

Laser-driven generation of ultra-relativistic positron beams

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technical staff



L. Romagnani



J. Vieira, N. Shukla,
L. Silva

- **INTRODUCTION**
 - Positron beam generation mechanisms
 - Laser Wakefield acceleration

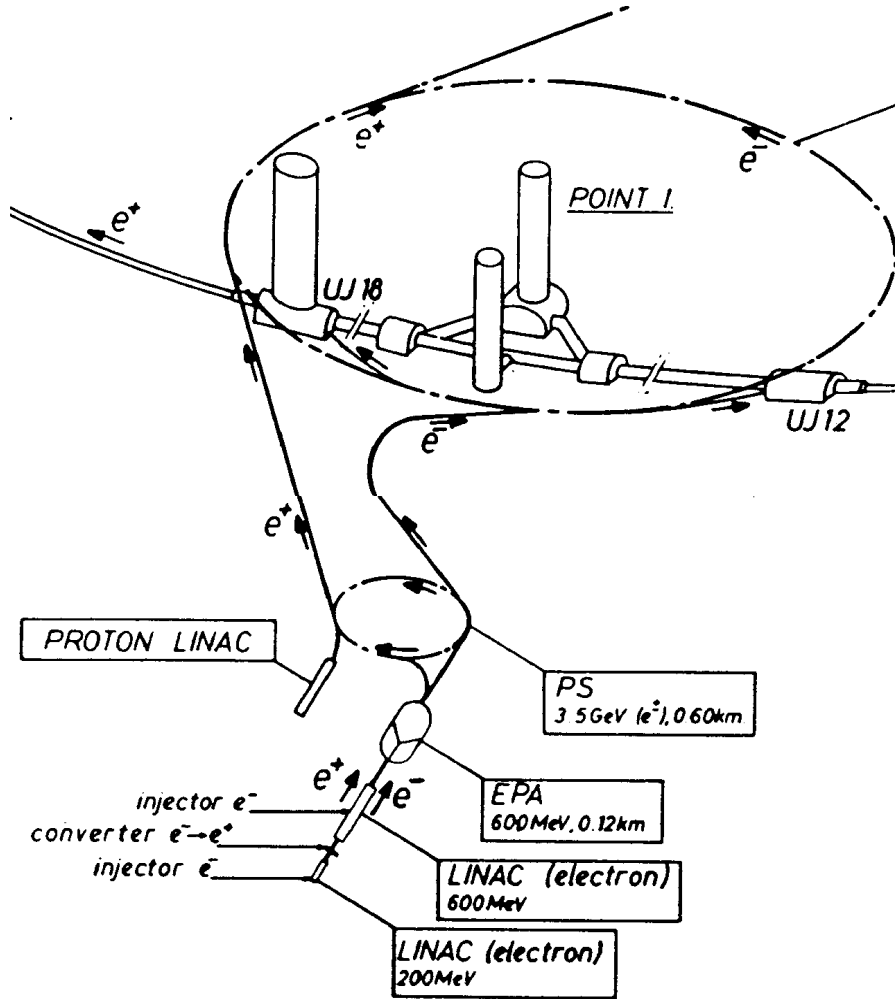
- **POSITRON BEAMS: SETUP**

- **POSITRON BEAM CHARACTERISTICS**
 - Spectrum
 - Divergence
 - Density
 - Duration
 - Emittance

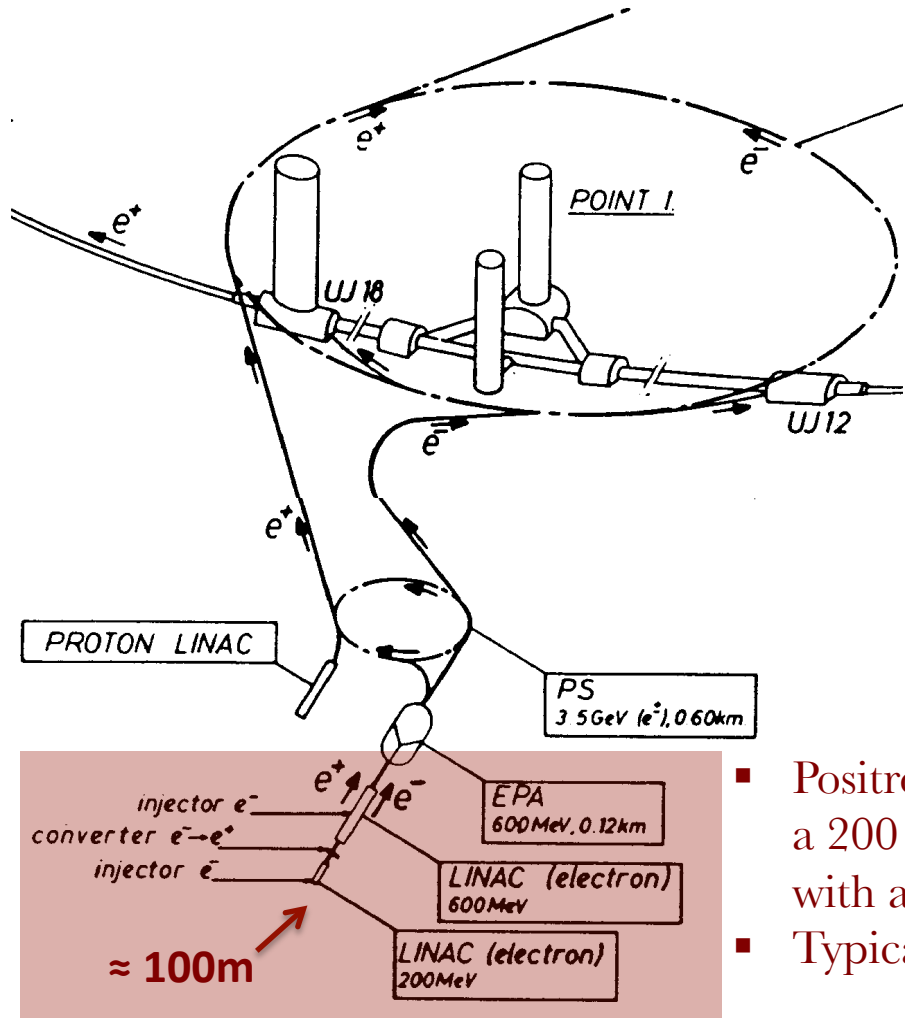
- **CONCLUSIONS AND OUTLOOK**
 - Positron luminosity

Introduction

- The largest electron-positron collider ever built was the LEP

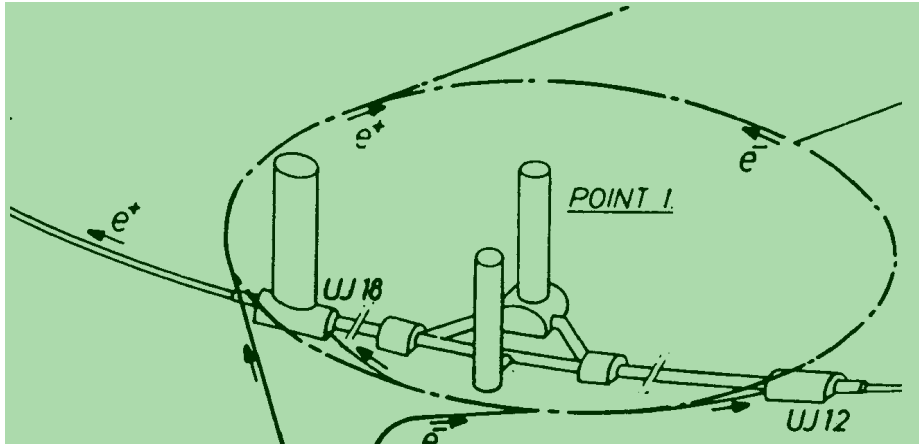


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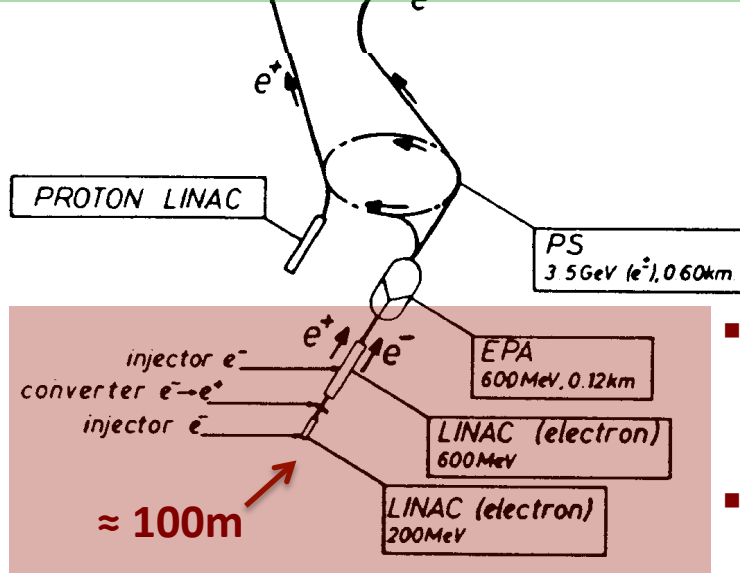


- Positrons initially generated during the interaction of a 200 MeV electron beam (from a 100m long LINAC) with a solid target
- Typical emittance at injection: 60π mm mrad

