SiD tracking using full detector simulation

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Outline

- Pattern recognition in SiD – is there a problem?
- VXD based tracking – can it work with realistic backgrounds?
- What and how was simulated
- Performance results
- Conclusion and plans

Pattern recognition in SiD

- In the tracking code for Large or Small detector design we used central tracker for initial track finding, and extrapolated found tracks to vertex detector to look for VXD hits close to it.. It was assumed that large number of hits in VXD makes it unpractical to use it as pattern recognition device.
- Using strips in central tracker, without possibility to measure hit Z position makes it unsuitable for good pattern recognition. Moreover, sparse spacing of central tracker layers does not allow to use them for pattern recognition of low Pt (Pt<0.5 GeV/c) tracks. So, it was suggested, that we will find tracks in VXD first, and extrapolate it to central tracker for improved momentum resolution.

VXD pattern recognition: problems

- There are too many hits in VXD:
  - Firstly, because VXD is close to the beam, so background level is very high here
  - Secondly, because electronics noise create fake hits. Huge number of pixels leads to considerable amount of fake hits even if registration threshold much higher than noise level. To have acceptable rate of noice hits, threshold should be at least 6 times noise r.m.s. It is not a big problem, as typical signal/noise ration in CCD is about 30. Setting registration threshold at 0.2 of average signal may lead to single layer inefficiency of about 2%, but because we can tolerate 1 missing hit in VXD, such inefficiency will not have impact on track reconstruction efficiency.

VXD pattern recognition: backgrounds impact

- Number of background hits per VXD layer for SiD with 1.2 cm radius of innermost layer:

layer	1	2	3	4	5
Nhits	11200	6200	2350	1200	720

Simple calculations, assuming that we require all 5 VXD layers have hit on track, and that we will attach to track hits within 0.1 mm from track candidate (it depends on momentum, of course), shows that we will make about 300 fake tracks in each event . It does not looks like acceptable level.

More problems

- Estimate on the previous page is correct only for very low momentum tracks (around 100 MeV). We can cut on momentum, and effect on number of fake tracks will be dramatic – inverse of 4^{th} power of momentum. But…
- We assumed requirements what all 5 layers have hits. This requirement decrease our reconstruction efficiency to the level of about 90%. Does not look like comfortable value. If we allow one missing hit, it will immediately rise our fake hits rate by 3 orders of magnitude, and in that case higher momentum cut (now it's effect will be only 2^{nd} power) will not help us.
- Next problem though technical but also not so simple – amount of processing time for pattern recognition exceeds 10 hours/event with such number of hits.

Solutions

- Lets constrain track origin to close to IP. If we constrain it to ±5 mm, it will dramatically reduce fake rate (by factor of about 1000), and pattern recognition computing time (at least by 100). Most of B decay tracks will be reconstructed with such constraint. And we can reconstruct higher energy tracks with larger impact parameter, starting pattern recognition in tracker. It was difficult to do for low momentum tracks, but for high momentum it is a possibility.
- We can add requirement to have more hits on track. Though not requiring all layers in VXD have hits, we still can require that track had minimum 5 or 6 hits, attaching hits from central tracker. Track with Pt of 150 MeV/c reaches first CT layer.

Tracking reconstruction algorithm I used

- First I selected 3 layers in VXD for pattern recognition. Attempt was repeated with different selections to exclude single layer inefficiency.
- For every hit in the outermost layer projection to area around IP limited Z and Phi regions of middle and inner layers to look for hits for pattern recognition. For every combination of hits within such regions track was drown and number of hits close to this track in all layers of VXD and central tracker was found. I required at least one more hit in VXD. Results for total required number of hits on the track ≥ 5 and ≥ 6 will be presented
- I did not use any track fitting, but I used outermost hit in central tracker to improve Pt resolution.

