Tilt angle and Crossing angle in Silicon Trackers

Hartmut Sadrozinski
SCIPP, UC Santa CRUZ, Santa Cruz, CA 95060 USA

In the ZEUS Silicon tracker, several effects will cause tracks to cross the detectors with a finite crossing angle in the r-ϕ plane They will influence the:

- Efficiency
- Position Resolution
- Material Budget(Xo & $$)

Beam tests have been done with varying crossing angles to map out this effect.

We consider here:

Finite detector size: skew [SK]
3 cm wide detectors @ min. radius r= 6.5cm= 13deg
@ max radius r= 14cm= 6.1deg

Lorentz Angle [LA] in 1.5T field:

holes	1.5*1.85	=	2.8deg
electrons:	1.5*7.9	=	11.9deg

Angular opening for 0.5 GeV particles [CP], ρ = 1.11m
@ min radius r=6.5cm= 1.7 deg
@ max radius r=14cm= 3.6 deg

Sharing

decreases the charge collected on one strip
assume 300 micron thick detector with 80micron pitch

Crossing angle ca	Strips crossed
[deg]	300*tan(ca)/80
5	0.33
10	0.66
15	1.00
20	1.36
25	1.75
28	2.00
30	2.16

Beyond crossing angle of 15deg, no single strips hit (always sharing!).

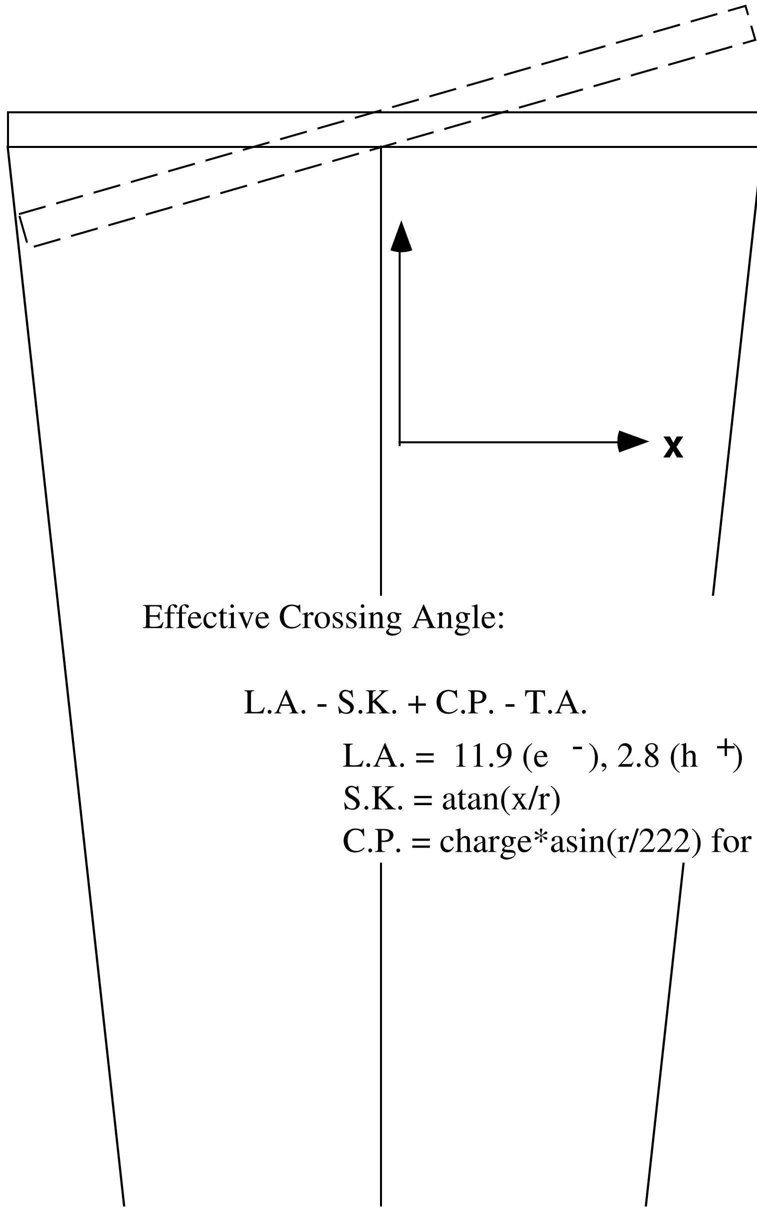
Beyond crossing angle of 28 deg: always sharing of three strips

