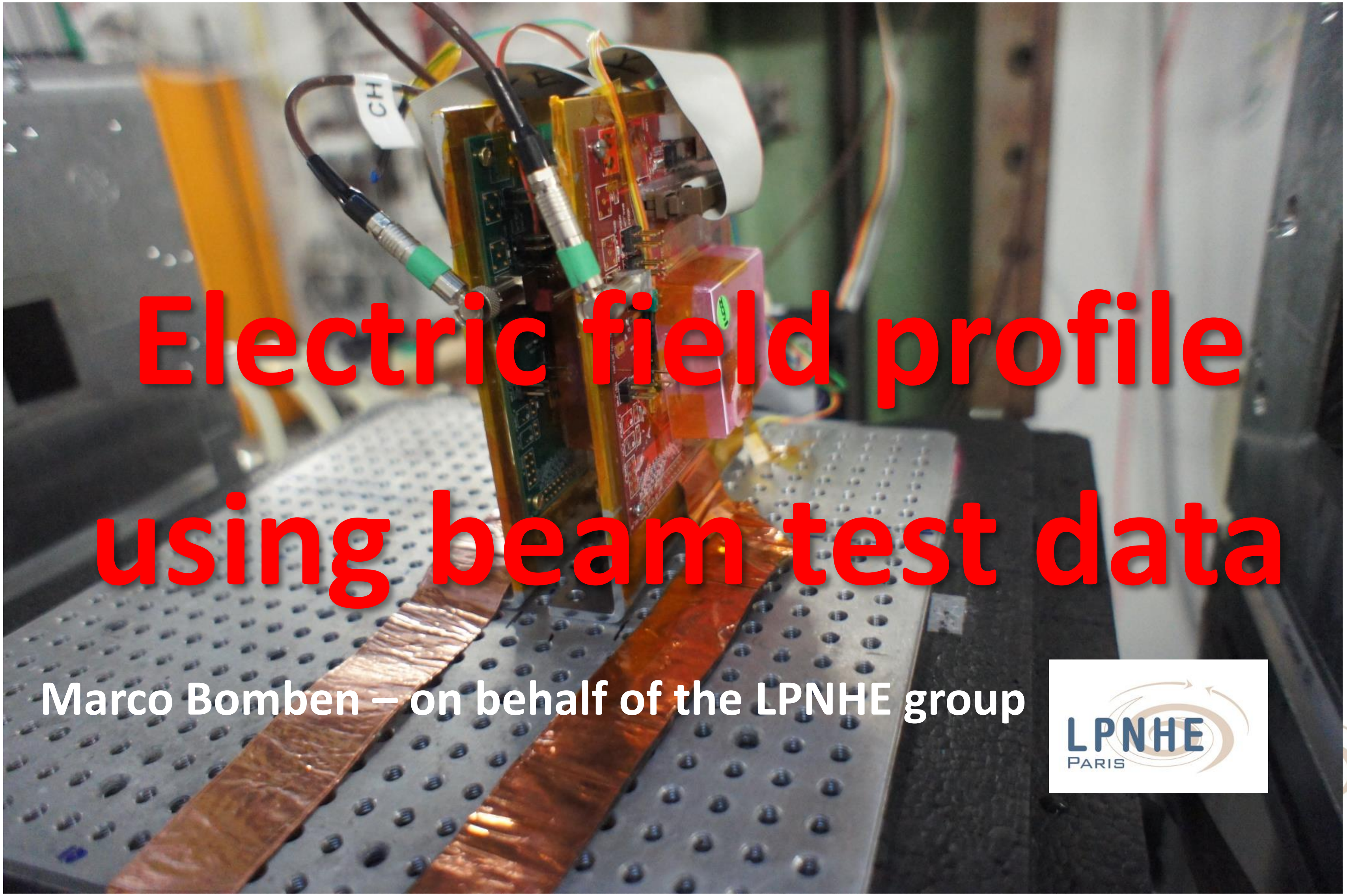
23rd RD50 meeting – 13-15/11/2013, CERN



Electric field profile using beam test data

Marco Bomben – on behalf of the LPNHE group

Outline

- Motivations
- The grazing angle technique
- Previous results and simulations
- Possible measurements
- How-to
- Timeline

Motivations

- Need to parameterize the electric field as a function of several variables and conditions:

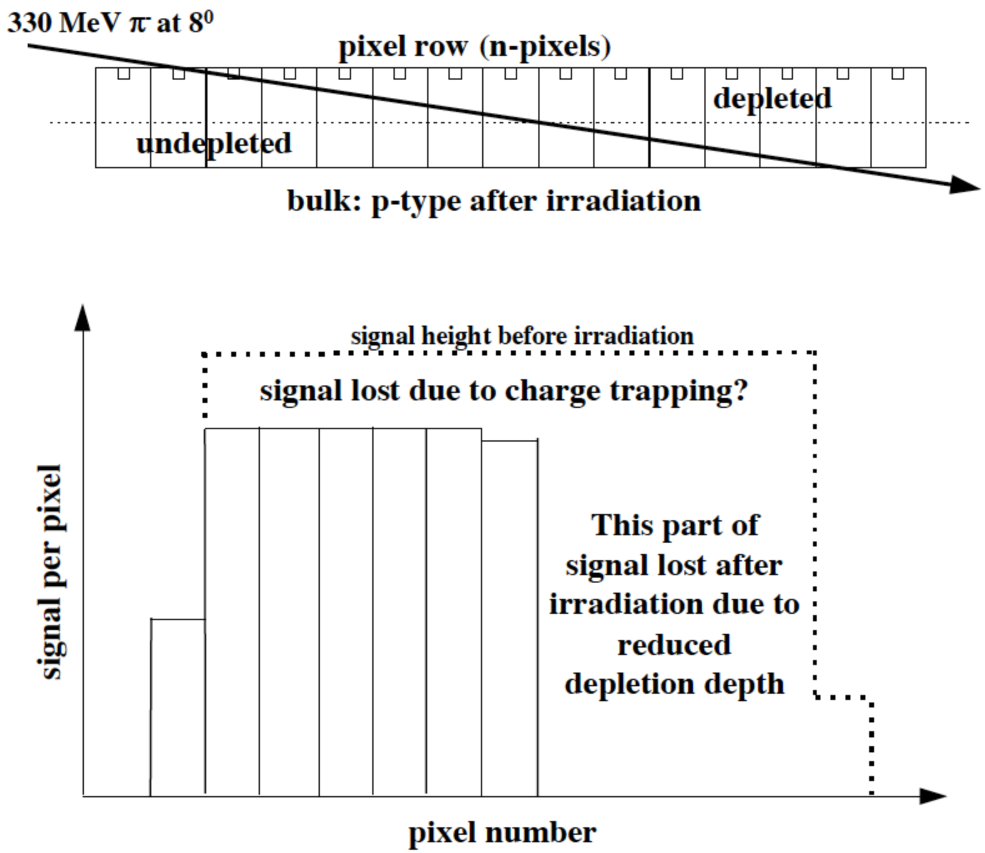
A. Fluence
B. Radiation type
C. Bulk material
D. Temperature
E. Annealing

e.g. needed for detector simulation (digitization)

- Done with Edge TCT measurements
- Possible with test beam data too

Grazing angle technique

- Technique developed by Henrich, Bertl, Gabathuler & Horisberger (CMS note 1997/021)



- Tracks enter at shallow angle wrt to the detector surface
- Charge collection efficiency as a function of the bulk depth
  - (Analog readout)

Exploiting the grazing angle technique

"Simulation of Heavily Irradiated Silicon Pixel Sensors and Comparison with Test Beam Measurements"
V. Chiochia et al., Nuclear Science, IEEE Transactions on , vol.52, no.4, pp. 1067- 1075, Aug. 2005

- Use this technique to perform ~ 1 µm resolved charge collection profiles

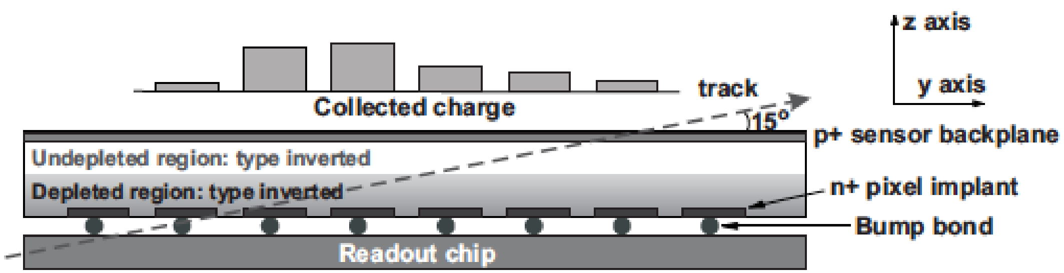


Fig. 2
THE GRAZING ANGLE TECHNIQUE FOR DETERMINING CHARGE COLLECTION PROFILES. THE CLUSTER LENGTH IS PROPORTIONAL TO THE DEPTH OVER WHICH CHARGE IS COLLECTED.

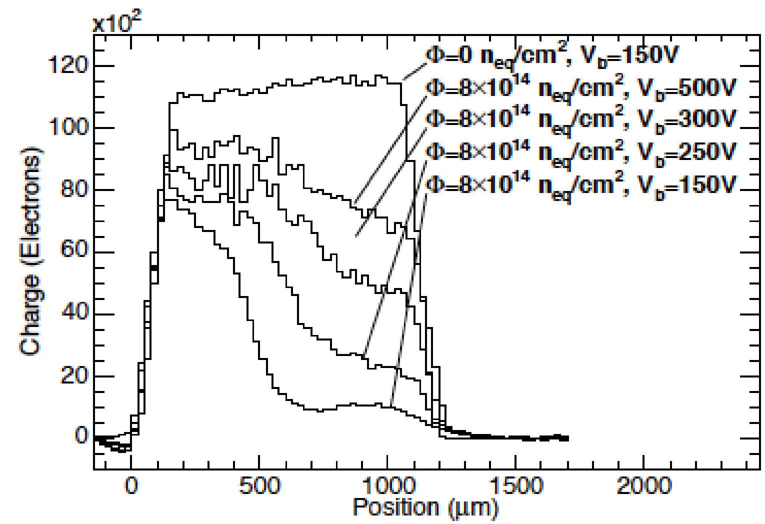


Fig. 3
CHARGE COLLECTION PROFILES FOR AN IRRADIATED ($\Phi = 8 \times 10^{14}$ N$_{eq}$/cm^2) AND AN UNIRRADIATED SENSOR ($\Phi = 0$ N$_{eq}$/cm^2) OPERATED AT SEVERAL BIAS VOLTAGES.

