Reconstruction in the luminosity detector with pixel sensors

Anastasia Karavdina

KPH, Uni Mainz

karavdin@kph.uni-mainz.de

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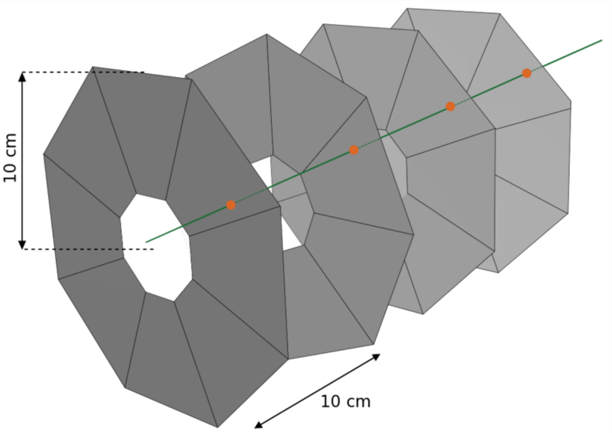
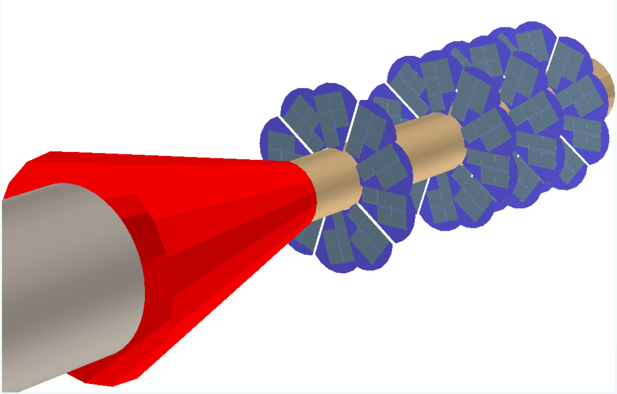
Design I: strip sensors



component	material	thickness [μm]	rad.length (X/X_0) [%]
strip sensor	silicon	150	0.159

Design II: pixel sensors



component	material	thickness [μm]	rad.length (X/X_0) [%]
cone support	kapton	20	0.027
flex-cable	kapton	50	0.0175
HV-MAPS	silicon	50	0.053
cooling disc	CVC-diamond	200	0.165
HV-MAPS	silicon	50	0.053
flex-cable	kapton	50	0.0175
one plane			0.306

Status [September 2012]

- For strip sensors: full reconstruction chain
  - ROOT geometry description → simulation
  - hit reconstruction
  - track search
  - track fit
  - back-propagation to IP
  - alignment procedure
- For pixel sensors:
  - preliminary ROOT geometry description → simulation
  - hit reconstruction
  - track search (based on merged hits)

Goals

- Full reconstruction chain running for pixel sensors
- Difficult to estimate hit errors for composite sensors structure → Kalman Filter as a new track fitter

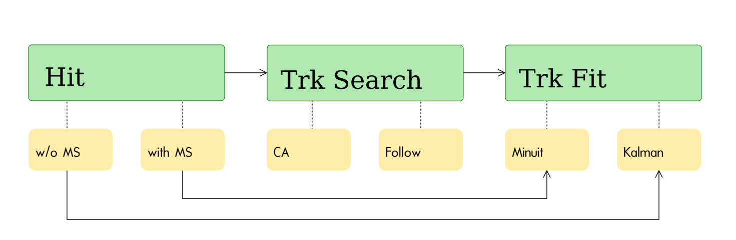
! warning !

To make code more general it was slightly rewritten. Also a few bugs were fixed.

- results for simulation with strip sensors:
  prove the reconstruction performance is the same like it was before
- results for simulation with pixel sensors:
  give idea about the reconstruction performance for this set-up

Please
don't try to compare any numbers between strip & pixel sensors!

