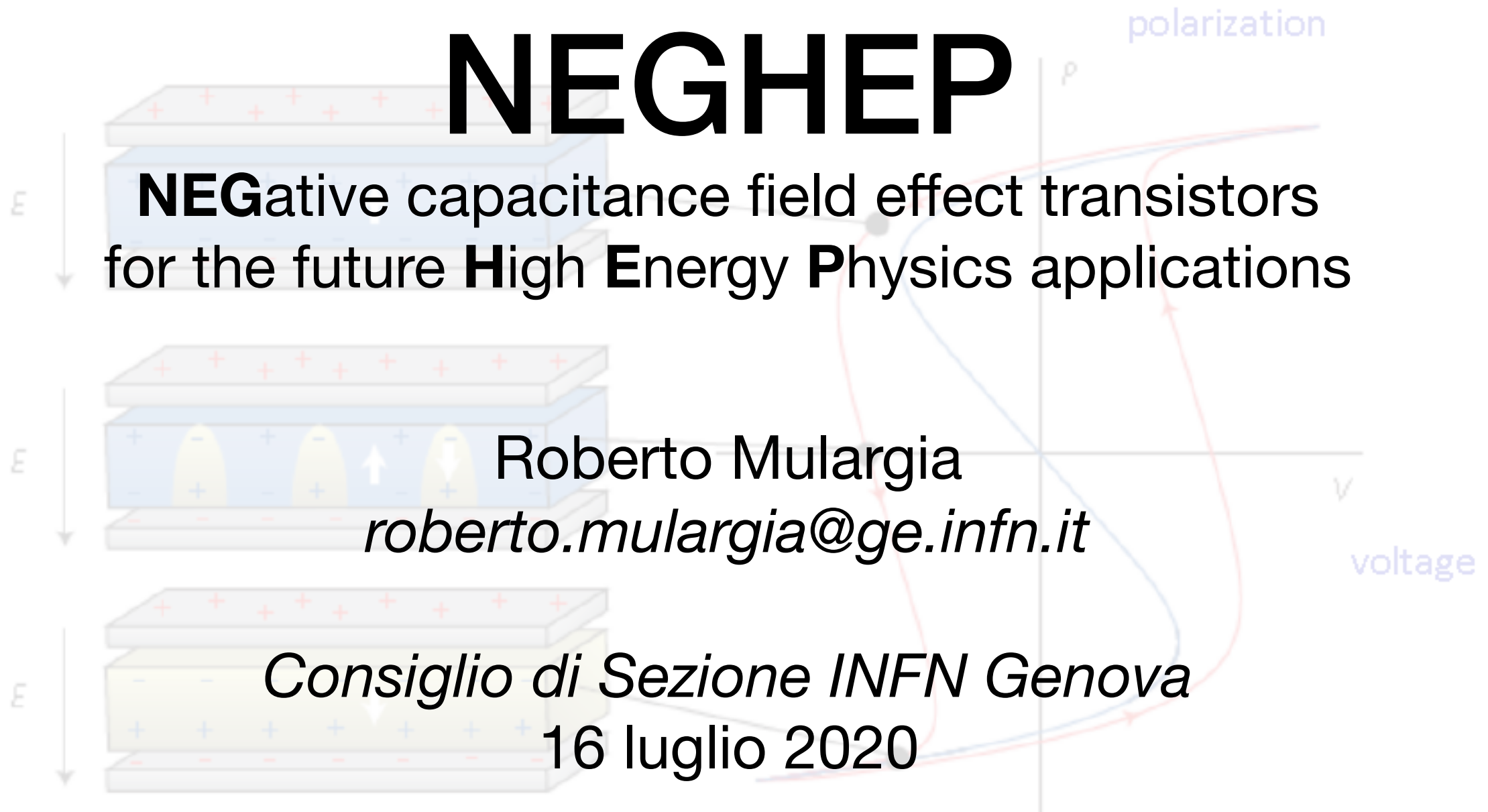




Istituto Nazionale di Fisica Nucleare

NEGHEP

NEGative capacitance field effect transistors
for the future **H**igh **E**nergy **P**hysics applications



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Consiglio di Sezione INFN Genova

