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HPD set-up tests of backside illuminated monolithic CMOS pixel sensor

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Outlook

- Application: non-destructive beam monitor for hadron therapy beams
- Device: back-thinned monolithic CMOS pixel sensors
- Qualification tests: imaging of low energy electrons in HPD-like structure
- Conclusions

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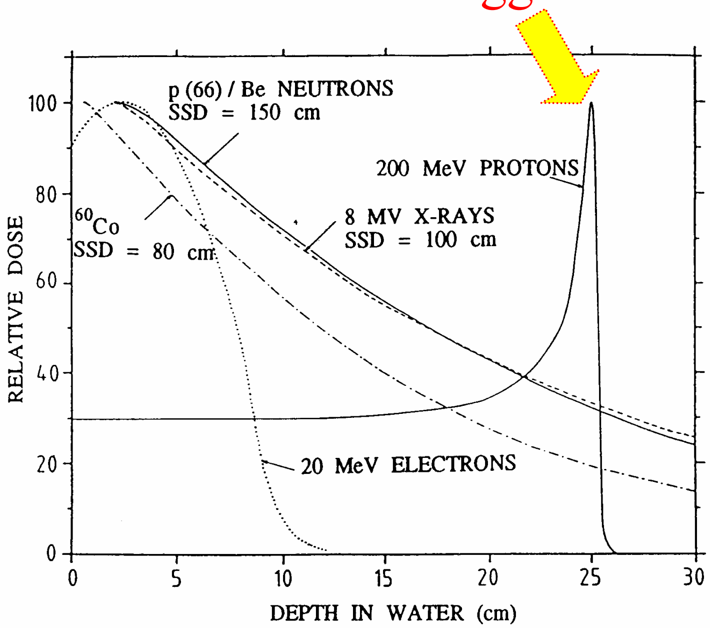
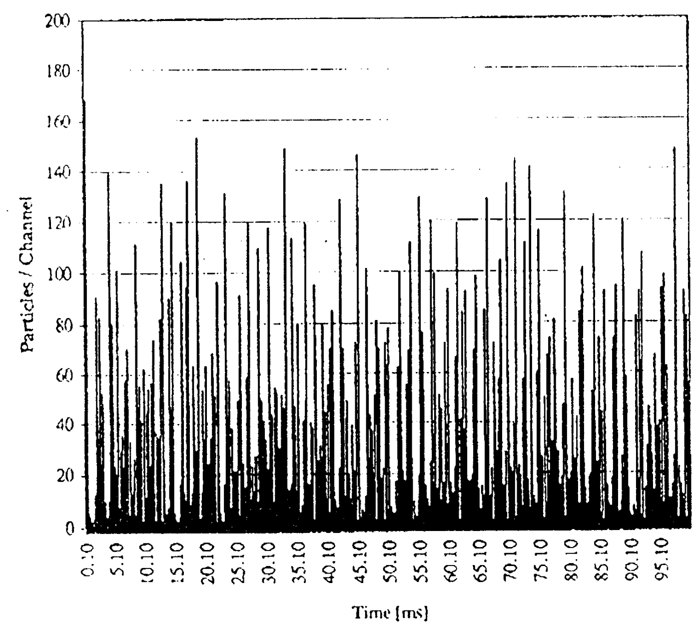
adrontherapy: use of a light ion beam for cancer irradiatio

Effective use of a:

Bragg curve





Cyclotron beam intensity fluctuation…

energy: 60 ÷ 250 MeV p, 120 ÷ 400 MeV/u $^{12}C^{6+}$
average intensity : 5 pA ($^{12}C^{6+}$) ÷ 8.3 nA (p)
beam average cross section (4 σ): 10 x 10 mm^2

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Aim for a 'real-time', non destructive beam monitoring

efficient operation of the accelerator complex
multiple measurements on the same beam
maximum safety to the patient

No such a device exist on the market!

