^{129m,131m,133m}Xe for gamma-MRI, a novel medical imaging technique

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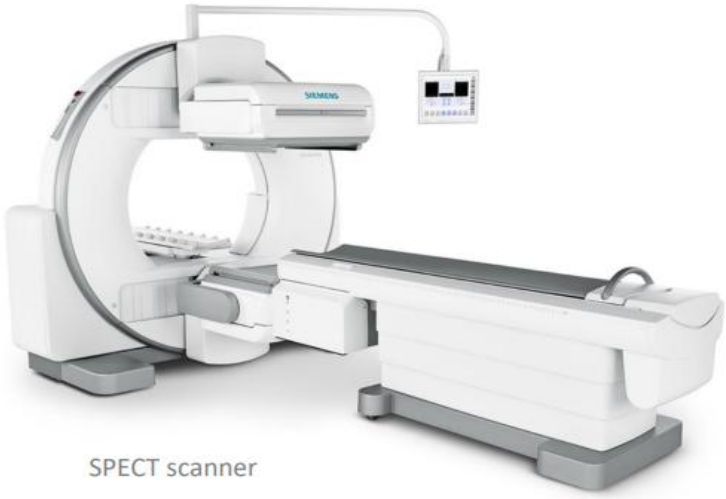
Gamma-MRI - motivation

NOVEL MEDICAL IMAGING MODALITY:
increased MRI sensitivity+improved SPECT resolution

MRI scanner

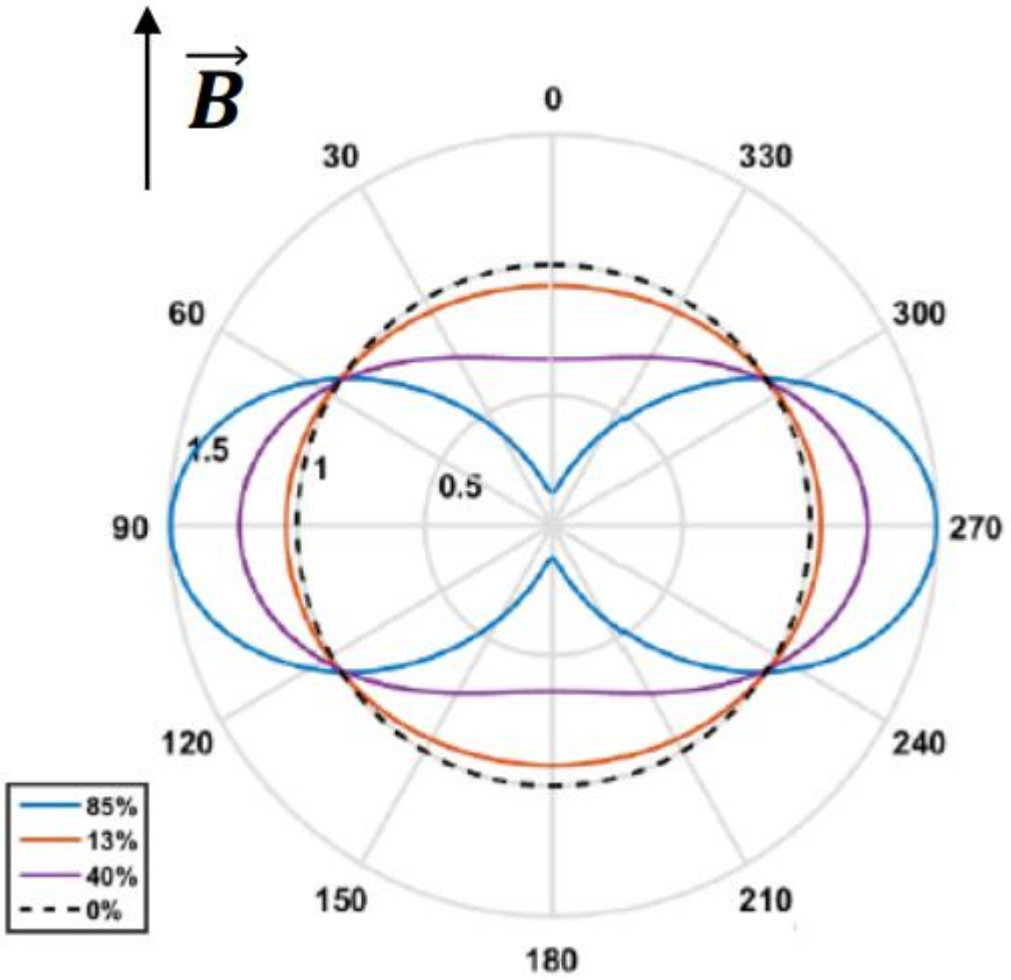


SPECT scanner

FET-OPEN project (H2020-EU.1.2.,H2020-EU.1.2.1),
European Union's Horizon 2022 , grant agreement No 964644

Gamma-MRI - principles

- **ASYMETRIC GAMMA EMISSION FROM ALIGNED RADIONUCLEI**



proof of principle
Y. Zheng, et al., Nature (537), 652 (2016)