16 luglio 2020

Collaborazione NEGHEP

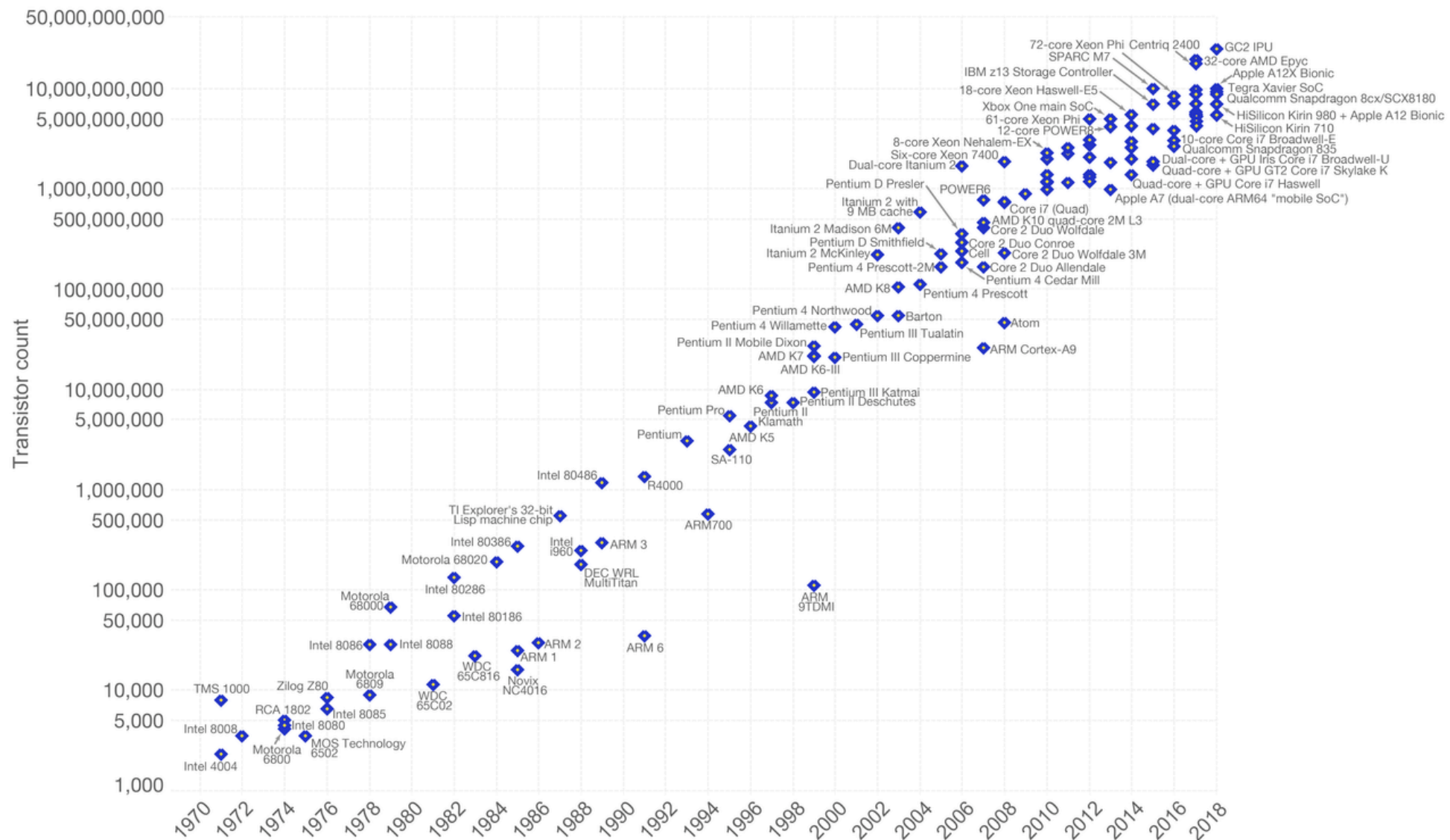
Grant per giovani ricercatori INFN
per anni 2020 e 2021.

