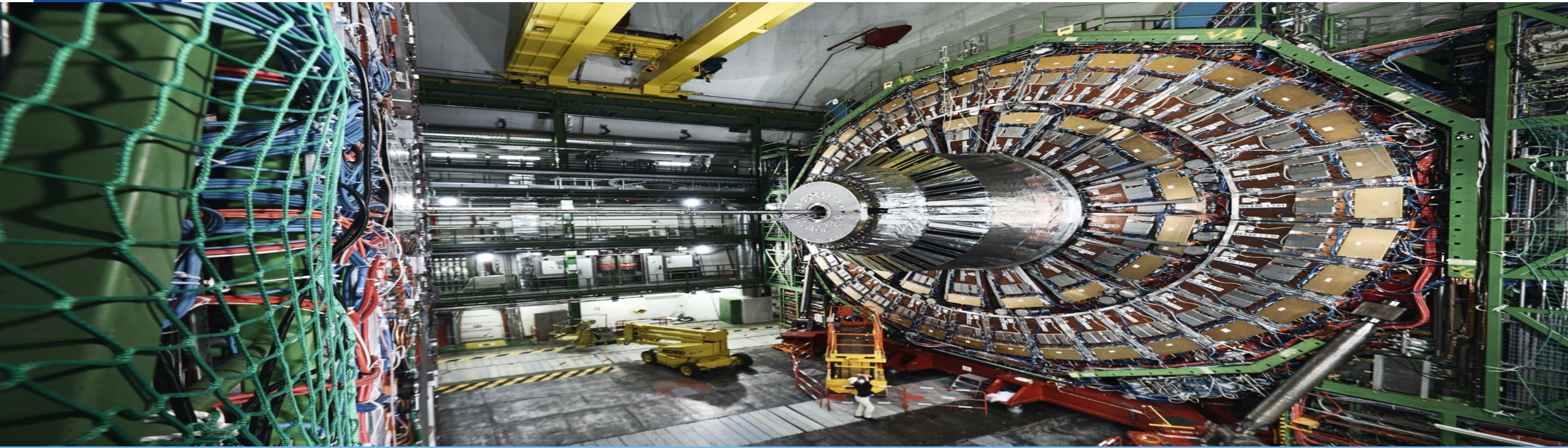


P3E – Polarized Electrons, Positrons and Polarimetry

E. Voutier for the JRA13 Team

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

Pushing further

the **intensity frontier** of polarized electron sources,

the **intensity frontier** of low energy polarized positron sources,

and the **precision frontier** of electron polarimetry.

P3E-1: High Intensity Polarized Electron Source

P3E-2: High Intensity Polarized Positron Source

P3E-3: High Precision Electron Polarimetry

Participating institutions : IJCLab, JGU, JLab, UH

High Intensity Polarized Electron Source

TASKS/Subtasks	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P3E-1. High Intensity Polarized Electron Source																
1.1 Modelling of photocathode quantum efficiency								MS75								
1.2 Proof-of-concept experimentation												MS76				

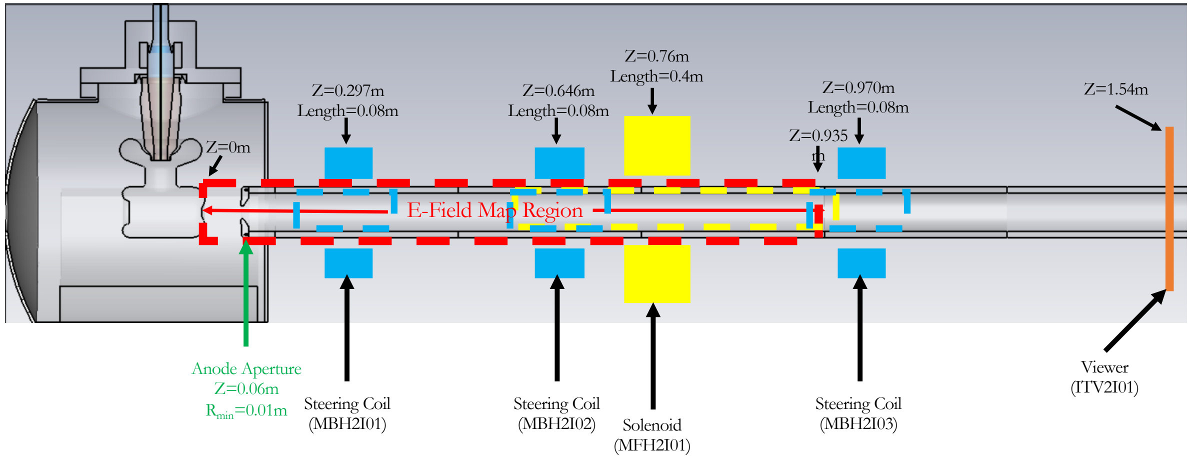
- No deliverable over the Reporting Period
- MS75 completed
- Good progress towards MS76

Completed

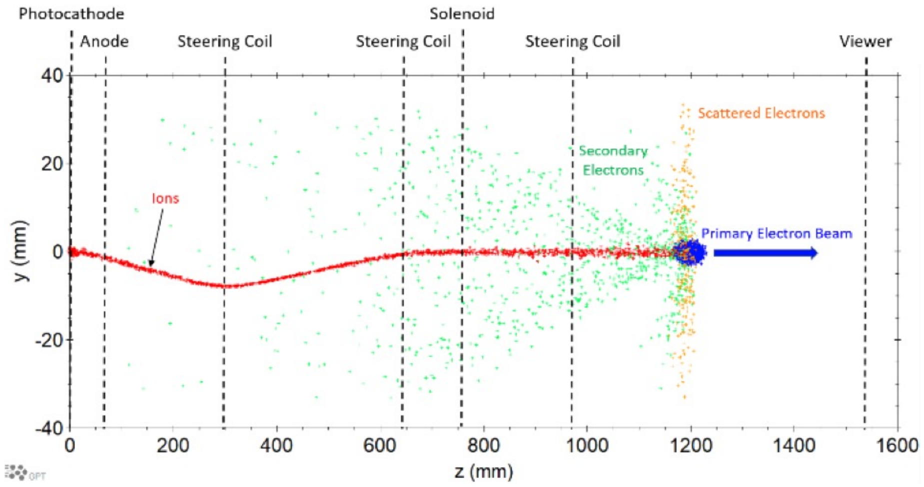
- Modelling and simulation of ion-bombardment

In progress

- Comparison of simulations and experiments



○ A new custom software was developed in the General Particle Tracer (GPT) framework to simulate electron-impact ionization of residual vacuum gasses and then track the secondary particles (ions, electrons) dynamics.