Gamma-MRI - principles

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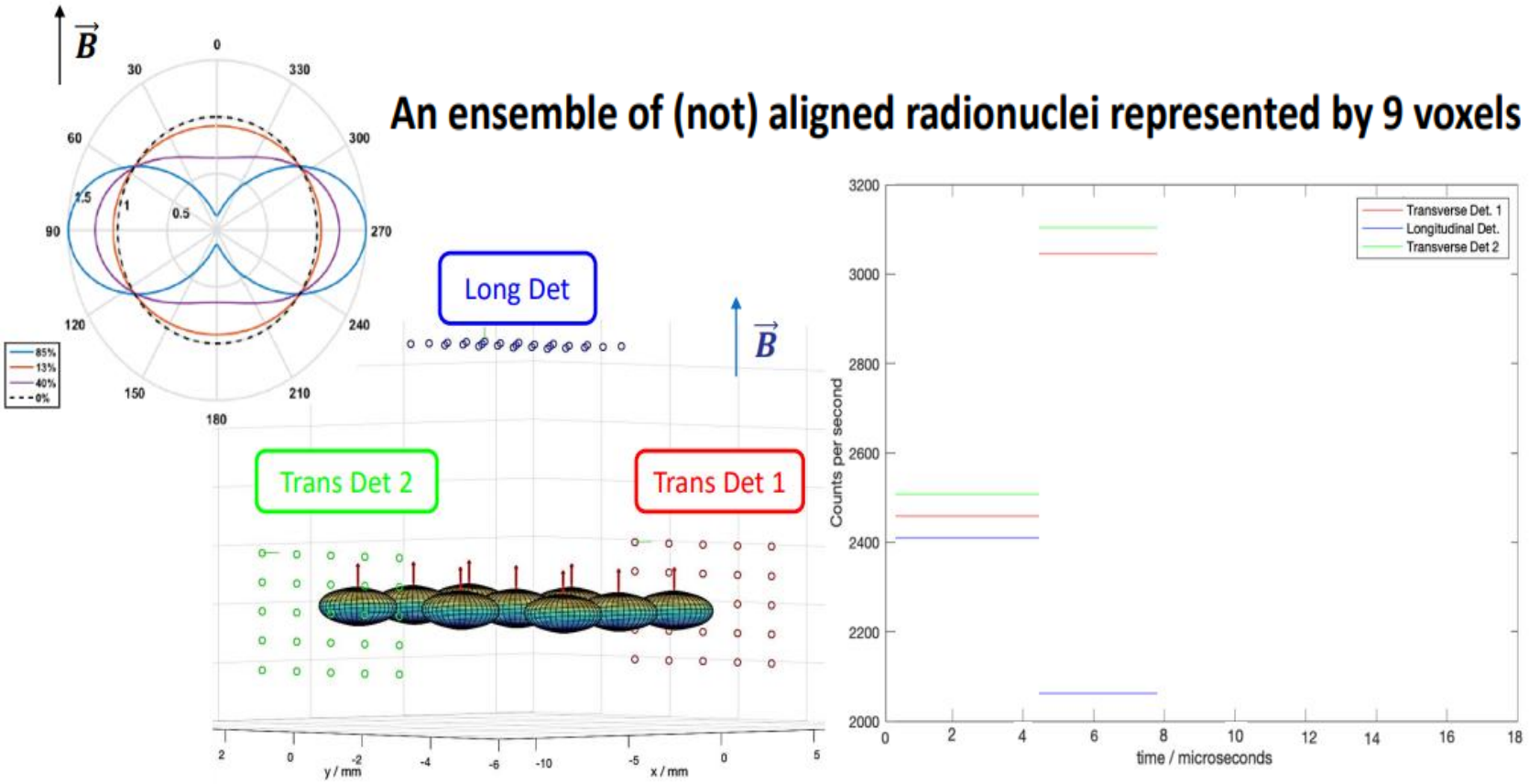

