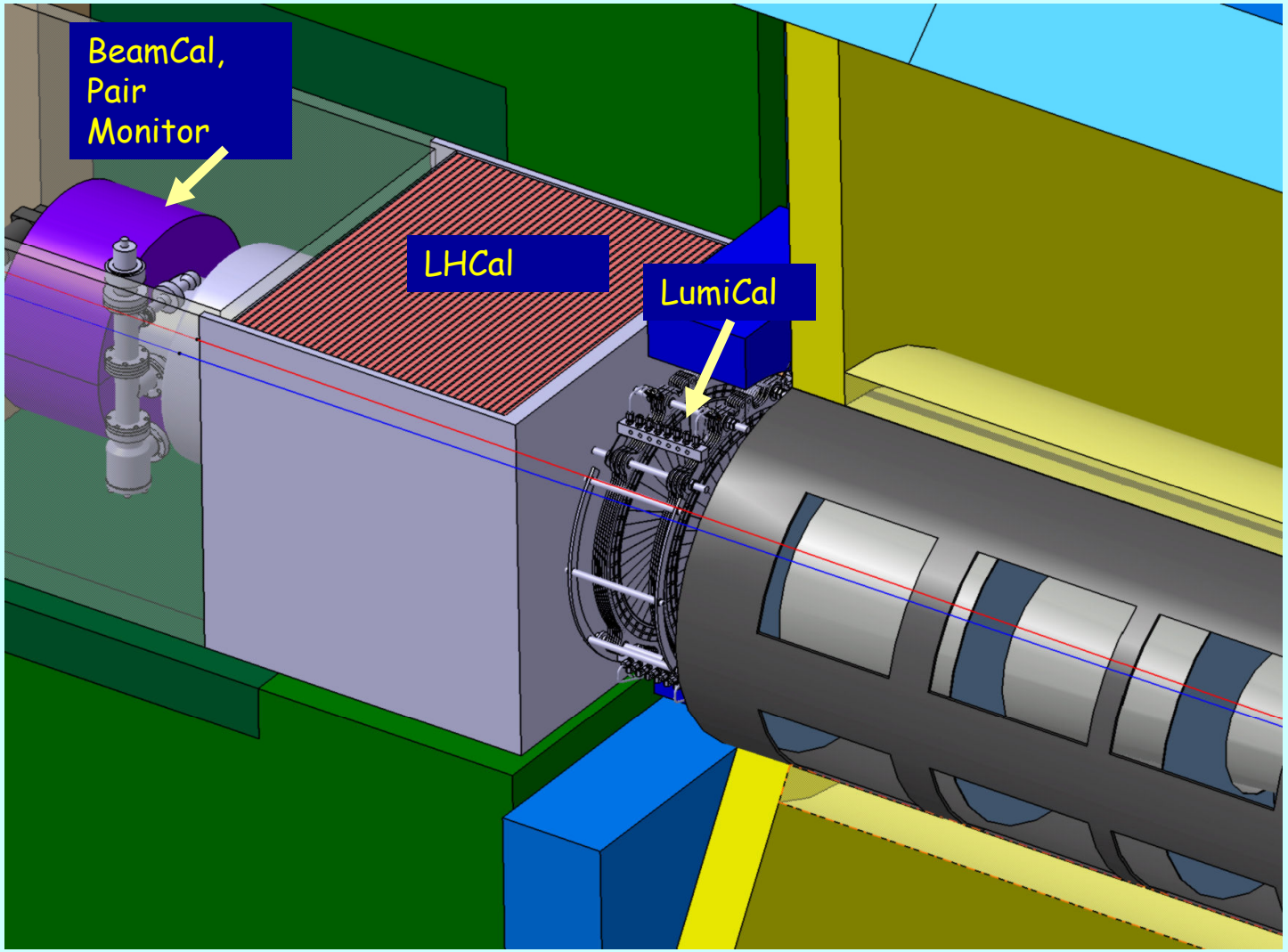
# Forward Region Instrumentation


Wolfgang Lohmann

DESY

On behalf of the FCAL collaboration

# Forward Region, ILD Detector



# Content

Recent Developments:

- Sensor Prototyping
- ASIC Development and Test
- System test
- PITZ test
- Applications of FCAL R&D at FLASH and CMS

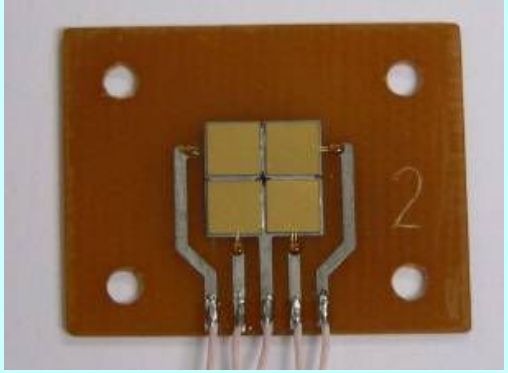
# BeamCal Sensors, GaAs

- n-type (Te or Sn - shallow donor) GaAs grown by Liquid Encapsulated Czochralski (LEC) method in Siberian Institute of Physics and Technology (Tomsk, Russia)
  low-ohmic material, filling the electron trapping centers EL2+
- Cr (deep acceptor) diffusion
-> high-ohmic

Thicknesses 150 – 200 μm

Metallization:
V (30 nm) + Au (1 μm) from both sides

Irradiation in a 10 MeV electron Beam, Doses up to 1.1 MGy



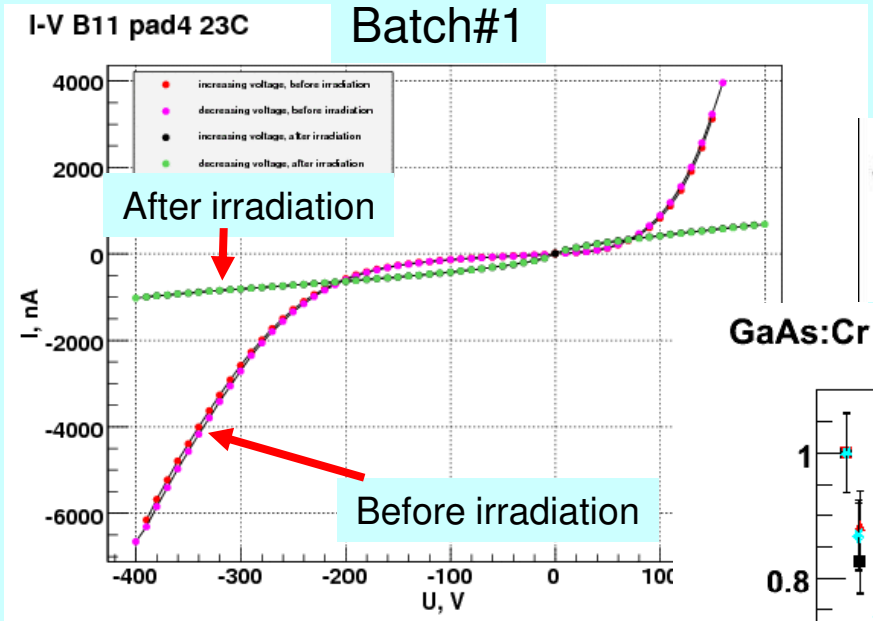

| Initial n-GaAs | Fabrication method |
|---|---|
| №1, n ≈ (1 -1.5)*$10^{17}$ $см^{-3}$ ,Te | Diffusion of Cr under temperatureT2 |
| №2, n ≈ (5 - 6)*$10^{16}$ $см^{-3}$, Te | Diffusion of Cr under temperature Tm |
| №3, n ≈ (1 - 3)*$10^{16}$ $см^{-3}$, Sn | Diffusion of Cr under temperature T1 |
| №4, n ≈ (2 - 5)*$10^{16}$$см^{-3}$, Te | p-ν-n- structure* |

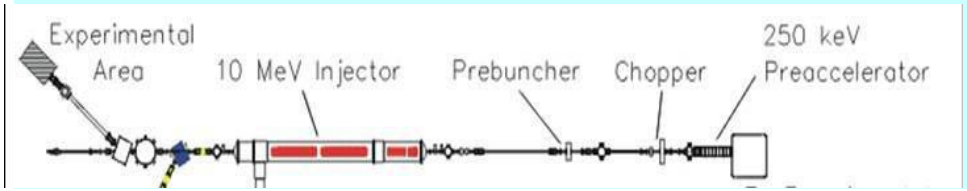
Notice T1 < Tm<T2.