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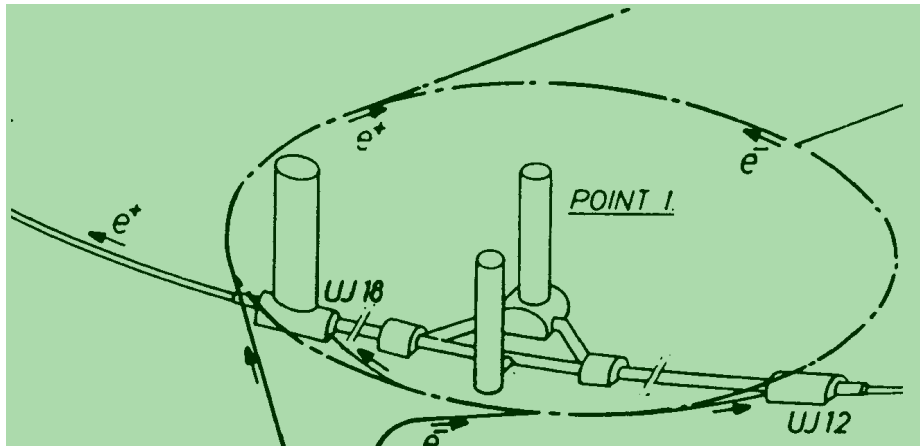


- Stored and cooled before being injected in a 27-km diameter synchrotron
- Twin electron beam also generated, with maximum energy of 209 GeV



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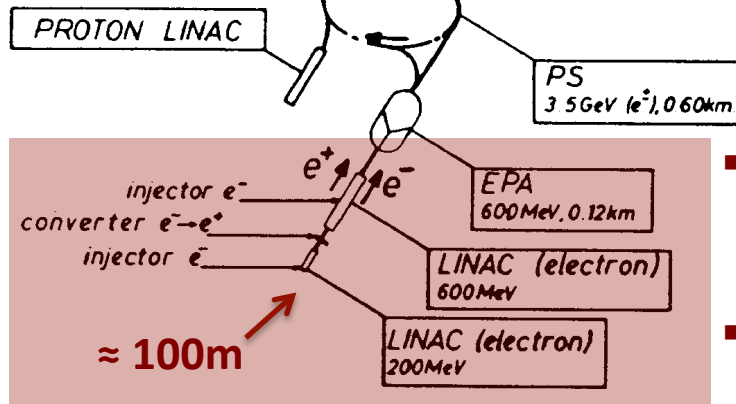
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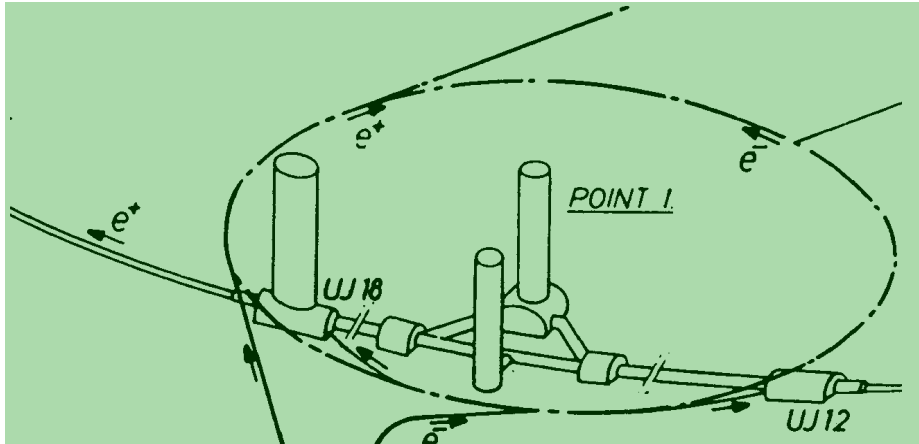
Positrons: $\sim 10^{11}$

Luminosity $\sim 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$



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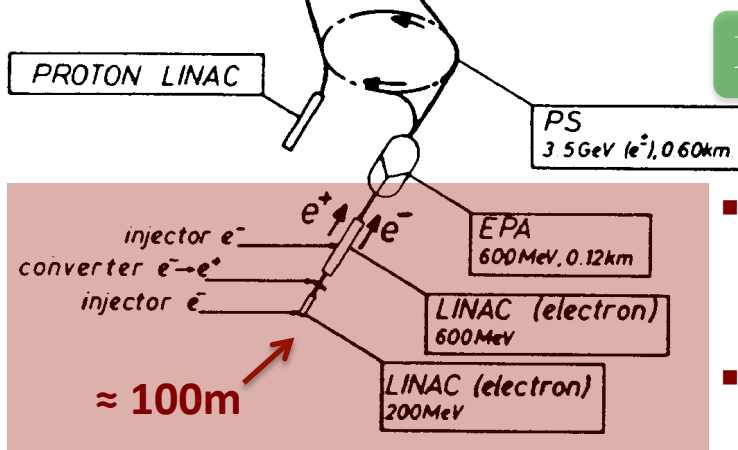
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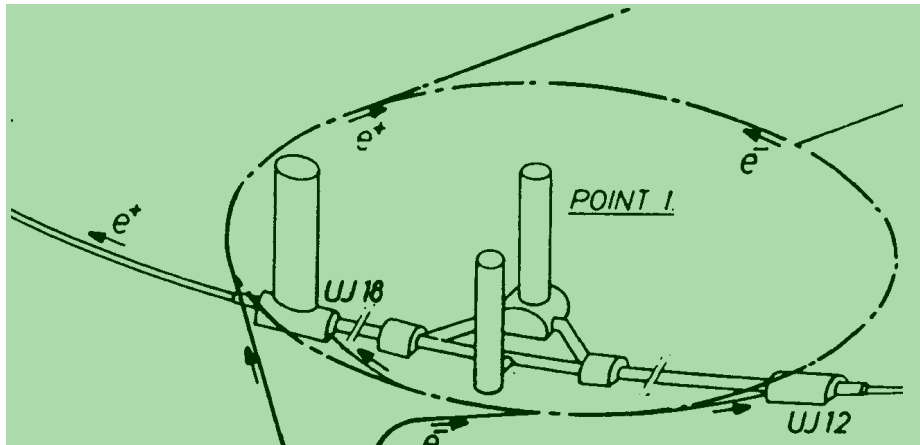
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New collider proposal: International Linear Collider

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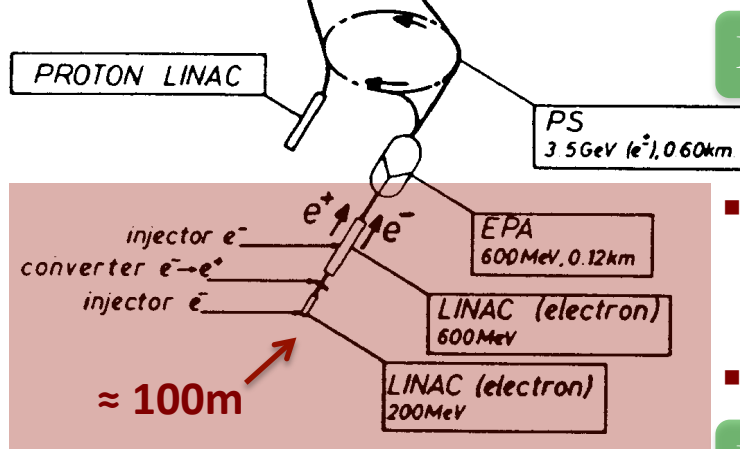
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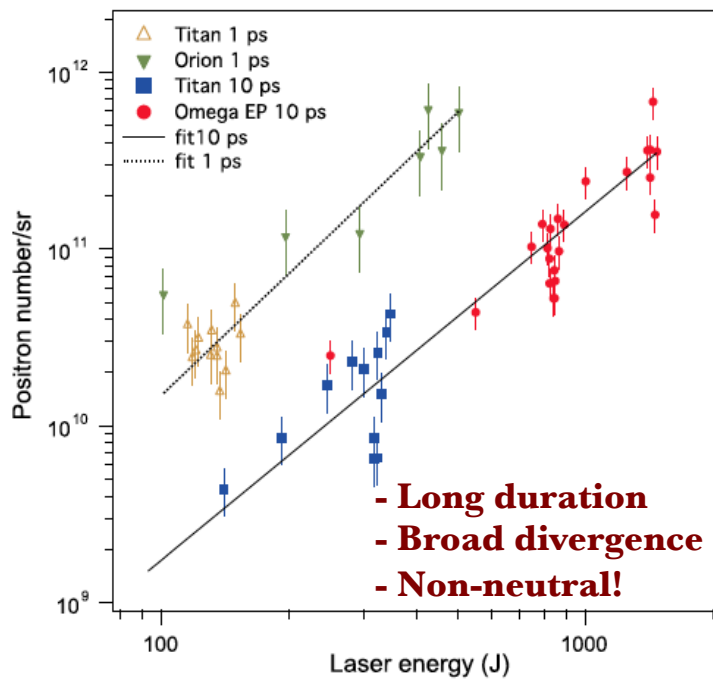
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Difficult to generate a neutral electron-positron beam!