Group	Partecipating list	Age	FTE
Perugia	Arianna Morozzi	32	1
	Daniele Passeri	51	0.1
Genova	Roberto Mulargia	31	0.1
TIFPA	Giancarlo Pepponi	45	0.2

La corsa alla miniaturizzazione

Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.

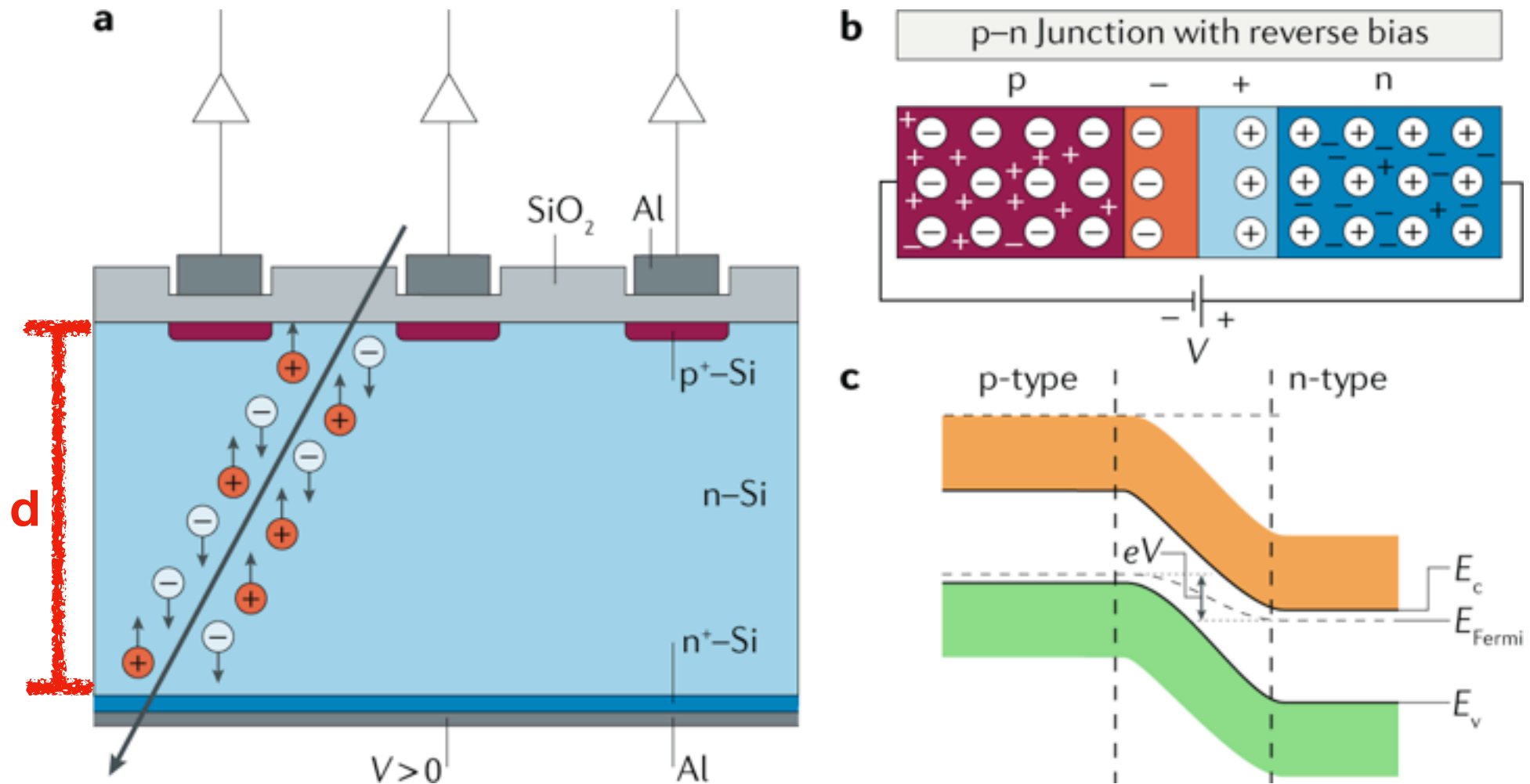


Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at [OurWorldinData.org](https://www.ourworldindata.org). There you find more visualizations and research on this topic.

