

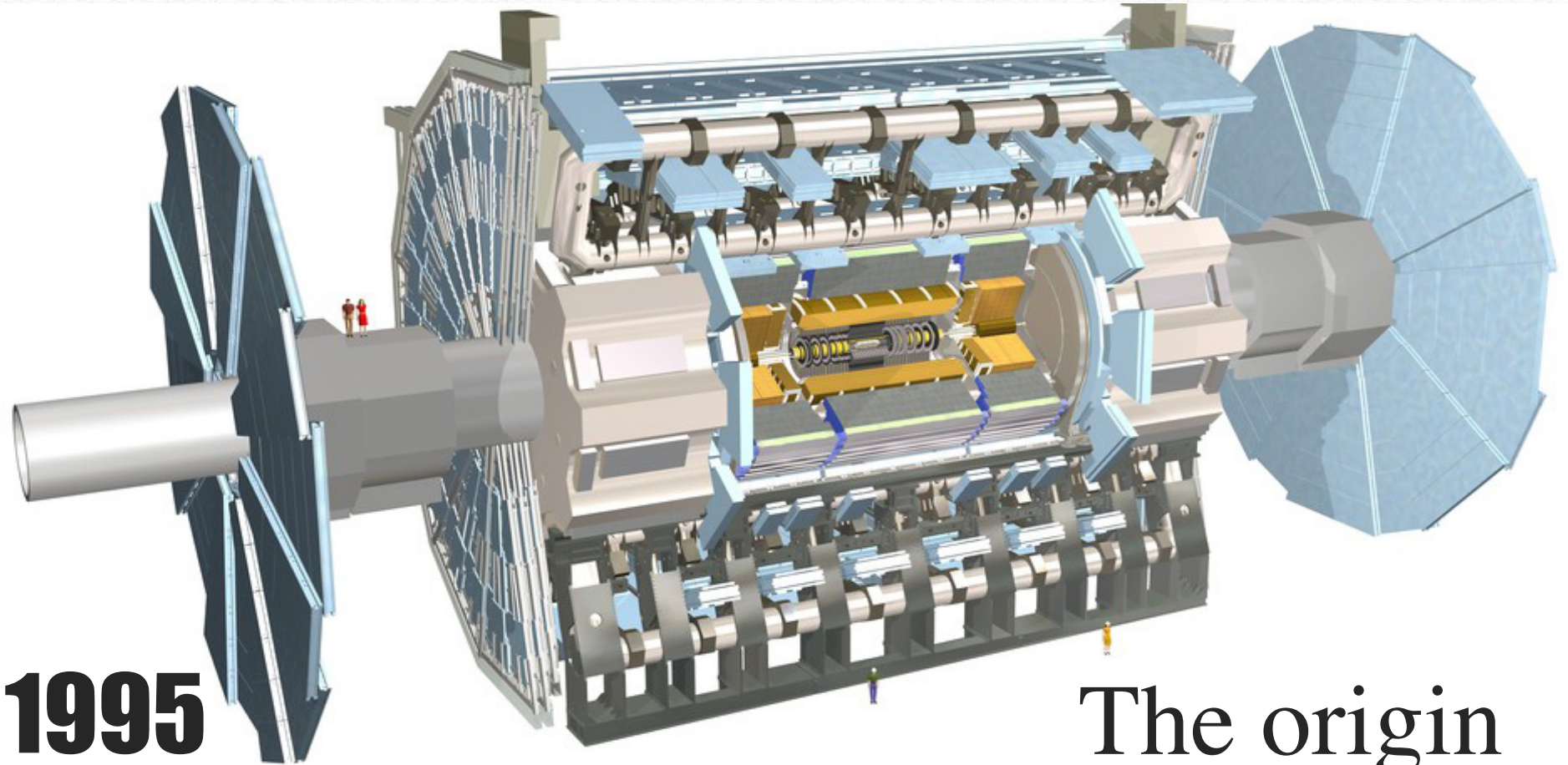
# Cross-border cooperation as a boost to innovation

