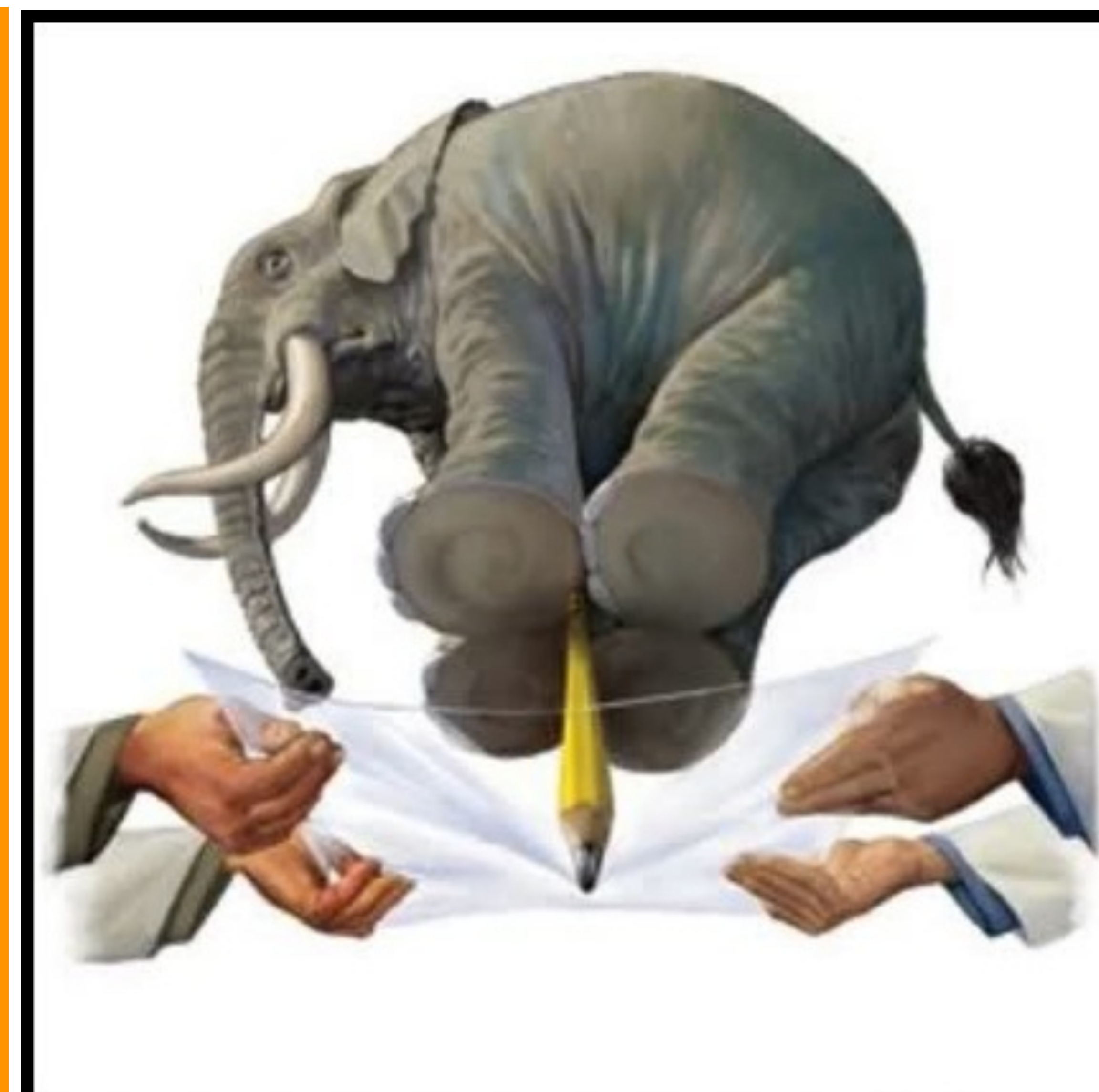
Nanostructured materials for particle detector

G. Chiodini - INFN Lecce

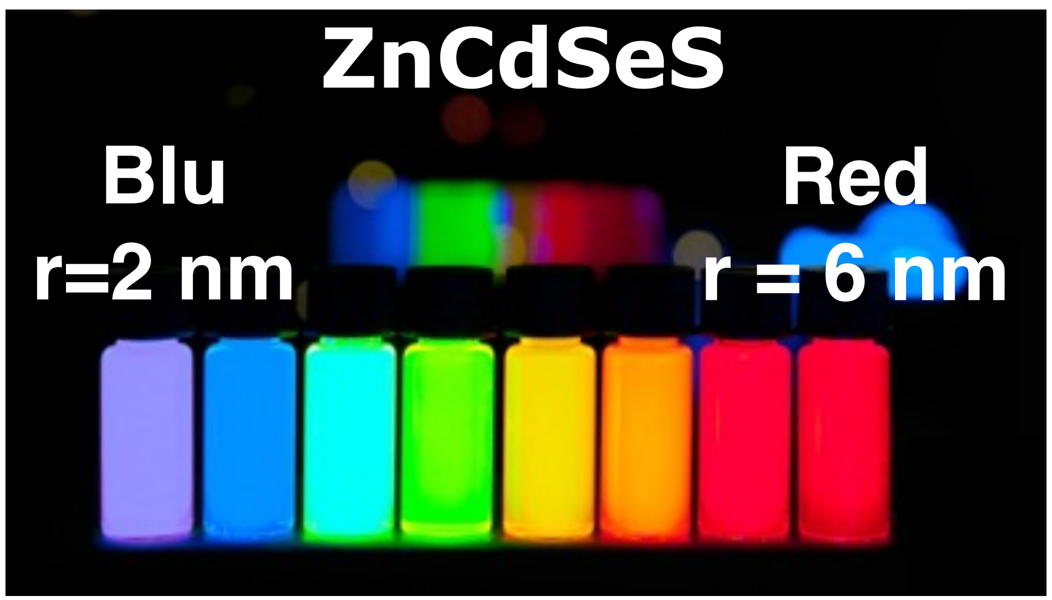


Overview

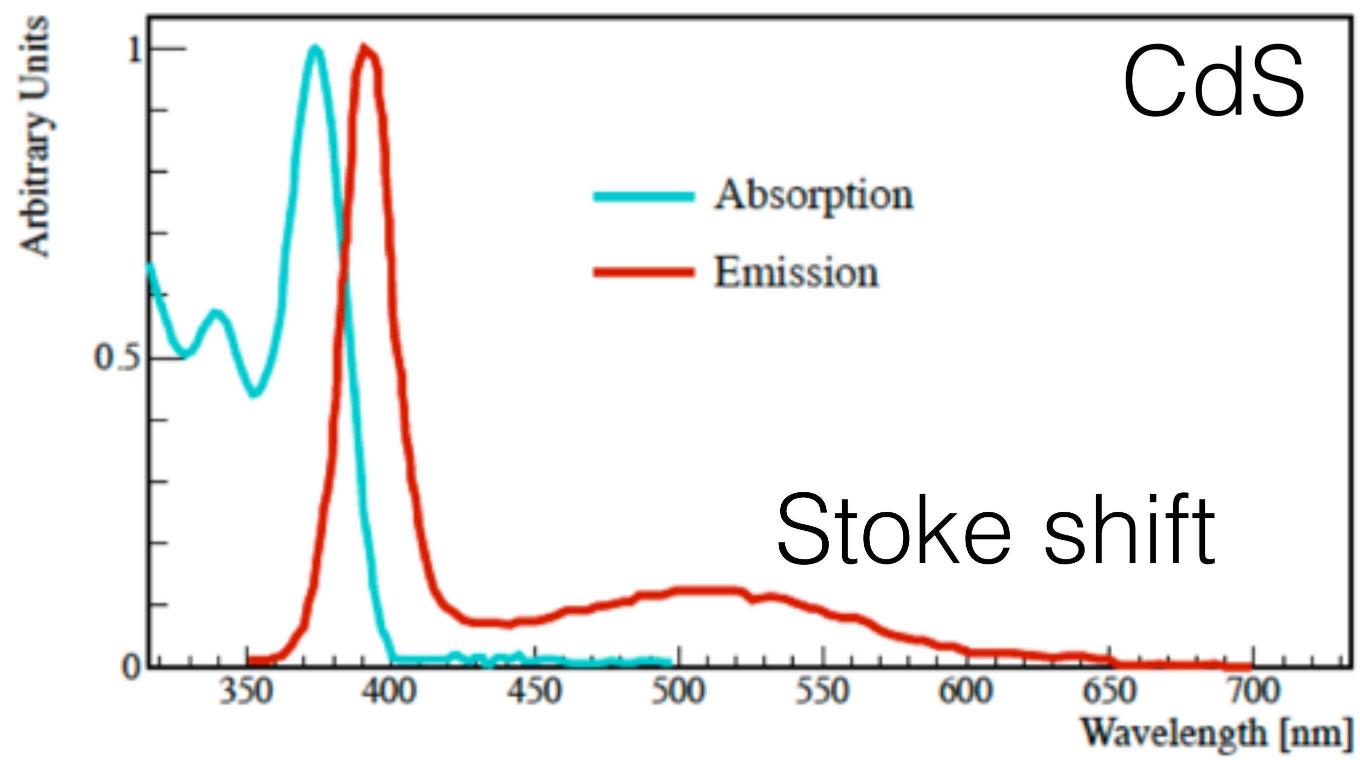
1. Quantum dots (QD)
2. Nanowire (NW) and Carbon nanotubes (CNT)
3. Graphene
4. Conclusions

Quantum Dot

QD are nanoparticles composed of periodic groups of III-V or II-VI semiconductor materials having a size-tunable absorption-emission spectra and high quantum efficieny



Excitation at λ=365 nm



Large batch of QD are commercially available in kg scale via the least toxic method: colloidal synthesis

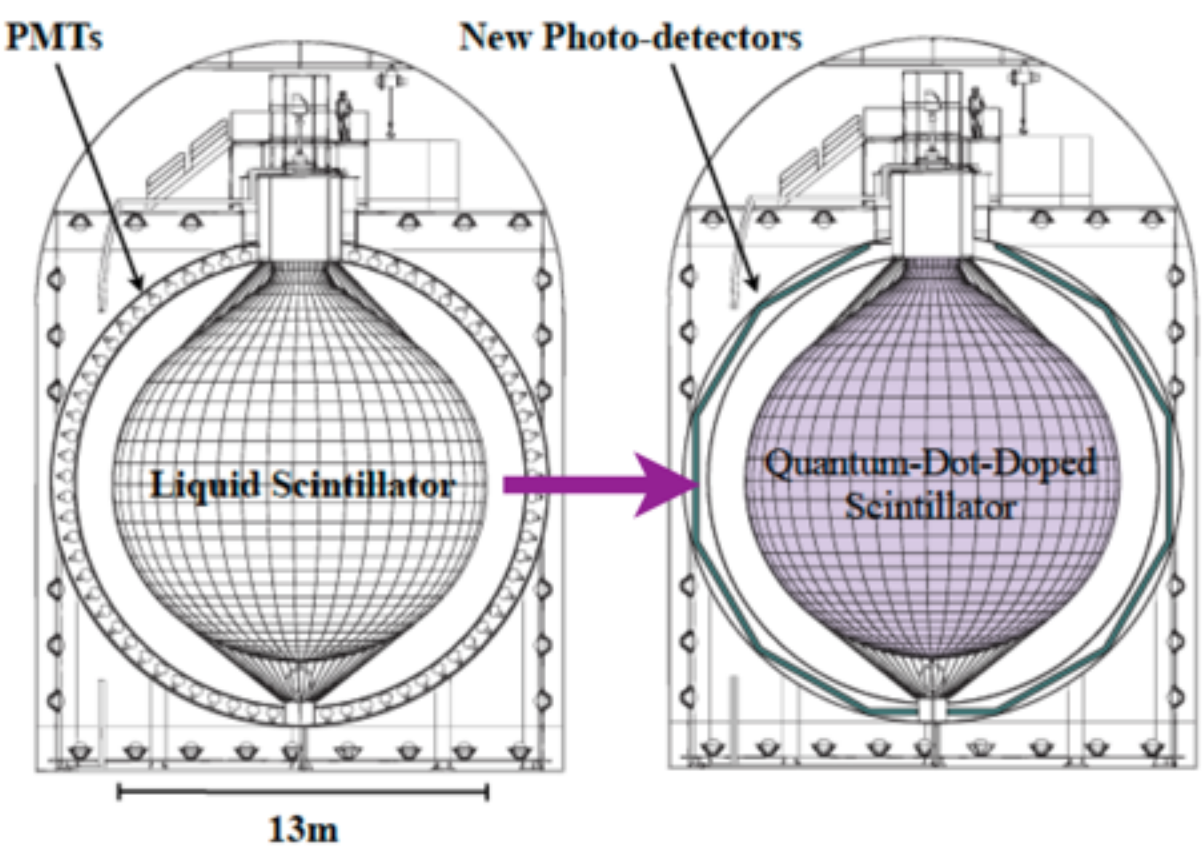
QD as liquid scintillator

Colloidal QD are diluted in a solvent: toluene (Scintillator) or water (Cherenkov)

