Novel applications and future perspectives of a fast diamond γ-detector

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Introduction

- ELI-NP[1]: new gamma source under construction in Magurele, Romania.
- Gammas produced by Compton interaction between electrons and a laser.
- Few 100s MeV electrons from LINAC.
- Resulting gamma energies between 0.2 and 20 MeV.
- Innovative complex optical system to generate 32 pulses of 10^7 photons each separated by 16 ns.
- Device necessary to monitor photon flux, stability, alignment and beam-shape.
- Differentiate relative fluxes of the various pulses.

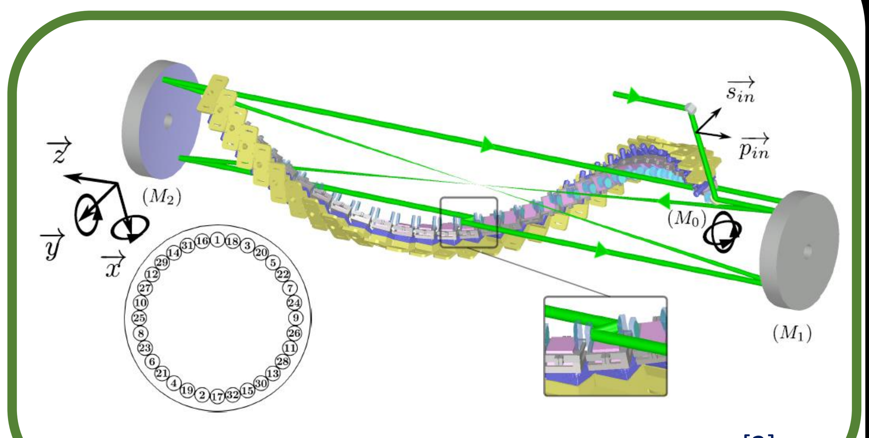


Fig 1. Diagram of the ELI-NP optical recirculator. [2]

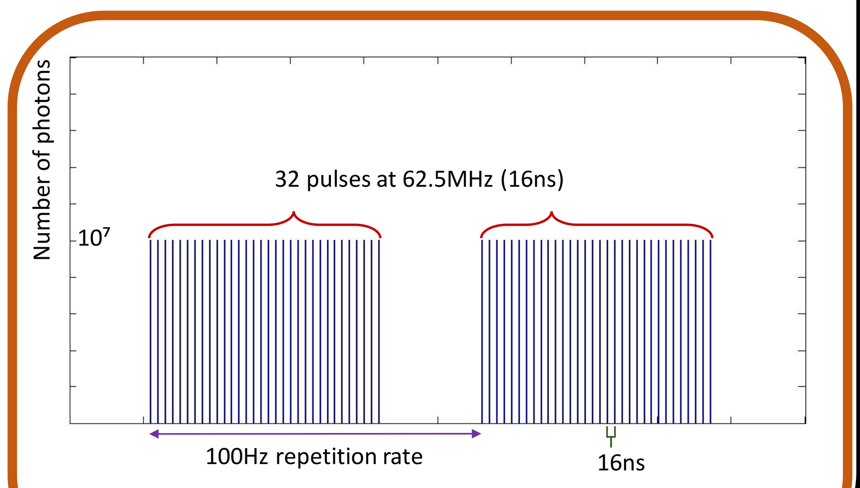


Fig 2. Time-structure of the pulsed beam at ELI-NP.

Detector

- Single-crystal diamond detector (5 x 5 x 0.5 mm³) with 400 V bias voltage.
- Semi-conductor behaviour.
- Few nanosecond pulse width.
- Radiation hard.
- Low efficiency, small surface -> non-destructive.
- Possibility of use in vacuum.
- Commonly used for electron detection and radiation safety.
- First steps in photodetection.

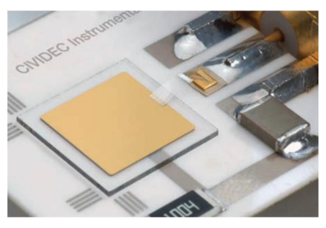
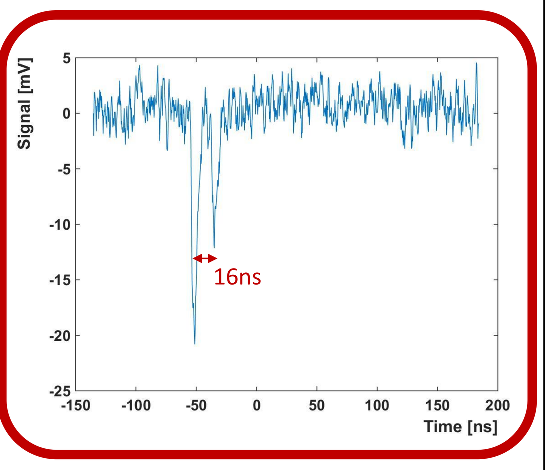


