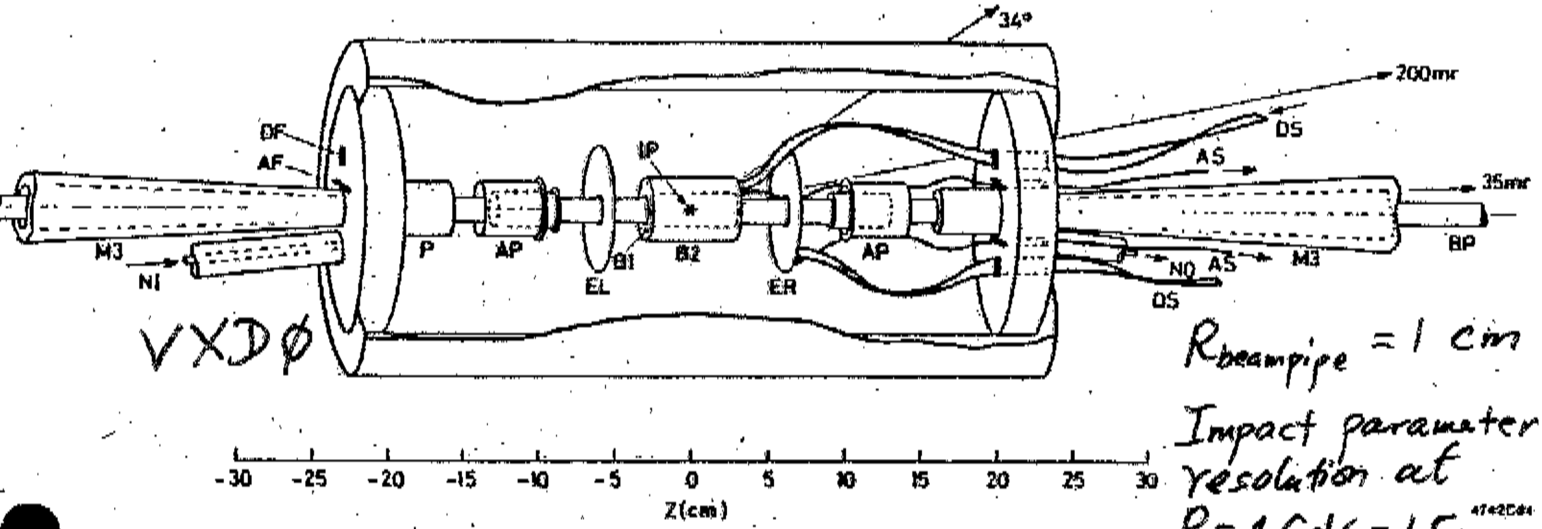
Vertex Detectors & R_b,R_c Measurements

Su Dong
Stanford Linear Accelerator Center

SLD Collaborations meeting
Oct/5/01
San Francis Yacht Club

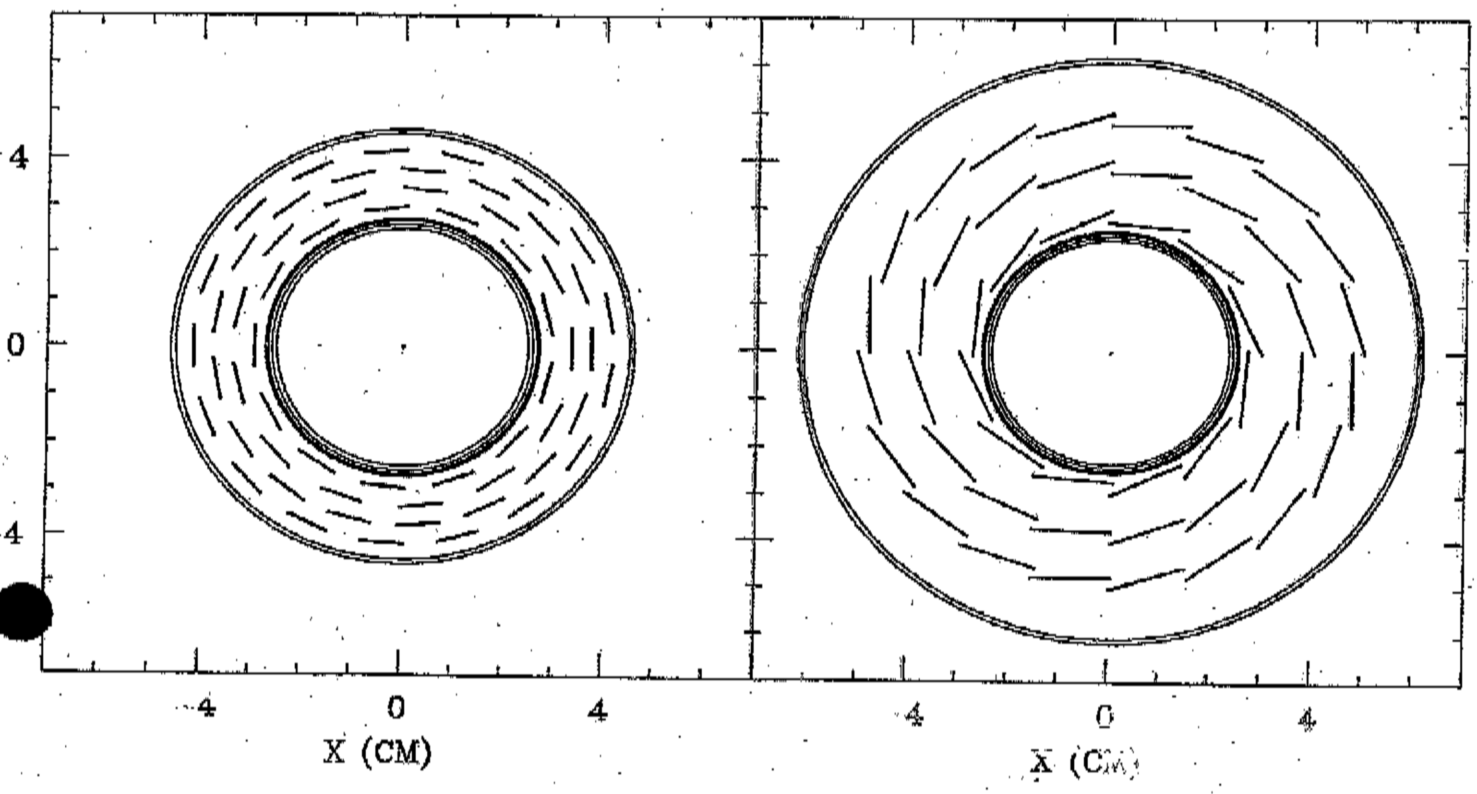
Vertex Detectors

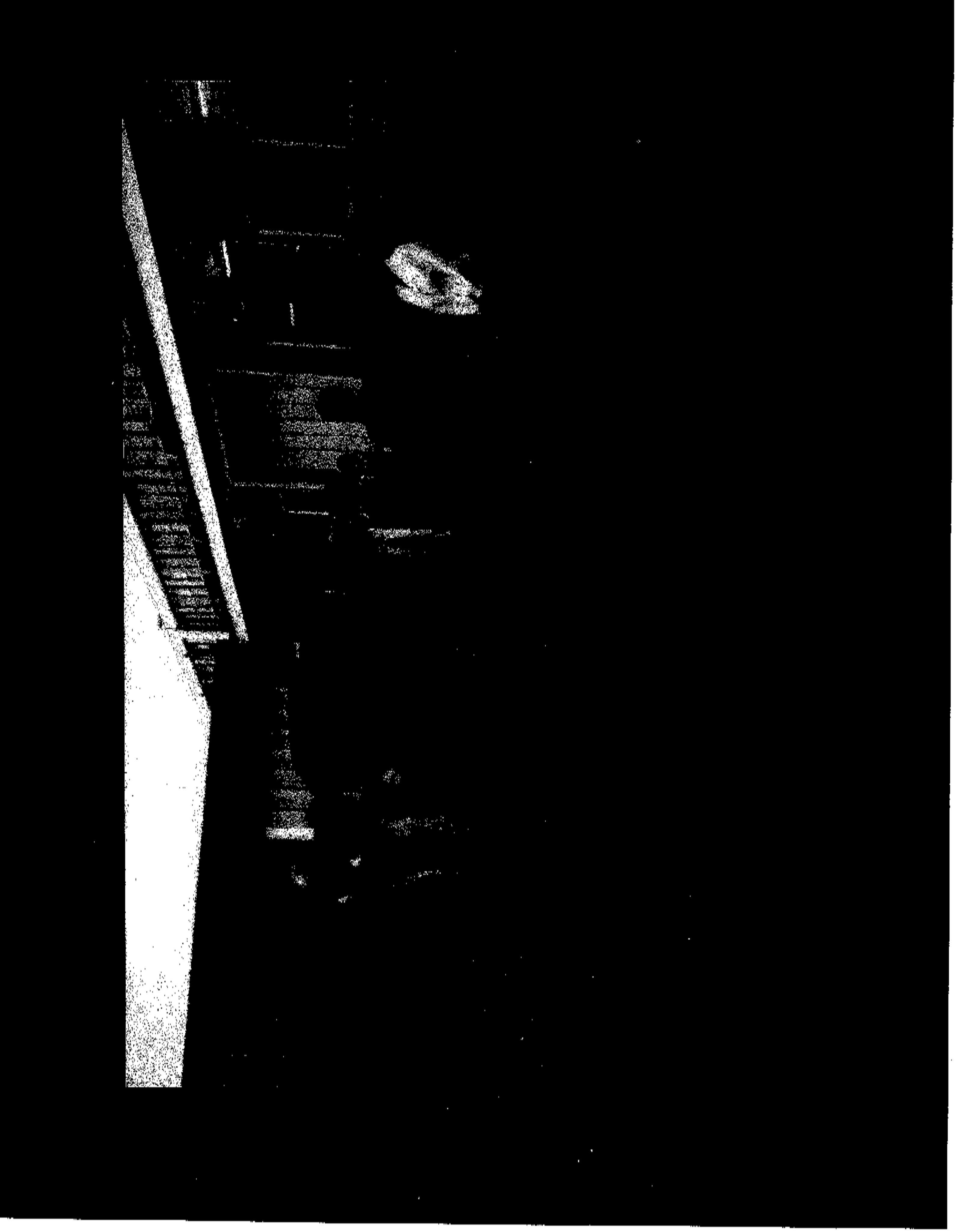


$R_{beampipe} = 1$ cm

Impact parameter resolution at $P = 1$ GeV $= 15 \mu m$

VXD−2 GEOMETRY　　VXD−3 GEOMETRY





Detector Material test with γ-conversions

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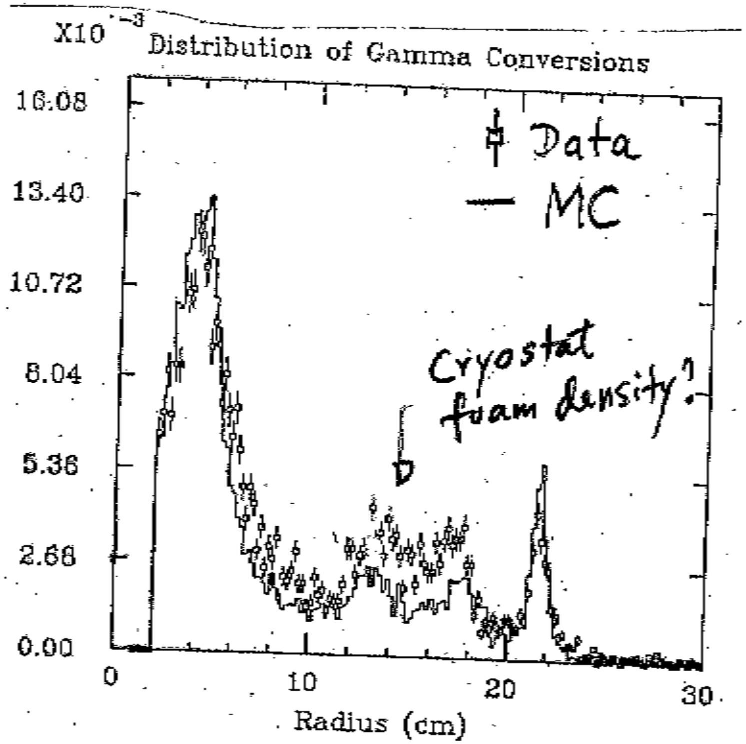
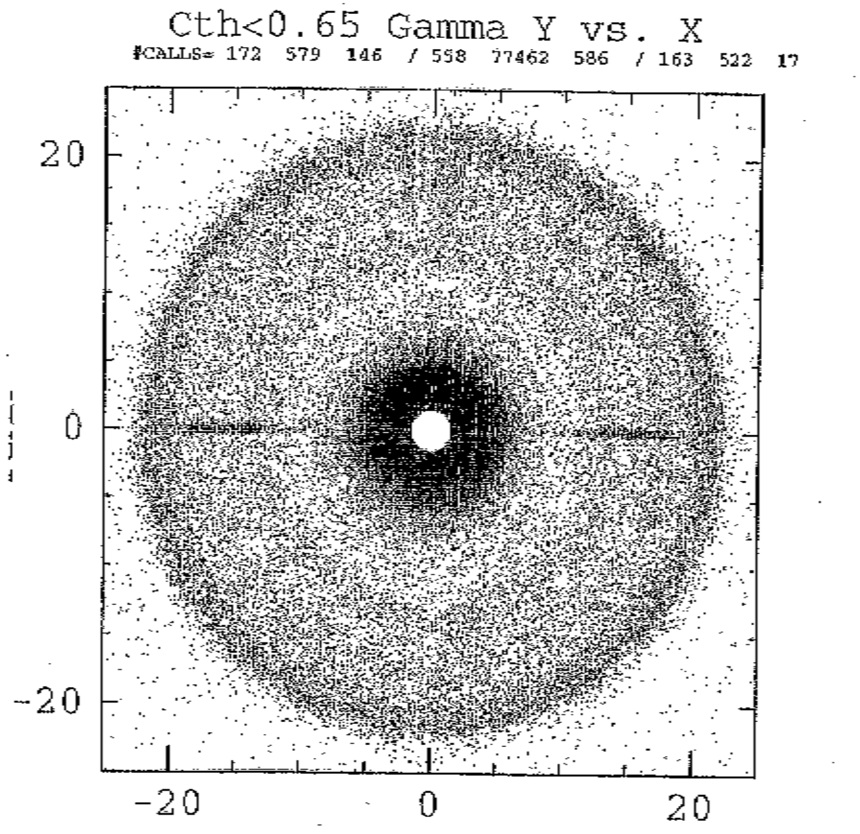
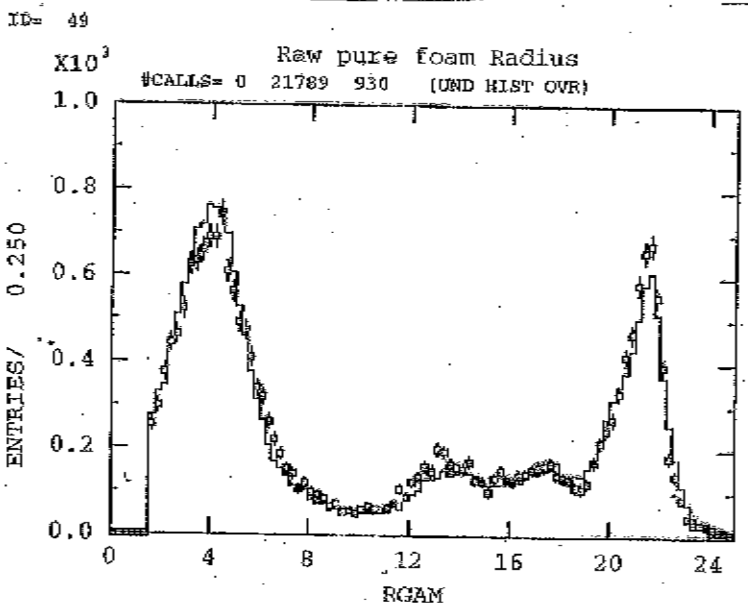
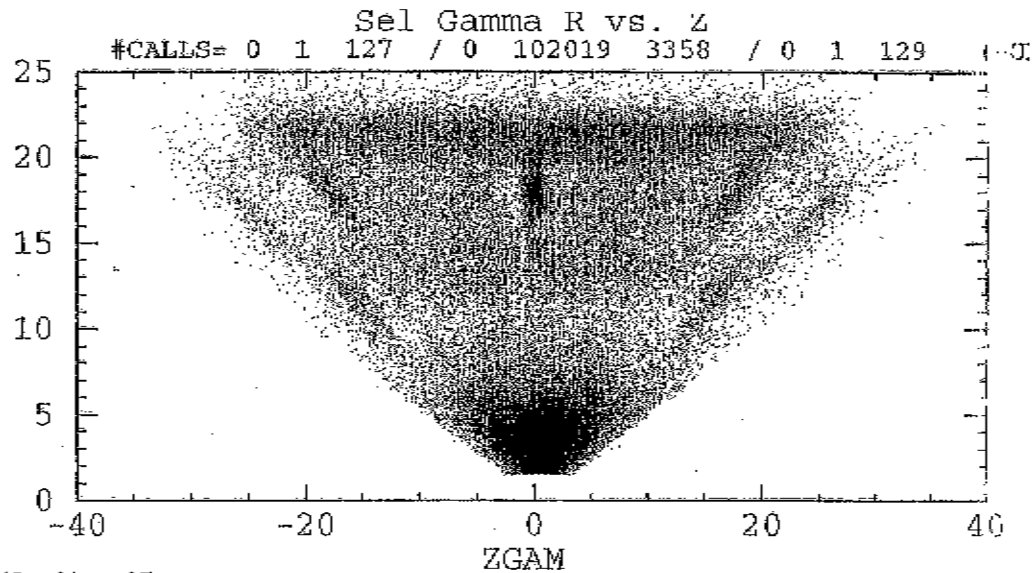
VXD2
Feb/95









:45 31JAN97

Understand Multiple Scattering

History of Multiple Scattered Formulae in PDG & GEANT