- ν oscillations
- Double-β decay

1g/L inverted hierarchy
10g/L normal hierarchy

1kton

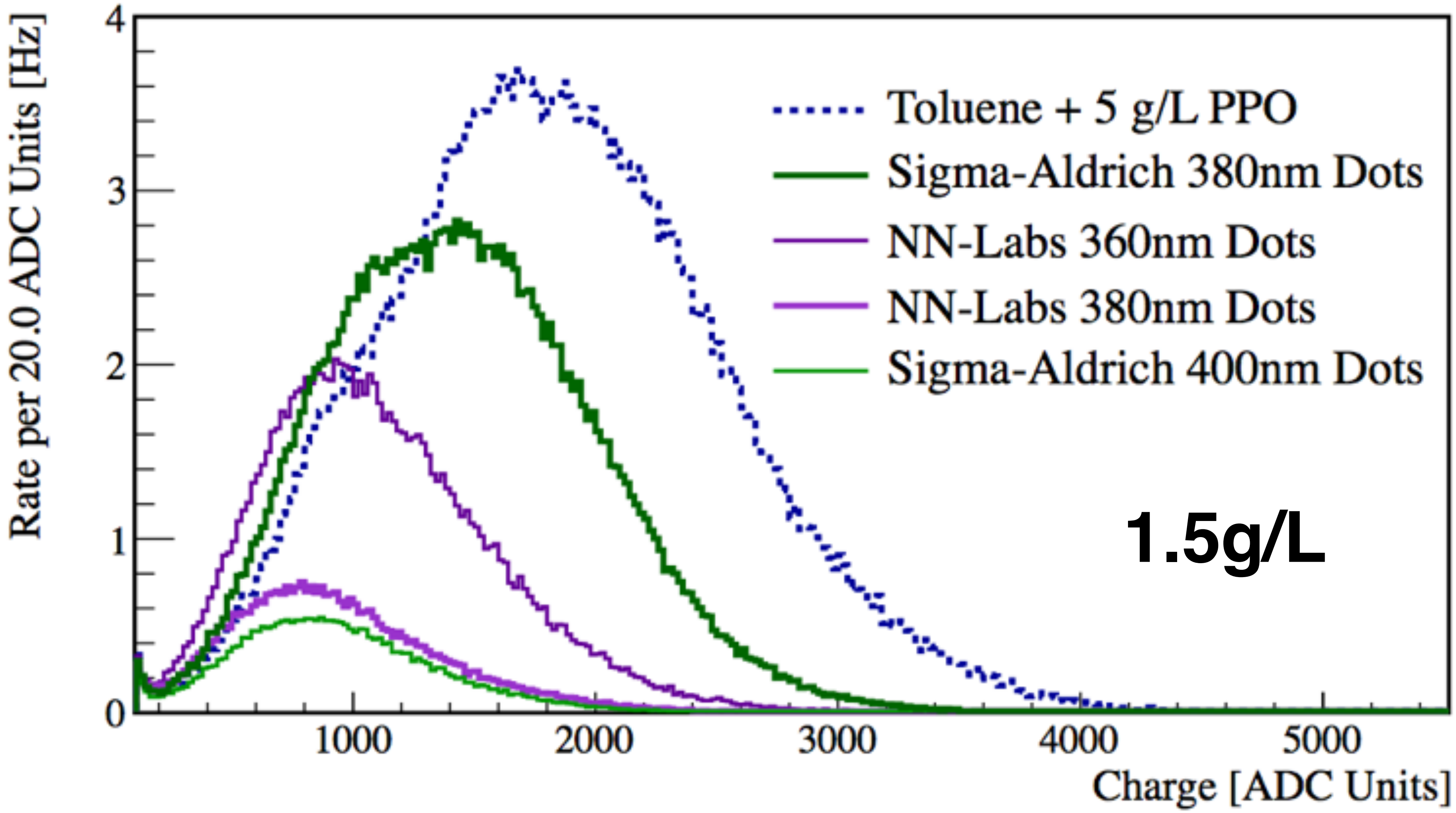


Isotope	Endpoint	Abundance
^{48}Ca	4.271 MeV	0.0035%
^{150}Nd	3.367 MeV	5.6%
^{96}Zr	3.350 MeV	2.8%
^{100}Mo	3.034 MeV	9.6%
^{82}Se	2.995 MeV	9.2%
^{116}Cd	2.802 MeV	7.5%
^{130}Te	2.533 MeV	34.5%
^{136}Xe	2.479 MeV	8.9%
^{76}Ge	2.039 MeV	7.8%
^{128}Te	0.868 MeV	31.7%

Source=Detector

QD vs PPO

β source spectra

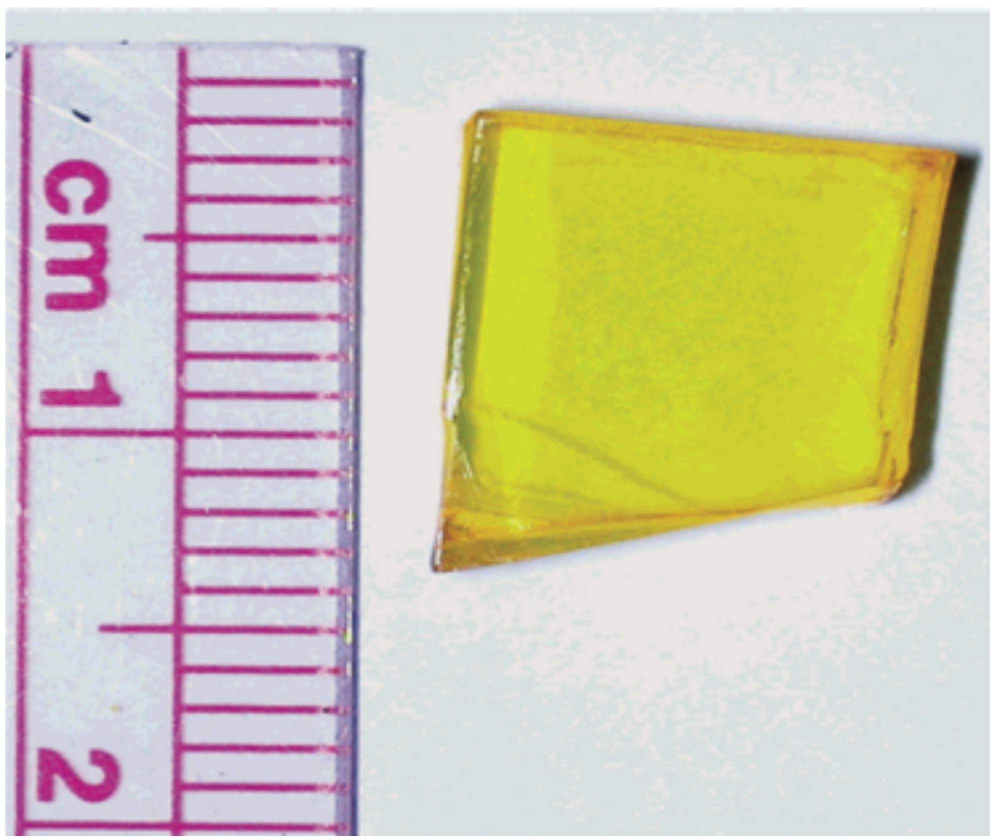


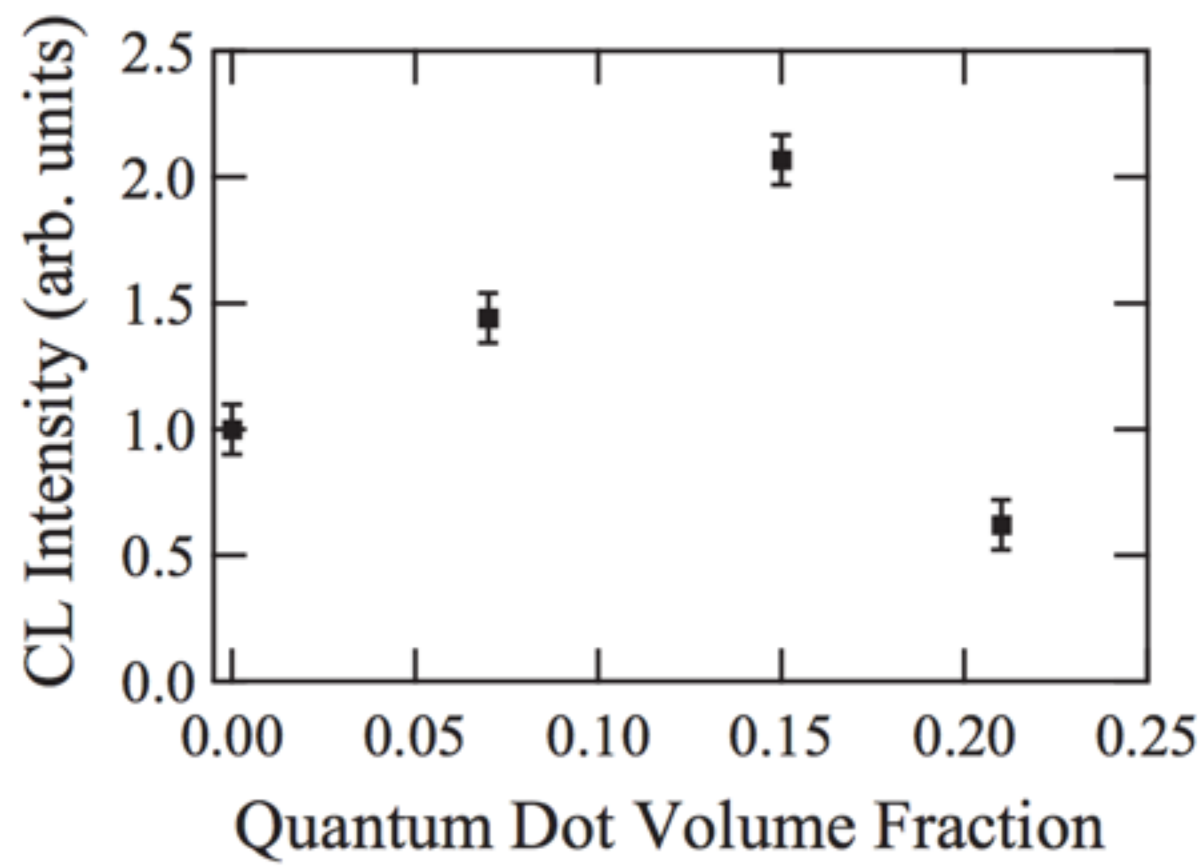
- Tune the peak to the newest Photo-Detector
- Increasing concentration:
  - Attenuation length
  - FRET (Förster Resonant Energy Transfer) non-radiative decay

QD as plastic scintillator or wavelenght shifter

QD are successfully embedded in solid matrix (PMMA, GLASS, SU8, MEH-PPV):

- E/eh like inorganic semiconductor (high E resolution)
- fabrication as plastic scintillator (low cost, large area, easy processing)

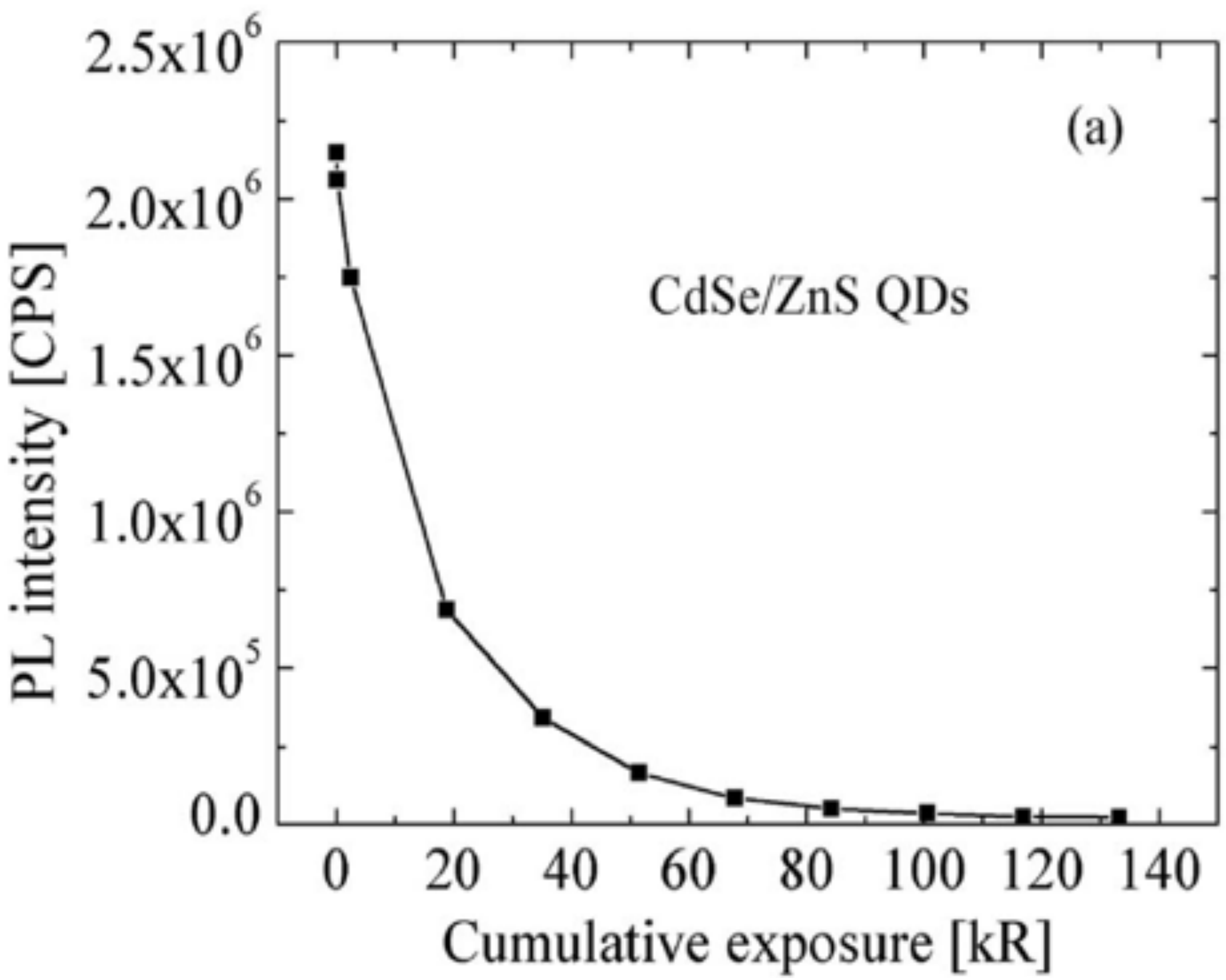




Theoretical expected 10 more QY but only factor 2 experimentally

QDOT-WLS in CNS5: INFN-PG and CNR-PG

QD still to go



Radiation hardness

APPLIED PHYSICS LETTERS 93, 173101 (2008)

