Research Activities at the Krakow Proton Therapy Centre

Where we are and where to go?

Antoni Rucinski
Institute of Nuclear Physics PAN

European Funds Smart Growth
Republic of Poland
FNP Foundation for Polish Science
European Union European Regional Development Fund

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

PAPER

Secondary radiation measurements for particle therapy applications: charged particles produced by ^{4}He and ^{12}C ion beams in a PMMA target at large angle

A Rucinski[1,2,8], G Battistoni[4], F Collamati[1], E De Lucia[3], R Faccini[1,5], P M Frallicciardi[6,9], C Mancini-Terracciano[1], M Marafini[1,7], I Mattei[4], S Muraro[4], R Paramatti[1,5], L Piersanti[3], D Pinci[1], A Russomando[1,5,10], A Sarti[2,3,7], A Sciubba[1,2,7], E Solfaroli Camillocci[1,5], M Toppi[3], G Traini[1,5], C Voena[1] and V Patera[1,2,7]

Secondary radiation measurements for particle therapy applications: Charged secondaries produced by ^{16}O ion beams in a PMMA target at large angles

A. Rucinski[a,b], G. Traini[d,a,‡], A. Baratto Roldan[k], G. Battistoni[c], M. De Simoni[d,a], Y. Dong[c,l], M. Fischetti[e,a], P. M. Frallicciardi[f,g], E. Gioscio[g], C. Mancini-Terracciano[a,d], M. Marafini[g,a], I. Mattei[c], R. Mirabelli[a,d], S. Muraro[i], A. Sarti[e,h,g], A. Schiavi[e,a], A. Sciubba[e,a,g], E. Solfaroli Camillocci[a,d,j], S. M. Valle[c,l], V. Patera[e,a,g]

Experimental setup @HIT

In 2014 we collected several millions of collisions with a PMMA target in different geometrical configurations.

Beams in therapeutical energy range:

- **Helium** (102, 125, 145 MeV)
- **Carbon** (120, 160, 180, 220 MeV)
- **Oxygen** (210, 260, 300 MeV)

- trigger (few kHz)
- beam (few MHz)
- Ekin from TOF
- different angular configurations

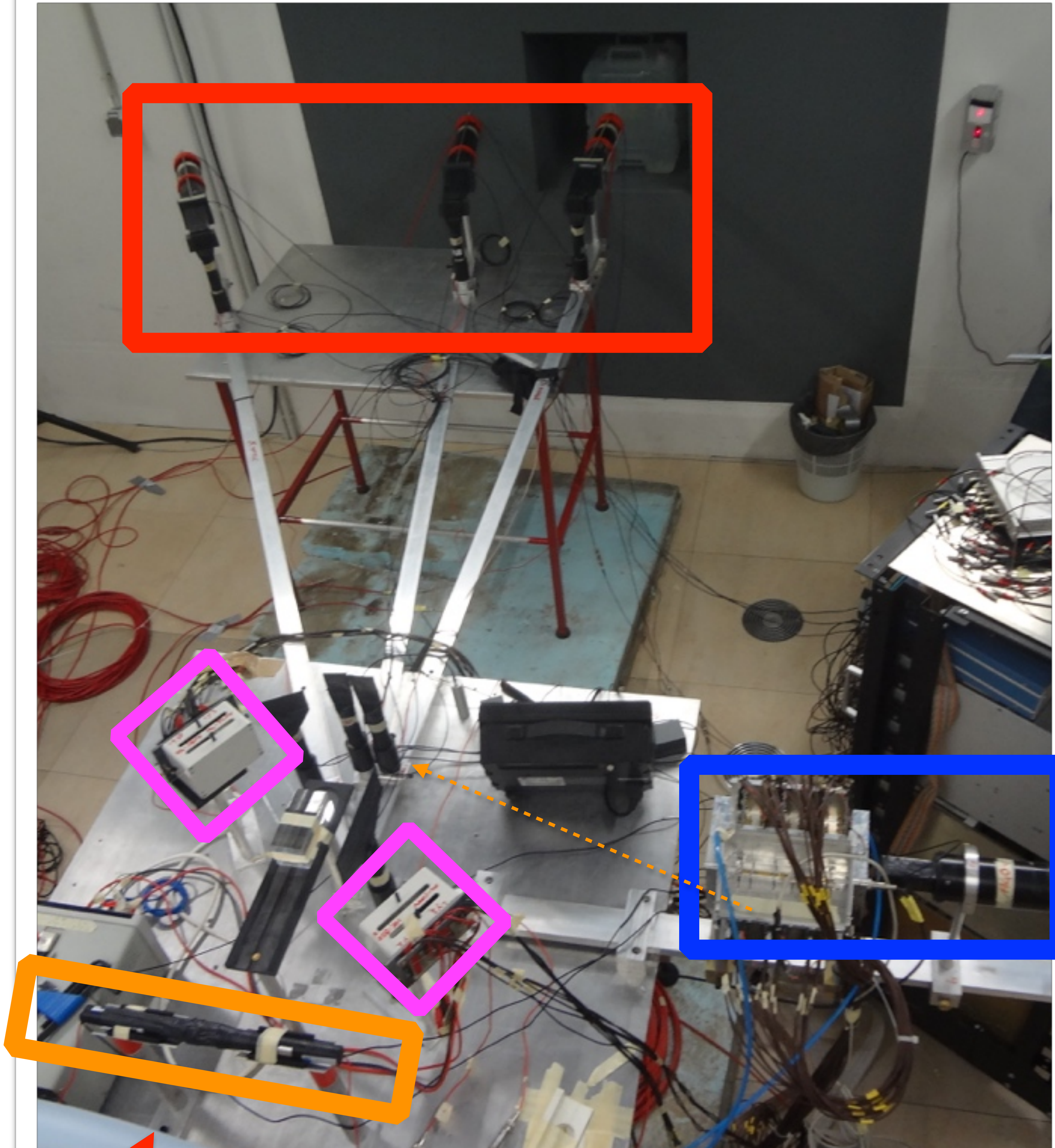
Start Counter (SC)

PMMA target

DCH + LYSO (60 & 90 deg)

