EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

WP7: New results on positrons

Implications for EuPRAXIA

Gianluca Sarri, A. Alejo, J. Warwick, G. Samarin, M. Cunningham, C. McCluskey
Queen's University Belfast, UK
g.sarri@qub.ac.uk

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Introduction

Three main ***representative*** applications have been identified for Eupraxia:

1. Betatron-based x-ray source for imaging (UK co-ordinator: **Z. Najmudin**)
2. Compton-based γ-ray source for industrial applications and high-field QED (UK co-ordinators: **C. Murphy and S. P. D. Mangles**)
3. Low-energy and high-energy positron beam-lines (UK co-ordinator: **G. Sarri**)

e^- requirements
high-charge (~nC?)
wider divergence ok!
large bandwidth ok!
Other applications?

Low-energy positron beam-line

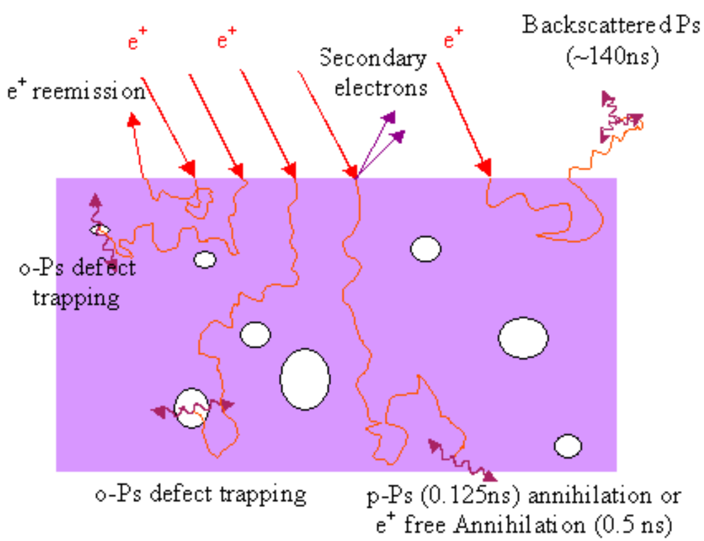
Energy:	tuneable from 0.5 to 5 MeV
Bandwidth:	100 keV
Charge/s:	tens of pC ($>10^8$ e^+)
Duration:	10s of ps
Emittance:	~ mm mrad

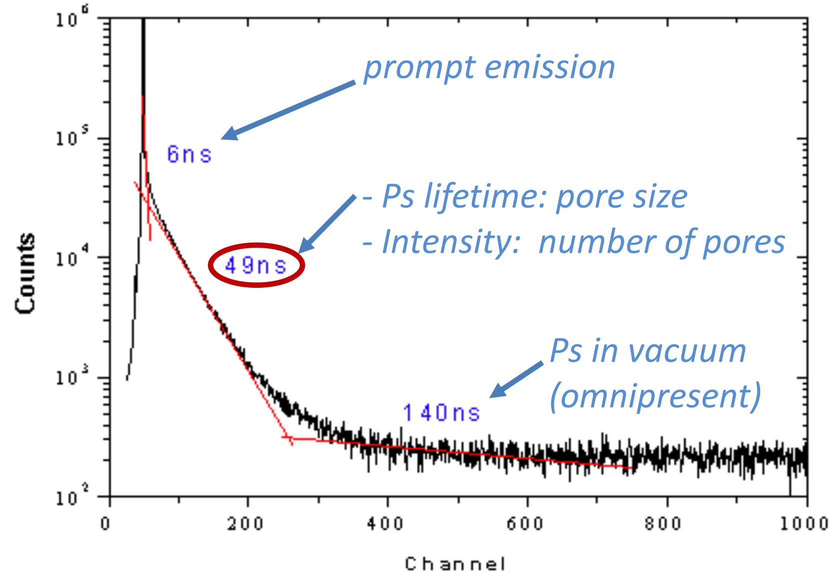
High-energy positron beam-line

Energy:	1 GeV
Bandwidth:	5%
Charge/beam:	~ 10 pC ($\sim10^8$ e^+)
Duration:	10 fs
Emittance:	0.2 mm mrad

Low - energy positrons

A high-charge source of low-energy positrons is particularly useful for volumetric, high-resolution inspection of materials (**PALS**: **P**ositron **A**nnihilation **L**ifetime **S**pectroscopy)





