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LUXE experiment at the Eu-XFEL

general setup considerations

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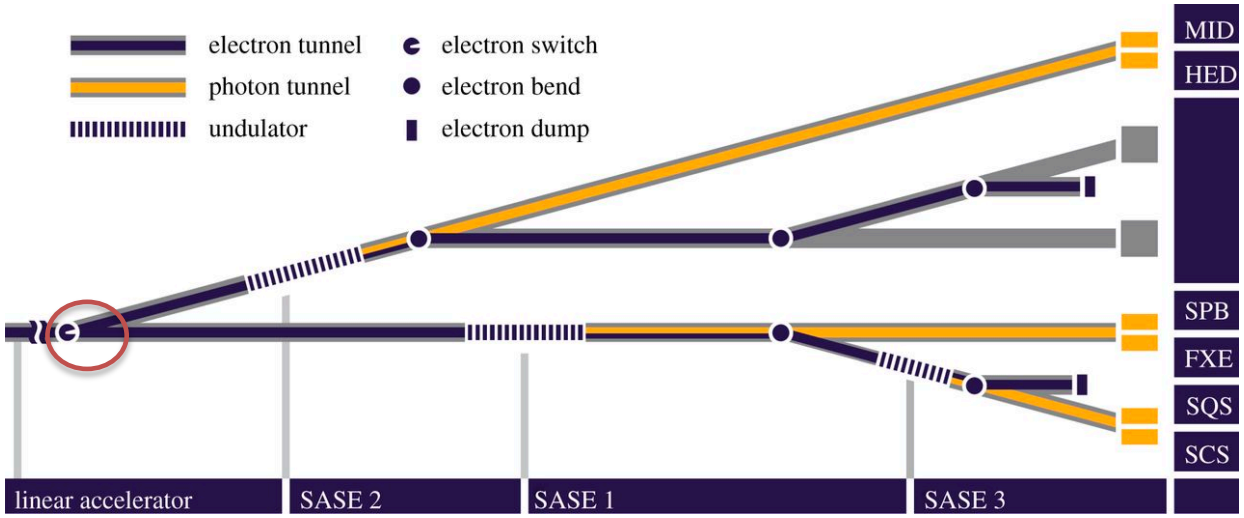
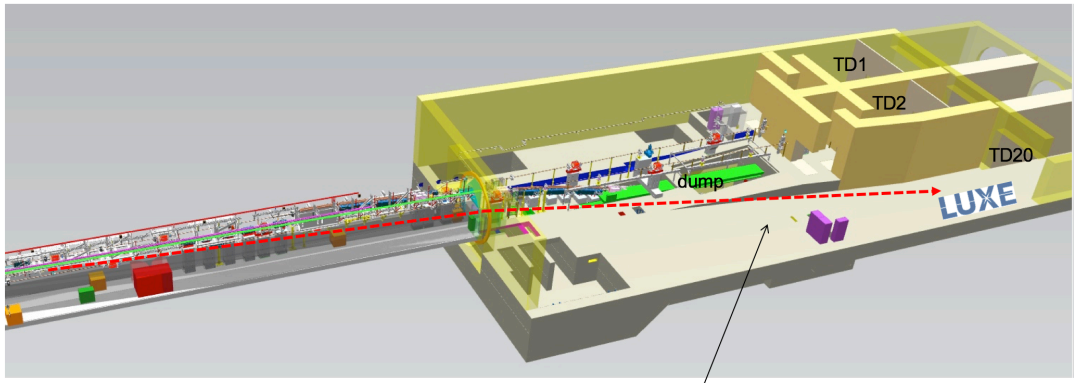
Location



90 m tunnel right after the first electron switch

Building in Osdorfer Born available right above it, with openings for laser transport

Accelerator Design



Start point of the second fan for XFEL

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General setup

Electron beam:
- Energy: 14 or 17.5 GeV
- $\Delta E/E$: $\sim 10^{-4}$
- Number of e^-: 6.2×10^9
- Beam size: 1 – 30 micron
- Duration: 1 – 80 fs (increases with charge)

Laser parameters:

	STAGE 0	STAGE 1
Energy [J]	0.35	7.0
Power [TW]	10	200
Intensity [W/cm^2]	10^{19}	2×10^{20}
ξ Parameter	1.5	6.8
χ Parameter	0.3	1.4