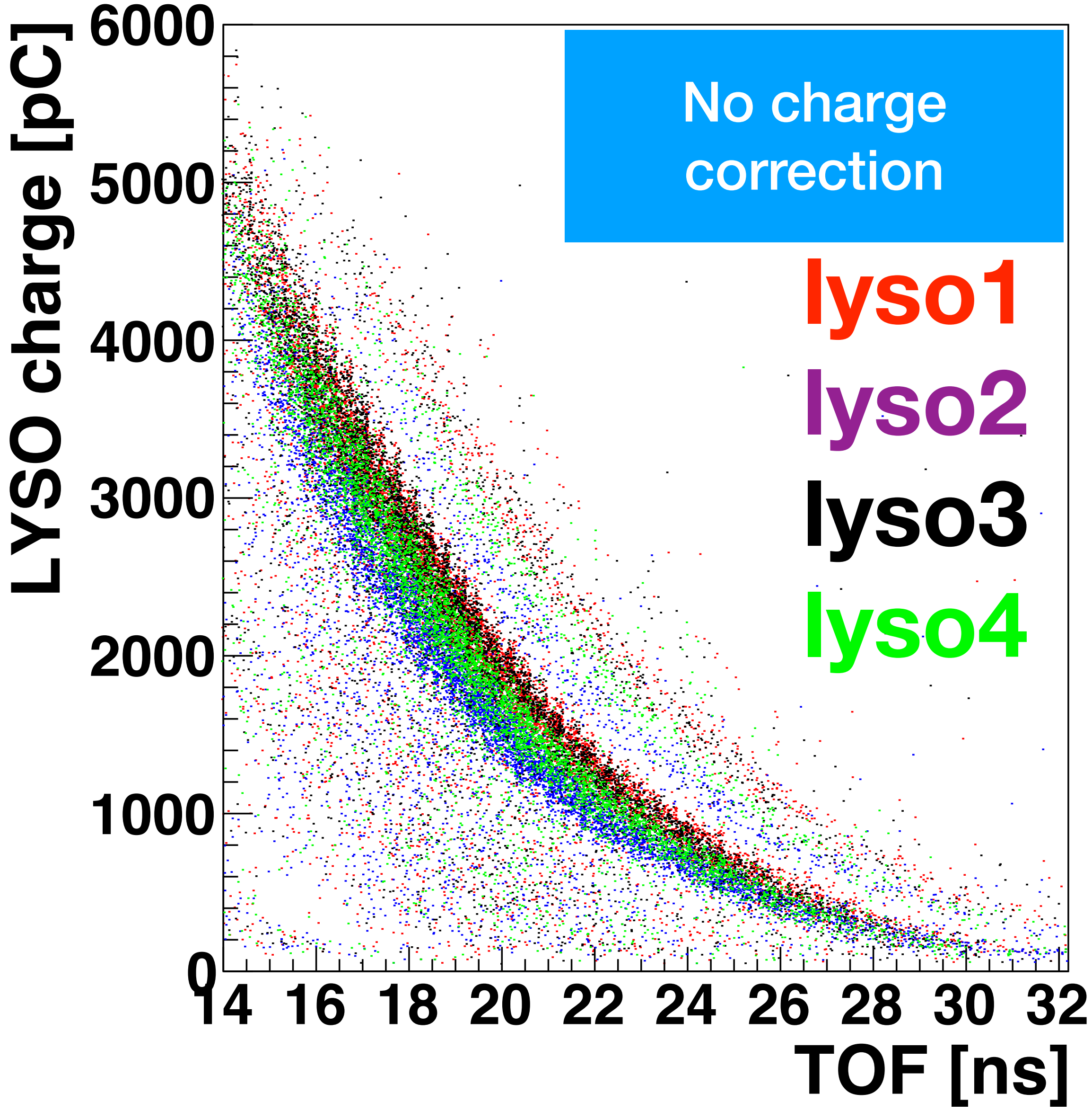
BGO

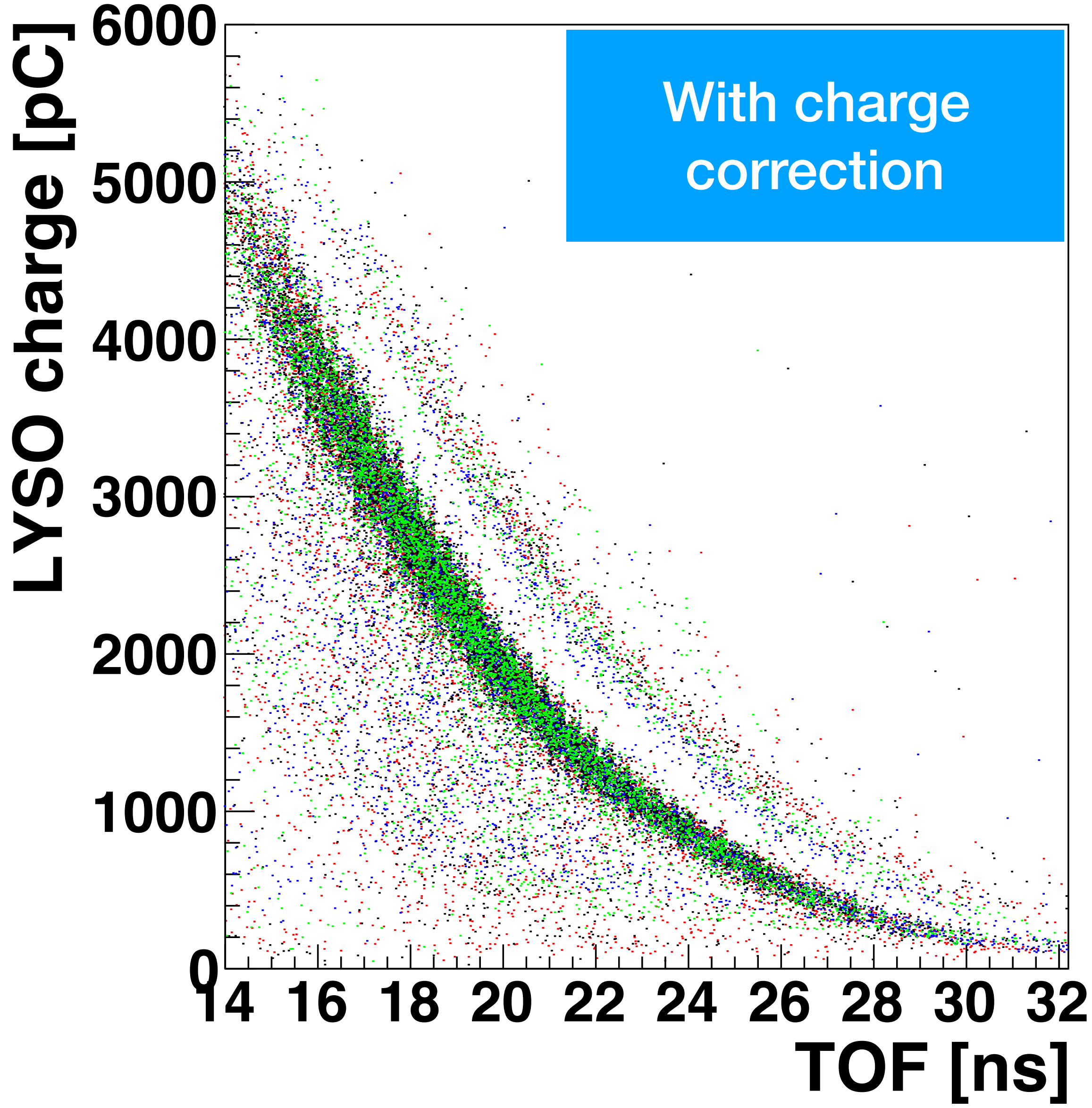
pixelated LYSO

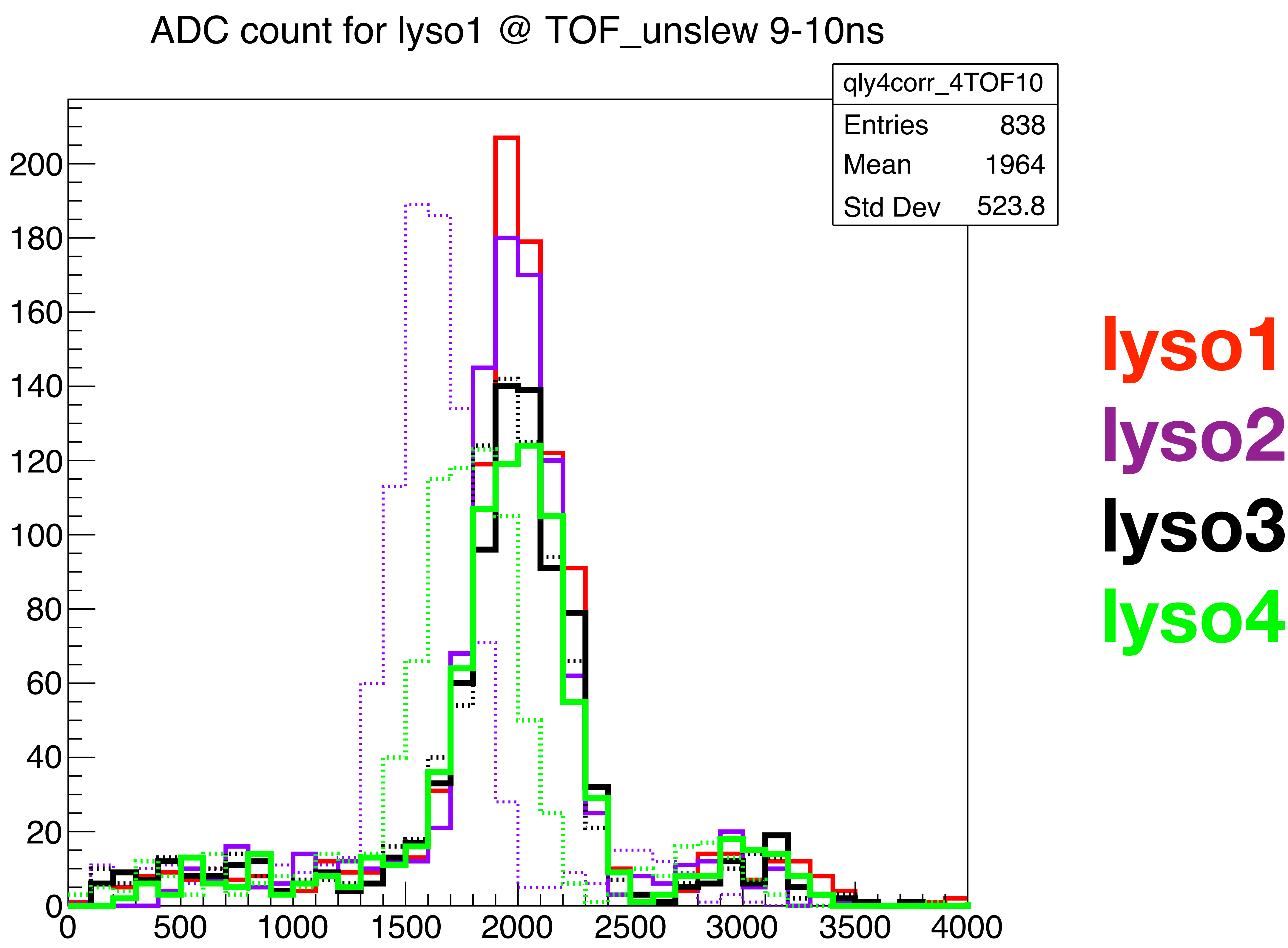


beam direction

Oxy 90deg inclCrazy



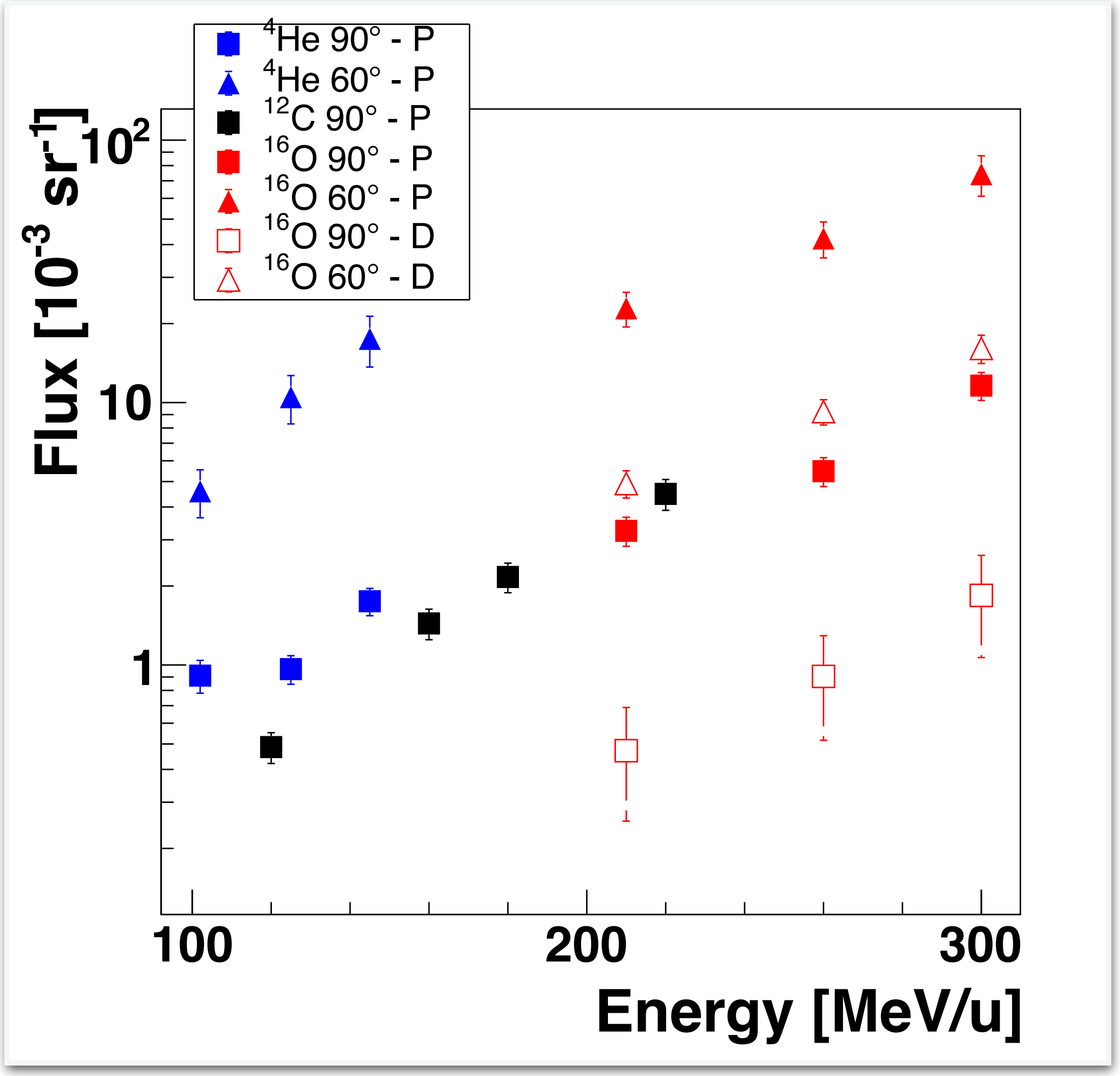




dotted - before correction
solid - after correction

Secondary radiation produced by ^{4}He, ^{12}C and ^{16}O beams

$$\Phi_{\mathrm{p,d,t}} = \frac{dN_{\mathrm{p,d,t}}}{N_{\mathrm{ion}}d\Omega} = \frac{1}{4\pi}\frac{1}{N_{\mathrm{ion}}\epsilon_{\mathrm{DT}}}\sum_{E_{\mathrm{kin}}^{\mathrm{Det}}}\sum_{z}\frac{N_{\mathrm{p,d,t}}(E_{\mathrm{kin}}^{\mathrm{Det}}, z)}{\epsilon_{\mathrm{p,d,t}}(E_{\mathrm{kin}}^{\mathrm{Det}}, z)},$$



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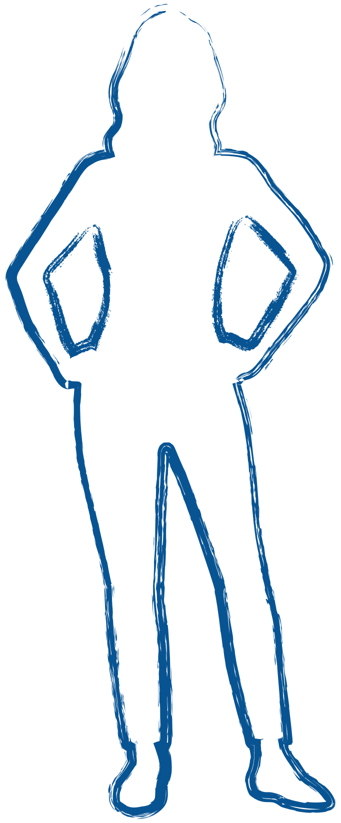
The Core 1/4 - our team

