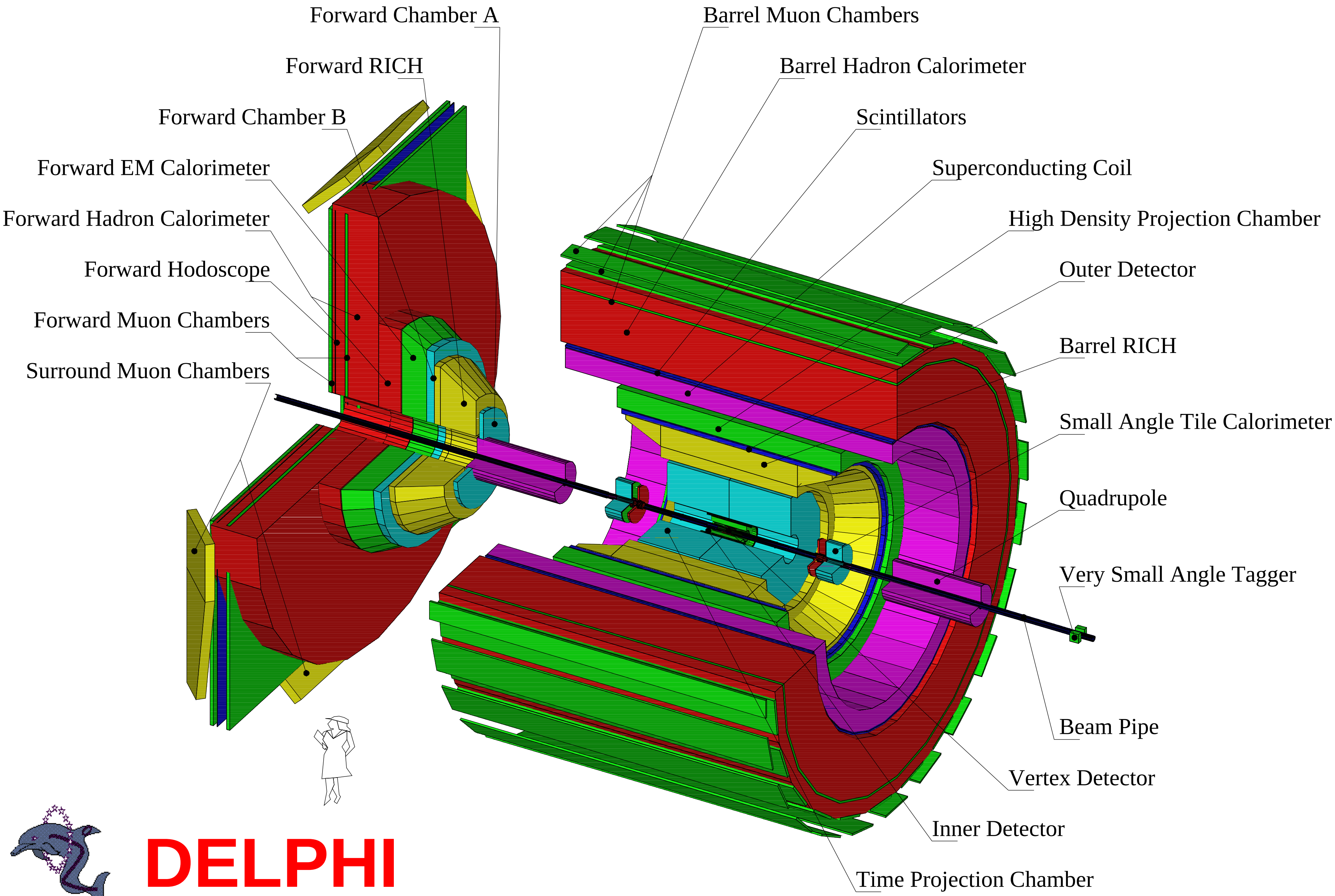
DELPHI Micro-Vertex Detector (and beyond..)

- The DELPHI Micro-Vertex Detector
- The DELPHI Micro-Vertex Detector
- The DELPHI Micro-Vertex Detector
- The DELPHI Micro-Vertex Detector
- The DELPHI Si-Tracker
- Radiation
- And beyond.


Forward Chamber A
Forward RICH
Forward Chamber B
Forward EM Calorimeter
Forward Hadron Calorimeter
Forward Hodoscope
Forward Muon Chambers
Surround Muon Chambers
Barrel Muon Chambers
Barrel Hadron Calorimeter
Scintillators
Superconducting Coil
High Density Projection Chamber
Outer Detector
Barrel RICH
Small Angle Tile Calorimeter
Quadrupole
Very Small Angle Tagger
Beam Pipe
Vertex Detector
Inner Detector
Time Projection Chamber

DELPHI

1987: First signs of DELPHI Micro-Vertex Detector

- L=59 mm,
  d=280 μm, 25 μm pitch.
- S/N(single-strip)=16!

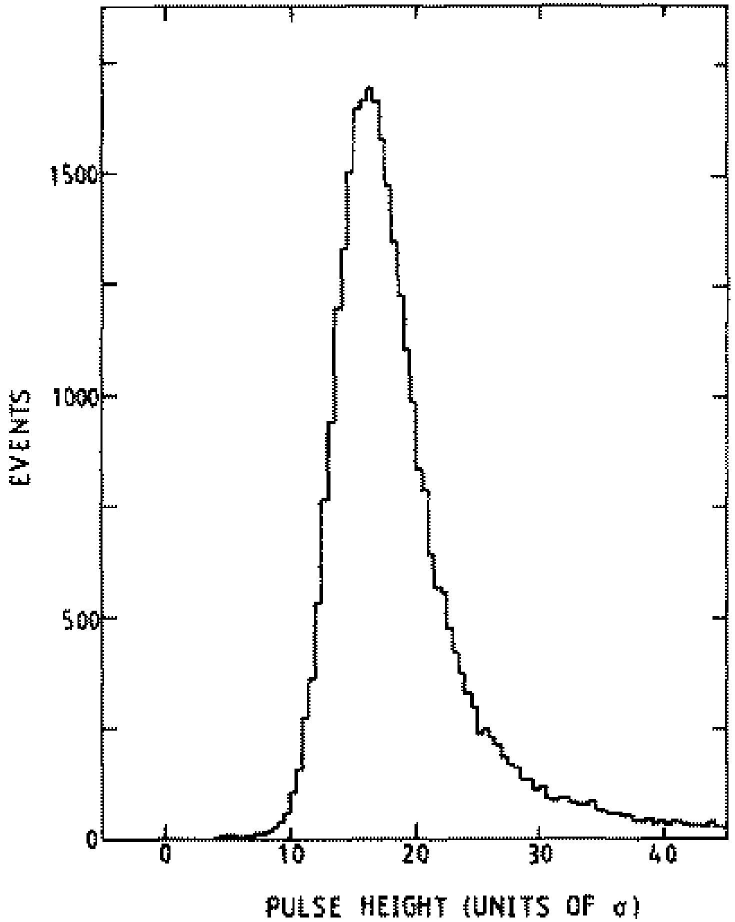


Fig. 5. Pulse height distribution for minimum ionizing particles.

Nuclear Instruments and Methods in Physics Research A256 (1987) 65–69 65
North-Holland, Amsterdam

LATEST RESULTS FROM SILICON MICROSTRIP DETECTORS WITH VLSI READOUT FOR THE DELPHI MICROVERTEX DETECTOR

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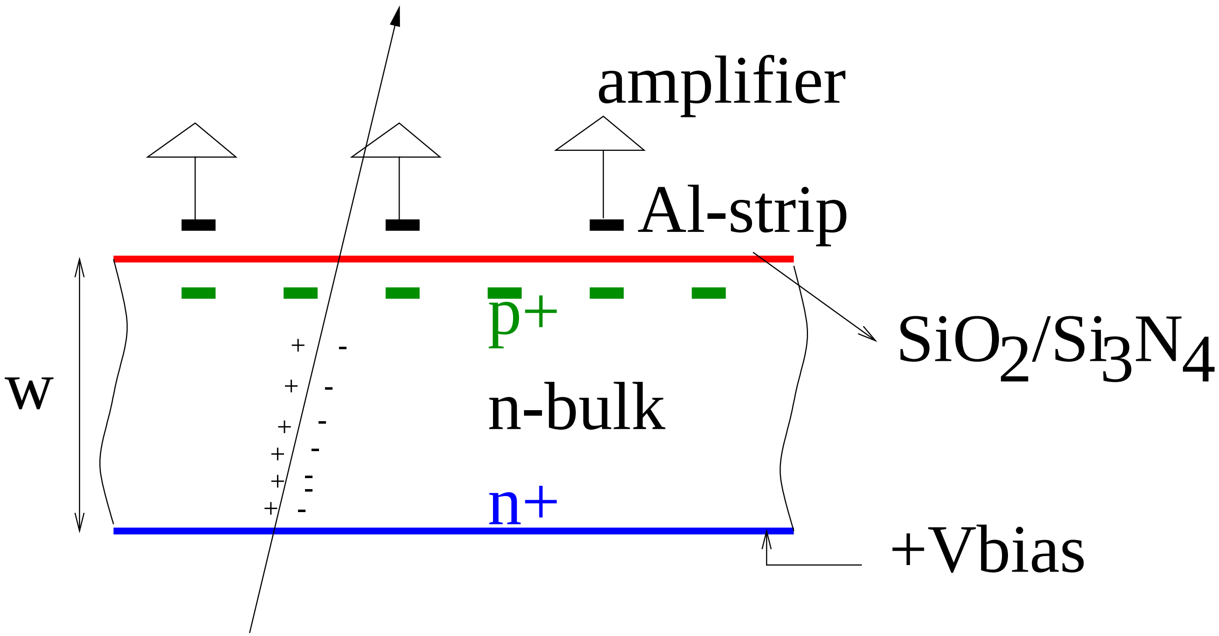
Received 13 November 1986

A silicon microstrip counter with 25 μm strip pitch and two 128-channel low noise VLSI readout chips ("MICROPLEX") has been tested in a 3.5 GeV negative pion beam at CERN. Results are given on the signal-to-noise ratio and on the cluster size spreading due to capacitive crosstalk.

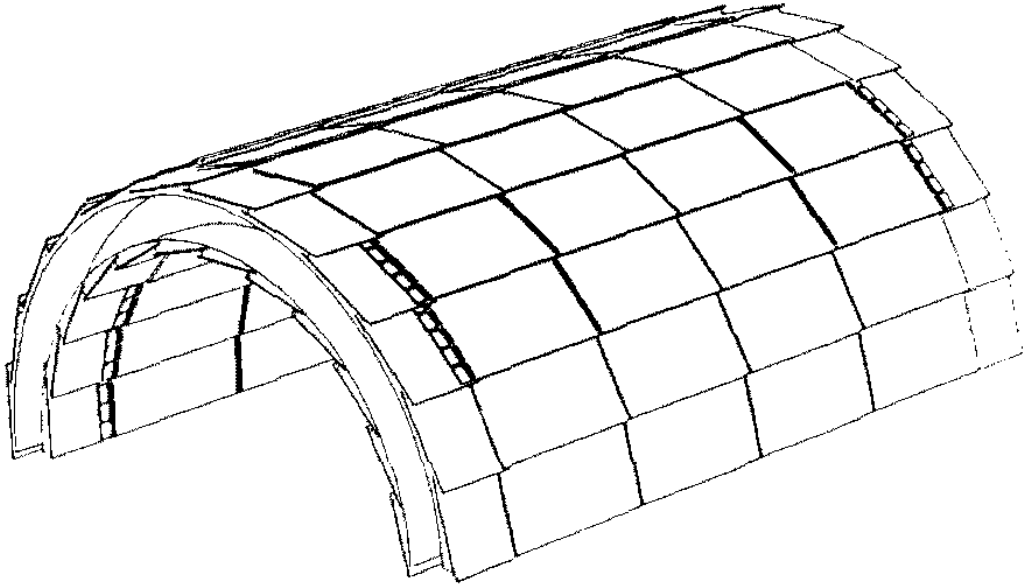
Basic ingredients of Si-detector



- w: typically 300 μm (=0.32%X_0), 24k e/h pairs produced.
- pitch
  - vertexing→precision→ match diffusion width ($\sqrt{mobility \times drift - time}$), typically 10$\mu$m. Hence 25$\mu$m pitch.
    Use floating strips+capacitive coupling and connect to 50μm pitch electronics.
  - tracking→save on electronics→ typically 200 μm read-out pitch with any number of floating strips.
  - pattern recognition: pixels (1×1 mm^2 to 50×50μm^2). Essentially the same as strips, but bias=DC, electronics is bump-bonded.

1998: Design DELPHI Micro-Vertex Detector

- Glue 4 sensors together.
- Bond 2-by-2, +Microplex chip



Nuclear Instruments and Methods in Physics Research A263 (1988) 215–220
North-Holland, Amsterdam

THE DELPHI SILICON STRIP MICROVERTEX DETECTOR

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N. BINGEFORS
University of Uppsala, Sweden

The silicon strip microvertex detector for the DELPHI experiment at LEP is presented. It consists of two cylindrical layers with a total of 165 888 strips. The design parameters of the final project are described.

The microstrip counters have a pitch of 16.6 μm, and are read out every 50 μm using the capacitive charge division method. The electronics used is the Microplex chip, an NMOS integrated circuit, which provides 128 channels of low noise charge sensitive amplifiers with multiplexed analog output. Results of signal-to-noise ratio from beam tests on prototype detectors are given and discussed.

1989: The DELPHI Micro-Vertex Detector

- Manpower increases
- Photo real sensor.

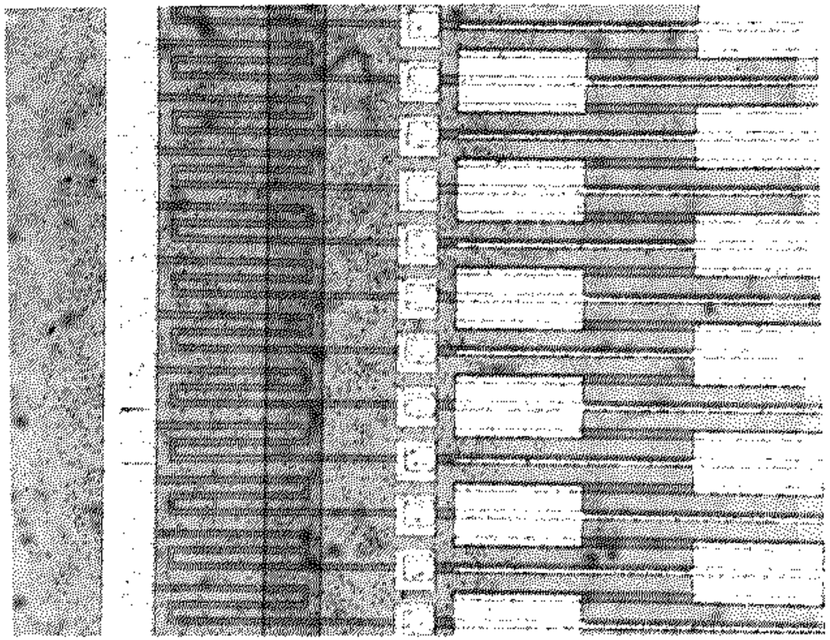

Fig. 5. Photograph of the bond pad area of an ac-coupled detector showing the bond pads, $60 \times 100\ \mu m^2$, the diode strips and the polysilicon resistors with $5\ \mu m$ line width.

