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EuPRAXIA

# WP6 Report: FEL considerations on the 5 GeV beam

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# The 5 GeV beam from INO

Phase space provided by P. Tomassini, obtained with the laser schemes from L. Gizzi, P. Tomassini *et al.*

INO-CNR
Istituto Nazionale di Ottica

## Electron Beam

| | | | |
|---|---|---|---|
| Peak current | $I_{peak} := 1716A$ | | |
| Beam Energy | $E := 4932.17 \cdot MeV$ | $\gamma := \frac{E}{m_0 \cdot c^2}$ | $\gamma = 9652.014$ |
| Energy spread | $\sigma_\gamma := \gamma \cdot 8.58 \cdot 10^{-3}$ | | |
| Emittances (normalized) | $\varepsilon_x := 0.152 \cdot mm \cdot mrad$ | | $\varepsilon_y := 0.15 \cdot mm \cdot mrad$ |

## Undulator Scheme A: PMU - gap = 5 mm

Type

Period length $\lambda_u := 1.4 \cdot cm$

Strength (RMS) $K := \frac{0.93 \cdot \frac{\lambda_u}{cm}}{\sqrt{2}}$ $K = 0.921$

Resonance $\frac{\lambda_u}{2 \cdot \gamma^2} \cdot \left(1 + K^2\right) = 0.139 \cdot nm$

**1.39 Å**

## Undulator Scheme B: Cryo - gap = 3 mm

Type $IWITYP := 0$

Period length $\lambda_u := 1.6 \cdot cm$

Strength (RMS) $K := \frac{1.75 \cdot \frac{\lambda_u}{cm}}{\sqrt{2}}$ $K = 1.98$

Resonance $\frac{\lambda_u}{2 \cdot \gamma^2} \cdot \left(1 + K^2\right) = 0.422 \cdot nm$

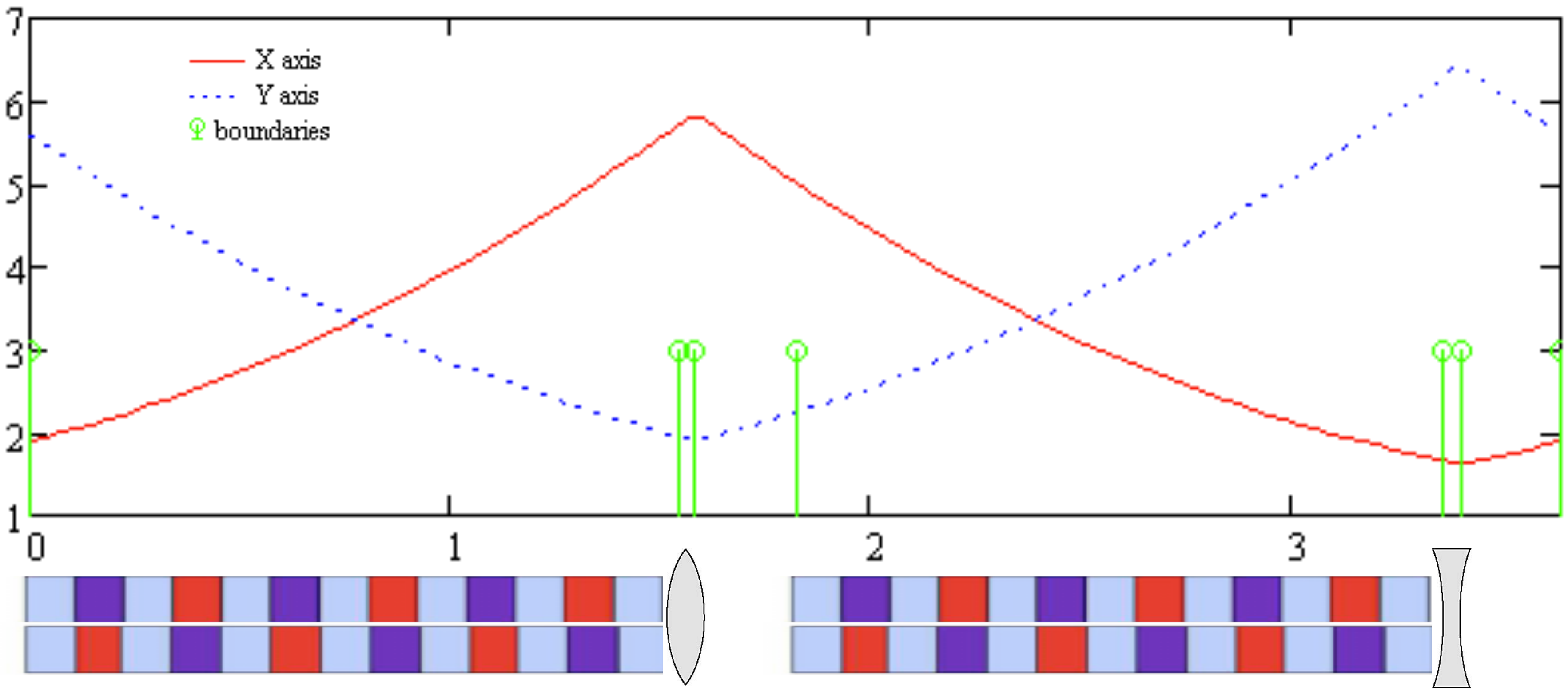
**4.22 Å**

# Undulator matching strategy

NWIG = 110    # of undulator periods

$\lambda_u$ = 1.4, 1.6 cm   $L_{u\_} := \lambda_{u\_} \cdot NWIG$   $L_u$ = 1.5, 1.8 m

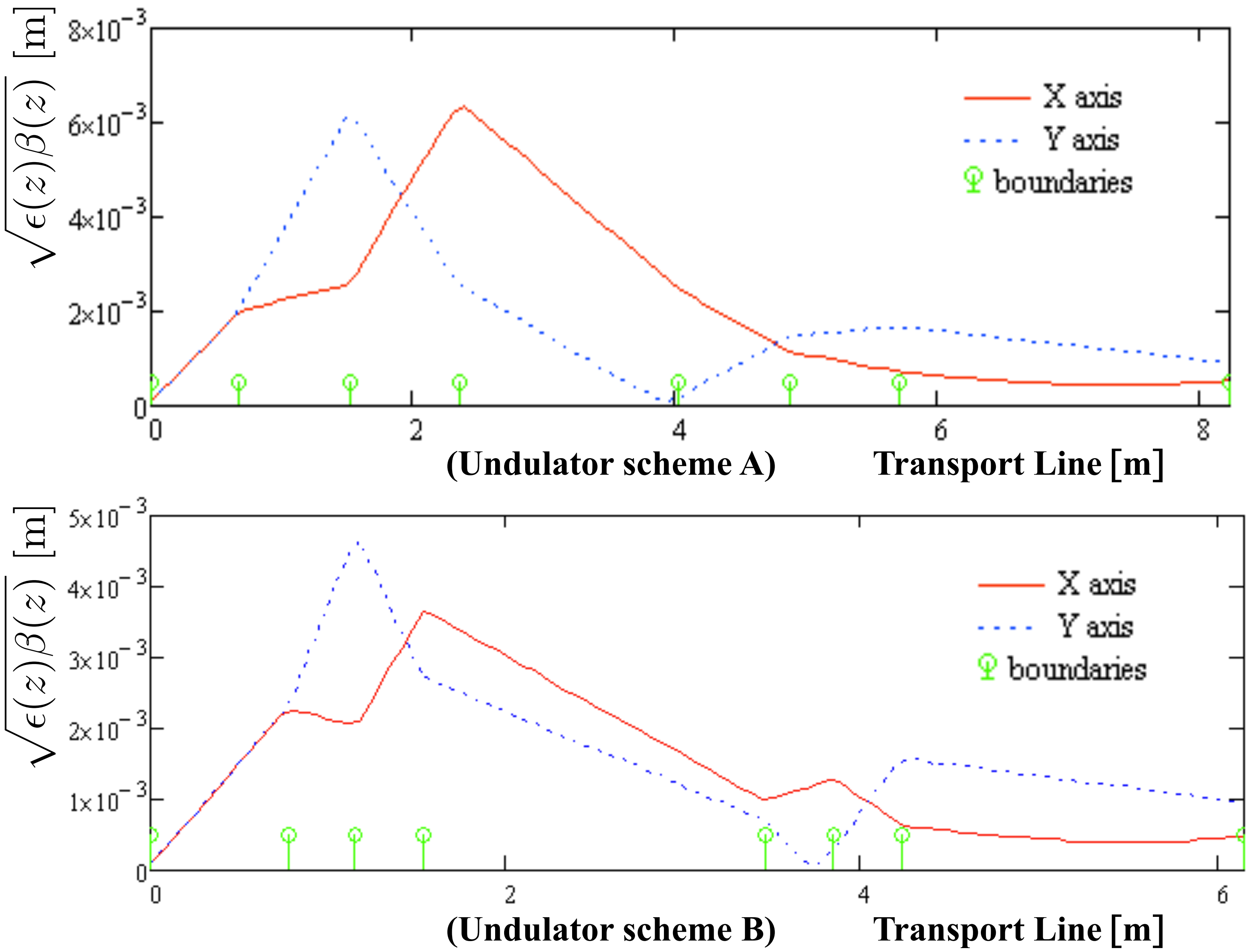
optical prop.   $h_x = -0.04$   $h_y = 2.04$



