Position Sensitive Detector Technologies at CERN

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Introduction

This document is the seventh of a series of surveys designed to inform UK industry of the wide range of technologies being developed at CERN, and which are available for transfer into industry. There will be a number of such surveys, focusing on different technologies, and different aspects of those technologies. The survey focuses exclusively on position sensitive detectors that are relevant to a wide range of applications in physics, analytical, medical and other instrumentation. These include: scintillators, solid state detectors, gas electron multiplier detectors, signal acquisition electronics and modelling software.

Contents

Introduction 1
Contents 1
Position Sensitive Detectors at CERN – The Opportunity 2
CERN Position Sensitive Detector Technologies Available for Technology Transfer 2
  Position Sensitive Detectors 2
    1. Crystal Clear Scintillators 2
    2. Medipix Detectors 4
    3. Gamma ray Detector for Positron Emission Tomography (PET) and single Photon Emission Computed Tomography (SPECT) 5
    4. Gas Electron Multiplier (GEM) Detector 6
    5. Amorphous Silicon Pixel Detectors 7
    6. Monopix Detector 7
    7. Imaging Silicon Pixel Array (ISPA) Detector 8
    8. Diamond Tracking Detector 9
    9. Rejuvenation of Detectors using Cryogenic Temperatures 10
    10. Low Noise Charge Sensitive Detector Front Ends 11
    11. Compton Camera 12
  IT 13
    12. GEANT4 13
More about Position Sensitive Detector Development at CERN 14
Further Information 14

Position Sensitive Detectors at CERN – The Opportunity

Today, a wide range of organisations use accelerators in many ways: for fundamental research, to diagnose and treat patients, to improve the performance of materials, to sterilise medical equipment and food, to manufacture products such as semiconductors, to coat surfaces in aircraft engines and artificial hips to improve life, to investigate how care engines wear out, to look for explosives and drugs in airports and harbours and to help survey for underground tunnelling.

All of these applications require specialist position sensitive detectors for control and calibration of the radiation beams and analysis of the information gained and CERN has been leading the developments in this field for the last fifty years. There is a wealth of leading-edge expertise in all types of radiation detectors which is highly relevant to the wide range of applications. Much of this expertise is available for transfer to organisations in the UK.

CERN Position Sensitive Detector Technologies Available for Technology Transfer

Position Sensitive Detectors

CERN has extensive expertise for integrating and optimising scintillators, detectors and electronics to provide the total detection solution to an application problem. The following section discusses projects underway.

1. Crystal Clear Scintillators

Description
The Crystal Clear Collaboration is a multidisciplinary collaboration, working on the development of new inorganic scintillators. It aims to find new and better fast scintillators, and new and better ways to use scintillators. The main materials studied are CeF3, PbWO4, and cerium-doped LSO, LYSO, LuAP, LuYAP crystals and hafnium glasses and ceramics. The scintillators being developed have maximum dimensions of 10cm diameter and 30 cm length and will detect particles up to 1 GeV in energy.

The project has achieved a number of milestones to date:

- A thorough understanding of the different mechanisms underlying the scintillation and radiation damage processes in Lead Tungstate crystals has been gained and producers in Russia and China have been helped to develop the mass production at an unprecedented scale and quality level;
- Research has established Cerium Fluoride (CeF_3) as a dense, fast, high light yield and radiation hard scintillator, suitable for High Energy Physics experiments. Work has been completed with Optovac (USA), SIC (China), BGRI(China), and Crytur (Czech Republic)) to develop an industrial scale production process for Cerium Fluoride scintillators. At the same time the project has greatly contributed to the understanding of cerium emission based scintillators;
- In collaboration with the French company "Le Verre Fluoré", a new family of heavy scintillating fluoride glasses has been developed, offering excellent perspectives for a new generation of "affordable" calorimeters and Cerenkov detectors;
- Development work, in collaboration with the Czech company Crytur, on high quality Yttrium Aluminate Perovskite crystals (YAP) has been completed. These crystals have a moderate density (5.36 g/cc), but give at least two times more light than BGO, with a

broad emission band centred around 370 nm, and a scintillation decay time of 30 ns. This scintillator is now extensively used in several types of medical probes and as screens in electronic microscopes. A special highly segmented YAP matrix has been built by Italian groups for a high resolution mammographic camera, a high resolution PET camera for small animal imaging, and YAP plates are being considered for high resolution ISPA tubes, also used for medical applications;
- The Collaboration has identified and pioneered LuAP ($LuAlO_3$:Ce) as a very promising new scintillator with a decay time of only 18 ns and a light yield which could possibly be 50% of NaI.

