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ILD optimisation workshop

VXD optimisation and low pt tracking

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Outline

Scope of VXD

Candidate designs

Track finding in VXD

Pair background and time resolution

- **Identification and study of ghosts and real pair bkg tracks**
- **Standalone pat. rec. or not?**

VXD time resolution, tracking and higgsinos

VXD role

Unprecedented (for collider exp) impact parameter resolution

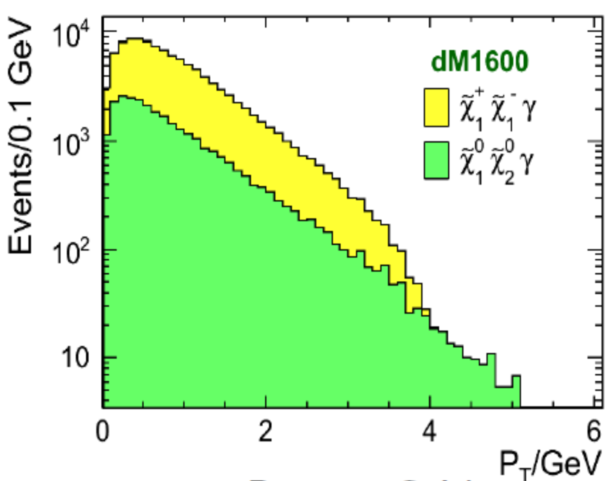
- Charm tagging

Efficient reconstruction of low momentum tracks

- Crucial for tracks that don't reach or create insignificant amount of hits in TPC
  - Reconstruction of vertex charge
  - Light higgsino study – few very soft particles in final state

M_h=124 GeV

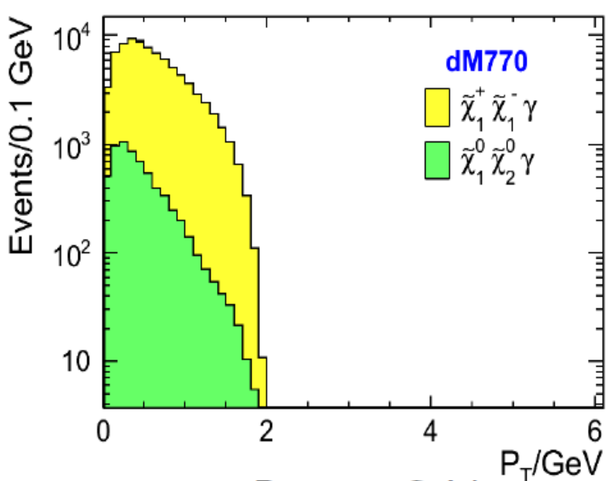
δm(chargino – neutralino) 1.59GeV



$P_T < 5$ GeV

M_h=127 GeV

δm(chargino – neutralino) 0.77GeV



$P_T < 2$ GeV

VXD optimisation challenges

Time resolution that can cope with beam – induced bkg while

- Sensors single point resolution ~ 3 μm
- MB / layer ~ 0.1% X0

Physics imposed requirements (spatial resolution, material budget) more or less understood

