Linearly polarised photons and determining the polarisation degree

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Outline

Motivation - N^* programme

N^* programme reliant on linear polarisation.

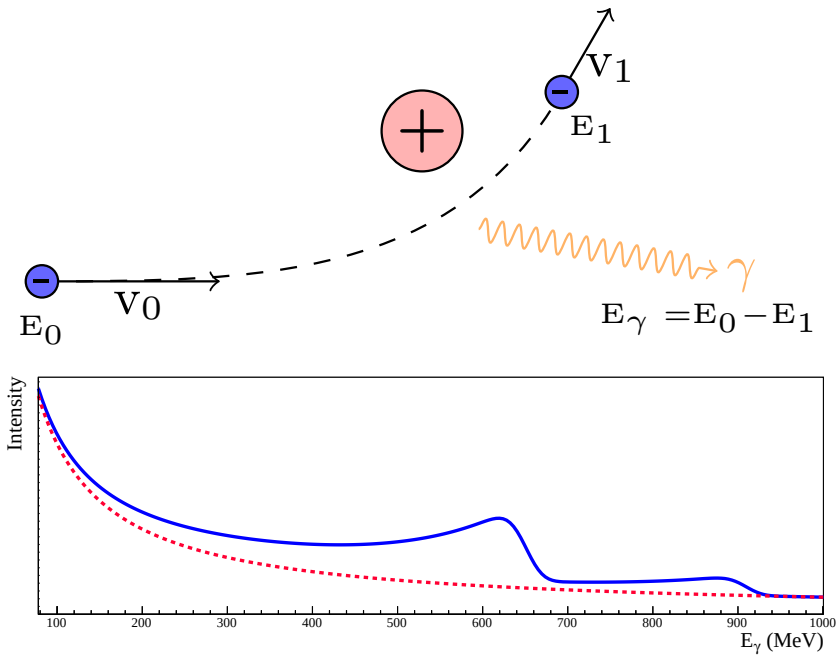
Beam		Target			Recoil			Target + Recoil			
					x'	y'	z'	x'	x'	z'	z'
		x	y	z				x	z	x	z
Unpol	σ_0		T			P		$T_{x'}$	$L_{x'}$	$T_{z'}$	$L_{z'}$
Linear	Σ	H	P	G	$O_{x'}$	T	$O_{z'}$				
Circular		F		E	$C_{x'}$		$C_{z'}$				

Motivation - Selection of Measurements

Experiment	Reaction	Obs	Energy	Syst Error	Method	Year
Yerevan	$p\gamma \rightarrow p\pi^0$	Σ	$0.5 \rightarrow 1.1 GeV$	3.2%	ANB	2001
Max III	$^{12}C(,p)^{11}B$	Σ	$40 \rightarrow 50 MeV$	5%	ANB	2016
Clas	$p\gamma \rightarrow p\pi^0$	Σ	$1.1 \rightarrow 1.8 GeV$	4%	Brems Fit	2013
CBELSA	$p\gamma \rightarrow p\pi^0$	G	$0.6 \rightarrow 1.3 GeV$	2.7%	ANB	2017
A2	$p\gamma \rightarrow p\pi^0$	Σ	$320 \rightarrow 650 MeV$	3%	Brems Fit	2016
GlueX	$p\gamma \rightarrow p\pi^0$	Σ	$8.1 \rightarrow 9.0 GeV$	1.5%	Triplet Pol	2017

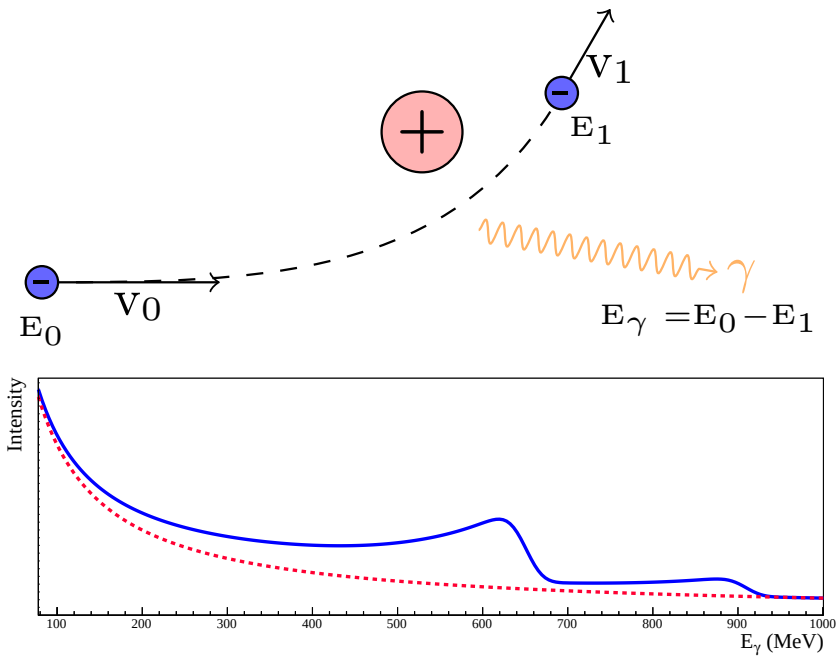
Outline

Generation of Coherent Bremsstrahlung



Generated using diamond radiator.
Cover full range beam energy.
Understood but complex polarisation energy dependence.

Generation of Coherent Bremsstrahlung



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Cover full range beam energy.
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[022,044...] primary contributions.
Other vectors angled to not overlap with region.
http://nuclear.gla.ac.uk/ kl/GlueX/cbremscans/scan.gif

Outline

Coherent Bremsstrahlung Fit

Currently widely used in most labs.

Pros:

Information provided by the photon tagger.

Polarisation over whole tagged photon energy range.

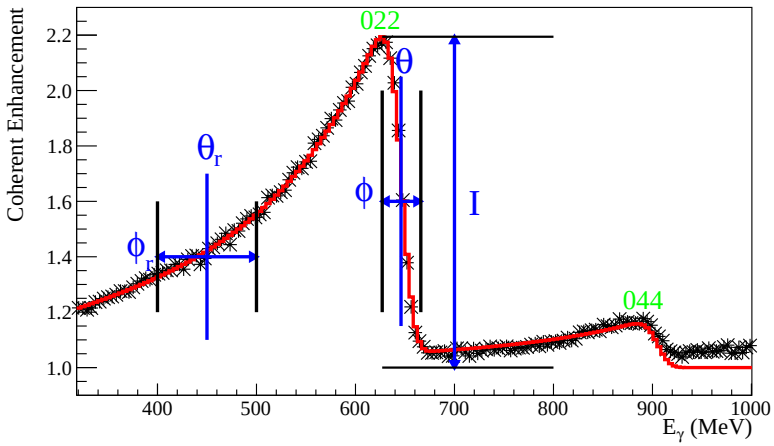
Cons:

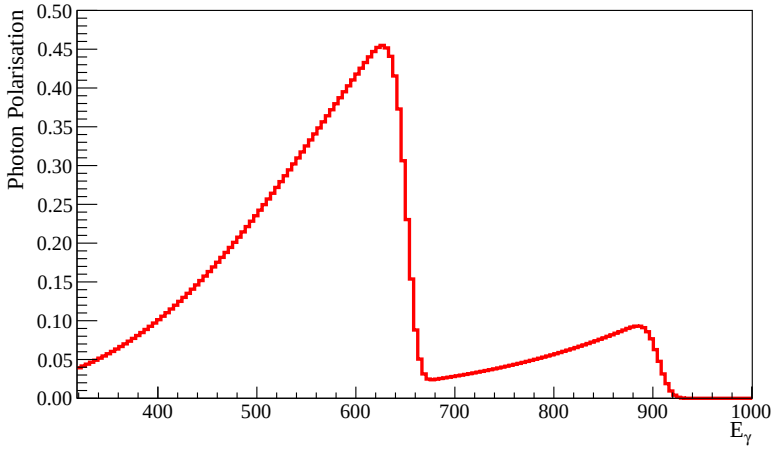
Very sensitive to orientation of diamond lattice.