154 Nuclear Instruments and Methods in Physics Research A277 (1989) 154–159
North-Holland, Amsterdam

PROGRESS IN THE CONSTRUCTION OF THE DELPHI MICROVERTEX DETECTOR

M. BURNS, H. DIJKSTRA, R. HORISBERGER, L. HUBBELING, B.D. HYAMS, G. MAEHLUM, A. PEISERT, J.P. VANUXEM, P. WEILHAMMER and A. ZALEWSKA *
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INFN, Milan, Italy

M. MAZZUCATO, F. SIMONETTO and G. ZUMERLE
INFN, Padua, Italy

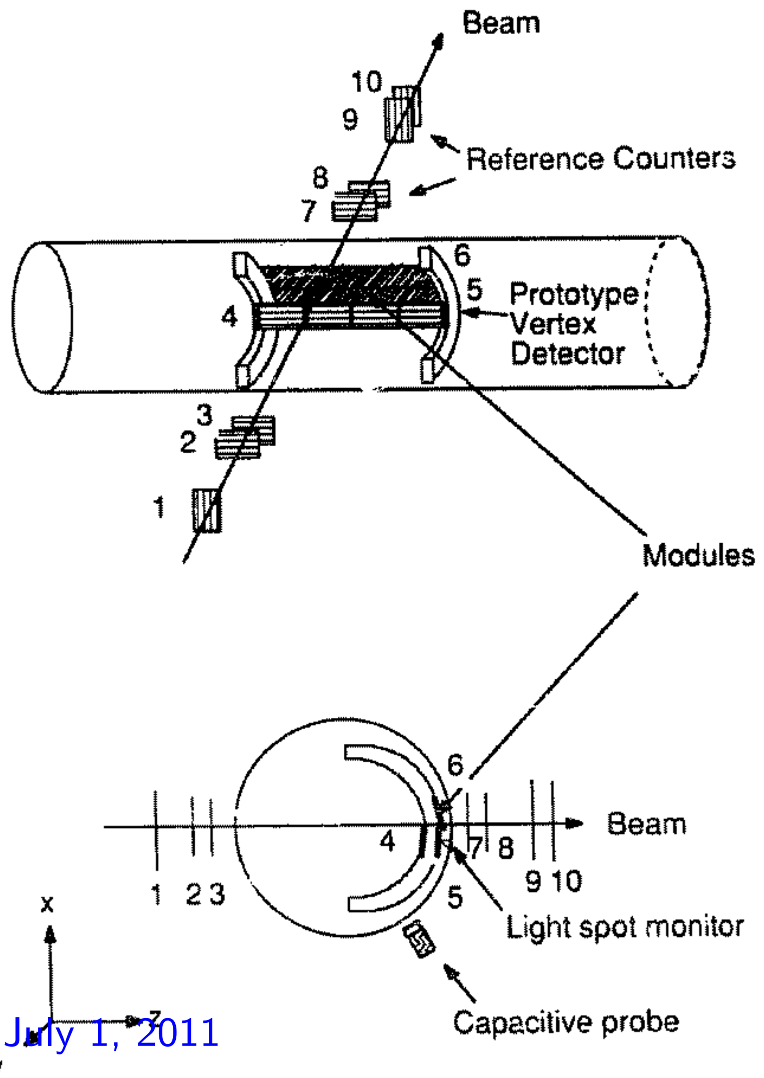
P. ALLPORT, G. KALMUS, P. SELLER, J. STANTON and M. TYNDEL
Rutherford Appleton Laboratory, Chilton, Didcot, Oxon., OX11 0QX, UK

N. BINGEFORS
University of Uppsala, Sweden

The design and progress in the construction of the DELPHI microvertex detector are presented. The layout is described, together with results on precision mounting of silicon detectors. The development of ac-coupled silicon microstrip detectors was an important contribution to the design. The use of low-power CMOS readout chips facilitates the cooling of the detector. A description of the fourth-generation readout processor for silicon strip detectors, the SIROCCO IV, implemented in FASTBUS, is given. Finally, two complementary systems for in-situ position monitoring of the detectors are described.

1990: DELPHI Micro-Vertex Detector in Beam

- MX3: S/N 16 for 12 cm long sensor.
- MVD-complete: 55 296 channels.
- Test: 10 880 channels



Nuclear Instruments and Methods in Physics Research A292 (1990) 75–80
North-Holland
75

BEAM TEST RESULTS FROM A PROTOTYPE FOR THE DELPHI MICROVERTEX DETECTOR

V. CHABAUD, H. DIJKSTRA, M. GRÖNE, M. FLOHR, R. HORISBERGER, L. HUBBELING, G. MAEHLUM, A. PEISERT, A. SANDVIK and P. WEILHAMMER

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G. BARICHELLO, M. MAZZUCATO, M. PEGORARO and F. SIMONETTO

INFN, Padua, Italy

P. ALLPORT and M. TYNDEL

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H.J. SEEBRUNNER

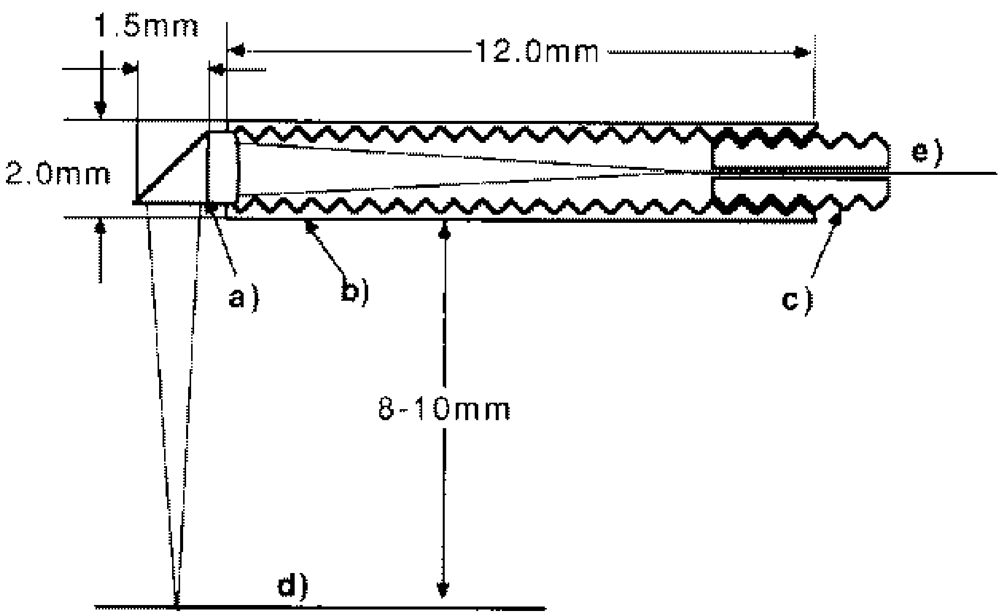
Fachhochschule Heilbronn, Heilbronn, FRG

Received 23 January 1990

Results are presented from a test in the CERN SPS North Area of a prototype of the DELPHI microvertex detector. Full-sized modules built up from prototype ac-coupled detectors and VLSI readout electronics were used. The spatial resolution of the detectors equipped with prototype VLSI chips was measured to be 6.5 μm. The system aspects, including the readout, were found to work well. Extrapolating to the final components we expect to achieve a measurement precision of 5 μm with the DELPHI microvertex detector.

Beam Test Performance

- Got $5\ \mu$m resolution.
- Tested stability with:
  - Laser spots on Outer layer.
  - Capacitive probes on end-rings.
  - Both systems also put into DELPHI, to measure movement between Inner Jet Chamber and MicroVertex: never really used...



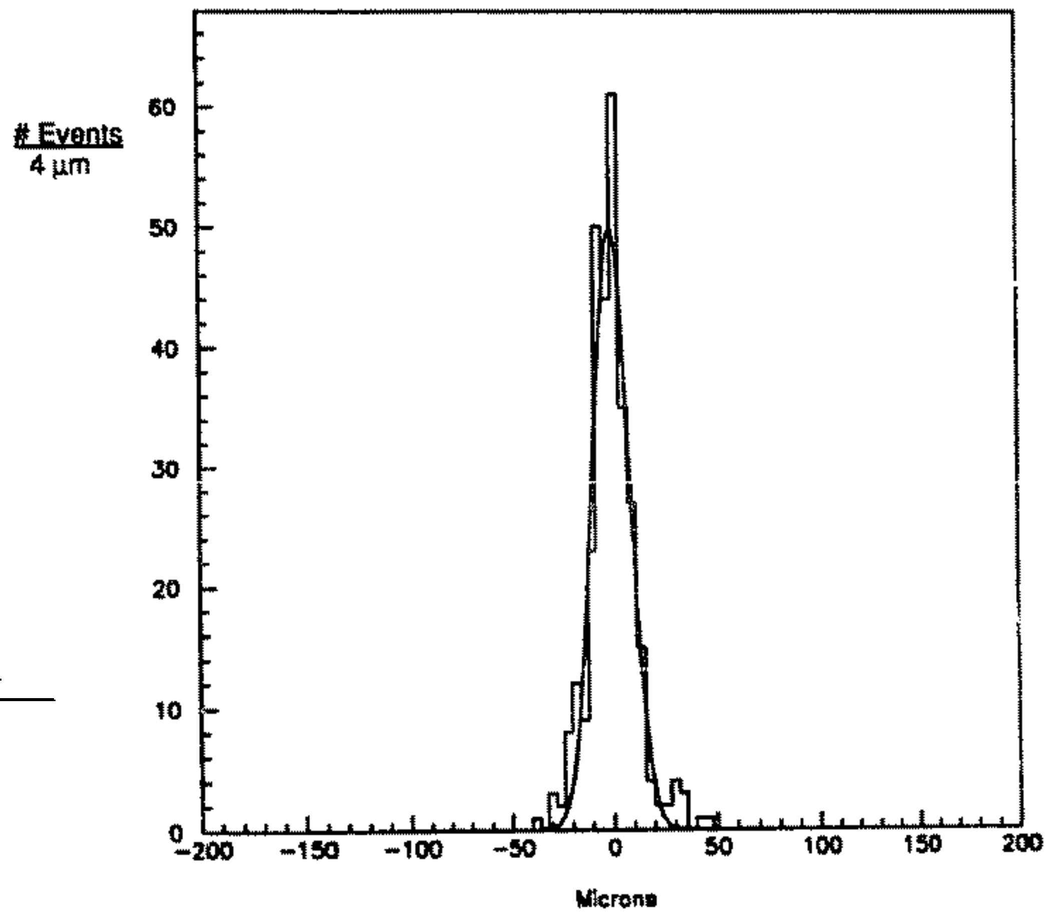
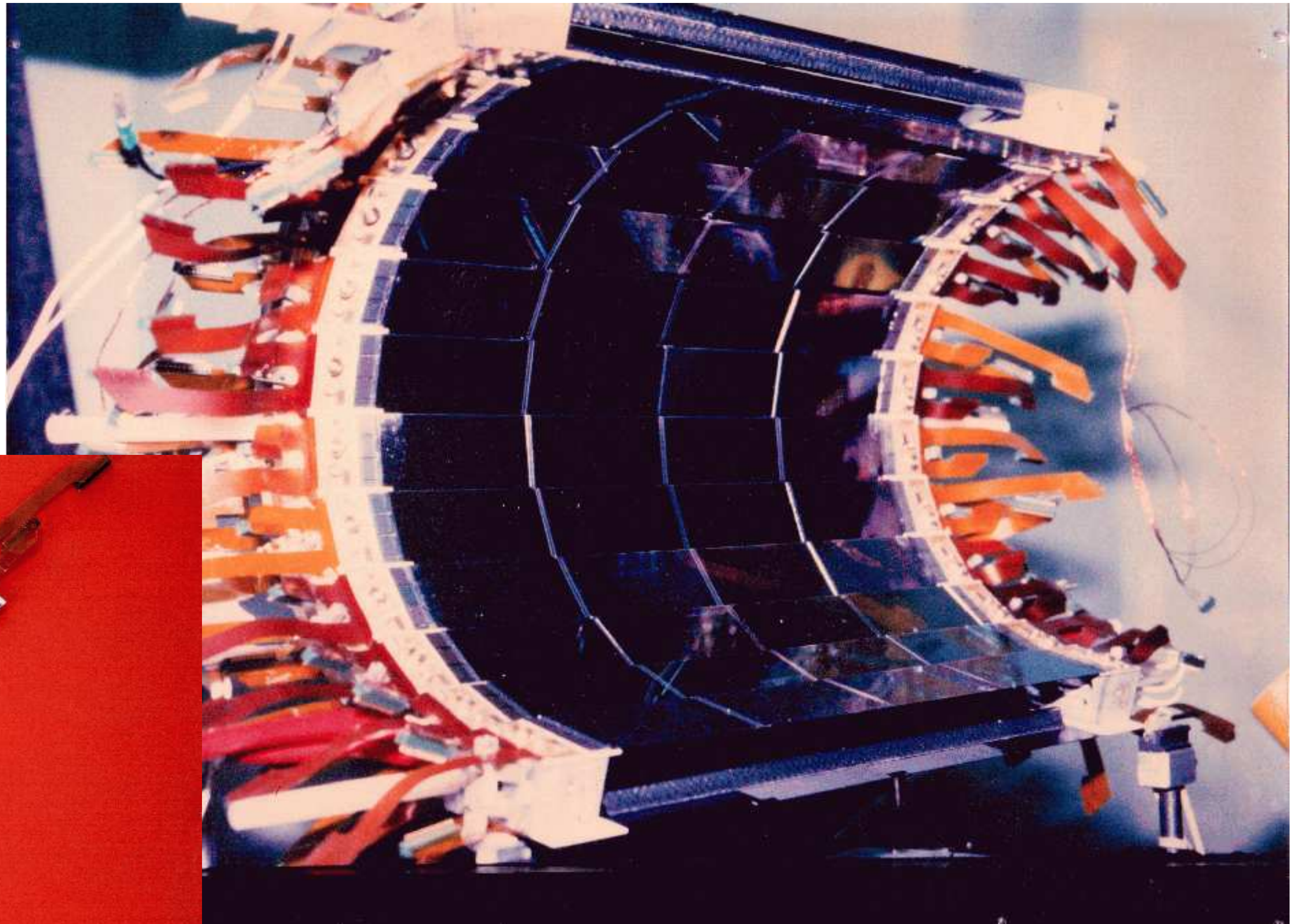


Fig. 8. Residues for the DELPHI half module.

