

SPADnet : Embedded Coincidence in a Smart Sensor Network for PET Applications

**Claudio Bruschini & Edoardo Charbon, EPFL & TU Delft
On Behalf of the SPADnet Consortium**

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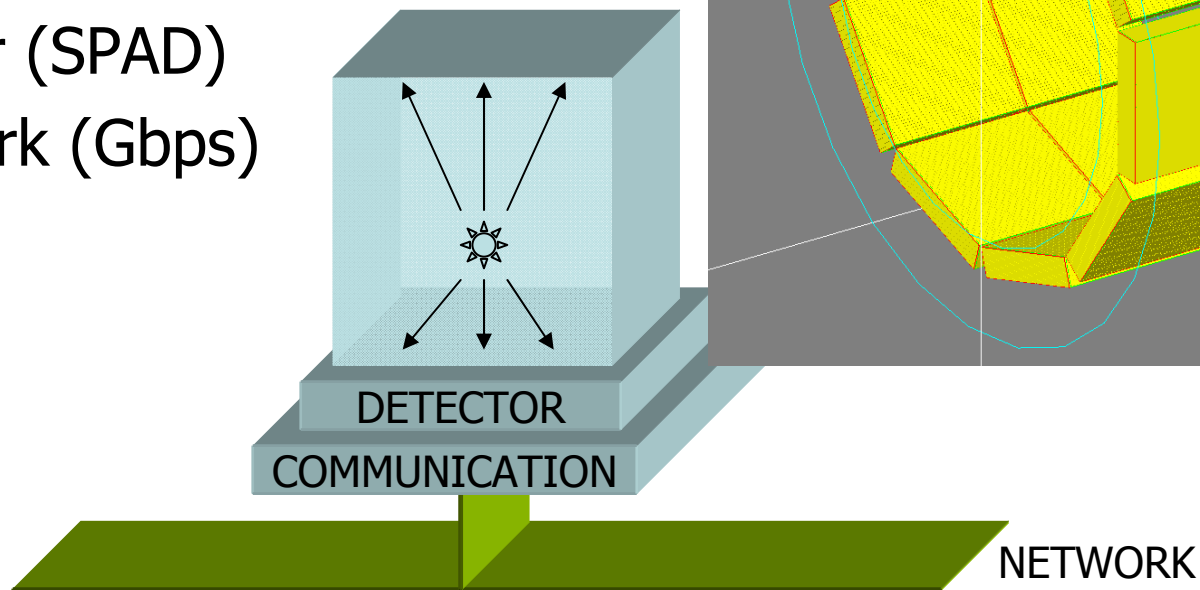


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SPADnet Concept & Requirements

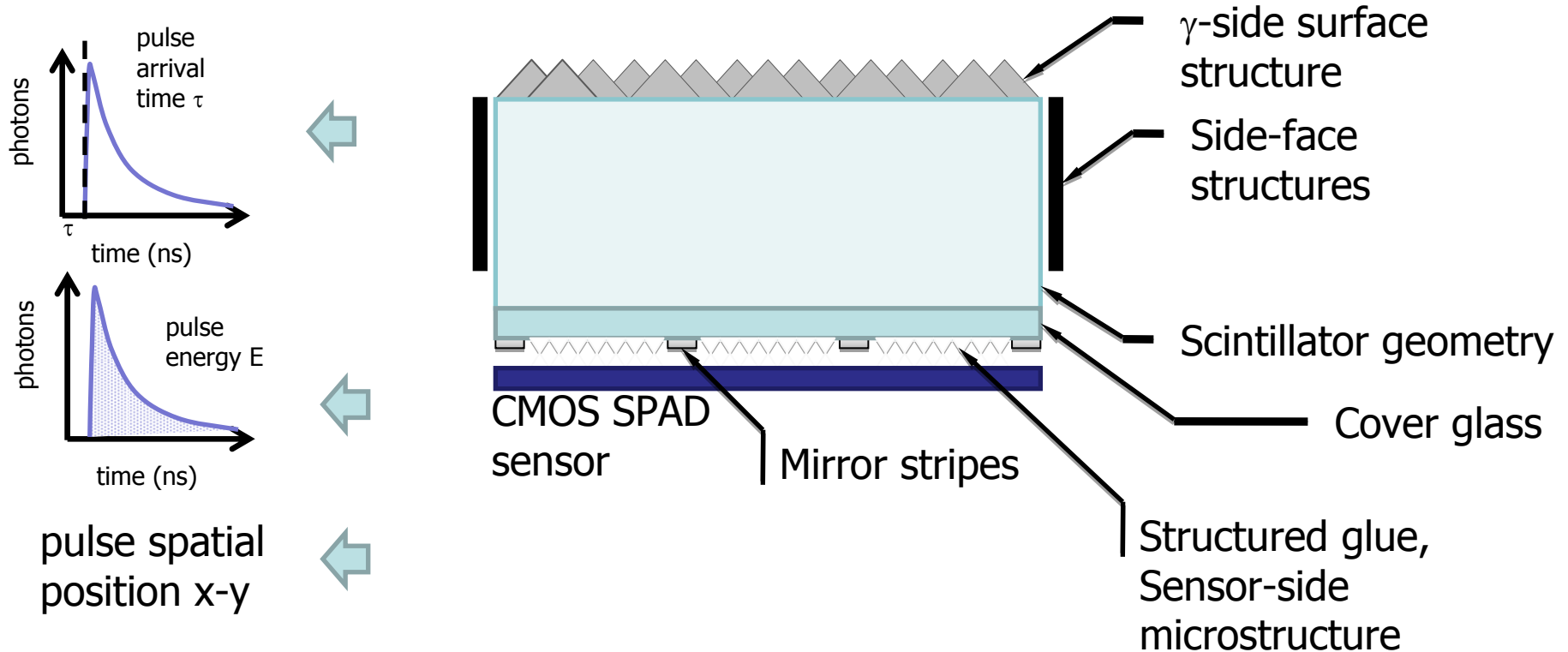
Photonic Component, comprising:

- Scintillator (LYSO)
- Sensor (SPAD)
- Network (Gbps)