Jakub

Monika

Magda Jan Antoni Agata



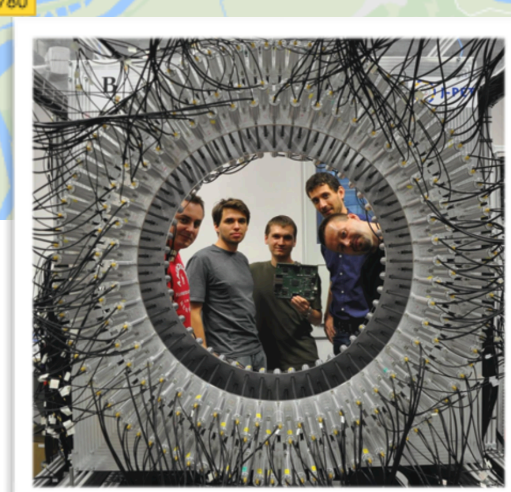
(Kasia)

European Funds Smart Growth | Republic of Poland | FNP Foundation for Polish Science | European Union European Regional Development Fund

The core 2/4: local collaboration

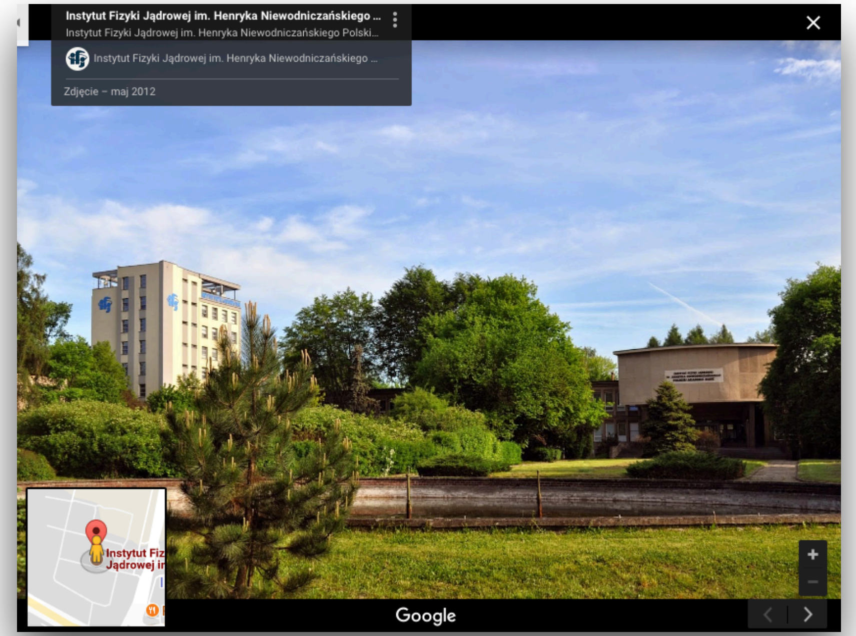
IFJ PAN & proton therapy centre

Radiation oncology centre (patients)



Jagiellonian University
J-PET labs:
plastic scintillator based whole body PET

Institute for Nuclear Physics
Polish Academy of Science
research institute



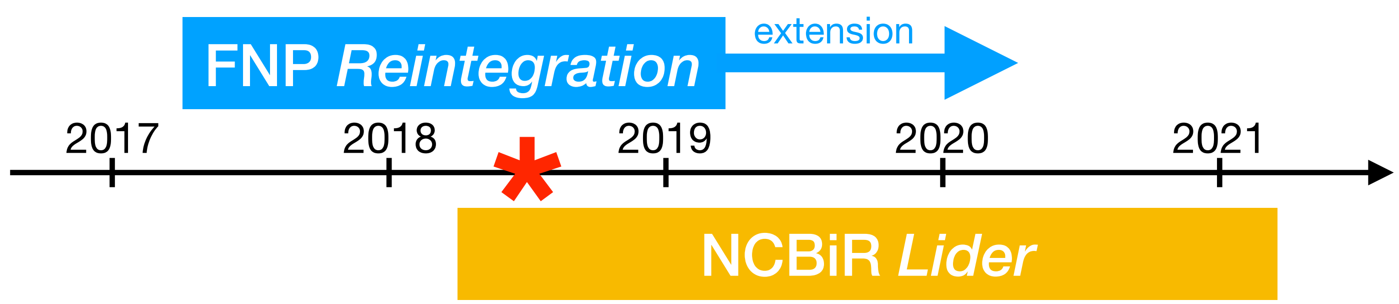
IFJ PAN

- 5 divisions
- 6th division of applications in physics (head: Pawel Olko) — new
  - Proton Radiotherapy Group
    - AR: Radiobiology + JPET
    - "Old" cyclotron, SHIELD-HIT (LG), Proton Grid Therapy, 3D printing
- CCB Proton Therapy Centre ↔ Krakow hospitals

580 employees (40 professors, 200 PhDs, 60 PhD students) – theoretical and experimental research

The Core 3/4- funding

- Monte Carlo, treatment planning and biological modelling



Budget of 0.46mln€ over 4 years

+ status funds

- Plastic scintillator PET-based detectors for proton therapy range monitoring

Enabling the translation of research results to Krakow proton centre?

Antoni Rucinski INSTITUTE OF NUCLEAR PHYSICS PAN
antoni.rucinski@ifj.edu.pl antoni.rucinski@gmail.com

The core 4/4 - research partners

- University of Rome
  - FRED MC-code
  - Hardware - charge secondary tracker / neutron detector
- Lyon CREATIS
  - Computational and analytical support
- Other proton centres
  - TIFPA
  - Maastro clinic

Trento Institute for Fundamental Physics and Applications

- US fraction

Antoni Rucinski INSTITUTE OF NUCLEAR PHYSICS PAN
antoni.rucinski@ifj.edu.pl antoni.rucinski@gmail.com

Outline

- Publications
- One year extension
- ERC starting grant

- **Project 1:** GPU-accelerated Monte Carlo FRED
    - Commissioning and validation (AAPM poster, Magdalena)
    - Treatment planning studies / Radiobiology / Moving targets
- **Project 2:** Plastic scintillator based PET detector for range monitoring

Generic MC codes

Clinical implementation of full Monte Carlo dose calculation in proton beam therapy

2008 **Geant4**

Harald Paganetti, Hongyu Jiang[1], Katia Parodi[2], Roelf Slopsema[3] and Martijn Engelsman

Published 13 August 2008 • 2008 Institute of Physics and Engineering in Medicine
Physics in Medicine & Biology, Volume 53, Number 17

A Monte Carlo pencil beam scanning model for proton treatment plan simulation using GATE/GEANT4

2011 **GATE/Geant4**

L Grevillot[1,2], D Bertrand[2], F Dessy[2], N Freud[1] and D Sarrut[1]

[1] Université de Lyon, CREATIS; CNRS UMR5220; Inserm U1044; INSA-Lyon; Université Lyon 1; Centre Léon Bérard, Lyon, France.
[2] IBA, B-1348, Louvain-la Neuve, Belgium.

E-mail: loic.grevillot@creatis.insa-lyon.fr

Received 28 February 2011, in final form 9 June 2011
Published 26 July 2011
Online at stacks.iop.org/PMB/56/5203

Monte Carlo simulations to support start-up and treatment planning of scanned proton and carbon ion therapy at a synchrotron-based facility

2012 **FLUKA**

K Parodi[1], A Mairani[1,2,4], S Brons[1], B G Hasch[1], F Sommerer[1,3], J Naumann[1], O Jäkel[1], T Haberer[1] and J Debus[1]

[1] Heidelberg Ion Beam Therapy Center and Department of Radiation Oncology, Heidelberg University Clinic, Heidelberg, Germany
[2] German Cancer Research Center, Heidelberg, Germany
[3] European Organization for Nuclear Research CERN, Geneva, Switzerland

E-mail: Katia.Parodi@med.uni-heidelberg.de

Received 28 November 2011, in final form 23 February 2012
Published 23 May 2012
Online at stacks.iop.org/PMB/57/3759

Experimental validation of the TOPAS Monte Carlo system for passive scattering proton therapy

2013 **TOPAS/Geant4**

M. Testa, J. Schümann, and H.-M. Lu
Department of Radiation Oncology, Massachusetts General Hospital, Harvard University Medical School, Boston, Massachusetts 02114

J. Shin and B. Faddegon
University of California San Francisco Comprehensive Cancer Center, 1600 Divisadero Street, San Francisco, California 94143-1708

J. Perl
SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025

H. Paganetti[a)]
Department of Radiation Oncology, Massachusetts General Hospital, Harvard University Medical School, Boston, Massachusetts 02114

Commissioning dose computation models for spot scanning proton beams in water for a commercially available treatment planning system

2013 **MC code unspecified**

X. R. Zhu,[a)] F. Poenisch, M. Lii, G. O. Sawakuchi, U. Titt, M. Bues, X. Song, X. Zhang, Y. Li, G. Ciangaru, H. Li, M. B. Taylor, K. Suzuki, R. Mohan, M. T. Gillin, and N. Sahoo
Department of Radiation Physics, The University of Texas MD Anderson Cancer Center, Houston, Texas 77030

(Received 10 September 2011; revised 11 March 2013; accepted for publication 12 March 2013; published 2 April 2013)

Characterization and validation of a Monte Carlo code for independent dose calculation in proton therapy treatments with pencil beam scanning

2015 **TOPAS/Geant4**

F Fracchiolla[1,2], S Lorentini[1], L Widesott[1,3] and M Schwarz[1]

[1] Azienda Provinciale per i Servizi Sanitari (APSS) Protontherapy Department, Trento, Italy
[2] Post Graduate School of Medical Physics 'Sapienza' University of Rome, 00185 Roma, Italy
[3] Department of Physics, Swiss Institute of Technology, 8092 Zurich, Switzerland

E-mail: Francesco.Fracchiolla@apss.tn.it

Characterizing a proton beam scanning system for Monte Carlo dose calculation in patients

2015 **TOPAS/Geant4**

C Grassberger[1,2], Anthony Lomax[2] and H Paganetti[1]

[1] Department of Radiation Oncology, Massachusetts General Hospital & Harvard Medical School, Boston MA 02114, USA
[2] Centre for Proton Radiotherapy, Paul Scherrer Institut, 5232 Villigen-PSI, Switzerland

E-mail: Grassberger.Clemens@mgh.harvard

RayStation

VARIAN medical systems

GPU-accelerated MC codes

2012

GPU-based fast Monte Carlo dose calculation for proton therapy

Xun Jia[1], Jan Schümann[2], Harald Paganetti[2] and Steve B Jiang[1]

[1] Department of Radiation Medicine and Applied Sciences, Center for Advanced Radiotherapy Technologies, University of California San Diego, La Jolla, CA 92037, USA
[2] Department of Radiation Oncology, Massachusetts General Hospital and Harvard Medical School, Boston, MA 02114, USA

E-mail: xunjia@ucsd.edu, jschuemann@partners.org, hpaganetti@partners.org and sbjiang@ucsd.edu

Received 3 July 2012, in final form 4 October 2012
Published 6 November 2012
Online at stacks.iop.org/PMB/57/7783

gPMC

2015

Photons only!