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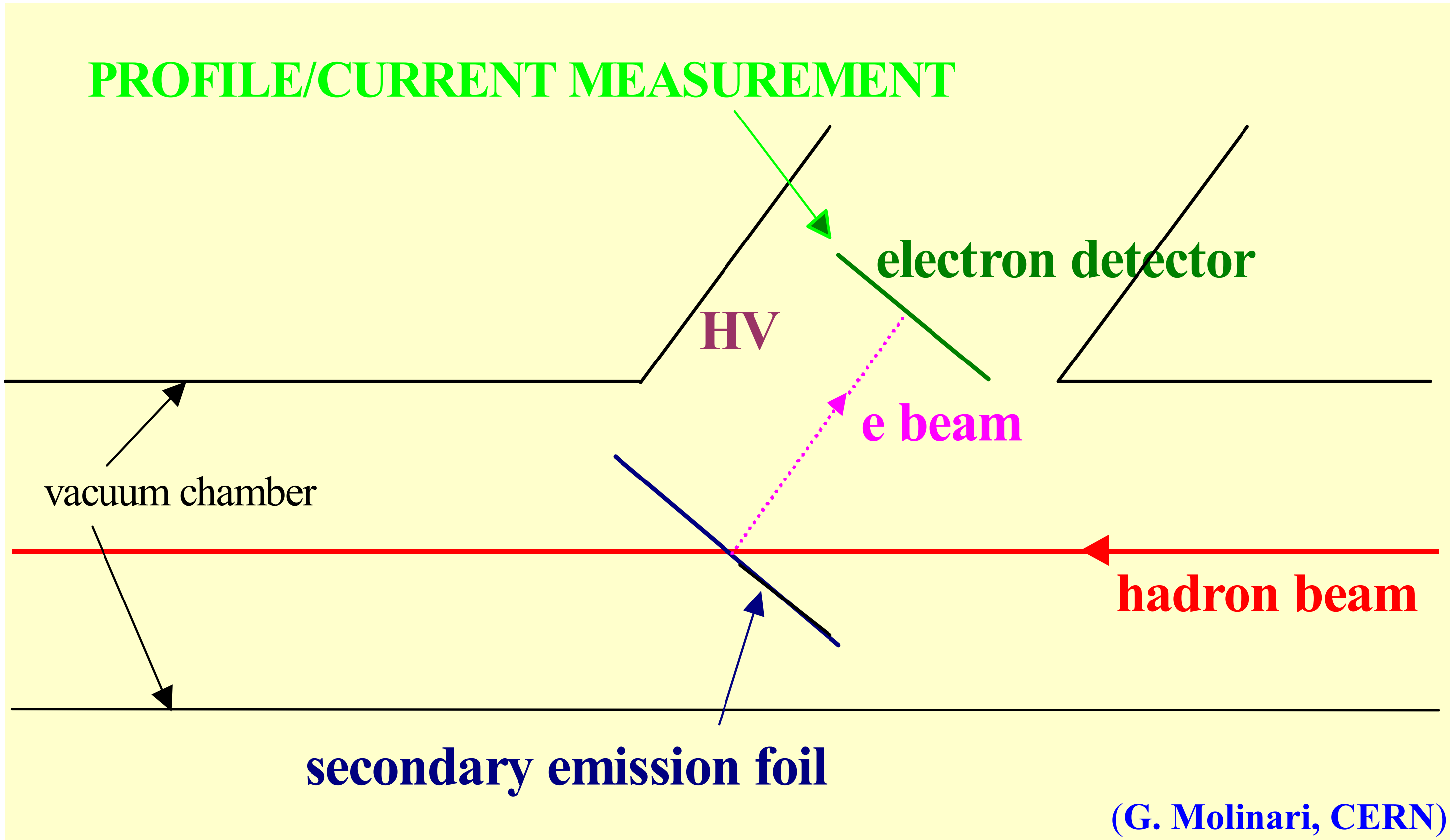
The solution: Secondary emission for Low Interception Monitoring (SLIM project)



collection of secondary electrons (SE) emitted by 0.1 – 0.4 µm aluminum (Al-Al_2O_3-Al) foils