Publication

- JACoW, IPAC 2021

Invited presentation at the

- 2021 International Accelerator Particle Conference

PhD Research of J. Yoskowitz (JLab/ODU)

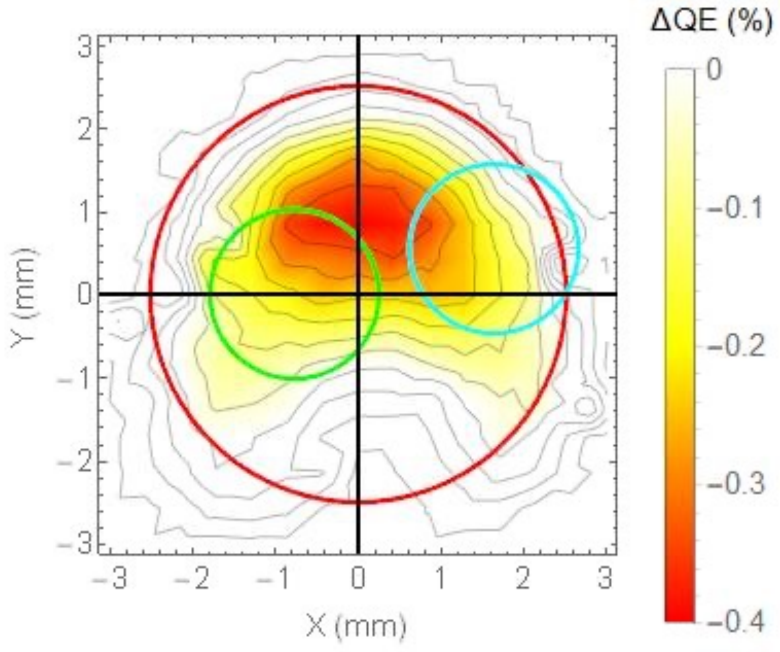
Publication
- JACoW, IPAC 2021

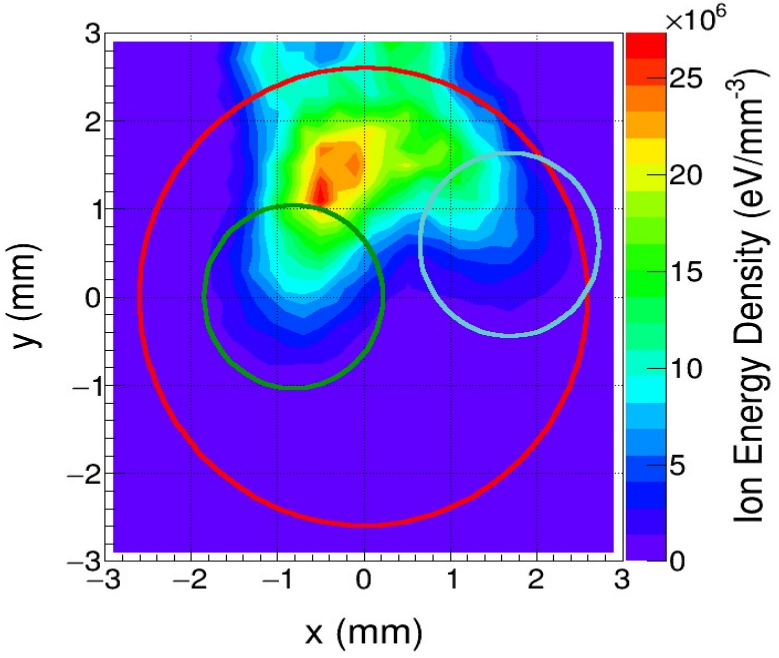
Invited presentation at the
- 2021 International Accelerator Particle Conference

PhD Research of J. Yoskowitz (JLab/ODU)

- The reduction of the quantum efficiency (QE) of the CEBAF photocathode during a 3-month run period, has been measured relatively to the location of the beam production point (laser spots).

- The simulation of the energy deposit by the back-bombardment of ions created within the anode-cathode gap, closely resembles the measured damage pattern.





Red circle: Photocathode active area (5 mm diameter)
Green circle: 1st laser spot (2 mm FWHM)
Cyan circle: 2nd laser spot (2 mm FWHM)

High Intensity Polarized Positron Source

TASKS/Subtasks	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P3E-2. High Intensity Polarized Positron Source																
2.1 Simulation of positron production, collection, deceleration				MS77				MS77						MS77		
2.2 Target stress simulation and experimental analysis				MS78						MS78			MS78			

- No deliverable over the Reporting Period
- Good progress towards MS77 and MS78

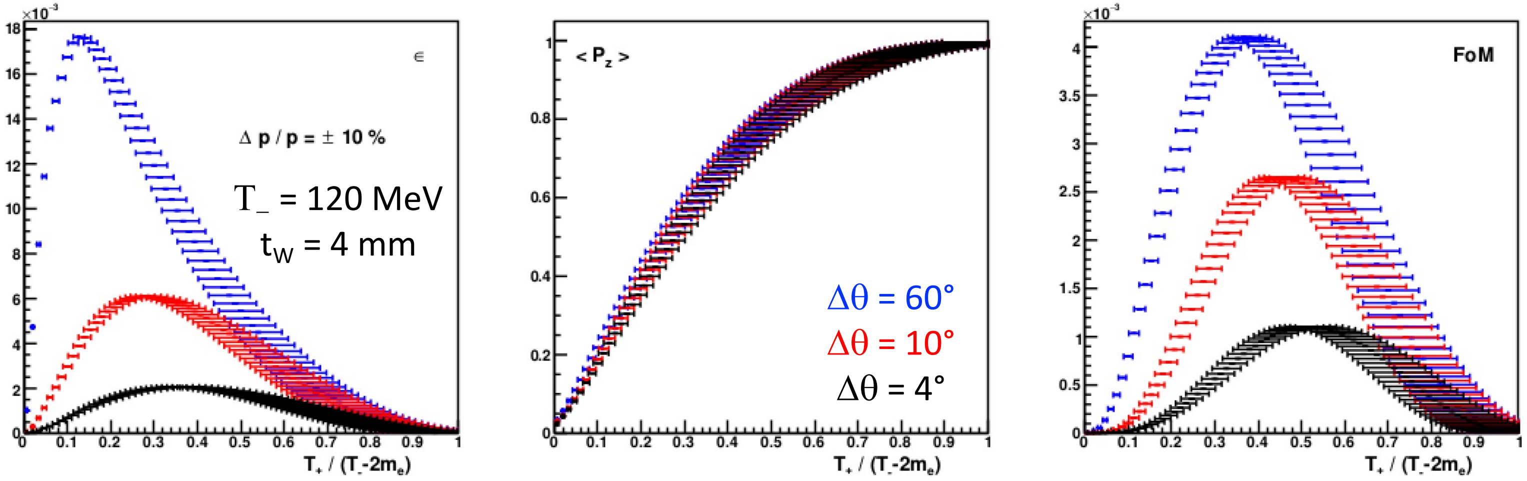
Completed

- Optimization of positron production
- Characterization of target production constraints