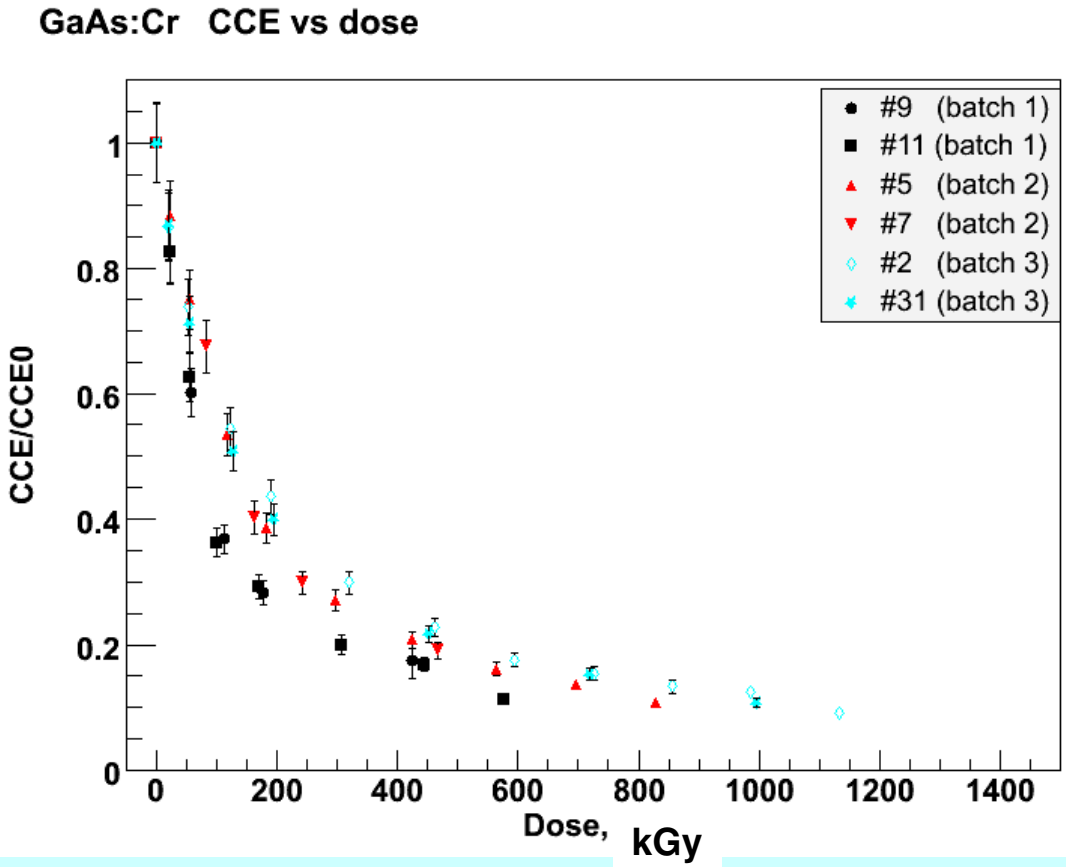
* - presence in the detector n- type low-resistance domain, all other detectors №1, 2, 3 had structure m-i-m: metal- insulator (high-resistance GaAs) –metal.

# BeamCal Sensors, GaAs

Irradiation with an 10 MeV electron beam (DALINAC, TU Darmstadt)
10 – 400 kGy/h




Up to 500 kGy a mip signal is clearly seen

Sensors with a lower concentration of shallow donor and Cr as deep acceptor show better rad. tolerance