A GPU OpenCL based cross-platform Monte Carlo dose calculation engine (goMC)

Zhen Tian, Feng Shi, Michael Folkerts, Nan Qin, Steve B Jiang and Xun Jia

Department of Radiation Oncology, University of Texas Southwe... Center, Dallas, TX 75390, USA

goMC

2017

Initial development of goCMC: a GPU-oriented fast cross-platform Monte Carlo engine for carbon ion therapy

Nan Qin[1], Marco Pinto[2], Zhen Tian[1], Georgios Dedes[2], Arnold Pompos[1], Steve B Jiang[1], Katia Parodi[2] and Xun Jia[1]

[1] Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, TX 75390, United States of America
[2] Department of Experimental Physics—Medical Physics, Ludwig-Maximilians-Universität München, Munich 85748, Germany

E-mails: xun.jia@utsouthwestern.edu and Katia.Parodi@physik.uni-muenchen.de

Received 2 September 2016, revised 2 January 2017
Accepted for publication 31 January 2017
Published 5 April 2017

goCMC

CrossMark

2016

Recent developments and comprehensive evaluations of a GPU-based Monte Carlo package for proton therapy

Nan Qin[1], Pablo Botas[2,3], Drosoula Giantsoudi[2], Jan Schuemann[2], Zhen Tian[1], Steve B Jiang[1], Harald Paganetti[2] and Xun Jia[1]

[1] Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, TX 75390, USA
[2] Department of Radiation Oncology, Massachusetts General Hospital and Harvard Medical School, Boston, MA 02114, USA
[3] Department of Physics and Astronomy, University of Heidelberg, Heidelberg, Germany

E-mail: xun.jia@utsouthwestern.edu, hpaganetti@mgh.harvard.edu, steve.jiang@utsouthwestern.edu

gPMC

2017

Fred: a GPU-accelerated fast-Monte Carlo code for rapid treatment plan recalculation in ion beam therapy

A Schiavi[1,2], M Senzacqua[1,2], S Pioli[1,5], A Mairani[3,4], G Magro[3], S Molinelli[3], M Ciocca[3], G Battistoni[6] and V Patera[1,2]

[1] Dipartimento SBAI, University of Rome 'La Sapienza', Rome, Italy
[2] INFN, Sezione di Roma 1, Rome, Italy
[3] CNAO, Pavia, Italy
[4] HIT, Heidelberg, Germany
[5] INFN, LNF, Frascati, Italy
[6] INFN, Sezione di Milano, Milan, Italy

E-mail: angelo.schiavi@uniroma1.it

Fred

Systematic clinical validation

Validation of a track repeating algorithm for intensity modulated proton therapy: clinical cases study

2016

Pablo P Yepes[1,2], John G Eley[3], Amy Liu[2], Dragan Mirkovic[2], Sharmalee Randeniya[2], Uwe Titt[2] and Radhe Mohan[2]

[1] Department of Physics and Astronomy, MS 315, Rice University, 6100 Main Street, Houston, TX 77005, USA
[2] Department of Radiation Physics, Unit 1420, The University of Texas MD Anderson Cancer, 1515 Holcombe Blvd., Houston, TX 77030, USA
[3] Department of Radiation Oncology, University of Maryland School of Medicine, 22 South Green St., Baltimore, MD 21201, USA

E-mail: yepes@rice.edu

gPMC

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

2018

PAPER

Comparison of Monte Carlo and analytical dose computations for intensity modulated proton therapy

Pablo Yepes[1,2,3], Antony Adair[1,2], David Grosshans[2], Dragan Mirkovic[2], Falk Poenisch[2], Uwe Titt[2], Qianxia Wang[1,2] and Radhe Mohan[2]

[1] Physics and Astronomy Department, Rice University, MS 315, 6100 Main Street, Houston, TX 77005, United States of America
[2] Department of Radiation Physics, Unit 1202, The University of Texas M. D. Anderson Cancer, 1515 Holcombe Blvd., Houston, TX 77030, United States of America
[3] Author to whom any correspondence should be addressed.

E-mail: yepes@rice.edu

Keywords: IMPT, Monte Carlo, analytical, proton therapy, particle therapy, dose, comparison

gPMC

>500 MD Anderson patients

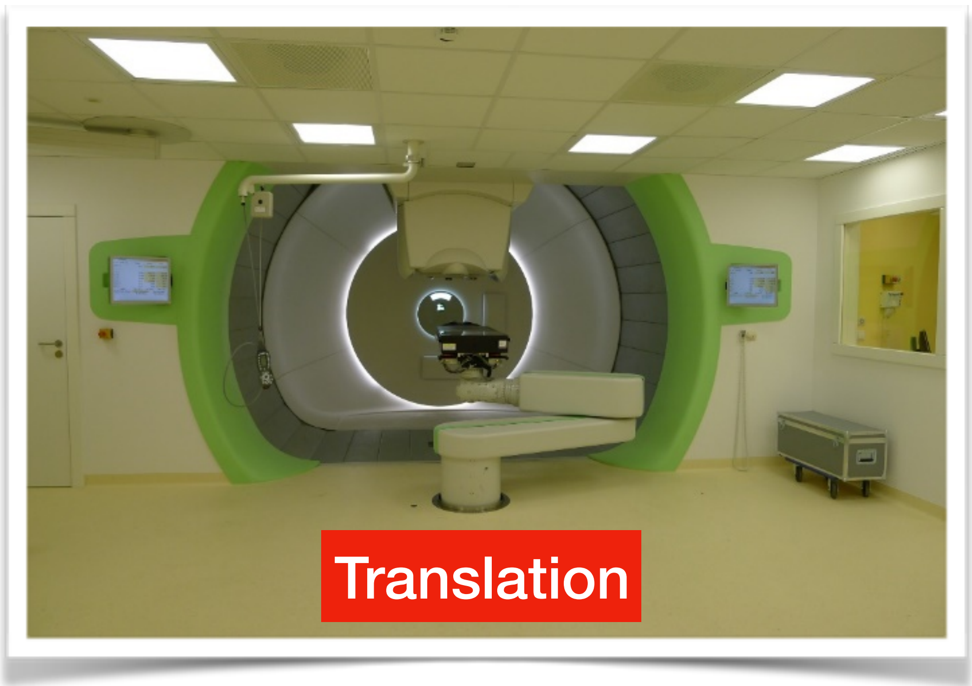
Project 1: Commissioning and validation of GPU-accelerated Monte Carlo FRED

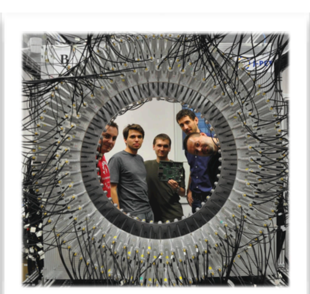
- Clinical experience with MC
- Support of patient QA
- Treatment planning studies (patient data)
  - Physical dose
  - LET-based RBE dose
  - Moving targets
- Development of
  - New treatment protocols
  - Adaptive approaches
  - Optimization algorithms (robust, multi-criteria, …)

Monte Carlo:
- Eclipse
- RayStation
- TOPAS
- GATE-RTion
- gPMC
- ……

one-click interface with Eclipse

But why don't you use AcurosPT?





Project 2: Plastic scintillator based PET detector for range monitoring - a feasibility study

Fred MC: the power of GPU

Validation vs. FLUKA and measurements @ CNAO (Schiavi et al. PMB 2017)

Fred: a GPU-accelerated fast-Monte Carlo code for rapid treatment plan recalculation in ion beam therapy

A Schiavi[1,2], M Senzacqua[1,2], S Pioli[1,5], A Mairani[3,4], G Magro[3], S Molinelli[3], M Ciocca[3], G Battistoni[6] and V Patera[1,2]

acc. x1000 wrt. full MC code

10^6 prim/s

Local computation unit

- Tabulated total stopping power in water (PSTAR)
- MCS models: single-,double-,triple-gaussian, 2 gauss+Rutherford
- Nuclear interactions: elastic and inelastic; fragmentation; local deposition of heavy ions; tracking of secondary protons and deuterons

10^8 prim/s

Prometheus: GPU cluster

VALIDATION OF A GPU-ACCELERATED MONTE CARLO TREATMENT PLANNING SYSTEM FOR PROTON BEAM THERAPY

AAPM 2018 JUL 29–AUG 2
BEYOND THE FUTURE!
60TH ANNUAL MEETING & EXHIBITION | NASHVILLE, TN

A.Rucinski[a]*, G.Battistoni[b], E.Góra[c], M.Durante[d], J.Gajewski[a], M.Garbacz[a], K.Kisielewicz[c], N.Krah[e], V. Patera[f], I.Rinaldi[g], B.Sas-Korczynska[c], T.Skóra[c], A.Skrzypek[a], F.Tommasino[d,h], E. Scifoni[d], A.Schiavi[f]

(a)Institute of Nuclear Physics PAN, Krakow, Poland, (b)INFN, Sezione di Milano, Italy, (c)Maria Sklodowska-Curie Institute - Oncology Center, Krakow Branch, Poland, (d)Trento Institute for Fundamental Physics and Applications, Italy, (e)CNRS, CREATIS UMR 5220, Lyon, France , (f)Sapienza University of Rome, Italy, (g)ZonPCT/Maastro clinic, Maastricht, the Netherlands, (h)Department of Physics, University of Trento, Italy

* antoni.rucinski@ifj.edu.pl

The authors acknowledge Dosimetry and Quality Control Laboratory of Cyclotron Centre Bronowice at the Institute of Nuclear Physics PAN, Krakow, Poland for supporting project activities. This project is carried out within the Reintegration programme of the Foundation for Polish Science co-financed by the EU under the European Regional Development Fund. This research was supported in part by computing resources of ACC Cyfronet AGH. We acknowledge the support of NVIDIA Corporation with the donation of the Tesla TitanX GPU used for this research.

Introduction

A Monte Carlo (MC) code can support development of treatment planning procedures, treatment plan verification and Proton Beam Therapy (PBT) research.

A **GPU-accelerated MC** Treatment Planning System (TPS) **Fred** (Schiavi et al. 2017) developed at the University of Rome (Italy) has been commissioned against the physical beam model used for patient treatment in Krakow PBT centre (Poland) aiming to support in the near future physical dose verification, biological dose calculation with variable RBE and 4D dose verification of moving target treatments.

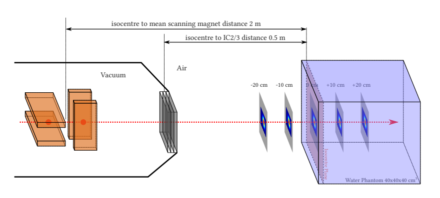
Krakow Proton Beam Therapy Centre (Poland)

- **Clinical operation from Oct 2016:**
  - Head & neck, eye cancer patients
  - ~100 patients treated with Gantry
- **Equipment**
  - Proteus C-235 cyclotron (IBA)
  - Pencil beam scanning
  - Eclipse TPS
  - Dedicated QA protocols
  - *old cyclotron:* 62 MeV protons dedicated 24/7 for research

Fast generation of proton beam model phase space library

Time performance of GPU-accelerated Fred MC code enables fast proton beam model phase space characterisation based on the PBT facility commissioning and/or periodic QA data. The proton beam model library includes information on single pencil beam: energy, momentum spread, emittance parameters, dosimetric calibration.