Rapid degradation of CdSe/ZnS colloidal quantum dots exposed to gamma irradiation

Nathan J. Withers,[1] Krishnaprasad Sankar,[1] Brian A. Akins,[1] Tosifa A. Memon,[1]

NADIR-WP4 in CNS5
INFN-TIFPA

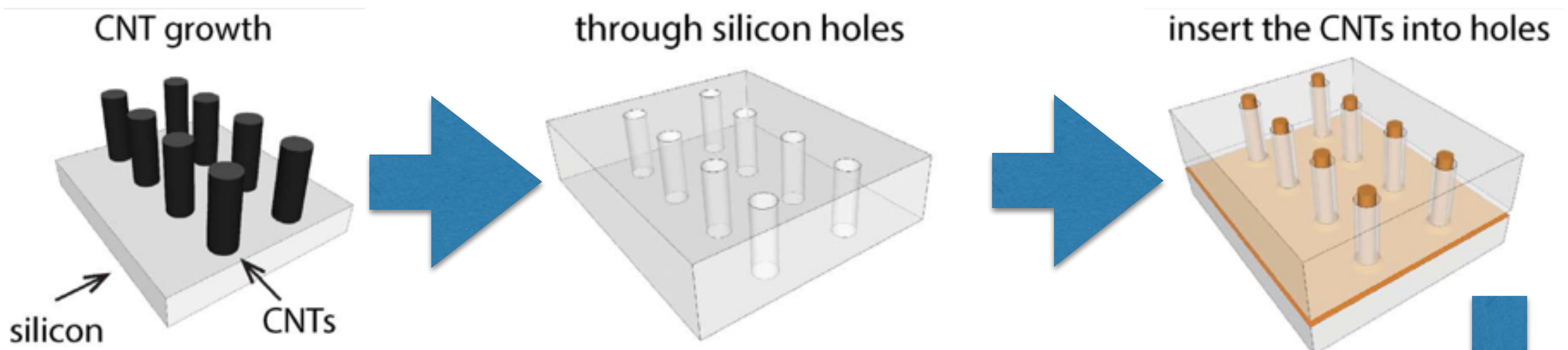
Blinking: Intermittency and on/off emission observed in colloidal quantum dots, nanorods, nanowires and some organic dyes.

Quenching: Off emission for near by gold nano particle

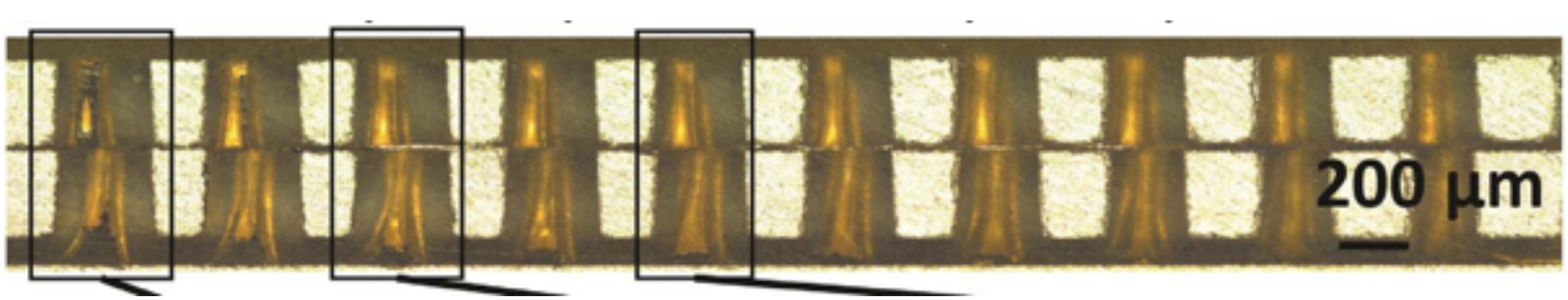
Non-radiative FRET (Fluorescence Resonance Energy Transfer)

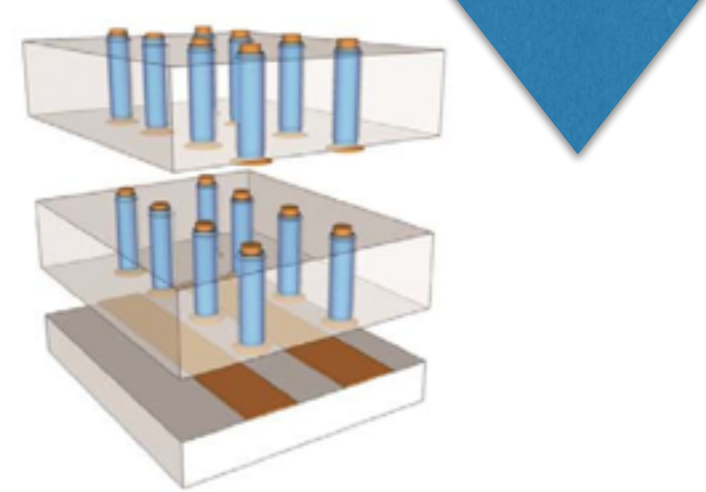
Interconnects and STV with CNT

Through Silicon Via with CNT



3D stacking with CNT





Easy, not expensive, fast (5 minutes CNT grow)

CNT and MNW grow in alumina template

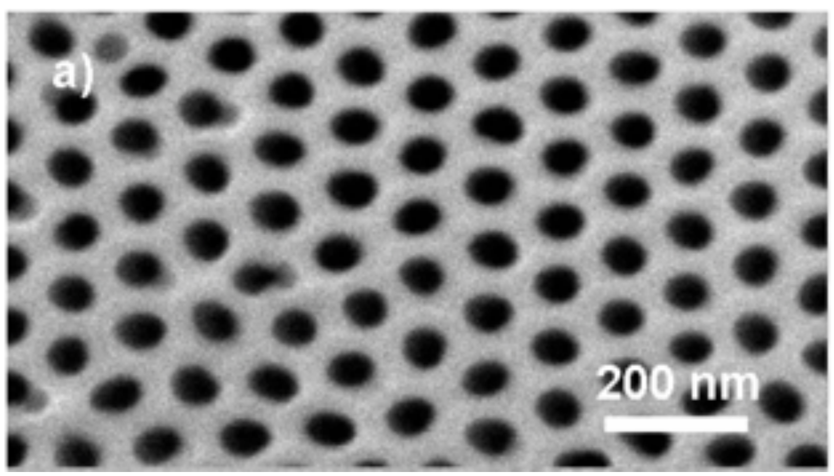
NANOCHANT1/2+CANTES+SERENA+ESOPO in CNS5

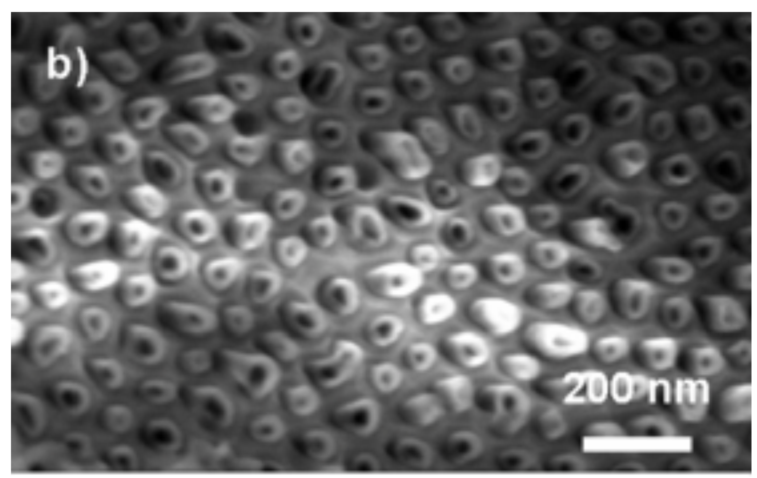
Group: **L.Malferrari, A. Montanari e F.Odorici** (INFN-Bo), R. Angelucci, **R. Rizzoli** e G.P. Veronese (CNR-IMM-Bo), M. Cuffiani e A. Jagminas (Unibo)

