INFN ROMA

Istituto Nazionale di Fisica Nucleare
Sezione di Roma

“Eppur si vede”

Francesco Collamati

Open Day INFN-Rm - 9.10.25

DISCLAIMER

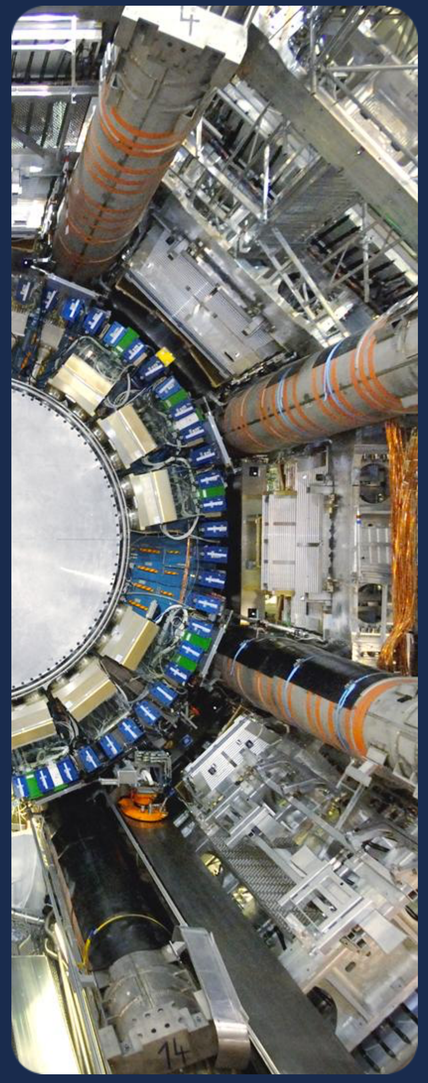
This will NOT be:

- ~~complete / systematic~~
- ~~“to scale”~~
- ~~splatter*~~

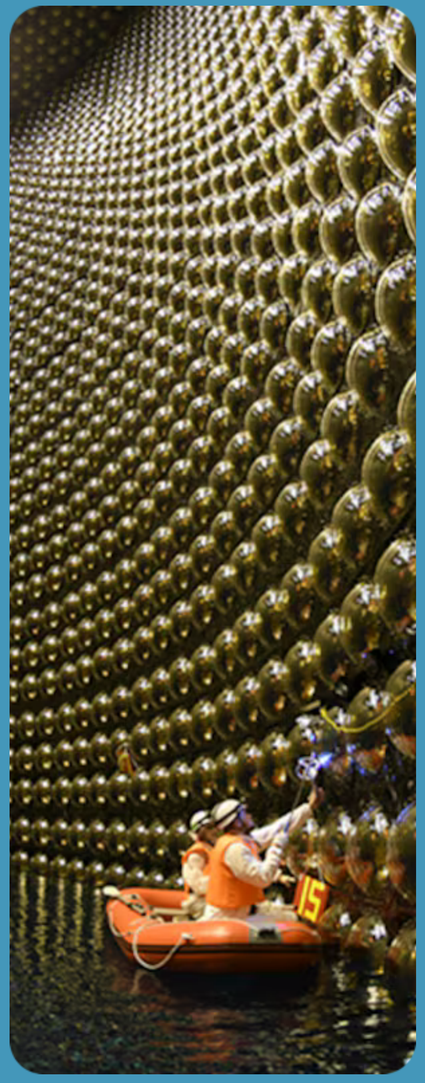
...but rather a (~)random walk
to give a **glimpse** and a **feeling**

* E version available online

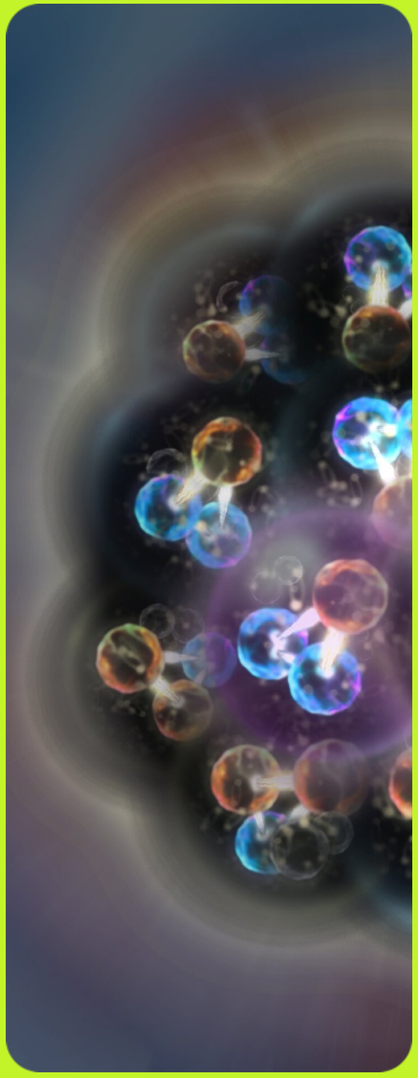
CSN1



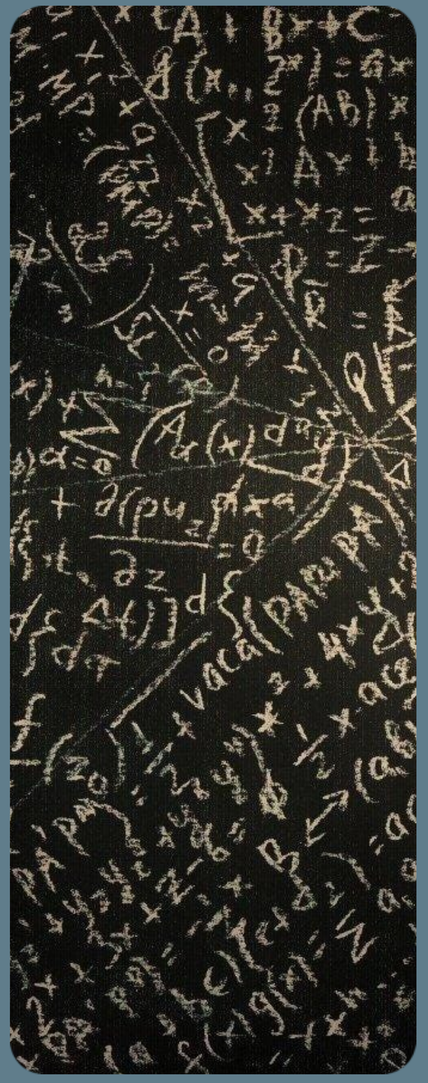
CSN2



CSN3



CSN4



CSN5

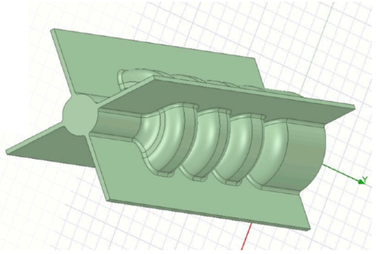
CSN5

- Accelerators
- Interdisciplinary Physics
- Electronics & Detectors
- Computing

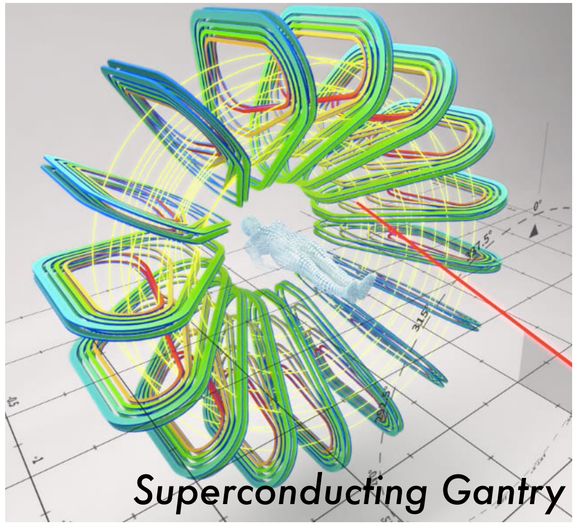
CSN5

Accelerators

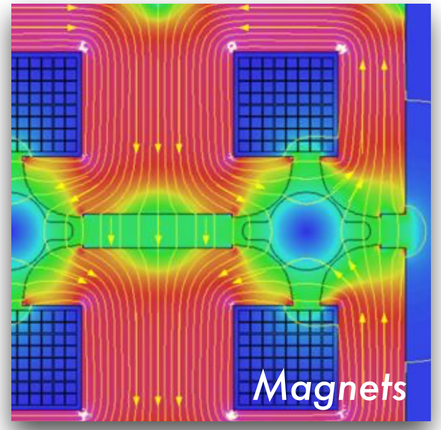
Applications

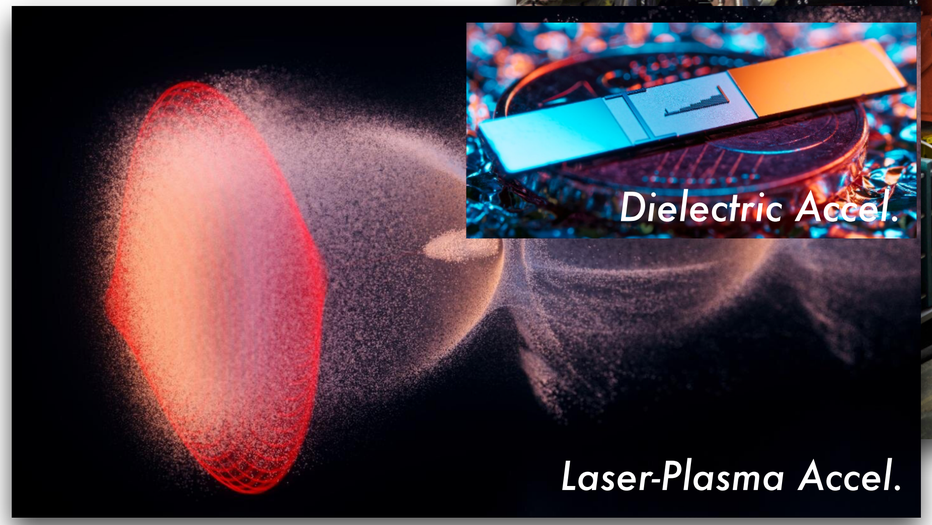


MIniaturised aCceleRatOrs Network



Base technologies for acceleration





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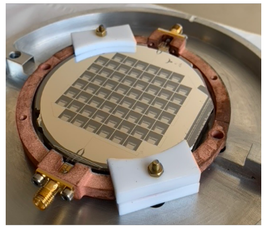
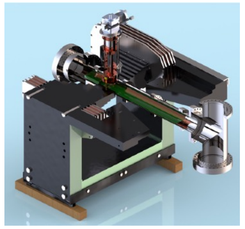
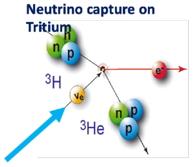
Detectors for experiments

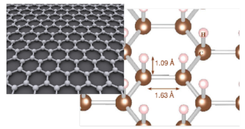


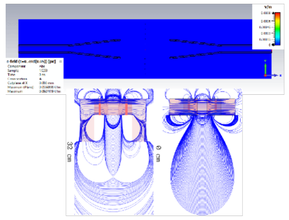
Bullkid (dark matter)

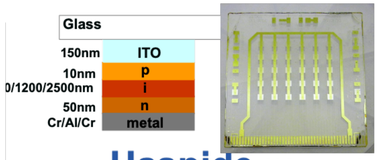




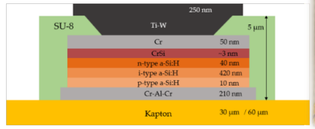
Ptolemy (CNB detection)

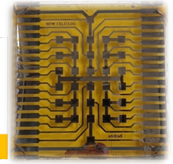






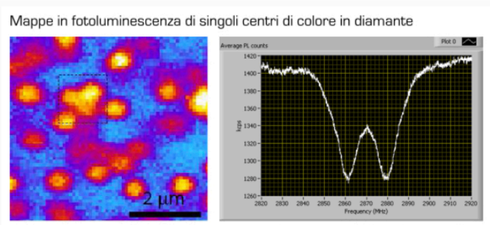
Kapton





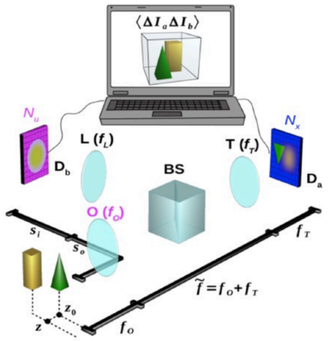
Haspide HAmorphous Silicon PIxel DEtector for ionizing radiation

Quantum Sensing & Quantum Imaging

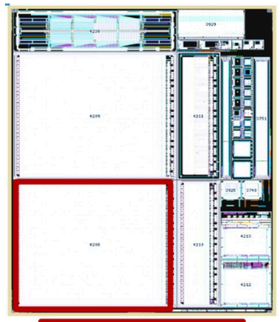


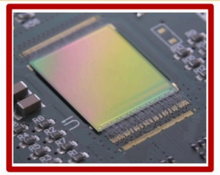
Risonanza magnetica di spin di un ensemble di centri NV in diamante letta mediante contrasto di luminescenza

http://www.solid.unito.it/RICERCA/Diamante/diesis/diesis.html



Electronics & Detectors

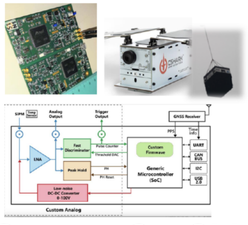




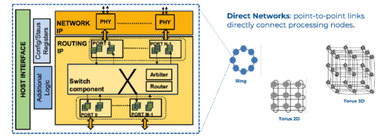
Microelectronics

Electronics

2 x 55 cm² 100 g/ch GEN1 | 50 cm² 21 g/ch GEN2 | 25 cm² 10 g/ch GEN3 | 4 cm² /ch¹ g/ch GEN4



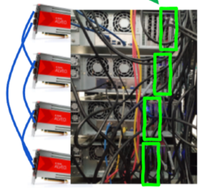
System-On-Chip



FPGA- based testbed

- **AMD Xilinx FPGA U200**
- 4x Supermicro servers
- Sapphire Rapids CPUs
- Gen3 PCIe

APEnetX prototypes connected point-to-point with QSFP28 cables



FPGA

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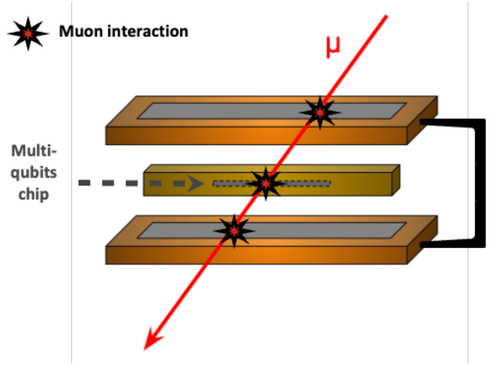
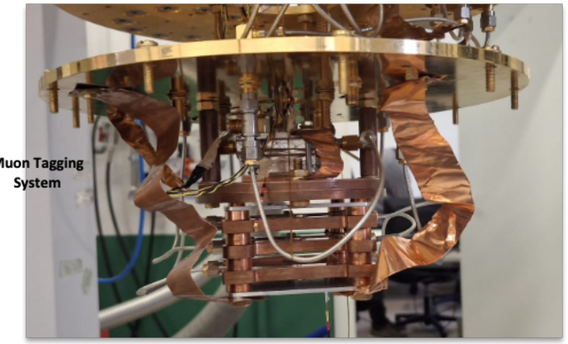
CSN5

Quantum Computing

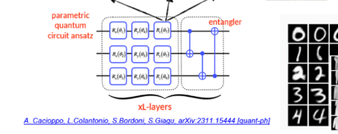
ACE-SuperQ



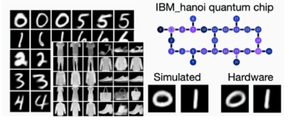


Artificial Intelligence

Quantum Machine-Learning

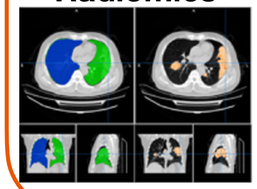


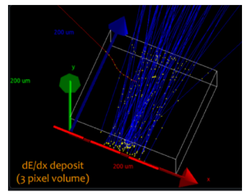
implemented and tested on real quantum hw



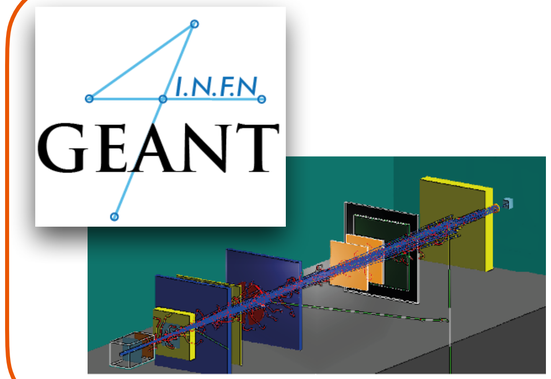
A. Caciappo, L.Colantonio, S.Bordoni, S.Giagu, arXiv:2311.15444 [quant-ph]

Radiomics

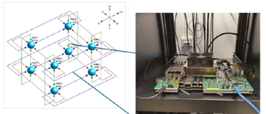




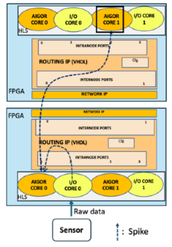
Detector Simulation



Neuromorphic Computing

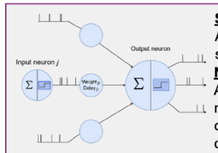


AMD Versal Premium VPK180



AIGOR

Neuromorphic computer architecture specialized for **energy efficiency, real-time processing, incremental learning**

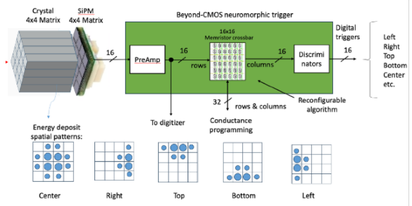


Spiking Neural Networks (SNNs):
Artificial neural networks that communicate through "spikes" or pulses, similar to biological neurons

Neuromorphic computing
A brain-inspired approach to hardware and algorithm design that efficiently realizes artificial neural networks, thanks to a highly parallel architecture, co-location of compute and memory units, asynchronous event-based computation and sparse, distributed information encoding through spikes

- Targeting primarily **dataflow-intensive applications in physics (Spiking Neural Networks, edge AI)**
- **Multi-FPGA architecture prototype**

MEMPHYS (MEMristive-CMOS hybrid electronics for experimental PHYSics)



Computing

CSN5

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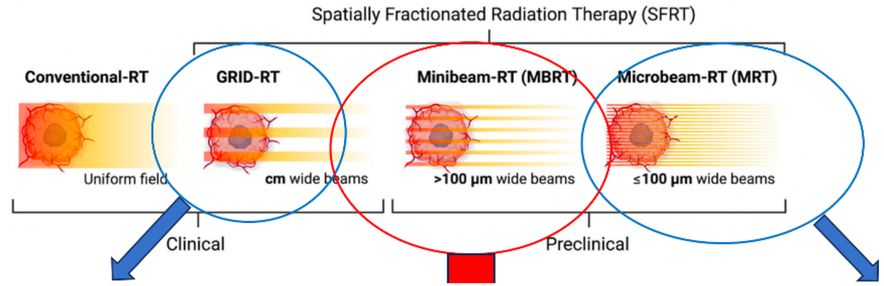
CSN5

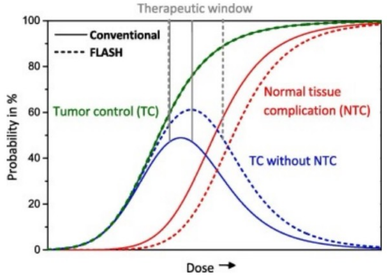
Interdisciplinary Physics

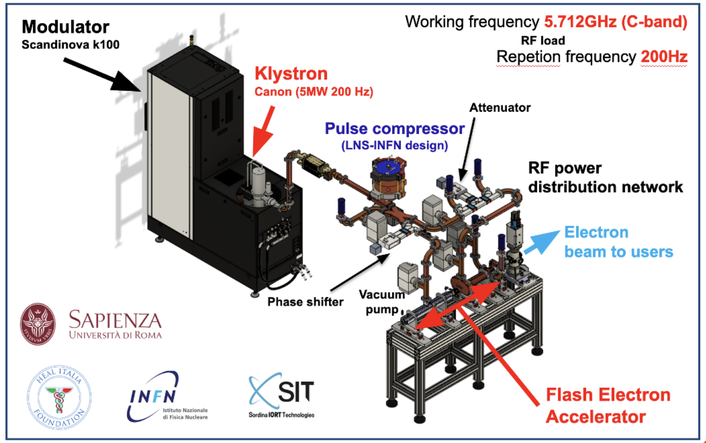
Medical Physics



Mini Beam

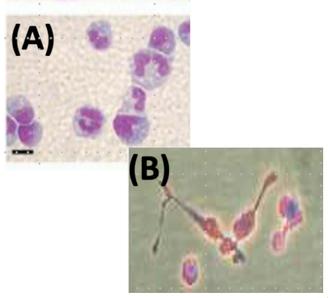
FRIDA





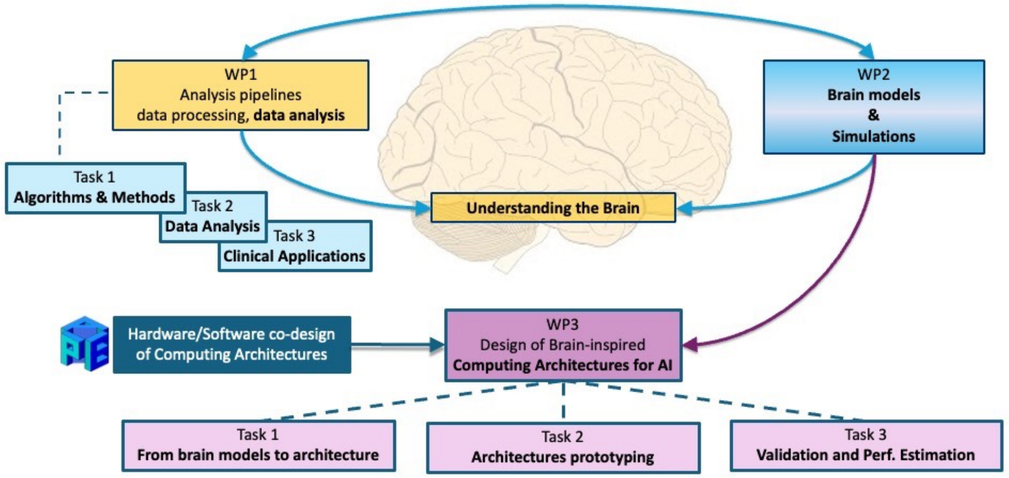
Biophysics

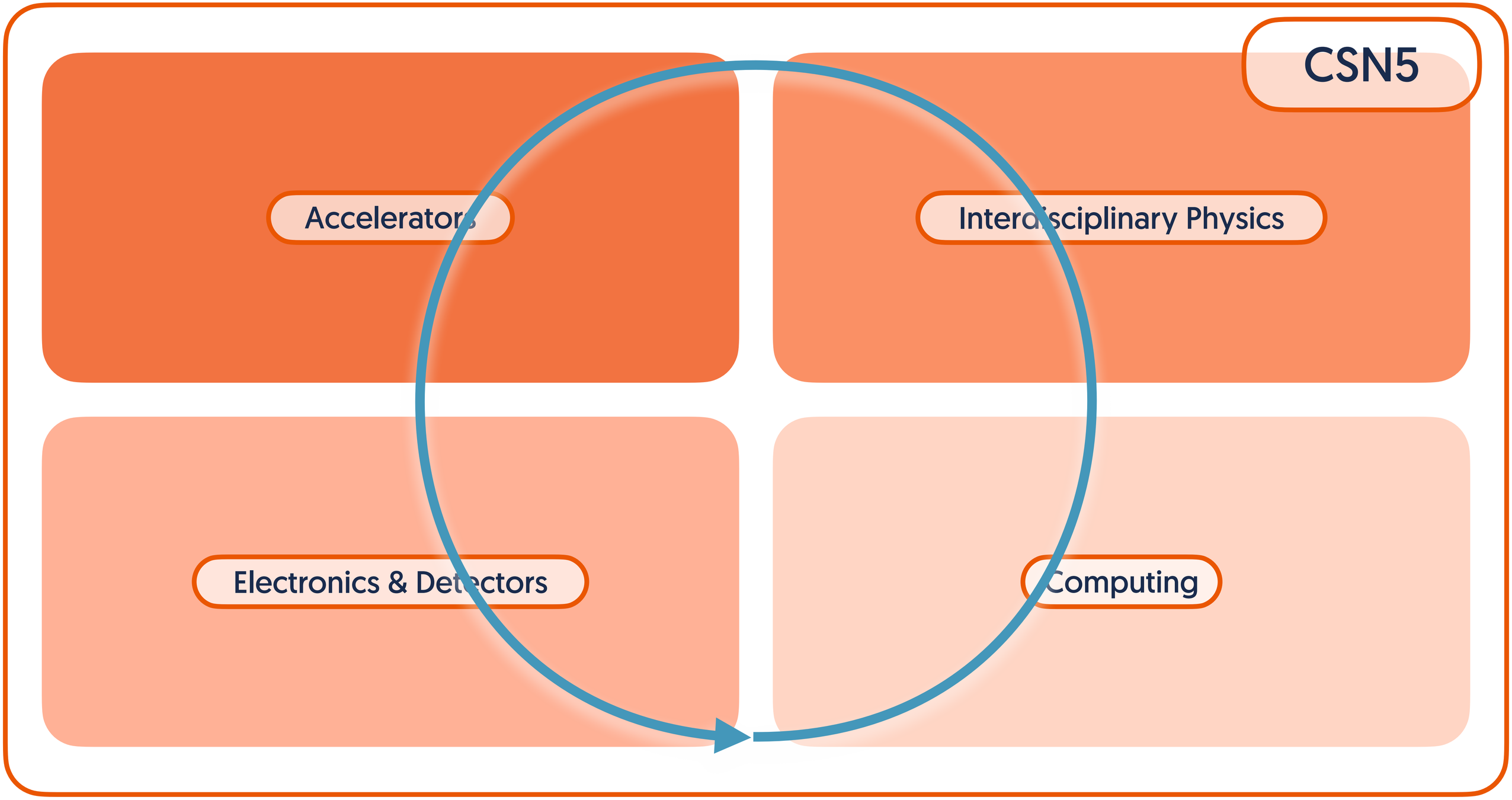
HL60
human promyeloblasts



Computational Neuroscience

BRAINSTAIN




CSN5
Accelerators
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Computing

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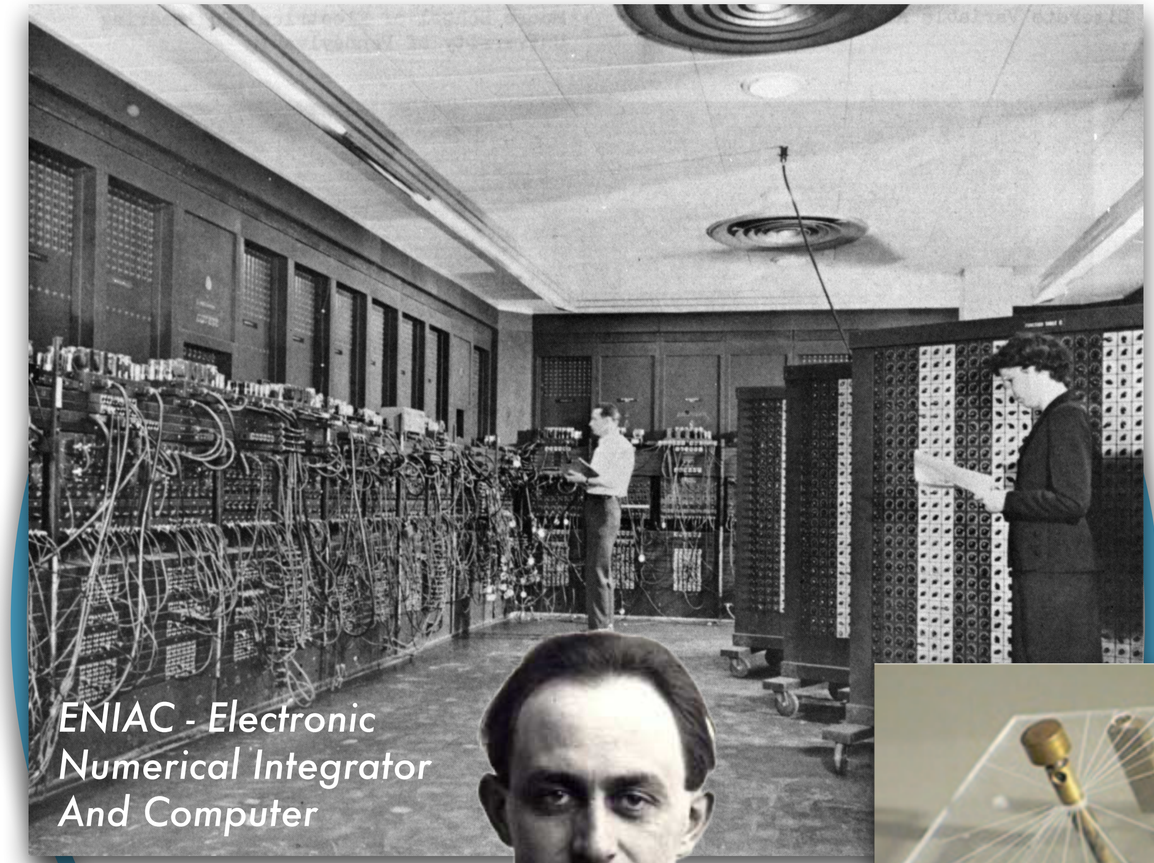
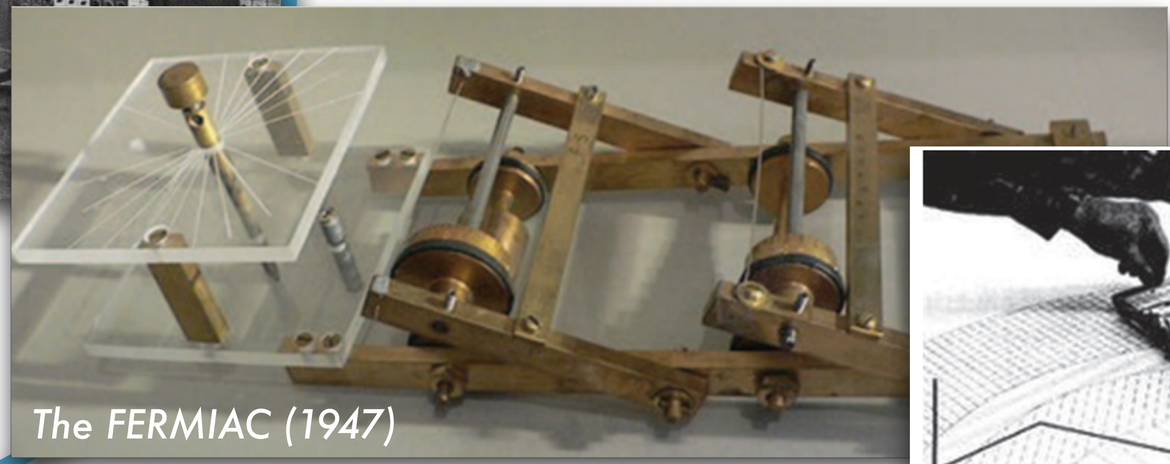
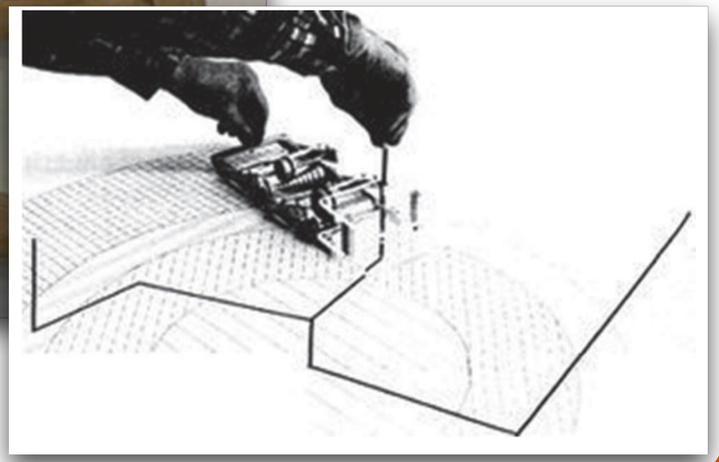