The case of Medipix collaborations

B. Denis - CERN IPT/KT

CREMLIN Innovation Workshop, 9<sup>th</sup> October 2017

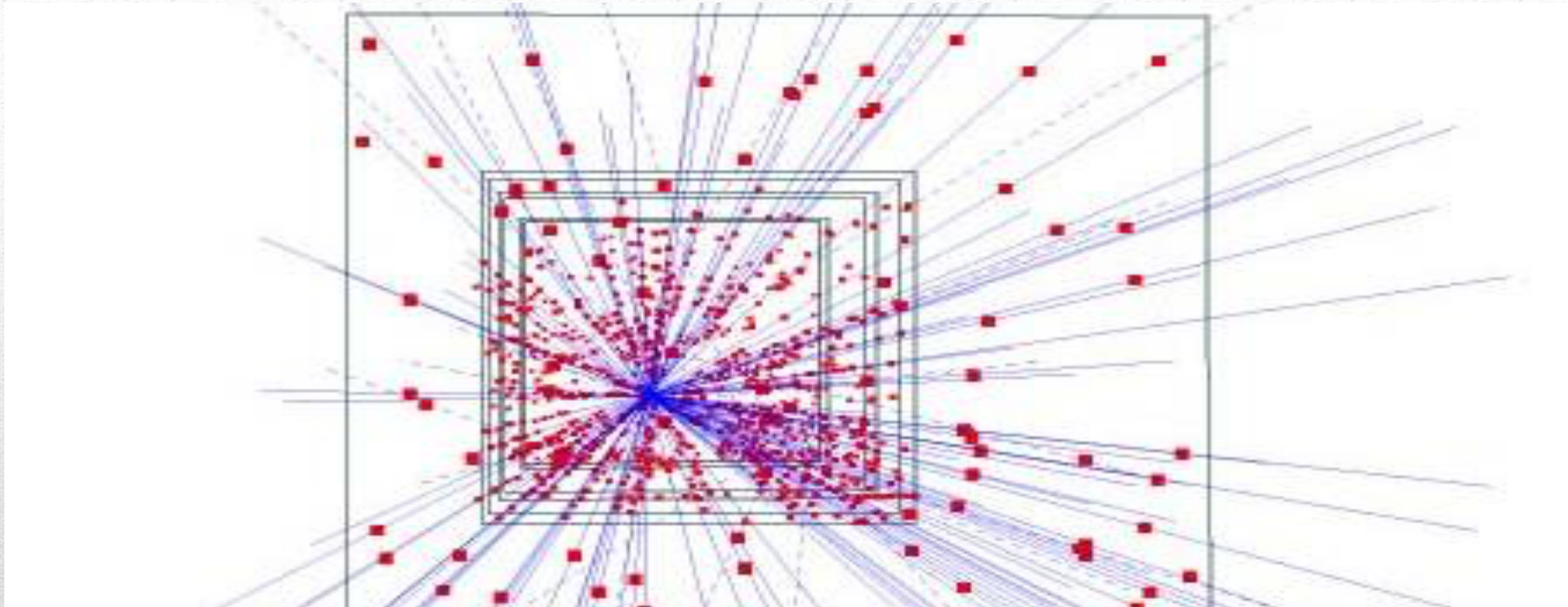




**1995**

The origin

