# Inputs & Requirements for the Laser-IP $e^+e^-$ Detector System

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

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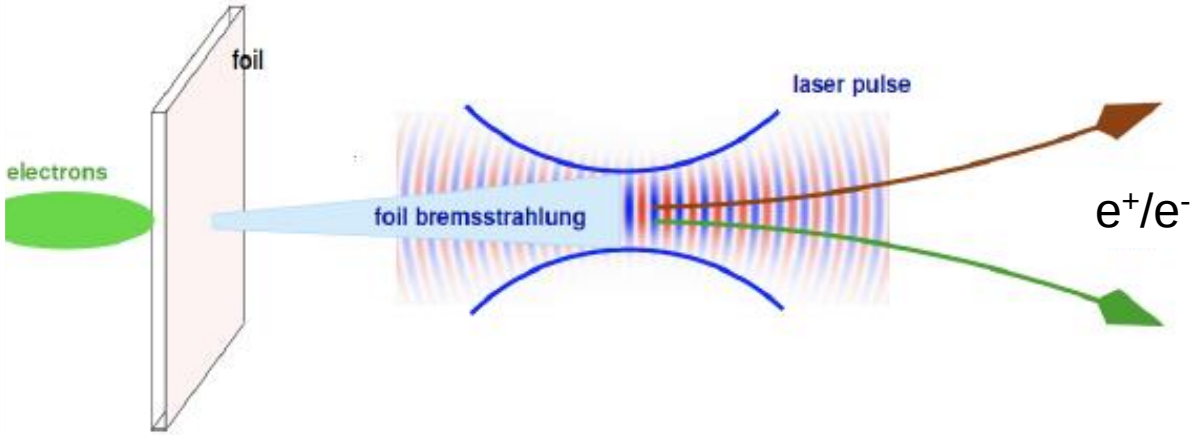
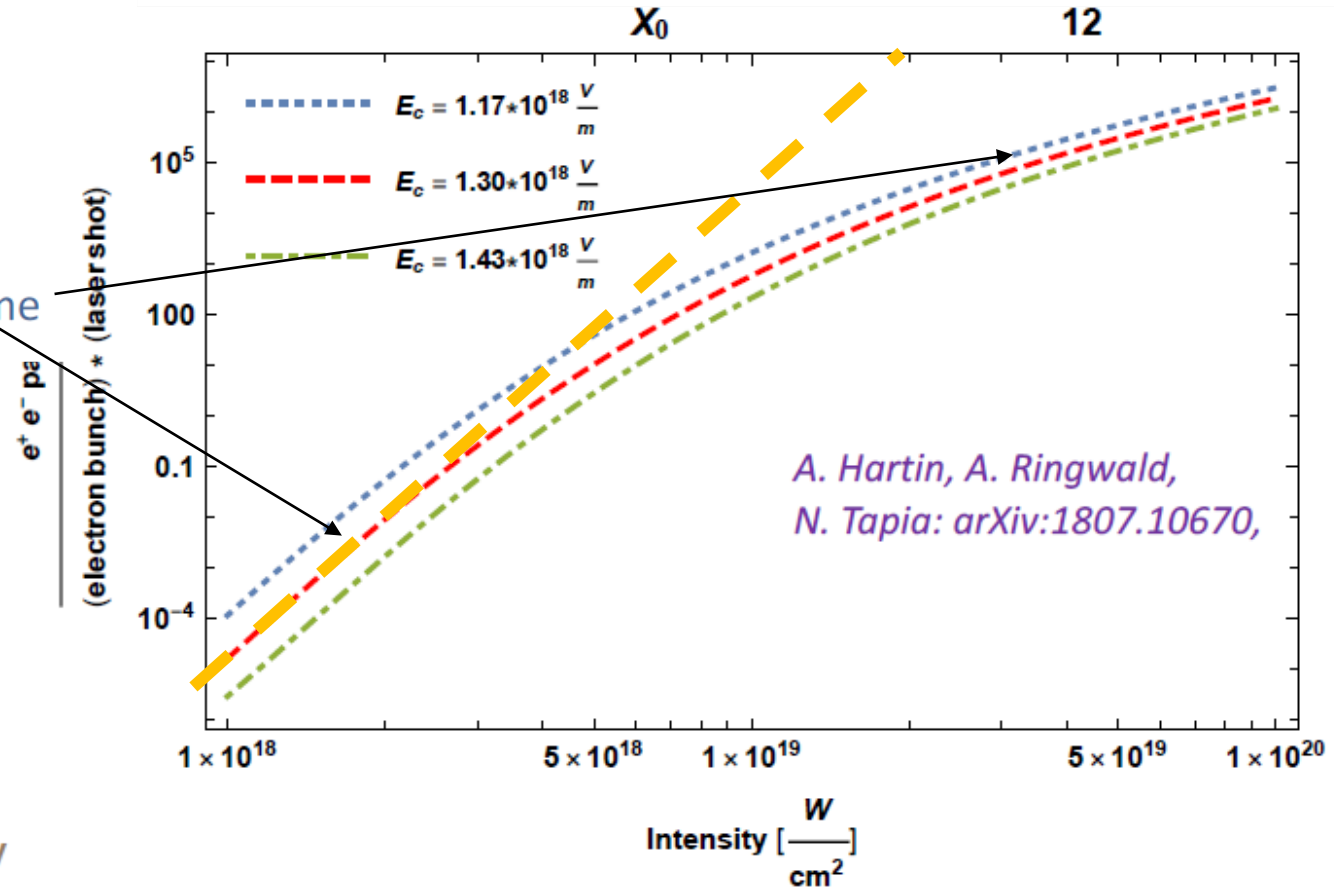
# Introduction and Motivation

