Bremsstrahlung photon beam monitoring.

LUXE fortnightly meeting

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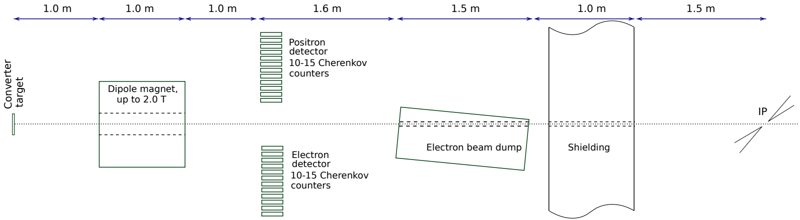
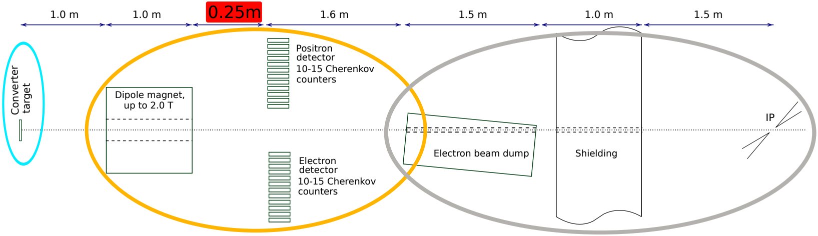
DESY
23 July 2019 (edit: 1 August 2019)

Experimental setup upstream from IP



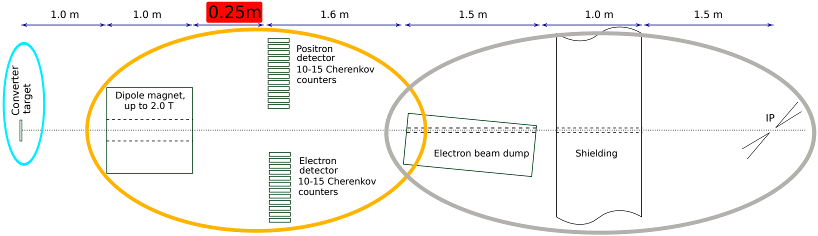
- XFEL bunch: 6.25×10^9 electrons at 17.5 GeV

Experimental setup upstream from IP



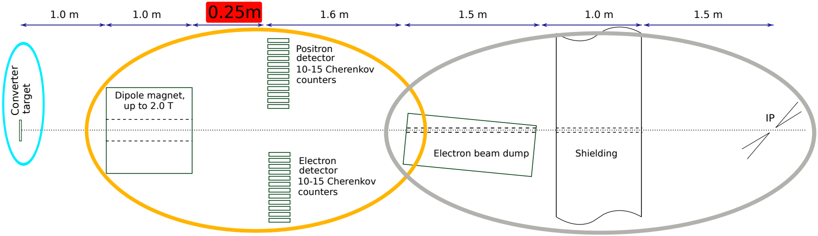
- XFEL bunch: 6.25×10^9 electrons at 17.5 GeV
- $e^- \rightarrow \gamma$ converter target: tungsten of $0.01 \times X_0$ (35μm).
- Magnet (tbc): 2T, 1m long, 1m behind target
- Detectors (tbc): cherenkov counters 25cm behind magnet, 1 cm^2 cells
- Last stages: XFEL e^- beam dump, shielding before IP

Motivations



- Monitoring of the bremsstrahlung photon beam upstream from the IP
  - **most important measurement:** determine N^{γ} at the IP
  - **extra:** γ energy spectrum and spatial distribution (x, y, z)

Motivations



- Monitoring of the bremsstrahlung photon beam upstream from the IP
  - **most important measurement:** determine N^{γ} at the IP
  - **extra:** γ energy spectrum and spatial distribution (x, y, z)
- Measurement of conversions ($\gamma^* \rightarrow e^+e^-$) after converter target
  - e^+, e^- deflected by magnet and measured in cherenkov counters
  - use of e^+/γ and e^-/γ correlations to reconstruct γ properties

Simulation and Analysis tools

- **GEANT4 simulation** performed by Sasha
  - simulation setup described here
  - 6.25×10^6 electrons $\times 48$ simulated [behind converter] ($\sim$ 5% of XFEL bunch)
    $\times 30$ simulated [behind magnet] ($\sim$ 3% of XFEL bunch)
  - e^-, e^+, γ recorded 1) 10cm behind converter target (i.e. before magnet)
    2) 25cm behind magnet