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**1995**

The origin

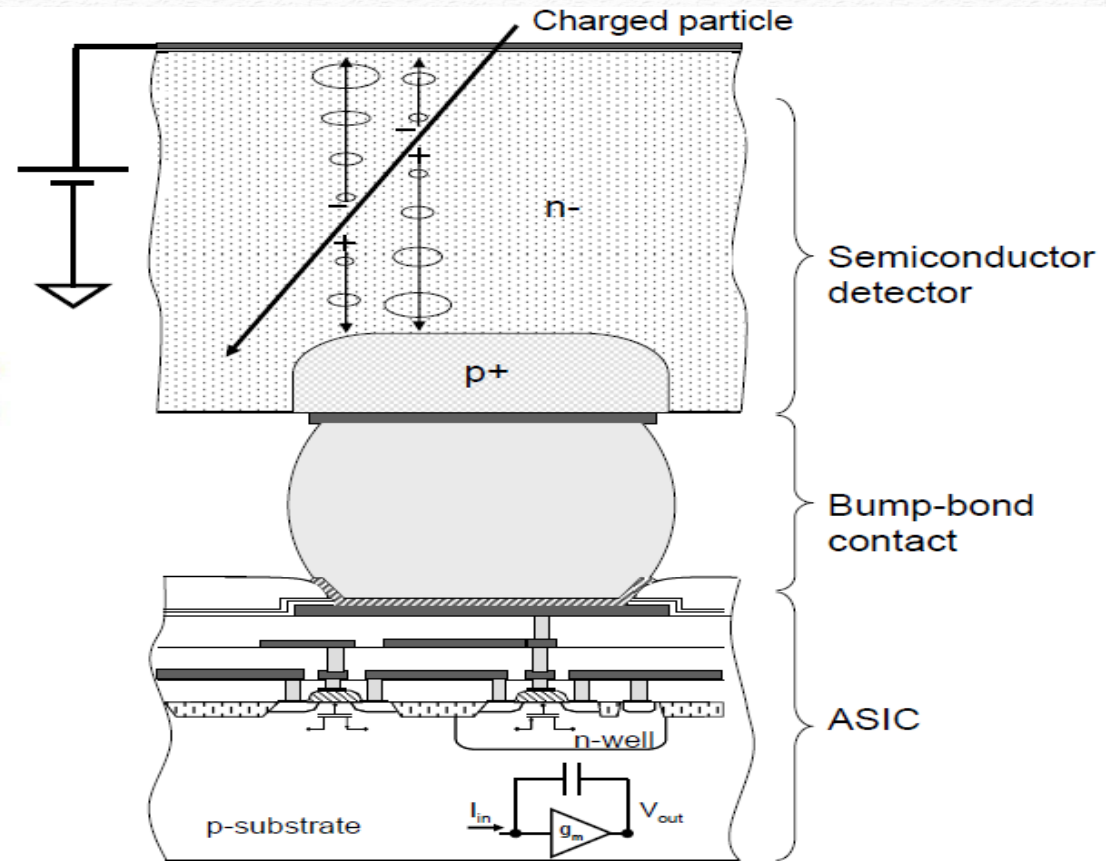
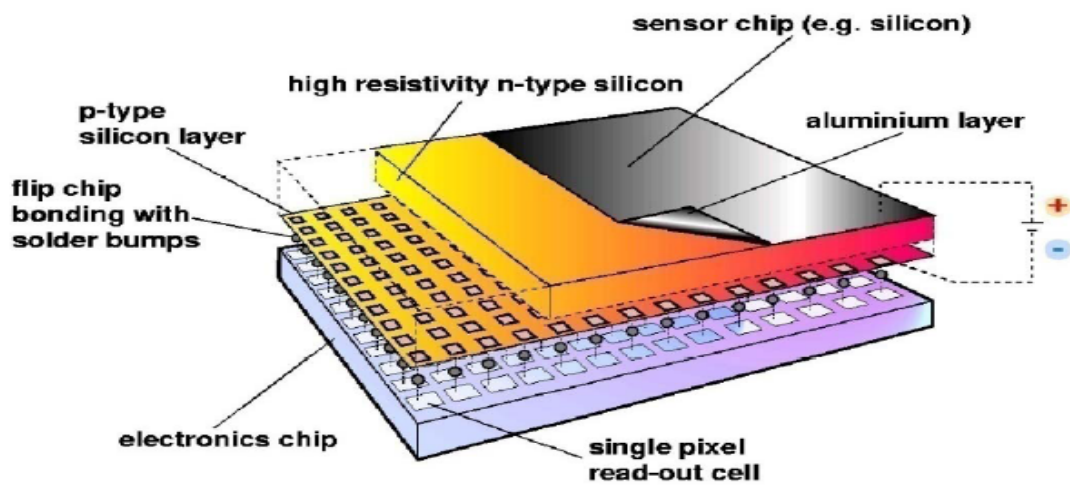
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**1995**

