



GATE activities @ NCBJ
opengatecollaboration.org

Wojciech Krzemień

Gate Scientific Meeting
31.03 2026

National Center for Nuclear Research

Research sector in NCBJ



HR EXCELLENCE IN RESEARCH

Nuclear Facilities
Operations
Department



Material Physics Department

LBM

Department of
Fundamental Research

Department of Nuclear
Techniques and
Equipment

Complexity Center



Radioisotope Centre
POLATOM

Division of Nuclear
Equipment HITEC

Science and Technology
Park

International Research
Agenda - NOMATEN

Scientific-and-Industry
Centers

One of the largest research institute in Poland
1195 employees, inc. 80 prof. & 170 PhD
PhD Study: ~45 students

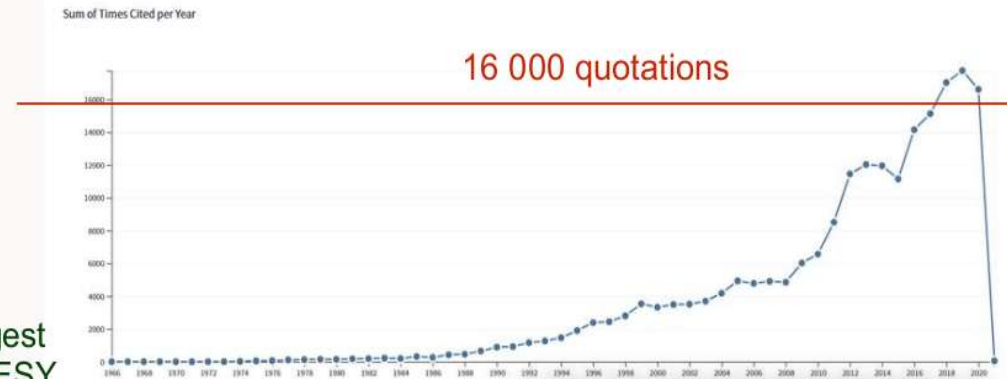
Scientific achievements:
~500 reviewed papers,
~16000 quotations each year,
5/4th position in Poland,

budget/year ~ 70 M€

124 different types projects

International collaborations with largest
laboratories in the world (CERN, DESY,
Grenoble, JParc, FAIR, Julich, ESS, JINR,
T2K), cooperation in many universities around the world

EU projects: success rate: 30%



¹³¹I hot cells



⁹⁰Y & ¹⁷⁷Lu hot cells



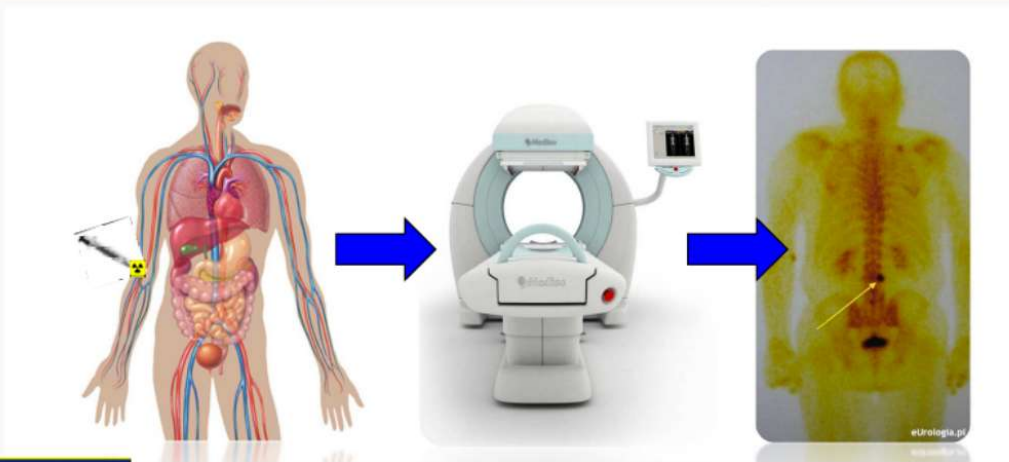
Radiopharmaceuticals with marketing authorisation

Quality Assurance System certified:

ISO: PN-EN ISO 9001:2015-10
cGMP and GLP



Radioisotope Centre POLATOM-NCBJ



Export to 80 countries
100% polish market
(except PET)