Crossing angle: 17 degrees

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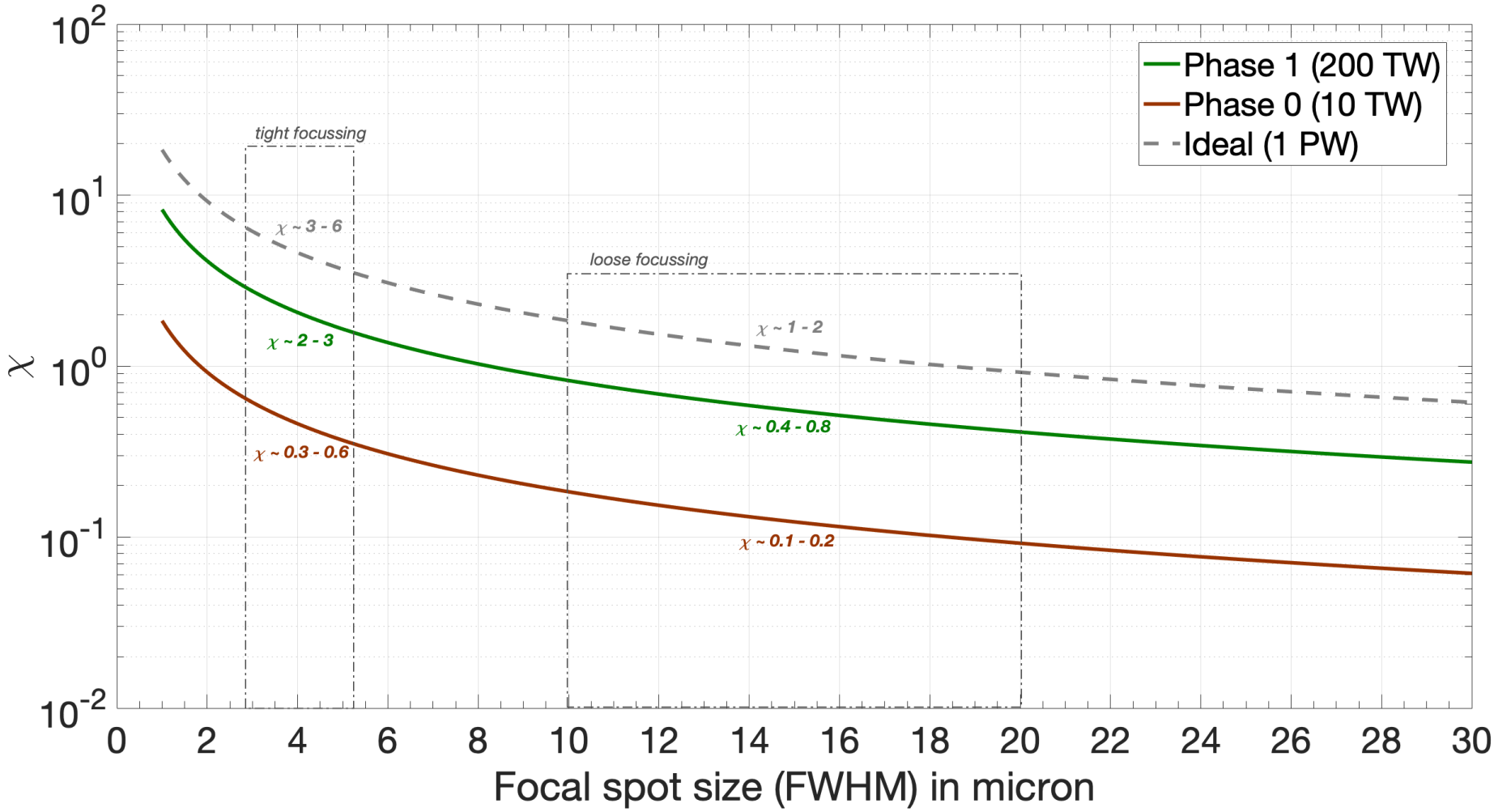
General setup



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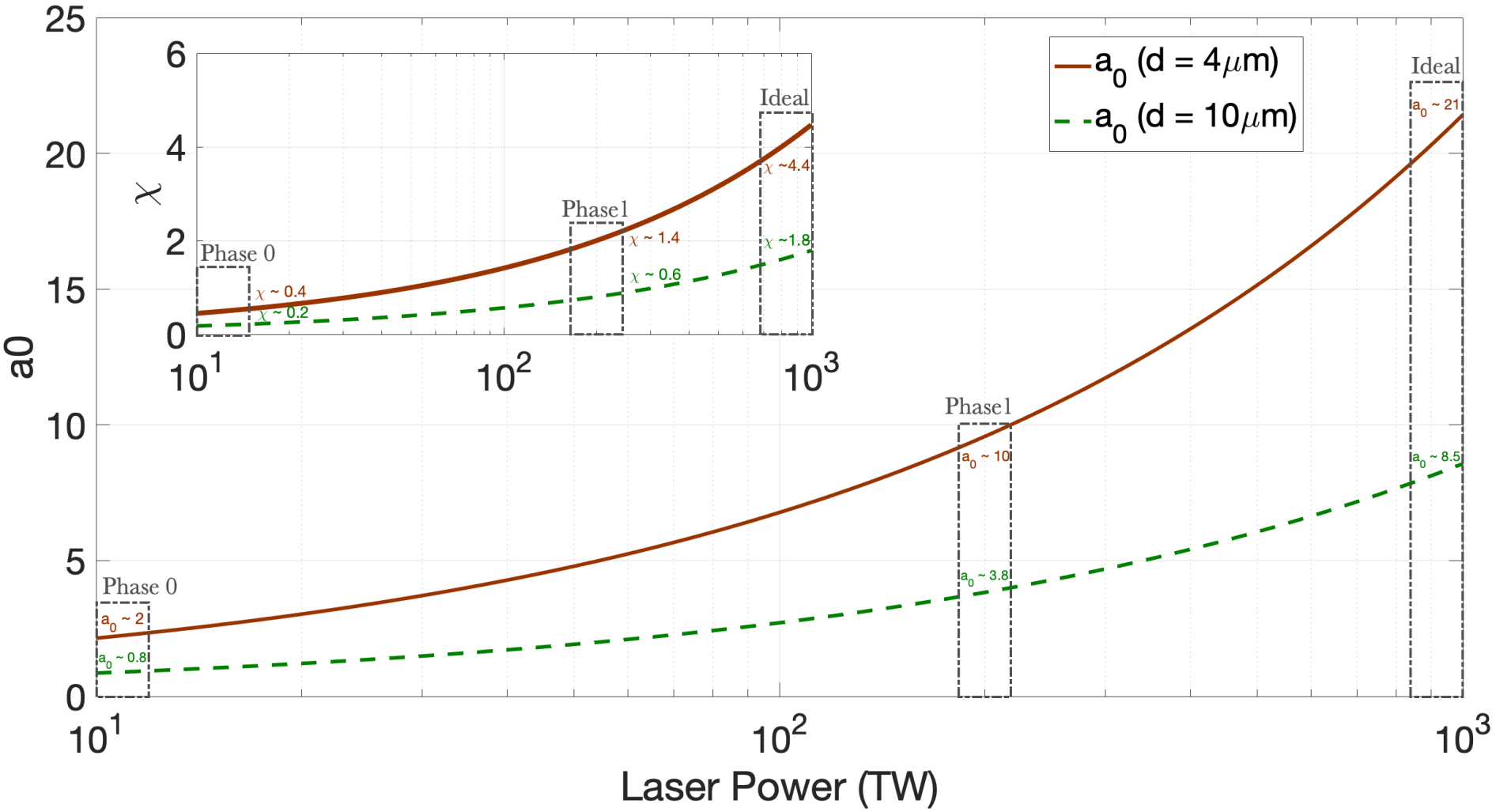
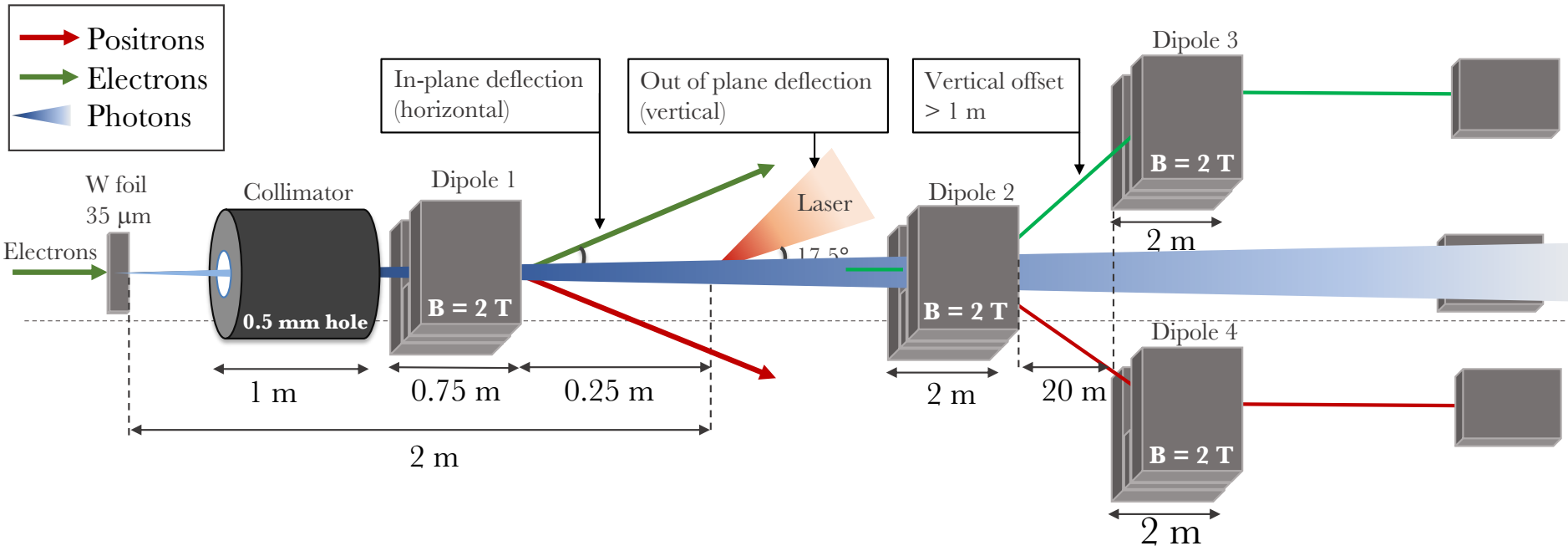