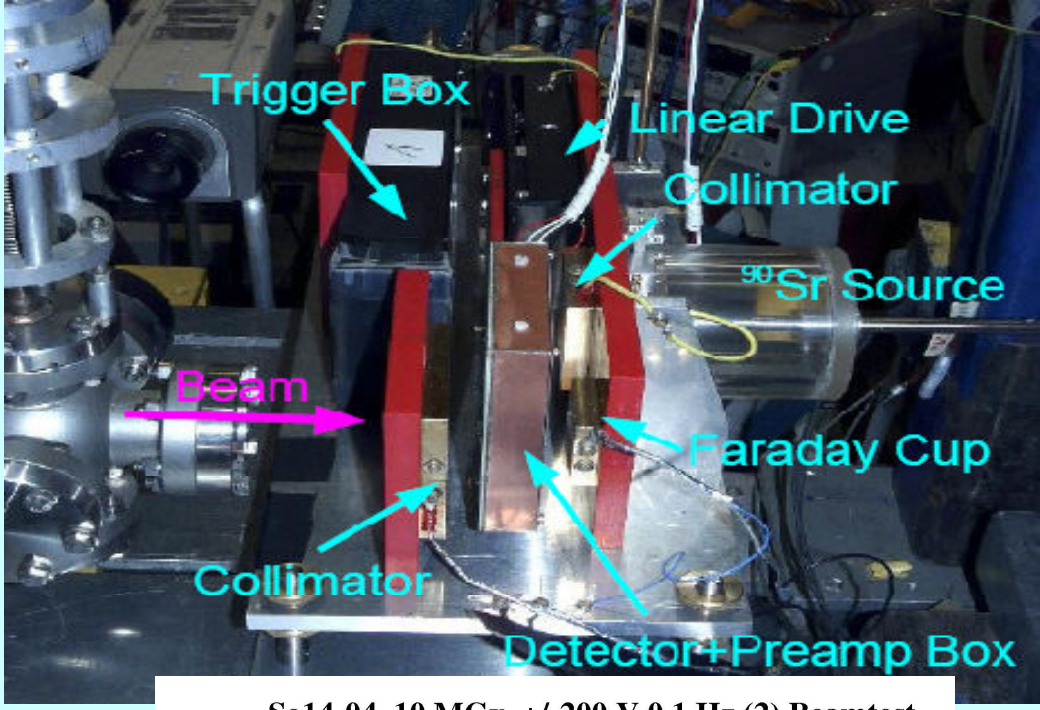
# BeamCal Sensors, Diamond

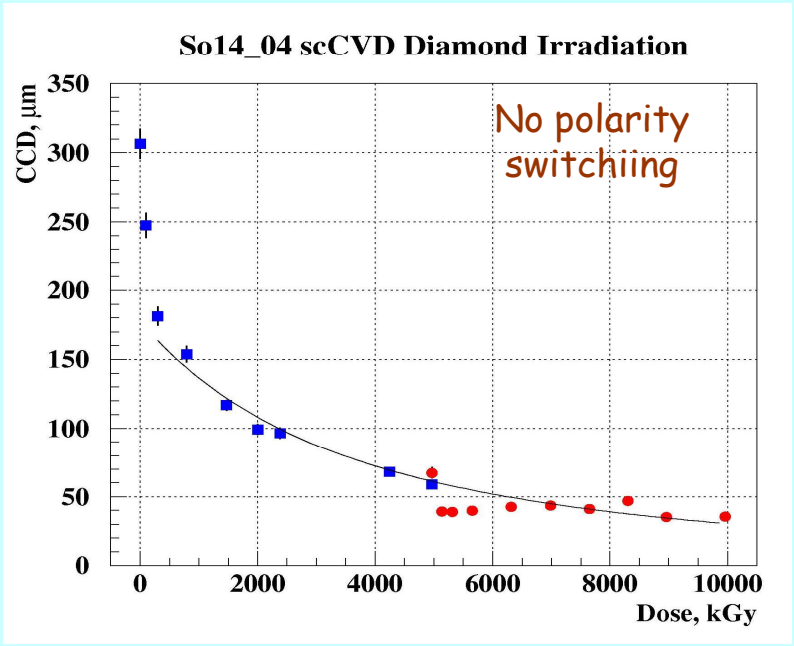
sCVD diamond (E6), 5x5x0.3 $mm^3$

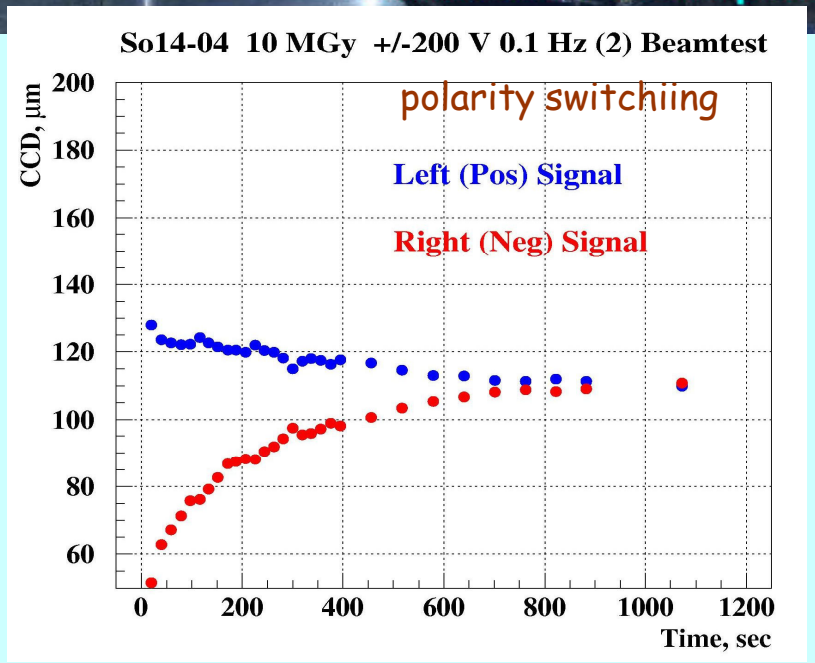
Irradiated in 2007 up to 5 MGy

2008: up to 10 MGy

New set-up, for switching polarity during the measurement



# BeamCal Sensors, Sapphire

Band gap: 9.9 eV

(diamond: 5.5 eV, Si: 1.12 eV

Single crystal, 1x1 $cm^2$,

cut 0001

Wafer: 30 cm diameter)

Metallization:

50/50/200 nm Al/Ti/Au




Ratio of the detector and Faraday cup currents

Charge collection efficiency: few %

~ 30 % of the initial charge collection efficiiency after 12 MGy

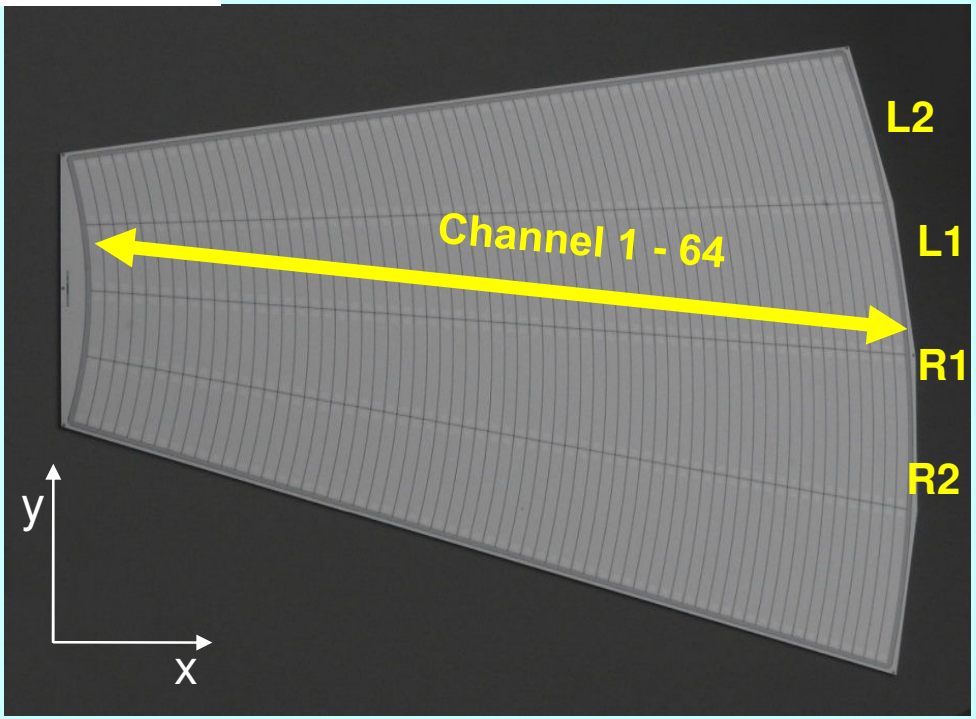
# Sensor prototypes (LumiCal)

## "Cracow-Design"

- High resistivity n-type Si
- 1,7mm p+ - strips
  with an Al-metallization
- Backplane: n+ implant
  and an Al-metallization
- 3 Guard rings

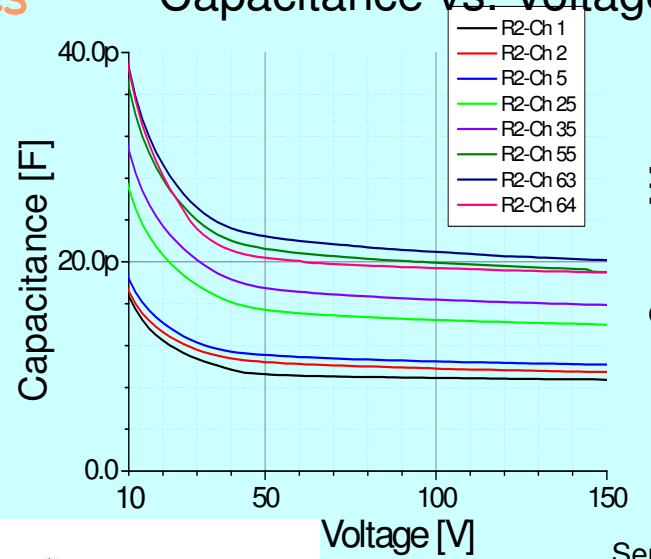
x-Size = 10,8cm
y-Size = 4…12cm
(6 Inch Wafers)

