SILICON CHIPS and SENSORS
what have these to do with RADIATION and PHYSICS

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BUSINESS BRIEFING

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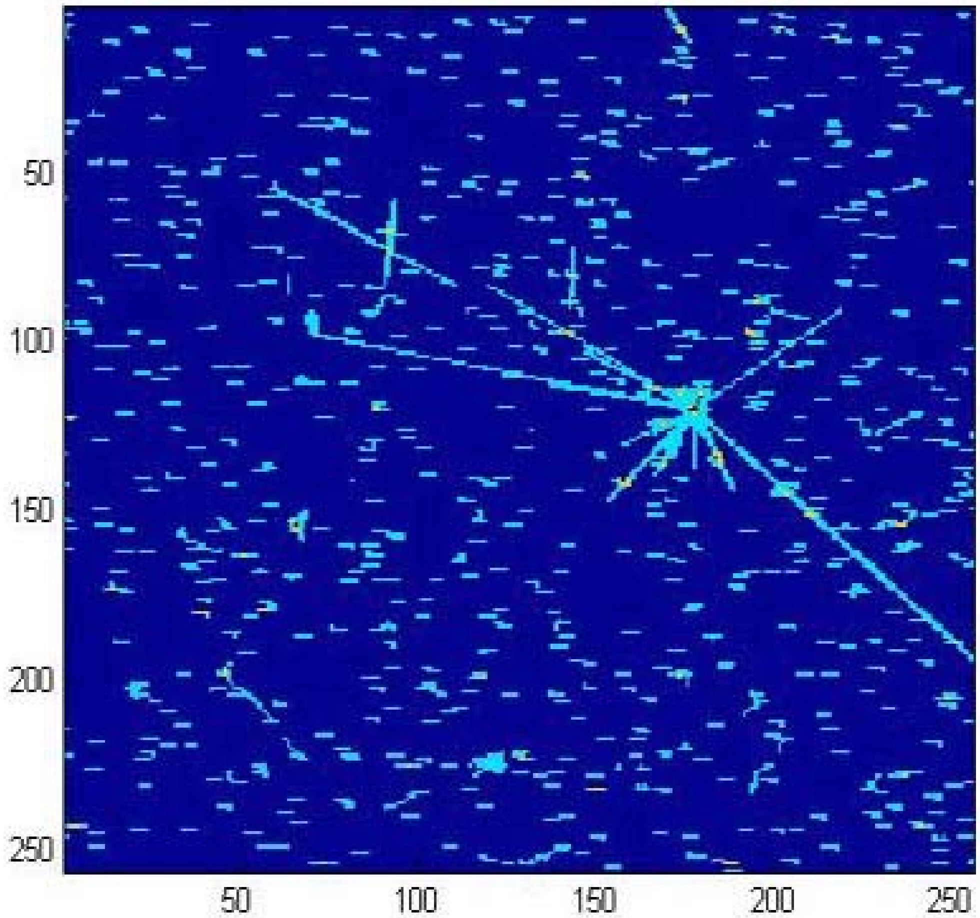
SIMPLE ANSWER,
FAR-REACHING EFFECTS