Medicines for 17 million
patients a year

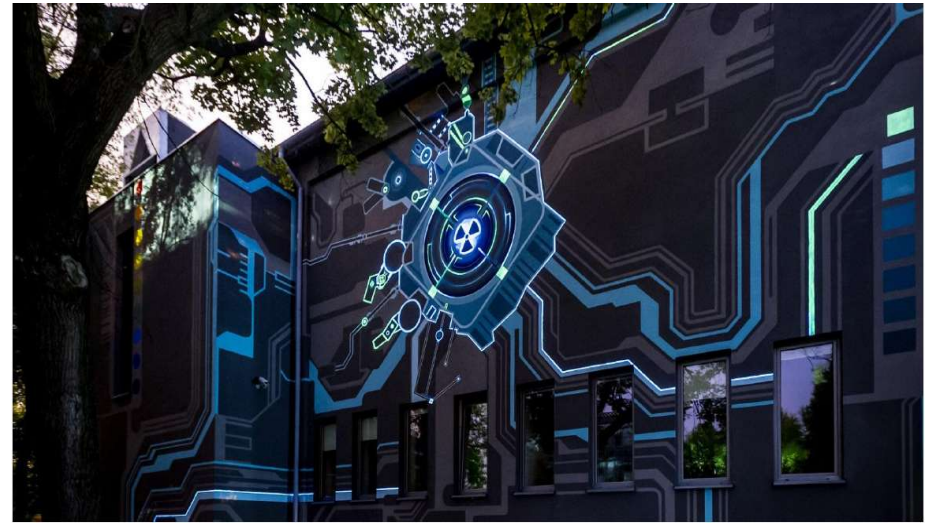


I-131



Mo-99





<https://www.ncbj.gov.pl/en/department-complex-systems>

- CIS computing cluster (1,4 PFLOPS, ~36 000 cores and 200 TB RAM)
- development of AI and Big Data processing methods
- data analysis in various applications
- development of novel imaging algorithms for medicine and industry

IMPET – Industrial Multiphoton PET Tomography

Objectives:

- **AI-enhanced** solutions for **industrial multiphoton** imaging
- use of **quantum correlation** measurements as complementary information to classical spatial distributions and to PALS methods.
- Development of new **positron emission particle tracking** algorithms
- project of the **industrial scanner** and the library of the **reconstruction methods**

Timeline: **1.02 2025 – 31.01 2028**

contract number: **First Team FENG.02.02-IP.05-0152/23**

Principal Investigator: **Wojciech Krzemień (NCBJ)**

Scientific cooperation:

- **Beatrix Hiesmayr (University of Vienna)**
- **David Sarrut (CREATIS - INSA Lyon)**

Commercial cooperation: **Creotech Instruments S.A.**

Total budget: ~ **940K euro**

Website: <https://pet.ncbj.gov.pl/>



Scientific collaborations

CREATIS Lyon, France

- David Sarrut → Gate development
- Aurelien Coussat → multiphoton image reco algorithms



- Beatrix Hiesmayr → quantum correlations in photon systems from Ps decays
- Tobias Sutter



- Kamil Dulski → positronium lifetime imaging, MC methods



Co-funded by the
European Union



ML-based scatter corrections

Symposium on AI and Reconstruction for Biomedical Imaging, K.Klimaszewski, M.Obara, London, March 9-10, 2026 (Poster)

M. Obara et al., "Data Generation for Machine Learning Classification of Coincidence Events for Siemens Biograph Vision Quadra PET," IEEE EUROCON 2025

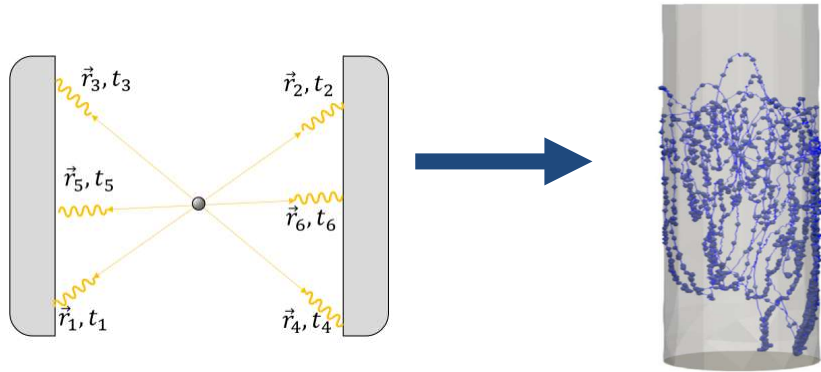
Novel Positronium Lifetime Imaging algo's

Symposium on AI and Reconstruction for Biomedical Imaging, R. Y. Shopa, London, March 9-10, 2026 (Poster)

In collaboration with **Kamil Dulski** (Jagiellonian University)

