ILD and Background

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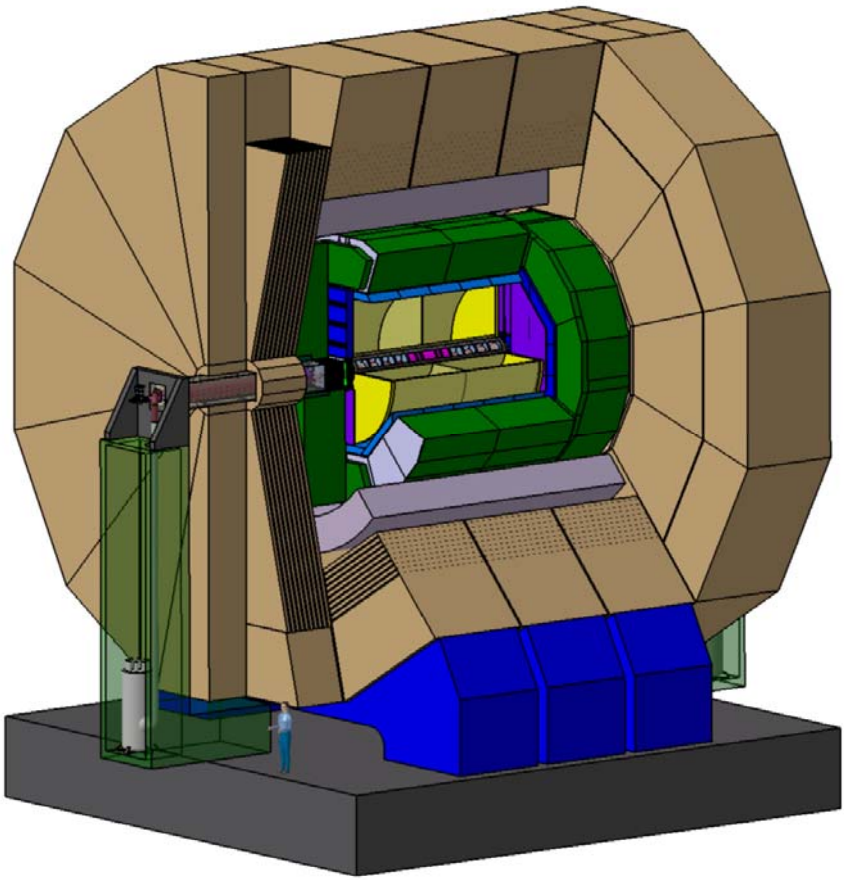


This talk:

- ❶ What was done for the LoI
- ❷ The issues
- ❸ What now?