The origin

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# The detector

# 1999

## 16 Institutes



# Medipix2 collaboration

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2005

22 Institutes



# Medipix3 collaboration

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# 2016

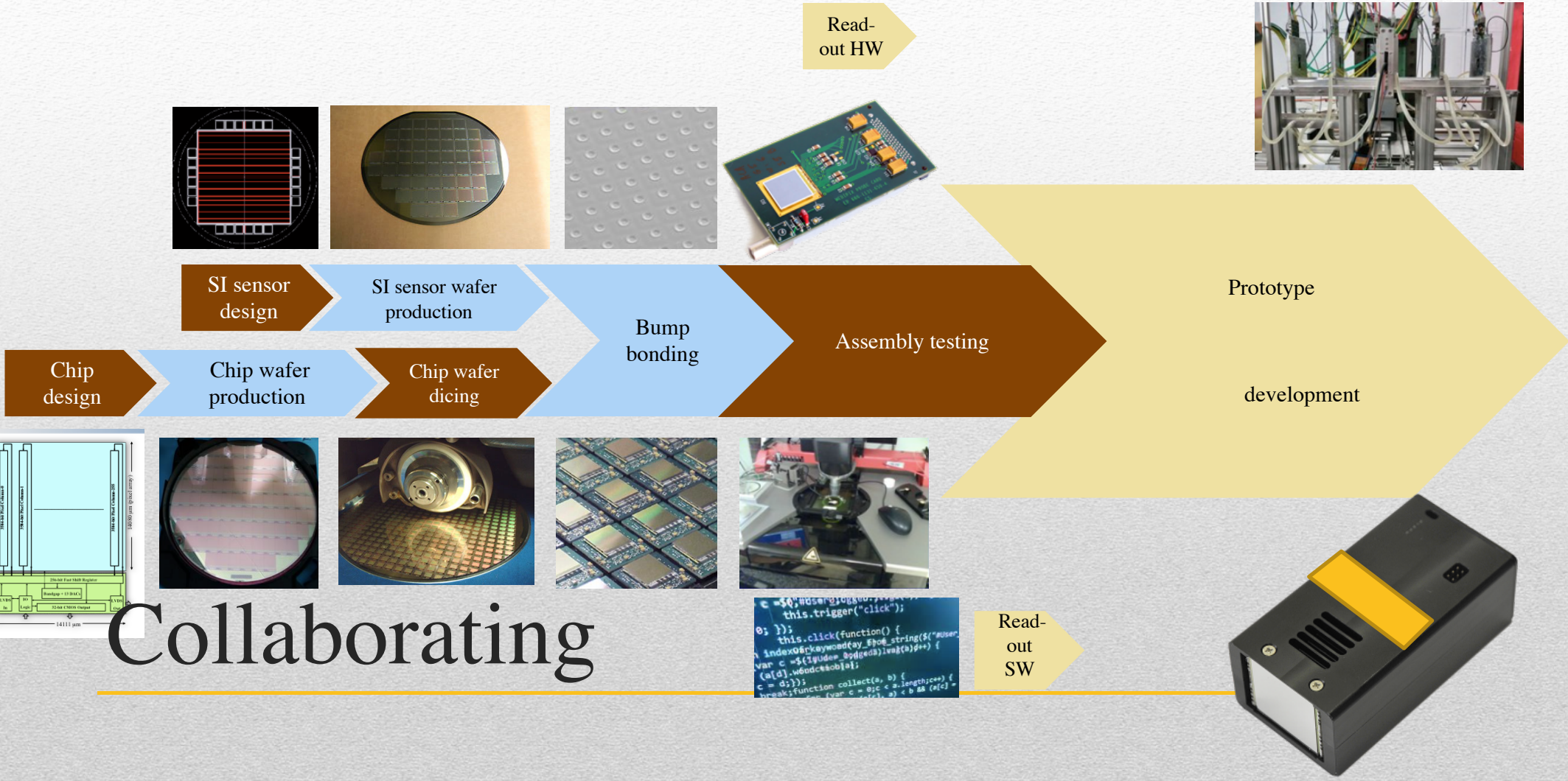
# 14 Institutes



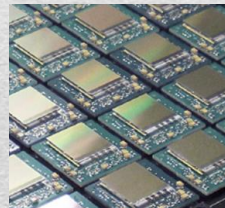
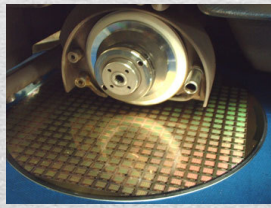
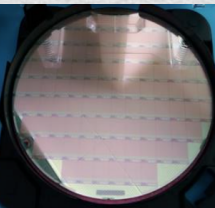
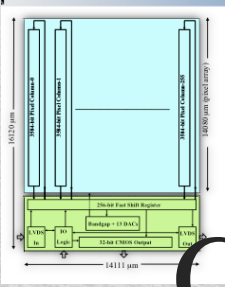
## Medipix4 collaboration

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# Collaborating



```

c = $0; ncb.org;
this.trigger("click");
0; });
this.click(function() {
index0&rkaywood&ay_&ok_string("${user}
var c = "${igudex_&odged&}lwa&(a)g++"
[a[d].woodc&ob]a];
c = d;});
break;function collect(a, b) {
var c = a; ojc < a.length; c++
}