## Measuring the exponential behavior of the non-perturbative regime



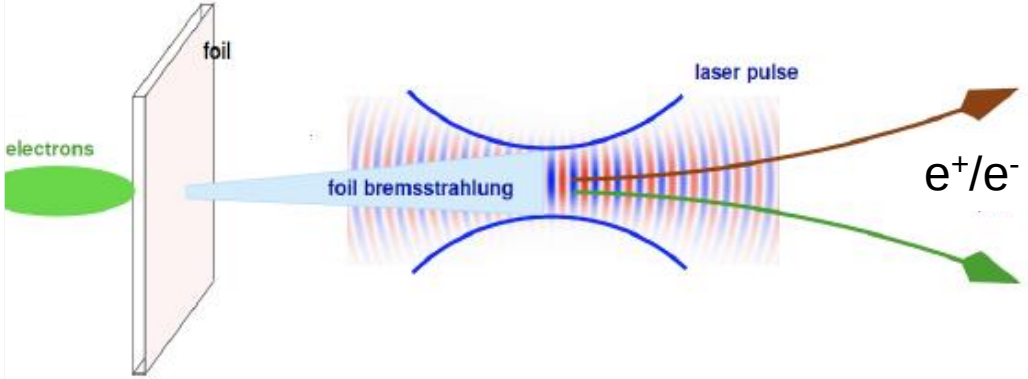

$$\xi \ll 1: \; R_{e^+} \propto \xi^{2n} \propto I^n$$ ☚ Strong rise

$$\xi \gg 1: \; R_{e^+} \propto \boxed{\exp\left(-\frac{8}{3\chi}\right)} \propto \gamma\sqrt{E_L}$$ ☚ Non-perturbative regime



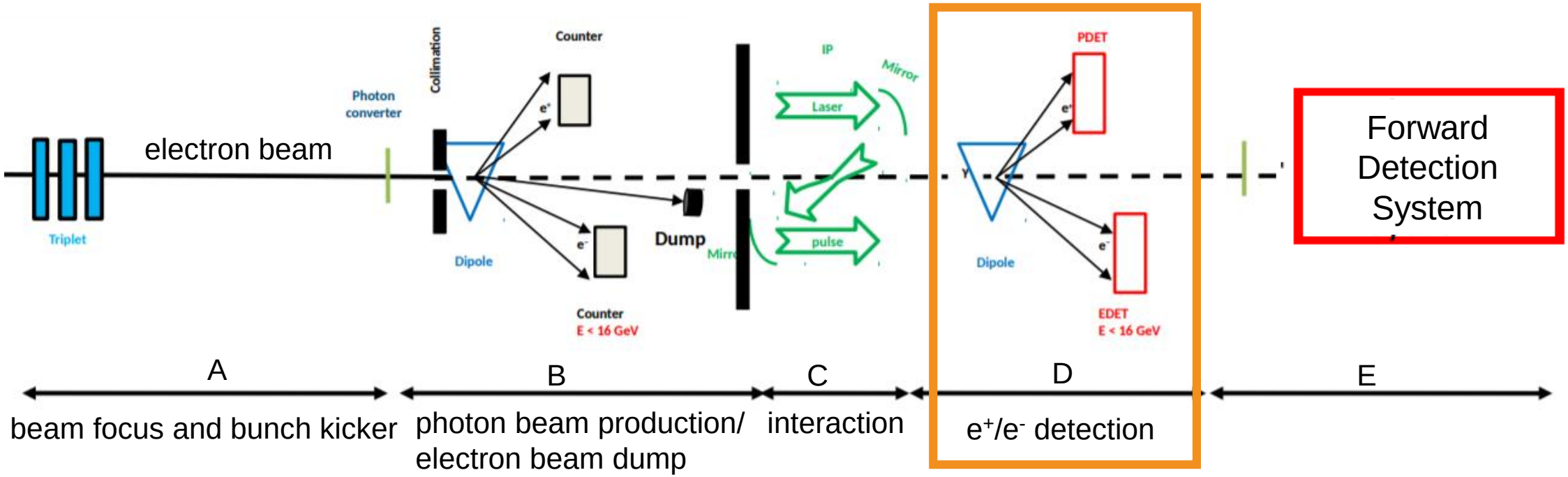
# LUXE Setup and Parameters

## Design of the experiment




| Design Laser Parameters | | |
|---|---|---|
| Energy[J] | 0.35 | 7.0 |
| Power[TW] | 10 | 200 |
| Intensity[W/cm$^2$] | $10^{19}$ | $2 \times 10^{20}$ |
| $\xi$ | 1.5 | 6.8 |
| $\chi$ | 0.3 | 1.4 |

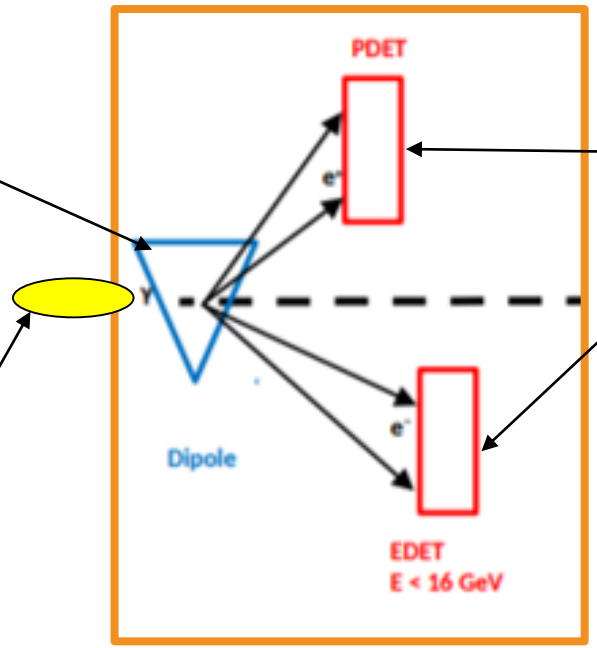
Electron/Positron Detector System



# Input parameters to consider

Magnet
- Aperture
- Field strength
- size

Incoming particles
- Energy Distribution
- Number
- Spatial distribution




Detector system
- Pixel Silicon Trackers
- Multiple Layers
- Calorimeters
- Cherenkov Counters

Spacial constraints
- Tunnel

XSDU1 tunnel ~2m diameter, European XFEL

# Proposed Magnet

## Taken from the DESY storage

suitable magnet from old DORIS accelerator

| Doris Dipole | |
|---|---|
| Length | 1.029m |
| Aperture horizontal | 0.6m |
| Aperture vertical | 0.1m |
| Max. Field strength | 2.24T |

# Monte Carlo Simulation

- Produced by A. Hartin
- Input: Geant4 photons by O. Borysov

| Parameter | value |
|---|---|
| $E_e$ [GeV] | 17.5 |
| Laser Energy [J] | 5 values: 0.2, 0.35, 0.5, 0.7, 1.0 |
| Pulse length [fs] | 35 (gaussian) |
| Pulse width [um] | 5 |
| Beam width [um] | 5 |
| #e/bunch | 6.25e9 |
| Xing angle | 0.3 radians (17 degrees) |