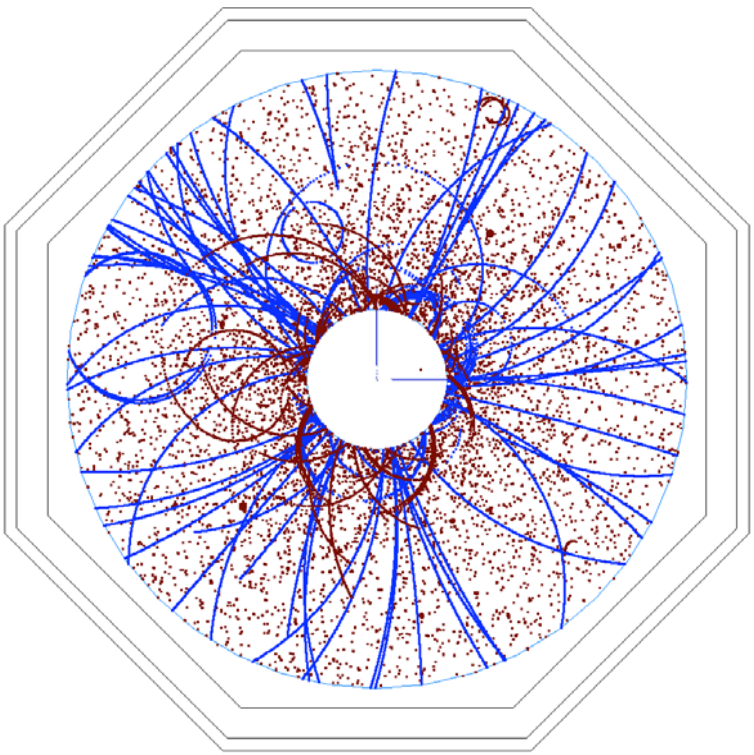
❶ What was done for the LoI

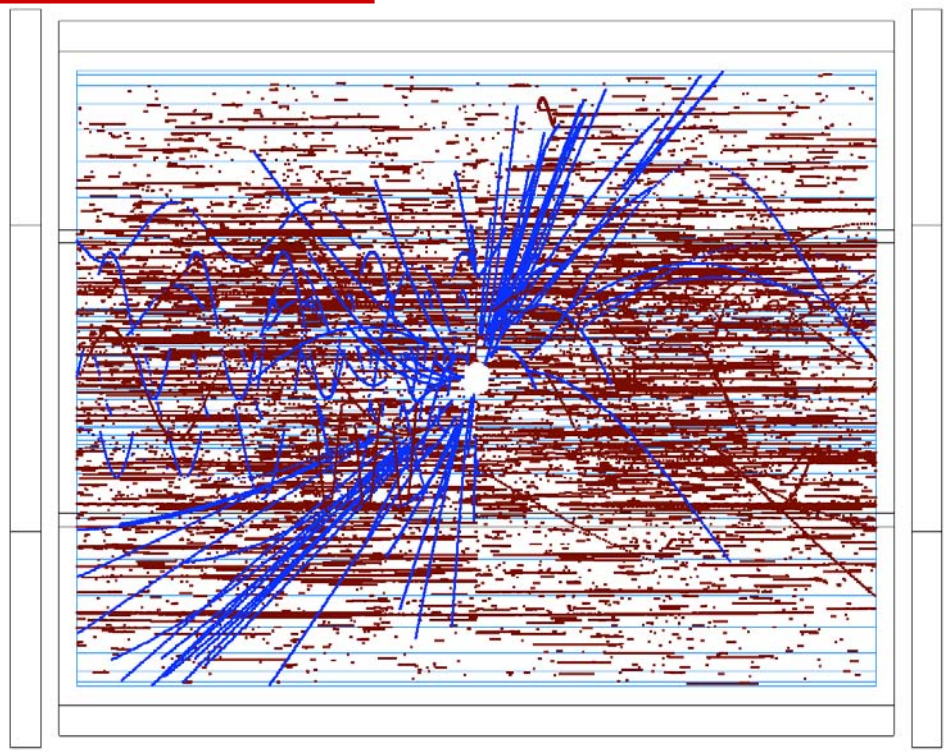
Background: TPC

S. Aplin

- ★ Simulated 2000 bunch crossings (BXs) of beam background
- ★ For TPC, conservatively take drift velocity to be **4 cm μs^{-1}**
- ★ Therefore fill TPC with **150 BXs** of background shifted in **z**
- ★ First order attempt to merge unresolvable hits
- ★ Superimpose on fully-hadronic top-pair events at 500 GeV