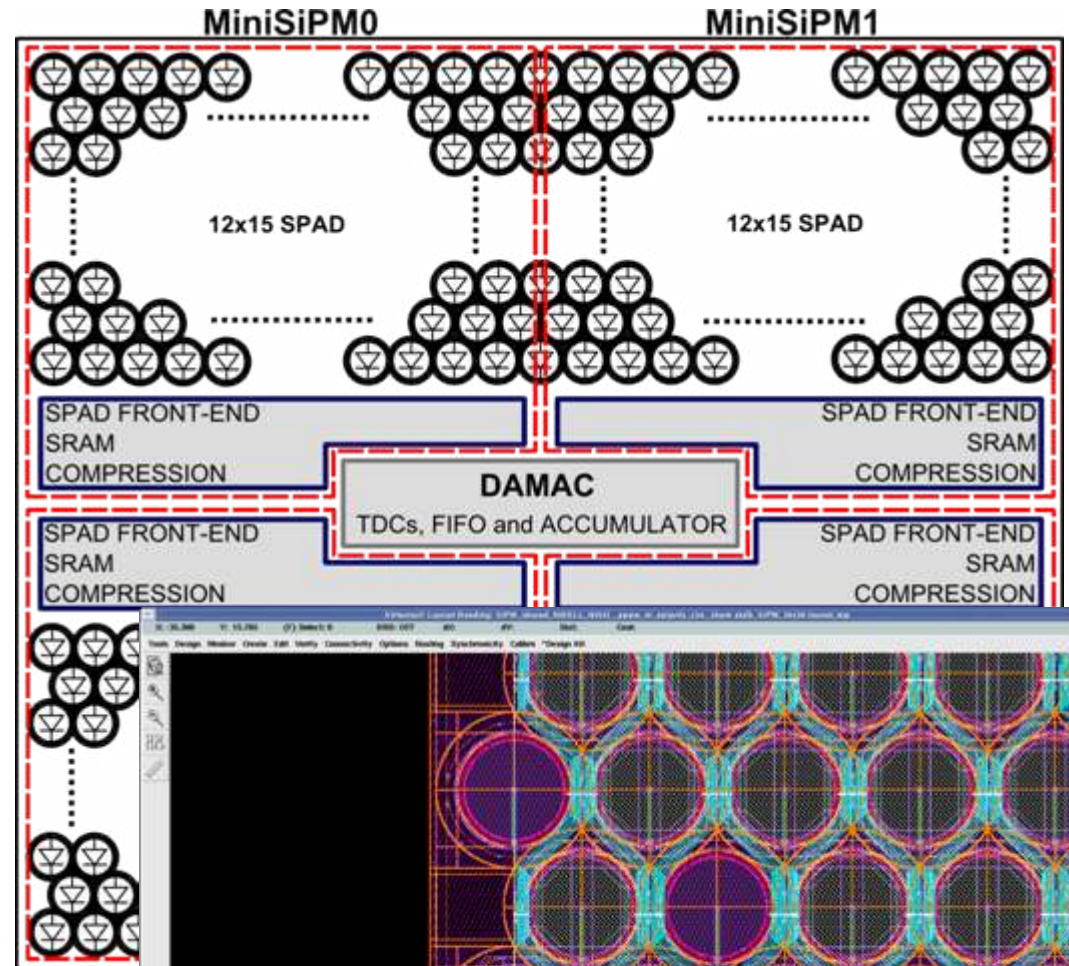
Scalable, modular System

Image Sensor and Coupling to Scintillator



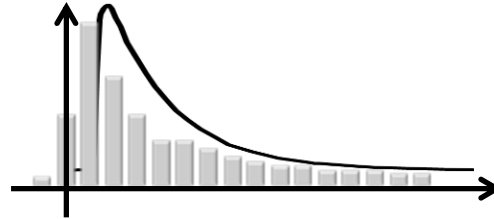
Pixel Architecture

- 2 x 2 mini-SiPMs
- 720 SPADs
- 1 active TDC
- $\sim 0.6 \times 0.6 \text{ mm}^2$
- 42.6% FF



Discriminating Gamma Events

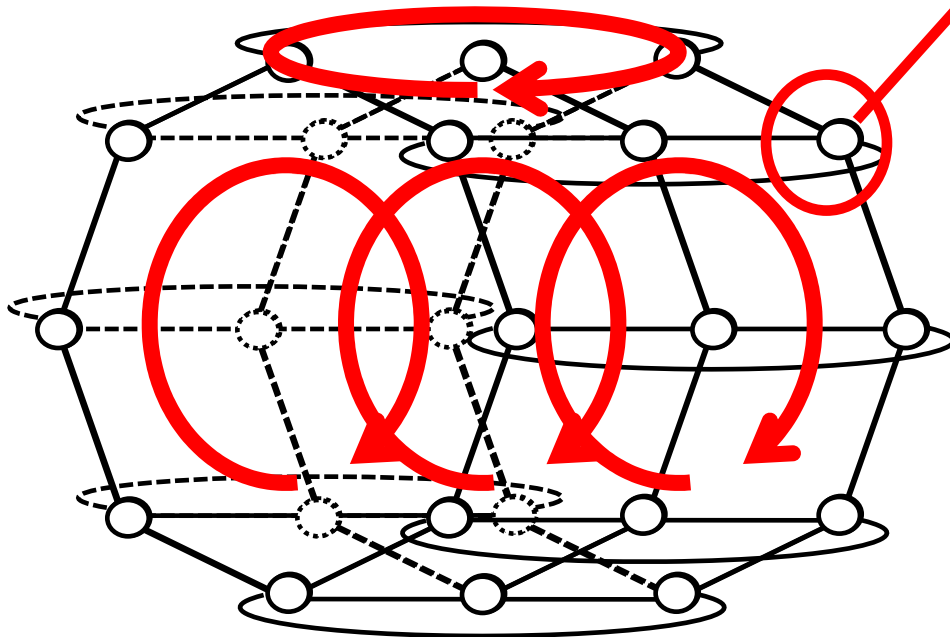
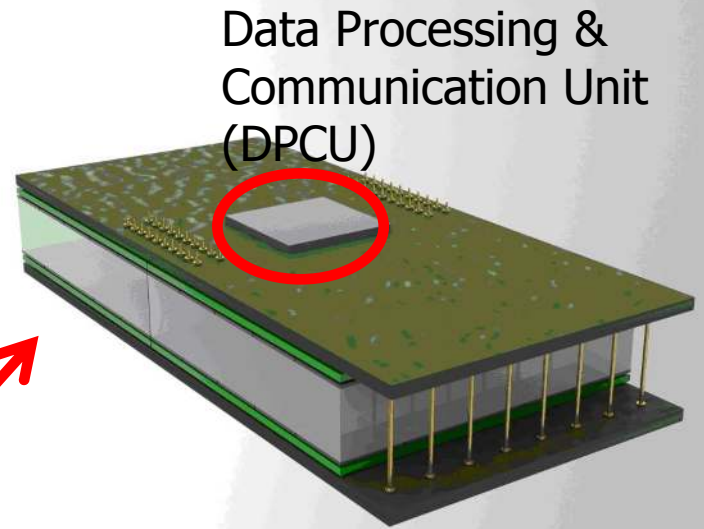
- Photons are counted in time bins \rightarrow discrete derivative



