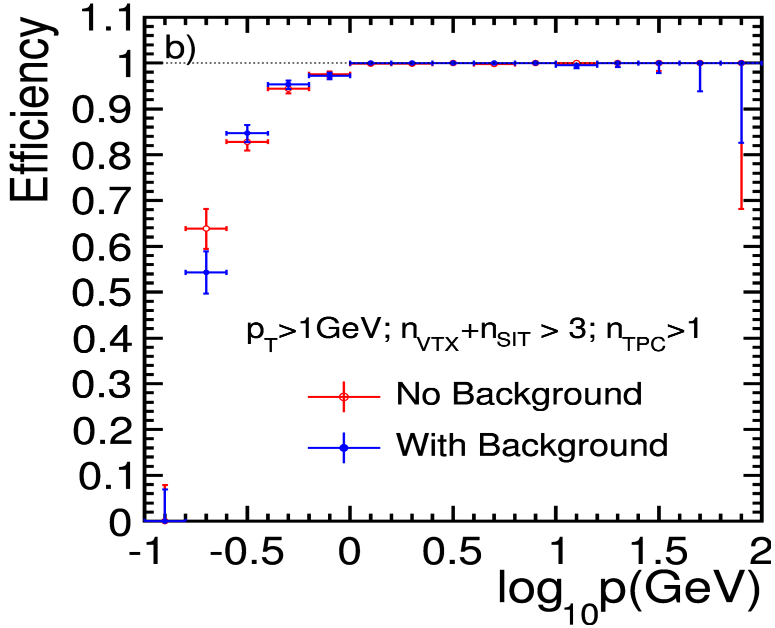
- pattern recognition in presence of background challenging
  - seeding for Si tracks changed
- **number of background ghost tracks dramatically decreased if BX tag used**
  - at least 1 SiT hit OR
  - at least 10 TPC hits
- much less tracks and higher p_T
- leftover tracks
  - relatively high p_T e^+/e^-
  - 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