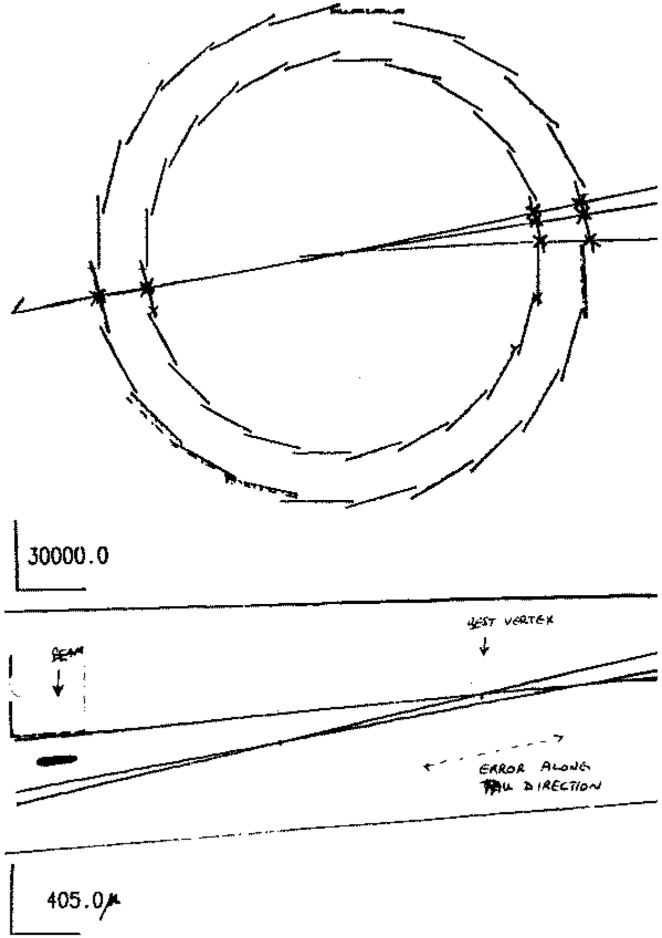
The 1990 Delphi Microvertex Detector

- Complete halve-shell
- Single Outer layer ladder.



1991: Did it work?

- Detector installed in March 1990
- Used 1990 data.
- Performed according to expectations!



Physics Letters B 267 (1991) 422–430
North-Holland

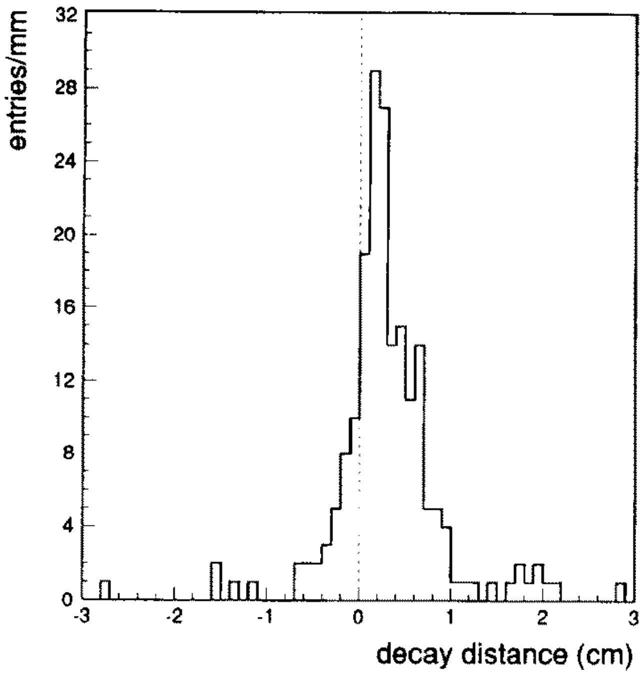
PHYSICS LETTERS B

A measurement of the lifetime of the tau lepton

DELPHI Collaboration

G.E. Theodosiou [x], A. Tilquin [aq], J. Timmermans [ab], V.G. Timofeev [f], L.G. Tkatchev [f],
T. Todorov [f], D.Z. Toet [ab], L. Tortora [q], M.T. Trainor [s], D. Treille [i], U. Trevisan [u],
W. Trischuk [i], G. Tristram [v], C. Troncon [r], A. Tsirou [i], E.N. Tsyganov [f], M. Turala [ap],
R. Turchetta [y], M.-L. Turluer [c], T. Tuuva [af], I.A. Tyapkin [f], M. Tyndel [d], S. Tzamarias [i].

The lifetime of the tau lepton has been measured by two independent methods using a silicon microvertex detector installed in the DELPHI detector. The signed impact parameter distribution of the one prong decays yielded a lifetime of $\tau_\tau = 321 \pm 36$ (stat.) ± 16 (syst.) fs, while the decay length distribution of three prong decays gave the result $\tau_\tau = 310 \pm 31$ (stat.) ± 9 (syst.) fs. The final value of the combined result was $\tau_\tau = 314 \pm 25$ fs. The ratio of the Fermi coupling constant from tau decay relative to that from muon decay was found to be 0.95 ± 0.04, compatible with the hypothesis of lepton universality.



What next: 1991

- LEP synchrotron radiation “mapped”
- Add extra shields and:
- Reduced beam-pipe:
  - 1990: 1.2 mm Al $\oslash = 160$ mm
  - $>$1990: 1.4 mm Be $\oslash = 106$ mm
- Add an extra layer.
- $\sigma^2 = (\frac{130 \to 69}{p_T})^2 + (7 \to 3 \times \sigma_{VD})^2$

Nuclear Instruments and Methods in Physics Research A328 (1993) 447–471
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

The DELPHI Microvertex detector

T. Adye, R. Apsimon, J. Bizell, L. Denton, G.E. Kalmus, J. Lidbury, P. Seller and M. Tyndel
Rutherford Appleton Lab., Chilton, UK

+another 67 authors...

The DELPHI Microvertex detector, which has been in operation since the start of the 1990 LEP run, consists of three layers of silicon microstrip detectors at average radii of 6.3, 9.0 and 11.0 cm. The 73728 readout strips, oriented along the beam, have a total active area of 0.42 m^2. The strip pitch is 25 μm and every other strip is read out by low power charge amplifiers, giving a signal to noise ratio of 15:1 for minimum ionizing particles. On-line zero suppression results in an average data size of 4 kbyte for Z^0 events. After a mechanical survey and an alignment with tracks, the impact parameter uncertainty as determined from hadronic Z^0 decays is well described by $\sqrt{(69/p_t)^2+24^2}$ μm, with p_t in GeV/c. For the 45 GeV/c tracks from $Z^0 \to \mu^+\mu^-$ decays we find an uncertainty of 21 μm for the impact parameter, which corresponds to a precision of 8 μm per point. The stability during the run is monitored using light spots and capacitive probes. An analysis of tracks through sector overlaps provides an additional check of the stability. The same analysis also results in a value of 6 μm for the intrinsic precision of the detector.

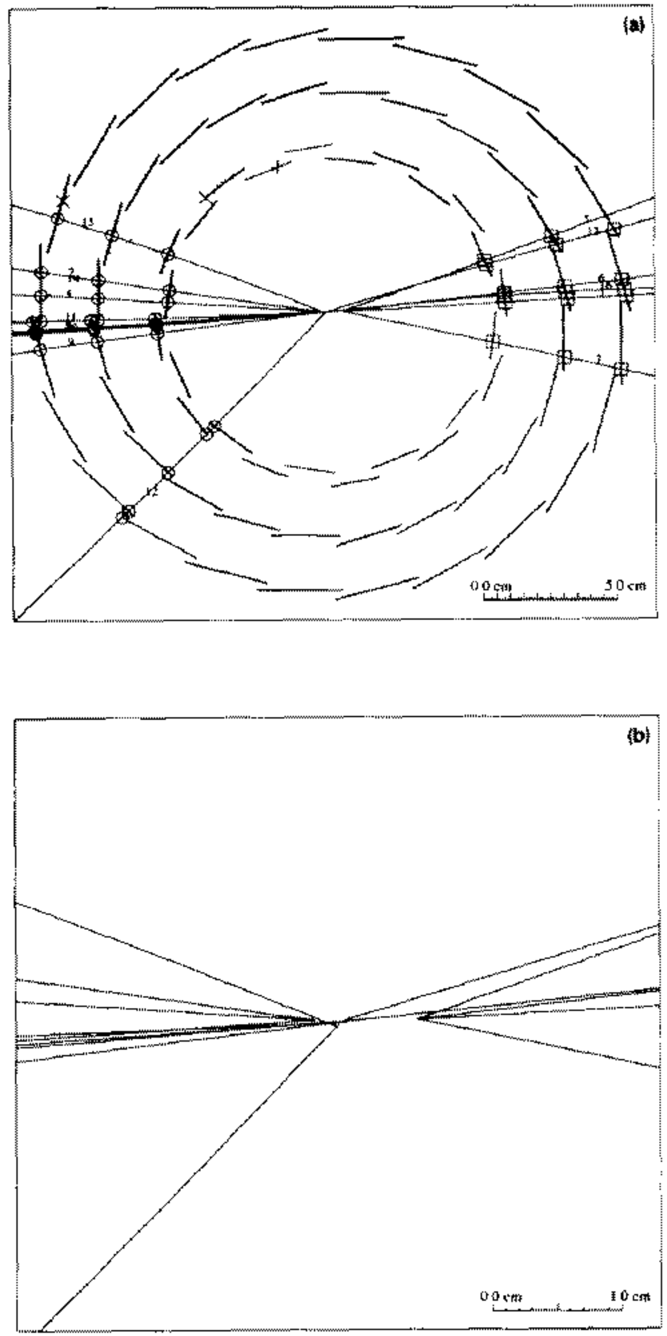
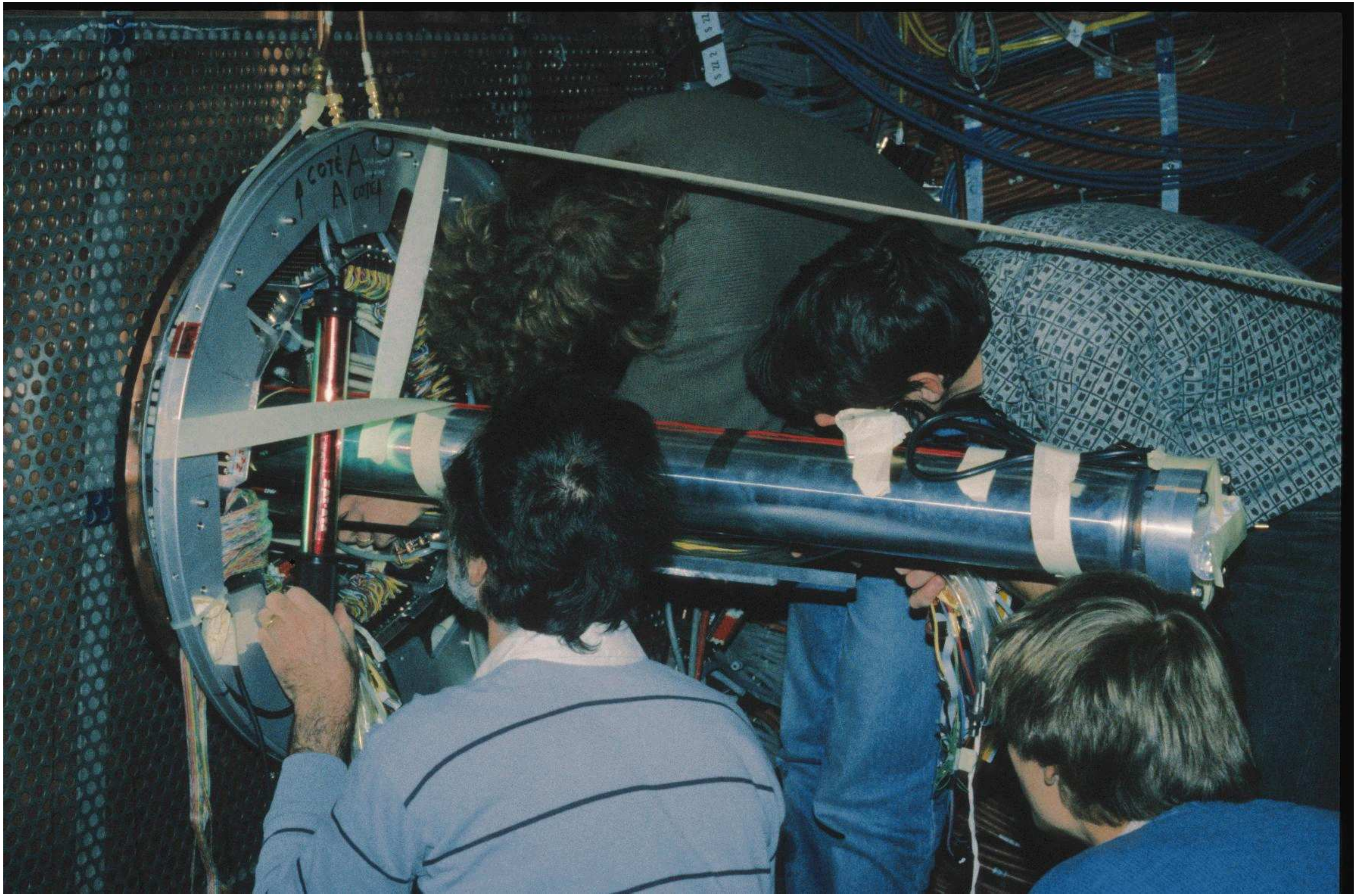