Indirect measurement.

Requires runs with amorphous radiator.

Parameters can vary with the same χ^2; giving an uncertainty on the polarisation of about 5%.





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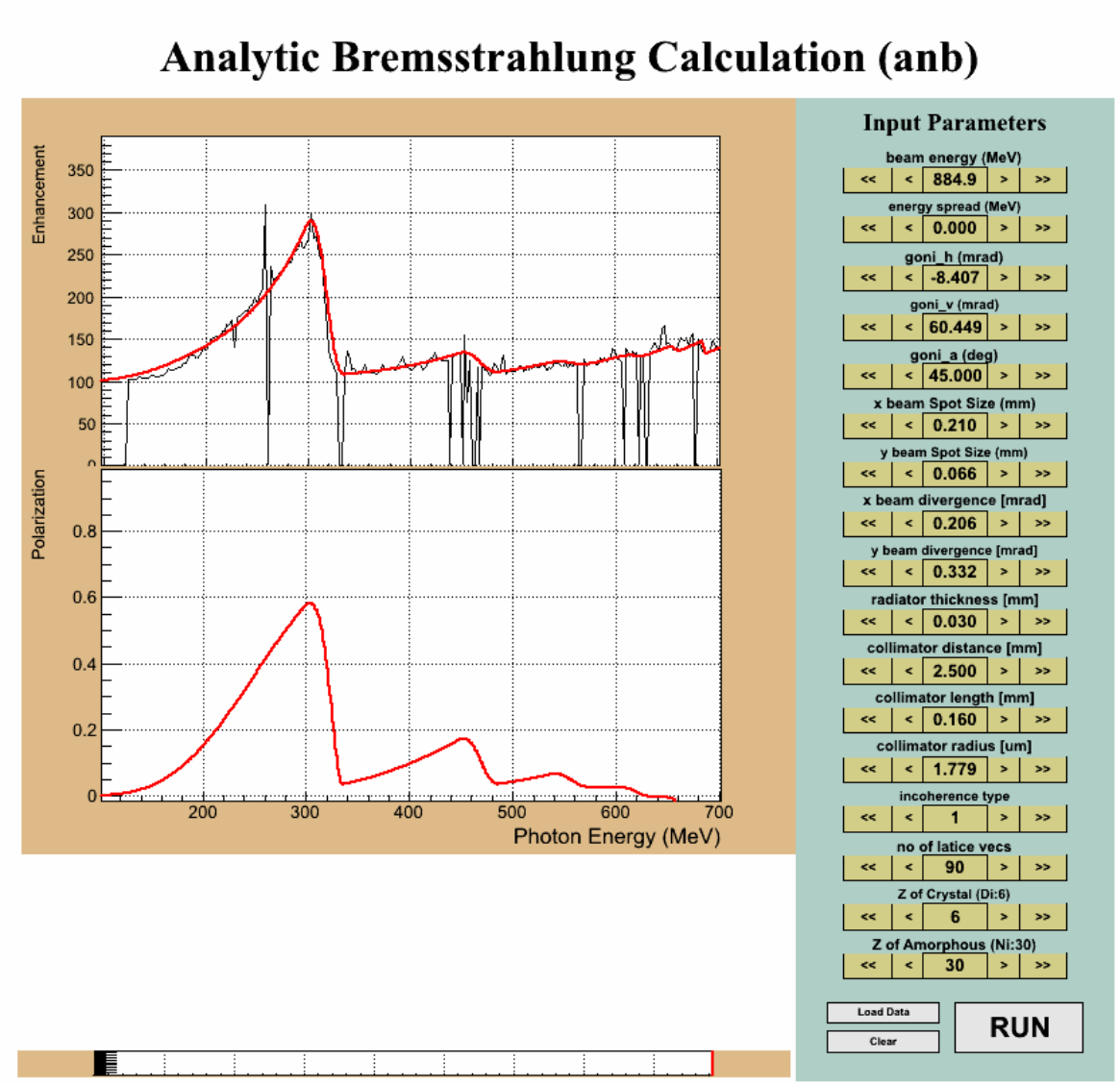


Outline

Nuclear Physics Reaction

Examples:
Coherent π^0 production off spin 0 nucleus (^4He,^{12}C,^{208}Pb)
ρ meson production.
π^0 production.
Pros:
Can use standard experimental detectors.
Direct continuous post collimation measurement.
Cons:
Precise measurement previously made.
Inherit systematic uncertainty.
Essential to confidently separate background channels.
Only valid for specific targets or secondary target needs to be added.

Outline

Pair and Triplet Production

Pros:

Electromagnetic processes described precisely by theory.

Direct continuous post collimation measurement.

No significant background reactions.

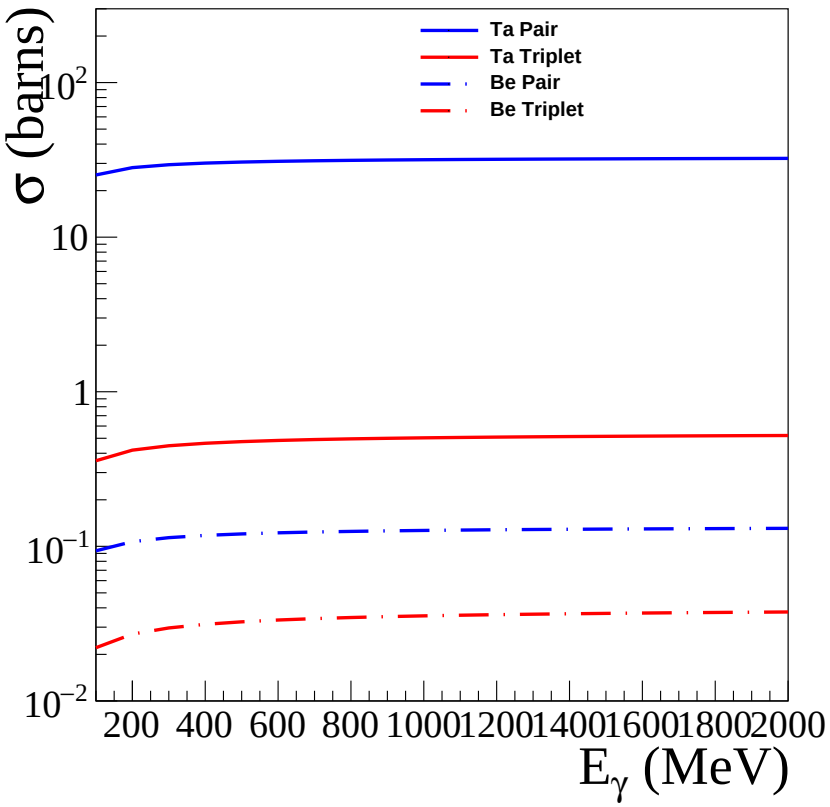
Cons:

Low count rates.

