University of Glasgow | Experimental Particle Physics

New detector concepts and developments

"How to manage charge trapping"

R. Bates
University of Glasgow

With special thanks to:
A. Affolder (Liverpool) : Silicon Strip results
M. Mathes (Bonn) : 3D testbeam analysis
H. der Graaf (NIKHEF) : GOSSIP
plus many ATLAS & RD50 colleagues

Contents:

- Strip detectors
  - P-type bulk devices
  - MCN_d post-processing
  - Won't mention thin silicon detectors
- 3D silicon detectors

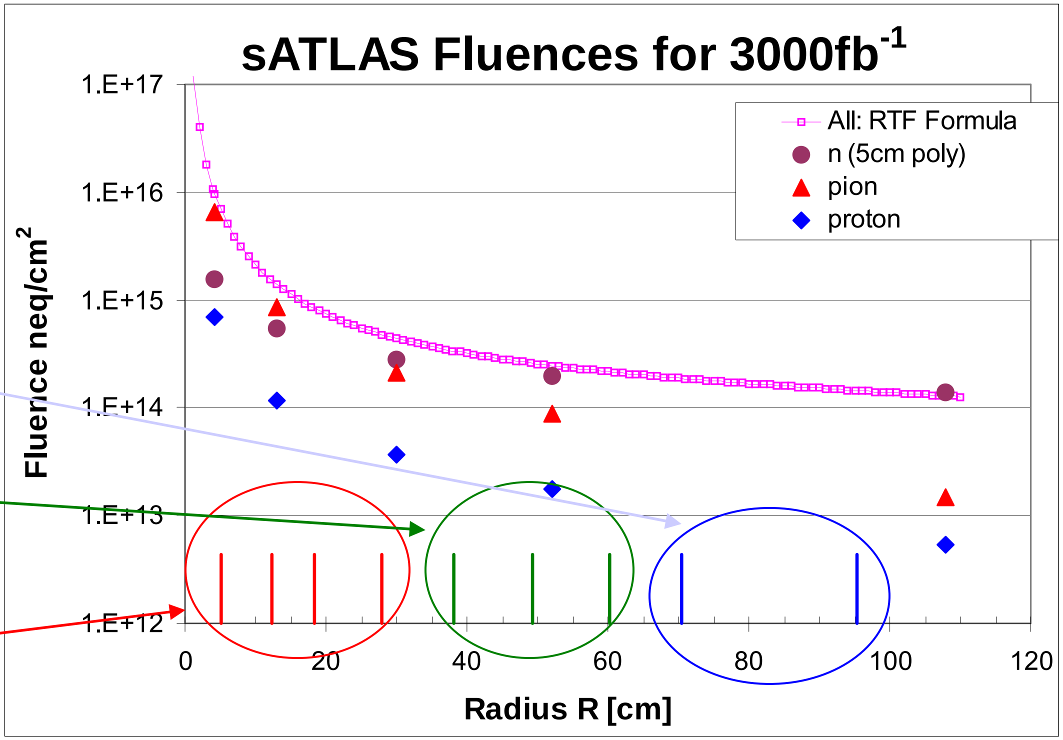
Fluence in Proposed sATLAS Tracker

Strip length and segmentation determined by occupancy< 2%

Long Strips

Short Strips

Pixels



ATLAS Radiation Taskforce http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/RADIATION/RadiationTF_document.html

Mix of neutrons, pions, protons depends on radius R

Long and short strips damage largely due to neutrons

Pixels damage due to neutrons and pions

Design fluences for sensors (includes 2x safety factor) **:**

Innermost Pixel Layer:	$1.6*10^{16}$ n_{eq}/cm^2 = 500 Mrad
Outer Pixel Layers:	$3*10^{15}$ n_{eq}/cm^2 = 150 Mrad
Short strips:	**$1*10^{15}$ n_{eq}/cm^2 = 50 Mrad**
Long strips:	**$4*10^{14}$ n_{eq}/cm^2 = 20 Mrad**

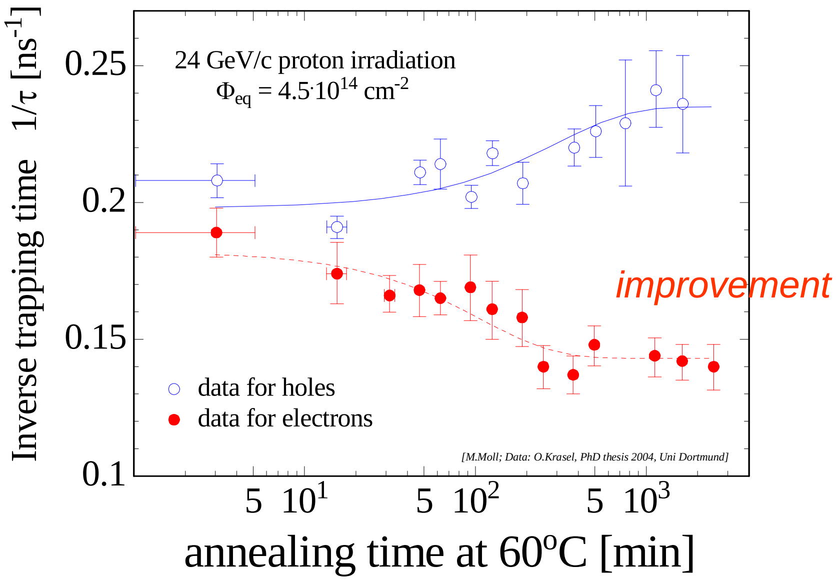
Need to study effect of both neutral (neutrons) and charged (proton) particle irradiations

Charge trapping

$$Q_{e,h}(t) = Q_{0e,h}\exp\left(-\frac{1}{\tau_{eff\ e,h}}\cdot t\right)$$ **where** $$\frac{1}{\tau_{eff\ e,h}} \propto N_{defects} = \beta_{e,h}\Phi$$

$\beta_e = 4.2\times10^{-16}cm^{-2}/ns,\quad \beta_h = 6.1\times10^{-16}cm^{-2}/ns$ From G. Kramberger et al., NIMA 476(2002), 645-651.

1/τ changes with annealing



$\tau_{eff}(10^{14}) = 20ns \qquad \lambda = v_{sat}\tau_{eff} = (10^7 cm/s)\times 2\times10^{-8}s = 2000\mu m$

$\tau_{eff}(10^{16}) = 0.2ns \qquad \lambda = v_{sat}\tau_{eff} = (10^7 cm/s)\times 2\times10^{-10}s = 20\mu m$

⇒ Decrease in CCE.

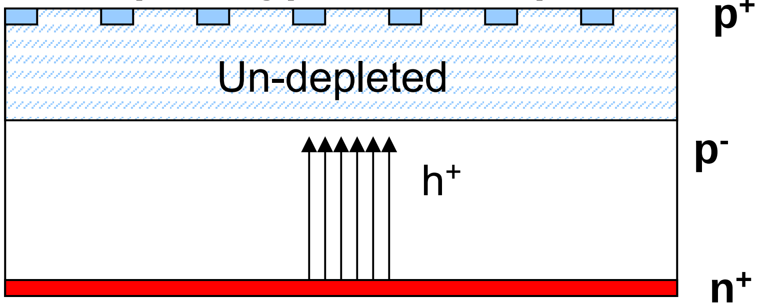
p-type strip detector

n^+ implants in a p^- bulk

P-strip vs. N-strip Readout

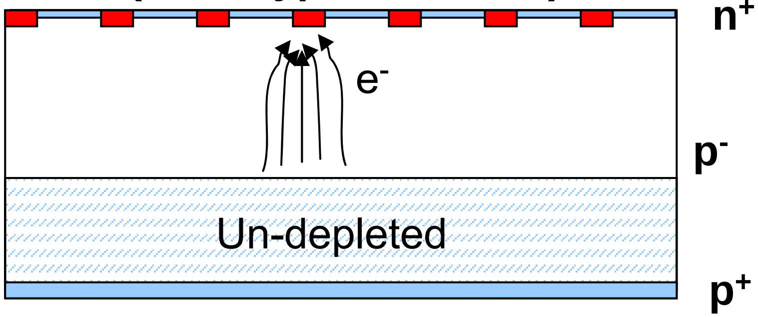
Type inversion turns lightly doped material to “p” type

“Standard” p-in-n geometry (after type inversion)



- Holes collected
- Deposited charge cannot reach electrode
  - Charge spread over many strips
  - Lower signal

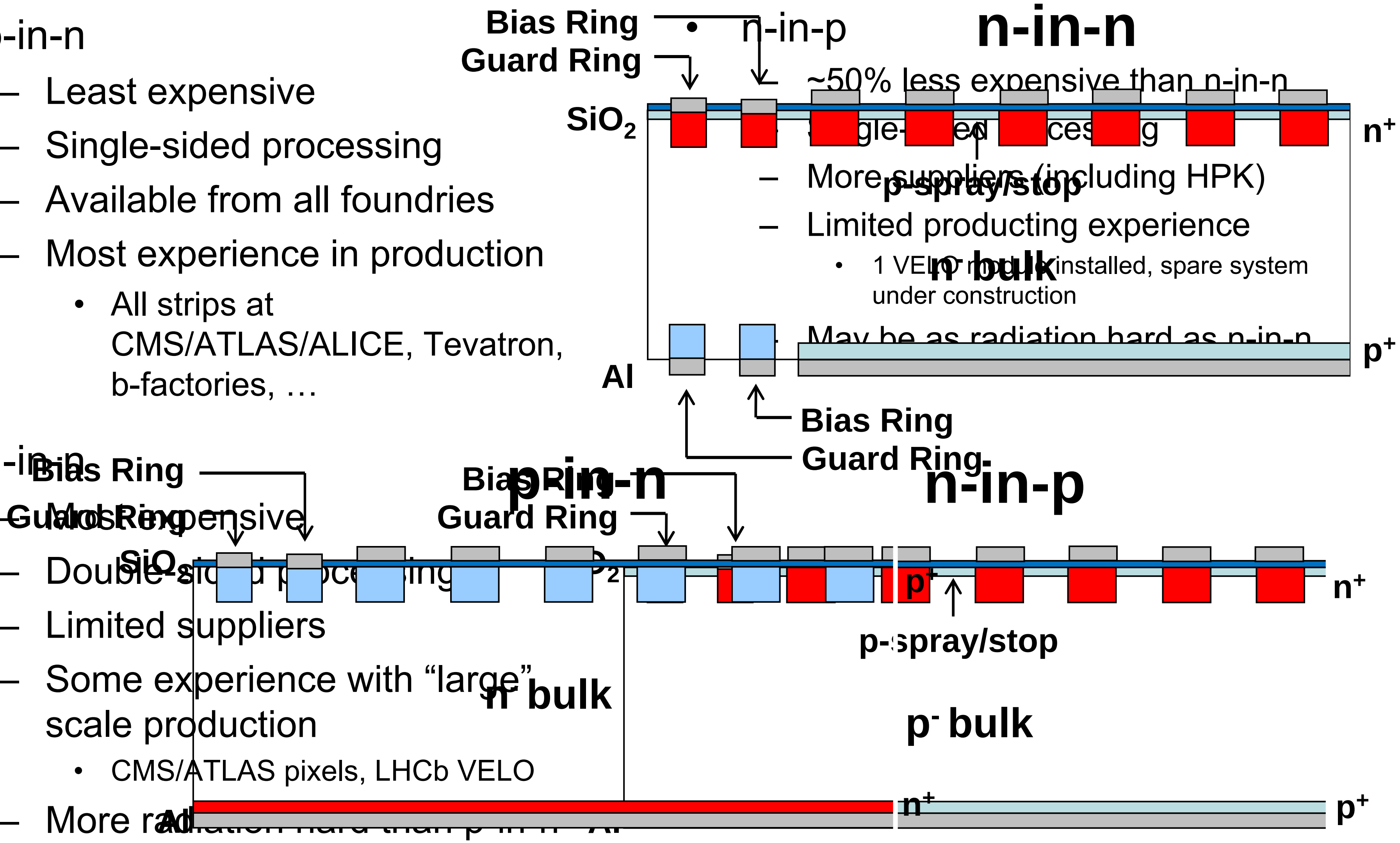
“New” n-in-p geometry
“New” n-in-n geometry
(after type inversion)



- Electron collected
  - Higher mobility and ~33% smaller trapping constant
- Deposited charge can reach electrode

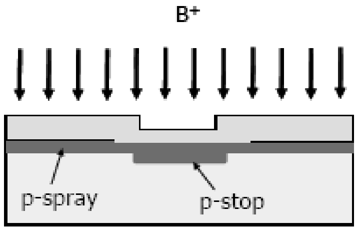
Silicon detector geometry choices

- p-in-n
  - Least expensive
  - Single-sided processing
  - Available from all foundries
  - Most experience in production
    - All strips at CMS/ATLAS/ALICE, Tevatron, b-factories, …
- n-in-n
  - Most expensive
  - Double-sided processing
  - Limited suppliers
  - Some experience with “large” scale production
    - CMS/ATLAS pixels, LHCb VELO
  - More radiation hard than p-in-n
- n-in-p
  - ~50% less expensive than n-in-n
  - Single-sided processing
  - More suppliers (including HPK)
  - Limited producting experience
    - 1 VELO module installed, spare system under construction
  - May be as radiation hard as n-in-n

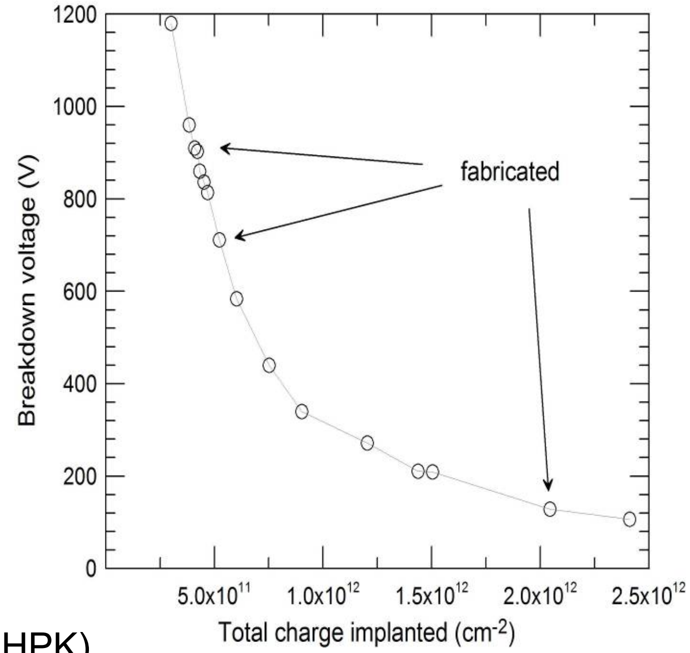


Development of surface treatment for n-in-p

- p-stop – better before irradiation
  - Local, high concentration doping
  - Limits feature size
- p-spray – better after irradiation
  - Uniform, lower concentration doping
- Moderated p-spray (combination of the above two)
  - Use a variable oxide thickness to change the boron doping



Simulation of V_{BD} as a function of the p-spray dose

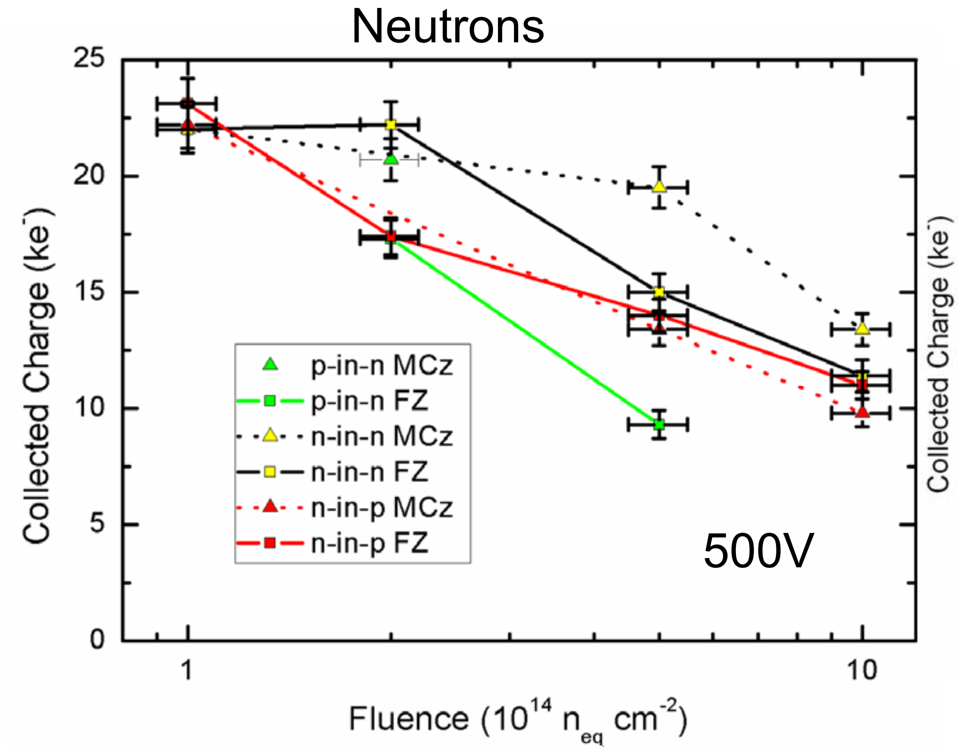


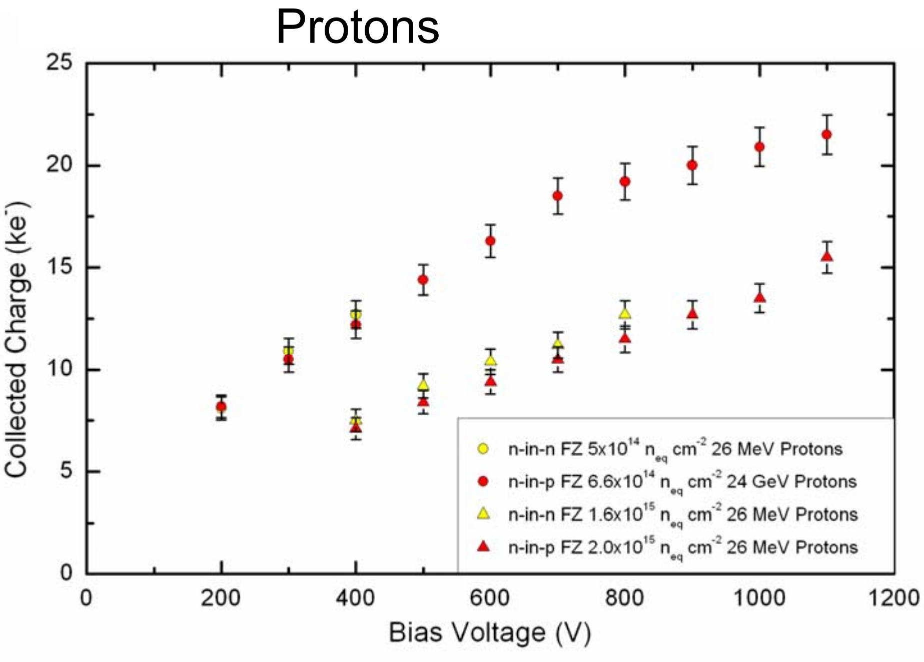
Measured V_{BD} on CNM devices

Technology	V_{BD}(V)	Std. error (V)
p-stop	400	± 15
p-spray	460	± 30
Moderate (228 nm)	370	± 40
Moderate (260 nm)	530	± 10
Moderate (290 nm)	310	± 10

Studies are being performed in RD50 (CNM, MICRON, FBK), ATLAS (HPK)

