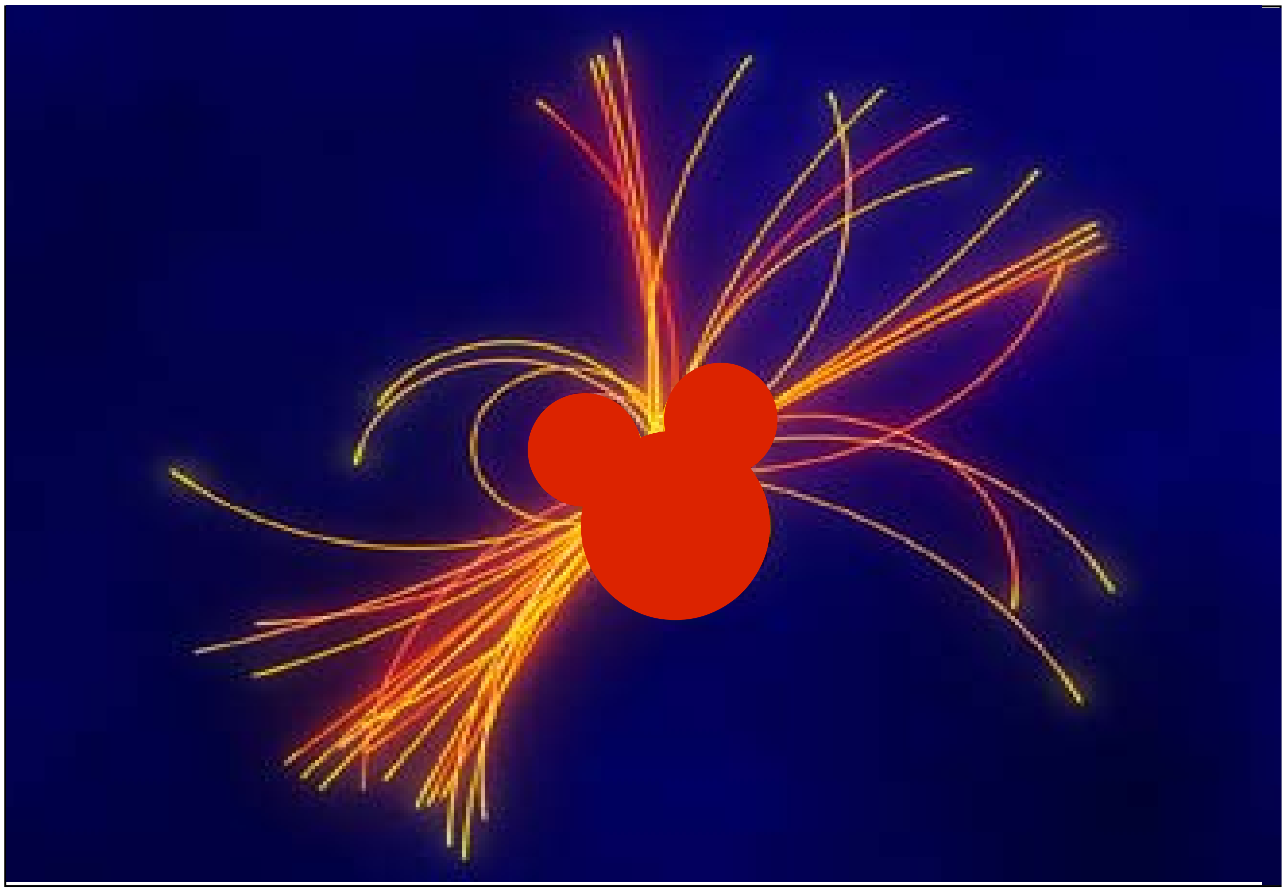
The Wonder of Science

2012 IEEE NSS/MIC/RTSD

IEEE MIC/NSS 2012
Anaheim (Disneyland Hotel)
conference summary

Thibault Frisson



IEEE MIC/NSS 2012 - Anaheim (Disneyland Hotel)

More than 1000 participants (guess), 54 exhibitors, etc.

- Nuclear Science Symposium
  Technology and instrumentation and their implementation in experiments for particle physics, nuclear and space sciences, accelerators, radiation environments, and homeland security.
- Medical Imaging Conference
  Foremost international scientific meeting on the physics, engineering and mathematical aspects of nuclear medicine based imaging
- Workshop on Room-Temperature Semiconductor X-Ray and Gamma-Ray Detectors

NSS :

- Sessions:
  - 3 Plenary Sessions
  - 46 Oral Sessions (3-4 in parallel)
  - Joint sessions (MIC/NSS, RTSD/NSS, MIC/RTSD, MIC/NSS/RTSD)
  - 2 Poster sessions
- Short and refreshed courses
- Special Linear Collider Event :
  - 6 Sessions: Introduction, ILC/CLIC Accelerator and Detector concepts, Spin-offs, Industrial Applications, Accelerator Instrumentation
  - Discussion Forum about LC Perspectives

IEEE MIC/NSS 2012 - Anaheim (Disneyland Hotel)

Big conferences, a lot of sessions...

… thankfully, I was not alone.

Thanks to Véronique Puill, Vanessa Tocut, Sergey Barsuk, Christophe Beigbeder, Julien Fleury, Christophe de La Taille, Roman Poeschl, Ludovic Raux, David Sarrut, Etienne Testa, Damien Thienpont for the advices, ideas, photos....

LAL @ IEEE MIC/NSS

- **Session chairs :** Sergey Barsuk, Christophe de La Taille
- **2 Invited talks:** Véronique Puill, Christophe de La Taille
- **3 talks:**
  - SCATS, a TDC for the PID of Superb Experiment (C. Beigbeder)
  - SPIROC: Design and Performance of a Dedicated Very Front-End for an ILC Prototype Hadronic Calorimeter with SiPM (L. Raux)
  - Interactions of Hadrons in the CALICE Silicon Tungsten Electromagnetic Calorimeter (ILC group)
- **4 posters:**
  - ASPIC: an Integrated Circuit for LSST CCDs Readout (V. Tocut)
  - Construction of a Large Scale Prototype of a SiW Electromagnetic Calorimeter for a Future Lepton Collider (ILC group)
  - SKIROC2, Front End Chip Designed to ReadOut the Electromagnetic Calorimeter at the ILC (S. Callier)
  - OMEGAPIX2: 3D Integrated Circuit Prototype Dedicated to Read Out Plannar Pixel Sensor (D. Thienpont)

- **Others LAL contributions:**
  - Test of a Compton Telescope Prototype Based on Continuous LaBr3 Crystals and Silicon Photomultipliers
  - Towards a Sub-Millimeter PET Prototype with Continuous LYSO Crystals and SiPM Matrices
  - Studies for Performance Improvement of a Small Animal PET Prototype Based on Continuous LYSO Crystals and SiPM Matrices