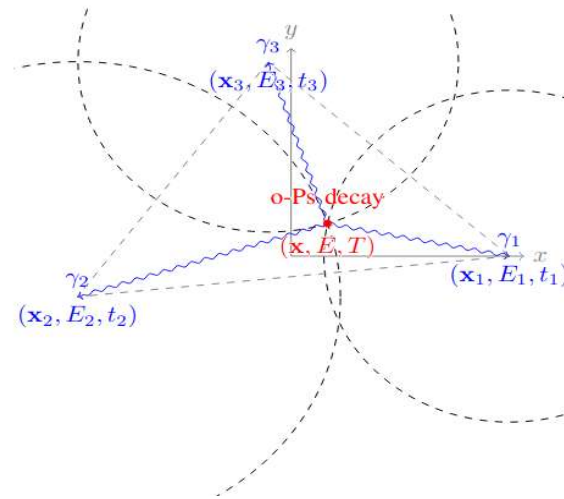
Positron Emission Particle Tracking

L. Raczyński



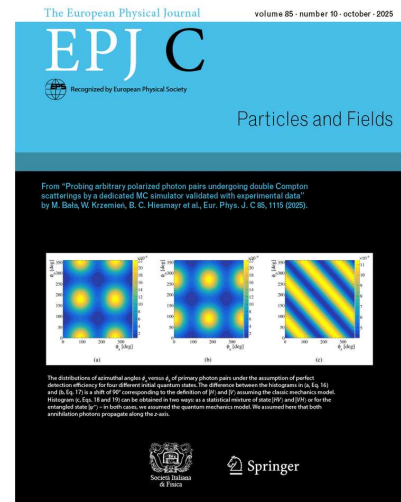
New ortho-positronium vertex reconstruction algo.

L. Raczyński, W. Krzemień



In collaboration with **Aurelien Coussat** (CREATIS - Lyon)

Models of multi-photon correlations



MC model for arbitrary two-photon initial state:
M. Bała, W. Krzemień, B.C. Hiesmayr, et al. Euro.Phys. J. C 85 (2025)

Multiple scattering formalism in quantum information language:
B. C. Hiesmayr, W. Krzemień, and M. Bała Sci Rep 14, 9672 (2024)

In collaboration with **Beatrix Hiesmayr** (IT:U and University of Vienna)
Tobias Sutter (University of Vienna)

Positronium decay source model with multiple annihilation channels

In collaboration with:

- Mateusz Bała (NCBJ)
- Kamil Dulski (Jagiellonian University)
- Wojciech Zdeb (NCBJ) et al.

Positronium Lifetime Imaging (+ other markers)

Home > EJNMMI Physics > Article

Phantom imaging demonstration of positronium lifetime with a long axial field-of-view PET/CT and ^{124}I

Original research | Open access | Published: 26 August 2025
Volume 12, article number 80, (2025) [Cite this article](#)

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L. Mercolli et al.

Home > EJNMMI Physics > Article

Positronium lifetime validation measurements using a long-axial field-of-view positron emission tomography scanner

Original research | Open access | Published: 30 August 2024
Volume 11, article number 76, (2024) [Cite this article](#)

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W. Steinberger et al.

Home > Communications Physics > Article

Oxygen sensing ability of positronium atom for tumor hypoxia imaging

Article | Open access | Published: 01 October 2020
Volume 3, article number 173, (2020) [Cite this article](#)

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K. Shibuya et al.

Home > Communications Physics > Article

Fast high-resolution lifetime image reconstruction for positron lifetime tomography

Article | Open access | Published: 26 April 2025
Volume 8, article number 181, (2025) [Cite this article](#)

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B. Huang et al.

RESEARCH ARTICLE | PHYSICAL SCIENCES

Positronium image of the human brain in vivo

PAWEŁ MOSKAŁ, JAKUB BARAN, STEVEN BASS, JAROSŁAW CHOIŃSKI, NEHA CHUG, CATALINA CURCEANU, ERYK CZERWIŃSKI, MEYSAM DADGAR, MANISH DAS, I.-J. AND EWA L. STEPIEN, +34 authors [Authors Info & Affiliations](#)

SCIENCE ADVANCES • 13 Sep 2024 • Vol 10, Issue 37 • DOI:10.1126/sciadv.ado2840

9219 33

P. Moskal et al.

RESEARCH ARTICLE | BIOPHYSICS

Positronium imaging with the novel multiphoton PET scanner

PAWEŁ MOSKAŁ, KAMIL DULSKI, NEHA CHUG, CATALINA CURCEANU, ERYK CZERWIŃSKI, MEYSAM DADGAR, JAN GAJEWSKI, ALEKSANDER GAJOS, GRZEGORZ GRUDZIEN, I.-J. AND WOJCIECH WIŚLICKI, +26 authors [Authors Info & Affiliations](#)