ENIAC - Electronic Numerical Integrator And Computer

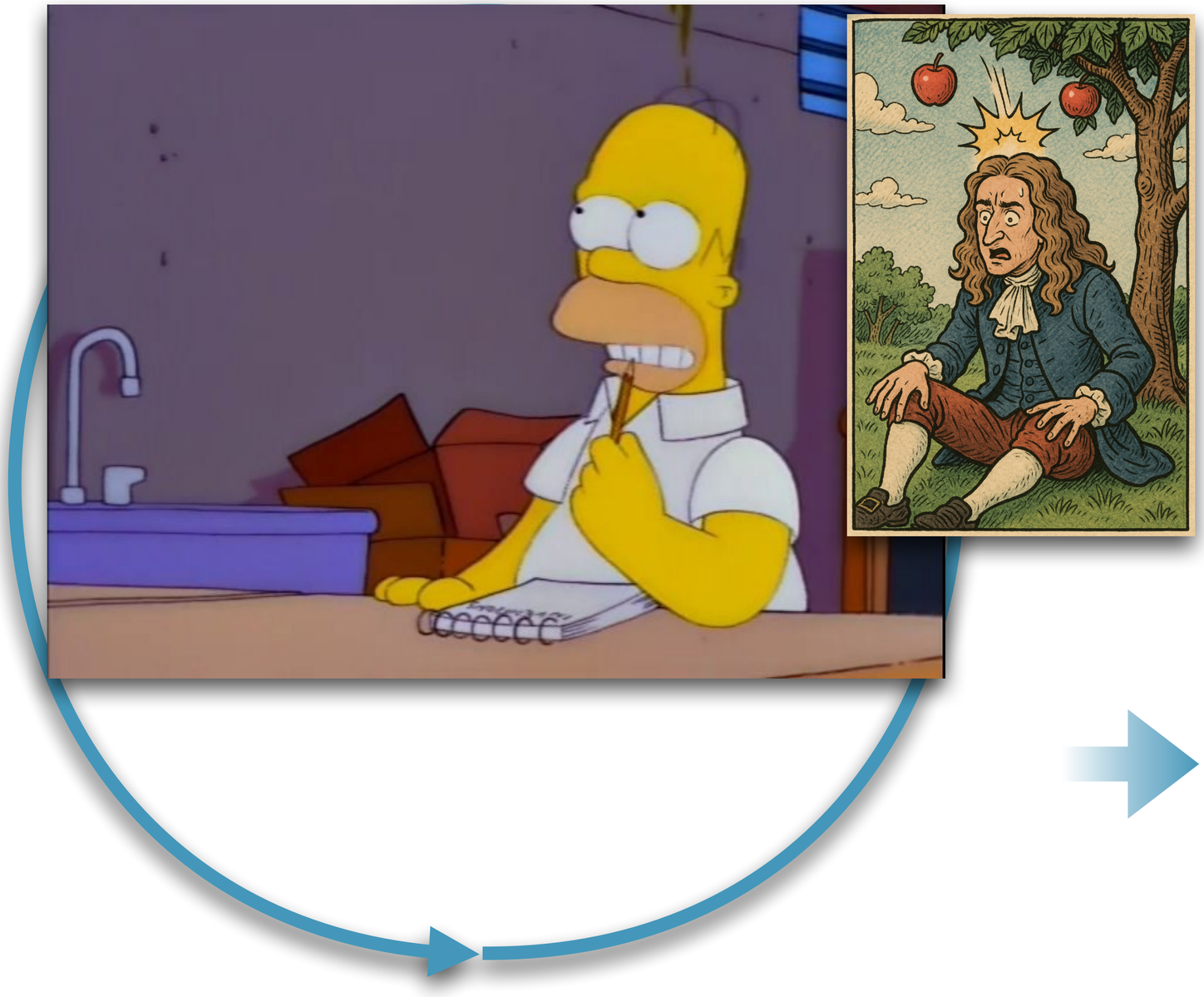
Do It Yourself

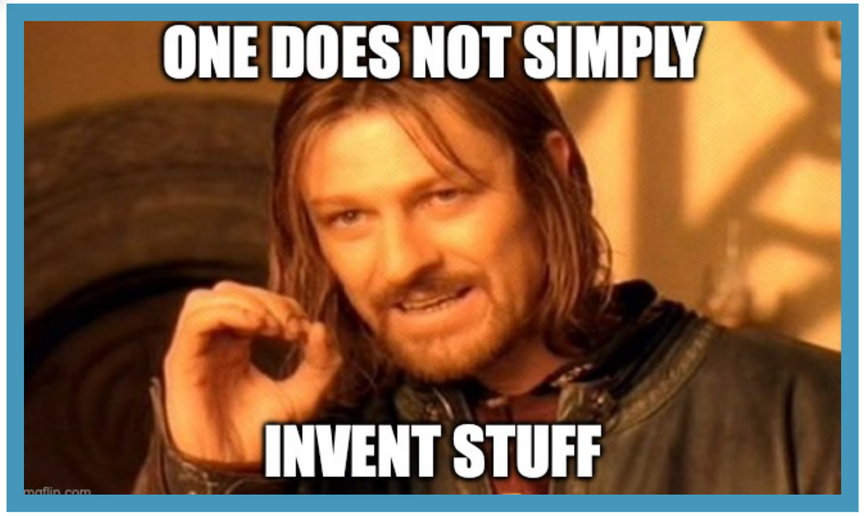


The FERMIAC (1947)



CSN5

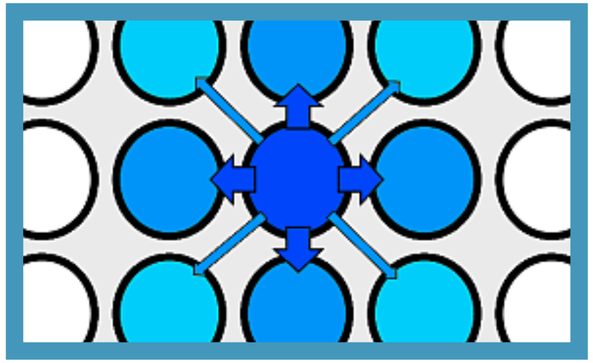




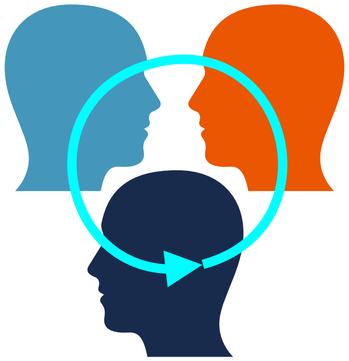
CSN5

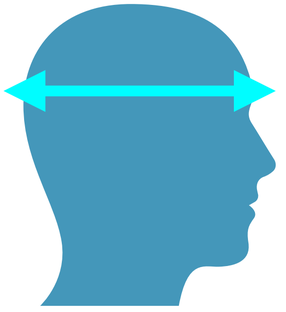
lay siege to you with other opportunities.

The closer you get to finishing, the more interesting everything else in your life becomes. It's as if you've put on distraction goggles. Things you never noticed pop up and dance

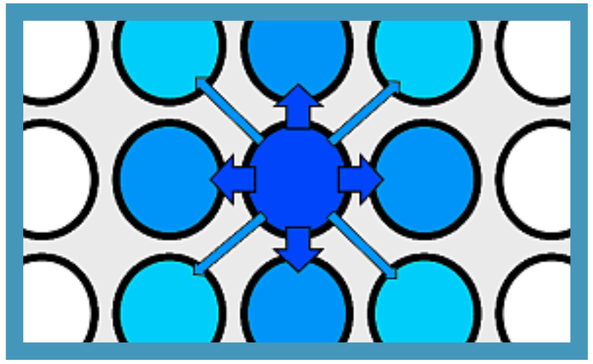


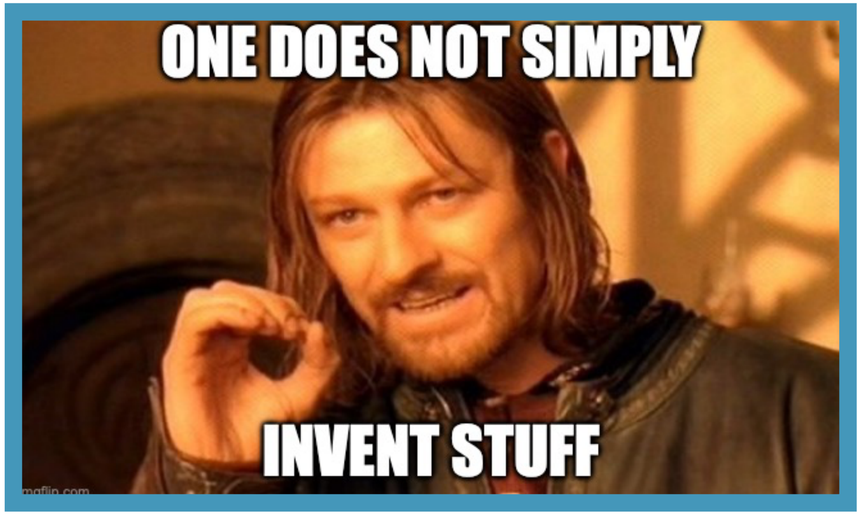
Crosstalk



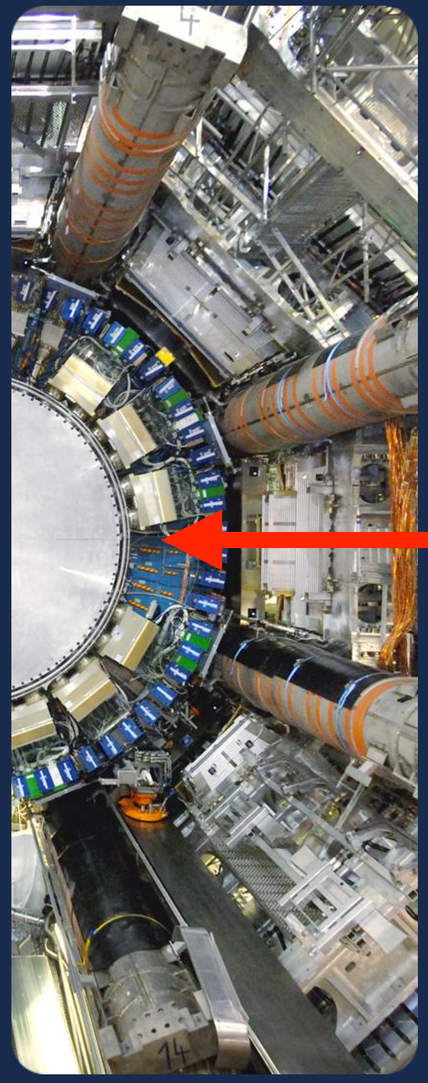


CSN5

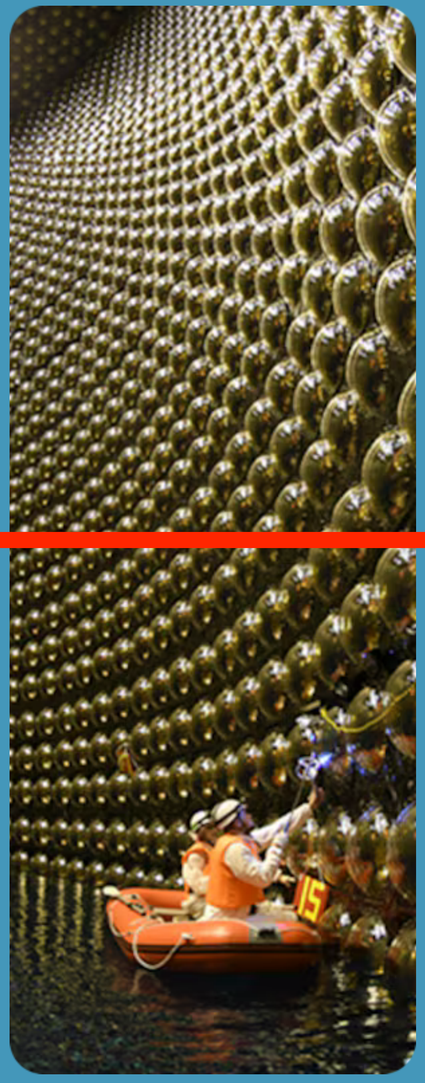




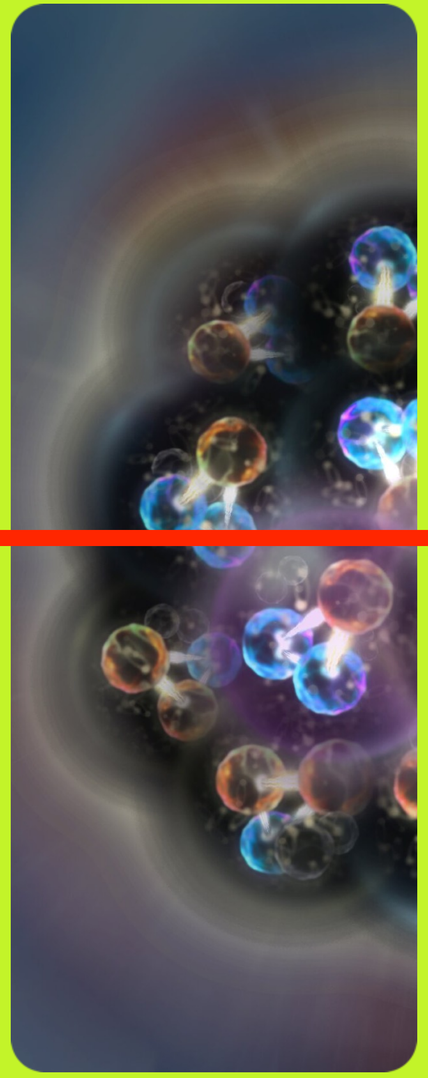
CSN1



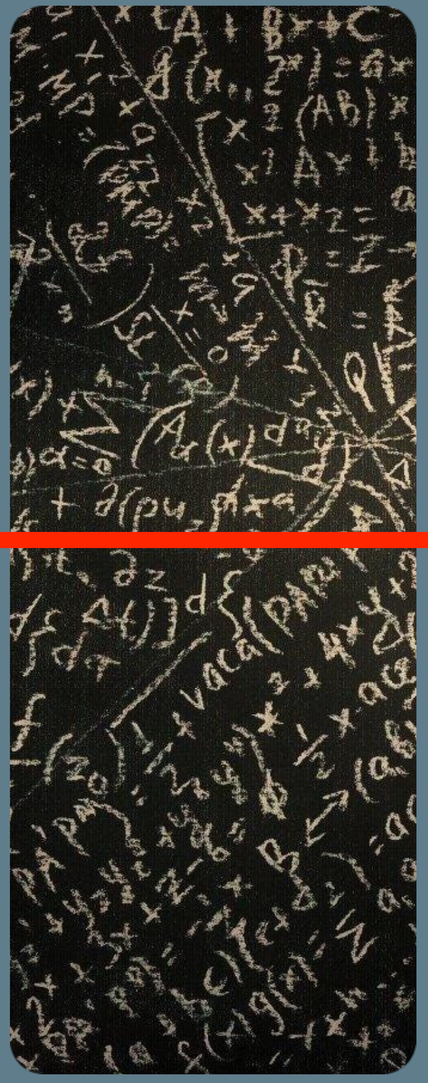
CSN2



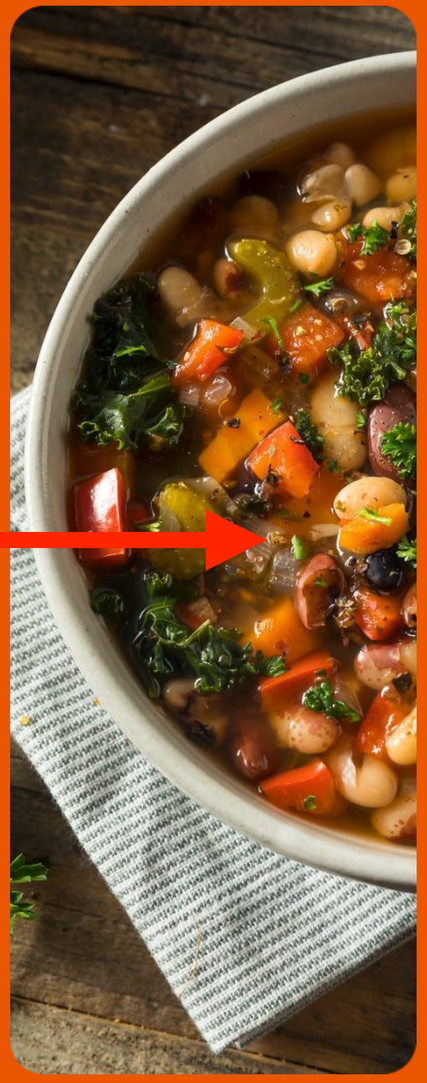
CSN3

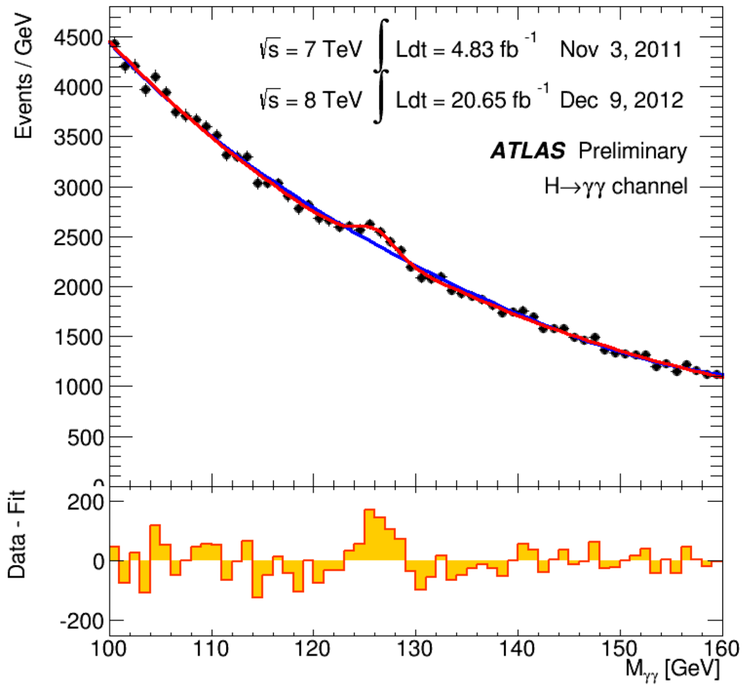


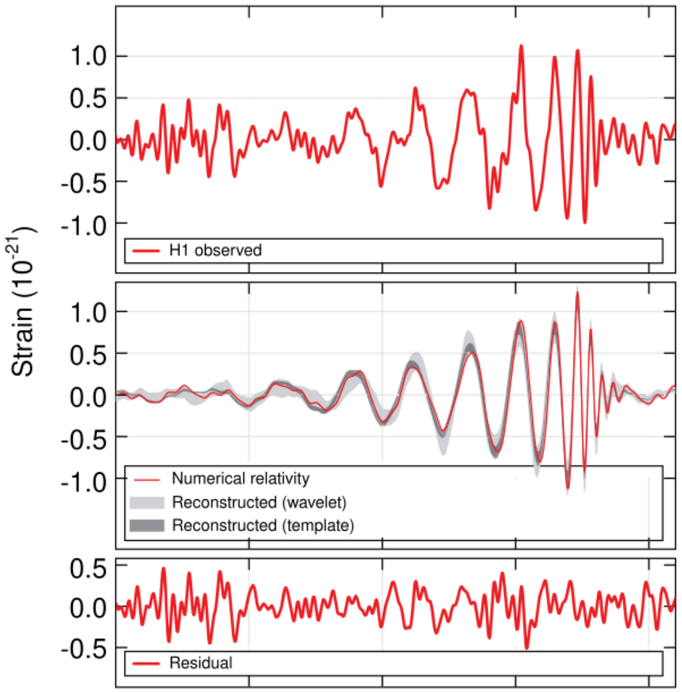
CSN4

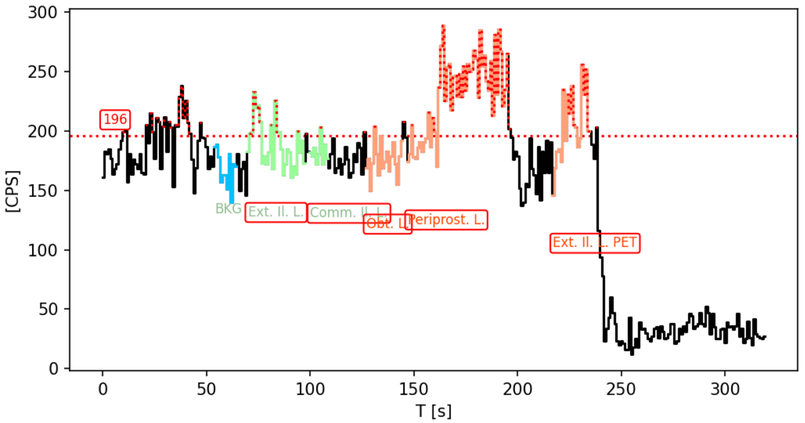


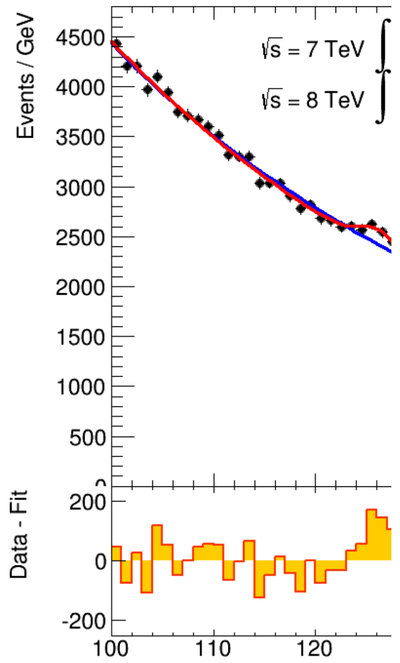
CSN5

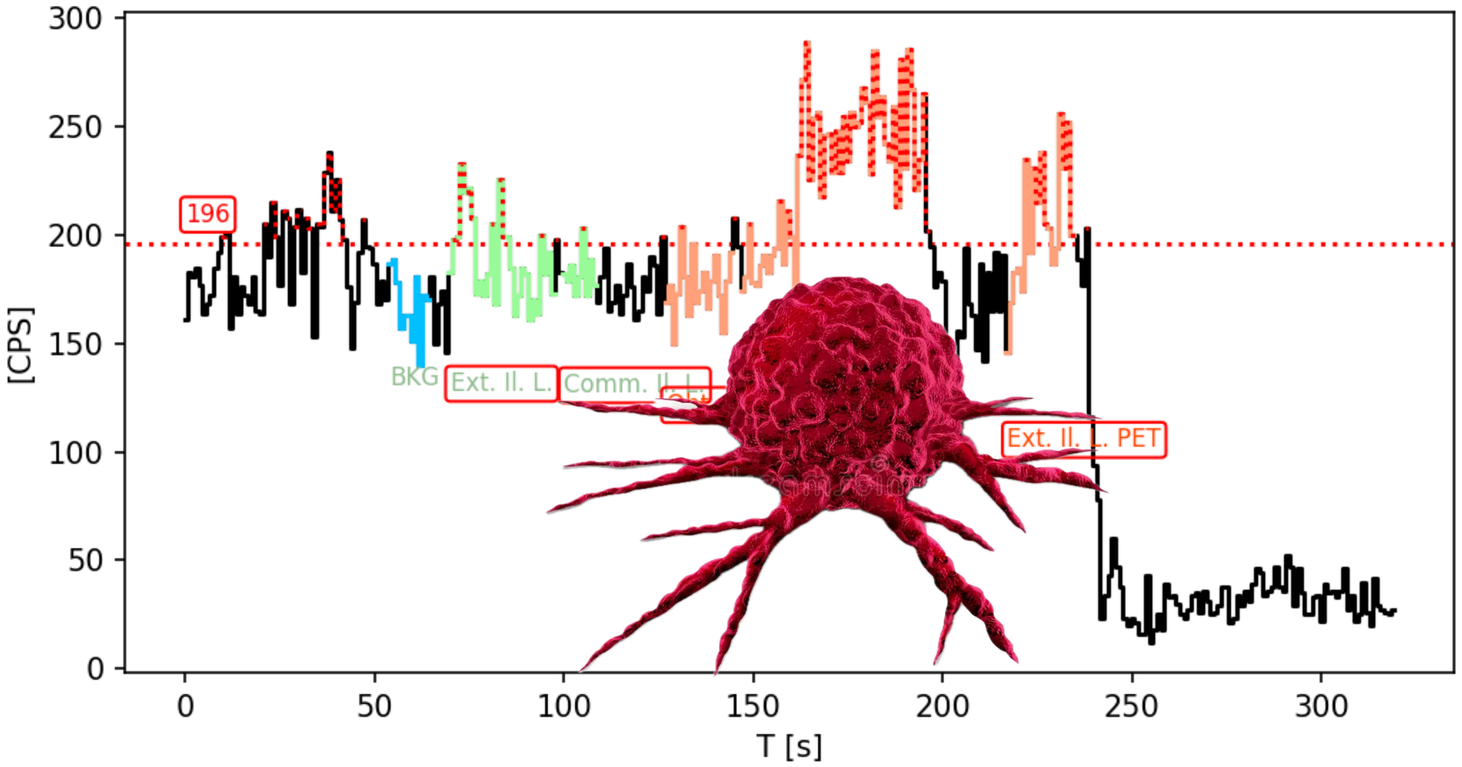



√s = 7 TeV ∫ Ldt = 4.83 fb-1 Nov 3, 2011
√s = 8 TeV ∫ Ldt = 20.65 fb-1 Dec 9, 2012
ATLAS Preliminary
H→γγ channel
Events / GeV
Data - Fit
Mγγ [GeV]

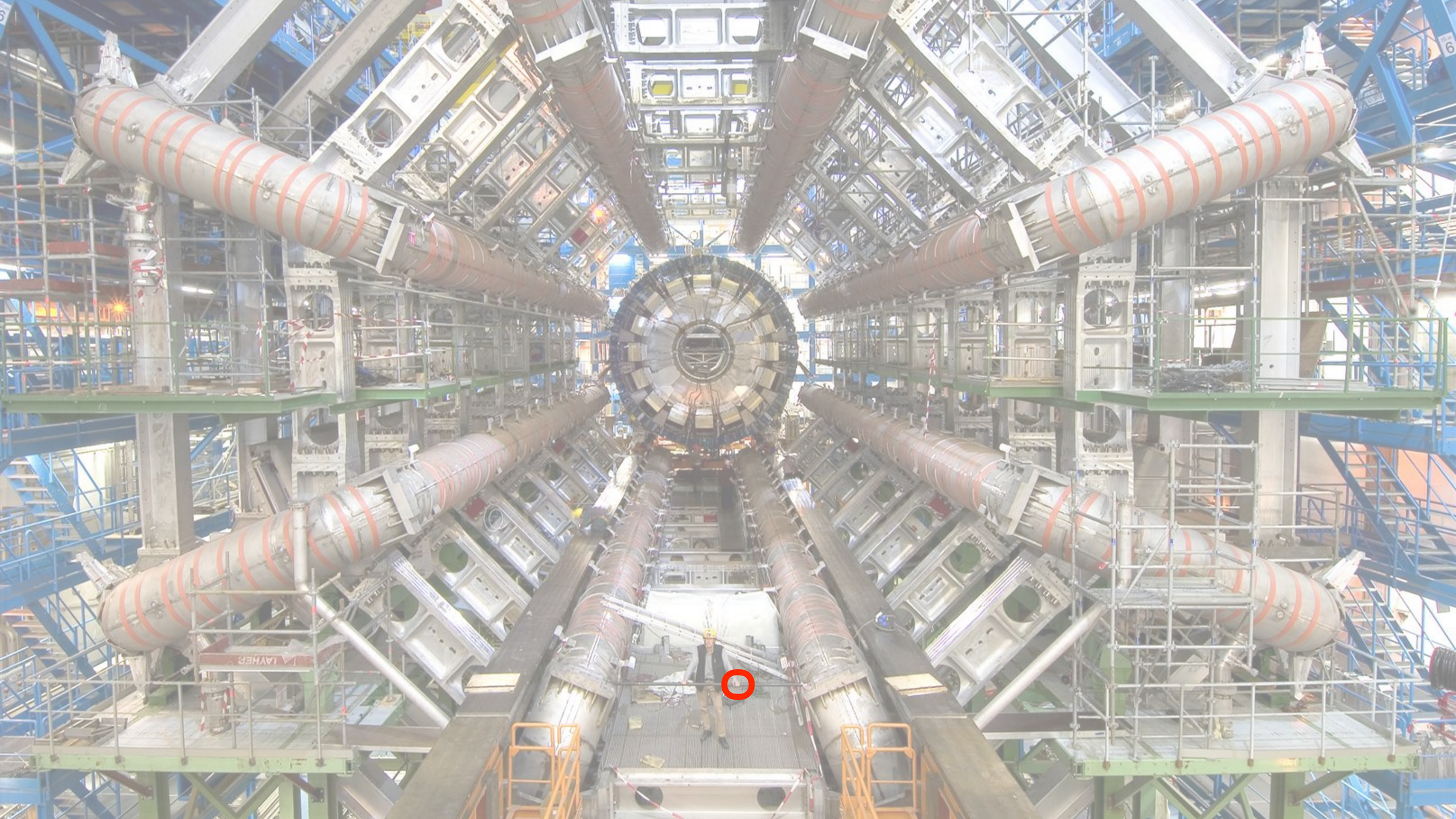

H1 observed
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Strain (10-21)

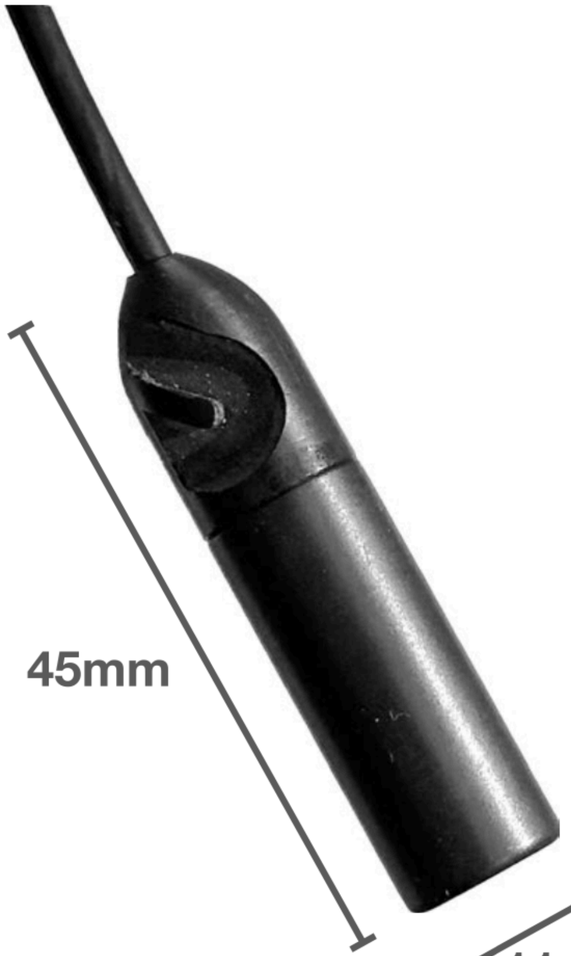

196
BKG
Ext. II. L.
Comm. II. L.
Obc. II.
Heriprost. L.
Ext. II. L. PET
[CPS]
T [s]

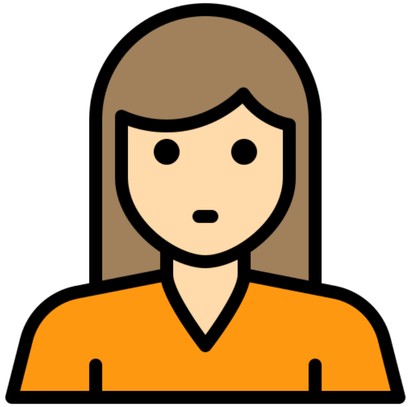

Events / GeV
√s = 7 TeV
√s = 8 TeV
Data - Fit

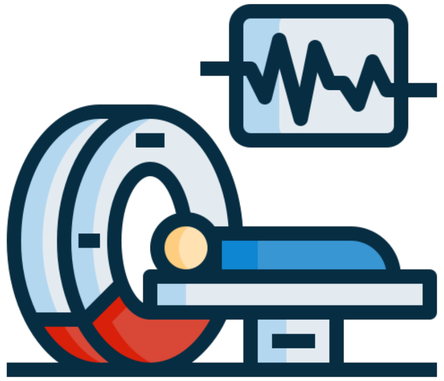

[CPS]
T [s]
196
BKG
Ext. Il. L.
Comm. Il. L.
Ext. Il. L. PET

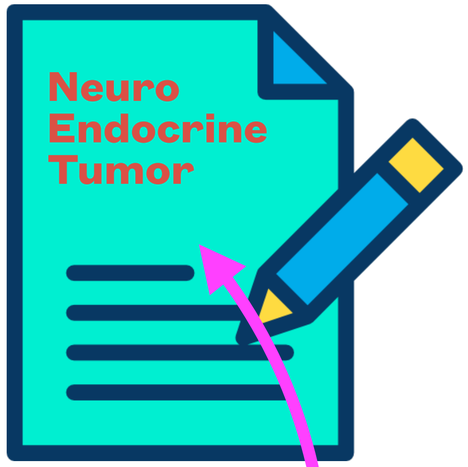

A



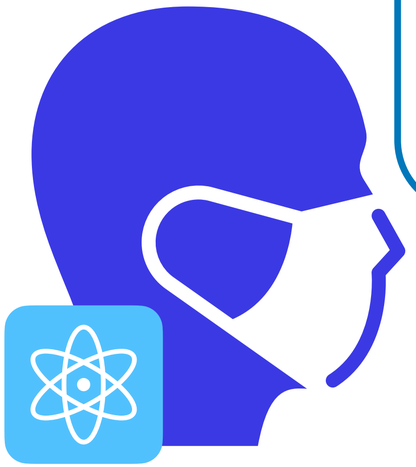

45mm
11mm





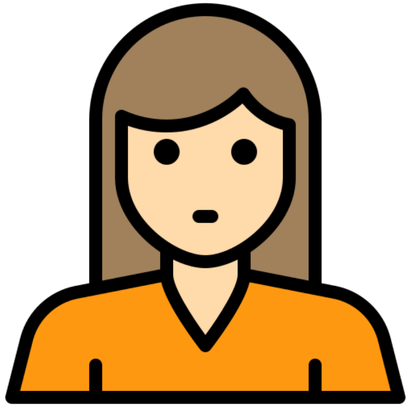


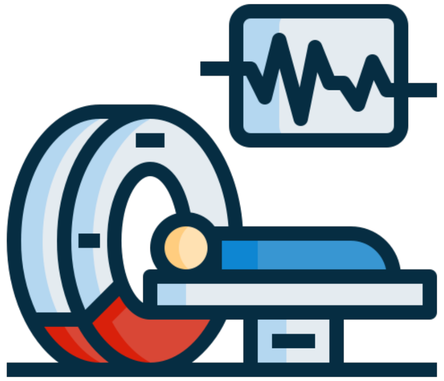
How can I remove the **whole** tumor?