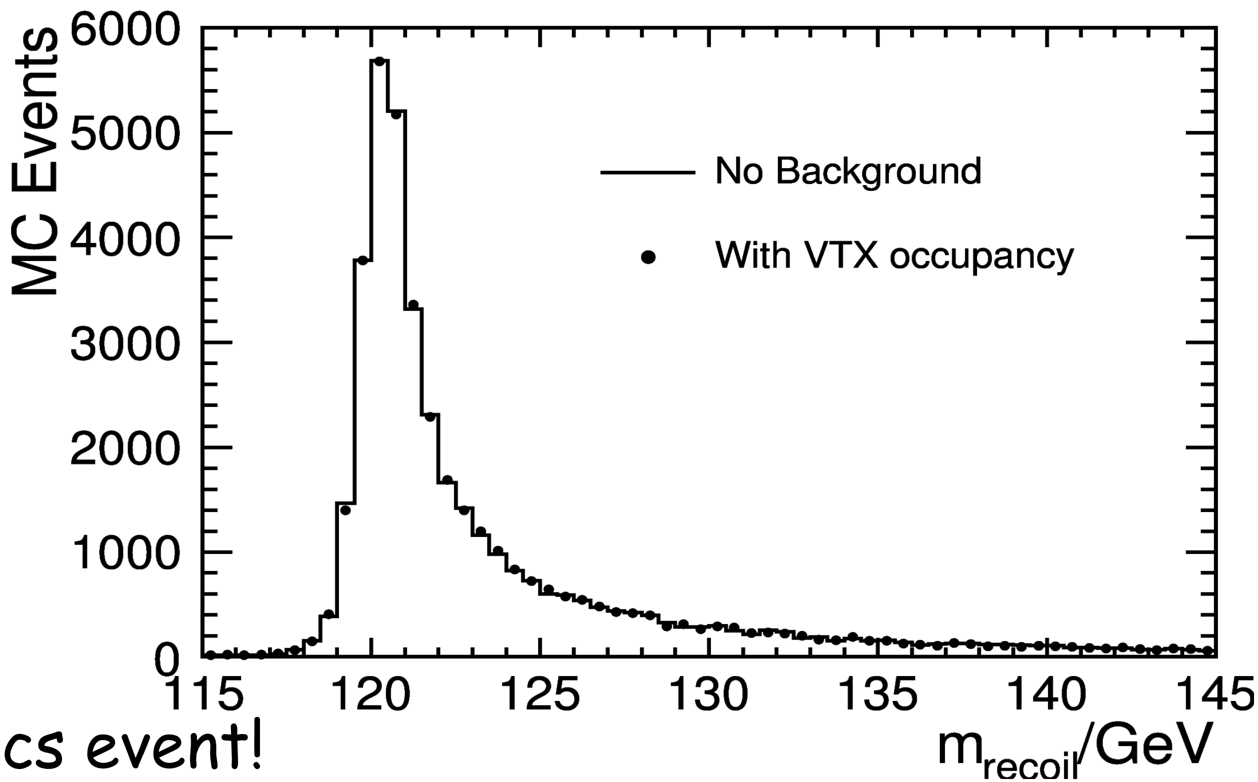




Impact on Physics Analyses

- 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

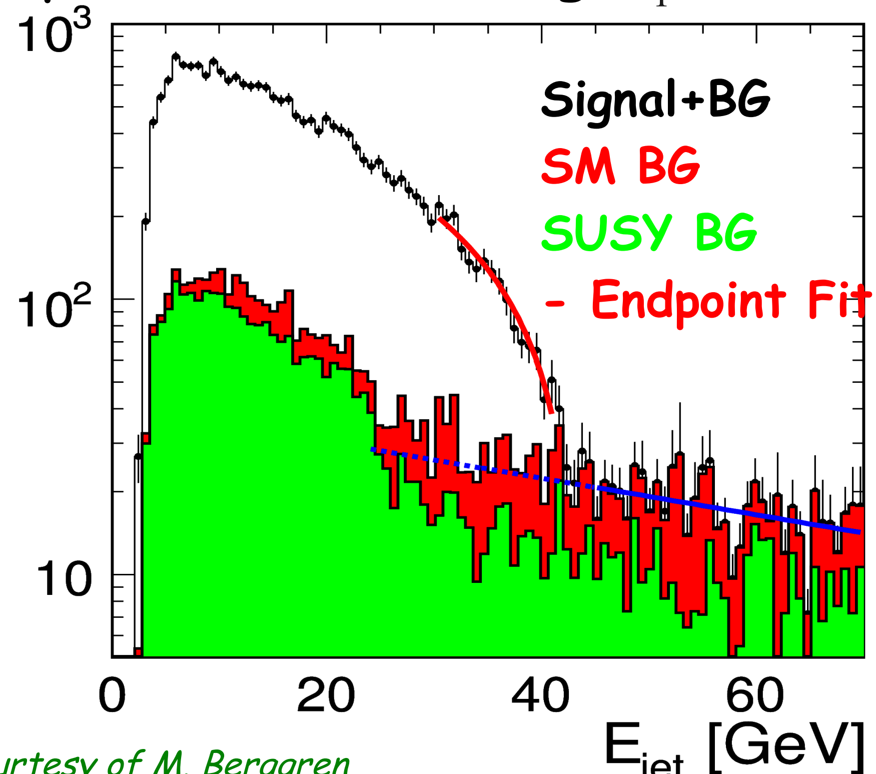
  overlayed for each physics event!