LAL @ IEEE MIC/NSS

LAL @ IEEE

Plan

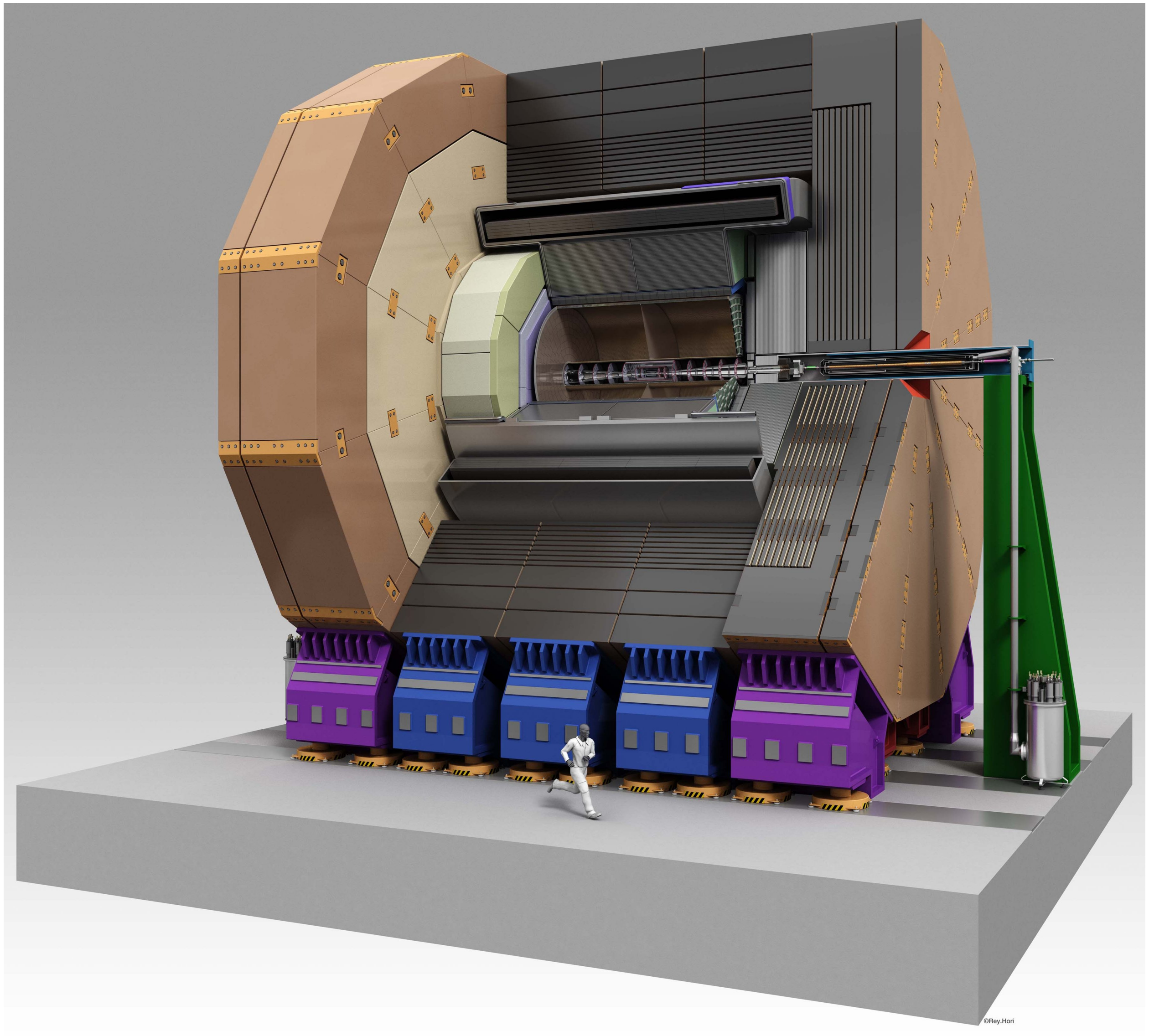
Vertex
Solid state detector

Trackers
Gazeous detectors

Calorimeters
Scintillators, PET

Combination of detectors
pCT

Software



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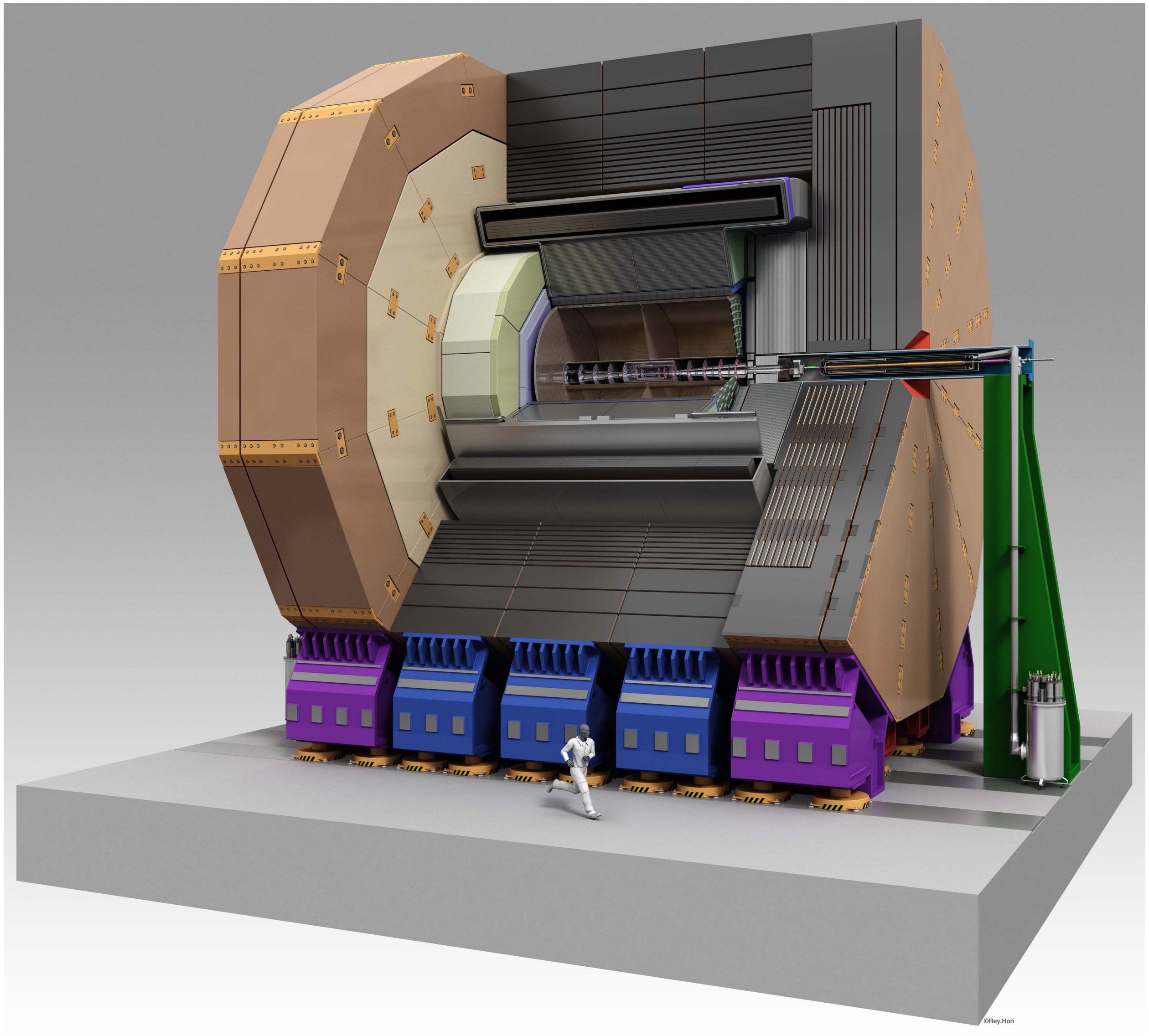


Solid-State detectors

4 sessions :

2 Semiconductor Tracking and Spectroscopy Detectors
2 New Concepts in Solid-State Detectors

LC detector R&D program in vertex: DEPFET, CMOS, 3D
→ Spinoffs in many HEP experiments: BELLE-II, superB, STAR, ALICE, CMS…

CMOS Developments

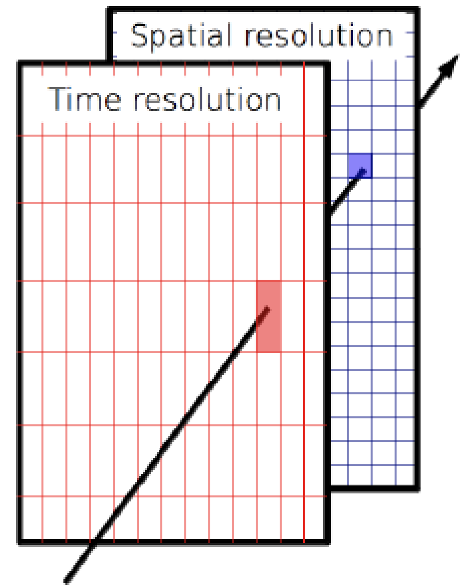
Excellent spatial resolution, very thin, integrated electronic, industrial process (ILC, superB, ATLAS...)

Needs:

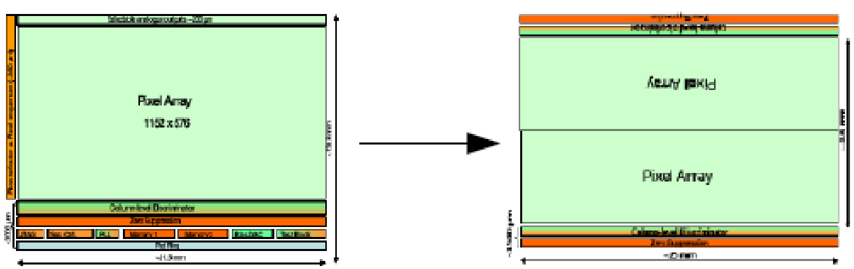
- reduce readout time
- reduce power consumption

Ex : ILC vertex ($\sqrt{s}$ = 500 GeV, 0.35 μm technology)

- Rolling shutter (power consumption)
- Double side layer, correlated measurement :
  - One face = highly segmented
  - Other face = large pixel, fast readout



Increase insensitive area ==> 0.18 μm techno



M. Winter

CMOS Developments

- 0.18 μm technology
  - High speed operation inside chip
  - Surface reduction in digital design
  - Reduce power consumption

In-pixel discriminator

- Don't have to drive the digital signal to the column end
  - Gain a factor of 2 in time resolution
- 2 -4 rows readout simultaneously
- Multiple rolling shutters

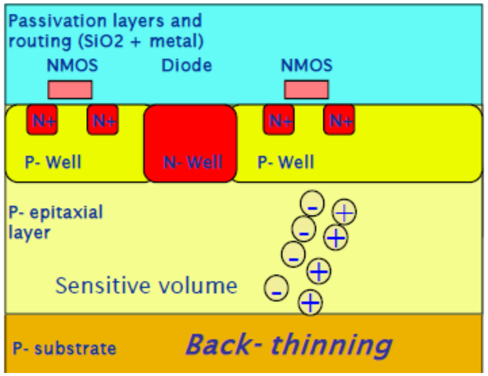
time resolution < 2 µs can be achieved

More rows switched on → higher power consumption

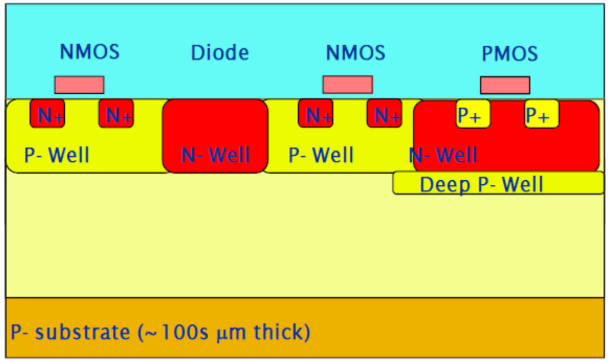
➔ 0.18 µm process offers reduced power dissipation

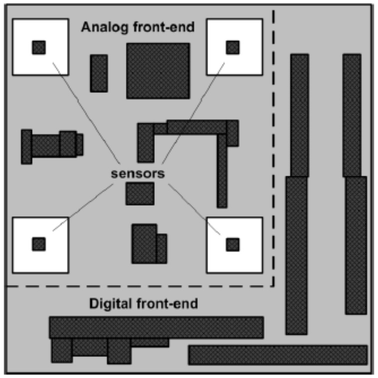
M. Winter

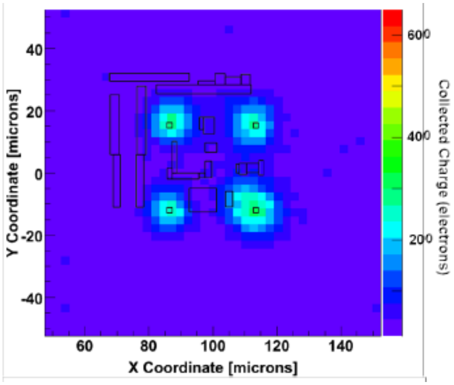
Quadruple Well CMOS Technology

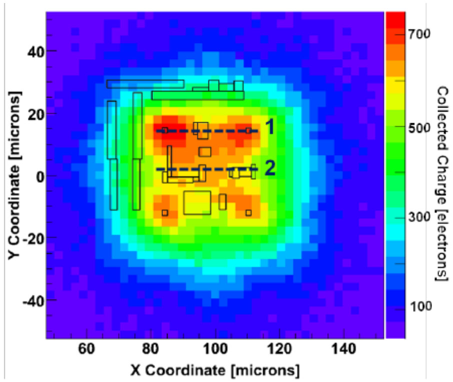


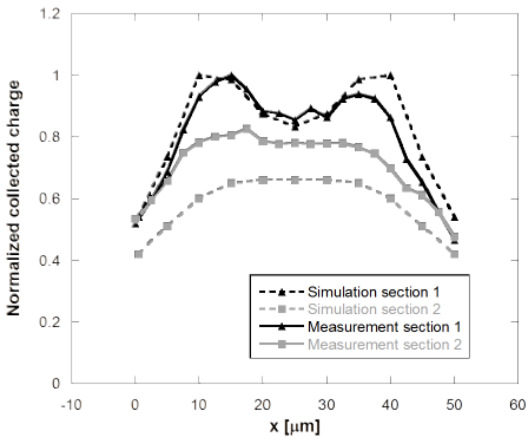
Optimize charge collection and readout electronics







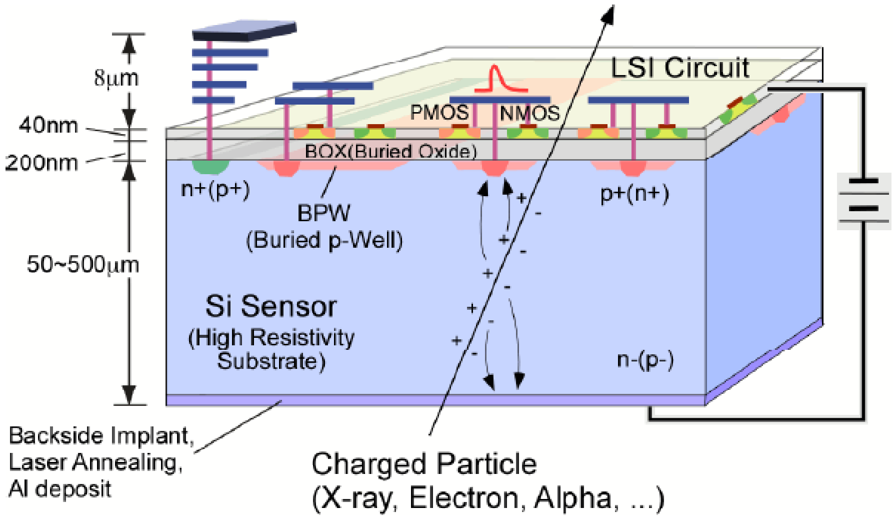




+ radiations hardness studies

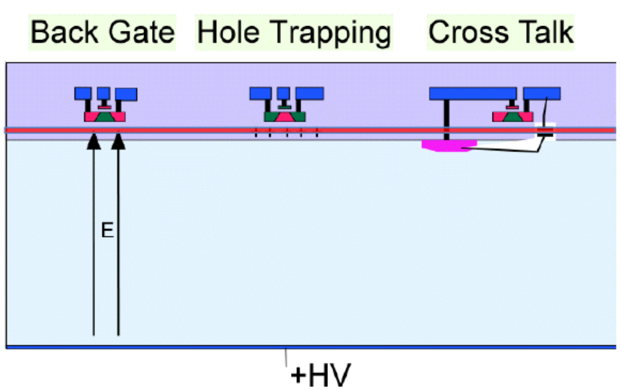
S. Zucca

Silicon on insulator - SOI



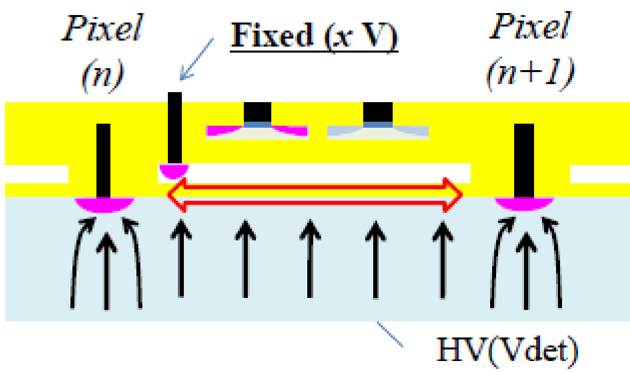
- No mechanical bonding. Fabricated with semiconductor process only, so high reliability, low cost are expected.
- Fully depleted thick sensing region
- On Pixel processing with CMOS transistors.
- Can be operated in wide temperature (4K-570K) range
- Based on Industry Standard Technology.