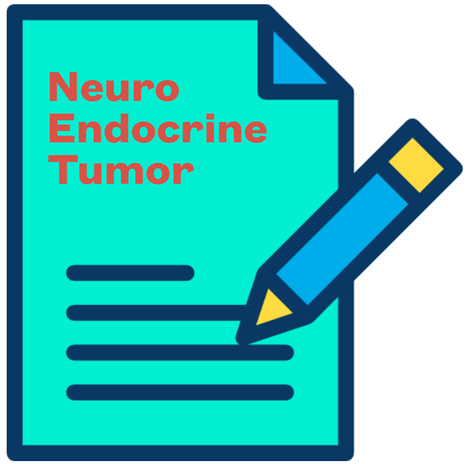


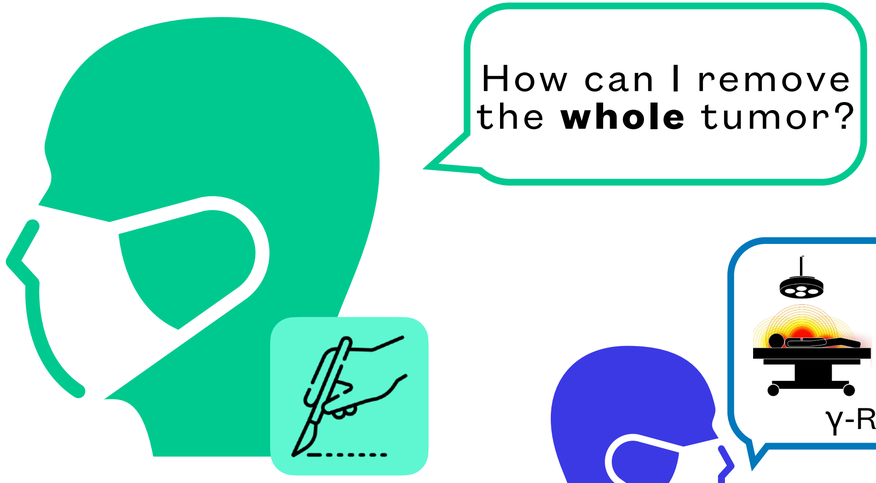
γ-RGS

~1-10cm

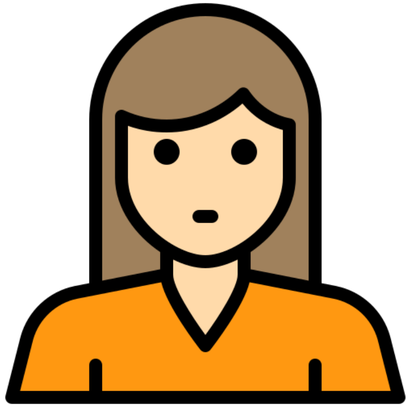


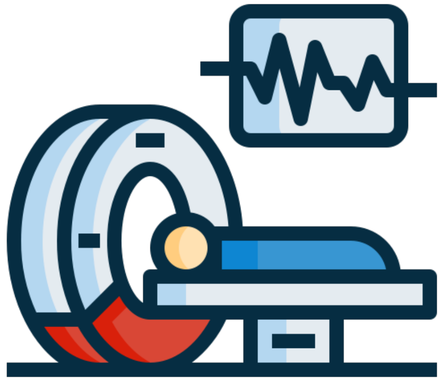


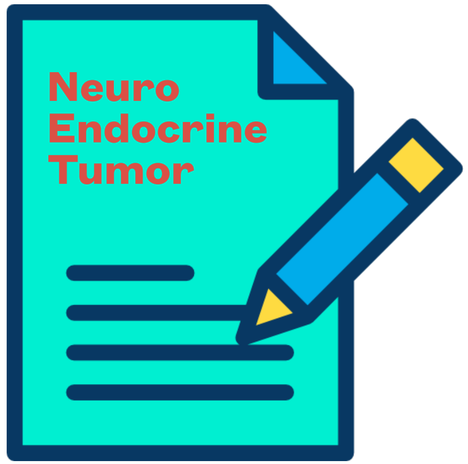

Neuro
Endocrine
Tumor


How can I remove the **whole** tumor?


γ-RGS

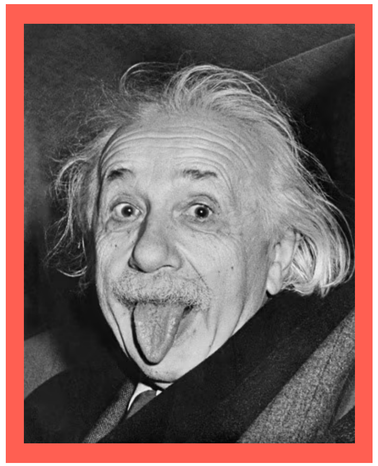






How can I remove the **whole** tumor?

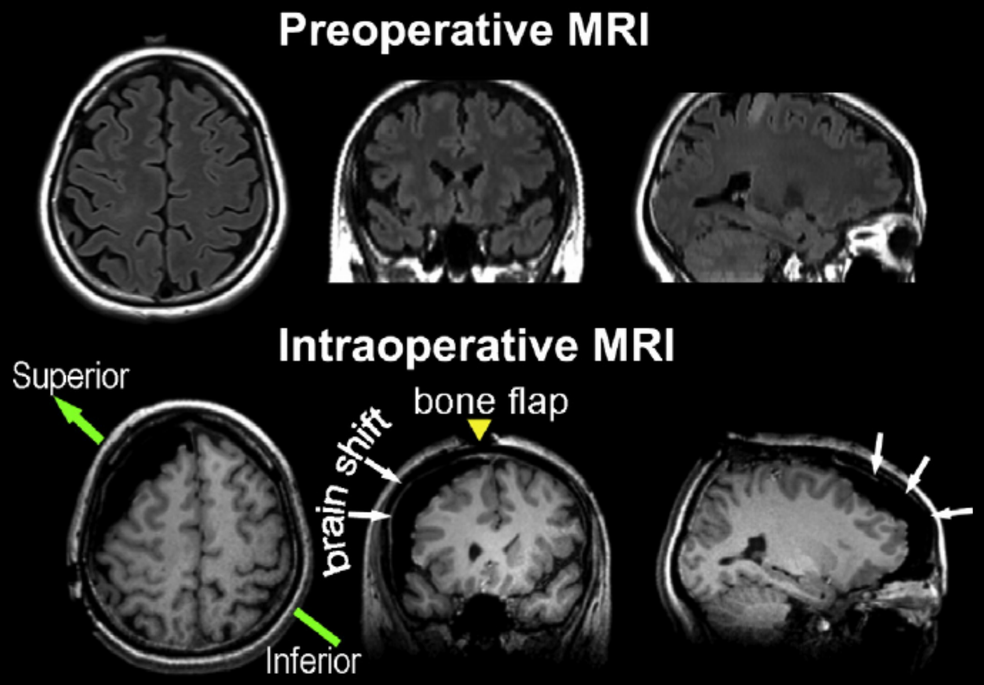
β-RGS!



~1-10cm →~1-10mm

Incredible amount of information is available **before** surgery

But then.... ***during*** surgery:



Radio Guided Surgery

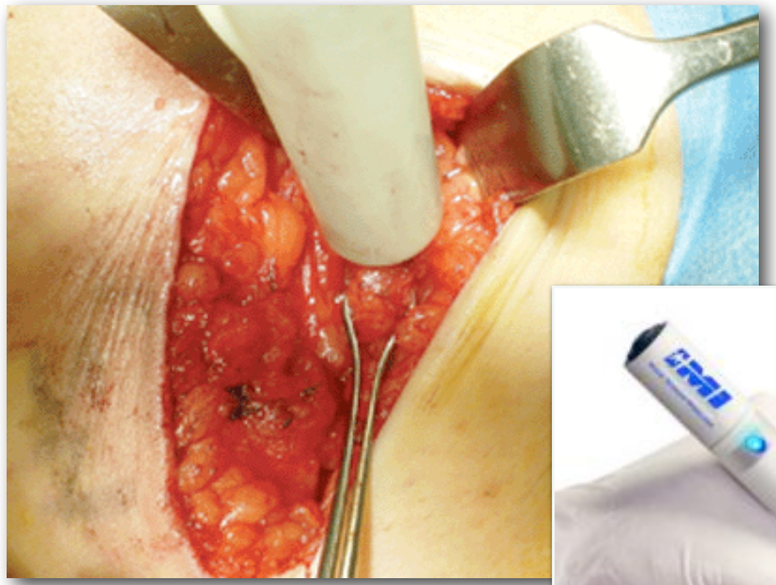
PROBLEM How to help the surgeon to completely remove the tumor?

Intra-operative Magnetic Resonance

PROBLEM How to help the surgeon to completely remove the tumor?

→ **Radio Guided Surgery**

- Before surgery, a radioactive tracer (e.g. ^{99m}Tc) is administered to the patient
  - ➡ It reaches tumor cells, that thus become source of radiation

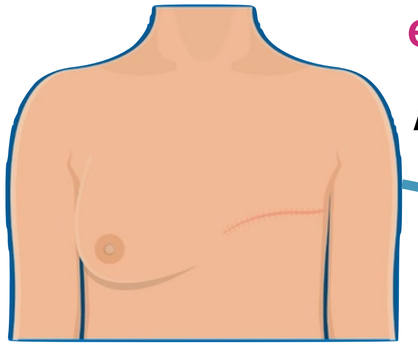


- During surgery, the surgeon uses a handeld radiation detector to identify the emission hotspots
  - ➡ Suggesting the possible presence of tumor residual

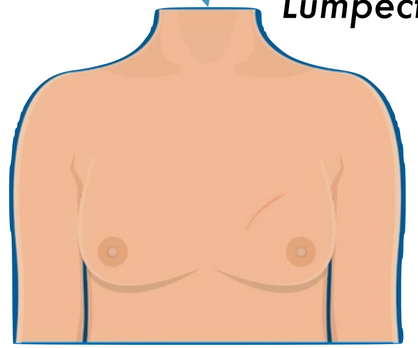
Radio Guided Surgery

Massive improvement in patients outcome

e.g. in breast surgery



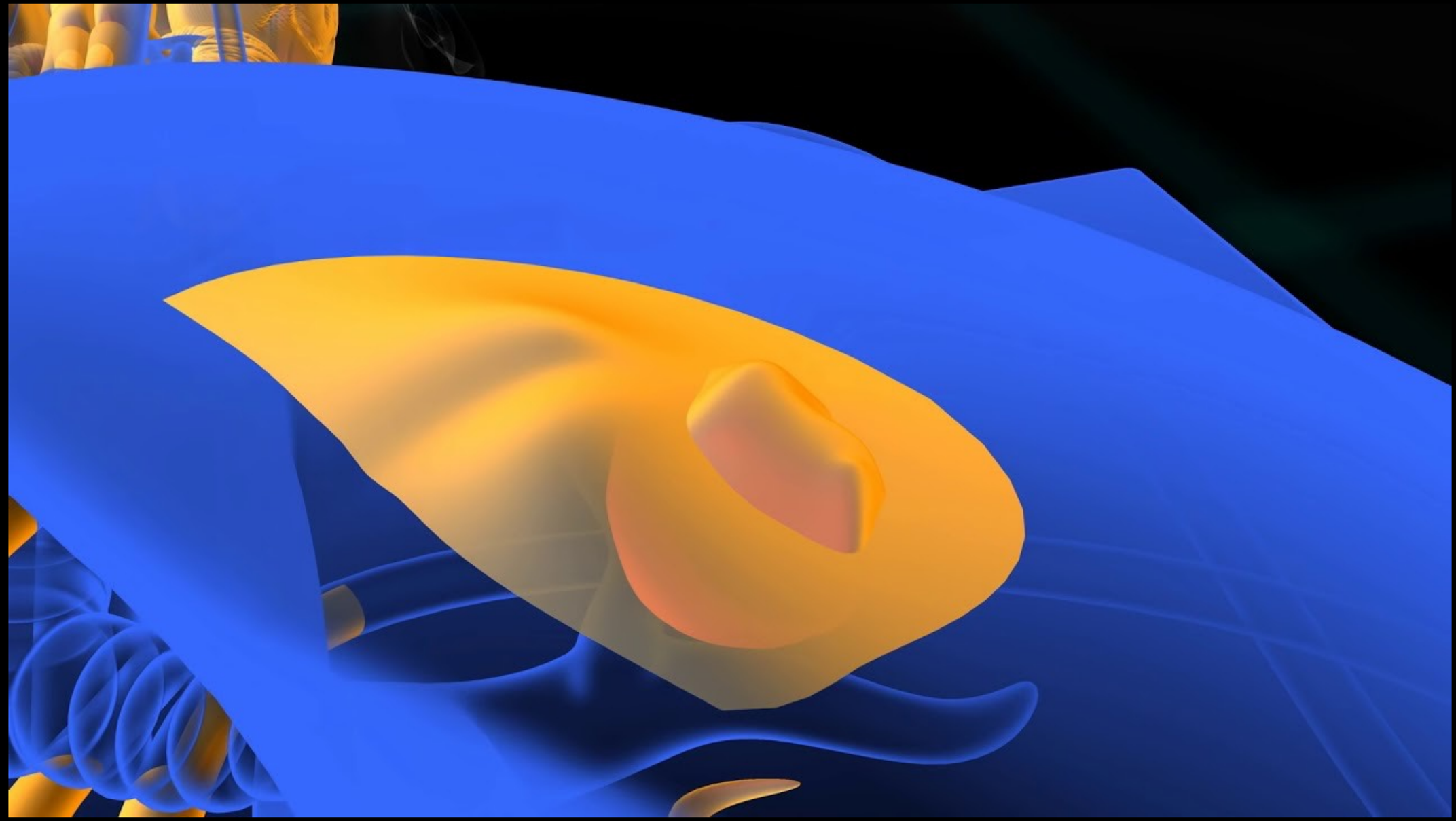
Mastectomy



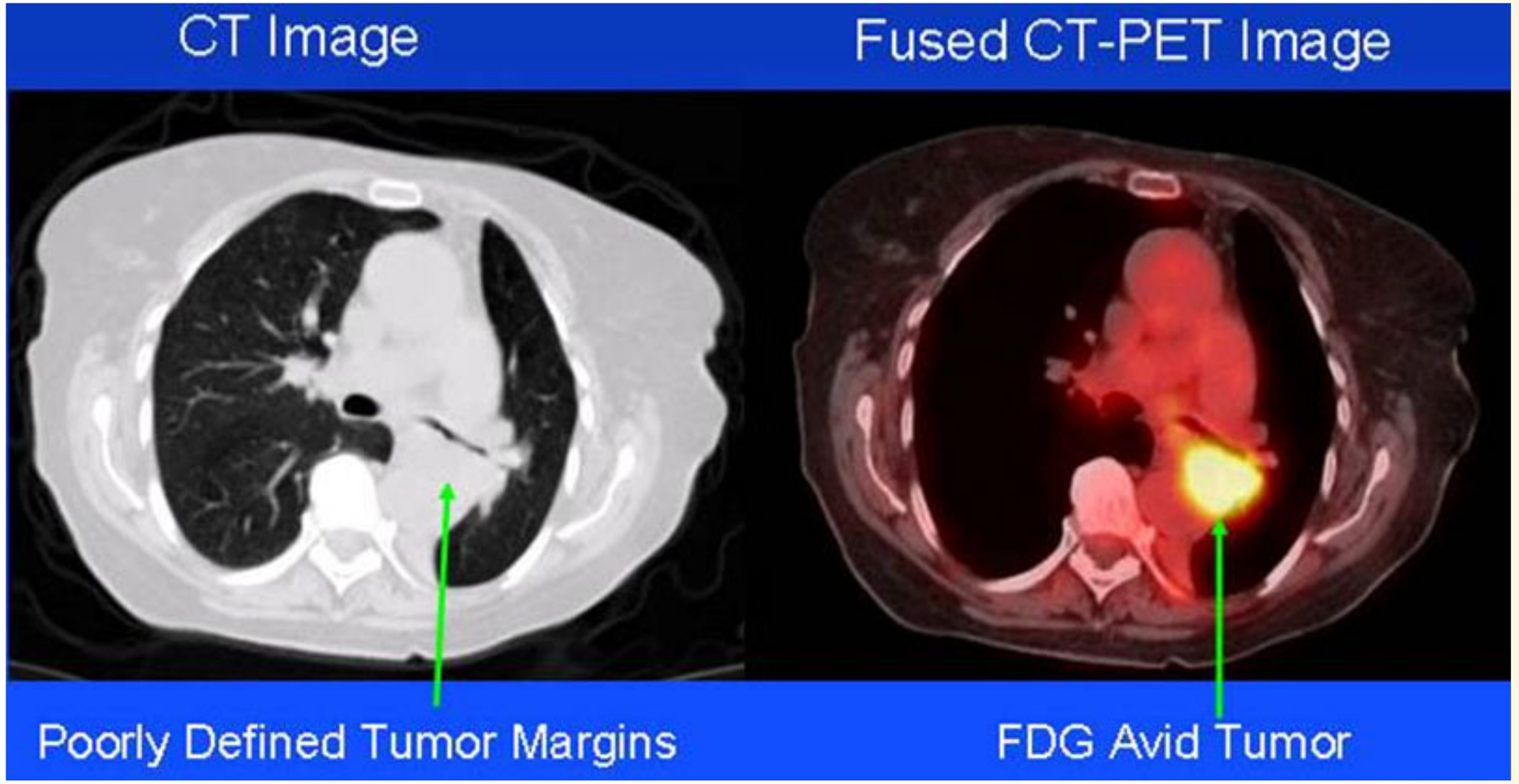
Lumpectomy

The Rise of PET Imaging

The Rise of PET Imaging



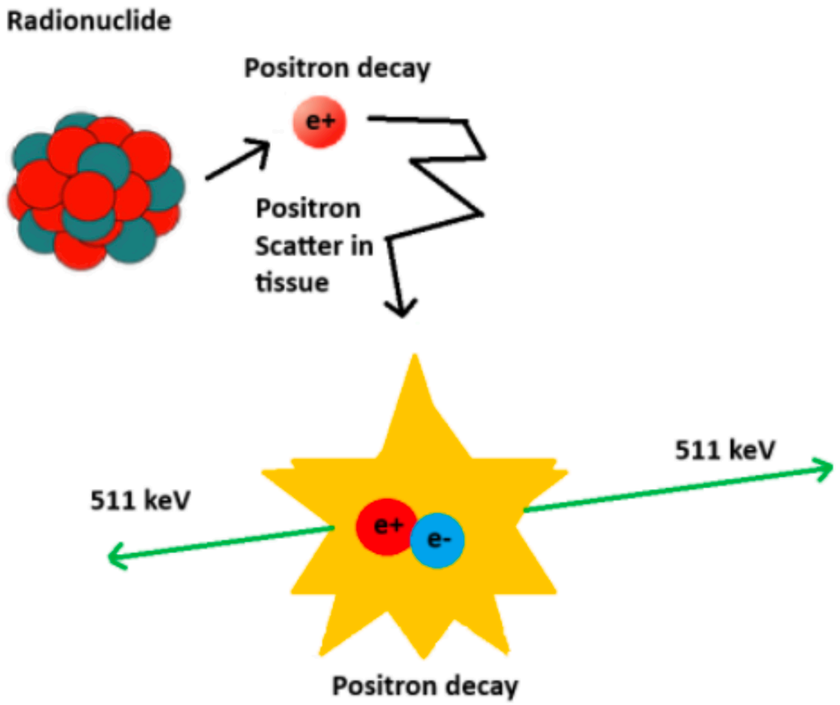
The Rise of PET Imaging

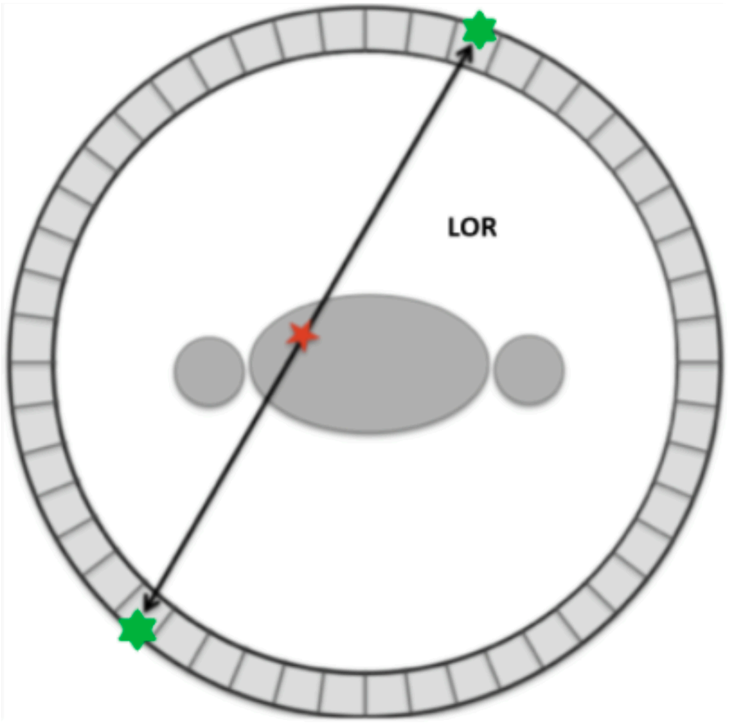


➡High Resolution
➡Functional Imaging

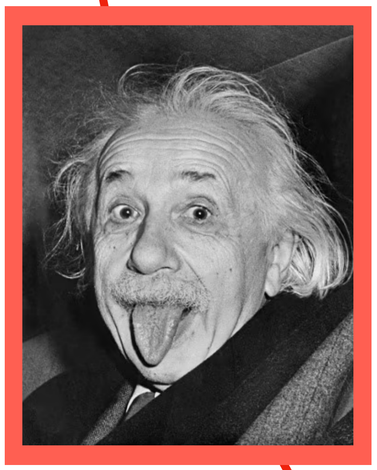
β^+ tracers

β+ tracers

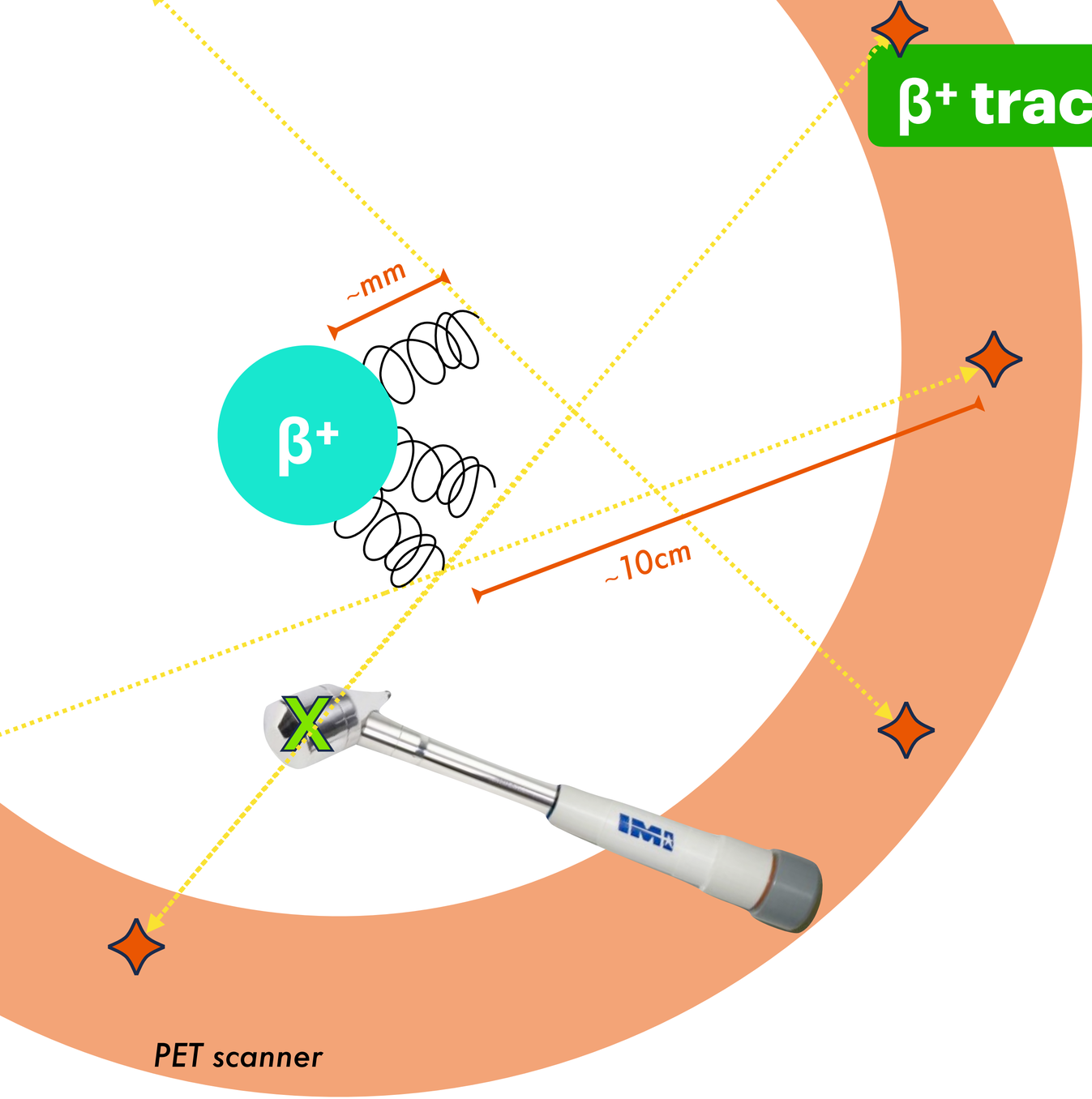




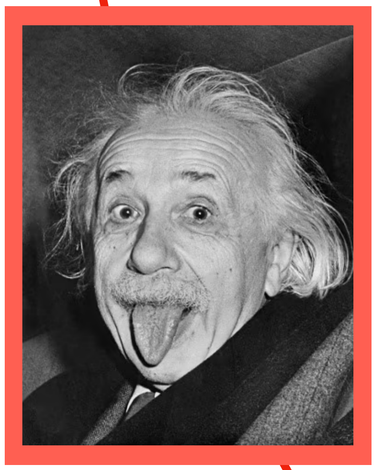
Stunning results on
pre-operative imaging...



Why not also
intra-operatively?



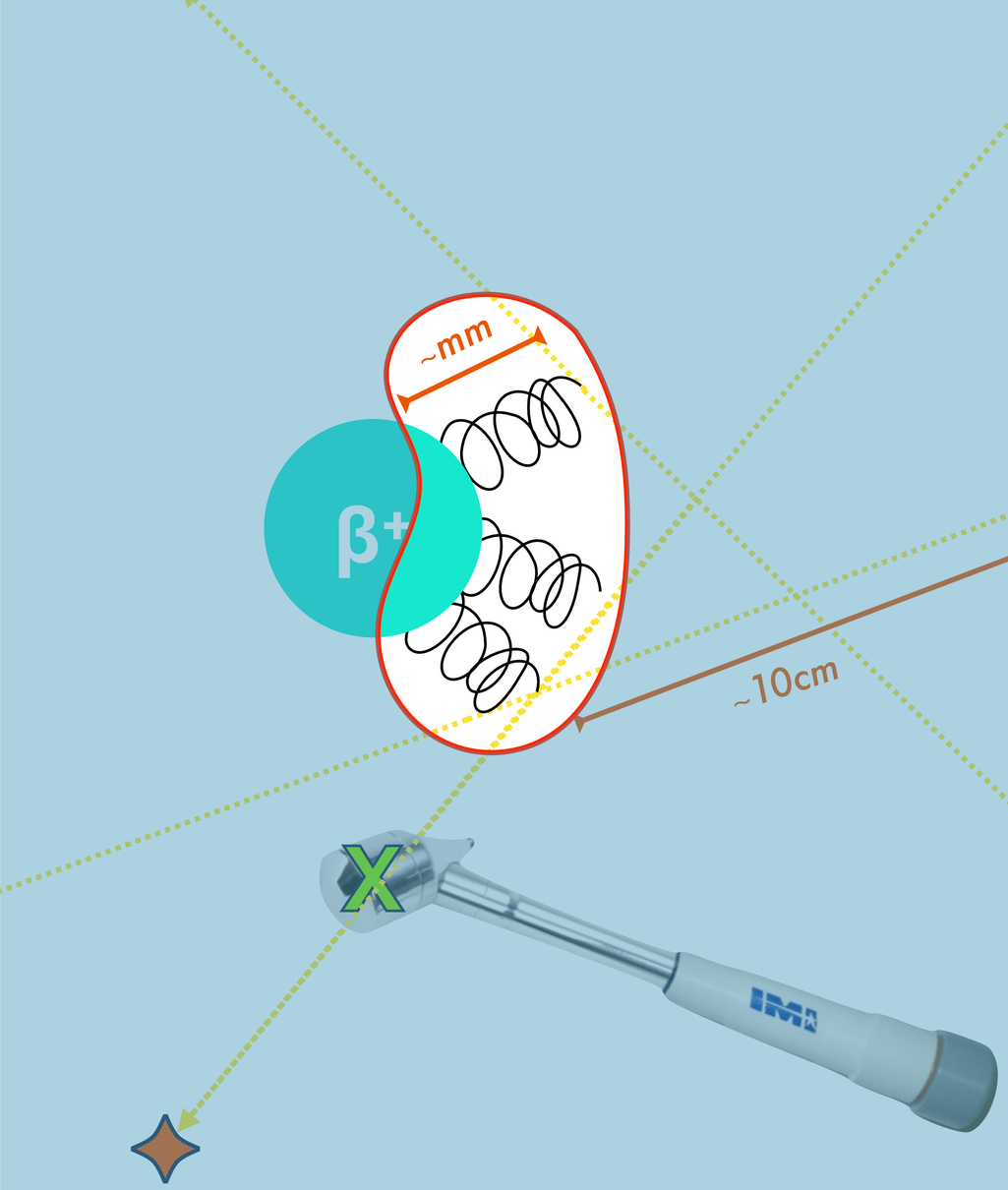
Stunning results on pre-operative imaging...

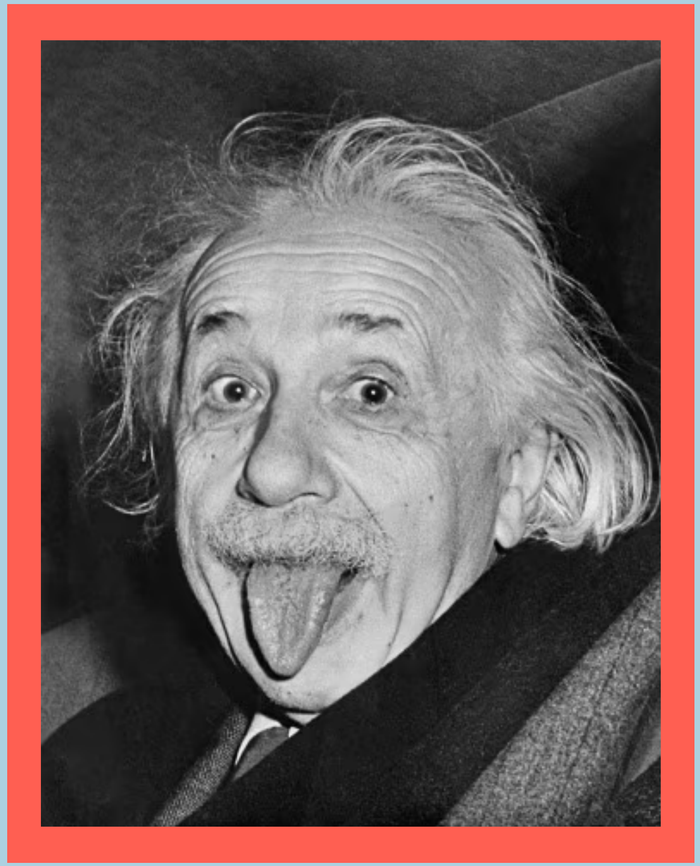


Why not also intra-operatively?

β+ tracers

Why not also intra-operatively?