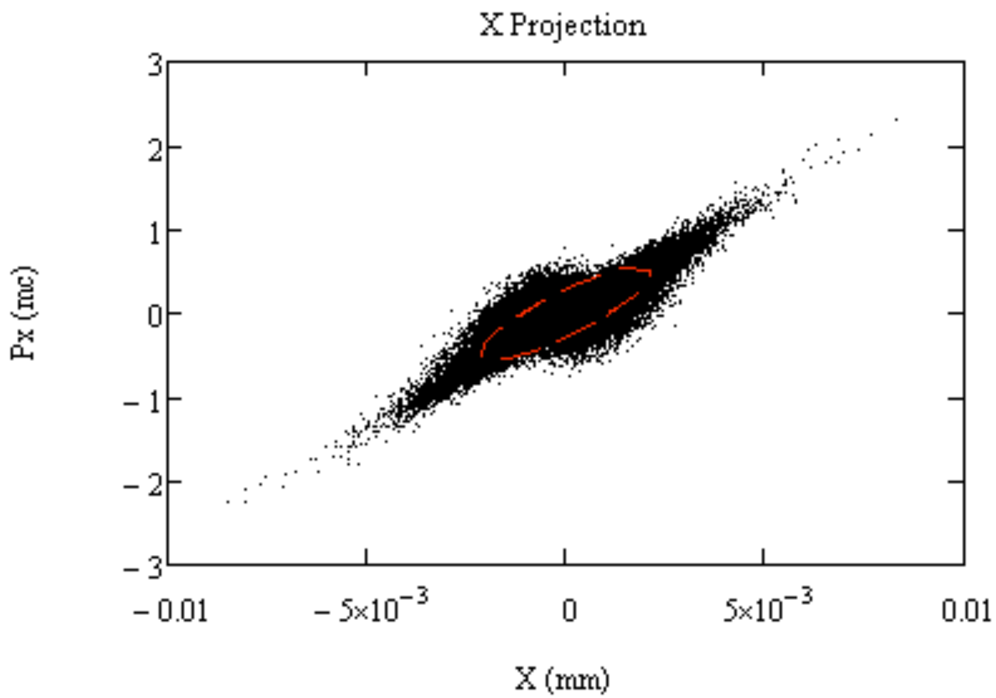

**Constraint: equal average β in x and y** $\langle \beta_X \rangle = \langle \beta_Y \rangle = 3.5\ \mathrm{m}$

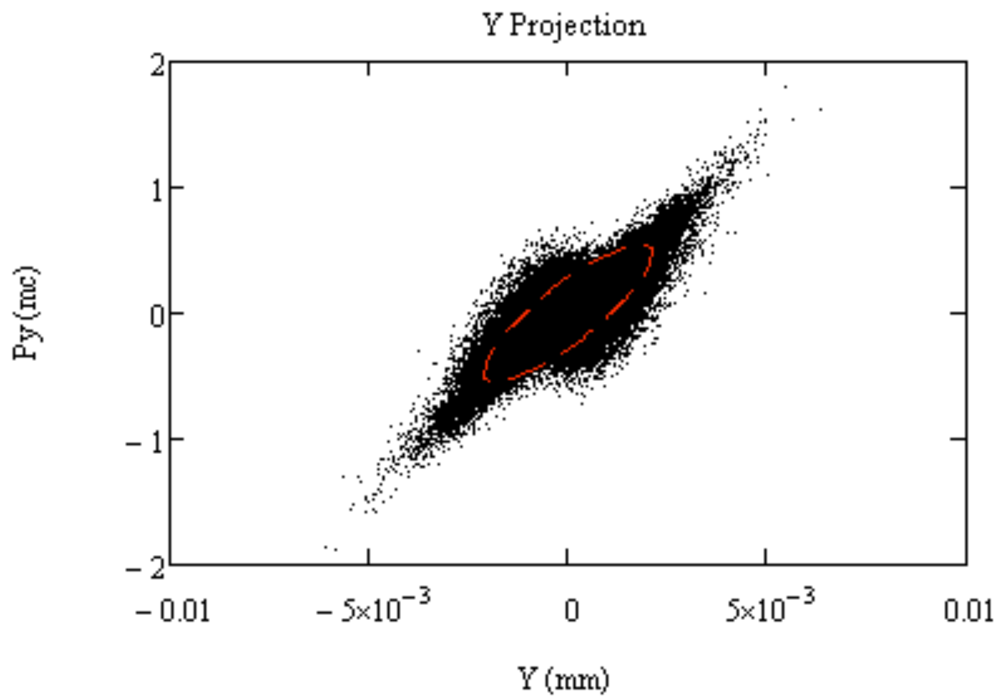
# Transport optics

The initial e-beam is transferred through a triplet of quadrupoles to match the Twiss parameters at the undulator entrance, in both cases