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

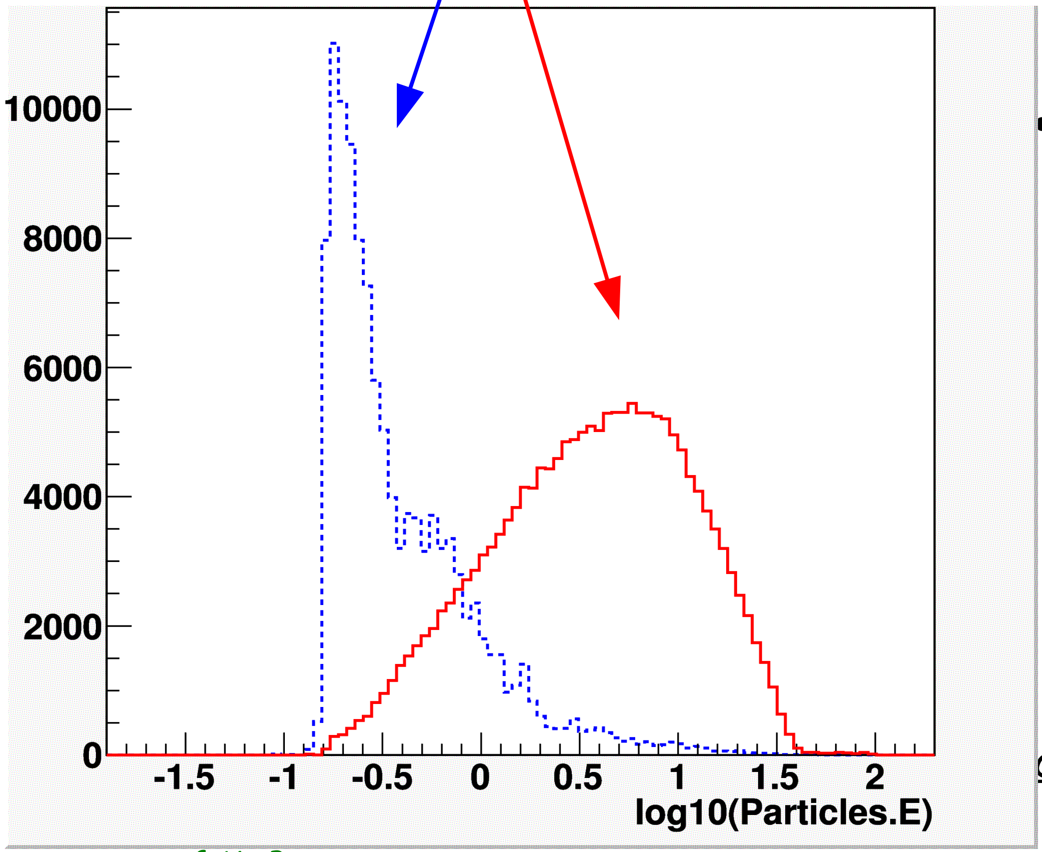
- requirements:
  - precision tracking
  - good particle identification
  - hermetic detector
  - **low machine background**
- stat. error on end-point: 0.1 GeV
- accounting for $\tilde{\chi}_1^0$ mass uncertainty: $0.1\ \text{GeV} \oplus 1.3\sigma_{LPS}$

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)