Track reconstruction with strip sensors

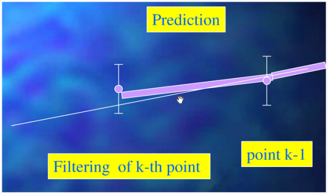


Features

- $0.03 < \theta < 0.05\ rad$ and $|\phi| < 0.25\ rad$ cuts on trk-cand
- To avoid "additional material" problem with GEANE, seed point of trk-cand shifted on z-axis for -350 μm (out of plane)

Kalman Filter

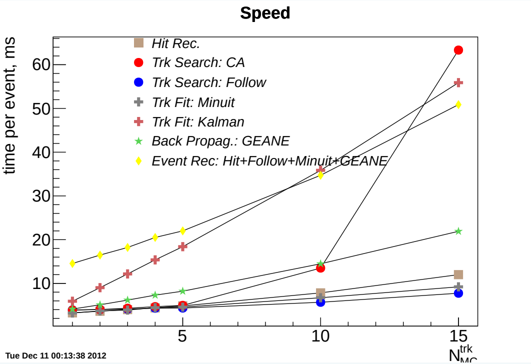
Recursive algorithm that finds the best estimate for the state of dynamic systems from a series of noisy measurements.



- GENFIT (Generic Track Reconstruction) provides tool for mathematics of Kalman Filter
- Requires external code for the propagation of particles in magnetic fields and materials
- Inside pandaroot GEANE is used as a propagator

Reconstruction speed: $P_{beam} = 15\ GeV/c$

(strip sensors)



1 trk per event:

- **Hit rec**: 3.19 ms
- **CA**: 3.81 ms **Follow**: 3.84 ms
- **Minuit**: 3.16 ms **Kalman**: 5.79 ms
- **GEANE**: 4.04 ms

Tot.: $\sim$ 15 ms

θ resolution [μrad] : strip sensors

(10^5 events)

	Cellular Automat		Track-Following	
P$_{beam}$, GeV/c	$Minuit$	$Kalman$	$Minuit$	$Kalman$
15	127.73	133.21	127.84	133.31
11.91	129.20	132.45	129.34	132.56
8.9	138.5	137.57	138.63	137.69
4.06	203.06	195.35	203.25	195.45
1.5	745.87	736.01	744.33	736.58

Missed & ghost tracks

Definition I (comparison between rec.trk and MC trk)

- good trk: $|\theta^{rec} - \theta^{MC}| < 4\sigma_\theta$ and $|\phi^{rec} - \phi^{MC}| < 4\sigma_\phi$
- ghost trk: MC track is alredy matched to another rec.trk
- missed trk: MC track wasn't assigned to any rec.trk

Definition II (hits matching)

- good trk: 70% hits are coming from the same MC trk
- ghost trk: less than 70% hits are coming from the same MC trk
- missed trk: MC track wasn't assigned to any rec.trk

Missed & ghost tracks: strip sensors

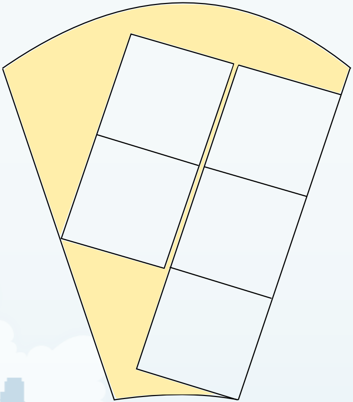
(4 mrad < θ_{MC} < 8 mrad, $2 \cdot 10^5$ events, $GEANT4$)

		CA		Follow	
		$missed, \%$	$ghost, \%$	$missed, \%$	$ghost, \%$
$15\ GeV/c$	$I:$	0.46	0.21	0.47	0.22
	$II:$	0.25	0	0.25	0
$11.91\ GeV/c$	$I:$	0.65	0.36	0.66	0.35
	$II:$	0.29	0	0.32	0
$8.9\ GeV/c$	$I:$	1.38	1.09	1.41	1.13
	$II:$	0.3	0	0.28	0
$4.06\ GeV/c$	$I:$	4.06	3.71	4.09	3.68
	$II:$	0.39	0	0.41	0
$1.5\ GeV/c$	$I:$	9.31	9.70	9.32	9.29
	$II:$	0.03	0	0.02	0