Applications

- High Energy Physics;
- Scintillators for electromagnetic calorimeter of CMS;
- Crystallography industry;
- Solid state physics;
- Medical Instrumentation:
  - Medical imaging;
  - PET scanners;
  - Mammography;
  - Neurosciences and detection of neurological disorders;
  - Oncology: cancer screening and detection, treatment follow-up;
- Industrial control devices;
- Security systems;
- Geological survey.

Benefits

The key benefits of the new scintillator materials being developed are:

- Higher density and stopping power giving higher yield, especially for low energy gamma rays;
- High light intensity per event for easier detection;
- Fast response time (rise and decay of light) allowing:
  - Detection of high numbers of events;
  - Use of high speed electronics;
- Reduced costs;
- Better resolution with smaller crystals;
- Increased radiation hardness.

References

- http://crystalclear.web.cern.ch/crystalclear/CCCProgramCrystaldata.HTM
- http://crystalclear.web.cern.ch/crystalclear/medical_imaging.htm
- http://crystalclear.web.cern.ch/crystalclear/HEP.html
- http://crystalclear.web.cern.ch/crystalclear/CCChistory.htm

Status

While developments in this field are continuing, the technologies are sufficiently mature for transfer to industry. Patents have been filed and further extension of the patent portfolio is underway. Licenses and technical support through collaboration projects or consultancy are available from CERN.

2. Medipix Detectors

Description

The Medipix ASIC is a high spatial, high contrast resolving CMOS pixel read-out chip working in single photon counting mode. It can be combined with different semiconductor sensors which convert the X-rays directly into detectable electric signals. This represents a new solution for various X-ray and gamma-ray imaging applications. By using thresholds it is able to cut out background and leakage currents, giving a much cleaner image.

The project has been split into two phases and the Medipix1 detector (a matrix of 64 x 64 pixels with square pixels measuring 170 microns on the side, a 3-bit threshold setting and a 15-bit counter) has been demonstrated. Even with the rather transparent silicon detector, a dose reduction of a factor of up to 30 (minimum tube settings) was achieved for some non-medical radiographic applications, while still providing all the necessary image information. In mammography application, it has been proven that a dose reduction to the patient of at least a factor 4 is achievable by using Gallium Arsenide sensors, providing a high gain in contrast resolution with respect to the conventional film-screen set-ups.

Following this success the Medipix2 successor chip was designed. The new square pixel measures 55 microns on the side which should result in a spatial resolution competitive with other imaging systems on the market. Moreover, each Medipix2 pixel cell has two thresholds, defining a selection window in energy, and a 13-bit counter. The reduced pixel dimension and increased complexity was achieved by using a 0.25 micron CMOS technology. The chip will be buttable on 3-sides in order to obtain larger detection areas.

The single photon counting PCC chips are intended to readout pixel semiconductor detectors for high resolution and high-speed X-ray imaging applications using X-rays, gamma-rays and particles, several of which are being addressed in the MEDIPIX collaboration.

Applications

- High Energy Physics;
- Medical Imaging:
  - X-ray imaging applications which should profit from this contrast enhancement;
  - Medical X-ray diagnosis which should benefit from dose reduction.

Benefits

- High sensitivity, large dynamic range and low contrast detectability, exceeding present charge integrating techniques; dose reductions of up to 30 times have been achieved as a consequence of these features;
- No sensitivity to dark currents, allowing for long exposure times under very low intensity illumination;
- High maximum count rates, allowing for high intensity illumination up to the order of 0.4 GHz/mm^2.

References

- http://medipix.web.cern.ch/MEDIPIX/
- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=specialproject&item_id=110

Status
The technology is proven and ready for transfer to industry. The technology is patented and the IP is controlled by CERN. Licenses and technical support through collaboration projects or consultancy are available from CERN.