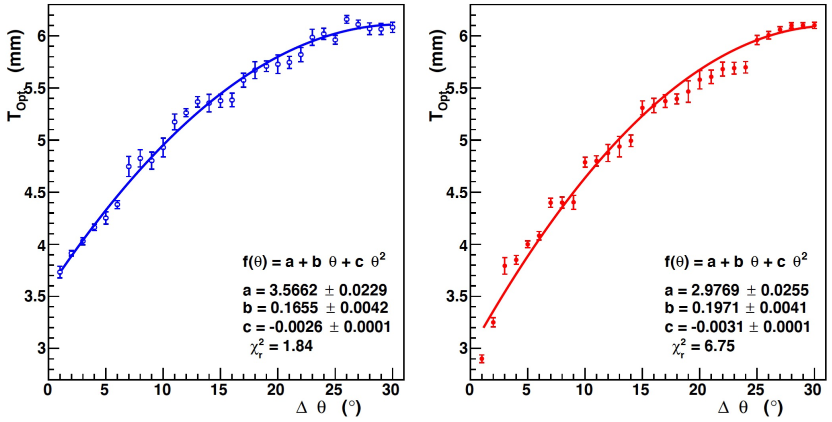
In progress

- Conceptual design of a high power positron production target
- Conceptual design of a low energy polarized positron source

The parameters of interest are the efficiency (ε), the average polarization ($<P_z>$), the Figure-of-Merit (FoM), and the positron momentum at maximum.



- Positron source performances strongly depends on the angular and momentum acceptances of the positron collection system.



- The optimum thickness of the positron production target is sensitive to the angular acceptance for positrons.
- The optimum thicknesses of unpolarized and polarized positron production are different.

Technical Note in preparation

PhD Research of S. Habet (IJCLab/JLab)

Invited presentation at the

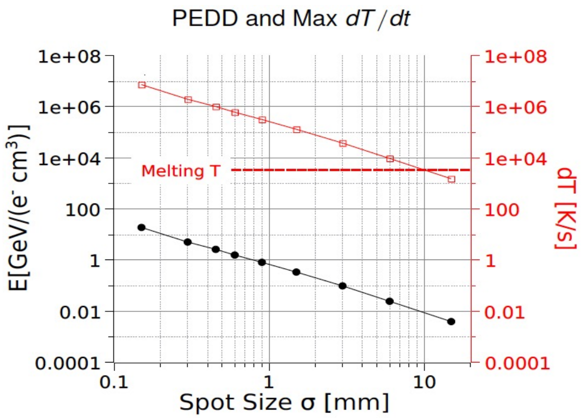
- 2021 French-Ukrainian Workshop

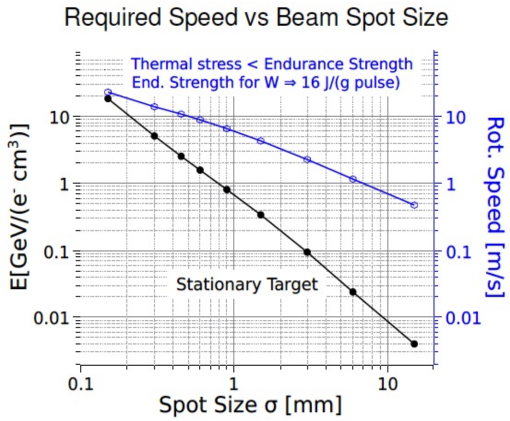
A. Ushakov (IJCLab/STRONG-2020)

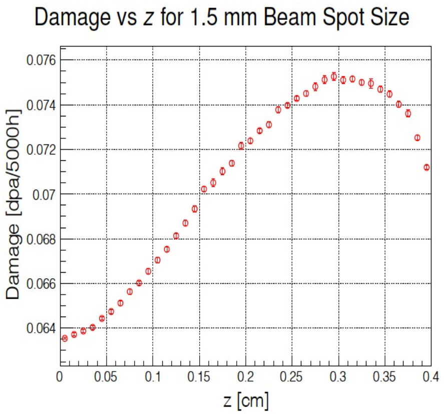
P3E Team (DESY/IJCLab/JGU/JLab/UH)

A 1 mA electron beam of 120 MeV deposes an average **17 kW** power inside a 4 mm W target.

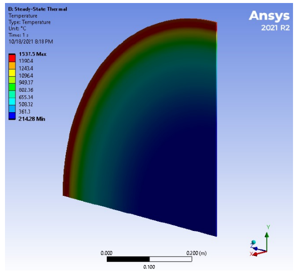
- The concept of a rotating positron production target has been characterized in terms of: the Peak Energy Deposited Density (PEDD), temperature rise, and radiation damage.