Working with a focal spot with FWHM of 10 μm will never allow $\chi > 1$ for a 200 TW system

Conceptual design (phot – laser)

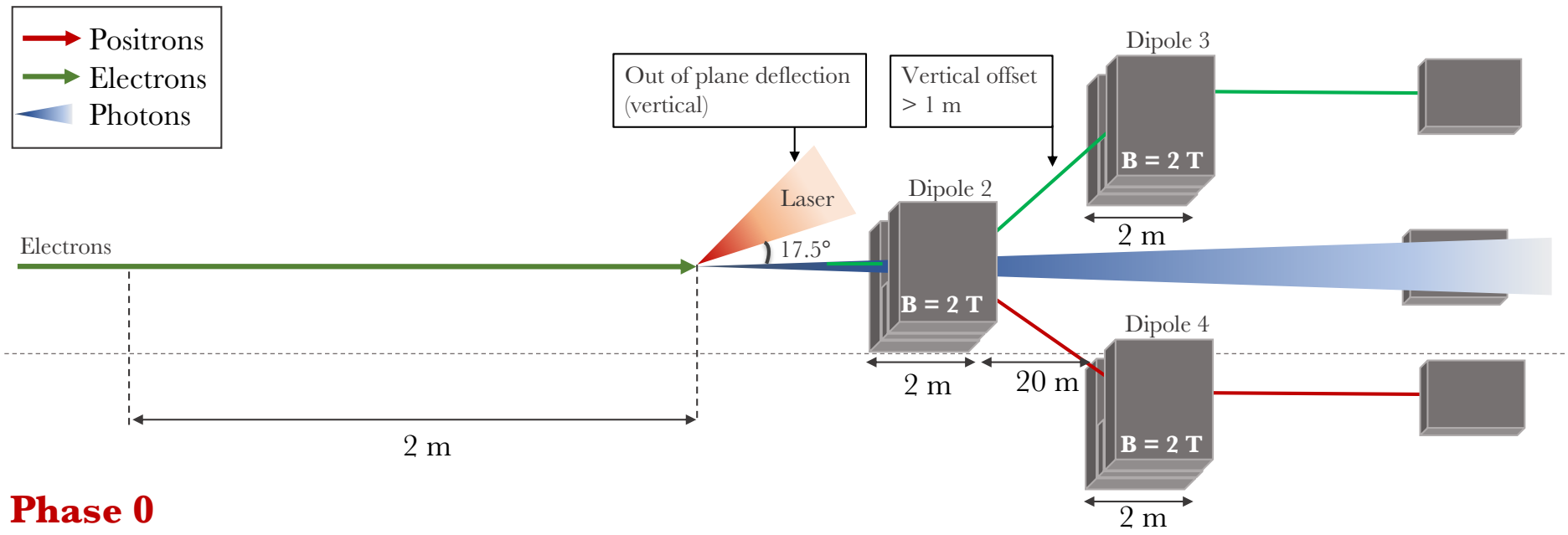


- 2m away from the interaction point, the 10 GeV photons will have a diameter of ~ 100 μm
  d_0 ~ 5 mm, 1/γ (@ 10 GeV) = 50 mrad => d_γ (@ 2m) = 100 mm

- 10 micron laser focal spot ➔ $(10/100)^2$ ~ 1% of the photons interacting with the laser
- 4 micron laser focal spot ➔ $(4/100)^2$ ~ 0.2% of the photons interacting with the laser

Phase 0: P_L=10 TW (2×10^{18} Wcm^{-2}, a_0 ~ 0.7, χ ~ 0.15) ➔ No pairs. However, good test-bed!
Phase 1: P_L=200 TW (4×10^{19} Wcm^{-2}, a_0 ~ 4, χ ~ 0.7) ➔ ~ tens of pairs per shot
Phase 2: P_L=1 PW (2×10^{20} Wcm^{-2}, a_0 ~ 7, χ ~ 1.5) ➔ ~ hundred pairs per shot

Conceptual design (e^- – laser)



Phase 0

- If we remove the collimator, dipole 1, and the tungsten foil, we can study electron-laser collisions
- In this case, we can assume the electron beam diameter to be 5 μm, so we can focus more tightly and achieve an intensity > 10^{19} Wcm^{-2} ($a_0 \sim 1-2$, $\chi \sim 0.2$). Effectively, a re-make of the E144 experiment
- Still hard to detect pairs (~0.1 per shot). However, not impossible. In Gemini, we can detect ~ 5 pairs in 30 shots
- We can also do detailed studies of radiation reaction and stochastic photon emission.