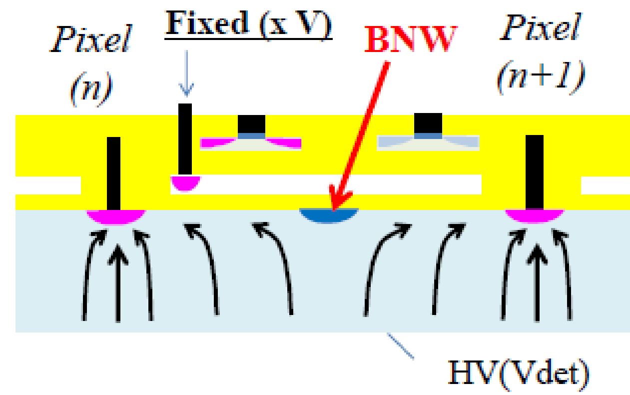
<u>Issues :</u>



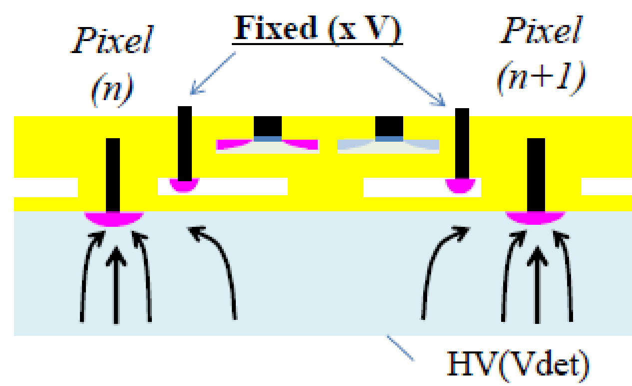
T. Miyoshi

SOI

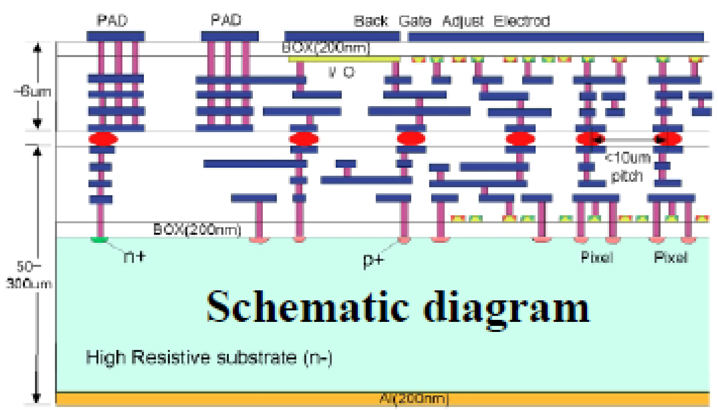




But middle SOI between pixels reduces charge collection efficiency

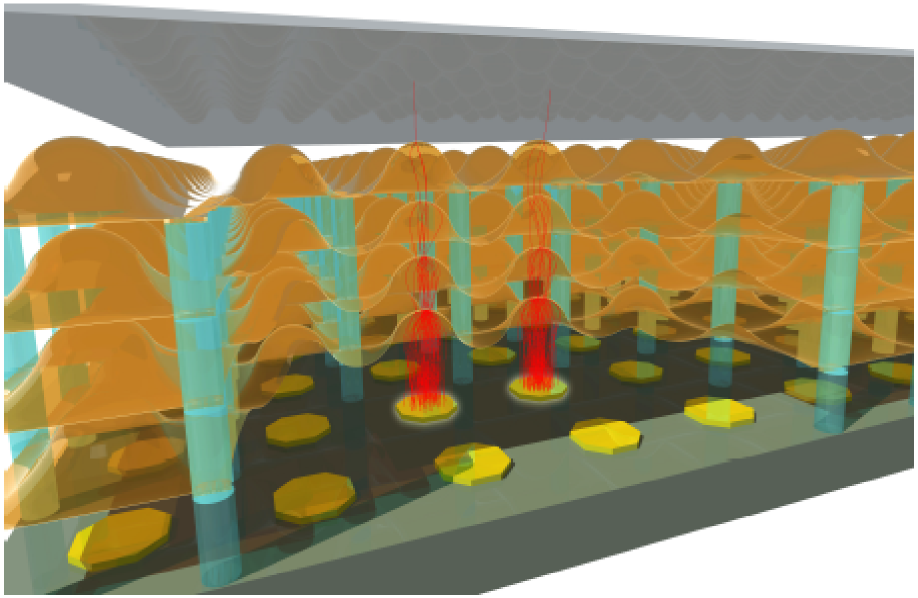


The first 3D chip in December

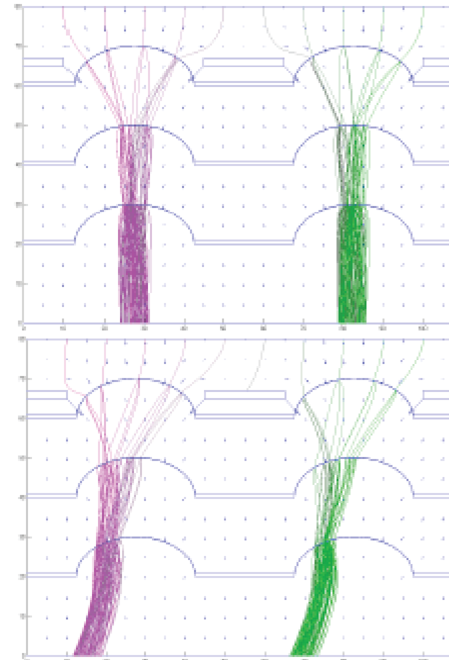


T. Miyoshi

Tipsy : single soft photon detector



Spacing dynodes = 20 μm
silicon-nitride layer



Efficient single photon detector

Time to pass through structure ~50 ps

Time resolution to detect a single soft photon is mainly determined by the time the electrons take to cross the last gap ~ps.

Spatial resolution ~10 μm, in both planar directions (pixel pitch)

“Will revolutionize electron detection in solid state atomic and molecular physics experiments" ???

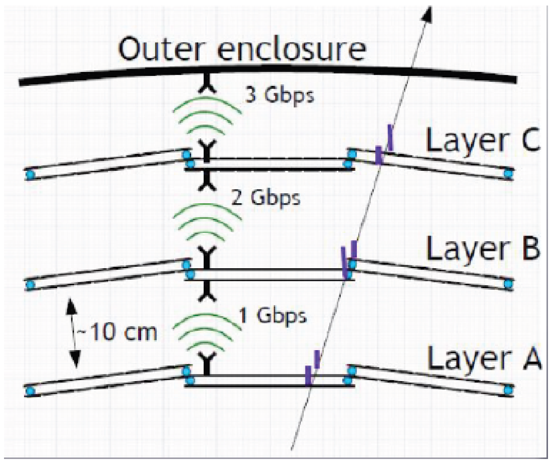
Waiting for test results...

H. van der Graaf

Wireless Transfer

Example @LHC: Innermost silicon layer:

- Required bandwidth is *50-100Tb/s*
- Detector divided into *20-50K* independent segments
- Required bandwidth per link is then *5 Gb/s*



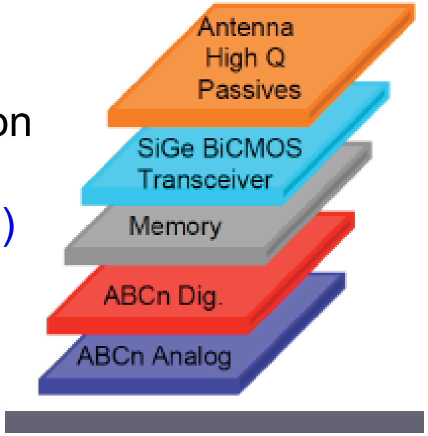
- Wireless unlicensed spectrum of 7-9 GHz bandwidth @ 60 GHz
- Able to send Gigabits/s (5-10 Gbps) of information over short distances (10 m)
- Largely unused today: low interference probability
- 60 GHz does not penetrate (walls, silicon): security
- Flexibility of placement
- Allows for integration of antenna(s)

60 GHz signal cannot penetrate through the silicon layers

- Send signal through the Silicon layer by a wire/vias connection

Antenna: Most of the EM energy drawn into the substrate

Difficult to deliver high output power (low supply and break-down voltage)



H. K. Soltveit

First prototype submission June 2013

Plan

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Solid state detector

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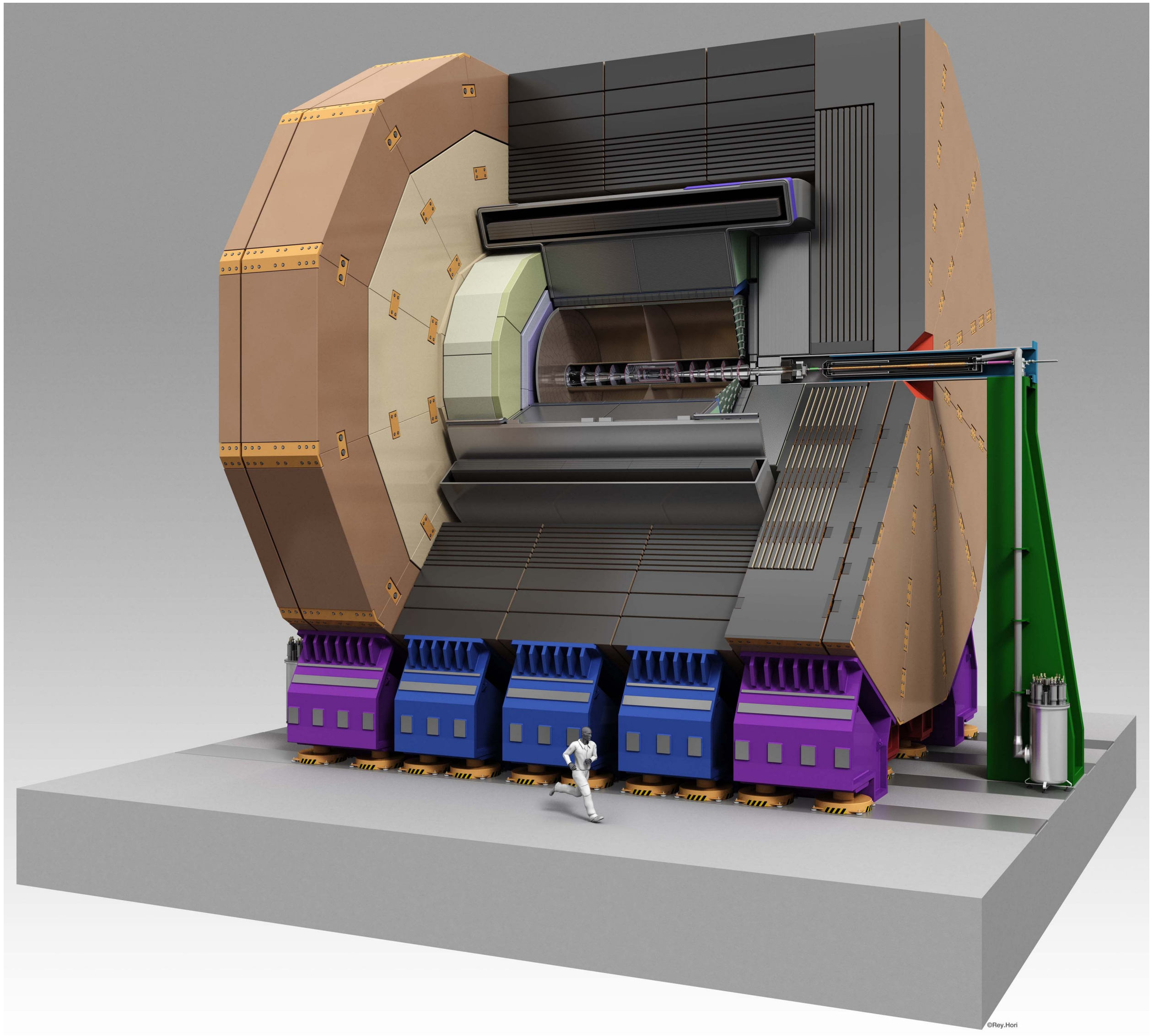
Calorimeters
Scintillators, PET

