Cellular Automaton Tracking for VXD based on Mini – Vectors

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Outline

- Cellular automaton based on mini – vectors
  - Cellular automaton tools
  - Mini - vectors
  - Performance
  - Robustness
- Outlook

Motivations

- Mainly the standalone VXD tracking
  - Track finding in the low P_T range (~ 100 MeV)
- Cellular automaton core tools already included in ilcsoft - used for FTD tracking
  - Can we use them for another subdetector?
- Added values of mini – vectors
  - Exploitation of the double sided structure of the VXD ladders
  - Are the MVs beneficial or detrimental for pat. rec?
- Study VXD configuration – sensor specifications
  - Speed, robustness ...

Detector Configuration

- Detector studied through these slides
  - DBD VXD, equipped with fast CMOS sensors

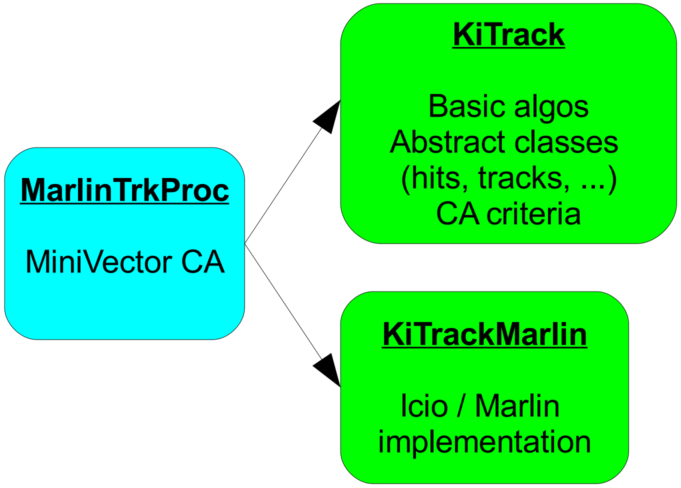
	DBD VXD		**Fast CMOS VXD**	
layer	$\sigma_{spatial}$ (μm)	σ_{time} (μs)	$\sigma_{spatial}$ (μm)	σ_{time} (μs)
L1	3 / 6	50 / 10	3 / 6	50 / 2
L2	4	100	4 / 10	100 / 7
L3	4	100	4 / 10	100 / 7

  - Overall number of VXD hits to deal with in pat. rec
    - DBD VXD: 160k
    - Fast CMOS VXD: 120k

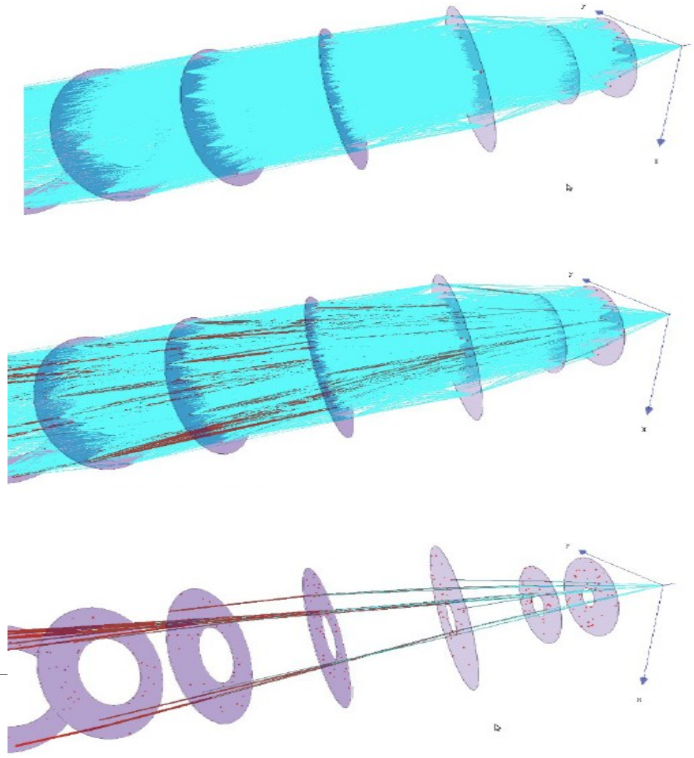
Cellular Automaton Tools

- <u>Core tools are already there for the FTD tracking</u>
- Very flexible
  - Appealing to be used for pattern recognition in other detectors
  - See R. Glattauer Diploma thesis