    ROOT ntuples location: /afs/desy.de/group/flc/luxe/bremsstrahlung/(b2t/)

- **Analysis code** (work in progress)
  - ROOT-based analysis code running on DESY batch system
  - modular implementation, everybody welcome to contribute

    git repository:
    https://username@stash.desy.de/scm/brem/bremphoton_analysis.git

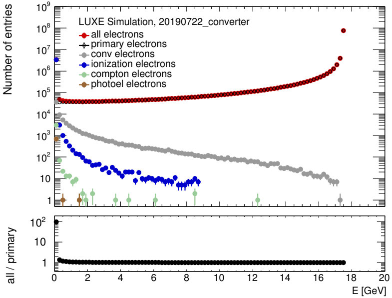
Number of particles

- **Particles 10cm behind converter:**
  - 96,941,816 electrons: 96.5% primaries, 3.4% ionization, 0.08% conversions, + very few compton/photo-electric
  - 27,004,279 photons $> 99.9999\%$ from brem + very few from annihilation
  - 79,263 positrons all from conversions

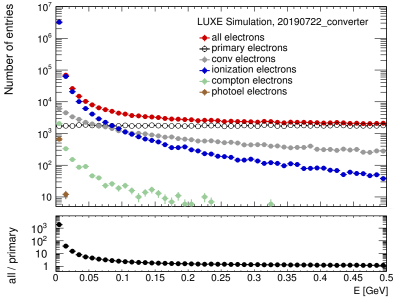
- **Particles 25 cm behind the magnet:**
  - 40% less particles simulated w.r.t behind converter
  - 58,439,205 electrons: 99.7% primaries, 0.26% ionization, 0.02% conversions, + very few compton/photo-electric
    $\sim$ no loss in magnet
  - 16,743,583 photons $> 99.9999\%$ from brem + very few from annihilation
    $\sim$ no loss in magnet
  - 11,409 positrons all from conversions
    $\sim$ 75% loss in magnet (due to low energy)

Electron energy [behind converter]

complete spectrum [0-20 GeV]



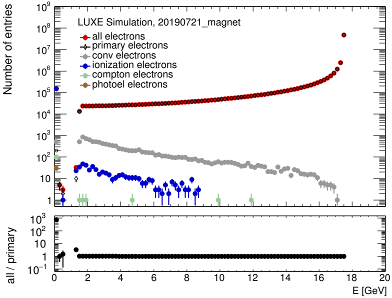
low energy spectrum [0-0.5 GeV]



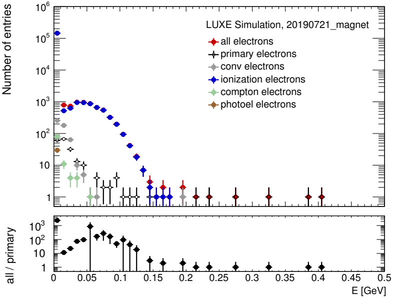
- electrons dominated by ionization for $E < 200$ MeV,
  primaries for $E > 200$ MeV
- conversions/primaries $< 3\%$ for E above 2 GeV
- compton/photo-electrical electrons sub-dominant everywhere

Electron energy [behind magnet]

complete spectrum [0-20 GeV]



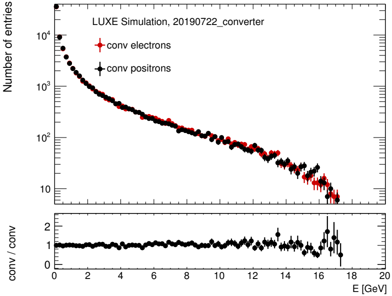
low energy spectrum [0-0.5 GeV]



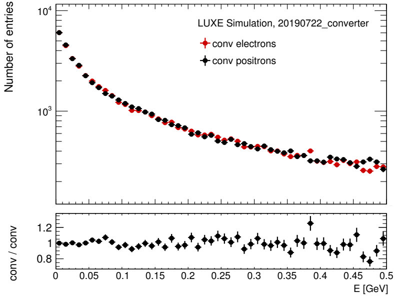
- no electrons between 150 MeV and 1.5 GeV due to magnet bending
- $E > 1.5$ GeV dominated by primaries ($> 97\%$ for $E > 2$ GeV)
- low energy electron remnant most likely not in detector acceptance
  [to be checked]

