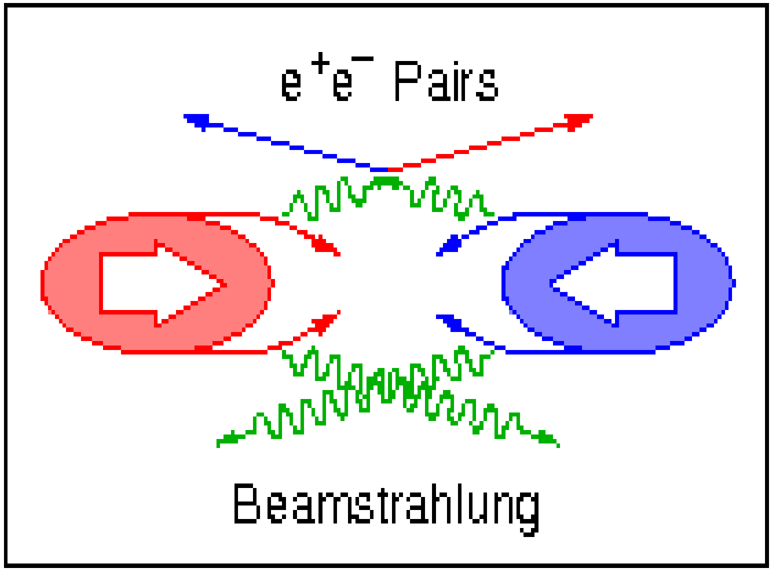
Beam Backgrounds at ILD: Review

- Introduction to beam induced backgrounds
  - Overlaying simulated background
- Pair Background in TPC and VTX
- Old SB09 Beam Backgrounds
- Summary of SiD backgrounf studies (T. Maruyama)
- $\gamma\gamma$ -> hadrons background
- Synchrotron radiation (M. Sullivan)
- Summary & Conclusions

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 smaller impact):
  - beam halo muons, beam gas interaction, synchrotron radiation from beam delivery, particle losses in extraction line, beam dumps

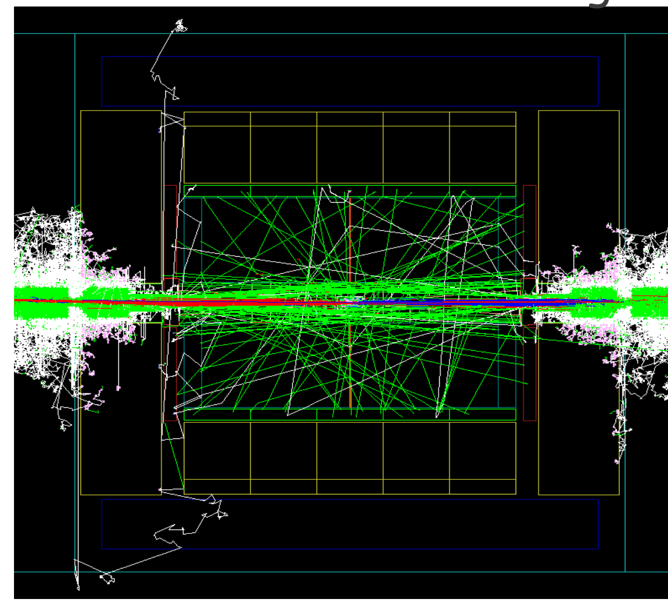
Pair Background: Generating & Simulating

- **generation of e^+e^- pairs:**
  - GP++ - DESY (also GP before)
  - GuineaPig, CAIN - Japan
- **full GEANT4 simulation of pair background in ILD detector**
  - 2 software models used (small differences in anti-DID magnetic field)
    - ILD00_fw (DESY)
    - ILD00_fwp01 (Japan, DESY)
  - 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

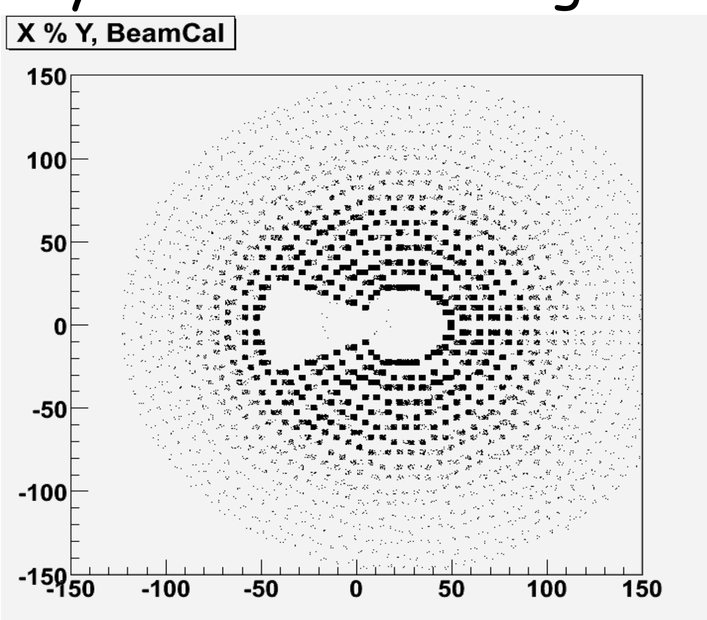
Simulating Beam Backgrounds

- from simulation - **mostly affected – VTX and forward detectors**
- due to readout time some detectors (VTX, TPC) will integrate a large number of bunch crossings for every physics event
  - for these detectors no time stamp (BX tag)
- to study pair background - necessary to find a way to simulate it together with physics evt

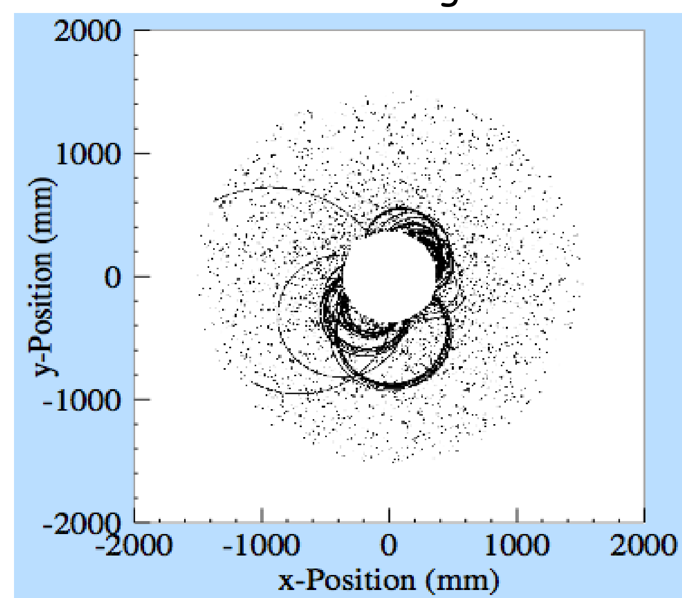
A. Vogel



1/10th of bunch crossing



Mokka hits in BCal (10BX)



Mokka hits in TPC (100BX)

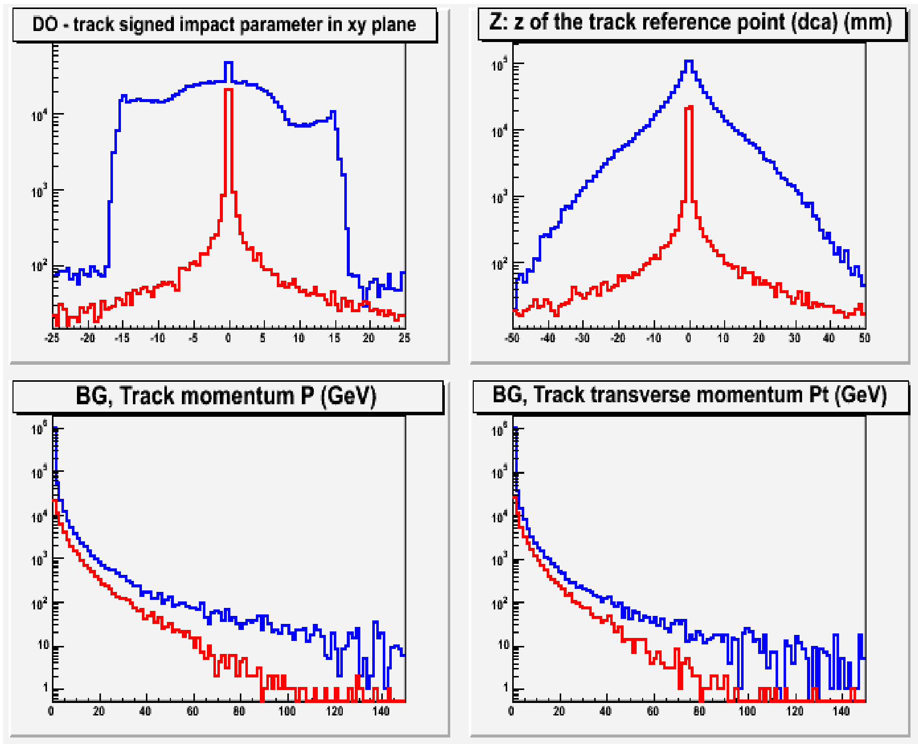
Salt & Pepper Background

until specified otherwise – LoI studies shown

• we have 2 way of imposing background pairs on real physics events

(1) salt & pepper BG in VTX

(2) overlayed background

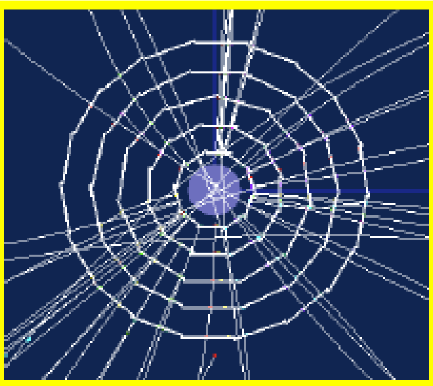


(1) **salt&pepper hits added to VTX** (VTXNoiseHits Marlin Processor)