http://www.hephy.at/fileadmin/user_upload/Publikationen/DiplomaThesis.pdf

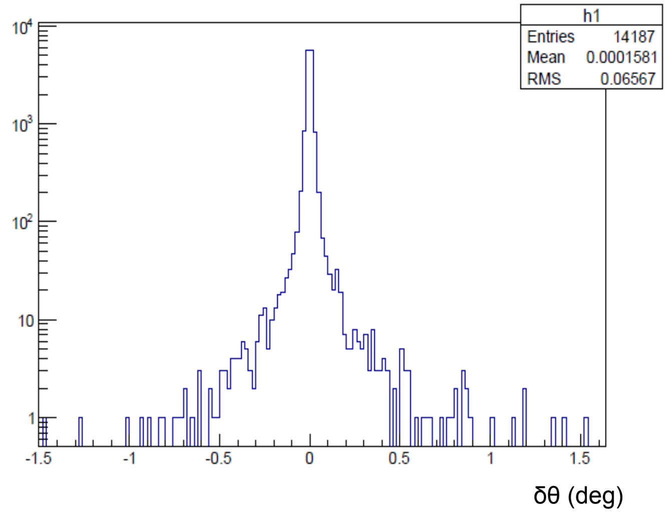


- ✔ VXD & mini – vectors related definitions of KiTrack abstract classes have been created in KiTrackMarlin
- ✔ Set of criteria for mini – vector connections have been defined in KiTrack
- ✗ Minor modifications in core tools
  - Pattern recognition is quite detector - specific...



Mini – Vector Tracking

- Mini – vector formation
  1) Hits in adjacent layers (dist 2mm) with max distance 5mm
  2) Or δθ between hits in adjacent layers (cut can go up to 0.1^0)
- Divide VXD into θ, φ sectors
  - Try to connect mini – vectors in neighbouring sectors
- Cellular automaton criteria
  - φ, θ pointing direction of the mini – vectors
  - No zig-zag (2 MV segments)
- ttbar sample, pair bkg included for √s = 500GeV
- Fast CMOS vertex detector



ttbar, δθ of hits belonging to a MV based on MC info

	Dist < 5mm	δΘ $<0.5^0$	δΘ $<0.3^0$	δΘ $<0.1^0$
VXD hits	10^5	10^5	10^5	10^5
MiniVectors	$3x10^5$	10^5	$6x10^4$	$2x10^4$
Connections	$O(10^5)$	$O(10^5)$	$< 10^5$	$\sim 10^4$
Raw tracks	$O(10^6)$	$O(10^6)$	$O(10^5)$	$< 10^5$
Time	~10min	~ 2min	~ 1min	~ 20 s

Comparison with FPCCD Tracking*

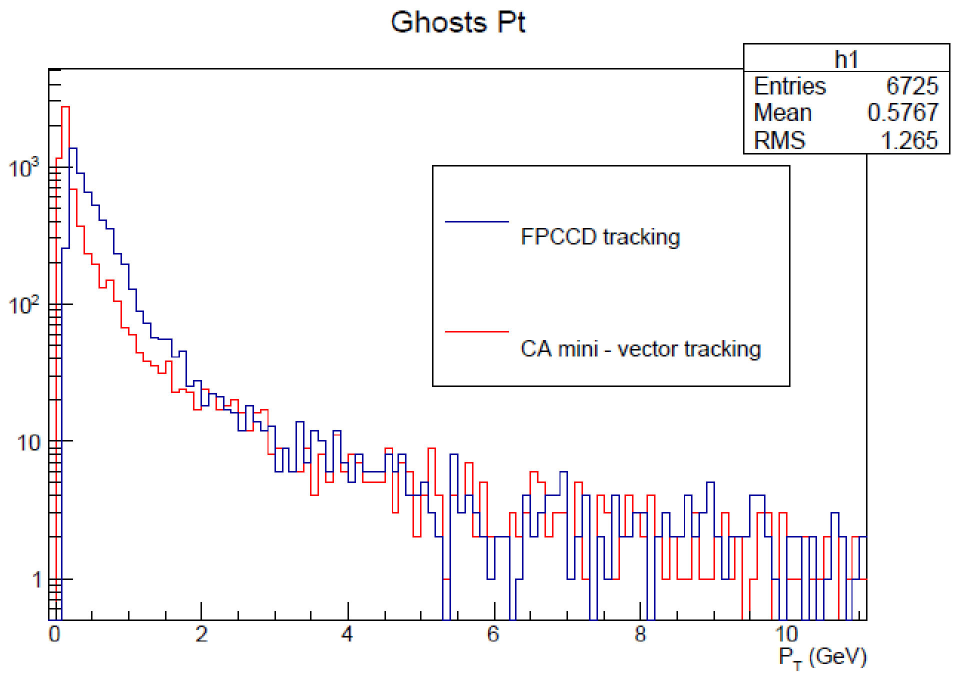
- FPCCD tracking
  - Most performant algorithm for standalone Silicon tracking in ILD
- Examined track sample
  - All charged tracks inside the geometrical acceptance of the VXD
- Definition of found track
  - 75% purity, ≥ 4 hits
- "Ghost" tracks
  - all tracks which does not correspond to a found MC particle
  - Could be pair bkg particles or combinatorics or misreconstructed tracks