SCIENCE ADVANCES • 19 Oct 2021 • Vol 7, Issue 42 • DOI:10.1126/sciadv.abh4394

P. Moskal et al.

31-12-2023 - Original article - Pages: 54 - 63

Positronium imaging in J-PET with an iterative activity reconstruction and a multistage fitting algorithm

Roman Y. Shopa, Kamil Dulski

Language versions: English

42 455

DOI: 10.5604/01.3001.0054.1826
GICID: 01.3001.0054.1826

Journals & Magazines > IEEE Transactions on Medical ... > Volume: 41 Issue: 10

Positronium Lifetime Image Reconstruction for TOF PET

Publisher: IEEE [Cite This](#) [PDF](#)

J. Qi, B. Huang et al.

Jinyi Qi; Bangyan Huang [All Authors](#)

Journals & Magazines > IEEE Transactions on Medical ... > Volume: 43 Issue: 6

SPLIT: Statistical Positronium Lifetime Image Reconstruction via Time-Thresholding

Publisher: IEEE [Cite This](#) [PDF](#)

Bangyan Huang; Tiantian Li; Gerard Ariño-Estrada; Kamil Dulski; Roman Y. Shopa; Paweł Moskał [All Authors](#)

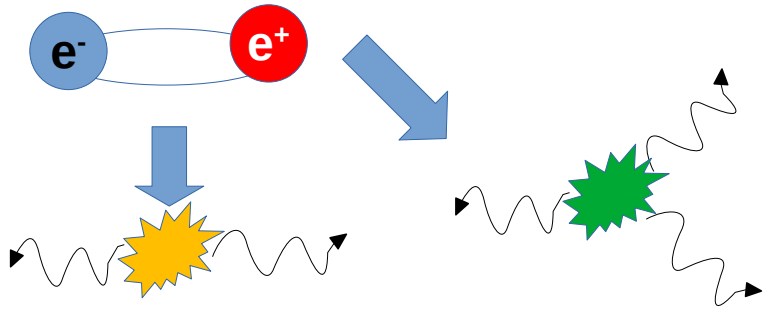
Applications:

- novel medical imaging techniques
- novel industrial imaging techniques

Challenge:
lack of the proper MC tools to perform the simulations

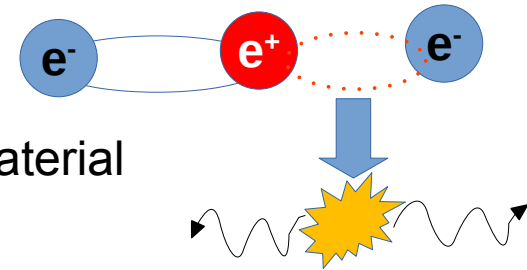
Positronium decay models

Positronium (Ps) decays



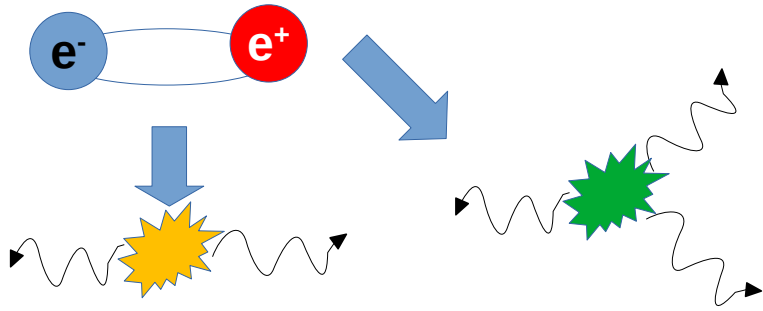
Pick-off

Depends on material surrounding



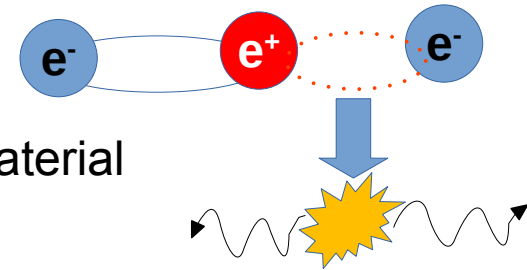
Positronium decay models

Positronium (Ps) decays

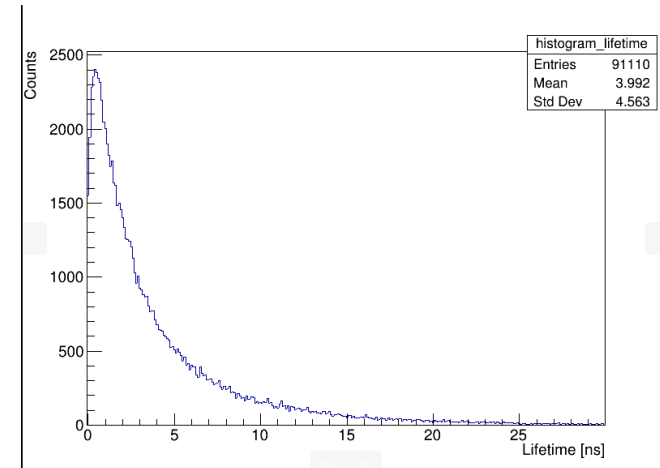
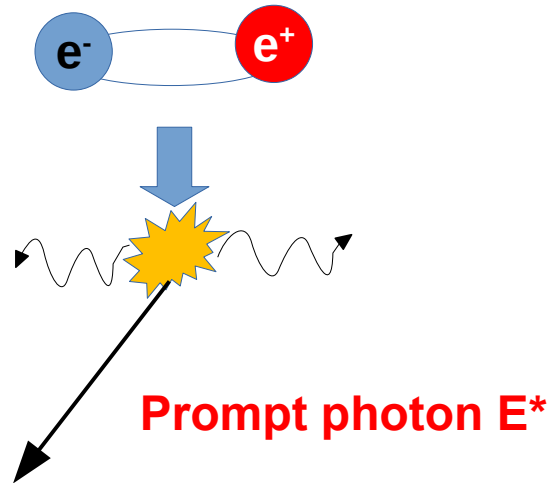


Pick-off

Depends on material surrounding



For PLI non-pure source emitter needed

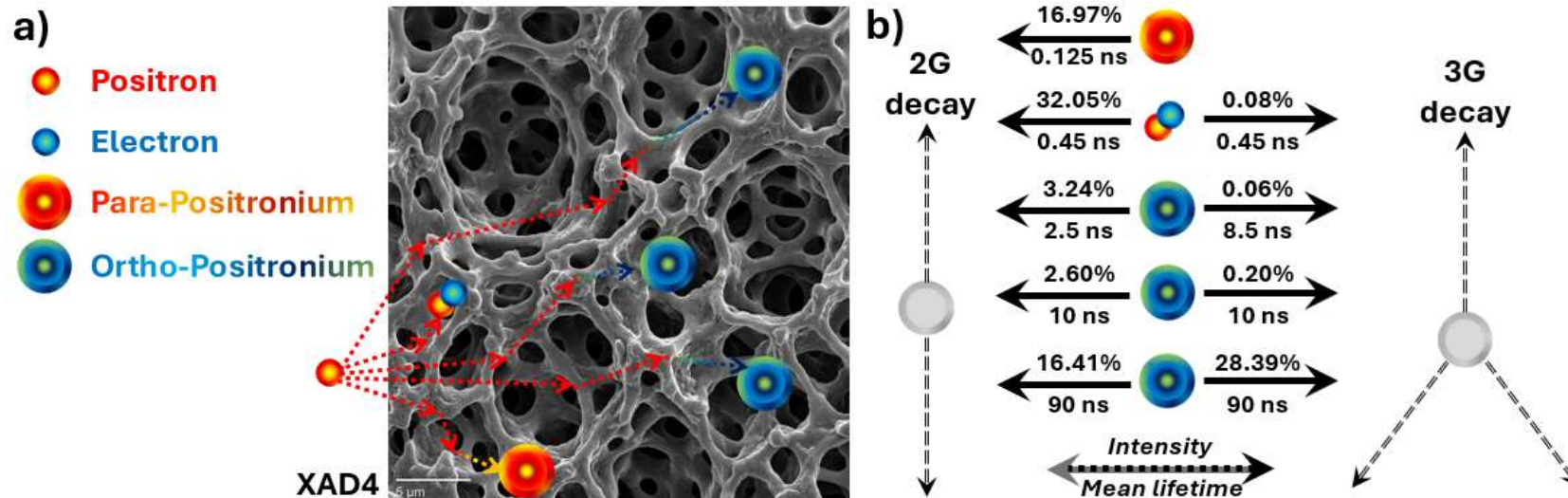


<p>Start (Ps formation): Emission of prompt photon</p>	<p>Ps Lifetime</p>	<p>Stop (Ps decay): Emission of annihilation photons</p>
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Available implementations

- No native positronium modelling in Geant4
- (Few) Geant4-based „in-house” models developed by some groups
 - Custom solutions for given purposes
 - Code not always „easily” available for the community
- First Ps decay model „**ExtendedVSource**” (GATEv > 9.3) by Mateusz Bała
 - Used by several groups in their researches → published articles.
 - Some (important) limitations:
 - Multi-channel modelling not accesible,
 - simplified prompt photon decay scheme,
 - no positron range modelling