Experimental setup

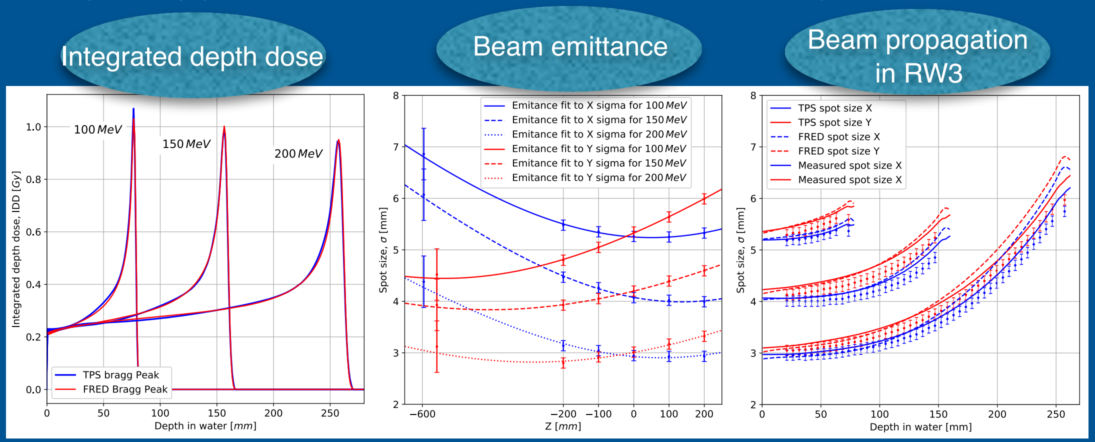


Simulations (Fred)

- IDD of single pencil beams in WP
- 10^8 primary protons

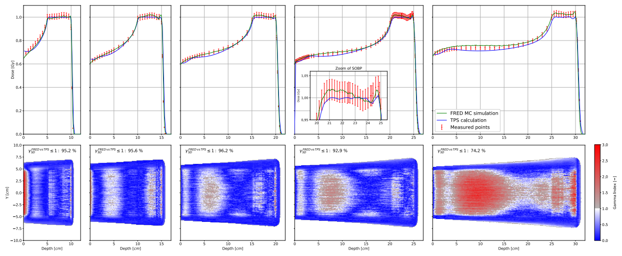
Data (Krakow PBT centre)

- DDD in Water Phantom (WP)
- lateral beam profiles in air & RW3



Validation: Fred simulations vs measurements

- Five dose cubes of different range (10x10x5cm³)
- 160 QA verification plans of patients treated in Krakow PBT centre
- Evaluation: Dose profiles and gamma index in water



Simulations (Fred)

- Dose cubes and patient QA verification plans recalculated in water phantom

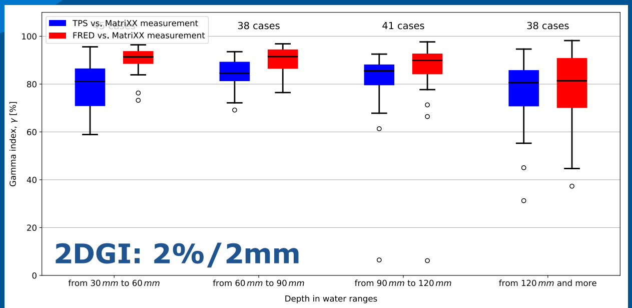
Data (Krakow PBT centre)

- SOBP DDD (dose cubes) measured with Markus chamber in water phantom
- Patient QA verification measurements performed with an array of ionisation chambers (MatriXX)

Fred time performance

(@5×10^5 protons /spot)

- **Dose cubes** (500cc)
  - Total time: <10'
  - Tracking rate: $3.0\text{-}12.6\times10^6$ [protons/s]
- **QA Verification plans**
  - Total time: 3'28s±1'41s
  - Tracking rate: $(8.5\pm1.6)\times10^6$[protons/s]



Conclusions: **Proton beam model used clinically in Krakow PBT centre for patient treatment was implemented in the in-house developed, GPU-capable Fred MC code and validated against the measurements. Fred offers accuracy, flexibility, and high dose calculation speed impossible to achieve with the currently available commercial systems.**

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[a]Institute of Nuclear Physics PAN, Krakow, Poland, [b]INFN, Sezione di Milano, Italy, [c]Maria Sklodowska-Curie Institute - Oncology Center, Krakow Branch, Poland, [d]Trento Institute for Fundamental Physics and Applications, Italy, [e]CNRS, CREATIS UMR 5220, Lyon, France , [f]Sapienza University of Rome, Italy, [g]ZonPCT/Maastro clinic, Maastricht, the Netherlands, [h]Department of Physics, University of Trento, Italy

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The authors acknowledge Dosimetry and Quality Control Laboratory of Cyclotron Centre Bronowice at the Institute of Nuclear Physics PAN, Krakow, Poland for supporting project activities. This project is carried out within the Reintegration programme of the Foundation for Polish Science co-financed by the EU under the European Regional Development Fund. This research was supported in part by computing resources of ACC Cyfronet AGH. We acknowledge the support of NVIDIA Corporation with the donation of the Tesla TitanX GPU used for this research.

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biological dose ca...
target treatments...

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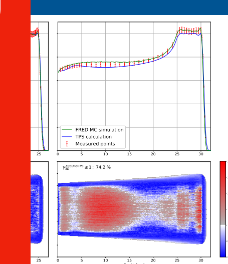
  - ~100 patients treated with Gantry
- **Equipment**
  - Proteus C-235 cyclotron (IBA)
  - Pencil beam scanning

Fast (one week) FRED MC commissioning

Using up-to-date QA data

Fast generation...

Time performanc...
MC code enable...
phase space cha...
PBT facility com...
QA data. The p...
includes informat...
energy, momen...
parameters, dosi...



Simulations (Fr...

- IDD of single pe...
- 10^8 primary protons
- lateral beam profiles in air & RW3

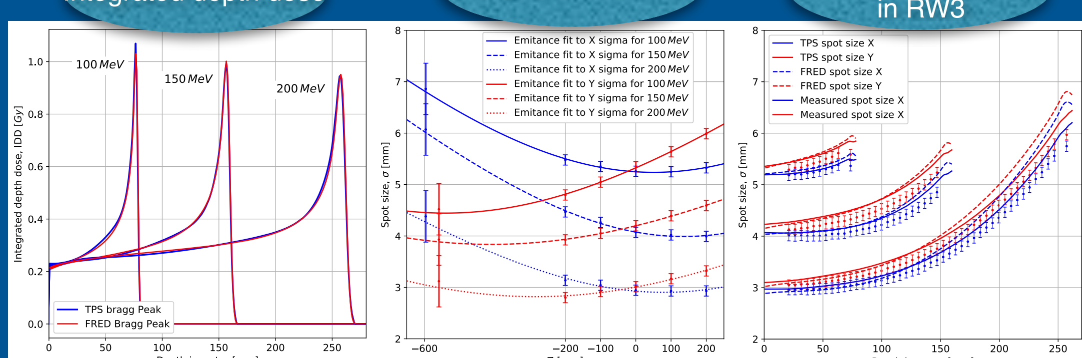
...e)

...measured with Markus chamber in water phantom

verification plans recalculated in water phantom

- Patient QA verification measurements performed with an array of ionisation chambers (MatriXX)

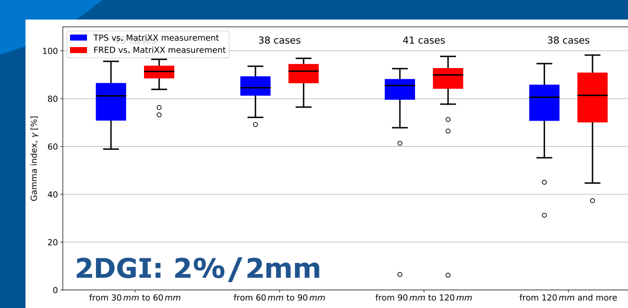
Integrated depth dose | Beam emittance | Beam propagation in RW3



Fred time performance

($@5\times10^5$ protons /spot)

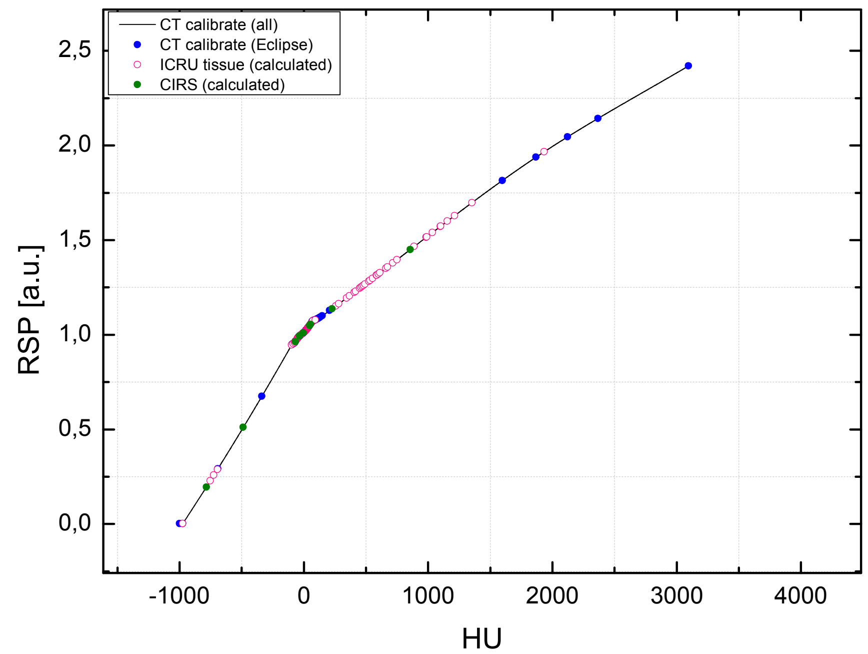
- **Dose cubes** (500cc)
  - Total time: <10'
  - Tracking rate: $3.0\text{-}12.6\times10^6$ [protons/s]
- **QA Verification plans**
  - Total time: 3'28s±1'41s
  - Tracking rate: $(8.5\pm1.6)\times10^6$[protons/s]



Conclusions: **Proton beam model used clinically in Krakow PBT centre for patient treatment was implemented in the in-house developed, GPU-capable Fred MC code and validated against the measurements. Fred offers accuracy, flexibility, and high dose calculation speed impossible to achieve with the currently available commercial systems.**

Next steps

- Treatment planning studies to compare clinical TPS with GPU-accelerated MC dose computation methods in CT data of patients

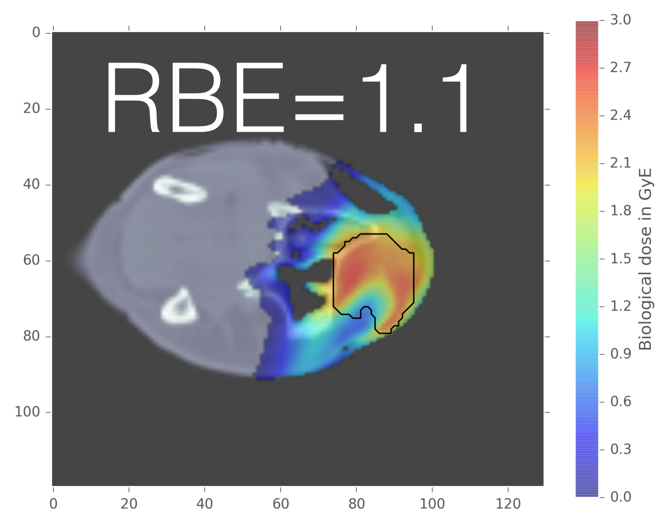


- Perform treatment planning studies accounting for variable RBE (AS)