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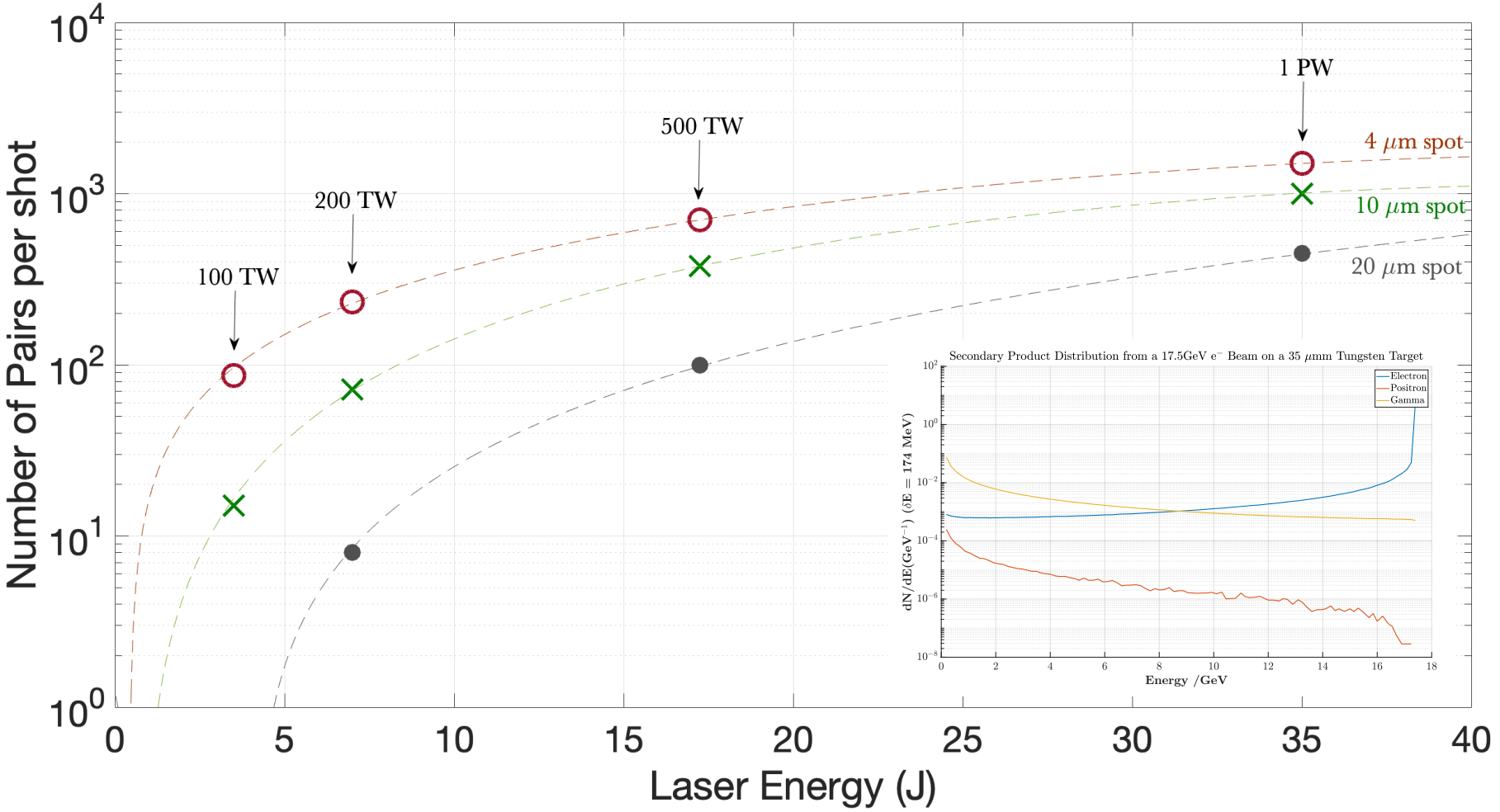
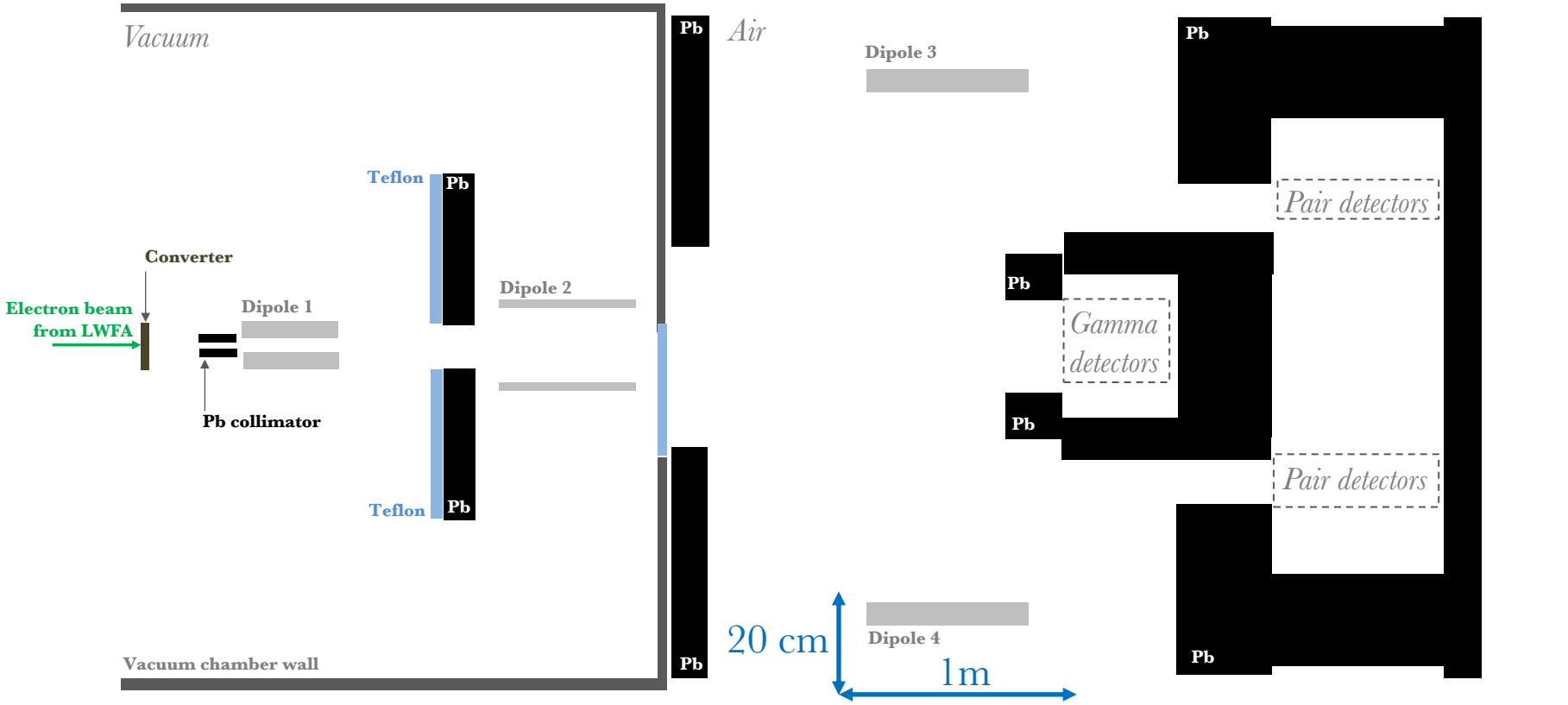
Estimates



