NSS Summary

Ingrid-Maria Gregor

IEEE

San Diego 2006

October 29 - November 4

Conference Program

Nuclear Science Symposium, Medical Imaging Conference and 15th International Room Temperature Semiconductor Detector Workshop

DESY Seminar
November 28th, 2006

Some Statistics

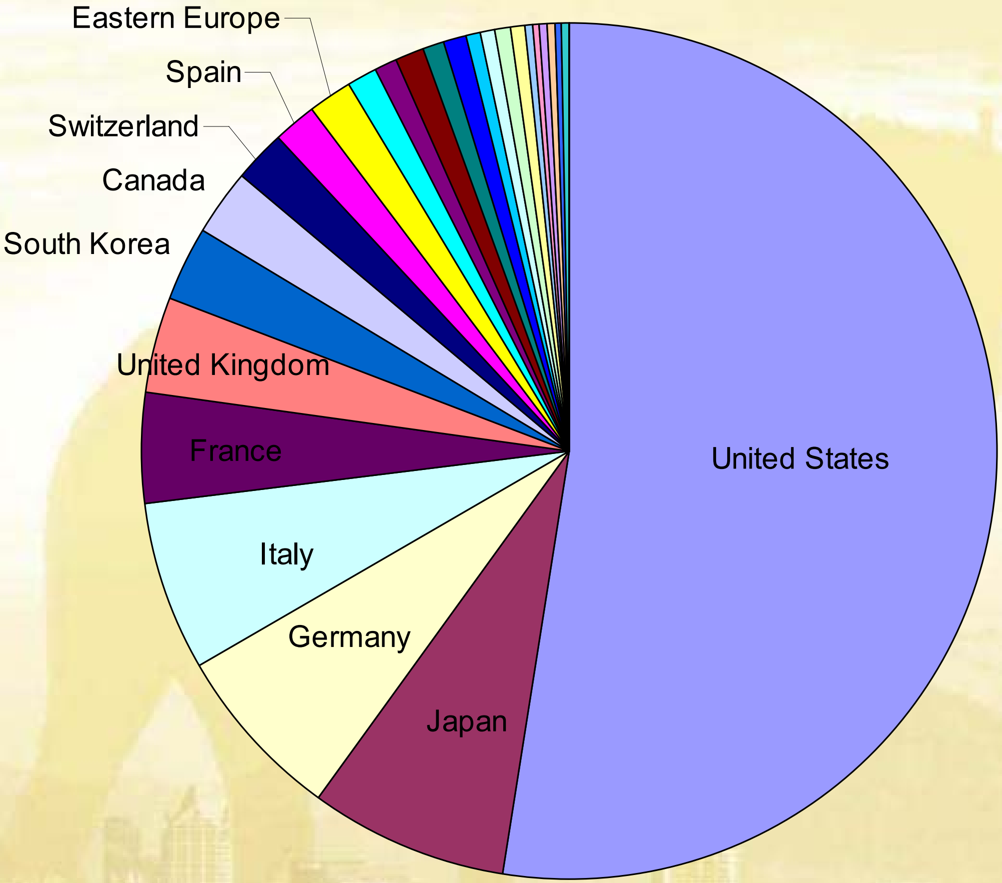
- NSS/MIC 2006: San Diego California Town&Country Resort
  - 2 Conferences with two days overlap
  - + 6 workshops
  - + 7 short courses
  - + RTSD (Room Temperature Semiconductor Detectors)
- NSS: **264 talks** (mostly parallel), **282 poster**
- MIC: 96 talks, 462 poster
- RTSD: 75 talks, 39 poster

- Workshops:
  - Third Workshop on the Nuclear Radiology of Breast Cancer
  - Micro-Pattern Gas Detectors: High Energy Physics and Beyond
  - Compton Scatter Imaging for Medicine, Astronomy and Industry
  - Innovative Techniques for Hadron Therapy
  - Bi-modality PET and MRI Workshop
  - GATE Workshop
- Short Courses:
  - Interaction of Radiation with Matter: Theory and Practice
  - Nuclear Science for Homeland Security
  - Integrated Circuit Front Ends for Nuclear Pulse Processing
  - Molecular Biology for Imaging Scientists
  - Detectors for PET and SPECT
  - Small Animal Imaging: Detectors and Technical Aspects
  - Image Quality

More Statistics

- 1572 attendees
- About 50% for NSS
- ~500 in plenary session
- 50-100 per parallel session

- 52% Americans
- 30% Europeans
- 12% Asia



General reception at pool: ~1000 people
(nobody fell into the pool)

Scientific Programme (NSS only)

N01 NSS Plenary
N02 Computing in HEP Experiments
N03 Detectors and El
N04 Gas Detectors I
N05 Photodetectors a
N06 Instrumentation
N07 Core Software T
N08 Data Acquisition
N09 Radiation Damag
N10 HEP & NP Instru
N11 Neutron Imaging
N12 Nuclear Measure
N13 Analog and Digit
N14 NSS Poster 1
N15 HEP & NP Instru
N16 Gas Detectors II
N17 Analog and Digit
N18 HEP & NP Instru
Detectors
N19 Synchrotron Rad
N20 Data Acquisition
N21 Astrophysics and
N22 Software for Rad
N23 HEP & NP Instru
N24 Gas Detectors II
N25 Analog and Digit
N26 Data Analysis an

N27 HEP & NP Instrumentation V: Detector Commissioning and Engineering Aspects
N28 Nuclear Measurements and Monitoring Techniques II
N29 Scintillators I - Plastics & Other Scintillators
N30 NSS Poster 2
N31 Software for Radiation Protection and Nuclear Medicine
N32 HEP & NP Instrumentation VI: Muon Detectors
N33 Trigger and Front End Systems
N34 Solid State Tracking Detectors
N35 Detector Software
N36 HEP & NP Instrumentation VII: Tracking Detectors and Neutrino Experiment Devices
N37 Scintillators II - Energy resolution - Radiation Damage
N38 Simulation: Physics Models and Validation
N39 Instrumentation for Medical and Biological Research
N40 Scintillators III - Composites - ZnO
N41 HEP & NP Instrumentation VIII: Particle ID Systems
N42 Photodetectors and Radiation Imaging II
N43 Scintillators IV - Lanthanide Scintillators - Light Yield - Time Response
N44 Astrophysics and Space Instrumentation II
N45 New Solid State Detectors
N46 HEP Software Systems

Pixel Detectors
LHC Experiments
ILC, SLHC, XFEL Devel.
Calorimetry
New Gas Detectors
Some fancy stuff

IEEE
San Diego 2006
Conference Program
October 29 - Nove

Nuclear Science Symposium

Medical Imaging Conference

15th International Workshop on
Room-Temperature Semiconductor
X- and Gamma-Ray Detectors

Special Focus Workshops

Town and Country Resort
& Convention Center

San Diego CA, USA

www.nss-mic.org/2006

IEEE

Overall Impressions

- Most talks (not all) are very detailed and well prepared
- LHC Experiments, ATLAS and CMS, are close to completion
  - Less “hardware” talks than previous years (obvious reasons)
  - Talks more in the direction of track simulation, data analysis and GRID
- SLHC developments are starting but very premature
- ILC is starting up, very nice results were presented
  - Pixel detectors, TPC developments, diamonds
- XFEL: one overview talk (Strueder, MPI) -> H. Graafma Oct. 10th
- Astrophysics: similar trends as in HEP detector development
  - Use of GEMS, Micromegas, smaller CMOS processes
- Electronics:
  - noise measurement and technology characterisation of 90nm and 130nm processes were presented

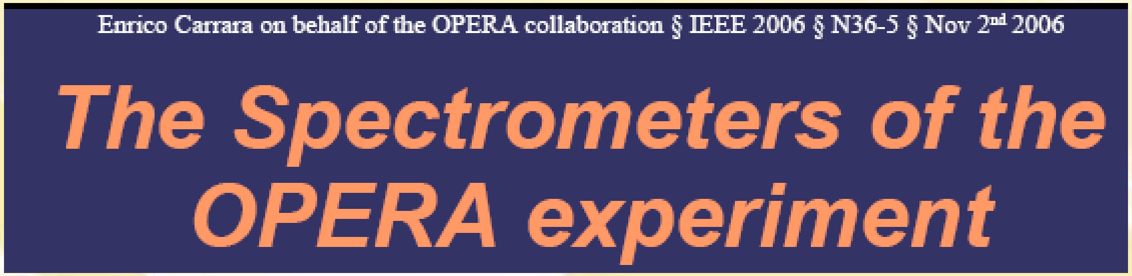
Gran Sasso

2 talks

First Results from Gran Sasso

CERN Neutrinos to Gran Sasso, CNGS:
Commissioning
and
First Operation

Edda Gschwendtner
CERN
on behalf of the CNGS project and commissioning teams

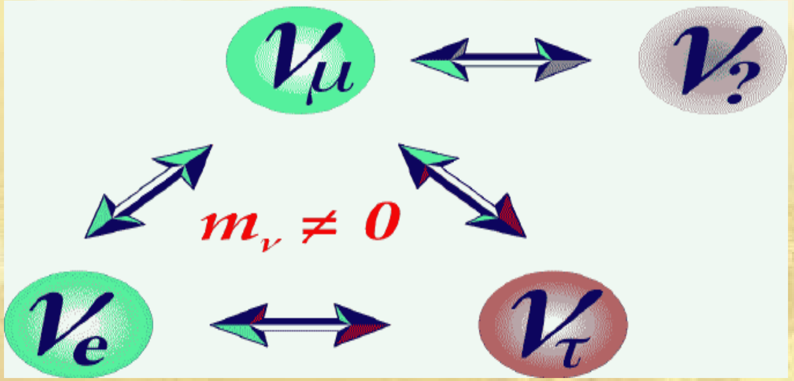


Enrico Carrara on behalf of the OPERA collaboration § IEEE 2006 § N36-5 § Nov 2nd 2006

The Spectrometers of the OPERA experiment

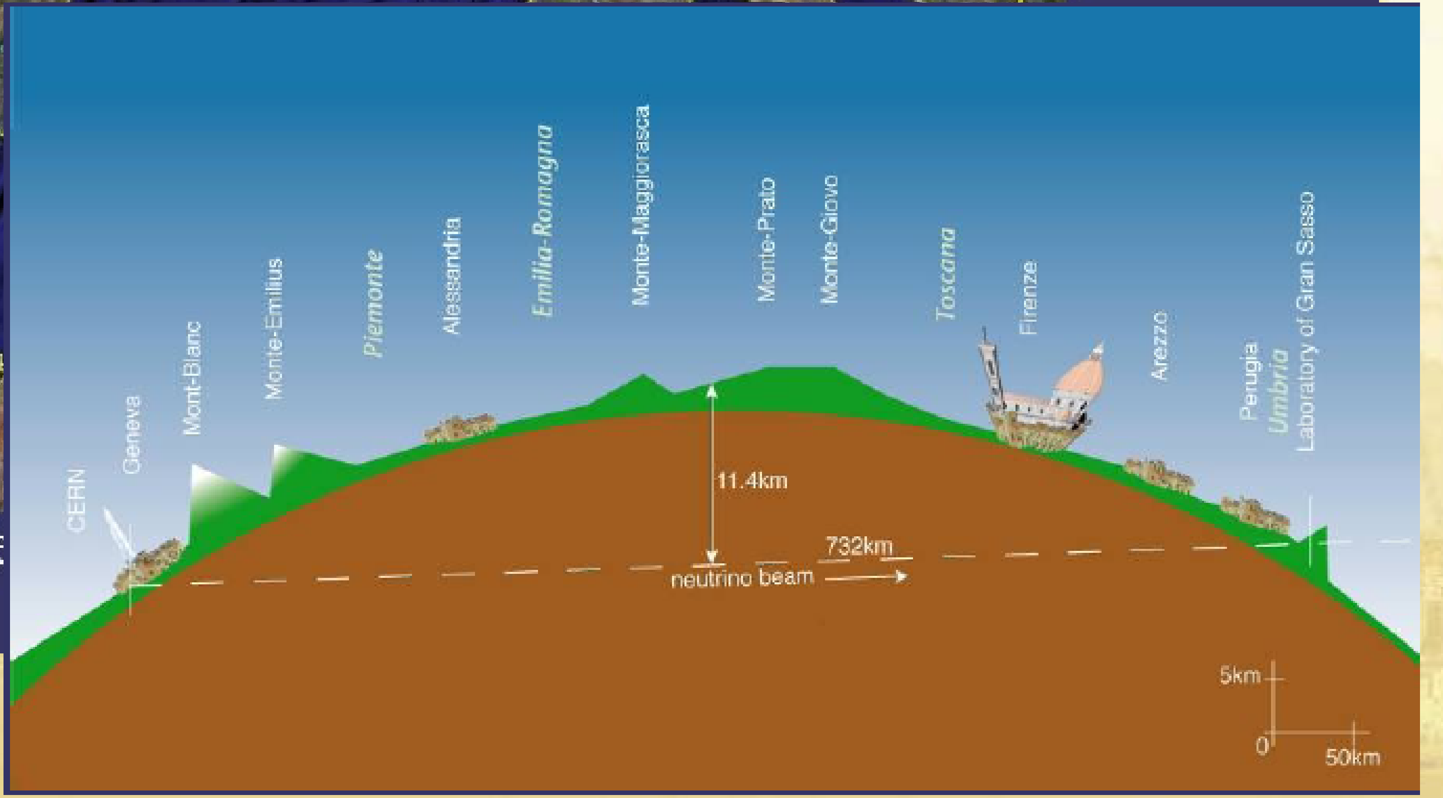
Neutrinos are massless in the Standard Model

- Many experiments on both solar and atmospheric neutrinos proved they oscillate from one kind (flavor) to another
- All these experiments (SuperKamiokande, SNO, MACRO, CHOOZ, etc.) observed disappearance of one kind of neutrino
- CNGS-OPERA is expecting to test for the first time the appearance of neutrinos of different flavor



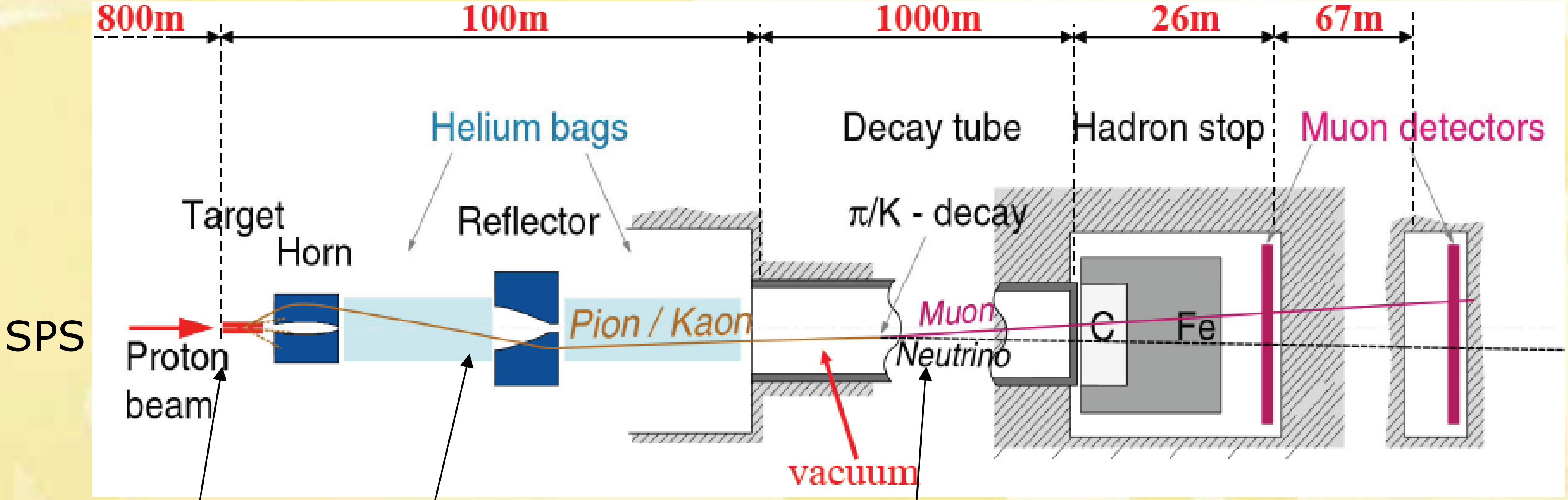
Location of Gran Sasso

Neutrino beam produce



CERN Neutrinos at Gran Sasso (CNGS)

Neutrino beam facility at CERN



Production of pions and kaons

energy-selected and guided

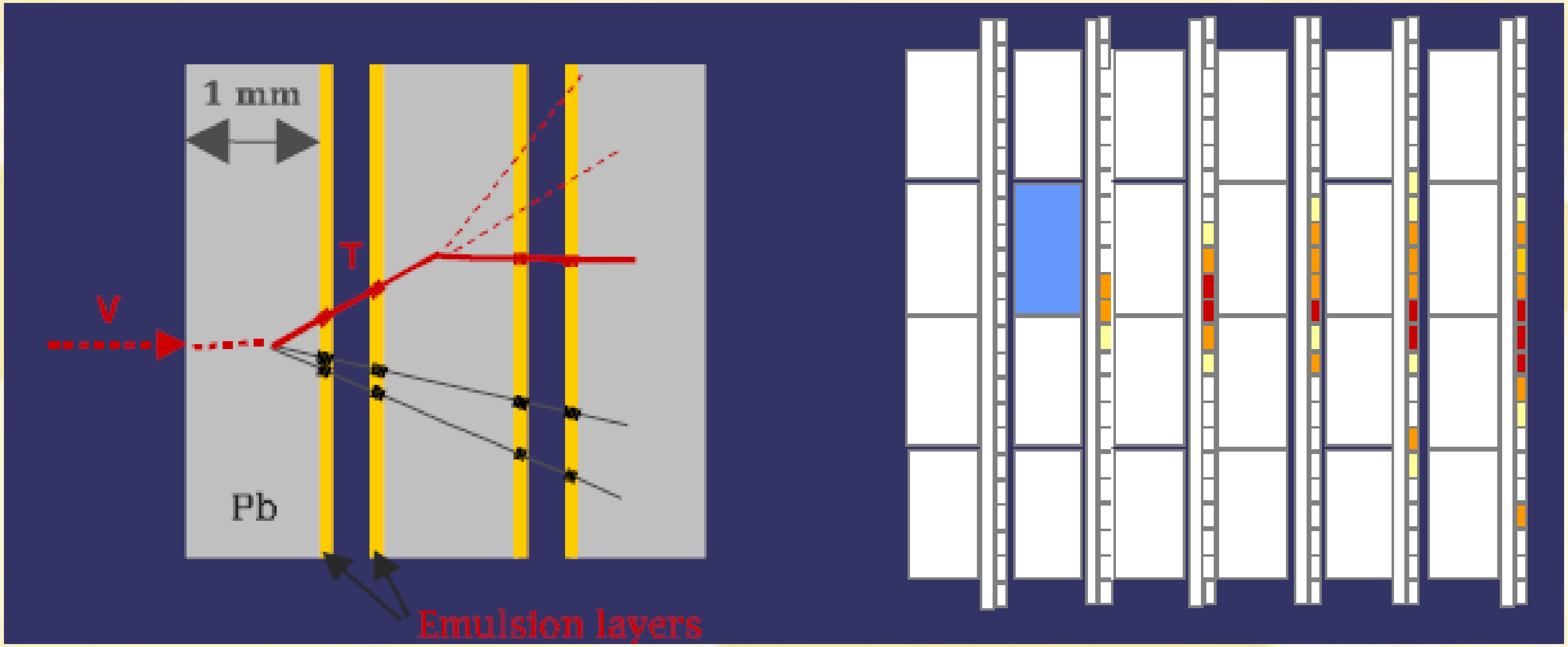
decay into muon-neutrinos and muons

$$p + C \rightarrow \text{(interactions)} \rightarrow \pi^+,\ K^+ \rightarrow \text{(decay in flight)} \rightarrow \mu^+ + \nu_\mu$$

CNGS Target Magazin

- Target unit consists of 13 graphite rods, each 10cm long, 4mm thin
- Five units are assembled, one unit is used, four spares