Irradiation Studies





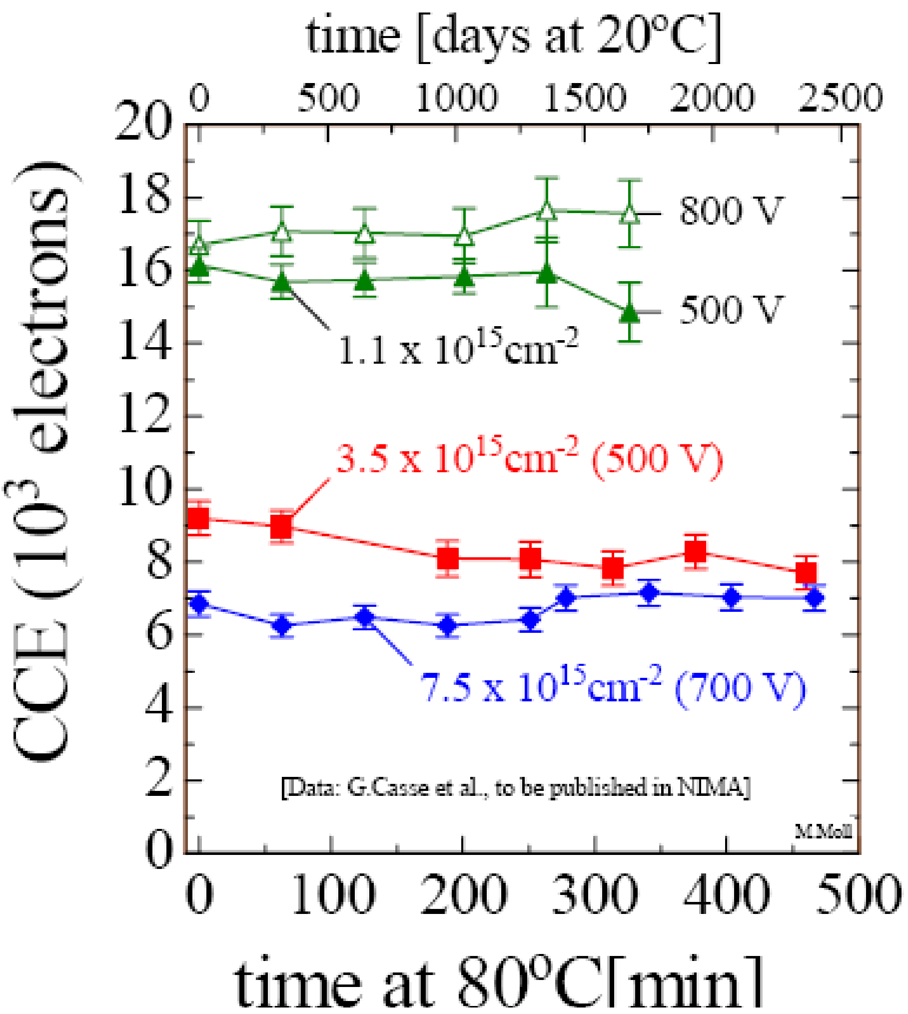
A. Affolder, presented at PSD8, to be published NIMA

- Presently, only n-in-n FZ and n-in-p FZ results available
  - Both show similar CCE ($5×10^{14}$ n_{eq} cm^{-2})
- More n-in-p MCz and n-in-n MCz wafer currently in process
  - New results available in 2009

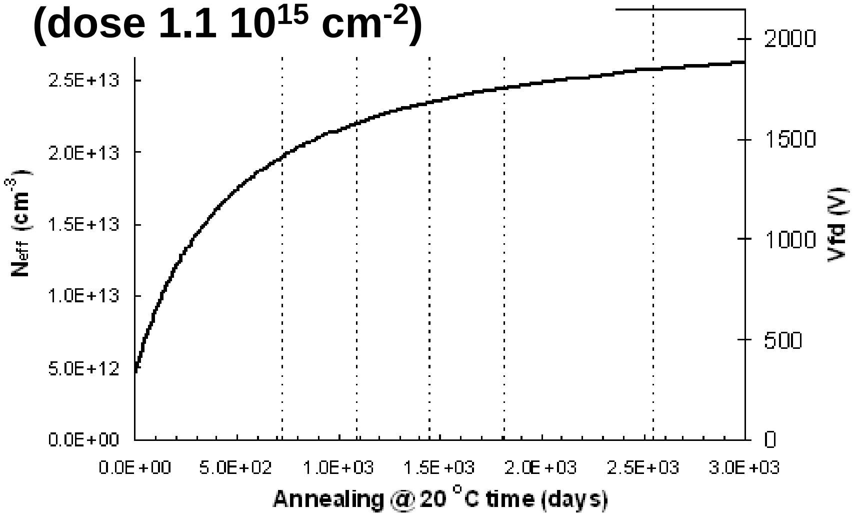
- Requirement: sufficient charge collection for short strip regions
- n-in-n FZ and n-in-p FZ similar in terms of CCE at these doses
  - n-in-n FZ highest CCE for doses < $5×10^{14}$ n_{eq} cm^{-2}
- n-in-p FZ shows best performance

- Best performance n-in-p, expected noise 750e, signal > 7500e @500V
- p-in-n (& n-in-n) detectors fine for short strip regions
- Situation improves at higher bias voltages
  - MCz slightly better for neutron irradiation
- MCz base line (cost and availability) as expected from CV measurements

Annealing



Expected V_{FD} from CV (dose 1.1 10^{15} cm^{-2})



- V_{fd} increases from 420V to 1900V
- Signal remains constant with annealing time at "low" bias
- Signal limited by trapping not depleted thickness of silicon

G. Casse et al. NIMA

Starting detector:
CNM miniature p-type 80µm pitch 280µm thick strip detector
23GeV proton irradiation

MCN_d

Multi-chip module – deposited

Goal and technology description

- Replace hybrid with circuit deposited directly on silicon wafer.
  - Use dielectric (BCB) and metal layers (Cu)
  - Achieve a higher level of integration
- Feature sizes
  - Lithographic resolution: 10 μm, recommended: 30 μm
  - Dielectric layer thickness: 3-15 μm
  - Metal layer thickness: 1 μm
  - Approx^{ly} one order of magnitude smaller than standard PCB.
- Study:
  - Influence of BCB on sensor's shape, IV, CV, CCE.
  - Influence of ground plane on sensor
  - Technology issues - quality, bondability, solderability, (flip-chipable)
- Prototype runs with Acreo, Sweden (http://www.acreo.se/)
  - First devices in Glasgow this week

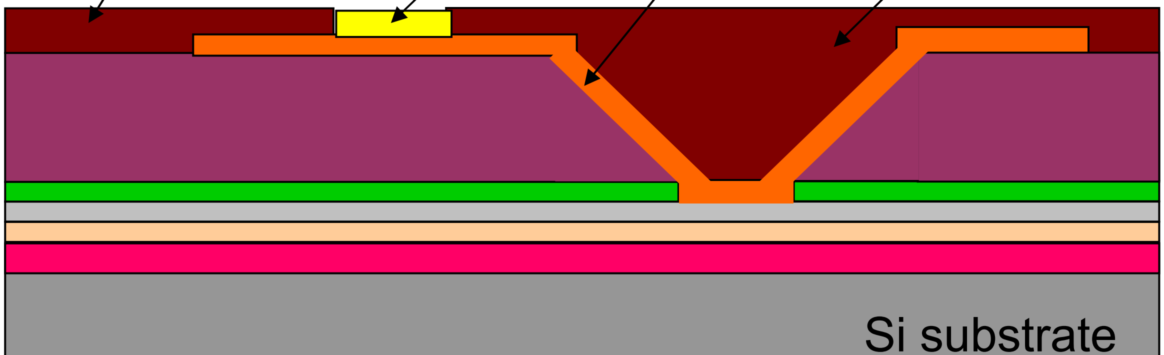
Cross section of the first run

Passivation
(3-4 µm BCB)

4 µm Ni +
150 nm Au

Cu/Ti layer
(1 µm)

Via
- etched opening in BCB (45 º)
- coated with Cu/Ti



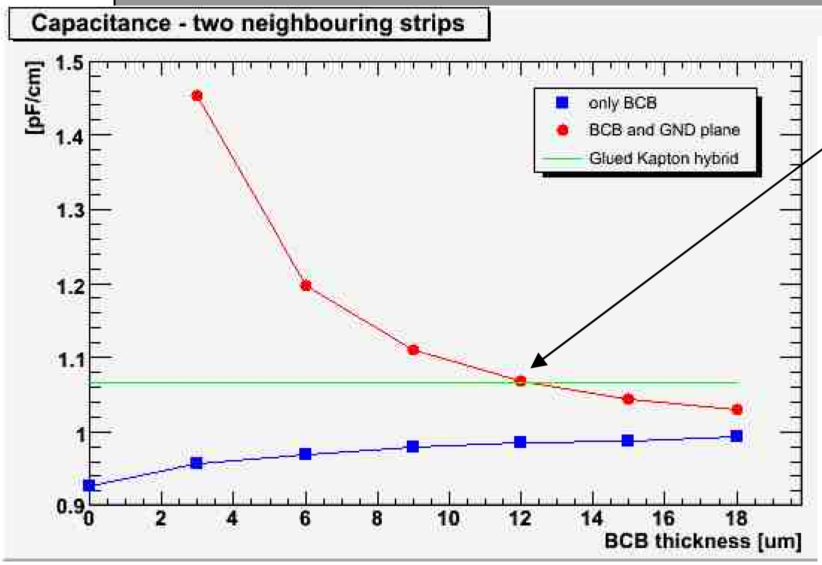
BCB (6 or 12 µm)
(dielectric)

passivation

Al strip

SiO_2

implant



Inter-strip capacitance of 12 µm BCB with GND plane = Kapton Hybrid and glue layer

- BCB: ε_r = 2.65, 3-18 µm BCB with/without grounded plane above
- Glue + Kapton: 50 µm Araldite 2011 ε_r = 4.0, 50 µm Kapton ε_r = 3.5, with a grounded plane above.

No modelling of (radiation induced) trapped charge. Experimental data required

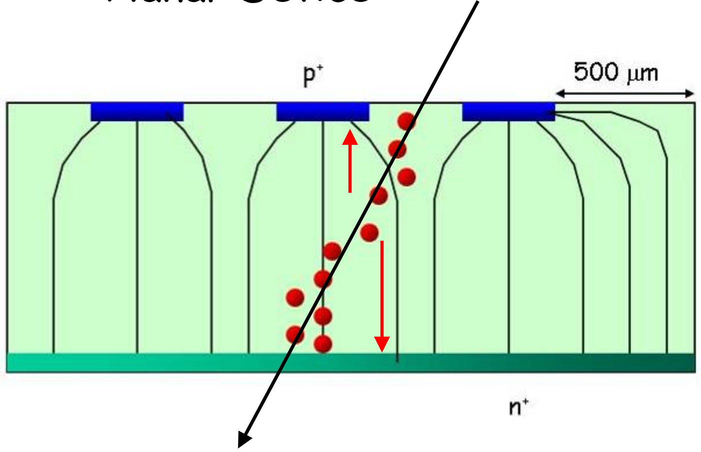
3D silicon sensor

Electrodes/implants penetrate the bulk normal to the surface

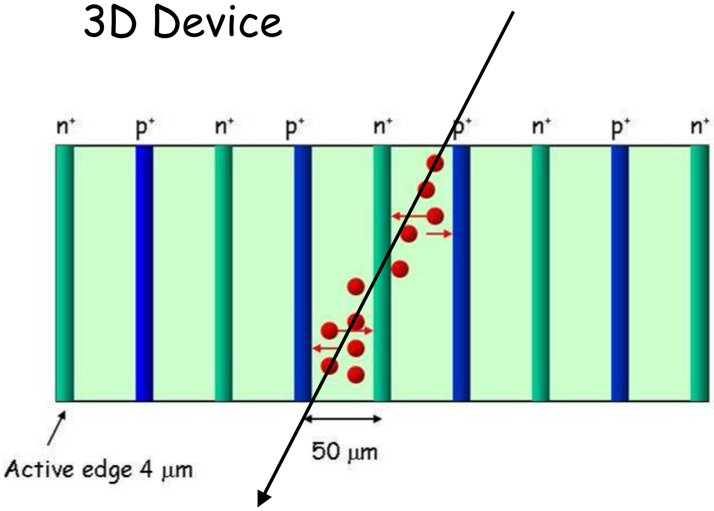
3D detectors

Proposed by Parker, Kenney 1995

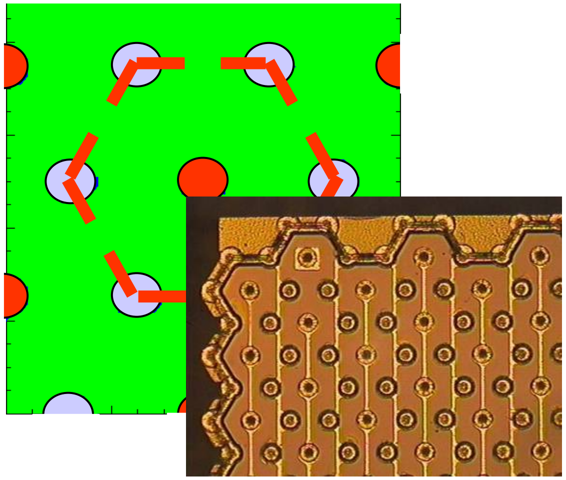
Planar Device



3D Device



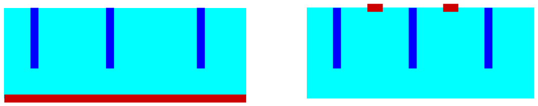
- Maximum drift and depletion distance governed by electrode spacing
  - Lower depletion voltages, $V \propto W^2$
  - Radiation hardness
  - Fast response
  - Active edges: same technology dope edges of sensor for edgeless detection efficiency
  - At the price of more complex processing
  - Narrow dead regions at wells



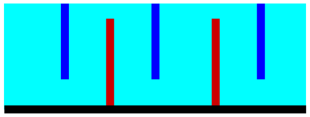
Unit cell defined by e.g. hexagonal array of electrodes

3D design family

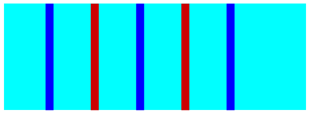
- Single Sided Single Type Columns (semi-3D)



- Double Sided Double Type Columns (double-sided 3D)



- Single Sided Double Type Columns (full 3D)



- Full 3D Invented in 1997 - S. Parker, C. Kenney, J. Segal
  - First produced in 1999 - Stanford Nanofabrication facility

Nucl. Instr. Meth. A, vol. 395, 328, 1997

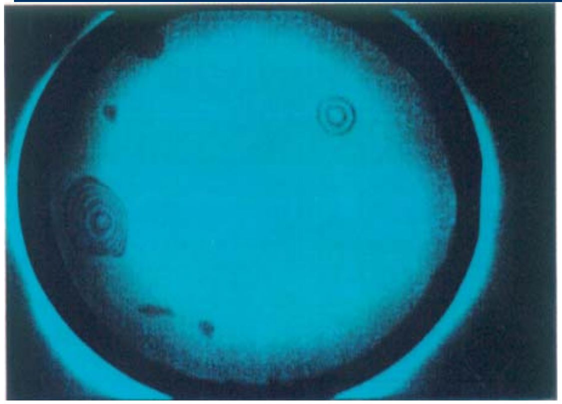
- Recent development: R&D towards experimental use
  - Improvements in micromachining make larger-scale, reliable production more feasible. Semi-industrial and industrial production has started: CNM/FBK/Sintef
  - Simplified structure: Double Sided, G. Pellegrini et al.

IEEE Trans. Nucl. Sci, vol. 54, no. 4, Aug. 2007
Nucl. Instr. Meth. A, vol. 592 (1), July 2008

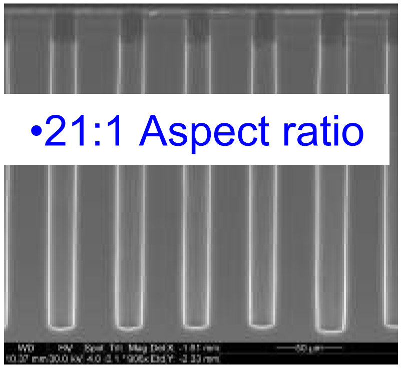
3D detector: processing

Non Standard Processing: Wafer bonding, Deep reactive ion etching , Low pressure chemical vapor deposition, Metal deposition
⇒ Mass production expensive but progressing

1) ETCHING THE ELECTRODES



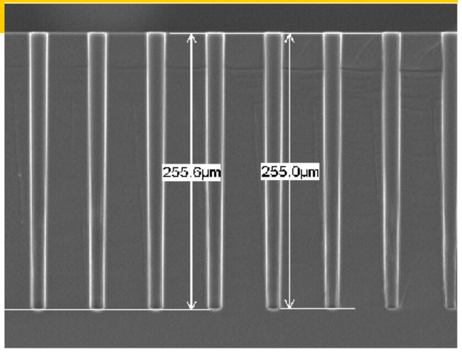
WAFER BONDING
(mechanical stability)
Si-OH + HO-Si -> Si-O-Si + H_2O

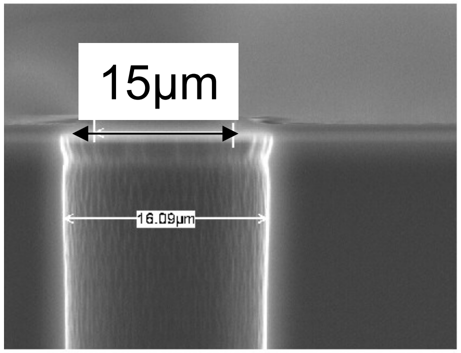


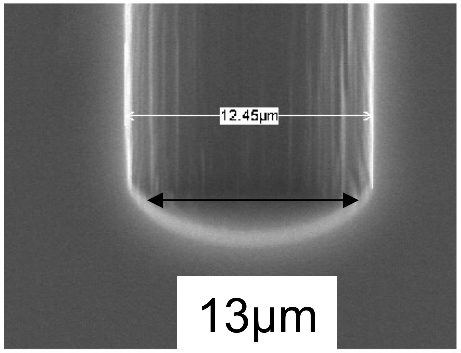
Aspect ration up to 25:1
Depends on processor

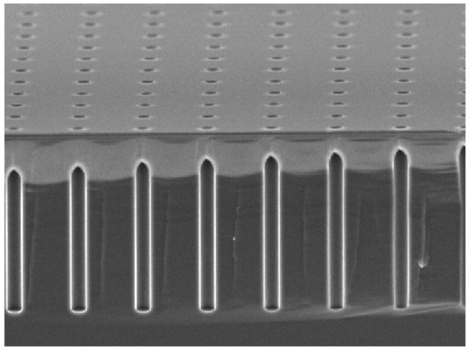
SINTEF

DEEP REACTIVE
ION ETCHING
(electrodes definition)
Bosh process
SiF_4 (gas) +C_4F_8 (teflon)









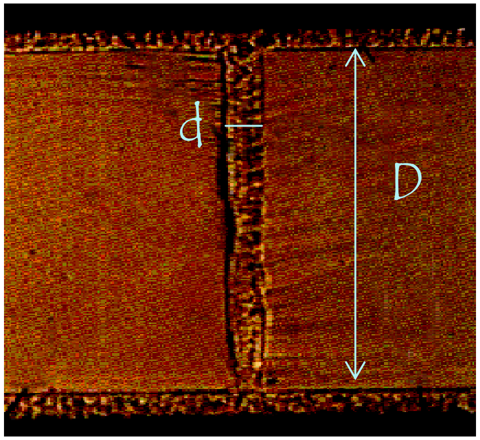
IceMOS Tech Ltd

3D detector: processing

2) FILLING THE ELECTRODES

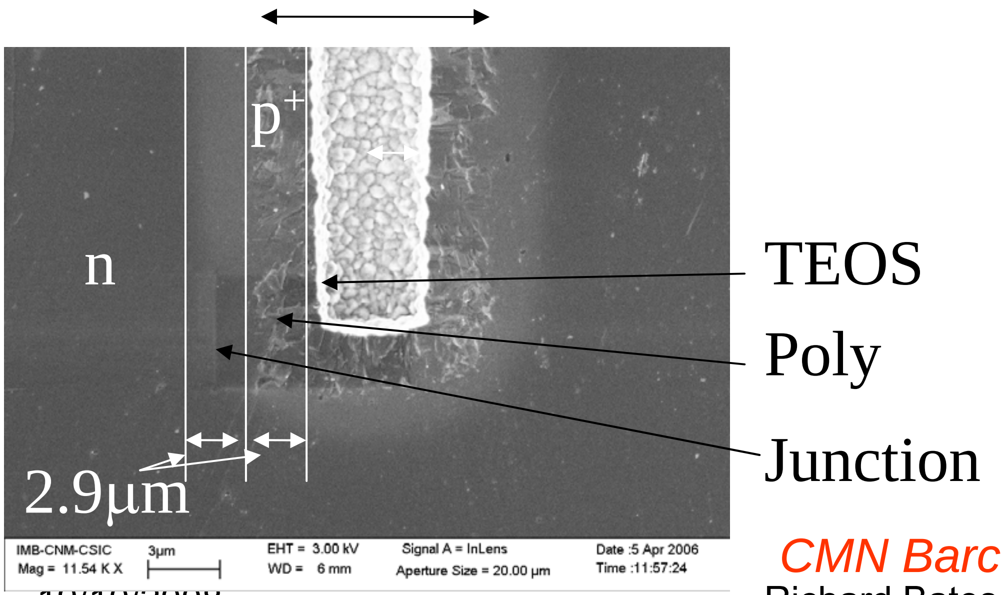
Stanford

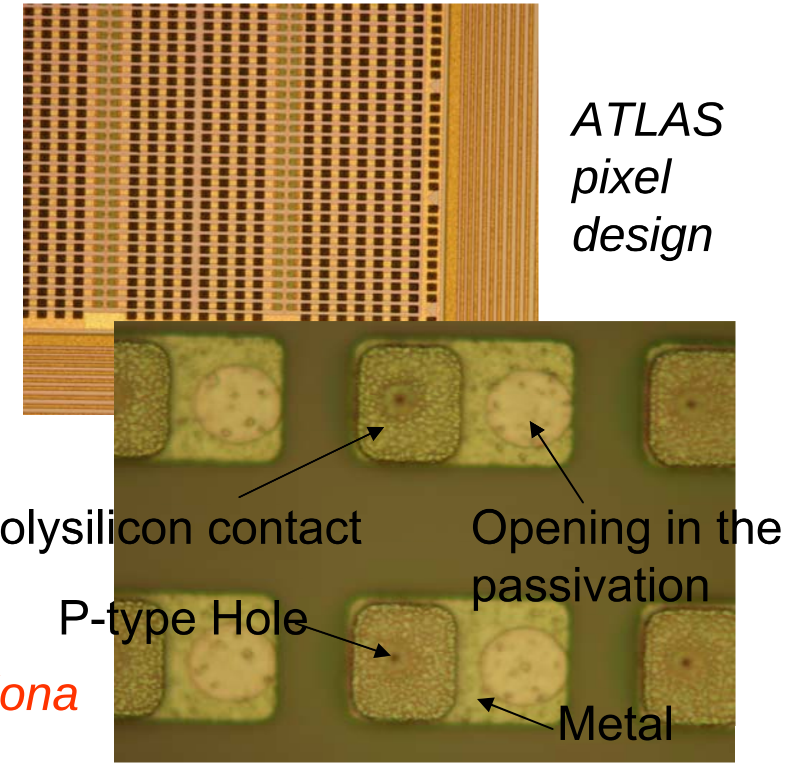
LOW PRESSURE CHEMICAL VAPOR DEPOSITION
(Electrodes filling with conformal doped polysilicon)
$2P_2O_5 + 5\,Si \rightarrow 4P + 5\,SiO_2$
$2B_2O_3 + 3Si \rightarrow 4\,B + 3\,SiO_2$