Assuming a 200 TW laser and 6x10^9 primary electrons, we need a S/N better than 10^8 at the detectors

Noise estimates Gemini

TOP VIEW (in scale):



Main sources of noise:

- secondary pairs from the converter
- effective dumping of the primary γ-ray beam
- laser light
- interaction of secondaries with magnets and apertures

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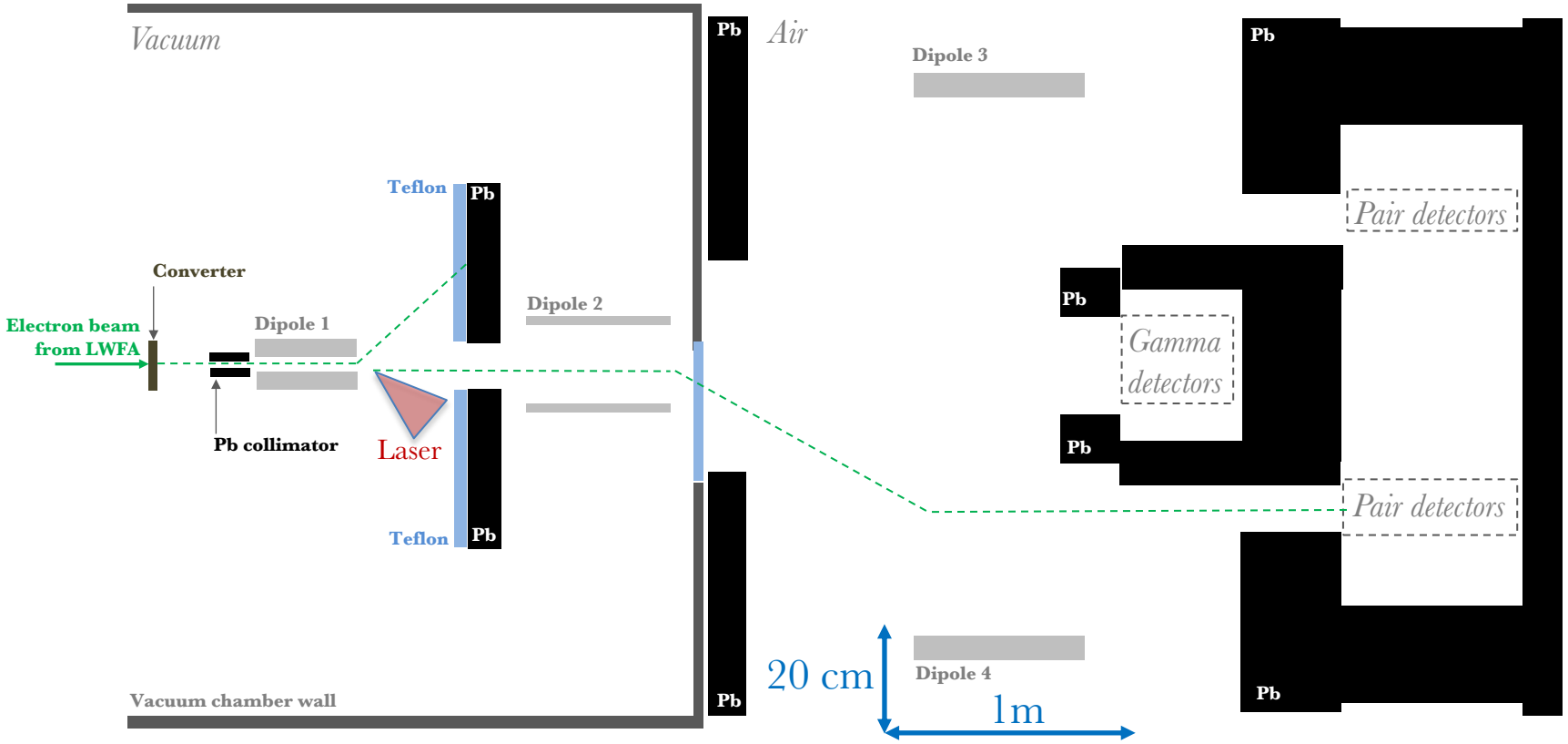

