Diamond Pixel Detectors

Steve Schnetzer
Rutgers University

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W. Adam[1], M. Atac[2], D. Bartoletto[3], E. Berdermann[4], P. Bergonzo[5], G. Bertuccio[6], F. Bogani[7], G. Bolla[3], E. Borchi[8], A. Brambilla[5], M. Bruzzi[8], C. Colledani[9], J. Conway[10], L. Cremaldi[11], P. D'Angelo[12], W. Dabrowski[13], P. Delpierre[14], A. Deneuville[15], J. Doroshenko[10], W. Dulinski[9], B. van Eijk[16], A. Fallou[14], F. Fizzotti[17], J. Foster[10], F. Foulon[5], M. Friedl[1], K.K. Gan[18], E. Gheeraert[15], B. Gobbi[19], G.P. Grim[20], G. Hallewell[14], S. Han[18], F. Hartjes[16], J. Hrubec[1], D. Husson[9], H. Kagan[18], D. Kania[18], J. Kaplon[21], R. Kass[18], T. Koeth[10], Y. Kozhevnikov[2], M. Krammer[1], S. Kwan[2], R. Lander[20], A. Logiudice[17], R. Lu[17], L. mac Lynne[10], S. Malik[19], C. Manfredotti[17], D. Meier[21], M. Mishina[2], L. Moroni[12], A. Oh[22], L.S. Pan[18], M. Pernicka[1], L. Perera[10], S. Pirollo[8], R. Plano[10]M. Procario[23], J.L. Riester[9], S. Roe[21], C. Rott[3], L. Rousseau[5], A. Rudge[21], J. Russ[23], S. Sala[12], M. Sampietro[6], S. Schnetzer[10], S. Sciortino[8], H. Stelzer[4], R. Stone[10], B. Suter[23], M. Swartz[24], R.J. Tapper[25], R. Tesarek[10], W. Trischuk[26], D. Tromson[5], E. Vittone[17], R. Wedenig[1], P. Weilhammer[21], C. White[27], X. Xie[24], W. Zeuner[22], M. Zoeller[18]

[1]Institut für Hochenergiephysik der Öste rr. Akademie d. Wissenschaften, Vienna, Austria, [2]FNAL, Batavia, U.S.A., [3]Purdue University, Lafayette, IN, U.S.A., [4]GSI, Darmstadt, Germany, [5]LETI (CEA-Technologies Avancees) DEIN/SPE - CEA Saclay, Gif-Sur-Yvette, France, [6]Polytechnico Milano, Italy, [7]LENS, Florence, Italy, [8]University of Florence, Florence, Italy, [9]LEPSI, IN2P3/CNRS-ULP, Strasbourg, France, [10]Rutgers University, Piscataway, NJ, U.S.A., [11]University of Mississippi, Oxford, MI, U.S.A., [12]INFN, Milano, Italy, [13]Faculty of Physics and Nuclear Techniques, UMM , Cracow, Poland, [14]CPPM, Marseille, France, [15]LEPES, Grenoble, France, [16]NIKHEF, Amsterdam, Netherlands, [17]Univerity of Torino, Italy, [18]The Ohio State University, Columbus, OH, U.S.A., [19]Northwestern University, Evanston, IL, U.S.A., [20]University of California, Davis, CA, U.S.A., [21]CERN, Geneva, Switzerland, [22]II.Inst. für Exp. Physik, Hamburg, Germany , [23]Carnegie-Mellon University, Pittsburgh, PA, U.S.A., [24]Johns Hopkins University, Baltimore, MD, U.S.A., [25]Bristol University, Bristol, U.K., [26]University of Toronto, Toronto, ON, Canada, [27]Illinois Institute of Technology, Chicago, IL, U.S.A.