Requires designated additional detector.

Lower energy coverage

Pair and Triplet Production



[NIST Database]

Pair Production

Photon Conversion in nuclear field.

$\gamma + N \rightarrow e^+ + e^- + N$

Higher reaction cross section.

Lower analysing power.

Triplet Production

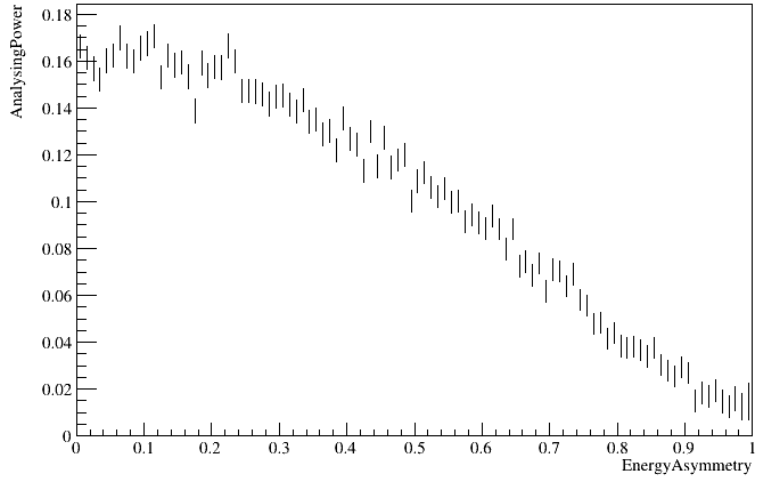
Photon Conversion in electron field.

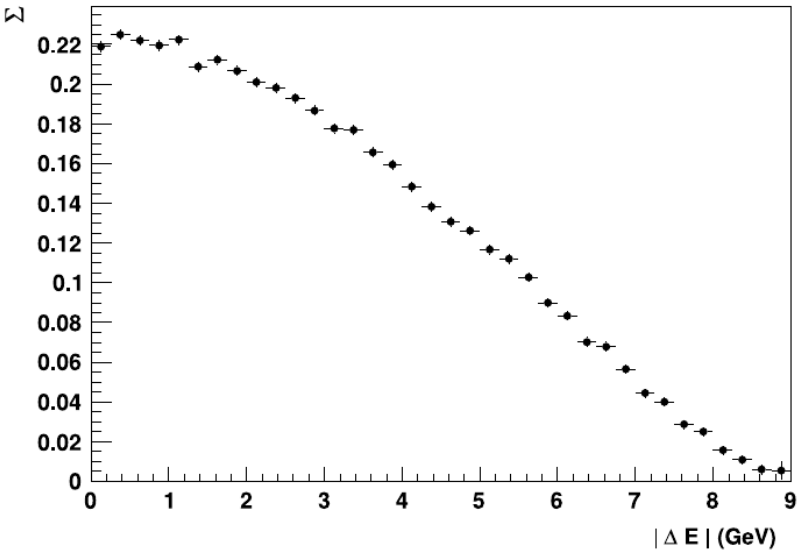
$\gamma + e^-_{atomic} \rightarrow e^+ + e^- + e^-_{recoil}$

Lower reaction cross section.

Higher analysing power.

Pair and Triplet Production





[M. Dugger et. al. NIM 867 (2017)]

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Outline

Triplet Polarimeter - GlueX

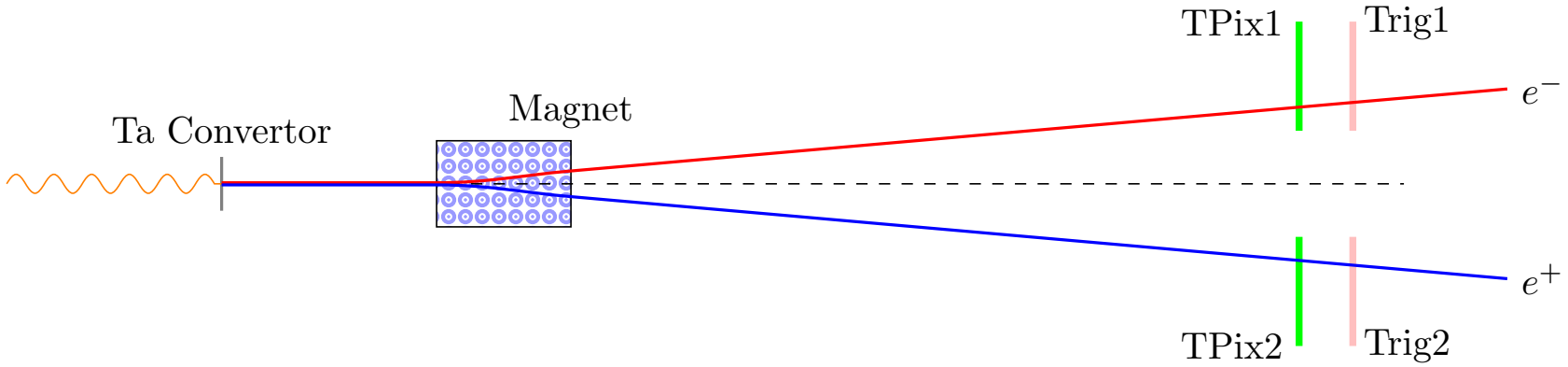
Systematic uncertainty estimated at 1.5%
Accumulate over beamtime to get enough statistics for binning polarisation by photon energy.