Simulation software for anisotropic gamma decay by R. Engel and E.L. Wistrom

proof of principle
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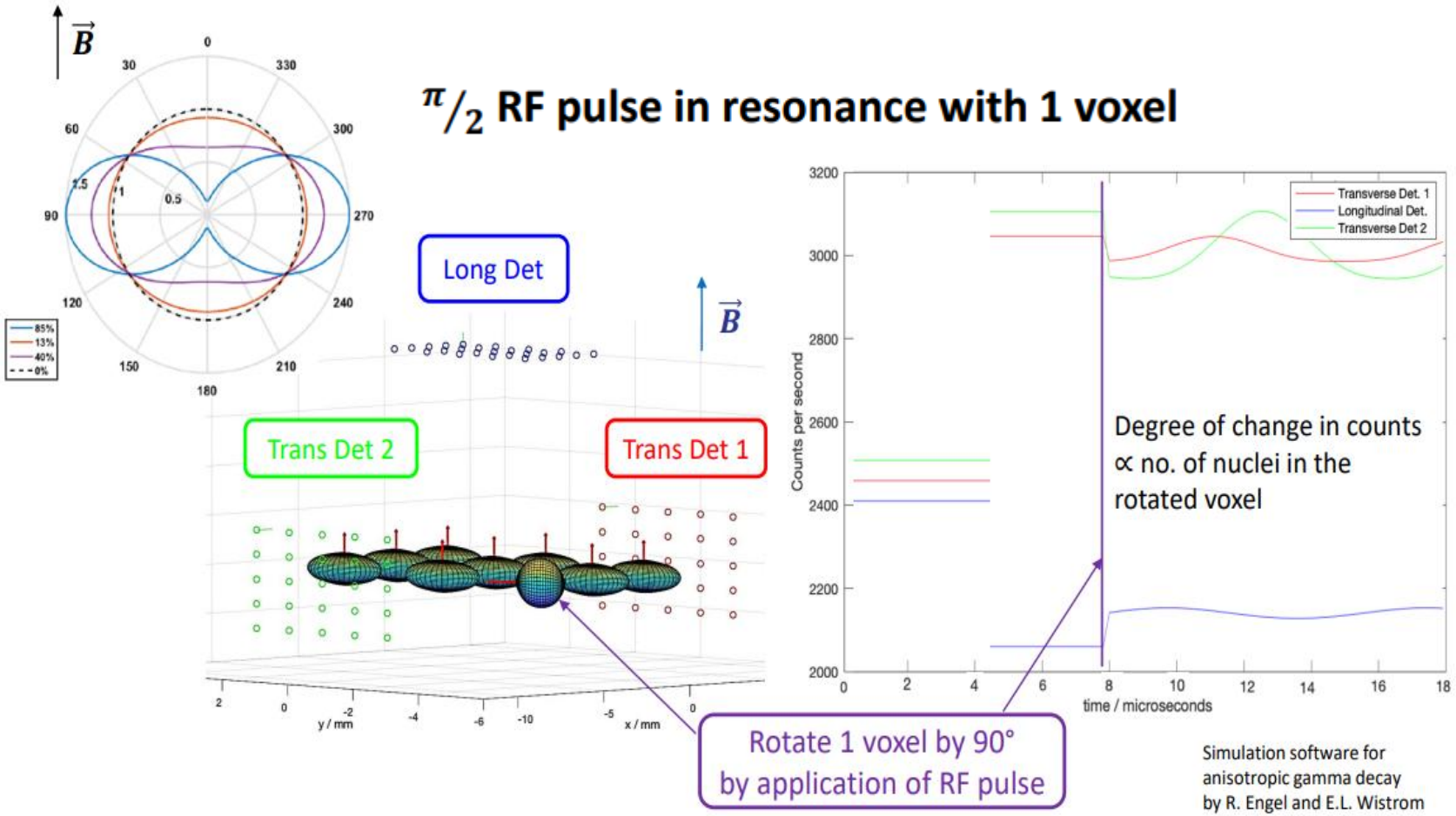
Gamma-MRI - principles

- **CHANGING GAMMA ASYMMETRY UPON RF-EXCITATION IN A GRADIENT FIELD**



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Gamma-MRI - principles

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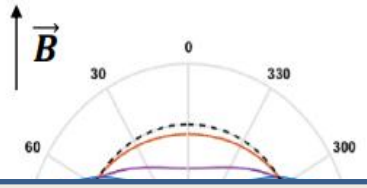
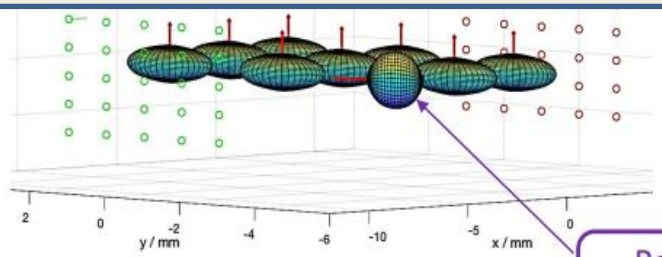


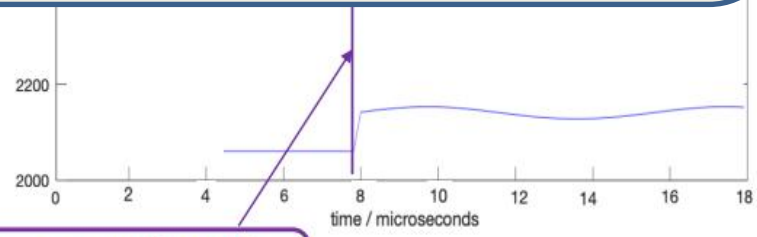
$\pi/2$ RF pulse in resonance with 1 voxel