Fit Gaussian to Molière formula core

PDG 73

$$\theta_0 = \frac{15\ MeV}{P\beta c}\sqrt{\frac{L}{L_R}}$$

PDG 86

$$\theta_0 = \frac{14.1\ MeV}{P\beta c}\sqrt{\frac{L}{L_R}}\left[1 + \frac{1}{9}log_{10}(\frac{L}{L_R})\right]$$

PDG 90

mistake

$$\theta_0 = \frac{13.6\ MeV}{P\beta c}\sqrt{\frac{x}{X_0}}\left[1 + 0.20\ ln(\frac{x}{X_0})\right]$$

PDG 92

$$\theta_0 = \frac{13.6\ MeV}{P\beta c}\sqrt{\frac{x}{X_0}}\left[1 + 0.038\ ln(\frac{x}{X_0})\right]$$

Non commute

This doesn't really wo:k. Must use Molière formula.

GEANT 3.11

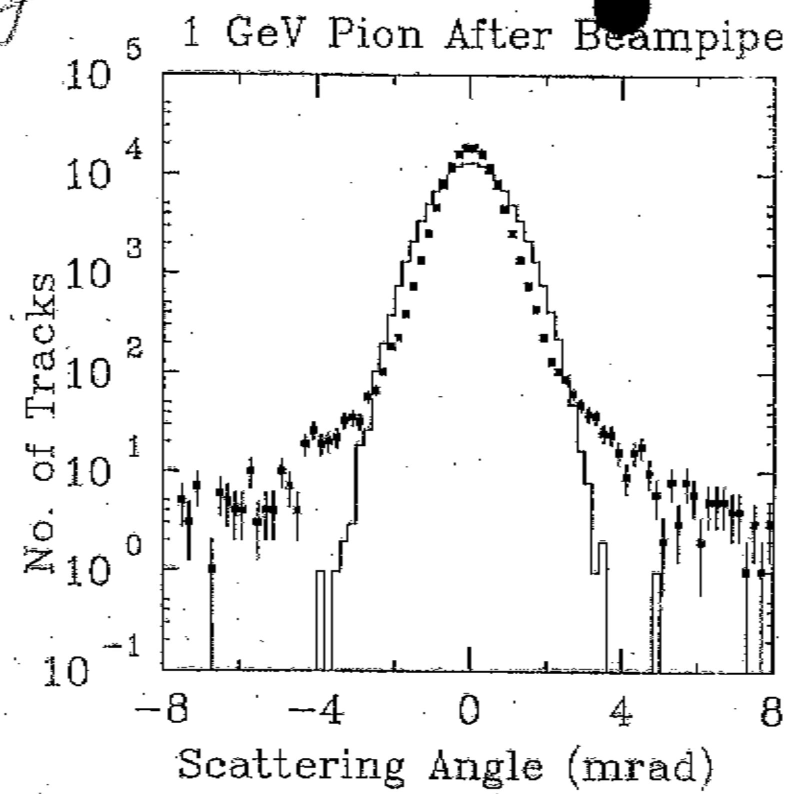
- **Default = Gaussian PDG 73 ("Rossi")**
- **"Original" Molière $\chi_c^2 \propto Z$**

GEANT 3.15

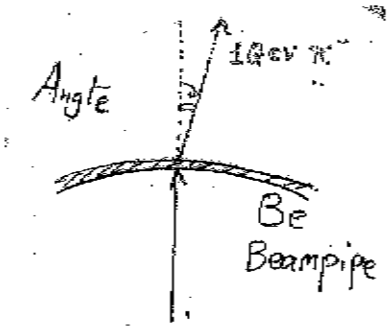
"Modified" Molière $\chi_c^2 \propto \sqrt{Z(Z+1)}$