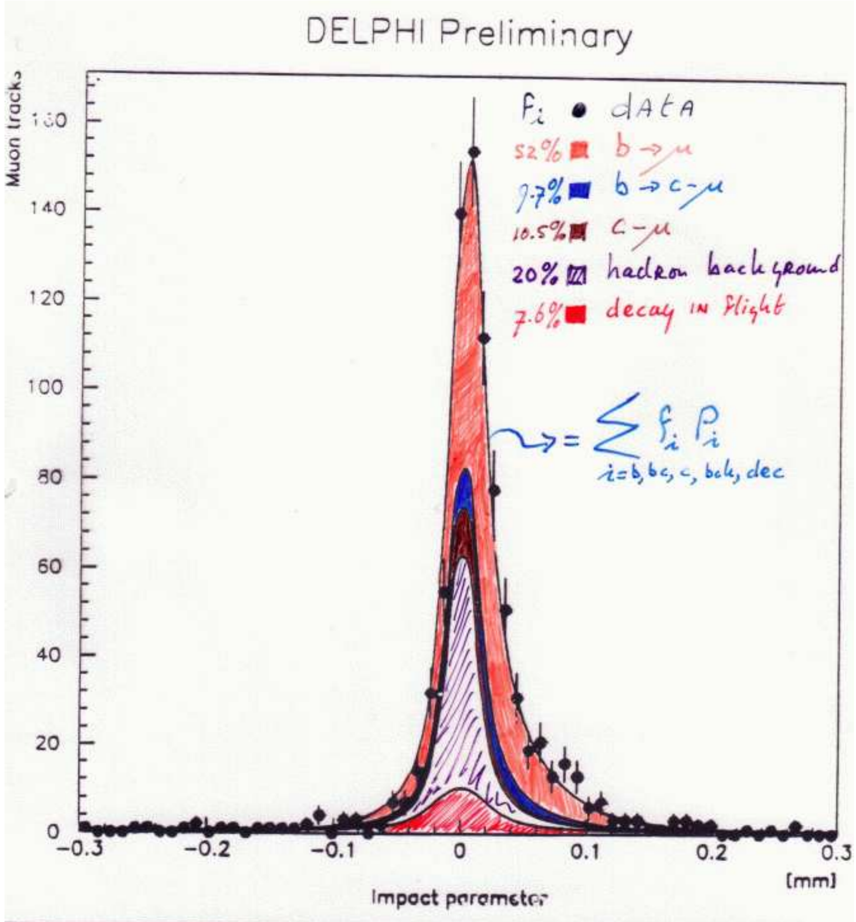
Fig. 1. Event display for a $Z^0 \to b\bar{b}$ candidate. Run 21582, event 6995.

On the DELPHI platform:



Three layer result:

- Allowed counting
  nr charged particles from secondary.
- Excellent B-tagging.



Physics Letters B 312 (1993) 253–266
North-Holland

PHYSICS LETTERS B

A measurement of the mean lifetimes of charged and neutral B-hadrons

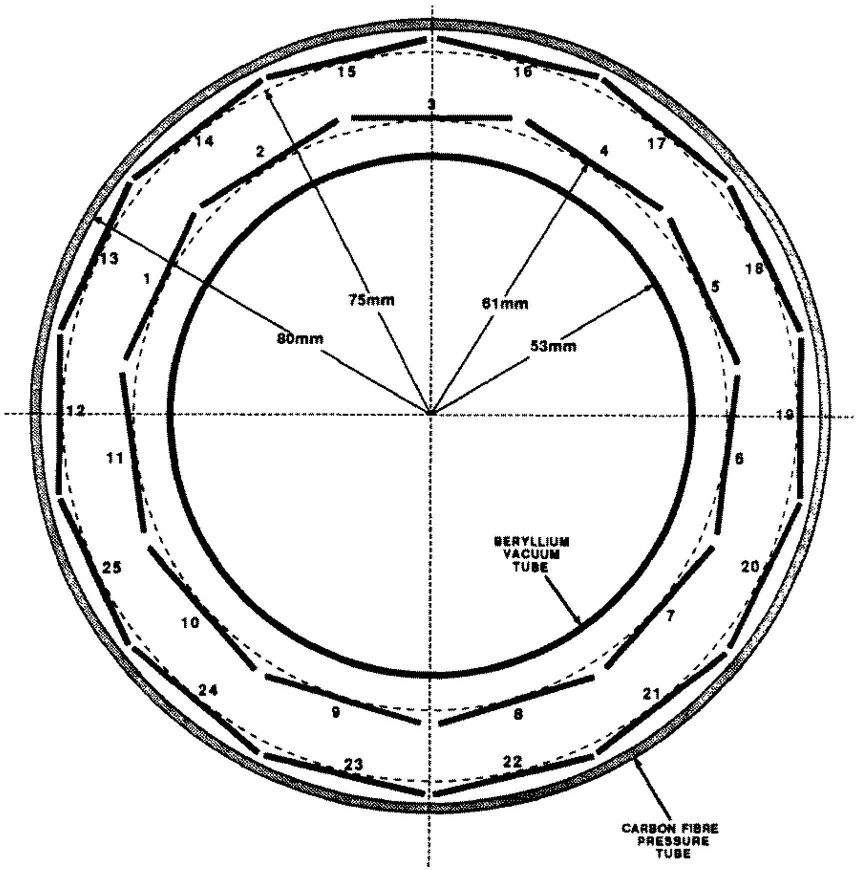
DELPHI Collaboration

J. Timmermans [ad], V.G. Timofeev [n], L.G. Tkatchev [n], T. Todorov [h], D.Z. Toet [ad], O. Toker [m], B. Tome [l], E. Torassa [at], L. Tortora [ao], D. Treille [g], W. Trischuk [g], G. Tristram [f], C. Troncon [aa], A. Tsirou [g], E.N. Tsyganov [n], M. Turala [p], M-L. Turluer [am], T. Tuuva [m], I.A. Tyapkin [v], M. Tyndel [ak], S. Tzamarias [u], S. Ueberschaer [ba], O. Ullaland [g], V. Uvarov [aq], G. Valenti [e],

The decays of B-hadrons have been reconstructed using the charged particles recorded in the DELPHI silicon microstrip detector. The sum of the charges of the secondaries determines the charge of the B-hadron parent. Some 232 114 multihadronic Z^0 decays recorded during the 1991 run of LEP at centre-of-mass energies between 88.2 GeV and 94.2 GeV yield 253 B-hadron candidates with well-measured charge. From these the mean lifetimes of neutral and charged B-hadrons are found to be 1.44 ± 0.21 (stat.) ± 0.14 (syst.) ps and 1.56 ± 0.19 (stat.) ± 0.13 (syst.) ps respectively. The ratio of their lifetimes is $1.09^{+0.28}_{-0.23}$ (stat.) ± 0.11 (syst.). Under some assumptions on the abundance and lifetime of the Λ_b^0 and B_s^0 states, the B^0 and B^+ lifetimes are inferred.

Mike and OPAL?

- Also OPAL profited from smaller beam-pipe radius (and from Mike..).
- Installed May 1991.



Nuclear Instruments and Methods in Physics Research A324 (1993) 34–52
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

The OPAL silicon microvertex detector

P.P. Allport [b], J.R. Batley [b], P. Capiluppi [a], A.A. Carter [h], J.R. Carter [b], S.J. De Jong [c], U.C. Dunwoody [b], V. Gibson [b], W. Glessing [c], P.R. Goldey [f], M.J. Goodrick [b], W. Gorn [i], R. Hammarstrom [c], G.G. Hanson [e], J.D. Hobbs [c], J. Hill [c], J.C. Hill [b], R. Humbert [d], F. Jacob [j], M. Jiminez [c], P. Kyberd [h], C. Leroy [g], X.C. Lou [e], A.J. Martin [h], J-P. Martin [g], C. Moisan [g], C.J. Oram [k], T.W. Pritchard [h], O. Runolfsson [c], P. Seller [j], R. Shaw [b], P. Singh [h], M.F. Turner [b], M. Uldry [c], D. Voillat [c], D.R. Ward [b] and K.H. Wolf [d]

A silicon strip microvertex detector has been designed, constructed and commissioned in the OPAL experiment at the LEP electron–positron collider. The microstrip devices incorporate a new FoxFET biassing scheme developed together with Micron Semiconductor Ltd., UK. The devices digitise with a precision close to 5 μm and have an exceptionally high signal-to-noise ratio. The associated microelectronics were all custom made for the OPAL project. The detector began operation in 1991 and has since continued to be part of the OPAL experiment, performing to a very high standard and opening up new areas of physics studies.

ity was invaluable. We thank M. Tyndel, H. Heijne and

July 1991

- Add z-readout to aid B-tagging.
  Installed spring 1994
- LEP $\sqrt{s}$: $90 \rightarrow 130 \rightarrow 209$ GeV
- Multi-jet events: WW, ZH
- Need to extend η-coverage.
  Installed spring 1996

Please Distribute to Your Group Members

Microvertex Upgrade Meeting
CERN 16th - 18th July

COPIES OF TRANSPARENCIES

(I) ***Summary of Facilities, Manpower, Effort Available***

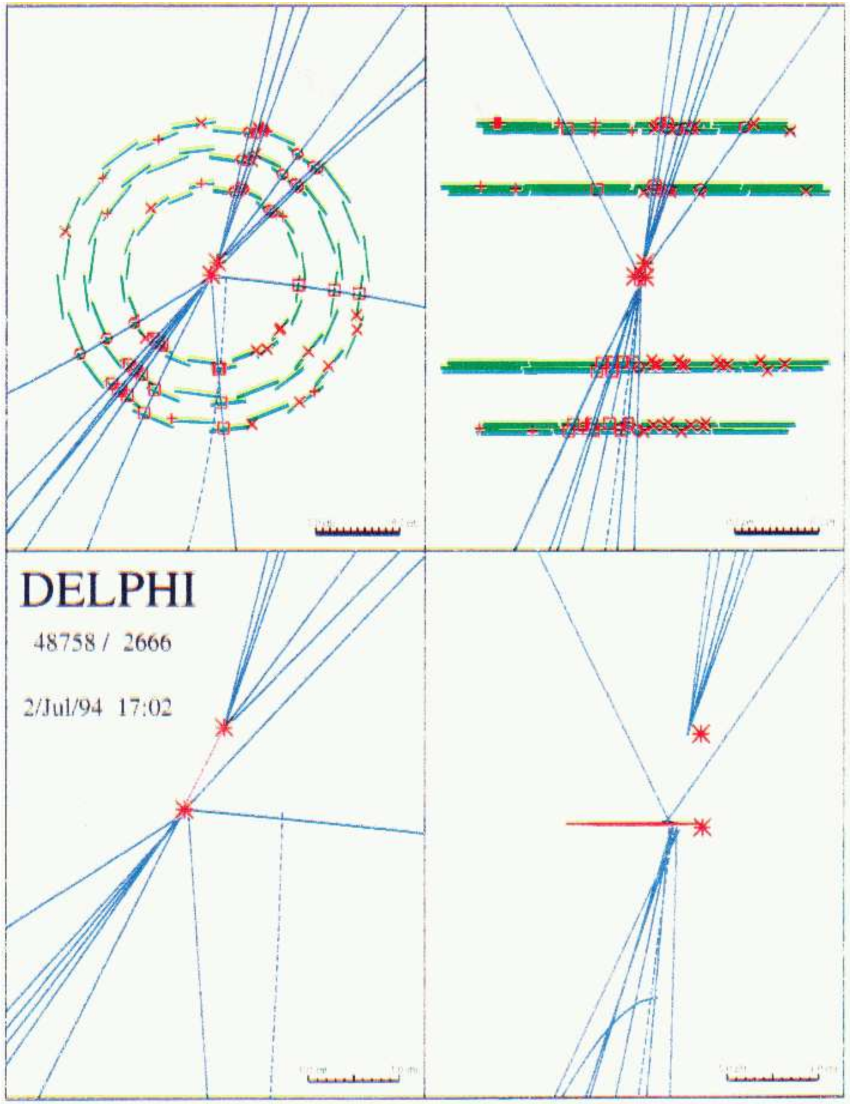
(II) ***Summary of Working Groups***

Microvertex Upgrade	(M. Tyndel)
Detectors	(A. Peisert)
Beam Tests	(W. Dulinski)
Electronics	(A. Smith)
Hybrids	(B. D'Almagne)
Module Assembly	(M. Tyndel)
Mechanics	(R. Brenner)
Online DAS	(P. Jalocha)
Offline	(M. Caccia)
Study of Vertex Reconstruction	(P. Rebecchi)
Organization & Time Schedule	(M. Tyndel)

(III) ***Next Co-ordination Meeting***

CERN, Tuesday 6th August, 14.30 h
24-1-016

MicroVertex 1994-1995:



N·H ELSEVIER

Nuclear Instruments and Methods in Physics Research A 368 (1996) 314–332

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The DELPHI silicon strip microvertex detector with double sided readout

V. Chabaud[a], P. Collins[a], H. Dijkstra[a], J.J. Gomez Cadenas[a], R. Keranen[a], S. Masciocchi[a], W. Trischuk[a], P. Weilhammer[a], Y. Dufour[b], R. Brenner[c], R. Orava[c], K. Osterberg[c], C. Ronnqvist[c], H. Saarikko[c,1], J.-P. Saarikko[c], T. Tuuva[c], M. Voutilainen[c], J. Błocki[d], P. Brückman[d], J. Godlewski[d], P. Jałocha[d], W. Kucewicz[d], H. Pałka[d], A. Zalewska[d], B. Bouquet[d], F. Couchot[e], B. D'Almagne[e], F. Fulda-Quenzer[e], P. Rebecchi[e], P.P. Allport[f], P.S.L. Booth[f], P.A. Cooke[f], A. Andreazza[g], P. Biffi[g], V. Bonvicini[g], M. Caccia[g], C. Meroni[g], M. Pindo[g], N. Redaelli[g], C. Troncon[g,*], G. Vegni[g], J. Cuevas Maestro[h], G.J. Barker[i], J. Bibby[i], N. Demaria[i], M. Flinn[i], P. Pattinson[i], M. Mazzucato[j], A. Nomerotski[j,2], A. Peisert[j], I. Stavitski[j], M. Baubillier[k], F. Rossel[k], M. Gandelman[l], S. Santos de Souza[l], R. Apsimon[m], M. Bates[m], J. Bizzell[m], P.D. Dauncey[m], L. Denton[m], W. Murray[m], M. Tyndel[m], J. Marco[n], C. Martinez-Rivero[n], M. Karlsson[o], J.A. Hernando[p]