Large-scale, high-energy laser systems

- Direct laser irradiation on solid targets
- Hot electrons propagating through the target
- Pair production in the nuclear field

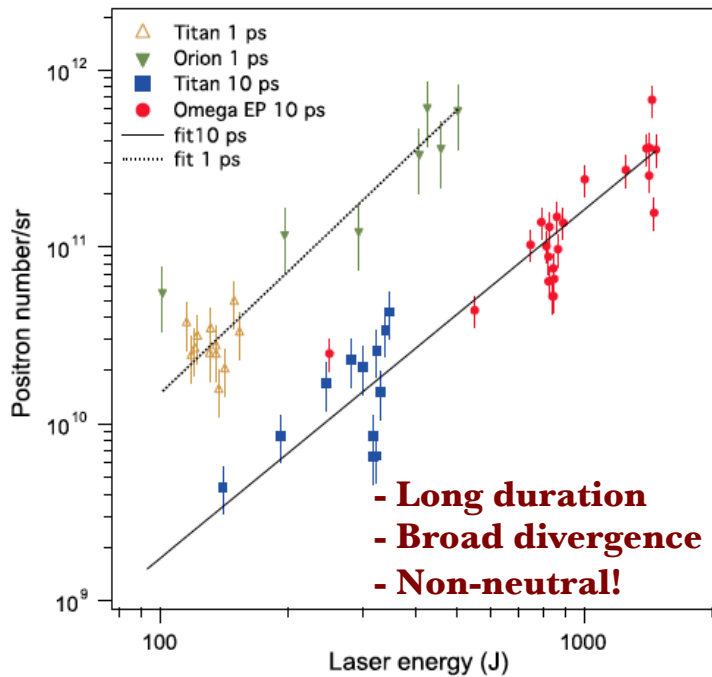


H. Chen *et al.*, Phys. Rev. Lett. 114, 215001 (2015)

E. Liang *et al.* Sci. Rep. 5,13968 (2015).

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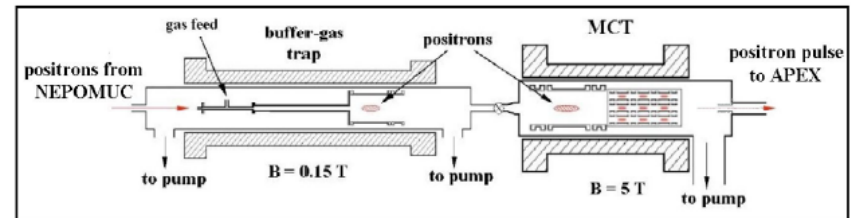
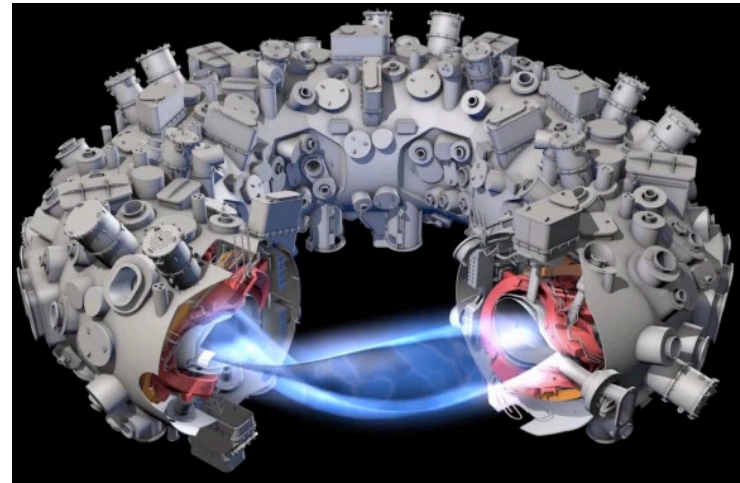


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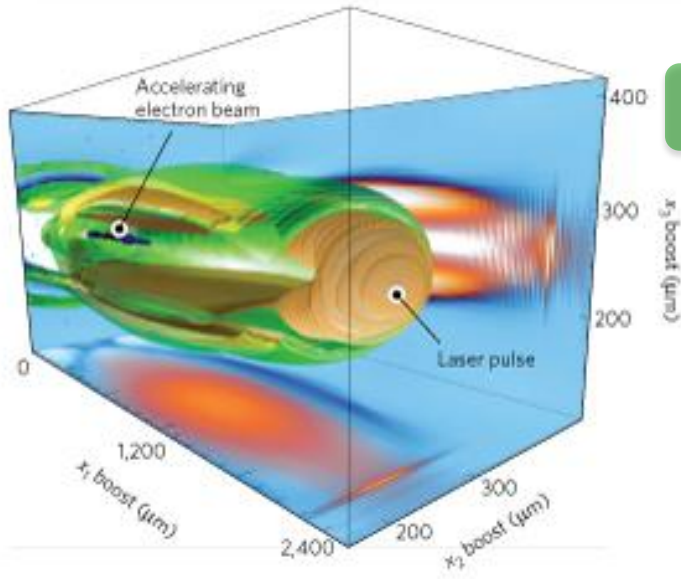
Positron injection in a stellarator

- Creation of a steady electron plasma
- Injection of positrons
- Short temporal confinement
- Non-relativistic plasma



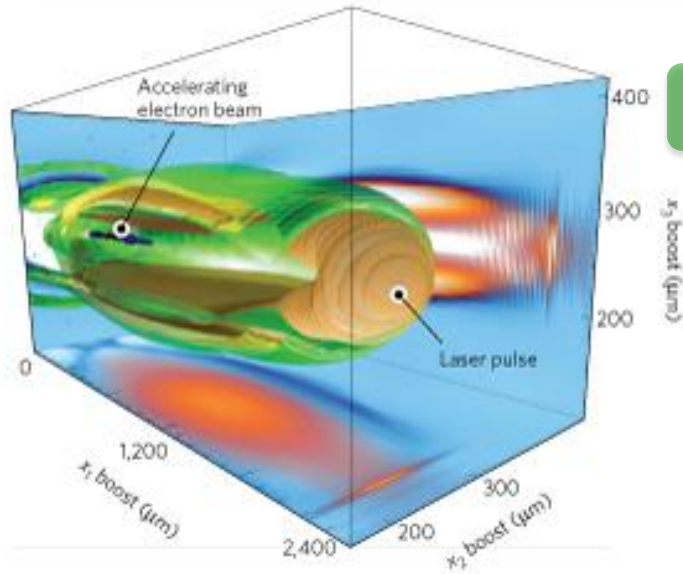
T. S. Pedersen *et al.*, New J. Phys. 14, 035010 (2012)

Wake-field based positron generator



Laser-wakefield electrons to trigger the cascade in a solid

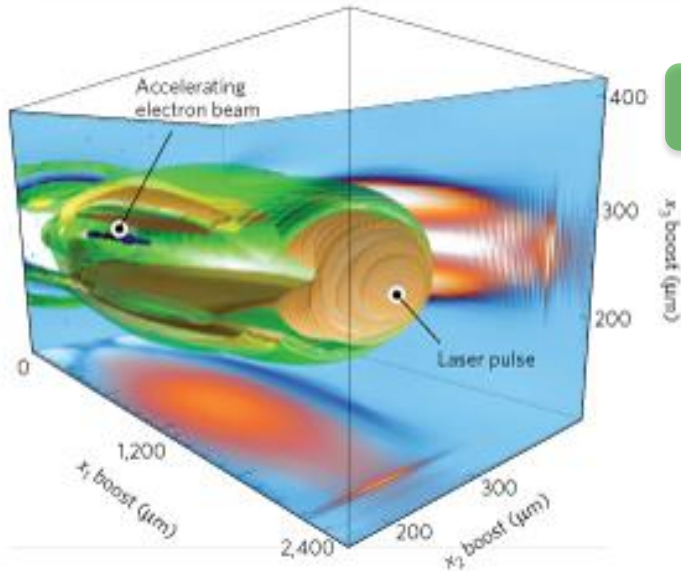
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Laser-wakefield electrons to trigger the cascade in a solid

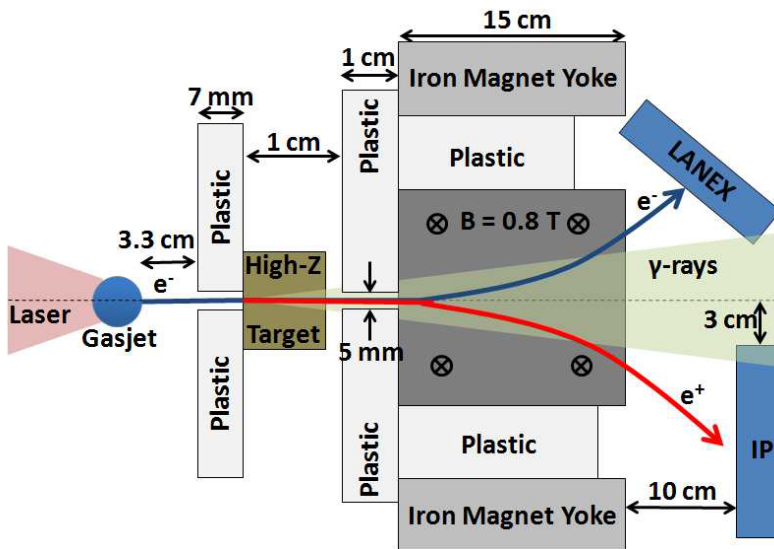
- ✓ Divergence: 1-5 mrad (from solid: ~ 20 degrees)
- ✓ Duration: ~ 10 fs (from solid: 1 – 10 ps)
- ✓ Energy: 100s of MeV (from solid: 10s of MeV)
- ✓ Laser energy: ~ 1 -10J (from solid: \sim kJ)
- ✓ Possibility of generating neutral e^-/e^+ beams in situ!