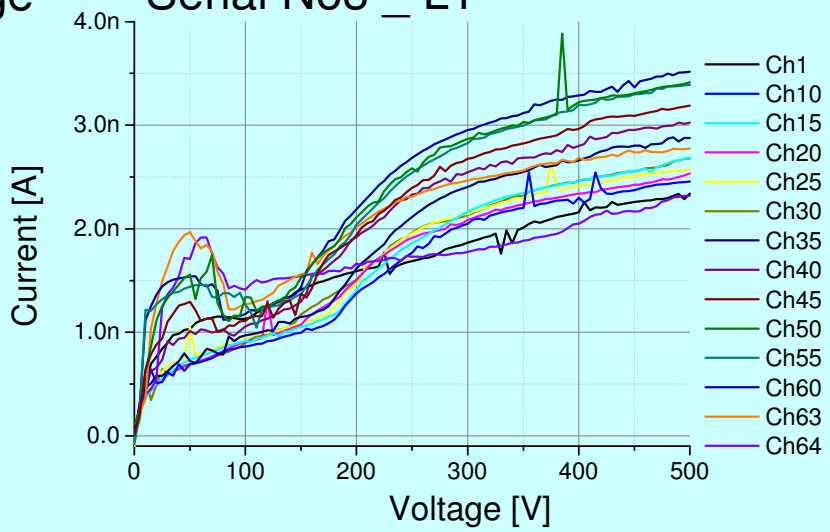
Hamamatsu
S10938-8380

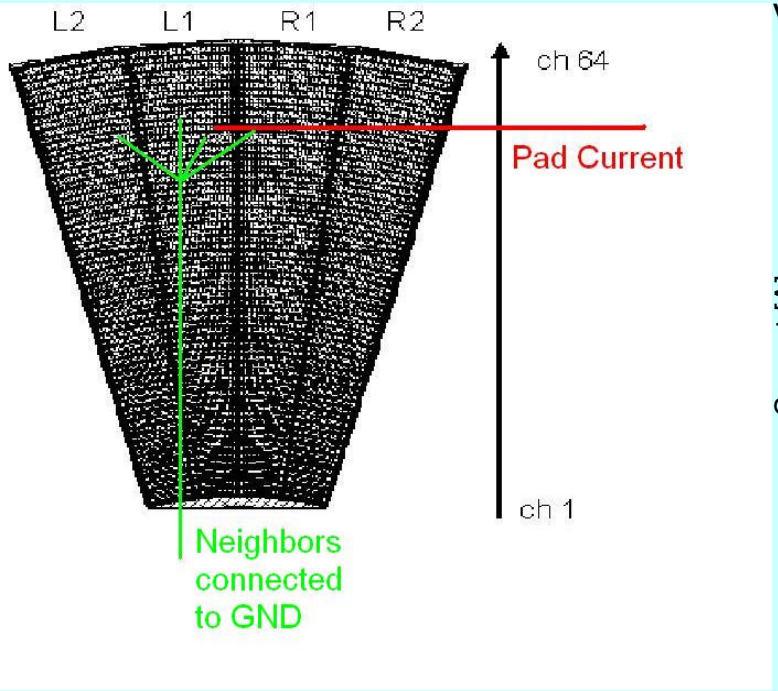


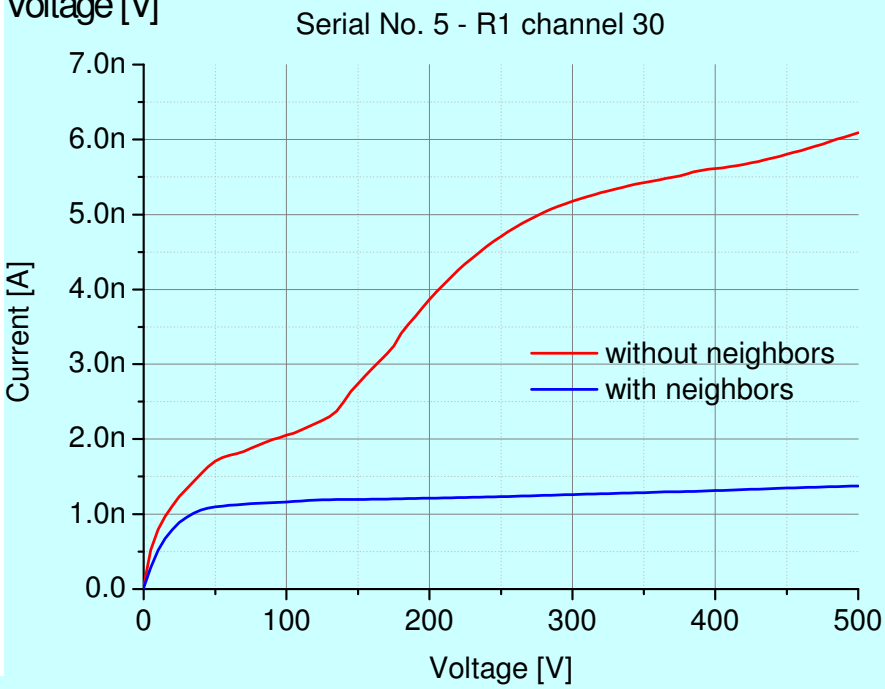

I(V) and C(V) measurements on Probe-stations in Tel Aviv, Cracow and DESY

# Sensor prototypes (LumiCal)

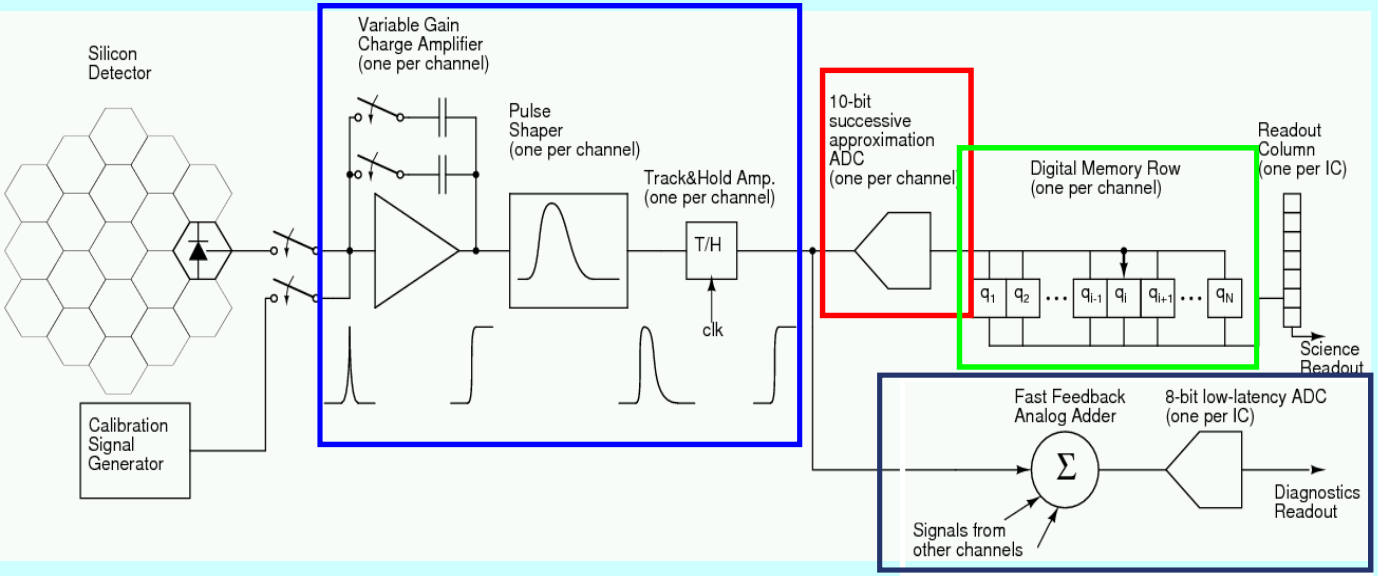


# ASIC development, BeamCal

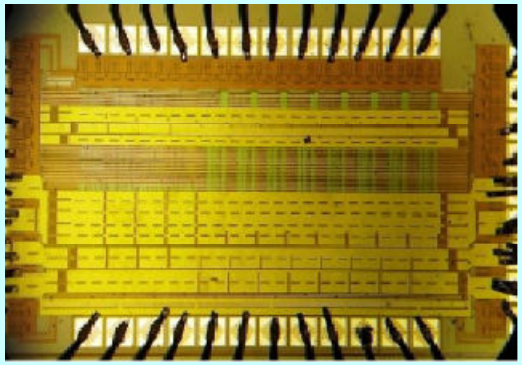


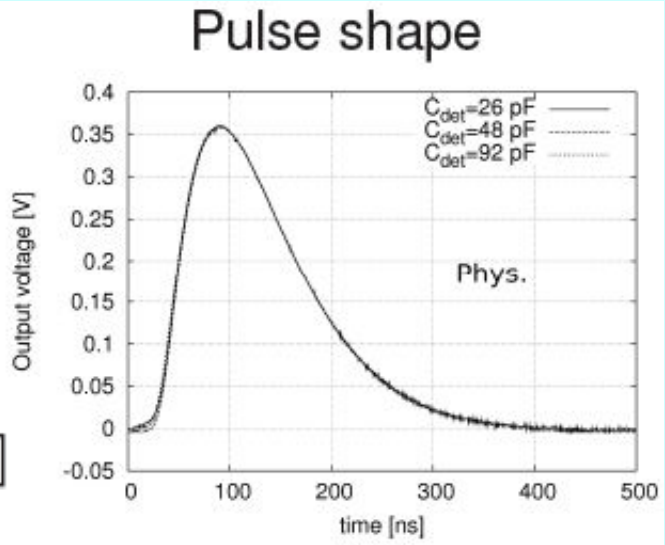

Design of a 32 channel prototype cuurently ongoing, First prototypes (smaller number of channels) will be ready in December

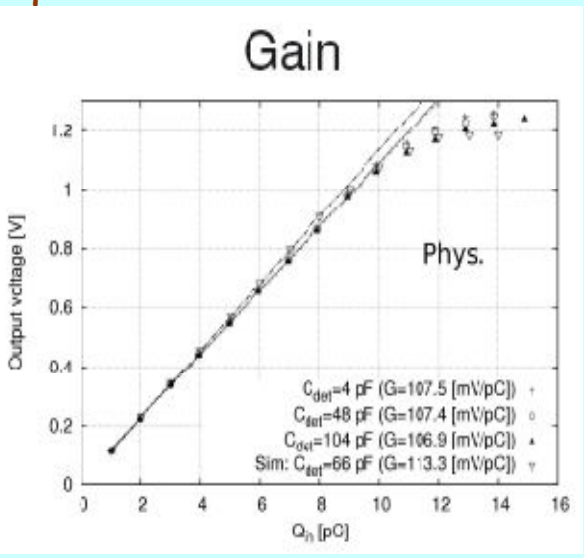
- Dual gain charge amplifier
  switchched capator filter
- ADC ASIC 10 bit successive approximation ADC (3.25 MS/s)
- Additional 8 bit low latency output (beam diagnostics