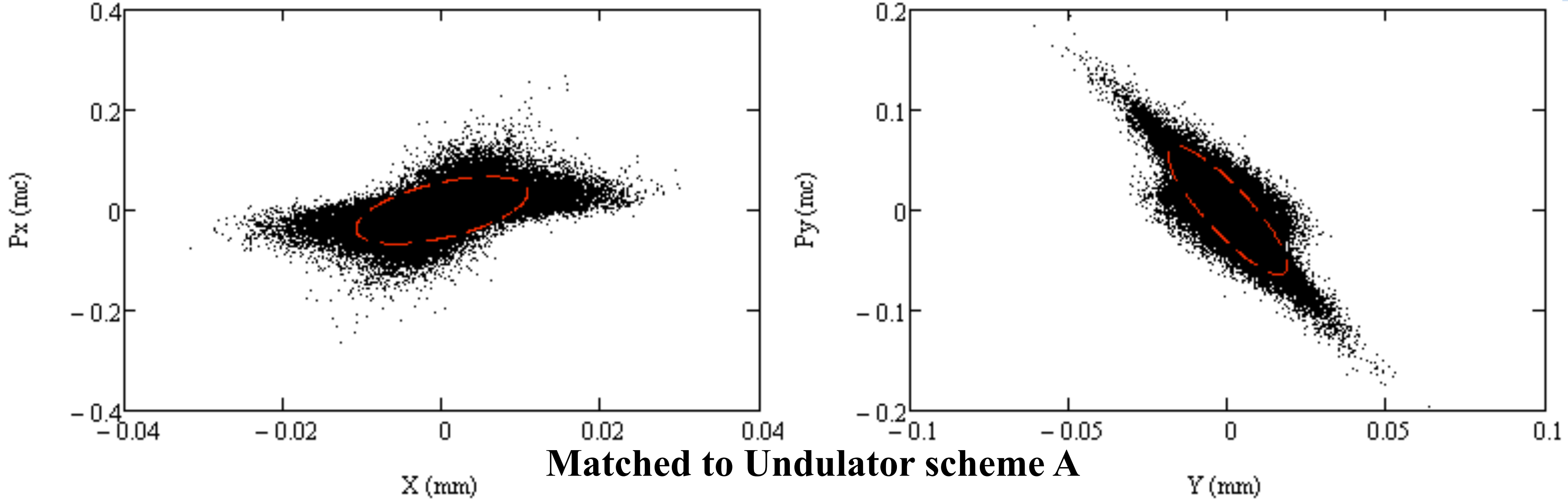
# Transverse profile before transport



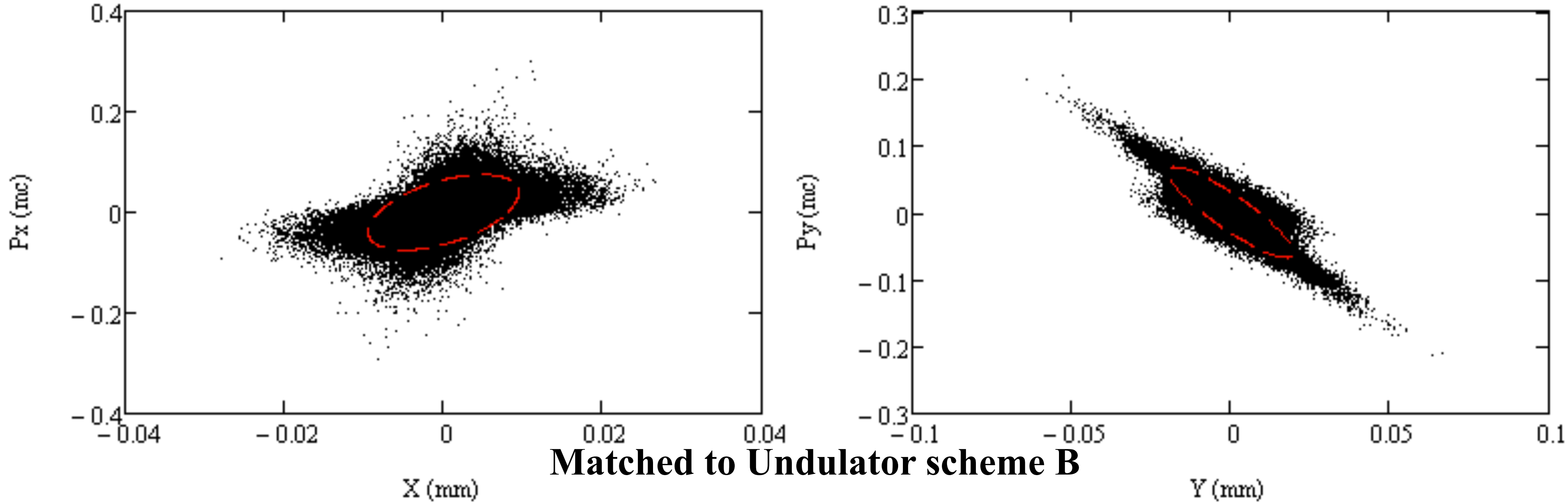




After transport, the e-beam phase space (~ 124k macroparticles, 10 pC) is implemented **S2E** particle-wise in **Genesis** (no Gaussian assumption) and driven into the undulator sections (~ 100 meters of full undulator + FODO chain)