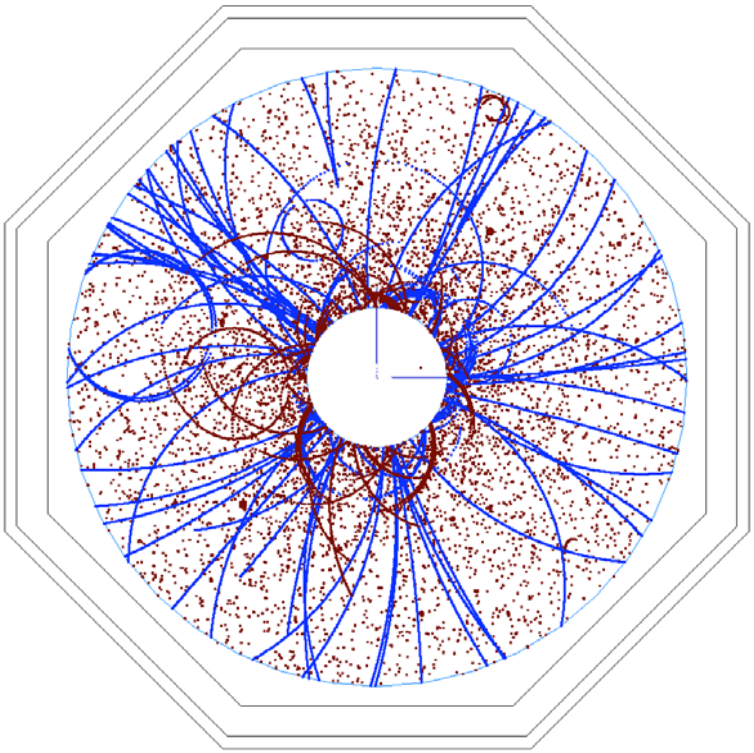
150 BXs of pair background

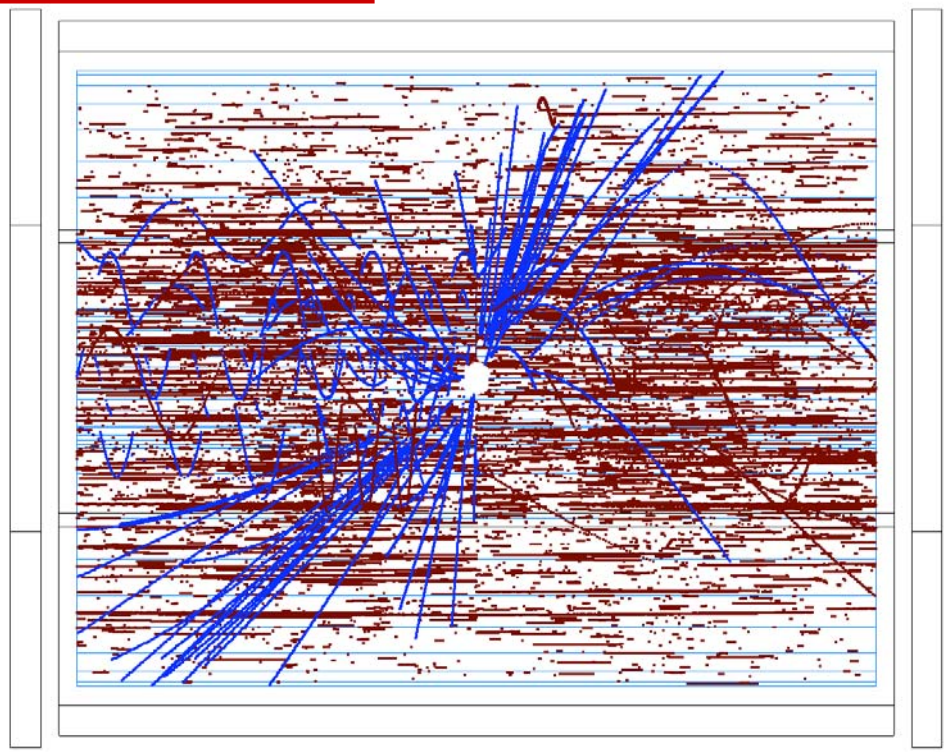




- ★ Large fraction of hits from low energy electrons/positrons from photon conversions
- ★ Form tight helices, “micro-curlers”, along length of TPC
- ★ Background concentrated on relatively few TPC readout pads
- ★ Developed PatRec software to identify and remove “micro-curlers”