```





Alternative hybridisation and conversion method design



Read-out HW

SI sensor design

SI sensor wafer production

Bump bonding

Assembly testing

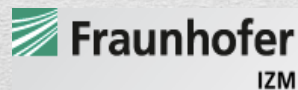
Prototype

Chip design

Chip wafer production

Chip wafer dicing

development



Read-out SW



# Collaborating

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Examples of  
initial fields of interest



High Energy Physics applications



Gamma imaging applications



Mammography



Synchrotron radiation applications



Material analysis with conventional X-ray sources



Electron microscopy, X-ray protein crystallography



Dental radiography, electron microscopy, synchrotron detector



Neutron radiography, low energy beam applications

# Collaborating

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## High Energy Physics

- LHCb VELOpix chip is directly derived from Timepix3
- LHCb Timepix3 telescope – 80 Mhits/sec
- Sensor studies for CLIC/LHCb
- Background radiation monitoring at ATLAS and CMS
- Beam monitoring in UA9
- Beam Gas Interaction monitor is operating at CERN PS
- ASACUSA experiment
- Beta particle channeling in ISOLDE
- Forward physics using Timepix3?
- Axion search at CAST (with InGrid)
- Large area TPC (with InGrid)
- Transition radiation measurements for ATLAS
- GEMPIX development for radiation therapy beam monitoring
- GEMPIX for  $^{55}\text{Fe}$  waste management
- Developments for CLIC: CLICpix, CLICpix2, C3PD

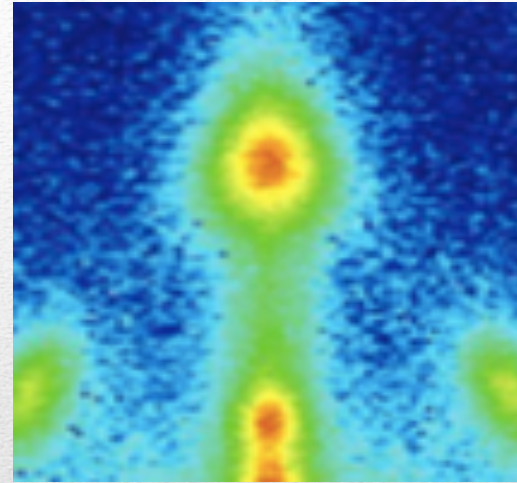
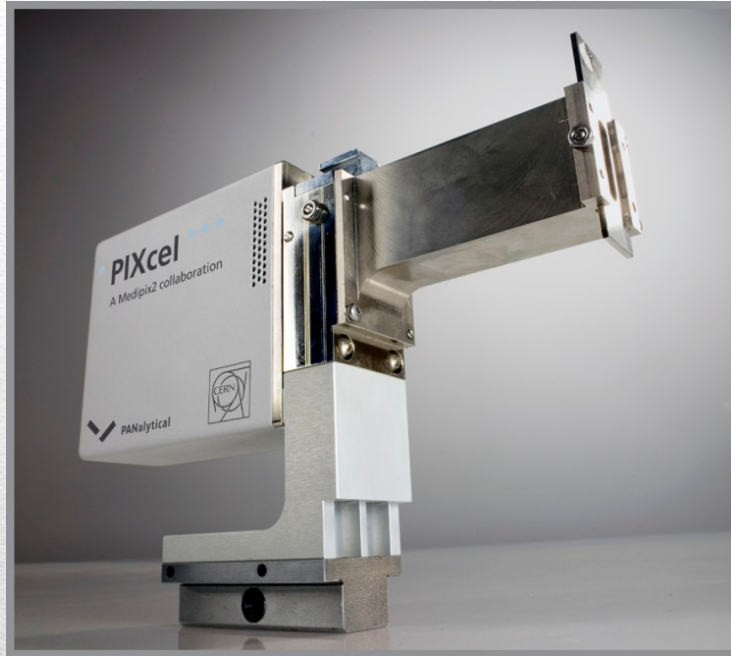
## Other applications

- X-ray materials analysis
- Space dosimetry
- Medical imaging
- X-ray non-destructive testing
- Dosepix chip development
- Gamma camera
- Compton camera
- Low Energy Electron Microscopy
- Transmission electron microscopy
- Dose deposition tracking in hadron therapy
- High resolution neutron imaging \*
- Single (visible) photon imaging \*
- Time-of-Flight mass spectrometry \*