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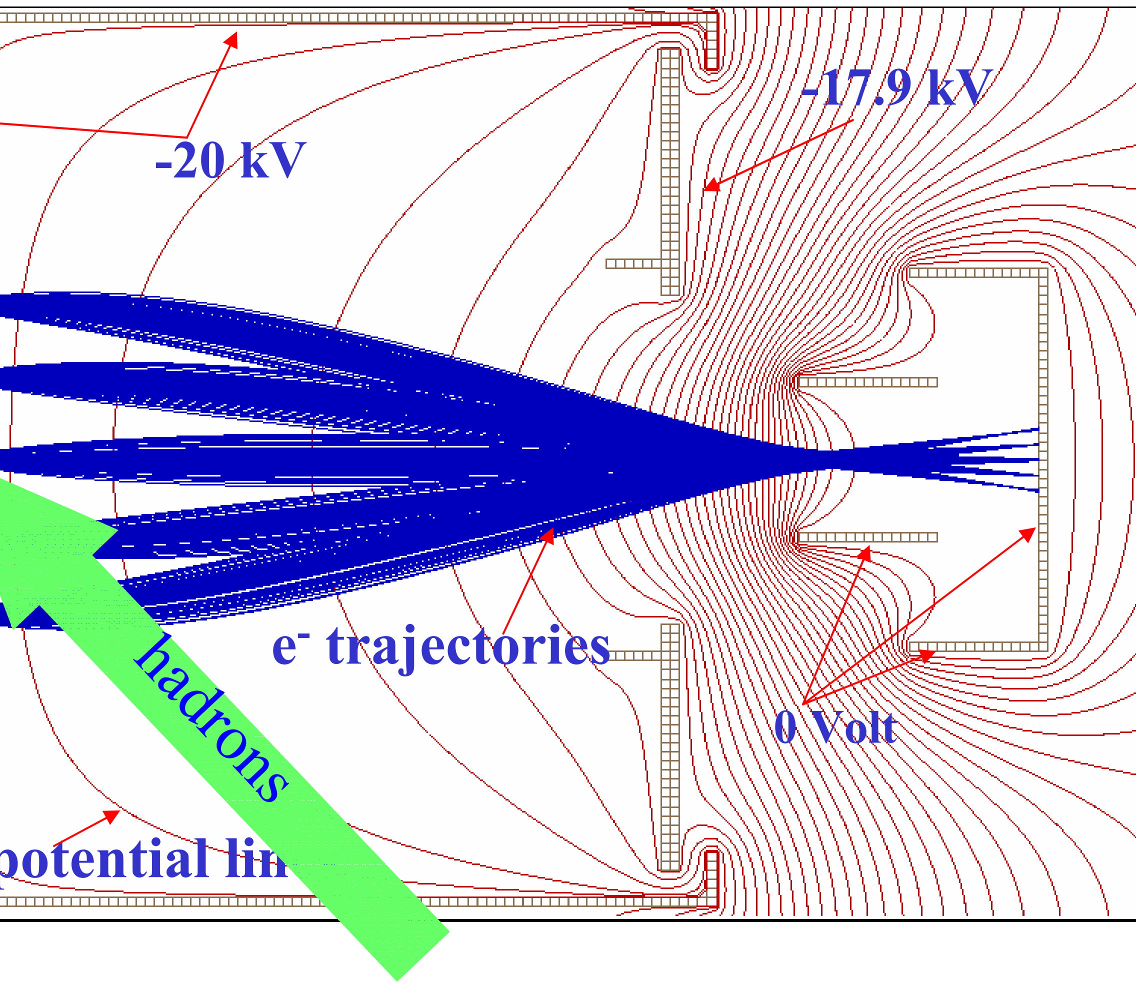
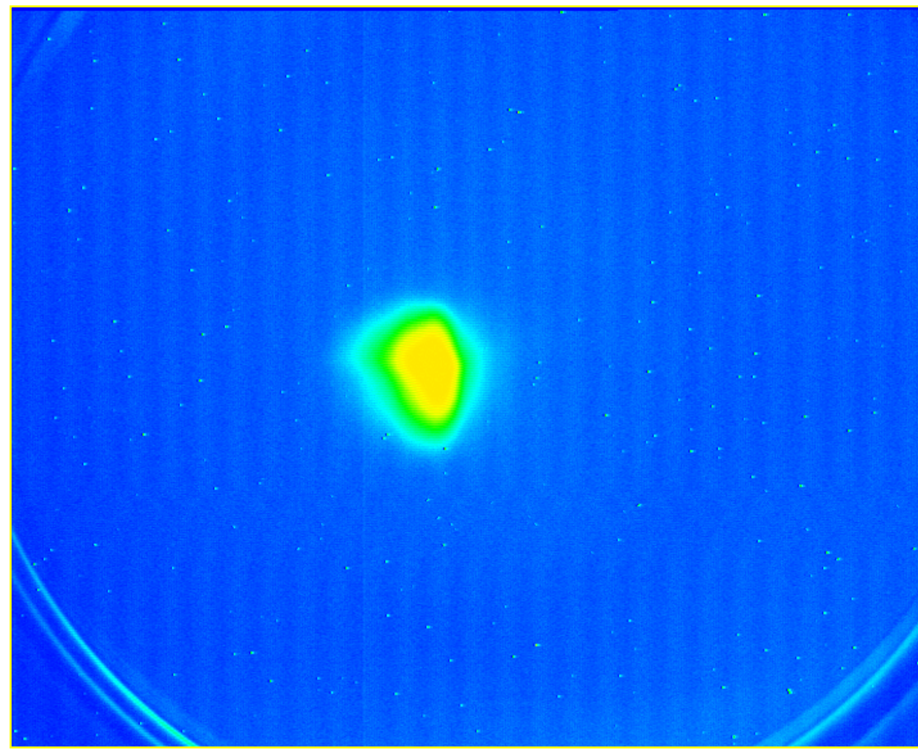
SLIM development within SUCIMA Collaboration

(CROSS) FOCUSING OPTICS





P-BEAM MEASURED BY SLIM
Scintillating screen + CCD camera

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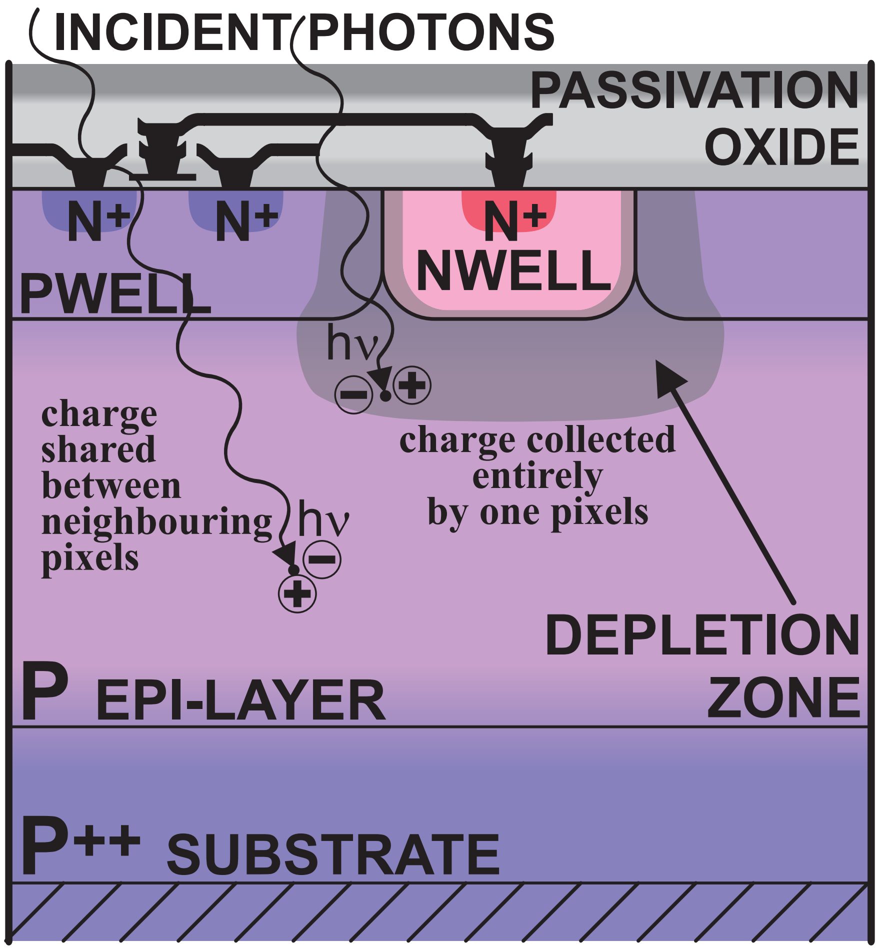
CMOS Monolithic Active Pixel Sensors (MAPS) principle