OPERA – the target

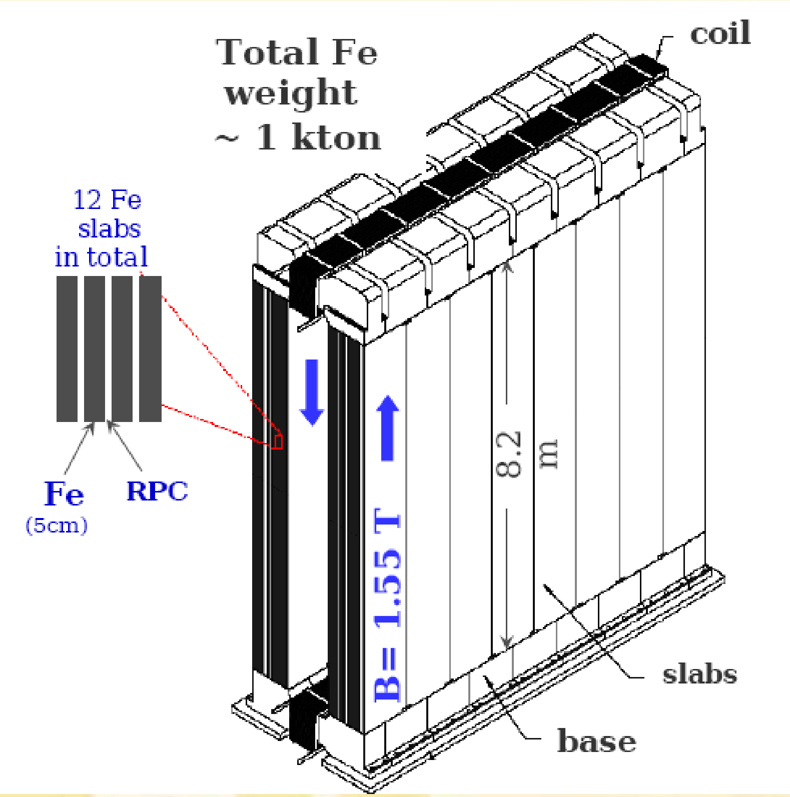


- Tau-Neutrinos identified through their charged current interaction
- Lead has a high Z and is a good target for interaction.
- Desired resolution in $\Delta m^2 = O(10^{-3}$ eV) requires a target mass of 2kt.-
- Brick walls are followed by 5900 m^2 of scintillator strips, for neutrino interaction trigger and brick localization

OPERA – the spectrometer

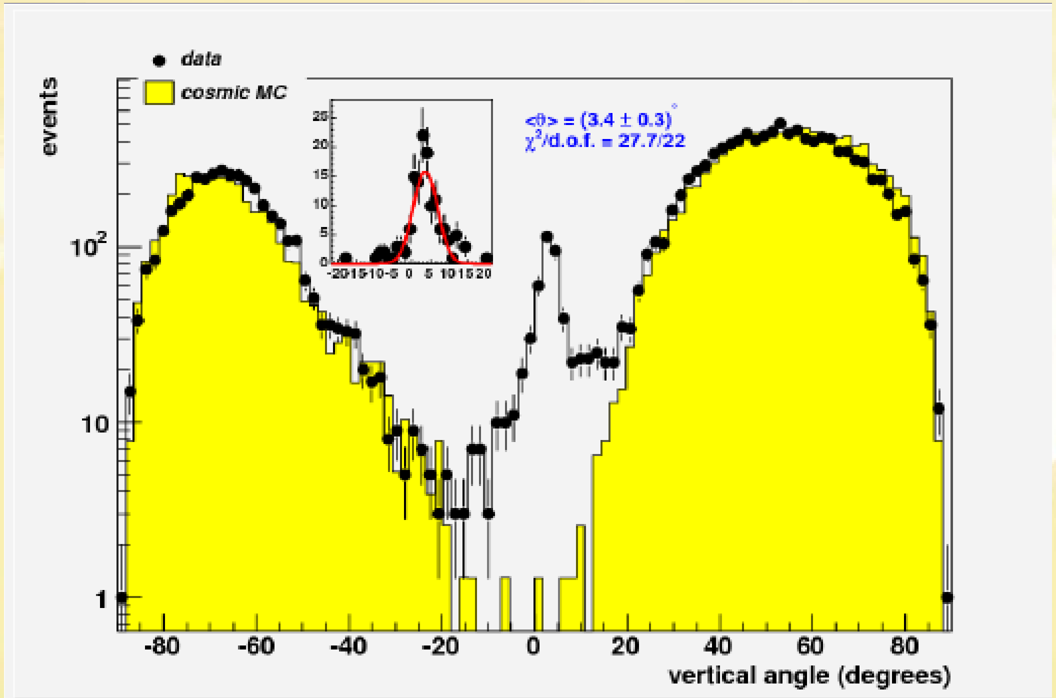
OPERA: General layout

- OPERA is a hybrid detector built in the GranSasso underground laboratories. Under 1400m of rock (3.7 km w.e.)
- It is composed of two supermodules, each of them consists of a target ECC and a magnetic spectrometer



- Each dipole magnetic spectrometer of OPERA consists of 462 RPCs (Resistive Plate Chambers)
- Total coverage of 3326m^2
- Spatial resolution ~1cm on single hit
- Aim is muon identification and momentum measurement

Results from August 2006 run



- Muon distribution on zenith angle in data and MC.
- Horizontal tracks come from beam neutrinos.

- 319 on-time events have been recorded and classified on August run
- Ultra-high purity is achieved thank to low background environment and time structure of the beam spills
- Spectrometers operated with >95% up-time its first long run

- Expected number of tau-neutrinos: 1-2 per year

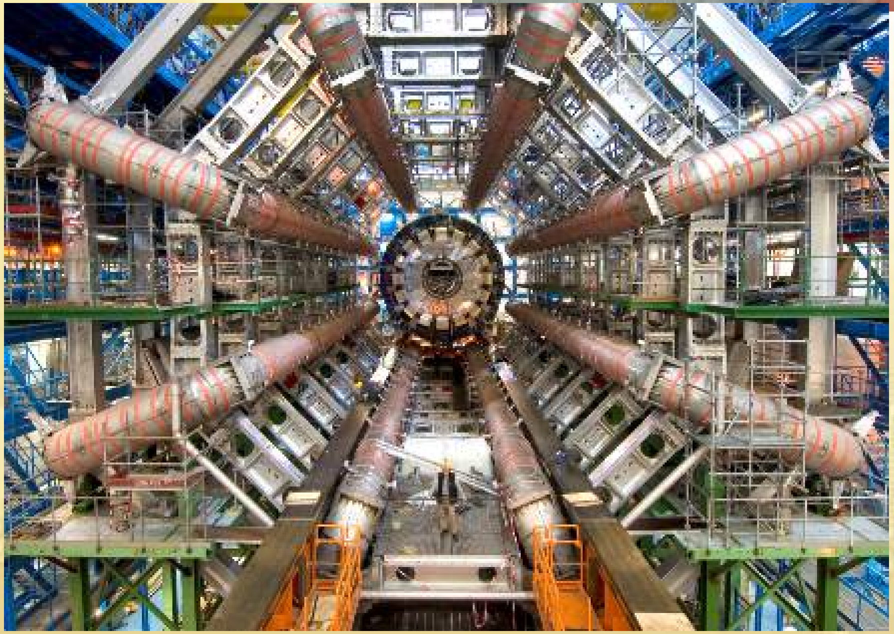
See article in current CERN Courier

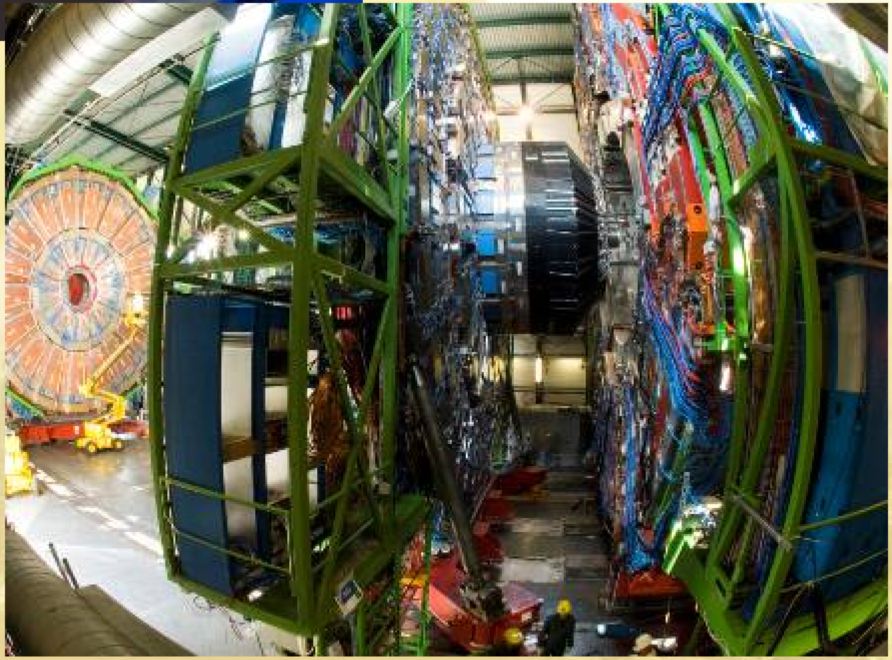
LHC Experiments

ATLAS: 34 records
CMS: 21 records
LHC-B: 1
Alice: 5
LHC general: 19

LHC gets ready …

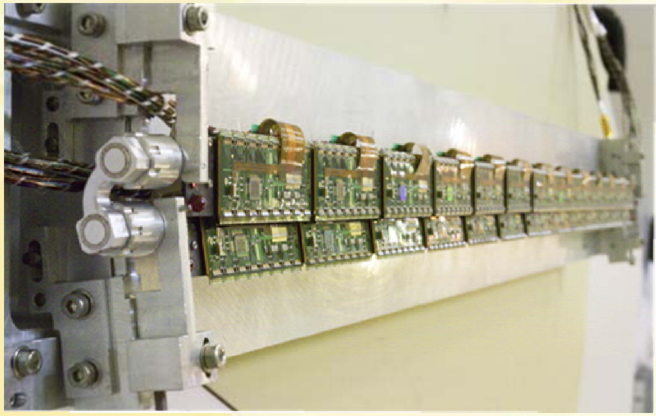
CERN press release TODAY:
CERN took delivery of the last superconducting main magnet for the LHC on 27 November

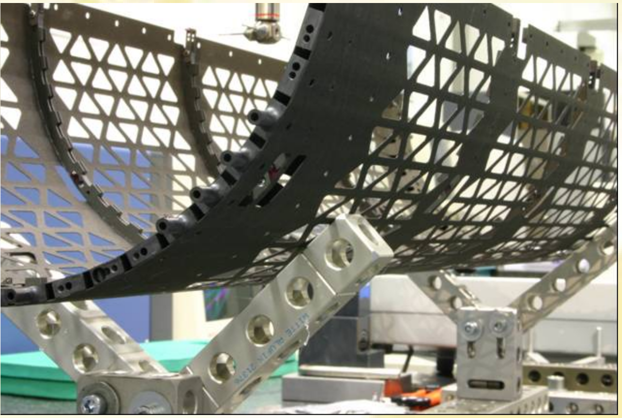


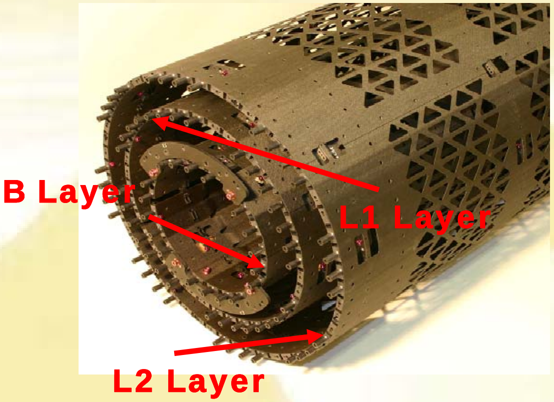


ATLAS Pixel Overview

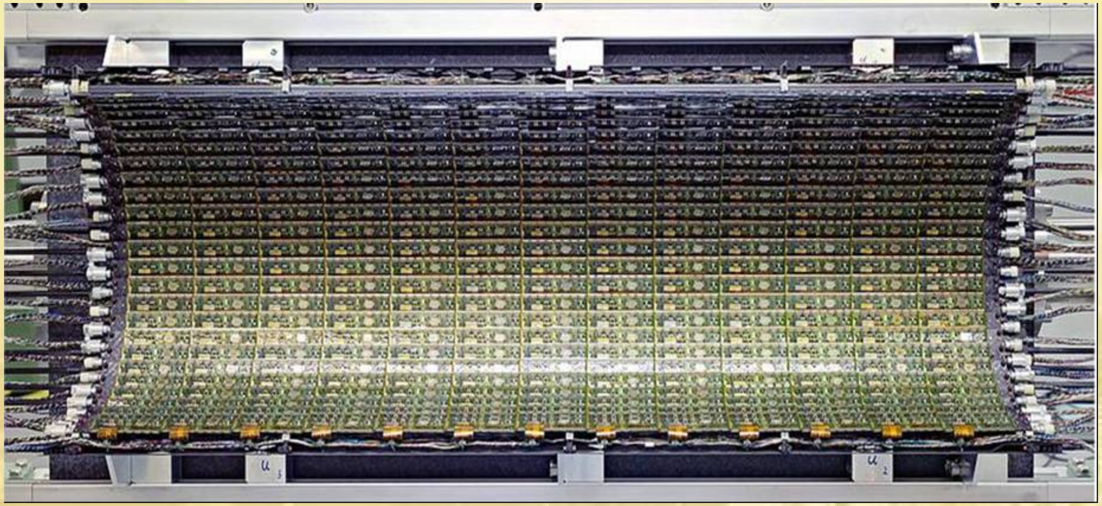
Carbon-carbon support structures: bi-stave (26 modules) → half shell → Barrel layer



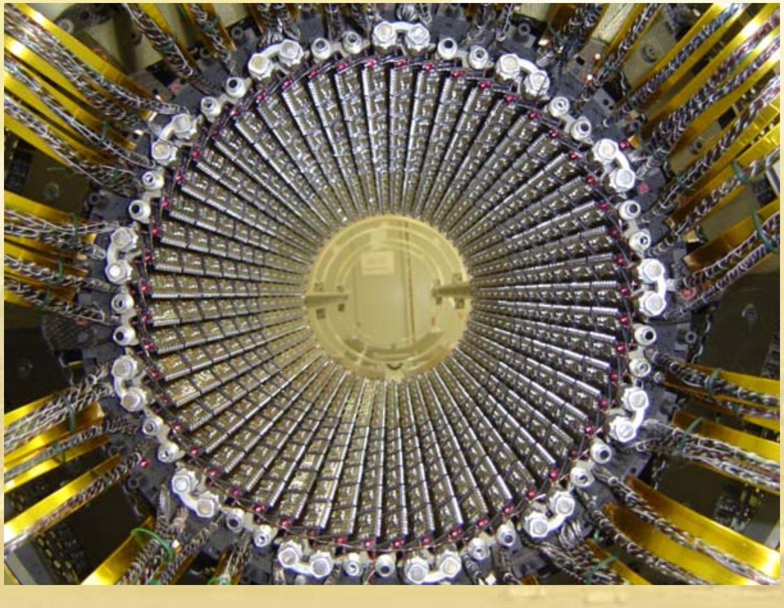




Load bi-staves into half-shells…

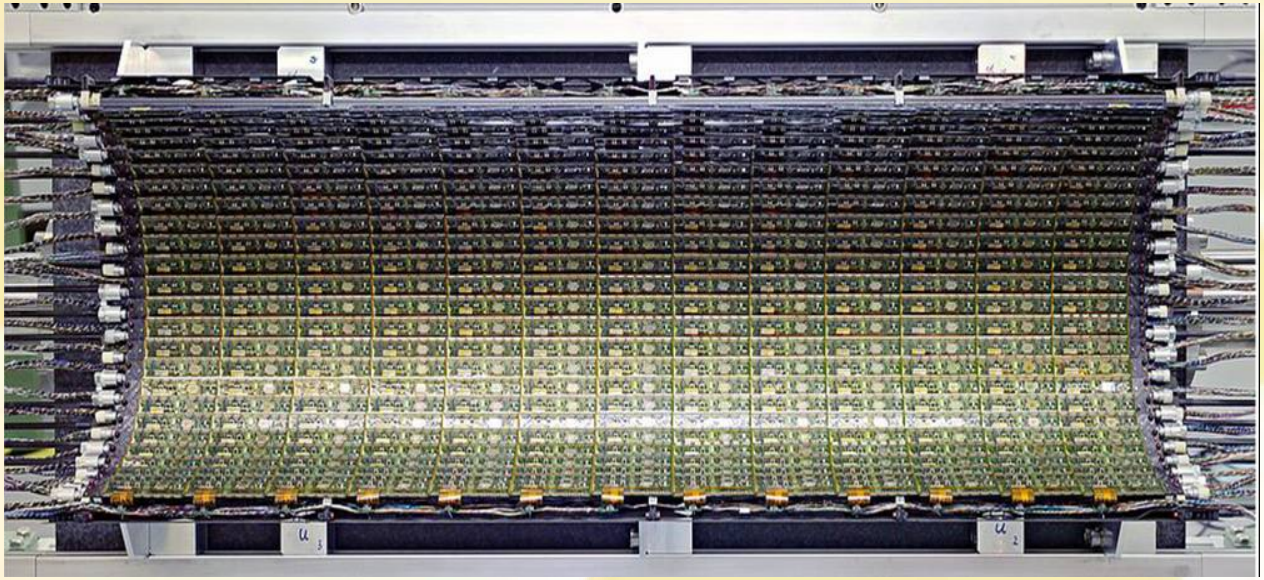


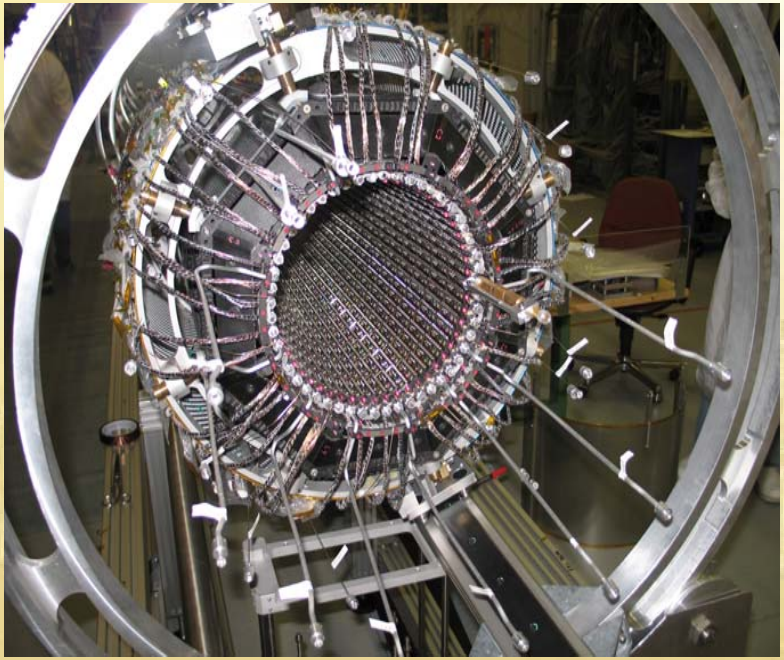
Clamp half-shells together.