Outline

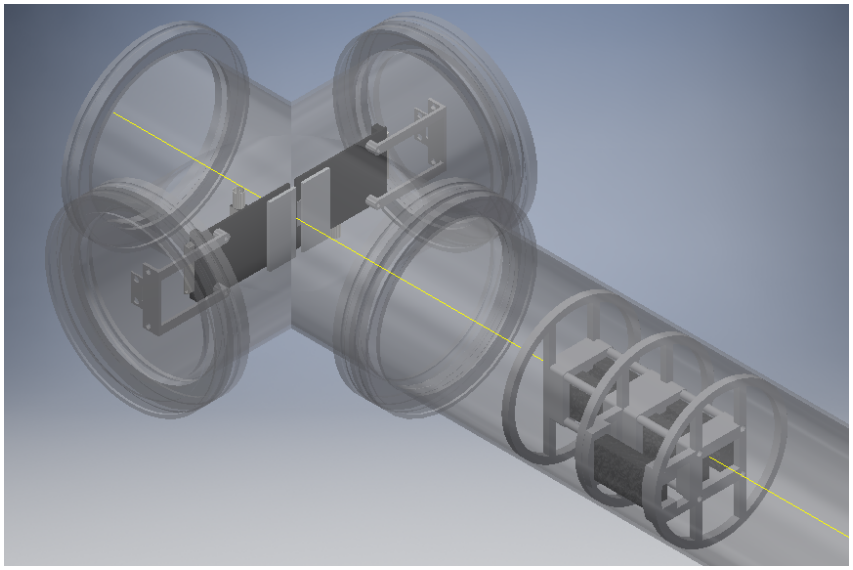
Prototype Pair Polarimeter

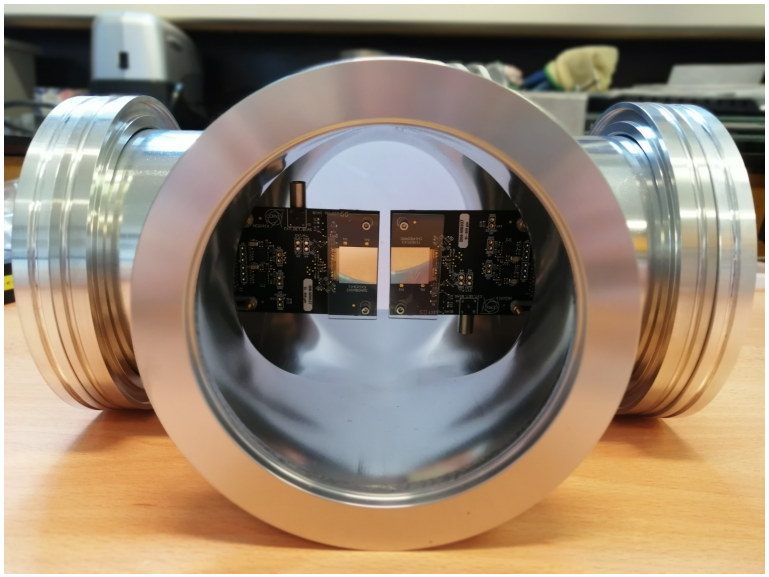
$\gamma + N \rightarrow e^+ + e^- + N$
$0.1 \rightarrow 1.5$ GeV tagged photon beam.
Pairs converted in Tantalum foil.
Separated from beamspot by dipole field.

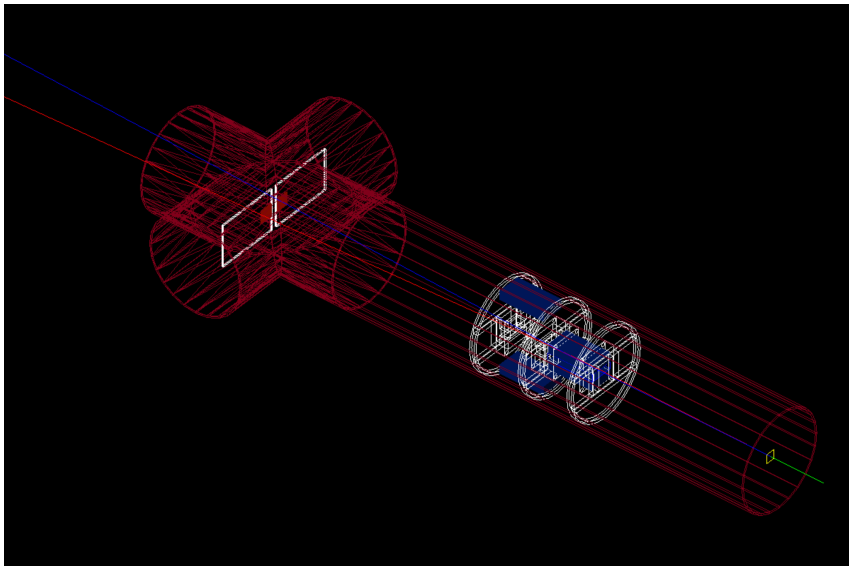
Two Timepix3 detectors.
Scintillation detectors form trigger.
Expected systematic error of $< 2\%$.
20 minutes of running under Mainz conditions.