•Parameterization of the Electric Field in simulations
•Comparison data/simulation (next slides)

Chiochia 2005/2006: results

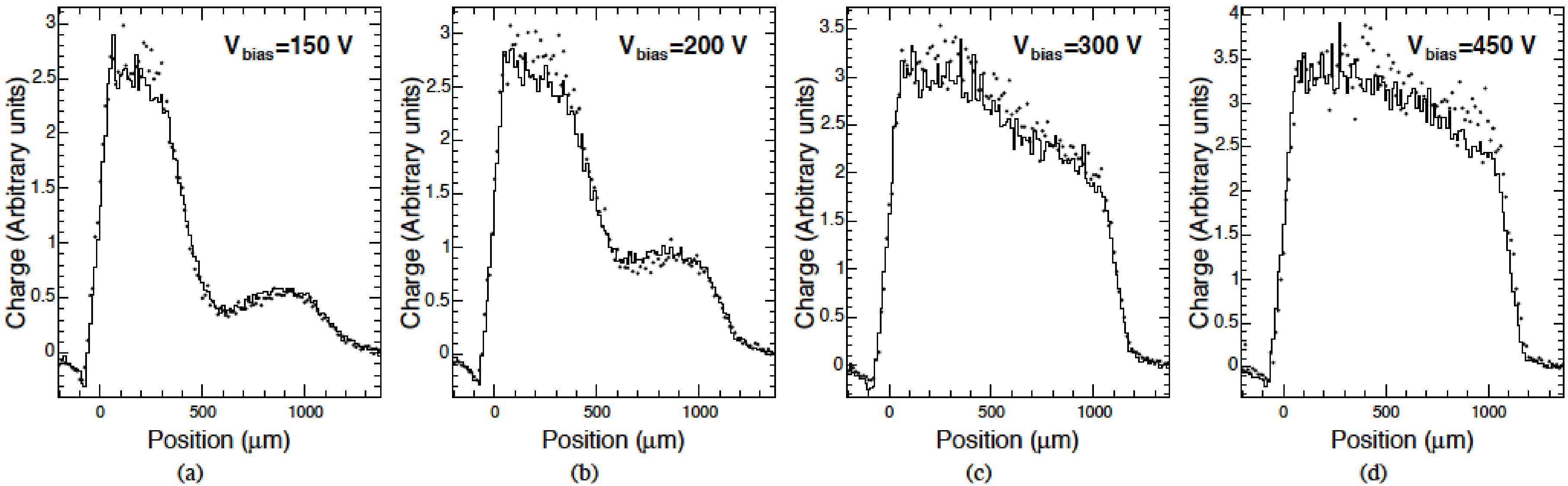


Fig. 10
THE MEASURED CHARGE COLLECTION PROFILES AT BIAS VOLTAGES OF 150 V, 200 V, 300 V, AND 450 V ARE SHOWN AS SOLID DOTS FOR FLUENCES OF 6×10^{14} N_{eq}/cm^2. THE BF SIMULATION IS SHOWN AS THE SOLID HISTOGRAM IN EACH PLOT.

- ✓Excellent agreement
- ✓Down to the details of wiggle between 500 and 1000 µm
- ✓All effects understood

Level of detail attained: DP effect

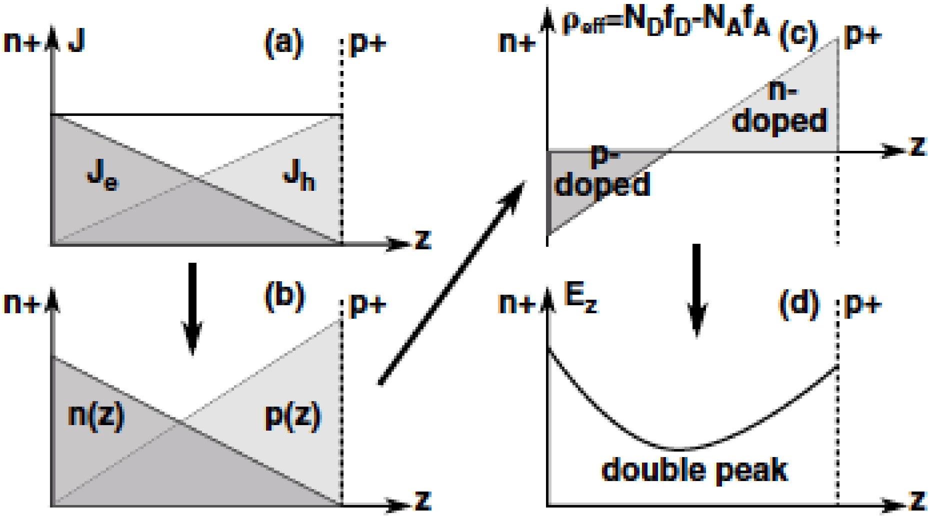
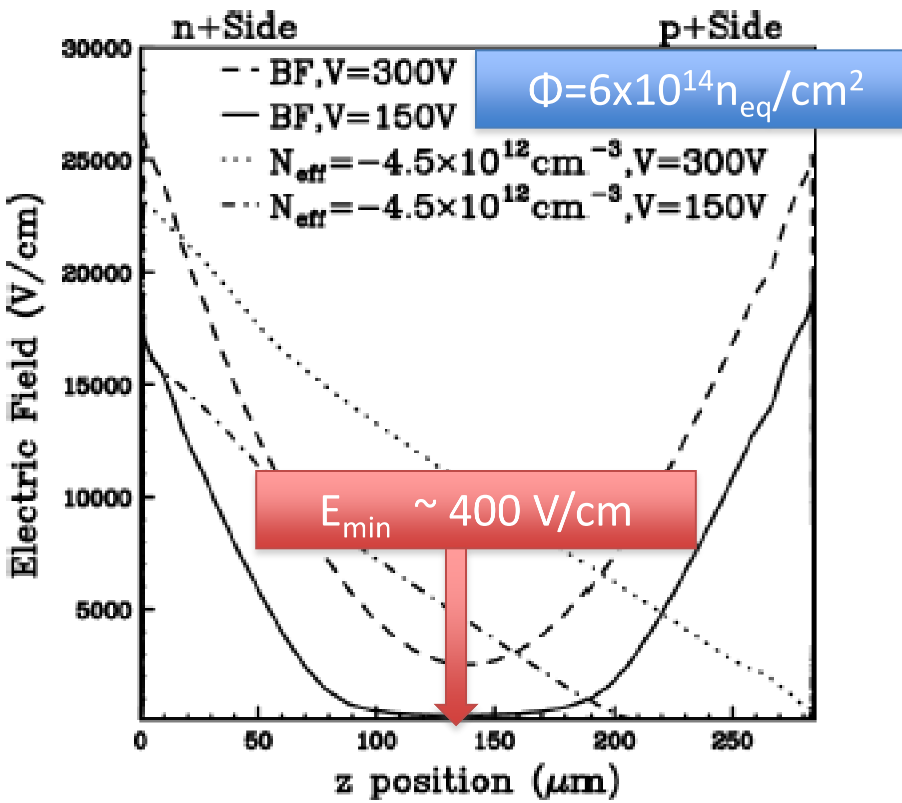


