“Beam test results of a 15 ps UFSD timing system”

https://arxiv.org/abs/1608.08681v2

Hartmut Sadrozinski "UFSD", CPAD, Oct 8, 2016

Beam Test CERN H8 Aug 17-25 2016, 180GeV π

Results from 3 stacked 1mm Ultra-fast Silicon Detectors (UFSD) & Č trigger counter* (σ_t=15ps)

* A. Ronzhin et al., Nucl. Instrum. Meth. A 623 (2010) 931–941.

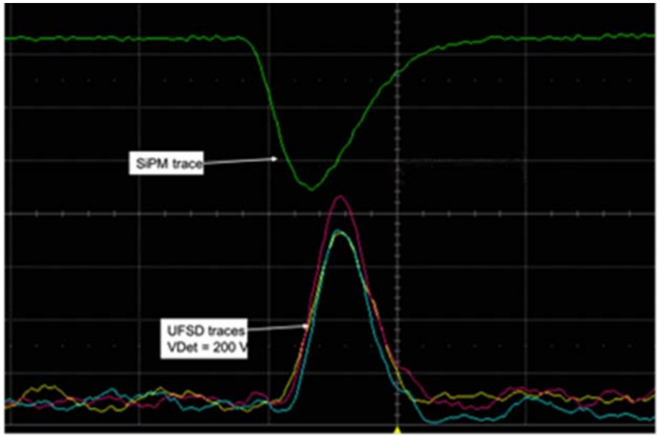
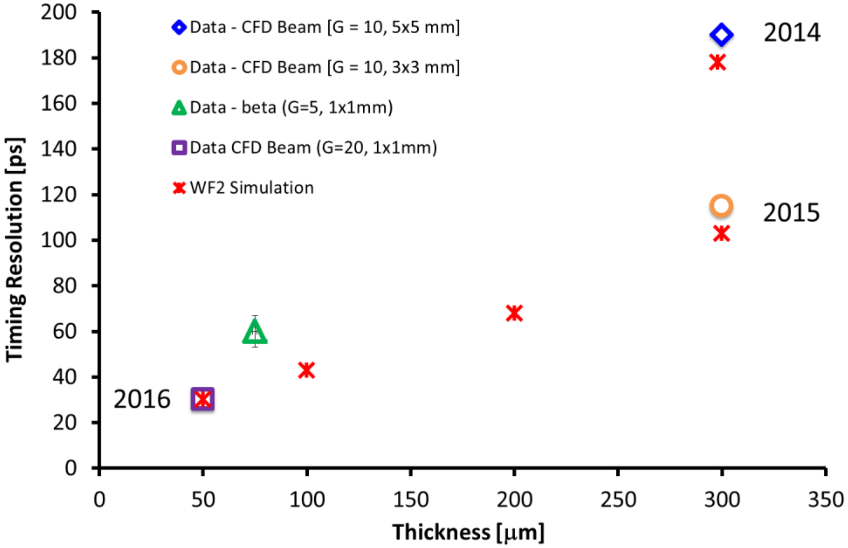


Figure 1 Screenshot of one event, showing the signals of 3 LGAD biased at 200 V and the SiPM at 28 V. Each horizontal division corresponds to 2 ns, while each vertical division is 100 mV.

Evaluate timing resolution (CFD ≈ 20%) for different combinations of sensors and trigger SiPM

Singles:	UFSD-SiPM & UFSD-UFSD (6 measurements)
Doubles:	<2 UFSD>/2 – SiPM (3 measurements)
Triplet:	<3 UFSD>/3 – SiPM (1 measurement)

Timing Resolution [ps]		
Vbias [V]	**200V**	**240V**
N=1 :	34.6	25.6
N=2 :	23.9	18.0
N=3 :	19.7	14.8



- **Good agreement with WF2**
- **Time resolution 26ps - 35ps**
- **Good matching of 3 UFSD sensors**
- **Time resolution of average of 3 UFSD:**
  20 ps (200V) & 15 ps (240V)
- **Timing resolution agrees**
  with expectation $\sigma(N) = \sigma(1)/N^{0.5}$
- **Improvement expected from 130nm ASIC**