$$\sigma_{IP} = a \oplus b/p\sin^{3/2}\theta$$

$$a \leq 5\mu m,\ b \leq 10\mu m\ GeV$$

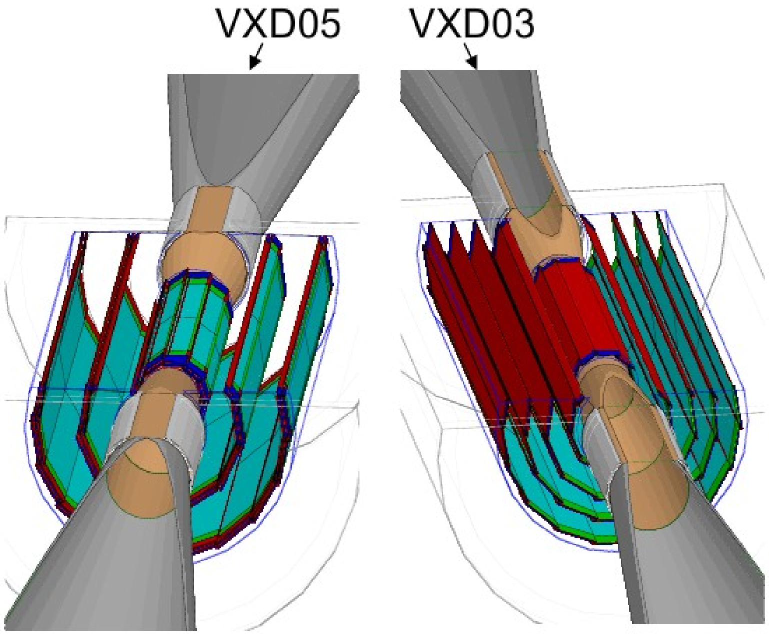
Machine induced requirements are more vague

- How fast we should be to effectively cope with pairs?

ILD VXD candidates (I)

2 main candidate geometries, one with 5 single layers and one with 3 double

- The last years the focus is on the double layers geometry
- No strong physics argument to chose double layers geometry over single layers
- Decision based on potential advantages on pattern recognition or bkg hit rejection envisaged by R&D groups
- Single layers is still alive (e.g. DEPFET)



ILD VXD candidates (II)

Many promising sensor technologies, in different maturity levels

A not exhaustive list

- FPCCD (readout between bunch trains) but very fine granularity (~6µm pitch)
- CMOS (layers equipped with 3-4 different sensors)
- DEPFET (optimised for a single layers VXD)
- SoI (SOFIST)

We will explore pair bkg effect on VXD performance for 2 CMOS designs and various hypothetical VXDs

	DBD VXD		Ideal VXD		Conservative VXD		Ambitious VXD	
layer	σ_{sp} (µm)	σ_{time}(µs)	σ_{sp} (µm)	σ_{time}(BXs)	σ_{sp} (µm)	σ_{time}(µs)	σ_{sp} (µm)	σ_{time}(µs)
L1 / L2	3 / 6	50 / 10	3/ 3	1 / 1	4 / 4	4 / 4	3 / 3	1 / 1
L3 / L4	4 / 4	100 / 100	3 / 3	1 / 1	4 / 4	8 / 8	3 / 3	2 / 2
L5 / L6	4 / 4	100 / 100	3 / 3	1 / 1	4 / 4	8 / 8	3 / 3	2 / 2

Tools to address VXD optimisation

We have 2 candidate geometries, various technologies with different sensor specifications

We have as well a number of pattern recognition approaches

A question need to be addressed is whether a standalone VXD tracking (therefore very efficient at low pt) would bring important advantages

- Would also impose very strict requirements to sensor design

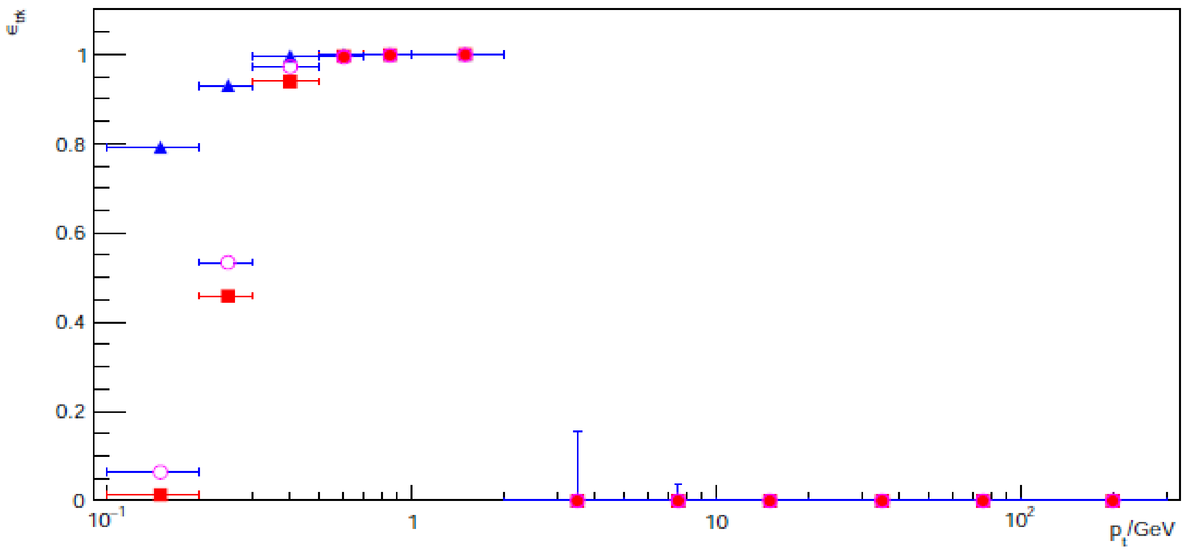
DBD silicon tracking shows poor performance in the presence of beam bkg