- Adaptation of Fred to perform 4D treatment planing studies

Biological modelling

Generic RBE clinic

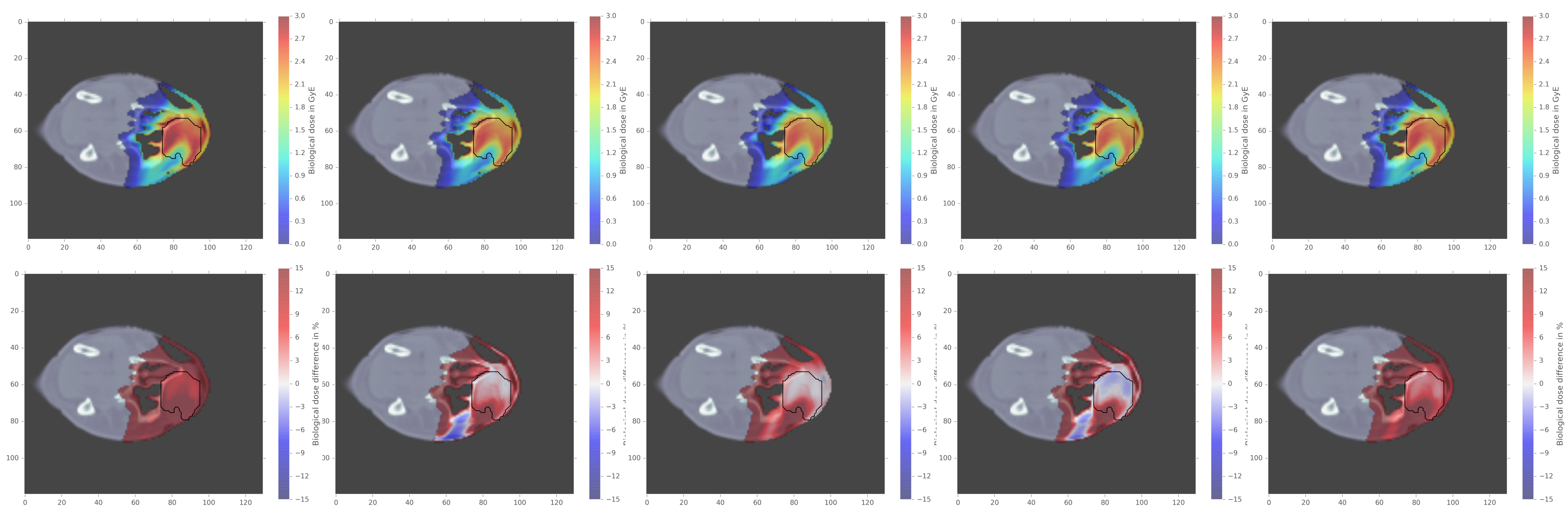


Fred-bio

GPU performance
+
Biological modelling

Variable RBE

Chen **Carabe** **MKM** **Wedenberg** **Wilken**



Not validated - Fred-bio vs TOPAS?

Moving targets:
breast cancer treatment with protons

- Objective: Comparison of 3D proton & photon treatment plans of breast cancer patients; Evaluation of
  - Heart dose
  - Left Anterior Descending Artery (LAD)
  - Left lung

- Evaluation of residual motion with breath-hold technique (4D CT data?) - Fred for 4D dose calculation

- Development of QA protocols

Courtesy of Kasia Czerska

Future plans (grant extension)

up to 12 months

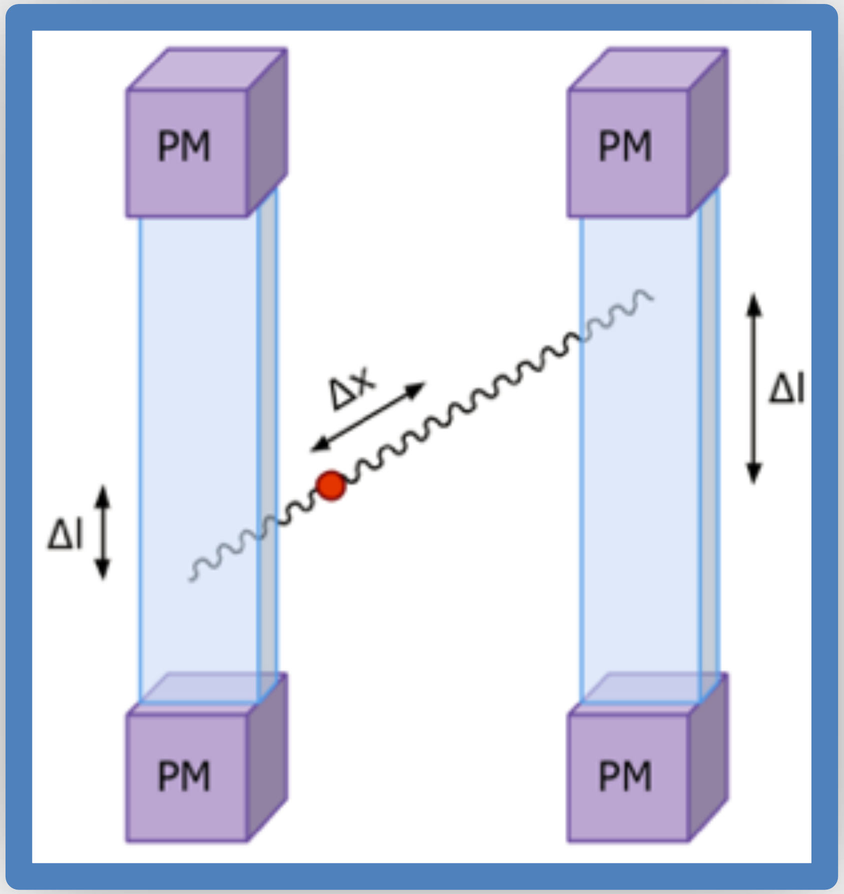
1. 1-click interface with ECLIPSE TPS
   (proof of concept, commercialisation)

2. Measure more accurately the proton pencil beam lateral penumbra (diamond detectors/MedPix/TRiP98)

3. Develop 4D QA protocol supported by Fred dose calculation - breast cancer case
   (log files, 4D CT data, moving phantoms, DIR algorithms)

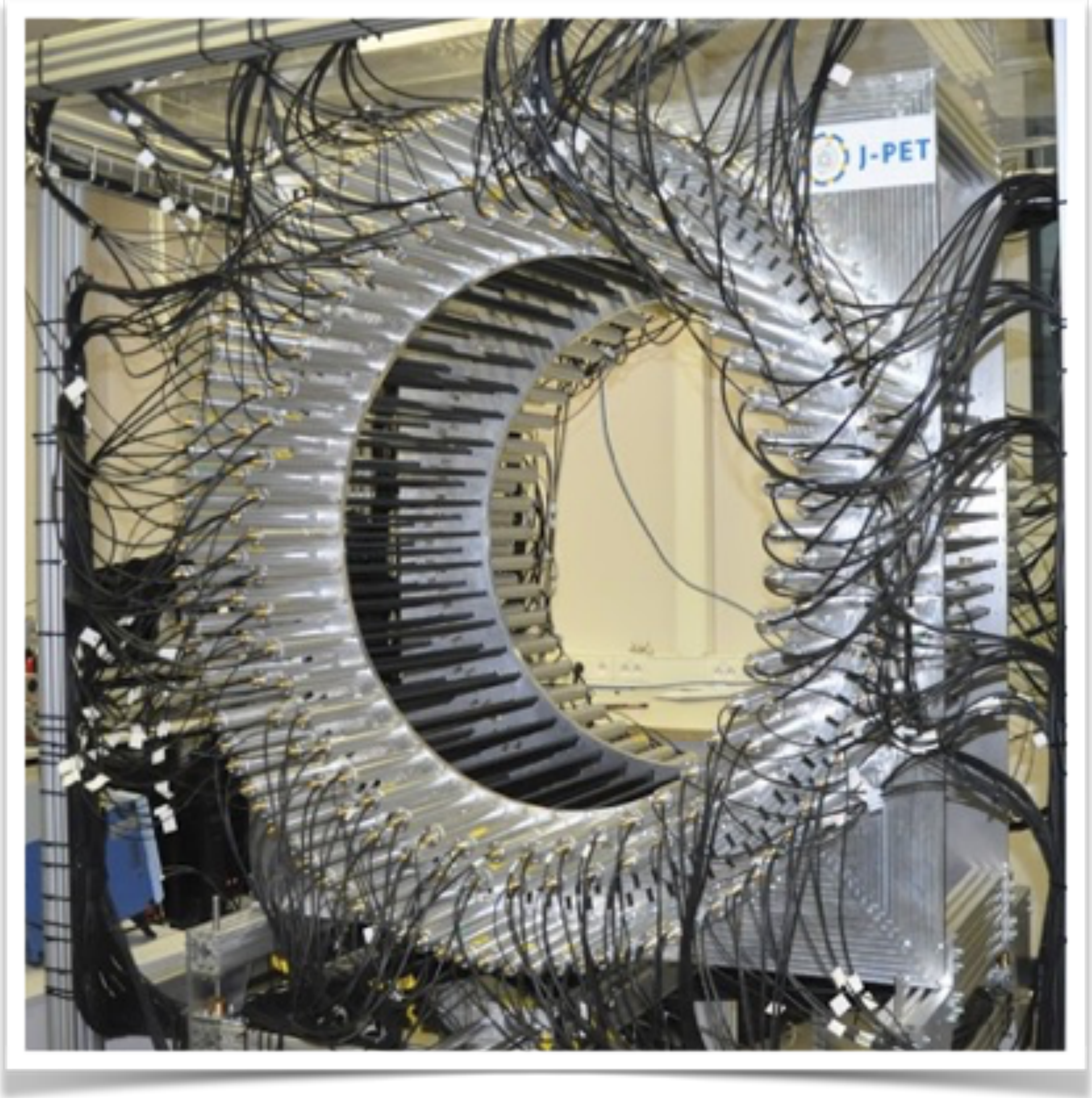
Plastic-scintillator based PET detector

- The principle of TOF-based PET-gamma detection.
- The light pulses produced in a strip are propagated to its edges and converted into electric signals by silicon photomultipliers (PM). They are read-out by fast on-board front-end electronics.
- A new modular construction allows a customized adaptation of the detector in the treatment room of a proton therapy facility.