Track fit: Kalman Filter

Merged hits (pixel sensors)

In contrast to strip sensors:
pixel sensors give 2D information by one side measurement
But we would like to have full ϕ covering



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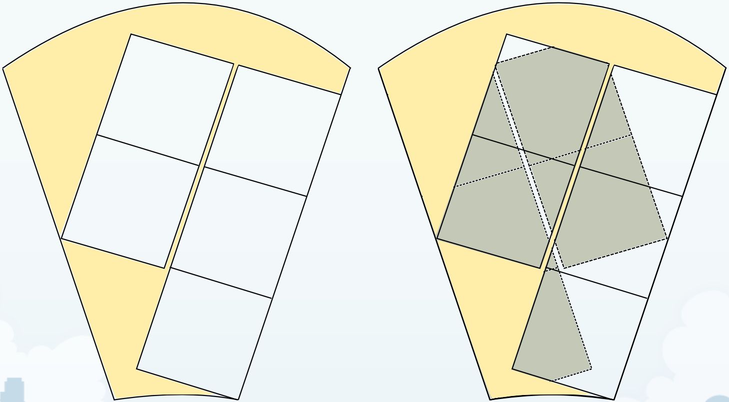
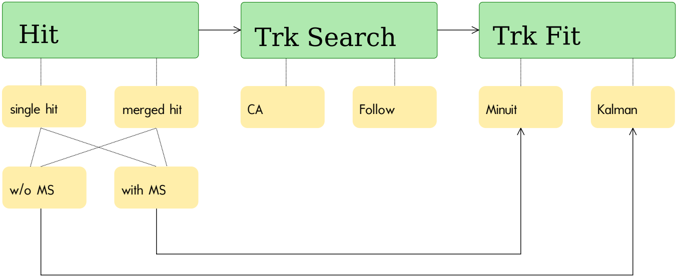


Track reconstruction with pixel sensors

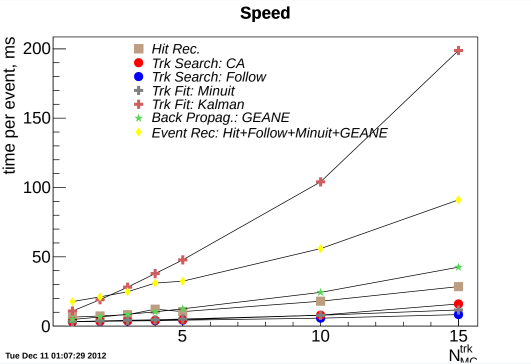


Features

- track search for "single" hits works only for CA!
  (has some issues, so no results will be shown today)
- $0.03 < \theta < 0.05\ rad$ and $|\phi| < 0.25\ rad$ cuts on trk-cand
- Seed point of trk-cand shifted on z-axis for -350 μm

Reconstruction speed: $P_{beam} = 15\ GeV/c$

(pixel sensors)



1 trk per event:

- **Hit rec(+merge)**: 6.25 ms
- **CA**: 3.12 ms **Follow**: 3.08 ms
- **Minuit**: 3.14 ms **Kalman**: 10.54 ms
- **GEANE**: 4.63 ms

Tot.: $\sim$ 18 ms

θ resolution [μrad] : pixel sensors

(with kapton cone, 10^4 events, $GEANT3$)

	Cellular Automat		Track-Following	
P$_{beam}$, GeV/c	$Minuit$	$Kalman$	$Minuit$	$Kalman$
15	91.39	91.32	90.86	90.83
11.91	103.27	103.55	102.998	103.188
8.9	114.04	113.91	113.65	113.38
4.06	216.761	217.644	215.8	216.34
1.5	1017.74	985.9	1000.95	978.44

Missed & ghost tracks

Definition I (comparison between rec.trk and MC trk)

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- missed trk: MC track wasn't assigned to any rec.trk

Missed & ghost tracks: pixel sensors

(4 mrad < θ_{MC} < 8 mrad, $2 \cdot 10^5$ events, GEANT4)