# Transverse profile after transport

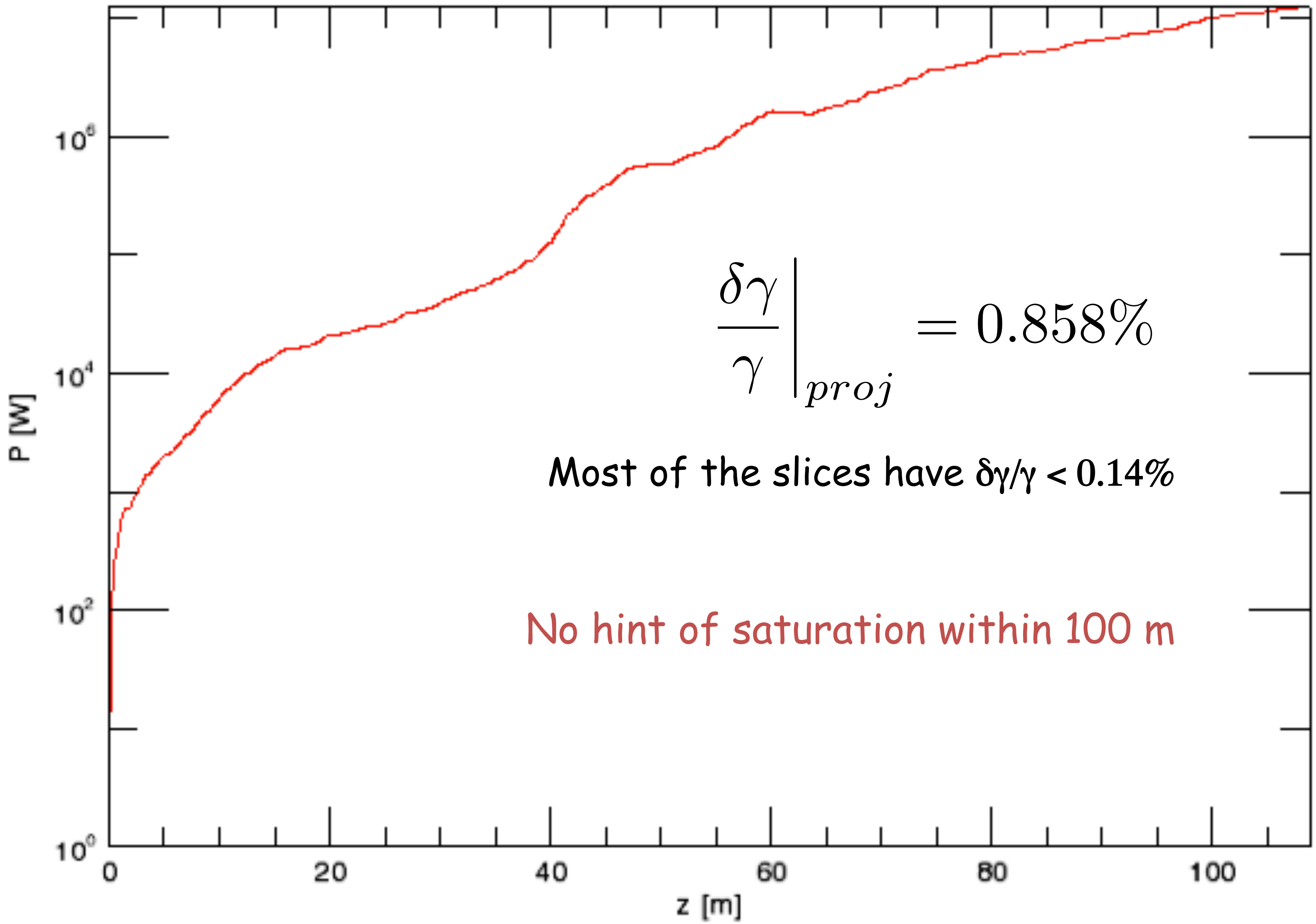



**Matched to Undulator scheme A**




**Matched to Undulator scheme B**

# FEL power growth: 1.39 Å target



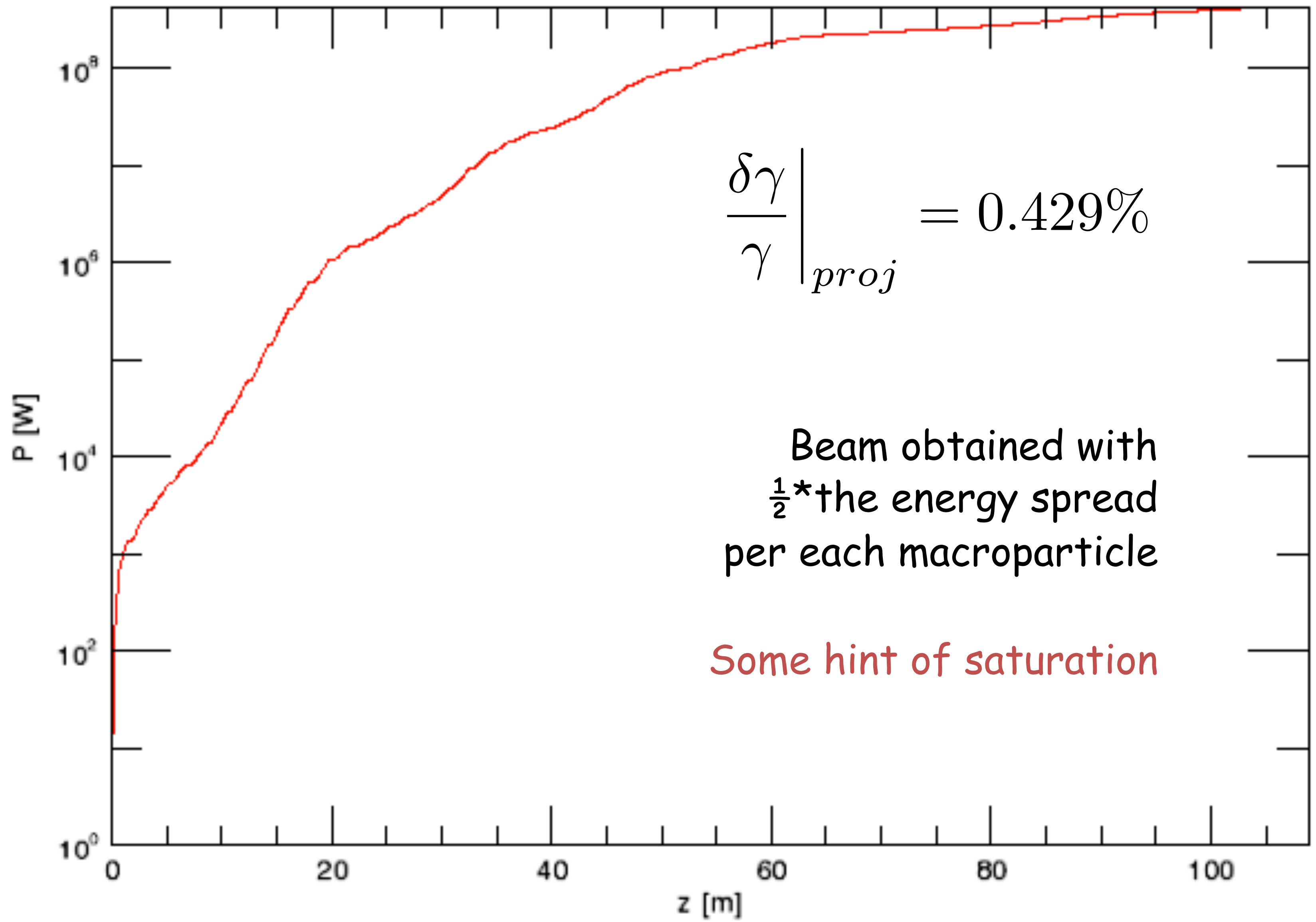

$$\left.\frac{\delta\gamma}{\gamma}\right|_{proj} = 0.858\%$$

Most of the slices have $\delta\gamma/\gamma < 0.14\%$