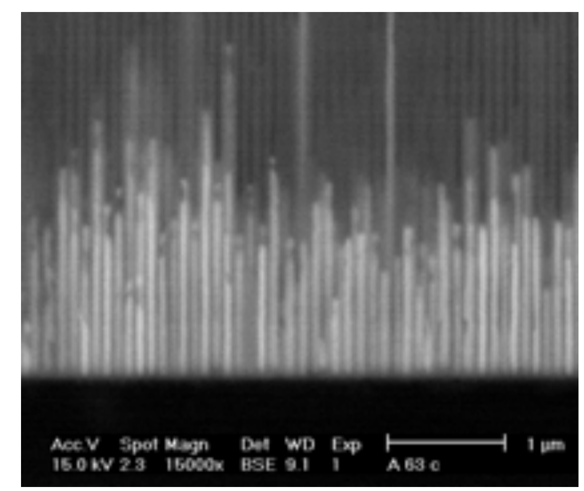
Porous anodic alumina (Al2O3) template

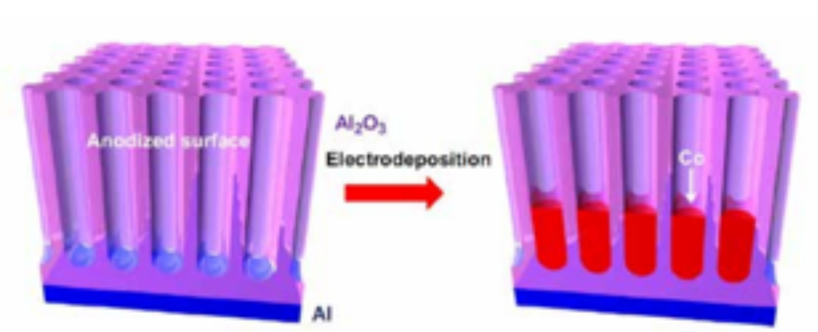
CNT by electro-deposition

Metallic NW (Co) by electro-deposition









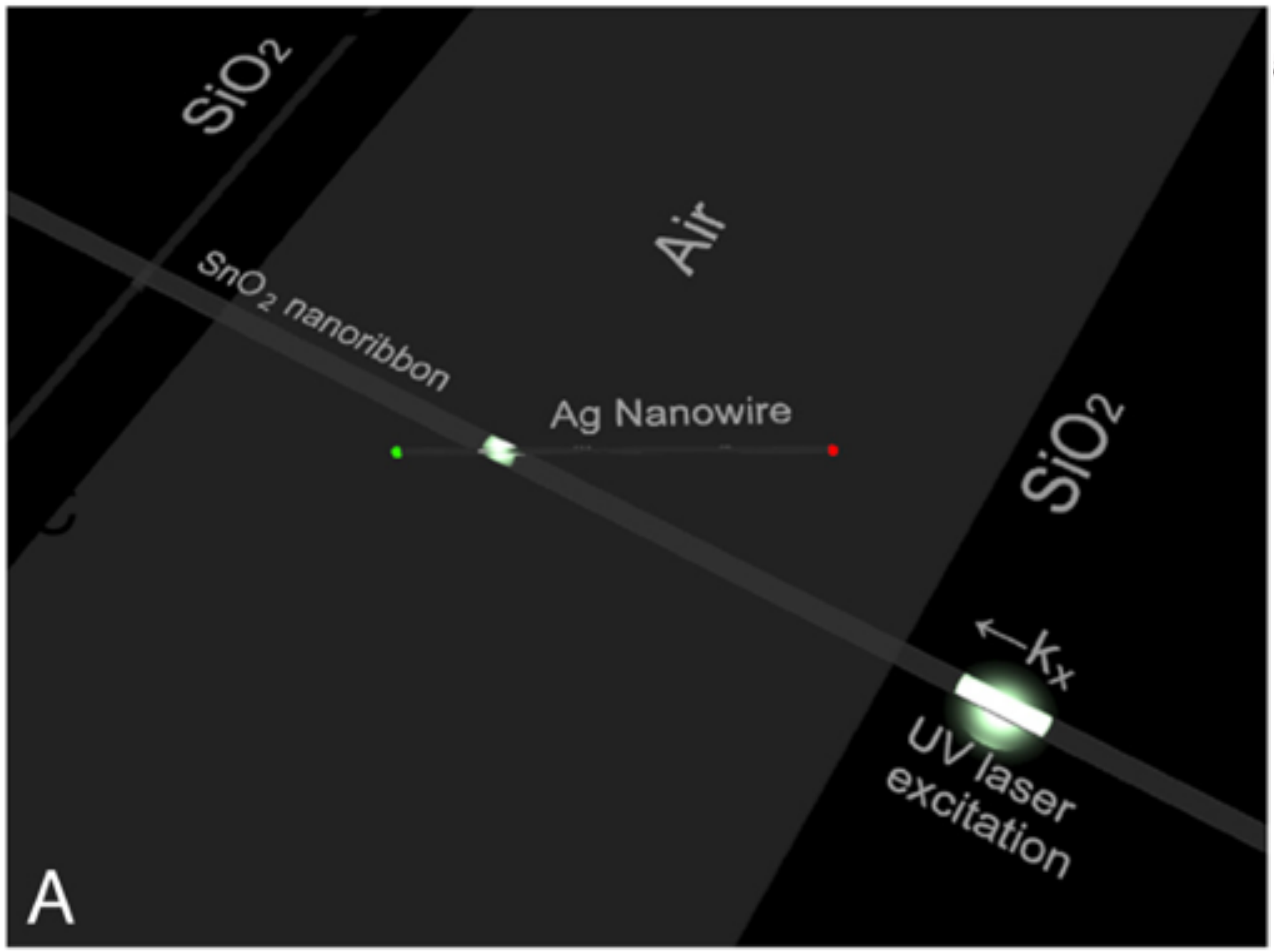
Efficienct CNT cold cathode based on field emission

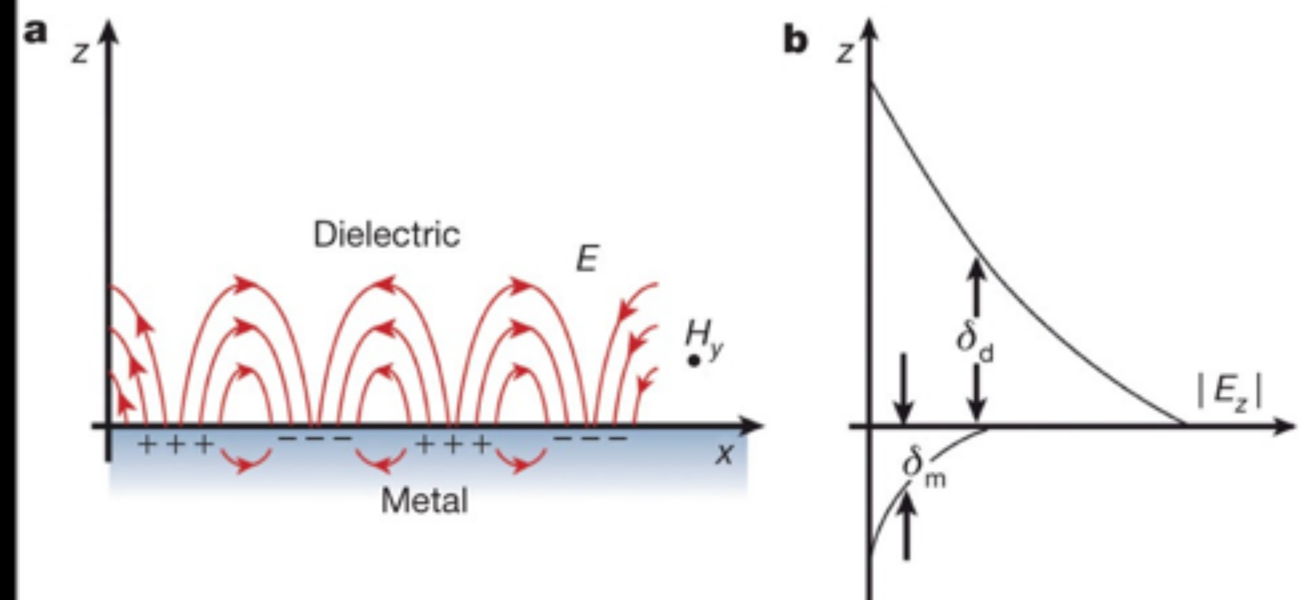
Porous alumina UV-trasmission enhancement @ 325 nm filled with SNW

preliminary @ INFN-Bo

SNW as plasmon waveguide

Plasmons are “quasi-particles” associated to collective surface oscillation of a free e- gas in the metal strongly interacting with a photon



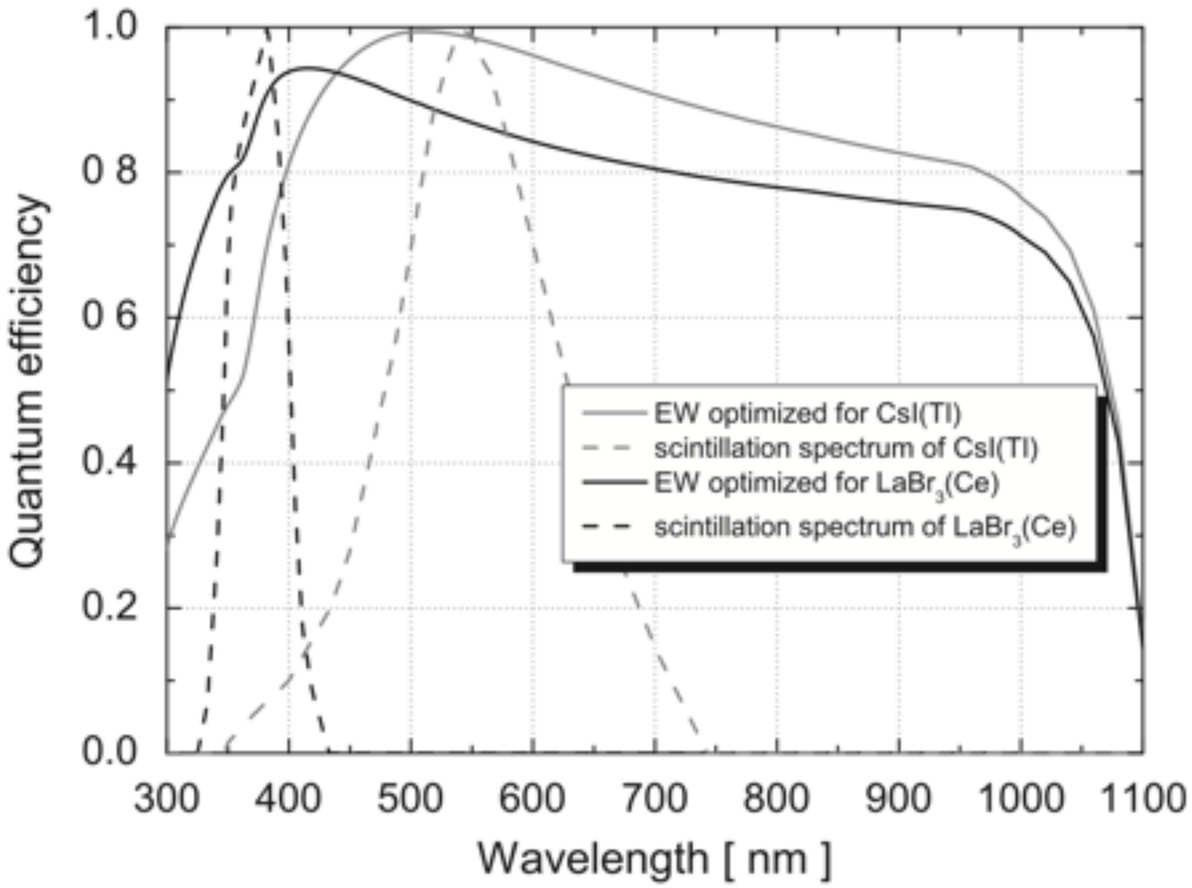


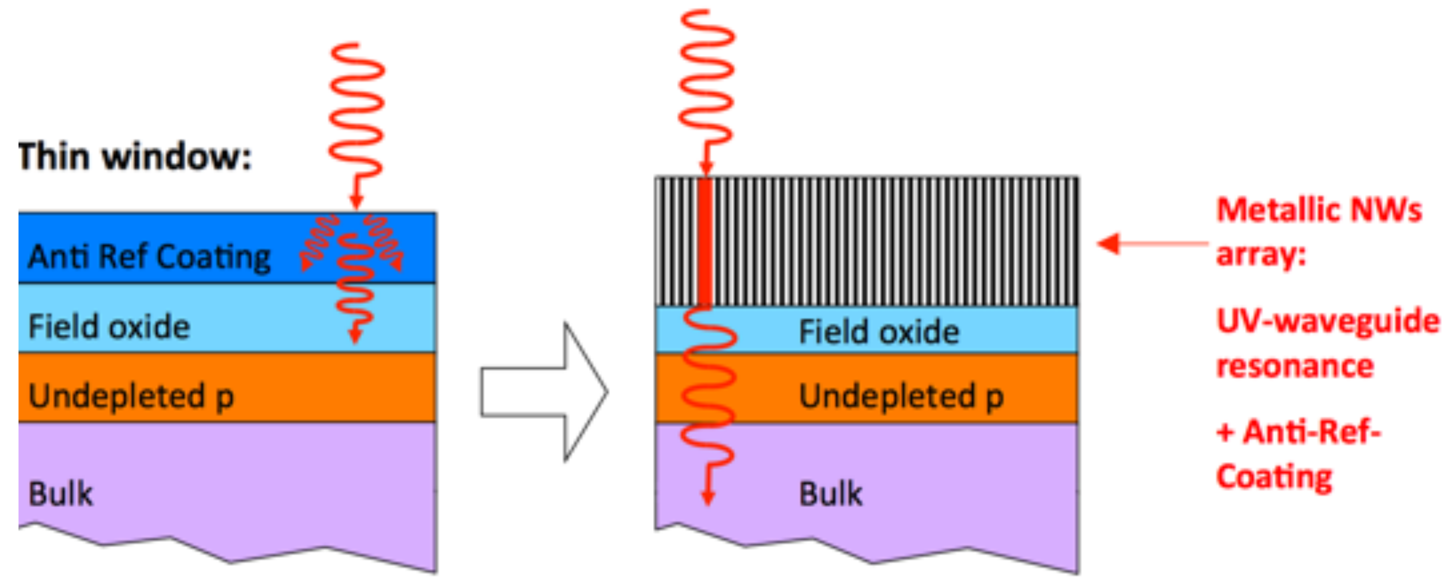
Plasmonic excitation in nanostructure have a size frequency dependency in the range of IR-VI-UV

Free-space photons -> SS excitation in SNW -> SS propagation in SNW -> free-space photon emission at the end or discontinuities in SNW

SDD+NW

Enhance SDD QE in UV by replacing AntiReflex Coating with SNW





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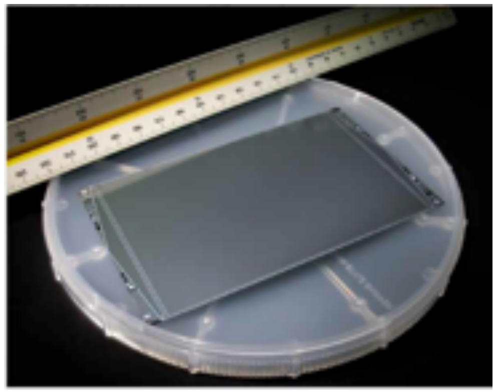
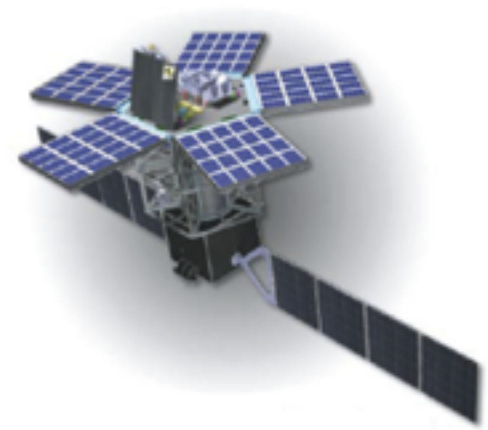
REDSOX2 in CNS5 (A. Vacchi)