MANIPULATION LIKE IN MRI

DETECTION LIKE IN SPECT

HIGH SPATIAL RESOLUTION+HIGH SENSITIVITY



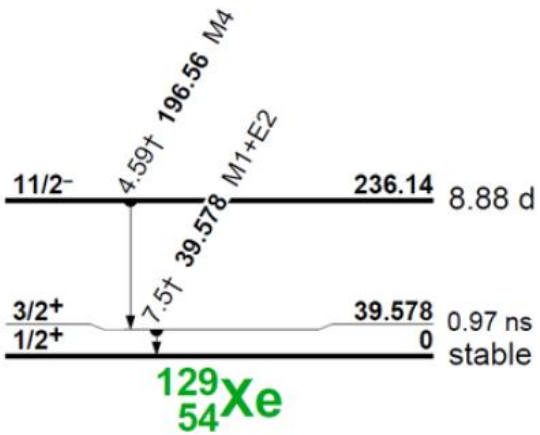


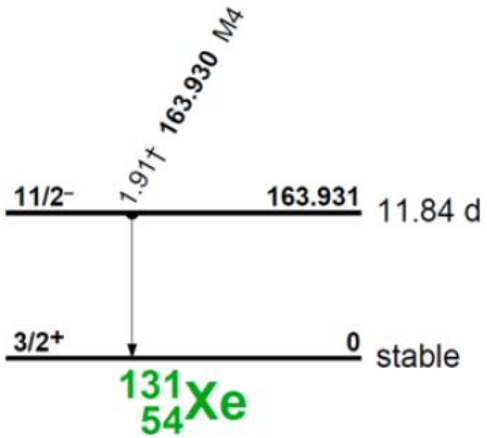
Rotate 1 voxel by 90°
by application of RF pulse

Simulation software for
anisotropic gamma decay
by R. Engel and E.L. Wistrom

proof of principle
Y. Zheng, et al., Nature (537), 652 (2016)

Gamma-MRI – ^{m}Xe nuclei





WHY ^{m}Xe:

- polarization of ^{129}Xe well estabished
- isomers with spin 11/2 show a very high degree of gamma emission asymmetry
- Xe (as a noble gas) is neutral to the human body
- ^{129}Xe is already used in MRI studies of the lungs and brain
- ^{133}Xe commonly used in brain imaging within the SPECT

Gamma-MRI – ^{m}Xe production

- **THERMAL NEUTRON IRRADIATION OF STABLE XENON IN REACTOR CORE**

NEUTRONS FOR SCIENCE

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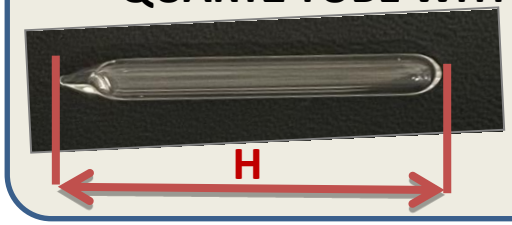
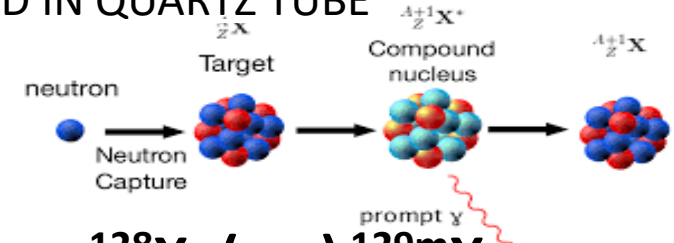
IRRADIATION OF STABLE ^{128}Xe/^{130}Xe ENCLOSED IN QUARTZ TUBE

QUARTZ TUBE WITH STABLE Xe



p_{Xe}=300mbar
(^{128,130}Xe >99.9%)
H=46-50 mm, V=0.8cm^3
d_{inner}=4mm,
d_{outter}=6mm



^{128}Xe(n,γ) ^{129m}Xe

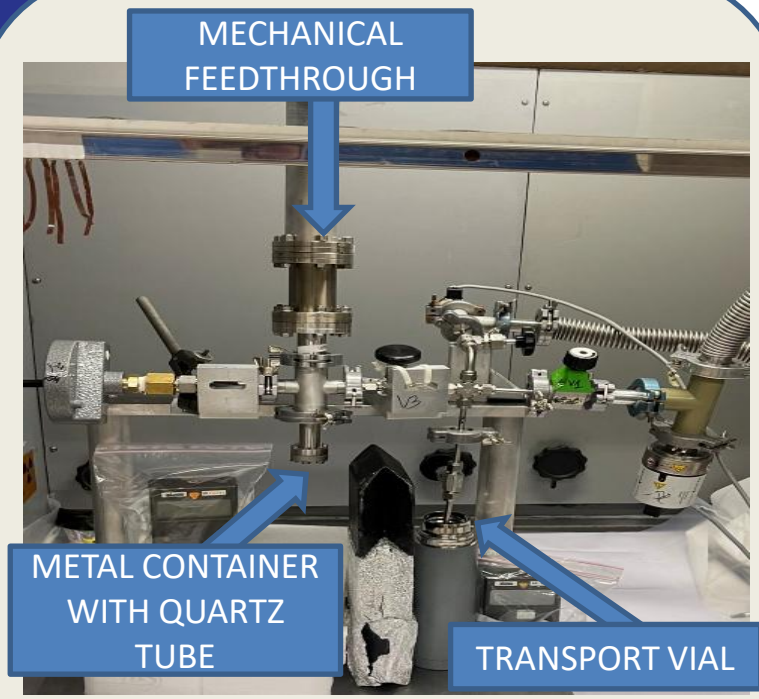
^{130}Xe(n,γ) ^{131m}Xe

*POSSIBLE PRODUCTION OF ANOTHER Xe ISOTOPES VIA DIFFERENT NUCLEAR REACTION LIKE (n,2n)