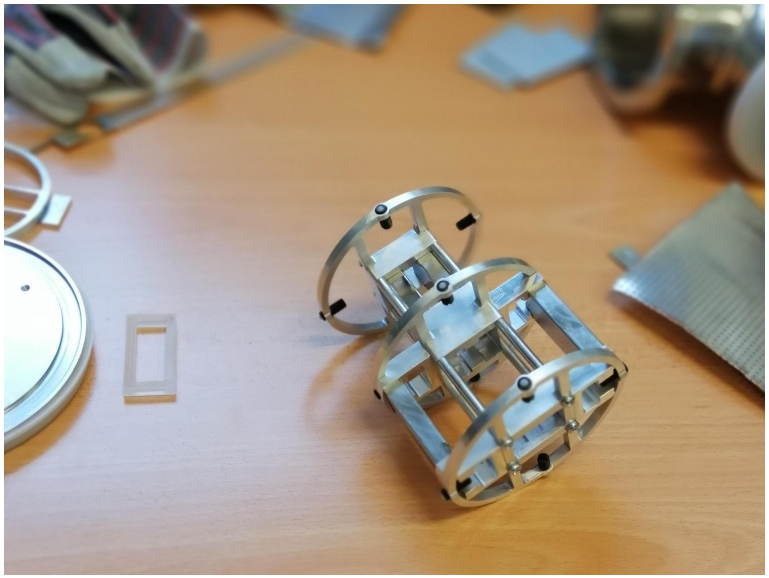


Prototype Pair Polarimeter



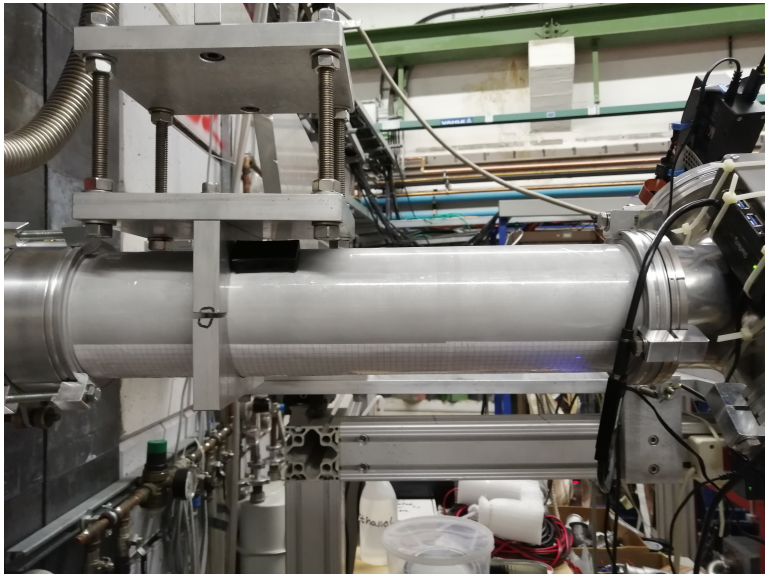


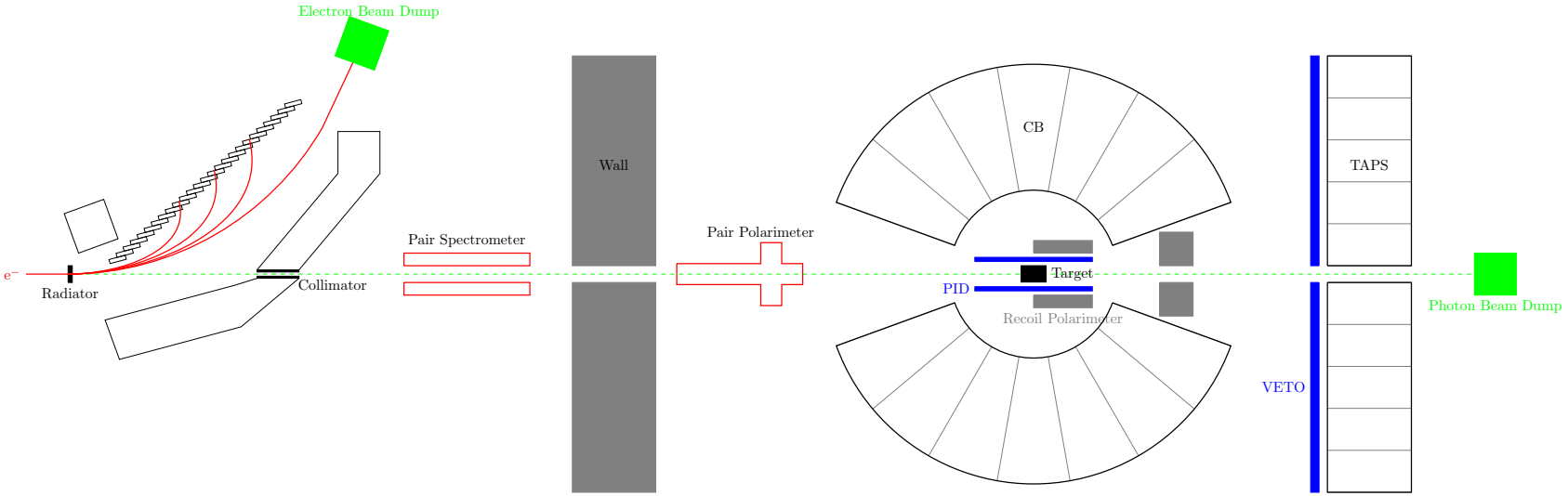




Tests - May - 2019

Location of the pair polarimeter for tests.





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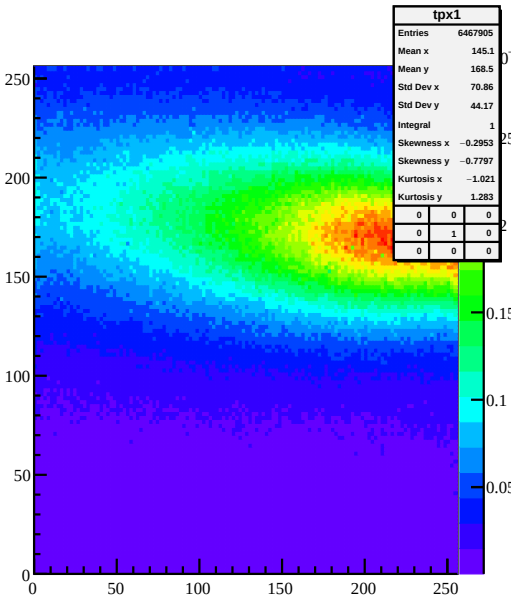
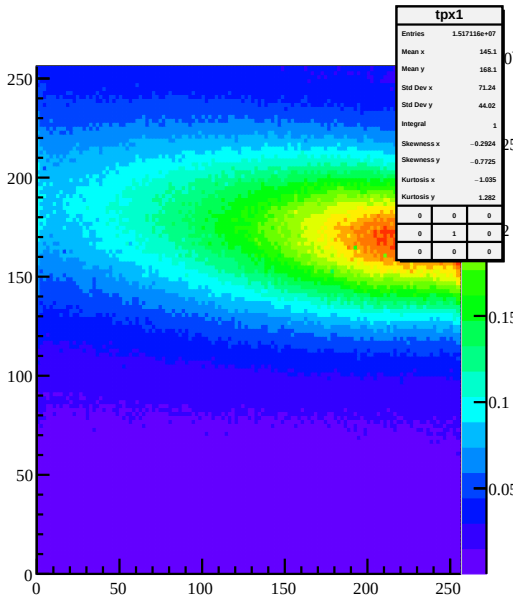
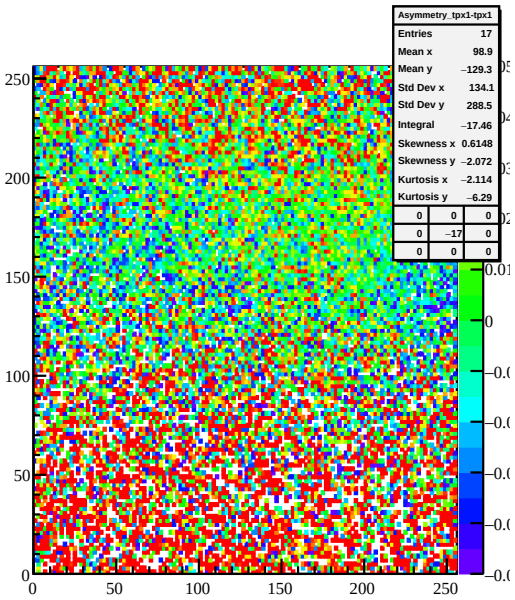
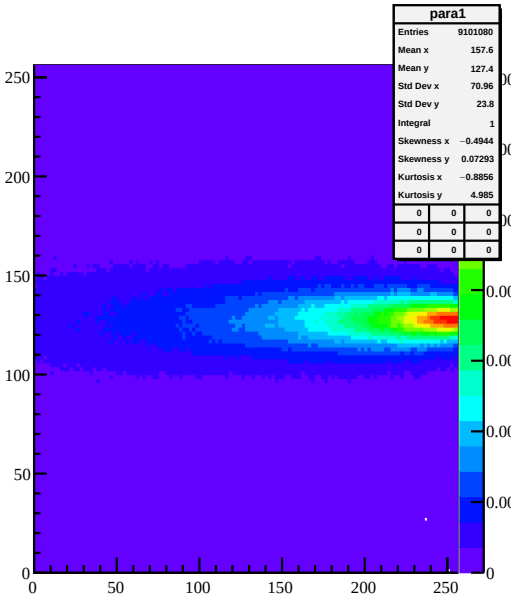
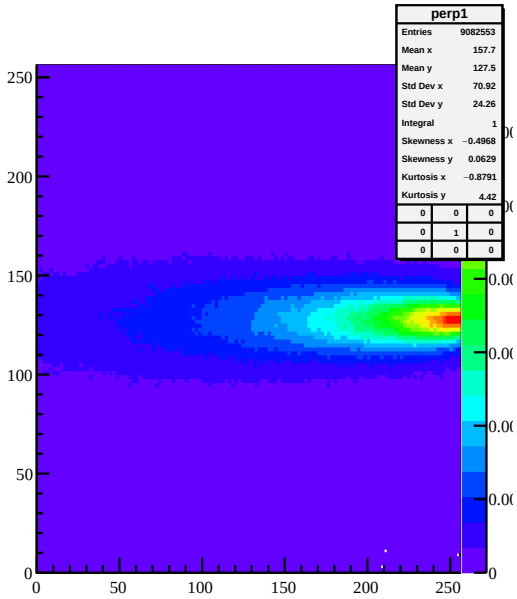
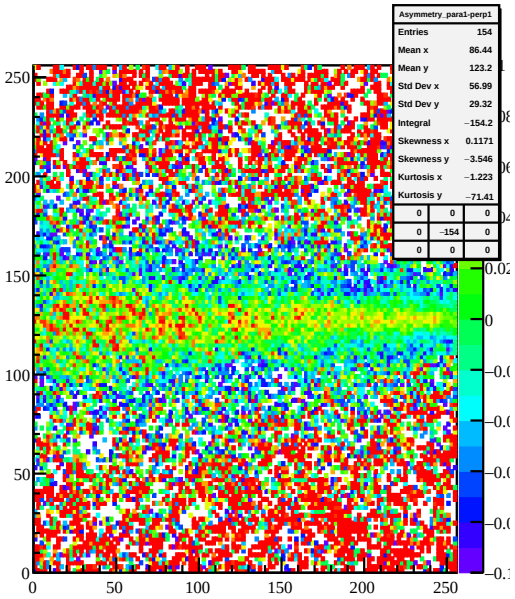