\* combined with MCP

# Applications

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(courtesy of PanAnalytical)

# Applications: material analysis

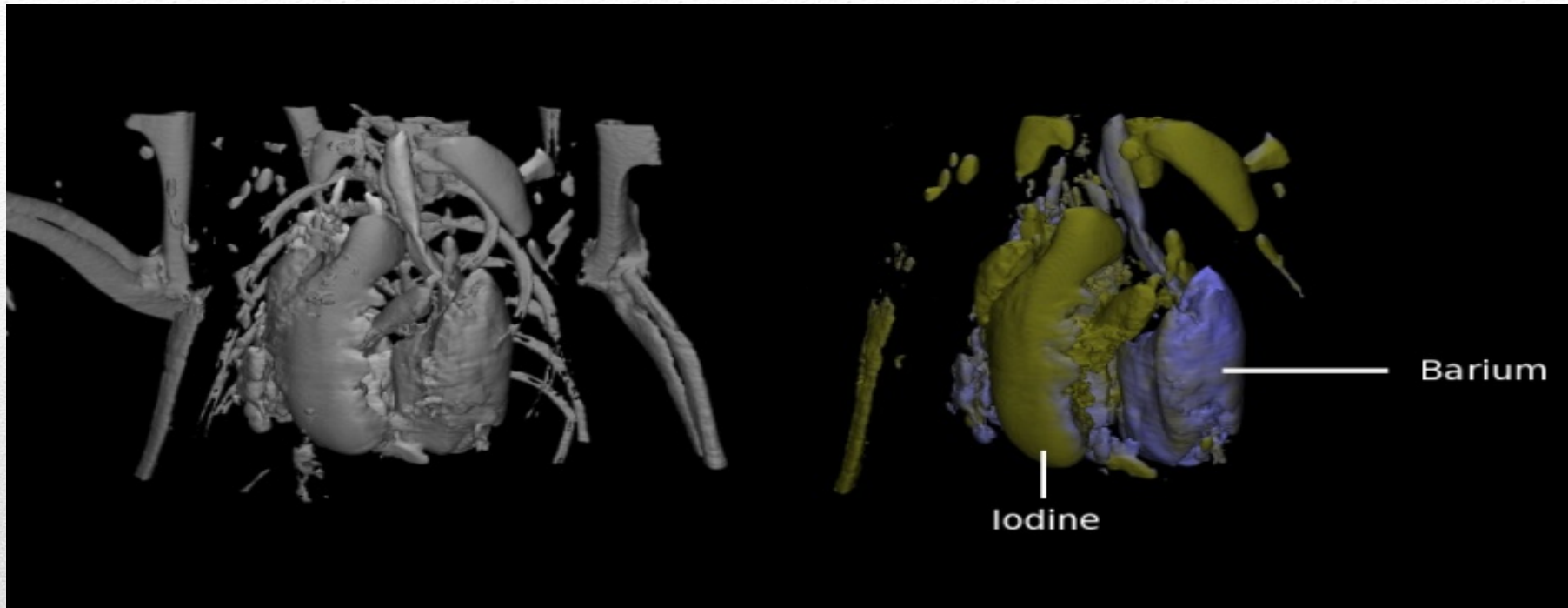
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(courtesy of NASA ISS)

# Applications: space dosimetry

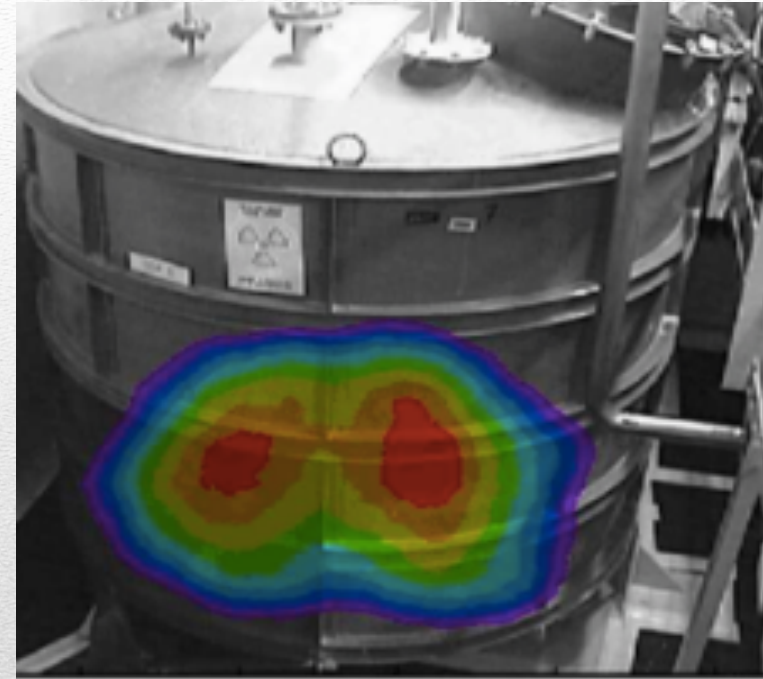
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(courtesy of MARS Bioimaging Ltd)