Abstract

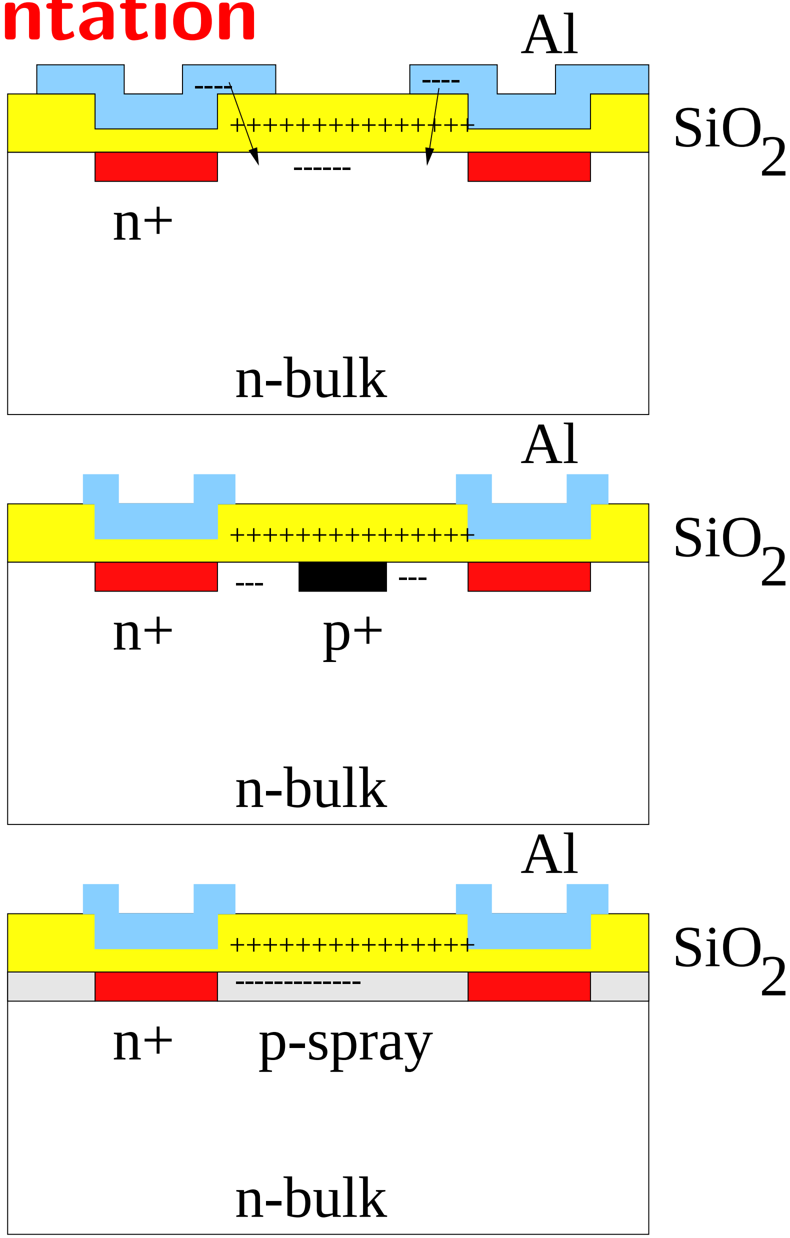
The silicon strip microvertex detector of the DELPHI experiment at the CERN LEP collider has been recently upgraded from two coordinates ($R\phi$ only) to three coordinates reconstruction ($R\phi$ and z). The new Microvertex detector consists of 125 952 readout channels, and uses novel techniques to obtain the third coordinate. These include the use of AC coupled double sided silicon detectors with strips orthogonal to each other on opposite sides of the detector wafer. The routing of signals from the z strips to the end of the detector modules is done with a second metal layer on the detector surface, thus keeping the material in the sensitive area to a minimum. Pairs of wafers are daisy chained, with the wafers within each pair flipped with respect to each other in order to minimize the load capacitance on the readout amplifiers. The design of the

- Add z-readout to two layers, but keep low X/X0→ Double Sided Sensors.
- Extended already coverage of "closer" layer.

n+ (z) Side Segmentation

Low resistance layer of free electrons near
Si-SiO_2 interface (+q in SiO_2) → short neighbouring strips

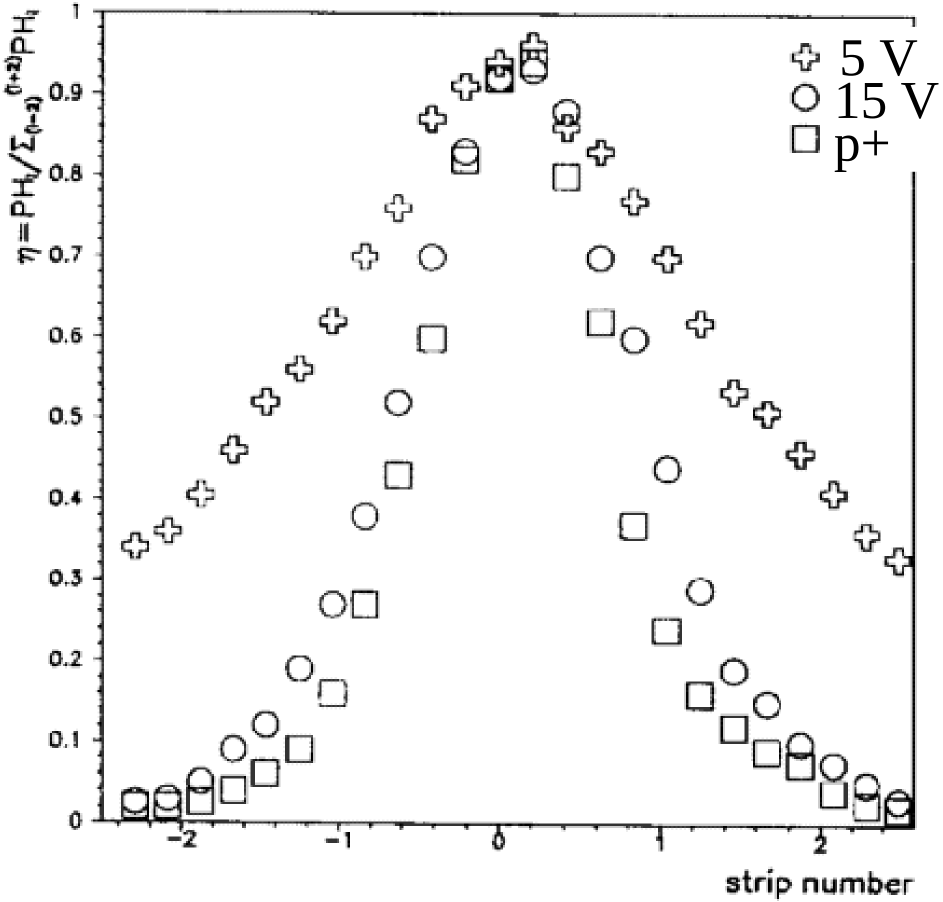
- Several solutions to interrupt the e-accumulation layer.
- Field plates: extended AC-coupling electrodes put at negative voltage relative to n+ implants:
- p-stops: high dose p-implants to interrupt accumulation layer. Originally just one big p-grid surrounding all n+ strips, now a p-atoll for every n-strip. Also a combination of p-stop and field plate has been produced to reduce high field region after irradiation at p-stops.
- p-spray: neutralise electrons by medium dose p-"spray" over whole surface. Added advantage is the lower field near the surface after irradiation. Also graded p-spray, modulate dose.



H.Dijkstra

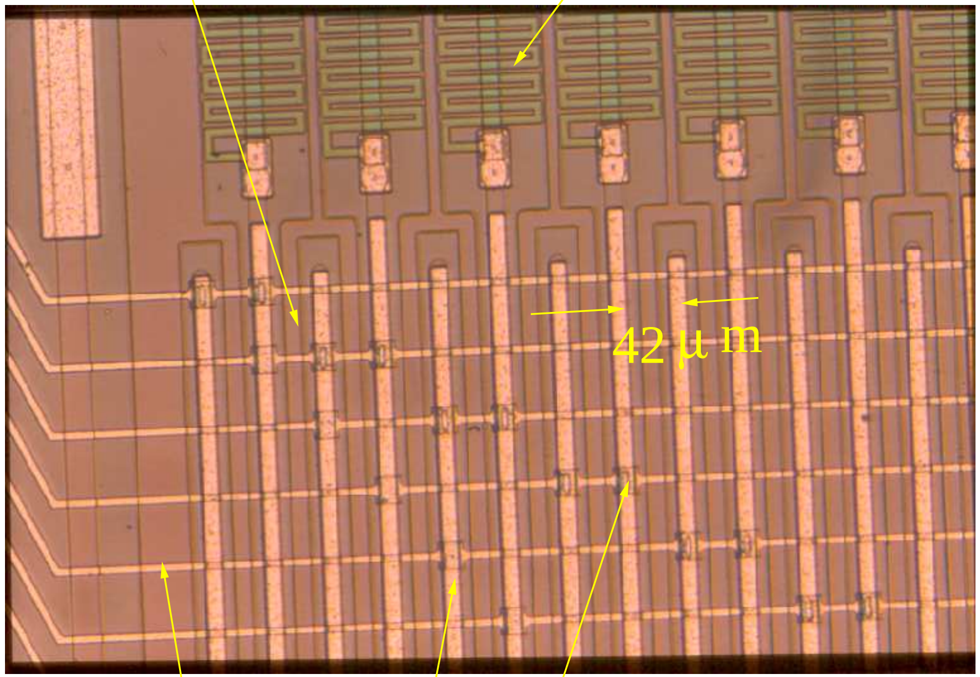
Field Plate Tests

- electronics=GND,
  p+=GND and n+ at $V_{depletion}$.
- SiO_2+Si_2N_3 layer can stand >150V.
- Scan over strips with 30 μm laser spot.
- Field plate δV 5 V
- δV 15 V
- p-side



Double metal layer and multiplexing

- Double sided detectors: use orthogonal strips, but keep electronics out of fiducial volume.
- Integrate routing lines on same detector with double metal layer and via's



- Closer layer: 2 strips with 49.5 μm and 1 strip with 49.5 μm pitch multiplexed to one amplifier.

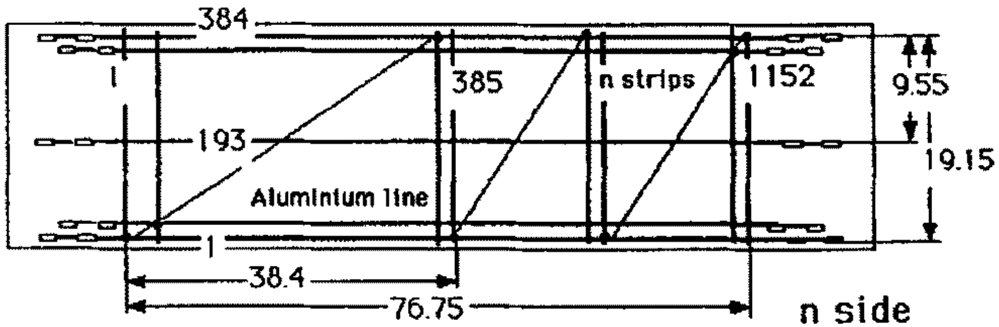
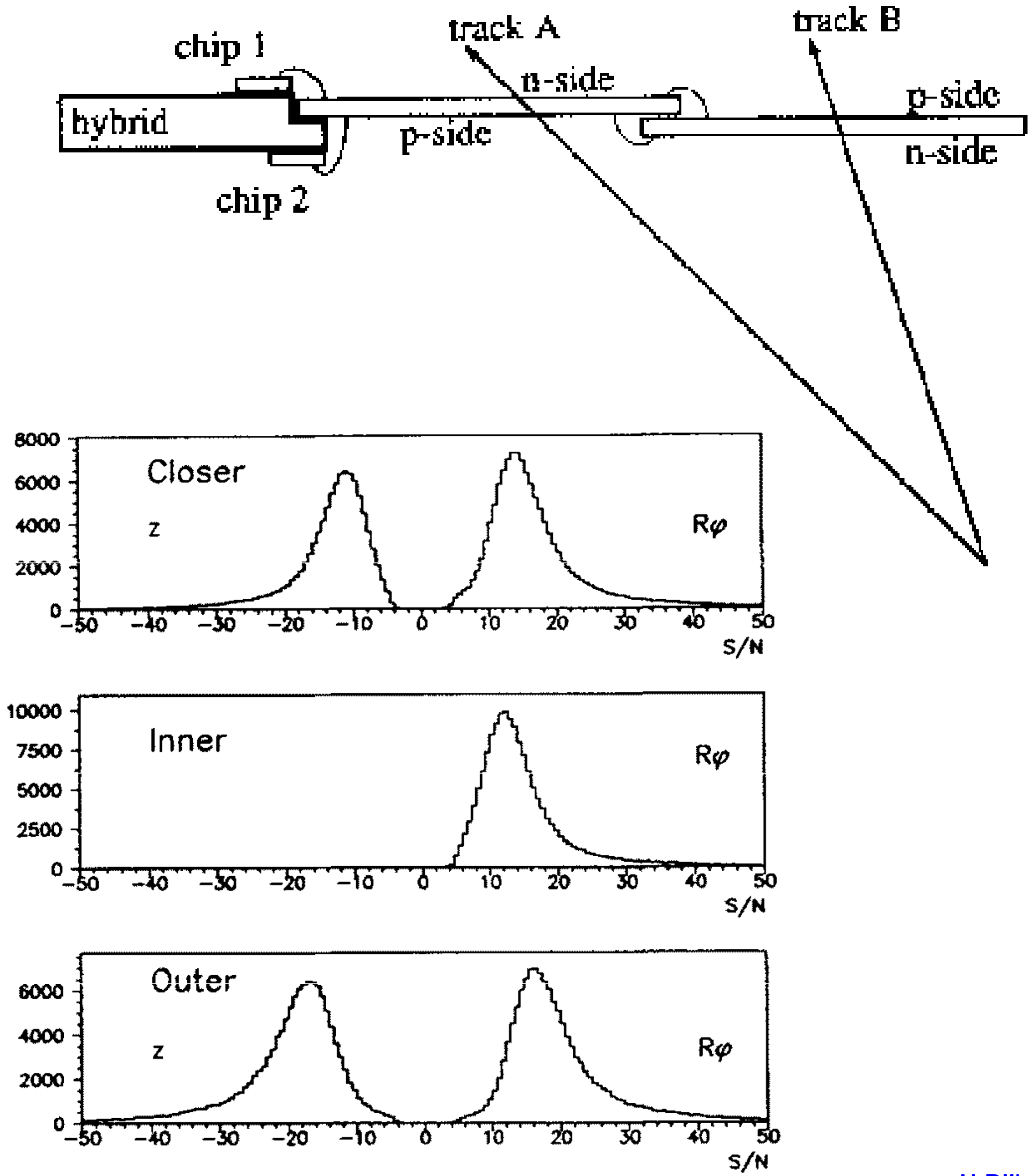


Fig. 6. The pattern of contacts between the two metal layers of a Closer layer detector (units are in mm).