150 BXs of pair background

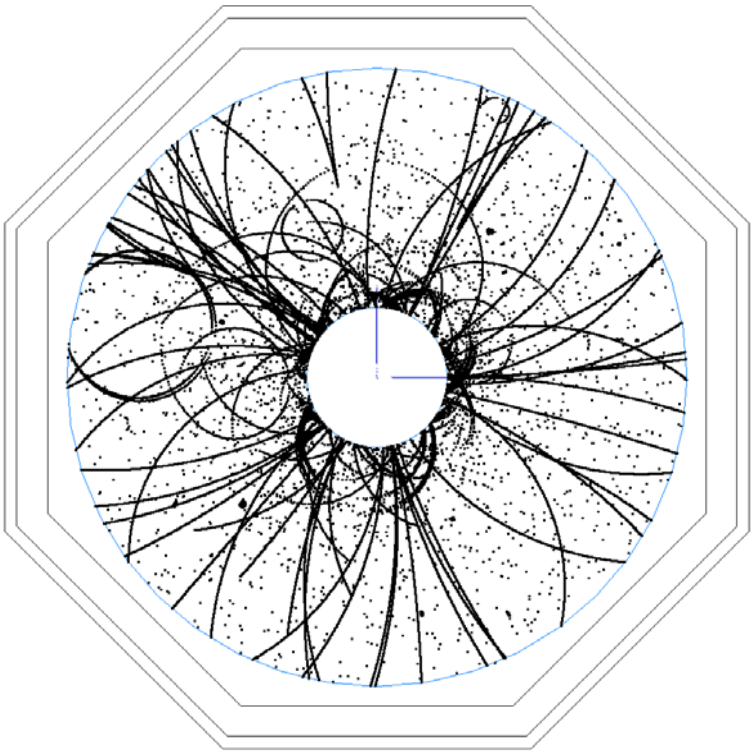


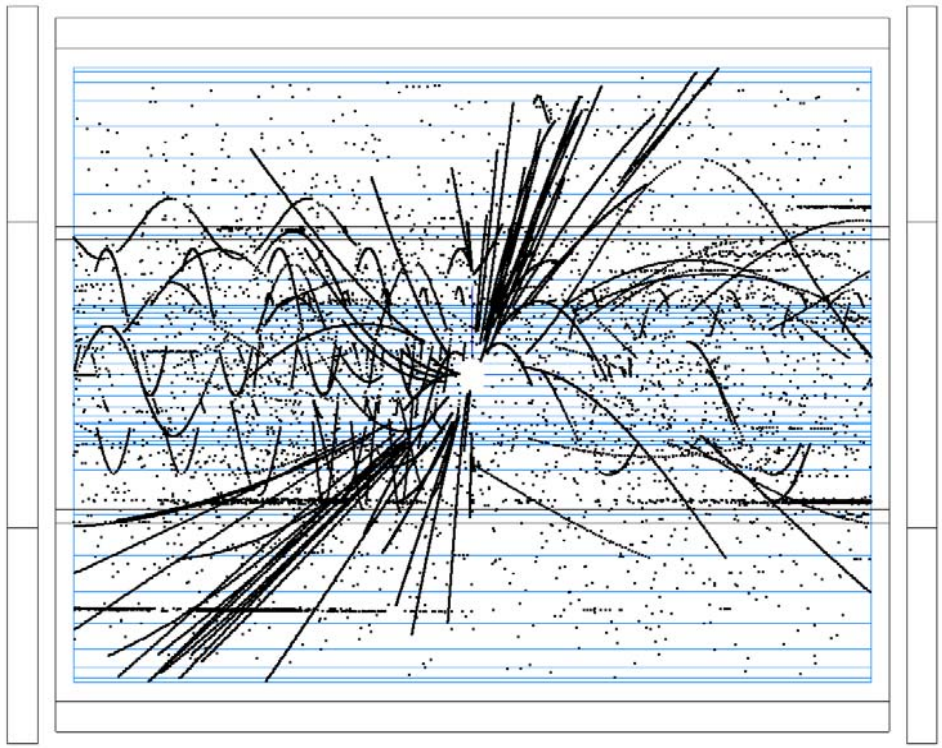


★ **Effective removal of large fraction of background hits**

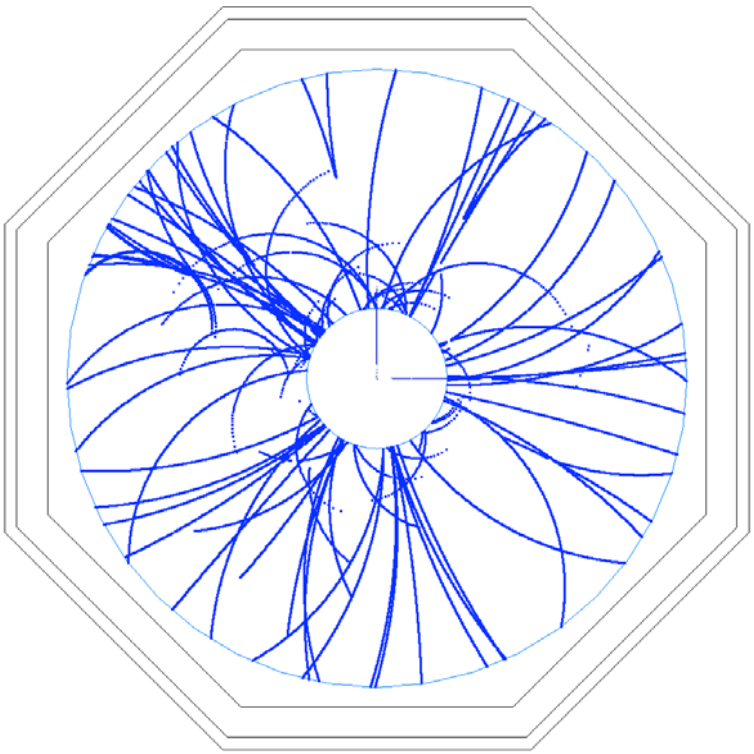
	Top (p_T>1 GeV)	Background
Raw hits	~8,600	~265,000
After	~8,500	~3,000

★ **By eye – clear that this should be no problem for PatRec**





- ★ **Superimpose 150 BXs TPC background on** $e^+e^- \to t\bar{t} \to 6\,\mathrm{jets}$
- ★ **For 100 events, NO loss in track-finding efficiency observed**
- ★ **Similar story for 3x nominal background, although some software issues….**
- ★ **Claimed a clear demonstration of the robustness of a TPC operating in nominal RDR ILC beam conditions**



Background: VTX

- ★ Background in VTX detector complicated by assumptions for Si pixel readout rate
- ★ IF one assumes single BX tagging capability then background is not an issue
- ★ For ILD studies "conservatively" assumed 30 μs / 125 μs integration times for VTX layers (0,1) and (2,3,4,5) respectively
- ★ Therefore VTX integrates over 83/333 BXs
- ★ Superimposed backg. on fully-hadronic top-pair events at 500 GeV

⇨ 200,000 background hits per event !