β+ tracers

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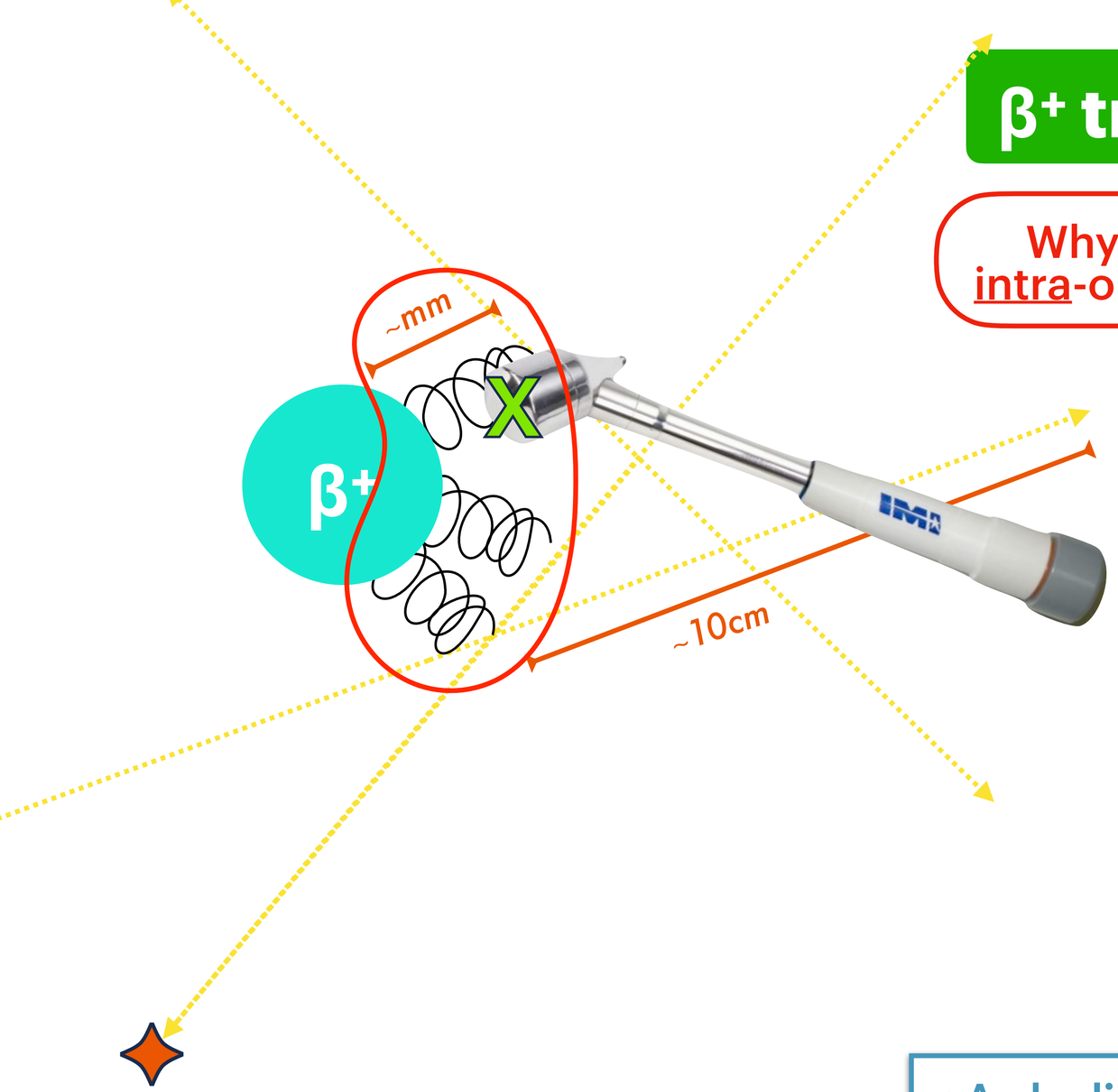
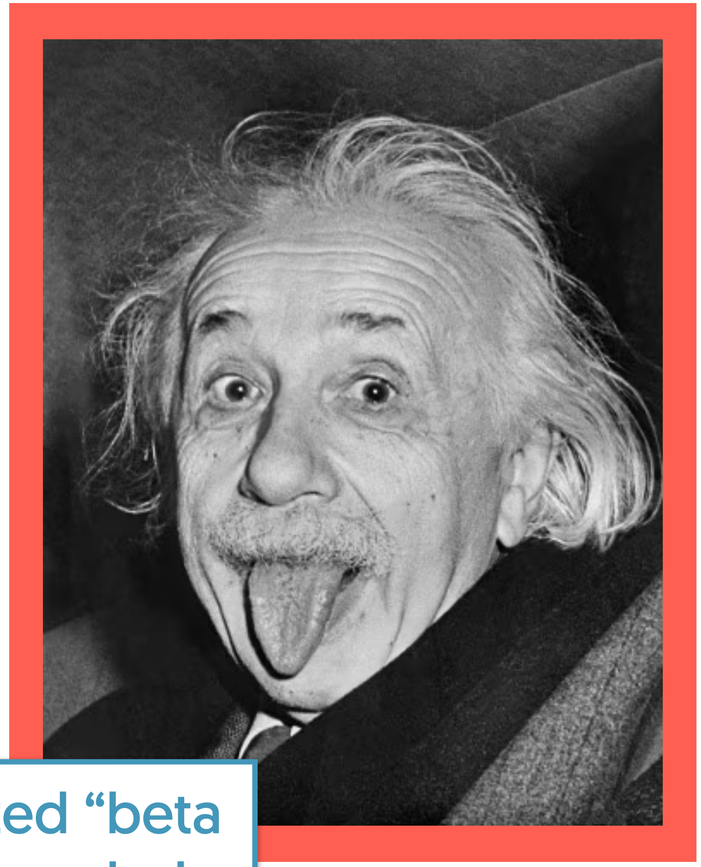
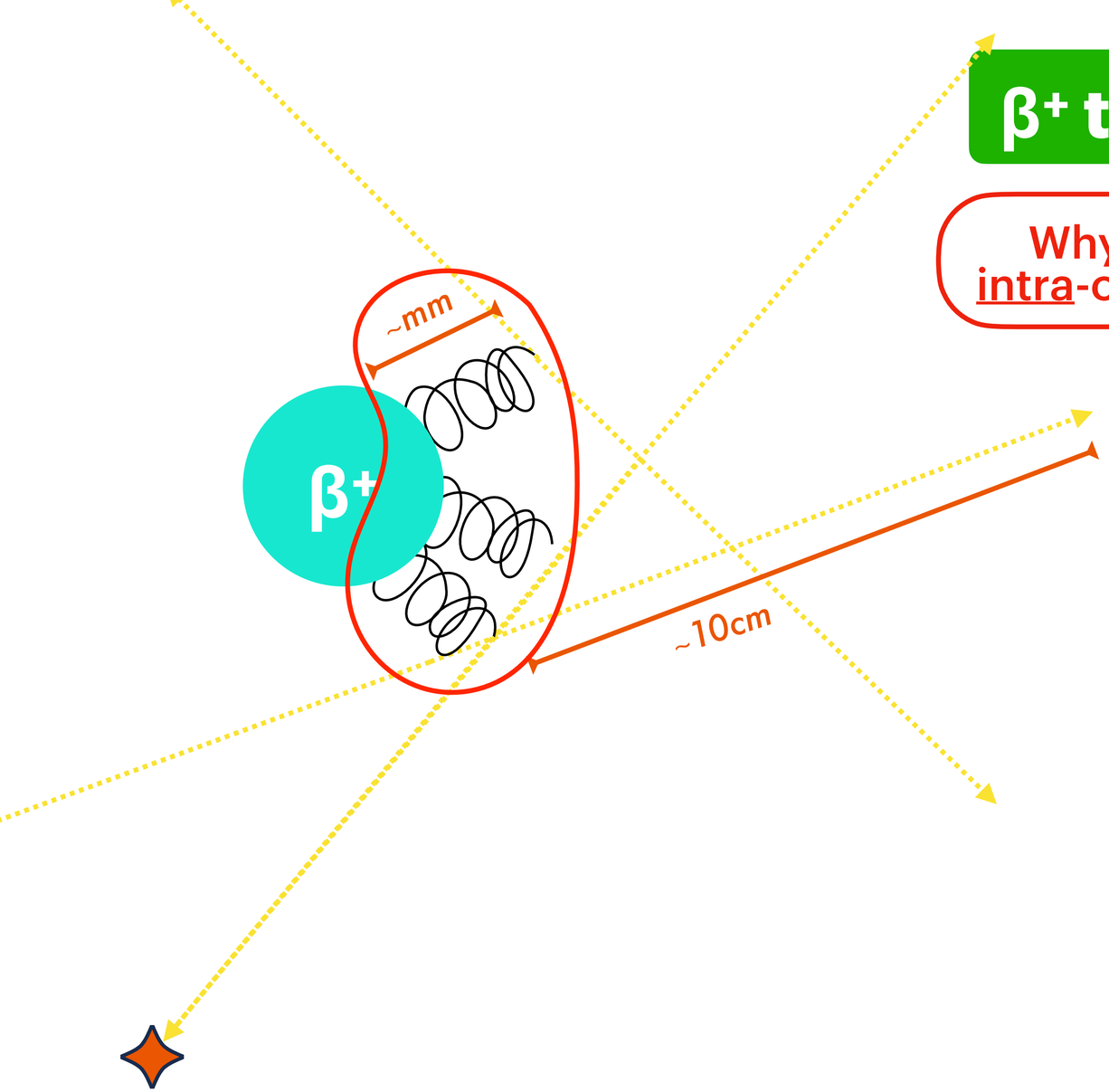




➡A dedicated “beta probe” is needed



β+ tracers

Why not also intra-operatively?

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Fun Fact: nothing new!

- “Dual approach”: β = β + γ - γ
- Low efficiency + non trivial electronics
- Huge size

β+ tracers

Why not also intra-operatively?

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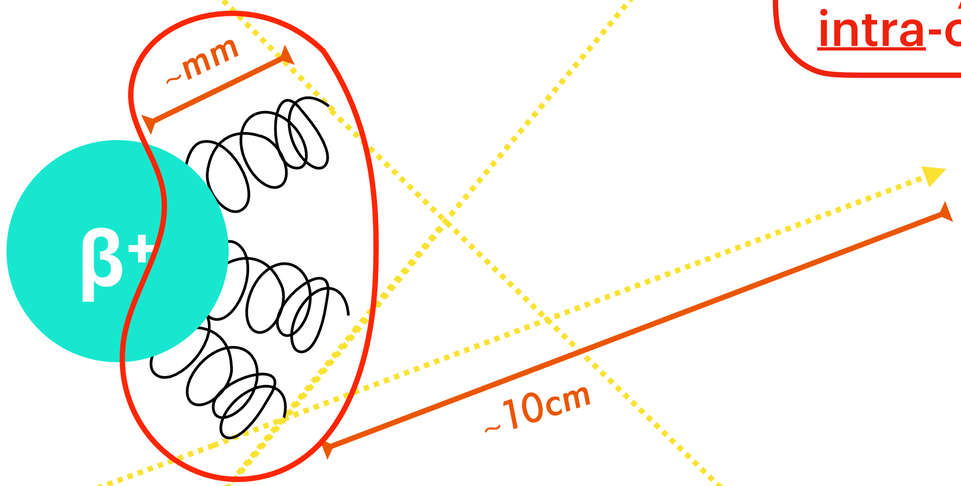

Fun Fact: nothing new!

- “Dual approach”: β = β + γ - γ
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- Using ^{32}P (τ=14d) 😳
- Geiger Counter ⚡⚡

β+ tracers

Why not also intra-operatively?

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Fun Fact: nothing new!

β+

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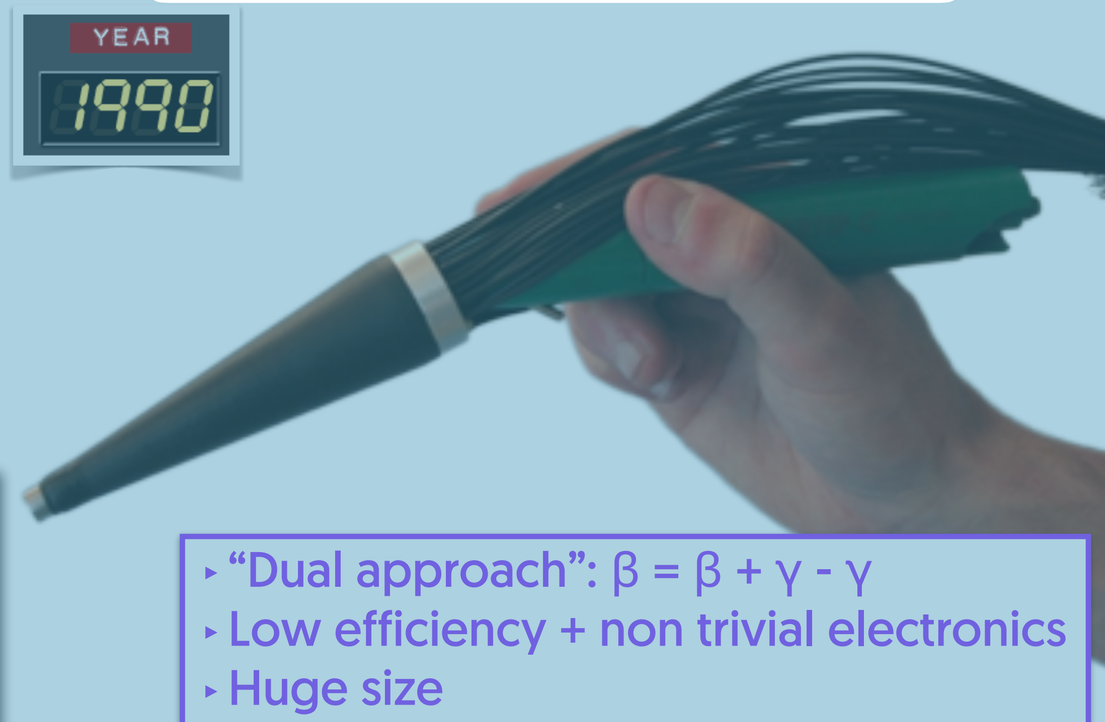

- “Dual approach”: $\beta = \beta + \gamma - \gamma$
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β+ tracers

Why not also intra-operatively?

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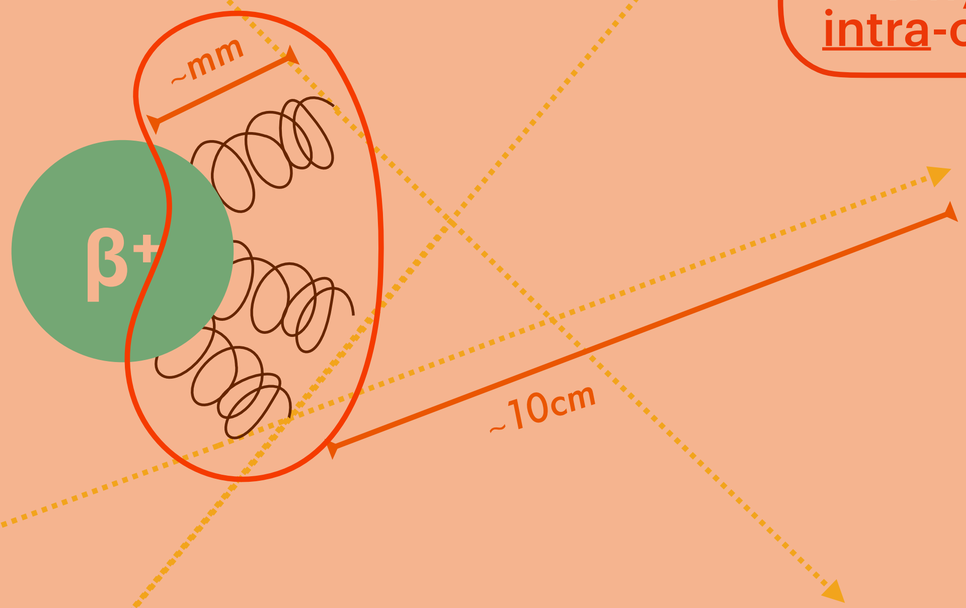

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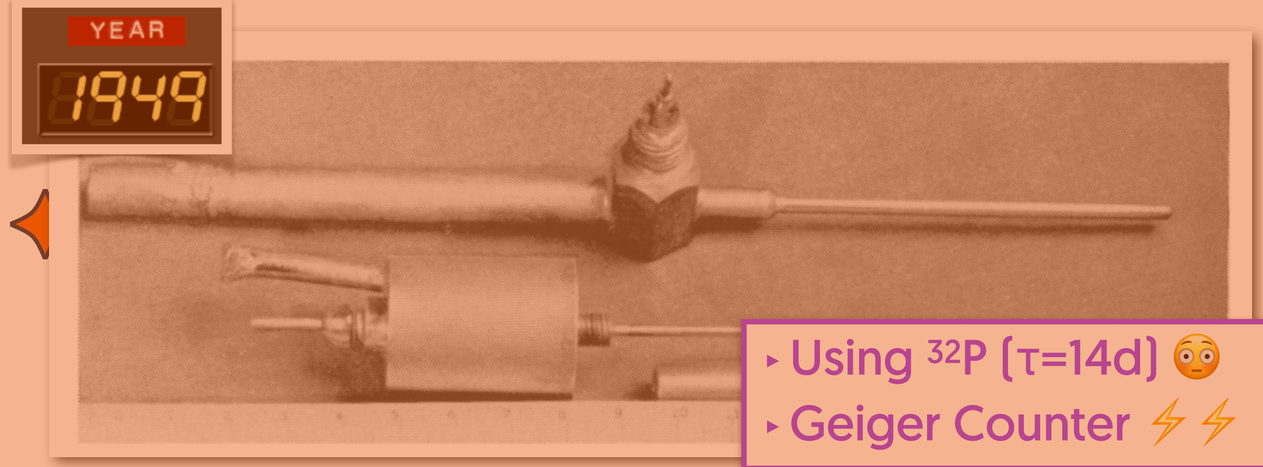
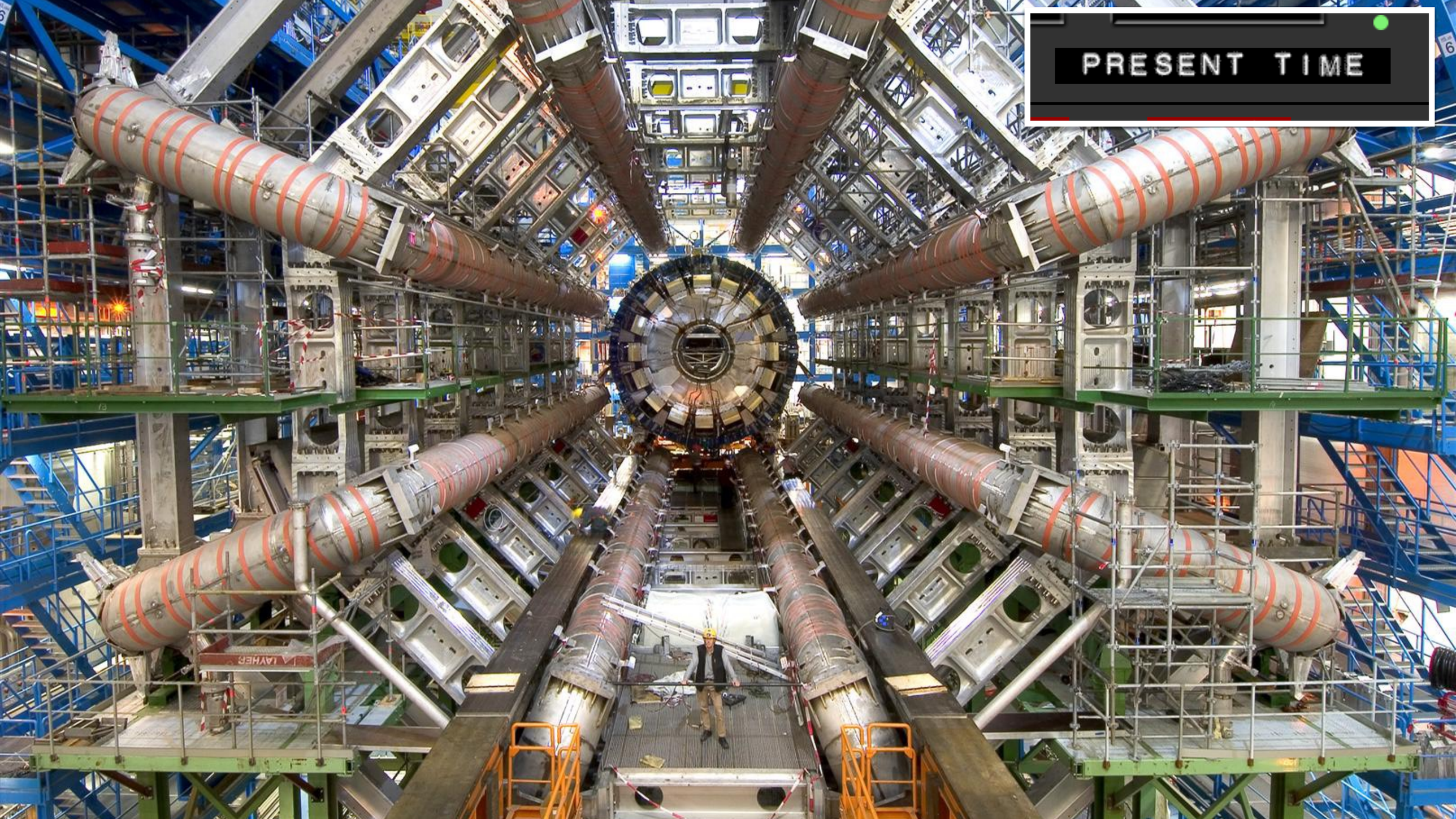
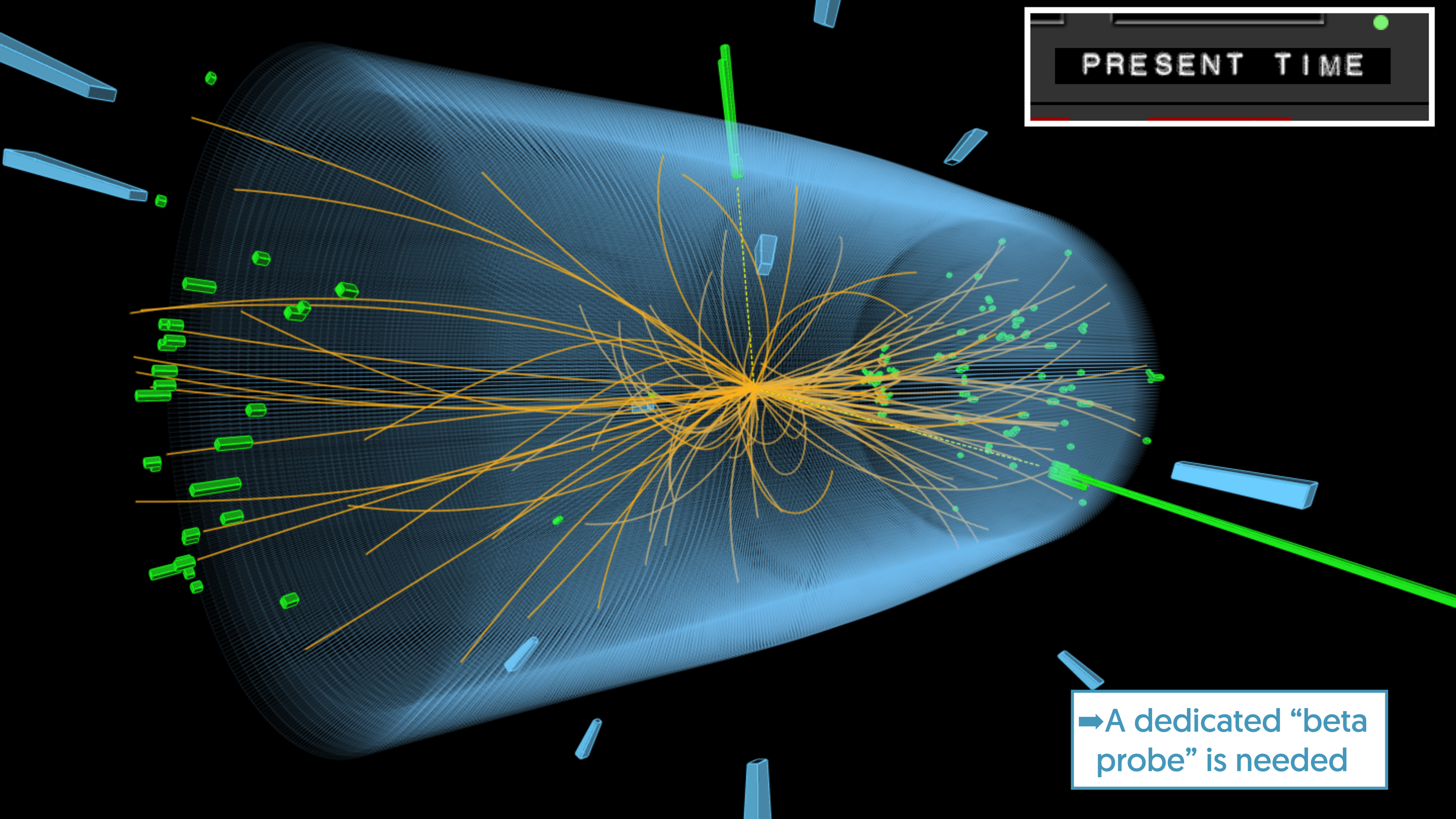
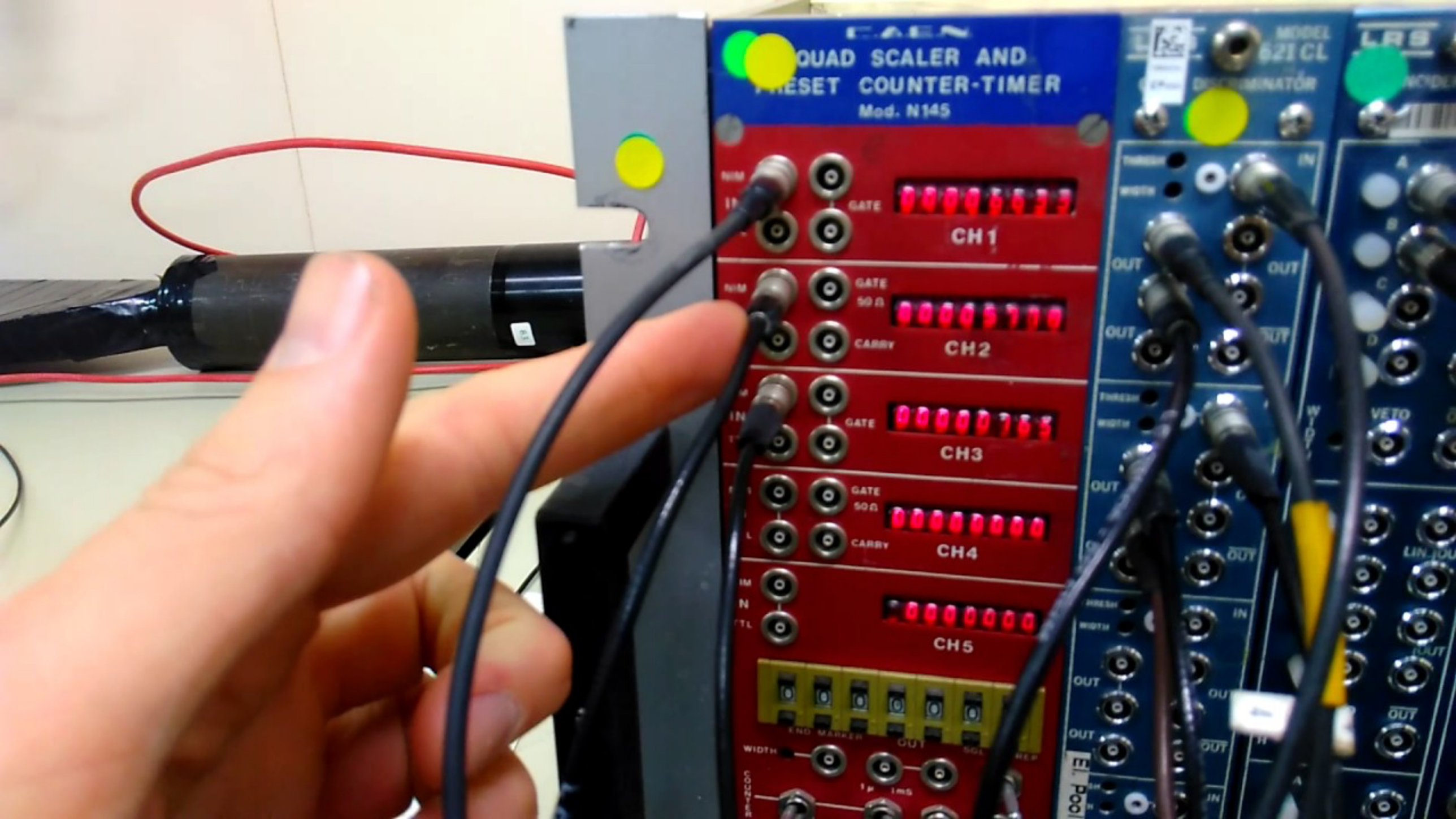


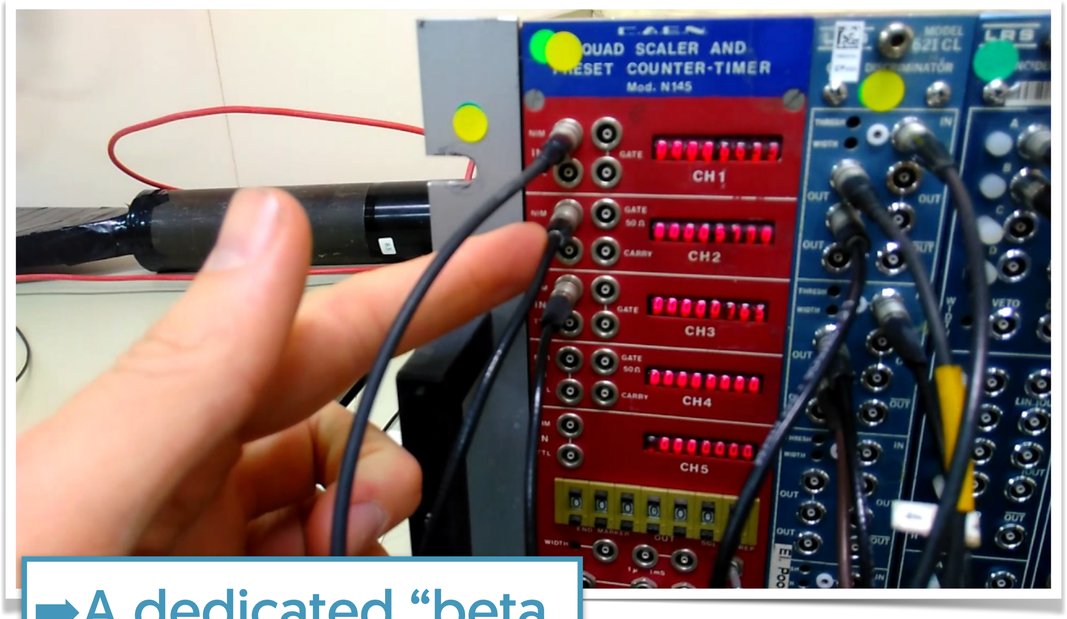
- Using ^{32}P (τ=14d) 😳
- Geiger Counter ⚡⚡


PRESENT TIME



➡A dedicated “beta probe” is needed


QUAD SCALER AND
PRESET COUNTER-TIMER
Mod. N145
GATE
CH1
GATE
50 Ω
CARRY
CH2
GATE
CH3
GATE
50 Ω
CARRY
CH4
CH5
WIDTH
MODEL
621 CL
LRS
VETO



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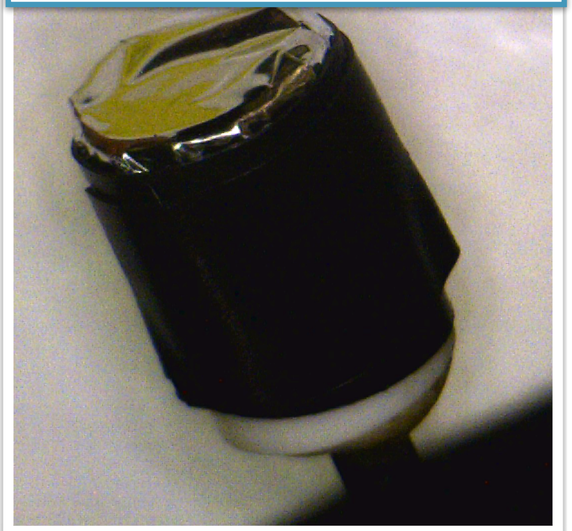
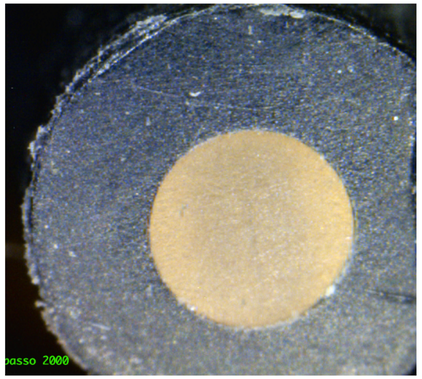
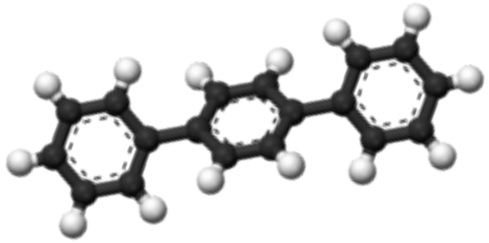


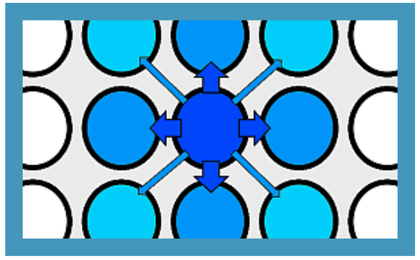


- Use p-terphenyl as detector element
  - Heat storage, opto-electronics, sunscreen lotions!
  - Wavelength shifter, doping component for liquid scintillators



Aromatic hydrocarbon isomer

$C_{18}H_{14}$



- High light yield (140% Antracene)
- Low density ($1.2\ g/cm^3$)

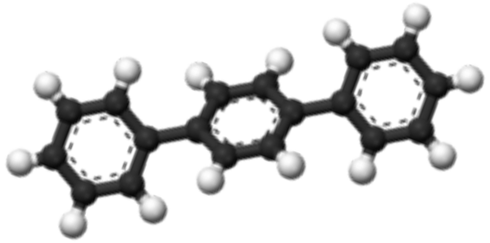
➡High sensitivity to charged particles

➡Intrinsic transparency to γ

How does it perform as β particles detector?

How does it perform as β particles detector?