- Time-to-digital converter (TDC) per pixel

TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC
TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC	TDC

Multi-Ring Sensor Network Architecture & Coincidence Detection



Coincidence packets are circulated first (30 bits, mainly timing information)

[If coincidence] True event Packet 64 bits

- Node information
- Scintillation τ , E , x - y

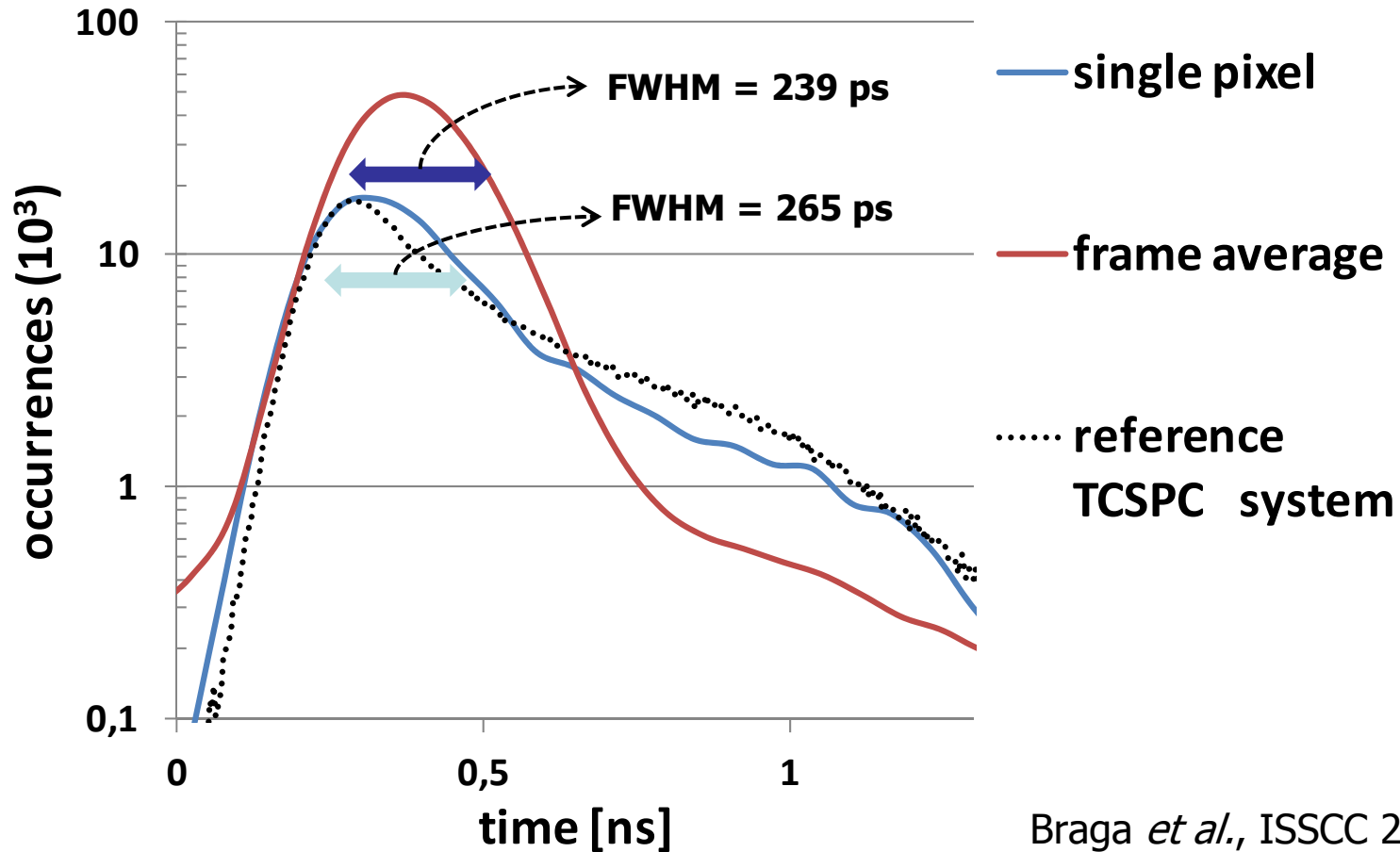
Preliminary Results