		CA		Follow	
		$missed, \%$	$ghost, \%$	$missed, \%$	$ghost, \%$
$15\ GeV/c$	$I:$	1.16	0.14	1.16	0.14
	$II:$	1.03	0	1.03	0
$11.91\ GeV/c$	$I:$	1.54	0.59	1.54	0.59
	$II:$	0.95	0	0.95	0
$8.9\ GeV/c$	$I:$	1.11	0.15	???	???
	$II:$	0.97	0	???	???
$4.06\ GeV/c$	$I:$	2.17	0.43	2.17	0.43
	$II:$	1.74	0	1.74	0
$1.5\ GeV/c$	$I:$	4.62	1.46	4.77	1.42
	$II:$	3.18	0	3.35	0

Track fit: Kalman Filter

Results & Plans

Results

- Reconstruction for pixel sensors design is running
- Kalman Filter can be used as track fit
- Track reconstruction performance is under study for both designs, results so far look reasonable

Plans

- Implement alignment for pixel sensors design
- Background study (new DPM version): point-like beam, beam smearing
- Background p.d.f to luminosity fit function (Kernel Density Estimator)

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Plans

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- Background study (new DPM version):
  point-like beam, beam smearing
- Background p.d.f to luminosity fit function
  (Kernel Density Estimator)

Looking forward to "It would be nice add\study\go deeply ..." ;)

Missed & ghost tracks: strip sensors

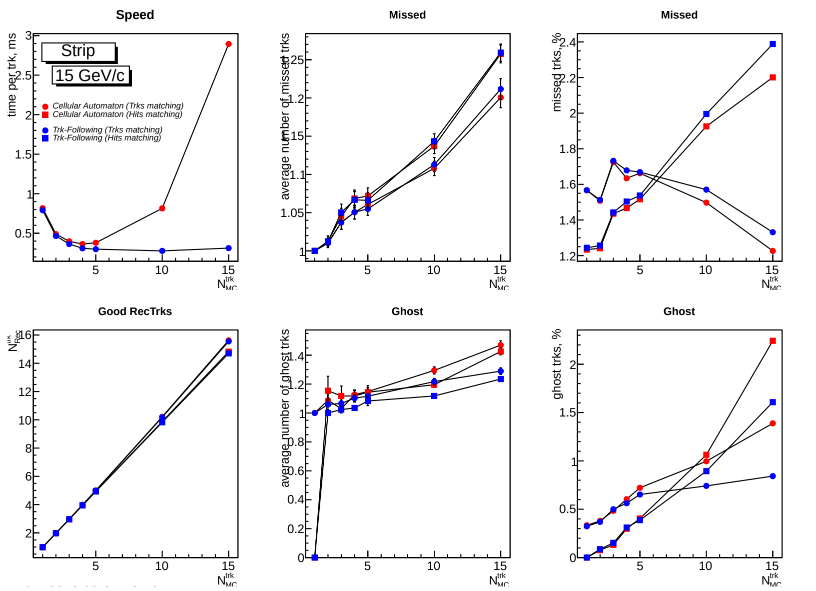
(4 mrad < θ_{MC} < 8 mrad, $2 \cdot 10^5$ events)

		CA		Follow	
		$missed, \%$	$ghost, \%$	$missed, \%$	$ghost, \%$
$15\ GeV/c$	$I:$	0.45	0.2	0.45	0.2
	$II:$	0.25	0	0.25	0
$11.91\ GeV/c$	$I:$	0.63	0.34	0.64	0.34
	$II:$	0.29	0	0.3	0
$8.9\ GeV/c$	$I:$	0.78	0.49	0.77	0.49
	$II:$	0.29	0	0.28	0
$4.06\ GeV/c$	$I:$	2.66	2.31	2.67	2.27
	$II:$	0.39	0	0.41	0
$1.5\ GeV/c$	$I:$	23.11	23.52	23.14	23.12
	$II:$	0.03	0	0.02	0