Radiation Levels of LHC Pixel Detectors

⇒ Expect 10^{14} π / cm^2 per year at

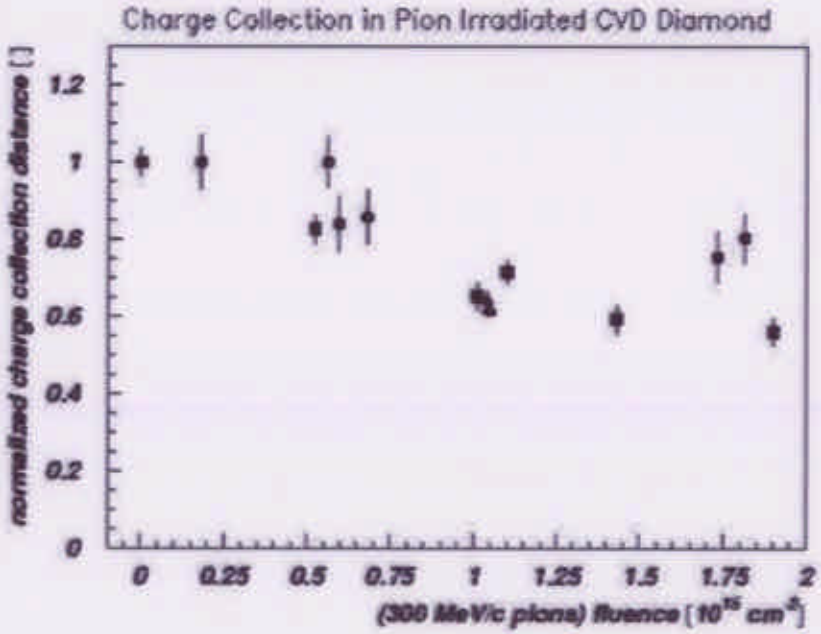
- full LHC luminosity
- 7 cm radius

⇒ Diamond inherently radiation hard material

- operate for 10 years at full luminosity

Pion Irradiation

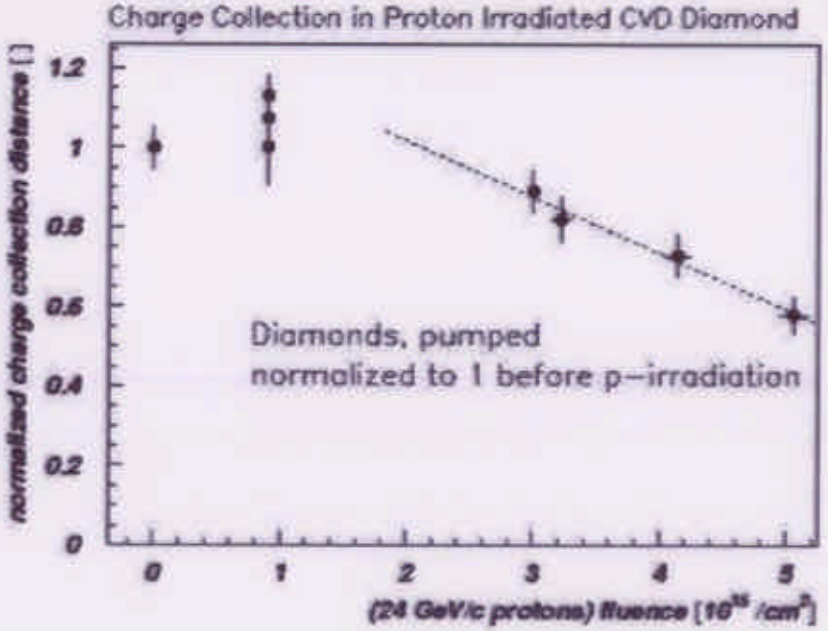
300 Mev/c π at PSI



- Pulse height constant up to 4.0×10^{14} π/cm^2
- 40% decrease at 2×10^{15} π/cm^2

Proton Irradiation

24 Gev/c protons at CERN/PS



- Pulse height constant up to 1×10^{15} p/cm^2
- 40% decrease at 5×10^{15} p/cm^2

Other Attractive Properties of Diamond

⇒ Operate at room temperature
- no complicated cooling system

⇒ Processing simple
- sputtering of Ti/W electrodes

⇒ No need for guard rings
- no leakage current after several years at LHC

⇒ Material reusable
- readout chips can be removed
- electrodes can be repatterned

⇒ Low capacitance
- dielectric constant
  - factor of two less than for silicon

Some Potential Disadvantages

⇒ Pulse height smaller than for silicon

- energy needed to produce e-h pair
  - diamond 3.6 eV
  - silicon 1.3 eV
- charge produced in diamond one half that in silicon
  - equivalent thickness in radiation length
- in present quality diamond full charge not collected
  - ≈ 70% of charge collected

    300 micron thick detector

⇒ Some spatial nonuniformity of pulse height

- CVD diamond films are polycrystalline
- some nonuniformity on scale of grain sizes
  - about hundred microns

Requirements for Viable Diamond Pixels

⇒ 100% hit efficiency

- using electronics developed for LHC

⇒ Spatial resolution comparable to silicon

- due to charge sharing from both
  - inclined tracks
  - Lorentz drift in magnetic field