ISOLDE

Gamma-MRI – ^{m}Xe production

- **THERMAL NEUTRON IRRADIATION OF STABLE XENON IN REACTOR CORE**



TRANSFER EFFICIENCY: up to **84(2)%**

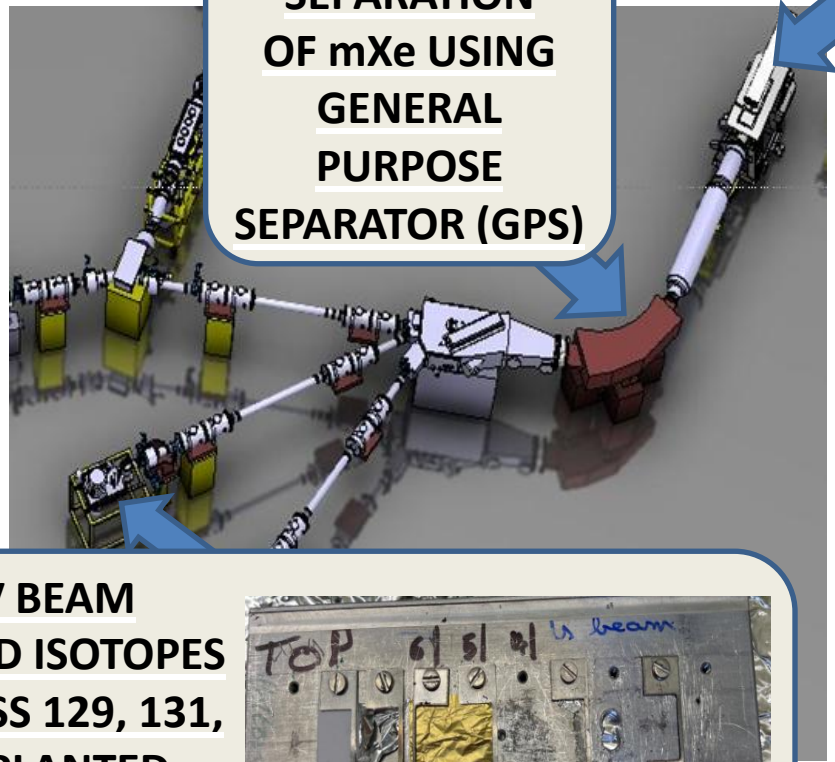
	Institute Laue-Langevin (RHF reactor)	National Centre for Nuclear Research (MARIA reactor)
^{129m}Xe	**^{129m}Xe: 186(3)*** ^{127}Xe: 0.07(1)*	**^{129m}Xe: 45(1)*** ^{127}Xe: 0.02(1)* ^{125}Xe: 0.01(1)*
^{131m}Xe	**^{131m}Xe: 199(4)***	**^{131m}Xe: 64(1)***

*UNIT: MBq/mg
mg - mass of irradiated stable Xe
(typical mass of one sample ~1.3mg)

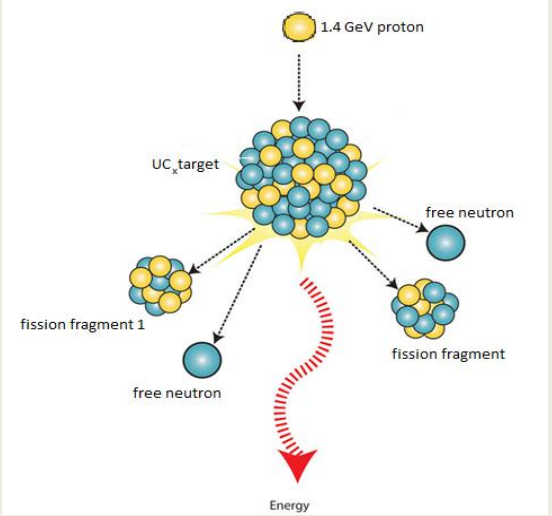
Gamma-MRI – ^{m}Xe production

- **ION-IMPLANTATION OF ^{129m,131m,133m}Xe INTO GOLD FOILS AT THE ISOLDE FACILITY IN CERN**

SEPARATION OF mXe USING GENERAL PURPOSE SEPARATOR (GPS)



PROTON BEAM HITTING UC_x TARGET

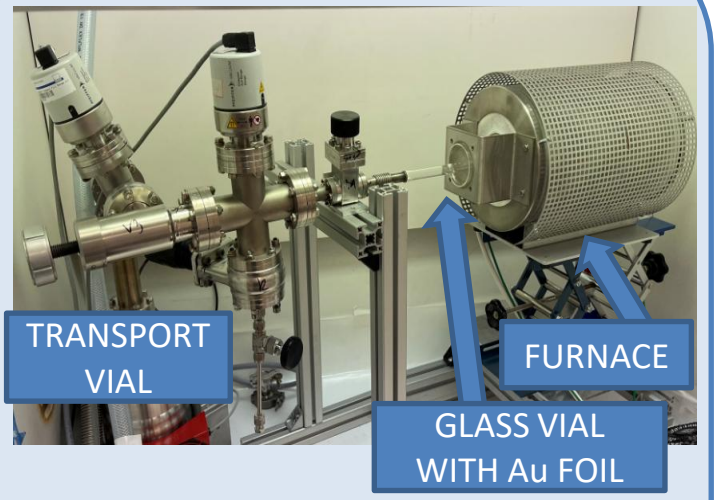


- **PRODUCED ISOTOPES EXTRACTED FROM TARGET USING:**
  - ✓ HEATING
  - ✓ PLASMA IONIZATION SOURCE (ARGON)
  - ✓ HIGH VOLTAGE