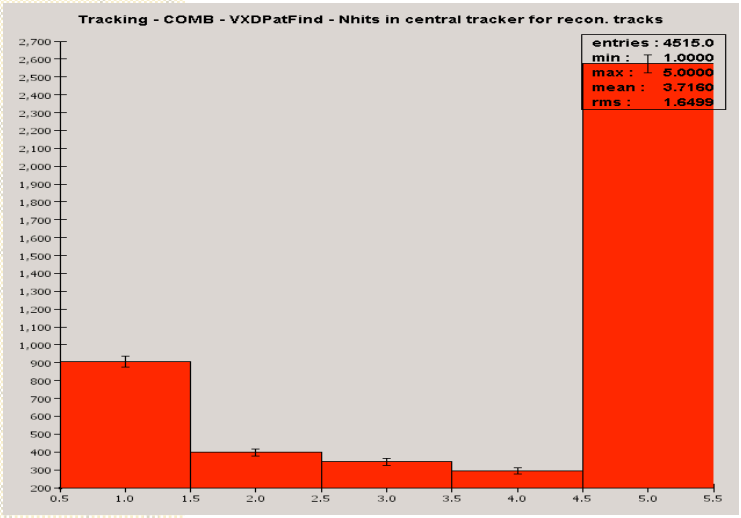
Results

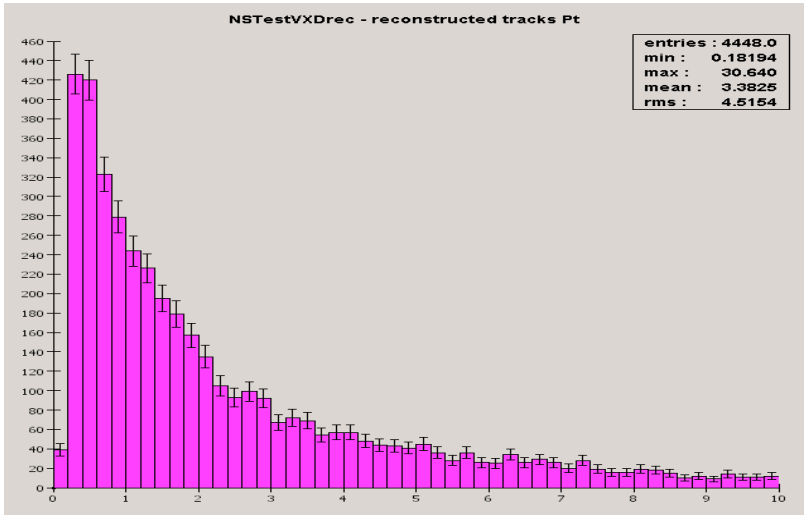
- First, some definitions:
  - I will look into MC truth for hits, assigned to track, and will call track reconstructable if MC particle meets my reconstruction requirements .
  - If all hits assigned to track belong to the same particle or to the decay chain of a single particle (with daughter momentum close to parent's one), I'll call this track "clean".
  - If track has one "alien" hit assigned, I'll cal it "damaged"
  - If track has more than one "alien" hit assigned, I'll call it "spoiled"
  - If track is made of hits, belonging to non-reconstructable particle, and has more than one "alien" hit assigned, I'll call it "fake"

Without backgrounds

	Reco Eff.	Clean tracks	Clean in vxd	Dam.	Spoil	Fake
5 hit, Pt 0.1	98.7%	96.7%	99.9%	2.9%	0.3%	0.3%
5 hit, Pt 0.2	99.4%	97%	99.9%	2.5%	0.2%	0.4%
6 hit, Pt 0.2	98.5%	96.2%	99.9%	3.3%	0.2%	0.4%