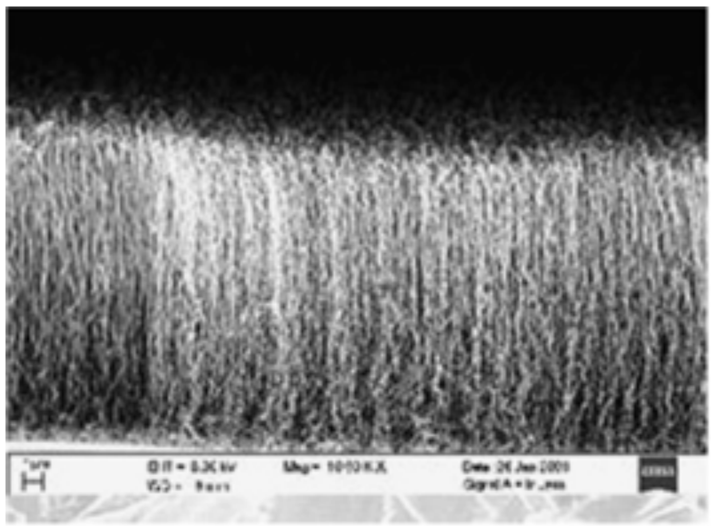
INFN/INAF/FBK SDD development



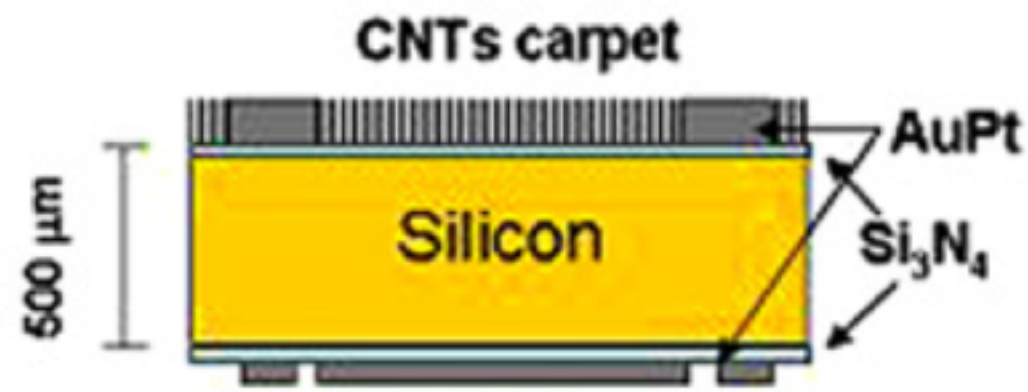


Multi-Wall-CNT

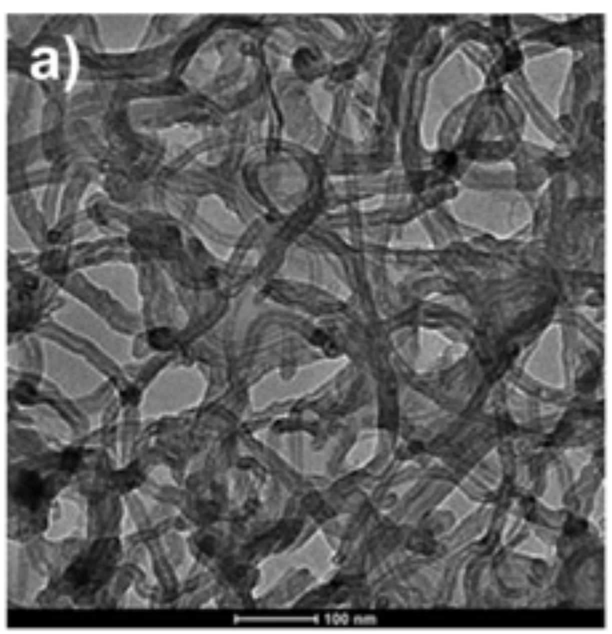
MW-CNT easier to fabricate but have different sizes



CVD deposition
INFN-NA+CNR-AQ

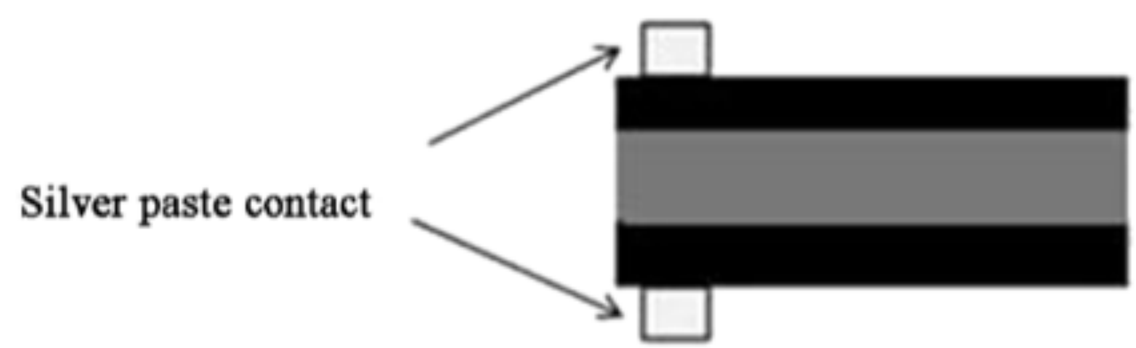


QE~40% at ~ 850 nm



Spray deposition
INFN-BA+CNR-BA

CNTs bush



QE~35% at ~ 180 nm

GINT+SINPHONIA+PARIDE in CNS5

Directional Dark Matter Searches with Carbon Nanotubes

LM Capparelli*, G Cavoto¶, D Mazzilli* and AD Polosa*,¶

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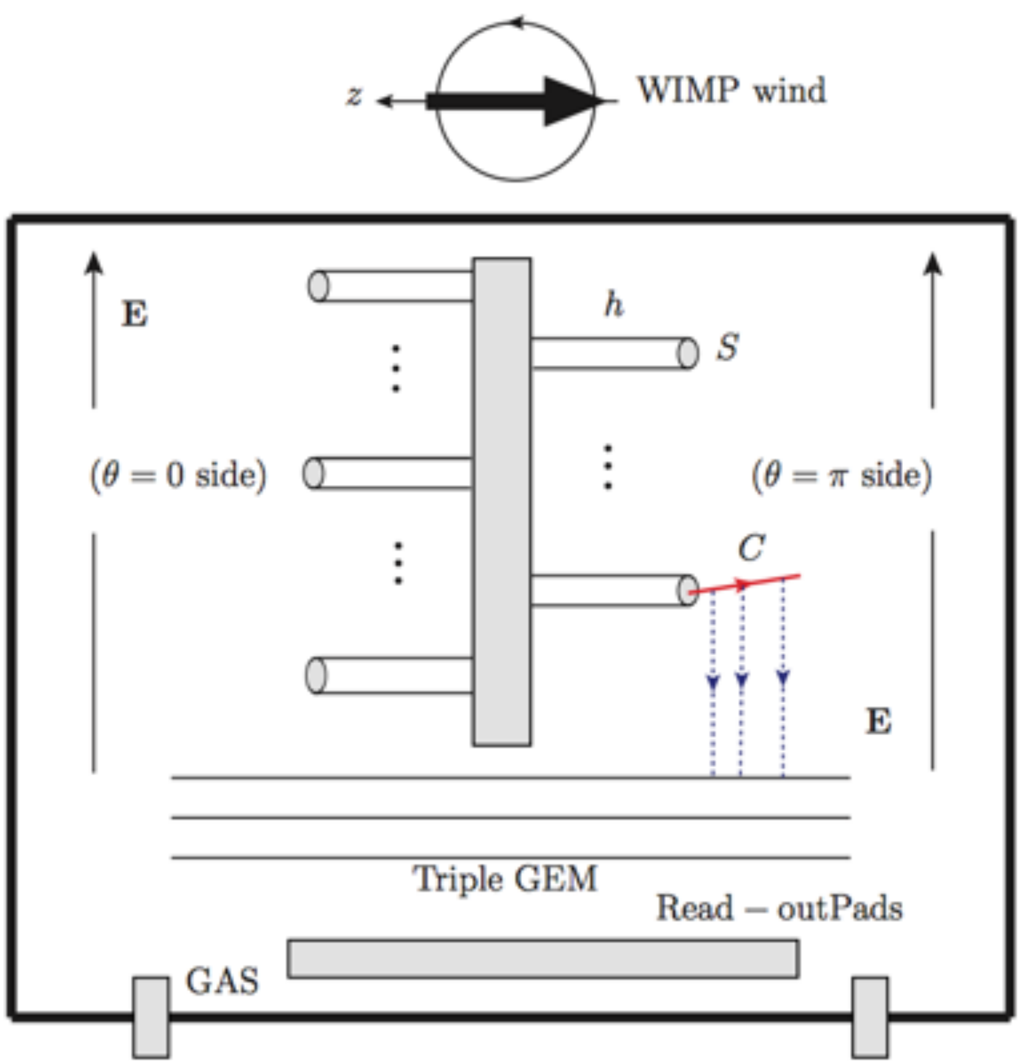
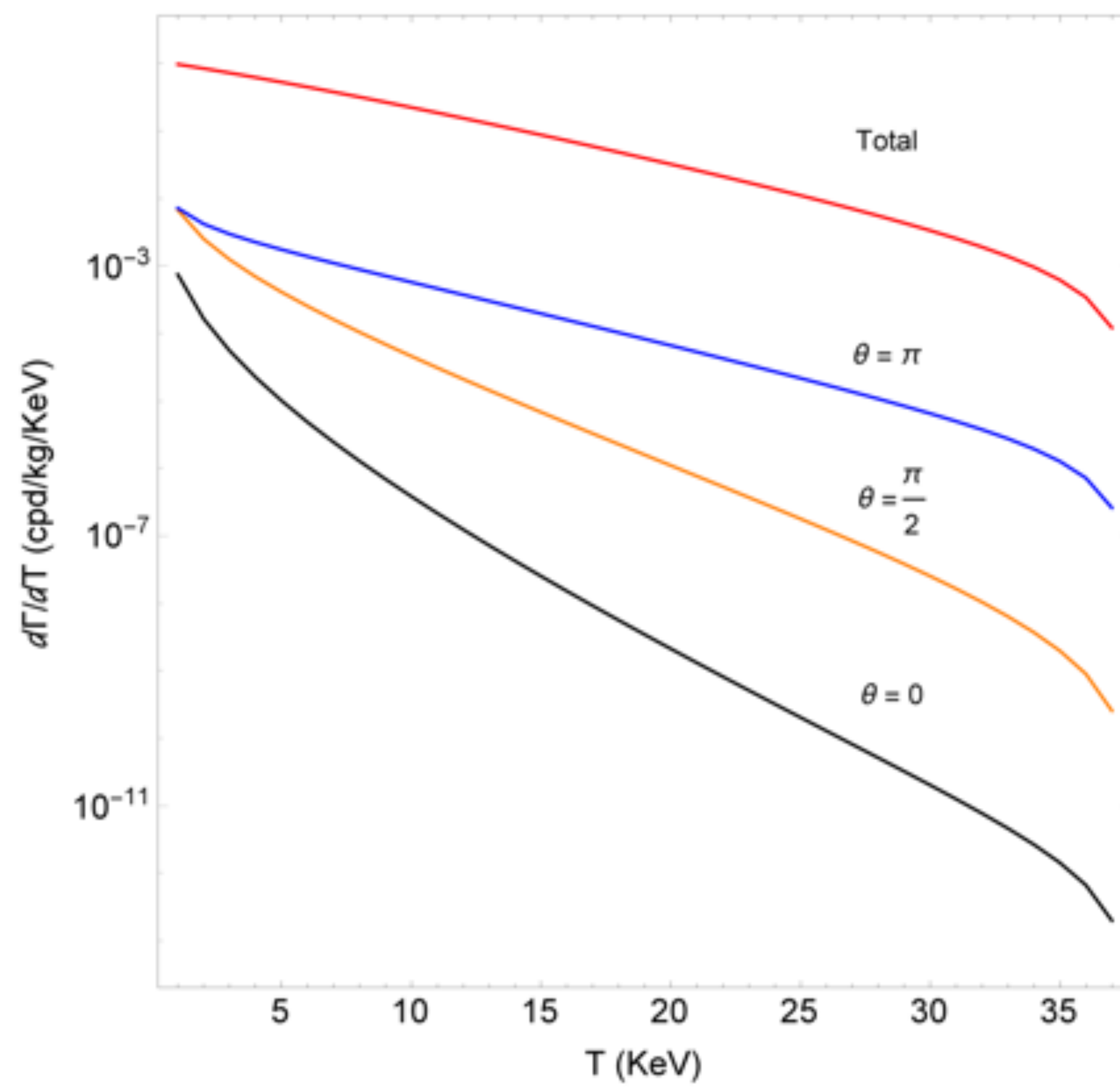
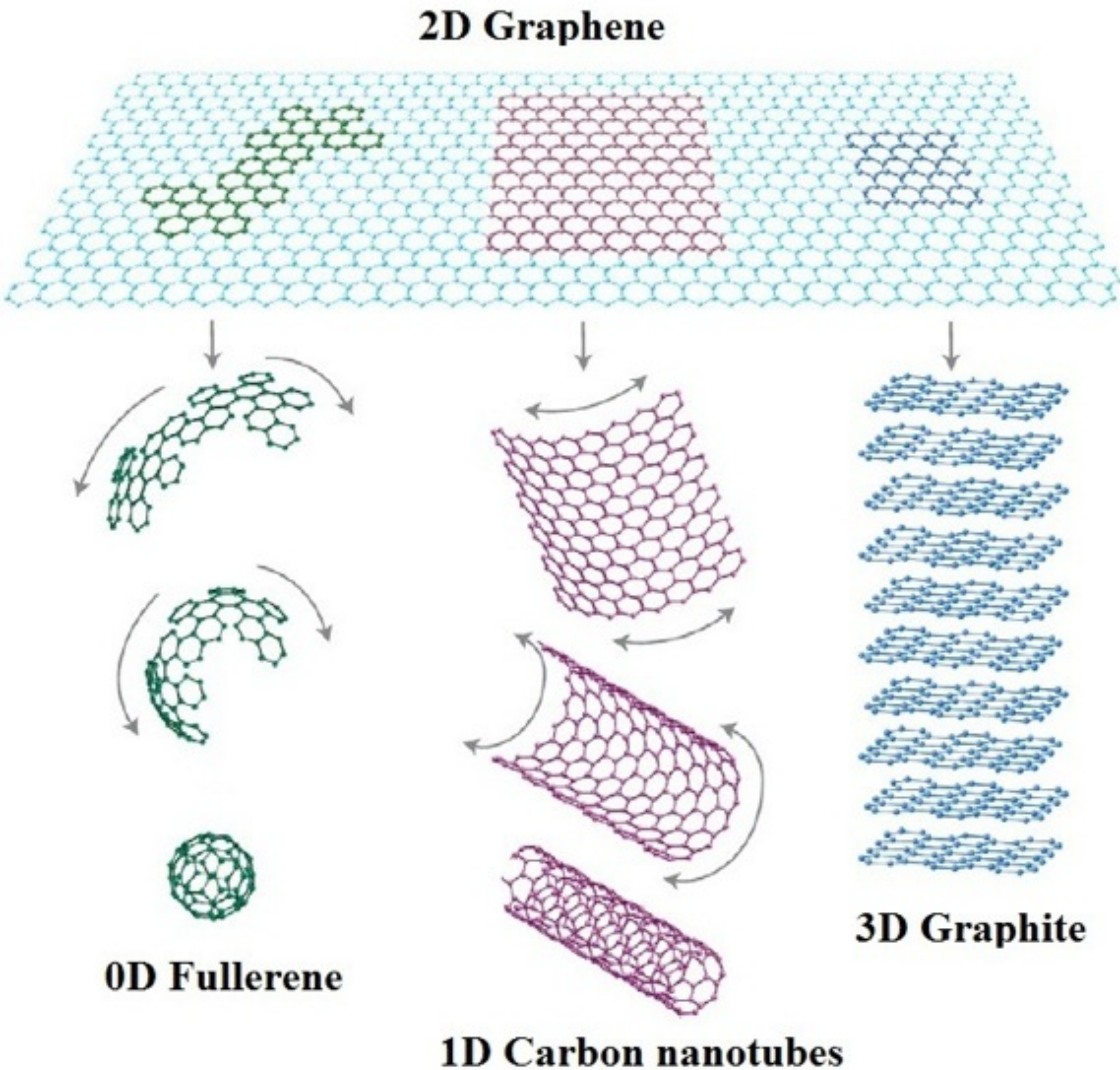
¶INFN Sezione di Roma, Piazzale Aldo Moro 2, I-00185 Roma, Italy