Sensor Micrograph

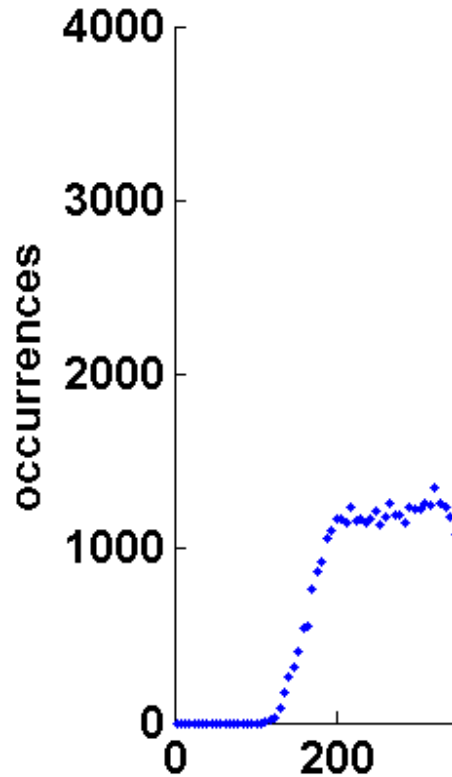


Braga *et al.*, ISSCC 2013

Characterization (Pulsed Laser): Timing



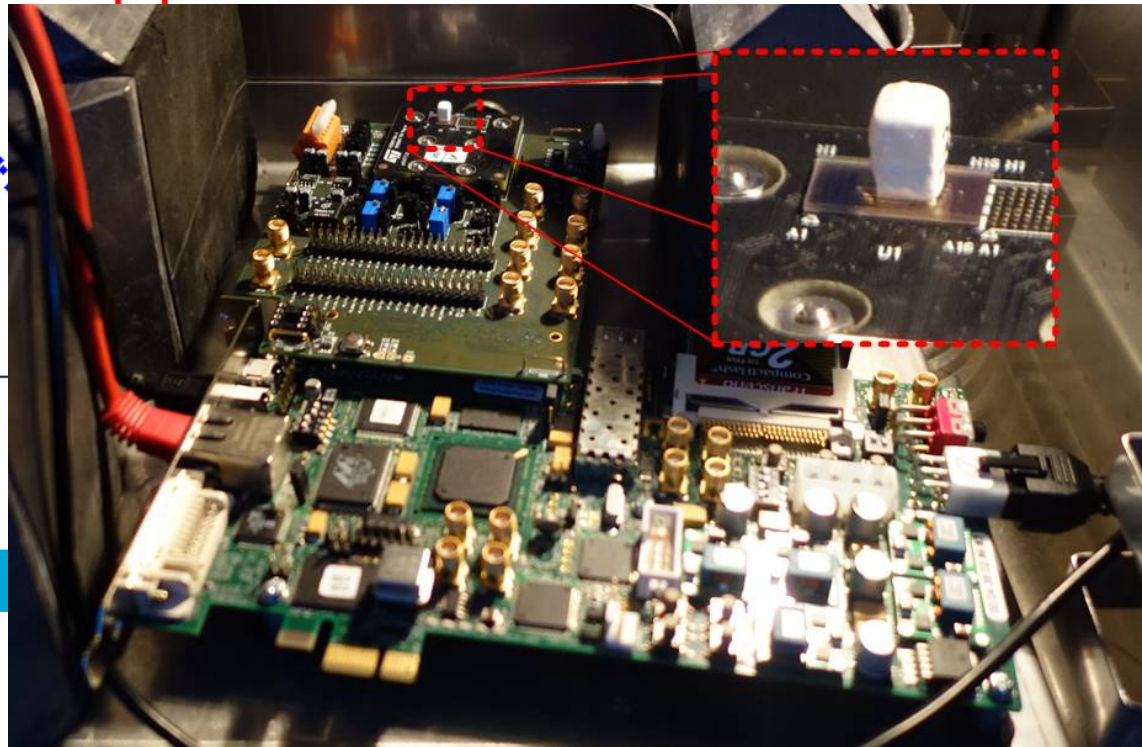
Characterization (^{22}Na , 370kBq): Energy Spectrum



511 keV

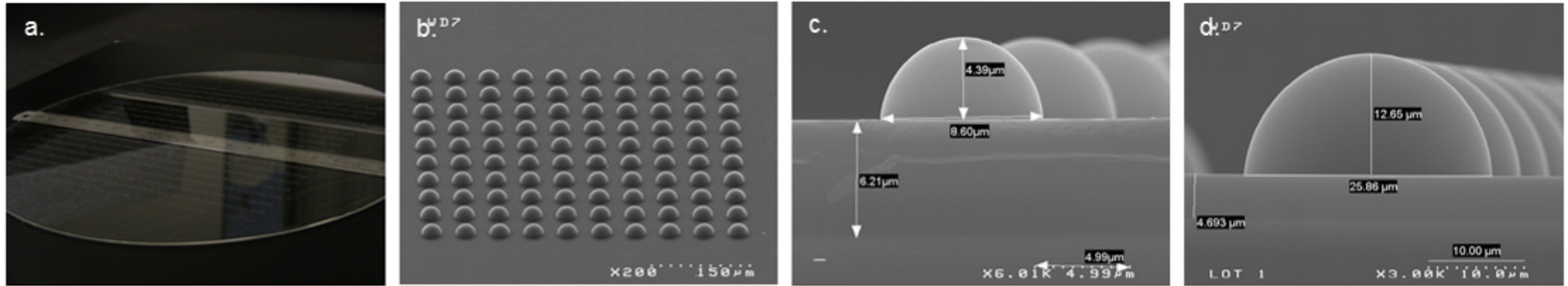
T = 20° C

LYSO scintillator crystal $3 \times 3 \times 5 \text{ mm}^3$
wrapped in Teflon

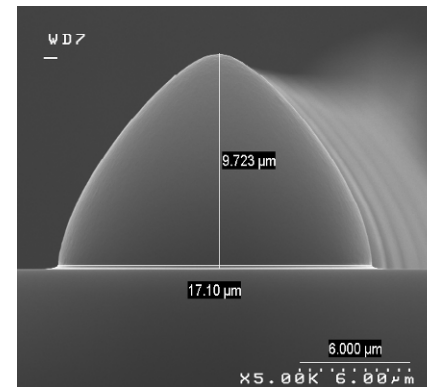
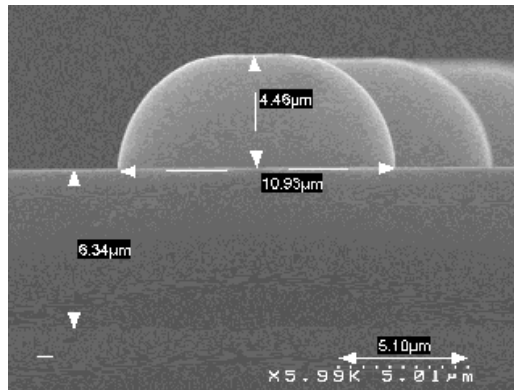