LEFT:
Effective crossing Angle 11.9+13=24.9deg
Positive 0.5GeV Particles: 11.9+13+1.7=26.6deg
Negative 0.5GeV Particles: 11.9+13-1.7=23.2deg

RIGHT::
Effective crossing Angle 11.9-13.0=-1.1deg
Positive 0.5GeV Particles: 11.9-13+1.7=0.6deg
Negative 0.5GeV Particles: 11.9-13-1.7=-2.8deg

Finite size arctan (1.5/6.5) = 13deg

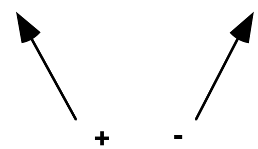
0.5 GeV particles: p=0.3B ρ, ρ=1.11m
arcsin(6.6/2/111)=1.7deg @r=6.5cm
arcsin(14/2/111)=3.6deg @r=14cm



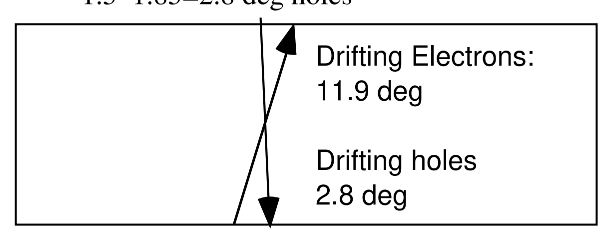
Effective Crossing Angle:

L.A. - S.K. + C.P. - T.A.

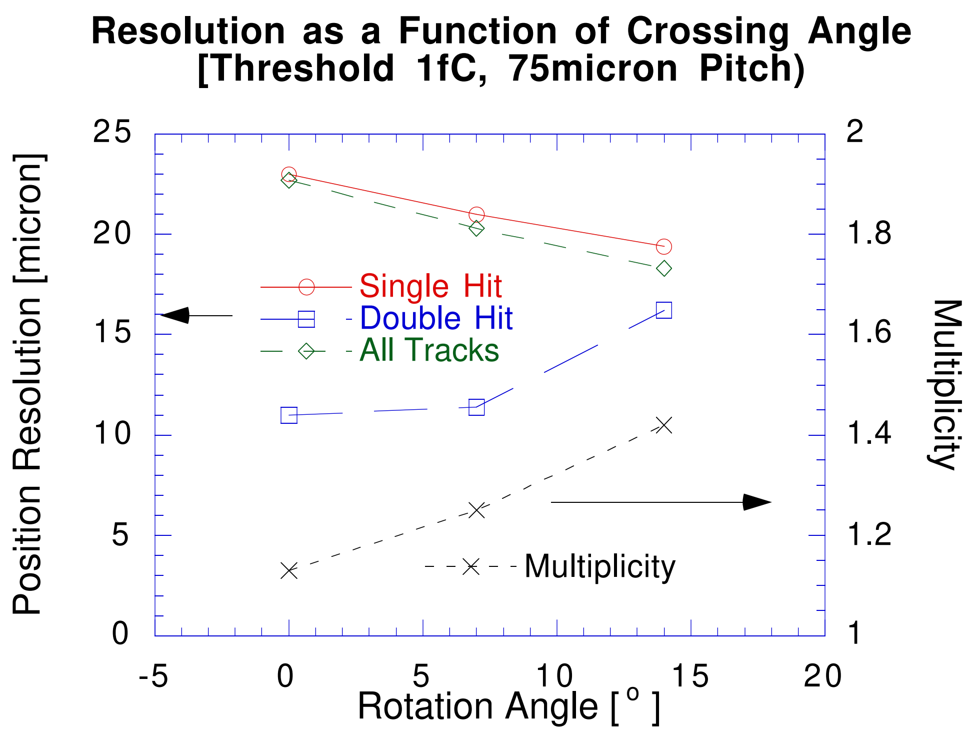
L.A. = 11.9 (e^-), 2.8 (h^+)
S.K. = atan(x/r)
C.P. = charge*asin(r/222) for 500MeV particles