Combination of detectors
pCT

Software



Gaseous detectors

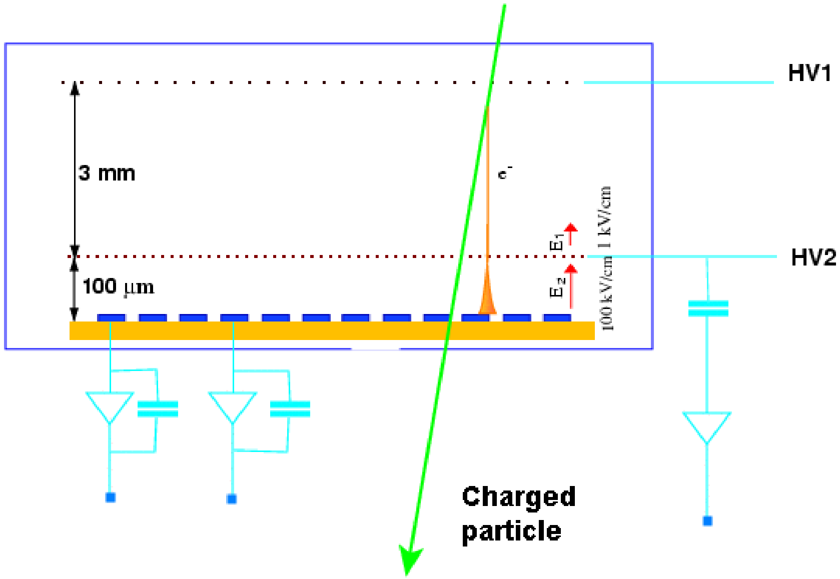
3 sessions:

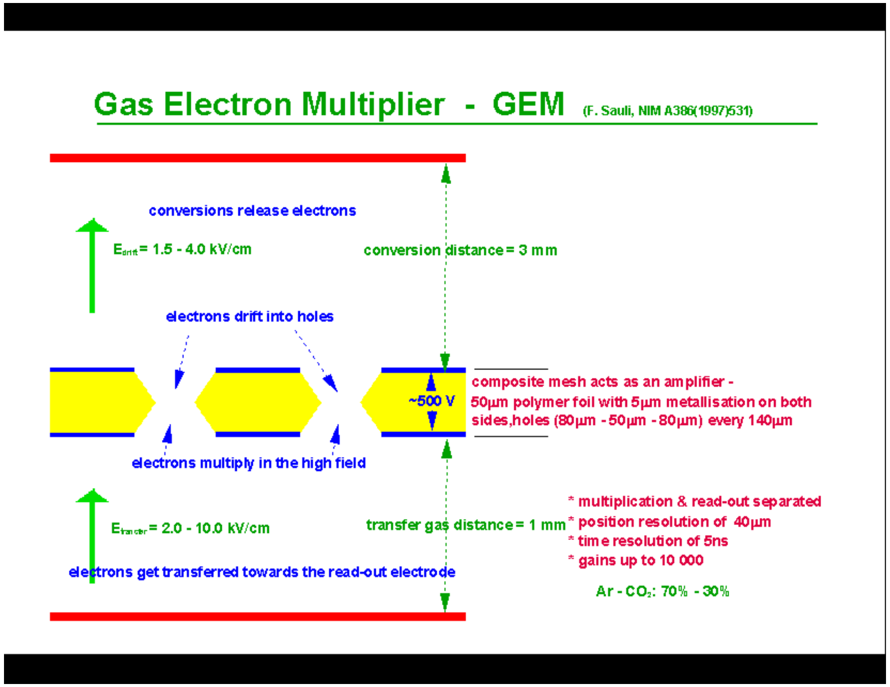
Mainly development and results of Micro Pattern Gas Detectors

Extensive R&D on TPCs carried out within the ILC → mutual benefit with others experiments: T2K, ALICE, Applications (Volcano tomography)

Gaseous detectors

Micro pattern detectors





- Pixelized detector (allow a very precise two-dimensional spatial measurement)
  can replace common silicon pixel detectors (lower cost, smaller radiation length)
- Drift space → information about the time component
- Very good radiation hardness (gas can be renewed)
- Low gain
- Sparks

Glass GEM

Conventional GEM foil : polymer

- Needs some support (soft material)
- Outgas

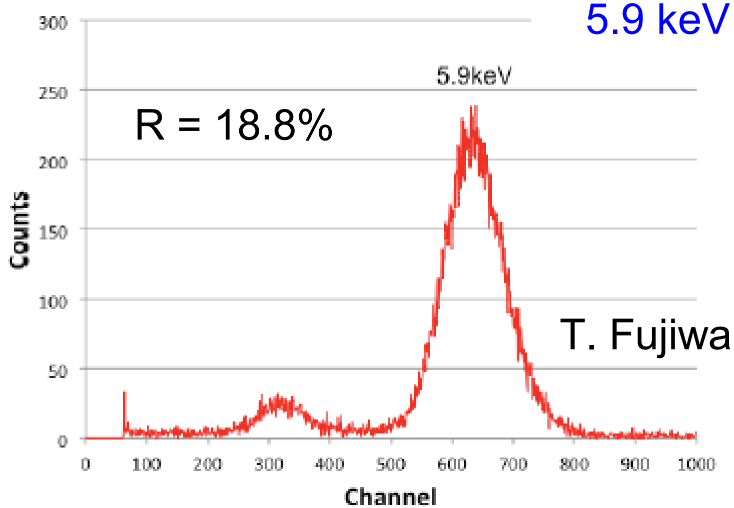
PEG3 :

- Commercially available
- photo-etchable → precise pattern
- High conductivity (avoid surface charge accumulation)
- Hardness and self supporting

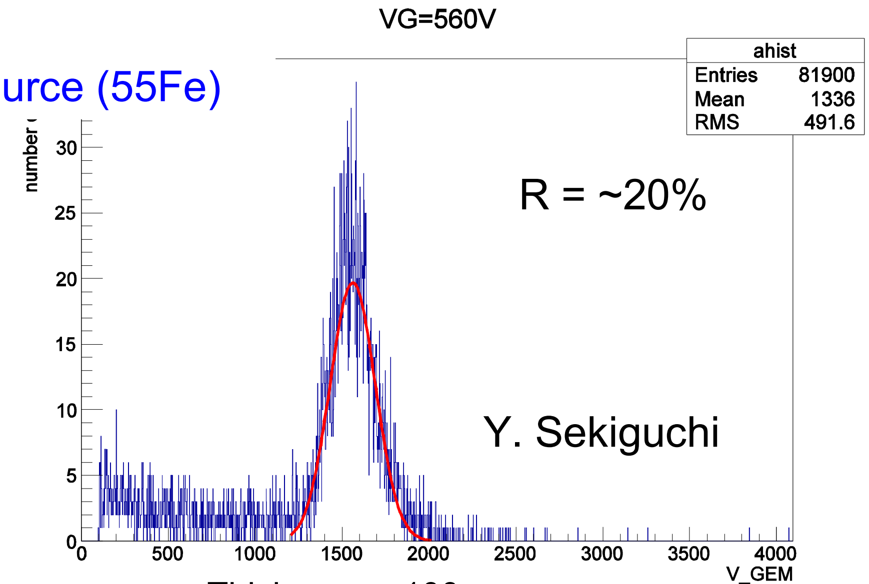
→

Higher gain
Good uniformity
Robustness
Low outgas
Tolerant for neutron irradiation

5.9 keV X-ray source (55Fe)



Thickness = 700 μm
Hole diameter = 170 μm
Pitch of the holes = 140 μm

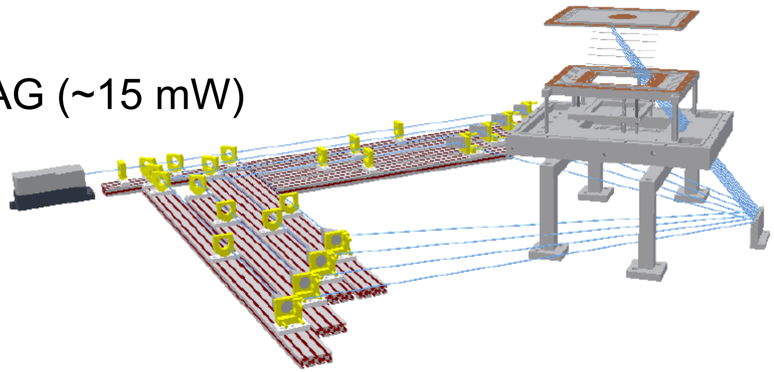


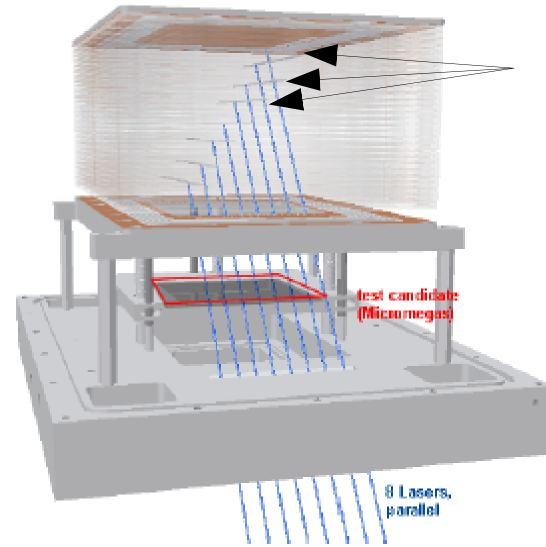
Thickness = 100 μm
Hole diameter = 70 μm
Pitch of the holes = 140 μm

+ Deuteron

Test facility

Nd:YAG (~15 mW)

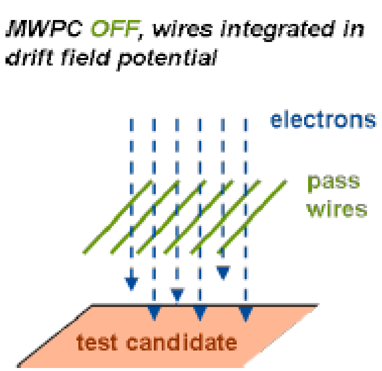


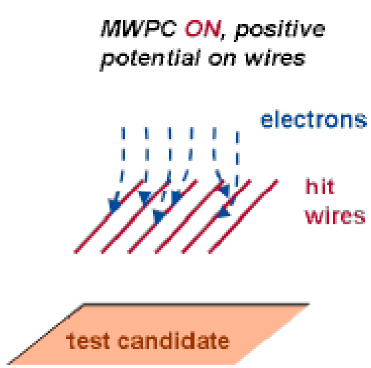


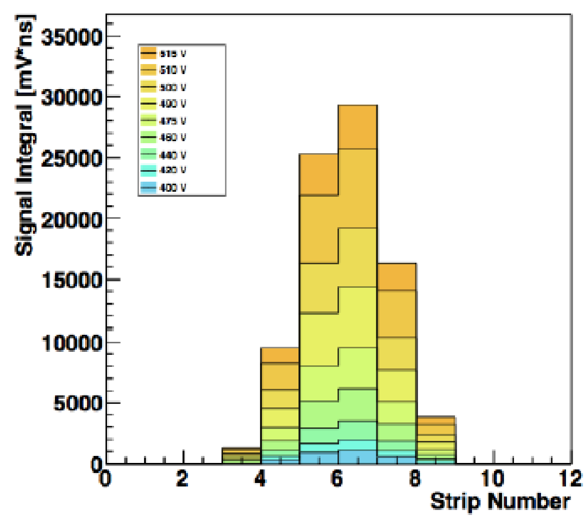
Aluminium strips

Photo-electrons fake ionisation electrons made by charge particles

Control measurement:







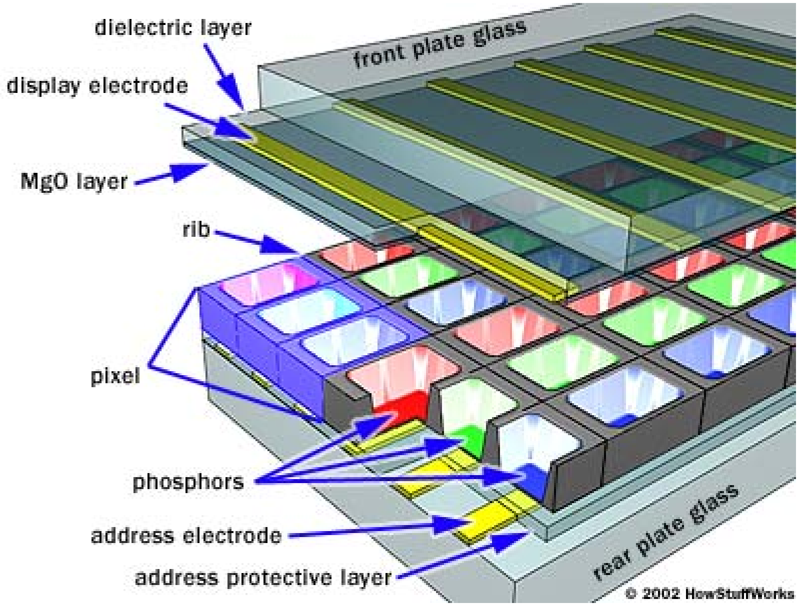
K. Temming

Plasma Panel Sensors

- Inherits many operational and fabrication principles common to PDPs:
  - – A dense micro-array of gas discharge cells or pixels
  - – Pixels bias for gas electrical discharge - Geiger mode operation
  - – Pixels are enclosed in hermetically-sealed glass panel
  - – Uses non-reactive, radiation-hard materials:
    - glass substrates, refractory metal electrodes, inert gas mixtures

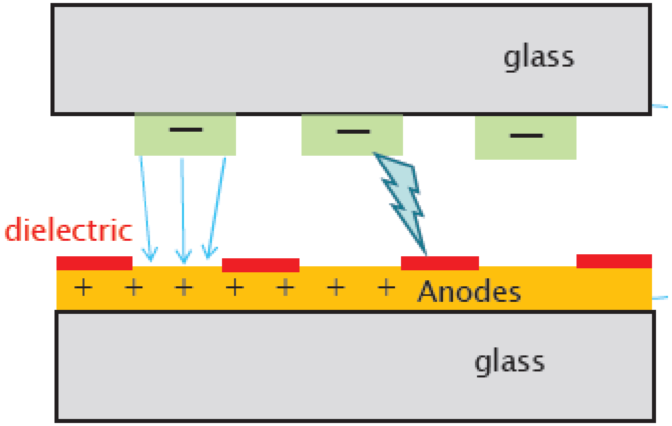
- High gain and inherently digital device with 2D readout

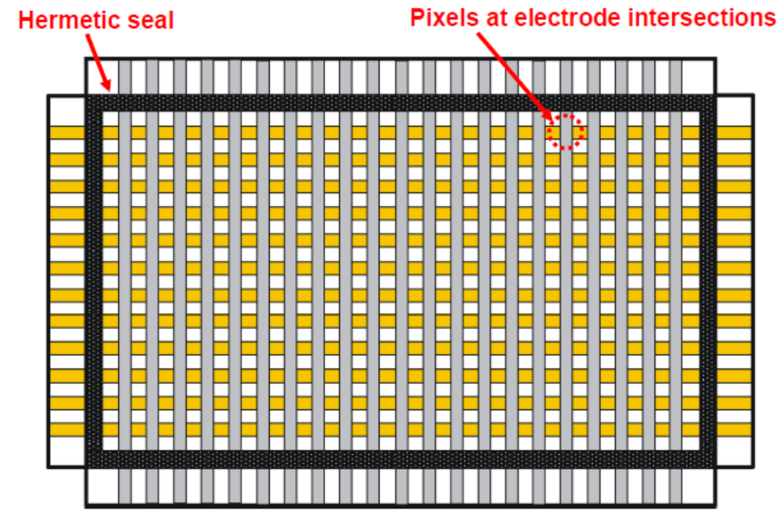
- Potential for:
  - Low power consumption
  - Large area & low cost
  - Ultra-thin (2 μm) cover plates
  - Conversion layers (neutrons, etc.)
  - < 1 ns response times
  - Very high granularity
  - Position resolution < 50 μm
  - Hermetic seal – long lifetimes

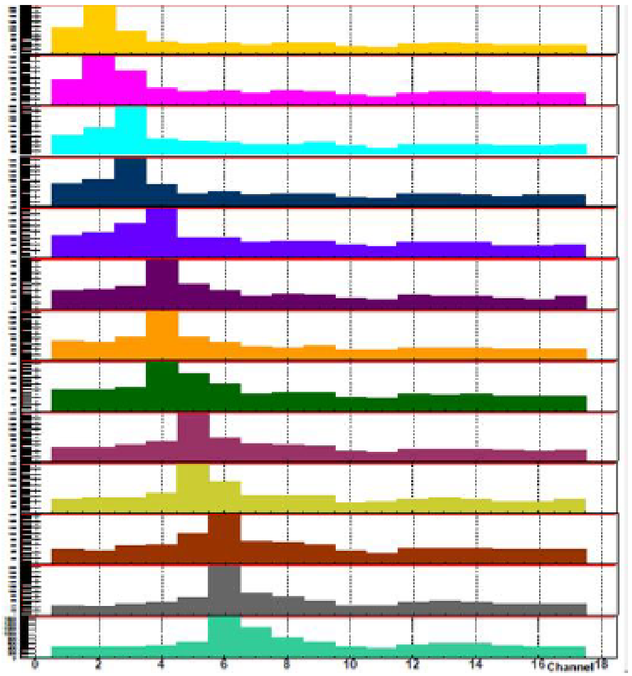


P. Friedman

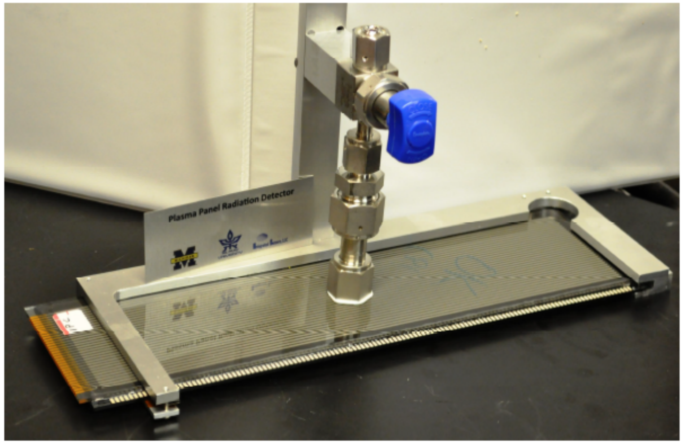
Plasma Panel Sensors







220 MeV proton beam
Step = 1 mm
Pixel pitch = 2.5 mm



P. Friedman

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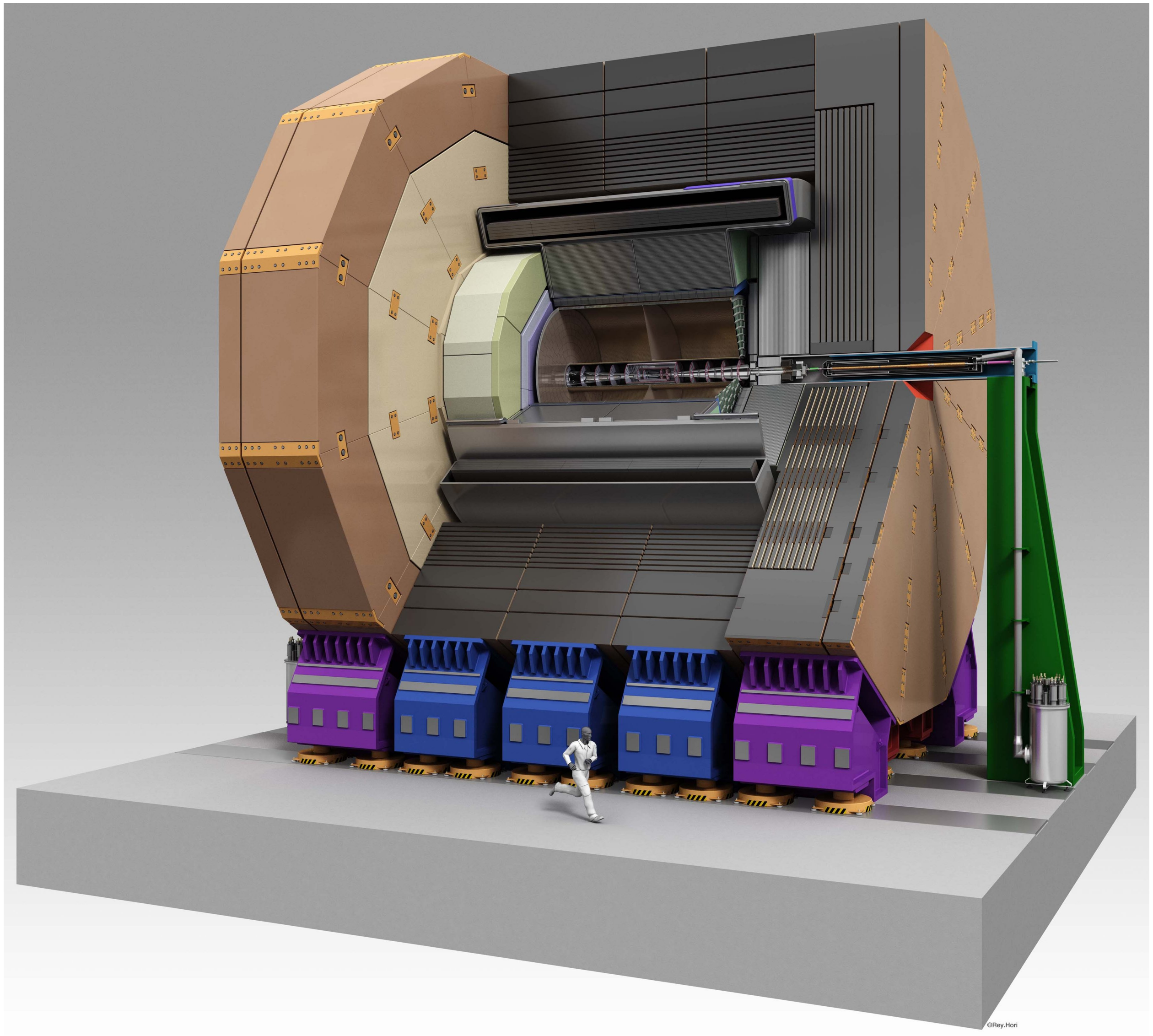
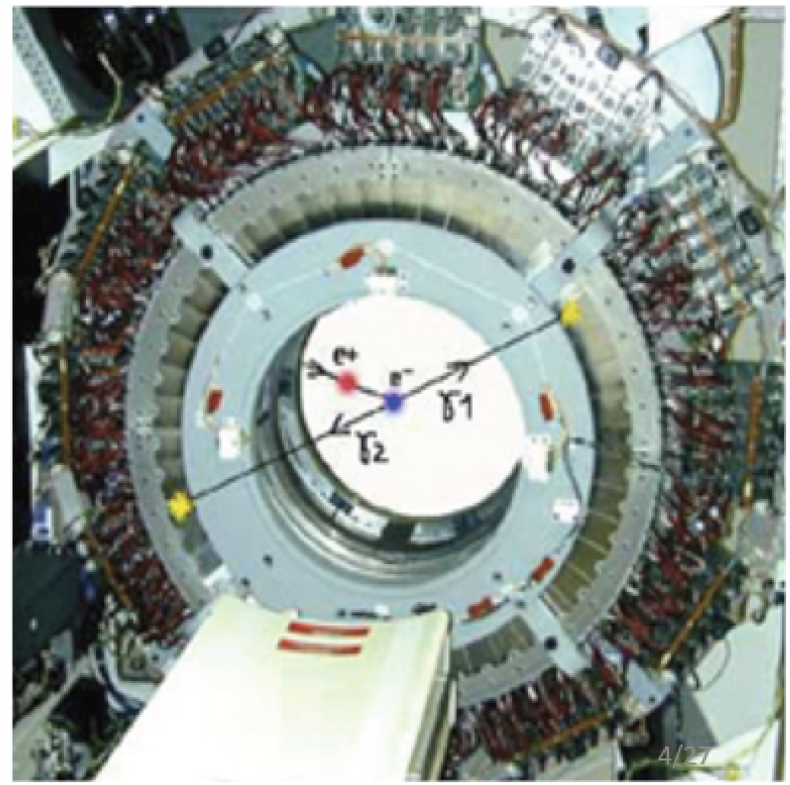