Fig 3. CIVIDEC diamond detector.[3]

Experiment

- First experiment at HIγS[4], Duke University, USA.
- Energy-range of gammas: 2 to 7 MeV.
- Only 10 photons per shot, combined with efficiency -> single-photon case.
- Signal amplified with a low-noise broadband amplifier.
- Data-acquisition with USB Wavecatcher[5]: 1024 points at 3.2 GHz sampling rate.

Fig 4. Diagram of the experimental set-up.



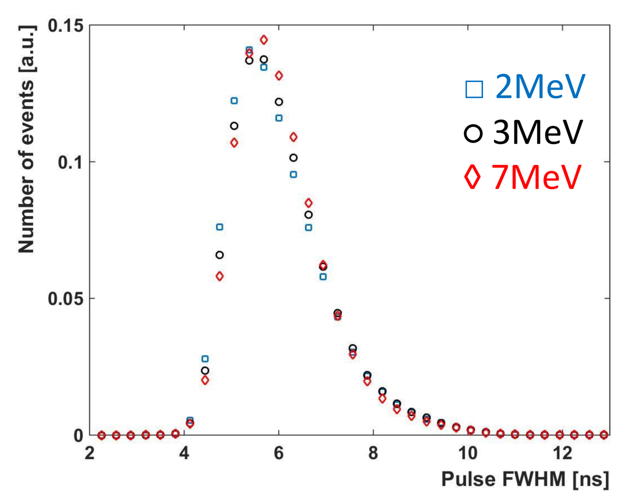


Fig 5. FWHM of the pulse signal at 3 energies.

- Fast response of diamond demonstrated with discrimination of 2 consecutive peaks separated by 16ns.
- 6.2 ns mean FWHM pulse duration, independent of energy.
- Charge collected independent of energy.
- Agreement with GEANT4 simulation: Flat spectrum between 1 and 10 MeV.

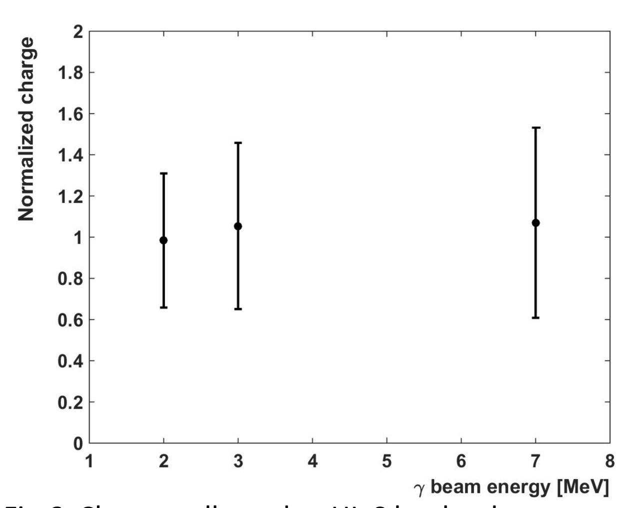


Fig 6. Charge collected at HIγS by the detector as a function of the gamma beam energy.

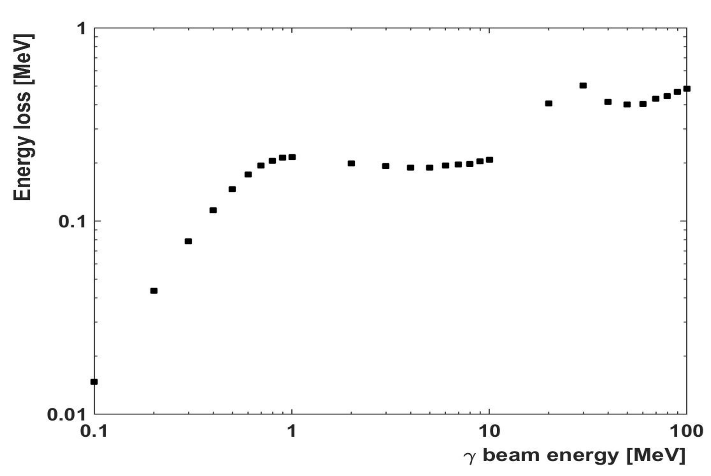


Fig 7. GEANT4 simulation of the energy deposited in the diamond for various gamma energies.

