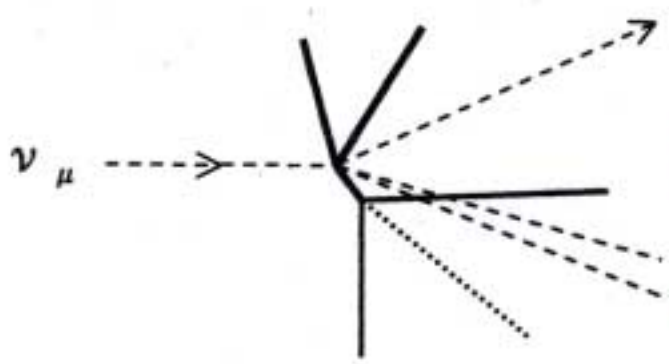
Super fragment search in CHORUS

nucleus containing charmed baryon



small i.p. black (~ few μm ?)
big energy release > hyperf
(Evis > ~200MeV)
or with thin track

I Image taking

II Overview of image analysis

III Super fragment search

IV Hyperfragment candidates
$\Lambda c \rightarrow \Sigma^+ \pi^+ \pi^- (\pi^0)$ decay

V Summary

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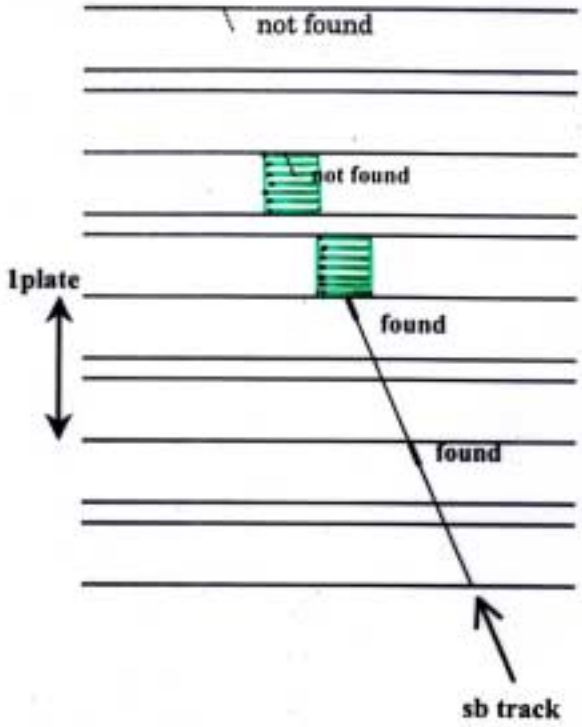
9-Mar-'02

Image taking



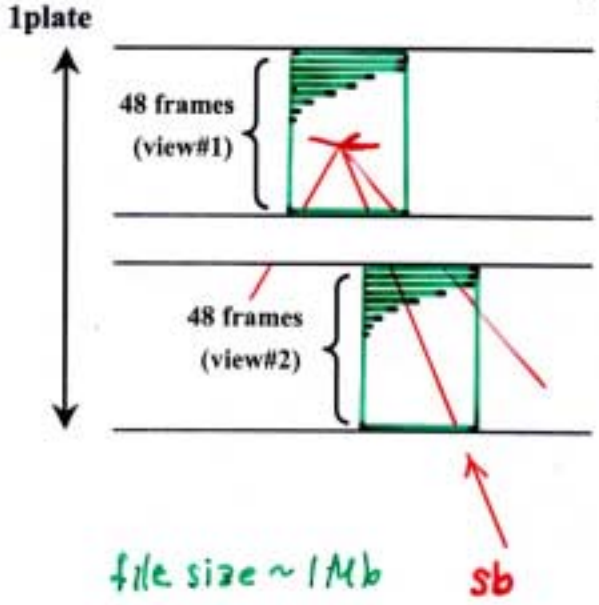
Scanback track is missed in a certain plate

Images taken in the plate where track is missed

Size of image :

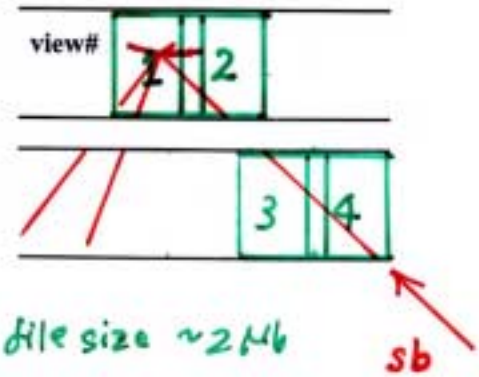
$\sim 150\,\mu m \times 130\,\mu m \times 350\,\mu m$ in each side

$(512^{pixels} \times 512^{pixels} \times 48^{frames})$

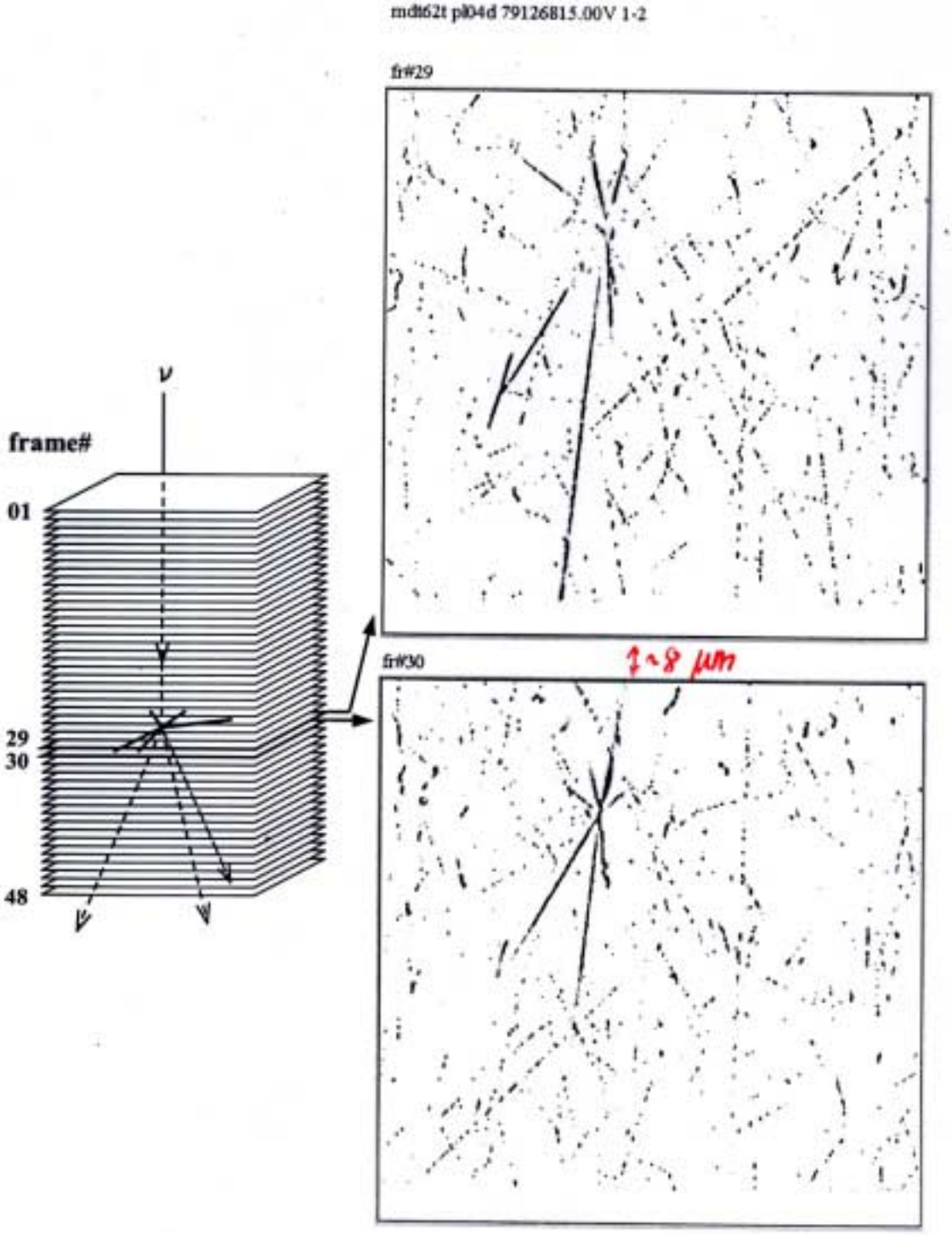


An image is consisted of 2~6 views
Each view consisted of 48 frames

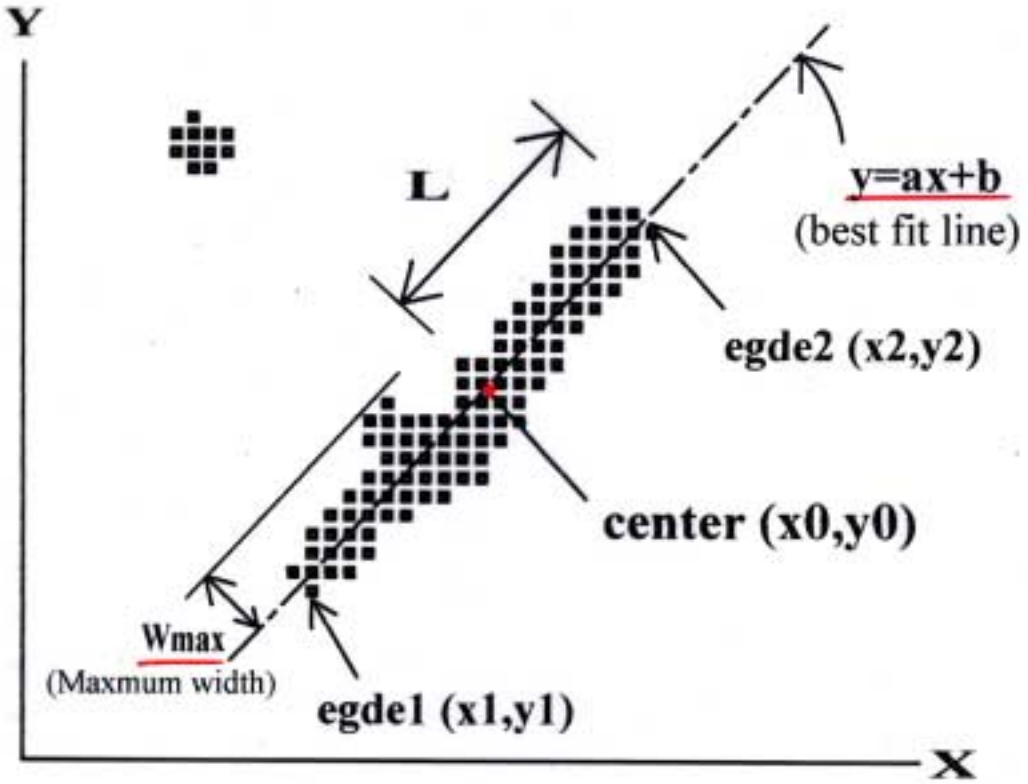
angle of scanback track is big



Sample of images



Parameter of a cluster



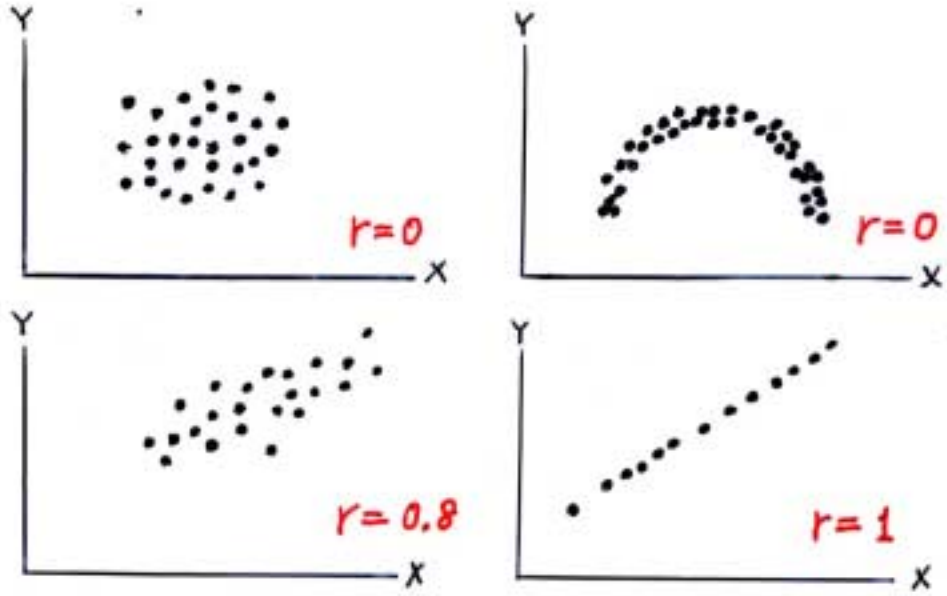
size (#pixel) n

correlation coefficient r

$$r = \frac{\sum_{i=1}^{n} (x_i - x)(y_i - y)}{(n-1)\, s_x\, s_y}$$

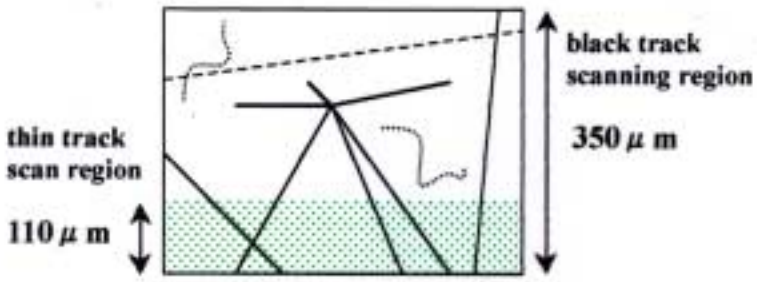
(xi,yi):position of pixel consist of a cluster

to know shape of cluster is line or not



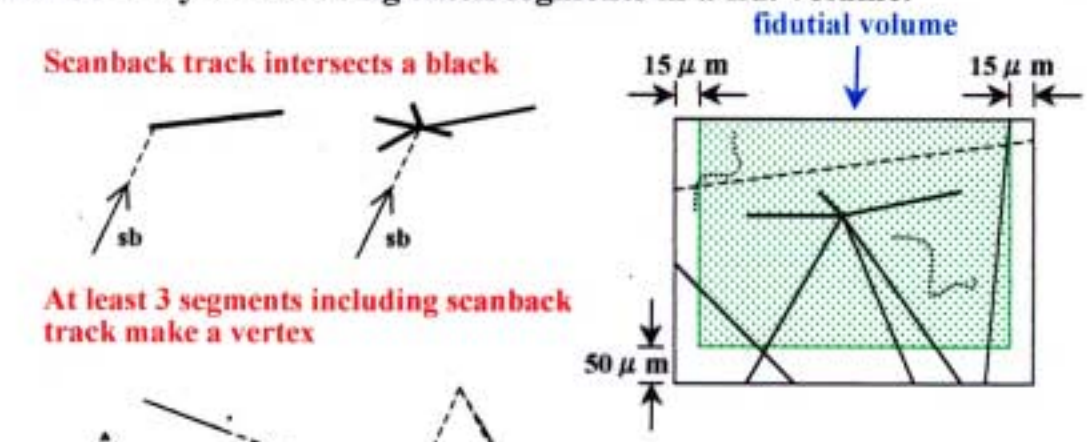
Overview of image analysis to search superfragment