A calorimeter for HEP / PET

CMS calorimeter system
(the humans are not part of the experiment)

PET calorimeter system
(a laying human fits into the detector bore)



E. Garutti

A calorimeter for HEP / PET

Calorimeter for LC

CALICE AHCAL → first large scale application of SiPMs

Calorimeter for PET

Huge detector volume
- Segmented in single channels
- Magnetic field

Medium detector volume
- Segmented in single channels
- Magnetic field (PET/MRI)

- Integration issues
- Photo-detection+electronics compatible with B field

Single channel
- Plastic scintillator
- Analog silicon-photomultiplier (SiPM)

Single channel
- Inorganic scintillator (crystal)
- Currently PMT or APD

- R&D on crystals with fast response and high light yield
- R&D on silicon-based photo-detectors (SiPM)

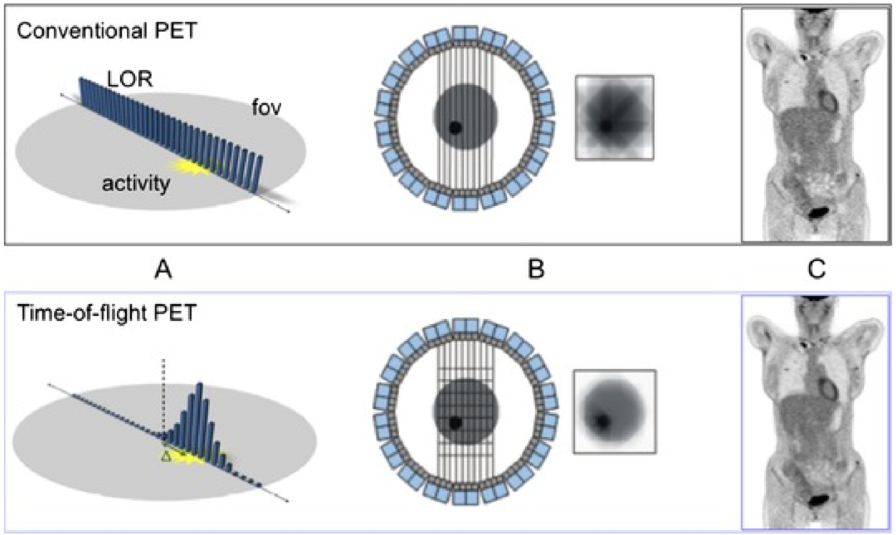
Readout electronics
- Multi-channel r/o chip
- Energy et time measurement

Readout electronics
- Multi-channel r/o chip
- Energy et time measurement

- ASIC design + r/o electronics boards and DAQ
- High speed data processing

E. Garutti

PET



TOF is growing slowly:

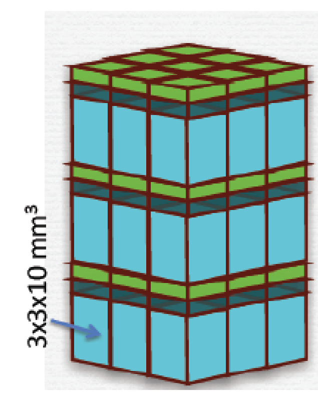
- faster scintillators
- high quantum-efficiency photodetectors

Multimodality approach (PET/MRI) will be more and more requested in the clinical practice.

Better for large patients : For an equivalent data signal to noise ratio, a 120 kg person would have to be scanned 2.3 times longer than a 60 kg person

Coincidence time resolution deteriorates for increasing crystal length

The sensitivity to 511 keV photons increases for increasing crystal length



Proposed design by
T. Takeshita (Uni. Shinshu)

Scintillation

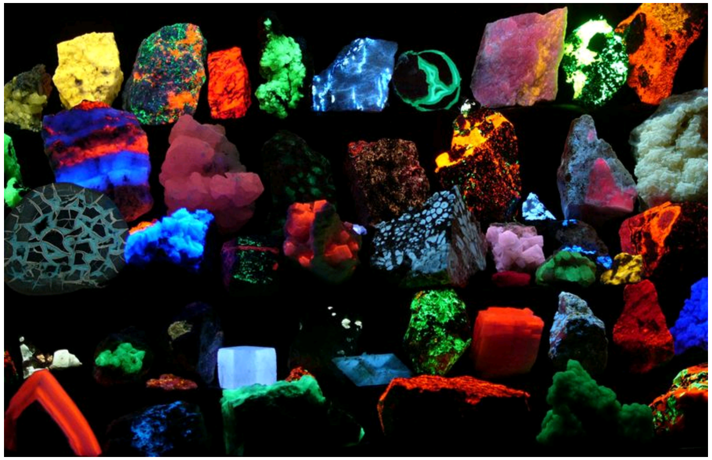
Scintillation detectors are widely used to measure radiation.

- Light yield: photons/MeV
- Emission spectrum
- Energy resolution
- Decay time: can have several time constants
- Density and Z: determine response to γ, e− and other electromagnetic processes
- PSD : Pulse Shape Discrimination
- Material type : powder, liquid, plastic, crystal...

→

@ IEEE: 4 sessions

Improvement of existing material or new materials: Mainly trade off between characteristics

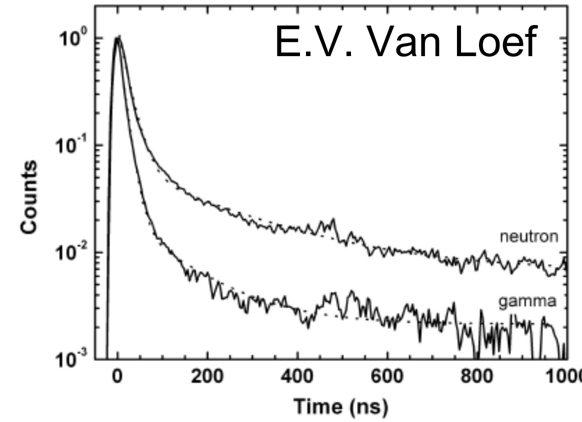


PSD

→ gamma/n discrimination
→ Dual readout calorimeters

Traditional plastic scintillators :

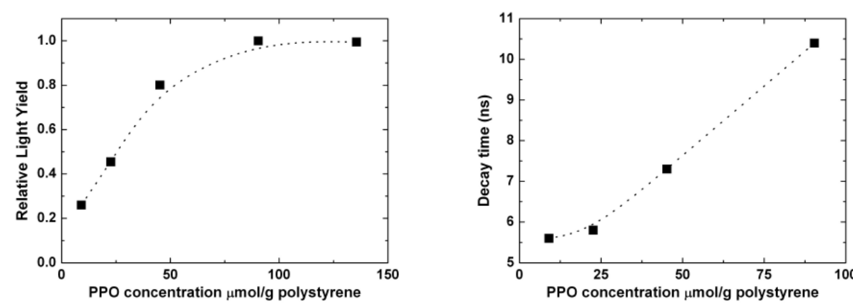
- Handling
- Can detect fast neutrons rather efficiently
- Low light yields
- Not provide efficient PSD



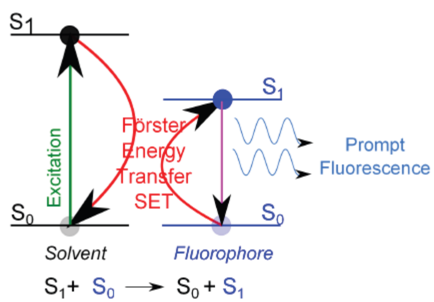
Scintillation decay after gamma ray and neutron excitation

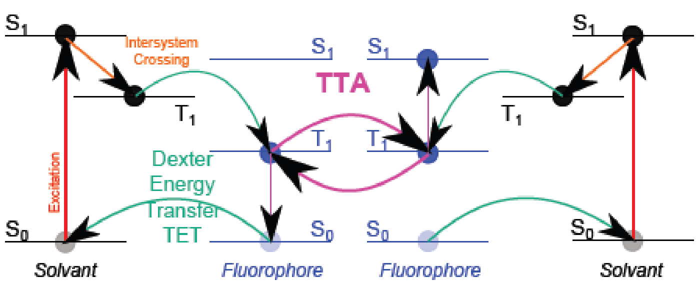
Doping → improve the light transmission mechanism.

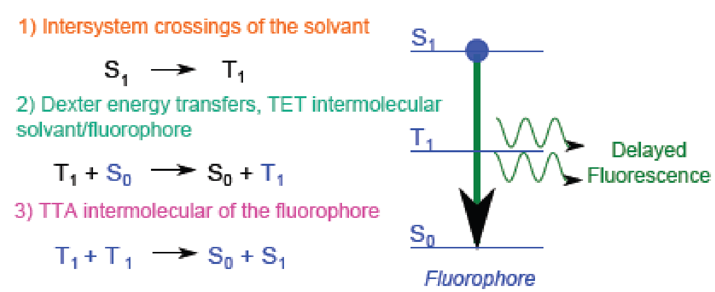
- Tailored wavelength shifters
- Additives



Characteristics as a function of the additives concentration







P. Blanc

Nanocomposites for Scintillation Applications

Quantum dots embedded in polymer/glass matrix

Wavelength of emitted light depends on QD size

Z. Kang

SiPM (MPPC)

3 sessions: Photodetectors and Radiation Imaging Detectors

- Mainly SiPM, all sessions have full house (The audience was standing in the corridor)
- Summary of the SiPM developments : Véronique's talk

+ Dedicated electronics (large part of the electronic sessions)

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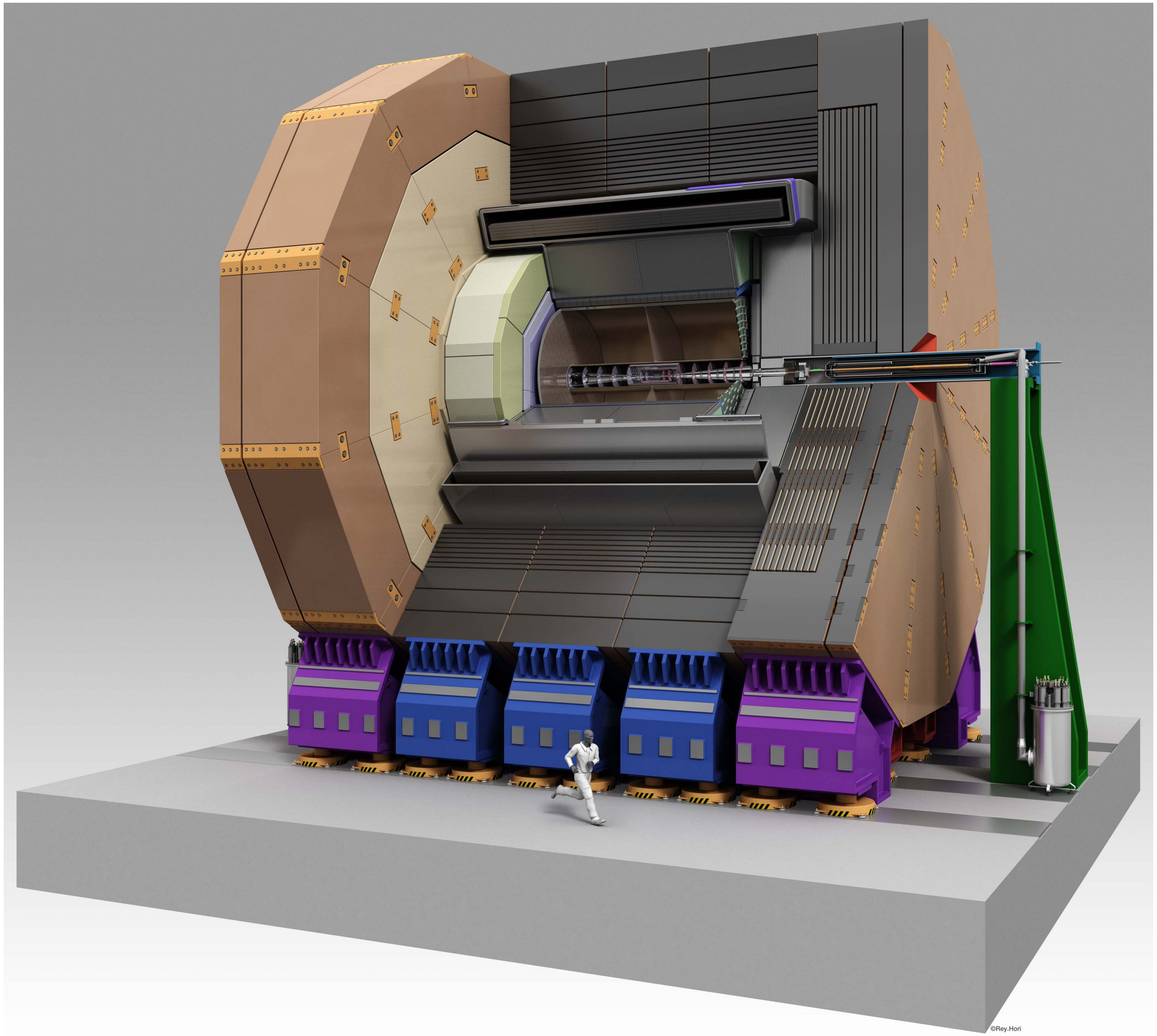