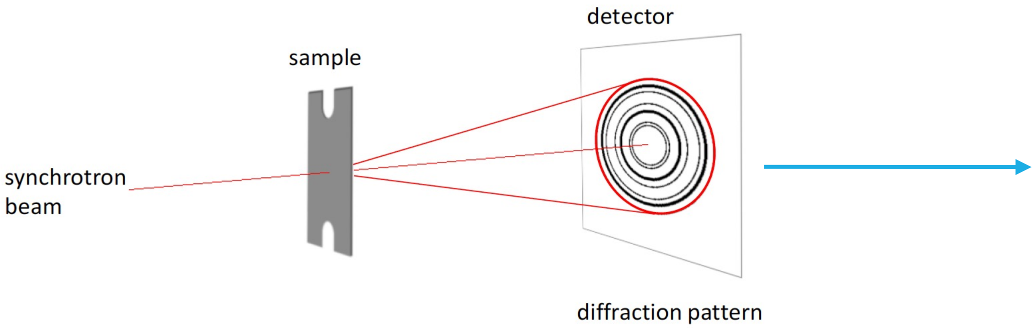


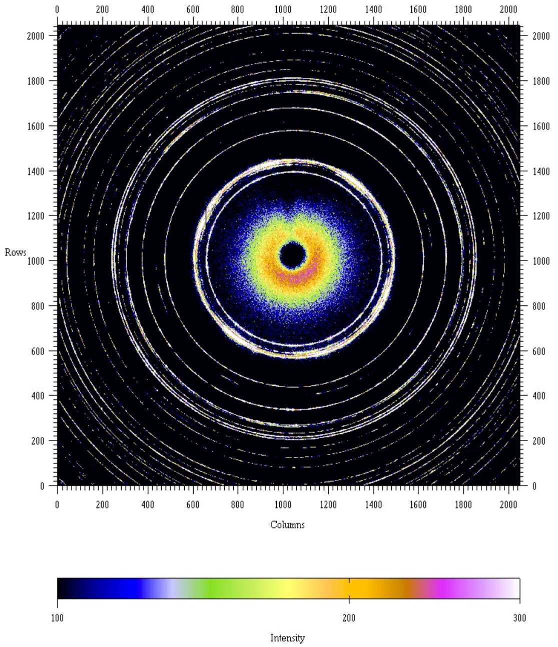
- A rotation speed of 5 (23) m/s is required for operation with a 1.50 (0.15) mm beam spot.
- A 15 cm diameter target would allow 5000 h operation without target change.



Towards a Conceptual Target Design…

- Ti-6Al-4V alloy targets have been irradiated with a 3.5 MeV electron beam at MAMI, under PEDD and thermal load conditions similar to **ILC expectations**.
- Structural damages are characterized with the HEMS beam line at PETRA III using a 87.1 keV photon beam.





Our goal is to perform similar measurements with ***120 MeV electrons****, using different target materials (pure W, alloys) under exposure conditions similar to* ***JLab expectations****.*

Publication

- Bachelor Thesis of T. Lengler

Invited presentation at the

- 2021 ILCX Workshop on Potential Experiment

T. Lengler (UH/Hereon)

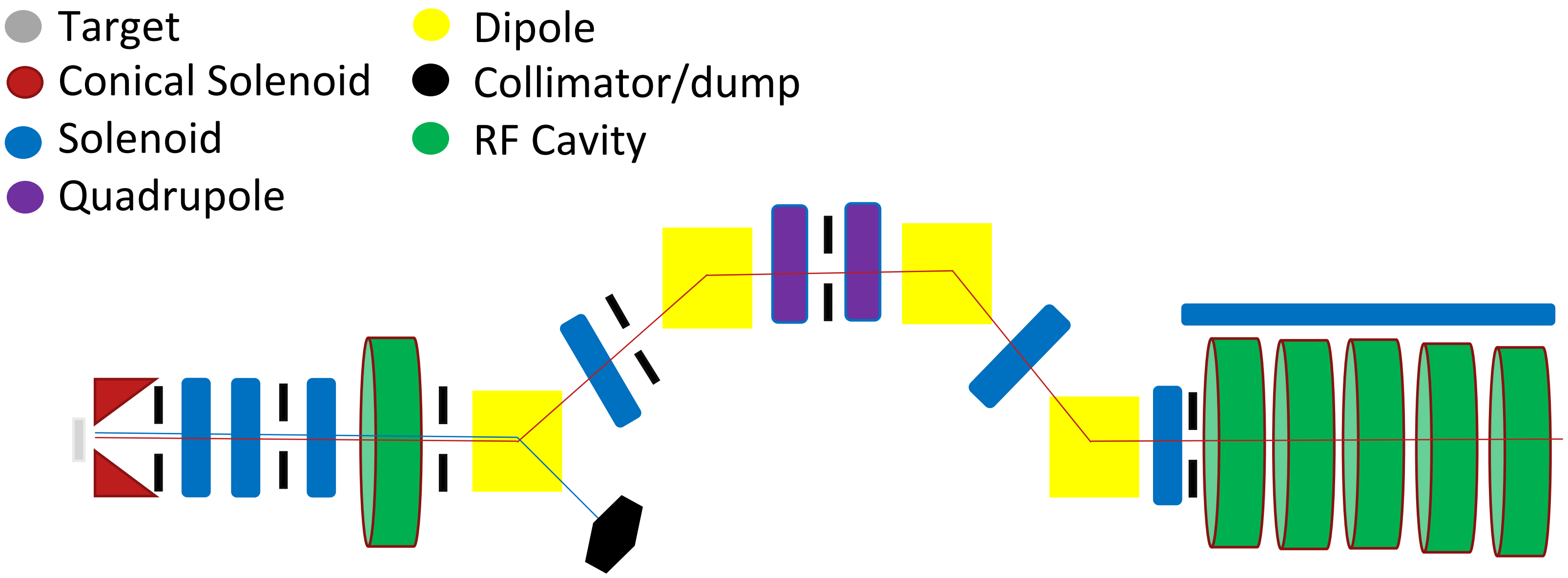
P3E Team (DESY/Hereon/IJCLab/JGU/JLab/UH)

Invited presentation at the

- 2021 International Spin Symposium

P3E Team (IJCLab/JLab)

- A new software has been developed to allow for the tracking of the spin of particles within the GPT framework.
- GPT is combined with a Multi-Objective Genetic Global Optimizer to obtain the best performances of a polarized positron source suitable for CEBAF.



Conceptual Design Report planned for late 2022

STRONG 2020

e+@JLab

Publications

- *An experimental program with positron beams at Jefferson Lab*, EPJ A Topical Issue (2021)

Invited presentations at the

- Center for Nuclear Femtography
- Meeting of the GDR-QCD/WG1
- Annual meeting of the Jefferson Lab User Organization

The investigation of the experimental physics program of positron beams at Jefferson Lab is developing further the **e+@JLab White Paper**, with new PAC proposals and a dedicated Topical Issue of the European Physics Journal A.