(Atomic electron screening effect)

Chateau Le Cresta Feb'95



HANDYPAK 15:32:55 8FEB94



GEANT 3.15 Molière

GEANT 3.11 Gaussian

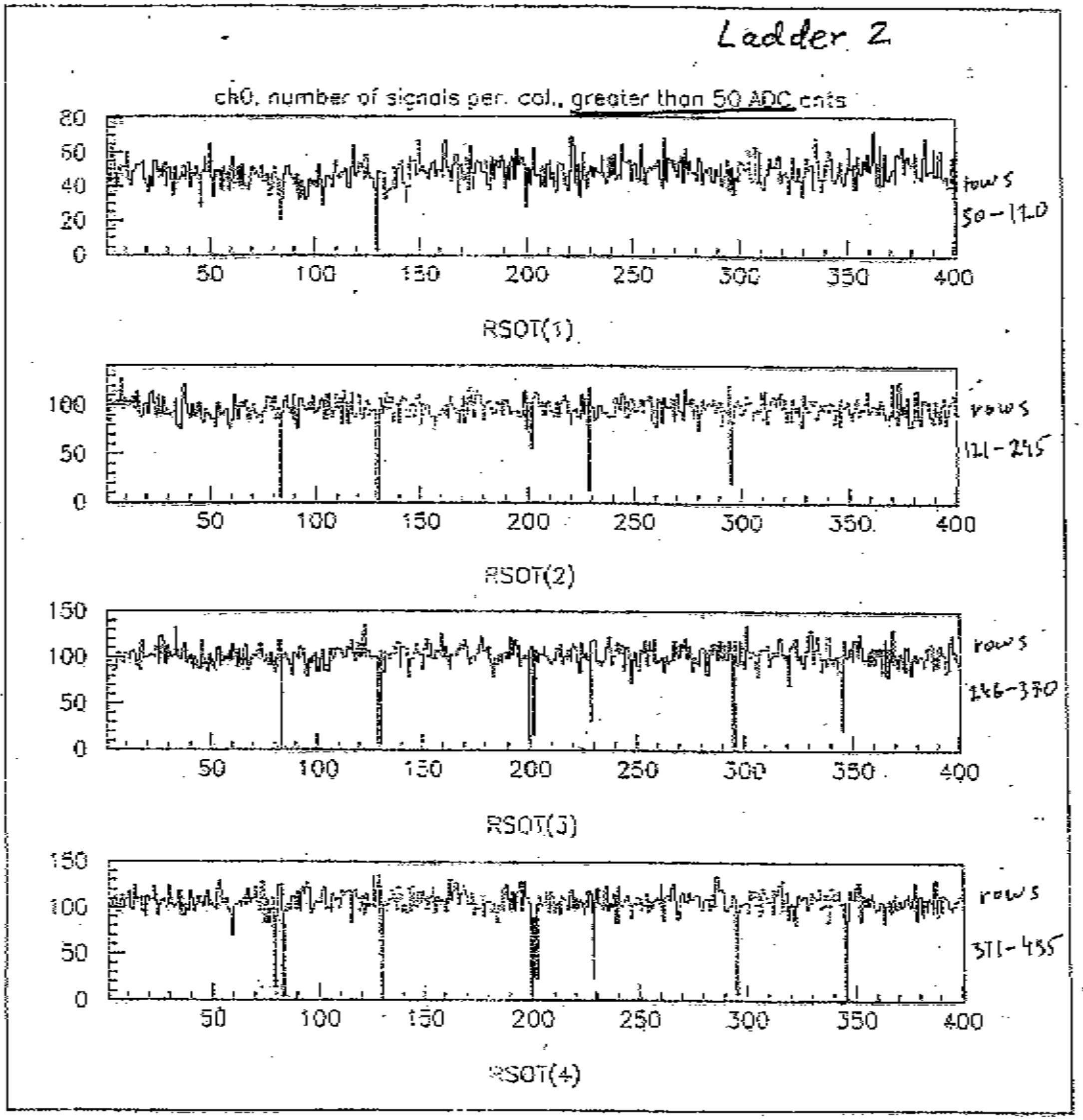
Reasons to build VXD3

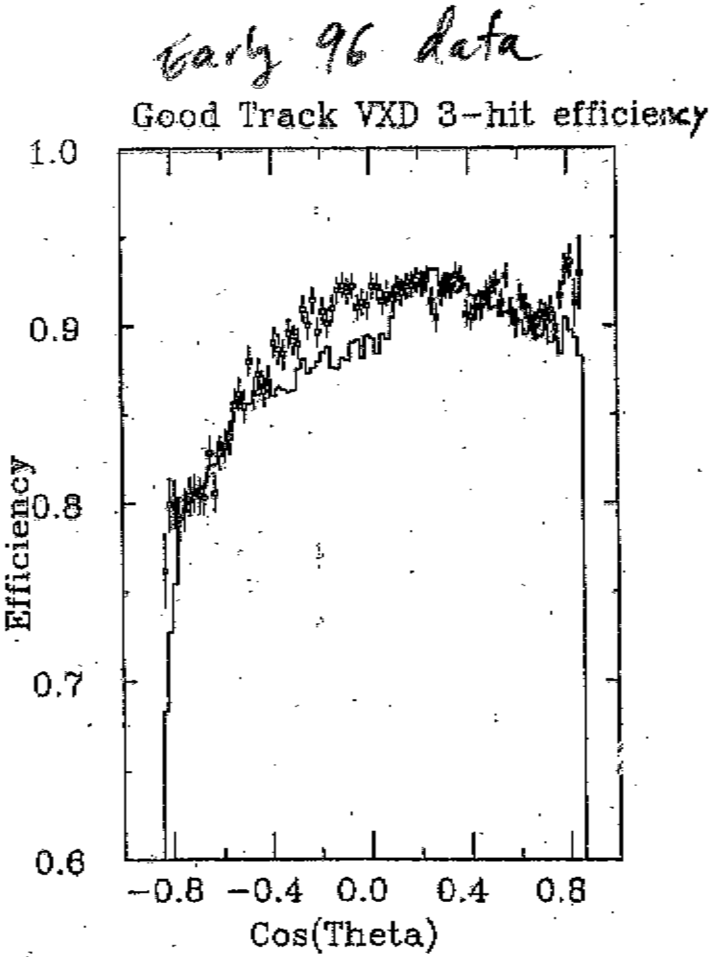
- **Stretched lever arm for better impact parameter resolution.**
- **Extended solid angle coverage.**
- **Self tracking with 3 layers**
- **Reduced material for less multiple scattering (*thin CCD, Be mother board, no more Gold!, plastic bands, thinner foams…)***
- **Better geometry for alignment**
- **Etc…**

However, the real reason was:

so that Marty can get his revenge on the electronics…

Anxious Moments with VXD3





Nick, 2
03/ /95

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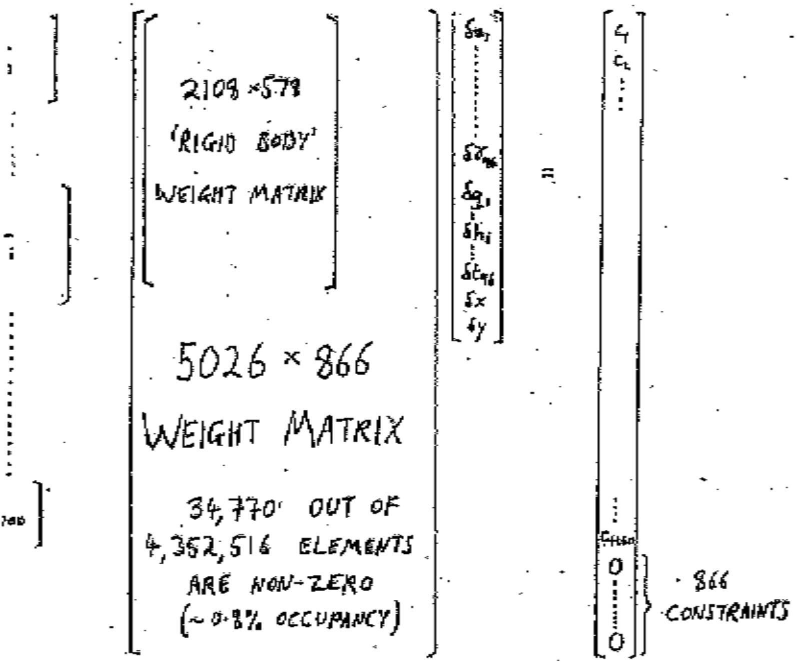
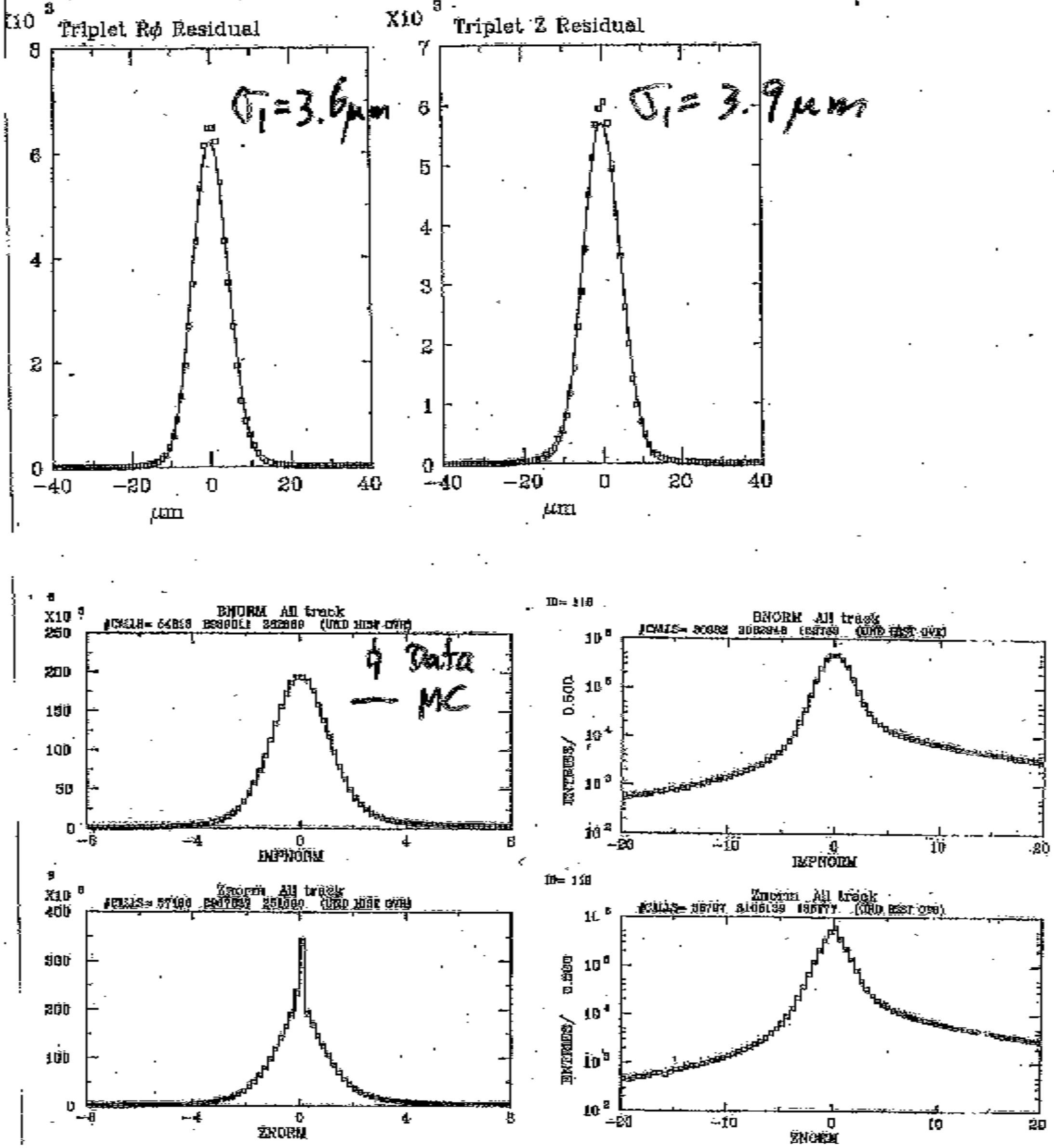
INTERNAL ALIGNMENT MATRIX EQUATION