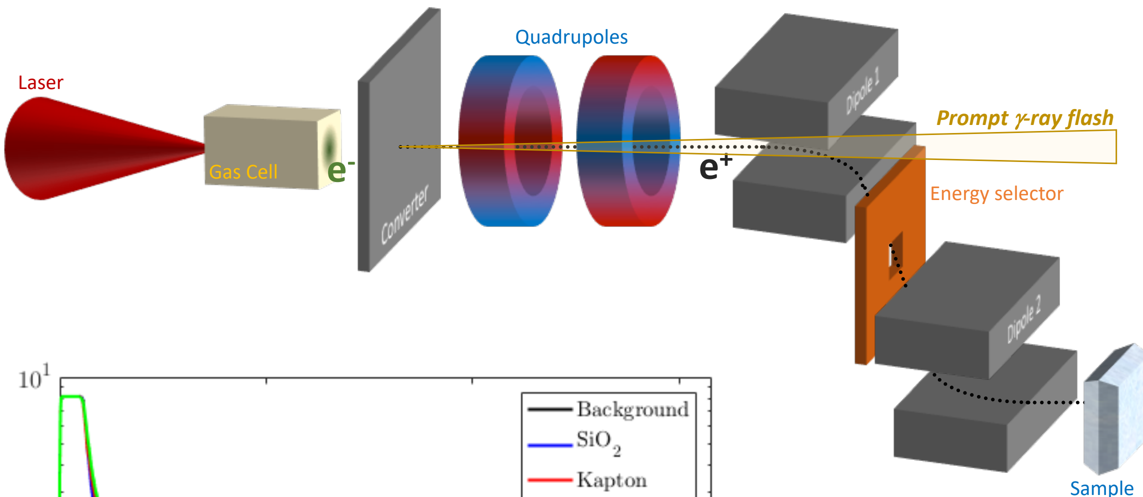
Currently done with β^+ decay radioactive sources:

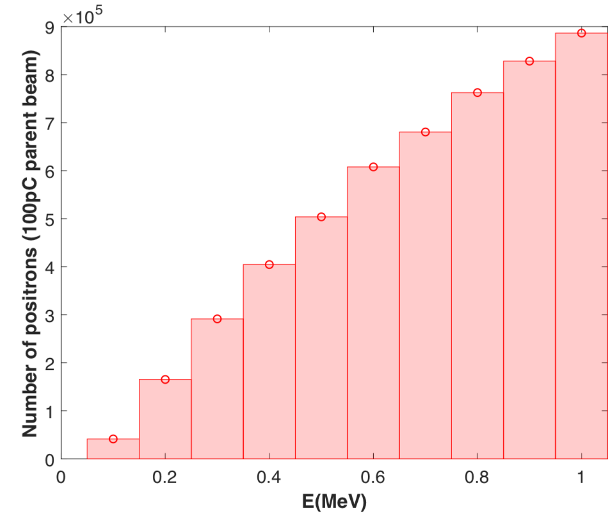
- X Fixed and relatively low e^+ energy
- X Long e^+ duration (> ns)
- X Continuous source

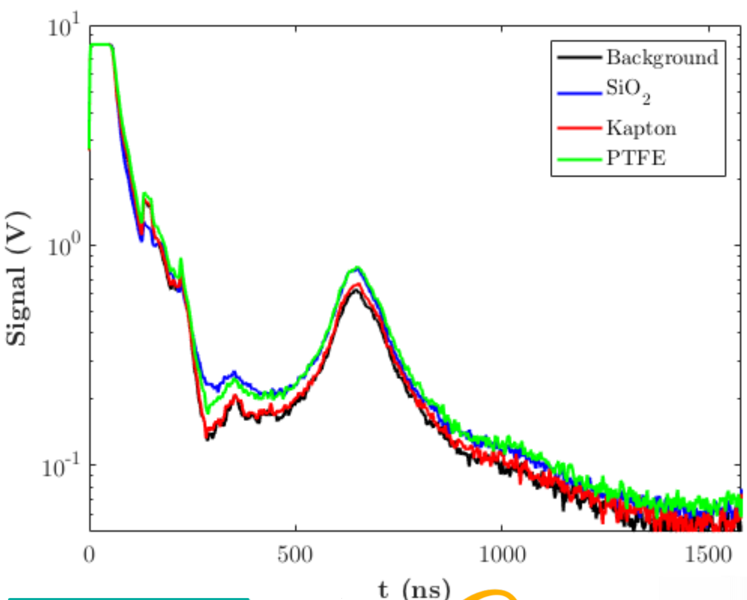
Laser-driven sources can provide a tuneable source of positrons with 10s of ps duration

Low - energy positrons

METHOD 1: *Irradiation of solid targets with laser-wakefield accelerated electron beams*







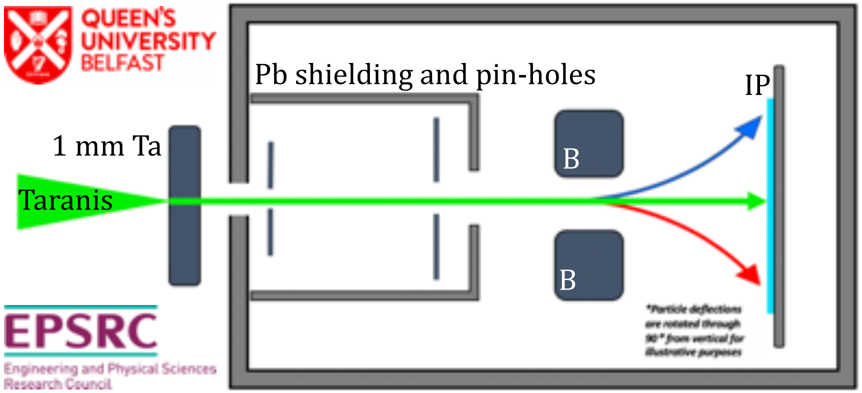
For a 100 pC, 5 GeV electron beam operating at 100 Hz we expect approximately **10^8 e$^+$/s at (1.0±0.1) MeV**