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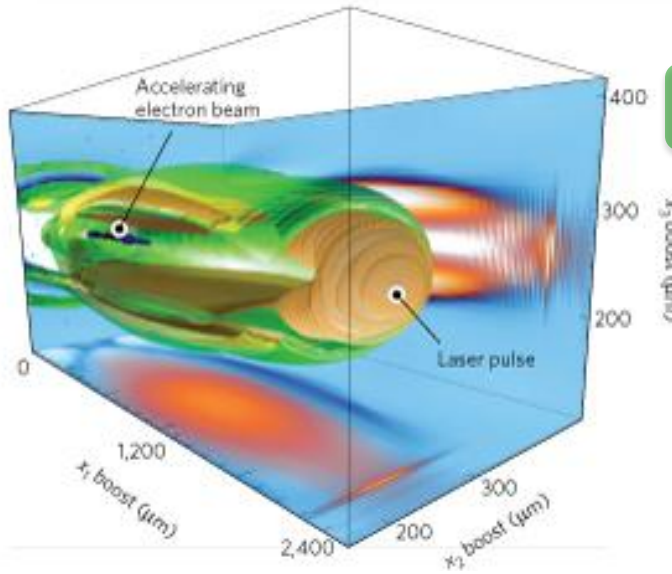


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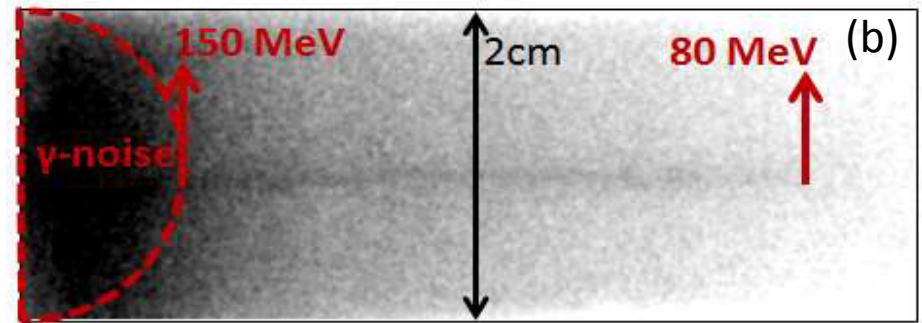
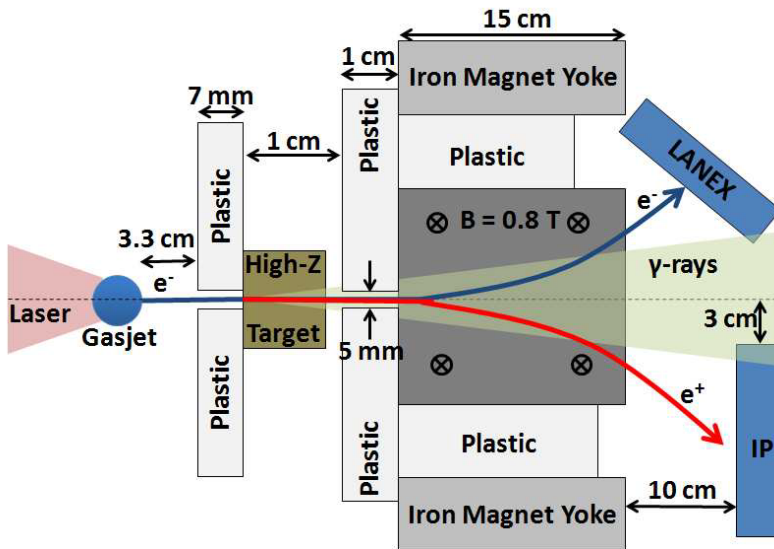


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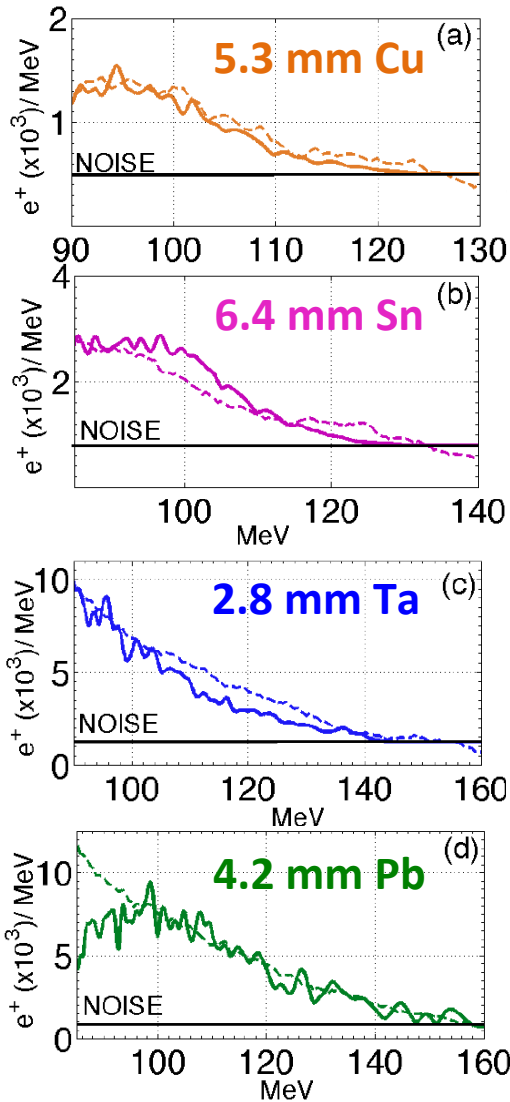


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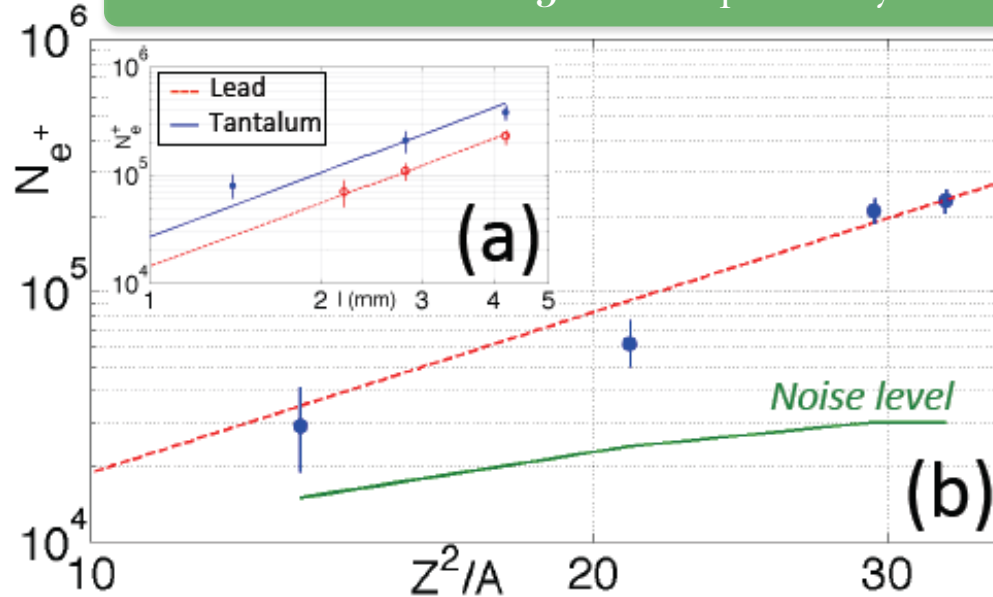
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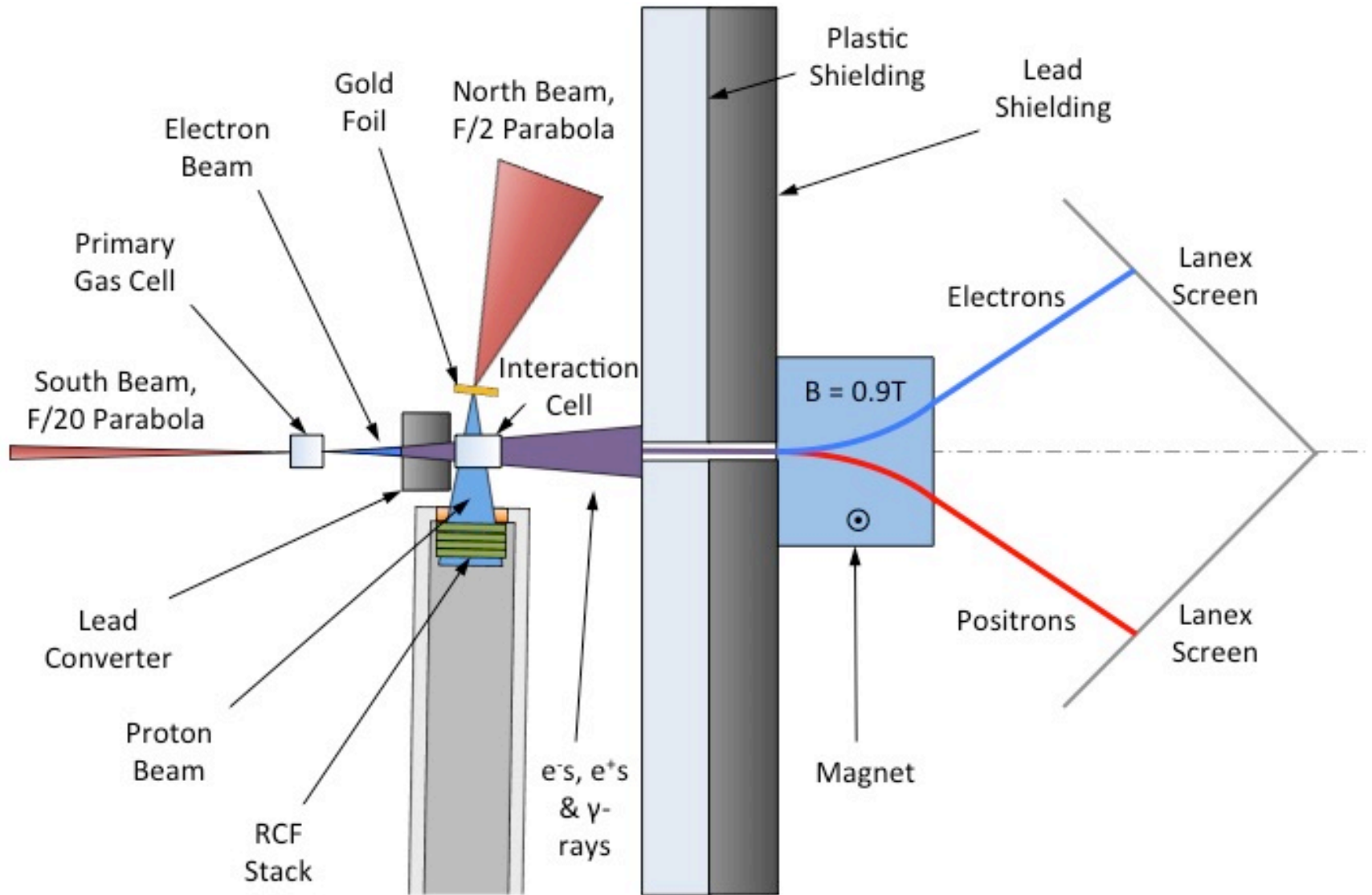