An Experimental Program with Positron Beams at Jefferson Lab

Regular Article - Experimental Physics

Eur. Phys. J. A (2021) **57**: 261

https://doi.org/10.1140/epja/s10050-021-00564-y

Regular Article - Experimental Physics

An experimental program with high duty-cycle polarized and unpolarized positron beams at Jefferson Lab

A. Accardi[2,31], A. Afanasev[4], I. Albayrak[35], S. F. Ali[63], M. Amaryan[42], J. R. M. Annand[29], J. Arrington[8], A. Asaturyan[65], H. Atac[48], H. Avakian[2], T. Averett[75], C. Ayerbe Gayoso[40], X. Bai[14], L. Barion[23], M. Battaglieri[2,3], V. Bellini[13], R. Beminiwattha[74], F. Benmokhtar[72], V. V. Berdnikov[63], J. C. Bernauer[55,61], V. Bertone[28], A. Bianconi[10,44], A. Biselli[68], P. Bisio[26], P. Blunden[64], M. Boer[21], M. Bondì[3], K.-T. Brinkmann[27], W. J. Briscoe[4], V. Burkert[2], T. Cao[31], A. Camsonne[2], R. Capobianco[57], L. Cardman[2], M. Carmignotto[2], M. Caudron[1], L. Causse[1], A. Celentano[3], P. Chatagnon[1], J.-P. Chen[2], T. Chetry[40], G. Ciullo[23,24], E. Cline[55], P. L. Cole[7], M. Contalbrigo[23], G. Costantini[10,44], A. D'Angelo[51,53], L. Darmé[25], D. Day[14], M. Defurne[28], M. De Napoli[13], A. Deur[2], R. De Vita[3], N. D'Hose[28], S. Diehl[27,57], M. Diefenthaler[2], B. Dongwi[31], R. Dupré[1], H. Dutrieux[28], D. Dutta[40], M. Ehrhart[1], L. El Fassi[40], L. Elouadrhiri[2], R. Ent[2], J. Erler[36], I. P. Fernando[14], A. Filippi[60], D. Flay[2], T. Forest[49], E. Fuchey[57], S. Fucini[46,47], Y. Furletova[2], H. Gao[19], D. Gaskell[2], A. Gasparian[30], T. Gautam[31], F.-X. Girod[57], K. Gnanvo[14], J. Grames[2], G. N. Grauvogel[4], P. Gueye[22], M. Guidal[1], S. Habet[1], T. J. Hague[30], D. J. Hamilton[29], O. Hansen[2], D. Hasell[12], M. Hattawy[42], D. W. Higinbotham[2], A. Hobart[1], T. Horn[63], C. E. Hyde[42], H. Ibrahim[69], A. Ilyichev[39], A. Italiano[13], K. Joo[57], S. J. Joosten[71], V. Khachatryan[19,20], N. Kalantarians[73], G. Kalicy[63], B. Karky[19], D. Keller[14], C. Keppel[2], M. Kerver[42], M. Khandaker[18], A. Kim[57], J. Kim[71], P. M. King[5], E. Kinney[9], V. Klimenko[57], H.-S. Ko[1], M. Kohl[31], V. Kozhuharov[25,54], B. T. Kriesten[14], G. Krnjaic[6,15], V. Kubarovsky[2], T. Kutz[4,12], L. Lanza[51,53], M. Leali[10,44], P. Lenisa[23,24], N. Liyanage[14], Q. Liu[37], S. Liuti[14], J. Mammei[64], S. Mantry[17], D. Marchand[1], P. Markowitz[38], L. Marsicano[3,26], V. Mascagna[16,44], M. Mazouz[41], M. McCaughan[2], B. McKinnon[29], D. McNulty[49], W. Melnitchouk[2], A. Metz[48], Z.-E. Meziani[71], S. Migliorati[10,44], M. Mihovilovič[34], R. Milner[12], A. Mkrtchyan[65], H. Mkrtchyan[65], A. Movsisyan[23], H. Moutarde[28], M. Muhoza[63], C. Muñoz Camacho[1], J. Murphy[5], P. Nadel-Turoński[56], E. Nardi[25], J. Nazeer[31], S. Niccolai[1], G. Niculescu[32], R. Novotny[27], J. F. Owens[59], M. Paolone[70], L. Pappalardo[23,24], R. Paremuzyan[21], B. Pasquini[43,44], E. Pasyuk[2], T. Patel[31], I. Pegg[63], C. Peng[71], D. Perera[14], M. Poelker[2], K. Price[1], A. J. R. Puckett[57], M. Raggi[50,52], N. Randazzo[13], M. N. H. Rashad[42], M. Rathnayake[31], B. Raue[38], P. E. Reimer[71], M. Rinaldi[46,47], A. Rizzo[51,53], Y. Roblin[2], J. Roche[5], O. Rondon-Aramayo[14], F. Sabatié[28], G. Salmè[50], E. Santopinto[3], R. Santos Estrada[57], B. Sawatzky[2], A. Schmidt[4], P. Schweitzer[57], S. Scopetta[46,47], V. Sergeyeva[1], M. Shabestari[45], A. Shahinyan[65], Y. Sharabian[2], S. Širca[34], E. S. Smith[2], D. Sokhan[29], A. Somov[2], N. Sparveris[48], M. Spata[2], H. Spiesberger[37], M. Spreafico[26], S. Stepanyan[2], P. Stoler[57], I. Strakovsky[4], R. Suleiman[2], M. Suresh[31], P. Sznajder[62], H. Szumila-Vance[2], V. Tadevosyan[65], A. S. Tadepalli[2], A. W. Thomas[66], M. Tiefenback[2], R. Trotta[63], M. Ungaro[2], P. Valente[50], M. Vanderhaeghen[36], L. Venturelli[10,44], H. Voskanyan[65], E. Voutier[1,g], B. Wojtsekhowski[2], M. H. Wood[11], S. Wood[2], J. Xie[71], W. Xiong[58], Z. Ye[67], M. Yurov[33], H.-G. Zaunick[27], S. Zhamkochyan[65], J. Zhang[14], S. Zhang[2], S. Zhao[1], Z. W. Zhao[19], X. Zheng[14], J. Zhou[19,20] and C. Zorn[2]