RADIATION GENERATES FREE ELECTRICAL CHARGE DIRECTLY in SEMICONDUCTOR Si

can be COLLECTED in ns using ADAPTED DEVICE STRUCTURE

PARTICLES in SILICON CHIP



MAKE 80 e^- charges per µm length

in GAS typically 1-2 e^- charges per mm

3 ASPECTS with RADIATION

silicon CHIPS as SENSORS
CMOS CHIPS as READOUT

DAMAGE of CHIPS by RADIATION

ATTO

MILLI

MICRO

GIGA NANO

TERA PICO

PETA FEMTO

10^{+18} EXA ATTO 10^{-18}

10^{+21} ZETTA ZEPTO

10^{+24} YOTTA YOCTO

MINIATURIZATION
IN
DETECTORS
SIGNAL PROCESSING
DATA HANDLING

VISUALIZATION far below ATOMIC DIMENSIONS

ALL with INDIRECT METHODS

- ENERGY LOSS --> IONIZATION

GAS	GM COUNTER WILSON CHAMBER MWPC
LIQUID	BUBBLE CHAMBER LAr CALORIMETER
SOLID	PHOTO EMULSION

- ENERGY LOSS --> LIGHT

GAS	FLUORESCENCE
LIQUID	SCINTILLATION
SOLID	CERENKOV RADIATION

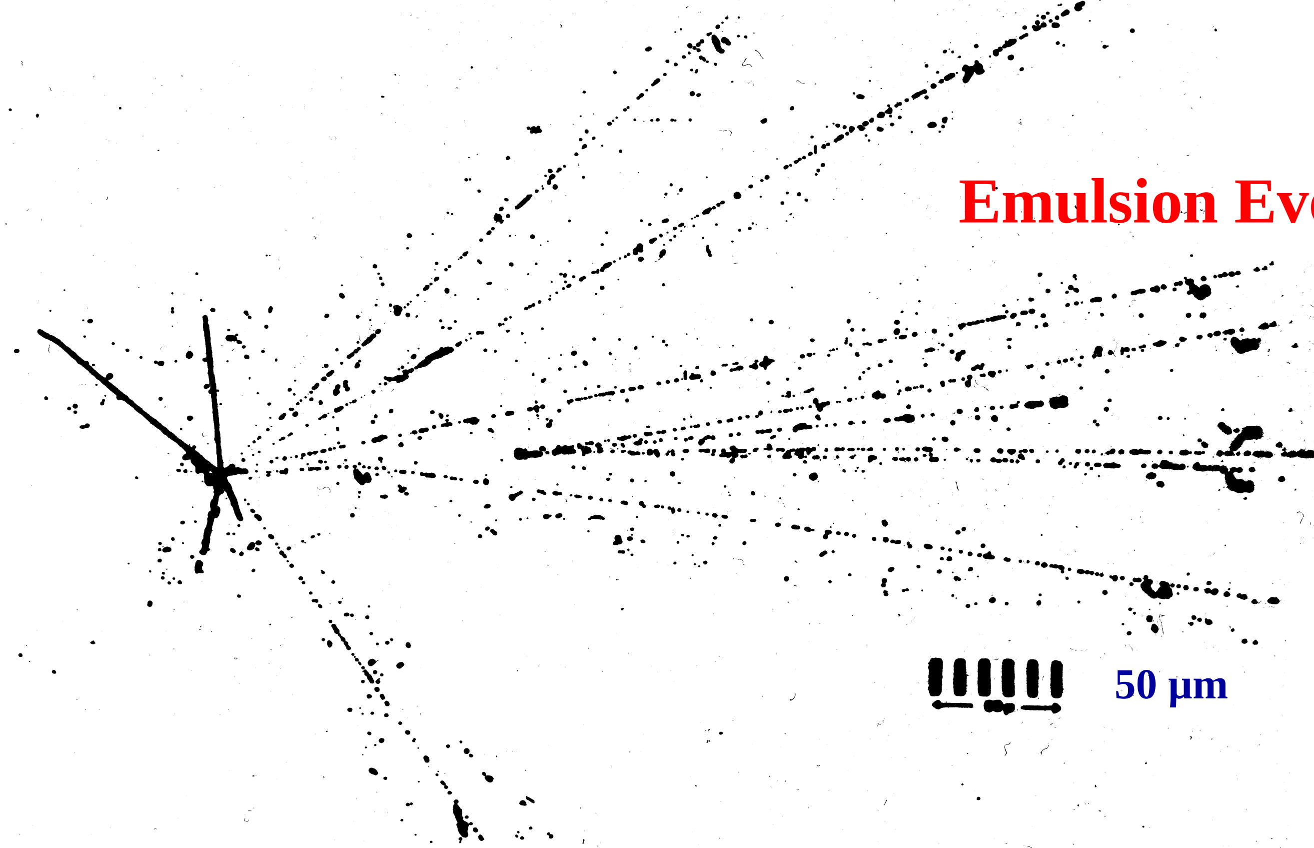
- NEUTRALS HAVE TO CONVERT TO BE SEEN

NUCLEAR EMULSION

SPECIAL, THICK FILM AgBr 3D, μm PRECISION

CHARM DECAY

Emulsion Event WA59 ~ 1985



SUCCESSIVE IONIZING TRANSFERS TO GRAINS MAKE LATENT IMAGE

MINIATURIZATION
&
SEGMENTATION
in
DETECTORS
PROCESSING CHIPS

USE TREND in INDUSTRY

PROGRESS in Si SENSORS

DEPENDS on AVAILABLE INDUSTRIAL TECHNOLOGY

0-D	SINGLE DIODE	1955
1-D	SEGMENTED DIODE mm	1960
QUASI 2-D	DOUBLE-SIDED STRIPS	1965
TRUE 2-D	CCD/MOS MATRIX	1971
	PIXELS MONO or HYBRID	1989
	PILLARS '3D'	1998
TRUE 3-D	VOXELS next step	?