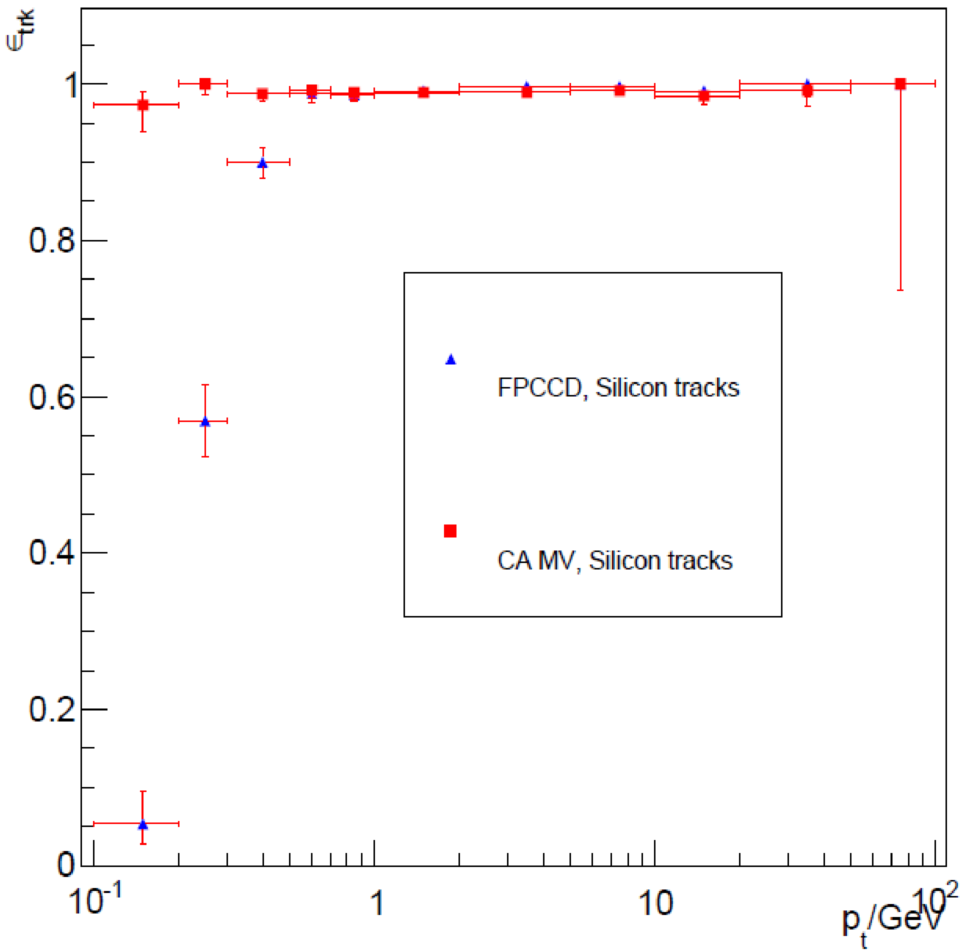
* as it was at beginning of March 2014

Comparison with FPCCD Tracking II

Sample: ttbar, √s = 500 GeV, fast CMOS VXD, pair bkg overlayed, 120 events

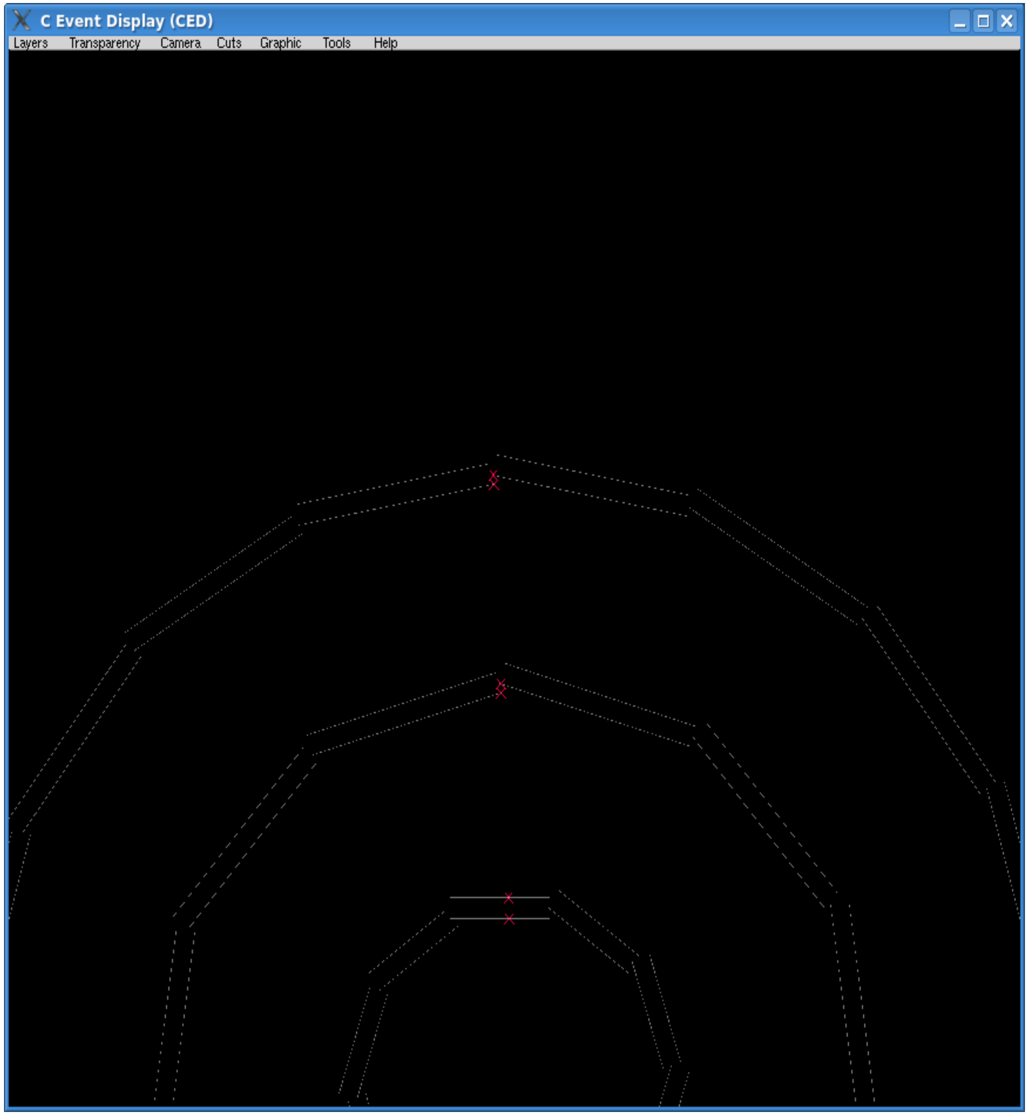
- Ghost tracks / evt (P_T > 1 GeV)
  - FPCCD: ~ 10
  - CA: ~ 8
- Time / evt
  - FPCCD: ~ 75 s
  - CA: ~ 25 s





Search for the lost tracks

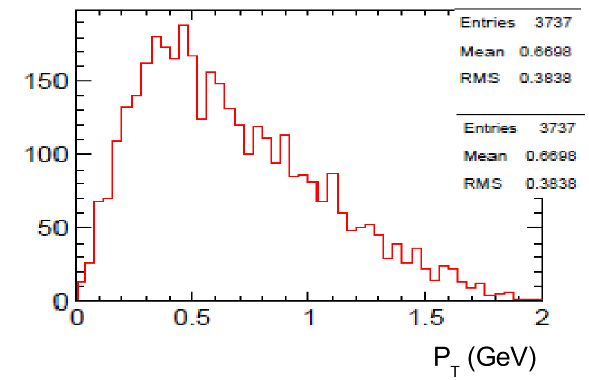
- Efficiency ~ 99% for P_T > 1 GeV
- Why we can't find this ~1% of tracks?
- Typical case of lost track, MC particle P_T = 21 GeV
- Particle doesn't create hits to all layers, in L4 and L6 crosses the insensitive electronic band
  - Can form mini – vectors only in inner layer
  - Need > 1 mini vector to reconstruct a track...
- Marginal effect in tracking but...
- ... what about alignment?