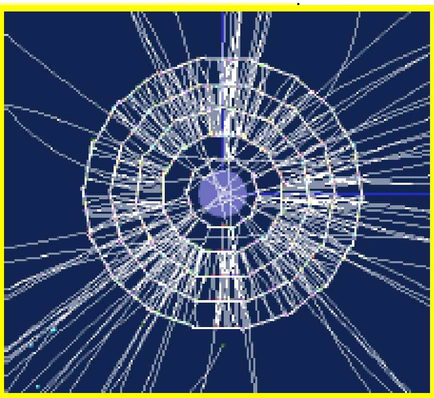
- isotropically distributed hits (according hit densities) added to SimTrackerHits collection after digitizing
- **layers 1-2: 83 BX/evt, rest 333 BX/evt (estimated from VTX readout times)**

• fully reconstructed tracks after chain

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)
- tracking not reliable?

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

Overlaying Background

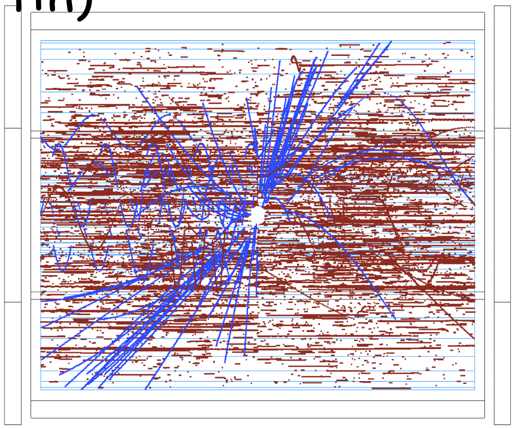
- isotropic background from S&P processor NOT realistic enough

(2) OverlayBX processor:

- 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)

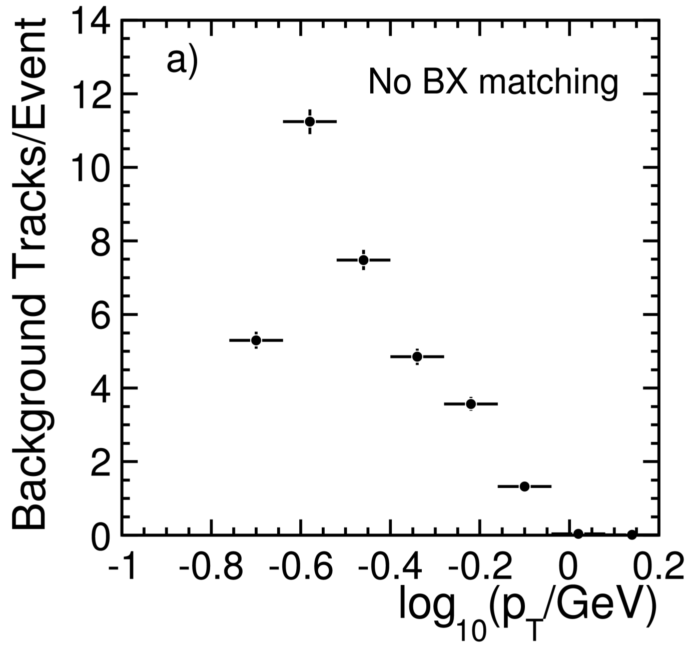


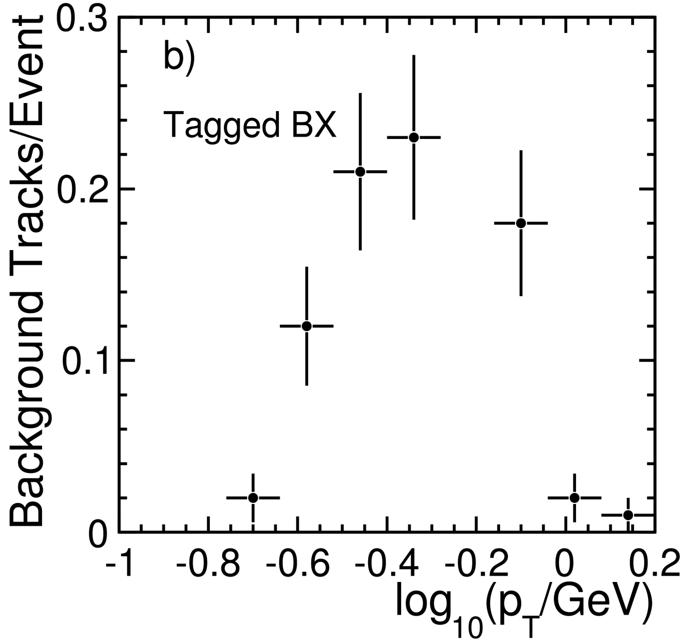
TPC hits for ttbar events overlayed with 150 BX of pair-background hits

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
  - tracks with 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
- track finding inefficiencies applied to $ZH \rightarrow \mu^+ \mu^- X$
  - effect from loss of hits in VTX due to occupancy negligible



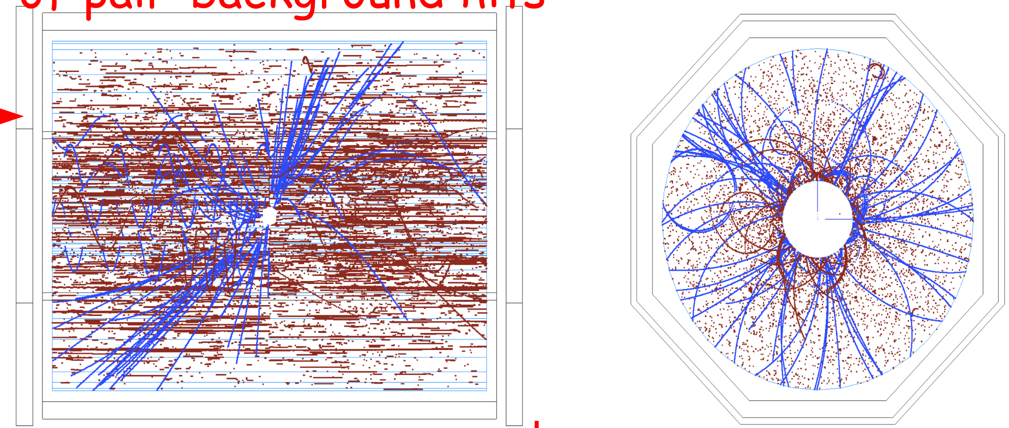


Beam Background in TPC

- **background hits in TPC →**

- ttbar events overlayed with hits from e^+e^- pairs
  - 150 BX overlayed

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

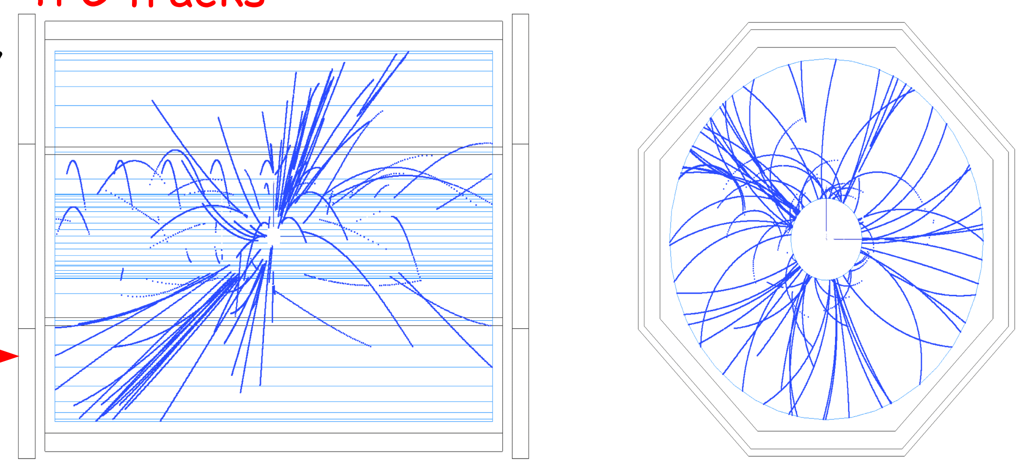


- specific pattern recognition software

- micro-curlers removed:
  - 99% background hits removed
  - 3% signal hits removed, only 1% hits from tracks $p_T > 1$ GeV