Flipped module design

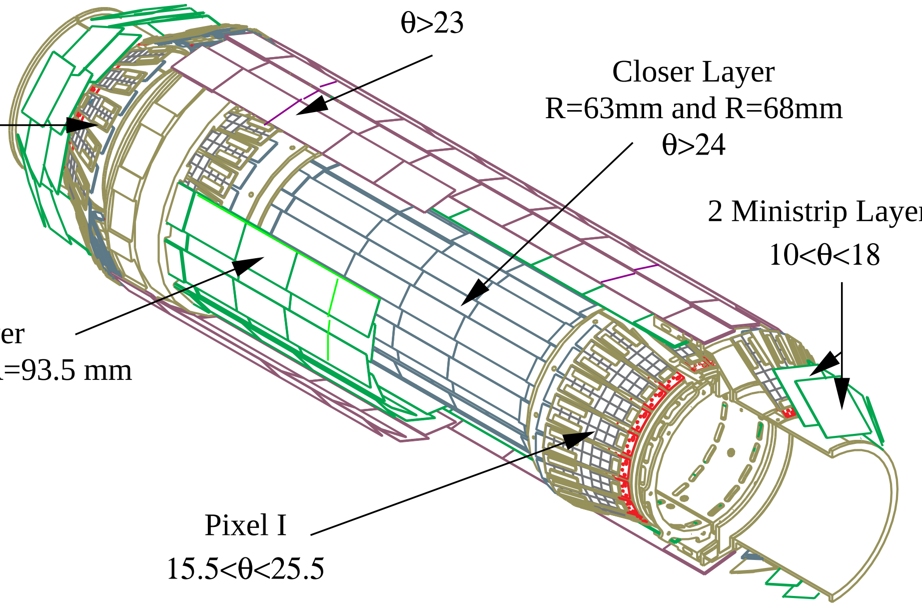
Double metal n-side → larger noise:
Flipped Module Design.

- Keep electronics out of barrel-acceptance!
- Noise equalising,
- Solve ambiguity using sign of charge.
- Electronics=GND,
  p+=GND and n+ at $V_{depletion}$.
- SiO_2+Si_2N_3 layer can stand >150V.



$\geq$1996: DELPHI Silicon Tracker

175k strip-channels, 1.2M pixels, 1.8 m^2 of Si



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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The DELPHI Silicon Tracker at LEP2

The DELPHI Silicon Tracker Group

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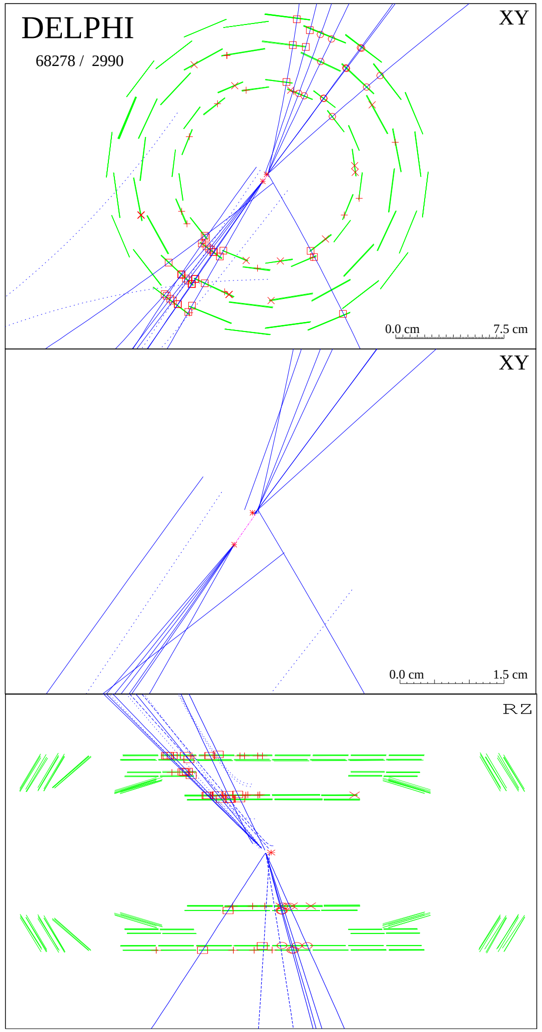
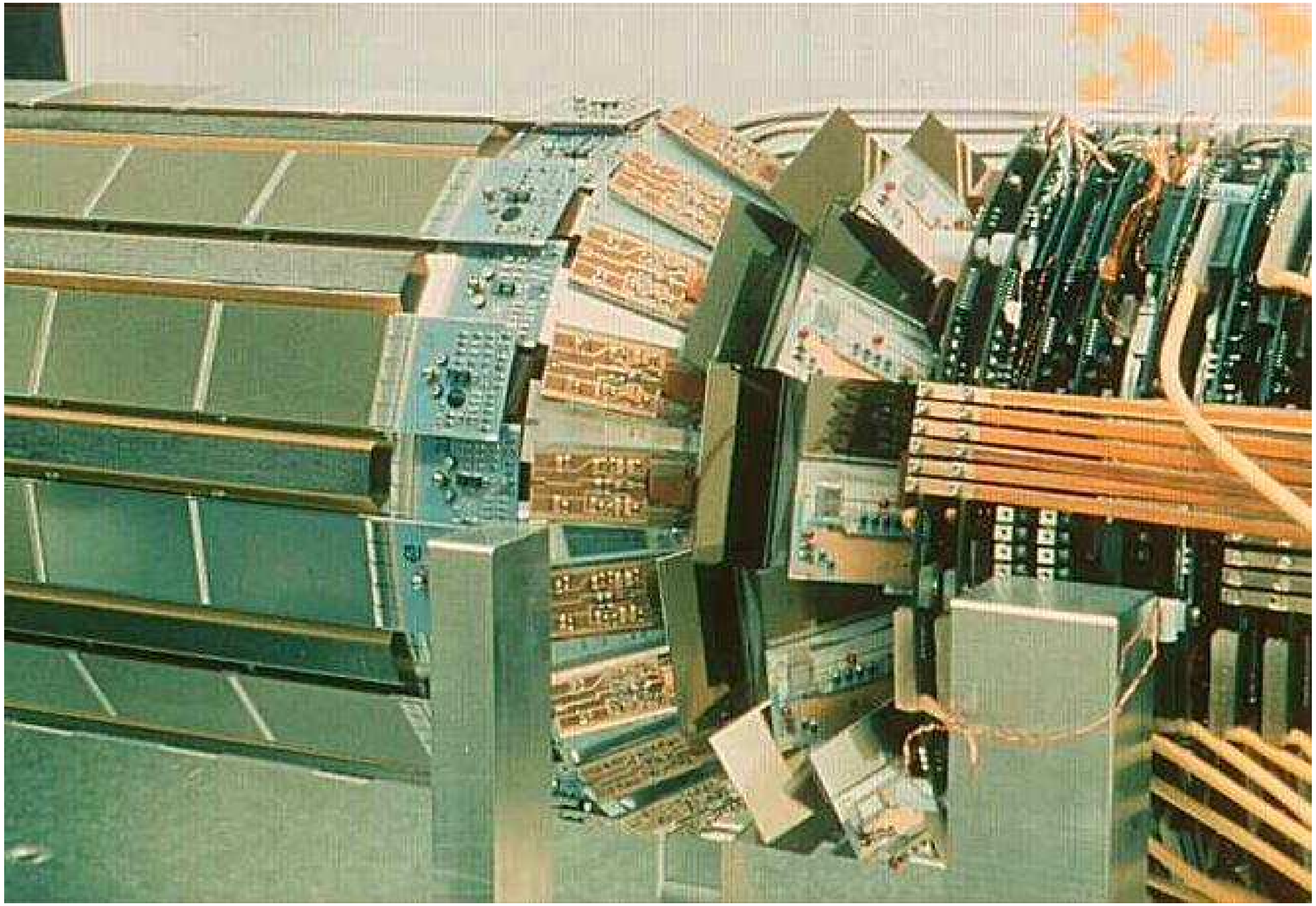
Abstract

The DELPHI Silicon Tracker, an ensemble of microstrips, ministrips and pixels, was completed in 1997 and has accumulated over 70 pb^{-1} of high-energy data. The Tracker is optimised for the LEP2 physics programme. It consists of a silicon microstrip barrel and endcaps with layers of silicon pixel and ministrip detectors. In the barrel part, three-dimensional b tagging information is available down to a polar angle of 25°. Impact parameter resolutions have been measured of $28\,\mu m \oplus 71/(p \sin^{3/2}\theta)\,\mu m$ in $R\phi$ and $34\,\mu m \oplus 69/p\,\mu m$ in Rz, where p is the track momentum in GeV/c. The amount of material has been kept low with the use of double-sided detectors, double-metal readout, and light mechanics. The pixels have dimensions of $330 \times 330\,\mu m^2$ and the ministrips have a readout pitch of 200 μm. The forward part of the detector shows average efficiencies of more than 96%, has signal-to-noise ratios of up to 40 in the ministrips, and noise levels at the level of less than one part per million in the pixels. Measurements of space points with low backgrounds are provided, leading to a vastly improved tracking efficiency for the region with polar angle less than 25°.

"Typical" DELPHI event, $\sqrt{s}$=161 GeV





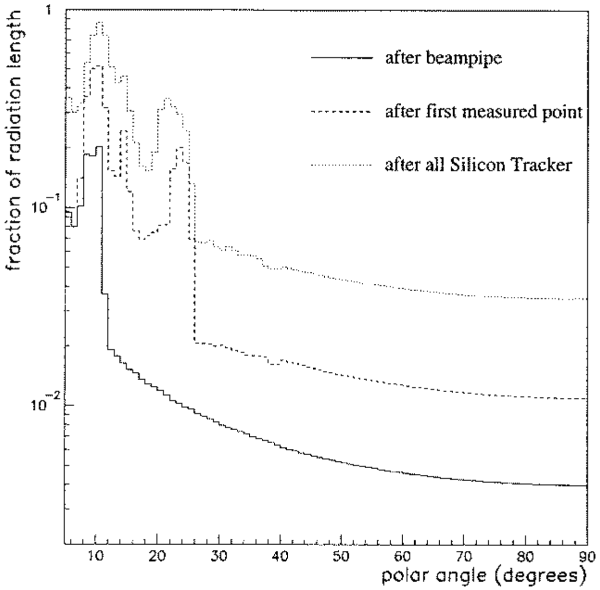
Si-Tracker: figures of merit.

- very low X/X0, and 3 layers:

$R\phi$ $28\ \mu m \bigoplus 71/(p.\sin^{3/2}\theta)\ \mu m$

Z $34\ \mu m \bigoplus 69/p\ \mu m$

- (p in GeV)



☺ Excellent agreement without Higgs.

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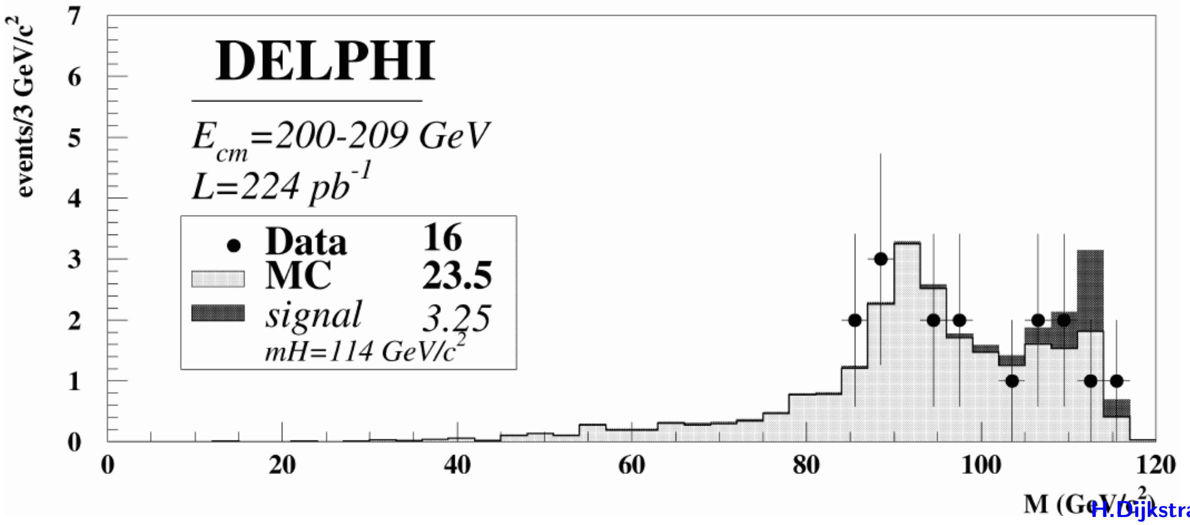
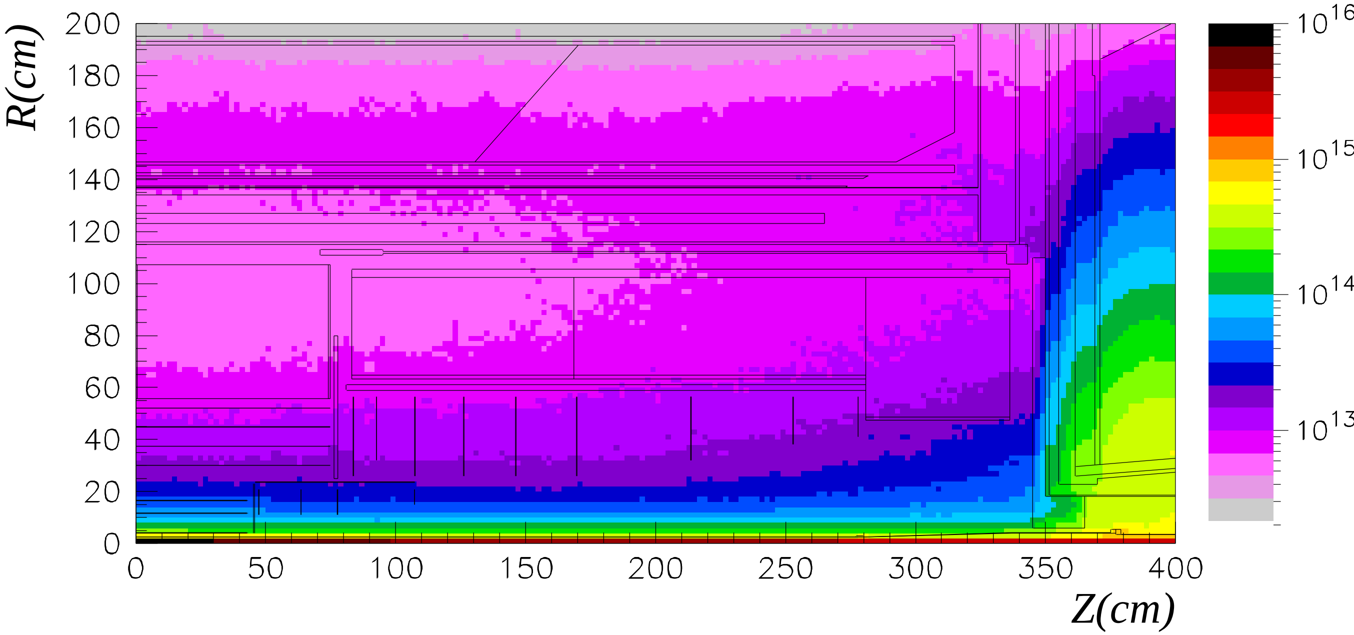