Kendall Reeves
University of Wuppertal

First Barrels: L2 and L1





- Production activities for modules and read out electronics now complete
- Loading of staves and sectors complete
- Both end caps, A and C, complete and at CERN
- Barrel layers L1 and L2 completed at CERN
- B-layer expected to be completed by end of November
- Large scale test, ~10% of detector, under preparation at CERN

Preparations: Detector Installation

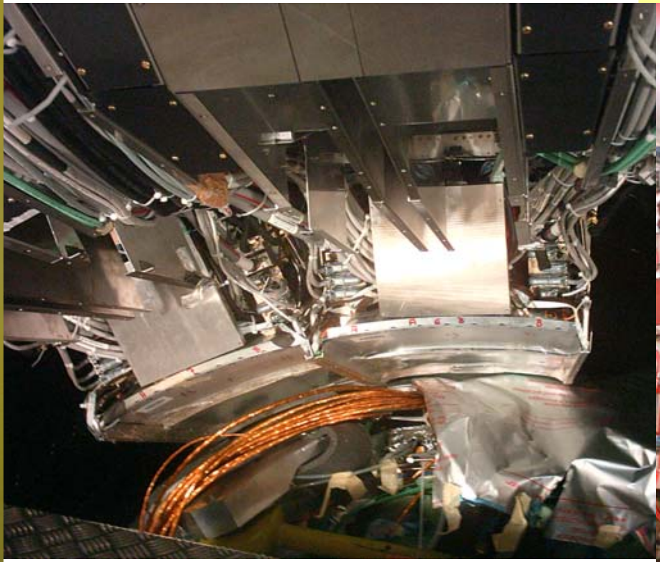

HCAL Insertion

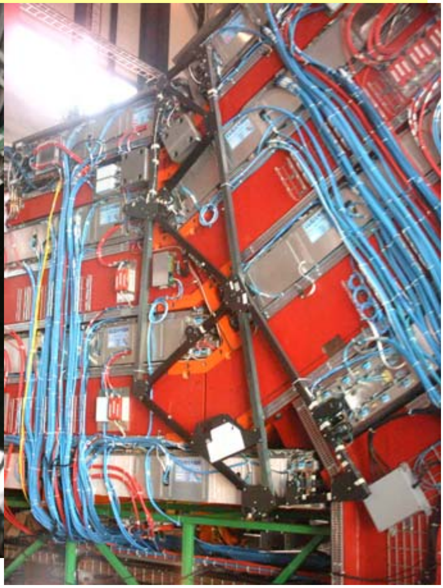

2 ECAL Super-Modules


Muon Chambers


Field Mapper

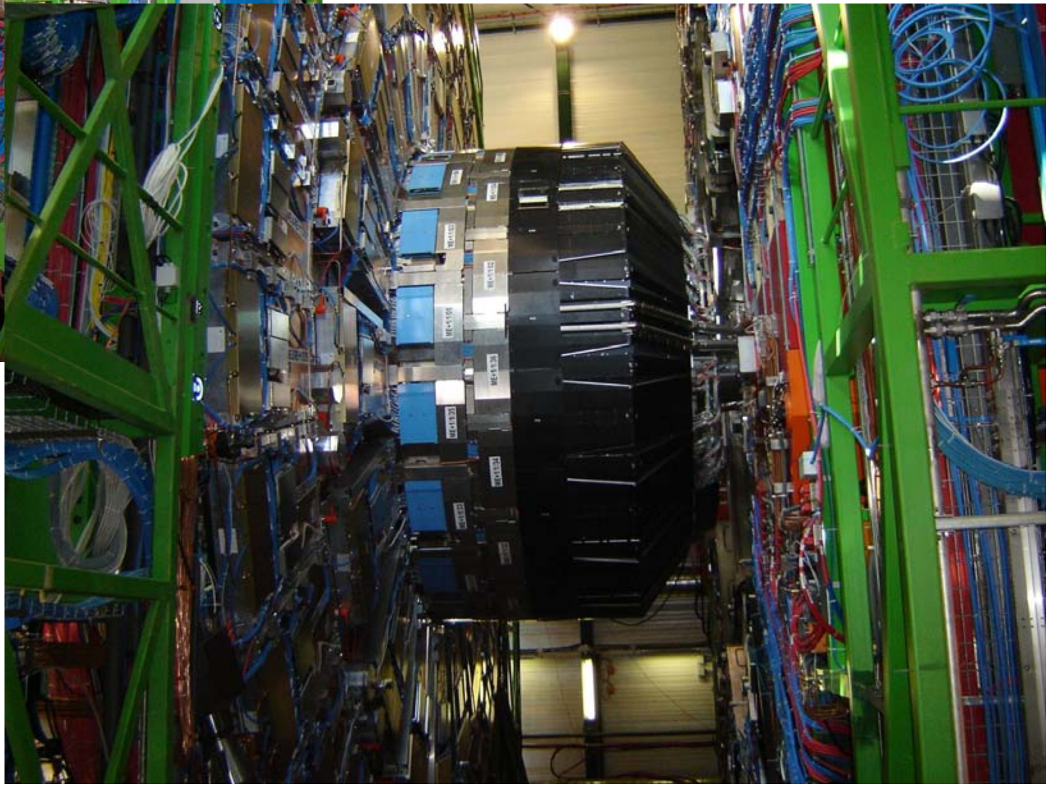
Tracker Insertion





Opening & Closing Procedures

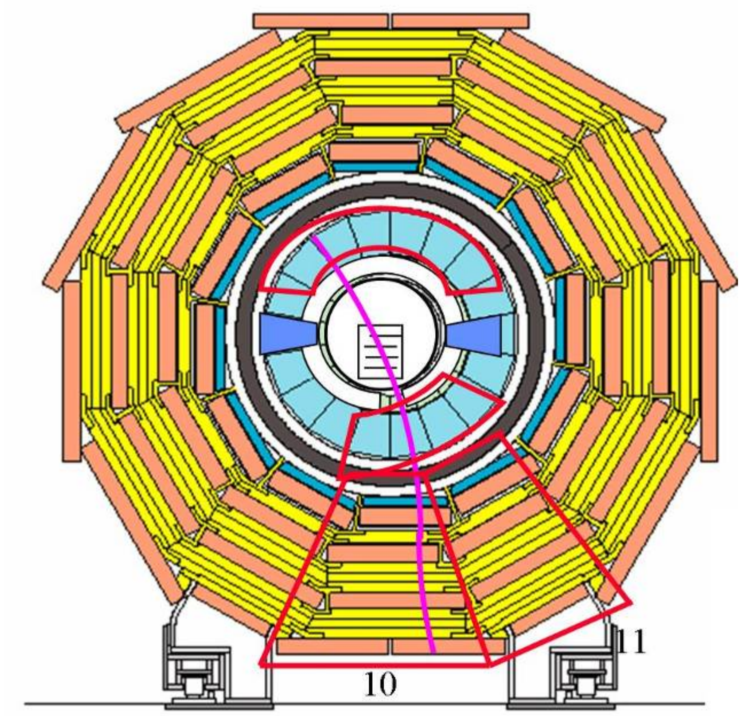
Closing and opening of the barrel & endcap yokes



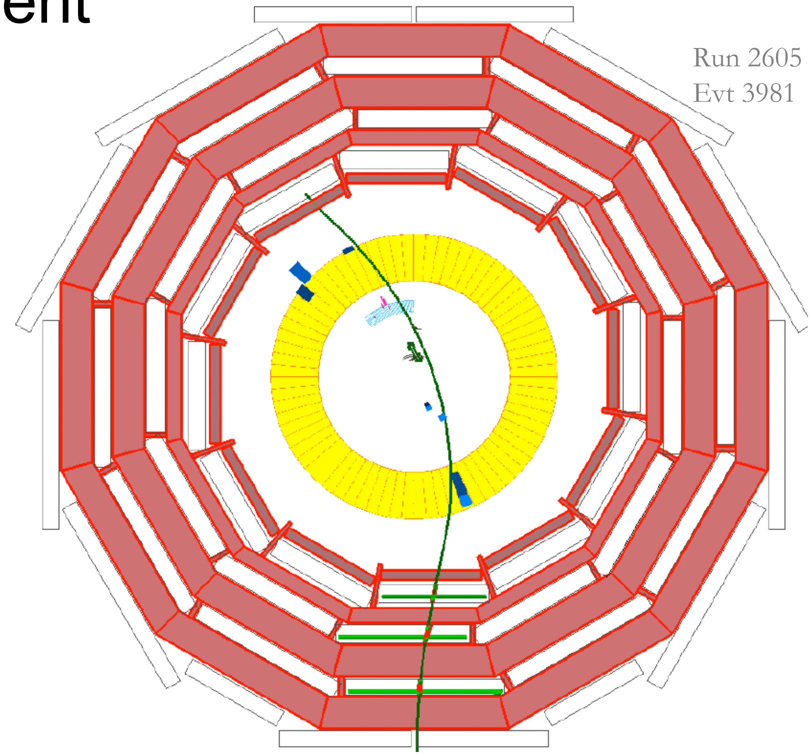
Air pads used to move the 5 barrel & 6 endcap elements of CMS

Cosmic Challenge Goals

- Integration of sub-detectors with central systems
  - Central DAQ and trigger systems
  - Synchronization of triggers and readout
  - Combined data taking and reconstruction
- Long-term stability, exercise of start-up procedures
- Detectors, electronics, power supplies in magnetic (fringe) field
- Alignment system vs. track alignment



Plan as of June 2004

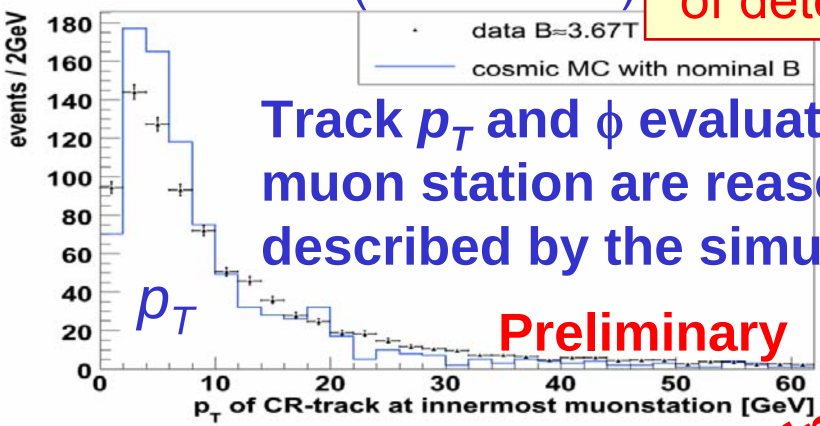


Reconstructed muon track in August 2006

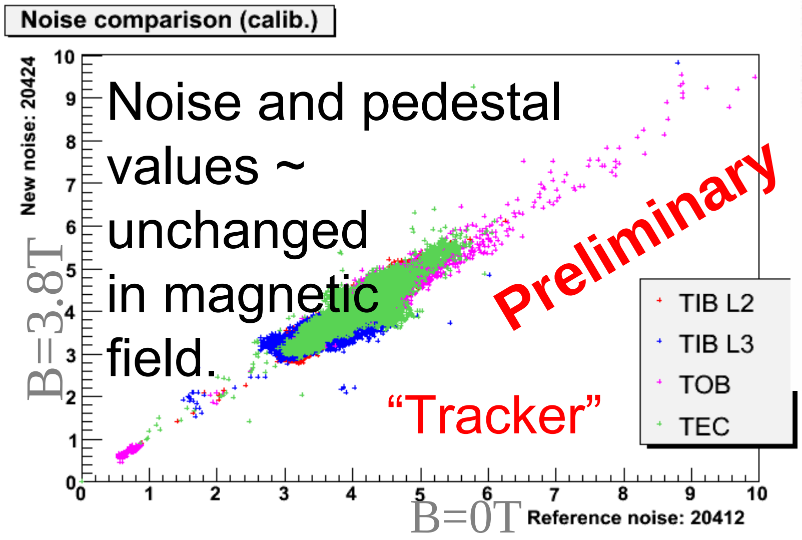
Some Preliminary Resu

Many many more analyses ongoing, covering various aspects of detector performance

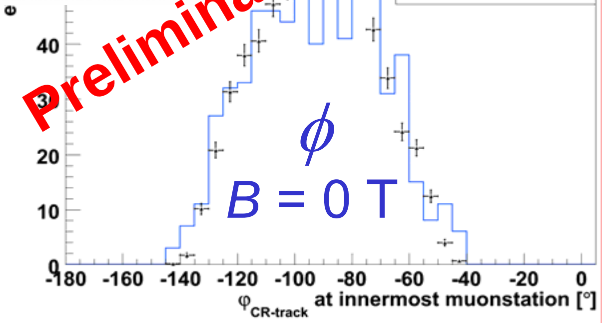
B = 3.67 T (MC for 4 T)

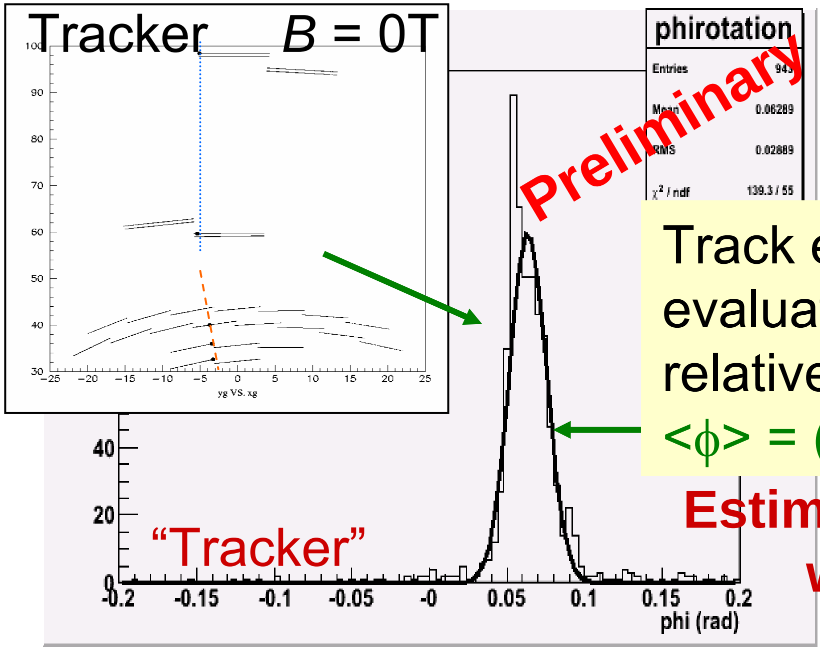


Track p_T and ϕ evaluated at innermost muon station are reasonably described by the simulation.



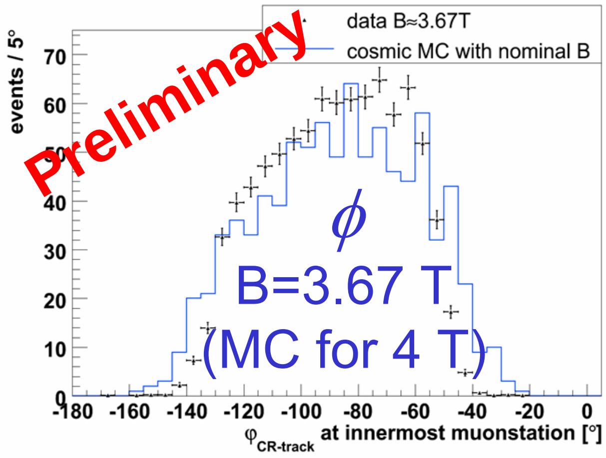
Noise and pedestal values ~ unchanged in magnetic field.





Track extrapolation to evaluate TIB-TOB relative rotation:
<ϕ> = (63,57 ± 0,27) mrad

Estimate 6k (4.5k) "tracks" with field on (off)

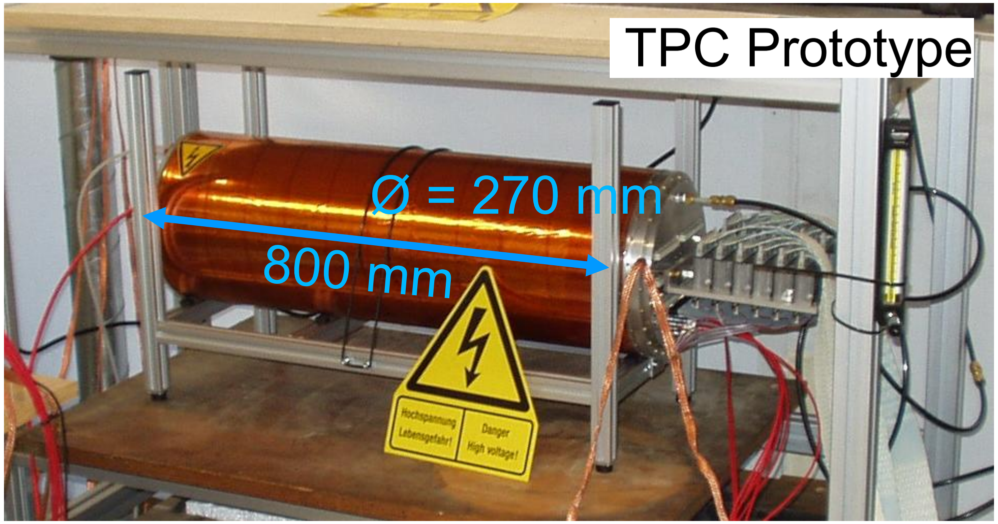


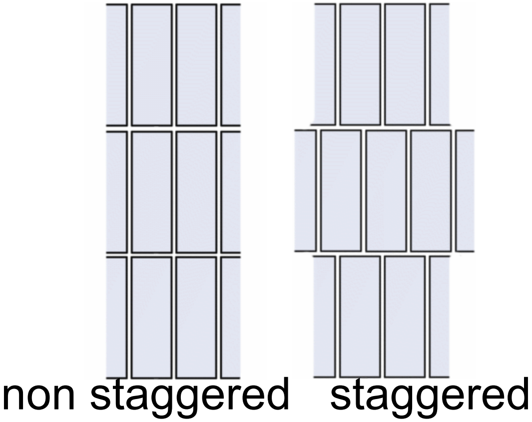
ILC Developments

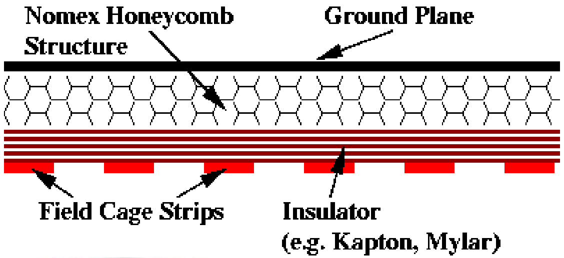
~14 talks in NSS
- 6 talks for the TPC
- 3 talks vertex related
- 1 DHCAL talk
- 1 BeamCAL

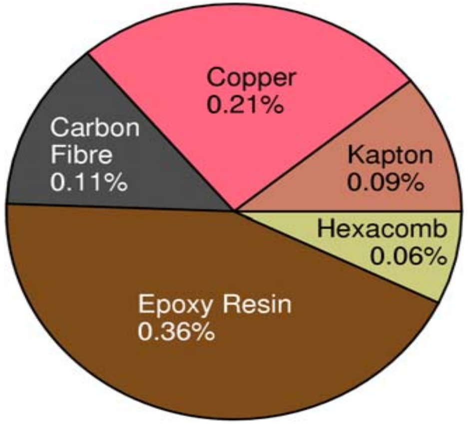
TPC Prototype and Measurement Setup

- MediTPC: prototype for resolution studies with long drift distances in high magnetic fields
  - sensitive volume: 666.0 x 49.6 x 52.8 mm^3
- triple-GEM amplification structure
- pad layout
  - rectangular pads, pitch: 2.2 x 6.2 mm^2
  - staggered and non-staggered
  - 24 pads in 8 rows
    - crosstalk in outer rows
    - → using inner 6 rows for analysis