improved reconstruction "killing" micro-curlers

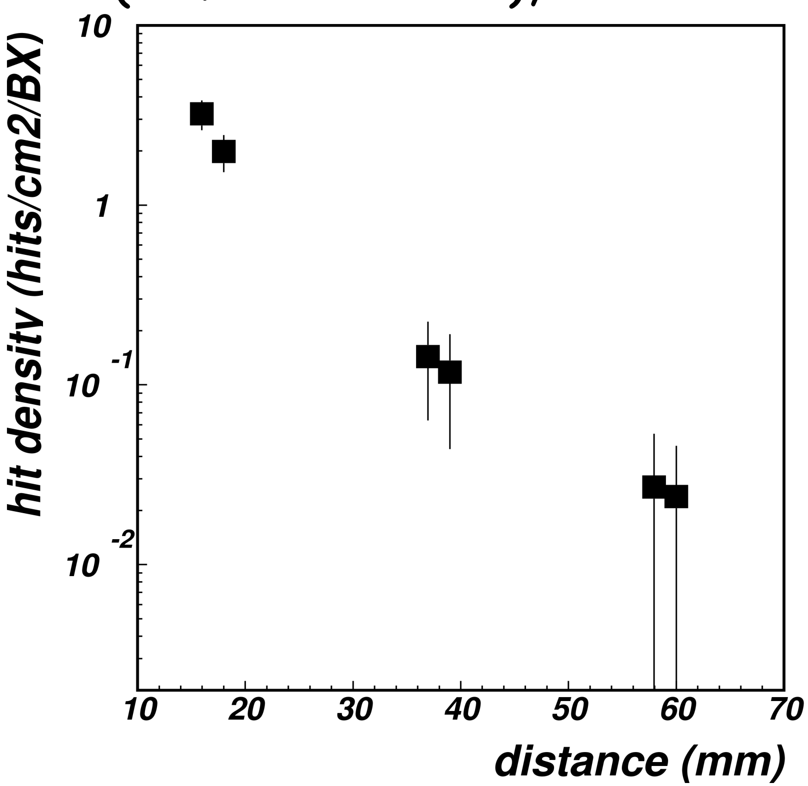
TPC tracks



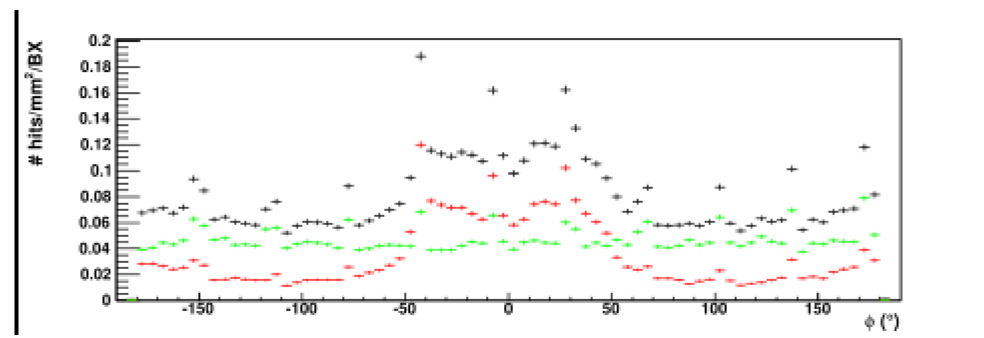
- remaining hits – no problem for track-finding pattern recognition software

Pair Background in VTX

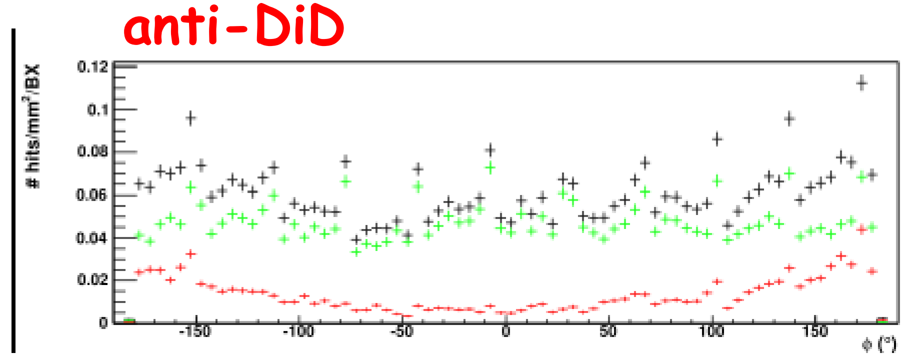
- hit densities calculated from number of hits in detector layers for 1 BX
  - average number of VTX hits calculated from Guinea Pig files simulated with Mokka (SimTrackerHit), ~100 BX used



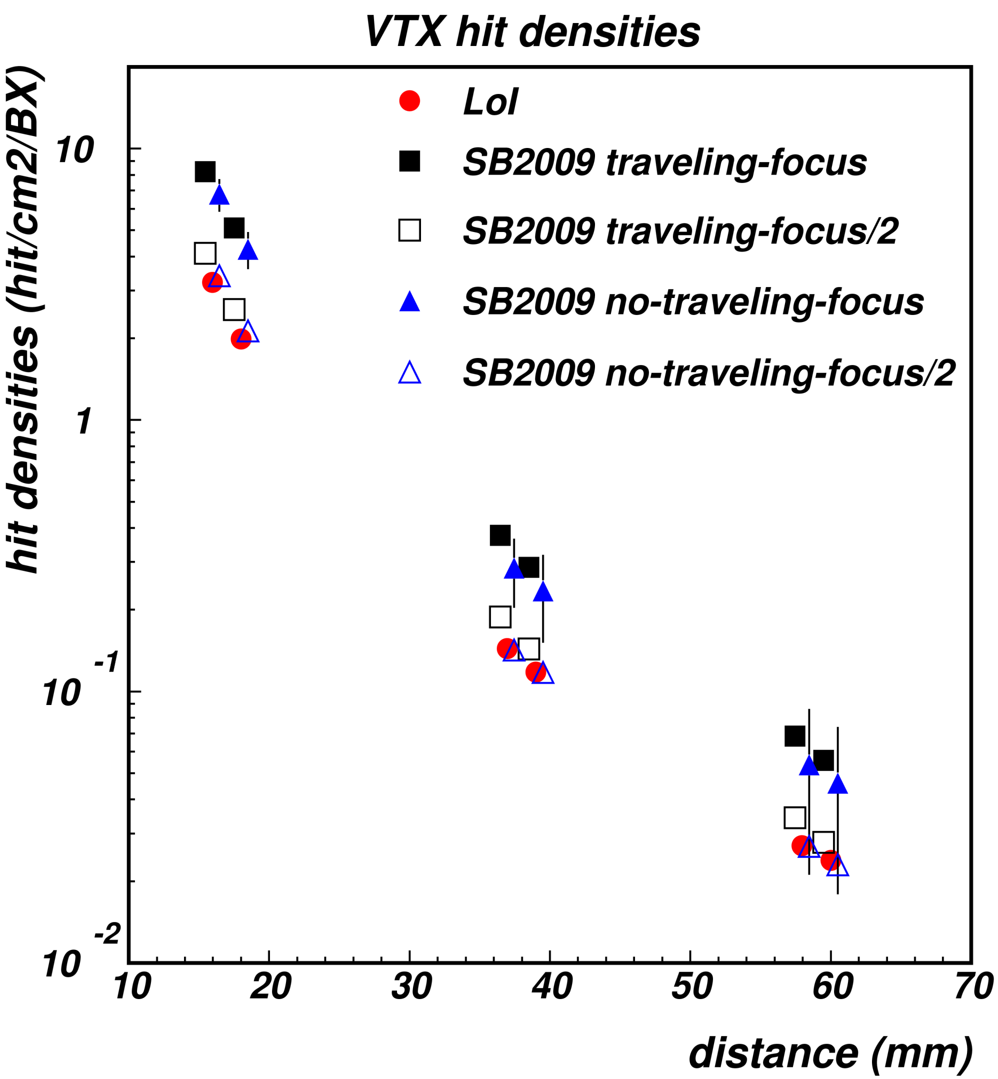
- VTX detector design studies ongoing
- there will be a design version of the VTX which should allow coping with the beam background, even for SB2009 grade at a radius of about 15-16 mm.
- simulation results showed that the anti-DID was a real relieve for VTX in certain azimuthal sector



anti-DiD



Old SB2009 Backgrounds in VTX



- old set of SB09 parameters: new background values
- 2 options for SB09
  - no traveling focus (NTF)
  - traveling focus (TF)
- in VTX SB09 (for 1 BX) gives twice as much background for NTF
  - for SB09 half as much BXs as LoI
  - for VTX almost the same hit densities as for LOI (NTF)
- TF adds about 30% more (per BX)

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
[hits/cm2/BX]	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
[hits/cm2/BX]	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

SiD Background Studies: Introduction

- Beam backgrounds are critically dependent on the IP beam parameters.
- Compare SB2009 and RDR at ILC 500 GeV
  - Beam pipe design
  - Vertex detector hits
  - BeamCal energy
  - Power load in the cryostats and the extraction line.
- Background sources (generated by Guinea-Pig)
  - Pairs
  - Radiative Bhabhas
  - Disrupted beam
- SiD detector and the extraction line in Geant 3

T. Murayama @ Eugene2011

•20 bunch crossings of pairs were generated for each beam parameters
•one bunch crossing of radiative Bhabhas was generated
•40 million beam particles were generated for disrupted beam but only low energy beam (E<0.65*Ebeam) were saved and processed
•Geant3 based SiD detector simulation package was used, which is different from the standard Geant4 based SiD simulation package used for physics bench marking.