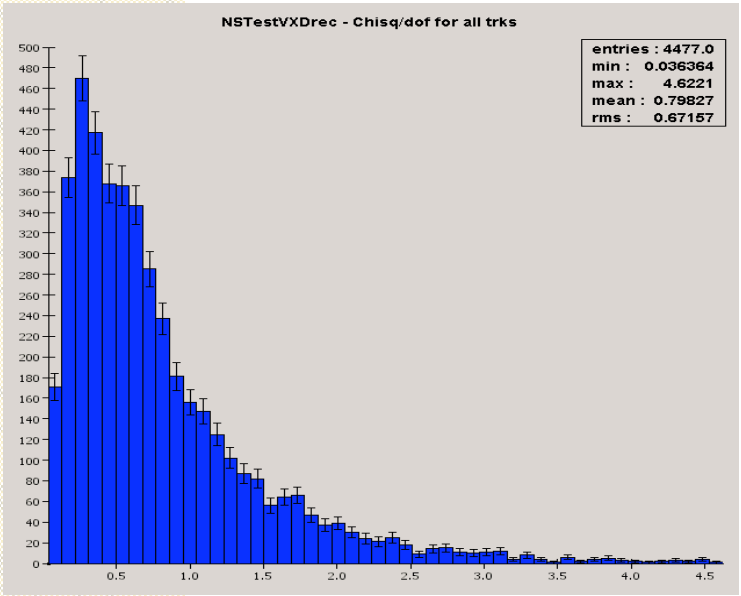
Some distributions

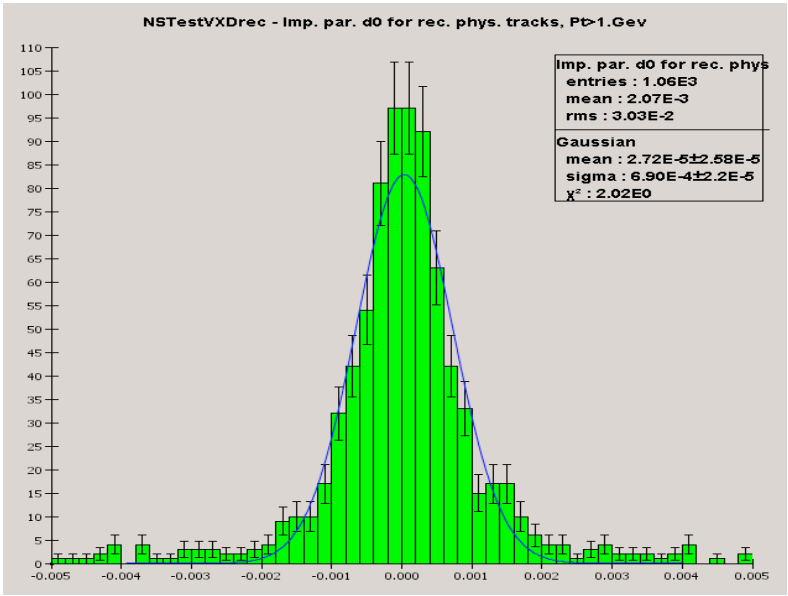




- Number of hits in Central Tracker for reconstructed tracks
- Pt of reconstructed tracks (Pt threshold 0.18 Gev)

More distributions





- Chi2 of reconstructed tracks
- Impact parameter (no fitting!) _ = 7_ !

How I added backgrounds

- I used background files for pair backgrounds, with 1 bunch crossing worth of background hits/event. I added 192 such events to each physics events. The same for gamma-gamma to hadrons – here I needed to add 54 such events to one physics. In that case all CT hits from background were added to event also. I called this “bad timing resolution in Central Tracker case.
- To simulate good timing resolution, I could remove all, but one background event worth of Central Tracker hits (but leaving all VXD background hits). We may simulate worse timing resolution by leaving more background events in CT.