Positrons energy [behind converter]

complete spectrum [0-20 GeV]



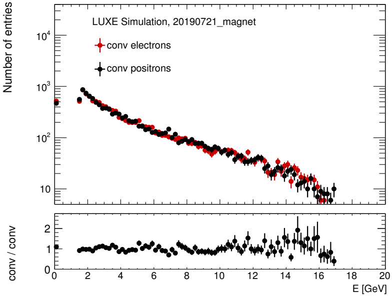
low energy spectrum [0-0.5 GeV]



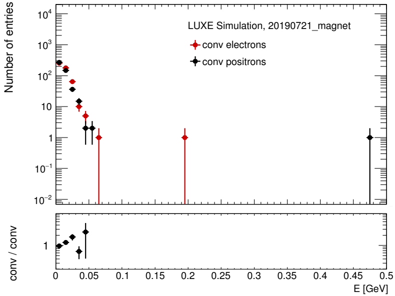
- same energy spectrum and number of e^+ than e^- from conversion $\rightarrow$ OK
- 82% of the positrons have $E < 2$ GeV $\rightarrow$ detector acceptance will be ~ 0.2
- positron beam focus: $\sigma_x \sim \sigma_y \sim 100\ \mu m$, $\sigma_z \sim 25\ \mu m$.

Positrons energy [behind magnet]

complete spectrum [0-20 GeV]



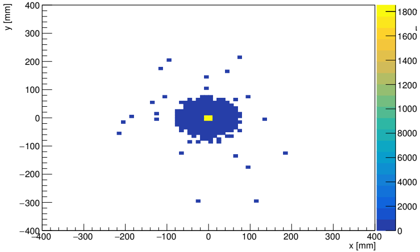
low energy spectrum [0-0.5 GeV]



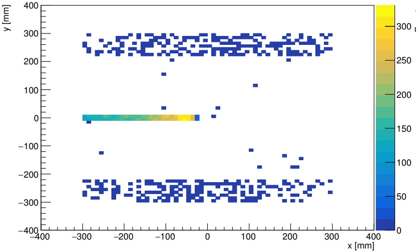
- same energy spectrum and number of e^+ than e^- from conversion $\rightarrow$ OK
- $\sim$ all the e^+ with $E > 2$ GeV make their way out from the magnet
- e^+ detector acceptance ~ 0.2, limited by the soft e^+ energy spectrum

Positrons in xy

behind converter



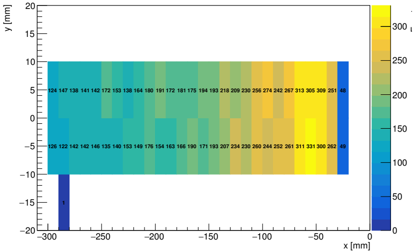
behind magnet



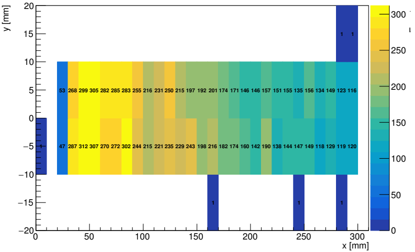
- e^+ well-focused behind converter
- e^+ populate $x \in$ [-30, 2 cm] after magnet $\rightarrow \sim$ 30 detector cells required
- some remnant between [20, 30 cm] in $|y|$ $\rightarrow$ low energy? **[to be checked]**

e^+/e^- from conversions behind magnet

positrons from conversions (= all)



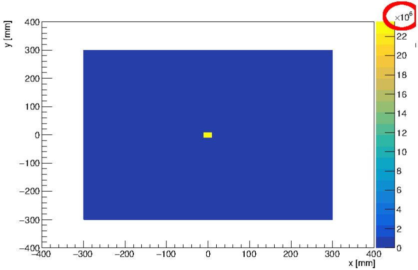
electrons from conversions
(<< primaries)



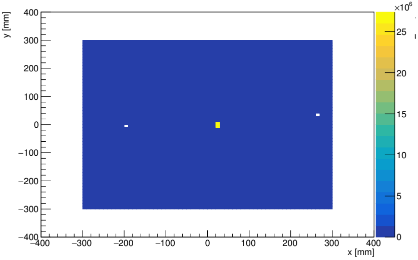
- need to $\times 33$ to get numbers from real XFEL bunch
- bin size = 1 cm^2 (i.e. expected cherenkov detector granularity)
- 4-10k positrons expected in each cell, 8-20k if one single bar in $y \in [-5, 5\text{ mm}]$ **[to be checked]**
- similar flux from electrons from conversions, but primary electrons dominate