IP parameters and pairs

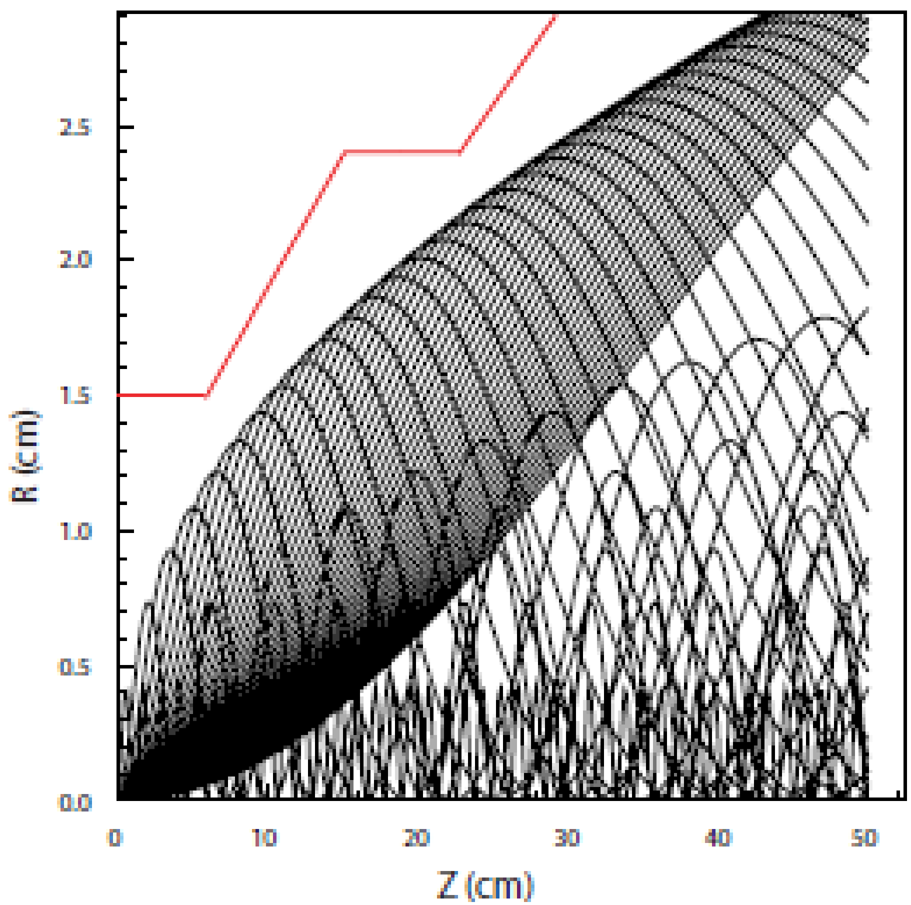
	500GeV RDR	500GeV TF	500GeV NoTF
Collision rate (Hz)	5	5	5
Bunch population (x1010)	2	2	2
Number of bunches	2625	1312	1312
RMS bunch length (mm)	0.3	0.3	0.3
Horizontal emittance (mm-mrad)	10	10	10
Vertical emittance (mm-mrad)	0.040	0.035	0.035
Horizontal beta function (mm)	20	11	11
Vertical beta function (mm)	0.40	0.20	0.48
Luminosity (x1034/cm2/s)	2.0	2.0	1.5
Number of pairs/BX (x103)	100 +/-0.9	232 +/- 2.5	178 +/-1.8
Total energy/BX (TeV)	200 +/- 3.8	583 +/- 11.1	430 +/- 8.1