First results with a 0.8J table-top laser system

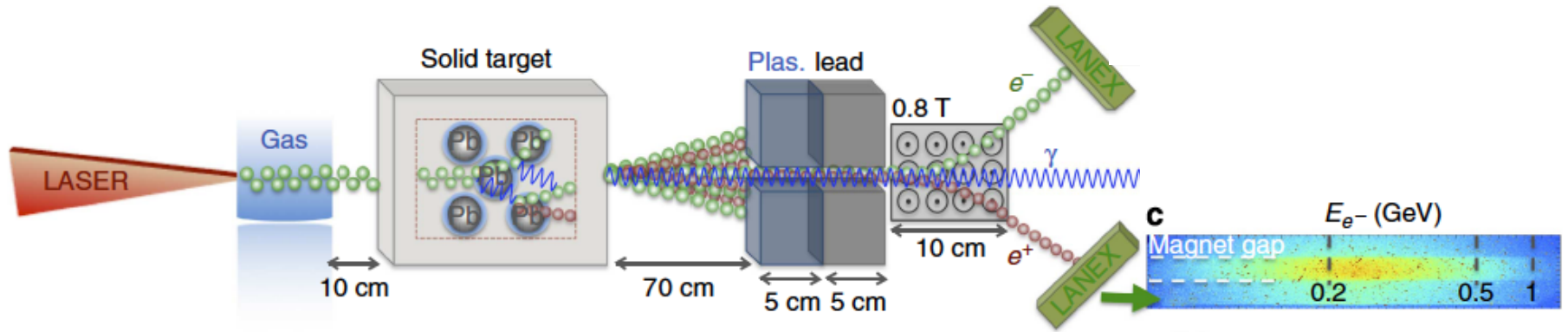


- Overall positron yield: 3×10^7
- Overall lepton yield: 3×10^8
- Positron density: $2 \times 10^{14} \text{ cm}^{-3}$
- Lepton density: $2 \times 10^{15} \text{ cm}^{-3}$
- Normalised emittance: $30 \pi \text{ mm mrad}$
- Divergence: 3 mrad

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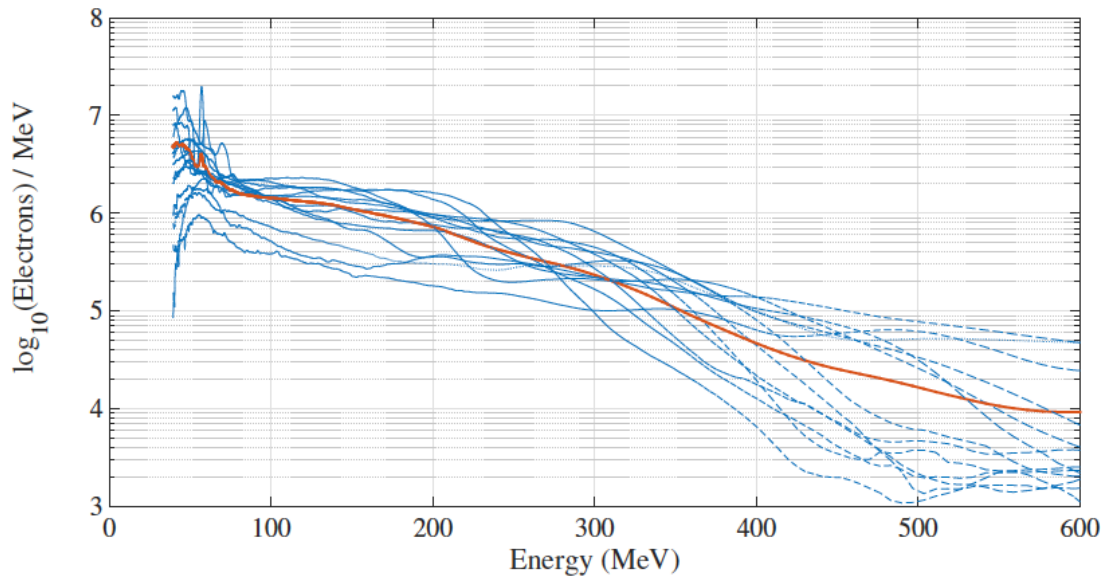
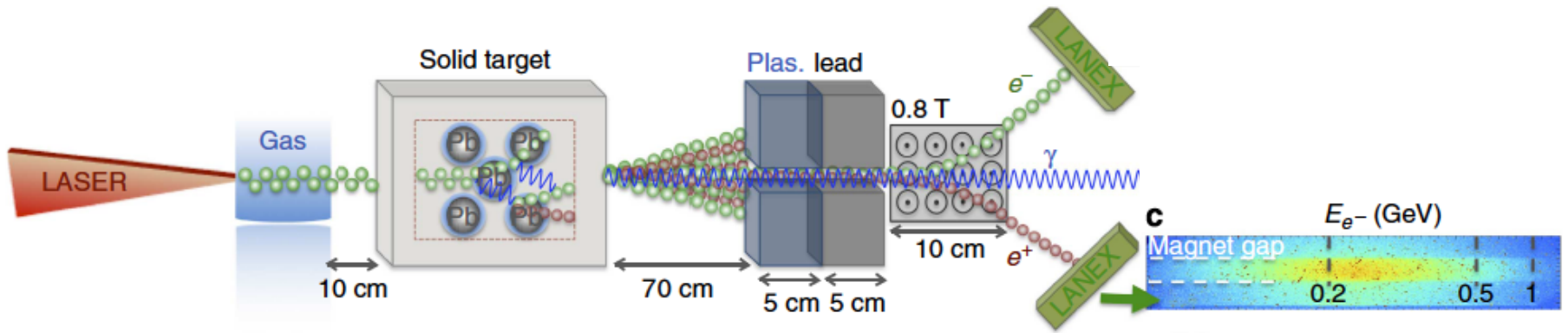