Weak dependence on electron beam energy. Similar positron yield for a 1 GeV electron beam

- X Broad divergence
- X Broad spectrum ➔ necessity of energy selection
- X High background noise

Low - energy positrons

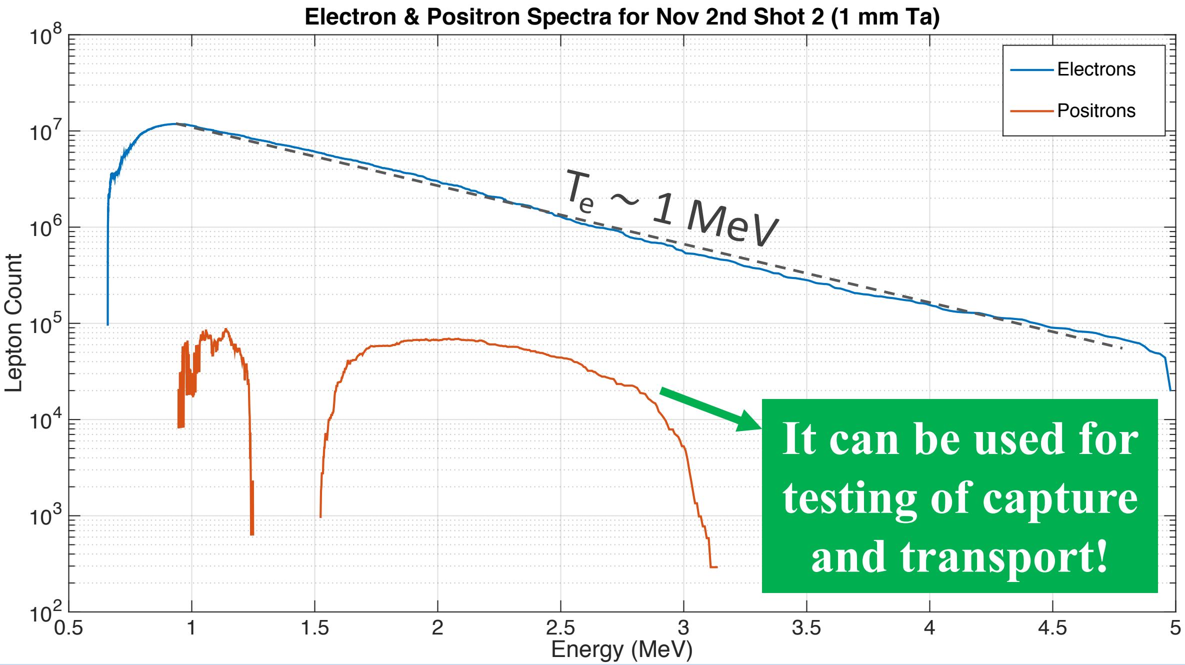
METHOD 2: *Direct laser irradiation of solid targets*