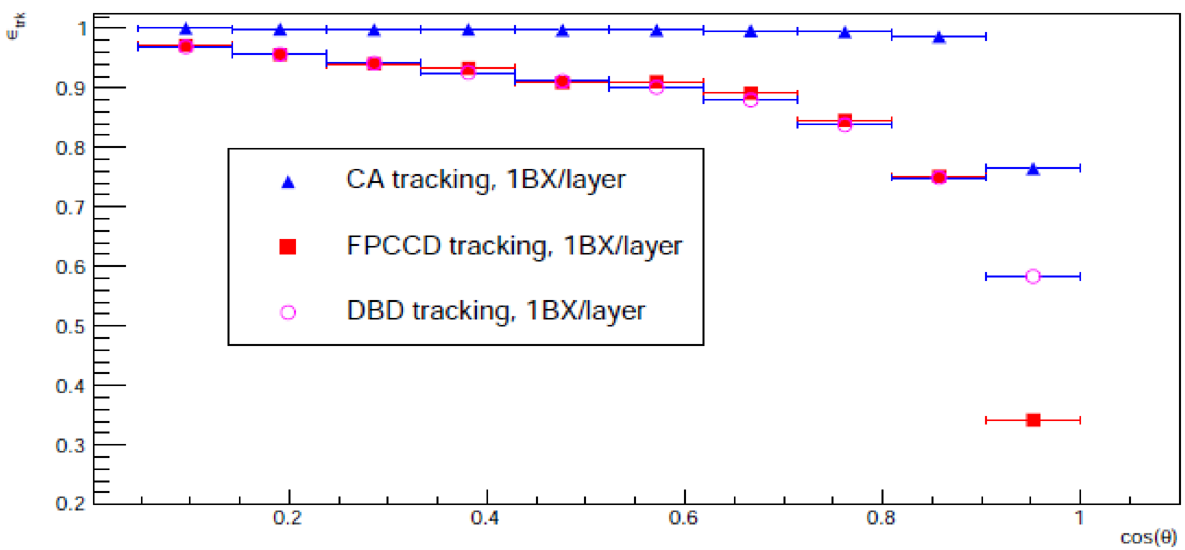
We will focus on

- Standalone VXD tracking based on minivectors
  - Makes sense in specific VXD designs (alternation of fast/precise layers)
- FPCCD tracking, initially developed for a FPCCD detector
  - Can be used to other VXD concepts as well
  - Use SIT (single BX time resolution) to form track seeds that are propagated inwards using a kalman filter

Why a standalone VXD tracking

Higgsinos, ideal VXD





Why a standalone VXD tracking

Advantages of a standalone VXD tracking to a study demanding on low pt track reconstruction

- # higgsino events that survive the selection filters for 500 fb^{-1} w/o pairs

	Fast sim	DBD	FPCCD	CA
No BKG	~4.6k	~2.9k	~3k	~4.5k

- But what will be the effect of pair bkg to tracking purity (ghosts / real pair tracks)?