Micro-Optical Structures

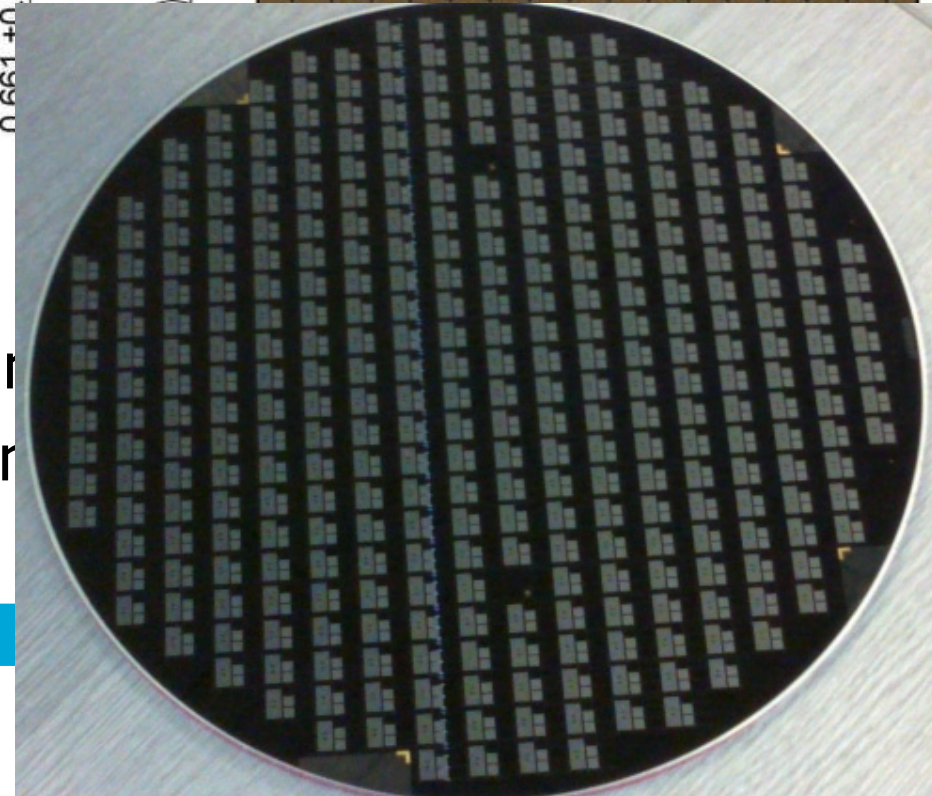
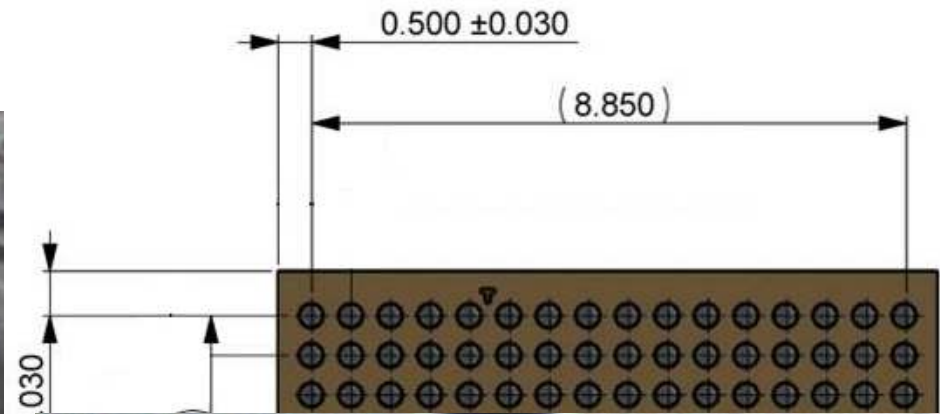
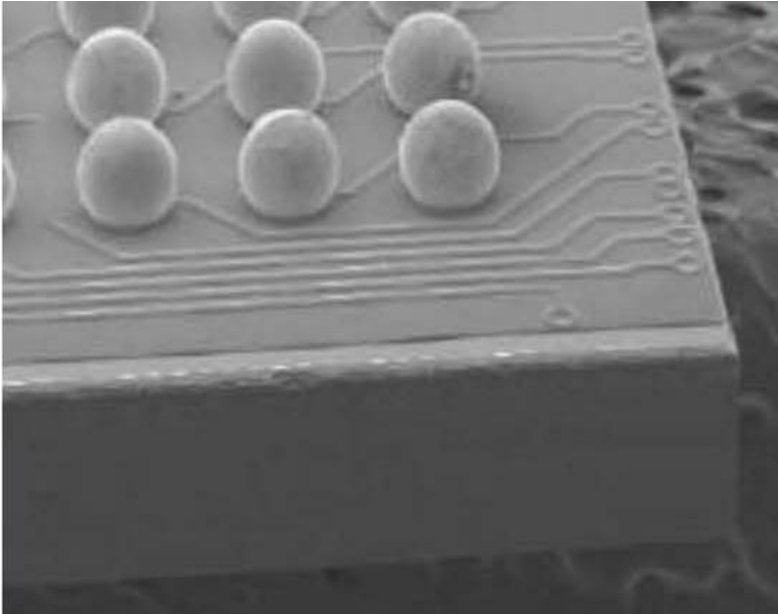
- Conventional hemispherical microlenses.