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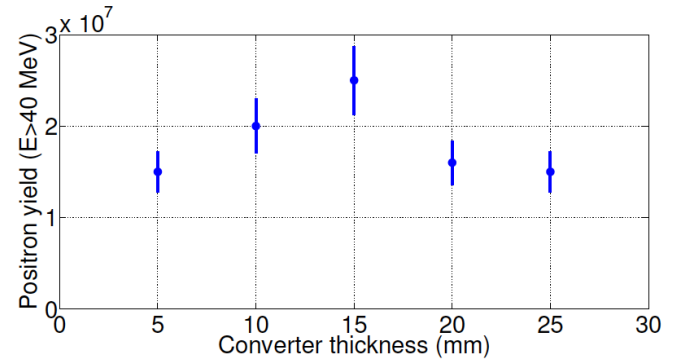
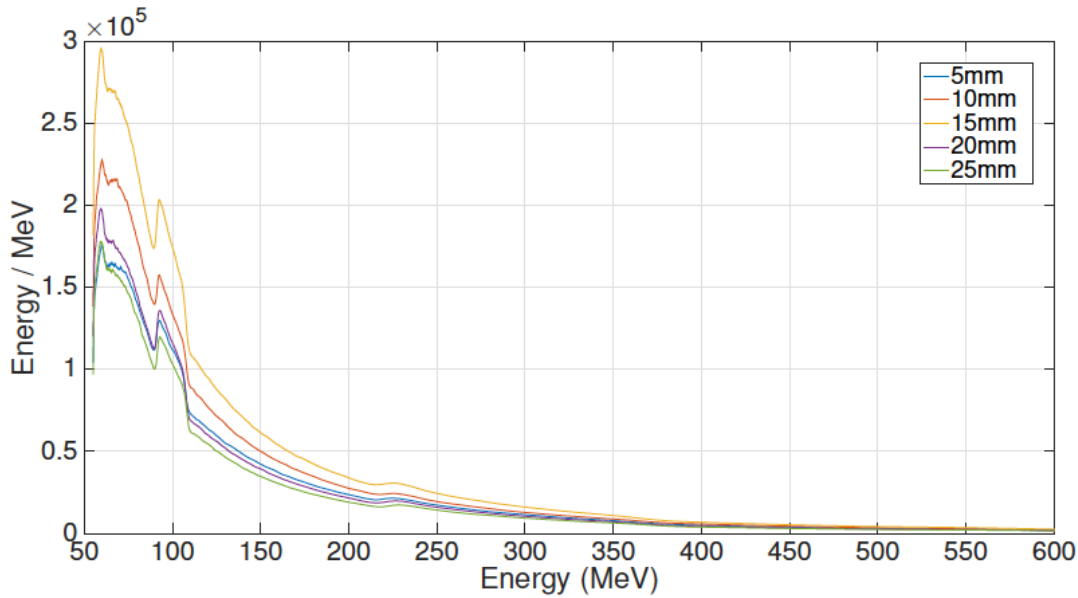
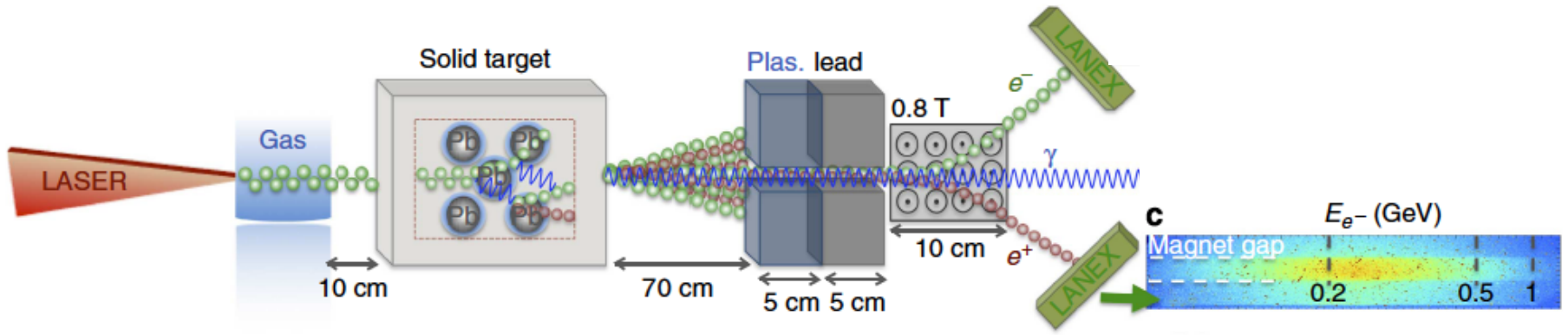
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Nature Communications
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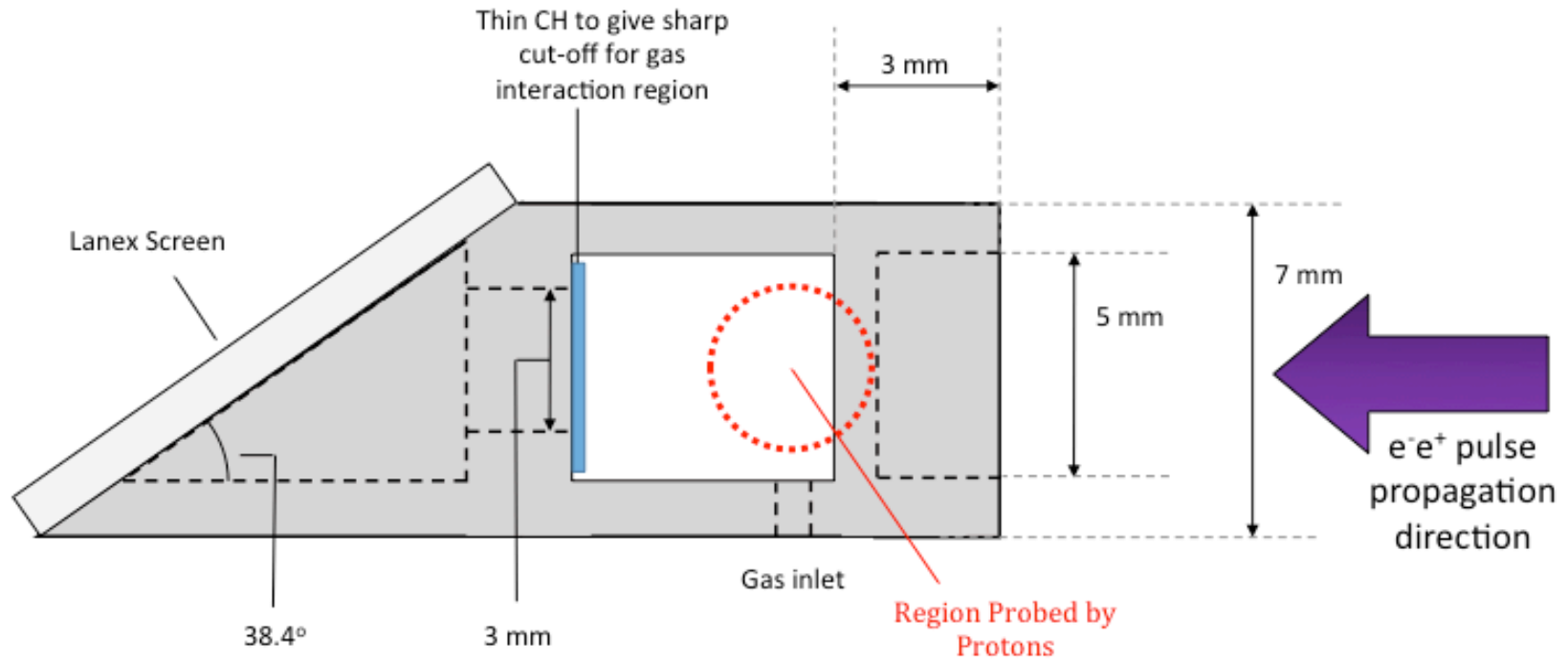
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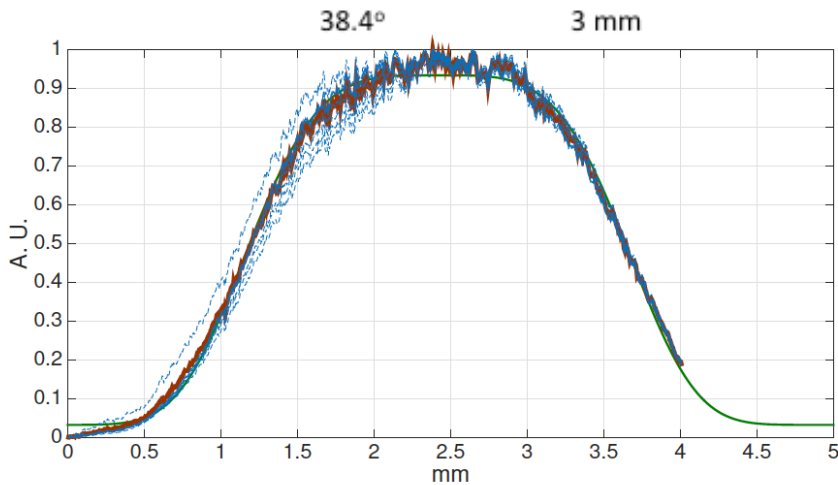
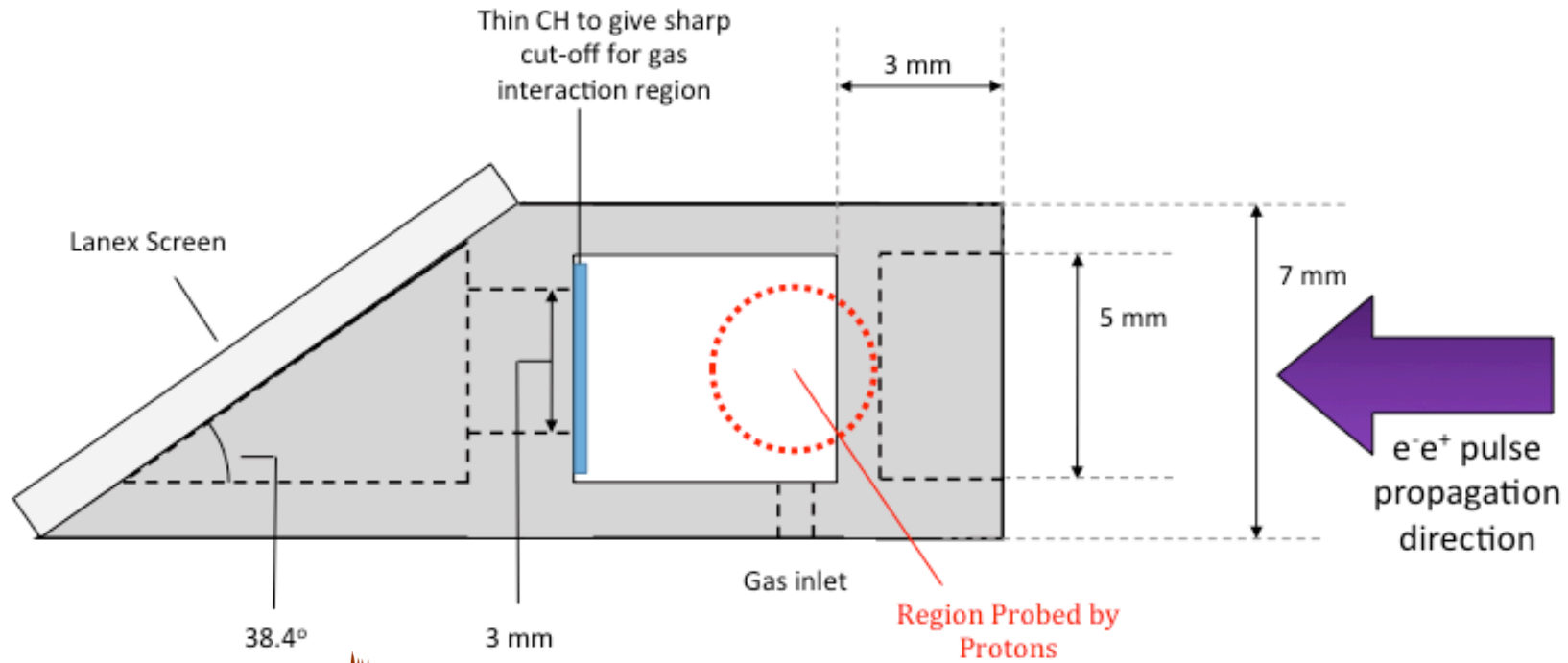
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G. Sarri *et al.*, PPCF accepted (2016)