METAL DEPOSITION
Shorting electrodes of the same type with Al for strip electronics readout or deposit metal for bump-bonding

10µm



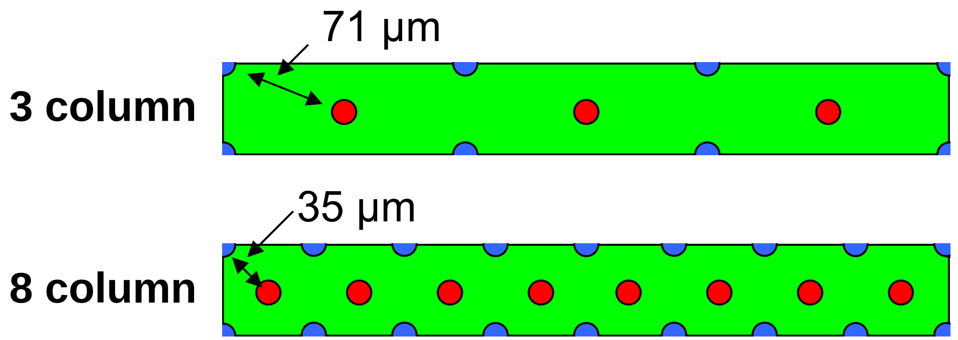


ATLAS pixel design

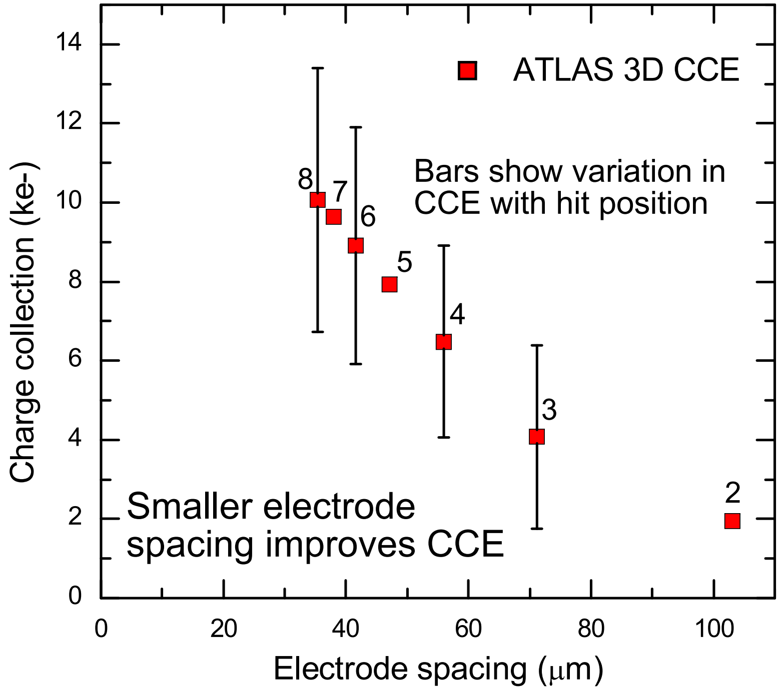
CMN Barcelona

Optimisation of ATLAS 3D structure

- ATLAS pixel is 400µm * 50µm
  - Different layouts available
  - Trade-offs between V_{dep}, CCE, capacitance, column area…



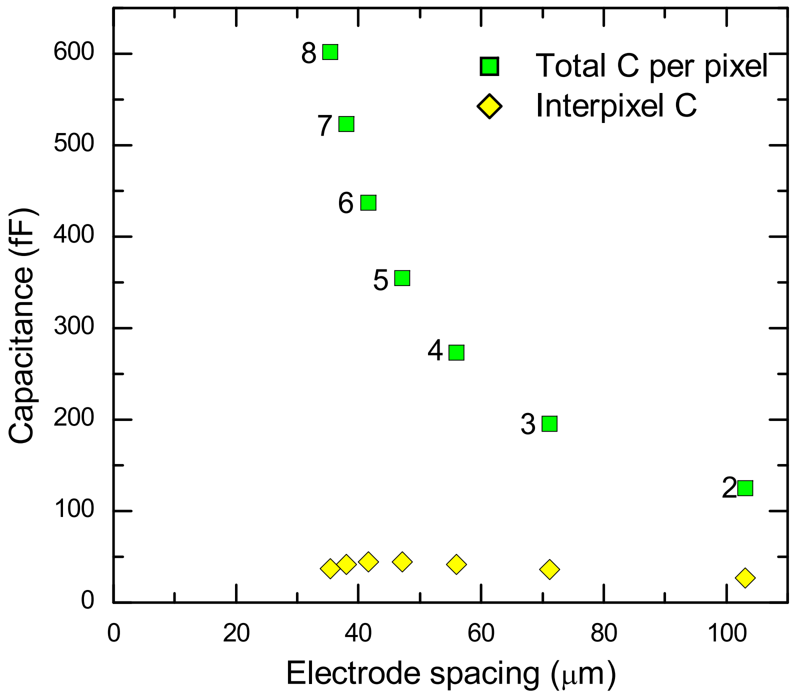
Charge collection with $10^{16} n_{eq}/cm^2$ radiation damage



Bars show variation in CCE with hit position

Smaller electrode spacing improves CCE

Capacitance at each pixel



Simulations

D. Pennicard et al.,
Nucl. Instr. Meth. A 592 (2008) 16

Testbeam results

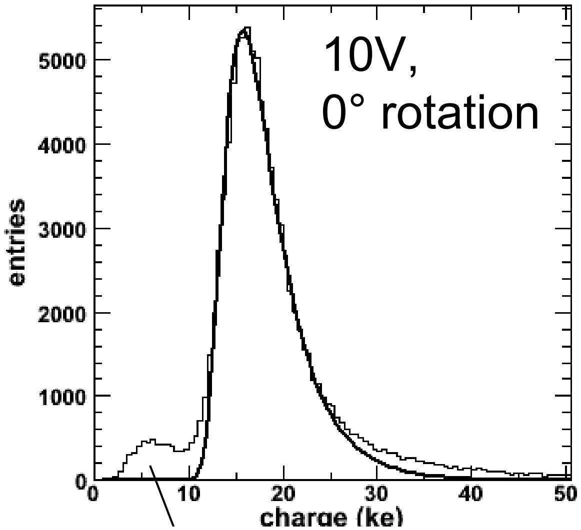
- Final analysis of the data taken end of October 2006
  - 3D-3E from Standford, 208 μm thick
  - 3D-3E (~3.2M raw events)
    - Tuning: Threshold 3000e, 30TOT@10ke
    - Angular scan (0°, 15°)
    - Bias scan (5V to 25V)
- Reference System
  - BAT-Telescope
    - Beam divergence <2mrad
    - Beam incidence angle known within ±1°
    - Hit prediction precision in the DUT 4-5μm

Aug 06 & Oct 07, H8 CERN
100 GeV/c pions

M. Mathes (Bonn)
ATLAS 3D pixel collaboration

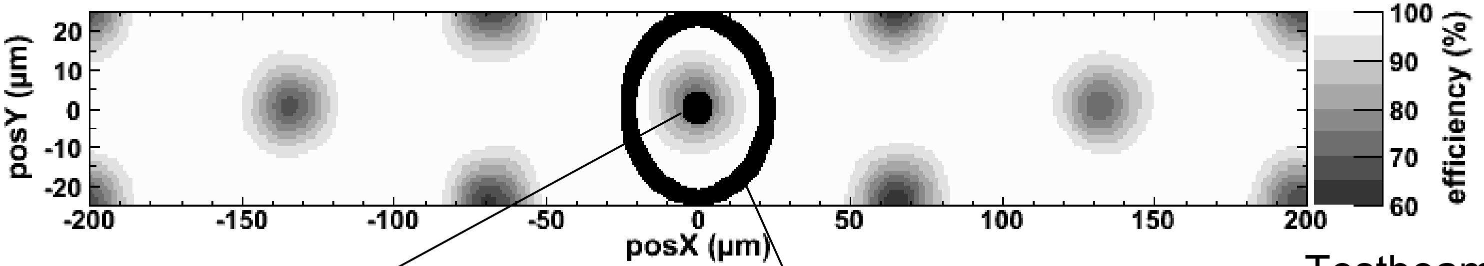
Bonn Telescope & analysis
4k e threshold: Saturation at 5V

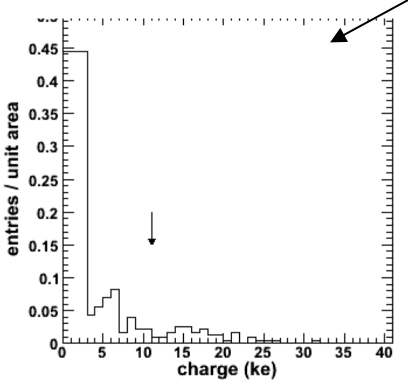
Testbeam results; 0° rotation

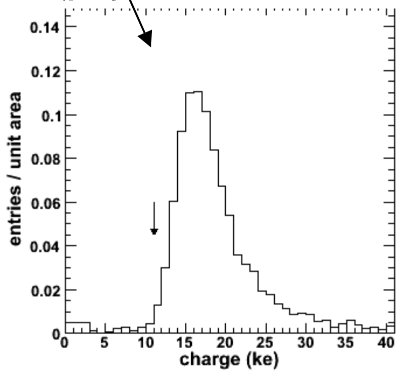


Charge distribution for hits in the 3D module

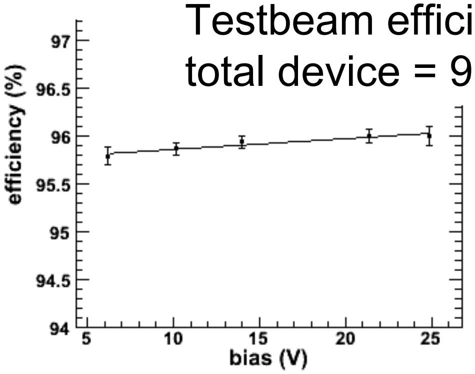
- Measured: MPV 15800e, FWHM 6800e
- Expected (208μm): MPV 16000e, FWHM 6200e
- Agrees perfectly within the ToT calibration uncertainty of 5-9%
- Population of entries at small charges indicate charge losses



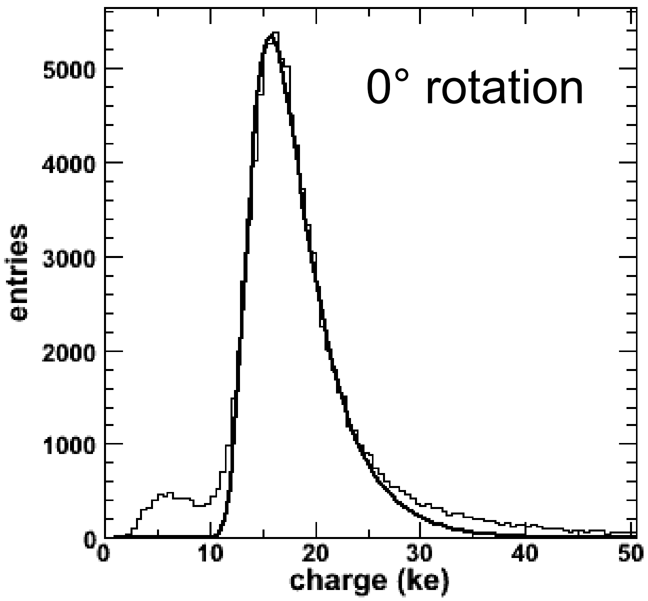


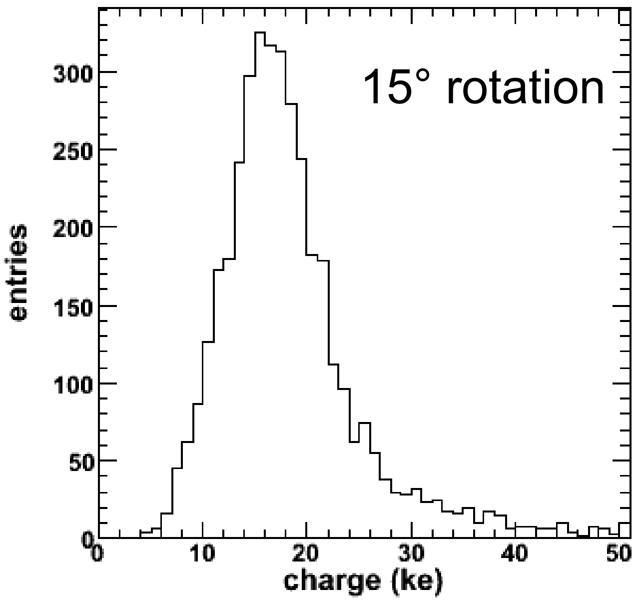


Testbeam efficiency of total device = 95.9 ± 0.1%



Testbeam results; 15° rotation





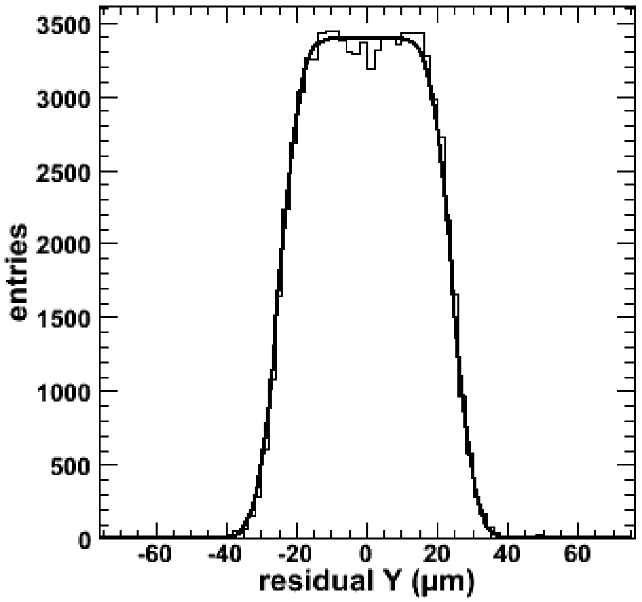
- Efficiency for inclined track of 15° = 99.9%±0.1%
- Lowest detected charge for 15° is 5000e
- No comfortable distance to threshold of 3000e

ATLAS 3D pixel collaboration

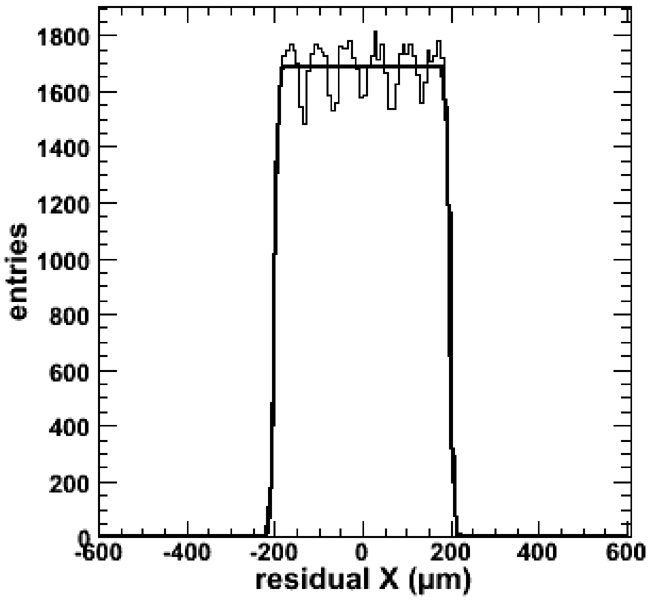
Paper just accepted by IEEE TNS for publication
“Testbeam Characterization of 3D Silicon Detectors”
preprint at arXiv:0806.3337

Resolution

50 μm direction



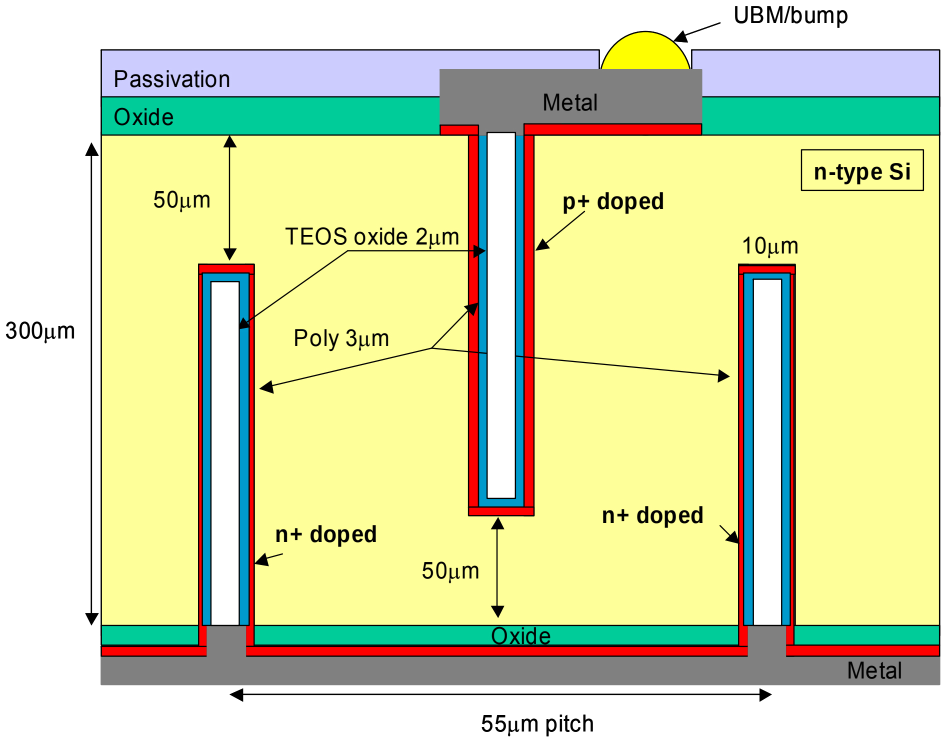
400 μm direction



- Centre of pixel with highest charge entry taken as reconstructed position
- Fit (rectangular function convoluted with Gaussian)
- 50 μm direction: width (49.4±0.1)μm, sigma (4.8±0.1)μm
- 400 μm direction: width (398.0±0.3)μm, sigma (6.4±0.2)μm
- Structure visible results from position depended efficiency