3. Gamma ray Detector for Positron Emission Tomography (PET) and single Photon Emission Computed Tomography (SPECT)

Description
In medical imaging Positron Emission Tomographs (PET) provide quantitative measurements on the metabolism of internal organs and their biochemistry by in vivo measuring specific activities of positron emitting radio-nuclides (mainly 18F fluorodeoxyglucose FDG). Over the last 20 years of continuous development PET scanners have demonstrated a tremendous potential for cancer diagnosis and treatment.
The challenge for advanced PET instrumentation is to optimise the performance (spatial resolution, acceptance, and system sensitivity) at the lowest possible construction and operation cost. This is particularly true for whole body ring scanners. CERN have developed a novel 3D-PET concept, which will provide higher performance at comparable or lower cost than existing operational scanners or known prototypes under development elsewhere.

The detector provides a full 3dimensional reconstruction of the two 511 keV gamma quanta emitted at the moment of the positron annihilation. The gamma reconstruction is free of any parallax error and results in a precise measurement of the Depth of Interaction (DOI). In addition to the detection of the gamma quanta by photoelectric effect, also a substantial fraction of events which underwent Compton scattering in the detector can be exploited. This approach increases the sensitivity of the scanner by a factor 2-3. The detector is made possible by the latest developments of advanced instrumentation, in particular single photon detectors, performed at CERN for the future Large Hadron Collider. The use of large area and highly pixelized Hybrid Photon Detectors (HPD) with enclosed VLSI self-triggering electronics allows for a cost efficient readout of finely segmented arrays of scintillator crystals.

Applications
- Positron Emission Tomography (PET);
- Single Photon Emission Computed Tomography (SPECT).

Benefits
- Increased sensitivity, contrast and resolution (3 – 4 times over existing technologies);
- Uniform imaging properties over complete field of view;
- Larger detectors ~ 20cm maximum;
- Provides higher performance at comparable or lower cost than existing operational scanners or known prototypes under development elsewhere.

References
- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=patent&item_id=368

Status
Patents have been filed and further patents will be filed in the future. Although the technology is still in the development stage, CERN will consider applications for licensing and for collaborative development projects.

4. Gas Electron Multiplier (GEM) Detector

Description

The gas electron multiplier (GEM) detector consists of a thin, metal-clad polymer foil, chemically pierced by a high density of holes. On application of a difference of potential between the two electrodes, electrons released by radiation in the gas on one side of the structure drift into the holes, multiply and transfer to a collection region. The multiplier can be used as detector on its own, or as a preamplifier in a multiple structure; in this case, it permits to reach large overall gains in harsh radiation environment.

The GEM manufacturing technology has been developed at CERN in the printed circuits workshop (EST-MT). A metal-clad polymer foil (copper on kapton) is coated on both sides with a photosensitive layer and exposed to UV light through a mask reproducing the desired holes' pattern. The metal is chemically removed in the holes, and the foil is immersed in a solvent for Kapton. The resulting foil has conductor on both sides, pierced by a high density of holes (typically 70 μm in diameter at 140 μm pitch). Close to a thousand GEMs of various shapes and sizes have been built so far, both for the requirements of HEP experiments and for other applications.

Applications

- High Energy Physics:
    - CMS, COMPASS, LHC-B,HERA-B;
- Plasma Diagnostics:
    - Interest has been shown also by groups working on plasma diagnostics around fusion machines and for gamma- and x-ray burst detection in astrophysics. Detection and localization of single electrons emitted by internal photo-cathodes is also being developed;
- Other Fields:
    - Astrophysics;
    - Medical Imaging.

Benefits

- Very high rate capability and time resolution;
- Good 2 axis spatial accuracy using triple GEMs;
- Near single photon counting performance;
- Sturdiness and reliability.

References

- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=technology&item_id=165
- http://gdd.web.cern.ch/GDD/applications.htm
- http://www.cerncourier.com/main/article/41/2/13
- http://dirac.web.cern.ch/DIRAC/Addendum/A/html/node48.html

Status

Proven and well developed technology that is available for transfer and immediate implementation by industry. The GEM Detector technology, inventor Fabio Sauli, is patented (WO99/21211) and non-exclusive licenses are available. Exclusive licences can be obtained for specific applications. No licence is available for dosimetry in water phantoms detector devices. CERN will consider collaborative projects for further development of the technology.