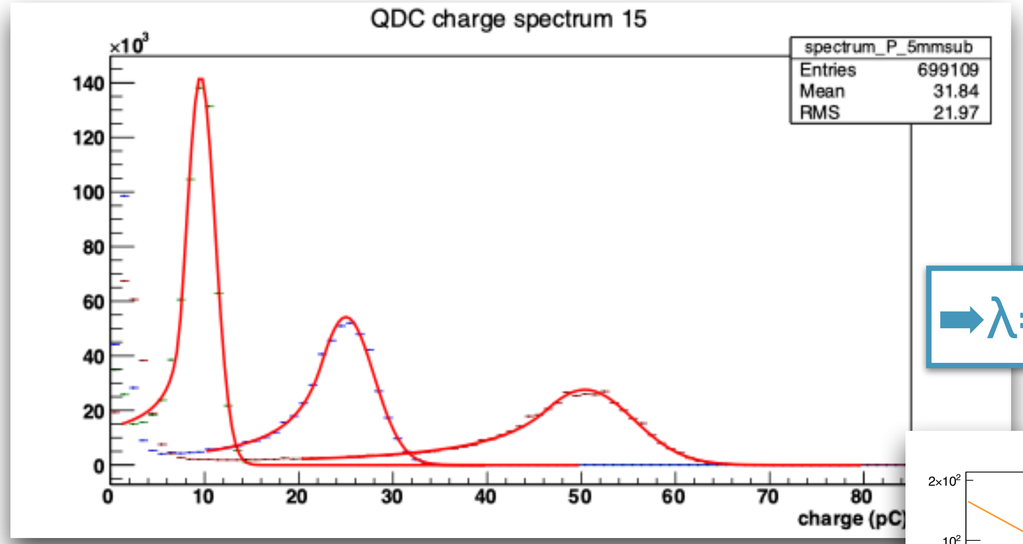
- Use p-terphenyl as detector element



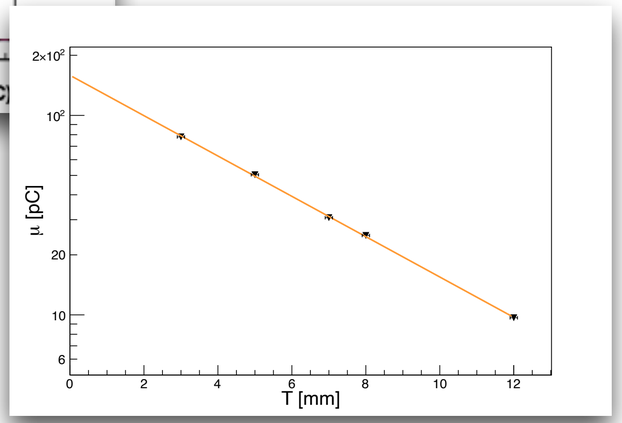
Aromatic hydrocarbon isomer

$C_{18}H_{14}$

- Scintillation Light Attenuation Length -



➡λ=(4.73±0.06)mm



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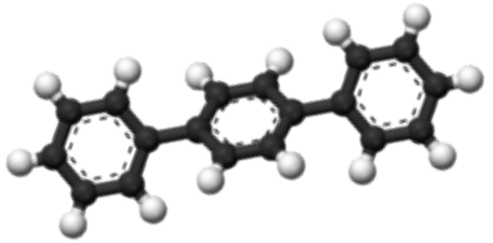
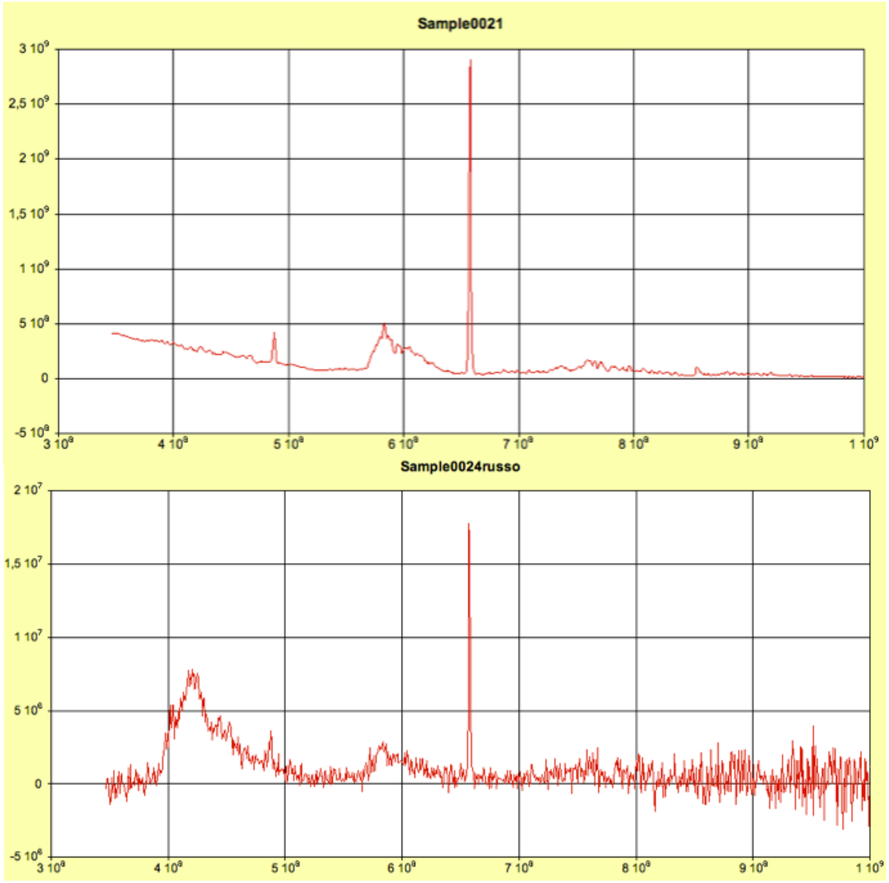


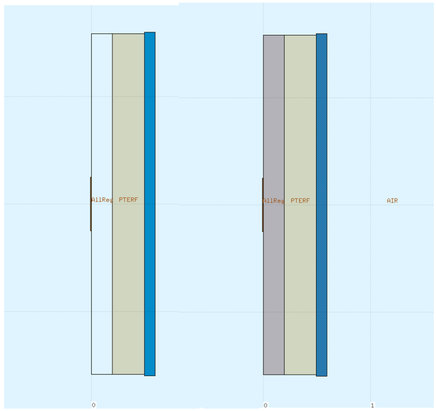
Aromatic hydrocarbon isomer

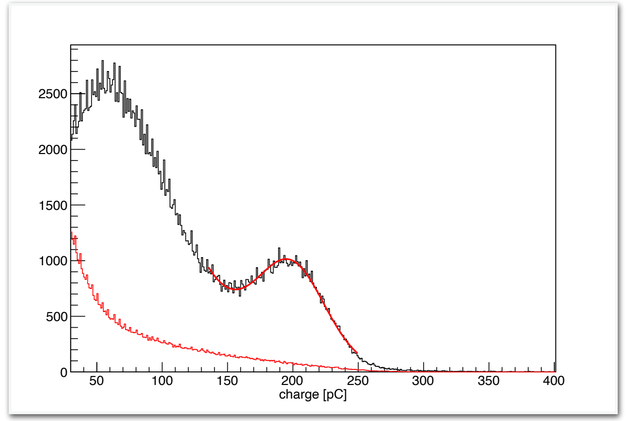
$C_{18}H_{14}$

- Scintillation Light Spectrum -

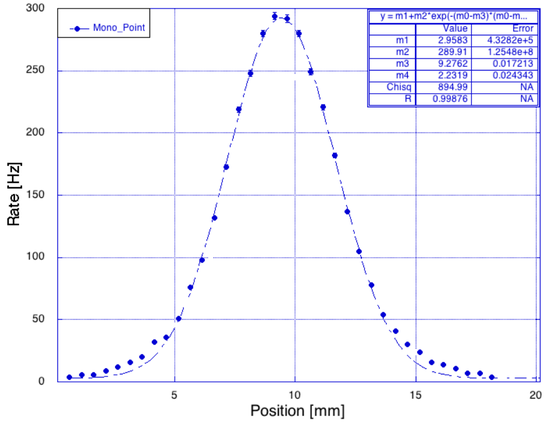


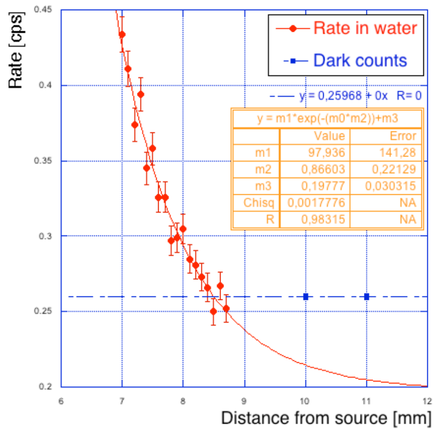
- β/γ Discrimination -





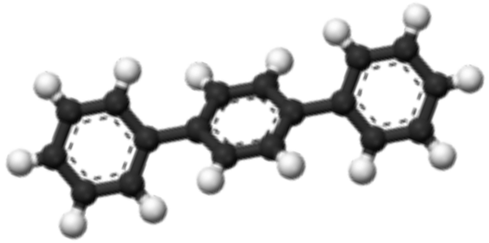
- Field of View -





How does it perform as β particles detector?

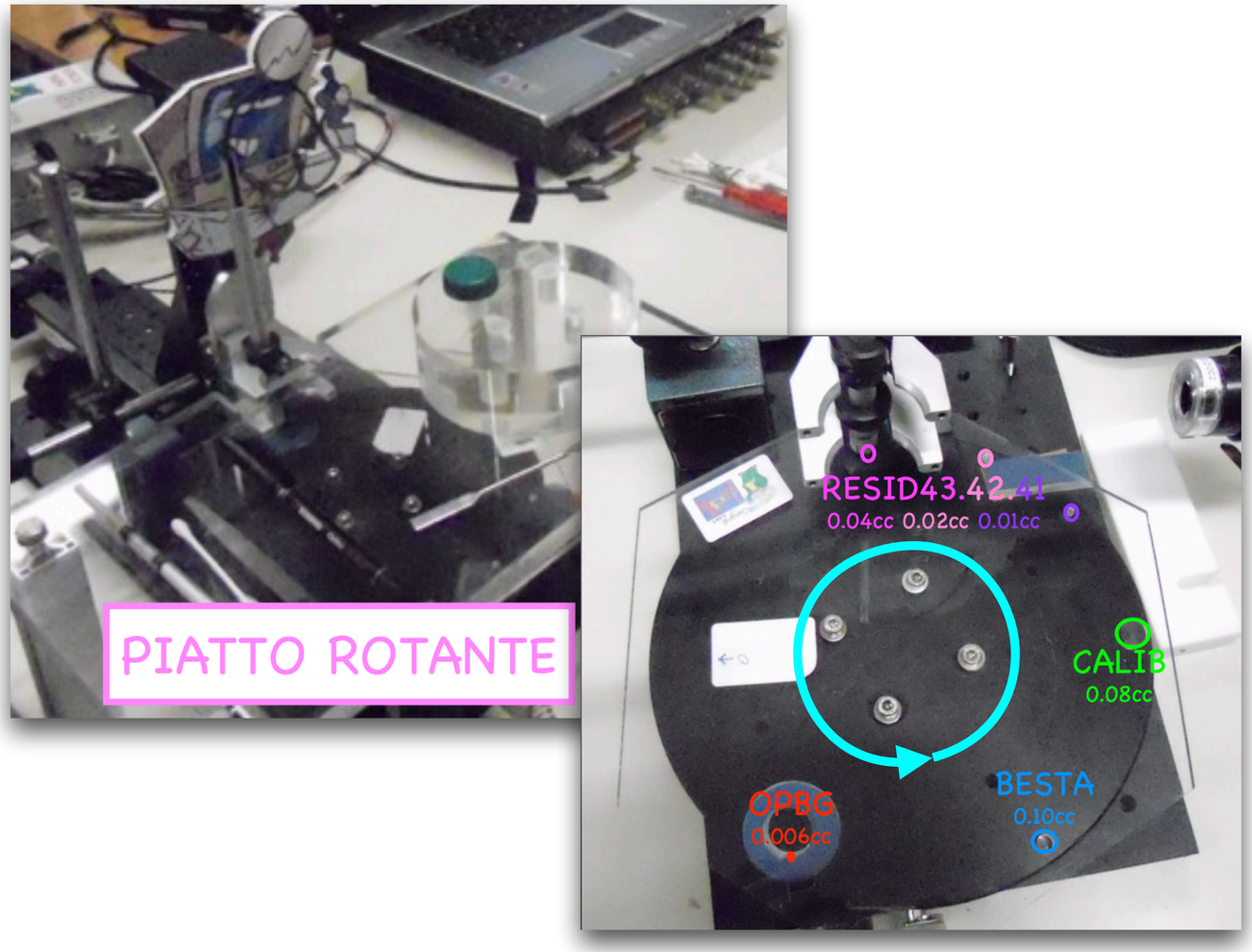
- Use p-terphenyl as detector element

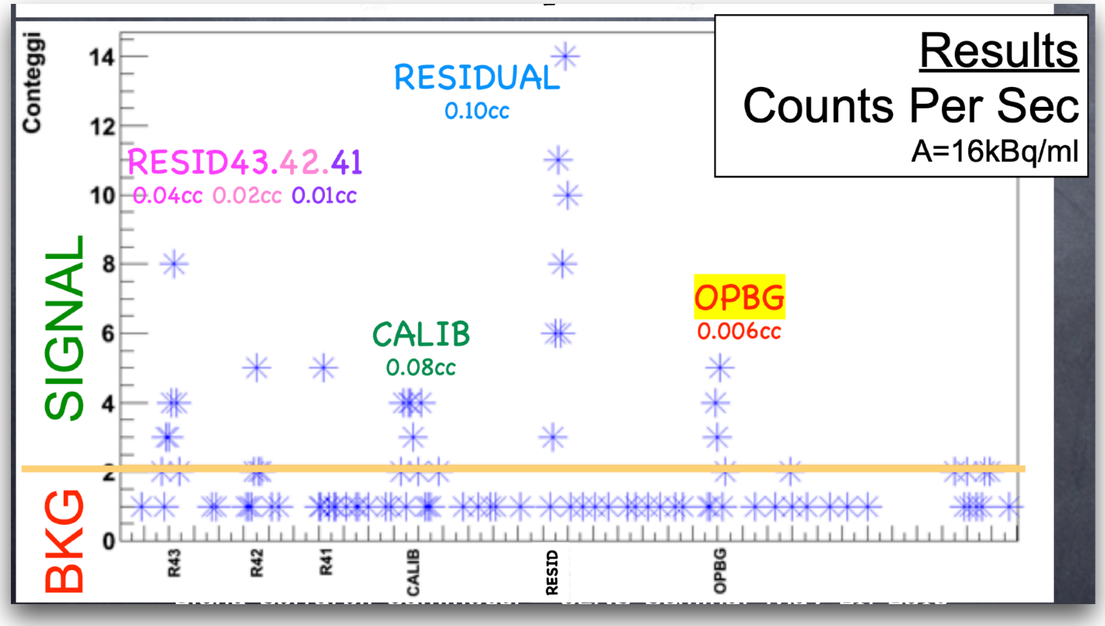


Aromatic hydrocarbon isomer

$C_{18}H_{14}$

- First Phantom Tests -





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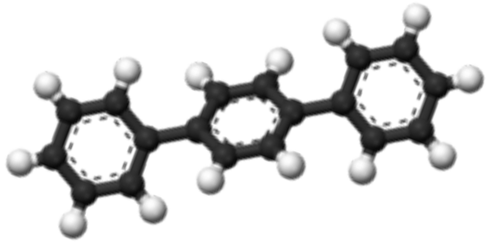
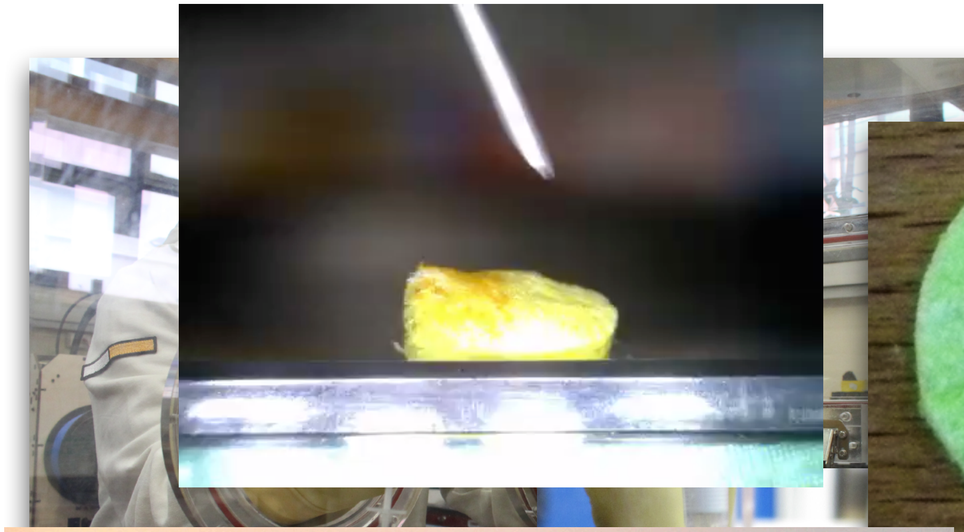
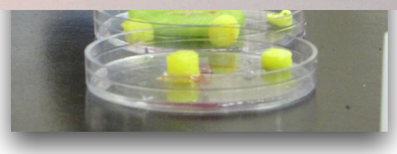


Aromatic hydrocarbon isomer

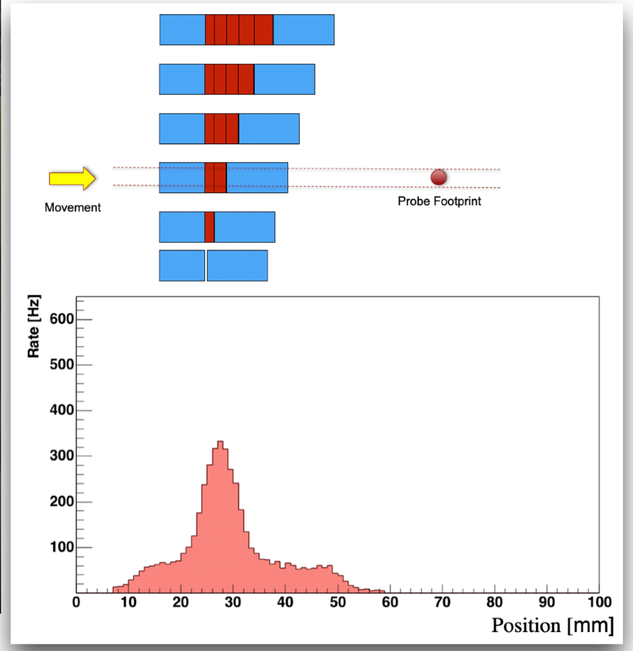
$C_{18}H_{14}$

- First Phantom Tests -





Do It Yourself



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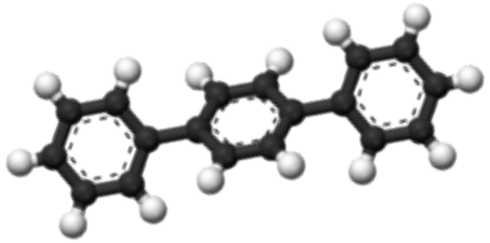
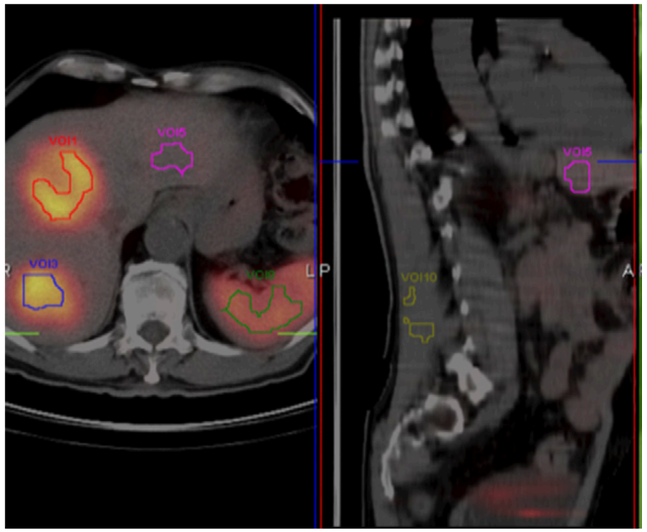
- Use p-terphenyl as detector element

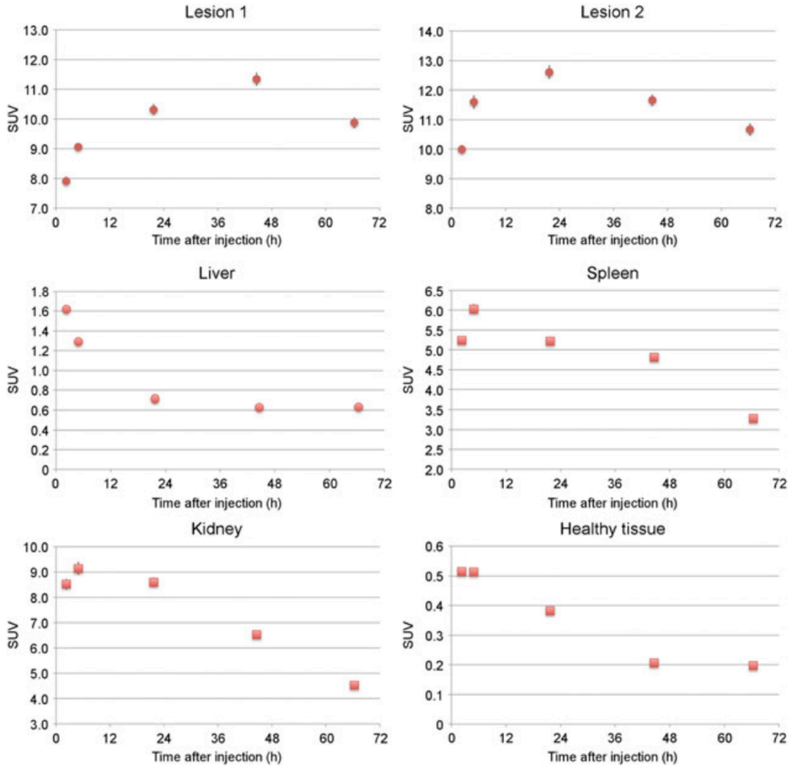


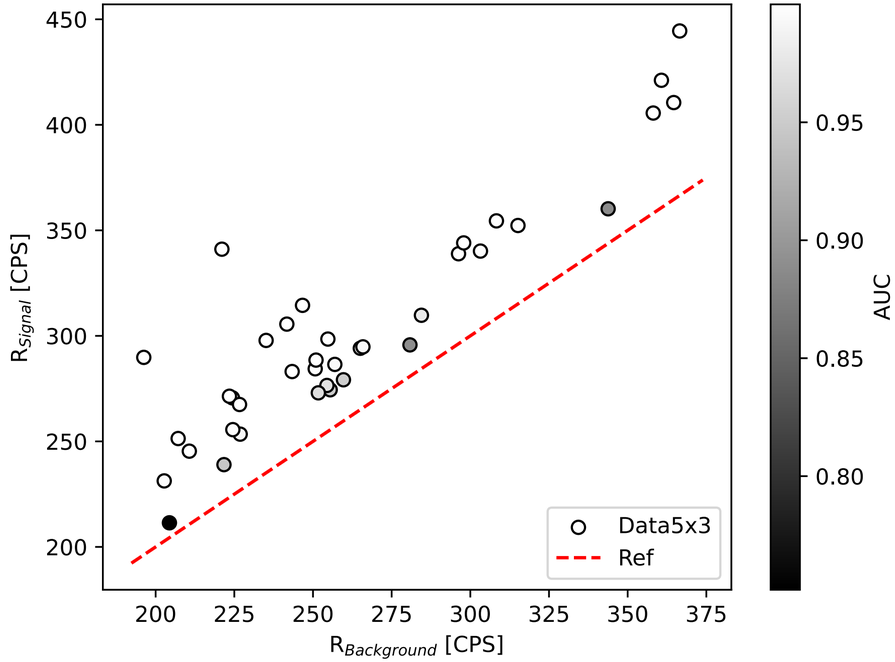
Aromatic hydrocarbon isomer

$C_{18}H_{14}$

- Use Cases Selection -

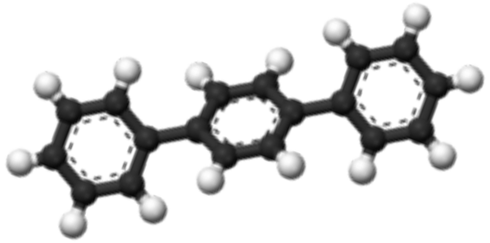






How does it perform as β particles detector?

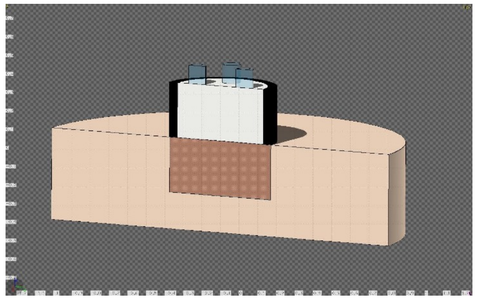
- Use p-terphenyl as detector element

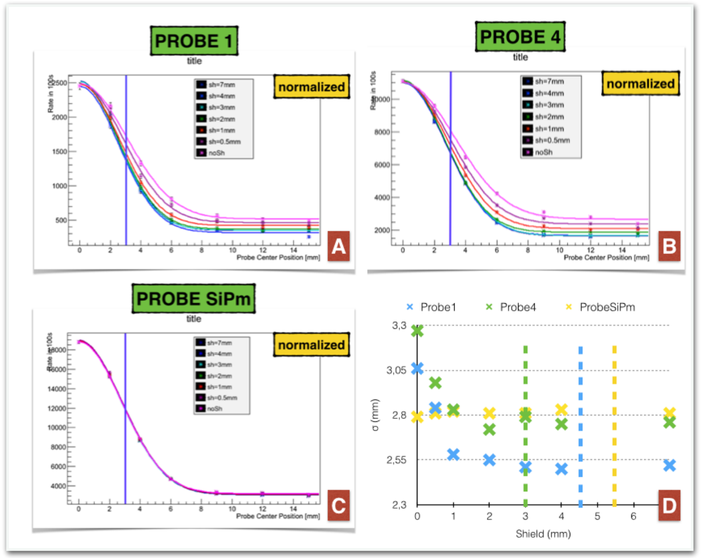


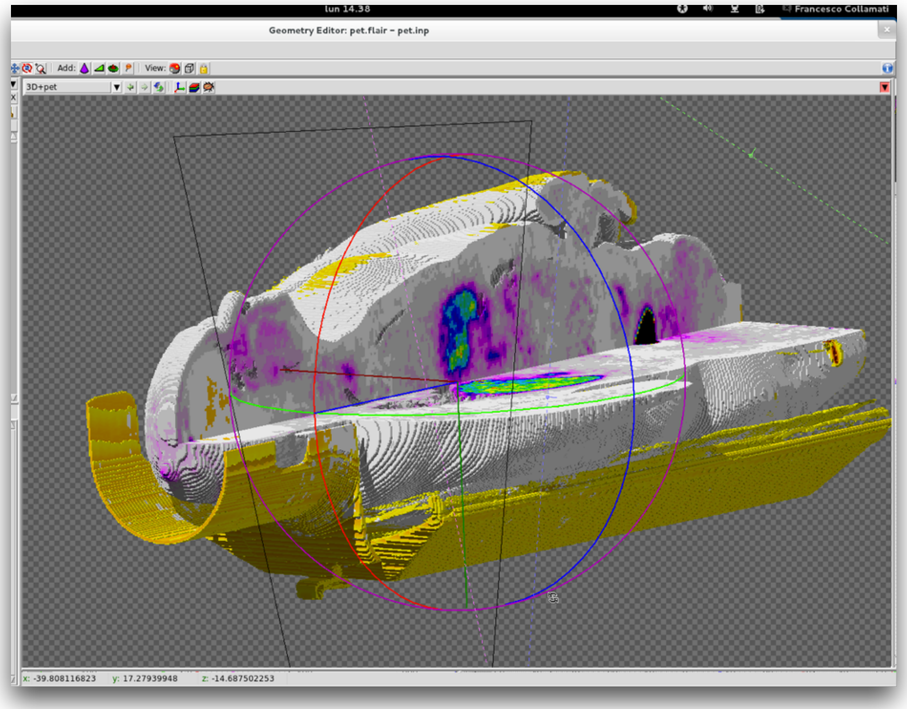
Aromatic hydrocarbon isomer

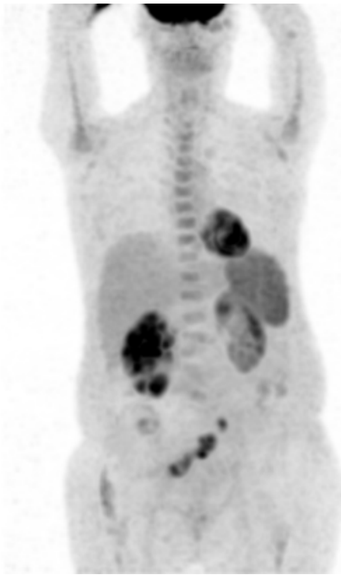
$C_{18}H_{14}$

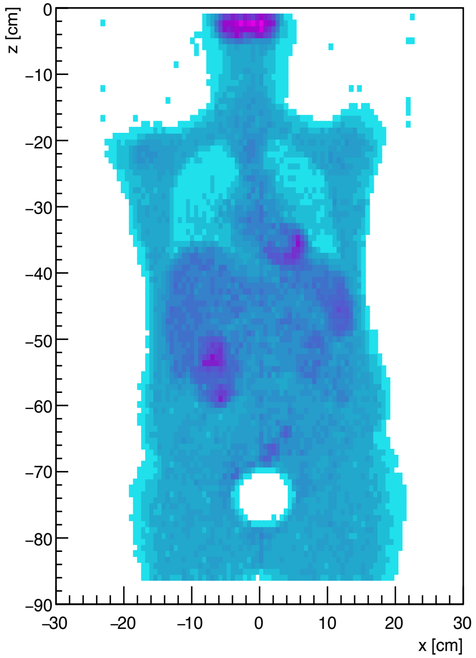
- Monte Carlo Simulations -











How does it perform as β particles detector?

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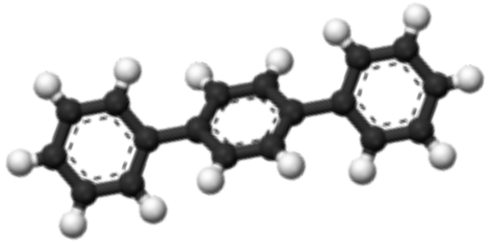
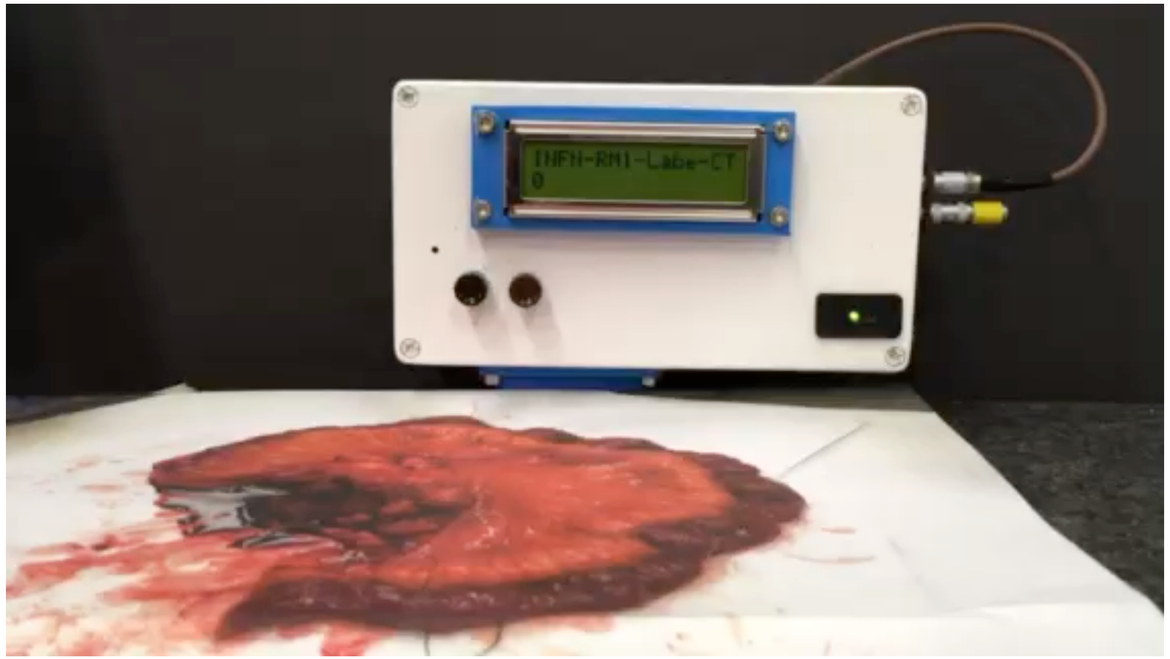


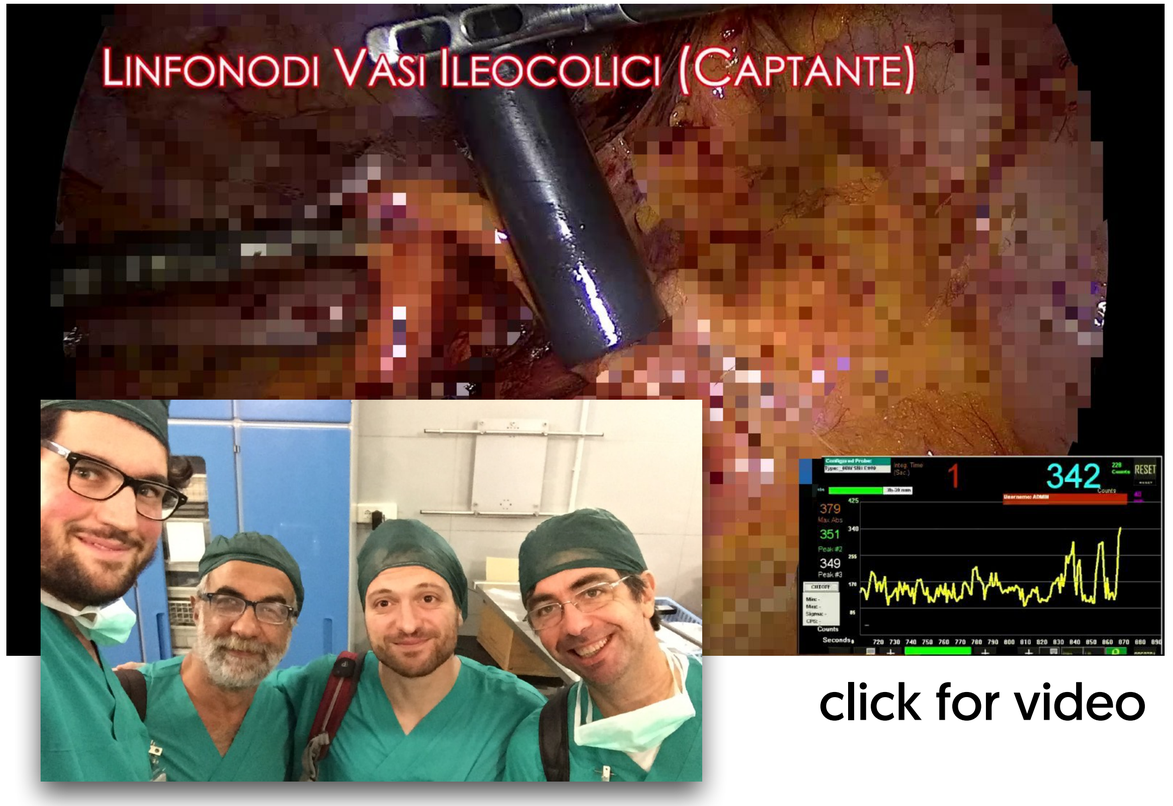
Aromatic hydrocarbon isomer

$C_{18}H_{14}$

- Patients Test -

ex-vivo ⟶ in-vivo

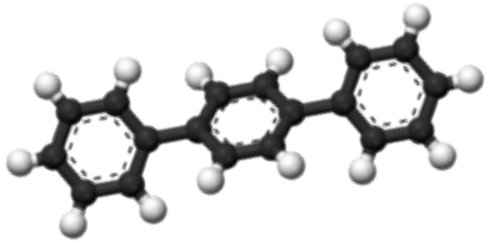




click for video

How does it perform as β particles detector?