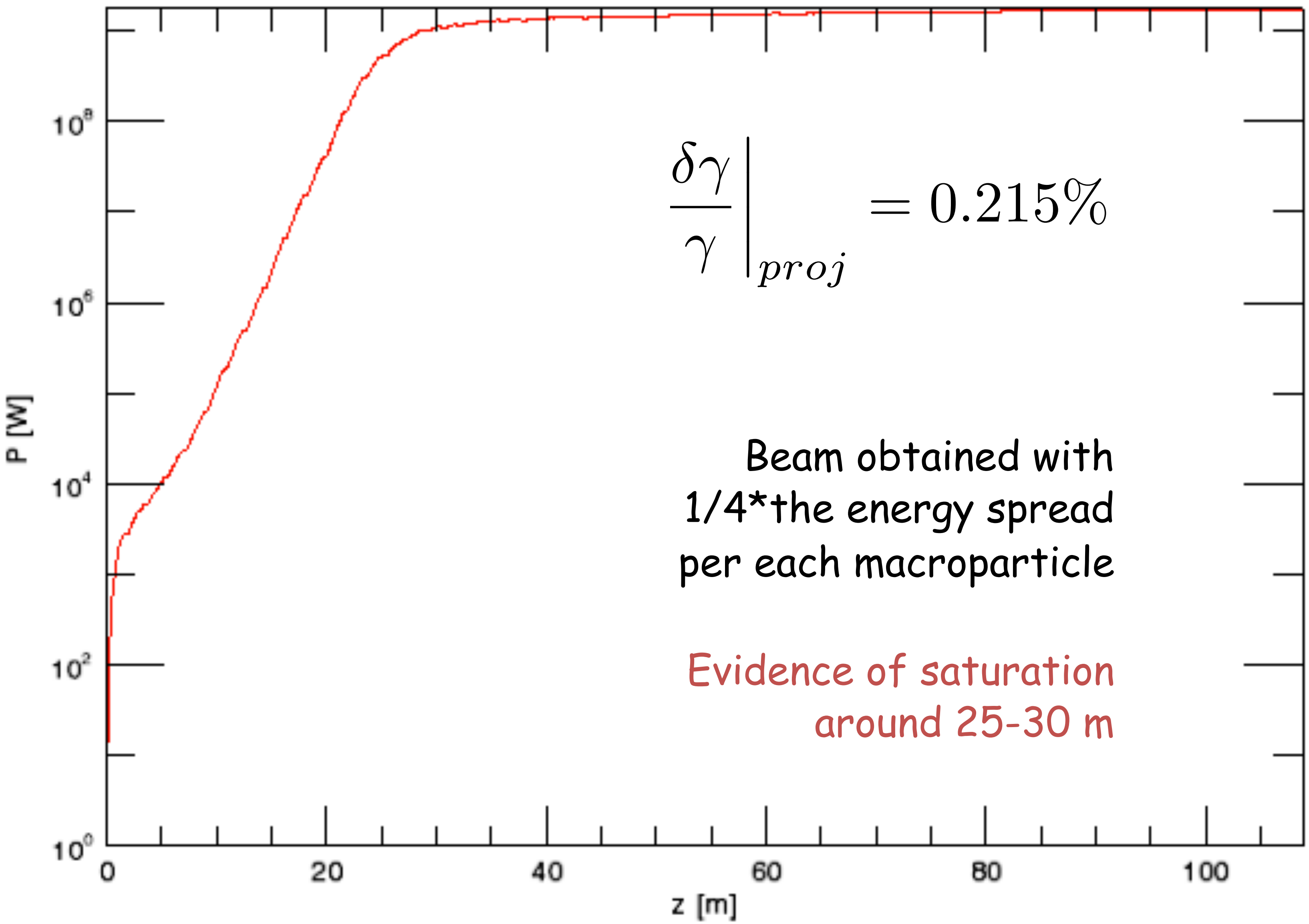
No hint of saturation within 100 m

# FEL power growth: 1.39 Å target





# FEL power growth: 1.39 Å target

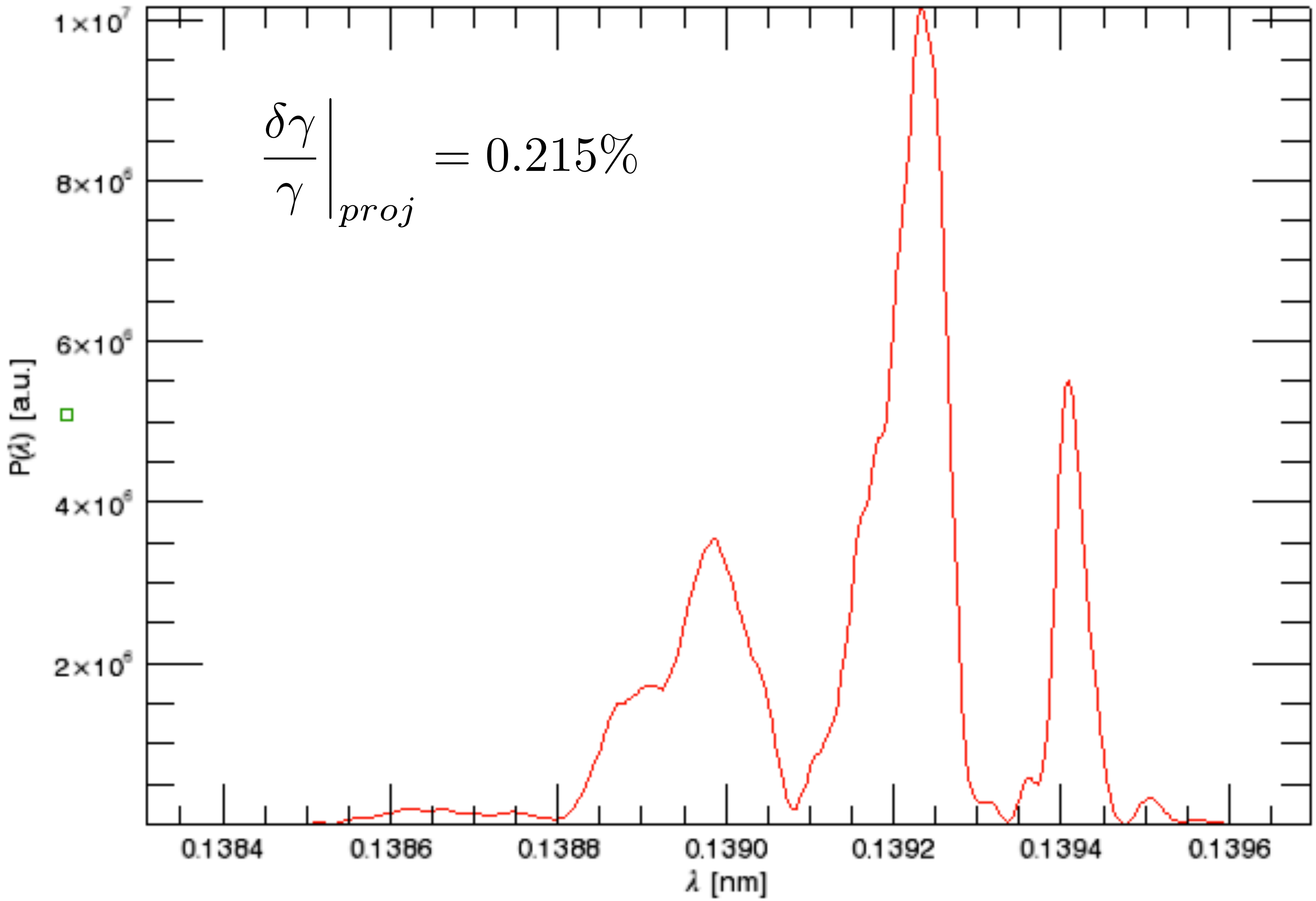



$$\left.\frac{\delta\gamma}{\gamma}\right|_{proj} = 0.215\%$$

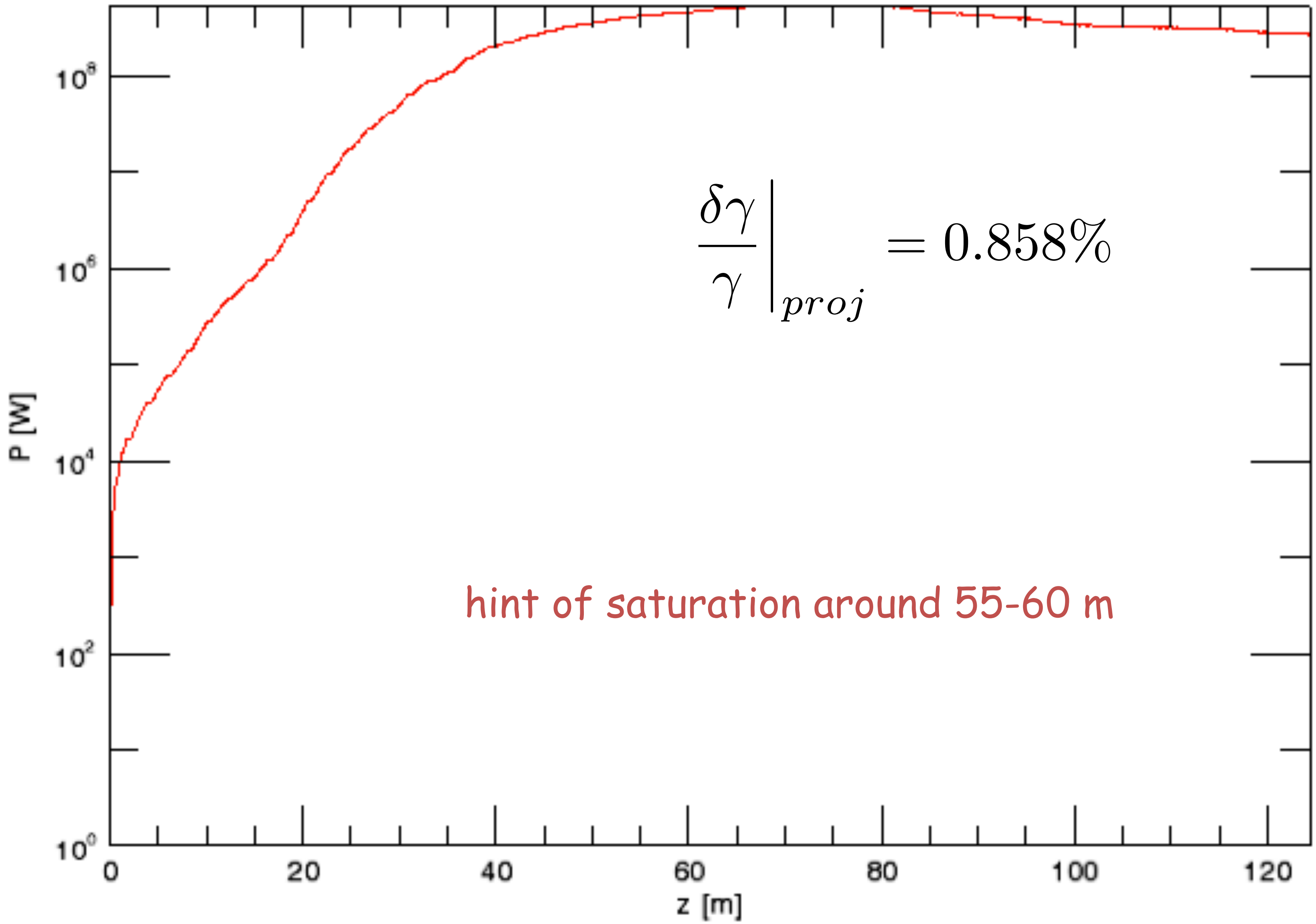
Beam obtained with
1/4*the energy spread
per each macroparticle