5. Amorphous Silicon Pixel Detectors

Description

CERN is developing a vertically integrated detector using thin-film on ASIC (TFA) or thin-film on CMOS (TFC) technologies. This highly integrated detector will consist of CMOS read-out electronics, an amorphous silicon detection layer and, where necessary, an integrated scintillator layer. The combination will create a detector that will have significant potential for high sensitivity and low level light detection. The technology can be wafer scaled.

The sensor currently consists of an array of 48 square pixels with 380 µm pitch based on a 30 µm n-i-p hydrogenated amorphous silicon film deposited on top of a VLSI chip. (A pixel pitch of 15µm is possible).Early prototypes are currently under test to evaluate and prove the technology. With maximum detection energy of 28 – 30 KeV, a scintillator layer will be needed for higher energy applications. . Direct conversion and single counting with photons of few keV energy has been demonstrated with ^{55}Fe.

Applications

- High Energy Particle Physics:
  - Radiation hard vertex pixel detector;
  - Low cost large area pad detector;
- Single photon X-ray imaging:
  - Hard X-ray with a scintillation layer, CT and PET scanner applications;
  - X-ray Fluorescence.

Benefits

- Large area detector > 1m^2;
- Room temperature operation;
- Lower cost than existing technologies;
- High radiation resistance for long lifetime.

References

- http://asi-hdet-project.web.cern.ch/asi-hdet-project/
- D. Moraes et al: A novel low noise hydrogenated amorphous silicon pixel detector Journal of Non-crystalline Solids 338–340 (2004) 729-731

Status

This project is still in the early research phase and CERN welcomes interest from companies wishing to join the research collaboration group.

6. Monopix Detector

Description

Monopix is a detector designed to perform single particle / photon counting using in a monolithic integrated circuit based on commercial deep or very deep CMOS technology. Pixel radiation sensors are arranged together in a monolithic circuit and an Active Pixel Sensor (APS) signal processing circuit is provided for converting the multi-electron level signals. This readout circuit performs fast signal amplification and fast signal discrimination. It also provides a fast logic signal or a fast analog signal each time a photon or a charge particle impinges on the radiation pixel sensor, without any additional peripheral processing circuit.

Several readout pixel circuits with their associated pixel sensor (typical size of 5um² to 10um²) are grouped together via an analogue or a digital single bus line to form a macropixel dimensioned to fit space resolution and desired pixel shape. Each macropixel is readout individually.

Applications

- High Energy Particle Physics:
  - Vertex detector;
  - Ultra sensitive photon detector;
- Space:
  - Ultra sensitive 2D single photon imager;
  - Star tracker;
  - High resolution ultra high sensitivity APS;
  - High resolution pixel radiation detector;
- Medical:
  - High resolution medical imager;
  - Biosensors based on light detection;
  - Single photon 2D sensor for molecular biology;
- Industrial applications:
  - Materials research, x-ray fluorescence.

Benefits

The readout circuit performs fast signal amplification and fast signal discrimination.
Also, it provides a fast logic signal or a fast analogue signal each time a photon or a charge particle impinges on the radiation pixel sensor, without any additional peripheral processing circuit.

References

- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=patent&item_id=268

Status

The technology under development and will be ready for transfer to industry in 2005. The technology is patented and the IP is controlled by CERN. Licenses and technical support through collaboration projects or consultancy are available from CERN.

7. Imaging Silicon Pixel Array (ISPA) Detector

Description

The Imaging Silicon Pixel Array (ISPA) detector is a hybrid photo-detector including a highly segmented pixel anode designed for scintillating fibres and RICH detectors. Hybrid Photon Detector (HPDs) detect light via photocathodes and accelerate the emitted photoelectrons by an electric field towards silicon PIN-anodes, where they are absorbed and generate electronic signals. Two specific types of HPDs have been developed:
1) Hybrid Photo Multiplier Tubes (HPMTs) for photon counting and gamma spectroscopy;
2) Imaging Silicon Pixel Array (ISPA)-tubes for optoelectronic cameras.

These devices consist of a vacuum envelope in which silicon diodes or pixel chips (anodes) are bombarded with accelerated photoelectrons from photocathodes . The acceleration is provided by applying a high voltage between cathode and anode (5 to 25 kV). Electrostatic fields can be arranged to provide electronic focusing and therefore, to maximise the photocathode active surface to the anode size.