Bad tracks I.
Ghosts

A track related to >1 true particles, when none of them contributes > 75% of the track hits, is defined as ghost

Ghosts are artefacts of the pattern recognition

- Can be suppressed via optimising the track algorithm
- Their minimisation is a crucial aspect of pattern recognition

Strategy of the study

- Overlay pair bkg according each VXD layer integration time to higgsino's sample
- Keeping the MC info of every pair particle
  - Huge computer resources (disc space, RAM)
  - We had to overlay only 1 BX in TPC
  - Therefore the study is restricted to the silicon tracks
    - Makes sense for VXD optimisation

Ghost rate

Calculate ratio ghost tracks / all tracks

VXD concept	Algorithhm	
	CA	FPCCD
1BX/layer	0.03%	0.3%
5BX/layer	0.4%	1.0%
20BX/layer	2.7%	~20%

Higgsino has low track multiplicity

Repeat the study to a 6 fermions sample, ideal VXD & CA tracking

- ~ 0.2 % ghosts / real tracks

Bad tracks II.
Pairs

Those are real tracks that the tracking algorithm should find...

Can be suppressed via

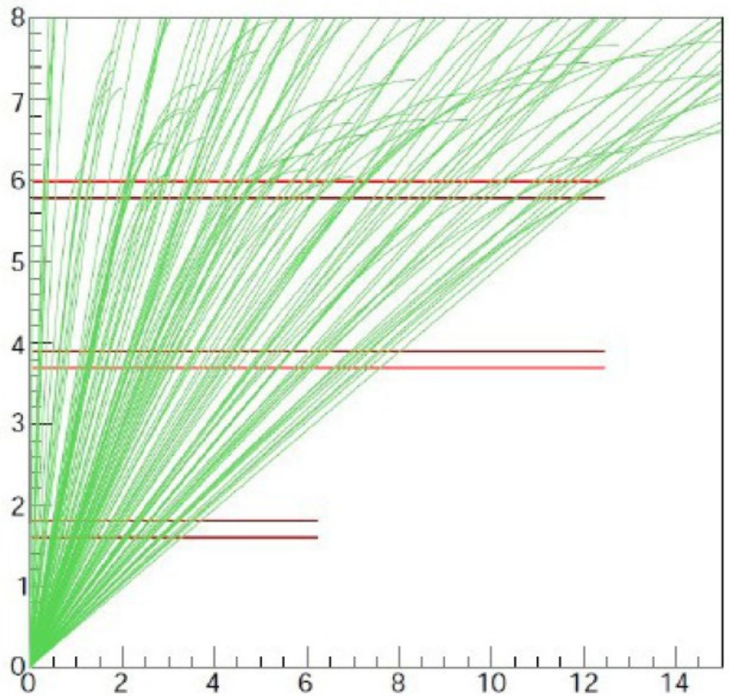
1) A faster detector
2) Hit rejection due to cluster shape (maybe – FPCCD approach)
3) With proper filters during analysis

Excellent probe for the detector's required time resolution

Pair tracks / event

Algorithm	VXD design		
	1BX/layer	5BX/layer	20BX/layer
FPCCD	0.3	0.9	6.1
CA	2.5	7.5	52.4