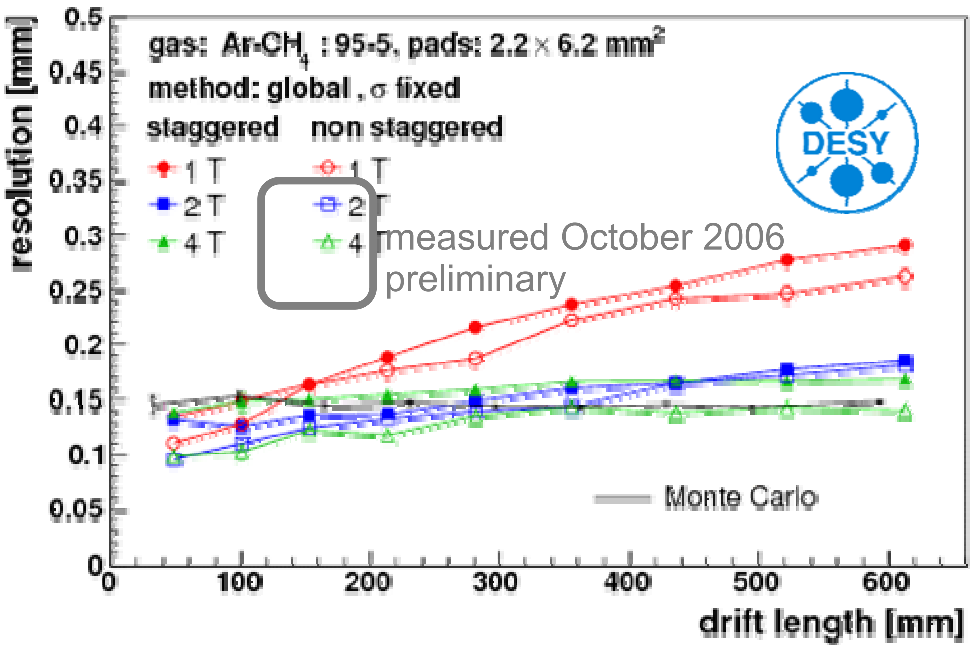




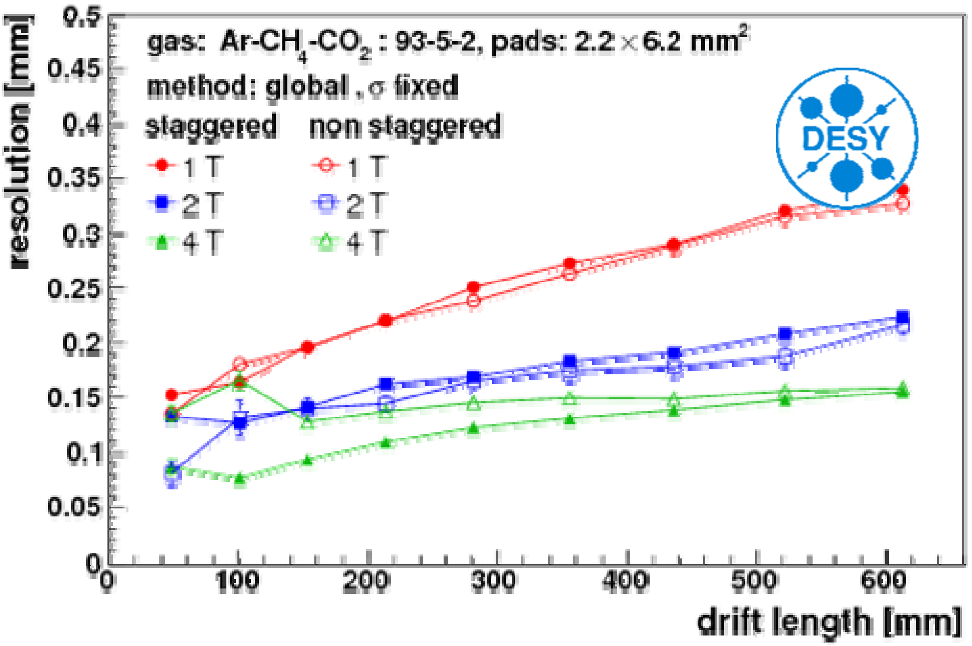
in X_0:
$\sum \approx 1\%$

Results

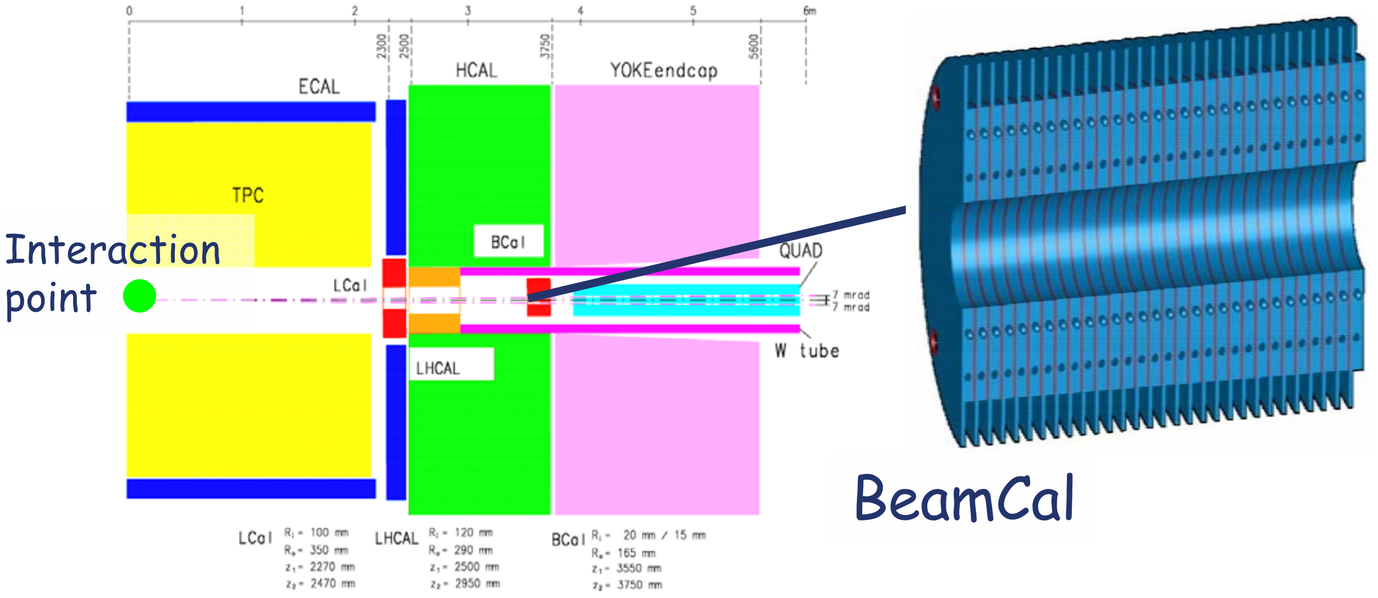
- resolution of 120 um for 0 drift length reached
    - dependence on drift length is as expected and limited by diffusion
    - for lower fields: good agreement between staggered and non staggered data sets
- in high fields there are still some indications that pads are too large
    - results for different layouts are not totally compatible
        - in particular at short drift distances
- resolution can still be optimized to reach the goal of 100 μm by
    - reducing the pad size
    - changing of the GEM setup (larger defocussing)
    - choice of the gas



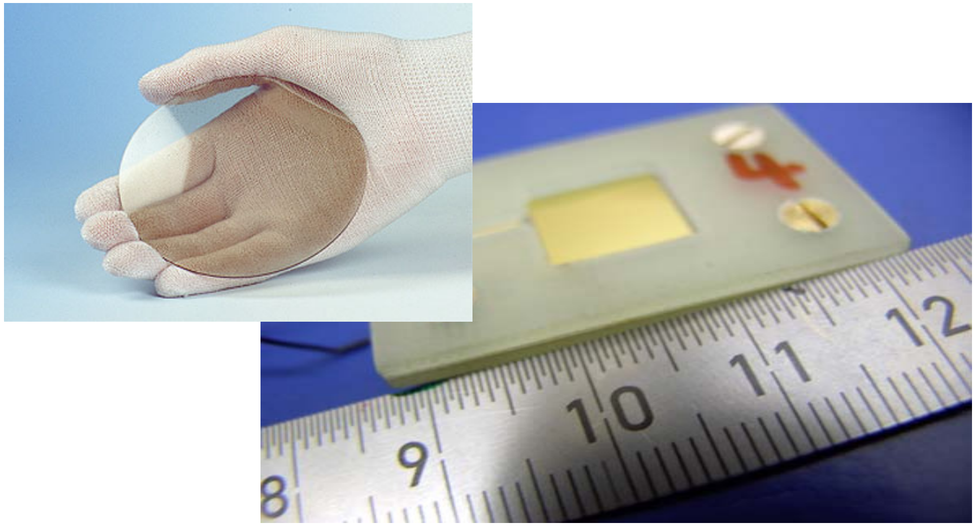
measured October 2006
preliminary



Polycrystalline CVD Diamonds for the Beam Calorimeter of the ILC



- EM calorimeter with sandwich structure:
  - 30 layers of 1 X_0 o3.5mm W and 0.3mm sensor

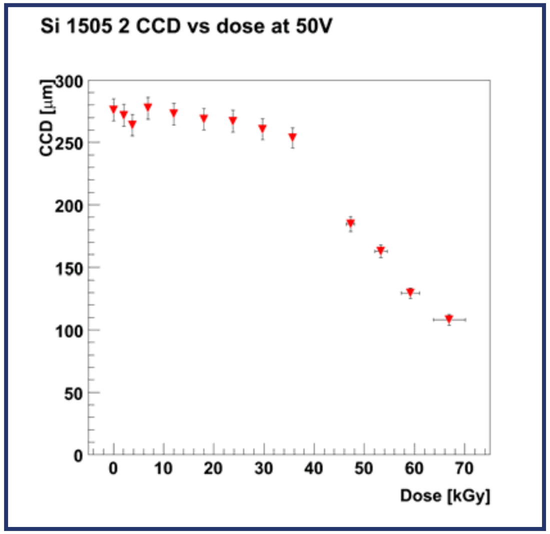


- pCVD diamonds are an interesting material:
  - radiation hardness (e.g. LHC pixel detectors)
  - advantageous properties like: high mobility, low ε_R = 5.7, thermal conductivity
  - availability on wafer scale

Charge Collection Distance vs. Dose

CCD = $Q_{meas}/Q_{induced}$ × thickness
Bias voltage = 400V ≈> 1 V/µm

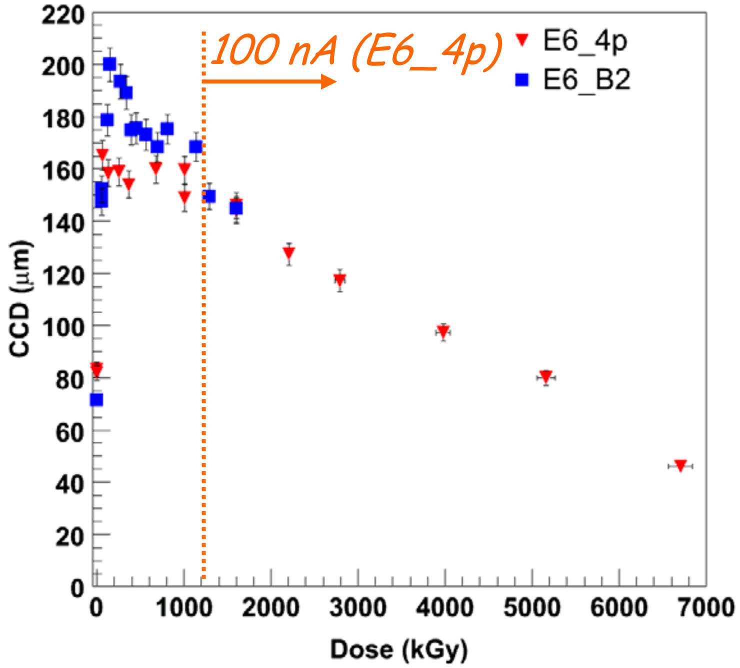
Silicon starts to degrade at 30 kGy.
High leakage currents.
Not recoverable.

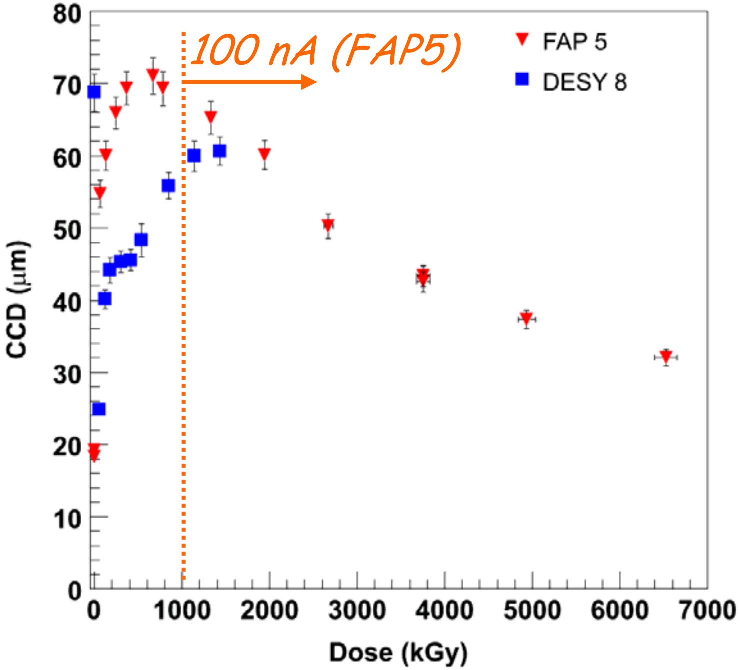


CVD diamond irradiated at the injector of the S-Dalinac in Darmstadt (10MeV e-)

After absorbing 7MGy:

CVD diamonds still operational!



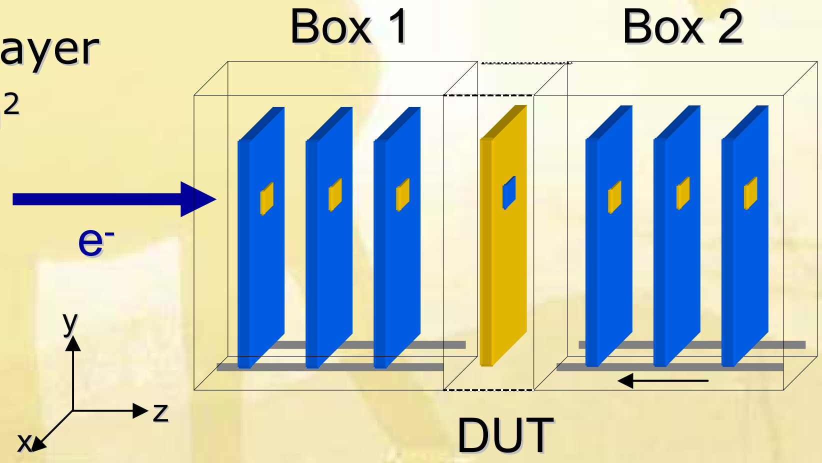


EUDET Telescope (JRA1)

- Provide testbeam telescope with:
  - Very high precision: <3 μm precision even at lower energies
  - High readout speed (frame rate >1kHz)
  - Easy to use: well defined/described interface
  - Large range of conditions: cooling, positioning, magnetic field

Demonstrator: middle of 2007

- Mimo*3 prototype developed for STAR microvertex upgrade (MAPS) with analog readout
- AMS 0.35 OPTO process with 12 μm epitaxial layer
- 30 × 30 μm^2 pitch: active area: 7.7 × 7.7 mm^2



Final Telescope: end of 2008

- Dedicated chip under development
- fast column parallel architecture with integrated CDS and discrimination
- active area: 2-4 cm^2, 25 × 25 μm^2 pitch

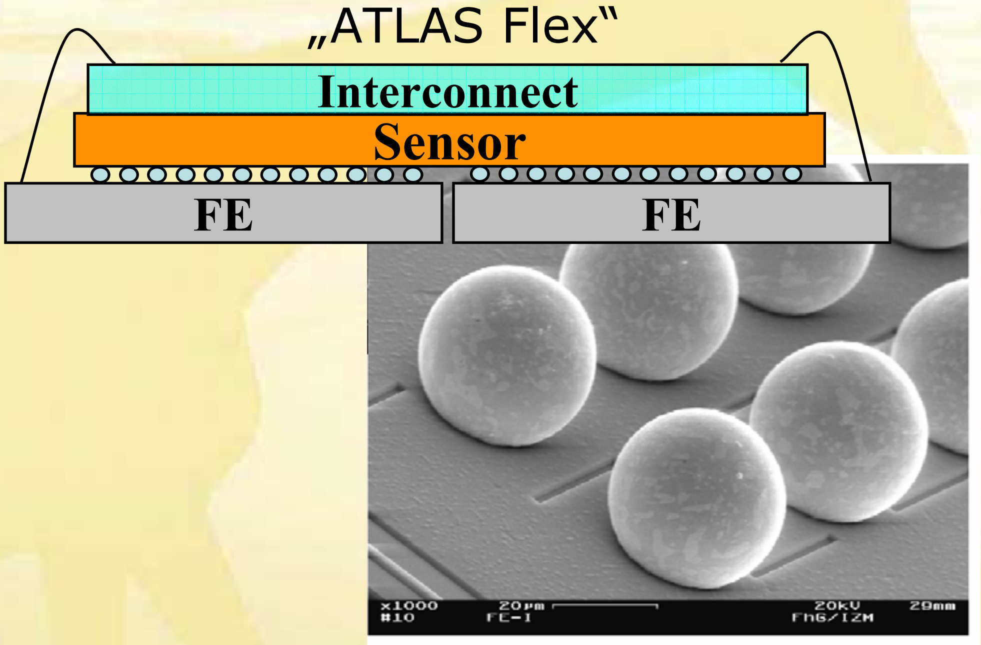
- DAQ hardware almost ready for integration at DESY
- preparation of sensor tests under way

New Pixel Detectors

Search on “pixel” in paper abstracts: >100 records

… pick the raisins

Why “New” Pixel Technologies

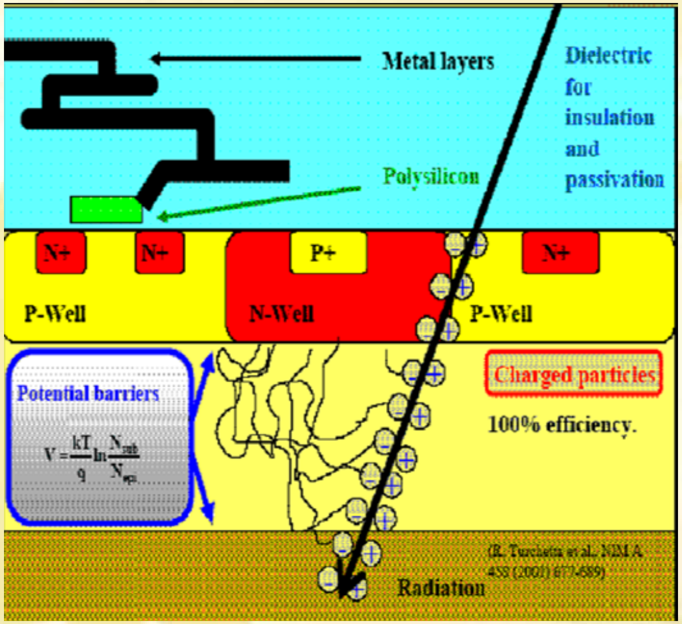


- “Classic” Pixel Detector -> Hybrid
  - Sensor and electronics are processed separately
  - Bump bonding connected them
  - DELPHI, ATLAS, CMS, ….

- For future experiments this concept difficult as too large X_0

- One option: monolithic active pixel (MAPS)

CMOS (Monolithic) Active Pixel - MAPS



(R. Turchetta et al., NIM A 458 (2001) 677-689)

- p-type low-resistivity Si hosting n-type ”charge collectors”
  - signal created in epitaxial layer
  - charge sensing through n-well/p-epi junction
  - excess carriers propagate (thermally) to diode

- Specific advantages of CMOS sensors:
  - Signal processing µcircuits integrated on sensor substrate (system-on-chip)
  - Sensitive volume (epitaxial layer) is ~10 µm thick
  - Standard, massive production, fabrication technology

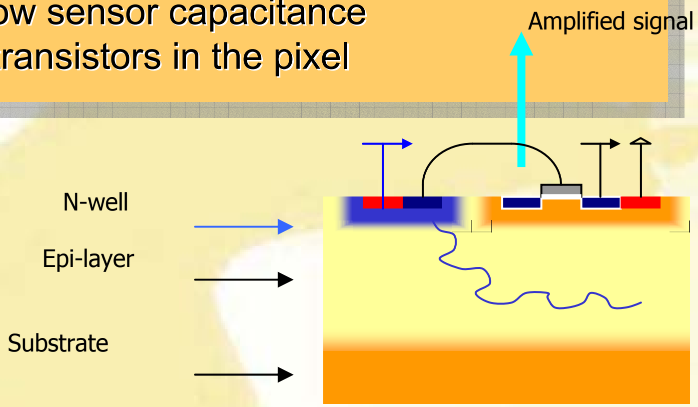
- Main R&D Directions:
  - High read-out speed, low noise, low power dissipation, integrated signal processing architecture
  - Optimal fabrication process, Thinning procedures, Radiation tolerance

On the "Market" (presented at NSS)

- Mimosa family (MimoStar) (Strasbourg)
  - Larger arrays (800x800 pixels) with fast column parallel architecture with integrated CDS and discrimination under way (EUDET telescope)
  - Take advantage of 0.35 μm OPTO process (AMS->Mobile CCD Production) to get reasonable large signal

The use of epi layer (or low-ohmic substrate) as sensor
- Charge collection mainly through diffusion
- very low sensor capacitance

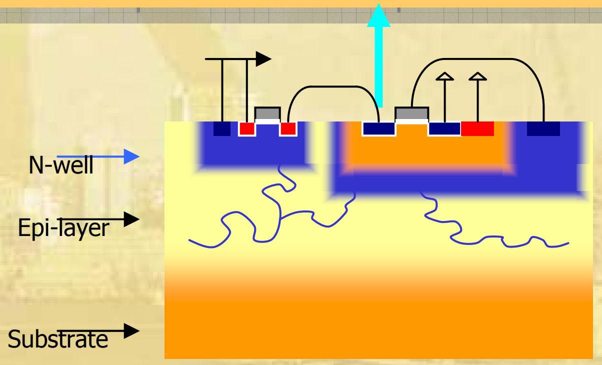
Only NMOS transistors in the pixel



- Apsel family (INFN)
  - Deep n-well used as shielding against disturbances from the substrate
  - The deep n-well (DNW) can be used as the collecting electrode
  - Pixel matrix 8x8, 50x50 μm^2 pixel size, analog readout
  - Process: ST130 (nm), new prototype in ST90

The use of epi layer (or low-ohmic substrate) as sensor and deep N-well as collecting electrode
- Charge collection mainly through diffusion
- Higher sensor capacitance

CMOS electronics in pixel…
but PMOS transistors are placed in the separate N-well

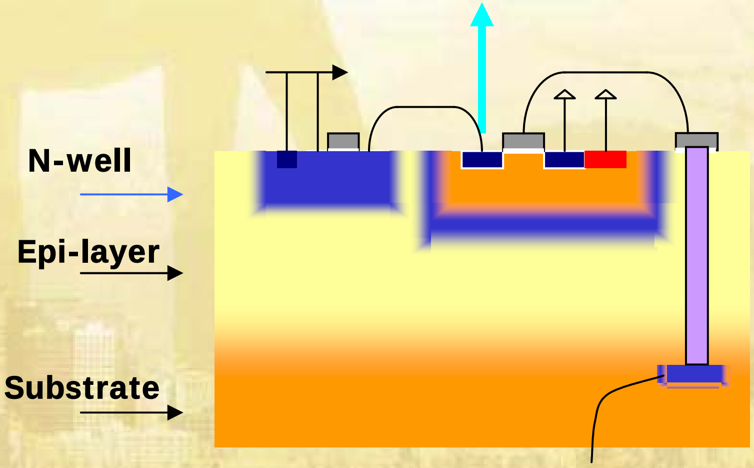


On the “Market” (presented at NSS)

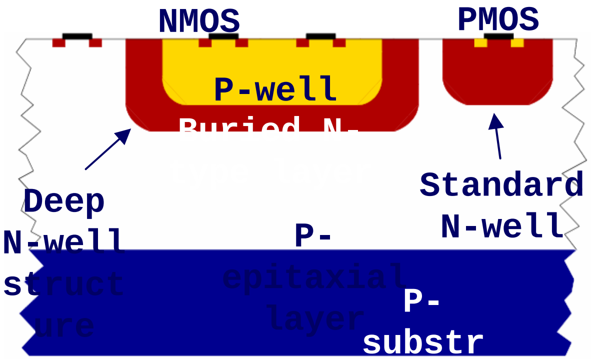
- SOI Pixel Detector (KEK, others)
  - Silicon on insulator
  - SOI known to be radiation tolerant and resistant versus SEU
  - Full depleted SOI CMOS process (0.15mm) -> enable to use thick, high resistivity Si and thin, low resistivity Si on same process