Double-sided 3D detectors

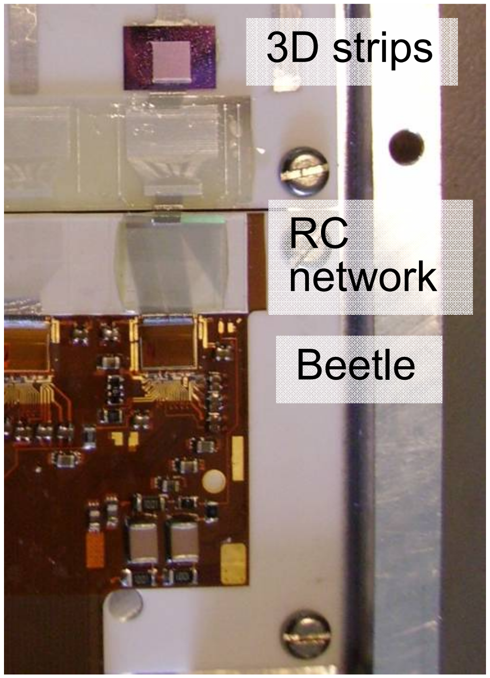
- Alternative 3D structure proposed by G. Pellegrini (CNM)
- N- and p-type columns etched from opposite sides of substrate
  - Columns do not pass through full substrate thickness
  - 250μm deep in 300μm substrate, for first run



DS Strip detector MIP test setup

- Tested with ^{90}Sr beta source

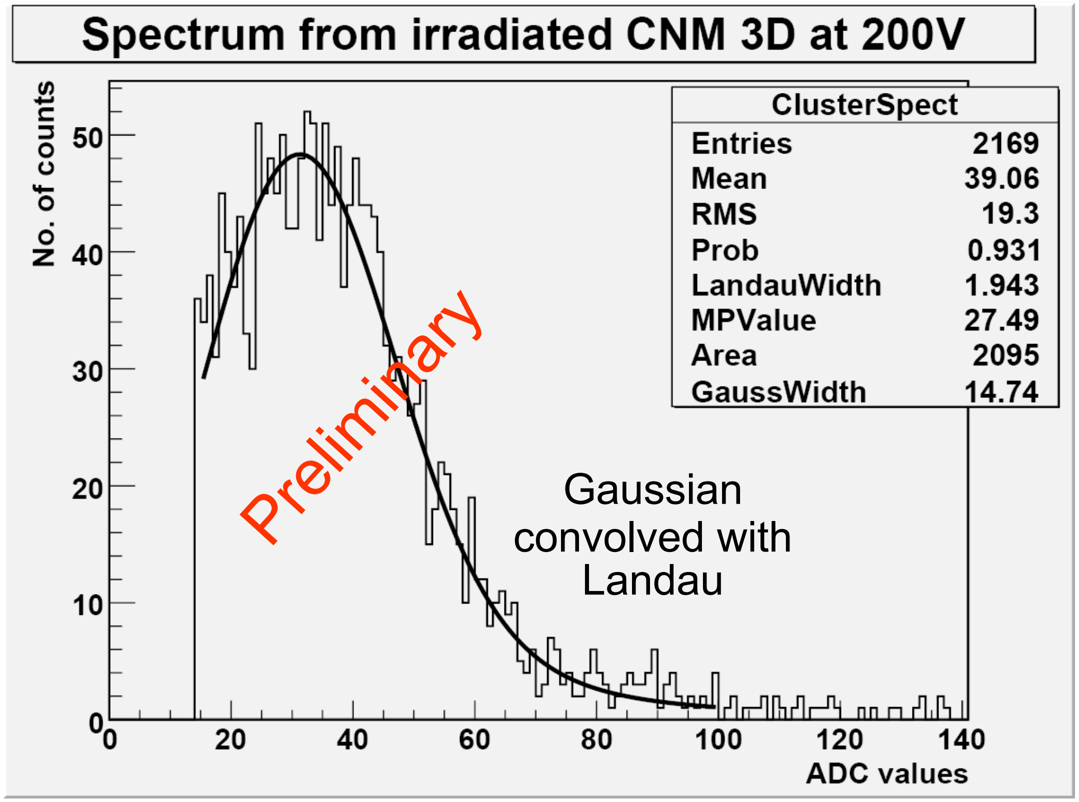
- **LHCb electronics (Velo, Si tracker)**
- Beetle readout chip
  - 40MHz readout rate
  - Analogue readout
- TELL1 readout board
- Strip detector is DC coupled
  - Added RC network chip to connect irradiated sensor to Beetle
  - Thanks to Jaakko Härkönen, Helsinki
  - R = 1 MΩ, C = 67 pF



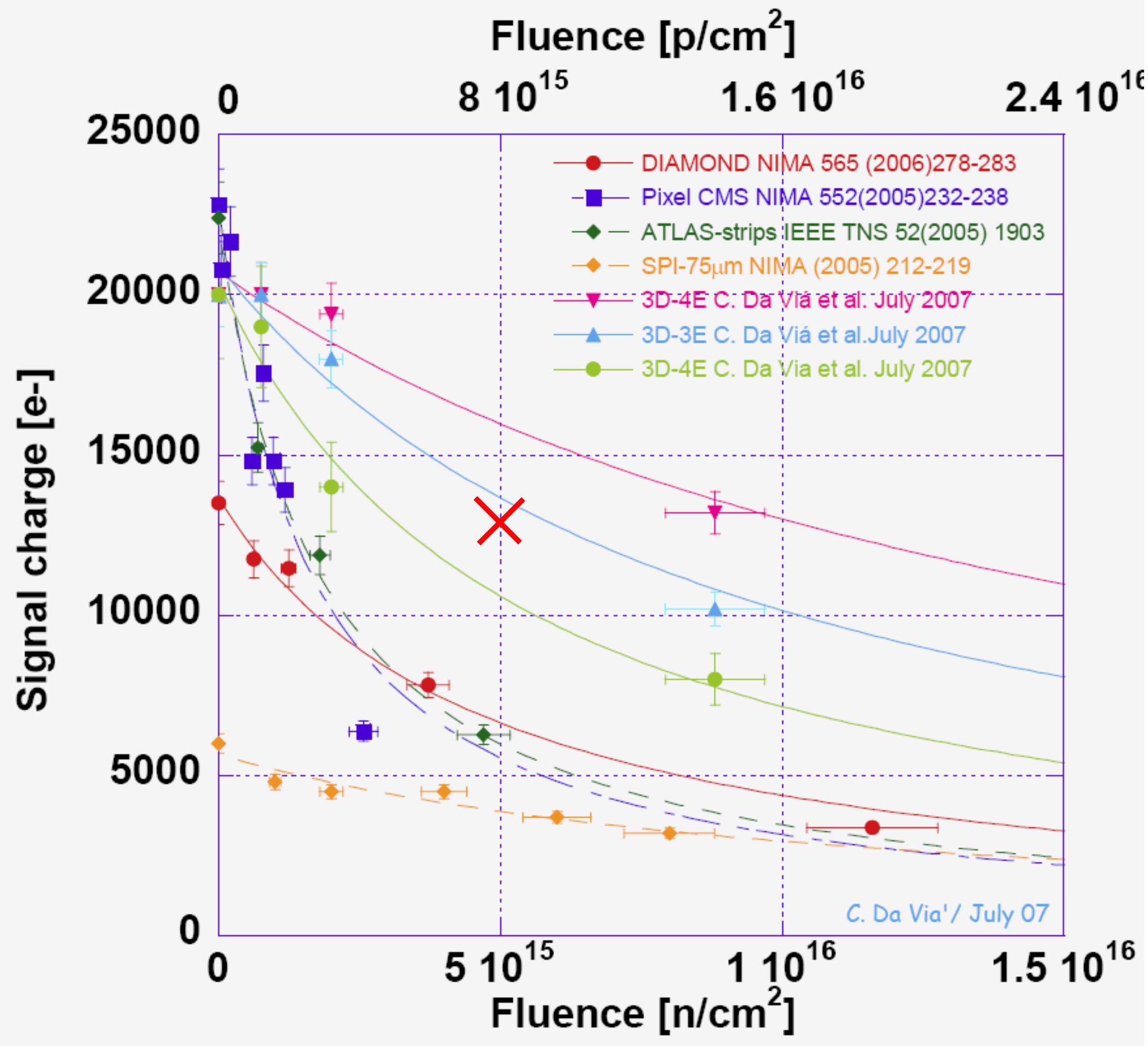
Charge collection in irradiated strips

- Strip detector irradiated to **$5*10^{15}n_{eq}/cm^2$** with reactor neutrons at Ljubljana
- When cooled, detector could be biased to 200V
- System calibrated with unirradiated, AC coupled n-in-p planar detector

- **12.8keV signal**

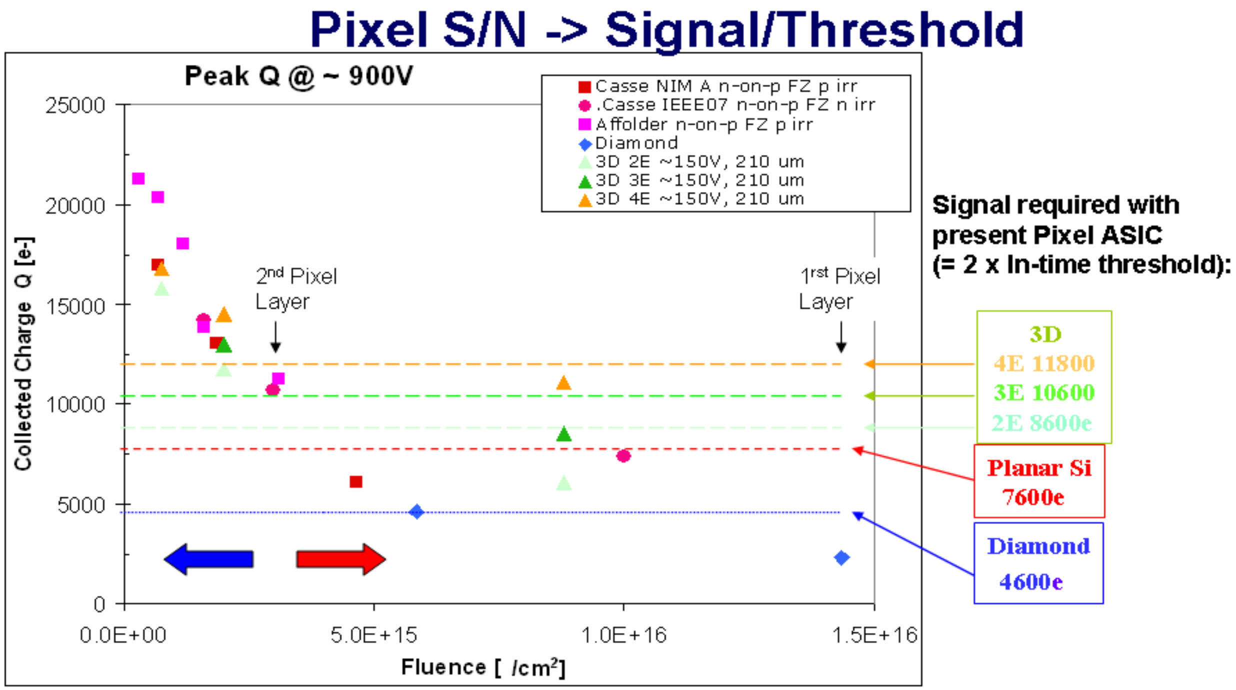


Summary of performance



Summary of performance

- For present ATLAS pixel R/O
  - Signal > 2 x In-time threshold
  - Present FE-I3, In-time threshold ≈ 4000e for Si planar pixel



Sadrozinski + Kagan

Need to optimize FEE

Marginal performance for innermost Pixel Layer

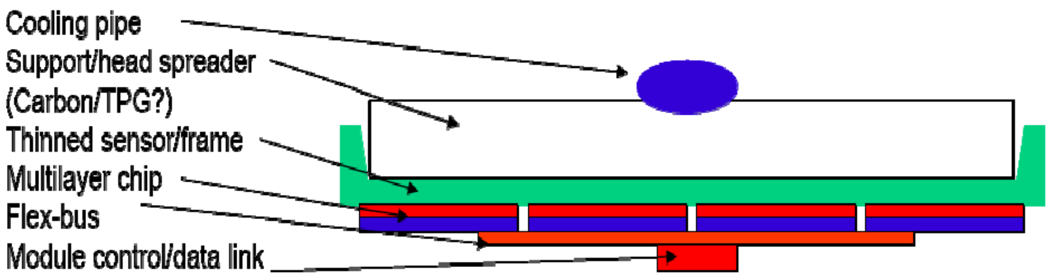
Other ideas

- Thin detectors and Vertical integration
  - Thin planar pixel sensors have reduced sensitive thickness
  - Lower depletion voltage
  - Lower currents
  - Lower signal requires lower noise/capacitance to get S/N
  - New interconnect technology – vertical integration
- GOSSIP
  - Gas volume above a CMOS ASIC with MEMS GEM
  - Demonstrated with CMOS pixel ASIC & Medipix/Timepix
  - Low power consumption, RT operation, no radiation reduction in charge collection
  - Possible aging concerns

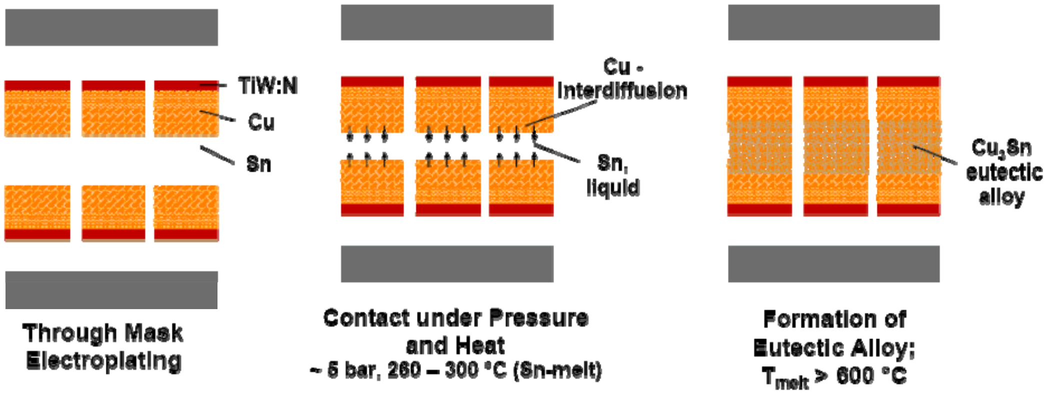
Thin Sensors and Vertical Integration

1) Low I_leak, low V_dep
2) Large live-fraction
3) SLID interconnection
4) 3D integration

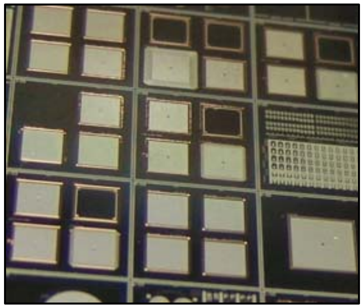
A sketch of the module concept

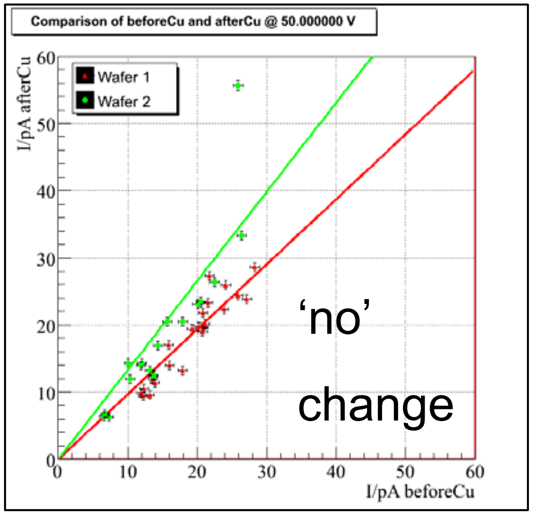


Solid Liquid Interdiffusion (SLID), IZM Munich



First diodes





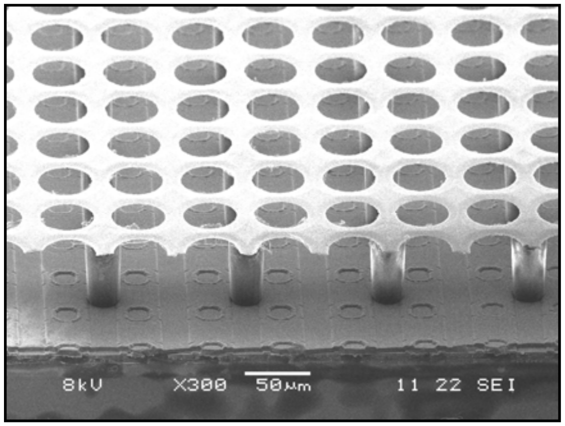
R. Nisius

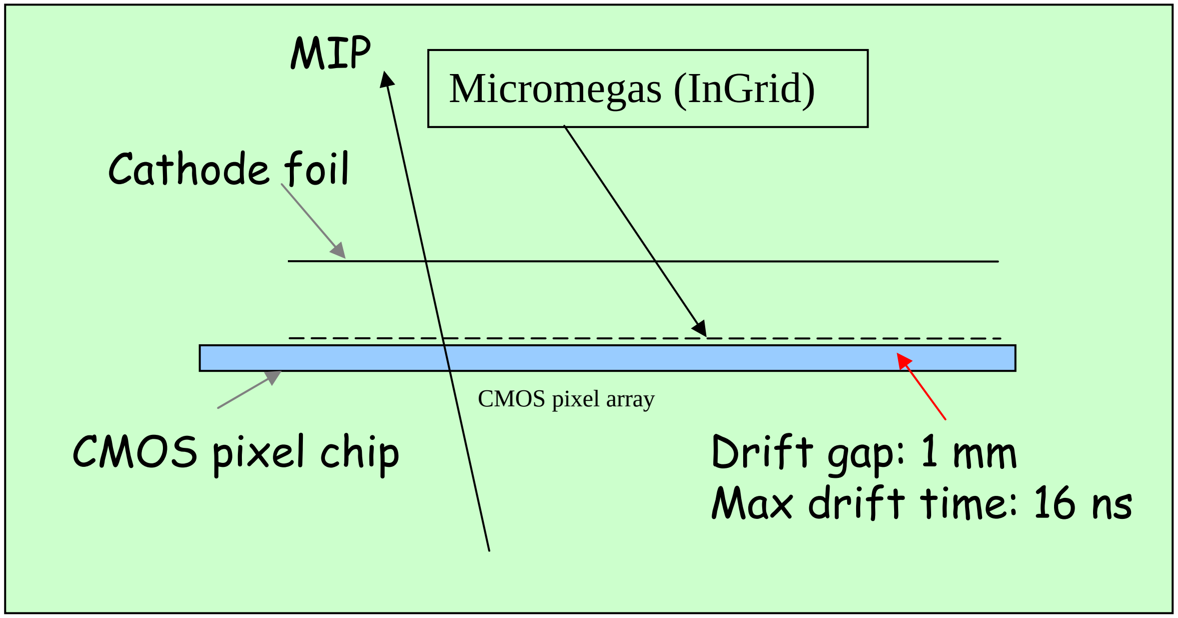
Conducted by: Bonn, Dortmund, MPI, Oslo, Interon, IZM

Gossip – Nikhef R&D

- Can Gossip be a realistic alternative for ID/pixel area at SLHC?
  - Gossip:
    - Generate charge signal in gas instead of Si (e-/ions versus e-/holes)
    - Amplify # electrons in gas (electron avalanche versus FET preamps)
  - Then:
    - No radiation damage in depletion layer or pixel preamp FETs
    - No power dissipation of preamps
    - No detector bias current
- Demonstrated with CMS Pixel ASICs
  - Possible showstoppers
    - Aging
    - HV breakdown
      - Use SiN

H. der Graaf (NIKHEF)





Drift gap: 1 mm
Max drift time: 16 ns

Summary

- Challenges of sLHC for silicon detectors outlined
- Strip detector solution shown
  - n-in-p detector
  - Fz or MCz still under investigation
  - Detailed design focus of ATLAS groups
- One possible solution for the 1st Pixel layer shown
  - 3D detectors
  - Higher charge than other proposed solutions
  - But higher capacitance
  - Problem still requires work!