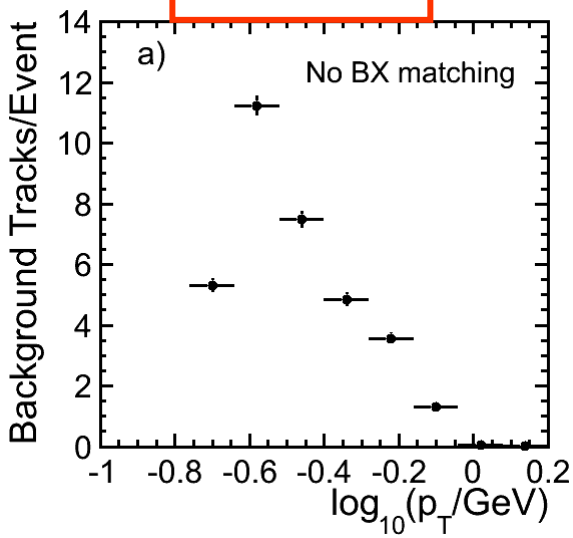
- ★ Also consider finite cluster size of background hits (~10 pixels)
- ★ Significantly increases occupancy

layer	Occ.
0	3.3 %
1	1.9 %
2	0.4 %
3	0.3 %
4	0.08 %
5	0.06 %

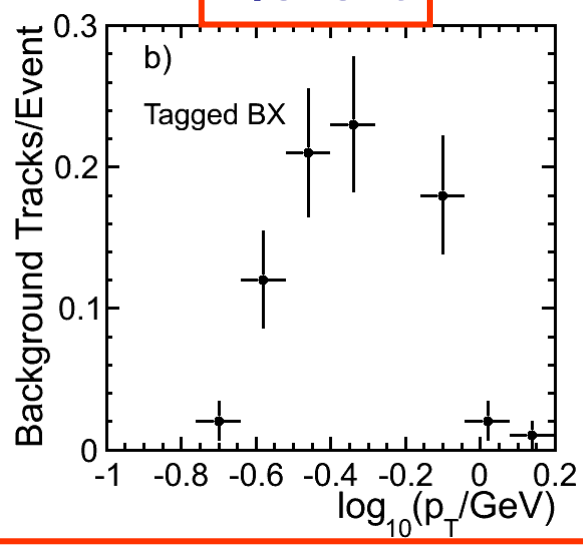
Background: VTX - fake tracks

- ★ Combinatorics produce fake "ghost" tracks
- ★ In addition there are some real electron/positron background tracks
- ★ Large combinatoric background challenges pattern recognition
- ★ Reconfigured current algorithm (not ideal)
- ★ From 83/333 BXs overlayed on $e^+e^- \rightarrow t\bar{t} \rightarrow 6$ jets :
  reconstruct ~34 "ghost" tracks/event (~1/3 are genuine)
- ★ Rejected by requiring at least 1 SIT hit or >10 TPC associated hits

34/event



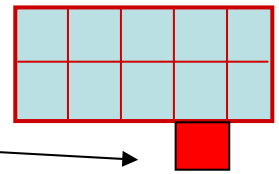
1/event



Left with ~0.5 GeV per event (mixture of real tracks/combinatorics)

Background: VTX – tracking efficiency

★ Two effects potentially reduce tracking efficiency:
- VTX pattern recognition
- Occupancy - assume physics hits next to background clusters lost



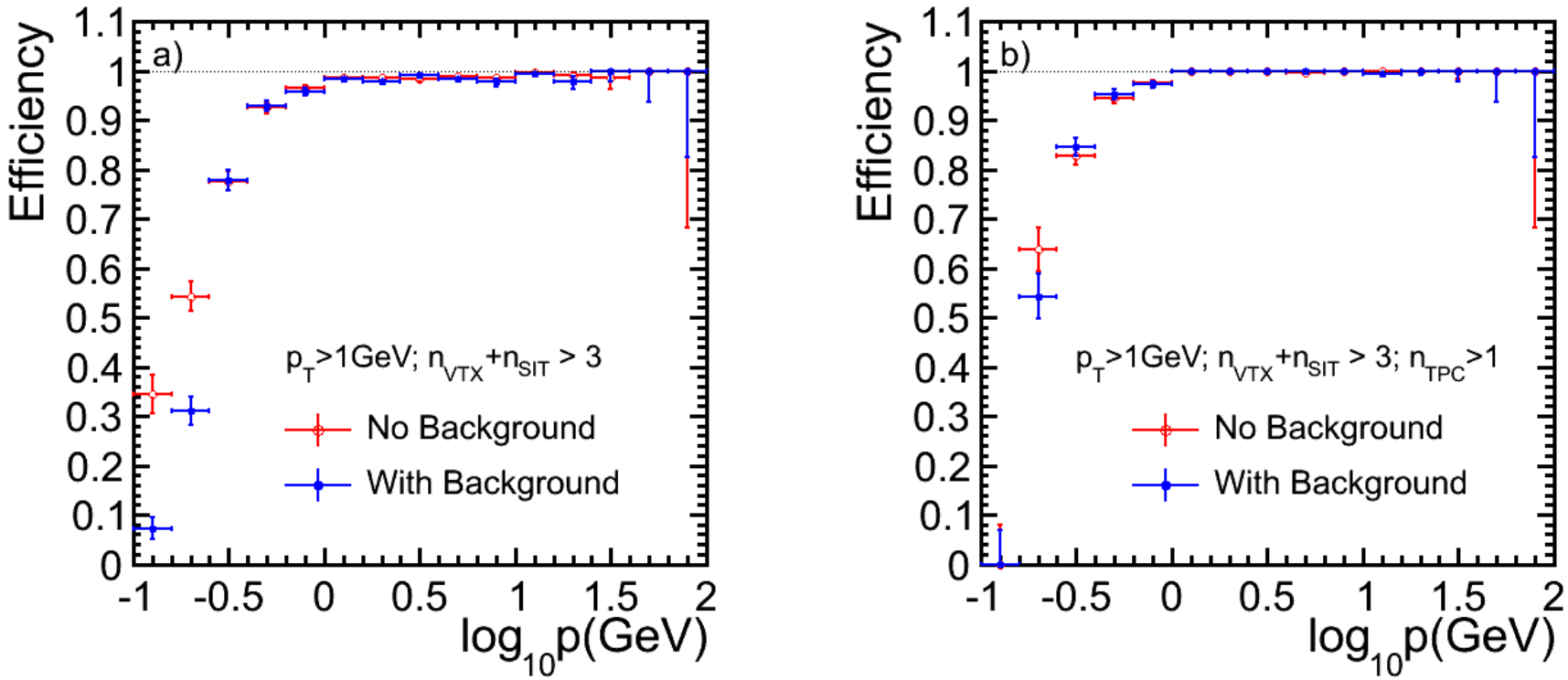
★ Use parameterisation of occupancy/cluster size to kill "physics" hits
+ superimpose 83/333 BXs VTX background
+ apply SIT/TPC BX-tagging requirements