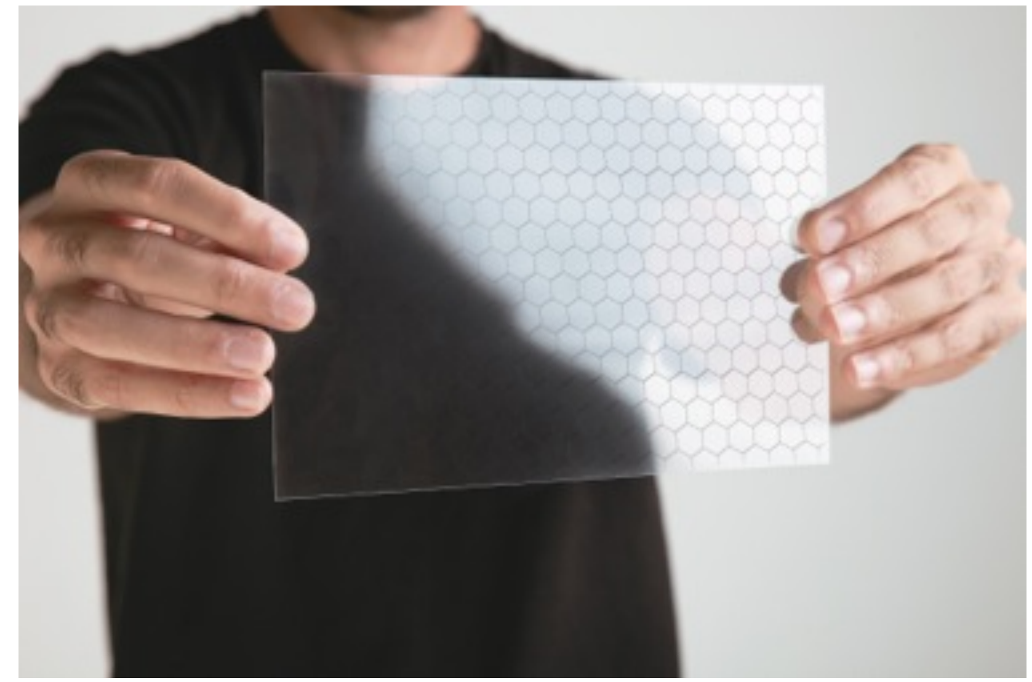




Graphene show time



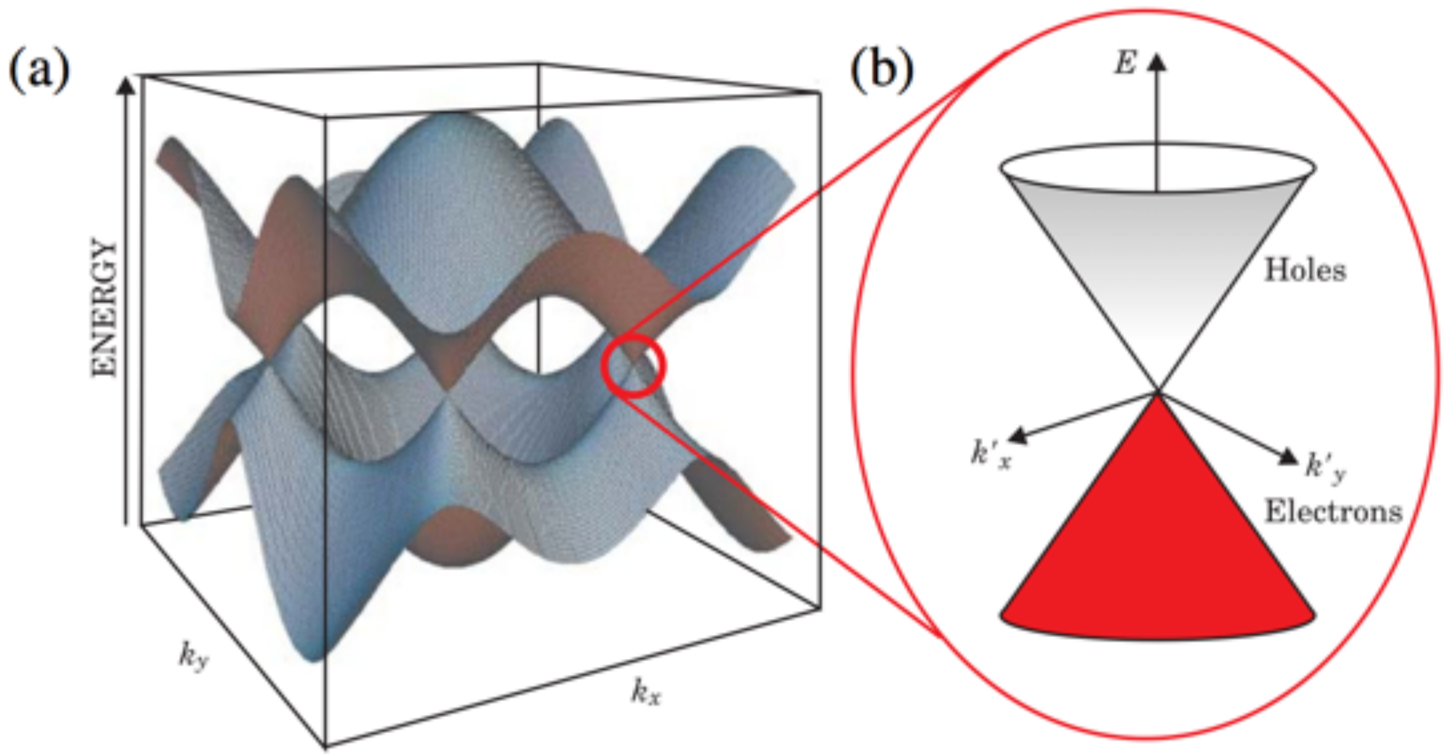
Monoatomic layer



Graphite have metallic or semiconductor behaviour according to the propagation axis.