Interesting talks

- Planar detectors
  - G. Casse, Liverpool: “Studies on Charge Collection Efficiencies for Planar Silicon Detectors after Doses up to 10e16 Neq/cm2 and the Effect of Varying Substrate Thickness" session N54 – Thursday
  - H. Sadrozinski, SCIPP: “CCE and its annealing in silicon detectors irradiated with pions, protons, and neutrons” session N15 – Tuesday.
  - K. Hara, Tsukuba: “Characteristics of the irradiated Hamamatsu p-bulk silicon microstrip sensors” session N19 – Tuesday.
- 3D
  - D. Pennicard, Glasgow: “Radiation hardness tests of double-sided 3D detectors” session N19 - Tuesday.
  - S. Kuhn, Freiburg: “Investigation of 3D silicon microstrip detectors for the sLHC” session N19 - Tuesday.
  - A. Zoboli, FBK: “Functional characterisation of 3D-DDTC Detectors” session N34 – Wednesday.
  - J. Kalliopuska, VTT: “Fabrication of edgeless 3D strip and pixel detectors using SOI wafers” session N34 – Wednesday.

Back-up slides

35. How to overcome CCE loss
36. Double junction
37. Signal from a detector
38. Irradiated CNM strip detector noise f(Bias)
39. CCE annealing (1.1 10^{15} p cm^{-2})
40. CCE annealing (7.5 10^{15} p cm^{-2})
41. MCN_d GND plane designs
42. B-layer upgrade
43. ATLAS FE-I4
44. Comparing double-sided to full 3D
45. Double-sided 3D CV
46. Double-sided 3D strip IV
47. CCE full 3D and DC
48. 3D fabrication at SINTEF
49. 3D Manchester results
50. 3D at VTT
51. 3D at FBK
52. 3D R&D summary slide
53. 3D R&D institutes
54. GOSSIP detector design
55. GOSSIP design cont.
56. GOSSIP Full post-processing of a TimePix
57. Tracking sensor material: gas versus Si
58. SiProt protection
59. SiProt protection cont.
60. GOSSIP aging
61. GOSSIP on CMS Pixel R/O

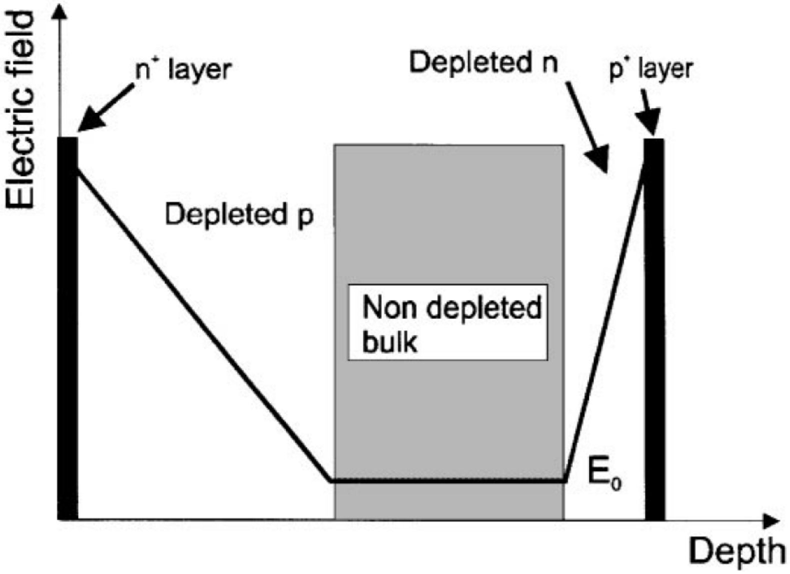
How to overcome CCE loss

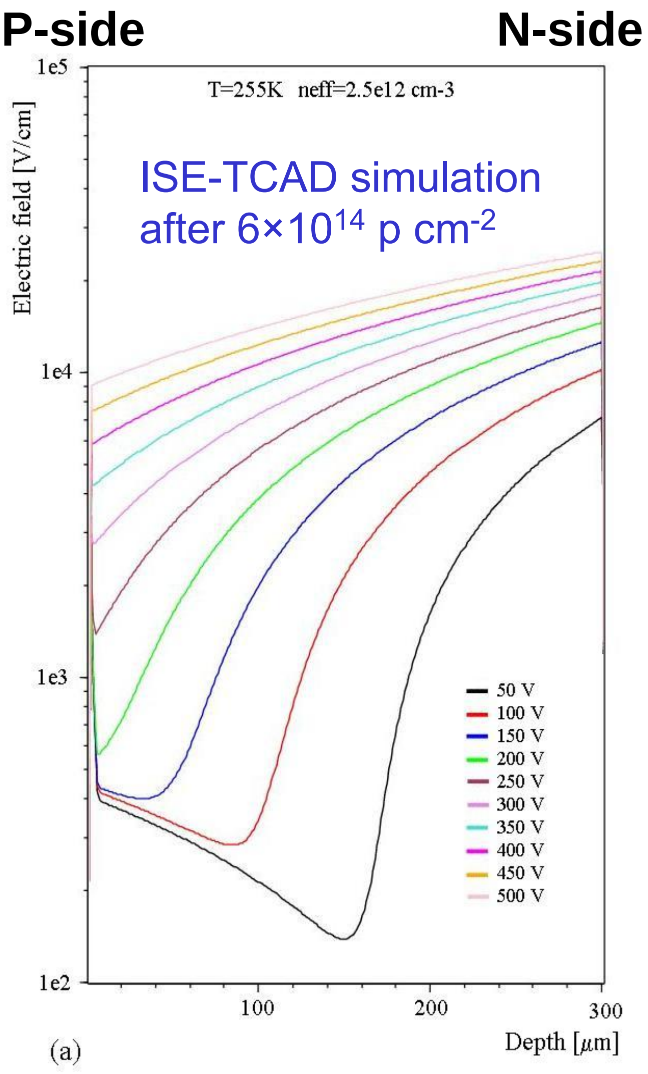
- Short n-in-p strips
  - Collects more charge than p-in-n after high fluence ✓
  - Cheaper than n-in-n ✓
  - Reduce noise as much as possible
- Thin detectors
  - Short drift distances ⇒ less trapping ✓
  - Higher E-fields (but at saturation drift velocity)
  - Limited initial charge! X
- 3D detectors

  Very close packed electrodes through device
  - Short collection distances with full MIP signal ✓
  - Complex, expensive, still very new X

  ⇒Pixel solution

Double Junction





ISE-TCAD simulation after 6×10^{14} p cm^{-2}

In fact, post irradiation E-field has a double junction structure with a low field (non-depleted) bulk in the middle of the sensor for biases below the full depletion voltage.

See G. Casse, et. al., NIMA **426** (1999) 140-146 and G. Kramberger, et. al., NIMA **579** (2007) 762-765

Signal from a detector

- Signal collected given by

$$Q = Q_o \cdot \varepsilon_{\mathrm{dep}} \cdot \varepsilon_{trap} \qquad \varepsilon_{dep} = \frac{d}{W} \qquad \varepsilon_{trap} = e^{-\frac{\tau_c}{\tau_t}}$$

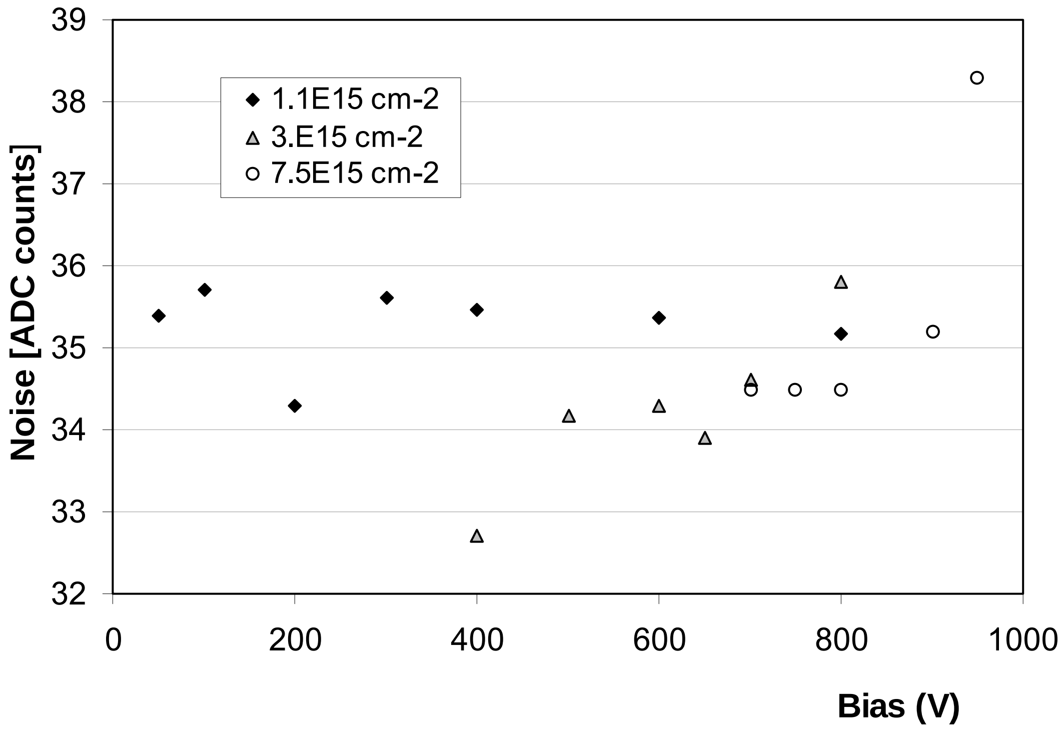
$$\tau_c = \frac{d}{v} = \frac{d}{\mu E}$$

- – W = device total thickness
- – d = active thickness of device
- – τ_c = carrier collection time
  - $\mu_n = 1350\mathrm{cm}^2\mathrm{V}^{-1}\mathrm{s}^{-1}$: $\mu_p = 480\mathrm{cm}^2\mathrm{V}^{-1}\mathrm{s}^{-1}$
  - Typical conditions: 100V, W=300um E=3.3kVcm^{-1}
  - Drift velocity: e= 4.45x10^{6}cms^{-1} & h=1.6x10^{6}cm^{-1}
  - Collection time: e=7ns, h=19ns
- – τ_t = carrier trapping time
  - $\propto 1/\Phi$

P-type miniature detectors from CNM

Noise results with 280µm thick 1x1 cm^{-2} miniature detector made by CNM. Remarkable robustness, after irradiation, both in term of breakdown voltage and noise. A value of about 34 ADC counts was the typical one measured with similar geometry standard ATLAS non-irradiated miniature sensors.

Measurements at -20°C



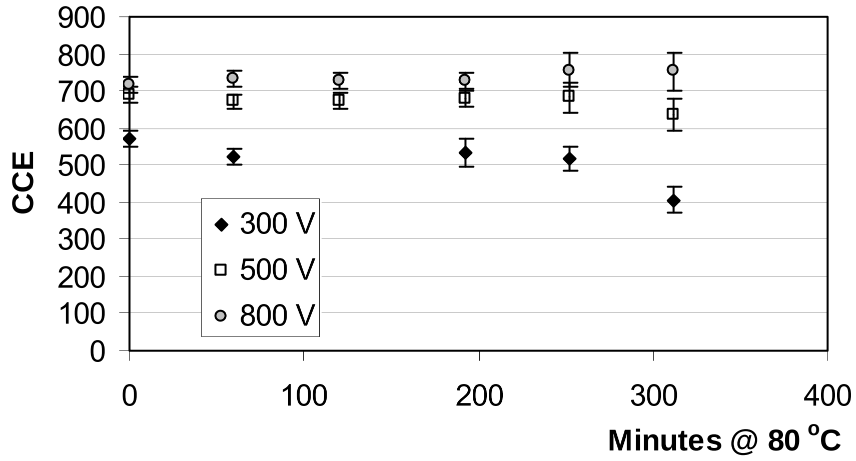
P-type miniature detectors from CNM

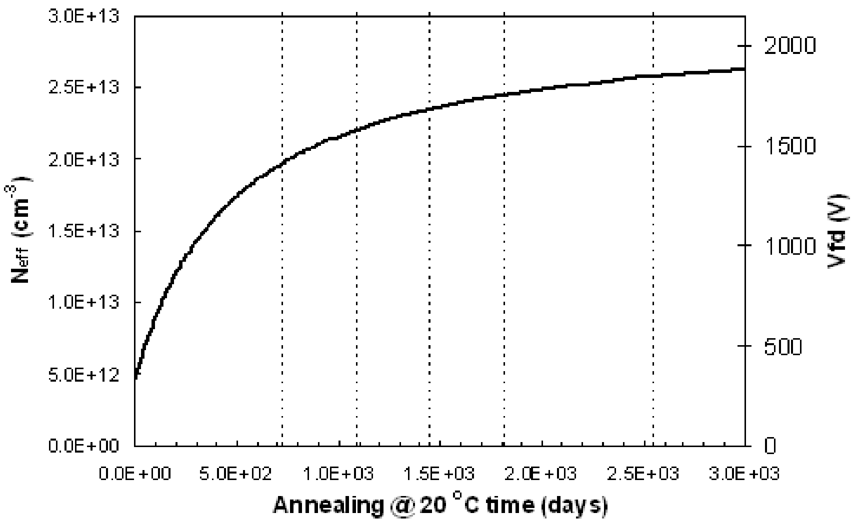
CCE annealing

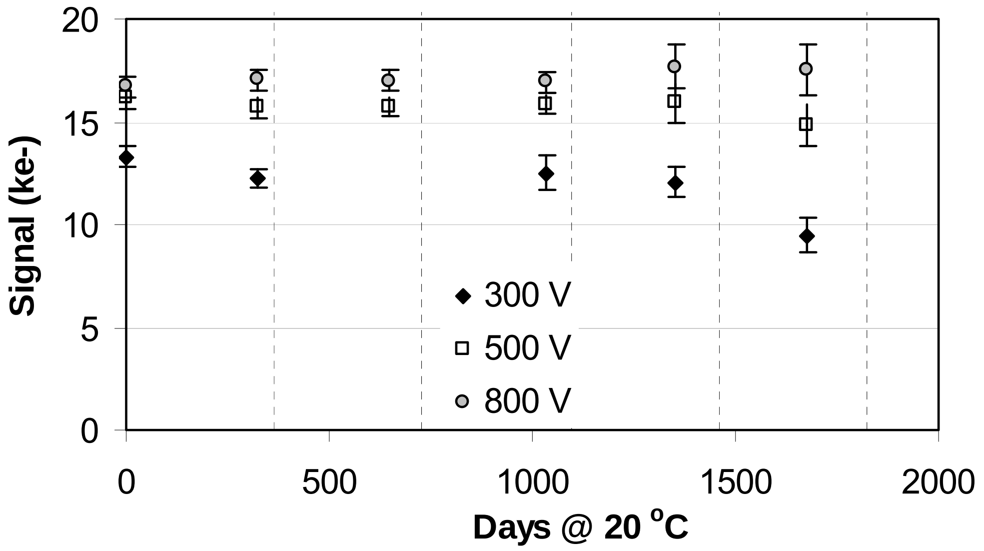
(1.1 10^{15} p cm^{-2})

Initial V_{FD} ~ 420V

Final V_{FD} ~ 1900V





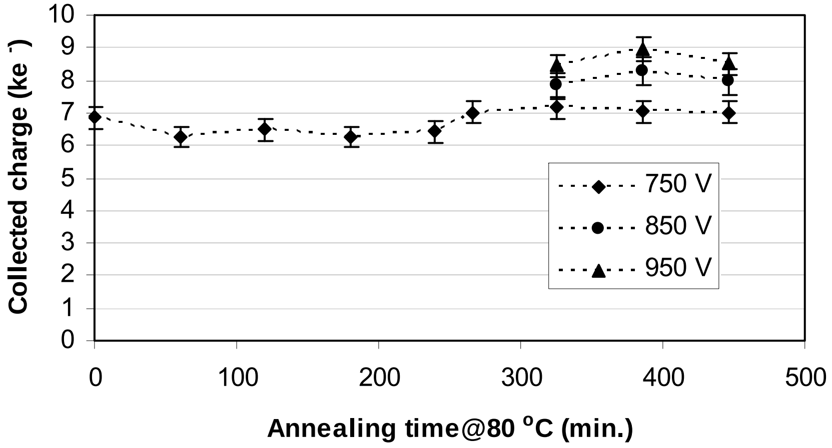


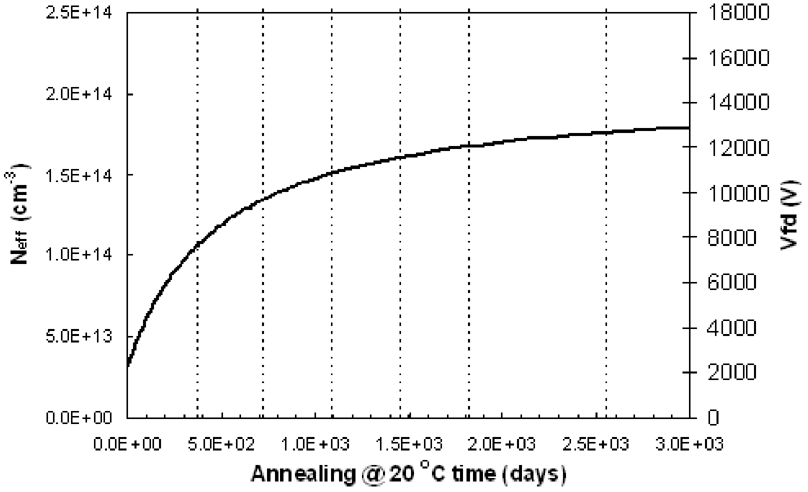
P-type miniature detectors from CNM

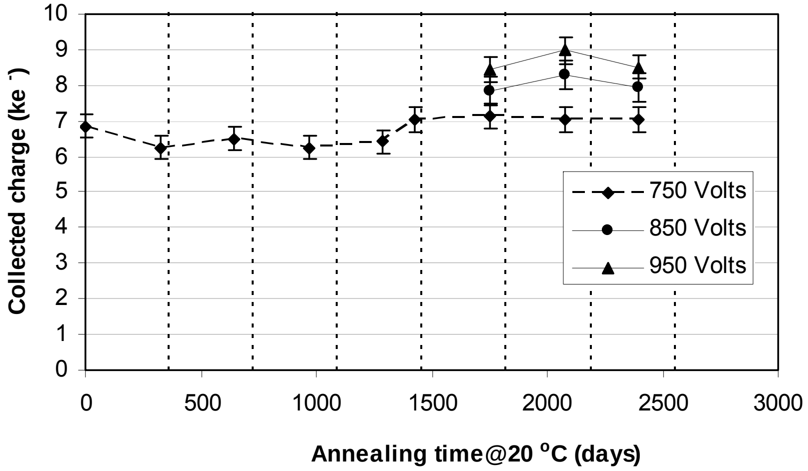
$7.5\ 10^{15}$ p cm^{-2}

Initial V_{FD} ~ 2800V

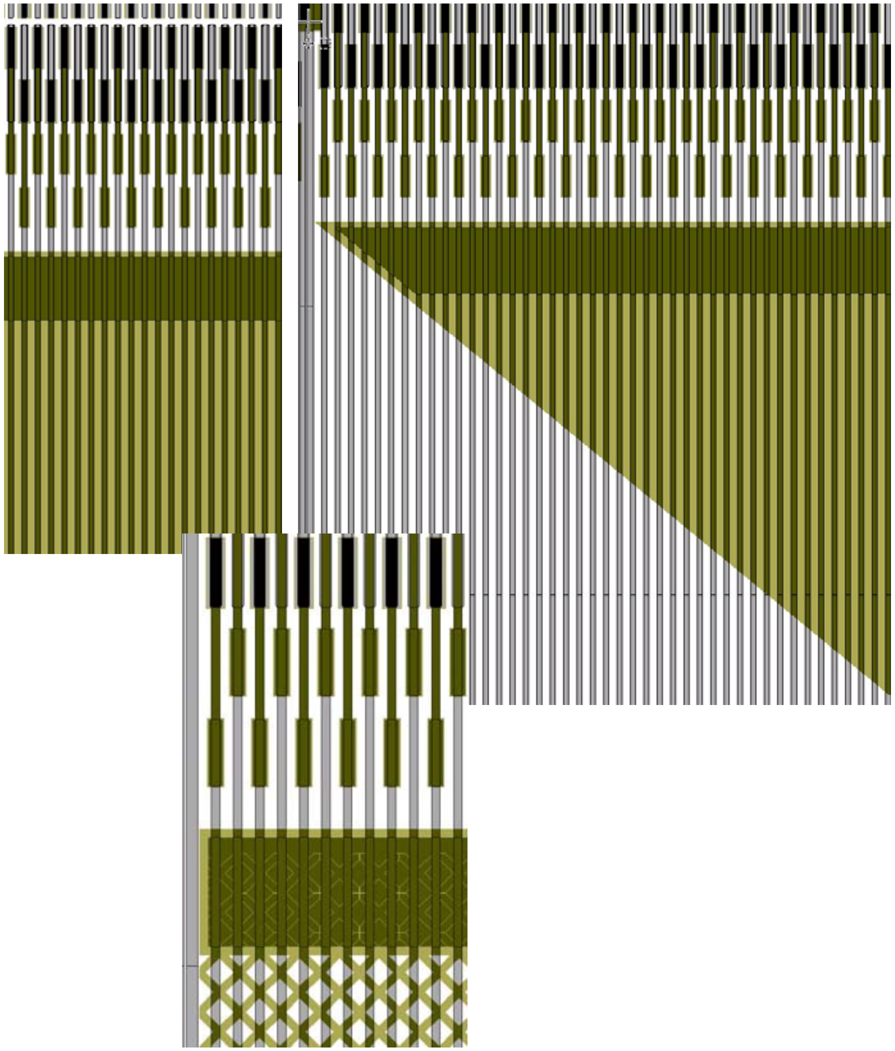
Final ~12000 V!