Lorentzangle:
1.5*7.9=11.9 deg electrons
1.5*1.85=2.8 deg holes



Position Resolution: somewhat better for larger angle (sharing)



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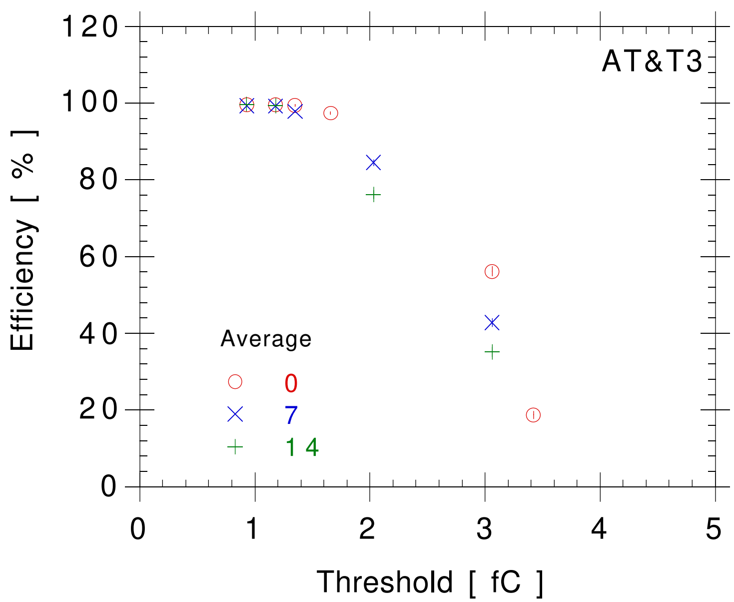
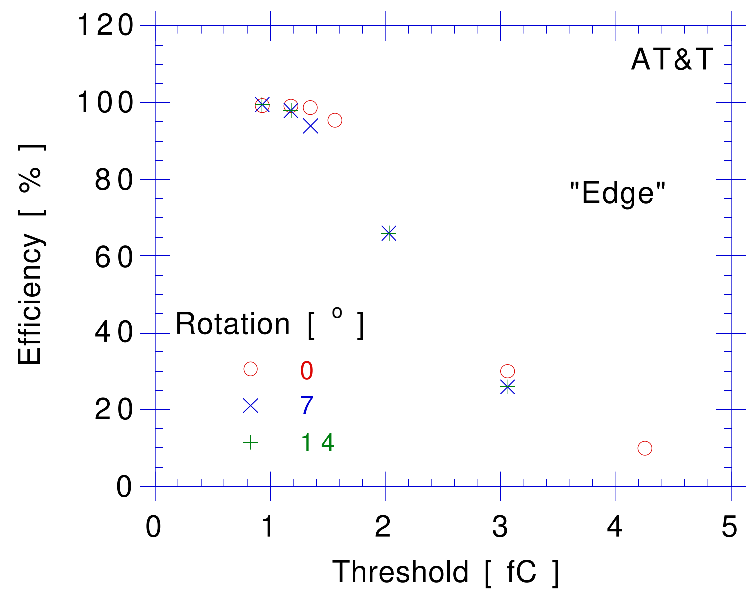
Efficiency: better for smaller crossing angle (sharing)





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Overlap (material+$$) better for smaller tilt angle

For complete coverage even for 500MeV particle need to overlap the detectors in r-ϕ