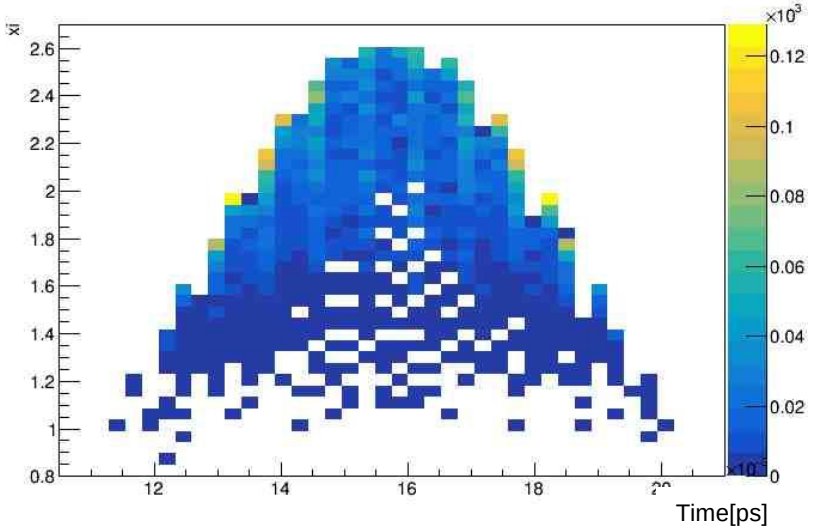
- Parameters for different Energies

| Energy [J] | 0.2 | 0.35 | 0.5 | 0.7 | 1.0 |
|---|---|---|---|---|---|
| Intensity [$10^{18}$ W/cm$^2$] | 5.7 | 10 | 14 | 20 | 29 |
| a0 or ξ | 1.1 | 1.5 | 1.8 | 2.2 | 2.6 |
| χ | 0.24 | 0.32 | 0.38 | 0.45 | 0.54 |

# MC simulated Interaction

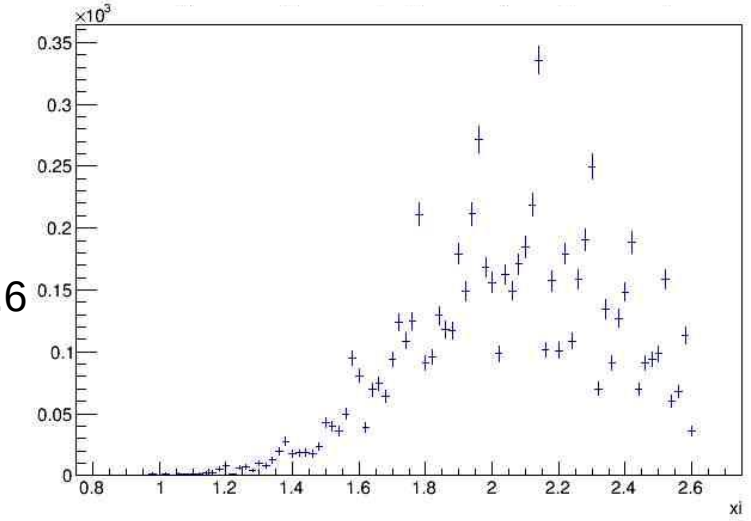
## Average of 1000 bunch crossings | 1.0J

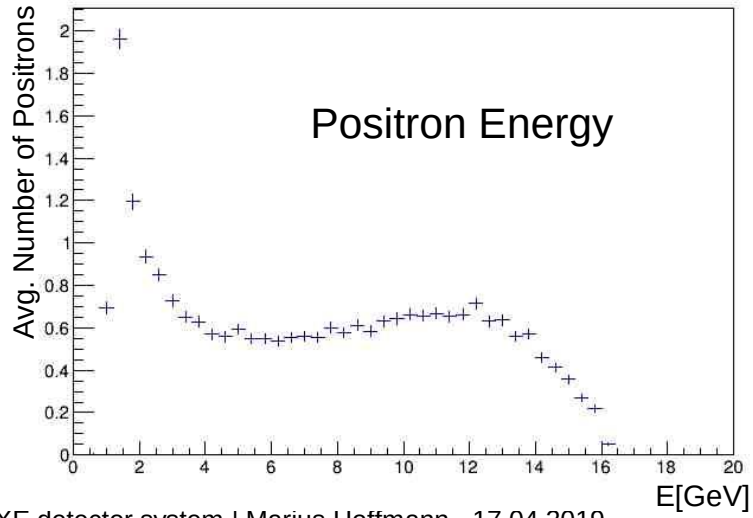
**Input:**
Monte-Carlo generated
laser-photon interactions
(A. Hartin)