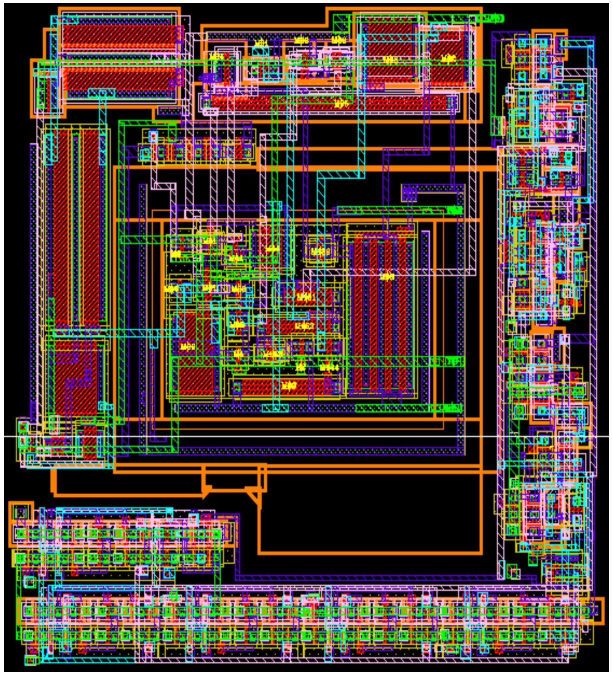
Allows using high resistive detector substrates and operation in fully depleted region
Gives possibility to use both type of transistors in readout channels

Sucima SOI is actually better known to “us” -> this year not presented at NSS



Deep N-well MAPS concept



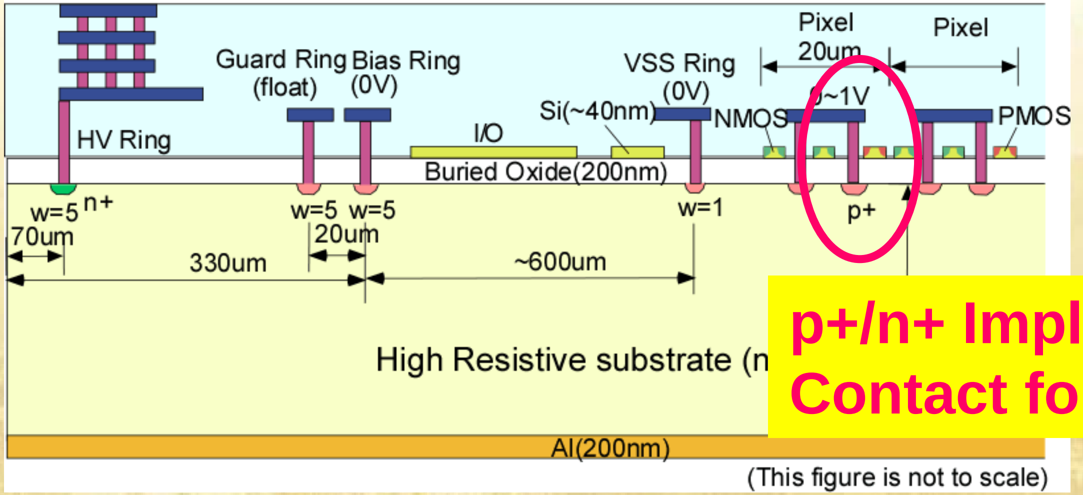


- In triple-well CMOS processes a deep N-well is used to isolate N-channel MOSFETs from substrate noise
- Such features were exploited in the development of deep N-well (DNW) MAPS devices
- New DNW MAPS structures with optimized noise and threshold dispersion characteristics have been recently submitted in the 130 nm, triple well STM CMOS technology
- Further activities are under way to optimize the elementary cell size and geometry, including
  - simplification of the pixel cell logic
  - MAPS development in a **90 nm CMOS** technology
  - physical device simulations

Monolithic Pixel Detector in a 0.15um SOI Technology

Feature of SOI (Silicon-On-Insulator)

- Full Dielectric Isolation :
  Latchup Free, Small Area
- Low Junction Capacitance :
  High Speed, Low Power
- No Well junction, Thin Film :
  Low Leakage, Low Vth Shift (~300 ºC)
- Small Active Volume :
  High Soft Error Immunity



(This figure is not to scale)

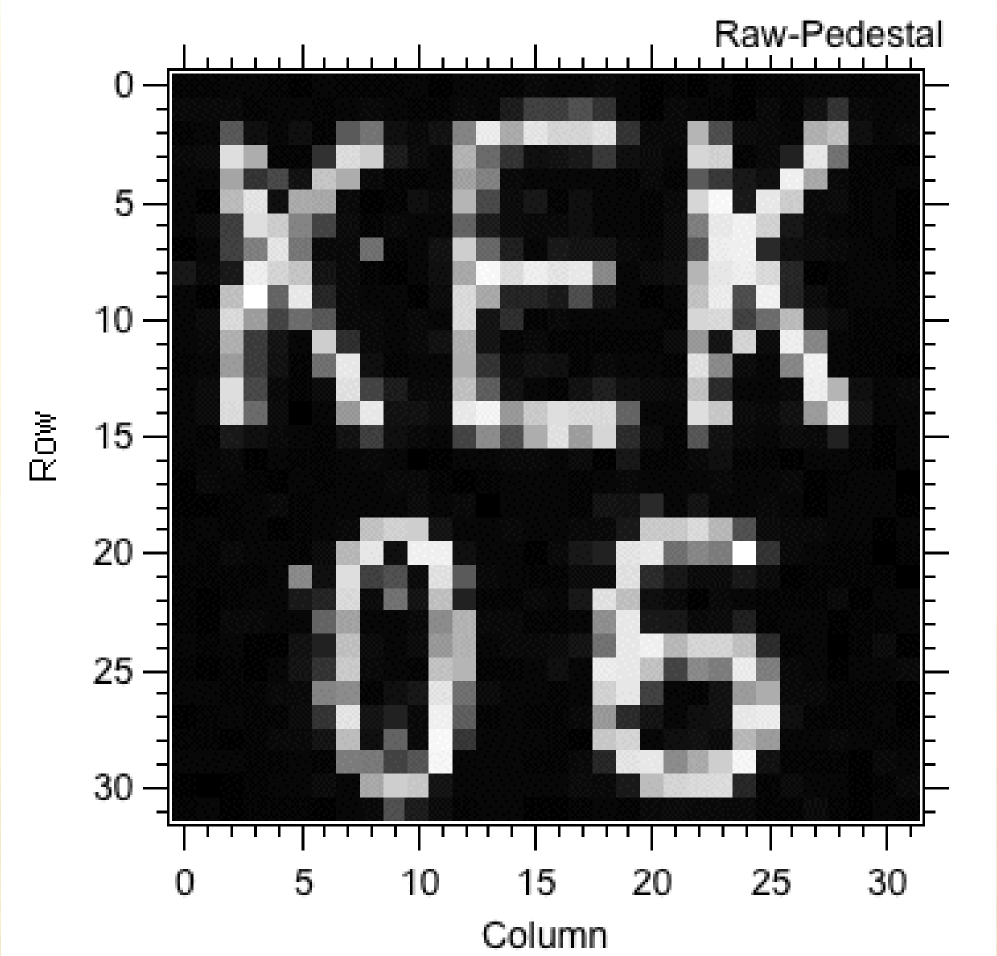
p+/n+ Implant and Contact formation

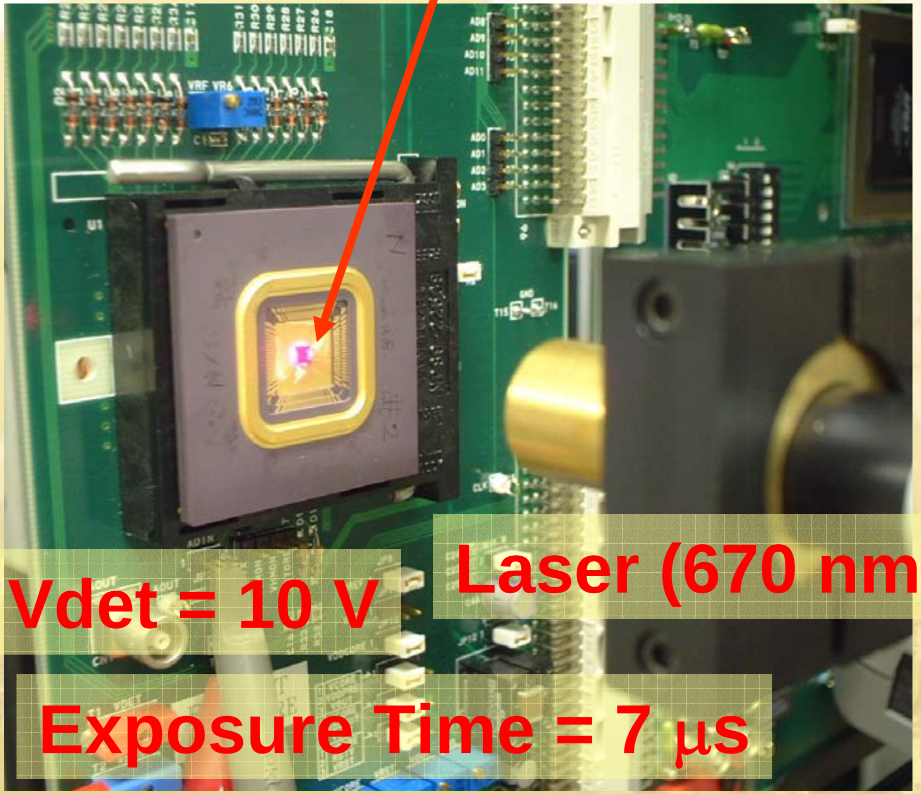
Yasuo Arai (KEK)

N34-4

Laser Image

32x32 image view with 670nm Laser and plastic mask





Vdet = 10 V

Laser (670 nm)

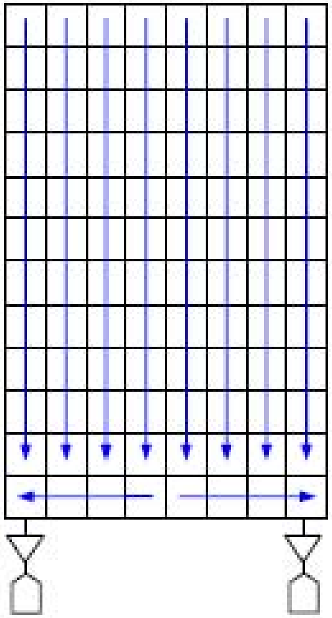
Exposure Time = 7 μs

CCD for ILC

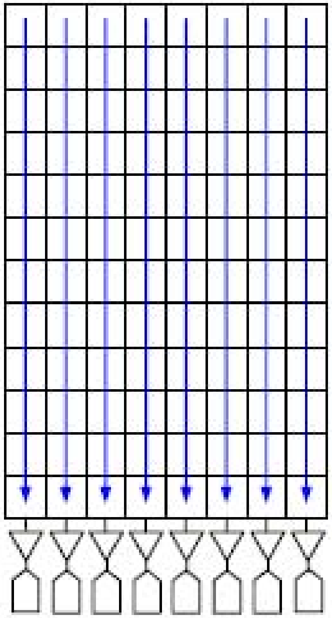
This time it means “charge coupled device”

Column Parallel CCDs

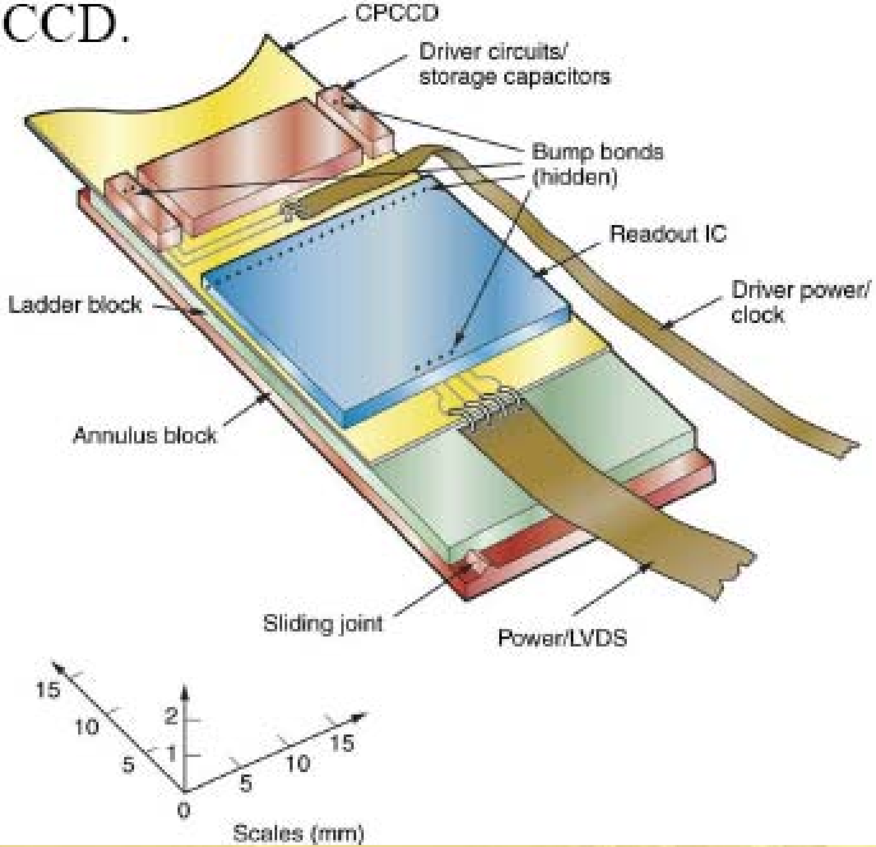
Classic CCD



CPCCD



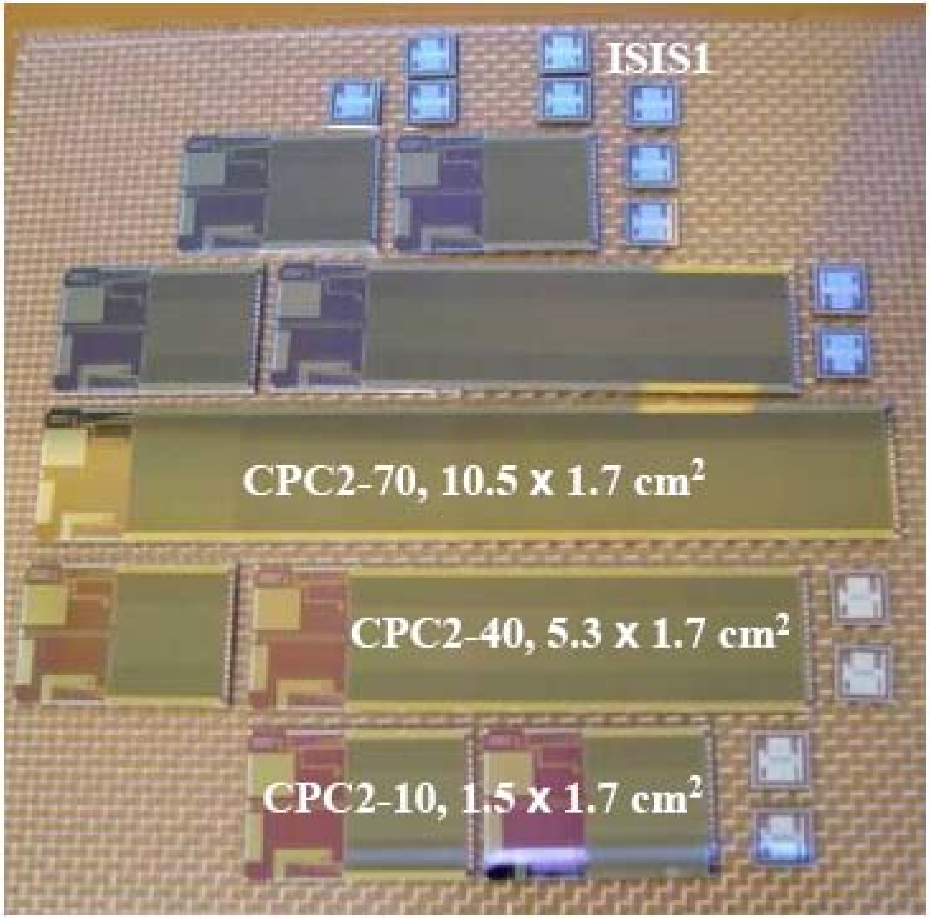
- Must bump bond driver IC to CCD.
- Further, every column requires amplifier, ADC, cluster finding...
- Bump bond custom readout chip to CCD.



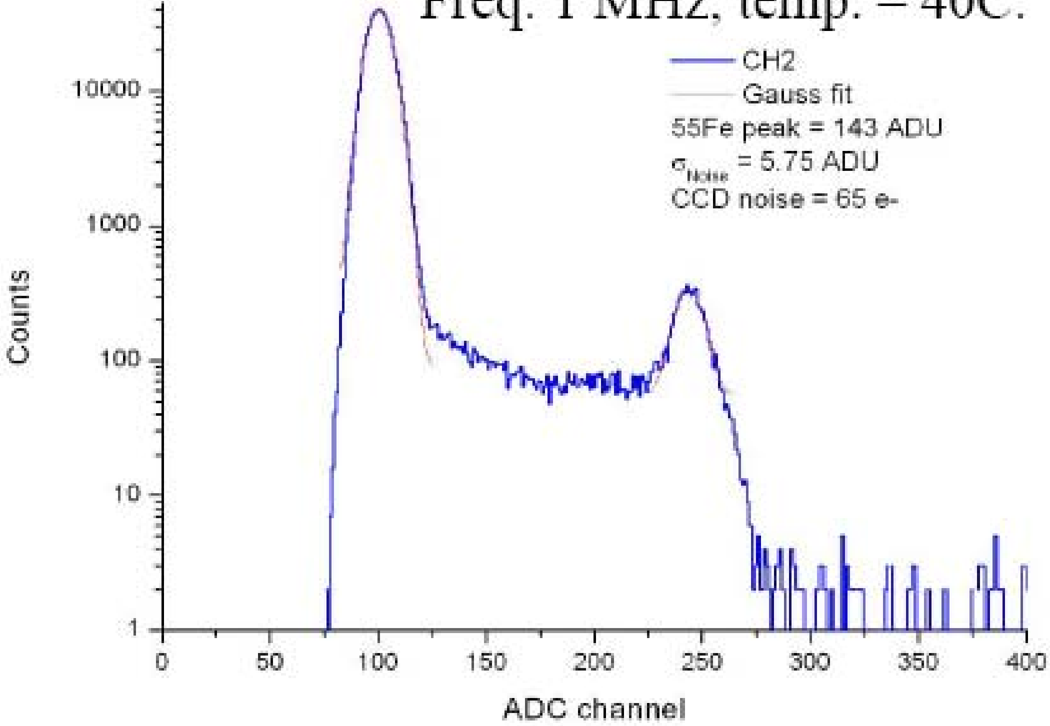
- Despite parallel processing, readout frequency of 50 MHz needed.
- Implies drive current = $V/\frac{1}{\omega C} \sim 20$ A.
- Voltage drop $20\ \text{A} \times 0.1\ \Omega = 2$ V.
- L of 1 mm bond wire ~ 1 nH, corresponds to 0.3 Ω at 50 MHz.

Next generation CPCCDs: CPC2

- Wafers with CPC2 chips of various sizes:



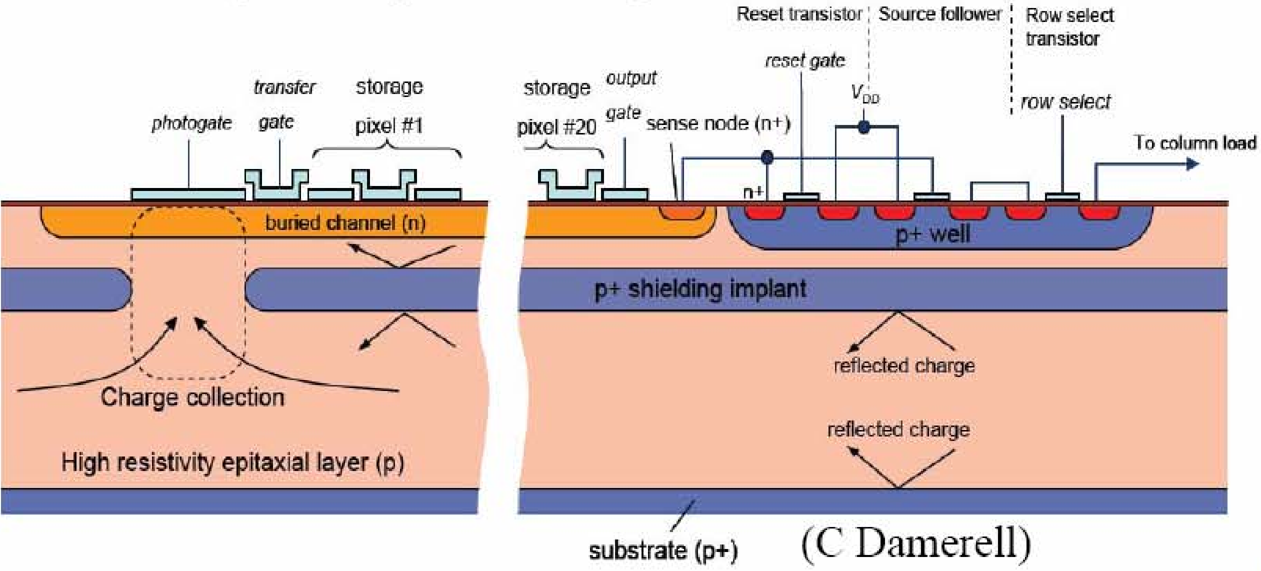
- Single/double level metal (latter recently delivered) on 100 Ω cm (25 μm epi) and 1.5 kΩ cm (50 μm epi) silicon.