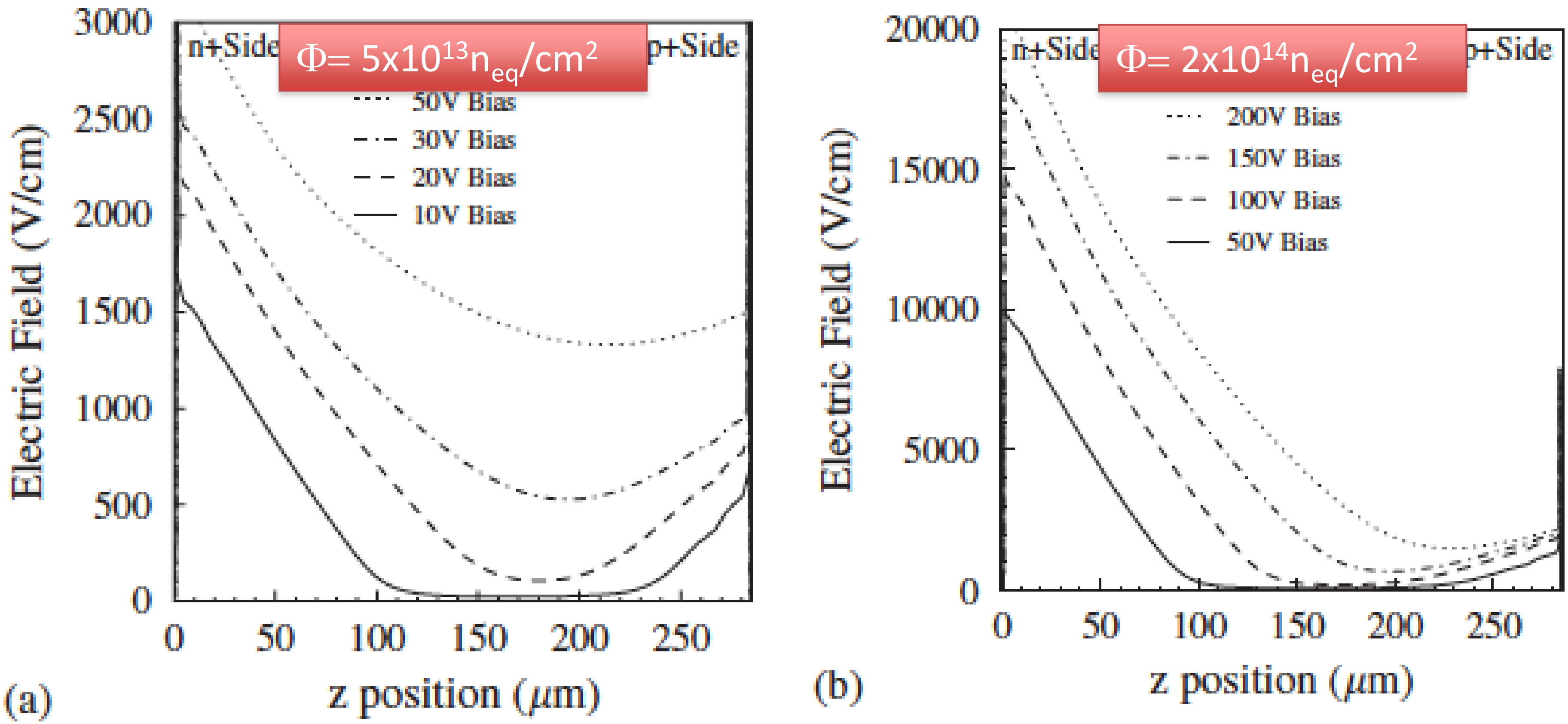
Fig. 6
AN ILLUSTRATIVE SKETCH OF THE EVL MODEL FOR A REVERSE BIASED DEVICE [20].