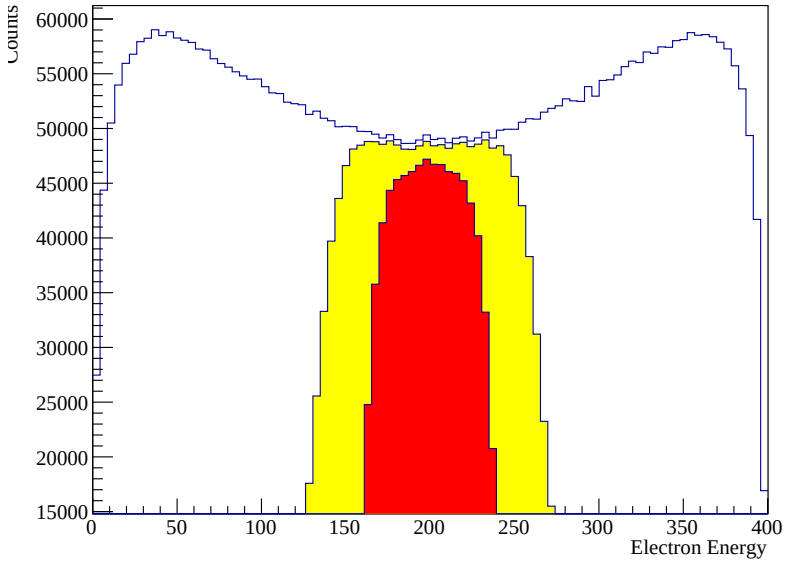


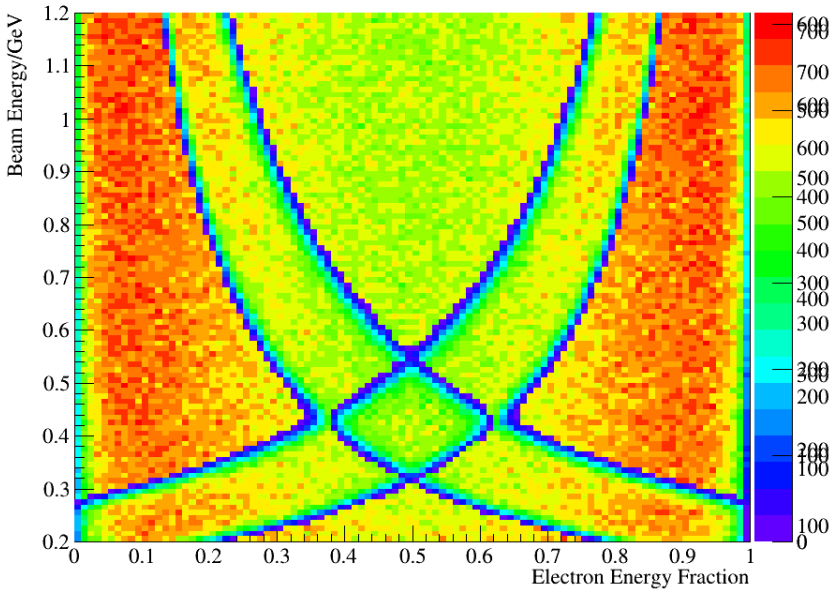


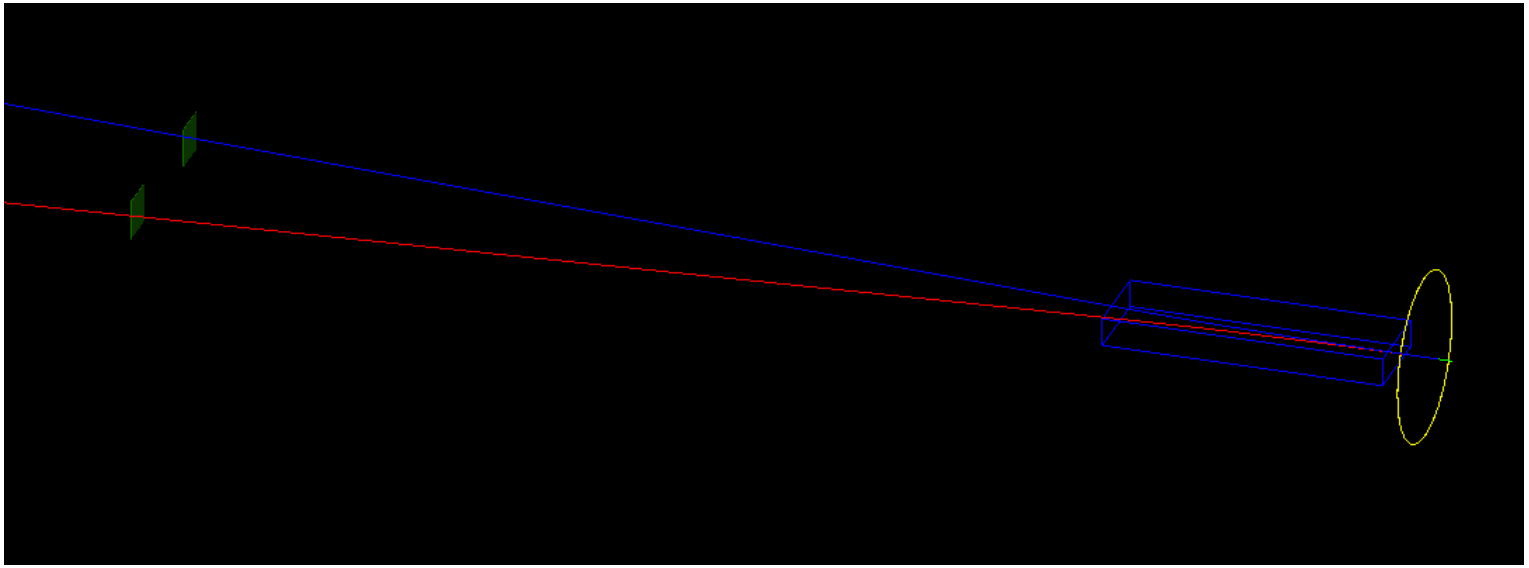




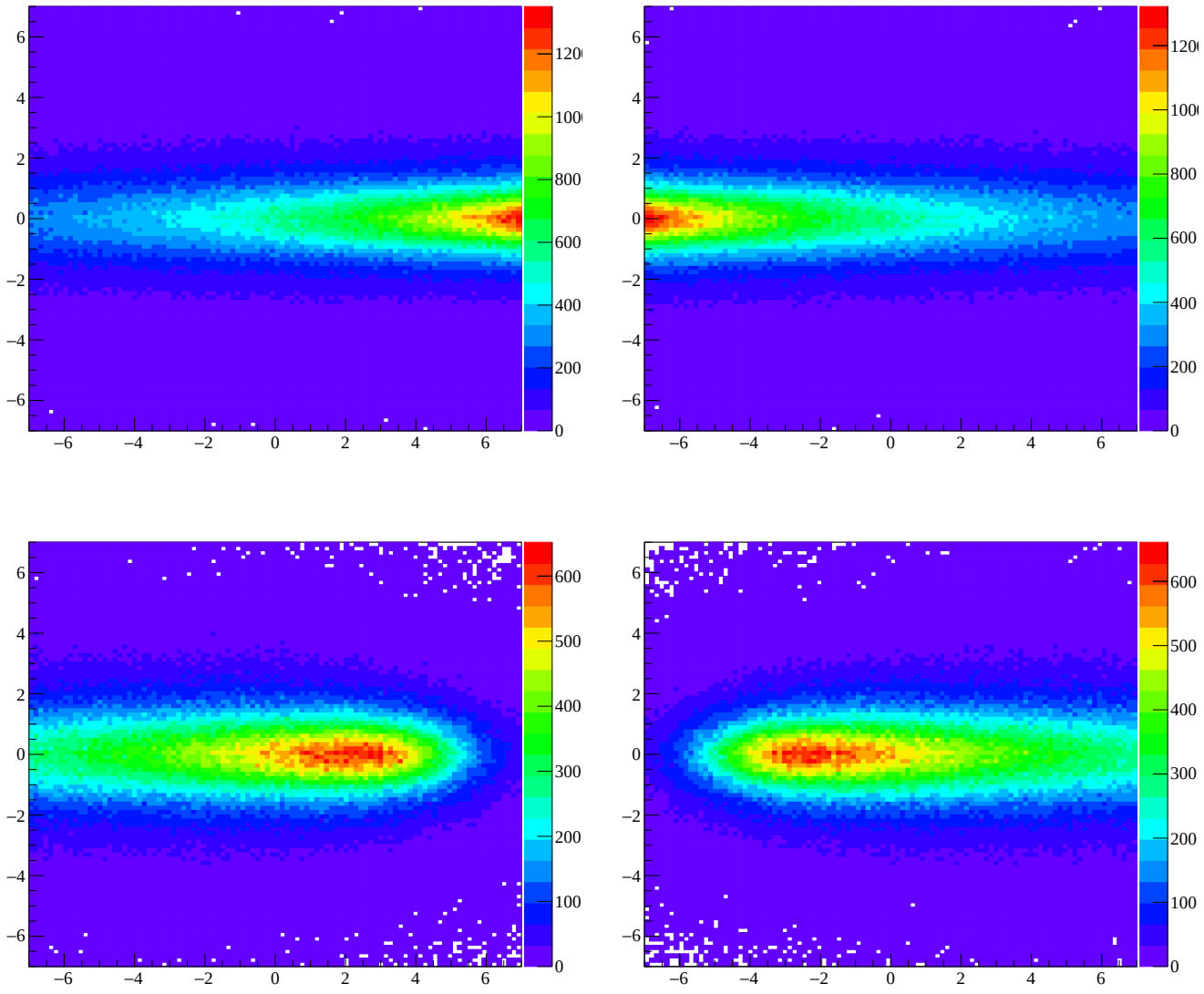
Prototype Pair Polarimeter - Simulation





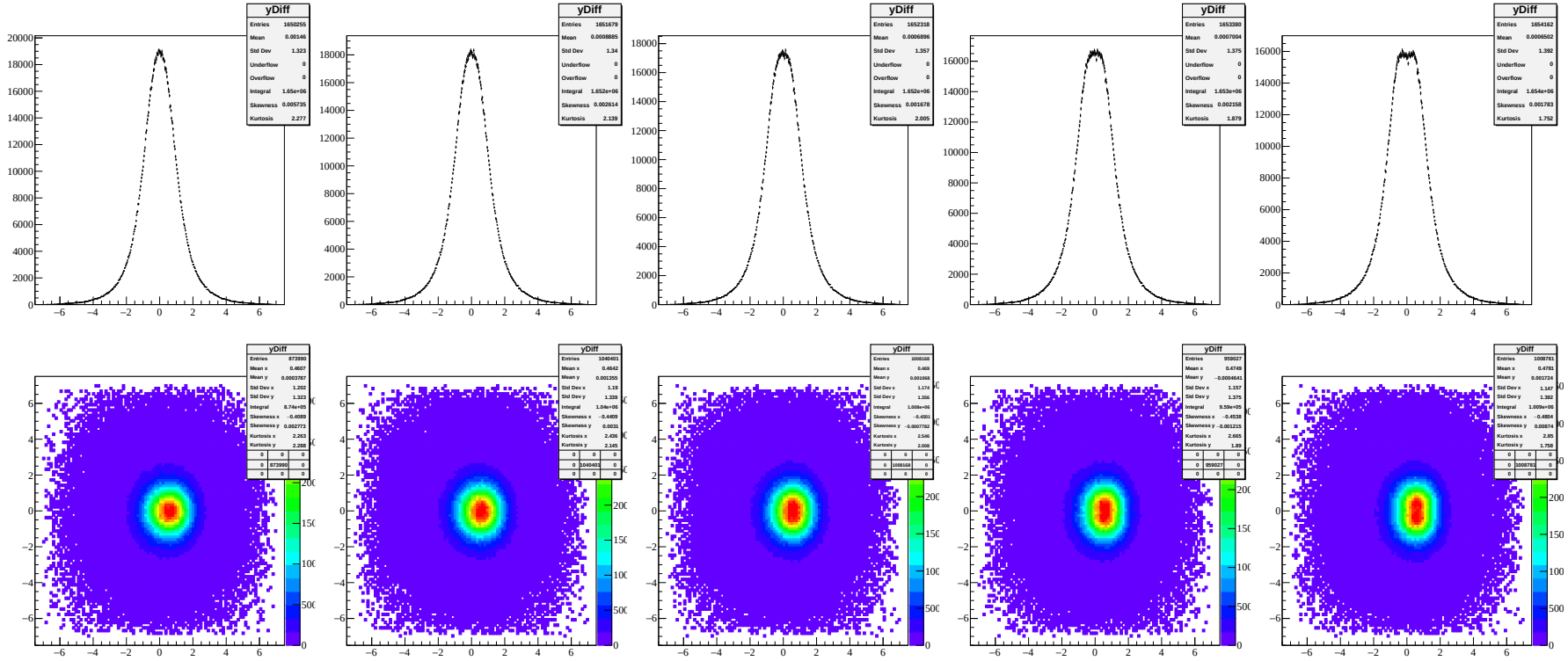


Polarisation Extraction

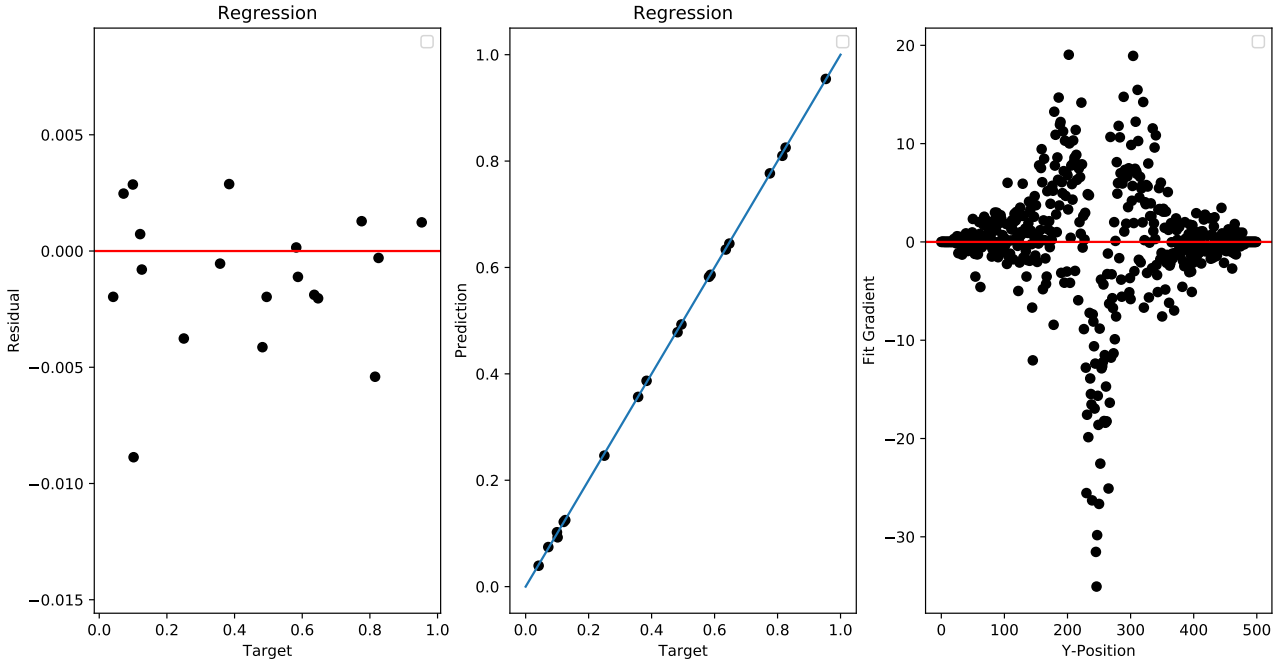


Polarisation Extraction

0→0.25→0.5→0.75→1 degree of polarisation