NOTE:

★ Care needed in interpreting efficiency results

★ Will get different results depending on denominator
e.g. if calculate efficiency for tracks with >100 TPC hits, the efficiency will be **100 %**

★ Produced results for:
- all charged particles with $p_T > 1$ GeV and $N_{VTX}+N_{SIT} > 4$
- as above, but for charged particles which reach the TPC (i.e. in MC leave at least 1 TPC hit)



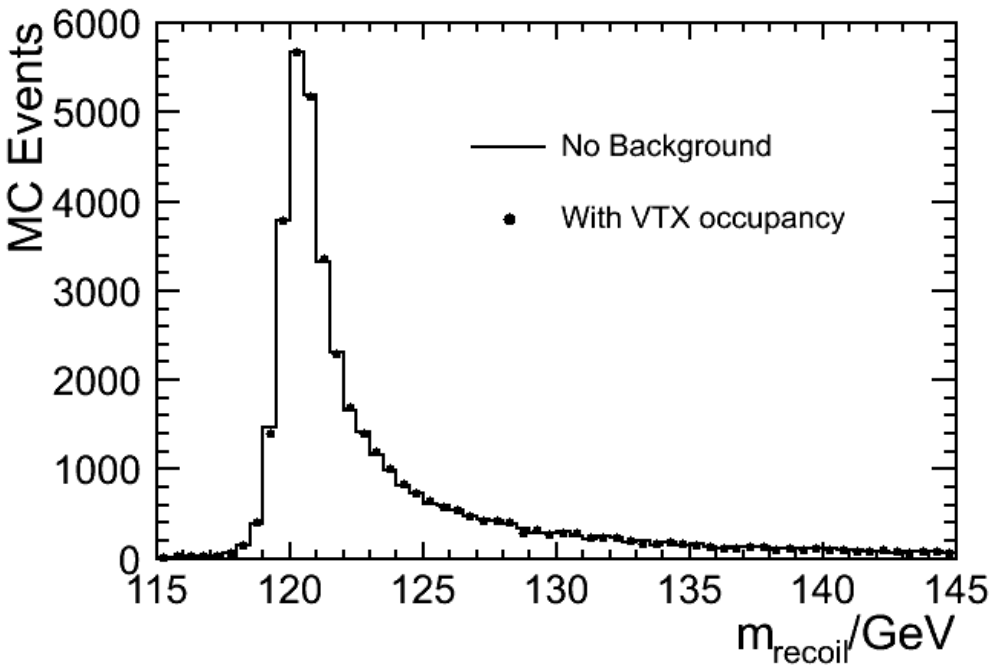
★ **Background mainly affects reconstruction of low p_T tracks**
- **p_T > 1 GeV: efficiency reduced by 0.1 %**

★ **For charged particles which reach TPC (i.e. don't decay/interact)**
- **p_T > 1 GeV: efficiency = 99.9 % in presence of background**

Nominal ILC background not a major problem for ILD concept

Impact in a physics analysis

- ★ Given limited time it was not possible to superimpose full 83/333 BX in VTX, 150 BX in TPC and 1 BX in SIT on physics events
  - CPU resources too large with current pattern recognition code
- ★ TPC track finding shown not to be an issue
- ★ Ghost tracks unlikely to be important for **ZH → μμX**
- ★ Only considered possible loss of hits due to occupancy in VTX
  - could degrade momentum resolution – fast to simulate…