"From digital cameras to particle tracking device"



-The active volume (epi-layer, ~10 µm thick) is underneath the readout electronics, providing 100% fill factor

-The charge generated by ionization is collected by the n-well/p-epi diode

-Charge collection is achieved through the thermal diffusion

The device can be fabricated using a standard, cost effective and easily available twin-tub CMOS process on epi substrate.
No post-processing (e.g. bump-bonding)!

System-on a chip approach possible

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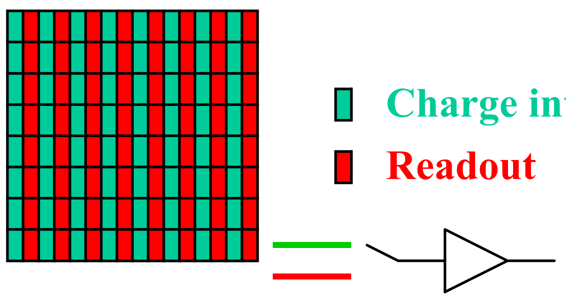
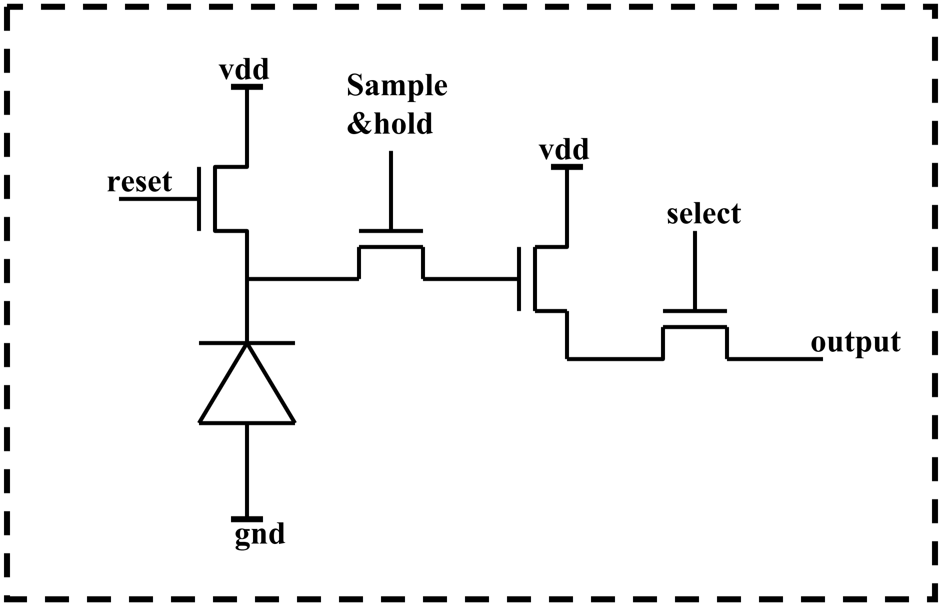
Requirements for electron imager

-sensitivity to 20 keV electrons
-active surface subdivided in 5000 cells (pads or pixels) or more;
-dynamic range 3 to 10^4 e-/pixel every 100 µs;
-10 KHz frame rate (to guarantee ± 2 % dose uniformity);
-no dead time