Experiments using the **TARANIS laser at QUB**

Laser

- E = (9.5 ± 0.4) J
- τ = (750 ±100) fs
- σ = 7 μm
- I = 2x10^{19} Wcm^{-2}



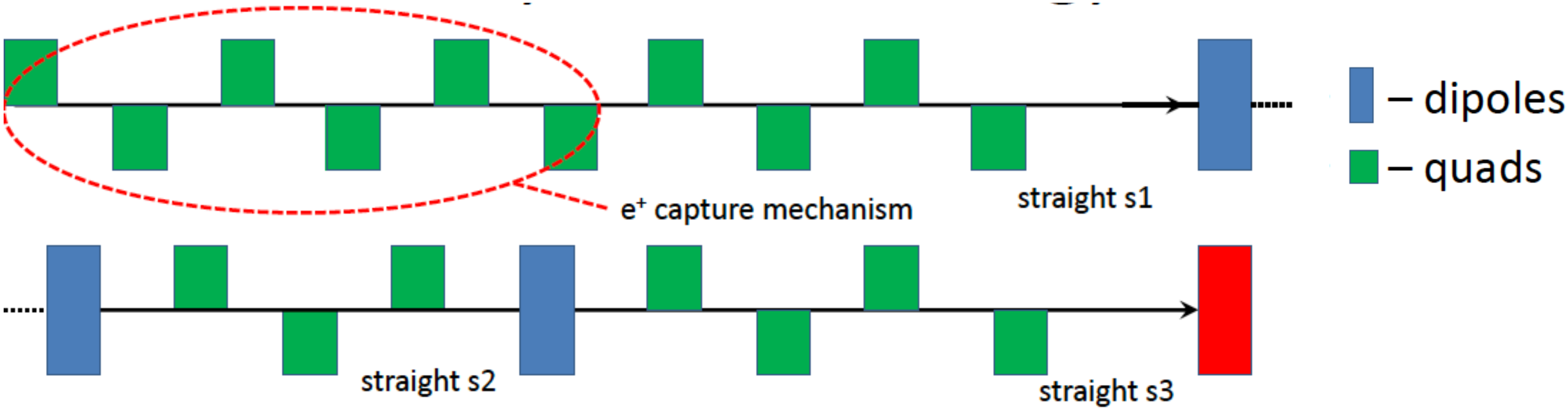
Electrons

- Conv. efficiency: ~ 10%
- Temperature: 1 MeV (JxB)
- e^- /sr/MeV: ~10^{11}

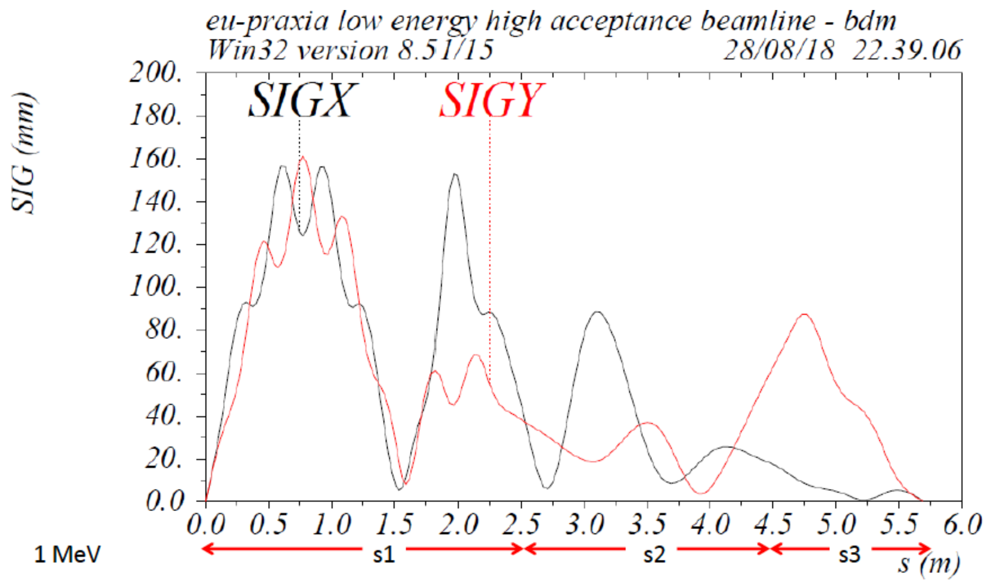
Positrons

- Max energy: ~ 3 MeV
- Duration: ~ ps
- e^+ /sr/MeV: ~ 3x10^8
- e^+ /sr/100keV BW: ~ 10^7