Design Features – ground planes



26 sensors per wafer

- 4 w/o GND plane (only BCB)
- 4 solid GND plane
- 6 triangular GND plane
- 3 x 4 meshed GND planes

Final metallisation

- Open band in the passivation (top)
- Ni/Au coating
- Additional pad bottom/right corner

Meshed planes

- 30 µm line, 50% fill factor
- 30 µm line, 25% fill factor
- 80 µm line, 50% fill factor

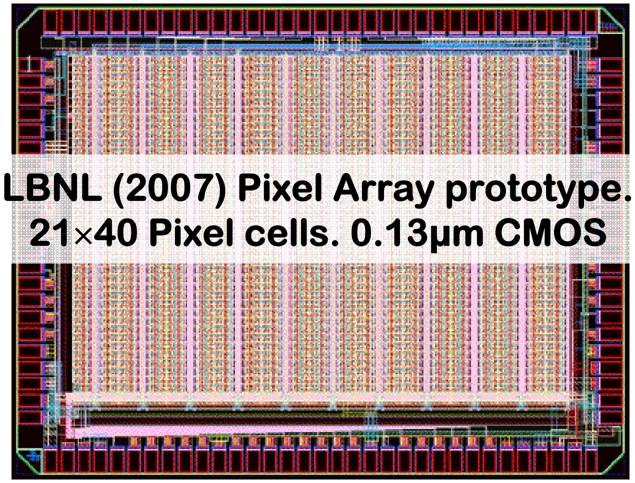
b-layer: Replacement → Upgrade

- 2012: b-layer replacement (after ~3 years of full LHC luminosity)
- 2016: replace completely the ID with a fully silicon version for s-LHC

- The B-layer replacement can be seen as an intermediate step towards the full upgrade. Performance improvements for the detector (here some issues more related to FE chip):
  - **Reduce radius** → Improve radiation hardness
    - 3D sensors, or possibly, thin planar detectors, epitaxial, diamond, gas, …?
  - **Reduce pixel cell size and architecture related dead time**
    - design FE for higher luminosity, use 0.13 μm 8 metal CMOS
  - **Reduce material budget** of the b-layer
    - ~3% $X_0 \rightarrow 2.0 \div 2.5\% X_0$
  - **increase the module live fraction**
    - increase chip size, > 12×14 $mm^{2,}$ possibly use "active edge" technology for sensor.
  - **Use faster R/O links**
    - move MCC to the end of the stave
- The B-layer for the s-LHC
  - radiation hardness: $10^{15} \rightarrow 10^{16}$ n_{eq}/cm^2
  - detector occupancies up by 15 times

New Pixel FE-ASIC

- Design of a new Front-End chip (FE-I4) as a Collaborative Work of 5 Labs: Bonn, CPPM, Genova, LBNL, Nikhef
- FE-I4 tentative schedule
  - 9/2007: Architecture definition
  - 10/2007: Footprint frozen
  - 01/2008: Initial Design review
  - 12/2008: Final Design review
- Some prototype silicon made of small blocks and analog part of the pixel cell in 0.13 μm.

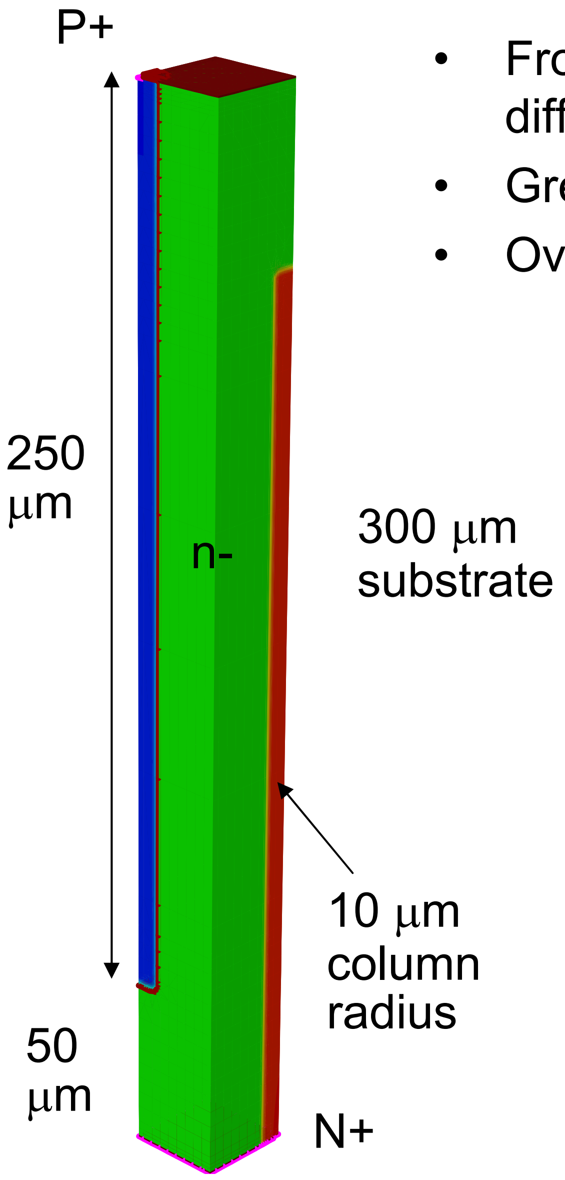


LBNL (2007) Pixel Array prototype. 21×40 Pixel cells. 0.13μm CMOS

Main Parameter	***Value***	***Unit***
Pixel size	50 x 250	μm^2
Input	DC-coupled negative polarity	
Normal pixel input capacitance range	300Ö500	fF
In-time threshold with 20ns gate	4000	e
Two-hit time resolution	400	ns
DC leakage current tolerance	100	nA
Single channel ENC sigma (400fF)	300	e
Tuned threshold dispersion	100	e
Analog supply current/pixel @400fF	10	μA
Radiation tolerance	200	MRad
Acquisition mode	Data driven with time stamp	
Time stamp precision	8	bits
Single chip data output rate	160	Mb/s

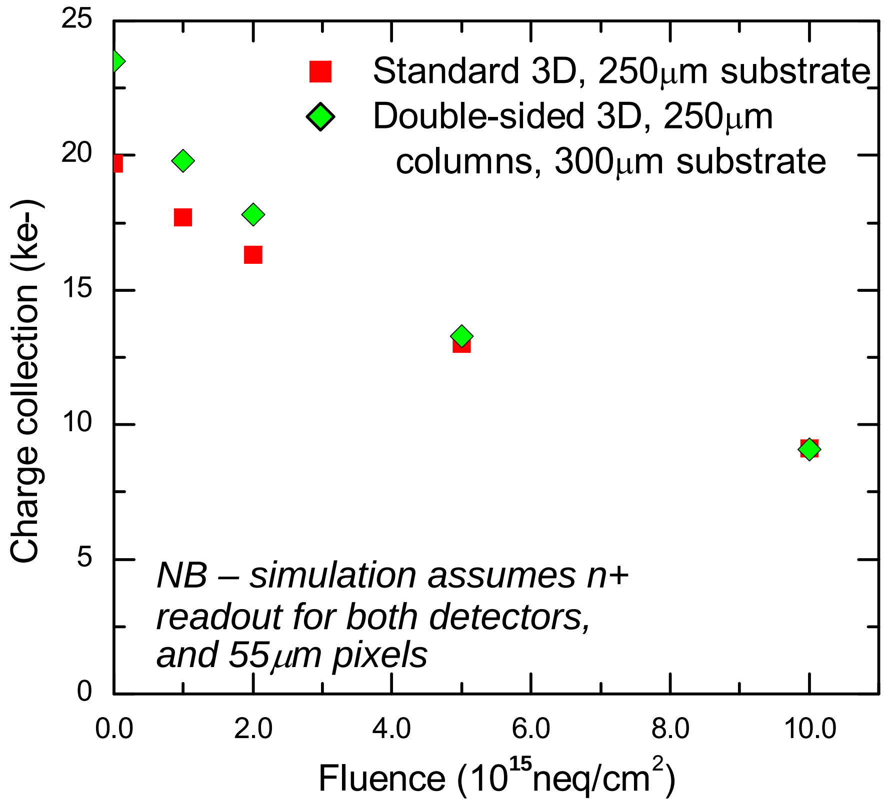
FE-I4 (B-layer Replacement) Specifications: main parameters

Comparing double-sided to full 3D



- Front and back surfaces have lower field and are more difficult to deplete X
- Greater substrate thickness for given column depth ✓
- Overall, expect similar radiation tolerance

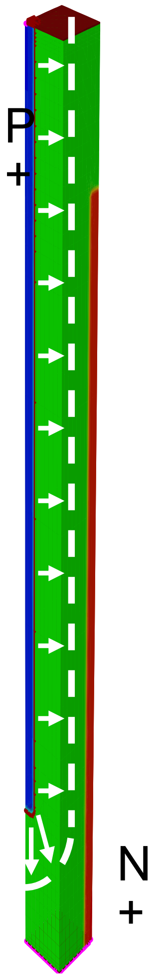
Charge collection simulation



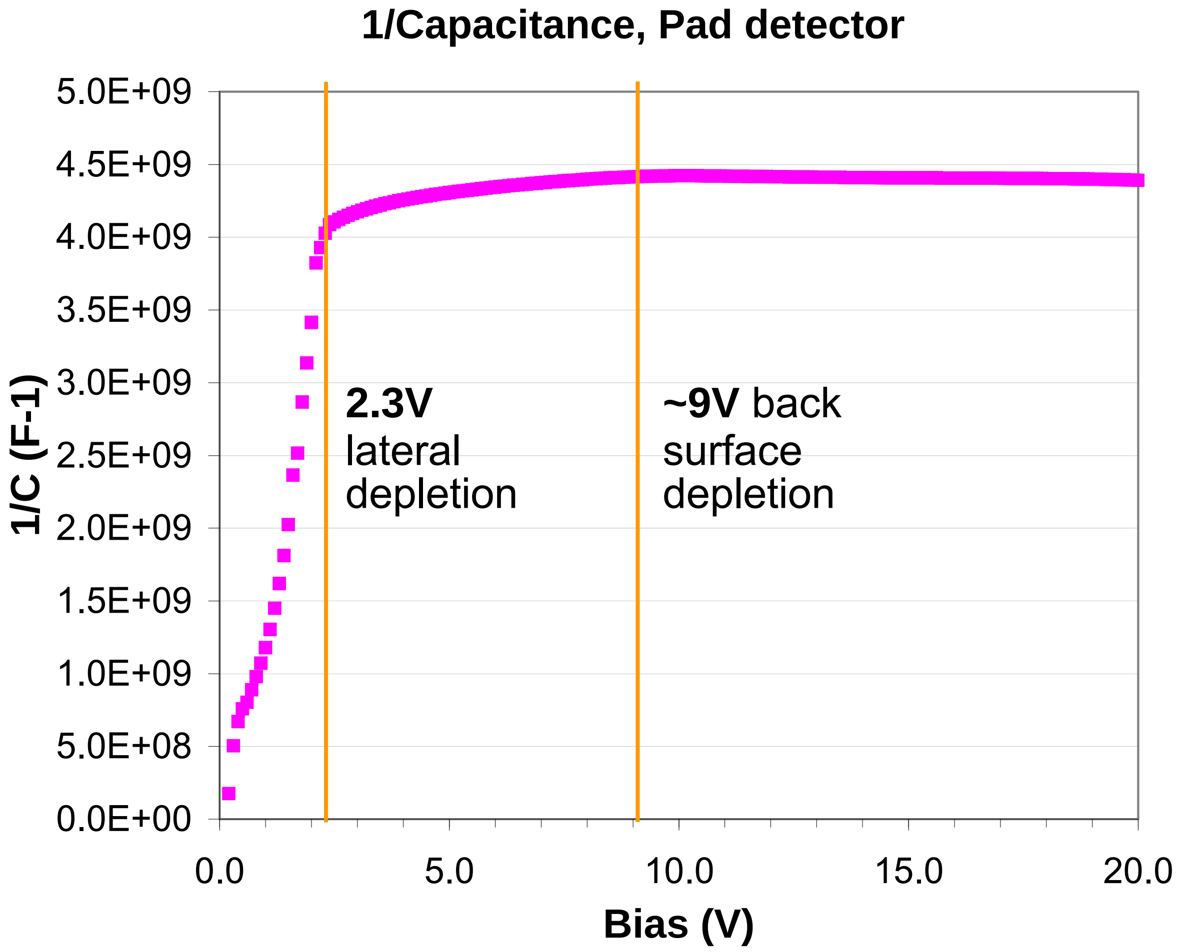
CV

- Pad detector – 90 * 90 columns, 55µm pitch

Lateral depletion around column (~2V in sim.)

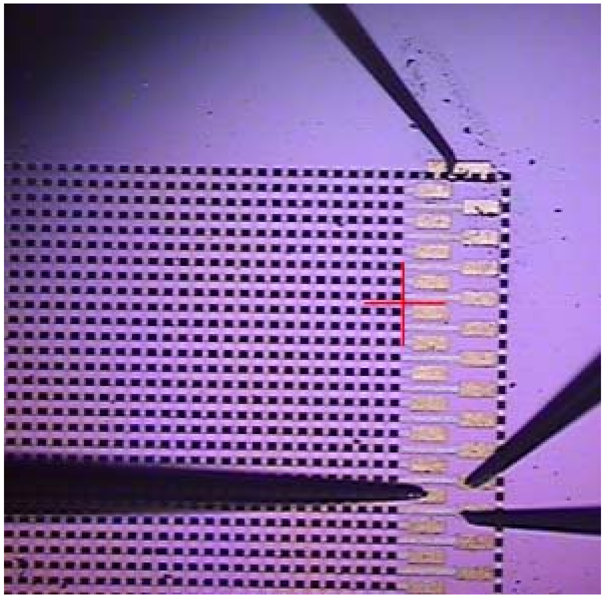


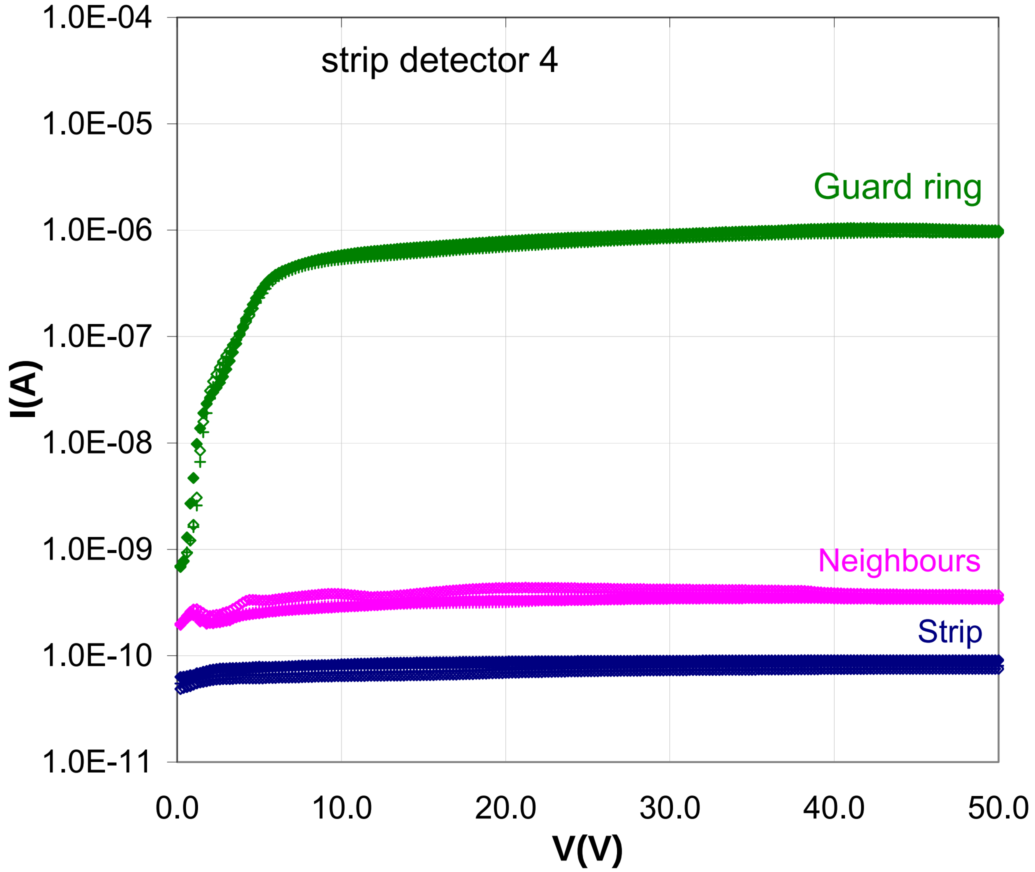
Depletion to back surface from tip of column (~8V in sim.)