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Positrons
Electrons
Photons

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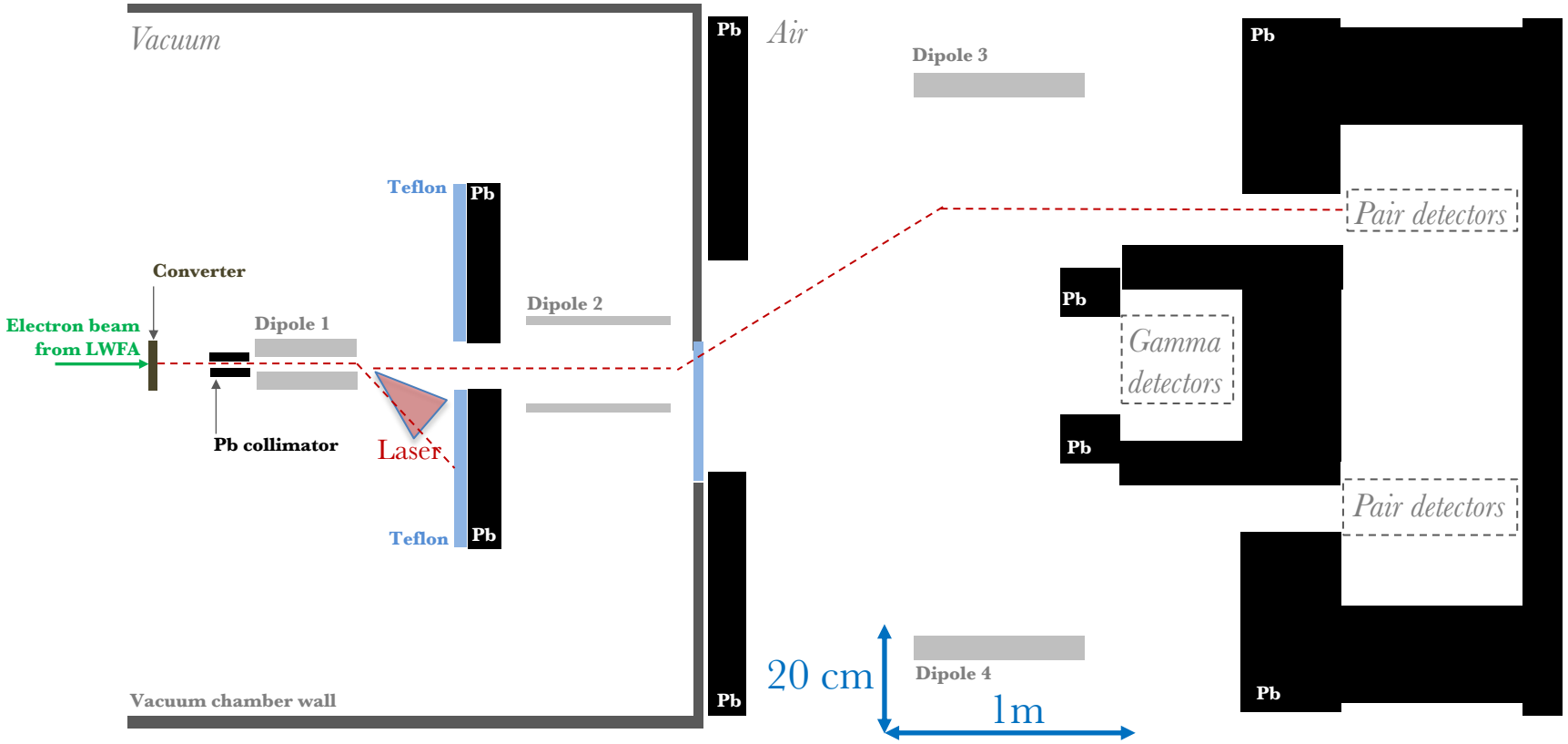

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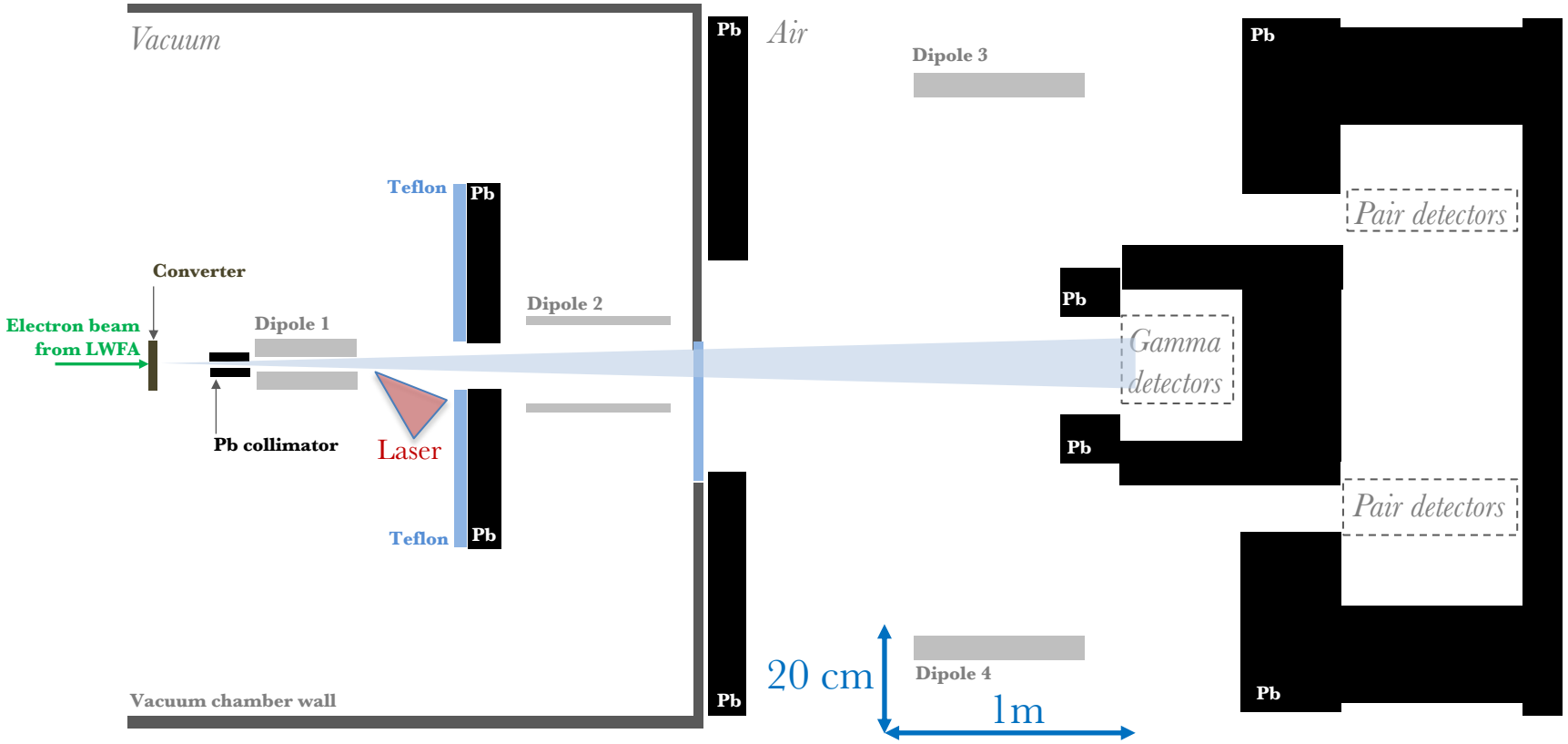