Evidence of saturation
around 25-30 m

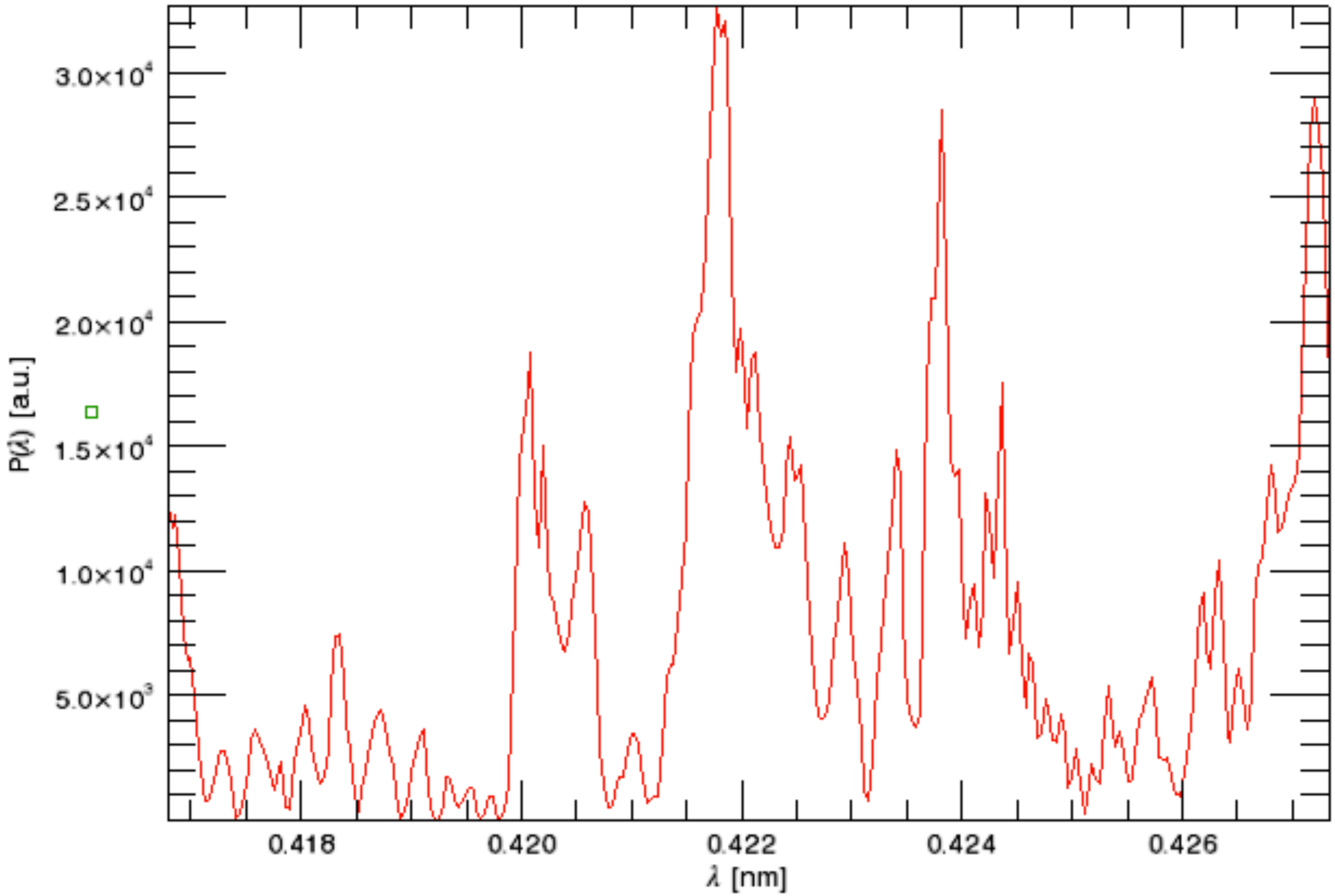
# FEL spectrum @ z ~ 26 m



# FEL power growth: 4.22 Å target



# FEL spectrum @ z ~ 54.4 m



# Outlook: food for discussion

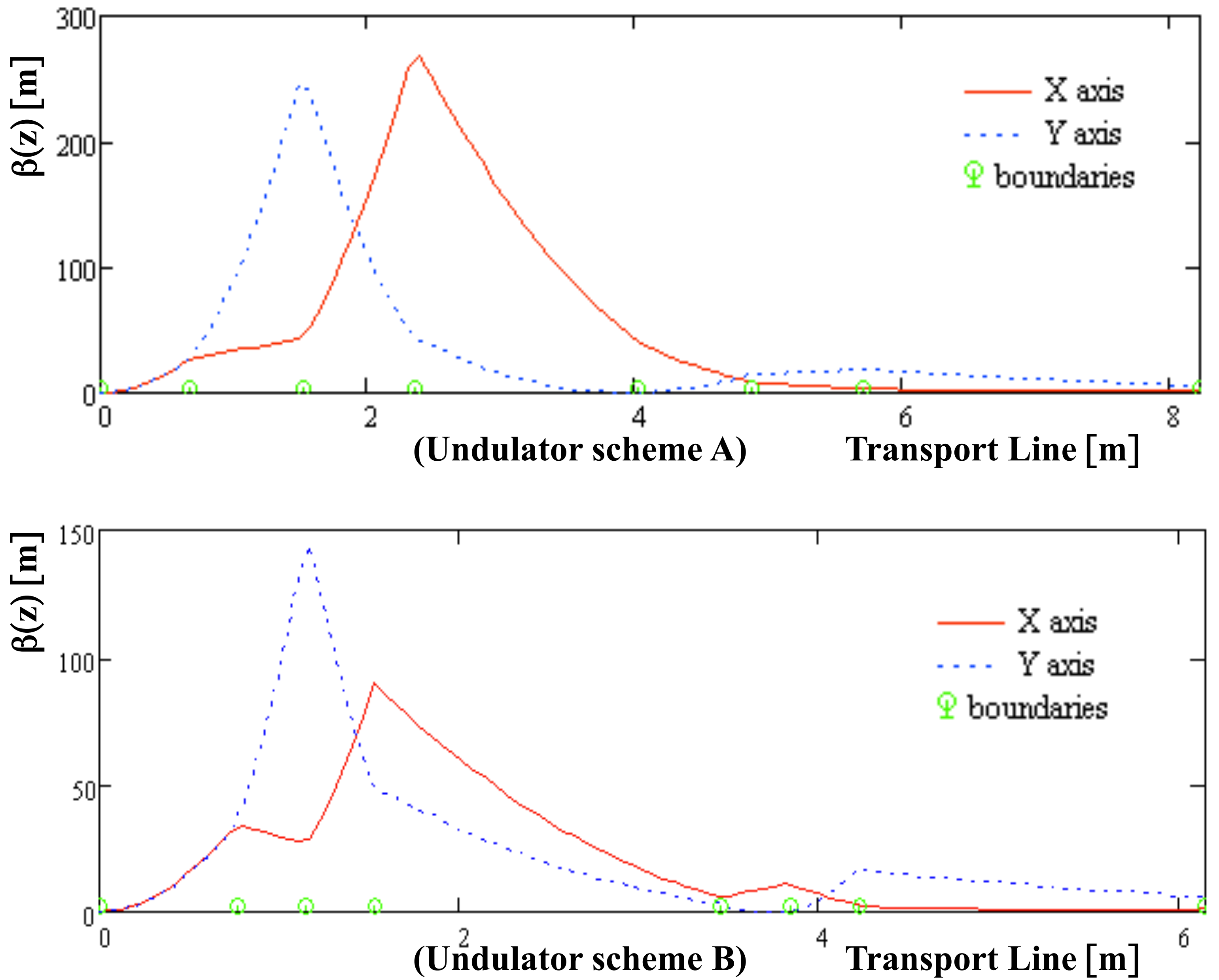
Horizon 2020

- targeting the 1 Å realm requires either a super-dream-beam, ~ 0.2% projected energy spread, or something else (e.g. the magnetic chicane á la Soleil)
- issues introduced with the magnetic chicane yet to be investigated (e.g. net loss of charge after the chicane, microbunching instability), and then… how compact?
- 4 Å within apparently easier reach with a ~ 5 GeV beam
- in progress: analysis of the LOA 1 GeV LWFA e-beam
- Vexata Quaestio: which way for a compromise? stretch the facility size or the $\lambda_{FEL}$ wavelength?

Please, stay FEL-tuned!