- The etching technique for the realization of the master leads to various shapes: Flat microlens (→ for parabolic structures) and sharp edge

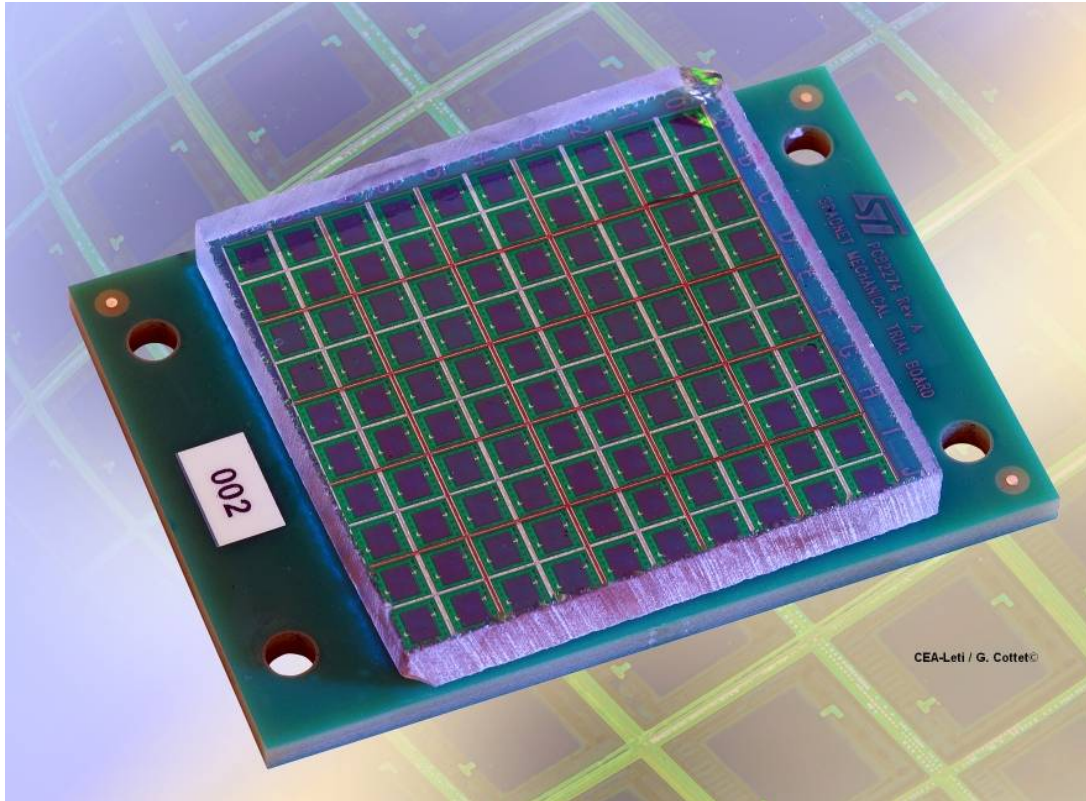


Compact Packaging: Through-Silicon Vias (TSVs)



- TSVs enable butting to micro
- No space lost with wirebond

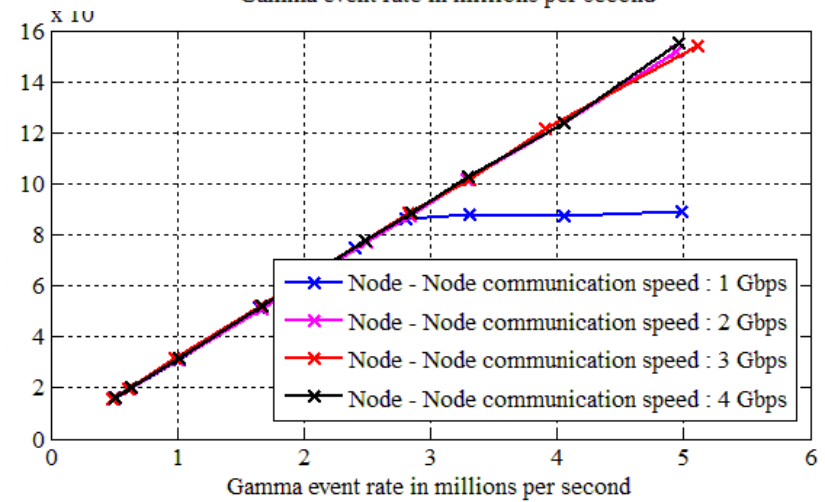
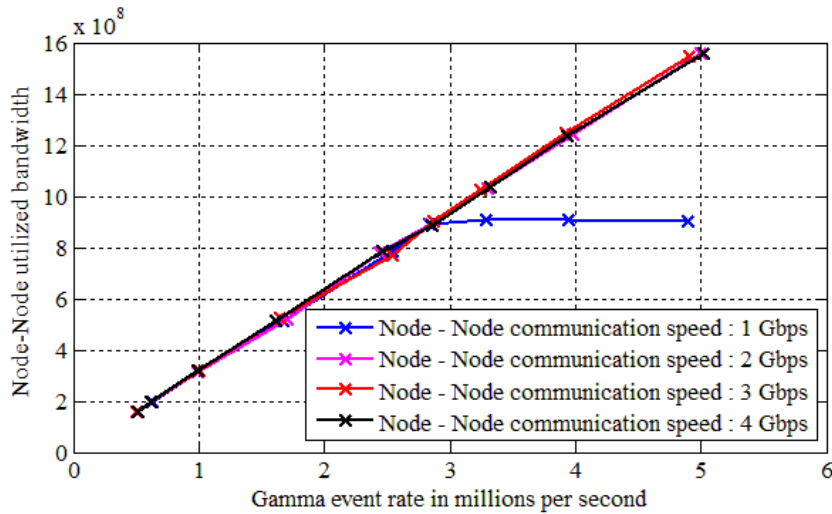
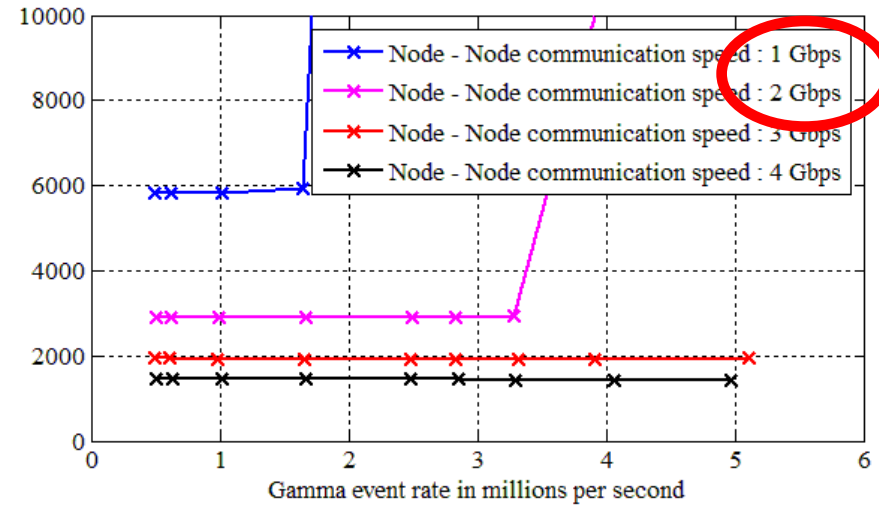
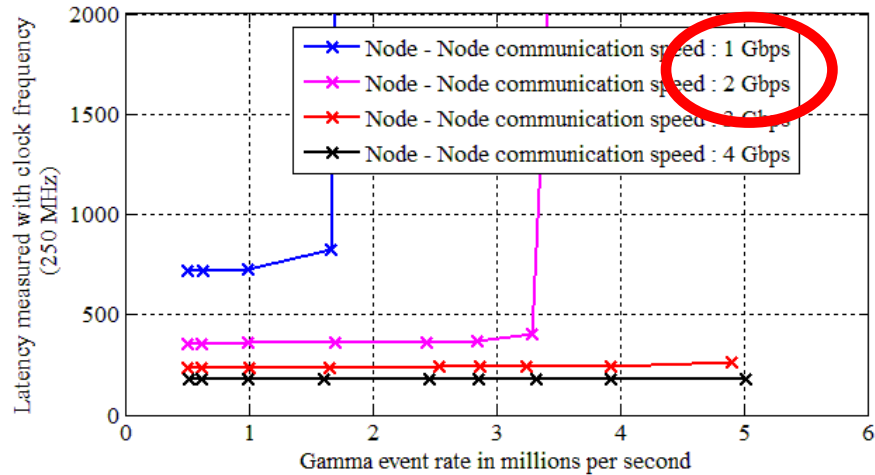
Preliminary Assembly Tests