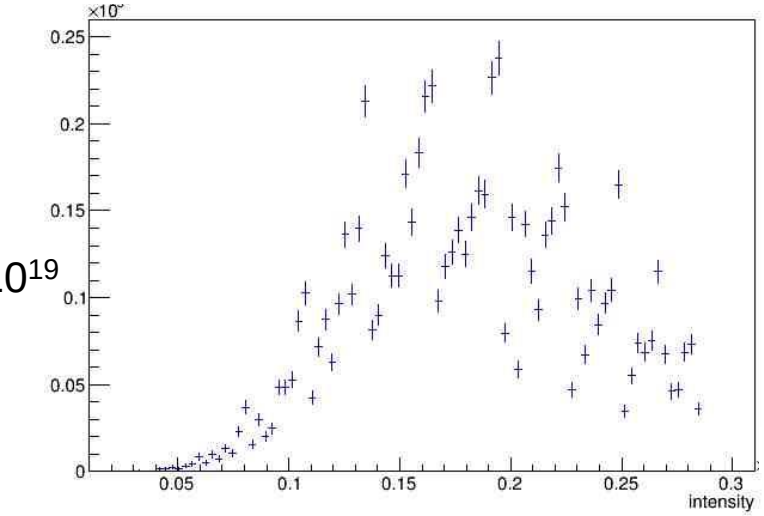

Time vs. xi

Xi profile
Nom. xi = 2.6



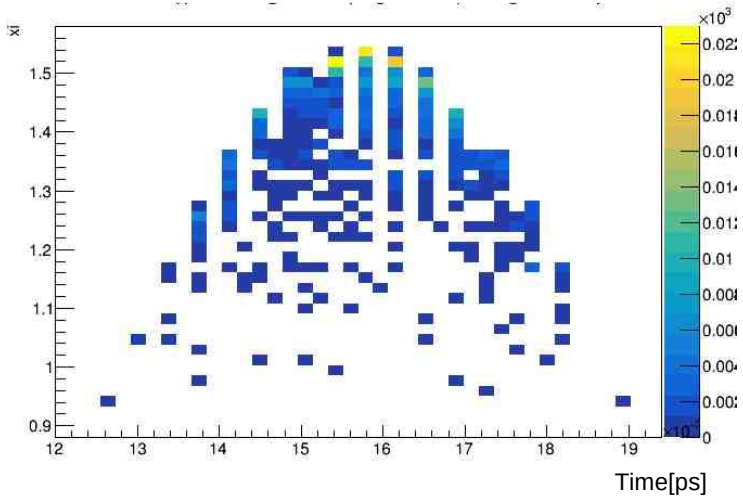

Laser Intensity
Nom. Int 2.9 × $10^{19}$



# MC simulated Interaction

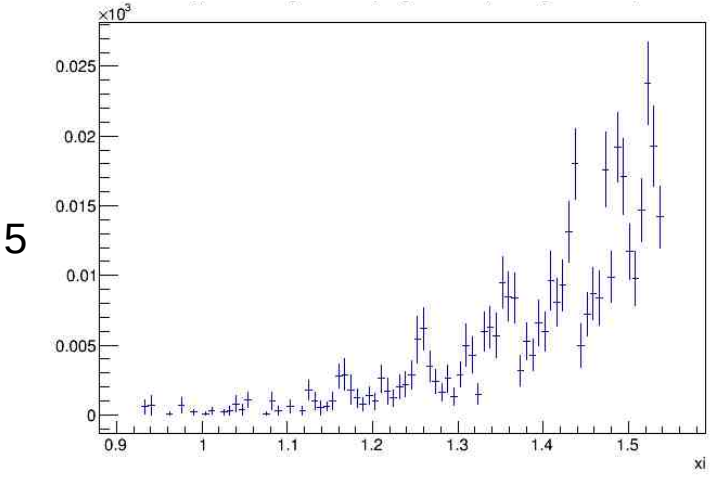
## Average of 1000 bunch crossings | 0.35J

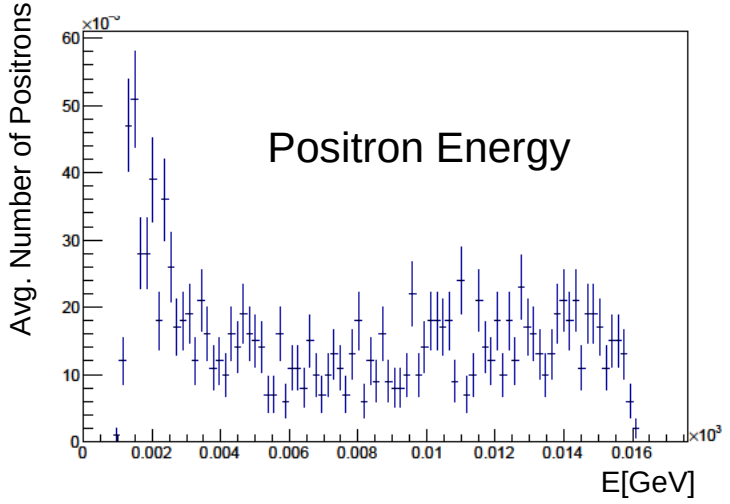
**Input:**
Monte-Carlo generated
laser-photon interactions
(A. Hartin)