60keV BEAM OF IONISED ISOTOPES WITH MASS 129, 131, 133 IMPLANTED IN ANNEALED GOLD FOILS

Gamma-MRI – ^{m}Xe production

- **ION-IMPLANTATION OF ^{129m,131m,133m}Xe INTO GOLD FOILS AT THE ISOLDE FACILITY IN CERN**



EXTRACTION EFFICIENCY : up to **84(1)%**

TRANSFER EFFICIENCY : up to **87(3)%**

	^{129m}Xe	^{131m}Xe	^{133m}Xe
HOT TARGET WITH p^+	**2.6(2)***	**3.4(3)***	**8.0(3)***
HOT TARGET NO p^+ **	**0.09(1)***	**0.09(1)***	**3.7(4)***
COLD TARGET NO p^+ **	**0.06(1)***	**0.01(1)***	**0.19(5)***

*UNIT: MBq/h (h - time of cellection)

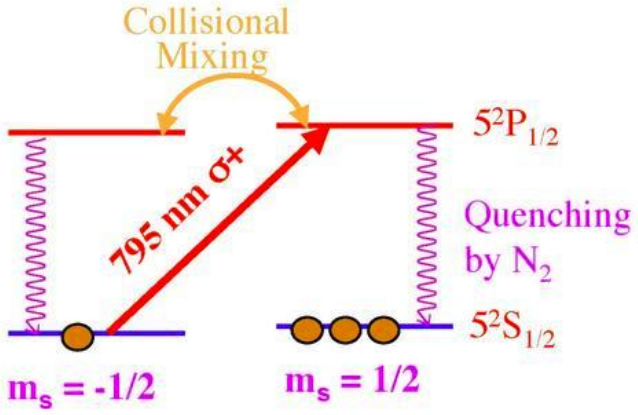
**production rate decrease with time after proton irradiation

POSSIBLE O_2 CONTAMINATION ON Au SURFACE DURING TRANSPORT BETWEEN IMPLANTATION AND EXTRACTION POINT
(POSSIBLE PROBLEM WITH POLARIZATION EXPERIMENT)

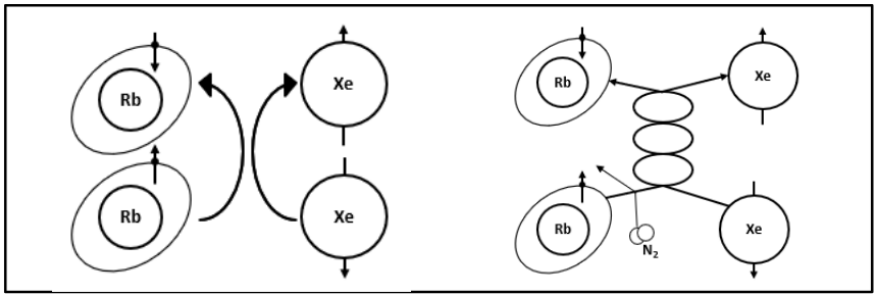
Gamma-MRI – ^{m}Xe polarization

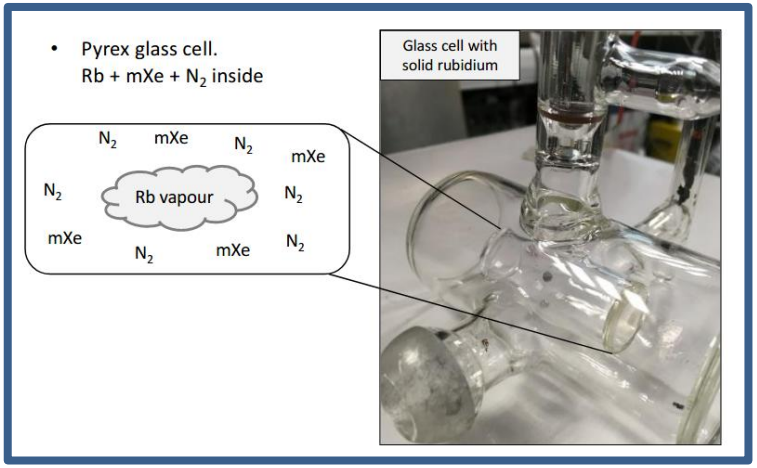
- **POLARIZATION EXPERIMENT:**
  - **METHOD: SPIN-EXCHANGE OPTICAL PUMPING (SEOP)**