(all) Electrons in xy

behind converter



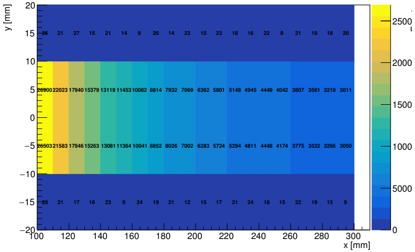
behind magnet



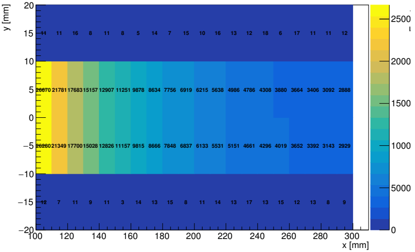
- well-focus primary/conversion e^- but large diffuse/low energy component from ionization before magnet
- ionization component still partially there after magnet
- high energy primary electrons displaced to $y = +2,3$ cm

e^- behind magnet

all electrons



electrons from primaries



- need to $\times 33$ to get numbers from real XFEL bunch
- bin size $= 1\ \mathrm{cm}^2$ (i.e. expected cherenkov detector granularity)
- 100-1000k electrons expected in each cell, 200-2000k if single bar in $y \in [-5, 5]$ **[to be checked]**
- $< 5\%$ not from primaries, dominated by conversions

Conclusion and outlook

– First look at bremsstrahlung photon beam monitoring

- ntuples and analysis code available at DESY and on git

– Detector occupancy

- electron side dominated by primary electrons, occupancy $\sim$ 200-2000k per XFEL bunch
- positron side dominated by conversions, occupancy $\sim$ 8-20k per XFEL bunch
  possible $\sim$ 1% contamination from e^- ionization, possibly suppressed by detector energy threshold **[to be checked]**
- occupancy can be tuned by moving back detectors + adding cells (currently +25 cm from magnet)

– Next steps

- understand/check correlations between detected e^-/e^+ and brem photons
- **$e^+ \to \gamma$ extrapolation model inputs:**
  - γ conversion rate as function of $E(\gamma)$
  - $e^+ \to \gamma$ energy splitting function for e^+ in acceptance
- **$e^- \to \gamma$ extrapolation model:** access to $E(\gamma)$?

Bremsstrahlung photon beam monitoring.

Back-up slides

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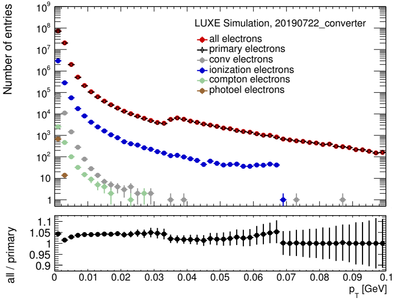
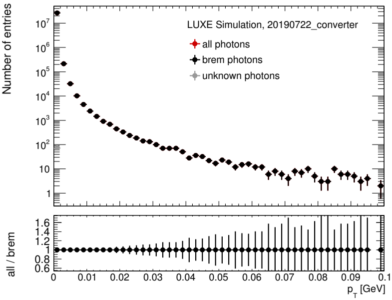
23 July 2019 (edit: 1 August 2019)

p_T behind converter

all electrons



all photons



Measurement idea (positrons)

1. **count the number of positrons falling in the counter acceptance**

   → deduce $N_{e^+}^{\mathrm{acc}}$ within 1.5-X_1 GeV, $X_1 - X_2$ GeV, ..., from geometrical acceptance

2. use positrons/photons correlations to reconstruct total number of photons (WIP)

3. use electron measurement to derive data-driven corrections to the positrons/photons correlation model (WIP, e.g. E(γ))

– Remarks

- **critical parameters:** detector acceptance (positron energy range) and efficiency (number of positrons), positrons/photons correlation model
- **correlation model inputs:** conversion rate as a function of photon energy, $\gamma \to e^+$ energy splitting function for e^+ in acceptance
- **electron measurements:** data-driven corrections (γ energy spectrum?)