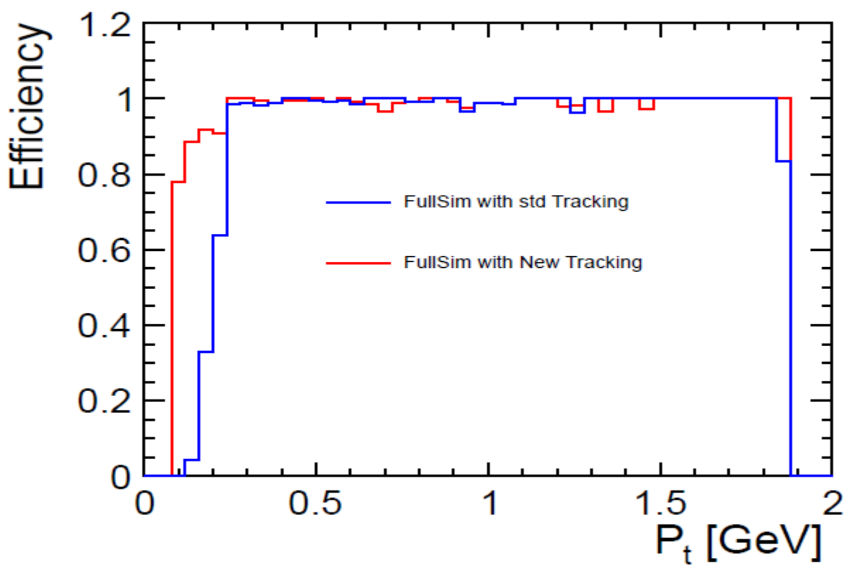
Light Higgsinos Study (Hale Sert)

- Investigating SUSY scenario with light Higgsinos
- Very soft fermions in the final state
  - Ideal sample to test the CA mini – vector algorithm
  - Replace the std Silicon tracking with the new algorithm
  - No pair bkg overlayed
  - Comparing the overall tracking performance for each Si tracking algorithm

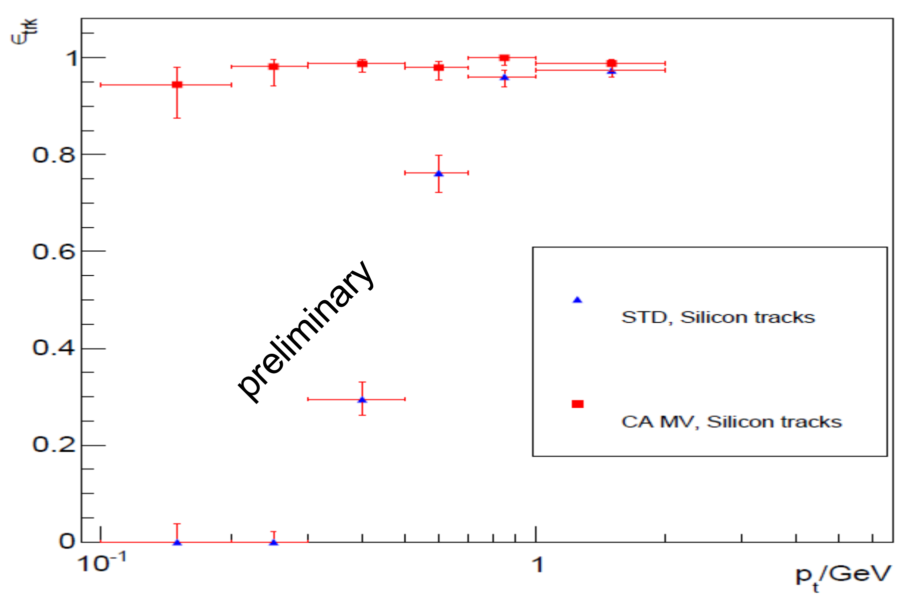
$$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-\gamma \rightarrow 2\tilde{\chi}_1^0\gamma\ W^*W^*$$
$$e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_2^0\gamma \rightarrow 2\tilde{\chi}_1^0\gamma\ Z^*$$
$$\rightarrow 2\tilde{\chi}_1^0\gamma\ \gamma$$



P_T distribution of stable and charged MC particles (cosθ < 0.9397)