Polarisation Extraction



Linear regression of histogram bins contents.

Fit line to the change in histogram bin fraction with polarisation.
Less than 0.5% error, would improve additional simulations.

Outline

Coherent Bremsstrahlung of the Future

Running at Bonn, Mainz and J-Lab for now
Speculative facilities:

- DAΦNE
- ILC (International Linear Collider) - 125 GeV real photons

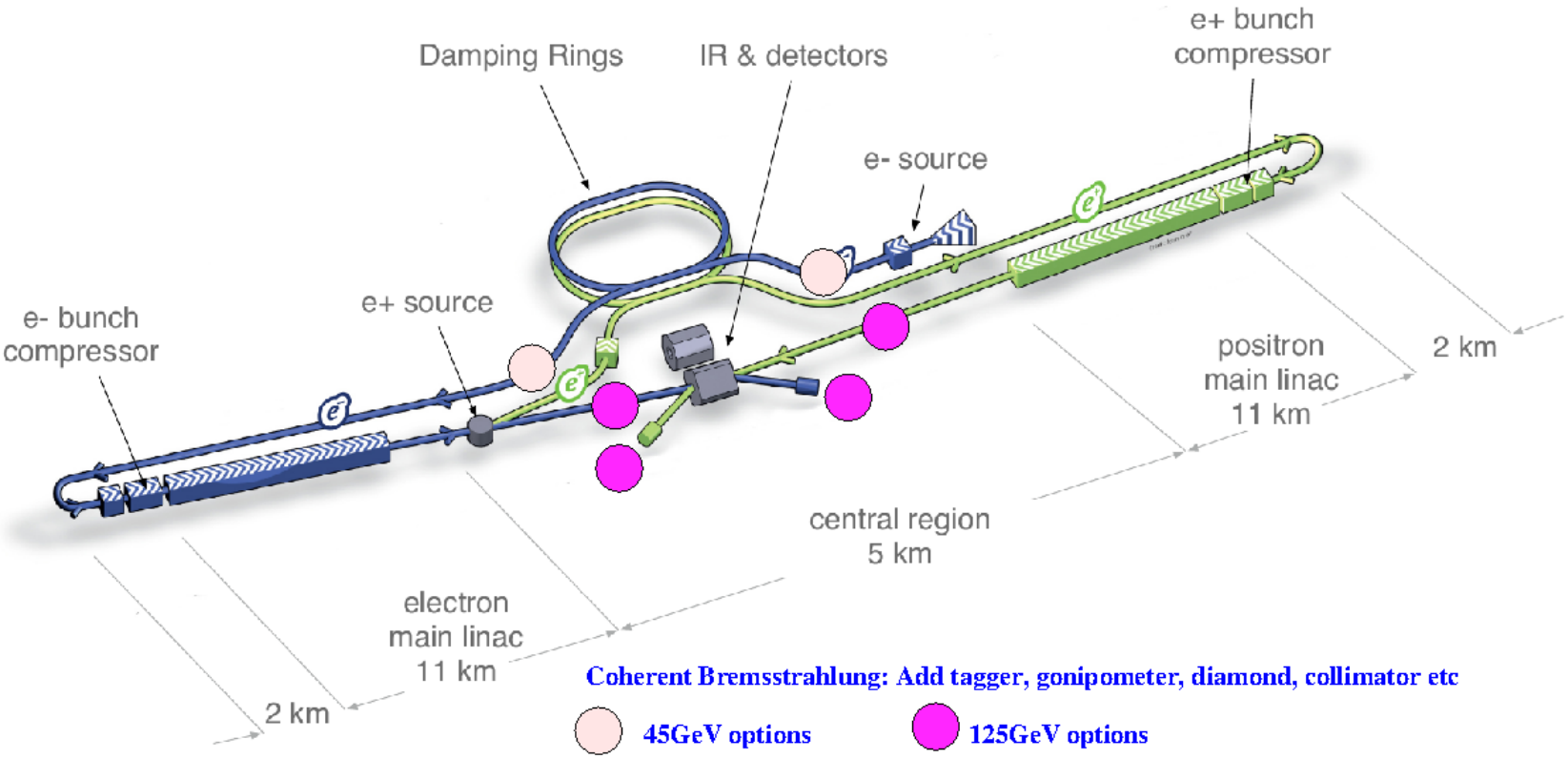


Figure 3.1. Schematic layout of the ILC, indicating all the major subsystems (not to scale).
From TDR Executive Summary (https://arxiv.org/pdf/1306.6327.pdf)

Summary

- Current methods for determining the degree of polarisation are no longer good enough.
- GlueX has proved the effectiveness of a polarimeter.
- A pair polarimeter would increase allow measurements at Mainz rates.

END