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Rivelatore di particelle segmentato

(Pixel Detector)



Deposito energia MIP
 $dE/dx = 3.87 \text{ MeV/cm}$

Energia di
 ionizzazione media
 $I_0 = 3.62 \text{ eV}$

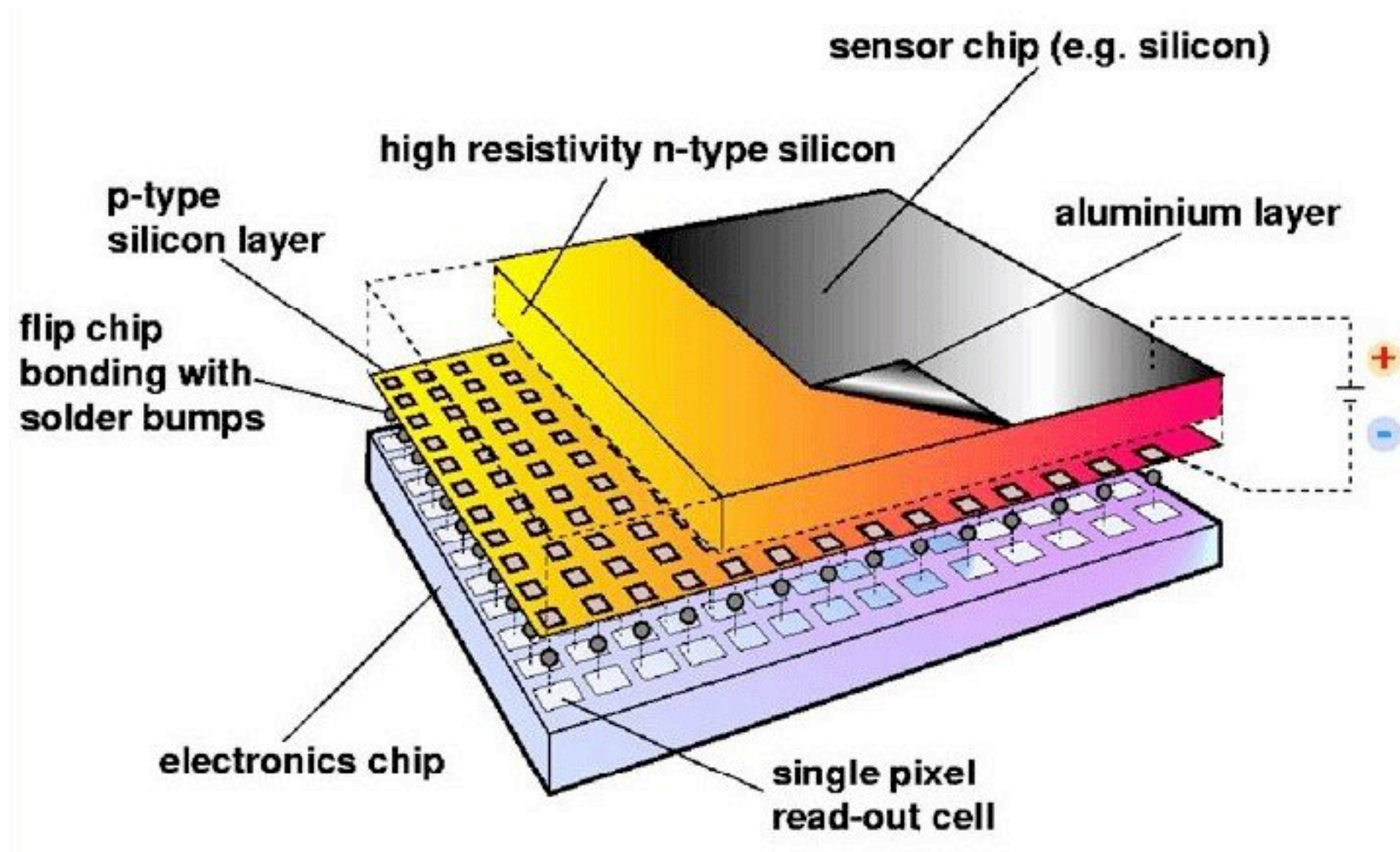
numero di coppie e-h

$$\frac{dE/dx \cdot d}{I_0}$$

$\sim 80 \mu\text{m}^{-1}$

Rivelatore di particelle segmentato

(Pixel Detector)