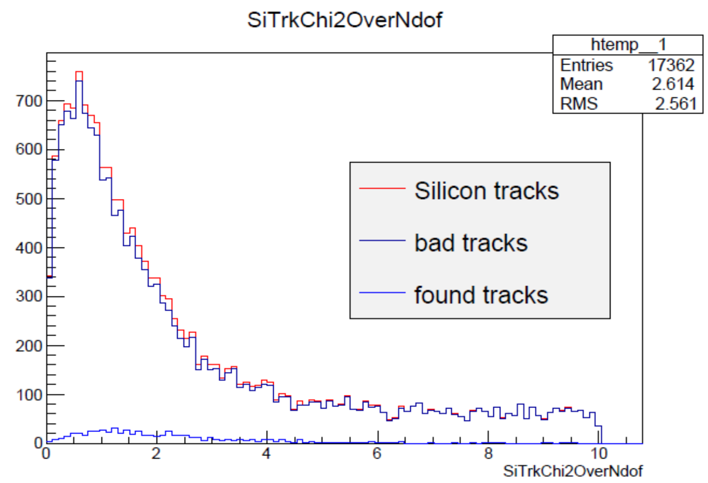
Adding pair bkg

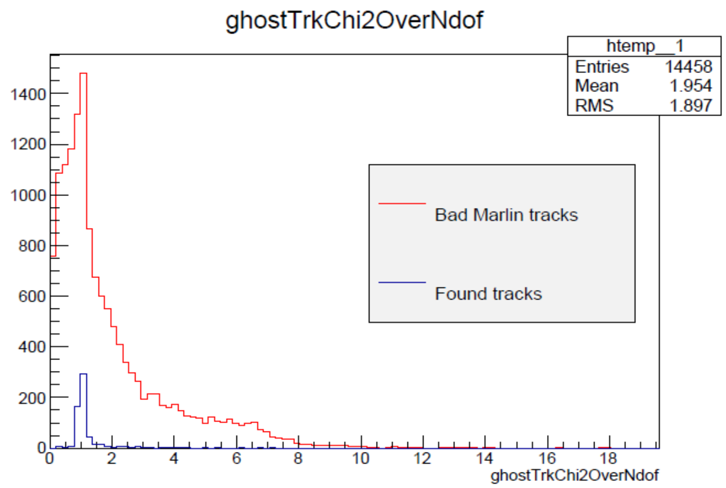


- Significant improvement to low P_T region!

"Bad" Tracks

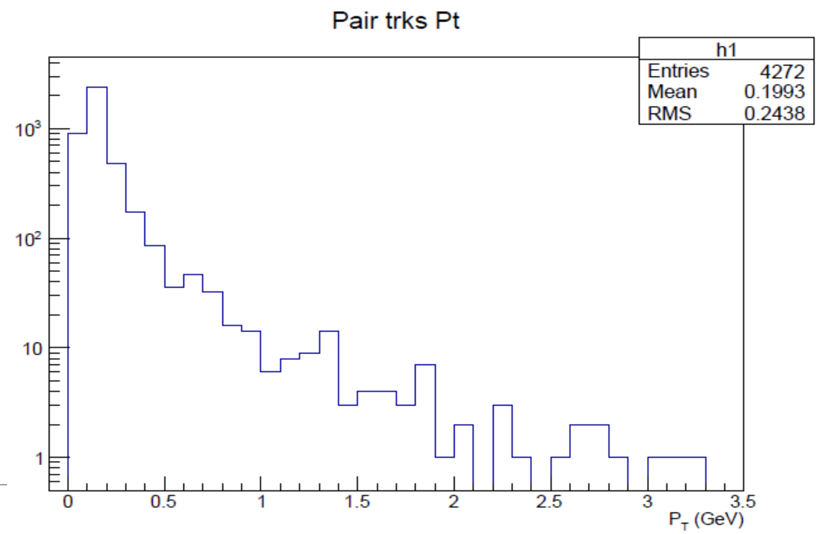
- Higgsino + pair bkg
- Events: 512
- Silicon tracks
- Marlin tracks
  - ~ 28 "bad" tracks / event