[1] Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405, Orsay, France
[2] Thomas Jefferson National Accelerator Facility, 23606, Newport News, VA, USA
[3] INFN, Sezione di Genova, 16146, Genova, Italy
[4] The George Washington University, 20052, Washington, DC, USA
[5] Ohio University, 45701, Athens, OH, USA
[6] Fermi National Accelerator Laboratory, 60510, Batavia, IL, USA
[7] Lamar University, 77710, Beaumont, TX, USA
[8] Lawrence Berkeley National Laboratory, 94720, Berkeley, CA, USA
[9] University of Colorado, 80309, Boulder, CO, USA
[10] Università degli Studi di Brescia, 25121, Brescia, Italy
[11] Canisius College, 14208, Buffalo, NY, USA
[12] Massachusetts Institute of Technology, 02139, Cambridge, MA, USA
[13] INFN, Sezione di Catania, 95123, Catania, Italy
[14] University of Virginia, 22904, Charlottesville, VA, USA
[15] Kavli Institute for Cosmological Physics, University of Chicago, 60637, Chicago, IL, USA
[16] Università degli Studi dell'Insubria, 22100, Como, Italy
[17] The University of North Georgia, 30597, Dahlonega, GA, USA
[18] Energy Systems, 95616, Davis, CA, USA
[19] Duke University, 27708, Durham, NC, USA
[20] Triangle Universities Nuclear Laboratory, 27708, Durham, NC, USA
[21] University of New Hampshire, 03824, Durham, NH, USA
[22] Facility for Rare Isotope Beams, Michigan State University, 48824, East Lansing, MI, USA
[23] INFN, Sezione di Ferrara, 44122, Ferrara, Italy
[24] Università degli Studi di Ferrara, 44121, Ferrara, Italy
[25] INFN, Laboratori Nazionali di Frascati, 00044, Frascati, Italy
[26] Università degli Studi di Genova, 16146, Genova, Italy
[27] Universität Gießen, 35390, Gießen, Germany
[28] IRFU, CEA, Université Paris-Saclay, 91191, Gif-sur-Yvette, France
[29] University of Glasgow, G12 8QQ, Glasgow, UK
[30] North Carolina A&T State University, 27411, Greensboro, NC, USA
[31] Hampton University, 23668, Hampton, VA, USA
[32] James Madison University, 22807, Harrisonburg, VA, USA
[33] Los Alamos National Laboratory, 87545, Los Alamos, NM, USA
[34] Faculty of Mathematics and Physics, University of Ljubljana, 1000, Ljubljana, Slovenia
[35] Akdeniz Üniversitesi, 07070, Konyaalti/Antalya, Turkey
[36] PRISMA+ Cluster of Excellence, Institut für Kernphysik, Johannes Gutenberg Universität, 55099, Mainz, Germany
[37] PRISMA+ Cluster of Excellence, Institut für Physik, Johannes Gutenberg Universität, 55099, Mainz, Germany
[38] Florida International University, 33199, Miami, FL, USA
[39] Institute for Nuclear Problems, Belarusian State University, 220040, Minsk, Belarus
[40] Mississippi State University, Mississippi State, 39762, Mississippi, MS, USA
[41] Faculté des Sciences de Monastir, Monastir, Tunisia
[42] Old Dominion University, 23529, Norfolk, VA, USA
[3] Università degli Studi di Pavia, 27100, Pavia, Italy
[4] INFN, Sezione di Pavia, 27100, Pavia, Italy
[5] University of West Florida, 32514, Pensacola, FL, USA
[6] INFN, Sezione di Perugia, 06123, Perugia, Italy
[7] Università degli studi di Perugia, 06123, Perugia, Italy
[8] Physics Department, Temple University, 19122-180, Philadelphia, PA, USA
[9] Idaho State University, 83209, Pocatello, ID, USA
[0] INFN, Sezione di Roma, 00185, Rome, Italy
[1] INFN, Sezione di Roma Tor Vergata, 00133, Rome, Italy
[2] Sapienza Università di Roma, 00185, Rome, Italy
[3] Università degli Studi di Roma Tor Vergata, 00133, Rome, Italy
[4] University of Sofia, Faculty of Physics, 1164, Sofia, Bulgaria
[5] Center for Frontiers in Nuclear Science, Stony Brook University, 11794, Stony Brook, NY, USA
[6] Stony Brook University, 11794, Stony Brook, NY, USA
[7] University of Connecticut, 06269-3046, Storrs, CT, USA
[8] Syracuse University, 13244, Syracuse, NY, USA
[9] Florida State University, 32306, Tallahassee, FL, USA
[0] INFN, Sezione di Torino, 10125, Torino, Italy
[1] RIKEN BNL Research Center, 11973, Upton, NY, USA
[2] National Centre for Nuclear Research (NCBJ), 02-093, Warsaw, Poland
[3] The Catholic University of America, 20064, Washington, DC, USA
[4] University of Manitoba, R3T 2N2, Winnipeg, MB, Canada
[5] A. Alikhanyan National Laboratory, Yerevan Physics Institute, 375036, Yerevan, Armenia
[6] CSSM, Department of Physics, University of Adelaide, 5005, Adelaide, SA, Australia
[7] Tsinghua University, 100084, Beijing, People's Republic of China
[8] Fairfield University, 06824, Fairfield, CT, USA
[9] Cairo University, 12613, Giza, Egypt
[0] New Mexico State University, 88003, Las Cruces, NM, USA
[1] Argonne National Laboratory, 60439, Lemont, IL, USA
[2] Duquesne University, 15282, Pittsburgh, PA, USA
[3] Virginia Union University, 23220, Richmond, VA, USA
[4] Louisiana Tech University, 71272, Ruston, LA, USA
[5] The College of William & Mary, 23185, Williamsburg, VA, USA

- The **e+@JLab EPJ A Topical Issue** comprises 20 contributions from a community of 230 physicists from 75 institutions and addresses the importance of positron beams for:
  - ✓ Two-photon effects in elastic scattering
  - ✓ Radiative effects in elastic scattering
  - ✓ The charge radius of the proton
  - ✓ The Parton Distributions
  - ✓ The Generalized Parton Distributions
  - ✓ Electroweak couplings
  - ✓ The search for light dark matter particles
  - ✓ Charged lepton-flavor violation

High Precision Electron Polarimetry

TASKS/Subtasks	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P3E-3. High Precision Electron Polarimetry																
3.1 Simulation of the polarimeter detector						MS79										
3.2 Technical design of the polarimeter detector																