Two interleaved arrays of 112x112 pixels each



Global shutter using 4T pixel circuit

The final device in production…

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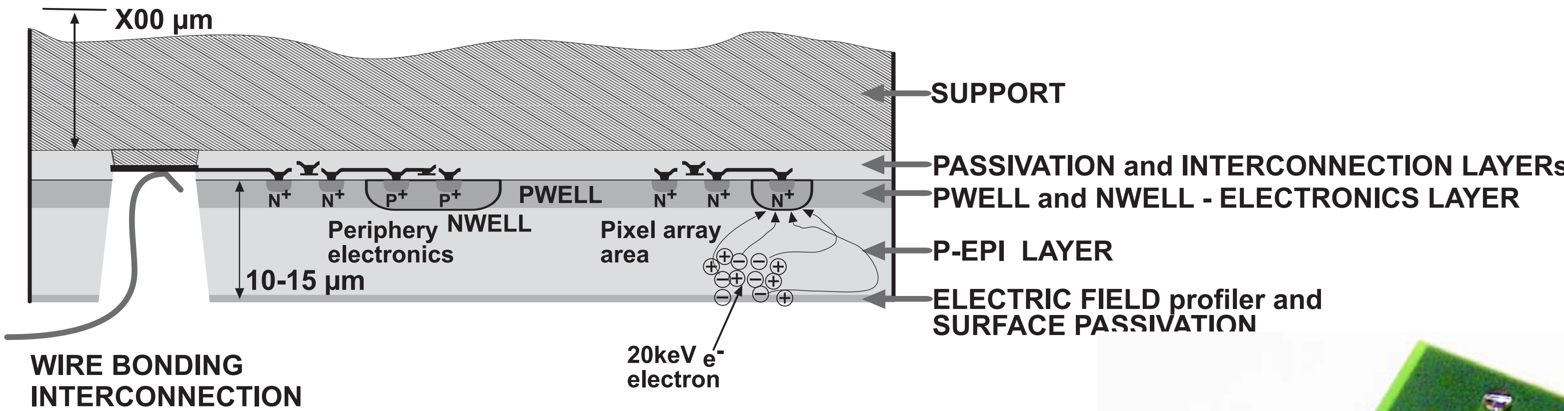
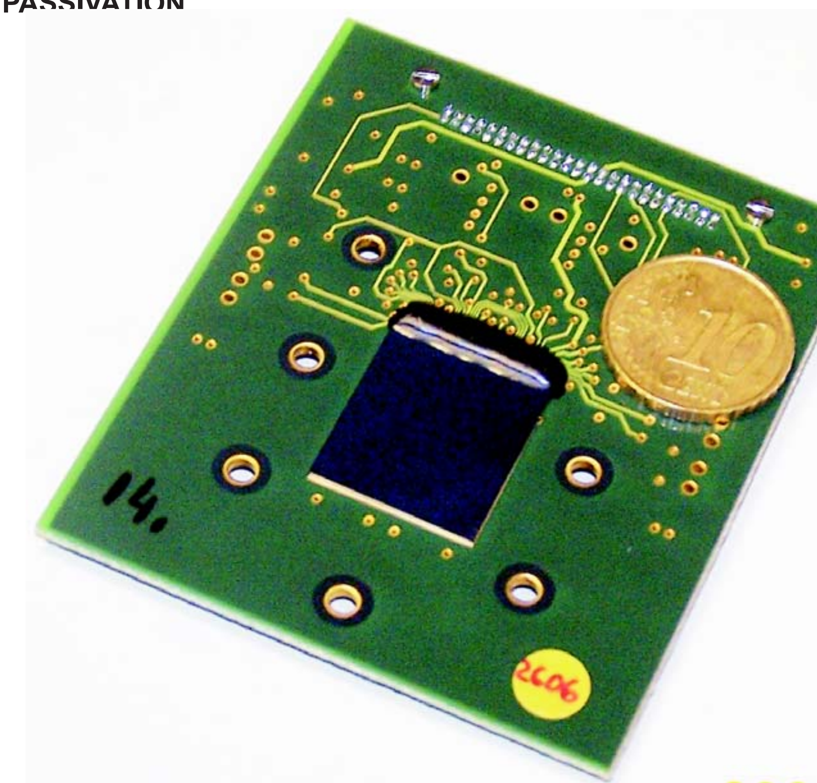
…demonstration of back-thinning and electrons imaging using existing device



Test vehicle: Mimosa5 prototype ($2x2\ cm^2$ device, 1 million pixels), thinned-down to the epitaxy layer (14µm)



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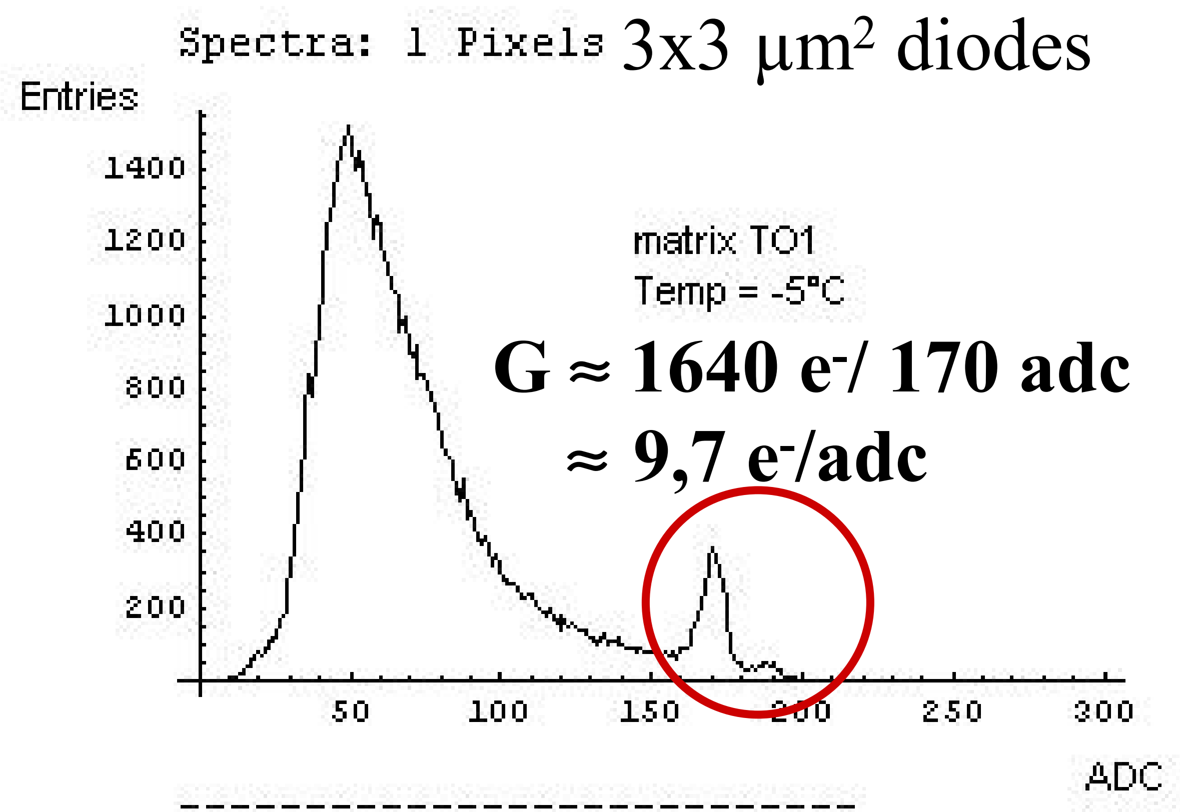
Standard calibration using 5.9 keV photons from ^{55}Fe source