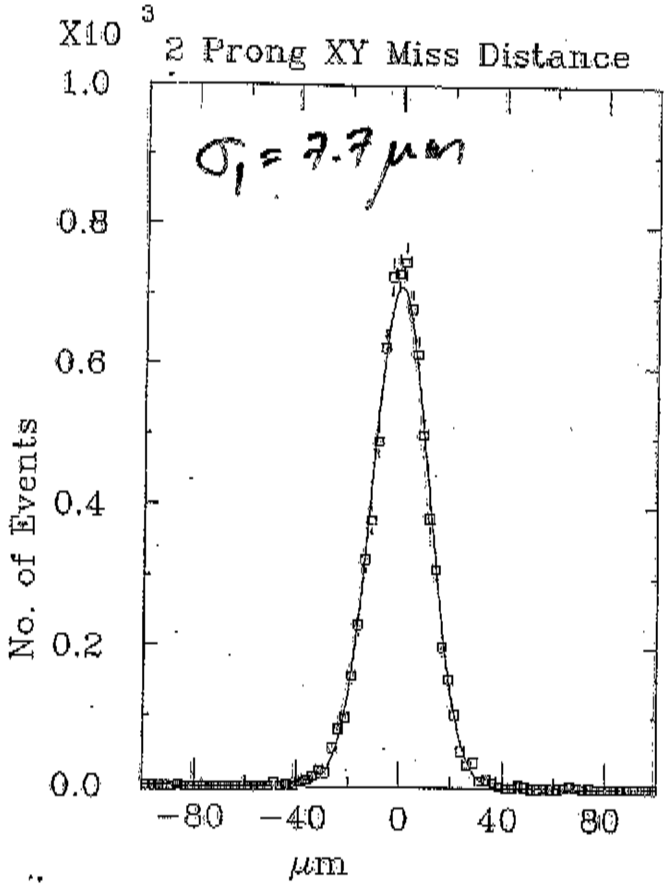


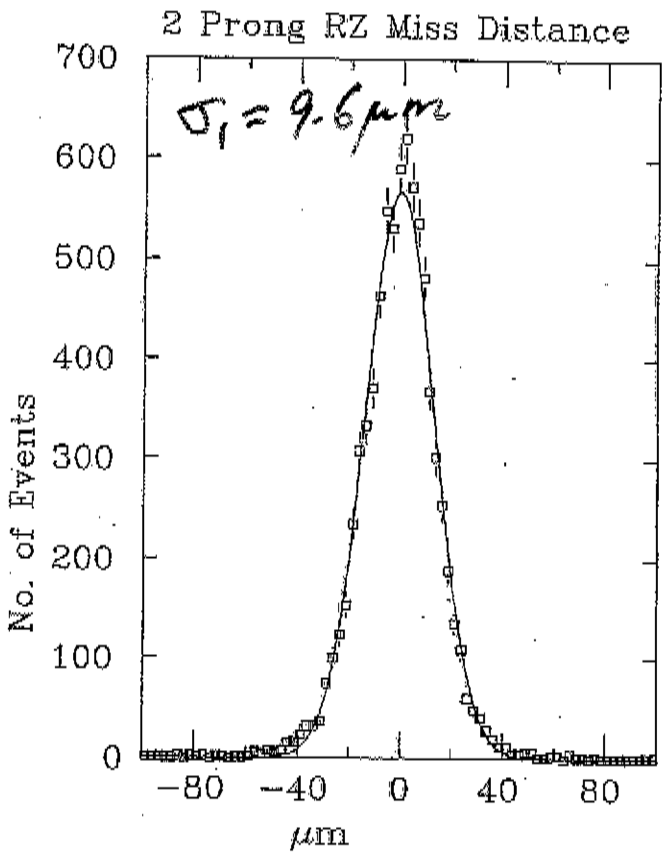
700 RESIDUAL FITS ⇒

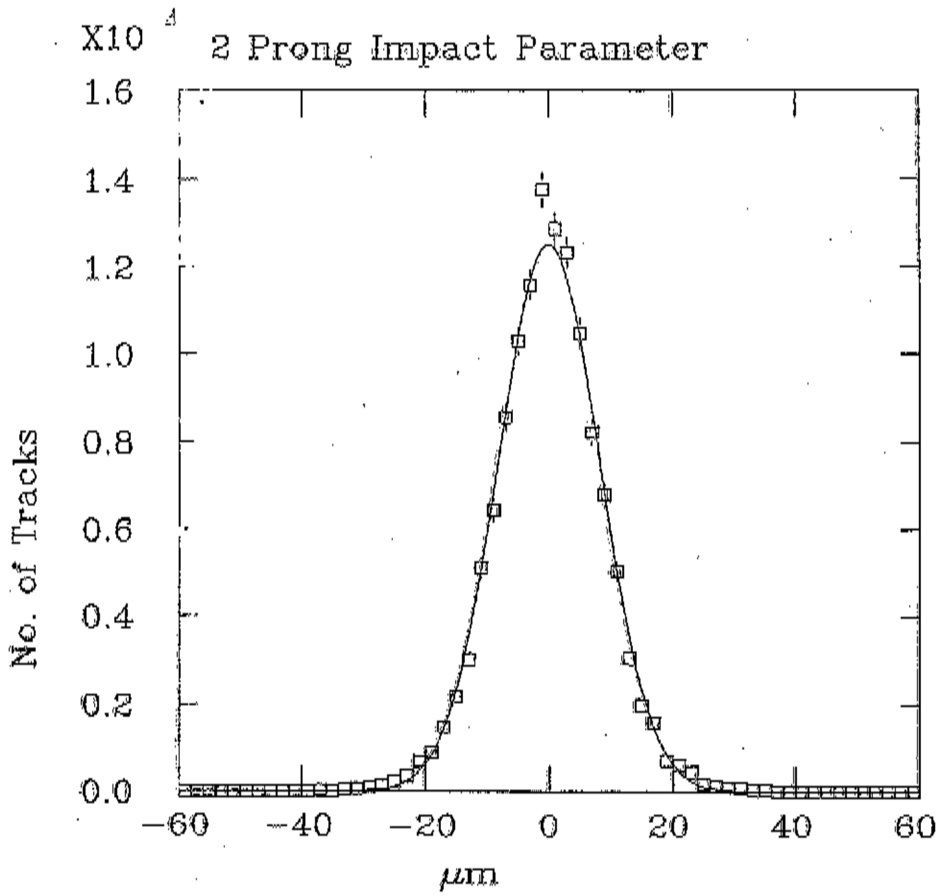
4,160 PARAMETERS c_i

+16,332 CORRELATION TERMS IN T_i

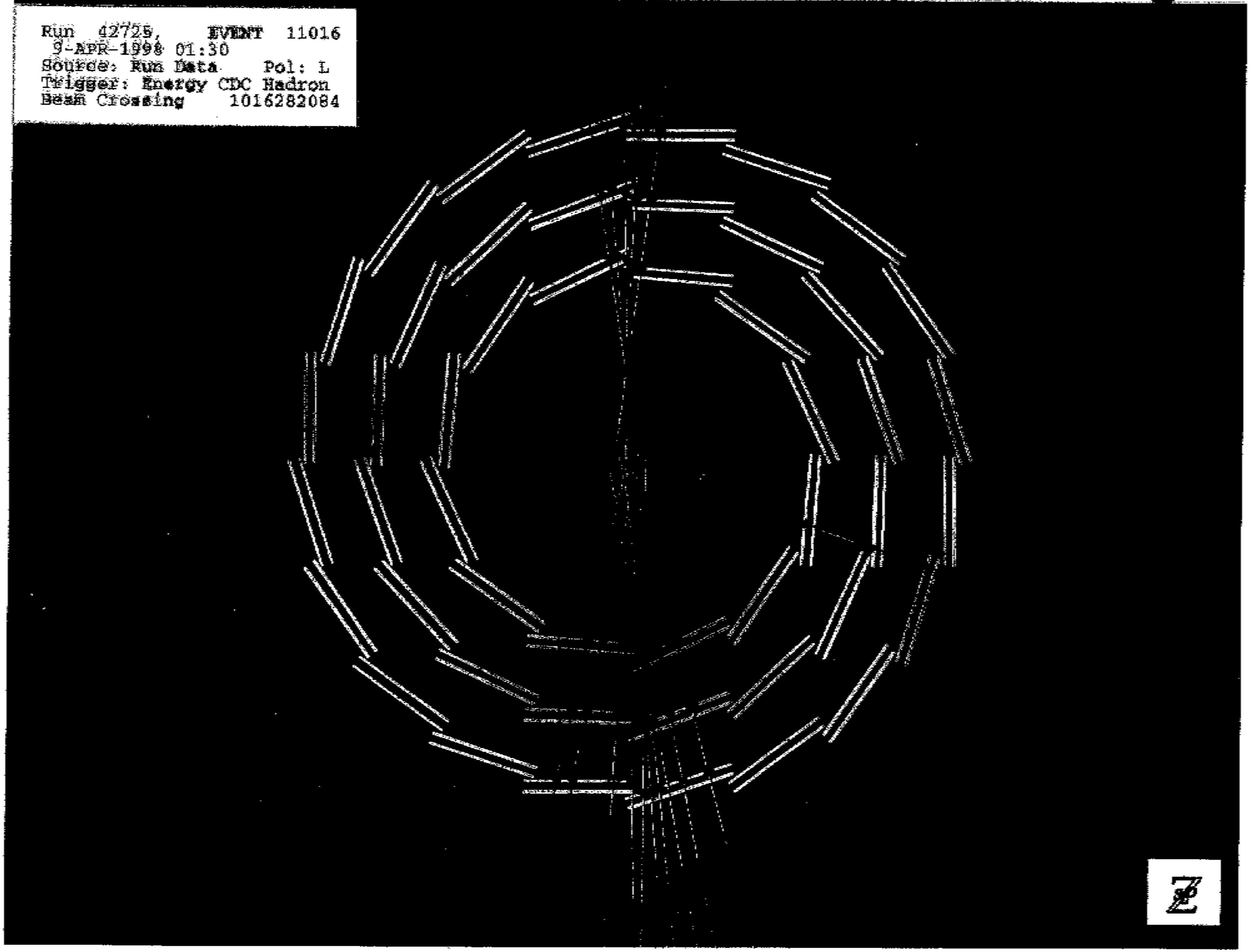
Dave Jackson

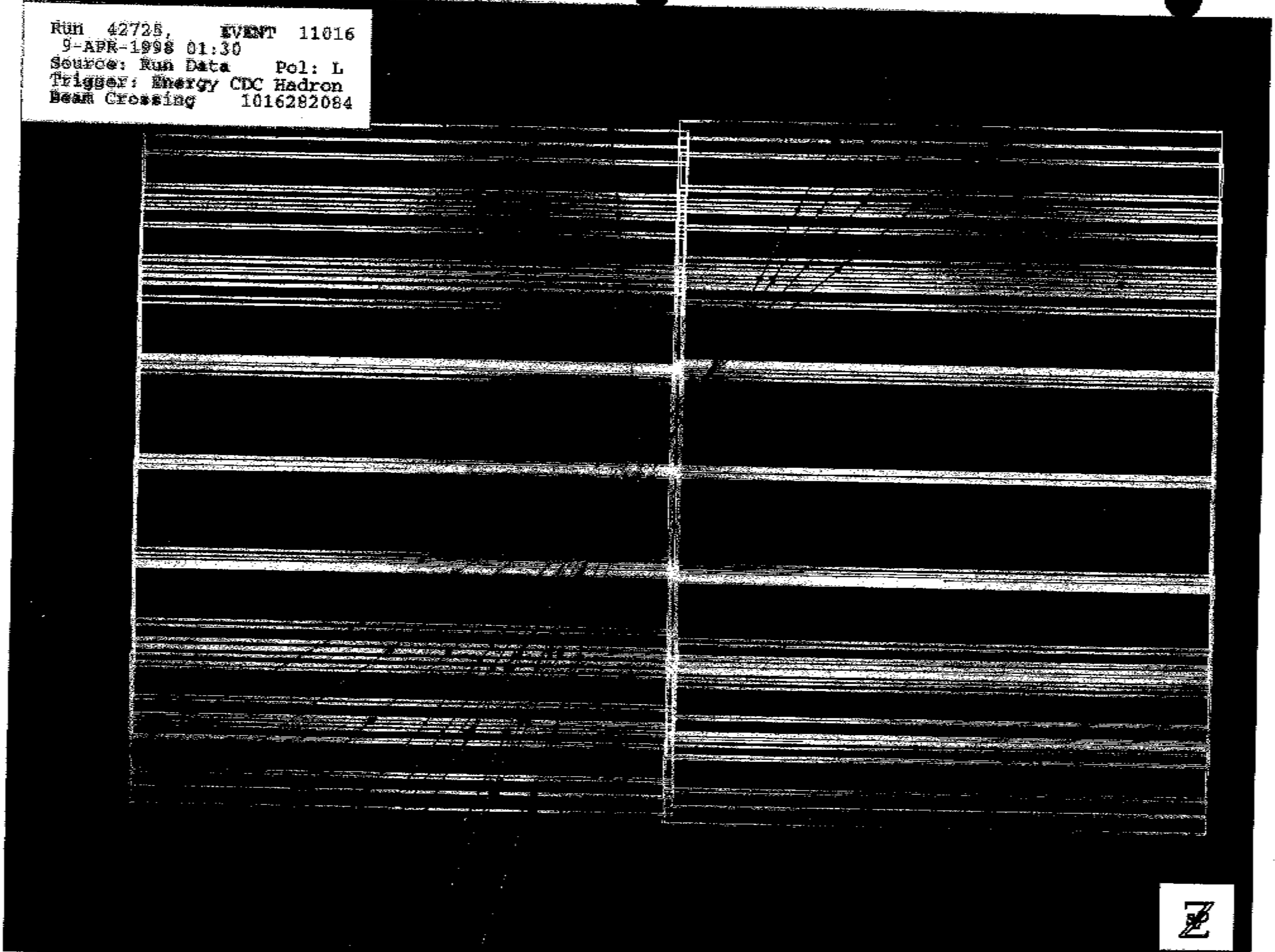


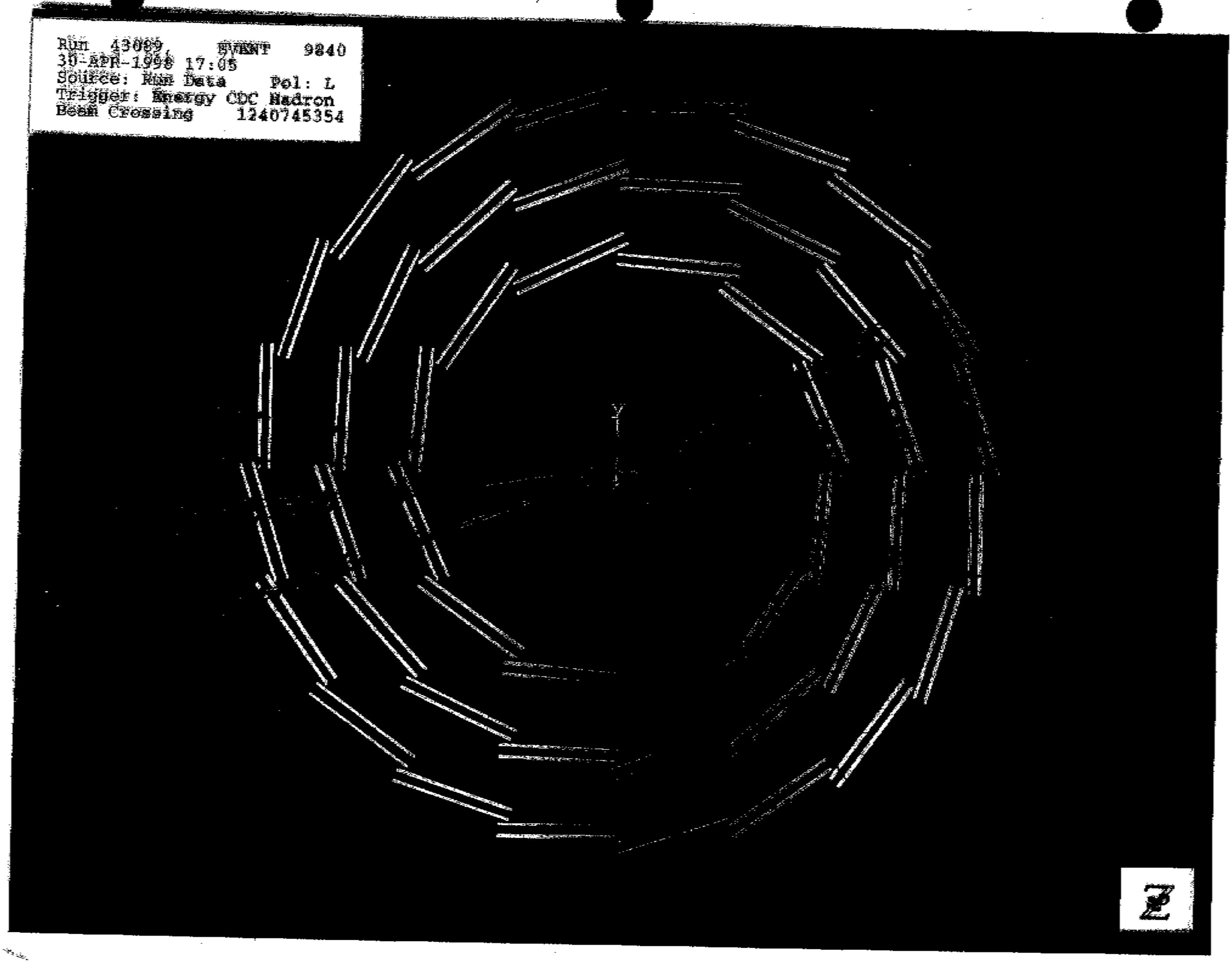


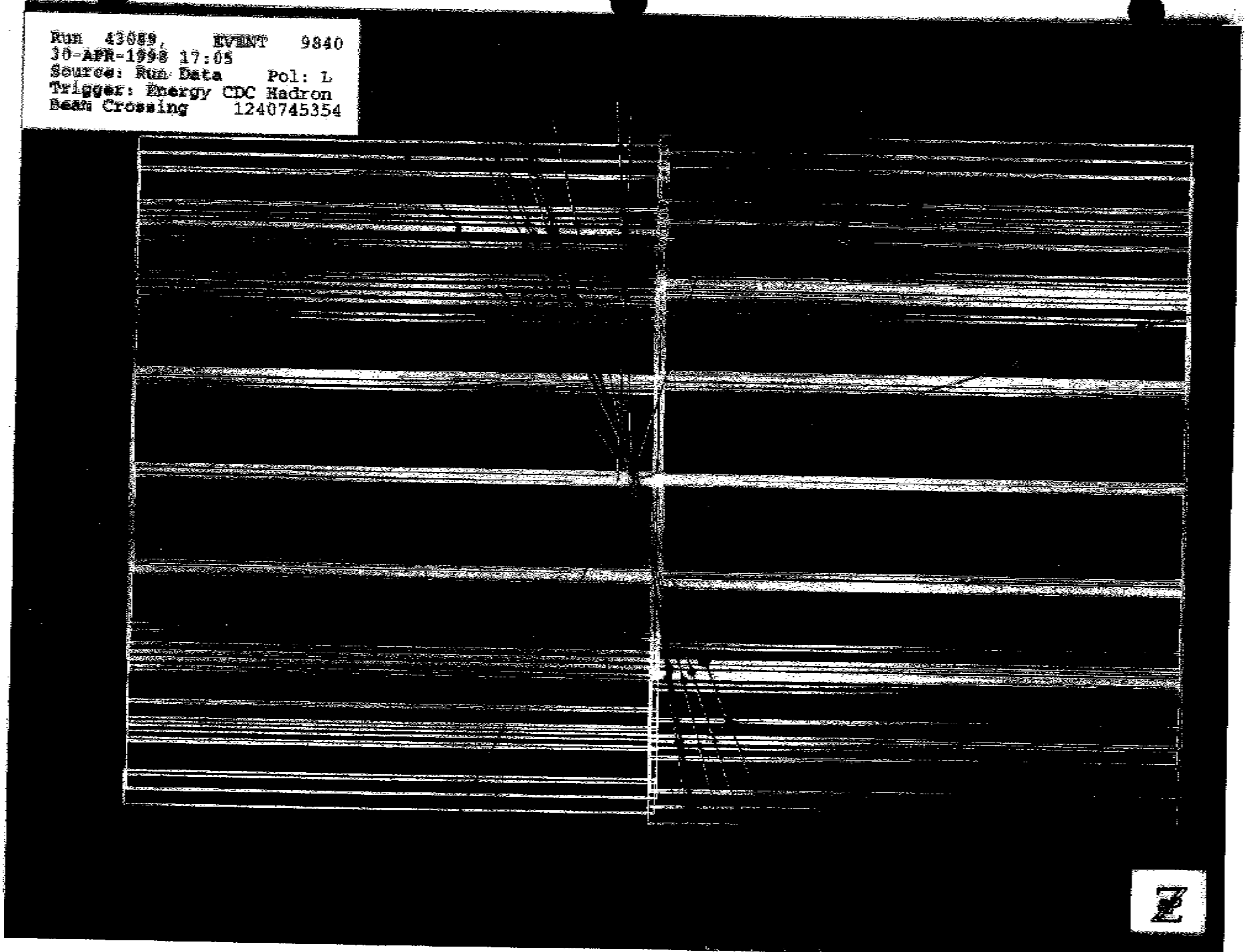


⇒ $\sigma_{\langle xy\ IP \rangle}$ ~ 4 μm


Run 42725, EVENT 11016