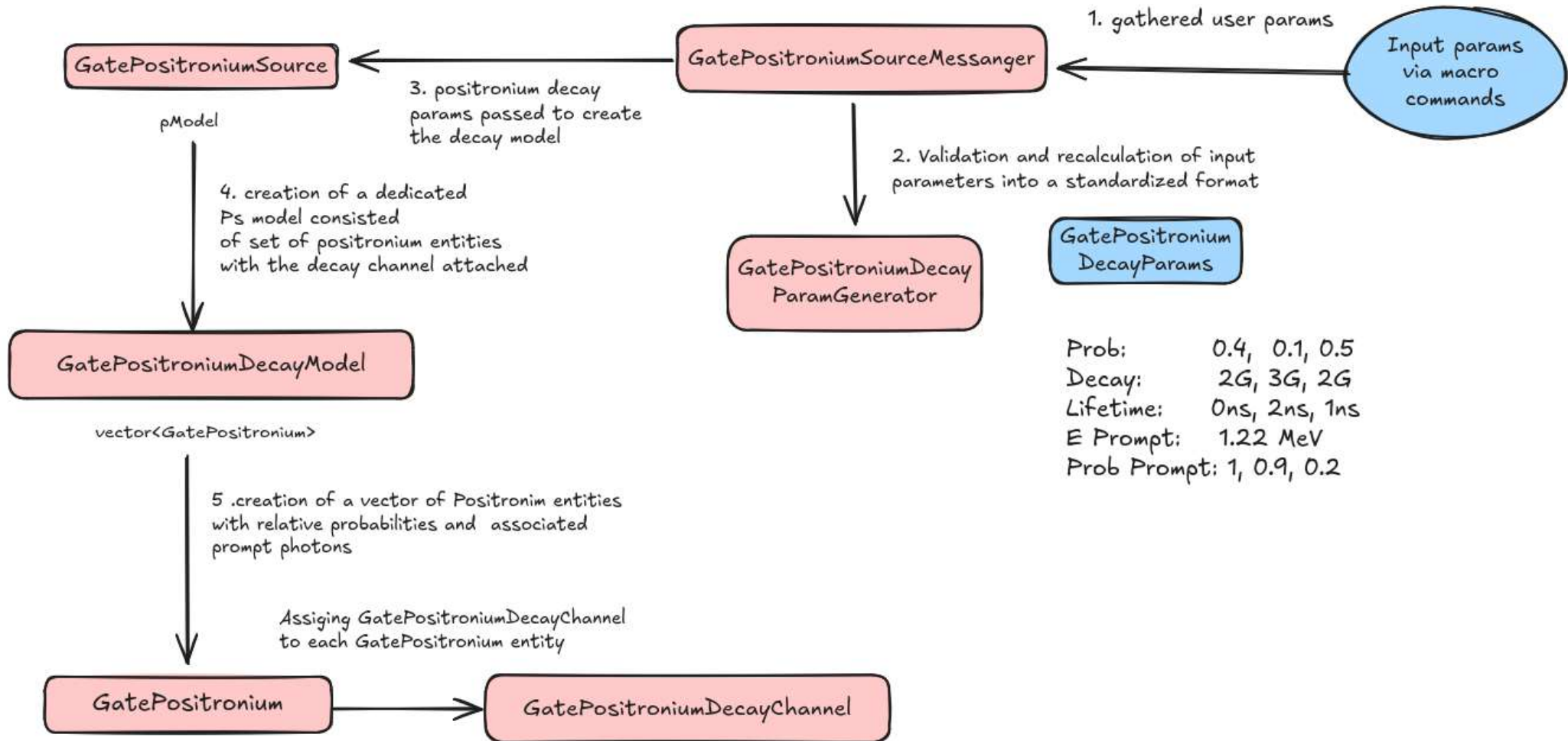
Positronium decay source with multiple annihilation channels



Functionalities

- multi-component decay mode
- complex decay scheme with non-trivial prompt photon emissions
- effective positron range modelling
- Set of helper functions to make the user life easier

Implementation scheme

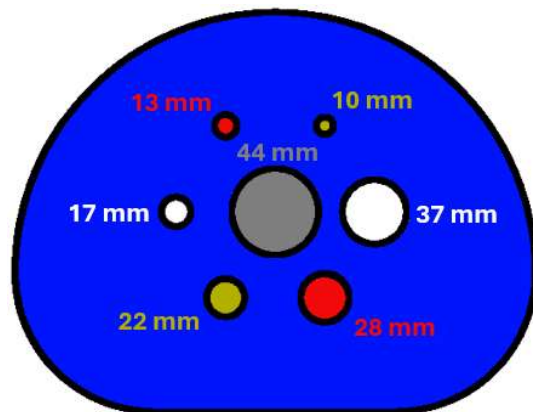


Tests and Benchmarks

Basic tests [done]:

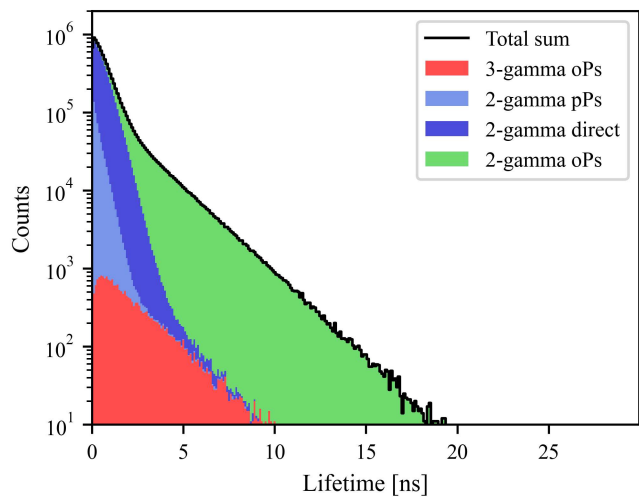
- Set of unit tests for methods developed (**ctest** mechanism used in Gate 9.4)
- Functional backward-compatibility tests with Gate v9.3
- Self-consistency checks to reproduce expected:
 - fractions of decay channels
 - lifetimes
 - kinematics
 - prompt decay schemes (e.g. using ^{68}Ga , ^{22}Na , ^{124}I sources)
 - 3g-to-2g ratio

Selected „more complex” use cases [almost finished]:

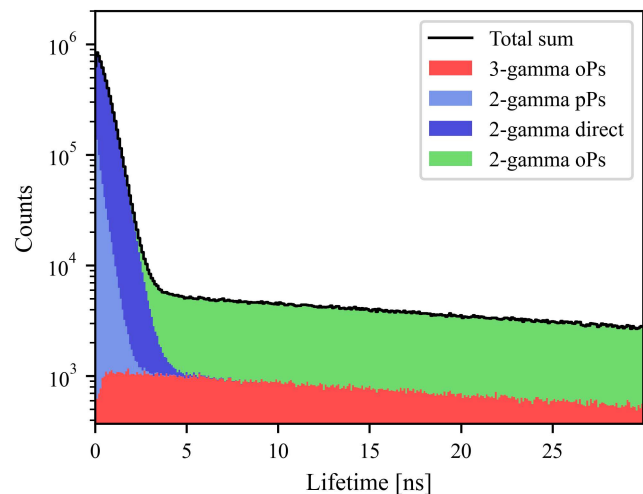
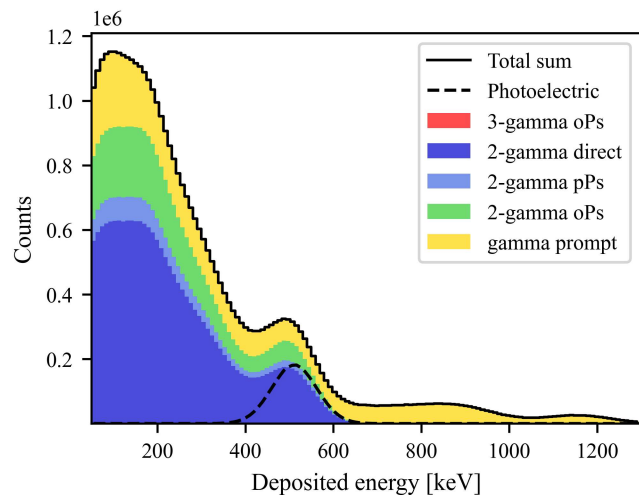


	p-Ps	direct	o-Ps ₁	o-Ps ₂	o-Ps ₃	o-Ps ₄
Intensity	13%	79%	4.8%	2.7%	2.2%	1.3%
Mean lifetime [ns]	0.125	0.4	2.1	6.3	21	58
Intensity	12%	69.5%	18.5%			
Mean lifetime [ns]	0.152	0.42	2.54			
Intensity	9.2%	76.3%	14.5%			
Mean lifetime [ns]	0.15	0.44	2.04			
Intensity	14%	62%	22%			
Mean lifetime [ns]	0.14	0.4	1.8			