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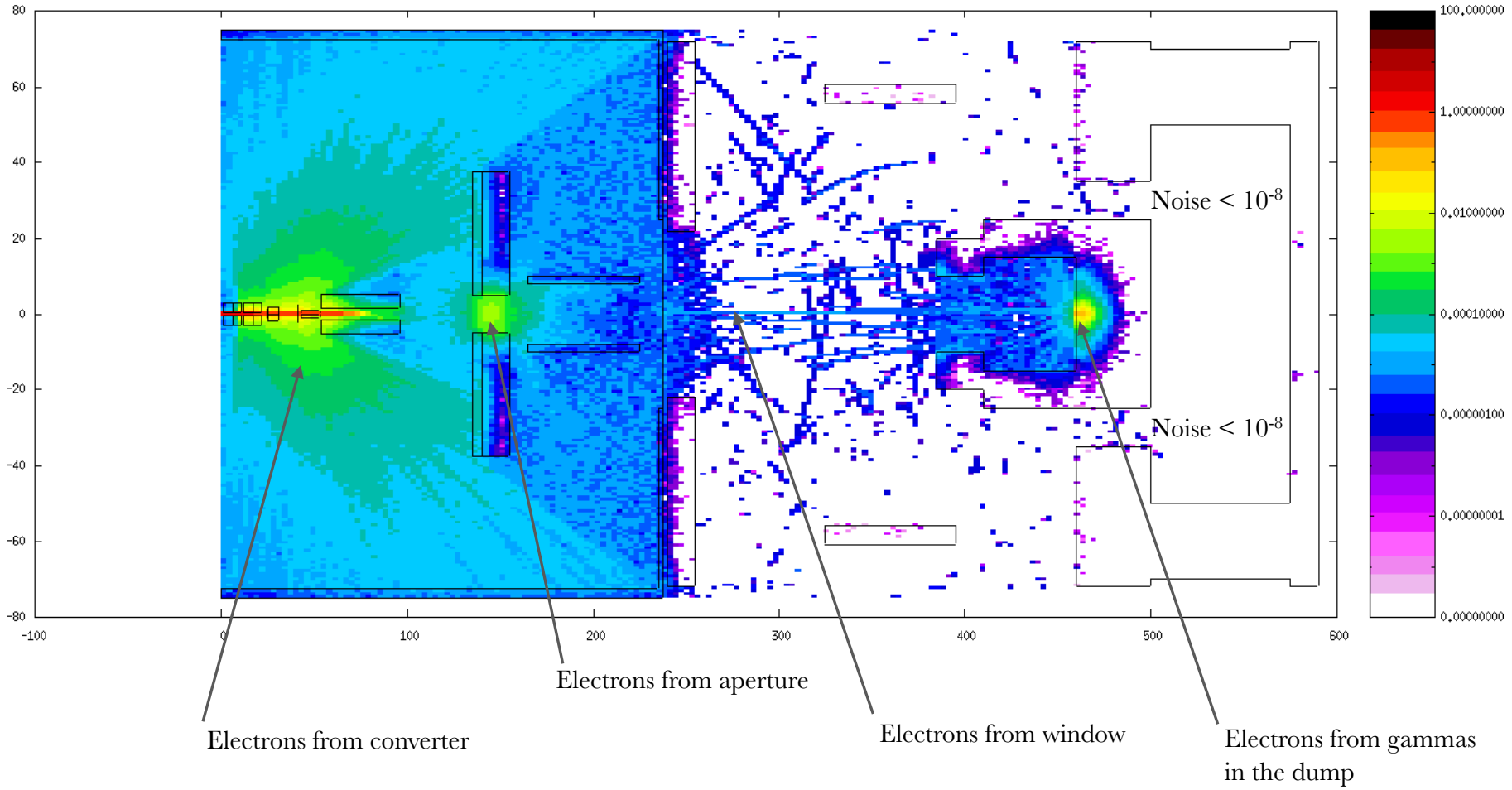
Electron MAP (top view)