T. Murayama @ Eugene2011

Beampipe design and pair edge

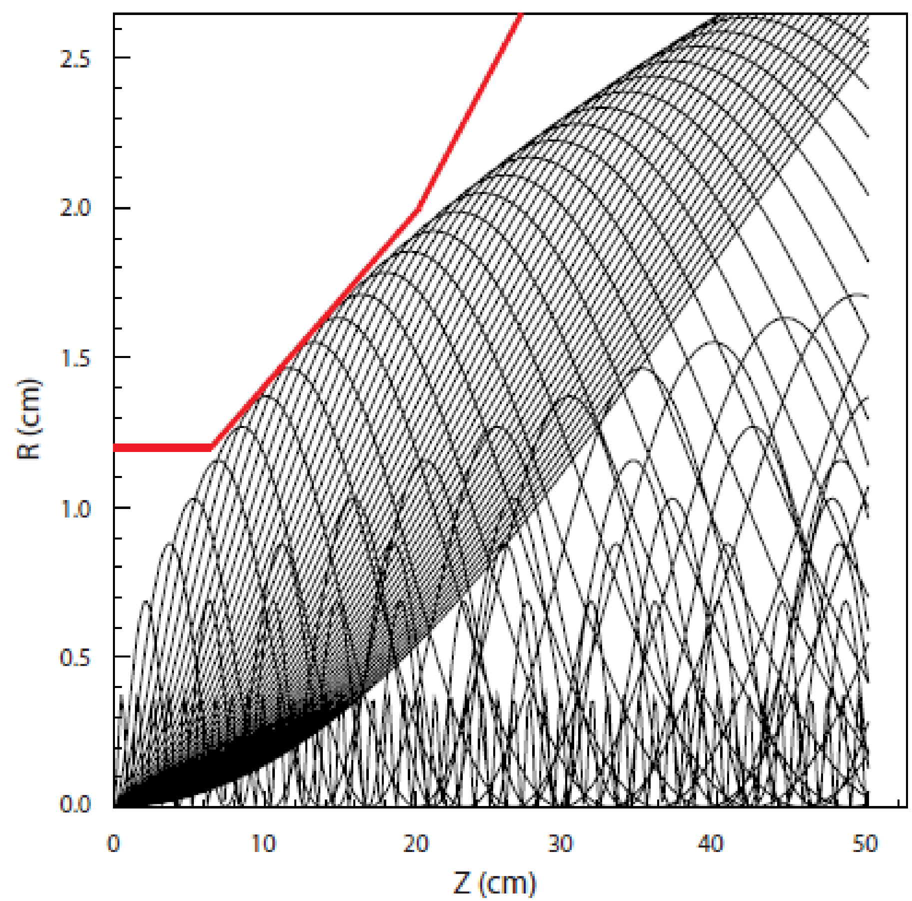
ILD Beampipe and 3.5 Tesla

SB2009 500 GeV TF



SiD Beampipe and 4 Tesla

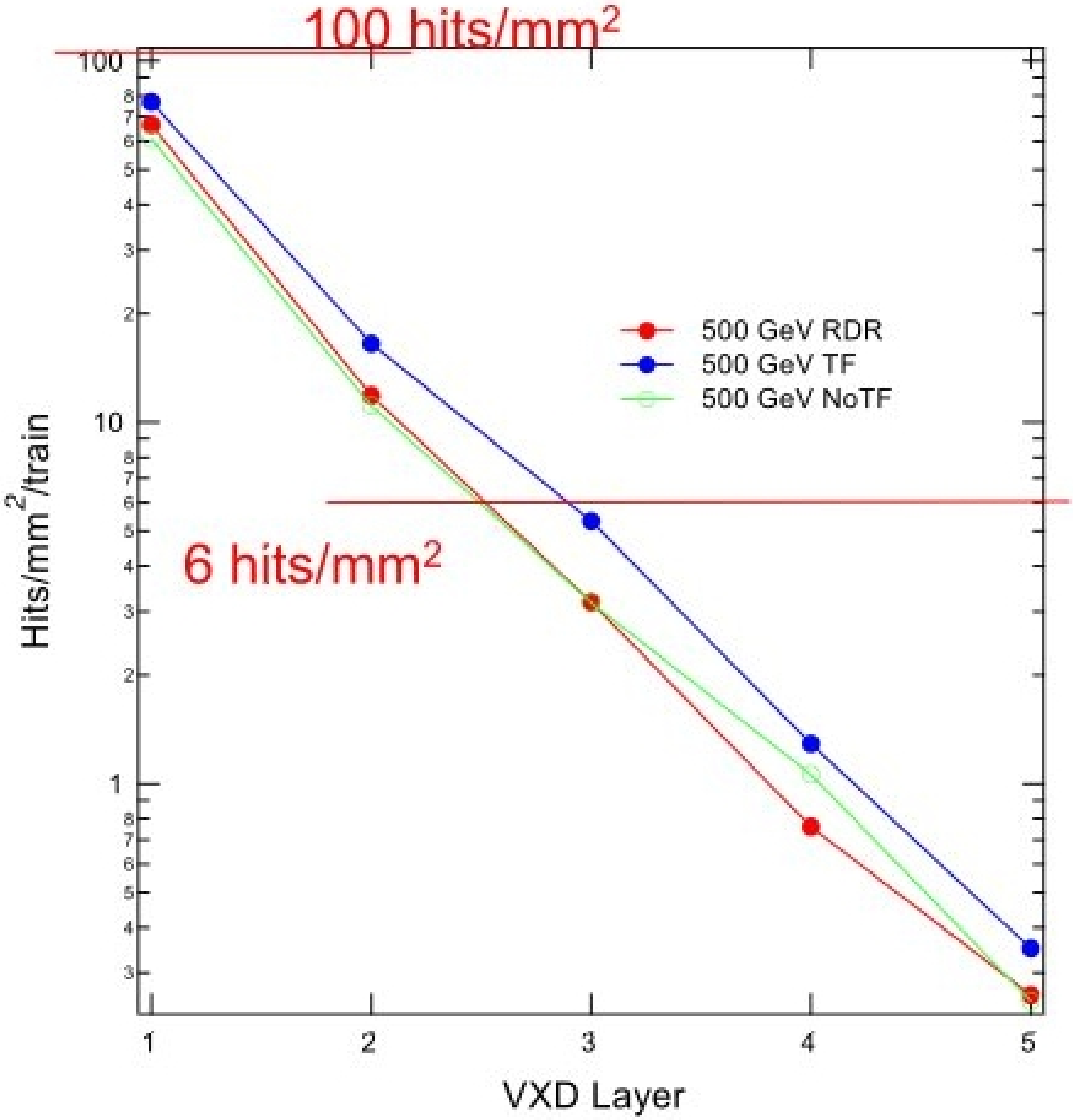
SB2009 500 GeV TF



T. Murayama @ Eugene2011

VXD hit density / train

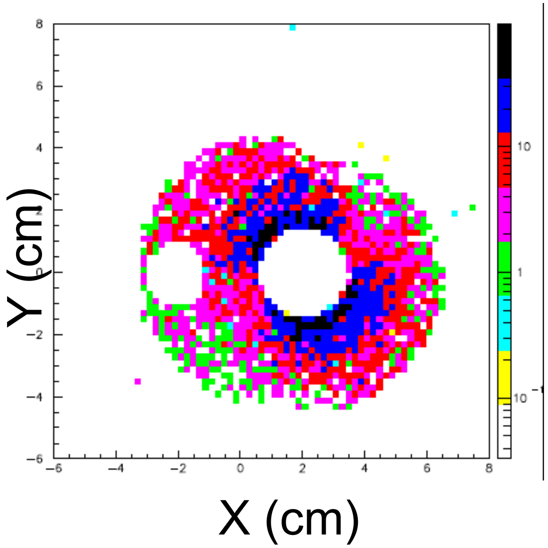
- Detector tolerance
- Use generic 1% pixel occupancy
- Dependent on sensor technology and readout sensitive window.
  - Standard CCD 20μm x 20μm
    - 2500 pixels/mm^2
    - 6 hits/mm^2/sw (assuming 1 hit→ 4 pixels)
  - Fine pixel CCD 5μm x 5μm
    - 40000 pixels/mm^2
    - 100 hits/mm^2/sw (assuming 1 hit→ 4 pixels)



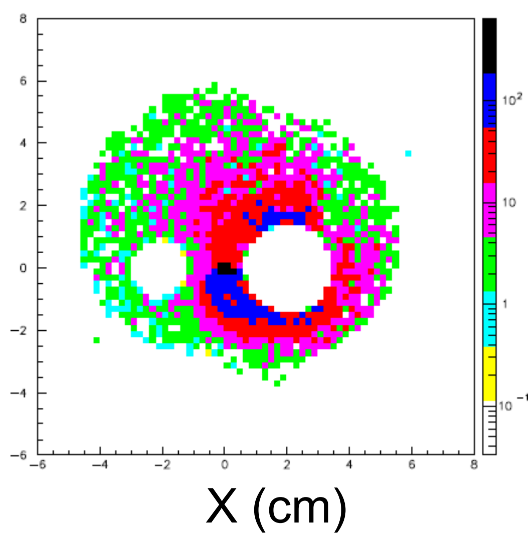
BeamCal Energy

GeV

RDR 500 GeV
Anti-DID



RDR 500 GeV
No-DID



One side energy/(2mm x 2mm) per bunch crossing

	500GeV RDR	500GeV TF	500GeV NO TF
NO-DID Energy (TeV)	20.9	58.8	45.3
Anti-DID Energy (TeV)	12.0	38.2	29.1
Anti-DID radiation (Mrad/year)	100	160	120

- Total pair energy going into the BeamCal is dependent on the DID field.
  - ANTI-DID ~ ½ NO-DID
- 500 GeV TF has x3 more energy/BX than RDR
  - More difficult to tag high energy e-.
  - SUSY search sensitivity is reduced.
- Yearly radiation level is about 50% more in 500 GeV TF.

T. Murayama @ Eugene2011

Summary

- The beampipe design is compatible with SB2009.
- There are 2x more VXD hits per bunch in SB2009, but #hits per train is comparable.
- There is 3x more BeamCal energy in SB2009.
  - The two-photon veto efficiency will be reduced; simulation study is in progress.
- Power load in the extraction line is comparable.
  - The power load to the cryostat from radiative Bhabhas is larger than from pairs.

Radiative Bhabhas

	Cryostat	Total
RDR	0.12 W	1.3 W
TF	0.17	1.5
NOTF	0.14	1.2

Pairs

- Power load in Cryostat1
  - RDR 56 mW
  - TF 82 mW
  - NOTF 61 mW

Disrupted beams

- No beam loss in RDR
- Total loss
  - TF 8 W
  - NOTF 11 W

$\gamma\gamma \rightarrow$ hadrons Background Studies: Rate

- Process $\gamma\gamma \rightarrow$ hadrons
  - CME = 500 GeV
- Cross section σ = 4.61E08 fb
- ILC luminosity per bunch crossing: L/BX= 1.5E30 1/(cm2s)

- Different final states contribute as background to different physics processes
- *Everything* contributes as beam background to all physics events
- Event rate R = L/BX * σ:

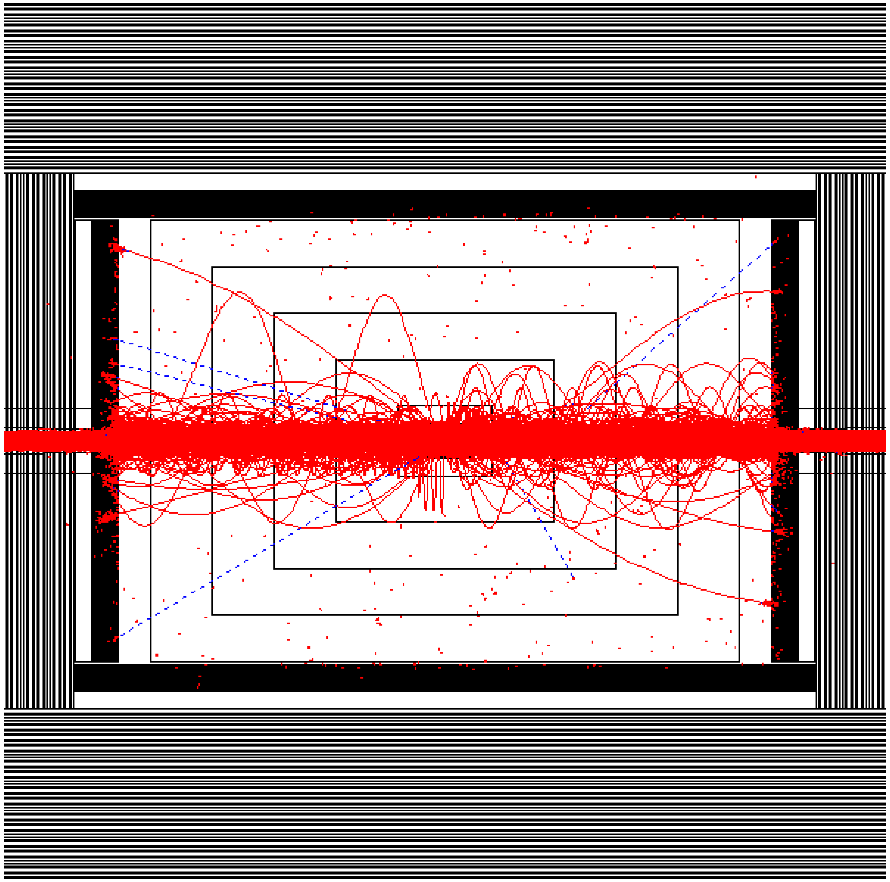
R = 0.7 $\gamma\gamma$ events/BX (old SiD estimates: 0.8 evts/BX)

- <u>These are real events, real tracks – not like pair background!</u>
- Need to simulate $\gamma\gamma$ events, study them, overlay, reconstruct etc...