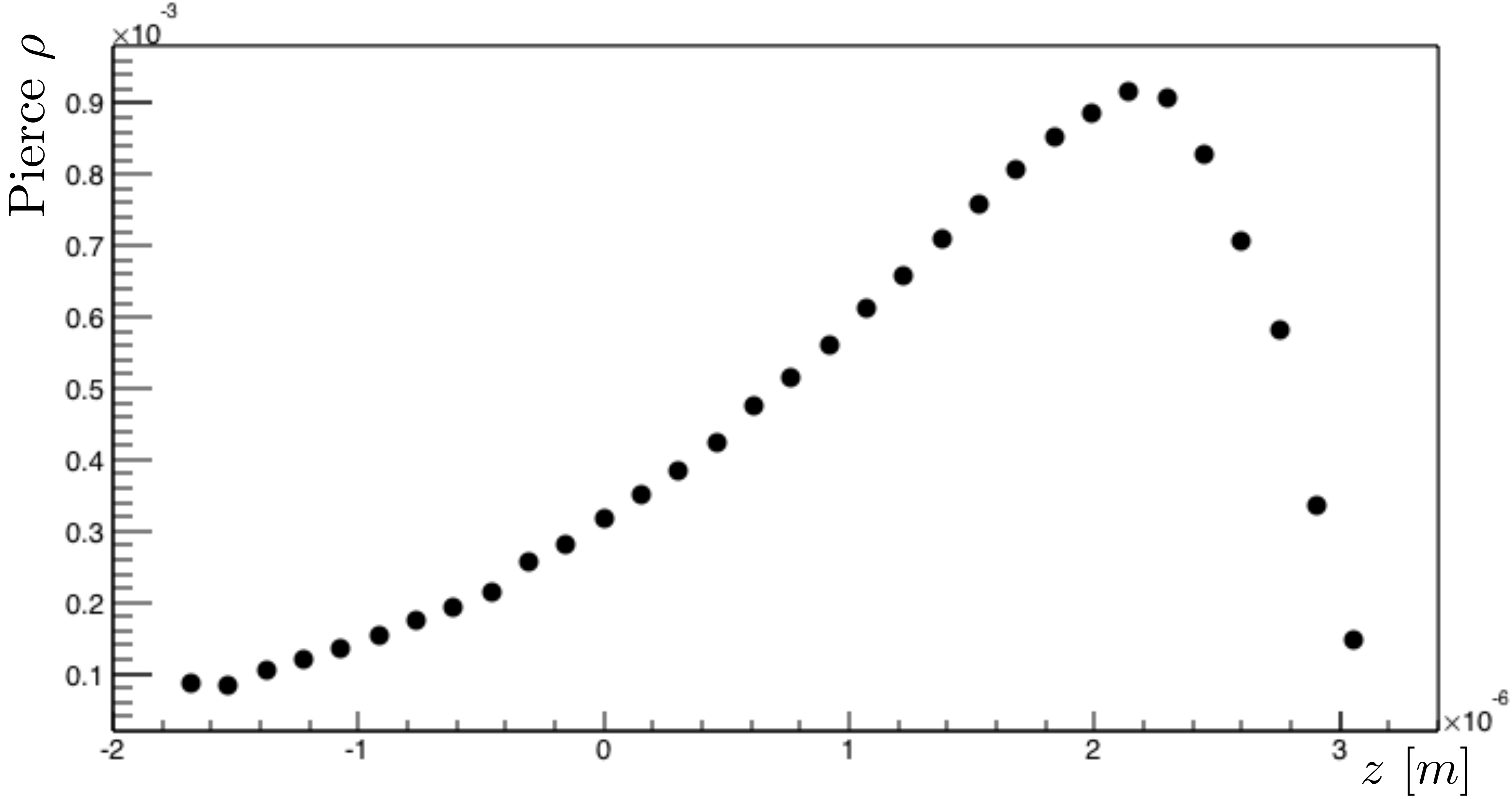
# Transport optics (I)

The initial e-beam is transferred through a triplet of quadrupoles to match the Twiss at the undulator entrance, in both cases



# For discussion





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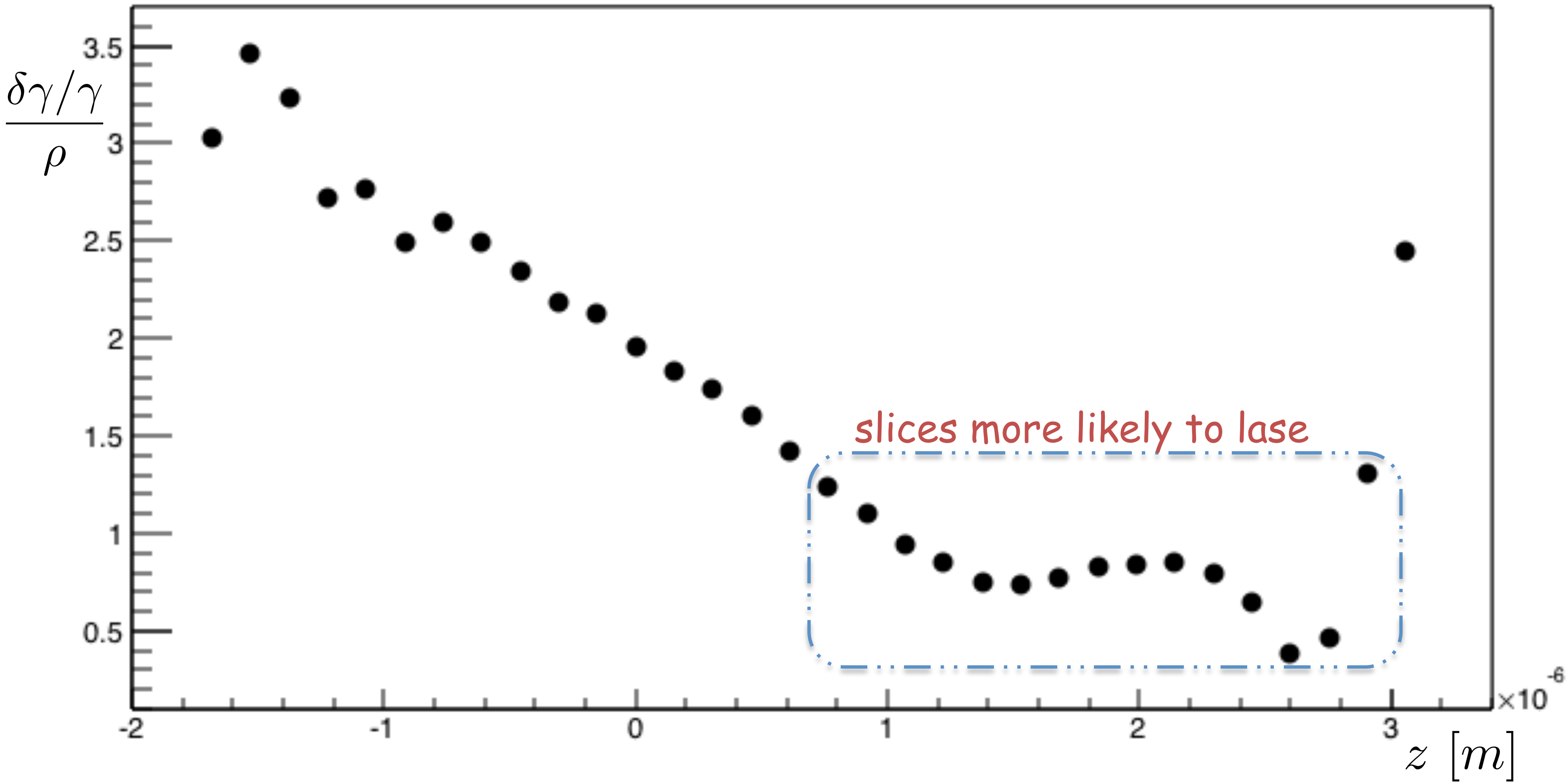