- LYSO slab and needle matrix assembly on a dummy tile
- Successful study of production-compatible assembly

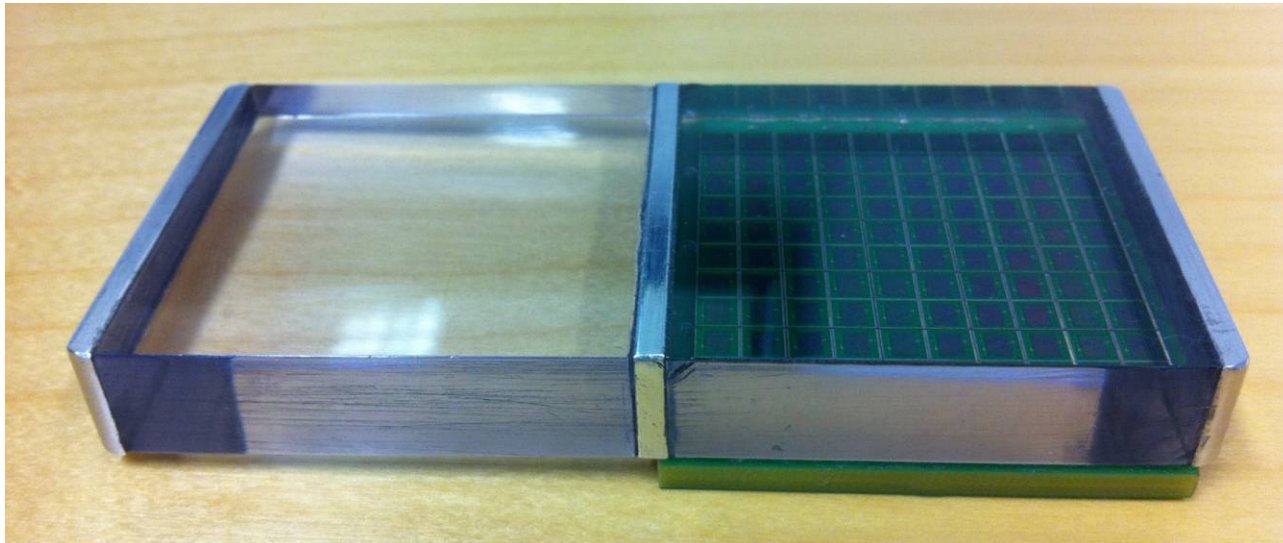
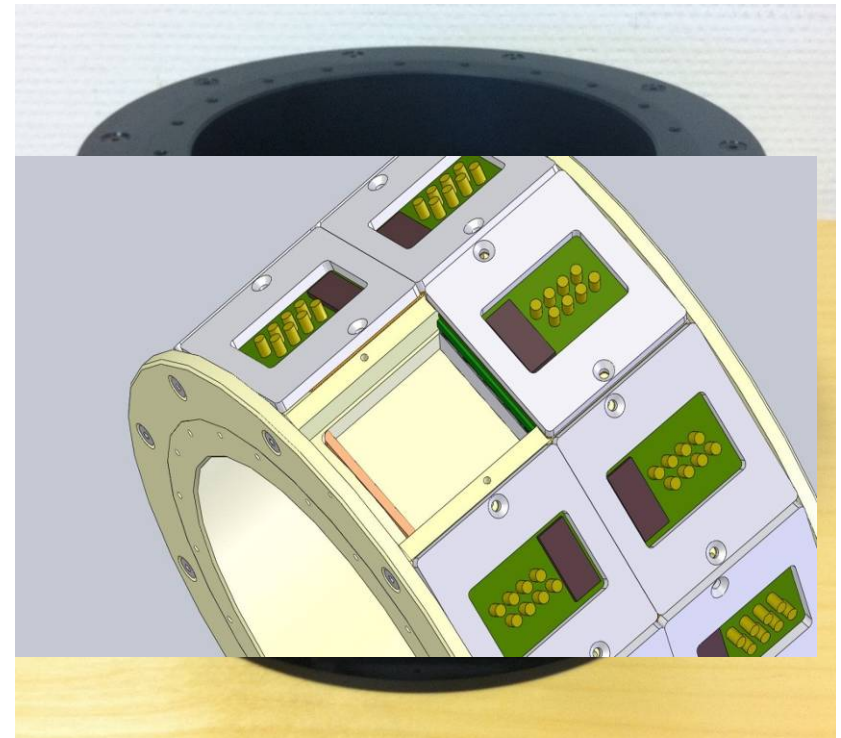
Assembly with similar TSV chips