Track fit: Minuit

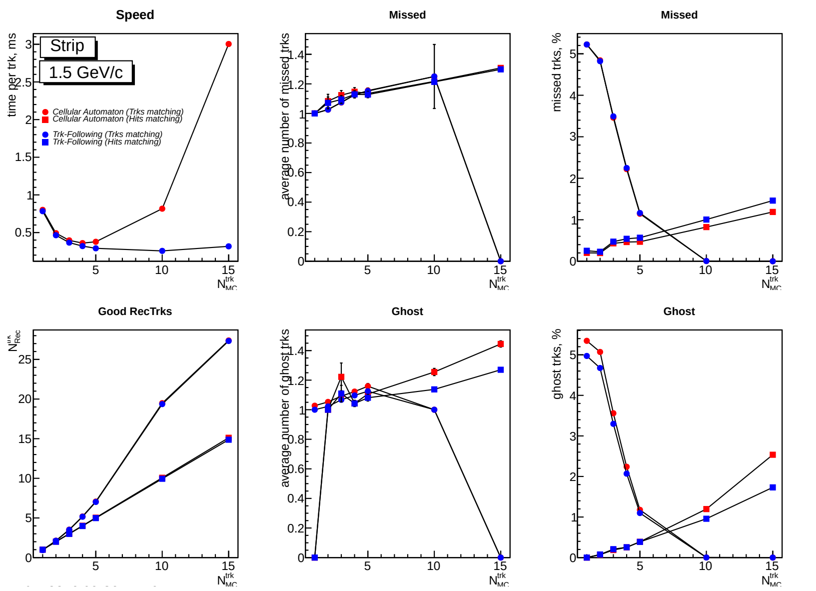
Missed & ghost tracks: strip sensors

$P_{beam} = 15\ GeV/c\ (10^4 events, GEANT3)$



Missed & ghost tracks: strip sensors

$P_{beam} = 1.5\ GeV/c\ (10^4 events, GEANT3)$



θ resolution $[\mu rad]$: pixel sensors

(with kapton cone)

Cellular Automat

	Minuit		Kalman	
$P_{beam},\ GeV/c$	$merged$	$single$	$merged$	$single$
15	77.45	77.74	76.80	76.03
11.91	96.08	96.71	94.65	93.99
8.9	111.66	111.61	108.47	110.93
4.06	244.19	243.65	230.94	237.28
1.5	1271.06	1252.11	1122.18	1084.28

Reconstruction on "single" hits should be improved!
(now it has bad efficiency)

Missed & ghost tracks: pixel sensors

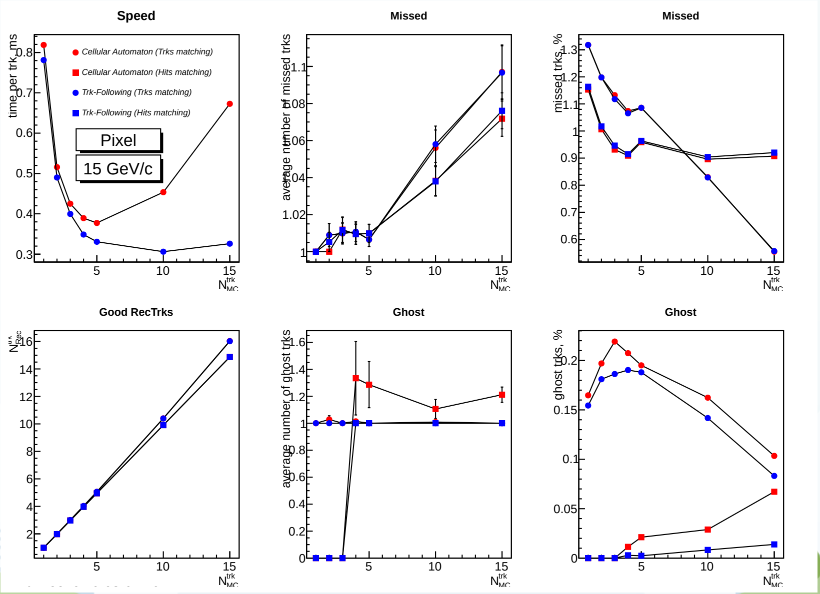
(4 mrad < θ_{MC} < 8 mrad, $2 \cdot 10^5$ events)