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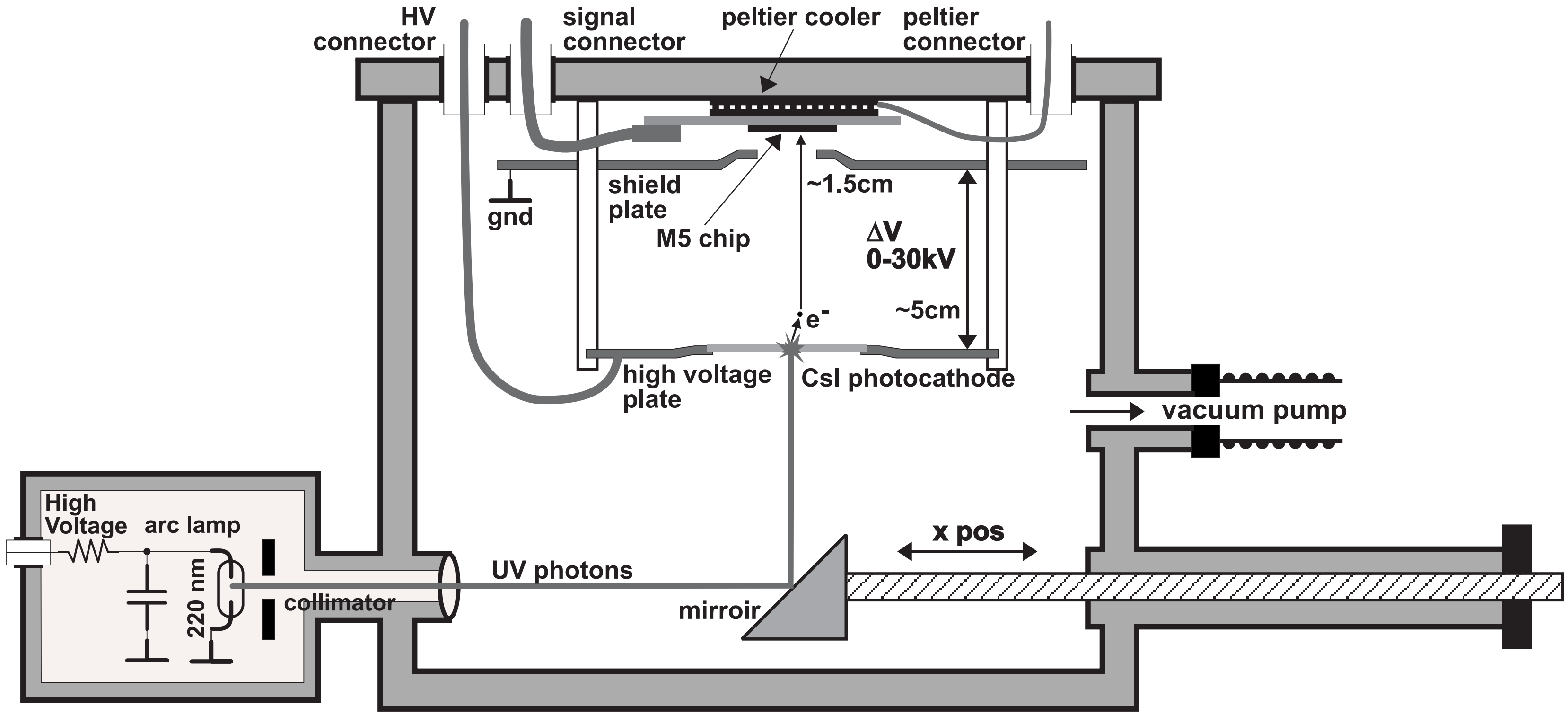
HPD test set-up at CERN



Simplified view of vacuum pot with proximity focusing optics HPD using CsI photocathode