Densità di potenza
consumata

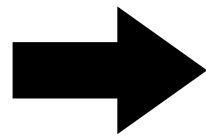
Rapporto
Segnale/Rumore

Flusso di dati
in uscita

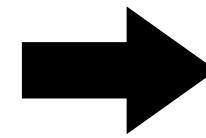
Minima carica rilevabile

La carica prodotta dal sensore dev'essere sufficiente per attivare uno switch digitale:
SOGLIA DI INVERSIONE DI TRANSISTOR

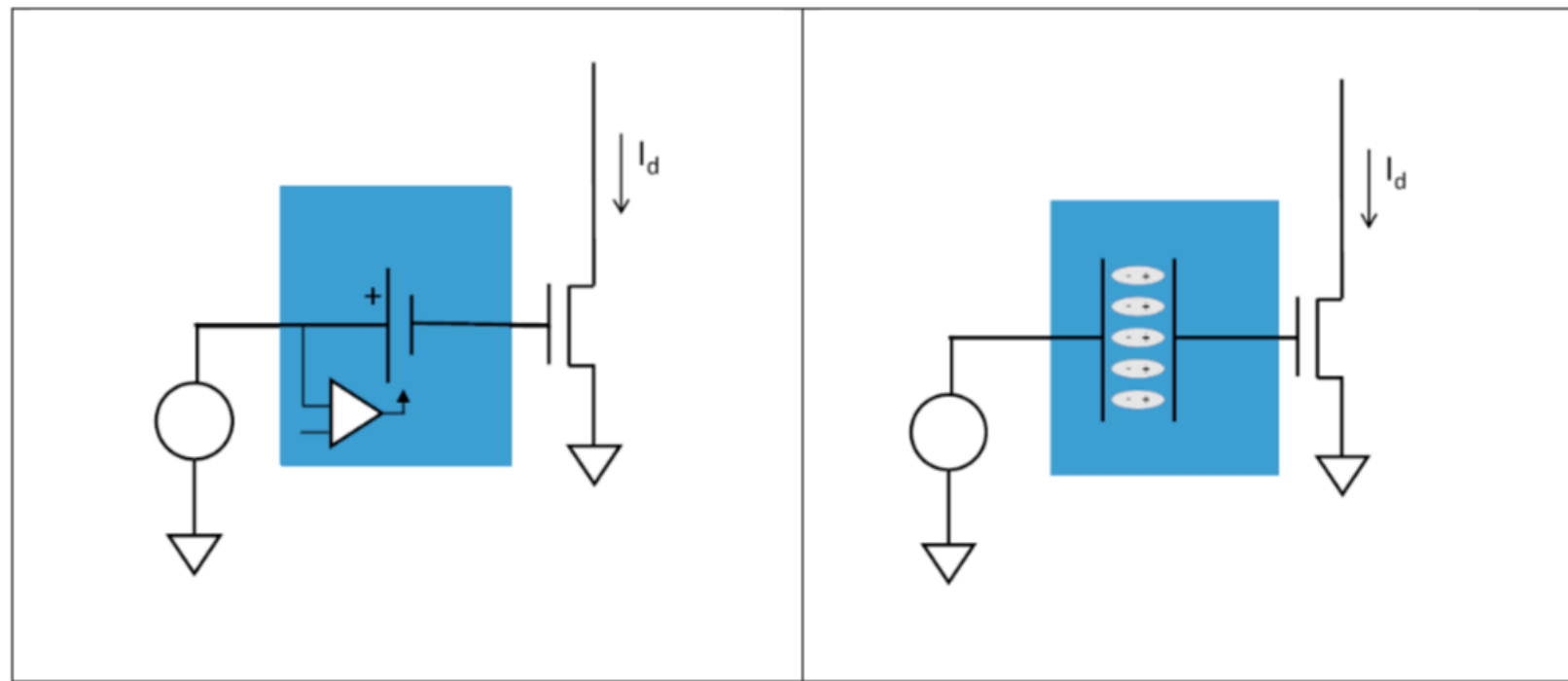