1. **Scan all tracks with tan θ < 0.5 penetrating at least 8 frames (~52 μ m) in a region of downstream 110 μ m.**
   (110 μ m is selsected to save CPU time)



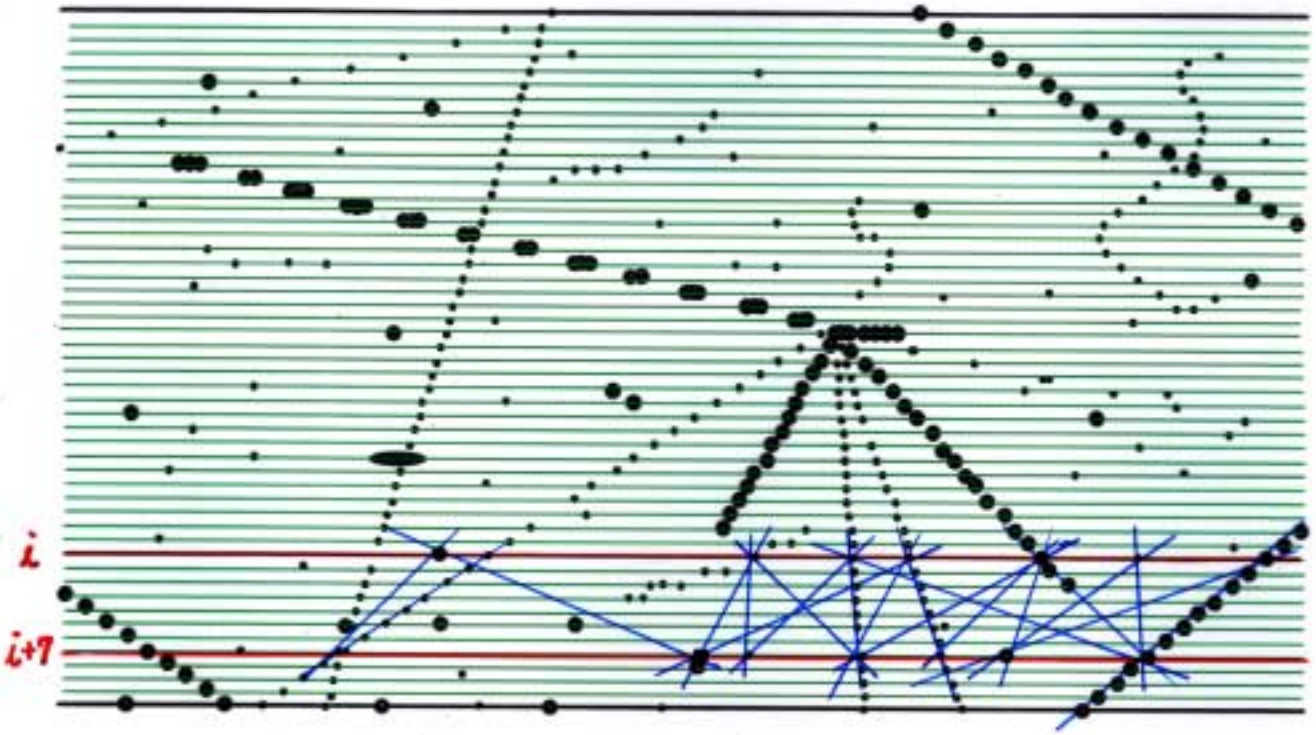
2. **Scan all black track with tan θ < 1.5**

3. **Search a 1ry vertex using track segments in a fid. volume.**

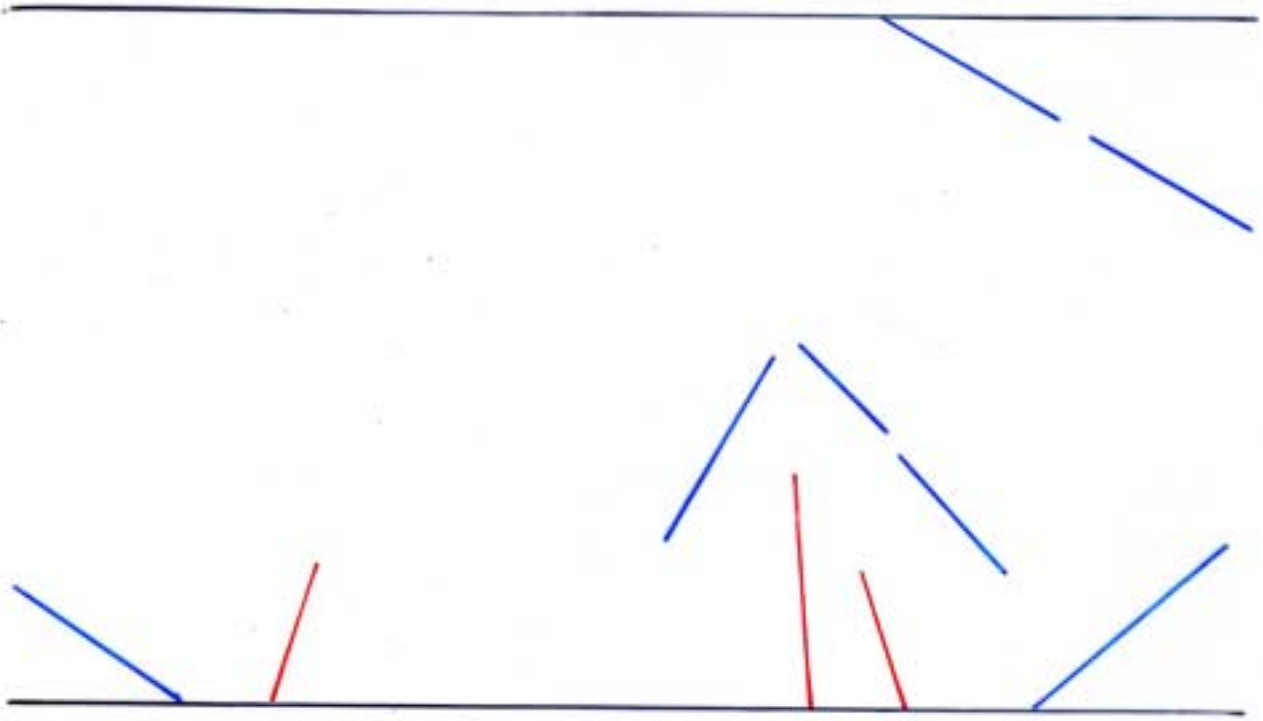


4. **Search black tracks with i.p.>2 μ m** or not lined clusters

Track scanning algorithm



1. Make lines using any 2 clusters in frame i and i+7 (d=52 micron) for thin track
   i+6 (d=45 μm) for black
2. Count the number of cluster on each line.
3. Find track segment.
4. If segment is found, extend a line.
5. Change i to i+1, and repeat



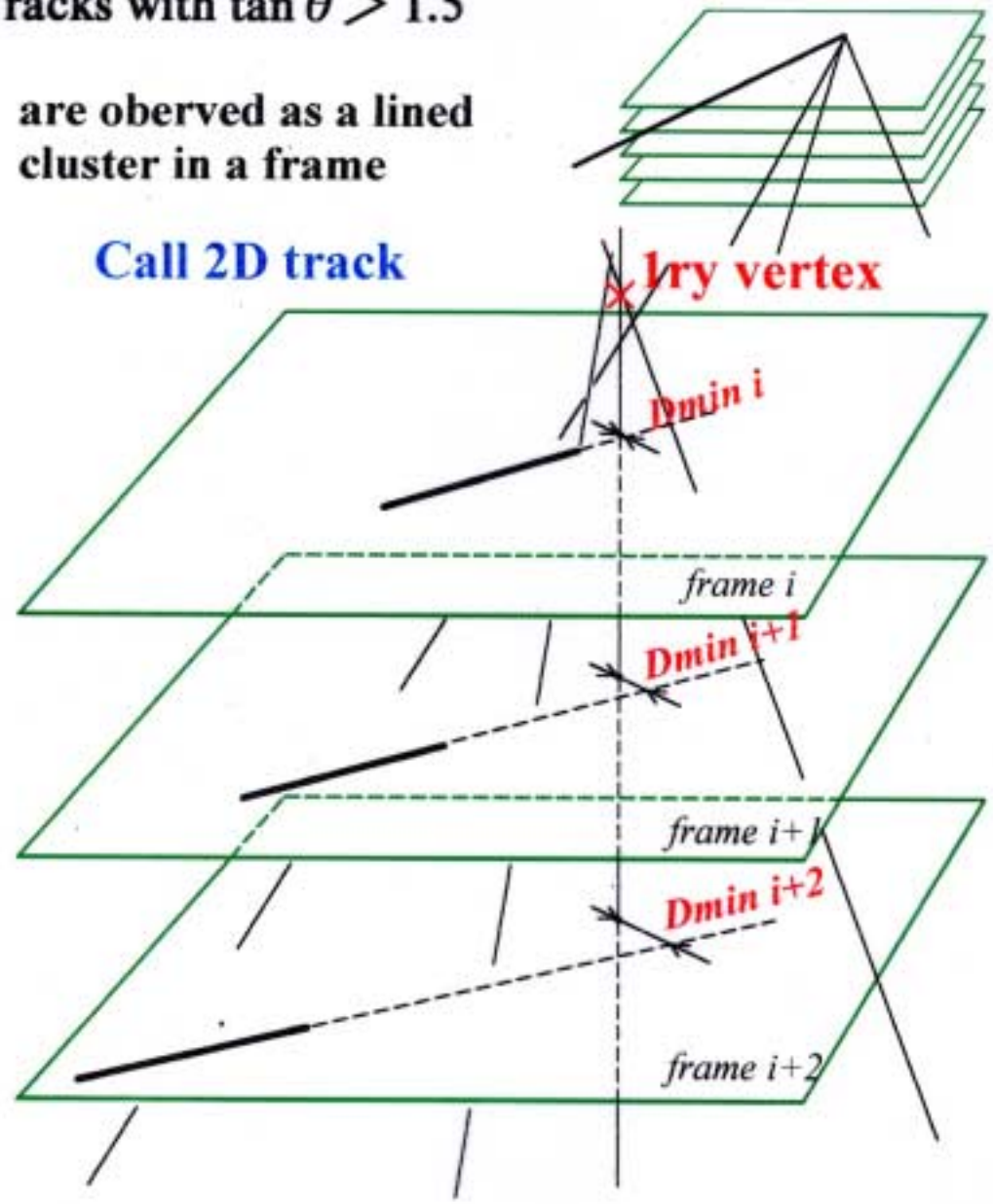
Several segments are found (average ~ 10/event)

call these segments 3D tracks

($\tan\theta < 1.5$)

Tracks with $\tan\theta > 1.5$

are oberved as a lined cluster in a frame

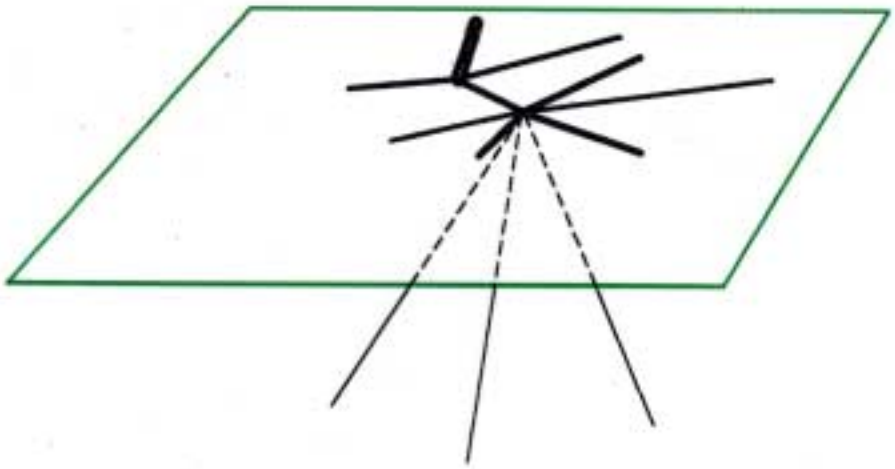


Get minimum distance in each frame within 3 frames($\sim 20\,\mu$m) from 1ry vertex.

If at least 1 frame Dmin > 2 μm → viewer check.