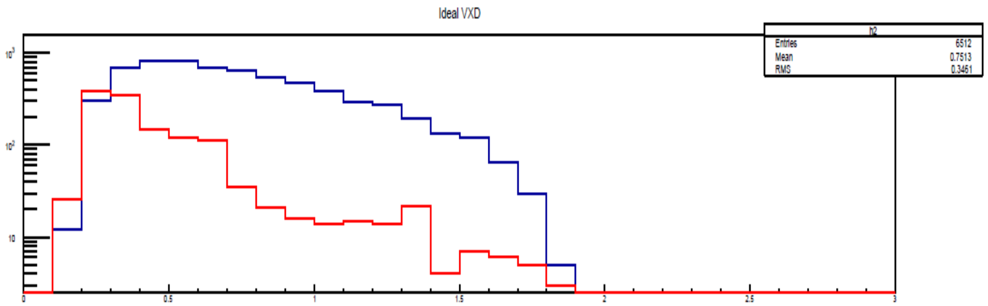
Pair background in the VXD for 10 BX

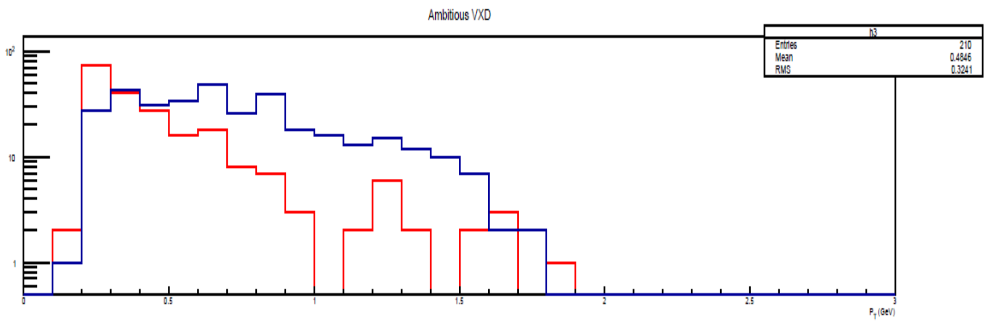


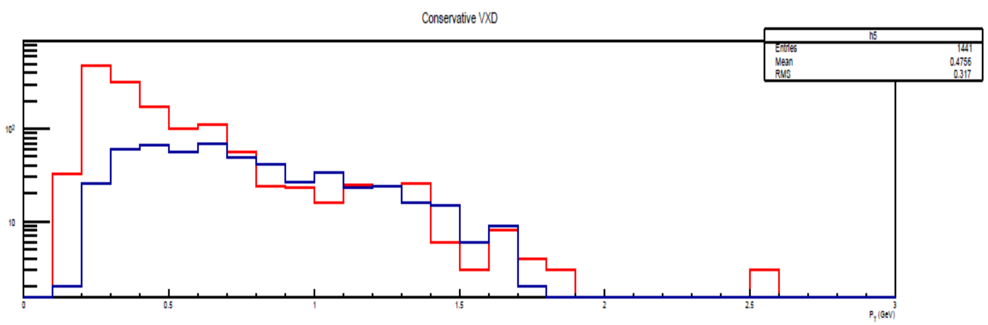
From Armin Taenzer

Pairs vs signal P_T distribution

FPCCD



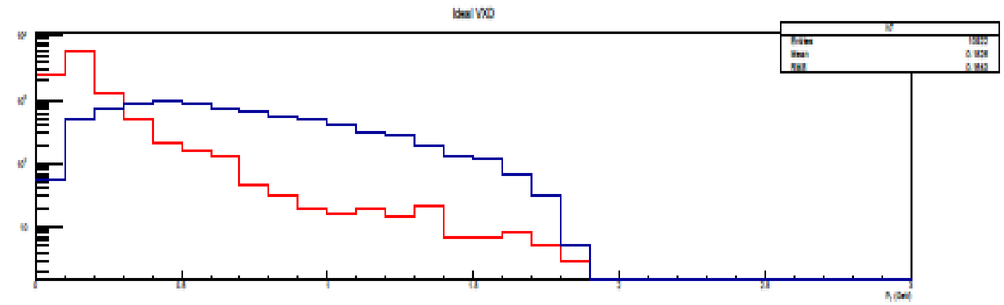




P_T (GeV)

Cellular automaton

1



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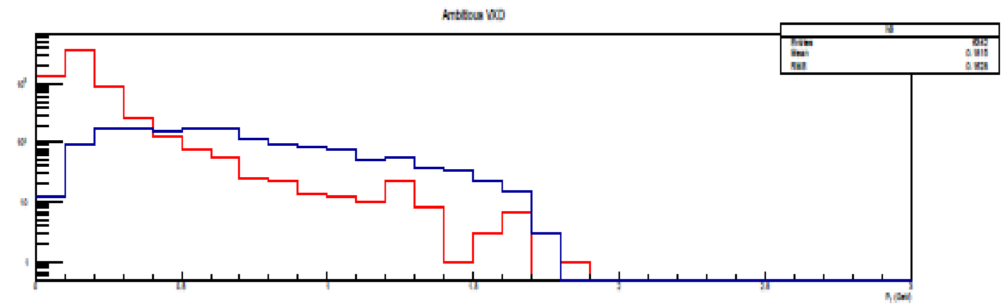