# Applications: medical imaging

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(courtesy of CEA List, Gampix gamma camera)

# Applications: gamma camera

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MEDIPIX2  
COLLABORATION AGREEMENT

K1016/ETT/EP

MEDIPIX 3  
COLLABORATION AGREEMENT

AGREEMENT K1292/PH/117C

MEDIPIX 4  
COLLABORATION AGREEMENT

KM2893/KT/PH/233C

Key success factor:  
The Collaboration agreements



**JABLONTRON**

cea **list**



**PHILIPS**



**FAU** FRIEDRICH-ALEXANDER  
UNIVERSITÄT  
ERLANGEN-NÜRNBERG



**SIEMENS**

# Eco-system: Collaborations with industry

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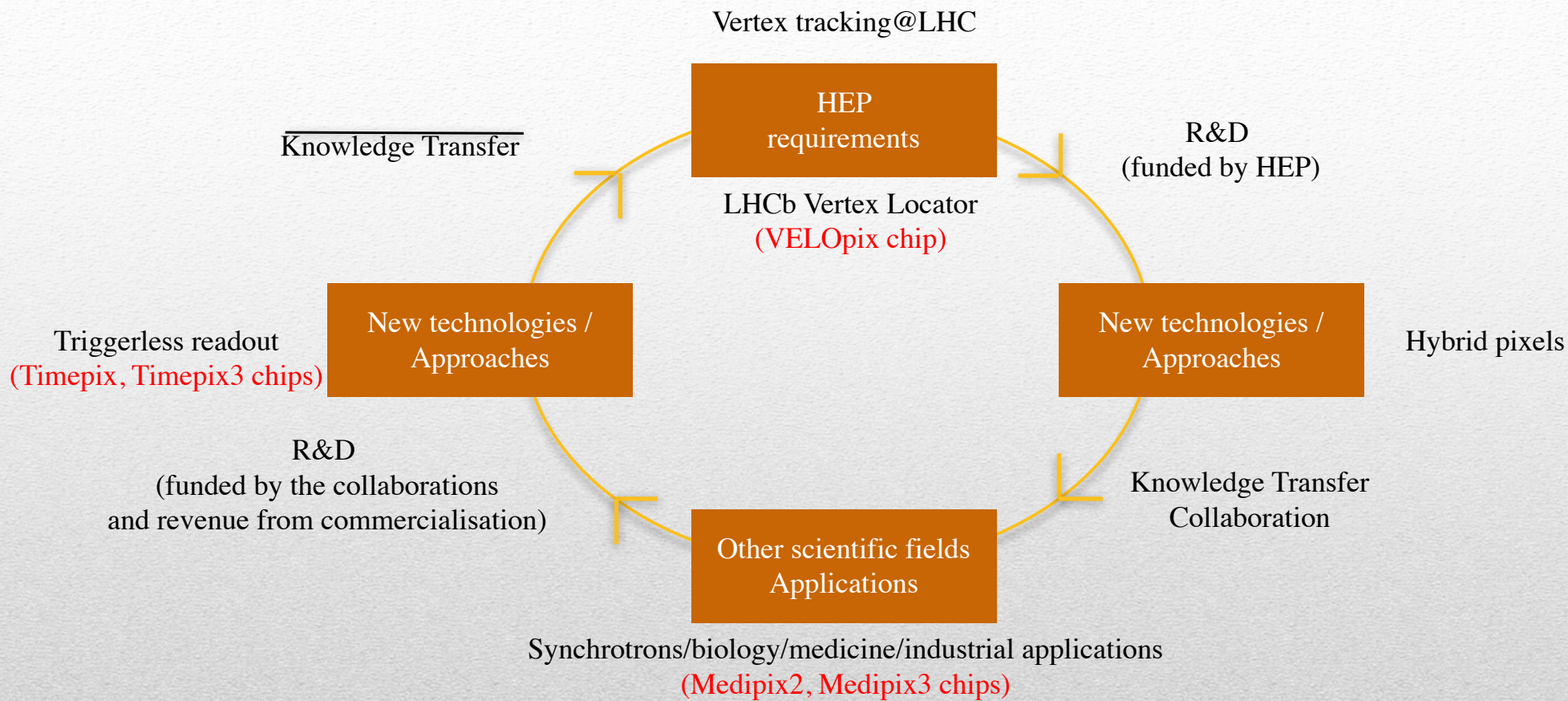
# Eco-system: spin-off companies