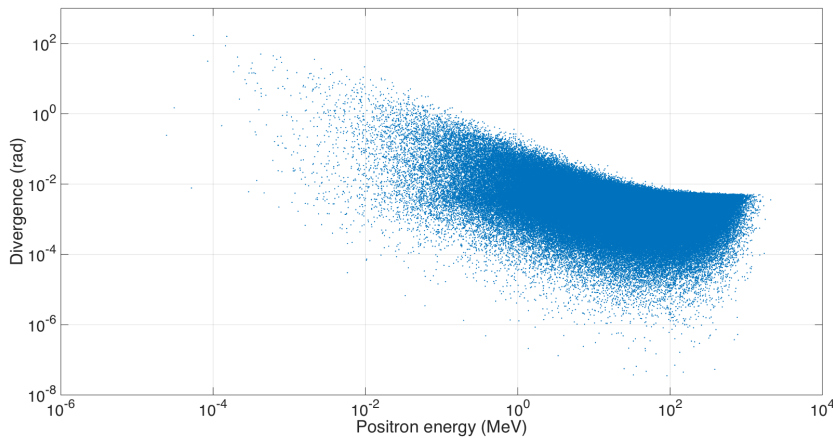
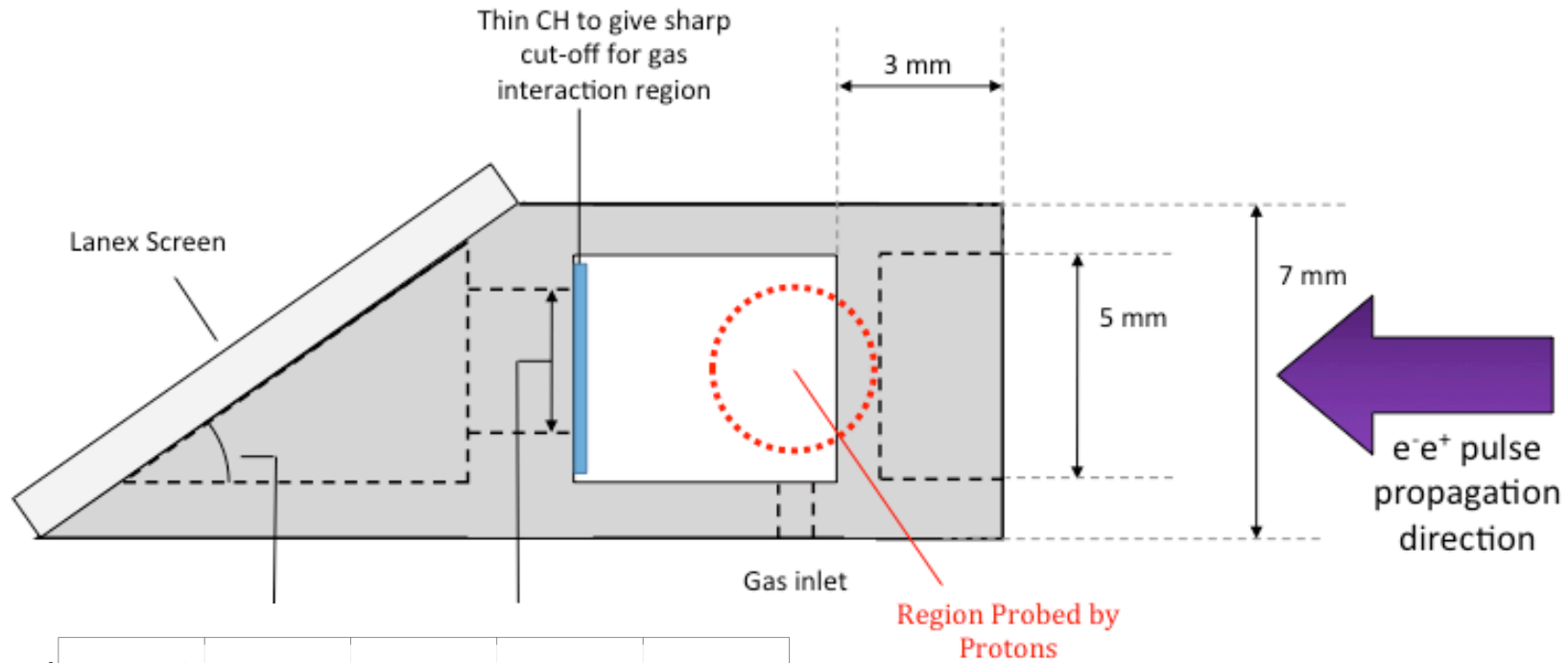
Beam profile





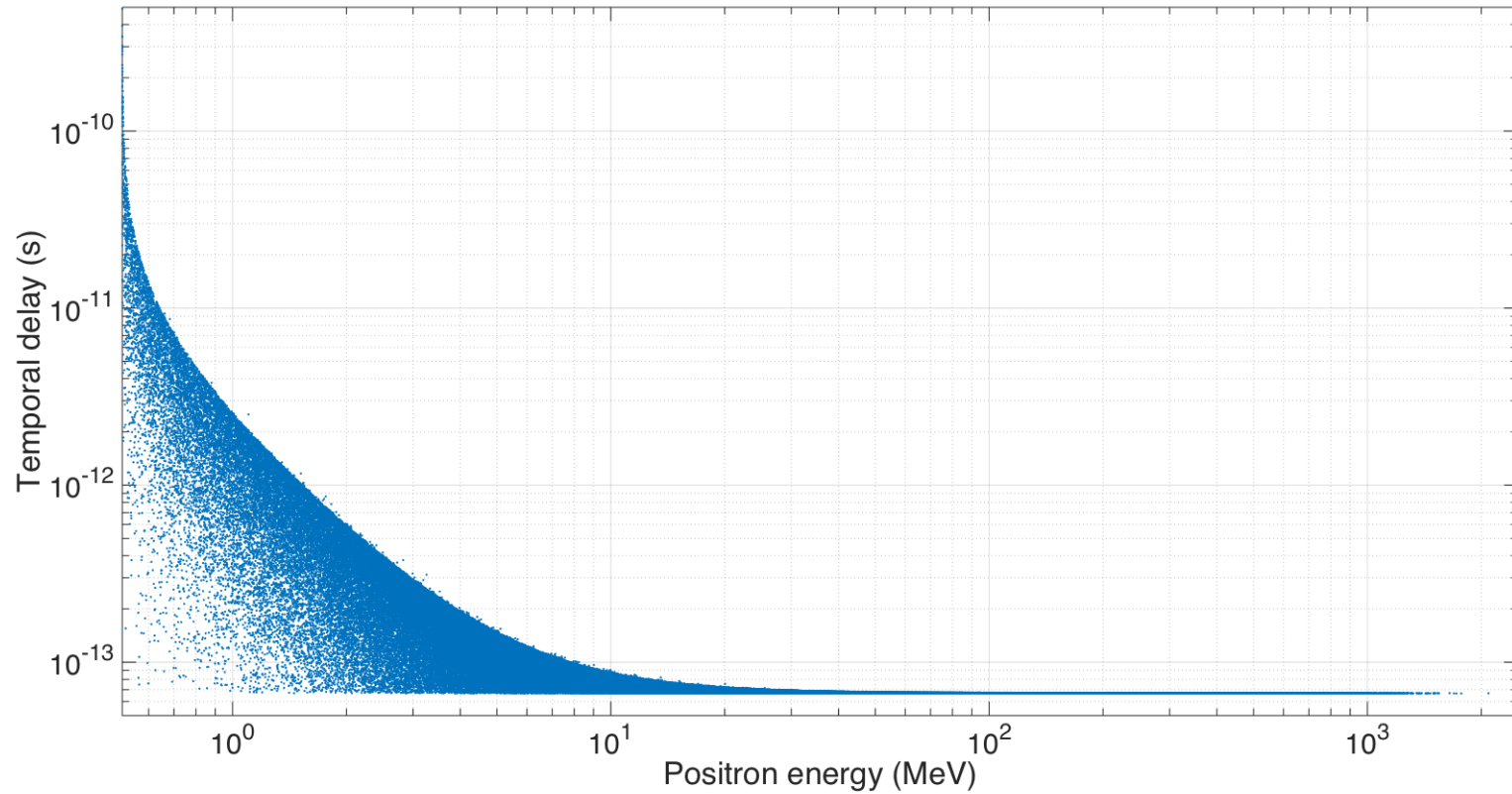
- ✓ Smooth profile after subtraction of γ -ray signal.
- ✓ Stable over a significant number of shots
- ✓ Consistent with an average Lorentz factor of 17