Extra Material as a function of tilt angle (ta):

r=6.5cm

tilt (ta) [deg]	Extra Area 1/cos(ta)	Due to gap=tan(ta)*sin(1.7)	Total
5	0.4%	0.3%	0.7%
10	1.5%	0.5%	2.0%
15	3.5%	0.8%	4.3%
20	6.4%	1.0%	7.4%

r=14cm

tilt [deg]	Extra Area 1/cos(ta)	Due to gap=tan(ta)*sin(3.6)	Total
5	0.4%	0.5%	0.9%
10	1.5%	1.1%	2.4%
15	3.5%	1.7%	5.2%
20	6.4%	2.3%	6.7%

Crossing angle as a function of tilt angle

The effective crossing angle depends on

- the charge collected (holes on p-side, electron on n-side) => Lorentz angle,
- the location on the detector and radius => Skew angle
- charge/momentum of the track and radius => charged part angle
- tilt angle

We evaluated it for

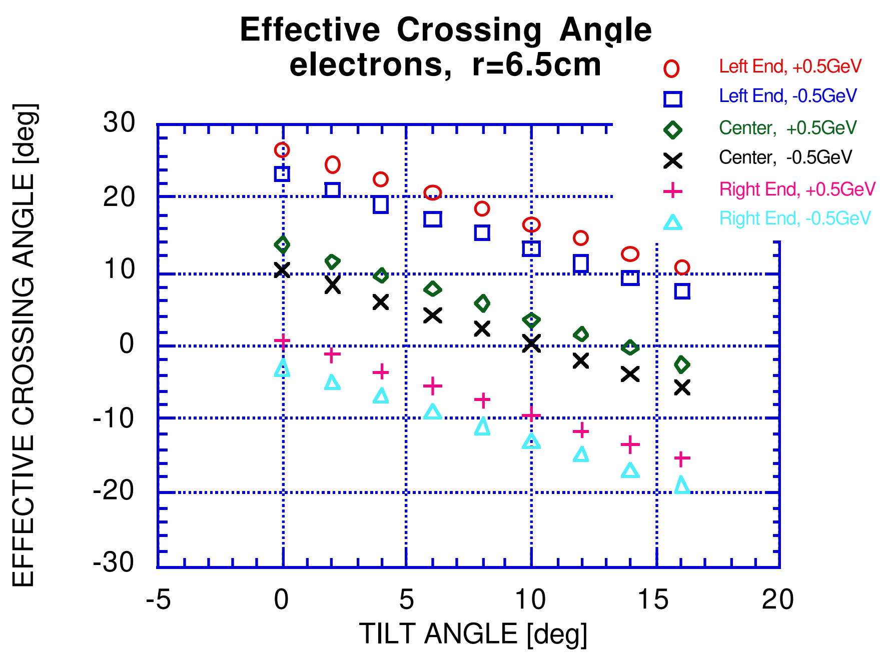
- electrons and holes
- min (6.5cm) and max (14cm) radius
- three locations on detector: center and two extreme edges
- two charges of 0.5GeV particles

Conclusions

A tilt angle of about 7^{o}, i.e. the average of the electron and hole Lorentz angles, is the best compromise to minimize the effective crossing angle.