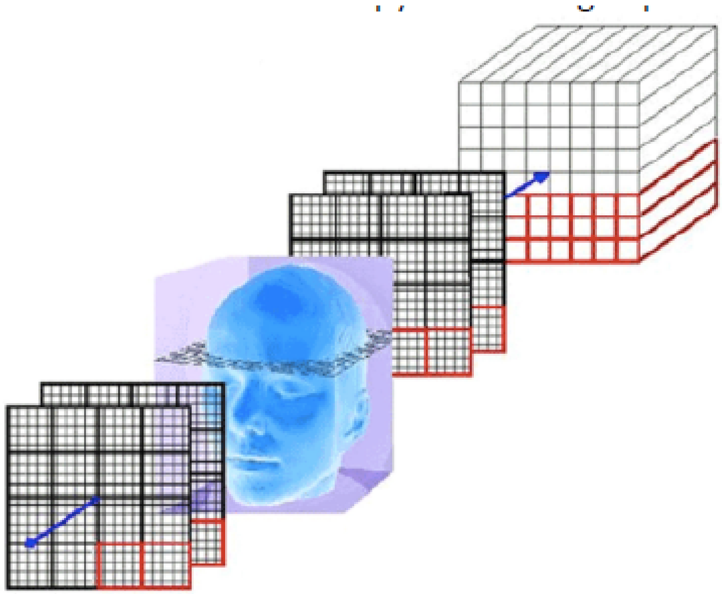
HEP Instrumentation

3 sessions :

- LHC detectors status
- LHC upgrades
- ILC detectors

Proton CT

Computed Tomography (CT) imaging is needed for
- – Target volume definition
- – Dose and range calculation
- – Patient alignment verification (CBCT)



Why pCT?
- Differences in the interaction of x-rays and protons with matter make proton range calculations uncertain (mm to cm)
- Materials of unknown stopping power and CT artifacts create additional uncertainties
- Less dose?

Single particle detection allows for
- – Rejection of unsuitable events ("data cuts")
- – Estimation of individual proton paths
- – Use of reconstruction algorithms based on single proton histories

Challenges of single particle detection
- – Requires high data rates (fast DAQ systems)
- – Need to develop computation tools

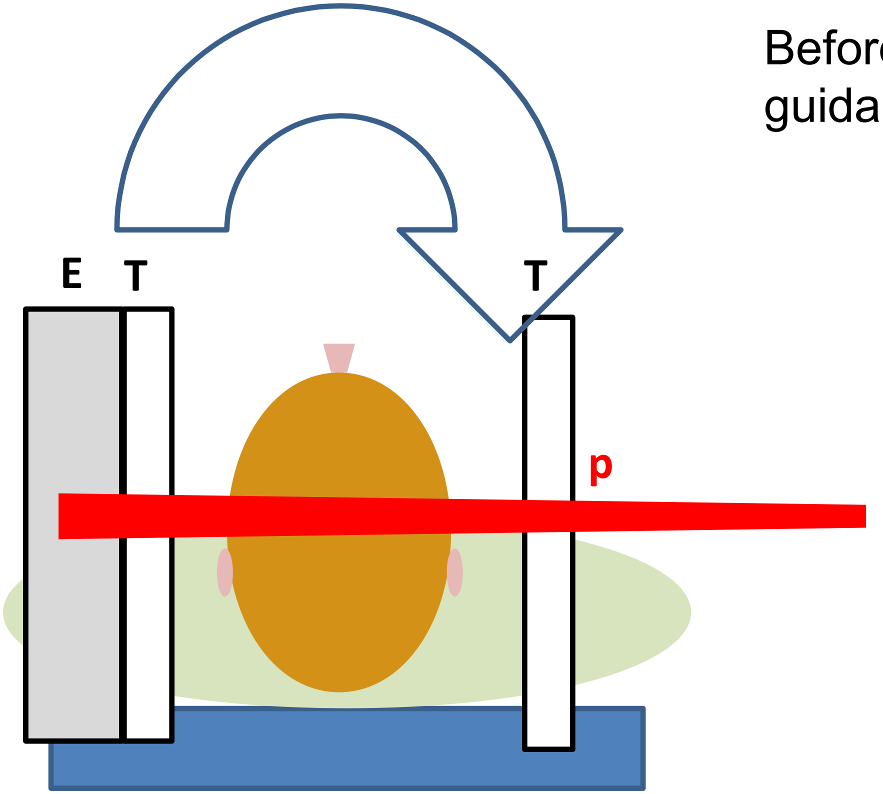
Proton CT (2011)

Collaboration	Tracker	Energy/Range Detector
INFN	SSD	Crystal + PD
LLU/UCSC/NIU	SSD	Crystal + PD
NIU/FNAL	SciFi+SiPM	Range+WLSF+SiPM
LLU/UCSC/CSUSB	SSD	MSS (Plastic Scint) + PMT
TERA	GEM	Range+WLSF+SiPM

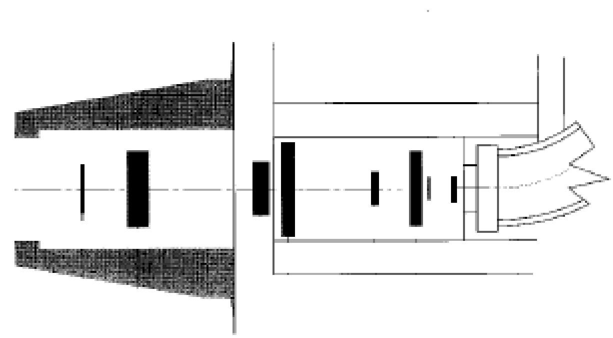
- SSD – Silicon strip detector
- Sci Fi – Scintillating fiber
- SiPM – Silicon photo multiplier
- GEM – Gaseous electron multiplier
- PD – Silicon photodiode
- WLSF – Wavelength-shifting fiber
- MSS – Multi-stage scintillator

R. W. Schulte

Multi-Purpose Proton Therapy Verification System



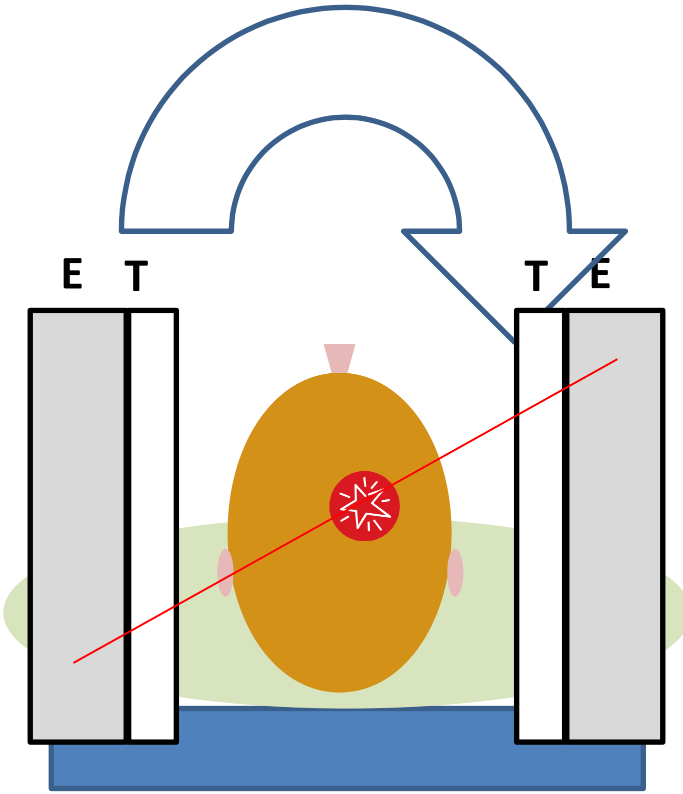
Before treatment: pCT for image guidance & replanning