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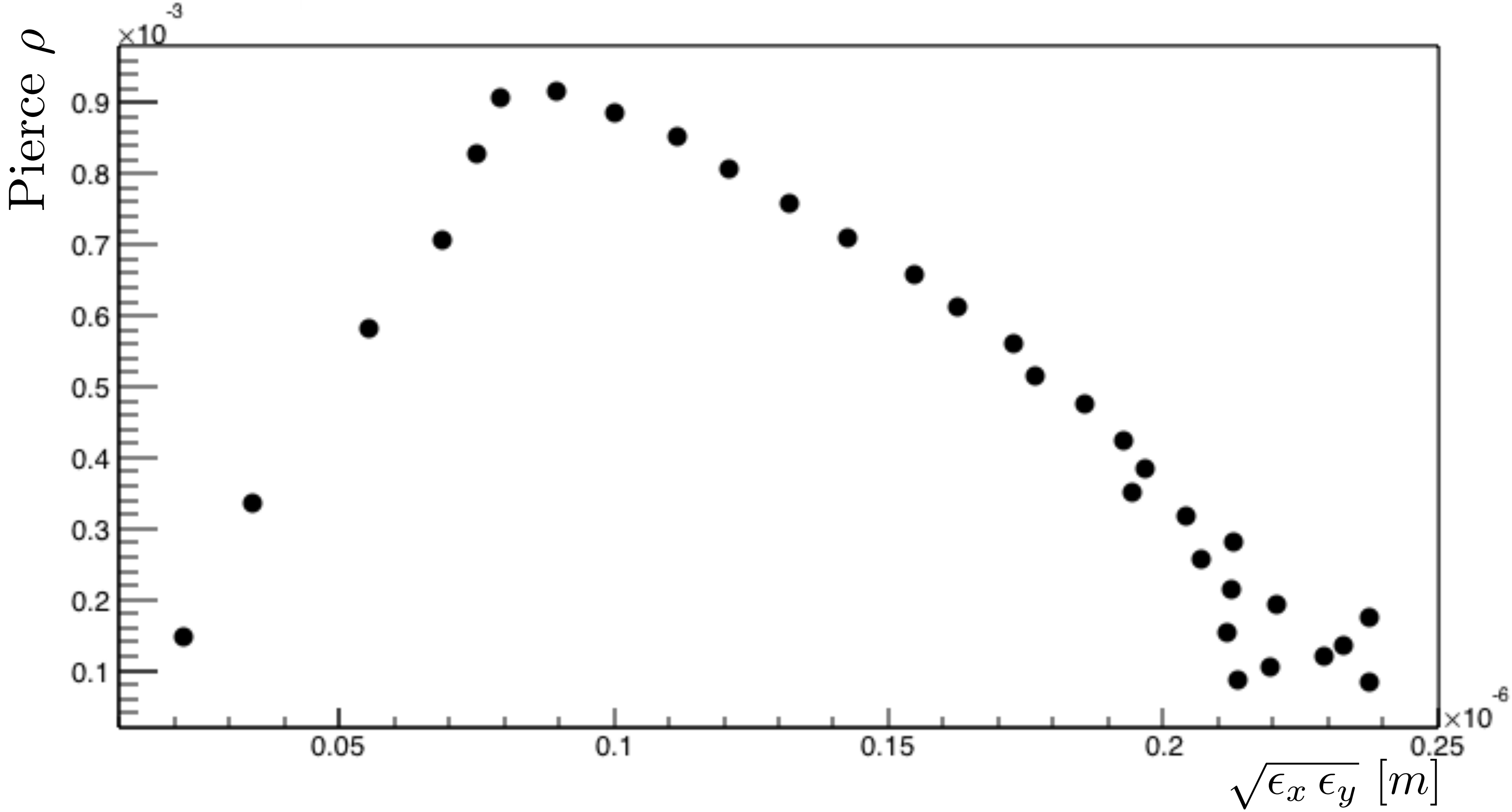
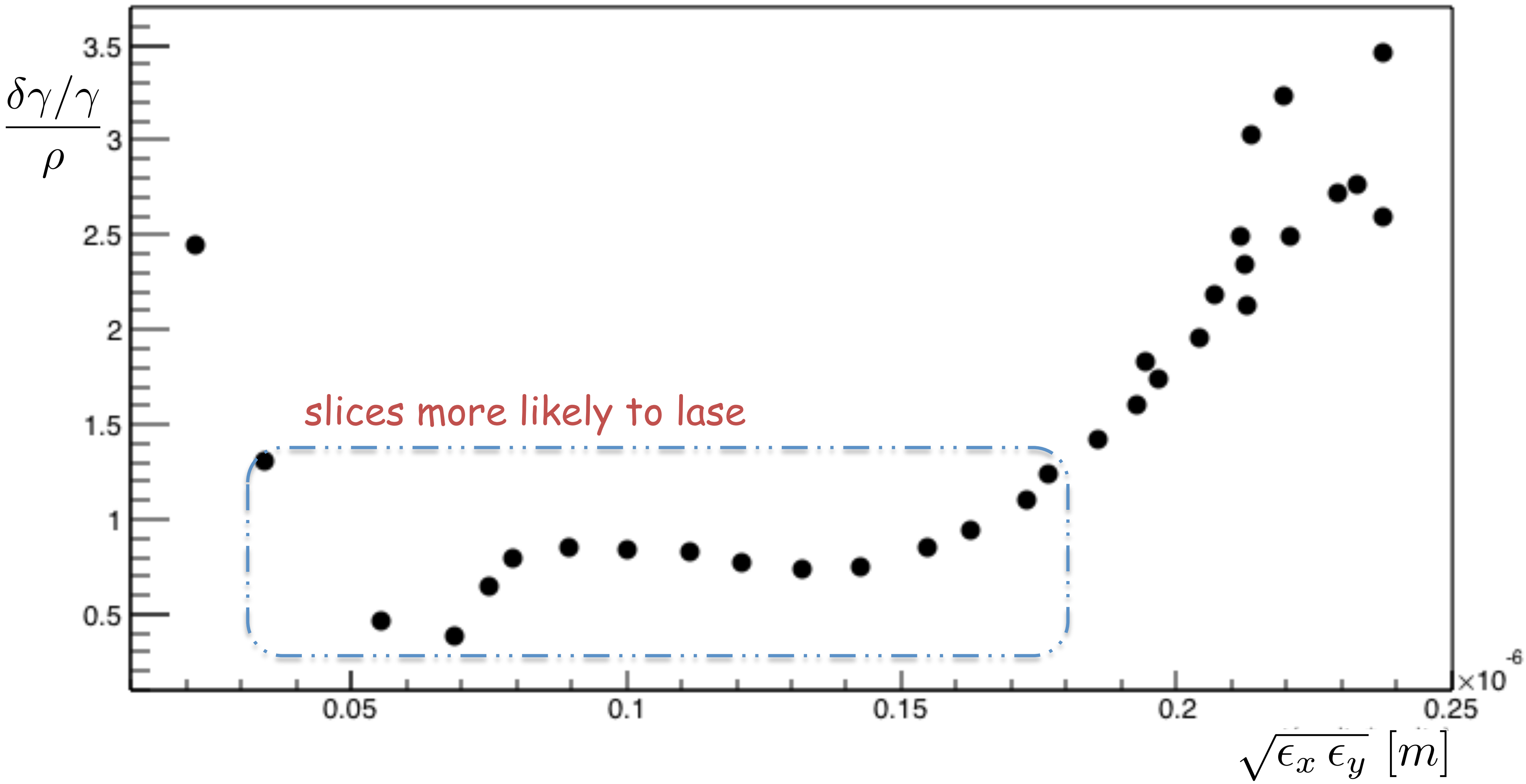


# For discussion



# Consortium

Horizon 2020

## 16 Participants

## 24 Associated Partners

*(as of December 2017)*

# Participating Institutions

Horizon 2020

**Associated Partners**
***(as of December 2017)***

1 **Shanghai Jiao Tong-University**, China
2 **Tsinghua University Beijing**, China
3 **ELI Beamlines**, International
4 **PHLAM, Université de Lille,** France
5 **Helmholtz-Institut Jena**, Germany
6 **HZDR (Helmholtz)**, Germany
7 **LMU München**, Germany
8 **Wigner Fizikai Kutatóközpont**, Hungary
9 **CERN**, International
10 **Kansai Photon Science Institute**, Japan
11 **Osaka University**, Japan
12 **RIKEN SPring-8**, Japan
13 **Lunds Universitet**, Sweden
14 **Stony Brook University & Brookhaven NL**, USA
15 **LBNL**, USA
16 **UCLA**, USA
17 **Karlsruher Institut für Technologie**, Germany
18 **Forschungszentrum Jülich**, Germany
19 **Hebrew University of Jerusalem**, Israel
20 **Institute of Applied Physics**, Russia
21 **Joint Institute for High Temperatures**, Russia
22 **Università di Roma 'Tor Vergata'**, Italy
23 **Queen's University Belfast**, UK
24 **Ferdinand-Braun-Institut**, Germany