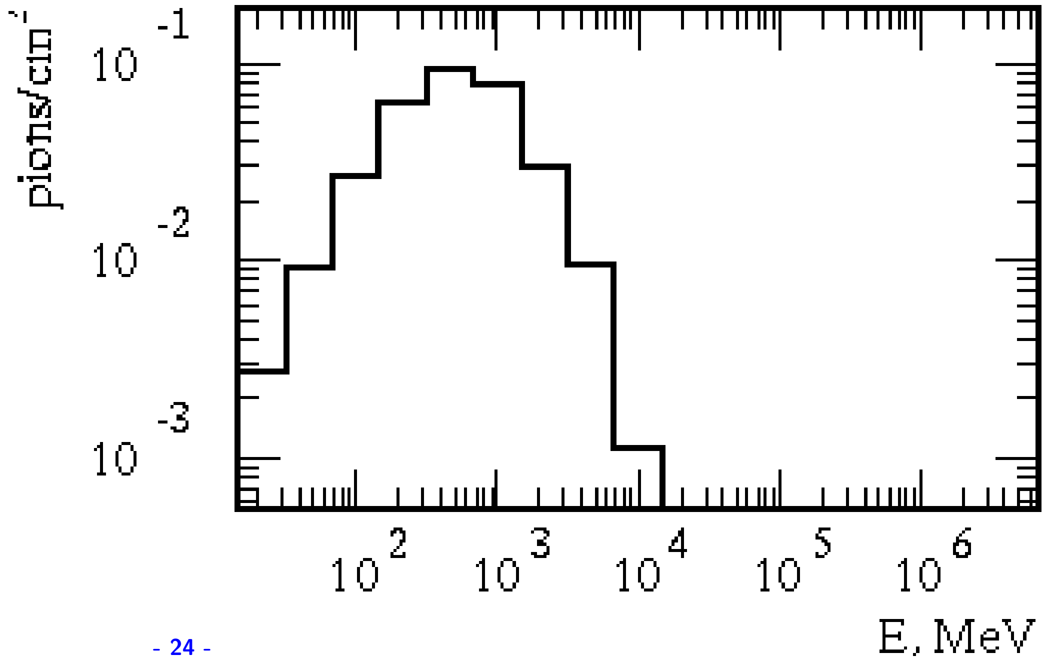
Radiation

Compare:

- LEP: $L = 0.3 \times 10^{32}/\text{cm}^2\text{s}$,
  σ_{Z^0}=30 nb: 1 e^+e^-/s
- LHC: $L = 10^{34}/\text{cm}^2\text{s}$,
  $\sigma_{inelastic}$=60 mb: 60$\times 10^7$ pp/s



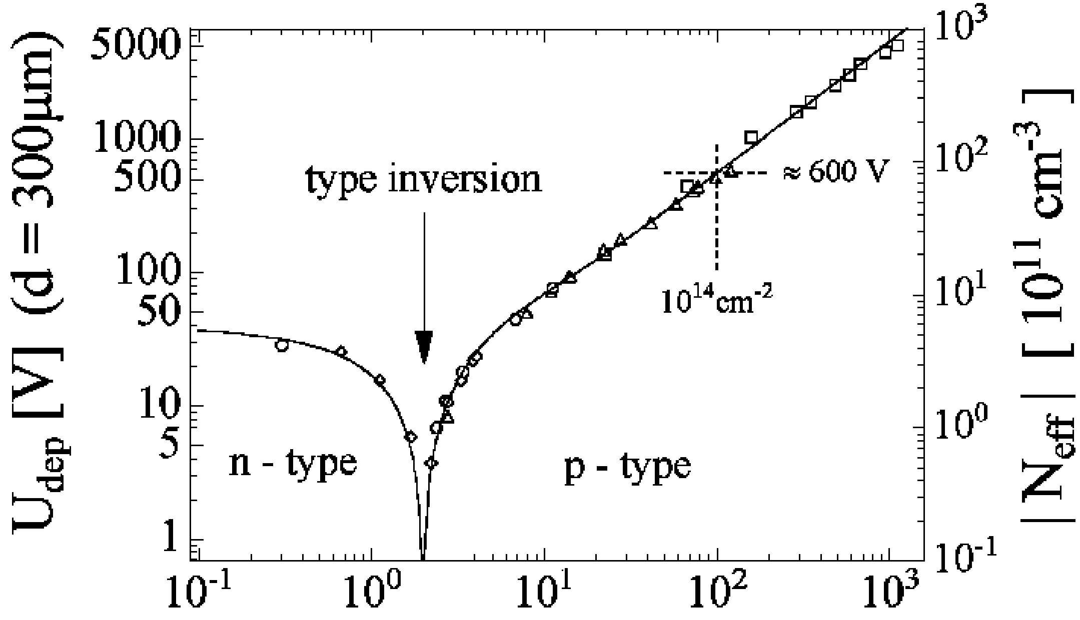
- ATLAS: Neutron
  (E>100 keV) fluence ($\text{cm}^{-2}\text{year}^{-1}$)



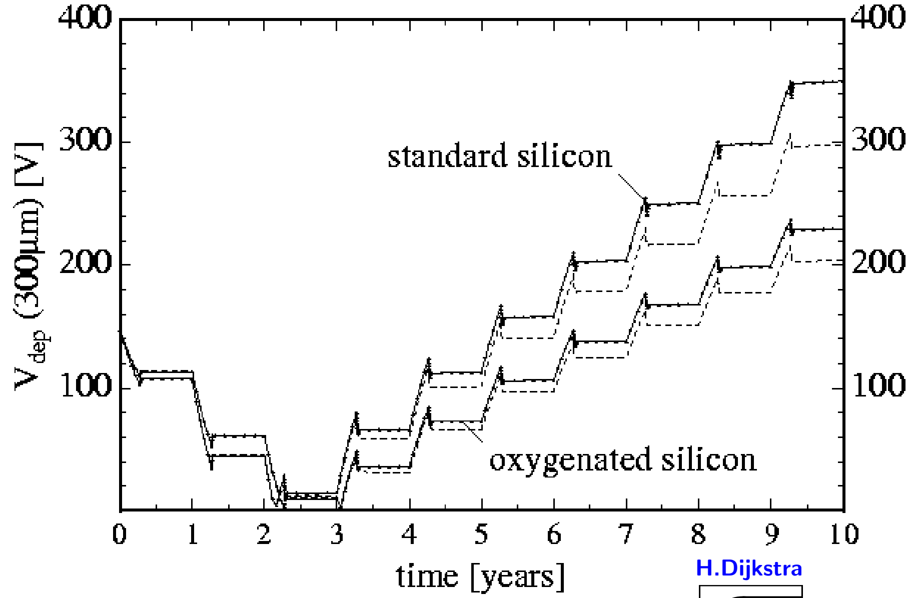
- LHCb at 1 cm radius:
  fluence (cm^{-2}) per pp interaction.
  $@\text{R} = 8\ \text{mm}$:
  $\sim 1 - 1.5 \times 10^{14}\ \text{n}_{\text{equiv}}/\text{cm}^2$ per year.

Radiation continued

- Space charge inversion: n→p-type
- $V \propto |N_{effective}|$



- Atlas strip detector layer at 30 cm.
- Dominated by neutron fluence.



Radiation basics

Induced charge $i\Delta t$ in two parallel electrodes:

Ramo (1939): $\Delta q = e\frac{d}{w}$

- Charge will only move in depleted(field) part of Si:

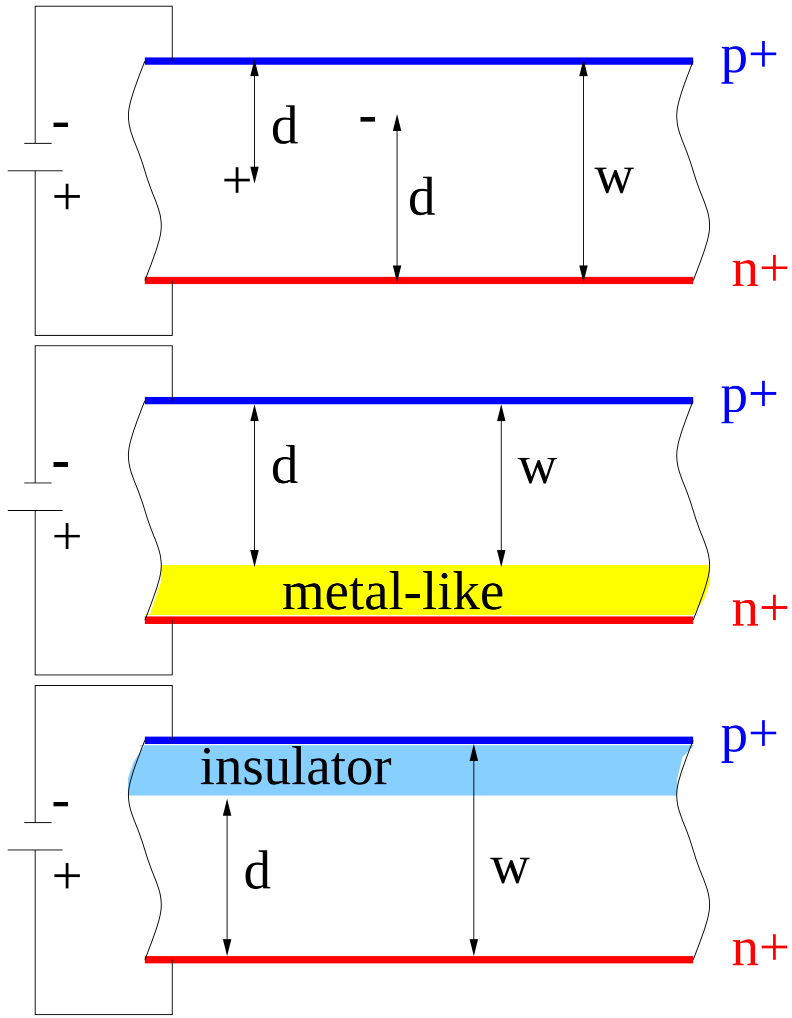
  $\frac{depleted-Si}{w} = \sqrt{\frac{V_{bias}}{V_{depletion}}}$

- If space charge is uniform this implies:

  $\Delta q = e\sqrt{\frac{V_{bias}}{V_{depletion}}} \propto \mathrm{CCE}$

Experiments with (non)-irradiated diodes measuring CCE:

- Use α-particles (range in Si $\cong 20\mu$m), illuminating both p+(e move) or n+(holes move).
- Conclusions:
  - Non-irradiated: undepleted=conducting
  - irradiated: undepleted=insulator

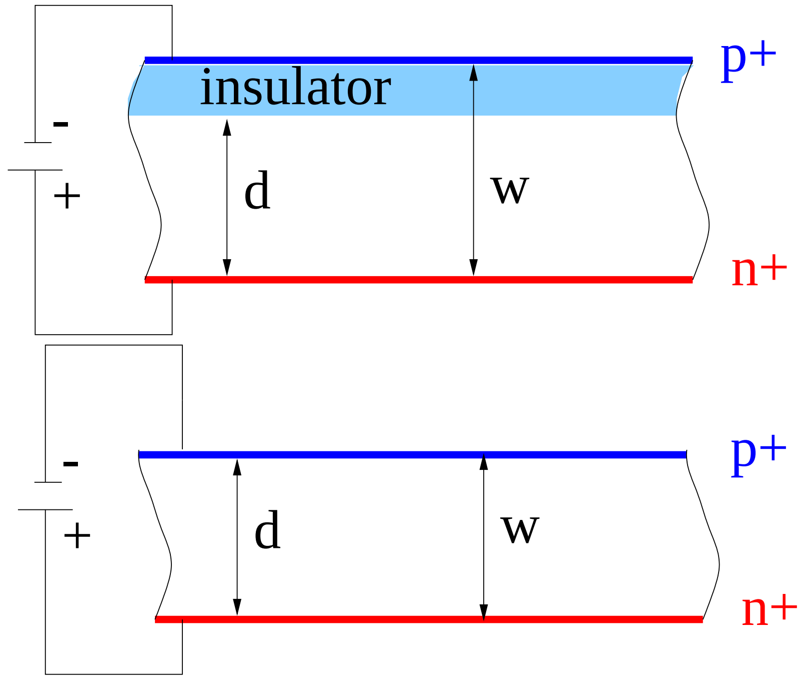


CCE in under-depleted irradiated detectors

Example for $V_{bias}/V_{depletion}$=50% for 300 μm thick irradiated detector, which needs 800V to deplete.