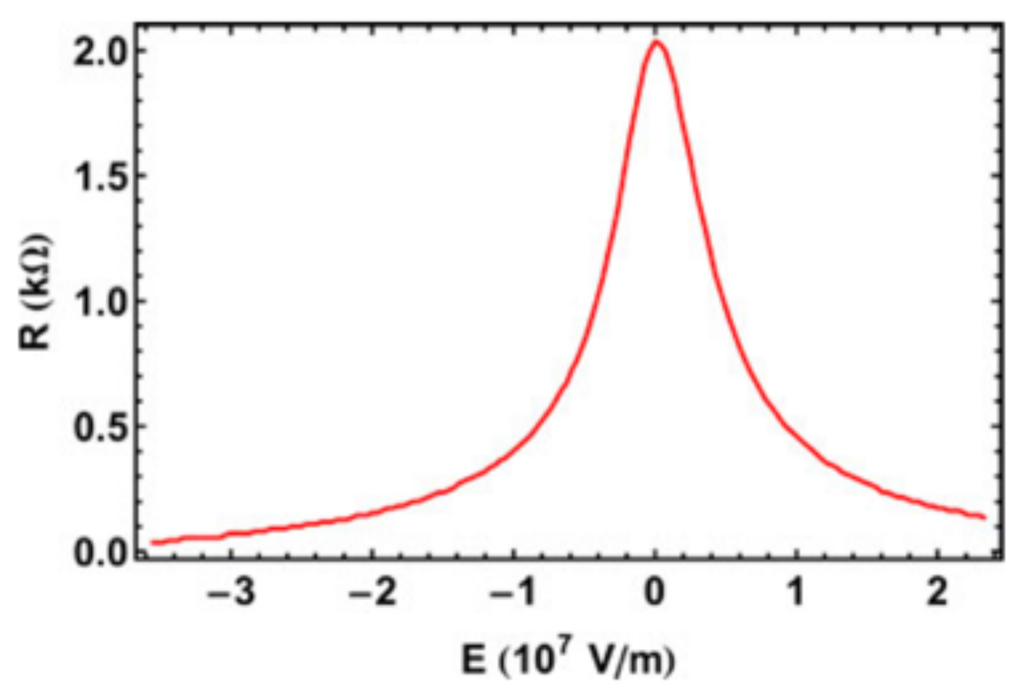
$$E_{gap} \sim 1 / R_{curvature}$$

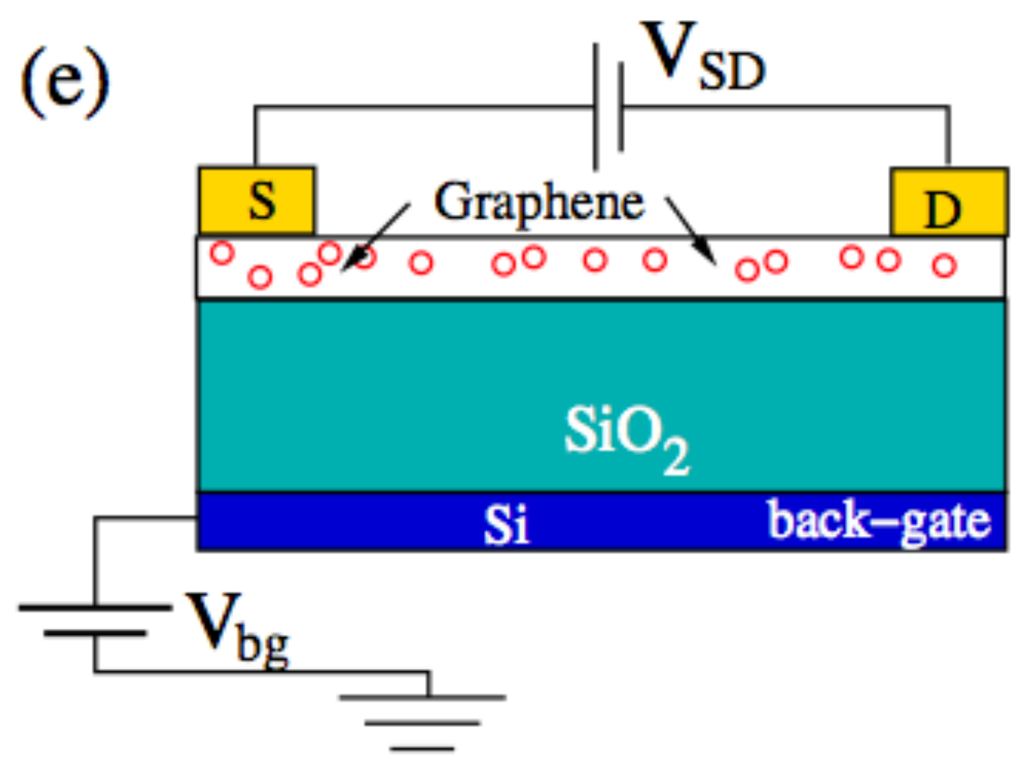
Graphene Dirac point



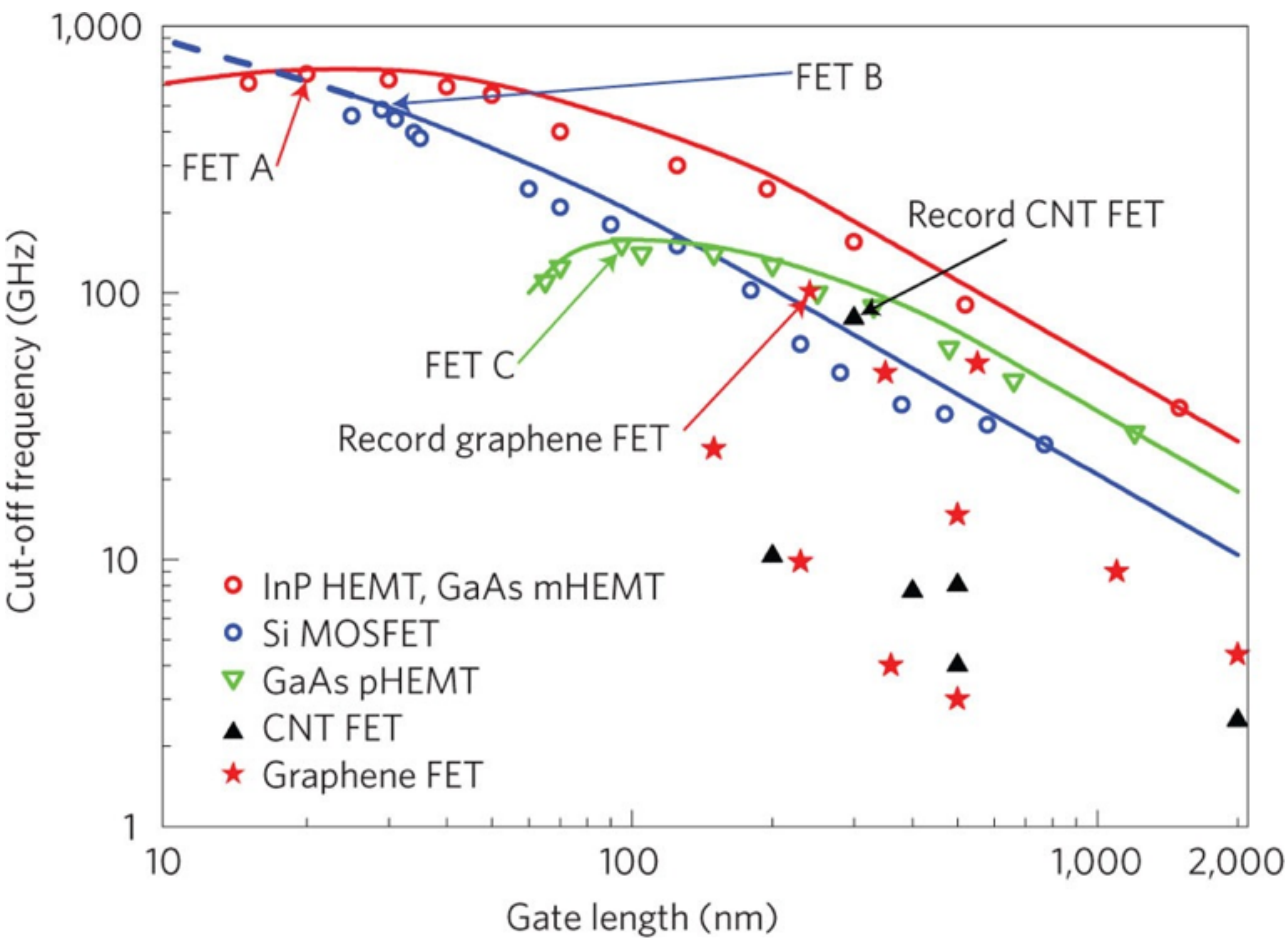
Graphene conduction band and valence bend touch in 6 points Egap = 0.

No ON/OFF transistors but analog FET Yes

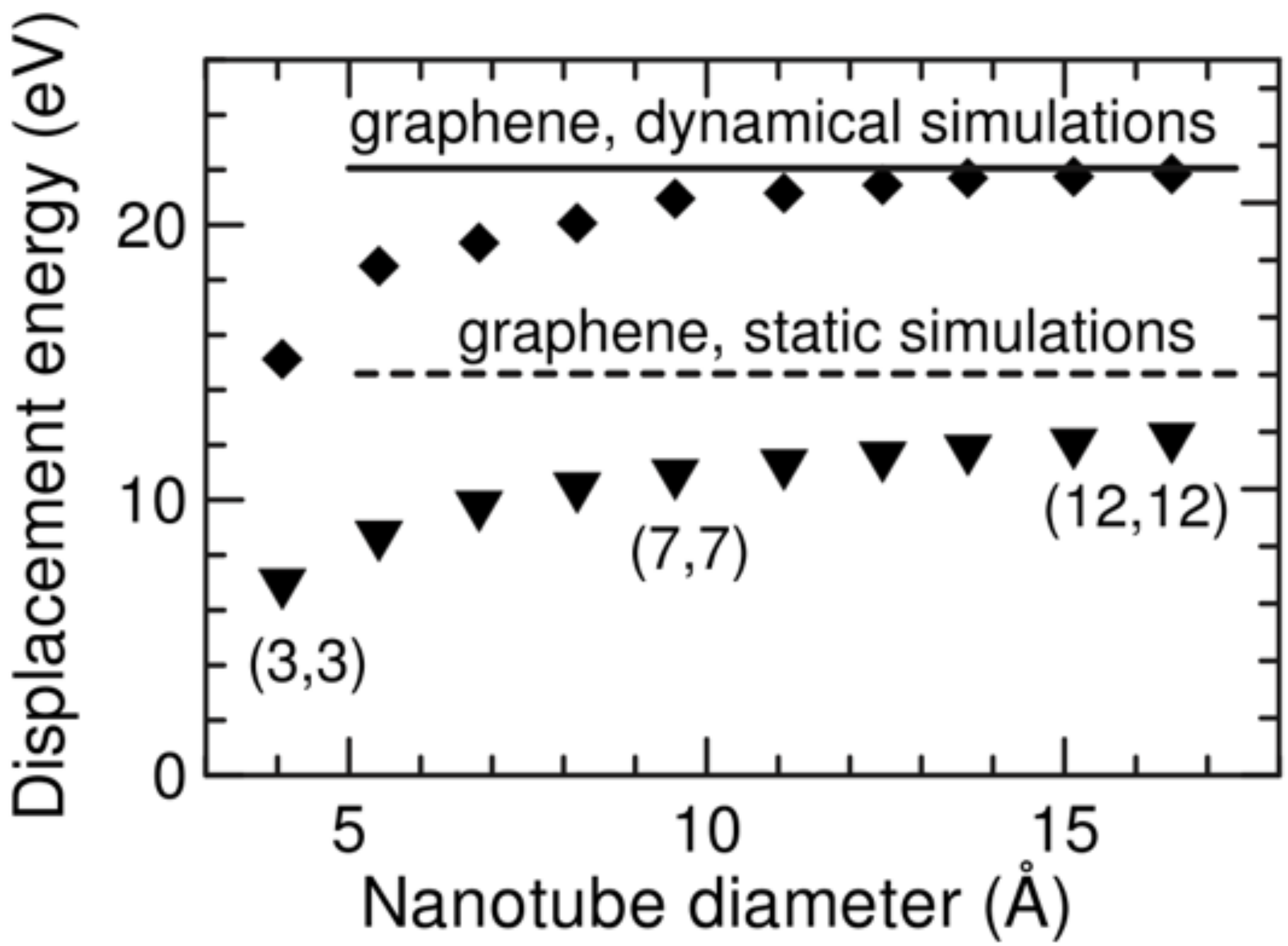




Graphene IRST Roadmap



G-FET and CNT-FET Radiation-hardness



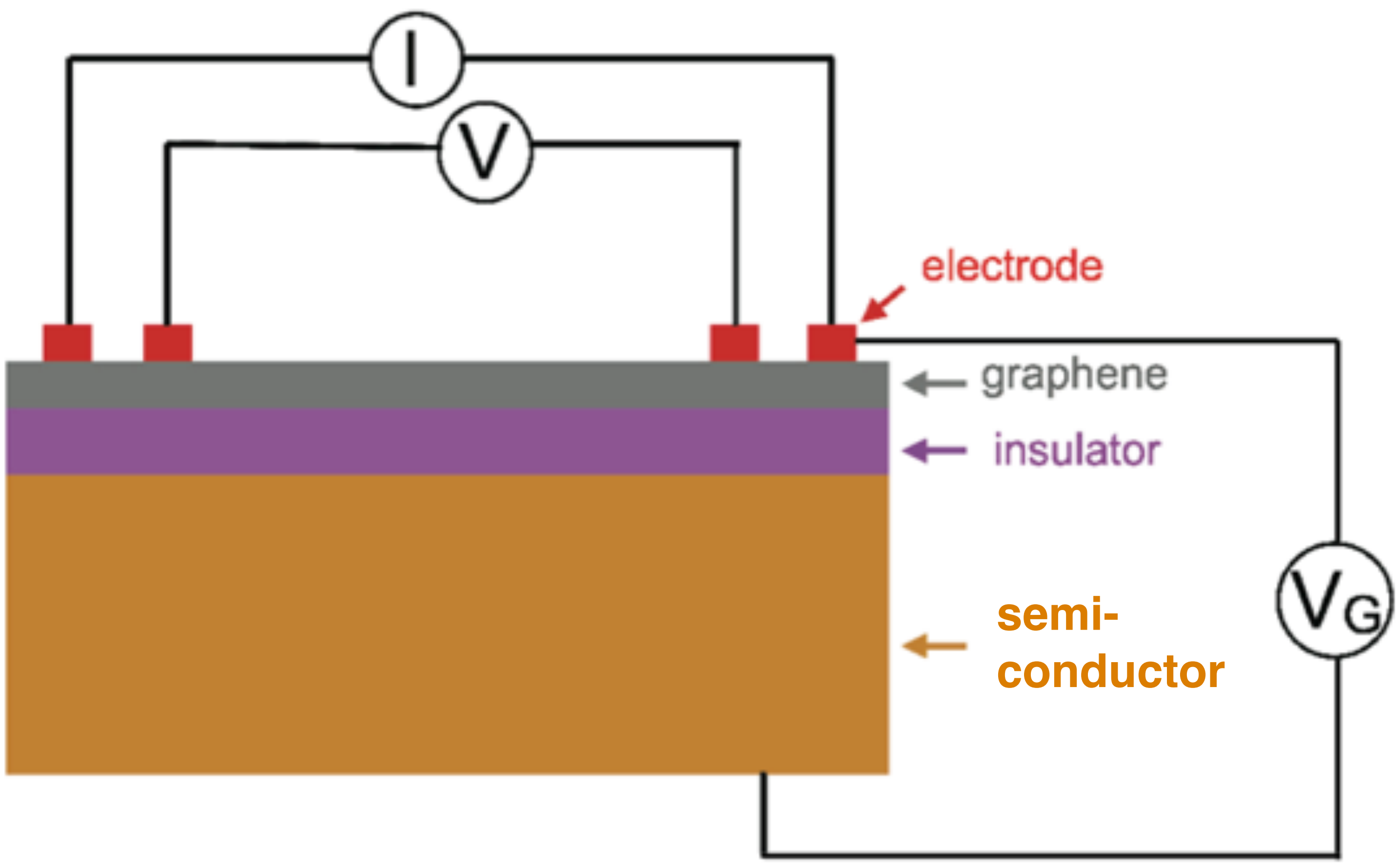
Fluence > 2 Mrad for Co60 source G-FET and CNT-TFT are unaffected