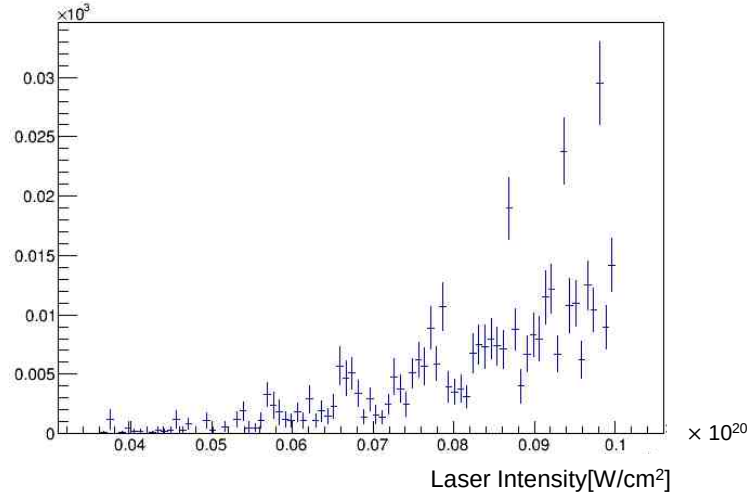

Time vs. xi

Xi profile
Nominal xi = 1.5



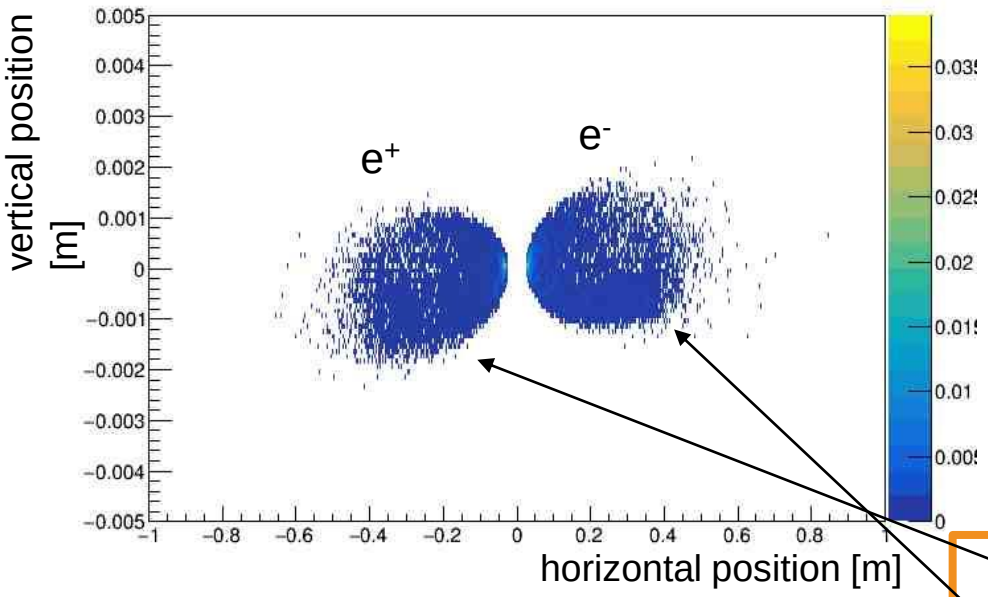



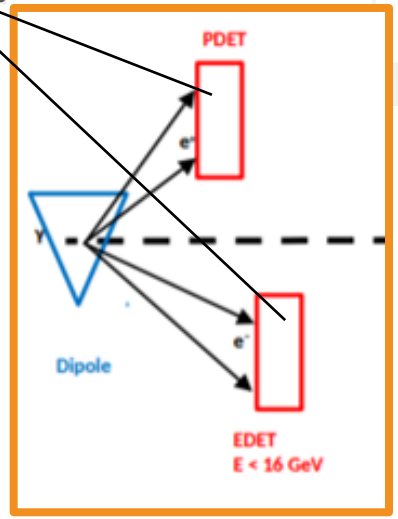

Laser Intensity
Nominal Int. $1 \times 10^{19}$



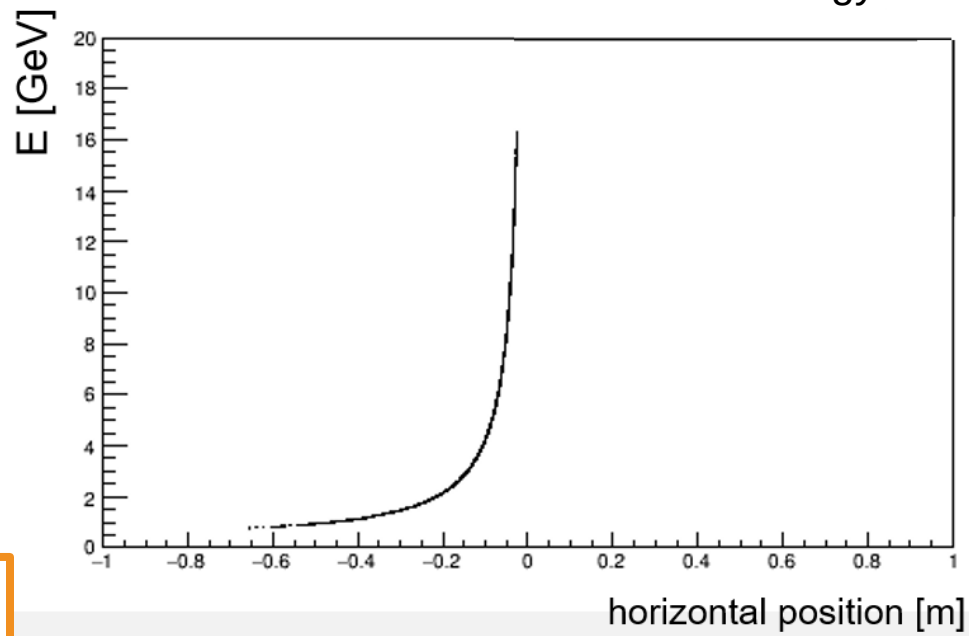
# Simulation of Magnetic Spectrometer

Particle Position