Freq. 1 MHz, temp. – 40C.

- Studies of fast (double metal) CPC2 to follow.

In-Situ Storage Image Sensor

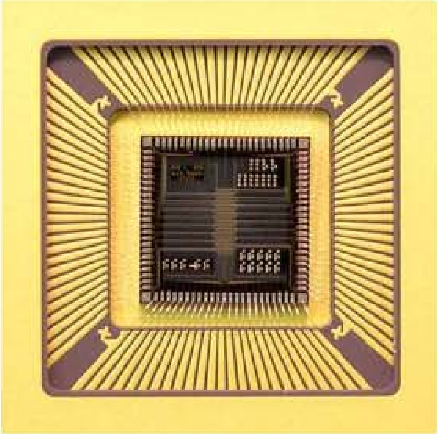
- Alternative to fast readout, store signal in pixel during bunch train.



(C Damerell)

- Drive at 20 kHz during bunch train.
- 1 MHz column parallel readout between bunch trains.
- Charge to voltage conversion when least affected by EMI.

- ISIS1, "proof of principle" device built by e2v.

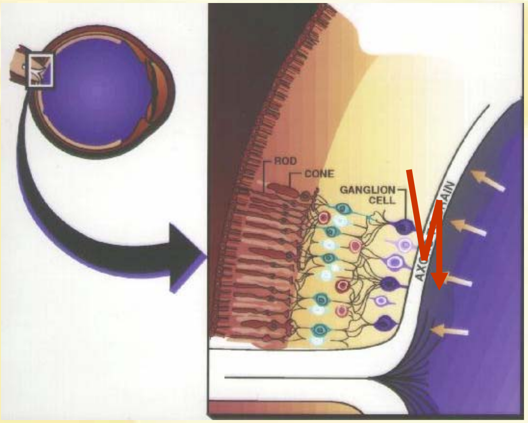


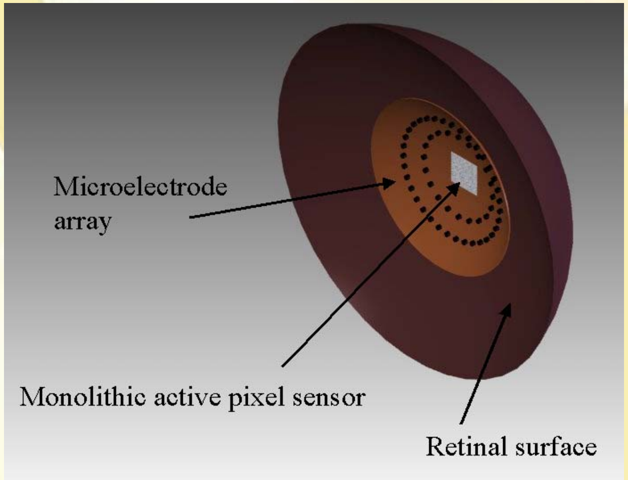
- 6 × 16 array of ISIS cells, each with 5-pixel buried channel CCD storage register.
- Cell pitch 40 × 160 μm^2, no edge logic.
- Chip size 6.5 × 6.5 mm^2.

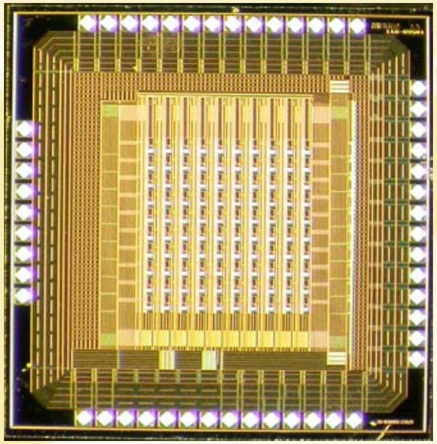
Pixel Sensors for Medical Applications

A CMOS Active Pixel Sensor and Microelectrode array for Retinal Stimulation

K. Mathieson, Glasgow







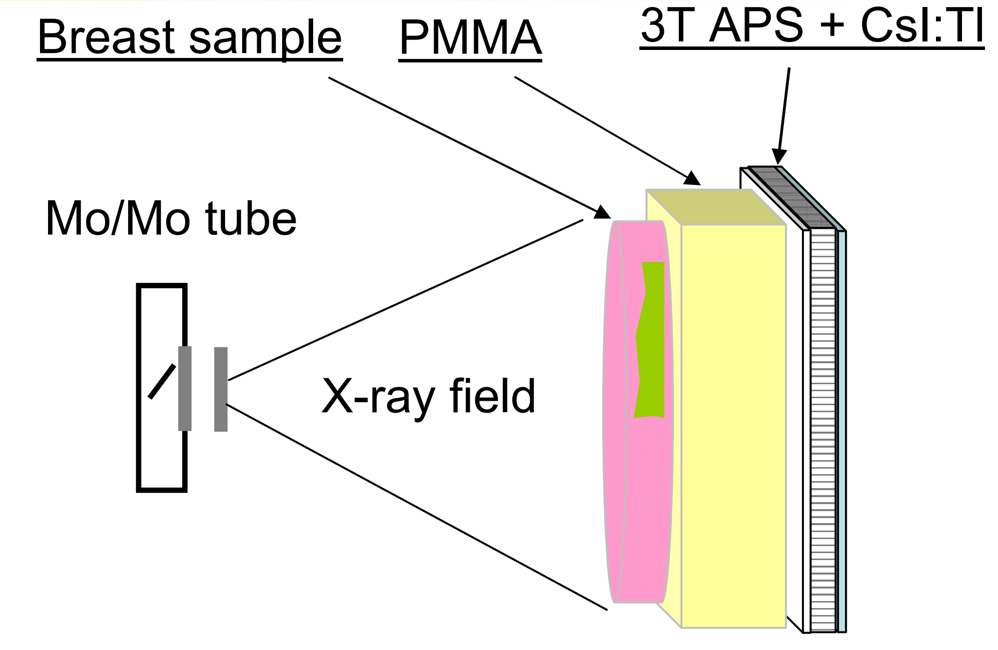
- 10x10 pixel matrix
- pixel pitch 100μm
- Each pixel contains
  - Photodiode
  - Voltage controlled oscillator (VCO)
  - Bi-phasic output driver
- Creates signals capable of stimulating retinal ganglion cells.

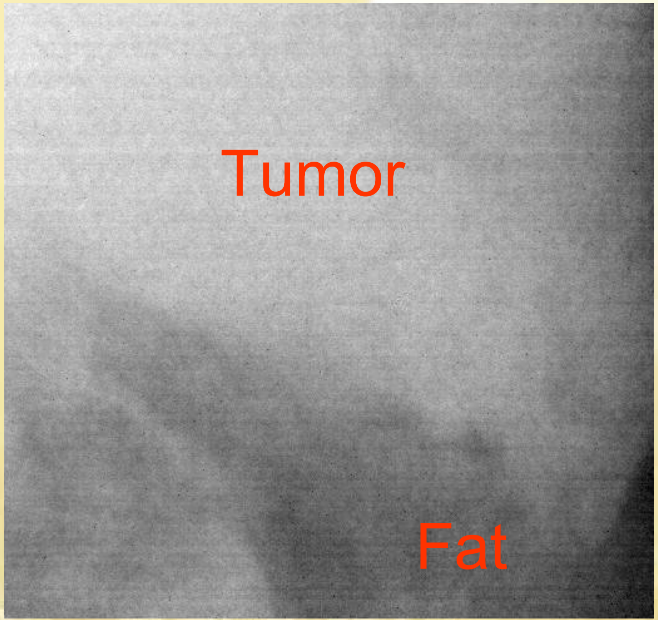
- Retinal experiments undertaken *in situ.*
  - Successful retinal recordings from very small ganglions
  - Voltage threshold of 400mV needed to elicit response from RGCs
  - …..
- Many issues still to be dealt with
  - Biocompatibility, power requirements, safe operating limits

A Novel Active Pixel Sensor with on-Pixel Analog-to-Digital Converter for Mammography

C. D. Arvanitis, UCL

- 3T APS (0.5 um) CMOS and On-pixel intelligent CMOS (0.35μm CMOS)
- X-ray image of a breast phantom
- Phantom composition (1 cm breast tissue and 3 cm of PMMA)
- Entrance exposure 282,5 μC/kg (30 kVp)





Breast phantom image (13 mm x 13 mm)

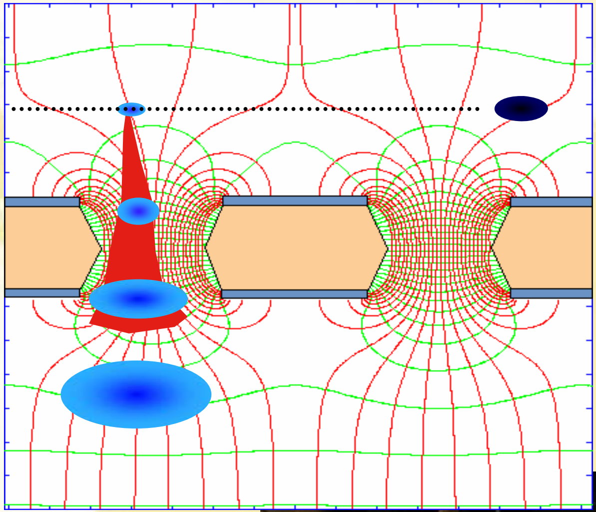
True on pixel x-ray intelligent imaging

New Gas Detectors

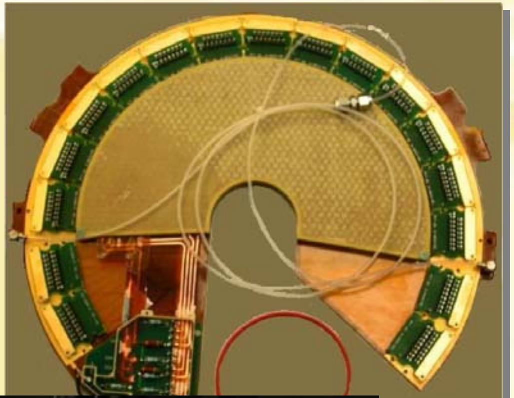
NSS/MIC:
50 contributions with GEMs, 15 contributions with Micromegas
Workshop:
Micro-Pattern Gas Detectors: High Energy Physics and Beyond, Maxim Titov

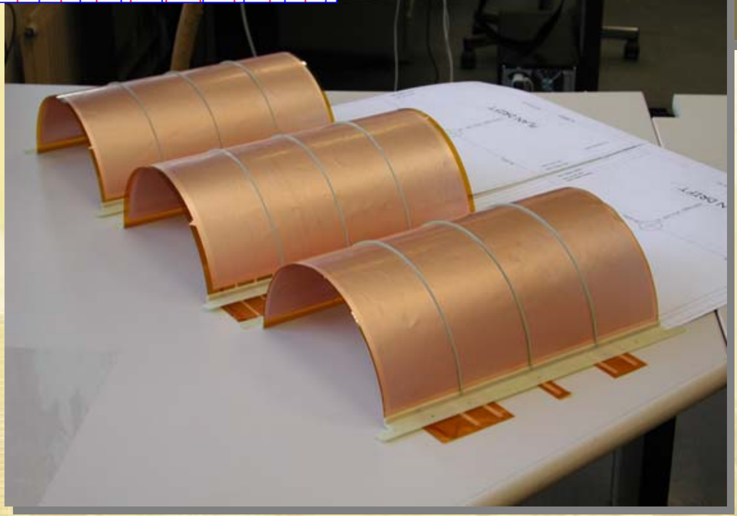
GEMs at a Glance

- GEM detectors in use or under construction for many experiments:
  - COMPASS
  - LHCb
  - TOTEM
  - LEGS
  - BONUS
  - PHENIX HBD
- Developments in particle physics
  - GEM TPC for ILC
  - High resolution pixel detectors
  - Neutron detectors
- Applications in other field
  - Soft X-ray polarimetry
  - Medical diagnostics, portal imaging
- GEMs now fabricated at several places:
  - CERN, 3M, TechEtch, SciEnergy
  - (Fabio: CERN is the best)



TOTEM

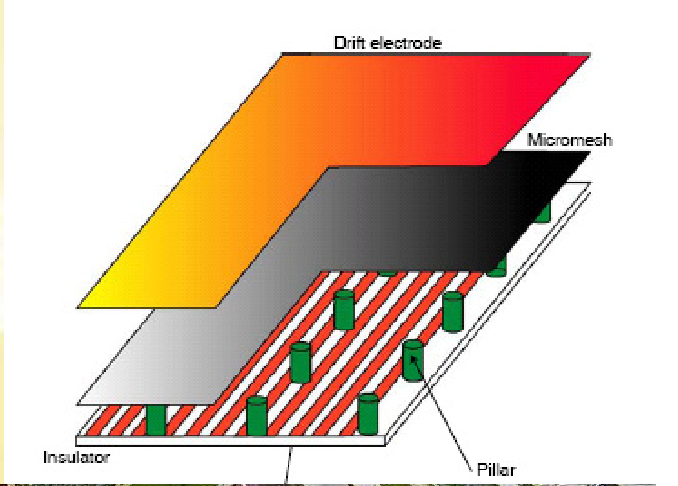




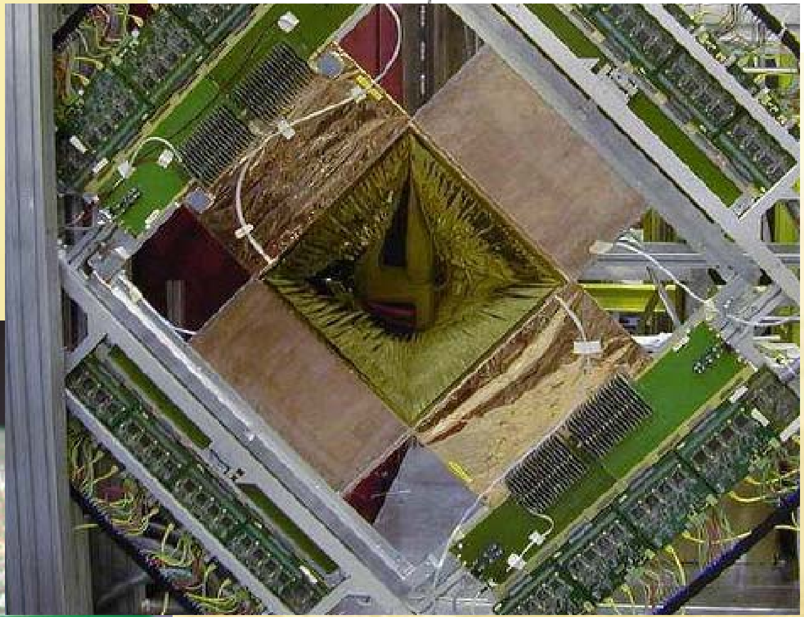
Cylindrical GEM (CERN devel.)

Micromegas at a glance

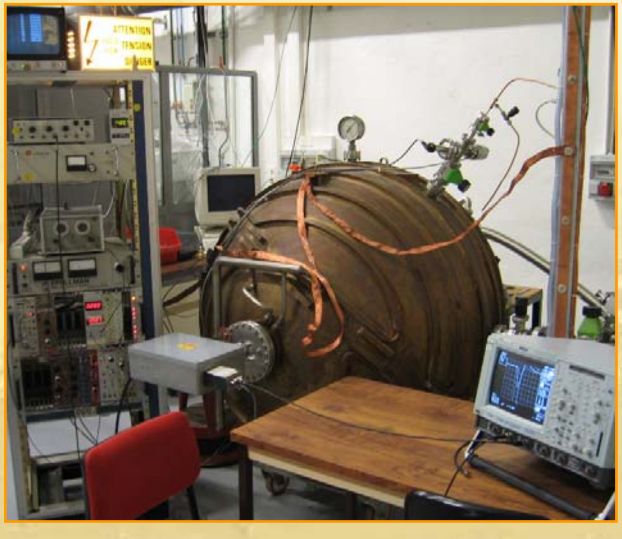
- Micromegas also to be found at many experiments:
  - COMPASS
  - NA48
  - Axions: CAST experiment
  - Neutrinos: spherical TPC



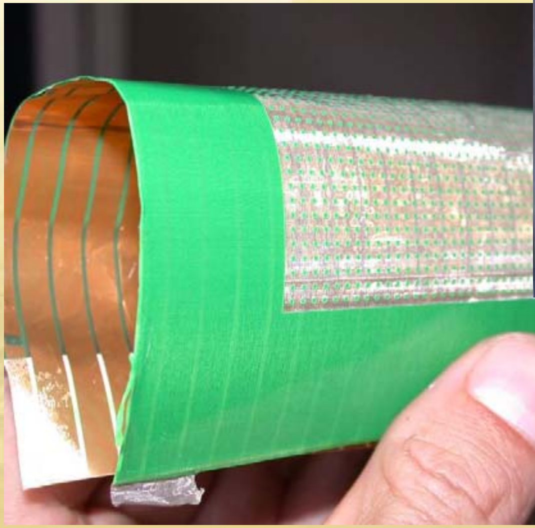
- Medical application
  - Neutron tomography



Spherical TPC

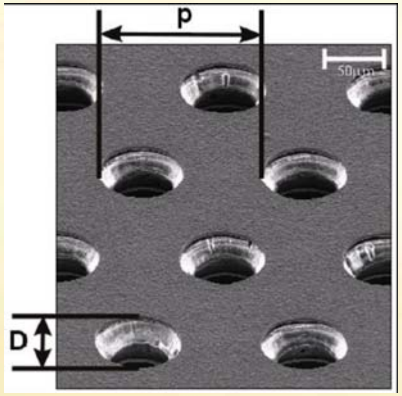


Ultrathin

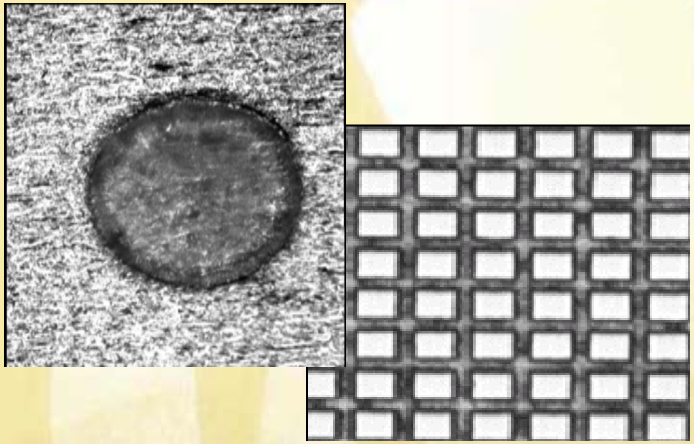


GEM and Micromegas

- Gas Electron Multiplier (GEM): two copper perforated foils separated by an insulator. The multiplication takes place in the holes. Usually used in 3 stages, even 4.
- Introduced by Fabio Sauli (1996)



- Micromegas : a micromesh sustained by 50-100 µm -high insulating pillars. The multiplication takes place between the anode and the mesh. One stage.
- Introduced in 1996



- Readout:
  - Pad readout (as FLC group) with following charge sensitive amplifier
  - FET readout: using separate FET array as switch for each pad and read out signal column-by-column (Chinese development)
  - Pixel readout (future)

Pixel Readout of Micro-Pattern Gas Detectors

Pro:

- no radiation damage in sensor: gas is exchanged
- modest pixel (analog) input circuitry: low power, little space
- no bias current: simple input circuit
- CMOS pixel chip main task: data storage & communication (rad hard)
- (12”) CMOS wafer → Wafer Post Processing
  - no bump bonding
- operates at room temperature (but other temperatures are OK)
- less sensitive for neutron and X-ray background
- 3D track info *per layer* if drift time is measured

Con:

- Gaseous chamber: discharges (sparks): destroy CMOS chip
- gas-filled proportional chamber: ‘chamber ageing’
- Needs gas flow