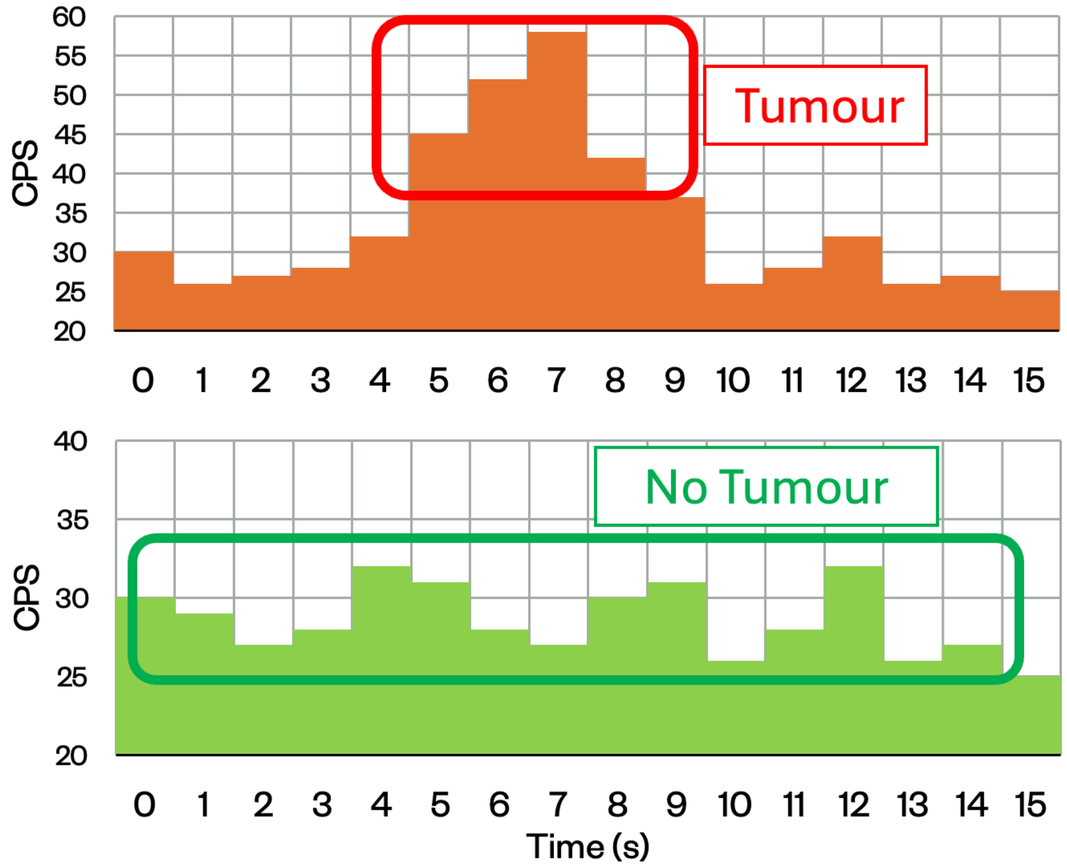
- Use p-terphenyl as detector element

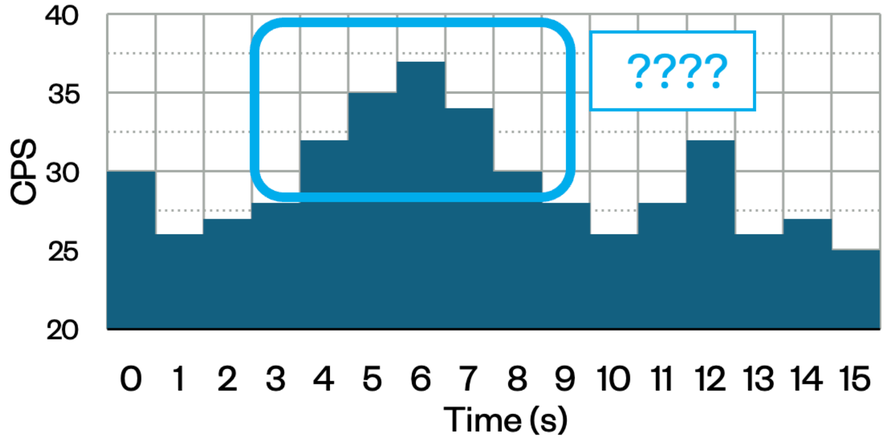


Aromatic hydrocarbon isomer

$C_{18}H_{14}$

- In-vivo Patients Test -





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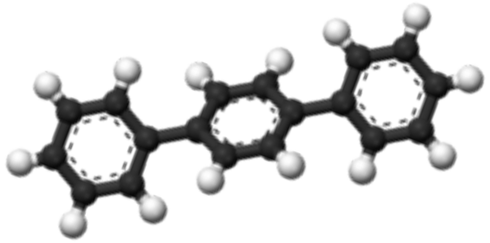

Aromatic hydrocarbon isomer

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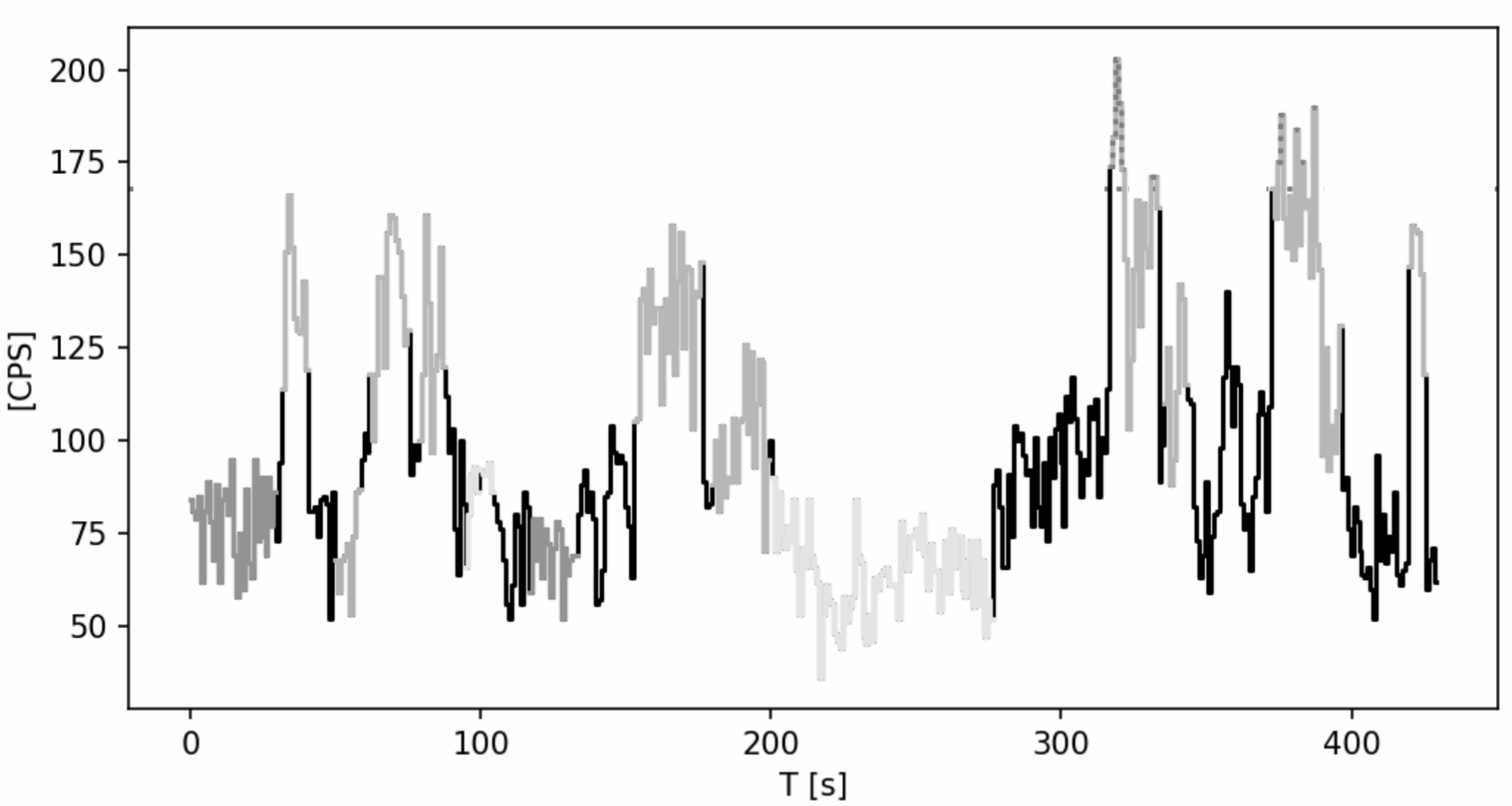
- In-vivo Patients Test -



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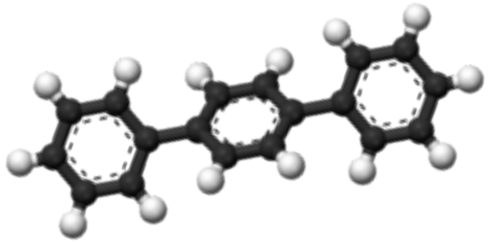

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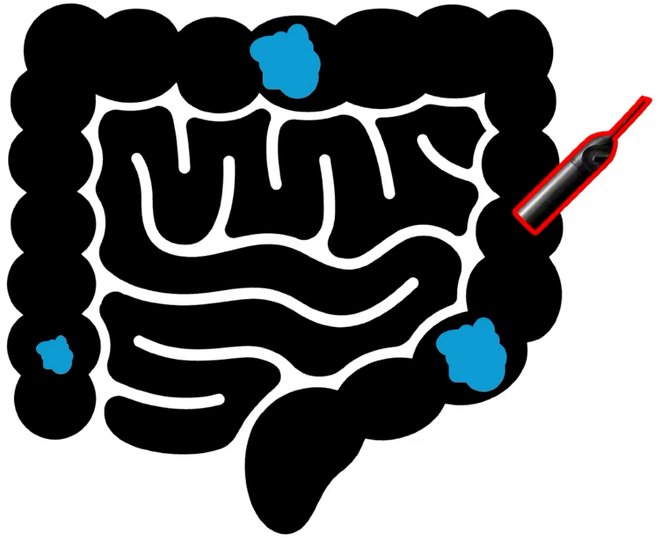
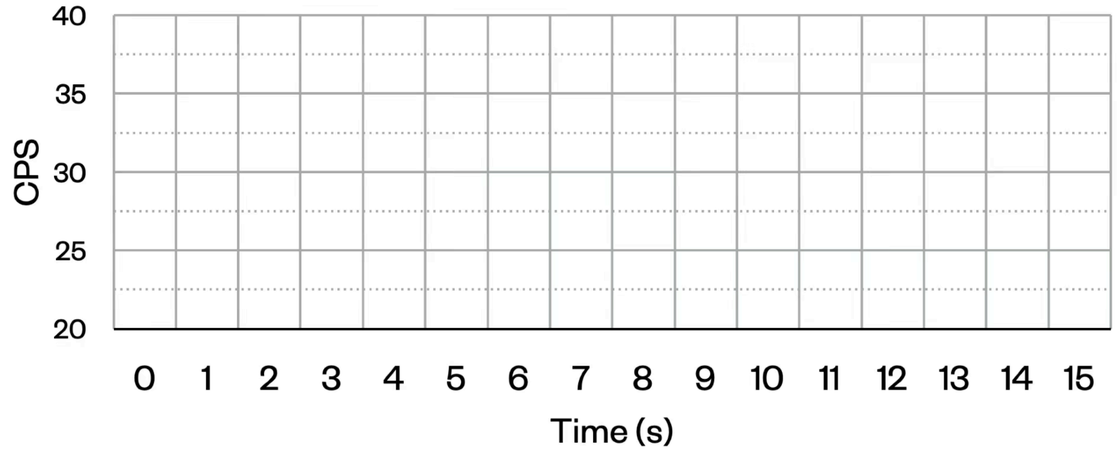
- In-vivo Patients Test -

Discrimination Algorithm 1: Background Sampling



1. The probe is moved for ~10s over an area *"assumed free of disease"* by the surgeon nearby the area of interest



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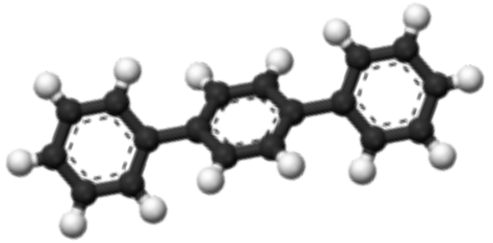

Aromatic hydrocarbon isomer

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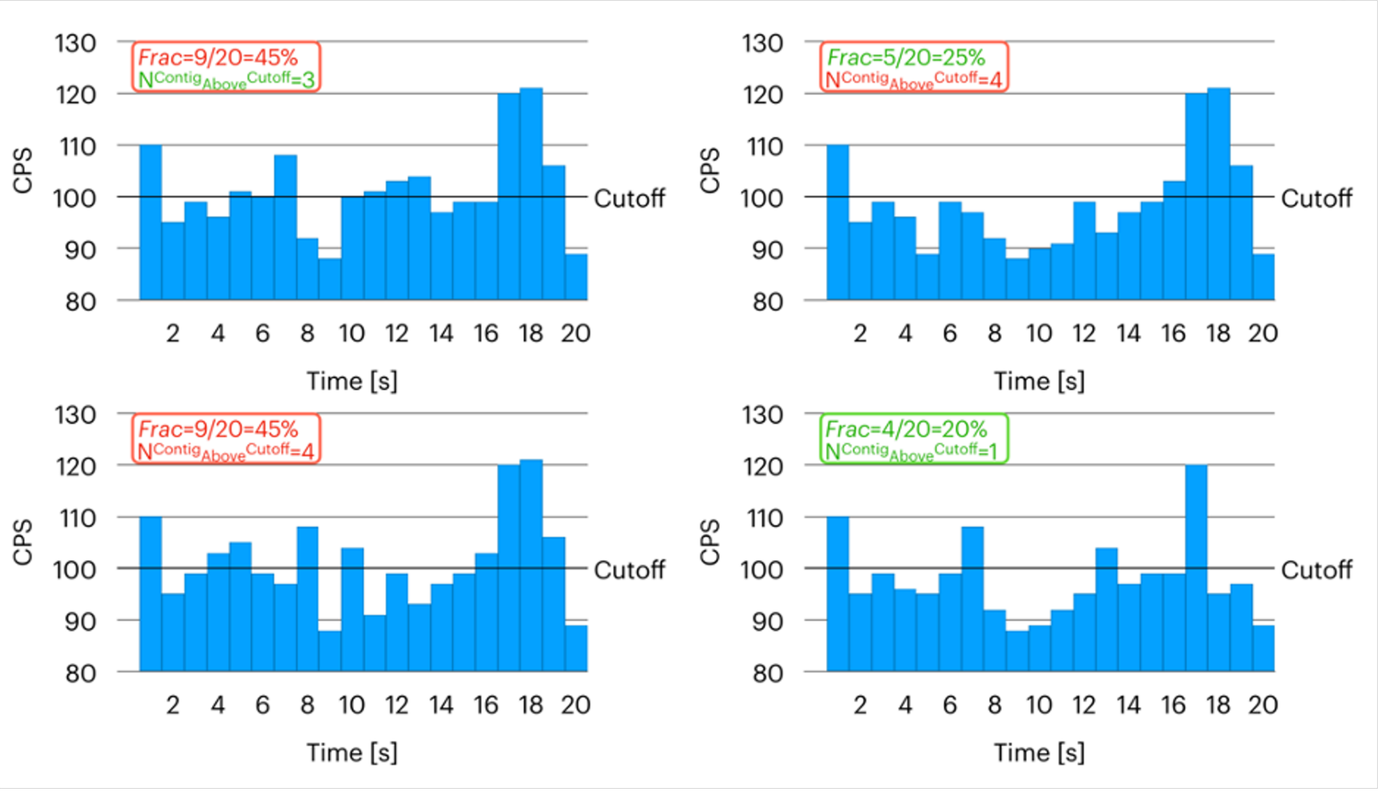
- In-vivo Patients Test -



- But this is not enough

? How "above" is "**above**" cutoff?

➡ We consider 3 parameters:

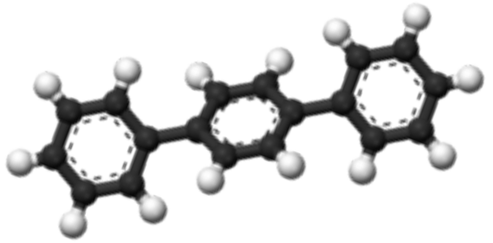
1. N_σ: Number of σ in cutoff definition:
   $C = \mu + N_\sigma * \sigma$
2. ε_{NUM}: Number of contiguous countings above cutoff
3. ε_{Frac}: Fraction of countings above cutoff

➡ We performed a ROC analysis variating these 3 parameters in their range (504 total values)

\+ Dataset splitting (train/test)

How does it perform as β particles detector?

- Use p-terphenyl as detector element



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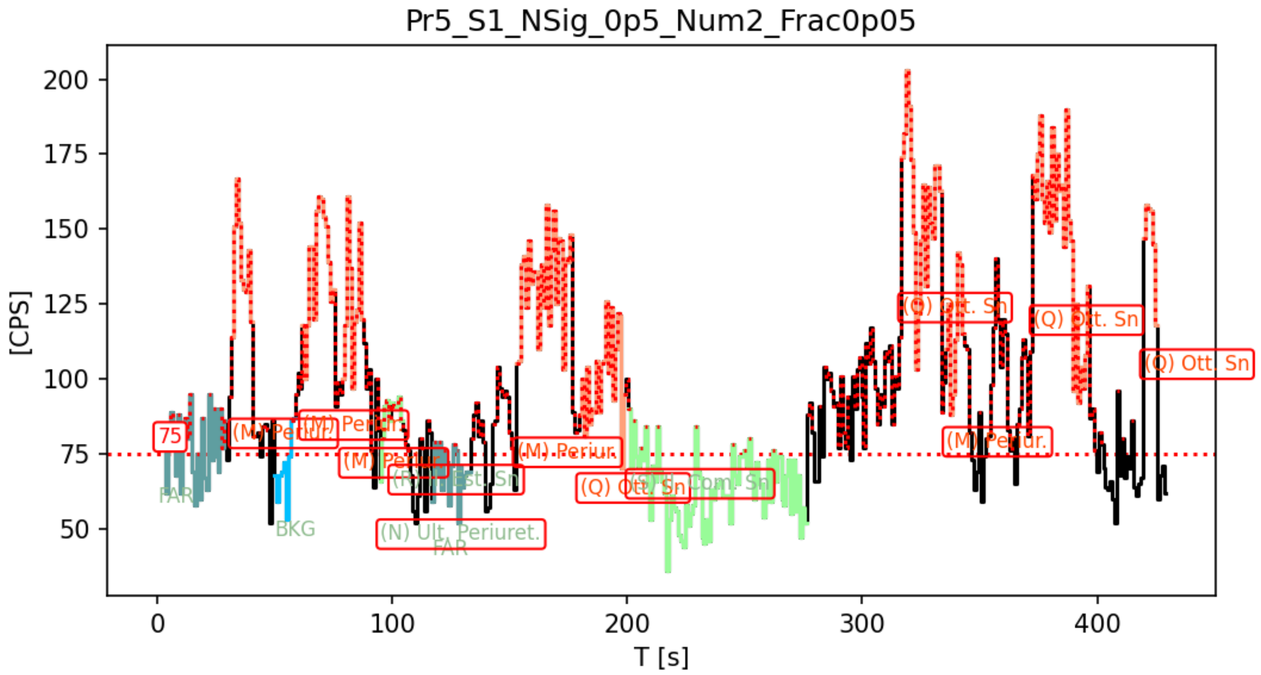

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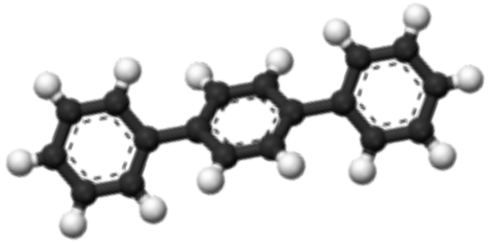

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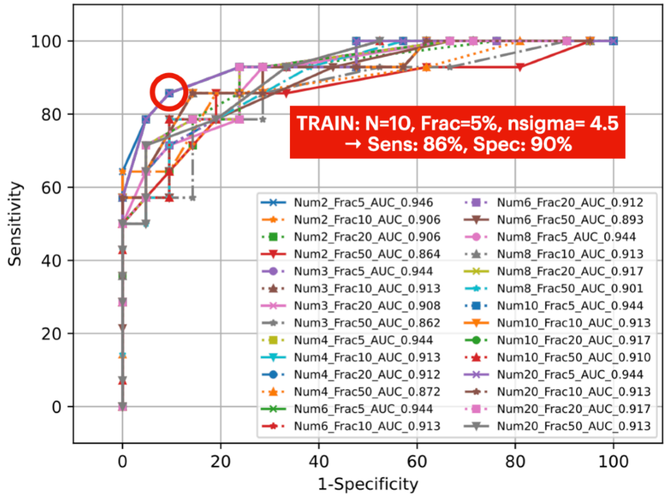

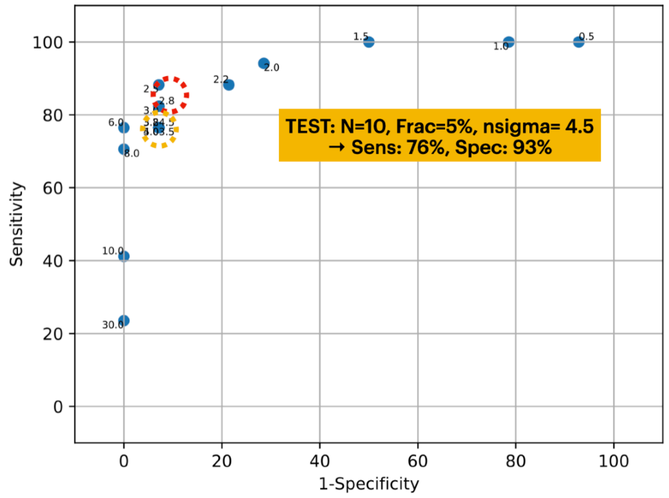

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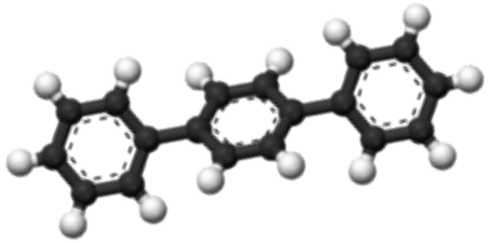

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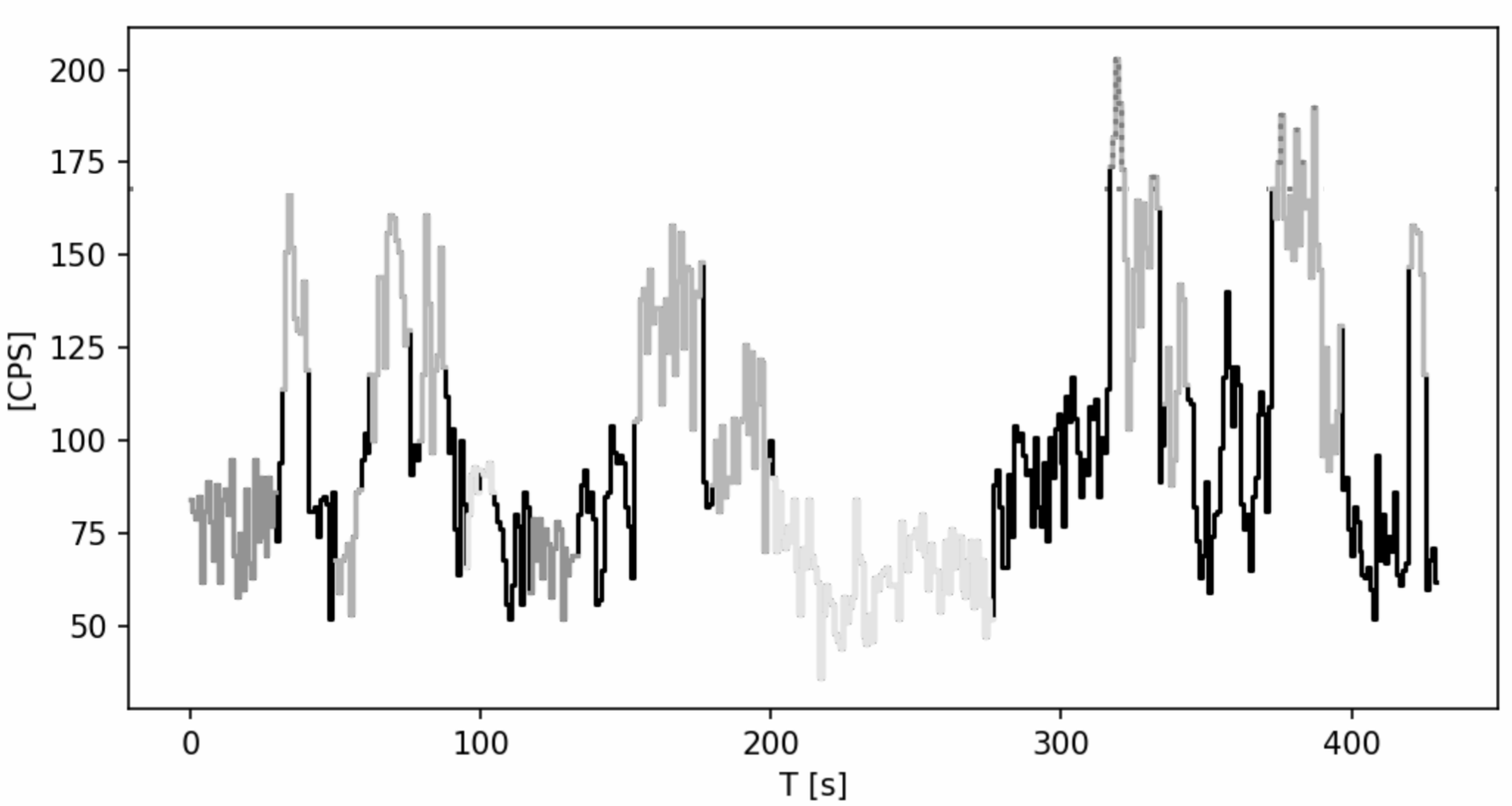
- In-vivo Patients Test -



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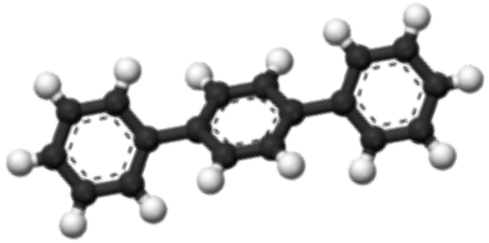

Aromatic hydrocarbon isomer

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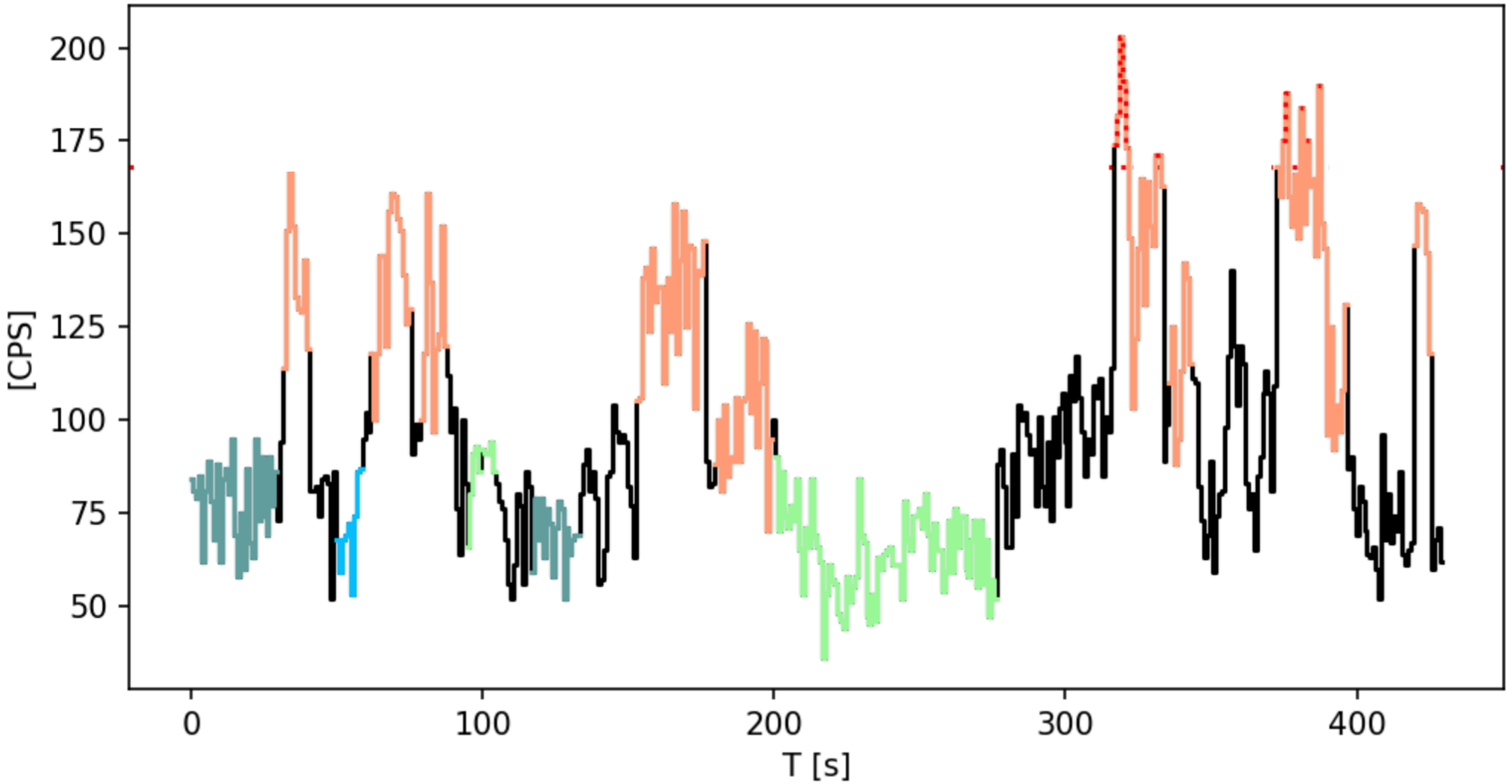
- In-vivo Patients Test -



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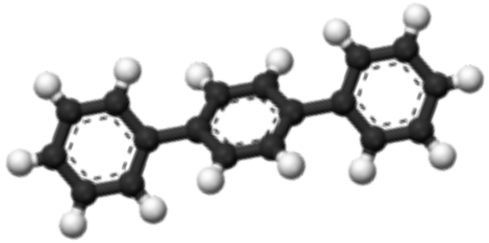


Aromatic hydrocarbon isomer

$C_{18}H_{14}$

- In-vivo Patients Test -

Results

European Journal of Nuclear Medicine and Molecular Im
https://doi.org/10.1007/s00259-024-06653-6

ORIGINAL ARTICLE

Check for updates

First-in-human validation of a DROP-IN β-probe for robotic radioguided surgery: defining optimal signal-to-background discrimination algorithm

Francesco Collamati[1] · Silvio Morganti[1] · Matthias N. van Oosterom[2] · Lorenzo Campana[1,3] · Francesco Ceci[4,5] · Stefano Luzzago[5,6] · Carlo Mancini-Terracciano[1,7] · Riccardo Mirabelli[1,3] · Gennaro Musi[5,6] · Francesca Nicolanti[1,7] · Ilaria Orsi[1,7] · Fijs W. B. van Leeuwen[2] · Riccardo Faccini[1,7]

True Positive Rate

- Sensitivity: 89%
- Specificity: 89%

True Negative Rate

Ann Surg Oncol
https://doi.org/10.1245/s10434-024-15277-x

Annals of SURGICAL ONCOLOGY
OFFICIAL JOURNAL OF THE SOCIETY OF SURGICAL ONCOLOGY

Check for updates

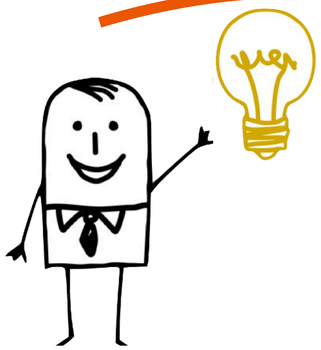
ORIGINAL ARTICLE – ENDOCRINE TUMORS

Radio-Guided Surgery with a New-Generation β-Probe for Radiolabeled Somatostatin Analog, in Patients with Small Intestinal Neuroendocrine Tumors