Strip detector IV

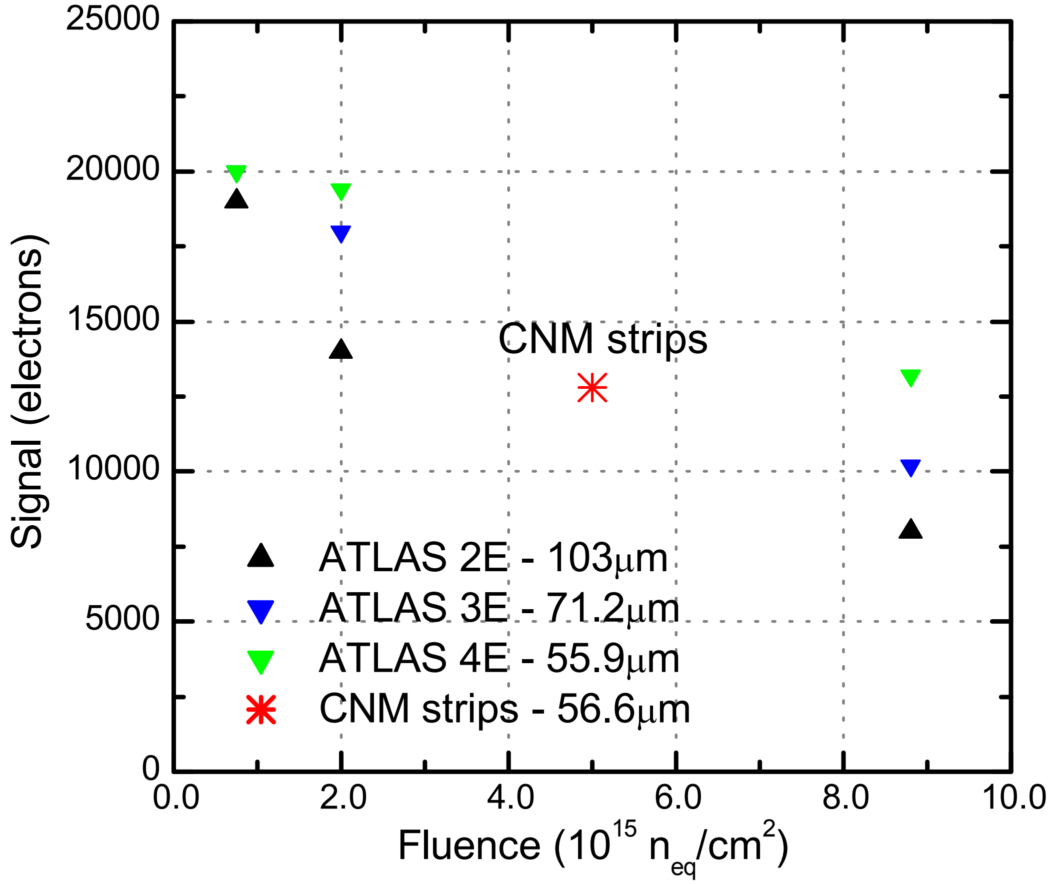
- 128 strips, 50 holes/strip, pitch 80μm, length 4mm
- Measured with 3 strips and guard ring at 0V, and backside biased
- Strip currents ~100pA (T=21˚C) in all 4 detectors
- Can reliably bias detectors to 50V (20 times lateral depletion voltage), no breakdown
- Capacitance 5pF / strip
- Guard ring currents vary:
  - Highest 20μA at 10V
  - Lowest 0.03μA at 50V





Comparison with other 3D detectors

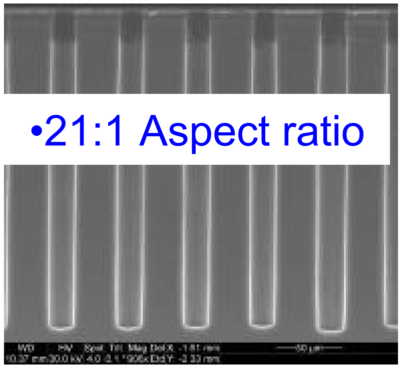
- Signal from Stanford 3D – Cinzia da Via (Manchester) NSS ‘07
  - 250μm columns in 250μm p-type substrate, n+ readout
  - Electrode spacings (indicated) are compatible with ATLAS pixels
- CNM strip results are similar



NB: Need to consider SNR to compare detectors

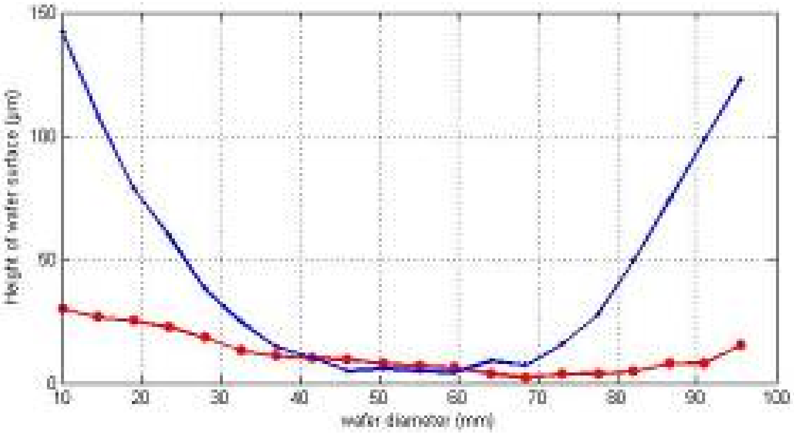
Hawaii/Stanford/Manchester + SINTEF

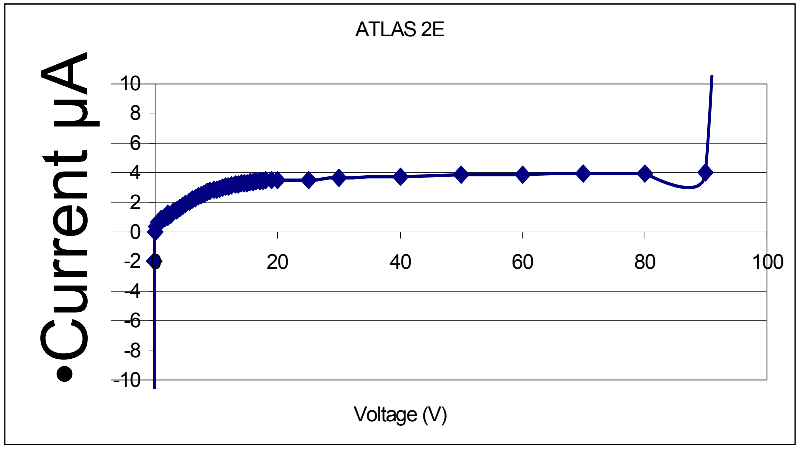
Sherwood Parker,
Cinzia DaVia *et al.*



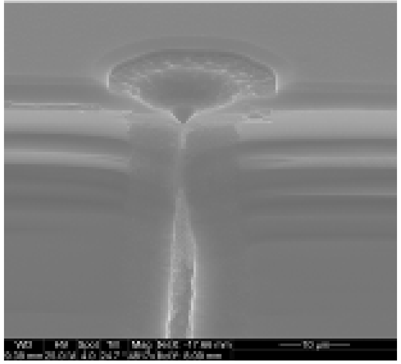
- 21:1 Aspect ratio

- **Semi-industrial production full 3D**
  - **Polysilicon filling and boron doping performed at Stanford**





- Wafer bowing
- Voids in filling

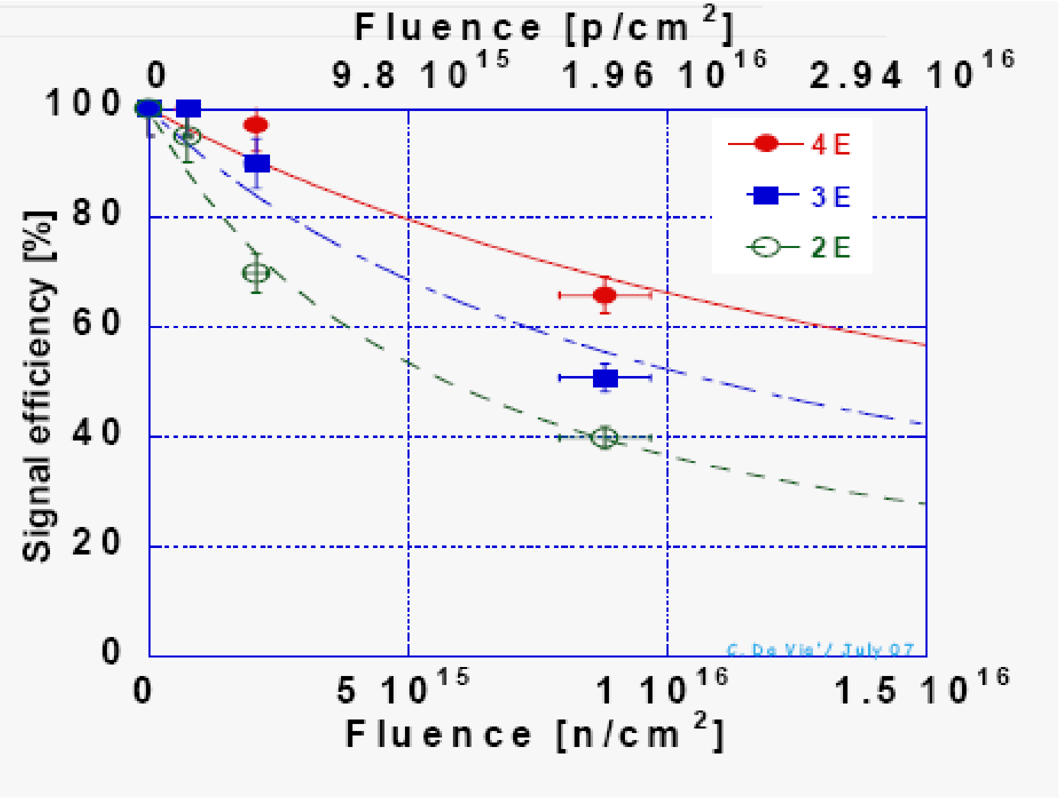


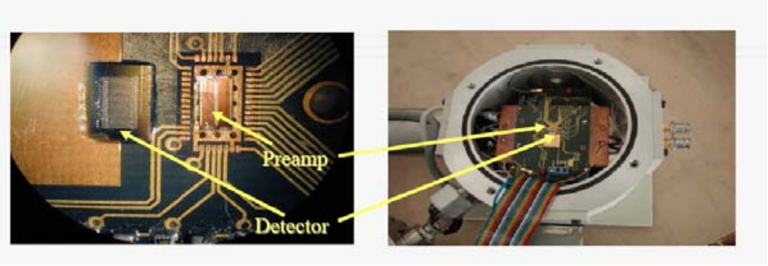
- Good hole etching performance
  - ATLAS 3D pixel produced

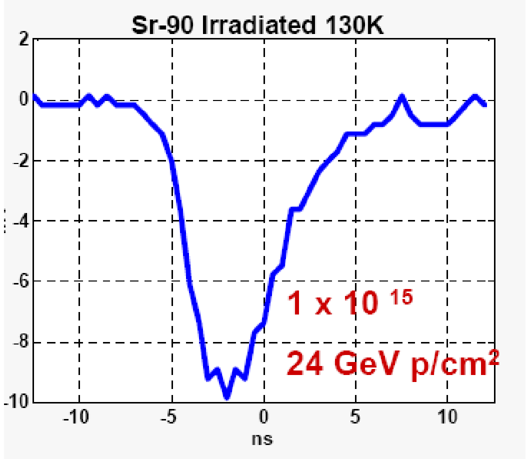
Hawaii/Stanford/Manchester cont..

Stanford fabricated devices

- Fast timing applications
- FP220 in ATLAS trigger







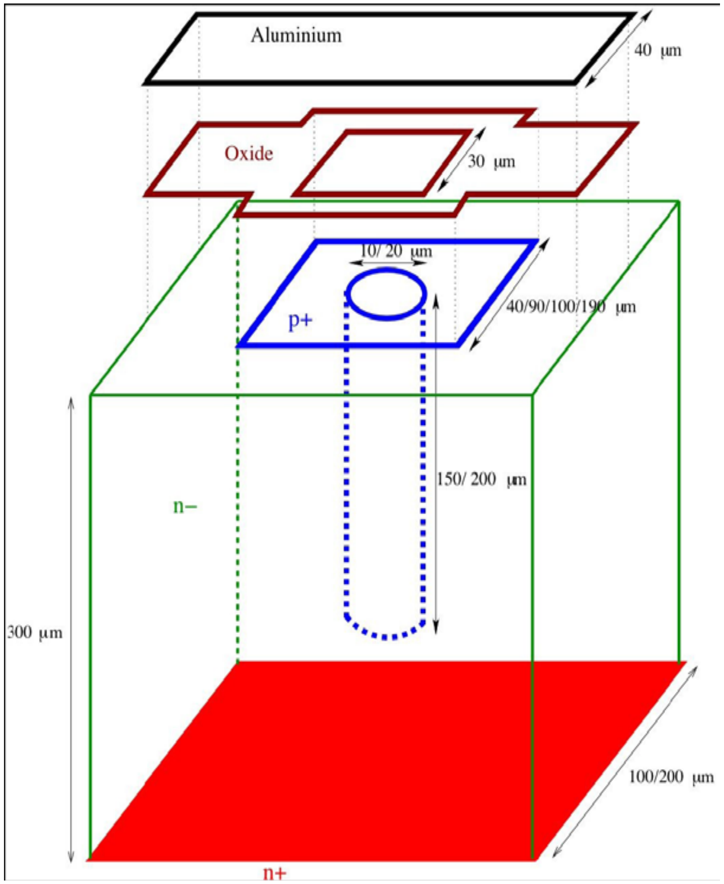
130K, RT 1.5ns
After irradiation

- Most advanced radiation results
- Results for different pixel configurations

VTT (Finland)

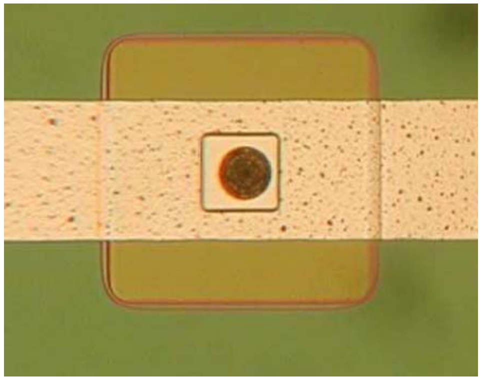
Juha Kalliopuska *et al.*

Single Sided Single Type (semi-3D)

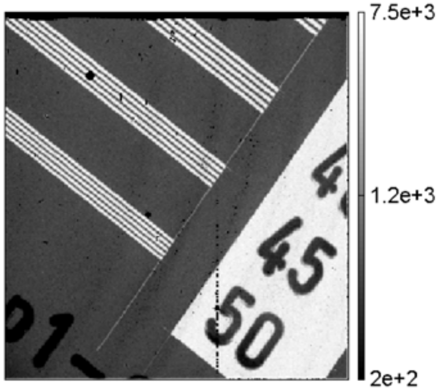


- **Large area strip and pixel detectors (~10 cm²)**
  - **Strip**
  - **Pixel with MediPix2**
- **Edgeless devices**
- **Plan full 3D run at end of 2008**

Semi-3D Strip

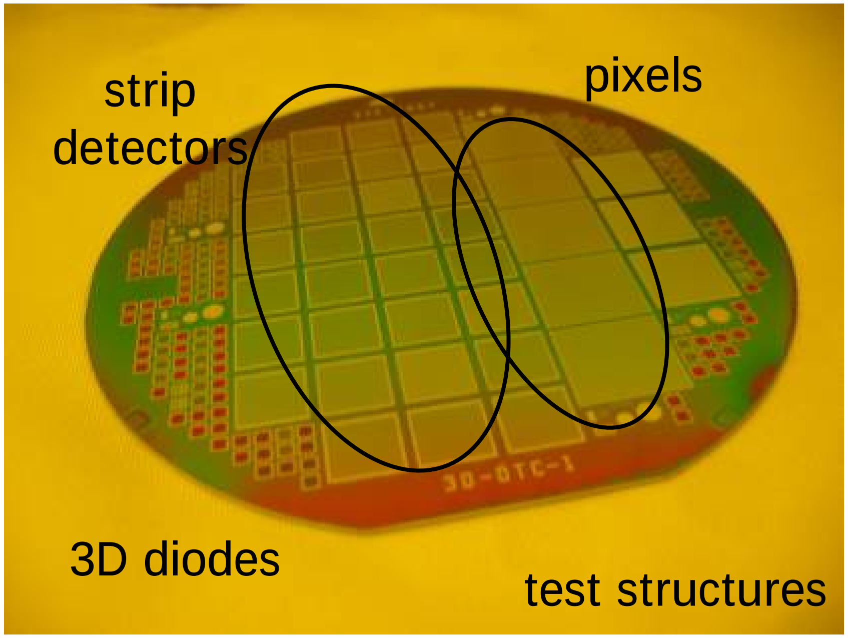


Semi-3D MediPix2 Image

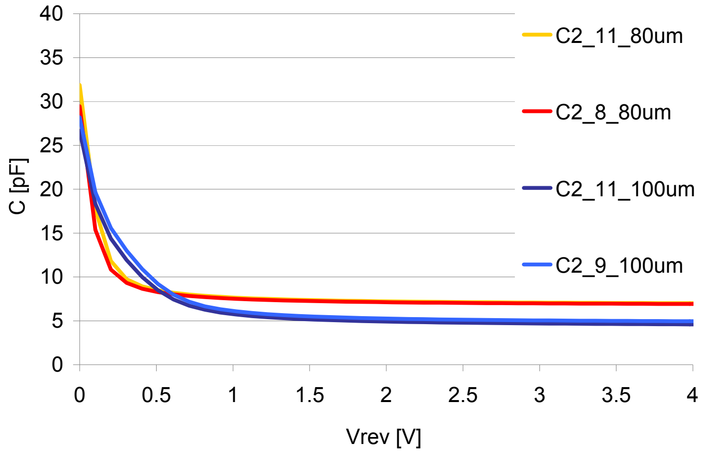


FBK (Trento)

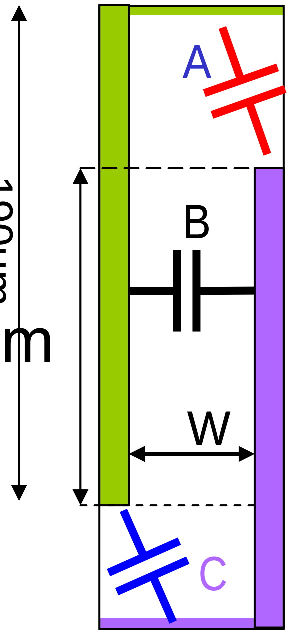
Maurizio Boscardin *et al.*

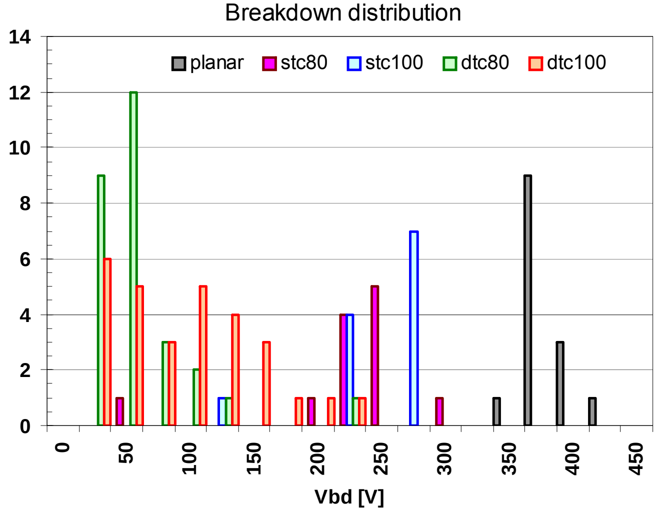


Double sided double type



- Single Sided Single Type
- Double sided double type
  - First batch made
  - Depleted **2V**
  - Some devices





Tested in CMS testbeam last week

Panja Luukka, Helsinki, Uli Parzefall, Freiburg

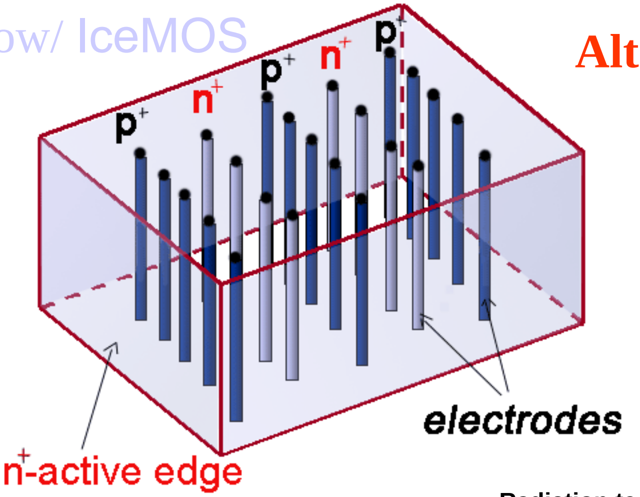
3D R&D

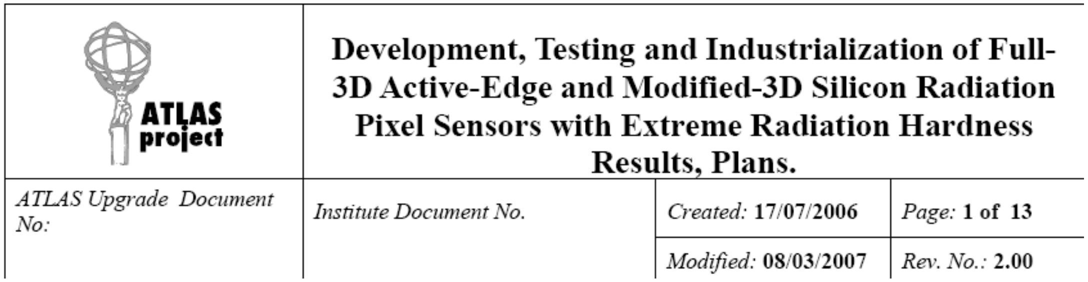
Full 3D structures

Stanford/Sintef

Glasgow/ IceMOS

Institutes:
Stanford
Manchester
Hawaii/LBL
New Mexico
Glasgow
Freiburg
Bonn
Praha
Genova
Oslo
IRST
+++

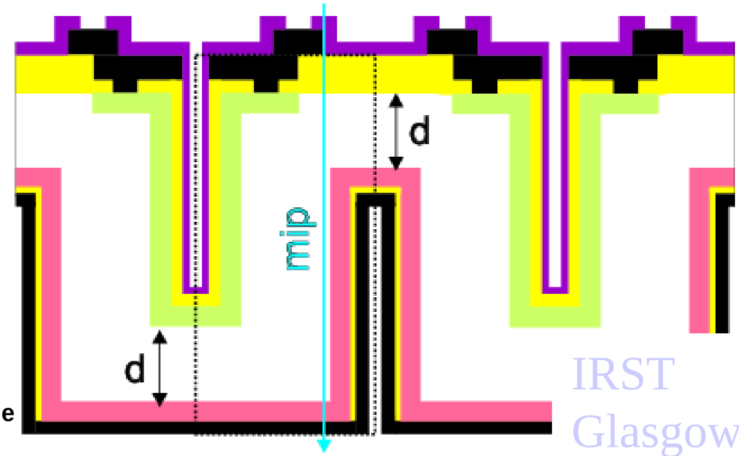




Development, Testing and Industrialization of Full-3D Active-Edge and Modified-3D Silicon Radiation Pixel Sensors with Extreme Radiation Hardness Results, Plans.