Si as RADIATION SENSOR

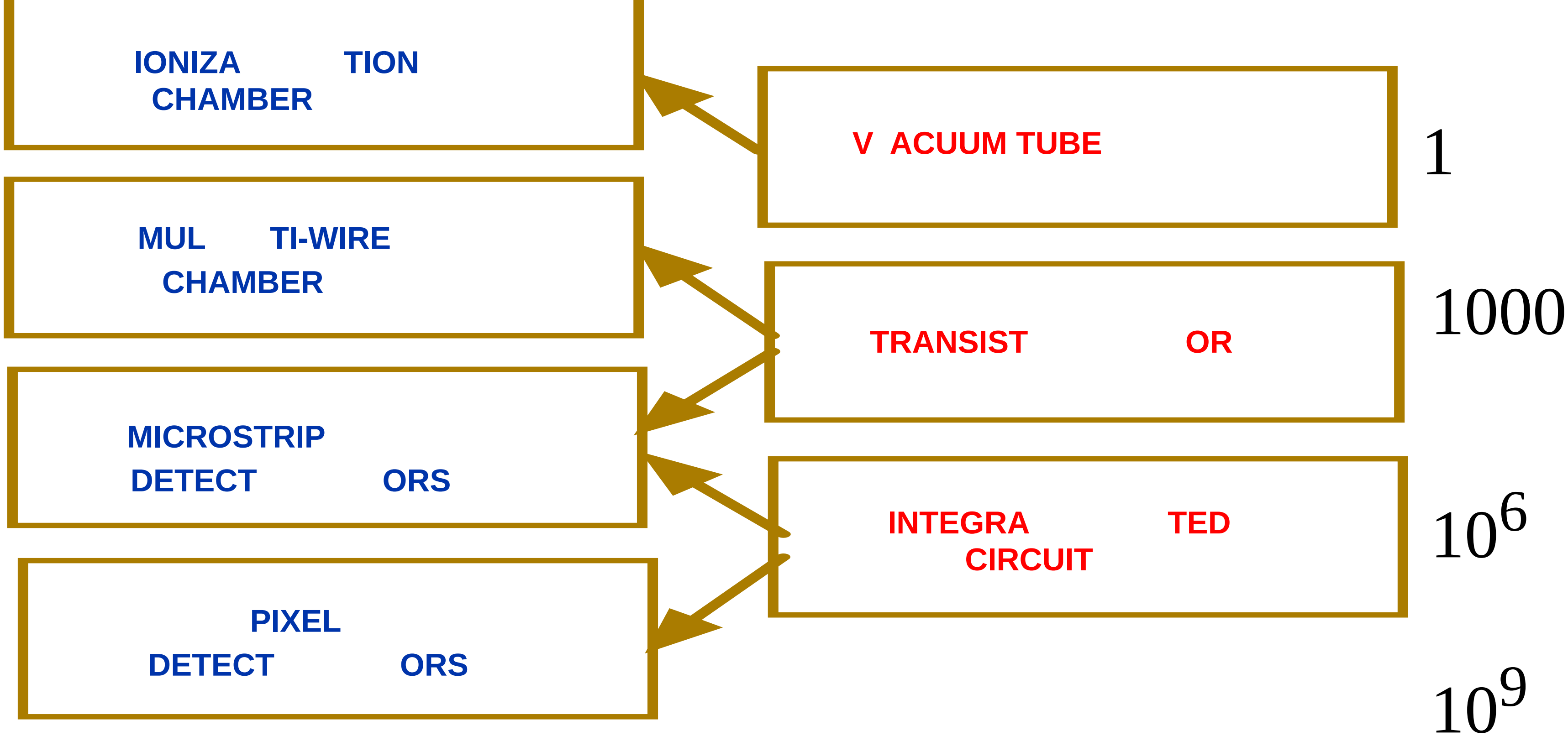
Si SEGMENTATION by LITHOGRAPHY < µm PRECISION