At least 5 different talks covering this topic

One Example

Triple GEM Setup with Medipix2 Readout

- **Naked Medipix2 used, no bump bonded Si converter**
- ***Pixel size 55µm, 256x256 Matrix***
- **dimensions of the *sensitive area*: *1,4x1,4cm²***

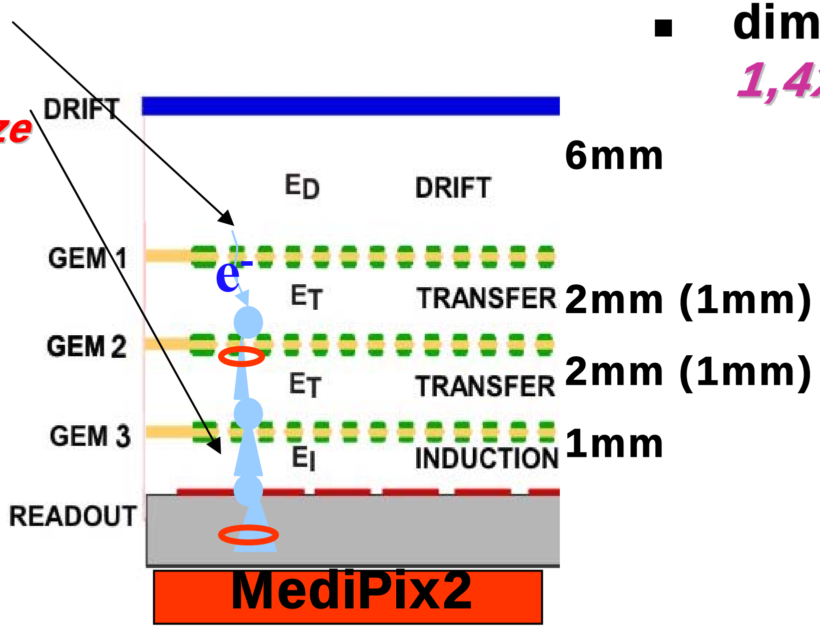
Potentials and fields:

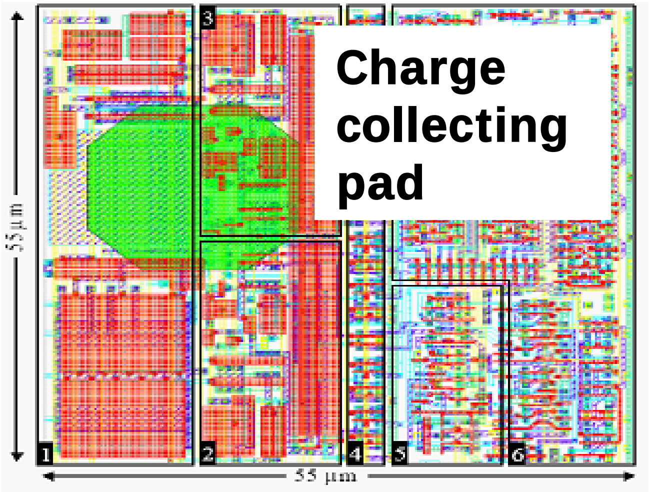
$E_D = 1.1$ kV/cm

$\Delta V_{GEM} = 404$ V

$E_T = 3.2$ kV/cm

$E_I = 4.2$ kV/cm

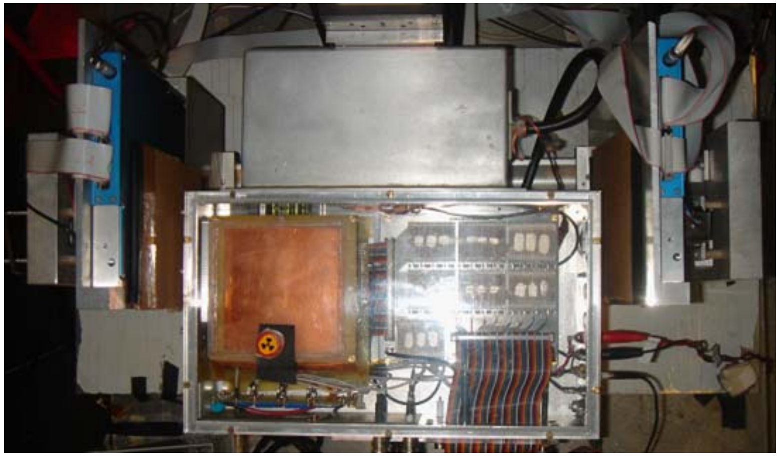


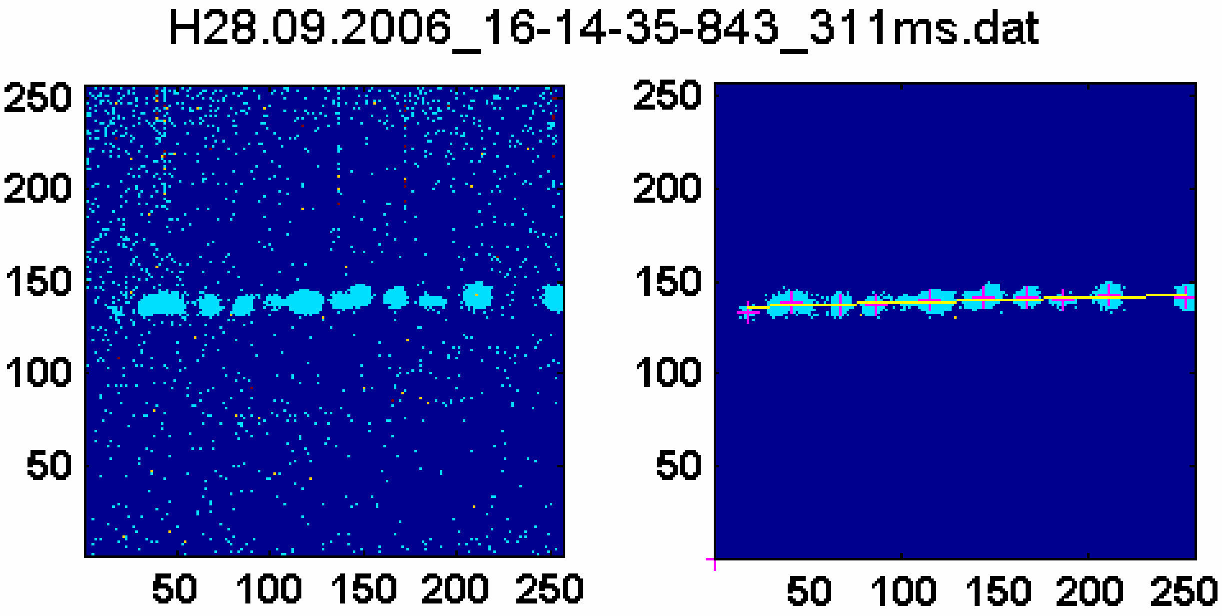


- **with the two thresholds of the MediPix2 chip a charge determination is feasible**

Triple GEM Setup with Medipix2 Readout

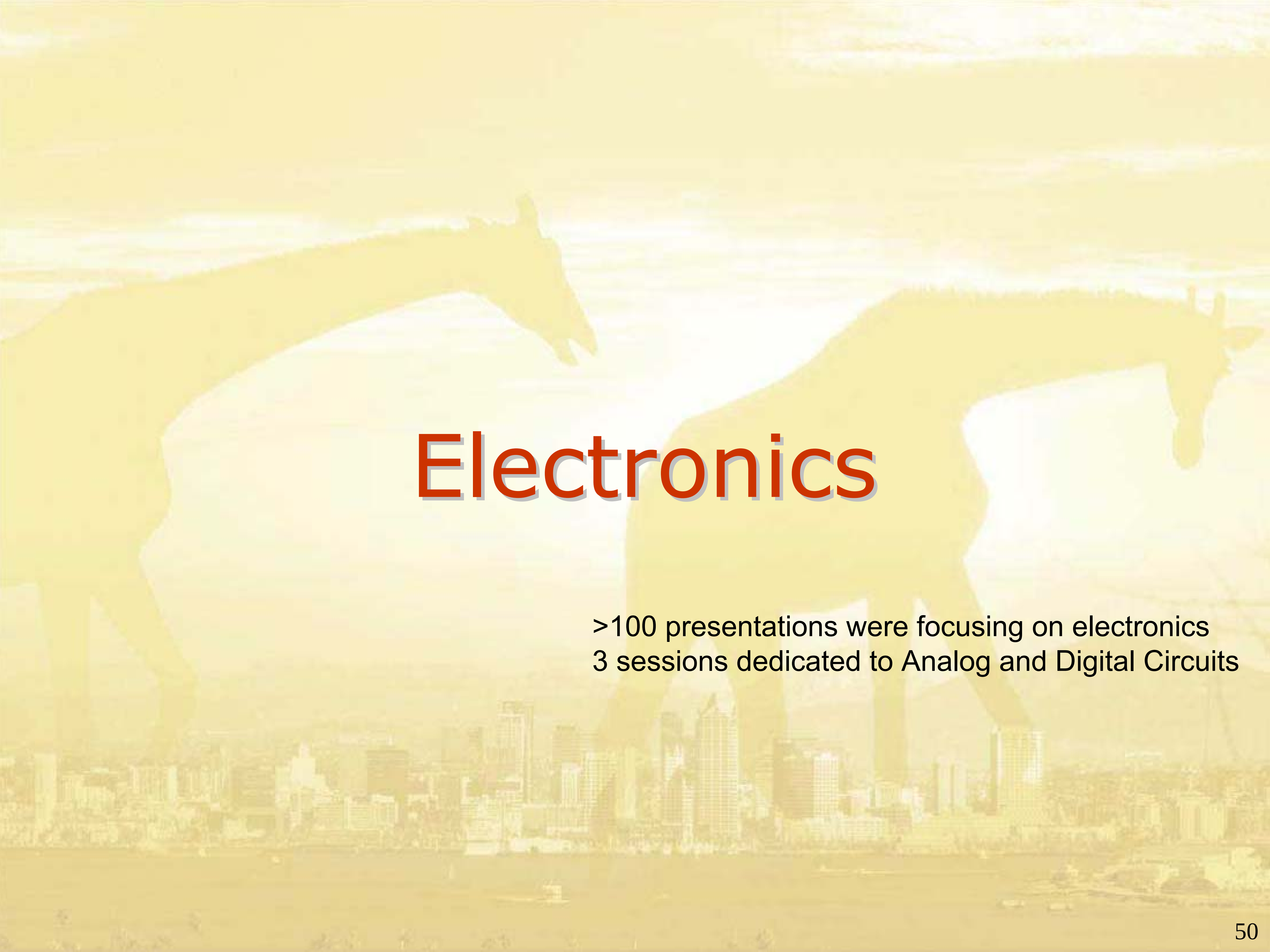
DESY Testbeam





Tracks are almost perfectly straight. Contribution of *multiple scattering is small*.

- excellent “point” resolution of σ_0~30 - 40 µm achieved by digital readout, better than common TPC readout schemes
- the TimePix is ready to be examined by the same setup
- it will provide higher flexibility because of the “time over threshold” feature

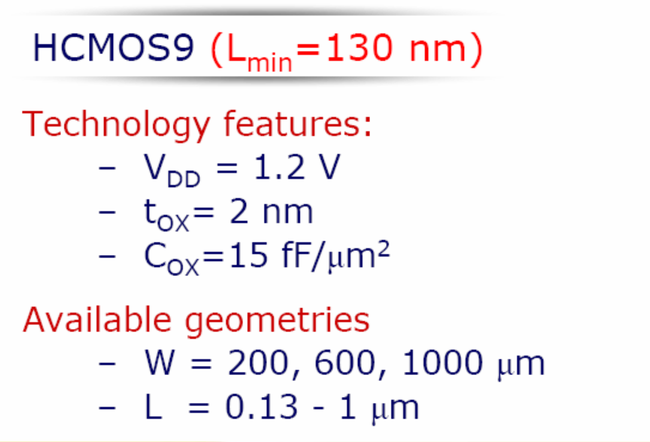


Electronics

>100 presentations were focusing on electronics
3 sessions dedicated to Analog and Digital Circuits

New Microelectronic Processes

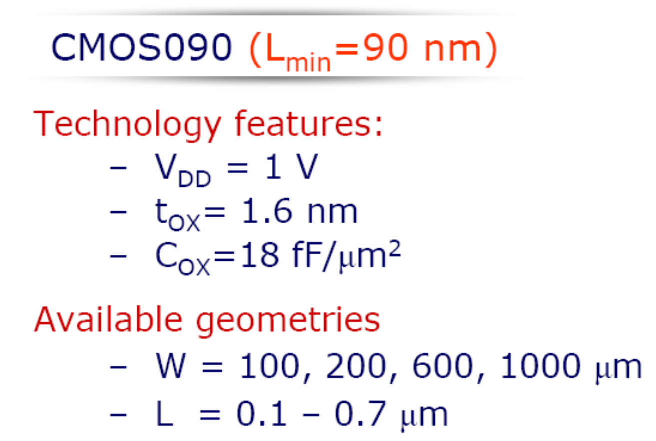
- Use of CMOS processes in the last two decades
    - deep impact on HEP instrumentation
- Quarter micron technology able to comply with the challenging design requirements of the LHC experiments in terms of
    - noise figure
    - power dissipation
    - radiation tolerance
- Luminosity and track densities expected at the next generation colliders set the demand for
    - increased spatial resolution
    - denser functional packing
    - higher radiation hardness
    - better noise/power trade-off
- HEP moving to more scaled CMOS processes technology
    - fight process obsolescence
    - study scaling down effects on the main design parameters



HCMOS9 (L_{min}=130 nm)

Technology features:
- V_{DD} = 1.2 V
- t_{OX}= 2 nm
- C_{OX}=15 fF/μm²

Available geometries
- W = 200, 600, 1000 μm
- L = 0.13 - 1 μm

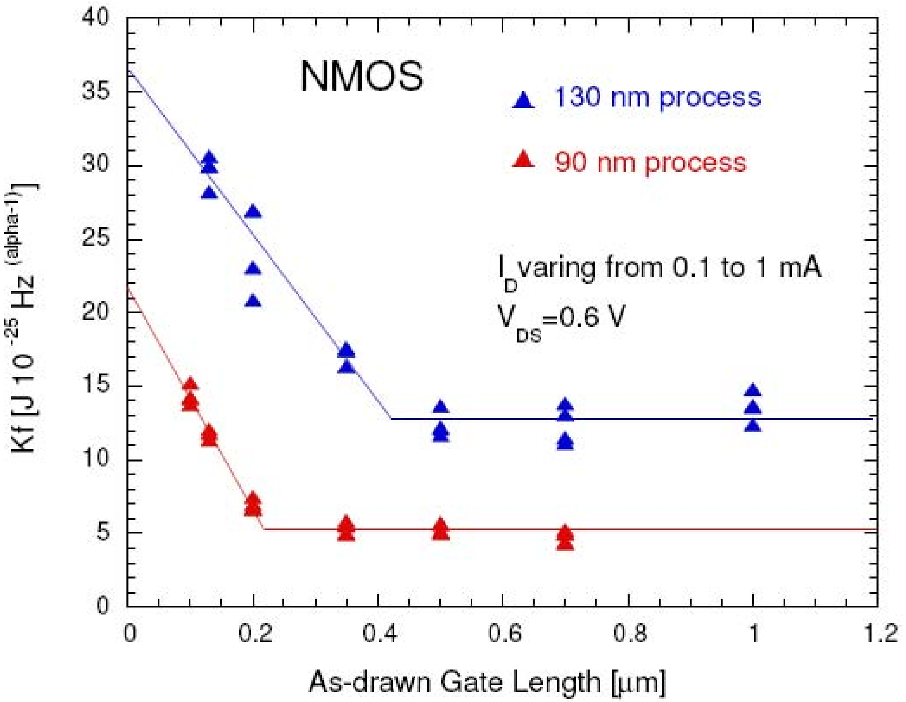


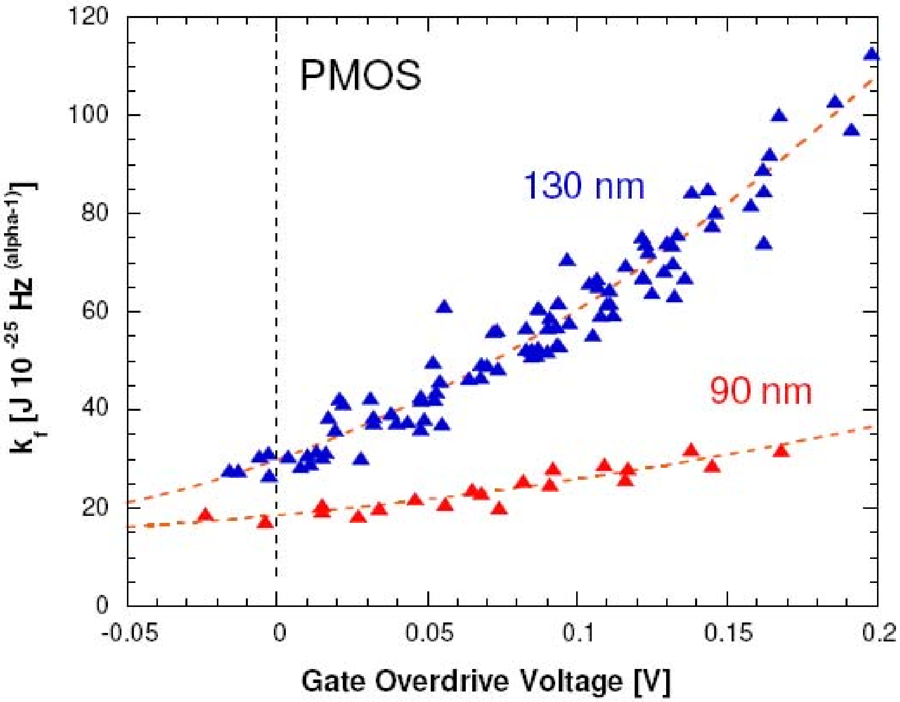
CMOS090 (L_{min}=90 nm)

Technology features:
- V_{DD} = 1 V
- t_{OX}= 1.6 nm
- C_{OX}=18 fF/μm²

Available geometries
- W = 100, 200, 600, 1000 μm
- L = 0.1 – 0.7 μm

1/f noise coefficient K_f





NMOS devices

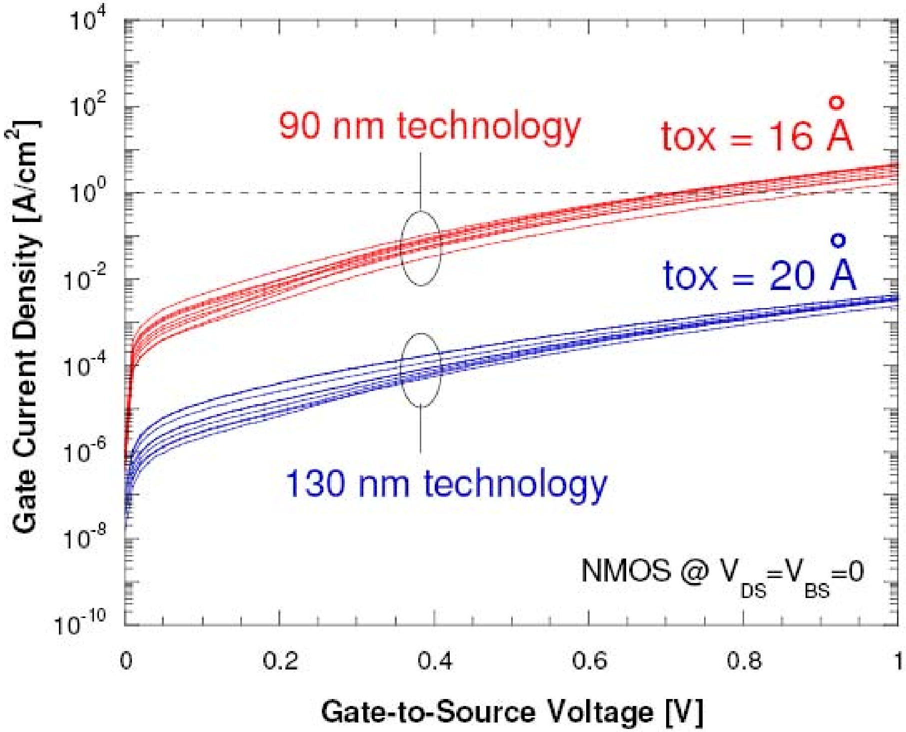
- Short channel devices (L<0.5 µm in 130 nm technology and L<0.2 µm in 90 nm technology) exhibit a K_f coefficient larger than for devices with longer channels
- K_f is to a large extent independent of the bias conditions
- K_f is lower in the 90 nm process by about a factor of 2