Test Beam Program

⇒ 100 GeV pions at Fermilab and CERN

⇒ Tracking telescope

- 8 planes of silicon microstrip detectors
- scintillating fiber array defines trigger region
- track extrapolation resolution
  - 2 μm in row direction
  - 7 μm in column direction

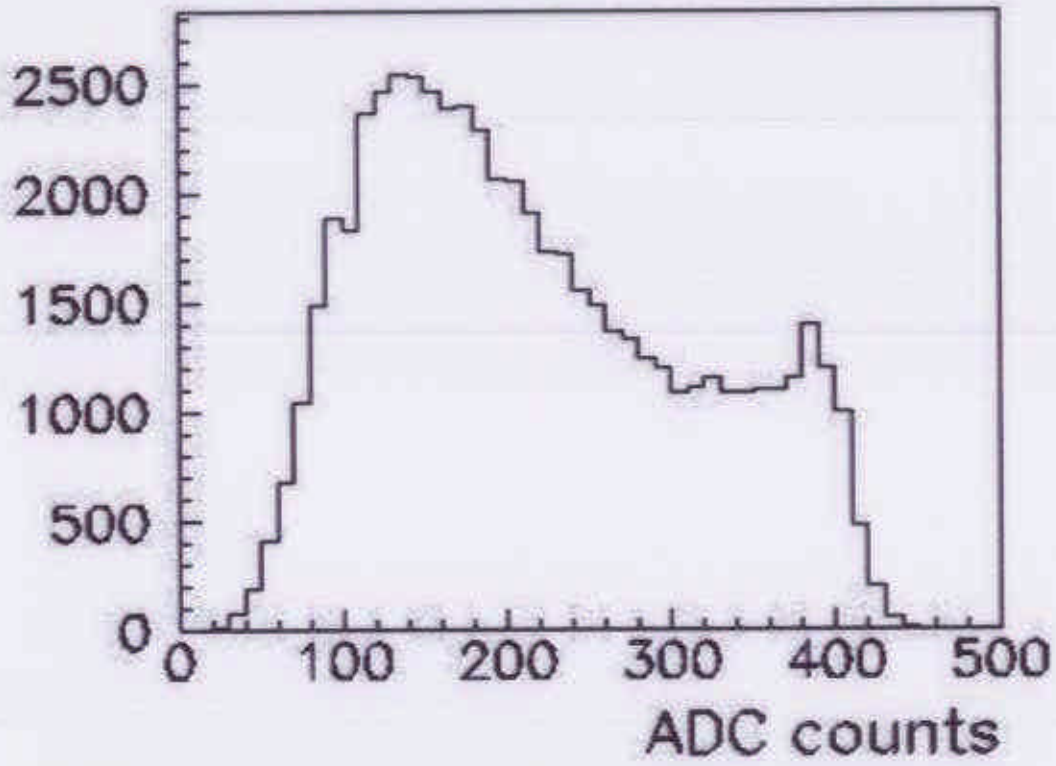
⇒ Diamond

- Produced by DeBeers Industrial Diamond Inc.
- Thickness: 500 μm
- Electrodes: sputtered Ti/W
- Indium bump-bonded to readout chip
- Applied field: 1 V/μm

⇒ Readout chip

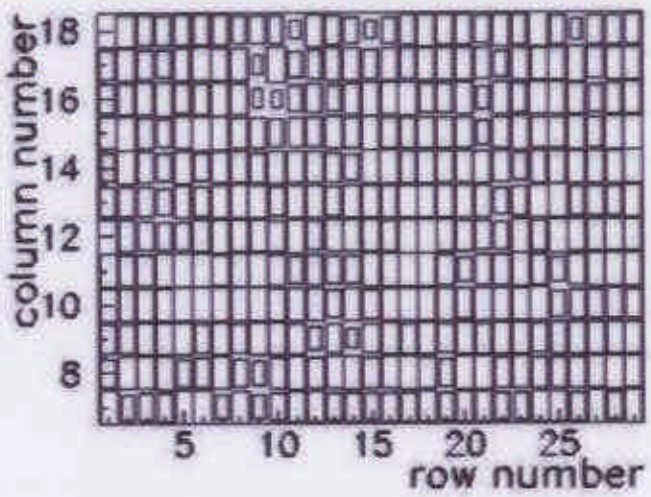
- Honeywell version of PSI30 CMS chip
  - 125 μm x 125 μm pixels
  - 24 columns x 32 rows
- Active area: 12 columns x 30 rows
- Calibration: 25 e^- per ADC count
- Noise rms: 300 e^-
- Pixel threshold: 2000 e^- ± 300 e^-