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HPD test set-up at CERN

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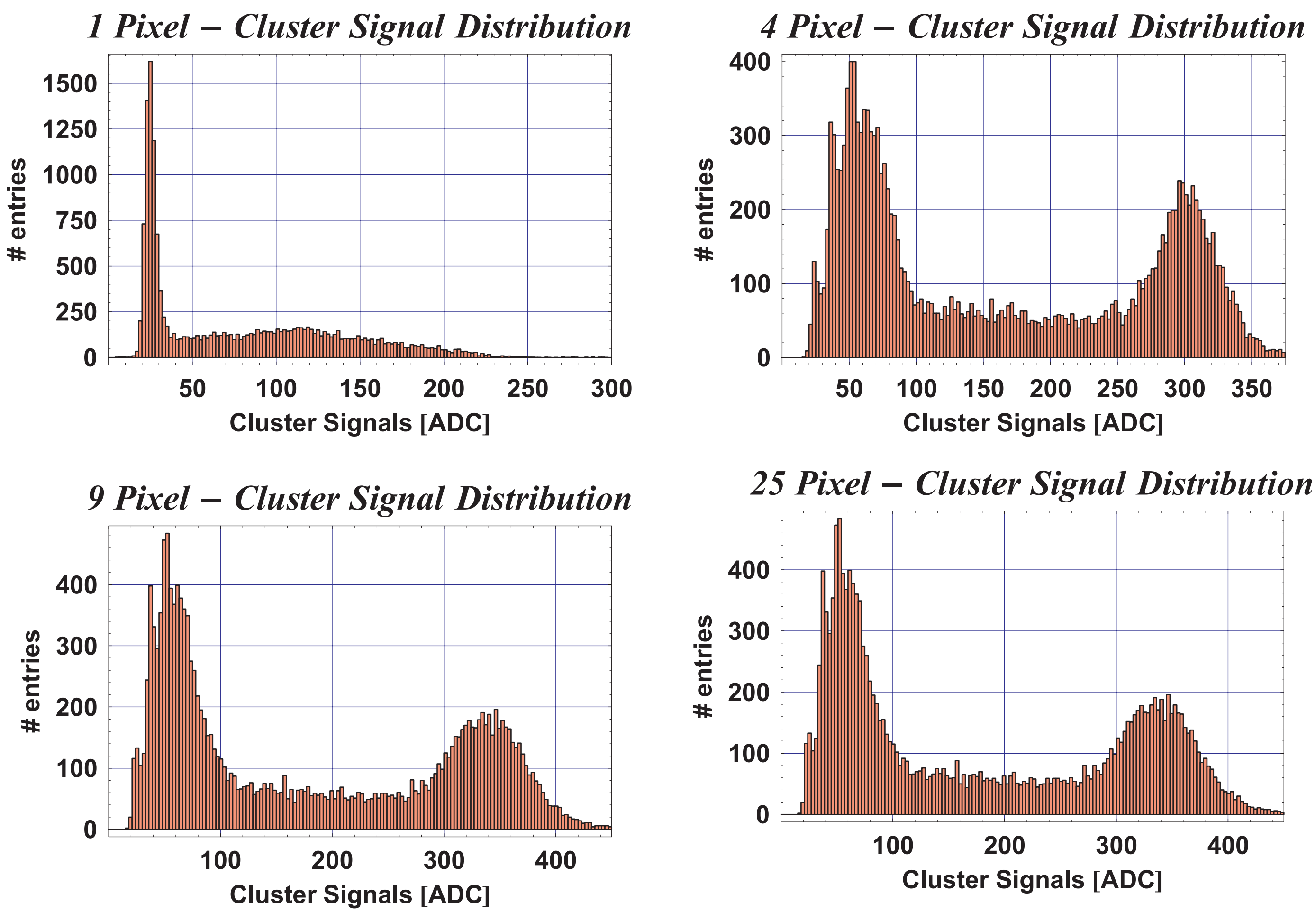
Spectrum of electrons emitted by photocathode

- 15kV

Data for 1st step – no cooling



Reconstructed signal clusters

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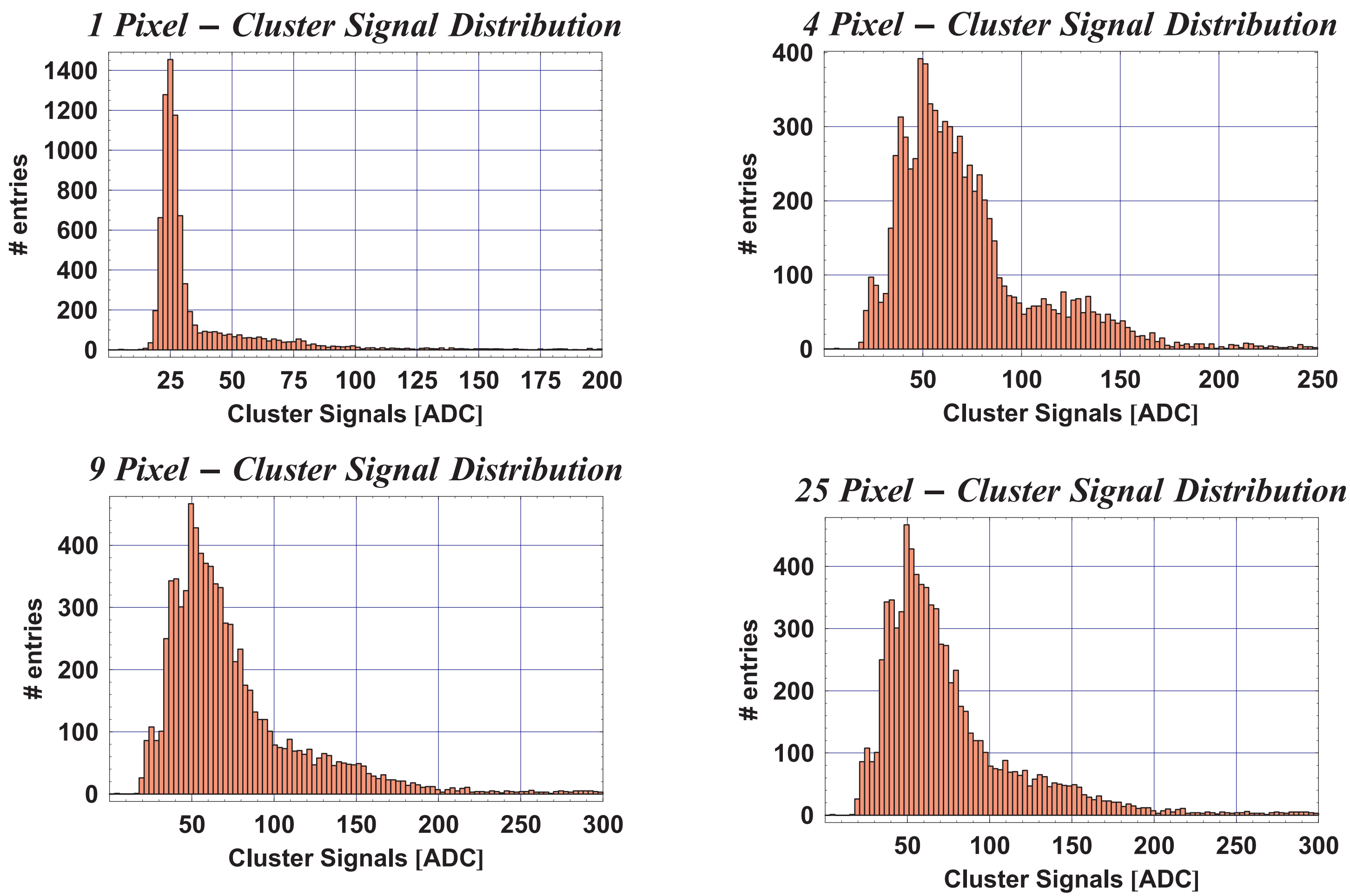
Spectrum of electrons emitted by photocathode