A silicon pixel detector has been applied in the ISPA-tube, containing up to 2048 small diodes bump-bonded to their electronic readout. Plans are to insert a 8196 pixel chip (ALICE1 chip). A scintillating crystal (YAP:Ce) has been applied as a support for the photocathode, hence providing an important increase in light yield and spatial resolution for ISPA-electronic cameras.

Applications

Applications span from X-ray and gamma cameras for biomedical diagnostics and material analysis, to extremely low-light imaging for high energy physics and astrophysics. A new twin head camera is being developed to image and morphological and physiological processes in humans. Coupled with a scintillating crystal it can provide gamma imaging with sub-millimetre accuracy for medical scintigraphy.

Benefits

The detector provides a physical image (X-rays) combined with a physiological image (gamma rays) in a small device for localised measurements of, for example the thyroid. This is equivalent to the combination of PET and CAT scanning. Doses can be reduced radically. Spatial resolution is improved tenfold, to a fraction of a millimetre (compared with 5mm or so for an Anger Camera).

- Sub millimetre resolution;
- Dose reduction of 4 – 5 fold;
- Can de-magnify field of view onto smaller sensors while retaining sub millimetre resolution.

Future Developments

- 70 – 80 mm detectors for heart and kidney imaging;
- Multi-detector arrays for breast, lymph gland and larger area medical imaging.

References

- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=technology&item_id=103

Status

Patents have been filed and further patents are expected to be filed in the future. Although the technology is still in the development stage, CERN will consider applications for licensing and for collaborative development projects.

8. Diamond Tracking Detector

Description

Precise tracking information as close as possible to the beam pipe at the highest luminosities is very important for the Physics Performance of all LHC and TEVATRON experiments. Polycrystalline CVD diamond is a promising material to go beyond Silicon in radiation hardness to build tracking devices which survive many years in these highest luminosity environments. The generated charge in diamond is 3600 electron-hole pairs per 100 microns compared with 10600 electron-hole pairs in Si. Samples are very reproducible and of good quality, not only in Charge Collection Distance (CCD), but also in leakage current, (non-)polarization, spatial resolution and detailed properties of the “Landau” distribution. Laboratory and test beam studies have been performed with CMS and ATLAS prototype chips to determine:

- Threshold;

- Hit efficiency;
- Spatial resolution of CVD diamond devices.

An experimental study has been made on the quality (using TCT technique) of CVD diamond as a function of the thickness of the sample and 6” wafers with 300µm collection depth have been achieved. Current devices are made from polycrystalline diamond material, but mono-crystalline devices are under development.

Applications

- Radiation detectors for high-luminosity experiments and applications up to at least 100 Mrad.

Benefits

Diamond is known to be radiation hard up to fluencies of 5 x 10^{15} protons/cm^2 and in particular also to photons and electrons up to at least 100 Mrad. This gives it a long lifetime as a high energy particle detector in environments with ultra-high luminosities.

References

- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=technology&item_id=148

Status

This technology is still under development and CERN welcomes ideas for collaboration projects.

9. Rejuvenation of Detectors using Cryogenic Temperatures

Description

Silicon strips and pixels are detectors of choice for front-line tracking applications in particle physics. Placed as close as possible to particle beams, they measure the tracks of particles as they emerge from collisions. At the LHC, the front-line trackers will be traversed by a mammoth thousand million million passing particles per square centimetre over the lifetimes of the experiments. Silicon detectors used as they have been in the past will not be able to cope because after long exposure to passing particles, defects appear in the silicon. These temporarily trap the electrons and holes – electron vacancies that behave like positively charged electrons – which are created when particles pass through. Since it is these electrons and holes which announce the passage of a particle, lattice defects destroy the signal.

Using experience gained in searches for cold dark matter particles, where small signals demand the sensitivity of cryogenic detectors, a group of physicists at Bern University decided to see what would happen when radiation damaged silicon detectors were cooled to cryogenic temperatures. They found that at temperatures below 100 Kelvin, dead detectors apparently come back to life. The explanation seems to be that at such low temperatures, electrons and holes normally present in silicon detectors which form a constant so-called 'leakage' current are themselves trapped by the lattice defects and no longer re-emitted. This leads to a situation in which most of the traps are filled and therefore inactive so electrons and holes released by passing particles can not be trapped and the signal returns.