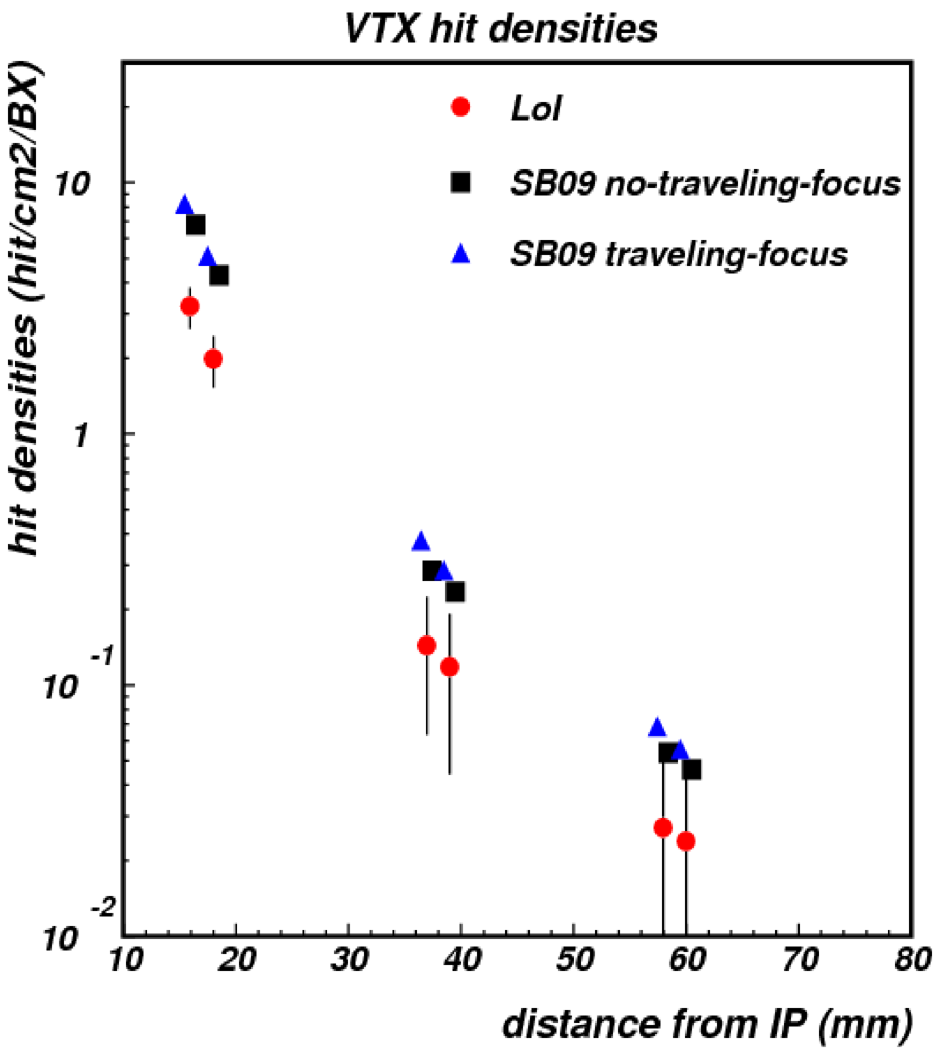
courtesy of M. Berggren

- 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

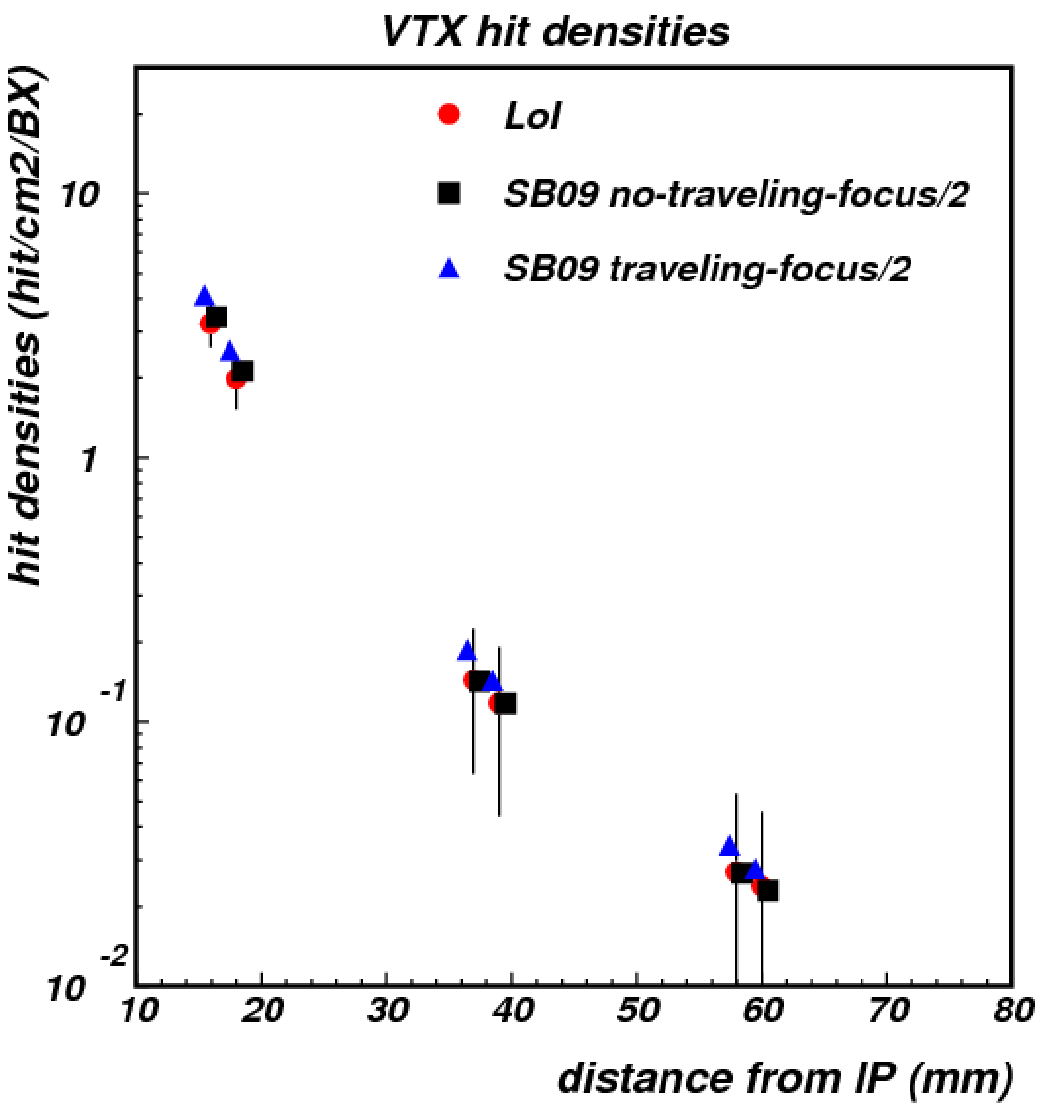
check also M. Berggren talk

SB2009 Backgrounds in VTX



- new set of beam parameters SB09 corresponds to new background values
- 2 options for SB09
  - no traveling focus (NTF)
  - traveling focus (maybe) (TF)
- VTX hit densities calculated as before
- in VTX SB09 (for 1 BX) gives twice as much background for NTF
- TF adds about 30% more (per BX)
- there might be other consequences of new beam setup – under study