# ASIC development, LumiCal

8 channel preamplifier ASIC, lab tests, matches the requirements






- $\mathrm{Noise}_{phys}[aC] = 522 + 2.08 \cdot C_{in}[pF]$
- $\mathrm{Noise}_{cal}[aC] = 48 + 4.65 \cdot C_{in}[pF]$

**Power consumption per channel: 8.9 mW**

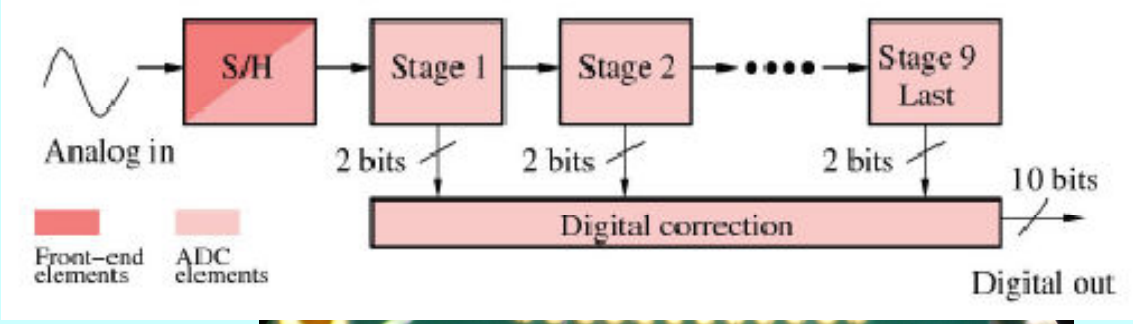
| Mode | Gain [mV/fC] | Noise@50pF [fC] | Linearity [pC] | Rate [MHz] | Crosstalk [%] |
|---|---|---|---|---|---|
| Physics | 0.107 | 0.62 | 10 | 3 | ≈1 |
| Calibration | ≈20 | 0.28 | 0.035 | 2.5 | ≈0.1 |

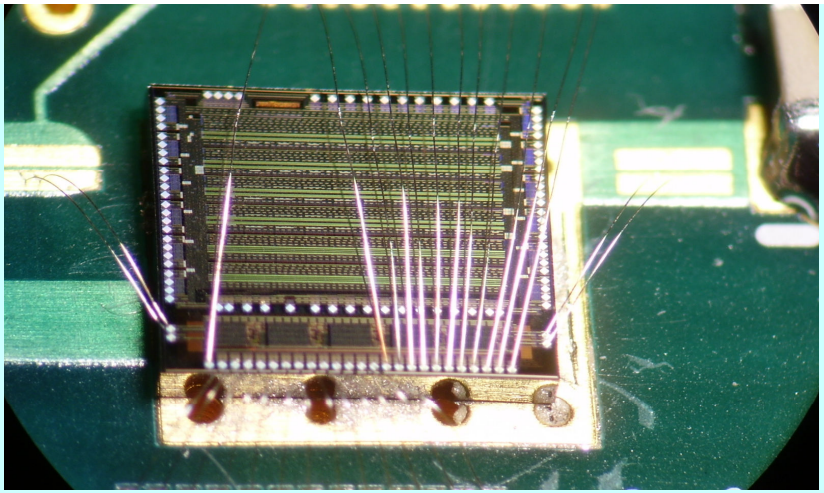
Ready for tests with sensors!

- PCB design for an assembly of ASIC and sensor
- Test in the lab and testbeam
- Redesign after these tests

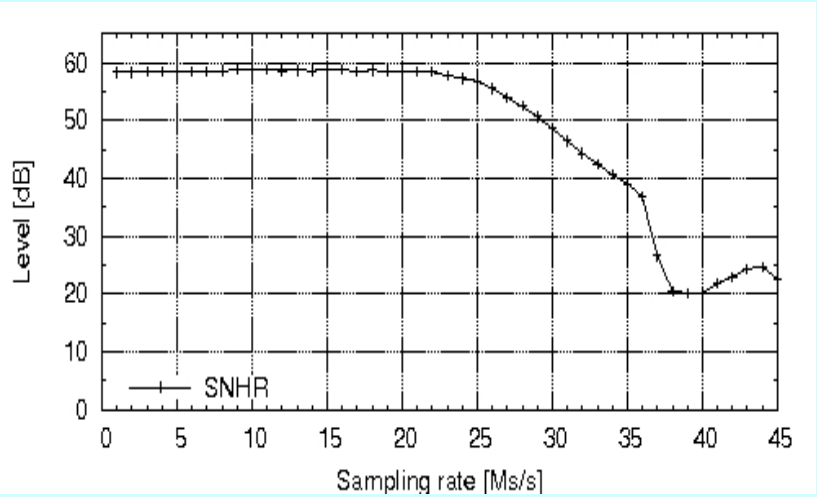
# ASIC development, LumiCal

One channel ADC ASIC (differential pipeline architecture)

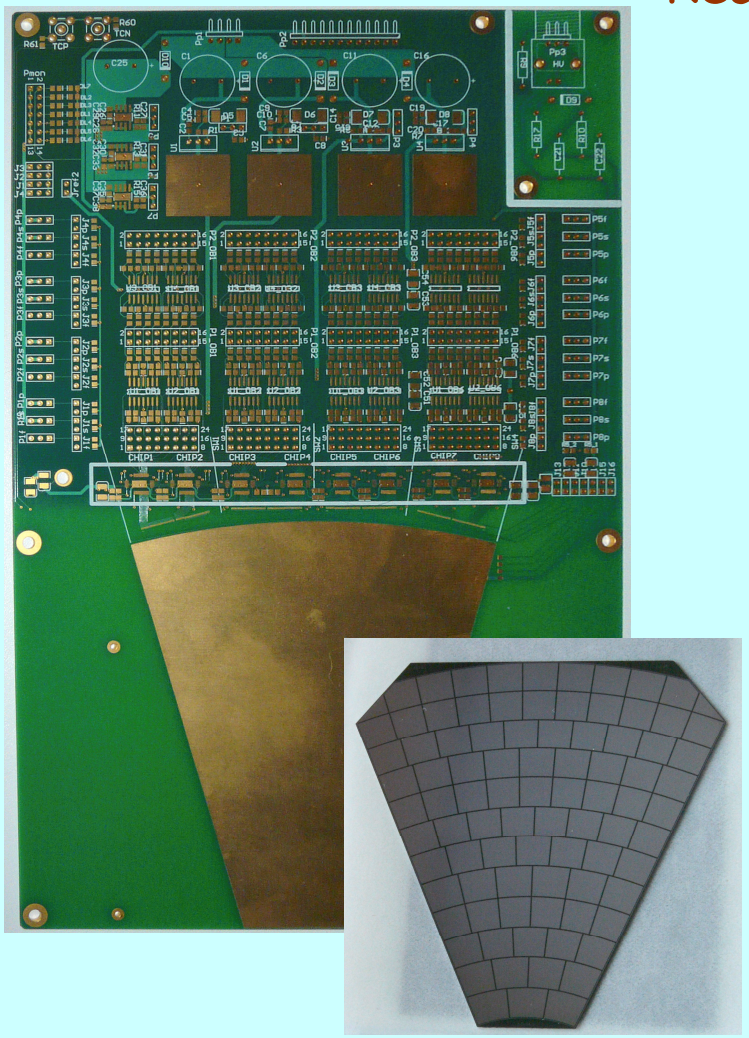


- New 10 bit ADC fully functional
- Stable operation up to 25 MHz
- Good static performance (DNL, INL, ENOB)
- Dynamic measurements just started
- Clock and power switching tests
- Preparation of a multichannel version