However closer investigation reveals that for extreme radiation doses the signal only recovers to half its initial value. It seems that electrons are still being trapped and only the holes remain free to form the signal. Since holes move just as quickly at cryogenic temperatures as electrons this may not be a problem, but it nevertheless needs to be understood. CERN's RD39 collaboration has picked up the reins and plans a series of detailed studies of the Lazarus effect over the coming year to investigate this phenomenon and to optimise the design of readout electronics for cold detectors. Already RD39 has done two test beam studies in collaboration with physicists from COMPASS, Delphi, LHCb, and NA50 to confirm that the effect is real. So far the results suggest that silicon detectors operated in the cold could remain the detectors of choice for a new generation of particle physics experiments.

Applications
- Several CERN experiments are potential users of cold, radiation-hard tracking devices.

Benefits
Among other potential benefits of operation at cryogenic temperatures are the use of large low-resistivity wafers, simple processing, higher and faster electrical signal (due to the higher mobility and drift velocity of carriers), and lower noise of the readout circuit. A substantial reduction in sensor cost could result.

Status
Extensive expertise in this field is available within CERN and is available for transfer to industry under collaboration or consultancy arrangements.

10. Low Noise Charge Sensitive Detector Front Ends

Description
Particle detectors often deliver an electric charge signal which needs to be amplified and filtered to be detected. The design of circuits which perform this task is a speciality in itself, and typical constraints are hit rate and required time resolution, maximum noise level (expressed in electrons!), dynamic range, and channel-to-channel uniformity.

A key parameter for charge detection front ends is the capacitance associated with the electrode to which the charge is delivered: a lower capacitance will allow lower noise and higher speed for the same power consumption.
- <500 fF: pixel detectors: highly segmented semiconductor detectors (~100 micron detecting element pitch). Here noise can be less than 100 electrons rms, the design is often limited by large hit rates, requiring fast (~25ns) recovery after a particle hit, and by channel-to-channel uniformity issues;
- 500fF - 50 pF: semiconductor strip and pad detectors: here designs are often severely power-constrained;
- >50 pF: large strips and gaseous detectors: Gaseous detectors often deliver the charge to the readout as a current extended over a relatively long time (microseconds), and special circuitry needs to be introduced to eliminate this long signal tail from the response to allow hit rates higher than the duration of the signal corresponding to each individual hit.

These charge sensitive front ends generally consist of a preamplifier and a filter which enhances the signal to noise ratio by rejection noise outside the signal band.

Applications
- Particle detectors;
- Sensor readouts.

Benefits

- Low noise signals;
- Higher speed.

References

- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=technology&item_id=1473

Status

The expertise available in CERN is available for transfer to industry under collaboration or consultancy arrangements.

11. Compton Camera

Description

The traditional technique in SPECT uses Anger cameras, in which the x-ray energy is converted in scintillators either by photo-electric absorption or by Compton scattering followed by photo-electric absorption. The direction of the x-ray is obtained through mechanical collimation, which reduces the flux of usable x-rays drastically. Typically, less than 1 in 10,000 γ-rays emitted by the organ are used for image reconstruction.

An alternative to the Anger camera is electronic collimation. Here the technique consists of using the COMPTON scattering process to determine the direction of the primary gamma-ray. The single Compton scatter occurs in a first detector, made in this case of silicon pad sensor arrays. The scattered photon is then observed in a second detector, in principle a scintillation (Anger) camera without a lead collimator, and its impact position is measured. In this technique the recoil energy of the electron and the position of the recoil electron in the silicon detector are measured. The direction of the recoil electron can in general not be measured since it has too low an energy and is fully absorbed in the silicon detector. However, the Compton equation allows the reconstruction of the direction of the original gamma-rays from the measured quantities within a conical ambiguity. Many events from each source point will solve this ambiguity. The spatial image resolution obtained with Compton collimation can be twice as good as with the Anger camera, and the efficiency can be up to 200 times greater.