1st step: Rb polarization



2nd step: ^{m}Xe polarization by Rb through hyperfine interaction

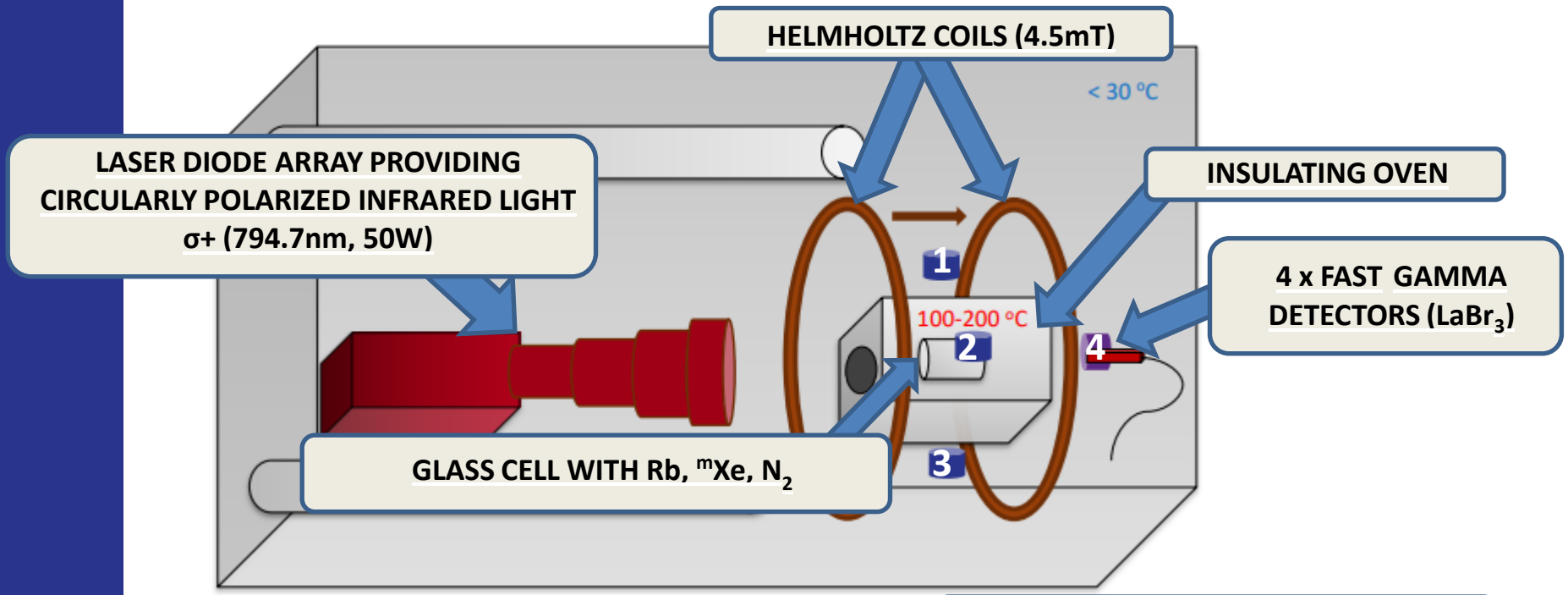




T.G.Walker, W.Harper, Rev.Mod.Phys.69(1997) 629-642

Gamma-MRI – ^{m}Xe polarization

- **POLARIZATION EXPERIMENT - SETUP:**
  - ❑ **METHOD: SPIN-EXCHANGE OPTICAL PUMPING (SEOP)**

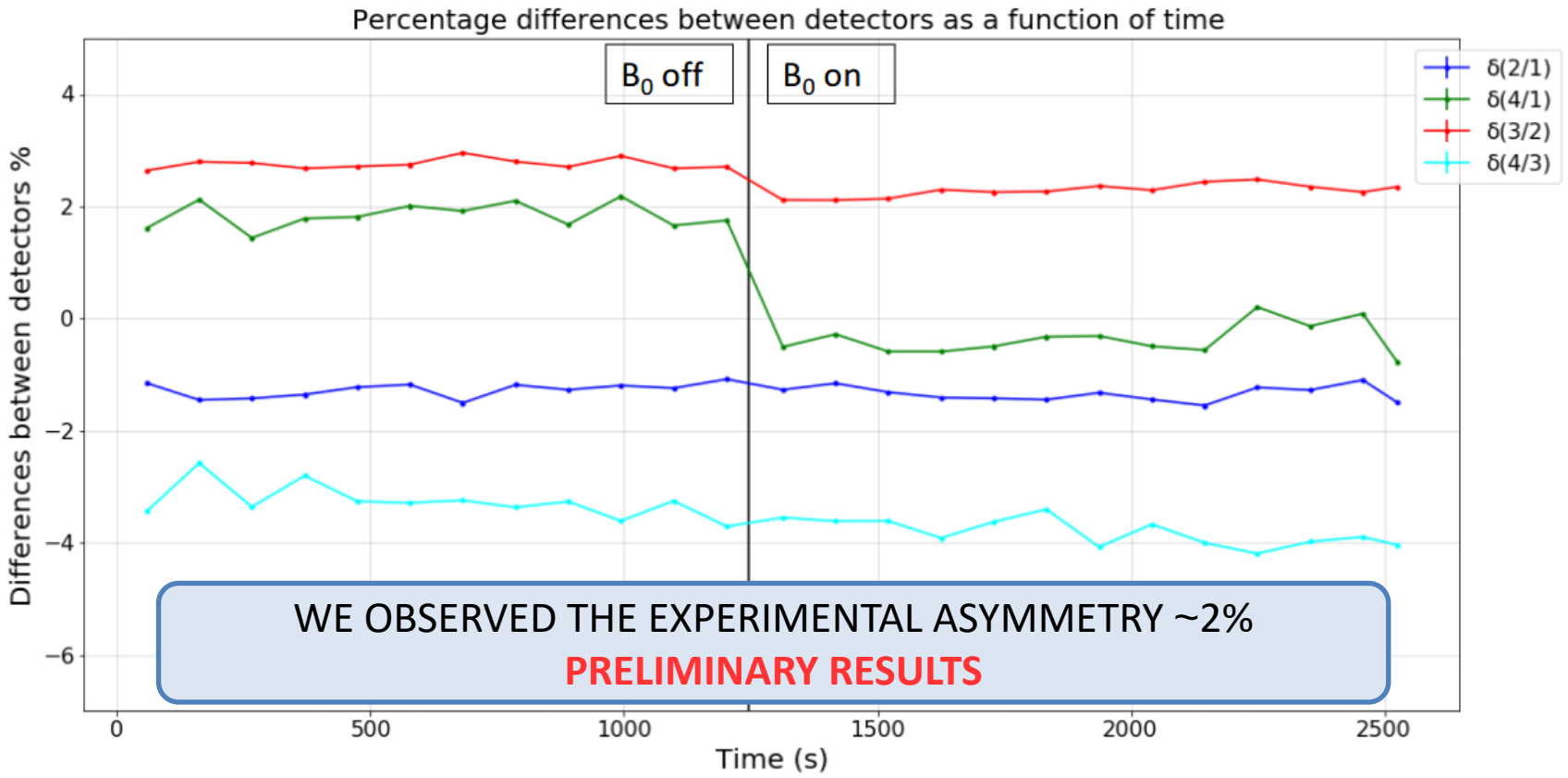


ASYMMETRY:

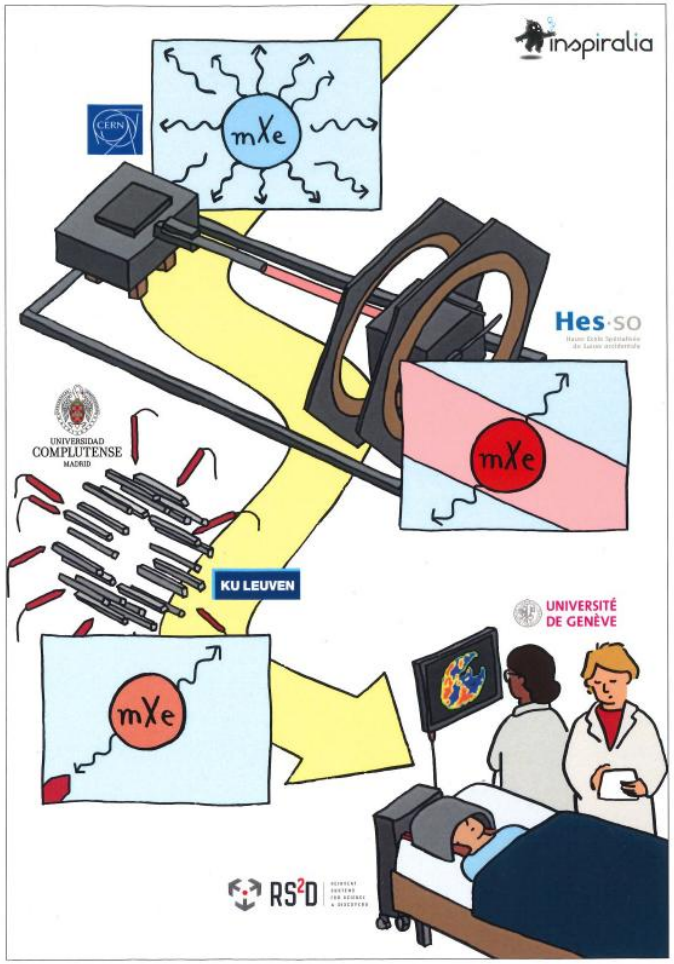
$$\delta(4/1) = \frac{det4 - det1}{det4}$$

Gamma-MRI – ^{m}Xe polarization

- **POLARIZATION EXPERIMENT – PRELIMINARY RESULTS:**



Summary



- gamma-MRI – novel medical imagining modality
- ^{129m,131m,133m}Xe produced successfully at difrent nuclear facilities and exctracted efficiently from the native containers
- Fully operational SEOP setup capable of polarizing Rb well and hinting Xe hyperpolarization
- First experimental gamma asymmetry was measured

gamma-MRI project website:
http://gamma-mri.eu

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