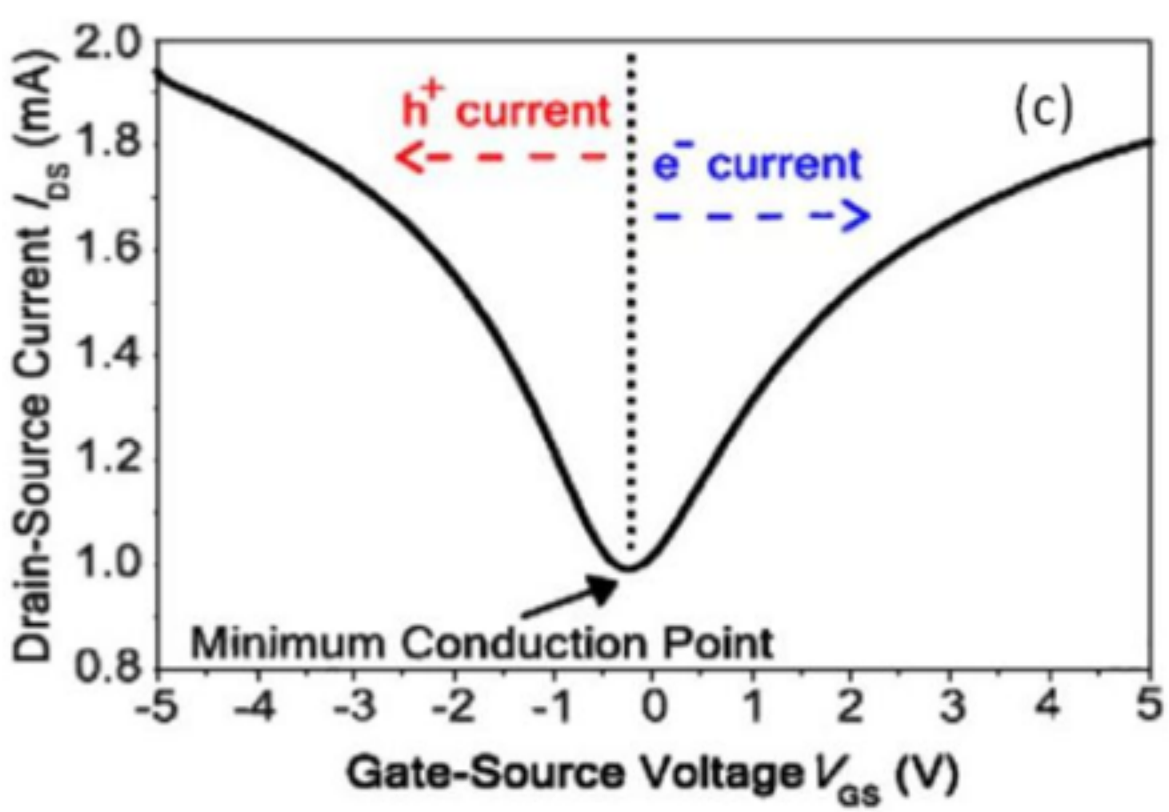
NO CHARGE DRIFT DETECTOR

Graphene field effect transistor as a radiation and photodetector

Author(s): Ozhan Koybasi; Isaac Childres; Igor Jovanovic; Yong P. Chen

Proc. SPIE 8373, Micro- and Nanotechnology Sensors, Systems, and Applications IV, 83730H (3 May 2012);

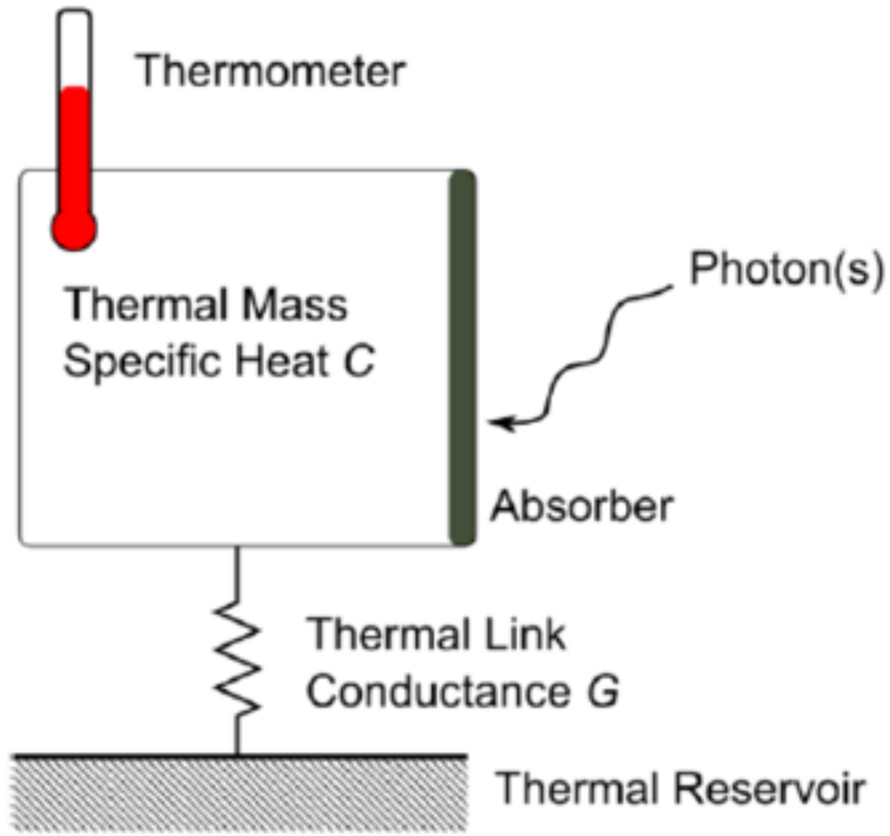


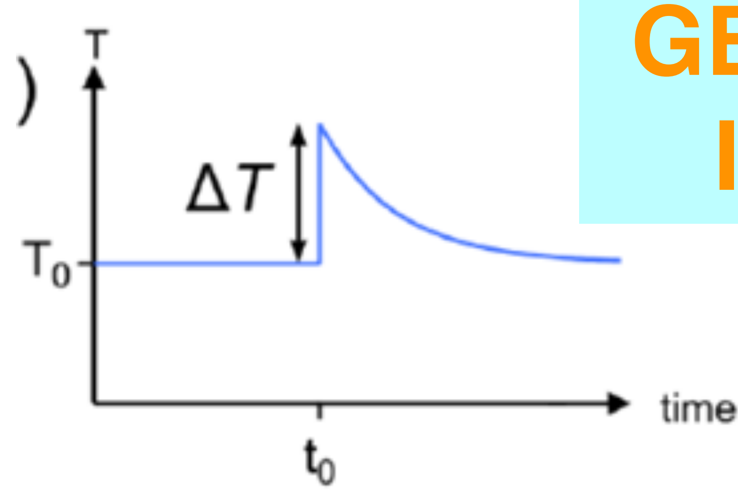


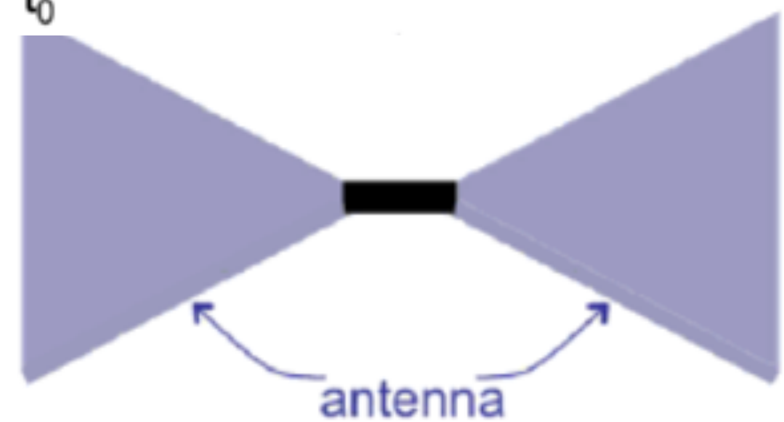
GARFIELD in CSN5 (Grant Giovani)

Graphene THz radiation bolometer

GBTD in CNS5
INFN-TIPFA







T=0.1K, A=4um2
n=10E12e-/cm2

$dE_{fluct} \sim 0.3 \mathrm{sqrt}(kT^2 Ce)$

t=Ce/Ge=0.4us

Ce=e- thermal capacitance (small 2E-22J/K just a atomic layer)
Ge=e- thermal conductance(small electron-phonon coupling)

Ideal condition extrapolating from T = 1 K (no measurements at 0.1 K)

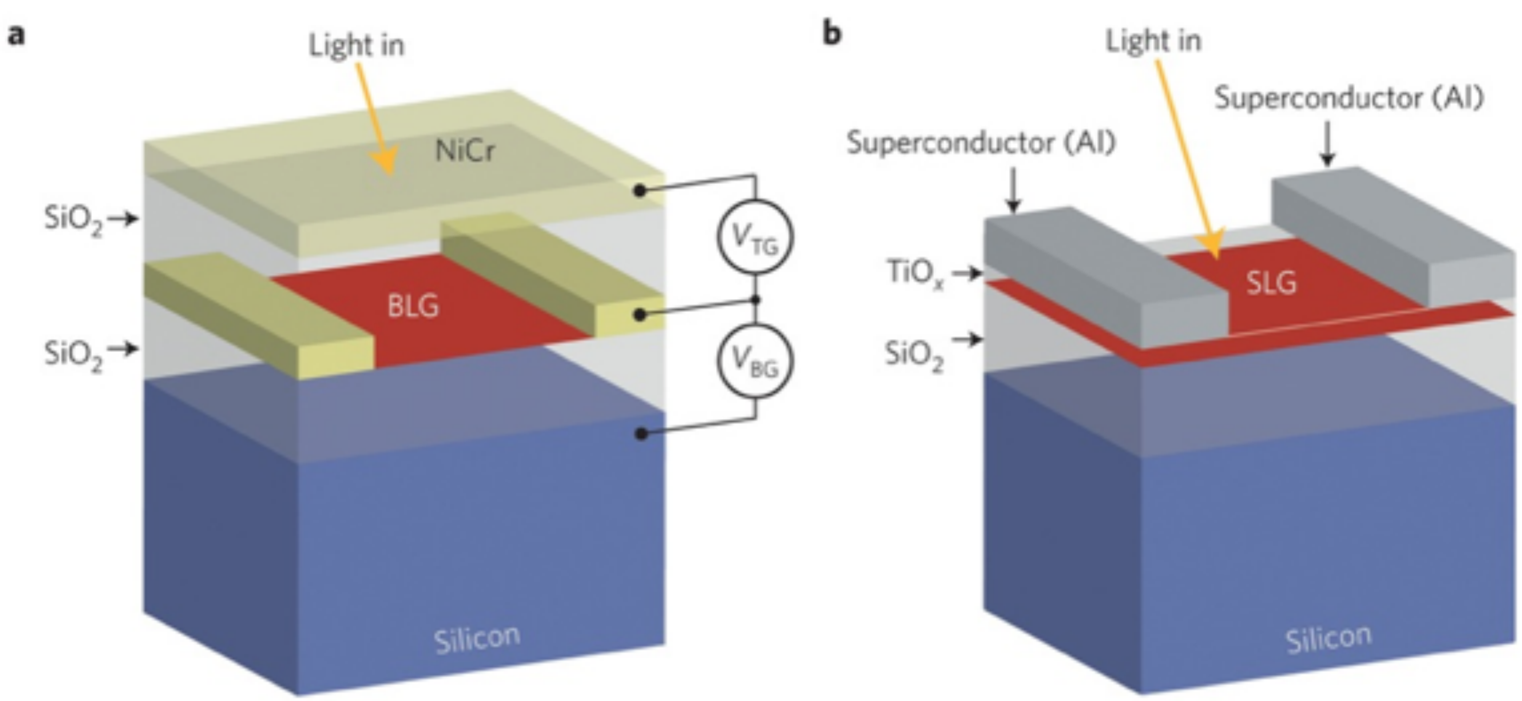
e-T readout in graphene

$$dE=sqrt(dE_{fluct}^2+dE_{readout}^2)$$

Due to small electron-phonon coupling almost no change in R_{DS}

Several readout schemes for e-T in graphene tried in lecterature:

- Johnson Thermal Noise: single photon capability but worse dE
- Double graphene layer: introduce a Te vs R_{DS} dependence (a)
- Superconductive contacts: Te vs SC tunnel junction resistance (b)



Benchmark for THz radiation detectors:

- TES (Transistor Edge Superconductor)
- KID (Kinetic Inductance detector)

Conclusions

- Nanostructured material are “new” to us but a lot happen out there since a long time (equivalent to useless?)

- A lot of nice idea turnout to be technologically too difficult (or too naive?)

- Few interactions between INFN groups and CNR groups some of them quite consolidate (saving private ryan)

Comment for discussion

- We are very busy with experiment maintenance, running, data analysis and future upgrade: let other make the technological development and when ready we can improve it and use it.

- It is strategic to survive, to get external found, to attract young people, to have new challenge, to maintain the leader-ship in technology.

    - Do every think is not possible and should not be done (synergy is an opportunity not a problem)

    - In synergy with others let's do what we are the best (ideas, device simulation, advanced front-end, interconnects, daq, data analysis, experiment in physics)