- They vary the input parameters of the model to reproduce the profiles they observe in data
- Max fluence investigated: $6x10^{14}$ n_{eq}/cm^2
- But… very interesting results at low fluences! (next slides)

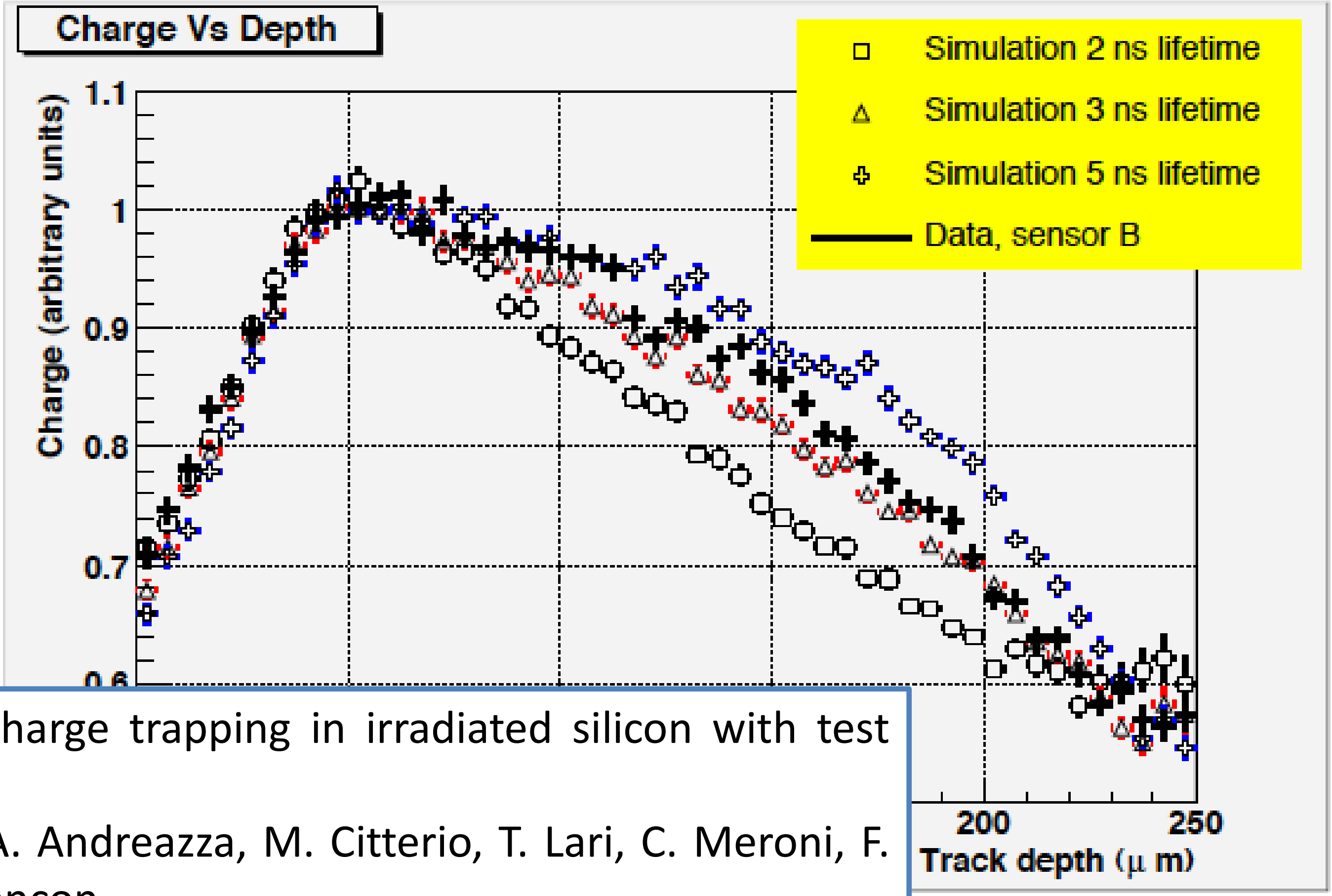
Low fluence and Double Peak

[“A double junction model of irradiated silicon pixel sensors for LHC”](#)
V. Chiochia et al., Nuclear Instruments and Methods in Physics Research A 568 (2006) 51–55



“Finally, we note that quantities like (depletion depth) and , which are related to the picture of uniform type inversion in irradiated silicon sensors, may correctly suggest reduced detector performance but given the evidence of double peak electric fields and free carrier trapping, have no physical significance.” Chiochia 2005