Summary

- Satisfying first results towards completion of planned device.
- Fast response demonstrated.
- First evidence of response independent of energy.

Beam-shape and Polarisation

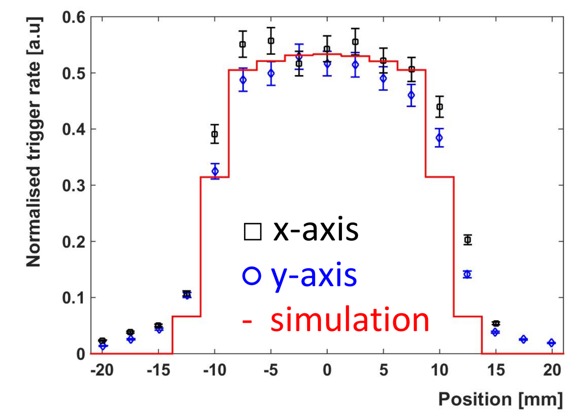


Fig 8. Trigger rate along the x- and y-axes for z = 63 m.

- Tentative evaluation of beam-shape by scanning on transverse plane (z = 63 m).
- Almost flat response due to large distance between interaction point and detector.
- Good concordance between measurements and simulation.

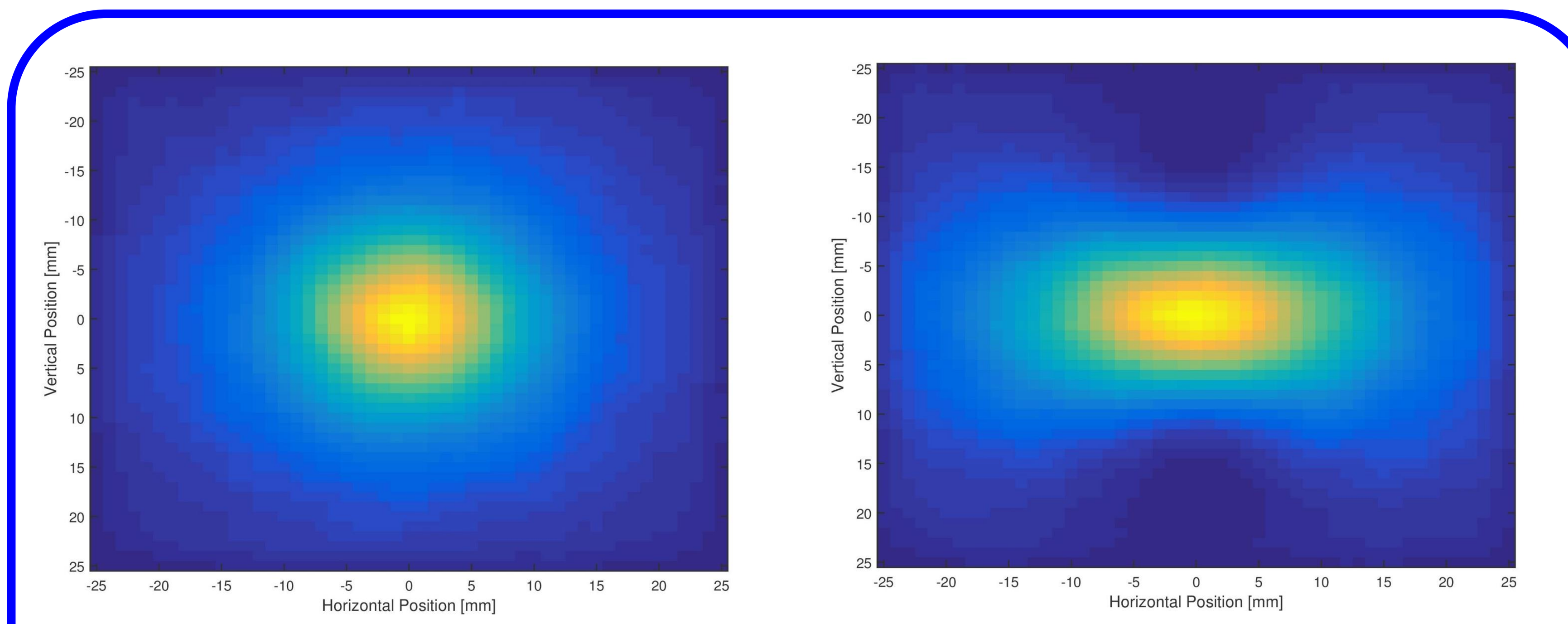


Fig 9. Transverse projection of a simulated gamma beam for a circular ($S_1 = 0; S_2 = 0$) and a horizontal($S_1 = 1; S_2 = 0$) polarisation

- Photon beam conserves laser polarisation for unpolarised electrons.
- By knowing production parameters α and β, Number of photons at a position (θ, φ) given by

$$N_\gamma \sim \alpha(1 + S_1.\beta(\theta).\cos(2\varphi) + S_2.\beta(\theta).\sin(2\varphi))$$ [6]

- Estimation of Stokes parameters S_1 and S_2 with a 10% precision.
- S_1 and S_2 uncorrelated.