- No deliverable over the Reporting Period
- MS79 completed

Completed

- GEANT4 modelling of the polarimeter

In progress

- Development of HV-MAPS pixel detectors

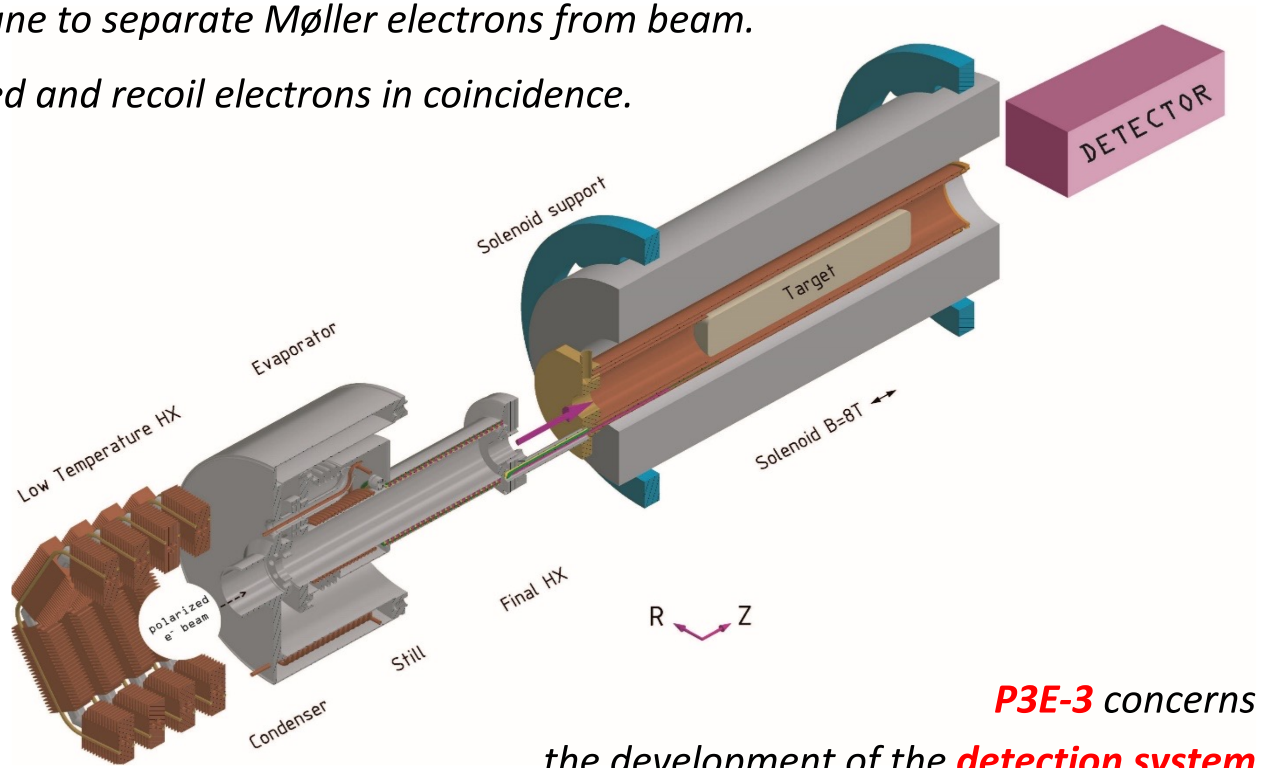
The Hydro-Møller Polarimeter

P3E Team (JGU)

- The P2 experiment at MESA asks for new polarimetry techniques capable to operate within **high beam current environment** and to achieve very small systematic uncertainties (**0.1%**).

☛ Measurement of the **double spin asymmetry** of the Møller scattering of a polarized electron beam off polarized electrons.

- *Trap and polarize atomic hydrogen in solenoidal high-field at 0.3 K.*
- *Requires dilution cryostat (under construction at Mainz).*
- *Magnetic chicane to separate Møller electrons from beam.*
- *Detect scattered and recoil electrons in coincidence.*



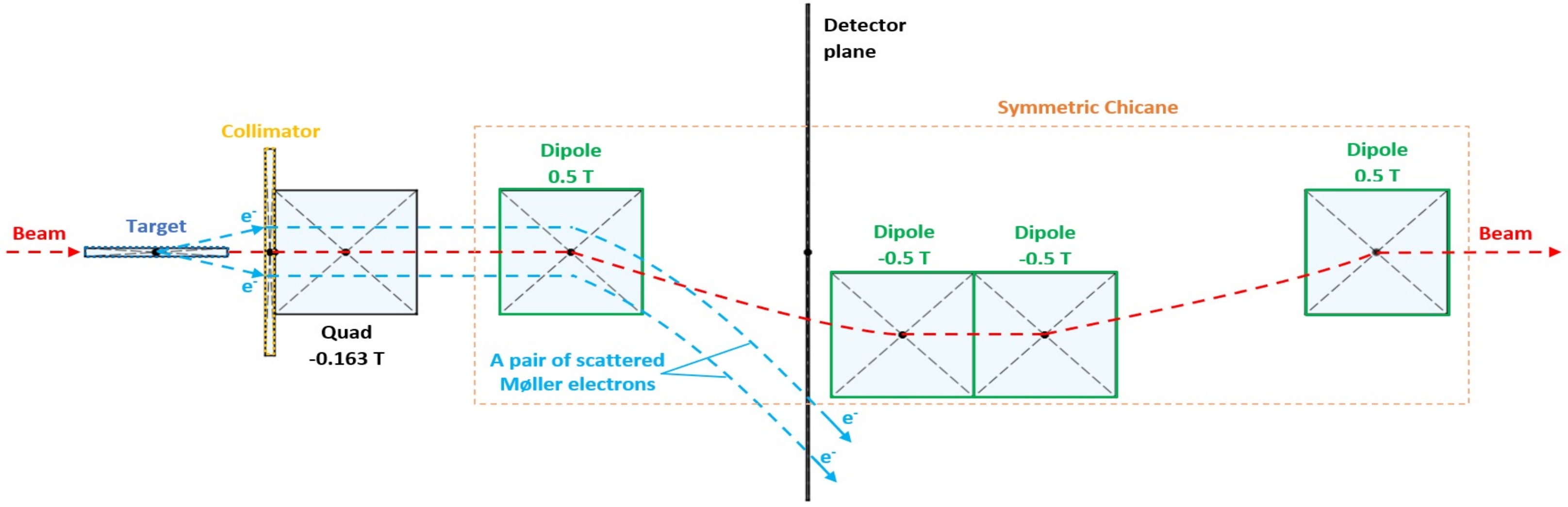
***P3E-3** concerns*

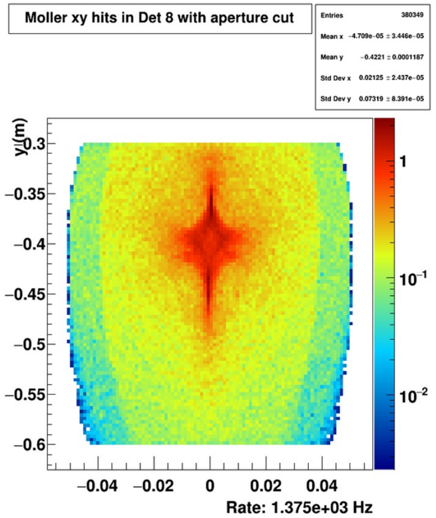
*the development of the **detection system***