Lari et al. with Atlas pixels

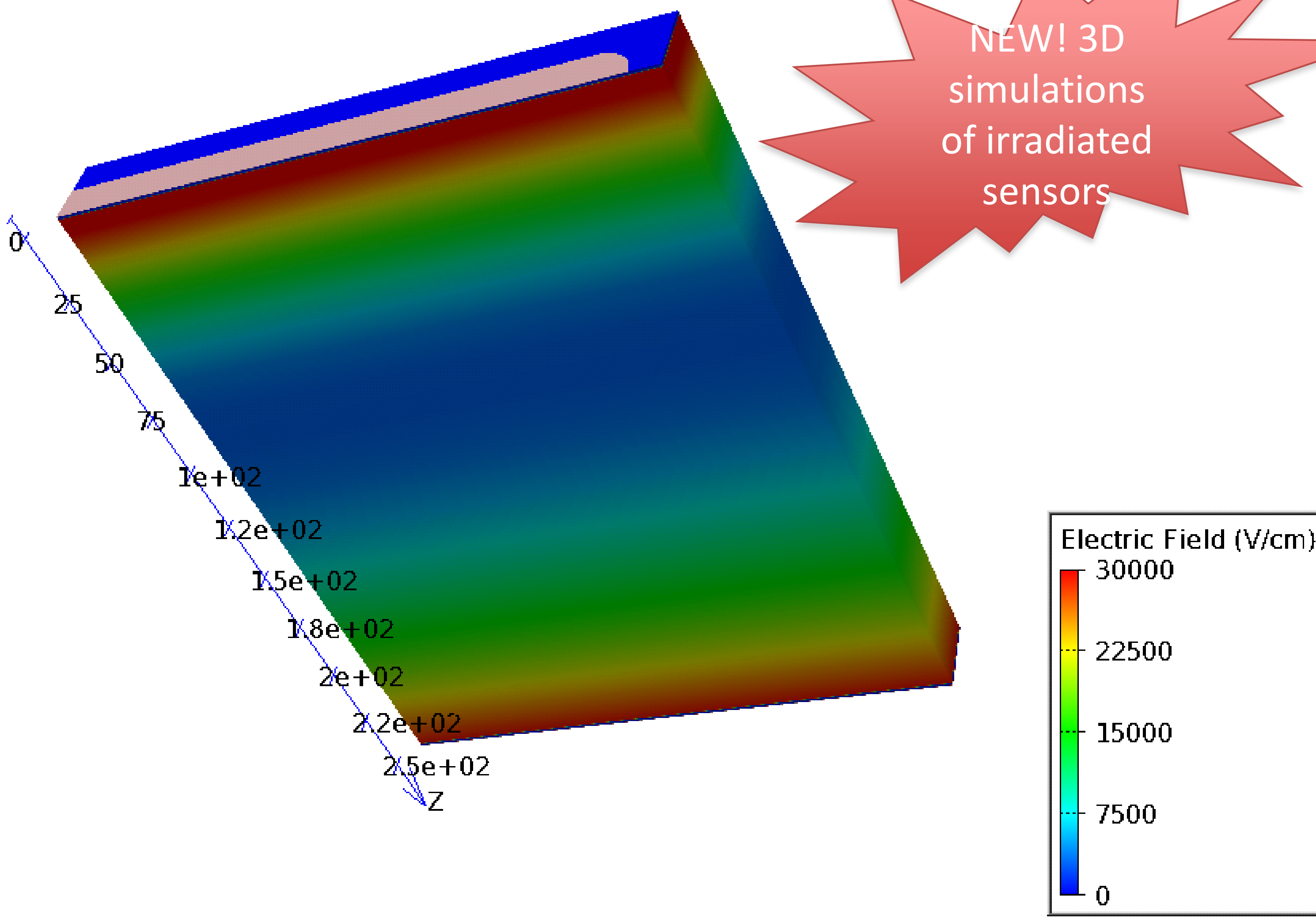


"A study of charge trapping in irradiated silicon with test beam data"
G. Alimonti, A. Andreazza, M. Citterio, T. Lari, C. Meroni, F. Ragusa, C. Troncon
ATL-INDET-2003-014