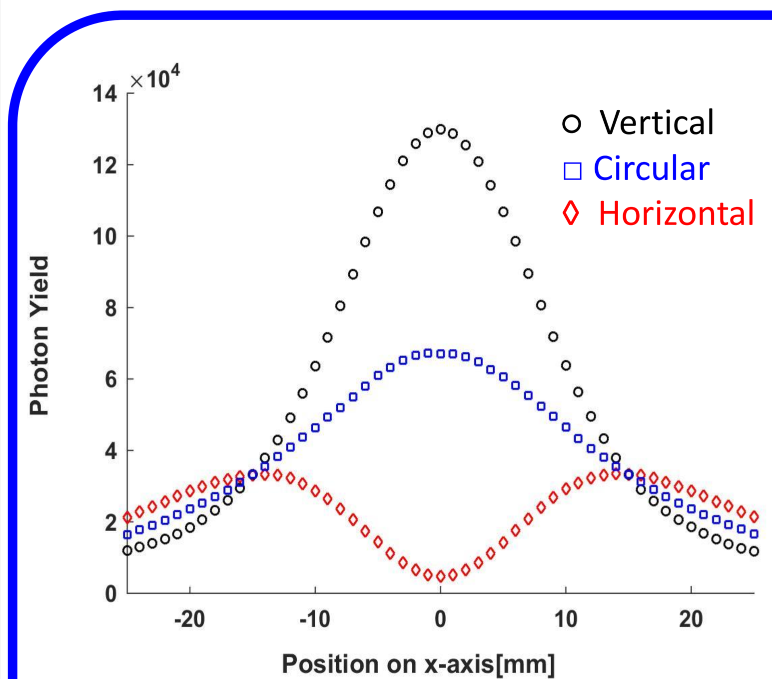


Fig 10. Various beam shapes for 3 given polarisations, for a simulation at y = 15 mm, z = 2600 mm, E = 200 keV.

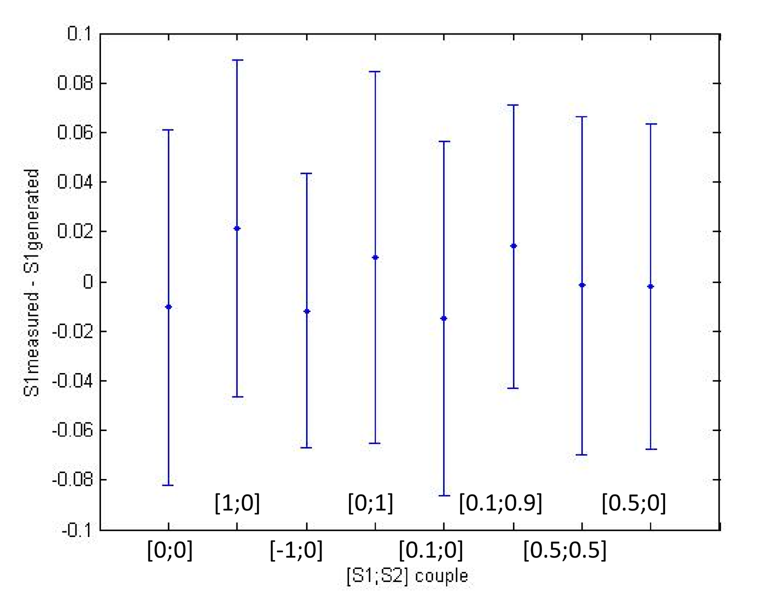


Fig 11. Difference between S1 measured at the end of the simulation and S1 generated initially, for various Stokes parameters.

Prospects

- Proving possible estimation of beam polarisation is next ambitious goal.
- Evaluate all background noise.
- Use in vacuum chamber to test mechanical constraints.
- Relative measurements of flux.
- Higher rate will give precision on current estimate of efficiency of 0.1%.
- Increasing efficiency achievable by using Tungsten converter.
- Experiment needed to calibrate diamond detector on a spectrum of energies (0.1-15 MeV).

References

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Acknowledgements

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