Diamond Pixel Pulse Height

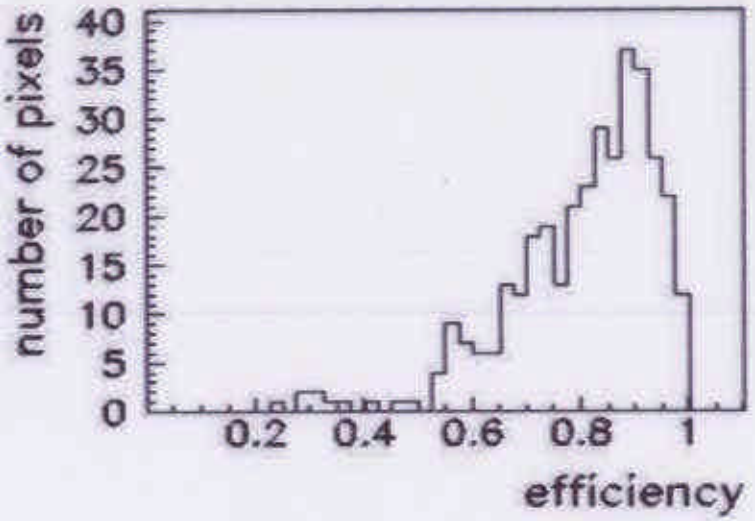


- 25 e^- per ADC count
- peak at 400 ADC counts due to chip saturation
- low pulse height tail due to fluctuation in threshold
  - threshold: 2000 e^- ± 300 e^-

Diamond Pixel Efficiency



Efficiency Map



Efficiency Distribution

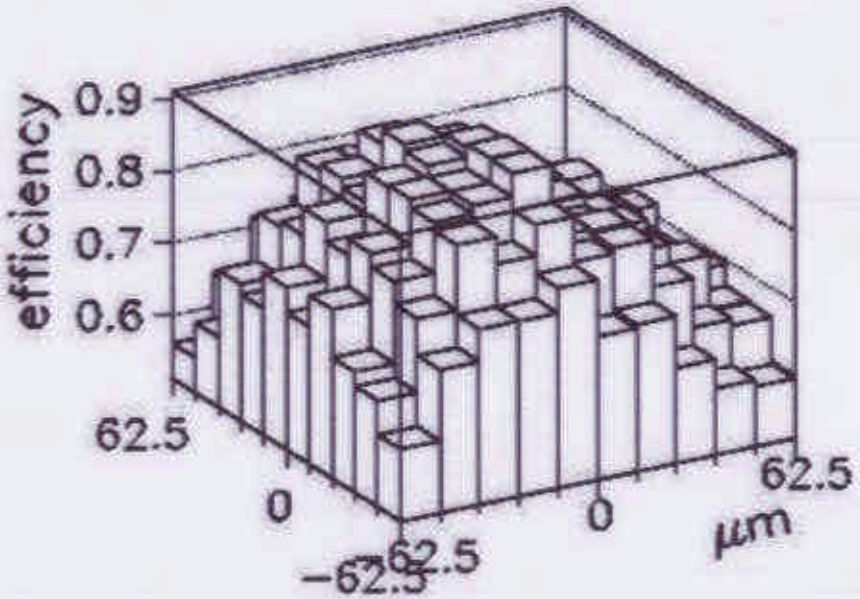
- About 100 tracks per pixel

$\Rightarrow$ Most probable efficiency: 90%

$\Rightarrow$ All pixels greater than zero efficiency

$\Rightarrow$ 97% of pixels greater 50% efficiency

Position Dependence of Efficiency



Map of efficiency within pixel
averaged over all pixels

⇒ Efficiencies: center of pixel: 85%
edge of pixel: 70%
corner of pixel: 60%

Summary

- Diamond Pixel Efficiency > 80%
  - Steps for improving this year
    - reduce threshold to 1500 e^-
    - increase diamond bias field
- By end of year
  - Spatial resolution measurement from
    - inclined tracks
    - Lorentz drift in magnetic field
- Next year
  - Higher quality diamond
  - Comparisons with silicon before/after irradiation
- Goal
  - Viable diamond pixel detector in 2002