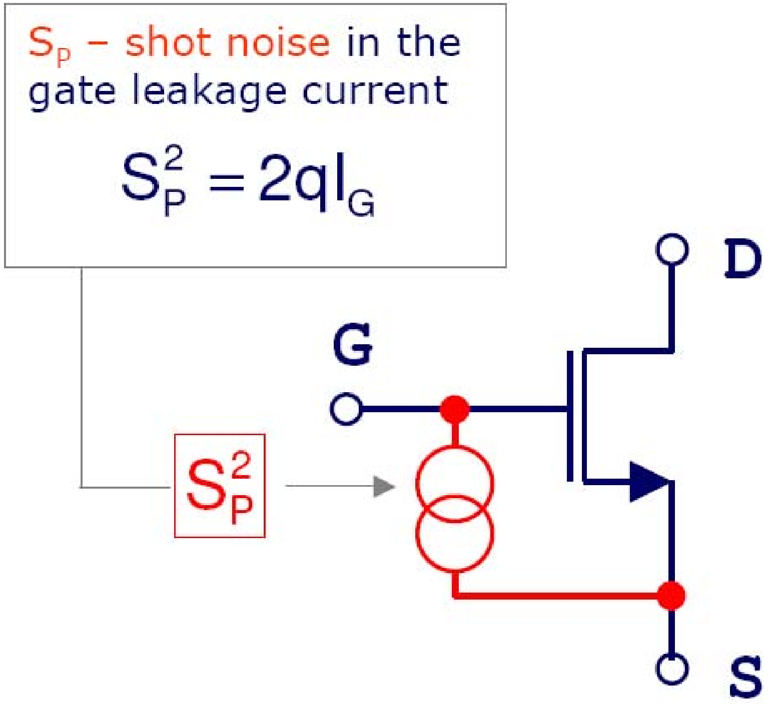
PMOS devices

- K_f coefficient is bias dependent (dependence is weaker in 90 nm technology)

Gate leakage current

Thinner gate oxide → higher leakage current I_G in 90 nm technology is about 3 order of magnitude higher than in 130 nm technology





S_p – shot noise in the gate leakage current

$$S_P^2 = 2qI_G$$

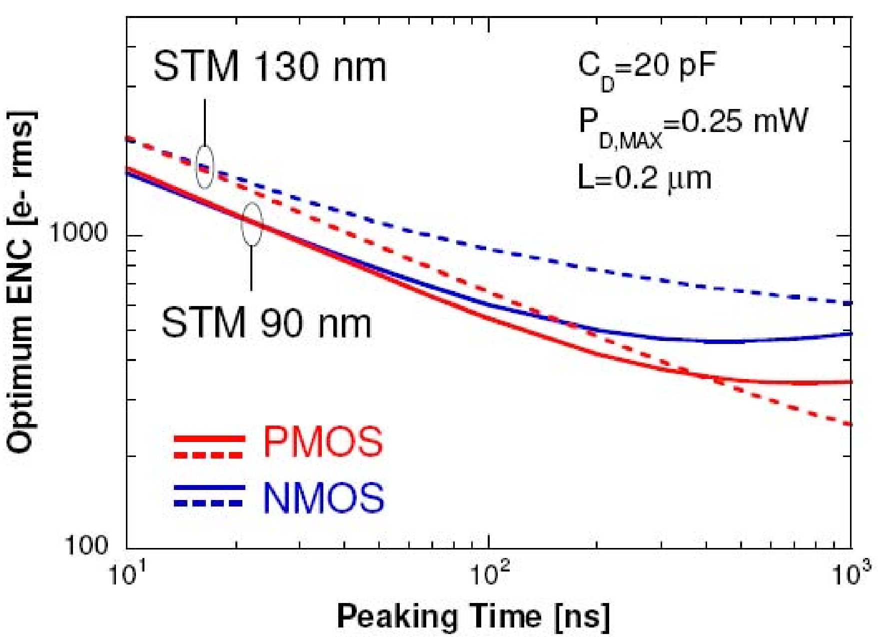
Shot Noise evaluation in 90 nm process:

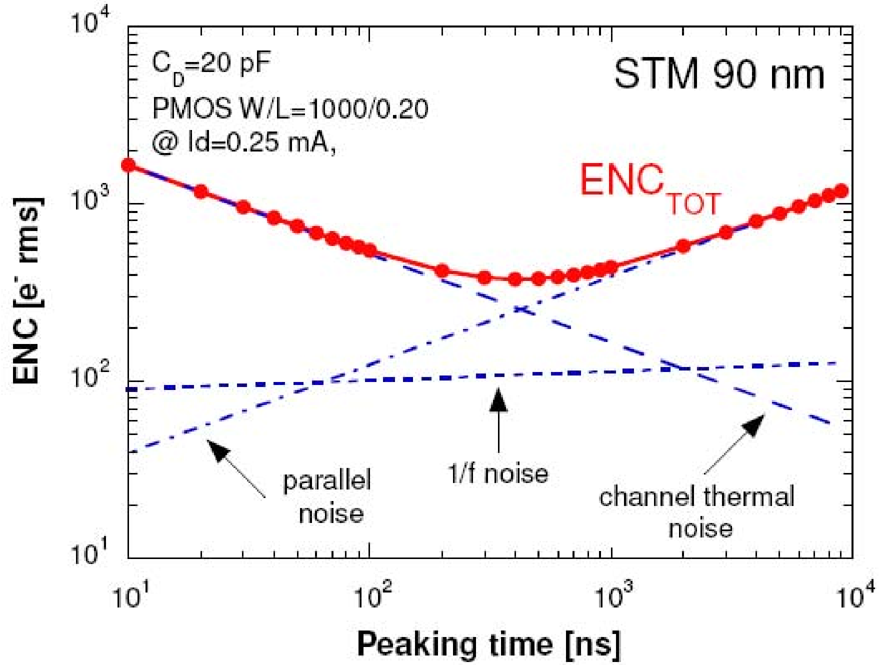
in the examined operating region current density ≈ 0.01 A/cm²

W/L = 1000/0.2 @ I_D=0.25 mA, V_{DS}=0.6 V → $I_G = 0.02\ \mu A$ → $S_p = 0.08\ pA/\sqrt{Hz}$

Low noise charge preamplifier design

- Circuit designers can take advantage of single device characterization to predict noise behavior of charge sensitive amplifiers
- ENC was evaluated in the case of a second order, unipolar (RC^2-CR) shaping processor





- In the explored peaking time and power range, PMOS input device always provides better noise performances than NMOS (except at t_p close to 10 ns)
- Using the 90 nm process may yield quite significant improvement with respect to the 130 nm technology, except at long shaping time
- In the 90 nm process at long shaping time ENC is dominated by noise contribution from gate current

Conclusions

- **Static, signal** and **noise measurements** have been performed on devices belonging to two different **CMOS technology** nodes, namely the **130 nm** and **90 nm** STM processes
- **Channel thermal noise** equations developed to describe the device behavior in the considered operating regions provide a **reliable model**, with short channel effect playing a minor role in both the considered processes
- **1/f noise** results confirm the behavior detected in previous submicron processes as far as the dependence on device polarity and bias and gate geometry is concerned
- Extracted noise parameters show that using the 90 nm process may ensure an improvement in the noise performances in applications where large signal dynamic range is not needed while miniaturization can be an asset
- **Gate leakage current** can be an issue when longer shaping time is used
- Characterization of the 90 nm technology will be completed with **radiation hardness tests** (open structure *vs* enclosed layout, study of possible STI effects)

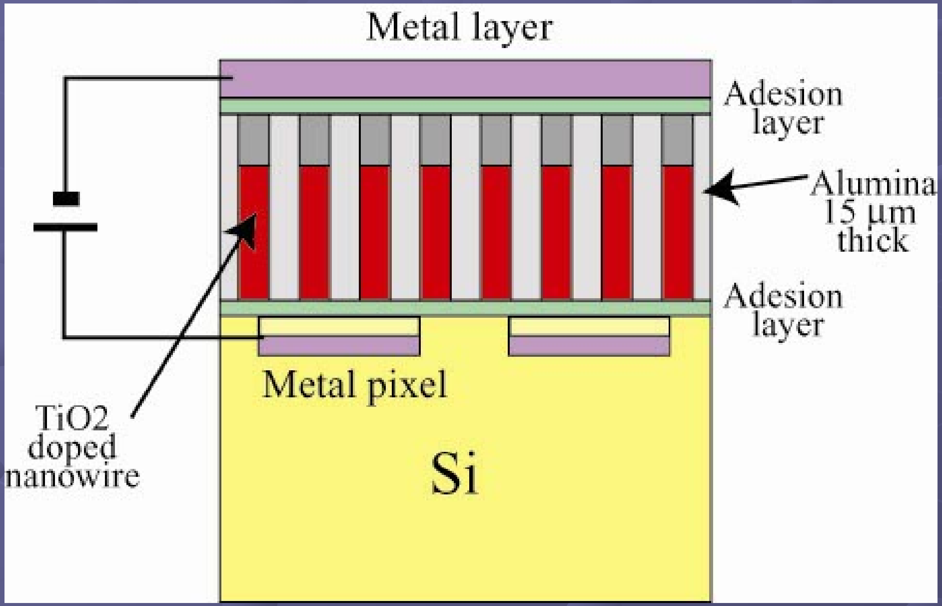
Something REALLY fancy

The NanoChanT project

- Aim:
  - use presently **available nanotechnologies** to build a position detector for ionizing particles
  - try to achieve a resolution of the order of **100 nm** (one order of magnitude better than what is achievable now with Si detectors)
- How:
  - *two basic ingredients:*
    - nanochannels, that are obtained from controlled anodization of Aluminum (Alumina, Al_2O_3) and that have a highly regular honeycomb-like geometry (from here the name *NanoChanT* that stands for “Nano Channel Template”)
    - nanowires made of Titanium Dioxide (TiO_2, an intrinsically n-type semiconductor) that are grown inside the nanochannels

The detector principle

Basic idea

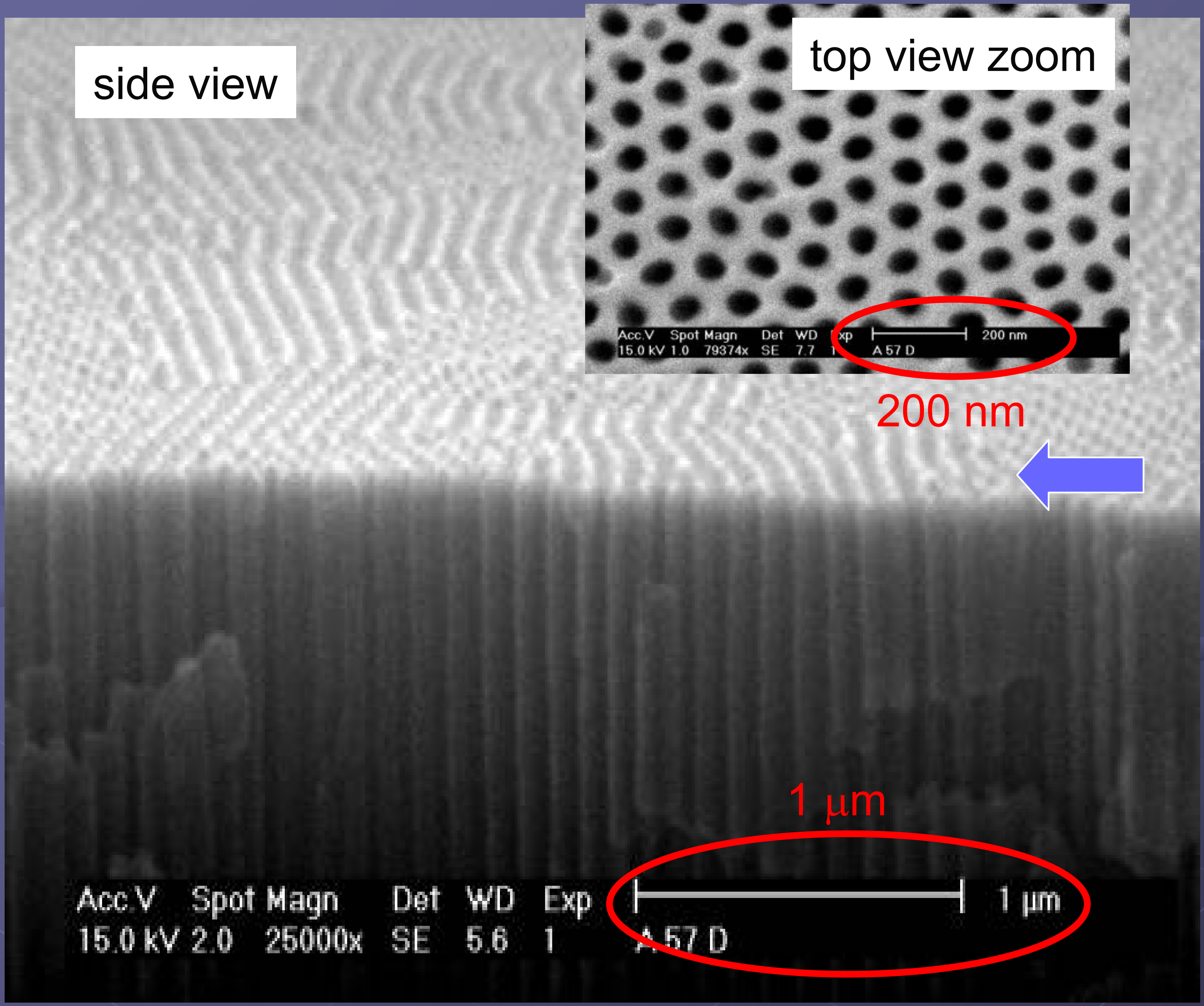


- Alumina layer is ~ 15 μm thick
  - it is an insulator and mechanically rigid
- TiO_2 nanowires fill the nanochannels
  - after doping, each wire form a p-n junction (reversed biased)
  - ionizing particles produce e-h pairs that are collected to produce a signal
- Advantages:
  - reduced charged diffusion (layer is thin and the charge is confined inside the wire)
- To read the charge:
  - use CMOS technology with pixels that collect the signal by group of nanowires

  ..but ready for future scale reductions

In order to dimension the geometry we need to simulate the energy deposited in the wires by a traversing particle !

The alumina template



Alumina template:

diameter (20-200 nm)
and
pitch (40-500 nm)

of the channels can be determined by the anodization condition (acid, temperature, voltage, time..)

Summary

Many thanks to all speakers who made their talks available!!

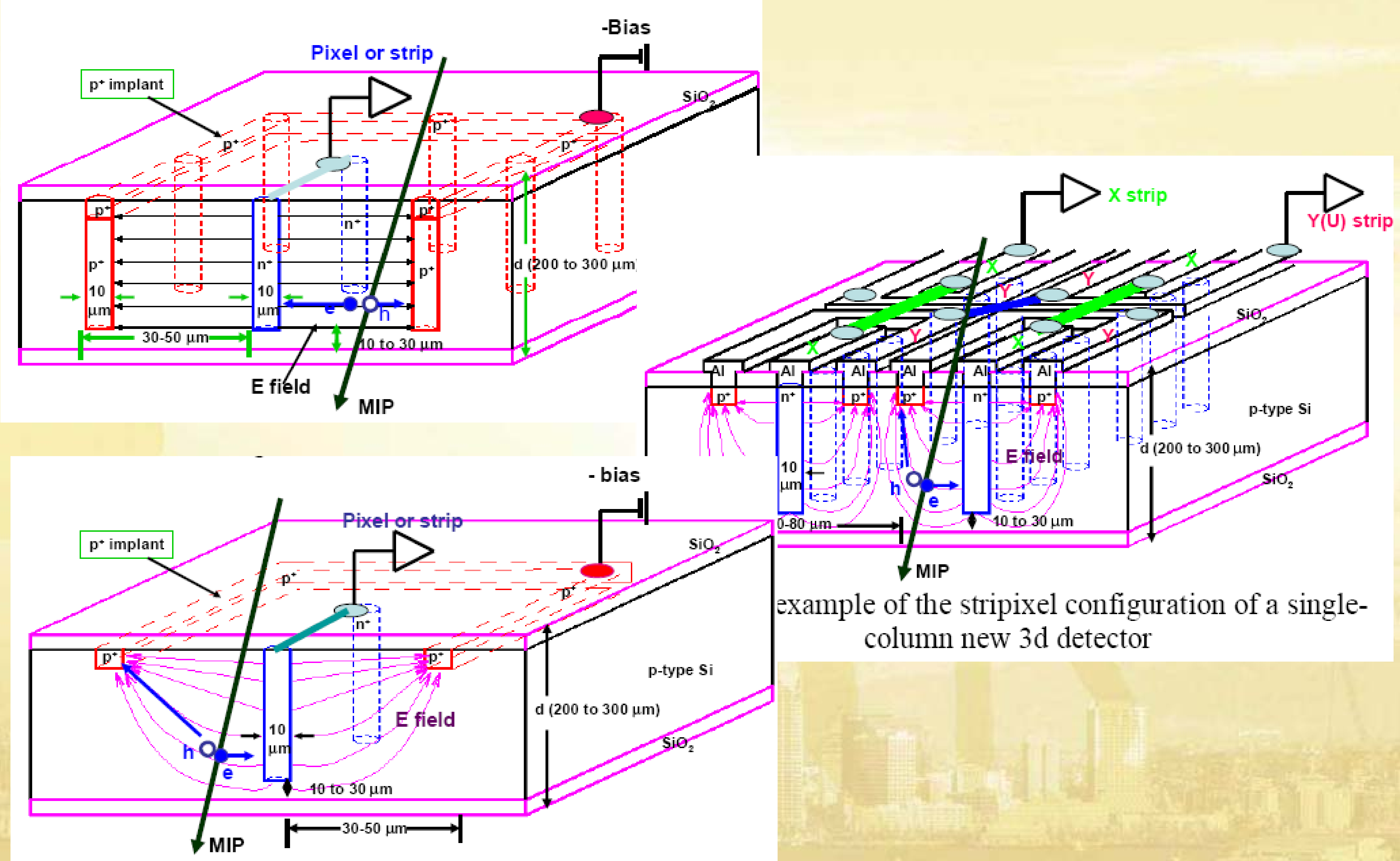
Backup Slides

Probably not needed ;-)

3D-Pixels (Parker-Detectors)

Sherwood Parker showed 75 slides in 20 minutes

3D-Variants



example of the stripixel configuration of a single-column new 3d detector

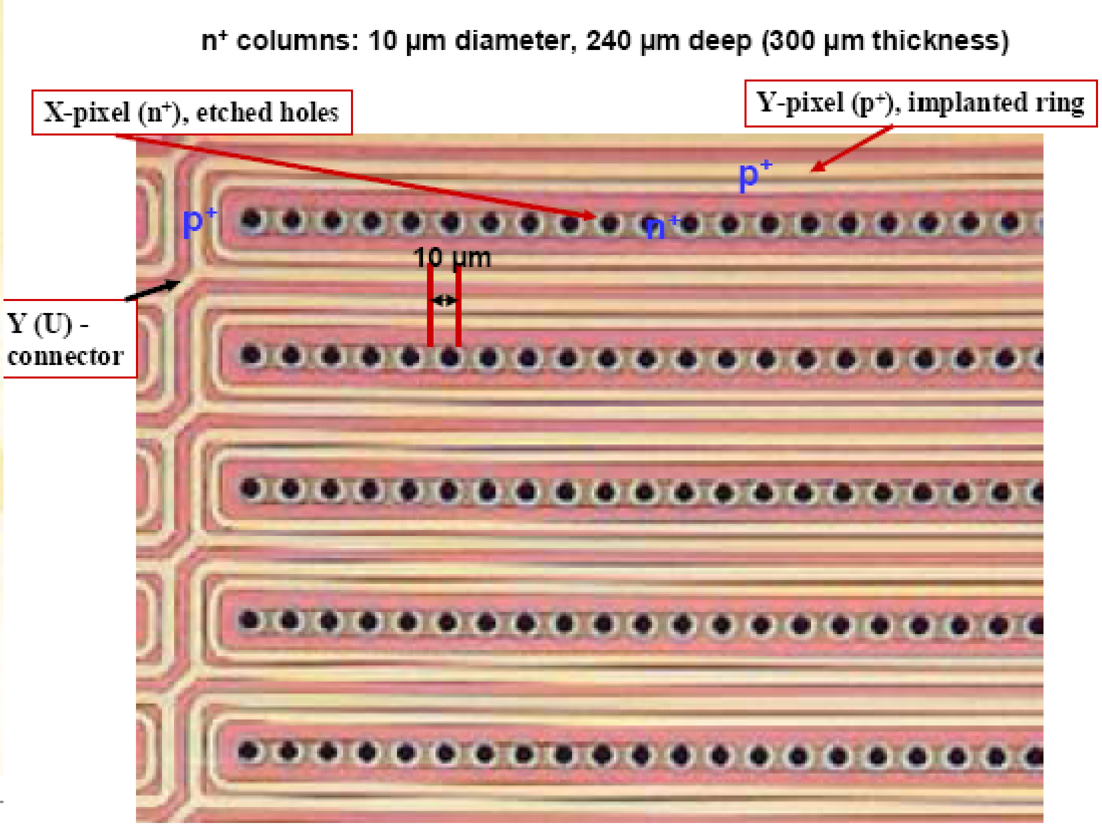
Fig. 2. One half of a single cell of a single-column new 3d detector

BUT:

pillars are dead volume

capacitance *60

RC because of pillar R



n⁺ columns: 10 µm diameter, 240 µm deep (300 µm thickness)

Fig. 5 Photography of a prototype single-column 3d detector