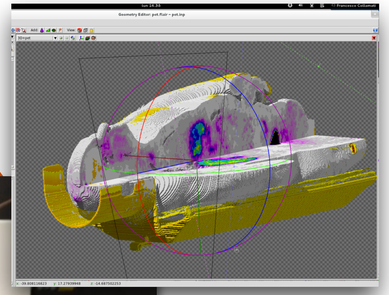
Emilio Bertani, MD[1,2], Francesco Mattana, MD[3], Francesco Collamati, PhD[4], Mahila E. Ferrari, MSc[5], Vincenzo Bagnardi, PhD[6], Samuele Frassoni, MSc[6], Eleonora Pisa, MD[7], Riccardo Mirabelli, PhD[4,8], Silvio Morganti, MSc[4], Nicola Fazio, MD[9], Uberto Fumagalli Romario, MD[2], and Francesco Ceci, MD[3,10]

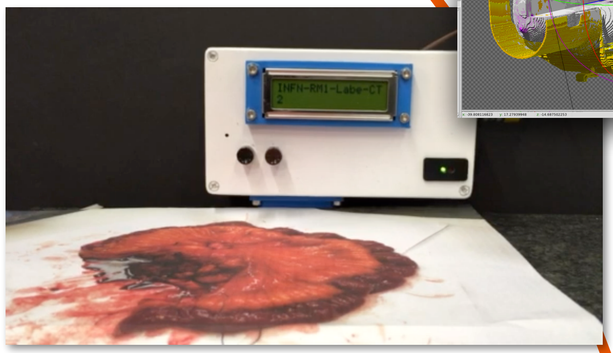
- Sensitivity: 80%
- Specificity: 91%

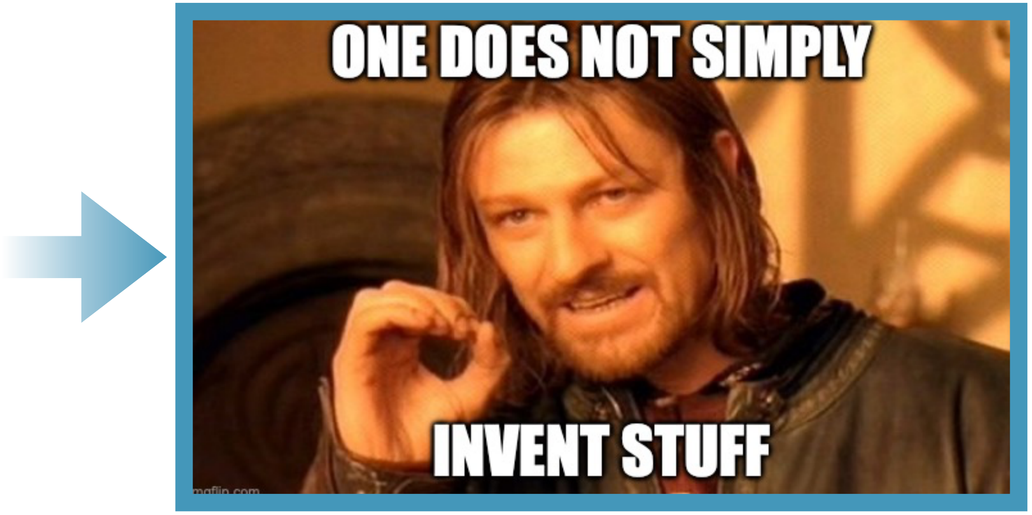
2012



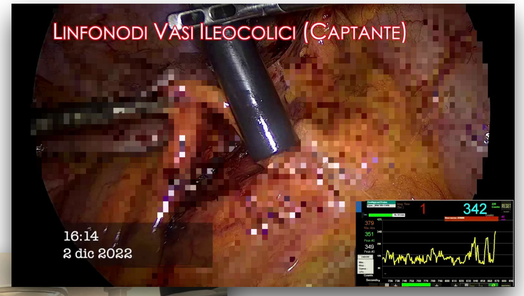
2014



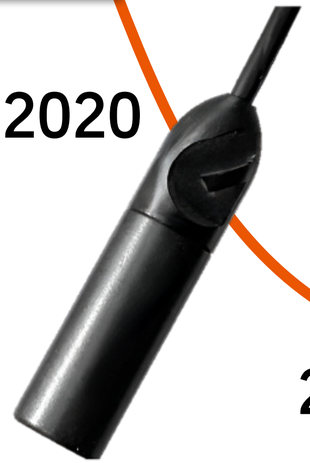




2018



2020



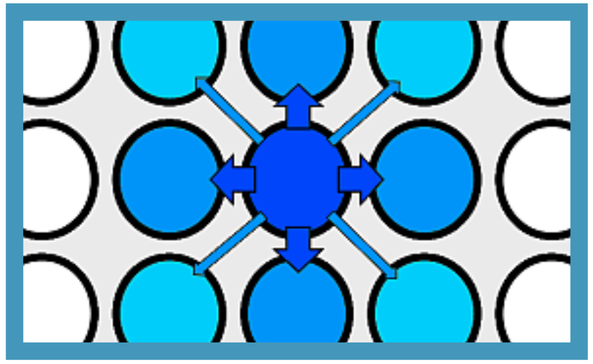
2021

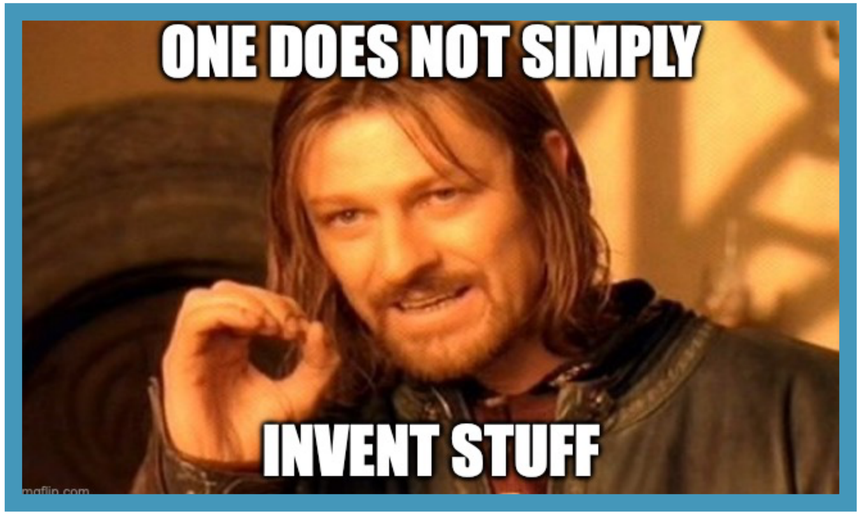
>50pts

2024

Radio Guided Surgery with β tracers

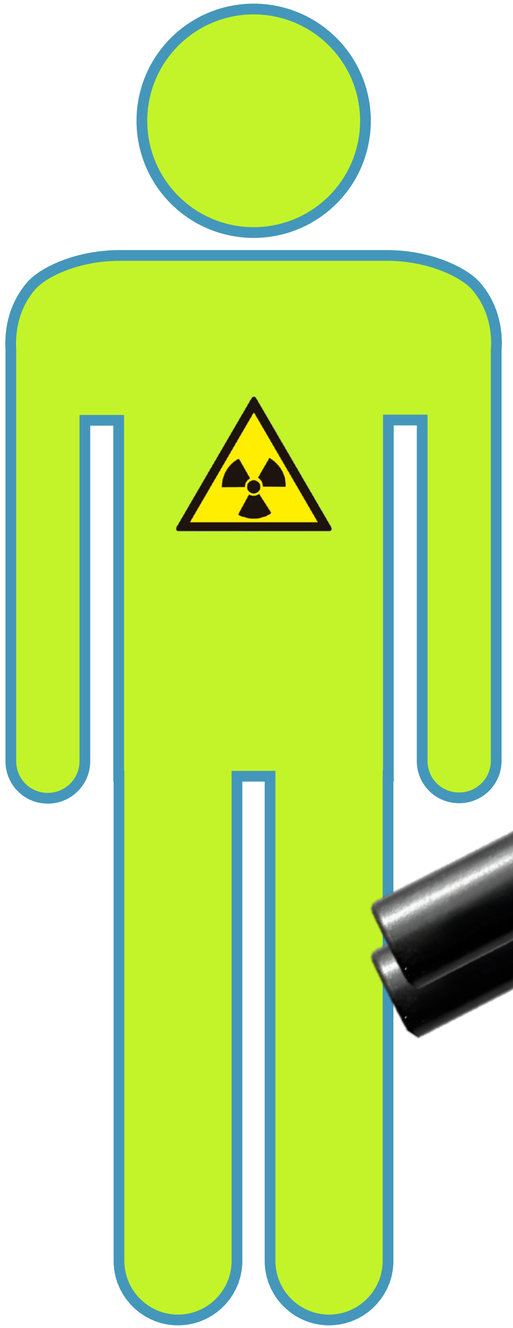
CSN5

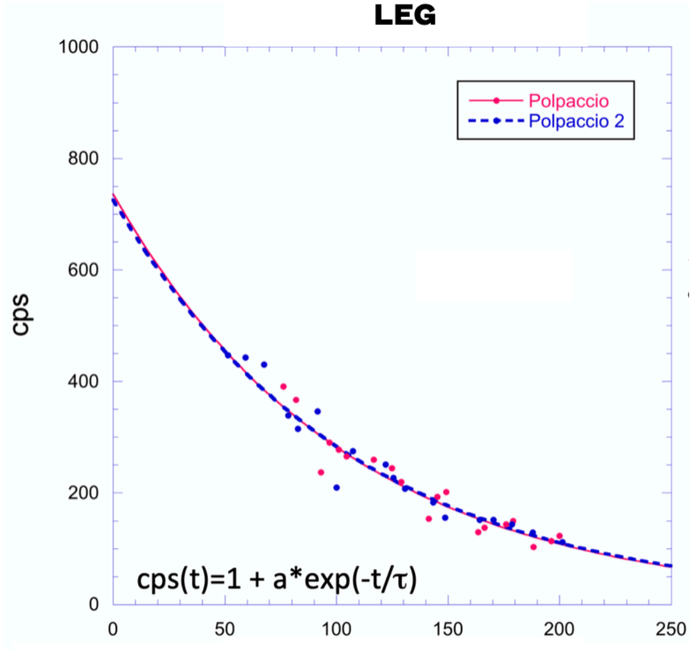


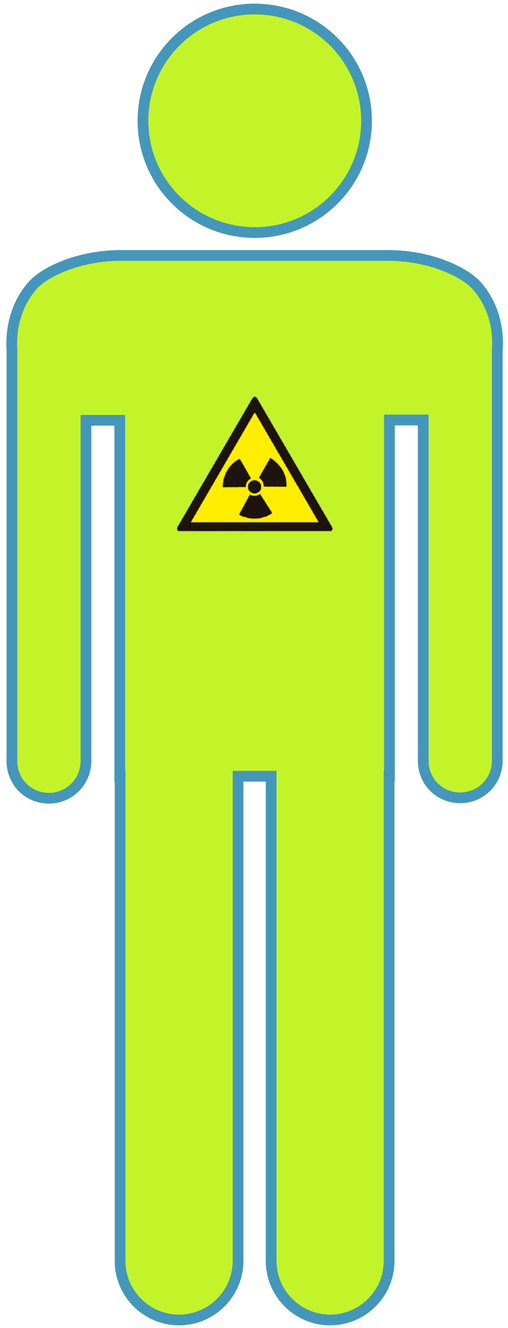


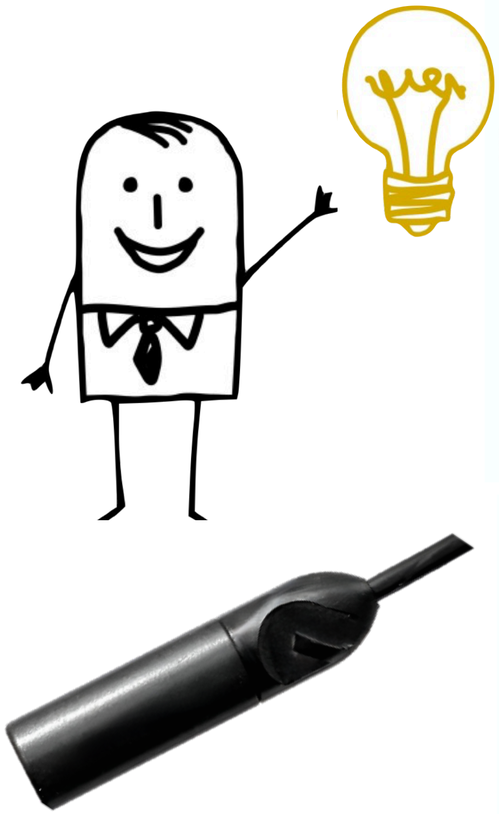

RUNNING
1432.
Cps
Mean
957,75 Cps
I.N.F.N. Sez. Roma1 - Labe -
ARCHOS

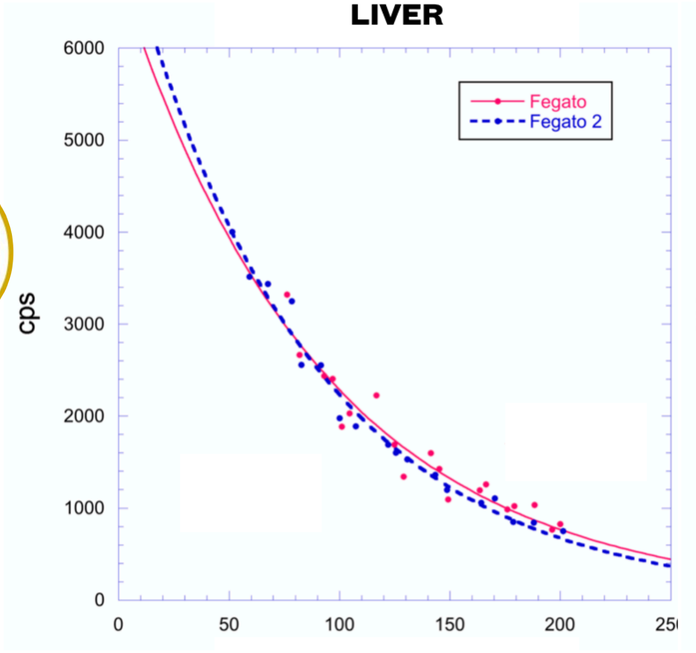

TV2

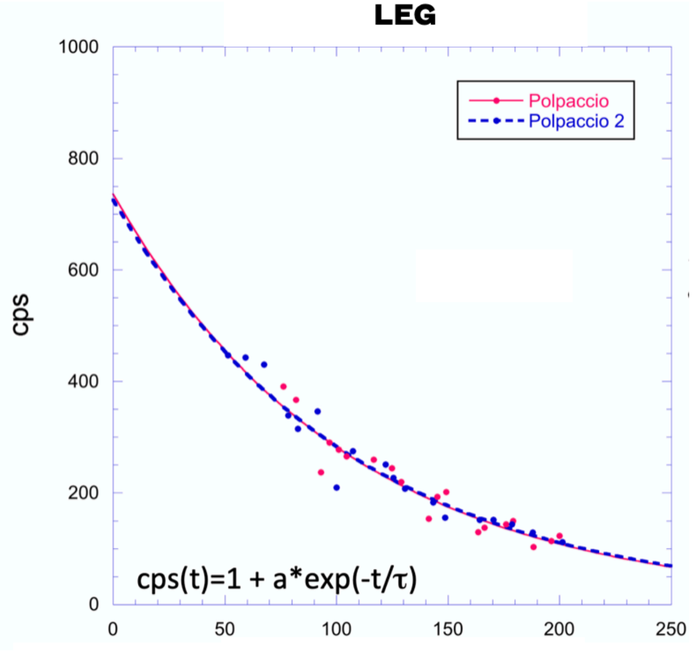


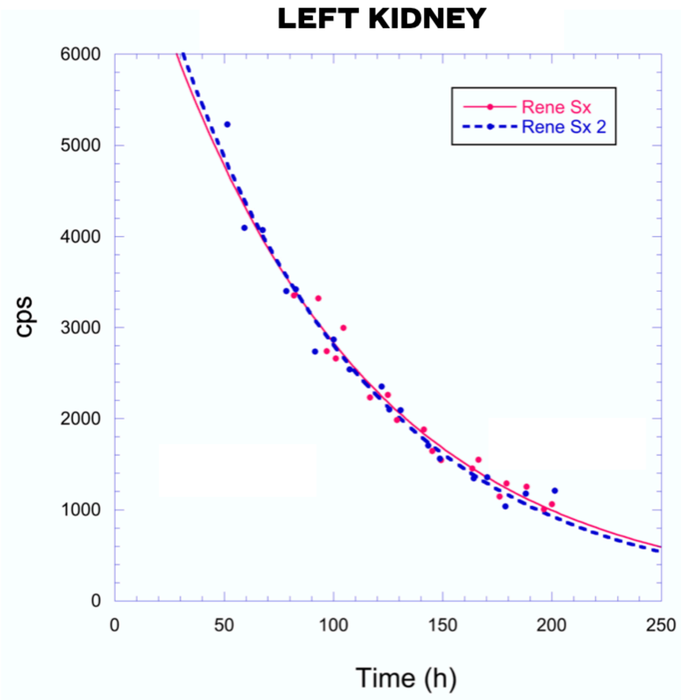

LEG
Polpaccio
Polpaccio 2
cps
1000
800
600
400
200
0
0
50
100
150
200
250
cps(t)=1 + a*exp(-t/τ)

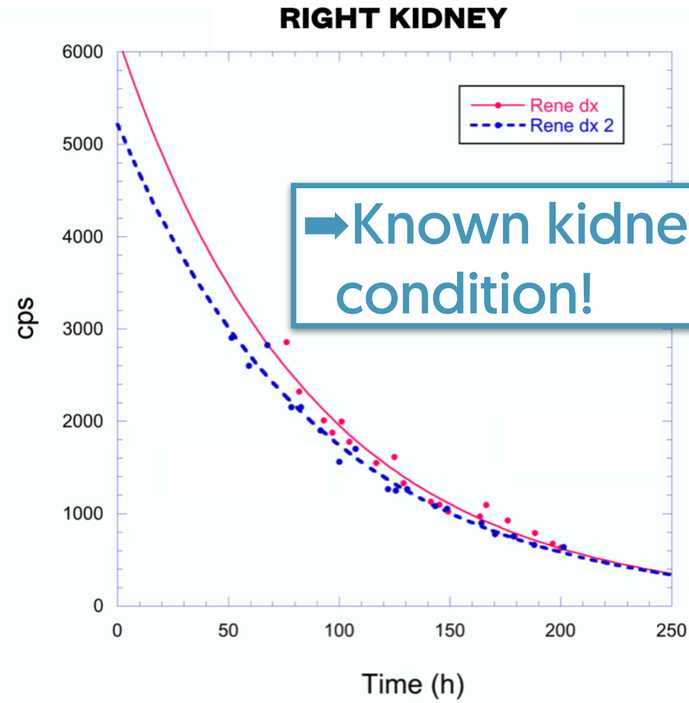




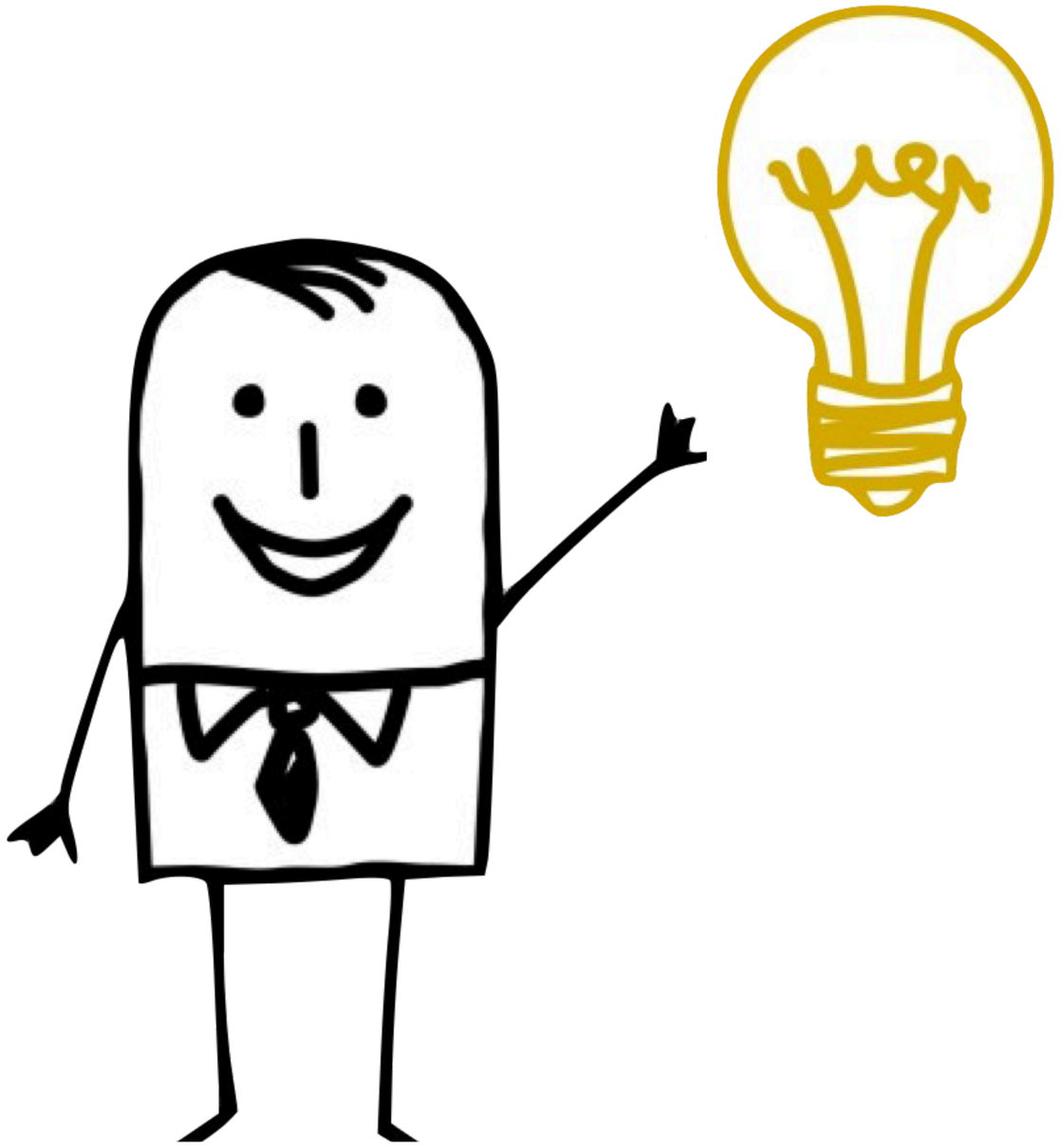






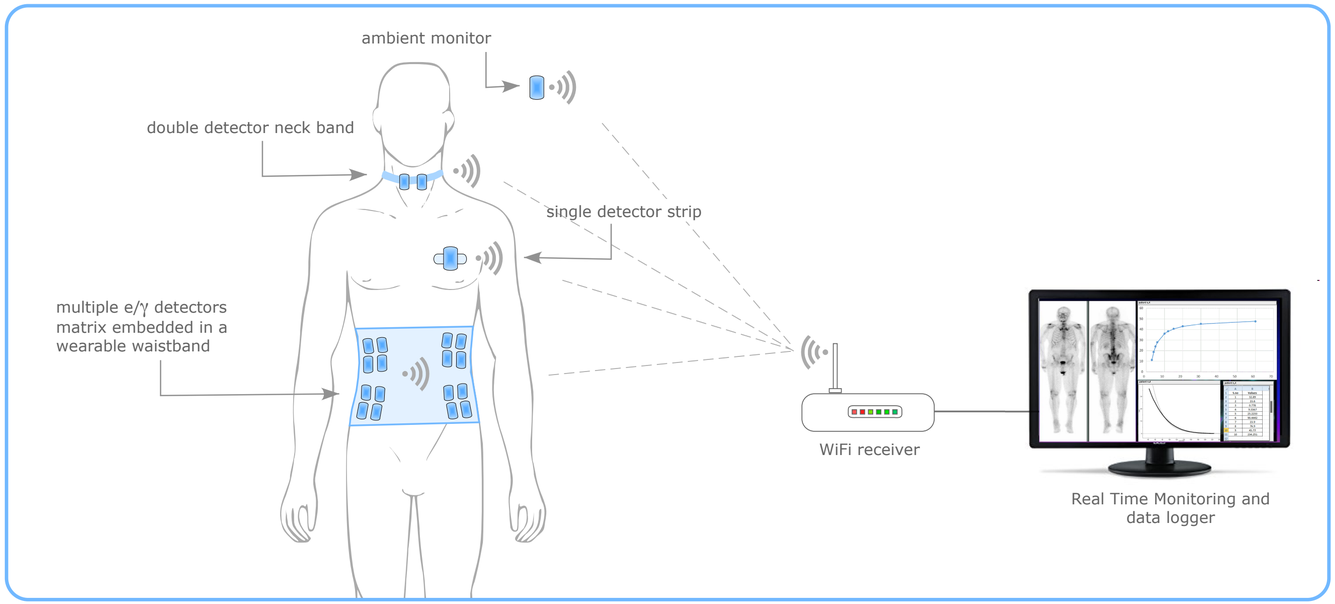


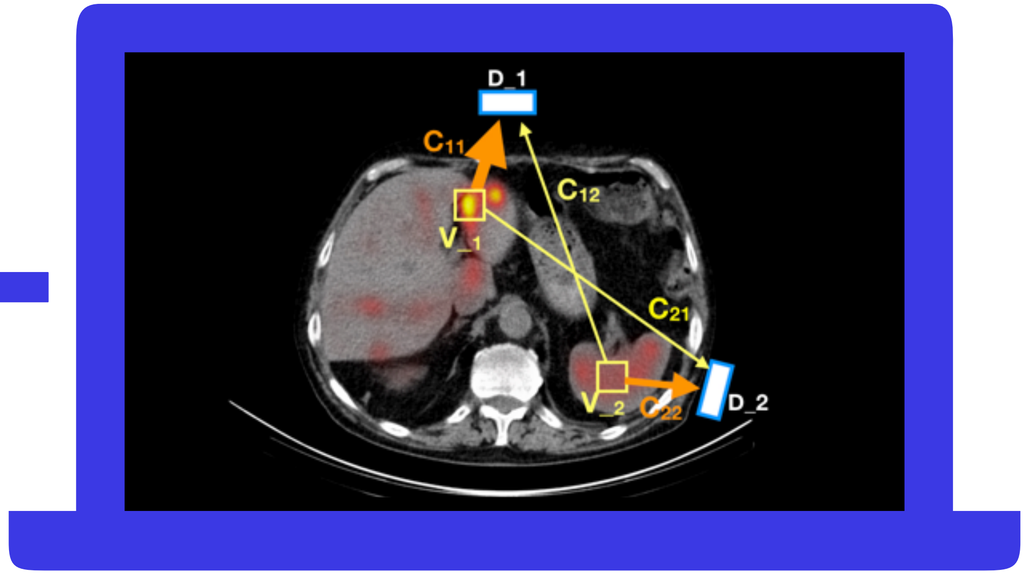
➡Known kidney condition!



WIDMApp

a Wearable Individual Dose Monitoring Apparatus





A Multi Channel System of Radiation Detector

☑ Wearable ➠ High Statistics
☑ At contact ➠ High Efficiency

A Software Algorithm fo Analysis and Deconvolution

➠ Identify the contribution to each detector from each organ

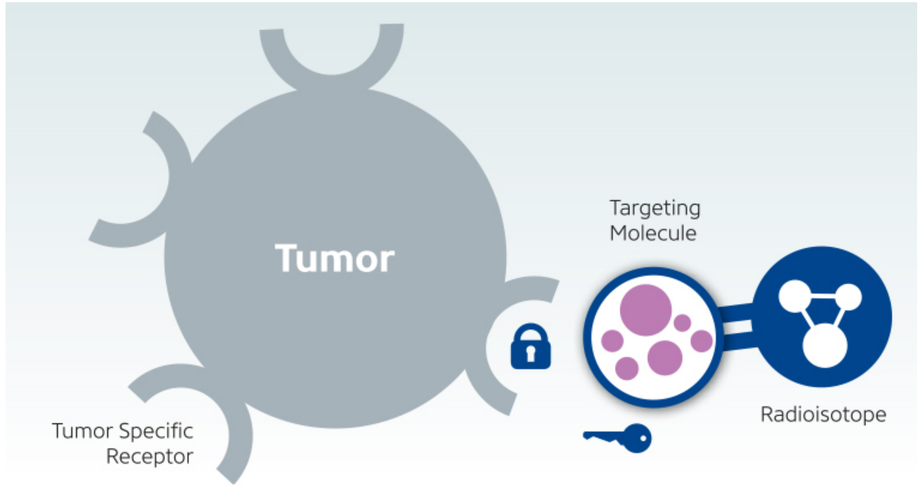
Real Time measurement of Tracer **Accumulation** and Transit

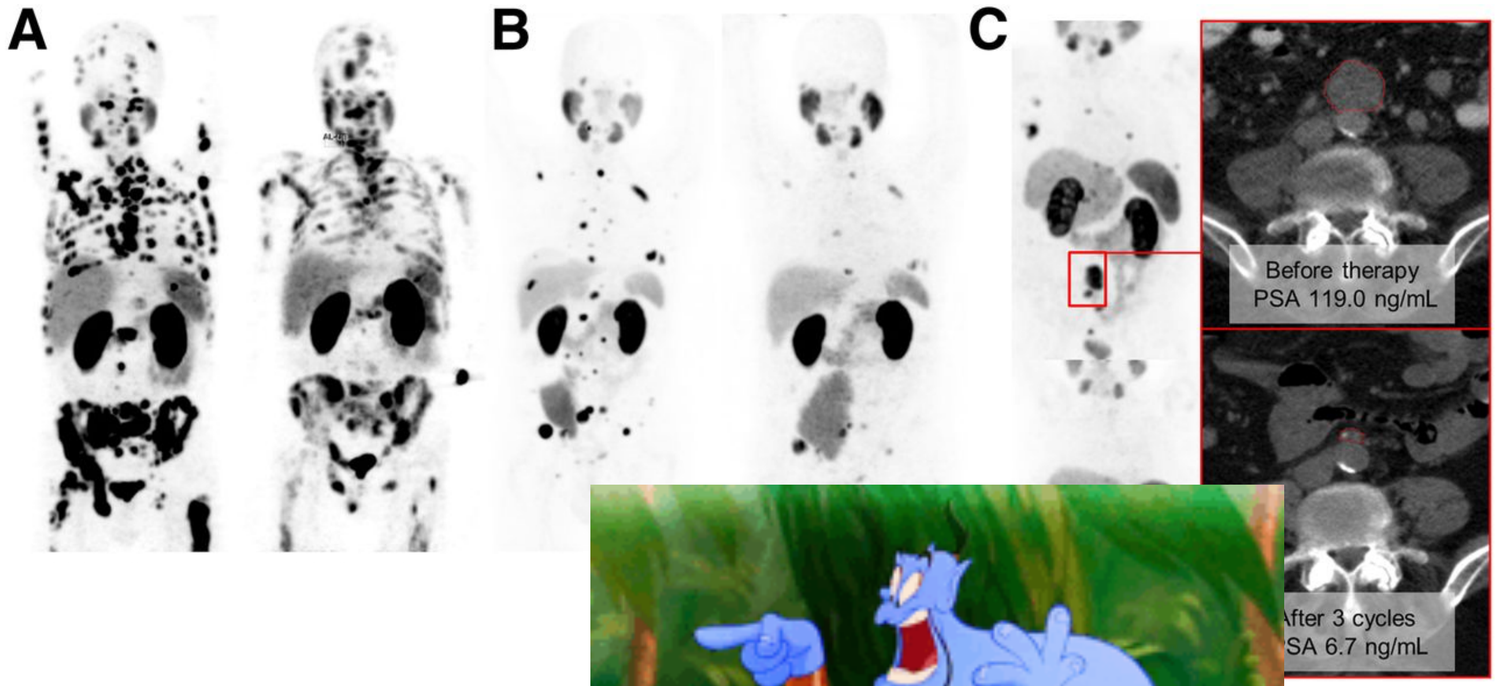
WIDMApp

a Wearable Individual Dose Monitoring Apparatus

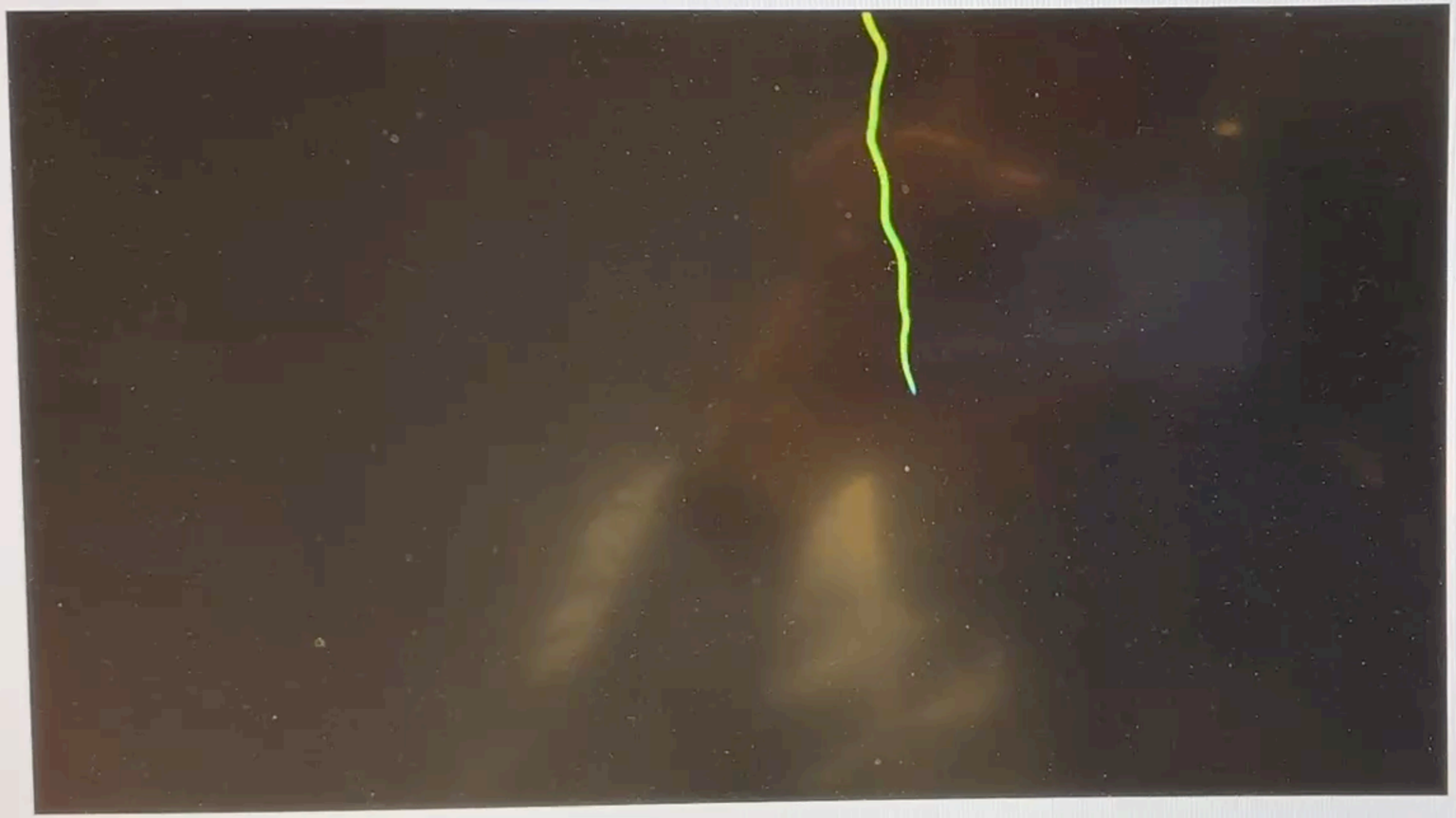
Target Radionuclide Therapy (TRT)