- 7.5kV

Data for 1st step – no coolinG



Reconstructed signal clusters

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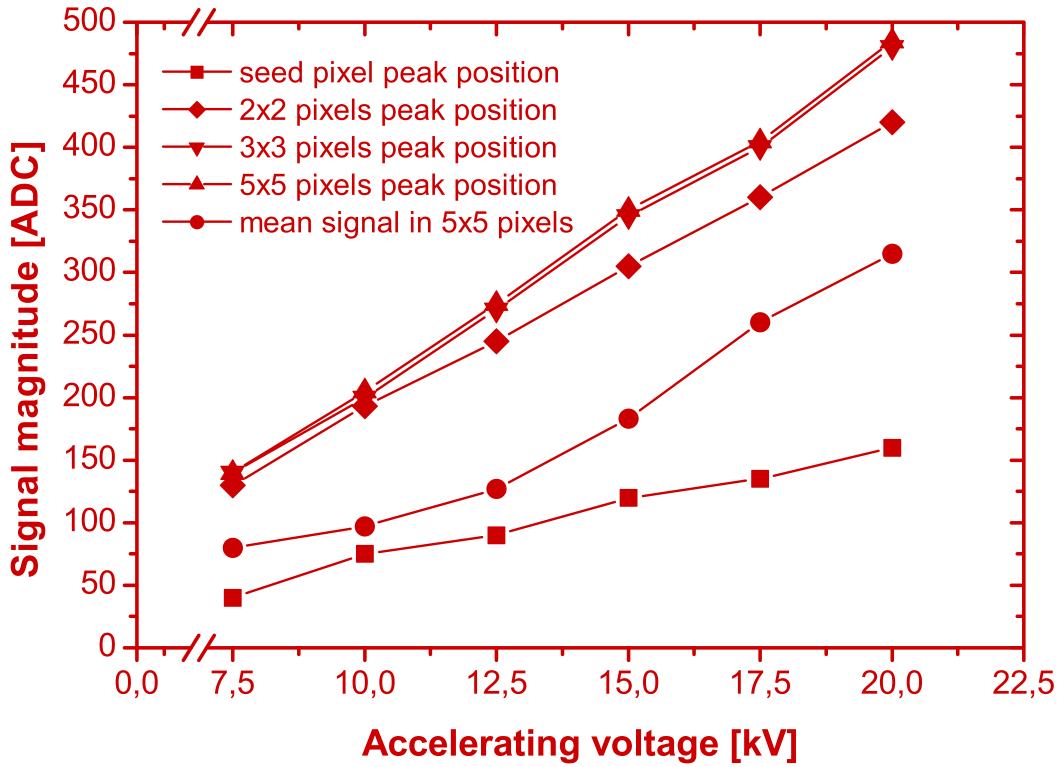
Voltage dependence of a signal

- 7.5kV – 20kV



- **Linear dependence « signal magnitude v.s. accelerating voltage »; x-axis intercept at 2.48kV!**

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Conclusions

- Novel back-thinning procedure successfully demonstrated on Mimosa5 CMOS monolithic pixel device
- Tests using HPD set-up confirm its low energy detection capabilities
- Final CMOS pixel prototype for SLIM/TERA in production
- Many new new application of the this device considered

Many thanks to Laura Badano and Ornella Ferrando, SUCIMA/TERA team members, for supplying me with all transparencies explaining SLIM idea and showing the first beam spot recorded with this device.