G. Sarri et al., PPCF accepted (2016).



- ✓ Energy-dependent divergence
- ✓ ~ 50 mrad at 5 MeV, ~ 10 mrad at 100 MeV

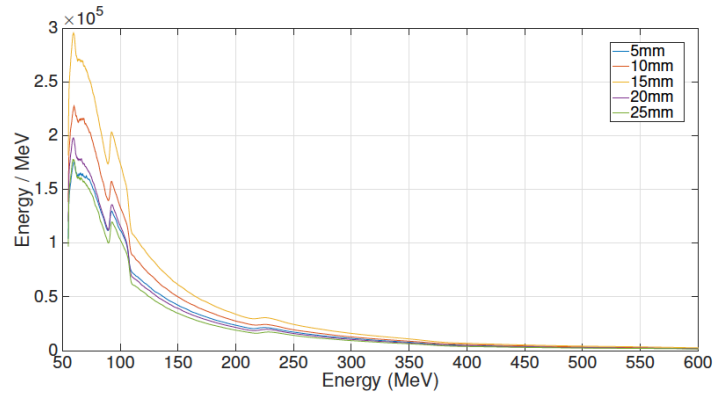
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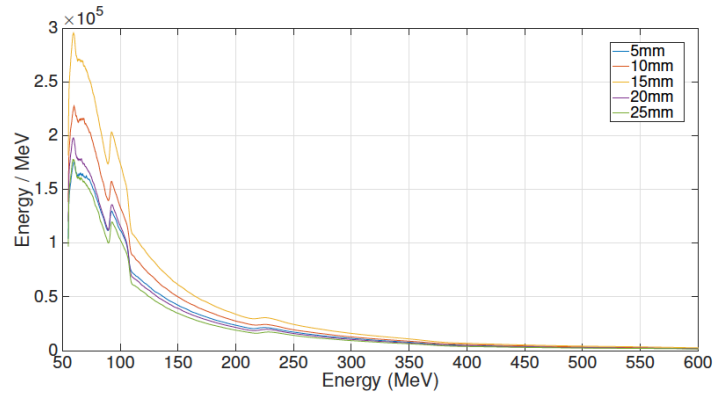
G. Sarri et al., unpublished (2016).

Conclusions and Outlook

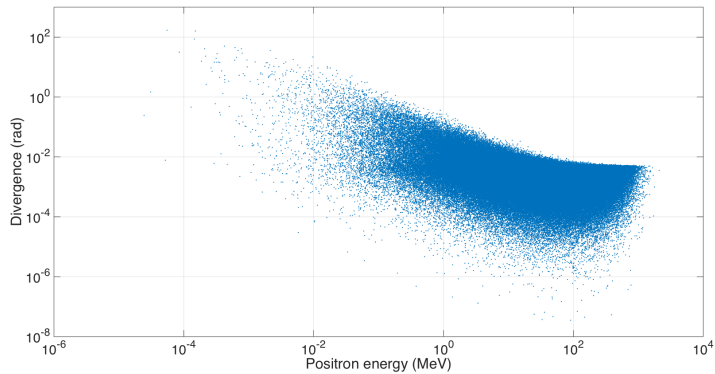
- High – energy positron beam in a **compact setup**



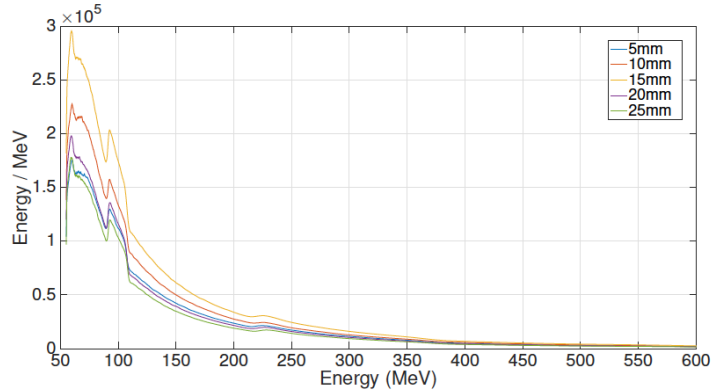
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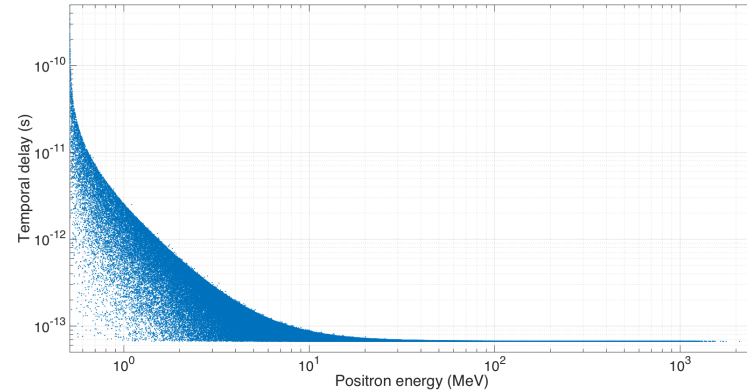
- Small divergence and source size



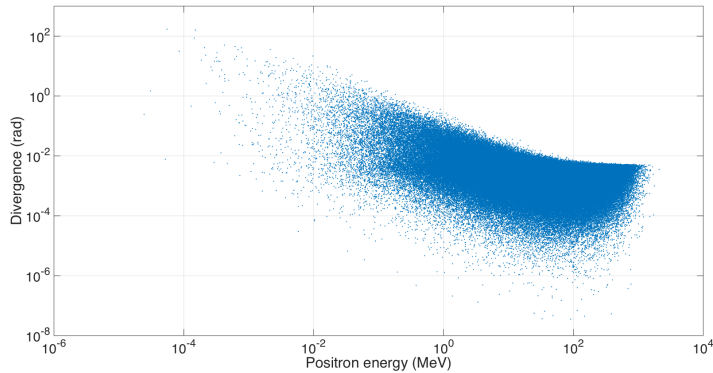
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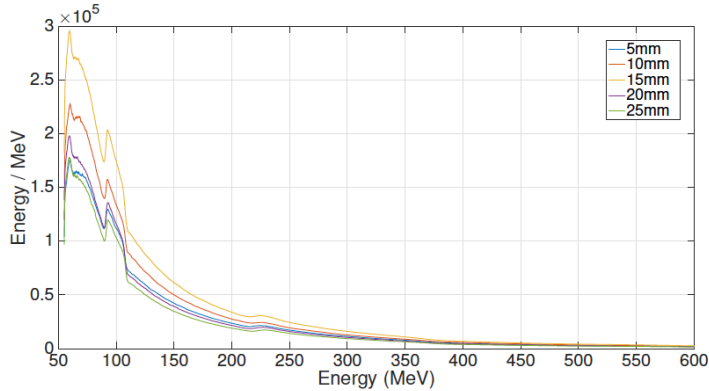
- Short duration



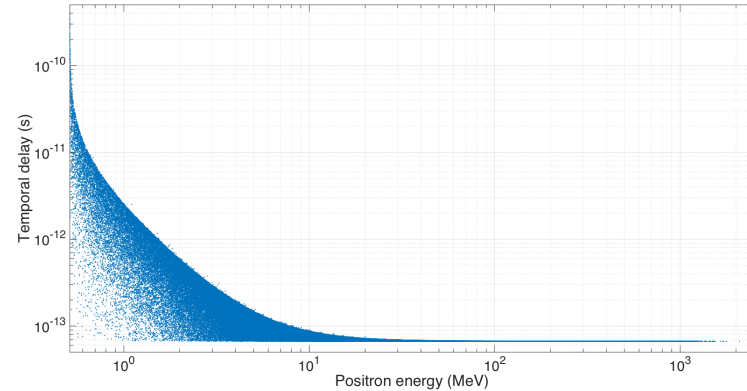
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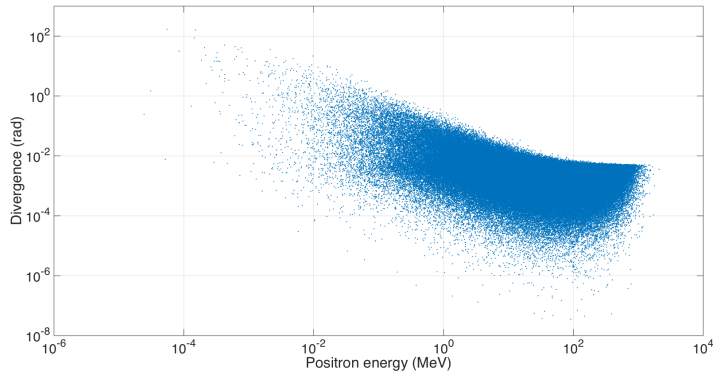
- High – energy positron beam in a **compact setup**



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- Luminosity and emittance

- **beam duration:** ~ 100 fs ($E > 10$ MeV)
- **positron current:** ~ 0.8 kA
- **emittance at 90 MeV:** $\sim (2.5 \pm 0.6) \pi$ mm mrad
(emittance in the LEP injector $\sim 5.5 \pi$ mm mrad)
- **luminosity @ 10 Hz:** $\sim 10^{24}$ cm $^{-2}$ s $^{-1}$
(luminosity required $\sim 10^{31}$ cm $^{-2}$ s $^{-1}$)

Thanks for your attention!

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