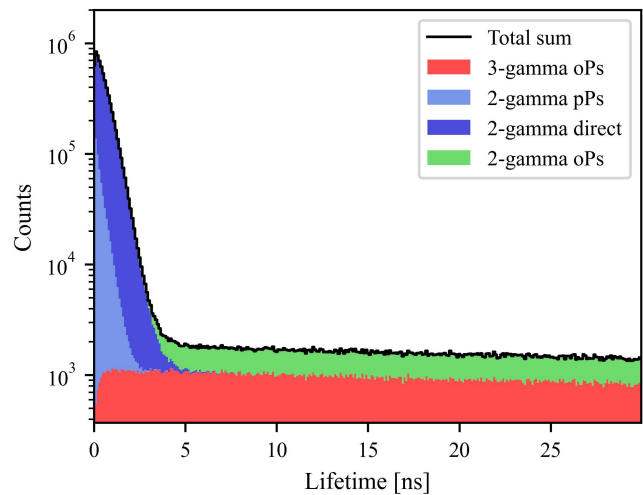
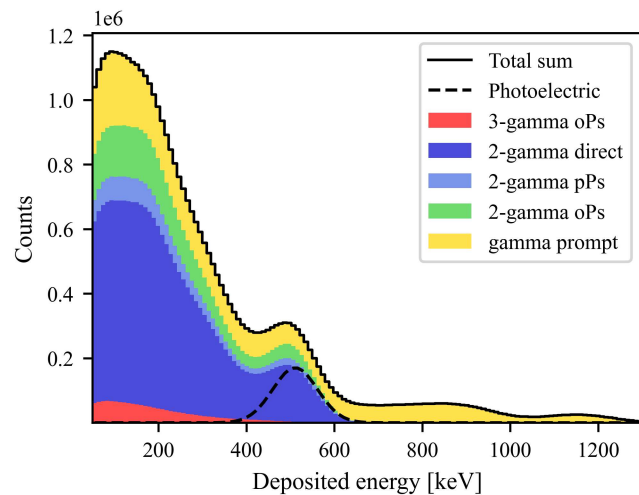
Simulations with a model of Siemens Biograph Vision Quadra (Gate 9.4)



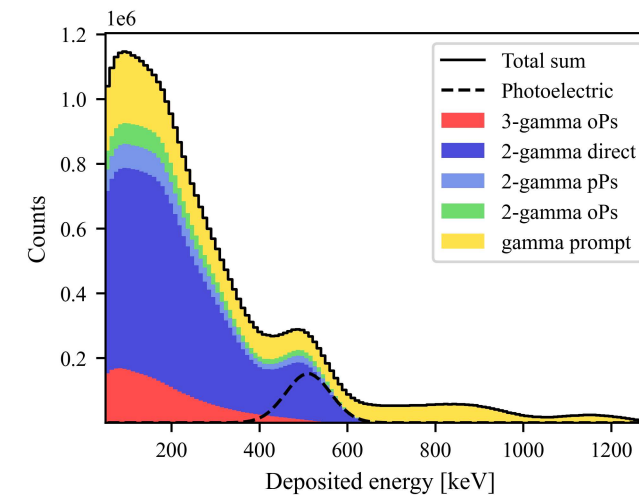
$$\tau(\text{oPs} \rightarrow 3\text{g}) = 2 \text{ ns}$$



$$\tau(\text{oPs} \rightarrow 3\text{g}) = 40 \text{ ns}$$



$$\tau(\text{oPs} \rightarrow 3\text{g}) = 100 \text{ ns}$$



Summary

New multi-channel positronium model for GATE:

- Implementation **[done]**
- Basic tests **[done]**
- Selected „more complex” use cases/benchmarks **[in preparation]**
- **Porting of the code to GATEv10 [done]**

In plans:

- Preparation of PRs **[almost done]**
- Finalization of user parameter handling in Gate 10 **[in progress]**
- Preparation of Docs **[:-)]**
- Validation with experimental data → in collaboration with M.S. Allen, C. Catana (MIT, MGH Martinos Center) and E. Roncali (UC Davis)

Other Gate-related activities

some memory leaks fixed

Memory leaks fixes + one refactorization by Konrad Klimaszewski for GATE 9v4

- GateVolumeID refactoring (as a thin wrapper to `std::vector`)
- Fix memory leaks in the digitizer code
- Added as a part of Gate 9v4.2 release

WMLQ2026 is approaching

**3rd International Workshop on Machine Learning and Quantum
Computing Applications in Medicine and Physics**

WMLQ2026

7 to 11 September 2026, Warsaw, Poland

<https://events.ncbj.gov.pl/event/468/page/606-home>



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Thank you for attention