9-APR-1998 01:30
Source: Run Data Pol: L
Trigger: Energy CDC Hadron
Beam Crossing 1016282084


Run 42725, EVENT 11016
9-APR-1998 01:30
Source: Run Data Pol: L
Trigger: Energy CDC Hadron
Beam Crossing 1016282084
Z


Run 43089, EVENT 9840
30-APR-1998 17:05
Source: Run Data Pol: L
Trigger: Energy CDC Hadron
Beam Crossing 1240745354
Y

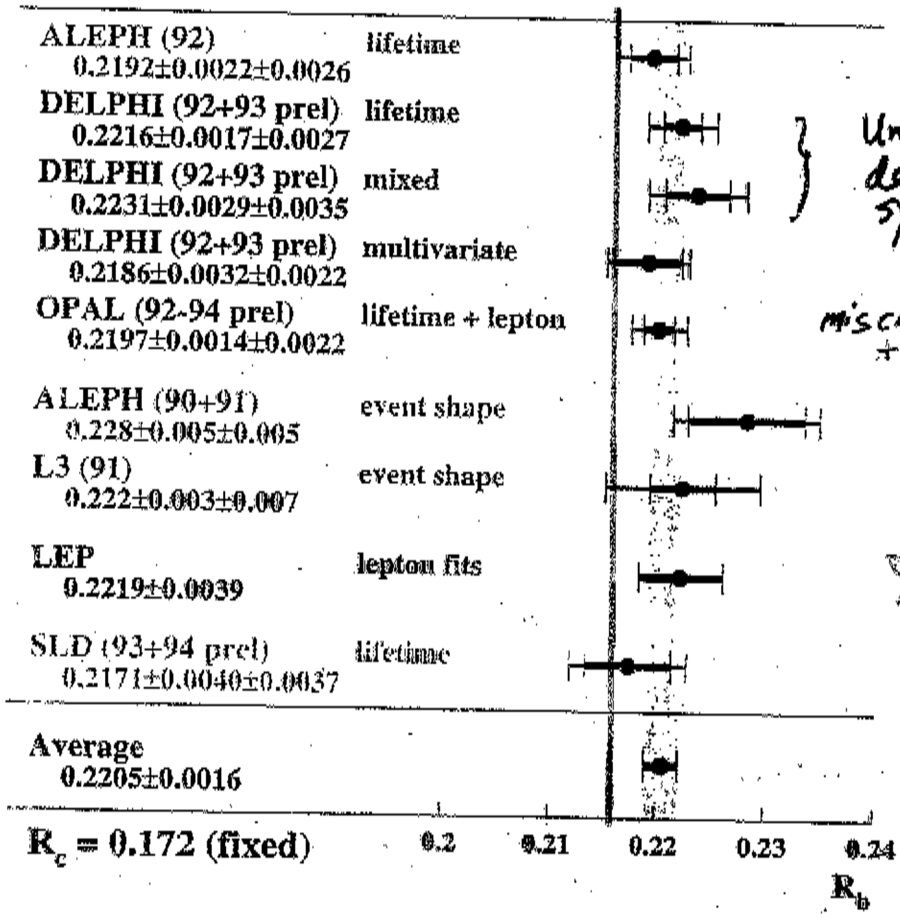


Run 43089, EVENT 9840
30-APR-1998 17:05
Source: Run Data Pol: L