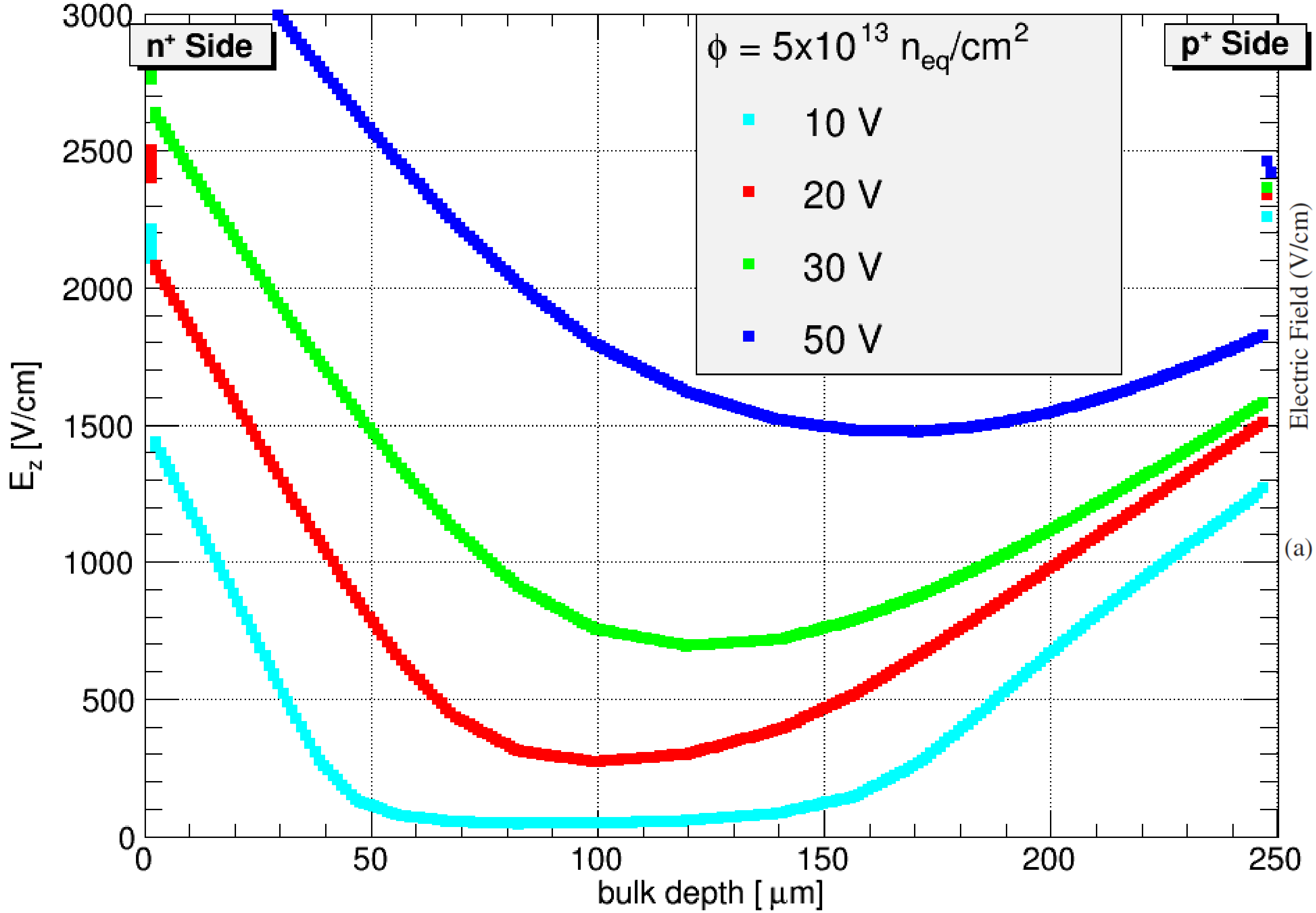
Figure 7: The simulated distribution of normalized pixel charge as a function of track depth is reported for several values of the lifetime and compared with the data taken with sensor B at 700 V.

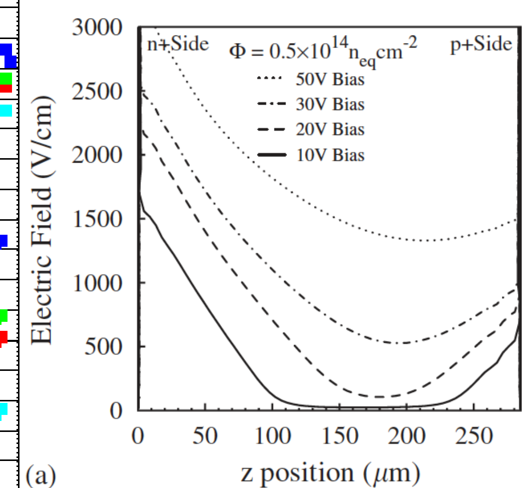
3D simulations

NEW! 3D simulations of irradiated sensors



Reproducing Chiochia results in 3D





Possible measurements

- Different geometries (strips and pixels)
- Different materials: *e.g.* DOFZ vs MCz
- Different radiations (n, p, π)
- Annealing studies too?
- Temperature dependence? (from simulations I see effects on the electric field profile)
- Magnetic field (to study radiation effects on charge sharing)
- Charge multiplication? (Dream: only if σ_{trk} ~ 1µm)

Possibilities opened

- In principle we could explore a lot of the phase space for bulk materials, electrodes geometries, running conditions…
- Investigating charge multiplication too!
- We can even try to 'tailor' the electric field with the input from from DLTS and TSC studies on defects

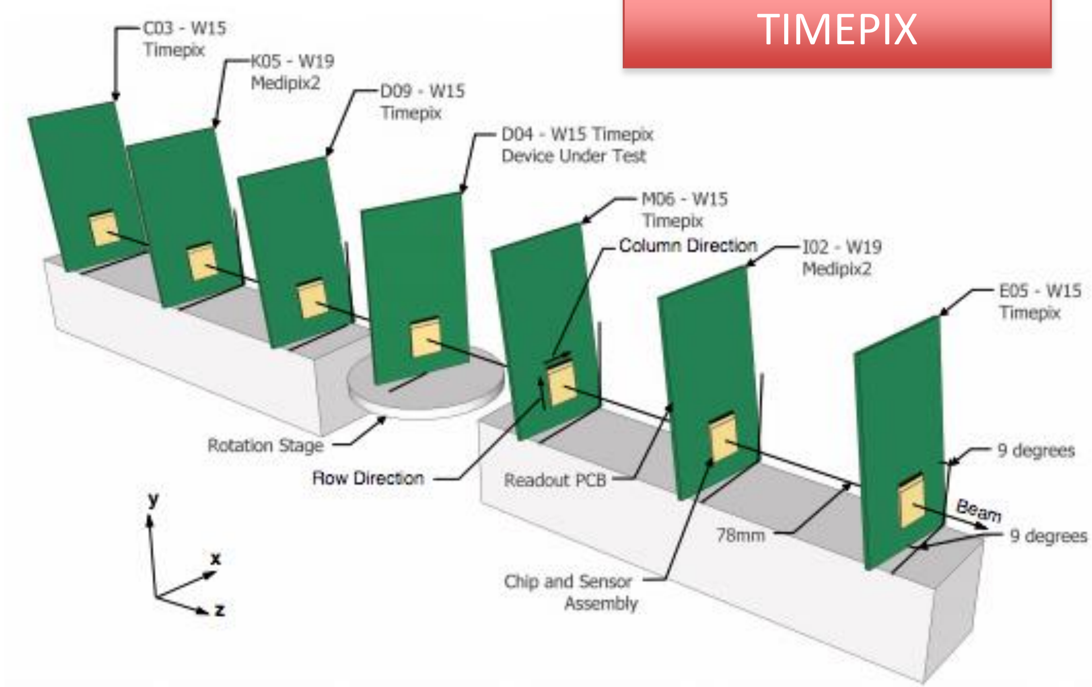
➢ Try several initial materials and see which is the "best" charge collection profile one can get