In a frame very near vertex

Black tracks are not isolated.
Shape of cluster is complecated even if hyperfragment is not produced



Cut a hole with radius of 1.5 μ m which center is a 1ry vertex.

no hyperfragment

All blacks are separated as lined cluster stop to analize

if exist a cluster with r<0.9 and size>250

go to viewer check

Accuracy of 1ry vertex

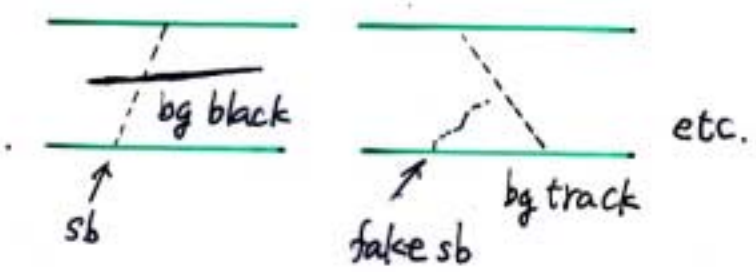
For mod71b
Checked vertices found by program with image-viewer for accuracy and measured vertex position manually

		#images	(#events)
mod71b	Analized	1011	(960)
	1ry found	488	(345)

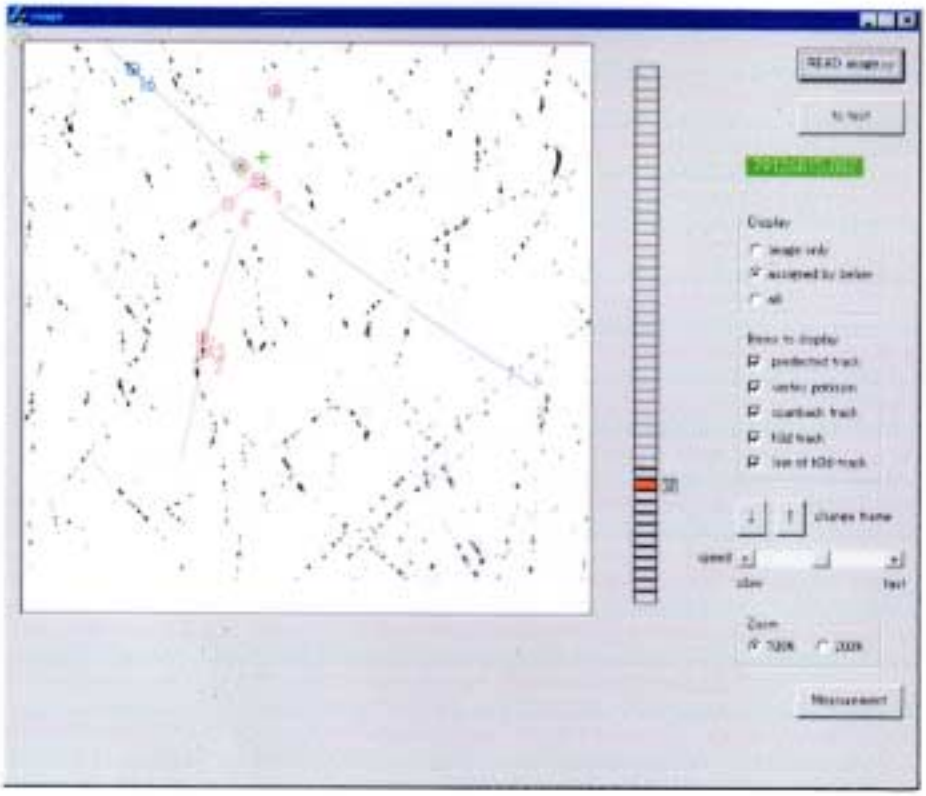
↓

Check and measure with image-viewer

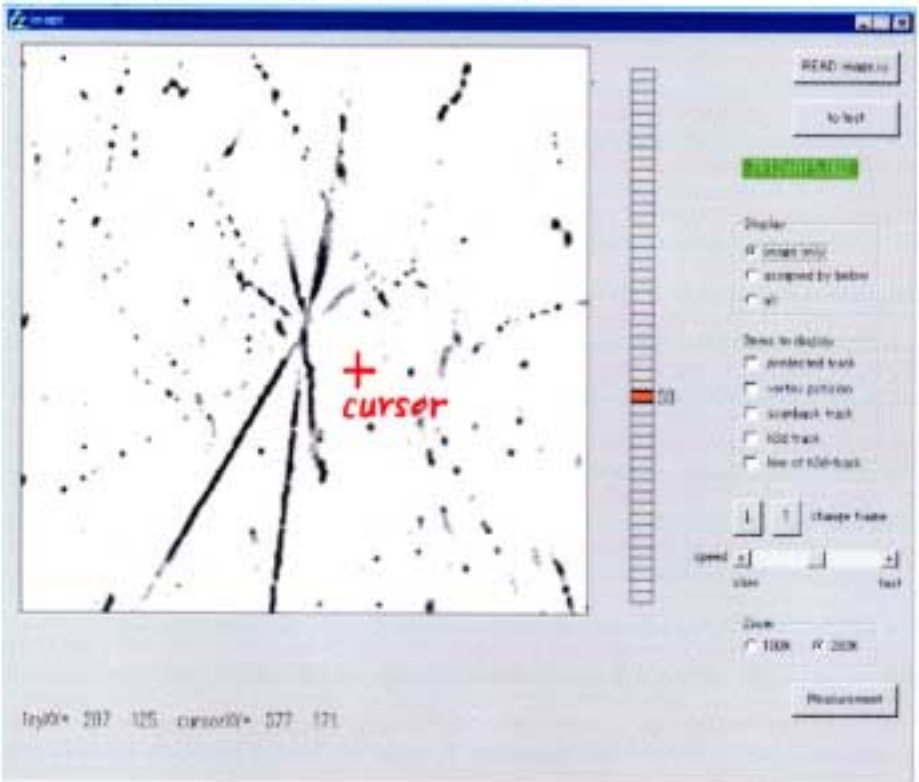
488 {
- Real vertex exist 479 images → measure
- Fake vertex 9 images

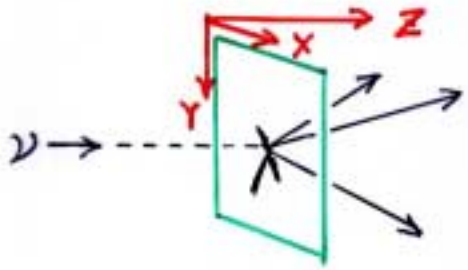


Display of image-viewer

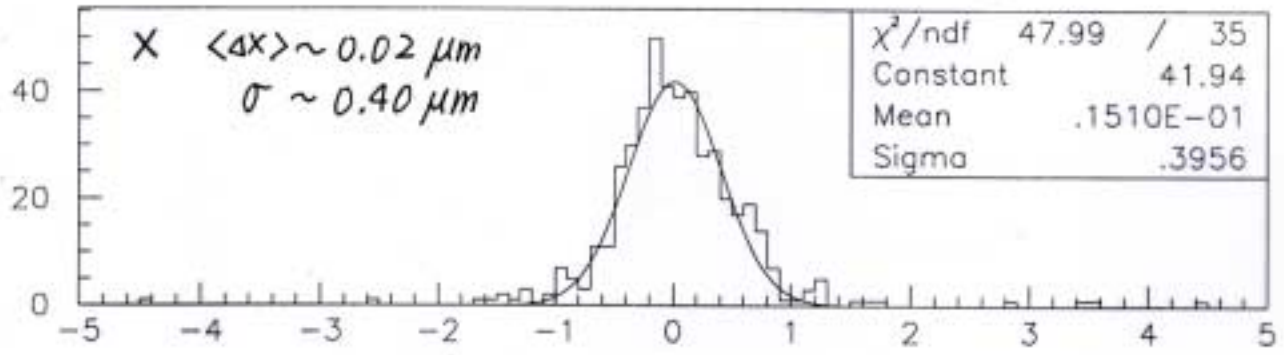


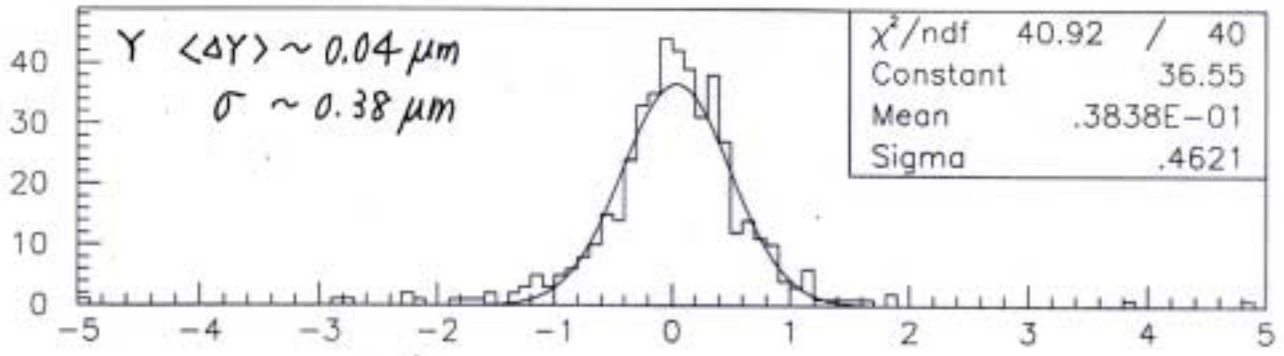
zooming (×200)、 measurement is possible

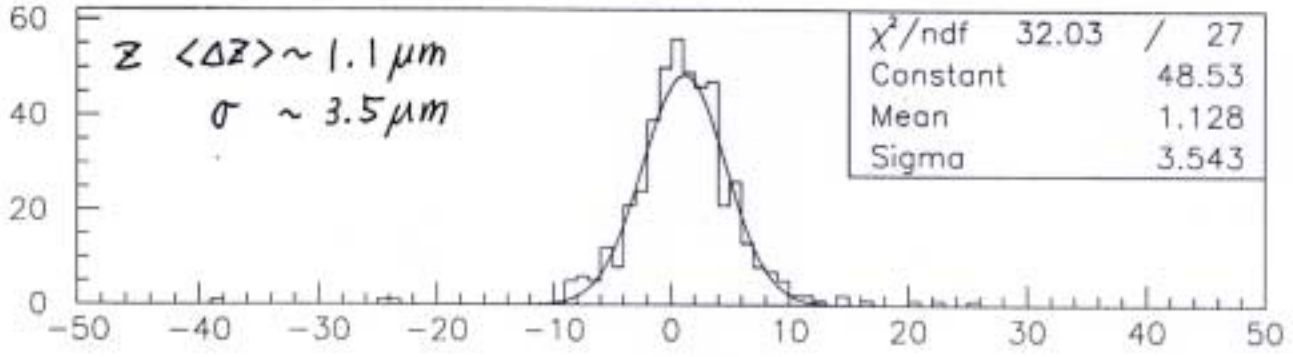




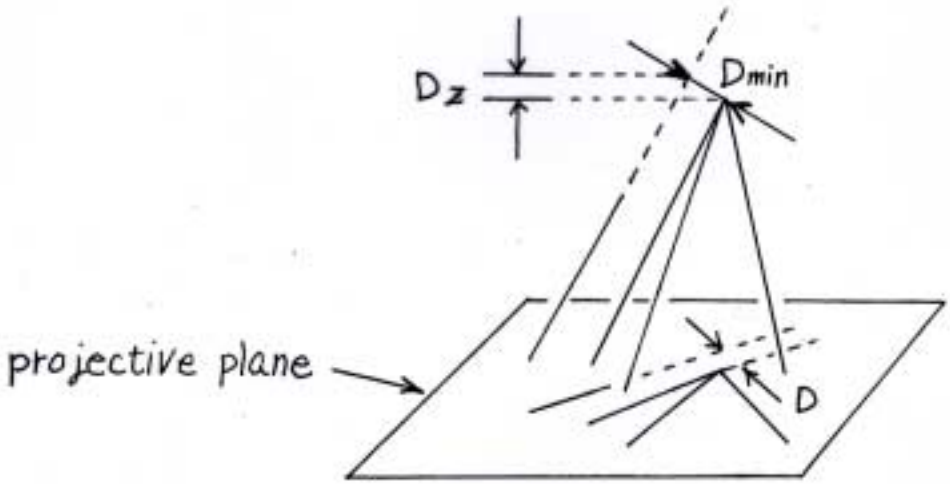
Vertex difference of program from person mesure.