# System Test in a beam

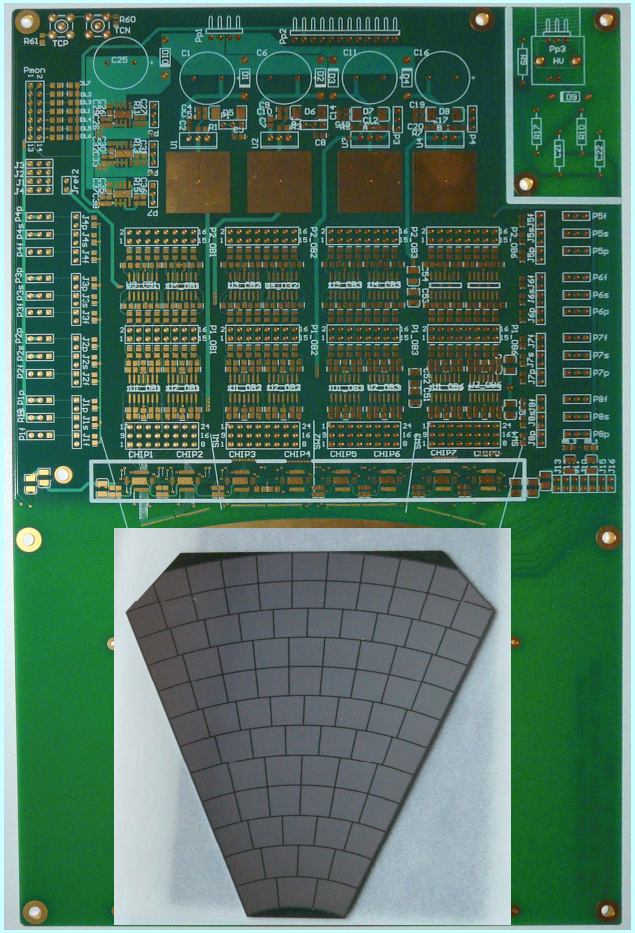


Template of a readout board, to be instrumented with FE ASICS

## Readout/Fanout of sensors

- fine pitch PCB, (100…200μm for a few channel FE chips)
- additional flexible PCM to be designed (matters of crosstalk & capacitive load)
- wire bonding or bump bonding to pads (wire bonding needs ~ 3mm gap between absorber tiles; conductive gluing also discussed)
- wire bonding to FE chip
- Silicon and GaAs sensor samples

# System Test in a beam



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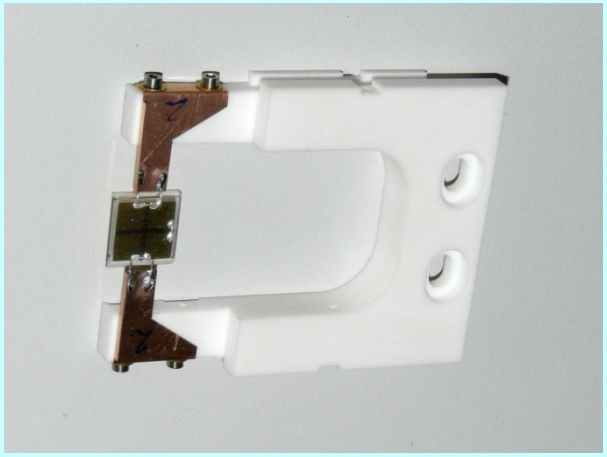
- wire bonding or bump bonding to pads (wire bonding needs ~ 3mm gap between absorber tiles; conductive glueing also discussed)
- wire bonding to FE chip
- Silicon and GaAs sensor samples
- Beam test planned 2010

# Test in PITZ

Electron beam, 14 MeV, bunches

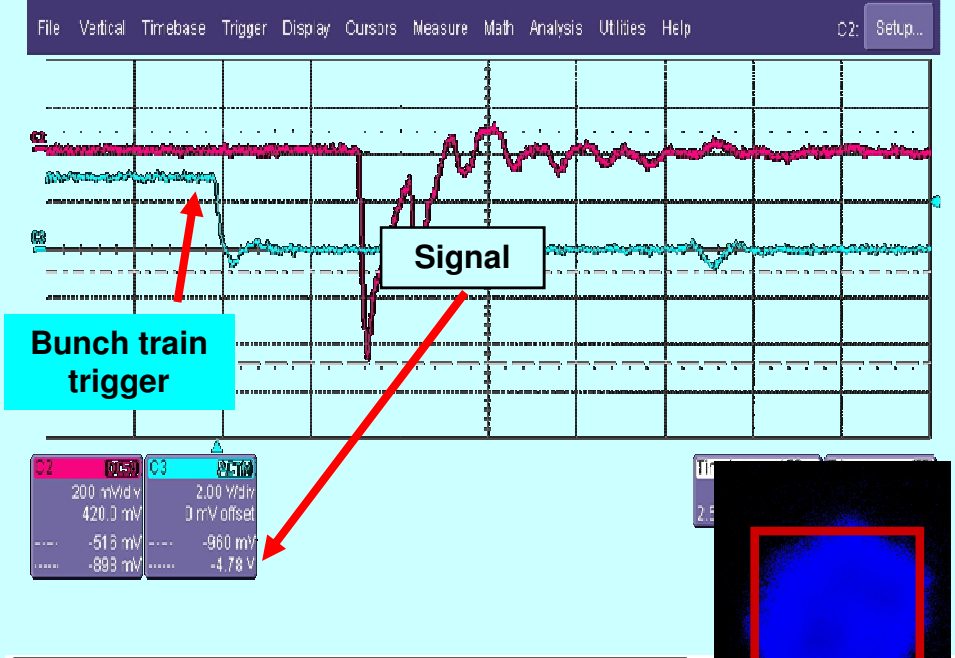
Diamond sensor was installed in the vacuum of the beam pipe

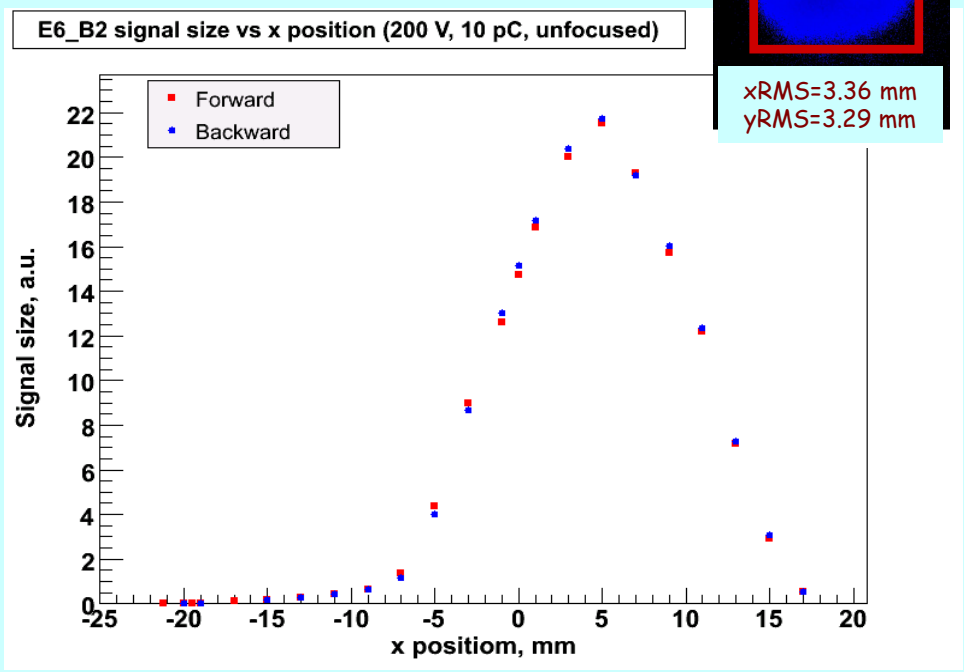


Moving the sensor through an electron beam,

Bunch charge: 1 pC to 1 nC
Beam spot: few mm²
Beam profile

EMI negligible !