A similar principle can be used for a PET device. Using two opposite Compton scatter detectors one selects a coincidence of Compton interactions of both 511 keV γ-rays originating from the e+e- annihilation in the organ under investigation. This can give very good resolution since the Compton scatter process is point-like with an inherent localisation of the recoil electron within 200 to 300 μm. Efficiencies can be made comparable to conventional scintillator PET detectors by choosing the appropriate thickness of silicon in the Compton scatter detector. Adding a scintillator block behind each silicon Compton scatter detector, in which the scattered photon is fully absorbed, will improve background rejection in a PET device.

Applications

- Nuclear Imaging techniques:
  - Single Photon Emission Computed Tomography (SPECT);
  - Positron Emission Tomography (PET).

Benefits

- Sensitivity - up to 200 times better than Anger SPECT;
- Spatial resolution - 2 – 3 times better than Anger cameras.

For PET applications, this camera is less expensive and more sensitive. New high-sensitivity crystals,LSO, LYSO, LuAP or LuYAP provide greater image sharpness due to the decreased size of the scintillation detector. This allows the diameter of the detector ring to be decreased, which in turn reduces the overall cost of the camera. Furthermore, in a dual layer configuration the large difference in decay time constants of LSO and LuAP (40 ns and 11 ns for 60% of the emitted light respectively) allow measurement of the depth of interaction, reducing the parallax error.

References

- http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=specialproject&item_id=68
- http://xray.web.cern.ch/xray/publications/Lyon2000PaperCERNPreprint.pdf

Status

Patents have been filed and further patents are expected to be filed in the future. Although the technology is still in the development stage, CERN will consider applications for licensing and for collaborative development projects.

IT

In order to handle the vast amounts of data that is generated in high energy particle physics experimentation, CERN has been developing a range of innovative computing and software technologies, some of which have application in Healthcare and Medical applications. These are:

12. GEANT4

Description

The Geant4 is a software package that simulates the passage of elementary particles through matter.

Geant4 provides a complete set of tools for all the domains of detector simulation: Geometry, Tracking, Detector Response, Run, Event and Track management, Visualisation and User Interface. An abundant set of Physics Processes handle the diverse interactions of particles with matter across a wide energy range, as required by Geant4 multi-disciplinary nature; for many physics processes a choice of different models is available. In addition a large set of utilities, including a powerful set of random number generators, physics units and constants, Particle Data Group compliant Particle management, as well as interfaces to event generators and to object persistency solutions, complete the toolkit.

Applications

Originally designed for the High Energy Physics experiments, GEANT has today found applications also outside this domain in the areas of medical and biological sciences, radioprotection and astronautics. The principal applications of GEANT in High Energy Physics are:

- The tracking of particles through an experimental setup for simulation of detector response;
- The graphical representation of the setup and of the particle trajectories.

Benefits

GEANT4 has exploited advanced software engineering techniques and Object-Oriented technology to improve the validation of physics results and at the same time to make possible distributed software design and development in the world-wide collaboration. The GEANT4 software process is based on the Booch Object-Oriented methodology, following an approach of spiral iterations and cycles of design and implementations. Problem domain decomposition and OOA&D have given a clean, unidirectional dependency structure of class categories.

References

- http://wwwasd.web.cern.ch/wwwasd/geant4/geant4.html

Status

Geant4 source code, documentation and installation guide is available from the CERN website.

More about Position Sensitive Detector Development at CERN

Particle physics experiments today generally contain a variety of different position sensitive detectors, each with a specialised task to aid the identification and measurement of particles. Close to collision point, tracking detectors reveal the paths charged particles take as they fly away. In order to support its research programme, CERN has an extensive programme of radiation detector research. Many of the developments have applications in a range of industries.

Scientists at CERN are aware of the benefits their research can have to improvements in industrial technologies and regularly review their research work to identify opportunities and applications.

Further Information

PPARC and CERN have active programmes to assist UK companies in partnering with the research base for collaborative development and transfer of relevant technologies from Particle Physics, Astronomy and Space Science into broader industrial applications. This support extends to include all options such as collaborative development, establishment of spinout companies, licence of patents, training and skills development.

There are numerous sources for further information and articles describing the technologies in more detail than is possible in this brief summary. For specific information relating to any of the technologies discussed, please contact Nathan Hill at the address given below.

Articles of interest can be found in the web publication version of the CERN Courier, at http://www.cerncourier.com.

Contacts:

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