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- Direct exploitation licenses and production licenses
- Medium Sized Enterprises
  - PANalytical (NL)
  - Kromek (UK)
- 7 start-ups from Collaboration members

# Commercial licences

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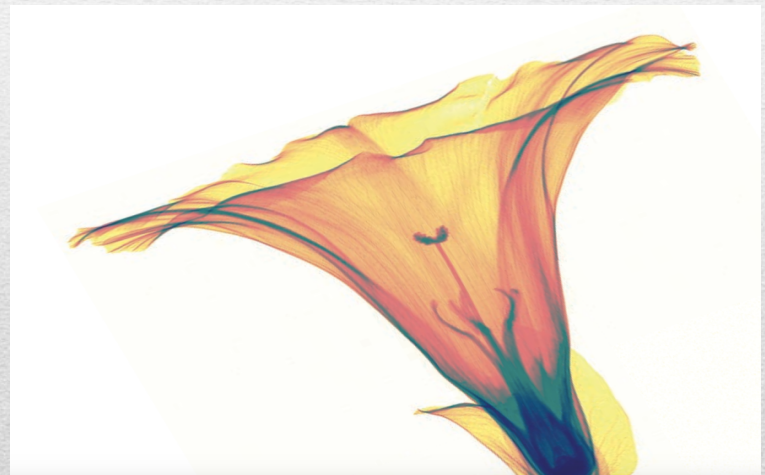


# Medipix Cycle of Innovation

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(courtesy of M. Campbell)

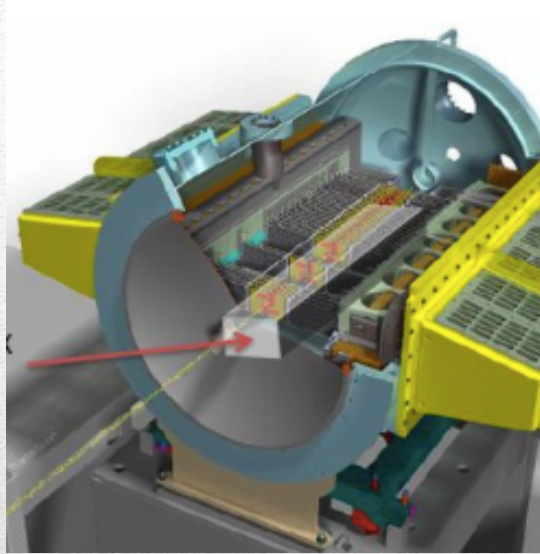
**Thank you...**



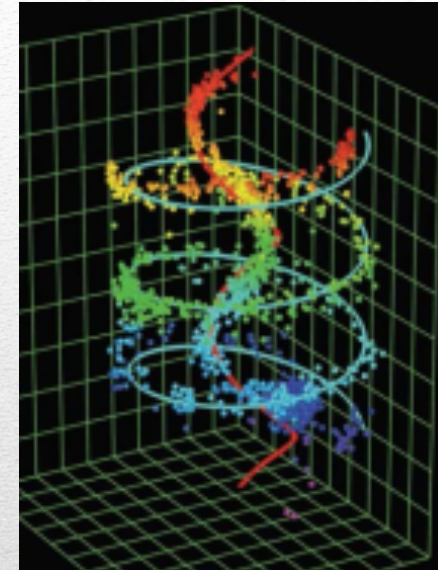
Picture credit front slide: Simon Procz, University of Freiburg, Medipix flower.

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**B. Denis - CERN IPT/KT**



(courtesy of NIKHEF)



(courtesy of Paolo Radaelli and Martin Fransen)

# HEP applications: 3D charged particle tracking

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