Now add backgrounds

	Reco Eff.	Clean tracks	Clean in vxd	Extra trks	Energ Fr. bck	Fake en fr f.
5 hit, bad t.	95.2% 99.0%	88.2% 94.0%	94.5% 99.2%	186	72.9 GeV	12 4.7Gev
5 hit, good t	95% 99%	90.8% 96%	99.9% 99.9%	164	69.6 GeV	6 1.7Gev
6 hit, Good t	97.3%	76.2%	99.9%	0.9	0.57 GeV	9 4GeV

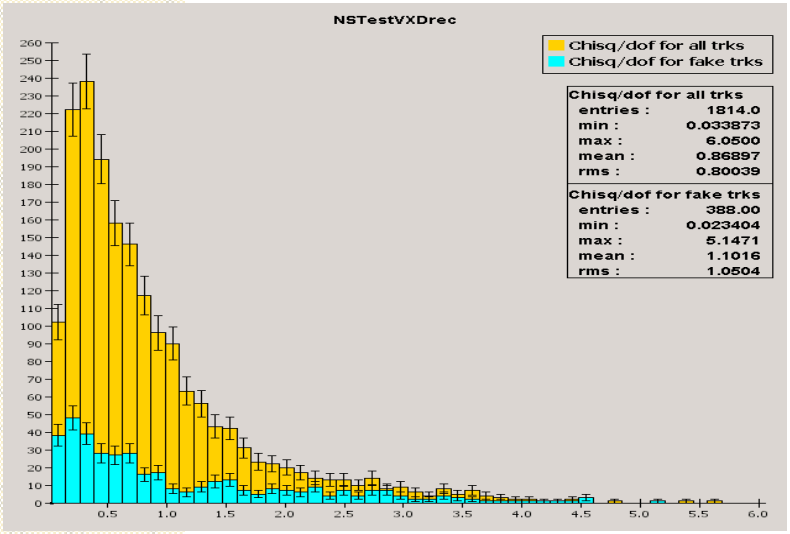
With 5 hits requirements there is no difference good or bad CT timing

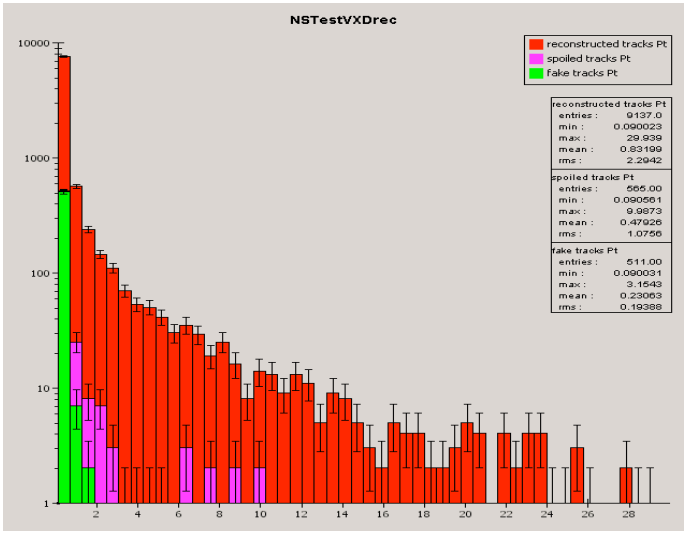
- Not a surprise, because essentially all tracks are reconstructed in VXD in that case. However, with bad CT timing fake tracks are really fake, because real background tracks reaching CT will be reconstructed, and will not be fake. In the case of good timing, “fake” tracks mostly are not fake in VXD, they are real background tracks here, accidentally finding continuation in CT.
- Number of reconstructed background tracks is pretty large (more than 150/event), and their contribution into total charge tracks energy is pretty significant. But they are all low momentum tracks, so they can be discriminated.

With 6 hits requriment

- With good timing almost all background hits are gone
- But large number of fakes. Their numbers should be almost the same as in case of 5 hits requirement, because this are the same not fake, but real background hits in VXD, which managed to pick up 1 hit in 1st layer of CT

And more distributions





- Chi2 distributions for good and fake tracks. Really we can't cut on it
- Pt distribution of good, spoiled and fake tracks

Conclusions and plans

- We see, that suggested solution works.
- Performance in endcap region should be checked next
- Combination with tracking starting from central tracker for higher momentum and larger impact parameters also is interesting item for investigation