		CA		Follow	
		$missed, \%$	$ghost, \%$	$missed, \%$	$ghost, \%$
$15\ GeV/c$	$I:$	1.17	0.16	1.18	0.15
	$II:$	1.01	0	1.03	0
$11.91\ GeV/c$	$I:$	1.65	0.70	1.66	0.71
	$II:$	0.94	0	0.95	0
$8.9\ GeV/c$	$I:$	1.41	0.51	1.44	0.47
	$II:$	0.92	0	0.97	0
$4.06\ GeV/c$	$I:$	14.72	13.06	14.76	13.02
	$II:$	1.67	0	1.73	0
$1.5\ GeV/c$	$I:$	68.88	65.76	69.17	65.82
	$II:$	3.18	0	3.35	0

track fit: Minuit

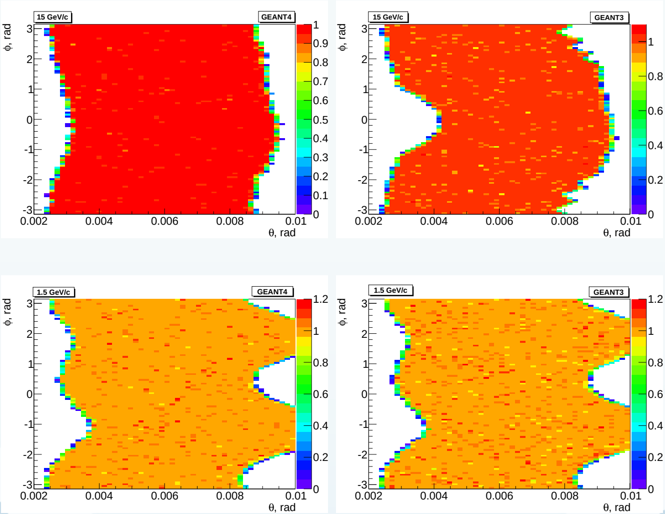
Missed & ghost tracks: pixel sensors

$P_{beam} = 15\ GeV/c\ (10^4 events, GEANT3)$



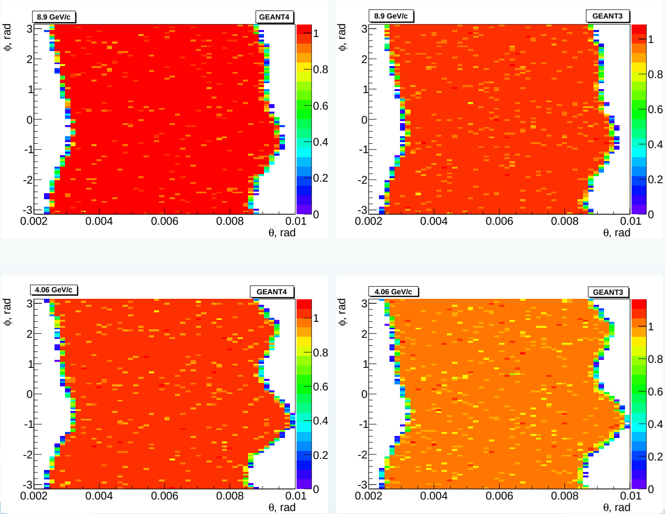
Acceptance difference with GEANT3 and GEANT4

strip



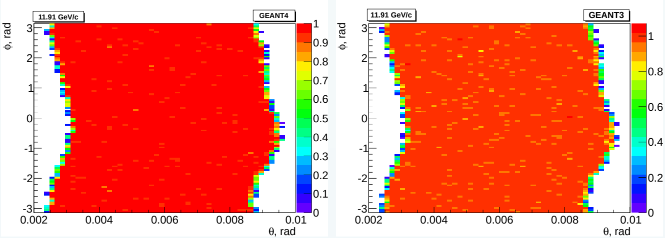
Acceptance difference with GEANT3 and GEANT4

strip



Acceptance difference with GEANT3 and GEANT4

strip



Acceptance difference with GEANT3 and GEANT4

pixel