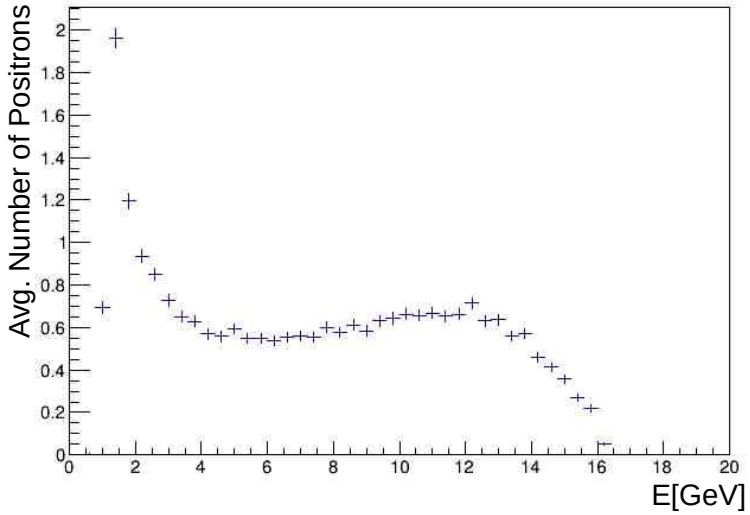




Positron Position vs. Energy



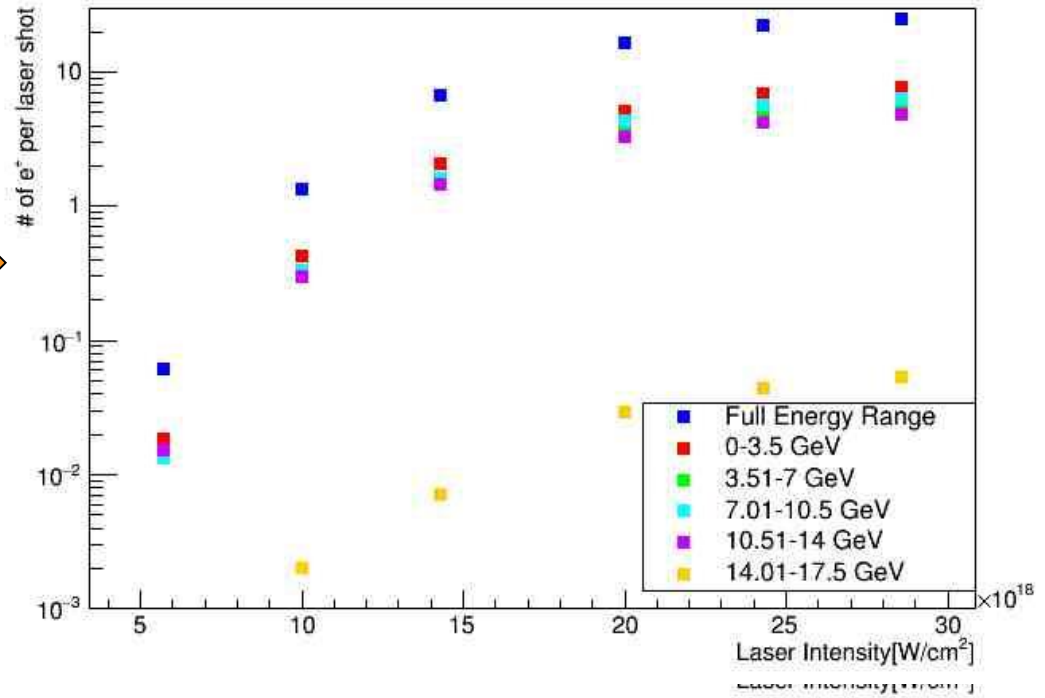
# $e^+e^-$ numbers after interaction

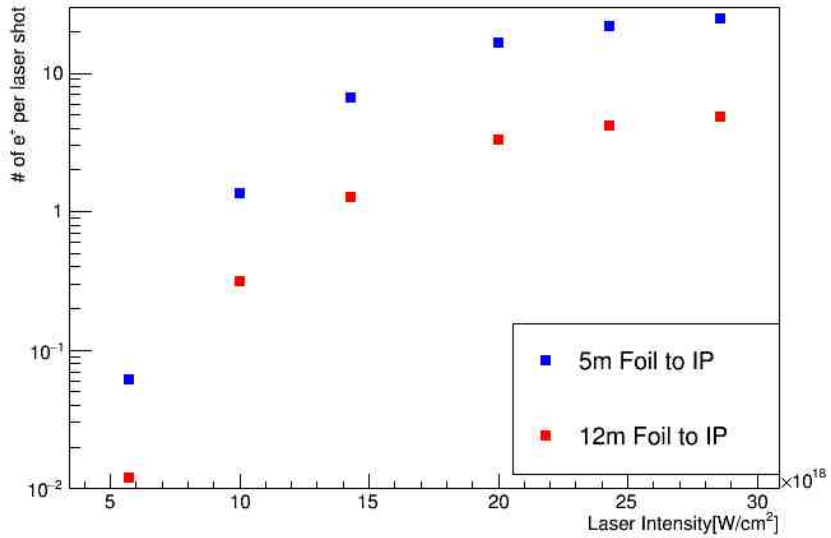
Energy spectrum of positrons




Slope is independent of Energy range

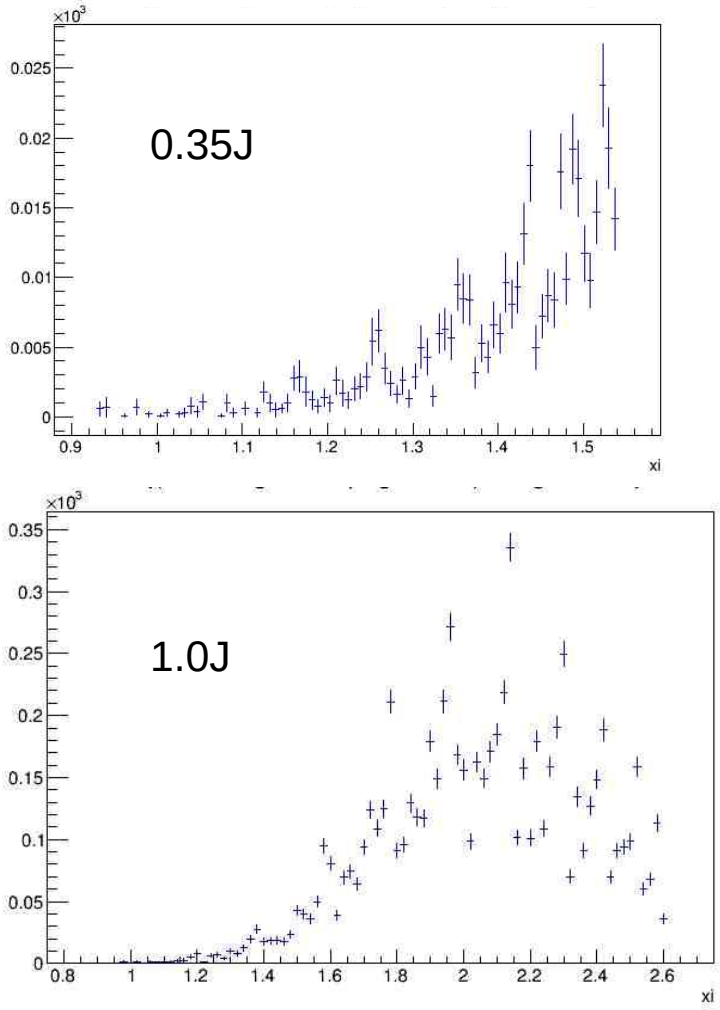
Number of positrons produced for Foil-IP 5m