N. Cartiglia et al, (INFN Torino, UC Santa Cruz, CNM Barcelona, IJS Ljubljana) https://arxiv.org/abs/1608.08681v2

UFSD Simulation WF2

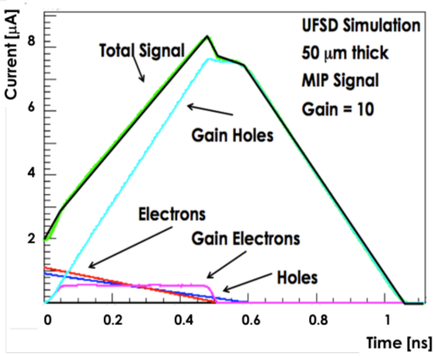
F. Cenna et al, “Weightfield2: a Fast Simulator for Silicon …..”, NIMA796 (2015) 149-153

$$\sigma_t^2 = \sigma_{TimeWalk}^2 + \sigma_{LandauNoise}^2 + \sigma_{Distortion}^2 + \sigma_{Jitter}^2 + \sigma_{TDC}^2$$

$$\sigma_{TimeWalk} = \left[\frac{V_{th}}{S/t_{rise}}\right]_{RMS} \propto \left[\frac{N}{\frac{dV}{dt}}\right]_{RMS}, \quad \sigma_{Jitter} = \frac{N}{dV/dt} \approx \frac{t_{rise}}{S/N}$$

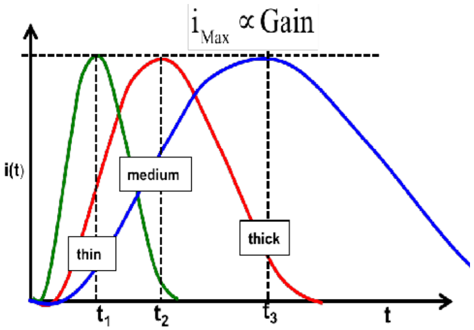
- ➢ **Maximize slope dV/dt (i.e. large and fast signals)**
- ➢ **Minimize noise N**