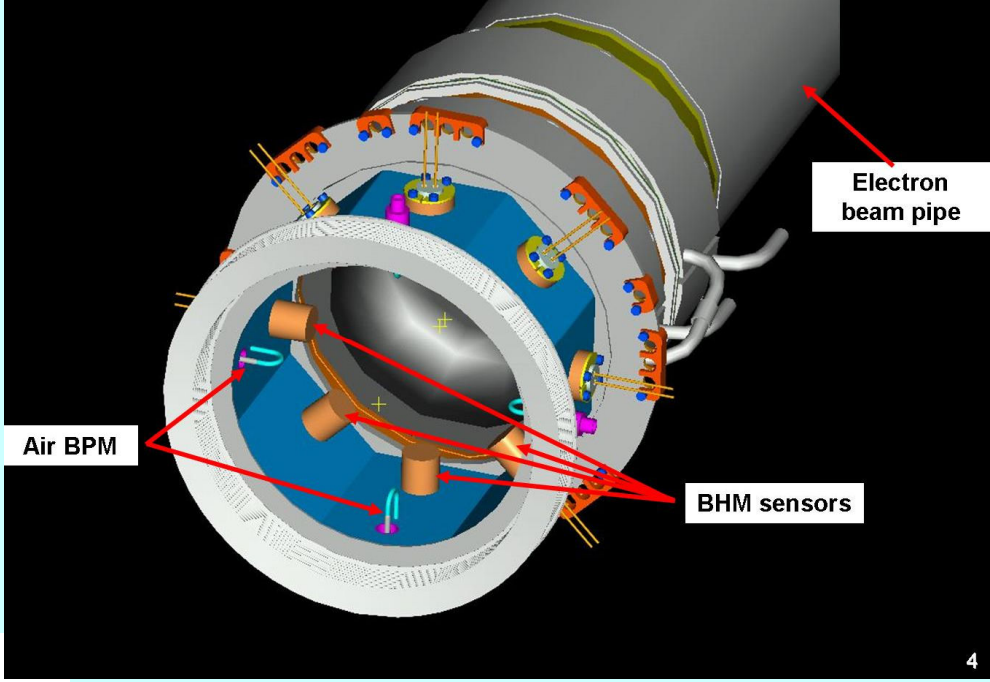


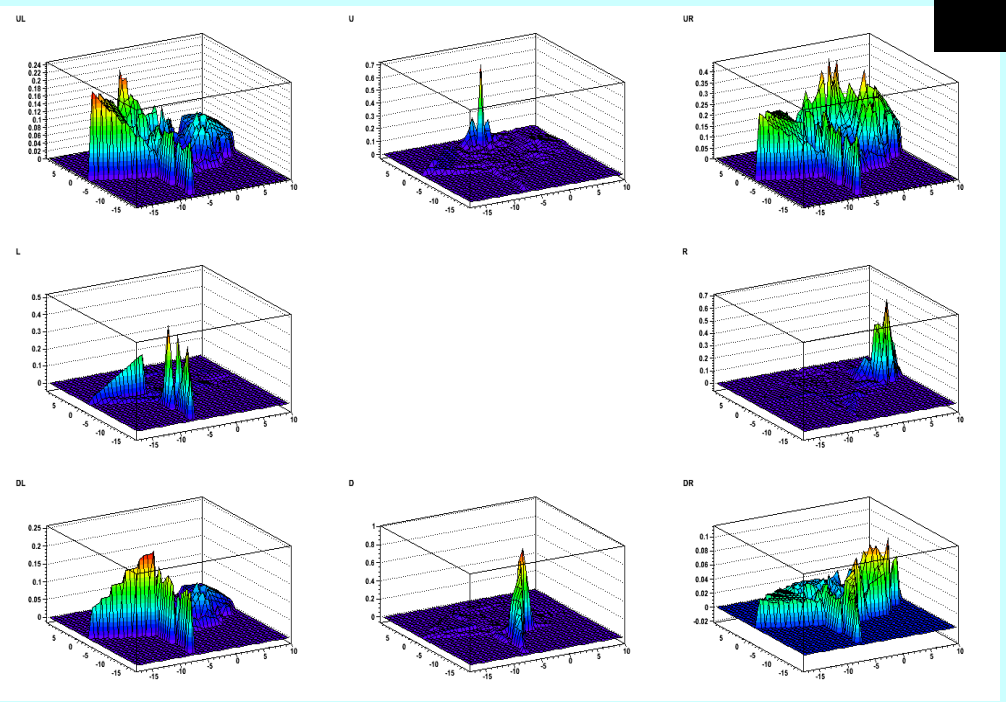



# Application at FLASH

FCAL designed, constructed and installed a Beam-Condition Monitor at FLASH (4 diamond and 4 sapphire sensors) BHM