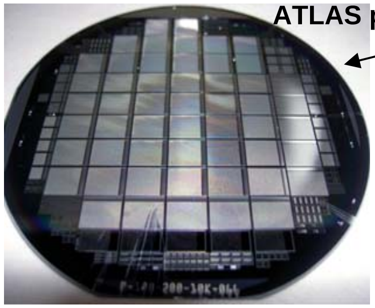
ATLAS Upgrade Document No:	*Institute Document No.*	*Created:* 17/07/2006	*Page:* 1 of 13
		Modified: 08/03/2007	*Rev. No.:* 2.00

Alternative geometry with double sided electrodes

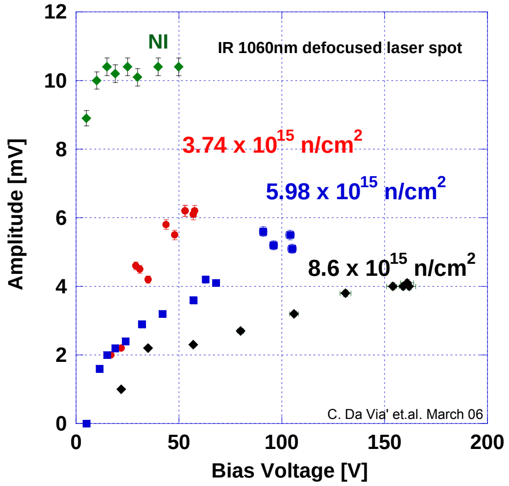


IRST
Glasgow/CNM

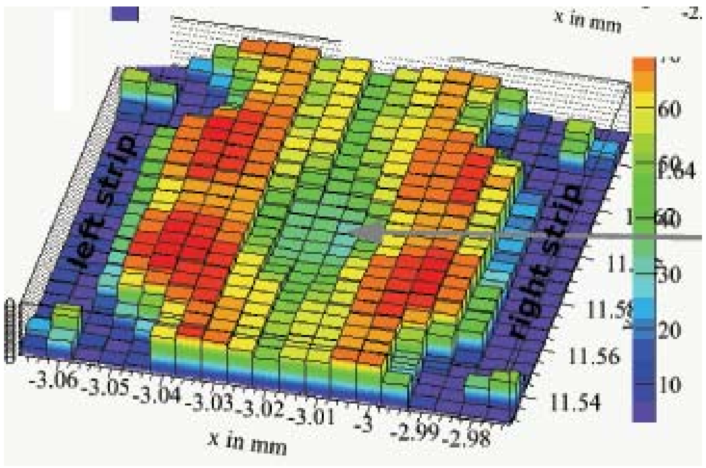
ATLAS pixel fabricated at Stanford

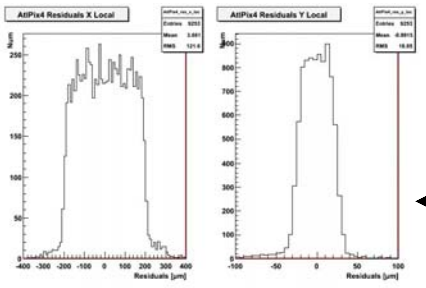


Radiation tests- Prague
CCE(V) with laser



IR scan 3D- IRST / Freiburg





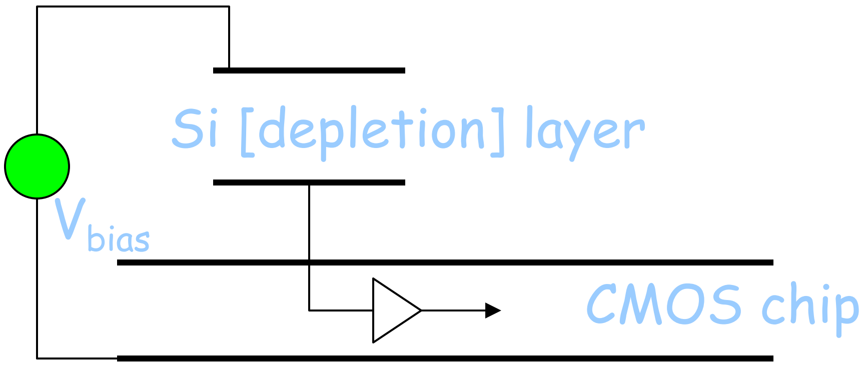
Test beam/data analysis from Bonn

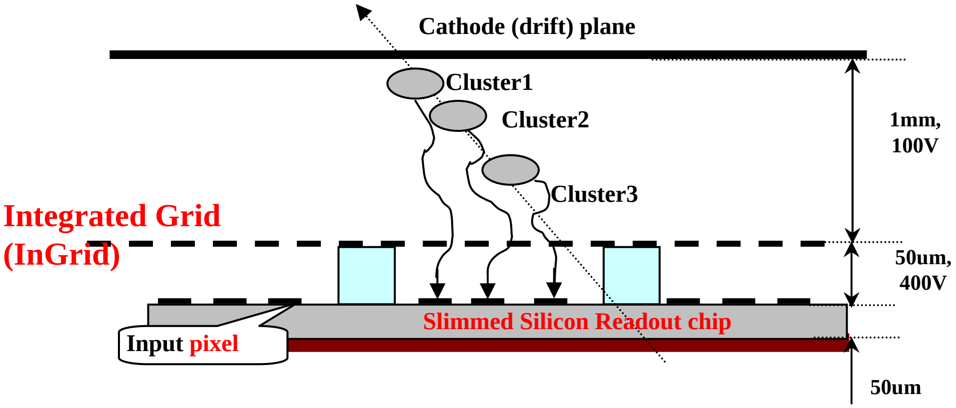
Richard Bates

R&D institutes

- Glasgow, Freiburg, CNM Barcelona (Centro Nacional de Microelectronica, Spain)
- Hawaii/Stanford/ Manchester + SINTEF
- FBK (prev. IRST), Trento
- VTT
- ATLAS 3D pixel upgrade collaboration
  - Institutes: Stanford, Manchester, Hawaii/LBL, New Mexico, Glasgow, Freiburg, Bonn, Praha, Genova, Oslo, FBK, CERN, CNM

Si (vertex) track detector GOSSIP





- Si strip detectors
- Si pixel detectors
- MAPs
- CCDs

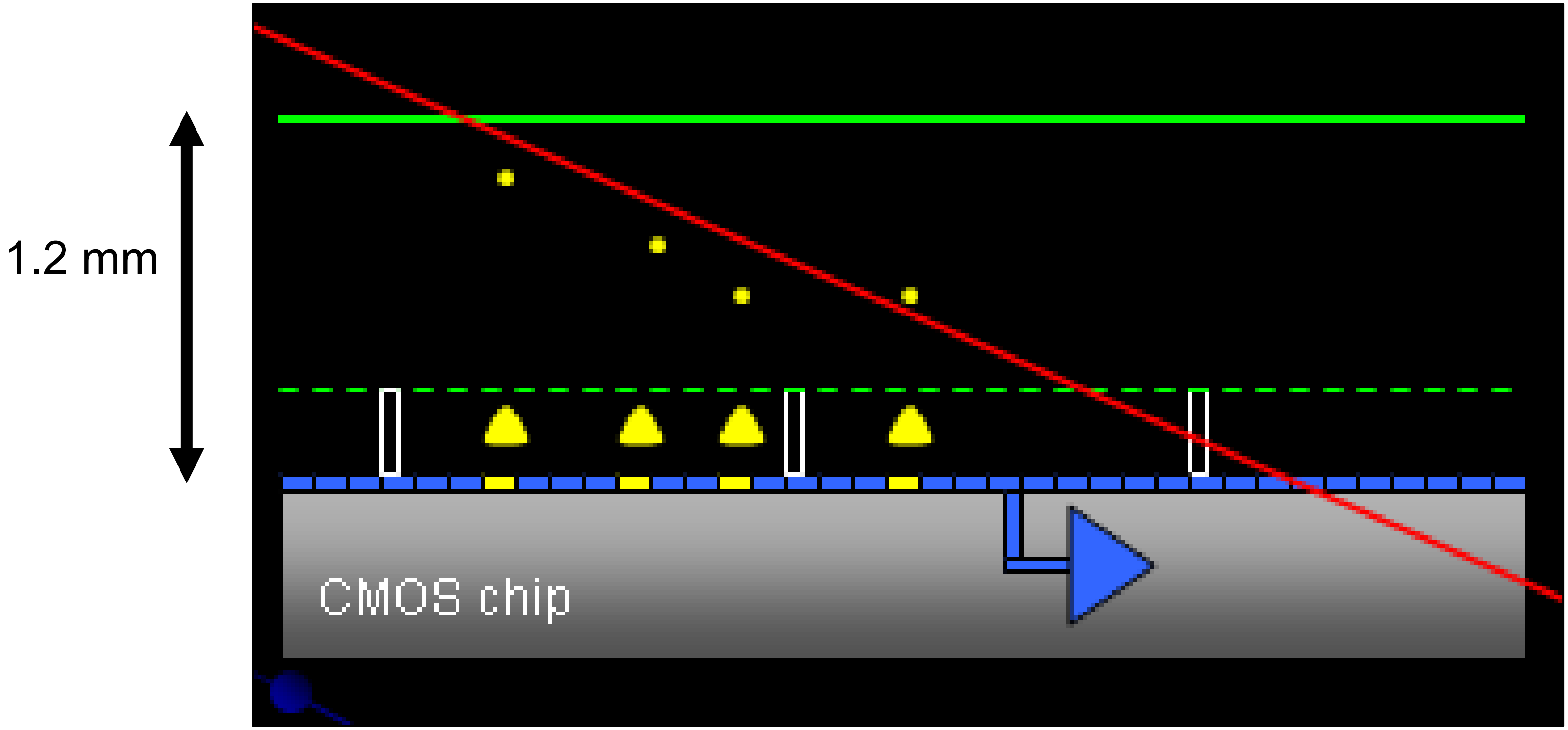
Gas: 1 mm as detection medium

99 % chance to have at least 1 e-

Gas amplification ~ 1000:

Single electron sensitive

All signals arrive within 20 ns

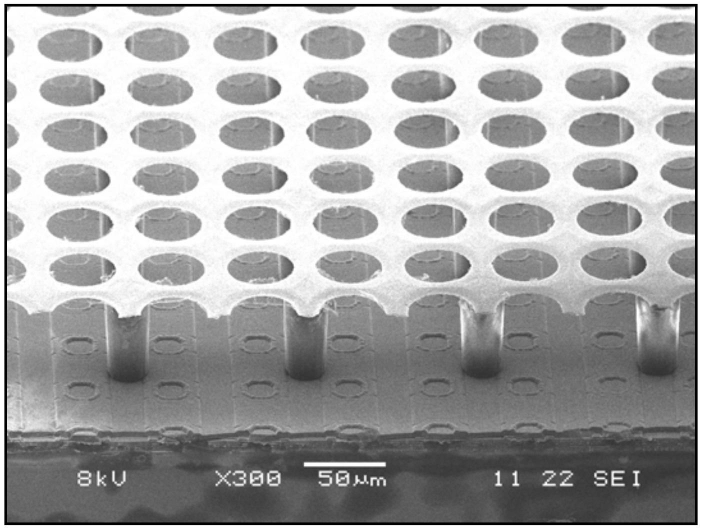


Gossip [Gas On Slimmed Silicon Pixels] replacement of Si tracker

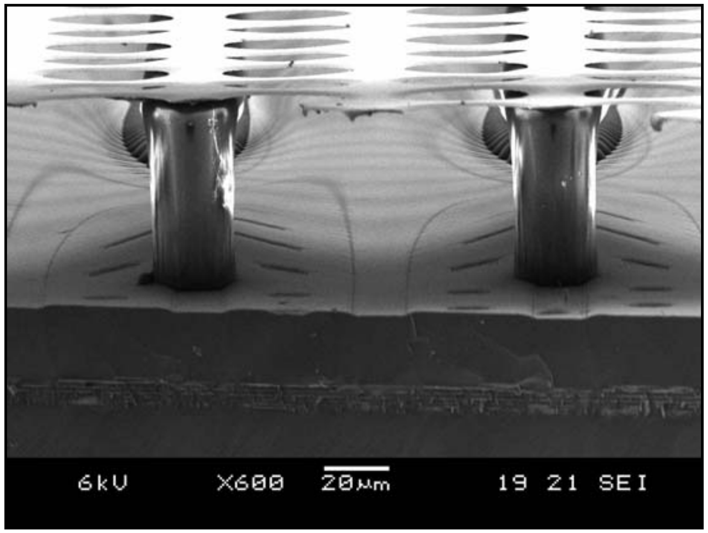
Essential: thin gas layer (1.2 mm)

Full post-processing of a TimePix

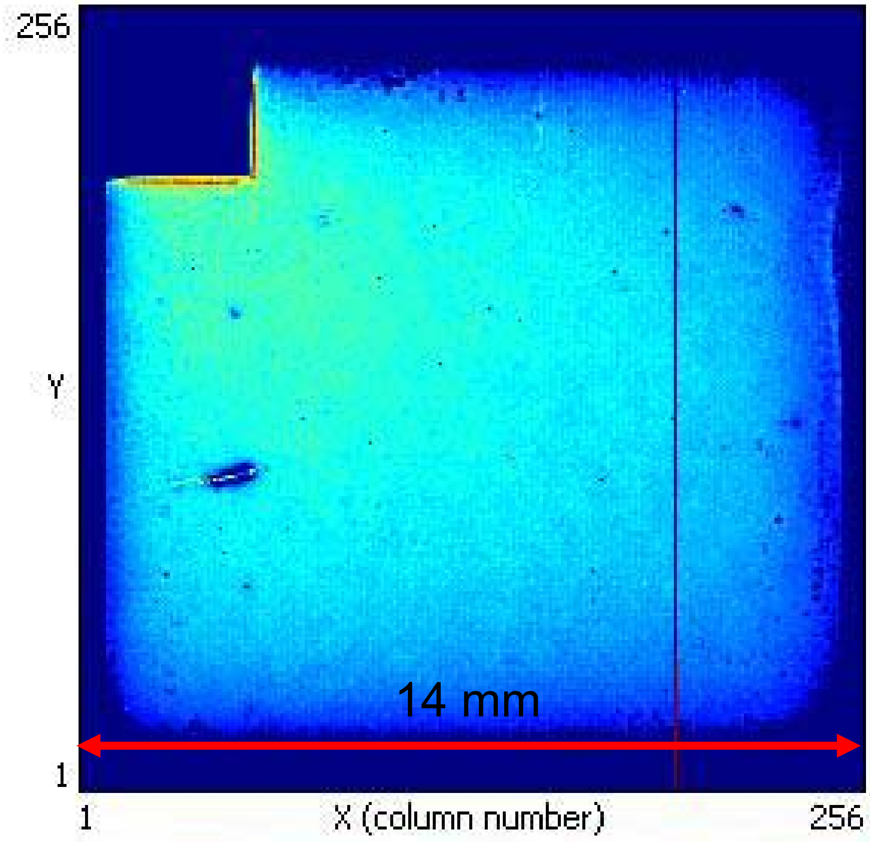
- Timepix chip + SiProt + Ingrid:



MESA+



IMT Neuchatel



"Uniform"

Charge mode

Tracking sensor material: gas versus Si

- primary electrons can simply be multiplied: gas amplification: low power

- gas can be exchanged: no radiation damage of sensor

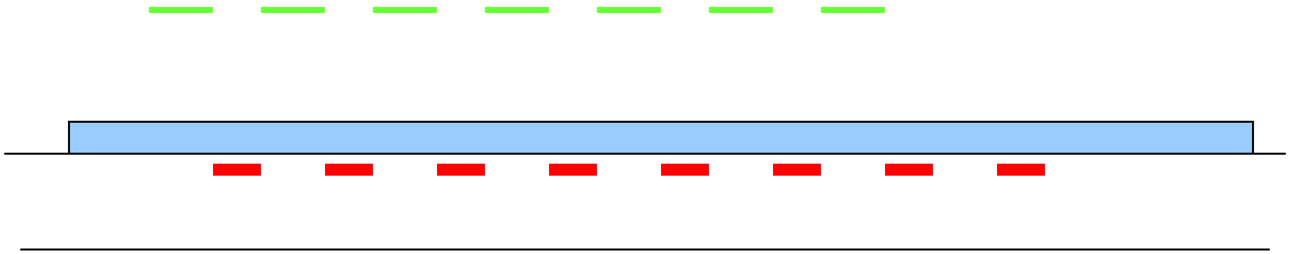
- no bias current: low power & simple FE circuits

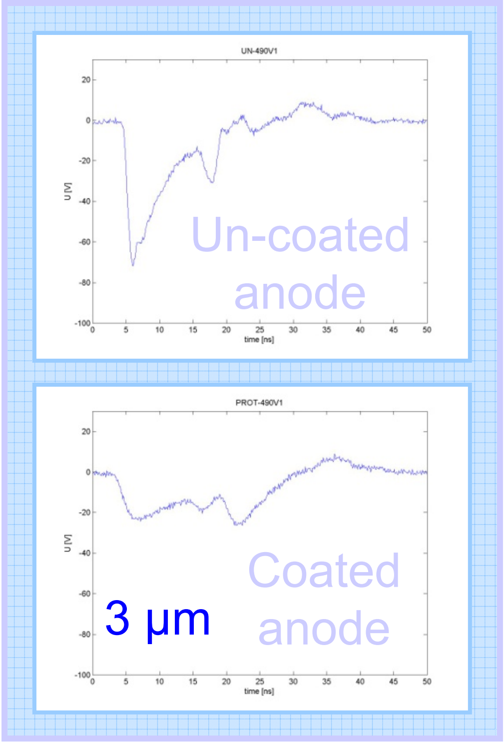
- it is light and cheap

- gas has a low ε_r: with small voxels the source capacity can be small (10 fF) allowing fast, low-noise, and low-power preamps

- no temperature requirements
- low sensitive for neutron and X-ray background [and can detect < 1 keV quanta!]
- δ-rays can be recognized
- [high ion & electron mobility: fast signals, high count rates are possible]

- discharges/sparks: readout system should be spark proof
- ageing: must be solved and must be understood / under control
- diffusion: limits max. drift length





SiProt protection against:

- hot spark plasma
- too large charge in pixel circuitry [principle of RPCs]
    - local reduction of E-field: quenching
    - widening discharge funnel: signal dilution
    - [increased distance of ‘influention’]

SiProt: a low T deposited hydrogenated amorphous silicon (aSi:H) layer

Up to 50 µm thick films, ~ 10^7 - 10^{11} Ω.cm

Sparks

July 2008: protection layer made of Si_3N_4 (Silicon Nitride), only 7 µm thick

$$3\ SiH_4 + 4\ NH_3 \rightarrow 3\ Si_3H_4 + 6\ H_2$$

Silicon Nitride is often applied as passivation layer:
top finish of chips.

With overdose of SiH_4:conductivity: high resistively bulk material

Favoured material for bearings in turbo chargers, jet engines

The application of SiNProt and InGrid on CMOS chip is likely
to become a standard, low cost procedure by industry
[compare bump-bonding of Si sensors & processing Si sensors]

Ageing

Radiation damage of CMOS pixel chip is relevant

- common for all tracking detectors
- believed to widthstand ATLAS Upgrade Dose in 90 nm technology

Radiation damage of sensor:
not relevant for Gossip sensor since this is gas being exchanged

Typical for gaseous detectors: the deposit of an (insulating) polymer on the electrodes of a detector. Decrease of signal amplitude

Little ageing expected:

- little primary ionisation (~ 10 e-/track)
- low gas gain (500 – 1000)
- large anode surface (compare pixel anode plane with surface of thin wire)
- E-field at flat anode ~3 lower than E-field at anode wire

GOSSIP-Brico: PSI-46 (CMS Pixel FE chip)

First prototype of GOSSIP on a PSI-46 (CMS Pixel FE chip)is working:

- 1.2 mm drift gap
- Grid signal used as trigger
- 30 µm layer of SiProt