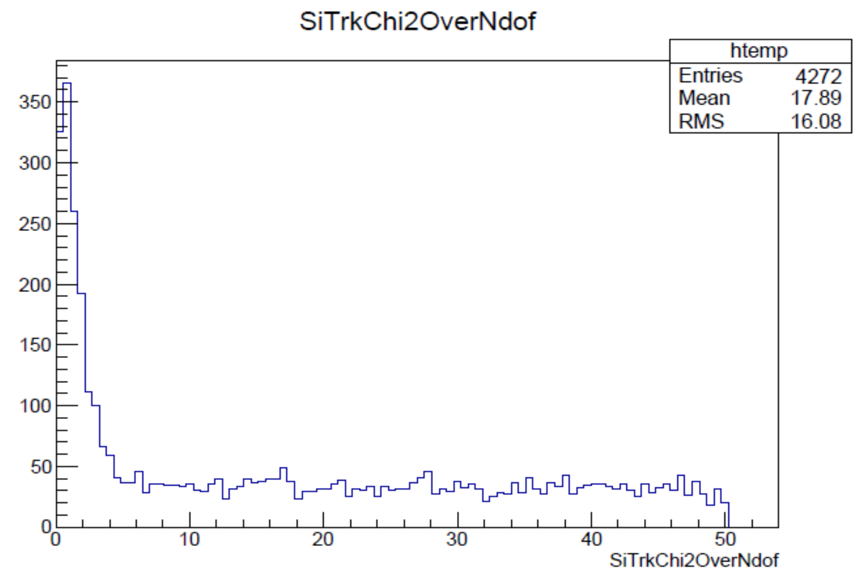




Where do they come from?