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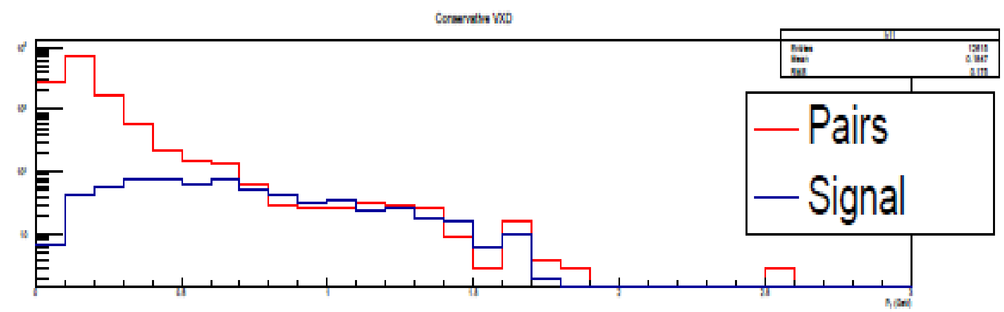

P_T (GeV)

1. Ideal
2. 5BX/layer CMOS
3. 20BX/layer CMOS

Higgsinos vs VXD design and pat. rec

Higgsino poses strict requirements on low pt tracking and bad tracks suppression

Scenario has been studied in fast simulation

Full simulation & reconstruction of 500 fb^{-1} for chargino & neutralino sample

- Overlaid beam pair bkg w.r.t. VXD layers integration time

No simulation/reconstruction of physics bkg so far

- Keep the same preselection cuts to separate physics from background as in fast simulation

Cheating in the particle ID

Goals

- Evaluate the effect of the “bad” tracks issue (not addressed in fast sim)
- Identify VXD requirements imposed by the feasibility of the study
- Validate & compare new pattern recognition

Pair bkg challenge

Chargino reconstruction: requirement for 1 lepton & 1 charged π and no other PFOs

- Suppress by ~10^2 the remaining SM bkg & significantly reduces the neutralino contamination
- Imposes very effective elimination of ghosts & pair tracks

Pairs have mostly low P_T

- Scan cut values – choose the one that maximises the S / B (where B is pair tracks)

	Fast sim	FPCCD		CA	
		P_T Cut (GeV)	Events	P_T Cut (GeV)	Events
Ideal	4.6k	0	2.3k	0.27	2.1k
Ambitious		0.28	2.1k	0.35	1.6k
Conservative		0.3	1.6k		

Polarised chargino cross section

- $\delta\sigma/\sigma = 1 / \sqrt{\varepsilon * \pi * \sigma * \int L dt}$
  - ε = # good events passing selection cuts / total good events
  - π = # good events passing selection cuts / all events passing selection cuts
  - Ideal VXD
    - $P_{e^+e^-}$, **$\delta\sigma/\sigma$ = 2.4%** (assuming physics bkg contamination remains same as fast sim)
  - Ambitious VXD
    - **$\delta\sigma/\sigma$ = 2.5%**
  - Fast sim
    - **$\delta\sigma/\sigma$ = 1.6%**

Conclusion

Large parameter space of VXD concepts

- 2 geometries, many technologies featuring various values for time / space resolution

Effect of pairs on pattern recognition and physics performance under study

- On going work to probe the minimum required time resolution

Higgsino analysis seems feasible for relatively fast detectors (not only for ideal ones)

- Need to keep in mind that is a semi-realistic study ($\gamma\gamma \rightarrow$hadrons not included, pefect particle ID)
- Stressed the importance of using SIT for seed generation to mitigate the effect of pairs (FPCCD tracking style)
- Standalone minivector VXD tracking shows very interesting performance for low pt track reconstruction (efficiency, fake rate, CPU perf)
- However the reconstruction of the track of pairs seems to put a limit on the benefit we can gain