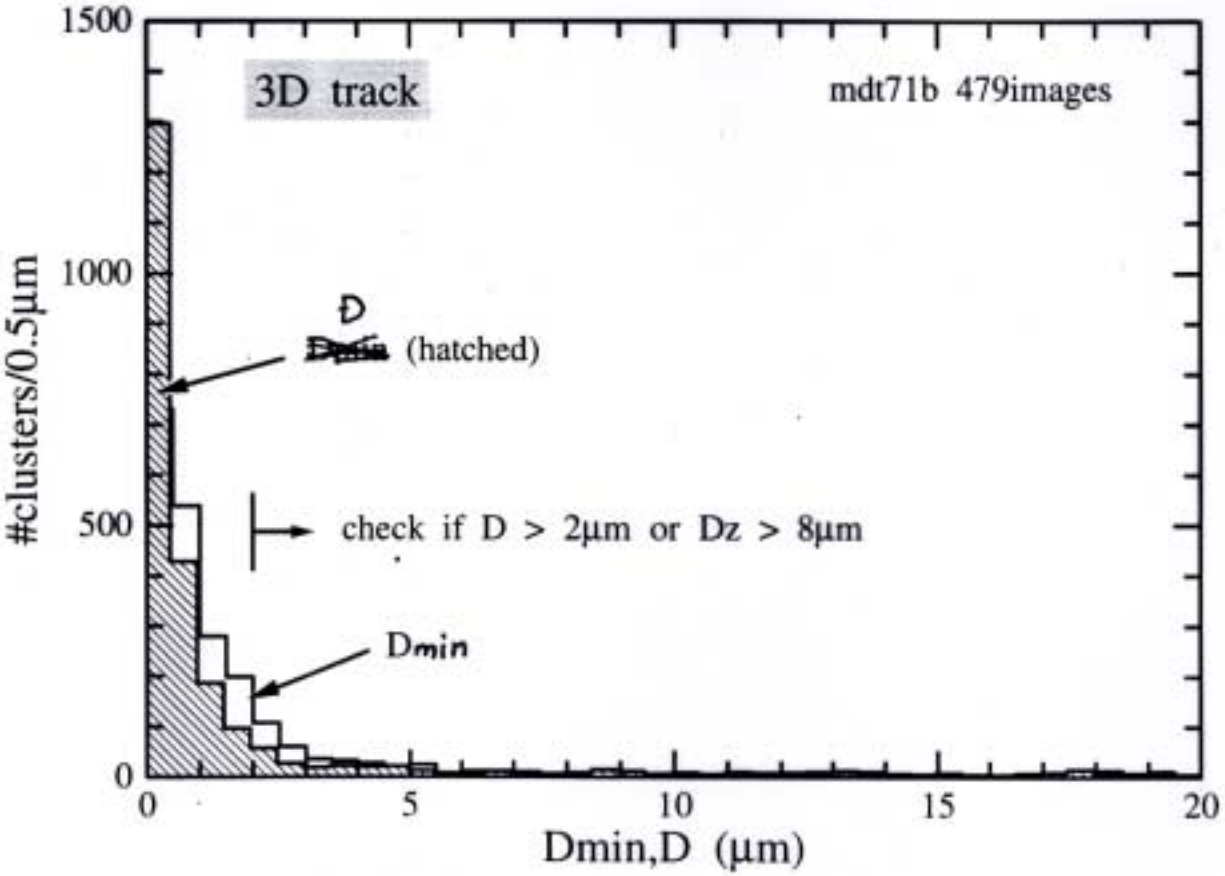


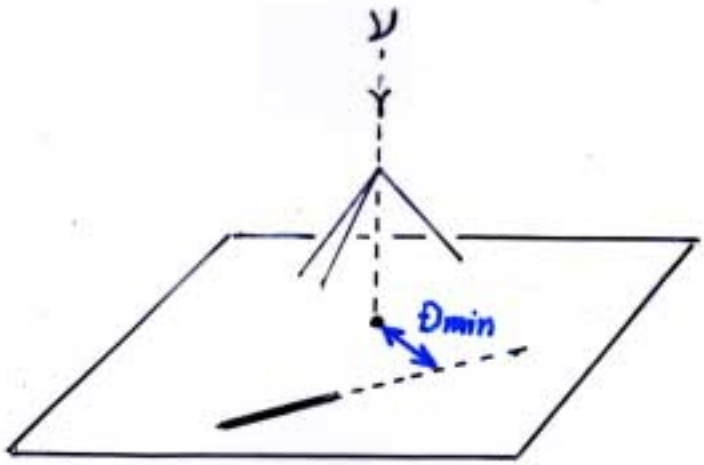


well agree

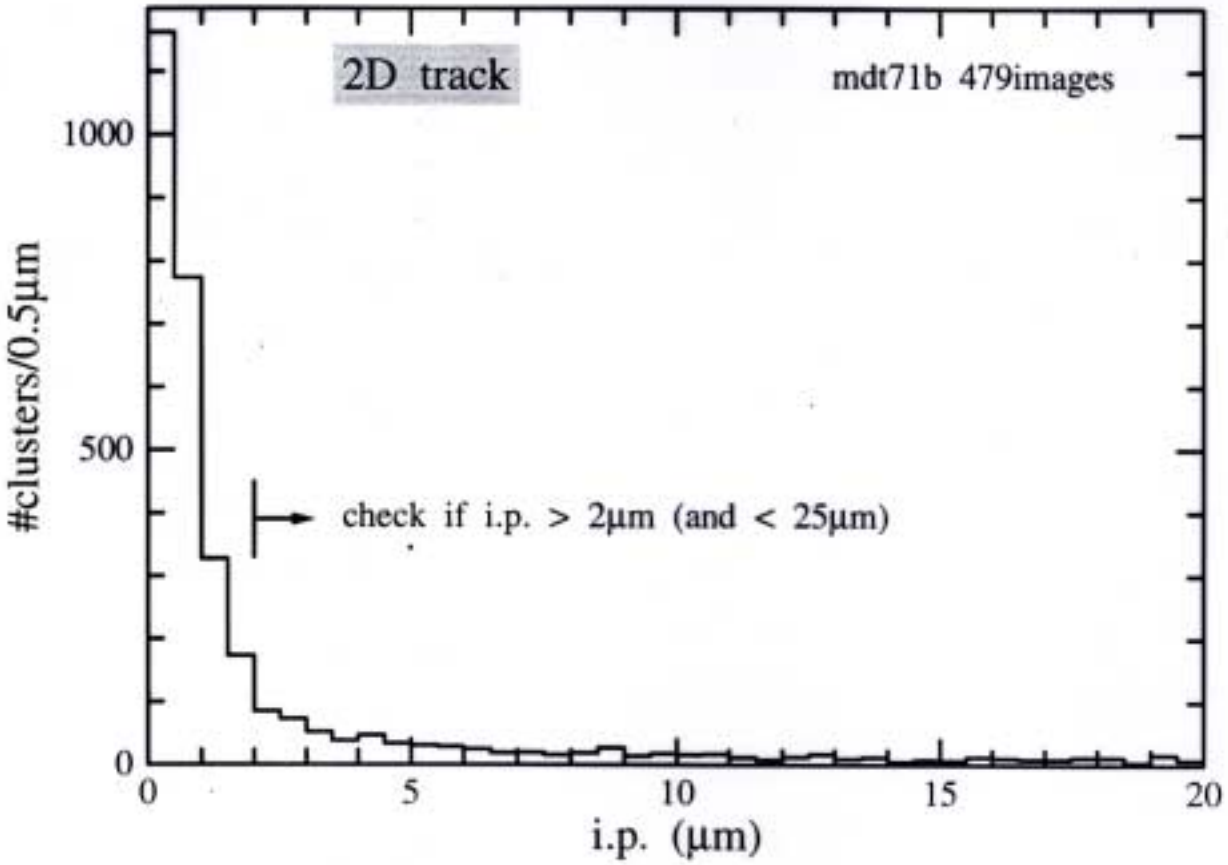


Dmin : minimum distance from a vertex position
D : minimum distance in a projective plane





Impact parameter of 2D track in each frame



Super fragment search

Images in '97 Run are analized

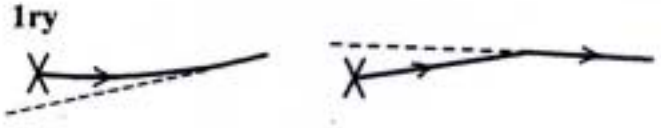
	#images	(#events)	Ratio (events)
#Images analized	**42559**	**(39586)**	**1.**
1ry found (in fiducial volume)	**20247**	**(14760)**	**0.373**
Have a black(s) with i.p.$\geqq 2\,\mu$ m or not lined clusters	**6803**	**(5668)**	**0.143**

Viewer check (check images by eye with an image-viewer)

2min/images

Result of viewer check

Most of them are curve or trivial scattering.

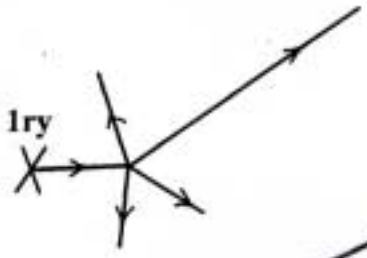


Manual check in em. **157** **(events)**

Result of manual check

157 events

Found 2ry vertex (39 events + (4 accidentally))

#prongs from 2ry vertex		#events + (accidentally)
4		3
3		9
2		6 + (1)
1		7
Hammer track with electron		7 + (3)
without thin track		4
Others (2ry int., bg?, ...)		3

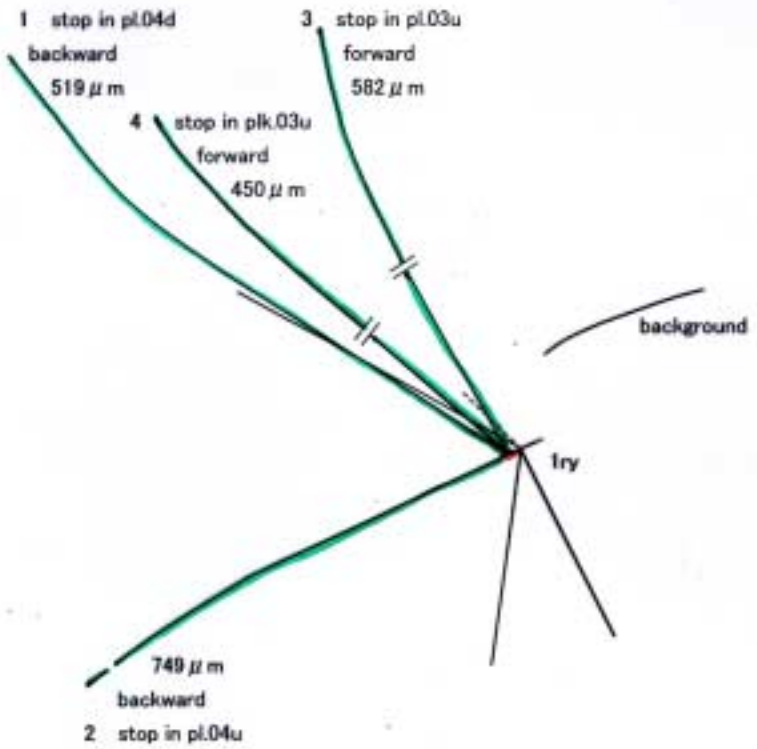
All 2ry tracks are followed and measured range

Background

(α decay, scatt+overlap track, scatt, ...) **114**

WA95 MDT 75B EV 81288152 date '01/Dec/12

PL# 04d

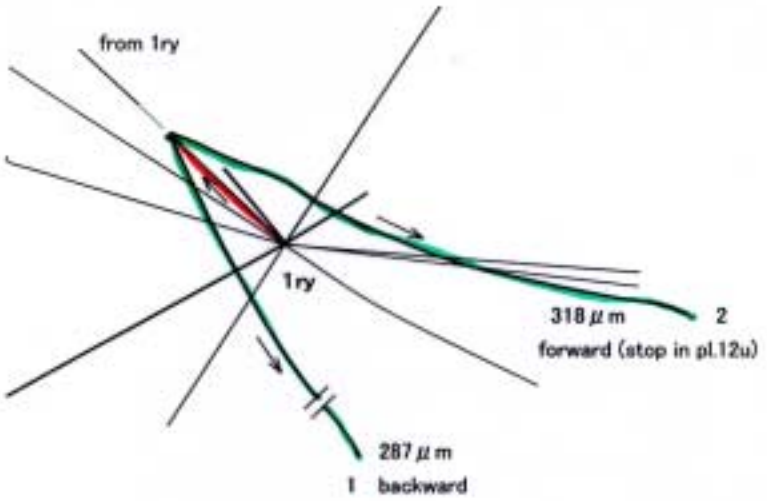


Track#	Length(μm)	E(MeV)	ID	
0	11			
1	519	9.7	(P)	
2	749	12.0	(P)	
3	582	10.3	(P)	
4	450	8.9	(P)	

Memo Evis ~40 MeV

WA95 MDT 61B EV 75779824 date '01/Dec/12

PL# 13d

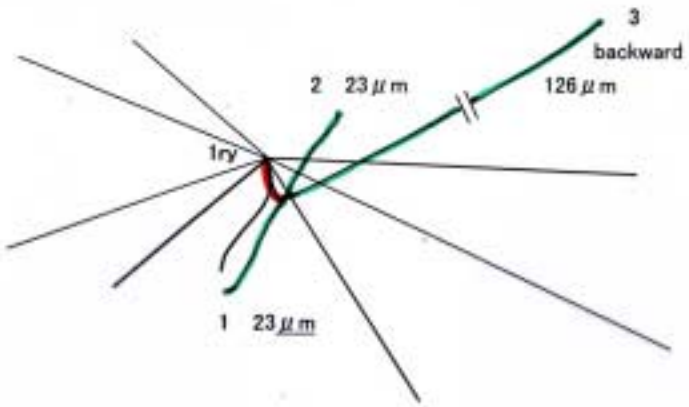


Track#	Length(μm)	E(MeV)	ID	
0	45			
1	287	6.8	(P)	
2	318	7.2	(P)	

Memo Evis ~ 14 MeV

WA95 MDT 75B EV 81811986 date '01/Dec/12

PL# 10d



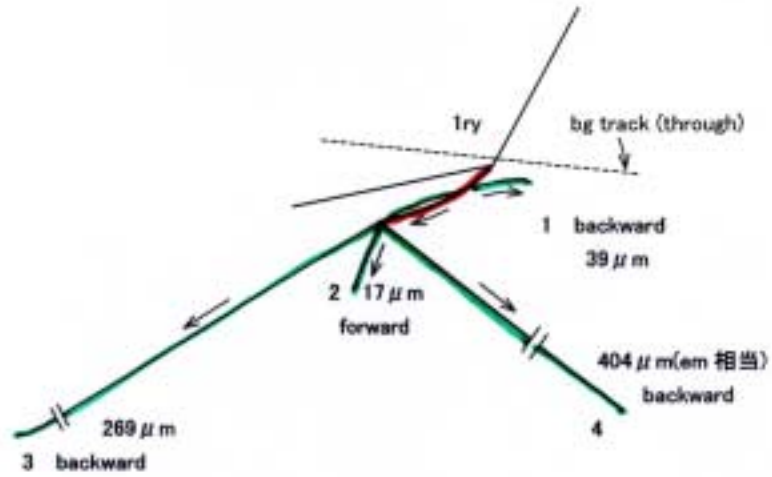
Track#	Length(μm)	E(MeV)	ID	
0	35			
1	23	1.4	(P)	
2	23	1.4	(P)	
3	126	4.2	(P)	

Memo

Evis ~ 7.0 MeV

WA95 MDT 75B EV 81430390 date '01/Dec/ 12

PL# 27d



Track#	Length(μm)	E(MeV)	ID	
	33			
1	39	2.0	(P)	
2	17	1.2	(P)	
3	269	6.5	(P)	
4	404	8.3	(P)	

Memo

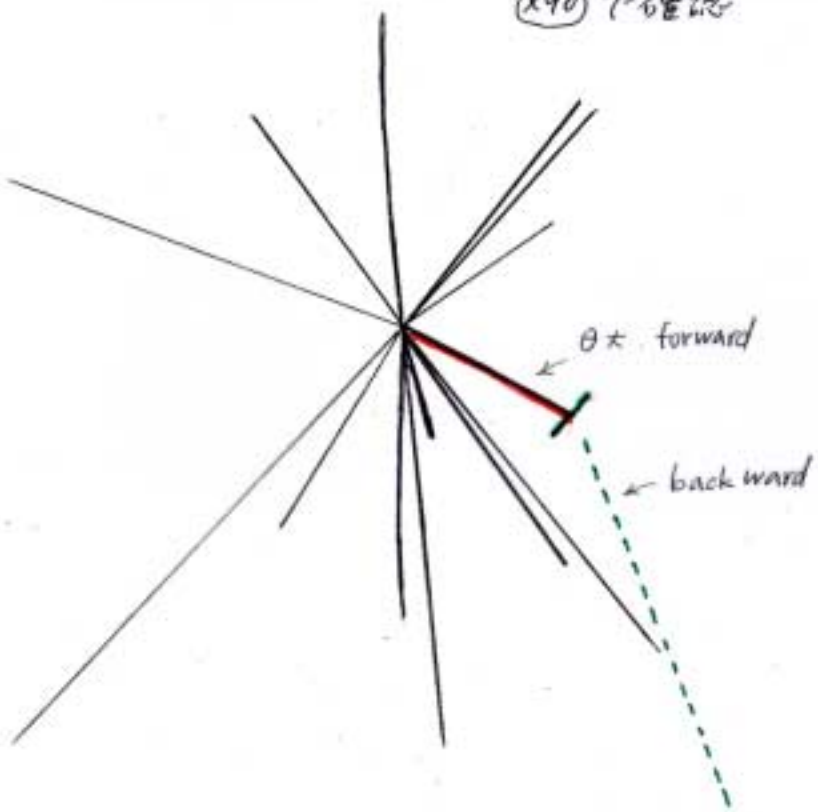
Evis~18.