- Only pair bkg file
- Events: 60
- ~ 30 / evt with χ^2 / ndf < 10



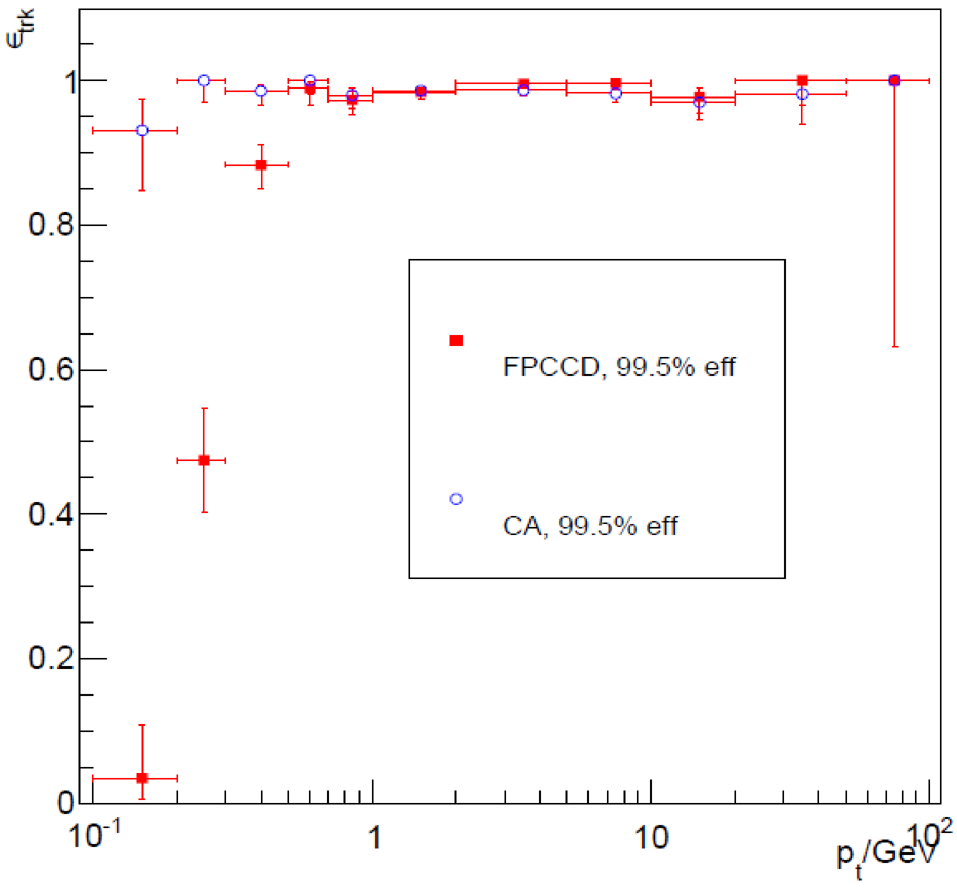


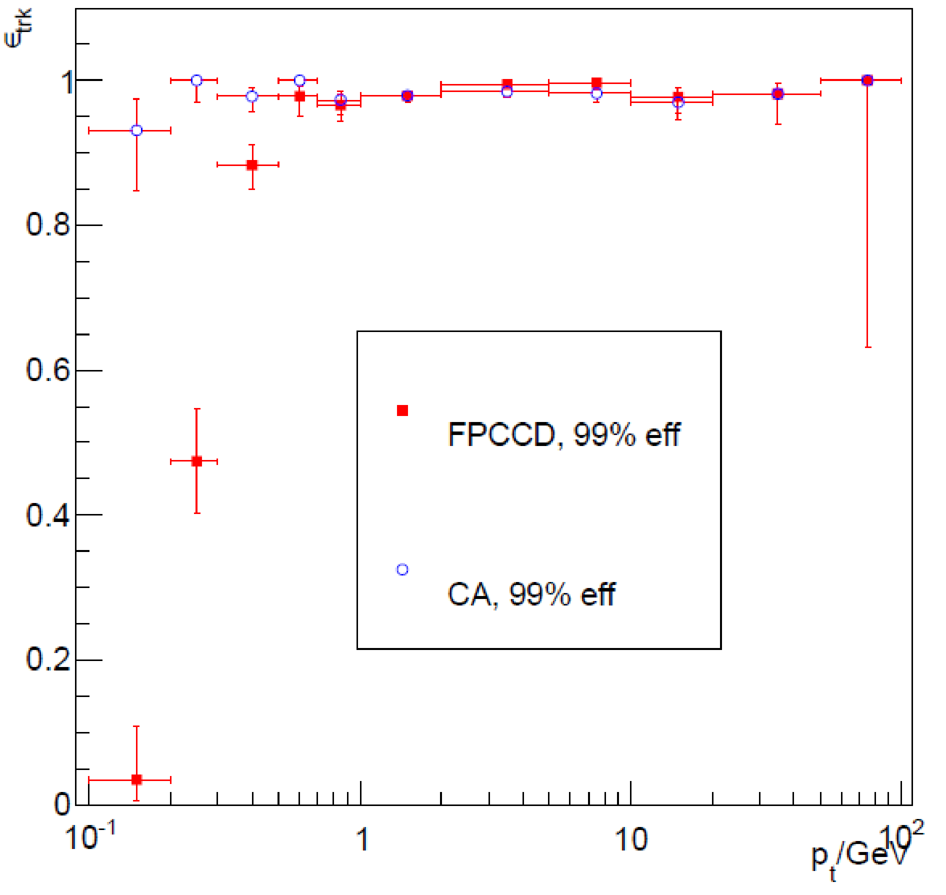
Robustness

- Mini – vector tracking can be sensitive to missing hits
  - What will happen if we don't have 100 % sensor detection efficiency?
    - Track finding eff. as a function of hit detection eff.
    - Studied values for hit detection efficiencies for the sensors: 99.5%, 99%

- Robustness vs combinatorics
- Up to which hit density the C.A. Algorithm can cope with?
- Is it performant for the DBD assumed sensors specifications (time resolution)
- One should account for the uncertainties in pair bkg simulations
- Also: changes in ILD configuration may have a significant impact on pair bkg hit densities
  - Anti – DID field, beamcal design ...

Robustness vs Missing Hits





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- Robustness vs combinatorics
- Up to which hit density the C.A. Algorithm can cope with?
- Is it performant for the DBD assumed sensors specifications (time resolution)
- One should account for the uncertainties in pair bkg simulations
- One should account for hits due to electronic noise (but probably marginal effect...)
- Also: changes in ILD configuration may have a significant impact on pair bkg hit densities
  - Anti – DID field, BeamCal design ...

Performance for Higher Hit Densities

- Severely compromised performance (CPU and efficiency) observed for DBD VXD option
  - FPCCD tracking performs better
- Why CA mini – vector is suffering?
  - For each MV, too many candidate MV to connect with in neighboring sectors
- Approach
  - Smarter selection of neighboring sectors
  - MV are small tracks – can point to the candidate sector
    - Fully exploit the MV concept
    - Work on going...

Summary & Outlook

- The results indicate that mini vectors improve significantly the tracking in the presence of beam bkg
- For a fast VXD
  - CA MV tracking shows very good perf. In terms of efficiency and CPU time
  - But too many "bad" tracks
    - Are they "bad" tracks (combinatorics) or real pair bkg tracks?
- For slower detectors / higher hit densities
  - Smarter sector connection (on going)
- Integration to overall tracking sw
  - CA MV shows promising performance as a part of the overall tracking
  - Improves significantly the efficiency on low P_T tracks
  - Few technical issues need to be resolved

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