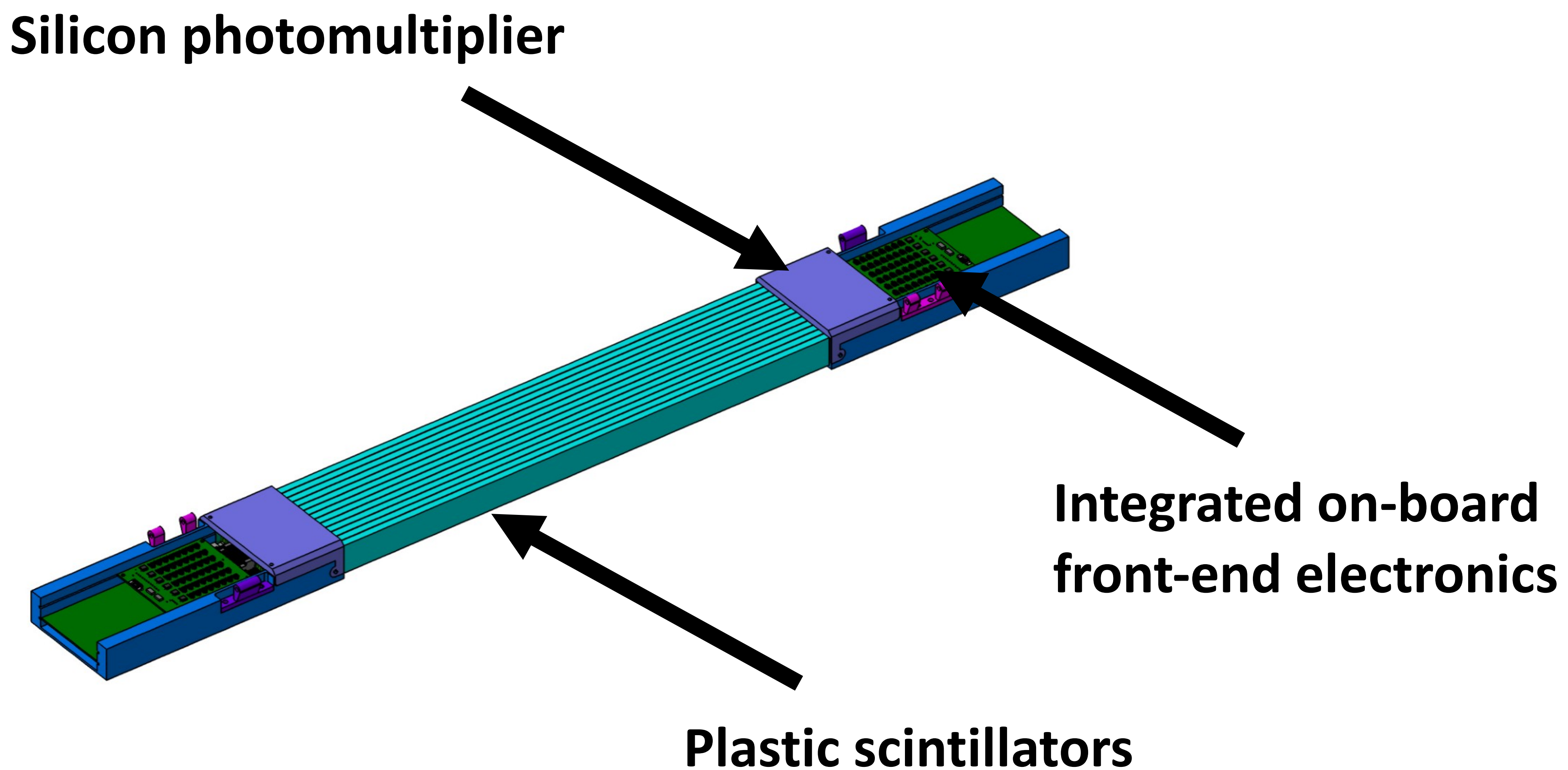
Plastic-scintillator based PET detector

- A prototype of a diagnostic strip-based whole body PET scanner has been developed and tested at the Jagiellonian University in Krakow.
- The system is composed of several modules for PET-gamma signal detection and provides data for 3D image reconstruction.
- The overall coincidence resolving time (CRT) of about 400 ps is superior compared to the state-of-the-art LSO-based PET scanners.

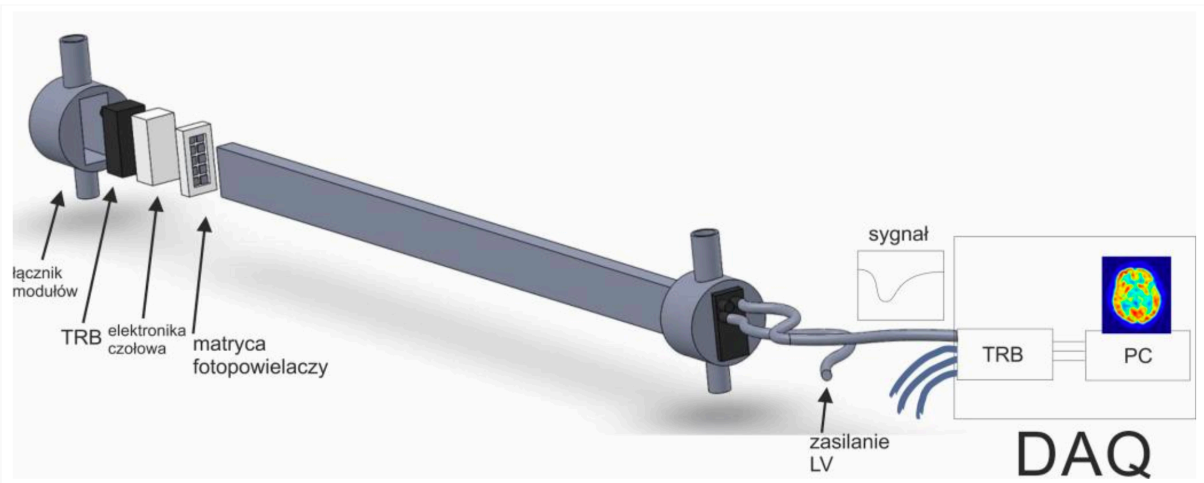


Modular plastic-scintillator based PET detector

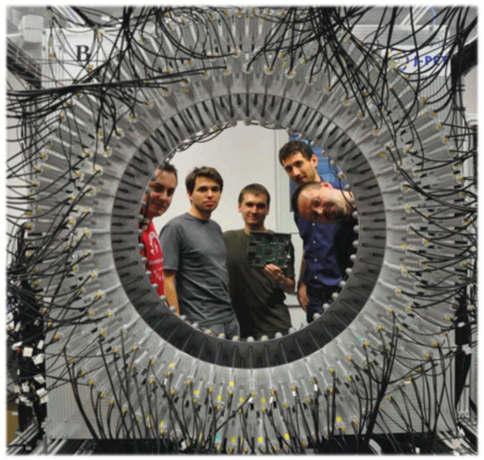
Schematic view of a single plastic scintillator detection module



J-PET technology for PBT range monitoring



- **Investigation and pre-clinical tests** to monitor beam range in PBT



Detector integration in the treatment room

- **Simulations and experimental tests** to assess feasibility of J-PET detector technique for proton beam therapy range monitoring.

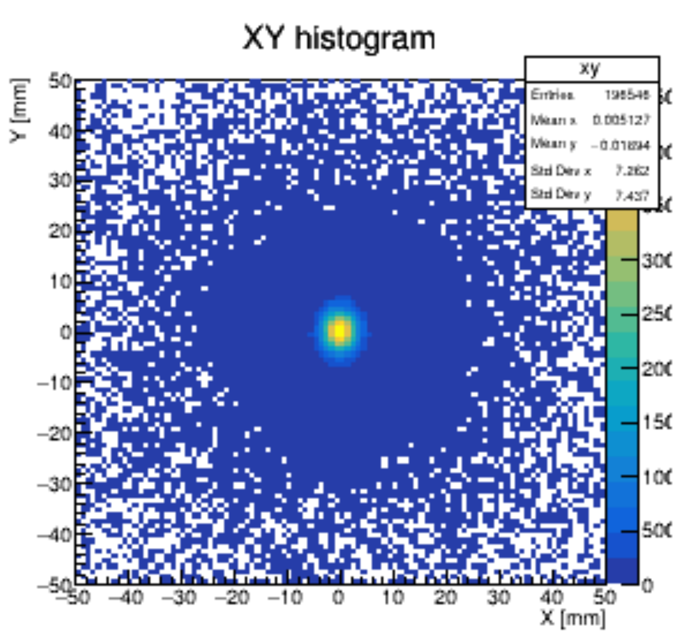
- The result of proposed study will be **design of range monitoring detector prototype** exploring **J-PET** technology.

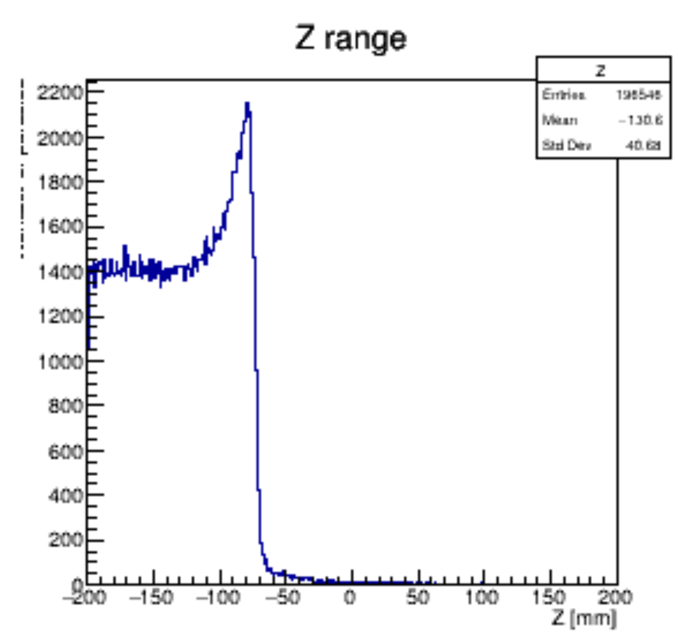
Monte Carlo simulations

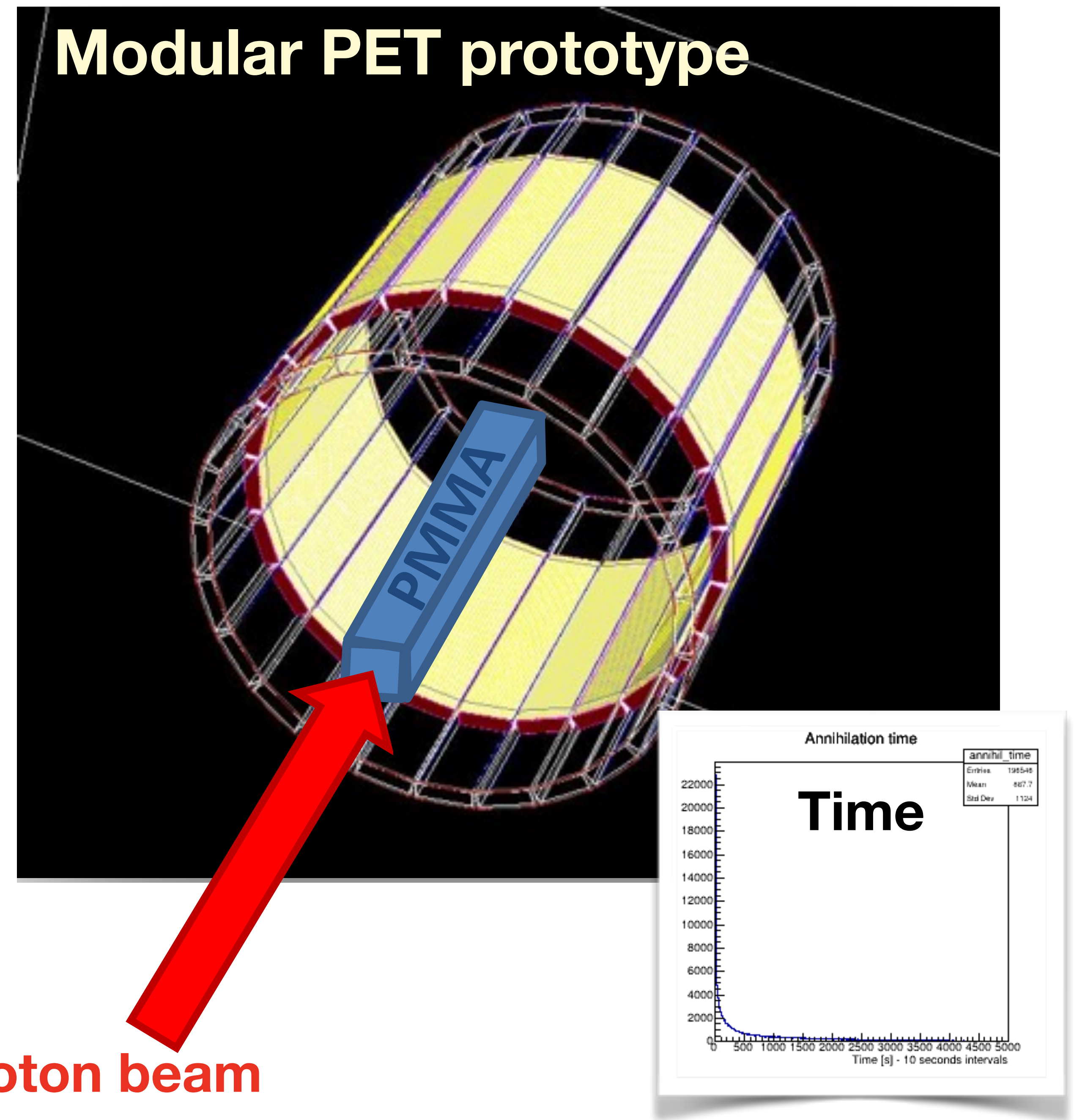
Determination of the coincidence events and tomographic reconstruction
- cylindrical geometry
- PET head modules

GATE vs TOPAS?