The measurement: how-to

- High resolution tracking system
- Need to easily rotate the DUT
  - High energy beam (CERN, Fermilab)
  - Telescope:
    - Timepix
    - Eudet/AIDA
    - Captan (fermilab)
    - Alibava
- DUT r.o.: analog? (beetle for strips?) ➔ next slide

"The telescope achieved a pointing resolution of 2.4 μm at the position of the device under test"

TIMEPIX



How-to: read-out chips

- What is needed:
  1. Compatibility with “common” sensors and telescopes
  2. Large ADC granularity
- Possible candidates:
  - Strips: **Alibava**
  - Pixel:
    1. “CMS”: PSI46: analog readout (with FEDs: 10 bit ADC)
    2. “Atlas”: FE-I3: 8 bit adc (cons: very few rocs left)
       - X FE-I4 has only 4 adc bits

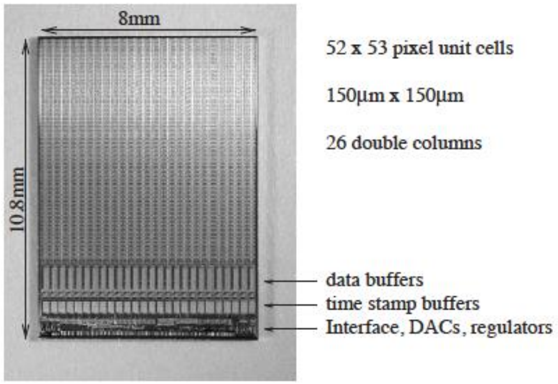
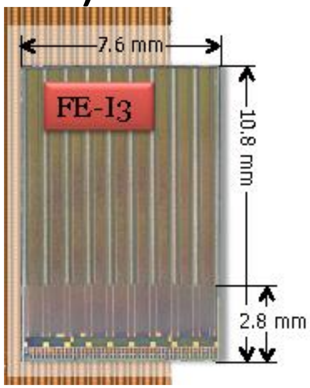


Fig. 1. PSI43 readout chip in DMILL technology for the CMS pixel detector.



Timeline

- Discuss this now and at the next RD50 meeting
- Understand which facility/telescope are the best
- Find money for the project (if measurements at Fermilab: expensive)
- Understand which samples measure and with which priority
- Involve immediately simulations WG to have machinery ready to prepare several scenarios for radiation damage model
- Book beam time

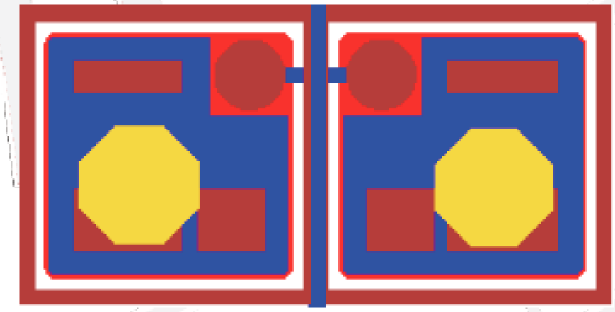
THANK YOU FOR YOUR ATTENTION

Backup material

CMS sensors

2004 CMS Pixel Beam Test

All results are based upon 125μmx125μm CiS pspray test sensors:



- 22x32 cells on each chip
- 285μm thick dofz substrate from Wacker
  - n- doped with ρ=2-5 kΩ-cm, <111> orientation
  - oxygenated at 1150C for 24 hours
- irradiated with 24 GeV protons at PS to fluences: $(5.9, 2.0, 0.47)\times10^{14}\ n_{eq}/cm^2$
- annealed for 3 days at 30°C
  - all sensors are "Standard Annealed"
- bump-bonded at 20°C, stored at -20°C

2

“Local” expertise

Marco Bomben

Francesco Crescioli

Giovanni Marchiori

Giovanni Calderini

Jacques Chauveau

- All of us have long beam test experience (BaBar, Atlas pixels upgrade)
- In particular

1. Marco is ATLAS pixel upgrade coordinator since Fall 2011
2. Giovanni C. contributed to IBL beam test data analysis
3. Francesco C. is working on trigger improvement for the Eudet/AIDA telescope