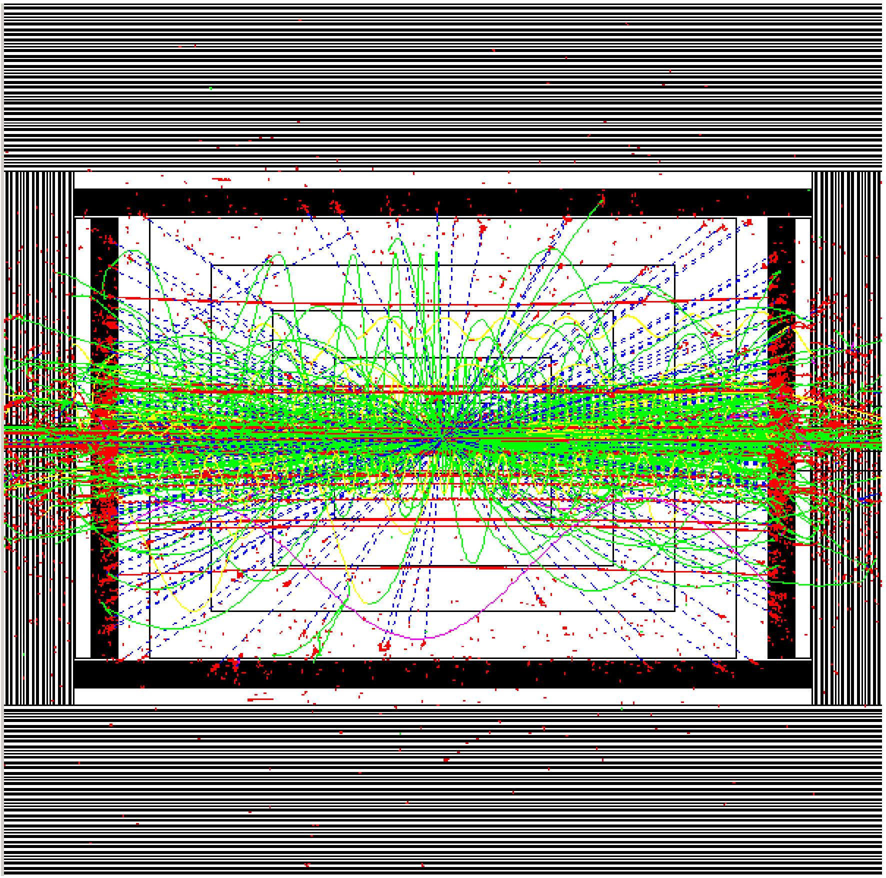
These are real events, real tracks – not like pair background

Background in Central Tracker of SiD

~8600 e+/e- / train



γγ→ hadrons   56 events / train

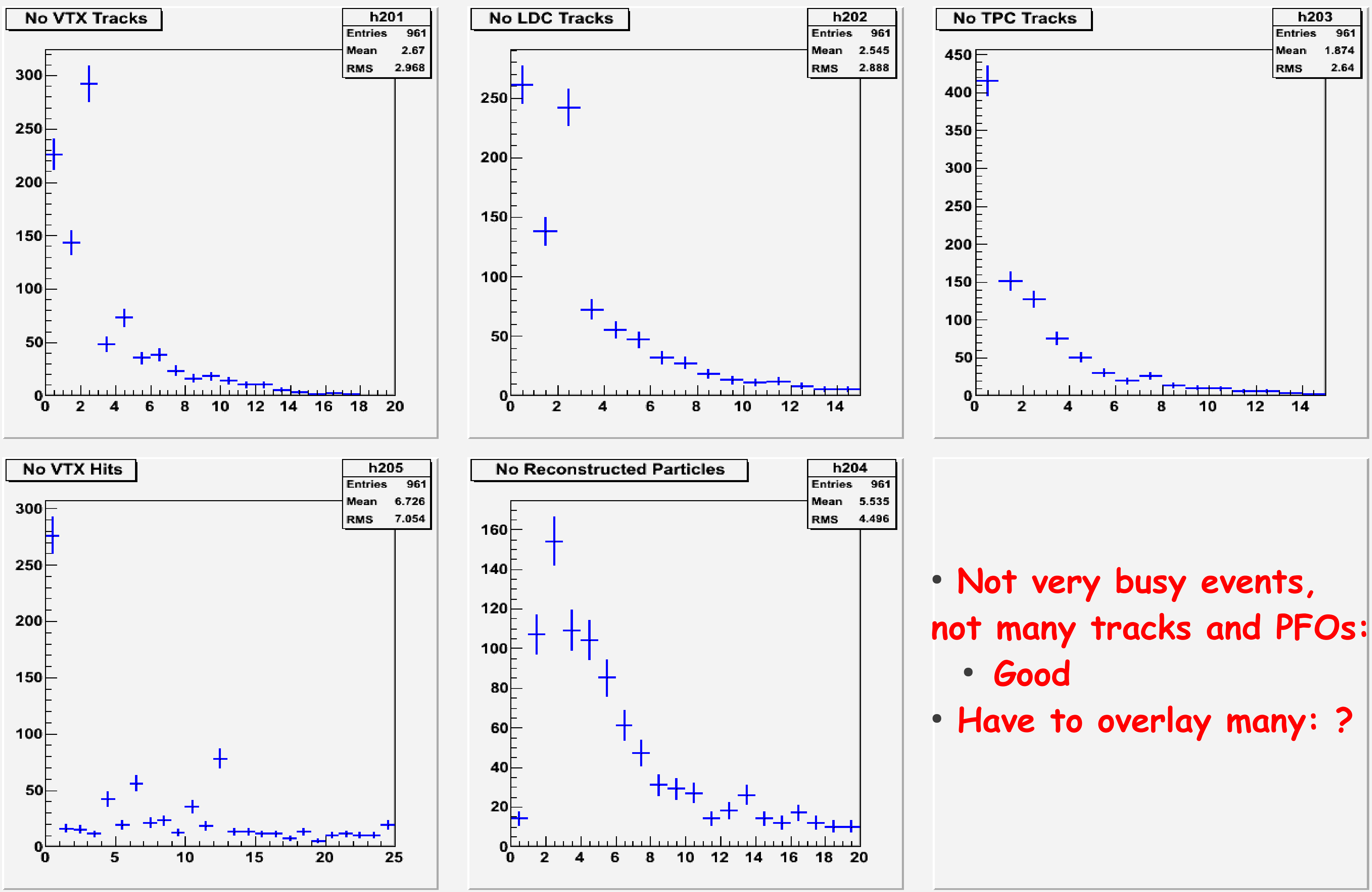


courtesy of T. Murayama

Simulation & reconstruction

- Generated in SLAC (T. Barklow) with PYTHIA
  - one big file with ~ 95000 events
  - CME = 500 GeV
  - Cross section σ = 4.61E08 fb
- Simulated with Mokka 2000 events and reconstructed 1000 events:
  - ILD00_fwp01 (best description for background studies)
- 500 top events overlayed with 0.7evt/BX of $\gamma\gamma$ events and reconstructed
  - for overlay used the same procedure & Marlin processor than for pair background studies (LoI)