CAN ONLY BE USED
with MICROELECTRONICS
READOUT CHIPS

DETECTOR SEGMENTATION and ELECTRONICS READOUT

Segmentation

ELECTRONICS
Miniaturization



READOUT ELECTRONICS
for
VARIETY of DETECTOR SYSTEMS

CUSTOM CHIP DESIGN

MOST CHIPS in 0.25 µm CMOS

40 MHz
LOW POWER
RESTRICTED SPACE, COOLING

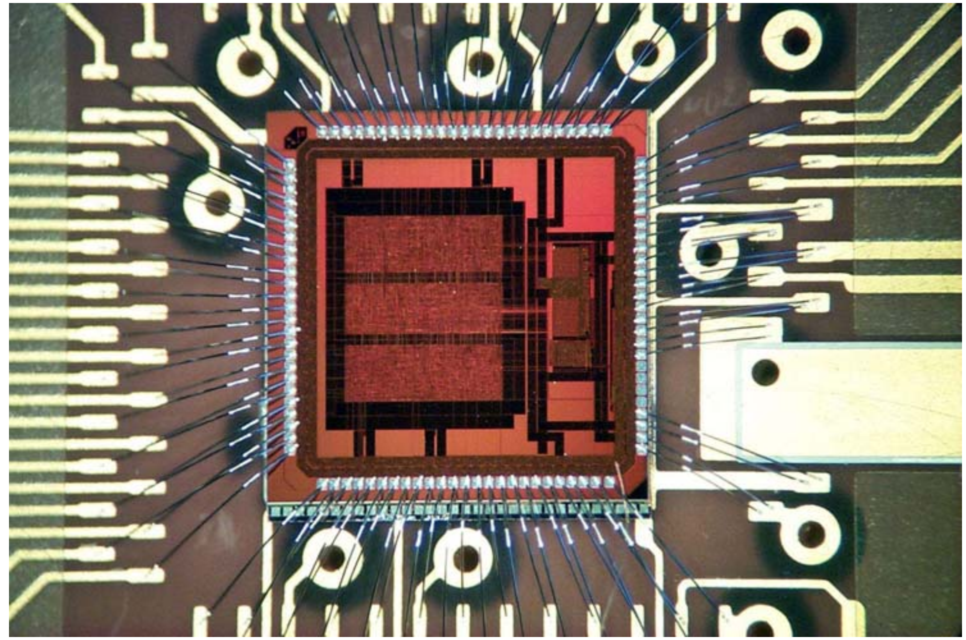
HIGH RADIATION ENVIRONMENT 0.01 to 10 kGy per year
single event upsets

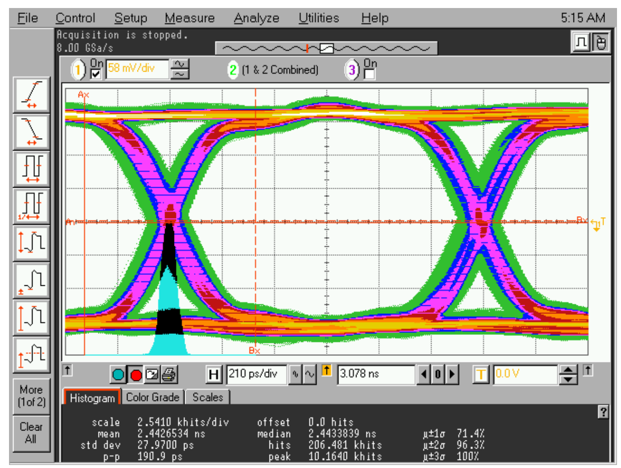
High Speed Serializer

LHC OPTICAL DATA LINK

Gigabit Optical Link (GOL)

- 0.8 and 1.60 Gb/s optical link
- Unidirectional
- < 300 mW
- G-Link and Gigabit Ethernet protocol
- Redundant logic