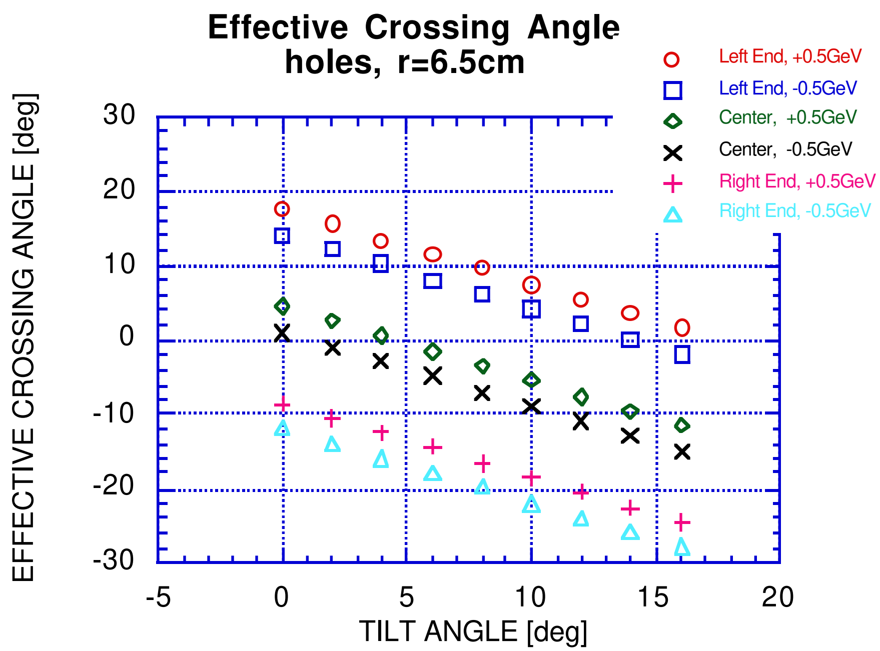
Crossing angle vs tilt for electrons @ r= 6.5cm: LA= 11.9°, SK = 13.0° CP= 1.7°

	LEFT		Center		RIGHT		Av	Max
Tilt	+	-	+	-	+	-		
0	26.6	23,2	13.6	10.2	0.6	-2.8	11.9	26.6
2	24.6	21.2	11.6	8.2	-1,4	-4.8	9.9	24.6
4	22.6	19.2	9.6	6.2	-3.4	-6.8	7.9	22.6
6	20.6	17.2	7.6	4.2	-5,4	-8.8	5.9	20.6
8	18.6	15.2	5.6	2.2	-7.4	-10.8	3.9	18.6
10	16.6	13.2	3.6	0.2	-9.4	-12.8	1.9	16.6
12	14.6	11.2	1.6	-1.8	-11.4	-14.8	-0.1	14.8
14	12.6	9.2	-0.4	-3.8	-13.4	-16.8	-2.1	16.8
16	10.6	7.2	-2.4	-5.8	-15.4	-18.8	-4.1	18.8
Formula	LA+SK+CP-T	LA+SK-CP-T	LA+CP-T	LA-CP-T	LA-SK+CP-T	LA-SK-CP-T	La-T	



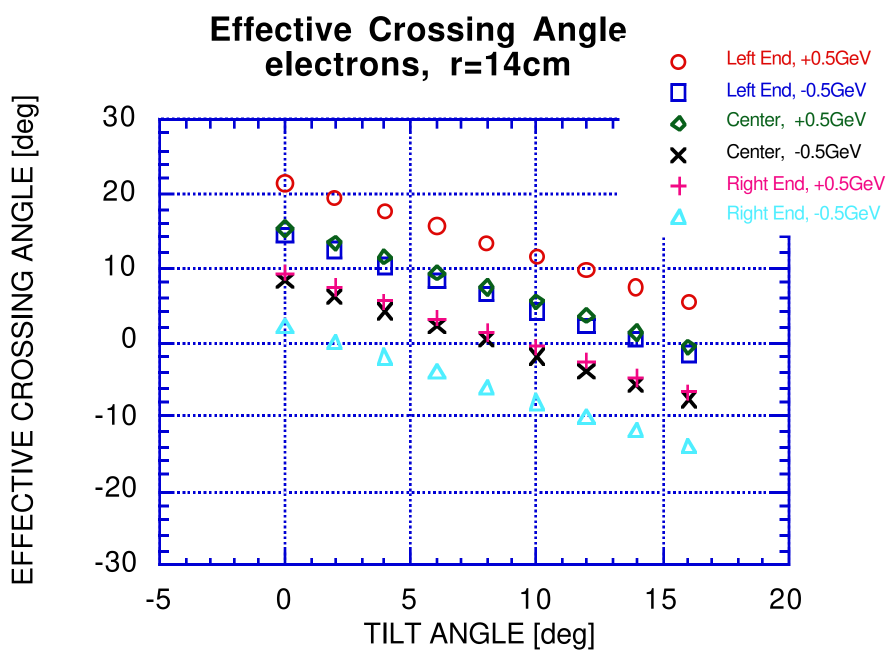
Crossing Angle vs tilt for holes @ r= 6.5cm: LA= 2.8^{o}, SK = 13.0^{o} CP= 1.7^{o}