Trigger: Energy CDC Hadron
Beam Crossing 1240745354
Z

"Rb, Rc Crisis"

Dave Charlton

EPS/95

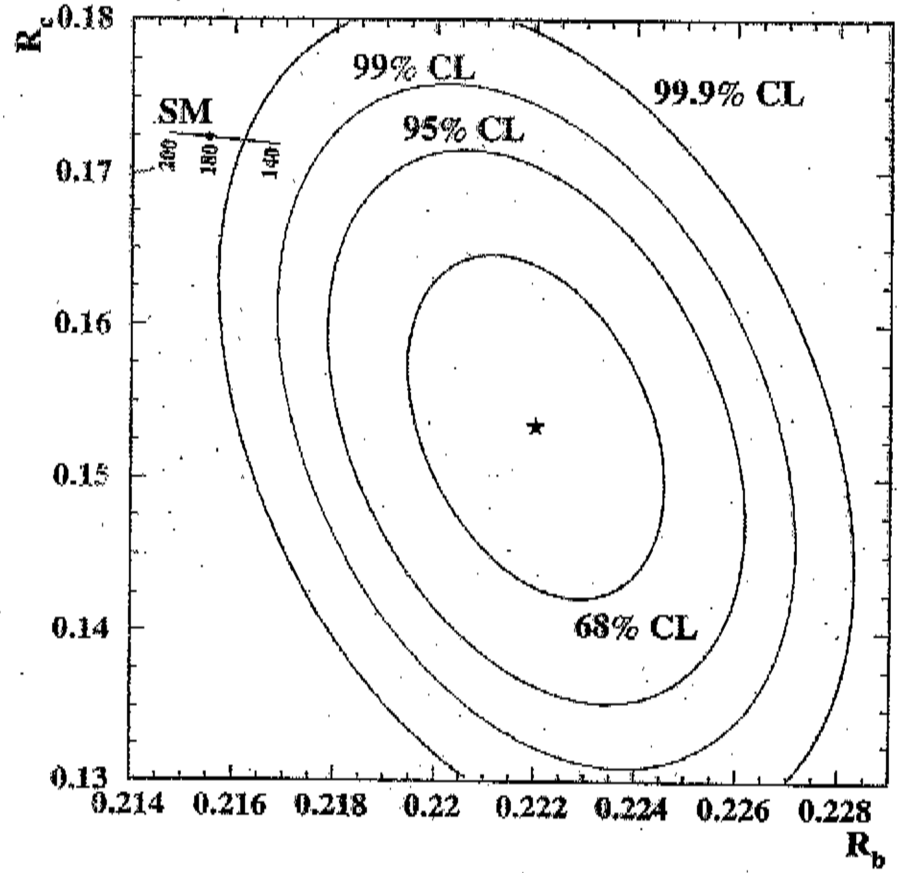


} Underestimated detector resolution systematic

miscalculated MC stat.

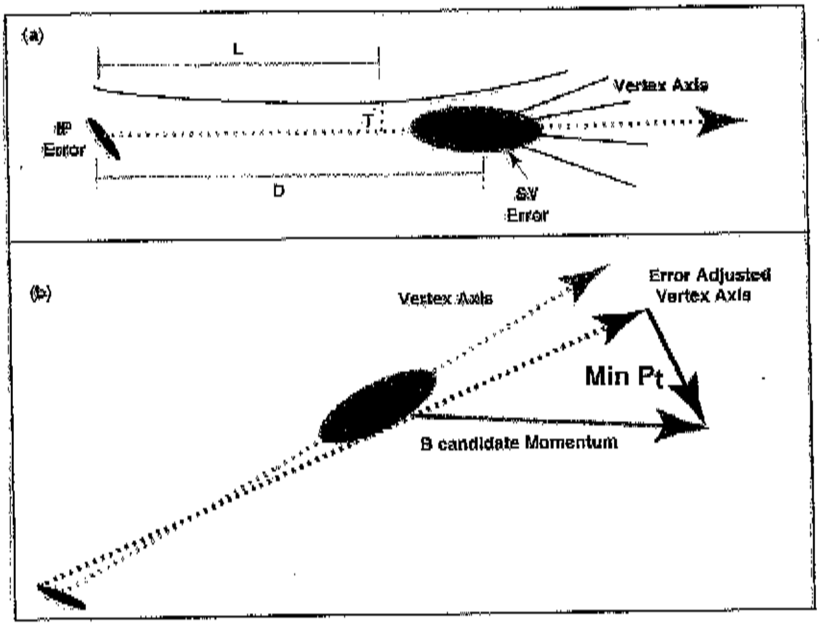
b-tag purity 92-96%

Sys dominated by charm systematic

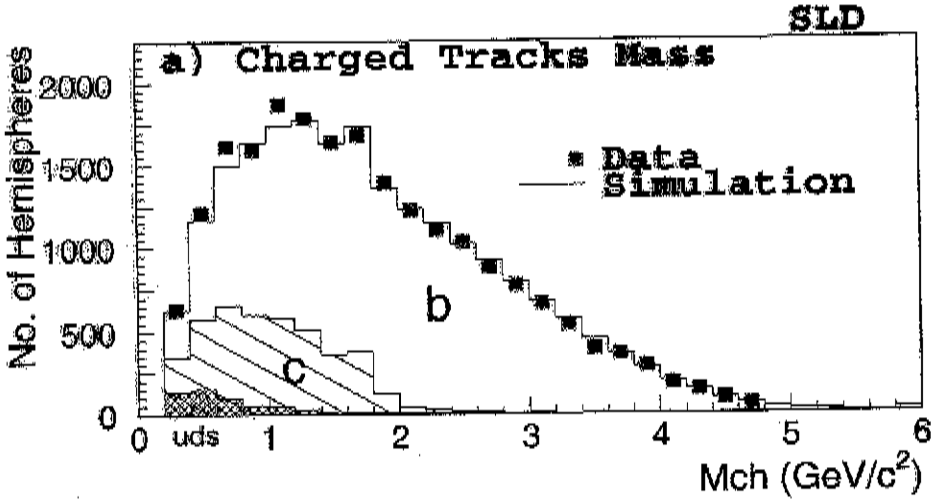


Rc problem was primarily correlated errors from using low Energy measurem[ent] results for Br / production rate