Operation in the "9 mA" run of FLASH was successful



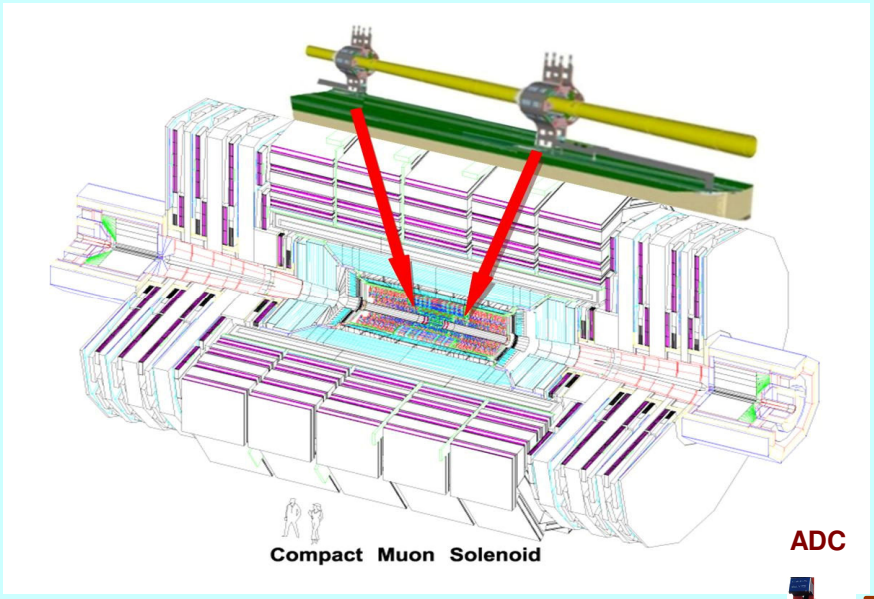



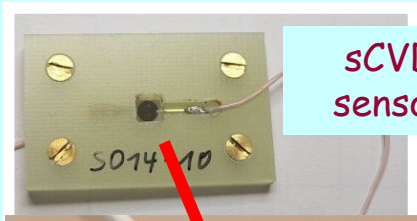

About one week of data taking In September 2009

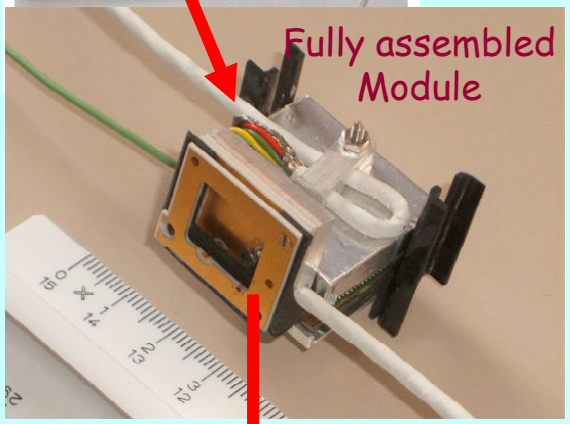
Analysis ongoing

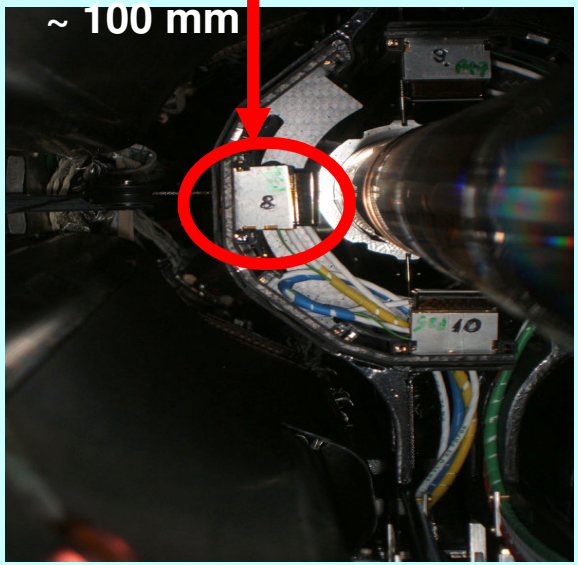
Preliminary results sweeping the beam

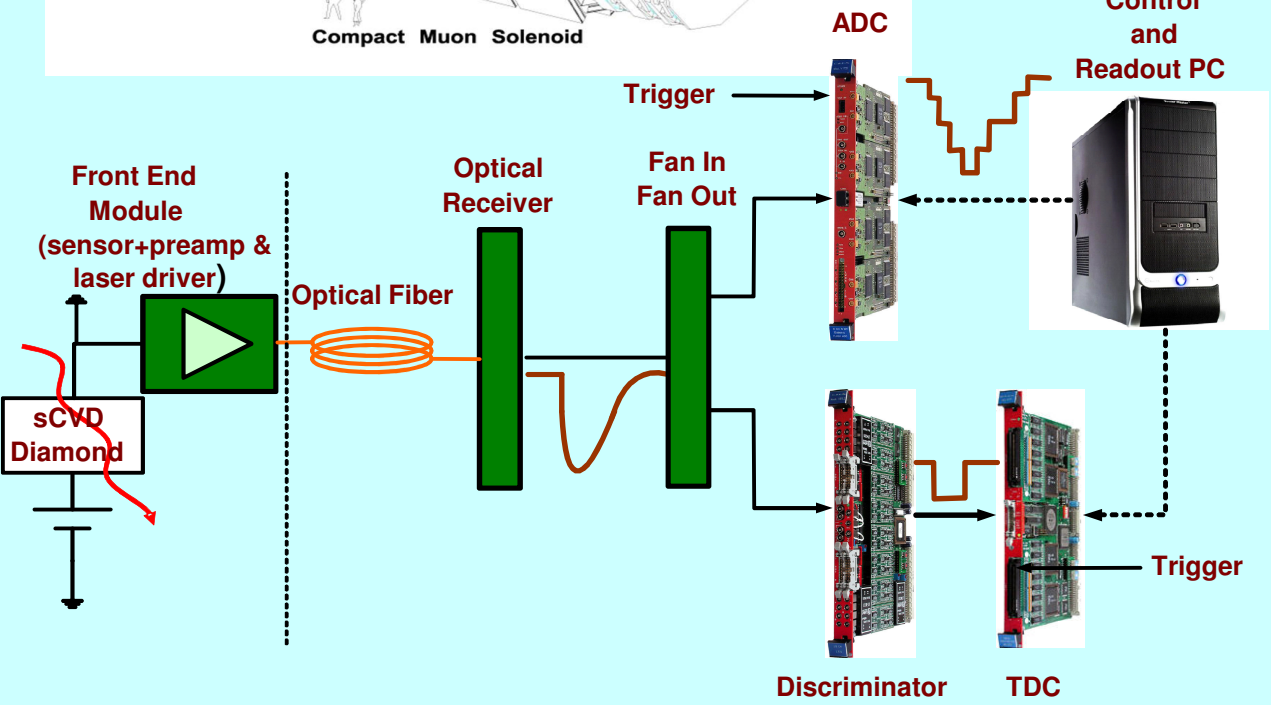
# Application at CMS: BCM1F



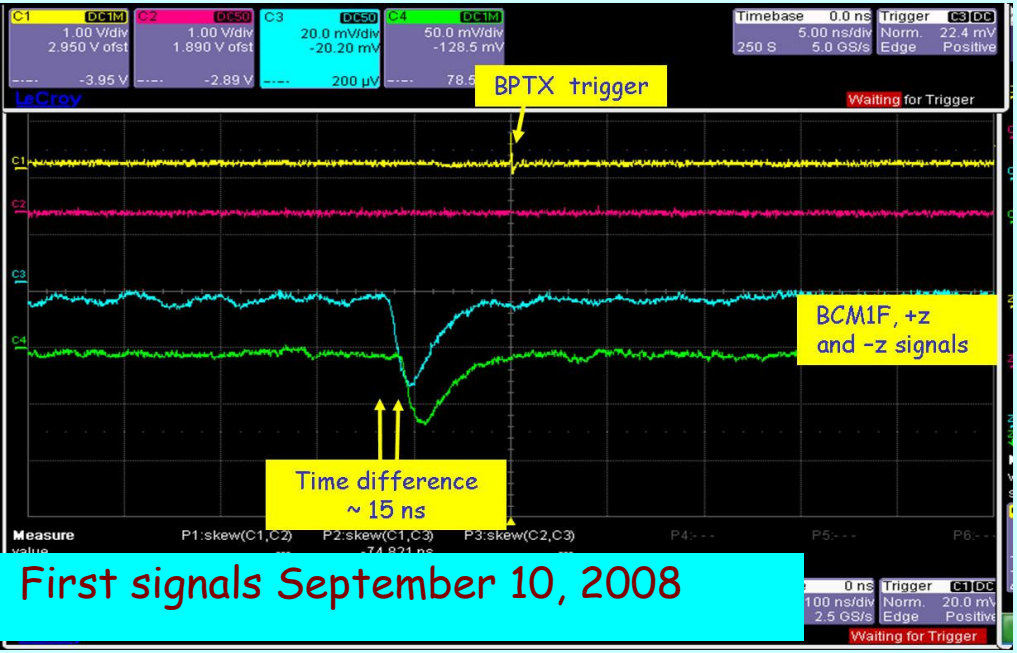



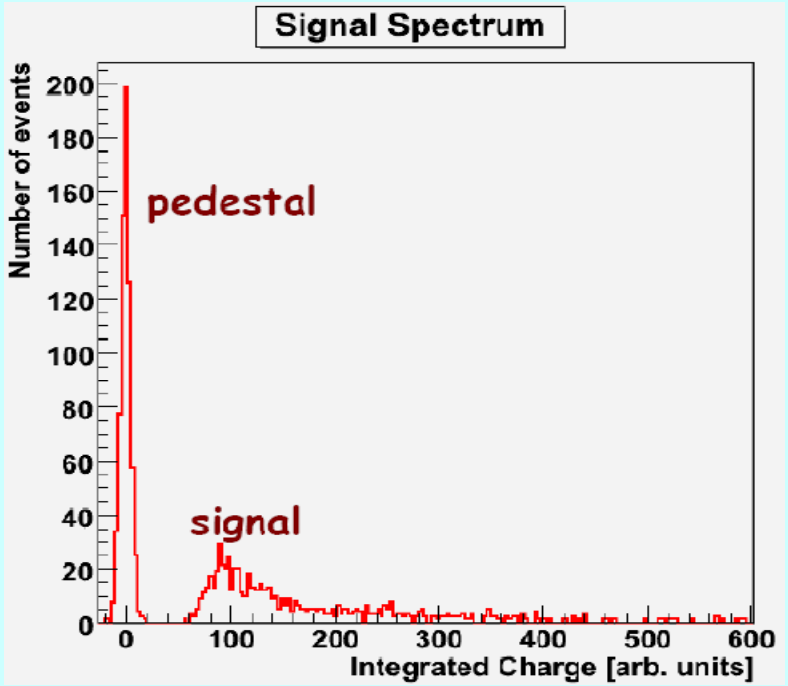



# Application at CMS: BCM1F

Data taken September , 2008

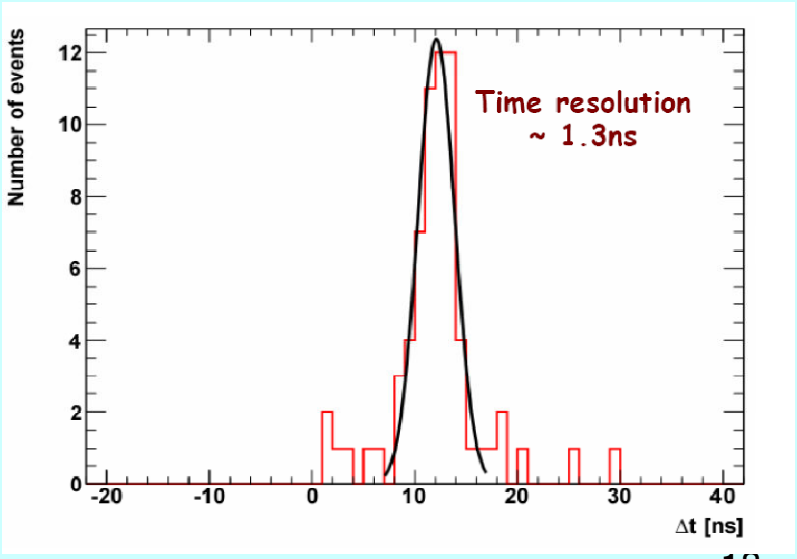



First signals September 10, 2008




Difference of the arrival time
in the two sensor planes

~ 12 ns  time of flight for 3.6 m



# Conclusions

- Investigation of the radiation hardness of GaAs, diamond and Sapphire up to 10 MGy. However, no baseline material for BeamCal sensors so far.
- Prototyping of Si sensors for Lumical successful.
- FE ASICS ready for test with sensors.
- System test in preparation.
- ADC ASICS – prototypes under test.
- First test of a diamond sensor in a bunched electron beam.
- Successful application of diamond sensors in CMS and FLASH.

# Backup

# BeamCal Sensors, Diamond

Study of the irradiated sensor in the lab using a $^{90}Sr$ β source