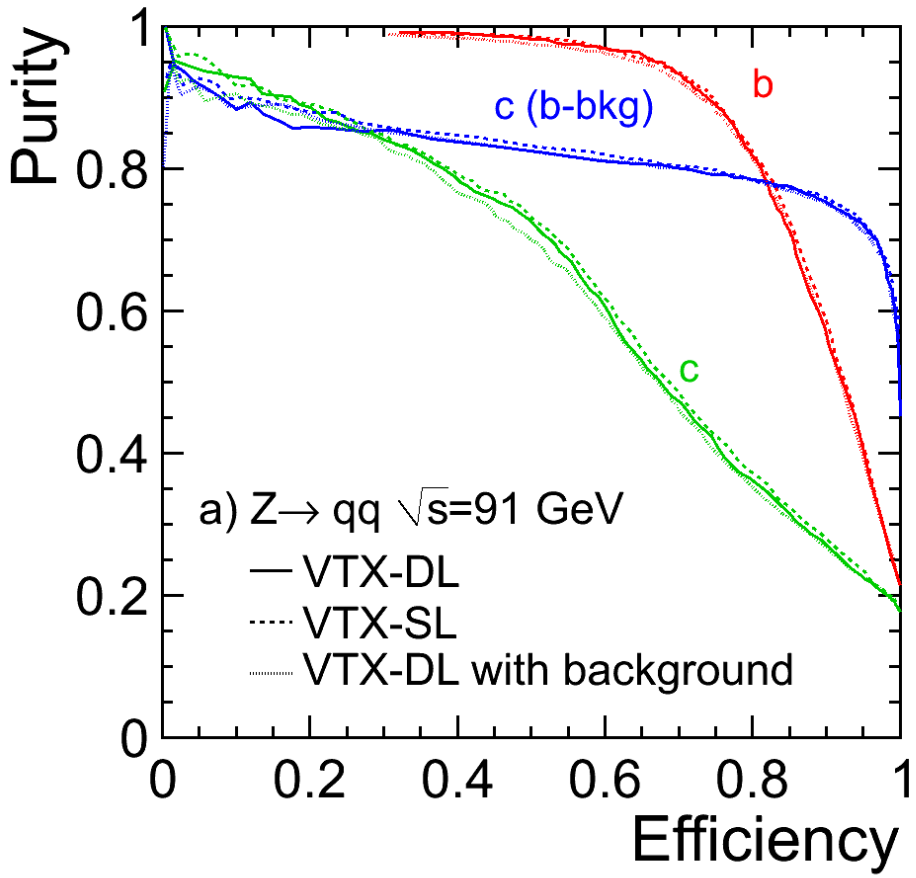


But, not a particularly sensible test !!!

Background: flavour tagging efficiency

★ **Simulated effect of VTX occupancy on flavour tag**

- **expected to be main contribution due to LCFIVertex track quality cuts**



★ **Essentially same performance**

★ **But again, only killing hits… may not be the full story**

❷ What are the issues?

Quite a few …

Issue #1: Background assumptions

- ★ Used nominal RDR 500 GeV background levels
  - Need to design for 1 TeV
- ★ For a TDR (although we're not there yet), also need to build in safety factor ~ x10 ?
- ★ Not clear that ILD could withstand this
- ★ Software certainly can't