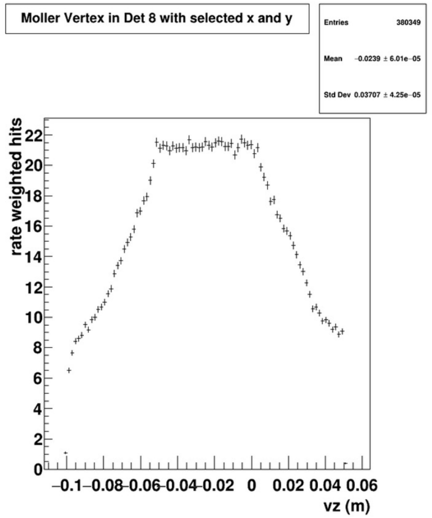
Polarimeter Simulation

P3E Team (JGU and R. Beminiwhatta, S. Riordan, M. Kravchenko, K. Kumar, V. Tyukin)

- The GEANT4 modelling of the polarimeter is used for optimizing magnets and apertures and identifying the best possible detector technology.

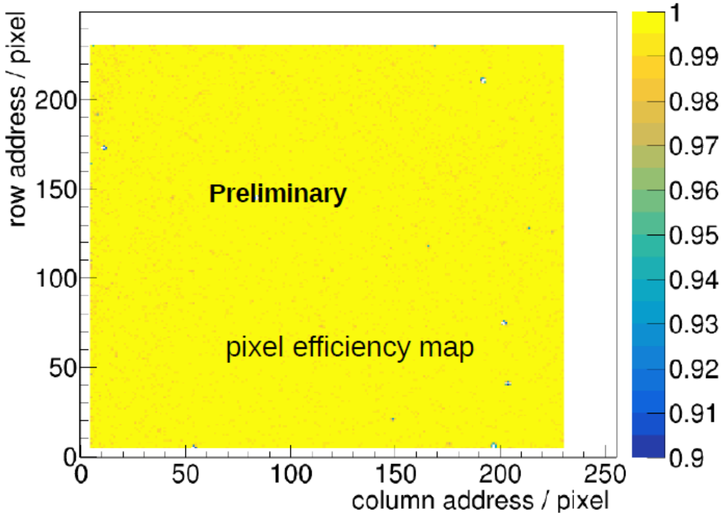




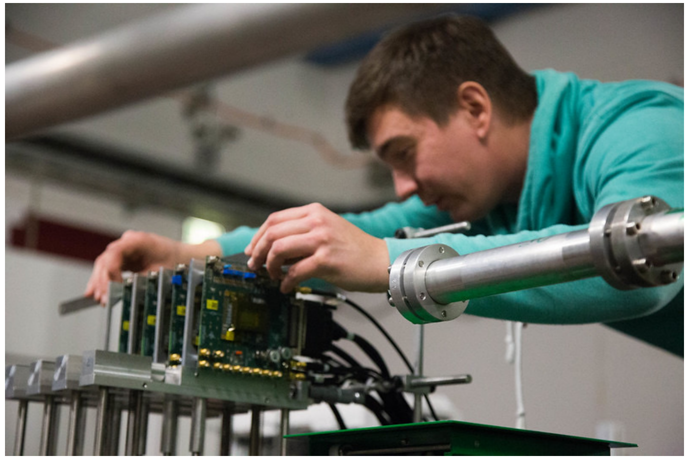


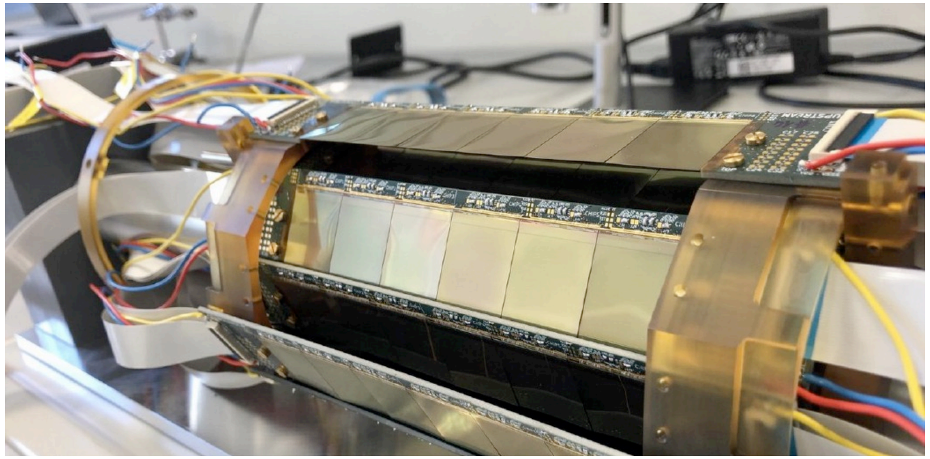
HV-MAPS Pixel Detectors

P3E Team (JGU)



- Full size (2x2 cm^2) sensors available.
- Extensive beam tests at DESY, PSI and MAMI.
- Promising results, issues identified and fixes available.
- First detector assembly operated in Mu3e integration run 2021.
- Submission of a fully integrable production version still in 2021.





Summary

Scientific Objectives

- **JRA13** is **on track** to deliver its committed objectives.
- Positron production target activities (P3E-2.2) suffered delays from the pandemic, but are now progressing smoothly.

Funding adjustments

- Part of the IJCLab funding (14.4 k€ / 20 k€) has been redirected from Travel to Personnel for hiring Dr. A. Ushakov.
- UH and IJCLab may consider the **transfer** of UH Personnel funding (40 k€) to IJCLab for the extension of Dr. A. Ushakov contract, with no impact on P3E scientific goals nor the UH commitment within P3E.