SB2009 Backgrounds in VTX

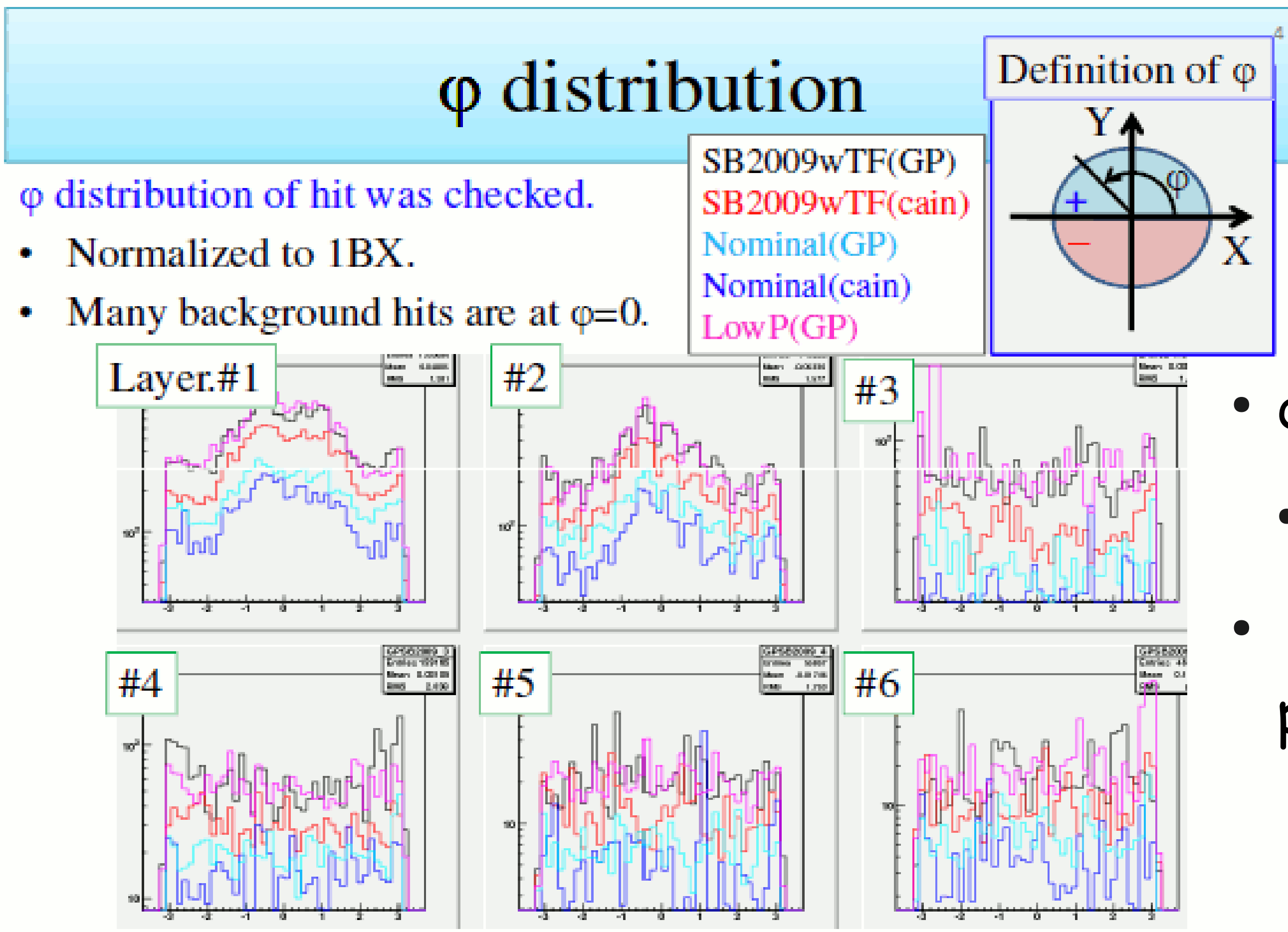


- for SB09 half as much BX as LoI
  - to compare hit densities integrated over readout times – need to divide by 2
- almost the same hit densities as for LOI (NTF)
  - a bit more with TF
- other analysis by K. Yoshida shows results 25-85% higher (depends which bins) for different Mokka parameters – under study which parameters to be used

SB2009 Backgrounds in VTX

- analysis by K. Yoshida – plots from his talk on optimization meeting:
  - GP, CAIN – WITH traveling focus
  - detector model: ILD00_fwp01
  - difference: range cut in Mokka

	SB2009wTF-500	
Layer	GP	CAIN
1	15.1	9.27
2	8.60	5.05
3	0.474	0.245
4	0.392	0.195
5	0.0856	0.0439
6	0.0717	0.0374



- differences understood
  - coming from range cut
- study how to continue in progress

SB2009 Backgrounds in Other Detectors

- similar growth in background in other detectors (factors in table given in respect to LoI numbers)
- numbers per BX: with readout time of 1BX – effectively more background then for VTX

detector	LoI	SB09 NTF	factor	SB09 TF	factor
SIT (den.)	0.017+-0.010	0.039+-0.022	2.3	0.046+-0.016	2.7
	0.004+-0.0026	0.0088+-0.0030	2.2	0.013+-0.008	3.3
FTD (den.)	0.0127	0.0240	1.9	0.031	2.5
	0.0085	0.0170	2.0	0.021	2.5
	0.0017	0.0036	2.1	0.0045	2.6
	0.0018	0.0039	2.2	0.0050	2.8
	0.0014	0.0027	1.9	0.0036	2.6
	0.0008	0.0019	2.4	0.0026	3.2
	0.0007	0.0018	2.6	0.0025	3.6
HCAL (hits)	8419 +-649	19998+-374	2.4	25020+-621	3.0
ECAL (hits)	155.0	386.0	2.5	501	3.2
TPC (hits)	408.0	1026.0	2.5	1275	3.1
SET (hits)	5.6	13.4	2.4	15.5	2.8
	6.0	14.7	2.5	16.7	2.8

Summary

- ILC faces novel problem of beam-related backgrounds
- we have to know its impact on reconstruction and physics analyses
  - we can generate background: GP, GP++, CAIN
  - we can simulate it
    - there are still open issues (range cut)
  - we are learning how to deal with it
    - few nice examples of reducing background
  - we start to do analyses with real background simulation
  - SB09 increases beam backgrounds by a factor of 2-3
    - under study if it has deeper consequences

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