T = tracker
E = Calo

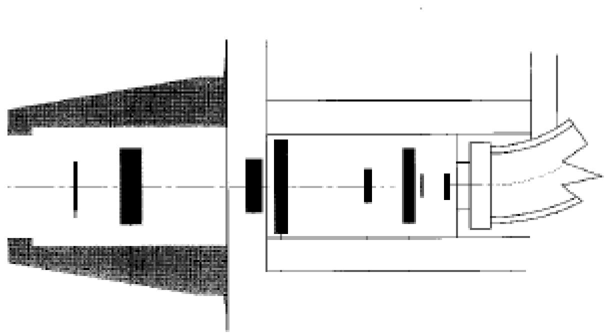
R. W. Schulte

Multi-Purpose Proton Therapy Verification System



Before treatment: PET for target localization

After treatment: PET detector for beam (and dose) verification

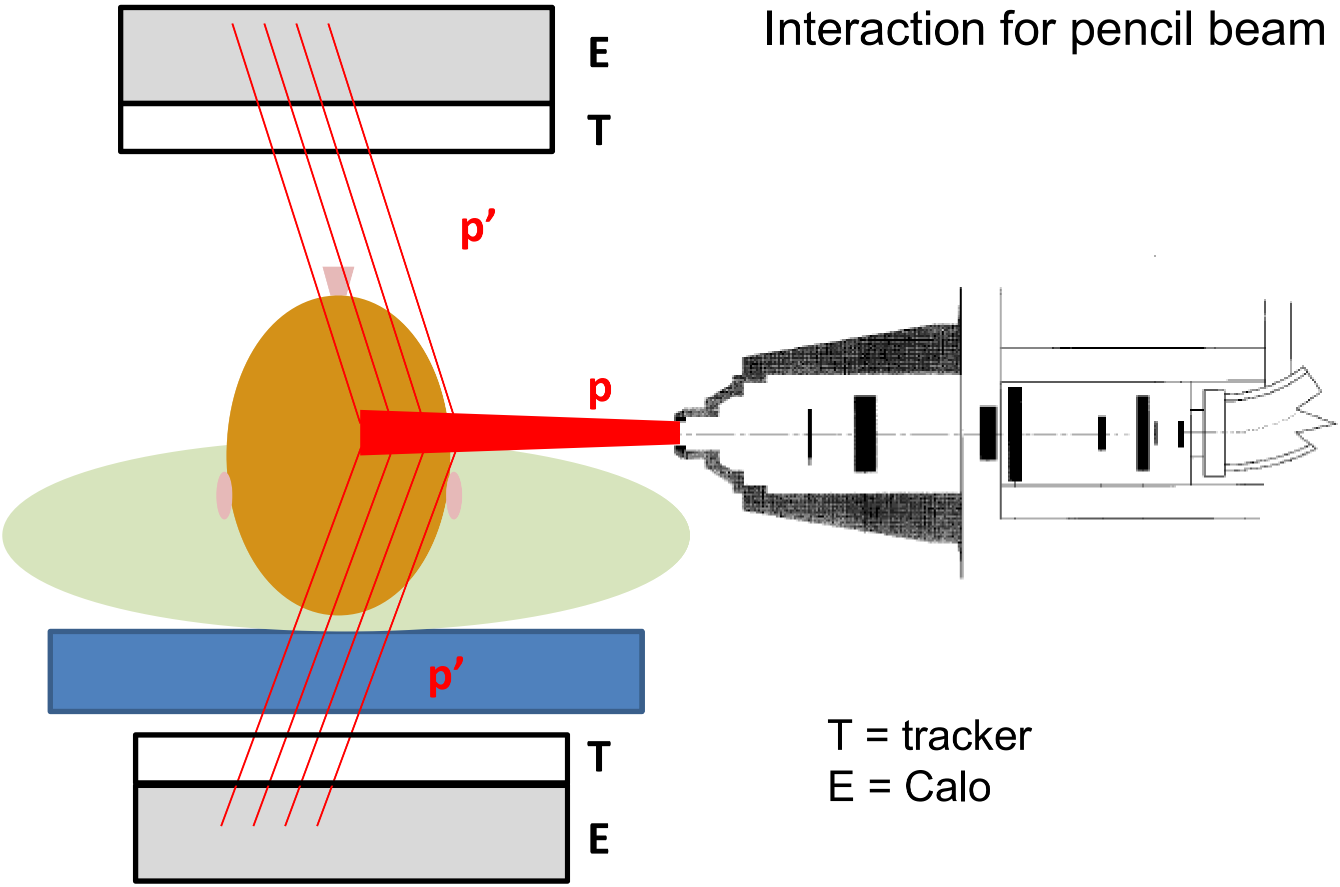


T = tracker
E = Calo

R. W. Schulte

Multi-Purpose Proton Therapy Verification System

During treatment: Interaction Vertex
Interaction for pencil beam monitoring



T = tracker
E = Calo

R. W. Schulte

Plan

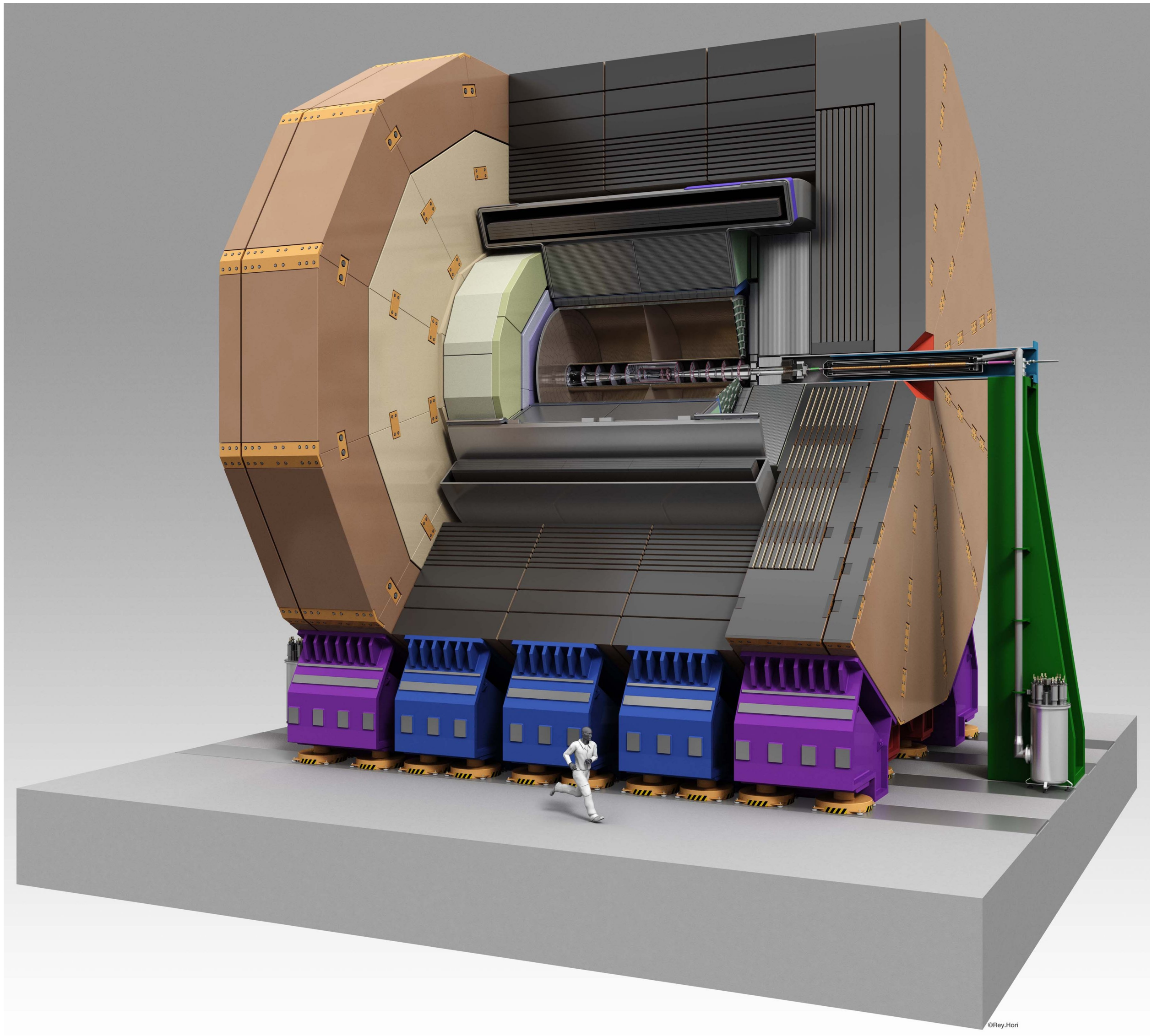
Vertex
Solid state detector

Trackers
Gazeous detectors

Calorimeters
Scintillators, PET

Combination of detectors
pCT

Software



Software

4 sessions

Simulation :

- Last improvements, new features of MCNP, FLUKA, Geant4
- Re-engineering of Geant4 at its age of majority (18 years)
  - Unneeded dependencies...
  - Work in progress and giving good results
- Theoretical talk on MC uncertainty
  - I bet nobody understood anything

Experimental software : Almost all papers are Geant4 related !!

Computing challenges :

- GPU → already obsolete ?
- ZEUS is very active in data preservation
  - Preserving simple ROOT N-Tuples (400 TB required)
  - Assuming that ROOT will be able to read them in 20 years
  - Validation system to check that changes in conditions (OS, architectures, etc.) produces statistically compatible results

HEP software

Simulation for medical applications

- GATE

PET

used by more than 50% of contributions (with simulation)

Hadrontherapy

(dosimetry)

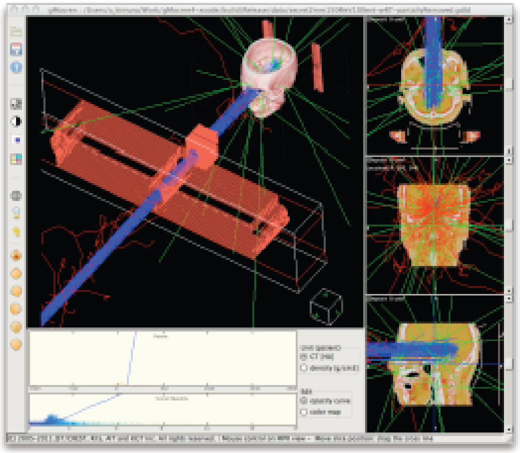
in progress

Hadrontherapy

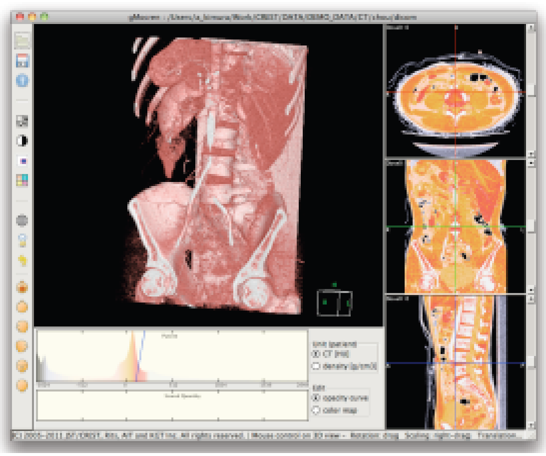
(imaging, multimodality)

Geant4 - Visualization

PTSim → G4 application (proton/ion therapy facilities)



gMocren (volume/data visualizer)

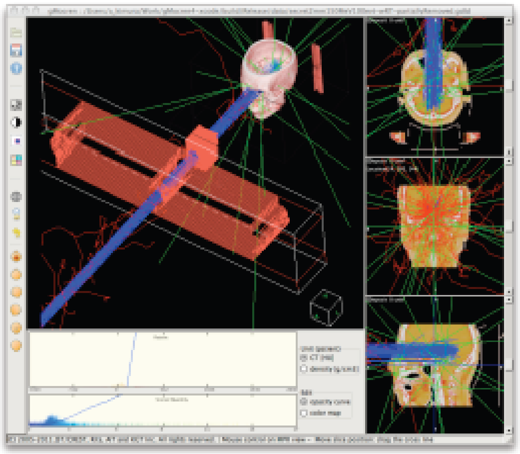


DICOM (patient image, treatment planning)

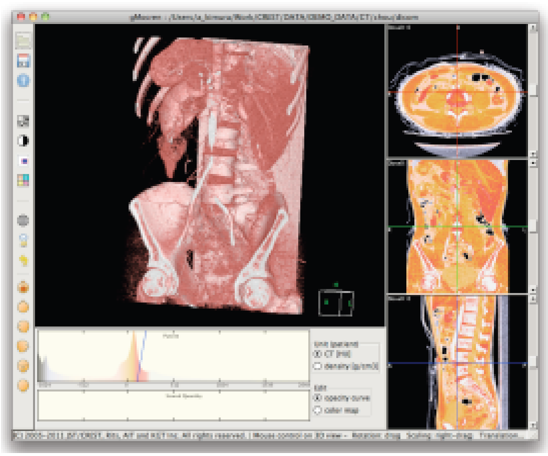
A. Kimura

Geant4 - Visualization

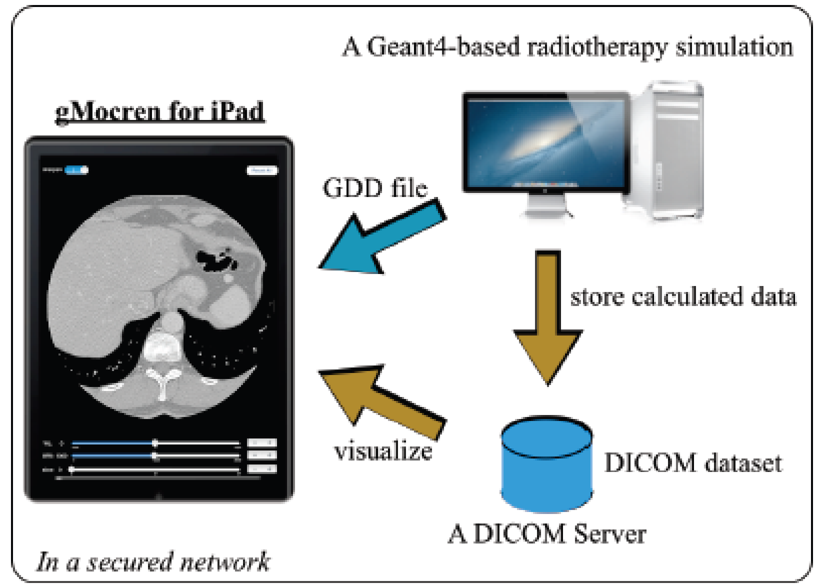
PTSim → G4 application (proton/ion therapy facilities)



gMocren (volume/data visualizer)



DICOM (patient image, treatment planning)



A. Kimura

Conclusion

NSS

- Analog and Digital Circuits (4 sessions)
- Instrumentation for Homeland Security (4 sessions)
- Neutron Detectors and Instrumentation (2 sessions)
- Experimental Reactor Instrumentation and Measurement
- Radiation Damage Effects (2 sessions)
- Astrophysics and Space Instrumentation (2 sessions)
- Nuclear physics Instrumentation (2 sessions)

MIC :

- PET (TOF, multimodality)
- ↑ On line imaging for hadrontherapy
- ↑ pCT

Very interesting but too many talks