Low - energy e^+ beamline

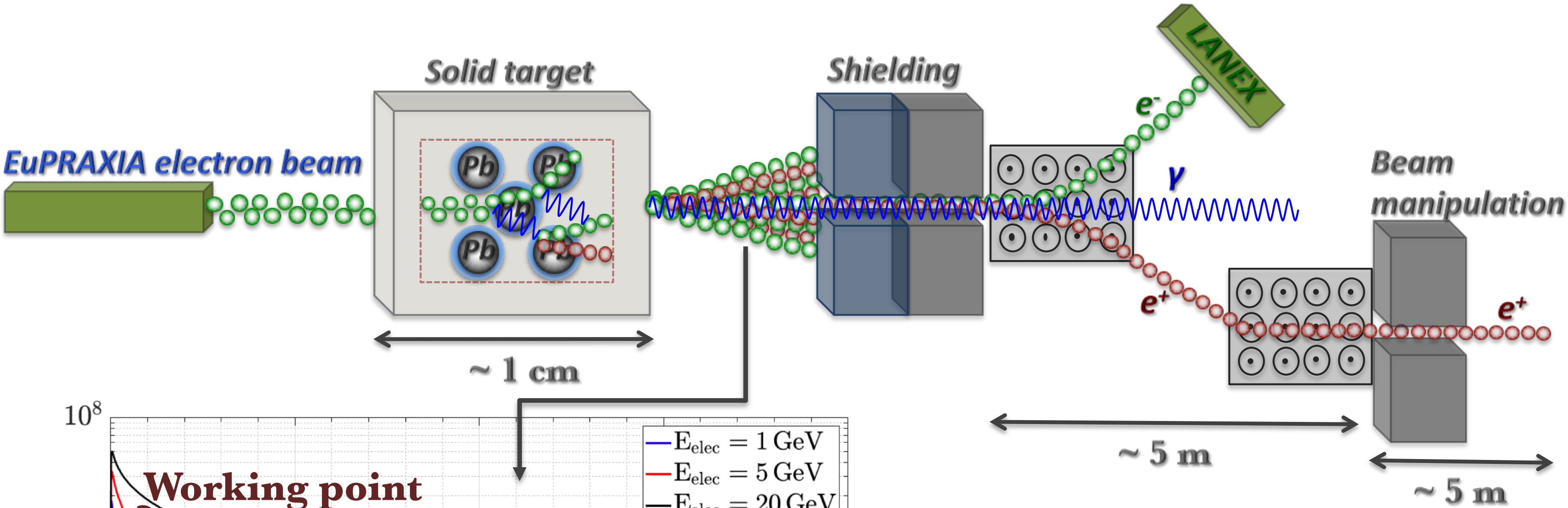


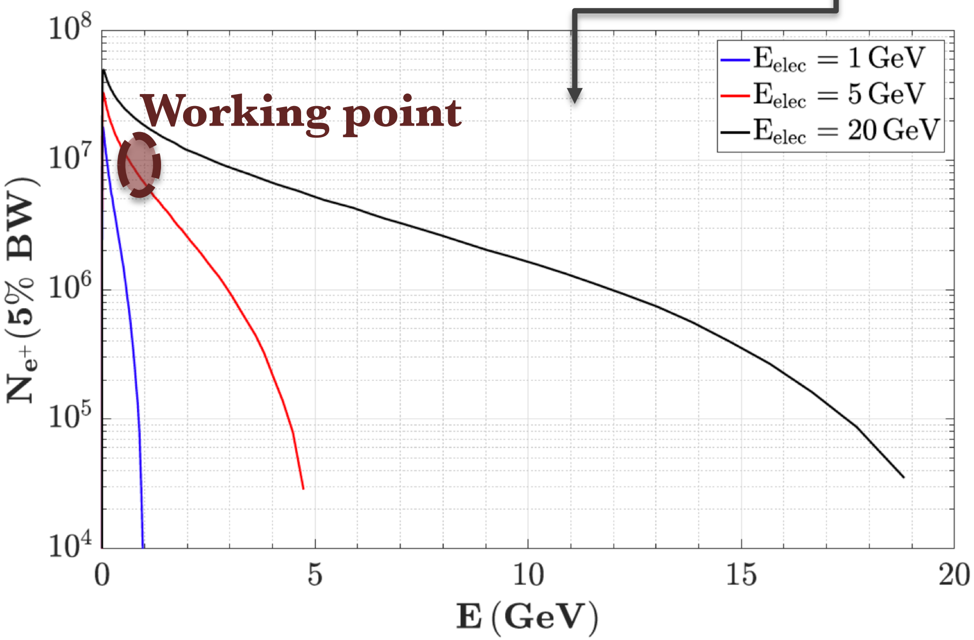
Work by Bruno Muratori and Jim Clarke, ASTeC, see talk by Jim Clarke on Tuesday at 16:30!



- 6 m of beam-line
- Beam size ~ 1-10 mm
- divergence ~ 20 mrad
- Duration at 1.0±0.1 MeV ~ 200 ps
- Assuming 100 Hz ~ $10^7 – 10^8$ e^+/s (comparable with LWFA case)

High energy positrons





A. Alejo et al., submitted (2018) Arxiv:1806.02633

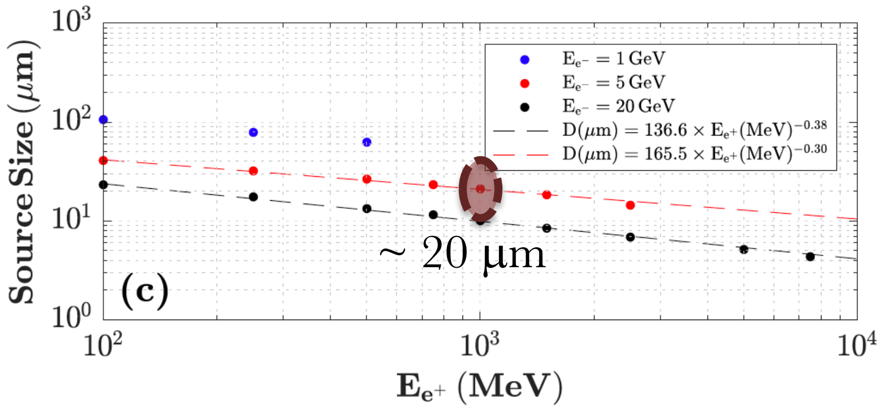
Assuming 100 pC at 5 GeV (5%)

- 10^7 positrons at 1 GeV (5%)
- Source size: **~ 10 micron**
- Divergence: **~ mrad**
- Duration: **few fs**
- Emittance: **< micron**
- Rep. rate: **0.1 – 1 kHz**
- Positrons/s: **10^9 – 10^{10}**