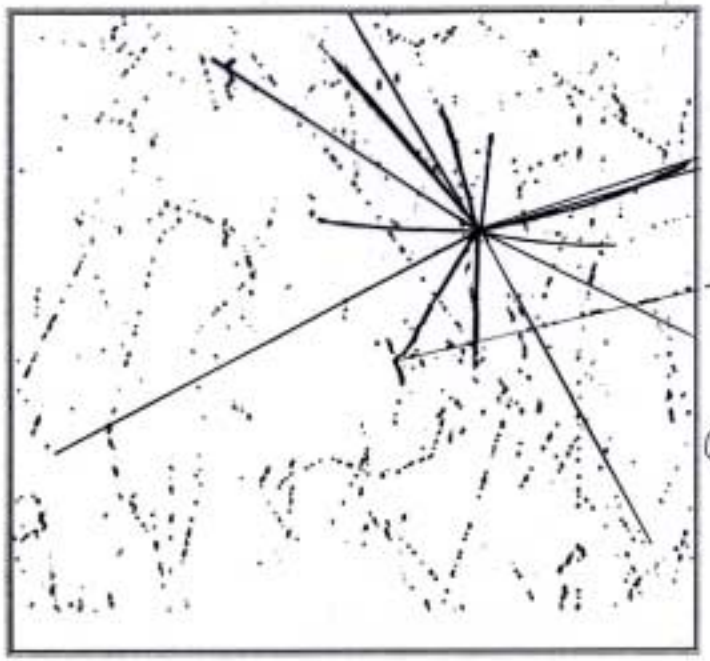
mdt62t29 pp.35 78249944.00V 0-1 (20)

'01年7月18日

X50 で sketch

X90 で確認

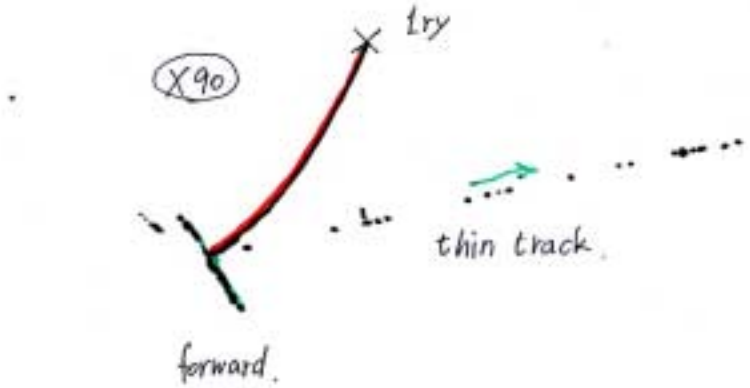




Nh≧14

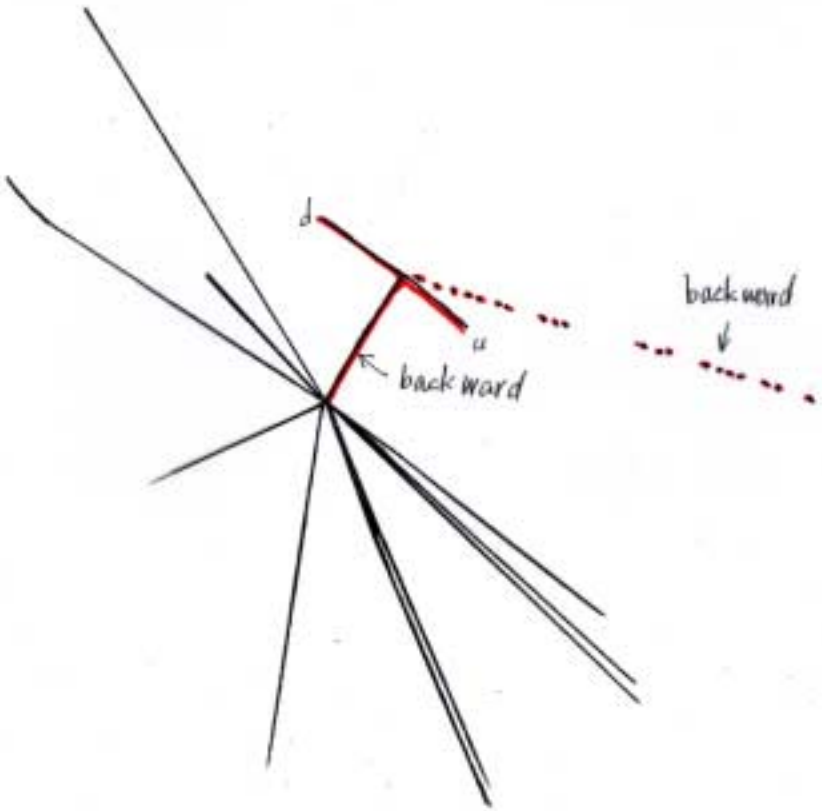
'01年7月21日

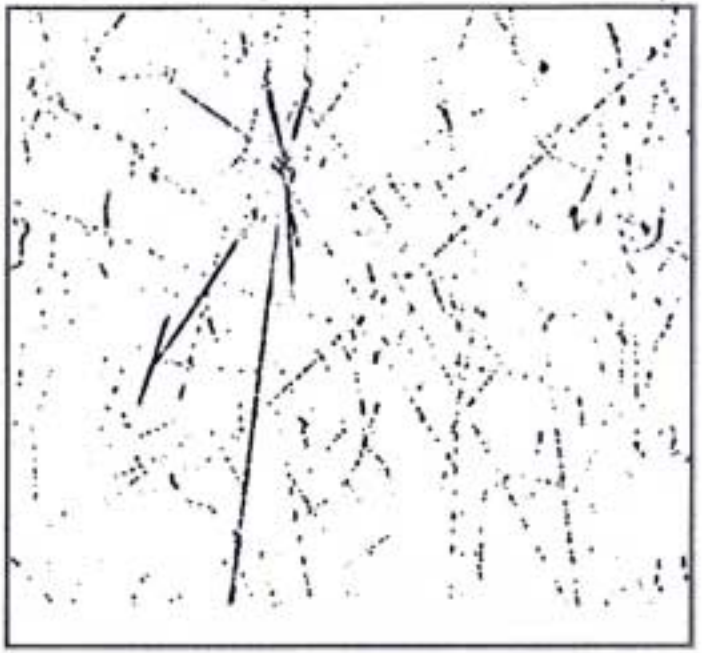
mdt62b29 pl1 var45 8133065800v 1-3 (2D) fr#13



mdt 72 t5 pl.3| 75896807.00T 0-1 (20) up

X50 '01年8月1日



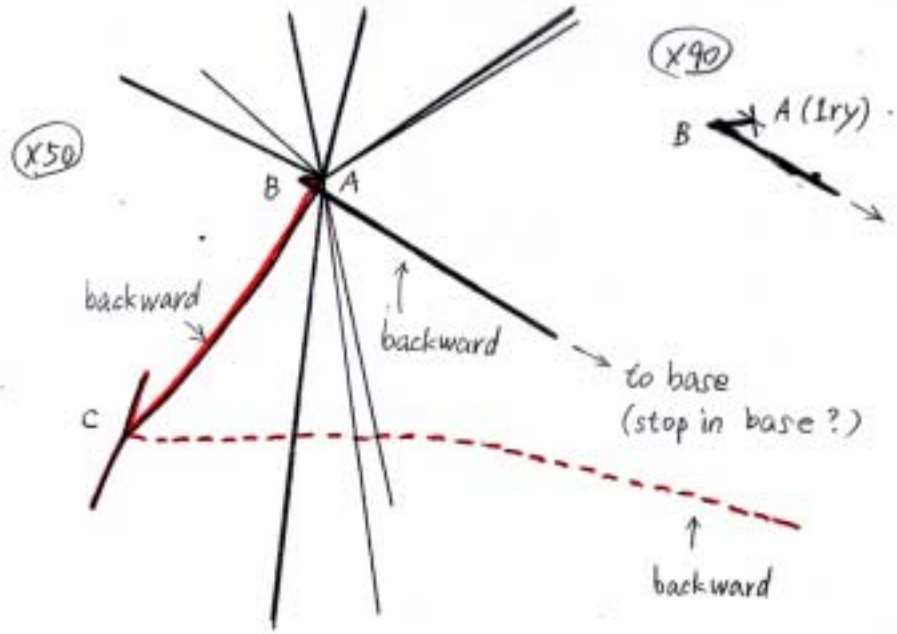


'01年7月1日

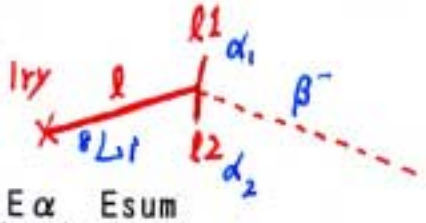
down

hammer track
+ black recoil (?)

mdt62b29 pl04 var45 79126815.00v 1-2 (2D/3D) fr#29



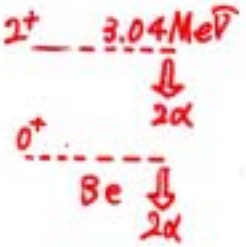
Hammer track with electron



Mdt	Event	Pl.	l(μm)	l1(μm) l2(μm)	Eα (MeV)	Esum (MeV)	memo
72T	75896807	31u	27.5	14.1 14.5	3.7 3.8	7.5	
62T	78249949	35u	29.5	5.5 5.6	1.7 1.7	3.4	
75B	78924158	10u	44.7	3.2 5.1	0.9 1.5	2.4	
62B	79126815	04d	50.4	9.7 11.4	2.8 3.0	5.8	
62B	81330658	11d	43.4	4.1 4.7	1.2 1.4	2.6	
62B	81523018	25u	43.2	4.9 7.8	1.5 2.3	3.8	
75B	82270230	28u	22.6	5.8 6.7	1.7 2.0	3.7	
58B	76000296	04u	70.7	4.6 5.9	1.3 1.8	3.1	not triggered (accidentally)
58T	80970796	16u	60.6	3.8 4.4	1.2 1.3	2.5	not triggered (accidentally)
56B	81154926	30u	25.7	5.4 7.2	1.6 2.2	3.8	not triggered (accidentally)

⟨3.9⟩

consistent with $^{8}Li \rightarrow {}^{8}Be^{*}\,\beta^{-}\,\bar{\nu}$, $^{8}Be^{*} \hookrightarrow 2\alpha$



not hypertragment

List of multi-pring 2ry vertex

Mdt	Event	Pl.	parent l (μm)	#prong	Visible E (MeV)		
62B	73660464	26u		3			
●82B	73831188	25u	6.9	3	>110 (π)	Trident?	with thin track
57B	76090364	23u	8.4	3	13.6		
●76B	76273799	11d	39	3	31.0	σ star?	Evis > 30 MeV
58T	78480676	28u	33	4	22.3	σ star?	
→●71B	78902354	05u	3.6	3	(94)	Λc	with thin track
●62B	79839619	31u	5.6	3	50.8		with fast proton
●62B	80331217	12d	4.2	3	59.2		with fast proton
●75B	81288152	04d	11	4	40.9		Evis > 30 MeV
75B	81430390	27d	33	4	18.0	σ star?	
75B	81811986	10d	35	3	7.0	σ star?	
61B	81126567	29d		3	7.0	σ star?	
61B	75779824	13d	45	2	14.0		
62B	77582905	31u	6.8	2	10.1		
86T	77711100	15d		2			
●86T	80248935	21u	21	2	37.5		with fast proton
75T	76285951	36u		2?			
57T	75924415	25d		2		(heavy+thin)?	
76B	77640997	09d	~58	2		accidentally	

1prong 2ry vertx

61B	76065394	20u	29.1	1			
62B	76173988	19d		1+blob			
65T	78861466	27u	68.7	1			
58B	79837369	16u		1+blob?			
75B	79488765	13u	·	1			
76B	80437996	10u	102	1			
57B	80952701	10u	75.3	1 (thin? Bg?)			

Identification of hyperfragment

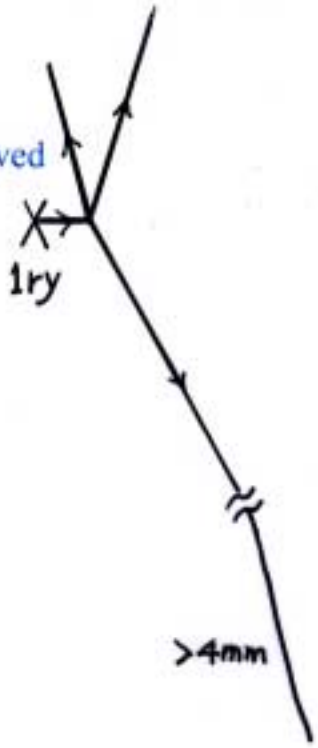
Candidate for hyperfragment

π -mesic decay

(1) $\Lambda^0 \rightarrow p + \pi^- + 37.8$ **MeV** (64.2%)
enegetic π^- is observed as thin track

(2) $\Lambda^0 \rightarrow n + \pi^0 + 41.1$ **MeV** (35.8%)
difficult

Non-mesic decay



(3) $\Lambda^0 + p \rightarrow p + n + 176$ **MeV**
energetic proton (>30MeV, called fast p) is observed as black track with range > 4mm
large energy release (Evis > 30 MeV)

(4) $\Lambda^0 + n \rightarrow n + n + 176$ **MeV**
large energy release (Evis > 30 MeV)

Candidate for Superfragment

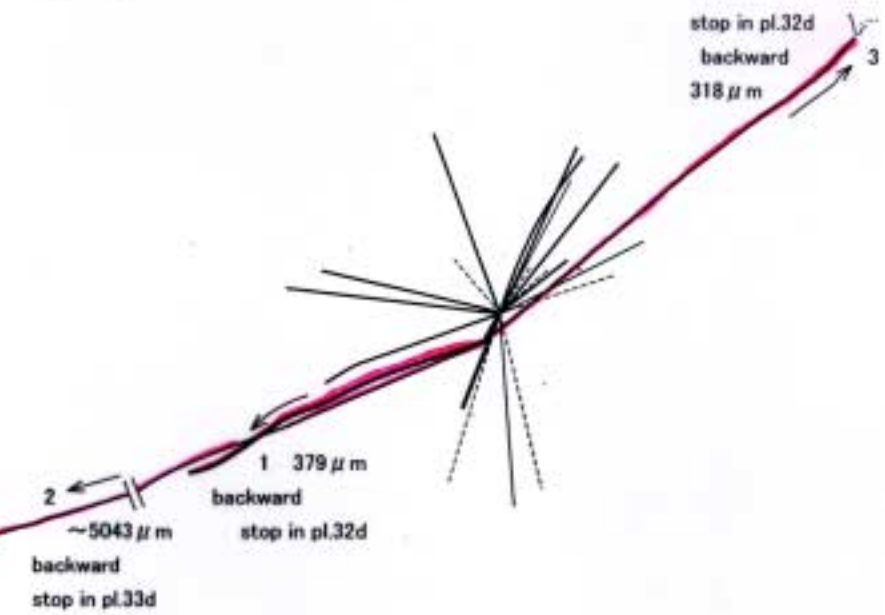
Much larger energy release ~ 1GeV

Much larger visible energy > 200MeV

Range is short (~a few μ m ?)