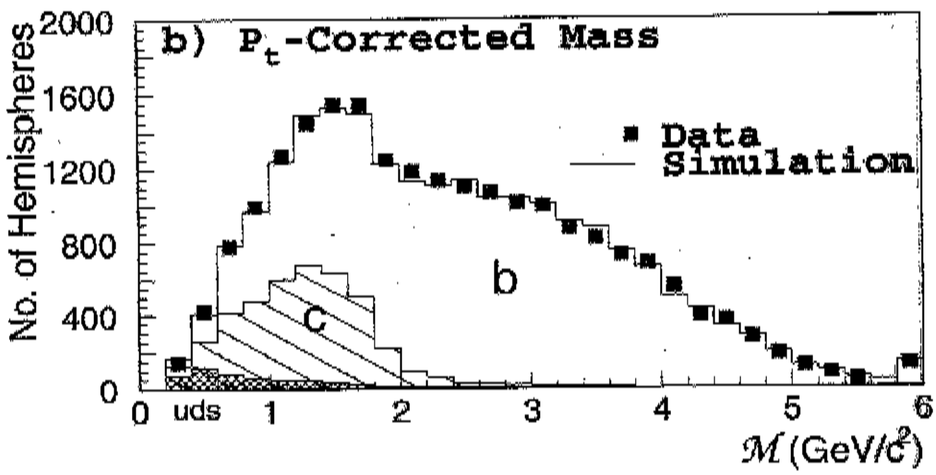
The SLD b Mass tag (Moriond-96)



$$M_{corr} = \sqrt{M_{rav}^2 + P_t^2} + |P_t|$$



$\epsilon_b = 24\%$ $\pi_b = 98\%$



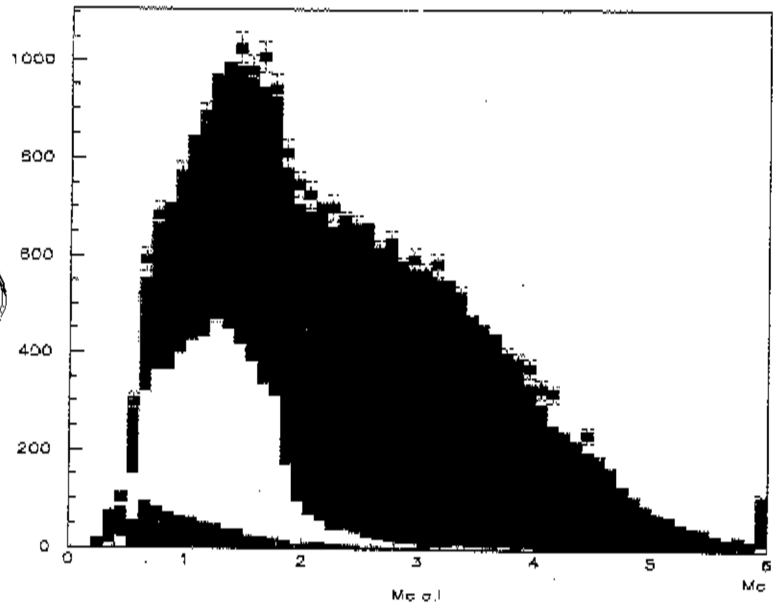
$\epsilon_b = 35\%$ $\pi_b = 98\%$

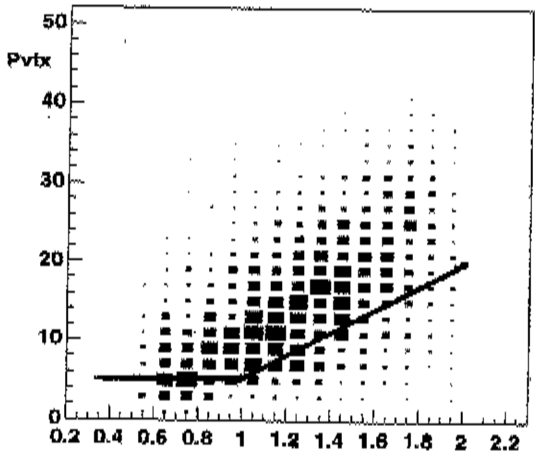
R_c from Vertex mass double tag

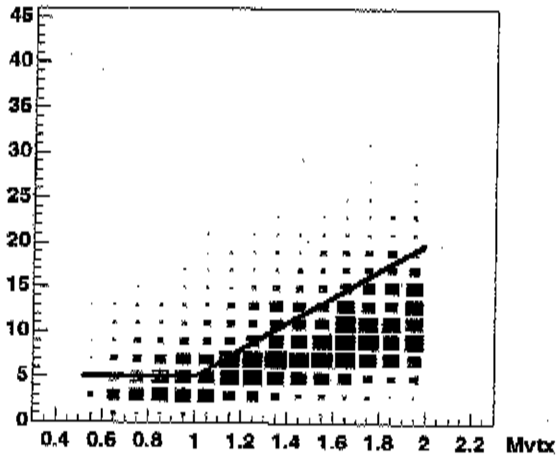
SLD Preliminary

LP 97

(First R_c from SLD was Winter-97 using VXD2 only)







c-efficiency = 11.2/14.0% (93-95/96)
c-purity = 67%

Preliminary 93-96:

$$R_c = 0.181 \pm 0.012_{stat} \pm 0.008_{sys}$$

← mainly $c\bar{c}$ hemisphere correlation

SLD R_b,R_c Chronology

- **Rb DPF-92: 2 event tags 92 data only**
  event ε_b=~55%, Π_b=~75%
  Rb = 0.231±0.012±0.026 (2D impact Homer)
  Rb = 0.213±0.011±0.029 (2D vertex SD)

- **Rb PRD: 3 event-tags 92-93 data**
  Rb = 0.229±0.011 (Homer,Jeff Snyder, SD)

- **Rb Summer-95: IP double-tag 93-95 data**
  hemisphere ε_b=31%, Π_b=94%
  Rb = 0.2171±0.0040±0.0044 (Homer)

- **Rb Moriond-96: mass double-tag 93-95 data**
  hemisphere ε_b=35%, Π_b=98%
  Rb = 0.2142±0.0034±0.0015
  (SD,Erez Etzion,Eric Weiss,John Coller + Dave J)

- **Rc Winter-97: mass/P double-tag 93-95 data**
  hemisphere ε_c=11%, Π_c=68%
  Rb = 0.2142±0.034±0.0015(Nicolo, Jun Yashima)

- **Rb,Rc Summer-97: first look at 96 VXD3 data**
  hemisphere ε_b=48%, Π_b=98%; ε_c=14%, Π_c=67%

- **Rb,Rc Summer-01: NN-tag Full VXD3 data R17**
  hemisphere ε_b=63%, Π_b=98.3%;
  ε_c=18%, Π_c=84% + 2 other tags
  Rb = 0.21641±0.00092±0.00082
  Rc = 0.1738 ±0.0031 ±0.0021
  (Nicolo, SD, Sean Walston + Tom Wright)

The NeuralNet b/c tag

Tom Wright improved the mass tag with additional kinematic information:

a) Track primary/secondary classification NN:

T, L, L/D, angle wrt vertex axis

(97% correct assignment)

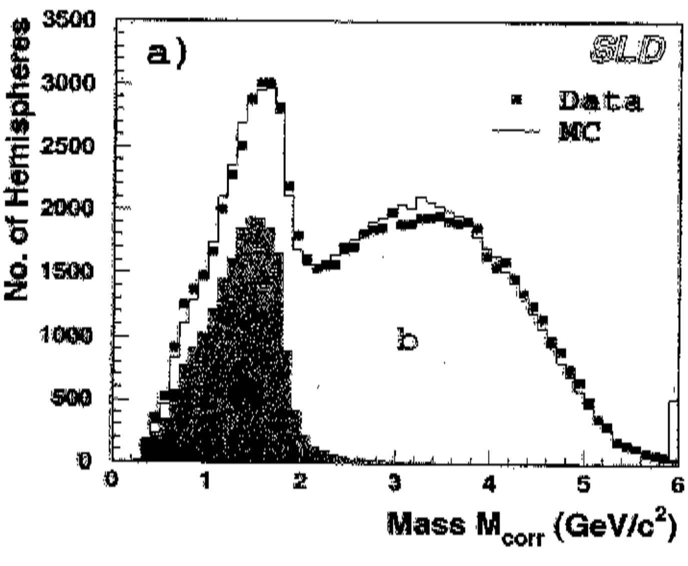
b) c/b separation NN:

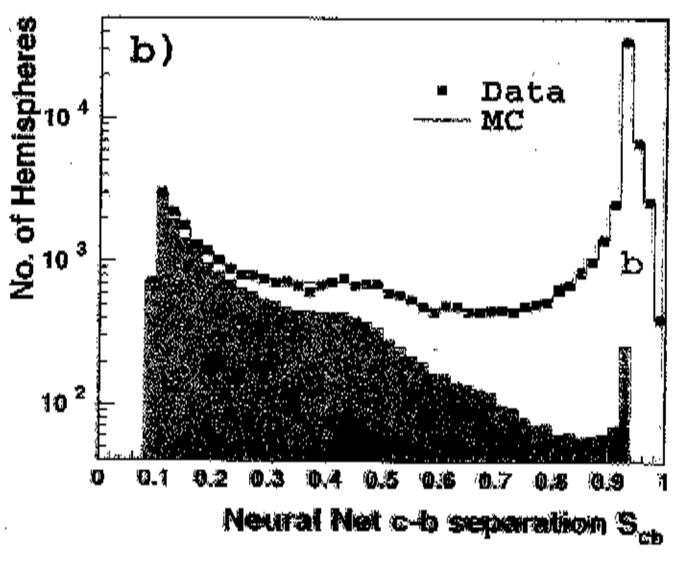
Pt corrected mass, secondary vertex momentum, vertex track multiplicity, vertex decay length

b/c tags:

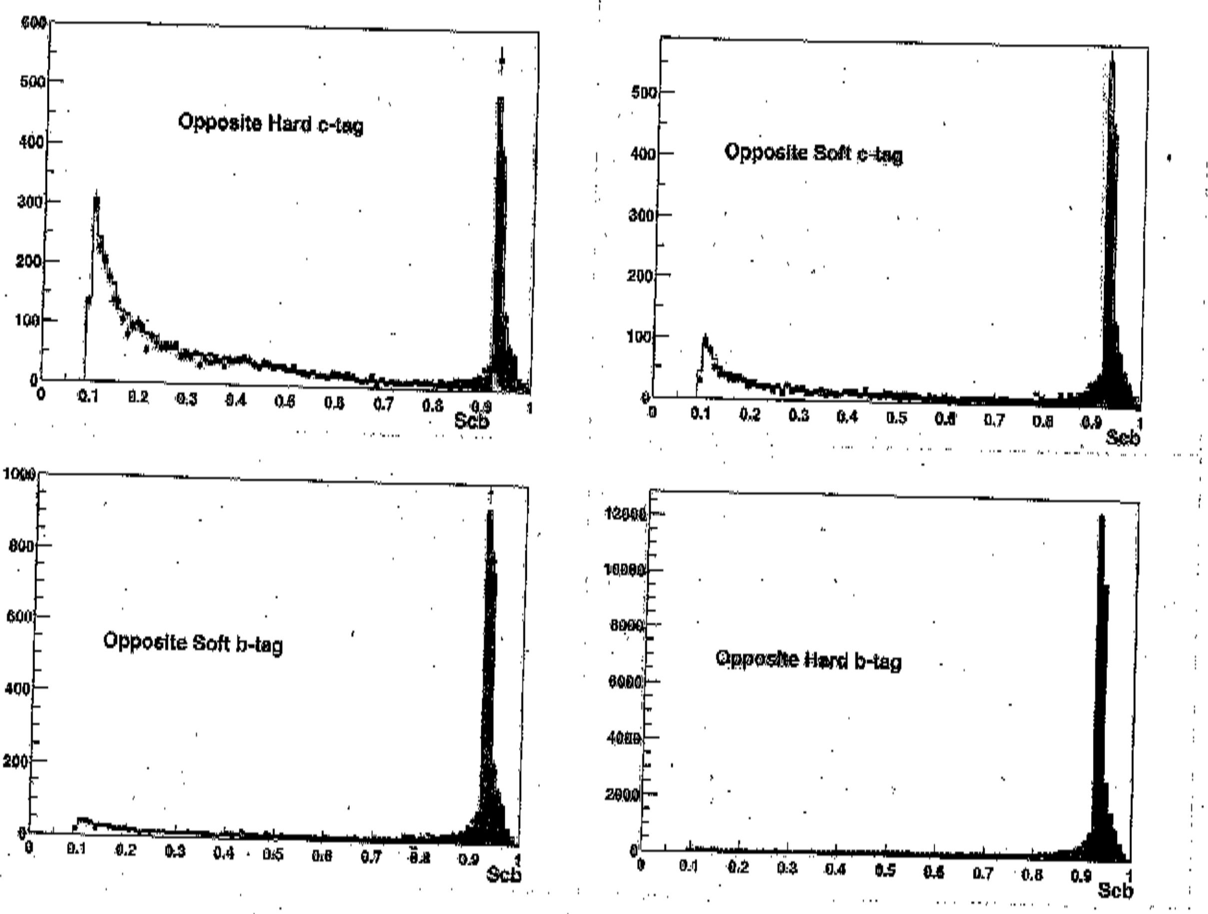
c/b sep>0.75: $\varepsilon_b = 63\%$ $\Pi_b = 98.3\%$

c/b sep<0.30: $\varepsilon_c = 18\%$ $\Pi_c = 84\%$





Current Rc tags



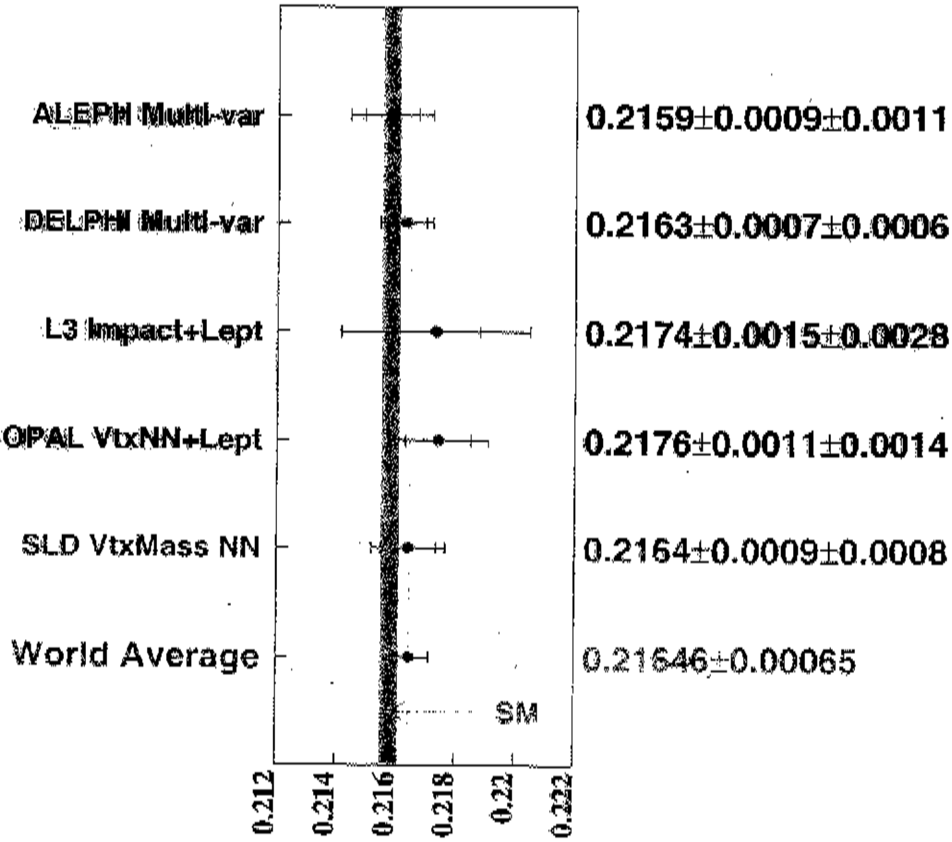
Tag Name	"c-pure"	"c-like"	"b-like"	"b-pure"
Tag Cuts	$S_{cb} < 0.3$	$0.3 < S_{cb} < 0.5$	$0.5 < S_{cb} < 0.75$	$S_{cb} > 0.75$
ϵ_b (%)	2.53	2.96	5.10	62.02
ϵ_c (%)	17.94	5.04	2.29	1.12
ϵ_{uds} (%)	0.05	0.10	0.12	0.07
b purity (%)	15.0	40.9	70.4	98.3
c purity (%)	84.2	55.3	25.1	1.4
uds purity (%)	0.9	3.8	4.5	0.3

$$\chi^2 = \sum_{ij} \frac{N_{ij}/N_{\text{tot}} - R_b\epsilon_i^b\epsilon_j^b C_{ij}^b - R_c\epsilon_i^c\epsilon_j^c C_{ij}^c - (1 - R_b - R_c)\epsilon_i^{uds}\epsilon_j^{uds} C_{ij}^{uds}}{\sigma(N_{ij}/N_{\text{tot}})}$$

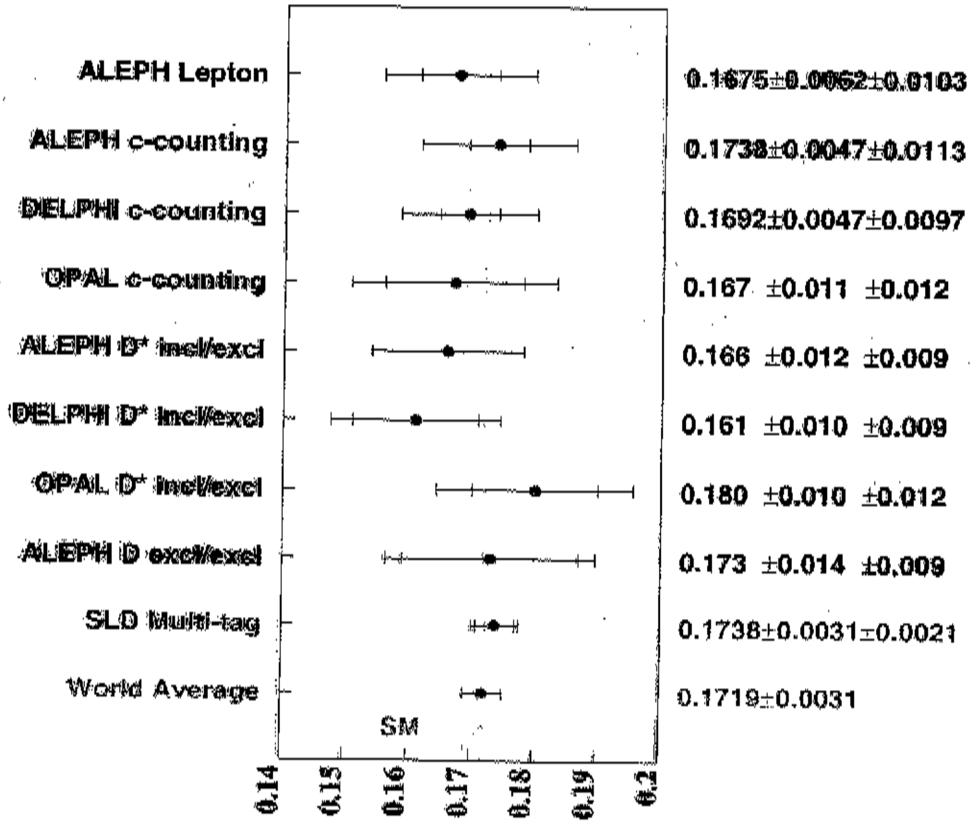
R_b, R_c results (Summer 2001)

Observable	R_b	R_c
Data sample	1993–1998	1996–1998
References	(46, 47)	(46, 49)
Measurement value	0.21641	0.17382
Statistical error	0.00092	0.00308
Monte Carlo statistics	0.00024	0.00095
Event selection bias	0.00026	0.00027
uds and charm physics	0.00042	0.00142
b-hemisphere correlation	0.00023	0.00025
$g \to c\overline{c}, g \to b\overline{b}$	−0.00023	−0.00082
Detector effects	0.00043	0.00079
R_c (± 0.006)	−0.00020	—
R_b (± 0.0015)	—	−0.00020
Total systematic error	0.00080	0.00209

R_b Measurements (Summer-2001)



R_c Measurements (Summer-2001)



Conclusions

- The SLD CCD vertex detectors have set a new standard in detector technology and unlikely to be matched any time soon. There is no need for argument of what you should use in future LC…

- The CCD vertex detector and small and stable SLC IP gave crucial advantage and unique characters to the SLD heavy flavor physics.

- SLD's Rb,Rc measurements made good use of the SLD detector advantage and incoporated important innovative analysis techniques to make leading contributions to the knowledge of Z0 to b,c quark couplings.