- A **radiopharmaceutical** is systemically injected to the patient
- Thanks to its **specificity** for the given tumor it bounds to it
- The emitted **radiation** destroys the tumor





Dynamic PET/CT study

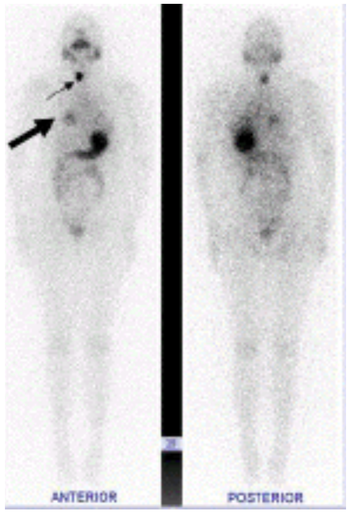


Frame Nr.	Duration(Second)
30	2
5	30
5	60
5	120
8	300

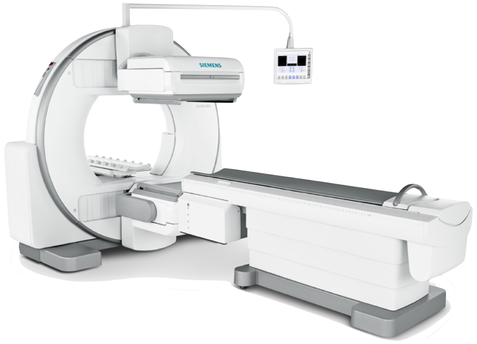
Target Radionuclide Therapy (TRT)

Dosimetry

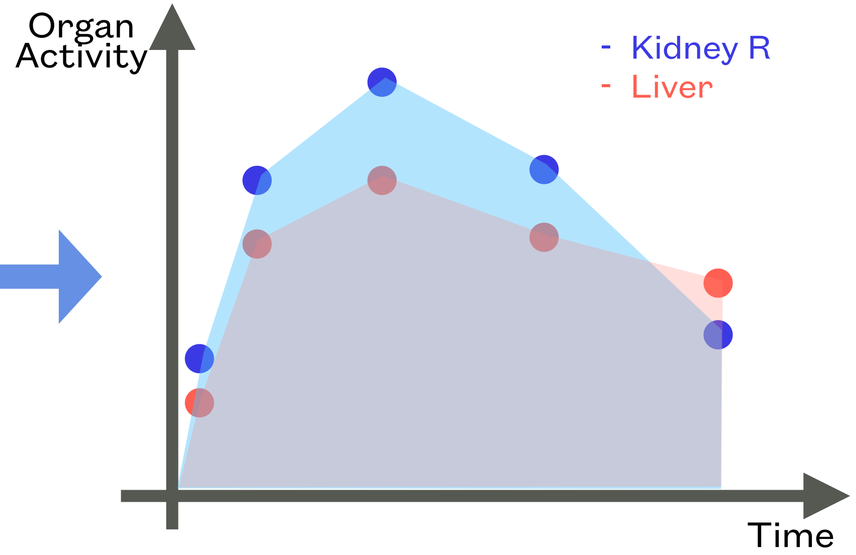
- Current **State of The Art**:
  - Typical current approach: ***null***
  - In few centers, repeated quantitative SPECT scans are performed



- Organs activities are measured at 1, 4, 24 and 70 h after injection



TIME ACTIVITY CURVES (TAC)



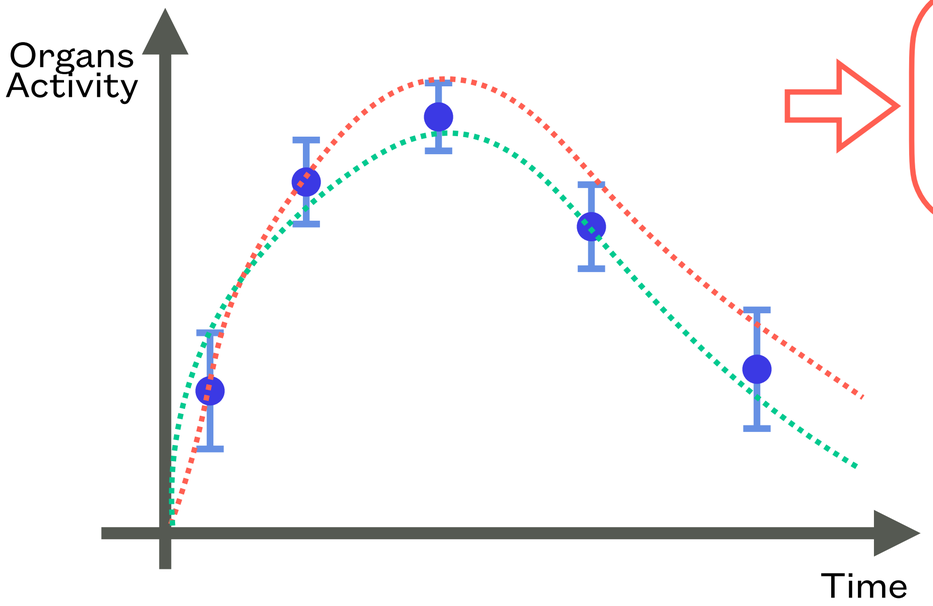
Organ	Total Dose
Kidney R	...
Kidney L	...
Liver	...
...	...

The integral of these curves allows to compute the total dose absorbed by each organ

Target Radionuclide Therapy (TRT)

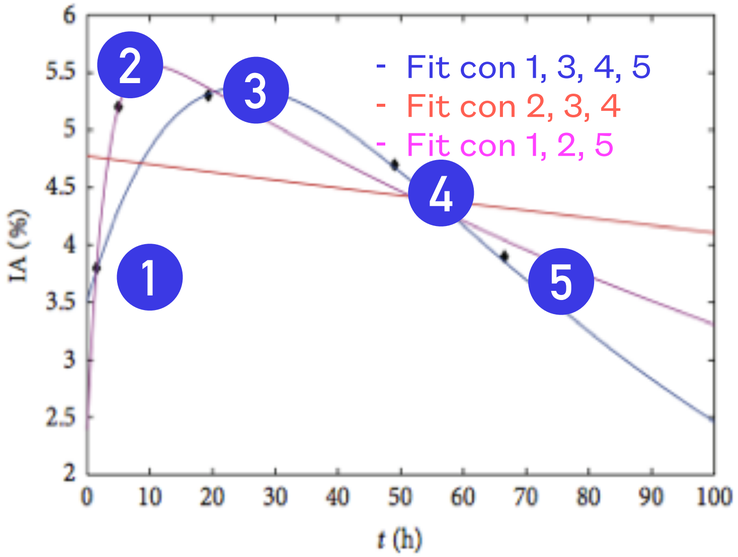
Dosimetry

- Limitations:



The curve integral depends strongly on the fitting function

Real case

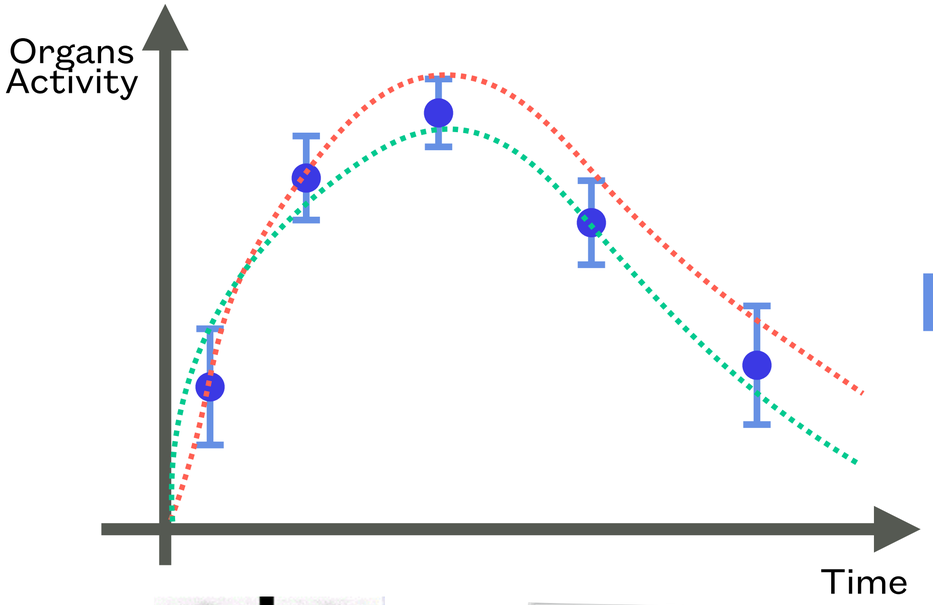


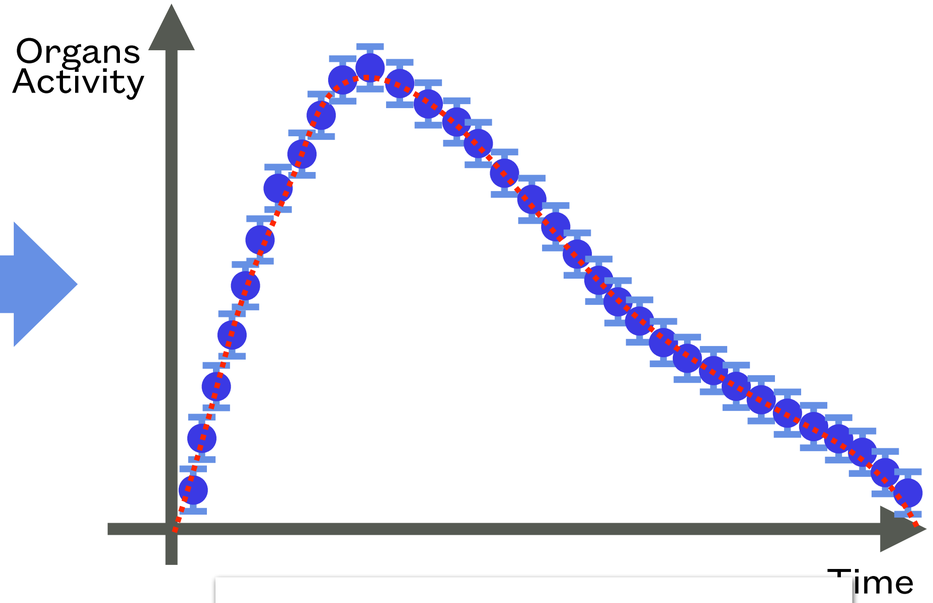
Final uncertainties of ~50% on organs' doses

Target Radionuclide Therapy (TRT)

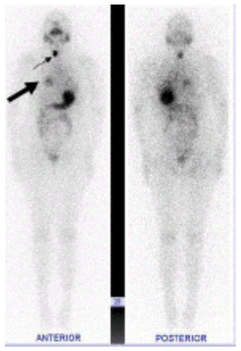
Dosimetry

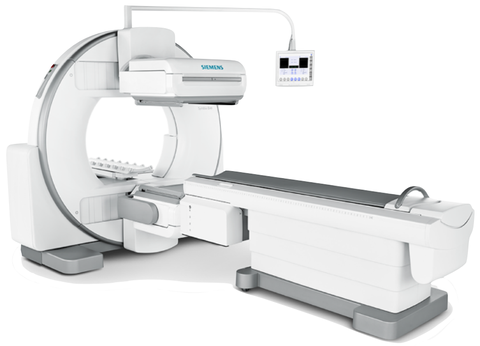
- The **WIDMApp** idea:





- ☑ Much more points
- ☑ Much smaller uncertainties





MUCH SMALLER UNCERTAINTY ON DOSE

WIDMApp

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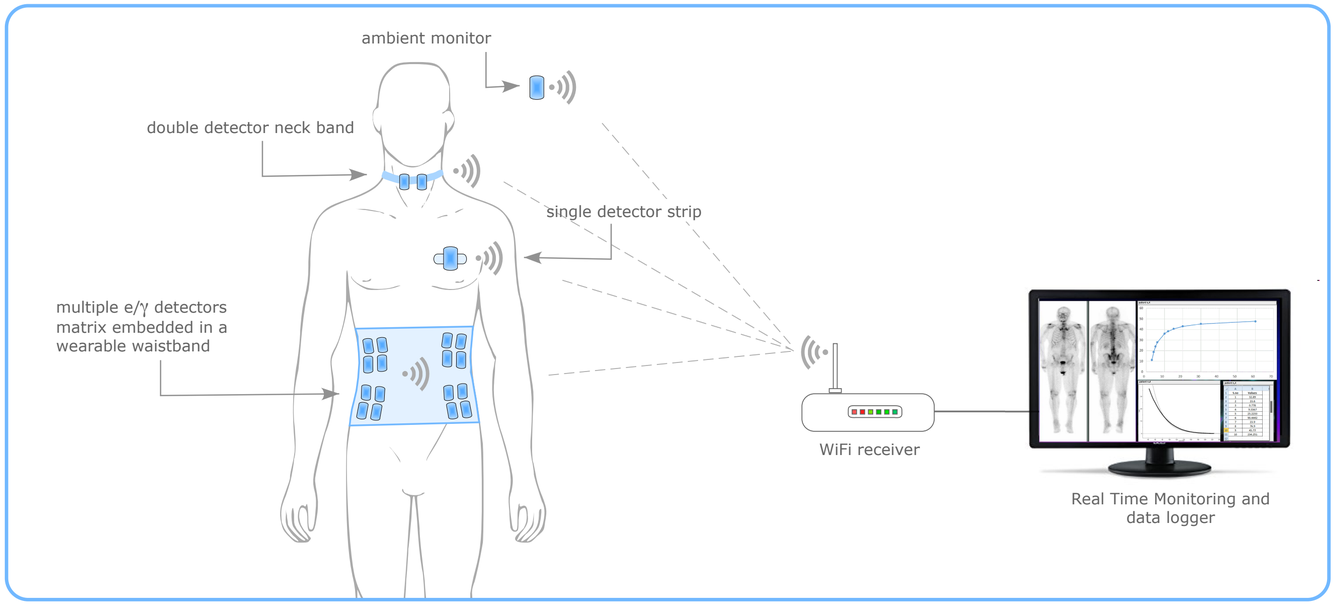

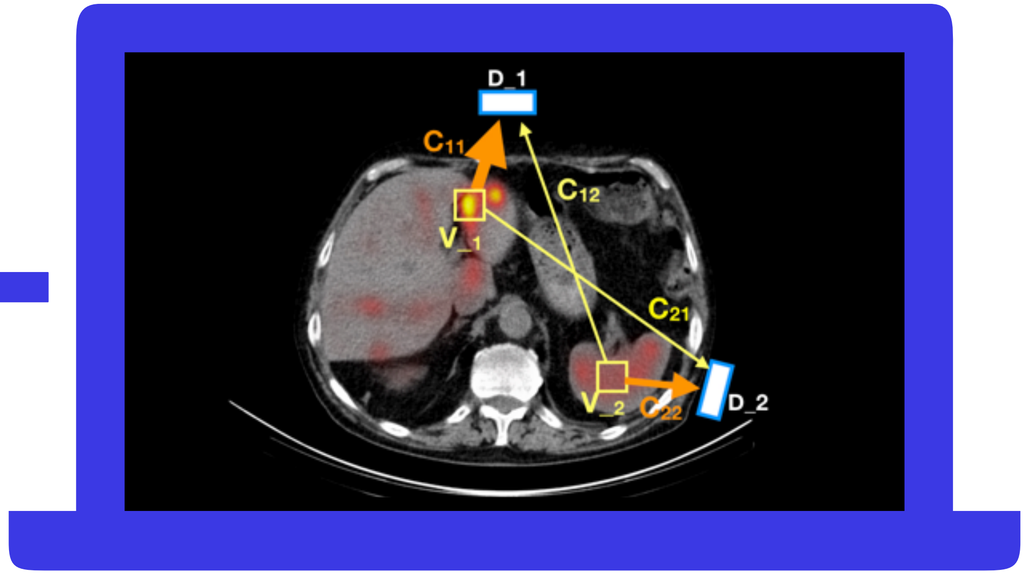

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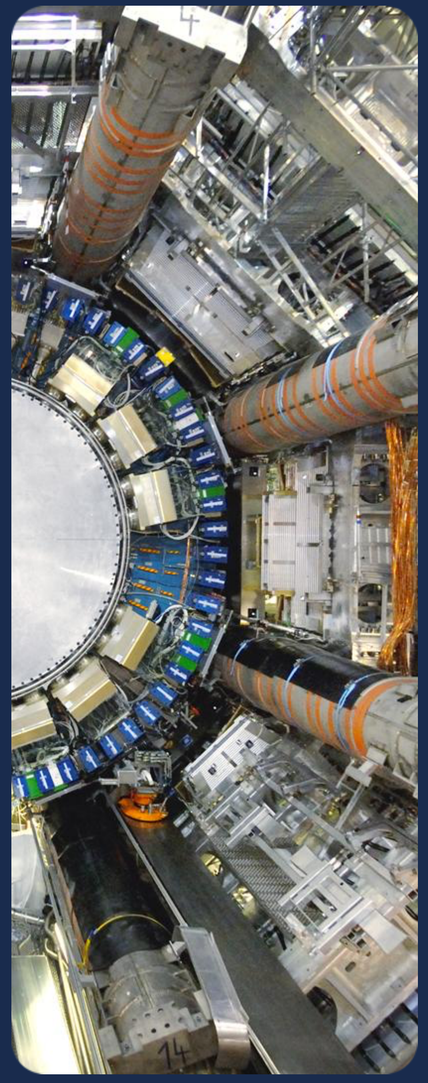
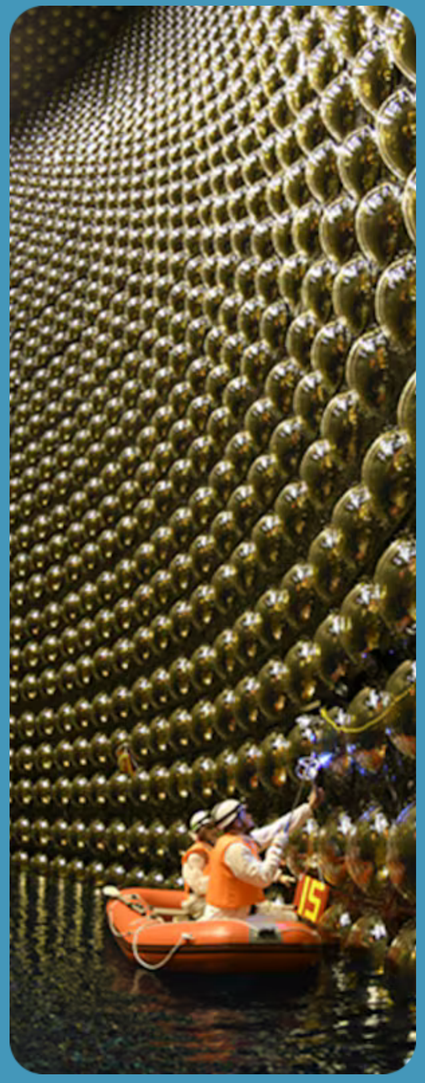
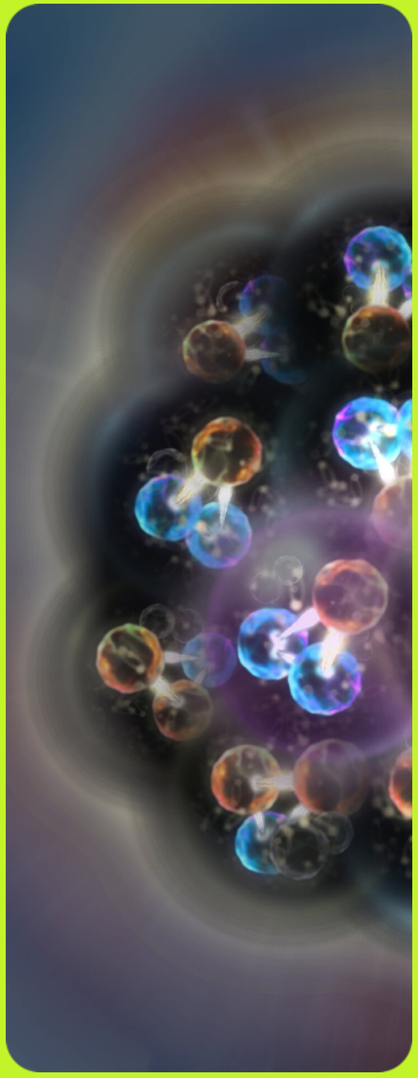
CSN1



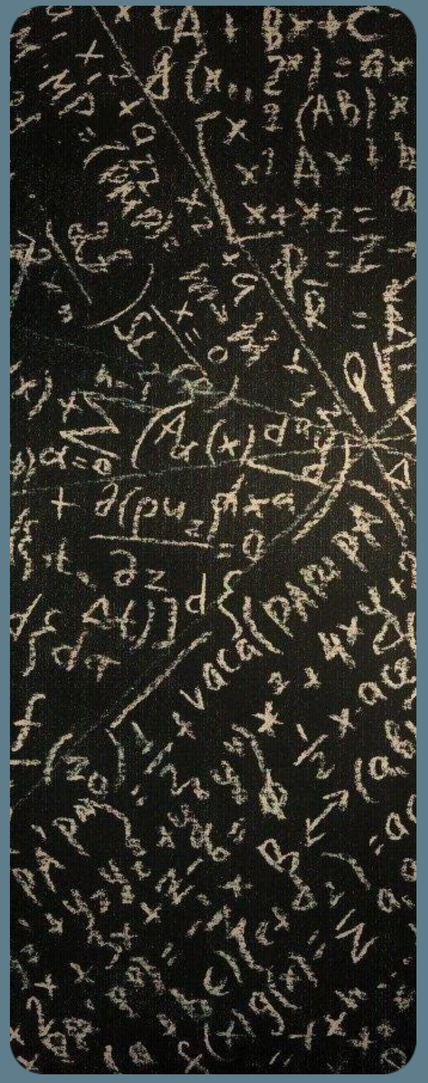
CSN2



CSN3

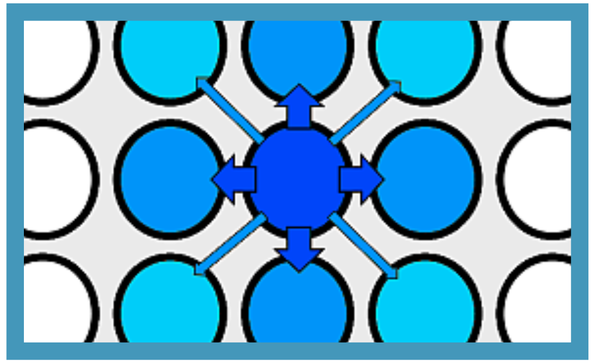


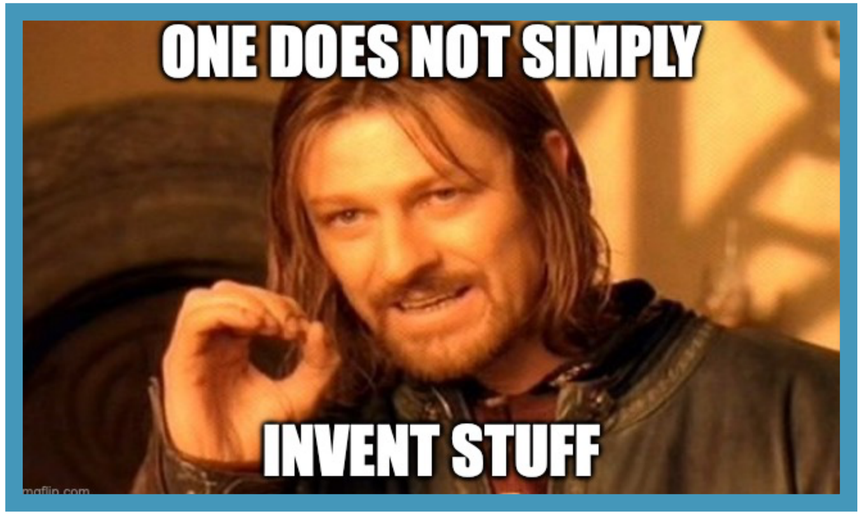
CSN4



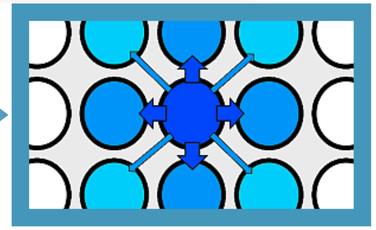
CSN5

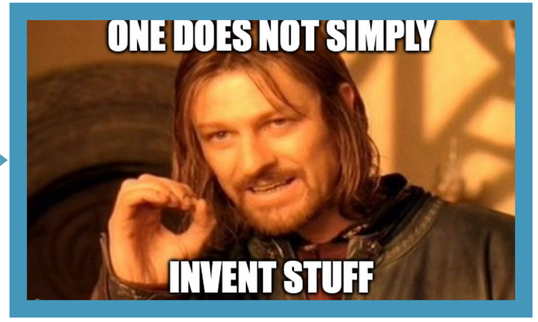
CSN5

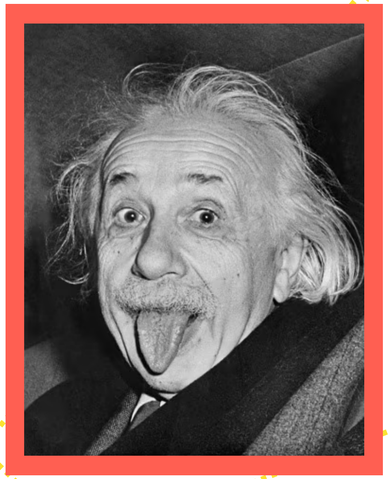


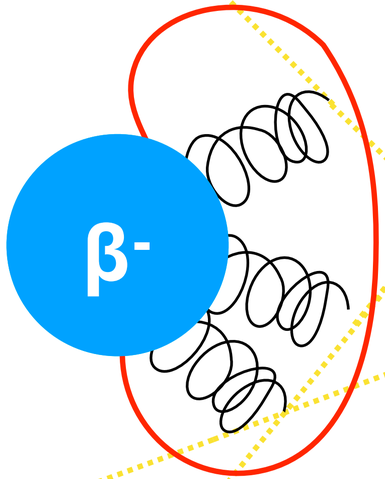


CSN5



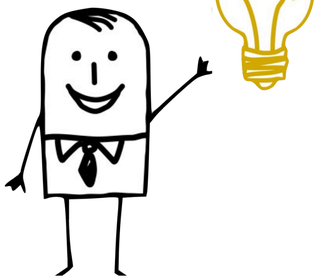






Radio Guided Surgery with β tracers

2012



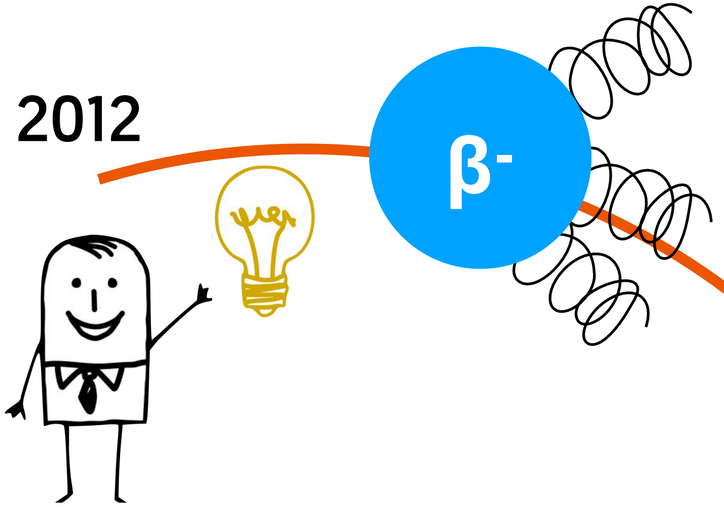
β-

>50pts

2024

Radio Guided Surgery with β tracers

2012

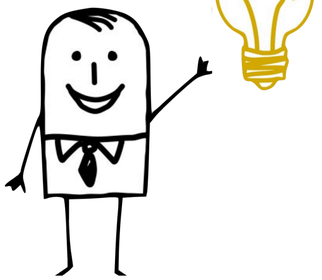


>50pts

2024

Radio Guided Surgery with β tracers

2012



β-

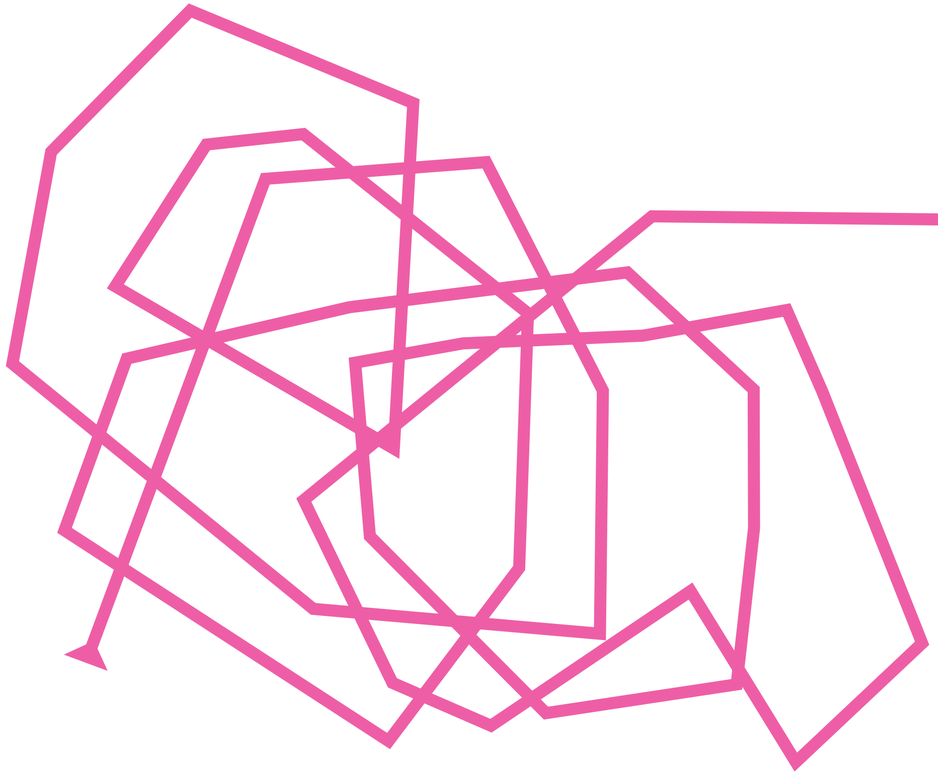
β+

Pursuing β- RGS we opened the way to PET-RGS!

>50pts

2024

Radio Guided Surgery with β tracers



WIDMApp

CSN5

INFN ROMA

Istituto Nazionale di Fisica Nucleare
Sezione di Roma