- Remember Ramo: $\Delta q = e\frac{d}{w}$

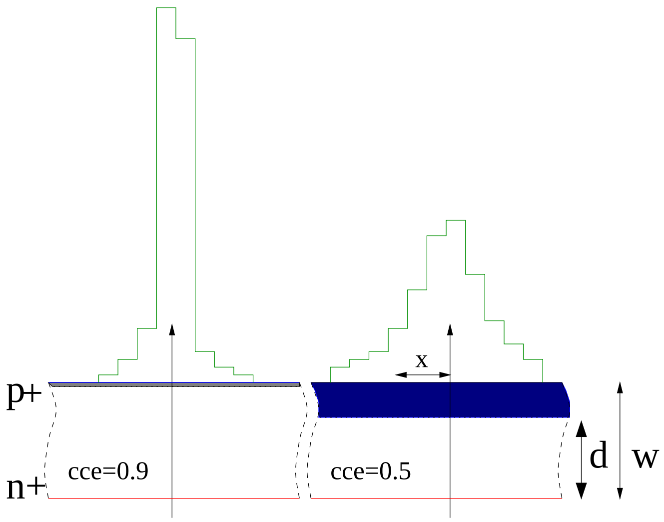
w	300μm thick	210μm thick
$V_{depletion}$	800 V	400 V
V_{bias}	400 V	400 V
d	210μm	210μm
e/h	19000	19000
Δq	13300	19000



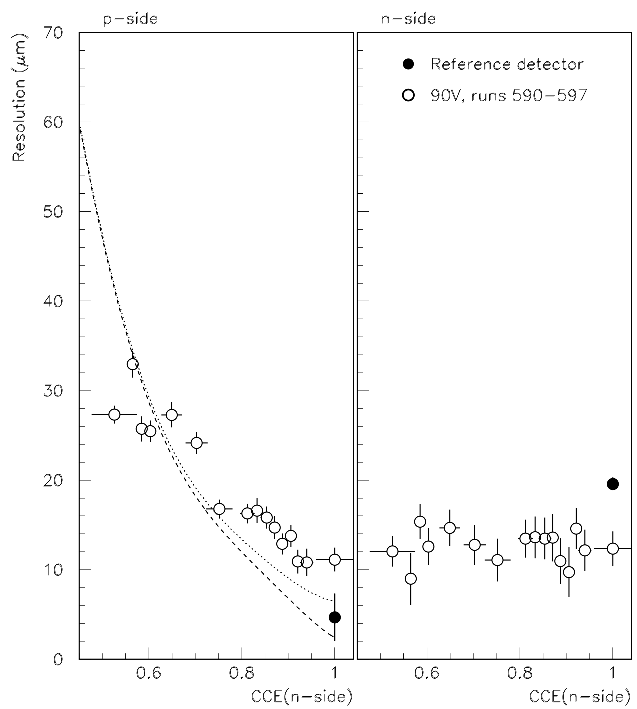
- Thinner silicon detectors are an advantage.!
- Additional advantage of thin-Si: less current, less power dissipation: further away from thermal run-away.

Diodes→Strips, i.e. charge sharing

- For non-irradiated detectors,
  charge sharing is due to track incidence angle diffusion.
- For irradiated detectors incomplete charge collection,
  due to under-depletion or trapping, is the extra cause.



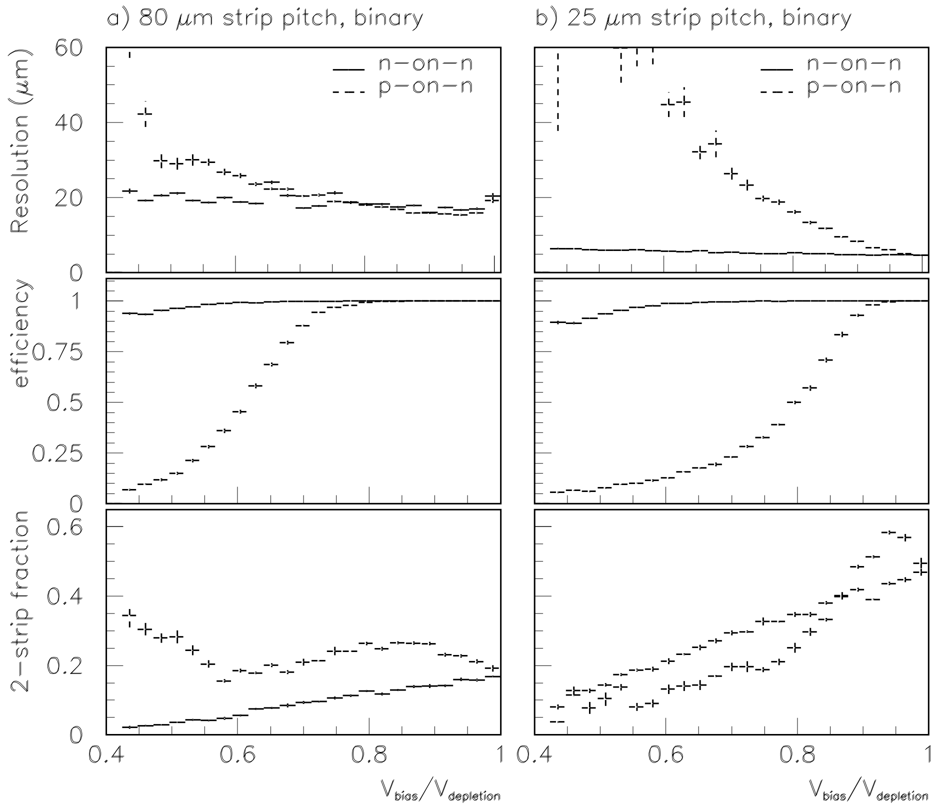
- Compare to data: irradiated DELPHi
  sensor: 25(50-readout)μm p-pitch, 42μm n-pitch.
- Line is a "naive" model with one free parameter: d.



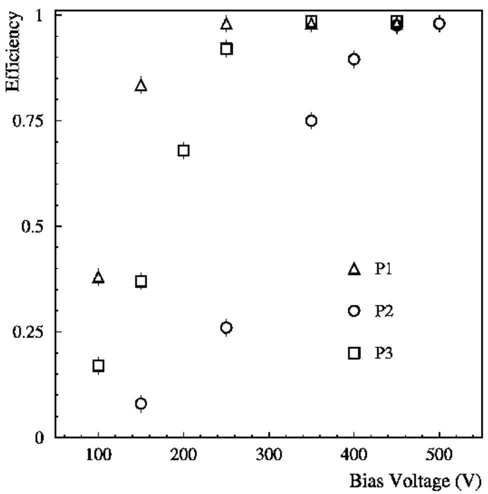
Charge sharing: resolution and efficiency modelling

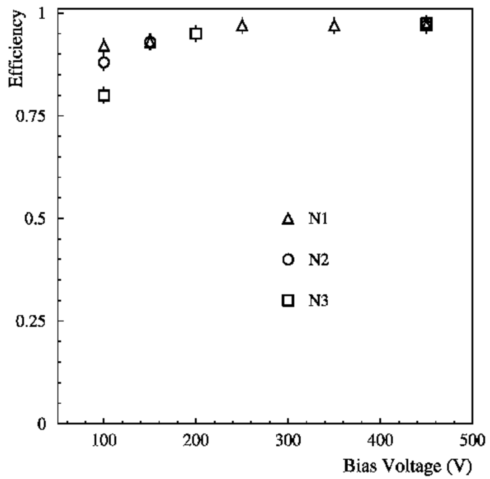
Model some "typical" detectors:

	ATLAS type	LHCb type
Thickness	300 μm	150 μm
Strip pitch	80μm	25μm
Noise	1500 ENC	1000 ENC
Threshold	6000 ENC	3000 ENC



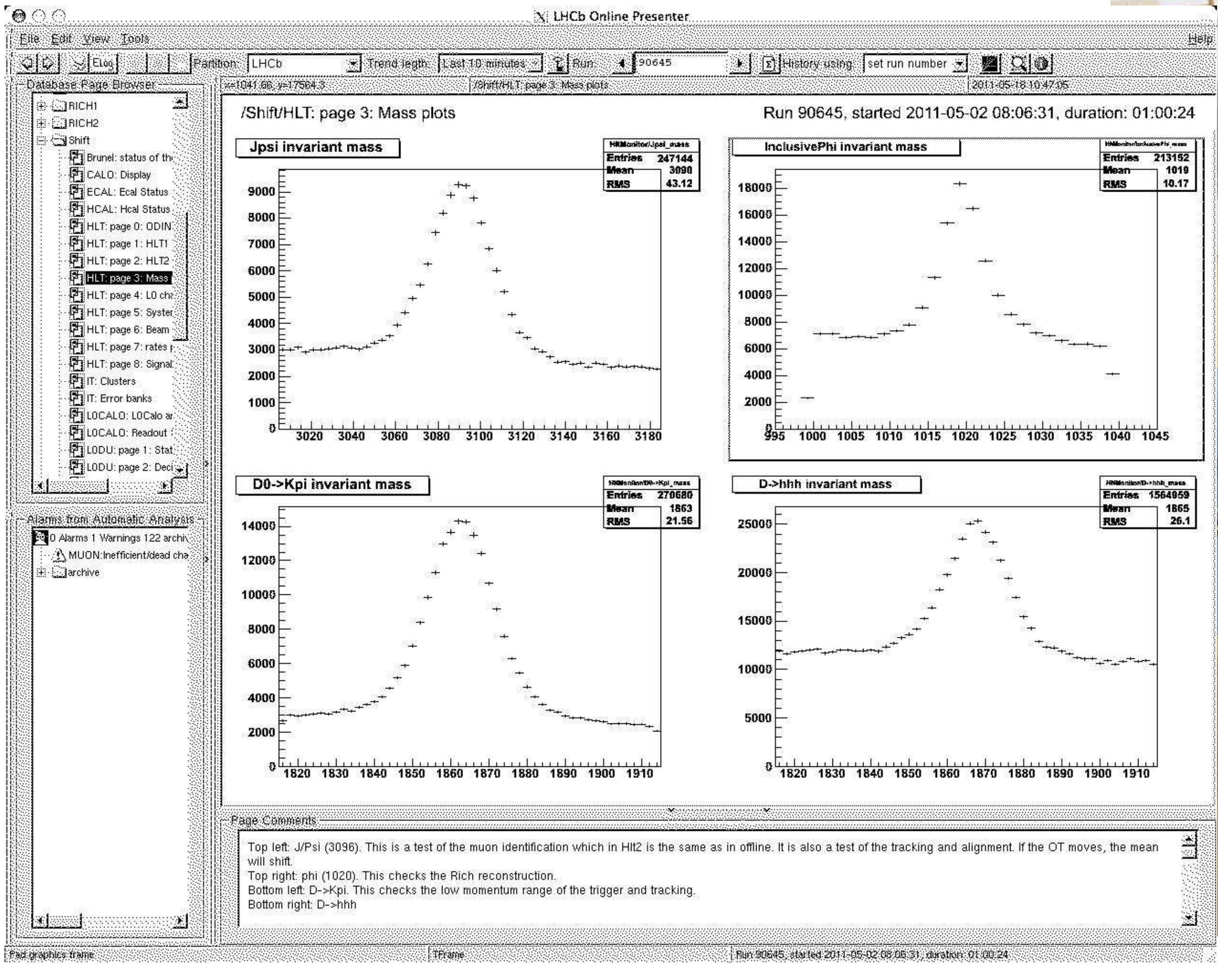
$\rightarrow$ coarser segmentation
makes you less sensitive to under-depletion.
Atlas beam-test results for 3×10^{14} 24 GeV p/cm^2:

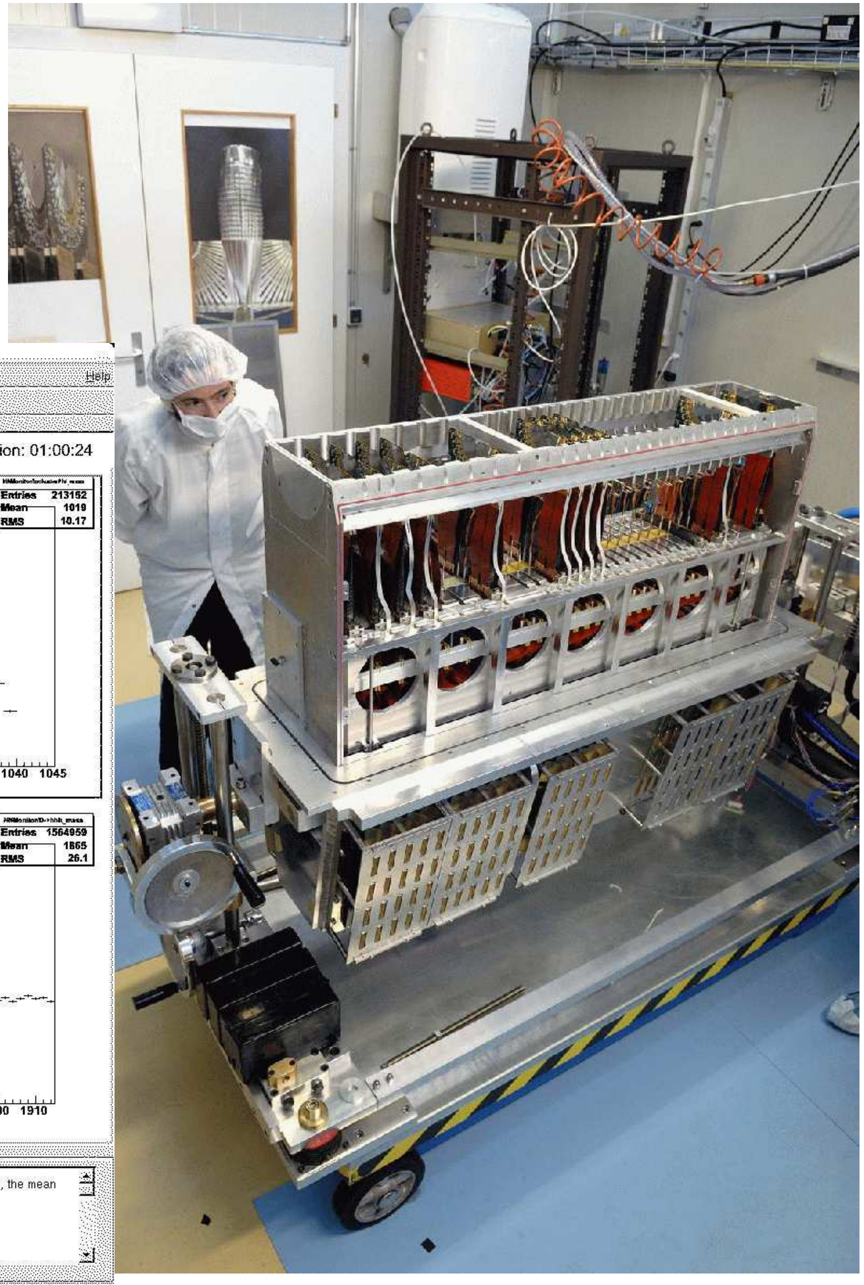




LHCb VErtexLOcator

- LHCb chose n-in-p, small pitch sensors.
- It took DELPHI “few months” to align, reprocess.
- LHCb on-line monitors charm yield.





Conclusions

- Mike had a HUGE impact on most of the Silicon Vertex Detectors around in HEP in the last ~ 25 years.
- While detectors came online,
  Mike was already looking for new horizons:
  upgrade, next accelerator etc..

- He continues doing so today!