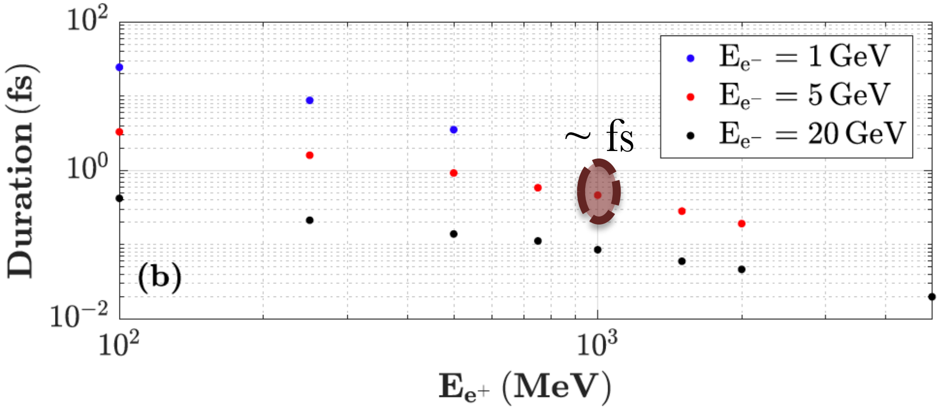
10^8 for 1 nC broadband electron beam

High energy positrons

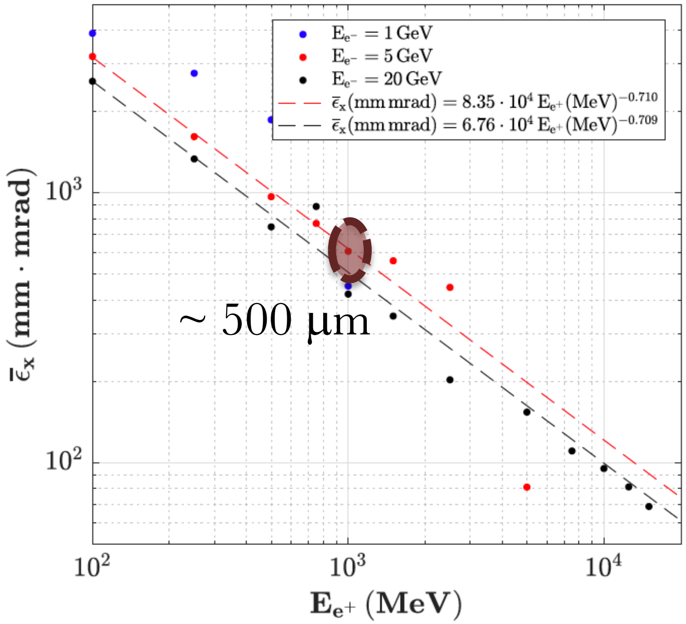
Source size



Duration at source



Normalised emittance



	Units	FACET-I	FACET-II	LWFA
E	GeV	21	10	1
P	W	7.4	9.6	3
Q_e	pC	350	500	2
σ_x	µm	30	4	10
σ_y	µm	30	4	10
σ_z	µm	50	6.4	0.6
ϵ_x^*	mm mrad	200	7	500
ϵ_y^*	mm mrad	50	3	500
ΔE	%	1.5	1	5
f	Hz	1	1	$10 - 10^3$
ℓ	$cm^{-2}s^{-1}$	5×10^{23}	6×10^{25}	10^{22-24}

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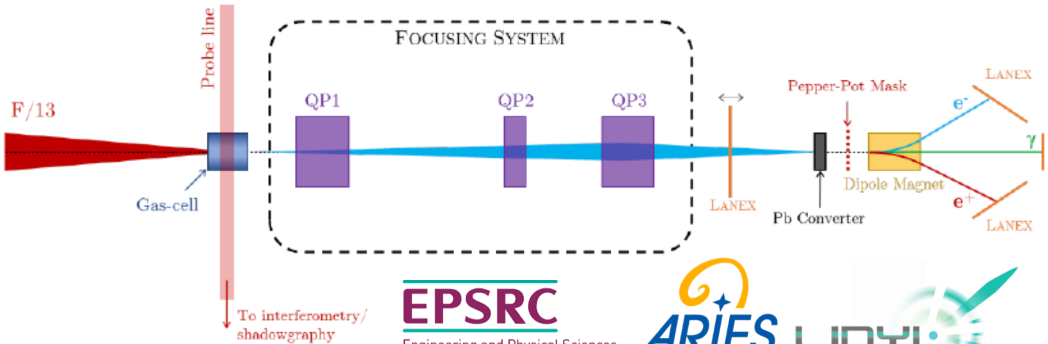
High energy positrons