WA95 MDT 62B EV 79839619 date '01/Dec/11

PL# 31u



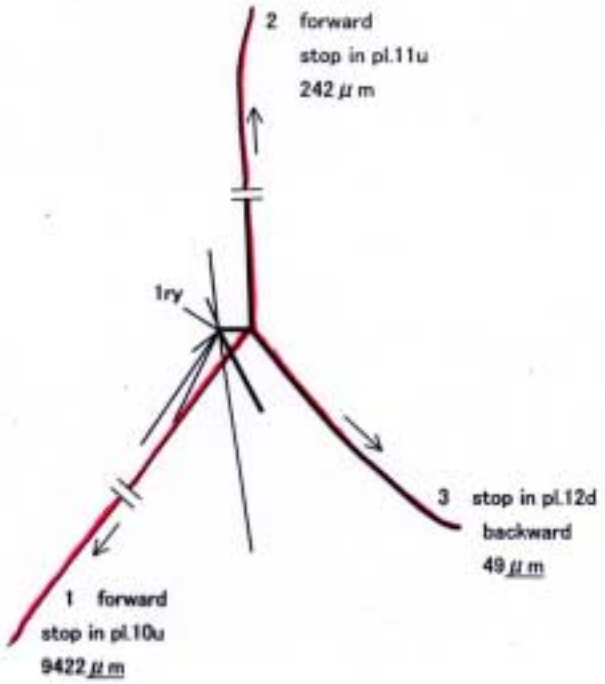
Track#	Length(μm)	E(MeV)	ID	
0	5.6			
1	379	8.0	(P)	
2	5043	35.6	(P)	
3	318	7.2	(P)	

Memo

Evis ~ 51 MeV

WA95 MDT 62B EV 80331217 date '01/Dec/12

PL# 12d × 90



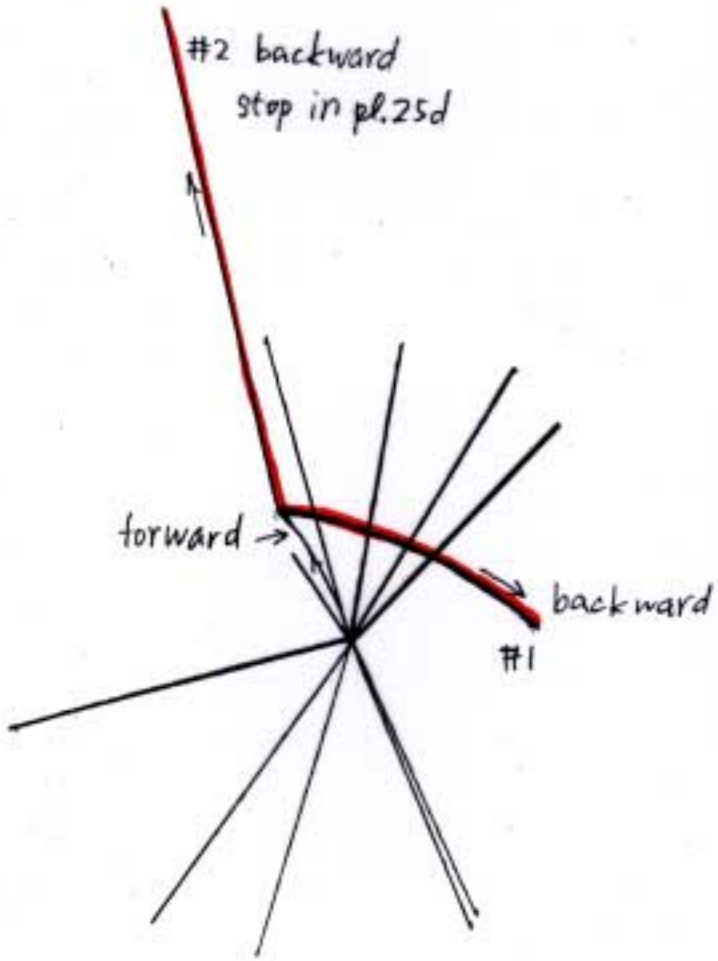
Track#	Length(μm)	E(MeV)	ID	
0	4.2			
1	* 9422	50.7	(P)	
2	242	6.2	(P)	
3	49	2.3	(P)	

Memo

Evis ~ 59 MeV

WA95 MDT 86T EV 80248935 date '01/Dec/14

PL# 21u



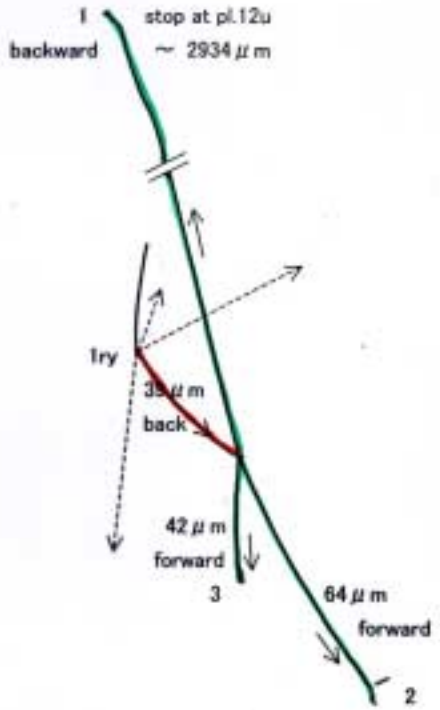
Track#	Length(μm)	E(MeV)	ID	
#	21			
# 1	94	3.5	(P)	
# 2	4618	34.	(P)	
#				
#				

Memo

Evis ~ 37.5

WA95 MDT 76B EV 76273799 date '01/ Dec/11

PL# 11d × 50



π⁻ capture

↗

Σ-star ?

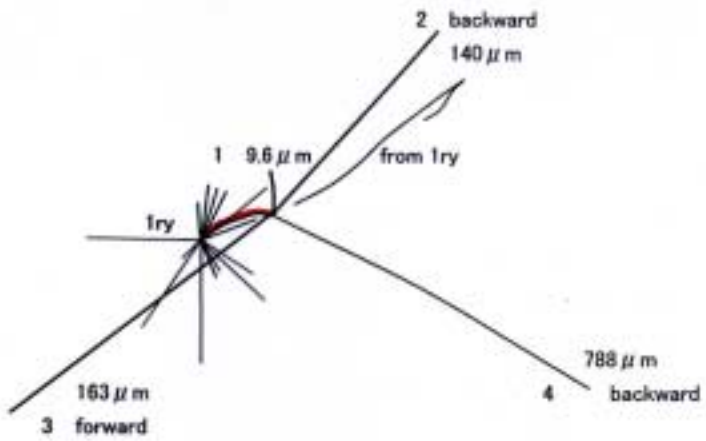
Track#	Length(μm)	E(MeV)	ID	
0	39			
1	2934	26.2	(P)	
2	64	2.7	(P)	
3	42	2.1	(P)	

Memo

Evis ~ 31 MeV no fast p

WA95 MDT 58T EV 78480676 date '01/Dec/12

PL# 28u

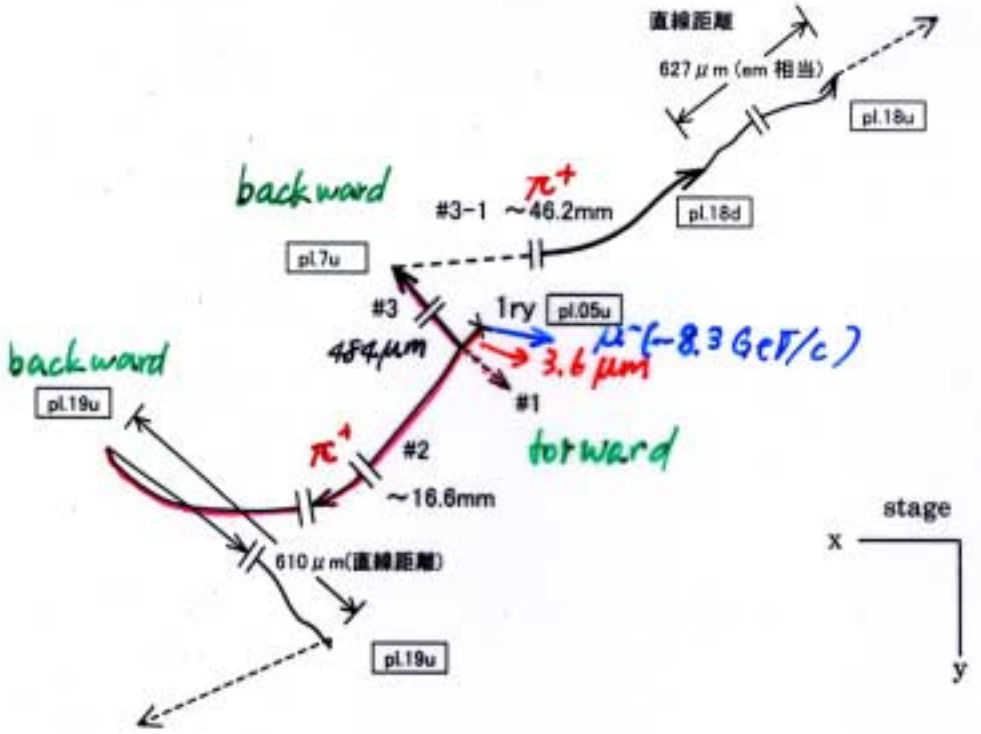


Track#	Length(μm)	E(MeV)	ID	
0	33			
1	9.6	0.74	(P)	
2	140	4.4	(P)	
3	163	4.9	(P)	
4	788	12.3	(P)	

Memo

WA95 MDT 71B　　EV 78902354　　date '01/Dec/20

PL# 05u

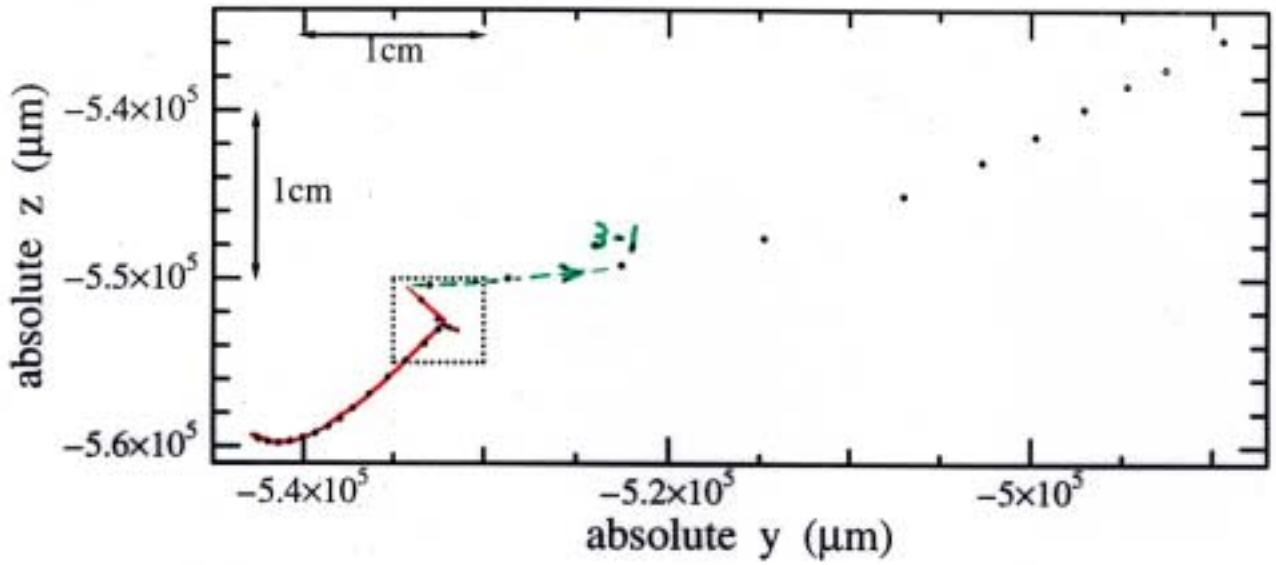


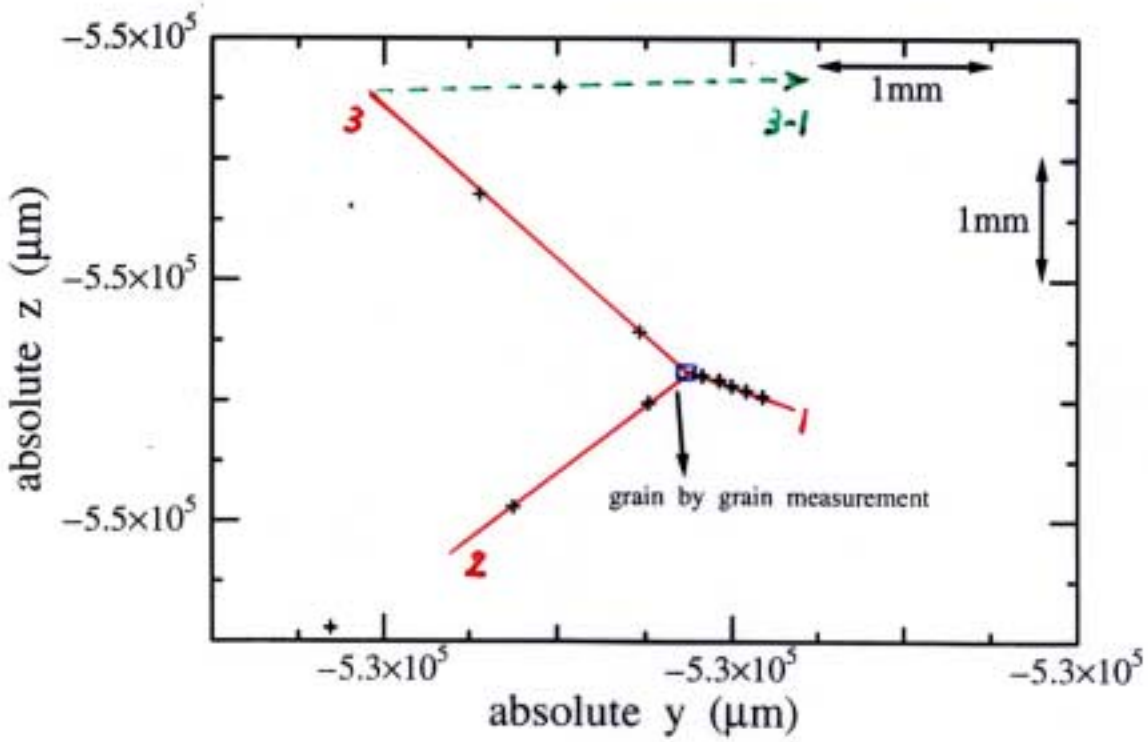
$(dx, dy, dz) = (2.24, 0.98, 2.6)\ \mu m$　$\ell \sim 3.6\ \mu m$　(grain by grain)