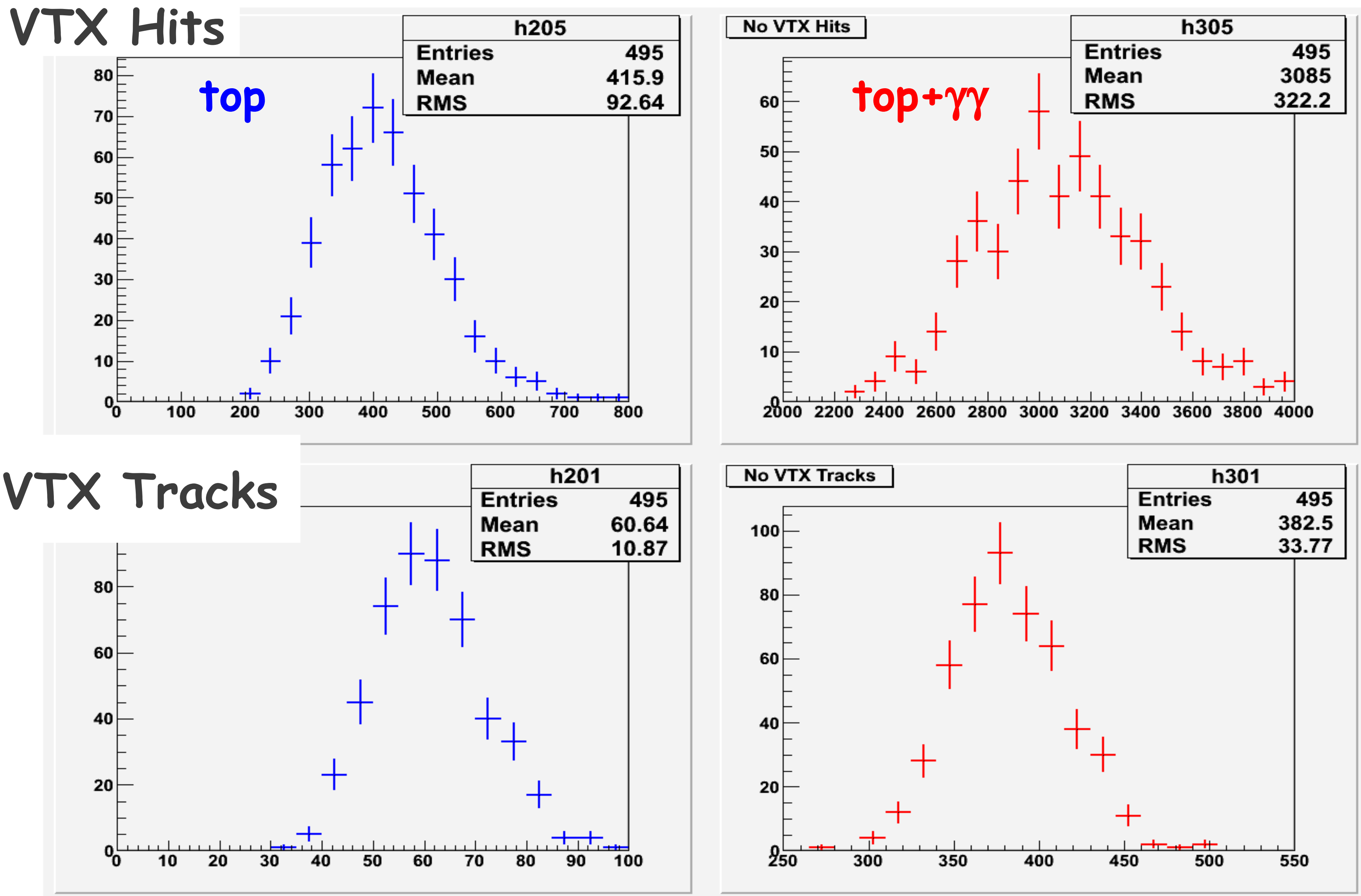
Reconstructed γγ Events



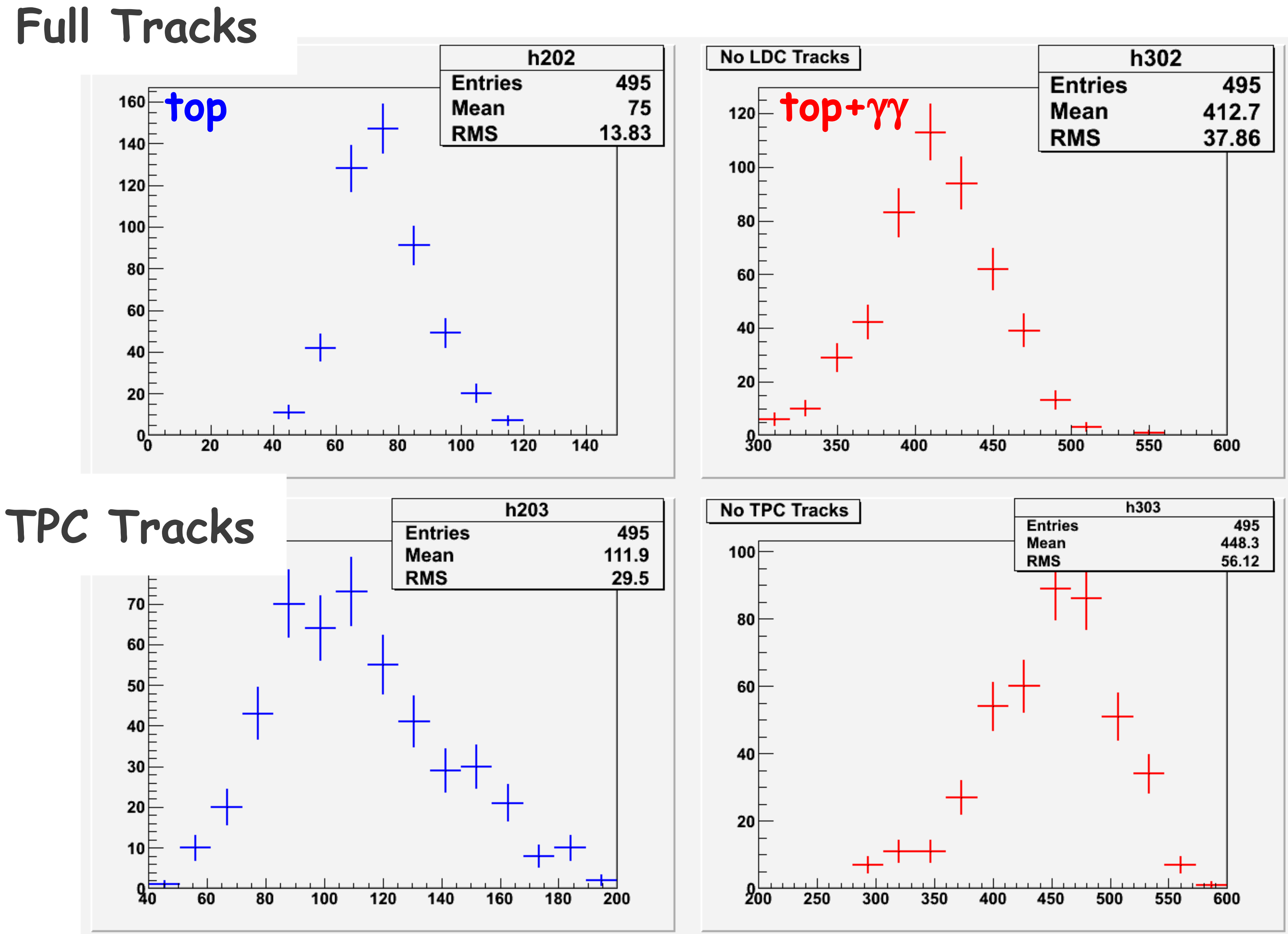
- Not very busy events, not many tracks and PFOs:
  - Good
- Have to overlay many: ?