LGAD Pulses

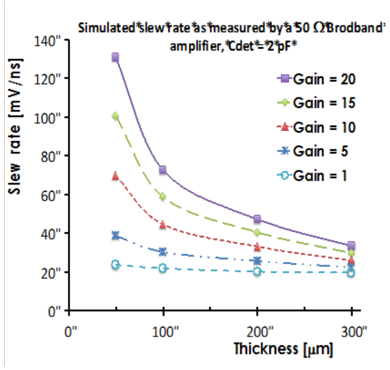


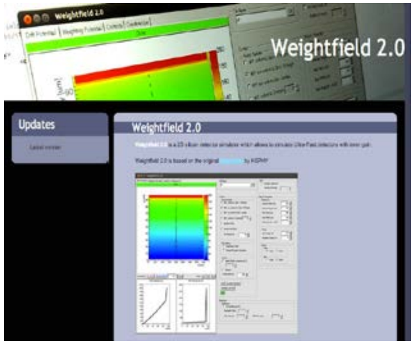
LGAD Thickness Effects

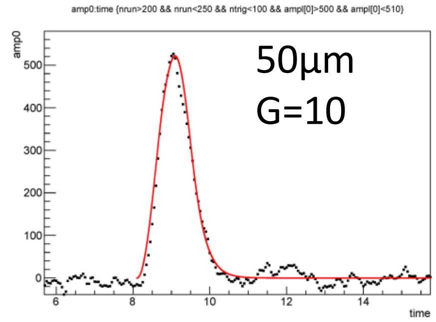
Rise time



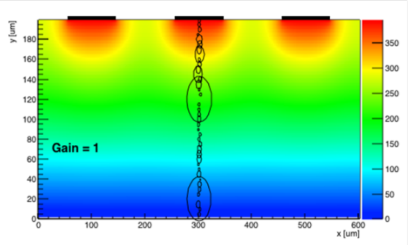
Gain - dV/dt

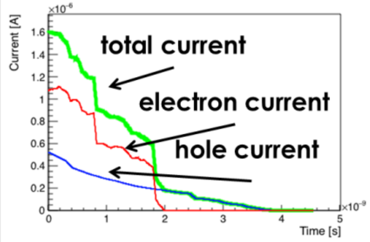




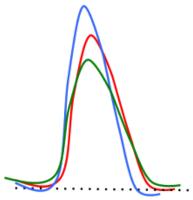


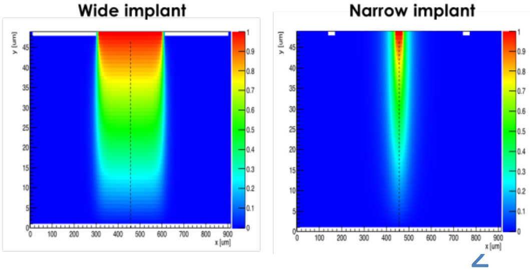
Landau fluctuations



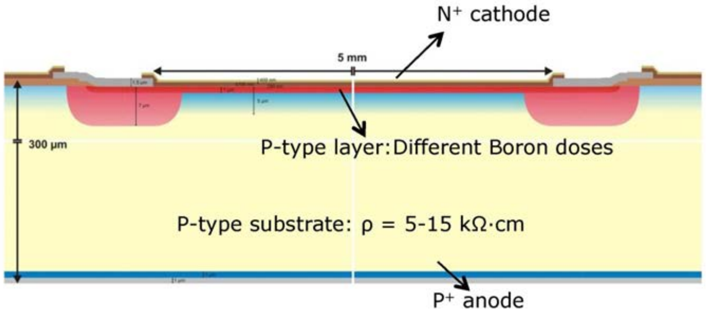


Pulse Distortions





Next Step: from Pads to Pixels



As part of a RD50 Common Project, **CNM Barcelona** fab'd about 10 runs of LGAD, with thickness 300µm -> 50 µm. INFN project at **FBK Trento** has produced 300µm LGAD, will deliver soon 50µm devices.
HPK is going to deliver the first UFSD end of Oct. 2016.

SLAC/Omega collaboration on ASIC (130nm)

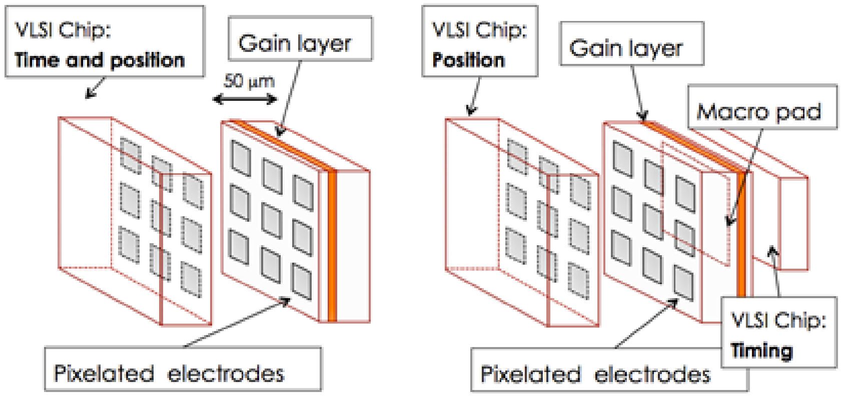
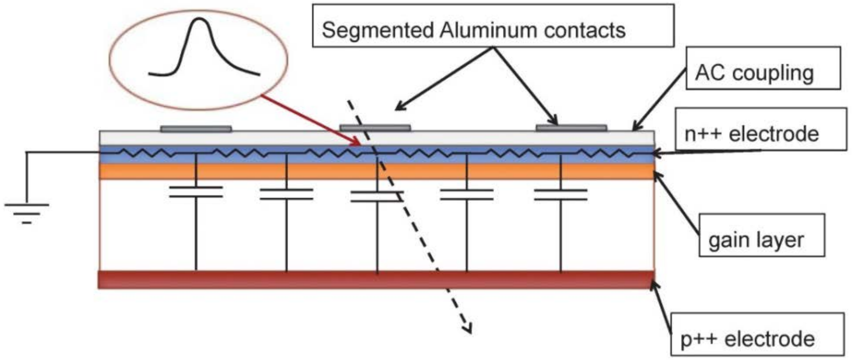


Figure 1 Sketch of a UFSD sensor and associated VLSI electronics. Left side: single read-out chip, right side: split read-out.

Single-sided and double-sided segmented LGAD (under test)



Un-segmented LGAD (AC-coupled, resistive n++ implant)

Will change the silicon sensor paradigm

Anything New in Silicon Detectors Timing: 1982 -> 2016?

H.G. Spieler, IEEE Trans. Nucl. Sci. 29, 1982

	Helmuth Spieler (1982): Heavy Ions	**UFSD (2016): MIPS**
Signal	Heavy Ion (>>> 10 MeV)	MIP (13keV) (+ Gain)
Sensors	Thin sensors	50µm
	Over-depletion of sensors	Large over-voltage: saturated drift velocity
	Capacitance (C =100pF) degrades slew-rate dV/dt	Small-area sensors C < 20pF
	Cooling to reduce “Plasma effect”	Cooling reduces leakage current, decreases jitter: increases gain, faster drift
Electronics	Charge Sensitive Amp	Current Amp
	Constant Fraction Discriminator. CFD=50% is best at largest dV/dt	CFD = 20-30% eliminates time walk, reduces Landau jitter
	Electronics degrades τ_{Rise}	2GHz SiGe, ASIC preserves τ_{Rise}
	Large noise compromises jitter	Low-noise amplifiers, ASICs (130nm)
	Minimize inductance	Minimize wire bond length
Analysis	“Residual jitter δ_t “	WF2: Landau Noise and field distortions: $\sigma^2_{LandauNoise} + \sigma^2_{Distortion}$
Resolution	8ps	25 ps

Facit: Gain, modern electronics and WF2 makes H. Spieler’s HI sensors work for MIP’s