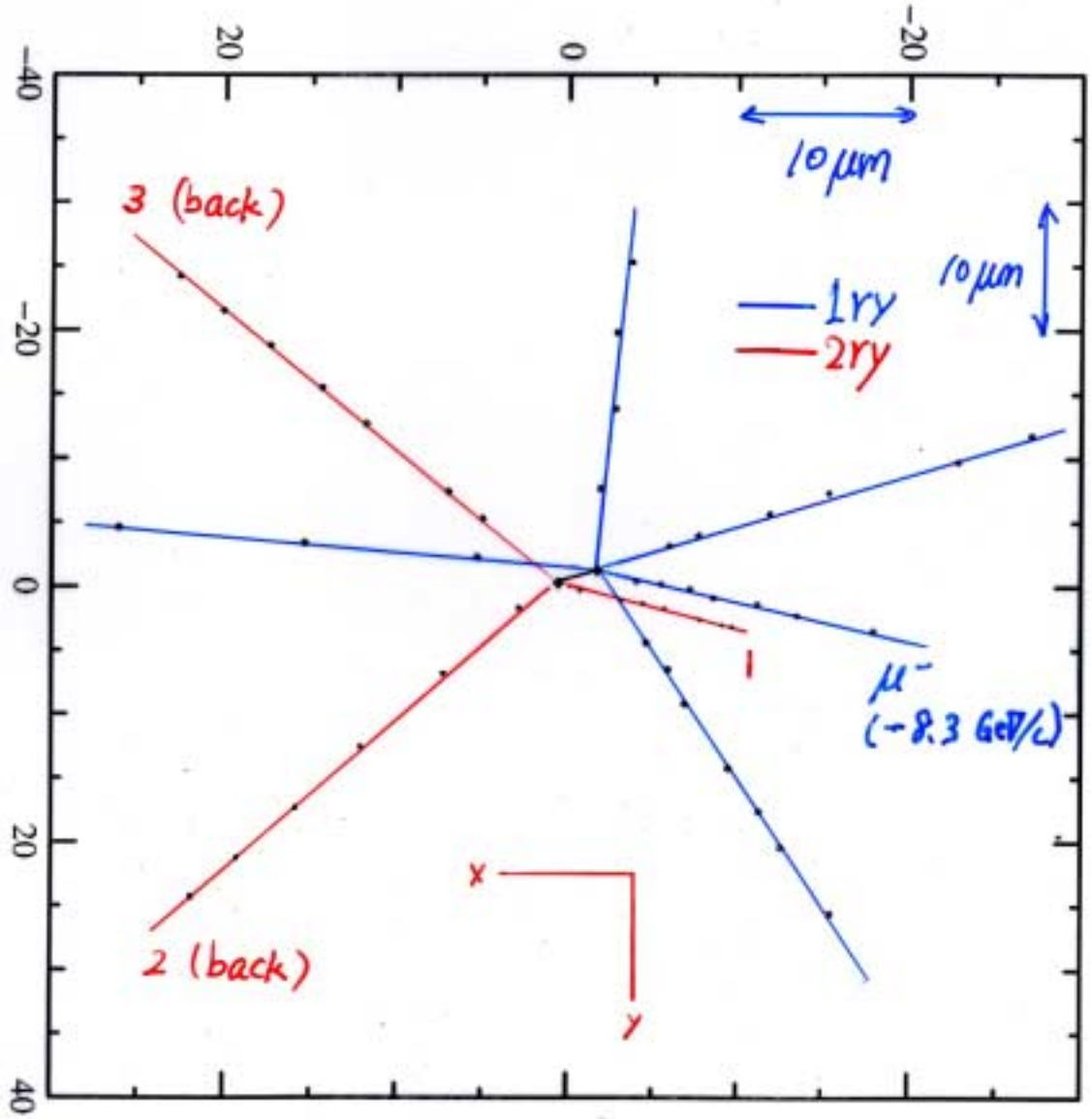
Track#	Length(μm)	P(MeV)	E(MeV)	ID	
#0	3.6			(Λc)	
#1	$> 3.26 \times 10^3$			(π^-)	go through pl.01
#2	16.6×10^3	99.8	32	π^+	
#2-1	~610			μ^+	
#3	484	414.5		Σ^+	
#3-1	46.2×10^3	145.4	62	π^+	
#3-1-1	~627			μ^+	
#3-2		486.2		(n)	

Memo

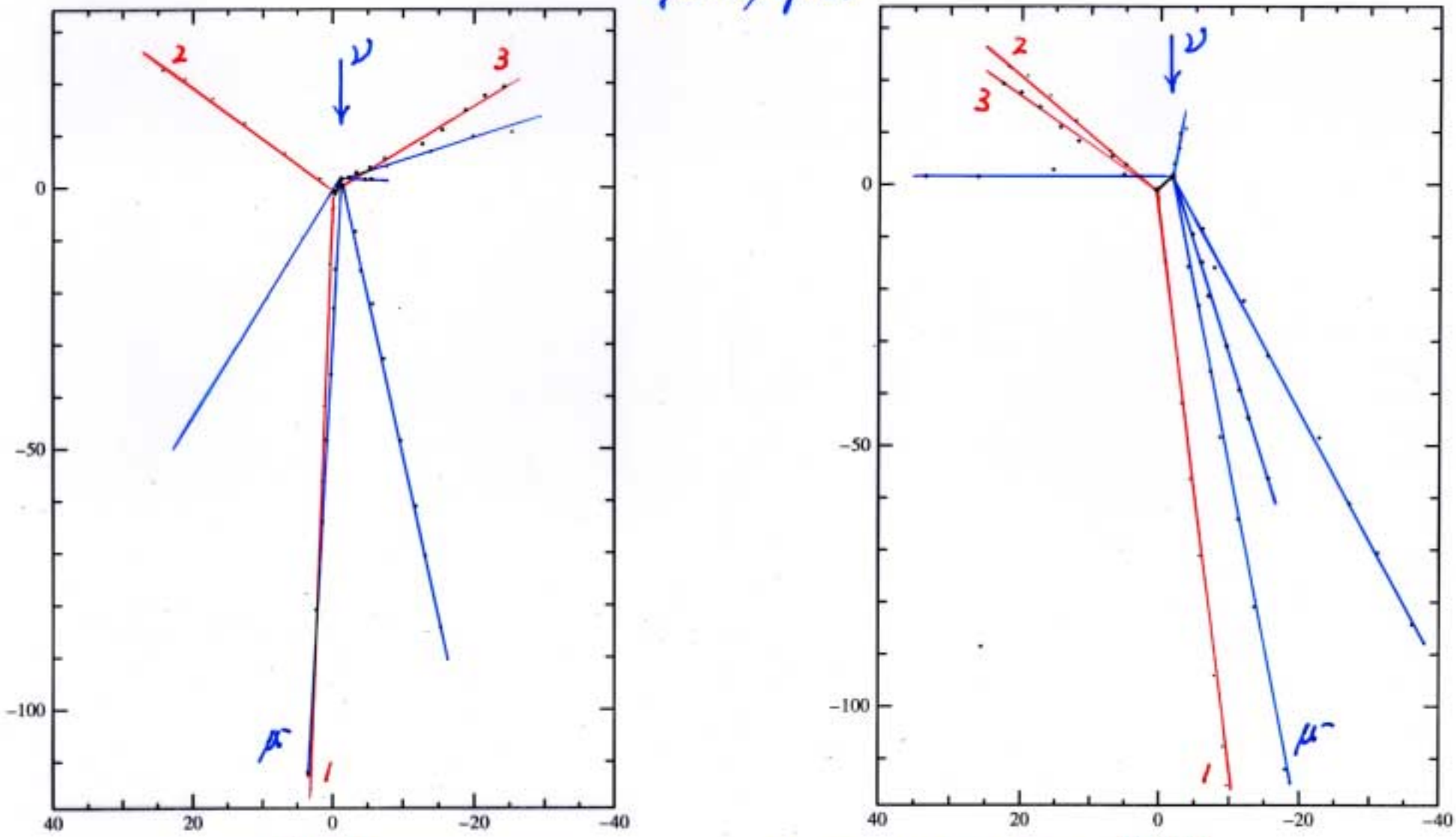
plate by plate measurement






20
0
−20
−40
−20
0
20
40
10 μm
10 μm
3 (back)
1ry
2ry
1
μ⁻
(−8.3 GeV/c)
x
y
2 (back)

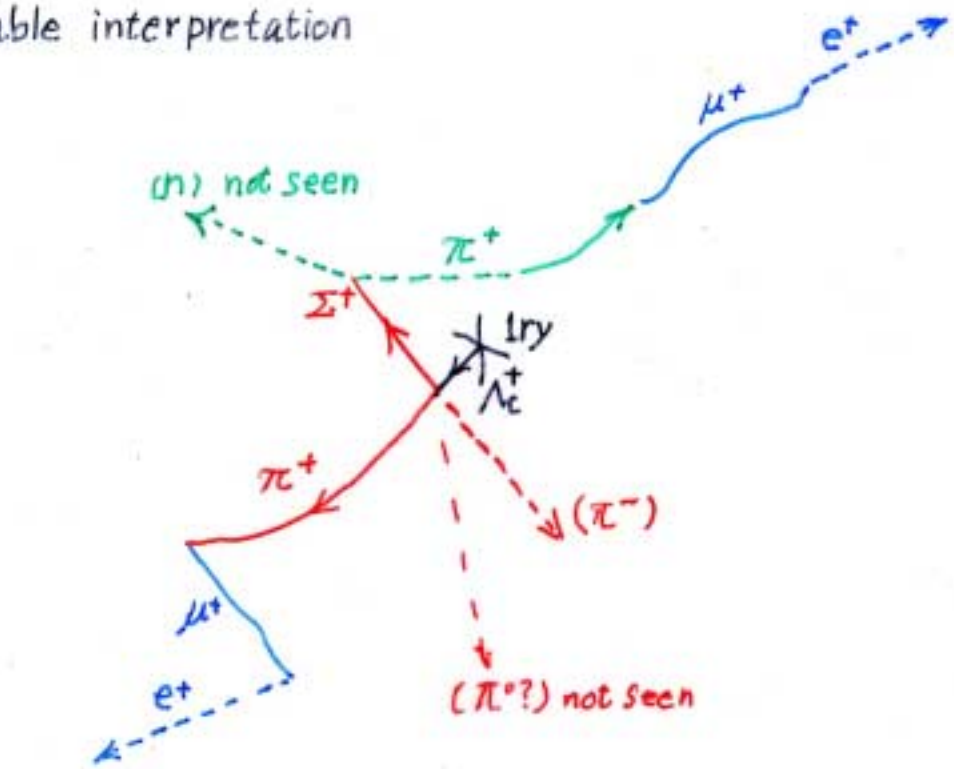
grain by grain



obtained $(\Delta X, \Delta Y, \Delta Z) \sim (2.2, 1.0, 2.6)\,\mu m$

$\ell \sim 3.6\,\mu m$

Most probable interpretation



$\Lambda_c^+ \to \Sigma^+ \pi^+ \pi^- (\pi^0?)$

$\hookrightarrow \mu^+ \bar{\nu} \to e^+ \nu \bar{\nu}$

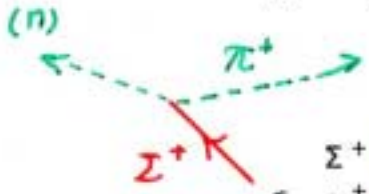
$\hookrightarrow (n)\, \pi^+$

$\hookrightarrow \mu^+ \bar{\nu} \to e^+ \nu \bar{\nu}$

Kinematic fit of track 3

Asumming $\Sigma^+ \to \pi^+ n$ (48.3±0.3%, Pmax=185MeV/c)

3 3-1



direction cosin

	clx	cly	clz	P(MeV)	Mass(MeV/c²)
Σ^+	0.566	−0.642	−0.517	$P_{\Sigma+}$	1189.4
π^+	−0.964	−0.922	−0.245	145	139.6
(n)	clxn	clyn	clzn	Pn	939.6

determine clxn, clyn, clzn, Pn and $P_{\Sigma+}$ using measured value

(clxn, clyn, clzn) = (0.771, −0.520, −0.368) Pn = 486 MeV/c

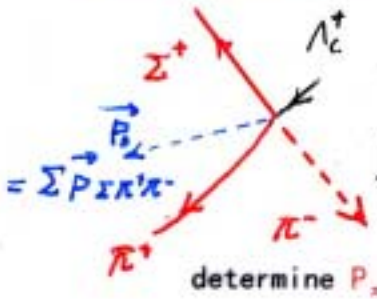
$P_{\Sigma+}$ = 415 MeV/c

obtain

$\tau \sim 4.6 \times 10^{-13}$ sec

Kinematic fit of 2ry vertex

Asumming $\Lambda c \rightarrow \Sigma^+ \pi^+ \pi^-$ (3.4±1.0%, Pmax=185MeV/c)
3 2 1



	direction cosin clx	cly	clz	P(MeV)	Mass (MeV/c²)
(Λc)	0.629	0.273	0.728	P_0	m_0
π^-	-0.090	-0.028	-0.966	$P_{\pi-}$	139.6
π^+	0.519	0.619	-0.590	99.8	139.6
Σ^+	0.576	-0.623	-0.530	415	1189.4

determine $P_{\pi-}$ and P_0, m_0

$P_{\pi-}$ = 819 MeV/c minimizing angle difference of P_0 and Λc

$\vec{P}_0$: $(clx_0, cly_0, clz_0) = (0.359, -0.287, 0.888)$ P_0 = 605 MeV/c

m_0 = 2180 MeV/c²

($m_{\Lambda c}$ = 2284.9)

fitting is not well

$\tau \sim 6.9 \times 10^{-14}$ sec

Asumming $\Lambda c \rightarrow \Sigma^+ \omega$, $\omega \rightarrow \pi^+\pi^-(\pi^0)$ (2.7±1.0%, Pmax=568MeV/c) (89.9±0.5%, Pmax=327MeV/c)

	direction cosin clx	cly	clz	P(MeV)	Mass (MeV/c²)
(Λc)	0.629	0.273	0.728	P_0	m_0
Σ^+	0.576	-0.623	-0.530	415	1189.4
π^-	-0.090	-0.028	-0.966	$P_{\pi-}$	139.6
ω(782.7) π^+	0.519	0.619	-0.590	99.8	139.6
(π^0)	$clx_{\pi0}$	$cly_{\pi0}$	$clz_{\pi0}$	$P_{\pi0}$	135.0

determine $(clx_{\pi0}, cly_{\pi0}, clz_{\pi0})$, $P_{\pi0}$ and $P_{\pi-}$
then determine P_0, m_0

$(clx_{\pi0}, cly_{\pi0}, clz_{\pi0})$ = (-0.010, 0.958, 0.288) $P_{\pi0}$ = 302

$P_{\pi-}$ = 477

ω (clx, cly, clz) = (0.010, 0.586, 0.810) P_ω = 723

(Pt to parent = 255)