EPSRC Engineering and Physical Sciences Research Council

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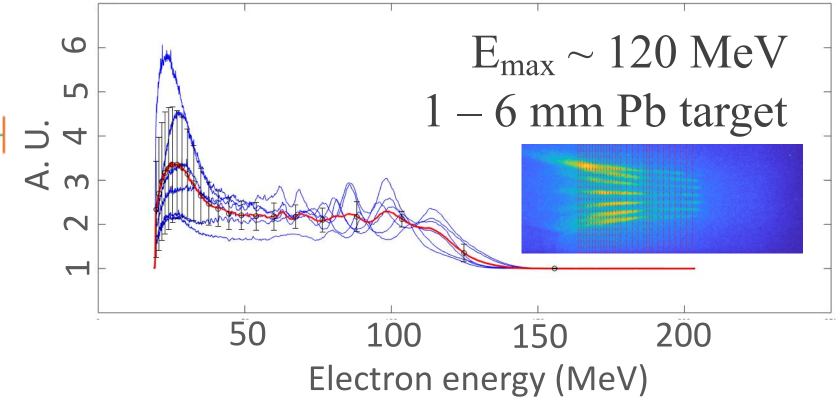
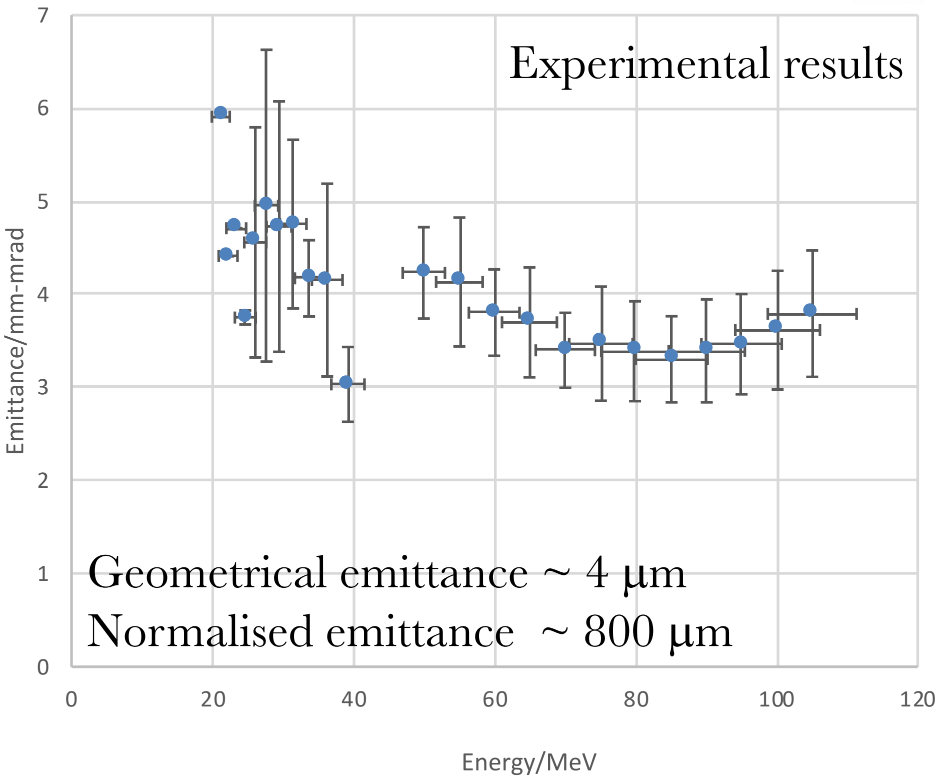
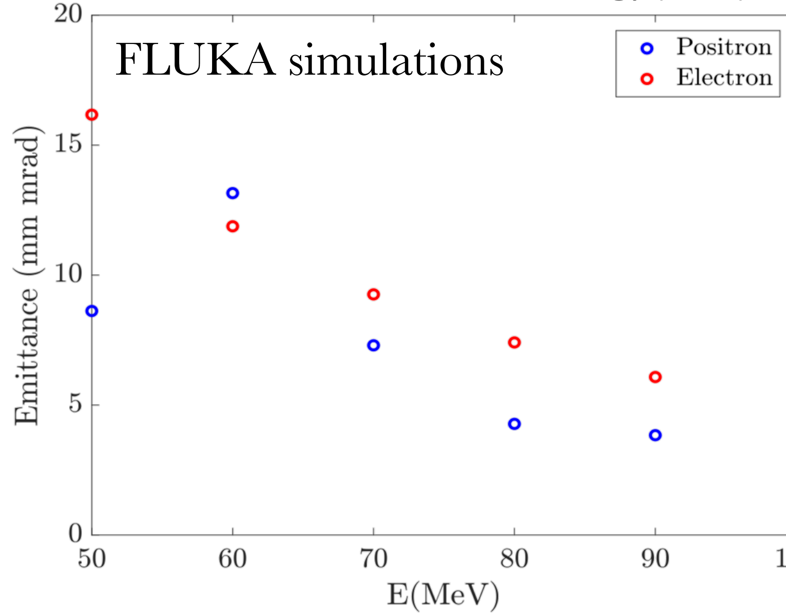
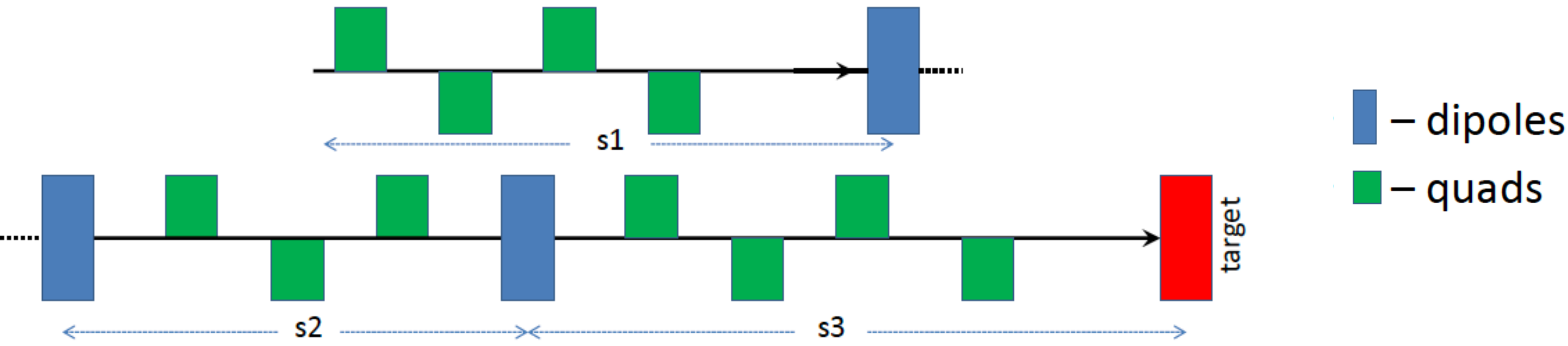