Foundry-Related Activities at CERN

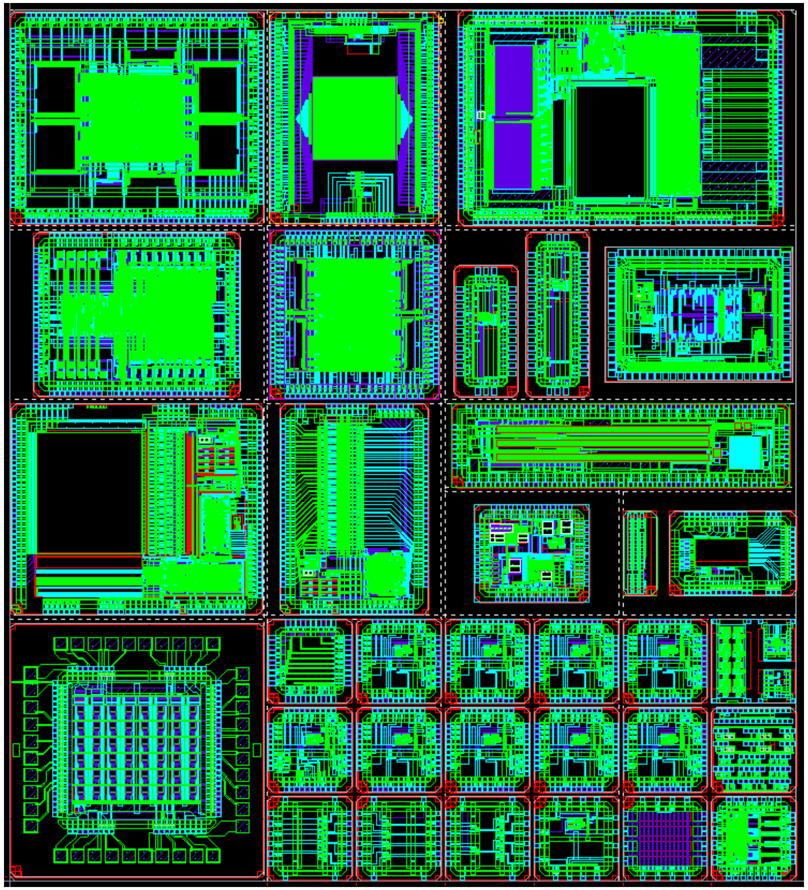
Organization of MPW for High Energy Physics community

- European and US Institutes, ~20 Design Groups
- 16 MPW and 25 production runs in 5 years