Σ^+ ω (clx, cly, clz) = (0.629, 0.273, 0.728) P_0 = 389

m_0 = 2225

($m_{\Lambda c}$ = 2284.9)

well fit

$\tau \sim 7.0 \times 10^{-14}$ sec

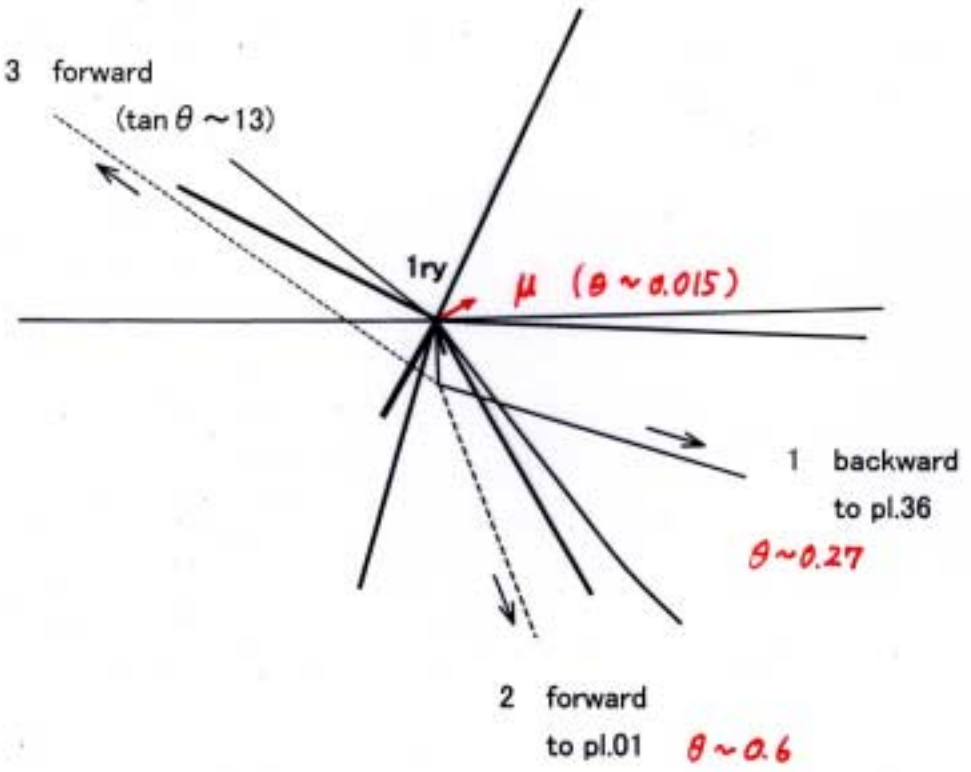
---

consistent with $\Lambda_c^+ \rightarrow \Sigma^+ \omega$, $\omega \rightarrow \pi^+\pi^-\pi^0$ (2.7±1.0%) (89.9±0.5%)

$\Lambda_c^+ \rightarrow \Sigma^+ \pi^+ \pi^-$ (3.4±1.0%) is not excluded due to small length of parent

WA95 MDT 82B EV 73831188 date

PL#25u

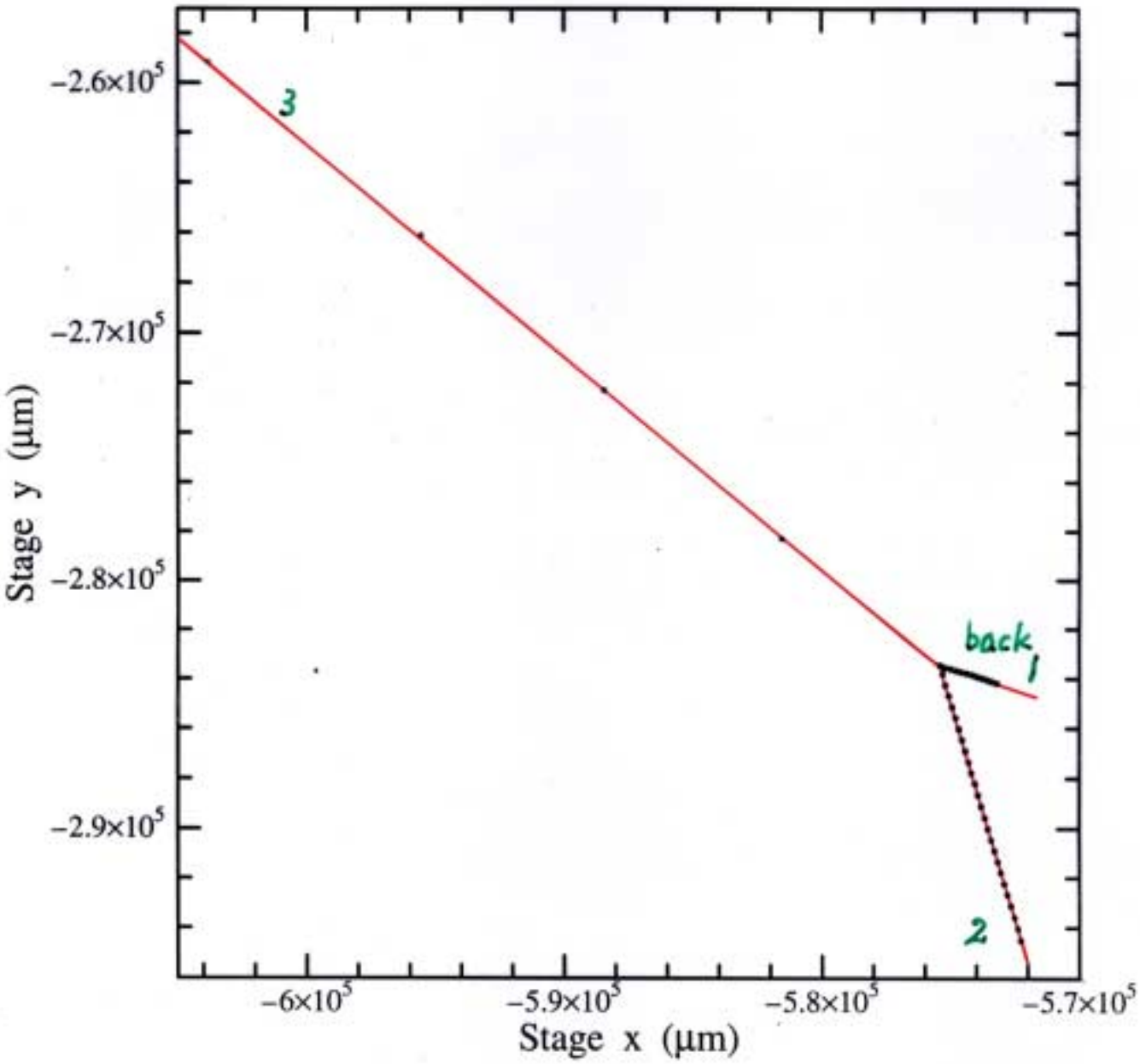


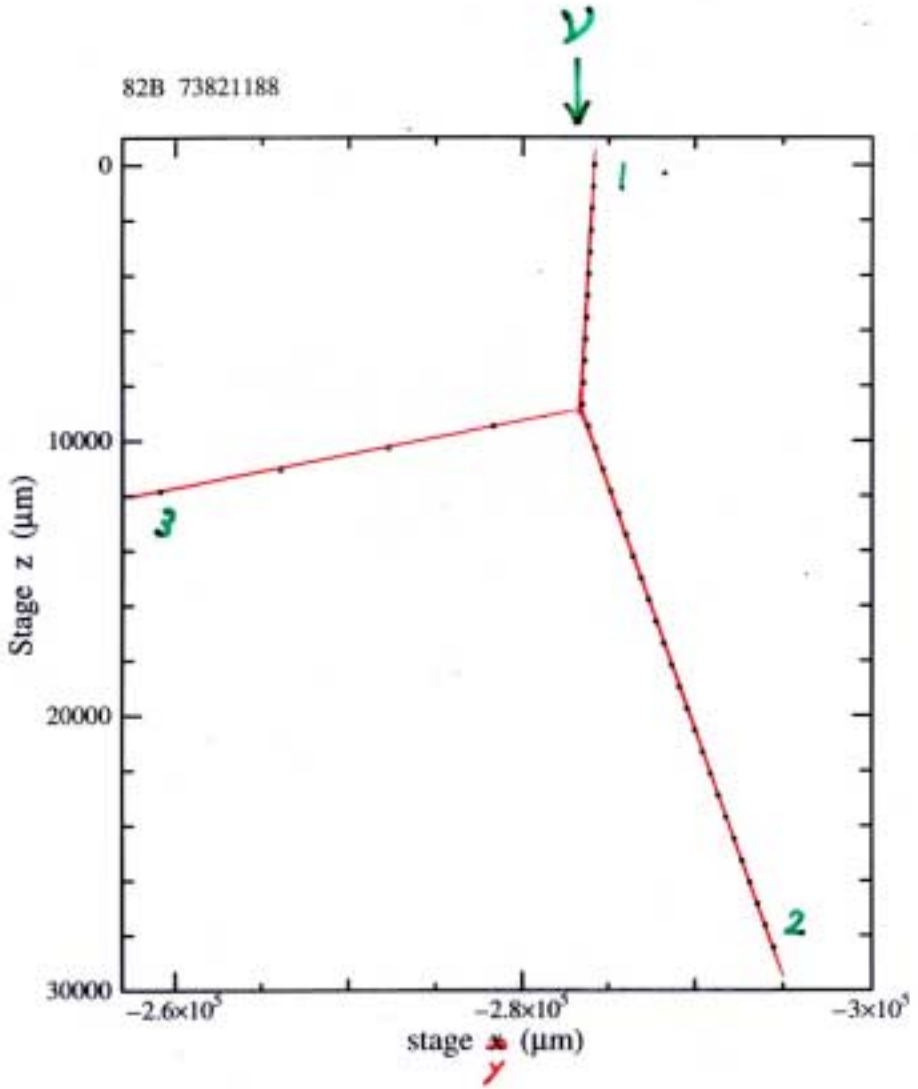
parent (gray?) (dx,dy,dz) = (0.9, 3.2, 6.1) μm in stage system

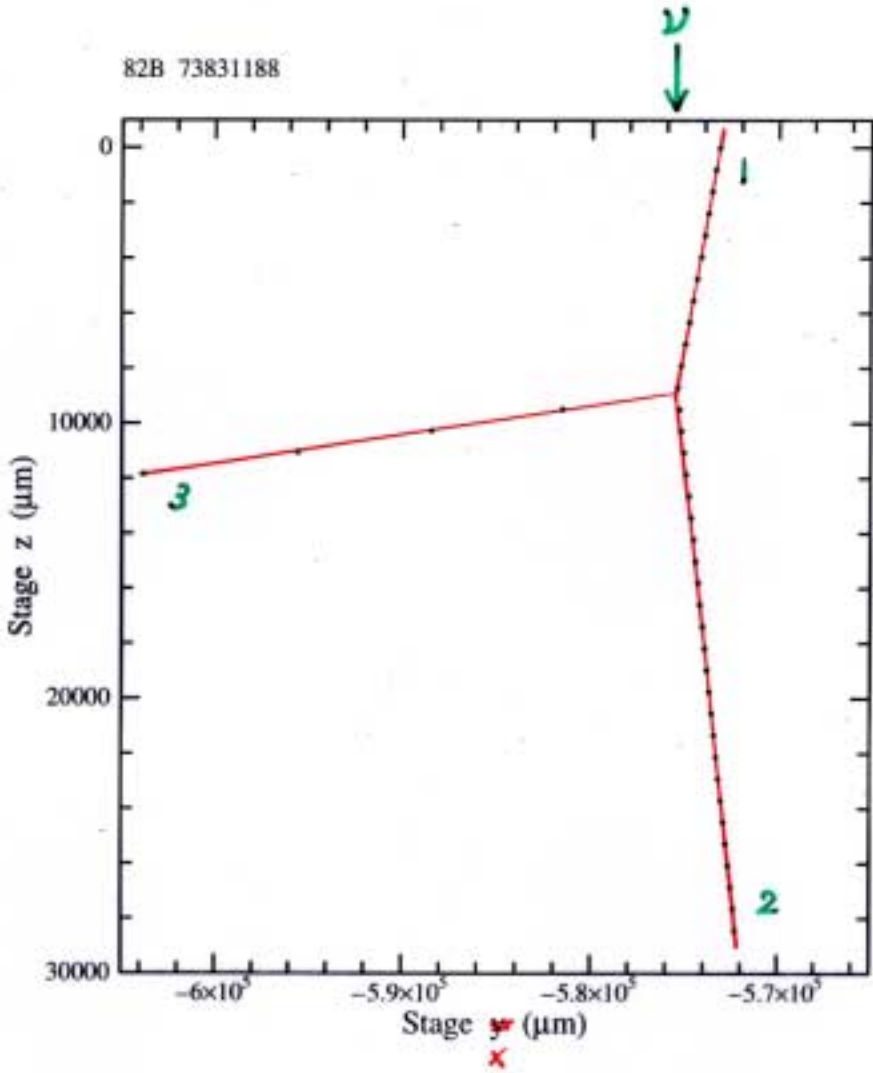
Track#	Length(μm)	E(MeV)	ID	
0	6.9			
1	>8.0×10³em +1.0×10³base	>21 >48	(π) (P)	>8.4×10³em 相当 thin or gray
2	>20×10³em +2.6×10³base	>37 >82	(π) (P)	>22×10³em 相当 thin
3	>36×10³em +5×10³base	>52 >112	(π) (P)	>38×10³em 相当 thin

Memo

Evis > 110 MeV (π assuming)
Evis > 242 MeV (p assuming)


−2.6×10^5
−2.7×10^5
−2.8×10^5
−2.9×10^5
Stage y (μm)
3
back
1
2
−6×10^5
−5.9×10^5
−5.8×10^5
−5.7×10^5
Stage x (μm)


82B 73821188
ν
1
2
3
0
10000
20000
30000
Stage z (μm)
−2.6×10^5
−2.8×10^5
−3×10^5
stage x (μm)
y


82B 73831188
ν
1
2
3
0
10000
20000
30000
Stage z (μm)
−6×10^5
−5.9×10^5
−5.8×10^5
−5.7×10^5
Stage y (μm)
x

Summary

43k images in '97 Run are analyzed

~ 14k 1ry vertices are found by analysis program

position accuracy $\sigma_{x,y} \sim 0.4\,\mu$m $\sigma_z \sim 3.5\,\mu$m (beam direction)

Clear $\Lambda c \rightarrow \Sigma^{+} + \pi$'s decay is identified

6 hyperfragment candidates are found

- 1 with thin track (trident?)
- 3 with fast proton
- 2 with visible energy > 30MeV (1 is σ-star?)

Further works

Measurement of I/I0, $p\beta$

Estimation of error, efficiency

Improvement of analysis program

Will try again to search super fragment