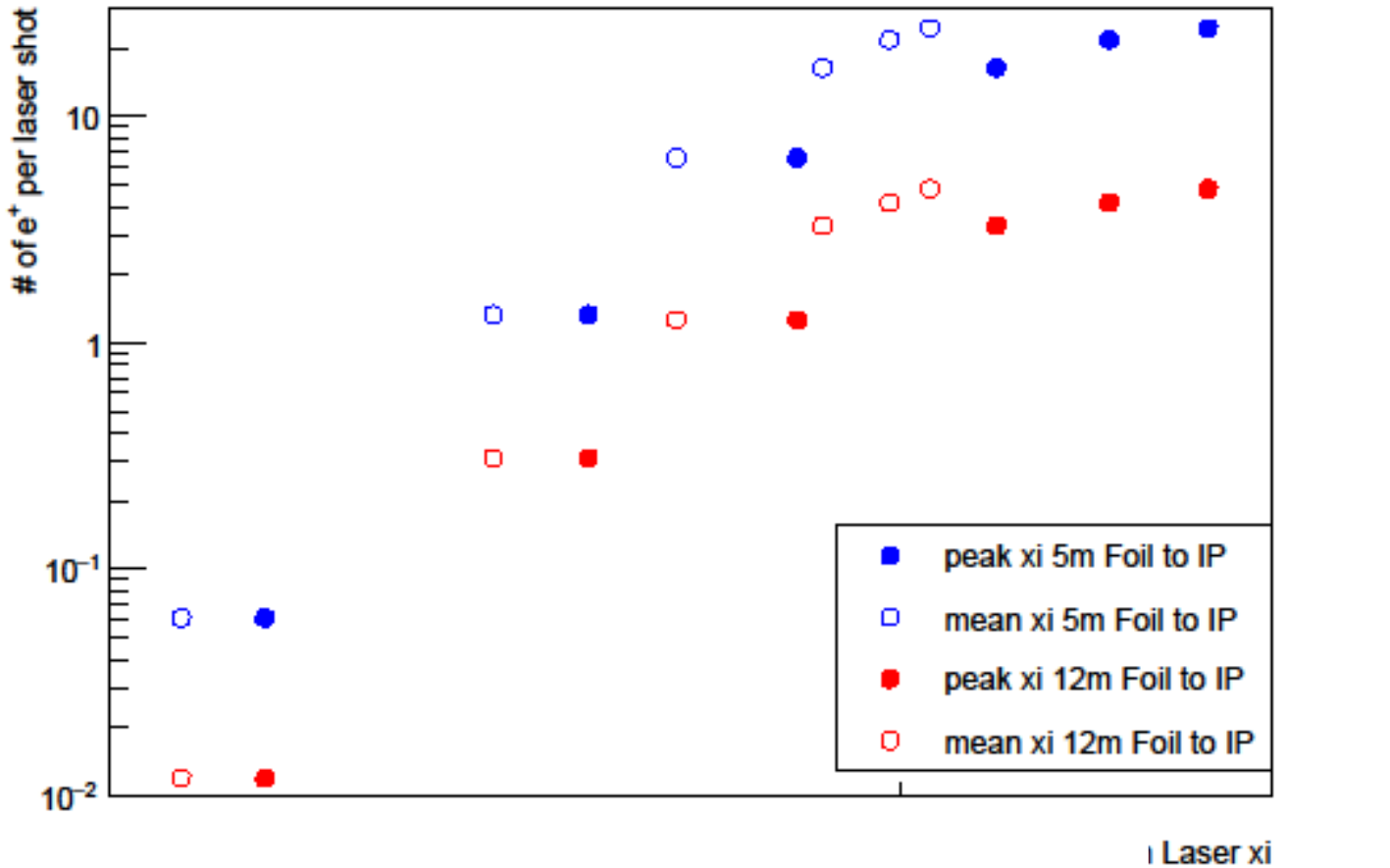


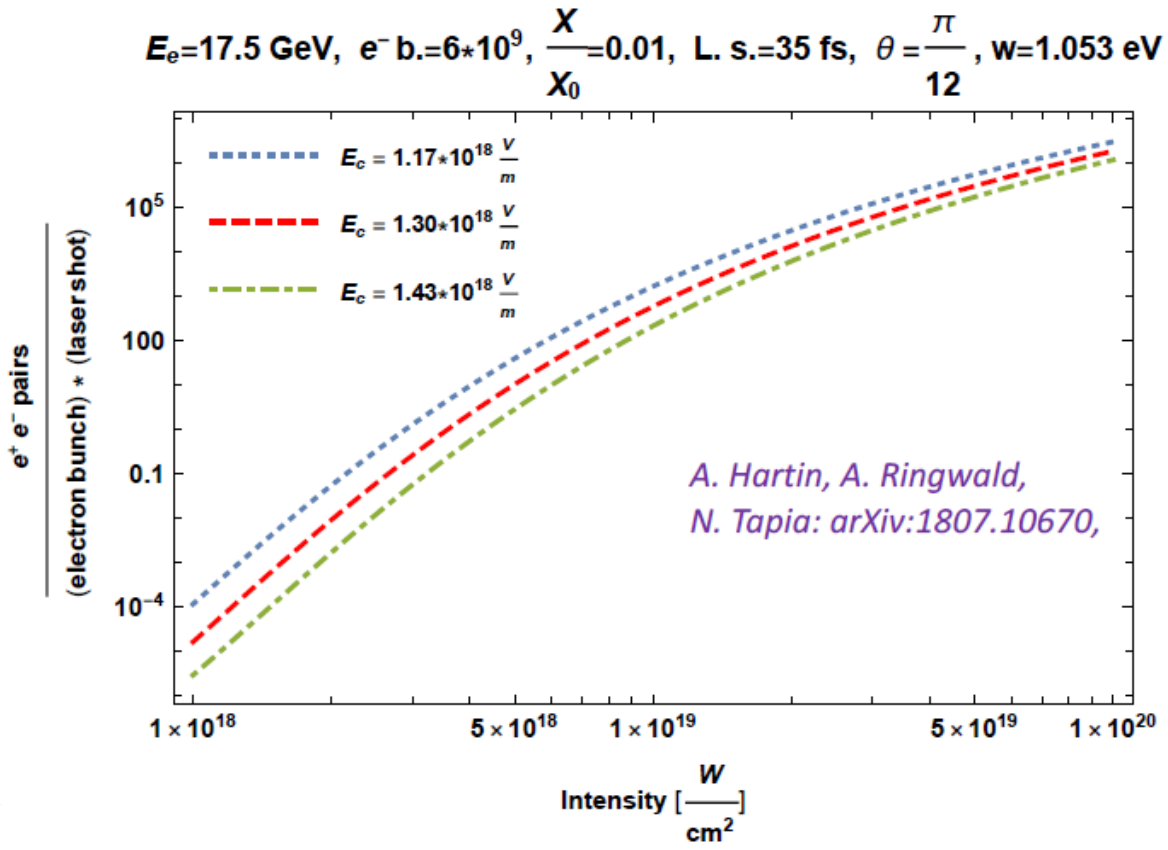

O(30) positrons for 1 J of laser energy
(Design Laser Energy = 7J)