Issue #2: Two photon background

- ★ Did not include "two photon" background

$$e^+e^- \rightarrow e^+e^- q\bar{q}$$

  - may not be a problem, but needs study, e.g. see CLIC experience…

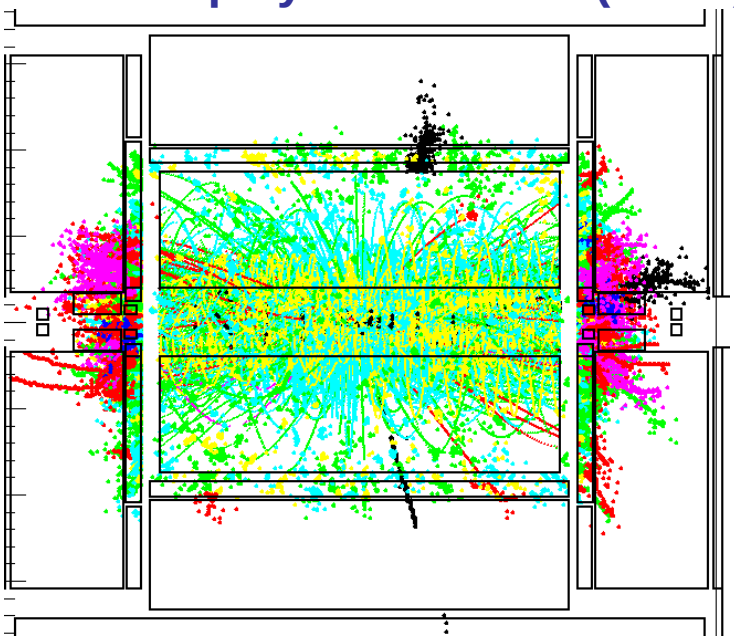
Two-photon → hadrons background at CLIC

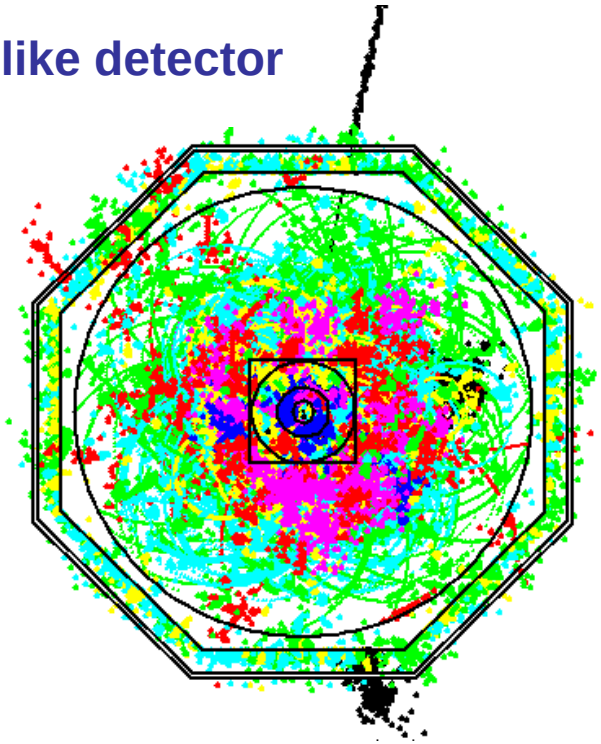
★**Preliminary** studies **(Battaglia,Blaising,Quevillon)** indicate significant two photon background for **3 TeV CLIC** operation

★Approx 13 particles per BX $(p_T > 0.15\,\mathrm{GeV}\ ,\ |\cos\theta| < 0.98)$

⇨ ~25 GeV visible energy per event

e.g. Event display for **150 BXs** (75 ns) in ILD-like detector





★ **NOTE:** integrated lumi in 1 CLIC BX ~ integrated lumi in 1 ILC BX
★ For ILC, cross-sections smaller and p_T of particles lower
★ BUT in ILD must consider VTX/TPC integration times

Issue #3: Software

- ★ Background studies stressed our software to breaking point **and beyond:**
  - Heritage F77 TPC PatRec software struggled with 3x nominal
  - Silicon tracking (VTX/SiT) ground to a halt
    - got around this by ignoring inner layers for track seeding
    - but still **very** slow
  - Ignored background in FTD **- is efficient PatRec possible in the current design with background ?**
- ★ Also used simplistic description of SiT/FTD strips
  - stereo strips not simulated
  - hits just treated as Gaussian 2D space points
  - clearly neglects potential reconstruction effects, ghosts etc.
- ★ No pixel pattern recognition in VTX (although realistic parameterisation)

Reconstruction software development is <u>essential</u>
But, do not underestimate, this is a major effort !

Issue #4: BX tagging

- ★ Bunch-crossing ID in background studies rather simplistic
  - Use associated SIT hit (assume single BX time stamp)
    - ♦ In practice, may not be so simple, strip reco?
  - Or if have associated TPC hits, assume this gives unique time-stamp
    - ♦ reasonable? TPC drift distance ~1-2 cm/BX
  - Nothing done for FTD tracks
  - Nothing for Calorimeters – for two photon background time-stamping likely to be important for neutrals
- ★ To progress, needs software development
  - timing currently not fully integrated into sim./reco.

Issue #5: “System Test”

- ★ For LoI studies, factorised several effects:
  - VTX inefficiency due to background clusters
  - Ghost tracks
  - TPC background
- ★ Reasonable approach (particularly given time), but difficult to convincingly assess potential physics impact, e.g. flavour-tagging
- ★ Would like a full simulation of all effects

Maybe other issues, suggestions/comments?....

❸ What Now?

Significant holes in our understanding of impact of background in ILD

Two approaches

- **Assume single BX tagging in all detectors**
- **Do some work…**

⇩

★ **Need to start to incorporate background into simulation in a more complete way, would imply:**
- **software framework effort**
- **reconstruction effort**

★ **But have to set reasonable goals**
- **full background overlay (VTX/TPC) in mass MC production not likely to be feasible**
- **But routine inclusion of real (as opposed to ghost) "tracks" from pair-background/two-photon background is probably feasible**

★ **Need to decide what to do and how to move forward…**

Comments?