We can use online electron diagnostics to infer the positron beam characteristics

High energy e^+ beamline



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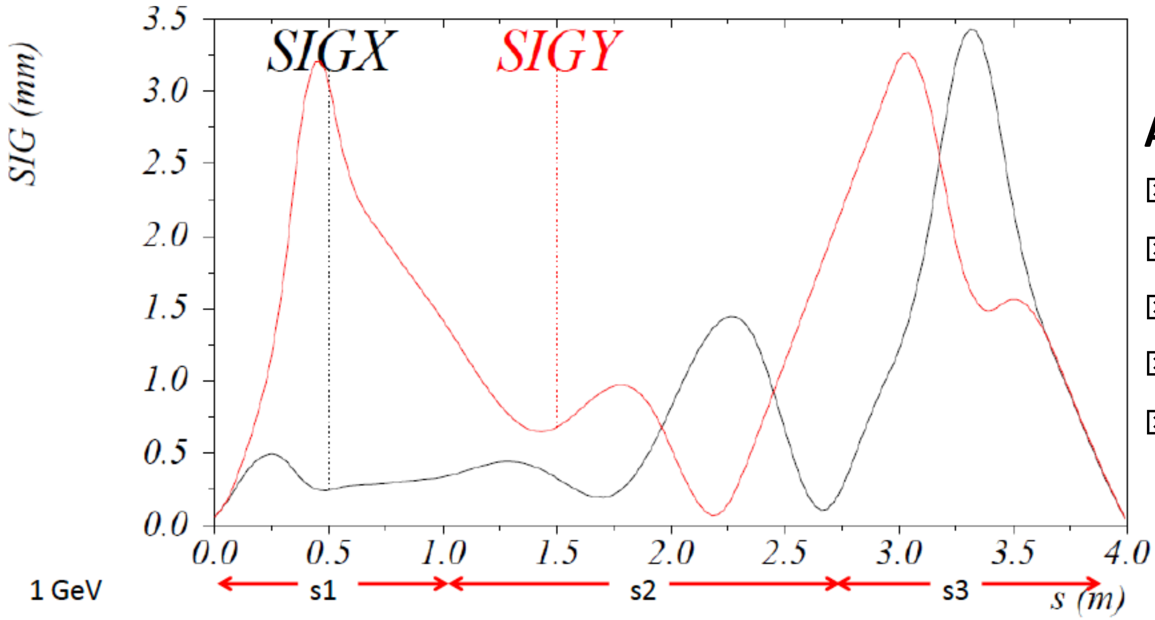

Assuming 1nC, 5 GeV e^- beam

- 4 m of beam-line
- Beam size ~ 50 μm
- divergence ~ 2 mrad
- Duration at 1.0±0.1 GeV ~ 10s fs
- ~ 10^7 e^+ at 1 GeV per laser shot

Conclusions

High-energy positron beam-line

FLUKA simulations indicate, for a 1nC 5GeV broadband electron beam, the following parameters at source for 1 GeV ±5% energy:

- Source size: 15 μm
- Divergence: 10 mrad
- Duration: 5-10 fs
- Charge: 20 pC
- Normalised emittance: 150 π mm mrad

Emittance and source size measured at 100 MeV. Necessity to repeat at ~ GeV

Collaborators at ASTeC are designing a beam transport and manipulation line that would guarantee, within 4m, the required bandwidth in a 50 μm beam with a 2 mrad divergence

Low-energy positron beam-line

Experiments carried out using TARANIS (QUB) indicate that, potentially, direct laser irradiation of solids is the preferred way

- Energy range: 0.5 – 3 MeV
- Number: ~ 10^7 e^+ /sr/100keV BW
- Duration: ~ ps

We can start testing elements of the transport line using TARANIS at QUB

Collaborators at ASTeC are designing a beam transport and manipulation line that would guarantee, within 6m, the required bandwidth in a ~ mm beam with a 20 mrad divergence

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Thanks for your attention!

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