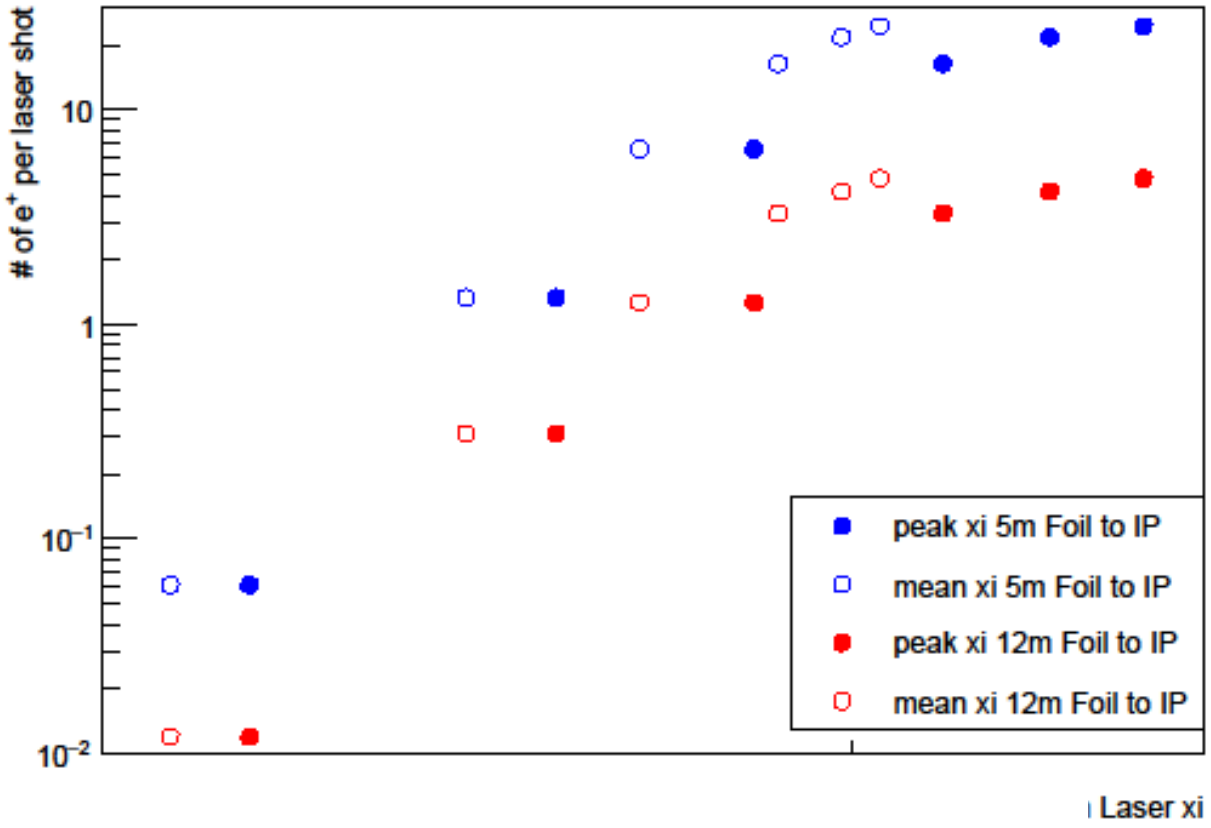
# Mean or Peak $\xi$ ?



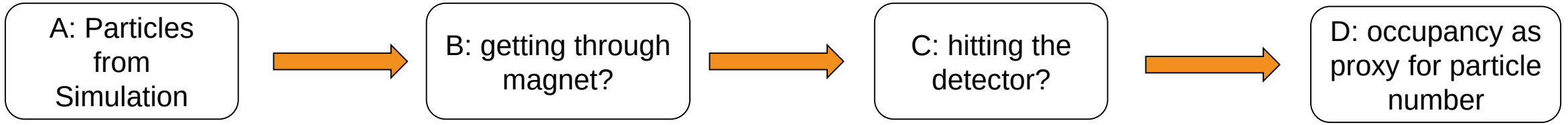



# Mean or Peak $\xi$ ?



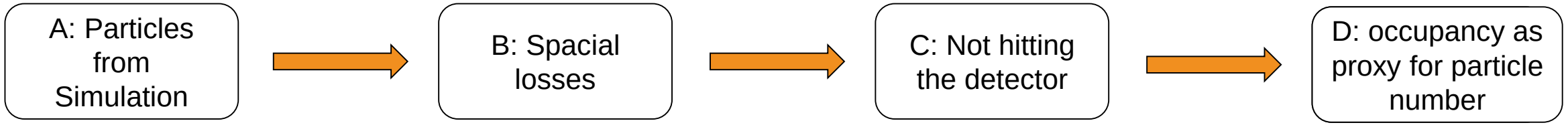
# Occupancy vs. Detector Granularity




| | | |
|---|---|---|
| E>1 GeV | | x_det < 1 m |
| x_magnet < 0.3 m | Aperture | y_det < 0.15m |
| y_magnet < 0.15m | | |

| Pixel size |
|---|
| 50 µm × 50 µm |
| 100 µm × 100 µm |
| 50 µm × 500 µm |
| 50 µm × 50 µm |
| 50 µm × 15000 µm (strip) |
| 1000 µm × 1000 µm |
| 10000 µm × 10000 µm |
| 1M µm × 150k µm |

# Occupancy vs. Detector Granularity




| Distance IP/Foil | A | B | C |
|---|---|---|---|
| 5m | 24.52 (100%) | 99.7% | 99.7% |
| 12m | 4.78 (100%) | 99.7% | 99.7 % |

| Pixel size [µm]<br><br>IP/Foil) | 50 × 50 | 100 × 100 | 50 × 500 | 100 × 15000 (strip) | 1000 × 1000 | 10000 × 10000 | 1M × 150k |
|---|---|---|---|---|---|---|---|
| 5m | 98.6% | 98.6% | 98.5% | 98.4% | 97.8% | 80.7% | 4.0% |
| 12m | 99.6% | 99.6% | 99.6% | 99.5% | 98.7% | 89.3% | 20% |

- **Granularity of up to 1mm**
- **Good granularity only needed in x plane**

# Pixel size / comparison with other experiments

Pixel Technology readily available

Additional Information from a Calorimeter?!

| Experiment | Pitch |
|---|---|
| ATLAS IBL | 50 µm × 250 µm |
| CMS Pixel Upgrade | 25 µm × 100 µm |
| LHCb | 55 µm × 55 µm |
| ALICE | 25 µm × 25 µm |
| CMS HGCAL | 0.5 $cm^2$ hexagons |

# How we want to proceed

1. **Finalize design simulation studies**

- Study Impact of Laser Pulse Shape
- Include track fitting
- Increase realism of detector

**2. Implement final design Full simulation in GEANT4**

**3. DESY test beam runs for validation of photon production models**

# Thank you for your Attention

## Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

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