65nm
 $\sim 5000e$



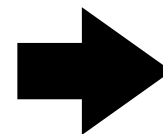
28nm
 $\sim 1000e$



<10nm
< 100e



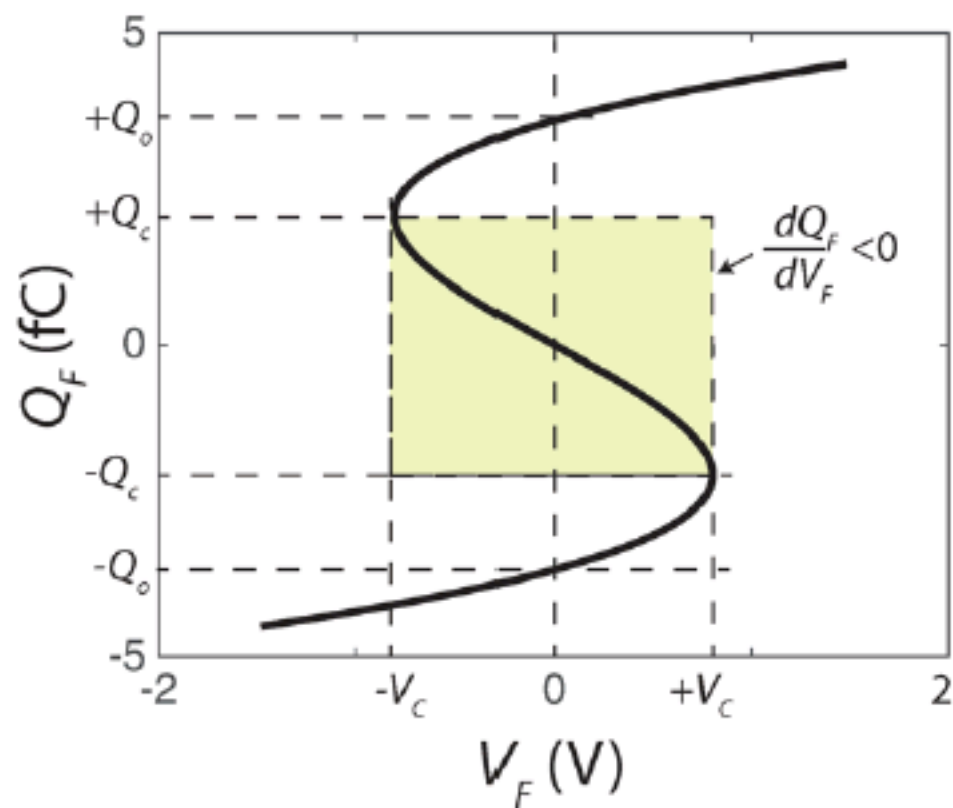
Meccanismo di potenziamento del segnale a soglia



Capacità *negativa* tra il segnale di input e circuito di lettura

Capacità negativa

MATERIALI FERROMAGNETICI (Perovskite)