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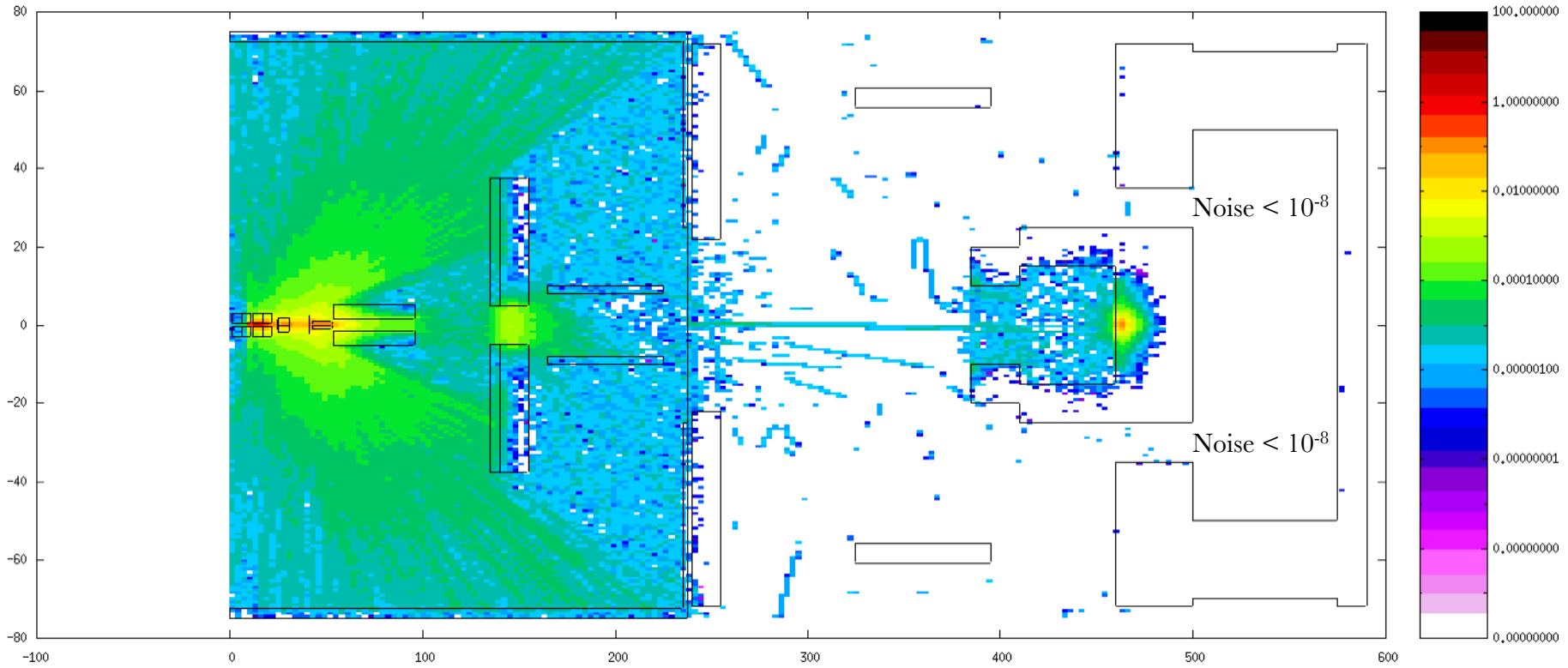
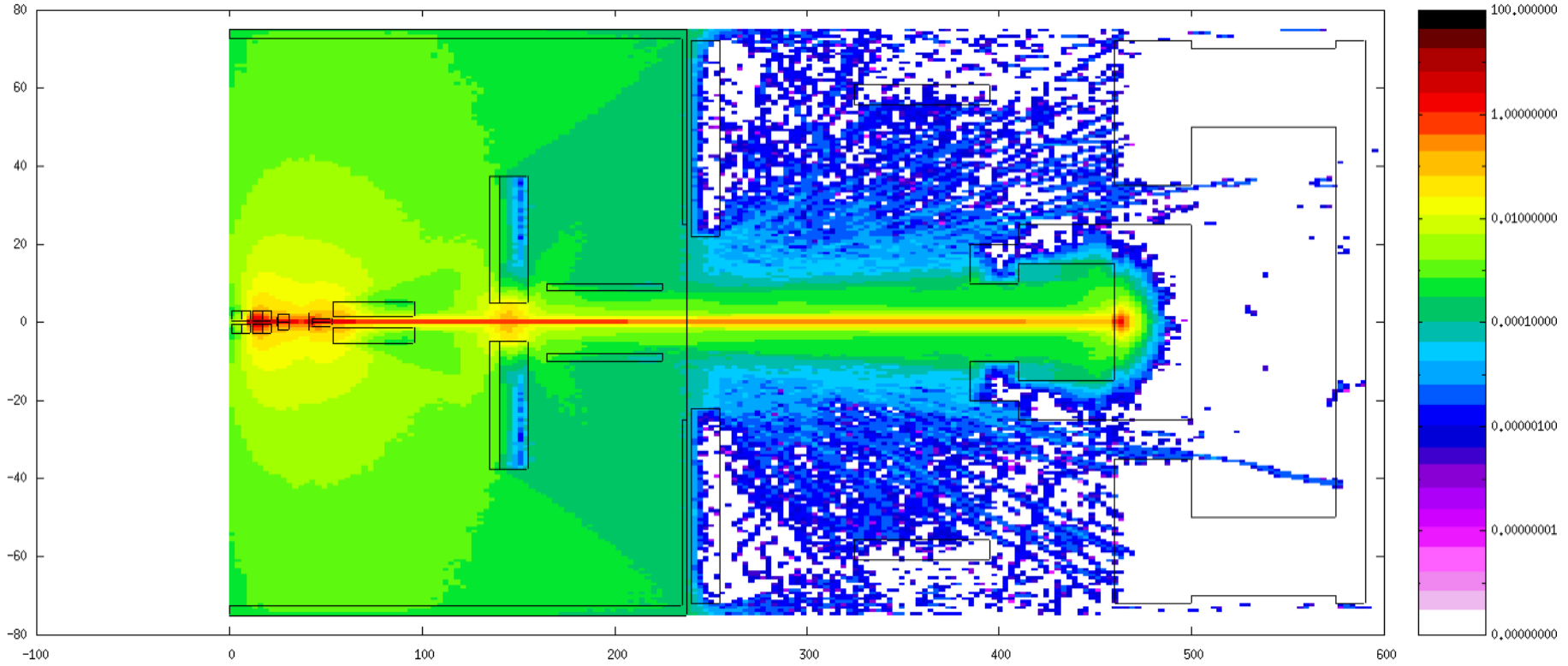
Positron MAP (top view)



Noise estimates Gemini

Photon MAP (top view)



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Conclusions

- Photon-laser interaction should be ~2m downstream of the tungsten foil
- For that to work, we need a rather strong magnet (~1.5 Tm) and a collimator
- 2m downstream, the photon beam has a diameter of approximately 100 microns

- In tight focus (4 micron) only 0.2% of the photons interact with the laser
- In a looser focus (10 micron) only 1% of the photons interact with the laser

- In phase 0 (10 TW), negligible amount of pairs. They only become detectable at 200 TW (10s of pairs per shot) but it is at 500 TW or more than they become significant (100s to 10^3 per shot)

- Assuming 600 pC electron beam, we need a S/N ratio better than 10^8. This was achieved in the Gemini experiments (2GeV electrons)