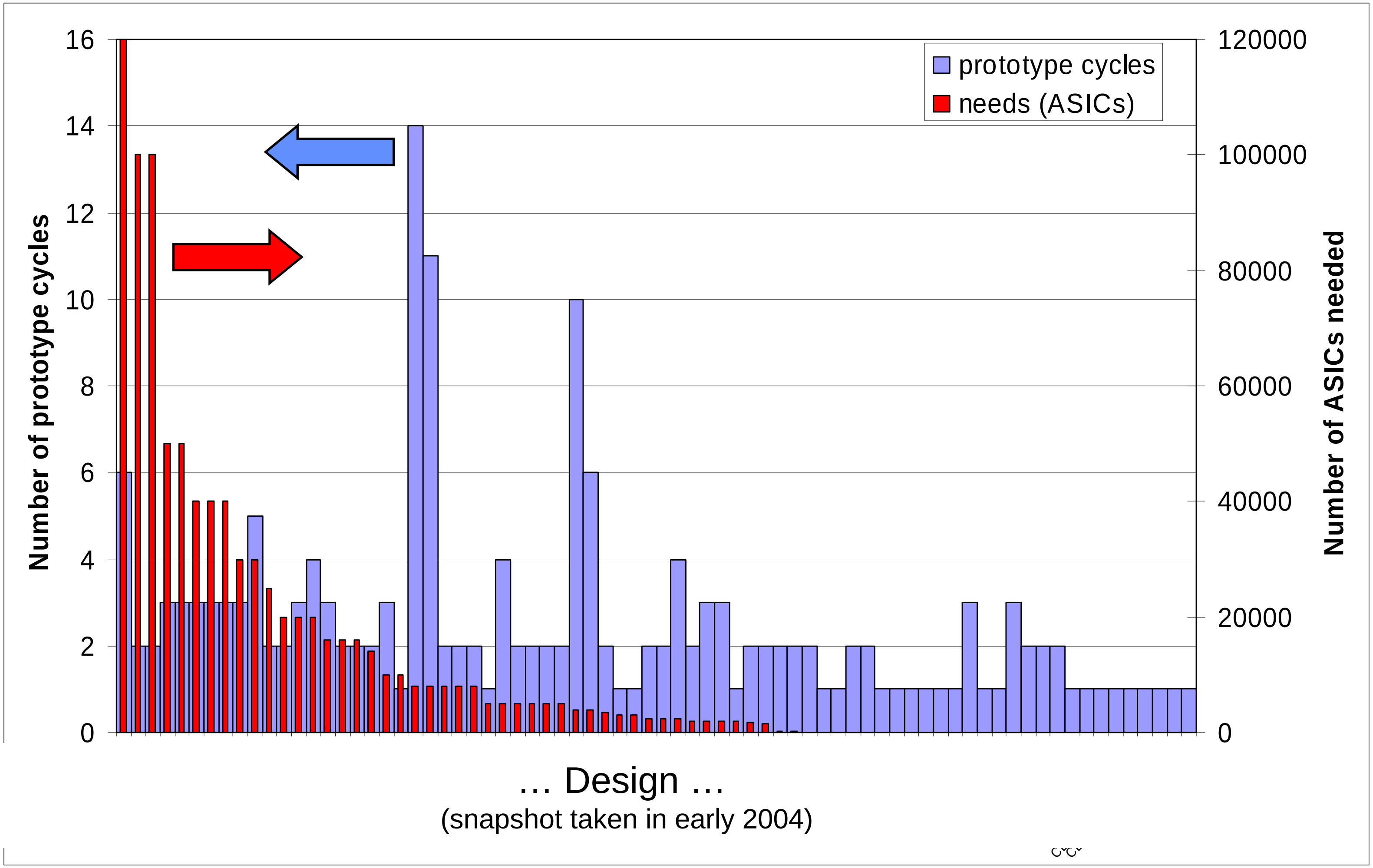
Handling of contracts for larger orders

Some commercial applications examples:

- **TDC**
  - Instrumentation commercial vendor
- **Medipix**
  - radiation imaging instrumentation
- **NINO**
  - fast analog front-end processor