	LEFT		Center		RIGHT		Av	Max
Tilt	+	-	+	-	+	-		
0	17.5	14.1	4.5	1.1	-8.5	-11.9	2.8	17.5
2	15.5	12.1	2.5	-0.9	-10.5	-13.9	0.8	15.5
4	13.5	10.1	0.5	-2.9	-12.5	-15.9	-1.2	15.9
6	11.5	8.1	-1.5	-4.9	-14.5	-17.9	-3.2	17.9
8	9.5	6.1	-3.5	-6.9	-16.5	-19.9	-5.2	19.9
10	7.5	4.1	-5.5	-8.9	-18.5	-21.9	-7.2	21.9
12	5.5	2.1	-7.5	-10.9	-20.5	-23.9	-9.2	23.9
14	3.5	0.1	-9.5	-12.9	-22.5	-25.9	-11.2	25.9
16	1.5	-1.9	-11.5	-14.9	-24.5	-27.9	-13.2	27.9
Formula	LA+SK+CP-T	LA+SK-CP-T	LA+CP-T	LA-CP-T	LA-SK+CP-T	LA-SK-CP-T	La-T	



Crossing angle vs tilt for electrons @r=14cm: LA= 11.8º, SK = 6.1º CP= 3.6º

	LEFT		Center		RIGHT		Av	Max
Tilt	+	-	+	-	+	-		
0	21.5	14.3	15.4	8.2	9.3	2.1	11.8	21.5
2	19.5	12.3	13.4	6.2	7.3	0.1	9.8	19.5
4	17.5	10.3	11.4	4.2	5.3	-1.9	7.8	17.5
6	15.5	8.3	9.4	2.2	3.3	-3.9	5.8	15.5
8	13.5	6.3	7.4	0.25	1.3	-5.9	3.8	13.5
10	11.5	4.3	5.4	-1.8	-0.7	-7.9	1.8	11.5
12	9.5	2.3	3.4	-3.8	-2.7	-9.9	-0.2	9.9
14	7.5	0.3	1.4	-5.8	-4.7	-11.9	-2.2	11.9
16	5.5	-1.7	-0.6	-7.8	-6.7	-13.9	-4.2	13.9
Formula	LA+SK+CP-T	LA+SK-CP-T	LA+CP-T	LA-CP-T	LA-SK+CP-T	LA-SK-CP-T	La-T	



Crossing angle vs tilt for holes @ r= 14cm: LA= 2.8^{o}, SK = 6.1^{o} CP= 3.6^{o}

	LEFT		Center		RIGHT		Av	Max
Tilt	+	-	+	-	+	-		
0	12.5	5.3	6.4	-0.8	0.3	-6.9	2.8	12.5
2	10.5	3.3	4.4	-2.8	-2.3	-8.9	0.8	10.5
4	8.5	1.3	2.4	-4.8	-4.3	-10.9	-1.2	10.9
6	6.5	-0.7	0.4	-6.8	-6.3	-12.9	-3.2	12.9
8	4.5	-2.7	-1.6	-8.8	-8.3	-14.9	-5.2	14.9
10	2.5	-4.7	-3.6	-10.8	-10.3	-16.9	-7.2	16.9
12	0.5	-6.7	-5.6	-12.8	-12.3	-18.9	-9.2	18.9
14	-1.5	-8.7	-7.6	-14.8	-14.3	-20.9	-11.2	20.9
16	3.5	-10.7	-9.6	-16.8	-16.3	-22.9	-13.2	22.9
Formula	LA+SK+CP-T	LA+SK-CP-T	LA+CP-T	LA-CP-T	LA-SK+CP-T	LA-SK-CP-T	La-T