Top Overlayed with γγ Events

- ttbar->6jets, 500 events, overlayed with γγ , 0.7evt/BX

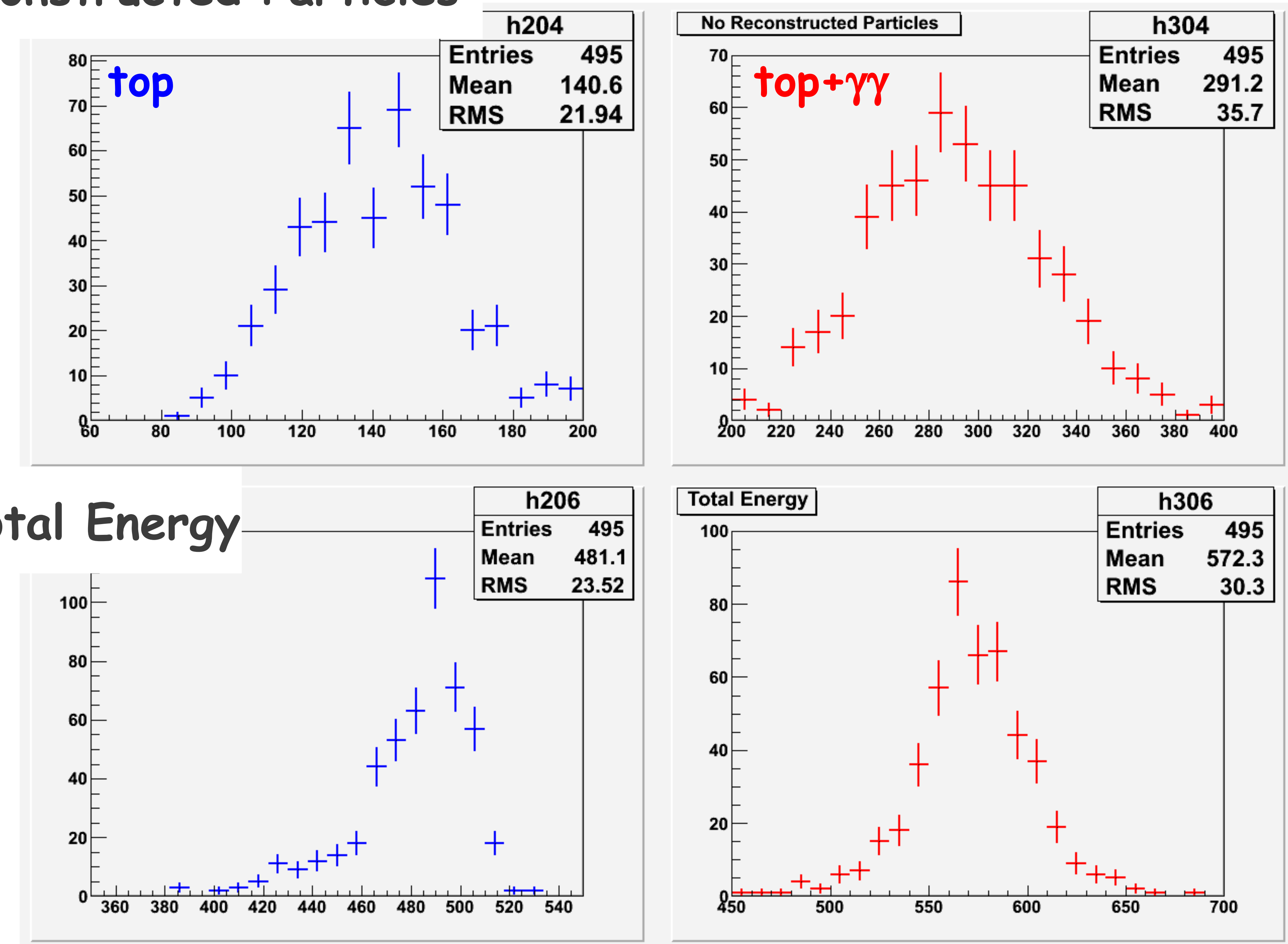


Top Overlayed with γγ Events



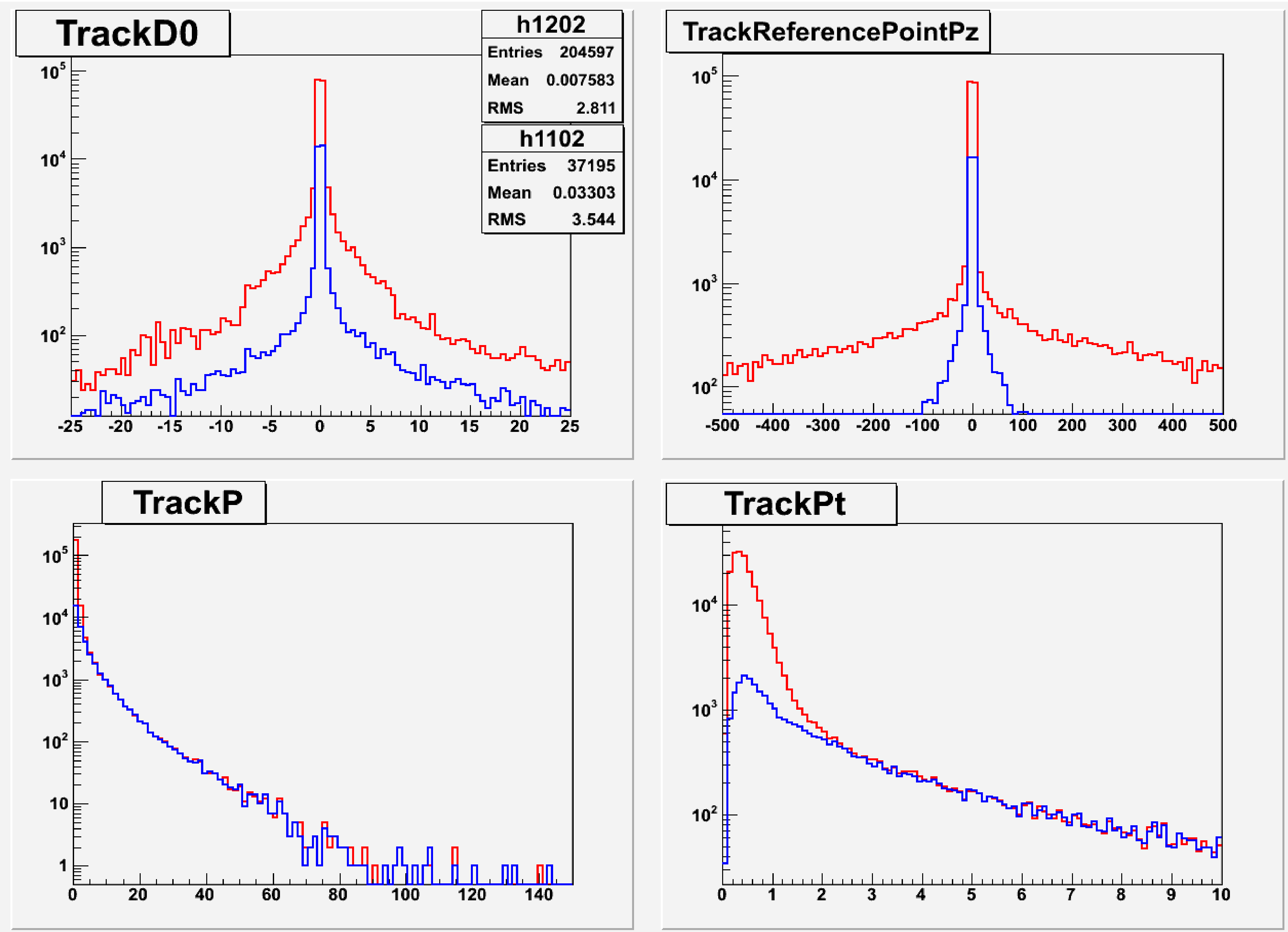
Top Overlayed with γγ Events

Reconstructed Particles

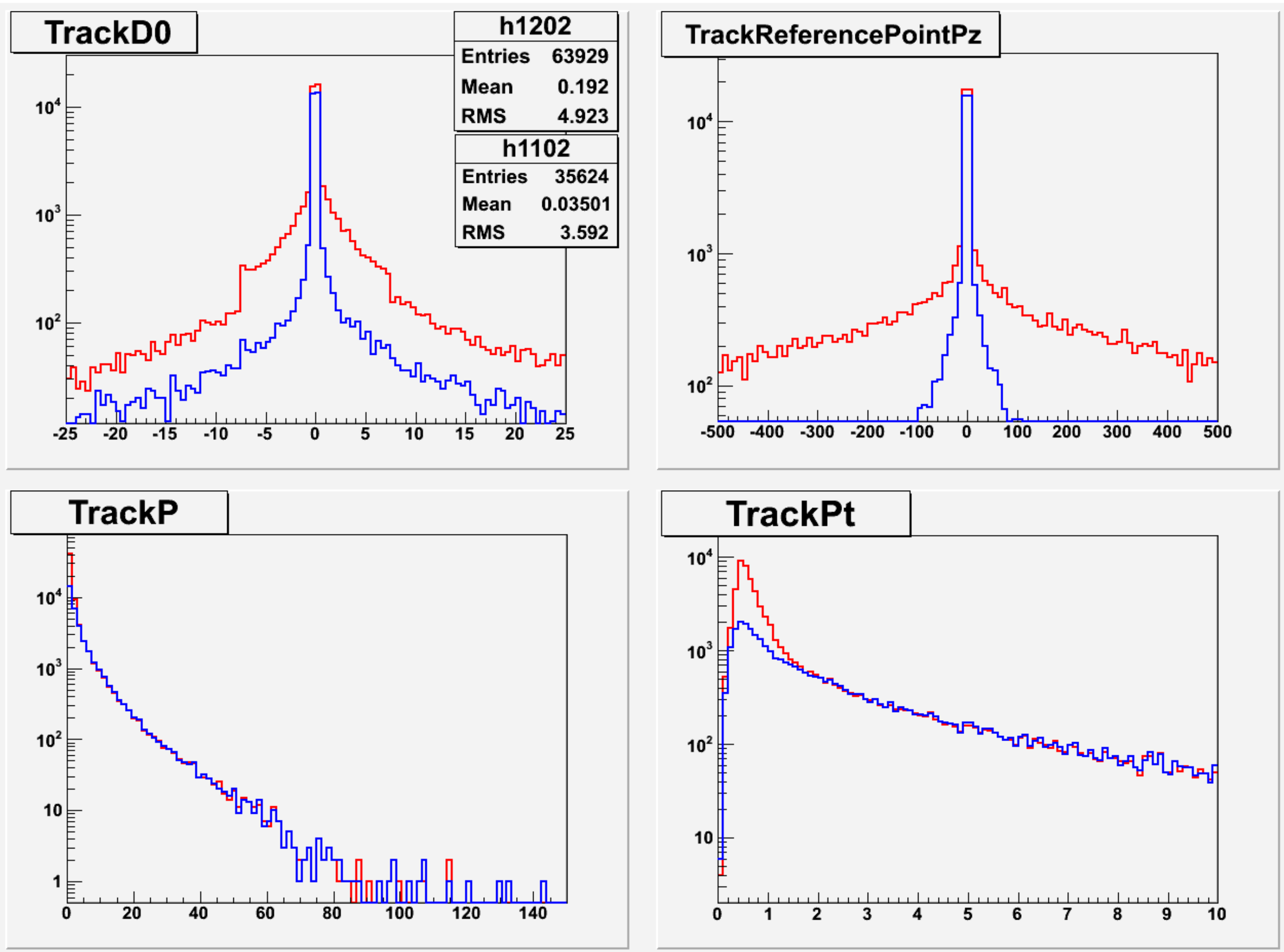


Total Energy

Top top+γγ Tracks



top   top+γγ



LoI cuts: SIT>1 || TPC>10

- **BG reduction ~70%**
- **signal reduction 4%**
  (ALL tracks)

- Probably tracks from γγ events can be distinguished from physics events by production vertex – they do not happen at the same IP
  - under study
  - realistic vertex distribution implemented in Mokka needed

Synchrotron Radiation: Introduction

- An important consideration is that the machine WILL NOT perform at design values either when the accelerator starts up nor when the first detector rolls online

- Yet the detectors will want to start taking data as soon as possible after startup AND they need to know when the machine settings (masks, coll., etc.) can damage subsystems

- Both B-factories had a preliminary minimal detector in place before the main detector rolled onto the beam line in order to see what the radiation levels were from the machine
  I'm sure this has been considered here

- In addition, simulation of the non-optimal machine can guide thinking about how to handle early machine conditions

Downstream SR Summary

- Rates look pretty good (too low to worry about)

- Need to do a more careful estimate of the backscatter rate (2% assumed right now)

- No backscatter rates worth noting on either the cryostats or the IP chamber

Upstream SR Summary

- Nominal case (mask radius 2.5 mm)
  - OK

- Opening up the mask to 5 mm radius
  - Some direct hits on upstream cryostats and on downstream septum. Levels very low with design gaussian beam profile. 6-8σ_x.

- Mask at 5 mm radius + non-gaussian tails
  - Power levels and photon rates increase as the beam tail particle density increases. With 0.5% in the tails photon rate may cause outgassing on cryo beam pipe

- No direct hits on IP beam pipe with mask out to 10 mm radius

Synchrotron radiation: Conclusions

- Nominal running conditions are OK

- Larger beam emittances and/or a larger upstream mask apertures start to allow hits first on cryostat beam pipes

- One then becomes sensitive to the high sigma transverse particle distribution in the beam bunch

Summary

- All the primary sources of SR look to be under good control
- Worth looking at secondary sources again to make sure they are (still) not a problem
- Important to try to model the non-ideal startup machine

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, PYTHIA
  - we can simulate it in GEANT4
  - we can overlay pair background and physics events
  - 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
    - need to repeat studies with newest beam parameters (already started)
    - already applied for physics analysis, needs more studies