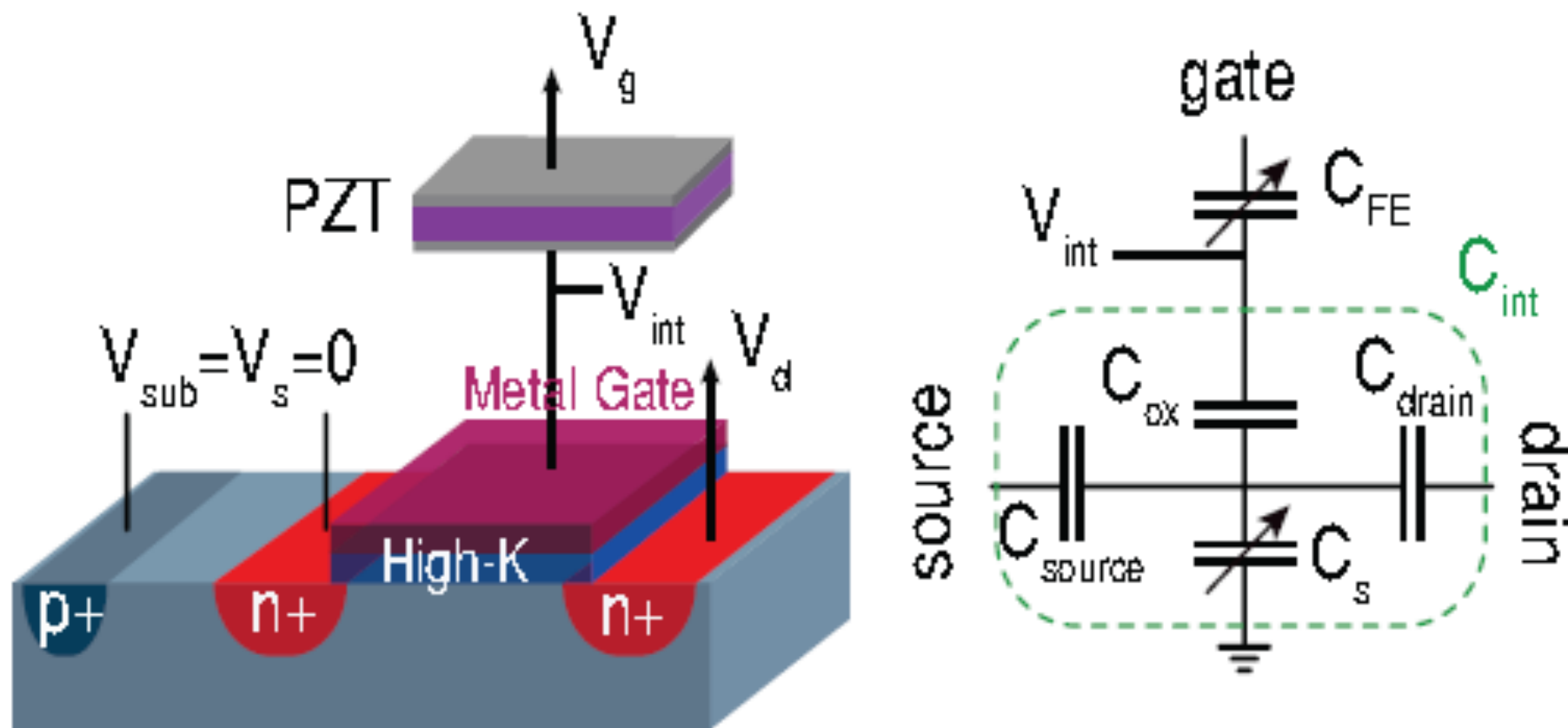
La carica è dovuta alla polarizzazione
in funzione della tensione

RISPOSTA NON LINEARE

piccole variazioni di tensione possono causare
grandi cambiamenti di polarizzazione:


**LA POLARIZZAZIONE SI INVERTE
SPONTANEAMENTE QUANDO LA TENSIONE
SUPERA UNA SOGLIA**

Transistor a Capacità Negativa



Sfida tecnologica nel combinare il processo produttivo a alta temperatura della Perovskite con quello a *bassa* temperatura dei circuiti integrati

Riepilogo Attività



Name
WP1: Material and technology
M1. Investigation of ferroelectric materials to be used
M2. Technological node specification
WP2: TCAD design
M3. TCAD modelling of ferroelectric materials
D1. TCAD ferroelectric material physics model (PMI library)
M4. Ferroelectric materials numerical simulation methodology set-up in TCAD
M5. TCAD geometry optimization of MOSFET and NC-FET
WP3: NC-FET design and manufacturing
M6. Design of MOSFET and NC-FET
D2. Tape-out (layout) of MOSFETs and NC-FETs (with different options)
M7. MOSFETs and NC-FETS production
D3. MOSFETs and NC-FETs
WP4: Testing
M8. Set-up of the measurement test bench
M9. Electrical characterization of MOSFETs and NC-FETs at die level
M10. X-ray irradiation up to 1 Mrad (1st irradiation campaign)
M11. Electrical characterization of MOSFETs and NC-FETs after 1st irradiation campaign
M12. X-ray irradiation up to 100 Mrad (2nd irradiation campaign)
M13. Electrical characterization of MOSFETs and NC-FETs after 2nd irradiation campaign

**GENOVA
(2021)**