Preclinical PET Network Simulations

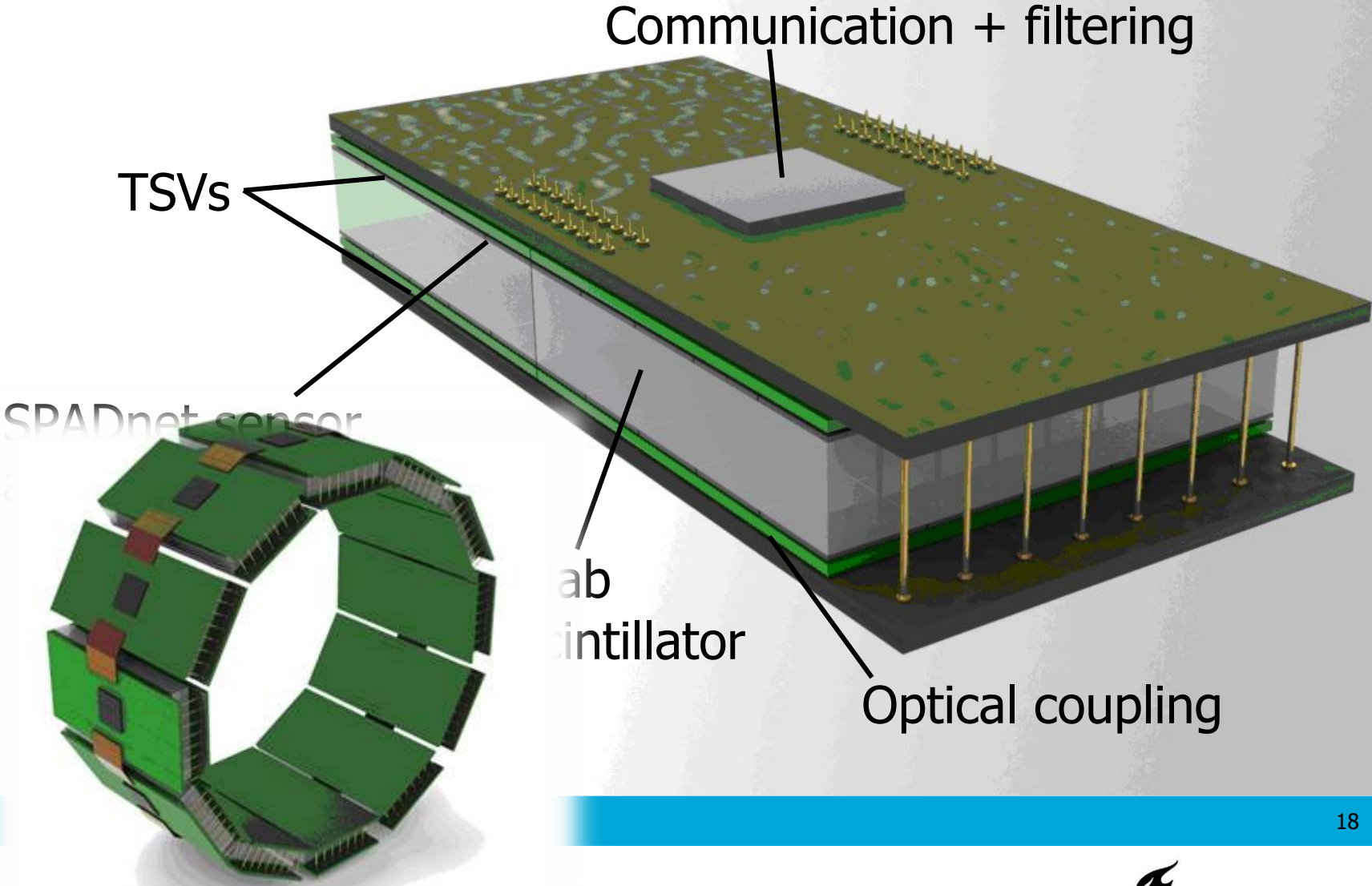


Preliminary System

- Non-magnetic material
- Mechanical stability (~ 3.5 kg crystal)
- Mechanical precision
- Flexibility
- Easy to mount on Mediso's existing gantry



Next: Complete Photonic Component



Conclusions - SPADnet Innovates in:

- Gamma detection via multi-pixel sensor with embedded TDCs and digital output
- Large format with through-silicon-via based packaging and CMOS compatibility
- Advanced optical coupling
- Scalable, multi-ring network with coincidence detection at gigabit data rates
- Image reconstruction exploiting spatial information

SPADnet Consortium - www.spadnet.eu

- **EPFL, Lausanne, Switzerland**
- **TU DELFT, Delft, Netherlands**
- **Univ. of Edinburgh, Edinburgh, Scotland**
- **Fondazione Bruno Kessler, Trento, Italy**
- **STMicroelectronics, Edinburgh, Scotland**
- **STMicroelectronics, Crolles, France**
- **MEDISO Ltd., Budapest, Hungary**
- **LETI, Grenoble, France**
- **Budapesti Muszaki es Gazdasagtudomanyi Egyetem (BUTE), Budapest, Hungary**