Design activities in HEP community

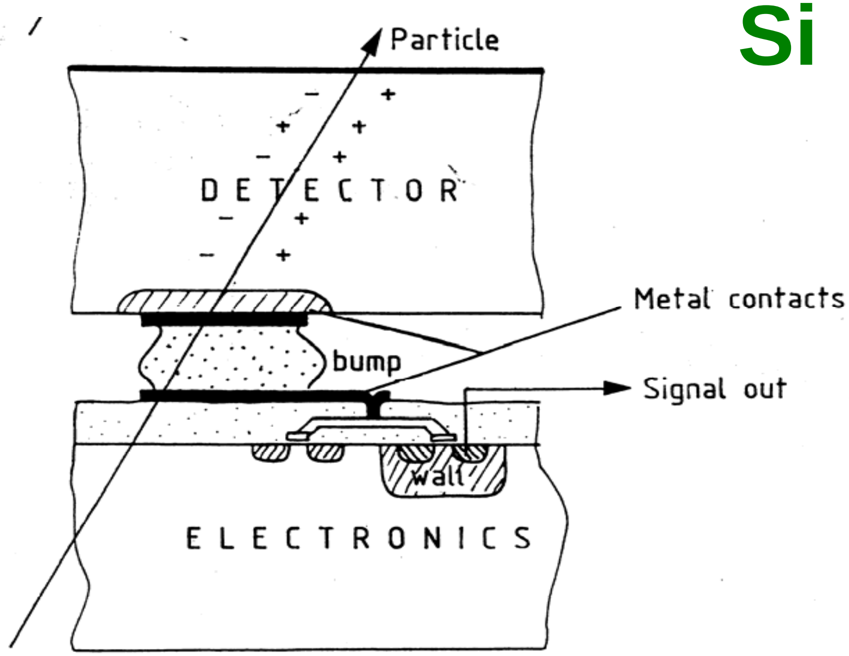


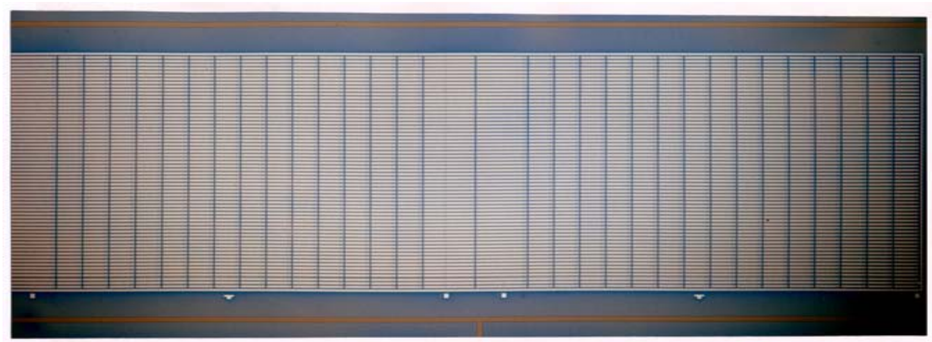
HYBRID Si PIXEL SENSOR 1991

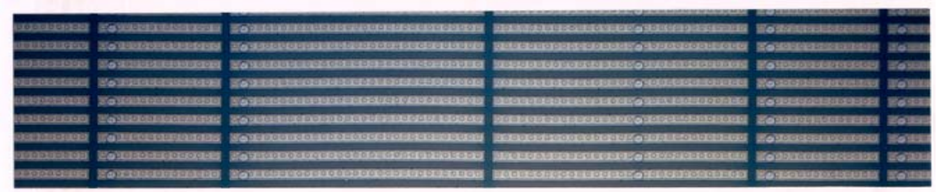
CERN : CAMPBELL, HEIJNE

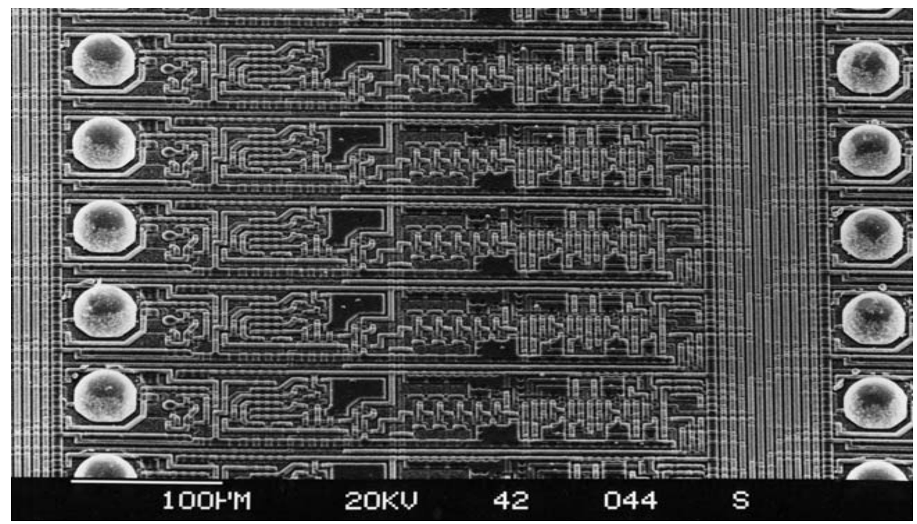
SENSOR MATRIX TRUE 2 - D

Si









BUMPS

+

READOUT ELECTRONICS

MANY NEW IDEAS
for
SUPER LHC, ILC, CLIC,...

PROJECTS

NATIONAL LABS
UNIVERSITIES
CERN

CLOSELY COORDINATED with LHC EXPERIMENTS

INTEGRATION
SPEED
POWER
COST
RELIABILITY

STUDY RADIATION HARDNESS

Summary of Radiation Effects

Cumulative effects

Total Ionizing Dose (TID)

Potentially all components

Displacement damage

Bipolar technologies
Optocouplers
Optical sources
Optical detectors (photodiodes)

Single Event Effects (SEE)

Permanent SEEs

SEL

CMOS technologies

SEB

Power MOSFETs, BJT and diodes

SEGR

Power MOSFETs

Static SEEs

SEU, SEFI

Digital ICs

Transient SEEs

Combinational logic
Operational amplifiers

Plans for 130 nm and 90 nm

- **Acquire an appropriate technology for SLHC, ILC and beyond**
  - Validate Radiation Tolerance as necessary
  - Assemble appropriate design tools to allow designs for HEP community
- **Provide a general commercial contract for 130 nm and 90 nm technologies for entire community**
- **Establish a long term technology and design service activity**
  - Technology = Silicon, design tools, MPW service, fabrication support, post-design support services, advanced packaging services

NEW DETECTORS ?

SILICON submicron **CMOS ALLOWS PIXEL FUNCTIONS**

SELECTIVITY CAN BE BUILT-IN

VERY LOW NOISE with SMALL PIXELS ~40 e^- rms

3D FUNCTIONS with HYBRID PACKAGING

TRACK VECTORS + SELECTIVITY

THIN DEVICES ARE RADHARD