- GATE software toolkit is currently used to investigate the proton beam induced β+ signal that can be detected by the plastic scintillator based diagnostic PET detector prototype.



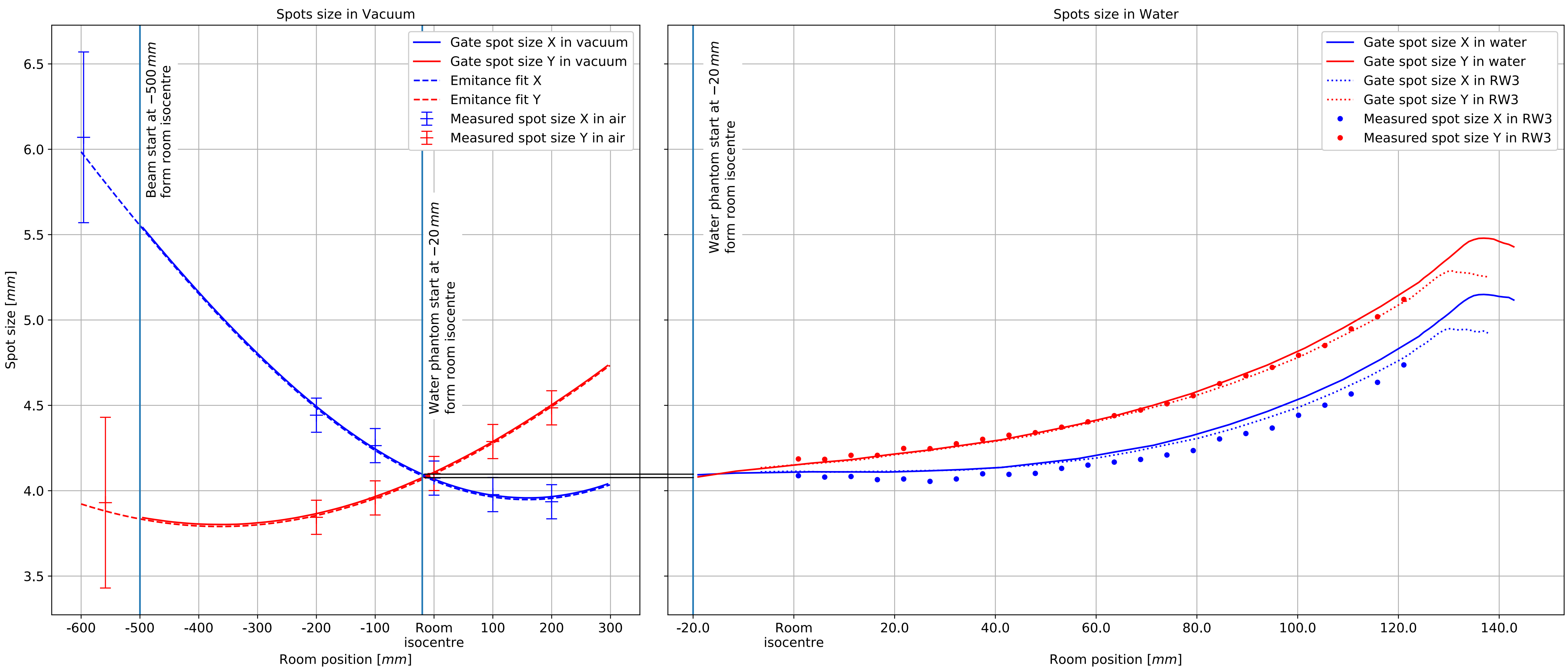




Proton beam

Krakow proton centre beam model in GATE

E=150 MeV



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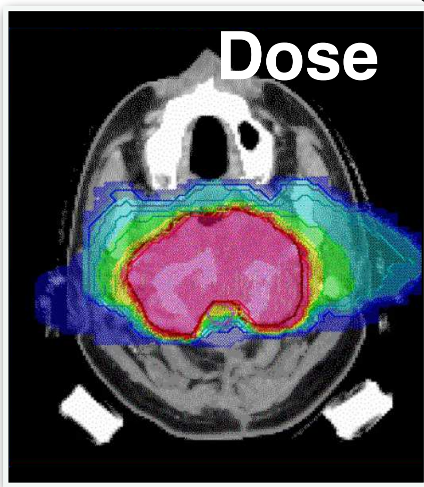
What next?

Radiotherapy challange…

Medicine



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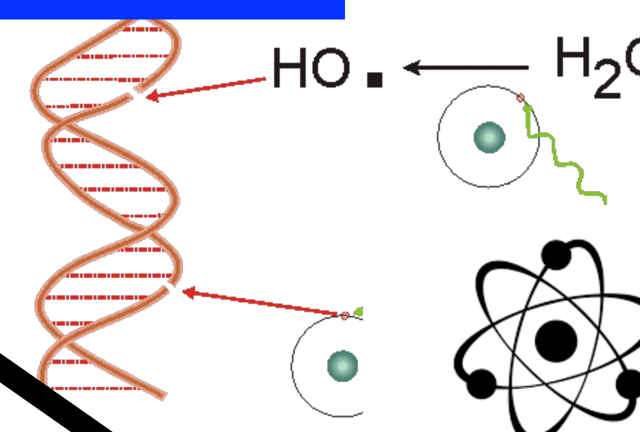
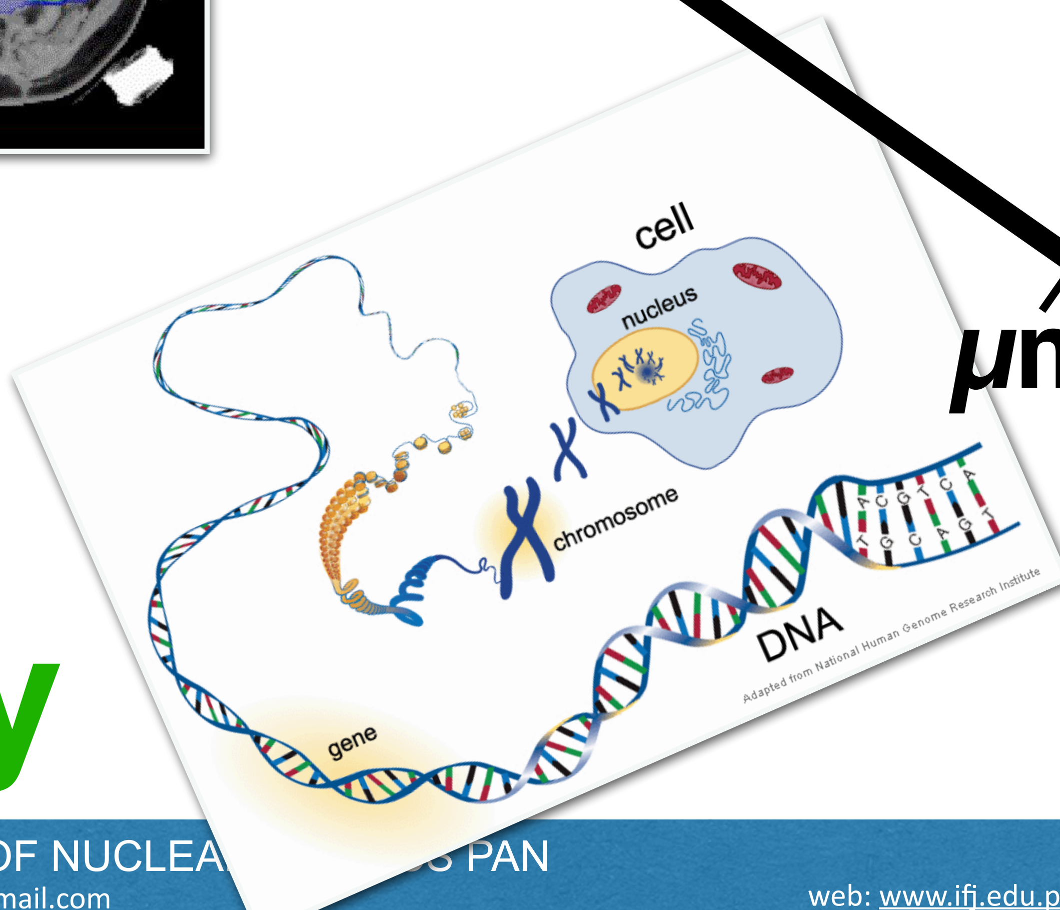
Physics

MC simulations @ nano scale



µm



Biology

Biological modelling

nm

Summary

- Krakow team / facility / projects / research partners

- Charge secondary based range monitoring (^{4}He, ^{12}C, ^{16}O)

- **Project 1:** GPU-accelerated Monte Carlo FRED
  - Commissioning and validation of the beam model
  - Treatment planning studies / Radiobiology / Moving targets
- **Project 2:** Plastic scintillator based PET detector for range monitoring

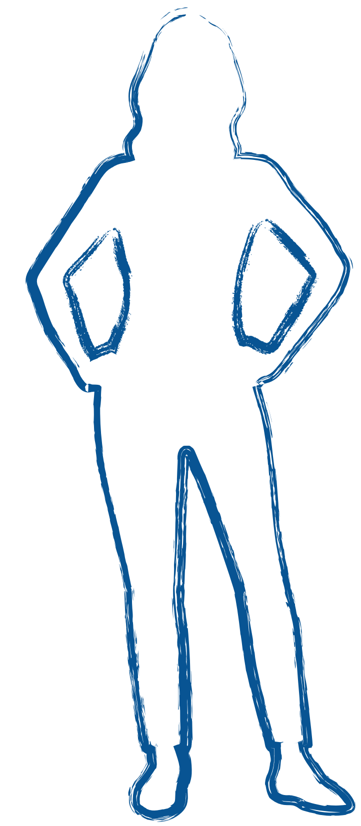
- Interest in nono-dosimetric approach to address the radiotherapy challenges

Thank you

Jakub

Monika

Magda Jan Antoni Agata



(Kasia)

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